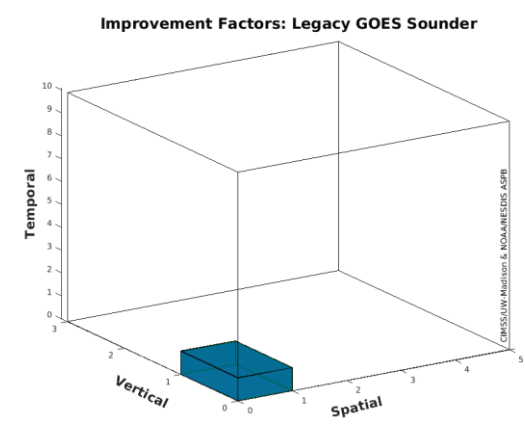


Information Content from the GeoXO Sounder (GXS)

AMS 2023



NOAA
National Satellite, and
Information Service

Jan, 2023

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<https://www.nesdis.noaa.gov/next-generation/geostationary-extended-observations-geoxo>

The first Geostationary Extended Observations (GeoXO) launch is planned for the early 2030s and will maintain and advance NOAA's critical geostationary observations through 2055.

GeoXO Constellation



GEO-West
Visible/Infrared Imager
Lightning Mapper
Ocean Color



GEO-Central
Hyperspectral Infrared Sounder
Atmospheric Composition
Partner Payload



GEO-East
Visible/Infrared Imager
Lightning Mapper
Ocean Color

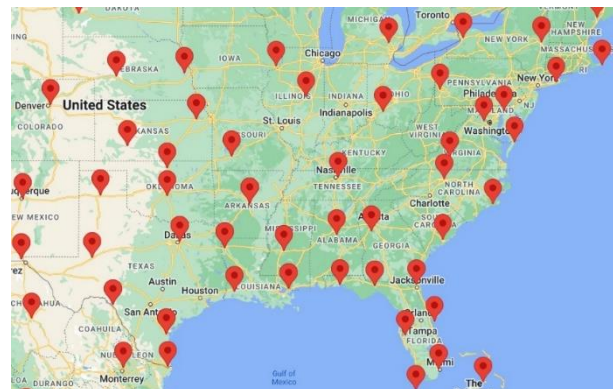
"For weather surveillance a geostationary hyperspectral infrared sounder would dramatically increase confidence in forecasts of hurricanes and other storms that originate over the ocean and head towards U.S. interests."

- Ken Graham, NWS Director (former NHC Director)



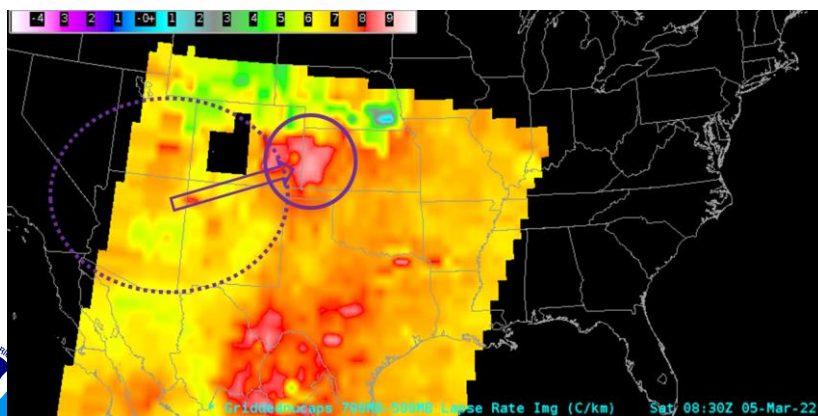
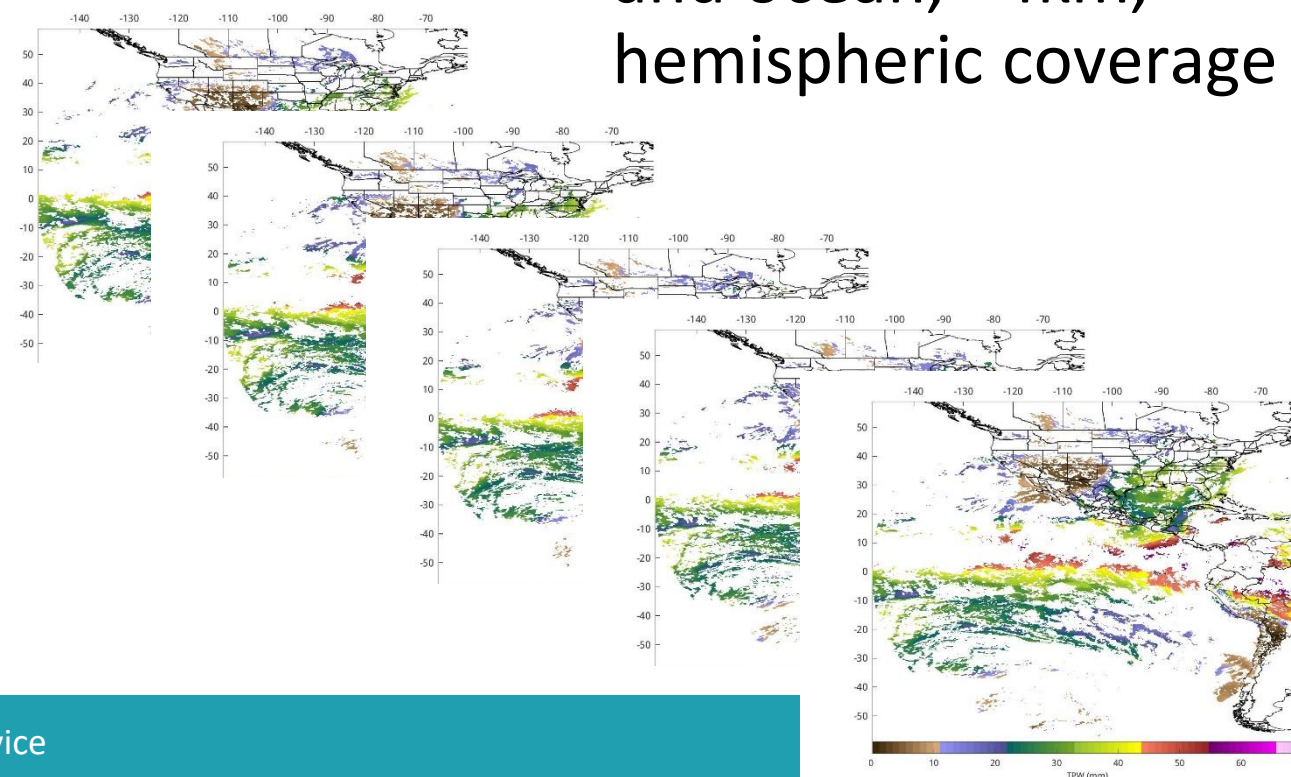
Vertical Moisture Information

Radiosondes
(2x/day),
scattered (mostly)
land locations



GeoXO Sounder
(at least hourly), land
and ocean, ~4km,
hemispheric coverage

LEO passes
(several/day over CONUS), land and
ocean, ~14-40km, global coverage





Spatial Resolutions: Ground Sample Distance and Angle

- The centroid-to-centroid distance between adjacent spatial samples on the Earth's surface, as measured at the Sub-Satellite Point, defines the ground sample distance (GSD). The ground sample angle (GSA) is the associated angle. A two-dimensional pixel is defined by the GSD in the East/West and North/South dimensions. The GXs shall have a GSA no larger than 112 microradians (**4 km at nadir**) for emissive channels.
- This is much improved over the legacy GOES Sounders and the current polar hyperspectral IR sounders.
 - ~10 km for legacy GOES Sounder
 - ~13 - 15 km for polar hyperspectral IR sounders.



Temporal Coverage

- In **Sounding Disk** mode, the GXS shall acquire each SD and perform all necessary housekeeping and calibration functions in **less than 60 minutes**.
- Scan modes of operations still being defined, in an interleaving mode, finer time resolution of the Super-regional (3000 km x 5000 km) and/or Mesoscale (1000 km x 1000 km) maybe possible
- Sounding Disk (SD) is a collection of spatial resolution elements viewing the earth where the local zenith angle (LZA) to a GOES is less than 62 degrees.

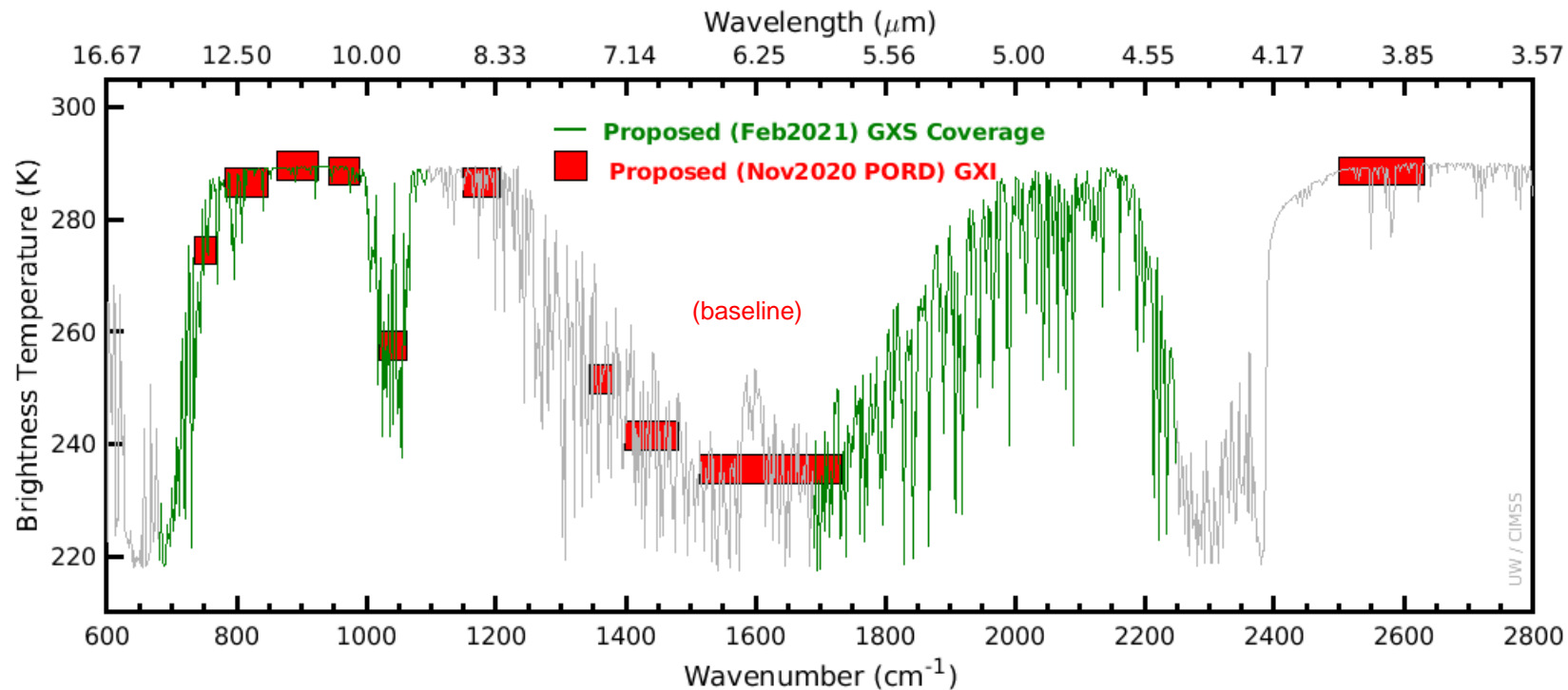
Sounding Spectral Range Table

Band	Wavenumber (cm ⁻¹)	Wavelength (μm)
LWIR region (temperature, LWIR window, ozone, NH ₃ , isoprene, HNO ₃ , low level moisture)	680- 1095	14.7 – 9.13
MWIR region (vertical moisture, window and temperature, N ₂ O and CO)	1689 – 2250	5.92 – 4.44μm

