Environment Canada Environnement Canada

Canada

Assimilation of surface sensitive infrared channels over land at Environment Canada

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Motivation

- Hyperspectral IR under-used over land and sea ice, i.e. not used if surface sensitive.
- Recent NWP context at EC is favorable:

- Flow-dependent background errors including surface skin temperature correlations with other variables
- Analysis grid at 50 km, model at 25 km
- 142 AIRS and IASI (METOP-A) channels assimilated: many sensitive to low level T, q, and T_s

Impact potential to explore over land

Challenges

- Adding valuable information of existing in-situ data sources such as surface and aircraft data
- Need a reliable cloud mask
- Reliable spectrally resolved surface emissivity
- Representativeness (e.g. variable topography)
- Relatively poor background field of T_s over land
- Radiance bias correction issue

Approach

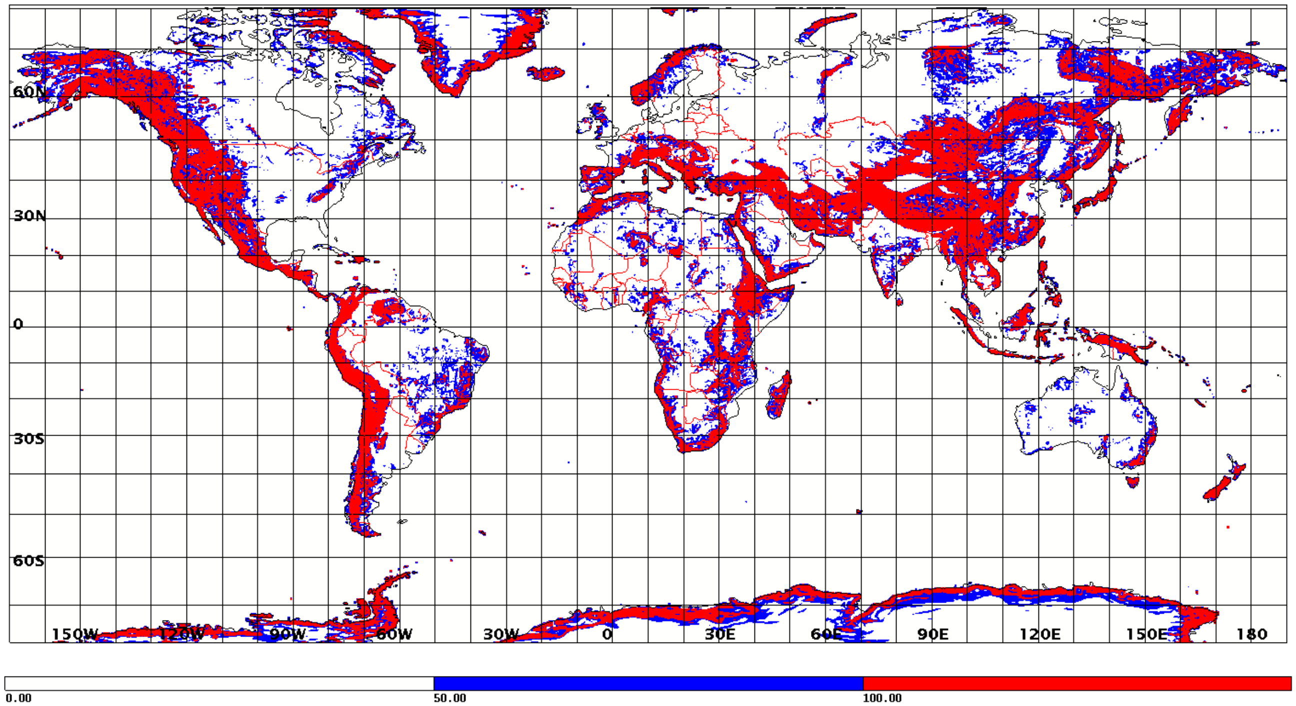
- EnVar with background errors from ENKF system, 192 members
- Added data evaluated are from AIRS and IASI over land
- Bias correction for surface sensitive channels based on oceanic data only
- Thinning of radiances is at 150 km
- T_s is part of model state, but T_s analysis increments are ignored
- Radiative transfer model: RTTOV-11
- Emissivity: U-Wisconsin atlas, fixed per month

Limiting criteria for assimilation

Assimilate under these restrictive conditions, following several sensitivity tests:

- Estimate of cloud fraction < 0.01
- Exclude latitudes 60-90 N/S and sea ice
- High surface emissivity (> 0.90)
- Relatively flat terrain (local height STD < 50 m)
- Diff between background T_s and rough retrieval based on inverting RTE limited to 4K

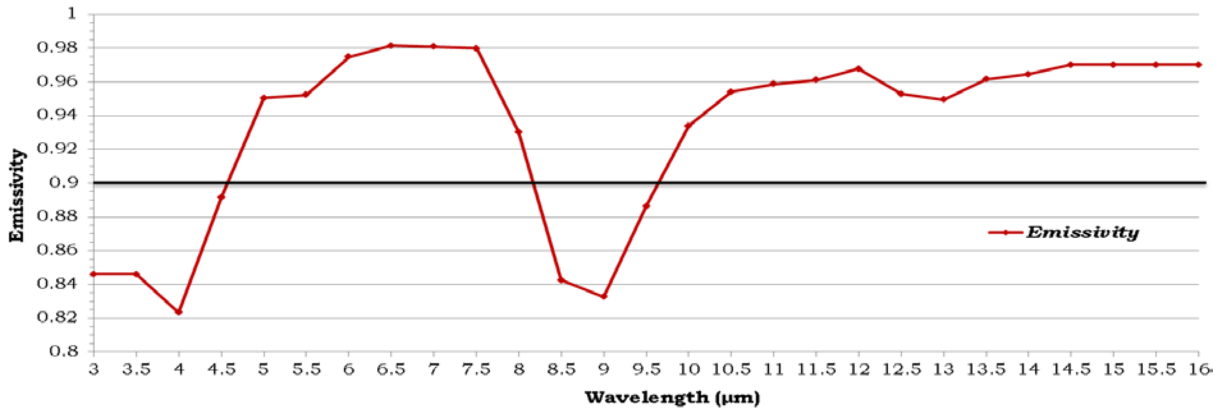
Limitation linked to topography



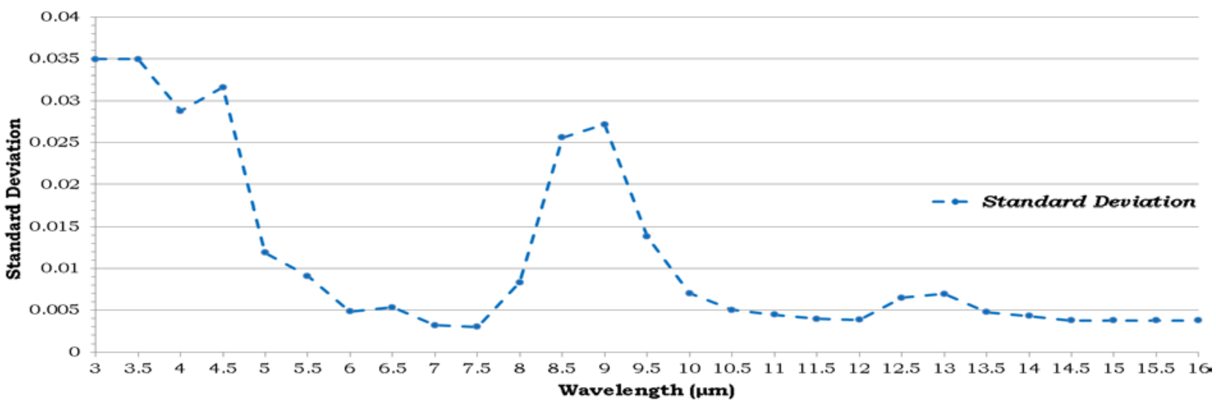
Criterion used: local STD of topography < 50 m (on 3X3 ~50 km areas)

