Improvements in the Use of Humidity from Hyperspectral IR

Presented by Benjamin Ruston

Nancy Baker, Steve Swadley, Tanya Maurer,
William Campbell, Rolf Langland - *NRL Monterey*
Karl Hoppel, John McCormack, Stephen Eckermann - NRL D.C.
and
Bryan Karpowicz – *SAIC*

Special thanks to Hyoung-Wook Chun

Issues with the Use of Humidity from Hyperspectral IR

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Outline

- NAVGEM model improvements
  - Stratospheric H_2O photochemistry
  - Update to Xu-Randall cloud physics
- Early experiments and anomalous behavior
  - Anomalous jacobians
  - Estimation of background error
  - Moisture “sprites”
- New channel sub-selection
  - Condition number of correlation matrix
- Current channel usage and error definition
  - AIRS, IASI and CrIS
  - GeoCSR
- Future Directions
  - Correlated error (see Campbell et al.)

NAVGEM Model Improvements

Stratospheric H_2O photochemistry

John McCormack (NRL-DC) began tests of parameterized H_2O photochemistry (McCormack et al., 2008) in NAVGEM v1.3.

This does a “relaxation” of the stratospheric water vapor to climatology on a long (several days) timescale. The moisture above the tropopause in the model has no sink term.

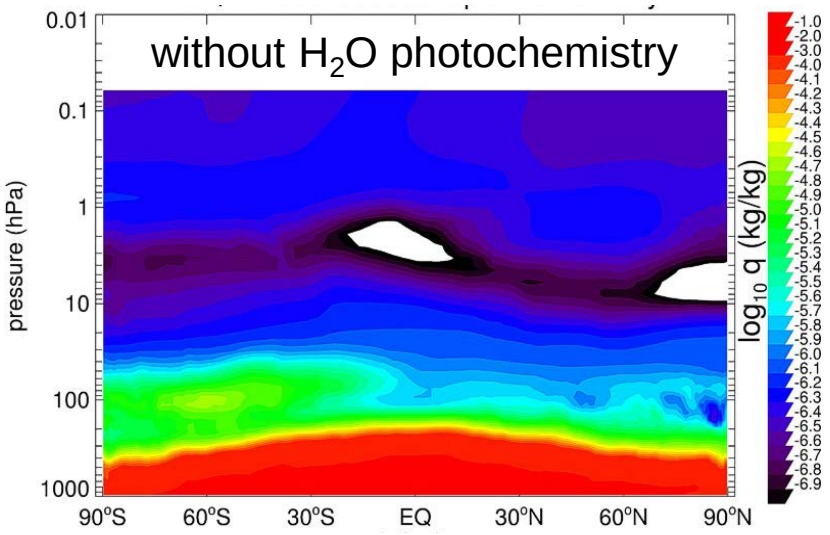
The moisture in the mid-stratosphere and upwards was being set to an arbitrarily small number which was too small.

