Meteorological Validation Report Contributions

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EUMETNET (FMI, Météo France, Met Office, DWD, KNMI), NLR, Thales	

Abstract

The purpose of this document is to report the content of WP11.2 MET contribution to R5 validation exercises and other demonstration activities. It will describe the expected benefits of MET to the ATM procedures validated and how well MET contribution was recognised to meet those expectations. Because MET was an enabler to those validation activities, the general SESAR validation methods are not applied to MET in isolation. However the benefits of enhanced MET to ATM were studied and deemed appropriate. MET prototypes are not validated themselves but demonstrated in ATM validation exercises.

Analysis of the results of MET contribution to these validation exercises and Large Scale Demonstrations show that the use of enhanced MET products in future ATM can bring significant added value for end users and has potential to increase the predictability of business/mission trajectory, improve situational awareness of all stakeholders, and improve flight efficiency. This could have a positive effect on the safety, capacity and fuel efficiency of aviation in Europe.

Technical interoperability of the MET-GATE as a way to disseminate MET information has been successfully demonstrated and it is recommended that it is used in future MET information dissemination in Europe. The benefits of probabilistic MET forecasts instead of the use of traditional deterministic ones seemed beneficial in many of the exercises. It is envisioned that after some common development with the MET and ATM community that many of the MET applications are ready for deployment.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	**Position & Title**	**Date**
[redacted] FMI	[redacted]	25/08/2016
[redacted] Met Office		19/05/2016
[redacted] Met Office		19/05/2016
[redacted] Météo France		20/05/2016
[redacted] NLR		09/06/2016
[redacted] NLR		09/06/2016
[redacted] / KNMI		20/06/2016
[redacted] Météo France		20/06/2016
[redacted] Thales Air Systems		30/05/2016
[redacted] DWD		16/05/2016

Reviewed By - *Reviewers internal to the project.*		
Name & Company	**Position & Title**	**Date**
[redacted] / EUMETNET EIG	[redacted]	24/06/2016
[redacted] Météo France		20/06/2016
[redacted] DWD		20/06/2016
[redacted] NLR		09/06/2016
[redacted] Thales Air Systems		30/05/2016

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	**Position & Title**	**Date**
[redacted] Swedavia	[redacted]	20/06/2016
[redacted] Swedavia		20/06/2016
[redacted] AT-One		20/06/2016
[redacted] Eurocontrol		20/06/2016
[redacted] SICTA		20/06/2016
[redacted] Selex		20/06/2016
[redacted]		20/06/2016

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	**Position & Title**	**Date**
[redacted] EUMETNET EIG	[redacted]	24/06/2016

[redacted] Met Office	[redacted]	13/06/2016
[redacted] Belgocontrol	[redacted]	13/06/2016
[redacted] Thales Air Systems	[redacted]	30/05/2016
[redacted] Météo France	[redacted]	20/06/2016
[redacted] NLR	[redacted]	20/06/2016
[redacted] Met Norway	[redacted]	20/06/2016
[redacted] DWD	[redacted]	20/06/2016
[redacted] KNMI	[redacted]	20/06/2016
[redacted] FMI	[redacted]	14/06/2016
[redacted] SHMI	[redacted]	20/06/2016

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
N/A		

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This deliverable consists of SJU foreground and EUMETNET Consortium background. The NWP models and meteorological information used to support the described 11.02 prototypes and validation/demonstration exercises belong to the respective National Meteorological Service.

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Executive summary

The role of WP11.2 in the SESAR1 programme is to support the operational work packages by contributing new MET information and expertise so that they can reach their validation objectives and maximise performance achievements. This is why WP11.2 contributes to validation exercises by delivering basic MET information and specially enhanced, consistent and harmonised MET information developed in WP11.2 for future ATM processes. As an enabler, the MET services themselves were not validated, but the benefits of them were studied as appropriate for the exercise.

In R5, MET contributions from 11.02 have been used in six validation exercises. Since most projects and WP's had already completed their development project plans before WP11.2 was initiated, it was difficult for WP11.2 to have advanced MET services integrated in some ATM validation exercises. As a result some of the exercises use only conventional MET products, in spite of the fact that they would have benefited from using of enhanced MET products; whilst others decided to disregard the dependency their operations have on meteorology, choosing to defer MET integration to SESAR2020.

The participation of WP11.2 in the validation exercises (with maturity level, respectively release number, indicated between brackets) were as follows:

- EXE-06.06.02-VP-513 de-icing Step1
- EXE-13.02.03-VP-700 Advanced Short-Term ATFCM including Network Supervision and interface with local Tools
- EXE-06.03.01-VP-669 Close out Airport Integration through SWIM
- EXE-06.03.01-VP-757 APOC performance Monitoring Management
- EXE-11.01.05-VP-791 Use of Global ensemble wind forecasts (GEWF) within planning process
- EXE-09.48-VP-811 Assess the operational need and principles of cockpit integration for AIS/MET cockpit functions

In addition MET contribution to Large Scale Demonstrations, such as TOPLINK, SWIM Master Class and SWIM Global Demo are also described here since they similarly demonstrate the benefits of enhanced, consolidated MET information services to operational ATM and flight planning processes Unfortunately not all demo results are available at the time of writing, but where possible preliminary results are indicated in this document

Analysis of the results of MET contribution to these validation exercises and Large Scale Demonstrations show that the use of enhanced MET products in future ATM will bring significant added value for end users and it has a potential to increase the predictability of business/mission trajectory, improve situational awareness of all stakeholders, and improve flight efficiency. This would have a positive effect on the safety, capacity and fuel efficiency of aviation in Europe.

Analysis of the MET contribution to exercises is still on-going in TOPLINK, but the preliminary results show, that the provision in real-time of MET hazard contours, observations and forecasts to ATC Flow Managers, Flight dispatchers, Pilots and Airport operators resulted in qualitatively significant added value for end-users. Further improvements are needed to increase vertical and time resolution of weather hazard warnings and additional dedicated MET products are also desired for visibility conditions on the ground, contoured areas of high winds en route, high resolution observation and nowcast of wind fields in terminal airspace and observation and forecasts airport MET parameters.

Technical interoperability of the MET-GATE as a way to disseminate MET information has been successfully demonstrated and it is recommended that it is used for future MET information dissemination in Europe. The benefits of probabilistic MET forecasts instead of the use of traditional deterministic ones seemed beneficial in many of the exercises. It is envisioned that after some common development with the MET and ATM community that many of the MET applications are ready for deployment.

It is recommended that additional work on MET prototypes for SESAR2020 be continued and that MET considerations should be made early on in any planning stages of a project. This will ensure continued customer engagement on the solutions required for the wide range of ATM users will cover the variation in requirements that they have.

After improvements on some of the MET prototypes demonstrated in the validations they are now ready for deployment (e.g. MET-GATE and winter weather prototypes). However for most of the developed prototypes it was not possible to demonstrate them adequately though they have a great potential to be products in future ATM with further work.

1 Introduction

1.1 Purpose of the document

This document provides the report of WP11.2 MET Contribution for R5 validation exercises. It describes the MET contribution arrangements and prototypes used in exercises as well as the MET demonstration results in validation exercises defined in 11.02.02-D35 Validation Plan Contributions - Ed 00.01.00.

R5 Validation exercises WP11.2 coordinators for each exercise are:

- EXE-06.06.02-VP-513 de-icing; Heikki Juntti (FMI)
- EXE-13.02.03-VP-700 Short-Term ATFCM; Anais Mermet, Jean-Louis Brenguier (Météo France)
- EXE-06.03.01-VP-669 A-CDM; Jaap Heijstek (NLR), Jan Sondij (KNMI), Svenja Koos (DWD)
- EXE-06.03.01-VP-757 APOC implementation; Pim van Leeuwen (NLR)
- EXE-11.01.05-VP-791 Use of ensemble weather forecast in flight planning; Jaap Heijstek (NLR), Jacob Cheung (Met Office), Jean-Louis Brenguier (Météo France)
- EXE-09.48-VP-811 AIS/MET Services and Data distribution; Anais Mermet, Jean-Louis Brenguier (Météo France)

WP11.2 also contributed to Large Scale Demonstrations (LSD). During SESAR1, WP11.2 had only limited opportunity to demonstrate benefits of enhanced MET prototypes for future ATM. This report will also describe the experiences regarding MET used in some LSDs as they are available at the time of writing. LSDs are still running, so final results of these will be described in the relevant LSD reports.

LSDs WP11.2 coordinators are:

- TOPLINK; Daniel Muller (Thales)
- SWIM Master Class; Svenja Koos (DWD), Anais Mermet (Météo France)
- SWIM Global Demo; Svenja Koos (DWD), Anais Mermet (Météo France)

Contrary to document: “11.02.02-D35 Validation Plan Contributions - Ed 00.01.00”, where details of validation exercises and Large Scale Demonstrations were not included, this report will summarise exercises or demonstrations, as well as describe their results (related to MET dependencies).

1.2 Intended readership

The primary audience for this document are all stakeholders participating to the validation exercises VP513, VP700, VP669, VP757, VP791, VP811 and reviewers of the results of these exercises.

In addition, this report will be of interest for those involved in the use of MET in future ATM, particularly related to the PCP, deployment and SESAR2020 planning.

1.3 Structure of the document

MET prototypes are not directly validated (only verified). As such, this document describes the MET ‘contribution’ and the results obtained from the MET perspective, to each of the identified validation exercises and demonstrations. The document is thus structured within this modified VALR template as appropriate. The detailed results of validation exercises will be described in the VALR of each exercise.

The document is organised as followed:

- Chapter 1 introduces the document. It defines the purpose and scope of the document and identifies its intended audience. It also provides a list of acronyms and terminology
- Chapter 2 presents content of MET contribution to validation exercises and LSD’s.

- Chapter 3 presents how the MET contributions to exercises are demonstrated as a whole. More details of this is included in Chapter 6
- Chapter 4 presents the results of MET contribution as a whole. Details of this is included in Chapter 6
- Chapter 5 presents conclusions and recommendations. It concludes experiences of MET contributions in SESAR1 as whole. Some recommendations to be taken into account in SESAR2020 are also presented.
- Chapter 6 presents in detailed level the MET contribution to each exercise or demonstration. Outcomes of MET will also be shown.

1.4 Glossary of terms

Table 1: List of terms

Term	Definition	Source
4DWxCube	The 4DWxCube is a (virtual) repository of shared consistent and translated meteorological information, produced by multiple METSPs and made available to ATM stakeholders via its SWIM compliant MET-GATE.	Proposed by P11.02.01 (OSED)
GRIB2	GRIB (GRIdded Binary) is a concise data format commonly used in meteorology to store historical and forecast weather data. It is standardized by the World Meteorological Organization's Commission for Basic Systems, known under number GRIB FM 92-IX.	WMO Manual on Codes No.306
MET product	MET information that are provided to the MET-GATE	P11.02.02
MET-GATE	The MET-GATE is a SWIM node enabling the discovery, access and retrieval of consistent and translated MET information, tailored to the ATM stakeholders' needs, from the 4DWxCube via SWIM compliant web services.	Proposed by P11.02.01 (OSED)
Mode-S EHS	Mode S is a Secondary Surveillance Radar process that allows selective interrogation of aircraft according to the unique 24-bit address assigned to each aircraft. Recent developments have enhanced the value of Mode S by introducing Mode S EHS (Enhanced Surveillance).	ICAO Doc 4444 and ICAO Doc 8168
NARSIM	NARSIM is the NLR real-time ATM Research Simulator, which supports R&D of MET impact on ATM.	NARSIM Tower brochure, NARSIM RADAR brochure
TOPLINK	A SESAR project, which aims to demonstrate the benefits of the deployment of System Wide Information Management (SWIM)-based services, including MET, aeronautical, corporate network and flight information services. The project aims to show the direct benefits that these advanced information services can bring to commercial airlines, air navigation service providers, and how these services can improve collaborative decision making between stakeholders	TOPLINK brochure

Term	Definition	Source
TOPMET	TOPMET, a SESAR demonstration project led by THALES, is bringing together seven European partners* to test a new set of meteorological services for use in Air Traffic Management (ATM) for the first time. Taking place in early 2014, the tests aimed to demonstrate improved accuracy in the monitoring and forecasting of adverse weather conditions, such as thunderstorms, turbulence and severe icing.	http://www.sesarju.eu/newsroom/all-news/topmet-“new-generation”-meteorological-services-be-tested-live-operational
SESAR 2020	The SESAR 2020 (Single European Sky ATM Research) Research and Innovation (R&I) Programme will demonstrate the viability of the technological and operational solutions already developed within the SESAR R&I Programme (2008-2016) in larger and more operationally-integrated environments.	SESAR2020 brochure

1.5 Acronyms and Terminology

Table 2: List of acronyms

Term	Definition
ADD	Architecture Definition Document
ACARS	Aircraft Communication Addressing and Reporting System
A-CDM	Airport Collaborative Decision Making
A-CWP	Advanced Controller Working Position
AIM	Aeronautical Information Management
AIS	Aeronautical Information Services
AMDAR	Aircraft Meteorological Data Relay
ANSP	Air Navigation Service Provider
AOP	Airport Operations Plan
AoI	Area Of Interest
APAMS	Airport Performance Assessment and Management Support
APOC	Airport Operations Centre
APP	Approach Control Service
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management

Term	Definition
ATV	Airport Transit View
AU	Airspace User
B2B	Business to Business
CAT	Clear Air Turbulence
CBA	Cost Benefit Analysis
CRZ	Cruise
DIMT	De-Icing Management Tool
DIW	De-Icing Weather class
DCB	Demand & Capacity Balancing
dDCB	Dynamic Demand & Capacity Balancing
DOD	Detailed Operational Description
EDIT	Estimated De-icing Time
ECZT	Estimated Commence of De-Icing Time
EEZT	Estimated End of De-icing Time
EFB	Electronic Flight Bag
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
EOBT	Estimated Off-Block Time
ER	Exploratory Research
EXE	Exercise
FOC	Flight Operation Centre
FPL	Flight Plan
GEWF	Global Ensemble Weather Forecast
GRIB2	Gridded Binary (version 2)
GWMS	Ground Weather Monitoring System
ICAO	International Civil Aviation Organization
IRS	Interface Requirements Specification

Term	Definition
INTEROP	Interoperability Requirements
IWIS	Improved Weather Information System
KPA	Key Performance Area
LTM	Flow Management Position
MET	Meteorological / Meteorology
MUAC	Maastricht Upper Area Control Centre
NATS	National Air Traffic Services (UK ANSP)
NM	Network Manager
NOP	Network Operations Plan
NMOC	Network Management Operations Centre
NWP	Numerical Weather Prediction
OFA	Operational Focus Areas
OSED	Operational Service and Environment Definition
PCP	Pilot Common Project
PDF	Probability density function
RR	re routing
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme, which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme, which addresses all activities of the SESAR Joint Undertaking Agency.
SPR	Safety and Performance Requirements
STAM	Short-Term ATFCM Measures
SUT	System Under Test
TAD	Technical Architecture Description
TMA	Terminal Manoeuvring Area, Terminal Area
TP	Trajectory Prediction / Trajectory Predictor

Term	Definition
TS	Technical Specification
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
VP	Verification Plan
VR	Verification Report
VS	Verification Strategy
WWI	Winter Weather Information
Wx	Weather
WxAoI	Weather Area of Interest
WWI	Winter Weather Information
4DWxCube	4 Dimensional Weather Cube

2 Context of the Validation

In WP11.2, an extensive literature review that covered SESAR documents was carried out to identify SESAR projects in which MET information is a prerequisite. WP11.2 organised two dedicated workshops aiming to raise the awareness to other WPs and OFAs on the availability and effective usefulness of MET support to their validation exercises in order to reach the exercises' objectives. Apart from the workshops, WP11.2 was represented at numerous other WP's and OFA's progress meetings. Numerous projects were approached to discuss and negotiate the acceptance of a MET contribution in their validation exercises. Since most projects and WP's had already completed their plans before WP11.2 was initiated, it was difficult for WP11.2 to have advanced MET services integrated in all relevant validation exercises.

The participation of WP11.2 in the validation exercises (with maturity level, respectively release number, indicated between brackets) are:

- EXE-06.06.02-VP-513 de-icing (V3, R5)
- EXE-13.02.03-VP-700 Short-Term ATFCM (V3, R5)
- EXE-06.03.01-VP-669 A-CDM (V3, R5)
- EXE-06.03.01-VP-757 APOC implementation (V3, R5)
- EXE-11.01.05-VP-791 Use of ensemble weather forecast in flight planning (V2, R5)
- EXE-09.48-VP-811 AIS/MET Services and Data distribution (V2)

The types of MET contribution to these six validation exercises are presented in the table below.

Validation exercise	Name of EXE	Existing MET information used (i.e. TAF, METAR, SIGWX etc)	Enhanced MET prototype used and 11.02 capability reference	Delivery via MET-GATE
VP513	De-icing Step 1 - V3	No	X1.6 Winter Conditions Forecast at Airports	No
VP700	Advanced Short Term ATFCM including Network Supervision and interface with Local Tools	No	X1. 4 Icing Forecast X1.5 Clear Air Turbulence (CAT) Forecast	Yes
VP669	Close out Airport Integration through SWIM	No	Deterministic MET forecast Ensemble MET forecast (COSMO-DE) X2.1 Mode-S New Sensors	No
VP757	APOC Performance Monitoring and Management	Only METAR and TAF	No	No
VP791	Use of Global ensemble wind forecasts (GEWF) within the flight planning process	Yes	X1.8 Ensemble MET forecast, xGEWF	Yes
VP811	Assess the operational need and principles of cockpit integration for AIS/MET cockpit	No	X1.1 Radar Composite for 3D convection X1.2 Nowcasting of Convection	Yes (early 4DWxCube prototype)

	functions		X1.4 Icing Forecast X1.5 Clear Air Turbulence (CAT) Forecast	

Table 3: The types of MET contribution to the exercises.

The types of MET contribution to three LSD and other demonstration activities are presented in the table below.

Name of LSD	Existing MET information used (i.e. TAF, METAR, SIGWX etc)	Enhanced MET prototype used and 11.02 capability reference	Delivery via MET-GATE
TOPLINK	TAF METAR SIGMET	X1.1 Radar Composite for 3D convection X1.2 Nowcasting of Convection X1.4 Icing Forecast X1.5 CAT Forecast X1.6 Winter Weather Conditions Forecast	Yes
SWIM Master Class	TAF METAR SIGMET Gridded winds	X1.1 Radar Composite for 3D convection X1.2 Nowcasting of Convection X1.4 Icing Forecast X1.5 CAT Forecast	Yes
Swim Global Demo	TAF METAR SIGMET	None	Yes

Table 4: The types of MET contribution to LSDs.

An analysis during the R5 system engineering review identified exercises where MET could have been incorporated into exercise parameters to reflect real-world scenarios where meteorology will be an unavoidable factor.

Adverse weather conditions can have severe impacts on many ATM processes. These effects and possibilities for enhanced MET solutions are widely described in MET-DOD document [6]. The new developments of the ATM processes will first be validated in nominal weather first and when proven successful, will be extended for use in adverse weather conditions. Many of these cases are planned in the SESAR 2020 Multi-annual Work Program [7] .

Many projects had challenges to use the newly developed enhanced MET prototypes in their exercises. This is because they did not consider enhanced MET products from the beginning, as WP11.2 had not been involved in early phase of the projects. Some projects even used MET data, whose origin were outside Europe, although similar European products were readily available.

The awareness of WP11.2's availability to support validation campaigns rose during SESAR1. WP11.2 received numerous requests for review VALP and VALR of ATM projects even if WP11.2 had no (prototype) contribution to them. Reviewing and discussions with them was very useful, but limited by time and resources available.

Because it has been difficult to find good demonstration opportunities for all enhanced MET prototypes, experiences acquired during the large scale demonstration activities have also been included in this report as an opportunity to show the value of enhanced MET to the future ATM procedures.

The MET prototypes demonstrated in validation exercises and large scale demonstrations are presented in the Table 5.

MET prototype		Related Validation EXE	Related other validation activities
X1.1	Radar Composite for 3D convection	VP811	TOPLINK, SWIM Master Class
X1.2	Nowcasting of Convection	VP811	TOPLINK, SWIM Master Class
X1.3	Super-Ensemble Mesoscale Forecast of Convection	N/A	
X1.4	Icing Forecast	VP700, VP811	TOPLINK, SWIM Master Class
X1.5	Clear Air Turbulence (CAT) Forecast	VP700, VP811	TOPLINK, SWIM Master Class
X1.6	Winter Conditions Forecast at Airports	VP513	TOPLINK
X1.7	MET support for Network capacity reductions due to weather across Europe	N/A	
X1.8	MET support to 4D trajectories	VP791(V2)	
X2.1	Mode-S EHS New Sensors	VP669 (partially)	
X2.2	E-AMDAR Humidity case studies	N/A	
N/A	4DWxCube - MET-GATE	VP700, VP811	TOPLINK, SWIM Master Class, SWIM Global Demo
N/A	Standard MET data (according ICAO Annex 3 [36])	VP757	TOPLINK, SWIM Master Class, SWIM Global Demo

Table 5: Enhanced MET prototypes to be demonstrated in validation exercises and Large Scale Demonstrations.

2.1 Concept Overview

Summary tables detailing the exercises under the scope of the Validation Report are presented in the 11.02.02-D35 Validation Plan Contributions [9] and Validation Reports, which will be published by responsible Projects of validation exercises. Context of MET Contributions for the validation exercises will be described here.

Concept overview of MET contribution to VP-513 De-icing Step 1 - V3

The focus of this validation is to explore the impact of a planning and execution phase for de-icing operations on the predictability of the Air Transit View (ATV) by the introduction of a de-icing management tool (DIMT). WP11.02.02 provides MET input (models and data) to VP-513 by contributing de-icing weather information and by exploring the added value of refined weather parameters [11].
P06.06.02 in VP-513 was supported by P11.02.02, which provided weather information to the DIMT prototype. The aim was to show that adding radar observations to standard ICAO weather information METAR and TAF improved the de-icing time stamps.

The Finnish Meteorological Institute (FMI) combined weather observations, forecasts and provided pre-defined weather categories for the De-Icing Management Tool (DIMT; named ODISS). The 4DWxCube and SWIM were not used in this validation experiment.

The aim of the experiment was to explore the effect of DIMT on the Air Transit View's (ATV's) preparation for de-icing operations. Together with Airport Operations Data Base (AODB), DIMT provides de-icing information as de-icing time-stamps. P11.02.02 provides MET input to VP-513 by providing weather information and exploring the added value of refined weather parameters.

Generally, the role of Task 11.02.02.03 MET Support in Pre-Operational Validation was to support the validation activities inside the OPS WPs in all MET-related matters. Validation of an integrated MET-ATM system was the direct responsibility of the OPS WPs.

This specific validation EXE-06.06.02-VP-513 shows that the new de-icing management procedure helps to predict the de-icing time of aircraft, thus optimizing the gate-to-gate times and supporting CDM at airports. It was determined that the role of MET was essential in these operations.

The WP11.2 contribution to EXE-06.06.02-VP-513 was to deliver the weather information (both real-time observations and forecast) needed in the experiment. MET information was transformed into a form that indicated the weather type relevant to de-icing.

Concept overview of MET contribution to VP-700: Advanced Short Term ATFCM including Network Supervision and interface with Local Tools

Integration of MET information into a NM tool was evaluated by VP700. Forecasts of convection, turbulence and icing, delivered by the 4DWxCube MET-GATE have been used to better anticipate the network sectors capacity and potential for overload. [38]

Concept overview of MET contribution to VP-669: Close out Airport Integration through SWIM

A meteorological data archive was been established to ensure weather scenarios were available to support the validation exercise execution (real-time simulation). WP11.2 provided deterministic numerical weather prediction (NWP) data as well as ensemble NWP data to enable probabilistic statements. This part of VP-669 used MET information in a simulation only environment using data from pre-defined case studies.[34]

WP11.2 also provided Mode-S EHS derived MET observation including temperature profiles to be used for the validation campaign.

Concept overview of MET contribution to VP-757: APOC Performance Monitoring and Management

WP 11.2 contribution consisted of the delivery of METAR and TAF information for a specified airport and time period to support the complex simulation (18 June 2013); no enhanced or consolidated MET prototype was used. Initially, GRIB2 weather grids were foreseen to be used in the exercise to improve realism and granularity of the weather data used in the real-time simulation facility employed in this exercise. The requested weather grids (2 sets) matching the exercise scenarios were provided by WP11.2 but were in the end not used by the exercise.[13]

Concept overview of MET contribution to VP-791: Use of Global ensemble wind forecasts (GEWF) within the flight planning process

The VP791 validation exercise includes trajectory creation and flight planning, utilizing global ensemble weather forecasts as well as a comparison against real flown flights. In order to allow a validation exercise without a huge amount of development work upfront, the aim was to integrate global ensemble weather forecasts into the regular trajectory optimization and flight planning process and to stick as closely as possible to current operational methods.[15]

Concept overview of MET contribution to VP-811: Assess the operational need and principles of cockpit integration for AIS/MET cockpit functions

VP811 focuses on the benefits of up-linking MET information to on-board systems. [23]

The objective of VP811 was to demonstrate a means to improve current situational awareness by uplinking AIS and MET information on board the aircraft before and during the flight. In addition provide pilots with new AIS/MET cockpit functions using these information to enhance performance of flight decision support tools and on-board systems.

The VP811 is split in 3 sub-exercises:

- EXE-09.48-VP-811: Assess the operational need and principles of cockpit integration for AIS/MET cockpit functions (Airbus)
- “AIS on EFB” (Honeywell) validation test
- “MET on EFB” (Thales) validation test

The sub-exercise led by Airbus used SIGMET delivered without any SWIM consideration. The second sub-exercise, led by Honeywell, focused on AIS information and did not use any MET information.

From an 11.02 perspective, only the third sub-exercise, led by Thales, is relevant. MET information delivered in this exercise includes nowcast of convection and forecasts of CAT and Icing. An early release of the 4DWxCube MET-GATE was also demonstrated in this exercise.

Concept overview of MET contribution to TOPLINK Lot 1 – LSD01.01 & Lot 2 – LSD02.06

The TOPLINK Lot 1 and Lot 2 projects have been using MET information provided by WP11.2 through the MET-GATE into numerous demonstration exercises.

The considered MET information is transferred from the MET-GATE to the TOPLINK platform through a set of SWIM Services:

- METAR service
- TAF service
- SIGMET service
- Airport MET forecast service
- Airport MET observation service
- MET Hazard EnRoute forecast service
- MET Hazard EnRoute observation service
- MET gridded forecast service

This information is collected into the TOPLINK platform, and is used as follows:

- Display (as a “MET layer”) on the integrated display (see Figure 1 below)
- Generation of automatic alerts in case of forecasted conflicts between a severe MET hazard or a SIGMET and a flight (for Airlines profiles), a control sector (for FMP profiles), a SID, STAR, RWY, or platform (for Airport profiles) (see Figure 2 below)
- Support to “what-if” mitigation scenarios (e.g. flight rerouting, sector capacity reduction, RWY configuration change, …) (see Figure 3 below)

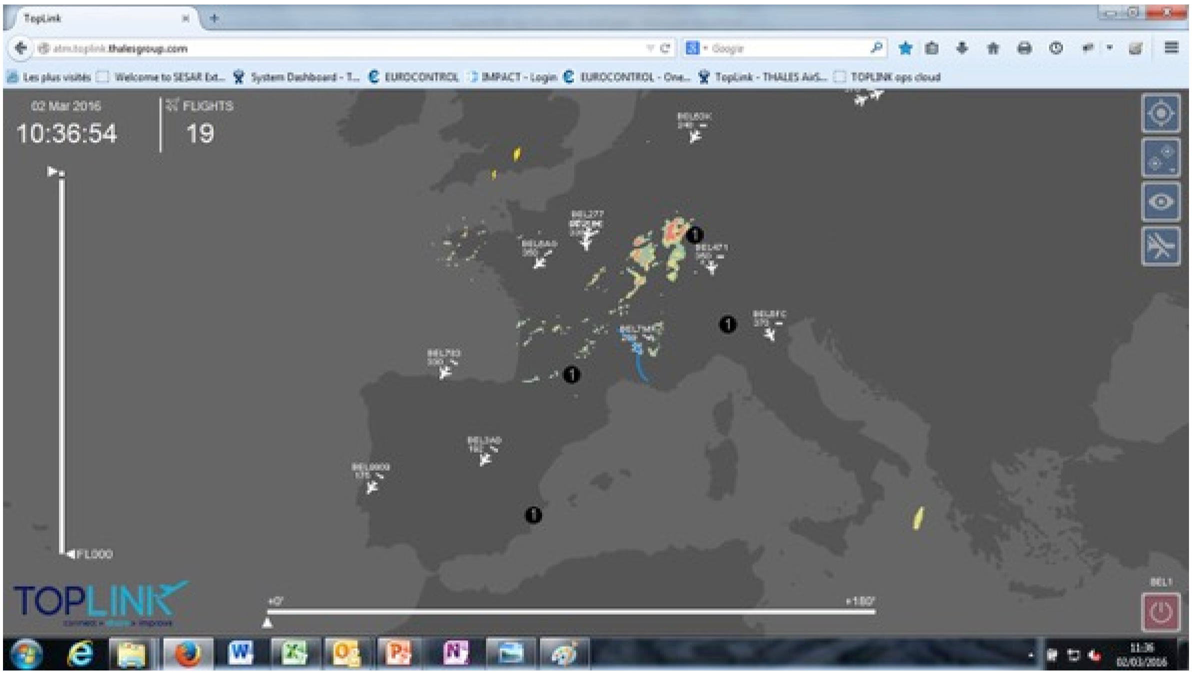

Figure 1 TOPLINK HMI: display of Flight & MET layers

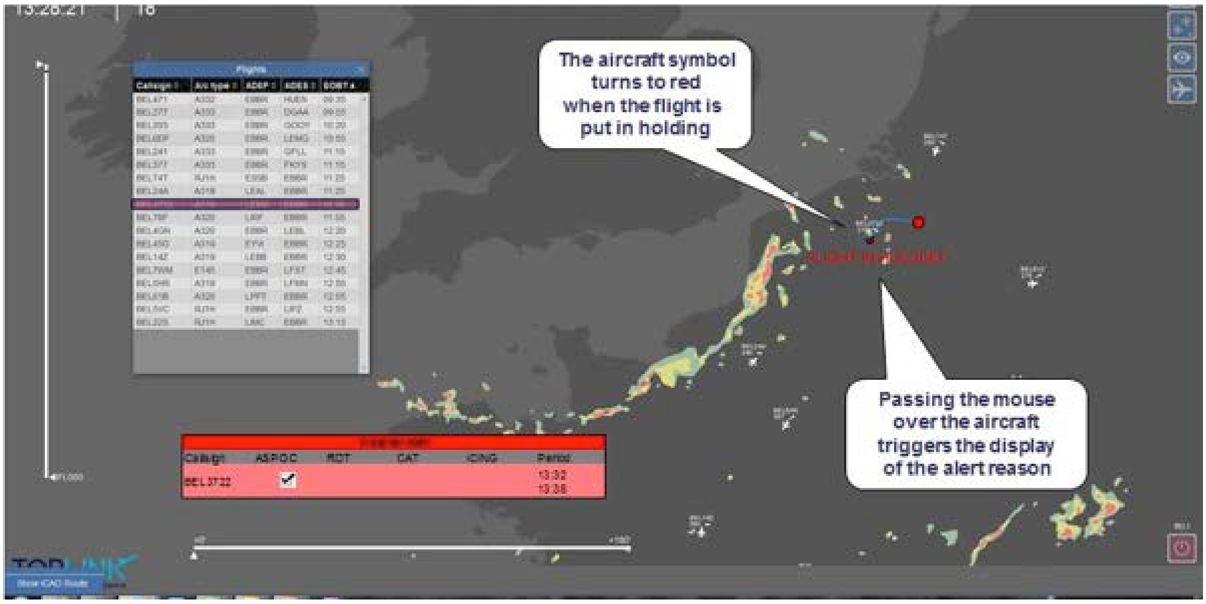

Figure 2 TOPLINK HMI: display of a MET alert.

