

A GEOS-Based OSSE for the “MISTiC Winds” Concept

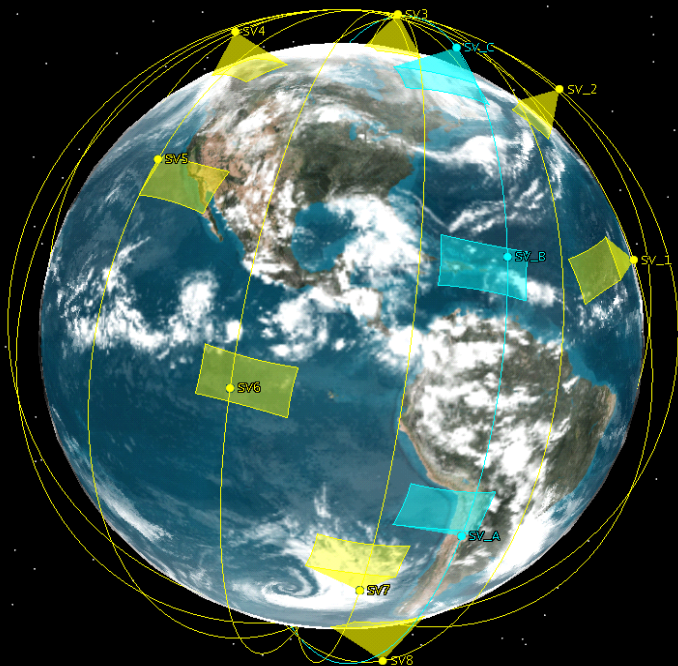
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MISTiC Winds



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

System Approach in NWP Context

- Use the GMAO's GEOS-based OSSE system to examine the impact of the MISTiC Winds concept on NWP
- Demonstrate impacts of:
 - both derived winds and radiances
 - observation error
 - constellation size (four – vs – one)
- Emphasize the importance of the water vapor channels

GEOS: Goddard Earth Observing System

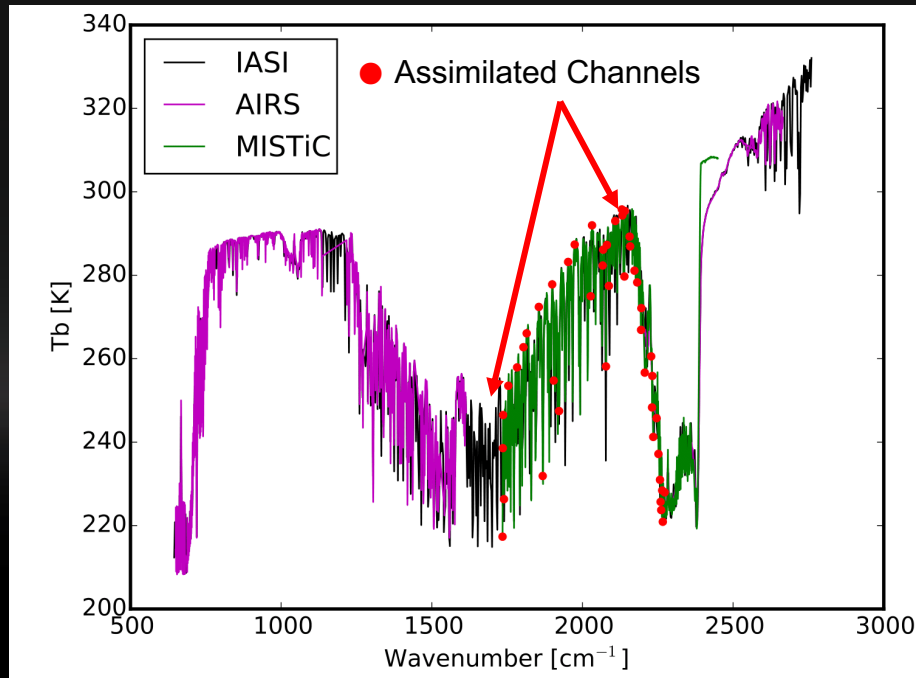
OSSE: Observing System Simulation Experiment

