An OSSE Investigating a Constellation of 4-5 µm Infrared Sounders

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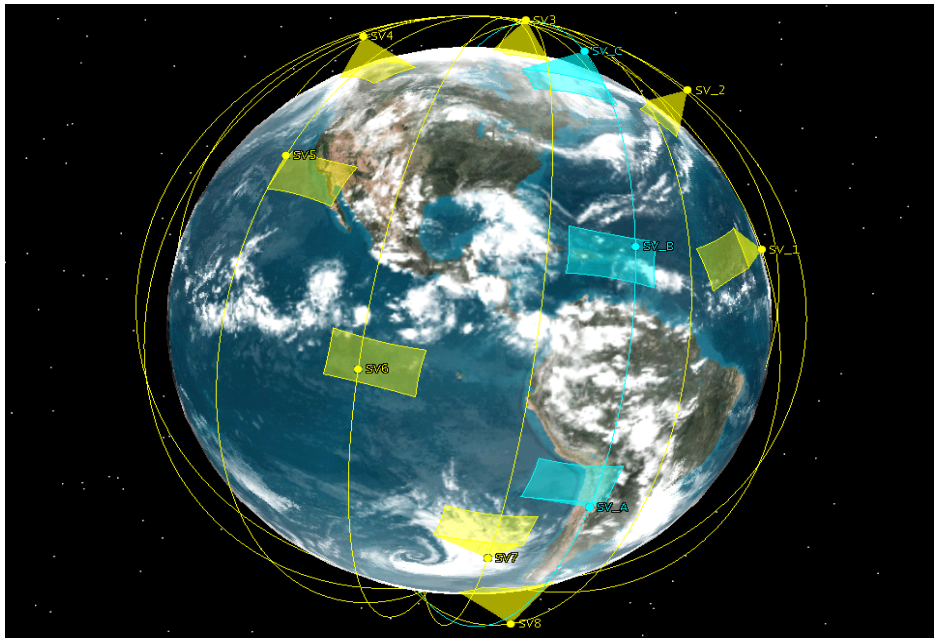
Brief Project Overview

Results presented based on an OSSE for MISTiC™ Winds

- MISTiC™ Winds provide High Spatial/Temporal Resolution Temperature and Humidity Soundings of the Troposphere
- The observing strategy is to retrieve atmospheric state and motion via LEO Constellation of MicroSats
  - Infrared spectrometer sampling the midwave
  - With the constellation approach, temporally subsequent sets of retrievals can then be used to perform feature tracking and retrieve atmospheric motion vectors (AMVs)
- Main goal of the study is to investigate the potential impact of these observations of both the *wind and radiance* information from the constellation

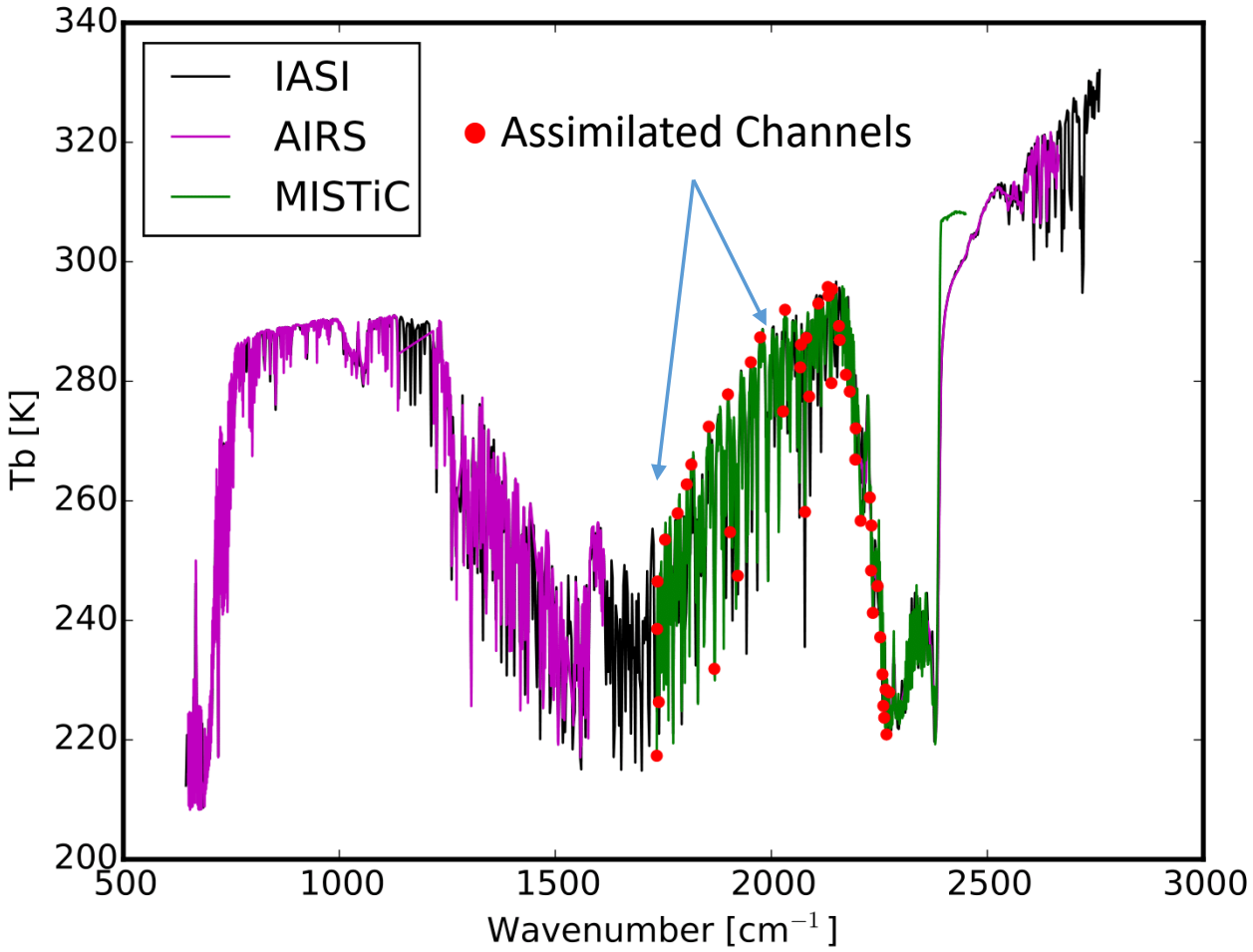
Study is performed on top of GMAO OSSE system

- Full 2016 Observing System
- Simulated from 7 km GEOS-5 Nature Run



MISTiC Winds = Midwave Infrared Sounder for Temperature and humidity in a Constellation for Winds

MISTiC Radiances



MISTiC spectral information is about 1/3 of AIRS, CrIS, IASI

- Simulated MISTiC spectrum shown in green, based on BAE-provided specs
- 590 channels ranging from 1735-2450 cm^{-1}

