OSSEs for Assessment of Hyperspectral Infrared Measurements from Geostationary Orbit in Support of Potential Manifest of a Hyperspectral Radiometric Spectrometer on GEO-XO

Presented to CGMS-48 Plenary, Session: HSIR observations,
Agenda item 4.2

Charter of Sounder Assessment Team

Assess the value of potential inclusion of an infrared hyperspectral radiometric spectrometer capability on the future NOAA geostationary satellite constellation: GEO-XO

Help formulate the information needed to include in industry studies of the future constellation performance baseline.

Review the current "state-of-the-science" and provide an assessment of the potential value to the National Weather Service applications for:

- weather prediction on the regional and global scales – including severe storm predictions;
- vertically resolved radiances and
- potential value to winds at all geographic scales.
- potential global benefit of a US hyperspectral radiometric spectrometer within the context of current and future hyperspectral instruments in geostationary orbit including:
  - The Chinese Geosynchronous Interferometric Infrared Sounder (GIIRS)
  - The European work on the Meteosat Third Generation – InfraRed Sounder (MTG-IRS)
- other applications including air quality monitoring, fire management, aviation safety, etc

Incorporate industry feedback on potential instrument configuration analyses that will explore the identified cost-efficient trade space of the potential infrared hyperspectral radiometric spectrometer observational capability.

This assessment team supports the next generation geosynchronous constellation, GEO-XO, pre-formulation activities of NESDIS/OSAAP

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OSSEs provide one aspect of the overall assessment

- OSSEs will provide relative prediction improvement metrics of inclusion of hyperspectral infrared signal into current observing system.
- OSSEs are part of official guidance
  - As part of the H.R. 353 from the 115th Congress, the Weather Research and Forecasting Innovation Act of 2017 stated in Sec. 2017 that *"The OAR must undertake Observing System Simulation Experiments (OSSE) to assess the value and benefits of observing capabilities and systems. OSSEs must be conducted before: (1) acquisition of major government-owned or government-leased operational observing systems with a lifecycle cost of more than $500 million, and (2) purchase of any major new commercially provided data with a lifecycle cost of more than $500 million. The OAR must complete an OSSE to assess the value of data from Global Navigation Satellite System Radio Occultation and from a geostationary hyperspectral sounder global constellation."*
- Results of prior OSSE studies have been included in the Sounder Assessment Team's findings – see E. Grigsby, et al., "Assessing the Potential Inclusion of An InfraRed Hyperspectral Radiometric Spectrometer in the Next Generation GEO Weather Satellite Constellation, AMS Annual Meeting 2020.

OSSE studies briefed here

Three research groups are developing independent OSSE/OSEs related to assessment of hyperspectral infrared measurements:

NOAA NESDIS and OAR/AOML

Leads: Dr. Lidia Cucurull and Kevin Garrett

Global Modeling and Assimilation Office (GMAO) as NASA-GSFC

Lead: Dr. Will McCarty

Cooperative Institute for Meteorological Satellite Studies (CIMSS) at University of Wisconsin

Leads: Dr. Jun Li and Tim Schmit

NOAA NESDIS/STAR and AOML simulations

Objectives

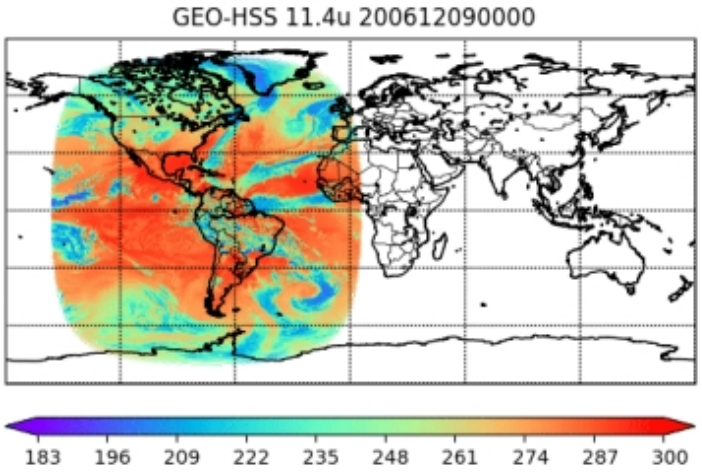
- Build on previous studies investigating impacts from GEO sounders
- Assess impact on NOAA global system (FV3GFS) 4DEnVar; high resolution regional (RAP/HRRR → FV3-SAR, WoF); and HWRF

