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Toward improving the assimilation of IASI and CrIS radiances over land into the NASA GEOS: LST Inversion and Validation

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Problematic

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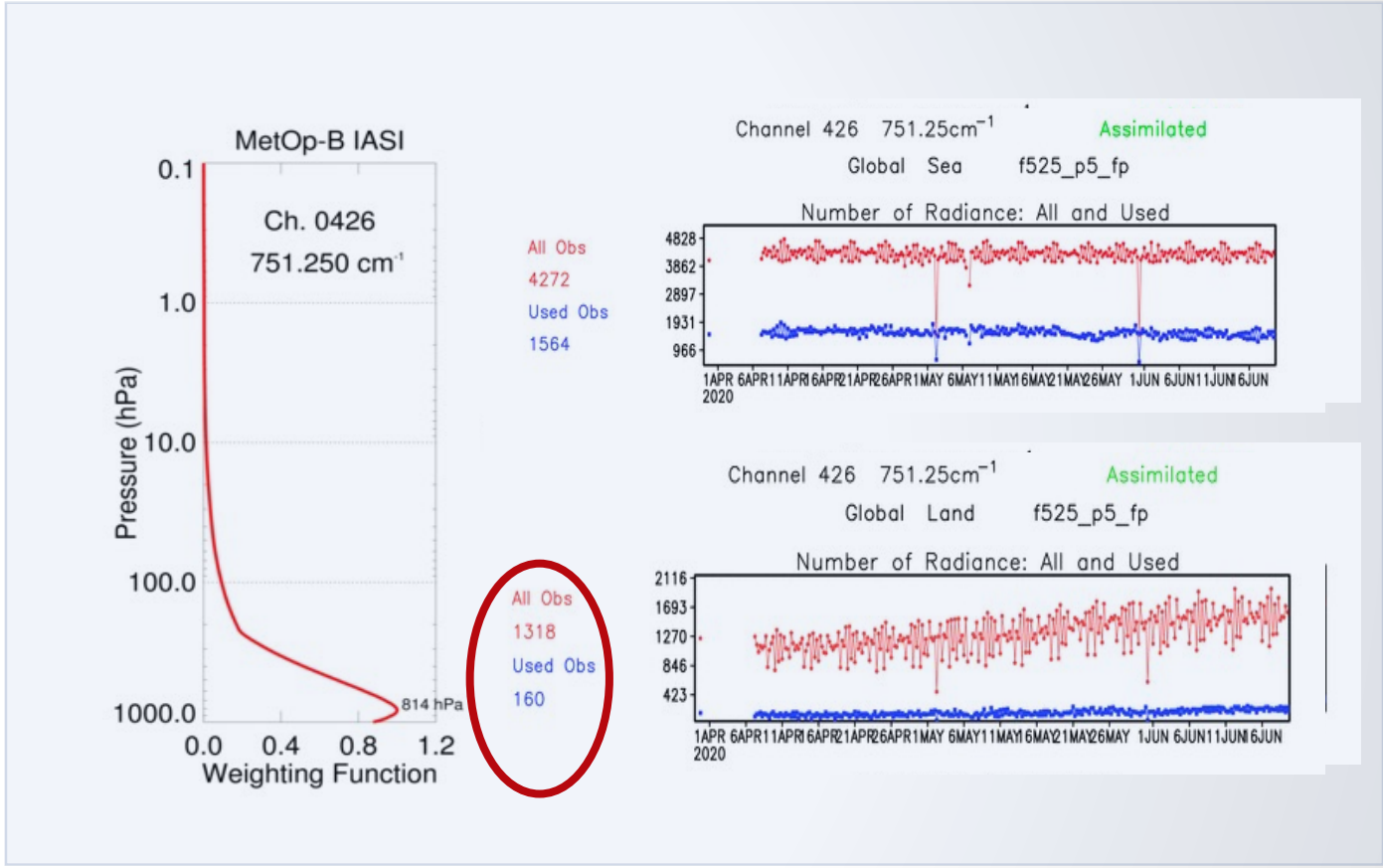
Assimilating surface-sensitive radiances over land is still challenging:

- Large uncertainties of the land physical surface emissivity model used in the CRTM
- Uncertainties of land surface state properties

- Currently very few IR radiances are assimilated over land.
- Large number of radiances are rejected by
  - Emissivity sensitivity check
  - Cloud detection check



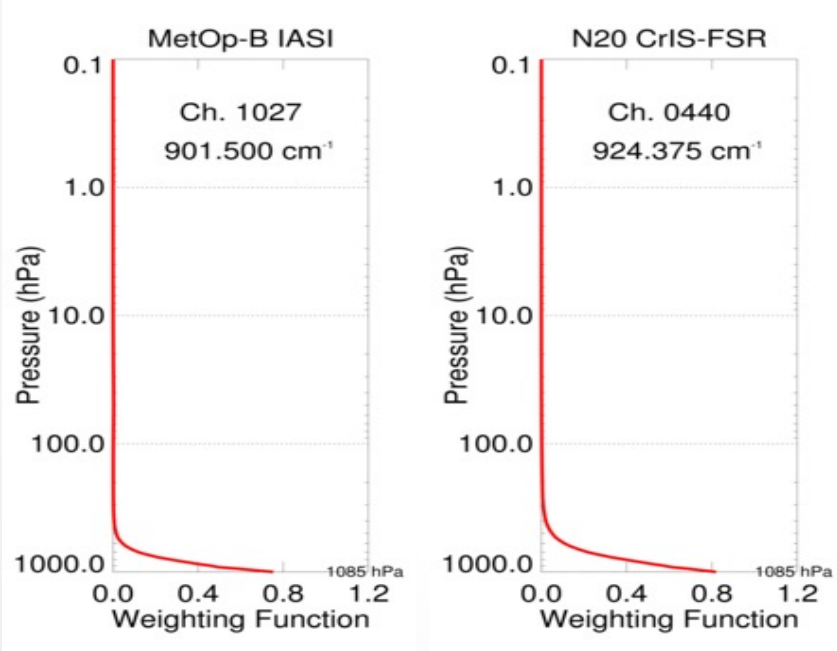
CrIS surface-sensitive channels are not assimilated yet over no-water surfaces in NASA GEOS.

Challenges

Enhancing the use of IR hyperspectral radiances over land in the NASA GEOS,

by studying the impact of retrieved LST from IASI channel 1194 and CrIS channel 501 (both at 962.50 cm^{-1}, 10.39 μm) on the simulation and assimilation of IASI and CrIS in the NASA GEOS.

The following results are focused on IASI surface sensitive channel 1027 and CrIS surface sensitive channel 440



References: IASI and CrIS channels selection to retrieve LST

Boukachaba, N., Zhu, Y., Pawson, S., 2022. "Toward enhancing the use of IASI and CrIS surface-sensitive radiances over land in the NASA GMAO GEOS data assimilation framework". Oral presentation, AMS Collective Madison Meeting. Topic: Satellite Applications for Hydrological and Land Science, Aug 09th, 2022, Madison, WI, USA.