White: accepted, red std > 100 m, blue 100 m >std> 50 m

Limitation linked to surface emissivity



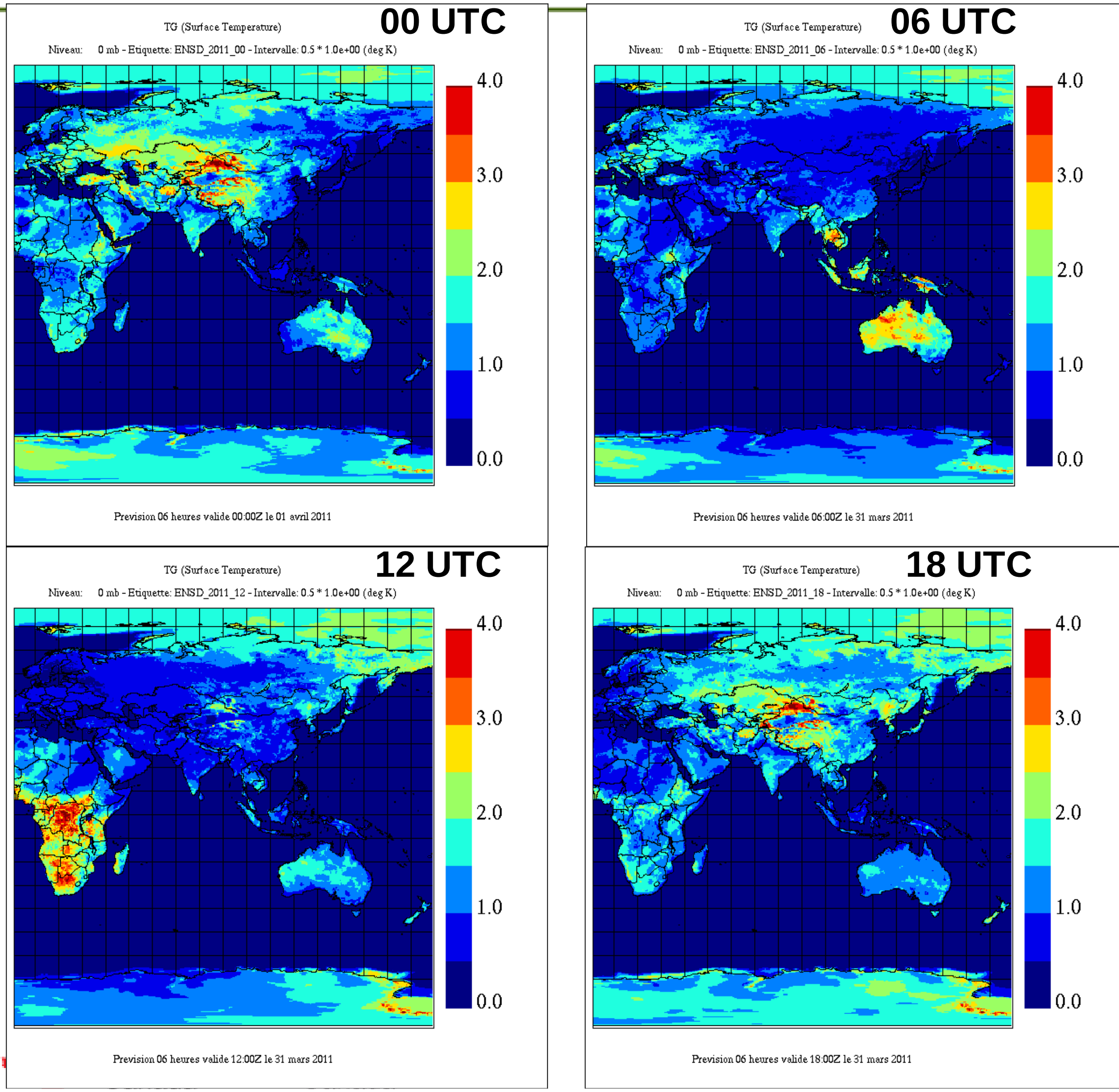
Emissivity over desert area



Error of estimate (from U-Wisconsin)

Accept only emissivity > 0.90 to limit uncertainty

Ensemble spread of T_s (Feb-Mar 2011)



Maximum ~15h local
In SH (summer)

Maximum at night
Tibetan area (winter)

Ts background error over land in 4Dvar is Constant: 3 K.

In EnVar, B is $0.5(B_{ENKF} + B_{NMC})$

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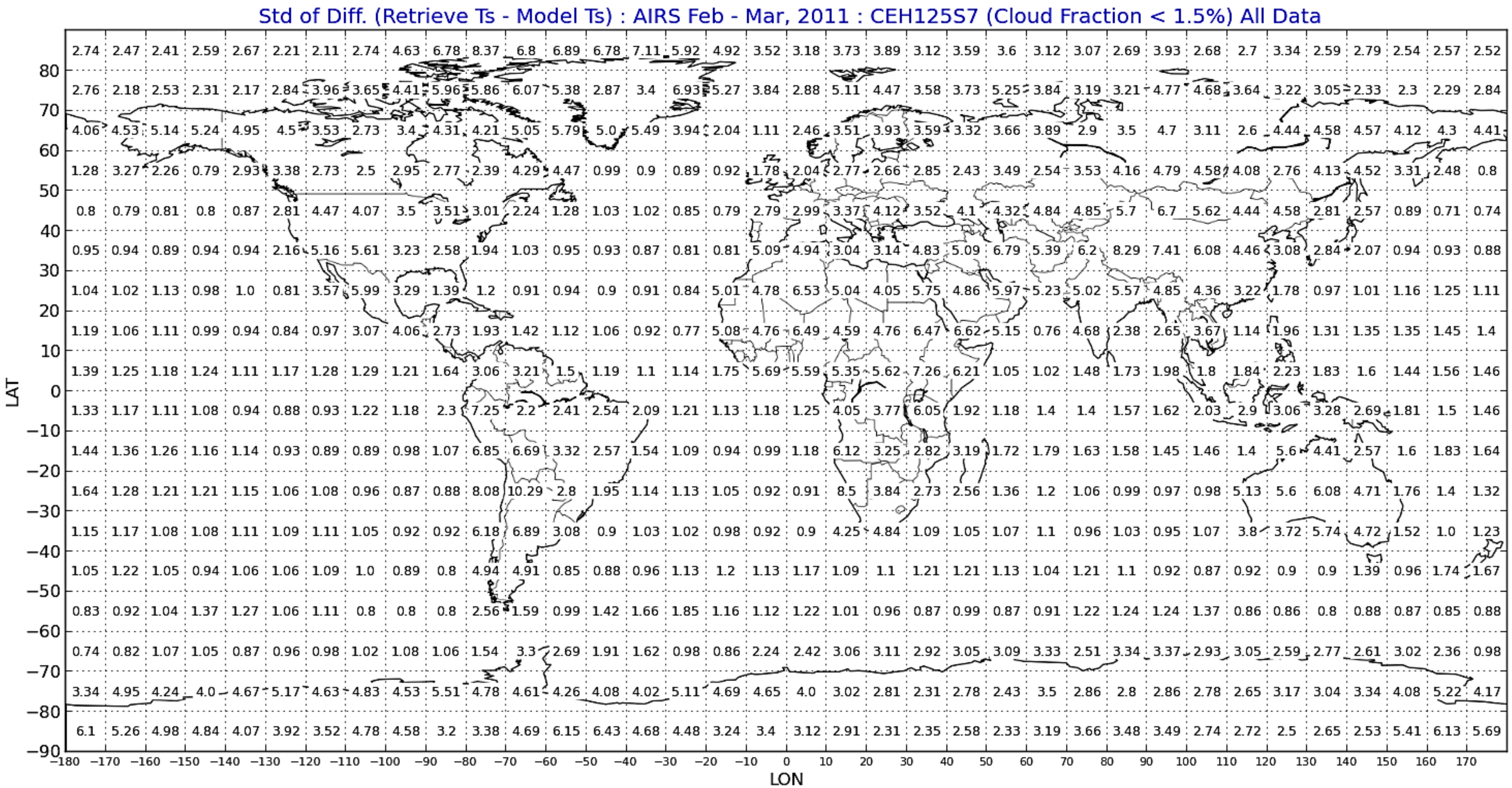
Std model vs retrieved T_s

