Improving the assimilation of CrIS and IASI surface-sensitive radiances over land in the NASA GMAO GEOS data assimilation framework

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INTRODUCTION

- Satellite Infrared radiances contain a wealth of information on the Earth's environment including its atmosphere and different surface properties. Their usefulness in generating quality data assimilation analyses has been demonstrated in numerous studies in the past. However, the potential of IR radiances to further improve the quality of the data assimilation is still not significant, especially surface-sensitive IR measurements. For example, measurements over land are not optimally assimilated currently in the GMAO GEOS system, due to large uncertainties in our knowledge of the surface conditions. In this study, we explore how the use of inverted Land Surface Temperature (LST) and accounting for the consistency between LST and the surface emissivity can affect the use and assimilation of IR data and therefore improve the quality of the analysis.
- The initial focus of this study is to enhance the use of the Infrared Atmospheric Sounding Interferometer (IASI) and Cross-track Infrared Sounder in the NASA GEOS data assimilation framework. We will extend the limited number of IR observations currently assimilated over land. In this work, we specifically propose to study the impact of retrieved LST from IASI and CrIS surface-sensitive channels on the quality of the analysis generated by the GEOS system in clear sky conditions.

Overview of Retrieved LST from CrIS and IASI

I. Problematic

- Land surface temperature forecasts are not yet realistic enough to use the IR information in the lower troposphere and near the surface above continents.
- Surface emissivity and cloud detection problems.

II. Challenges

- Identification of the appropriate CrIS and IASI surface-sensitive channels to retrieve LST.
- Study the impact of these retrieved LST on the simulation and assimilation of CrIS and IASI in the GEOS model.

III. LST retrievals from CrIS and IASI

Radiative transfer equation inversion

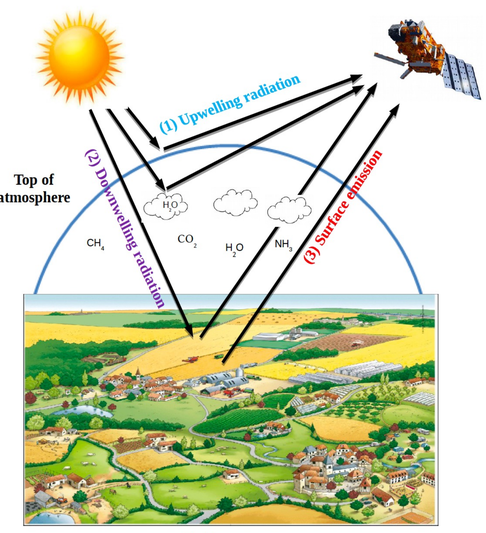
[Karbou et al., 2006]

$$LST = L\left[\frac{R_\nu(\theta) - L_\nu^{\uparrow}(\theta) - \Gamma_\nu(\theta)(1-\varepsilon_\nu(\theta))L_\nu^{\downarrow}(\theta)}{\Gamma_\nu(\theta)\,\varepsilon_\nu(\theta)}\right]^{-1}$$

where L is the Planck function. $\varepsilon\nu$, $\Gamma\nu$, $L^{\uparrow}\nu$ and $L^{\downarrow}\nu$ represent the surface emissivity, the atmospheric transmission, and the atmospheric upwelling and downwelling radiances at channel ν, respectively.

Atmospheric transmission, atmospheric upwelling and downwelling radiances are computed using the CRTM.

