Identifying and Quantifying Temperature Dependent Biases in the CRTM Ocean Emissivity Model Using The NCEP GDAS.

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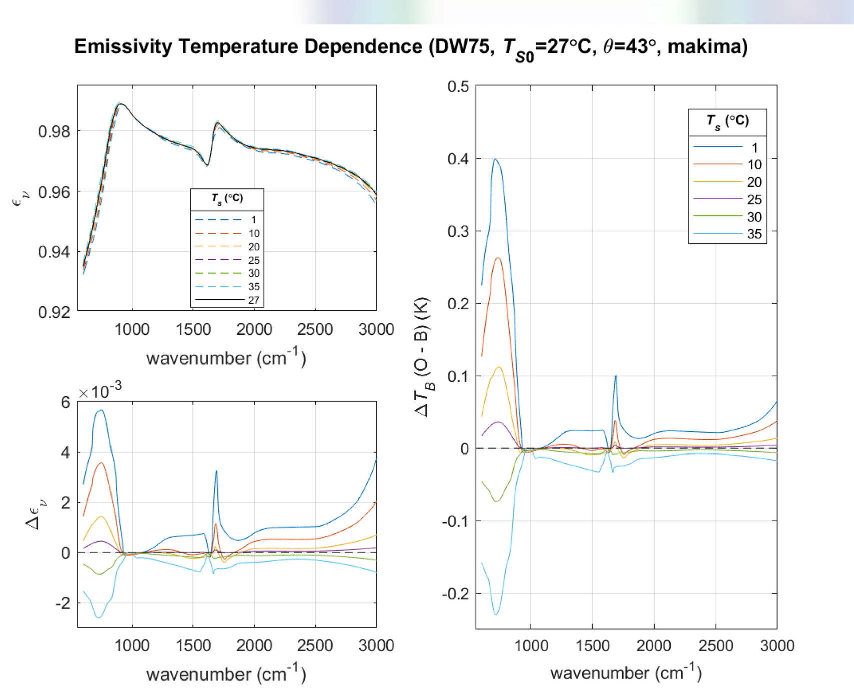
Introduction

An accurate ocean infrared surface emissivity model is an integral part of the National Centers for Environmental Prediction (NCEP) Global Data Assimilation System. It is an anchor point for the variational bias correction scheme and crucial for the surface and near-surface infrared radiance assimilation. Identifying, quantifying and reducing the systematic errors in the ocean surface emissivity model will improve the current assimilation system and the future coupled ocean-atmosphere assimilation system.

