

SESAR Innovation Day 2013, Stockholm, Sweden

Downscaling as a way to predict hazardous conditions for aviation activities

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Applied Mathematics

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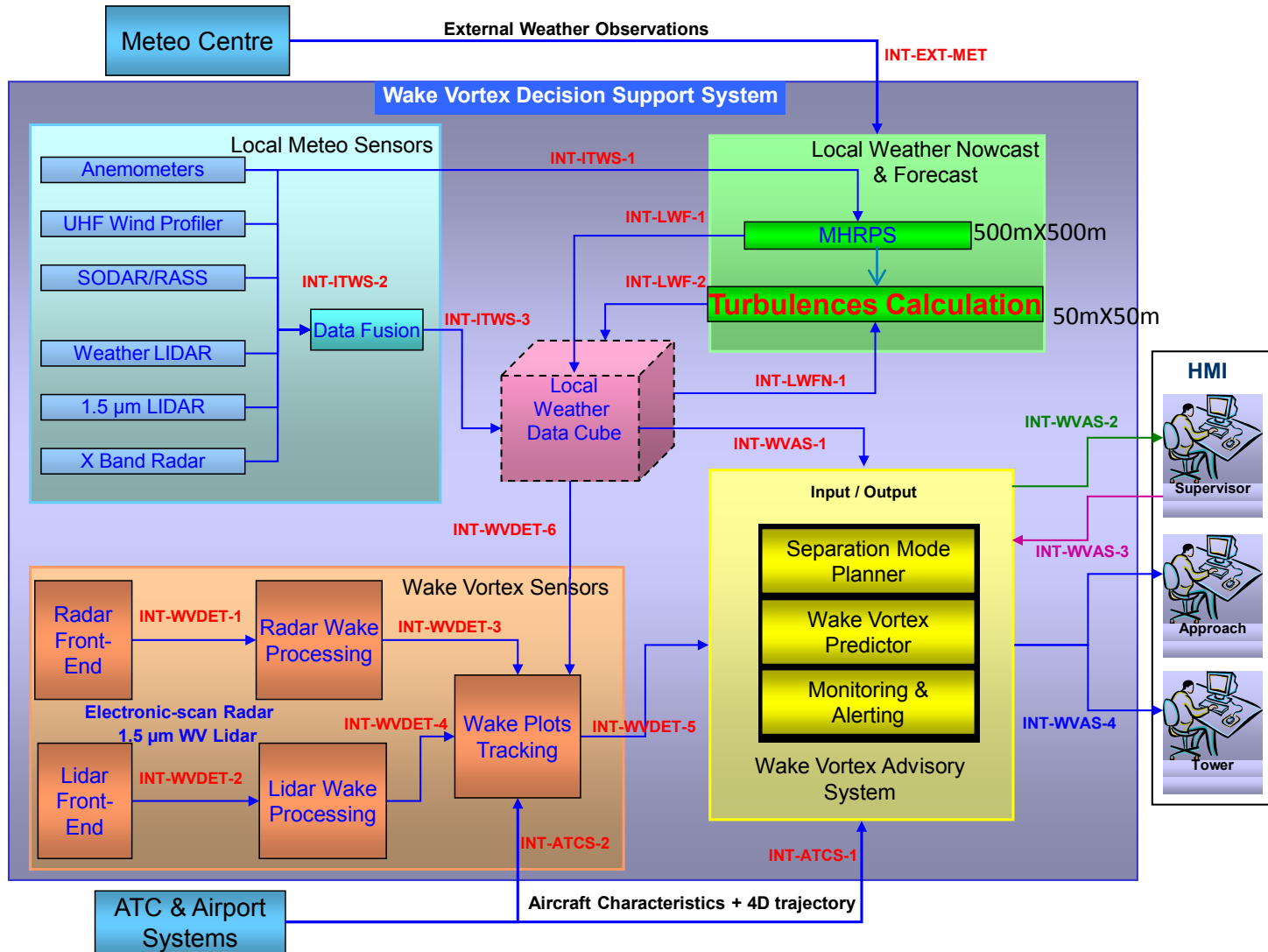
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OVERVIEW

- Context
- Background
- Flow in complex terrain
- Forecast
- Computational efficiency and robustness
- Validation strategy
- Conclusion

Context: WP 12.2.2



NON-NORWEGIAN AIRPORTS (Terrain)



NORWEGIAN AIRPORTS (Terrain)



Background: Aviation



Widerøe DH8A on May 1st 2005
The Aviation Herald

Hammerfest Airport

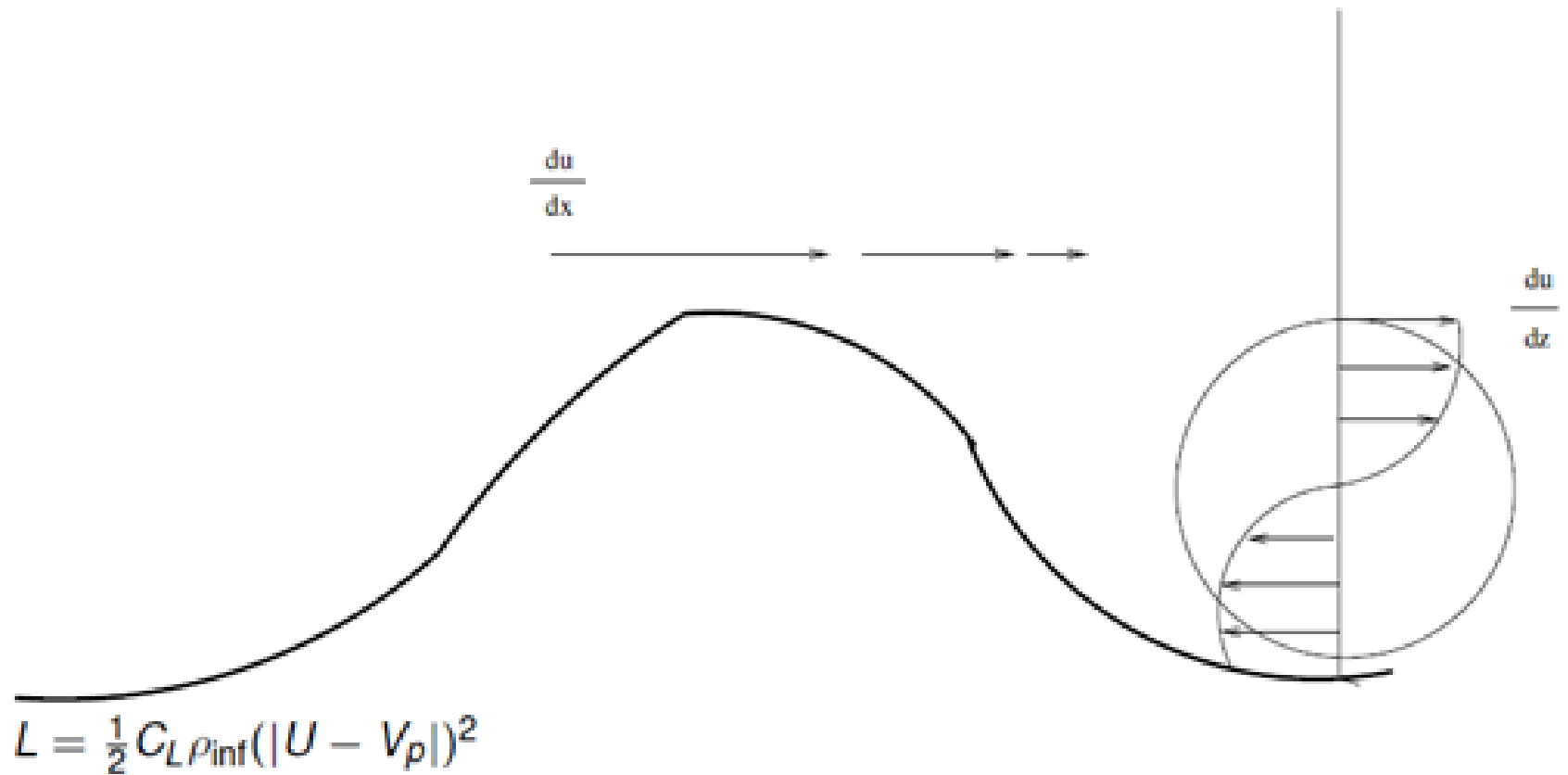
Just before landing the wind speed veered and increased, creating a tail wind.

The increase in the descent rate was compensated, but was insufficient, and the plane had a touch-down on the right main landing gear, with the leg failing and the aircraft sliding on its belly.

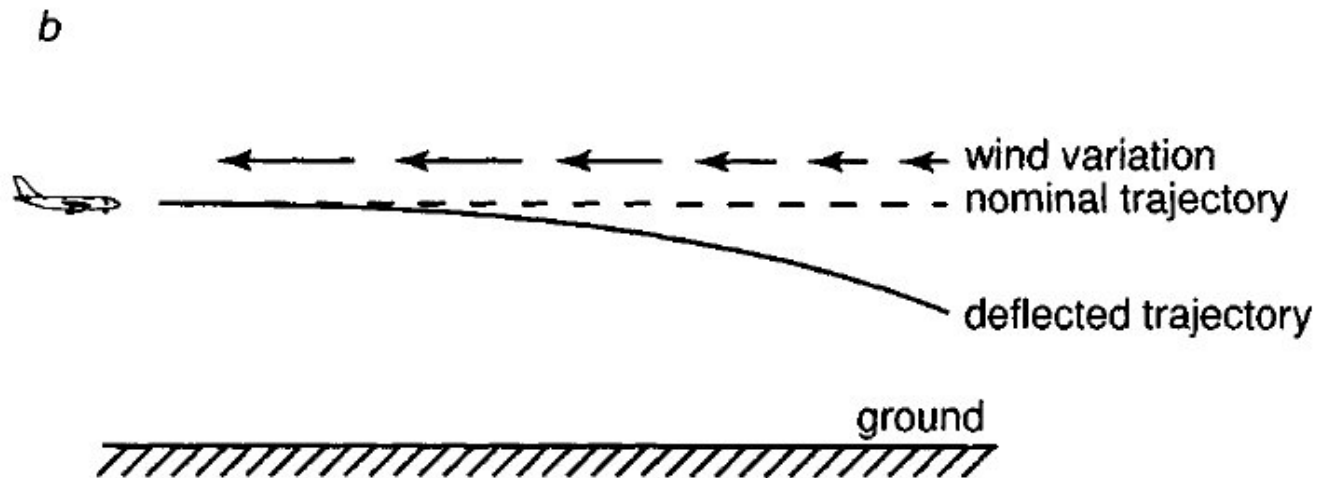
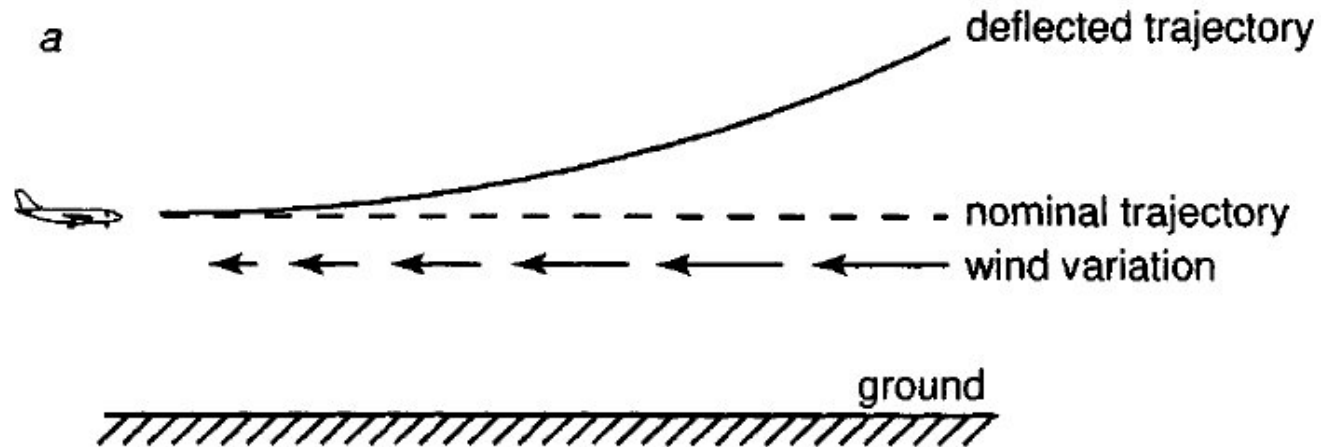
The aircraft was written off and Widerøe was criticized for permitting landings under too high winds and gusts

Norwegian Civil Aviation Authority imposed stricter wind regulations upon the airport.

