Surface Dependent Correlated Infrared Observations Errors in the FV3 Framework

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Introduction

The GFS upgrade earlier this year included the introduction of the new FV3 dynamical core.

In the next implementation correlated error for CrIS and IASI will become operational.

Research with correlated error has been ongoing at NCEP and has primarily focused on AIRS, ATMS and IASI observations over sea surfaces, in the old GFS framework. The forecast impact was neutral for AIRS and ATMS, whereas IASI had a slightly positive impact.

Infrared observations have different error characteristics over land, therefore these errors should be treated accordingly.

Accounting for error correlations can tighten cloud detection, as observation errors become smaller.

Questions to address: Can accounting for correlated error improve the use of infrared observations over land? What impact will correlated error have in the FV3 framework, and how will stricter cloud detection change these results?

Estimating Observation Errors and Covariances

Full covariances for IASI (Metop-A and Metop-B) and CrIS (NPP and N20) are computed. To compute observation variances and covariances, the Desroziers diagnostic is used. The success of this method depends entirely on the accuracy of the **B** matrix (Bathmann 2018).

To recondition the computed **R** matrices, eigenvalues that are smaller than λ_{max}/K are set equal to this value, where $K = 125$ for CrIS and $K = 200$ for IASI. Next, a subset of the diagonal values of **R** are inflated as

$$\mathbf{R}_{r,r} = \mathbf{R}_{r,r} A_r.$$

The value of A_r is empirically tuned. Window channels warrant larger inflation while water vapor channels warrant smaller inflation. For IASI, off-diagonal elements affected by apodization are also inflated by this factor.

