Simulations for hyperspectral infrared measurement impact assessment for GEO-XO

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Introduction

- OSSEs are one of the many assessments being considered by GEO-XO Hyperspectral Value Assessment Team led by Ed Grigsby
  - The team chronicled results from OSSE/OSEs performed by several research over the past several years
  - The team also partnered with three research groups to execute experiments tailored to GEO-XO constellation considerations using the most current models and data assimilation systems – ***these are summarized here***

- OSSEs are not expected to provide absolute prediction improvement, but rather provide assessments of relative measurement impact to forecasts

- Challenges and Limitations
  - Small teams for an extensive simulation experiment
  - Models will advance by the 2030-2050 timeframe of GEO-XO operation
  - Radiative transfer accuracy in the shortwave infrared

Experiment Teams

Three research groups have developed independent OSSE/OSEs related to assessment of hyperspectral infrared measurements for GEO-XO:

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 QOSAP simulations

Objectives

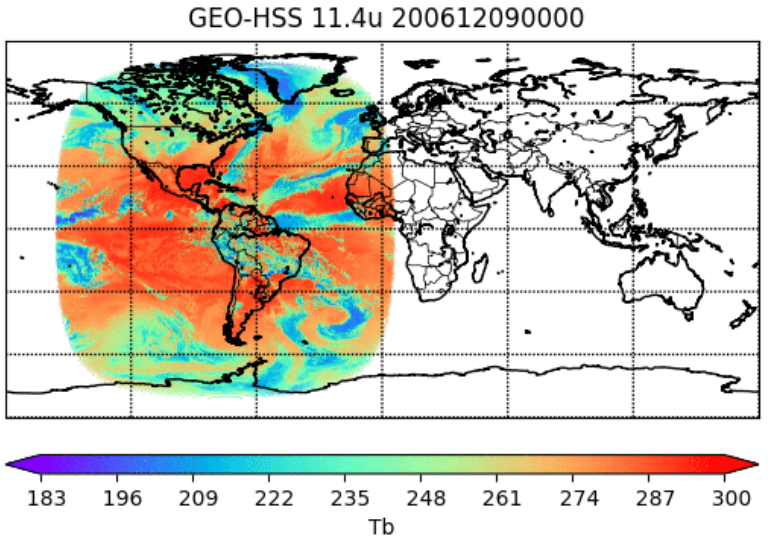
- Build on previous studies investigating impacts from GEO sounders
- Assess impact on NOAA global system (FV3GFS) 4DEnVar; high resolution regional (RAP/HRRR → FV3-SAR, WoF); and HWRF

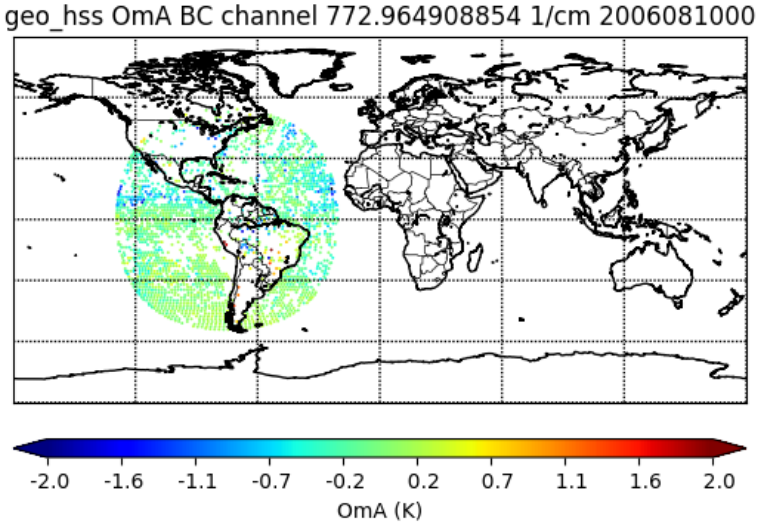
Approach

- 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, Ful Disk
- OSSEs Underway for 08/09 2006 G5NR (Results expected 09/2020)
  - Global FV3GFS 4DEnVar (clear sky/perfect obs, different strategies tested)
  - HWRF Hybrid 3DVar (clear sky/perfect obs)
- Future planned OSSEs
  - Global Fv3GFS 4DEnVar (all-sky/errors added)
  - HWRF Hybrid 3DVar (all-sky/errors added)
- Longer-term: Simulate mesosector for WoF OSSE