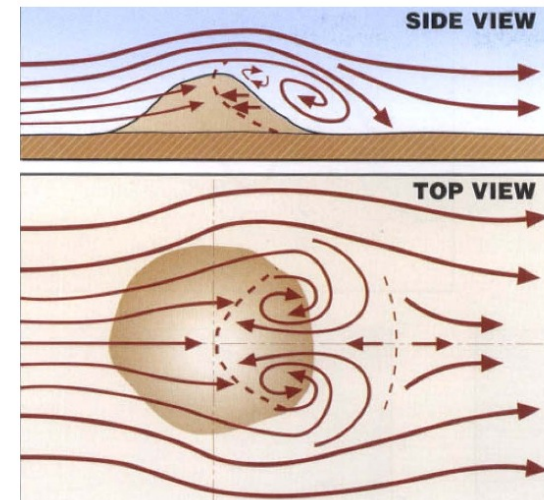
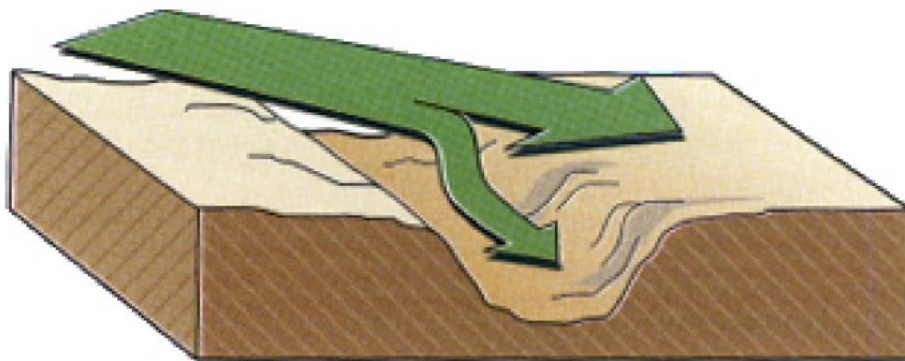
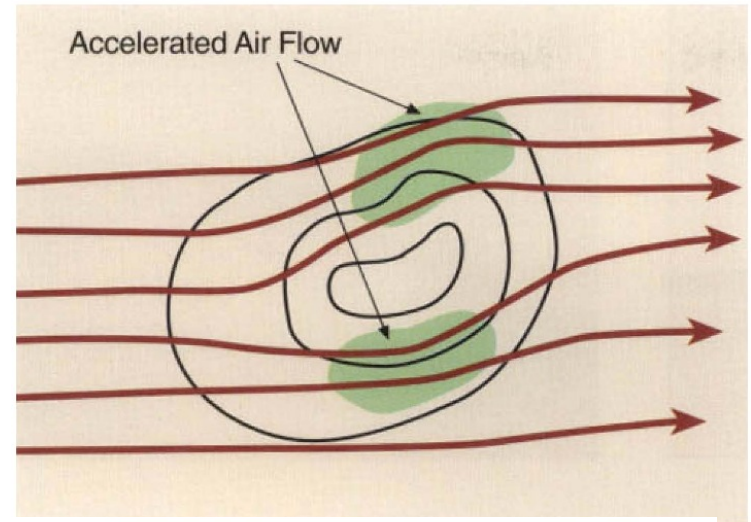
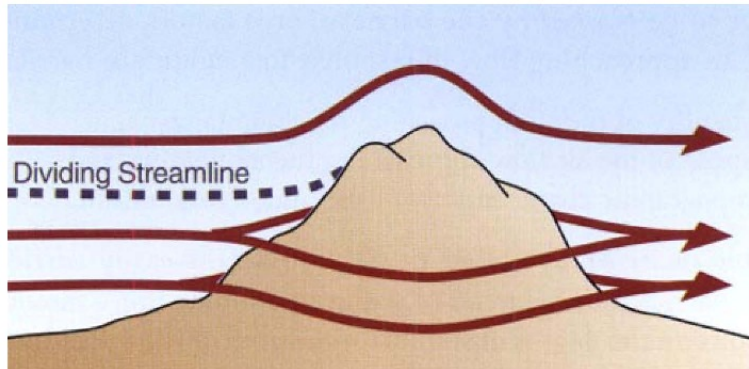
Wind shear in mountainous terrain



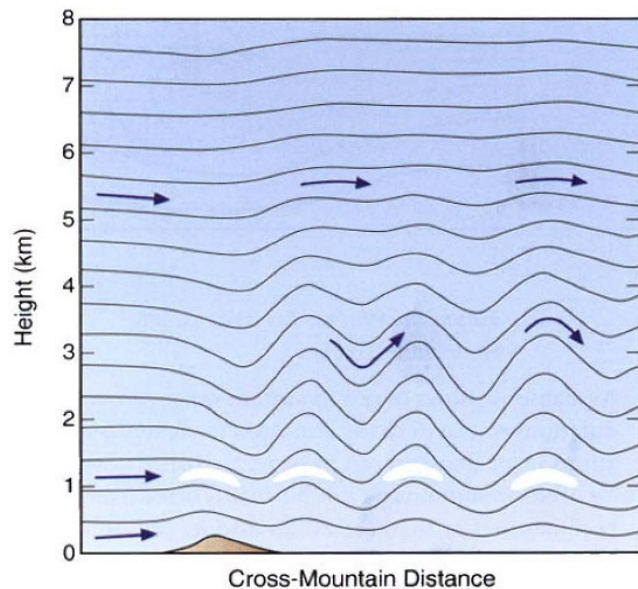
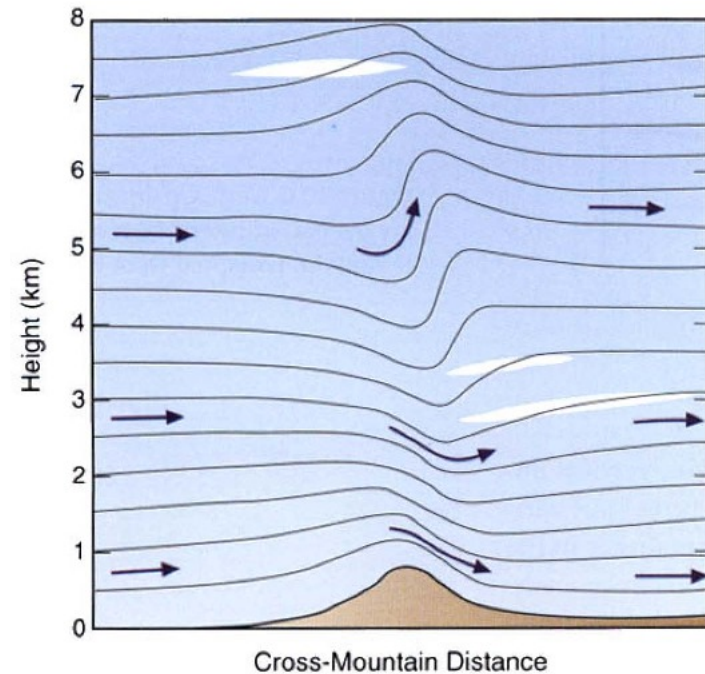
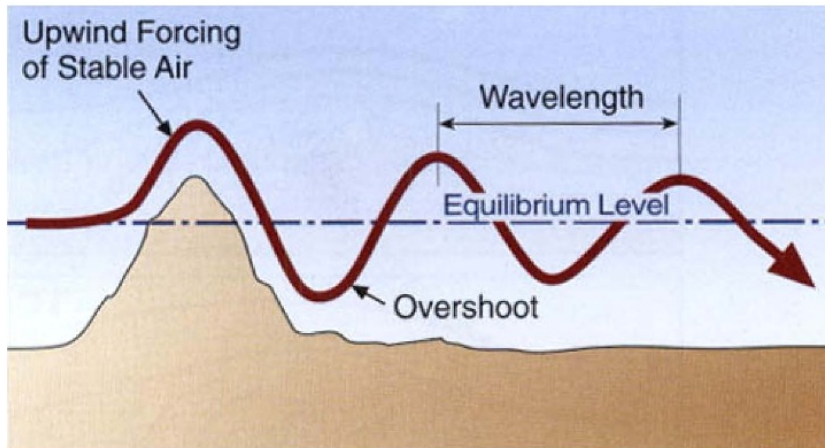
HORIZONTAL SHEAR



Mountain waves: Qualitative Characteristics



Mountain waves: Characteristics



- Maximum amplitude on the leeward-side of the hill
- Successive hills might enhance or diminish the strength of the waves
- The waves are more pronounced when the buoyant and inertial forces are comparable. The ratio is defined by Froude no.

Can the flow characteristics be modelled ?

Governing Equations

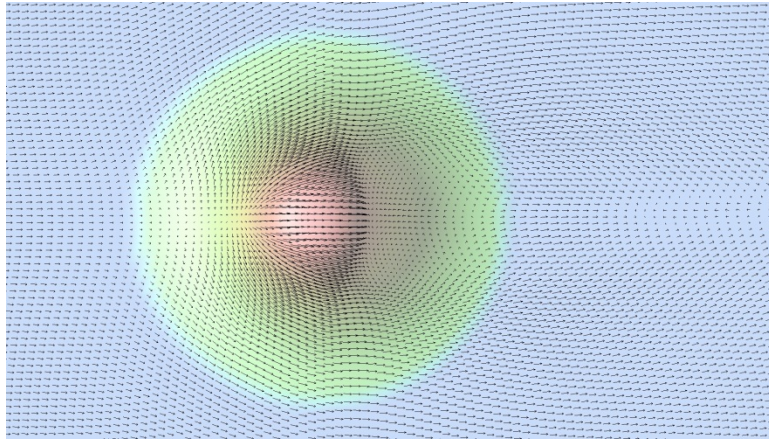
$$\frac{D\mathbf{u}}{Dt} = -\nabla \left(\frac{p_d}{\rho_s} \right) + \mathbf{g} \frac{\theta_d}{\theta_s} + \frac{1}{\rho_s} \nabla \cdot \mathbf{R} + \mathbf{f}$$

$$\frac{D\theta}{Dt} = \nabla \cdot (\gamma_T \nabla \theta) + q$$

$$\frac{DK}{Dt} = \nabla \cdot (\nu_T \nabla K) + P_k + G_\theta - \epsilon$$

$$\frac{D\epsilon}{Dt} = \nabla \cdot \left(\frac{\nu_T}{\sigma_e} \nabla \epsilon \right) + (C_1 P_k + C_3 G_\theta) \frac{\epsilon}{k} - C_2 \frac{\epsilon^2}{k}$$

