LIMITATIONS OF THE COMPARISONS MODEL VS. OBSERVATIONS ON THE EXAMPLE OF A COST728 MODEL EVALUATION STUDY

Ekaterina Batchvarova[1,2], Sven-Erik Gryning[2], Markus Quante[3] and Volker Mathias[3]

[1]National Institute of Meteorology and Hydrology, Sofia, Bulgaria
(Ekaterina.Batchvarova@meteo.bg)
[2]National Laboratory for Sustainable Energy, RISOE DTU, Denmark
(ekba@risoe.dtu.dk)
[3]GKSS, Geesthacht, Germany

CONTRIBUTING

The presented work continues collaboration within COST 728 - A. Aulinger, C. Chemel, G. Geertsema, B. Geyer, H. Jakobs, A. Kerschbaumer, M. Prank, R. San José, H. Schlünzen, J. Struzewska, B. Szintai, R. Wolke are participating the present work through model outputs and discussions in connection with Case 1 inter comparison exercise.

COST Action 728

www.cost728.org

- Chair Ranjeet S Sokhi, UH, UK

ENHANCING MESO-SALE METEOROLOGICAL MODELLING CAPABILITIES FOR AIR POLLUTION AND DISPERSION APPLICATIONS

Participants from

Austria, Belgium, Bulgaria, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, Turkey, UK

Plus

- JRC (ISPRA)
- Non-COST: USA, Canada, Russia, Macao
- International cooperation: NOAA, USEPA, WMO

Challenges for knowledge in meteorology for air pollution and other applications

- Requirements from society evolve
- Science is advancing in different directions
- Higher order of complexity in models
- Larger run times
- Large amount of input and output data
- Can require larger computing platforms
- Users of complex modeling systems are less familiar with all approaches and models incorporated
- Evaluation of models is very complex task

- Measurement techniques develop, become more sophisticated and the issues of data interpretation, calibration, missing data treatment, etc are to be discussed

Structure of COST728, Topics addressed

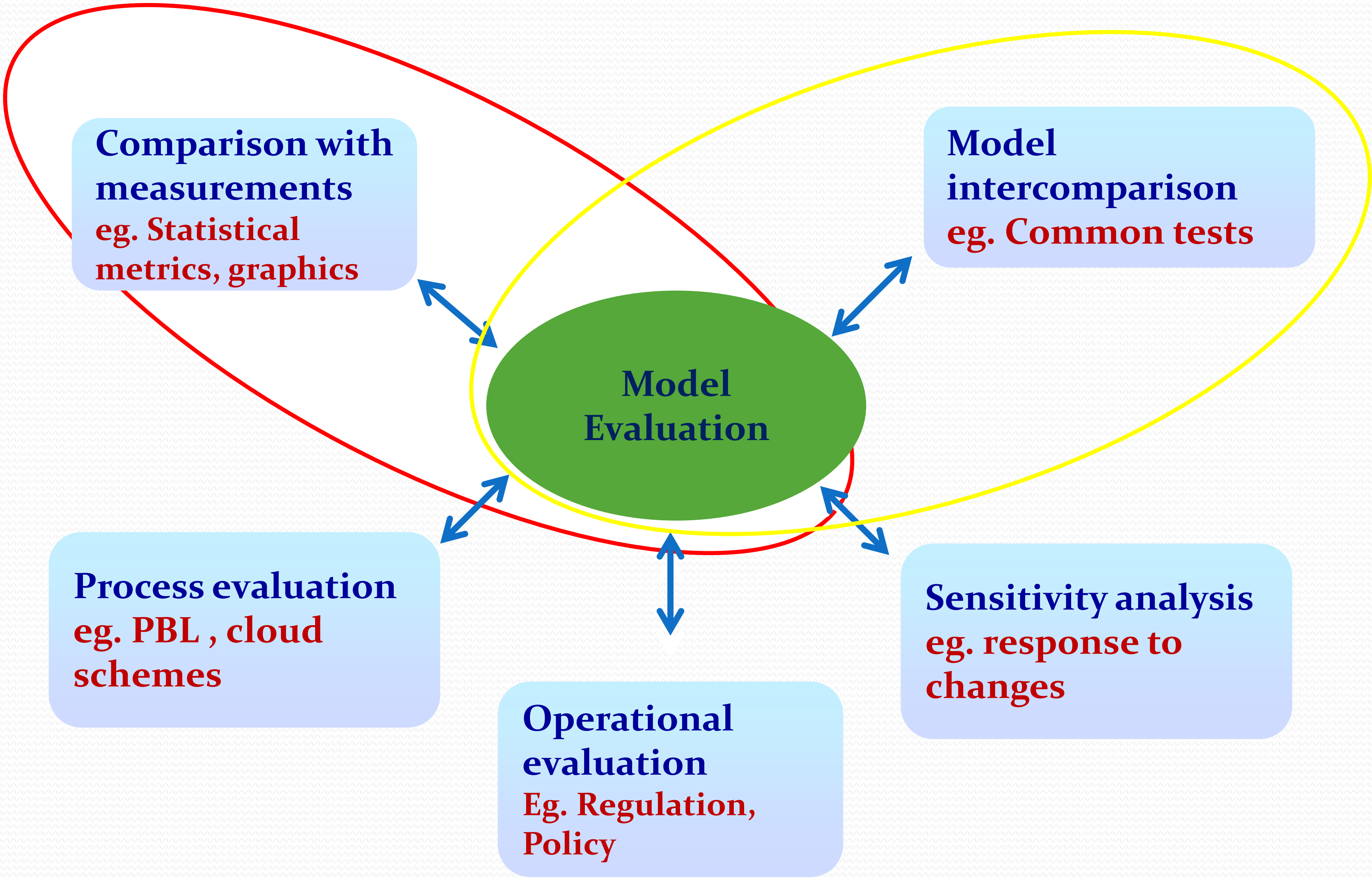
WG1 - Meteorological parametrization/applications (Maria Athanassiadou, UK Met Office, Sven-Erik Gryning, Risoe DTU)

WG2 - Integrated systems of MetM-CTM, interfaces, module unification, strategy (Alexander Baklanov, DMI)

WG3 - Mesoscale models for air pollution and dispersion applications (Mikhail Sofiev, FMI)

WG4 - Development of evaluation tools and methodologies (Heinke Schluenzen, University of Hamburg)

Model Evaluation Methods



Evaluation of models vs observations

- **CASE 1 – Winter/spring 2003 PM – stagnant conditions**
- **CASE 2 – Spring 2006 Forest fires (Russia) – LRT**
- **CASE 2 – Summer 2006 – PM/O3**
- **Others**
  - **Summer 2003 Fires Portugal, Po Valley**

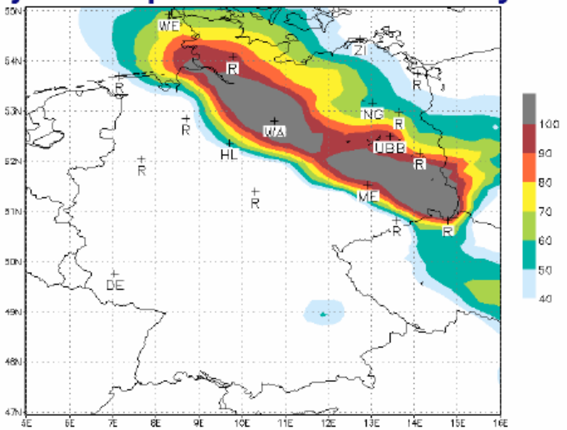
1) Modeled vs observed concentrations at surface

2) Modeled vs observed concentrations at 5 levels (ENSEMBLE)

3) Modeled vs observed meteorology at surface and 5 levels

4) **Modeled vs observed profiles of mean values and fluxes – masts, RSs, WPs**

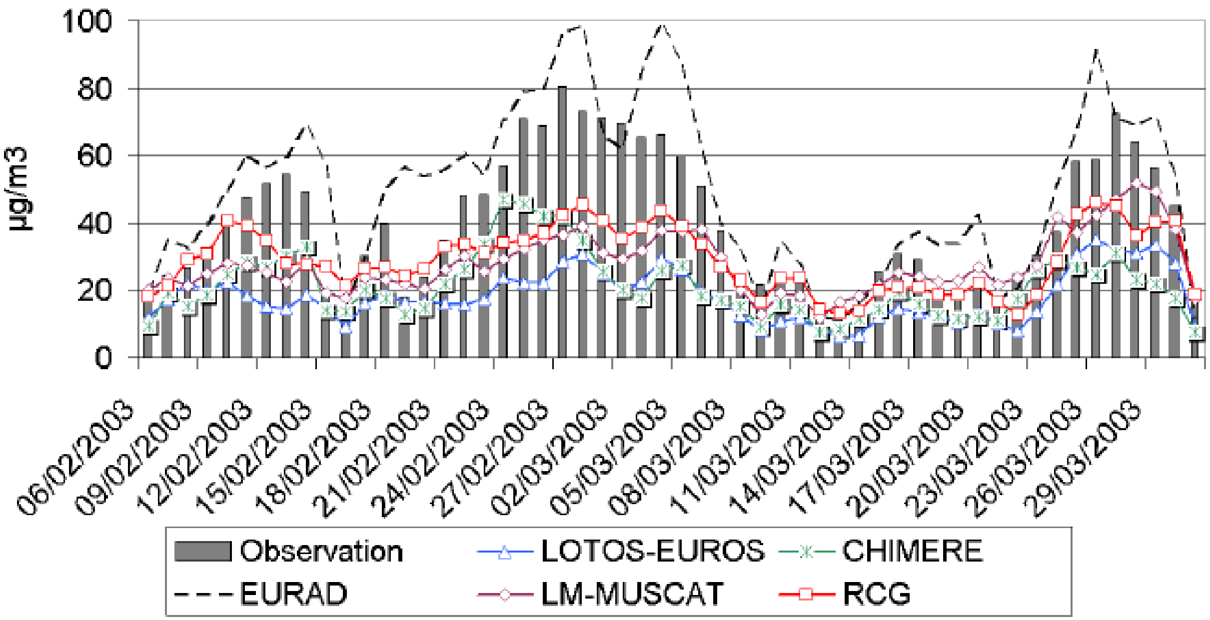
Major PM episodes over Germany



PM10 observations in Germany reached daily averaged values upto 100 μgr/m³.

