Data assimilation in mesoscale NWP models

Helsinki Urban Modeling Workshop
15.6.2005

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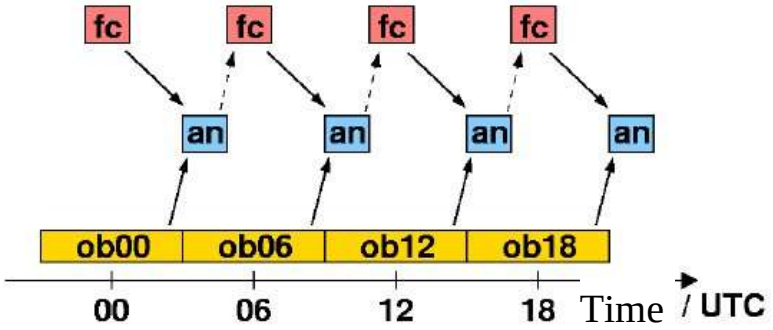
Content

- Data assimilation concepts
- Observations
  - Which observations to use in data assimilation
  - Geographical distribution of the observations
  - Problems
- Use of Helsinki testbed data

Data assimilation concepts

- Purpose: use all the available information to determine as accurately as possible the state of the atmospheric flow --> analysis.
- Analysis is a statistical combination of observations and short-range forecast.



- A good analysis is required for a good forecast.

Data assimilation concepts

- Analysis equation $x_a = x_b + K(y-Hx_b)$ can be solved by:
  - Defining the optimal gain matrix K
    - Optimal interpolation
    - Kalman filter
  - Minimizing a quadratic cost function $J = J_b + J_o$
    - 3D- and 4D- variational assimilation

Data assimilation concepts

- If:
  - The model is perfect.
  - Input data is the same (initial background, and its error covariances, distribution of observations and their error covariances).

  the 4D-Var analysis at the end of the time interval is equal to Kalman filter analysis at the same time.

Mesoscale viewpoints

Variational assimilation:

- Relatively easy to use observations which are not model variables.
- 4D-Var takes into account the observation time.

Kalman filter:

- Computationally very expensive.

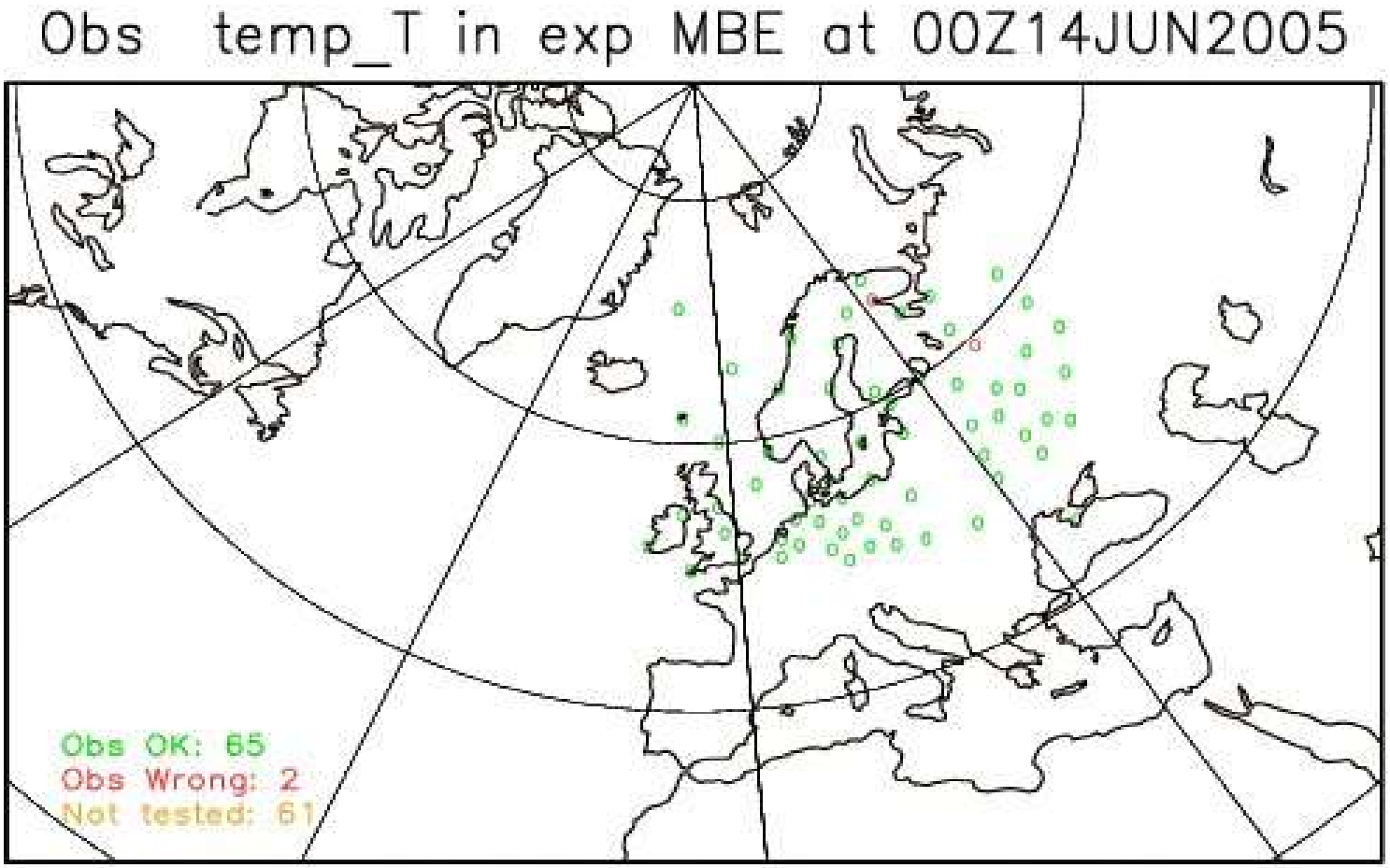
Ensemble Kalman filter:

- Takes a statistical approach to the solution of the Kalman filter equations.
- Time-varying background error covariance.

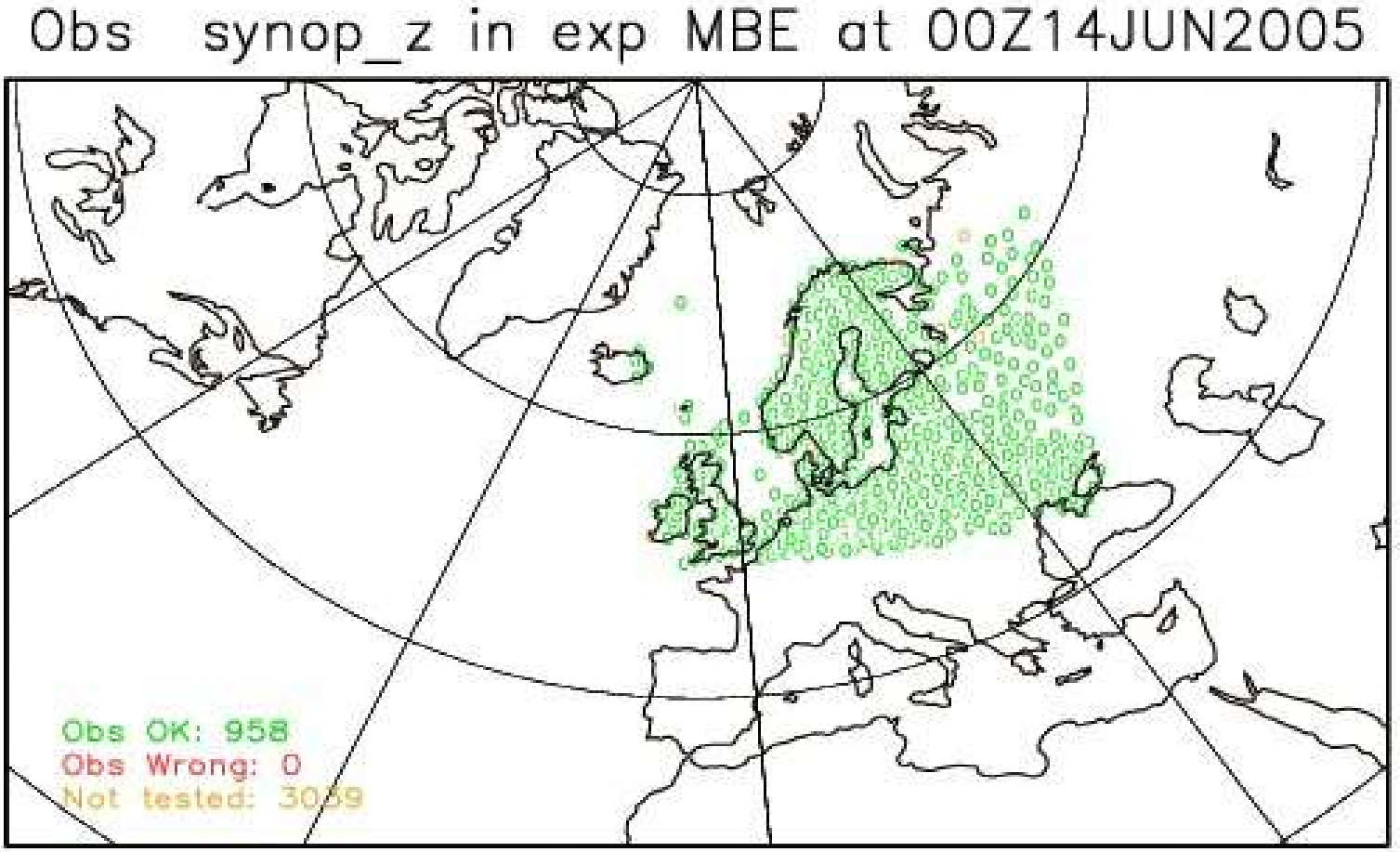
Weather observations, *in situ*

- Soundings
  - Vertical profiles of temperature, humidity and wind.
- Synoptic observation network
