

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

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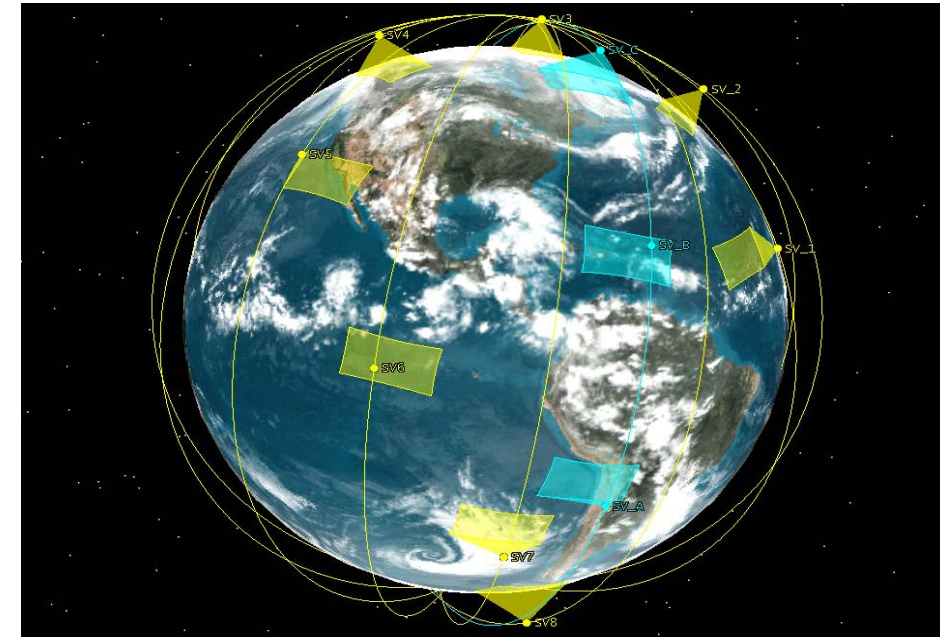
Brief Project Overview

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

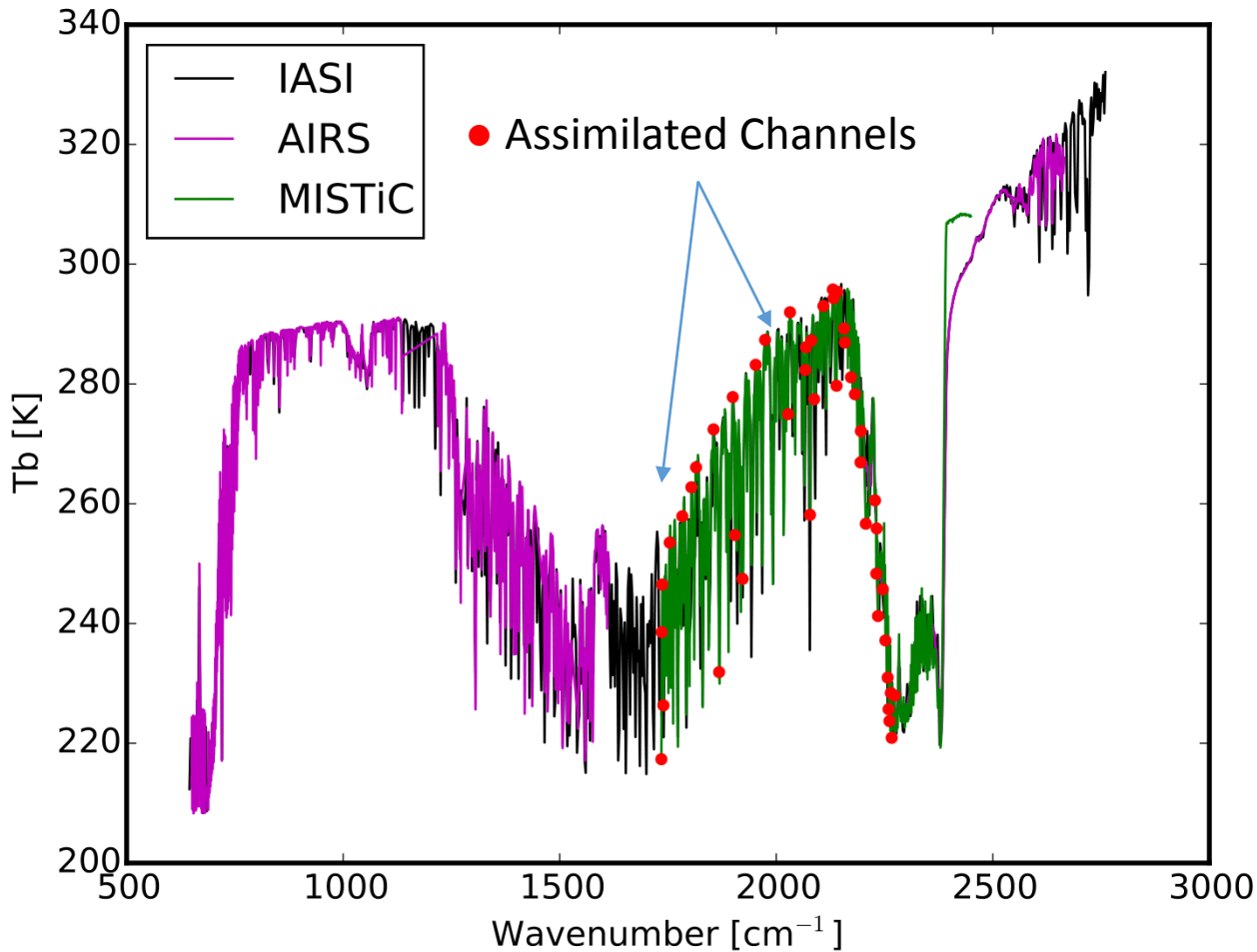
Study is performed on top of GMAO OSSE system

