Impact of Assimilation of Radiosonde and UAV Observations on Numerical Weather Prediction Analyses and forecasts in the Arctic and Antarctic

Timo Vihma[1], Tuomas Naakka[1], Qizhen Sun[2], Tiina Nygård[1], Michael Tjernström[3], Marius Jonassen[4], Roberta Pirazzini[1] and Ian Brooks[5]

1 Finnish Meteorological Institute, Helsinki, Finland

2 National Marine Environmental Forecasting Center, Beijing, China

3 Department of Meteorology and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden

4 The University Centre in Svalbard, Longyearbyen, Norway

5 School of Earth and Environment, University of Leeds, Leeds, UK

Motivation

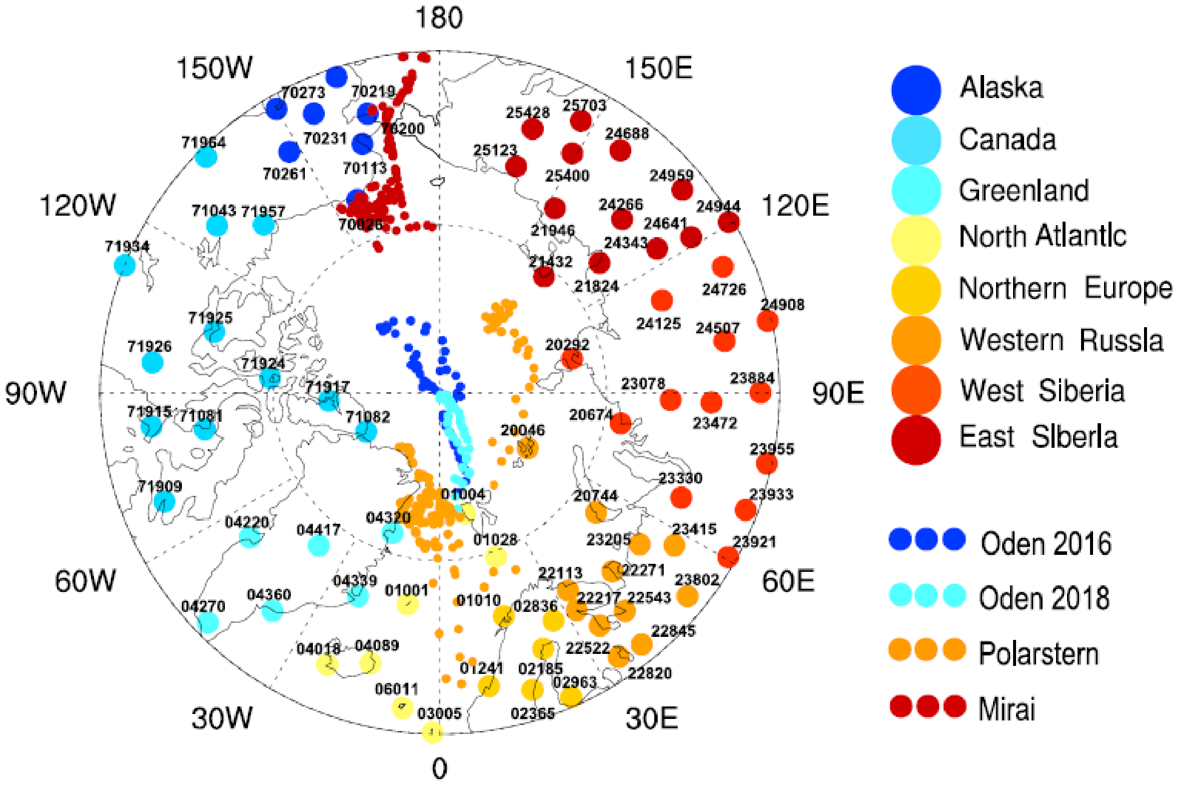
Weather forecasting in the Arctic and Antarctic is a challenge above all due to rarity of observations to be assimilated in numerical weather prediction (NWP) models.