Errors and Correlation Matrices

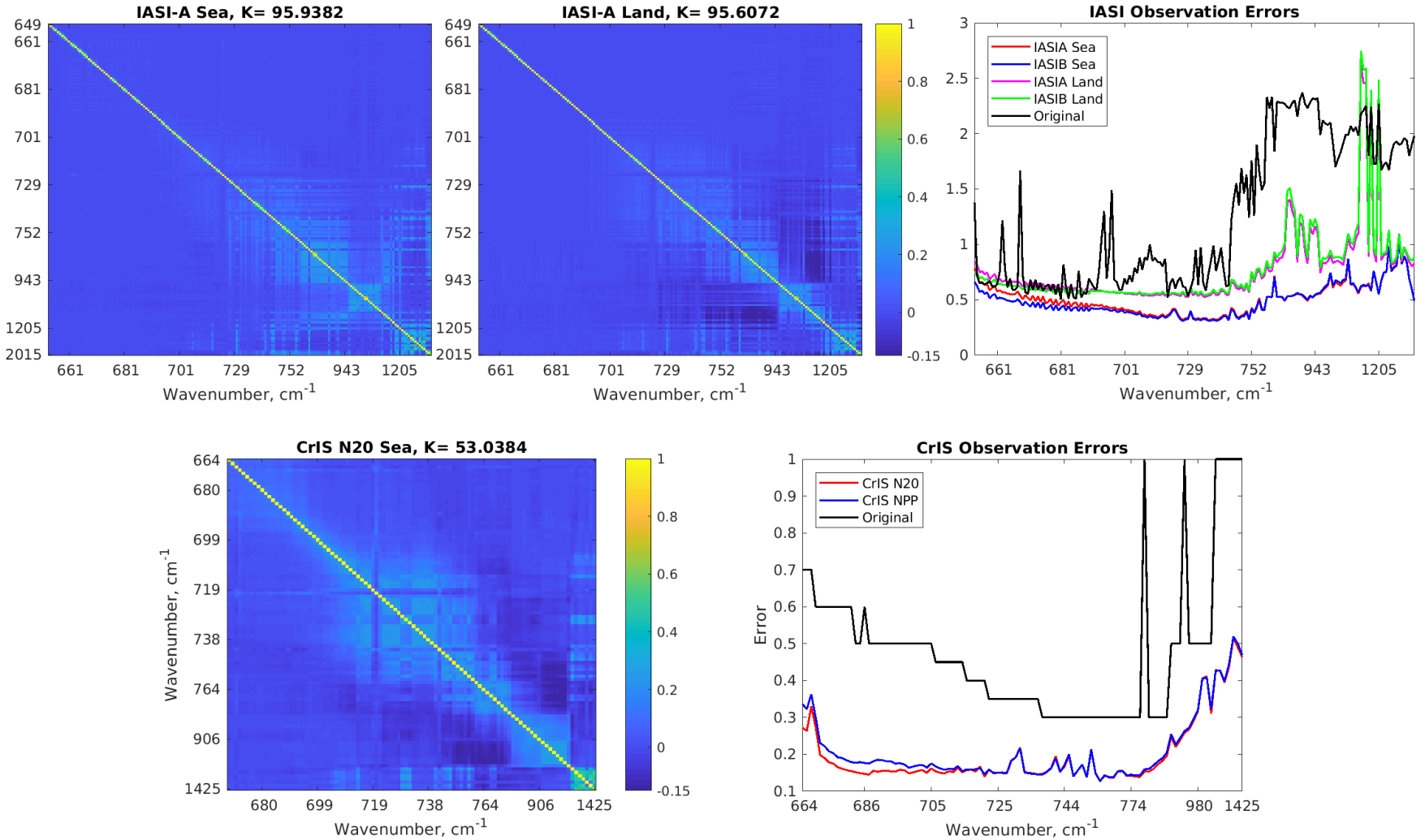


Figure: Error correlation matrices (left) for IASI-A and CrIS N20, and new observation errors compared to the old errors (right) after reconditioning.

Quality Control

Quality control uses observation errors in the cloud detection algorithm, and in the final gross check.

- The gross check excludes observations for which OMG is greater than three times the obs error.

- For the infrared, a cloud is detected if

$$D \sum_{j=1}^{\text{no. channels}} \frac{(\text{BT}^{\text{obs}} - \text{BT}^{\text{clr}})^2}{\sigma_j^2} > \sum_{j=1}^{\text{no. channels}} \frac{(\text{BT}^{\text{obs}} - \text{BT}^{\text{calc}})^2}{\sigma_j^2},$$

for some $0 < D \leq 1$. A channel j is rejected if the cloud to space transmittance is greater than 0.02.

Using the smaller Desroziers errors results in much stricter cloud detection, and a rejection of up to 20% more observations.