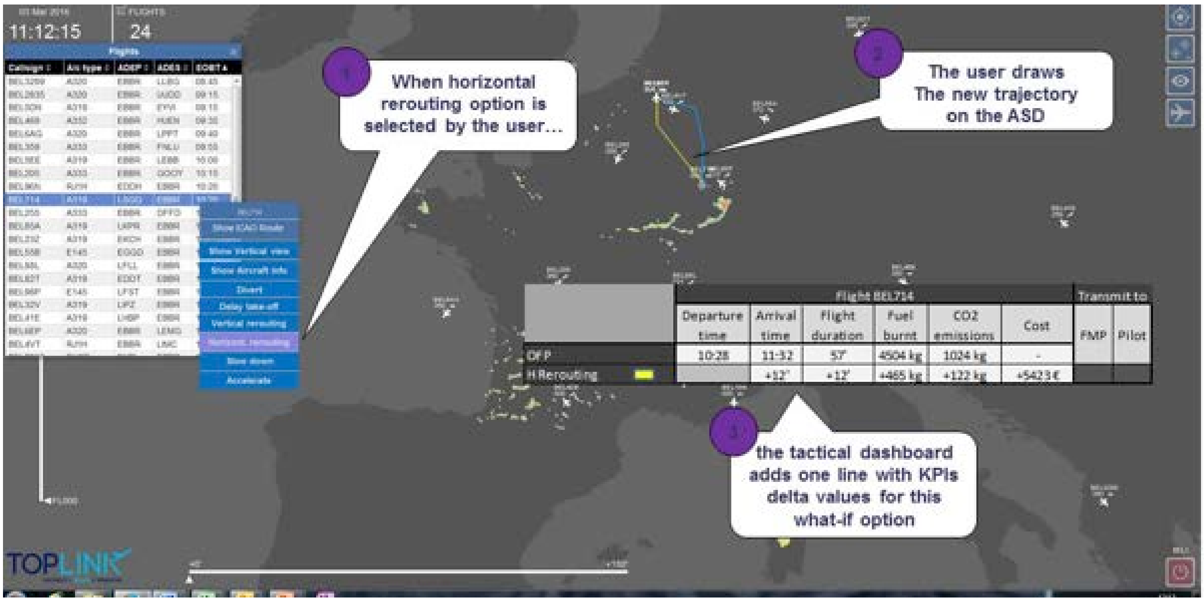

Figure 3 TOPLINK HMI: support to flight rerouting following a MET alert.

These profiles are customized for the following exercises:

- EXE 0101.D111: trial supporting AFR pilots in the cockpit
- EXE 0101.D131: trial supporting AFR pilots in the cockpit (Paris CDG arrivals)
- EXE 0101.D115: trial supporting BEL pilots in the cockpit
- EXE 0101.D141: trial supporting Air Corsica pilots in the cockpit
- EXE 0206.D211, 212, 214: : trial supporting ENAC general aviation pilots in the cockpit (pre-flight, execution, and post-flight phases)

- EXE 0101.D121: trial supporting DSNA FMPs (Aix and Bordeaux ACCs)
- EXE 0101.D124: trial supporting Croatia Control FMPs (Zagreb ACC)
- EXE 0101.D127: trial supporting Austro Control FMPs (Vienna ACC)

- EXE 0101.D132: trial supporting DSNA Approach Supervisor and ADP Platform Supervisor (Paris CDG Airport)

- EXE 0101.D115: trial supporting Brussels Airlines Fleet Managers (Brussels OCC)
- EXE 0101.D142: trial supporting Air Corsica Fleet Managers (Ajaccio OCC)
- EXE 0101.D146: trial supporting HOP! Fleet Managers (Nantes OCC)
- EXE 0206.D213: trial supporting ENAC General Aviation Fleet Managers (Toulouse OCC)

The 15 exercises are planned for execution between June and September 2016.[17][18]

Concept overview of MET contribution to SWIM Master Class 2015

The SWIM Master Class is a contest organised by EUROCONTROL every year since 2012. The purpose is to encourage ATM actors to become familiar with SWIM and to develop applications which apply the SWIM concepts.

There are 3 categories of participants:

- Developers of SWIM-enabled ATM applications
- Developers of SWIM-enabled ATM information services

- Providers of SWIM infrastructures or services

The intention of the contest is that SWIM-enabled ATM applications consume SWIM-enabled ATM information services.

On the behalf of EUMETNET EIG, Météo-France in cooperation with DWD and UKMO, provided access to a set of services built in the framework of SESAR WP11.2.2 through the 4DWxCube / MET-GATE. The proposed services relied on legacy MET products and 11.02 products: Radar Composite for 3D convection, Nowcasting of Convection, Icing Forecast and CAT Forecast.

Concept overview of MET contribution to SWIM Global Demo

The Global SWIM demo is a worldwide demonstration project with 3 main objectives:
- raise SWIM awareness in a global context
- Prove the interoperability of systems around the world
- prepare the deployment of SWIM as SWIM is part of PCP

Given the complexity of the project, the high number of systems involved and the limited timeframe, only legacy MET information is used in the project (TAF, METAR and SIGMET). They are delivered through the 4DWxCube MET-GATE.

2.2 Summary of Validation Exercise/s

2.2.1 Summary of Expected Exercise/s outcomes

Expected Outcomes of MET contribution to exercises and the ATM procedures validated are summarised in table 6 below.

Exercise number / LSD Name	MET service delivered to exercise.	Expected Meteorological outcome
513	De-Icing Index (DIW) to DIMT based on enhanced Winter Weather Information (WWI) for next 3 hours. Machine to machine product.	Enhanced Winter Weather Information (WWI) supports de-icing management better than conventional ICAO products. That increases the accuracy of estimated de-icing time of individual airplane and increases the predictability of business/mission trajectory. Usefulness of enhanced WWI to de-icing coordinators will be assessed.
700	MET Hazard forecast service : convection, icing and clear-air-turbulence	The integration of MET in flow management techniques showed the real time operations should improve pro-active decision making regarding the STAM concept. STAM measures should be better anticipated.
669	Provision of accurate actual / forecast MET data as well as expert advice. The required MET data has been recorded during a measurement campaign at Braunschweig airport and then translated over the Malpensa airport layout. The data set includes data from standard sensors, such as AWOS, up to highly sophisticated 'remote sensing' equipment, such as Doppler RADAR and Doppler LIDAR, or a CEILOMETER, and cameras. Deterministic and ensemble NWP data as well as Mode-S EHS data are provided for the same area and time.	According to the Milano Malpensa environment, the data set includes the following MET events: • Thunderstorm • Fog • Tail wind • Snow The MET Quality of Service (QoS) concerns the required parameters, the time horizon, and the update rate, and solutions to identified gaps, if any.
757	Only METAR and TAF data have been provided for the required simulation airport and required simulation day.	No expected outcome other than that the data provided supported EXE757 during validation.
791	Provision of GEWFs throughout all levels of the atmosphere	The use of GEWFs allow the uncertainty of any given trajectory to be assessed, which in return provides confidence in decisions made in the flight planning process.
811	Convection observation and nowcast and icing and clear-air-turbulence	Having improved MET information on-board should enhance crew situational

	forecast	awareness, flight safety and flight efficiency
TOPLINK	METAR, TAF and SIGMET service Airport MET forecast service MET Hazard EnRoute forecast and observation service	Demonstrate the benefits of using advanced new MET products in supporting tools for Traffic Flow Managers, Flight Dispatchers, Pilots, Airport Supervisors, in order to: - Optimize Airspace & Airports capacity - Increase IFR flights predictability - Reduce cost of flights for Airlines - Reduce Environmental impact - Improve flight safety
SWIM Master Class	METAR, TAF and SIGMET service Airport MET forecast service MET Hazard EnRoute forecast and observation service. MET gridded forecast service.	Promote 11.02 products. Demonstrate the utility, relevance, performance and ease of use of the MET services
SWIM Global Demo	METAR, TAF and SIGMET service	Demonstrate the worldwide interoperability of the 4DWxCube MET-GATE

Table 6: Expected outcomes of MET Contribution to exercises

2.2.2 Benefit mechanisms investigated

Benefit mechanisms of MET in VP513

The influence of MET information on the **predictability** of De-Icing management is straightforward. The accuracy of the De-Icing weather class (DIW) influences to the accuracy of EDIT.

Expected benefits from DIW are [10]:

- **Predictability**: Better estimation of de-icing time of aircrafts and improvement of CDM process

Benefit mechanisms of MET in to VP700

Expected benefits from **MET- NOP Integration** are [12]:

- **Predictability**:
  - Better estimation of traffic in specific TVs;
  - Insight in the distribution of flights in traffic volumes with areas of significant WX in the vicinity.
- **Safety:**
  - Proposal of RR to AO out of significant WX;
  - Avoidance (double control at planning level) of potential encounter of convective WX;
  - Contribution to less deviations of trajectory due to early knowledge of significant WX conditions.
- **Fuel efficiency:**
  - Contribution to realistic fuelling (including significant WX avoidance).

Benefit mechanisms of MET in VP669

It this exercise predictability more precisely means punctuality, which could also be used instead of predictability in the text covering exercise 669.

From the start, P06.05.05 has focused on the Key Performance Area “Predictability” as a pre-requisite for benefits in other KPA’s. Under the assumption that predictability will be improved by the concept, the benefit mechanisms indicate possible positive impact on other KPA’s.

The following Key Performance Areas (KPAs) have been listed as primarily relevant to EXE.06.03.01-VP-669:

- **Predictability:**
  - A better resources allocation resulting from the continuous monitoring of the airport performances and the selection of the Runway configuration more appropriate for the current operational and weather conditions is expected to lead to a more stable (and so predictable) surface traffic movements;
  - Availability of Relevant MET information on time as well as of the expected to positively impact on the stakeholders’ situation awareness increasing the predictability of surface movements.
- **Human Performance:**
  - The provision of accurate, timely and complete information is expected to bring benefits to both stakeholders’ workload and situation awareness
- **Capacity:**
  - A better resources allocation is expected to have a positive impact on the runway capacity shortage and, therefore, on the runway throughput.

Related to MET, the exercise envisages the availability of MET services through the implementation of a SWIM Technical infrastructure (MET Information Exchange, SESAR Solution #35). The following MET Information Exchange benefit mechanism applies:

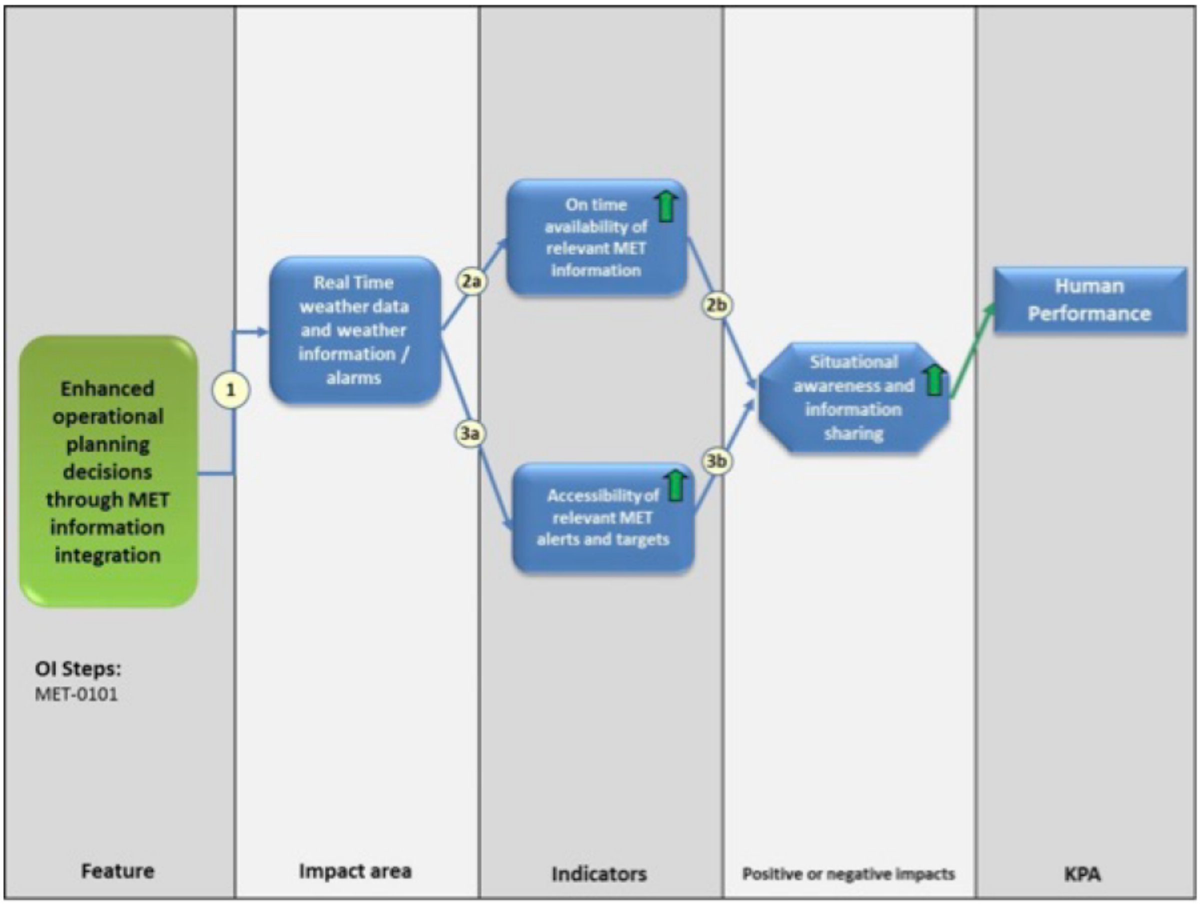

Figure 4 EXE.06.03.01-VP-669 MET Information Exchange Benefit Mechanism [13]

N°	Mechanism descriptions
1	**Real Time weather data and weather information and alarms** Enhanced operational planning decisions through MET information integration as described in the feature means, improving as primary impact the predictability and as secondary impact the flexibility, efficiency and capacity for the information sharing within the APOC and collaborative decision making due to the display of real time weather data and information and alarms.
2a	**On time availability of relevant MET information** Receive and/or have access to on time available relevant MET information.
2b	**Situational awareness and information sharing** Common situational awareness increases through real-time access to all relevant APOC stakeholder for assisting collaborative decision making in adverse situations or resource re-planning which links to human performance as primary impact
3a	**Accessibility of relevant MET alerts and targets** Receive and/or have access to information about on time available relevant MET alerts and warnings when the situation exceeds the individual thresholds (defined in the system for the given airport)
3b	**Situational awareness and information sharing** The relevant stakeholder will increase the situational awareness through MET alert/warning tool in order to make timely right decisions according to the forecasted weather information which links to human performance as primary impact

Table 7: EXE.06.03.01-VP-669 MET Information Exchange Benefit Mechanism description[13]

Benefit mechanisms of MET in VP757

None beyond current practice, since no specific WP11.2 MET prototypes have been used to support VP757.

Benefit mechanisms of MET in VP791

The benefit mechanisms can be best derived when looking at sample data and discuss with aircraft operators what the most suitable KPIs especially in regards to Cost and Fuel efficiency are.

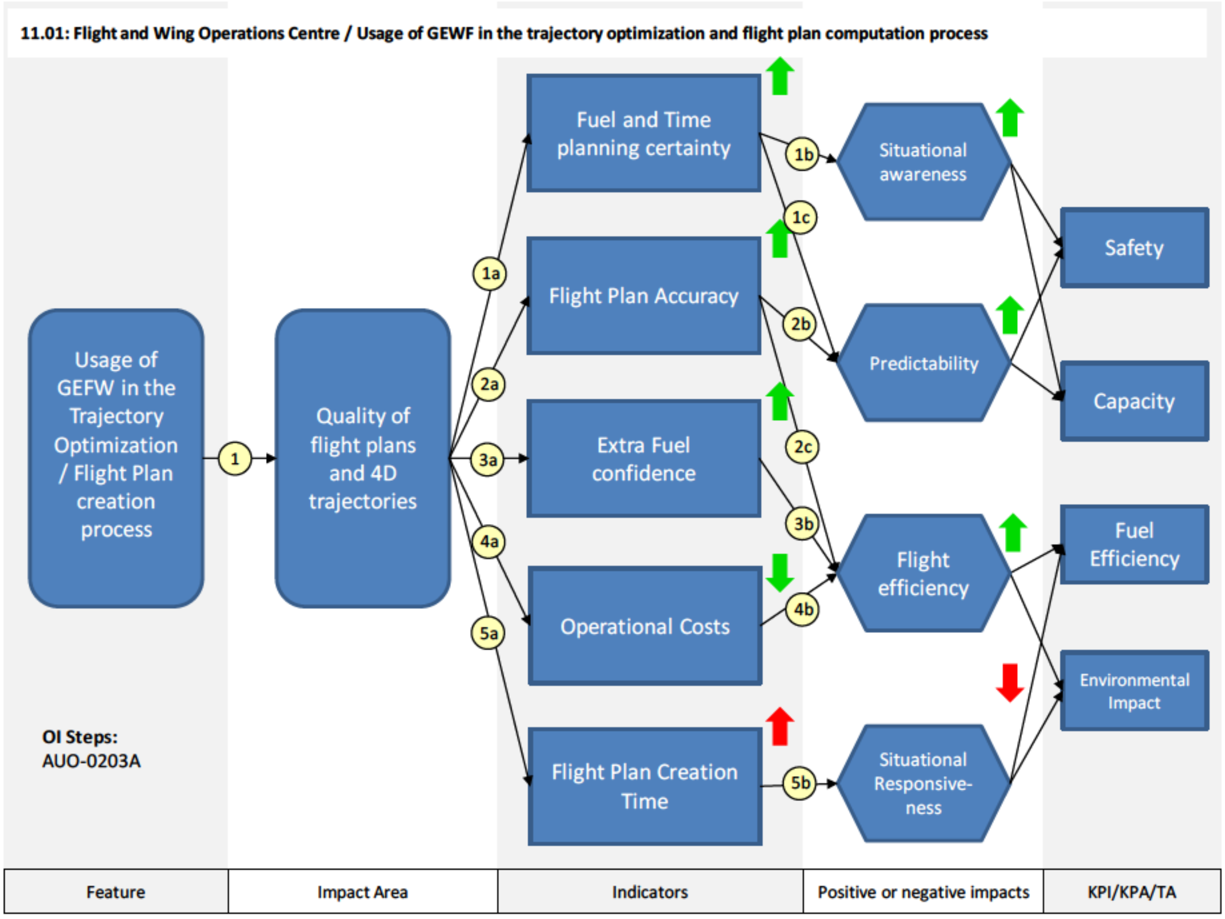

Figure 5 Flight and Wing Operations Centre / Usage of GEWF in the trajectory optimisation and flight plan computation process [20]

The benefit mechanism is based upon the usage of GEWF in the regular trajectory optimization and flight plan creation process. A detailed description on the trajectory optimization and flight plan creation process can be found in the document [22]

Following table relates the SESAR Performance Framework's KPAs with the benefits the civil airspace users' expected to be validated throughout the FOC involvement in the exercise.

KPA	Expected Benefit
Safety	A higher certainty of the fuel and time planning leads to a better situational awareness and predictability, hence improves safety as the real evolution of the flight can be better anticipated. It is also expected that, by using global ensemble weather forecasts, situations where one would land below the regulatory minimum fuel are reduced hence safety is increased.

KPA	Expected Benefit
Capacity	A higher certainty of the time planning (4th dimension of a trajectory) increases potential capacity since the necessity of adding buffers to the airspace capacity is reduced.
Fuel Efficiency	Pilots are adding extra fuel based on the actual weather situation, forecasted weather situation and last but not least gut feeling. The latter influence on extra fuel mentality can be addressed by the usage of probabilistic weather. It is expected that pilots will take less extra fuel by using probabilistic weather models.
Environmental Impact	Lower extra fuel amounts reduce the trip fuel and hence CO_2 emissions. Less airspace capacity buffers lead to lesser detours and hence also lowers the environmental impact.

Table 8: Benefit mechanism investigated

Benefit mechanisms of MET in VP811

The following KPAs will be addressed [16]:

- **Efficiency**

  Pilot will be able to better anticipate some situations (receiving updated MET info) and so to be more efficient in order to prepare for an alternative trajectory (e.g bad weather, ...)

- **Safety**

  The current media used by the pilots to obtain MET information is either not updated during the flight (SIGMET) or available only as a voice service (VOLMET) or as text oriented information. Project 9.48 assumes that a digitalized format is available, providing structured information suitable for machine processing, and delivered to the A/C by means of data communication. This will enable advanced processing of the information in the cockpit (structured texts, graphics), thus the safety will be increased, due to improved understanding of the presented information leading to better situational awareness.

- **Cost efficiency**

  The display of severe weather will allow flight crew to avoid severe weather while minimizing the additional track miles, thus optimizing fuel consumption.

Benefit mechanisms of MET in TOPLINK Lot 1 – LSD01.01and Lot 2 – LSD02.06

The 15 TOPLINK exercises planned between June and September 2016 will assess the benefits of using new MET information, on KPIs such as “extra fuel burn”, “extra-cost”, “flight predictability”, “arrival delays”,…over the duration of the trials.
The resulting figures will be collected in the TOPLINK Lot 1 and Lot 2 final reports, due in October 2016. The tables below summarize the KPIs and metrics planned for assessment, for each stakeholder category.

Objective Identifier	Objective	KPA	KPI Identifier	KPI	KPI unit
Airlines Objectives & KPÏs					
OBJ-0101-110	Reduce extra fuel burn over an Airline fleet	***Efficiency*** (Fuel)	**KPI-0101-110**	Estimated fuel consumption increase due to unexpected adverse weather or airspace configuration changes	kg
OBJ-0101-210	Reduce extra cost over an Airline fleet	***Efficiency*** (Cost)	**KPI-0101-210**	Estimated cost increase due to unexpected adverse weather or airspace configuration changes	k€
OBJ-0101-310	Improve predictability of flights for an Airline	***Predictability***	**KPI-0101-310D**	Departure delays due to unexpected adverse weather or airspace configuration changes	mn
			KPI-0101-310A	Arrival delays due to unexpected adverse weather or airspace configuration changes	mn
OBJ-0101-510	Improve passenger comfort in adverse weather conditions for an airline	***Safety***	**KPI-0101-510**	Duration of severe turbulence encounter	mn
OBJ-0101-610	Improve flight safety in adverse weather conditions for an airline	***Safety***	**KPI-0101-610**	Duration of flight encounter with unexpected adverse weather	mn
OBJ-0101-615	Improve flight safety through early distribution of arrival information in the cockpit for an airline	***Safety***	**KPI-0101-615**	Number of arrival flights with late RWY allocation change	Nb / time period
OBJ-0101-710	Reduce arrival delays over an airline fleet	***Punctuality***	**KPI-0101-710**	Arrival delay vs schedule due to unexpected adverse weather or airspace configuration changes	mn

Table 9: List of KPIs for Airlines exercises

Objective Identifier	Objective	KPA	KPI Identifier	KPI	KPI unit
ANSPs Objectives & KPÏs					
OBJ-0101-120	Reduce extra fuel burn over an ANSP traffic flow	***Efficiency*** (Fuel)	**KPI-0101-120**	Estimated fuel consumption increase due to the implementation of Weather-related Scenarios & STAMs	kg
OBJ-0101-220	Reduce extra cost over an ANSP traffic flow	***Efficiency*** (Cost)	**KPI-0101-220**	Estimated cost increase due to the implementation of Weather-related Scenarios & STAMs, or to Weather-related regulations.	k€
OBJ-0101-320	Improve predictability of flights for an ANSP	***Predictability***	**KPI-0101-320G**	Ground delays induced by unexpected adverse weather in the FIR	mn
			KPI-0101-320F	In-flight delays induced by unexpected adverse weather in the FIR	mn
OBJ-0101-420	Improve airspace capacity management for an ANSP	***Capacity***	**KPI-0101-420**	Estimated average capacity index (taking into account the un-usable sectors due to unexpected adverse weather)	%
OBJ-0101-620	Improve flight safety in adverse weather conditions for an ANSP	***Safety***	**KPI-0101-620**	Duration of flight encounter with unexpected adverse weather	mn
OBJ-0101-720	Reduce induced arrival delays over an ANSP traffic flow	***Punctuality***	**KPI-0101-720**	Arrival delay vs schedule due to unexpected adverse weather or airspace configuration changes in the FIR	mn

Table 10: List of KPIs for ANSPs exercises

Objective Identifier	Objective	KPA	KPI Identifier	KPI	KPI unit
Airports Objectives & KPÏs					
OBJ-0101-130	Reduce extra fuel burn over an Airport traffic flow	***Efficiency*** (Fuel)	**KPI-0101-130**	Estimated fuel consumption increase - when due to unexpected adverse weather or airspace/RWY configuration changes over the TMA	kg
OBJ-0101-230	Reduce extra cost over an Airport traffic flow	***Efficiency*** (Cost)	**KPI-0101-230**	Estimated cost increase for Airlines-when due to unexpected adverse weather or airspace/RWY configuration changes over the TMA	k€
OBJ-0101-330	Improve predictability of flights for an Airport	***Predictability***	**KPI-0101-330D**	Departure delays -when due to unexpected adverse weather or airspace/RWY configuration changes over the TMA	mn
			KPI-0101-330A	Airport contribution to the arrival delays - when due to unexpected adverse weather or airspace/RWY configuration changes over the TMA	mn
OBJ-0101-430	Improve Airport capacity	***Capacity***	**KPI-0101-430D**	Index of actual use of the available capacity at Departure	%
	Improve Airport capacity		**KPI-0101-430A**	Index of actual use of the available capacity at Arrival	%
OBJ-0101-630	Improve flight safety in adverse weather conditions for an Airport	***Safety***	**KPI-0101-630W**	Duration of flight encounter with unexpected adverse weather	mn
			KPI-0101-630G	Number of Go-Around procedures due to unexpected adverse weather	Nb / time period
			KPI-0101-630R	Number of arrival flights with late N/S or S/N rerouting due to unexpected adverse weather or Airspace/RWY configuration change	Nb / time period
OBJ-0101-730	Reduce induced arrival delays over an Airport traffic flow	***Punctuality***	**KPI-0101-730**	Arrival delay vs schedule due to unexpected adverse weather or airspace configuration changes in the TMA	mn

Table 11: List of KPIs for Airport exercises

Objective Identifier	Objective	KPA	KPI Identifier	KPI	KPI unit
General Aviation Objectives & KPÏs					
OBJ-0206-110	Reduce extra fuel burn for a GA operator	***Efficiency*** (Fuel)	**KPI-0206-110**	Estimated fuel consumption increase due to unexpected adverse weather or airspace configuration changes	kg
OBJ-0206-210	Reduce extra cost for a GA operator	***Efficiency*** (Cost)	**KPI-0206-210**	Estimated cost increase due to unexpected adverse weather or airspace configuration changes	k€
OBJ-0206-310	Improve predictability of flights for a GA operator	***Predictability***	**KPI-0206-310D**	Departure delays due to unexpected adverse weather or airspace configuration changes	mn
			KPI-0206-310A	Arrival delays due to unexpected adverse weather or airspace configuration changes	mn
OBJ-0101-610	Improve flight safety in GA operations	***Safety***	**KPI-0206-610**	Duration of flight encounter with unexpected adverse weather	mn

Table 12: List of KPIs for General Aviation exercises

Benefit mechanisms of MET in SWIM Master Class

The SWIM Master Class 2015 benefits are expected in term of visibility and advertisement of the work done in WP11.2

Benefit mechanisms of MET in SWIM Global Demo

The SWIM Global Demo benefits are expected in term of publicity and advertisement of the work done in WP11.2 (enhanced MET prototypes distributed by MET-GATE).

2.2.3 Summary of Validation Objectives and success criteria

WP11.2 does not validate its services, it only verifies them. The role of WP11.2 is to support the validation exercises using MET, listed at the beginning of Chapter 2, in achieving their objectives. The MET service prototypes are developed and verified based on end user's requirements. However, it is the end user's responsibility to choose which MET services are selected, and how they are used. The validation scenarios which have connections to MET contributions are listed as expressed in Validation Plans of each exercise. If for an exercise the Validation Objective Status is "OK", WP11.2 assumes, the selected MET Service provision is "OK" as well (even though this hasn't been confirmed). A Validation Objective Status not having been assigned the status "OK", might have been caused by inappropriate selection, use, or performance of MET Services, or by something else, and WP11.2 would be happy to assist addressing the issue concerning MET Services. In case WP11.2 concludes that MET Services have not been the cause of the issue, this conclusion is clearly indicated (by "OK") per validation exercise objective.

2.2.4 Summary of Validation Scenarios

MET Scenarios in VP513

The applicable high level validation scenarios are listed below. Scenarios are judged to belong to the categorisation "normally used airports" in the Airport utilization scenarios category. The validation exercises will be executed during winter conditions; hence the Meteorological conditions scenarios "Icing conditions" and "Precipitation". [6]

Identifier	SCN-06.02-VALS-MET1.0003
Scenario	Icing Conditions
Status	<In Progress>

Identifier	SCN-06.02-VALS-MET1.0006
Scenario	Precipitation
Status	<In Progress>

Table 13: Validation Scenarios of 513

MET Scenarios in VP700

Two VP700 scenarios are MET-related. The first scenario describes the implementation of a STAM horizontal rerouting due to overload detection. In this scenario, the flow manager has to deal with the detection of an area of severe turbulence crossing the proposed route. The second scenario describes the impacts on the capacity when clear-air-turbulence has been reported in a given sector above a given flight level.