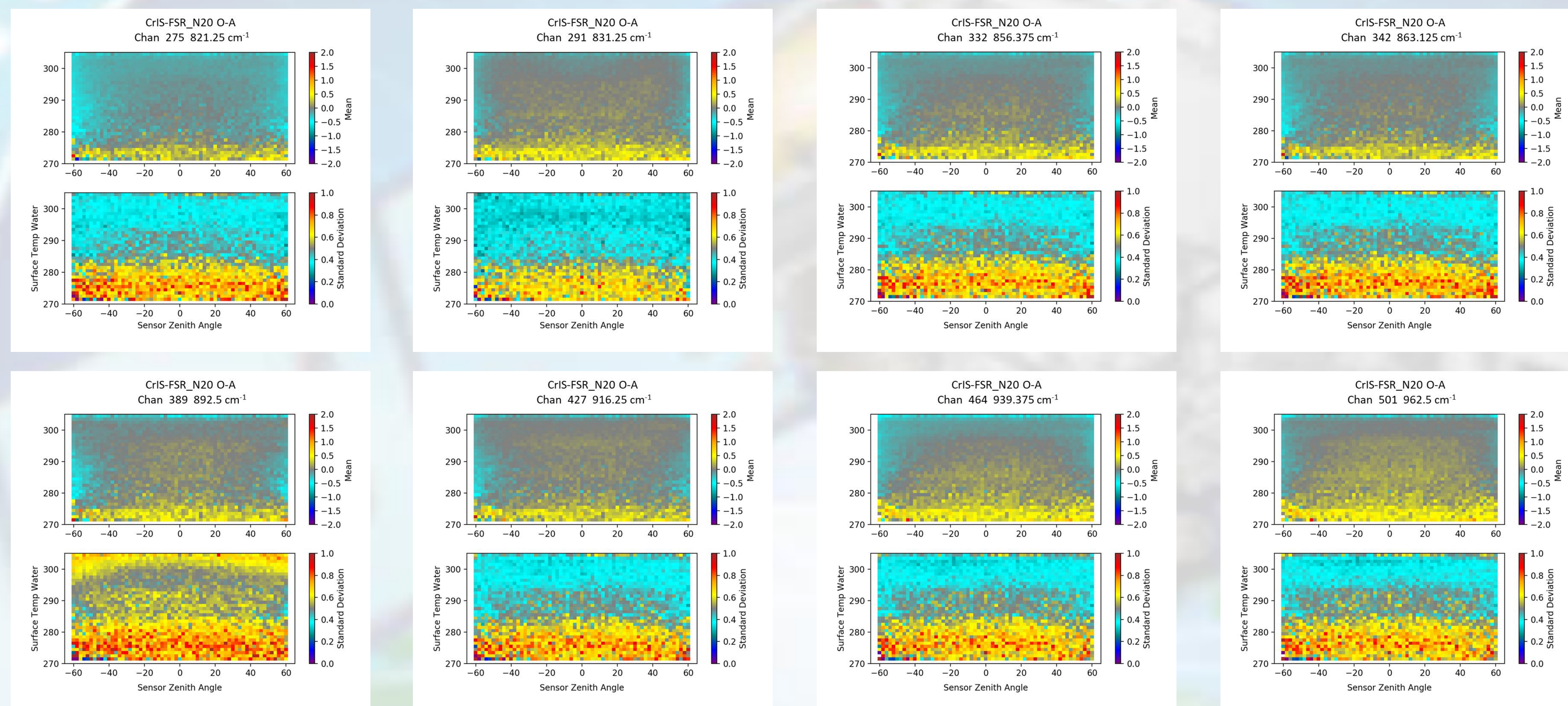
Specifically, we have identified and quantified two types of temperature-dependent errors which are not fully accounted for in the current Community Radiative Transfer Model (CRTM) IR Sea Surface Emissivity (IRSSE) model, 1) the spectral temperature dependence and 2) the scan angle dependence. The spectral temperature dependence is primarily within the 800–900 cm -1 window region, where previous studies found the actual emissivity to decrease at colder temperatures. The temperature dependence is also found to be exacerbated at large scan angles. Hyperspectral radiances from the Cross-track Infrared Sounder (CrIS) and Infrared Atmospheric Sounding Interferometer (IASI) instruments will be used to compute observation minus analysis (O − A) statistics for the range of scan angles and ocean surface temperatures to quantify temperature-dependent emissivity biases. We find significant, first-order temperature-dependent biases in global O − A statistics, indicating that ocean emissivity models (e.g., the CRTM and SARTA IRSSE) will need to include temperature dependence.

Emissivity Temperature Dependence

Small residual deficiencies still exist in the current IRSSE model under certain conditions. Findings by Nalli et al. (2008) and more recently by Liu et al. (2017) found a significant temperature dependence on surface emissivity which could be as much as 1K. These temperature dependencies are in the 800 – 900 cm^{-1} region.



