Impact of wind profile observations on forecast of the nocturnal boundary layer

Tobias Finn (1, 2), Felix Ament (1, 3), Gernot Geppert (4)

(1) Universität Hamburg; (2) Universität Bonn; (3) Max-Planck Institut für Meteorologie; (4) University of Reading

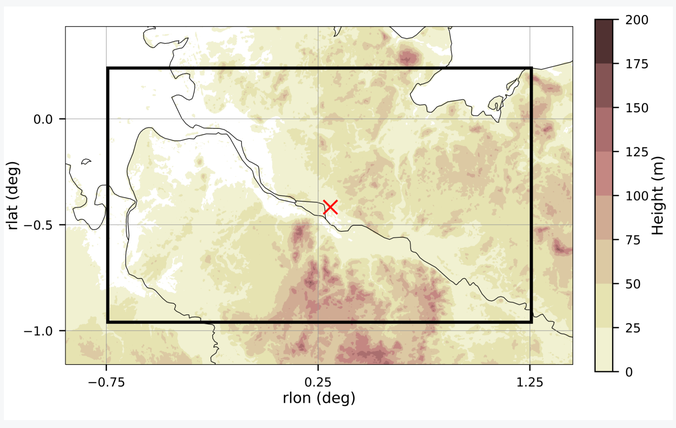
Introduction

- Many model errors in the nocturnal boundary layer (NBL) for numerical weather prediction due to influence of small-scale processes
- Often wind observations for upper troposphere → Only sparse wind profile observations within the atmospheric boundary layer
- Wind is coupled to stratification via turbulence theory → Idea: Information about stratification is encoded in wind profile observations
- New and more observations (e.g. LiDARs for wind speed in hub height) of wind profile within the atmospheric boundary layer

What is the effect of assimilation of wind profile observations in the nocturnal boundary layer?

COSMO-HH

- Model: COSMO with Terra-ML
- Metropolitan area around Hamburg
- Horizontal resolution: 0.004° (ca. 450 m)
- 50 vertical levels (Terra-ML: 7, like COSMO-DE)
- 3D-turbulence (LES-like, developed for LITFASS project)
- 40 Ensemble members + 1 deterministic run
- Boundary and initial data: ICON-EU EPS



Surface height of COSMO-HH in rotated pole coordinates. The black reactangle shows the used model area and the red cross symbolizes the position of the observations.

KENDA-LETKF

- Multiplicative inflation (ρ = 1.5)
- No horizontal localization
- Vertical localization with Gaspari-Cohn (0.3 ln(hPa))
- Hourly 4D-LETKF assimilation

Observations

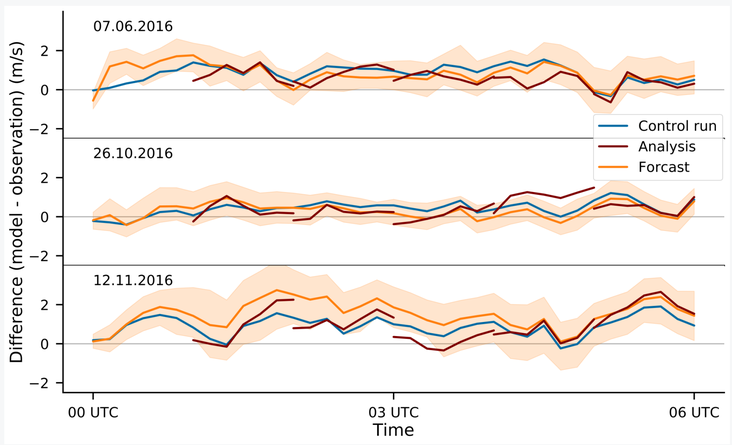
- Single point observations of U- and V-wind
- In 6 different heights (from 10 m up to 280 m)
- Averaged values over 10 minutes
- Calculated observation error: 0.4 m/s