Identifier	SCN-07.06.01-VALP-0700.130
Scenario	STAM Horizontal Rerouting impacted by Significant WX
Status	<In Progress>

[SCN]

Identifier	SCN-07.06.01-VALP-0700.140
Scenario	Significant WX impacts Capacity- FLCAP STAM
Status	<In Progress>

Table 14: Validation Scenarios of 700

MET Scenarios in VP669

The following 3 scenarios are used in the VP-669 validation exercises as described in the VALP [33]:

- a general validation of the available MET information
- a validation of the MET information provided during technical problems and unavailable forecasts
- testing the adjustability of thresholds

Identifier	SCN-06.05.05-VALP-0001
Scenario #1	24 hours of operation will be simulated (fast-time simulation). During this time several weather phenomena (e.g. thunderstorm, turning wind directions, heavy rain, etc.) will be simulated. The participants will - if an alarm is raised - analyse the weather situation with the HMI of WISADS. On the other hand it will be checked, whether the weather data is available for other systems in the SWIM-network.
Identifier	SCN-06.05.05-VALP-0002
Scenario #2	Under the assumption that several weather sensors or the connection to the weather forecast are malfunctioning, the behaviour of the technical system is tested.
Identifier	SCN-06.05.05-VALP-0003
Scenario #3	In this scenario several exercises will be performed. The main goal is to validate the possibilities of configuring the thresholds.

Table 15: P6.5.5 scenarios concerning MET and used in EXE 669

A meteorological data archive has been established to ensure weather scenarios are available for the validation exercise execution (real-time simulation). WP11.2 provided deterministic numerical weather prediction (NWP) data as well as ensemble NWP data to enable probabilistic statements. WP11.2 also provided Mode-S EHS MET data including temperature profiles to be used for the validation campaign.

The Requirements Coverage table entries related to WP11.2 are summarized in Appendix B.

MET Scenarios in VP757

For VP757 the following three scenarios have been selected out of the 5 employed for the VP013 validation exercise:

EXE-06.03.01-VALP-757.001	In validation exercise #1 an airport faces a capacity constrained situation as a result of scheduled works on the apron. An external disruption then further reduces the departure flow, leading to congestion on the apron. This exercise will support the comparison for managing the situation with or without an APOC, focusing on the feasibility of the performance management concept
EXE-06.03.01-VALP-757.002	In validation exercise #2 an airport is faced with a heavy thunderstorm instead of a forcasted light thunderstorm. This adverse condition will affect the daily operation of all airport stakeholders. This exercise supports the comparison for managing the situation with or without an APOC, focusing on the feasibility of the performance management concept introduced in OFA05.01.01 OSED Edition 3
EXE-06.03.01-VALP-757.003	In validation exercise #3, a terminal will be evacuated due to an incident at the security control. The designated authorities stop operations at the security passages to Lounge 1 because a passenger has inadvertently walked away from security check with a suspicious bag. The authority informs the responsible entity of the situation by telephone. When the event occurs, the responsible security personnel stop all security control activities in the affected terminal, hence the available capacity drops to zero instantaneously. After the complete evacuation of the terminal and reaching an all-clear for the incident, the security controls are started again with full capacity. At this time all remaining waiting passengers need to be security checked.

Table 16: Validation Scenarios of 757 [14]

MET Scenarios in VP791

WP11.2 will generate and provide MET information relevant for Network related operations, Step 1. Twenty-five transatlantic flights will be selected and analysed in terms of actual route flown and actual fuel burnt. All flights will have been executed between 2015-02-12 14:00Z and 2015-02-14 19:00Z.

Scenario ID	Scenarios Description
SCN-11.01.05-VALP-0001.0100	Flight planning is performed with a single deterministic upper air weather database. The flight planning results based on the single deterministic upper air weather database do not provide any information about the probability and predictability of the weather for the given flight. Operational Context: Fixed • Flight date: 12th of February 2015 • Route structure of the 12th of February 2015 Used tools: • Sabre AirCentre Flight Plan Manager
SCN-11.01.05-VALP-0001.0200	Using the GEWF, the weather provider stakeholder determines that, at the given day, the weather situation is uncertain for a specific area and citypair. Operational Context: Fixed • Flight date: 12th of February 2015 • Route structure of the 12th of February 2015 Used tools: • Sabre AirCentre Flight Plan Manager
SCN-11.01.05-VALP-0001.0300	Using the GEWF, the weather provider stakeholder determines that, at the given day, the weather situation is certain for a specific area and citypair. Operational Context: Fixed • Flight date: 12th of February 2015 • Route structure of the 12th of February 2015 Used tools: • Sabre AirCentre Flight Plan Manager

Table 17: Validation Scenarios for 791[15]

MET Scenarios in VP811

Only the sub-exercise led by Thales is relevant.
Note the scenarios have been adjusted compared to the VALP. The following reflects this[23]:

Events:

Here are the events to be included into different scenarios in order to cover the objectives regarding the MET information function on EFB.

Events to be included

1. Selection of the uplinked weather layer on EFB
    a. Display of the uplinked weather layer on EFB

Content of scenarios

Several events were included per scenario.

During one session (7h with the same flight crew), were played:
- 1 scenario from flight preparation to end of flight, whose focus was on the use of all available MET information (METAR, TAF, icing, convection, Clear Air Turbulence, MET parameters around the airport)
- 1 scenario in CRZ phase, whose focus was on convection information
- 1 scenario in CRZ phase, whose focus was on Clear Air Turbulence information

In Flight Preparation phase: there will be reception out-board of MET info on EFB.
In CRZ phase: there will be reception on-board of MET info on EFB.

Flight scenarios were based on autopilot flying to allow full attention to the checked system.
The following conditions are expected to be tested, either individually or simultaneously:

For the "Meteorological information on EFB for En Route" function :

- o Phenomena that were evaluated: METAR, TAF, Clear Air Turbulence, convection, Icing, MET parameter around the airport
- o Several type of severity
- o Phenomena encounter with FPLN or not (in 4D)

The applicable high level validation scenarios are listed below.

Identifier	SCN-09.48-VALP-THA1.0001
Scenario	During flight preparation, Get and Check significant weather along Flight plan thanks to CAT, Icing and Convection.

Identifier	SCN-09.48-VALP-THA1.0002
Scenario	During flight preparation, Get and Check significant weather at FPLN airports : departure, destinations, alternates thanks to : METAR TAF

Identifier	SCN-09.48-VALP-THA1.0003
Scenario	During flight preparation, Get weather for take off computation thanks to : METAR, Departure temperature, pressure, wind forecasts

Identifier	SCN-09.48-VALP-THA1.0004
Scenario	During flight execution, Get and Check significant weather along Flight plan thanks to CAT, Icing, Convection

Identifier	SCN-09.48-VALP-THA1.0005
Scenario	During flight execution, Check new FPLN trajectory to avoid significant weather along FPLN thanks to : Convection

Identifier	SCN-09.48-VALP-THA1.0006
Scenario	During flight execution, Check new FPLN trajectory to avoid significant weather along FPLN thanks to : Convection

Identifier	SCN-09.48-VALP-THA1.0007
Scenario	During flight execution (descent phase), Check MET parameters to prepare the landing.

Table 18: Validation Scenarios of 811

2.2.5 Summary of Assumptions

MET has not be validated in isolation within exercises. Instead it is treated as an enabling component and the exercise results to not interrogate MET the performance of MET on its own. Exercises didn't cover all possible weather types. Assumptions concerning MET issues are described in the table below.

EXE n:o /LSD name	Description of Assumptions concerning MET contribution in EXE/LSD
513	Three DIW classes describe weather accurately enough for de-icing management purposes. Extreme weather conditions are disregarded from weather cases studied in EXE
700	As the assessment is planned through the means of passive shadow mode, non-nominal situations will not be assessed during the experiment; neither the performance assessment will be possible.
669	High-resolution deterministic and ensemble model forecast data, and downlinked Mode-S EHS data, timely available and sufficiently accurate to enhance airport collaborative decision making.
757	No assumptions are relevant to this exercise since no MET services have been provided other than standard METAR and TAF data provision.
791	Each GEWF member will be provisioned in the standard GRIB database format as upper air data is currently exchanged. 1.25° resolution wind speed wind direction temperature surface data max wind tropopause Forecast time [h] =6,9,12,18,21,24,27,30,36 FLs=50,100,125,180,240,270,300,320,340,370,390,450,530 GEWF members should be generated and transmitted not later than 2h after the legacy upper air database publication
811	The flight preparation phase will be performed out-board the cockpit environment, for instance on a typical engineer desk There will not be any surrounding traffic (and no radio communication shared with other traffic) There will not be any ATC and AOC simulation tool involved The simulation will not take into account MET events on the Aircraft model (wind / temp will have no impact on aircraft behaviour). The simulation of the visual environment will not take into account the MET phenomenon. Due to time constraints and as there is no need to evaluate the EFB functions during a full flight, several short scenarios will be performed especially in flight preparation and during cruise. The main avionics functions are provided as a supporting environment only: EFIS, FMS, AFS, and they will not interact with the EFB.

TOPLINK	Impact on ATM operations has been analysed, assuming the provision of weather observation and forecast on: - Convection & lightning impacts - Clear Air Turbulences (CAT) - In-flight icing - Winter conditions on the ground In addition, regulatory MET information (METAR, TAF, SIGMET) is also provided as background information.
SWIM Master Class	N/A
SWIM Global Demo	N/A

Table 19: Validation Assumptions

3 Conduct of Validation Exercises

3.1 Exercises Preparation

WP11.2 hoped to contribute to more exercises as MET has effects on many processes and operations developed in SESAR. Principally, there could have been many more exercises, which could benefit from improved utilisation of MET information. The late start of WP11 relative to the other SESAR works packages; complexity, budget and resources are the main reasons why only a limited number of exercises adopted enhanced MET information developed by WP11.2.

Some of the ATM procedures or technical systems were not yet at a mature enough level to be capable to use enhanced probabilistic MET information in their decision making procedures. There exists a need to continue a close cooperation between MET and ATM also in SESAR 2020 IR phase and use enhanced MET prototypes in the validations of that project.

Phases of preparation and execution of MET contribution followed more or less the steps:

1. WP11.2 received request for a MET contribution to validation EXE or WP11.2 found a potential project, which could benefit for MET (normal situation, specifically P11.2.1 actively worked to identify cases)
2. WP11.2 proposed MET content of MET contribution.
3. Few iterations carried out before the content of MET contribution was identified
4. ATM expressed the critical thresholds of MET parameters following the practices expressed in MET Detailed Operational Description (MET-DOD) [6]
5. WP11.2 prepared the MET information/products to be available in the EXEs in the form required.
6. Training of users of MET in EXE was organized as needed.
7. MET contribution executed as agreed.
8. The feedback and other information about the usability and level of quality of MET in EXE was analysed and conclusions made
9. Results are reported in that document from a MET point of view and in VALRs of each exercise in ATM point of view.

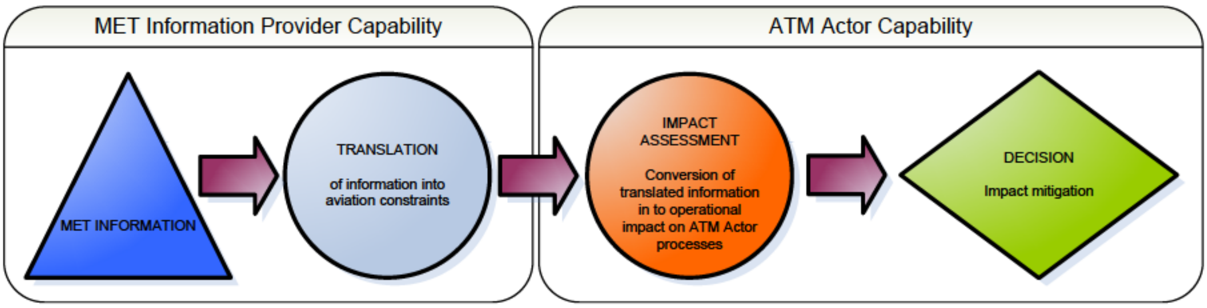

Figure 6 MET & ATM responsibilities in view of MET information provision and use [6]

3.2 Exercises Execution

Procedures are listed in the previous chapter. Below are expressed the dates of validation exercises and other demonstrations if known.

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
Exercise #513	De-icing Step 1 - V3	01/02/2015	31/03/2016	15/02/2015	30/06/2016
Exercise #700	Advanced Short Term ATFCM including Network Supervision and interface with Local Tools	29/02/2016	04/03/2016	Subsequently	At the moment of writing this report, analysis and VALR has not been yet finalized
Exercise #669	Close out Airport Integration through SWIM	01/03/2016	03/03/2016	04/03/2016	31/05/2016
Exercise #757	APOC Performance Monitoring and Management	February 2016	February 2016	Subsequently	At the moment of writing this report (early June 2016) analysis and the VALR had not yet been finalized.
Exercise #791	Use of Global ensemble wind forecasts (GEWF) within the flight planning process	01/09/2015	18/12/2015	01/10/2015	31/12/2015
Exercise #811	Assess the operational need and principles of cockpit integration for AIS/MET cockpit functions	23/01/2015	30/01/2015	Subsequently	02/06/2015
TOPLINK	n/a	4/06/2016	30/09/2016	subsequently	19/10/2016
SWIM Master Class	n/a	23/06/2015	10/12/2015	n/a	n/a
SWIM Global Demo	n/a	January 2016	09/06/2016	n/a	n/a

Table 20: Exercises execution/analysis dates

3.3 Deviations from the planned activities

In most cases the planning of MET contribution continued up to the starting date of Validation EXE, so normally no deviations for plans were needed. If there were deviations, they are mentioned in Chapter 6.

3.3.1 Deviations with respect to the Validation Strategy

N/A

3.3.2 Deviations with respect to the Validation Plan

EXE no /LSD name	Deviations of MET Contribution with respect to D35 VALP
513	A classification of DIW was modified during validation campaign. More details in chapter 6.1.2.3
700	None
669	None
757	Exercise has been conducted in correspondence with the EXE 757 VALP using the MET data provision of 11.2 – no deviations in this respect.
791	A revised linear correlation of planed fuel burn vs. actual fuel burn was undertaken to better reflect the spread of the ensembles forecasts.
811	Only Thales sub-exercise has to be considered and no deviations occurred
TOPLINK	None so far
SWIM Master Class	N/A (not mentioned in D35)
SWIM Global Demo	N/A (not mentioned in D35)

Table 21: Deviations of MET Contribution with respect to VALP

4 Exercises Results

4.1 Summary of Exercises Results

Taking into account the challenges to actually use and validate WP11.2 prototypes in validation exercises aimed at validating other, non-MET objectives, the results of MET contribution have been positive. During the validation exercises and other demonstrations reported in this document it became clear that through the use of enhanced MET products in future ATM, the predictability of business/mission trajectories will increase and the situational awareness of all aviation stakeholders will be enhanced as well as the flight efficiency. All this can be expected to have a positive effect on the safety, capacity and fuel efficiency of aviation.

Positive effects of enhanced MET to ATM and aviation itself can be seen in different phases of flights and different ATM operations. At a high level they are listed in the tables below (chapter 4). The reader is referred to chapter 6 for a more detailed overview.

Exercise number / LSD Name	Expected Meteorological outcomes	Results of Meteorological outcomes
513	Enhanced Winter Weather Information (WWI) supports de-icing management better than conventional ICAO products. Assess the usefulness of enhanced WWI to de-icing coordinators.	Enhanced winter weather improves weather forecast to de-icing management. De-icing time is dependent on weather. More accurate weather forecast influences positively to predictability of de-icing time. [11] Detailed case studies showed that using weather radar information as a part of enhanced winter weather improves the timing forecast of snow or sleet for the first 1-2 hours De-icing coordinators would be better served by enlarged weather information than only DIW value. [11]
700	The integration of MET in flow management techniques closed to the real time operations should improve pro-active decision making regarding the STAM concept. STAM measures should be better anticipated.	Having MET hazards forecast information supports the NMOC and local units in informed decision taking. It helps anticipate the sectors overload and identity adjacent sectors that may be used to download traffic.
669	Meteorological data archive containing weather scenarios for the validation exercise execution, with assimilated Mode-S EHS MET data including temperature profiles. The archive contains Deterministic as well as Ensemble Weather Prediction data, the latter enabling probabilistic Decision Support statements.	Predictability of both the Manage and Monitor Airport Performance services improved through the use of accurate MET information (including observations and forecast).

757	The validation exercise aimed to validate APOC Performance Monitoring and Management against three operational scenarios. The second of these scenarios involved a heavy thunderstorm (whereas only a light thunderstorm was forecasted).	No MET prototypes were involved in this exercise (only standard METAR/TAF data provision).
791	The MET data was to be used to compare live flights crossing the North Atlantic to ascertain if fuel and time improvements could be achieved with the new information available.	The validation project showed that the MET data can help to improve trajectory prediction and fuel reductions in flights when used in a consistent way.
811	Having improved MET information on-board should enhance crew situational awareness, flight safety and flight efficiency	The adequacy of the MET information superposed with Flight Plan and the A/C position was shown. The utility of the "Meteorological information on EFB for En Route" function to anticipate long term weather avoidance was demonstrate
TOPLINK	All results from TOPLINK exercises will be collected in October 2016	Initial results have clearly demonstrated significant reductions in flight cost and improvements to fuel efficiency and route/network predictability
SWIM Master Class	The customer could request and receive the MET data provided via the MET-GATE.	MET-GATE services were used in 3 innovative applications. EUMETNET EIG won the award in the category "Service" for best in class, demonstrating the significant benefits and maturity of the solutions developed
SWIM Global Demo	Global interoperability of European MET data with other participants	The interoperability of the MET-GATE services has been demonstrated in front of the global ATM community.

Table 22: Summary of Validation Exercises Results

4.1.1 Results on concept clarification

N/A

4.1.2 Results per KPA

All validation exercises are aiming to improve some Key Performance Areas relevant for that domain.
The connection between MET contributions delivered had a weaker or stronger influence on the KPAs depending on the exercise performed.
MET used in some of the exercises had been planned to support the KPAs at optimum level, while in some other exercises there could have been more sophisticated MET prototypes available or it may have been possible to develop a support tool to better achieve the desired KPAs.
In the table below the KPAs of each exercise are listed and it is described how MET contribution influences these.

Exercise number	KPAs	Description of MET influence for KPA
513	Predictability	The influence of the MET contribution could not be measure directly measured regarding predictability. Yet the connection

		between the accuracy of timing of snow, sleet, freezing rain and estimated de-icing time (EDIT) is straightforward. So it is evident that when accurate DIW forecast improves, the EDIT may also provide more accurate business/mission trajectory predictability of The amount of that improvement was not calculated in the exercise, as to achieve this in the validation the MET contribution itself would have had to be assessed.
700	Capacity Predictability	The MET information that was used in VP700 enabled identification of weather that could impact on the ATM network. By identifying these with a graphical displays there was a reduction in hotspots as traffic was diverted around hazardous weather ensuring better predictability of location in space and time of aircraft in busy areas of airspace.
669	Capacity Efficiency Predictability Environmental Sustainability Safety	The use of deterministic and ensemble NWP around the airport revealed that WISADS displays relevant weather data (e.g. tailwind information, thunderstorm, fog, snow) earlier, in a more comprehensible and usable format than METAR/TREND/TAF. Consequently this improves predictability and safety. The situational awareness of the local MET conditions enabled simulation of a generic airport stakeholder in order to propose relevant decisions, e.g. change runway configuration, positive effect of capacity.
757	Capacity	No MET prototypes were involved in this exercise (only standard METAR/TAF data provision). Nevertheless, the second scenario involved a heavy thunderstorm (whereas only a light thunderstorm was forecasted); it would be interesting to know the impact of this 'error' in the weather forecast on e.g. KPA capacity. The VALR of EXE757 is however not yet available at the time of writing this document.
791	Capacity Efficiency Environmental Sustainability Safety	The validation exercise demonstrated a potential increase in fuel efficiency by the creation of statistical confidence values for over burn due to upper air weather. The use of ensembles to predict flight tracks also has the benefit of improved environmental impacts from the use of less fuel and ensures the safe path of a flight as greater situational awareness of pilots and ATC to avoid dangerous weather. The difficulty to create a direct relation between the trip fuel confidence and fuel efficiency is the fact that extra fuel is the sole discretion of the pilot in command.
811	Efficiency	The use of EFB can ensure an aircrew's workload can be kept on a stable level by providing them with up-to-date valid en-route meteorological information on an EFB. By using the new functionality to manage several MET information types the flight crew can be sure that the most relevant information reaches the cockpit and provides for efficient flight routing.

Table 23: Summary or Results per KPA

The demonstration activities SWIM Master Class and SWIM Global Demonstration did not focus on a specific KPA. Their main purpose was the advertisement of the functionalities of the 4DWxCube – MET-GATE and the technical interoperability with ATM systems worldwide.

4.1.3 Results impacting regulation and standardisation initiatives

None directly, but this will be considered during deployment.

Ongoing and regular communications and coordination occurs as a matter of routine between the NMS's participating in SESAR, EUROCONTROL and regulating bodies of EASA and ICAO on matters affecting aviation meteorology.

4.2 Analysis of Exercises Results

Validation exercises WP11.2 supported by MET contribution were not planned for validating enhanced MET prototypes developed in WP11.2. Yet these exercises as well as Large Scale Demonstrations were used as an opportunity to demonstrate the benefits of enhanced MET information no future ATM. That arrangement was not optimum for studying the value of enhanced MET to ATM, but it was done at a level which was possible. Part of the analysis is still on-going in some exercises and LSDs.

4.2.1 Unexpected Behaviours/Results

In case of any unexpected behaviour or result existed, it is listed in table below.

EXE no /LSD name	**Unexpected Behaviours in the MET contribution**
513	None
700	None
669	None
757	None
791	None
811	None
TOPLINK	All results from TOPLINK exercises will be collected in September 2016
SWIM Master Class	None
SWIM Global Demo	None

Table 24: Unexpected behaviours of MET Contribution

4.3 Confidence in Results of Validation Exercises

4.3.1 Quality of Validation Exercises Results and Significance of Validation Exercises Results

The individual observations for each validation can be accepted to be accurate. Yet it should have been taken into account the limited time periods which exercises were conducted and the limited number of user opinions. It is not always possible to make general results from the limited number of opinions and weather scenarios experienced.

Most validation exercises and demonstrations had very short active time periods. When considering the effects of weather during real-time exercises/demonstrations, it may not be realistic to expect a wide variety of weather scenarios to be validated. To get comprehensive information about the effects of real weather on aviation, a longer period of study should be used compared with what was available in these exercises. Adverse weather by its nature infrequent; if effects of adverse weather are to be studied then it should be selected for the time of validation starting from the expected weather.

VP-513 managed to validate against its preferred weather type , in that the days of validation were chosen based on the weather forecasts.
To accommodate multiple adverse weather phenomena occurring in a short time period, recorded weather data were used in EXE 669. However, a disadvantage of such an approach is that the time resolution of the forecast cannot be changed, and the impact of an adverse weather event may be restricted to the single time slot in which the event occurs.

For exercises which utilised only a MET simulation, they were not validating a truly end-to-end process which included the generation of MET products and their delivery via MET-GATE.

5 Conclusions and recommendations

5.1 Conclusions

The various validations and demonstrations utilising MET information in SESAR1 have clearly shown the strong dependency all aspects of aviation have on weather and the vital role timely and accurate MET information plays in achieving optimum performance and predictability. The following paragraphs summarise these conclusions for each specific exercise or demonstration activity.

Experiences of the MET contribution to **VP513** indicates that by using enhanced winter weather prototype developed in WP11.2, the accuracy of de-icing weather type and specifically the timing of precipitation periods, will increase. Most benefits were to be gained 1-2 hours ahead which will improve the accuracy of estimated de-icing time, which in turn influences the predictability of the complete business/mission trajectory. The VP also found ways to further improve the winter weather prototype, such as to increase the ability to take into account the orographic and marine effects on winter precipitation. Using probability forecasts instead of deterministic would better describe the expected weather development possibilities more realistically and indicate the confidence or risk. Technically it is also possible to deliver probabilistic winter weather information; however it has not yet been demonstrated operationally. It is hoped this aspect of meteorological information will be better integrated in S2020 or SESAR Deployment.

The MET contribution to **VP700** involved provision of MET information for an ATC tool to monitor aircraft and identify potential hot spot locations.

- The tool allowed viewing MET forecasts together with ATFCM measures (regulations and STAM)
- The tool showed the different significant weather and the forecast evolution.
    - o Supported with the forecast, NMOC and local units have more knowledge to support an informed decision taking.
- The tool allowed to identify and mark the areas that required monitoring (WxAoI)
    - o Areas directly affected by the weather and adjacent areas that could be used to download traffic (diverted flows)

Experiences of MET the contribution to **VP669** indicates that

- Consolidated Mode-S data will be beneficial for enhancing the accuracy of local Airport MET products.
- Because of the complex evaluation and due to the responsibility of the human decision-making process, the MET information and probabilistic data, even if they are complex, are to be considered very necessary in order to take decisions on a forecast basis.
- Individual scenarios using individual ensemble members could be used instead of a probabilistic approach. This technique could provide a more robust 'what-if' scenario approach.
- The possibility to have forecast MET data may, in the future, allow integrated airport workload planning and improve the efficiency of the airport operations.

Based on experiences of the MET contribution to **VP757** no concrete conclusions can be made, since only standard METAR/TAF data has been provided in support of this exercise. It has demonstrated the need for S2020 projects considering APOC activities to better understand their dependency on meteorology and utilise the more comprehensive array of new MET solutions to maximise performance and safety.

Experiences of MET contribution to **VP791** indicate that ensemble wind forecasts can be utilised for trajectory planning tools. Their use can assist in ensuring efficient flight planning which can assist in safety and fuel economy by understanding the environment that an aircraft will pass through on its cruse phase of flight. While there were not sufficient flights to form a mathematically robust analysis the initial results were very encouraging.

Experiences of MET contribution to **VP811** indicate that:

- The validation itself had limitations. It did not use all relevant MET information that would be useful in the cockpit and there is significantly more that can be done to improve accessibility, display and understanding of the information (which had been outside the scope of WP11.02).
- The validation exercise confirmed the need for display of the flight plan and of the aircraft position, along with a display of MET phenomena and information, to improve the weather situational awareness along the flight plan and during flight.
- The involved Airspace users have also made a number of pertinent remarks and suggestions that should help improve the functional planning for the next phases of the project. Among the top requested improvement was to minimise the time to achieve a comprehensive briefing of the whole meteorological situation along the flight plan. In other words, enhancing the user interface, which was outside the scope of 11.02. A conclusion is that MET experts should have a role to play in designing the user interface.

Experiences of MET contribution in **SWIM Global Demo** shows that MET information can be disseminated in a globally interoperable way by using MET-GATE services, but it is a complex issue to tackle. Technical interoperability for new MET services has yet to be successfully proven. [37]

Experiences of MET contribution in **SWIM Master Class** indicates that MET information is key for many aspects of SESAR. It demonstrates that the solution proposed by WP11.2.2 is able to address the needs of various ATM applications.

Preliminary experiences of MET contribution to **TOPLINK** indicates that:

- The provision in real-time of MET hazards contours observation and forecast to ATC Flow Managers, Flight dispatchers, Pilots and Airport operators results in a qualitatively very significant added value for end-users. Moreover the consistency of the information between all stakeholders is greatly appreciated. Also the “seamless” character of MET information (in terms of geographical coverage), and its “generic” character (i.e. displayed per type of hazard, rather than per product or per MET Service Provider) is also greatly appreciated.
- The absence of information on the confidence level of the provided information limits the operational use of such information, and prevents end-users, at the current stage, making actual operational decisions based on this new information
- Live observations have resulted, in a large number of cases, in a good level of consistency between the MET information provided through the MET gate, and the actual weather situation. However some situations of divergence have been encountered.
- Some artefacts in the operational information delivered to end users is created, due to the finite sampling of MET information, especially over time (e.g. wrong prediction of the time/place when/where a flight trajectory will intersect a hazardous MET area), and along the vertical axis (e.g. which operational Flight Levels are impacted, and which ones are weather-free)
- Some types of information are currently not provided, and judged by end users of high interest as soon as available, such as:
  - Observation and forecast of MET parameters on all airports of interest for an Airline (main and alternates), beyond the display of METARs and TAFs
  - Forecast of visibility conditions on airports

Analysis of the results of MET contribution to these validation exercises and Large Scale Demonstrations show that the use of enhanced MET products in future ATM can bring significant added value for end users and has potential to increase the predictability of business/mission trajectory, improve situational awareness of all stakeholders, and improve flight efficiency. This could have a positive effect on the safety, capacity and fuel efficiency of aviation in Europe.

5.2 Recommendations

The high level recommendations stemming from all validation and demonstration activities undertaken by 11.02 can be summarised as follows:

a) MET considerations, dependencies and solutions need to be incorporated into operational project planning from their inception – it is very difficult to materially modify project premises and plans part way through their development.

   Recommend: for S2020, the SJU should consider a more forthright approach to encourage operational projects to include appropriate MET information services and to coordinate more effectively with MET experts to determine how this can be achieved.

b) While not a technical consideration, to enable the desirable technical innovations across aviation with the use of MET strong guidance from SJU towards operational projects which have a dependency on MET is essential; fostering a more comprehensive approach to solving ATM problems. This will avoid a tendency from some projects to concentrate on solving a 'pure' ATM issue without consideration of 'real-world' realities, such as adverse weather.

   Recommend: for S2020, the SJU should ensure MET expertise is embedded within those projects with a strong dependency and that addressing this dependency is not viewed as an "optional extra", but as a fundamental and essential consideration. Validations in S2020 should be at a level of maturity whereby more comprehensive end-to-end processes are demonstrated (encompassing the delivery of real-time MET information services).

c) The way in which MET information is physically used i.e. the interface or graphics employed by the end user, must be universally considered. This is also important from the perspective of demonstrating the capabilities of MET information services. A picture is a far more persuasive and effective tool than a data file, especially when trying to encourage more widespread consideration of the new MET tools or information that are available.

   Recommend: For all S2020 instances of MET information being used, SJU should ensure that attention be given to whether visualisation is required. An option to produce "generic" visualisation could be considered for P18.04, but specialist tailored applications would need to be addressed at user project level.

d) Validation exercises which encompassed MET information (with the exception of VP791), did not consider the overall performance gains achieved by the MET component of their exercise. In order to fully understand the dependency and CBA for MET in each project, there needs to be greater consideration of analysing this dependency in detail. MET has been verified in terms of meeting requirements, including accuracy, but further work is required to evaluate specific performance benefits to the end-to-end system as a result of integrating enhanced MET information services.

   Recommend: It would be helpful for validations in S2020 to analyse more closely, perhaps through 'what-if-scenarios", the role MET information has. In particular, information is required from validations on the performance benefit achieved from integrated MET information.

e) Specific resource needs to be assigned to provide operational projects with MET expertise to assist in designing their prototypes and corresponding validation exercises or demonstrations. In this way, solutions which encompass 'real-world' issues such as weather can be given prominence in a more realistic exercise. This will ensure solutions are not developed in 'silos', instead demonstrating more mature and comprehensive results that are ready for deployment.