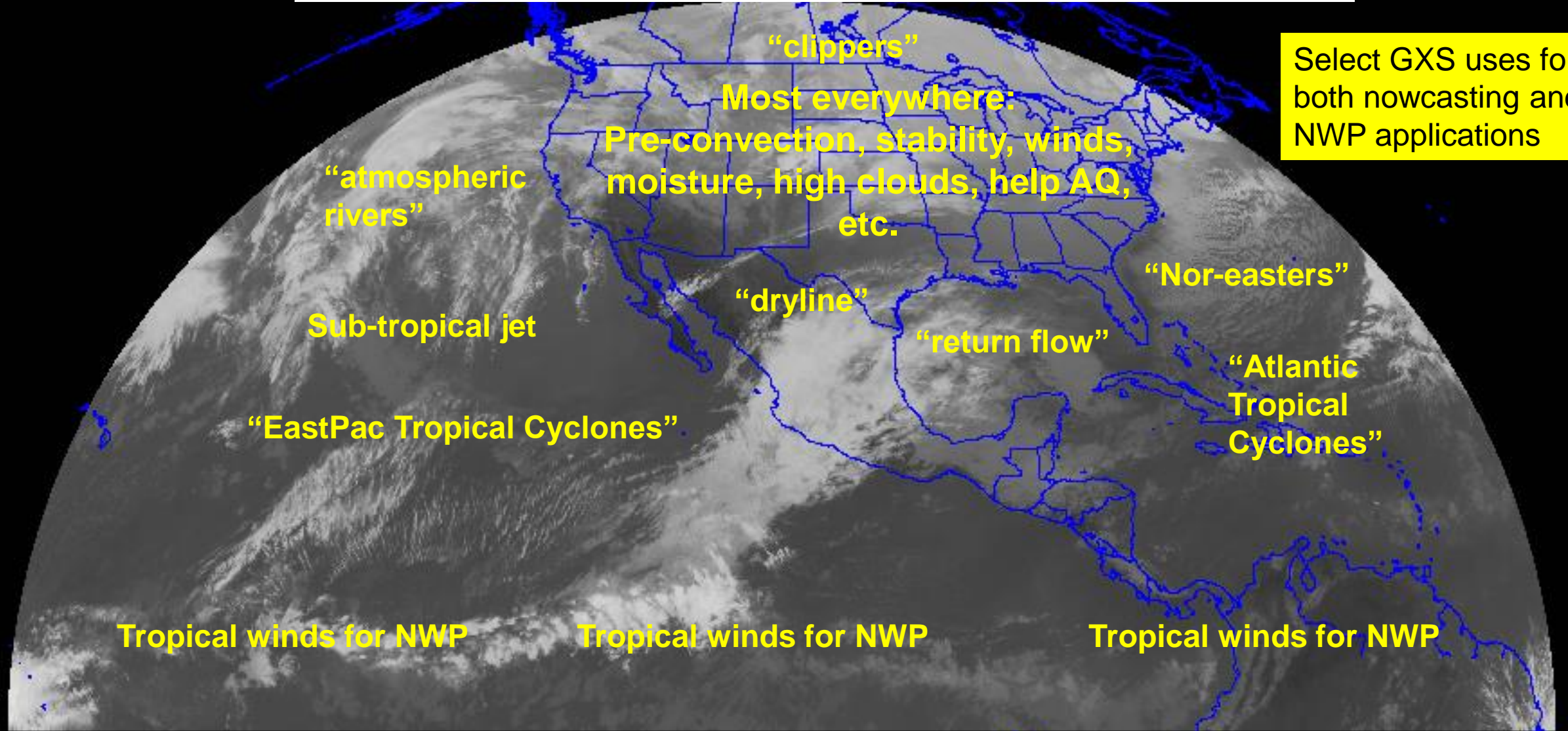
Spectral

Maximum Width for Sounding Channels Table

Spectral Range	Wavenumber (cm ⁻¹) (FTS)	Wavelength (μm) (Grating)
680- 1095 (cm ⁻¹) 14.7 – 9.13 (μm)	0.625	0.0052
1689 – 2250 (cm ⁻¹) 5.92 – 4.44 (μm)	0.625	0.0012

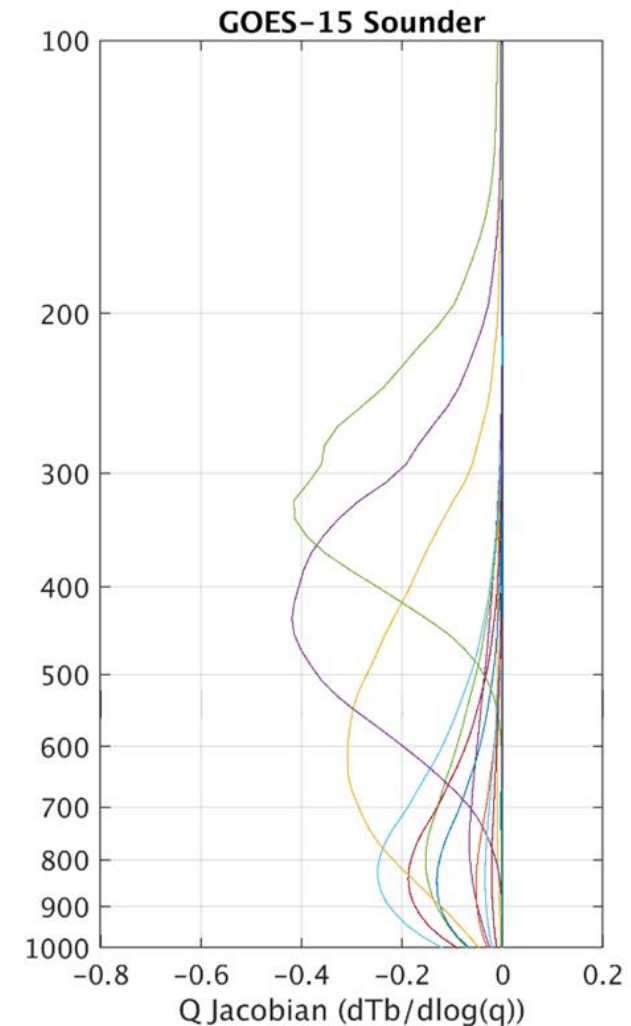
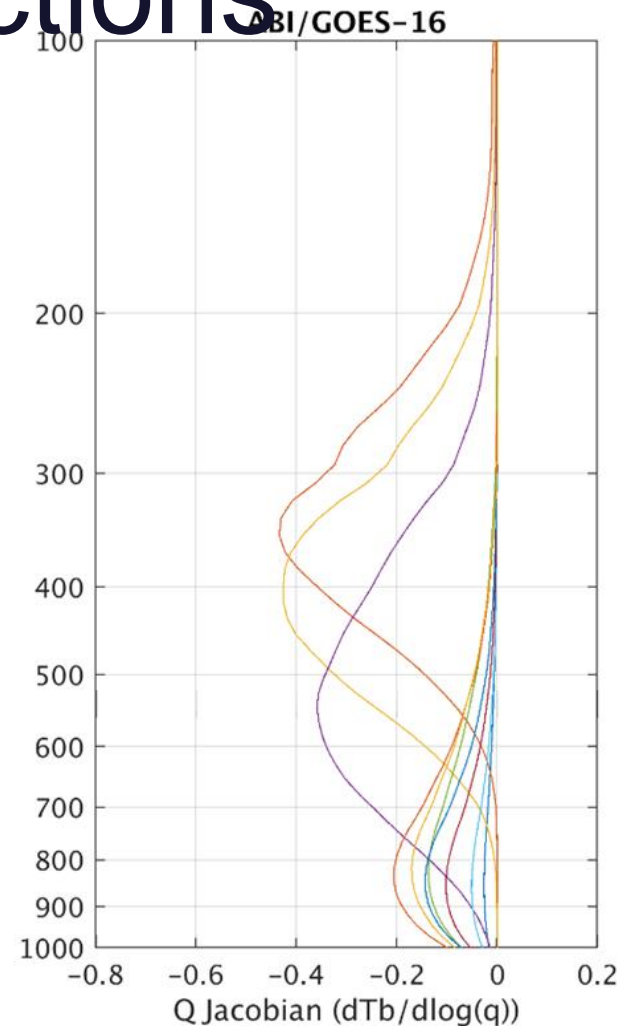
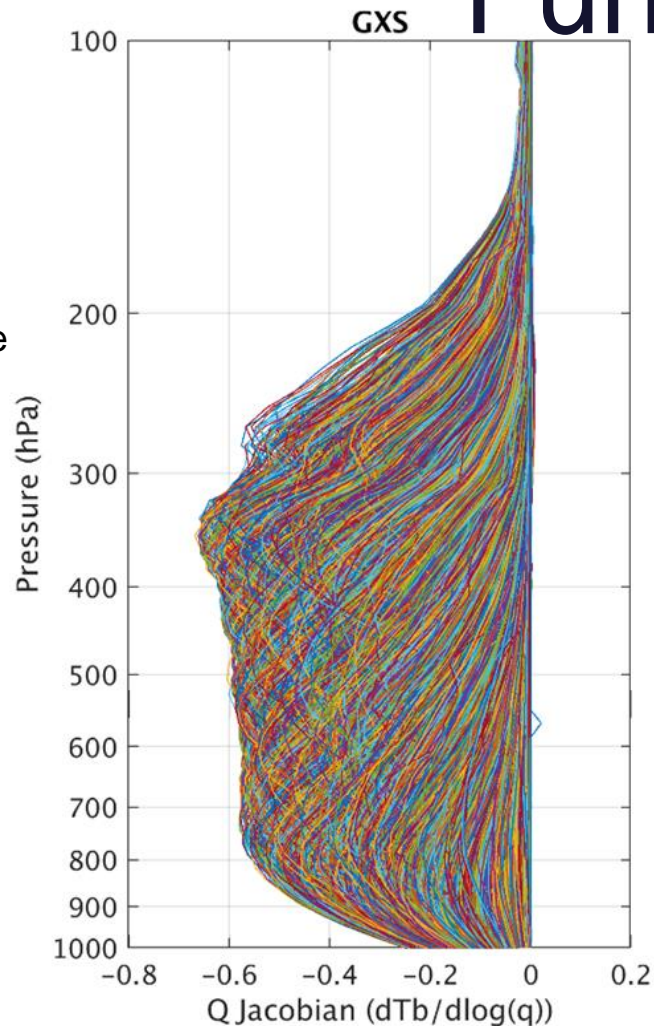


Sample GeoXO Sounder Uses



GeoXO GXS Moisture Weighting Functions

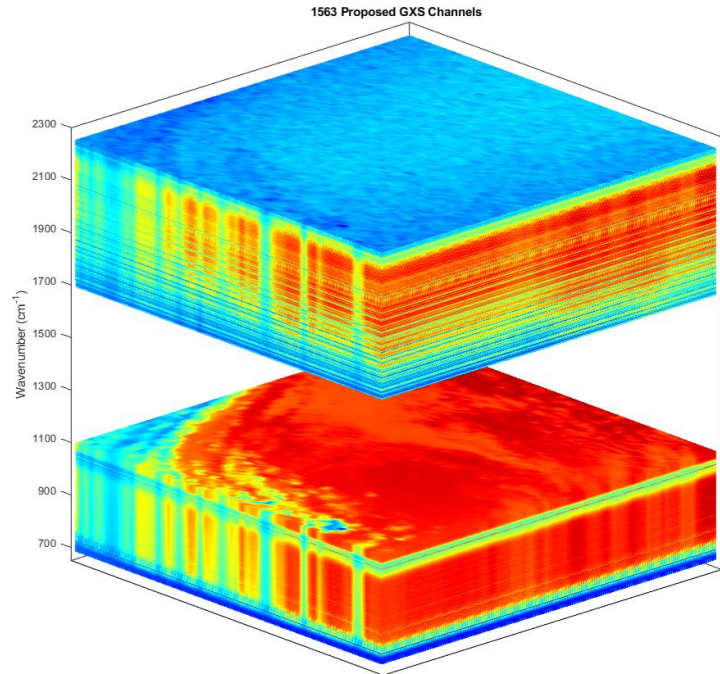
- GeoXO IR-Sounder (GXS) Science Working Group has computed the Weighting functions for the nominal specifications of GXS.
- Weighting functions (aka Jacobians) show where in the atmosphere information comes from.
- These plots show the weighting functions for moisture.
- These are also important for picking channels for data assimilation, although as many as possible should be used.