COST728 CASE STUDY 1
February – March 2003
PM episode over ermany

1) Modeled vs observed concentrations at surface

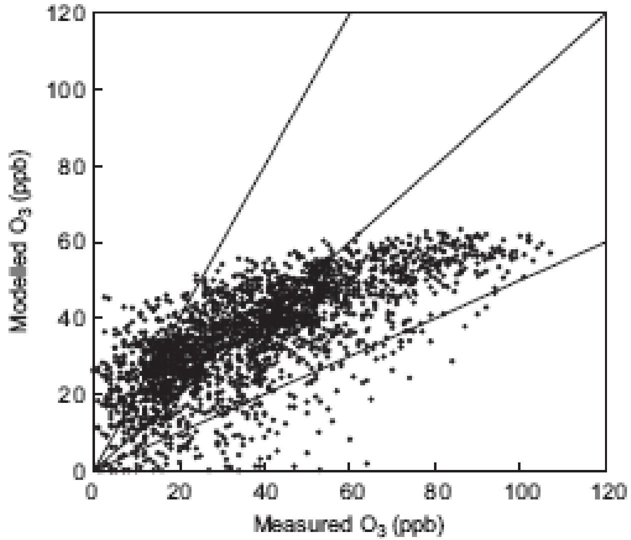


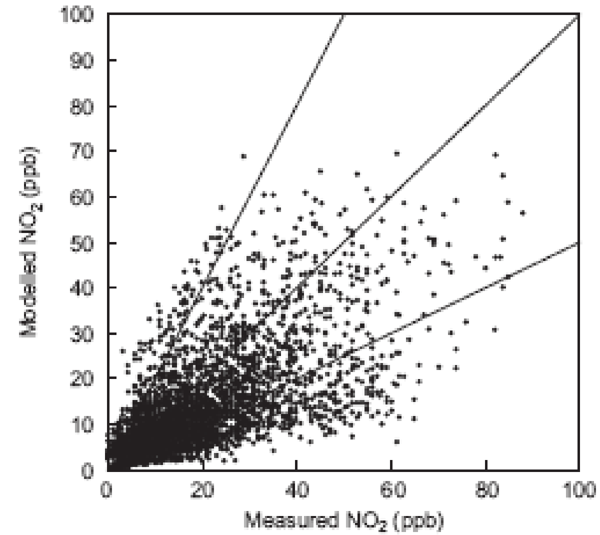
Meteorological conditions: South-easterly winds, stable conditions, low wind speeds, relatively low temperatures, strong and shallow surface inversions

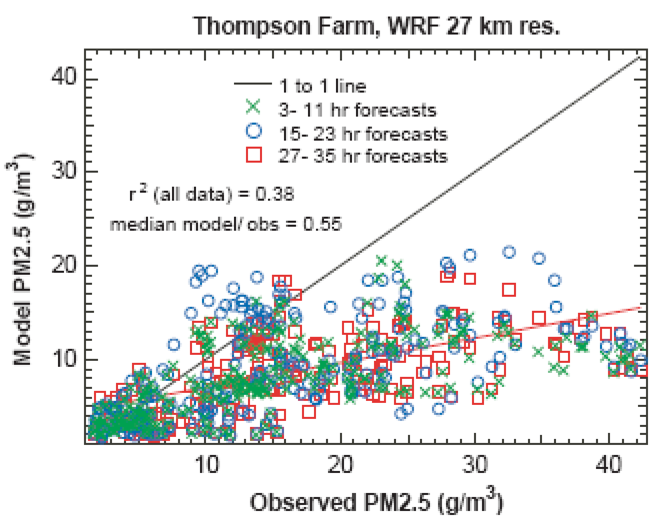
SE England, June 2001

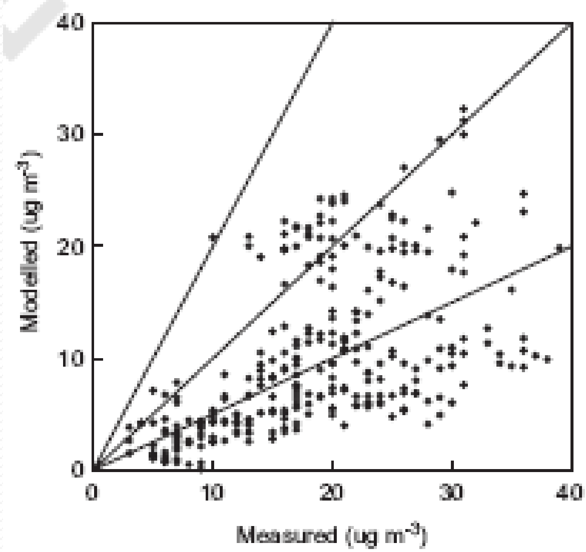
1) Modeled vs observed concentrations at surface

WRF-Chem
July 2002
Source: Grell et al 2005









MM5-CMAQ
June 2001
Source: Yu et al 2008
-CMAQ
June 2001
Source: Yu et 2008

Typical

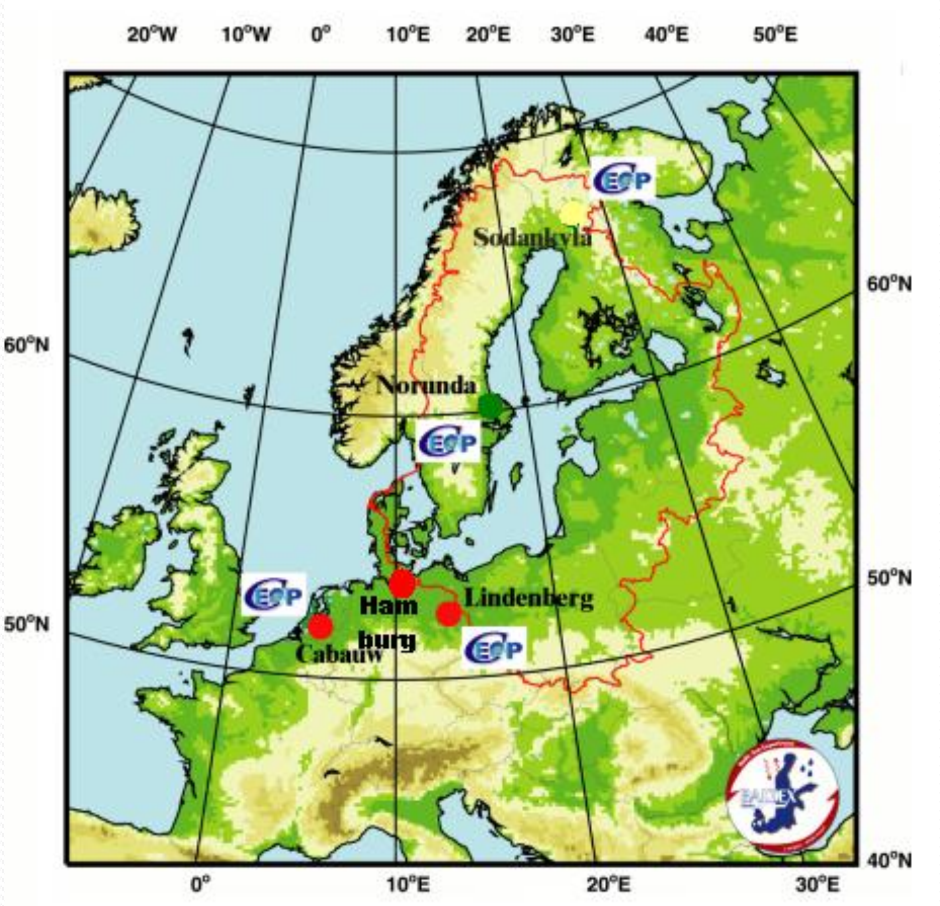
- Majority of AQ systems of models under predict PM concentrations near the ground
- Large scatter in modeled-observed concentrations scatter plots
- Large differences between models

Emissions

Meteorology

- Models use different parameterizations of turbulence and mixing and parameterizations reflect ideal conditions
- Models predict and use different Atmospheric Boundary-Layer height. How is this related to observations? The ABL height is a parameter defined in different way in the fields of temperature, humidity, wind, aerosol. The different measuring techniques correspond also to diverse definitions.
- Therefore the discussions within COST728 concluded that modeled and measured profiles of meteorological parameters are to be firstly compared rather than ABL height.

Meteorological measurements at sites with tall masts and ABL profile measurements – non-routine data



Hamburg

•320 meter mast: wind speed, wind direction, temperature, sensible heat flux, momentum flux at 10, 50, 110, 175 and 250 m (5 levels)

Cabauw

•200 meter mast: wind speed, direction and temperature at 2,10, 40, 80, 140 and 200 m)

•Wind profiler data up to 5 km

•Radiosoundings at 0 and 12 UTC

Lindenberg

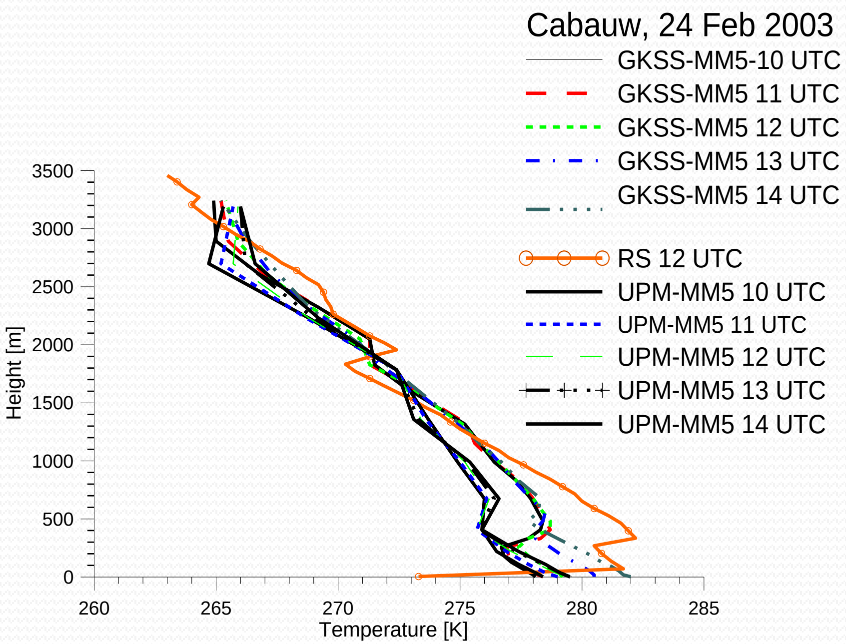
•99 meter mast over grassland: wind speed, wind direction and temperature at 40 and 98 m

•28 meter mast over forest: wind speed, wind direction and temperature at 28 meters above the forest)