   Recommend: For S2020, MET expertise should be available to operational projects and SJU need to ensure that MET solutions are included where relevant and not treated as an "optional extra". It is of particular importance to ensure that 11.02 prototypes are made available for integration and use within S2020 validations, through the inclusion of EUMETNET EIG and the participating National Meteorological Services (NMS).

Recommendations, specific to individual exercises and demonstrations are as follows:

Based on MET contribution to **VP513** it is recommended to develop ATM decision making procedures to use probabilistic forecast in close co-operation with MET service providers in SESAR2020 and

SESAR ER projects. It shall be mapped also other actors in Local, Sub regional and Network levels who would benefit from winter weather forecasts and apply appropriate products to their use to increase the runway throughout, flight efficiency and safety. Useful MET Winter Weather Products to aviation are:

- Local De-icing Index to main airport in Europe for de-icing management use
- Winter weather index to main airports in Europe for ATM use in all levels from local to Network
- Local runway state forecast for runway maintenance and Apron use.

The MET contribution to **VP700** was the provision of MET information into a visualisation tool used by ATC. The recommendations from the validation relate to the way that data is visualised in the tool (e.g. filtering by FL, or aircraft type, use of contours, inclusion of jet stream and SIGMET impact assessments) all of these weather types were provided by the MET-GATE and as indicated it is for the users to visualise the information appropriate to them.

Based on the MET contribution to **VP669** it is recommended that:

- To increase the communication and clarification of the necessary parameters for all scenarios in advance and for operational use
- During the simulation in the exercise for adverse weather conditions due to fog, it was detected that part of the necessary data (e.g. forecasted visibility, parameter adverse condition, all probabilities, though ensemble data were available) were unavailable and that the representation on time scales needed to be improved.
- To develop the display and use of probabilistic MET information.
- To enhance the units and scales for MET parameters such as wind speed, temperature and others. During the exercise it became evident that the display accuracy of some parameters was not suitable.
- It is recommended to place further emphasis on
    - Probabilistic adverse conditions forecast
    - Probabilistic Thunderstorm Forecast
    - Probabilistic LVP forecast
    - (Probabilistic) snow forecast
    - (Probabilistic) de-icing category

Based on the MET contribution to **VP757** no real recommendations can be made. Reason for this is that only standard METAR/TAF data had been used in this exercise.

Based on the MET contribution to **VP791** it is recommended that further research into GEWF is used with additional live flight trials (such as part of the V3 validation exercises) and a move towards a fully automated process will be of benefit. The long term implements to ensemble prediction, particularly in relation to vertical model levels available, will also assist in demonstrating the befits of ensemble trajectory prediction.

Based on the MET contribution to **VP811** it is recommended for the next phases to perform some evolutions of MET on EFB for ENROUTE functions to reach the identified validation objectives. The main efforts should focus on the improvement of the time for the user to get the awareness of the whole meteorological situation along the flight plan and the availability of all the functions with a good level of maturity.

Based on the MET contribution to **TOPLINK** it is recommended that, in order to enable actual decision-making processes, and to reach the targeted improvements on ATM-related KPIs:

- further improvements have to be implemented in the provision of MET hazard information (object contours), such as :
    - To ensure a ***seamless observation/nowcast/forecast*** horizon from ***0 to 3 hours*** (at least) , or even ***6 hours*** (desired) for all MET hazards products (Cb, CAT, Icing)
    - To improve the ***vertical resolution*** of MET hazards objects (possibly through data interpolation) to ensure that significant information is provided for each authorized Flight Level (i.e. at least ***1000 ft*** resolution)
    - To improve the ***time resolution*** of MET hazards objects (possibly through data interpolation) to avoid discontinuities and artefacts in the monitoring of weather conflicts with flight trajectories and alerts (i.e. typically 5 mn resolution)
- A better understanding and control of the validity of MET hazard information is required, namely:
    - In addition to the information itself, to provide e.g. a "***confidence index***" (e.g. 100% for an observation, and a value derived from probabilistic or ensemble information, for the forecast)
    - In order to "calibrate" this confidence index, to execute large scale ***calibration campaigns*** using e.g. aircraft /pilot observations. Such campaign could be used to deliver a "***MET Data Quality***" label enabling the usage of such information into ATM decision–making processes.
- Some additional dedicated MET products should be provided to ATM and Airspace users such as:
    - Systematic provision of observation and forecast ***airport MET parameters*** on (virtually) all aerodromes used by commercial and general aviation
    - Observation and forecast of ***visibility conditions*** on the ground (mainly at airports)
    - Observation and forecast of ***contours of areas with high winds*** (en route , or in terminal airspace)
    - High resolution observation and nowcast of ***wind fields in terminal airspace***

Technical interoperability of MET-GATE as a way to disseminate MET information which has been successfully proven in **SWIM Master Class 2015** and **SWIM Global Demo** and it is recommended to use that in all future MET information dissemination.

In the future SESAR 2020 and SESAR Deployment Manager will be able to take forward the experiences from SESAR1. In particular from these validation projects there is clear need of probabilistic weather forecasts in future ATM procedures and tools and that any tools should be easy for users to understand and use in an operational environment. The uses of MET information have traditionally struggled to fully utilise weather information due to many reasons (e.g. not suitable for purpose, time scales, fundamental understanding, etc) this became evident in some of the Validation Projects where the impact of MET was either ignored or only OPMET data was requested. In SESAR2020 the SJU can assist the LVP planning by highlighting the transversal projects that can assist them having a complete and well rounded project.

It is recommended that additional work on MET prototypes for SESAR2020 be continued and that MET considerations should be made early on in any panning stages of a project. This will ensure continued customer engagement on the solutions required for the wide range of ATM users will cover the variation in requirements that they have.

These validation exercises indicate that MET contribution will be even more important in SESAR 2020 than it has been in SESAR 1. We should learn from the experiences of SESAR1, that MET should be involved in the projects in their early phase for effective validation planning in SESAR 2020.

6 Validation Exercises reports

MET contribution to validation exercises are described are described in this chapter.

The relevant information on TOPLINK is contained in sections 3-5 of the "Revised Demonstration Plans", deliverables LSD01.01-D02 and LSD02.06-D02, available on the SJU Extranet, and will not be repeated here.

The relevant information on the SWIM Master Class and SWIM Global Demo are contained in sections 3 to 5.

6.1 Validation Exercise #513; MET Contribution Report

Content from this section was primarily taken from D06.06.02-19 De-icing Validation Plan [10]and D06.06.02-20 De-icing Validation Report [11]

6.1.1 Exercise Scope and MET Contribution to support it

The aim of the experiment was to explore the effect of DIMT on the Air Transit View's (ATV) preparation for de-icing operations. Together with Airport Operations Data Base (AODB), DIMT provides de-icing information as de-icing time-stamps. P11.02.02 provides MET input to VP-513 by providing weather information and exploring the added value of refined weather parameters.

Classification of de-icing weather class (DIW) determines the time needed for individual plane to be de-iced. The significant impact of the weather at a specific time as well as the thresholds is based on information from de-icing coordinators at the Helsinki, Stockholm and Oslo airports. These three airports have similar thresholds, but they might be different elsewhere.

The significant weather conditions in DIW were snow, sleet, rain, freezing rain and frost formation. Freezing fog was omitted. Also, airplanes spending the night at the airport were not included in the study.

The dependency between weather and DIW is seen in the table below.

Effect on aircraft	DIW=3, severe	DIW=2, medium	DIW=1, light	DIW=0, no need for de-icing
Ice on plane	Freezing rain/drizzle			
Snow on plane	Heavy snow or sleet, visibility cased from precipitation below 2 km, deduced from weather radar information	Light/moderate snow or sleet, visibility cased from precipitation above 2 km, deduced from weather radar information		
Frost on plane			Risk for frost formation on the plane surface. Temperature between -3….+1 and humidity over 75%	
No remarkable				All other cases

contamination on plane				

Table 25: The DIW classes and meteorological thresholds used.

For the needs of validation exercise VP-513, the Finnish Meteorological Institute (FMI) collected a set of meteorological data to form an enhanced winter weather prototype for de-icing weather class observations and forecasts. DIW formed by that prototype is named as DIWe, enhanced De-Icing Weather class product. For comparison purposes, also De-Icing Weather class based on TAF forecast was created. It is named DIWt, De-Icing Weather class based on TAF forecast. DIWt forecasts DIW based purely on TAF forecast; no additional MET information is used.

Enhanced Winter Weather (DIWe) information used in the exercise is gathered from meteorological data as follows:

Occurrence and intensity of precipitation are based on weather radar images. The movement of precipitation areas (needed in DIW forecasts) is based on the AROME NWP wind at 850 hPa. AROME NWP is a computer program that calculates weather parameters such as pressure, temperature, wind, humidity and precipitation based on weather observations and physical equations. A computer calculates the parameters from the time of observation for every 6 hours for coming days. [19]

- The phase of precipitation (snow, sleet or rain) is based on METAR.
- Temperature (T) and Dew Point Temperature (Td) have been taken from METAR. The forecasted changes of T and Td are based on the AROME NWP model. The humidity forecast is based on T-Td difference.
- The movement of the precipitation area is not accurate, because the real movement does not always follow the AROME 850 hPa wind exactly. To reduce this uncertainty, all radar echoes inside the 60-degree sector around the direction of the wind are taken into account. Some uncertainty comes from the fact that the strength of the radar echoes can change with time, but this cannot be taken into account in deterministic forecasts like this one. However, for snowfall this development parameter is much smaller than e.g. for thunderstorms.

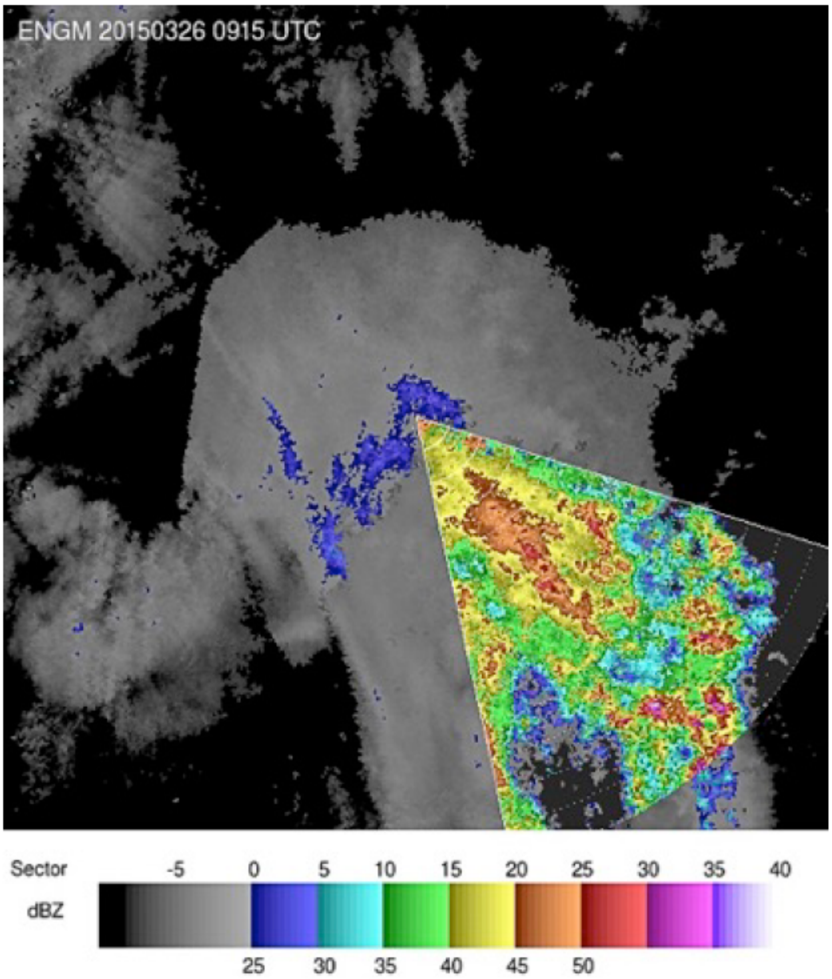

Figure 7 A weather radar image from a 60-degree sector around the steering wind (850 hPa wind). The echoes within the sector are included in the calculations of the probability of precipitation. The colours indicate the strength of the echoes in dBz, which in turn is related to the visibility in snowfall.

Forecast time	DIW will be forecasted if probability is over	One class lower DIW forecasted if probability is between
Observation	60%	20-59%
+15 min	60%	20-59%
+30 min	60%	20-59%
+45 min	60%	20-59%
+60 min	60%	20-59%
+75 min	60%	20-59%
+90 min	60%	20-59%
+105 min	60%	20-59%
+120 min	60%	20-59%
+135 min	60%	20-59%
+150 min	60%	20-59%

+165 min	60%	20-59%
+180 min	60%	20-59%

Table 26: The thresholds of probability distribution of DIW 2015 winter [11]

An example of probabilistic DIW values is shown in Table 27, which presents values calculated from the radar image in Figure 7.

9:15 UTC	time	DIW=0	DIW=2	DIW=3
obs	26/03/15	0.00	0.54	0.46
+15 min	26/03/15 09:30	0.00	1.00	0.00
+30 min	26/03/15 09:45	0.00	0.99	0.01
+45 min	26/03/15 10:00	0.00	0.81	0.19
+60 min	26/03/15 10:15	0.00	0.74	0.26
+75 min	26/03/15 10:30	0.00	0.76	0.24
+90 min	26/03/15 10:45	0.00	0.81	0.19
+105 min	26/03/15 11:00	0.01	0.94	0.05
+120 min	26/03/15 11:15	0.02	0.97	0.01
+135 min	26/03/15 11:30	0.08	0.89	0.03
+150 min	26/03/15 11:45	0.16	0.75	0.08
+165 min	26/03/15 12:00	0.35	0.58	0.07
+180 min	26/03/15 12:15	0.56	0.37	0.07

Table 27: Probabilistic DIWe values [11]

In that case:

- +60 min forecast DIW value is 2, because the probability of class 3 (26 %) is below 60 %, but the probability of class 2 (74 %) is above it.
- +180 min forecast DIW value is 1, because the sum of probabilities of class 3 and class 2 are below 60 % and the temperature and humidity show risk for frost.

6.1.2 Conduct of Validation Exercise

6.1.2.1 Preparations to MET contribution

The delivery method of the DIW observations and forecasts to the DIMT was agreed on with the Telespazio and P06.02.02. The message including the DIWe observation and +3 hour forecast at 15 min time steps delivered to Telespazio was delivered via internet connection. The product was updated every 15 minutes

Technically delivery was organized by simple REST type Web http-interface.

Web request (icaoId=Icao_Code) from Telespazio to FMI and Response from FMI Web-server to Telespazio was like (Timestamp;DIW value):

2015-03-03 04:00:00;1
2015-03-03 04:15:00;1
2015-03-03 04:30:00;1
2015-03-03 04:45:00;2
2015-03-03 05:00:00;2
2015-03-03 05:15:00;2
2015-03-03 05:30:00;3
2015-03-03 05:45:00;2
2015-03-03 06:00:00;1
2015-03-03 06:15:00;1
2015-03-03 06:30:00;1
2015-03-03 06:45:00;1
2015-03-03 07:00:00;0

The 4DWxCube prototype was not used because it was not available at the time.

6.1.2.2 MET contribution execution

In the reference scenario, de-icing coordinators used the MET services available normally at the airports. That meant mainly METAR observations and TAF forecasts were used. No specific De-Icing Weather (DIW) product was available.

In the solution scenario, de-icing coordinators used DIMT in de-icing management and DIMT includes the specific De-Icing Weather information. Principally DIMT took into account forecasted DIW, but it was also visible for de-icing coordinators.

The application that delivered the numerical values of DIWs to DIMT was tested together with Telespazio. Service started on 11 February 2015 and ended on 31 March 2016.

The MET information was to be provided to Helsinki and Stockholm. Helsinki was replaced by Oslo after the MET contribution plan had been published.

The winter 2014/2015 was uncommonly warm and during the days of the scheduled validation experiment the weather conditions requiring de-icing were few. Only some cases from Oslo could be used, and none from Stockholm. That is why the EXE continued during winter 2015/2016. This is the reason why the deliverables 11.02.02 D34 Validation Report Contributions in support of Release 3 & 4 were never published, but will be combined into 11.02.02 D36 Validation Report Contributions in support of Release 4 & 5, which was published 30/6/2016.

The feedback from de-icing personnel about DIW was scant. Task 11.02.02.03 did not receive any answers for the common questionnaire during winter 2014/2015; during 2015/2016 three answers were received from Stockholm.

6.1.2.3 Deviation from the planned activities

During the winter of 2014/2015 the de-icing coordinators stated that DIWe slightly underestimated DIW classes in situations with snow. Also, some confusion arose from value 1 forecasts in cases with a low probability of snow, because it indicated frost, not snow.

This was the reason why during the winter of 2015/2016 the “one class lower” classification wasn’t used and the thresholds of forecasted DIW classes were modified as presented in the table below:

Forecast time	DIW will be forecasted if probability is over
Observation	60%
+15 min	60%
+30 min	60%
+45 min	60%
+60 min	60%
+75 min	60%
+90 min	57,5%
+105 min	51,25%
+120 min	45%
+135 min	41,75%
+150 min	38,5%
+165 min	35,25%
+180 min	32%

Table 28: The thresholds of probability distribution of DIW 2016 winter

6.1.3 MET contribution Results

6.1.3.1 Summary of MET contribution Results

In this experiment the MET services themselves were not validated. Yet the DIWe quality was verified from February 2015 to March 2015. Values of DIWe was compared to DIWt. The quality indicator used here was a hit rate. A hit means that the forecasted class is the same as the observed one. The hit rate is the percentage of hits among all forecasts.

The services and their usefulness to De-icing management were investigated by discussing them with the users of DIMT.

The objective was to show that DIWe accuracy is better than DIWt accuracy. Improved accuracy of the de-icing weather type will directly lead to more accurate EDIT of each aircraft and so improve the predictability of de-Icing time.

Verification results of enhanced DIW forecasts

DIWe and DIWt were compared to each other. The DIW's were calculated for airports ENGM (Oslo Gardemoen) and ESSA Stockholm Arlanda for 1 February – 31 March 2015. 24 hours 7 days per week measurements are used in that verification study. The results are presented below.

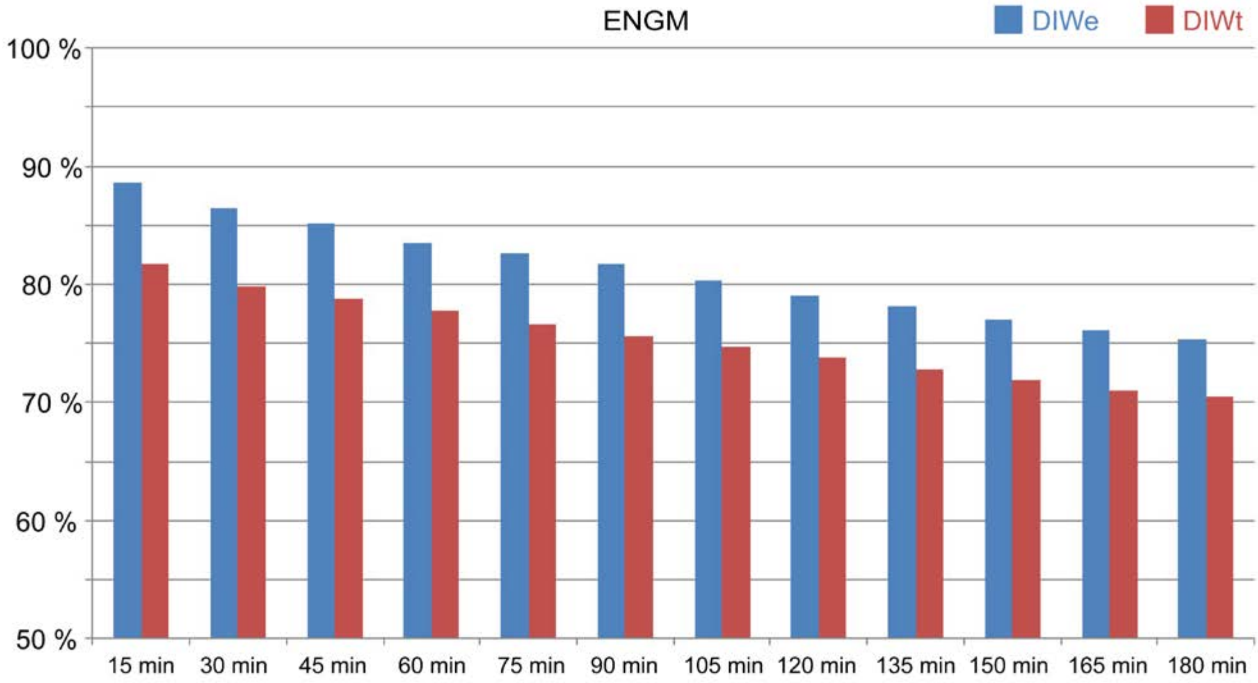

Figure 8 Hit rates for DIWe and DIWt at Oslo Gardemoen. 15 min-180min forecast time.

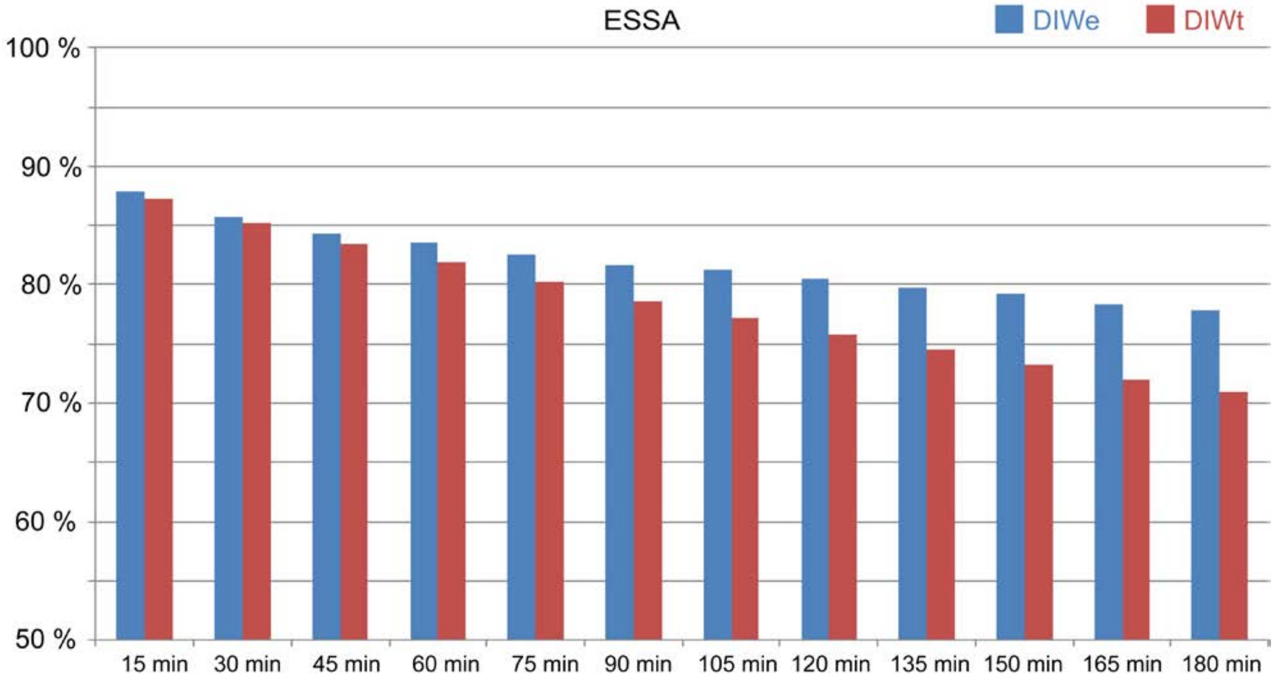

Figure 9 Hit rates for DIWe and DIWt at Stockholm Arlanda. 15 min-180min forecast time.

Based on the average values of DIWe and DIWt it can be concluded that DIWe improves the quality of the MET information. During verified period the class 0 (no-deicing need) cases dominates. To get more precise information about the quality DIWe in the days of de-icing weather exists, it was analysed case studies of the days of planned validations.

Case studies of individual days of validations

The level of DIWe accuracy was studied more precisely on each validation days. Summary of these results is:

- Using weather radar information improves the accuracy of DIWe especially for the first 1 – 2 hours.
- The strength of snow was underestimated during some of the heavy snow periods in Oslo. The orographic effect of orography on the precipitation amount should be taken better into account in the DIWe product.
- Snow showers developing over open sea may appear in radar images only shortly before they come to coastal airport.
- DIWe has challenges with the accurate forecasting of the phase of precipitation when that is fluctuating between rain-sleet-snow.
- DIWt is not suitable for de-icing management when precipitation strength varies.

User feedback

Some general comments were got after validation days. During January and February 2016 a meteorologist from SMHI was present in the three experiments and collected user feedback from a questionnaire. The results are presented below.

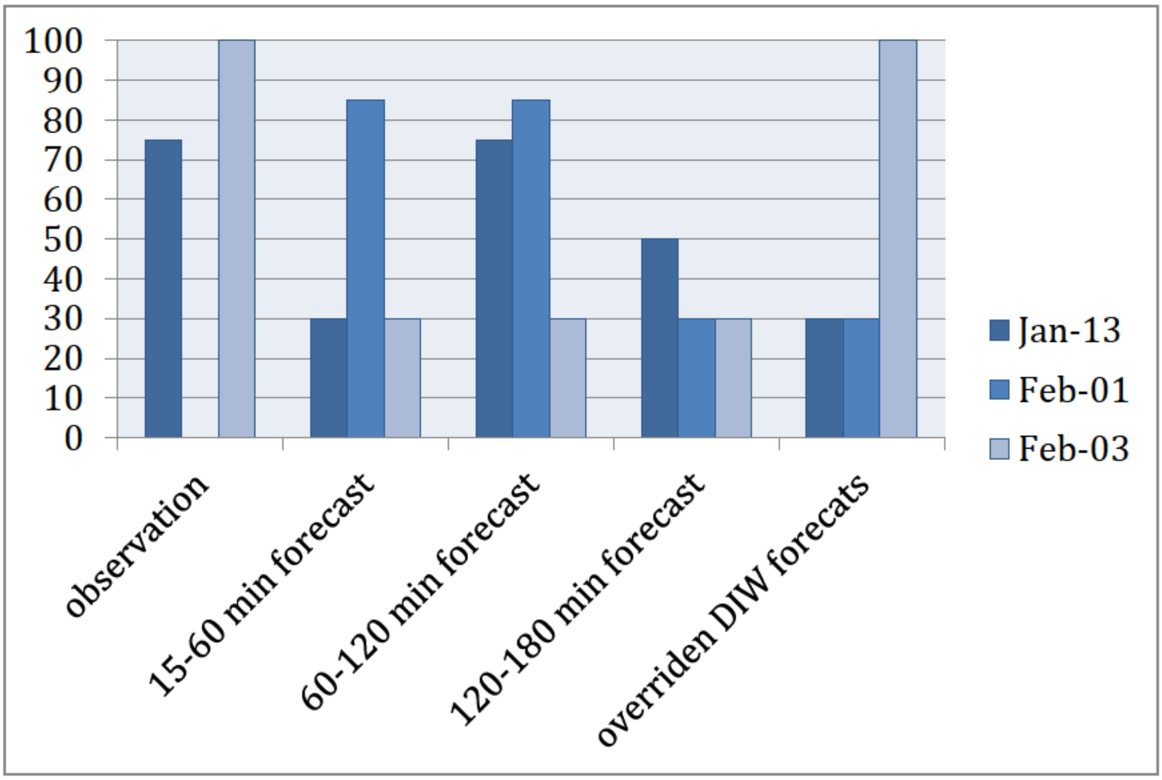

Figure 10 Users' opinion of the correctness of DIW observations and forecasts and the percentage of overridden DIWe forecasts during the validation days in Stockholm Arlanda in 2016.

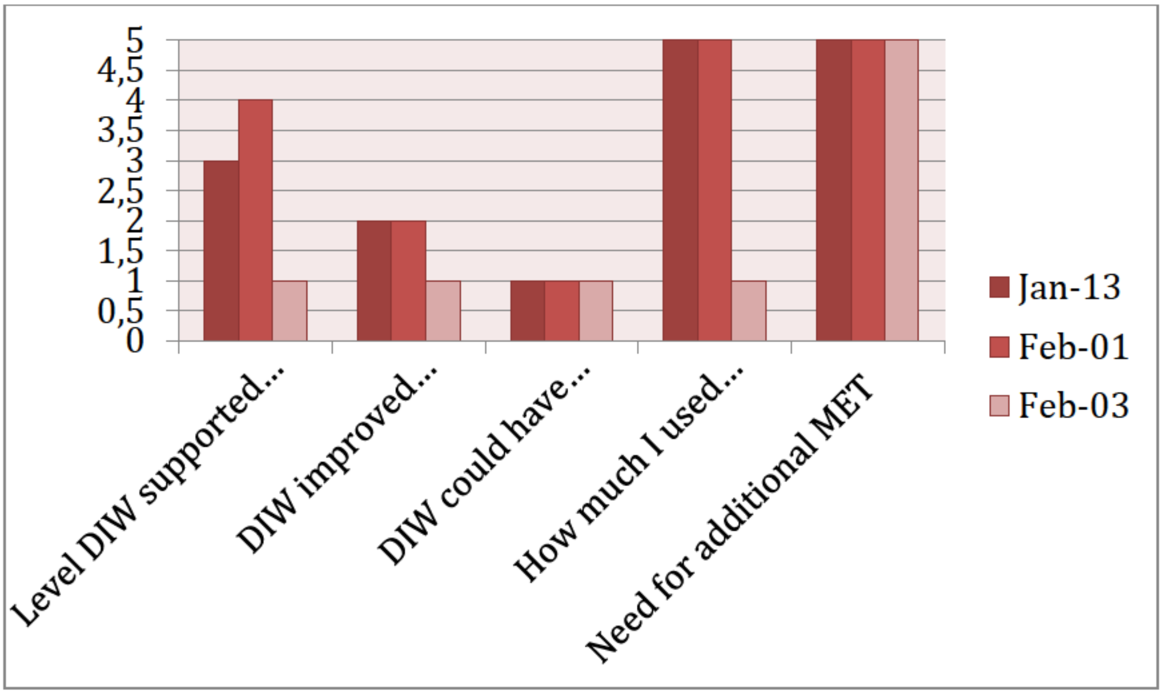

Figure 11 User opinion of the usefulness of DIW and how much additional MET was used or needed during 3 validation days in Stockholm Arlanda 2016. 1= not at all, 5= very much.

Because the number of answers is very limited strong conclusions could not be made.

It is clear DIW supports the de-icing management, but the product as it was used in exercise is not enough for de-icing coordinators, they need additional MET information too. Improvements in the weather services are desirable in the future.

