Final Verification Report: 4DWxCube – Local MET prototypes

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Abstract

This document describes the verification exercise results of the Local Meteorological (MET) prototypes of the MET Domain System "4DWxCube". (11.02.01-D31) and it is focused on the Local (Airport & Approach) operational user environment. It follows the planned verification exercises described in 11.02.02-D16 (Verification Plan) based on consolidated MET capabilities as joint effort of European National Meteorological Services members of EUMETNET. This document is the update of the initial verification report and is the final version of verification results for Local MET prototypes developed in SESAR 1 project.

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This deliverable consists of SJU foreground and EUMETNET Consortium background. The NWP models and used to support the described prototypes, belong to the respective National Meteorological Service.

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Executive summary

This document is the update of the initial verification report 11.02.02.-D08 and describes the complete verification exercise results of the Local Meteorological (MET) prototypes of the MET Domain System “4DWxCube” achieved in SESAR 1 programme. It is focused on the Local (Airport and Approach) operational user environment. The verification activities were performed by collaboration between the different National MET Service providers involved in WP11.2 which provide MET information to the ATM and airspace users of the local operational user environment (OUE) via the 4DWxCube. The main focus was to verify the consistency and harmonisation of MET information and that MET information is based on the latest science to provide the users with a common view of MET and the highest performance of information possible.

This verification report includes six exercises. The first two exercises focuses on the consistency, harmonisation and the use of the latest science. In the next two exercises, the properties and accuracy of the consolidated and translated MET information was inspected. Additional verification activities demonstrate the verification of the general availability of MET information and the reliability of MET information which was tested within the verification exercises of the MET-GATE.

This report shows satisfactory results. Recommendations and limitations are given to each specific verification exercise analysis, if necessary.

1 Introduction

1.1 Purpose of the document

This document provides the verification report of the Local MET prototypes of the MET Domain System (DS) "4DWxCube". It describes the results of verification exercises defined in 11.02.02-D16, VP – Local OUE [8] and how they have been conducted. The verification activities are focused on requirements of MET technical specifications expressed in 11.02.02-D13 [7] based on consolidated MET capabilities developed as joint effort of European National Meteorological Services members of EUMETNET EIG. The verification activities were performed by collaboration between the different National MET Service (NMS) partners involved in WP11.2 who provide MET information to the ATM and airspace users of the local OUE via the 4DWxCube. The main focus was to verify the consistency and harmonisation of MET information and that MET information is based on the latest science to provide the users with a common view of MET and the highest performance of information possible.

The verification report informs the reader about the features of MET information that is made available for aviation stakeholders in Europe.

1.2 Intended readership

The intended readership of the verification report is equal to the readership envisaged for the verification plan.

This document is mainly intended for project partners and related projects which need MET information in support of their conceptual and operational activities. The intended audience of this document are initially the WP11.2 projects to support suitable validation exercises. Operational work packages (OPS WPs) and Operational Focus Areas (OFAs) that might be interested in the results are primarily project partners within WP6 Airport operations and WP8 Information Management.

Any OFA contributing to the Local OUE as well as their related projects needing MET Information in support of their architectural concepts is envisaged as intended audience. In particular, the following OFAs are identified as interested audience:

- OFA 05.01.01 and its contributing operational and technical projects;
- OFA 01.03.01 and its contributing operational and technical projects.

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1.3 Structure of the document

The document is structured as follows:

Chapter 1 introduces the document and describes the intended readership and terminology;
Chapter 2 provides background information and summarises verification exercises and objectives;
Chapter 3 defines the conduct of verification exercises;
Chapter 4 provides the verification exercise results and analysis;
Chapter 5 includes conclusions and recommendations;
Chapter 6 includes the verification exercise reports.

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	Proposed by WP11.02, 11.02.01

Term	Definition	Source
	made available to ATM stakeholders via its SWIM compliant "MET-GATE".	D31 Ed. 00.01.05 TAD
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 WP11.02, 11.02.01 D31 Ed. 00.01.05 TAD

1.5 Acronyms and Terminology

Table 2: List of Acronyms

Term	Definition
4DWx	4 dimensional weather data
AMDAR	Aircraft Meteorological Data Relay
AOP	Airport Operation Plan
ATM	Air Traffic Management
CAT	Clear Air Turbulence
C&T	Consolidation and Translation
DS	Domain System
E-AMDAR	EUMETNET-AMDAR
EUMETNET	European Meteorological Network
(Mode-S) EHS	(Mode-S) Enhanced Surveillance
FB	Functional Block
MET	Meteorology or Meteorological
MET-GATE	MET information services Generation, ATM Tailoring and Exchange
METSP	MET Service Provider
Mode-S	Mode-Selective
NMS	National Meteorological Service
OFA	Operational Focus Area
OPS-WP	Operational Work Package
OUE	Operational User Environment
QoS	Quality of Service

Term	Definition
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)
SUT	System Under Test
SWIM	System Wide Information Management
TAD	Technical Architecture Description
TS	Technical Specification
VP	Verification Plan
VR	Verification Report

2 Context of the Verification

The verification activities analyse the features of MET information that is made available for ATM and airspace users in Europe. It is focused on MET technical specifications expressed in 11.02.02-D13 [7] based on consolidated and translated MET prototypes. This report describes the results of the conducted verification exercises which are specified in 11.02.02-D16 [8].

2.1 System Overview

The Verification Plan [8] provides detailed information about the developed MET prototypes. There has been no specific system under test used for the verification exercises. The MET information have been scientifically tested or inspected and analysed manually. The tables below summarize the conducted exercises.

Verification Exercise ID and Title	EXE-11.02.02-VP-LOC1.0001 : Consistency of MET information
Leading organization	EUMETNET EIG
Verification exercise objectives	OBJ-11.02.02-VP-LOC1.1001
Rationale	The purpose of this exercise is to verify that the Local MET prototypes produce consistent MET products.
Verification Technique	Inspection
Dependent Verification Exercises	-

Table 3: Objectives verified in EXE-11.02.02-VP-LOC1.0001

Verification Exercise ID and Title	EXE-11.02.02-VP-LOC1.0002: Use of latest science for MET information
Leading organization	EUMETNET EIG
Verification exercise objectives	OBJ-11.02.02-VP-LOC1.1002
Rationale	The purpose of this exercise is to verify that the Local MET prototypes are produced on the knowledge of latest science.
Verification Technique	Inspection
Dependent Verification Exercises	-

Table 4: Objectives verified in EXE-11.02.02-VP-LOC1.0002

Verification Exercise ID and Title	EXE-11.02.02-VP-LOC1.0003: MET parameter properties
Leading organization	EUMETNET EIG
Verification exercise objectives	OBJ-11.02.02-VP-LOC1.1007
Rationale	The purpose of this exercise is to verify that the Local MET prototypes produce MET products with the requested properties.
Verification Technique	Inspection
Dependent Verification Exercises	-

Table 5: Objectives verified in EXE-11.02.02-VP-LOC1.0003

Verification Exercise ID and Title	EXE-11.02.02-VP-LOC1.0004: MET information accuracy
Leading organization	EUMETNET EIG
Verification exercise objectives	OBJ-11.02.02-VP-LOC1.1008
Rationale	The purpose of this exercise is to verify that the Local MET prototypes produce high accuracy MET products.
Verification Technique	Test
Dependent Verification Exercises	-

Table 6: Objectives verified in EXE-11.02.02-VP-LOC1.0004

Verification Exercise ID and Title	EXE-11.02.02-VP-LOC1.0005: MET products production
Leading organization	EUMETNET EIG
Verification exercise objectives	OBJ-11.02.02-VP-LOC1.1003 OBJ-11.02.02-VP-LOC1.1004 OBJ-11.02.02-VP-LOC1.1005
Rationale	The purpose of this exercise is to verify the production of the MET products from Local MET prototypes.
Verification Technique	Inspection
Dependent Verification Exercises	-

Table 7: Objectives verified in EXE-11.02.02-VP-LOC1.0005

Verification Exercise ID and Title	EXE-11.02.02-VP-LOC1.0007: MET data reliability
Leading organization	EUMETNET EIG
Verification exercise objectives	OBJ-11.02.02-VP-LOC1.1009
Rationale	The purpose of this exercise is to verify the reliability of MET products.
Verification Technique	Test/Analysis
Dependent Verification Exercises	EXE-11.02.02-VP-4DWC.0007 [11]

Table 8: Objectives verified in EXE-11.02.02-VP-LOC1.0007

2.2 Summary of Verification Exercise/s

2.2.1 Summary of Verification Objectives and Success Criteria

The verification objectives have been derived from the requirements of the 11.02.02-D13 Technical Specifications [7] and are expressed in detail in 11.02.02-D16 Verification Plan [8].

