Surface temperature for Atmospheric Sounding

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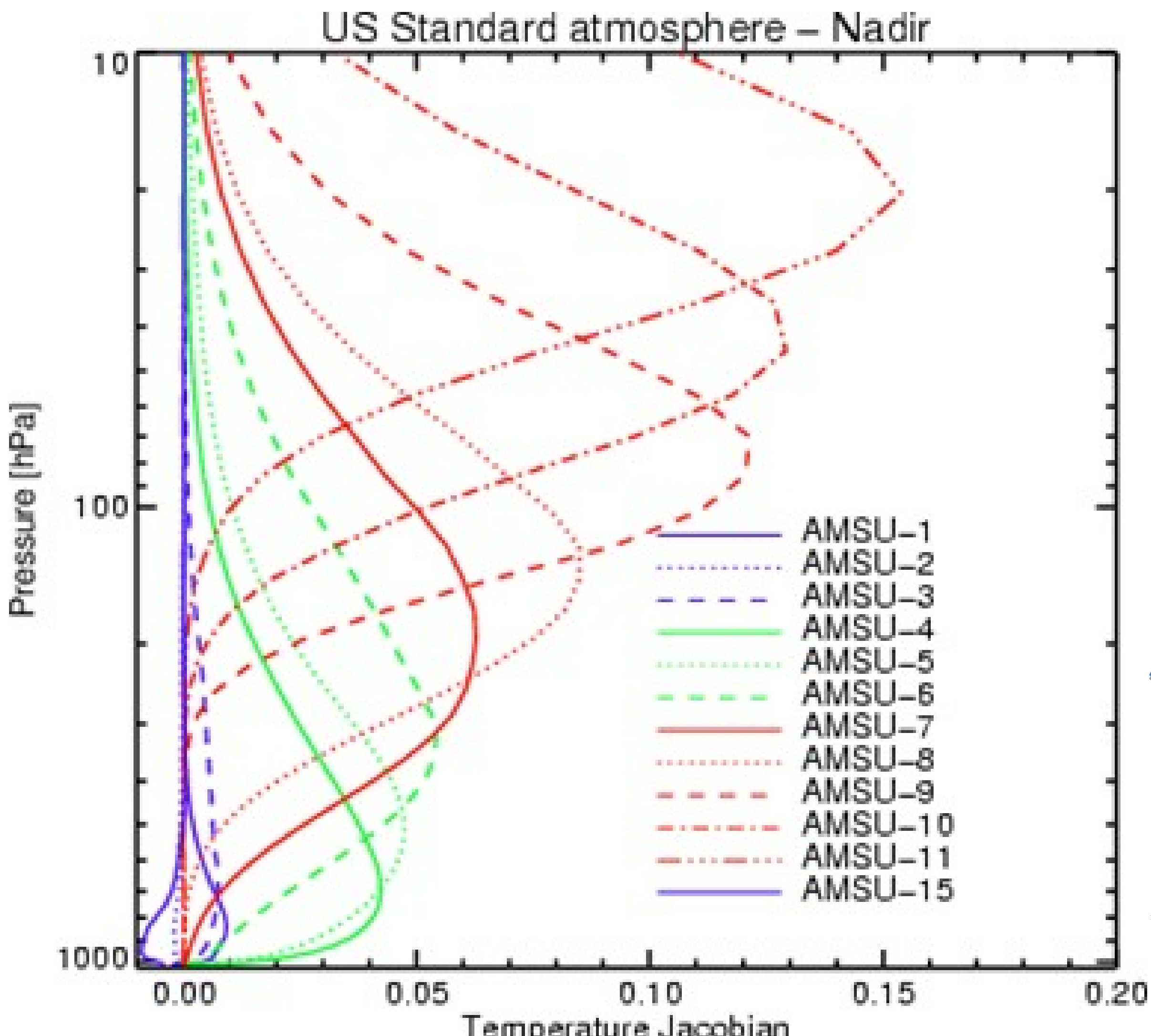
Ongoing Investigations:

- Better characterise the background errors for Tskin (more Gaussian in distribution, scene and time dependent);
- Investigate the possibility of moving away from sink variable to a full field control variable (possibly correlated spatially and with other atmospheric parameters).

For the atmospheric sounding community the surface is a problem e.g. AMSU-A:



Can we separate atmospheric information from surface effects?

Surface temperature

Recap: why does it matter for sounders?

- Top of atmosphere radiance sensitivity to emissivity (ε) errors scale with transmission (τ) squared: $\Delta T_N = T^*.\Delta\varepsilon.\tau^2$

- Top of atmosphere radiance sensitivity to skin temperature errors scale with transmission: $\Delta T_N \rightarrow \varepsilon.\Delta T^*.\tau$

- AMSU-A channel 6 (400 hPa: τ=0.006, ε=1, **HBH**^{T}~0.1 K):
  - **ΔT^* > 17K, $\Delta\varepsilon$ > 10 (!)**

- AMSU-A channel 5 (750 hPa: τ=0.07, ε=1, **HBH**^{T}~0.1 K):
  - **ΔT^* > 1.4K, $\Delta\varepsilon$ > 0.07**

- AMSU-A channel 4 (950 hPa: τ=0.2, ε=1, **HBH**^{T}~0.1 K):
  - **ΔT^* > 0.5K, $\Delta\varepsilon$ > 0.01**

- AMSU-A channel 3 (Surface: τ=0.6, ε=1, **HBH**^{T}~0.1 K):
  - **ΔT^* > 0.2K, $\Delta\varepsilon$ > 0.001**

How do different centres solve this?