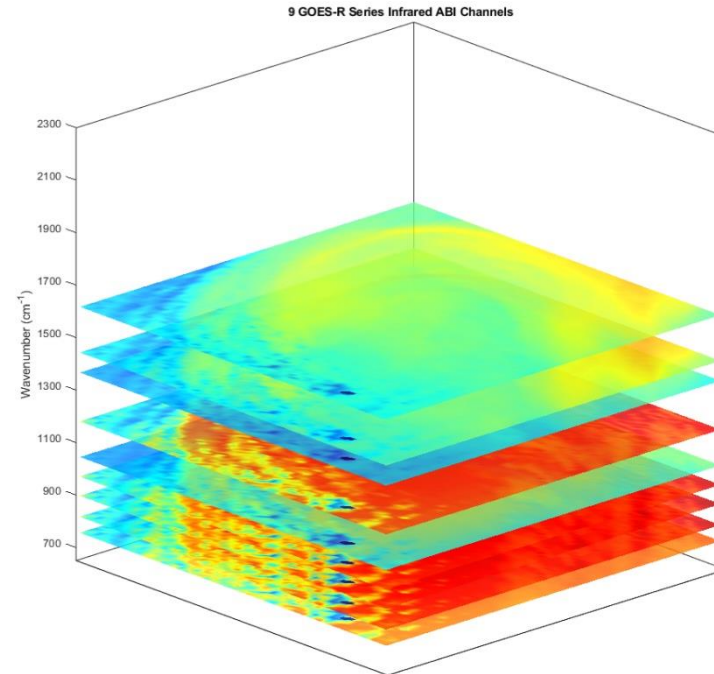
They show how much more vertical information GXS will provide compared to ABI or the previous GOES Sounders, this is in part to the many more overlapping spectral bands.

More spectral bands means more vertical information for temperature and moisture

GXS



ABI



IASI granule used to show the great improvement of the GXS over previous geostationary capabilities. Not shown are the improved temporal or spatial attributes of the GXS.

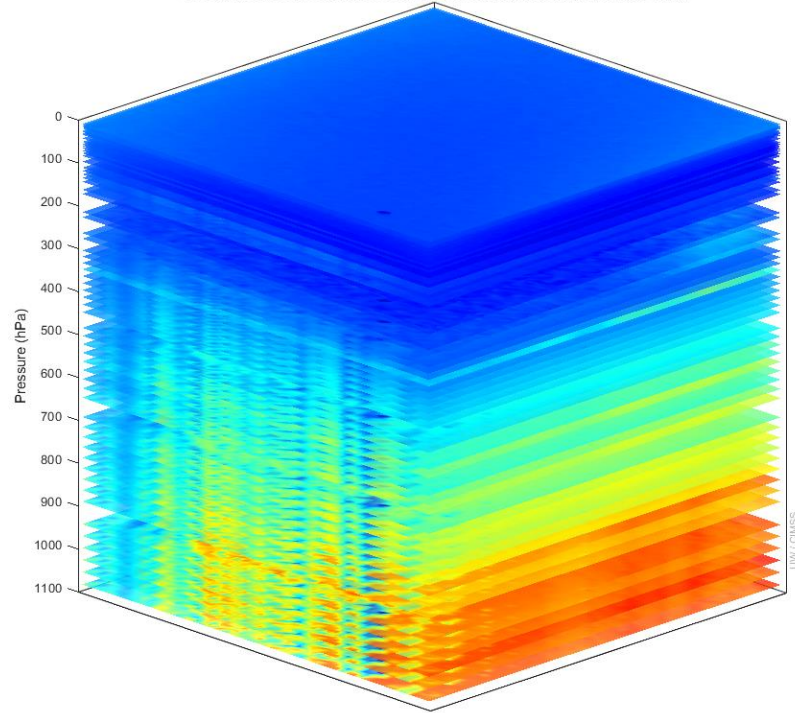
There is more than six times (temperature) and four times (moisture) of number of independent pieces of vertical information compared to the ABI.

Number of Independent Pieces of Vertical Information

Temperature	13	2
Moisture	11	2.5

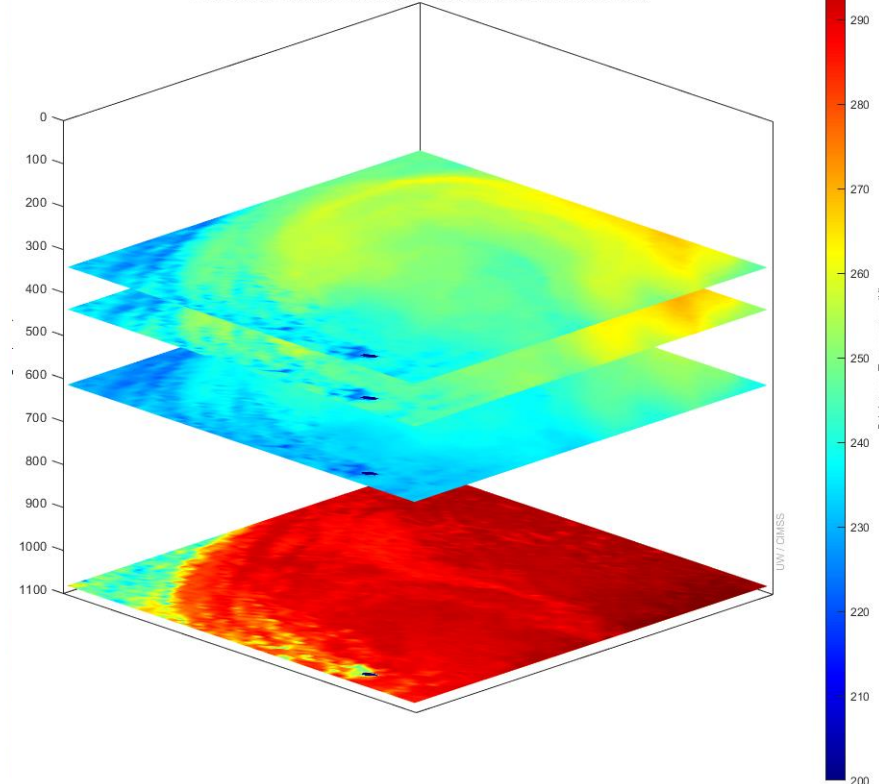
GeoXO Sounder

1563 Proposed GXS Channels Sorted by Peak Height (Unique Heights Only)



ABI

GOES-R ABI Channels Sorted by Peak Height (Unique Heights Only)



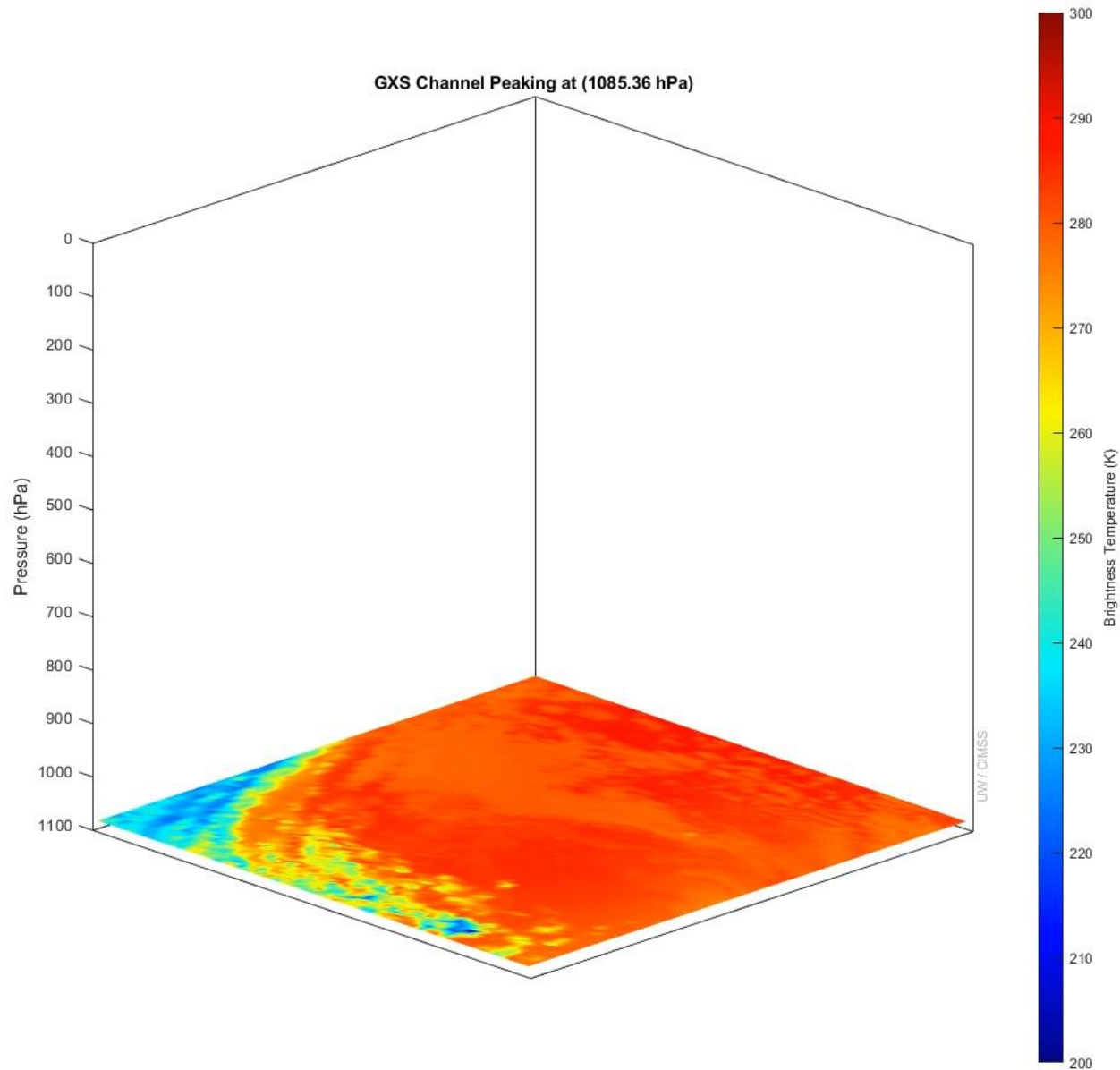
The GeoXO Sounder (GXS) will provide much greater vertical atmospheric information than the ABI or the broad spectral band GOES Legacy Sounder, from the surface up to the stratosphere.