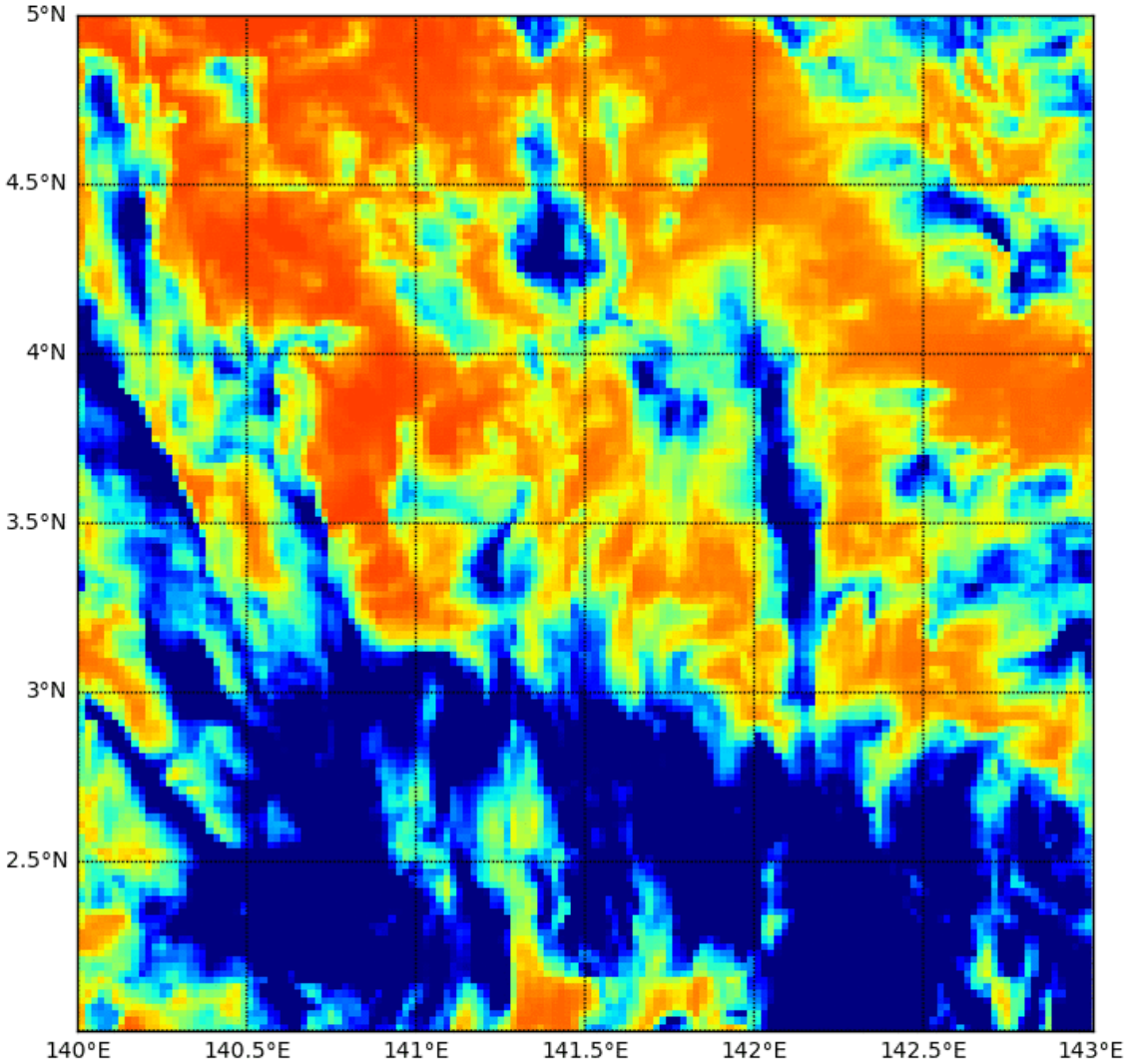
All cases perform a channel selection, down-selecting to 46 channels

- Necessary as correlated observation error are not considered in the analysis
- Thermal contrast in the water vapor, temperature sounding channels is a proxy for independent information content

MISTiC radiance errors are estimated using convolved IASI radiances

Wind Simulation in an OSSE

Himawari-8, 1 May 2017 00-02 UTC, 10 min incr



Atmospheric Motion Vector (AMV) Retrieval

- An inference of the wind via feature tracking
  - Clouds and water vapor gradients
- Traditionally via satellite imagery
  - advantages in spatial and temporal resolution compared to sounding
  - Largest errors in height assignment

Wind Simulation in an OSSE

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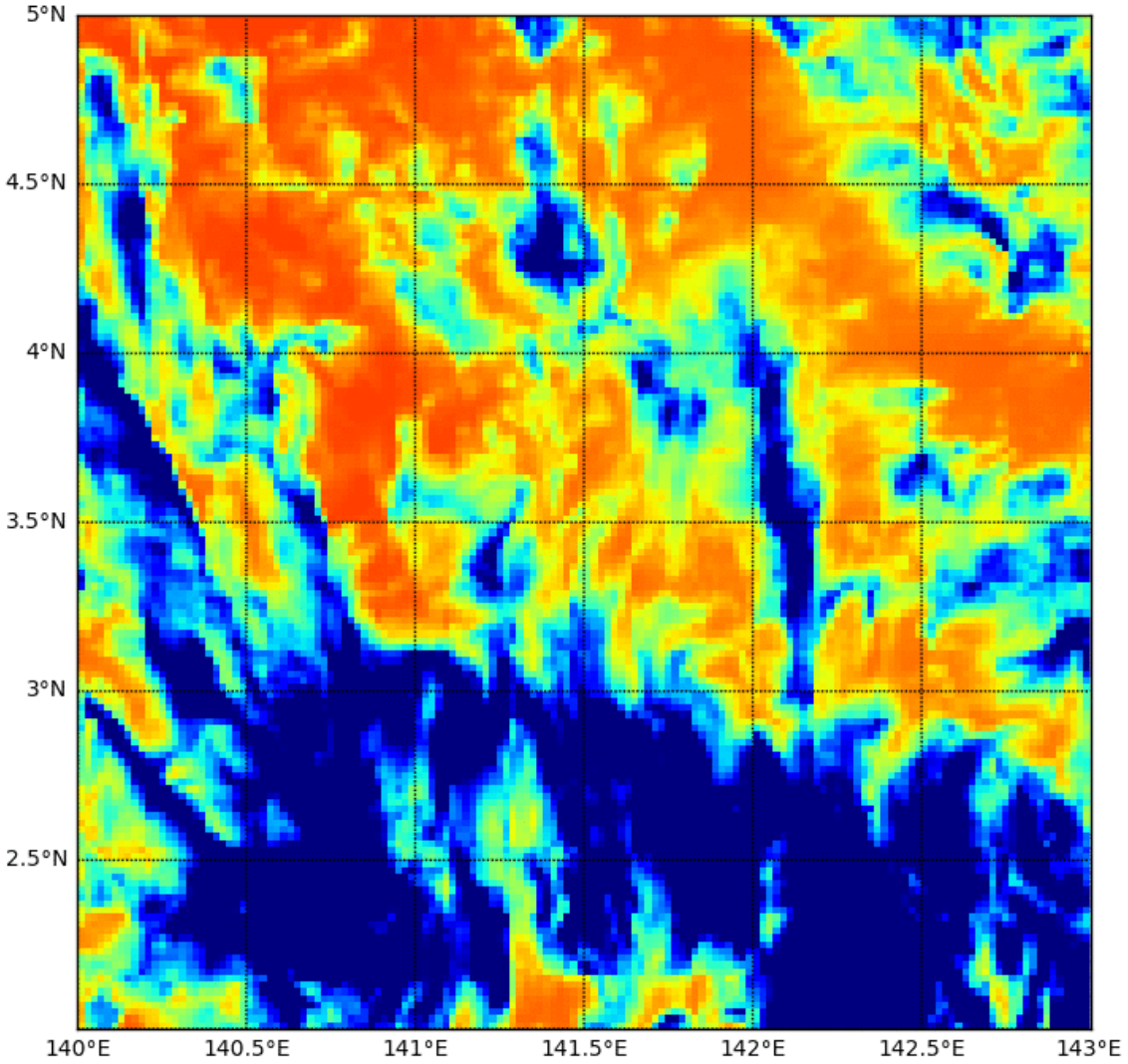
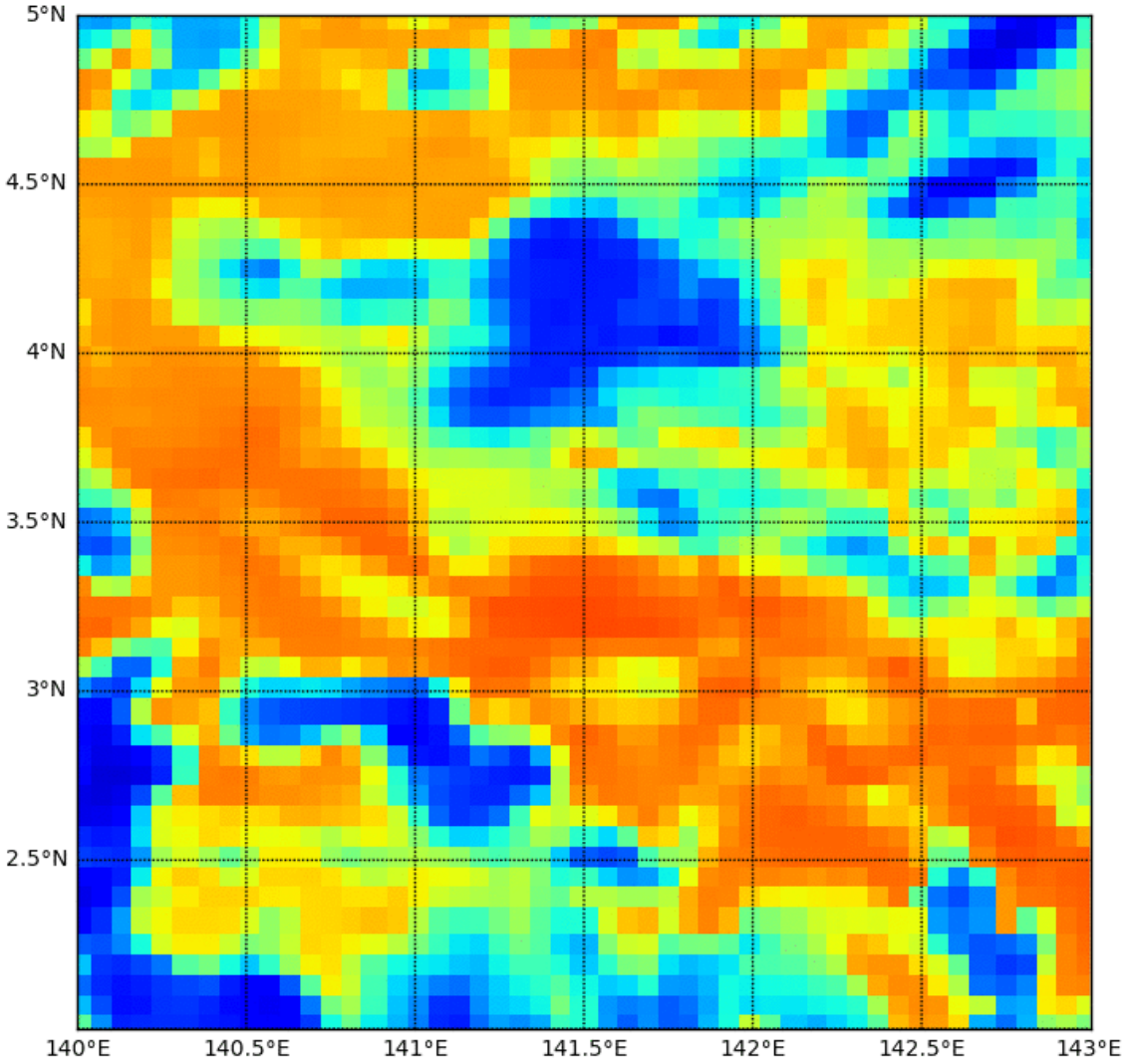