As observations are expensive and logistically challenging, it is important to evaluate the benefit that additional observations could bring to NWP.

This study had Arctic and Antarctic components

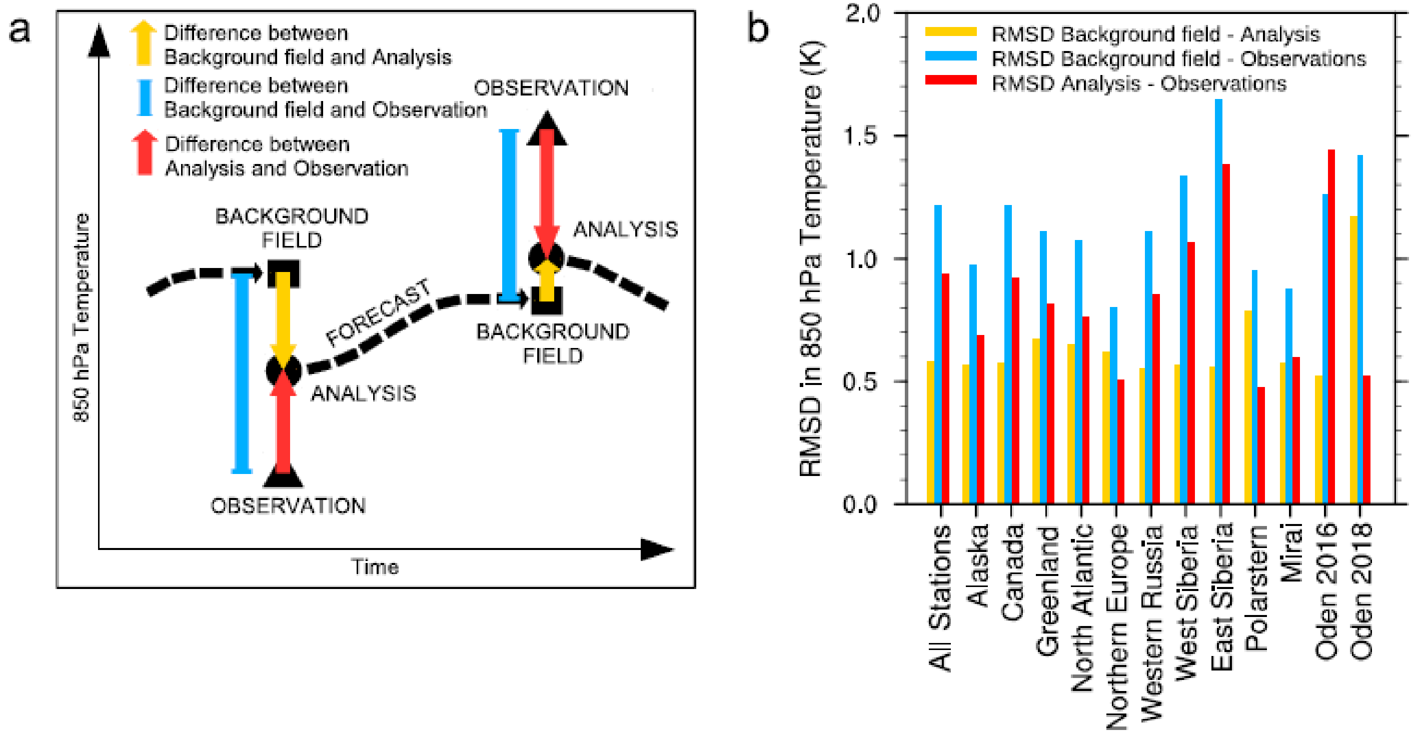
Arctic (Naakka et al., 2019, GRL):

- The effects of the spatial coverage of the network on numerical weather prediction were evaluated by comparing radiosonde observations from land station (IGRA) and marine expeditions with operational analyses and background fields (12-hr forecasts) of the ECMWF
- Focus was on 850 hPa level temperature for January 2016 – September 2018.



