Surface skin temperature for satellite data assimilation

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1. Introduction

Progress has been made over the last decade regarding the extended data usage over land and sea-ice for microwave (MW) sounding data at ECMWF. Surface-sensitive MW radiances over land and sea-ice have a significant positive forecast impact in the ECMWF system (*Bormann et al., 2017*). More recently, significant progress has been made in using mid-tropospheric hyperspectral infrared (IR) data from IASI, CrIS and AIRS over land surfaces (*Eresmaa et al., 2017*). The use of additional IR data over land is demonstrated to significantly improve the quality of analyses and resulted in better headline medium-range forecasts (*Eresmaa et al., 2017; Eresmaa and Lupu, 2017*). Efforts will continue to enable the assimilation of infrared surface-sensitive channels down to the surface over land. The larger uncertainties in skin temperature are the main limiting factor on fully exploiting MW and IR radiances in the lower troposphere over land and sea-ice areas.

This poster gives an overview of recent activities at ECMWF for better characterising the description of surface skin temperature, with focus on improving the specification of background errors for surface skin temperature in 4D-Var. Given that in the current ECMWF hybrid 4D-Var, an Ensemble of Data Assimilations (EDA) is used to generate situation-dependent background errors for the high-resolution deterministic forecast (*Bonavita et al., 2012*), it is proposed here to replace the constant values of the background errors standard deviation for surface skin temperature with estimates from the ECMWF EDA. Initial investigations suggest the EDA could provide guidance on error variations due to surface type, diurnal phase and atmospheric influences.

2. Skin temperature treatment as 'sink variable'

- At ECMWF, the surface skin temperature is treated as a so-called 'sink variable', in which surface forcing signals from the radiance or from undetected residual cloud accumulates.
- It is an independent variable, separate from other atmospheric variables in the background error covariance and uncoupled from the skin temperature at other locations.
- It is represented by a single value retrieved at each observed radiance location and is allowed to change during the analysis. This estimate plays no further role other than to model the radiances (i.e., does not affect the subsequent forecast or the next analysis).
- Disadvantage: Potential for aliasing real atmospheric information into skin temperature.

Experiments

Assimilation experiments were run in the Cy43r3 version of the ECMWF system at T_{CO}399 resolution (~55 km) from June to September 2016 to evaluate the impact of disabling the skin temperature 'sink variable'.

Control: ECMWF data assimilation and forecasting model with all operational observations and use of a skin temperature 'sink variable' for all IR/MW clear-sky radiances.

Model SKT: Same system configuration, except using the skin temperature from ECMWF model during the 4D-Var assimilation ('sink variable' disabled).

Disabling the 'sink variable'

- Temperature errors show a significant degradation in the Tropics and the high-latitudes.
- At T+12, the increase in the standard deviation errors in temperature in own-analysis scores is a reflection of larger temperature increments. However, degradations in the Tropics between 1000-850hPa persist at day 5 forecast range (*Fig.1*)
- The Model SKT run, slightly degrades the fit to conventional observations (*Fig.2*).

