Downscaling as a way to predict hazardous conditions for aviation activities

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***Abstract*—This paper presents a multiscale terrain induced turbulence and wind shear alert system for air traffic management. The system which is operational on 20 Norwegian airports since 1st July 2009 has been approved by the Norwegian Civil Aviation Authority. The paper starts with a brief technical description of the system followed by a quantitative description of its computational demand and robustness. In the following section, results from the system is compared against synoptic data obtained from airports and Flight Data Recorder (FDR) of some aircraft. Finally, a strategy to communicate the predictions from the system to the Air Traffic Management in real time is explained.**

I. Introduction

Airlines have made it possible for people to travel almost anywhere in the world for fairly affordable prices. It has also broken many barriers and allowed families to live in different countries and still keep in touch. In fact, air travel between countries is so cheap in some parts of the world that it is often the cheapest way to travel. For instance, one of the cheapest modes of transportation in Europe at the moment is air travel. In a country like Norway where the construction of railway and road network is a tedious job, it is perhaps the most convenient mode of transportation of people and goods. However, the convenience comes at the cost of comfort and safety because of the unfavorable flight conditions prevailing in the mountainous regions. The regions are characterized by recirculations, mountain waves, hydraulic transitions, rotors and vortices which are all hazardous flying conditions. For the flight operation to be pleasant it is important to predict these hazardous flying conditions. Such predictions are complicated by the existence of a wide variety of spatio-temporal scales involved in the atmospheric flow. Most atmospheric processes are limited to a certain time- and length-scale, which is reflected in their classification into global-, meso-, and microscale processes. The overlapping between the chosen scales of interest and the scales of any physical process determine whether the process may be neglected, parameterized (empirically or physically) or directly resolved in a model. It is obvious that all scales are interrelated. Kinetic energy is passed down from larger scales to smaller scales and is finally dissipated as heat. Unfortunately, it is not possible to satisfactorily resolve all the scales in a computationally tractable way using a single model. It is however possible to tackle this problem by coupling different models with each targeting different climatic scales. For example a global model with a grid size of $200km-300km$ may be coupled with a meso scale model having a grid resolution of $1km - 20km$, which itself may be coupled with a micro scale model with a resolution of $10 - 100m$.

SINTEF ICT and Norwegian Meteorological Institute have been involved in the development and deployment of a Multi-scale Turbulence prediction system for 20 Norwegian airports. The system has been approved by the Norwegian Civil Aviation Authority (NCAA). In this paper, we describe the methodology and the computational costs associated with it as well as its accuracy in predicting local wind and turbulence so that the results from the model can be used with greater confidence. We achieve this through a unidirectional nesting between HIRLAM (High Resolution Local Area Modeling), UM (Unified Model) and SIMRA (Semi Implicit Method for Reynolds Averaged Equations). The assumptions here is that an inaccurate flow estimate can be transformed into a more accurate one by applying better information about terrain and scales at a smaller scale. This paper starts with a description of the various models involved (HIRLAM, UM and SIMRA) followed by the forecasting setup (domain size, grid resolution) for different models. Details of the computation resources utilized along with the computational demands of different models are presented next. Comparison of numerical results against synoptic and FDR data is presented next. Finally, a strategy to communicate the predictions of the multiscale system to Air Traffic Management in real time is explained.

II. Technical Description

A. Filtered equations of Motion

Atmospheric flow at any scale (global, meso or micro) like any other fluid flow is governed by the conservation of mass, momentum, energy and scalars like humidity. The conservation laws are mathematically described by Equations 1, 2 and 3.

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{u} = 0 \tag{1}$$

$$\frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot \rho \mathbf{u}\mathbf{u} + \mathbf{f} \times \rho \mathbf{u} = -\nabla p - \rho \mathbf{g} - \nabla \cdot \langle \rho \mathbf{u}^{'} \mathbf{u}^{'} \rangle \tag{2}$$

$$\frac{\partial \mathbf{C}}{\partial t} + \nabla \cdot \rho \mathbf{C}\mathbf{u} = \mathbf{S} - \nabla \cdot \langle \mathbf{C}^{'} \mathbf{u}^{'} \rangle \tag{3}$$

where $\mathbf{u}$ is the mean velocity vector, p is the mean pressure, and ρ is the mean density. The mean temperature, specific humidity and cloud water are components of the vector $\mathbf{C}$. Note that the mean value operator $\langle\rangle$ is disregarded in the first moments.