Approach

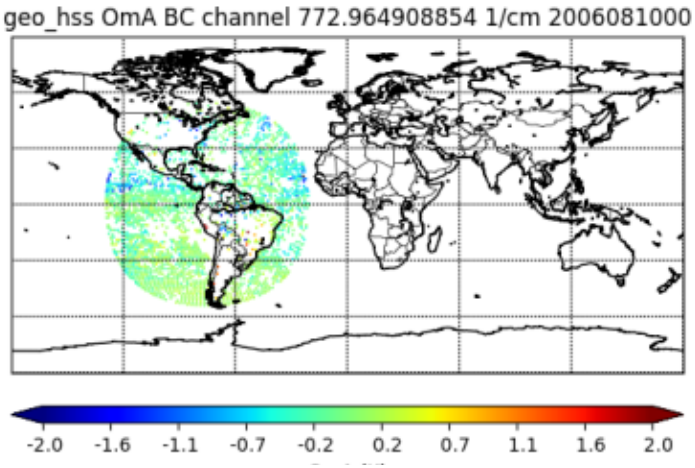
- Evolution of Community Global OSSE Package (COSS - Consolidated Observing Systems Simulator, led by NOAA/AOML QOSAP)
  - Interface with various NOAA forecast models and Nature Runs
  - Add capability to simulate error-added satellite observations from any orbit (LEO/GEO)
  - Leverage CRTM to simulate any spectral range/resolution; extended to simulate cloudy radiances
- Simulate GEO Hyperspectral IR Sounder
  - Simulate scan geometry/geolocation/FOV size from 75° W (~4 km)
  - Full disk, ½ hourly resolution; Meso-sector, 5-minute resolution (1000 x 1000 km)
  - Spectral coverage: IASI
  - Combine simulated orbit data with Nature Run data and CRTM to create observational datasets for OSSEs
- OSSEs
  - Warn-on-Forecast (simulate meso-sector over CONUS for case studies)
  - Hurricane (simulate meso/full disk for observations in/around TCs)
  - Global (simulate full disk for assimilation)

STAR/AOML experiment status and path forward

- Simulating GOES-E orbit with 4 km resolution observations
  - Full disk, CONUS, and mesosector configurations
  - 30 minute, 15 minute, 5 minute refresh
- Using to GEOS-5 Nature Run (G5NR) to simulate IASI radiances, Full Disk
- OSSEs Underway for 08/09 2006 G5NR (Results expected 09/2020)
  - Global FV3GFS 4DEnVar (clear sky/perfect obs)
  - Global Fv3GFS 4DEnVar (all-sky/errors added)
  - HWRF Hybrid 3DVar (all-sky/errors added)
- Longer-term: Simulate mesosector for WoF OSSE