G5NR, 1 May 2006, 00-02 UTC, 30 min inc



Wind Simulation in an OSSE

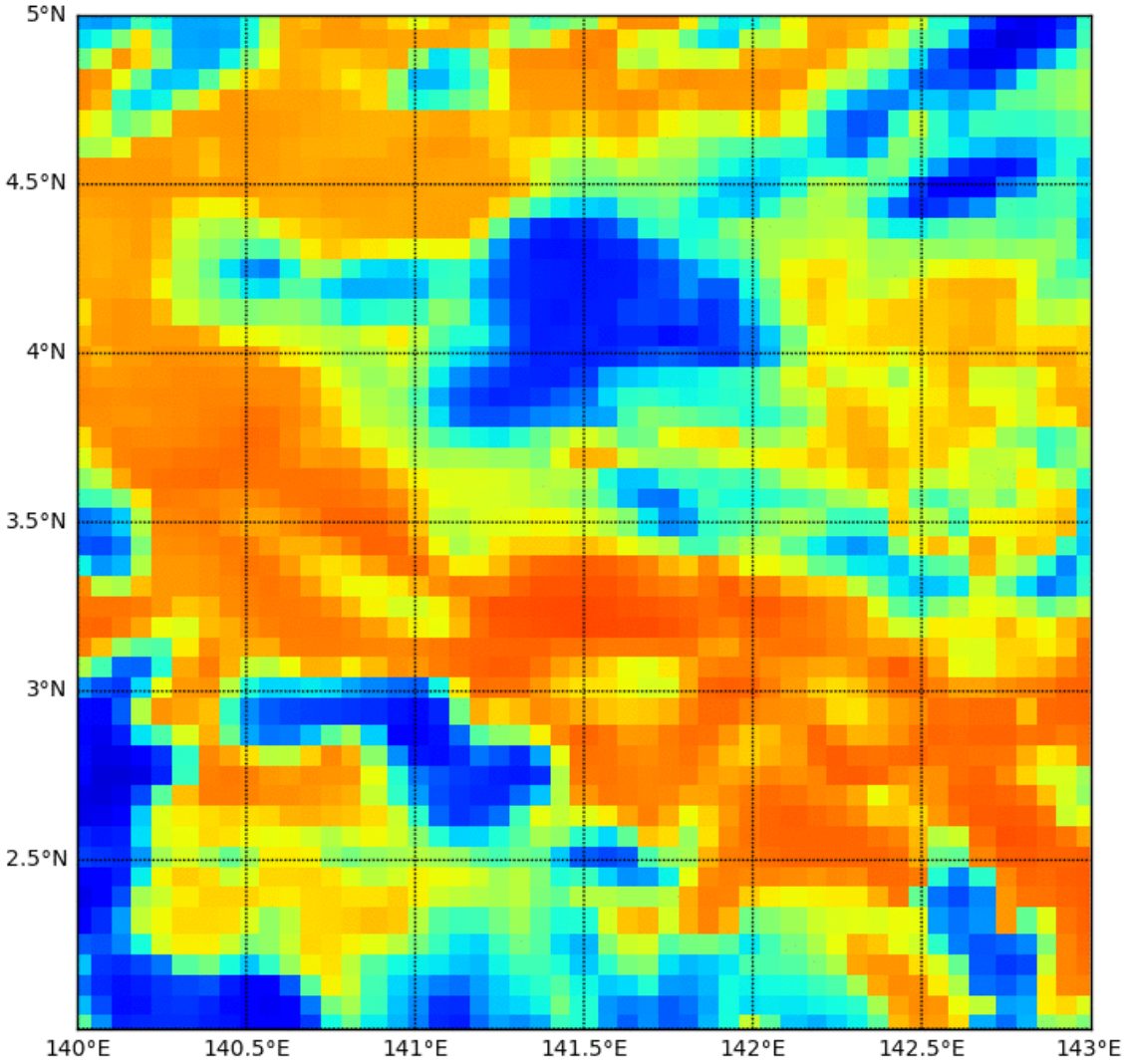
NR feature tracking is not an option

- We developed a simulator that estimates the location of AMVs without performing feature tracking

Radiance simulation

- Must incorporate both clouds and clear sky information for a realistic distributions of observations
  - No error does not mean cloud-free
- Not described here, but observations and error proxy data developed by Isaac