- 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}

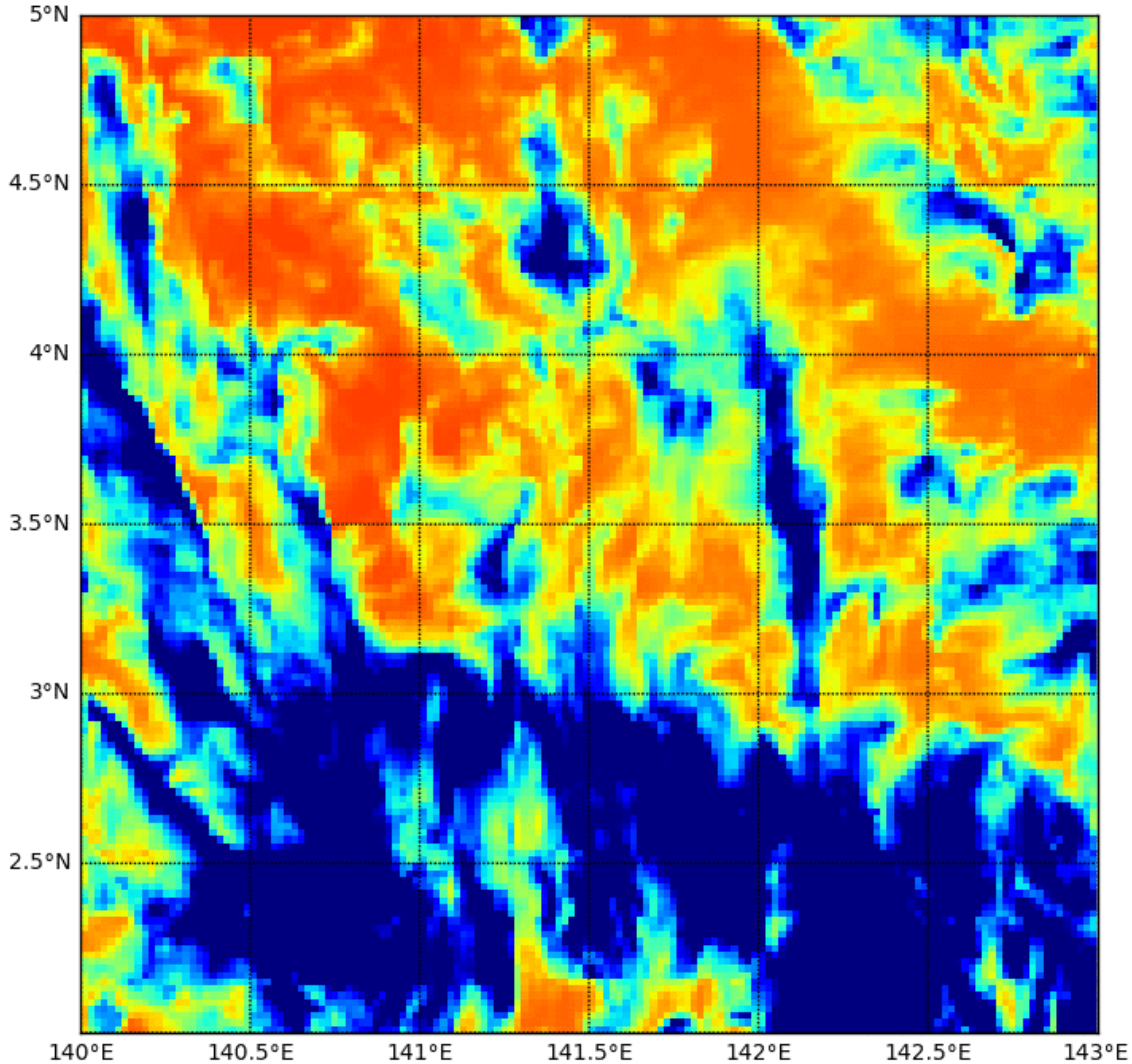
All cases perform a channel selection, down-selecting to 46 channels