Boukachaba, N., Zhu, Y., Pawson, S., 2021. "Improving the assimilation of IASI surface-sensitive radiances over land in the NASA GMAO GEOS data assimilation framework". Poster at the AGU Fall Meeting (virtual), 13-17 December, USA.

Boukachaba, N.: Contribution of IASI IR hyperspectral satellite observations over land in the convective scale AROME model., Ph.D. thesis, INP Toulouse, https://oatao.univ-toulouse.fr/19257/

LST retrievals from IASI and CrIS
(Single-Channel method)

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Radiative transfer equation inversion

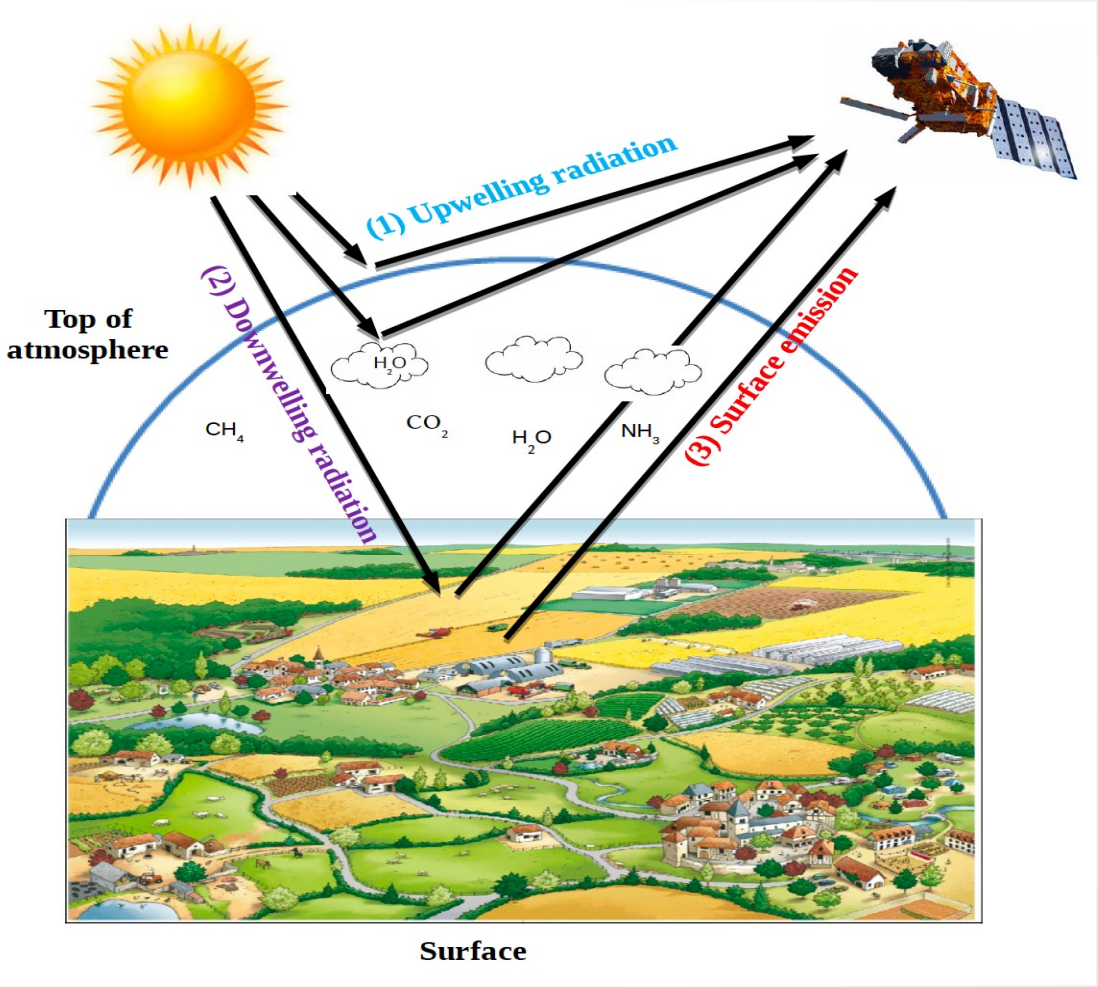
[Karbou et al., 2006]

$$LST = L\left[\frac{R_v(\theta) - L_v^{\uparrow}(\theta) - \Gamma_v(\theta)(1-\varepsilon_v(\theta))L_v^{\downarrow}(\theta)}{\Gamma_v(\theta)\varepsilon_v(\theta)}\right]^{-1}$$

where L is the Planck function. ε_v, Γ_v, $L_v^{\uparrow}$ and $L_v^{\downarrow}$ represent the surface emissivity, the atmospheric transmission, and the atmospheric upwelling and downwelling radiances at channel v, respectively.

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

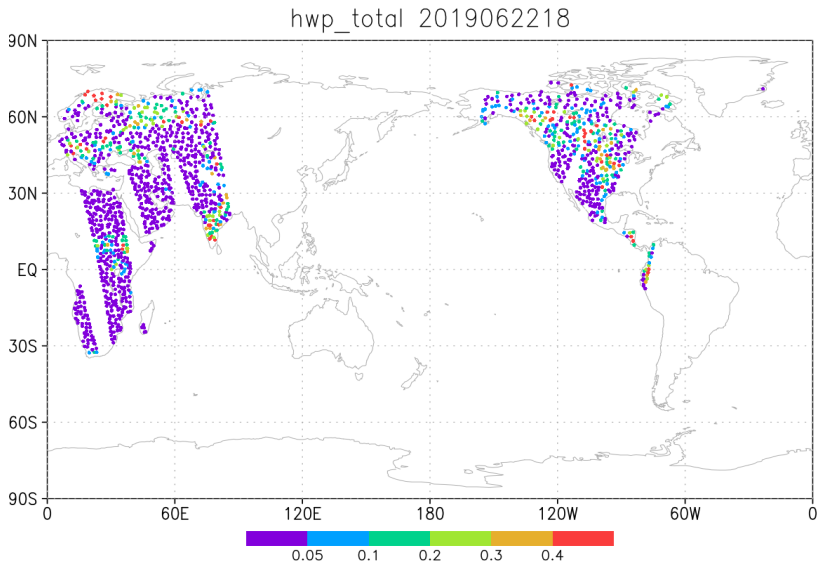
Use of:
NPOESS* type-based IR emissivity

