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

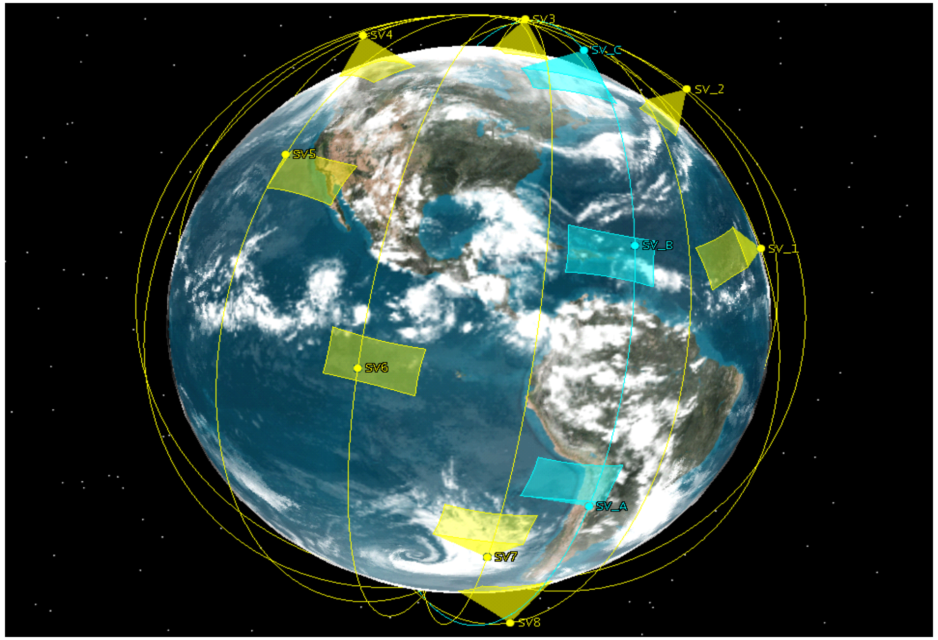
Will McCarty[1,2]
[1]Global Modeling and Assimilation Office
[2]NASA Goddard Space Flight Center

J. Blaisdell[3], M. Cordero-Fuentes[1,4], D. Carvalho[1,5], M. Chattopadhyay[1,4], R. Errico[1,5], R. Gelaro[1,2], L. Kouvaris[3], I. Moradi[1,6], S. Pawson[1,2], N. Prive[1,5], M. E. Sienkiewicz[1,4], and J. Susskind[2]
[3]Science Applications International Corporation
[4]Science Systems and Applications, Inc.
[5]Goddard Earth Sciences Technology and Research
[6]Earth System Science Interdisciplinary Center

9 January 2018

Brief Project Overview

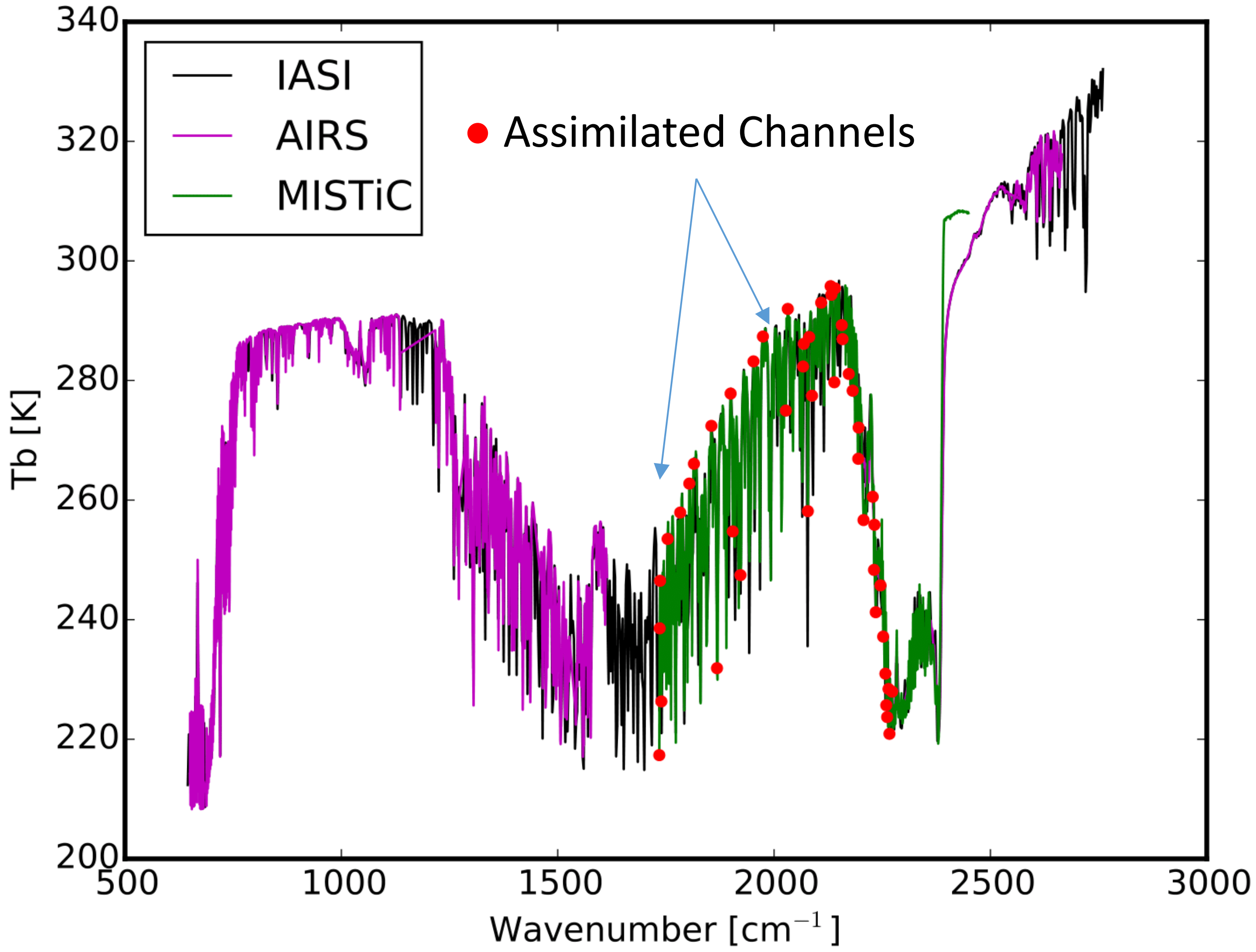
- Results presented based on an OSSE for MISTiC™ Winds
  - MISTiC™ Winds provide High Spatial/Temporal Resolution Temperature and Humidity Soundings of the Troposphere
  - The observing strategy is to retrieve atmospheric state and motion via LEO Constellation of MicroSats
    - Infrared spectrometer 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