GXS will provide above today's capabilities:

- The boundary layer near/just above the surface.
- Information throughout the atmosphere.
- Other trace gas information (N_2O , CO , NH_3 , O_3 , etc.).
- Many more levels of water vapor information.

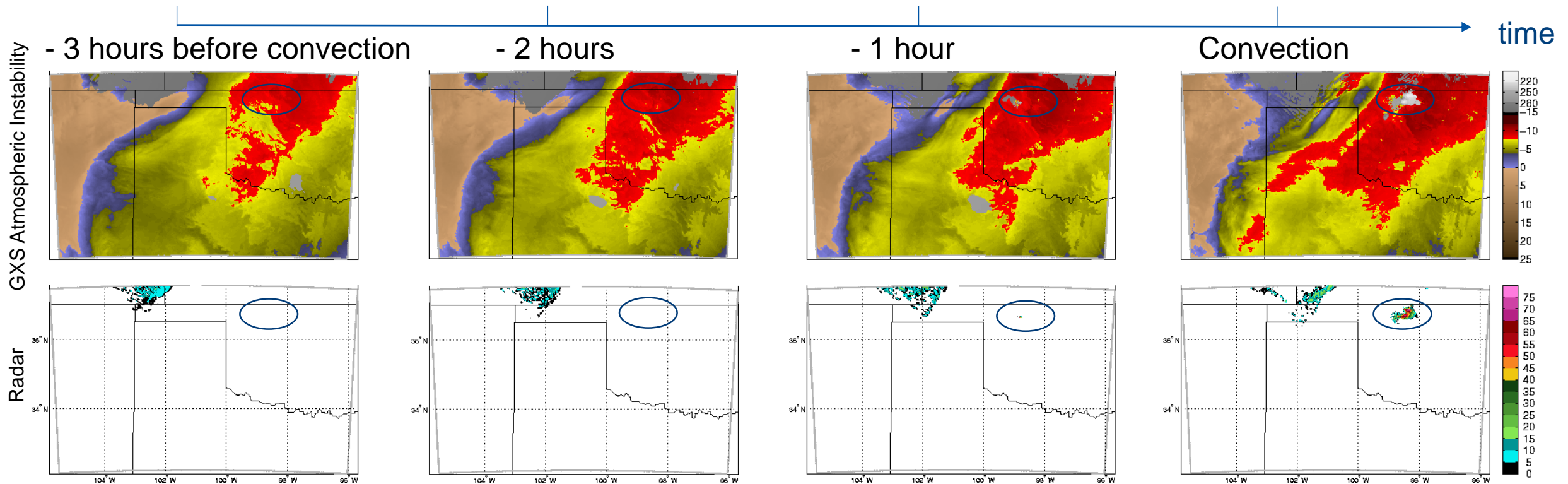
Proposed GeoXO Sounder
1563 IR Bands Total
Sorted by Peak Pressure
(related to height) in the
atmosphere and only one
shown for each unique
layer in the forward
model.

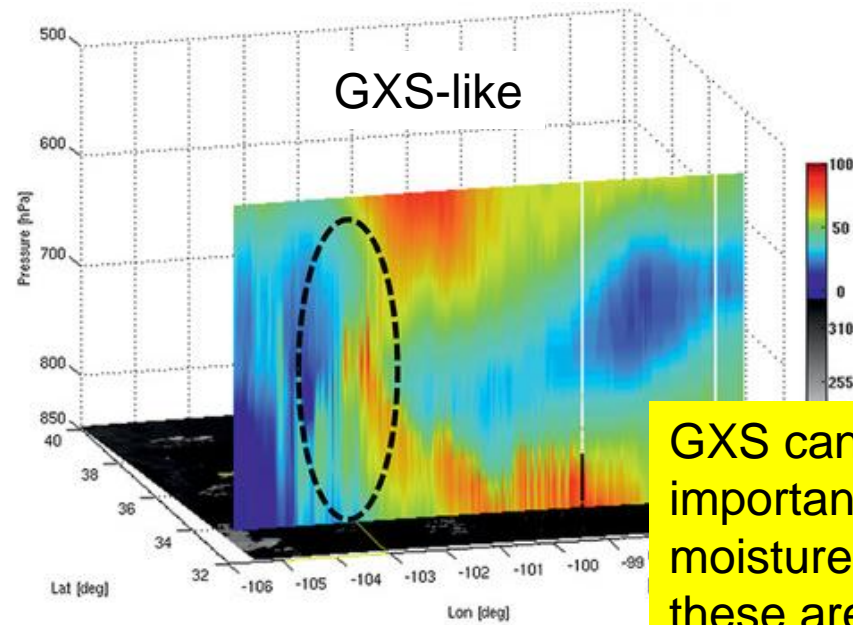
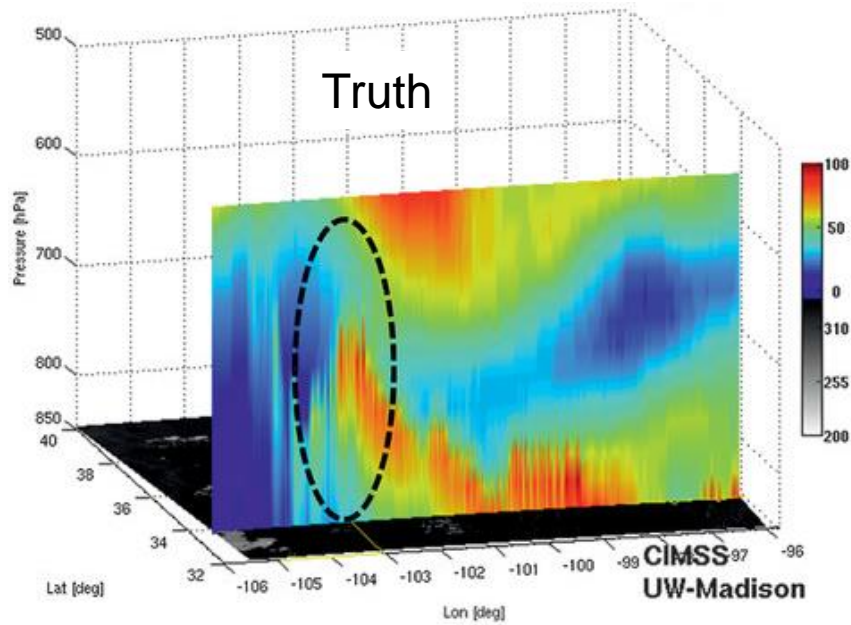
Animation



GeoXO GXS Can Monitor Conditions ripe for Thunderstorms; increasing lead times

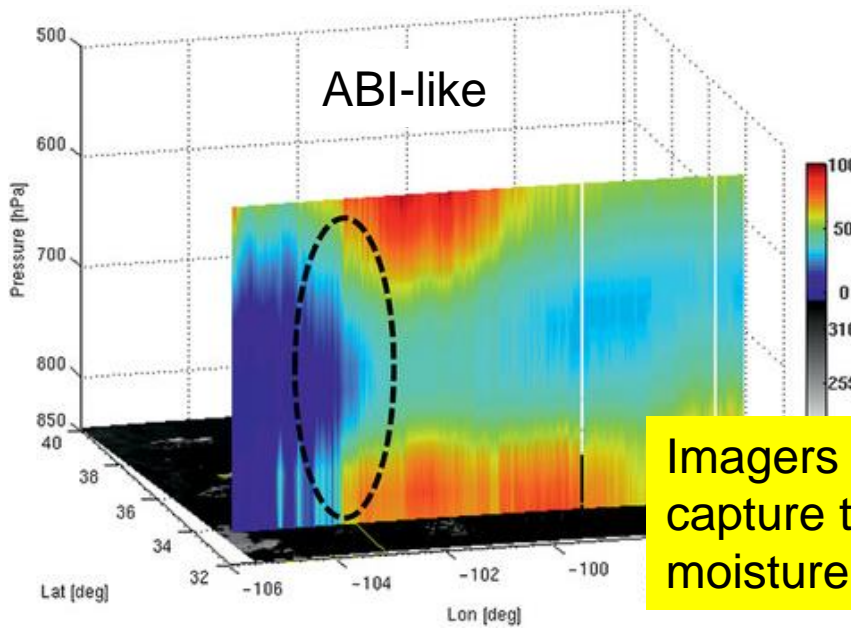
The GXS - sounder can provide hours more lead time of atmospheric instability compared to waiting for the radar echoes. The GXS does this via uniquely monitoring upper-level drying; low-level moisture pooling; and atmospheric flow before the clouds form. These are important vertical moisture changes; as they are key to the prediction of convection. The GXI will not provide the detailed vertical moisture or temperature information (not shown).



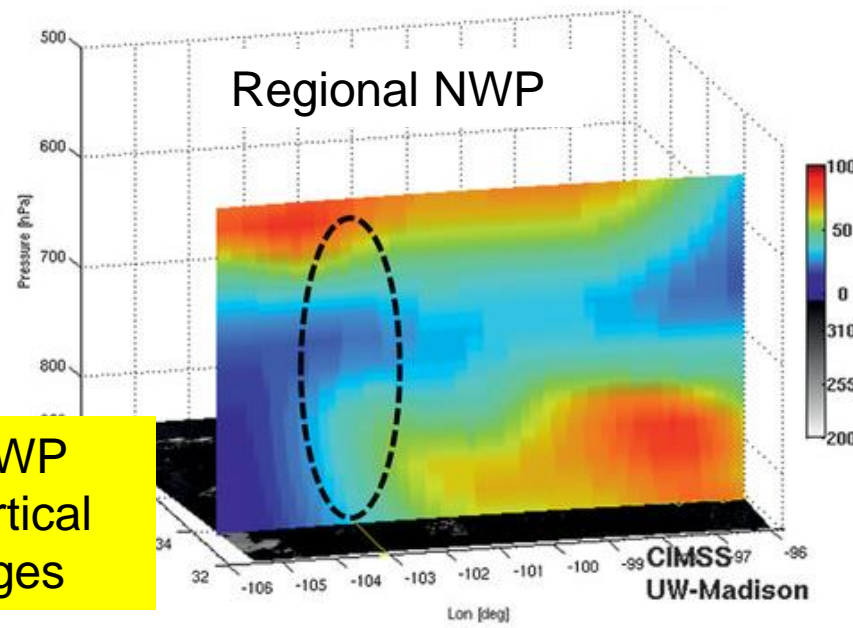


GXS can monitor important vertical moisture changes; these are the key to the prediction of convection

