Impact of GMPE based SST-pertubations on the LETKF ensemble data assimilation system at DWD

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Introduction

Since January 21, 2016 DWD runs a global 40km resolution 40 member hybrid ensemble data assimilation system as part of the operational numerical weather prediction system using the ICON model.
Atmospheric perturbations are initially generated choosing a random sample from a climatological B-matrix which is obtained by the NMC method. Localization is applied to preserve the error correlations on the relevant scales. The perturbations evolve in time by the dynamics of the forecast model, the convergence of the different ensemble members in the LETKF analysis is prevented by inflation to prior spread.
For the surface however, there was no separate initial perturbation implemented when the ensemble was first introduced,and the analysis for snow, soil moisture and SST was taken from the deterministic analysis. This lack of variability lead to unsatisfying spread in the boundary layer, therefore additional surface perturbations were added.
For SST and soil moisture a stochastic method was then used to generate perturbation patterns. Variations in snow were introduced through the cycling and the different temporal evolution of the model dynamics of the single ensemble members. These modifications showed positive impact on the spread skill relation and on the forecast quality in the boundary layer.
The stochastic pattern for SST-perturbations is generated using error correlations based on Gaspari Cohn functions (Gaspari and Cohn, 1999), with characteristic length and time scale. The scales is set to 100 km and 1000 km for the superposed functions in the horizontal and 1 day in time with an amplitude of 1 K.
The GHRSST Multi Product Ensemble GMPE (Matt et al., 2012), allows an alternative approach to introduce SST perturbations which represent the uncertainty of the ensemble. Unlike the stochastic method which improves the system as the LETKF gives the largest weight to the "best" ensemble members, the perturbations based on GMPE represent uncertainties itself much more realistic in regions of high horizontal SST gradients, since these are based on uncertainties in the type of underlying observation database and analysis method. Therefore it is assumed that introducing this knowledge in the ensemble leads to more realistic spread in the lower boundary layer of the atmospheric forecast model, and a positive impact on the forecast with respect to coastal regions and heavy storm cyclones over the ocean.

Experimental setup

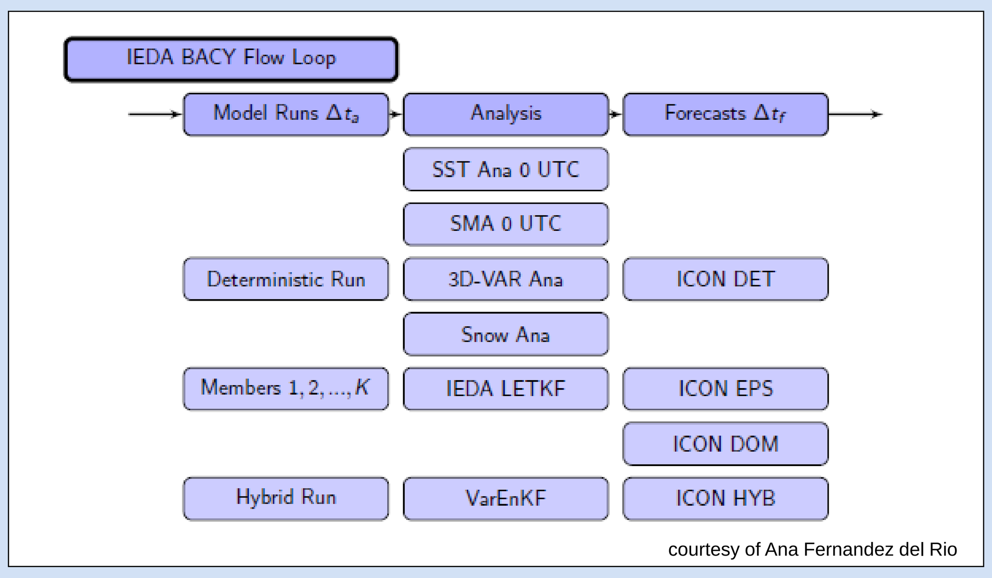
Four ensemble data assimilation experiments for the period 20160201-20160204 were conducted to assess the impact of GMPE based SST perturbations on the weather forecast system

1. No SST petурbations
2. Stochastic perturbations with 2d horizontal and time correlations based on Gaspari-Cohn functions with appropriate length and time scale (present operational method).
3. GMPE based SST-perturbations generated by random linear combinations of the available GMPE members.
4. Same as Experiment 3. but SST-perturbation inflated by factor 2.