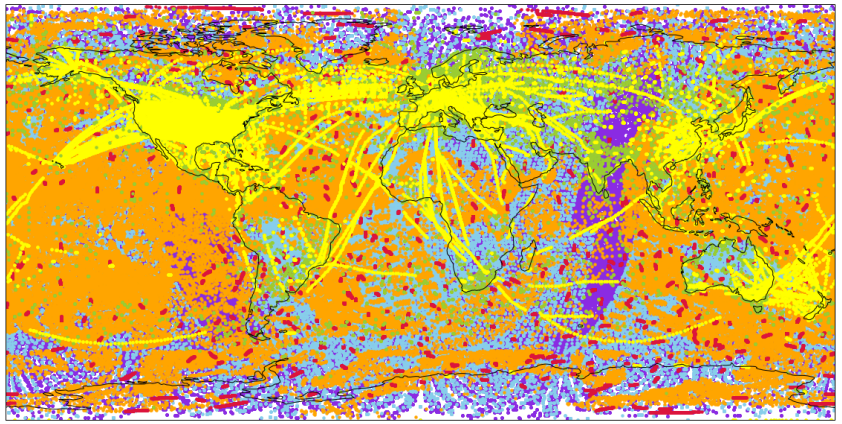
NASA-GSFC GMAO simulations

Objective

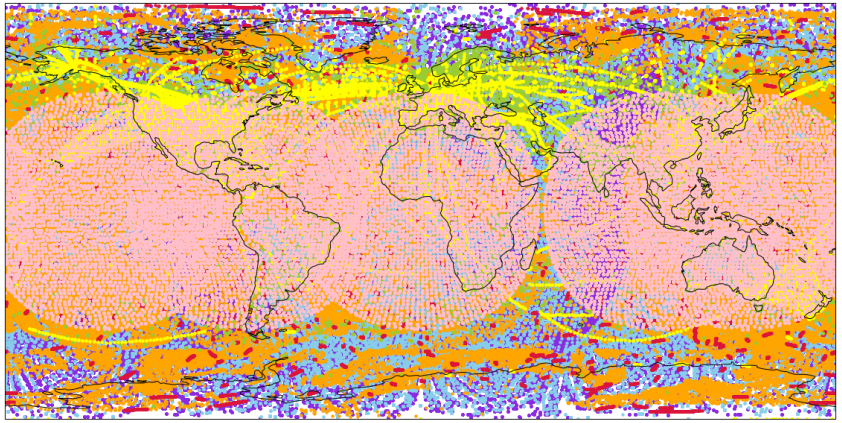
- The proposed work aimed to *simulate and assimilate hyperspectral infrared radiance observations measured from a geostationary orbit* in the context of a future GOES sounder
- The GMAO Meteorological OSSE framework (Ron Errico and Nikki Prive)
  - Goddard Earth Observing System (GEOS) atmospheric data 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**