Update to Xu-Randall cloud physics

Improved use of prognostic cloud information when computing cloud fraction

NAVGEM v1.3
Parameterized H_2O Photochemistry

Spec. Humidity Analysis 15 Nov 2011



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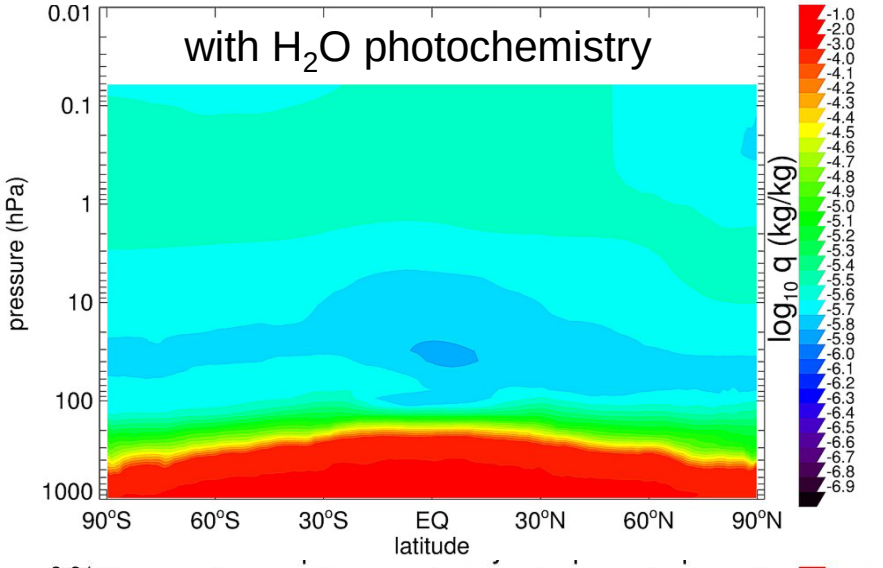
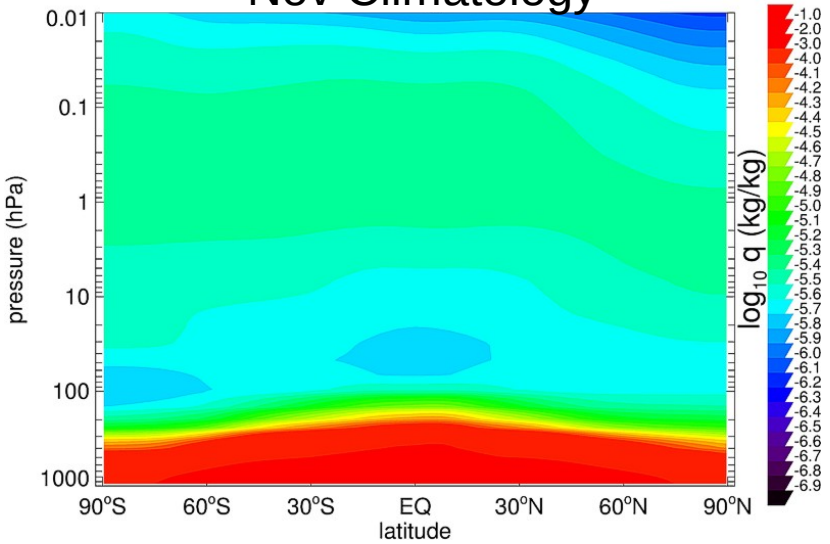
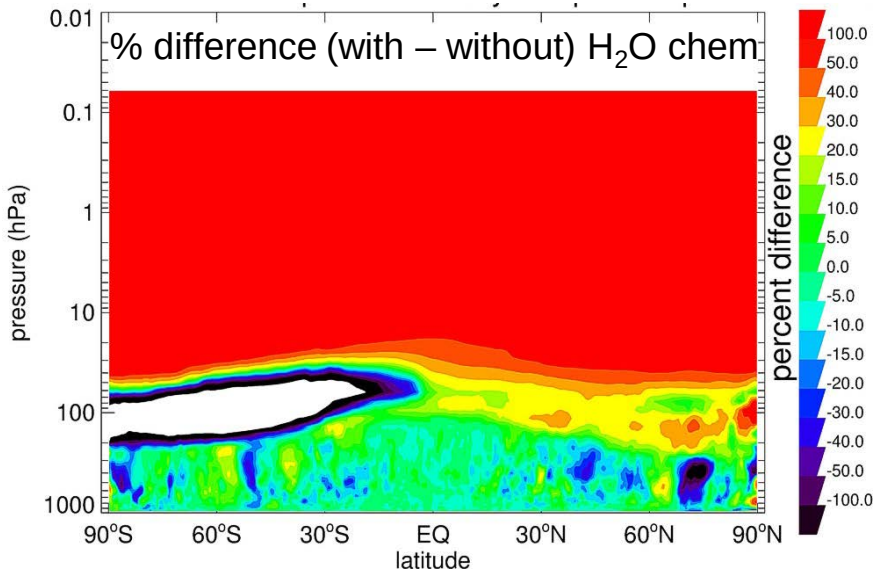
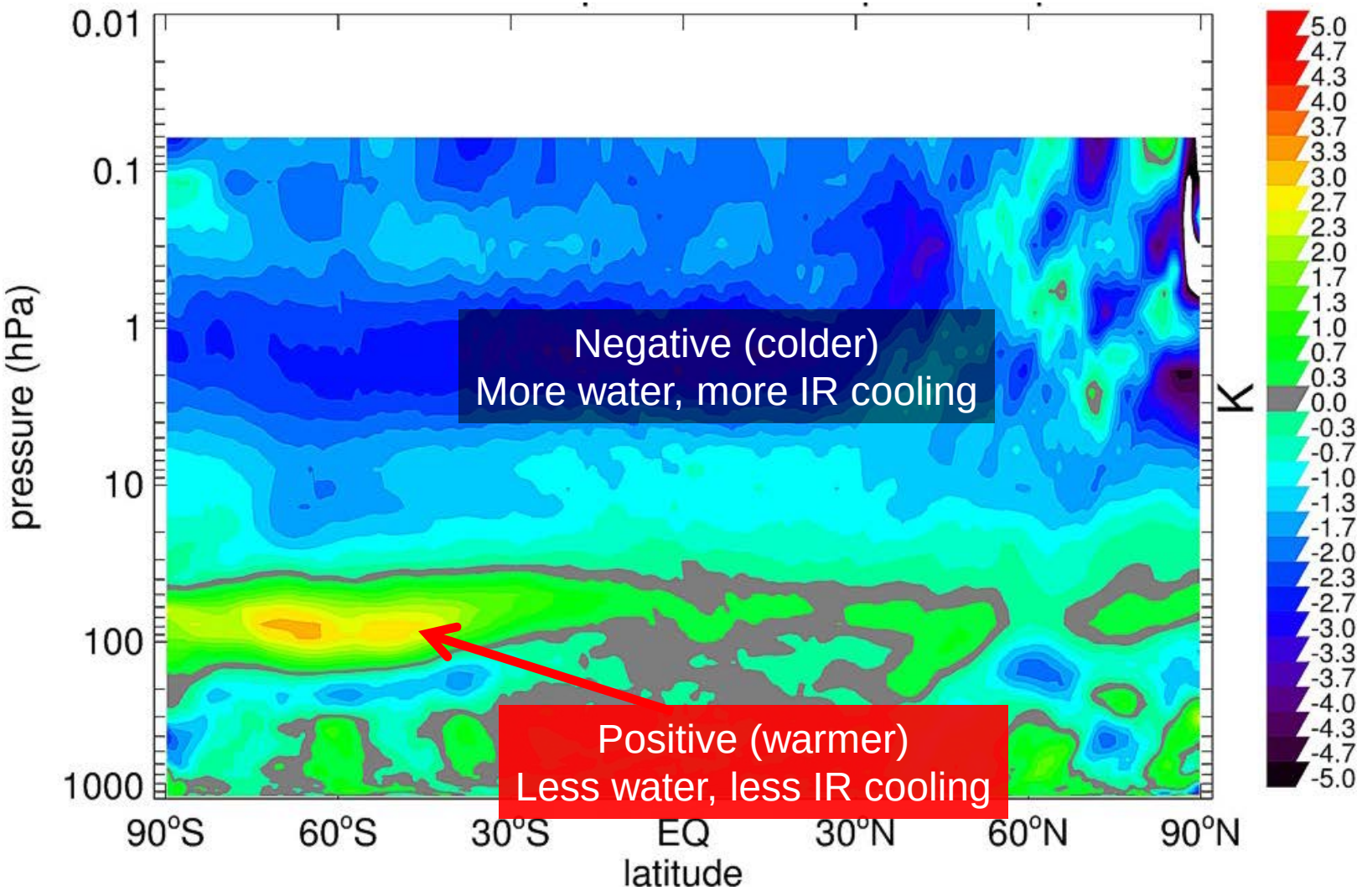