Verification objective ID	Verification objective title	Success criterion
OBJ-11.02.02-VP-LOC1.1001	Inspection of consistency of MET information	MET information is consistent in the specified area.
OBJ-11.02.02-VP-LOC1.1002	Inspection of the use of latest science in the MET prototypes	Latest science is used in the MET prototypes
OBJ-11.02.02-VP-LOC1.1003	ICAO regulated MET information production inspection	ICAO regulated MET information is produced by the Regulatory MET prototype.
OBJ-11.02.02-VP-LOC1.1004	Inspection of production of forecasts and observations of key meteorological parameters at surface and aloft.	Requested meteorological parameters are produced by the Nominal MET prototype.
OBJ-11.02.02-VP-LOC1.1005	Inspection of production of forecasts and observations of significant weather parameters.	Significant weather parameters are produced by the Significant MET prototype.
OBJ-11.02.02-VP-LOC1.1007	MET products properties inspection	MET products fulfil the requirements expressed in TS 11.02.02-D13.
OBJ-11.02.02-VP-LOC1.1008	MET products properties test	MET parameters fulfil the accuracy requirements expressed in TS 11.02.02-D13.
OBJ-11.02.02-VP-LOC1.1009	MET data reliability test	MET data is reliable when provided by certified MET provider and access to data is successful.

Table 9: Summary of Verification Objectives

2.2.2 Choice of methods and techniques

No changes regarding verification methods and techniques as compared to the Verification Plan [8].

2.2.3 Verification Exercises List and Dependencies

The exercise EXE-11.02.02-VP-LOC1.0007 MET data reliability is dependent on the MET-GATE verification process by T11.02.02.02. It has been verified within EXE-11.02.02-VP-4DWC.0007 [11] and detailed results are published in the 4DWxCube-MET-GATE verification report [12].

3 Conduct of Verification Exercises

3.1 Verification Exercises Preparation

The preparatory activities are described in the Verification Plan [8]. There are no differences to be identified.

3.2 Verification Exercises Execution

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
EXE-11.02.02-VP-LOC1.0001	Inspection of consistency of MET information	01/10/2015	10/12/2015	01/12/2015	15/12/2015
EXE-11.02.02-VP-LOC1.0002	Inspection of the use of latest science in the MET prototypes	01/09/2014	01/03/2015	01/02/2015	13/03/2015
EXE-11.02.02-VP-LOC1.0003	Inspection of MET parameter properties	01/10/2015	10/12/2015	01/12/2015	15/12/2015
EXE-11.02.02-VP-LOC1.0004	Test of MET information accuracy	01/01/2014	10/12/2015	01/12/2015	15/12/2015
EXE-11.02.02-VP-LOC1.0005	Inspection of MET products production	01/01/2014	10/12/2015	01/12/2015	15/12/2015
EXE-11.02.02-VP-LOC1.0007	Test of MET data reliability	01/12/2014	30/04/2015	15/02/2015	31/05/2015

Table 10: Verification Exercises execution/analysis dates

3.3 Deviations from the Planned Activities

N/A

3.3.1 Deviations with Respect to the Verification Strategy

N/A: a verification strategy was not produced.

3.3.2 Deviations with Respect to the Verification Plan

There are limited deviations from the plan where the low visibility conditions in X1.6 refer only to winter weather conditions as the prototype has focussed its functionality on prediction of winter conditions and the availability of probability of sand/dust storms were only partly fulfilled dependent on the specific type of probability data.

4 Verification exercises Results

4.1 Summary of Verification Exercises Results

Verification Exercise ID	Verification Objective ID	Verification Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Verification Objective Analysis Status
EXE-11.02.02-VP-LOC1.0001	OBJ-11.02.02-VP-LOC1.1001	Verify by inspection the consistency of MET information	CRT-11.02.02-VP-LOC1.1001	MET information is consistent in the specified area.	It is verified that Local MET prototypes provide consistent MET information in a specific geographical domain depending on the kind of MET information.	OK
EXE-11.02.02-VP-LOC1.0002	OBJ-11.02.02-VP-LOC1.1002	Verify by inspection the use of latest science in the MET prototypes	CRT-11.02.02-VP-LOC1.1002	Latest science is used in the MET prototypes	It is verified that Local MET prototypes provide MET information based on the latest science.	OK
EXE-11.02.02-VP-LOC1.0003	OBJ-11.02.02-VP-LOC1.1007	Verify by inspection that the MET prototypes produce MET products with the properties (such as update rate, area of interest, time resolution) specified in the requirements expressed in TS 11.02.02-D13..	CRT-11.02.02-VP-LOC1.1007	MET products fulfil the requirements expressed in TS 11.02.02-D13	It is verified that Local MET prototypes depending on the MET parameter provide MET products fulfilling the MET product properties requirements.	OK
EXE-11.02.02-VP-LOC1.0004	OBJ-11.02.02-VP-LOC1.1008	Verify by test that the accuracy of MET products fulfil the requirements expressed in TS 11.02.02-D13.	CRT-11.02.02-VP-LOC1.1008	MET products fulfil the accuracy requirements expressed in TS 11.02.02-D13	It is verified that Local MET prototypes provide MET products fulfilling the MET product accuracy requirements.	OK
EXE-11.02.02-VP-LOC1.0005	OBJ-11.02.02-VP-LOC1.1003	Verify by inspection of the METSP's MET product portfolio the production of ICAO Annex 3 regulated MET information.	CRT-11.02.02-VP-LOC1.1003	ICAO regulated MET information is produced by the Regulatory MET	It is verified that ICAO regulated MET information is made produced by the Regulatory MET prototype.	OK

Verification Exercise ID	Verification Objective ID	Verification Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Verification Objective Analysis Status
				prototype.		
EXE-11.02.02-VP-LOC1.0005	OBJ-11.02.02-VP-LOC1.1004	Verify by inspection of the METSP's MET product portfolio the production of deterministic, probabilistic and ensemble forecasts and observations of meteorological parameters at the surface and aloft.	CRT-11.02.02-VP-LOC1.1004	Requested meteorological parameters are produced by the Nominal MET prototype.	It is verified that most observations and deterministic and probabilistic forecasts of nominal MET information are produced.	Partially OK
EXE-11.02.02-VP-LOC1.0005	OBJ-11.02.02-VP-LOC1.1005	Verify by inspection of the METSP's MET product portfolio the production of deterministic, probabilistic and ensemble forecasts and observations of significant weather parameters.	CRT-11.02.02-VP-LOC1.1005	Significant weather parameters are produced by the Significant MET prototype.	It is verified that observations and deterministic and probabilistic forecasts of some significant MET information are produced, but several probabilistic MET products are not available yet for local use.	Partially OK
EXE-11.02.02-VP-LOC1.0007	OBJ-11.02.02-VP-LOC1.1009	Verify by test that the MET information is reliable.	CRT-11.02.02-VP-LOC1.1009	MET data is reliable when provided by certified MET provider and access to data is successful.	It is verified that MET data produced by MET prototypes is reliable and accessible.	OK

Table 11: Summary of Verification Exercises Results

4.2 Analysis of Verification Exercises Results

EXE-11.02.02-VP-LOC1.0001, EXE-11.02.02-VP-LOC1.0002, EXE-11.02.02-VP-LOC1.0003, EXE-11.02.02-VP-LOC1.0004 and EXE-11.02.02-VP-LOC1.0007 are verified successfully. EXE-11.02.02-VP-LOC1.0005 is verified partially successfully.

Further details can be found in the specific Verification Exercise Reports in chapter 6 and in the following table (Table 12) consisting of Technical specification requirements expressed in 11.02.02-D13 TS [7] and their verification results.

