Doppler-radar wind data assimilation in Numerical Weather Prediction models

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WHY USE RADAR WIND OBSERVATIONS IN NUMERICAL WEATHER PREDICTION MODELS?

- The aim is to increase resolution in numerical models $\rightarrow$ observations are needed with high spatial and temporal resolution.

- Radar wind observations are one possible source of information.

- Radar winds could give extra information especially in forecasting of quickly developing mesoscale systems, where wind information is important (geostrofical adjustment is weak.)

REPRESENTATIVENESS ERROR

- Resolution of the observations $>$ resolution of the numerical model

  $\rightarrow$ representativeness error.

- Possibilities to decrease representativeness error
  - Provide vertical profiles of horizontally averaged wind (VAD technique).
  - Use observations with sparse resolution.
  - Generate spatial averages i.e. superobservations.

DATA ASSIMILATION

- The aim is to determine an optimal initial state for NWP model, i.e. analysis.

- Analysis is a combination of observations (y) and model background state (x^b), which can be for example 6h forecast.

- 3D-Var assimilation technique is based on minimizing the cost function J.

$$
\begin{aligned}
J = J_b + J_o = \; & \tfrac{1}{2}(\mathbf{x} - \mathbf{x^b})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x^b}) \\
& + \tfrac{1}{2}(H\mathbf{x} - \mathbf{y})^T \mathbf{R}^{-1} (H\mathbf{x} - \mathbf{y})
\end{aligned}
$$

OBSERVATION OPERATOR FOR RADAR WINDS

- Observation operator H makes it possible to use also observations which are not model variables.

- For VAD wind profiles the observation operator consists only of interpolating the model wind field to the observation location.

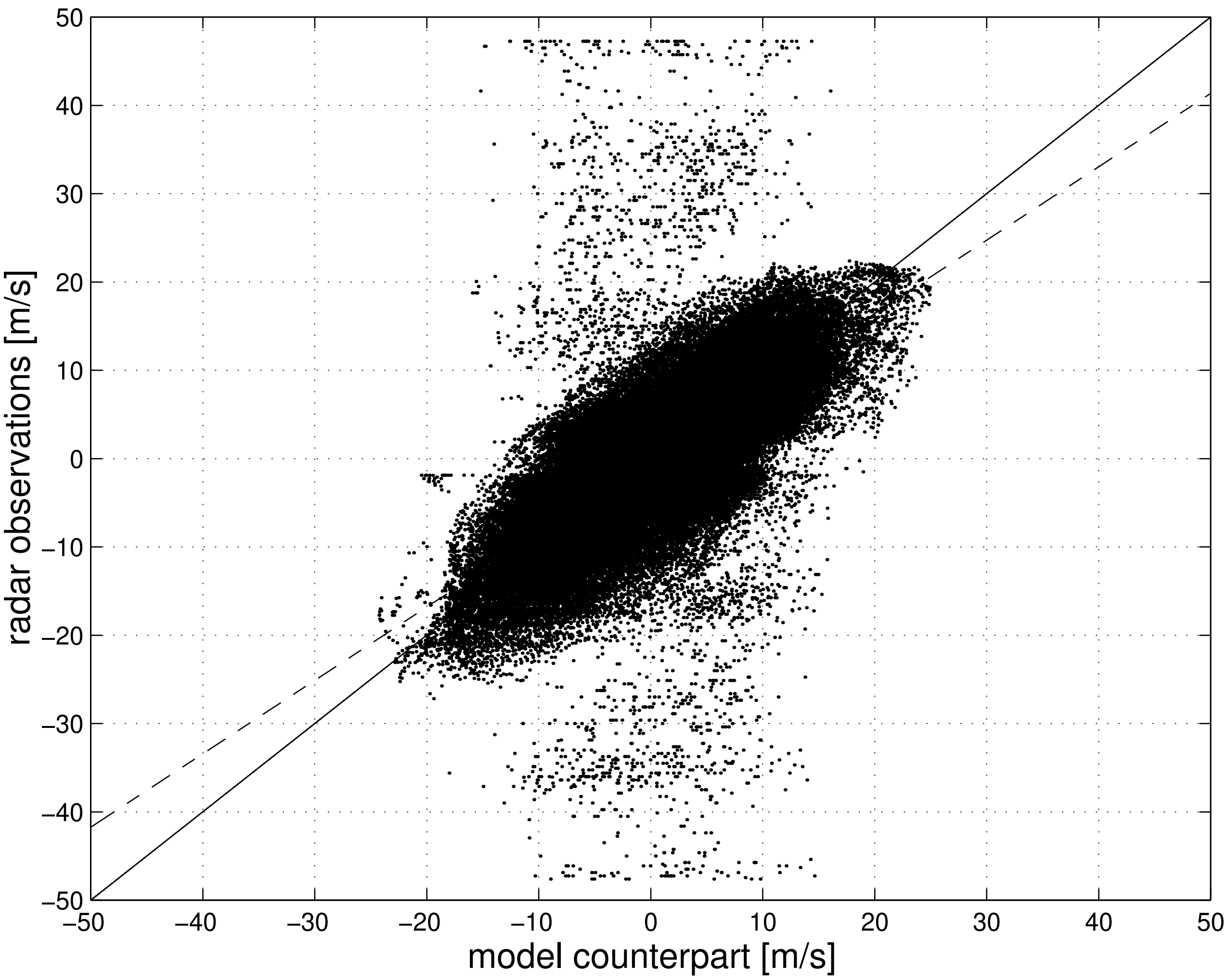
- For radial winds the observation operator consists of:

