Evaluating short-range forecast impact of temperature retrievals in the CPTEC/INPE LETKF

Fábio L. R. Diniz[1*], Ricardo Todling[2], Dirceu L. Herdies[1] and Luis G. G. de Gonçalves[1]

[1] *Centro de Previsão de Tempo e Estudos Climáticos (CPTEC), INPE, Cachoeira Paulista, São Paulo, Brazil*

[2] *Global Modeling and Assimilation Office (GMAO), NASA Goddard Space Flight Center, Greenbelt, Maryland, USA*

*fabio.diniz@cptec.inpe.br

Abstract

The Center for Weather Forecast and Climate Studies from the Brazilian National Institute for Space Research (CPTEC/INPE) through its Group on Data Assimilation Developments (GDAD) is evaluating the observation impacts in the Local Ensemble Transform Kalman Filter (LETKF) that is on the way to complete development and testing at that center. Since 2011 an ensemble-based approach, following Liu and Kalnay (2008; QJRMS, 134, 1327-1355), for observation impact evaluation has been added to the CPTEC/INPE LETKF data assimilation system. Currently this capability only applies for conventional observations since the use of radiances within the LETKF framework is a work on the way. Thus the purpose of this presentation is to evaluate the short range forecasts impact of *in situ* and remote sensing observations currently available at CPTEC/INPE LETKF in the presence of temperature retrievals.

Current CPTEC/INPE DAS: PSAS

$$\mathbf{x}^a = \mathbf{x}^b + \mathbf{K}[\mathbf{y}^o - \mathbf{H}(\mathbf{x}^b)]$$

$$\mathbf{K} = \mathbf{B}\mathbf{H}^T[\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R}]^{-1}$$

$\mathbf{x}^a \in \mathbb{R}^n$ analysis vector
$\mathbf{x}^b \in \mathbb{R}^n$ background vector
$\mathbf{K} \in \mathbb{R}^{n\times p}$ gain matrix
$\mathbf{y}^o \in \mathbb{R}^p$ observation vector
$\mathbf{H} : \mathbb{R}^n \to \mathbb{R}^p$ observation operator
$\mathbf{B} \in \mathbb{R}^{n\times n}$ background error covariance matrix
$\mathbf{R} \in \mathbb{R}^{p\times p}$ observations error covariance matrix
n dimension of model space
p dimension of observation space

Future CPTEC/INPE DAS: LETKF

$$\mathbf{x}^{ai} = \bar{\mathbf{x}}^b + \mathbf{X}^b\tilde{\mathbf{K}}\mathbf{v} + \delta\mathbf{x}^{ai}$$

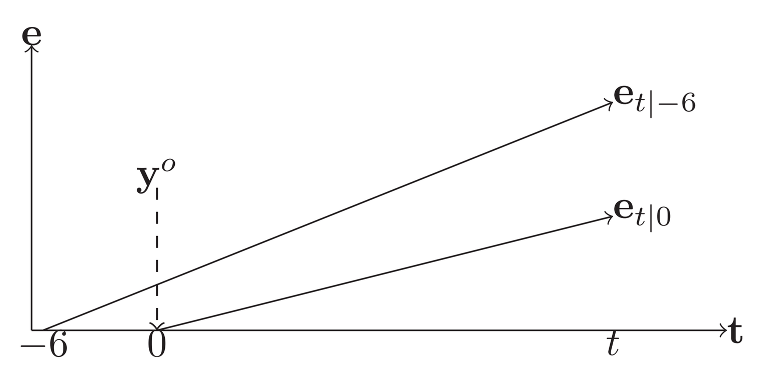
$$\tilde{\mathbf{K}} = [(K-1)\mathbf{I} + (\mathbf{H}\mathbf{X}^b)^T\mathbf{R}^{-1}\mathbf{H}\mathbf{X}^b]^{-1}(\mathbf{H}\mathbf{X}^b)^T\mathbf{R}^{-1}$$

$\mathbf{x}^{ai} \in \mathbb{R}^n$ i^{th} analysis vector
$\bar{\mathbf{x}}^b \in \mathbb{R}^n$ background vector mean
$\mathbf{X}^b \in \mathbb{R}^{n\times m}$ background perturbations matrix
$\tilde{\mathbf{K}} \in \mathbb{R}^{m\times p}$ gain matrix in the ensemble subspace
$\mathbf{v} \in \mathbb{R}^p$ innovations
δ difference between i^{th} ensemble member and ensemble mean
K number of ensemble members
m dimension of ensemble space