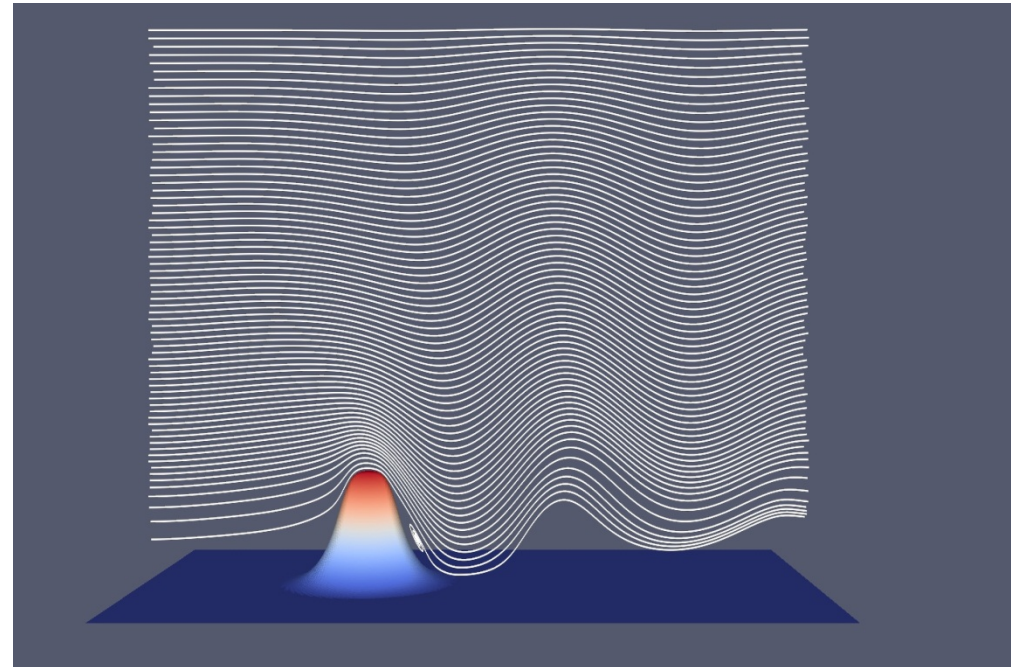
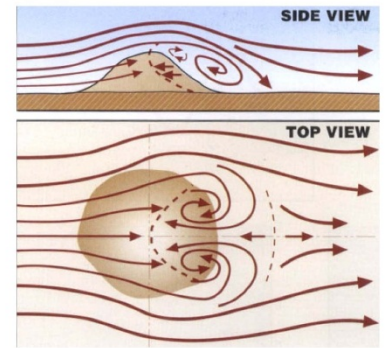
Mountain Waves



$Fr=1$, stable stratification

$$Fr=U/(NL)$$

$$N^2=(g/T)(dT/dz)$$



Maximum amplitude on the leeward side of the hill

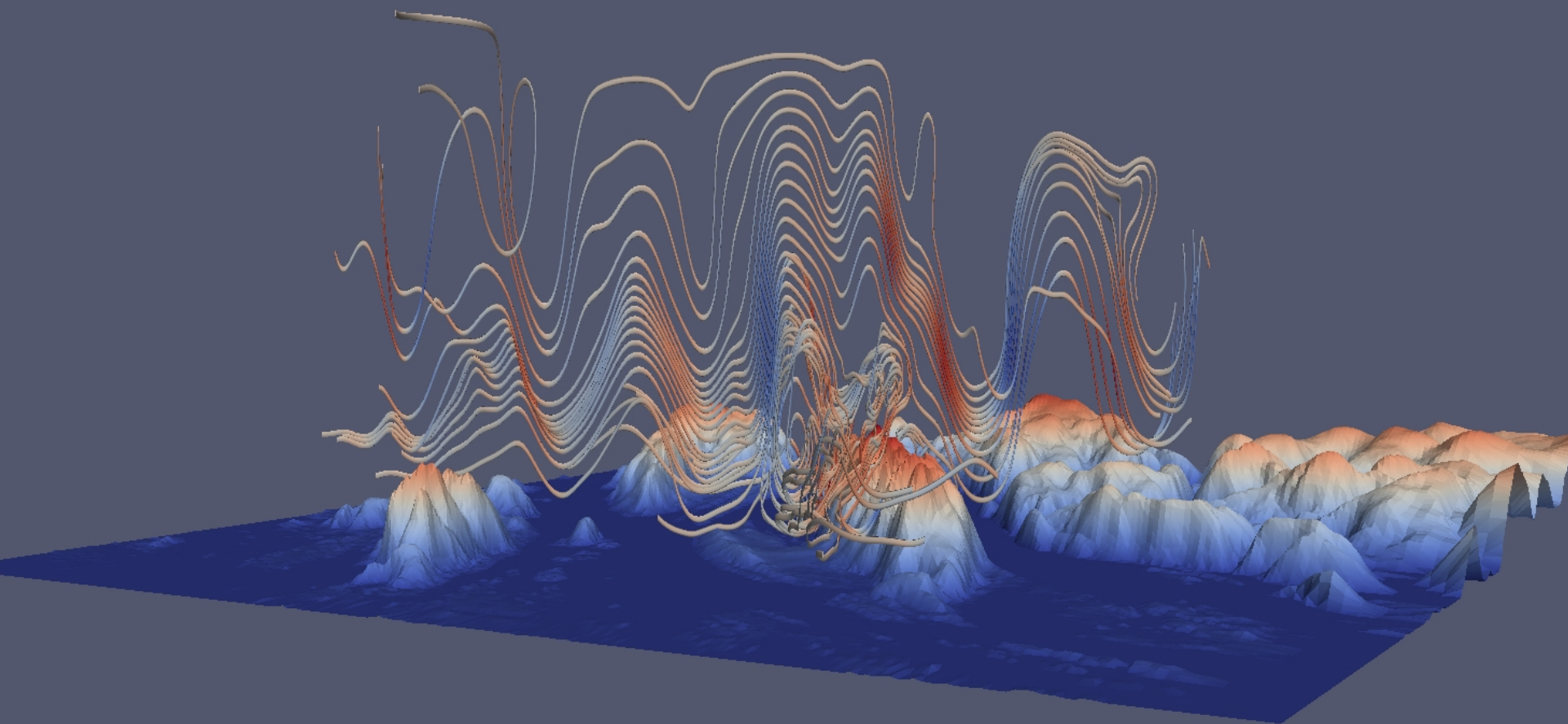
SANDNESSJØEN AIRPORT: STOKKA

Sandnessjøen Airport

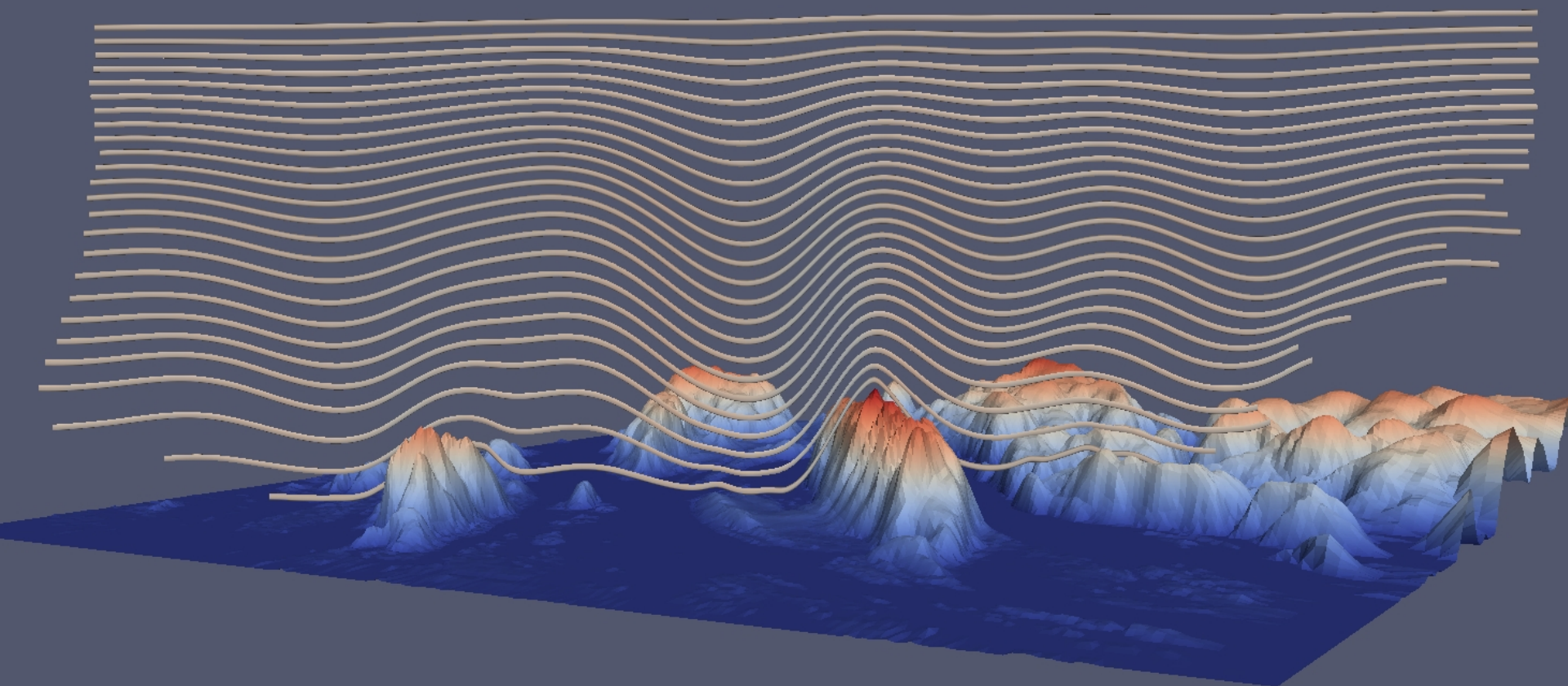
Tail wind on both directions of the runway

© 2012 Google/SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 GeoEye
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics

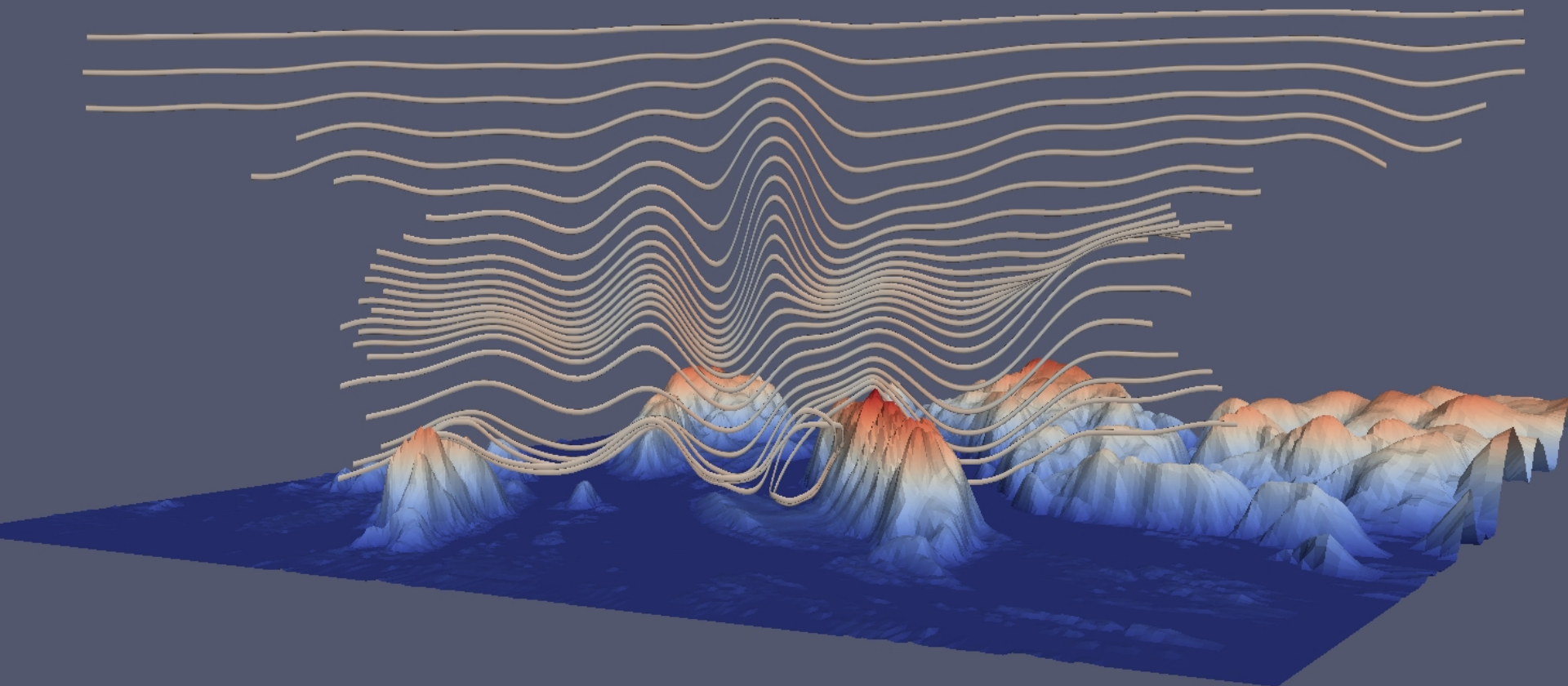
Google earth

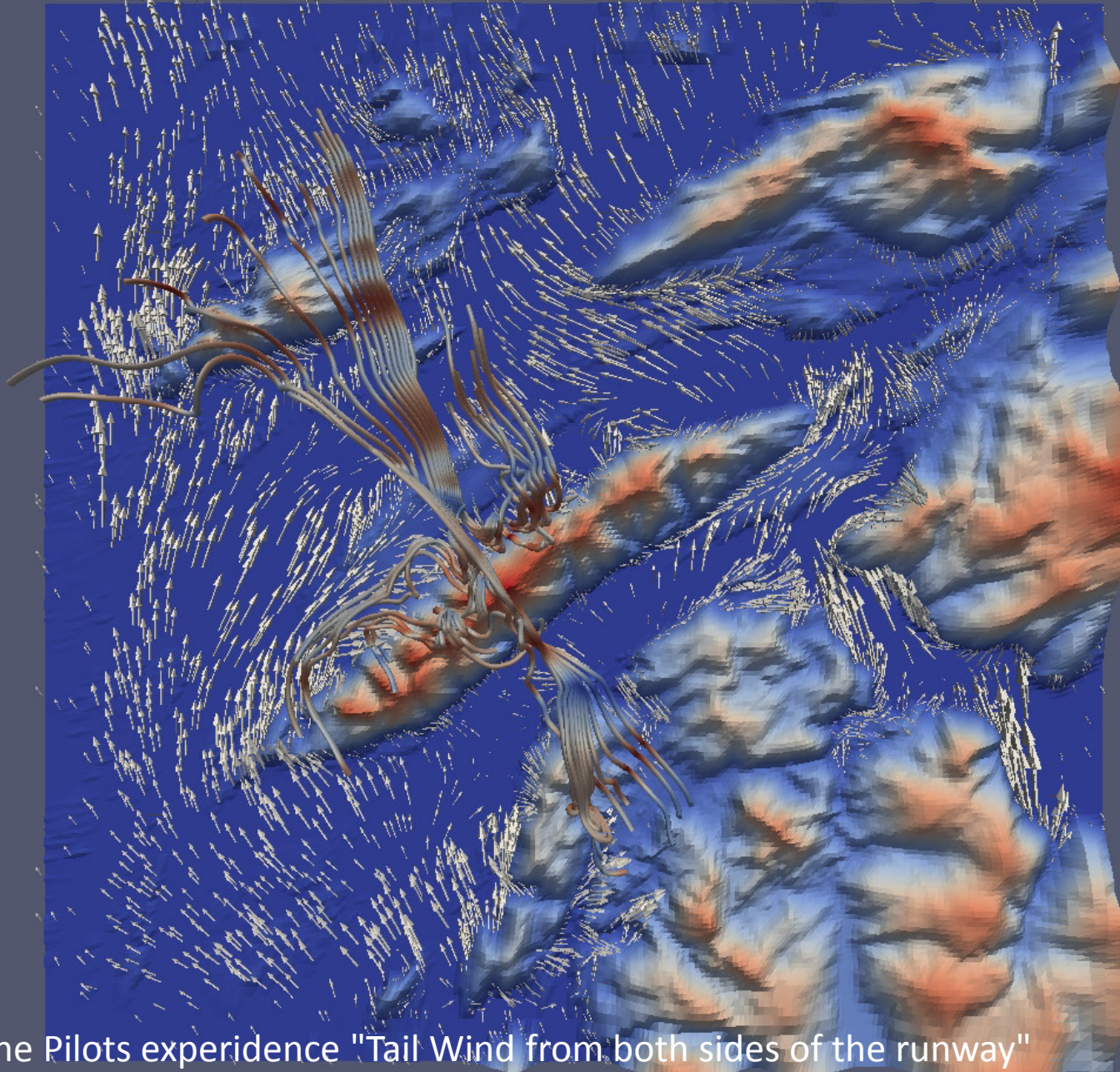


$Fr=0.2$, Lateral movement of air more pronounced



$Fr=1$, Ideal condition for the propagation of waves
Waves are diminished by destructive interference





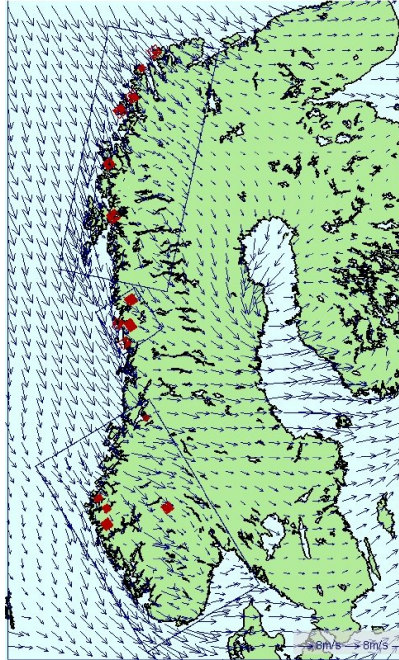
Confirm the Pilots experience "Tail Wind from both sides of the runway"

The simulations seem to confirm pilot's reports BUT.....

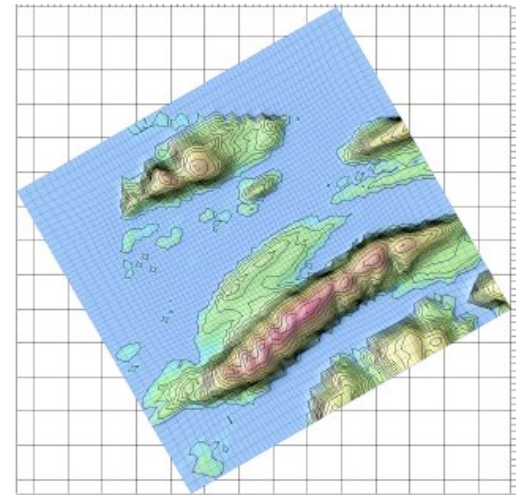
Can we forecast flight conditions ?



Global scales: seasonal changes,
Sea currents etc.



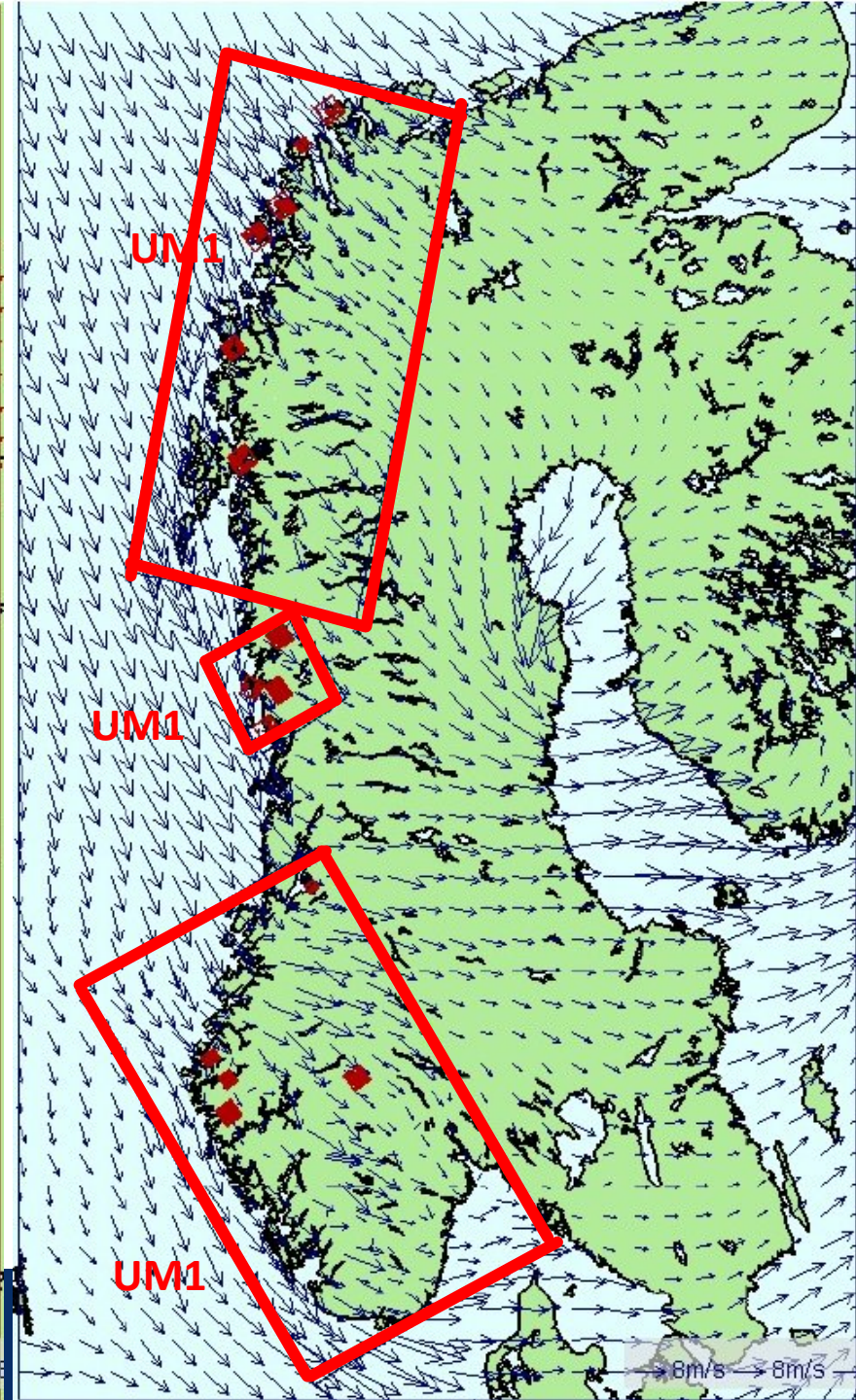
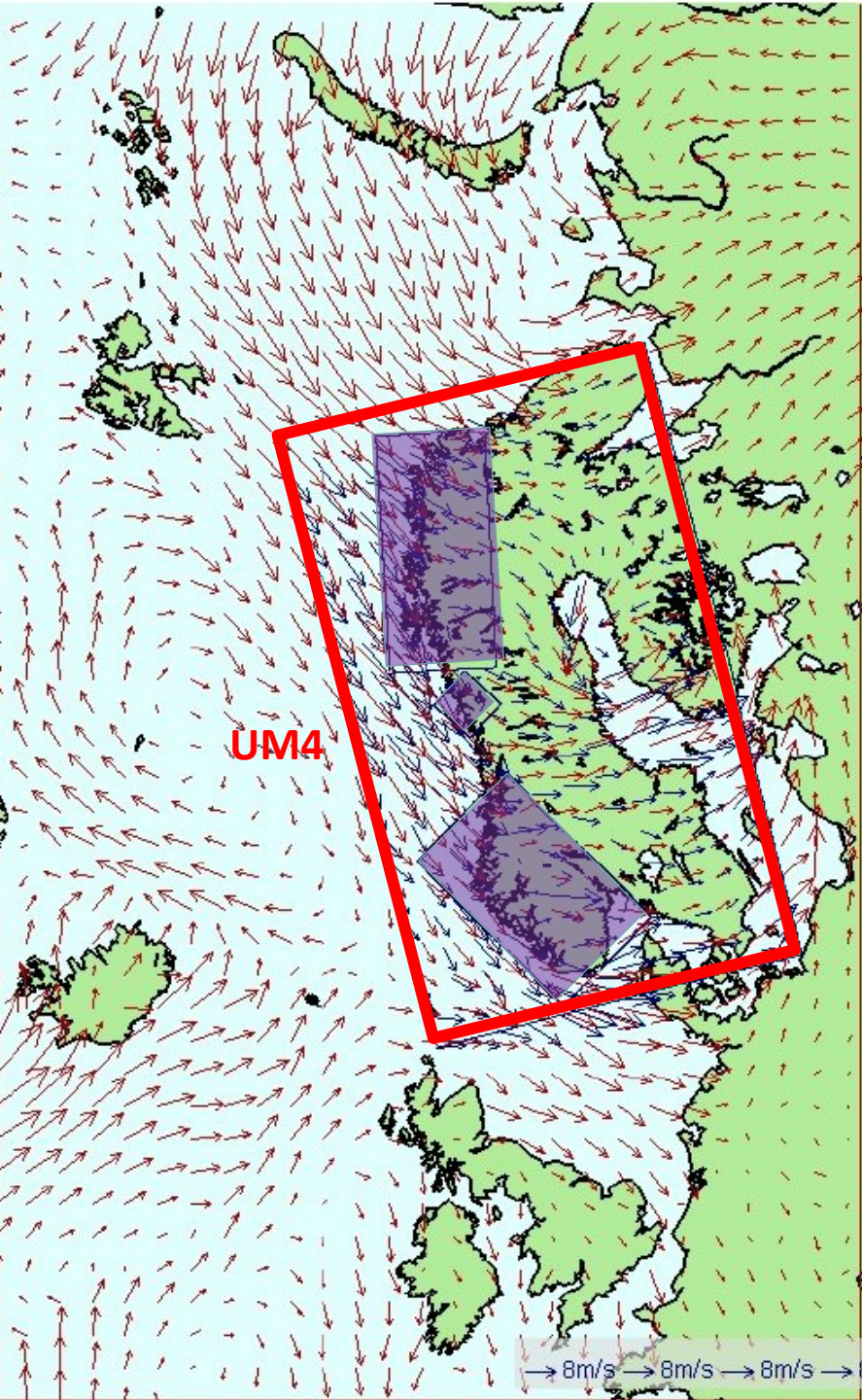
Meso scales: effects of large
mountains, sea, forest, precipitation