B. *Turbulence closures*

The mesoscale models (UM4 and UM1) used in this study use a dynamic one equation model while the microscale model (SIMRA) uses a two-equation model. The estimation of turbulent kinetic energy in both the models are accomplished through Equation 4.

$$\frac{\partial K}{\partial t} = \nabla \cdot K\mathbf{u} = P + G - \epsilon - \nabla \cdot \langle K^{'} \mathbf{u}^{'} \rangle \tag{4}$$

where $P = -\langle \mathbf{u}^{'} \mathbf{u}^{'} \rangle \cdot \nabla$ and $G = -\langle \rho^{'} w^{'} \rangle g/\rho \approx \theta^{'} w^{'} \rangle g/\theta$. In the one-equation model the turbulent length scale is specified algebraically from

$$\ell_t \approx \frac{min(\kappa z, 200m)}{1 + 5Ri} \tag{5}$$

where

$$Ri = \frac{(g/\theta)\partial\theta/\partial z}{(\partial u/\partial z)^2} \approx -\frac{G}{P} \tag{6}$$

In convective conditions the stability correction $(1 + 5Ri)$ is replaced by $(1 - 40Ri)^{-1/3}$. The gradient Richardson number is supposed to be smaller than $1/4$. The turbulent dissipation is estimated from $\epsilon = (C_\mu^{1/2} K)^{3/2}/\ell_t$. The turbulent viscosity coefficient is given as a turbulent velocity $u_t = (C_t^{1/2} K)^{1/2}$ multiplied by a turbulent length scale, $\nu_t = u_t \ell_t$.

In the two-equation model the eddy viscosity is expressed as $\nu_t = C_\mu K^2/\epsilon$, and ϵ is estimated dynamically from

$$\frac{\partial \epsilon}{\partial t} + \nabla \cdot \epsilon \mathbf{u} = (C_{\epsilon 1} P + C_{\epsilon 3} G - C_\epsilon 2\epsilon)\frac{\epsilon}{K} - \nabla \cdot \langle \epsilon^{'} \mathbf{u}^{'} \rangle \tag{7}$$

The coefficients are $(\kappa, C_\mu, C_{\epsilon 1}, C_{\epsilon 2}, C_{\epsilon 3}, \sigma_K, \sigma_\epsilon) = (0.4, 0.09, 1.92, 1.43, 1, 1, 1.3)$. [5]

C. *Different models and their technical description*

1) HIRLAM: High Resolution Local Area Modelling (HIRLAM) numerical weather prediction model is a hydrostatic model operational in Denmark, Finland, Iceland, Ireland, Netherland, Norway, Spain and Sweden. The core of the model is based on a semi implicit semi-Lagrangian discretization of the multi-level primitive equations using a hybrid coordinate in the vertical direction. For the horizontal discretization, an Arakawa C-grid is used. The dynamic variables computed in the

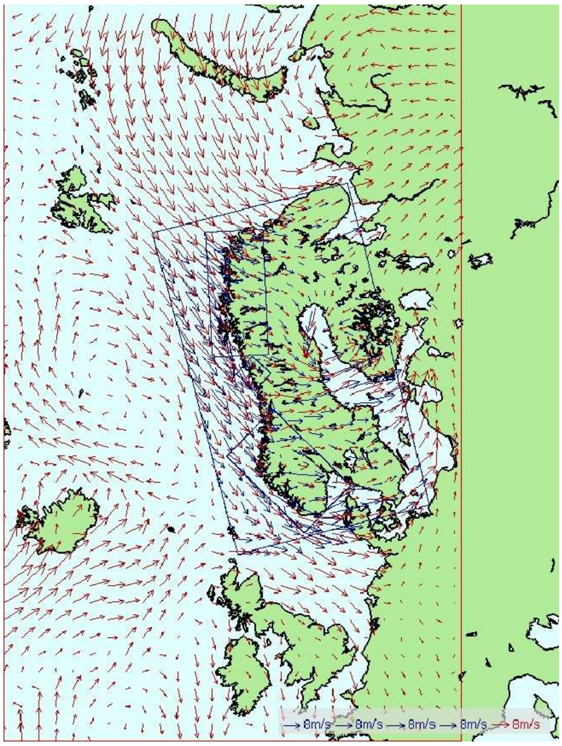


Fig. 1. HIRLAM domain (red) along with the UM4 and three UM1 subdomains (blue)