Use of:
NPOESS* type-based IR emissivity



*National Polar-orbiting Operational Environmental Satellite System

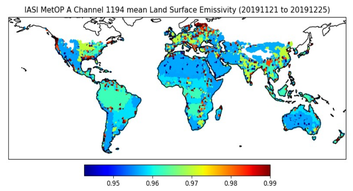
Identification of the appropriate CrIS and IASI surface-sensitive channels to retrieve LST

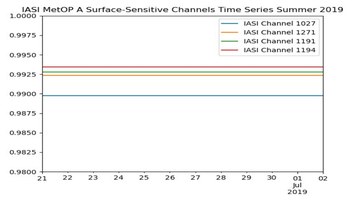
IASI and CrIS surface-sensitive channels

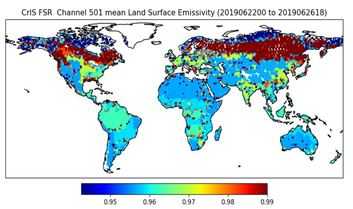
IASI			
Channels	Level	Wavenumber (cm^{-1})	Wavelength (μm)
1027	201	901.50	11.09
1271	211	942.50	10.61
1191	208	943.25	10.60
1194	209	962.50	10.39

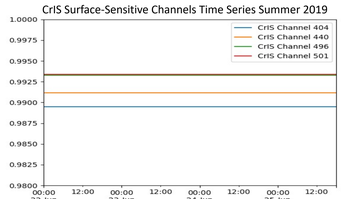
CrIS			
Channels	Level	Wavenumber (cm^{-1})	Wavelength (μm)
404	195	901.87	11.08
440	200	924.37	10.81
496	217	959.37	10.42
501	219	962.50	10.38

Land surface emissivity at IASI and CrIS selected channels









Some conclusions

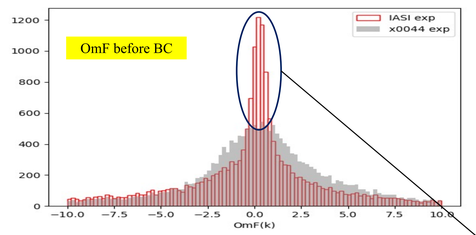
1. IASI and CrIS surface-sensitive channels:
   - IASI channel 1027 (11.09 μm) and CrIS channel 404 (11.08 μm) have the large surface emissivity variation over land types.
   - IASI channels 1191 and 1271 (10.60 μm and 10.61 μm, respectively) and CrIS channel 440 (10.81 μm) are quite similar.
   - IASI channel 1194 (10.39 μm) and CrIS channels 496 and 501 (10.42 μm and 10.39 μm, respectively) have the less emissivity variation across surface types.

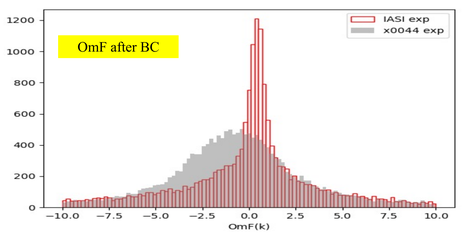
2. NPOESS type-based spectra LUT used is fixed. It is just a function of frequency and surface type.

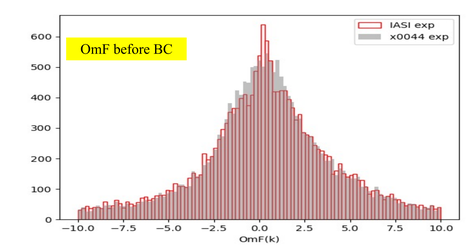
3. After several comparisons of IASI and CrIS surface sensitive channels, IASI channel 1194 and CrIS channel 501 was chosen to retrieve LST in the NASA GEOS.

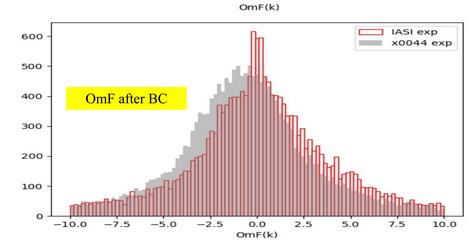
Results

Histograms of IASI Channel 1027 OmFs only over land (shaded: using model LST)