  $v_h = u \sin\theta + v \sin\theta$

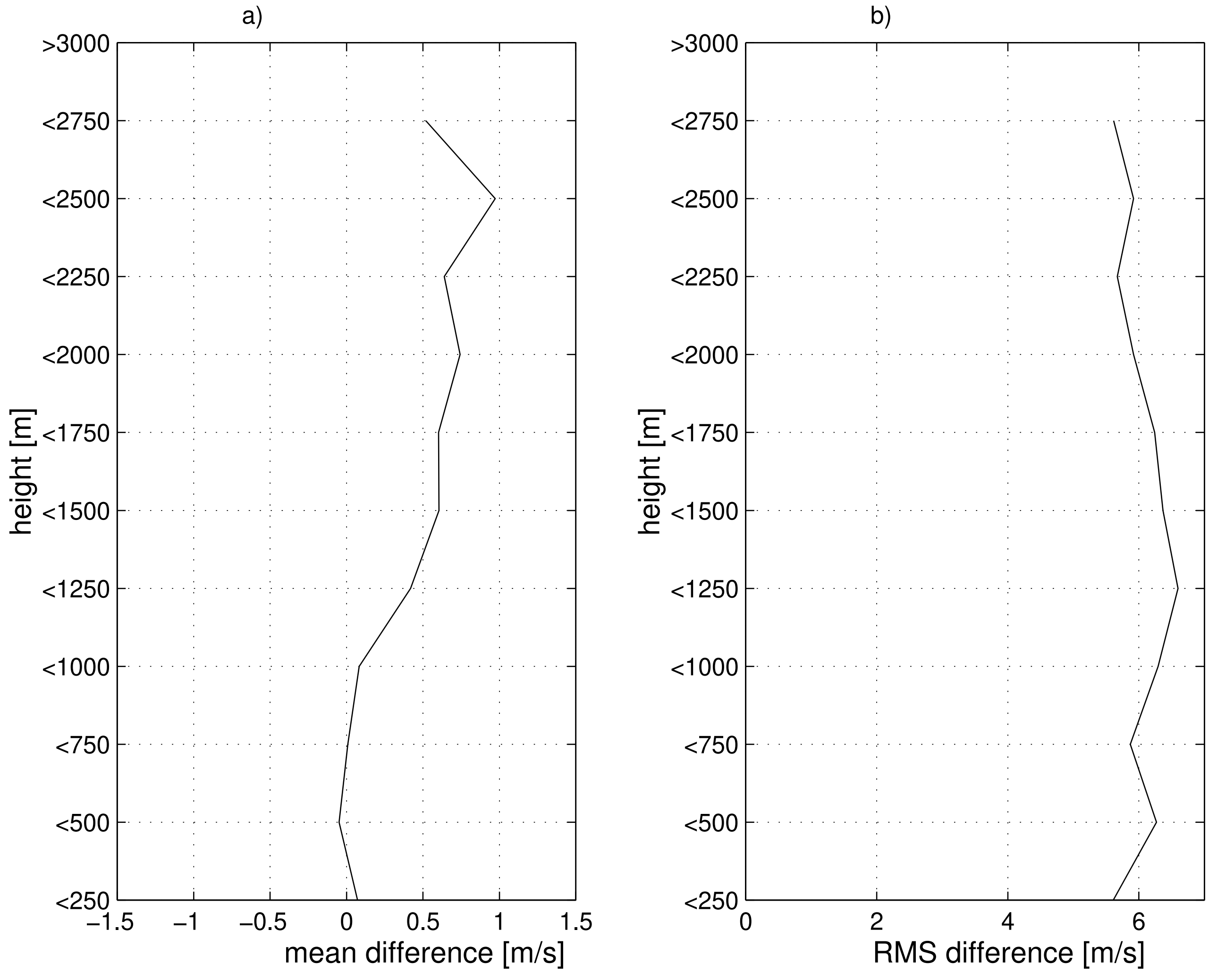
  $v_r = v_h \cos(\phi + \alpha)$

  (θ the azimuth angle, ϕ the elevation angle and α approximates the influence of earth's curvature.)