Micro scales:
terrain effects,
mountain waves

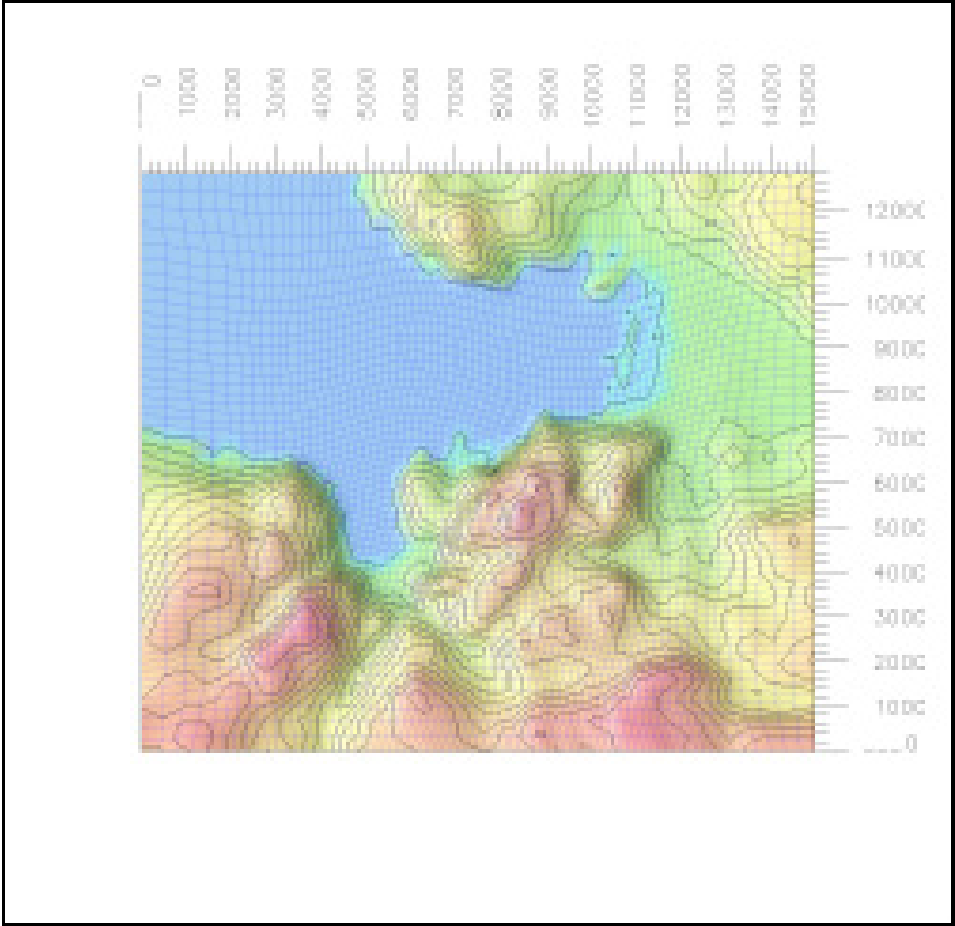
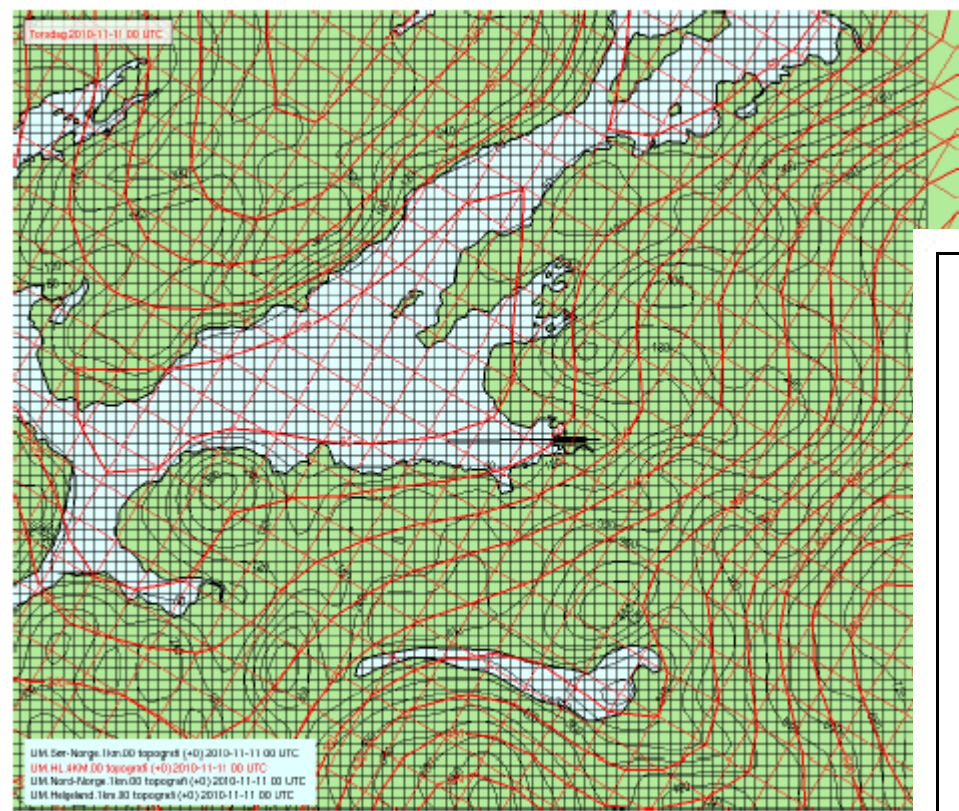
Each model is capable of resolving only a particular
range of spatio-temporal scales

**The problem can be handled through nesting of
different models**



**N
E
S
T
I
N
G**

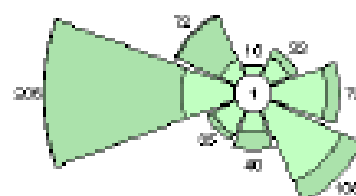
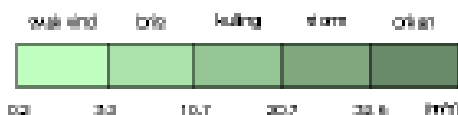
Værnes airport



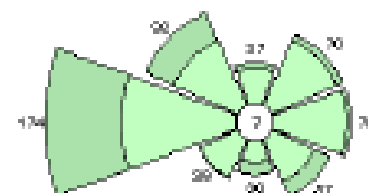
Værnes

Tiderom: 01.05.2010 – 31.08.2010

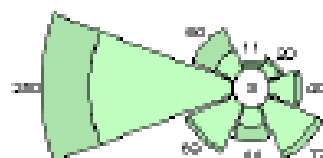
Antall tilfeller: 576



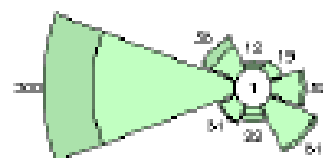
synop:00...21 (3)



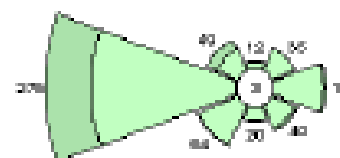
Hilsa4:00+8,+12,+15,+18 12+9,+12,+15,+18



Simns:00+9,+12,+15,+18 12+9,+12,+15,+18

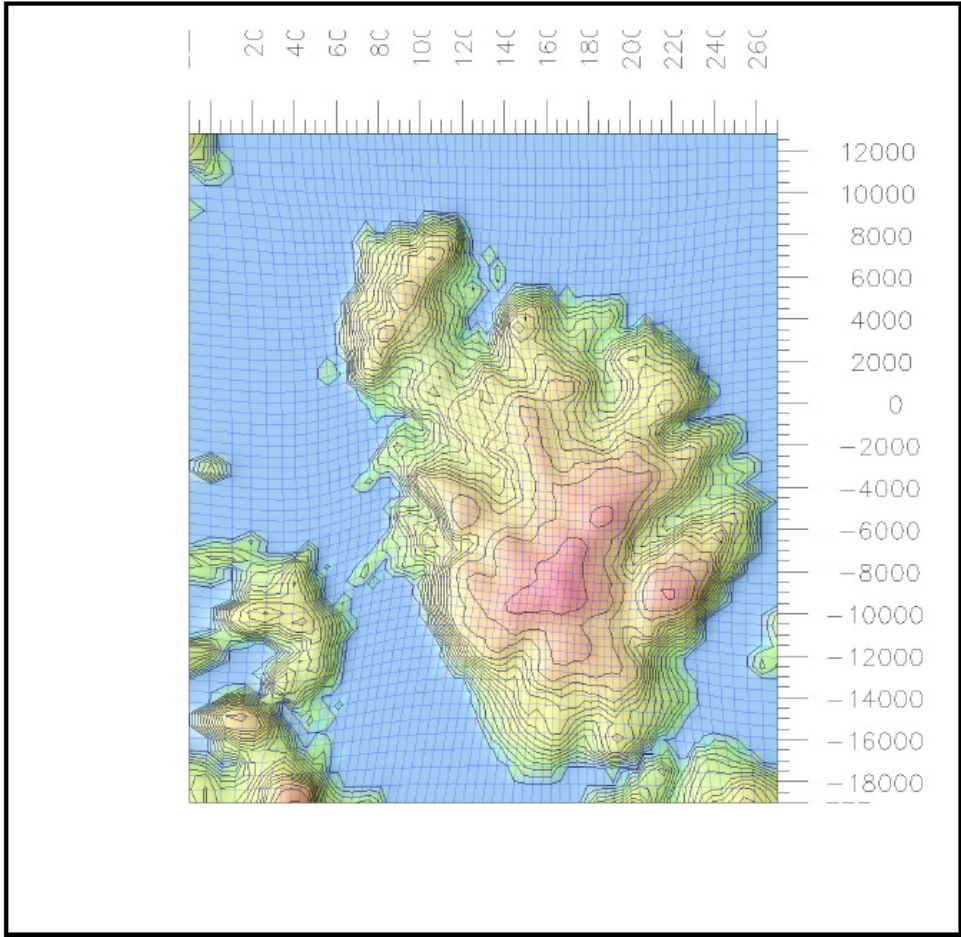
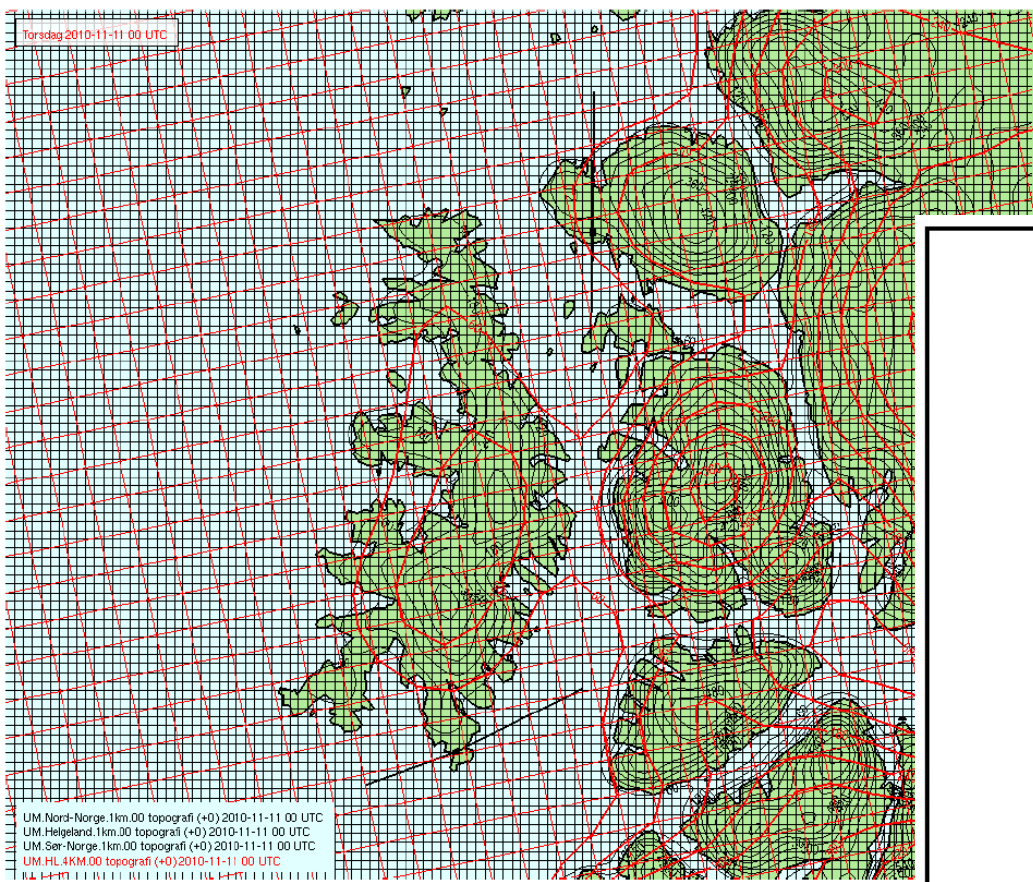