NWP: Numerical Weather Prediction

Context: GMAO's work on OSSEs and Wind Data Assimilation

- GMAO's "7-km GEOS-5 Nature Run" (7km-G5NR) provides the "truth"
- GEOS OSSE system (Errico et al.) includes:
 - simulation of complete current observing system
 - careful treatment of observation error for all instruments
 - ability to use GMAO's suite of tools to assess observation impacts
- Suited to test a wide range of new observations and sampling strategies
- Daily products from the GEOS data assimilation system are used widely in support of NASA's missions
- GEOS is being used in several "wind-focused" projects, including:
 - Scatterometers, including Rapidscat
 - GPM/GMI all-sky radiance
 - MISR-based winds (JPL-GMAO)
 - Loon (Google-SGT-GMAO)
 - CYGNSS impacts in reanalysis context (JPL-GMAO)

MISTiC Winds: Radiances - Context and Use in GEOS

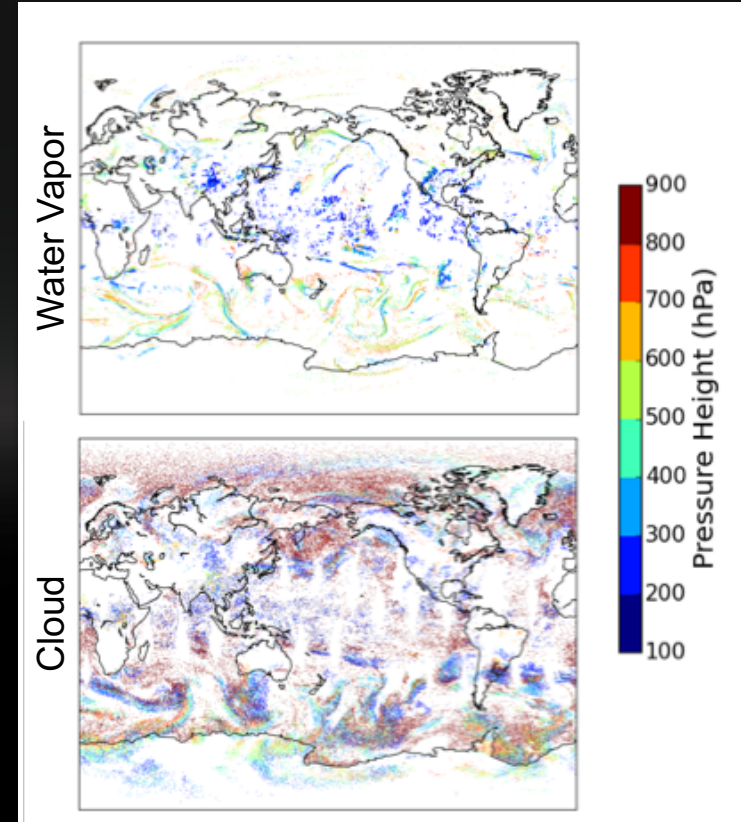


- MISTiC Winds radiances span about 1/3 the spectral range of AIRS, CrIS, IASI
 - Simulated MISTiC spectrum shown in green, based on BAE-provided specs
 - 590 channels (1735-2450 cm⁻¹)
- Down-selected to 46 channels for OSSEs
 - Necessary as correlated observation error not considered in the analysis
 - 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

Observation Simulation – Wind

Wind Simulator

- Observations are derived from 7km-G5NR and are “downscaled” (from 7km, 30-min) for this work
- Probability of cloud AMV is determined as a function of modeled 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 distributions of trackable features
 - Exploits assets of data assimilation to produce regularly gridded fields



Experimental Configuration

Control (Present-Day Observing System) - CTL

- Described in Errico et al. (GMAO Tech Memo 2017)
- Simulates full Observing System (circa 2016)
 - Conventional: RAOB, surface, aircraft
 - Satellite Retrieved: GEO AMVs (Himawari/MeteoSat/GOES), Polar LEO AMVs (MODIS Aqua/Terra)
 - Radiances:
 - 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