3 h GEO-HSS animation at ½ hourly sampling for 11.2 um window channel



O-A at 772 cm-1 for 2006-08-10 00Z cycle, after quality control

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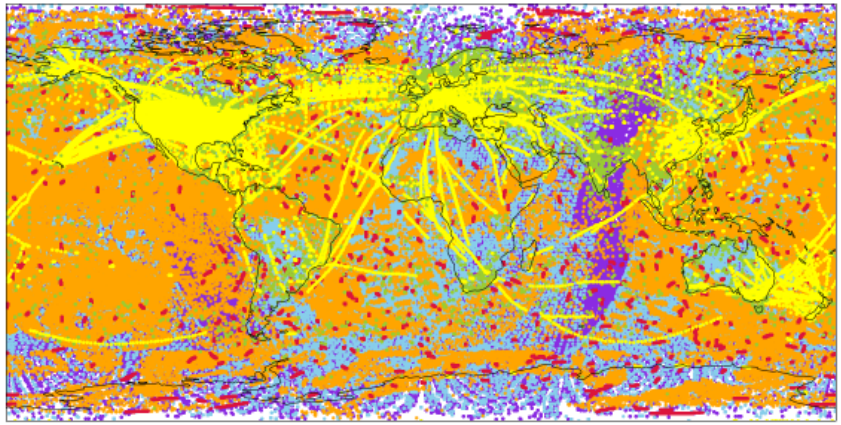
NASA-GSFC GMAO simulations

Objective

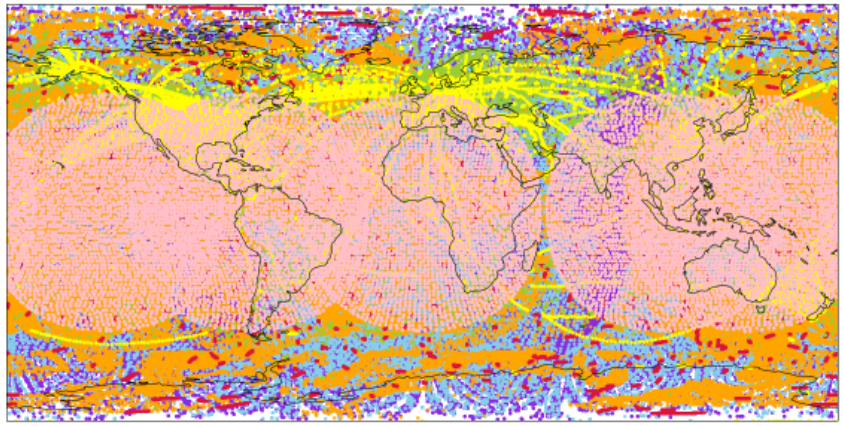
- The proposed work aimed to *simulate and assimilate hyperspectral infrared radiance observations measured from a geostationary orbit* in the context of a future GOES sounder
- The GMAO Meteorological OSSE framework (Ron Errico and Nikki Prive)
  - Goddard Earth Observing System (GEOS) atmospheric data assimilation system (ADAS)
  - The baseline system is fully developed, *based on a 2015 observing system*
  - 1/4° (C360) model grid spacing
  - *4D-EnVar*
  - Simulations based on 7 km GEOS-5 Nature Run (G5NR)

Approach

- Simulate five GEO-IR sounders with MTG-IRS-like spectral coverage in potential global configuration (longitudinal sub-satellite points 0°, -75°, -135°, 140.7°, 105°)
- Design perturbations of various spectral and spatial configurations based on full system simulation
- While no error modeling is performed in this study, the observations do have clouds
  - Clouds are signal (even if they are screened in assimilation)
  - Graybody assumption based on Nature Run clouds



Baseline observing system **– colors indicate radiances, RO, AMV, SCAT, conventional measurements**