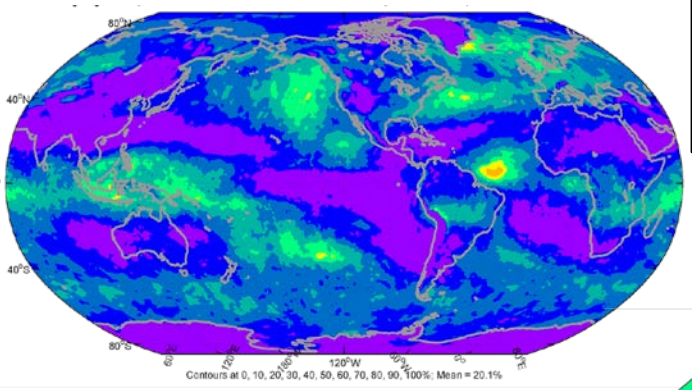
Parameterized H_2O Photochemistry: Reducing Forecast Temperature Bias

288-Hour Forecast Temperature Difference: (with – without) H_2O chem



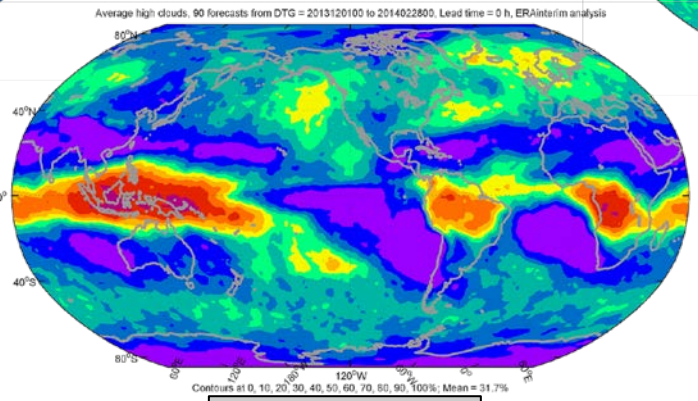
NAVGEM v1.3
Improved Cloud Fractions (Xu-Randall)

High cloud cover: DJF 2013/2014



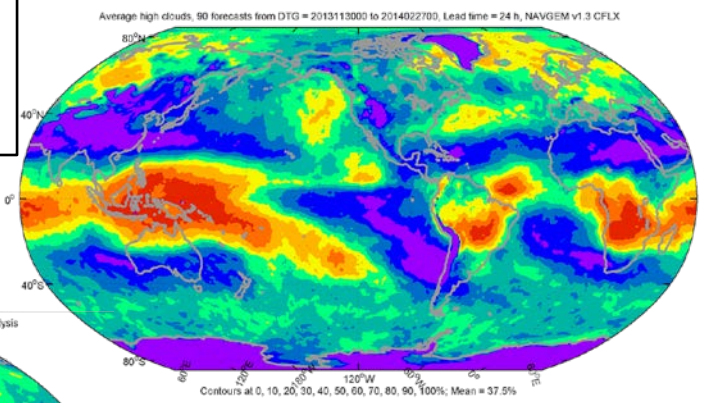
NAVGEM v1.2.1

Mean = 20.1%



ERA-interim analysis

Mean = 31.7 %



NAVGEM v1.3

Mean = 37.5 %

- **The high cloud cover shows perhaps the most notable improvement, particularly in tropical convective regions.**
- **Significant improvement in the surface solar radiation budget.**

Assimilation of IR water vapor

Early experiments

Trouble with convergence of system tracked down to IASI water vapor jacobians

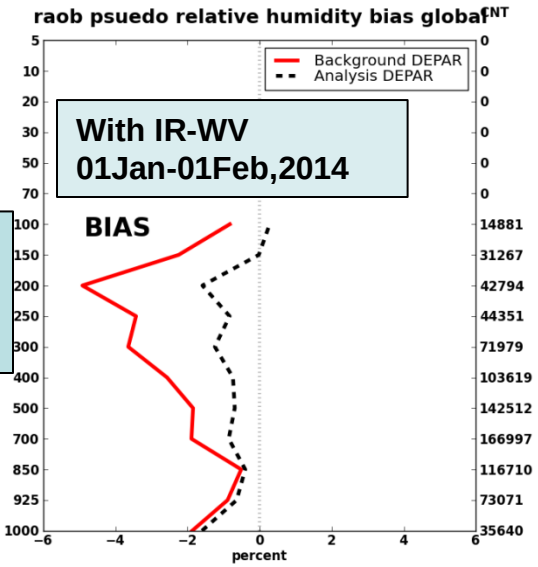
Found that using estimates of background error transformed into radiance space using the jacobians are useful in diagnosing a priori is the jacobian was not “well-behaved.”

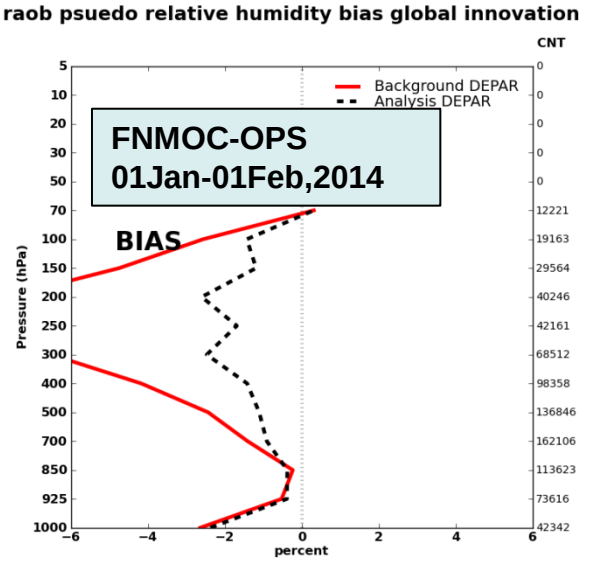
Improved background humidity enables IR (IASI) water vapor radiance assimilation