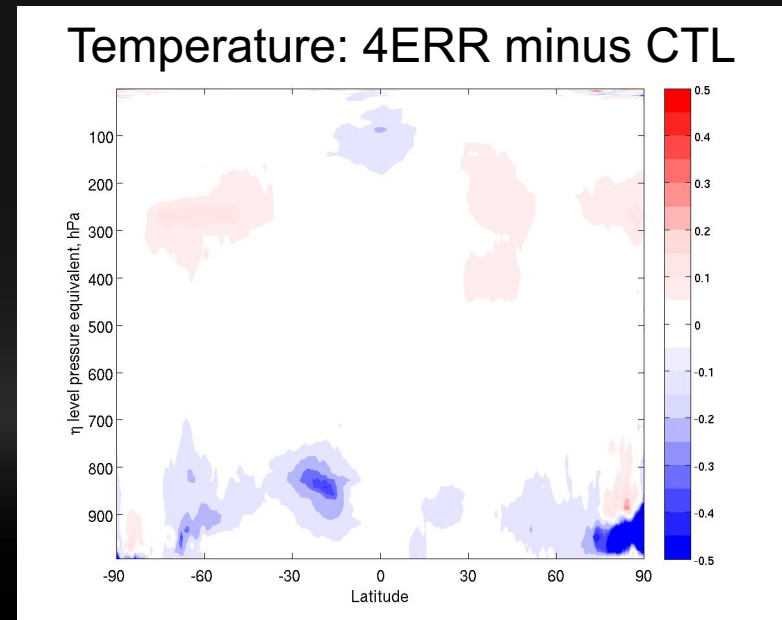
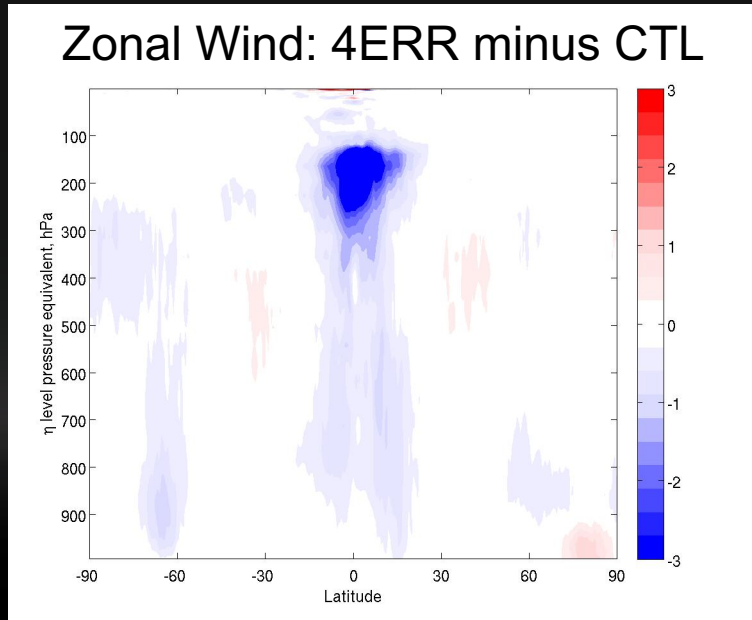
Perfect MISTiC Winds – 4PERF

- 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

Realistic MISTiC Winds – 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, July-August