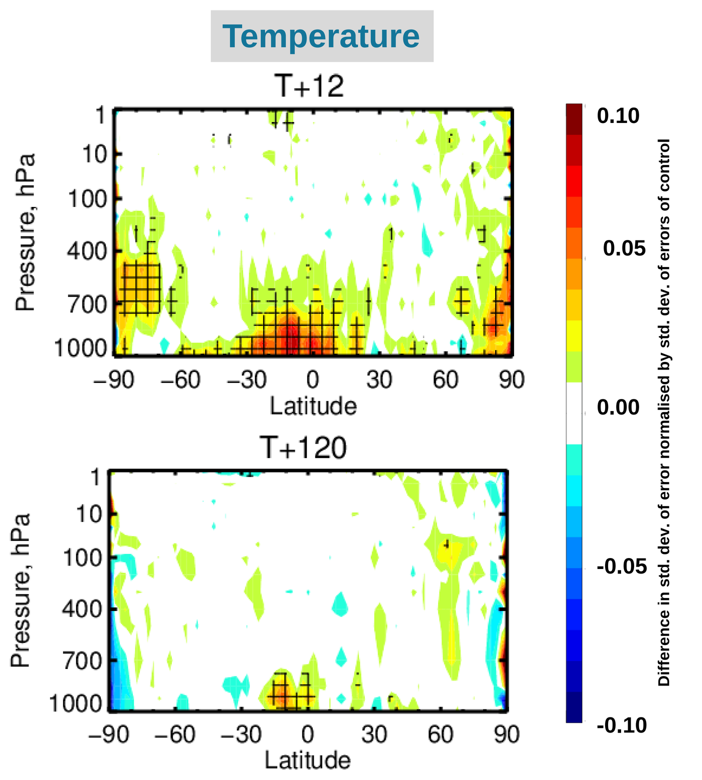

Fig. 1: *Normalised change in standard deviation errors in temperature, verified against each run's own analysis Yellow/red areas indicate increased forecast errors when disabling skin temperature sink variable and hence degraded forecasts. Hatching indicate statistical significance at the 95 % level.*

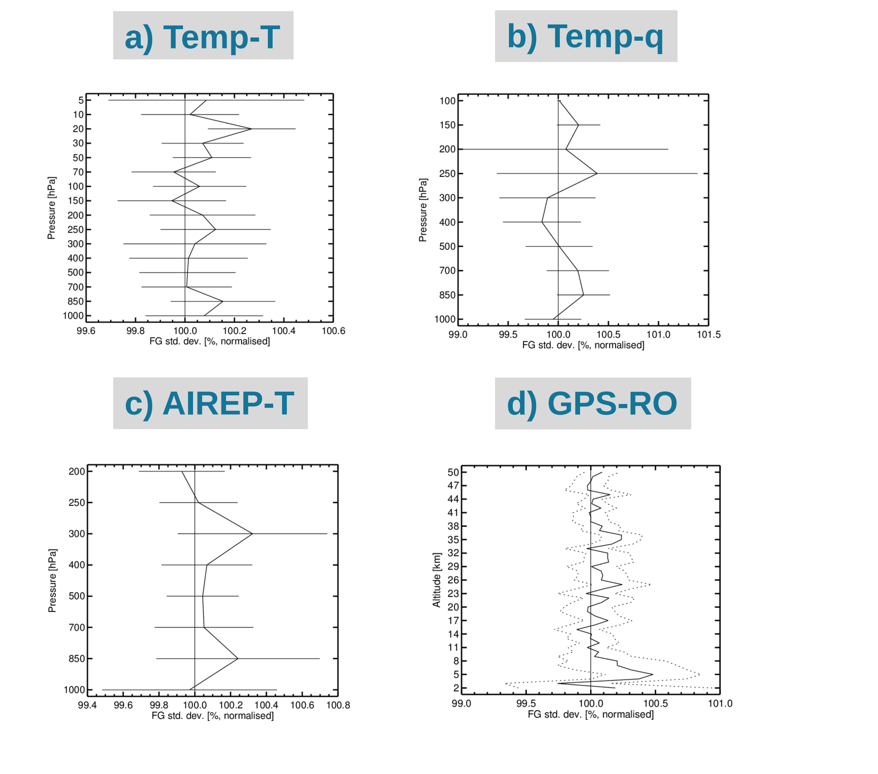

Fig. 2: *Normalised difference in the standard deviation of background departures between Model SKT experiment and the Control for conventional observations a)TEMP-T, b) TEMP-q, c) AIREP-T and d) GPS-RO. Values are for used data averaged globally from June to September 2016. Values are normalised to the control so that a shift left indicates a reduction. The horizontal bars indicate 95% confidence interval.*