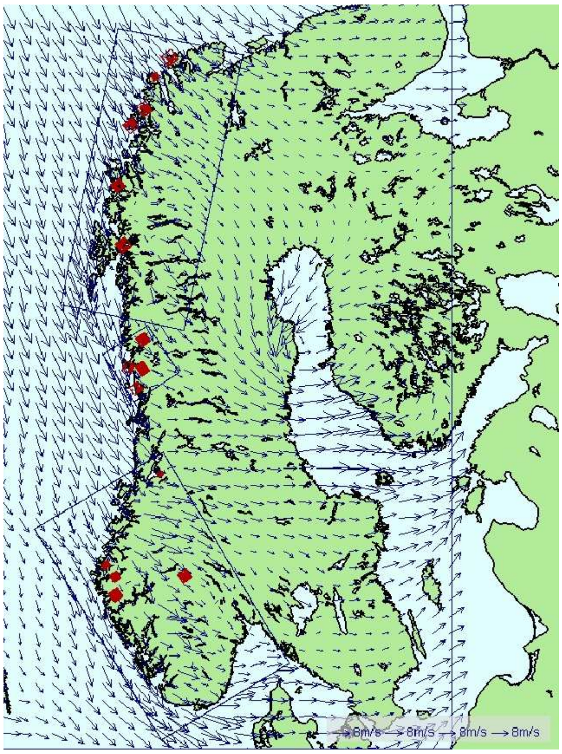


Fig. 2. UM4 domain (blue) with three UM1 (blue) and SIMRA (red) subdomains

model are horizontal wind components, temperature, specific humidity, cloud water and surface pressure. More details on the dynamical and numerical aspects of HIRLAM can be found in the HIRLAM Scientific Documentation, December 2002 ([8]). The model has a variety of parameterization schemes for sub-grid scale physical processes. Initial and boundary conditions are normally taken from the ECMWF (European Centre for Medium-Range Weather Forecasts) model. At the upper boundary a condition of zero vertical velocity is imposed.

2) Unified Model: The UK Met Office Unified Model as used in the Norwegian Met Office is a non-hydrostatic numerical weather prediction model which uses a rotated spherical terrain following grid. The model is based on an Arakawa C grid which is a staggered configuration which means that the computation points of the velocity is displaced half grid length in horizontal and vertical directions compared to the computation points of temperature, moisture and other scalars. Model prognostic parameters include 3D wind, potential temperature, specific humidity, density, cloud particles and rain. The model uses semi-implicit time integration and semi-Lagrangian advection scheme. Physical parameterizations accounts for the influence of clouds, gasses and ice crystals on radiation. Turbulence is modelled using the one equation model approach described in the last section. The surface is described as a composite of 9 different surface types. When the model is run with 1 km resolution convection and orographic roughness are assumed to be resolved. Physiography is based on the UM Ancillary generation system with the GLOBE dataset for orography and orographic roughness, the IGBP (International Geosphere-Biosphere Programme) classification data (IGBP, 2010) for surface types and the Wilson and Henderson-Sellers, 2010 data for vegetation and soil parameters.

3) Semi IMplicit Reynolds Averaged Model: Semi IMplicit Reynolds Averaged (SIMRA) model is a fully three-dimensional model for anelastic flow. It makes use of the Boussinesque approximation. The model solves prognostic equations for all velocity components, potential temperature and pressure (Equations 1, 2 and 3). Turbulence is modelled using two equations: one for turbulent kinetic energy (Equation 4) and another for turbulent dissipation (Equation 7). A projection method is used for the solution of the Reynolds equations, and a mixed finite element formulation is used for space discretization. Since the effects of Coriolis force at this scale is negligible this is ignored in the model. A Taylor-Galerkin method is used for time discretization. A special feature of this model is the use of logarithmic element interpolation at the near-ground location in order to satisfy logarithmic boundary conditions accurately. This model has been tested against various data, from two-dimensional flow over a single hill in neutral and stratified flow [2] to three-dimensional flow over different hill shapes [4]. The code has been parallelized using Message Passing Interface (MPI).

All the three models mentioned above have been coupled to run simultaneously provided that the boundary condition data from the higher model is available.

TABLE I
HARDWARE DETAILS

Operating system	AIX 5.3
Queueing/scheduling system	LoadLeveler
Total space for shared temporary storage	33TB
Total space for home directories	48TB
Max addressable memory	$180 \times 13 + 6 \times 128$ GB

TABLE II
SIMULATION DETAILS

Models	Nodes	Proc.	Grid cells X,Y,Z	Domain (km) X,Y,Z	Sim. time (min)
UM4	27	432	$300, 500, 38$	$1200, 1200, 40$	11
UM1-NN	59	944	$336, 752, 70$	$336, 752, 40$	56
UM1-MN	3	48	$144, 152, 70$	$144, 152, 40$	42
UM1-SN	63	1008	$400, 656, 70$	$400, 656, 40$	51
SIMRA-HA	1	16	$61, 61, 41$	$28, 32, 3$	40
SIMRA-VA	1	16	$75, 61, 41$	$15, 13, 2$	29

D. Hardware Configurations

The multiscale system runs on 'NJORD' which is a distributed shared-memory system consisting of IBM p575+ nodes interconnected with a high-bandwidth low-latency switch network (HPS). The system has a total of 192 nodes partitioned into 186 computational nodes, 4 Input/Output nodes and 2 login nodes. All the 186 computational nodes are shared memory nodes with 8 dual-core power5+ 1.9GHz processors each. 180 of the computational nodes have 32GB memory while the other six have 128 GB memory. The disk storage system is accessed through IBM's distributed parallel Input/Output General Parallel File System (GPFS). The system is well-suited for large scale parallel MPI and OpenMP applications, as well as applications that combine these two communication paradigms. Other details are summarized in Table I.