- 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

Nature run clouds used in simulation to produce realistic yields

Wind Simulation in an OSSE

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

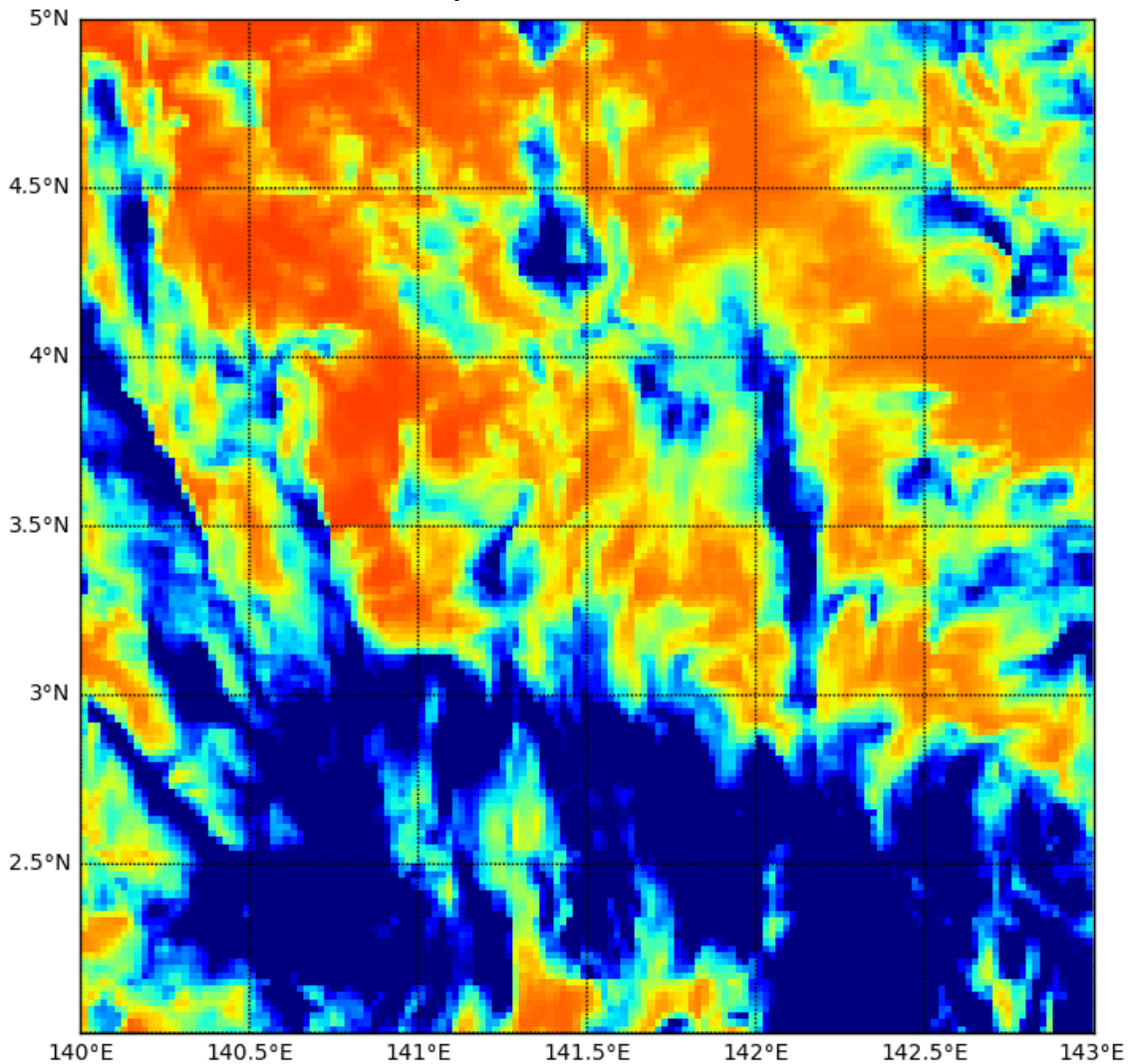


Atmospheric Motion Vector (AMV) Retrieval