Some content via K. Maschhoff (BAE)

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}

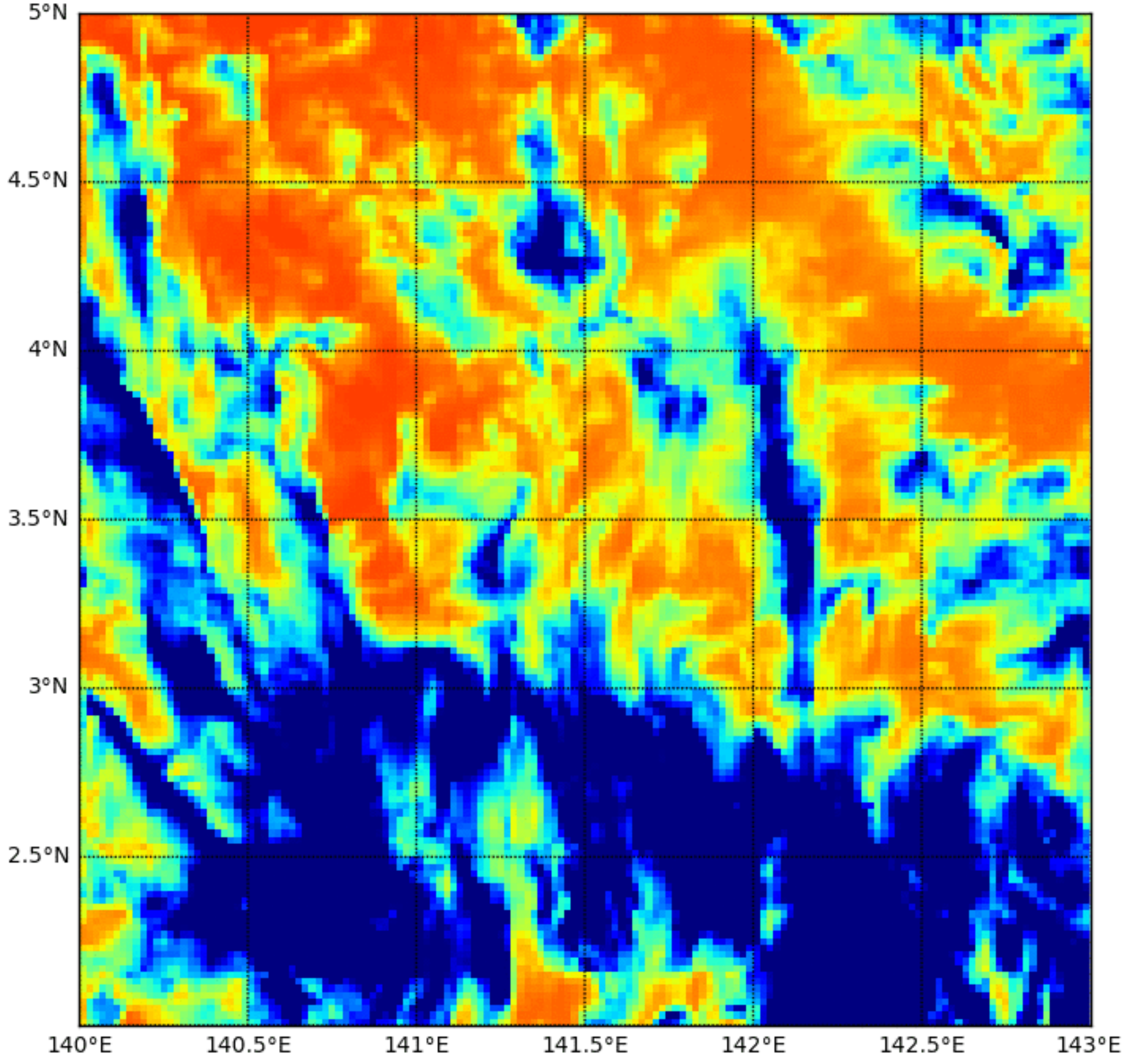
All cases perform a channel selection, down-selecting to 46 channels