Method 1: Use short range forecast.

e.g. at JMA

T* = Tskin (from NWP model)

Pro: Does not alias atmospheric information into Tskin

Con: Tskin can have large random and systematic errors which are not well known.

Method 2: Use a skin temperature "sink variable"

e.g. at ECMWF

T* = Tskin + increment from 4D-var using ε estimated using first guess for τ, Tskin, and assuming either specular or Lambertian reflection.

Pro: 4D-var takes care of everything

Con: ε used in 4D-var is by construction consistent with Tskin. So if we increment Tskin can we believe this? Could alias real atmospheric information into Tskin.

How do different centres solve this?

Method 3: Solve simultaneously for τ and ε before (or in) 4D-var

e.g. at Met Office with 1D-var, nobody doing this in 4D-var?

T^* = Tskin + increment from 1D-var, $\varepsilon = \varepsilon_{FG}$ + increment from 1D-var

Pro: ε and Tskin used in 4D-var are self-consistent and consistent with an improved guess for the local value of τ.

Con: Expensive to maintain 1D-var. Complex to implement in 4D-var (how to define control variable?).

Method 4: Estimate and remove systematic error

e.g. being investigated at CPTEC

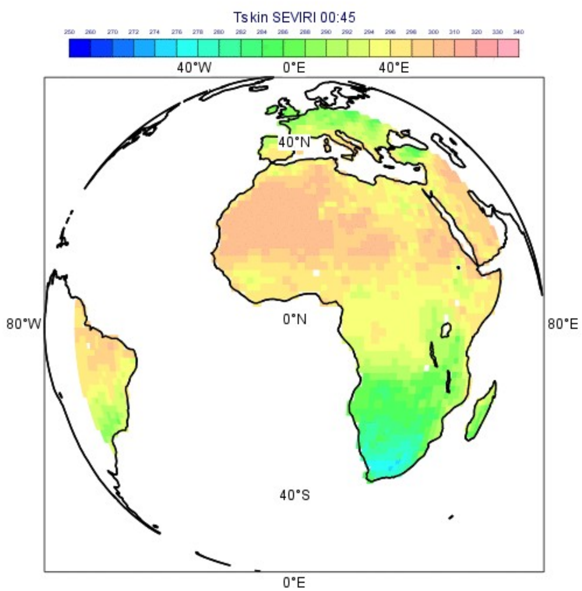
$T^* = \text{Tskin} + \overline{(\text{Tskin} - \text{Tref})}$ e.g. use Land SAF Tref

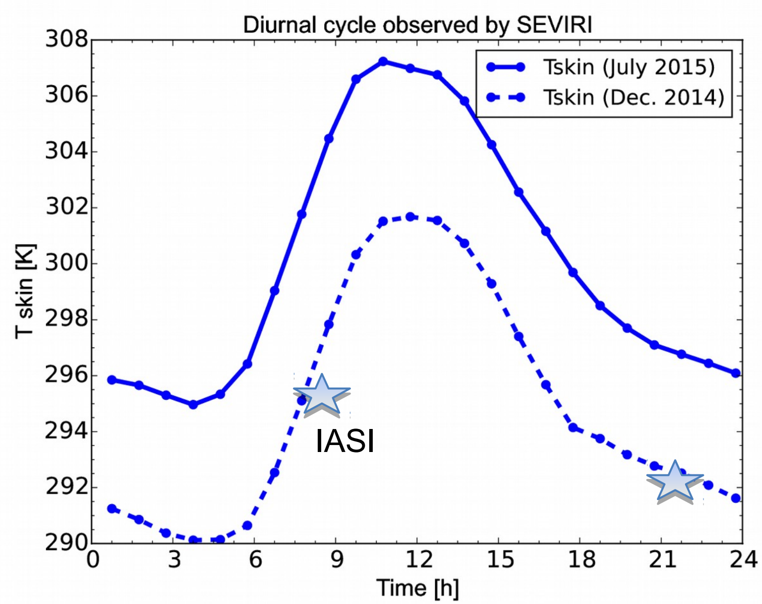
Pro: Will not alias random error in atmospheric information into Tskin.

Con: Will not capture instantaneous Tskin error e.g. due to wrong clouds in short range forecast.