Identifier	Description	Verification Method	Verification Exercise	Verification result
REQ-11.02.02-TS-LOC2.0001	The Regulatory MET Prototype shall produce the following common - Local Routine (MET) - Special Report - METAR - TREND - TAF - Forecast for Take-Off - Aerodrome Warning - Wind Shear Warning - meteorological satellite - ground-based weather radar products with issue time, update rate, accuracy and templates in accordance to ICAO Annex 3 and ICAO Doc 7754.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.1101	The Nominal MET prototype shall produce observation products for - surface wind speed - surface wind direction - surface wind gusts - surface headwind - surface gust headwind - surface crosswind - surface gust crosswind - visibility for each runway direction with an update rate of 10 minutes.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.1102	The Nominal MET prototype shall produce Runway Visual Range (RVR) observation products for TDZ, MID and END position of each runway with an update rate of 30 seconds.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.1103	The Nominal MET prototype shall produce observation products for - cloud base height - cloud amount - vertical visibility - ceiling - precipitation type - precipitation characteristics - precipitation qualitative intensity - precipitation quantitative intensity - obscuration phenomena type - obscuration phenomena characteristics - obscuration phenomena intensity - 2m air temperature - 2m dew point temperature - relative humidity - QNH - QFE - heat radiation information	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
	for one location representative for the whole airport with an update frequency according the received information.			
REQ-11.02.02-TS-LOC2.1104	The Nominal Local MET prototype shall produce Runway surface temperature observation product for the TDZ of each runway with an update rate of 10 minutes.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Not Fulfilled
REQ-11.02.02-TS-LOC2.1105	The X2.1 MET prototype shall produce observation products for - wind speed aloft - wind direction aloft - headwind aloft - crosswind aloft - temperature for an area of minimum 10 nautical miles around the airport extending from the surface up to 5000ft, with vertical resolution of 500ft up to 2000ft and 1000ft up to 5000ft, slant resolution of 0,5 nautical miles and an update rate of 10 minutes.	Test	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.1106	The X1.1 MET prototype shall produce observation products for - convective activity information - lightning information for an area of minimum 120 nautical miles around the airport with an update frequency according the received information.	Test	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.1107	The Nominal Local MET Prototype shall average the surface MET observations with the averaging period in accordance with ICAO Annex 3.	Analysis	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.1108	The Nominal Local MET Prototype shall produce observation products for - 2m air temperature - 2m dew point temperature - runway surface temperature with an accuracy of 0.1°C.	Analysis	EXE-11.02.02-VP-LOC1.0004	Partially Fulfilled (not for runway surface temperature)
REQ-11.02.02-TS-LOC2.1109	The Nominal Local MET Prototype shall produce cloud amount observation with the accuracy of ±1 okta, in the range of 0/8-8/8.	Analysis	EXE-11.02.02-VP-LOC1.0004	Fulfilled
REQ-11.02.02-TS-	The Nominal Local MET Prototype shall produce cloud base height observation with the accuracy of ±10 m up to 100 m and ± 10 % above 100	Analysis	EXE-11.02.02-VP-LOC1.0004	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
LOC2.1110	m.			
REQ-11.02.02-TS-LOC2.1201	The Nominal Local MET prototype shall produce forecast products for - surface wind speed - surface wind direction - surface wind gusts - surface headwind - surface gust headwind - surface crosswind - surface gust crosswind - visibility - Runway Visual Range (RVR) - runway surface temperature for each runway (direction for headwind) with an update rate of 10 minutes.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Partially Fulfilled (visibility, RVR and runway surface temperature not forecasted for each runway with update rate of 10 minutes)
REQ-11.02.02-TS-LOC2.1202	The Nominal Local MET prototype shall produce forecast products for - cloud base height - cloud amount - vertical visibility - precipitation type - precipitation characteristics - precipitation qualitative intensity - precipitation quantitative intensity - obscuration phenomena type - obscuration phenomena characteristics - obscuration phenomena intensity - 2m air temperature - 2m dew point temperature - relative humidity - QNH - QFE for one location representative for the whole airport with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.1203	The Nominal Local MET prototype shall produce ceiling forecast products for one location representative for the whole airport with an update rate of 10 minutes.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.1204	The Nominal MET prototype shall produce forecast products for - wind speed aloft - wind direction aloft - headwind aloft - crosswind aloft - temperature	Test	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
	for an area of minimum 10 nautical miles around the airport extending from the surface up to 5000ft, with vertical resolution of 500ft up to 2000ft and 1000ft up to 5000ft, slant resolution of 0,5 nautical miles and an update rate of 10 minutes.			
REQ-11.02.02-TS-LOC2.1205	The Nominal Local MET Prototype shall produce forecast product - 2m air temperature - 2m dew point temperature - runway surface temperature with an accuracy of 0.1°C.	Analysis	EXE-11.02.02-VP-LOC1.0004	Fulfilled
REQ-11.02.02-TS-LOC2.1301	The Nominal Local MET prototype shall produce probabilistic forecast products for - surface wind speed - surface wind direction - surface wind gusts - surface headwind - surface gust headwind - surface crosswind - surface gust crosswind - visibility - Runway Visual Range (RVR) - runway surface temperature for each runway (direction for headwind) with an update rate of 10 minutes.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Partially Fulfilled (visibility, RVR and runway surface temperature not forecasted for each runway with update rate of 10 minutes)
REQ-11.02.02-TS-LOC2.1302	The Nominal Local MET prototype shall produce probabilistic forecast products for - cloud base height - cloud amount - vertical visibility - ceiling - precipitation type - precipitation characteristics - precipitation qualitative intensity - precipitation quantitative intensity - obscuration phenomena type - obscuration phenomena characteristics - obscuration phenomena intensity - 2m air temperature - 2m dew point temperature - relative humidity - liquid precipitation, freezing precipitation and snow occurrence - precipitation intensity above or below one or more thresholds - precipitation and snow amount for one location representative for the	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
	whole airport with an update frequency according the received information.			
REQ-11.02.02-TS-LOC2.1303	The Nominal MET prototype shall produce probabilistic forecast products for - wind speed aloft - wind direction aloft - wind direction in classes of the 8 main compass directions for an area of minimum 10 nautical miles around the airport extending from the surface up to 5000ft, with vertical resolution of 500ft up to 2000ft and 1000ft up to 5000ft, slant resolution of 0,5 nautical miles and an update rate of 10 minutes.	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Not Fulfilled
REQ-11.02.02-TS-LOC2.1304	The Nominal Local MET Prototype shall produce probabilistic forecasts for - 2m air temperature - 2m dew point temperature - runway surface temperature with an accuracy of 0.1°C.	Analysis	EXE-11.02.02-VP-LOC1.0004	Fulfilled
REQ-11.02.02-TS-LOC2.1305	The X1.3 MET prototype shall produce a seamless prediction of ensemble forecast products for - 2m temperature - 2m relative humidity - 10m wind speed - 6hour precipitation accumulation In a high spatial and temporal resolution covering GER-FR-UK territory.	Test	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2101	The Significant Local MET prototype shall produce observation products about the occurrence and severity level of significant weather conditions in line with the ICAO Annex 3 terminology for an area of minimum 120 nautical miles around the airport with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2102	The X1.6 MET prototype shall produce observation products of - severity level and occurrence of de-icing conditions in classes of: no icing, light, moderate, severe and extreme. - severity level and occurrence of low visibility conditions in classes of no LVC, CATI, CATII, CATIIIa, CATIIIb &	Test	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
	CATIIIc. based on pre-defined stakeholder thresholds for one location representative for the whole airport with an update rate of 30 minutes.			
REQ-11.02.02-TS-LOC2.2103	The Significant Local MET prototype shall produce - low-level wind shear (including microburst) - low-level turbulence observation products for the final approach area for each runway (direction) with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2104	The Significant Local MET prototype shall produce occurrence and magnitude of low-level temperature inversion observation products for one location representative for the whole airport with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2105	The Significant MET Prototype shall send on observed Information on observed significant weather conditions immediately after detection.	Analysis	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2106	The Significant Local MET Prototype shall consider lightning ended 10 minutes after the last lightning stroke.	Analysis	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.2201	The X1.2 MET prototype shall produce convective activity information forecast products for an area of minimum 120 nautical miles around the airport with an update frequency according the received information.	Test	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2202	The Significant Local MET prototype shall produce forecast products about the occurrence and severity level of significant weather conditions in line with ICAO Annex 3 terminology for an area of minimum 120nautical miles around the airport with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2203	The Significant Local MET prototype shall produce - low-level wind shear (including microburst)	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
	- low-level turbulence forecast products for the final approach area for each runway (direction) with an update frequency according the received information.			
REQ-11.02.02-TS-LOC2.2204	The X1.6 MET prototype shall produce - severity level and occurrence of de-icing conditions in classes of: no icing, light, moderate, severe and extreme. - severity level and occurrence of low visibility conditions in classes of no LVC, CATI, CATII, CATIIIa, CATIIIb & CATIIIc. forecast products based on stakeholder thresholds for one location representative for the whole airport with an update rate of 30 minutes.	Test	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Partially Fulfilled (low visibility forecasts only in winter precipitation)
REQ-11.02.02-TS-LOC2.2205	The Significant Local MET prototype shall produce occurrence and magnitude of low-level temperature inversion forecast products for one location representative for the whole airport with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2206	The X1.4 MET prototype shall produce forecast products of severity levels and occurrence of icing conditions in classes of no-icing light moderate, severe for the lower atmosphere (approach) with a temporal resolution of 1 hour and update rate of 6 hours.	Test	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2301	The Significant Local MET prototype shall produce probabilistic forecast products for - thunderstorm occurrence at or in a defined area around the airport - thunderstorm duration above or below one or more thresholds for an area of minimum 120 nautical miles around the airport with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled
REQ-11.02.02-TS-LOC2.2302	The Significant Local MET prototype shall produce probabilistic forecast products about the occurrence and severity level of significant weather conditions, based on stakeholder thresholds for an area determined locally with a default area of minimum 120 nautical miles around the airport	Inspection	EXE-11.02.02-VP-LOC1.0005	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
	with an update frequency according the received information.			
REQ-11.02.02-TS-LOC2.2303	The Significant MET prototype shall produce - low-level wind shear (including microburst) - low-level turbulence probabilistic forecast products for the final approach area for each runway (direction) with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Not Fulfilled
REQ-11.02.02-TS-LOC2.2304	The Significant MET prototype shall produce - severity level and occurrence of de-icing conditions in classes of: no icing, light, moderate, severe and extreme. - severity level and occurrence of low visibility conditions in classes of no LVC, CATI, CATII, CATIIIa, CATIIIb & CATIIIc. probabilistic forecast products based on stakeholder thresholds for one location representative for the whole airport with an update rate of 30 minutes.	Inspection	EXE-11.02.02-VP-LOC1.0005	Not Fulfilled
REQ-11.02.02-TS-LOC2.2305	The Significant MET prototype shall produce occurrence and magnitude of low-level temperature inversion probabilistic forecast products for one location representative for the whole airport with an update frequency according the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Not Fulfilled
REQ-11.02.02-TS-LOC2.2306	The Significant MET prototype shall produce probabilistic forecast products for - Blowing snow occurrence - Blowing sand occurrence - Freezing fog occurrence - Sand storm occurrence - Volcanic ash occurrence - Funnel cloud occurrence for one location representative for the whole airport with an update frequency according to the received information.	Inspection	EXE-11.02.02-VP-LOC1.0005	Not Fulfilled
REQ-11.02.02-TS-LOC2.2307	The X1.3 MET prototype shall produce a seamless ensemble forecast product for convective activity (depending on the received parameter) to enable probabilistic information in a high spatial and temporal resolution	Inspection	EXE-11.02.02-VP-LOC1.0003 EXE-11.02.02-VP-LOC1.0005	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
	covering GER-FR-UK territory.			
REQ-11.02.02-TS-LOC2.9001	The MET prototypes shall produce MET products consistent in time and across the different Operational User environments.	Review of Design	EXE-11.02.02-VP-LOC1.0001	Fulfilled
REQ-11.02.02-TS-LOC2.9002	The MET prototypes shall produce MET products based on latest science in observation and forecasting techniques.	Review of Design	EXE-11.02.02-VP-LOC1.0002	Fulfilled
REQ-11.02.02-TS-LOC2.9003	The MET prototypes shall send forecast verification results on request.	Analysis	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.9004	The MET prototypes shall send on warnings when the MET observation from a designated MET product for a pre-defined location and parameter exceeds a user-defined threshold.	Inspection	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.9005	The MET prototypes shall send on warnings when the MET forecast from a designated MET product for a pre-defined location and parameter exceeds a user-defined threshold.	Inspection	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.9006	The MET prototypes shall send on warnings when the MET probability forecast from a designated location and parameter exceeds a user-defined threshold.	Inspection	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.9007	The MET Prototypes shall produce forecast MET products with temporal resolution of 1 hour between T+0 and T+6hr, 3 hours between T+6 and T+48hr and 6 or 12 hours between T+48 and T+168hr.	Review of Design	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.9008	The MET parameter and the thresholds to be used in the probability forecasts by the MET Prototypes shall be predefined and determined locally for each airport.	Review of Design	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.9009	The Nominal Local MET Prototype shall produce forecasted wind aloft with temporal resolution of 10 minutes between T+0 and T+3 hours.	Review of Design	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-	The Nominal Local MET Prototype shall produce forecasted wind aloft	Review of	EXE-11.02.02-VP-LOC1.0003	Fulfilled