Approach to observation impact

Methods to measure observation impact without data denial or add-on experiments: adjoint-based method [1] and ensemble-based method [2] (see also [3]). Needs to define a measure of forecast error:

$$\begin{aligned} J &= \frac{1}{2}\left(\mathbf{e}_{t|0}^{\mathrm{T}}\mathbf{C}\mathbf{e}_{t|0} - \mathbf{e}_{t|-6}^{\mathrm{T}}\mathbf{C}\mathbf{e}_{t|-6}\right) \\ &= \left(\mathbf{e}_{t|-6} + \frac{1}{2}\mathbf{X}_{t|-6}^{f}\tilde{\mathbf{K}}_0\mathbf{v}_0\right)^{\mathrm{T}}\mathbf{C}\,\mathbf{X}_{t|-6}^{f}\tilde{\mathbf{K}}_0\mathbf{v}_0 \end{aligned}$$



$$I = \left\langle \mathbf{v}_0, \tilde{\mathbf{K}}_0^{\mathrm{T}}\mathbf{X}_{t|-6}^{f\mathrm{T}}\mathbf{C}\left(\mathbf{e}_{t|-6} + \frac{1}{2}\mathbf{X}_{t|-6}^{f}\tilde{\mathbf{K}}_0\mathbf{v}_0\right)\right\rangle$$