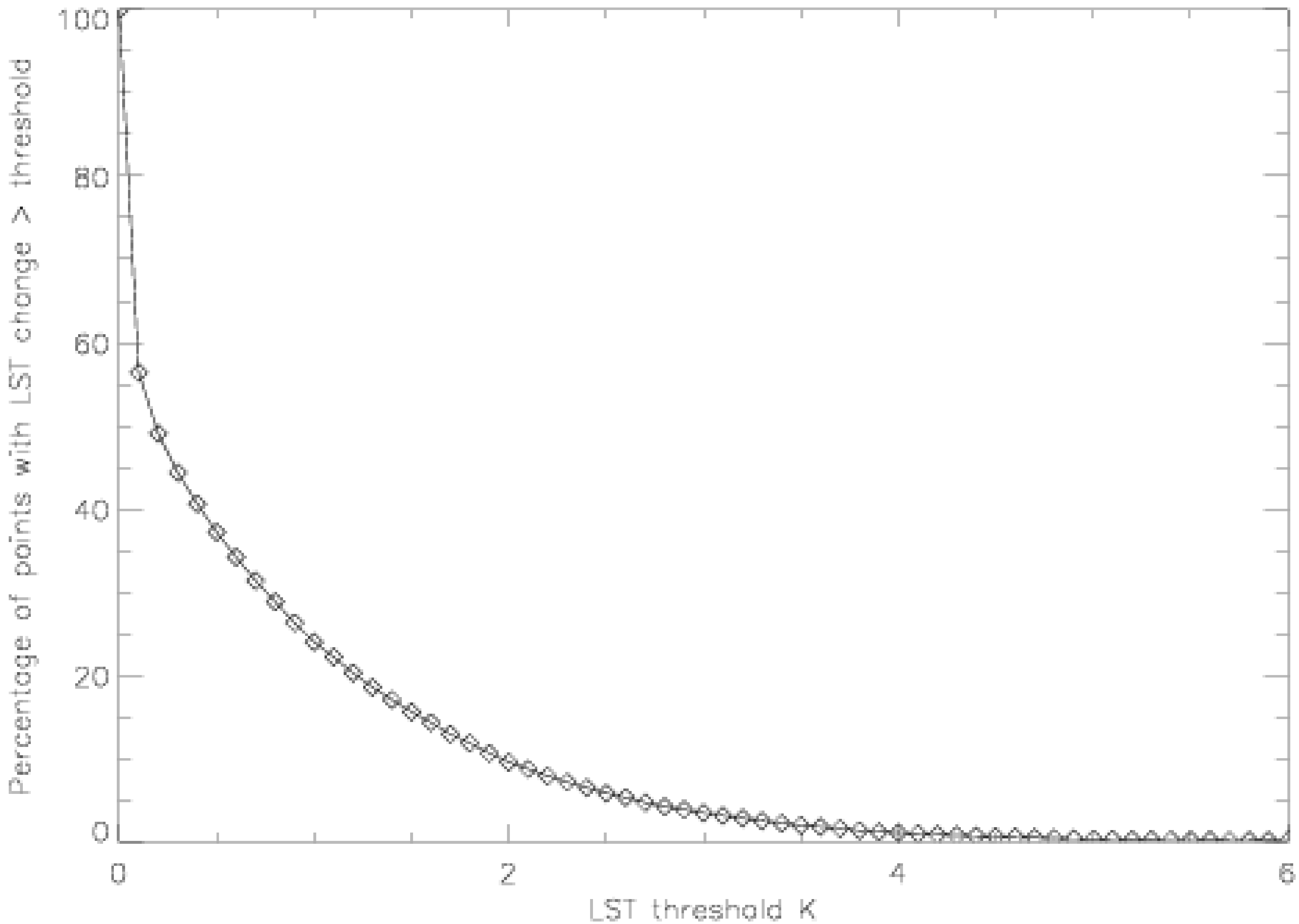
Skin temperature issues

- Tskin is not independently observed
- Highly reactive in space and time (in nature)
- Error characteristics of our model STK are poorly known (scene / time dependent)
- Polar orbiting satellites have a very biased diurnal sampling of the skin temperature (2 passes per day)
- Spatial representativeness with a 20Km satellite pixel versus model SKT