Also, the users want to have additional information besides one numerical value of DIW. Providing additional weather parameters could work as a solution. It must be kept in mind that the DIWe planned to that exercise was machine-to-machine product, it was never planned to be used directly by de-icing coordinators.

Free comments revealed a need for more training on the use of the MET product. It was not clear to users how the DIWe worked. Also, it was concluded that the weather during the past few hours should be included in DIMT, so it would have shown the weather over whole ATV [11]

6.1.3.1.1 Results on concept clarification

N/A

6.1.3.1.2 Results per KPA

The influence of improvements of DIW to the predictability, when used enhanced winter weather service instead of ICAO Annex 3 services, couldn't measure directly in the exercise. Yet the connection between the accuracy of timing of snow, sleet, freezing rain and estimated de-icing time (EDIT) is extremely strong. So it is evident that when accuracy DIW forecast improves, the EDIT also get more accurate and that influences positively to predictability of business/mission trajectories of airplanes.

6.1.3.1.3 Results impacting regulation and standardisation initiatives

N/A

6.1.3.2 Analysis of MET contribution Results

DIWe and DIWt were compared to each other. The DIW's were calculated for airports ENGM (Oslo Gardemoen) and ESSA Stockholm Arlanda for 1 February – 31 March 2015. 24 hours, 7 day per week measurements were used in that verification study. Most of that time DIW was in class 0. Conclusions of verification is presented in Chapter 6.1.3.1

Also the usefulness of enhanced MET was investigated by making case studies of individual days, when validation has been ran or planned to be ran. Every individual forecast have been analysed during these days and reasons for the cases of DIW value forecasted to wrong class declared. Conclusions of that is presented in Chapter 6.1.3.1

After exercise feedback was requested and conclusions documented when then they had been recived. Answers to questionnaires were analysed. Results user feedback is presented in Chapter 6.1.3.1

6.1.3.2.1 Unexpected Behaviours/Results

None.

6.1.3.3 Confidence in Results of MET contribution

6.1.3.3.1 Quality of MET contribution Results

Amount of data used to study the benefits of enhanced MET to de-icing management is limited such that statistically significance is low. Yet the case studies show some of the properties of DIWe.

6.1.3.3.2 Significance of MET contribution Results

The amount of user opinions is limited such that strong general conclusions cannot be made. Also the verification time period could have been longer and amount of situations, when de-icing is needed more numerous to give more precise results and stronger conclusions.

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

The MET contribution to the experiment was found useful. FMI delivered the DIW forecast directly to DIMT. The system's technology worked as planned. DIMT used DIW for de-icing management, but de-icing coordinators also checked the DIW numerical values.

De-icing coordinators felt that one numerical value as the only weather product is not sufficient for them. They desired additional graphical information about the weather to see how the DIW values were reached.

It was suggested that past weather should also be included in DIW. This should be included in the DIMT operations. Close co-operation between MET and DIMT developers is needed for the DIW forecasting system and DIMT to work together seamlessly.

A two-month systematic verification in Stockholm and Oslo airports in winter 2015 showed that enhanced winter weather information predicts the de-icing weather class more accurately than TAF information.

Detailed case studies showed that using weather radar information as a part of enhanced winter weather improves the timing forecast of snow or sleet for the first 1-2 hours. The cases also revealed some limitations of the prototype DIWe:

- After two hours' forecasting time tools other than weather radar are needed to improve the DIWe forecast. Numerical Weather Prediction (NWP) products could be a solution.
- Thresholds of heavy/moderate snow are not always "correct". The DIWe used in this experiment was deterministic, but the nature of the forecast is probabilistic. Probabilistic DIWe forecasts can be developed, but that kind of information in DIMT would be processed differently from the current methods.
- It is not always possible to forecast the movement of radar echoes correctly when using NWP wind at a fixed level as a steering wind. Other methods for extrapolating the movements of radar echoes should be adopted.
- Mountains and open sea nearby affect the amount of precipitation, which may lead to wrong DIWe forecasts for airports near them. This issue needs further study.

6.1.4.2 Recommendations

Enhanced probabilistic Winter Weather Information can be created, but ATM can't at the moment use it in their decision-making procedures. By nature, interpretation of probabilistic forecasts is a challenge for human users, but natural for automatic decision making systems (e.g. with cost-loss approach). It would a beneficial area for applied research in SESAR 2020 project. To get successful results a close co-operation is essential.

In that exercise Enhanced Winter Weather information was used only for de-icing management. There exists many other procedures at local and network level, which will benefit that. These are worth more research in SESAR 2020 and in Exploratory Research.

There exist still possibilities improve Winter Weather forecasting capacity. Especially local effects need more attention. These are also areas of Exploratory Research projects.

6.2 Validation Exercise #700; MET Contribution Report

The Content from this section can primarily be gained from the and P13.02.03 VP 700 Validation Plan [12] and P07.06.01 VP 700 Validation Report [38]

6.2.1 Exercise Scope and MET Contribution to support it

The VP700 focuses on the application of Short Term ATFCM Measures (STAM).

Tactical traffic regulations as currently applied by the NM limit the traffic entering a sector through the systematic allocation of departure slots to all concerned flights, regardless of how they contribute to the expected overload.

This process, remaining valuable in case of major imbalance, turned out to be not optimal when the demand does only slightly exceed the available capacity.

Short Term ATFCM Measures (STAM) consist in smoothing the sector workload by reducing traffic peaks using short term measures such as small ground delay, flight level capping or small re-routings applied to a limited number of flights. Already this can make the traffic less complex for ATC.

The effective application of STAM requires an improved information quality for traffic forecast.

The contribution of WP11.2.2 to VP700 is to provide MET hazards forecasts to the NMOC (Network Management Operations Centre) in order to assist the process of STAM creation.

6.2.2 Conduct of Validation Exercise

6.2.2.1 Preparations to MET contribution

Clear-Air turbulence forecast, icing forecast and convection forecast have been delivered to the NOP through the MET-GATE SWIM services. X1.4, X1.5, X1.7 and the MET-GATE have been used in VP700.

MET information has been provided as gridded data for several flight levels. A processing has been applied in the MET-GATE to cover special needs of the NM in term of granularity (5km*5km).

The MET situation monitoring has been done through a standalone tool dynamically updated with significant weather coming from the 4DWxCube. It allowed the operator to estimate significant weather when applying STAM measures. The overall process is as follows:

- Significant weather phenomena will be displayed as “MET cubes” on the map
- In D-day NMOC identifies areas where eventual tactical measures (e.g. STAM measure) may be necessary and are or will be affected by significant weather.
- NMOC highlights those areas for monitoring (evolution of hotspot and Significant weather).
- Through the available process, NMOC seeks information on the local impact (potential capacity reduction within a certain time.
- NMOC may trigger the STAM implementation through the usual coordination process.

<u>Characteristics of the MET monitoring display:</u>

- Each significant phenomenon i.e. Turb/Con/Icing can be enable/disable
- Cubes symbols are depicted in yellow (light), orange (medium) and red (severe) on the map for each phenomena.
- Regulations and STAMs are shown as well as SIGMET data

A NM-MET tool display, as shown in Figure 12 has been prototyped in a secondary display, parallel to the NOP portal.

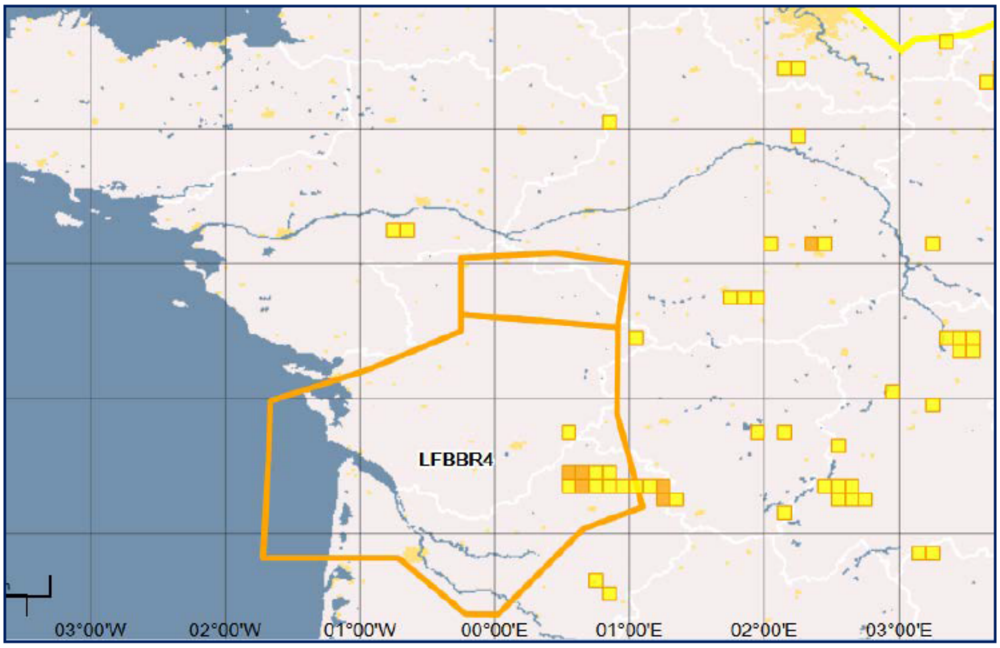

Figure 12 : NOP MET Display

6.2.2.2 MET contribution execution

EXE-13.02.03-VP-700 is a Passive Shadow Mode / Live Trial on STAM including Network Supervision and interface with local tools connected via SWIM (B2B)

The exercise took place from February 29 to March 4, 2016.
The schedule was the following (all times are in local Brussels, Paris, Rome time)

Date	Period	Activity
2016/02/29	10:00 – 13:00	VP700 Dry Run
2016/03/01	10:00 – 13:00	VP700 Dry Run
2016/03/02	07:00 – 12:30	Formal VP700 Session
2016/03/03	07:00 – 12:30	Formal VP700 Session
2016/03/04	07:00 – 12:30	Formal VP700 Session

Weather information has been used in two VP-700 validation scenarios as they have been developed in D47 VALP:

- STAM Horizontal Rerouting impacted by Significant WX (SCN-07.06.01-VALP-0700.0130)
- Significant WX impacts Capacity- FLCAP STAM (SCN-07.06.01-VALP-0700.0140)

Scenarios are described below.

STAM Horizontal Rerouting impacted by Significant WX

Identifier: SCN-07.06.01-VALP-0700.0130

This particular scenario describes actions taken when an overload is detected by a Local LTM and in its coordination for the implementation of an STAM horizontal rerouting with the affected LTM; the latter detects an impact due to weather considerations. In parallel NMOC performs their Network impact assessment, supported by the weather information, and can also identify the impact which is communicated to the Local LTM

Detection and negotiation (-2 hours)

LTM MUAC detects and creates a hotspot in MASxx. To resolve it MUAC creates first in proposal, STAM horizontal rerouting to offload MASxx. In its coordination with the affected LTM NATS, the latter detects an impact as the rerouted flights would cross an area of severe turbulences. In parallel, NMOC has got notified of the hotspot creation and subsequently of the creation in proposal of the STAM horizontal rerouting. NMOC performs the impact analysis of the proposed STAM in the Network, considering significant weather as well as EC and OC methods as usual. In the impact analysis NMOC also identifies the area of severe turbulences that would be crossed.

Implementation (- 1 hour)

LTM MUAC modifies the STAM rerouting to avoid the turbulences as indicated by NATS. The modified measure is checked against by NATS that agrees and finally the measure is promoted to be implemented.

Post- Implementation Monitoring and Observation

LTMs and NMOC monitor using the local tools and the NM weather display respectively the evolution of forecasted turbulence.

LTM and NMOC monitor the effectiveness of the implemented measure, in order to adjust, and optimise ATC protection and flight efficiencies and minimise delays

The NM weather application gets updated by weather observations by 4DwC. The display confirms the occurrence of the forecasted turbulence.

Significant WX impacts Capacity- FLCAP STAM

Identifier: SCN-07.06.01-VALP-0700.0140

This particular scenario describes actions taken when Clear Air Turbulence has been reported by the National MET Service Provider above FL290. A level cap measure is required to present an A/C into a different sector to that originally planned.

Monitoring (D-1 to D Day)

The LTM maintains a general picture of weather at D-1 and identifies clear air turbulence, which may result in a reduction in ATM capacity within their area of responsibility. On the D Day, the LTM informs NMOC (via information sharing on the NOP or phone call).

NMOC identifies the **reported air** turbulence on the NM weather application, creates a weather Area of Interest –WxAoI- and changes the contour of the WxAoI to green to indicate active monitoring.

Initiate (– 4 to 3 hours)

New weather forecast is published by 4DwC and updates the NM weather application which confirms the turbulence CAT above FL290. NMOC monitors the load on the affected area.

The LTM identifies at 4/3 hours a potential period of excessive demand/workload within the sector family group where capacity may be reduced due to this phenomena. Situation is monitored and measures are left until approximately 1.5 to 1 hour before EOBT to assess the maturing weather situation.

Negotiate (- 1.5 to 1 hour)

The LTM carries out an initial assessment and concludes to create a STAM level cap rerouting. NMOC gets notified that the STAM has been created in state proposal. After the M-CDM coordination with relevant actors (FM, ATC, and Airspace Users) the STAM measure is agreed.

Implement (- 1 hour to 30 minutes)

The STAM measure is promoted to implementation. NMOC gets notified that the STAM has been promoted to implementation.

LTM and NMOC monitor using the local tools and the NM weather display respectively the evolution of forecasted turbulence.

LTM and NMOC monitor the effectiveness of the implemented measure, in order to adjust, and optimise ATC protection and flight efficiencies and minimise delays.

Observation
The NM weather application gets updated by weather observations by 4DWxCube. The display confirms the occurrence of the forecasted turbulence.
LTM and NMOC monitor the effectiveness of the implemented measure

6.2.2.3 Deviation from the planned activities

No deviation related to MET contribution has been identified.

6.2.3 MET contribution Results

6.2.3.1 Summary of MET contribution Results

The following results have been obtained:

Validation Objective	Validation Objective Title	Success Criterion ID	Success Criterion Text	Metrics /Indicators	VP-700 results	Validation Status Objective
OBJ-07.06.01-VALP-MET1.7100	Operational feasibility of consideration of weather in the STAM process	CRT-07.06.01-VALP-MET1.7100	Positive operational feedbacks about WX dissemination and significant WX consideration when creating STAM proposals.	**S**MET **04** Operational feedbacks about WX dissemination	Positive Feedback: EHAMA04M regulation implemented due to weather on March 4th, 2016	**Okay**
		CRT-07.06.01-VALP-MET1.7101	4D WX cube graphical presentation increases weather awareness and provides enough granularities to detect if weather avoidance is considered/achieved when creating STAM	**SMET 01** Number of WXAoI created in the sector **SMET 02** Number of WXAoI converted into Hot Spots VP-700 **SMET 03** Elapsed time between the WXAoI creation and hotspot creation, when applies	Five WX Areas of Interest created during the trials: • LFEEKD2F • LFRRZIU • LFBBBDX • LFBBP3 • LFBBP12 This concept was modified and decided that hotspot are not created directly from the WAoI: - Network role as trial observer - Hotspot creation left to FMP;	**Partial** as NM could create WXAoIs but could not create Hotspots **SMET 02** and **SMET 03** could not be measured
OBJ-	Roles and	CRT-	Roles and	**SMET 05**	**Feedback was Positive**	**Okay**

07.06.01-VALP-MET1.7200	responsibility of WX management in STAM application	07.06.01-VALP-MET1.7200	responsibilities have been determined to be clear and consistent by all concerned actors. In particular NMOC role	Operational feedbacks about roles and responsibilities being clear and consistent		
OBJ-07.06.01-VALP-MET1.7300	Operational feasibility of consideration of weather in the STAM process	CRT-07.06.01-VALP-MET1.7300	Positive operational feedbacks about the feasibility of considering the impact of significant weather when creating/applying the STAM measure (RR or eventually delay or flight level capping) to resolve a hotspot.	**SMET 04** Operational feedbacks about WX integration	On March 3rd a Screen Shot shows how Convention, Turbulence and Icing Areas are dentified. Other view shows simultaneously the areas where imbalances are detected, the neighbouring areas and the forecasted significant weather in both Opportunities for Ground delay or level capping measures are detected	**Okay**
OBJ-07.06.01-VALP-MET1.7400	Impact of Weather information on Traffic Volume capacity	CRT-07.06.01-VALP-MET1.7400	Correspondence between the NMOC created monitored areas-WXAoIs - (sensitive to DCB imbalances and with significant weather forecasted) and related measures consequently implemented	**SMET 07** Duration of forecasted Weather phenomena versus actual duration	This concept was modified and decided that hotspot are not created directly from the WAoI **SMET 07 could not be measured**	**NOK**
		CRT-07.06.01-VALP-MET1.7401	Significant weather phenomena (turbulence / Convection / Icing) integrated with DCB improves the identification with more anticipation, of possible capacity shortfalls and imbalances.	**SMET 04** Operational feedbacks about WX integration	Refer to CRT-07.06.01-VALP-MET1.7300, **Positive Feedback**	**Okay**

Table 29 : Summary of Validation Exercises Results regarding MET in VP700

6.2.3.1.1 Results on concept clarification

N/A

6.2.3.1.2 Results per KPA

As stated in 07-06-01 VP700 VALR [38], The VP700 ECTL/DSNA sub-exercise did not foresee coverage of performance related objectives.

6.2.3.1.3 Results impacting regulation and standardisation initiatives

The results of the shadow mode trial shall impact neither the regulation, nor standardisation initiatives. However, as the STAM concept is part of the PCP package, a list of recommendations is provided for future evolution of both the concept and the tool (for the V3/V4 maturity phase).

6.2.3.2 Analysis of MET contribution Results

VP700 demonstrates the benefits of the MET integration in ATFCM tools especially when creating STAM proposals. The map functionality of the tool under validation allows viewing weather forecasts together with the areas subject to ATFCM measures and also has a functionality that allows viewing weather forecasts together with areas subject to ATFCM measures. . An example of this Map is shown below in Figure 13.

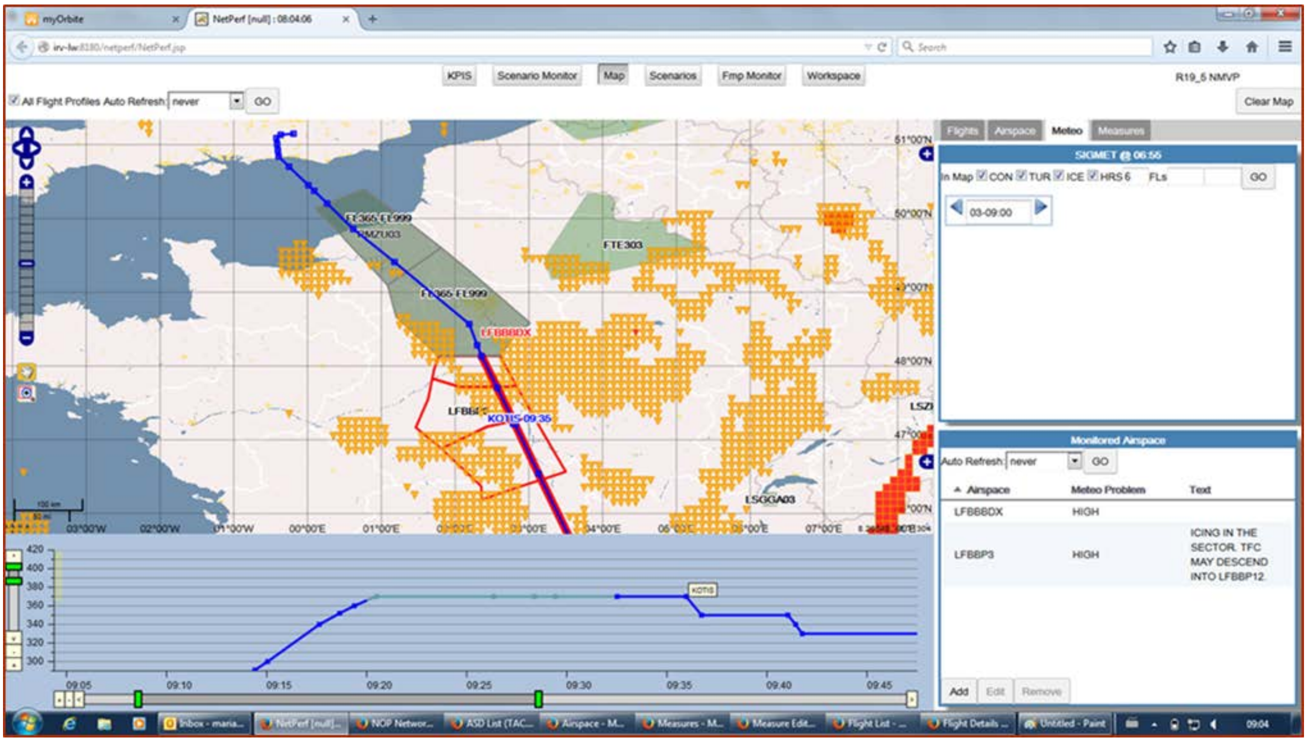

Figure 13 : Weather forecasts subject to short term planning ATFCM measures

According to the weather phenomena, the tool allows to mark an Area of Interest, for monitoring airspace where traffic may ask for vertical change.

This kind of displays may add information for the relevance of the most suitable traffic to be chosen for a given STAM. (RR or Flight Level capping) and its likelihood to face significant weather

In Figure 14, one sector, LFBBP3 is identified for monitoring; as due to the weather phenomena, traffic may ask for descending.

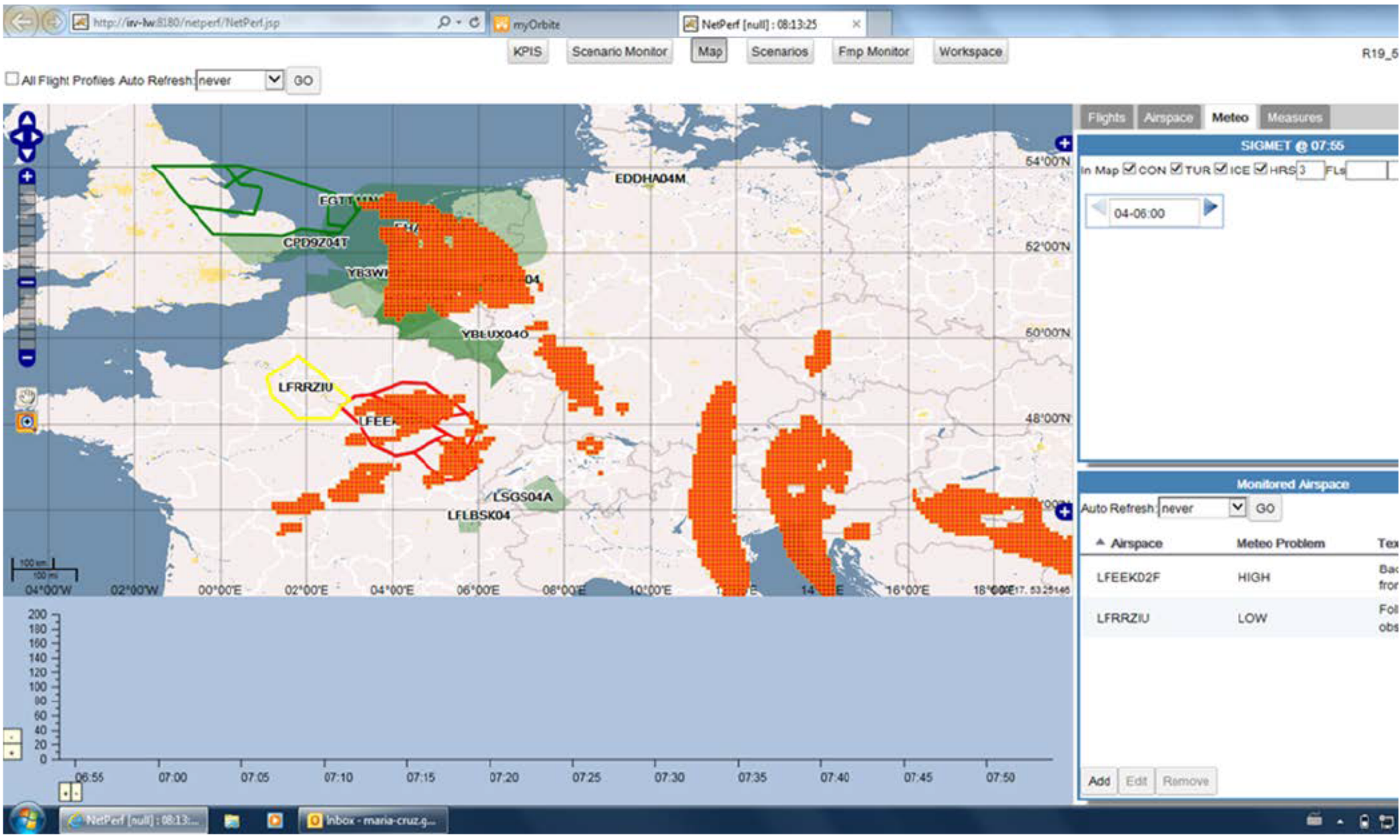

Figure 14 : WX Areas of Interest

Furthermore, the tool has a convention coding representation of some phenomena chosen for the validation, described in Table 30

The expected behaviour of flights affected by such conditions could be:

1. Avoid convective weather, both horizontally and vertically – go round the storm. It could imply an airborne decision and also potential CHG of FPL.
2. Avoid turbulence normally by changing level, more frequently by descending: Airborne decision.
3. Icing avoidance, normally by changeing level, asking for descent. Some type of aircrafts, turbo propellers are more sensitive to icing and more likely for in-flight descending.

Should an STAM measure put the selected traffic on a significant weather, there is some potential anticipation on the flight behaviour

Table 30 : representation of MET phenomena

Weather Phenomena	Geometric presentation	Weather impact	Colour coding
TURBULENCE	Squares	LOW	Yellow
CONVECTION	Triangle	MEDIUM	Orange
ICING	Inverted triangle	HIGH	Red

In VP700 exercise, FMPs did not share the same weather displays as NM. It has been identified as a drawback to clearly share roles and responsibilities, even is the feedback of NM has been positive on that topic.

6.2.3.3 Confidence in Results of MET contribution

The quantitative data is judged to be of reasonable quantity and good quality.

Considering the relatively small scope of the exercise, the level of statistical significance is rather limited.

6.2.4 Conclusions and recommendations

6.2.4.1 Conclusions

- The tool allowed viewing weather forecasts together with ATFCM measures (regulations and STAM)
- The tool showed the different significant weather and the forecast evolution.
    - Supported with the forecast, NMOC and local units have more knowledge to support an informed decision taking.
- The tool allowed to identify and mark the areas that required monitoring (WxAoI)
    - Areas directly affected by the weather and adjacent areas that could be used to download traffic (diverted flows)

6.2.4.2 Recommendations

In the exercise, the only MET information used to identify the sectors that would need to be overload is the hazards forecasts. A recommendation is to add more MET information in the calculation of the weather network impact assessment:

- Jet Streams phenomena
- SIGMET

A B2B service providing the weather network impact assessment would have an interest for control centres.

Another recommendation is to make the application more proactive and able to inform the operator (NMOC) of a network situation that according to one or multiple criteria deserves attention and possibly an action.

The alerts will consider several parameters contributing to traffic demand like density (entry counts or probabilistic counts), initial complexity (determined by flows or city-pairs), weather, reservation areas status with their different weights and the thresholds to compare to capacity.

From a MET perspective, the web services allows to user to configure a subscription accordingly to a severity level. The MET contribution to this recommendation would be to advertise this functionality and support the MET services users.

6.3 Validation Exercise #669; MET Contribution Report

The content for this section is derived from 06.03.01 EXE-669 Validation Plan [33] and 06.03.01 EXE-669 Validation Report [34].

6.3.1 Exercise Scope and MET Contribution to support it

Scope is described in Chapter 2.1

6.3.2 Conduct of Validation Exercise

6.3.2.1 Preparations to MET contribution

Use of Mode-S Enhanced surveillance data

In order to provide the best MET data, Mode-S EHS surveillance data was used. Determining the impact of the high quality of such MET data on EXE 669 is considered very complex, WP11.2 considered a sub-problem: quantify the impact of the use of Mode-S Enhanced surveillance data, assimilated in nowcasts, on trajectory prediction. At a later stage, this work could be continued by considering TP based Decision Support Systems, and then the EXE 669 situation.

Thus, in WP11.2, an initial comparison was made to determine to which extent using Mode-S EnHanced Surveillance (EHS) data in weather prediction affects flight time estimates produced by TP. The tests comprised part of inbound flights to Amsterdam Airport Schiphol, from FIR entry to IAF, and the impact of the predicted wind on ETO@IAF, the Estimated Time the aircraft flies Over the Initial Approach Fix. The test data represent times during the day at which there is a lot of traffic within the Schiphol area able to downlink Mode-S EHS data.

See Figure 15 for three descent trajectories, in red colour, in the Dutch FIR, one flight (no. 1) coming from the south over IAF “RIVER”, and two (no. 2, resp. no. 3) coming from the east over IAF “ARTIP”. Trajectories no. 1 and no. 2 represent standard arrival routes (STARs) actually used for inbound traffic to Schiphol.

Figure 15Three trajectories inbound to Schiphol, drawn on a map.

For each of the three trajectories, a comparison was made between ETO@IAF calculated by TP using standard meteorological forecast data, versus ETO@IAF when using nowcast enhanced with assimilated Mode-S surveillance data. The meteorological data had been supplied by KNMI for 10 different days in 2015. Each standard meteorological dataset contains six hourly updates, thus 4 updates per day, while each update contains seven deterministic predictions: one nowcast and six predictions for 3, 6, 9, 12, 18 and respectively 24 hours in the future. Each nowcast data set enhanced with assimilated Mode-S data contains hourly updates, totalling to 24 updates per day. Each update contains 55 predictions: for the first six hours, one per 10 minutes, and beyond six hours, one per hour. Figure 16 illustrates a typical difference between the two sets.

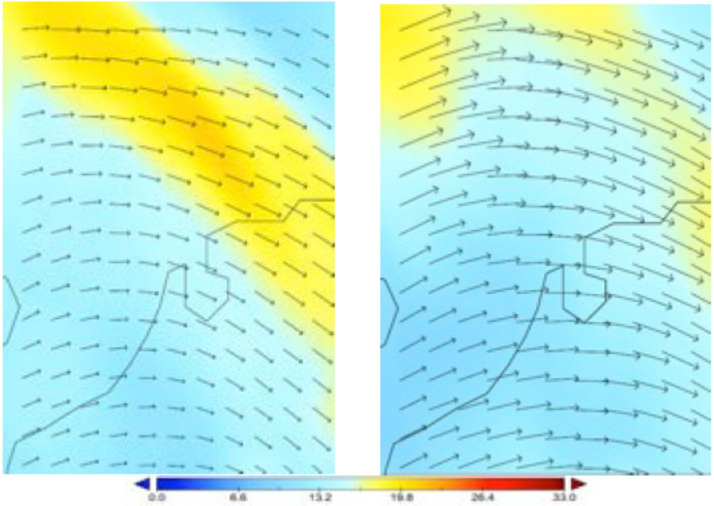

Figure 16 Wind vector and magnitude [m/s] at FL 100, 10-05-2015: Standard forecast 12:00Z (left), and Mode-S EHS nowcast 14:50Z (right).