Identifier	Description	Verification Method	Verification Exercise	Verification result
TS-LOC2.9010	with temporal resolution of 1 minute between T+0 and T+10 minutes.	Design		
REQ-11.02.02-TS-LOC2.9011	The Nominal Local MET Prototype shall produce probability forecasts for wind speed aloft in classes of 5kt in 1000 ft intervals up to 5000 ft above ground level.	Review of Design	EXE-11.02.02-VP-LOC1.0003	Fulfilled
REQ-11.02.02-TS-LOC2.9012	The MET prototypes shall produce reliable (not corrupted) MET products.	Inspection	EXE-11.02.02-VP-LOC1.0007	Fulfilled
REQ-11.02.02-TS-LOC2.9013	The frequency of a MET prototype failure, especially for wind products provision, shall be very low (undefined).	Inspection	EXE-11.02.02-VP-LOC1.0007	Fulfilled
REQ-11.02.02-TS-LOC2.9014	The MET prototypes shall produce MET products with an accuracy as least as high as required by ICAO Annex 3	Analysis	EXE-11.02.02-VP-LOC1.0004	Fulfilled
REQ-11.02.02-TS-LOC2.9015	The products produced by the MET prototypes shall be approved by authorized organisation for aviation usage (e.g. by EASA).	Inspection	N/A	N/A

Table 12: Local Technical Specification [7] requirements and verification results from verification exercises

Many METSP provide ICAO Annex 3 products and forecasts though they also have available improved forecasts that are above and beyond the minimum requirements of ICAO Annex 3. As this data is available, customers should be able to access the higher performance data as it will give improved resolution, data availability and timeliness which will assist in decision making, risk management and planning over all time scales.

Requirements REQ-11.02.02-TS-LOC2.1104, REQ-11.02.02-TS-LOC2.1108 were not fulfilled in the verification exercises because METSPs don't provide runway surface temperature observations. Requirement REQ-11.02.02-TS-LOC2.1201 was not fulfilled because visibility, RVR and runway surface temperature are not forecasted for each runway with update rate of 10 minutes but they are available for airports.

The METSP's were not able to provide following Significant MET prototype probability forecasts in the verification exercise: low-level wind shear, low-level turbulence, de-icing conditions severity level and occurrence, low visibility conditions severity level and occurrence, low level temperature inversion, - Blowing snow occurrence, Blowing sand occurrence, Freezing fog occurrence, Sand storm occurrence, Volcanic ash occurrence, Funnel cloud occurrence (requirements REQ-11.02.02-TS-LOC2.2303, REQ-11.02.02-TS-LOC2.2304, REQ-11.02.02-TS-LOC2.2305, REQ-11.02.02-TS-LOC2.2306

4.2.1 Unexpected Behaviours/Results

There are no further unexpected behaviours or results identified which have not been addressed in the section above (4.2).

5 Conclusions and recommendations

5.1 Conclusions

Consistency of consolidated MET products produced by MET Prototypes has been verified successfully for the specified geographical areas, mostly covering parts or the whole of Europe. All Local MET prototypes provide consolidated and translated MET information based on the latest science. The Local MET prototypes provide MET products according to the requested MET information properties depending on the specific kind of MET parameter. The consolidated and translated MET products produced by MET Prototypes fulfil the MET information requirements considering accuracy. ICAO regulated MET information is produced by the Regulatory MET prototype. All observations of nominal meteorological parameters at surface and aloft and significant meteorological parameters are produced by MET Prototypes. The same applies for deterministic forecasts except for RVR, visibility except in winter precipitation and runway surface temperature forecasts where the high update rate of 10 minutes is not verified.

Probabilistic forecasts of runway surface temperature, RVR, visibility are not produced as well as the production of probabilistic wind direction classes is not produced regularly yet. This information is not predicted on a regular basis as they are very computing power intensive and therefore very expensive and the significant events occur only occasionally. On occasion the information can be calculated and predicted for the respective geographical areas.

5.2 Recommendations

The Local MET prototypes are currently available only in the specified geographical areas. Therefore, only validation exercises within these areas can be supported with the respective MET information. The ongoing advancement of the Local MET prototypes is necessary to ensure they will always be based on the latest science.