~ 1K over ocean ;   ~2.5-5.5 K over land and sea ice

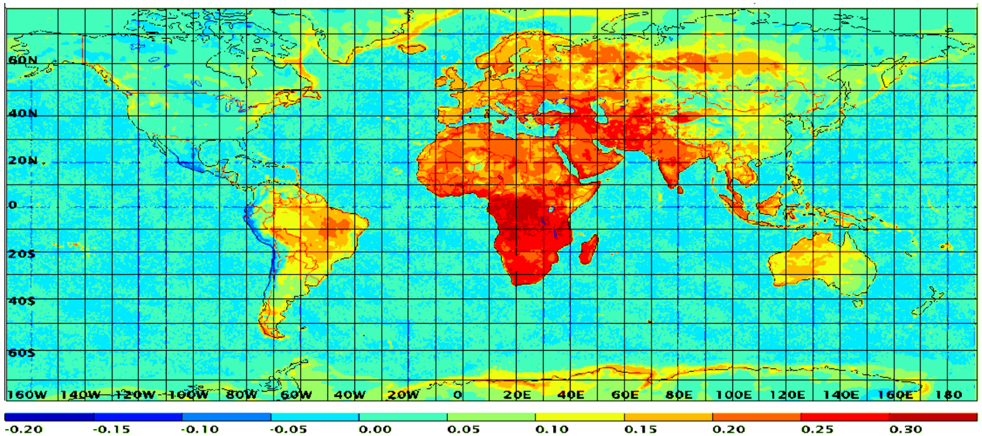


Error estimate from retrievals comparable to ensemble spread

Error correlation between T_{skin} and T_{air}

$E[(T_s - T_{s\text{-}avg})(T - T_{air\text{-}avg})]^{1/2}$ avg of 192 members, 2-month period

12 UTC



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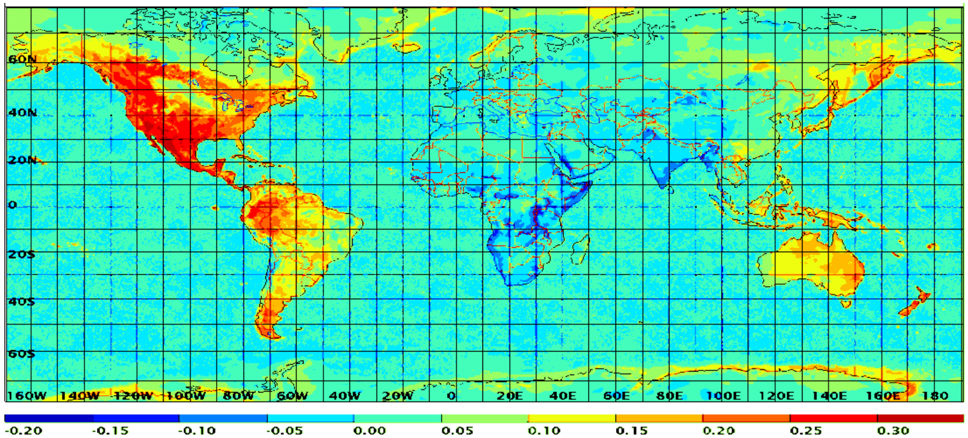
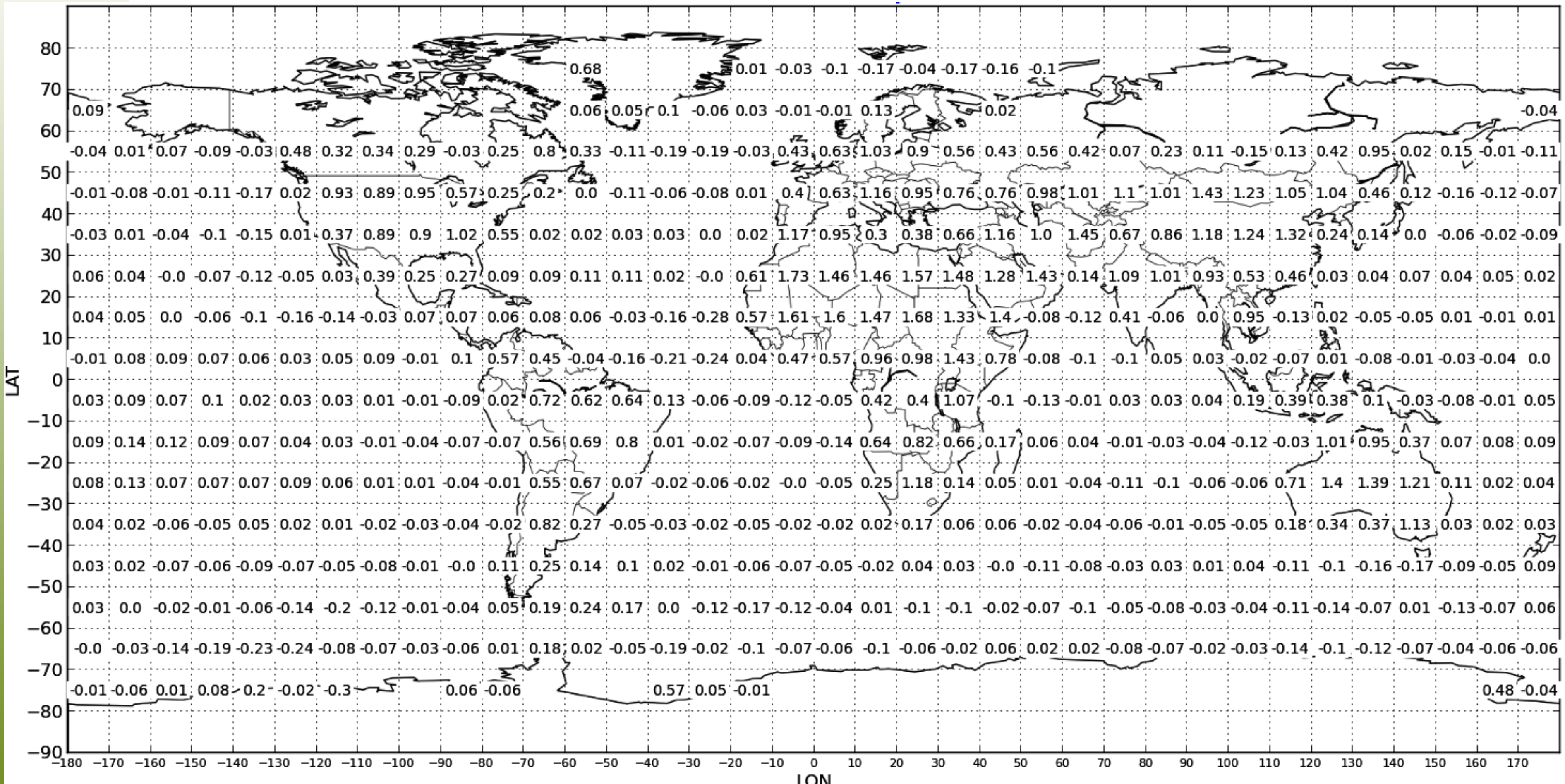