- 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

Nature run clouds used in simulation to produce realistic yeilds

Wind Simulation in an OSSE

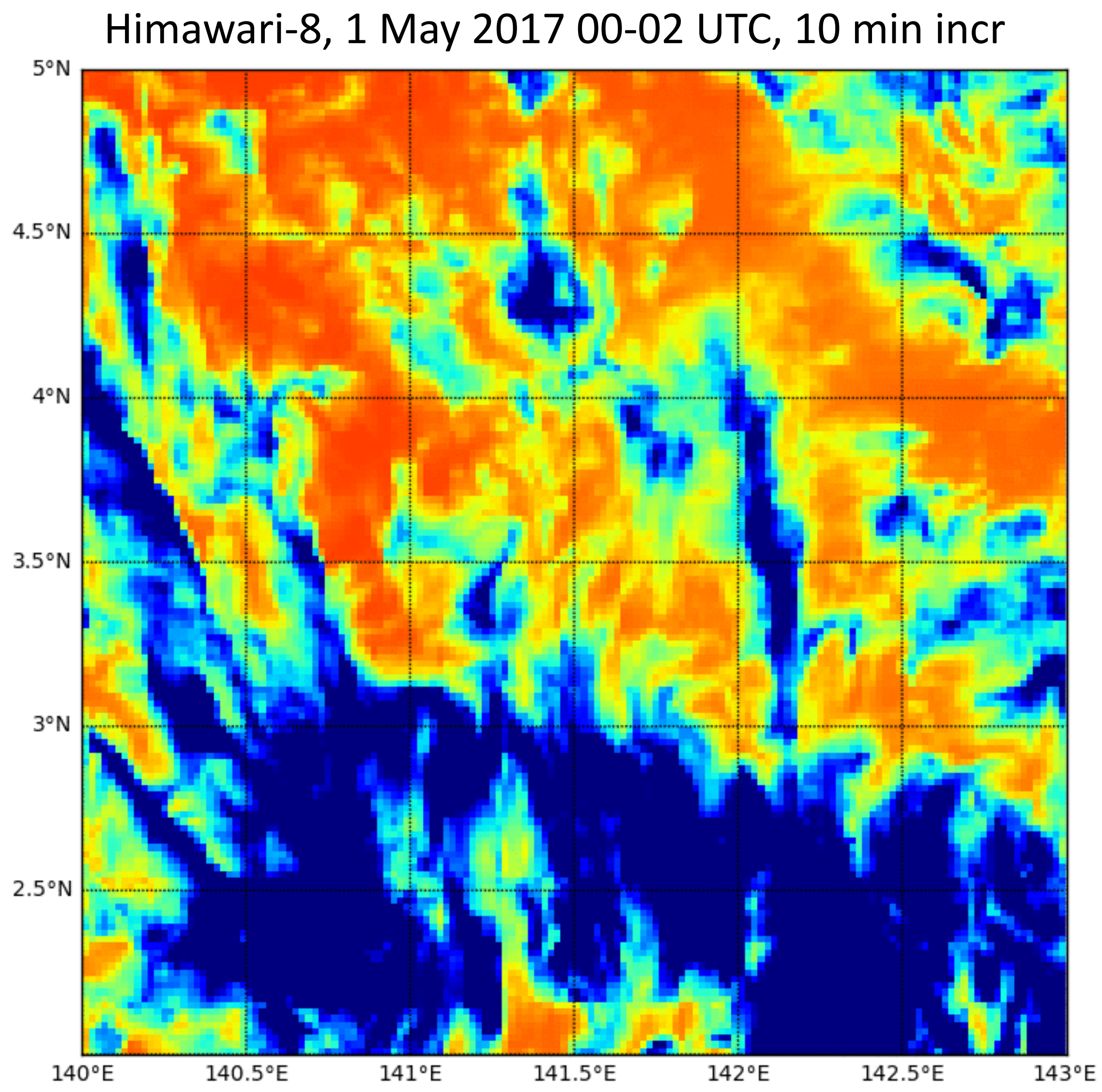
Himawari-8, 1 May 2017 00-02 UTC, 10 min incr

