Investigating the Impacts of Hyperspectral Infrared Sounders in Geostationary Orbits Using Observing System Simulation Experiments

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Background

This work simulates and assimilates hyperspectral infrared radiance observations measured from a geostationary orbit in the context of future GOES sounders

Observing System Simulation Experiment (OSSE):

- A simulation experiment to assess sensitivities and capabilities of proposed observing systems
- The GMAO Meteorological OSSE framework (Errico et al. 2017)
- Goddard Earth Observing System (GEOS) atmospheric data assimilation system (ADAS)

The baseline system is fully developed, based on a 2017 observing system

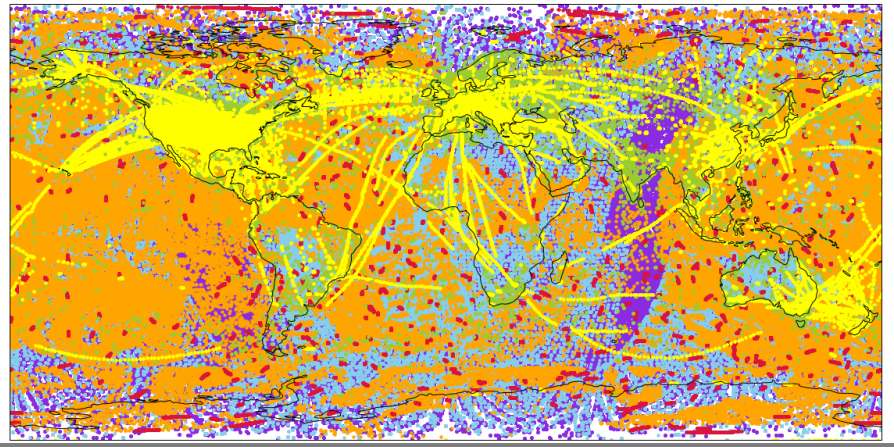
- 1/4° (C360) model grid spacing
- 4D-EnVar
- Simulations based on 7 km GEOS-5 Nature Run (G5NR)

GMAO OSSE Baseline System

Observations simulated from 7 km GEOS-5 Nature Run (G5NR), based on a 2017 Observing System:

Remotely Sensed	Conventional

• Microwave Radiance
  • AMSU-A, MHS, ATMS, SSMIS
• Infrared Radiance
  • HIRS-4, IASI (x2), AIRS, CRIS
• Radio Occultation Bending Angle
• Atmospheric Motion Vectors (MODIS, GEO)
• Scatterometer Wind Vector (ASCAT)
	• RAOB
	• Dropsondes
	• Pibal
	• Aircraft
	• Ocean and land surface winds
	• Profilers