T_{air} at ~941hPa

Error correlation between T_{skin} and T_{air} at low levels is typically positive in daytime but often negative at night.
It is zero over ocean since SST is not perturbed.

Mean (O-B) AIRS-787, assimilated

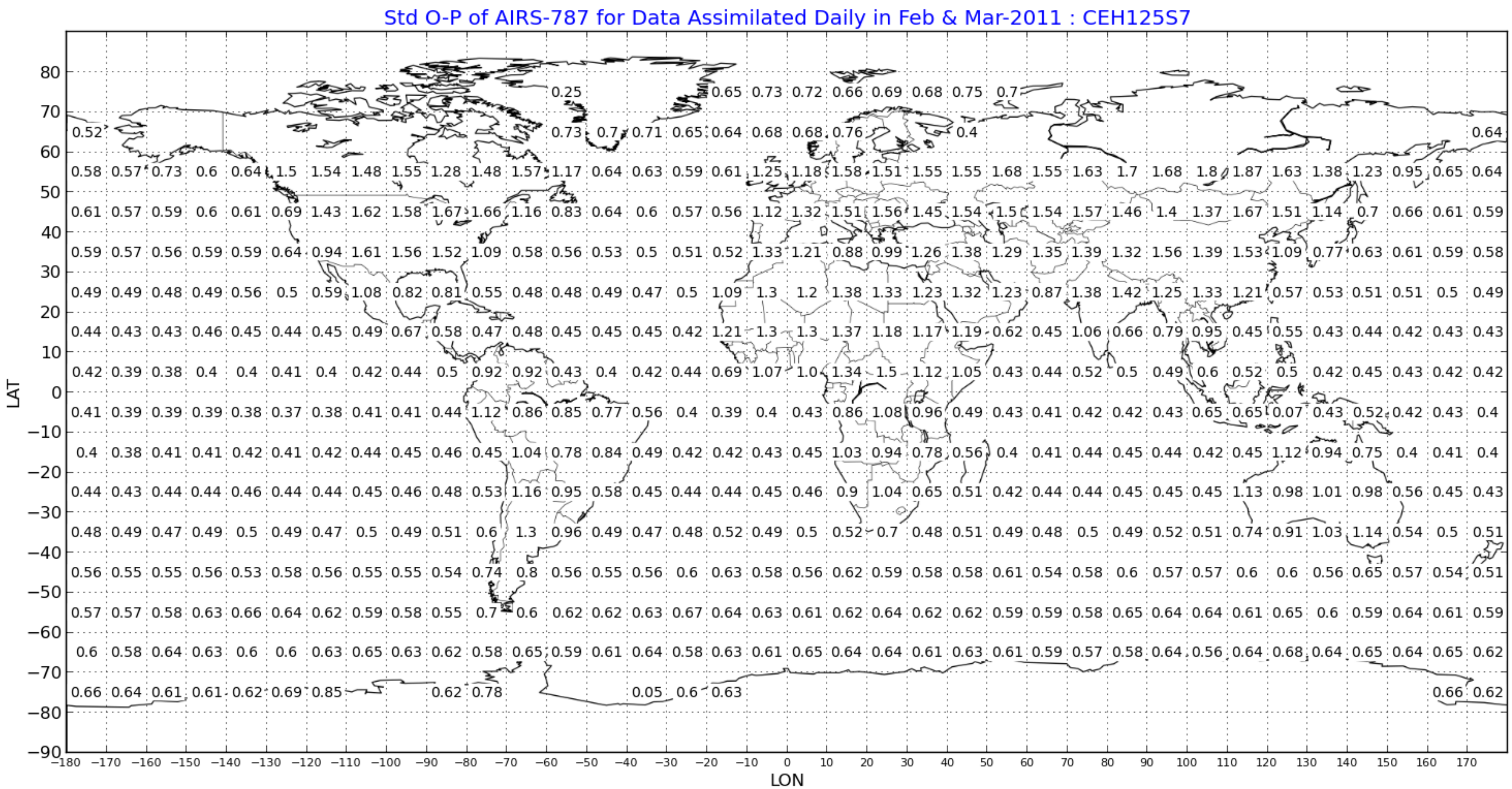
~0 over ocean; ~0.5-1.5 K over land



(O-B) distribution over land skewed on warm side

STD (O-B) AIRS 787, assimilated

~ 0.5 K over ocean ; ~ 1.0-1.5 K over land



Results

2-month assimilation Feb 1- March 31 2011

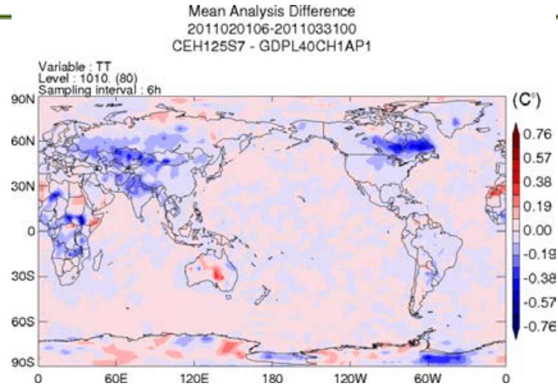
CNTL: Equivalent to newly implemented Envar

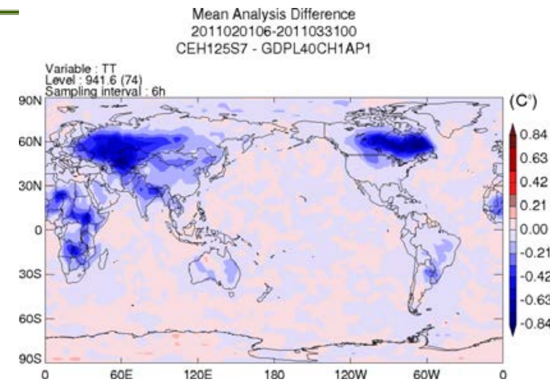
EXP: same + surface-sensitive AIRS and IASI (Metop A) over land under specified conditions