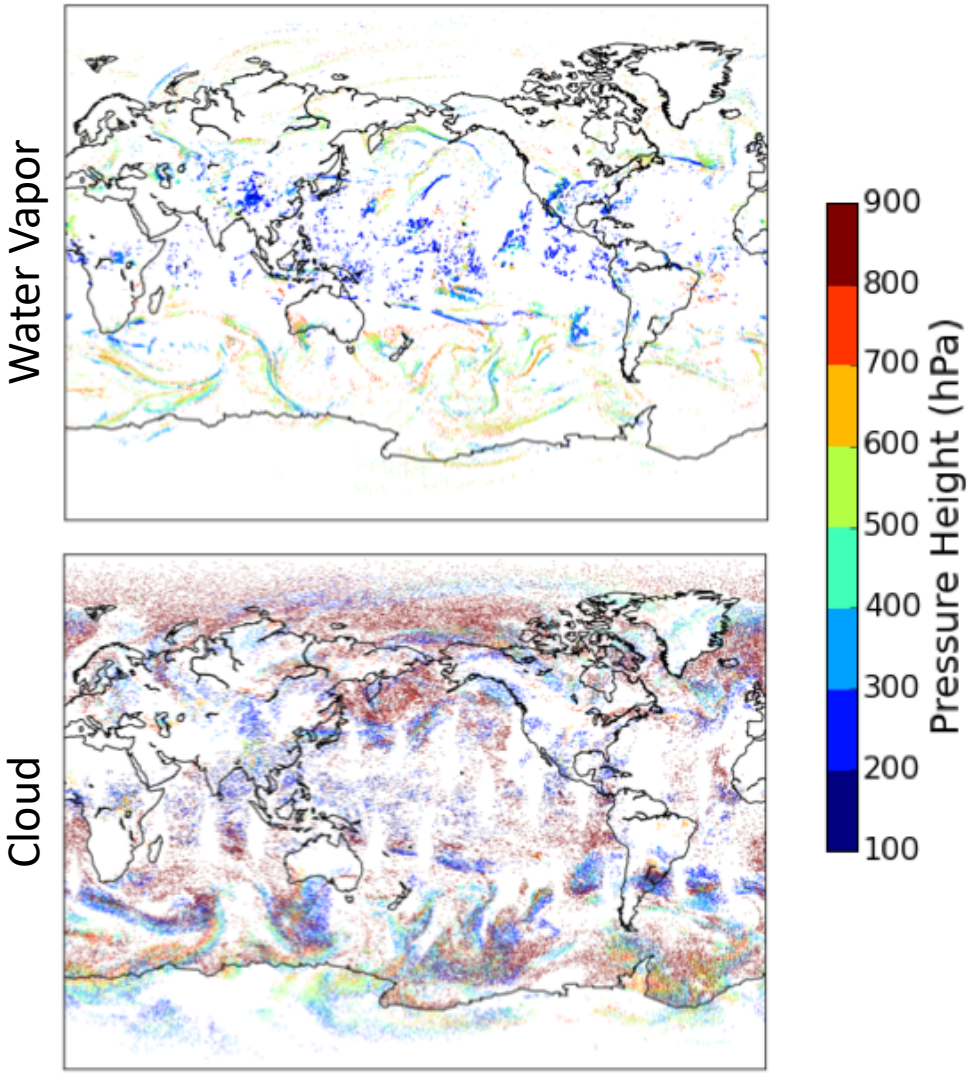
G5NR, 1 May 2006, 00-02 UTC, 30 min inc



Observation Simulation - Wind

Wind Simulator

- Observations are derived from NR
- Probability of cloud AMV is determined as a function of NR cloud fraction
  - Considers sub-column based on maximum-random overlap
- Probability of water vapor AMV determined on *fixed pressure surfaces*
  - Function of RH and RH gradient
- The purpose of this is that an observing system based on AMVs will not have regular sampling
  - Based on distribution of trackable features
  - The strength of data assimilation to produce regularly gridded fields



Experiment Configuration

Control – GMAO OSSE System

- Full Observing System circa 2016
  - Conventional: RAOB, surface, aircraft
  - Satellite Retrieved: GEO AMVs (GOES/ Himawari/MeteoSat), Polar LEO AMVs (MODIS Aqua/Terra)
  - Radiance:
    - IR: AIRS, IASI (Metop-A/B), CrIS, HIRS (Metop-A)
    - Microwave T: AMSU-A (NOAA-15/18/19, Metop-A/B, Aqua), ATMS, SSMIS F17
    - Microwave Q: MHS (NOAA-18, Metop-A/B)
  - All observations have error models applied

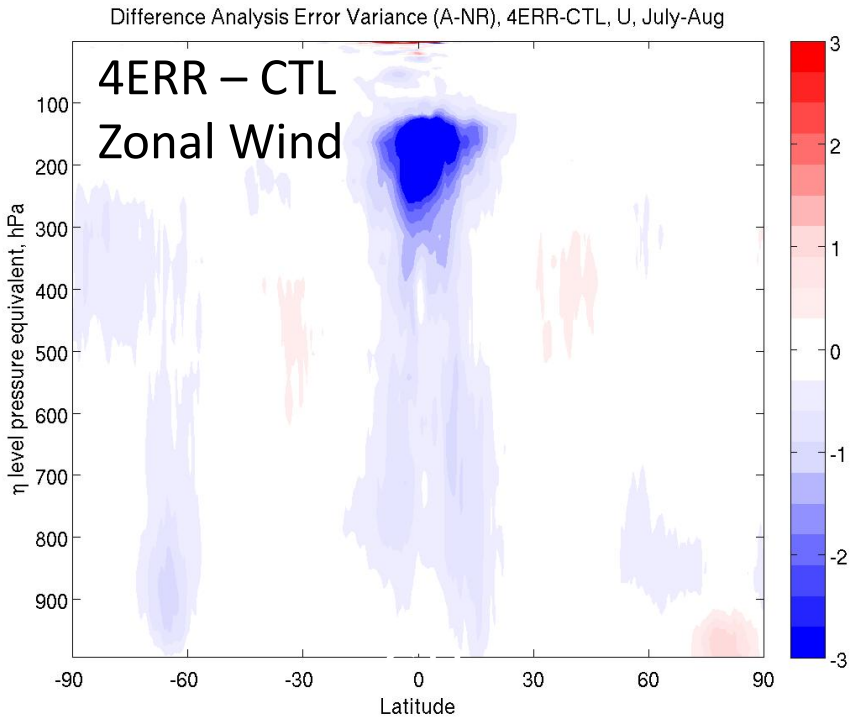
Experiment – 4PERF

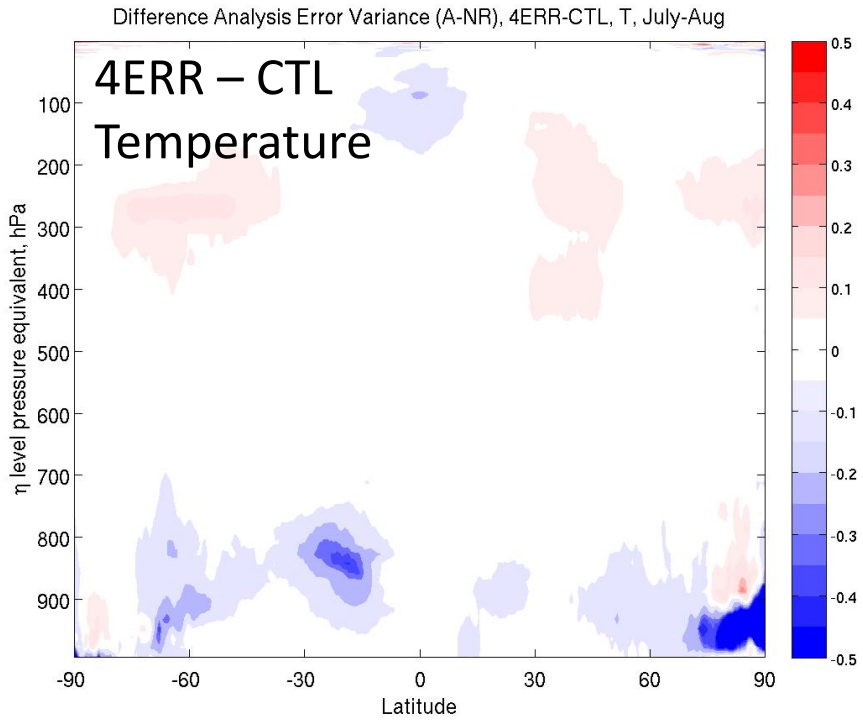
- Control + 4 Orbit Configuration
  - MISTiC Radiances (*46 channel selection*)
    - Channel selection performed to reduce interchannel correlations
  - MISTiC AMVs (Cloud & WV)
  - No additional errors applied to either radiances or AMVs

Experiment – 4ERR

- 4PERF + error covariance models applied to radiances and winds

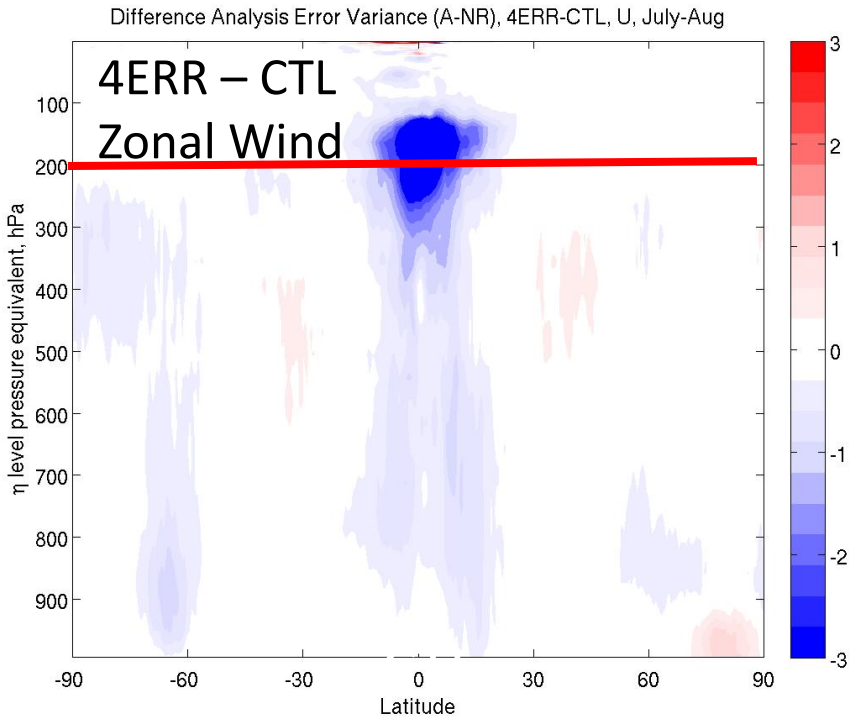
Analysis Error Variance Difference – Zonal Average