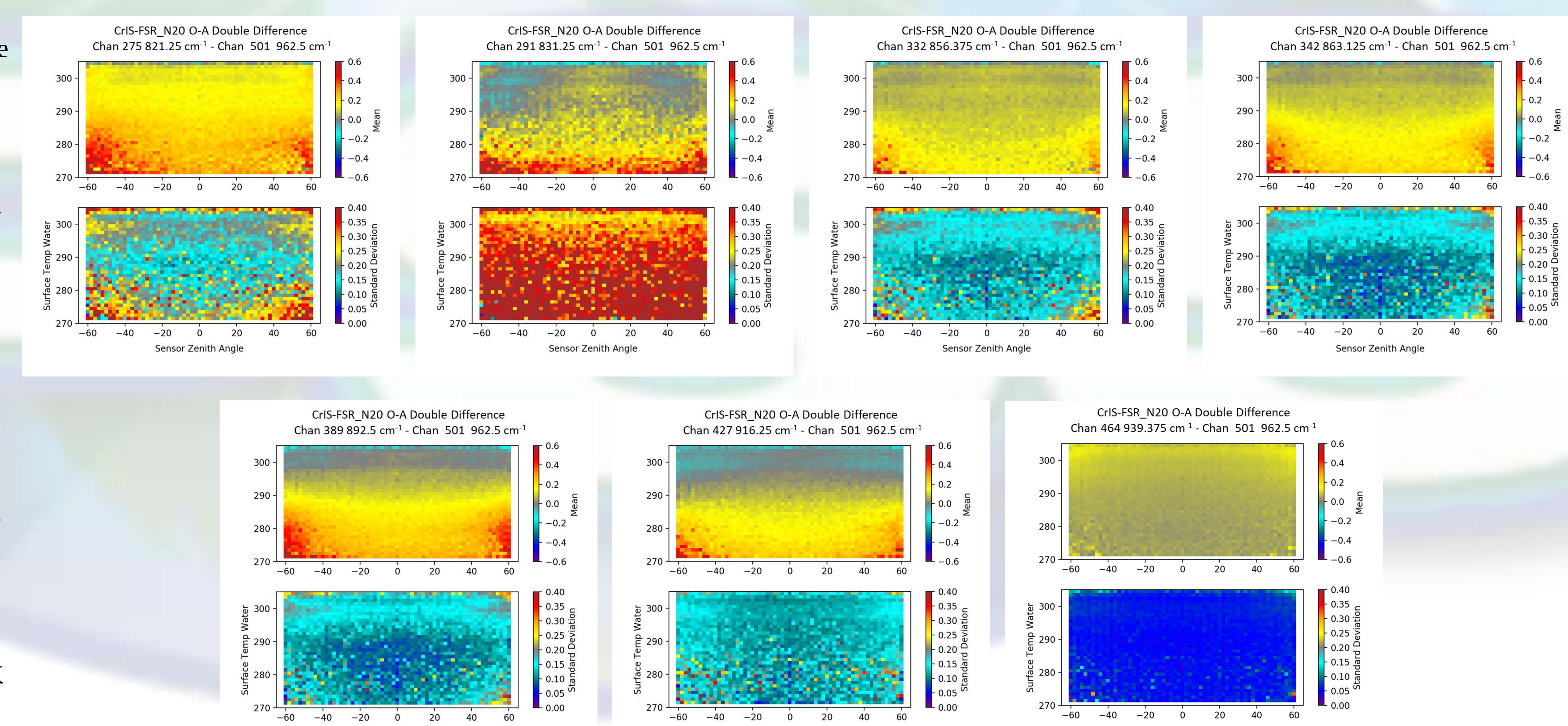
2-Dimensional Observation – Analysis (O-A) statistics for various CrIS channels showing the emissivity errors of temperature (vertical) and scan angle (horizontal). Top panels are temperature bias. Bottom panels are temperature standard deviations. Colder ocean temperatures consistently have larger Brightness Temperature biases and larger fit errors. Data are for clear profiles from 15 July – 31 August 2019. O-A statistics from the low resolution Version 15.2.0 of NCEP's FV3GFS using the default Community Radiative transfer model's IR sea surface emissivity model.



Subtracting the O-A from two different channels, or double difference, minimizes the atmospheric and radiative transfer model errors and highlights the emissivity and scan angle differences between the two channels. Channels that are sensitive to temperature emissivity are subtracted from a channel that is not to highlight this error.

The top panels are O-A – O-A mean (bias) from a channel with temperature sensitive emissivity minus a channel which does not. Differences from top to bottom indicate the temperature sensitivity. The bottom panels are the O-A – O-A standard deviations. The standard deviations are expected to be relatively constant. The lower left plot is the O-A – O-A difference between two non-temperature dependent channels.

Significant surface temperature dependence is visible on the order of 0.5 K for most 800 – 900 cm^{-1} channels. Similar results are found for CrIS-FSR_NPP, IASI_MetOP-a and IASI_MetOP-b (not shown).