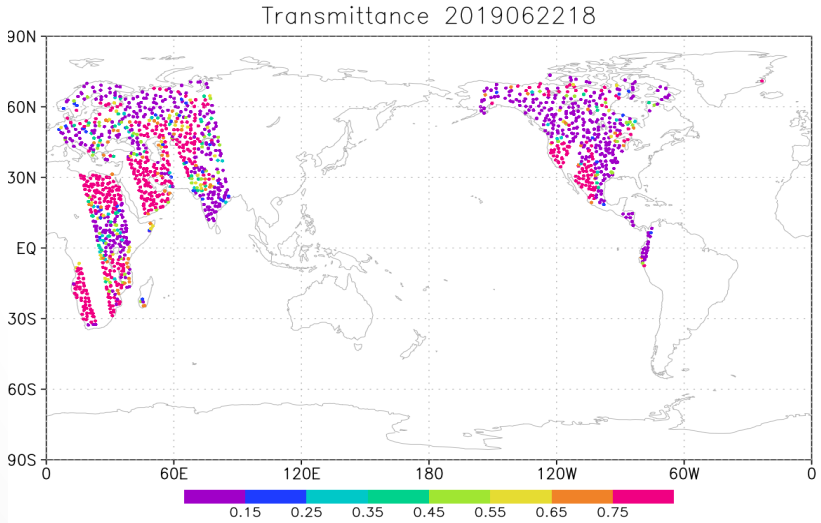


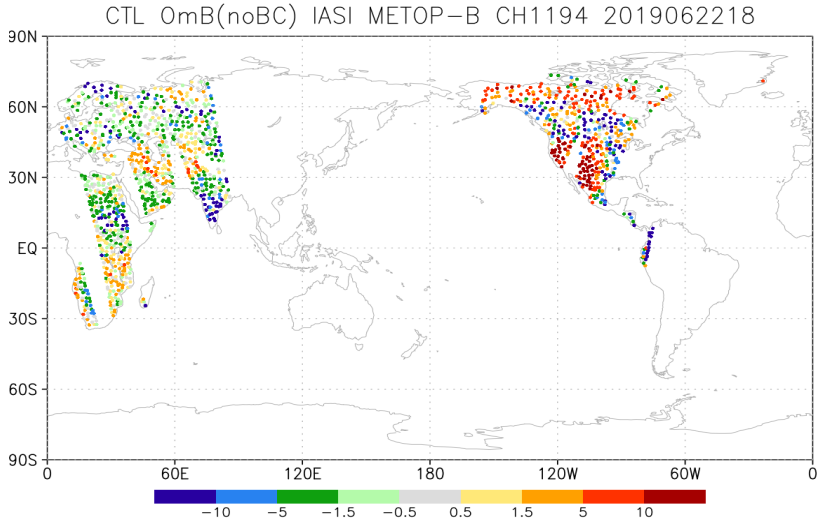
*National Polar-orbiting Operational Environmental Satellite System

Quality control of radiances used for LST retrieval

- Gross check filter (absolute difference between background* and observation is less than 5K),
- Vertically integrated hydrometeors present in the measurements are less than 0.1 kg/m**2,
- Atmospheric transmittance values are larger than 0.15,
- Difference between the background LST and the retrieved LST are less than 10 K.







*Short-range forecast of the GEOS

Courtesy of Y. Zhu

LST retrievals: IASI results

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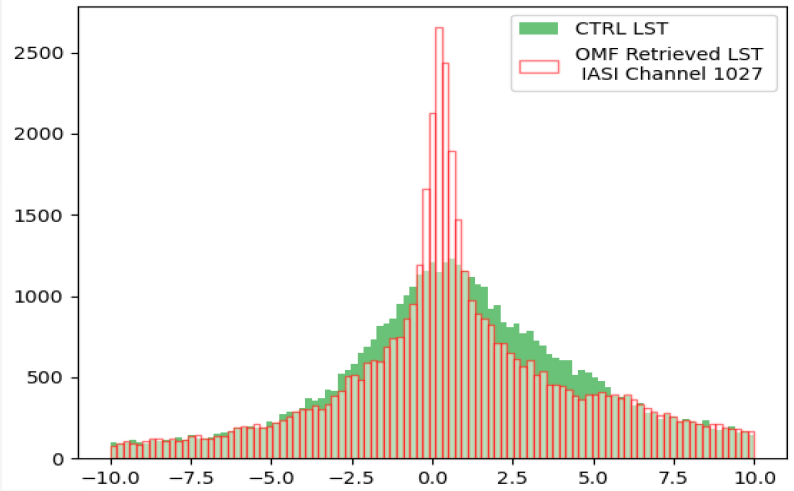
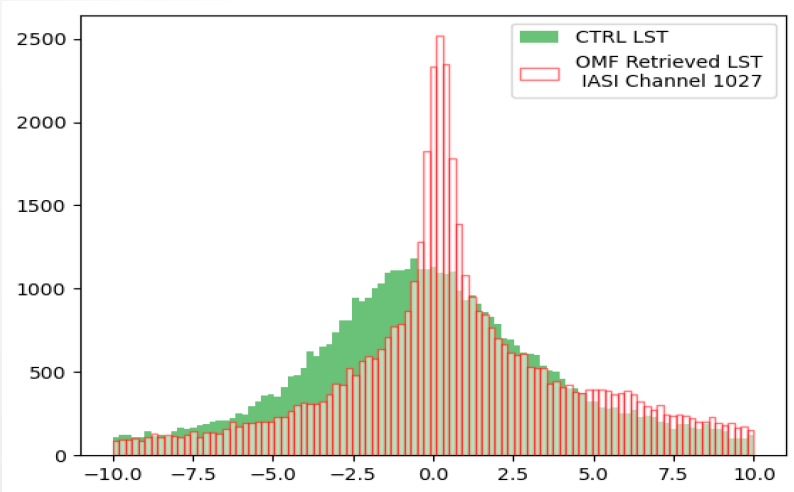
Histogram OmFs CTRL* LST vs OmFs LST at IASI Channel 1027 Over land only for all data (2019062200-2019063018)