Quality Control

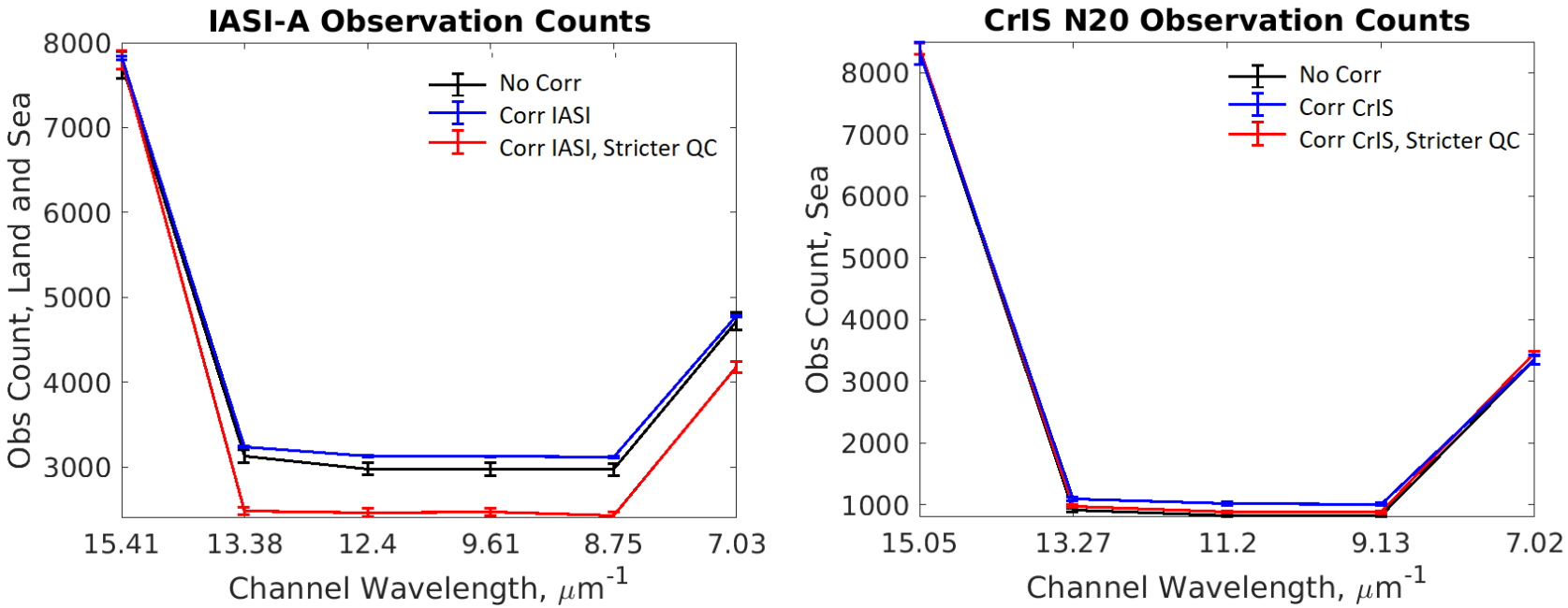


Figure: The average number of observations passing quality control in one cycle.