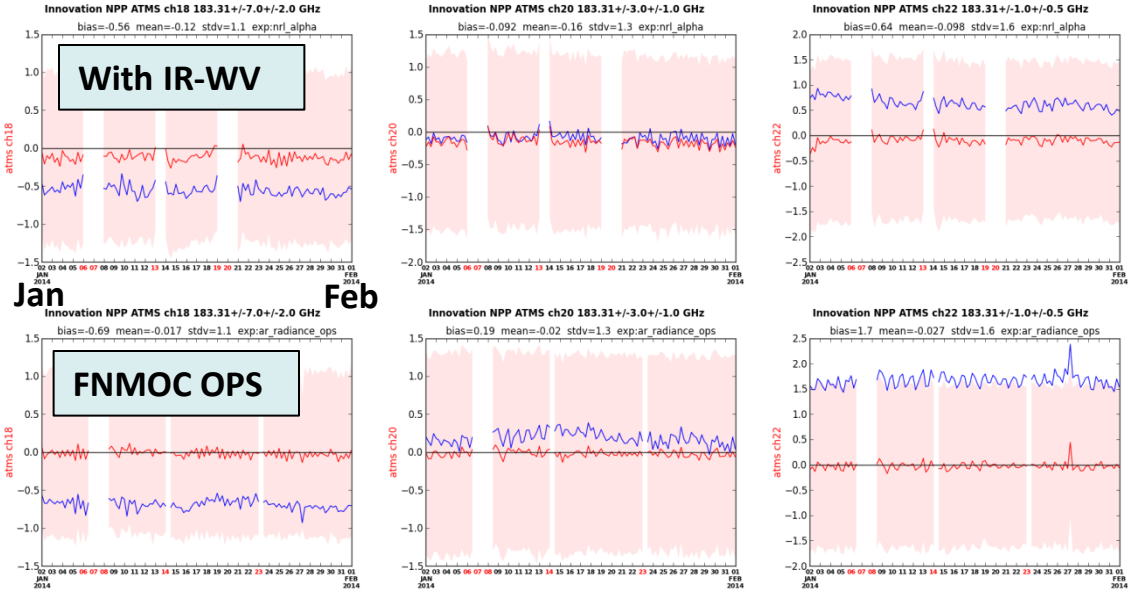
- **reduced radiosonde humidity bias** at upper levels
  (red and black dashed lines)

- **reduced MW radiance bias** in water vapor channels
  (blue lines in top three images)

Adding IR water vapor radiances improves fit to both Radiosonde and MW radiances







Assimilation of IR water vapor

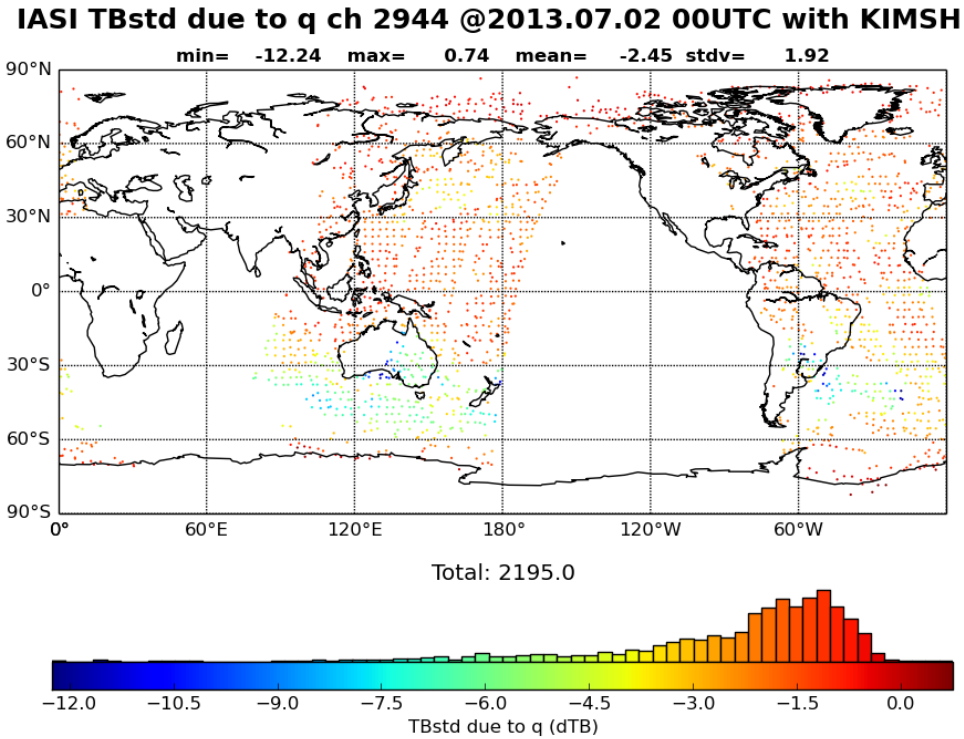
Issue #1

Oddly behaved water vapor Jacobians.

These are episodic only occurring usually in the northern hemisphere summer and for a single or two consecutive cycles.