•Wind profiler data up to 5 km

•Radiosoundings at 0, 6, 12 and 18 UTC

Radiosonde measurements

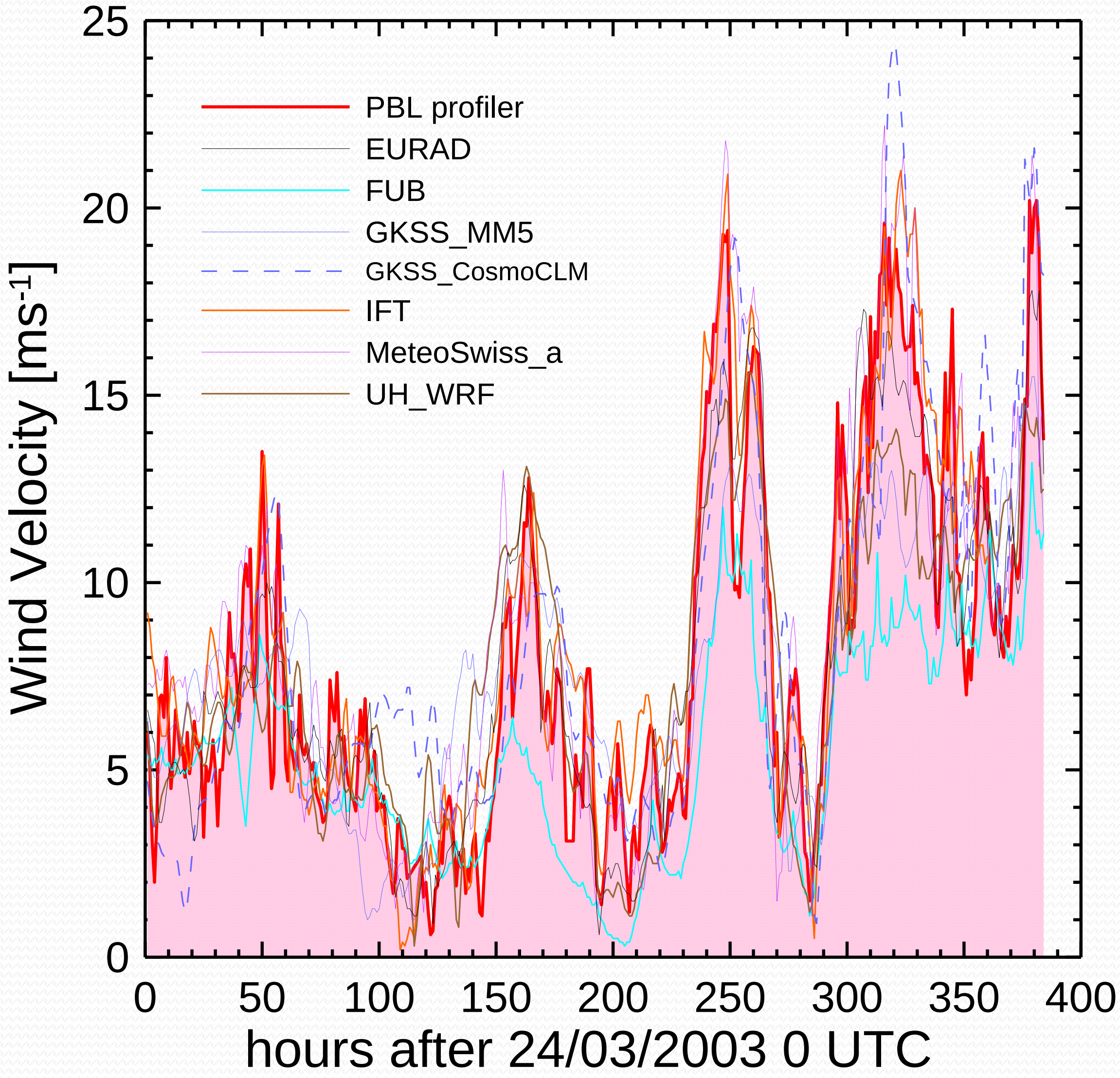


- Large differences RS vs models within the entire BL
- Models smooth the meteorological fields in space and time