The weather data sets were projected on a trajectory grid so they could be input to the BADA based NARSIM trajectory predictor. NARSIM is the NLR Air Traffic Management Research Simulator, BADA is the EUROCONTROL Base of Aircraft (derived performance) Data. The results from the tests were encouraging: the improvement in ETO@IAF due to the use of Mode-S EHS assimilated nowcast ranged from -10 seconds to +19 seconds, depending on the weather circumstances.
A typical example is given by the three trajectories and wind data from May 10th, 2015, indicated in Figure 15, and Figure 16. The TP is run for two flights entering the FIR at 14:50Z, and passing IAF about ten minutes later. Then the following meteorological data is available:

- Standard forecast valid from 12:00Z, and
- Mode-S EHS nowcast data valid from 14:50Z.

As the total flight duration is about ten minutes, and the next update of MET data is at time 15:00Z, no newer meteorological data could be used in the calculation. The difference in predicted flight times for an Airbus A320 using standard forecast and, respectively, Mode-S EHS nowcast are shown in Table 31.

Trajectory nr.	**Wind data sets (standard/nowcast)**	**Difference in flight time (sec)**
1	12:00Z / 14:50Z	5
2	12:00Z / 14:50Z	12
3	12:00Z / 14:50Z	19

Table 31: Difference in predicted flight time along the trajectories indicated in Figure 15, caused by the difference in weather data indicated in Figure 16.

As expected, the difference in predicted flight time increases if the difference in the forecast component along the trajectory (headwind/tailwind) increases on average. This relatively small difference in wind speed along trajectory no. 1, which is on a standard arrival route for traffic inbound to Schiphol, explains the relatively small difference of 5 seconds flight time along that trajectory. The difference of 12 seconds along trajectory 2, which is on another standard arrival route to Schiphol, is quite significant when used in a time-based environment, particularly if separation between aircraft is aimed to be kept around 30 seconds. Along the less frequently used trajectory no. 3, the difference of 19 seconds has been encountered. The research could be extended by considering more test situations, and producing statistical results.

To understand the difference of the validation requirement status of VALR 669 and the evaluation of the MET contribution the report of P15.04.09c confirms: “The COSMO-EPS and the Mode-S data have not been used due to the fact that the data came quite late with respect to the end of development tasks and there was not enough time to implement the whole processing chain up to alert and display in WISADS prior to the exercise. It should be noted, that the deterministic forecasts were sufficient to validate the V3 concept and that these data, especially the ensemble data, will be a vital ingredient for the future of impact assessment of weather on ATM processes.” [35]

6.3.2.2 MET contribution execution

Content of MET contribution is described in Chapter 2.2.4

6.3.2.3 Deviation from the planned activities

N/A

6.3.3 MET contribution Results

6.3.3.1 Summary of MET contribution Results

6.3.3.1.1 Results on concept clarification

High-resolution deterministic and ensemble model forecast data, including downlinked Mode-S EHS data, timely available and sufficiently accurate (e.g. updated every ten minutes) is beneficial to enhance airport collaborative decision making.

6.3.3.1.2 Results per KPA

The following conclusions are based on VALR 669 [34]:

Human performance

- It was concluded, that the MET information used in the solution scenarios is broader in scope compared to what is currently available, and it enables better planning. For instance, there was an enhancement of information sharing between APOC stakeholders derived from the MET alerts and warnings provided by decision support tools, and it also provided updated MET data for runway management tools. Therefore, the results indicate that the system tested in exercise 669 did improve *situational awareness* with respect to the status quo. The increase of situational awareness gives benefits also in terms of *Safety*.

Capacity

- The impact of the meteorological event on *capacity* appeared to be restricted to a single time slot where the event happened, and as a consequence it was not possible to show the event evolution.

Airport Efficiency

- It was concluded that the possibility to have forecast MET data can, in the future, allow integrated airport workload planning and improve the *efficiency* of the airport.

Punctuality

- The impact of the meteorological event on *punctuality* was restricted to a single time slot where the event happened, and consequently it was not possible to show the event evolution.

Departure Delay

- MET data provided for testing delay appeared to suffice.
    - Delay was observed in all tested weather conditions and measured as the difference between scheduled off-block time (SOBT) and estimated off-block time (EOBT) or actual off-bock time (AOBT), when the latter was available.

  - These delay indicators were shown on the HMI, and were applicable to the fog event scenario. Peak delay and average delay could be observed during the period where the system detected the fog condition.

Safety

- The validation exercise did not show a direct positive impact on safety, but it was demonstrated that the usage of ensemble weather forecasts provide a realistic picture of the uncertainty in weather which can be used to improve the situational awareness of pilots and ATC to avoid dangerous weather. The increase of situational awareness also gives benefits in terms of Safety.

6.3.3.1.3 Results impacting regulation and standardisation initiatives

The use of high-resolution deterministic and ensemble model forecast data and downlinked Mode-S EHS, is not covered by ICAO Annex 3 Appendix A[36].

6.3.3.2 Analysis of MET contribution Results

6.3.3.2.1 Views of key personnel

In addition to the MET service provision to EXE 669, the following key persons were interviewed on the MET support provided:

- Daniel Gavrila (Selex)
- Antonio Nuzzo (ENAV)
- Roberto Omenetto (ATC controller)
- Aniello Napolitano (Selex)

Question 1. *Is the Met provision as expected, required, and/or planned? if not, what aspects are missing?*

Answer: "In general, the Met provision is as expected. However, the level of uncertainty of the MET data forecast is missing. Further, the forecast MET data for the first hour of the exercise was missing. Then, the granularity is too low (1 hour interval). The SESAR required granularity is 10 minutes. Finally, RVR forecast data was missing."

Comment by WP11.2: Nowcast data, especially for convection and thunderstorms (X1.2 MET prototype) could have been provided. Only model forecasts had been requested. The SESAR required granularity according to the MET OSEDs depends on the specific MET parameter. Some MET elements are more stable (like air pressure) and a 10 minutes update has not been stated as required.

Question 2. *Could you describe the impact of the MET service provision on the current exercise outcome?*

Answer: "The impact of the MET service on the current exercise outcome is very big. Therefore the accuracy and reliability of the MET data service needs to be high."

Question 3. *Which aspects of the MET service provision would you prefer to see delivered in a similar exercise/operation in the future?*

Answer: "From a software engineering point of view, the MET data provided by WP11.2 was very difficult to handle. The data was formatted in GRIB file format, and the file size was very large (about 1 GB size). The GRIB format has a complex structure and is difficult to parse. We could parse the GRIB file only once to retrieve information, because the reading process is slow due to the badly designed API. Furthermore, the surface area covered by the MET data provision was too large. This had a negative impact on the software application performance as well. Therefore, we have the following suggestion with respect to MET data provision:

- Improve the API to read the GRIB file format
- Provide only MET data of the relevant area around the airport. The currently provided area was too large."

Comment by WP11.2: The surface area could have been easily decreased to just one point. The area has been agreed on with P15.04.09 c to enable a better calculation for the probabilities. The smaller the area, the lower the data volume would have been.

6.3.3.2.2 Unexpected Behaviours/Results

See Table 6 for the Expected outcome of MET Contribution to exercise 669. Regarding the MET services delivered to EXE 669, no unexpected behaviour or problem has occurred. Regarding the use of the MET services, some users noted (see the interview reported in section 6.3.3.2 that the level of uncertainty of the MET data forecast seemed to be missing. However, the level of uncertainty is represented by the spread of the MET ensemble members.

6.3.3.3 Confidence in Results of MET contribution

6.3.3.3.1 Quality of MET contribution Results

The exercise made use of pre-recorded MET data in the vicinity and at Braunschweig Airport, to ensure data concerning required weather phenomena would be available during the exercise. See section 2.2.4 Table 36 , for indications "**NOK**" mostly concerning missing local airport weather phenomena.

6.3.3.3.2 Significance of MET contribution Results

From MET point of view, the statistical significance of the MET contribution is very high, about 87% if counted by the number of requirements from Appendix D in VALR 669 involving MET data: 129 out of a total of 149. See also Table 36 and the interview reported thereafter in which the significance of the Met component was confirmed.

6.3.4 Conclusions and recommendations

6.3.4.1 Conclusions

See section 5.1. In addition, the GRIB interface is seen as very complex, and difficult to handle. This is an issue emerging from the interview reported after Table 36. Some validation exercises involving MET data uncertainty did not use the uncertainty information present in the MET ensemble data. Some local airport observation data were not available, due to the fact that pre-recorded MET data translated from another airport environment was used.

6.3.4.2 Recommendations

See section 5.2 In addition, it is recommended to make sure the system using the MET service is adequately able to input the required MET data. It would be best, if validation exercises involving MET data uncertainty would be redone, but it is anticipated difficult to isolate these from the larger test scenarios. The same can be said regarding the scenarios involving local airport MET data.

6.4 Validation Exercise #757; MET Contribution Report

Real-time validation exercise 757 aimed to demonstrate that within an APOC it is possible:

- For different stakeholders to maintain situational awareness of current and predicted airport performance based on the information at their disposal
- Accurately identify predicted severity levels so as to facilitate the decision making process
- Implement the changes agreed to manage and mitigate the deviation from the plan.
- Employ working methods which use the previously defined collaborative decision making process at the airport level and simultaneously increase the 'knowledge' available to the individual operational unit.

6.4.1 Exercise Scope and MET Contribution to support it

Real-time validation exercise 757 aimed to validate APOC Performance Monitoring and Management against three operational scenarios. These scenarios can be summarized as follows:

- EXE-06.03.01-VALP-757.001: an airport faces a capacity constrained situation as a result of scheduled works on the apron. An external disruption then further reduces the departure flow, leading to congestion on the apron.
- EXE-06.03.01-VALP-757.002: an airport is faced with a heavy thunderstorm instead of a forecasted light thunderstorm. This adverse condition will affect the daily operation of all airport stakeholders.
- EXE-06.03.01-VALP-757.003: a terminal will be evacuated due to an incident at the security control.

For all relevant operational scenarios, METAR and TAF data has been provided by WP11.2 for the required scenario date and required airfield. See [14] for further details.

6.4.2 Conduct of Validation Exercise

6.4.2.1 Preparations to MET contribution

Initially, also more detailed GRIB2 weather data grids were foreseen to be included in the exercise. These grids have been calculated and provided but were in the end not used in the exercise.

6.4.2.2 MET contribution execution

For all operational scenarios, METAR and TAF data has been provided by WP11.2 for the required scenario date and required airfield.

6.4.2.3 Deviation from the planned activities

None

6.4.3 MET contribution Results

6.4.3.1 Summary of MET contribution Results

For all operational scenarios, METAR and TAF data has been provided by WP11.2 for the required scenario date and required airfield.

6.4.3.1.1 Results on concept clarification

No MET prototypes were in the end involved in the validation exercise. Hence no results can be demonstrated.

6.4.3.1.2 Results per KPA

No MET prototypes were in the end involved in the validation exercise. Hence no results can be demonstrated per KPA.

6.4.3.1.3 Results impacting regulation and standardisation initiatives

No MET prototypes were in the end involved in the validation exercise. Hence no results can be demonstrated.

6.4.3.2 Analysis of MET contribution Results

No MET prototypes were in the end involved in the validation exercise – only METAR/TAF data has been provided. Analysis of MET contribution results is therefore irrelevant.

6.4.3.2.1 Unexpected Behaviours/Results

None.

6.4.3.3 Confidence in Results of MET contribution

6.4.3.3.1 Quality of MET contribution Results

No MET prototypes were in the end involved in the validation exercise. Hence not relevant.

6.4.3.3.2 Significance of MET contribution Results

No MET prototypes were in the end involved in the validation exercise. Hence not relevant.

6.4.4 Conclusions and recommendations

6.4.4.1 Conclusions

No MET prototypes were in the end involved in the validation exercise. Conclusions could only be drawn from the METAR/TAF data provided. Nevertheless, the second scenario involved a heavy thunderstorm (whereas only a light thunderstorm was forecasted); it would be interesting to know the impact of this 'error' in the weather forecast on overall APOC decision making processes and in particular also the impact on relevant KPAs (e.g. capacity). The VALR of EXE757 is however not yet available at the time of writing this document.

6.4.4.2 Recommendations

No MET prototypes were in the end involved in the validation exercise. Therefore, it makes no sense to formulate any recommendations.

6.5 Validation Exercise #791; MET Contribution Report

The content of this section is derived mainly from the Validation Plan and Validation Report from WP 11.01.05 D15 – EXE791 [20][21]

6.5.1 Exercise Scope and MET Contribution to support it

The validation exercise EXE-791 aimed to validate whether an ensemble of global upper air datasets can improve the flight planning process. The validation exercise reached maturity status V2 and included trajectory creation and flight planning utilizing global ensemble weather forecasts as well as a comparison against real flown flights.

Currently one deterministic upper air database published every six hours is used in the trajectory creation and flight plan calculation process. The aim is to integrate global ensemble weather forecasts into the regular trajectory optimization and flight planning process to move as closely as possible towards current operational methods to allow an early and efficient adaptation by computerized flight planning service providers.

6.5.2 Conduct of Validation Exercise

6.5.2.1 Preparations to MET contribution

The probabilistic weather forecasts are for global ensemble wind forecasts and represent a set of global upper air databases that are bundled into an ensemble. The data in GRIB2 format was accessed via MET Models and converted to have the correct resolution, and coverage.

This data was exchanged via legacy means (e.g. FTP). This validation exercise did not use SWIM compliant transport methods, but there was discussion on how such data can be exchanged in a SWIM environment (such as via the 4DWxCube in the future.

6.5.2.2 MET contribution execution

This validation exercise is run by WP11.1 with the contribution of WP11.2. Due to the unpredictable nature of weather a part of the exercise will be performed at specific days where the upper wind situation is considered uncertain in an area of interest (e.g.: North Atlantic).

WP11.2

- Performed GEWF model reliability validations
- Analysed whether a given day is considered certain or uncertain
- Prepared the GEWF files that are used in the validation for a given day
- Provided the GEWF to P11.1.5 via FTP or similar transportation protocols
- Assisted in determining a day and city pair where “the weather” was very uncertain.
- Provided GEWF data bases for the given days of the selected flights.
- Provided deterministic upper air data bases for the given days of the selected flights.

Joint activities with W11.1.5 included

- Selection of validation days based on weather uncertainty
- Computation of fuel burn and flight time distributions taking the trajectory ensembles as an input.
- Ensuring the recorded weather data and flight data are consistent (synchronized) in time and space dimensions.

The aim was that all measured upper air data are represented by at least one member of the GEWF, meaning that the deviation in upper air data in the deterministic flight plan lays within the extremes of at least one GEWF member

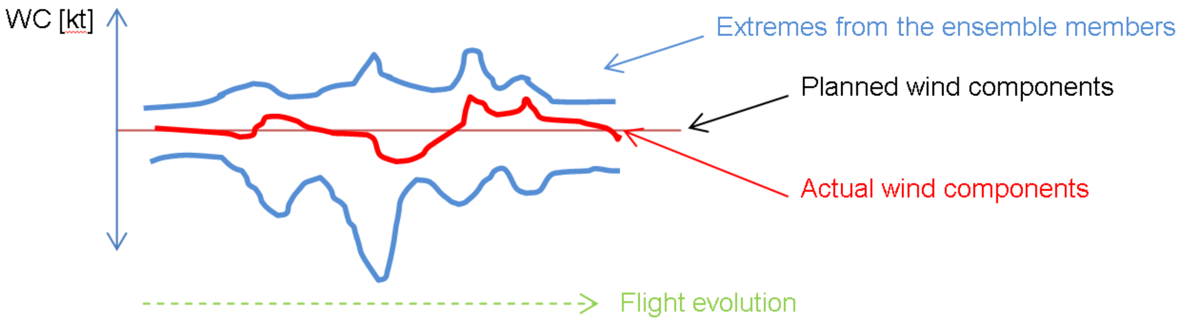

Figure 17 Example GEWF reliability ensemble spread

The forecast winds at e.g.: 250hPa (FL340) are compared with the observed winds at the same flight level from ACARS observational datasets in order to demonstrate the capability of the GEWFs to capture the spread of weather scenarios and thus underline the usefulness of the models for ATM applications. The derived probabilistic score used to demonstrate this is known as a Relative Operating Characteristic (ROC) curve. This curve, and the area below it (a score value ranging from 0.5 to 1, 1 being the best score possible), give an indication of the GEWF's ability to forecast the envelope of possible weather situations.

For two observational datasets (September 2014 and January 2015), all models gave scores in the range 0.80 to 0.95, thus illustrating an excellent level of model reliability.

For the sake of clarity, the reliability of the ACARS data precision is not assessed with this exercise.

6.5.2.3 Deviation from the planned activities

None

6.5.3 MET contribution Results

6.5.3.1 Summary of MET contribution Results

The validation exercise showed clear and expected results, but also highlighted aspects that need to be changed for a follow up exercise. It also unveiled that the regulation is not always clear enough to make conclusions and recommendations. Below a quick summary on the results and findings:

- The data for actual ZFW, actual fuel degradation factor, the flown route, actually used real cost index and actually used FMS cost index needs to be 100% accurate. This is to ensure that scatter due to inaccuracy of these parameters is reduced to the absolute minimum.
- A higher sample size should be considered in a follow up exercise
- The contingency fuel in current mode of operations is covering MET and ATC deviations without a definition how much of the contingency fuel is meant to cover which type of deviation. This is for a good reason though since a clear distinction between the two contingency fuels would most likely demand for a higher amount. A true comparison between the GEWF extra fuel and the contingency fuel currently computed can therefore not be made.
- One of the most interesting aspects that should be further analysed was that some of the most uncertain (highest spread in fuel and/or time) results were not in the anticipated areas. So a follow up exercise should also concentrate on scenario SCN-11.01.05-VALP-0001.0300.
- Using the GEWF increases the awareness of the uncertainty of e.g. the fuel burn estimate. Moreover, implementing decisions based on such a quantified uncertainty, e.g. choose the minimum extra fuel amount to avoid refuelling at an alternate airport, is expected to contribute to a statistically better predictable ATM system. Indeed, it is expected that even airlines willing to accept a risk of unforeseen refuelling in order to minimise fuel cost, will not increase this

risk once they receive a GEWF based estimate thereof. Thus, overall the use of GEWF will improve the predictability of the ATM system, even if only slightly.

The concept of trajectory ensembles (see section 3.2.3 in the validation plan EXE-791 Step1 V2 (BMT-MET D15 [20]) was assessed from the standpoint of feasibility, without using a large sample size. The reason for this is that each sample would require the execution of the trajectory to really qualify the results and this aspect of the validation exercise is dependent on the general model reliability results.

Most stable in this context means that only high level cruise portions with few step climbs and descents were considered. The reason for this is that climb and descent speeds are not captured in the POS reports and have a significant influence on fuel burn and time.

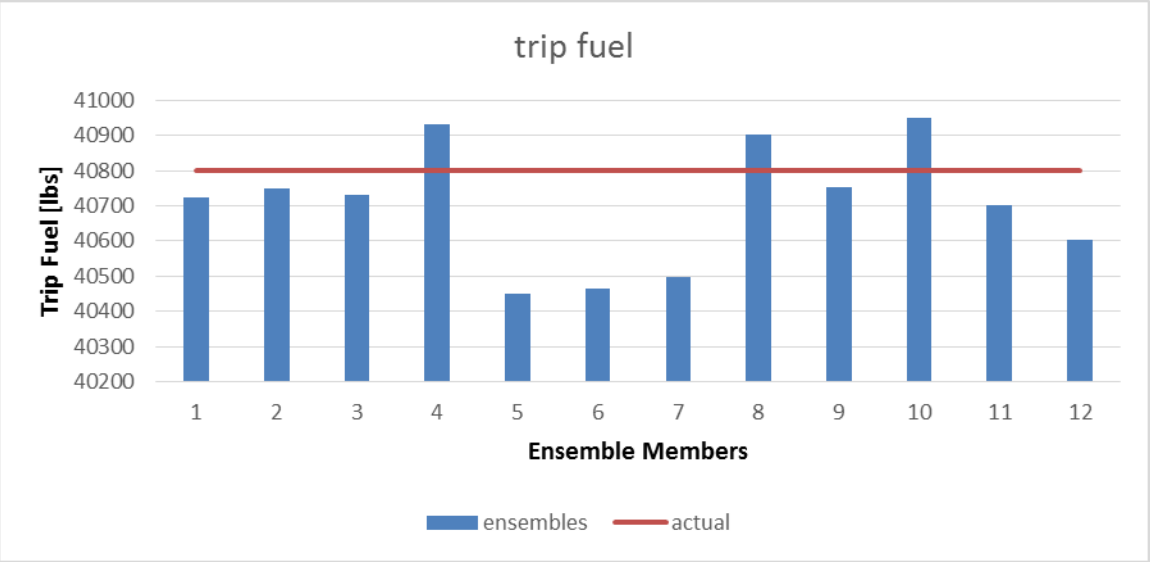

Figure 18 An example Trip Fuel Distribution for all 12 ensemble members

In order to compare the flight specific distributions, all the results of all flights are brought together into one chart. For each flight the mean trip fuel and trip time is computed as well as the 95 percentile. These values are compared against the trip fuel and trip time deviation between the actual trip fuel and trip time and the predictions performed with the first ensemble member which represents the deterministic weather database.

Comparing actual wind vs. planned wind and actual cruising speed vs. planned cruising speed (see pictures bellow) one can see that the difference is rather small.

Still the mean fuel burn difference of more than 1000lbs is very high, leading to the conclusion that the actual ZFW was much lower than the planned one.

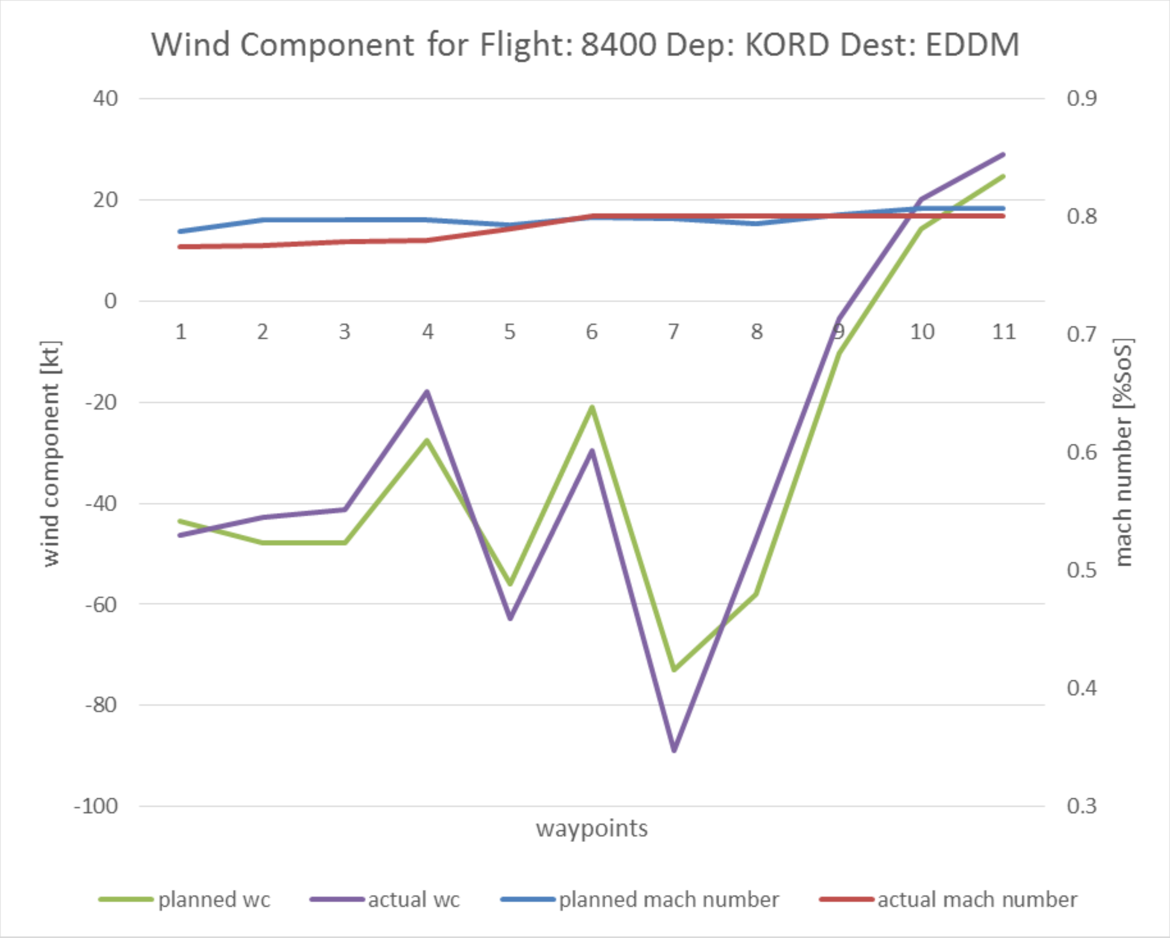

Figure 19 Planned and actual wind component on flight 8400

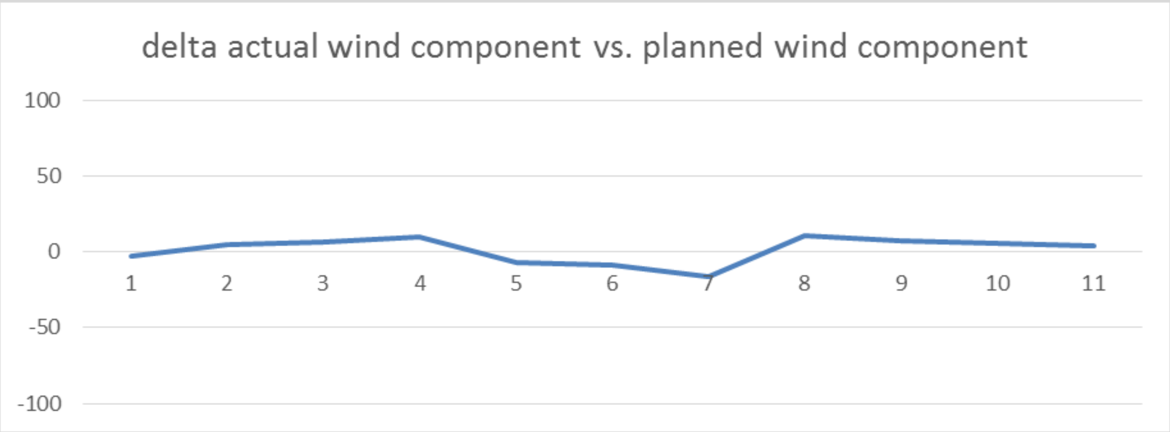

Figure 20 Delta between the planned and actual wind component on flight 8400

6.5.3.1.1 Validation results on concept clarification

N/A

6.5.3.1.2 Results per KPA

Capacity

- The validation exercise did not show that flight plans are getting more certain in the time dimension, but a correlation between the spread in trip time respectively trip fuel and the overtime respectively over burn could be identified. Due to the fact that trip time and trip fuel are related a lower spread in trip time (= higher time certainty) can be achieved by sacrificing fuel and vice versa a lower spread in fuel can be achieved by sacrificing time.

Fuel Efficiency

- The validation exercise demonstrated a potential increase in fuel efficiency by the creation of statistical confidence values for over burn due to upper air weather. The difficulty to create a direct relation between the trip fuel confidence and fuel efficiency is the fact that extra fuel is the sole discretion of the pilot in command.

Environmental Sustainability

- The environmental impact can be reduced if the extra fuel taken is reduced. Depending on the aircraft and load the fraction of the reduced extra fuel that can be saved varies between 10% and 20%. This factor is called transport factor. This means that 1000kg reduced extra fuel and a transport factor of 10%, saves 100kg of trip fuel for that flight. 900kg will still be in the tanks upon landing.
- In order to clearly say whether the use of GEWF in flight planning decrease the environmental impact, a larger sample of flights needs to be validated and pilots need to be included. The key is again that pilots trust and make use of the confidence value and overall pilot's added extra fuel is reduced, hence overall trip fuels are reduced, hence the environmental impact is reduced.

Safety

- The validation exercise did not show a direct positive impact on safety, but it was demonstrated that the usage of global ensemble weather forecasts provide a realistic picture of the uncertainty in weather which can be used to improve the situational awareness of pilots and ATC to avoid dangerous weather.

6.5.3.1.3 Results impacting regulation and standardisation initiatives

N/A

6.5.3.2 Analysis of MET contribution Results

In this experiment the MET services themselves were not validated. The validation exercise was conducted using real flown trajectory data and real upper air weather data; hence the operational significance is considered to be high. The results of the validation exercise furthermore support the assumptions made.

The results underline both an operational significance to predictability and efficiency aspects of trajectories as well as statistical significance, since not all KPAs can be measured directly. Especially when it comes to extra fuel mentality only a large sample of flights and utilizing live trials can show whether the use of GEWFs really make a significant difference.

Exercise ID	Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status

EXE-11.01.05-VP-791	OBJ-11.01.05-VALP-0001.0100	GEWF usability in the trajectory creation process	CRT-11.01.05-VALP-0001.0101	A linear correlation between the spread in fuel and time of the trajectory ensembles and the actually occurred fuel and time deviations is identified.	The exercise showed that the data corresponds to the anticipated linear correlation.	OK
	OBJ-11.01.05-VALP-0001.0200	GEWF usability in the flight plan calculation process	CRT-11.01.05-VALP-0001.0201	The correlation between fuel and time spread of the trajectory ensemble members and the fuel and time deviation of the flight plans provides accurate extra fuel computation results.	The exercise showed a correlation between the over burn and extra fuel determined by the ensembles.	OK
	OBJ-11.01.05-VALP-0001.0300	GEWF impact on fuel efficiency	CRT-11.01.05-VALP-0001.0301	The use of GEWF increases fuel efficiency compared to the Reference Scenario	The exercise showed that a better over burn prediction can be made hence extra fuel decisions can be improved.	OK
	OBJ-11.01.05-VALP-0001.0400	GEWF impact on predictability	CRT-11.01.05-VALP-0001.0401	The use of GEWF quantifies the predictability of weather on the trajectory as opposed to the Reference Scenario in which the predictability is unquantified.	The exercise showed that GEWFs help to quantify the predictability for a given situation. See section	Revised (OK)

Table 32: Summary of Validation Exercises Results [21]

6.5.3.2.1 Unexpected Behaviours/Results

N/A

6.5.3.3 Confidence in Results of MET contribution

6.5.3.3.1 Quality of MET contribution Results

Two topics have been identified that impact the quality of the results and should be considered and planned for in a follow-up exercise. The first one is more accurate and actual input parameters (related to Aircraft factors) and the second topic is the maximum wind data to be included in the GEWF.