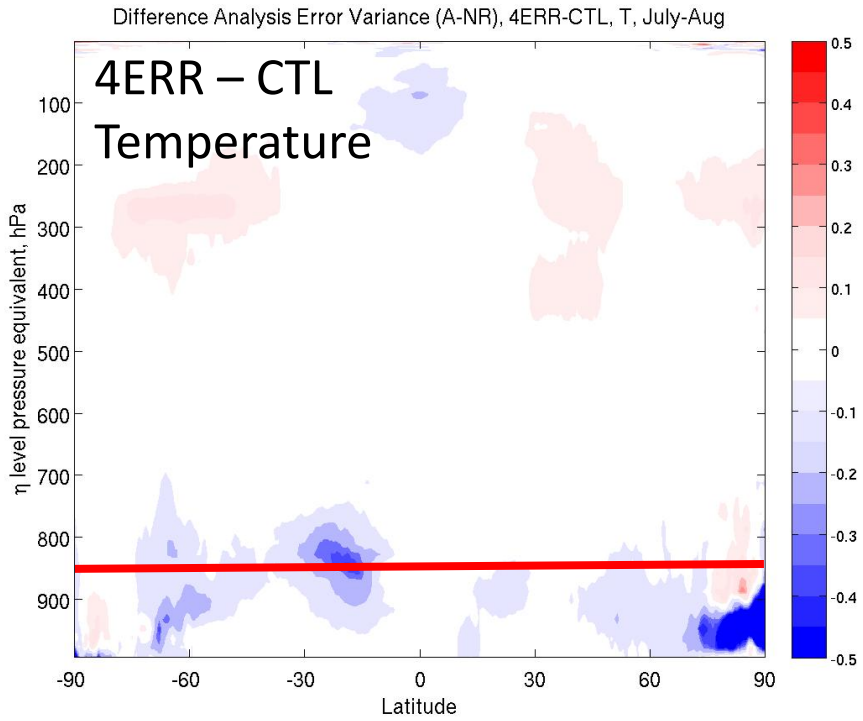




- Error variance calculated relative to Nature Run truth
- Difference relative to CTL – Blue (red) indicates addition of MISTiC obs reduced (increased) error
- Not shown, but 4PERF shows similar pattern, but with more improvement throughout

Analysis Error Variance – Zonal Average





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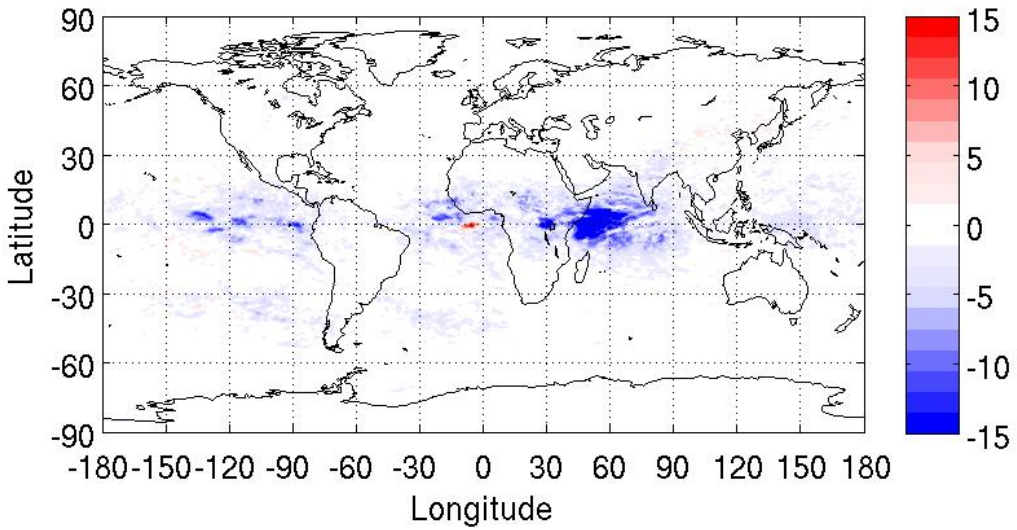
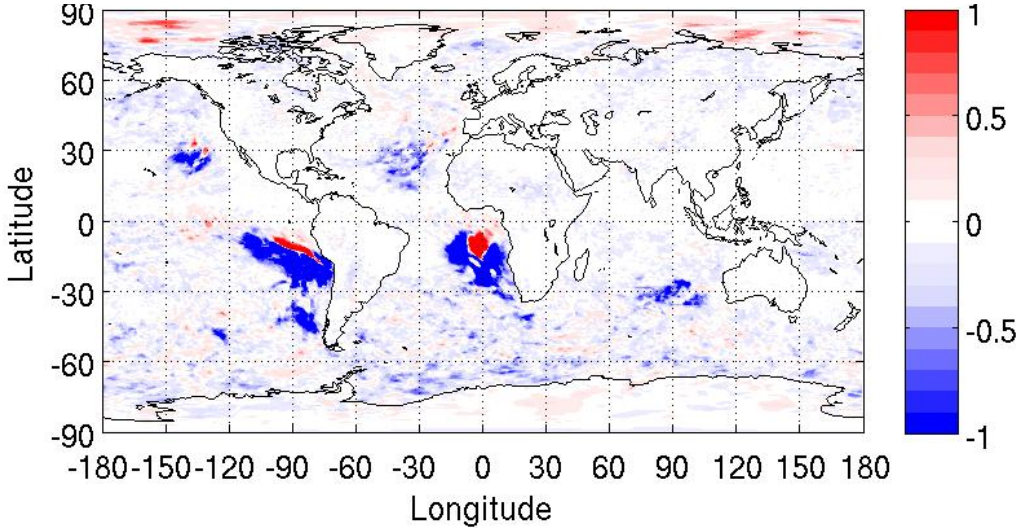
Analysis Error Variance Difference

Zonal Wind, ~200 hPa 4ERR - CTL



Temperature, ~850 hPa, 4ERR - CTL



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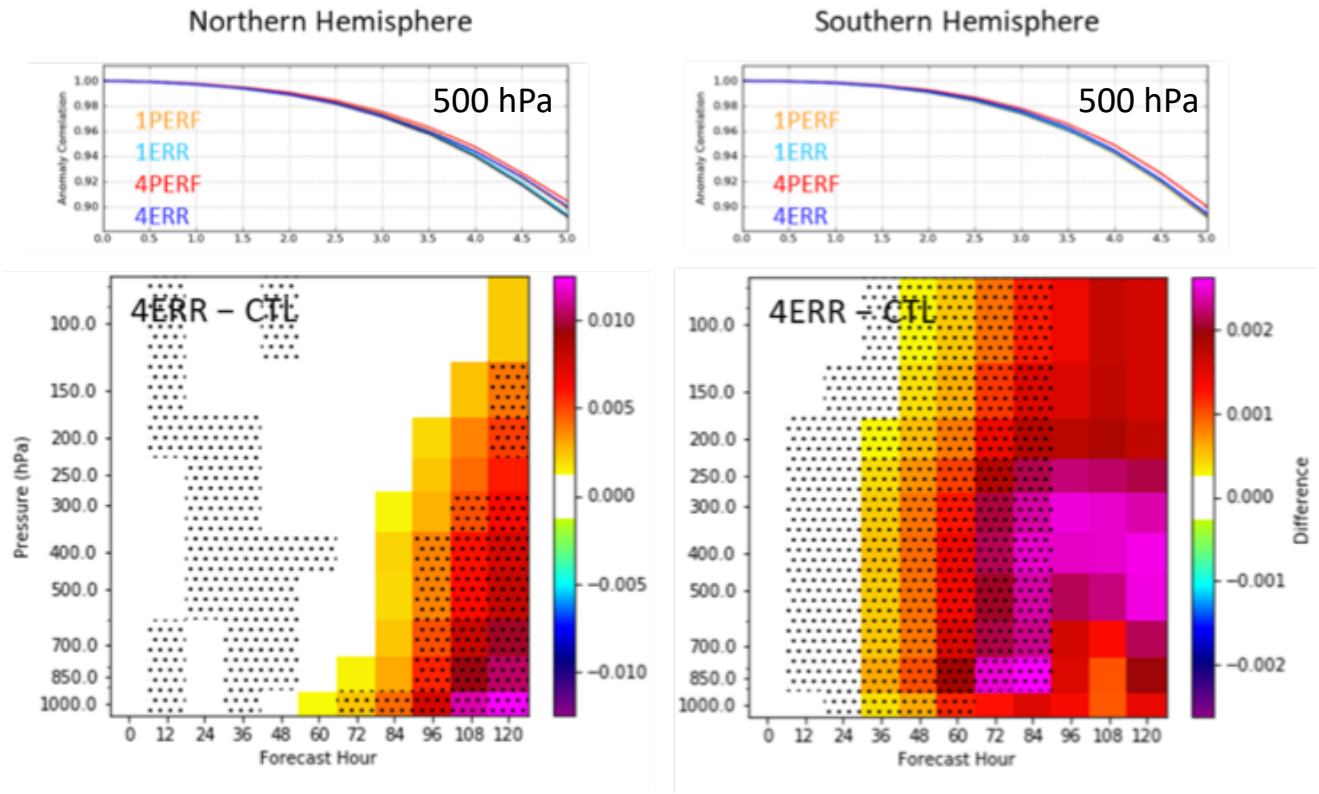
Forecast Skill – Z Anomaly Correlation P vs. time