IASI water vapor assimilation Anomalous Jacobians

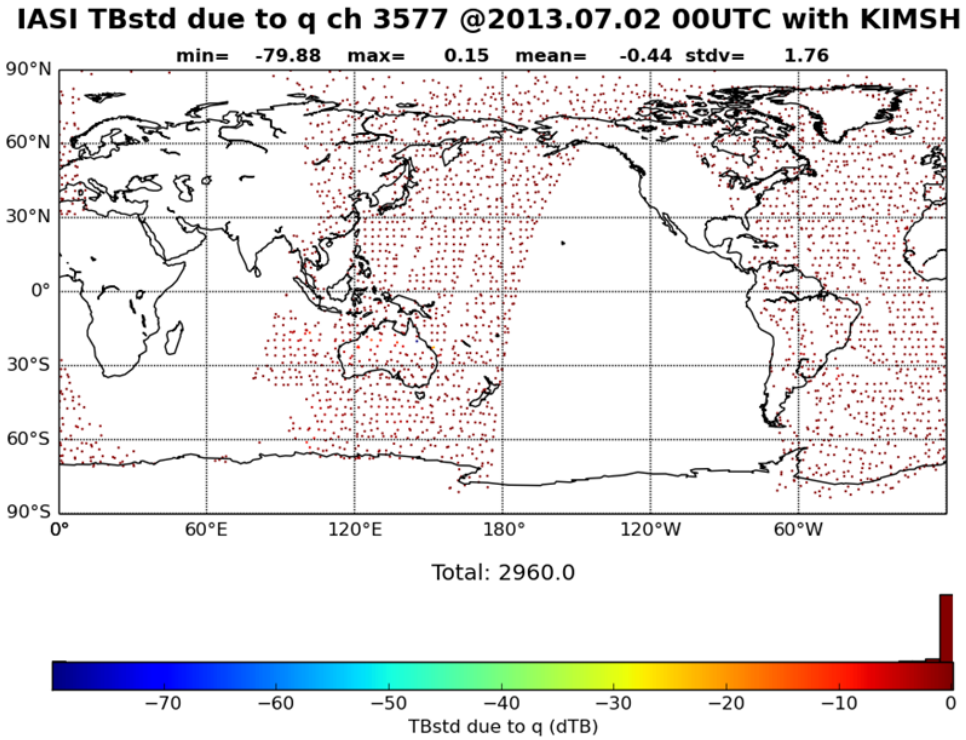
Use a background perturbation to find a ΔT_B for each pixel
- this is normal -



A “well-behaved” channel shows estimates of model background errors projected into Tb space by Jacobian has small range.

IASI water vapor assimilation Anomalous Jacobians

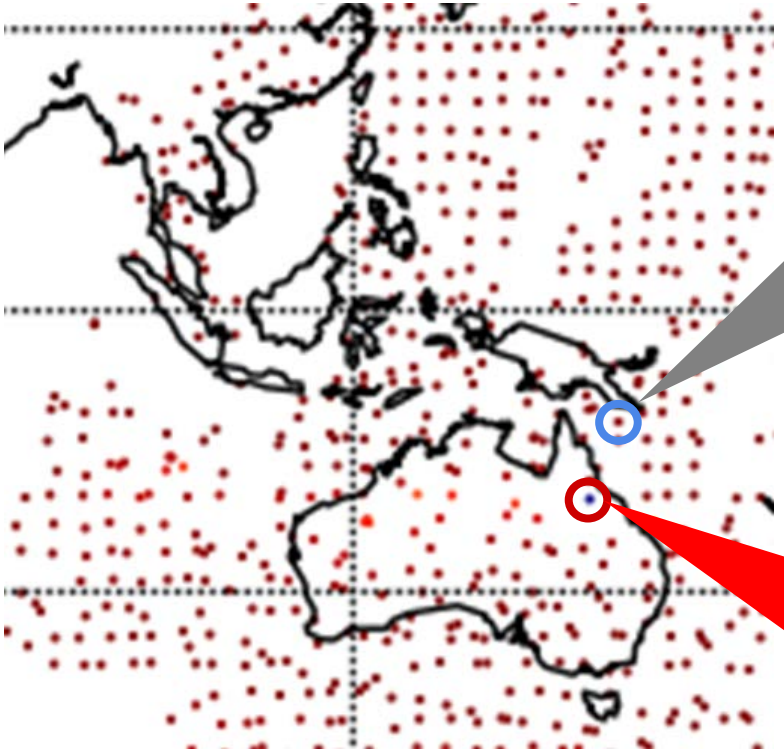
The range of the ΔT_B due to a background perturbation has obvious outliers



However, an anomalous channel shows estimates of model background errors projected into Tb space by Jacobian has large outliers.

IASI water vapor assimilation Anomalous Jacobians

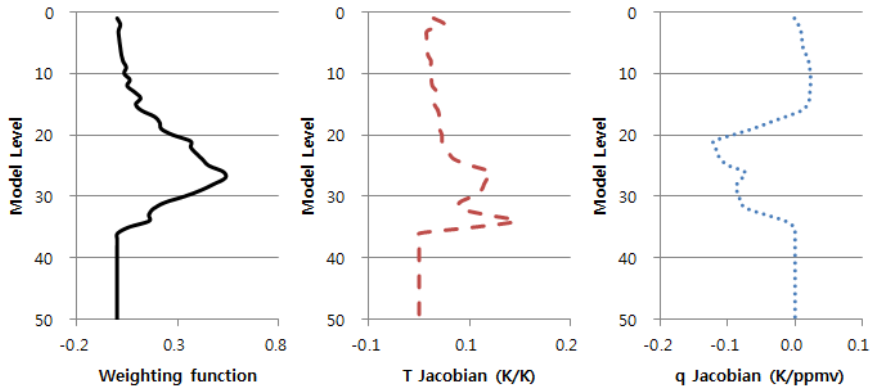
The range of the ΔT_B due to a background perturbation has obvious outliers



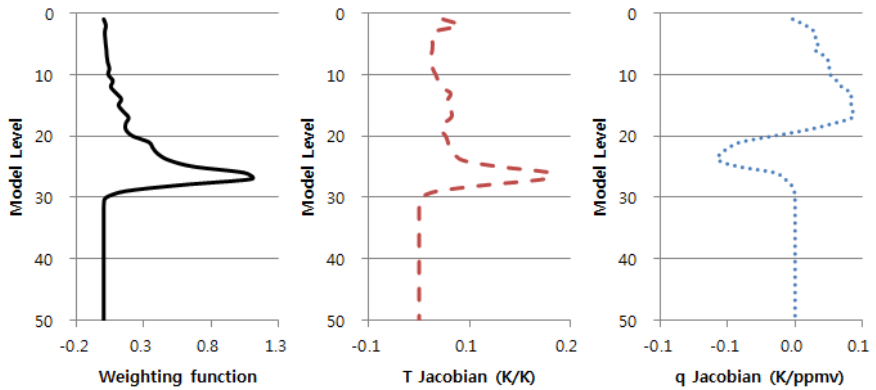
The anomalous jacobian increases the relative weight of the observation due to high background error compared to observation error

IASI water vapor assimilation Anomalous Jacobians

Abnormal Point



Normal Point



Double Peaked structure in both T and q Jacobian

* near tropopause

These have been found in both RTTOV and CRTM. The root cause has not been determined, likely a combination of the model input vertical resolution and RT model assumptions.