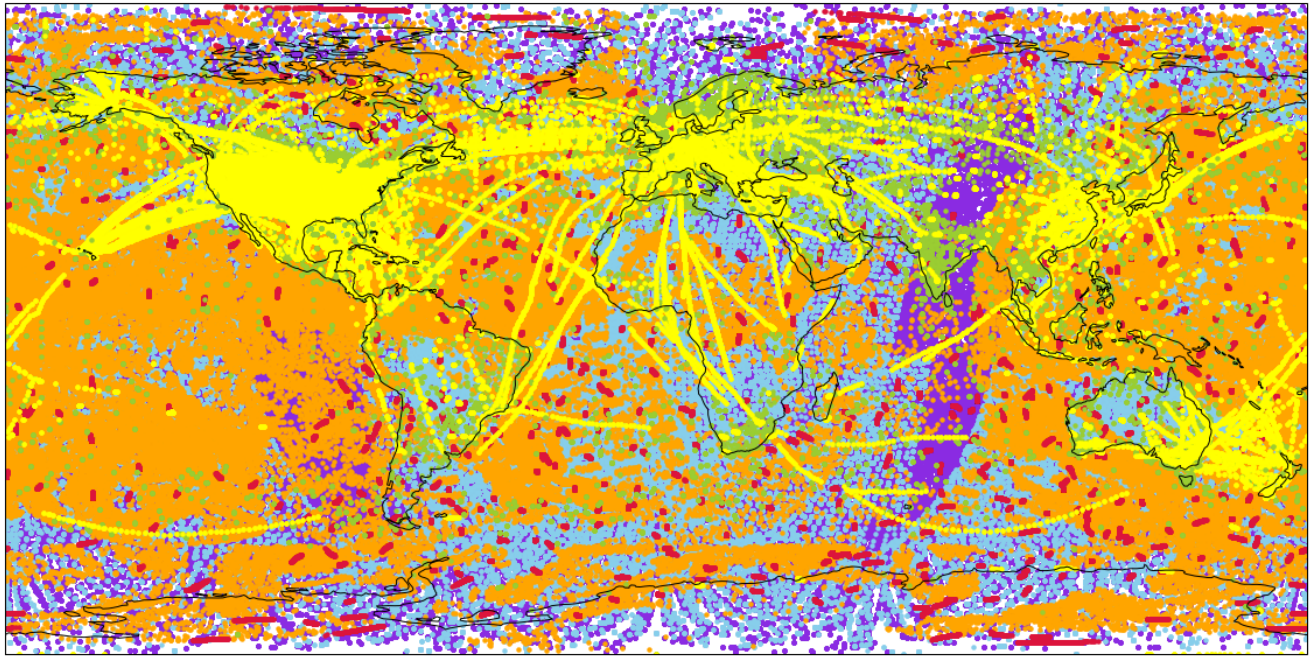
Experimentation

CTL: The GMAO Baseline System

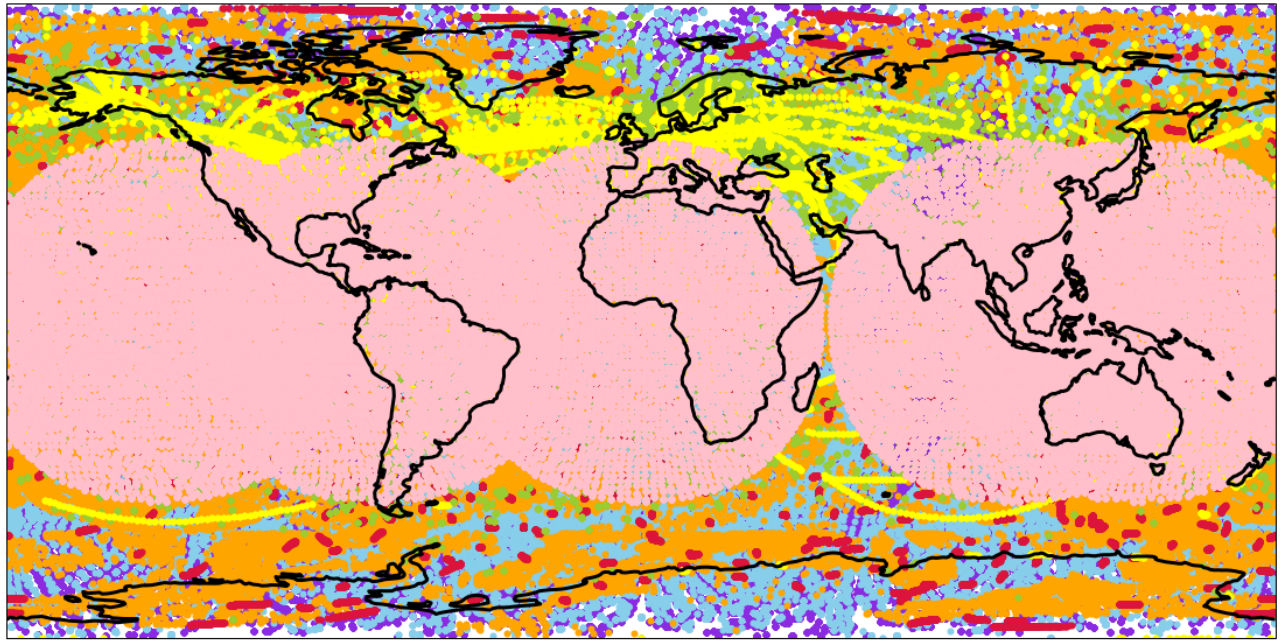
GEOIR: CTL + Five identical Geo-IR sounders were simulated to represent a future global constellation, utilizing longwave channel selection:

- Meteosat Third Generation (0.0° satellite subpoint)
- Himawari (140.7°)
- GOES-East (-75.0°)
- GOES-West (-137.0°)
- FY-4A (105.0°)

Baseline Observations: Radiances + RO + AMV + SCAT + Conventional



LWFULL: Baseline + 5 Geostationary Sounders



GEOIRS Instrument Specs

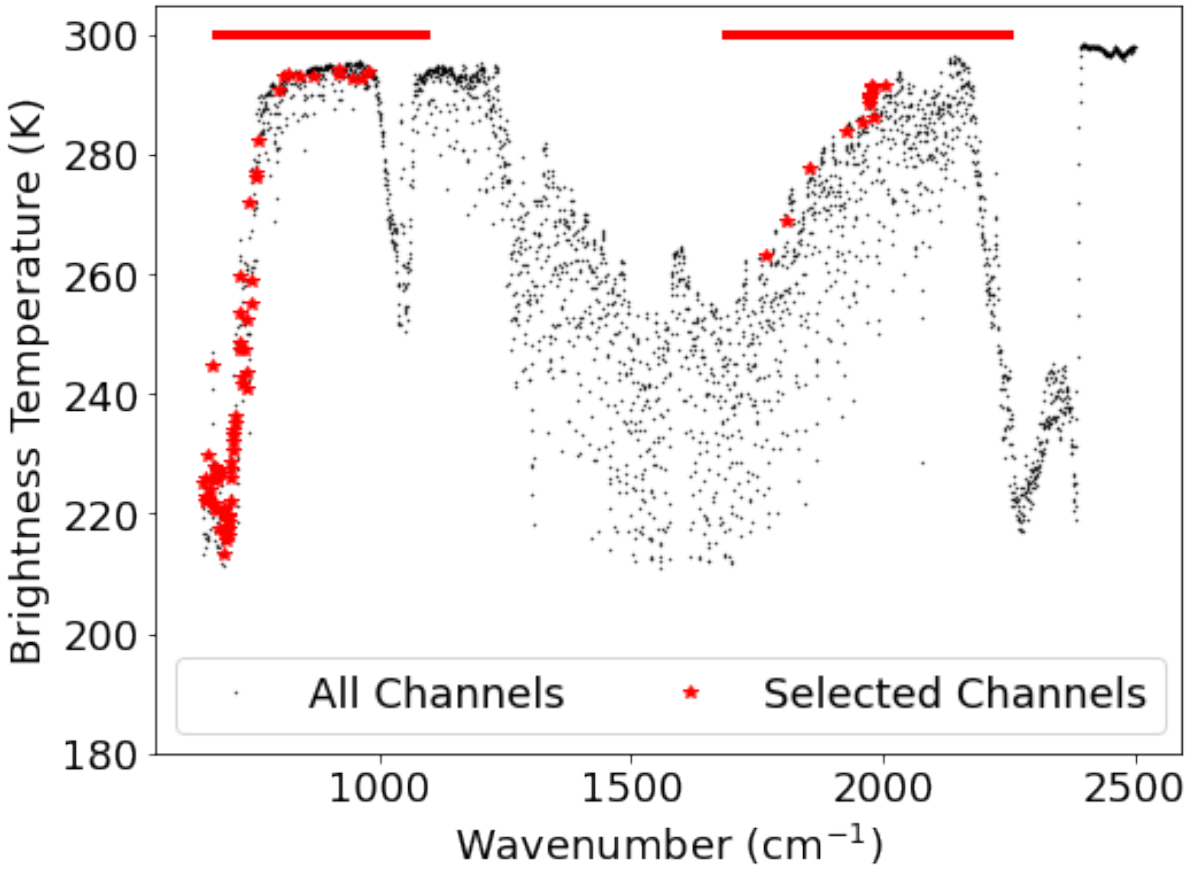
Meteosat Third Generation-Sounder (MTG-S) Infrared Sounder (IRS) as baseline

– Spectral Response Function similar to MTG-S IRS; triangular SRF

– Instrument spectral range: 650 – 2500 cm^{-1} (15.4 – 4.0 μm)

– Spatial Resolution of 4 km (affects cloud-free yield)