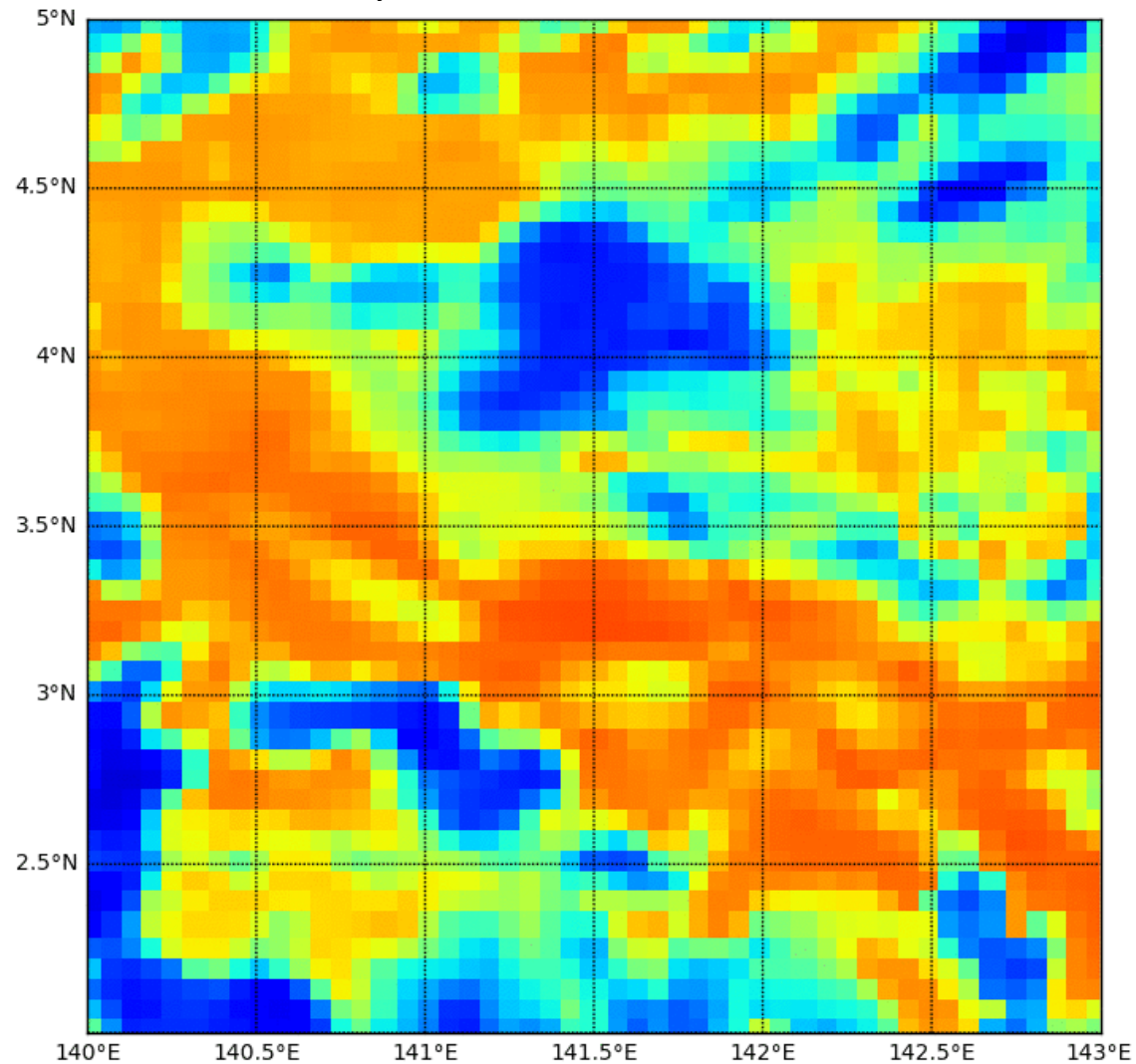
- An inference of the wind via feature tracking
 - Clouds and water vapor gradients
- Traditionally via satellite imagery
 - advantages in spatial and temporal resolution compared to sounding
 - Largest errors in height assignment