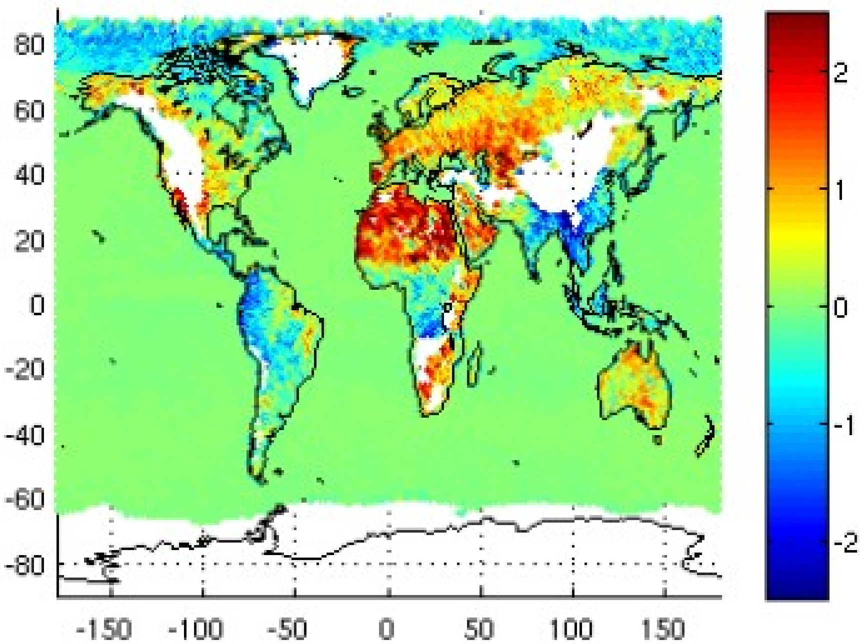


Change to LST at ECMWF

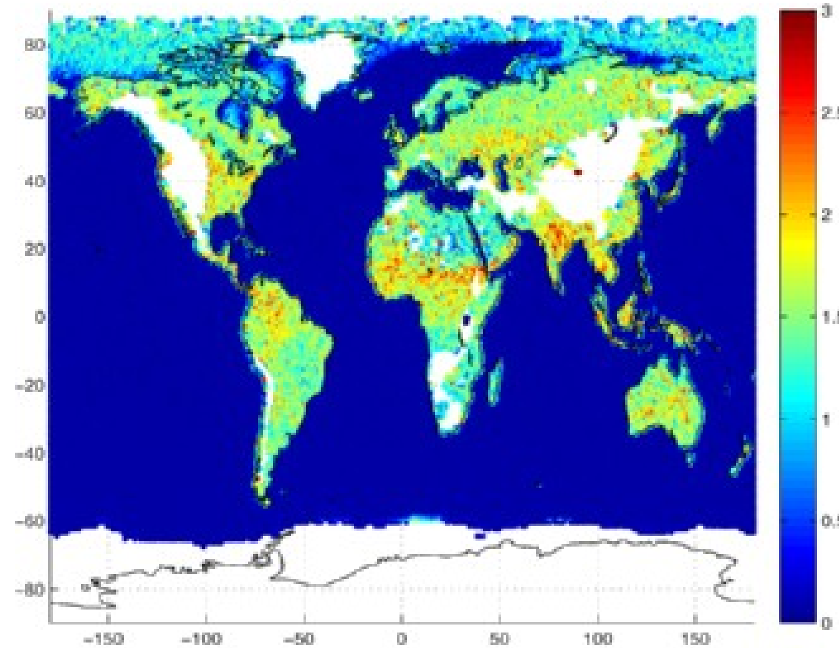


Use a skin temperature "sink variable"

Mean(Tsink – Tmodel)

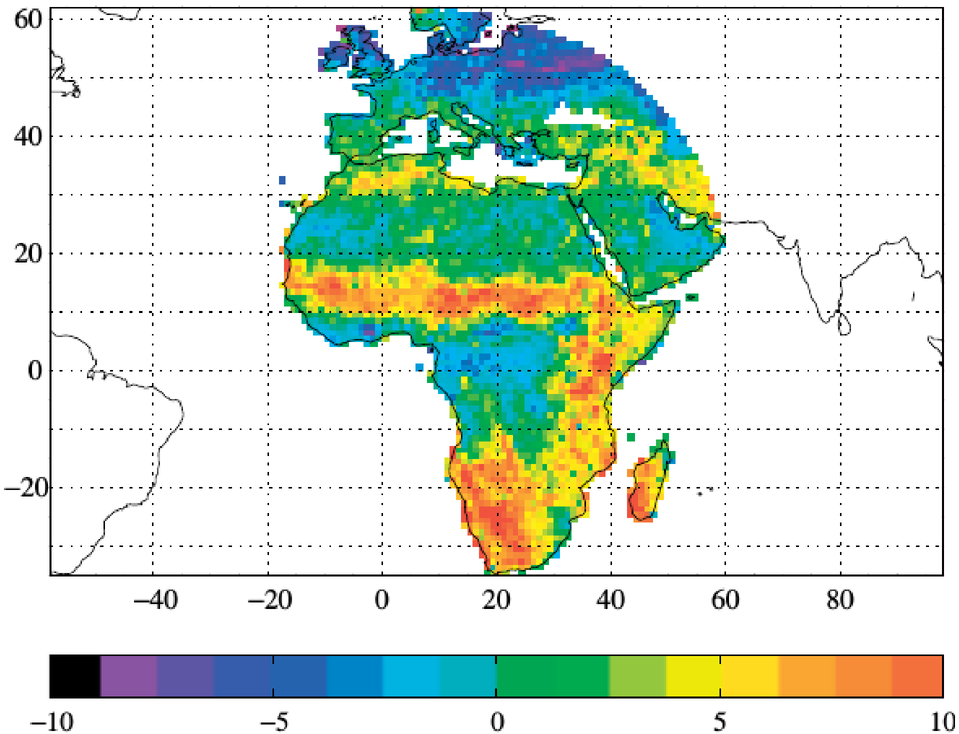


Stdev(Tsink – Tmodel):