Wind profilers

915 MHz   1290 MHz   482 / 1290 MHz

COST 728: Wind velocity – obs / model



Wind velocity at Lindenberg at about 500 m asl

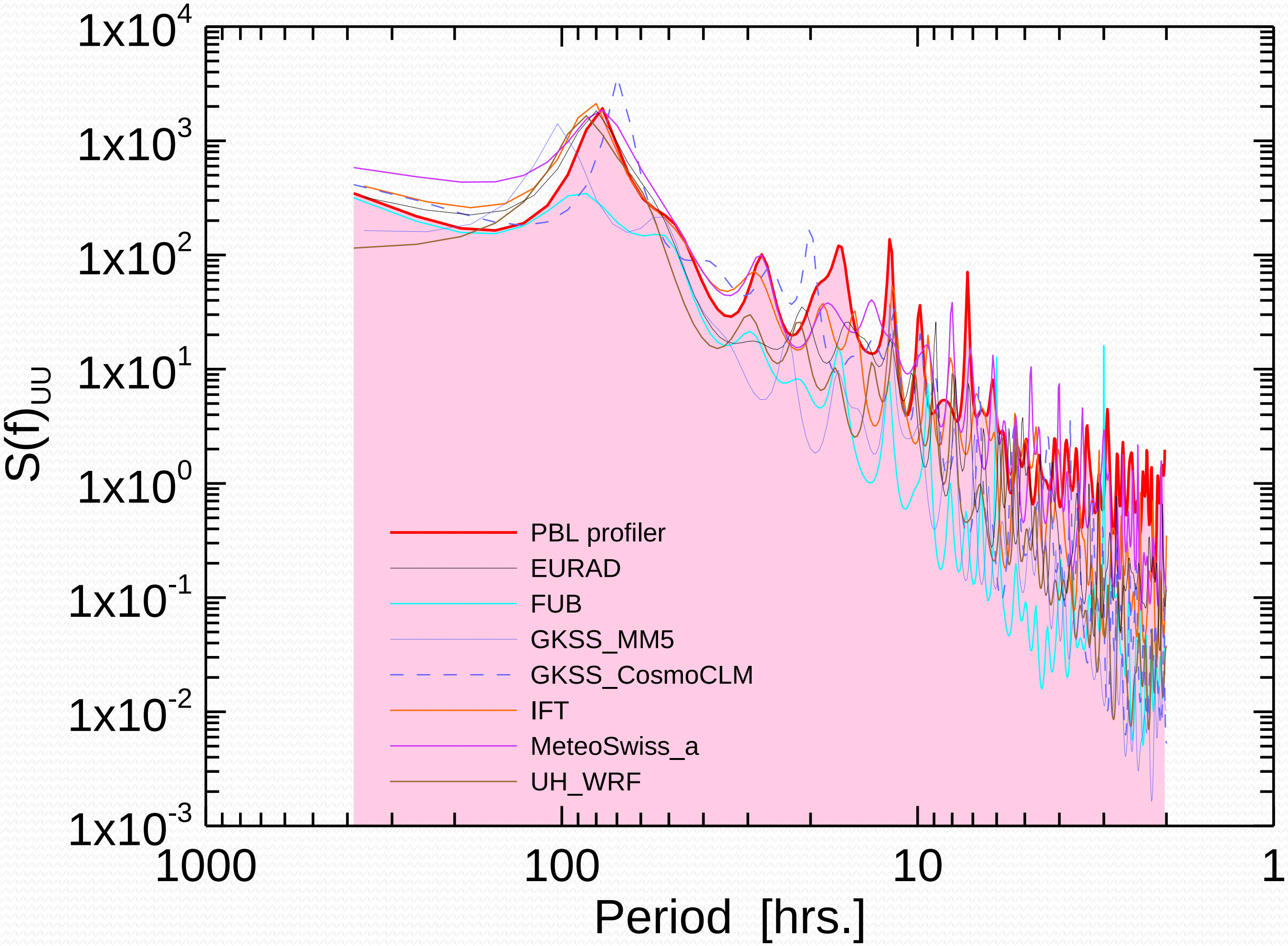
time series

24.02.2003 to 11.03.2003

some systematic deviations – phase / amplitude

COST 728: Wind velocity – obs / model

24.02.2003 to 11.03.2003



Wind velocity at Lindenberg at about 500 m asl

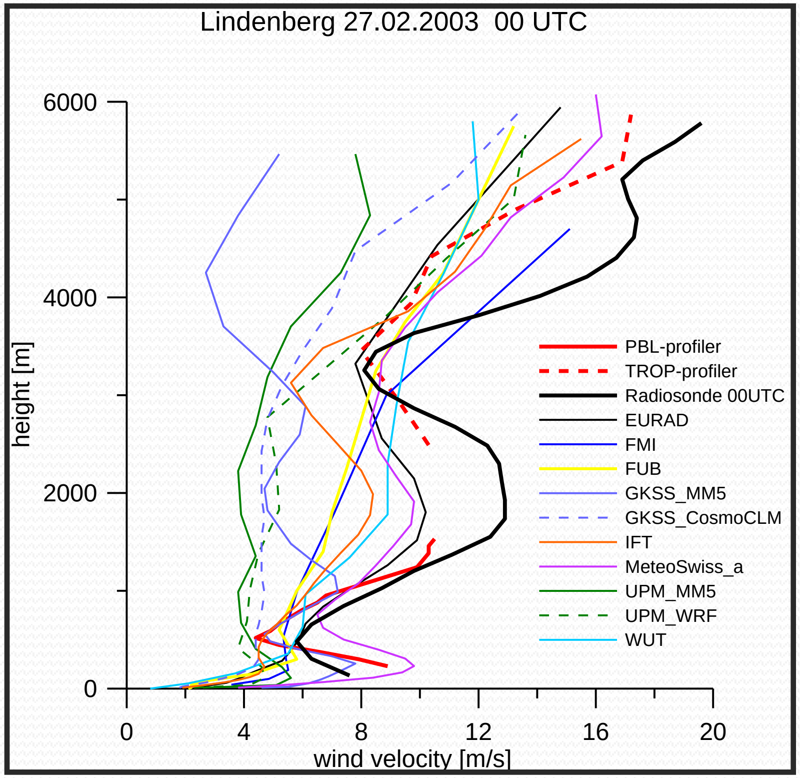
power spectra

Only models with highest resolution capture intraday fluctuations

Wind profiles – obs /model

wind direction wind velocity

Lindenberg



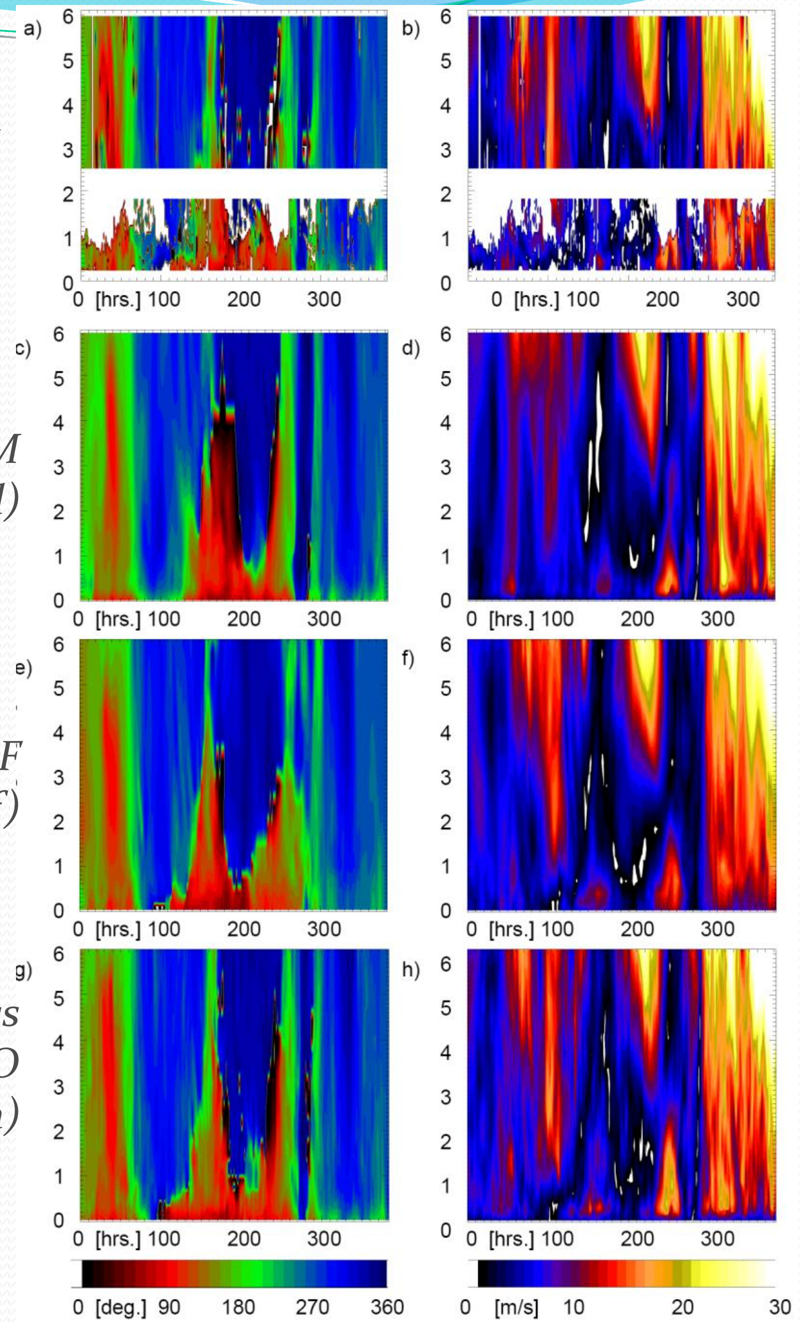
Observation

(a, b)

COSMO-CLM
(c, d)

UPM-WRF
(e, f)

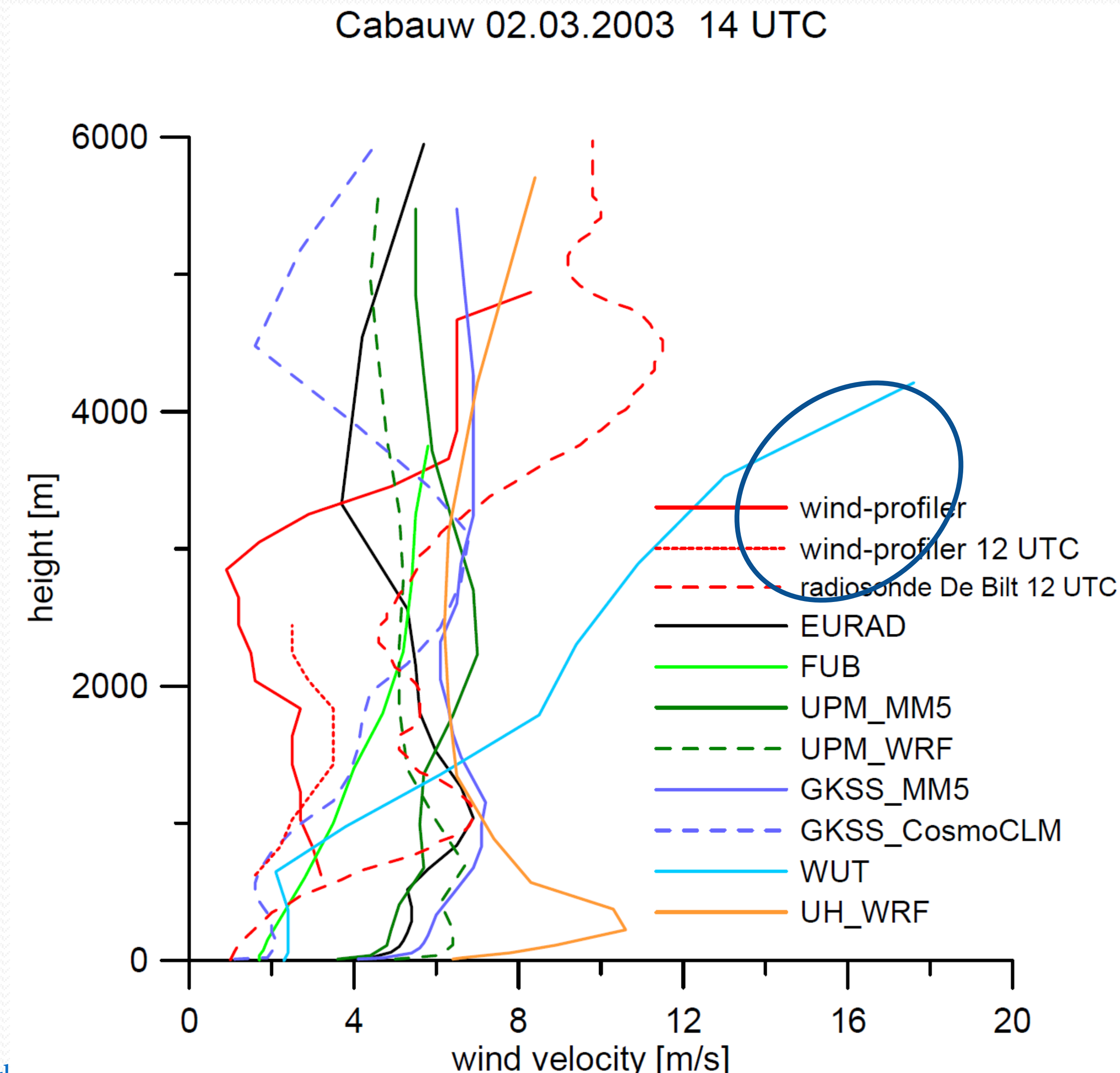
Meteo Swiss
- COSMO
(g, h)



at the hour

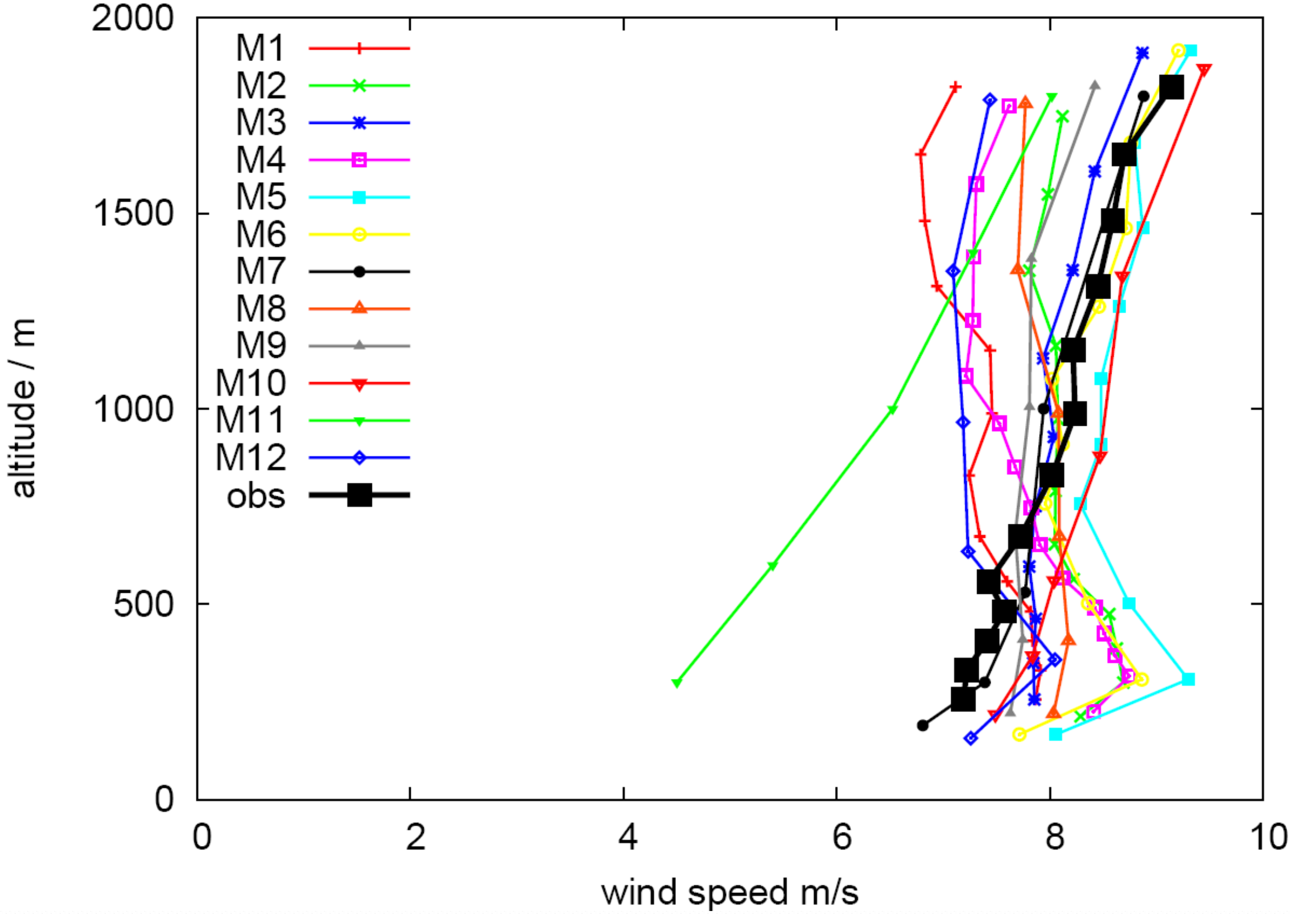
entire period (hourly)

RISØ DTU, Denmark --- NIMH BAS, Bulgaria --- GKSS, Germany


Cabauw 02.03.2003 14 UTC
6000
4000
2000
0
height [m]
0
4
8
12
16
20
wind velocity [m/s]
wind-profiler
wind-profiler 12 UTC
radiosonde De Bilt 12 UTC
EURAD
FUB
UPM_MM5
UPM_WRF
GKSS_MM5
GKSS_CosmoCLM
WUT
UH_WRF