Results

Fig. 2 shows the initial perturbation of SST for the different experiments and the impact on the spread of screen level temperature as on T(850 hPa) after a 6 day forecast. The stochastic perturbation induces much stronger overall variability while GMPE generates little perturbation outside the typical regions of uncertainty. Doubling the amplitude (bottom panels) induces stronger patterns up to the top boundary layer. This study motivates longer DA experiments to make a quantitiative assessment of the impact on using GMPE SST perturbations in the NWP system.

The global NWP forecast system at DWD



ICON deterministic SST analysis

- Daily SST analysis at 0:00 UTC.
- Bg. field NCEP 0.5° SST 2d-Var analysis from previous day.
- Blending of background with conventional Observations from ships, moored and drifting buoys for the last 3 days using successive correction (Cressman method).
- Radius of influence is set to 430 km for the first iteration
- Observation weight is reduced by a factor 0.2 / day.
- NOAA MMAB High resolution Sea Ice Concentration at 1/12 deg resolution (~9 km).
- NOAA Sea Ice product contains lake ice, however lake ice is calculated seperately by the „Flake"-model.

Generation of SST perturbations

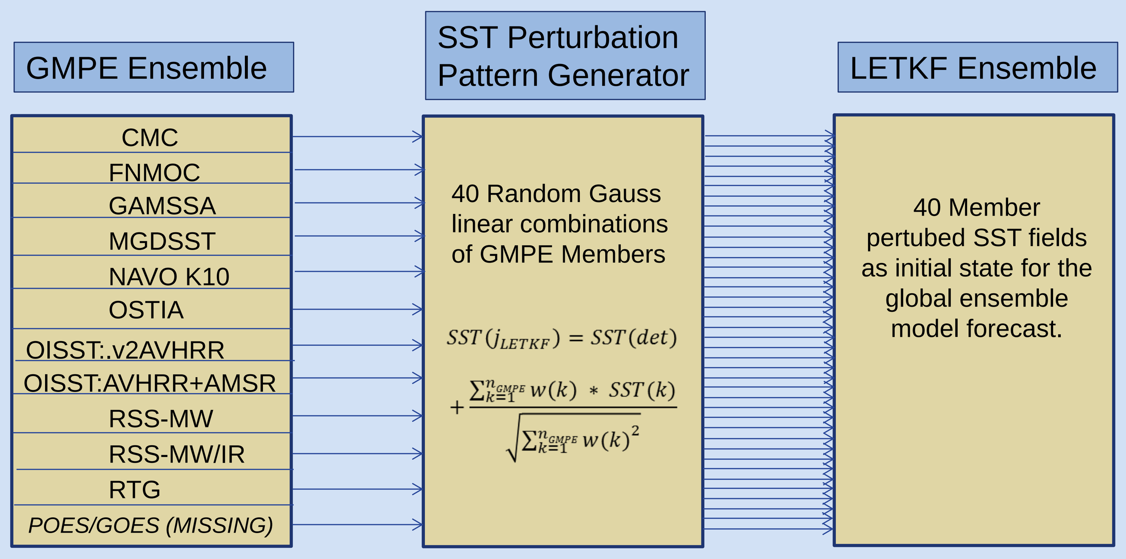


Figure 1

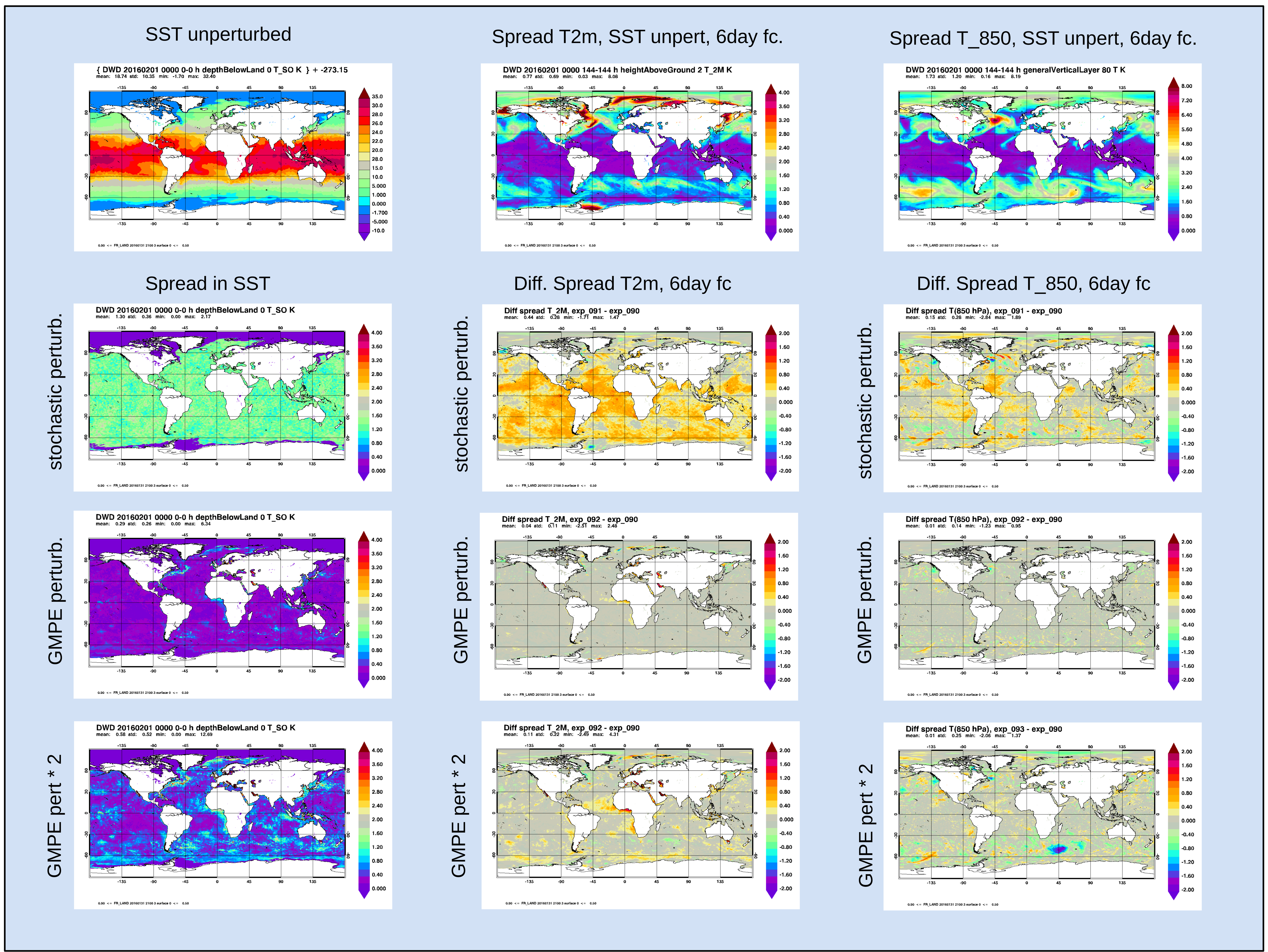


Figure 2

Summary and Outlook

The impact of using GHRSST MPE for initialisation of an NWP ensemble prediction system is addressed to introduce more realistic perturbations of the SST in strong gradient regions.
The experiments show clear differences for the spread of the atmospheric parameters for a 6 day forecast, not only near the surface but also in T(850hPa), which demonstrates propagation of the perturbation through the boundary layer.
The GMPE based experiments increase the spread where expected, but might underestimate it in weak gradient regions as most of the contributing products provide foundation temperature. The atmosphere however „sees" the surface skin temperature. Therefore a combination of statistical and GMPE based perturbations should be further investigated.
The impact on the spread of storm tracks is also an interesting aspect which will be investigated in future.
The short experiment period limits the temporal evolution of the perturbation, more elaborate quantitative investigations are planned to assess the benefit for the NWP system.

References
Gaspari, G., and S. Cohn, 1999: Construction of correlation functions in two and three dimensions. QJR Meteorol. Soc., 125, pp 723-757.
Martin, M., et al. 2012: Group for High Resolution Sea Surface temperature (GHRSST) analysis fields inter-comparisons. Part 1: A GHHRSST multi-product ensemble (GMPE). Deep sea res. II, 77-80, p 21-30.

Acknowledgement
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