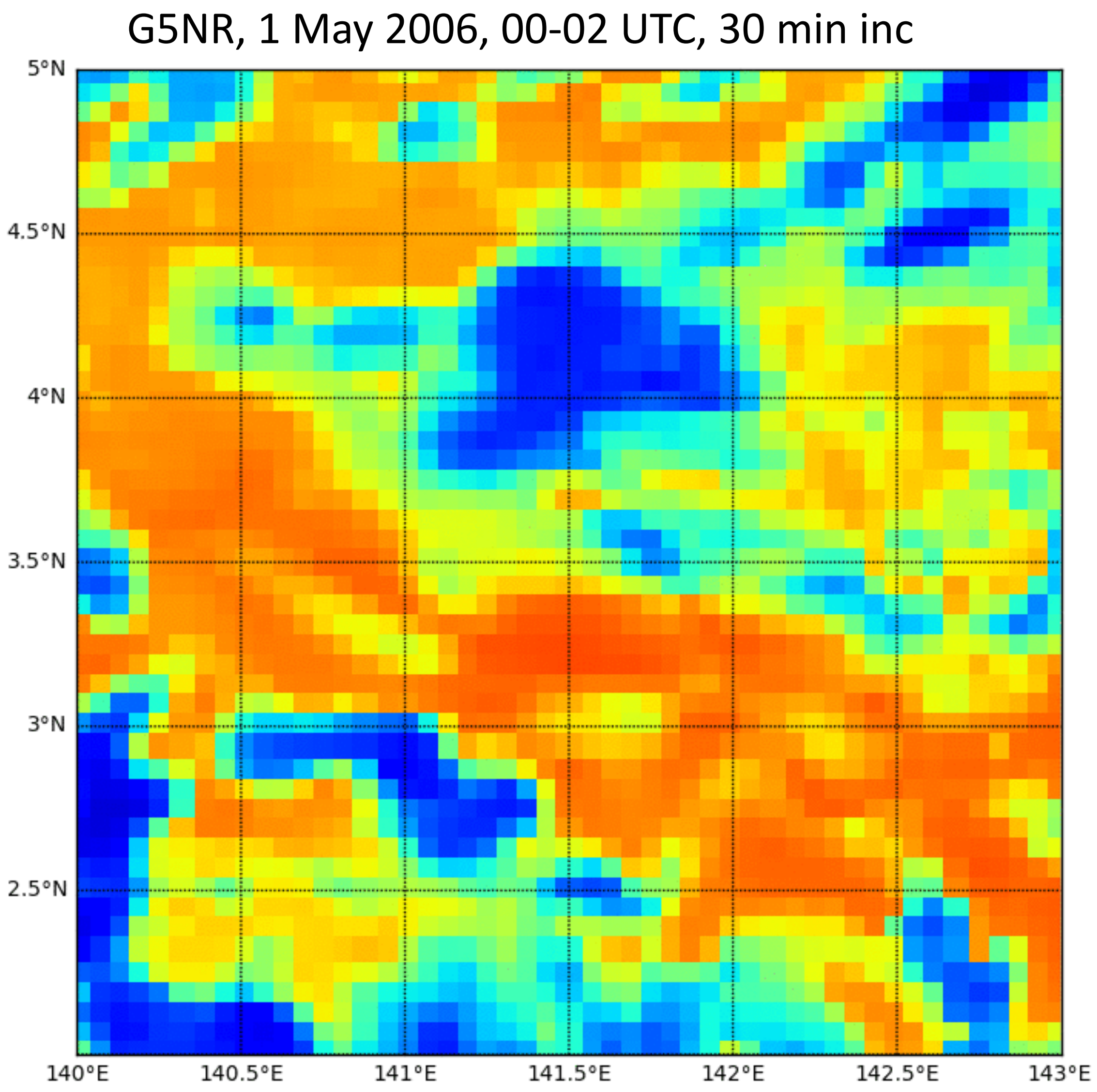


Atmospheric Motion Vector (AMV) Retrieval

- 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

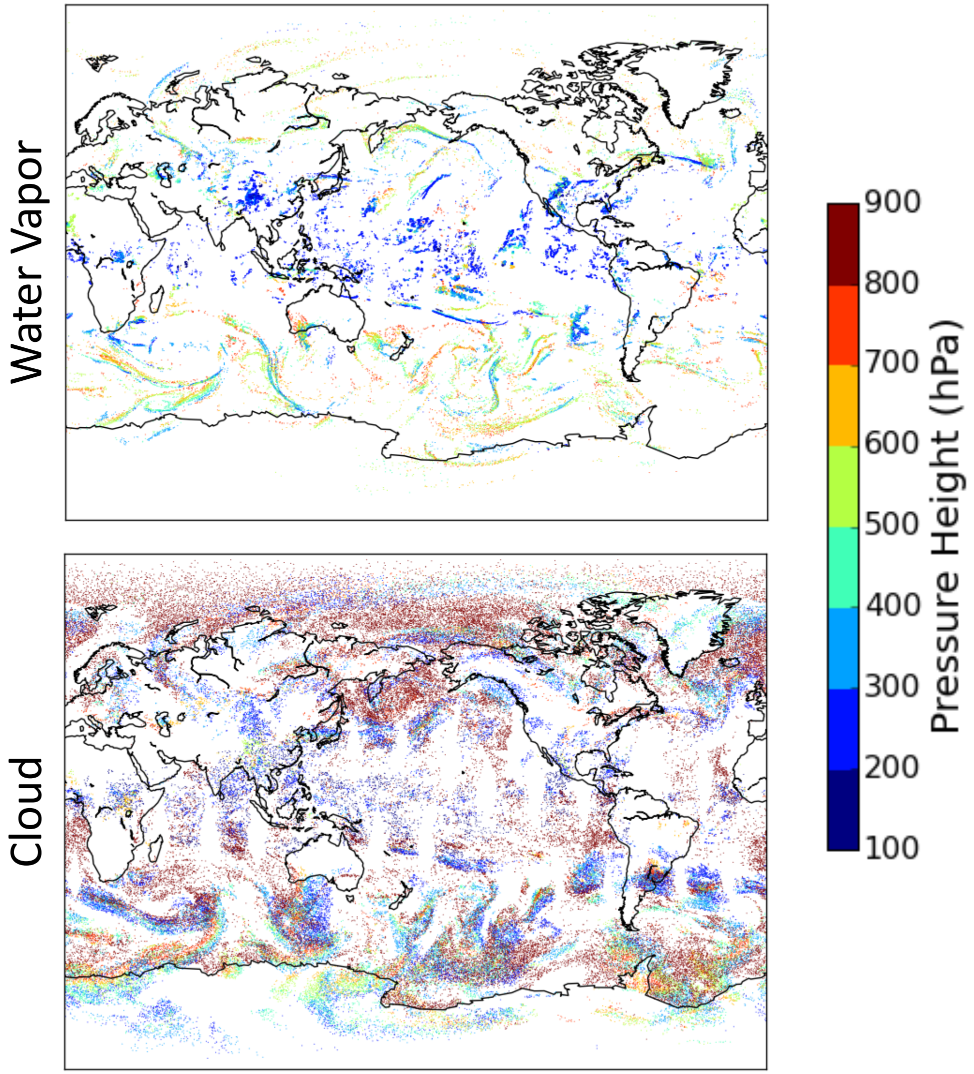




Observation Simulation - Wind

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

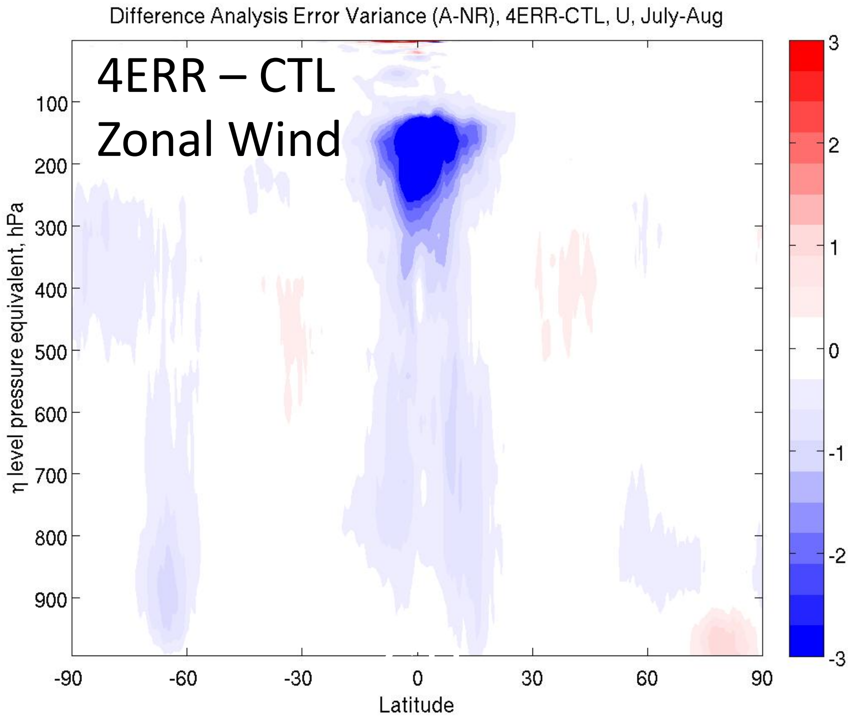
- MISTiC Radiances (*46 channel selection*)