OmF before BC

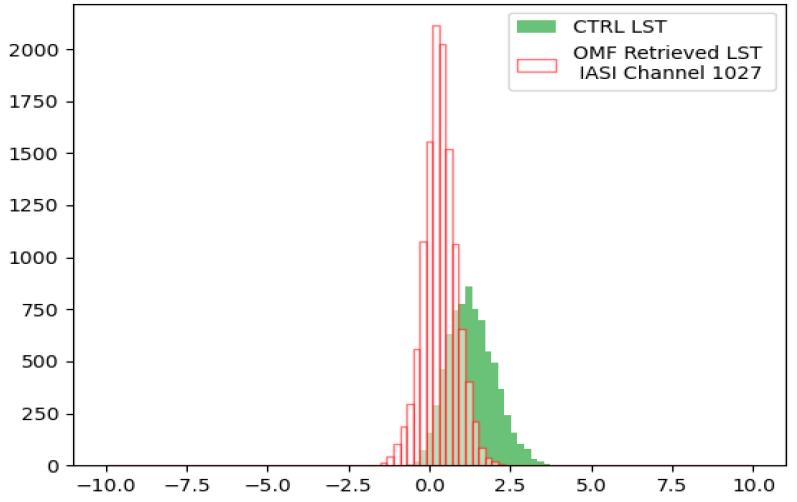


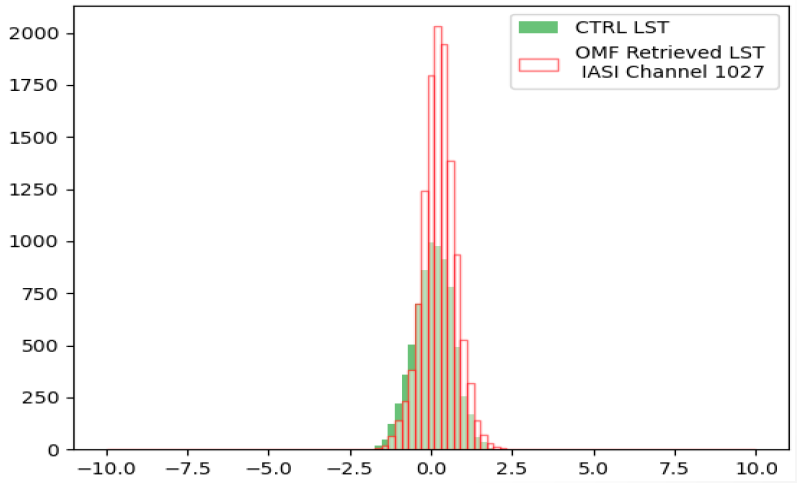
OmF after BC



*using background LST

Histogram OmFs CTRL LST vs OmFs LST at IASI Channel 1027 Over land only for data passing quality control (2019062200-2019063018)





More data assimilated in the new experiment with OmF around zero.

OmFs CTRL LST vs OmFs Retrieved LST from IASI 2019070100-2019070118

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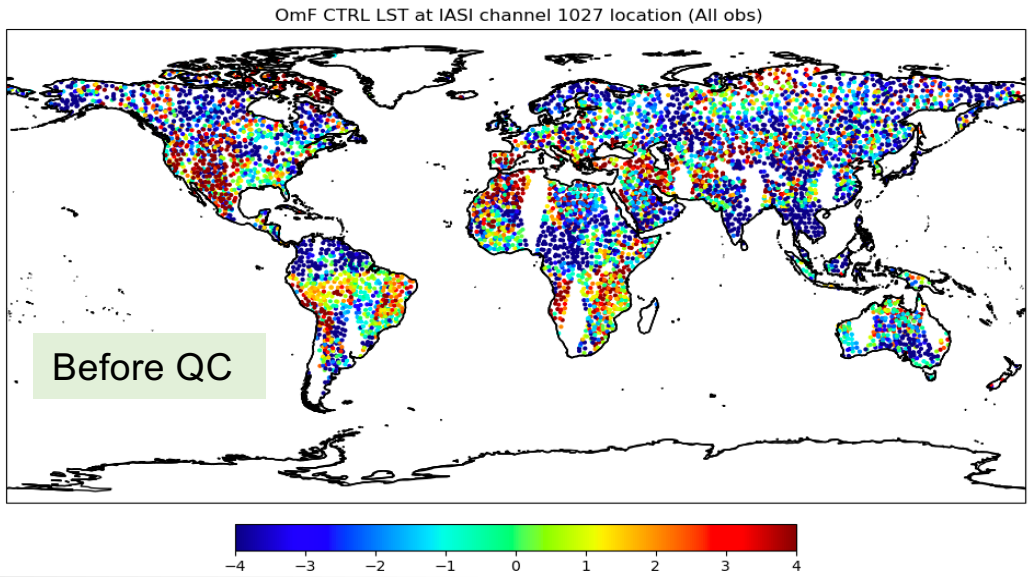
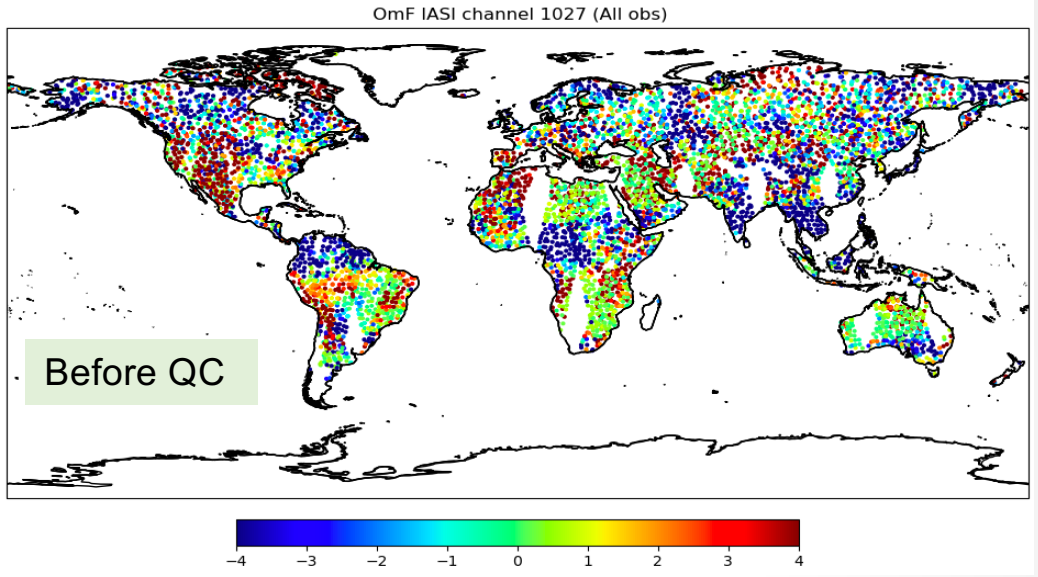
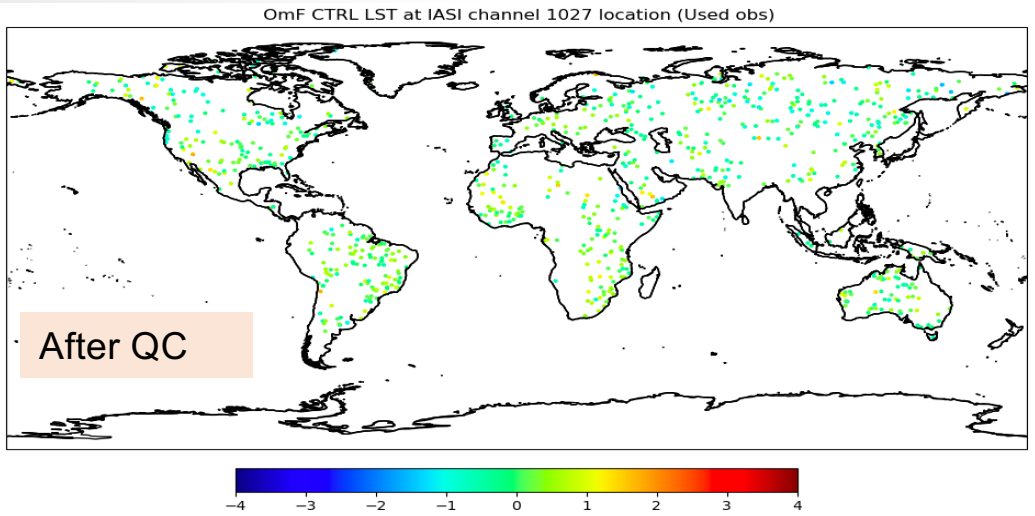
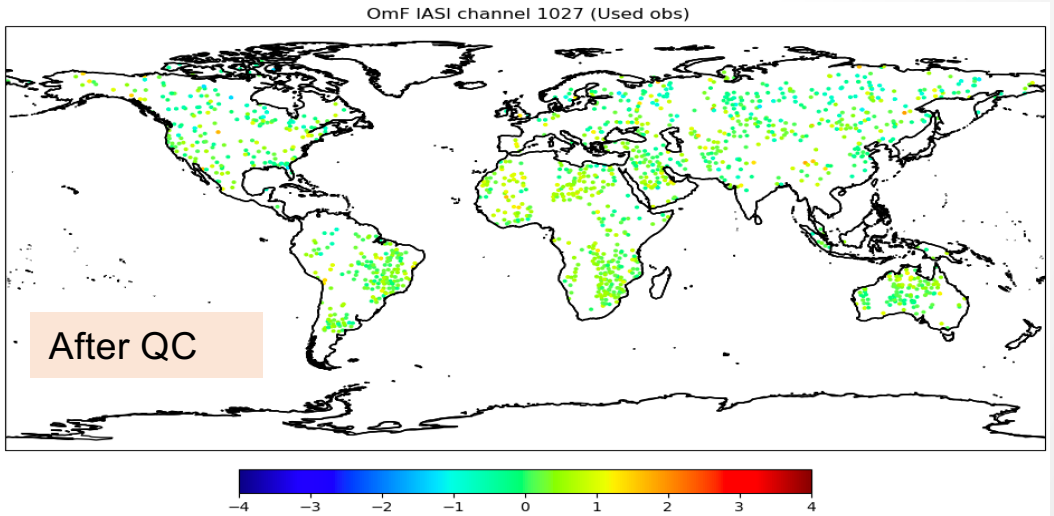
OmF CTRL LST