UIM1:00+9,+12,+15,+18 12+9,+12,+15,+18

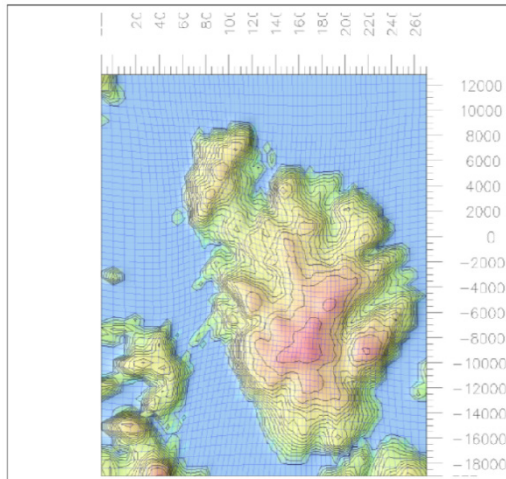


UIM4HL:00+9,+12,+15,+18 12+9,+12,+15,+18

Hammerfest airport



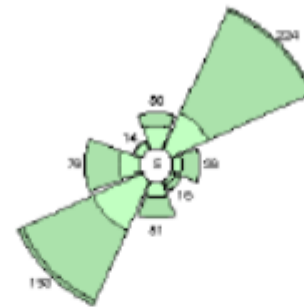
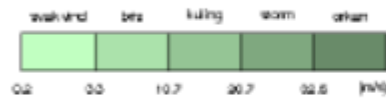
Hammerfest



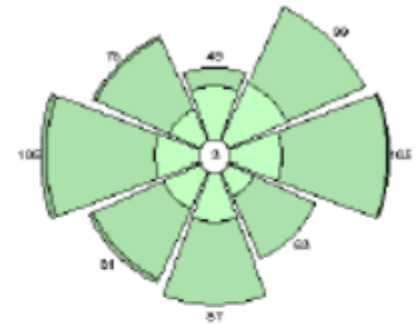
Hammerfest

Tidssrom: 01.05.2010 – 31.08.2010

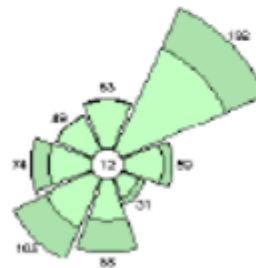
Antall dreier: 670



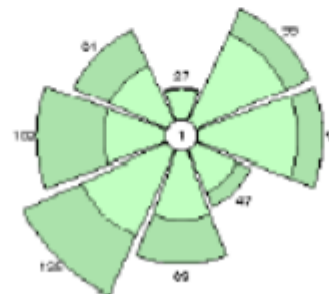
synop:00,...,21 / 3



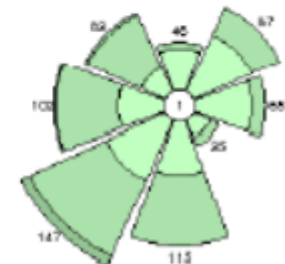
Hkian:00+9,+12,+15,+18 12+9,+12,+15,+18



Sinns:00+9,+12,+15,+18 12+9,+12,+15,+18



UM1:00+9,+12,+15,+18 12+9,+12,+15,+18



UM4HL:00+9,+12,+15,+18 12+9,+12,+15,+18

Is the model Computationally efficient and robust?

NJORD: Hardware Configurations

- Mythologically

NJORD is the God of the wind and fertility as well as the sea and merchants at sea and therefore was invoked before setting out to sea on hunting and fishing expeditions. He is also known to have the ability to calm the waters as well as fire.

- Technically

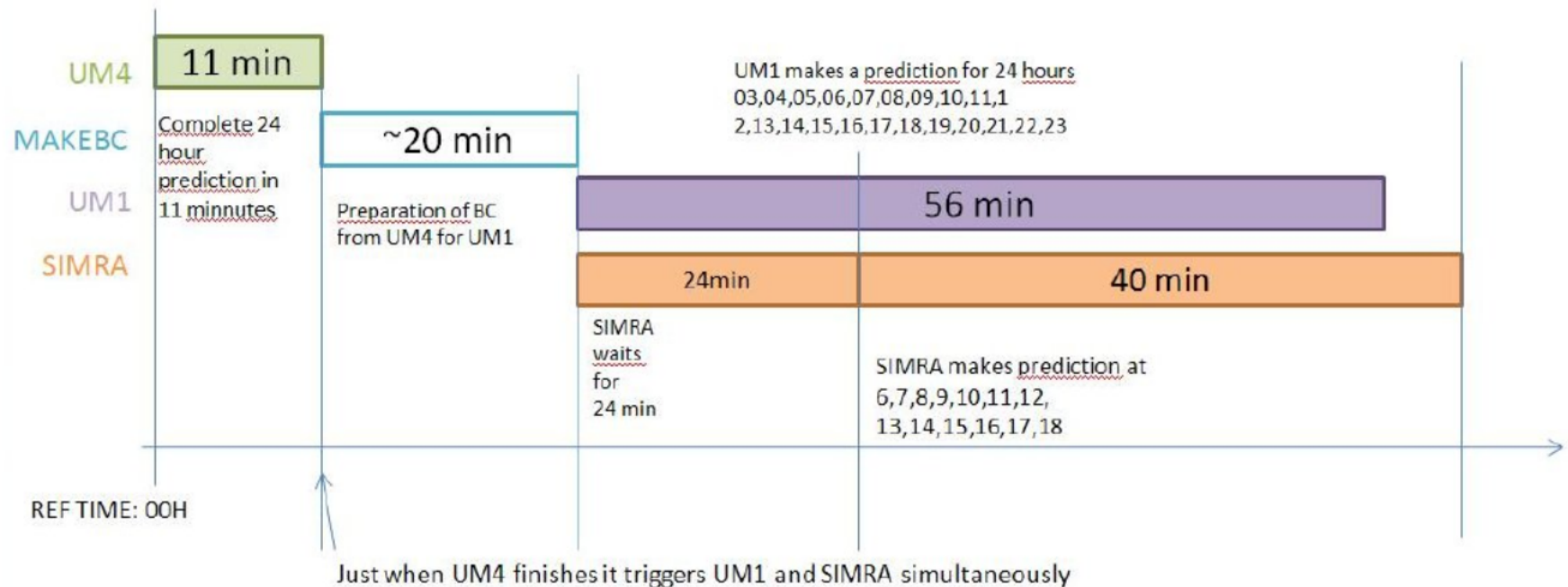
192 nodes partitioned into 186 nodes, 4 input/ output nodes.

186 nodes are shared memory nodes with 8 dual core power 5+ 1.9GHz processors each

180 of the computational nodes have 32 GB memory each

The code is parallelized using MPI

Models	Nodes	Proc.	Grid cells ($\Delta X \times \Delta Y \times \Delta Z$)	Domain (km) ($X \times Y \times Z$)	Sim. time (min)
UM4	27	432	$300 \times 500 \times 38$	$1200 \times 1200 \times 40$	11 min
UM1-NN	59	944	$336 \times 752 \times 70$	$336 \times 752 \times 40$	56 min
UM1-MN	3	48	$144 \times 152 \times 70$	$144 \times 152 \times 40$	42 min
UM1-SN	63	1008	$400 \times 656 \times 70$	$400 \times 656 \times 40$	51 min
SIMRA-HA	1	16	$61 \times 61 \times 41$	$28 \times 32 \times 3$	40 min
SIMRA-TR	1	16	$75 \times 75 \times 41$	$26 \times 32 \times 3$	40 min
SIMRA-ST	1	16	$71 \times 61 \times 41$	$27 \times 26 \times 3$	29 min
SIMRA-VA	1	16	$75 \times 61 \times 41$	$15 \times 13 \times 2$	29 min



Robustness ?

Airport	All data missing	Some data missing	No. of forecast possible	% operated with all data	% operated with all some data
Hammerfest	21	39	730	91.5	97.1
Tromsø	1	1	226	99.1	99.6
Stokka	15	19	730	95.3	97.9
Værnes	28	20	730	93.4	96.2

Validation strategy ?

ALTA

Normal Flight path



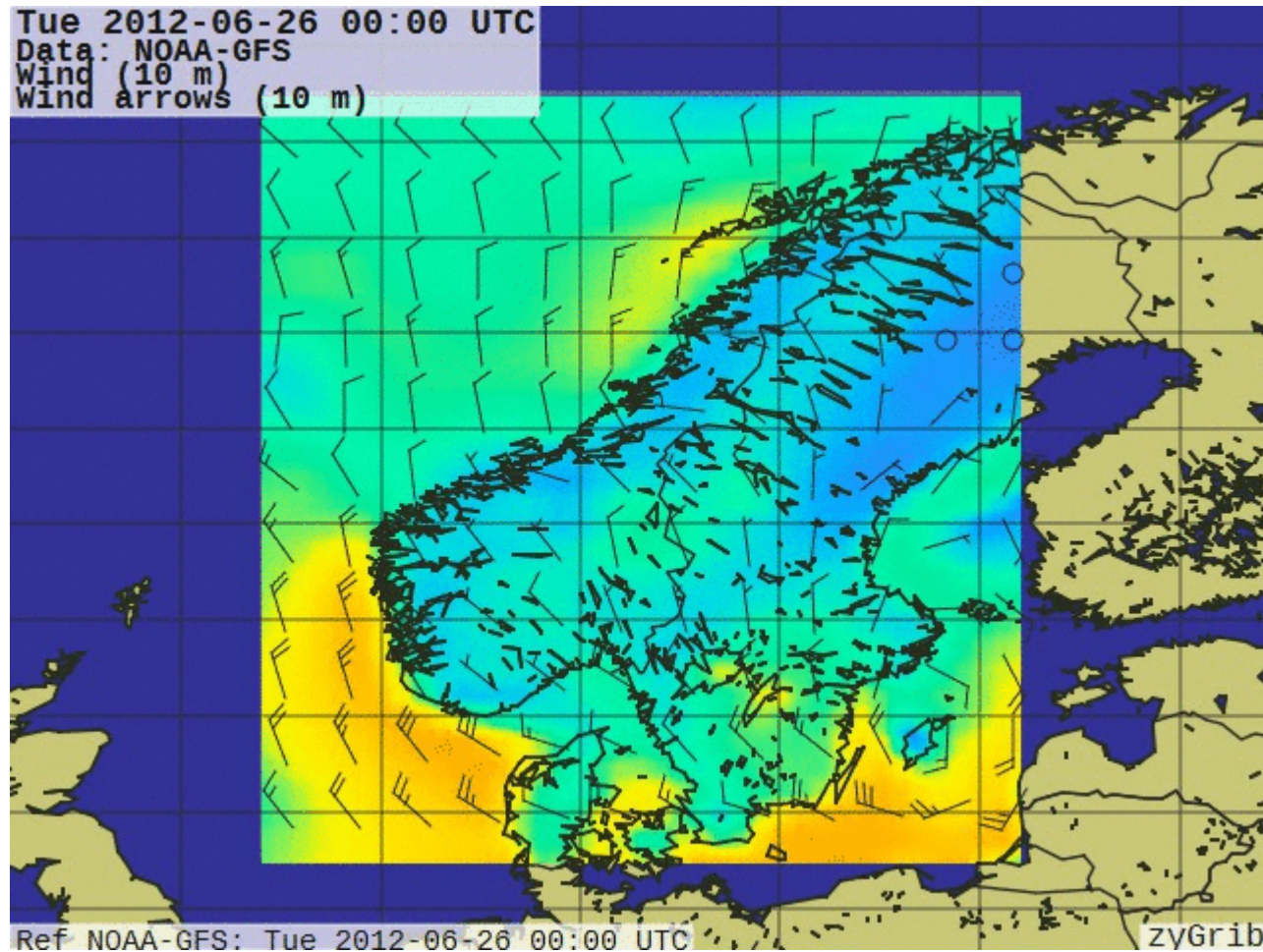
PILOTS REPORT:

Image © 2012 TerraMetrics

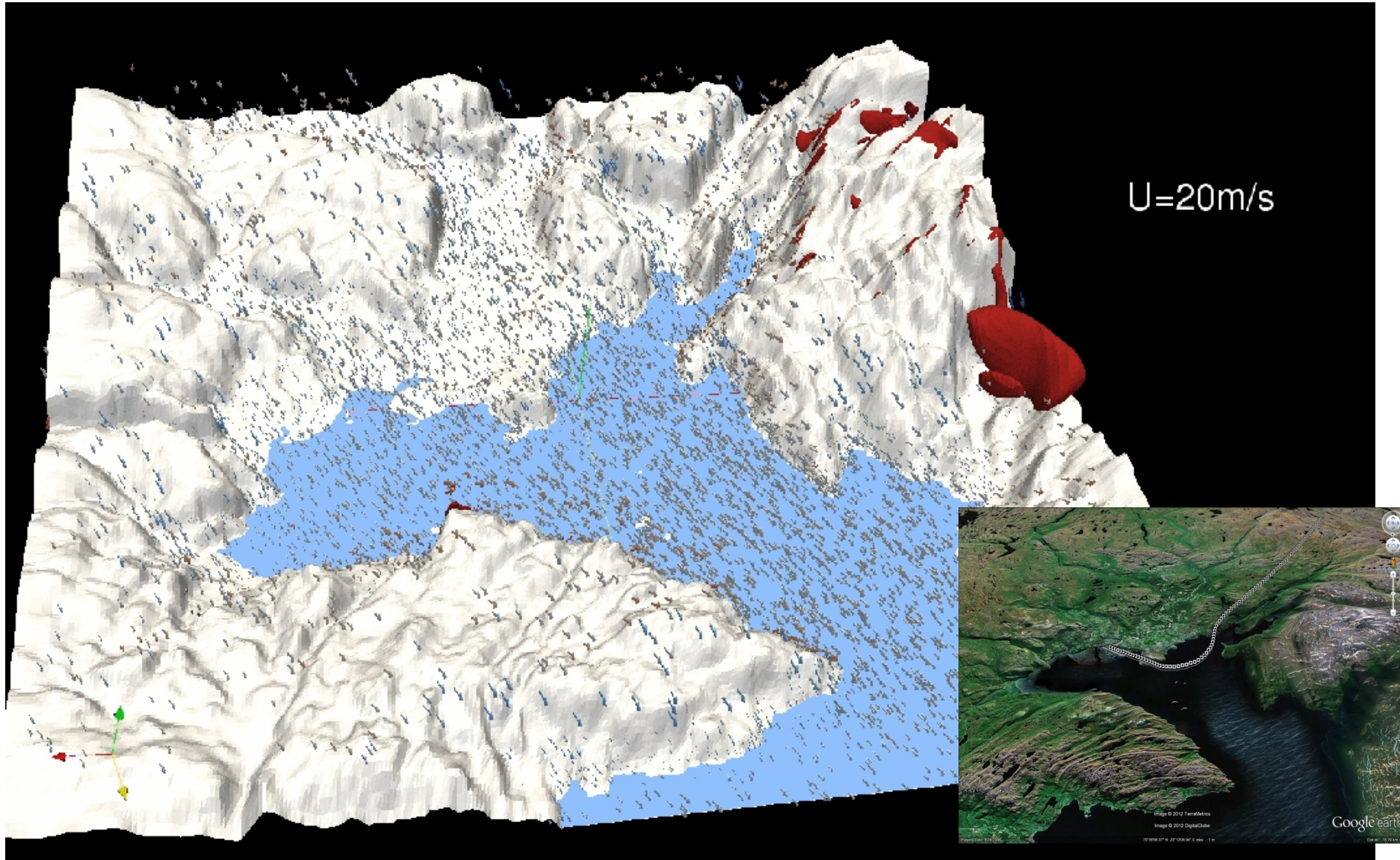
Image © 2012 DigitalGlobe

Google earth

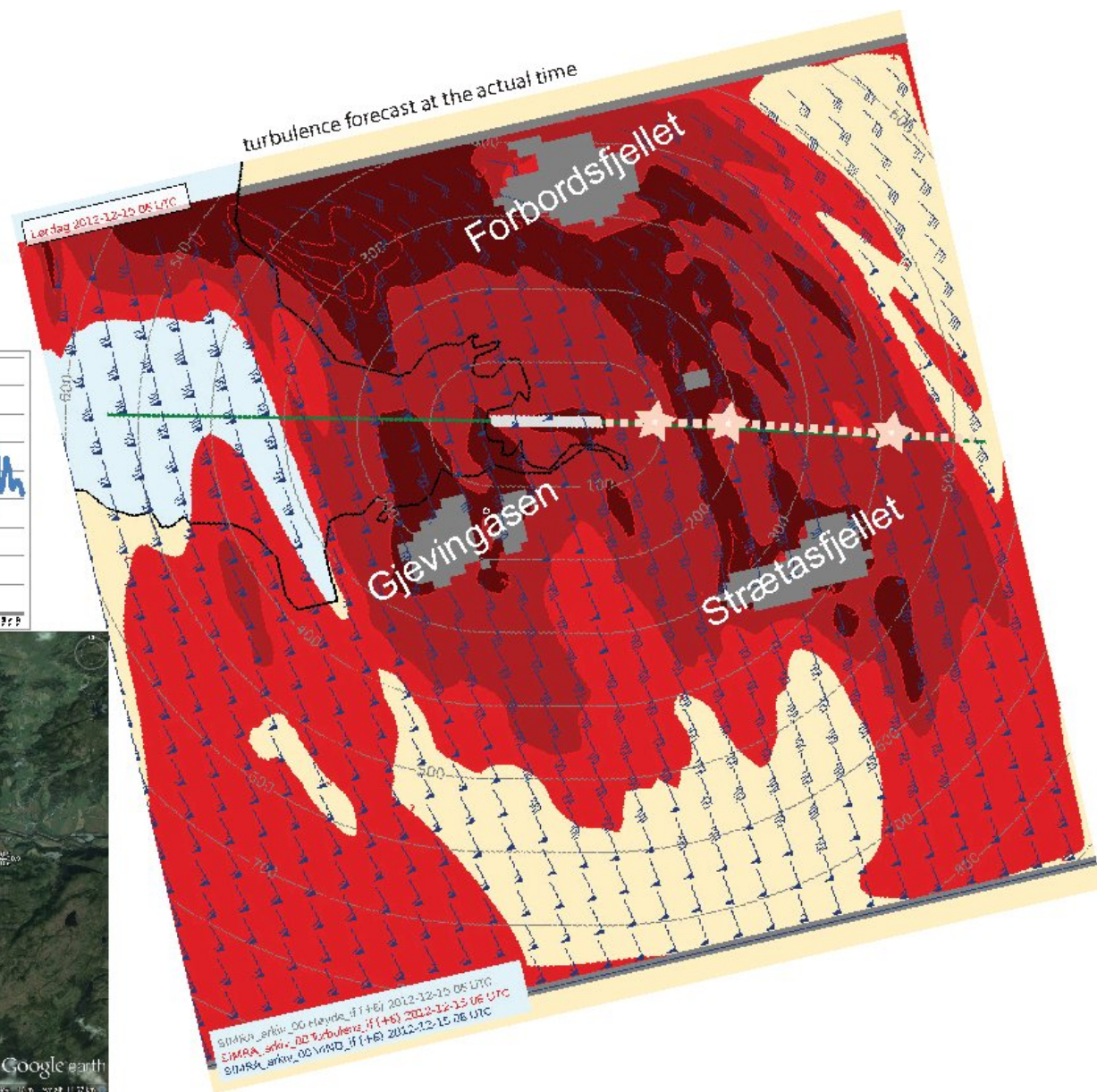
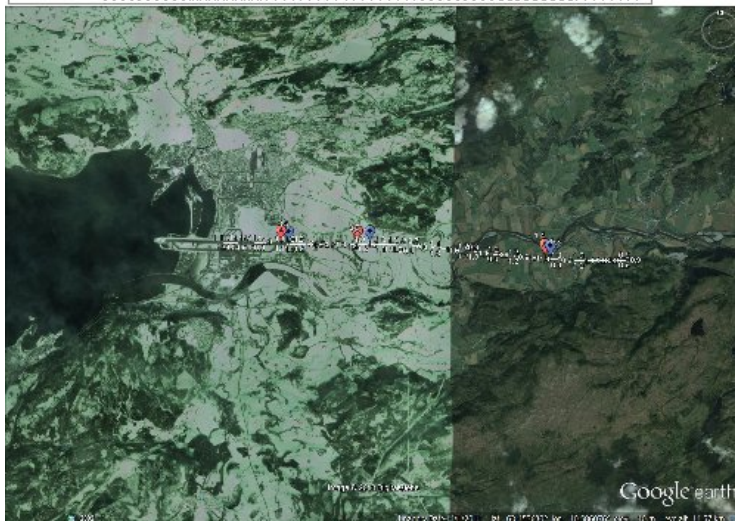
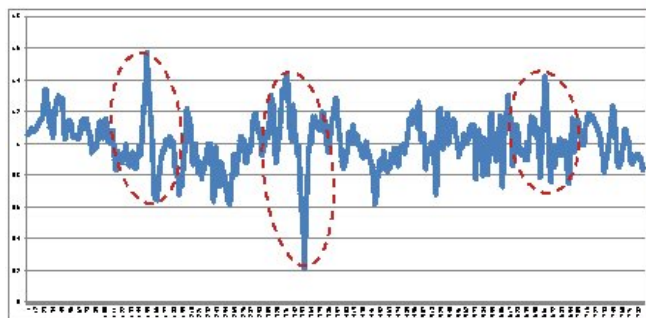
Realistic Boundary condition to run offline simulations