  - Channel selection performed to reduce interchannel correlations
- MISTiC AMVs (Cloud & WV)
- No additional errors applied to either radiances or AMVs

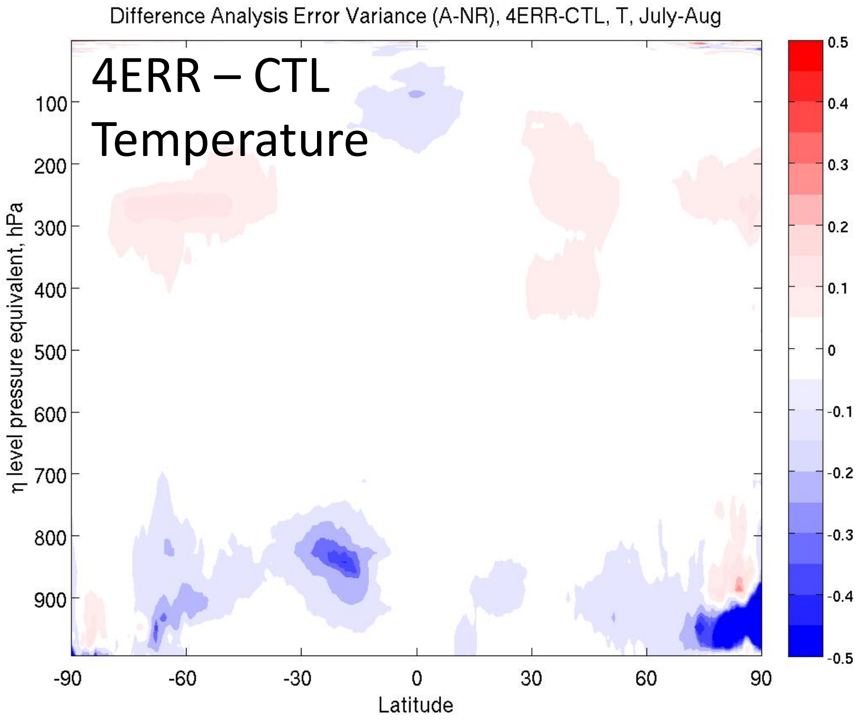
Experiment – 4ERR

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

- Himawari specs used for AMVs
- Convolved IASI radiances uses for radiance error estimation