Skin temperature bias with respect to SEVIRI LST

SEVIRI LST minus Met Office



Pavelin and Candy

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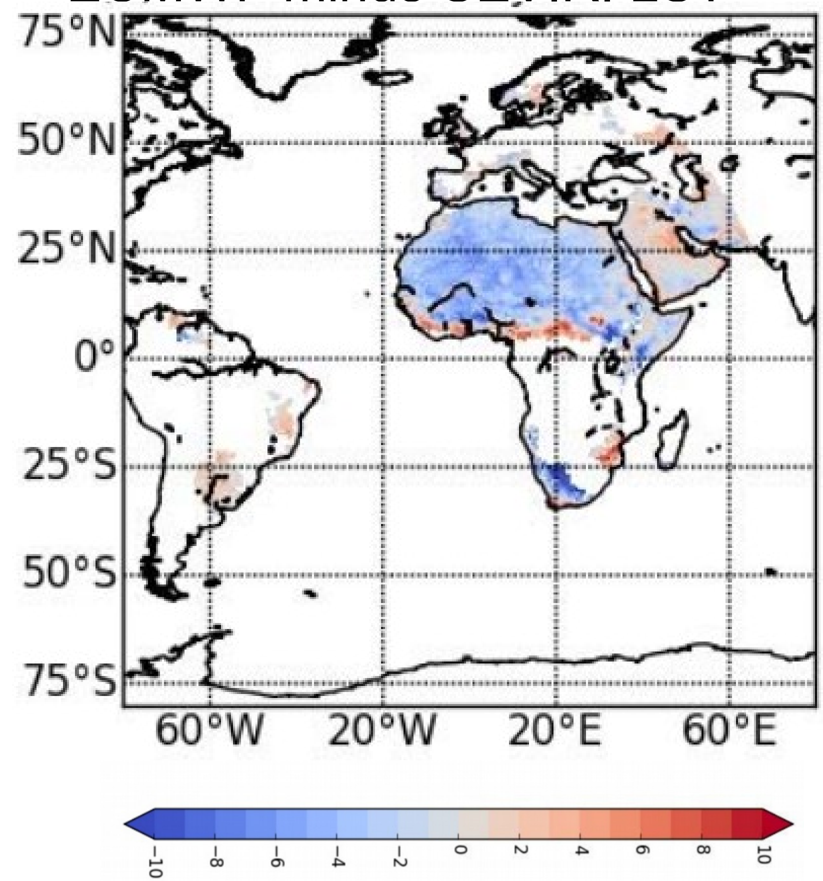
Volume 140, Issue 681, pages 1198-1208, 7 AUG 2013 DOI: 10.1002/qj.2218
http://onlinelibrary.wiley.com/doi/10.1002/qj.2218/full#fig1