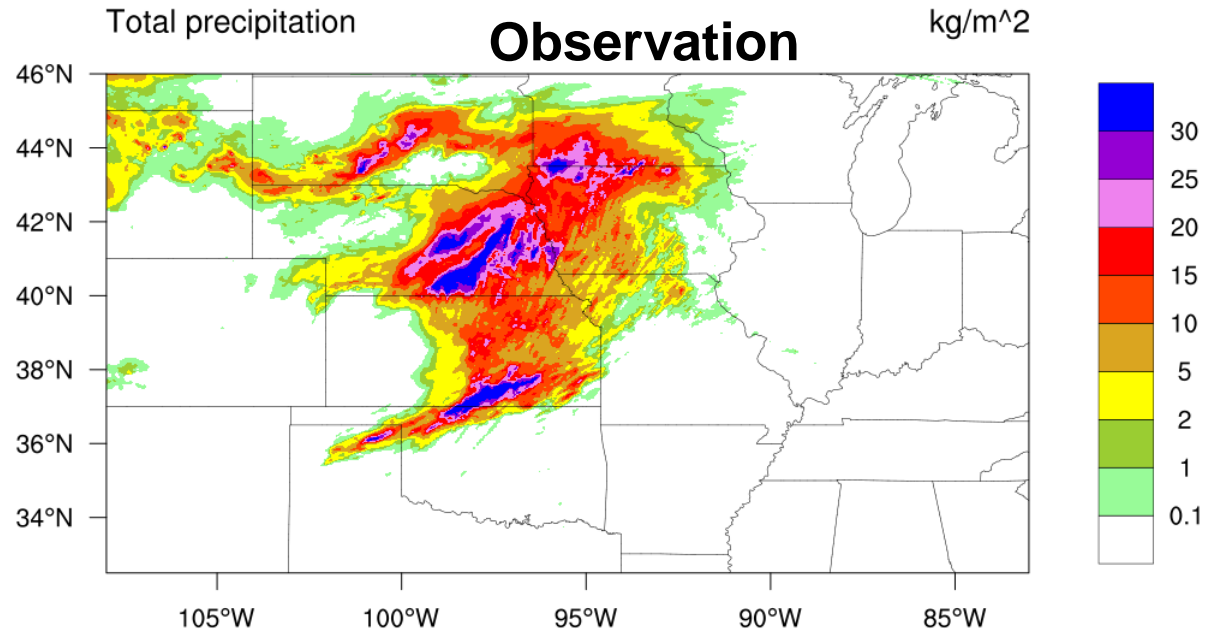
12-June-2002 20 UTC
Relative Humidity [%]



Imagers nor NWP capture the vertical moisture changes

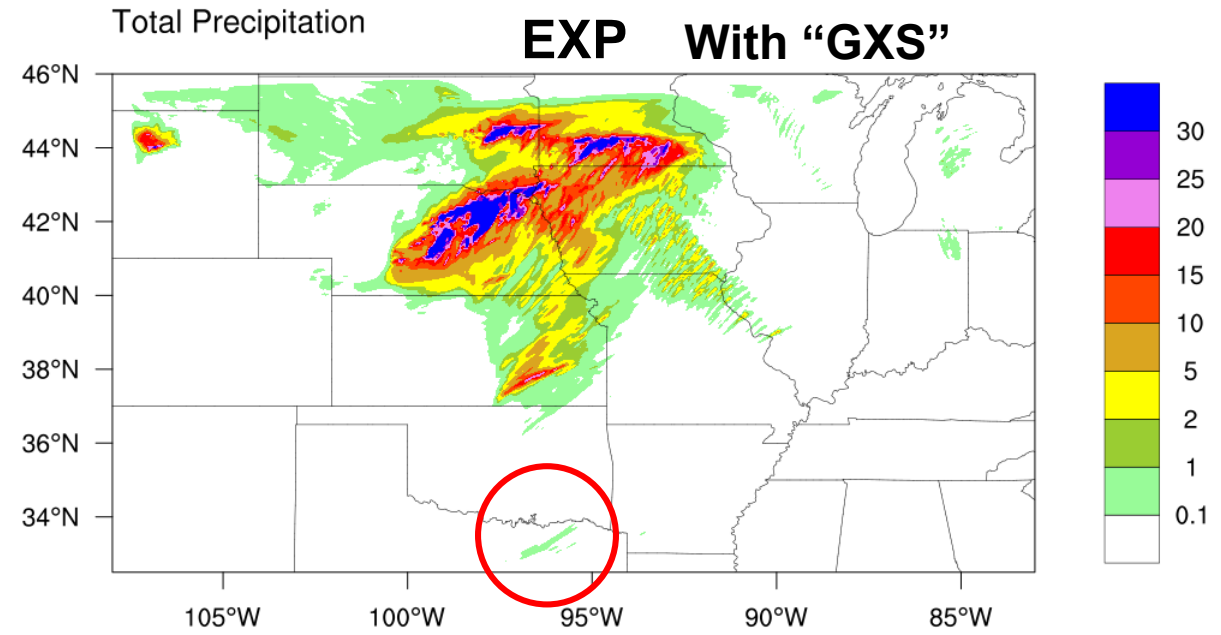
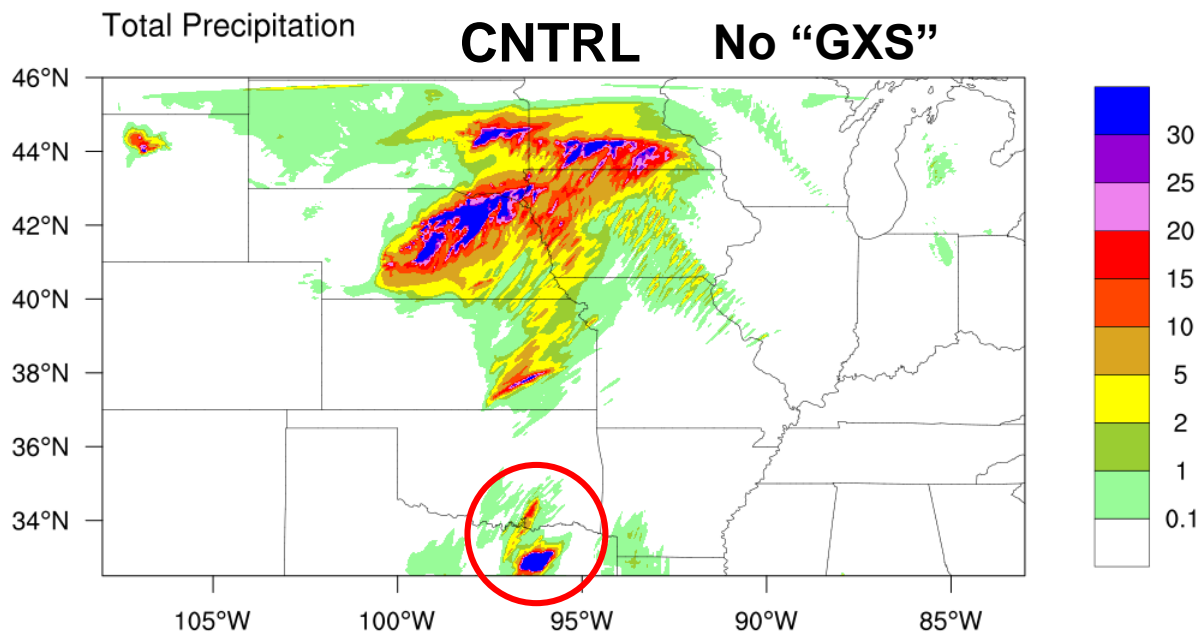


Hybrid OSSE: Precipitation Impact Verification

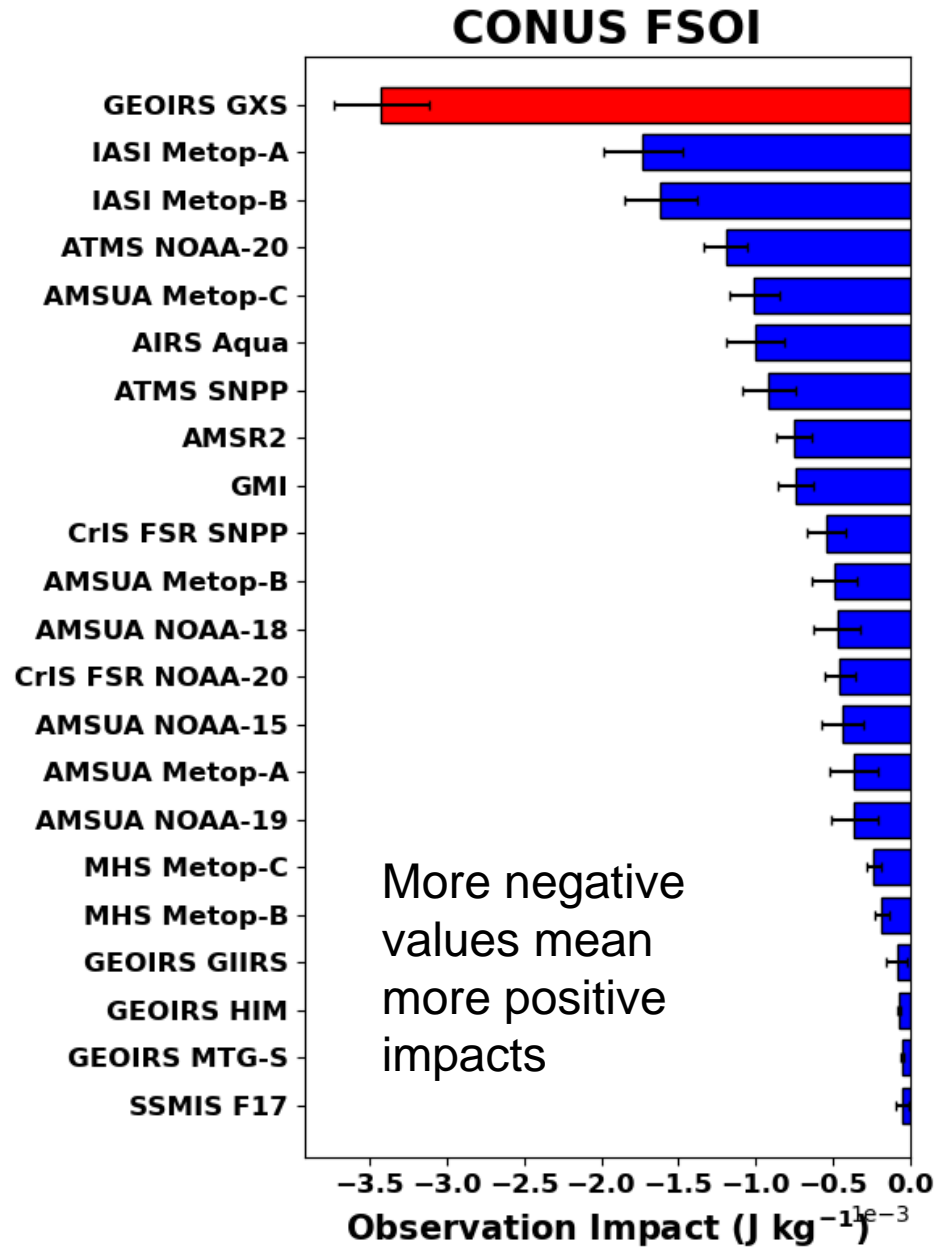


2019-5-27 06UTC – 12UTC

- The high spectral IR was able to remove a spurious storm over Eastern Texas!
- A false heavy precipitation that might lead to a false warning!



