Constrained Bias Correction for Satellite Radiance Assimilation in Limited Area Model

Wei HAN

NWPC/CMA,Beijing,China Email : hanwei@cma.gov.cn

ABSTRACT

Radiance bias correction is crucial to the successful assimilation of satellite radiance observations which are typically affected by biases that arise from uncertainties in the absolute calibration, the radiative transfer modeling, or other aspects. These biases have to be removed for the successful assimilation of the data in NWP systems. There are several issues in the implementation of the bias correction method in limited area models (LAMs) which was originally developed for global models. One of these important issues is how to separate the observation bias from the innovations if there are obvious model diurnal biases in LAMs using adaptive bias correction in 3D-Var. In this study, the constrained bias correction scheme is proposed and tested considering the estimate of radiometric uncertainties and the relative model diurnal bias. Enhanced cooperation between NWP and other ITWG groups are recommended for the validation and characterization of satellite radiance bias estimation.

1. Motivation

Bias correction is essential for successful use of satellite radiance

-FSO view: BC could change the impact sign $\delta J = \left\langle \frac{\partial J}{\partial \mathbf{y}}, \mathbf{y}-H\mathbf{x}_b-\mathbf{b} \right\rangle$

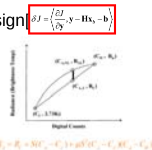
-No absolute calibration in radiance

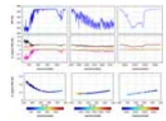
-Bias dependence on scene temperature

Bias correction issues in LAMs[6]

-Limit samples

-Model diurnal bias





Tobin et al,2013, Fig8:On-orbit RU estimates for a typical warm Earth view spectrum collected on 24 February 2013.

Progress in RT and calibration uncertainty estimation[7]

2. Methodology

Constrained Bias Correction[4]

-Background term for bias estimation

-Use of uncertaity information of RT and calibration

$$
\begin{aligned}
2J(\mathbf{x},\boldsymbol{\beta}) = {} & (\mathbf{x}_b-\mathbf{x})^T\mathbf{B}_x^{-1}(\mathbf{x}_b-\mathbf{x}) \\
& +(\boldsymbol{\beta}-\boldsymbol{\beta}_b)^T\mathbf{B}_\beta^{-1}(\boldsymbol{\beta}-\boldsymbol{\beta}_b) \\
& +[\mathbf{y}-H(\mathbf{x})-b(\mathbf{x},\boldsymbol{\beta})]^T\mathbf{R}^{-1}[\mathbf{y}-H(\mathbf{x})-b(\mathbf{x},\boldsymbol{\beta})] \\
& +\gamma^2[b(\mathbf{x},\boldsymbol{\beta})-\mathbf{b}_0]^T\mathbf{R}_b^{-1}[b(\mathbf{x},\boldsymbol{\beta})-\mathbf{b}_0]
\end{aligned}
$$

Constraints

-Physical based bias model

-Priori uncertainty estimate of observation bias

-The time evolution of bias (cycle period of bias coefficients)

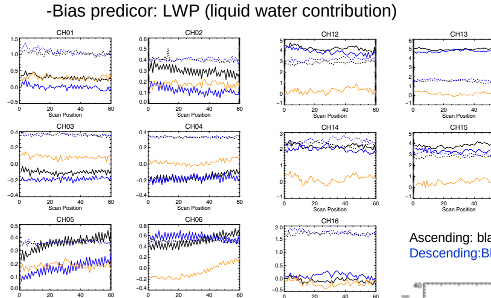
-Consideration of model bias [2,5]

3. Case Study: Bias correction of SSMIS imager channels[3]

Bias model for SSMIS imager channels

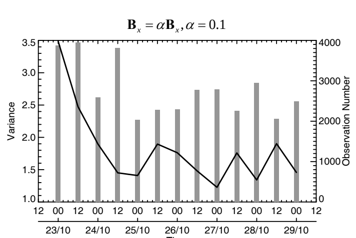
-Scan bias (Ascending and Descending)

-Bias predicor: LWP (liquid water contribution)

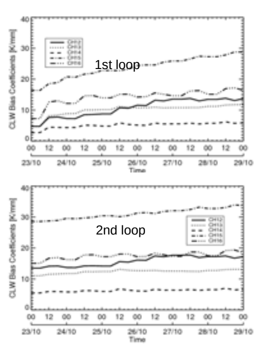


Ascending: black
Descending:Blue

Spin-up of the bias coefficients



The background variance of coefficient of LWP predictor for F16 SSMIS channel 12 during the spin-up.