Cloud Detection

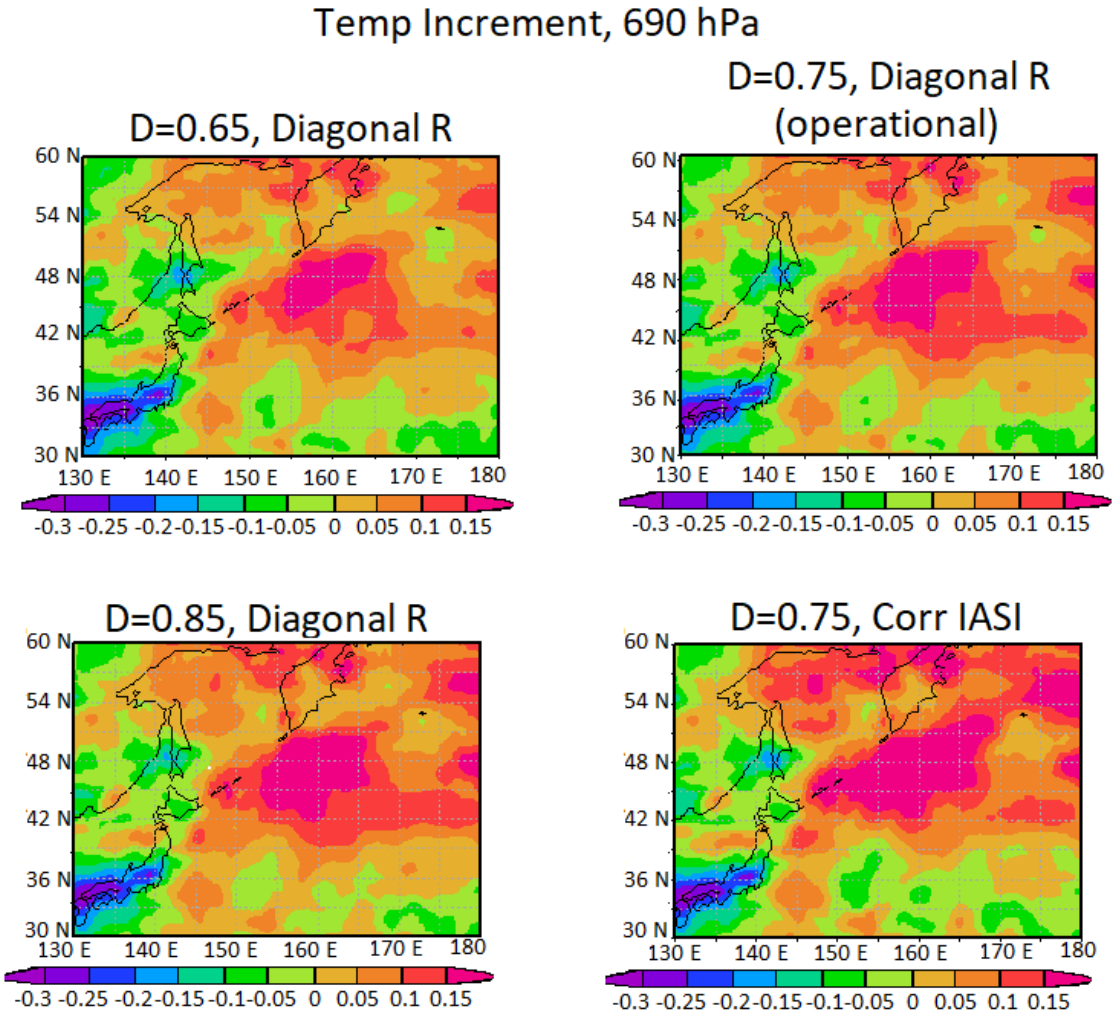


Figure: Temperature increments at 690 hPa, in a typically cloudy region. Cloud detection becomes stronger as D increases, and with correlated error, leading to larger increments.

Cloud Detection

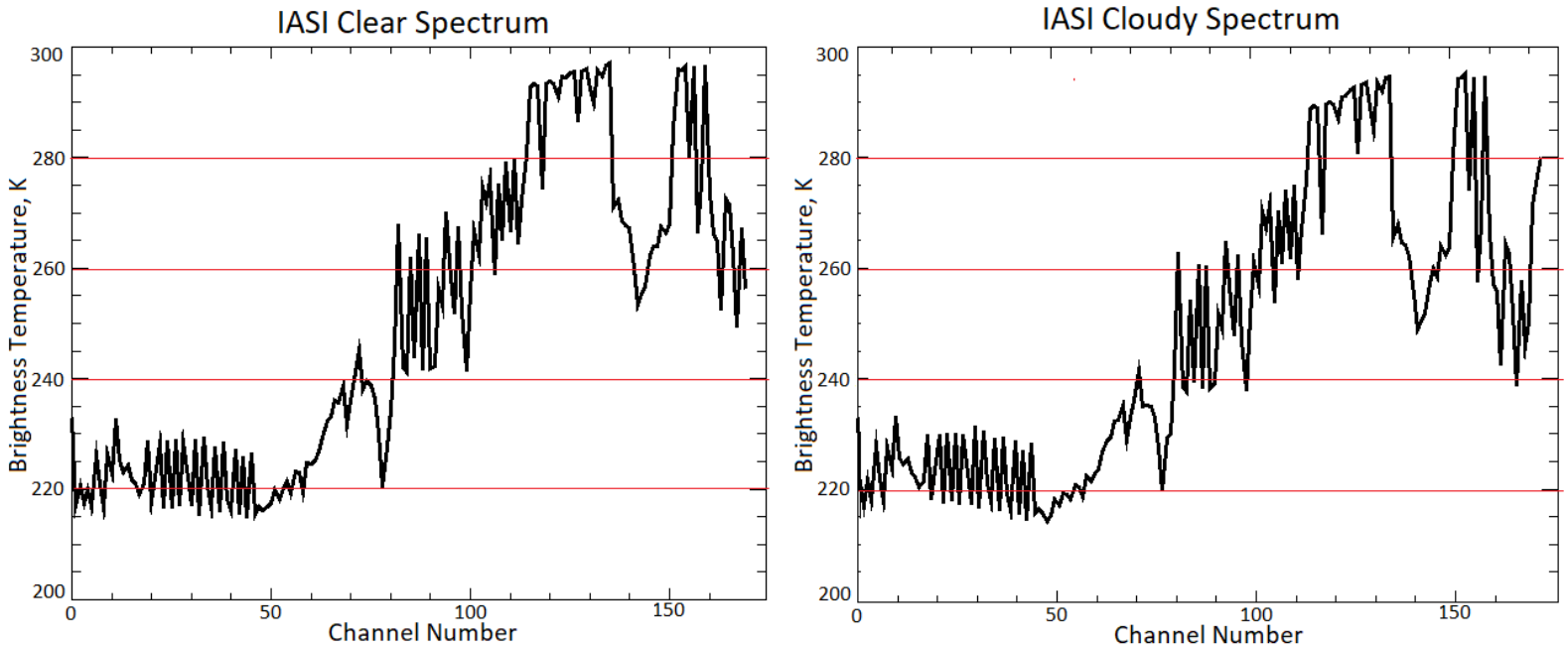


Figure: The spectrum of two IASI observations passing quality control for all channels; a suspected clear observation (left) and a suspected cloudy observation (right).