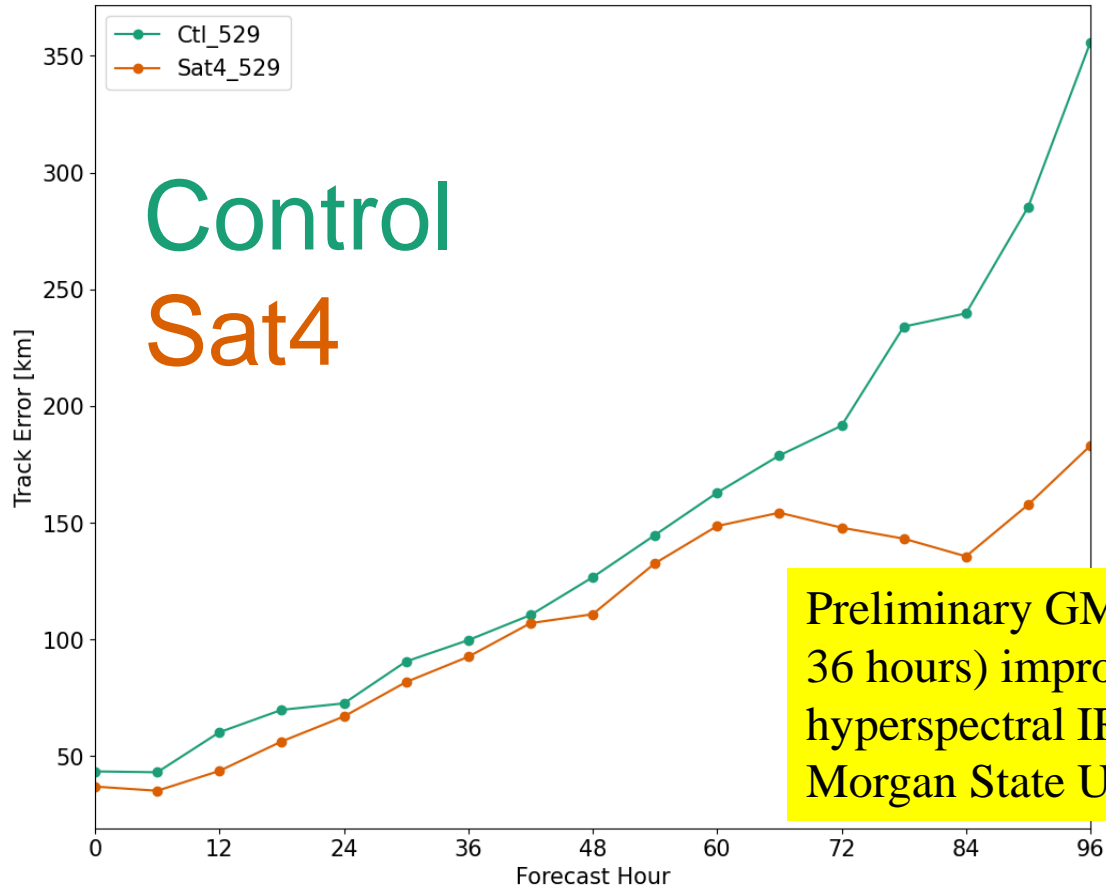
FSOI (24-hr)



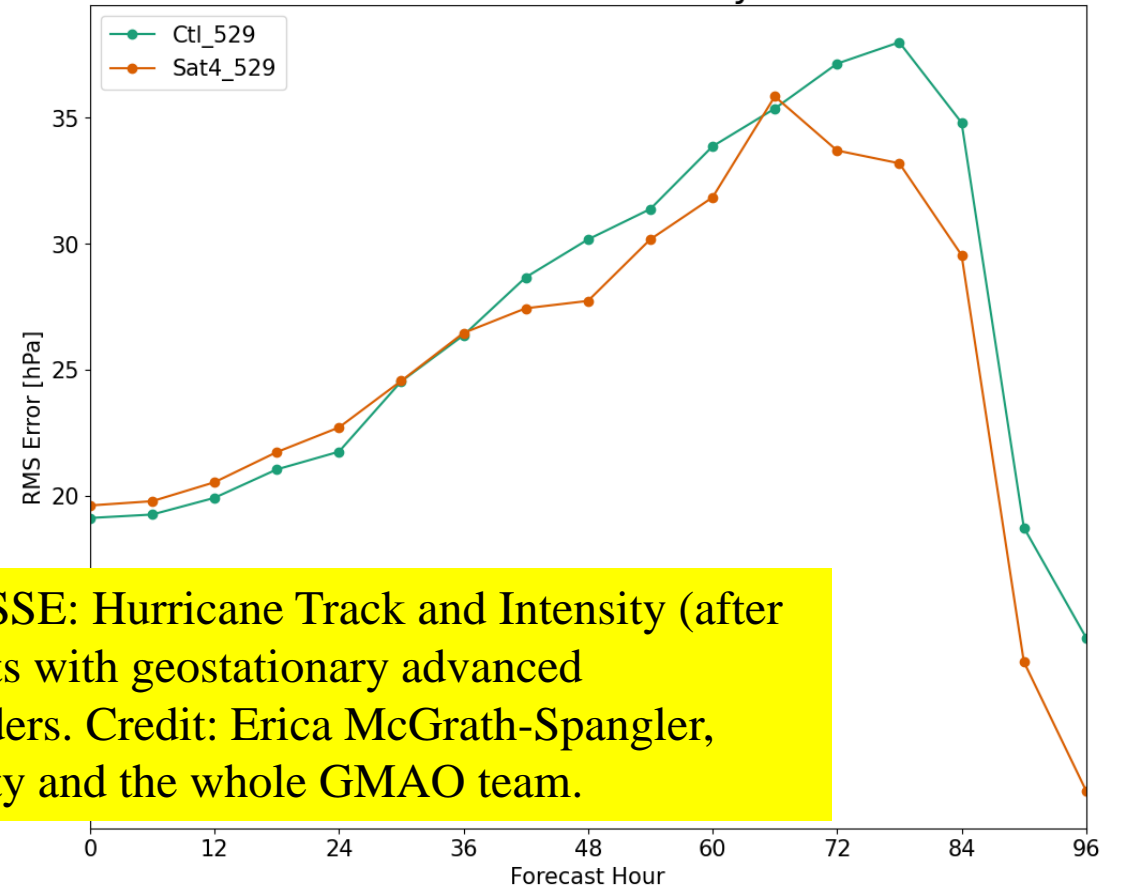
Preliminary NASA's GMAO OSSE: GXS has more than twice the positive impact as the second closest contributor over the contiguous US region (included the 4 analysis times). These scores are for 24-hr forecasts. A negative value is a positive impact. Credit: Erica McGrath-Spangler, Morgan State University and the whole GMAO team.

Forecasts

AL03 Forecast Track Error



AL03 Forecast Intensity Error

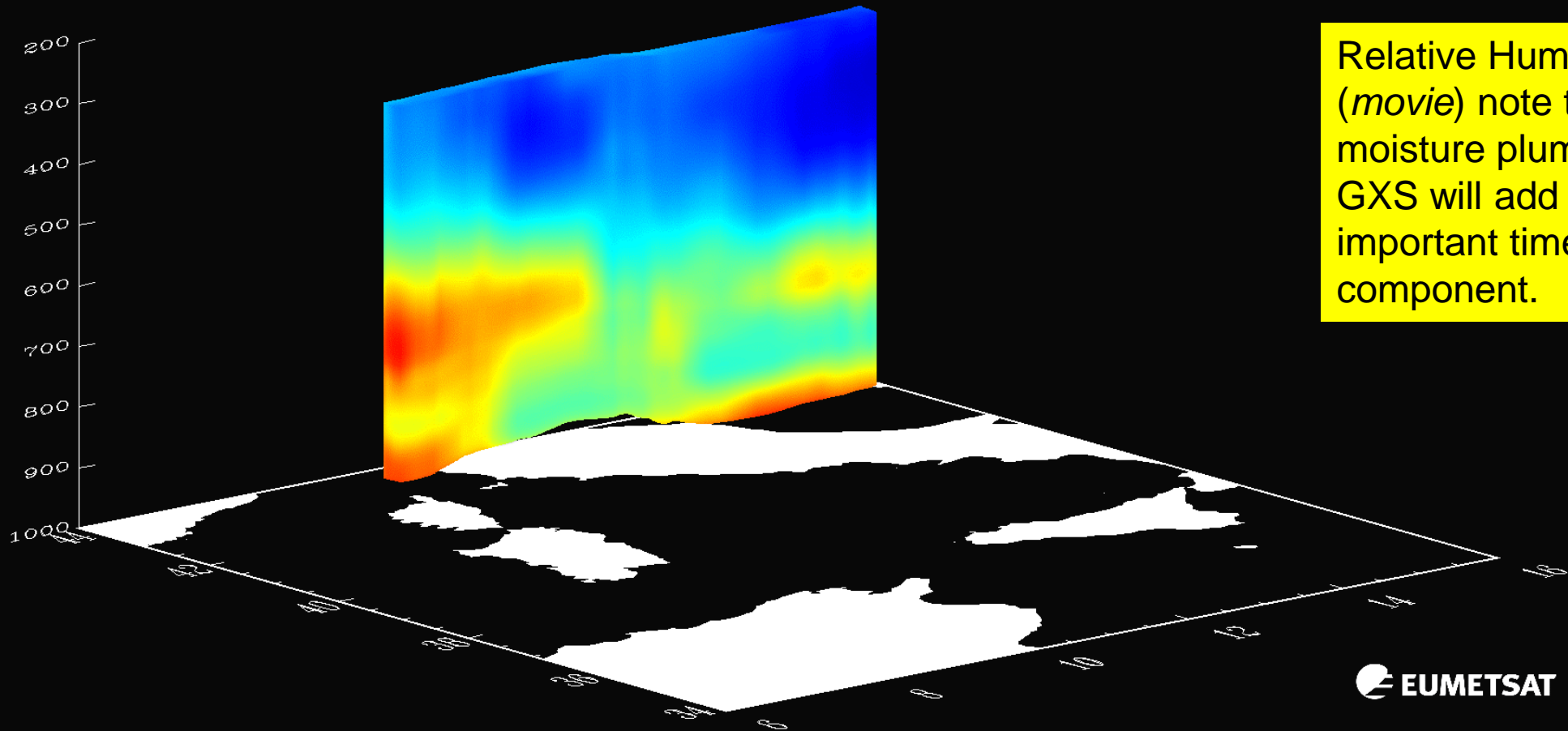


Preliminary GMAO OSSE: Hurricane Track and Intensity (after 36 hours) improvements with geostationary advanced hyperspectral IR Sounders. Credit: Erica McGrath-Spangler, Morgan State University and the whole GMAO team.