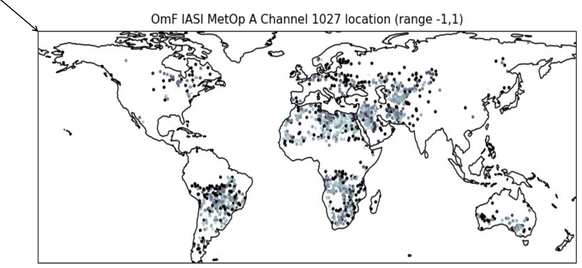






If LST is retrieved using radiances with |OmF|<10K

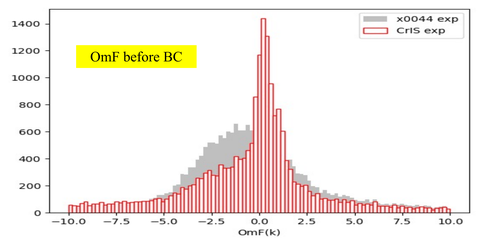
- LST is retrieved from IASI channel 1194 and CrIS channel 501 (both at 962.5 cm^{-1}/10.39μm) and compared with background LST (x0044 experiment).
- Red bars uses the retrieved LST. Grey bars are from x0044 using background LST. The figures show one week of results (20190622-20190628).
- The use of retrieved LST from IASI channel 1194 and CrIS channel 501 improved the OmFs of the other IASI/CrIS surface-sensitive channels by increasing the number of assimilated observation (specially over specific areas like Sahara).

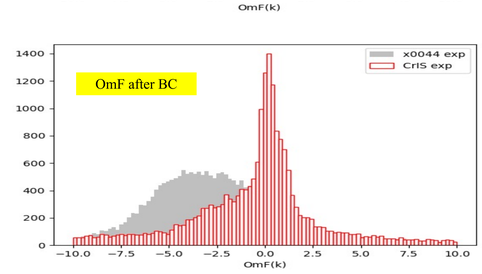


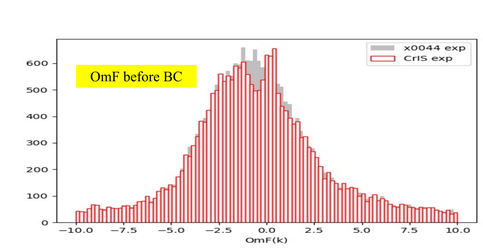
If LST is retrieved using radiances with |OmF|<1K

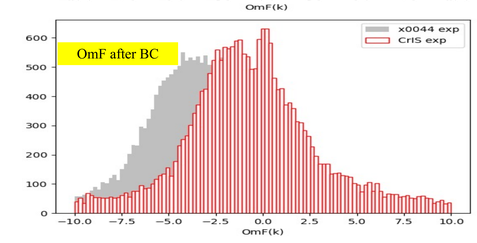
- By tightening the quality control from 10K to 1K, the number of assimilated observations reduces and OmFs from IASI or CrIS experiments are quite similar to OmFs of x0044.
- Bias correction (BC) needs some adjustment. BC coefficients from x0044 are not working well with the new experiment (e.g., IASI OmFs after BC are higher than OmFs before BC and need to be re-spinup. Not shown). CrIS is showing slightly better results using the same BC.
- The preliminary results are very encouraging. More experiments need to be done to determine the appropriate quality control and bias correction to use while retrieving LST from IASI and CrIS in the GEOS data assimilation framework.

Histograms of CrIS Channel 404 OmFs only over land (shaded: using model LST)









Summary and future work

- Assimilating surface-sensitive radiances over land is still challenging: (1) large uncertainties of the land physical surface emissivity model used in the CRTM, (2) Uncertainties of land surface state properties
- Selecting IASI surface-sensitive channel 1194 and CrIS surface-sensitive channel 501 to retrieve LST at locations where there is no cloud/precipitation. The difference between background LST and retrieved LST can be larger than 6K.
- Next step will be taking closed look to quality control and bias correction. Also, evaluate statistics of simulated radiances with NPOESS type-based IR emissivity.

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