Cloud Detection

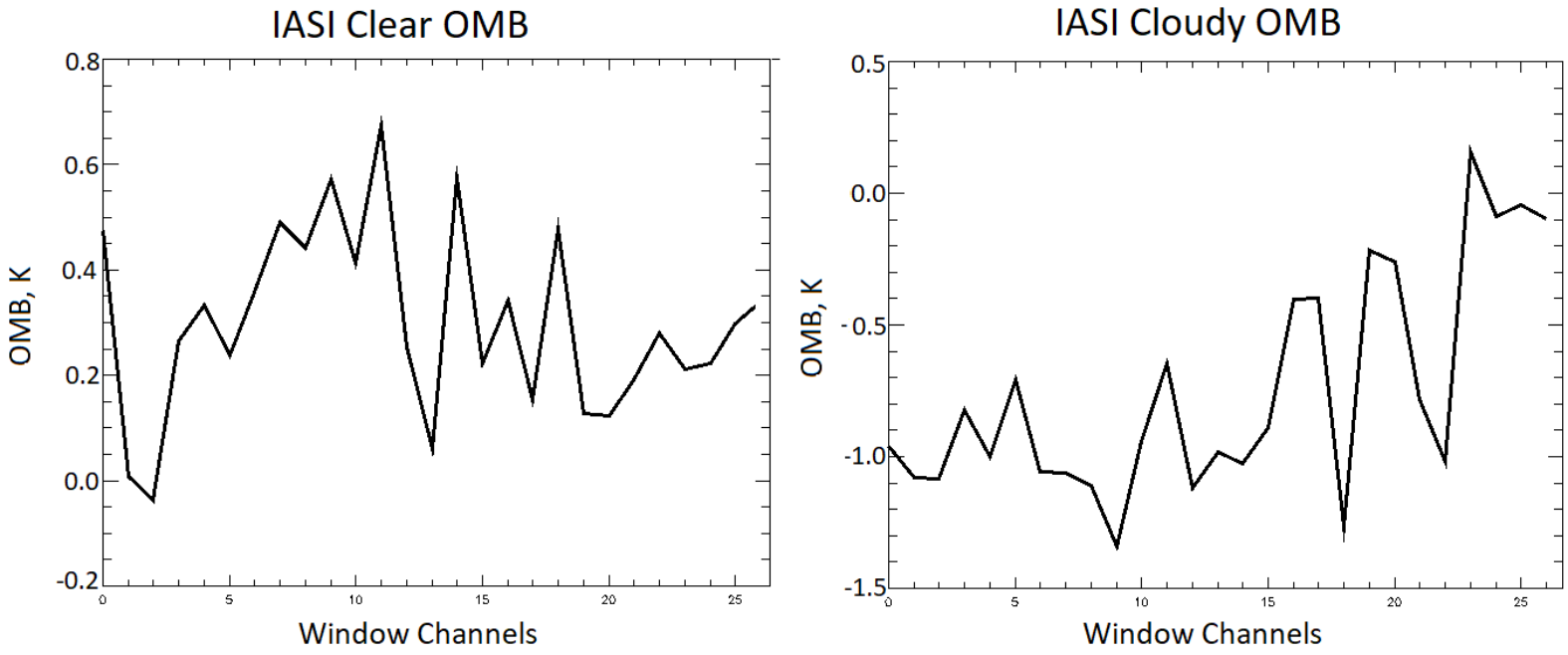


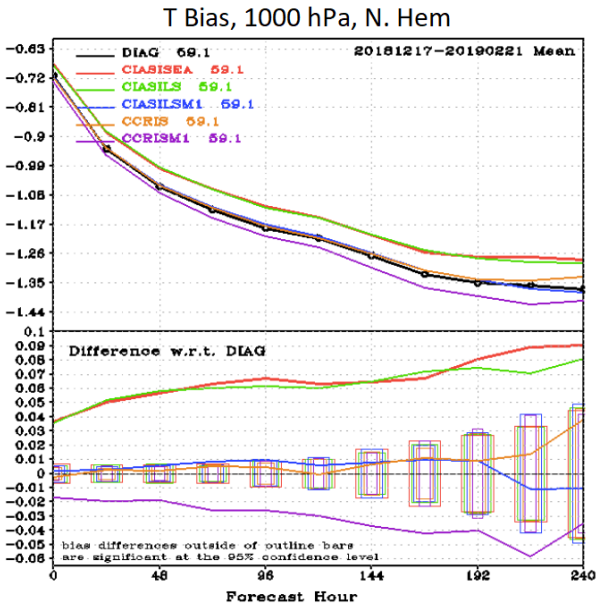
Figure: IASI OMB for window channels passing quality control; a suspected clear observation (left) and a suspected cloudy observation (right).