  - Surface pressure, 10m wind, 2m temperature and humidity.
- Aireps
  - Temperature, humidity and wind
  - Vertical profiles from airports and free atmosphere from flight-path.

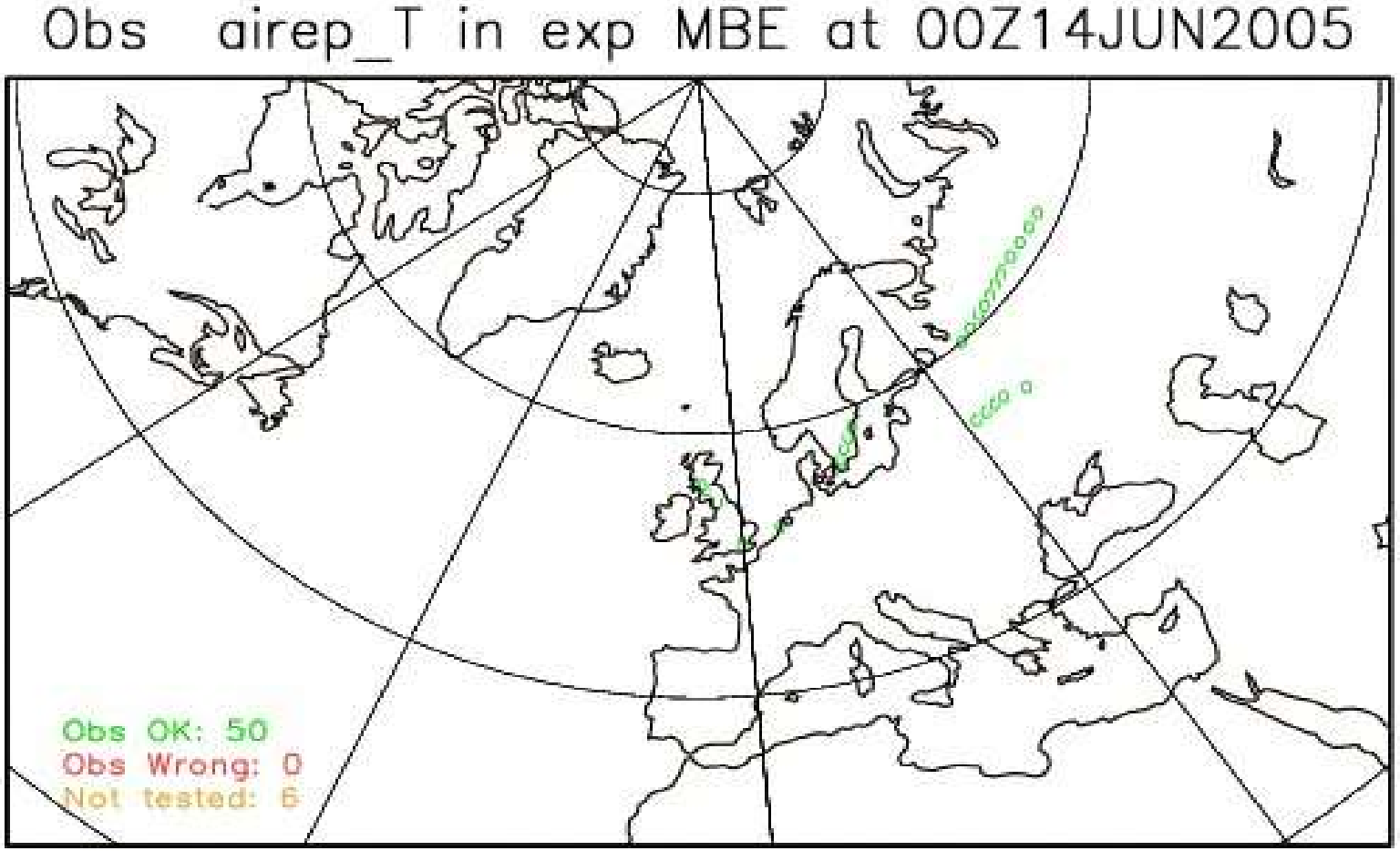
Geographical distribution of observations: TEMP