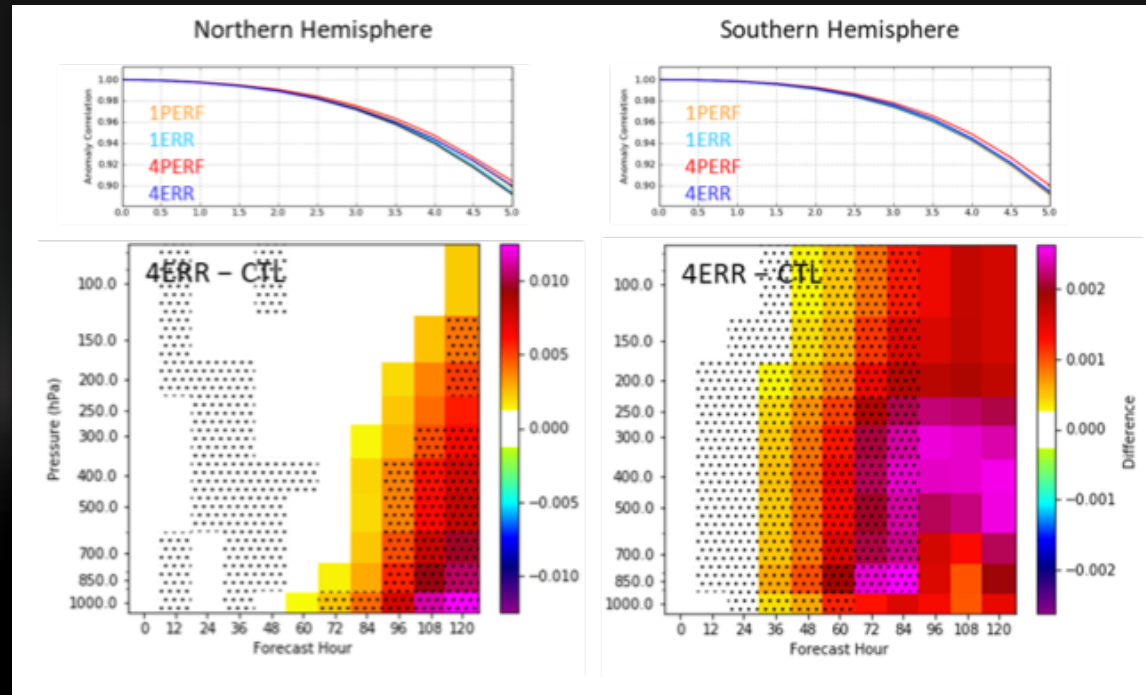


Error variance calculated relative to Nature Run (truth)

Difference relative to CTL – MISTiC Winds observations lead to an error reduction (blue)
in more regions than a degradation (red)

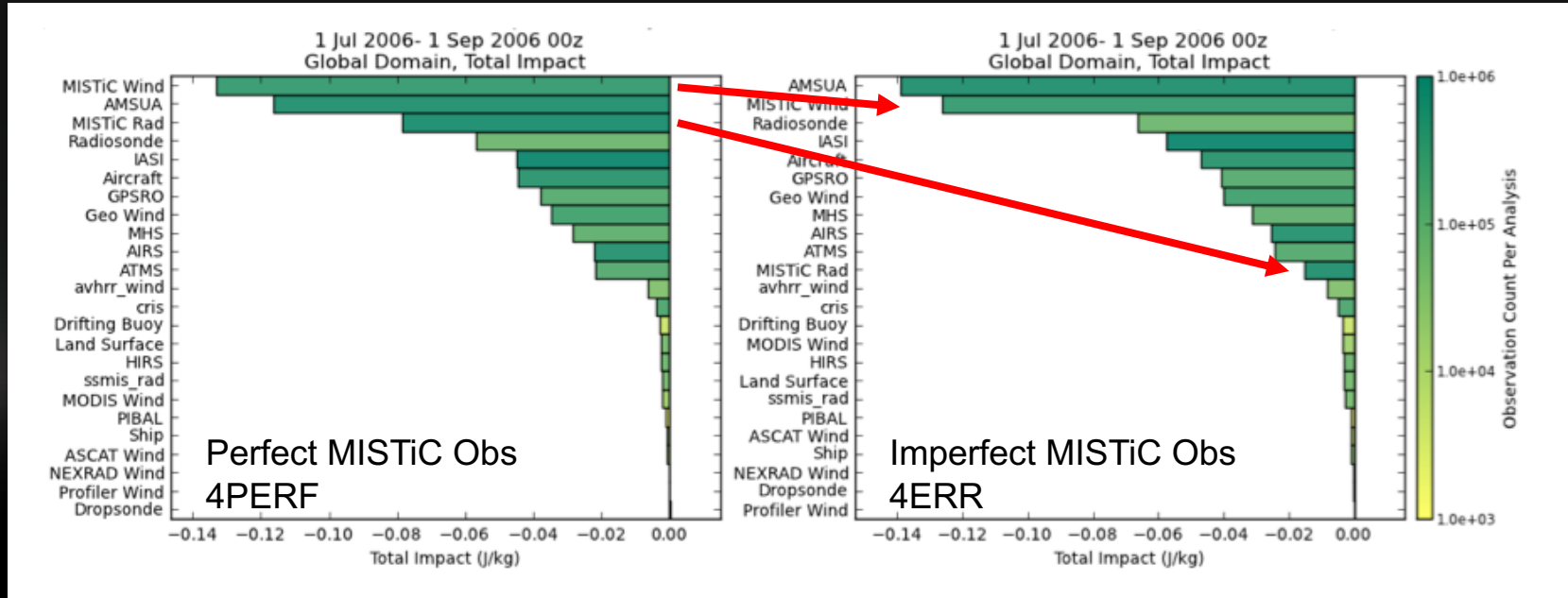
Experiment 4PERF (not shown) has a similar pattern with more improvement throughout