6 Verification Exercises reports

The following table (Table 13) summarizes which MET prototypes have been verified in which specific verification exercise:

MET prototype	Verification exercise	Conducted: yes/no
Radar composite of 3D convection	EXE-11.02.02-VP-LOC1.0001	Yes
	EXE-11.02.02-VP-LOC1.0002	Yes
	EXE-11.02.02-VP-LOC1.0003	Yes
	EXE-11.02.02-VP-LOC1.0004	Yes
	EXE-11.02.02-VP-LOC1.0005	Yes
Nowcasting of convection	EXE-11.02.02-VP-LOC1.0001	Yes
	EXE-11.02.02-VP-LOC1.0002	Yes
	EXE-11.02.02-VP-LOC1.0003	Yes
	EXE-11.02.02-VP-LOC1.0004	Yes
	EXE-11.02.02-VP-LOC1.0005	Yes
Super-ensemble mesoscale forecast of convection	EXE-11.02.02-VP-LOC1.0001	Yes
	EXE-11.02.02-VP-LOC1.0002	Yes
	EXE-11.02.02-VP-LOC1.0003	Yes
	EXE-11.02.02-VP-LOC1.0004	Yes
	EXE-11.02.02-VP-LOC1.0005	Yes
Icing forecast	EXE-11.02.02-VP-LOC1.0001	Yes
	EXE-11.02.02-VP-LOC1.0002	Yes
	EXE-11.02.02-VP-LOC1.0003	Yes
	EXE-11.02.02-VP-LOC1.0004	Yes
	EXE-11.02.02-VP-LOC1.0005	Yes
Winter weather conditions forecast at airports	EXE-11.02.02-VP-LOC1.0001	Yes
	EXE-11.02.02-VP-LOC1.0002	Yes
	EXE-11.02.02-VP-LOC1.0003	Yes
	EXE-11.02.02-VP-LOC1.0004	Yes
	EXE-11.02.02-VP-LOC1.0005	Yes
MODE-S EHS derived MET information	EXE-11.02.02-VP-LOC1.0003	Yes
	EXE-11.02.02-VP-LOC1.0005	Yes
E-AMDAR MET information	EXE-11.02.02-VP-LOC1.0003	Yes
	EXE-11.02.02-VP-LOC1.0005	Yes

Table 13: Verification of MET prototypes

The EXE-11.02.02-VP-LOC1.0007 has been performed by the MET-GATE and uses Regulatory MET products as well as existing MET forecast products due to the capabilities of the 4DWxCube - MET-GATE prototype.

6.1 Verification EXE-11.02.02-VP-LOC1.0001 Report

6.1.1 Verification Exercise Scope

The exercise EXE-11.02.02-VP-LOC1.0001, Consistency of MET information, is an inspection of the input data and processing methods of consolidated and translated MET products where consistent and harmonised MET information is currently available. The Local MET prototypes are addressed in this verification exercise. It is checked whether the requirement REQ-11.02.02-TS-LOC1.9001 [8] is met or not.

6.1.2 Conduct of Verification Exercise

6.1.2.1 Verification Exercise Preparation

The MET capabilities developed within P11.02.02 applicable for the local operational user environment (OUE), and therefore part of the Local MET prototypes, are used for this verification exercise. The addressed MET information is listed in the respective exercise procedure described in the Verification Plan [8]. There is no specific configuration necessary for conducting this exercise because the inspection is performed manually.

6.1.2.2 Verification Exercise execution

It will be evaluated where consistent and harmonised MET information is currently available. This verification exercise is run five times, once for each MET capability belonging to the Local MET prototypes.

Each verification execution is a manual inspection of the processed input data and method applied to compute consistent MET information. It is evaluated where consistent MET information is available.

The consistency inspection is performed at the late stage of prototype development, mostly between October 2015 and December 2015.

1: Inspection of radar composite of 3D convection information

Radar scans from the French and UK radar network are ingested in the consolidation tool which produces 3D gridded multi radar reflectivity products currently on two domains (400kmx400kmx12km) centred on London Heathrow and Paris Charles-de-Gaulle airports.

2: Inspection of nowcasting of convection information

The national convection nowcasting tools from Météo-France, Met Office and DWD are translated into harmonised convection warning levels. For safety reasons the maximum warning level available is chosen in the overlap regions during consolidation process which produces a consistent output covering the three national territories.

3: Inspection of super-ensemble mesoscale forecast of convection information

Output MET parameter from the contributing ensemble weather prediction systems of Météo-France, Met Office and DWD are processed to compute probability maps of weather events. This MET capability focuses on convection indicators which are consolidated at the national model edges without unphysical discontinuity. Therefore consistent, harmonised probability information of predictors of convective activity is computed over the geographical area covered by the contributing systems.

4: Inspection of icing forecast information

The national icing forecast products from Météo-France, Met Office and DWD are translated into harmonised icing warning levels. For consolidation the Pepe &Thomson [9] method is applied to produce consistent icing information within the geographical domain covered by the contributing systems.

5: Inspection of winter conditions forecast at airports information

The winter weather prototype consists of several different kinds of MET information to forecast winter weather conditions at airports. The surface conditions forecast is computed by FMI's friction algorithm on the basis of SMHI's numerical weather prediction data including the amount of water, snow and ice on the surface. De-icing weather classes based on thresholds received from de-icing local agents and are analysed and predicted based on many different kinds of MET information such as weather radar data, METAR observations and high resolution NWP model output. The application of a standardised method to forecast winter weather conditions at different airports by using consistent and harmonised input data as weather radar composites, METARs and the same NWP system concludes in a consistent winter weather forecast for several airports. Though, it needs to be considered that the local stakeholders may provide different thresholds which leads to inconsistency in the warning levels if thresholds are applied.

6.1.2.3 Deviation from the planned activities

N/A: There is no deviation from the planned activities.

6.1.3 Verification exercise Results

6.1.3.1 Summary of Verification exercise Results

It is verified that Local MET prototypes provide consistent MET information in a specific geographical domain depending on the kind of MET information. Considering the currently limited areas the requirement 11.02.02-TS-LOC1.9001 has been verified successfully.

6.1.3.2 Analysis of Verification Exercise Results

1: Inspection of radar composite of 3D convection information
Consistent 3D radar information is available and verified in two domains of a size of 400km x 400km x 12km centred on London Heathrow and Paris Charles-de-Gaulle airports.

2: Inspection of Nowcasting of convection information
Consistent convection nNowcasting information is available and verified covering Germany, France and United Kingdom plus Ireland.

3: Inspection of super-ensemble mesoscale forecast of convection information
Consistent super-ensemble information for convection is available and verified covering the ensemble prediction system domains provided by Météo-France, Met Office and DWD.

4: Inspection of icing forecast information
Consistent icing forecast information is available and verified covering Europe.

5: Inspection of winter conditions forecast at airports information
Winter weather conditions forecast is available for European airports and is verified to be consistent for Luleå/Sweden airport.

6.1.3.2.1 Unexpected Behaviours/Results

N/A

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

The verification exercise was successful.

6.1.4.2 Recommendations

The consistency of the Local MET prototypes is limited to the specified domains.

6.2 Verification EXE-11.02.02-VP-LOC1.0002 Report

6.2.1 Verification Exercise Scope

The exercise EXE-11.02.02-VP-LOC1.0002, Use of latest science for MET information, is an inspection of the processed data and techniques applied to consolidate and translate MET information for MET products provided by the Local MET prototypes. It is checked whether the requirement REQ-11.02.02-TS-LOC1.9002 is fulfilled [8].

6.2.2 Conduct of Verification Exercise

6.2.2.1 Verification Exercise Preparation

The MET capabilities developed within P11.02.02 applicable for the local OUE and therefore part of the Local MET prototypes are used for this verification exercise. The addressed MET information is listed in the respective exercise procedure described in the Verification Plan [8]. There is no specific configuration necessary for conducting this exercise because the inspection is performed manually.

6.2.2.2 Verification Exercise execution

It will be evaluated if the MET products are produced on the basis of the latest science. This verification exercise is run five times, once for each MET capability belonging to the Local MET prototypes. Each verification execution is a manual inspection of the processed input data and method applied to compute consistent MET information. It is evaluated whether the techniques correspond to the latest knowledge of science available.

An actual detailed timing cannot be given for each verification run. The inspection of applied techniques was performed as soon as the first prototype was available, mostly between September 2014 and March 2015. The MET Prototypes have been in the late stage of their development since the initial Verification Report so no major structural changes that could affect the use of latest science have not emerged. New inspection was therefore unnecessary and the results are equal to the published ones in the initial verification report.

1: Inspection of radar composite of 3D convection information

Radar scans from the French and UK radar network are ingested in the consolidation tool which produces 3D gridded multi radar reflectivity products. The radar used operational by NMSs are the most advanced radar systems for meteorological needs and are replaced successively when enhanced measurements systems are developed. The computation of a three dimensional radar product based on two dimensional radar measurements is a very advanced technique based on the latest science.

2: Inspection of Nowcasting of convection information

The convection Nowcasting tools from Météo-France, Met Office and DWD use high quality measurements of weather radars, lightning detection systems and satellites as well as data from NWP systems which are enhanced continuously based on the latest science. Improving the performance of Nowcasting tools is an ongoing development process by including the most advanced knowledge of science.