Assimilation of IR water vapor

Issue #2

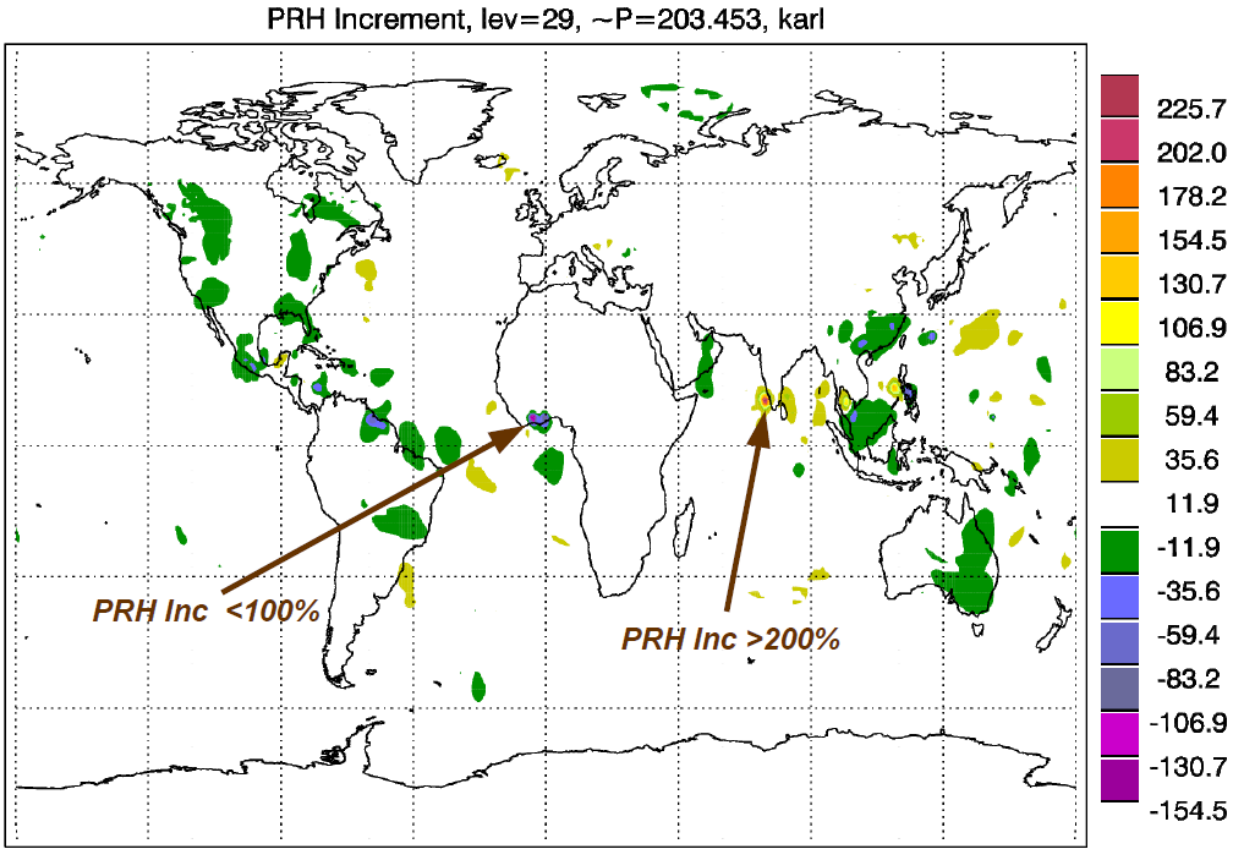
Extreme moisture increments

Nicknamed “moisture sprites”, these were discovered in the pseudo relative humidity increment, but are under investigation with evidence pointing toward the TLM and adjoint model used in the assimilation system.

Examining large PRH Increments in NAGVEM

Isolated, large -- even huge -- positive or negative PRH increments
(typically just north of Equator near tropopause)