Naakka et al. (2019), GRL.

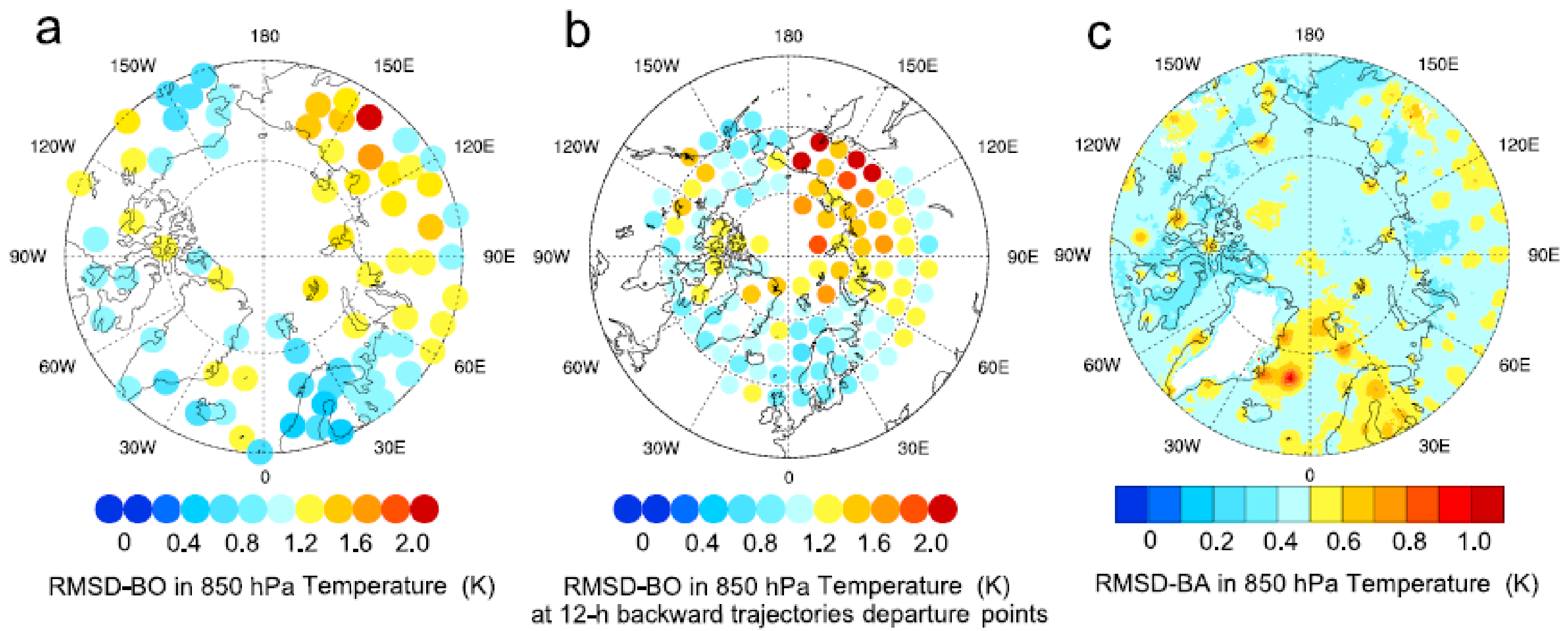
Results for the Arctic



Naakka et al. (2019), GRL.

Figure 2. (a) Schematic illustration on assimilation cycles, (b) regional mean of root-mean-square difference (RMSD) in 850-hPa temperature between background fields and analyses (RMSD-BA), between background fields and radiosonde observations (RMSD-BO), and between analyses and radiosonde observations (RMSD-AO).