Impacts on Forecast Skill: Height Anomaly Correlation (pressure-time)



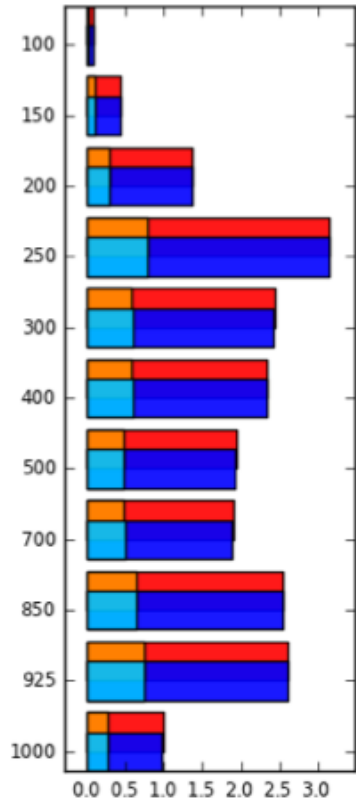
Forecast skill improvements: largest with 4 MISTiC systems and when obs errors are neglected
 Are largest close to the surface in NH, but throughout column in SH
 Retain significance out to 5 days in NH, but only out to about 2.5 days in SH

Forecast Impact (FSOI Metric)



MISTiC Winds observations have a substantial impact on the skill of 24-hour forecasts, traced using an adjoint-based impact tool. Accounting for observation error shows that MISTiC Winds wind data have a high impact, while the impact of the radiances drops substantially in the “mix”

No of Obs used
(millions)