OmF IASI LST









The new experiment generates more OmFs around zero.

Assimilated LST

CTRL LST vs Retrieved LST from IASI channel 1027 for data passing QC (2019070100-2019070118)

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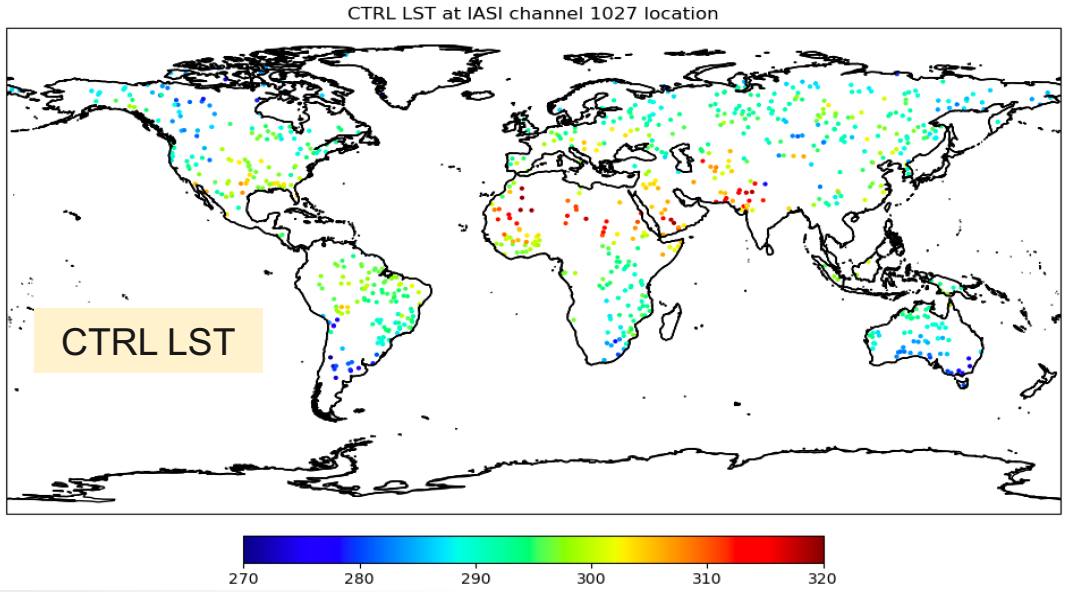
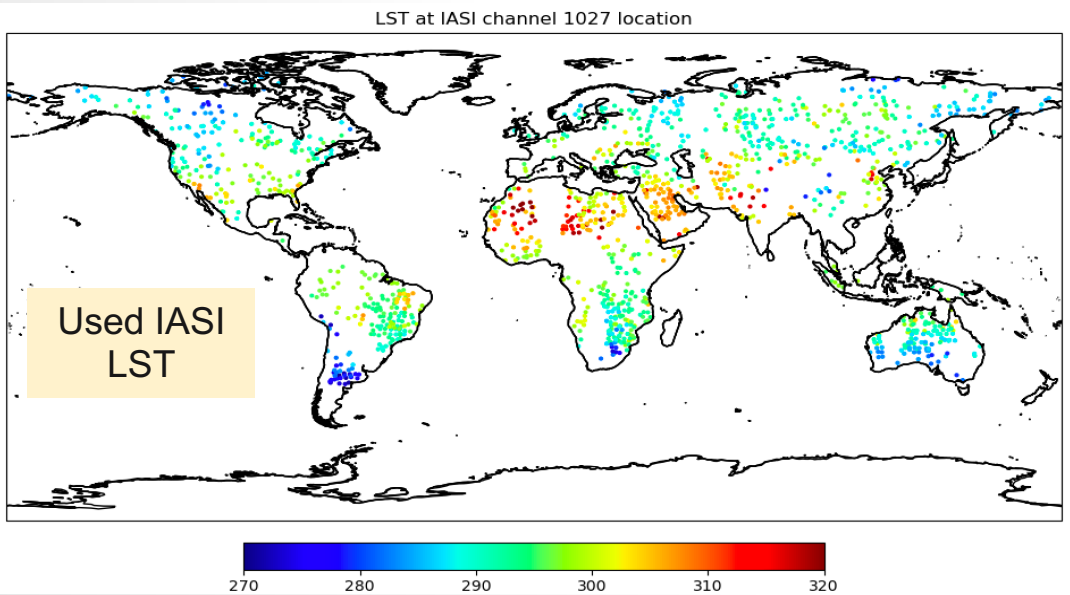
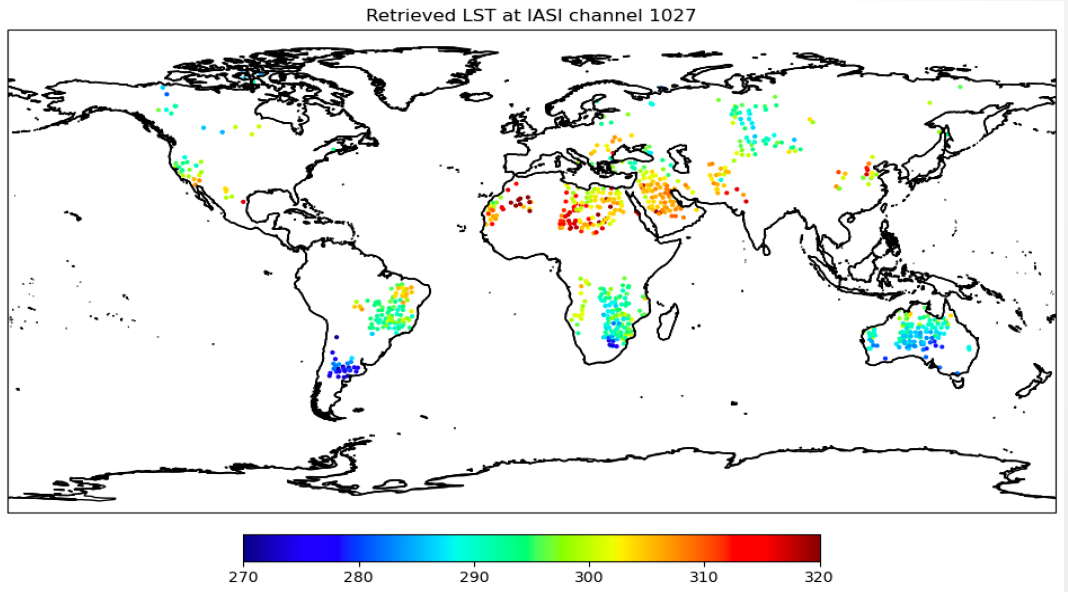