Comparison of the analyses and background fields showed that radiosoundings had a remarkable impact on improving operational analyses but the impact had a large geographical variation. In particular, radiosonde observations from islands (Jan Mayen and Bear Island) in the northern North Atlantic and from Arctic expeditions substantially improved analyses suggesting that those observations were critical for the quality of analyses and forecasts. Comparison of two cases with and without assimilation of radiosonde sounding data from expeditions of Icebreaker Oden in 2016 and 2018 in the central Artic Ocean showed that satellite observations were not able to compensate for the large spatial gap in the radiosounding network.



Naakka et al. (2019), GRL.

Figure 3. (a) Root-mean-square difference (RMSD) in 850-hPa temperature between background fields and radiosonde observations (RMSD-BO) at the sounding stations in January 2016 to September 2018. (b) Root-mean-square value of differences between background fields and radiosonde observations in 850-hPa temperature associated with departure points of 12-hr backward trajectories ending at the 76 Arctic radiosounding stations in January 2016 to December 2017. Only grid boxes containing more than 100 trajectory departure points were plotted. (c) RMSD in 850-hPa temperature between background fields and analyses (RMSD-BA) in January 2016 to September 2018.

In the areas where the network is reasonably dense, the density of the sounding network was not the most critical factor for the quality of background fields. Instead, the quality of background field was more related to how radiosonde observations were utilized in the assimilation and to the quality of those observations.

Antractic (Sun et al., 2020)

We applied radiosonde sounding and Unmanned Aerial Vehicles (UAV) observations from an RV Polarstern cruise in the ice-covered Weddell Sea in austral winter 2013 to evaluate the impact of their assimilation in the Polar WRF model.

Results

Our Polar WRF experiments revealed small or moderate impacts of radiosonde and UAV data assimilation. In any case, the assimilation of both data on average improved the analyses of air temperature, wind speed and, in particular, air humidity.