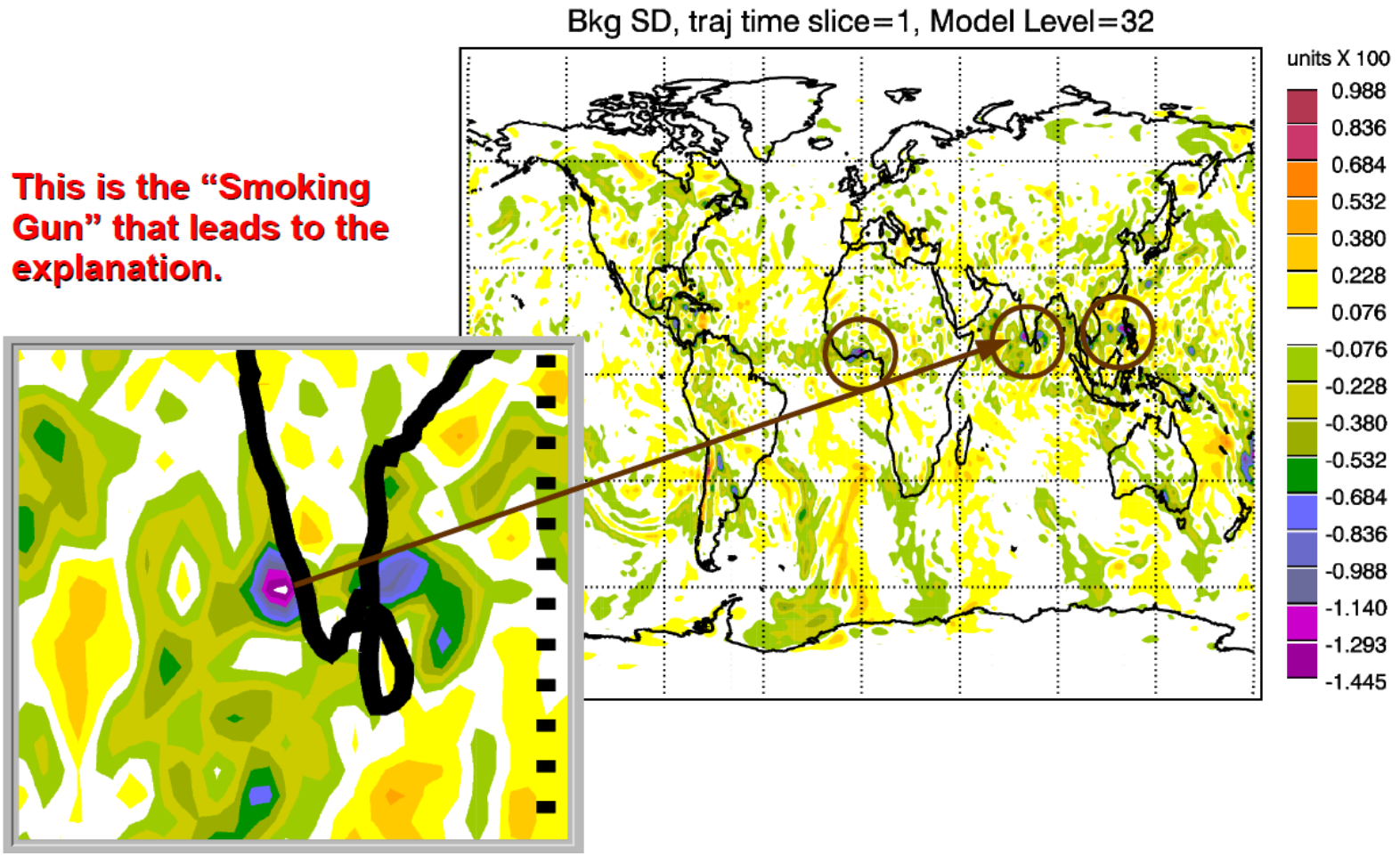
These values “grow” during the TLM forward integration



Examining large PRH Increments in NAGVEM

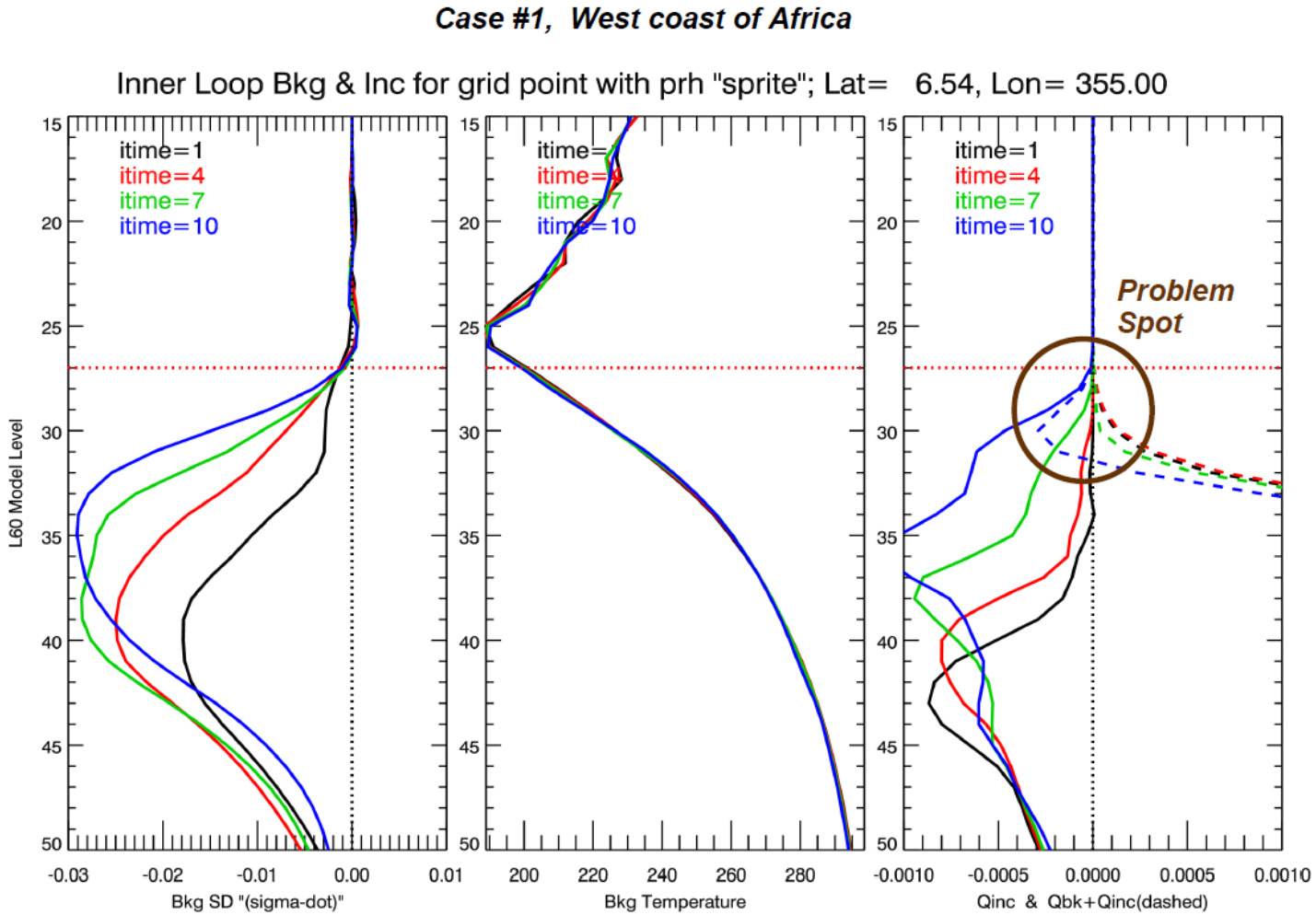
The moisture “sprites” occur when the vertical velocity (sigma-dot) is large

This is the “Smoking Gun” that leads to the explanation.