Wind Simulation in an OSSE

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



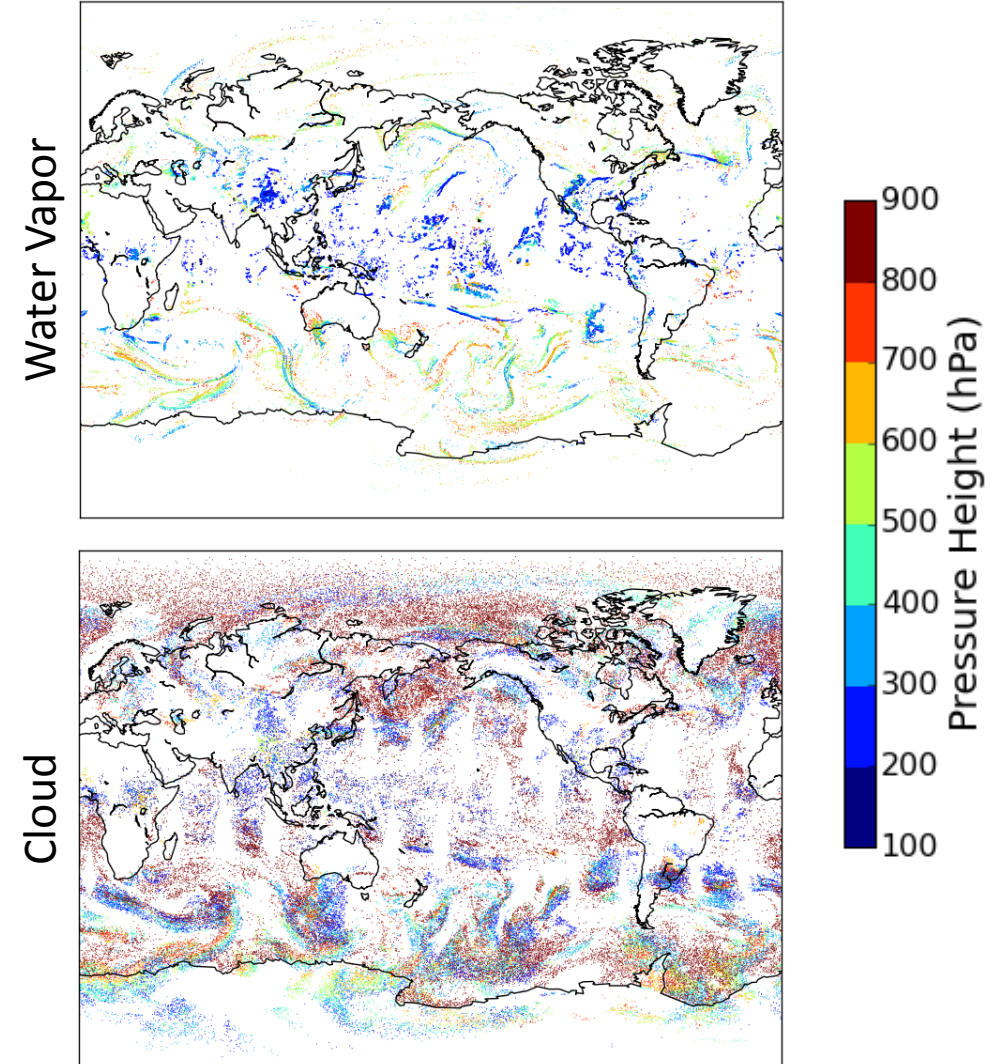
G5NR, 1 May 2006, 00-02 UTC, 30 min inc



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

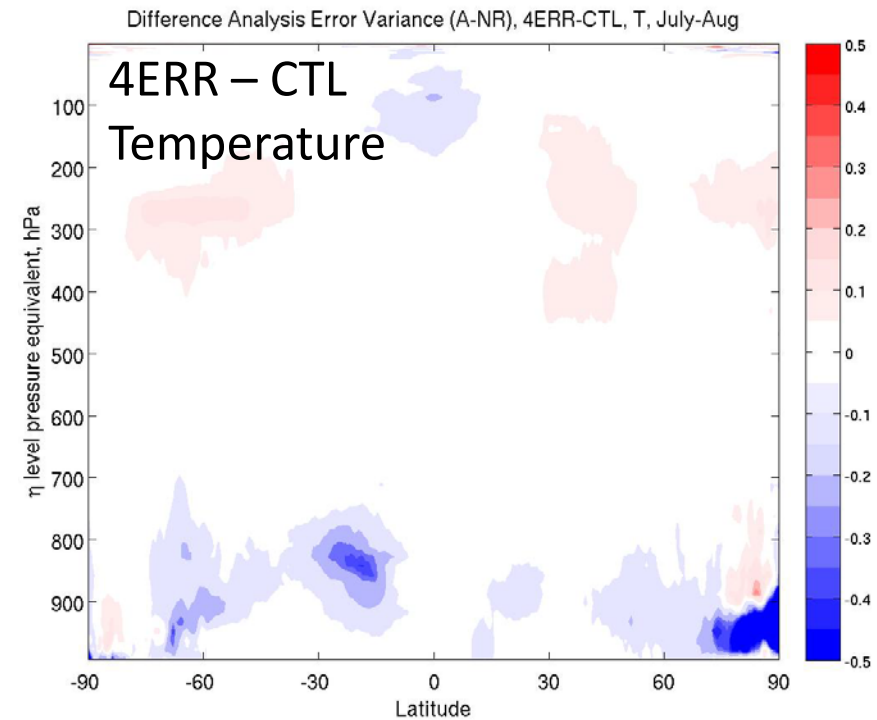
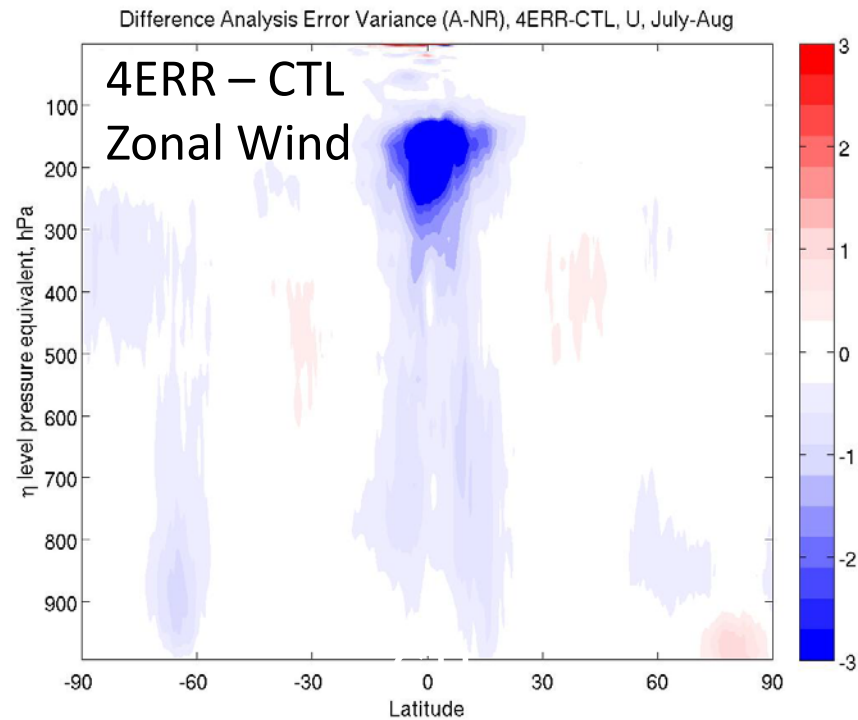
- MISTiC Radiances (*46 channel selection*)
 - Channel selection performed to reduce interchannel correlations
- MISTiC AMVs (Cloud & WV)
- No additional errors applied to either radiances or AMVs