Mean T difference Exp-Control

Surface | **~941hPa**

Analysis





Cooler analysis at low levels on average

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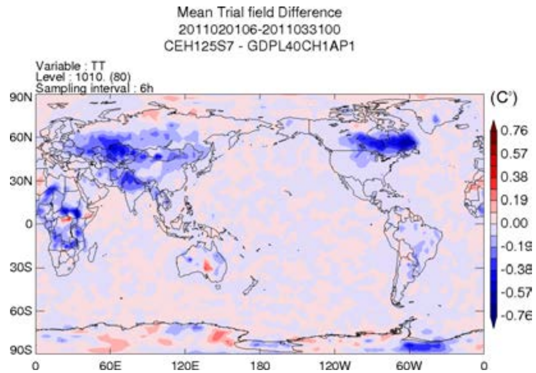
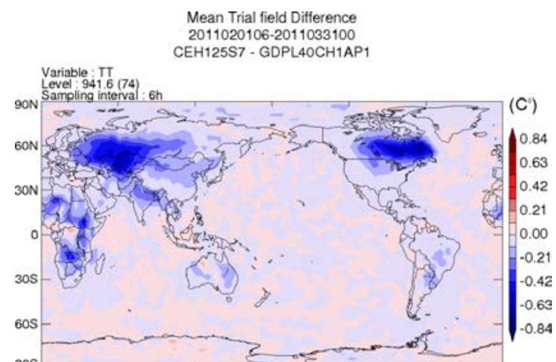
Trial





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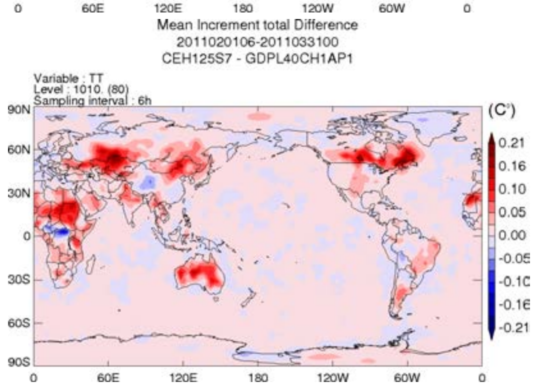
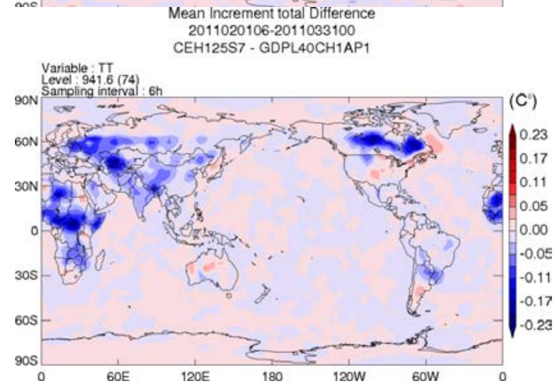
Increment





Mean positive Increments near the surface only

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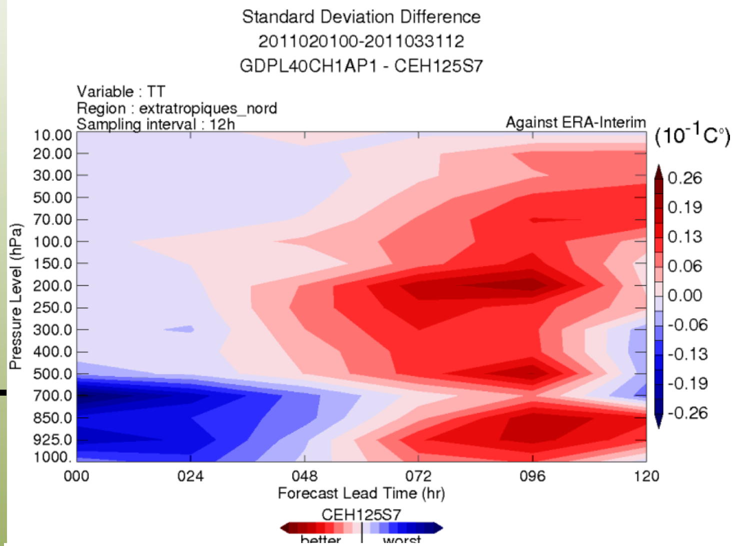
T STD difference vs lead time

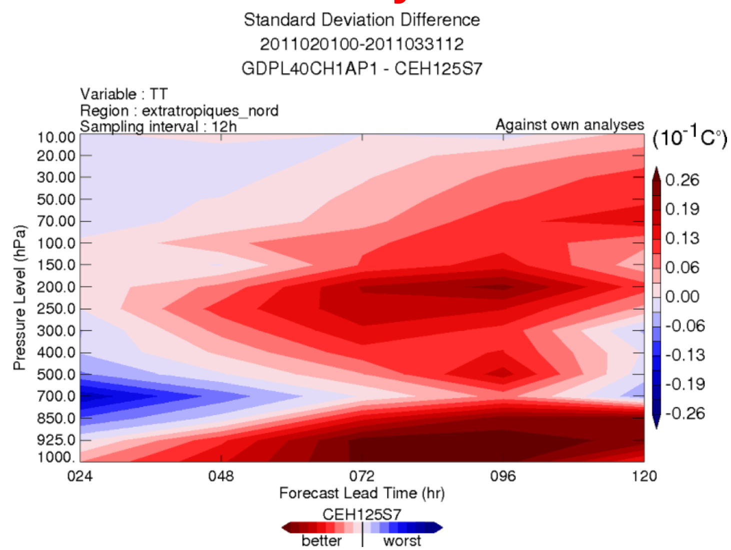
red/blue means pos/neg impact of experiment

