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

Accept only emissivity > 0.90 to limit uncertainty

Emissivity over desert area

Error of estimate (from U-Wisconsin)
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, $B = 0.5(B_{ENKF} + B_{NMC})$
Std model vs retrieved $T_s$

$\sim 1K$ over ocean; $\sim 2.5-5.5 K$ over land and sea ice

Error estimate from retrievals comparable to ensemble spread
Error correlation between $T_{skin}$ and $T_{air}$

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

$T_{air}$ 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

Analysis = Trial + Increment

Surface

Cooler analysis at low levels on average

~941hPa

Mean positive Increments near the surface only
T STD difference vs lead time

red/blue means pos/neg impact of experiment

vs ERA Interim

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

Bias improved at all times, std improved at 72-h and beyond
Temperature anomaly correlation
NH-Extratropics

EXP / CNTL

Significant impact at days 3-4
Validation vs radiosondes 120-h

North America

NH-extratropics

EXP CNTL

18
Added yield: about 17%
(for surface sensitive channels)

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
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

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