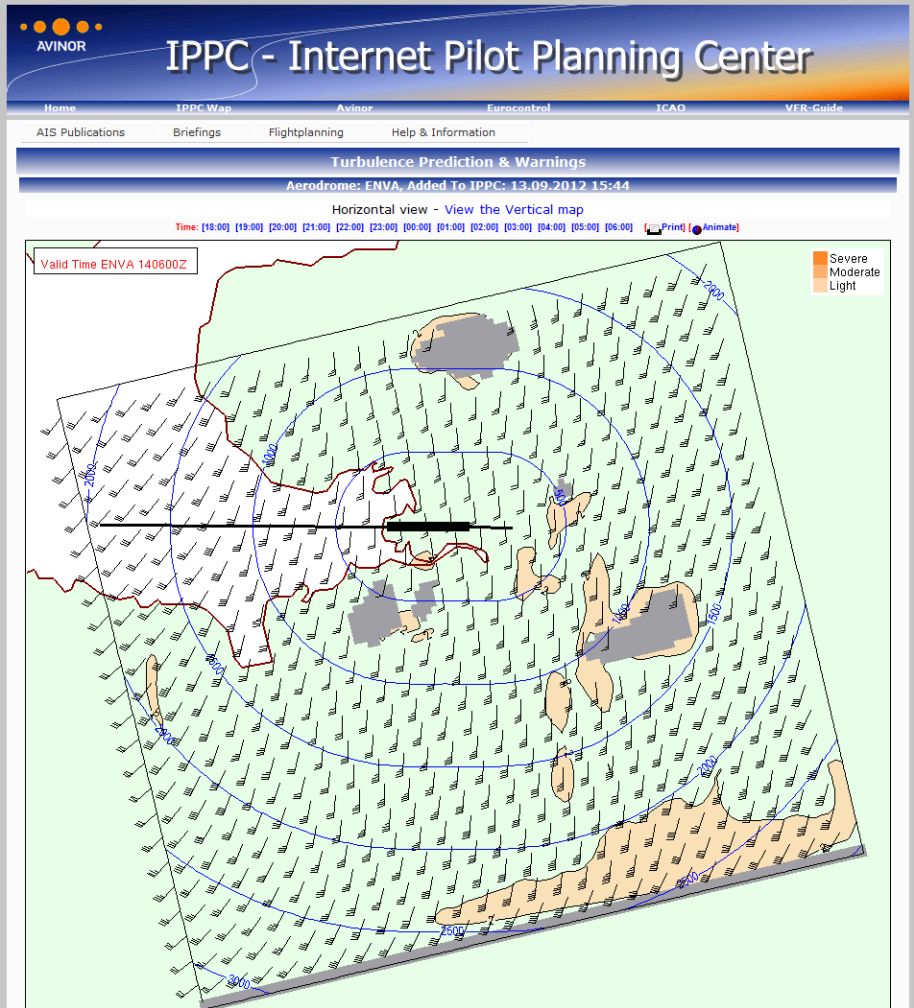
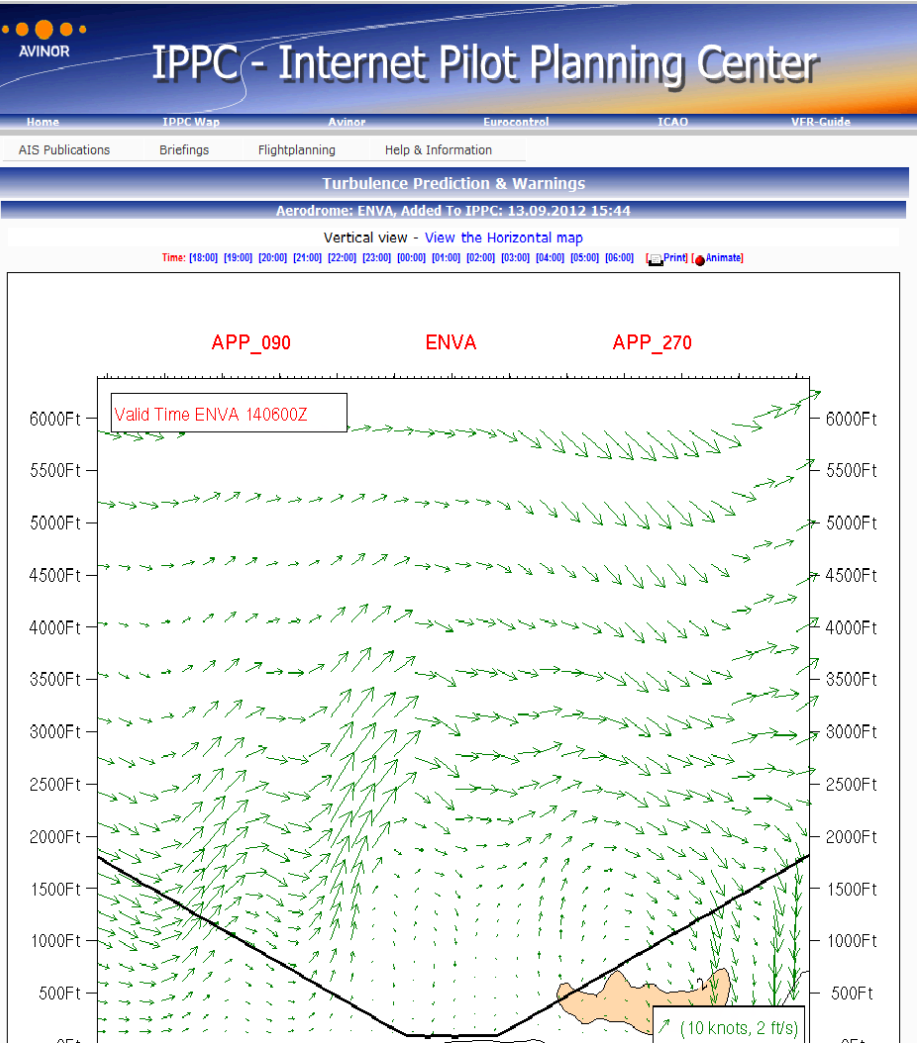


Turbulence Intensity Contour (3) as a function of free stream speed



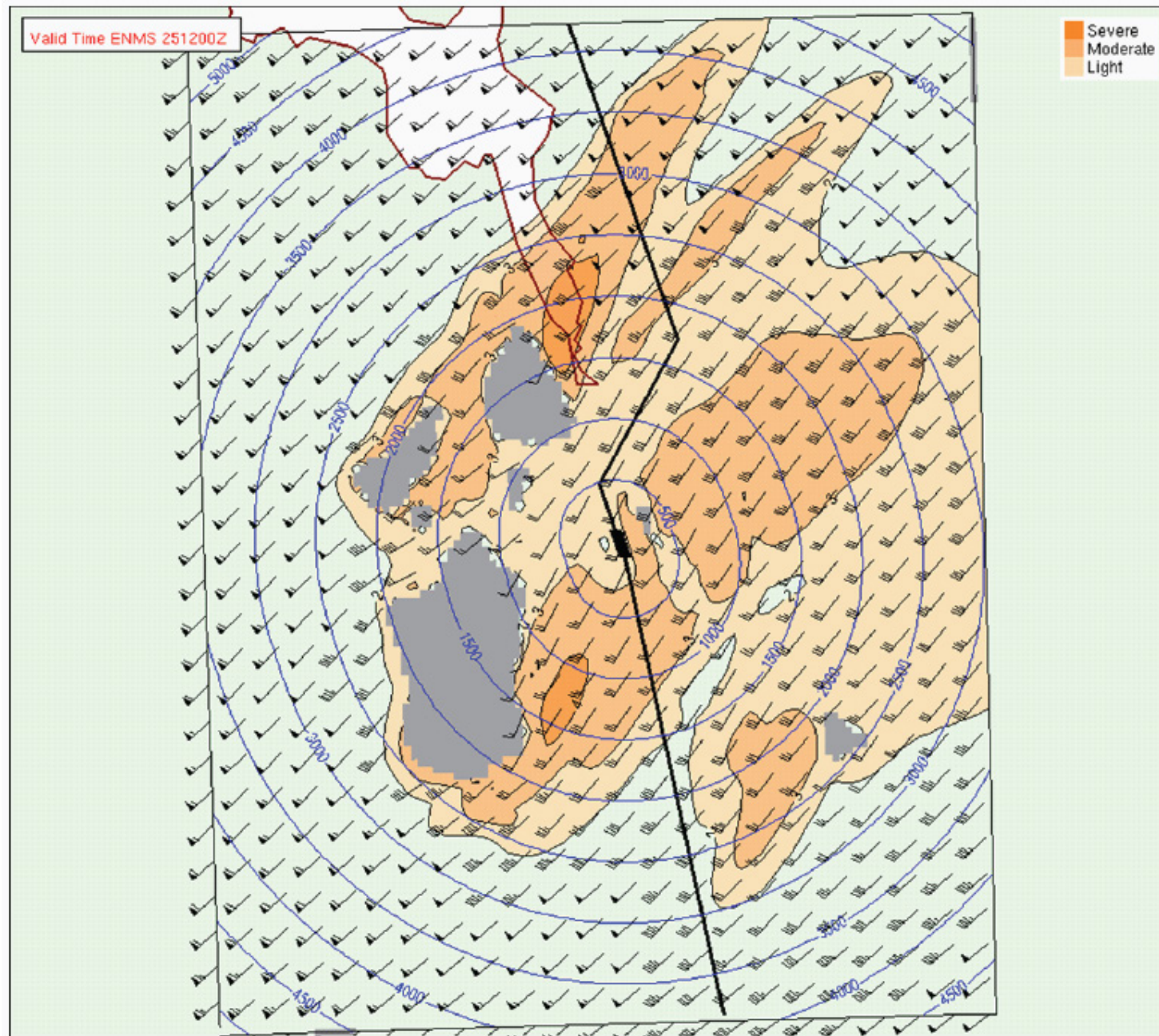
“Stars” represent locations along the AC take-off path that have large variations of measured values of “vertical g” (FDR data)



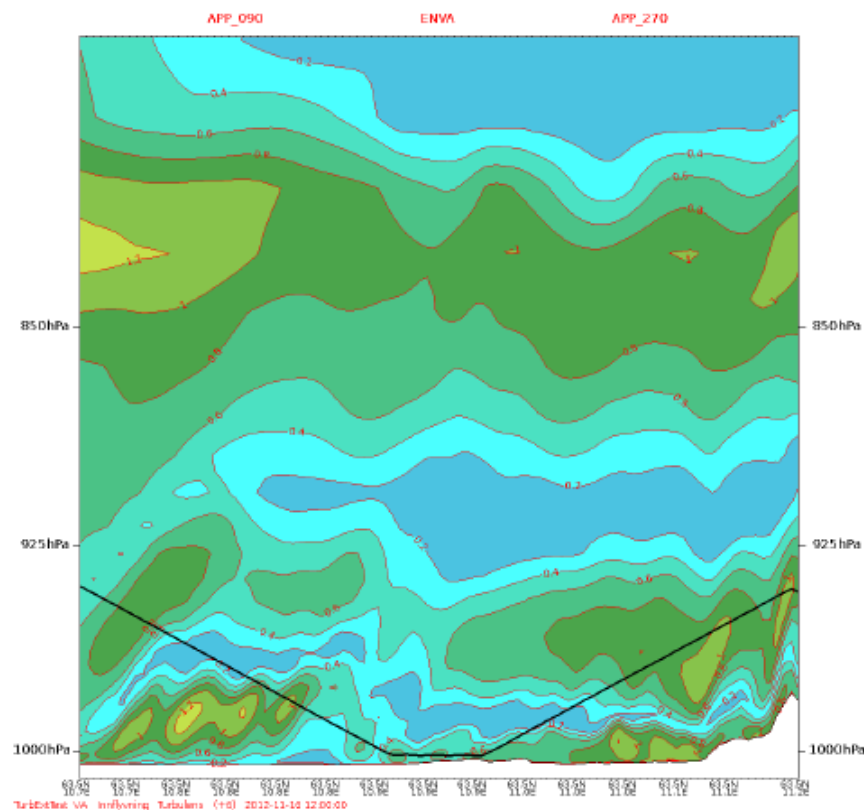


Valid Time ENMS 251200Z

Severe
Moderate
Light



Automatic Wind Shear and Turbulence Alert System



Conclusion

- Operational Multiscale Model
- The prediction system confirms the experiences recorded in the pilots reports and gives possible explanations
- The code has been validated extensively against wind tunnel data for cubes, hills, cylinders
- There is a scarcity of data for the validation of numerical codes but flight data, wind farm data, weather station data can be used together to get better insight into the flow at microscales.
- The data from the different sources can be used for fine tuning and validating the model



NORWAY IS STILL BEAUTIFUL