ECMWF minus SEVIRI LST



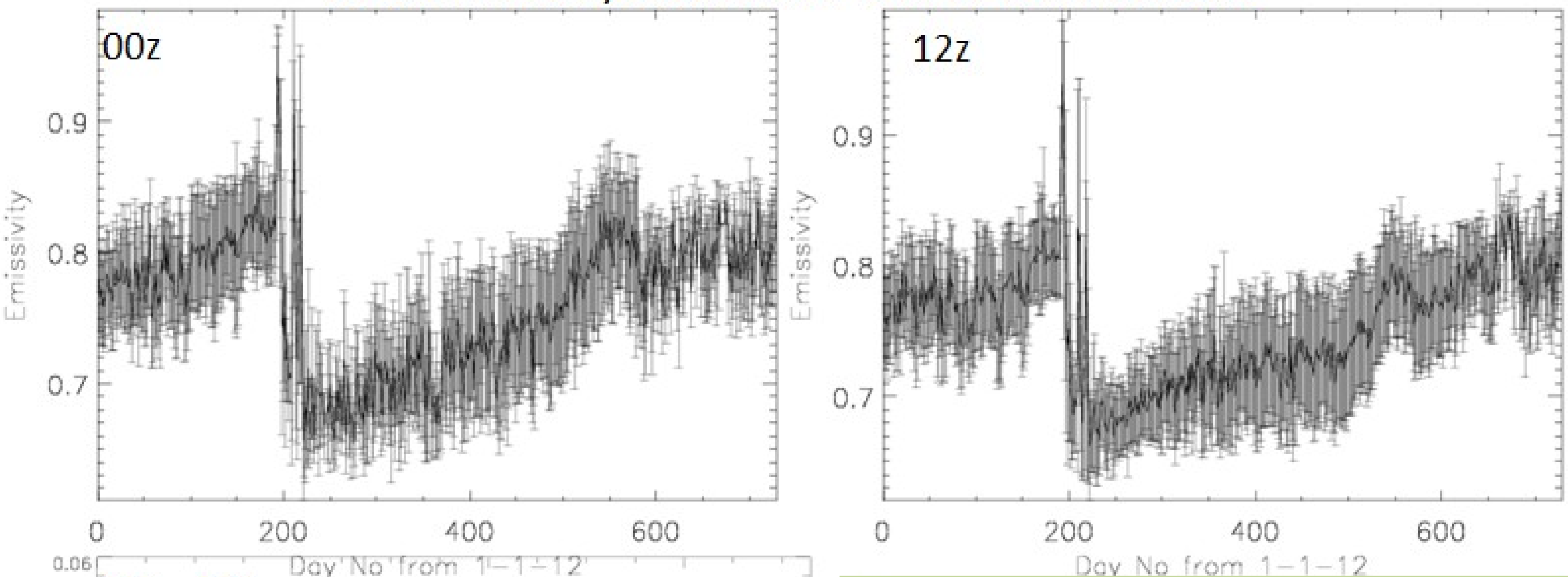
Trigo et al., ECMWF Tech. Memo 2015

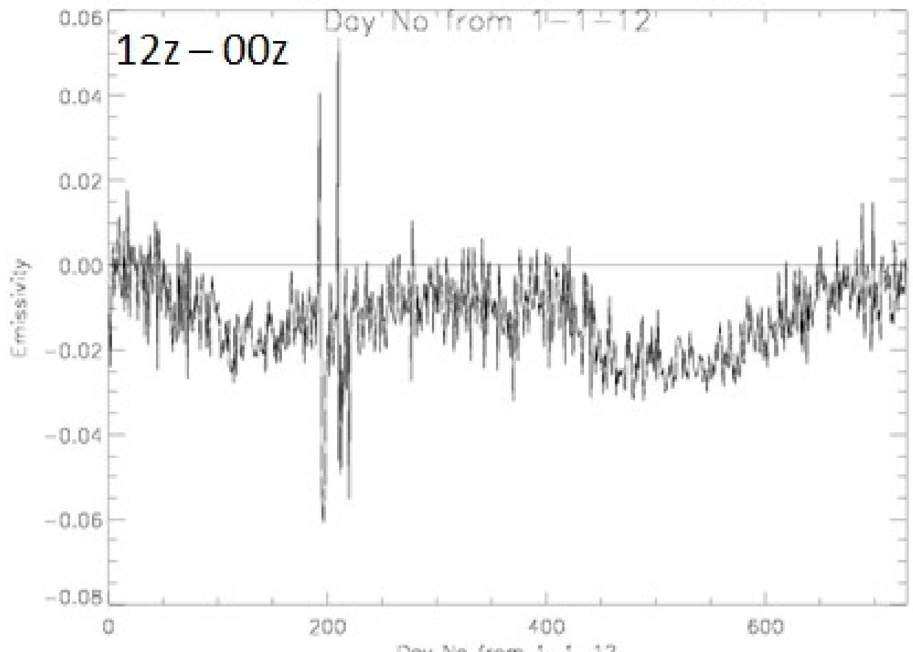
Issues with the ECMWF sink variable approach

- The emissivities contain a lot of real information
  - E.g. Greenland “melt event” in 2012
  - Onset and melt of snow

- The emissivities also exhibit unphysical behaviour due to skin temperature errors.
- Cloud screening needs good Tskin and emissivity, but Tskin is changing during minimisation.
- Complex to maintain
- It is almost certain atmospheric information aliases into Tskin and is “lost”