3. EDA based background errors estimates

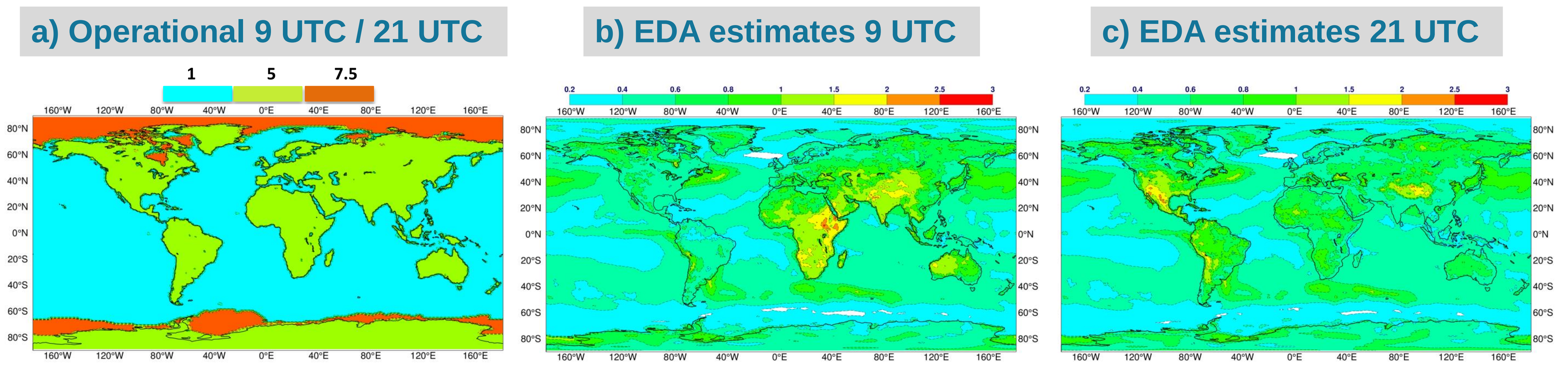

Fig. 3: *Examples of background error standard deviations of skin temperature: a) assumed in operational assimilation experiments, b)-c) average estimated from ECMWF EDA valid at 9 UTC and 21 UTC. A sample of 36 EDAs over June 2016 – May 2017, each with 25 members, was used to compute the background error standard deviations of skin temperature at 9 UTC and 21 UTC, respectively.*

- The spread of the EDA is used to provide situation-dependent aspects of the skin temperature background error. An example is shown in *Figs. 3b-3c,* suggesting a more complex model of skin temperature background error than we currently have in ECMWF operations (where the background error standard deviation for skin temperature are set to 5 K over land and 7.5 K over sea-ice, compared to 1 K over sea, to reflect the larger uncertainty in the background values, see *Fig. 3a)*. Variations in skin temperature variance in the EDA are closely related to surface properties (*e.g.,* vegetation cover, wind effects on ocean emissivity) and atmosphere interactions (clouds, humidity). Land surfaces show diurnal variations of the skin temperature depending on the solar zenith angle.
- The size of the estimates is less than 1.5 K for large regions of the globe (*Figs.3b-3c*) and calibration factors might be applied to the sampled EDA distribution, in particular over land and sea-ice surfaces, as shown in *Fig.4* and used in experiment **EDA SKT**.

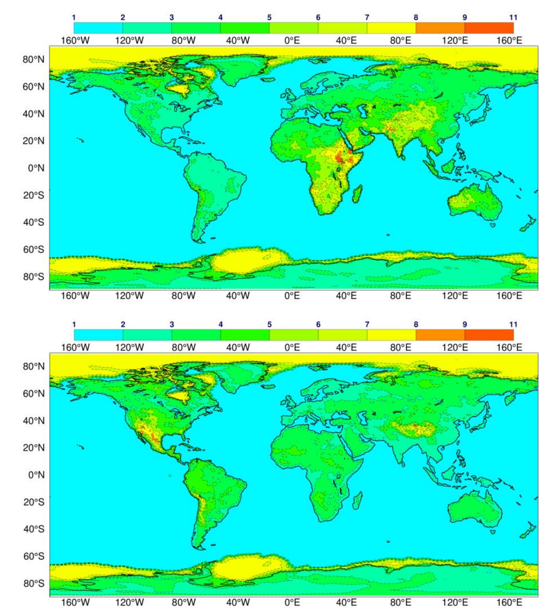

Fig. 4: *Rescaled EDA estimated for skin temperature background errors standard deviations for use in assimilation experiments at 9UTC (top) and 21UTC (bottom).*