Forecast skill improvement apparent in perfect observations, less apparent in error-added experiments

- Positive impact in all cases to day 2.5
- Largest near surface in NH, consistent through column in SH

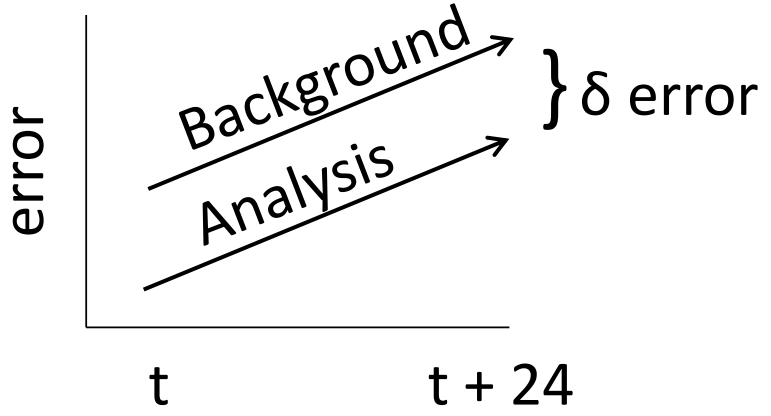
4ERR shows skill improvement, but lesser magnitude than 4PERF

- Still significant at 5 days through most of troposphere in N. Hem
- Significance loss at 4-5 days in S. Hem
- 4PERF (not shown) maintains significance through all forecast hours



Forecast Sensitivity - Observation Impact (FSOI)

- FSOI is a measure of 24 hour forecast error reduction projected into observation space
- Each assimilated observation has its own impact metric
  - Allows for the aggregation of the metric in different ways
    - per instrument, channel, footprint, etc.
- **A negative value equates a reduction in error, so NEGATIVE = GOOD**



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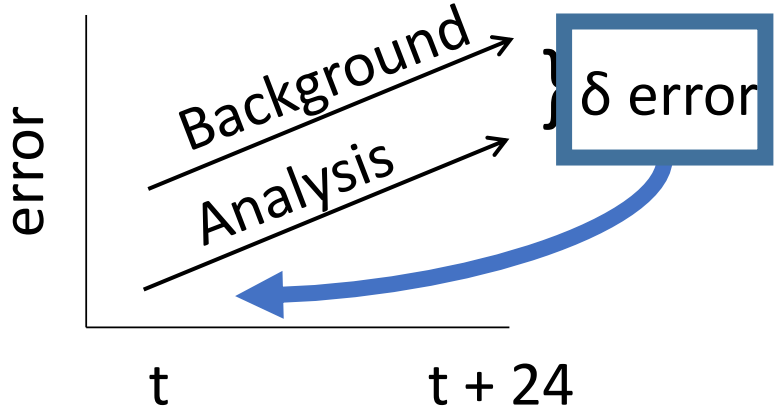
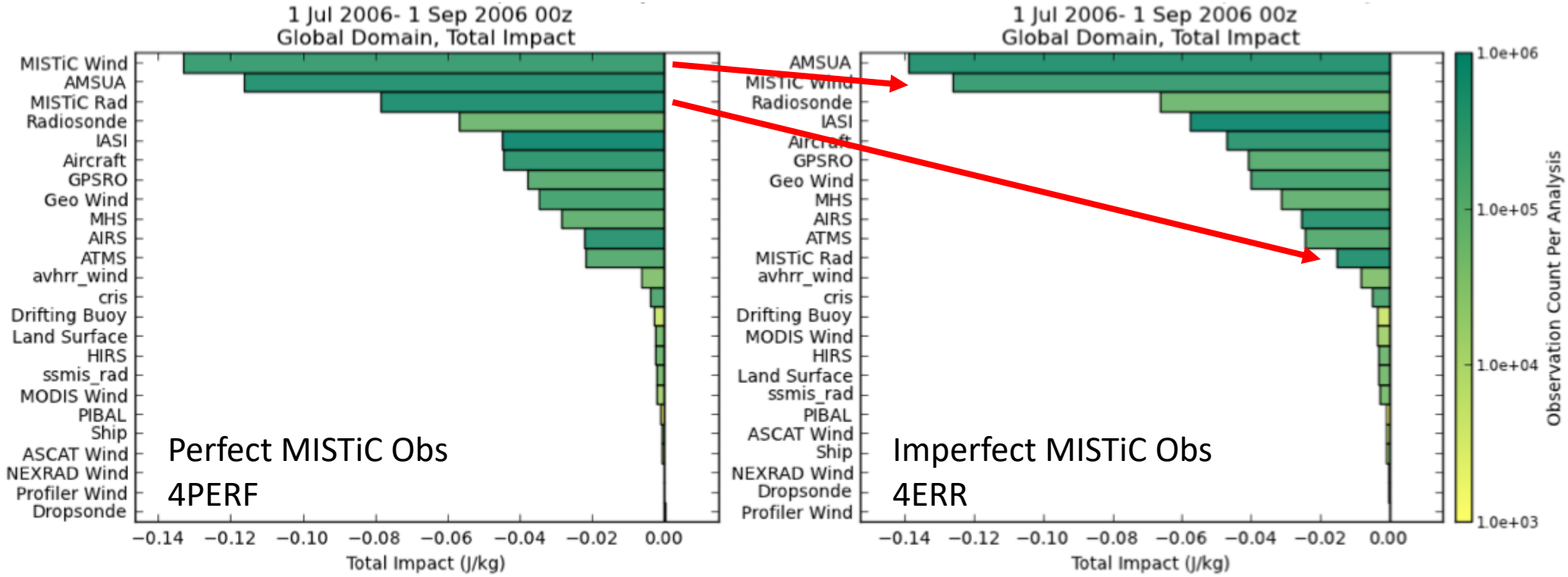


Forecast Impact (FSOI Metric)