Some bulk statistics

Average profiles of wind speed

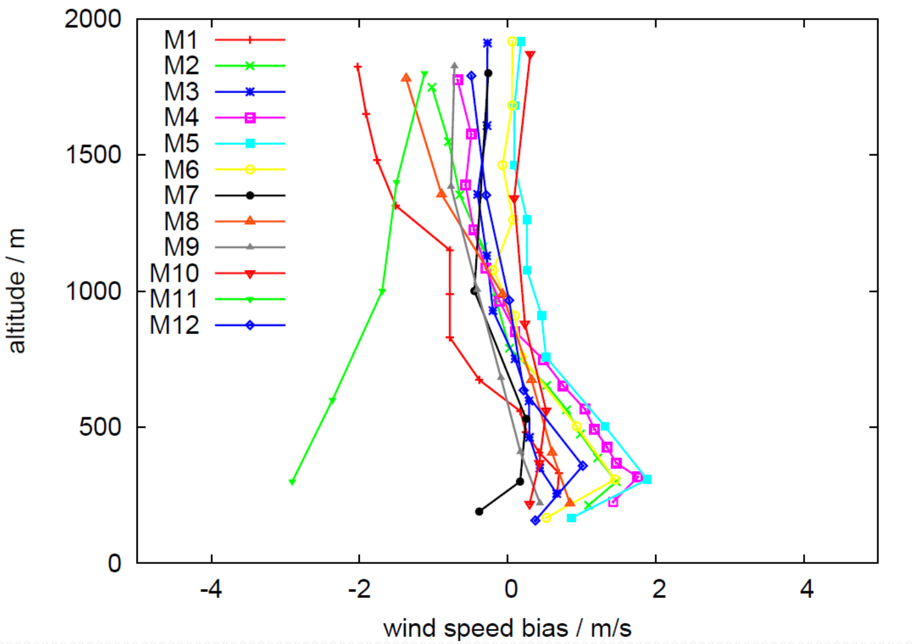


at Lindenberg, 24.02.2003 to 11.03.2003; based on hourly data

Some bulk statistics

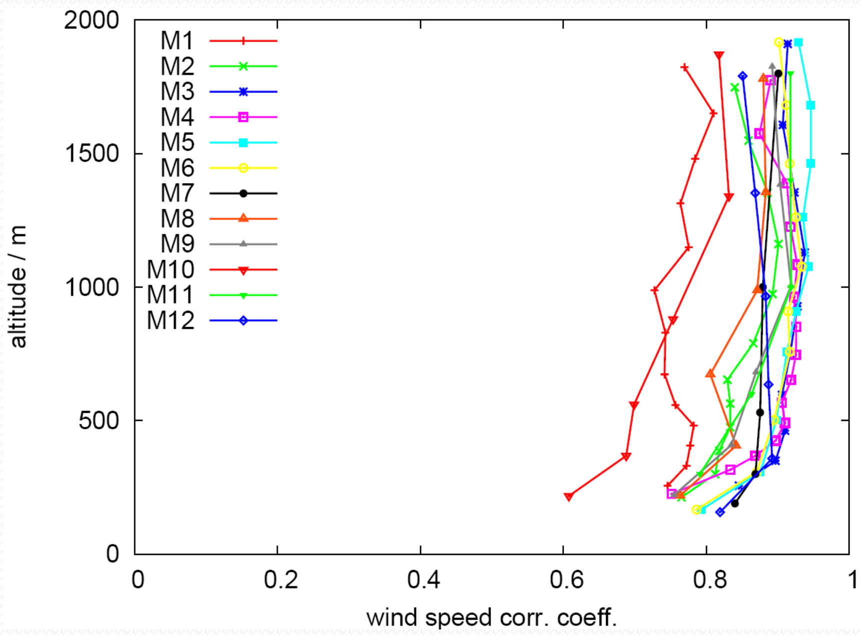
Average profiles of

wind speed **bias**



Correlation coefficient

for wind speed



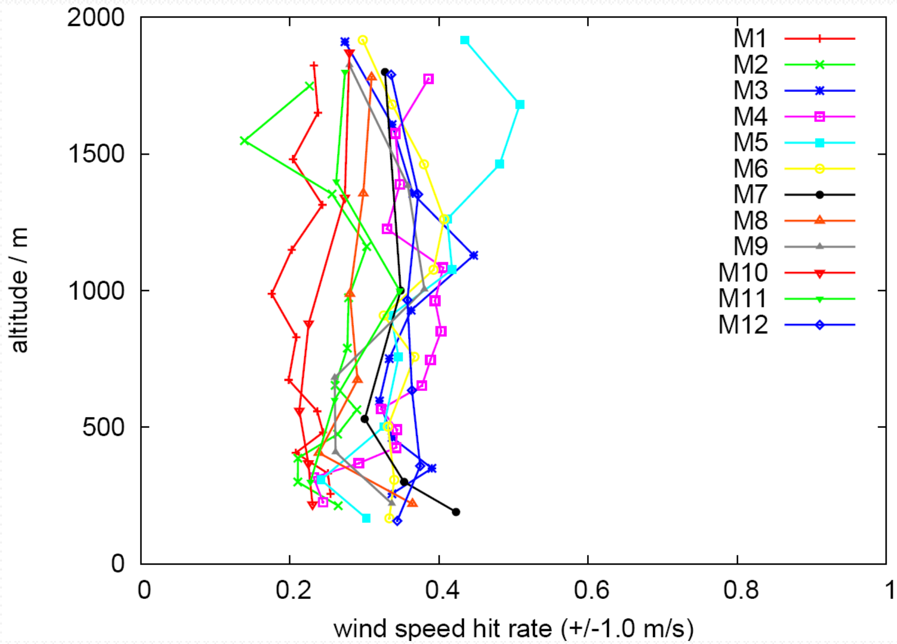
at Lindenberg, 24.02.2003 to 11.03.2003; based on hourly data

Some bulk statistics

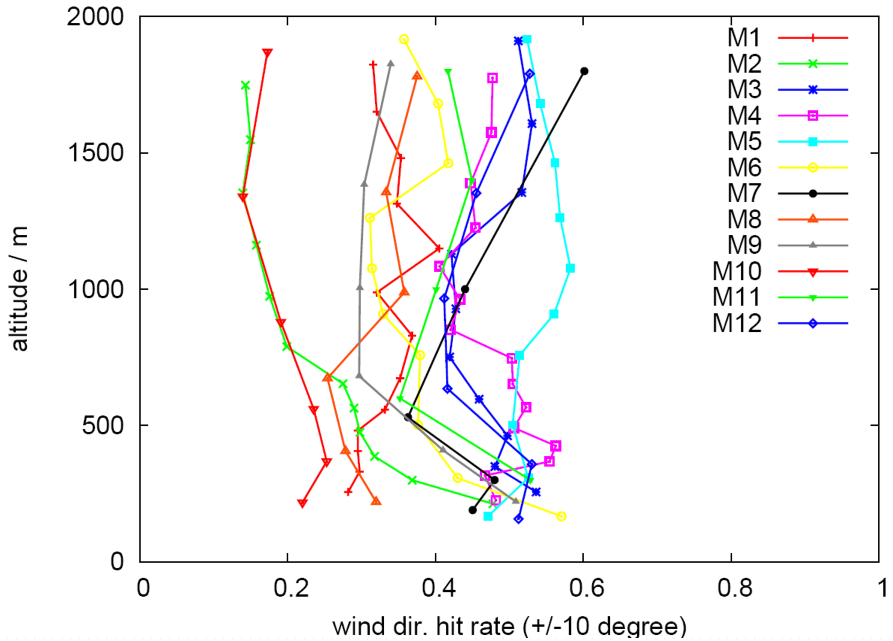
COST 728, test case 1

Average profiles of

wind speed **Hit Rate**



wind direction **Hit Rate**



at Lindenberg, 24.02.2003 to 11.03.2003; based on hourly data

Concluding remarks

Compared to radio sonde data wind profiler observations have the advantage of much higher time resolution (at least hourly data). The RS and WP measurements are representing different volumes, therefore should not expected to be close.

Some points can be made on models performance:

- underestimation of wind speed above PBL by many models and overestimating within the PBL
- hit rate WS (± 1ms^{-1}): 0.2 to 0.4 hit rate WD (± 10°): = 0.2 to 0.6
- local circulation systems → sufficient model resolution (~6 km)

➢ **effective resolution is larger than 4 times the grid resolution**

Mast Profiles:

Hamburg

320-meter mast: wind speed, wind direction, temperature, sensible heat flux, momentum flux at 10, 50, 110, 175 and 250 m (5 levels)

Cabauw

200-meter mast: wind speed, direction and temperature at 2,10, 40, 80, 140 and 200 m)
Wind profiler data up to 5 km
Radiosoundings at 0 and 12 UTC

Lindenberg

99-meter mast over grassland: wind speed, wind direction and temperature at 40 and 98 meters
28-meter mast over forest: wind speed, wind direction and temperature at 28 m above the forest)
Wind profiler data up to 5 km
Radiosoundings at 0, 6, 12 and 18 UTC

The period 24 February - 11 March 2003

We note that we can have a perfect model without an exact match with the measurements.

How close is close enough to be within the limits of representativiness?

In other words when will it be worthwhile to look for improvements in the models and when are the model predictions within the statistical range given by the representativiness of the measurements.

The mean square relative error ε depends on the averaging time T of the parameter x.

$$\varepsilon^2 = \frac{\sigma_{x,T}^2}{\langle x \rangle^2} = \frac{2\sigma_x^2}{\langle x \rangle^2}\frac{\tau}{T}$$

Where $\sigma_{x,T}^2 / \langle x \rangle^2$ is the mean-square relative error (the standard deviation of parameter x when integrating over duration T divided by the mean of x) and τ is the integral time scale of the parameter.

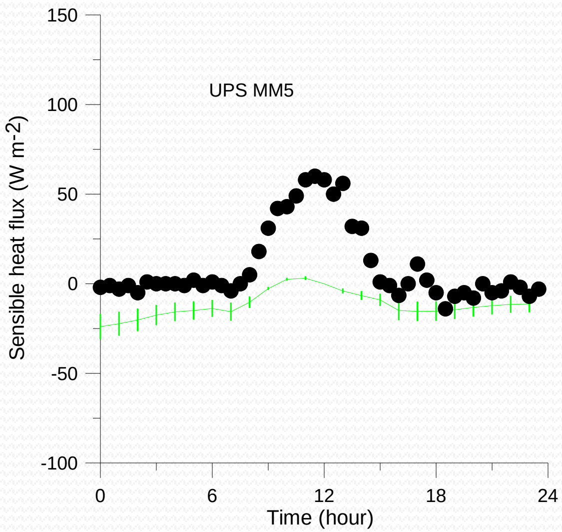
For the wind speed we have $\varepsilon^2 = \left(\sigma_{u,T} / \langle u \rangle\right)^2$

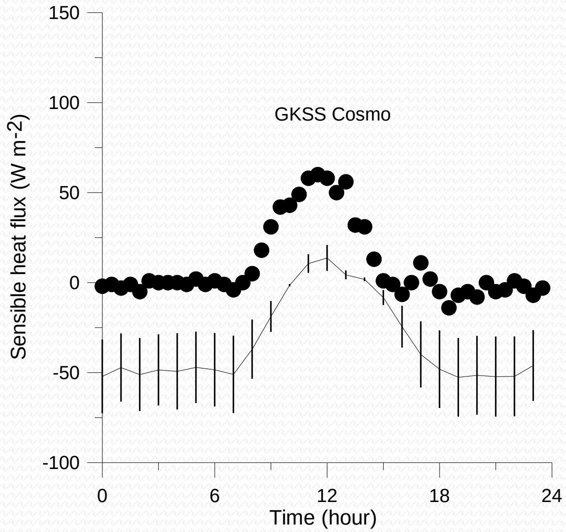
and for the sensible heat flux $\varepsilon^2 = \left(\sigma_{w\theta,T} / \langle w\theta \rangle\right)^2$