E. Simulation details

For Norway we have a single UM4 model covering the whole of Norway with a $4km$ resolution. However, there are three different $UM1$ domains which we refer to as UM1-NN (Northern Norway), UM1-MN (Mid Norway) and UM1-SN (Southern Norway) (as shown in Figures 1 and 2). Similarly the domains for microscale simulations corresponding to Hammerfest and Værnes are referred to as SIMRA-HA and SIMRA-VA. The two airports lie in the UM1-NN and UM-SN domain respectively. The whole system is evolving with time

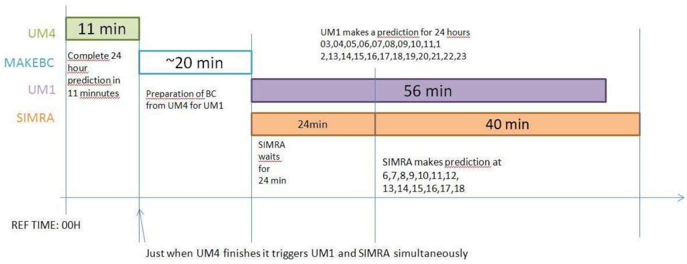


Fig. 3. Schematic of the scheduling of the Multiscale system for Hammerfest

TABLE III
AVAILABLE FORECAST FROM SIMRA RUNS. THE TWO LAST COLUMNS SHOW THE PERCENTAGE OF FORECASTS AVAILABLE EITHER COMPLETE OR THE SUM OF COMPLETE RESULTS AND THE RESULTS WHEN SOME OF THE DATA ARE MISSING

Airport	All data missing	Some data missing	No. of forecast possible	% operated with all data	% operated with some data
Hammerfest	21	39	730	91.5	97.1
Værnes	28	20	730	93.4	96.2

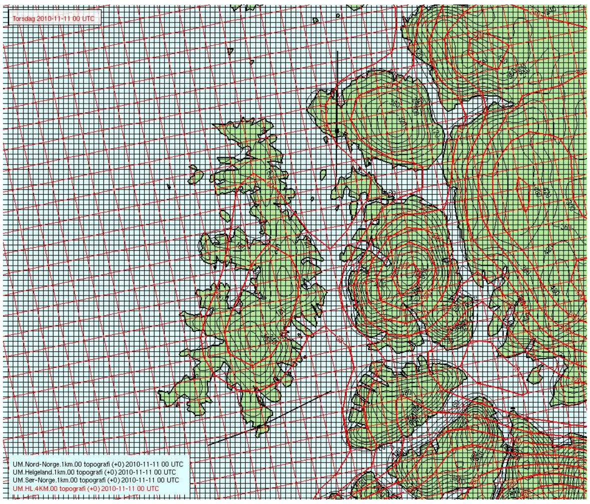
depending upon the state of the computational resources. The system information presented in this paper corresponds to the time during which the presented validation was conducted. The computational resources utilized by different models as well as the domain and grid sizes and simulation time for different models are presented in Table II. Figure 3 gives a schematic of how the system runs on the machine. The UM4 model is triggered at $00:00H$. It takes just 11 minutes to complete a forecast of the next 24 hours. These results are then used to force UM1 models every 20 minutes. Preparation of the boundary condition files for UM1 takes a total of approximately 20 minutes after which all the UM1 and SIMRA models are launched simultaneously. SIMRA has to wait for the results from UM1 to be used as boundary conditions. All the SIMRA simulations are steady state which means that 12 different simulations are conducted to make a prediction from $06:00H$ to $18:00H$. The results from the SIMRA model are post-processed and finally displayed on the website www.ippc.no to be used by the warning system. All the simulations (UM4, UM1 and SIMRA) are rerun at $12:00H$ and the results are updated.

Table III gives the availability of forecasts from the microscale model (SIMRA) on our systems as numbers and as percentage of the possible forecasts (two computational runs each day and hence $365 \times 2 = 730$ runs). We see that there have been available complete data sets for more than 91% of the possible runs. Most of the missing runs have been caused by some computational weaknesses in the UM model which are being identified and fixed from time to time.

III. VALIDATION

The microscale code SIMRA has been rigorously validated against wind tunnel and field experiment data. In the forecasting context, the unavailability of data complicates the validation work. So far the only data which has been readily available from the airports are the wind magnitude and directions recorded every 10 minutes at a height of $10m$ above the ground. We call these synoptic data. More recently we have been able to obtain data from the Flight Data Recorder (FDR) of selective flights. The data consists of wind magnitude and directions, potential temperature and vertical and horizontal G-forces at $8Hz$ frequency along the whole flight path. While the data recorded at $10m$ height above the ground gives information about the low level atmospheric conditions (which is very localized in nature), the FDR data gives information about turbulence and atmospheric conditions at higher altitudes.