Examining large PRH Increments in NAGVEM

The adjoint and TLM “sweep” through the assimilation window.
After convergence, the solution contains 13 half-hour increments.
The increment with itime=7 is valid for the center of the assimilation window.



Examining large PRH Increments in NAGVEM

In the TLM, only the Q advection is performed using a semi-lagrangian algorithm.

It was confirmed that if the vertical wind advection is removed aloft the large humidity increments are eliminated.

There may be an issue with the way the semi-lagrangian mositure was formulated.

Final not generally broadcast fact:
The current TLM and adjoint were created from the previous operational model NOGAPS, and the TLM and adjoint of NAVGEM is yet to be transitioned.

Assimilation of IR water vapor

Issue #3

Re-examining water vapor channel selection

Channel sub-selection

Re-examination of channel selection

Are there any neighboring channels?

Does the channel exhibit consistent behavior regarding fit to model?

Does the channel exhibit beneficial (or neutral) forecast sensitivity to observation impact?

Are the runs assimilating the channels showing positive or neutral forecast scores?

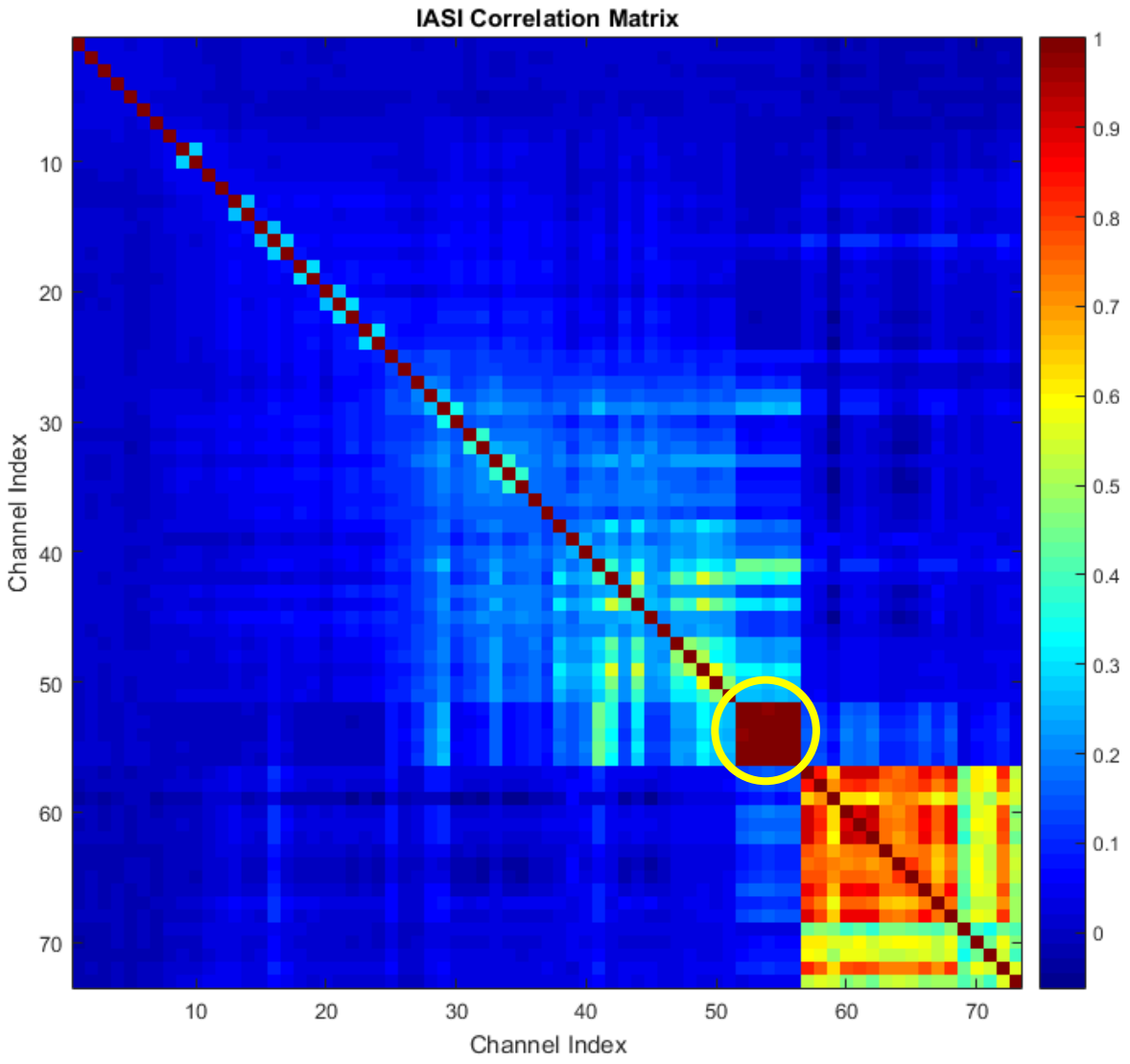
Correlation matrices

Does the channel show significant independent information from *a posteriori* diagnostics?

- This caused a revision in IASI selection already operational, and helped to guide final decisions on AIRS and CrIS water vapor channel selection

Channel sub-selection

- Water vapor channels 2889, 2944, 2948, 2951, and 2958 have very high error correlation (>0.98)
- The eigenvectors corresponding to the 4 smallest eigenvalues project only on to these 5 channels
- It makes sense to **use the Desroziers diagnostic to do *a posteriori* channel selection**, which has the bonus of improving the condition number of the correlation matrix, and thus solver convergence



Summary

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  - Update to Xu-Randall cloud physics
- Early experiments and anomalous behavior
  - Anomalous jacobians
  - Estimation of background error
  - Moisture increments identifying issue with TLM/adjoint model
- New channel sub-selection
  - Condition number of correlation matrix
- Current channel usage and error definition
  - AIRS, IASI and CrIS
  - GeoCSR
- Future Directions
  - Correlated error (see Campbell et al.)