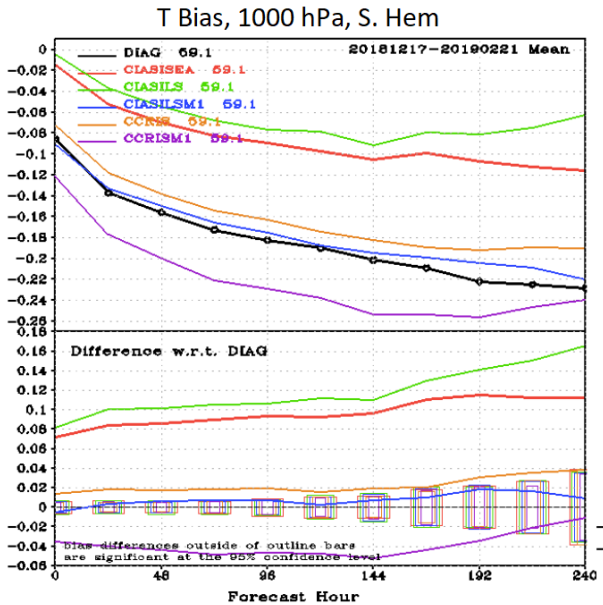
Forecast Impacts: Exp setup

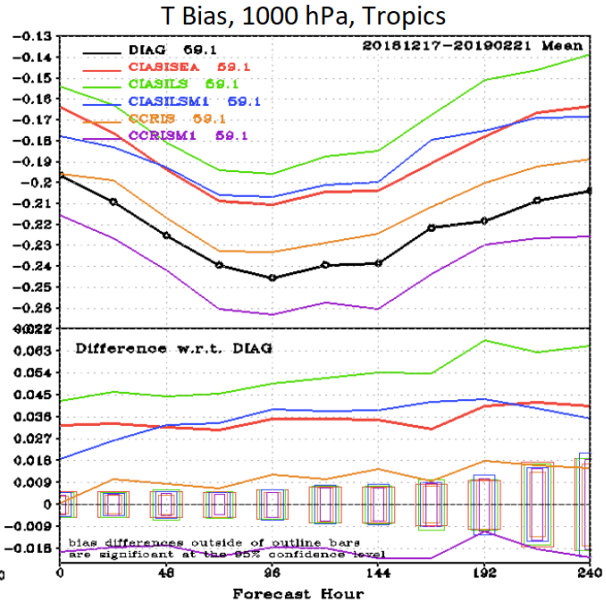
Six experiments:
Diag: The control. No correlated error
CIASISea: Correlated error for IASI over sea only, stricter cloud detection
CIASILS: Correlated error for IASI over sea and land, stricter cloud detection
CIASIM1: Correlated error for IASI over sea and land, without stricter cloud detection (old obs errors in qc)
CCrIS: Correlated error for CrIS over sea, stricter cloud detection
CCrISM1: Correlated error for CrIS over sea, without stricter cloud detection (old obs errors in qc)

Run FV3GFS for two months from December 2018-February 2019, at low resolution.