Experiment – 4ERR

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

- 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

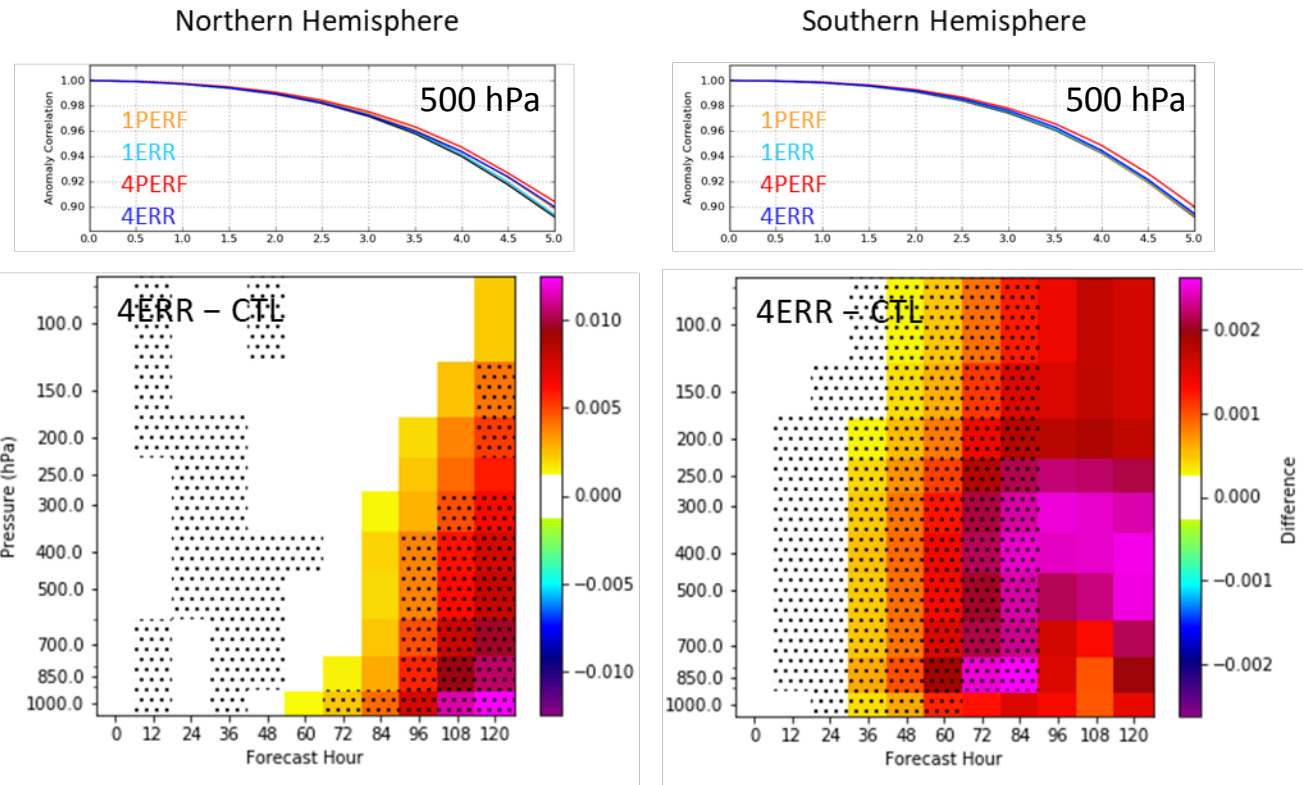
Forecast Skill – Z Anomaly Correlation P vs. time