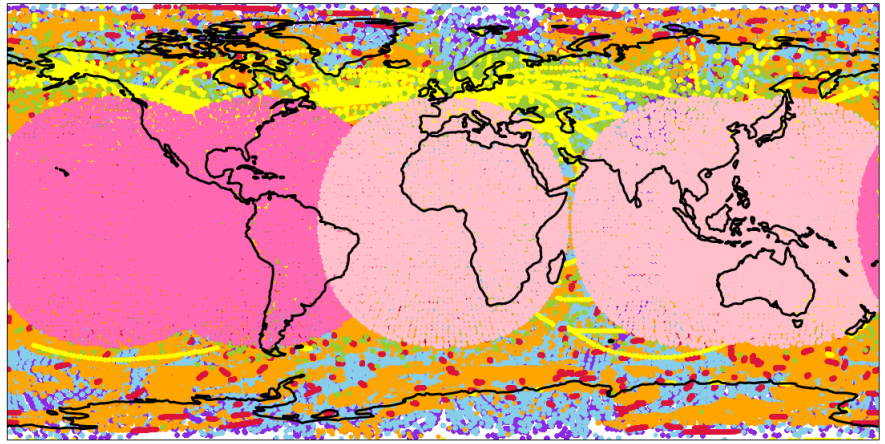


Experiment observing system **– Baseline (top map) + GEO sounder (pink color)**

NASA-GSFC GMAO observation set up

Infrared perturbations for GMAO GEO-XO OSSEs

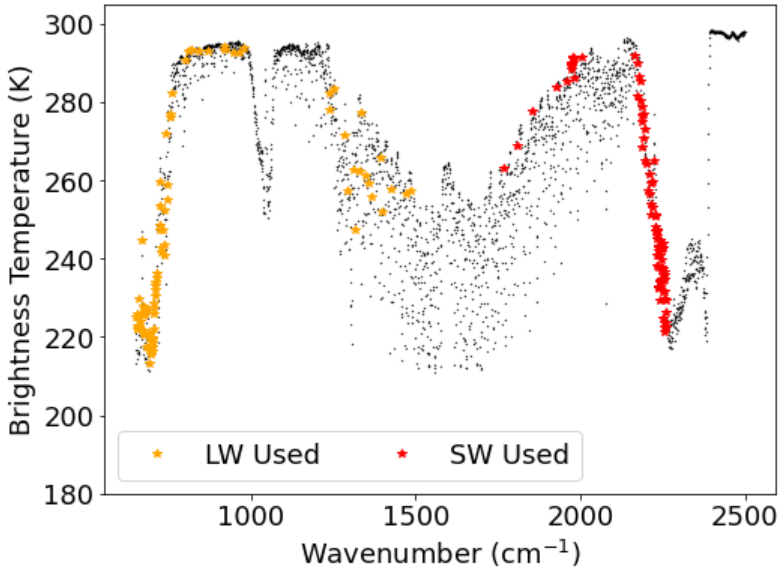
- LW Full Ring (0°, -75°, -135°, 140.7°, 105°)
- LW Reduced Ring (0°, -75°, -135°)
- SW Full Ring
  - LW: 0°, 105°, and 140.7°;
  - SW: -75°, -135°
- SW Reduced Ring
  - LW: 0°;
  - SW: -75°, -135°



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



NASA-GSFC GMAO current status and path forward

Preliminary findings – Full ring (SW vs LW)

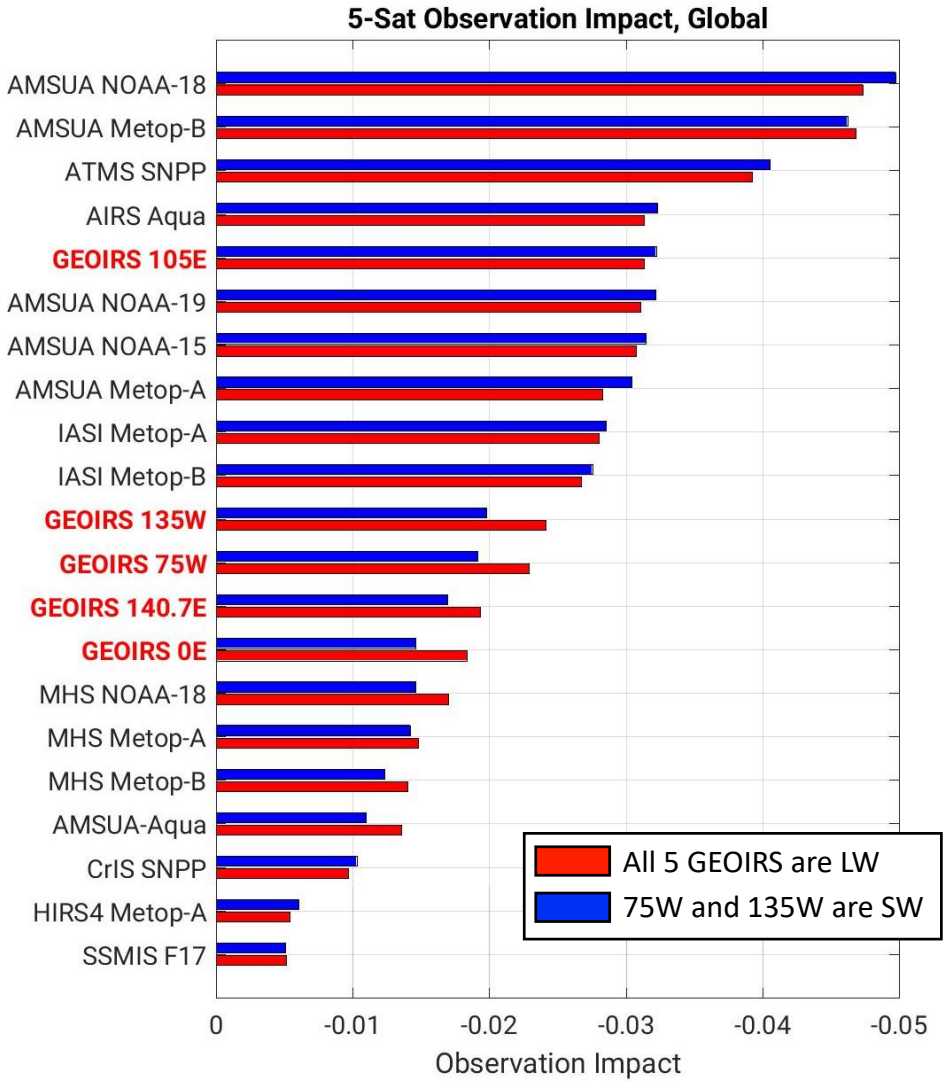
- LW Full Ring (0°, -75°, -135°, 140.7°, 105°)
  - More accurate for 800 and 1000 hPa
- SW Full Ring (LW for 0°, 140.7°, 105°; SW for -75°, -135°)
  - Relative improvement between 400 and 800 hPa, most notable in the southern midlatitudes
- However, difference between SW and LW are much smaller than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