Forecast Impact: Temperature Bias near Surface







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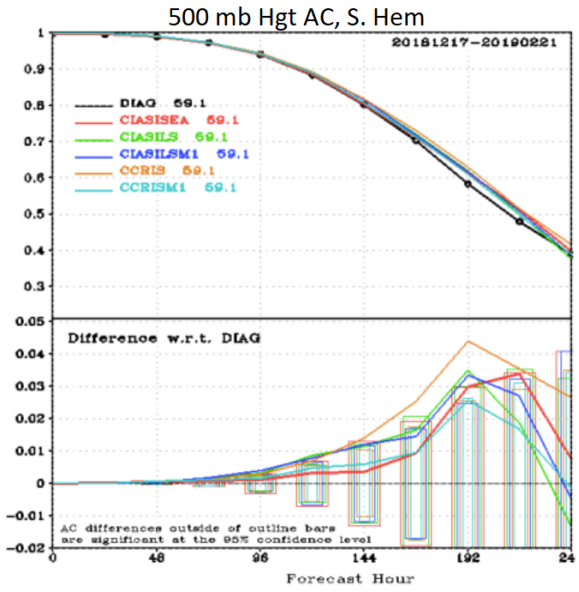
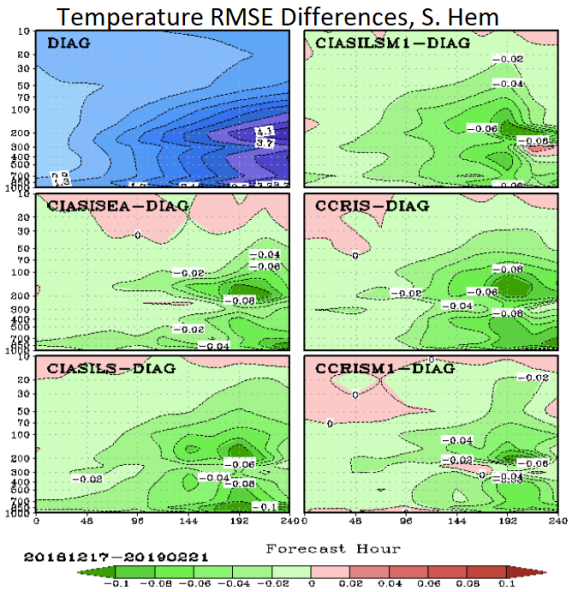
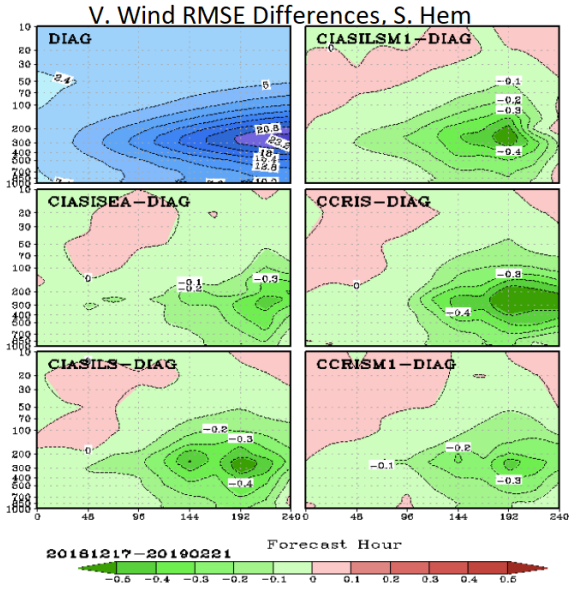
Forecast Impact







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Forecast Impact: Fits to IASI Channels