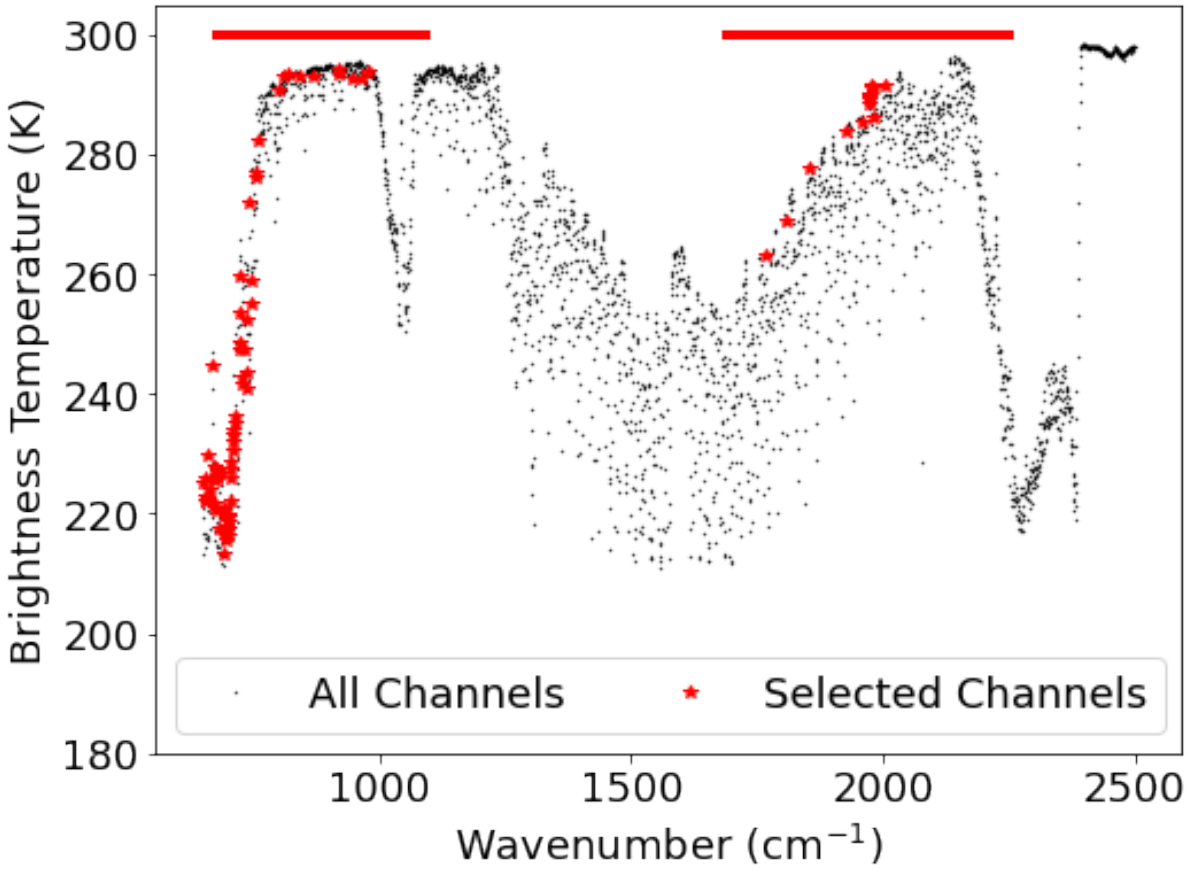
– Hourly ‘full-disk’ scan



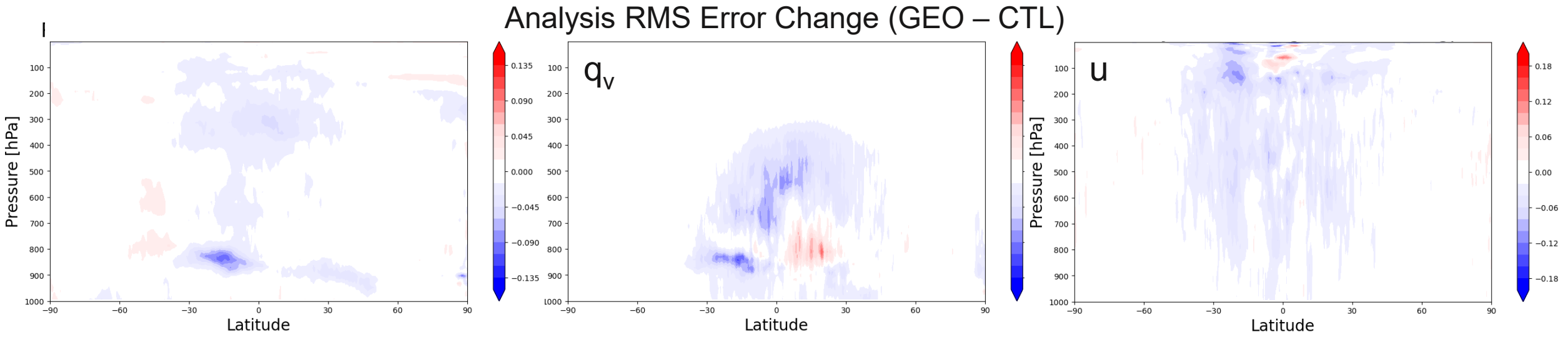
Channel Selection

Channel Selection: 87 channels

- 70 T/window channels (< 1000 cm-1)
- 15 H_2O_v channels (1780 to 2005 cm^{-1})
- Channel selection based on Geo-XO specified bands (red bars)
  - Note - this experiment did not account low wavenumber truncation of LW band
  - Includes channels between 650-680 cm^{-1}
- 180 km spatial thinning (consistent w/ polar IR)



Analysis Error Reduction



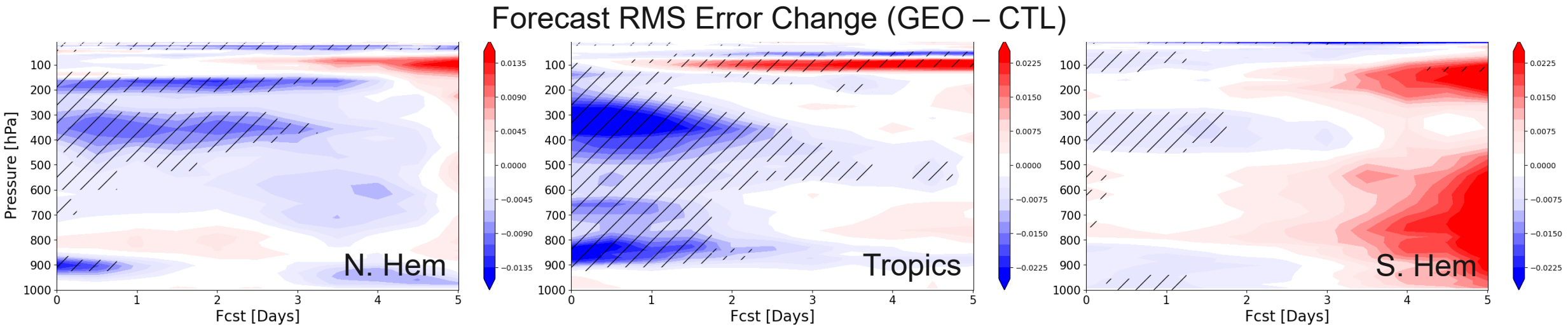
Analysis error calculated against the NR; Change in Error shown

- Blue (red) equates to a reduction (increase) in analysis error by adding Geo-IR

Largest impacts seen in water vapor and wind

- Temperature is already measured by the polar orbiters
- The wind response is really the added temporal information
- Water vapor is a combination of improved transport and analysis

Forecast Skill



Short-term Temperature forecast improvements seen in Tropics and both hemispheres

- Medium-range improvement lost largely in NH, entirely in SH
- Some degradation seen ~ day 5 for SH
- Tropical middle tropospheric most-consistent improvement