3: Inspection of super-ensemble mesoscale forecast of convection information

Ensemble weather prediction is an enhanced technique of deterministic NWP. The consolidated MET information ingested EPSs from Météo-France, Met Office and DWD, all of which are enhanced continuously based on the latest science. This method ensured a smooth transition without any unphysical discontinuity at the model domain boundaries, nor a loss of quality, thereby producing

consistent high-resolution MET information over a large geographical area based on the latest state of the art.

4: Inspection of icing forecast information

The icing forecast products from Météo-France, Met Office and DWD are based on NWP systems which are enhanced continuously based on the latest science. The Pepe &Thomson [9] method is the chosen technique considering the latest knowledge of science to consolidate the forecasts of the contributing NMSs to reach a consistent icing forecast with the best performance possible.

5: Inspection of winter conditions forecast at airports information

The winter weather condition forecast prototype ingests MET parameter from SMHI's or FMI's NWP systems which are both enhanced continuously based on the latest science. The performance of the FMI's friction algorithm is verified continuously for every new implemented module. The De-icing weather classes are predicted based on weather radar among others which are the most advanced radar systems for meteorological needs and are replaced successively when enhanced measurements systems are developed.

6.2.2.3 Deviation from the planned activities

N/A: There is no deviation from the planned activities.

6.2.3 Verification exercise Results

6.2.3.1 Summary of Verification exercise Results

It is verified that Local MET prototypes provide MET information based on the latest science. The requirement 11.02.02-TS-LOC1.9002 has been verified successfully.

6.2.3.2 Analysis of Verification Exercise Results

1: Inspection of radar composite of 3D convection information

The consolidated 3D radar information is based on the latest science.

2: Inspection of nowcasting of convection information

The consolidated nowcasting of convection information is based on the latest science.

3: Inspection of super-ensemble mesoscale forecast of convection information

The consolidated super-ensemble information for convection is based on the latest science.

4: Inspection of icing forecast information

The consolidated icing forecast information is based on the latest science.

5: Inspection of winter conditions forecast at airports information

The winter weather conditions forecast is based on the latest science.

6.2.3.2.1 Unexpected Behaviours/Results

N/A

6.2.4 Conclusions and recommendations

6.2.4.1 Conclusions

The verification exercise was successful.

6.2.4.2 Recommendations

The ongoing advancement of the Local MET prototypes is necessary to ensure they will always be based on the latest science.

6.3 Verification EXE-11.02.02-VP-LOC1.0003 Report

6.3.1 Verification Exercise Scope

The exercise EXE-11.02.02-VP-LOC1.0003, MET parameter properties, is an inspection of the properties of consolidated and translated MET information. The Local MET prototypes are addressed in this verification exercise. It is checked whether the requirements addressing properties of MET information are met or not.

6.3.2 Conduct of Verification Exercise

6.3.2.1 Verification Exercise Preparation

The MET capabilities developed within P11.02.02 applicable for the Local OUE and therefore part of the Local MET prototypes are used for this verification exercise. The addressed MET information is listed in the respective exercise procedure described in the Verification Plan [8]. There is no specific configuration necessary for conducting this exercise because the inspection is performed manually.

6.3.2.2 Verification Exercise execution

The properties of the consolidated MET information will be evaluated. This verification exercise is run five times, once for each MET capability belonging to the Local MET prototypes.

Each verification execution is a manual inspection of the metadata of the MET information. It is evaluated if the MET properties of the available consolidated and translated MET information met the features specified in the TS requirements.

An actual detailed timing cannot be given for each verification run. The MET properties inspection is performed at the late stage of prototype development, mostly between October 2015 and December 2015.

1: Inspection of radar composite of 3D convection information

Geographical coverage: two areas of 400km x 400km one centred on London Heathrow airport and the other on Paris Charles-de-Gaulle airport

Horizontal resolution: 2km²

Vertical resolution: 100m (up to 12 km)

Temporal resolution: none, (observation)

Forecast horizon: none (observation)

Update rate: 5 minutes

2: Inspection of nowcasting of convection information

Geographical coverage: Germany, France and United Kingdom including Ireland

Horizontal resolution: ~ 1.1km x 1.1km

Vertical resolution: 2D, plus cloud top height
Temporal resolution: 15 minutes
Forecast horizon: T+1 hour
Update rate: 15 minutes

3: Inspection of super-ensemble mesoscale forecast of convection information
Geographical coverage: Germany, France, extending domain covering United Kingdom including Ireland under development
Horizontal resolution: 2.2 x 2.2 km² (0.027° x 0.022° grid)
Vertical resolution: specific vertical pressure levels
Temporal resolution: 1 hour
Forecast horizon: T+24 hours
Update rate: 24 hours

4: Inspection of icing forecast information
Geographical coverage: Europe
Horizontal resolution: 5 x 5 km²
Vertical resolution: 10 pressure levels
Temporal resolution: 3 hours
Forecast horizon: T+24 hours
Update rate: 6 hours

5: Inspection of winter conditions forecast at airports information
Harmonized MET airport parameter like e.g. air temperature, runway surface temperature, relative humidity, dew point temperature, precipitation are available with the following properties:
Geographical coverage: Helsinki and Stockholm (specific TMAs in FIN-SWE-NOR territory)
Horizontal resolution: 500m²
Vertical resolution: none (2D information)
Temporal resolution: 15 minutes
Forecast horizon: T+3 hours
Update rate: 1 hour

6: Inspection of the properties of MODE-S EHS derived MET information
Mode-S EHS observations (wind speed, wind direction, temperature)
Quality: wind speed: 1,5m/s;
wind direction: 10-15°
temperature: 1-2K
Formats: BUFR, WMO7, NetCDF, ASCII
Time: since 1st January 2013 till present
Geographic coverage: MUAC air space
Temporal resolution: 15 minutes batches
Latency: approx. 10 min.

Case studies
With HIRLAM:
Semi operational since 2014
Geographical coverage: France, Germany, United Kingdom and South of Norway

SW corner: 50.5°N and 1.5°E
Horizontal resolution: 0.1° x 0.1° grid (approx. 10 x 10 km)
Vertical resolution: 40 levels
Temporal resolution: 10min up to 6 hours, afterwards 1hour
Forecast horizon: 24hours (improvements up to 15 hours)
Update rate: 1 hour

With HARMONIE:
Case study covers period from 18th November to 31st December 2013
Geographical coverage: from NE corner 48,5°N / 8,2°E to 58,8°N / 22,2°E
Horizontal resolution: 2,5km x 2,5km
Vertical resolution: 65 levels
Temporal resolution: 1 hour
Forecast horizon: 24hours (improvements up to 6 hours)
Update rate: 3 hours

7: Inspection of the properties of E-AMDAR MET information
Case study covers period from 1st March to 31st May 2011
Exemplary number of AMDAR humidity measurements: 15,390 by 40 aircraft (30th March)
Geographical coverage: Eastern US, 100°W / 29°N to 70°W/ 43°N
Horizontal resolution: 7km x 7km
Vertical resolution: 40 layers, resolution decreasing by height
Temporal resolution: 6 hourly
Forecast horizon: T+78h for 00 and 12 UTC, T+48h for 06 and 18 UTC
Update rate: 6 hours

6.3.2.3 Deviation from the planned activities

N/A: There is no deviation from the planned activities.

6.3.3 Verification exercise Results

6.3.3.1 Summary of Verification exercise Results

It is verified that Local MET prototypes provide MET information fulfilling the MET information properties requirements depending on the kind of MET parameter. The geographical coverage expands from single TMAs to consistent MET information covering Europe. The horizontal resolution varies between several hundreds of meters to a few kilometres. The vertical resolution of the 3D MET information ranges from 100m to only a few representative, specific pressure levels. The temporal resolution differs between 15 minutes for very short term forecast and 3 hours for short term forecasts. The forecast horizon lies between 1 hour and 24 hours. The Local MET prototypes based on observations have an update rate of 5 minutes while Nowcasting tools in small areas are updated every 15 minutes. The ensemble forecast has the longest update rate with 24 hours.

6.3.3.2 Analysis of Verification Exercise Results

The consolidated and translated MET information of the Local MET prototypes fulfil all requirements concerning the involved kind of MET parameter. The Local MET prototypes do not cover the medium term planning phase beyond 48 hours though some could be extended by degrading the temporal resolution or/and the update rate.

The verification exercise has not been performed yet for MET information outside the consolidated MET information as WP11.2 development is focused on this kind of MET information. Therefore, some requirements have not been verified (mostly Airport Met parameter and aloft parameter). A full list of verified requirements can be found in Table 12.