We use a method suggested in Sreenivasan, Chambers and Antonia, *Boundary-Layer Meteorology **14, 1978*** to determine the relative error for wind speed and sensible heat flux for a given averaging time T

$$\sigma_{u,T} = \sqrt{12}\sqrt{\frac{z}{Tu}}\,u \qquad \sigma_{w\theta,T} = 8\sqrt{\frac{z}{Tu}}\,w\theta$$

Lindenberg, 24 February 2003: sensible heat flux at 2.4 meter over grass

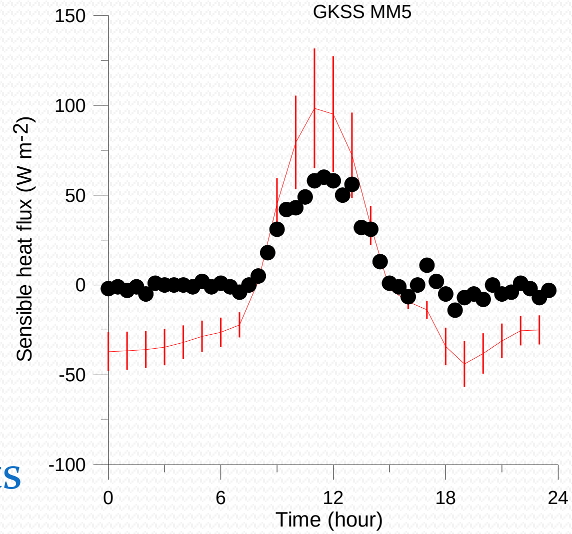


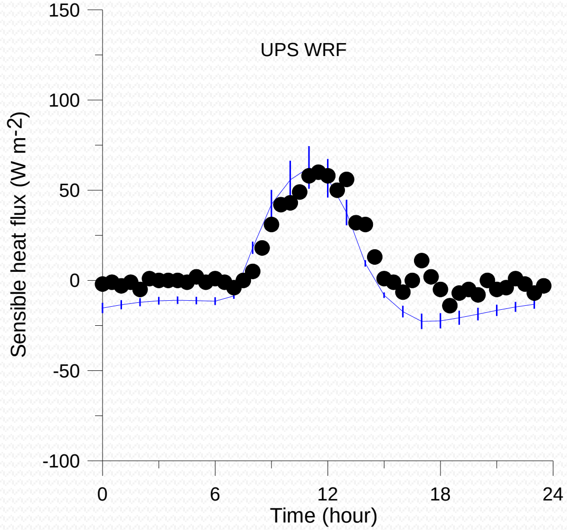


- observations

Full lines – Model predictions

Bars – representati-viness of measurements



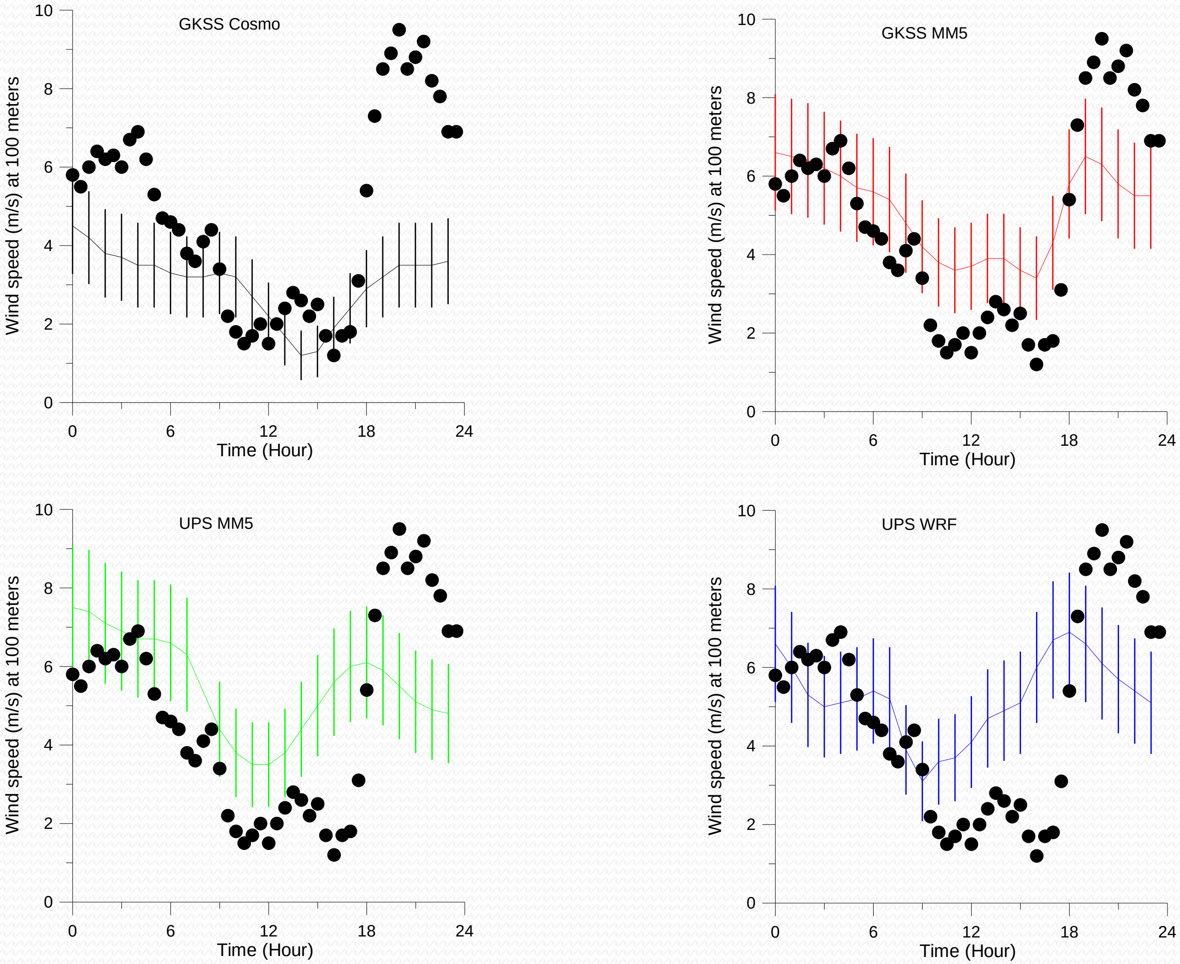


Lindenberg, 24 February 2003: wind speed at 100 meters over grass (close to a model level)

- observations

Full lines – Model predictions

Bars – representati-viness of measurements

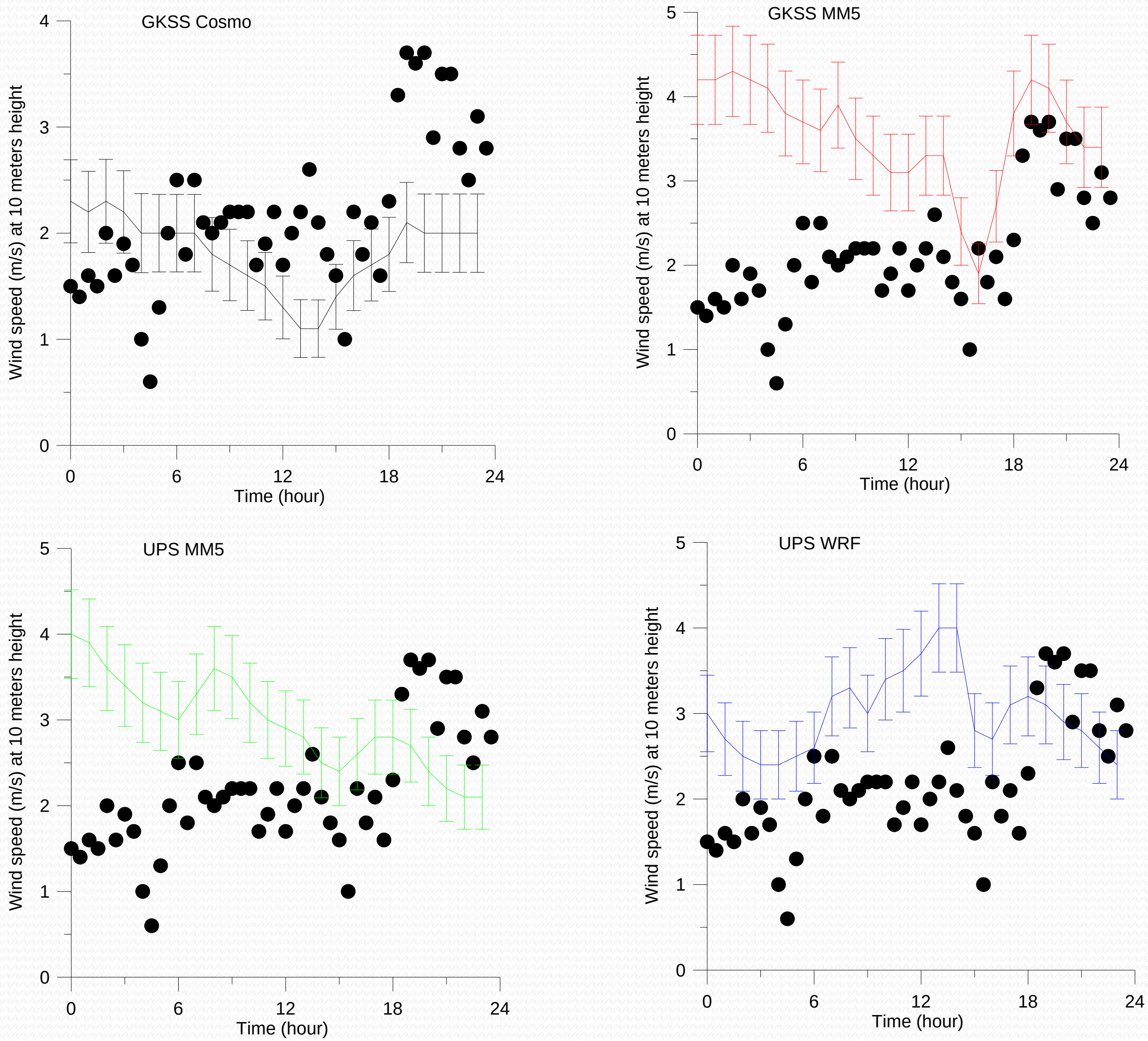


Lindenberg, 24 February 2003: wind speed at 10 meters over grass

- observations

Full lines – Model predictions

Bars – representati-viness of measure-ments



Conclusions:

•Progress in model developments is based on comparison with data.

•It is essential to evaluate the models on profile measurements, not just traditional surface measurements

•The representativiness of the measurements should be taken into account in any model evaluation against measurements.

•The representativiness is a function of the length scale of turbulence (height in the surface layer) and averaging time of the measurements (as a first rough approximation)

•We note that we can have a good model without an exact match with the measurements.