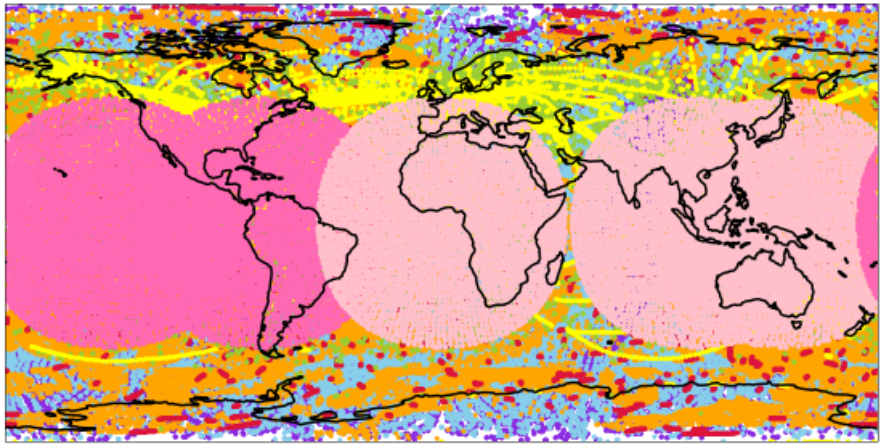


Experiment observing system **– Baseline (top map) + GEO sounder (pink color)**

NASA-GSFC GMAO observation set up

Infrared perturbations for GMAO GEO -XO OSSEs

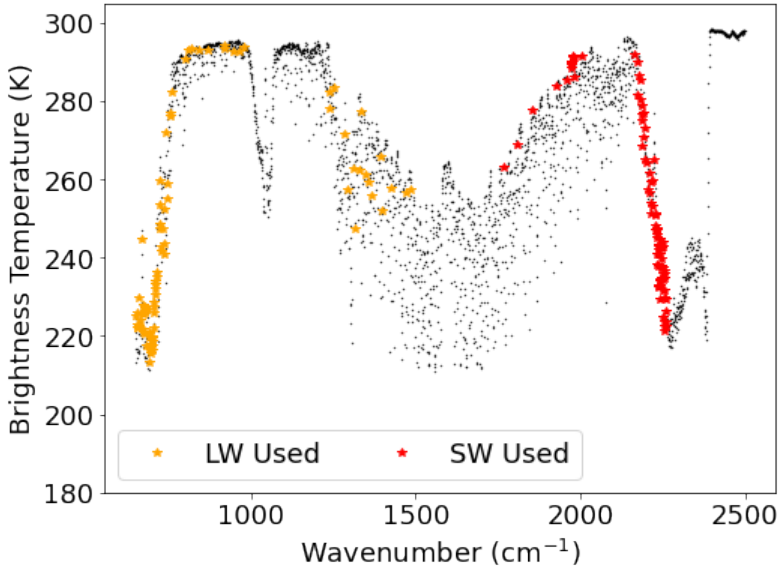
- LW Full Ring (0°, -75°, -135°, 140.7°, 105°)
- LW Reduced Ring (0°, -75°, -135°)
- SW Full Ring
  - LW: MTG-S, Himawari, and GIIRS;
  - SW: GOES-East & -West
- SW Reduced Ring
  - LW: MTG-S; SW: GOES-East & -West



Example of "SW Full Ring"

Channel selection

- Longwave (orange) and shortwave (red) channel selections shown below
- 91 Shortwave channels vs. 87 Longwave channels
  - More in troposphere, less in stratosphere
  - Non-LTE sensitivity avoided
  - Using 'dirty' side of 4.3 μm CO_2 absorption due to RT uncertainty