6.3.3.2.1 Unexpected Behaviours/Results

N/A

6.3.4 Conclusions and recommendations

6.3.4.1 Conclusions

The requirements concerning MET parameter properties addressed in the Technical Specification [7] have been verified successfully for consolidated and translated MET information. The verification exercise was successful.

6.3.4.2 Recommendations

The verification exercise focusses on the consolidated Local MET prototypes and could be extended to the general available local MET information from NMS's to verify the kind of MET information that are not included in the consolidated MET information like specific surface MET parameter at the airport.

6.4 Verification EXE-11.02.02-VP-LOC1.0004 Report

6.4.1 Verification Exercise Scope

The exercise EXE-11.02.02-VP-LOC1.0004, Accuracy of MET information, is tested for each MET capability involved in the consolidation and translation development process. The output data of consolidated and translated MET information is verified. The Local MET prototypes are addressed in this verification exercise. It is checked whether the requirements concerning the accuracy of MET information (REQ-11.02.02-TS-LOC2.9014, 1108, 1109, 1110, 1205 and 1304) are met by the consolidated and translated MET information or not.

6.4.2 Conduct of Verification Exercise

6.4.2.1 Verification Exercise Preparation

The MET capabilities developed within P11.02.02 applicable for the local OUE and therefore part of the Local MET prototypes are used for this verification exercise. The addressed MET information is listed in the respective exercise procedure described in the Verification Plan [8]. There is no specific configuration necessary for conducting this exercise because the inspection is performed separately for each MET capability.

6.4.2.2 Verification Exercise execution

It will be evaluated if the accuracy of consolidated and translated MET information met the specified requirements. This verification exercise is run five times, once for each MET capability belonging to the Local MET prototypes.

Each verification execution is a manual test of the processed output data of the consolidated MET information. An actual detailed timing cannot be given for each verification run. The accuracy test was performed after the first prototype was available and repeated for each development status to ensure to apply the most appropriate consolidation method to achieve the best performance result. Most work is conducted between September 2014 and March 2015 and continued at the late or final stage of MET capability development between October 2015 and December 2015

The current available requirements only address Airport MET parameters which are only addressed in the MET capability about winter weather conditions and indirectly by the single ensemble systems used in X1.3 or request an accuracy at least as required by ICAO Annex 3.

REQ-11.02.02-TS-LOC1.9014: The MET prototypes shall produce MET products with an accuracy as least as high as required by ICAO Annex 3.

REQ-11.02.02-TS-LOC1.1108: The Nominal Local MET Prototype shall produce observation products for 2m air temperature, 2m dew point temperature and runway surface temperature with an accuracy of 0.1°C.

REQ-11.02.02-TS-LOC1.1109: The Nominal Local MET Prototype shall produce cloud amount observation with the accuracy of ±1 okta, in the range of 0/8-8/8.

REQ-11.02.02-TS-LOC1.1110: The Nominal Local MET Prototype shall produce cloud base height observation with the accuracy of ±10 m up to 100 m and ± 10 % above 100 m.

REQ-11.02.02-TS-LOC1.1205: The Nominal Local MET Prototype shall produce forecast product of 2m air temperature, 2m dew point temperature and runway surface temperature with an accuracy of 0.1°C.

REQ-11.02.02-TS-LOC1.1304: The Nominal Local MET Prototype shall produce probabilistic forecast product of 2m air temperature, 2m dew point temperature and runway surface temperature with an accuracy of 0.1°C.

Detailed list of all respective MET prototypes (X1.1 – X1.4 + X1.6, X2.1+X2.2)

1: Inspection of the properties of 3D radar composite convection information

Parameter: a high resolution 3D radar mosaic and 2D radar products indicative of convective storm severity: 45 dBZ echo tops (TOP45), Vertically Integrated Liquid (VIL), maximum reflectivity (ZMAX) and height of maximum reflectivity HZmax

Accuracy: The root mean square error (RMSE) is around 2 +/-1dB below 10km and increases rapidly above. The bias ranges from 0dB at 0.5km to 5 dB at 12km. An increasing bias for the schemes with height also means with distance from the radars. The UKM bias tends to be more homogeneous with height than the FRM one. The UKM methods overestimates the reflectivity by 2dB above 2km while FRM methods starts by underestimating the reflectivity by up to 2dB below 2km and overestimates the reflectivity by up to 3 dB above 4km. Both schemes largely overestimate the reflectivity above 10 km.

2: Inspection of properties of the nowcasting of convection information

Parameter: Convection severity class

Accuracy: The verification results of the national tools are good and very similar in comparison to each other. The absolute values are quite low for probability of detection and high for the false alarm rates due to the very strict verification method. The British input to the consolidated nowcasting of convection product shows strong over warning (highest false alarm rate). Therefore its usage has been limited to the British domain. In the overlap regions with the two other model domains the highest warning level of the German and French domain has been used for the consolidated product to ensure safety.

3: Inspection of the properties of the super-ensemble mesoscale forecast of convection information

Parameter: 2m-temperature, 2m-relative humidity, 10m-wind speed, 6h- precipitation accumulation

Accuracy: The superensemble concept appears to be feasible. The meteorological quality of the superensemble is generally slightly superior to all national systems in the overlap regions. In non-overlap regions, the superensemble is equivalent to using the local national ensemble. The national ensembles have varying forecast performance, but the superensemble tends to either beat all of them or be similar to the best. It means that it can be a bad idea to ditch a model because it is not as good as another: model diversity brings substantial user value (at least when all considered models have comparable performance, such as here).

4: Inspection of the properties of icing forecast information

Parameter: Consolidated icing forecast parameter (intensity)

Accuracy: All national models perform nearly identical in the case of icing yes/no. The consolidated icing product shows the highest accuracy by combining all three models in a deterministic poor-man ensemble: the ratio of probability of detection to false alarm rate is then the highest.

5: Inspection of the properties of winter conditions forecast information

Parameter: Harmonized MET airport parameter, e.g. air temperature, runway surface temperature, relative humidity, dew point temperature, precipitation

Accuracy: Friction is not an easy parameter to verify. Maintenance operations (snow ploughing and especially chemical spreading) have a very strong impact for the runaways. Runaways may be clear of ice and snow when model assumes that there is still ice and snow remaining. However, the verification results, probability of detection and false alarm rate are good (approx. 0,85 and 0.40). In the maintenance point of view it is typically more important to overestimate than underestimate the expected slipperiness. It has been noticed that the used numerical model underestimates the friction in case of snow on the surface.

6: Inspection of the properties of MODE-S EHS derived MET information

Parameter: Mode-S EHS observations, model parameter (esp. wind, temperature)

Accuracy: The findings of assimilation of Mode-S EHS are that the HARMONIE model with Mode-S EHS scores better on short-range forecast (up to 6 hours into the forecast) when verified against independent wind and temperature observations. Improvement in wind speed for T+6h in 875 hPa 1%, in 400 hPa 2%.

7: Inspection of the properties of E-AMDAR MET information

Parameter: Model forecast of icing conditions based on E-AMDAR observations

Accuracy: The case study has shown that the probability of detection for icing conditions increases by including AMDAR humidity measurements in the data assimilation of numerical weather prediction systems. The probability of detection decreases which means that the no icing conditions have been predicted less often correct, the false alarm rate increases slightly.

6.4.2.3 Deviation from the planned activities

N/A: There is no deviation from the planned activities.

6.4.3 Verification exercise Results

6.4.3.1 Summary of Verification exercise Results

It is verified that Local MET prototypes fulfil the accuracy requirements.

6.4.3.2 Analysis of Verification Exercise Results

The MET capabilities involved in the development of consolidated local MET information do not cover nominal MET information except the MET parameter included in the winter weather condition forecast.

As the NMS's are bound to follow ICAO Annex 3 standards, requirement REQ-11.02.02-TS-LOC1.9014 is fulfilled naturally by any MET service provider.

The accuracy of the surface/2m Airport MET parameters (1108) is verified successfully within the winter weather condition prototype.

The accuracy of the probabilistic nominal Airport MET parameters (1304) are verified indirectly by the accuracy of the multi-model ensemble prototype X1.3.

By analysis of the MET Service providers product portfolio and its accuracy the requirements REQ-11.02.02-TS-LOC1.1109, 1110 and 1205 can be stated as verified successfully, 1108 as partially fulfilled as it is verified except for the runway surface temperature observation product.

6.4.3.2.1 Unexpected Behaviours/Results

N/A

6.4.4 Conclusions and recommendations

6.4.4.1 Conclusions

The verification exercise was successful.

6.4.4.2 Recommendations

The accuracy requirements could be specified in more detail and extended to further parameters of MET information to represent and show the accuracy and other performance features of the consolidated MET information.