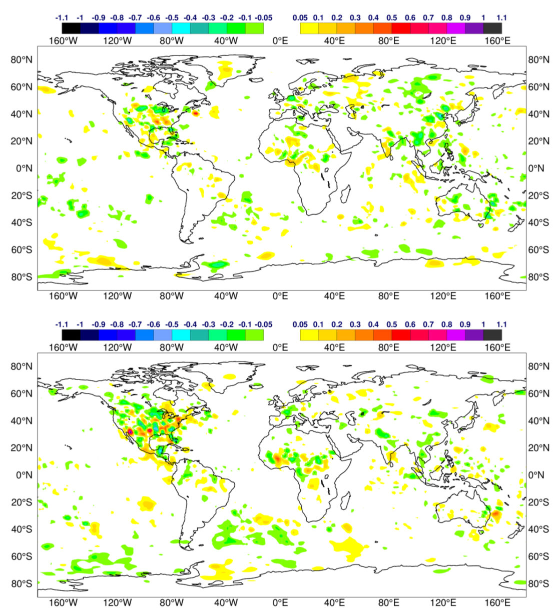

Fig. 5: *Root Mean Square temperature increment differences (experiment EDA SKT minus Control) over the first 10 days of the test period (June 2016) at 1000 hPa at 9UTC (top) and 21UTC (bottom).*

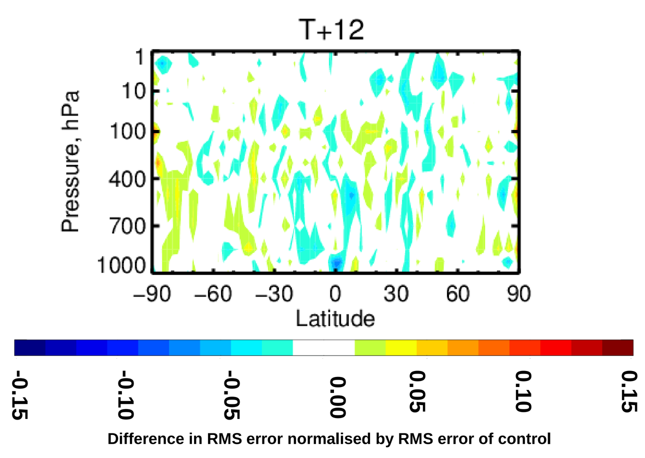

Fig. 6: *As Fig.1 but for RMS error in temperature (EDA SKT minus Control).*

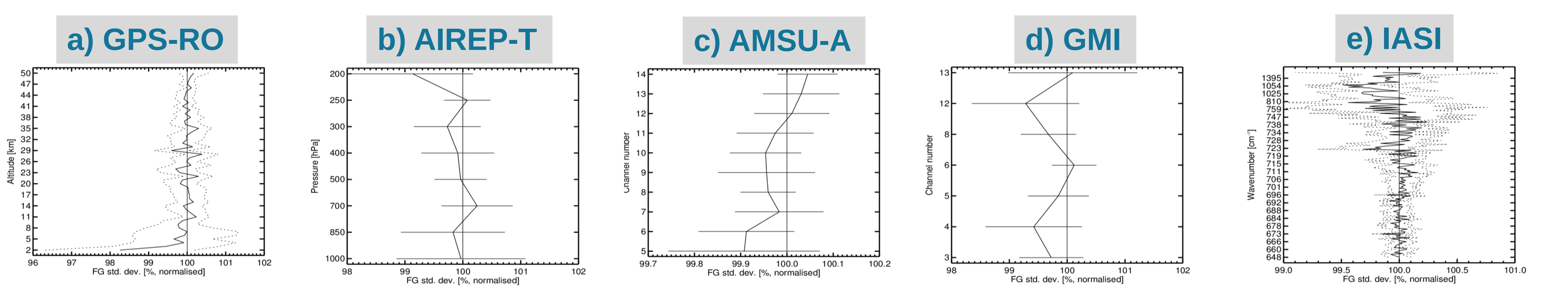

Fig. 7: *As Fig.2, but for EDA SKT minus control over the first 10 days of the test period (June 2016). Preliminary results show improved fit to many observation types.*

References

Bonavita, M., L. Isaksen, and E. Hólm, 2012: On the use of EDA background error variances in the ECMWF 4D-Var. Q.J.R. Meteorol. Soc., **138**: 1540–1559.

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4. Summary

- Surface skin temperature is the main limiting factor in using more satellite data over land and sea-ice. Further progress in the assimilation of surface-sensitive channels in these regions will require a revision of the method used to specify skin temperature.
- Specification of the background errors for skin temperature can have a significant effect on the use of the satellite sounding radiances, as the ratio between atmospheric and surface background errors largely determines the partition of increments between these two.
- Experiments show that the skin temperature sink variable effectively protects the analysis from aliasing surface forcing signals from the radiances or undetected residual cloud into atmospheric increments.

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