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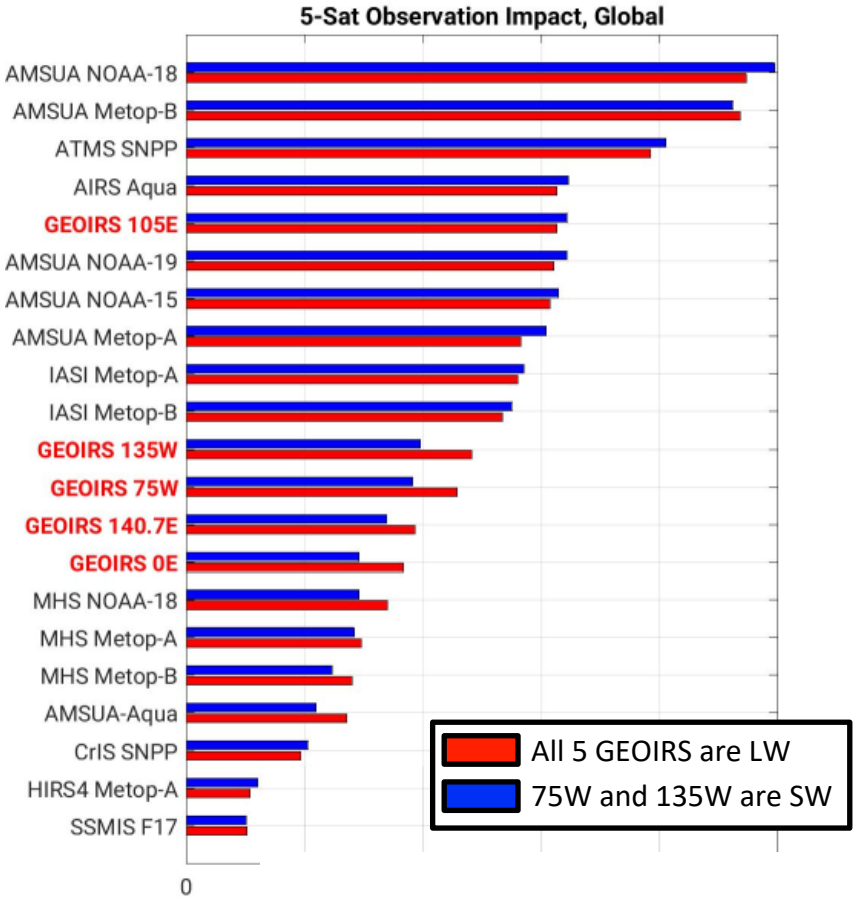
NASA-GSFC GMAO current status and path forward

Preliminary findings – Full ring (SW vs LW)

- LW Full Ring (0°, -75°, -135°, 140.7°, 105°)
  - More accurate for 800 and 1000 hPa
- SW Full Ring
  - Relative improvement between 400 and 800 hPa, most notable in the southern midlatitudes
- However, difference between SW and LW are much smaller than the difference between either experiment and CNTRL.

Caveats

- No Simulated errors were added to the GEO-IR measurements
- Full utilization of SW still in its infancy



Example of OSSE-based assessment that ranks impact of observations by instrument

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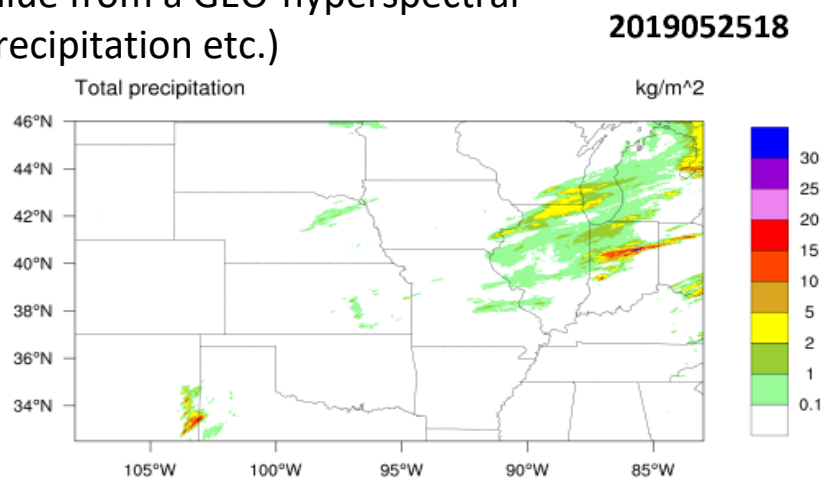
CIMSS/STAR Hybrid OSSE for Local Severe Storms

Objective

Real case demonstration of relative impact and added value from a GEO-hyperspectral IR sounder for local severe storm (LSS) forecast (heavy precipitation etc.)