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

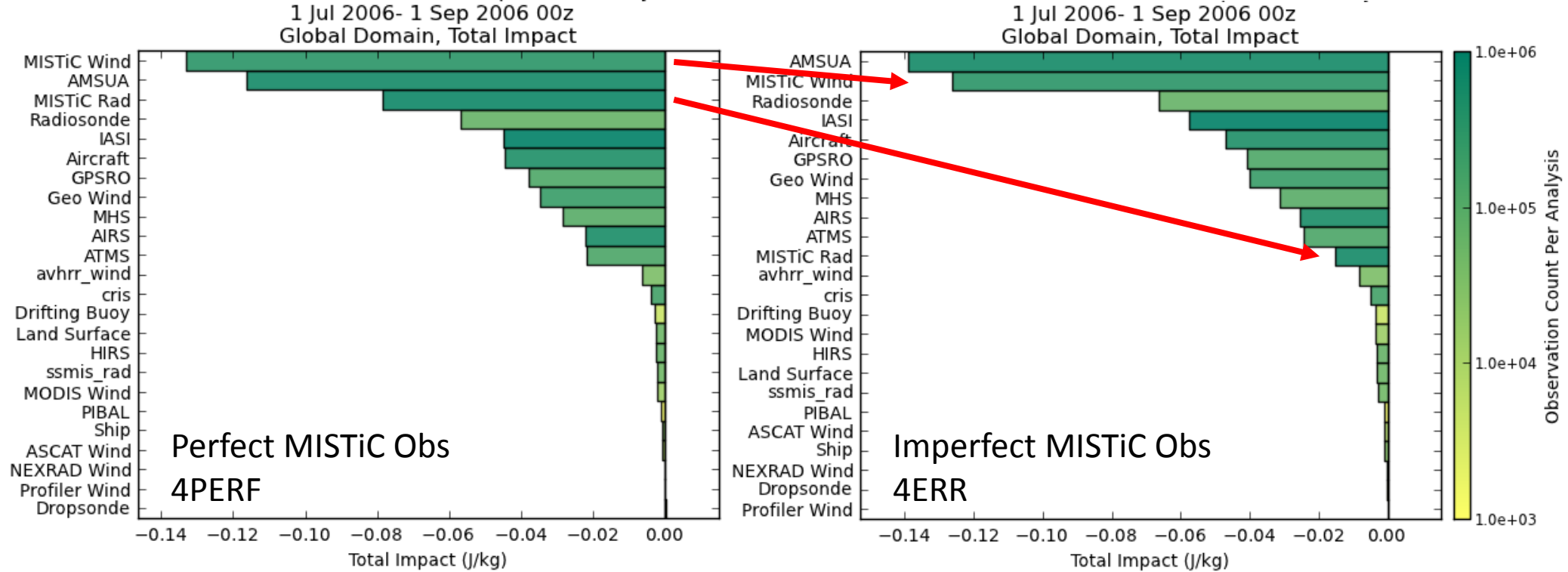
- Positive impact in all cases to day 2.5
- Largest near surface in NH, consistent through column in SH

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)