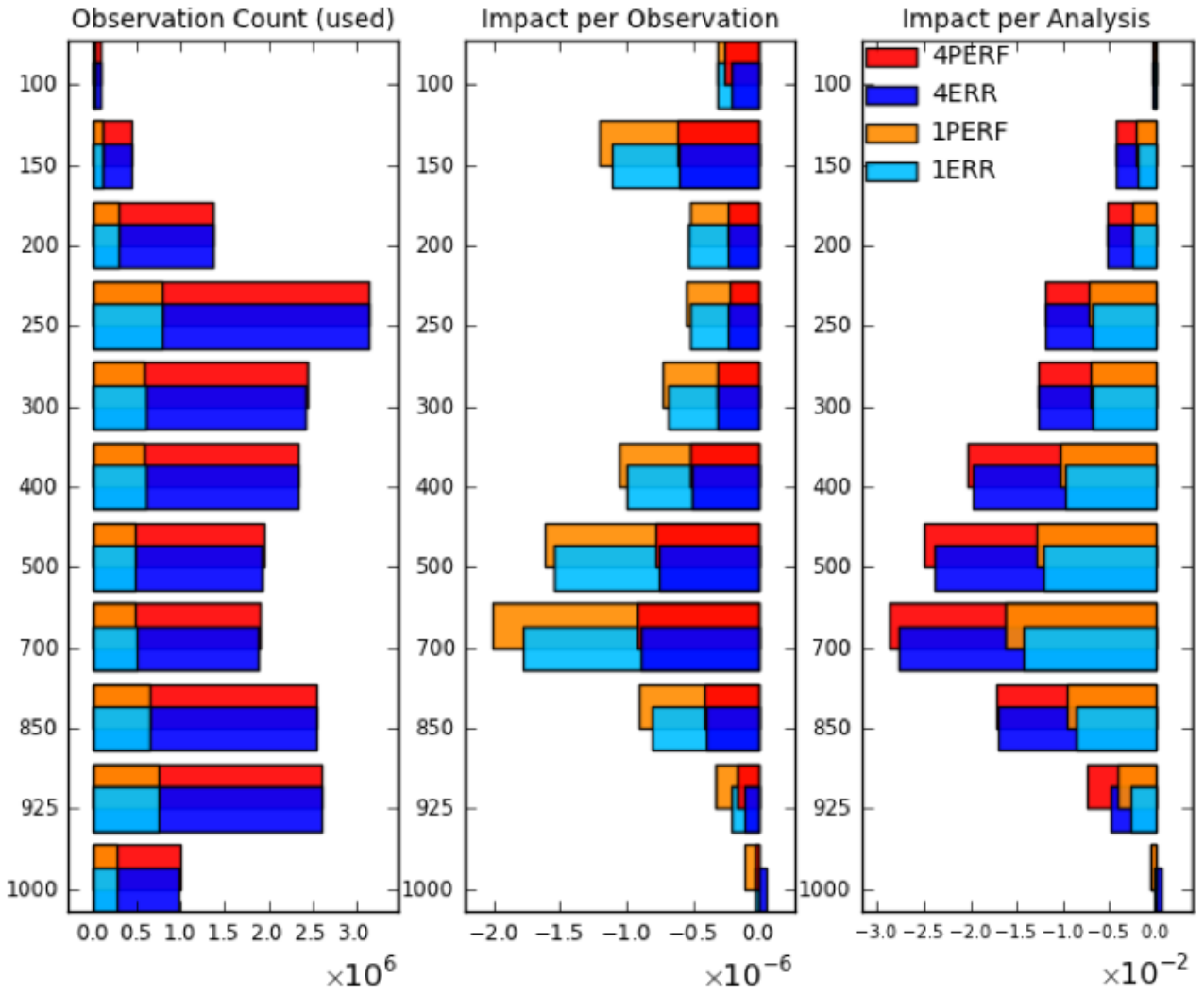
Considering perfect observations, MISTiC has the potential for reducing 24 hr forecast error

- When realistic are applied, the radiance impact is reduced greatly

MISTiC AMV FSOI

Cloud and WV AMVs combined

- Sampling strategy results in consistent distribution through troposphere
- Shows highest impact measurements come from middle troposphere



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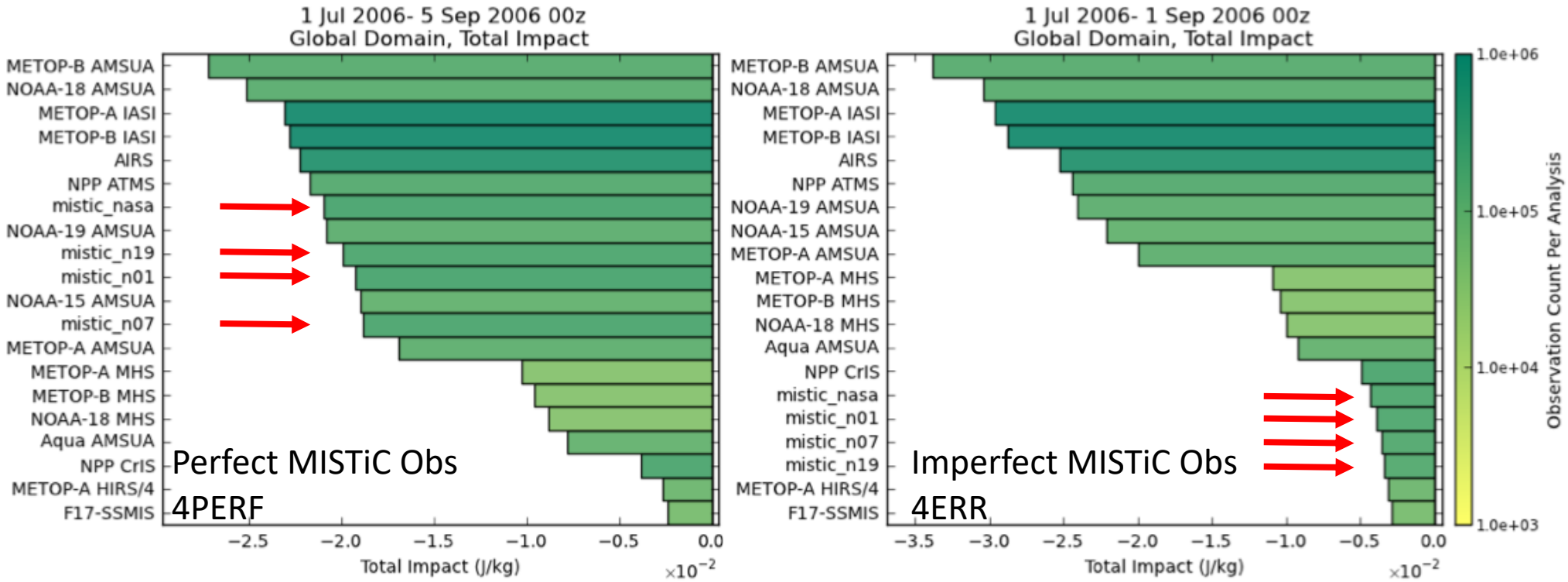


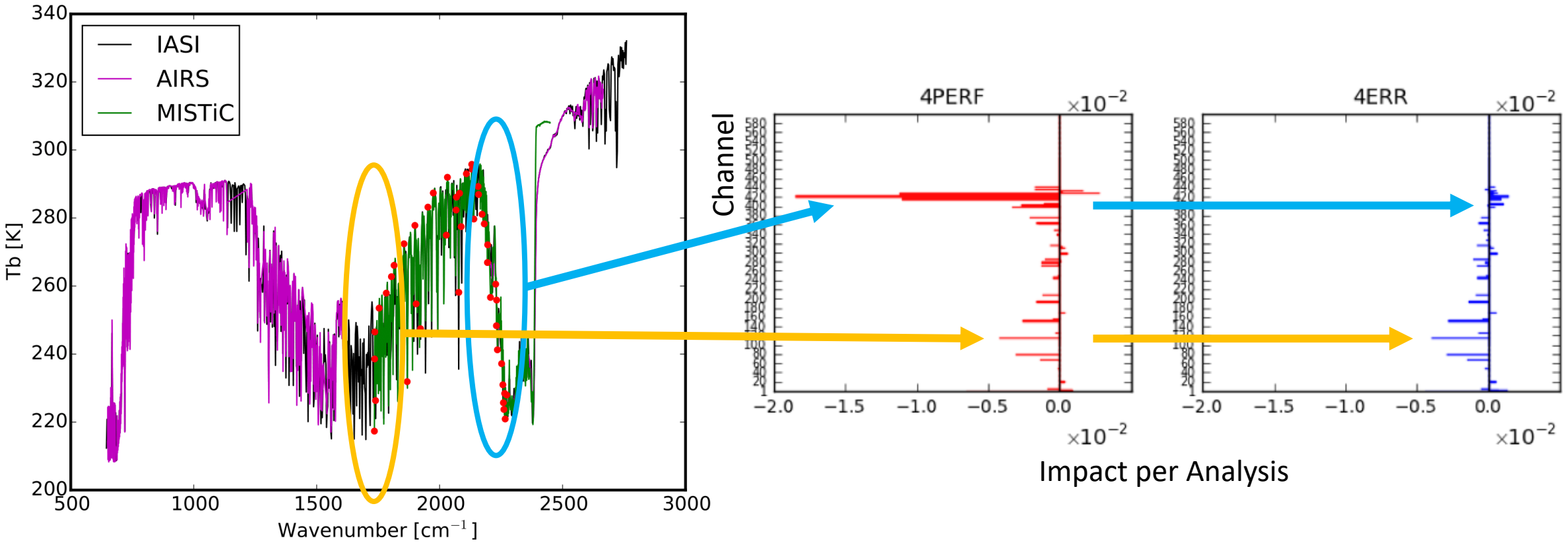
– Perfect observations show a similar impact to an AMSU-A

– Imperfect observations show sub-CrIS impact

- we know why CrIS is low – not a knock on instrument

MISTiC Radiance FSOI

FSOI by channel



Conclusions and Interpretation

The impact of four-orbital planes providing ‘global’ coverage
- Analysis error reduction showed primarily improvement with more observations in for U, T, and q
  - Small degradations are likely systematic in assimilation methodology (e.g. avoid highest moisture channels)
- Full constellation resulted in significant forecast skill improvement in both hemispheres (not shown)
- Metrics/improvements scale down when considering a single plane versus four