Increase the number of assimilated observations over specific region over land in the new experiment.

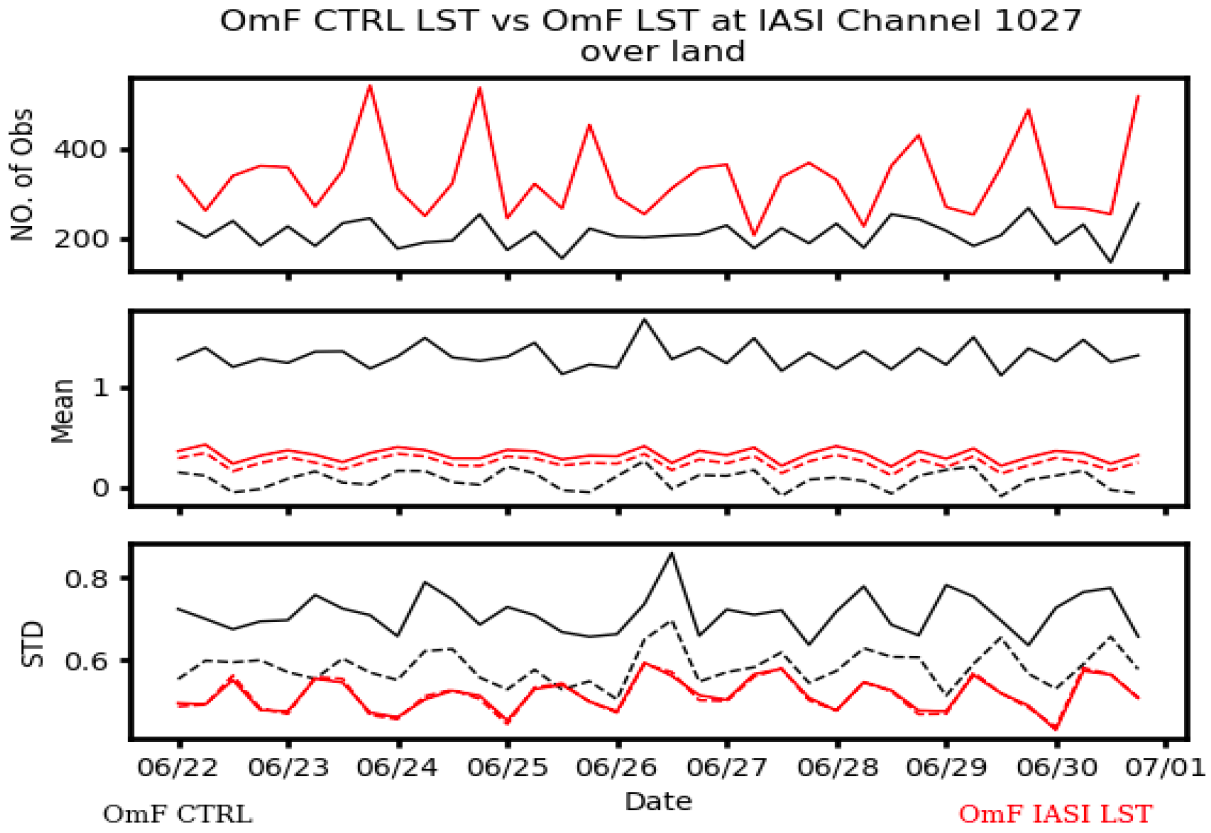
LST can only be retrieved at locations where there is no cloud/precipitation. Otherwise, CTRL LST is used.



Retrieved LST after QC



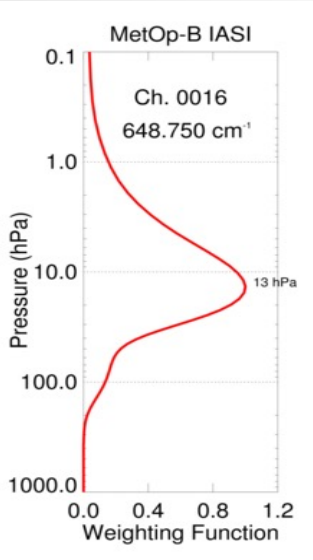
Time series OmF CTRL LST vs OmF LST at IASI channel 1027 over land (one week)