•In other words a model cannot be improved if the measuremenst fall within the statistical range.

ACKNOWLEDGEMENT

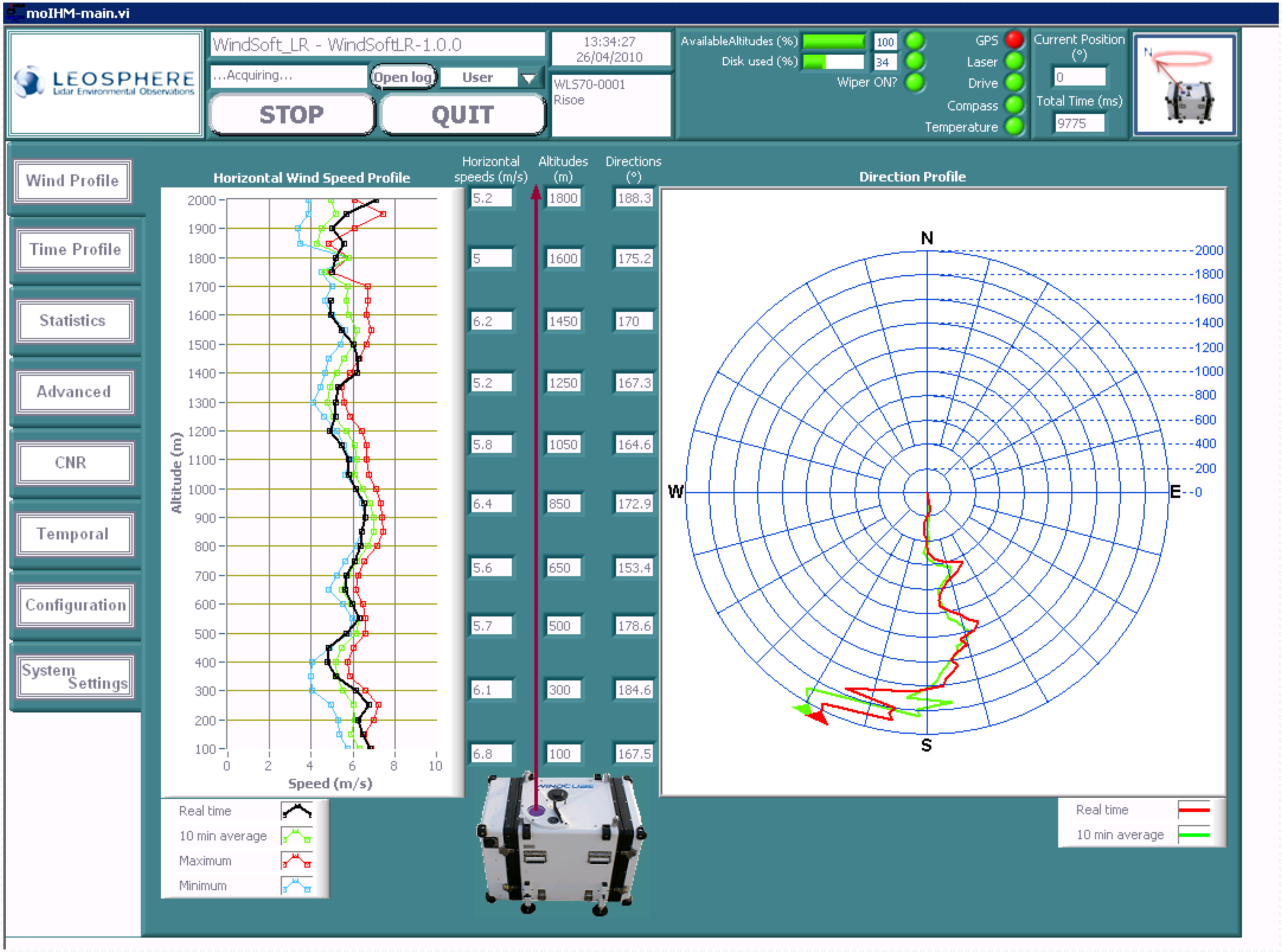
- The data from Lindenberg are provided through the CEOP/GEWEX BALTEX (Baltic Sea Experiment) database and it is a pleasure to acknowledge the Deutscher Wetterdienst (DWD) - Meteorologisches Observatorium Lindenberg / Richard Assmann Observatorium who originally provided the measurements for the data base.

- We thank Myles Turp (UK Met Office) for providing data from the CWINDE project as well as Wolfgang Adam (German Weather Service) and Henk Klein-Baltink (KNMI) for providing additional wind profiler data for Lindenberg and Cabauw, respectively.

- The study is supported by the **Danish Council for Strategic Research, Sagsnr 2104-08-0025** and the EU FP7 Marie Curie Fellowship VSABLA.

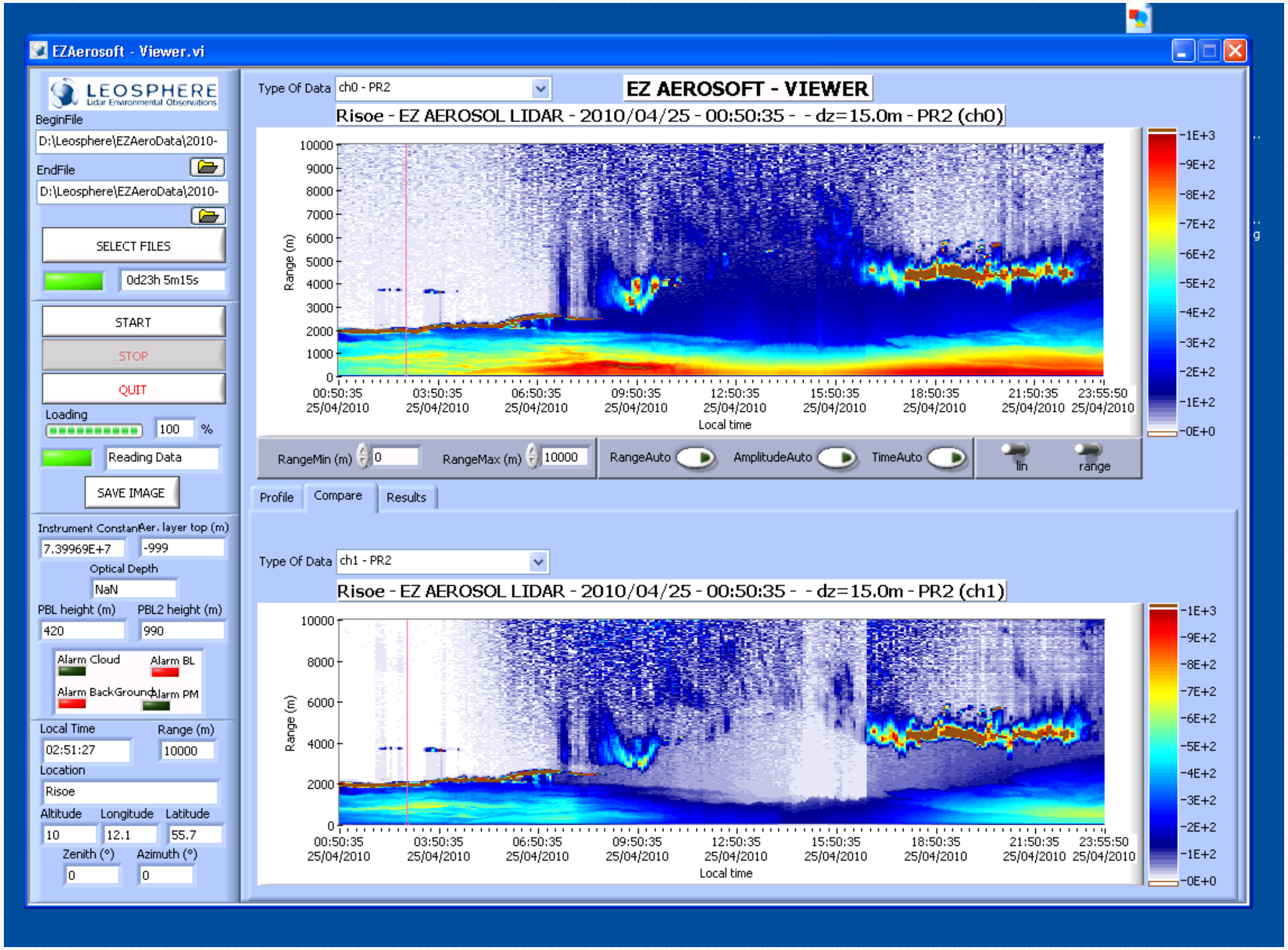
- The work continues collaboration within COST 728 - A. Aulinger, C. Chemel, G. Geertsema, B. Geyer, H. Jakobs, A. Kerschbaumer, M. Prank, R. San José, H. Schlünzen, J. Struzewska, B. Szintai, R. Wolke are participating the present work through the discussions in connection with Case 1 inter comparison exercise.