Results

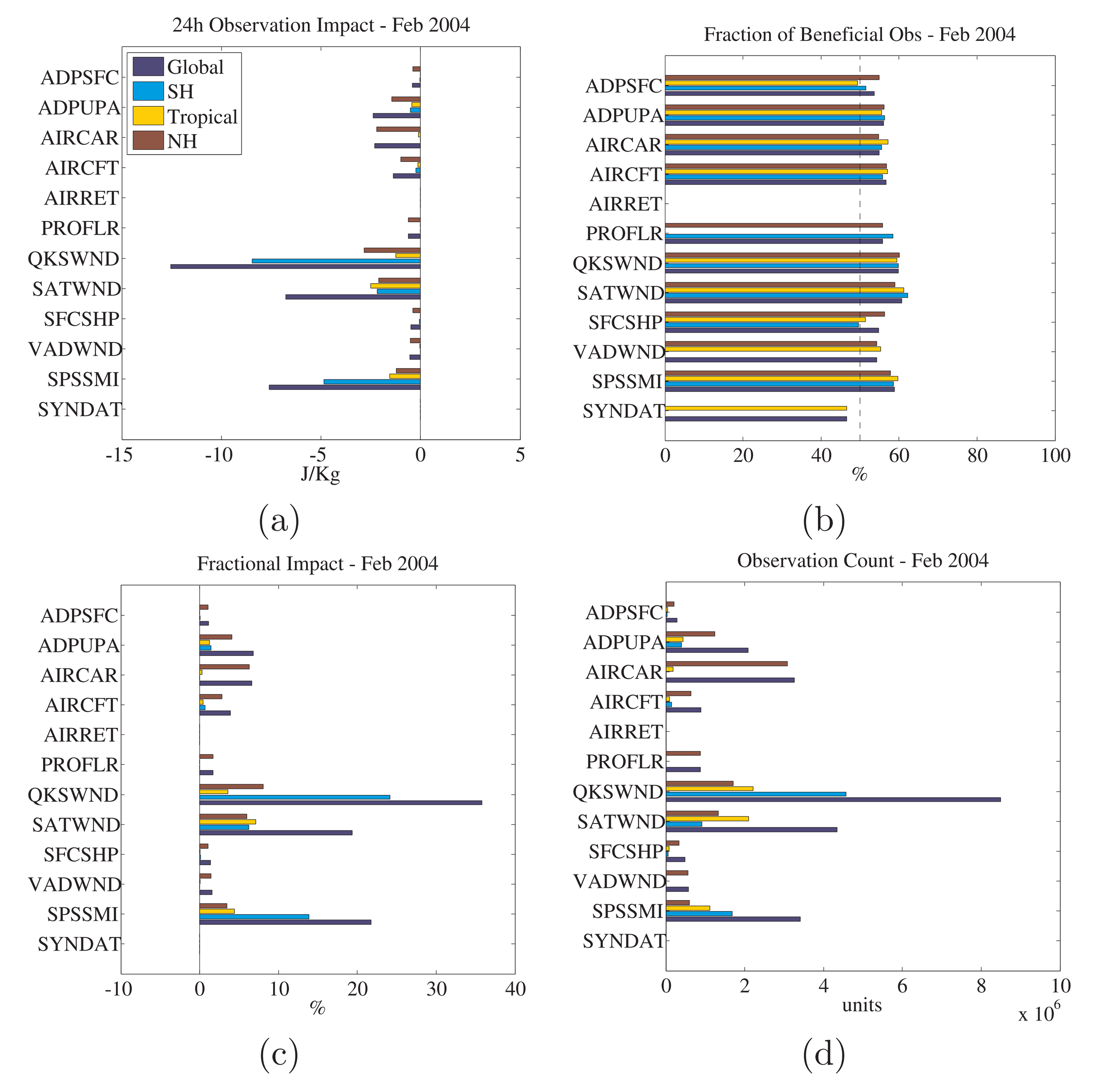


Figure 1: Results of various observation types (excluding AIRS retrievals) on the 24 h forecasts from 0000, 0600, 1200 and 1800 UTC combined during February 2004 in CPTEC/INPE LETKF to regions: Global (90°S-90°N, dark blue), Southern Hemisphere (80°S-20°S, light blue), Tropics (20°S-20°N, yellow) and Northern Hemisphere (20°N-80°N, brown): (a) Daily average impacts. The units are Jkg^{-1}. (b) Fraction of observations that reduces the 24 h forecast error. The units are percentage. (c) Fractional impacts. The units are percentage. (d) Total number of observations. The scale factor is 10^6.

