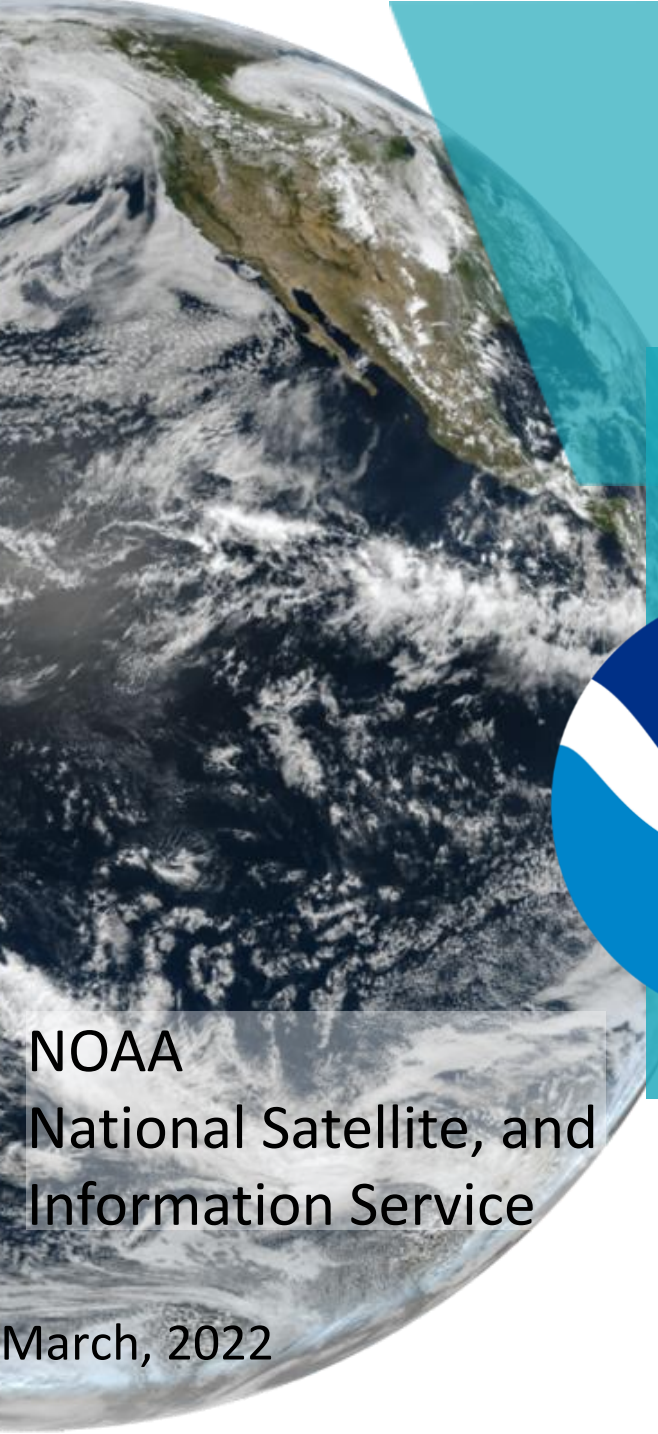
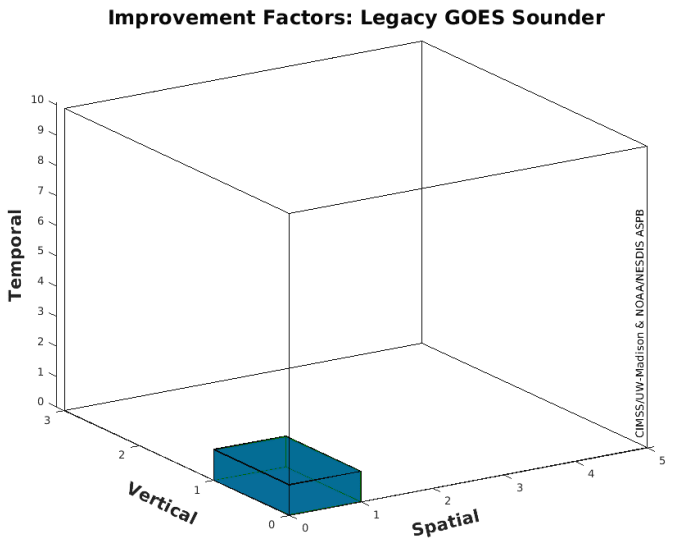