The fit of radial wind superobservations with the model background ($y = 0.83H\mathbf{x}^{\mathbf{b}} - 0.19$)



Mean (a) and RMS difference (b) between the background and the observations as a function of height.



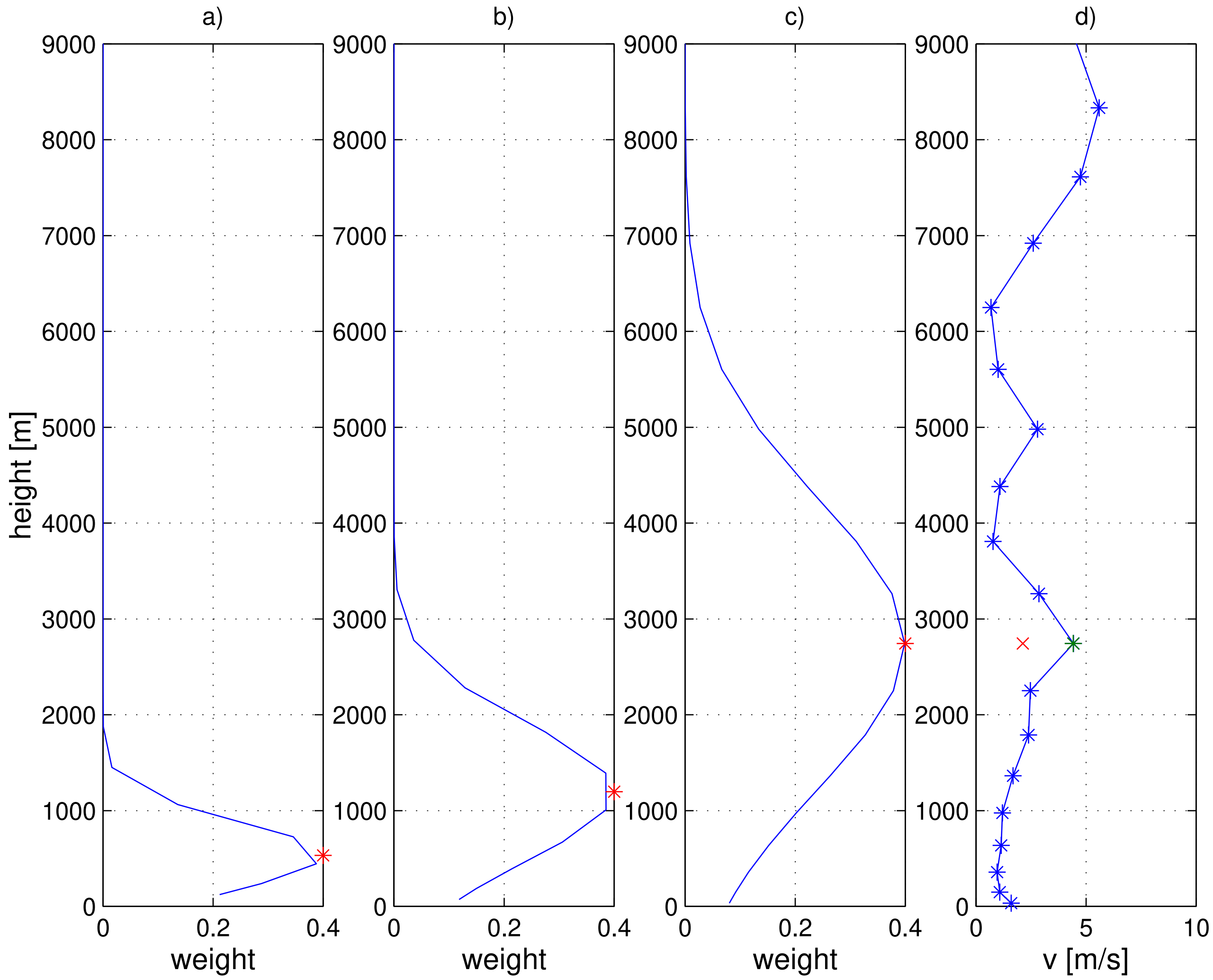
GAUSSIAN WEIGHT FUNCTION IN OBSERVATION OPERATOR

- A height dependent mean difference in data; model background $>$ observed wind.