Fcst hour	0	24	48	72	96
# Fcsts	16	13	9	5	1

GeoXO GXS is the only sensor to monitor vertical moisture on high time and space scales

EARS-IASI L2 :: RH :: M01_20170513195732Z_20170513200907Z



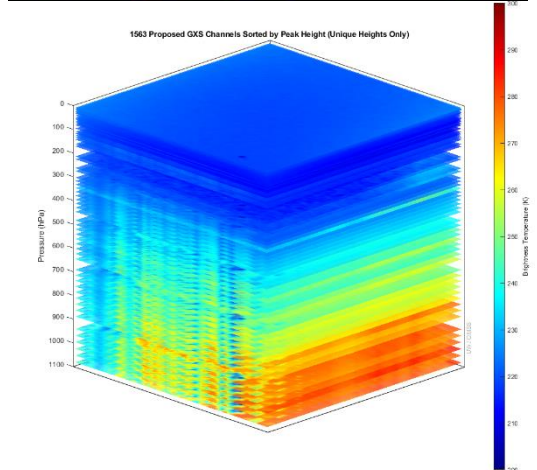
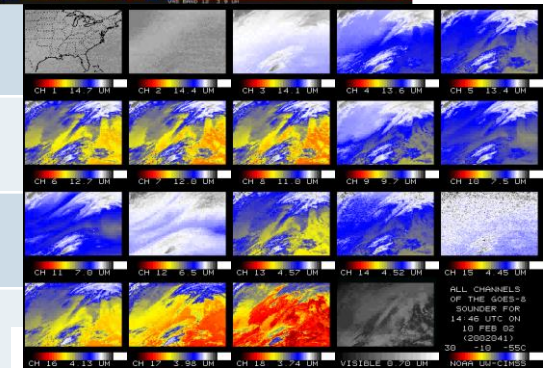
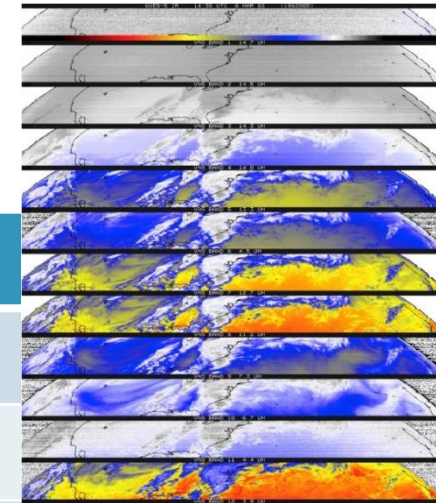
Relative Humidity
(*movie*) note the elevated
moisture plumes.
GXS will add the
important time
component.

Need for high spectral & temporal observations

- **High-spectral-resolution observations provide much more information**
 - Imagers average out important vertical information
 - LEO has shown the many benefits, especially on the global scale, lacks time resolution
- Forecasting Applications – fill in critical gaps wrt vertical moisture, wind and temperature
 - **Nowcasting and Numerical weather prediction**, especially on the regional/mesoscales
- Additional applications
 - **improve derived products with only advanced imager data**
 - cloud-top properties, atmospheric motion vectors, dust detection, land and sea surface temperatures
 - **New areas**
 - Moisture flux, capping inversion, surface emissivity, trace gases (Ozone and Carbon Monoxide, etc.) and climate
- **Economic impacts** (“billions” ...) More with the benefits of 4dvar analysis ...
- Critical Component of the **Global Constellation**

U.S. Geostationary Sounders

Item	# IR bands	Sounding
First Experimental	12	GOES-4 VAS (1980)
First Operational	18	GOES-8 (1994)
100x improved	~1500	High-spectral IR (203?)



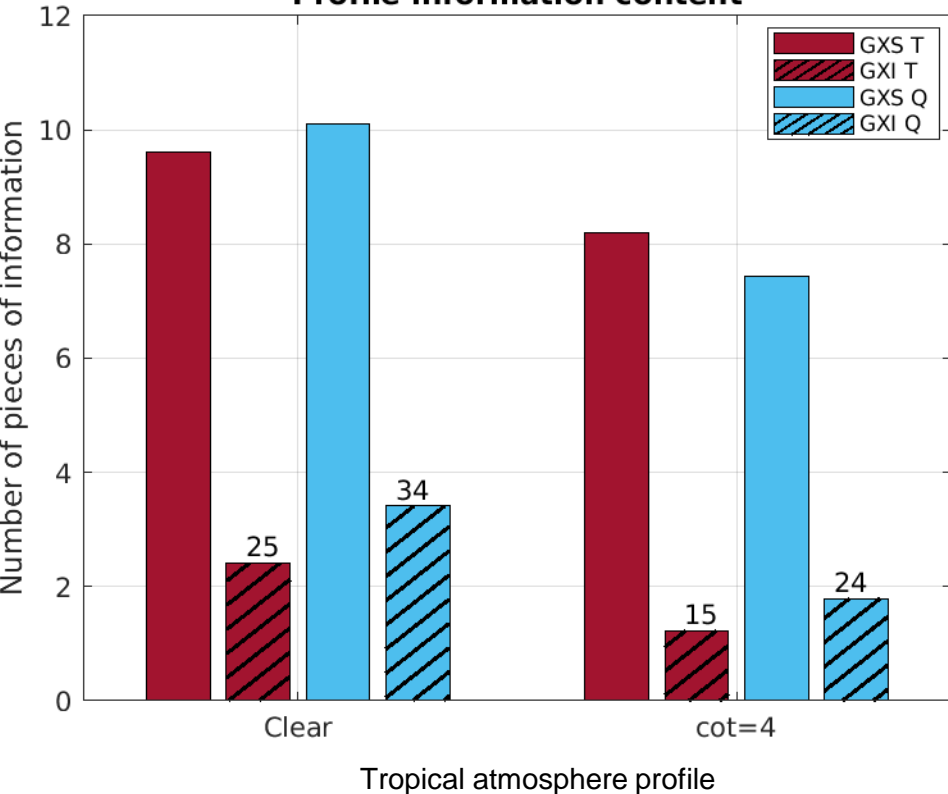
The GOES-R series included advanced imagers, the first geostationary lightning mapper and space weather instruments.



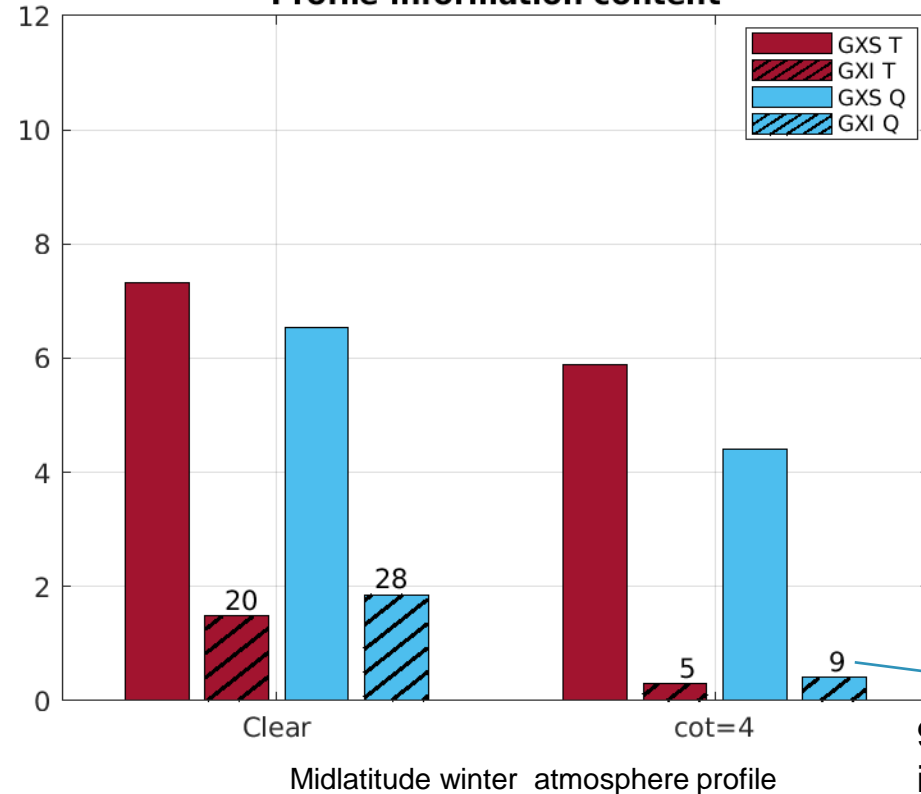
GXS information content is much more than GXI

Cloud top pressure = 300 hPa

Profile information content



Profile information content



GXS has 3-5 times more vertical information than the GXI in clear skies, and 4-20 times more vertical information than the GXI in thin clouds

9 means GXI has 9% of moisture information content compared with GXS when COT is 4.

- Numbers on top of bars show the percentage (%) of information content from GXI compared to GXS
- High clouds reduce information content of T/Q, but significantly less impact from GXS

More Information

<https://www.ssec.wisc.edu/geo-ir-sounder/>

- Home
- OSSE
- Proxy
- Other Benefits
- Needs
- On-orbit examples



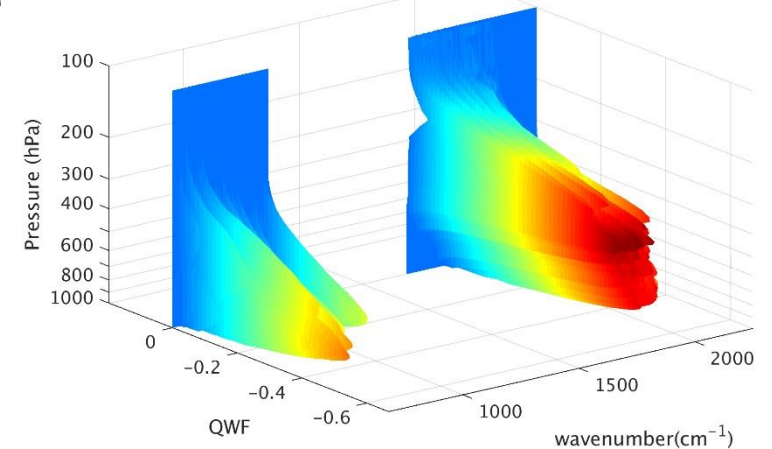
NOAA NESDIS Tech Report: Geostationary Extended Observations (GeoXO) Hyperspectral InfraRed Sounder Value Assessment Report

<https://repository.library.noaa.gov/view/noaa/32921>

<https://www.nesdis.noaa.gov/next-generation-satellites/geostationary-extended-observations-geoxo>

- PORD:

<https://www.nesdis.noaa.gov/next-generation/geoxo/geoxo-sounder-gxs>





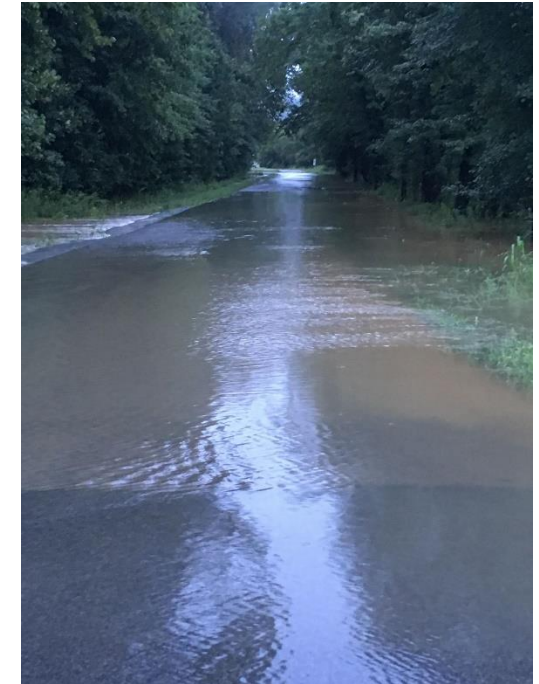
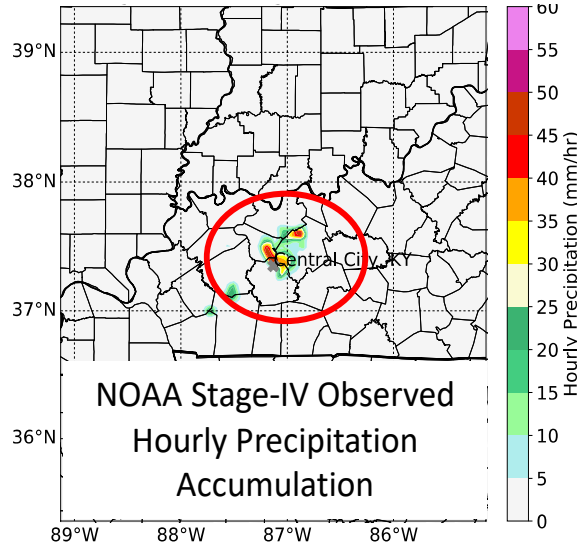
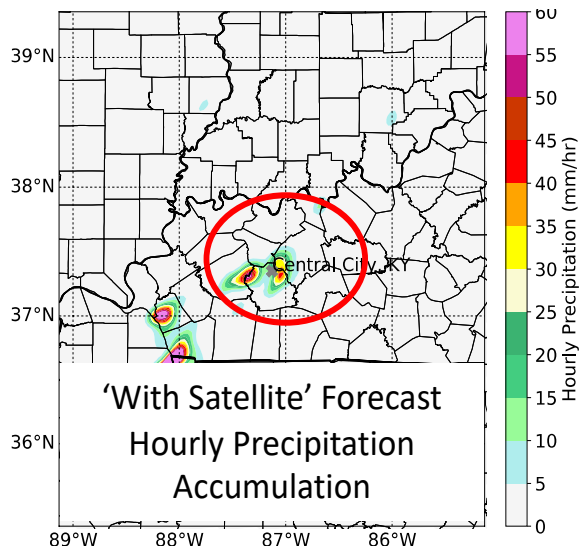
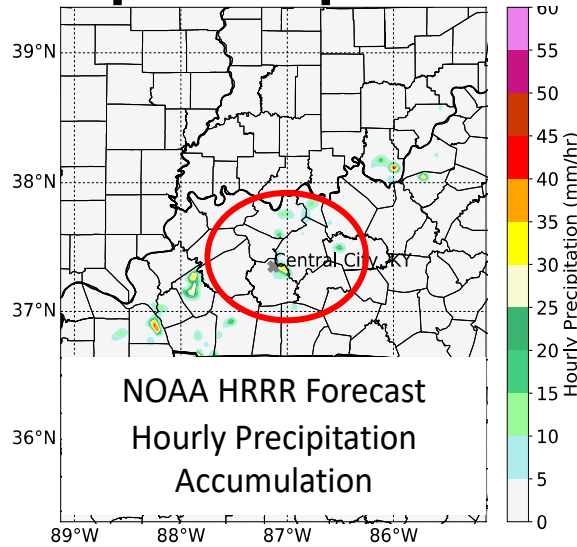
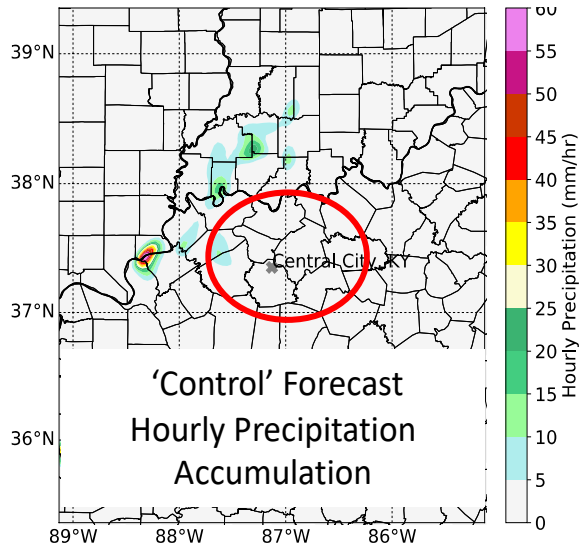
Backup



"Even though this historic journey has been 60+ years in the making, we are just scratching the surface. [The] biggest next step is the **GEO hyperspectral sounder!** Address the high resolution ΔT opportunity observed across the entire Earth System. Europe and Asia are leading the effort to launch and operate Geostationary Sounders. We are now the followers... we should be reasserting our past leadership position."

Dr. Louis W. Uccellini, Former NWS Director, February 24, 2020

Forecasts with high spectral and time resolution satellite data greatly improve precipitation forecasts

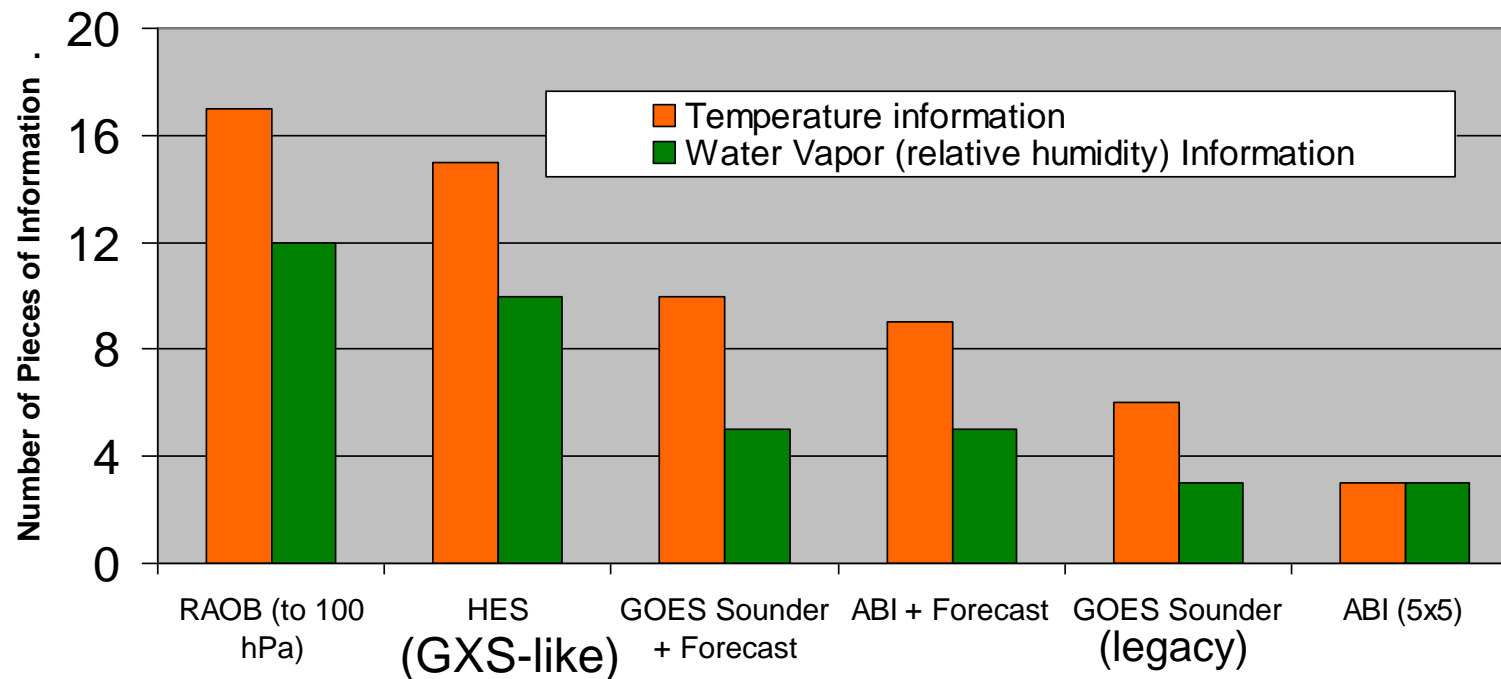


NWS

KY flooding: 9-hour forecasts of hourly accumulated precipitation for the period 01:00 to 02:00 CDT, on August 5, 2022. The control forecast is obtained from the same model and conventional observations used for the 'Satellite' forecast but without the assimilation of the satellite moisture profile data. Without the satellite profiles, the heavy rain was not forecast by the model.

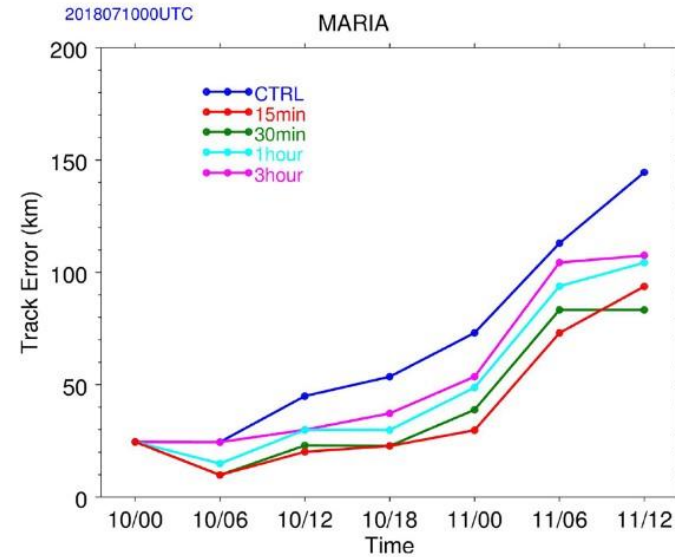
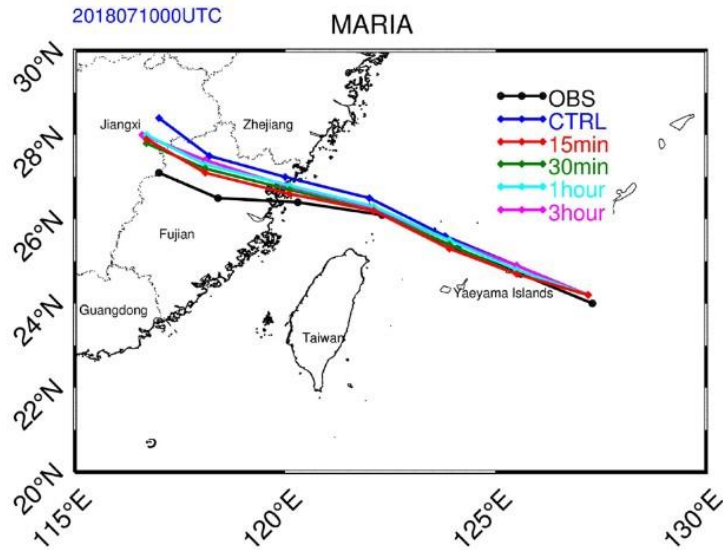
Information Content

Profile Information Content



The relative vertical number of independent pieces of information is shown. The *moisture* content is similar between the ABI and the legacy GOES Sounder. The legacy GOES Sounder does show more *temperature* information than the ABI. The ABI is not close to the information content of a high-spectral IR sensor.

Improved track and intensity forecasts



The 36 h track forecast for Typhoon Maria from 0000 UTC on July 10, 2018. The black, blue, red, green, cyan, and magenta lines indicate the Best Track, control experiment, 15 min, 30 min, 1 and 3 h, respectively.

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GL093672>

Improving tropical cyclone forecasts with high temporal/spectral IR observations.

Track & intensity forecasts for Typhoon Maria are most improved with 15 min data, the track (> 40%) and the intensity (18%).

Precipitation forecasts also improved.