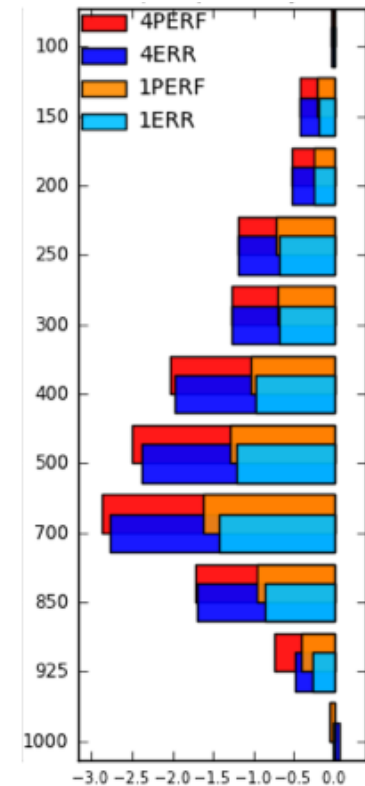


Impact of MISTiC Wind AMVs

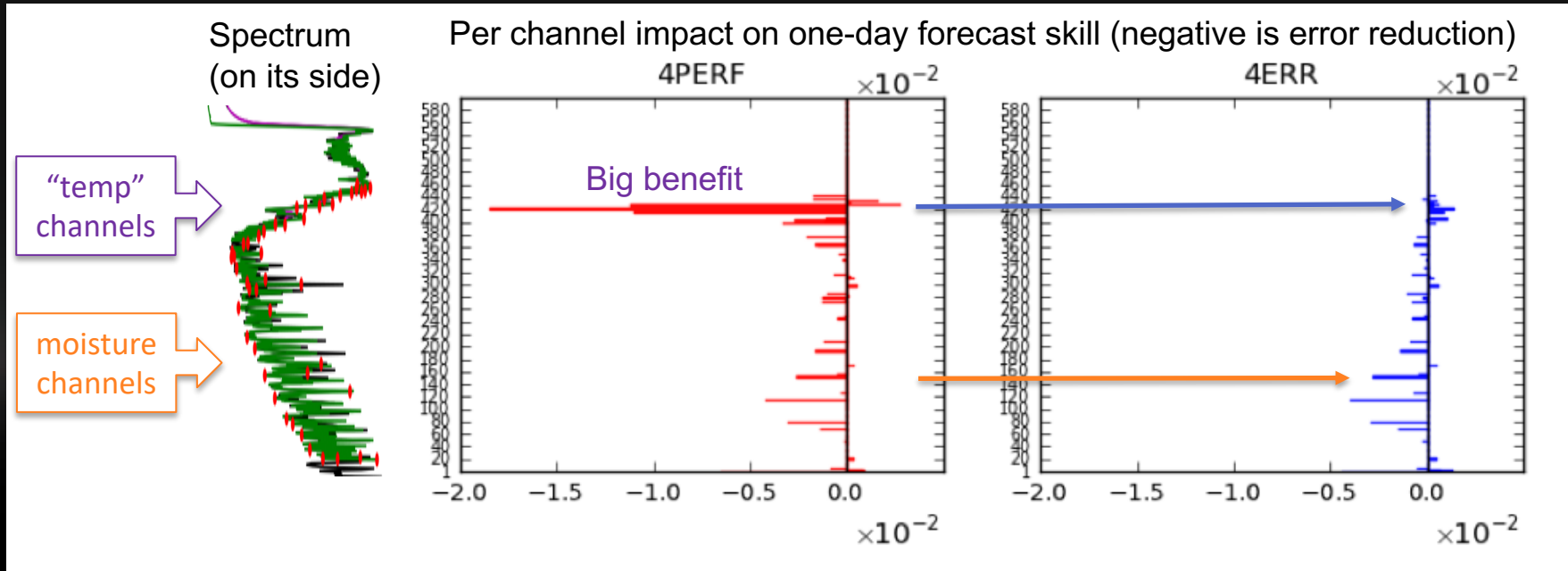
Cloud and WV AMVs combined

- The MISTiC Winds sampling strategy results in a consistent distribution of observations through troposphere
- The OSSE demonstrates that the highest impact of MISTiC Winds measurements comes from middle troposphere
- It is the winds derived from water-sensitive radiances that are the most impactful

Impact per Obs
(negative is good!)



FSOI Metric for the MISTiC Winds Spectral Radiances



Moisture channels: beneficial impacts persist from “perfect” to “imperfect” case
Temperature channels: large beneficial impact in “perfect” observation scenario turns around when errors are introduced – main uncertainty here is in radiation transfer model – this is not a limitation of the observation concept and will be addressed

Summary of Main Results

- This GEOS OSSE study has demonstrated the beneficial impacts of the MISTiC Winds concept on global weather prediction
- A four-plane constellation has more impact than a single plane
- The most beneficial impact is from the mid-tropospheric winds derived from radiance channels that are not available from other platforms
- It is important to perform a detailed analysis of errors and their impacts
- Development of (used) radiation-transfer code in the short-wave IR is likely to lead to more beneficial impacts – this is also applicable to existing hyperspectral data
- The GMAO's GEOS OSSE suite is suited to other studies, including active wind sensing techniques

Future Developments that will Enhance GMAO's Contributions

- Repeat MISTiC Winds experiments in a 4D assimilation system
- Radiation transfer model – better represent the IR “temperature” (CO₂) channels
- Systems approach to combinations of passive-active wind measurements
- Other metrics – extreme weather, air pollution, etc. (close to GMAO's core)
- Move away from any “twin” issues as GEOS model evolves (new PBL, cloud, etc.)
- New Nature Run at higher resolution (GEOS has been run at 1.5km globally)