(a) Topography in the vicinity of the Hammerfest Airport



(b) UM4 (red) and UM1 (black) mesh

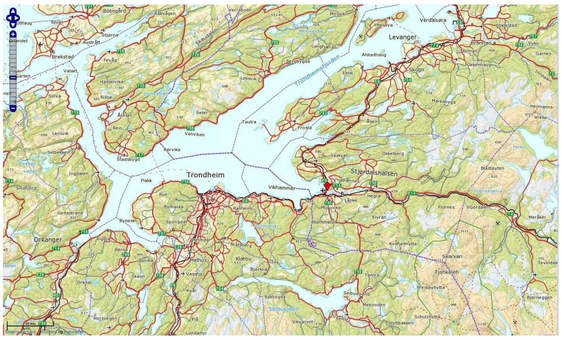
Fig. 4. Hammerfest

Basis of these type of validation work is the operational storage of both observations and model output in secured databases. In this way all data for validation are available for further investigation if necessary. All the simulation results are interpolated horizontally to the position of the observation with Bessel interpolation with good interpolation accuracy. To compare with observations at times off the hourly available model data a linear interpolation in time is carried out. In order to quantify the results for the wind in some way, we have computed the square root (S_{uv}) of the mean of the squared standard deviations of the component errors of the two wind components u and v (S_u and S_v). The formula is:

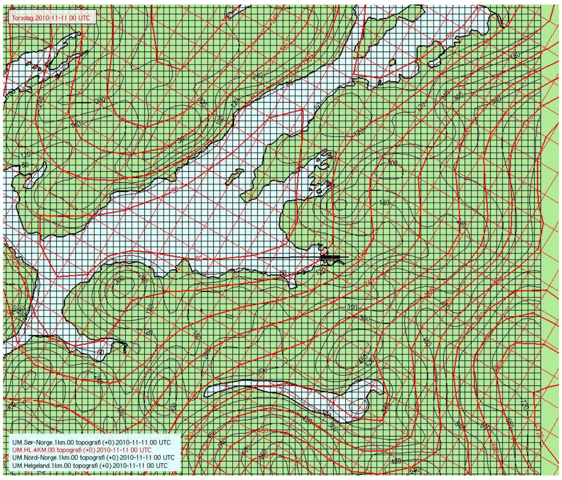
$$S_{uv} = \sqrt{\frac{1}{2}\left(S_u^2 + S_v^2\right)} \tag{8}$$

A. Validation: Hammerfest

In this subsection we present a comparison of the numerical results with synoptic data for the Hammerfest Airport. Hammerfest Airport is the airport serving the town of Hammerfest in Finnmark, Norway. The airport is located north of the town centre. Although the airport is located on an island which is relatively flat it is characterized by a chain of small hills comprising of Vardfjellet ($166m$), Vedhammeren ($266m$),



(a) Værnes map



(b) Værnes Mesh: UM4 (red), UM1(black)

Fig. 6. Værnes

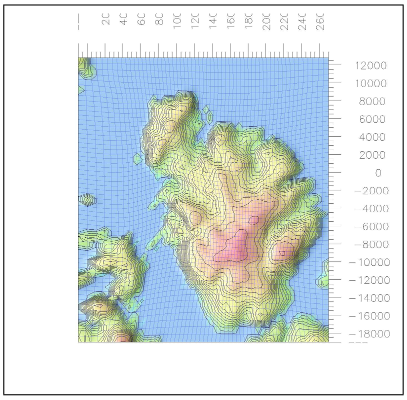
Storfjellet ($328m$) running parallel to the runway $750m$ to the north and another small chain comprising of Fuglenesfjellet ($150m$) $1000m$ to the south (see Figure 4(a)). The airport thus lies in the valley known as the Fuglenesdalen which is an ideal configuration for the channeling of flow and to certain extent explains the observed dominant wind direction. The dimension of these hills are so small that they are not adequately represented in any of the models except SIMRA. It should be noted from Figure 4(b) that both UM4 and UM1 has a reasonable number of computational nodes to resolve the topography of the island. However, the small hills (explained earlier in the paragraph) appear to have a very strong local influence and is unfortunately not resolved in these models. SIMRA resolves these topographical features quiet well and the windrose diagram in Figure 5(c) reflects that. HIRLAM, UM4 and UM1 all give a uniformly distributed windrose. SIMRA on the other hand predicts the dominant wind directions quiet accurately. Another conclusion from the figure is that the wind magnitude is overpredicted in HIRLAM and UM4 but underpredicted in UM1 and SIMRA. This is a good example to show that even when the boundary conditions are inaccurate the downscaling can improve the accuracy of prediction if the flow is significantly impacted by local scales it is capable of resolving.