The GEWF databases used in this exercise did not include the maximum wind parameter. The maximum wind parameter is an additional data point for each location in a GRIB upper air weather database. A typical GRIB database contains wind and temperature information for each location at standard FLs. In addition to that, the FL, wind speed and direction for each location is given which has the locally highest wind speed.

The usage of the MAX WIND parameter will increase the resolution of the provided wind data and improve the results.

The figures below shall explain the difference. Please be advised that the shown FLs are NOT the standard FLs and it also does not contain the wind direction. However it is considered sufficient to demonstrate the usage of the MAX WIND parameter.

Without the MAX WIND parameter a wind value lookup at FL320 would result in a value which is interpolated from the FL 300 and FL 350 value, hence something around 70. Using the MAX WIND parameter the wind lookup at FL 320 would result in correctly applying the predicted wind from that FL.

If the MAX WIND is located at a FL above or below the two nearest standard FLs from the planned cruising FL, then it has no influence on the planning.

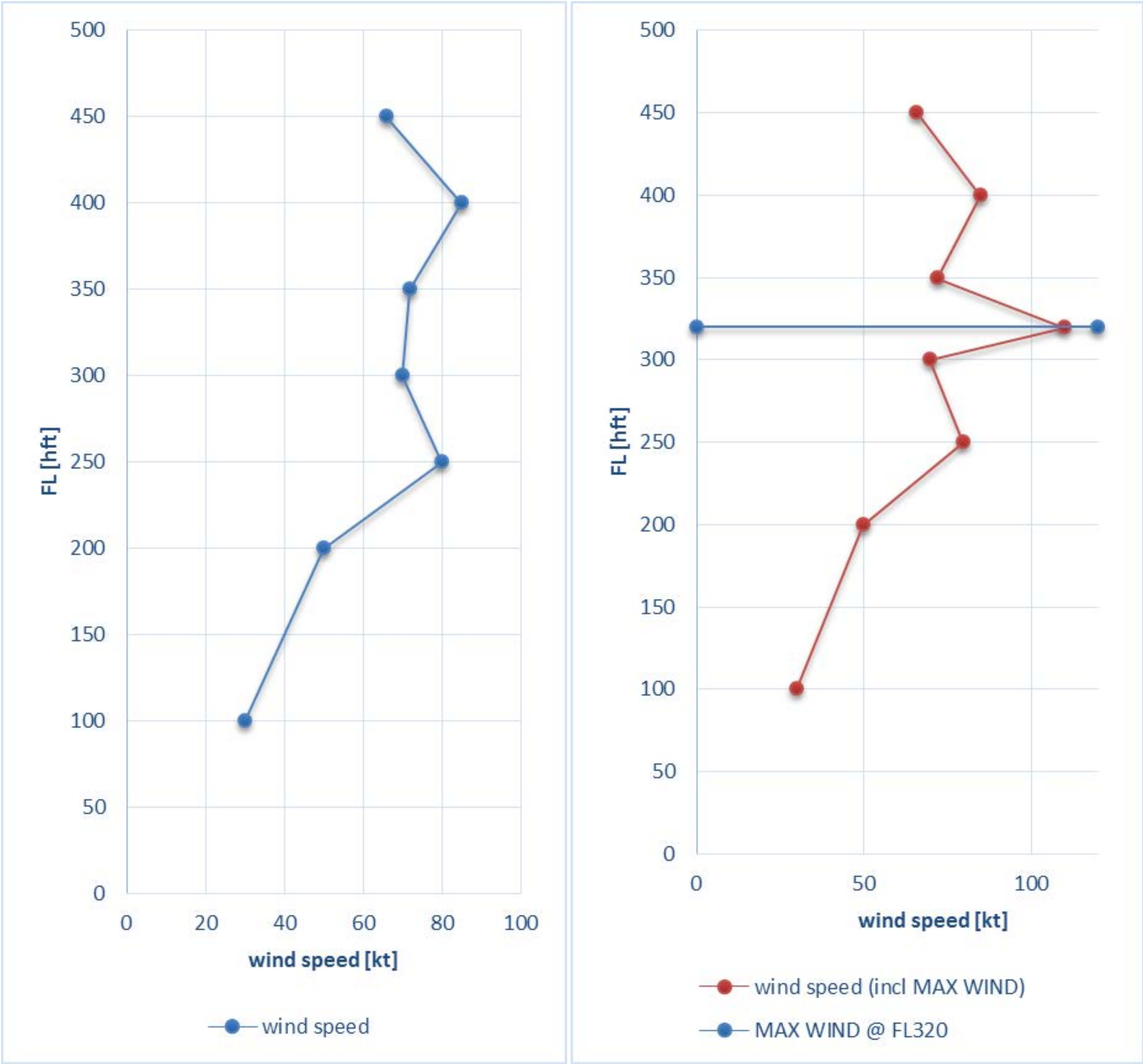

Figure 21 Wind speed without MAX WIND parameter (left). Wind speed with the MAX WIND parameter (right)

6.5.3.3.2 Significance of MET contribution Results

The validation exercise was conducted using real flown trajectory data and real upper air weather data; hence the operational significance is considered to be high. The results of the validation exercise furthermore support the assumptions made.

The results underline both an operational significance to predictability and efficiency aspects of trajectories as well as statistical significance, since not all KPAs can be measured directly. Especially when it comes to extra fuel mentality only a large sample of flights and utilizing live trials can show whether the use of GEWFs really make a significant difference.

6.5.4 Conclusions and recommendations

6.5.4.1 Conclusions

The conclusions for the validation exercise EXE-791 Step1 V2 (BMT-MET) regarding the utilisation of Ensemble Global Wind Forecasts for Trajectory Prediction can be split into technical conclusions and concept relevant conclusions and is summarized as below:

Conclusions concerning technical aspects

- GEWFs can be utilized by the trajectory creation and flight panning tools used for the validation exercise
- Several manual steps are required to enable the trajectory creation and flight panning tools to use GEWFs
- The gross trajectory creation and flight planning processing time increases, since n[1] number of trajectories need to be analysed. However, these steps can be parallelized, hence theoretically only the resources required increase and the gross trajectory creation and flight planning times should remain the same.

Conclusions concerning the concept

From the validation exercise we have the following encouraging observations:

- The probability distribution of a flight's trip fuel during cruising portions (incl. step climbs and step descents) can be assessed by the use of GEWFs
- The probability distribution of a flight's trip time during cruising portions (incl. step climbs and step descents) can be assessed by the use of GEWFs
- A flight's trip fuel and trip time during the take-off, initial climb and final descent/approach phase is highly unpredictable since during these flight phases the number of ATC interventions and resulting (nearly) weather independent deviations from the planned trajectory is high. Hence the approach to isolate the main cruising portion for the analysis is considered to be the right one.
- The exercise demonstrated that the 95 percentile (represented by one member out of the twelve members of the GEWF) is a conservative value for extra fuel from a safety perspective.
- The conclusions are based on a small number of flights and are therefore mathematically not robust although very encouraging.

It is expected the envisaged maturity V3 validation exercise would confirm these observations

6.5.4.2 Recommendations

The recommendations for the validation exercise EXE-791 Step1 V2 (BMT-MET)[21] can also be split into technical recommendations and concept relevant recommendations and is summarized as below:

Recommendations concerning technical aspects

- The processing of GEWFs should be fully automated. This includes the transfer of the data, the processing and ingestion into the trajectory creation and flight planning tools.

[1] Where n is the number of ensembles

- The creation of trip fuel and trip time probability distributions should be fully automated and should not require the cloning of flights or any manual step.
- The trip fuel and trip time probability distributions should be visible to dispatchers and pilots in order to enable a V3 validation exercise including live trials.
- The GEWFs should include the MAX WIND data points to increase the accuracy.

Recommendations concerning the concept

- It is recommended to perform the envisioned future V3 validation exercise including live trials.
- Scenario SCN-11.01.05-VALP-0001.0300 should be assessed in a future V3 validation exercise
- Next to the approach introduced in section the Validation report [21] section 2.2.1 and further discussed in section 4.2.3 additional (user defined) trajectory selection mechanisms should be developed, before analysing each of these trajectory's sensitivity to the GEWF.
- Improvements to the upper air weather forecast especially with respect to the vertical resolution should be analysed

Methodologies to assess the significance of using GEWF in the trajectory selection process in the planning phase should be developed.

6.6 Validation Exercise #811; MET Contribution Report

6.6.1 Exercise Scope and MET Contribution to support it

Only the sub-exercise led by Thales is relevant in terms of MET validation.

This exercise enabled the validation of MET information display for ENROUTE function on The Link By Thales® simulator at Thales Toulouse facilities. The MET information was displayed on a hardware display platform representative of an EFB. The high-level objectives of the validation test were to check the correct integration in an operational scenario of considered function. This exercise focused on one function "Meteorological information on EFB for En Route".

The complete description of VP811 results can be found in document referenced as [23]

6.6.2 Conduct of Validation Exercise

6.6.2.1 Preparations to MET contribution

This exercise was run on "The Link By Thales®" simulator which integrates a full avionics cockpit with full EFIS, FMS and AFS avionics systems plus 2 simulated EFB.

The following MET information was made available for the exercise by Météo-France, DWD and UKMO :

- METAR and TAF
- Convection observations and forecasts
- Icing observations and forecasts
- Clear Air Turbulence forecasts
- Wind, Temperature, Pressure, Humidity at departure and destination airports

Data formats and services definition have been discussed upstream with the technical team of Thales. An early version of the 4DWxCube MET-GATE was used for this exercise.

MET products were delivered in proprietary formats though web services allowing the user to use several input arguments such as the validity time and the area of interest.

The MET on EFB function was hosted on 2 simulated EFB.

6.6.2.2 MET contribution execution

6.6.2.2.1 Preparatory activities

The preparatory activities were as follows:

- Design of the validation events and procedure during runs and the associated detailed scenarios (July 2014)
- Validation of the THALES MET information on EFB function till September 2014
- Technical integration of the THALES MET information on EFB function on the THALES "The Link By Thales®" cockpit simulator (September 2014)

6.6.2.2.2 Execution activities

The exercise execution was done during 3 sessions of 1 day at the THALES "The Link By Thales®" Simulator in Toulouse.:

- 23th of January, 2015
- 29th of January, 2015
- 30th of January, 2015

The execution activities were as follows:

- Present the project and the validation exercise to all participants;
- Train (familiarize) the participants with the platform;
- Perform all the planned simulator runs;
- Get required feedback from participants (questionnaires and debriefing sessions).

Evaluations were based around 4 scenarios:

- Scenario #1 : Nominal flight preparation – Short range flight;
- Scenario #2 : Nominal flight execution – Short range flight (corresponding to the execution of the flight of scenario #1);
- Scenario #3 : Long range flight – focus on convection during enroute;
- Scenario #4 : Long range flight – focus on clear air turbulence during enroute.

Objectives of the validation exercise are described in Table 33 below.

OBJ-09.48-VALP-THA1.0001	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Flight Assess the benefits of the “Meteorological information on EFB for En Route” function to improve pilots situation awareness
OBJ-09.48-VALP-THA1.0002	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the flight crew level of workload with “Meteorological information on EFB for En Route” function global management
OBJ-09.48-VALP-THA1.0003	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the Flight Crews' efficiency to use all interfaces and devices related to “Meteorological information on EFB for En Route” function in an operational context.
OBJ-09.48-VALP-THA1.0004	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the procedure adequacy to manage MET information in nominal case of WX Uplink
OBJ-09.48-VALP-THA1.0005	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the utility of the display of the “Meteorological information on EFB for En Route” function
OBJ-09.48-VALP-THA1.0006	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the usability of the display of the “Meteorological information on EFB for En Route” function
OBJ-09.48-VALP-THA1.0007	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the integration of the function into current functions in the cockpit
OBJ-09.48-VALP-THA1.0008	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the utility of the function to support operational tasks
OBJ-09.48-VALP-THA1.0009	SCN-09.48-VALP-THA1.0001,2,3,4,5,6,7	Assess the utility of the superposition of the Flight Plan and A/C position with MET information

Table 33 : VP811 MET related objectives

6.6.2.2.3 Post execution activities

The post execution activities were as follows:

- Analyse the results of the simulation
- Synthesise and consolidate the results in a Validation Report.

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6.6.2.3 Deviation from the planned activities

N/A

6.6.3 MET contribution Results

6.6.3.1 Summary of MET contribution Results

Success Criterion ID	**Success Criterion**	**Exercise Results**	**Validation Objective Status**
CRT-09.48-VALP-TH01.0001	Situation awareness is supported by the display of MET information on the EFB display. MET information is correctly integrated in the EFB.	Achieved	**OK**
CRT-09.48-VALP-TH01.0002	The Flight Crew is able to perceive and interpret task relevant information and anticipate future events/actions thanks to the MET information on EFB display.	**Achieved**	**OK**
CRT-09.48-VALP-TH02.0001	The level of workload is estimated as acceptable after analysis of MET display management.	**Achieved**	**OK**
CRT-09.48-VALP-TH02.0002	The level of head-down time and visual channel load is acceptable.	**Not Achieved**	**NOK**
CRT-09.48-VALP-TH03.0001	Flight Crews are able to perform interactions with MET devices and interfaces with an acceptable level of usability (access, guidance, information presentation and interface layout organisation)	**Achieved**	**OK**
CRT-09.48-VALP-TH03.0002	Handling of cockpit HMIs for MET are fluent and do not compromise the flight crew tasks.	**Not Achieved**	**NOK**
CRT-09.48-VALP-TH04.0001	No major difficulty to manage/handle the display of uplinked WX information	**Achieved**	**OK**
CRT-09.48-VALP-TH05.0002	Utility of the "Meteorological information on EFB for En Route" function to anticipate long term weather avoidance	**Achieved**	**OK**
CRT-09.48-VALP-TH06.0001	Minimal actions required to use the function (Is there a way to do it shorter?) - action conciseness - no difficulty to use the function.	**Not Achieved**	**NOK**
CRT-09.48-VALP-TH06.0003	Intra or inter consistency of the interaction to access and load additional information regarding to similar interactions.	**Achieved**	**OK**
CRT-09.48-VALP-TH06.0004	Consistency of the interaction associated to the three modes of uplink available.	**Not Achieved**	**NOK**

Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
CRT-09.48-VALP-TH06.0005	Visual salience of the hazardous phenomena (distinguishing by format and/or behaviour of the phenomena, highlighting,…)	**Achieved**	**OK**
CRT-09.48-VALP-TH07.0002	Use of " Meteorological information on EFB for En Route " do not require specific training	**Not Achieved**	**NOK**
CRT-09.48-VALP-TH08.0002	Adequacy of the geographical coverage for long term use.	**Achieved**	**OK**
CRT-09.48-VALP-TH08.0003	Adequacy of the contract mode of uplink (for each type of phenomena) and especially the automatic update.	**Achieved**	**OK**
CRT-09.48-VALP-TH08.0004	Adequacy of the phenomena covered by the "Meteorological information on EFB for En Route" function (Convection, CAT, Icing)	**Achieved**	**OK**
CRT-09.48-VALP-TH09.0001	Adequacy of the Flight Plan display superposed with MET information.	**Achieved**	**OK**
CRT-09.48-VALP-TH09.0002	Adequacy of the A/C position display superposed with MET information.	**Achieved**	**OK**

Table 34: Summary of Validation Exercises Results: MET on EFB (Source : Table 14 of *09.48-D05-Validation Report for AIS MET Services and Data Distribution*)[23]

6.6.3.1.1 Results on concept clarification

N/A

6.6.3.1.2 Results per KPA

The following benefits are related to 3 KPA: efficiency, cost and effectiveness:

- Improvement of situation awareness by providing the crew with meteorological information on EFB (OBJ-09.48-VALP-THA1.0001)
- Keeping crew's workload on a stable level by providing them with up-to-date valid en-route meteorological information on EFB (OBJ-09.48-VALP-THA1.0002)
- From today's perspective a crew have to integrate textual and graphical information in order to avoid flying through dangerous areas (OBJ-09.48-VALP-THA1.0003)
- The new function will the capacity to manage several MET information (OBJ-09.48-VALP-THA1.0004)
- Function will provide an easier access to the relevant meteorological information (OBJ-09.48-VALP-THA1.0005)
- Keep crew's workload on a stable level by providing then with display with up to date meteorological information (OBJ-09.48-VALP-THA1.0006)
- Keep crew workload on a stable level by connecting this new function to other systems using meteorological information (OBJ-09.48-VALP-THA1.0007)
- The new function will be supported by easiness of use (OBJ-09.48-VALP-THA1.0008)

6.6.3.1.3 Results impacting regulation and standardisation initiatives

N/A

6.6.3.2 Analysis of MET contribution Results

6.6.3.2.1.1 Qualitative Results

The qualitative results below represent a synthesised compilation of airspace users general feedback reported during validation sessions.

Missing features:

Some users highlighted limitations of the validation exercise itself. They noted the exercise covered not all the functionalities and not all the MET services that it could. They noted also that the validated system was not as mature as it could have been in some areas.

Among the missing services, they have reported that a dynamic depiction of the flight and of the weather phenomena could have been implemented to help the understanding of the dynamic evolution of the weather situation in the flight context. Another service that could have been implemented is a service of sharing encounters with hazardous weather phenomena such as Clear Air Turbulence, with other aircrafts in the vicinity.

Some phenomena were also not provided by the system at the time of the validation. They hence confirmed the following services would have to be provided by the system: Winds, temperature, volcanic ashes, Ice crystal, SNOWTAM and all known significant weather features (SIGWX).

It was also confirmed that the coverage of the MET service should have been worldwide and not only in the area of the scenarios simulated flights.

Flight plan and aircraft position display:

The validation exercise confirmed the need for display of the flight plan and of the aircraft position, along with the display of MET phenomena and information, to improve the weather situational awareness along the flight plan and during flight.

It has also been suggested to add some flight plan modification capability, such drag & drop or display of waypoints around path, directly on the MET function display, in order to facilitate the elaboration of the avoidance strategy of hazardous weather.

MET products improvements:

Some remarks have been made on the MET products used during the validation exercise. Some information was missing such as altitude correction (density or delta compared to standard atmosphere), and the bottom of the convective cells (only the flight level of the top of the cells was provided). The update rate of the MET information should also be improved.

6.6.3.2.1.2 MET Data flow measures

Table below provides typical data link data flow measure on a 40 minutes flight over France, with the system used during the validation exercise.

Data are not filtered and provided over an oversized geographic area compared to what is just needed for the considered flight plan. These values are hence to be considered as very conservative (oversized) and not as definitive bandwidth requirements.

Time (minutes)	Data item	Size (Kbytes)	Comments
0	Clear Air Turbulence over Atlantic - Europe - Africa	283	Preflight loaded
0	Icing forecast over Europe	357	Preflight loaded
0	Icing observation over Europe	119	Preflight loaded
1	METAR messages	5	28 METAR updated
1	TAF messages	40	182 TAF updated

Time (minutes)	Data item	Size (Kbytes)	Comments
2	Convection over Europe	17	
2	Ground Weather Radar over France	53	
4	METAR messages	46	263 METAR updated
4	TAF messages	41	189 TAF updated
5	METAR messages	46	263 METAR updated
5	TAF messages	37	169 TAF updated
5	Convection over Africa	60	
7	Ground Weather Radar over France	52	
9	METAR messages	73	414 METAR updated
9	TAF messages	46	209 TAF updated
10	METAR messages	73	413 METAR updated
10	TAF messages	39	179 TAF updated
12	Ground Weather Radar over France	51	
14	METAR messages	113	642 METAR updated
14	TAF messages	46	210 TAF updated
15	Icing observation over Europe	119	
15	METAR messages	111	632 METAR updated
15	TAF messages	12	53 TAF updated
17	Ground Weather Radar over France	48	
19	METAR messages	115	652 METAR updated
20	METAR messages	63	357 METAR updated
20	TAF messages	10	46 TAF updated
21	Convection over Africa	60	
22	Ground Weather Radar over France	49	
24	METAR messages	63	357 METAR updated
24	TAF messages	14	65 TAF updated
25	METAR messages	58	332 METAR updated
27	Ground Weather Radar over France	51	
29	METAR messages	68	386 METAR updated
29	TAF messages	15	68 TAF updated
30	METAR messages	11	60 METAR updated
30	TAF messages	14	66 TAF updated
32	Ground Weather Radar over France	50	
34	METAR messages	56	319 METAR updated
34	Convection over Africa	60	
35	METAR messages	56	318 METAR updated
35	TAF messages	14	65 TAF updated
37	Ground Weather Radar over France	51	
39	METAR messages	116	660 METAR updated
39	TAF messages	16	73 TAF updated
40	TAF messages	13	59 TAF updated
	Total:	2150	KBytes
	Total time:	40	minutes

Time (minutes)	Data item	Size (Kbytes)	Comments
	Average Bandwidth	7,2	kbps

Table 35: MET data flow measure

6.6.3.2.2 Unexpected Behaviours/Results

N/A

6.6.3.3 Confidence in Results of MET contribution

6.6.3.3.1 Quality of MET contribution Results

The collected quotation and the averaged results were well representative of the qualitative feedback performed during “warm” debriefing just after each scenario run. Moreover, trends of results (qualitative and quantitative) were quite homogeneous among evaluators. It is hence considered the degree of confidence in the results is high.

6.6.3.3.2 Significance of MET contribution Results

The validation exercise was done by selected airspace users coming from different companies and organizations: 4 were active crew members in airlines (Long Range Aircraft, Medium range Aircraft, Helicopter), 1 was a flight test pilot from an aircraft manufacturer, and 4 were representative of 4 different expert groups.

Therefore one can consider a sufficient number of different, skilled and pertinent Airspace Users have been involved in this validation exercise.

We hence have a good level of confidence in the validation results.

6.6.4 Conclusions and recommendations

6.6.4.1 Conclusions

This exercise has enabled the validation of MET information display for ENROUTE function on The Link By Thales® simulator at Thales Toulouse facilities, during three sessions of one day each, in January 2015. This exercise was conducted by Thales teams and the validation was performed by Airspaces Users coming from various airlines, companies and organizations.

The best quoted validation objectives of the exercised function were:

- The adequacy of the Flight Plan display superposed with MET information
- The adequacy of the A/C position display superposed with MET information
- The utility of the “Meteorological information on EFB for En Route” function to anticipate long term weather avoidance
- The adequacy of the contract mode of uplink (for each type of phenomena) and especially the automatic update

The worst quoted validation objectives of the exercised function were:

- The acceptable level of head-down time and visual channel load
- The requirement for minimal actions to use the function and their conciseness & the easiness to use the function
- The requirement for non-specific training to use the function

The involved Airspaces users have also done a lot of pertinent remarks and suggestions that should help improve the function for the next phases of the project. Among the top requested improvement is the time to get the awareness of the whole meteorological situation along the flight plan that has to be shortened to a minimum.

6.6.4.2 Recommendations

It is recommended for next phases to perform some evolutions of the MET on EFB for ENROUTE function to reach the identified validation objectives. The main efforts should focus on the improvement of the time for the user to get the awareness of the whole meteorological situation along the flight plan and the availability of all the functions with a good level of maturity.

A large scale demonstration exercise is recommended to validate the function before deployment.

7 References

7.1 Applicable Documents

[1] Template Toolbox 03.00.00
https://extranet.sesarju.eu/Programme%20Library/SESAR%20Template%20Toolbox.dot

[2] Requirements and V&V Guidelines 03.00.00
https://extranet.sesarju.eu/Programme%20Library/Requirements%20and%20VV%20Guidelines.doc

[3] Templates and Toolbox User Manual 03.00.00
https://extranet.sesarju.eu/Programme%20Library/Templates%20and%20Toolbox%20User%20Manual.doc

[4] European Operational Concept Validation Methodology (E-OCVM) - 3.0 [February 2010]

[5] EUROCONTROL ATM Lexicon
https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

7.2 Reference Documents

The following documents provide input/guidance/further information/other:

[6] 11.02.02-D26 MET-DOD – Ed 00.02.00

[7] SESAR 2020 Multi-annual Work Program

[8] 11.02.02 D33 - Validation Plan Contributions in support of R3 and R4, *Edition: 00.01.00 Date 30/05/2014*

[9] 11.02.02-D35 Validation Plan Contributions - Ed 00.01.00

[10]D06.06.02-19 De-icing Step 1 – V3 Validation Plan (VALP) VP513

[11]D06.06.02-20 De-icing Step 1 – V3 Validation Report (VALR) VP513

[12]P13.02.03-VP700 VALP_SAL-15Sept

[13]009, V2 Validation Report (VALR), VP-669, Ed. 00.00.07

[14] D141, EXE-06.03.01-VP-757 Validation Plan, V3, Ed. 00.01.01, 22/10/2015

[15]D25 – D11.1.5-2c-MET FOC Validation Report – EXE-791 Step1 V2 (BMT-MET)

[16] 09.48-D04-Validation Plan VP-811

[17]LSD01.01 TOPLINK Lot 1, Demonstration Plan D02, Ed 00.01.01

[18] LSD02.06 TOPLINK Lot 2, Demonstration Plan D02, Ed 00.01.01

[19]The AROME-France Convective-Scale Operational Model; Y. Seity, P. Brousseau, S. Malardel, G. Hello, P. Bénard, F. Bouttier, C. Lac, and V. Masson Météo-France CNRM-GAME, Toulouse, France AMS Journal 6 April, 2011

[20]11.01.05-1 D15 FOC Validation Plan- EXE-791 Step 1 V2 (BMT-MET), March 2015

[21]11.01.05 D15 FOC Validation Report- EXE-791 Step 1 V2 (BMT-MET)March 2016

[22] D02 - D11.01.01-2c FOC Definition of the trajectory requirements for Step 2 and Step 3 as available, including gap analysis, support to standardization report from AU perspective, Ed 00.01.01

[23] VP 811 Validation Report for AIS/MET Services and Data distribution, Ed 02.00.00

[24]WP C.03, C.03-D03-Regulatory Roadmap Development and Maintenance Process
https://extranet.sesarju.eu/Programme%20Library/Forms/General.aspx

[25]WP C.03, C.03-D02-Standardisation Roadmap Development and Maintenance Process https://extranet.sesarju.eu/Programme%20Library/Forms/General.aspx

[26]SESAR Business Case Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[27]SESAR Safety Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[28]SESAR Security Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[29]SESAR Environment Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[30]SESAR Human Performance Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[31]D07 Guidance on list of KPIs for Step 1 Performance Assessment Ed1 https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[32] ATM Master Planhttps://www.atmmasterplan.eu

[33] DEL-06.03.01-D139-EXE-669 Validation Plan for V3 EXE.06.03.01-VP-669, performed under OFA05.01.01, in the Release 5 timeframe.

[34] DEL-06.03.01-D140-EXE-669 Validation Report for EXE.06.03.01-VP-669, carried out within the context of OFA05.01.01 during the Release 5 timeframe

[35] D13 - Report on support to V3 validation OFA 05.01.01, 15.04.09 c, Ed. 00.01.00, March 2016

[36] ICAO International Standards And Recommended Practices, Annex 3 – Meteorological Service for International Air Navigation, ICAO, 2010.

[37] 11.02.02-D43 SWIM Global Demo – Ed.00.01.00

[38]VP700 VALR : DEL-07 06 01-**D05** Step 1 Validation Report 2016 – Ed 00.02.00 https://extranet.sesarju.eu/WP_07/Project_07.06.01/Project%20Plan/Step%201/Validation%20Report/07%2006%2001-D05%20Step%201%20Validation%20Report%202016.docx

Appendix A KPA Templates

Where applicable templates for validation results for certain KPAs should be used to ensure completeness and gap analysis. These templates are:

- Safety Assessment template [27];
- Human Performance Assessment template [30];
- Security Assessment Template [28];
- Environment Assessment template [29].

All deviation from the assessment guidance shall be justified.

Appendix B Requirements Coverage of MET contribution to EXE 669

This appendix contains comments from WP11.2 on the detailed reporting on the MET services to EXE 669, contained in Appendix D of the VALR [34]. The Requirements Coverage table therein shows the requirements coverage, using the following short status descriptions:

- **NOT COVERED**
  Operational requirements are not covered by a validation objective, deviations with respect to the Validation Plan e.g. exercise not run / validation objective not analysed due to an unexpected limitation on the Validation Platform/prototype. These requirements do not lead to a requirement on WP11.2, and are therefore omitted from the current document.
- **OK**
  Operational requirement is covered by a validation objective (as per Validation Plan) and achieves the expectations (validation objectives analysis status is OK). The MET contribution has been achieved to fulfil the requirement.
- **OUT OF SCOPE**
  The requirement could not be validated as it had been agreed it was technical not feasible to complete or not purpose of the validation scenarios and therefore not necessary to provide the respective MET contribution.
- **NOK**
  Operational requirement is covered by a validation objective (as per Validation Plan) but does not achieve the expectations (validation objectives analysis status is NOK).
- **PARTIAL**
  The expectations have not been reached completely but some aspects have been achieved.

The MET relevant part of the Requirements Coverage table has been copied here, the column on the right containing the Requirement status value from MET perspective, using the same short status descriptions as in VALR [34]. The agreement between WP11.2 and EXE 669 for WP11.2 to prepare the weather forecast data according to the MET measurements at Braunschweig airport taken by 15.04.09c during the first half of 2015 ensures consistent observation and forecast data. The concerning required weather phenomena would be available for off-line use during the exercise from that archive. The provision of ensemble data instead of probabilistic data was agreed with 15.04.09c, in view of the Ground Weather Monitoring System being able to calculate the probabilistic data from the provided ensemble data. Therefore, the REQ V&V Status [34] of MET contribution with status "**OUT OF SCOPE**", "**PARTIAL**", and particularly, "**NOK**", has been re-evaluated from WP 11.2 perspective, and reported in or in the comments just below Table 36.