50 GHz Emissivity Greenland 30-50W 70-80N in 2012-13

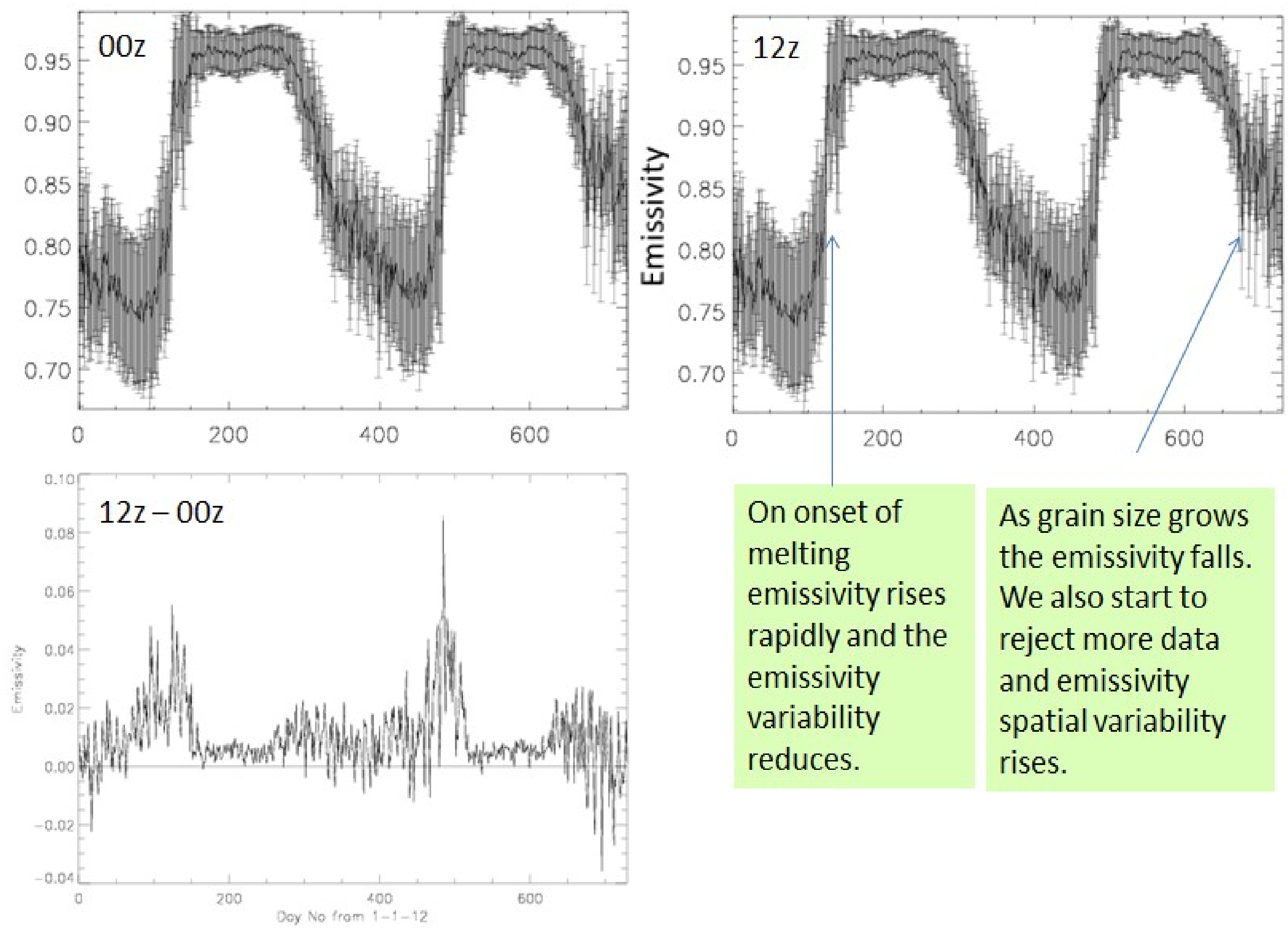




The dramatic Greenland ice event in 2012 is easily seen in retrieved emissivities from the AMSU-A 50 GHz channel.

The dramatic oscillations in emissivty, followed by a re-freeze and lower emissivity, followed by a gradual re-burial of the re-frozen layer.

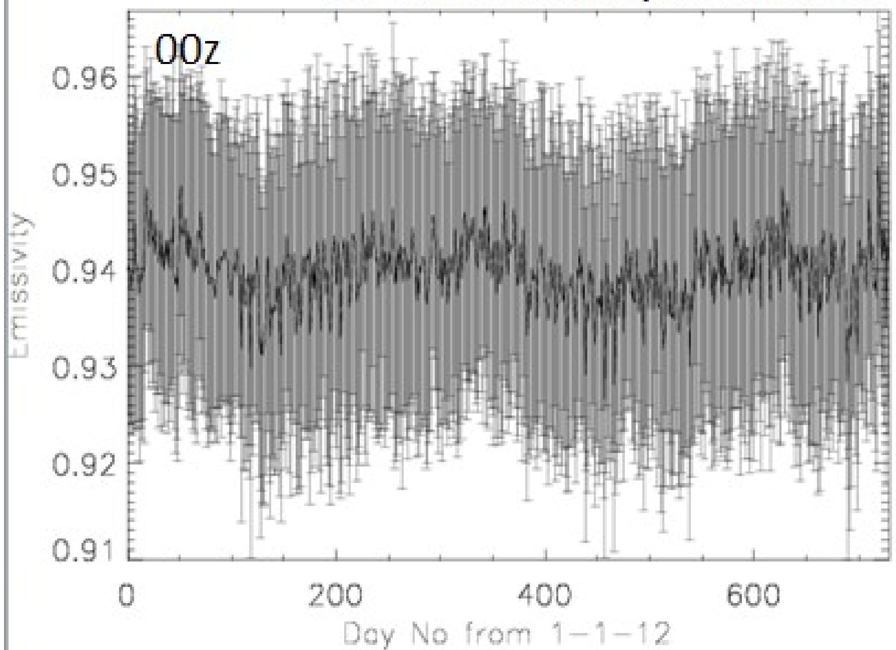
50 GHz Emissivity Siberia 90-150E 60-70N in 2012-13