Geographical distribution of observations: Surface observations



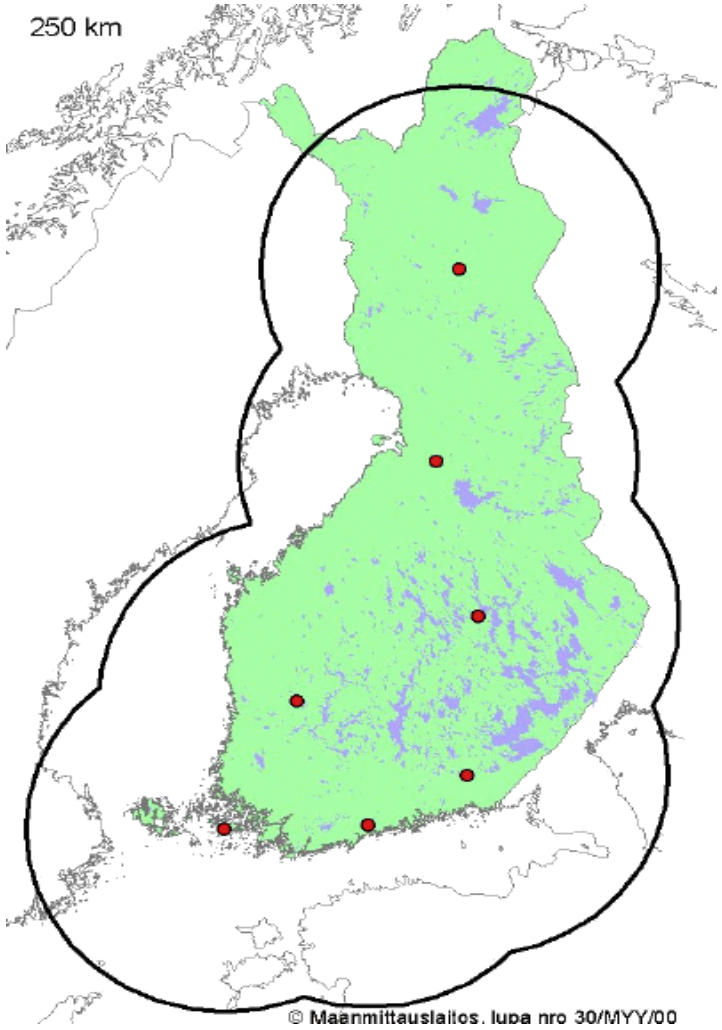
Geographical distribution of observations: Airep



Weather observations, *remote sensing*

- Satellites
  - Irradiance --> vertical profiles of temperature and humidity.
  - Scatterometer data --> winds near the ocean surface.
- Weather radars
  - Radar radial wind.
  - Radar reflectivity.
- Windprofilers
  - Vertical wind profiles.
- GPS
  - Zenith and slant total delay observations --> moisture and temperature.

Radar networks



Problems related to observations

Problem:

- In most cases the analysis problem is under-determined because the observation network is sparse compared to the model resolution.

Solution:

- Use background information in the form of a priori estimate of the model state.
- Background information is typically a short range forecast calculated from the previous analysis.

Problems related to observations

Problem:

- Observations are irregularly distributed.
- Observed quantity is not necessarily a model variable.

Solution:

Use the background information:

- Model variables are interpolated from the gridpoints to the observation location.
- A model counterpart to the observed quantity is calculated from the model variable with so called observation operator.

Problems related to observations

Problem:

- Observation errors
  - Random, systematic and gross errors.
  - Representativeness error: observation represents a phenomena which the NWP model can not resolve.

Solutions:

- Random errors are accounted with statistical methods.
- Systematic errors are removed from the observations if possible.
- Observations with gross errors are eliminated.
- Data thinning decreases representativeness error.

Summary

- The aim of data assimilation is to produce an accurate analysis of the state of the atmosphere.
- Conventional observation network is quite sparse and observations are irregularly distributed.
- Remote sensing observations become more and more important when the model resolution increases.

Use of Helsinki testbed data

- The impact of the dense observation network on analysis and forecasts
  - Assimilation experiments with 9 km resolution HIRLAM model.
  - Main data source: Doppler radars (4 + 1), 1 wind profiler.
- Modeling of the measurement campaign periods for verification purposes.
- Research on atmospheric processes: convective rain (intensity and state), stable boundary layer, sea and land breeze (modeling and development of the methods).