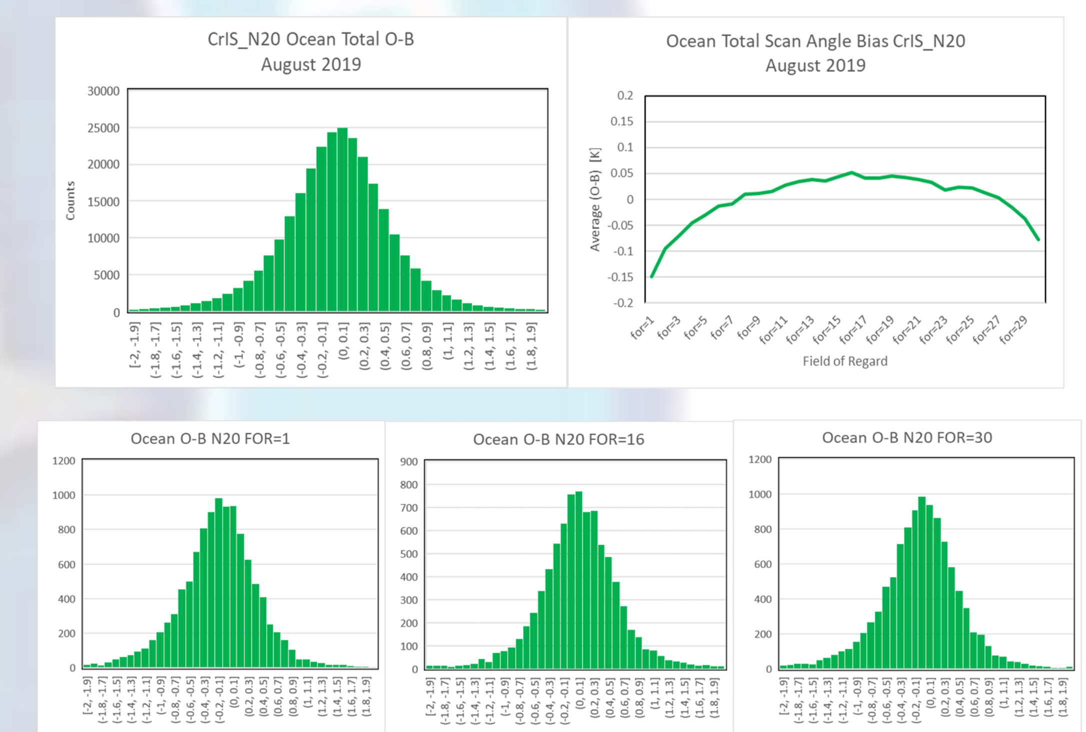


Clear Profile Determination

In the past, a major source of inconsistency has been the selection of clear profiles. Starting 7 March 2019, NESDIS/OSPO incorporated the Enterprise VIIRS cloud mask. This significantly increased the quality of the clear profiles over ocean selected by NWP.

Below, are histograms of O-B statistics for surface channel #501. If the statistics are cloud free, they will generally have a normal distribution. Using the VIIRS cloud mask significantly improves the distribution overall and at each portion of the scan angle (Jung et al. 2019).

The left panel highlights that there are still scan angle errors of about 0.2K.



References

Jung, J. A., A. Heidinger, H. Sun and M. Goldberg, 2019: Development and Use of VIIRS Cloud Information in the CrIS-FSR SDRs for NWP, *2019 Joint Satellite Conference*, Boston MA, 28 Sept – 04 October 2019.

Nalli, N. R., P. J. Minnett, E. Maddy, W. W. McMillan, and M. D. Goldberg, 2008: Emissivity and reflection model for calculating unpolarized isotropic water surface leaving radiance in the infrared. 2: Validation using Fourier transform spectrometers. *Appl. Optics*,**47**(25), 4649-4671.

Liu, E. H., A. Collard, and J. Derber 2017: Inter-comparison between CRTM and RTTOV in NCEP Global Model, *15th JCSDA Technical Review Meeting & Science Workshop on Satellite Data Assimilation*, 17 – 19 May 2017.

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