Look forward: Tall Wind Project



Wind
Lidar
Wind
profile

Tall Wind Project

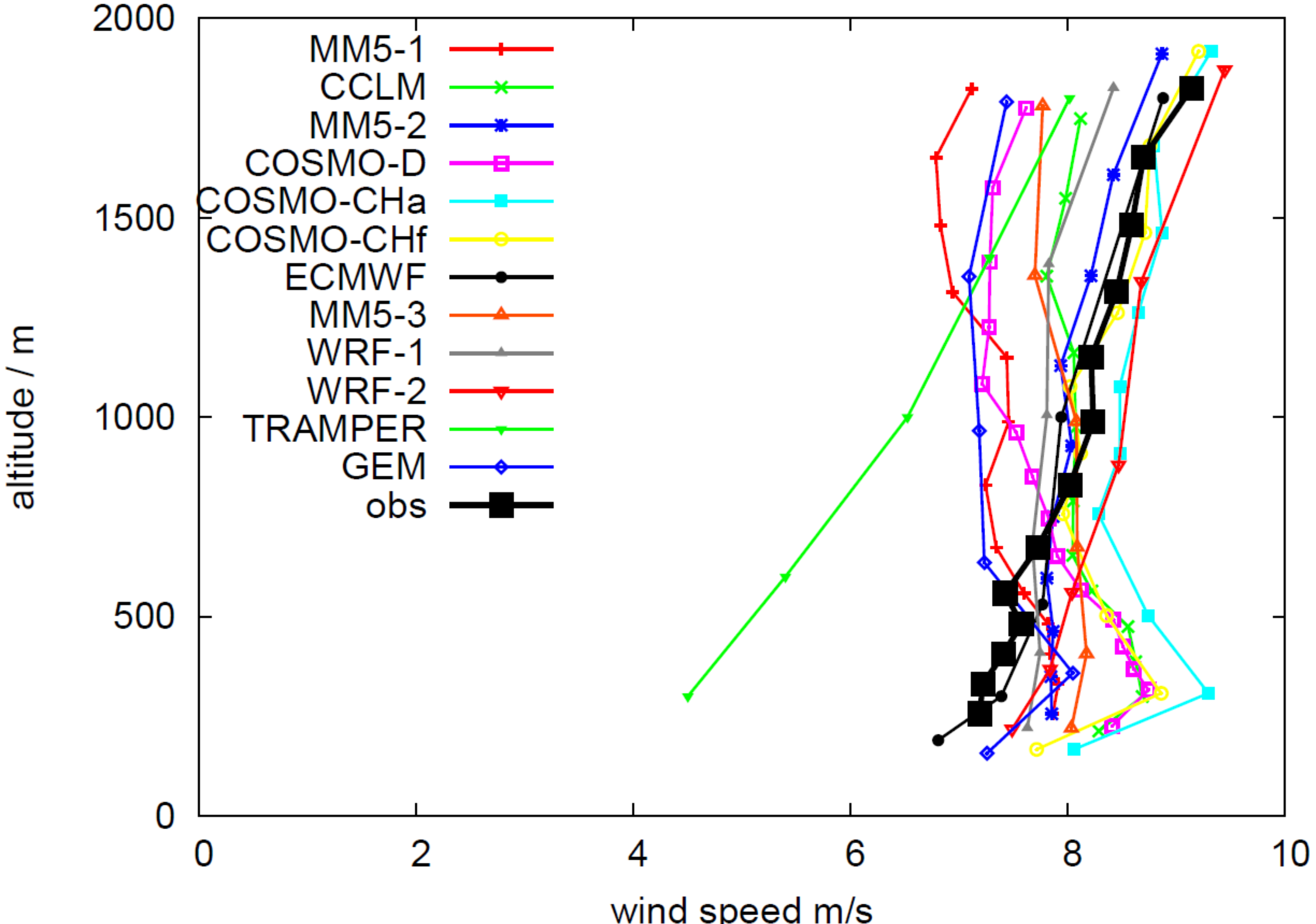


Aerosol
Lidar
ABL
height

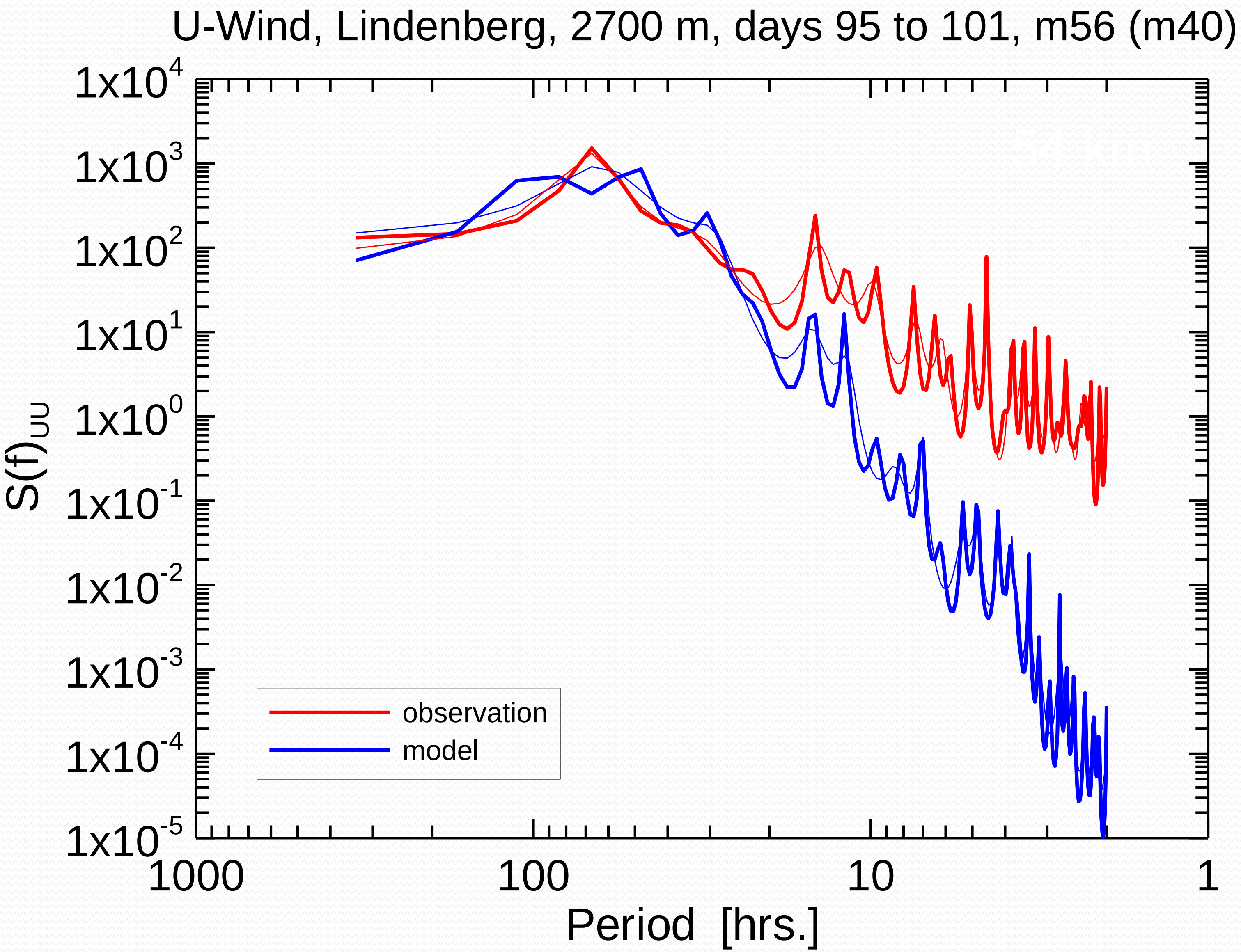
Tall wind project is based on the experience from previous studies.
It will monitor simultaneously wind speed profile up to
2-3 km (wind lidar) and PBL height (aerosol lidar) at 3 sites:
flat homogeneous, urban and marine

WRF model with high order turbulence closure
will provide predictions and store the results
(including fluxes) for further analysis.

Thank you for your attention!

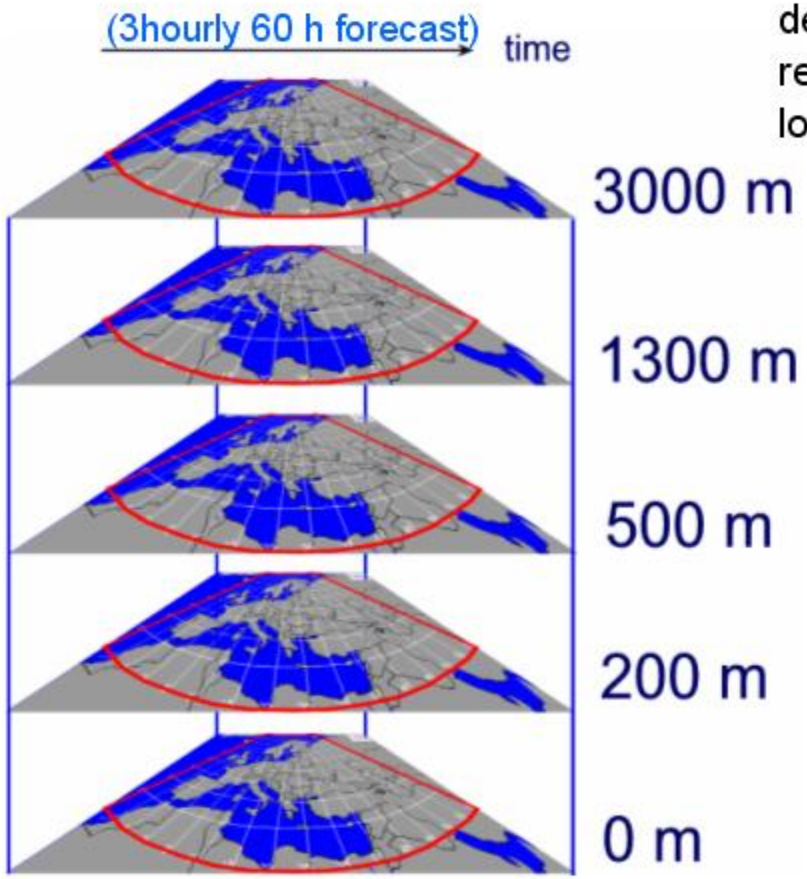

MM5-1
CCLM
MM5-2
COSMO-D
COSMO-CHa
COSMO-CHf
ECMWF
MM5-3
WRF-1
WRF-2
TRAMPER
GEM
obs
altitude / m
wind speed m/s
0
500
1000
1500
2000
0
2
4
6
8
10

Power - observation/model

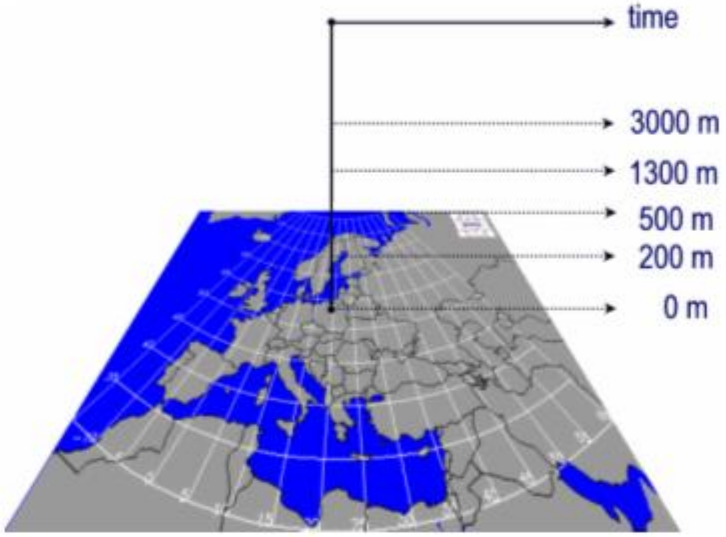


Major collaboration with JRC (ISPRA)
ENSEMBLE - A system to reconcile disparate national forecasts of medium and long-range atmospheric dispersion

- Air concentration at 5 vertical levels
- Time integrated concentrations
- Dry and wet deposition



0.5 x 0.5 degrees resolution in lat long



ENSEMBLE Outputs

Chemical species

- Instantaneous concentrations at all levels
- Instantaneous exchange coefficient for scalars
- Instantaneous Dry deposition cumulated since release start
- Instantaneous Wet deposition cumulated since release start
- Precipitation cumulated since release start

Meteorological variables

- 1-hour-average module of horizontal wind
- 1-hour-average Horizontal wind direction
- 1-hour-average Boundary layer height
- 1-hour-average Cloud cover fraction
- 1-hour-average Surface temperature

Species

SO2, SO4, NO, NO2, NO3, HNO3, O3, NH3, PM2.5, PM10, HCHO, CO, NH4, PPM2.5 (Primary PM2.5), EC (Elemental carbon), OC (Organic carbon), SS (Sea salt), D (Dust), T728 (Tracer-728, NOx emission non-reactive, non-depositing), AOD550