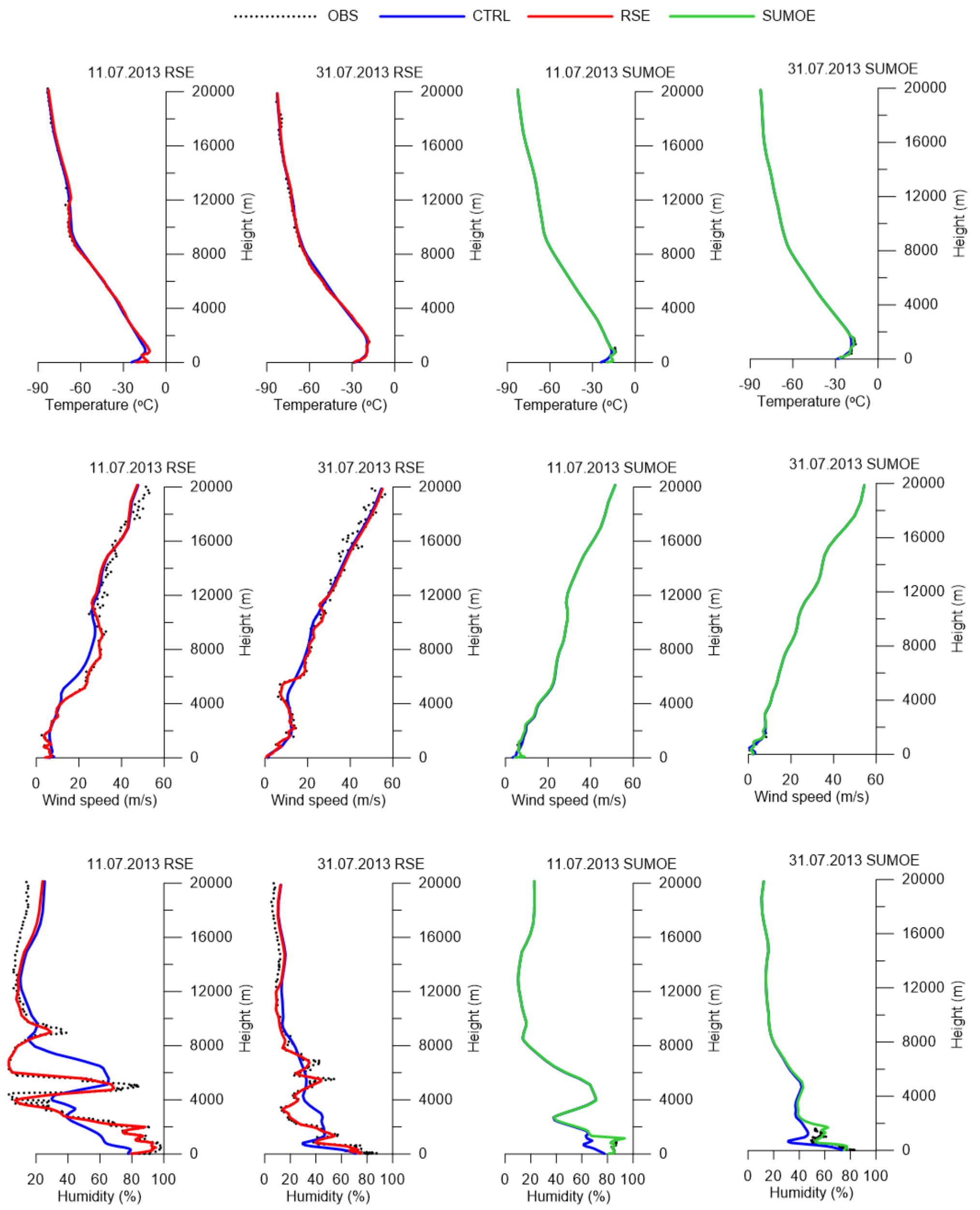


Figure. Profiles of air temperature, wind speed and relative humidity based on RS observations (black dotted lines on two leftmost columns), SUMO observations (black dotted lines on two rightmost columns), analysis of CTRL (blue lines), analysis of RSE (red lines), and analysis of SUMOE (green lines).

The impact on the results of 5-day long Polar WRF experiments was often felt over distances of at least 300 km from the observation site