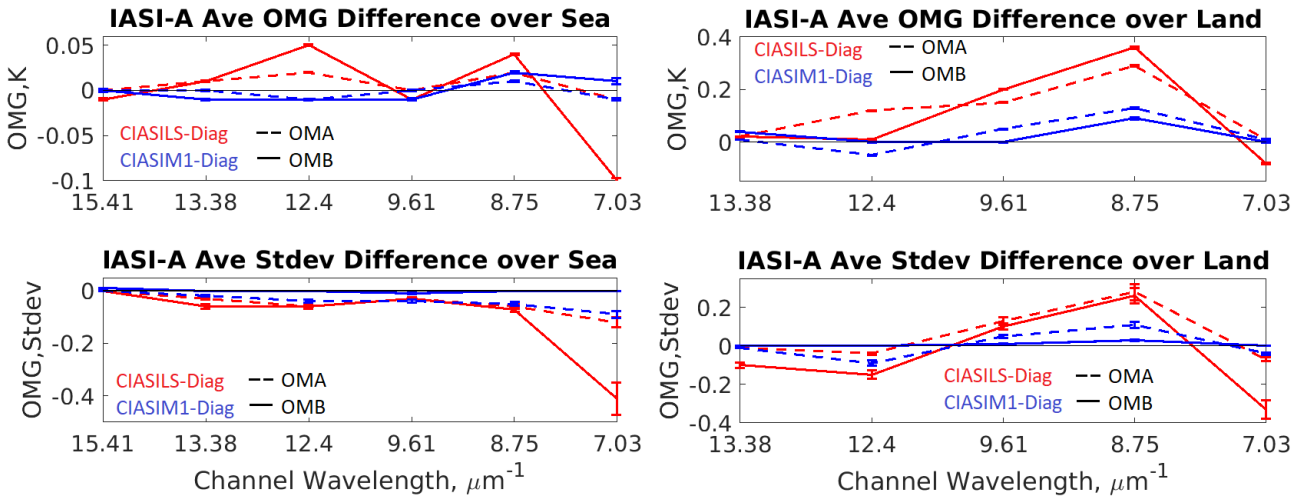

Figure: The differences between the Diag and correlated IASI OMB (solid) and OMA (dashed) fits, over sea (left) and land (right). Negative values indicate an improved fit with correlated error.

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Forecast Impact: Fits to CrIS Channels

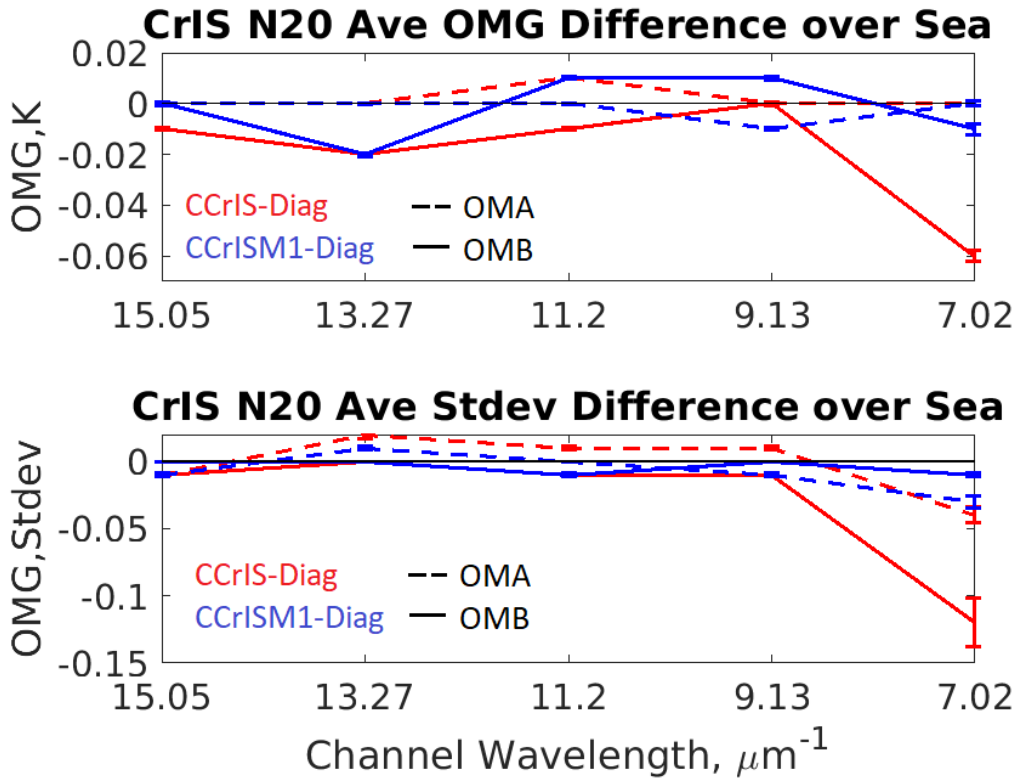

Figure: The differences between the Diag and correlated CrIS OMB (solid) and OMA (dashed) fits, over sea. Negative values indicate an improved fit with correlated error.

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Conclusion

- Correlated error for IASI (land and sea) and CrIS (sea) will be become operational in the GFS v16 implementation.

- Correlated error has a positive forecast impact, especially in the southern hemisphere. Adding correlated error over land improved the IASI results.

- The stricter cloud detection from smaller observation errors improves on these results, and, in particular, improves temperature biases near the surface.

- Correlated error and more stringent cloud detection tend to improve the OMG fits to the respective instruments, especially in water vapor channels. However, IASI ozone and quartz channels had degraded fits over land.

- Future work will focus on adding other surfaces, and on handling correlated error in all-sky assimilation.