vs ERA Interim

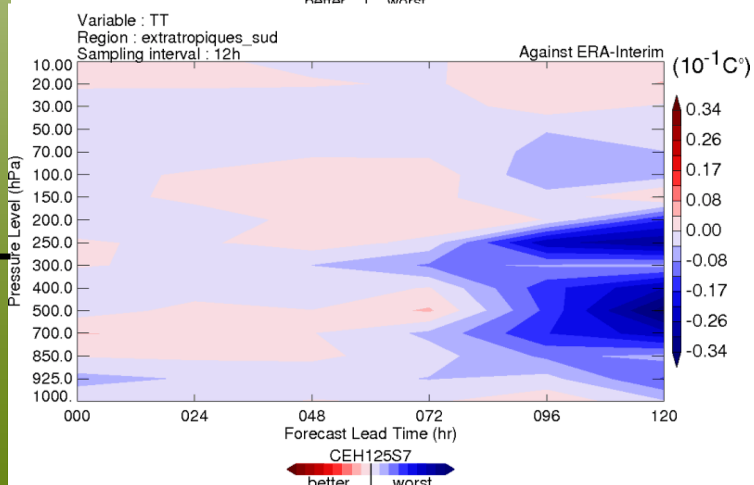
vs own analysis

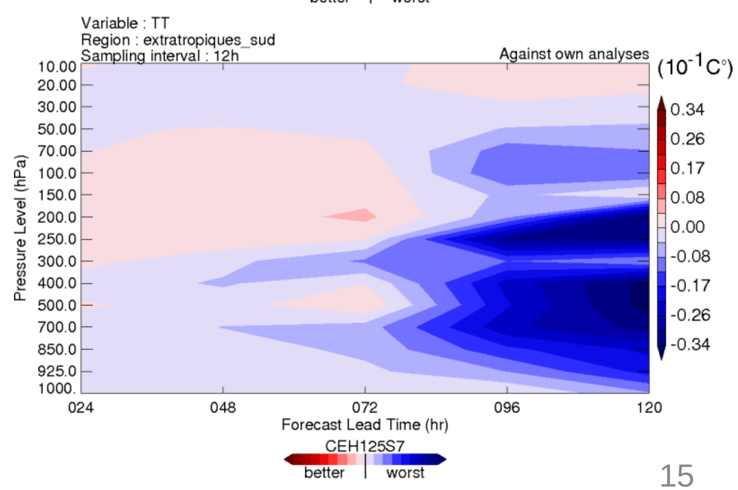
NH-Extra-Trop





SH-Extra-Trop





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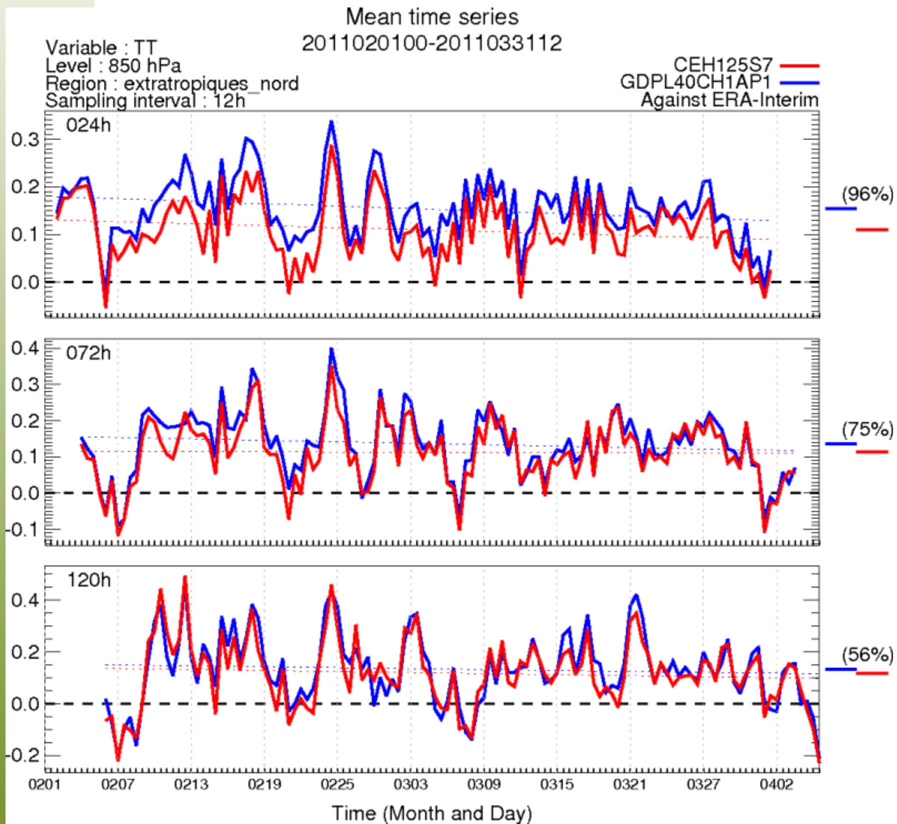
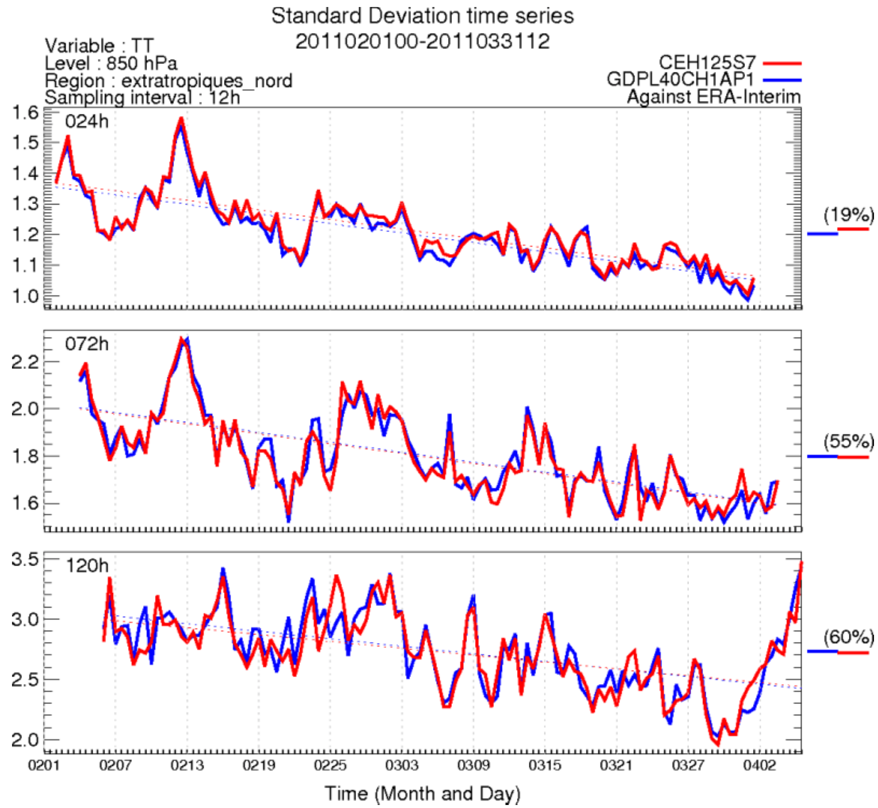
Time series of T bias, T std at 850 hPa vs ERA-Interim, at 24-h, 72-h, 120-h, NH-extro