US Plans for Geostationary Hyper-spectral Infrared Sounders

GeoXO Sounder (GXS)

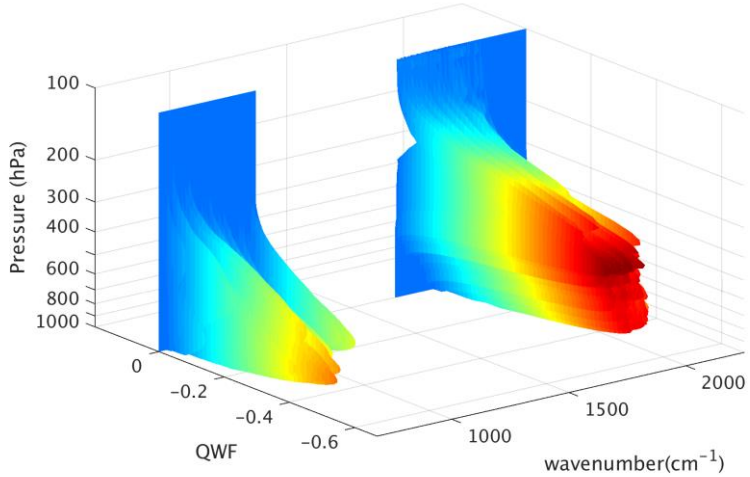
NOAA
National Satellite, and Information Service

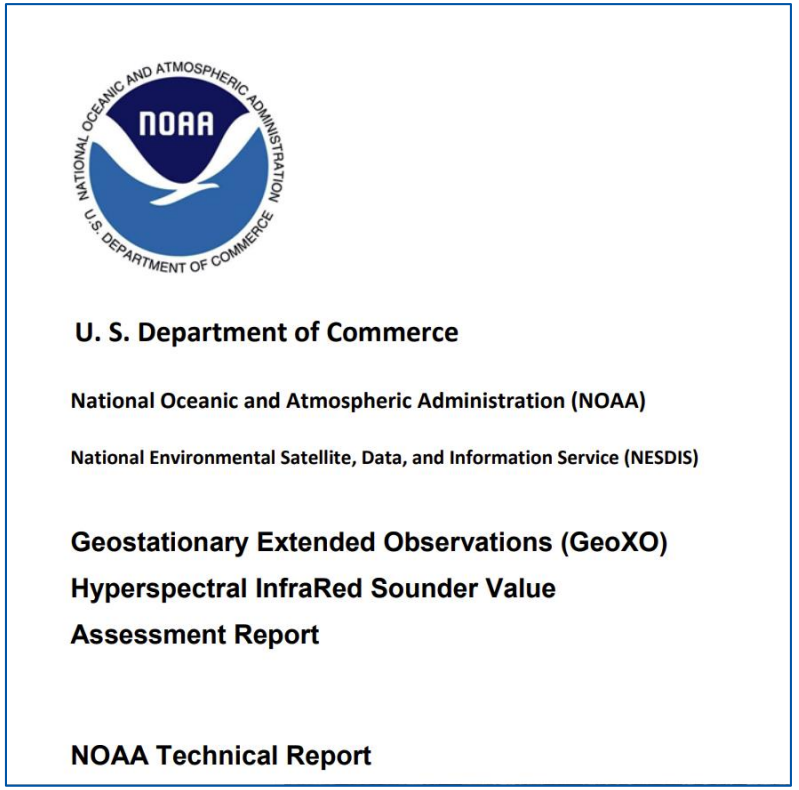
March, 2022

Tim Schmit, NOAA NESDIS STAR CoRP ASPB
GXS Team, Zhenglong Li, Joel McCorkel, etc., ……