Experimental design - model

WRF-ARW v3.9.1:

- 9 km and 3 km horizontal resolution (RAP/HRRR)
- 51 vertical layers from surface to 10 hPa
- Microphysics scheme: Thompson aerosol
- Longwave & shortwave radiation: RRTMG
- PBL scheme: Yonesei University scheme (YUS)

Experimental design – DA system

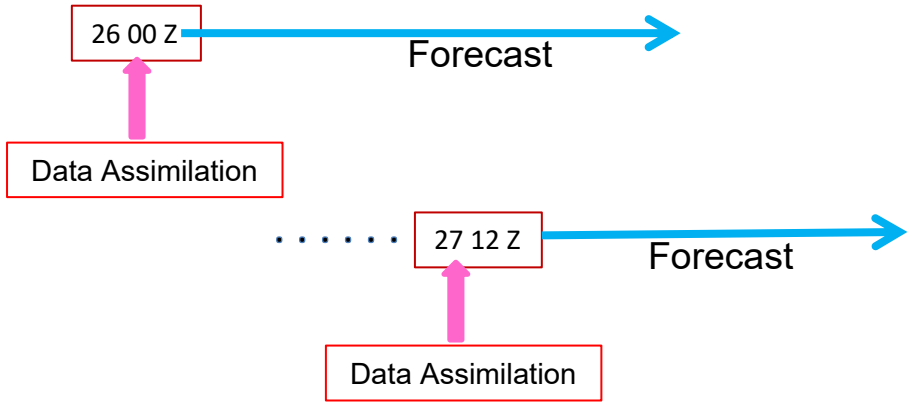
GSI-DTC v3.7:

- Background field: NCEP global final analysis (0.25 ◦)
- Satellite data thinning at 60 km
- Background and observation error: global model
- Satellite bias correction (BC): enhanced BC method
- Assimilated window: 3-hour

Assimilated data:

- PrepBUFR (conventional data)
- AMSU-A onboard NOAA-15/-18/-19, Metop-A/-B
- ATMS onboard SNPP
- IASI onboard Metop-A/-B
- CrIS FSR onboard S-NPP and NOAA-20