OSSE Caveats

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

New experiments

- Geostationary microwave simulation
- Simulating 50 GHz channels for temperature and 183 GHz channels for humidity
- GOES-East and -West positions with hourly refresh
- Clear-sky only



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

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.)

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)

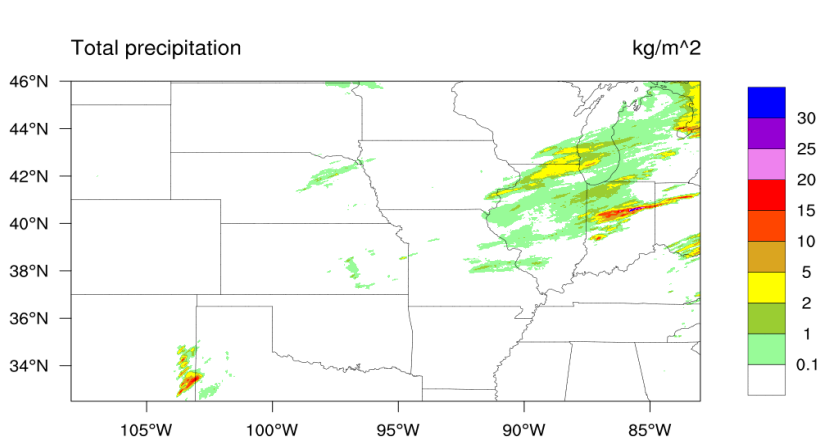
DA system
GSI-DTC v3.7:

- 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

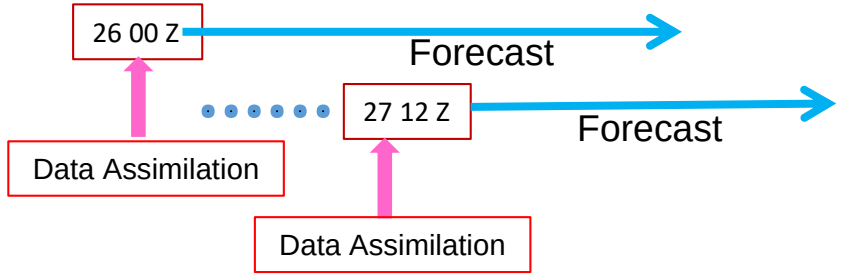
Assimilated data:

- 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

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

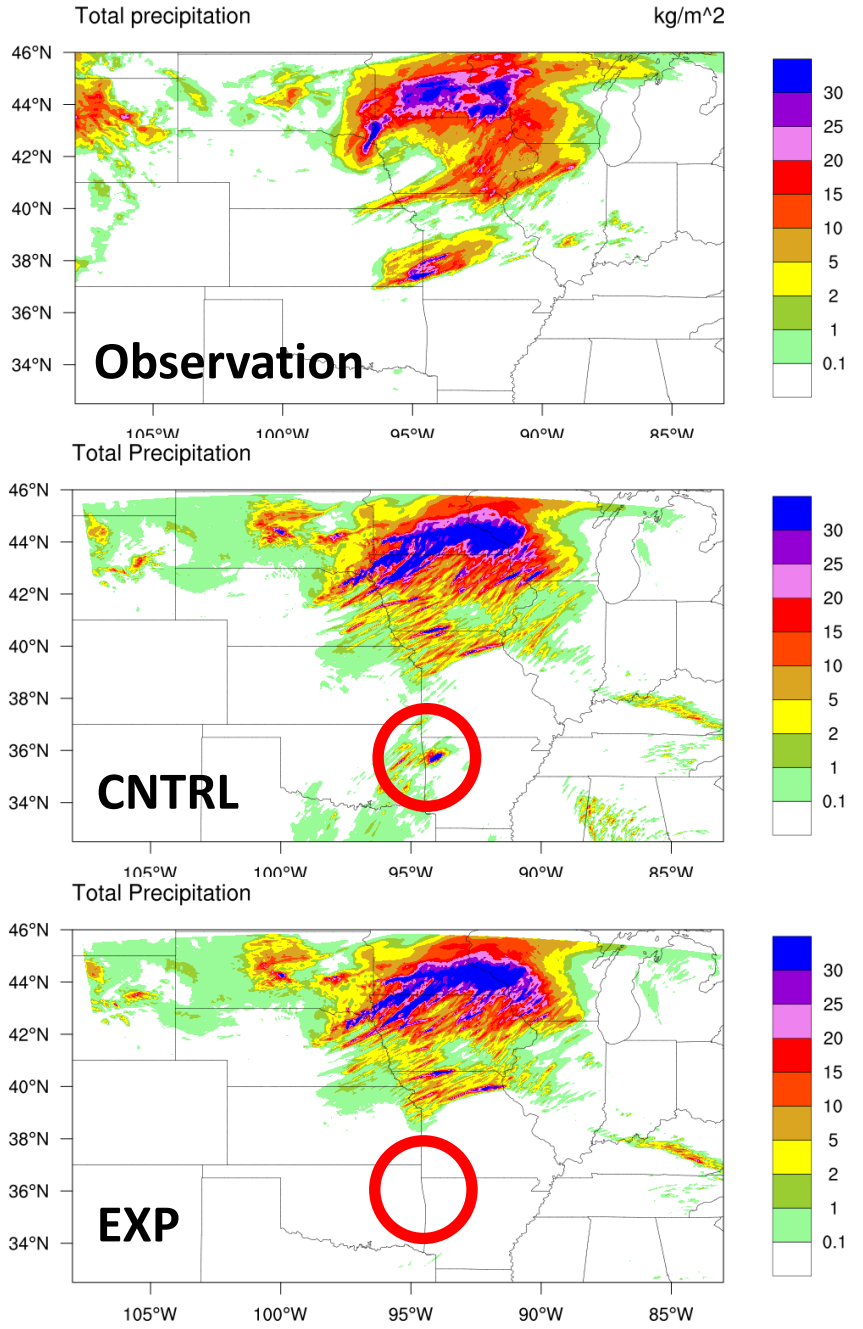


Case II: 2019-5-25 18z to 2019-5-28 18z



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).



Summary

- Experiments to simulate geostationary-based hyperspectral IR measurements have shown distinct forecast skill improvement
  - ✵Significant forecast error reduction out to five days for certain pressure heights
  - ✵Significant forecast impact relative to other measurement types
  - ✵Increased accuracy for severe storm prediction test cases

- Teams are working to incorporate results of these OSSEs into the Hyperspectral IR Sounder Value Assessment Report

- Geostationary-based microwave measurement experiment is running now
  - ✵East and West positions that complement the simulated IR measurements