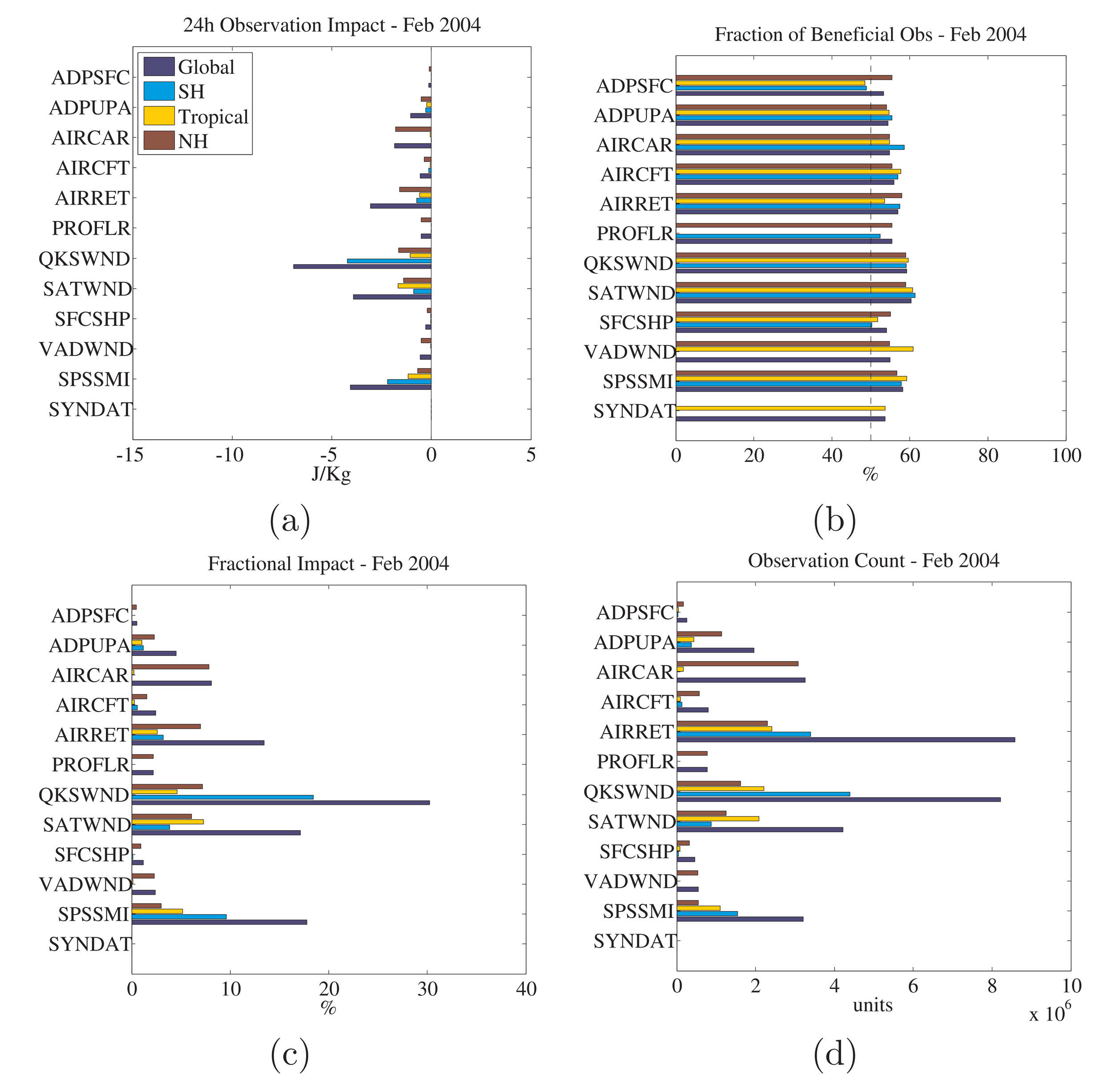


Figure 2: Results of various observation types (including AIRS retrievals) on the 24 h forecasts from 0000, 0600, 1200 and 1800 UTC combined during February 2004 in CPTEC/INPE LETKF to regions: Global (90°S-90°N, dark blue), Southern Hemisphere (80°S-20°S, light blue), Tropics (20°S-20°N, yellow) and Northern Hemisphere (20°N-80°N, brown): (a) Daily average impacts. The units are Jkg^{-1}. (b) Fraction of observations that reduces the 24 h forecast error. The units are percentage. (c) Fractional impacts. The units are percentage. (d) Total number of observations. The scale factor is 10^6.