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

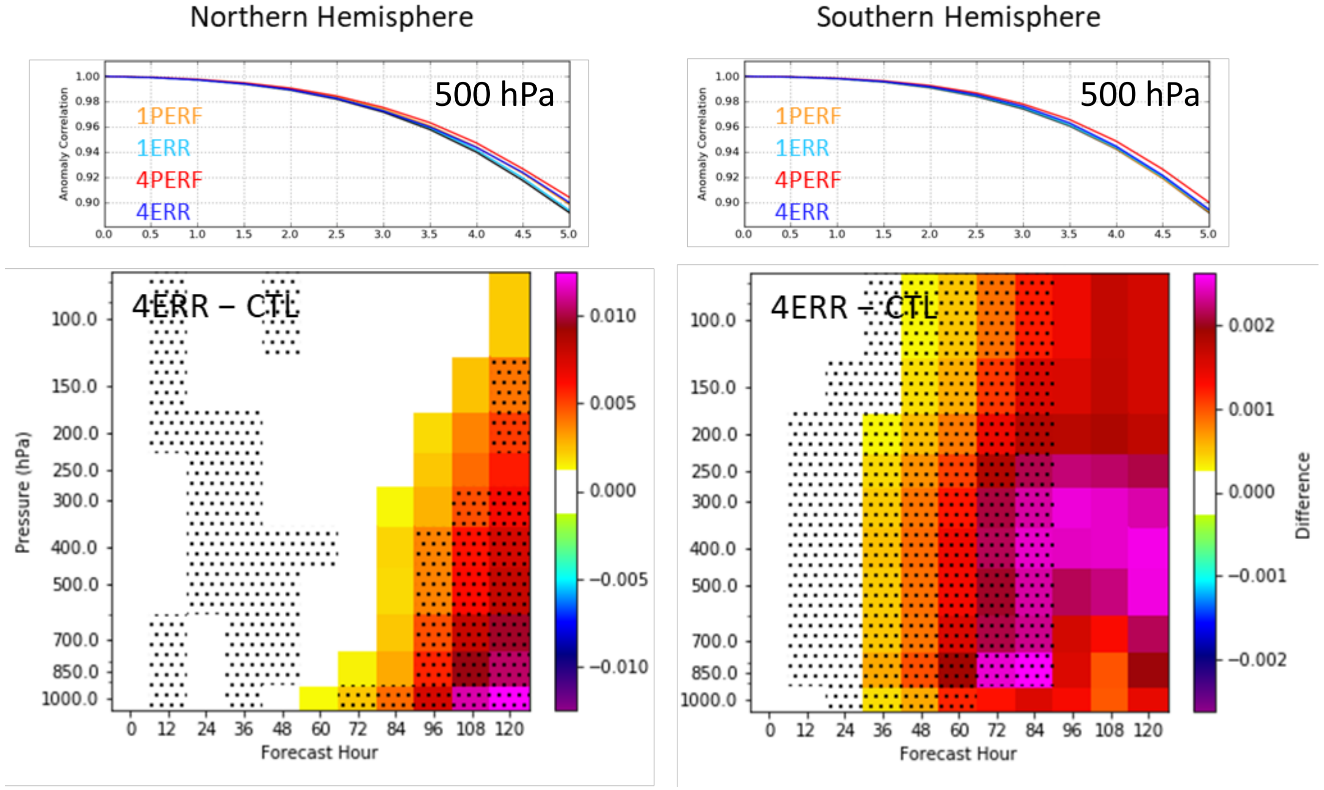
Forecast Skill – Z Anomaly Correlation P vs. time