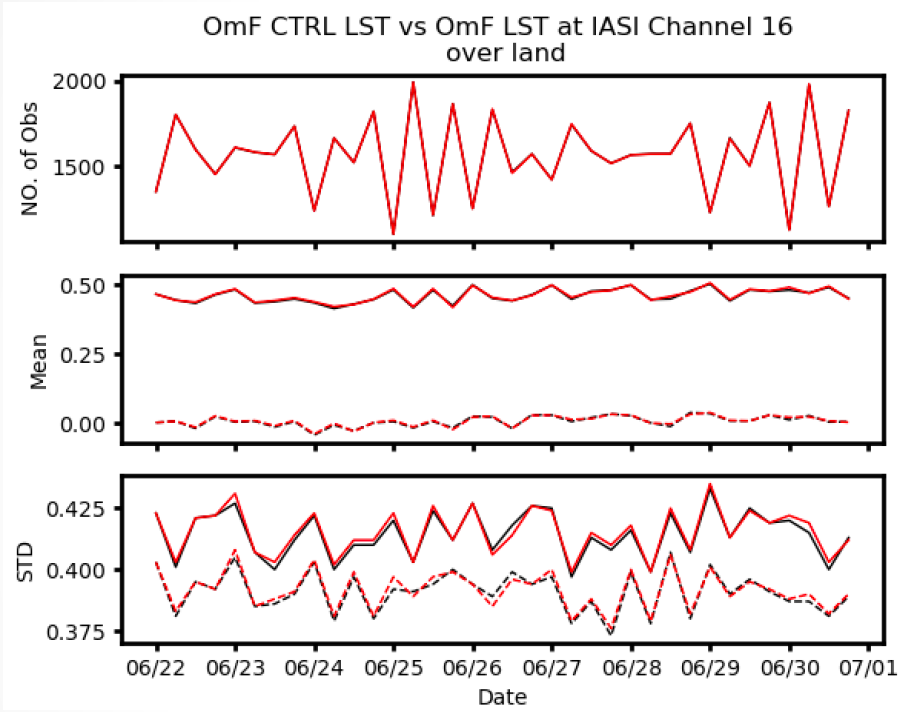


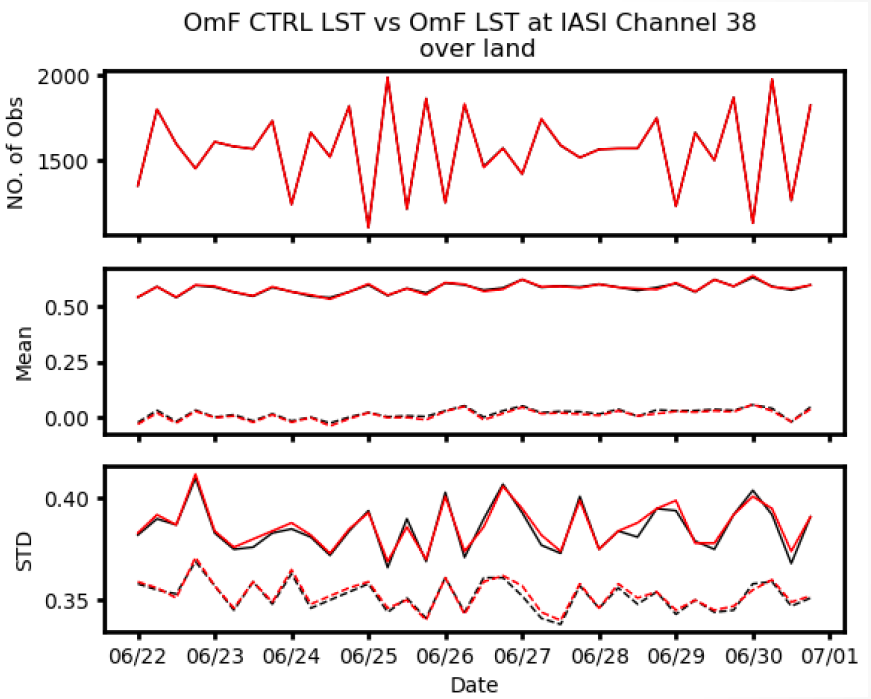
___ Before BC
----- After BC

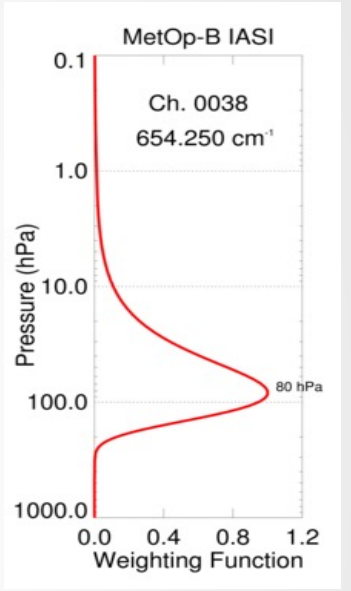
Better results in the new IASI experiment.

Time series OmF CTRL LST vs OmF LST at IASI channels 16 and 38 over land (one week)









Neutral impact on mid and high picking channels

___ Before BC
----- After BC

LST retrievals: CrIS results

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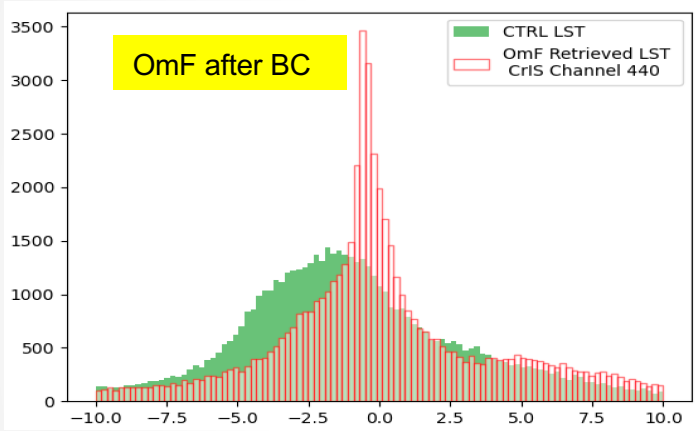
Activating the assimilation over land of CrIS surface-sensitive channel in the GEOS without perturbing the system.

NO CrIS data is currently assimilated over land in the GEOS.

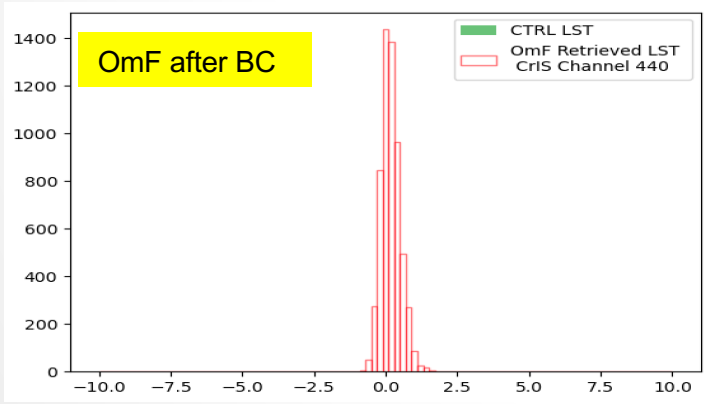
Histogram OmFs CTRL LST vs OmFs LST at CrIS Channel 440
Over land only (2019062200-2019063018)

Before QC



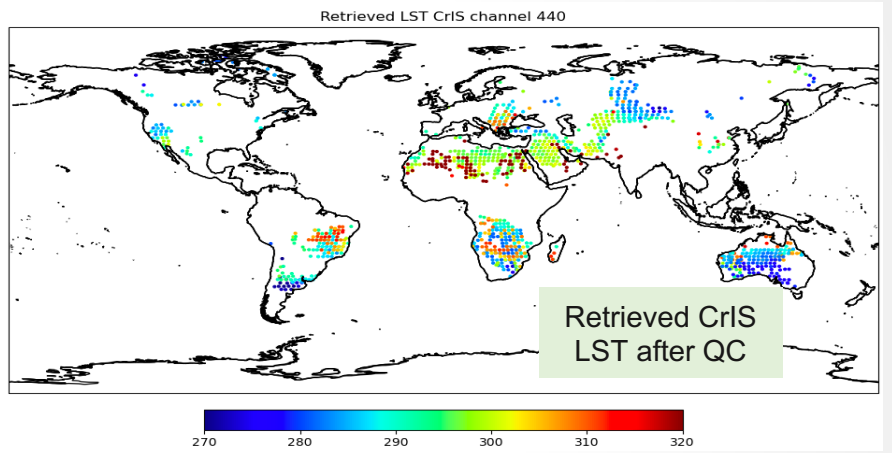
BC doesn't work in CTRL experiment but works well in CrIS experiment due to the adjustment made to BC.