Inclusion of error model provides an indication of real benefit versus ‘idealized’ benefit
- Results consistently degraded when error model was included
- FSOI-indicated degradation due to shortwave radiances partially due to assimilation shortcomings

Overall, there is an expected benefit to be gained from MISTiC (or similar) constellation
- This OSSE helps quantify this benefit
- Provides some bounds to both ‘expected’ and ‘ideal’ impact

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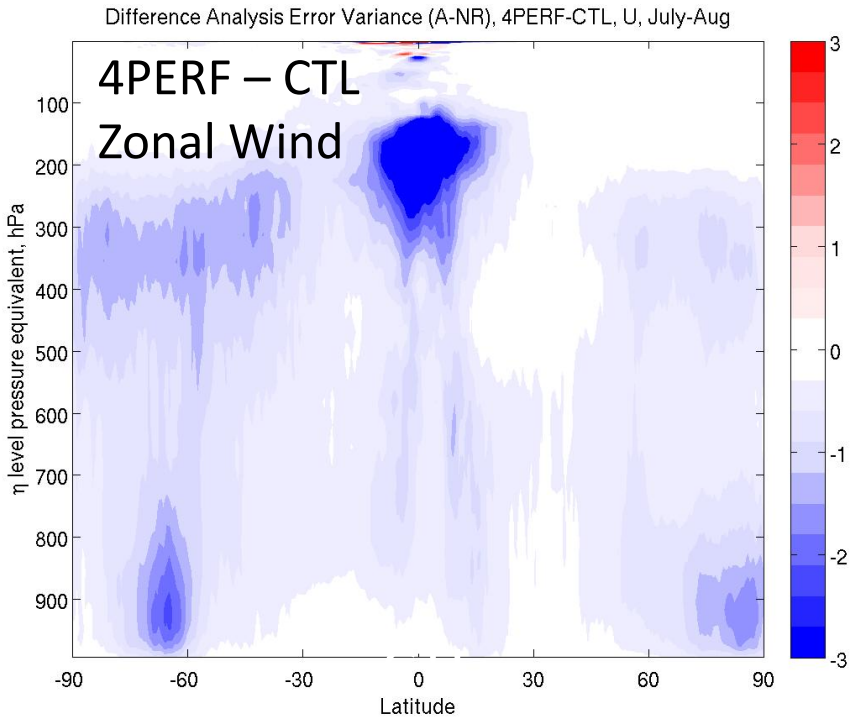

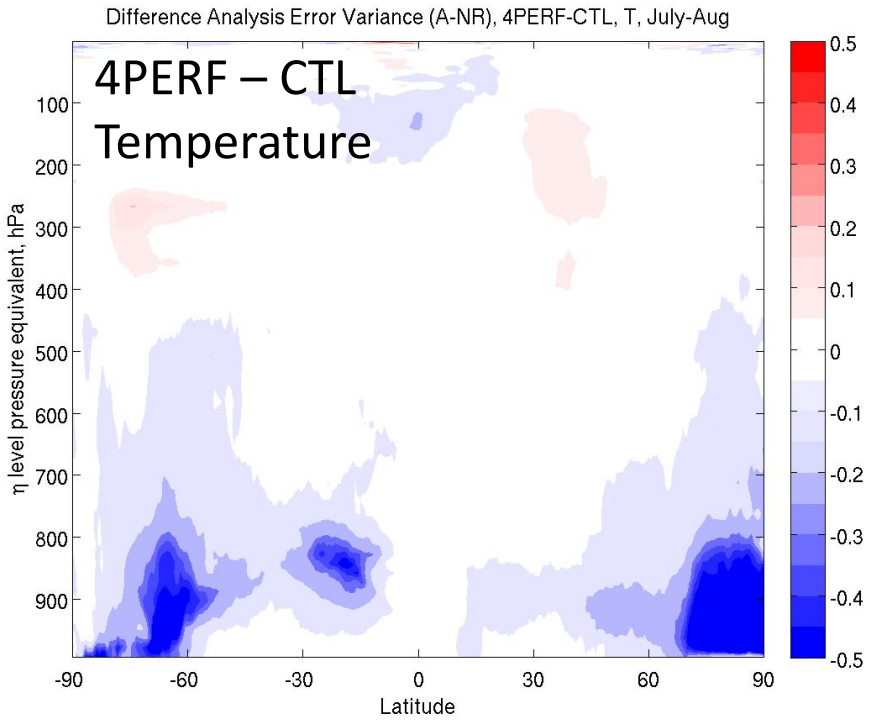

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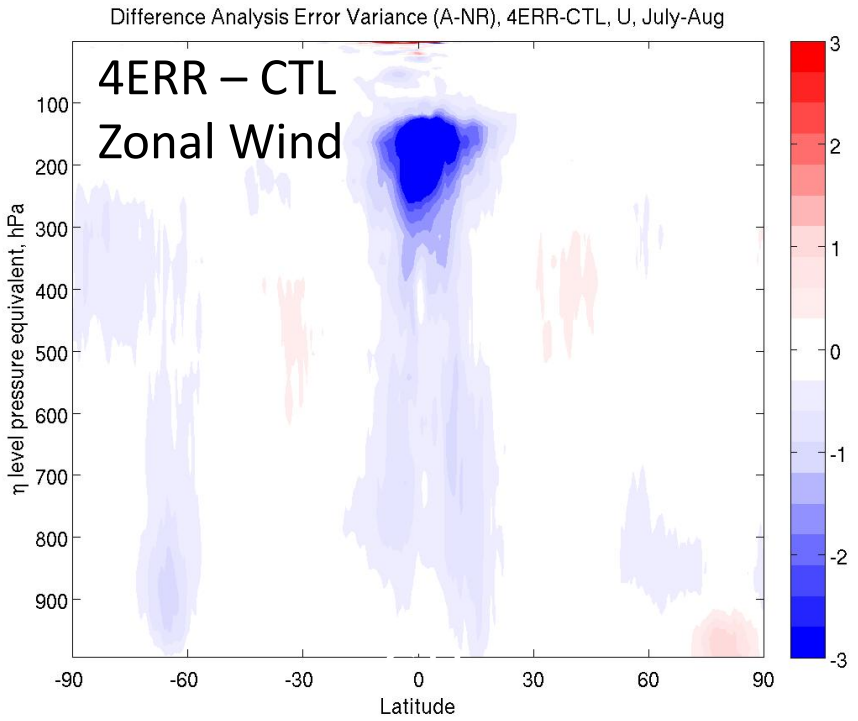

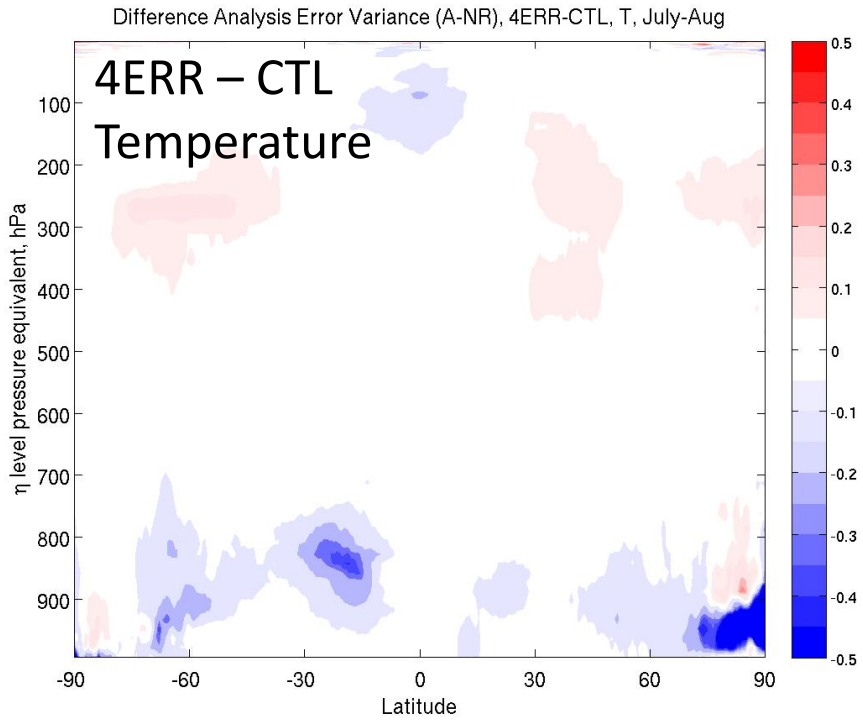

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