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

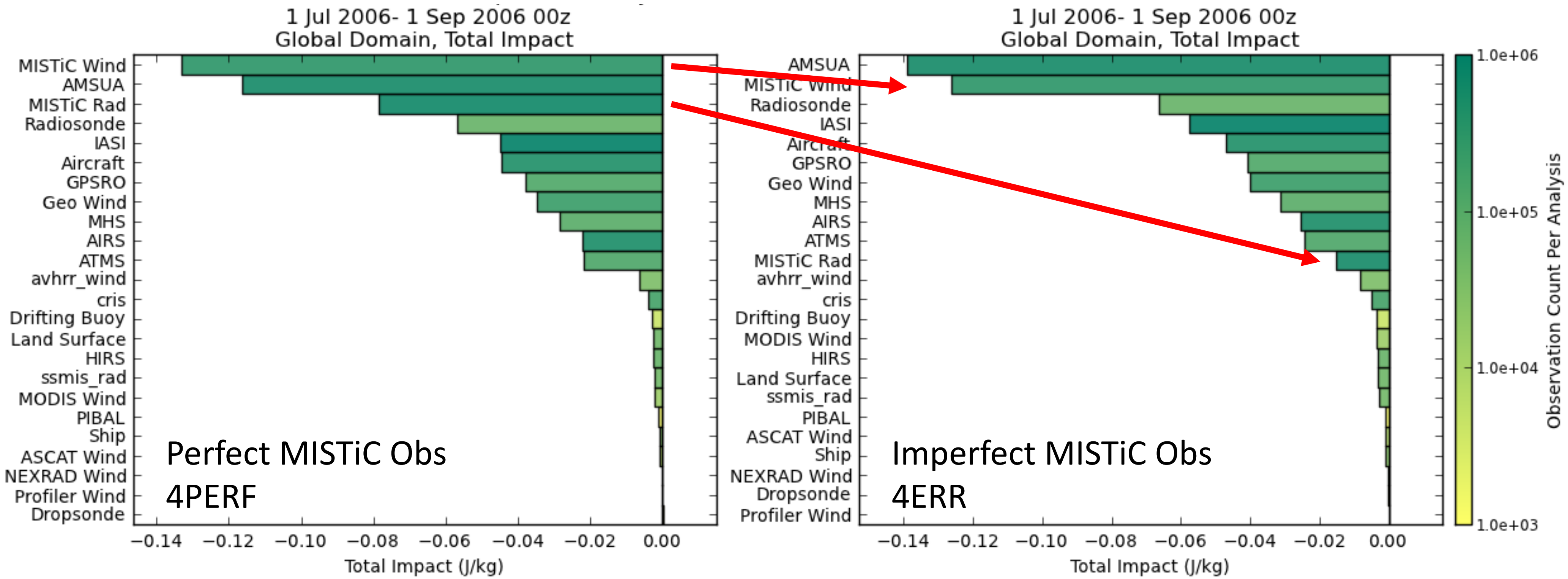
- Positive impact in all cases to day 2.5
- Largest near surface in NH, consistent through column in SH

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 Impact (FSOI Metric)



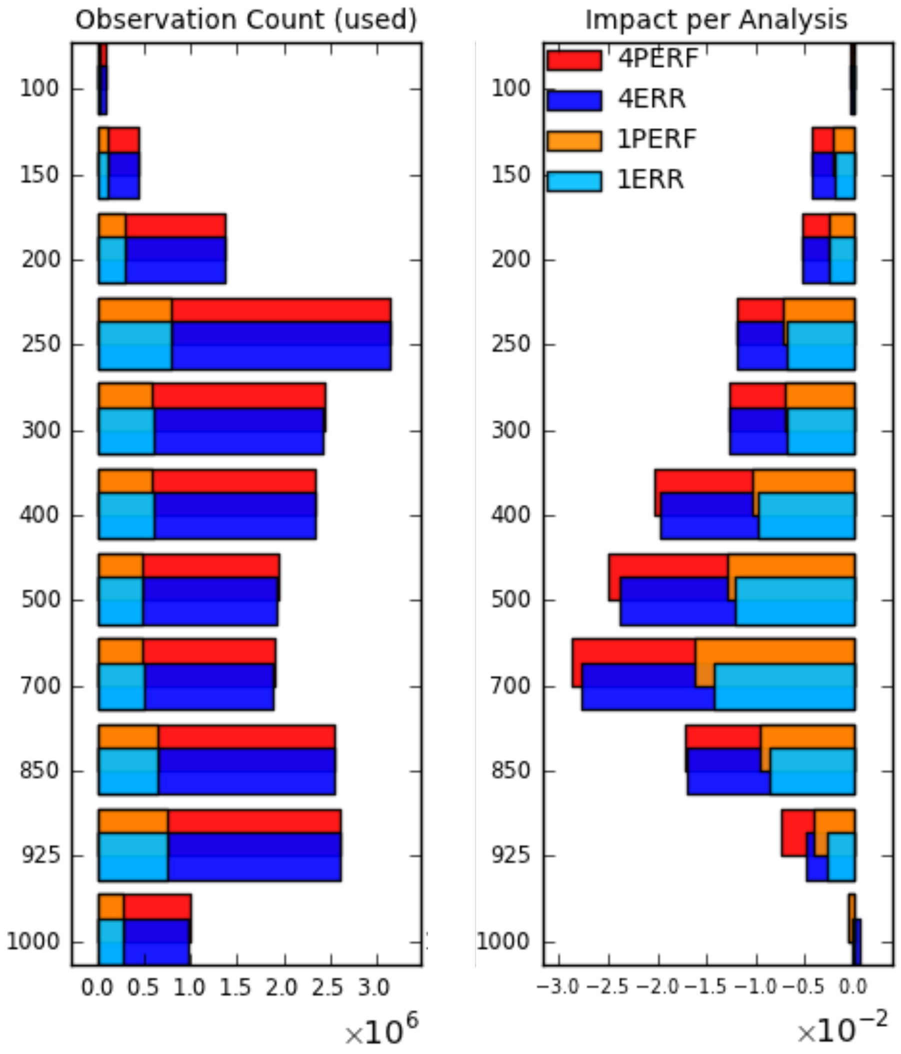
Considering perfect observations, MISTiC has the potential for reducing 24 hr forecast error