Introduction

- Tim Schmit, Research Satellite Meteorologist
  - Specializing with GOES (GOES-7 -> GOES-18)
  - Madison, Wisconsin
- Product Lead for GXS science
  - David Johnson, instrument lead
  - Jim Yoe, user lead
- The GXS will supply unique information to better monitor the current state of the atmosphere
  - Vertical moisture profiles, Atmospheric winds at many levels, Vertical temperature profiles, some information on Trace Gases
- So, the future state can be better forecast
  - Clouds, thunderstorms, winds, temperatures, moisture,
  - Air quality, etc.
  - Nowcasting, short-term forecasts
  - NWP (regional and global)
- References
  - https://www.ssec.wisc.edu/geo-ir-sounder
  - https://www.nesdis.noaa.gov/next-generation/geostationary-extended-observations-geoxo





History

FOREWORD

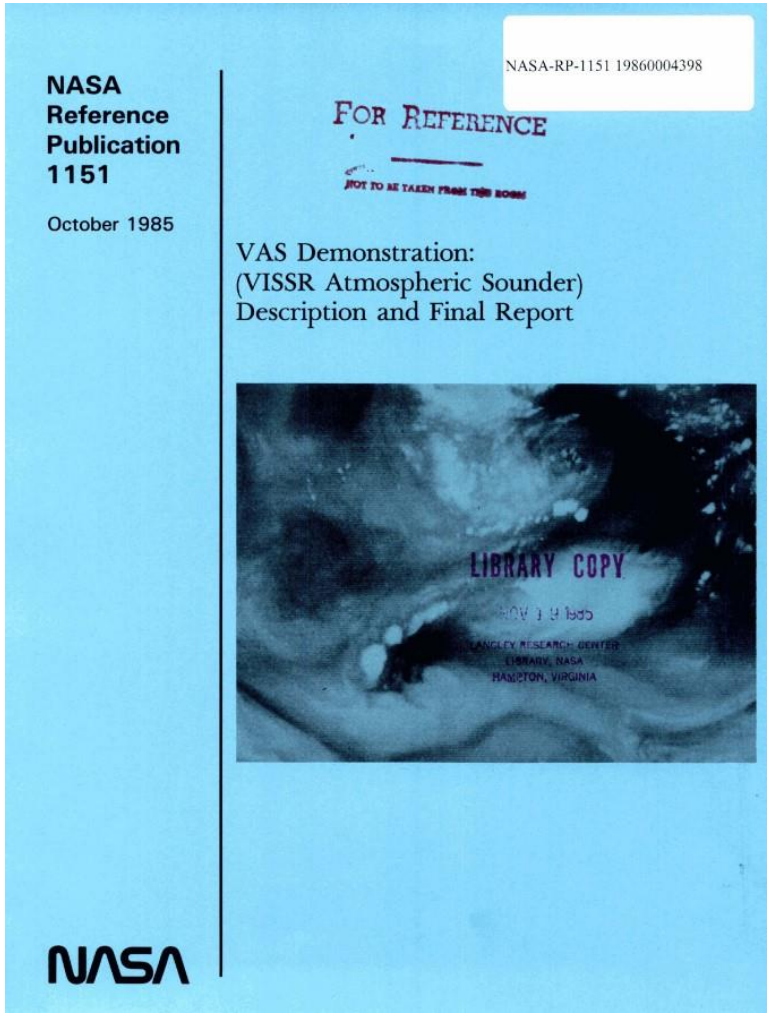
What about the future?

These results are the foundation for future satellites. The VAS experience suggests that extension into the microwave region, and **increased spectral resolution in the infrared region,** are essential so that we can obtain soundings through persistent clouds and **with improved vertical resolution**. Geostationary microwave instruments and high spectral resolution infrared interferometers are **feasible and would be highly useful**.