Spin-up of the bias coefficients

4. Validation of Bias Correction

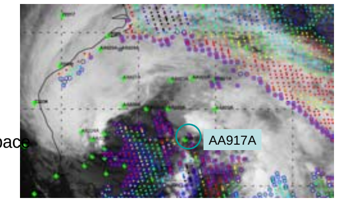
$$H(\mathbf{x}_b-\boldsymbol{\varepsilon}_b)=\mathbf{o}-\mathbf{o}_b$$

$$-H\boldsymbol{\varepsilon}_b=\mathbf{o}-H\mathbf{x}_b-\mathbf{o}_b$$

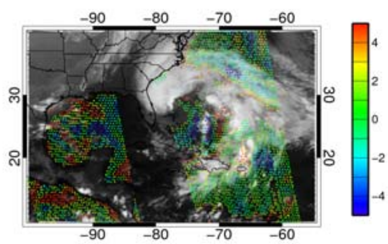
Collocated independent unbiased obs.

-map the background error to radiance space

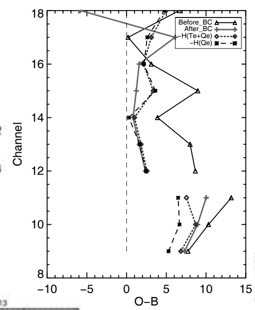
Using observation operater H

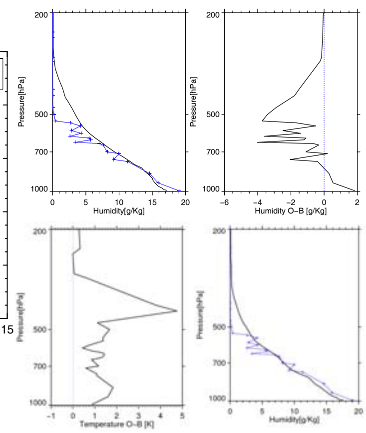


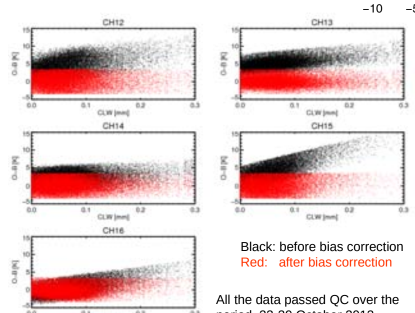
Dropsonde observations at 00Z Oct. 27,2012



O-B of F16 SSMIS CH14(22GHz,V) passed QC

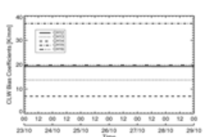




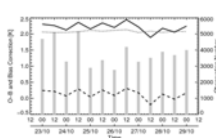


Black: before bias correction
Red: after bias correction

All the data passed QC over the period 23-29 October 2012



Time evolution of LWP coefficients in Hurricane Sandy Experiments.



Solid: O-B before bias correction
Dotted: bias correction
Dashed: O-B aftre bias correction
Grey bar: assimilated obs. number

USING ALL AVAILABLE INFORMATION

5. Results and Discussion

-Background term for observation bias estimation

$\gamma^2[b(\mathbf{x},\boldsymbol{\beta})-\mathbf{b}_0]^T\mathbf{R}_b^{-1}[b(\mathbf{x},\boldsymbol{\beta})-\mathbf{b}_0]$

-Uncertainty of observation operator and calibration

- channel, scene temperature

- pre-lauch and on-orbit

-Adaptive update of the bias correction coefficients

$(\boldsymbol{\beta}-\boldsymbol{\beta}_b)^T\mathbf{B}_\beta^{-1}(\boldsymbol{\beta}-\boldsymbol{\beta}_b)$

-Validation of bias estimation and correction

-collocated independent unbiased observations

-inter-comparison among operational NWP centers

-NWP,CLIMATE, RT and Calibration GROUP

- characterize the uncertainties of the bias correction

- physical based observation bias model

Bias Correction + RT + Calibration

REGIONAL +GLOBAL

NWP+CLIMATE

Acknowledgements This study was supported by funding from the International S&T Cooperation Program of China(ISTCP) under Grant no. 2011DFG23210.

Reference

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