B. *Validation: Værnes airport*

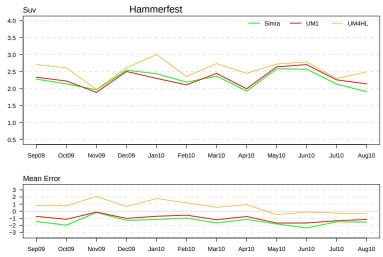
Trondheim Airport, Værnes is an international airport located in Stjørdal, $19km$ east of Trondheim. Figure 6(a) shows the terrain variation in the vicinity of the airport and figure 6(b) shows the mesh used in the UM4 and UM1 models. It is noteworthy that, in contrast to the Hammerfest case, the two models have adequate resolutions to model the effects of the terrain. For the westerly wind which is also the dominant wind direction, there is no substantial terrain influence on the flow in the close vicinity of the airport ($3km$ radius) and this is also observed in the similarity of the windrose predicted (figure 7(c)) by SIMRA, UM1 and UM4 models. Errors are small for all models (figure 7(b)). It should be mentioned that most of the time the wind direction is westerly, a conditions which does not pose any serious threat to aviation activities. However, the south easterly wind which prevails occasionally leads to the development of strong turbulent zones along the frequently used landing or take off paths. This kind of situation is rarely picked up by the UM4 and UM1 models. To test the performance of the SIMRA code we obtained the FDR data from two flights operating at the airport within a time window of 40 minutes on 15.12.2012 between $6-7pm$. Figure 8 shows a comparison of the turbulence experienced by the aircrafts and the associated turbulent intensity predicted by the numerical model. In the present study big and sudden variations of the G-force experienced by the aircrafts have been treated as indicators of the atmospheric turbulence experienced by the aircrafts. The exact locations along the flight path where these large variations were recorded have been marked with stars. One can clearly see that these are also the sites associated with high level of turbulence according to the numerical model.

IV. COMMUNICATION OF RESULTS TO THE PILOTS

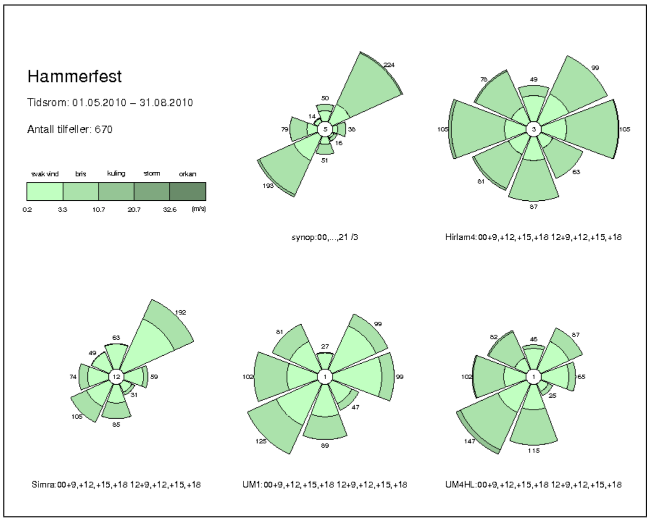
As shown in the previous section the model is capable of predicting the characteristics of terrain induced turbulence but the results from such a model has to be assimilated and processed in a turbulence alert system by the Air Traffic Management (ATM) in real time. To achieve this the model has been parallelized and coupled to the numerical weather prediction system used by the Norwegian Meteorological Office. To make the results more comprehensible, the 3D velocity and turbulence fields are projected onto an upside-down conical section centered in the middle of the runway (9(a)). The conical angle is chosen so as to include the glide path of the kind of aircrafts that operate in the region. The 3D fields are also projected onto a vertical plane containing the glide path (9(b)). Both the projections are dynamically plotted and presented on the pilots planning webpage (www.ippc.no). A snapshot from this website is shown in the figure 9. Three different levels of turbulence intensity are depicted in these figures using different colors. The ATM and pilots are expected to use these results as guidelines in planning their activities. Another option is also being implemented to reduce an unnecessary need of referring to the webpage every now and then. In this, the turbulence intensity field in a three-dimensional cylindrical volume along the flight path is extracted



(a) SIMRA mesh



(b) S_{uv} (top) and mean error (bottom)



(c) Windrose data for different models

Fig. 5. Validation of forecasts for the Hammerfest Airport area from May to August in 2010.

as shown in the figure 10 and checked for the critical values. If a zone with critical value of turbulent intensity is identified then an alarm is triggered and a message is sent to the air traffic management authorities to take precautionary measures. This system is presently in operational mode for twenty Norwegian airports. The first ones were operational already in 2007.

V. Conclusion and Future Work

A multiscale local flow prediction system with four levels of downscaling has been discussed. The HIRLAM weather prediction data provided boundary conditions to a mesoscale model covering the whole of Norway with a resolution of $4km$. This model in turn provided the boundary conditions to three different mesoscale models having a resolution of $1km$ each and covering northern, mid and southern Norway. Embedded in these three mesoscale domains, the two microscale models predicted the more local flow characteristics which the mesoscale models were not capable of. The computational resources utilized by the different models and were described in detail. The results from different models were then compared against the synoptic data and presented in terms of windrose. These observations were then analyzed with respect to the terrain resolved in different models. It was found that the downscaling was not of much value for the most probably wind direction encountered at the Værnes airport however for south easterly wind the model did well to predict the turbulent conditions experienced by the aircrafts. Most important findings of the study is enumerated below.