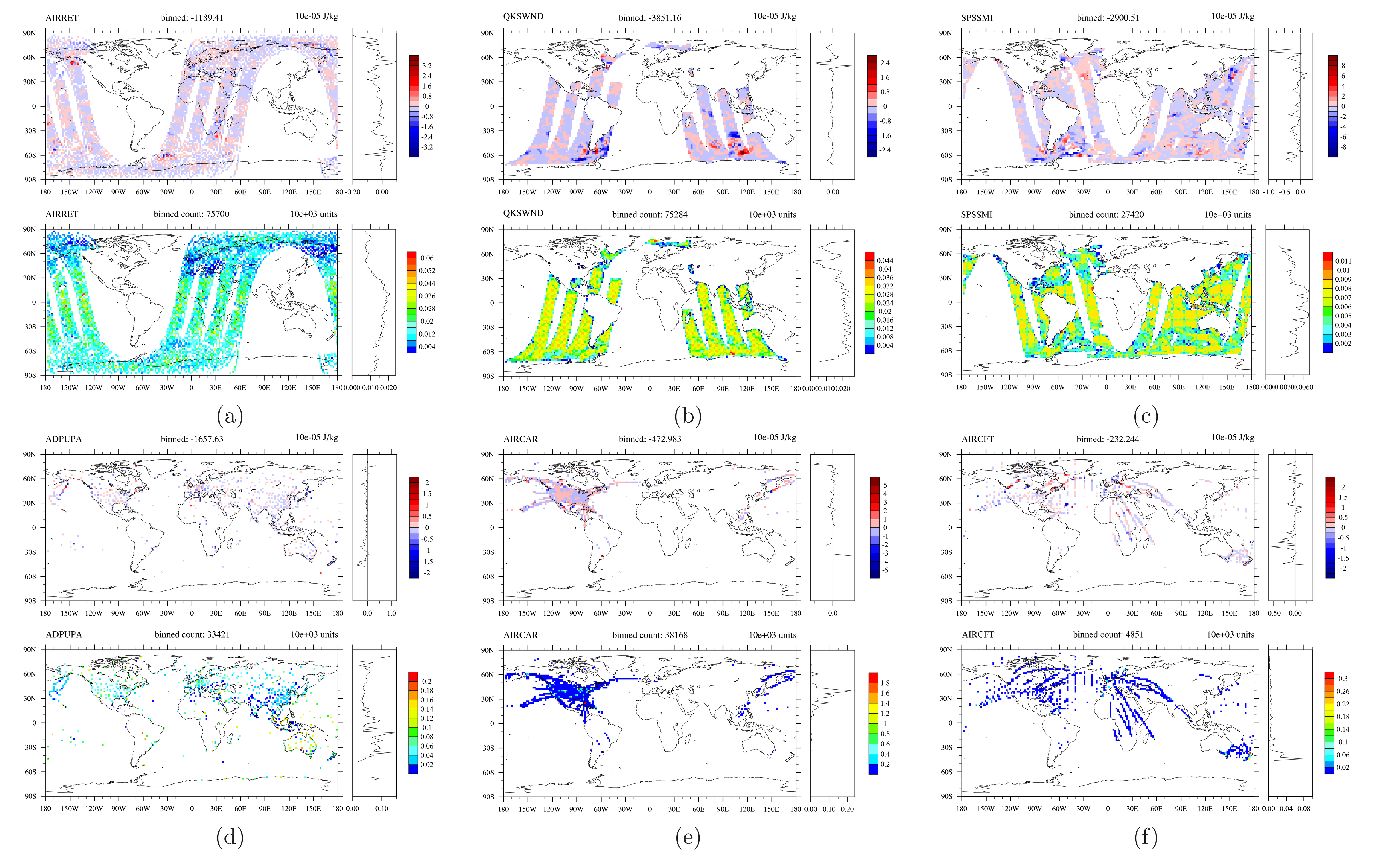


Figure 3: Observation impact of various observation types on the 24 h forecasts at 0000 UTC February 26, 2004: (a) AIRRET, (b) QKSWND, (c) SPSSMI, (d) ADPUPA, (e) AIRCAR and (f) AIRCFT. Results represent 1.875°×1.875° gridded average values. The scale factor is 10^{-5} and the units are Jkg^{-1}.

Experimental setup

- AGCM-CPTEC/INPE T_Q62L28
- LETKF-CPTEC/INPE 40 members
- Total energy norm (dry)
- Observation impact on all 24 h forecasts from 0000, 0600, 1200 and 1800 UTC for February 2004
- Conventional observations are assimilated
- AIRS retrievals version 5.0.14.0 thinned to approximately 150 km

u	v	T	$\mathbf{p}_s$	Obs group	Description
•	•	•	○	ADPUPA	RAOB's
•	•	•	-	AIRCFT	AIREP PIREP ASDAR
•	•	•	-	AIRCAR	MDCRS ACARS
-	-	•	-	AIRRET	AIRS Retrievals
•	•	•	•	SFCSHP	SHIP BUOY
○	○	○	•	ADPSFC	SYNOP METAR
•	•	-	-	SYNDAT	Sinthetycs (BOGUS)
•	•	-	-	PROFLR	Profilers
•	•	-	-	VADWND	VAD winds
•	•	-	-	SATWND	JMA EUMETSAT NESDIS
•	•	-	-	SPSSMI	SSM/I
•	•	-	-	QKSWND	QuikScat

Conclusions

Assimilation of *in situ* and remote sensing observations in the presence of temperature profile data from AIRS version 5.0.14.0 retrieval products using CPTEC/INPE LETKF system improved 24 h forecasts. The set of observations plays an important role in modulating the impact of any subset. For instance, while excluding temperature retrievals the ocean surface winds have a much larger impact than including retrievals. The total impact of temperature retrievals for the Northern Hemisphere region is relatively large, even though their count is small. More than 50% of the total number of temperature retrievals assimilated reduces the 24 h forecast error for all selected regions.

Future works

- Investigate the impacts on forecasts beyond 1 day.
- Include a metric that explicitly accounts for moisture effects.
- Assimilate humidity profiles from AIRS retrievals.
- Revaluate impacts in the presence of humidity profiles.

References

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