3 Test cases with stable NBL

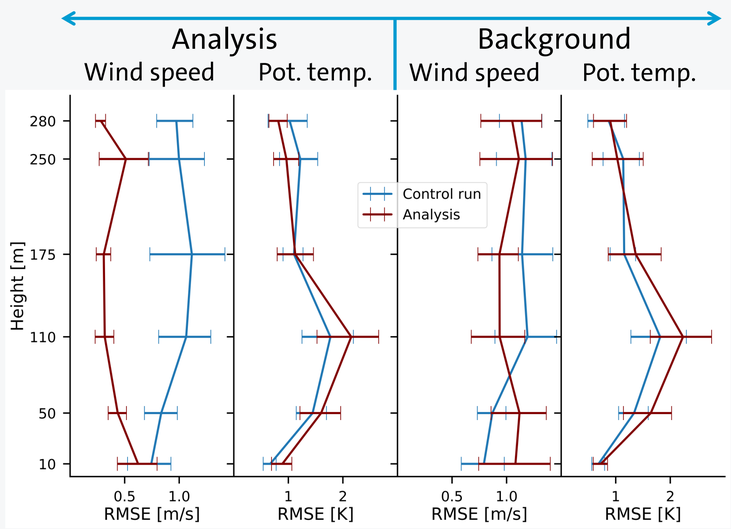
- 1 x Control run without assimilation
- 1 x Analysis cycle with continous hourly assimilation
- 1 x Forecast started based on analysis at 00Z

Slightly positive impact on wind speed in the NBL

- Analysis: Positive impact on wind speed; Neutral impact on stratification
- Background: Positive impact on wind speed; Negative impact on stratification; High uncertainty
- In 2/3 cases forecast in wind speed and pot. temperature better than control run



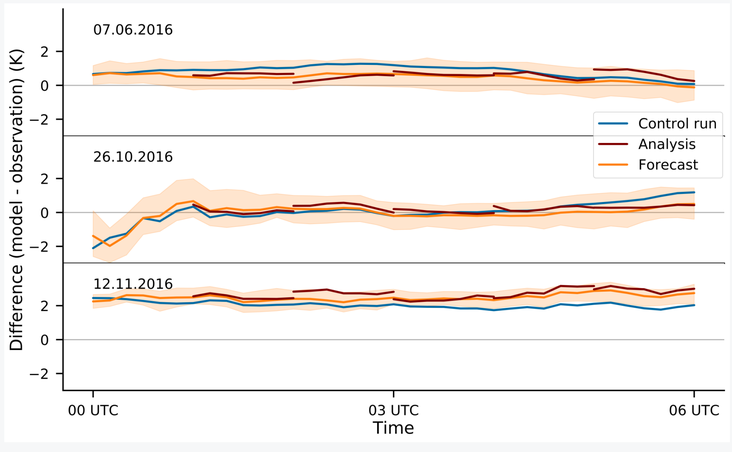
Difference in wind speed in 50 m height between model runs and observations with ensemble spread of forecast as tubes



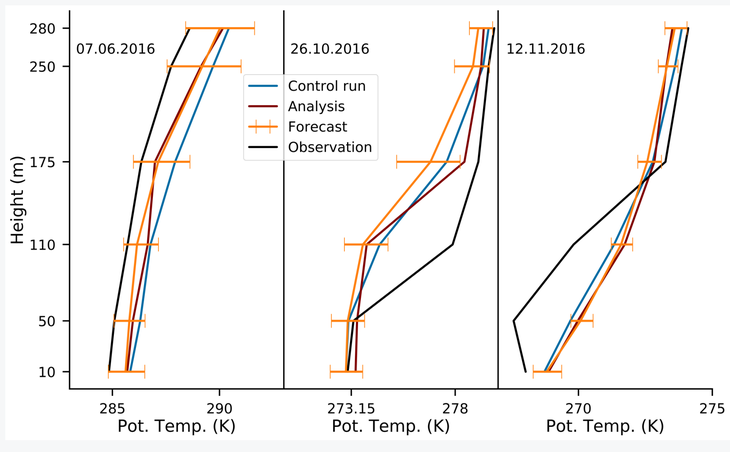
RMSE of assimilation and control against observations for times between 00Z and 06Z for analysis and background forecast

LETKF cannot counter-balance missing processes within the NBL

- COSMO has problems with processes in the NBL (26.10. wrong ABL height, 12.11. missing feature)
- Forecast degeneration due to assimilation → model disturbance is larger than positive impact → trajectory backdrops to model state → only disturbance remains
- Analysis cycle shows no positive impact compared to forecast started at 00Z



Difference in potential temperature in 50 m height between model runs and observations with ensemble spread of forecast



Height distribution of potential temperature between different model runs and observation at 03Z for three different test cases

Conclusion and outlook

- Positive impact of U- and V-wind assimilation on wind speed in the NBL
- Partial positive impact on potential temperature, if the model can represent the dominating processes within the NBL → positive impact is caused by forward propagation of analysis and not by update step of LETKF
- Degeneration due to assimilation is explainable with remaining model disturbances instead of positive nudging impact
- Model seems to be more important than assimilation within the NBL → it may look different with more observations
- COSMO has problems with strongly stratified NBL → COSMO is not (yet) capable for such small-scale processes?

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