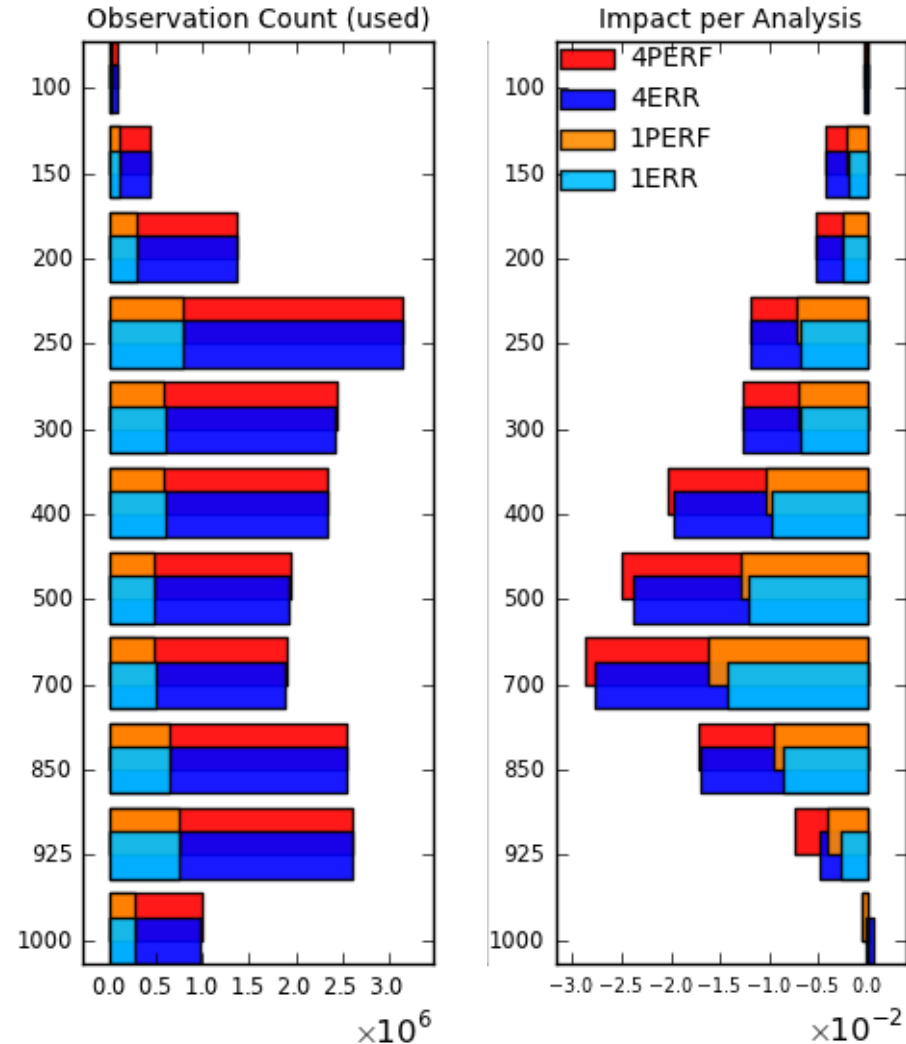
Considering perfect observations, MISTiC has the potential for reducing 24 hr forecast error

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

MISTiC AMV FSOI

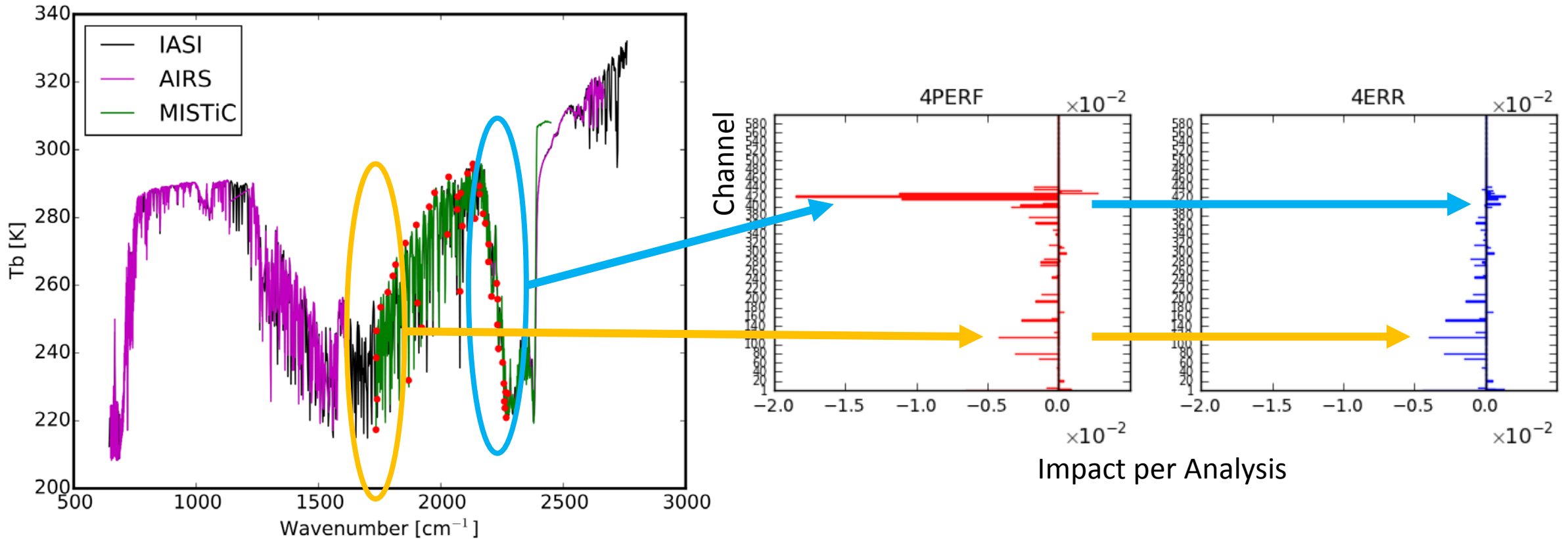
Cloud and WV AMVs combined

- 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