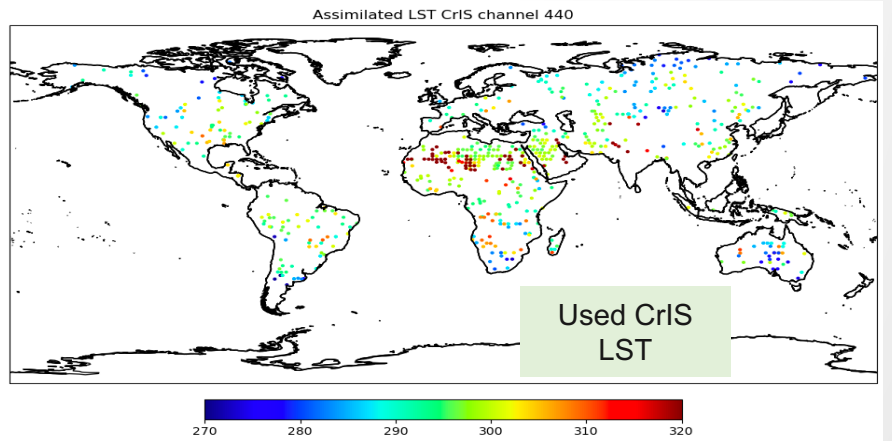
After QC



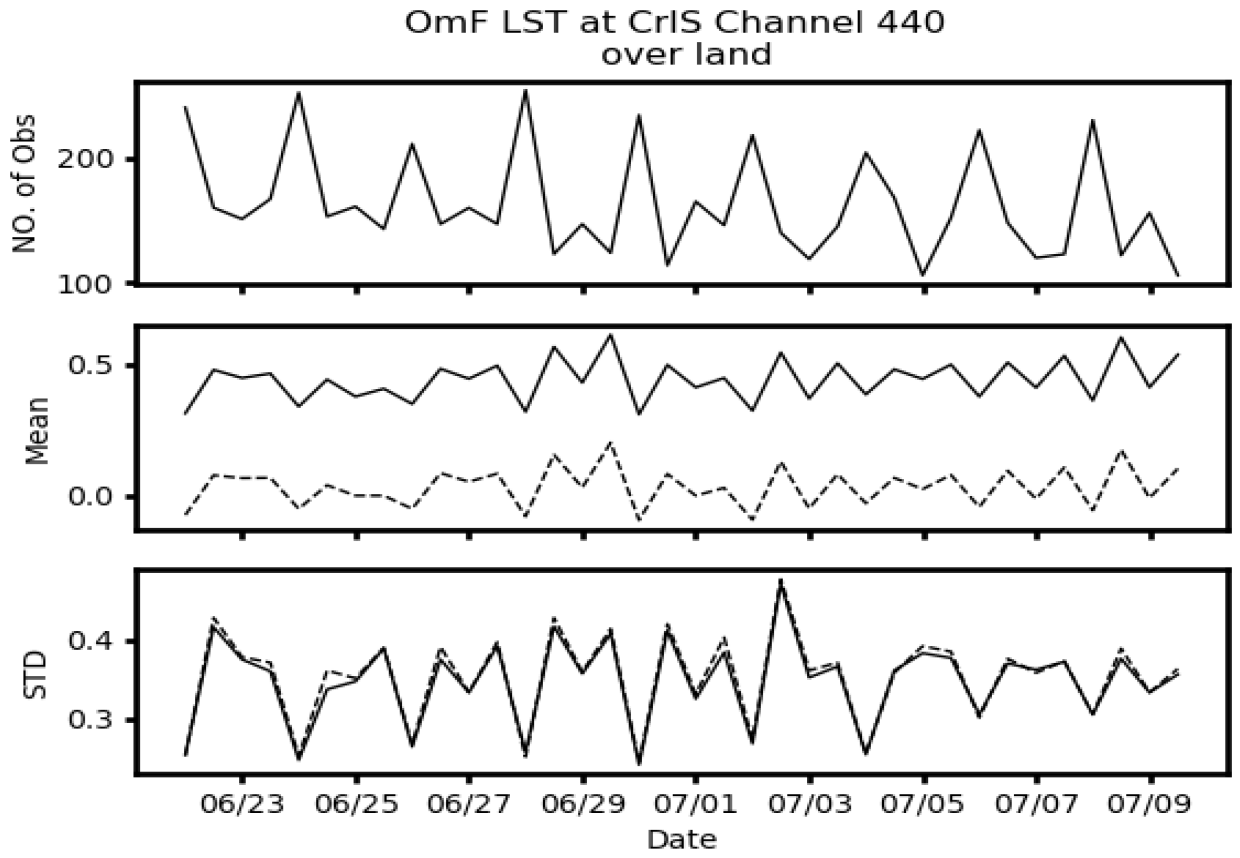
No CrIS data are passing QC over land in the CTRL.

(2019070100-2019070118)





Time series OmF CTRL LST vs OmF LST at CrIS channel 440 over land (one week)



Good results in the new CrIS experiment.

___ Before BC
----- After BC

Some conclusions and future work

The results of assimilating IASI surface-sensitive channel 1194 and CrIS surface-sensitive channel 501 over land in the NASA GEOS model is very encouraging.

The next step of this study is to assess the impact of these retrieved LST from IASI and CrIS on the analysis and the medium range forecast.

LST retrievals from IASI and CrIS will be validate using ERA5 LST product.

Thank you

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Abstract

Title: Toward improving the assimilation of IASI and CrIS radiances over land into the NASA GEOS: LST Inversion and Validation

Assimilating surface-sensitive radiances over land is still challenging for both infrared (IR) and microwave (WV) essentially because of the large uncertainties of the land physical surface emissivity model used in the CRTM and the uncertainties of land surface state properties. Currently very few IR radiances are assimilated over land in the NASA Goddard Earth Observing System (GEOS). Large number of radiances are rejected by the emissivity sensitivity check as well as the Cloud detection check. This study focuses on enhancing the assimilation of Infrared Atmospheric Sounding Interferometer (IASI) and Cross-track Infrared Sounder (CrIS) over land in the GEOS forecasting and data assimilation framework. To reach this goal, the Land surface Temperature (LST) is first inverted using IR radiances from IASI and CrIS selected channels to use it as surface boundary parameter for the assimilation of the rest of IASI and CrIS surface-sensitive channels. This work will present a full assessment of the quality of this LST by comparing it and its spatio-temporal variability to LST predicted by the GEOS model. The impacts on the quality of the resulting analysis and subsequent forecast will also be discussed.