BIAS **STD** **EXP CNTL**



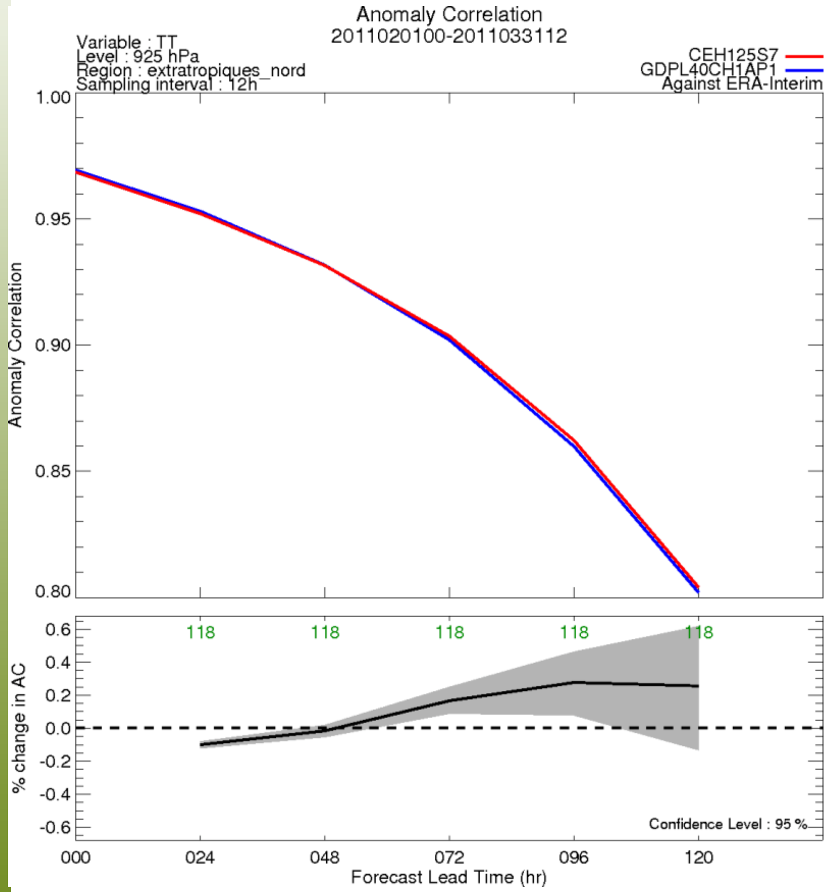


Bias improved at all times, std improved at 72-h and beyond

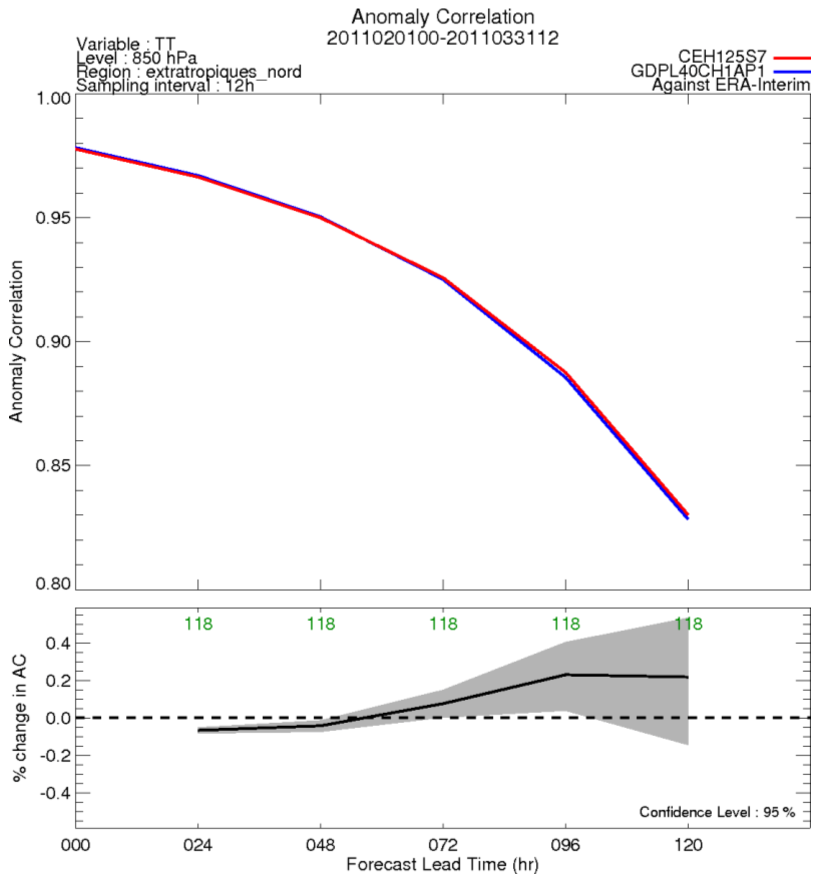
Temperature anomaly correlation NH-Extratropics