- We saw a clear gain in the accuracy of prediction by downscaling. The gain was more pronounced in the case of Hammerfest where the local irregularities in the terrain was significant.
- SIMRA and UM1 underpredicts the wind magnitude while HIRLAM and UM4 overpredict the wind magnitudes (figures 5(b) and 7(b)).
- Errors during the summer season is minimum (figures 5(b) and 7(b)).
- The model is computationally very efficient and robust.
- The model is capable of predicting the actual turbulent conditions experienced by the aircrafts.

Acknowledgements

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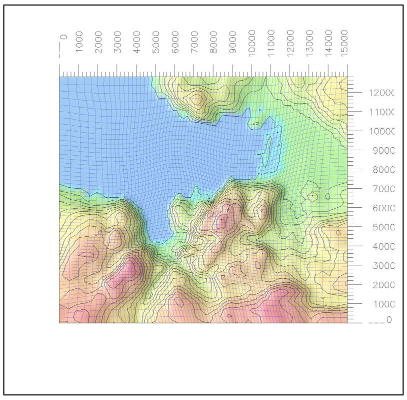
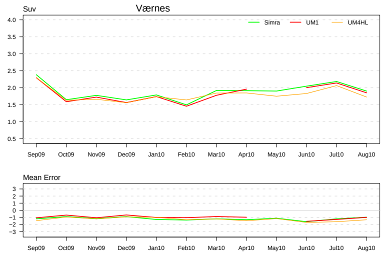
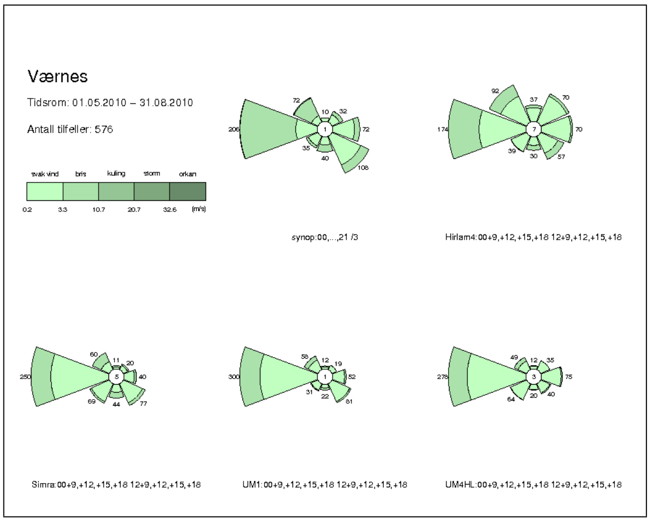


(a) SIMRA mesh

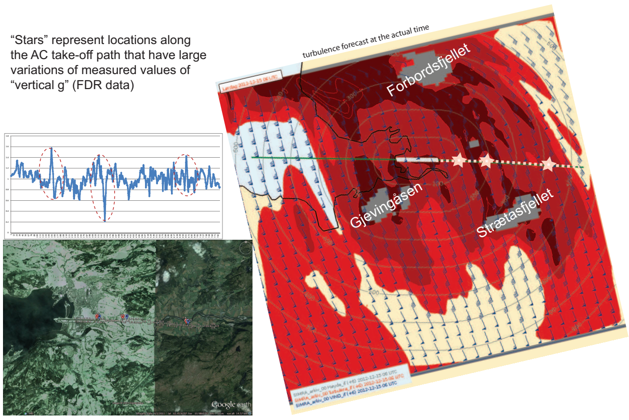


(b) S_{uv} (top) and mean error (bottom)

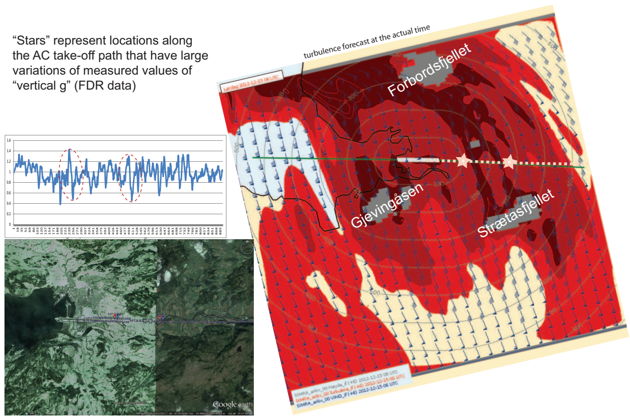


(c) Windrose for different models

Fig. 7. Validation of forecasts for the Trondheim Airport Værnes area from May to August in 2010.