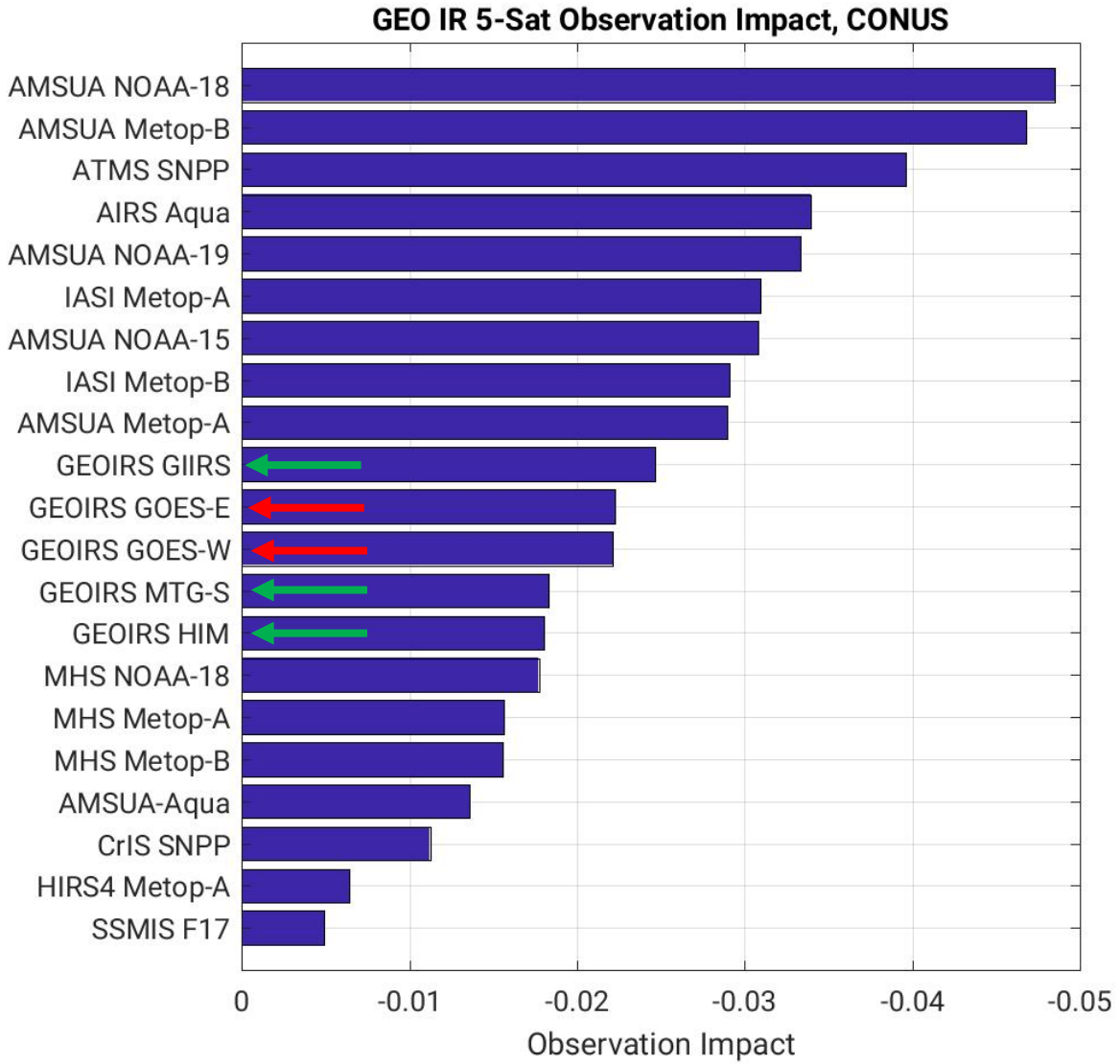
- Water vapor improvement most consistent; winds vary like temperature

Forecast Sensitivity to 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
  - e.g. per instrument, channel, footprint, etc.