EXP / CNTL

925 hPa



850 hPa

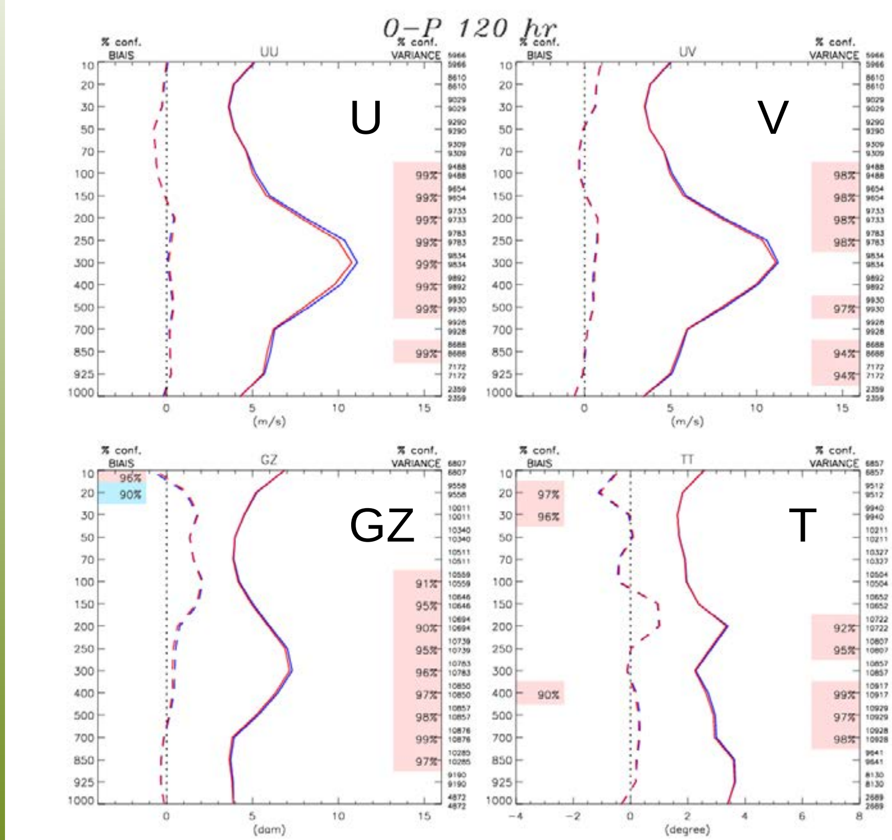


Significant impact at days 3-4

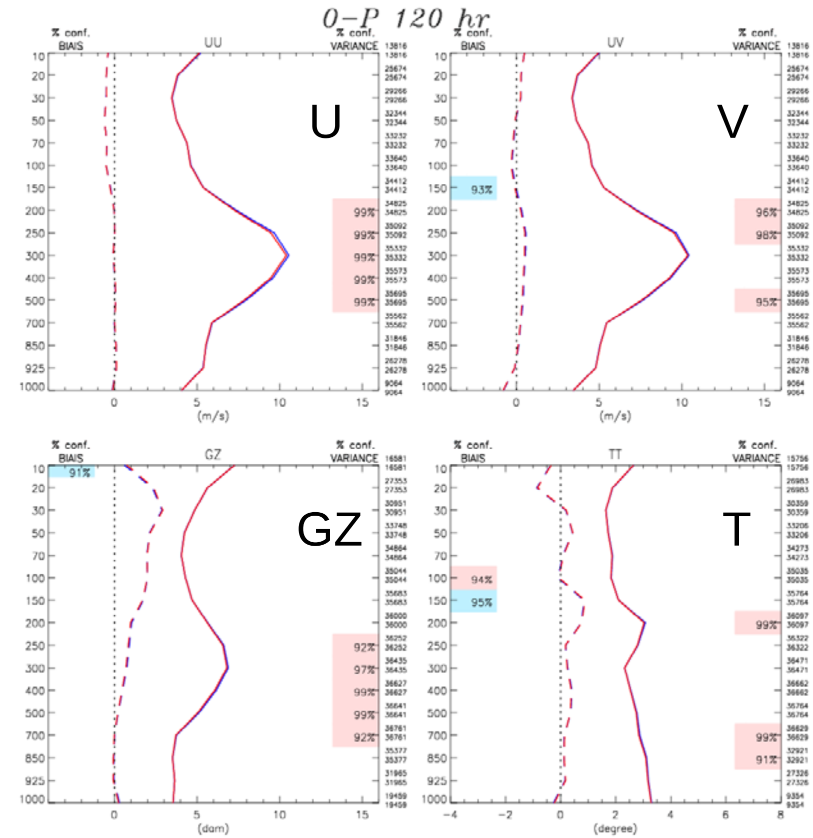
Validation vs radiosondes 120-h

EXP CNTL

North America



NH-extratropics

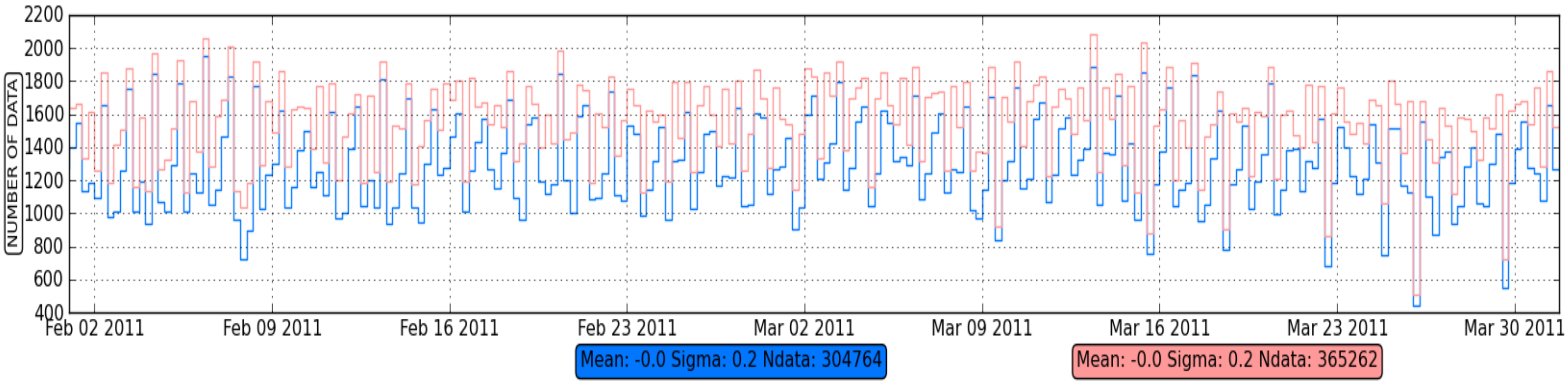


Added yield: about 17%

(for surface sensitive channels)

CNTL
EXP

Number of radiances assimilated for surface channel AIRS 787
CNTL: ~1290/6h EXP: ~1550/6h



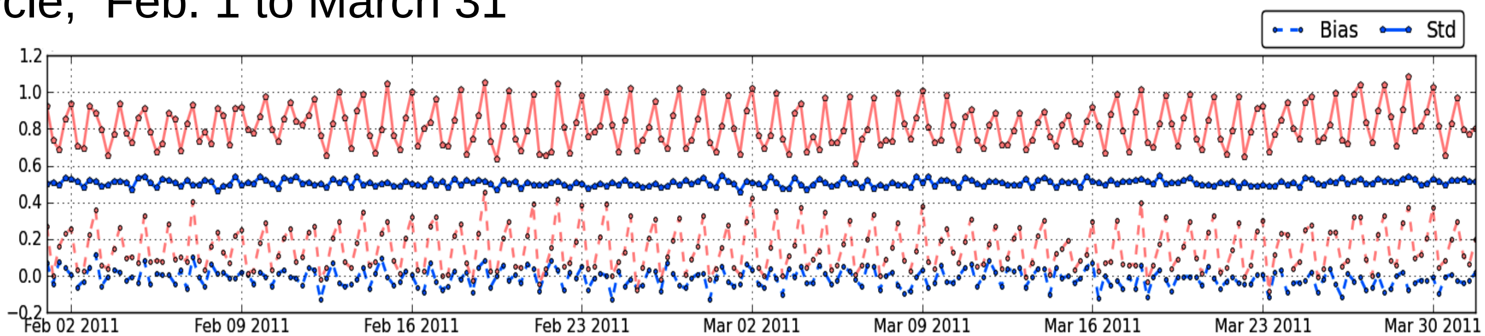
Region: world, EXP excludes surface-sensitive channels at latitudes > 60 N/S
Radiance thinning is at 150 km

Std/bias of (O-B) and (O-A), AIRS 787

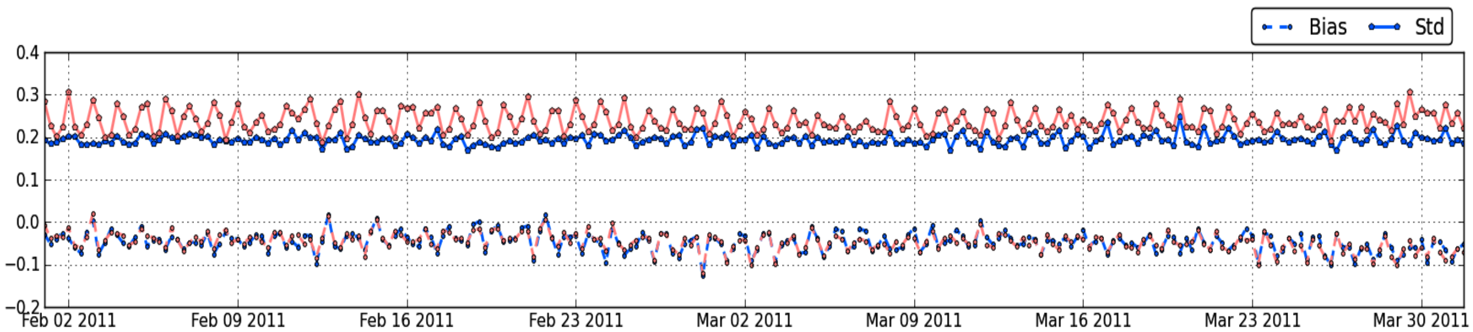
CNTL (ocean only) EXP (ocean + land)

6-h cycle; Feb. 1 to March 31

O-B



O-A



No major impact on analysis bias. Over land std (O-P) is ~1.7 K, Bias is ~1.2K, and std (O-A) is ~0.4 K.

Conclusion

- Encouraging results, significant positive impact in NH
- Impacts up to day 5 significant
- Consistent results vs analysis and radiosondes
- Negative impact early in forecast in NH requires investigation

Way forward:

- Ongoing summer cycle including Cris and IASI (Metop B)
- Assimilate retrieved Ts in land surface analysis to add consistency with atmospheric analysis
- Seek consistency in emissivity definition in assimilation and in the model (broadband)
- Validate/improve cloud detection

This work to appear in JAMC, Dutta et al., 2016