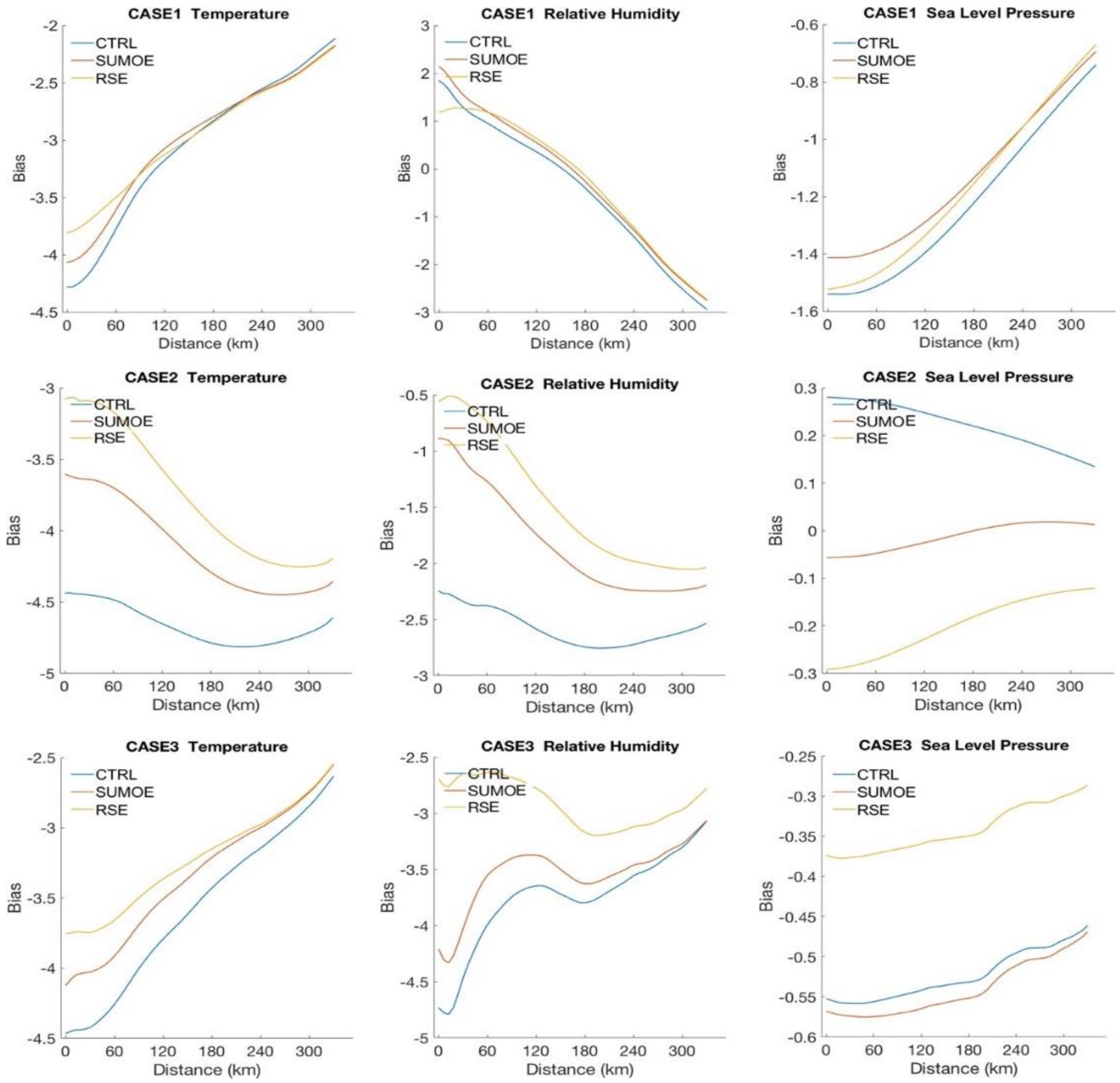


Figure: Dependence of the five-day-averaged bias on the distance from RV Polarstern for 2-m air temperature and relative humidity and MSLP. The bias was calculated using ECMWF analyses as a reference.

Sun et al. (2020)

Conclusions

Arctic analyses:

• In the Arctic, radiosonde observations substantially improve the operational analyses and cannot be replaced by satellite observations

• The impact of radiosoundings on analyses varies substantially in space and is largest in the northern Atlantic and in the central Arctic

• Where the sounding network is sufficiently dense, the background field quality depends on the quality and utilization of radiosoundings

Antarctic experiments:

• All experiments succeeded in capturing the main features of the evolution of near-surface variables, but the effects of data assimilation varied between different cases.

• Due to the limited vertical extent of the UAV observations, the impact of their assimilation was limited to the lowermost 1-2 km layer, and assimilation of radiosonde data was more beneficial for modelled sea level pressure and near-surface wind speed.

• Considering the perspectives for technological advance, atmospheric soundings applying UAV have a large potential to supplement conventional radiosonde sounding observations.

References

Naakka, T., T. Nygård, M. Tjernström, T. Vihma, R. Pirazzini, and I. M. Brooks (2019). The impact of radiosounding observations on numerical weather prediction analyses in the Arctic. Geophys. Res. Lett., DOI: 10.1029/2019GL083332.

Sun, Q., Vihma, T., Jonassen, M., and Zhang, Z. (2020). Impact of Assimilation of Radiosonde and UAV Observations from the Southern Ocean in the Polar WRF Model. Adv. Atm. Sci., 37, 1-14, doi: 10.1007/s00376-020-9213-8.