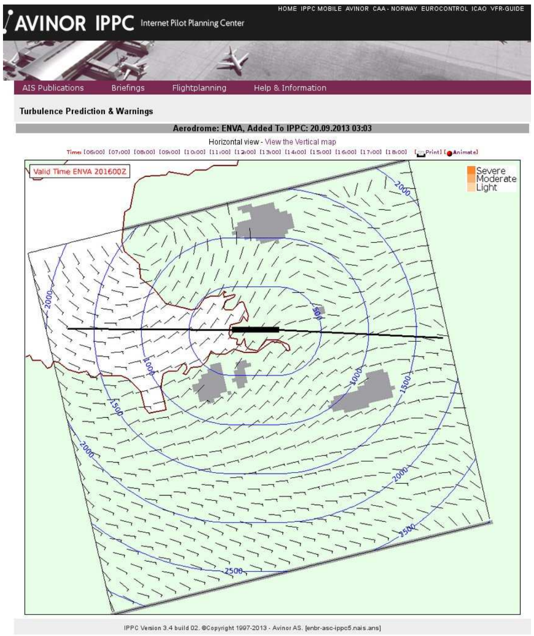


(a) Flight 1

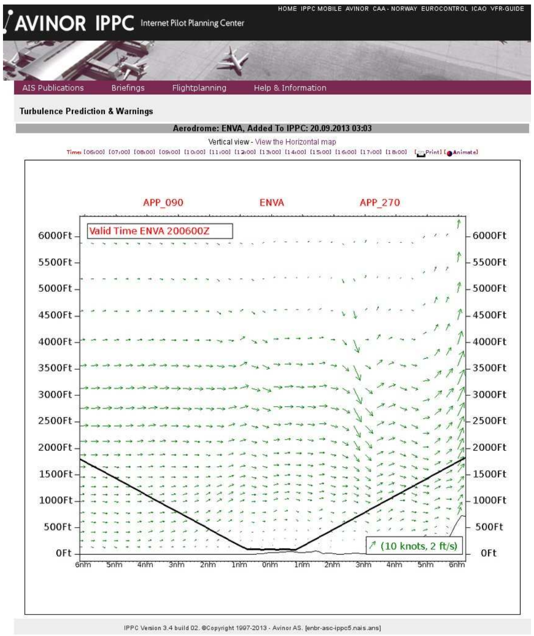


(b) Flight 2

Fig. 8. Comparison against the FDR data (Graph in blue is the G-force from the FDR,the contours in red is that of the turbulent intensity. The star marks correspond to spots of high turbulence intensities)

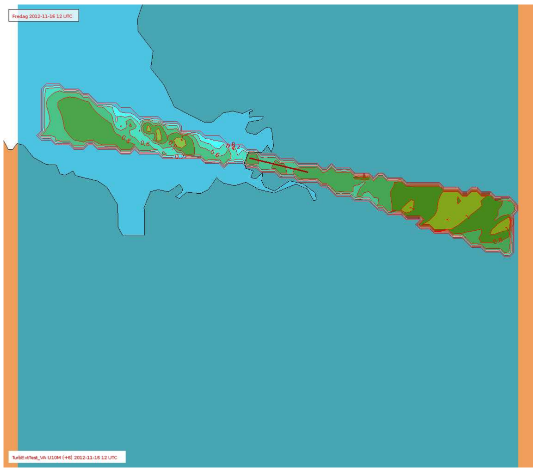


(a) Velocity field and turbulence intensity projected on a conical surface containing the flight path

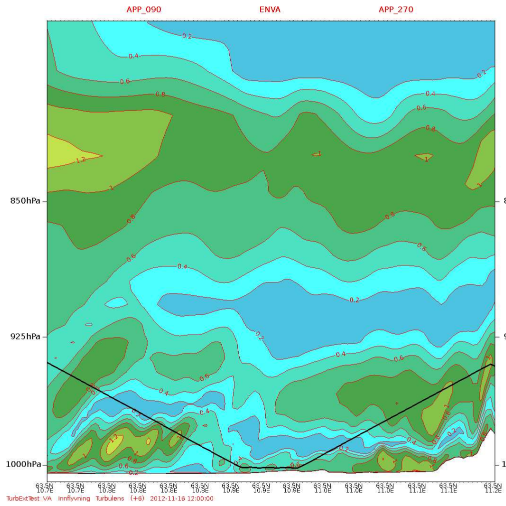


(b) Velocity field and turbulence intensity projected on a vertical plane containing the flight path

Fig. 9. Snapshot from the www.ippc.no website



(a) Aerial view



(b) Lateral view

Fig. 10. Turbulence intensity along a flight path close to Værnes

present study.

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.

[2] K.J. Eidsvik and T. Utnes, *Flow Separation and Hydraulic Transitions over Hills Modelled by the Reynolds Equations*, Journal of Wind Engineering and Industrial Aerodynamics, 67, 403-413, 1997.

[3] GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80305-3328, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/mgg/topo/globe.html)

[4] T. Utnes and K.J. Eidsvik, *Turbulent Flows over Mountanous Terrain Modelled by the Reynolds Equations*, Boundary Layer Meteorology, 79, 393-416, 1996

[5] T.B. Gatski, M.Y. Hussain and J.L. Lumley, *Simulation and Modelling of Turbulent Flows*, Oxford University Press, Oxford, 314pp, 1996

[6] http://igbp.net/

[7] http://dss.ucar.edu/datasets/ds767.0/

[8] http://hirlam.org/