Case II: 2019-5-25 18z to 2019-5-28 18z

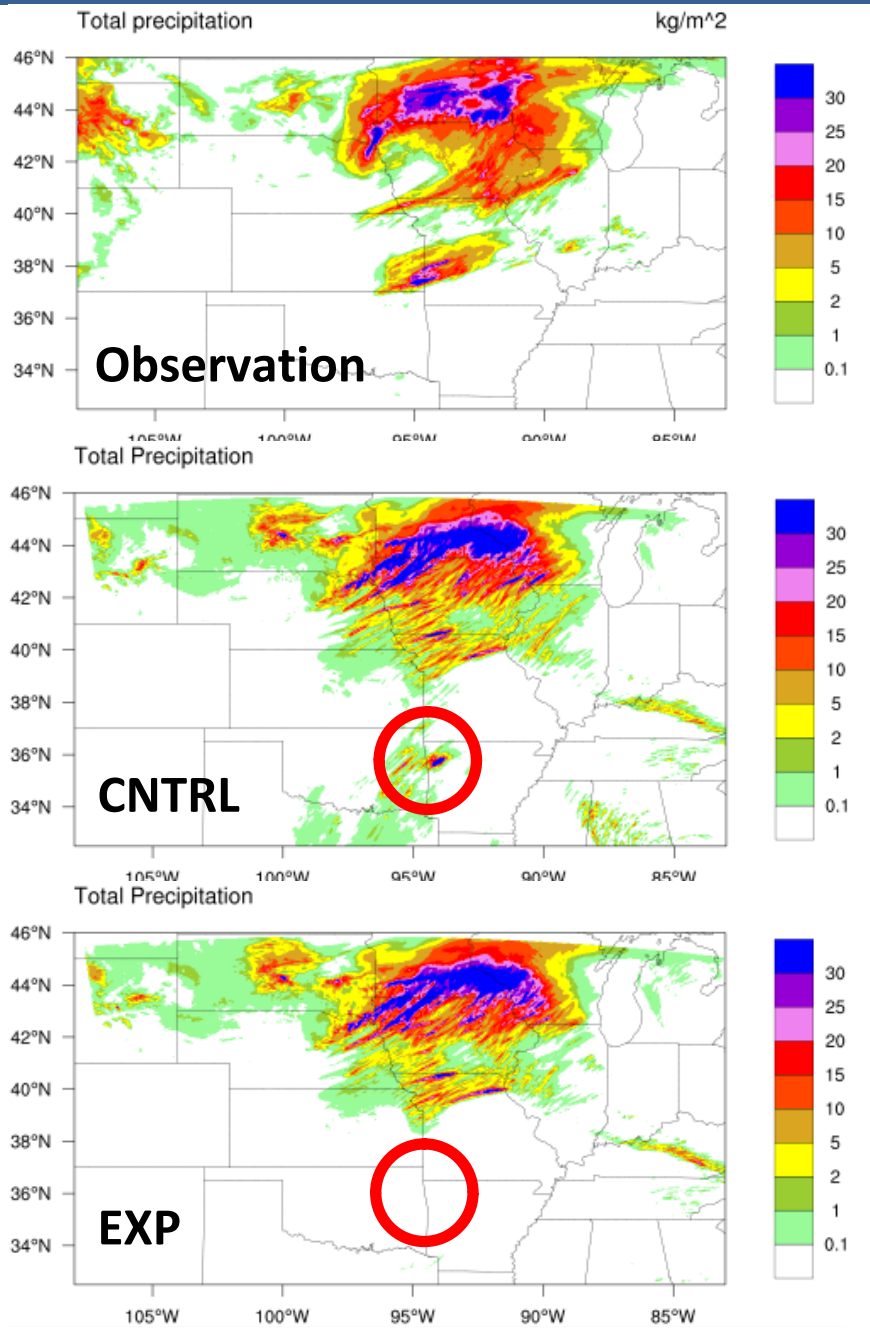


CNTRL: GTS+AMSU-A+IASI+ATMS+SNPP CrIS FSR

EXP: GTS+AMSU-A+IASI+ATMS+GEO CrIS FSR

CIMSS/STAR Hybrid OSSE results

- ✓ A "hybrid" OSSE allows for real observations for most and simulated for the high-spectral IR sounder, both validation and hybrid OSSE verification indicate confidence for impact studies using hybrid OSSE;
- ✓ A second case with longer storm period (from May 2019 over CONUS) was run by "hybrid" OSSE, similar results are found as CASE I;
- ✓ Impact studies show:
  - Improved moisture
  - Improved temperature
  - Some improvement for winds
  - Improved precipitation
- ✓ A manuscript is under preparation, CIMSS/UW results and findings are consistent with what JMA has done using simulated GEO profiles from ERA5 for assimilation:
  - Okamoto et al. 2020: Assessment of the potential impact of a hyperspectral infrared sounder on the Himawari follow-on geostationary satellite, Scientific Online Letters on the Atmosphere (https://doi.org/10.2151/sola.2020-028).



Assessment Team Path Forward / Schedule

Path Forward

- Incorporate new findings from assessment team
  - Complete OSSE/OSE analysis to extend analytic record data
  - Complete applications assessment
- Extend benefit analysis to include detailed societal benefit analytics
- Document findings and report:
  - Ensure decision makers have timely value assessment to underpin strategy for future system formulation

Schedule

- Complete value assessment in 3rd Qtr CY 2020
  - Incorporate additional analyses and assessments into findings
  - Extend value assessment to include comprehensive societal benefits
- Prepare report and out-brief to include in GEO-XO Milestone-1 Review

Key issues of relevance to CGMS/for consideration:

- Feedback is encouraged from international community on these experiments and various spectral and spatial perturbations investigated here.

- Continue OSSE development for risk reduction and preparation for implementation/assimilation of new measurements.