- Reason: broadening of the radar beam is not taken into account?

- Possible solution: Use gaussian weight function in vertical instead of linear interpolation when defining the model counterpart to the observation height.

The shape of the gaussian weight function in vertical with measurement ranges 15 km, 45 km and 85 km (a,b and c). d) Model wind profile for v-component.



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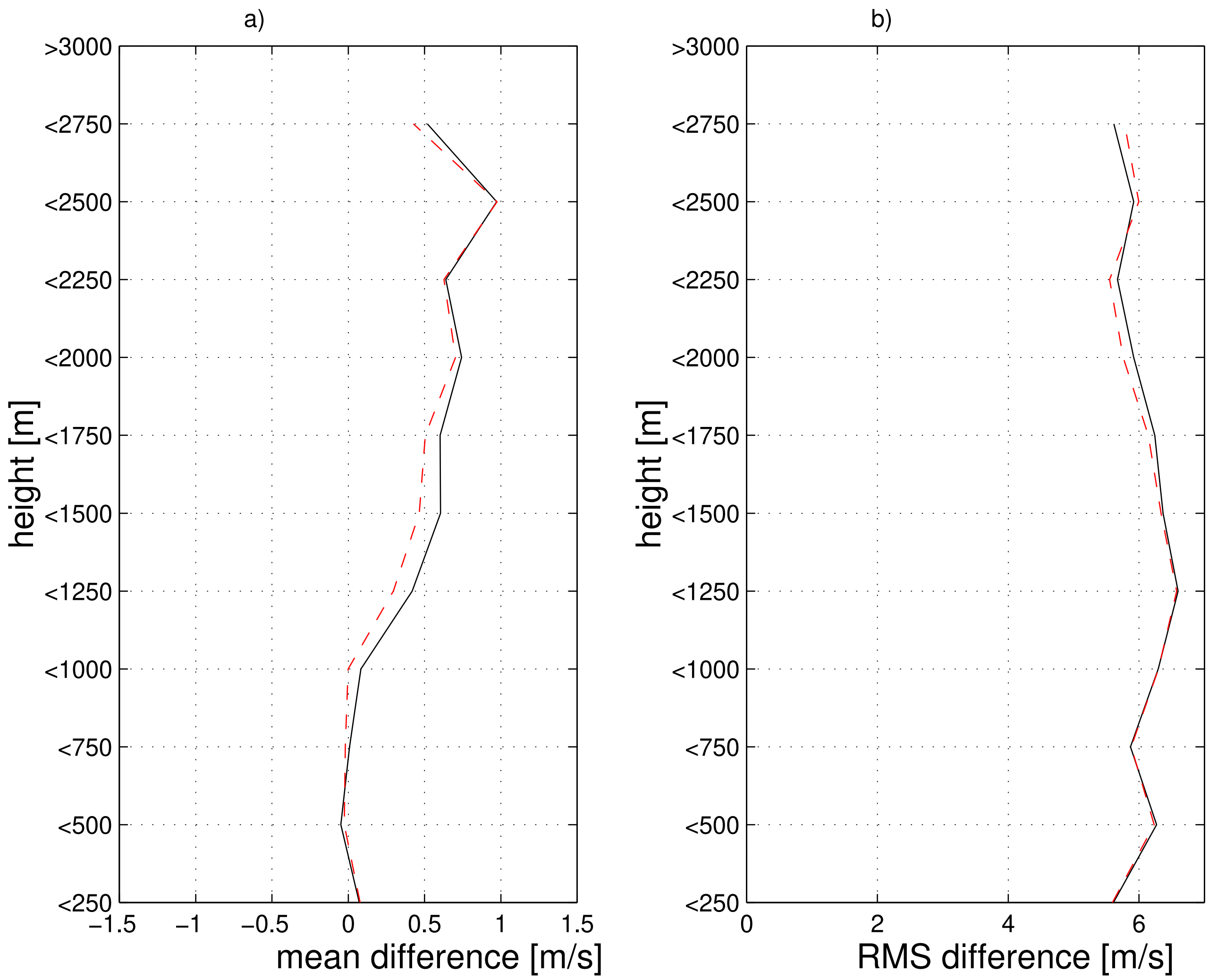

SUMMARY

- Limited area models require observations with high spatial and temporal resolution. Radar winds are one possible source of information.

- Height dependent mean difference between the background and the observations can be reduced by about 0.2 m/s by using Gaussian weight function in vertical in the observation operator.

- Another source of height dependent mean difference

  – Bending of the radar beam is not properly taken into account.