6.5 Verification EXE-11.02.02-VP-LOC1.0005 Report

6.5.1 Verification Exercise Scope

EXE-11.02.02-VP-LOC1.0005, MET products production is an inspection of the involved NMS's MET product portfolio of the availability of deterministic, probabilistic and ensemble forecasts and observations of meteorological parameters at the surface and aloft. The availabilities of Local MET prototypes are also addressed in this verification exercise. It is checked what MET information is produced to which area/location.

6.5.2 Conduct of Verification Exercise

6.5.2.1 Verification Exercise Preparation

A questionnaire was constructed to find out what MET information is currently available in each actively involved stakeholders NMS's (MO, DWD, Meteo France, FMI, Met Norway, KNMI). The questionnaire includes the requirements from the 11.02.02-D13, Updated TS, Local OUE [7].

The questionnaire was divided into 11 parts:

I Availability of ICAO products

II Performance of ICAO products

III Availability of MET parameters (airport, surface)

IV Availability of MET parameters aloft (nominal weather)

V Availability of MET parameters aloft (significant weather)

VI Local MET Expert activity

VII MET parameter details (accuracy, update rate, granularity...)

VII MET aloft parameter details (accuracy, update rate, granularity...)

IX MET Nominal weather parameter details (accuracy, update rate, granularity...)

X MET significant weather parameter details (accuracy, update rate, granularity...)

XI Safety issues

Parts I, III, IV and V are the ones concerning the MET information availability so they were addressed in this verification exercise.

6.5.2.2 Verification Exercise execution

First, it will be evaluated if Local MET prototypes, including consolidated and translated MET information, are currently available. This verification exercise is run five times, once for each MET capability belonging to the Local MET prototypes.

Secondly, it will be evaluated what MET products are currently produced by each involved stakeholders NMS's. This verification exercise was run only once.

The verification runs for Local MET prototypes have been conducted between September 2014 and March 2015. The availability inspection of Local MET prototypes was conducted from these verification reports. The verification runs were completed with new requirements from the 11.02.02-D13, Updated TS, Local OUE [7] between October 2015 and December 2015.

The survey to determine the involved NMS's product portfolio for production of MET information was conducted between March 2st and March 30th 2015. The survey was completed with new requirements from the updated TS, Local OUE [7] in December 2015. The answers were analysed by the Local OUE leader to determine if all availability requirements are currently fulfilled.

Detailed list of all respective MET prototypes (X1.1 – X1.8, X2.1 +X2.2)

Ref	Prototype Name	Availability
X1.1	Radar composite for 3D convection	Available (Met Office, Météo France)
X1.2	Nowcasting of Convection	Available (DWD)
X1.3	Super-ensemble mesoscale forecast of convection	Available (Météo France)
X1.4	Forecast of Icing	Available (DWD)
X1.5	Forecast of CAT (not local)	Available (Met Office)
X1.6	Winter weather	Available (FMI, SMHI)
X1.7	Network capacity (not local)	Not available (Met Office)
X1.8	4D Trajectory (not local)	Partly available (Met Office, Météo France)
X2.1	Mode-S EHS observations of wind/temp and enhanced NWP	Available (KNMI)
X2.2	E-AMDAR	Available (DWD)

6.5.2.3 Deviation from the planned activities

N/A: There is no deviation from the planned activities.

6.5.3 Verification exercise Results

6.5.3.1 Summary of Verification exercise Results

It is verified that all the MET information included in the Local MET prototypes are available with specific properties depending on the kind of MET parameter.

It is concluded that at the moment not all required MET parameters expressed in 11.02.02-D13, Updated TS, Local OUE [7] are available from the involved NMS's.

6.5.3.2 Analysis of Verification Exercise Results

Local MET Prototypes inspection:

1: Inspection of radar composite of 3D convection information:

Consistent 3D radar information is available in two domains centred on London Heathrow and Paris Charles-de-Gaulle airports.

2: Inspection of nowcasting of convection information

Consistent convection nowcasting information is available covering Germany, France and United Kingdom including Ireland.

3: Inspection of super-ensemble mesoscale forecast of convection information

Consistent super-ensemble information for convection is available covering the ensemble prediction system domains provided by Météo-France, Met Office and DWD.

4: Inspection of icing forecast information

Consistent icing forecast information is available covering Europe.

5: Inspection of winter conditions forecast at airports information

Winter weather conditions forecast is available for European airports.

6. MODE-S EHS data and MODE-S EHS enhanced forecasts

MODE-S EHS observations and enhanced forecasts are available for MUAC airspace and a larger model domain covering this airspace.

7. E-AMDAR

Case study to show the benefit for MET forecast products by including on board measurements of humidity data in the NWP models, no prototype for validation produced.

General MET information inspection by questionnaire:

The inspection of involved NMS's product portfolio by questionnaire revealed that the availability of ICAO products (part I of questionnaire) is compliant. All observations (except runways surface temperature) and deterministic forecasts (except RVR) of nominal meteorological parameters at surface and aloft and significant meteorological parameters are made available by the involved NMS's. However probabilistic forecasts of RVR, visibility, wind direction classes and several significant MET phenomena are not available at the local scale (or even at all).

6.5.3.2.1 Unexpected Behaviours/Results

N/A

6.5.4 Conclusions and recommendations

6.5.4.1 Conclusions

The verification exercise was successful. The MET information of the Local MET prototypes is available as requested in the specified areas.

6.5.4.2 Recommendations

The inspection of the NMS's product portfolio could be extended to further EUMETNET EIG members across Europe (there are 31 European National Meteorological and Hydrological Services represented by EUMETNET EIG). Several probabilistic MET parameters are calculated by the ensemble prediction systems but are not translated on a regular basis into MET products for aviation.

6.6 Verification EXE-11.02.02-VP-LOC1.0007 Report

6.6.1 Verification Exercise Scope

The exercise EXE-11.02.02-VP-LOC1.0007, MET data reliability was conducted as part of the EXE-11.02.02-VP-4DWC.0007 described in Updated Verification Plan: 4DWxCube – MET-GATE [11]. The results of the verification are published in Updated Verification Report: 4DWxCube – MET-GATE [12].

6.6.2 Conduct of Verification Exercise

6.6.2.1 Verification Exercise Preparation

N/A

6.6.2.2 Verification Exercise execution

The preferred verification methods were inspection and design review. The verified requirements include aspects of data reliability and technical safety.

6.6.2.3 Deviation from the planned activities

N/A: There is no deviation from the planned activities.

6.6.3 Verification exercise Results

6.6.3.1 Summary of Verification exercise Results

It is verified that MET products are reliable and immediate access to incoming data is successful. The reliability requirements originated from TS and IRS are satisfied by the MET-GATE.

6.6.3.2 Analysis of Verification Exercise Results

The aspect of the immediate availability of incoming data could be verified in this group related to the MET-GATE verification test component 'reliabComponent'. It could be verified successfully that incoming data is made available to requesting HTTP clients by the MET-GATE Prototype instance shortly afterwards (delay of few seconds due to internal processing of the non-operational system).
The MET products provided by certified MET Service provider could be accessed uncorrupted and are therefore classified as safe and reliable.

6.6.3.2.1 Unexpected Behaviours/Results

N/A

6.6.4 Conclusions and recommendations

6.6.4.1 Conclusions

The verification exercise was successful for the set of verification objectives which could be a priori verify at all. The index mechanism was only analysed with regards to its implementation. Bulk tests confirming also its suitability in high-performance cases were not yet implemented.

The verification exercise was successful by accessing reliable MET information immediate on demand.

6.6.4.2 Recommendations

N/A

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] Requirements for MET Information (11.02.01), “MET Technical Architecture Description (TAD)”, 11.02.01 – D31, Ed. 00.02.00, October 2015

[7] MET Information Systems Development Verification & Validation (11.02.02), “Updated Technical Specification (TS), Local OUE”, 11.02.02-D13, Ed. 00.01.00, October 2015

[8] MET Information Systems Development Verification & Validation (11.02.02), “Updated Verification Plan: 4DWxCube – Local MET prototypes”, 11.02.02-D16, Ed 00.01.00, October 2015

[9] Pepe, M.S. and Thompson, M.L., 2000, Combining diagnostic test results to increase accuracy, Biostatistics 1,2, pp. 123 – 140

[10] ICAO Annex 3

[11] MET Information Systems Development Verification & Validation (11.02.02), “Updated Verification Plan: 4DWxCube – MET-GATE”, 11.02.02-D29, Ed 00.01.00, October 2015

[12] MET Information Systems Development Verification & Validation (11.02.02), “Final Verification Report: 4DWxCube – MET-GATE”, 11.02.02-D30, Ed 00.01.00, February 2016

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