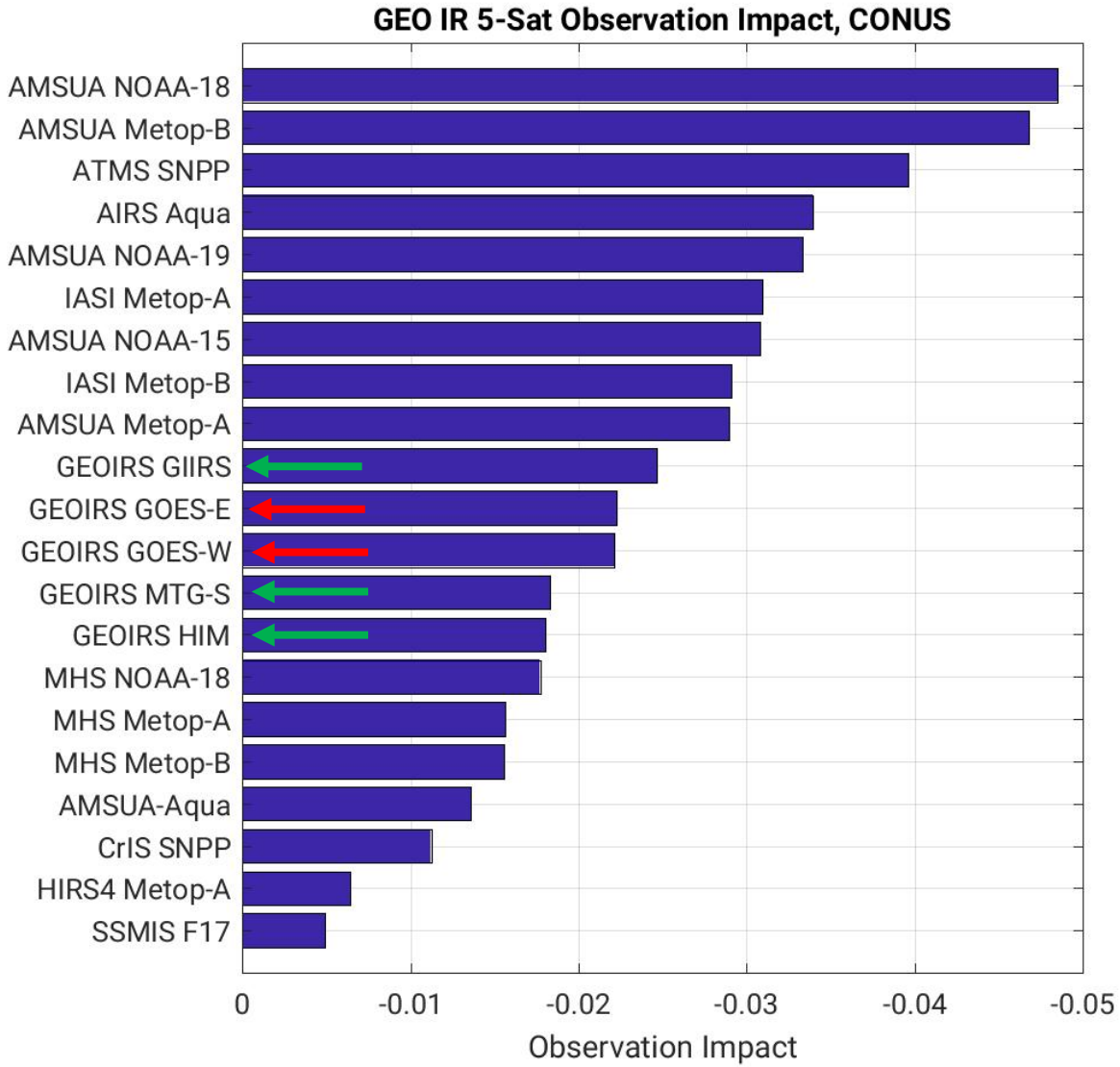
A negative value equates a reduction in error, so NEGATIVE = GOOD



Forecast Sensitivity to Observation Impact (FSOI)

GOES-East and GOES-West show similar forecast error reduction by this metric

- GIIRS/FY-4A location the largest due to lack of AMVs
- GOES-West has large water coverage in disk



Conclusions

This study aimed to quantify the potential role of a global constellation of geostationary hyperspectral infrared sounders in the context of the global observing system

- Largest impacts relative to wind, water vapor
- The earth is well-observed by hyperspectral IR sounders in LEO
  - Better spectral resolution due to lower orbit
- Temporal information of GEO == wind information
  - Improved flow via tracer effect
- There are likely optimizations that can be performed for these instruments
  - More in-depth channels

The role of ‘Perfect Observations’

- The GEO IR Sounder Instruments are ‘at an advantage’ by not having modeled errors
- The baseline observations do have modeled errors

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