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET1.0001	All meteorological services shall as a minimum requirement be compliant Annex 3 to the Conven ion on International Civil Aviation: "Meteorological Service for International Air Navigation (17th Edition) AMD 76"where not further specified.	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0003	The AOP shall be provided with actual METAR information of the aerodrome	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0004	The AOP shall be provided with actual MET REPORT Information of the airport	MET-0101	EXE-06.03.01-VP-669	**OK**

[2] See list comments below this table

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET1.0005	The AOP shall be provided with actual TAF information of the airport	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0006	The AOP shall be provided with actual TREND information of the airport	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0007	The AOP shall be provided with actual Aerodrome Warning information	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0008	The AOP shall be provided with actual SNOWTAM information of the airport	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0010	The AOP shall be provided with a reduced set of MET data in reduced resolu ion from +48h in the future to +168h in the future, as defined and adjusted by the steer airport performance process	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0011	The Steer Airport Performance Service shall set and adjust on a regular basis MET parameter thresholds for warning generation in he rules engine, advised by a MET Service provider if necessary	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0023	The Steer Airport Performance service shall, in cooperation with a Met service provider, define and adjust areas around the airport where probabilistic hunderstorm forecasts are provided by the Met service provider.	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.0026	The post operations analysis service shall have access to the following MET data to be able to recreate the MET situation and perform post operational analysis: ICAO Annex 3 compliant products (METAR, MET REPORT, TREND, TAF, Aerodrome Warnings) Wind (speed, gust and direction; obs & fcst) Visibility and RVR (obs & fcst) Significant weather (Precipitation, Thunderstorm, obs & fcst) Other Present weather (obs & fcst) Clouds and vertical visibility (obs & fcst) Atmospheric pressure (obs & fcst) Air Temperature (obs & fcst) Dew point temperature (obs & fcst) Adverse weather conditons (obs & fcst) De-icing conditions (obs & fcst) Thunderstorm, electric storm warning (obs & fcst)	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET1.3101	The reduced set of MET data from +48h onwards shall at least comprise the elements: wind, temperature, precipitation and a level of confidence herefore; furthermore probabilities for adverse conditions	MET-0101	EXE-06.03.01-VP-669	**OUT OF SCOPE**
REQ-06.05.05-OSED-MET2.0001	The AOP shall be provided with actual Cloud Base height at the airport	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0002	The AOP shall be provided with predicted Cloud Base height at the airport	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0003	The AOP shall be provided with actual ceiling or vertical visibility information at the airport	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0004	The AOP shall be provided with predicted ceiling or vertical visibility information at the airport	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0005	The AOP shall be provided with probabilities for predicted height of ceiling or vertical visibility at the airport above/below determined hresholds	MET-0101	EXE-06.03.01-VP-669	**OK**

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET2.0006	The AOP shall be provided with total predicted cloud amount	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0007	The AOP shall be provided with total actual cloud amount	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0008	The AOP shall be provided with he actual mean surface wind direction and variation thereof	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0009	The AOP shall be provided with predicted mean surface wind direction and variation thereof	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0010	The AOP shall be provided with surface wind direction probability distribution forecasts for the 8 main surface wind direction classes (N,NE,E,SE,S,SW,W,NW)	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0011	The AOP shall be provided with he actual mean surface wind speed	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0012	The AOP shall be provided with actual surface wind gusts	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0013	The AOP shall be provided with he predicted mean surface wind speed	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0014	The AOP shall be provided with predicted surface wind gusts	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0015	The AOP shall be provided with probabilities for predicted surface wind speed above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0016	The AOP shall be provided with actual cross wind speed component and gust for all runways	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0017	The AOP shall be provided with predicted cross wind speed component and gust for all airport runways	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0018	The AOP shall be provided with probabilities for cross wind speed for all runways above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0019	The AOP shall be provided with actual head wind speed component and gusts for all runways	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0020	The AOP shall be provided with predicted head wind speed for all runways	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0021	The AOP shall be provided with probabilities for head wind speed for all runways above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0022	The AOP shall be provided with actual winds aloft: mean wind speed in 500 ft intervals up to 2000 ft above ground level, and in 1000 ft intervals above up to 5000 ft above ground level	MET-0101	EXE-06.03.01-VP-669	**OK**

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET2.0023	The AOP shall be provided with predicted winds aloft: : mean wind speed in 500 ft intervals up to 2000 ft above ground level, and in 1000 ft intervals above up to 5000 ft above ground level	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0024	The AOP shall be provided with actual winds aloft: mean wind direction in 500 ft intervals up to 2000 ft above ground level, and in 1000 ft intervals above up to 5000 ft above ground level	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0025	The AOP shall be provided with predicted winds aloft: mean wind direction in 500 ft intervals up to 2000 ft above ground level, and in 1000 ft intervals above up to 5000 ft above ground level	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0026	The AOP shall be provided with probabilis ic winds aloft forecast: probability distribution in classes of 5 KT in 1000 ft intervals up to 5000 ft above ground level	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0027	The AOP shall be provided with probabilis ic winds aloft forecast: probability distribution for predicted wind direction within the 8 main direction classes (N,NE,E,SE,S,SW,W,NW) in 1000 ft intervals up to 5000 ft above ground level	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0028	The AOP shall be provided with actual QFE	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0029	The AOP shall be provided with predicted QFE	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0031	The AOP shall be provided with actual QNH	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0033	The AOP shall be provided with predicted QNH	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0034	The AOP shall be provided with actual visibility	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0035	The AOP shall be provided with predicted visibility	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0036	The AOP shall be provided with probabilities for predicted visibility above/below determined hresholds	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0037	The AOP shall be provided with all actual RVR for each runway	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0038	The AOP shall be provided with predicted RVR for each rwy.	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0039	The AOP shall be provided with probabilities for predicted RVR above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0040	The AOP shall be provided with he actual mean 2m Temperature	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0041	The AOP shall be provided with he predicted mean 2m Temperature	MET-0101	EXE-06.03.01-VP-669	OK

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET2.0042	The AOP shall be provided with probabilities for predicted 2m temperature above/below determined hresholds	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0044	The AOP shall be provided with he actual mean Dew Point Temperature	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0045	The AOP shall be provided with he predicted Dew Point Temperature	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0046	The AOP shall be provided with probabilities for predicted dew point temperature above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0048	The AOP shall be provided with he actual Surface Temperature on all TDZ	MET-0101	EXE-06.03.01-VP-669	PARTIAL WP11.2 not involved
REQ-06.05.05-OSED-MET2.0049	The AOP shall be provided with he at least one predicted Surface Temperature at the airport	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0050	The AOP shall be provided with probabilities for predicted Surface temperature above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0052	The AOP shall be provided with he actual relative Humidity	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0053	The AOP shall be provided with he predicted relative Humidity	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0054	The AOP shall be provided with probabilities for predicted relative Humidity above/below determined hresholds	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0055	The AOP shall be provided with actual precipitation observations, including type of precipitation [rain, snow, freezing rain, showers…] and qualitative intensity of precipitation [light/moderate/heavy]	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0056	The AOP should be provided additionally with actual quantitative precipitation intensity in [mm/h] where available	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0057	The AOP shall be provided with predicted precipitation values, including type of precipitation [rain, snow, freezing rain, showers…], qualitative intensity of precipitation [light/moderate/heavy], time of begin and duration of precipitation [hh mm],and amount of precipitation [mm]/amount of snow[cm]	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0058	The AOP should be provided addi ionally with predicted quantitative precipita ion intensity in [mm/h]	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0059	The AOP shall be provided with probability of occurrence of liquid precipitation	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0060	The AOP shall be provided with probability of occurrence of snowfall	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0062	The AOP shall be provided with probabilities for predicted precipitation intensity above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	OK

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET2.0063	The AOP shall be provided with probabilities for predicted precipitation amount above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0064	The AOP shall be provided with probabilities for predicted snowfall amount above/below determined hresholds	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0065	The AOP shall be provided with actual hunderstorm/CB cell activity/lightning data within a locally defined area (default value 120 miles radius around the airport).	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0066	The AOP shall be provided with predicted hunderstorm/CB cell activity/lightning data within a locally defined area (default value 120 miles radius around the airport).	MET-0101	EXE-06.03.01-VP-669	PARTIAL
REQ-06.05.05-OSED-MET2.0067	The AOP shall be provided with probabilities of forecasted thunderstorm occurrence at the aerodrome	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0068	The AOP shall be provided with probabilities of forecasted thunderstorm occurrence in locally defined areas around the aerodrome	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0069	The AOP shall be provided with probabilities of hunderstorm duration at the aerodrome above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0070	The AOP shall be provided with he actual turbulence situation on final approach for each runway	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0071	The AOP shall be provided with he predicted turbulence situation on final approach for each runway.	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0072	The AOP shall be provided with he actual wind shear situation on final approach of all runway directions	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0073	The AOP shall be provided with he predicted wind shear situation on final approach of all runway directions	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0074	The AOP shall be provided with probabilities of predicted turbulence on final approach for each runway below/above determined thresholds	MET-0101	EXE-06.03.01-VP-669	PARTIAL
REQ-06.05.05-OSED-MET2.0075	The AOP shall be provided with probabilities of predicted wind shear on final approach below/above determined thresholds	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET2.0076	The AOP shall be provided with actual occurrence and magnitude of low level temperature inversions above determined thresholds	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET2.0077	The AOP shall be provided with predicted occurrence and magnitude of low level temperature inversions above determined thresholds	MET-0101	EXE-06.03.01-VP-669	NOK (PARTIAL)
REQ-06.05.05-OSED-MET2.0078	The AOP shall be provided with probability of forecasted occurrence of low level temperature inversions above determined thresholds	MET-0101	EXE-06.03.01-VP-669	NOK (PARTIAL)
REQ-06.05.05-OSED-MET2.0079	The AOP shall be provided with Information regarding type of runway contaminants	MET-0101	EXE-06.03.01-VP-669	OK

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET2.0080	The AOP shall be provided with he depth of runway contaminants	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0081	The AOP shall be provided with other actual present weather elements (other than previously stated; e.g. blowing snow, blowing sand, volcanic ash, freezing fog...) including intensity of present weather.	MET-0101	EXE-06.03.01-VP-669	**OUT OF SCOPE**
REQ-06.05.05-OSED-MET2.0082	The AOP shall be provided with other forecasted present weather elements (other than previously stated; e.g. blowing snow, blowing sand, volcanic ash, freezing fog...) compliant with ICAO Annex 3 to he Convention on International Civil Aviation: "Meteorological Service for International Air Navigation (17th Edition) AMD 76"	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0083	The AOP shall be provided with probability of occurrence of forecasted present weather element blowing snow, above thresholds set by the Steer Airport Performance Service.	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0084	The AOP shall be provided with probability of occurrence of forecasted present weather element blowing sand, above thresholds set by the Steer Airport Performance Service.	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0085	The AOP shall be provided with probability of occurrence of forecasted present weather element Freezing Fog	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0086	The AOP shall be provided with probability of occurrence of forecasted present weather element sand storm	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0087	The AOP shall be provided with probability of occurrence of forecasted present weather element volcanic ash	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.0088	The AOP shall be provided with probability of occurrence of forecasted present weather element Funnel Cloud (Tornado/ Water Spout)	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.3611	The AOP shall be provided with probability of occurrence of freezing rain	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET2.3612	The AOP shall be provided with probability of occurrence of freezing drizzle	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET3.0001	The AOP shall be provided with occurrence of any actual adverse weather condi ion	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET3.0002	The AOP shall be provided with he severity level of any actual adverse weather condition	MET-0101	EXE-06.03.01-VP-669	**OUT OF SCOPE**
REQ-06.05.05-OSED-MET3.0003	The AOP shall be provided with probabilities of occurrence of adverse weather conditions	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET3.0004	The AOP shall be provided with probabilities for severity levels of predicted adverse weather	MET-0101	EXE-06.03.01-VP-669	**OK**
REQ-06.05.05-OSED-MET3.0005	The AOP shall be provided with he "end of lightning activity" in an defined area at or around the aerodrome.	MET-0101	EXE-06.03.01-VP-669	**OK**

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET3.0006	The AOP shall be provided with actual de-icing category (no de-icing/light/moderate/severe/extreme)	MET-0101	EXE-06.03.01-VP-669	OUT OF SCOPE
REQ-06.05.05-OSED-MET3.0007	The AOP shall be provided with forecasted values of de-icing category (no de-icing/light/moderate/severe/extreme)	MET-0101	EXE-06.03.01-VP-669	OUT OF SCOPE
REQ-06.05.05-OSED-MET3.0008	The AOP shall be provided with probabilities of forecasted de-icing categories above/below determined thresholds	MET-0101	EXE-06.03.01-VP-669	OUT OF SCOPE
REQ-06.05.05-OSED-MET3.0009	The AOP shall be provided with actual AWO conditions (No AWO, CAT I, CAT II,....)	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET3.0010	The AOP shall be provided with forecasted AWO conditions (No AWO, CAT I, CAT II,....).	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET3.0011	The AOP shall be provided with probabilities of forecasted AWO condi ions (No AWO, CAT I, CAT II,....) above/below determined threshold (e.g. CAT II)s	MET-0101	EXE-06.03.01-VP-669	NOK
REQ-06.05.05-OSED-MET3.3013	The rules engine shall create an element "Adverse weather condition" from multi-parameter threshold assessment of weather elements contributing to adverse weather conditions	MET-0101	EXE-06.03.01-VP-669	OK WP11.2 not directly involved
REQ-06.05.05-OSED-MET3.3014	The rules engine shall create an element "De-Icing category" from multi-parameter threshold assessment of weather elements contributing to de-icing conditions	MET-0101	EXE-06.03.01-VP-669	PARTIAL WP11.2 not directly involved
REQ-06.05.05-OSED-MET3.3015	The Probabilistic Thunderstorm Area Forecast shall derive severity classes (none, light, medium, severe) from the probability of occurrence of thunderstorms and the probable intensity, density and alignment of hunderstorms for each area of interest (e.g. sectors) for all time steps of interest	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET3.3016	The AOP shall be provided with Probabilistic Thunderstorm Area Forecasts data	MET-0101	EXE-06.03.01-VP-669	OK
REQ-06.05.05-OSED-MET4.0001	Each stakeholder HMI shall be able to flag values if parameters surpass local thresholds set by the steer airport performance process	MET-0101	EXE-06.03.01-VP-669	OK WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.0002	Each stakeholder HMI shall display a pool of MET data defined by the steer airport performance service	MET-0101	EXE-06.03.01-VP-669	OK WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.0003	The HMI shall flag/highlight all parameter values in he MET data listing which are linked to adverse weather conditions in case of actual adverse conditions	MET-0101	EXE-06.03.01-VP-669	OK WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.0004	The HMI shall flag/highlight all parameter values in he MET data listing which are linked to adverse weather conditions in case of forecasted adverse weather conditions	MET-0101	EXE-06.03.01-VP-669	OK WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.0005	The actual and forecasted thunderstorm activity shall additionally be visualized by displaying appropriate weather radar, lightning, satellite or derived products	MET-0101	EXE-06.03.01-VP-669	OK WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.0006	The HMI shall consist of several sec ions, one of which shall be displaying he Probabilistic Thunderstorm Area Forecast	MET-0101	EXE-06.03.01-VP-669	PARTIAL WP11.2 not directly involved

OSED REQ ID	Ops Req Title	OI Step	EXE Title	REQ V&V Status of MET contribution according WP11.2[2]
REQ-06.05.05-OSED-MET4.0007	The precipitation ac ivity shall additionally be visualized by displaying appropriate weather radar, satellite or derived products	MET-0101	EXE-06.03.01-VP-669	**OK** WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.3008	The HMI shall be able - but not restricted - to display all relevant data on one screen for no-need-to-touch-MET-display capability	MET-0101	EXE-06.03.01-VP-669	**OK** WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.3012	The HMI configurability shall include arrangement and position of element on screen, number and selection of different parameters, Hierarchy and logic of different sections (Data Lis ings, Alerts & Warnings, Observation, WXR and derived products)	MET-0101	EXE-06.03.01-VP-669	**PARTIAL** WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.3013	The HMI shall have comprehensive Listing of MET Parameters with displayed values for all time stamps relevant	MET-0101	EXE-06.03.01-VP-669	**OK** WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.3014	In the HMI MET parameter listing, (derived) parameters such as adverse condi ions, Thunderstorms, LVC and the probability thresholds hereof shall be displayed on a prominent spot.	MET-0101	EXE-06.03.01-VP-669	**PARTIAL** WP11.2 not directly involved
REQ-06.05.05-OSED-MET4.3015	The default hierarchy of displayed data shall be: 1. alerts and warnings in regards to adverse conditions 2. weather radar and derived products / Observations 3. MET data listings /Forecasts	MET-0101	EXE-06.03.01-VP-669	**OK** WP11.2 not directly involved

Table 36: Requirements Coverage table (WP11.2 related) [34]

Comments on Table 36 entries concerning WP11.2 involvement, and with 'REQ V&V Status of MET contribution' other than "OK":

1. REQ-06.05.05-OSED-MET1.3101: Status is 'out of scope' as it had been agreed to provide T+27h as maximum forecast horizon because the current ensemble prediction system runs operationally only up to 27hours on a high-resolution, local scale. No data beyond T+27h have been provided. Deterministic data could have been provided.
2. REQ-06.05.05-OSED-MET2.0038 and REQ-06.05.05-OSED-MET2.0039: RVR is a measured dimension and not directly predicted by a numerical weather prediction system.
3. REQ-06.05.05-OSED-MET2.0048: Actual Surface Temperature could have been calculated based on the temperature information available for several vertical levels..
4. REQ-06.05.05-OSED-MET2.0063: Probabilities of predicted precipitation amount beyond determined thresholds could have been calculated out of several model output parameters from the ensemble dataset.
5. REQ-06.05.05-OSED-MET2.0066: Enhanced MET forecast products could have been provided on a shorter time range though.
6. REQ-06.05.05-OSED-MET2.0067 up to and including REQ-06.05.05-OSED-MET2.0069: Probabilities of thunderstorms could have been calculated out of several model output parameters from the ensemble dataset.
7. REQ-06.05.05-OSED-MET2.0073 up to and including REQ-06.05.05-OSED-MET2.0075: Turbulence and wind shear information could have been calculated out of the model output parameter (turbulent kinetic energy with a wind shear term).
8. REQ-06.05.05-OSED-MET2.0077 and REQ-06.05.05-OSED-MET2.0078: Temperature inversion information could have been calculated based on the temperature information on several vertical levels.

9. REQ-06.05.05-OSED-MET2.0081 and REQ-06.05.05-OSED-MET3.0002: actual weather data has not been requested, that information could have been provided as part of Regulatory MET products (METAR / SPECI).
10. REQ-06.05.05-OSED-MET3.0006, REQ-06.05.05-OSED-MET3.0007, REQ-06.05.05-OSED-MET3.0008 and REQ-06.05.05-OSED-MET3.3014: De-icing information has not been requested by WP11.2 though X1.6 MET prototype covers this information.
11. REQ-06.05.05-OSED-MET3.0010 and REQ-06.05.05-OSED-MET3.0011: THE AWO conditions has not been requested, the information might have been calculated out of the numerical weather model output parameters.
12. REQ-06.05.05-OSED-MET4.0001 up to and including REQ-06.05.05-OSED-MET4.0007, REQ-06.05.05-OSED-MET4.3008, REQ-06.05.05-OSED-MET4.3012, REQ-06.05.05-OSED-MET4.3014 + REQ-06.05.05-OSED-MET4.3015: HMI and visualization is out of scope of WP11.2 contribution, therefore no direct involvement in the HMI processes though in the MET data displayed.

Table 7 of DEL-06.03.01-D140-EXE-669 [33] provides a summary of exercise results, including an evaluation, from EXE 669 perspective, of Met service provision. We have provided the status "OK" on the Met Service provision in each row of this table, for the following reason. It is the end user's responsibility which Met services are selected, and how they are used. Then, if for each exercise the VAL OBJ Status is "OK", we assume the selected Met Service provision is "OK" as well. Please note, an objective not having been assigned the status "OK", might have been caused by inappropriate selection, use, or performance of Met Services, or by something else, and WP11.2 would have been prepared to support solving the issue.

VAL OBJ ID	VAL OBJ Title	Exercise ID	Success Criteria	Exercise Results	VAL OBJ Status per Exercise	MET Service provision Status
OBJ-06.03.01-VALP-A669.0010	Evaluate whether the airport stakeholders' perceived situational awareness is improved	EXE.06.03.01-VP-669	Involved stakeholders confirm that all the relevant performance indicators are displayed	The results indicate that the system tested in this exercise does improve situational awareness with respect to the *status quo*.	**OK**	**OK**
			Involved Stakeholders confirm the accuracy of the information received			
			Involved stakeholders confirm that their perceived situa ional awareness is improved			
OBJ-06.03.01-VALP-A669.0020	Validate the positive impact on controllers' workload	EXE.06.03.01-VP-669	Stakeholders confirm they are supported in their planning activities through the information displayed	The results of the exercise show that the workload would stay the same or lower.	**OK**	**OK**
OBJ-06.03.01-VALP-A669.0030	Validate that in a capacity constrained situation, automatic DCB calculations of the runway management support tool will be capable of improving airport performance in terms of departure punctuality compared to the reference scenario	EXE.06.03.01-VP-669	Involved stakeholders confirm that they are able to improve departure punctuality indicators	Departure punctuality reached approximately 60% in high traffic level conditions.	**OK**	**OK**
			Departure punctuality is improved with respect to the reference scenario			
OBJ-06.03.01-VALP-A669.0040	Validate that in a capacity constrained situation, automatic DCB calculations of the runway management support tool	EXE.06.03.01-VP-669	Involved stakeholders confirm that they are able to reduce departure delay indicators	The tool provided valuable suggestions for runway configuration in order	**OK**	**OK**

VAL OBJ ID	VAL OBJ Title	Exercise ID	Success Criteria	Exercise Results	VAL OBJ Status per Exercise	MET Service provision Status
	will be capable of improving airport performance in terms of departure delay compared to the reference scenario		Departure delay is reduced with respect to the reference scenario	to decrease departure delay.		
OBJ-06.03.01-VALP-A669.0050	Validate that in a capacity constrained situation automatic DCB calculations of the runway management support tool will be capable of improving airport performance in terms of runway departure capacity shortage compared to the reference scenario	EXE.06.03.01-VP-669	Involved stakeholders confirm that they are able to reduce runway departure capacity shortage Runway departure capacity shortage is reduced with respect to he reference scenario	The display of departure capacity was useful to understand the demand for current airport capacity. It helped the Airport Tower Supervisor to have a clear view of the airport's actual traffic so as to make strategic decisions.	OK	OK
OBJ-06.03.01-VALP-A669.0060	Validate that in a capacity constrained situation automatic DCB calculations of the runway management support tool will be capable of improving airport performance in terms of Total airport capacity shortage compared to the reference scenario	EXE.06.03.01-VP-669	Involved stakeholders confirm that they are able to reduce total airport capacity shortage Total airport capacity shortage is reduced with respect to he reference scenario	The Airport Tower Supervisor confirmed that the availability of RMAN and ASDI could be very useful for planning purposes in order to optimize resource alloca ion.	OK	OK
OBJ-06.03.01-VALP-M669.0010	Validate that MET information (including required MET data and ICAO bulletins) is available via SWIM	EXE.06.03.01-VP-669	All airport stakeholders receive complete, consistent and relevant MET information, both real-time and forecast.	The relevant MET data was provided by IWIS via SWIM, which delivered the data to RMAN and ASDI for further processing. The correctness and completeness of the data was not validated during the V3 validation, but this does not imply that the objective was not fulfilled. The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.	OK	OK
OBJ-06.03.01-VALP-M669.0020	Validate that MET alerts generated and targets are relevant in the management of adverse weather conditions.	EXE.06.03.01-VP-669	All airport stakeholders receive complete, consistent and relevant MET information, both real-time and forecast. A warning shall be generated if one of the requested MET data is not available A warning shall be generated if the alerts can't be processed due to missing MET data.	The exercise revealed that WISADS displays relevant weather data (e.g. tailwind information, thunderstorm, fog, snow) earlier, in a more comprehensible and usable format than METAR/TREND/TAF. Consequently this improves the Predictability KPA.	OK	OK

VAL OBJ ID	VAL OBJ Title	Exercise ID	Success Criteria	Exercise Results	VAL OBJ Status per Exercise	MET Service provision Status
				RMAN receives complete, consistent and relevant MET data via SWIM, (simulating a generic airport stakeholder in order to propose relevant decisions, e.g. change runway configuration, positive effect of capacity).		
OBJ-06.03.01-VALP-M669.0030	Possibility to adjust the thresholds related to MET alerts and targets.	EXE.06.03.01-VP-669	Each OSB team can adapt the hresholds for alerts and targets as needed at their relevant airport/APOC premises.	During the valida ion exercises he possibility to adjust the thresholds was shown.	**OK**	**OK**
OBJ-06.03.01-VALP-C669.0010	To validate the readability and the meaningfulness of textual information displayed by the A-CWP.	EXE.06.03.01-VP-669	The controller appreciates meaning, font types, dimension and colour of the information displayed by the A- CWP.	It was found that the font size on the axis could be increased to improve user accessibility.	**OK**	**OK**
OBJ-06.03.01-VALP-C669.0020	To validate the readability and the meaningfulness of the graphical objects, symbols and visual representa ions in the A-CWP	EXE.06.03.01-VP-669	The controller appreciates symbols, objects and type displayed on the A-CWP.	The feedback was positive and some suggestions are derived regarding graphical interface improvement.	**OK**	**OK**
OBJ-06.03.01-VALP-C669.0030	To validate consistency and completeness of the information displayed by the A-CWP.	EXE.06.03.01-VP-669	The controller confirms that the displayed information is coherent and complete to enable management of the traffic in a safe manner.	It was found that the usability of the displayed information could be improved, e.g. by displaying only the main data.	**OK**	**OK**
OBJ-06.03.01-VALP-C669.0040	To validate the adequacy of the number and sequence of ac ions on graphical objects needed to accomplish the control tasks.	EXE.06.03.01-VP-669	The controller confirms that the number and the sequence of actions required to perform tasks is acceptable.	Due to the introduction of a new tool the training is recommended.	**OK**	**OK**
OBJ-06.03.01-VALP-C669.0050	To evaluate whether the situational awareness of the controller is improved with the integra ion and exploitation of the new functions developed.	EXE.06.03.01-VP-669	The controller confirms that his/her situa ional awareness is improved with the integration and exploitation of the new functions.	The results indicate that the system tested in this exercise does improve situational awareness with respect to the *status quo* (see **Error! Reference source not found.**A).	**OK**	**OK**
OBJ-06.03.01-VALP-C669.0060	To evaluate the impact on ATCO workload with the integra ion and exploitation of the new func ions developed.	EXE.06.03.01-VP-669	The controller confirms that the workload is kept at an acceptable level while performing tasks.	The controller stated that the workload stayed the same or decreased with the integrated systems.	**OK**	**OK**
OBJ-06.03.01-VALP-S669.0010	To validate that SWIM TI provides European ATM Service Description for the METAR Service to share METAR bulletins.	EXE.06.03.01-VP-669	The objective will be successfully achieved if the European ATM Service Descrip ion for the METAR Service is in place and communicates the required information (i.e. METAR bulle ins) The objective will be successfully achieved if the service is at least at the 'SWIM Ready' compliance	The relevant MET data were provided by IWIS via SWIM, which delivered the data to RMAN and ASDI for further processing. The correctness and completeness of the data was not validated during the validation, but this does not imply that the objective was not fulfilled.	**OK**	**OK**

VAL OBJ ID	VAL OBJ Title	Exercise ID	Success Criteria	Exercise Results	VAL OBJ Status per Exercise	MET Service provision Status
			level.	The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.		
OBJ-06.03.01-VALP-S669.0020	To validate that SWIM TI provides TAF Service to share TAF bulletins according to SVA003 requirements.	EXE.06.03.01-VP-669	The objective will be successfully achieved if the TAF Service is in place and communicates the required information (i.e. TAF bulle ins).	The relevant MET data were provided by IWIS via SWIM, which delivered the data to RMAN and ASDI for further processing. The correctness and completeness of the data was not validated during the validation, but this does not imply that the objective was not fulfilled.	OK	OK
			The objective will be successfully achieved if the service is at least at the 'SWIM Ready' compliance level.	The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.		
OBJ-06.03.01-VALP-S669.0030	To validate that SWIM TI provides SNOWTAM Service to share SNOWTAM bulletins according to SVA003 requirements.	EXE.06.03.01-VP-669	The objective will be successfully achieved if the SNOWTAM Service is in place and communicates the required information (i.e. SNOWTAM bulletins).	WISADS was able to display SNOW events, but unfortunately the MET data was not available for this scenario, but this does not imply that the objective was not fulfilled.	**OK**	**OK**
			The objective will be successfully achieved if the service is at least at the 'SWIM Ready' compliance level.	The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.		
OBJ-06.03.01-VALP-S669.0040	To validate that SWIM TI provides Airport MET Observa ion bulle ins according to SVA003	EXE.06.03.01-VP-669	The objective will be successfully achieved if the AirportMETObservation Service is in place and	The relevant MET data were provided by IWIS via SWIM, which delivers the data to	**OK**	**OK**

VAL OBJ ID	VAL OBJ Title	Exercise ID	Success Criteria	Exercise Results	VAL OBJ Status per Exercise	MET Service provision Status
	requirements.		communicates the required information (i.e. AirportMETObservation bulle ins).	RMAN and ASDI for further processing. The correctness and completeness of the data was not validated during the validation, but this does not imply that the objective was not fulfilled.		
			The objective will be successfully achieved if the service is at least at the 'SWIM Ready' compliance level.	The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.		
OBJ-06.03.01-VALP-S669.0050	To validate that SWIM TI provides AirportMETForecast Service to share AirportMETForecast bulletins according to SVA003 requirements.	EXE.06.03.01-VP-669	The objective will be successfully achieved if the AirportMETForecastService is in place and communicates the required information (i.e. AirportMETForecast bulle ins).	The relevant MET data were provided by IWIS via SWIM, which delivers the data to RMAN and ASDI for further processing. The correctness and completeness of the data was not validated during the validation, but this does not imply that the objective was not fulfilled.	OK	OK
			The objective will be successfully achieved if the service is at least at the 'SWIM Ready' compliance level.	The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.		
OBJ-06.03.01-VALP-S669.0060	To validate that SWIM TI provides MET REPORT/SPECIAL Service to share MET REPORT/SPECIAL bulletins according to SVA003 requirements.	EXE.06.03.01-VP-669	The objective will be successfully achieved if the MET REPORT/SPECIAL is in place and communicates the required information (i.e. MET REPORT/SPECIAL bulle ins).	The relevant MET data were provided by IWIS via SWIM, which delivers the data to RMAN and ASDI for further processing. The correctness and completeness of the data was not validated during the validation, but this does not imply that the objective was not fulfilled.	OK	OK
			The objective will be successfully achieved if the service is at least at the 'SWIM Ready' compliance level.	The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from		

VAL OBJ ID	VAL OBJ Title	Exercise ID	Success Criteria	Exercise Results	VAL OBJ Status per Exercise	MET Service provision Status
				incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.		
OBJ-06.03.01-VALP-S669.0070	To validate that SWIM TI provides TREND Service to share TREND bulletins according to SVA003 requirements.	EXE.06.03.01-VP-669	The objective will be successfully achieved if the TREND is in place and communicates the required information (i.e. TREND bulle ins). The objective will be successfully achieved if the service is at least at the 'SWIM Ready' compliance level.	The relevant MET data were provided by IWIS via SWIM, which delivers the data to RMAN and ASDI for further processing. The correctness and completeness of the data was not validated during the validation, but this does not imply that the objective was not fulfilled. The service providing MET information was implemented and shown to be working properly, otherwise the entire validation would have suffered from incomplete results. The SW M Compliance Report also certified the highest level of compliance for all relevant MET services in this exercise.	OK	OK

Table 37: Summary of 669 Validation Exercises Results (WP11.2 related) [34]

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