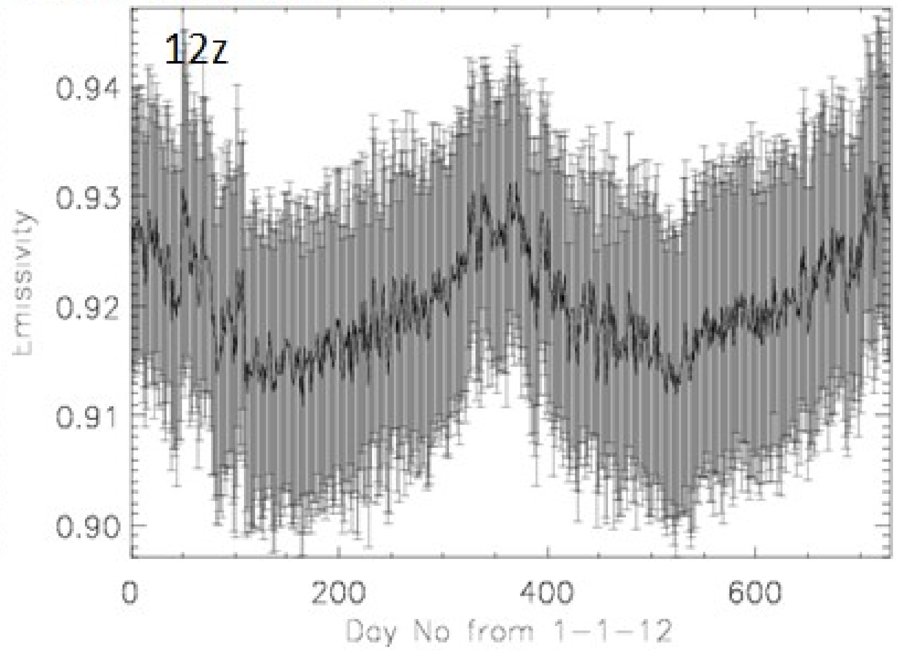


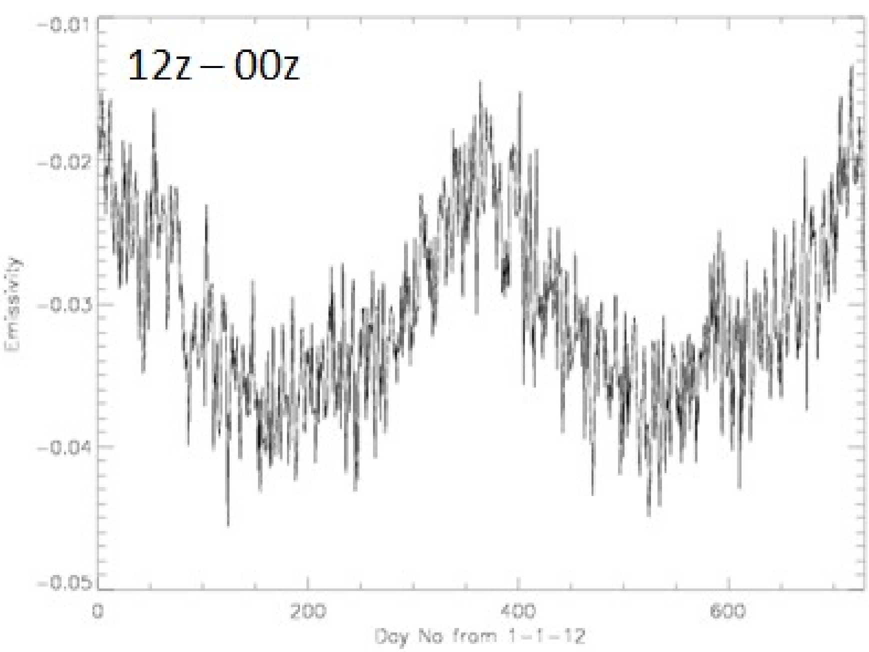
On onset of melting emissivity rises rapidly and the emissivity variability reduces.

As grain size grows the emissivity falls. We also start to reject more data and emissivity spatial variability rises.

50 GHz Emissivity Sahara 10W-25E 18-29N in 2012-13







There is no reason to expect an annual cycle in emissivity for the Sahara.

At 00z there is almost no variation, but at 12z there is a large variation.

Almost certainly impact of model Tskin errors. Can we trust Tskin in snow regions anymore?

Way forward and discussion points

•We need better model Tskin!

•**This is the main limiting factor in using more satellite sounding data over land.**

•We need to characterise uncertainty much better than we do now:

- Random vs systematic errors: which is more important?
- Improved estimate of uncertainty in model Tskin: how ?
- Uncertainty in Satellite Tskin (needs good emissivity, cloud screening)?
- Intercomparison with products e.g. Land SAF LST: will this help or just make more work? Are their uncertainties well characterised?
- Intercomparison between centres e.g. as done in the past by Ben Ruston (ECMWF-MetO-NRL) and myself (MetO-CPTEC). Did this help?

•Encourage land and cryosphere modellers to look at NWP emissivity and skin temperature estimates – this will bring insight into their information content and value.

•A step towards coupled models and coupled data assimilation.