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

MISTiC AMV FSOI

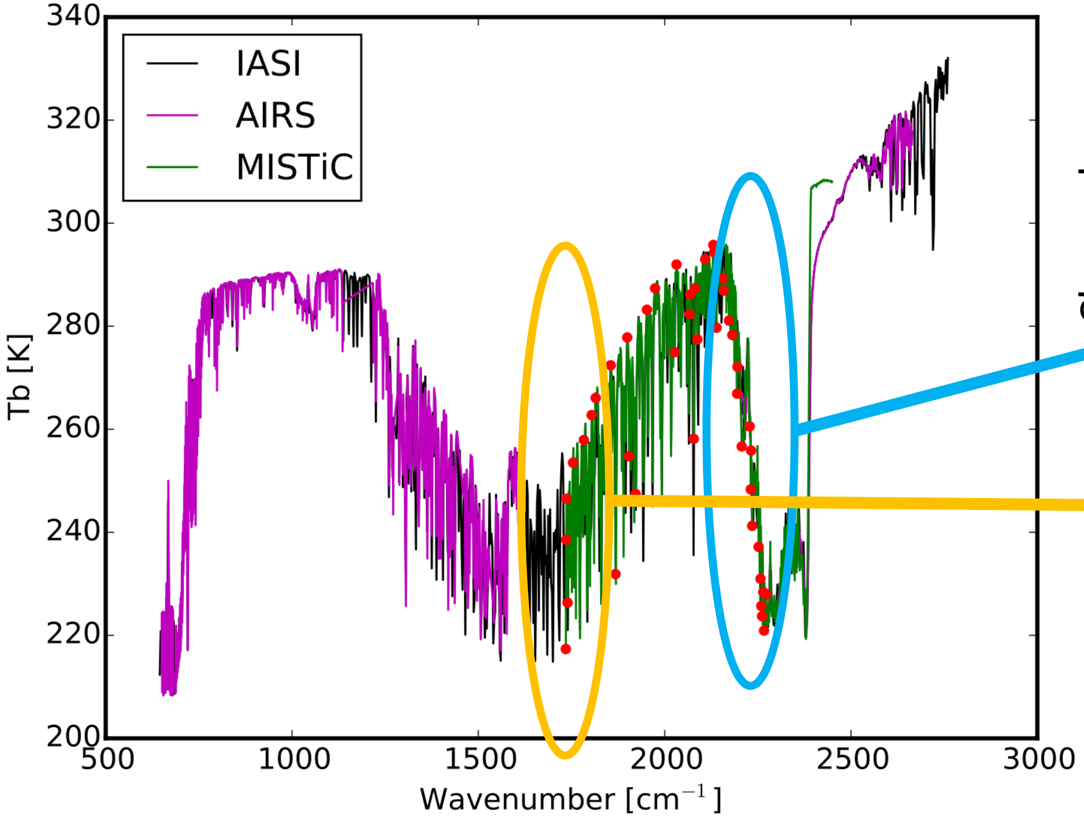
Cloud and WV AMVs combined

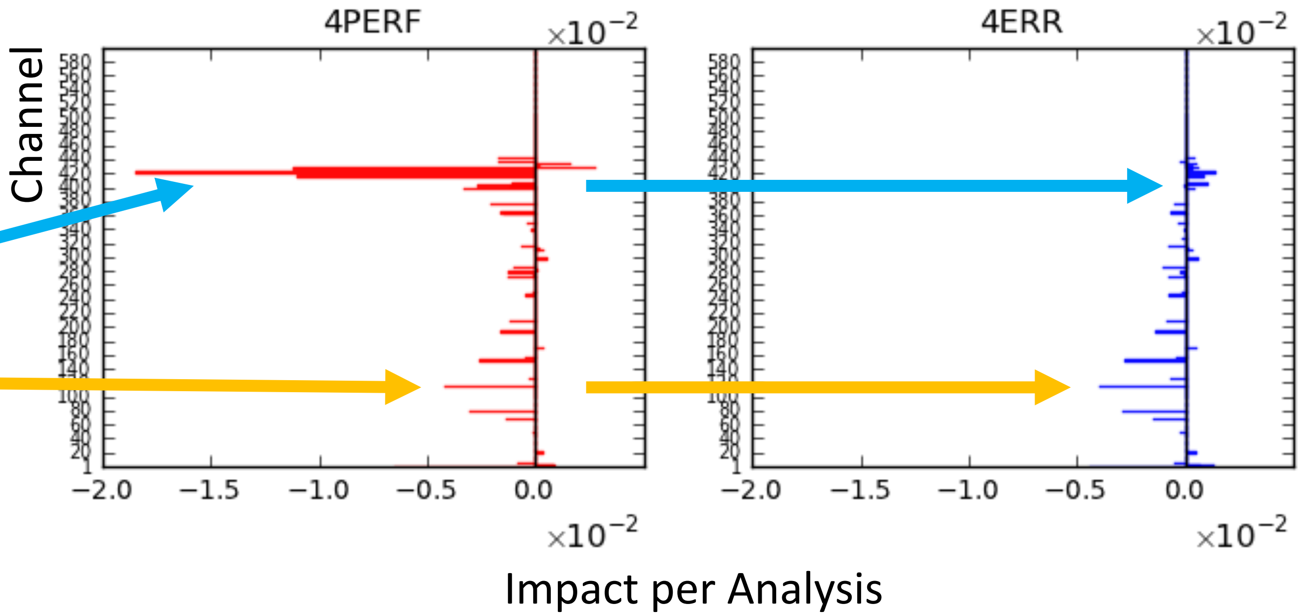
- Sampling strategy results in consistent distribution through troposphere
- Shows highest impact measurements come from middle troposphere



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 showed signs of significant forecast skill improvement in both hemispheres
- 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