The administrative mechanisms of interagency cooperation must be put into motion as soon as possible to accomplish this. **We must not lose the momentum ....**

Professor Verner E. Suomi
Director
Space Science and Engineering Center
University of Wisconsin-Madison
1985

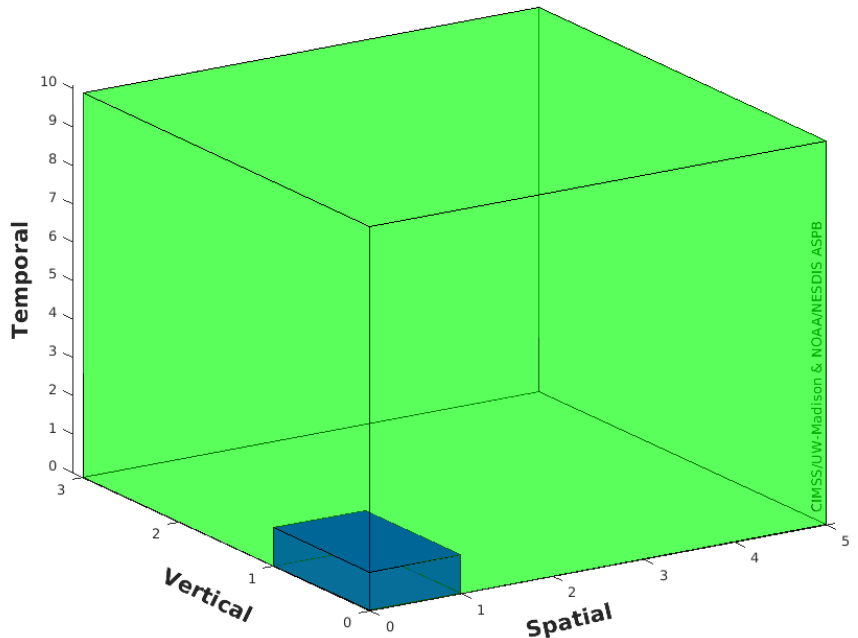
[Bold highlights added]



GXS/Legacy GOES Sounder ~ ABI/Legacy Imager

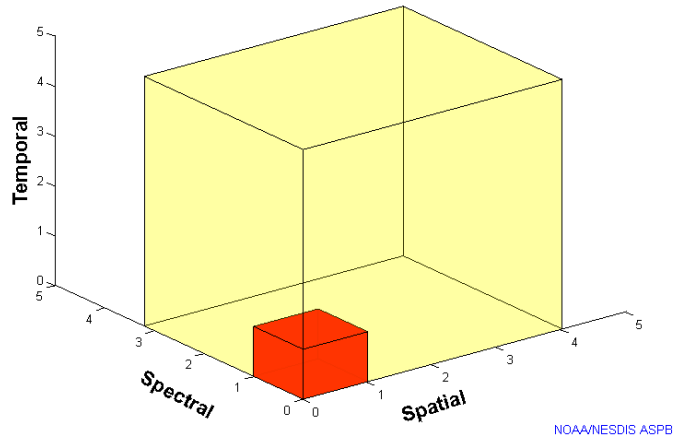
- GeoXO Sounder could be something like 3, 5 and 10 times improved (vertical, spatial and temporal) over the legacy geo sounder! (The legacy sounder had many operational uses: moisture, winds, atmospheric stability, clouds, etc.)

Improvement Factors:
GeoXO Sounder and Legacy geo Sounders



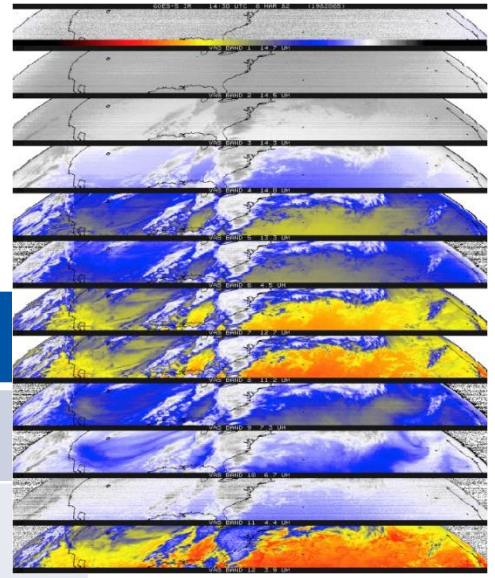
- "Everyone" knows about the ABI being 3, 4 and 5 times (spectral, spatial and temporal) improved over the legacy geo imager.

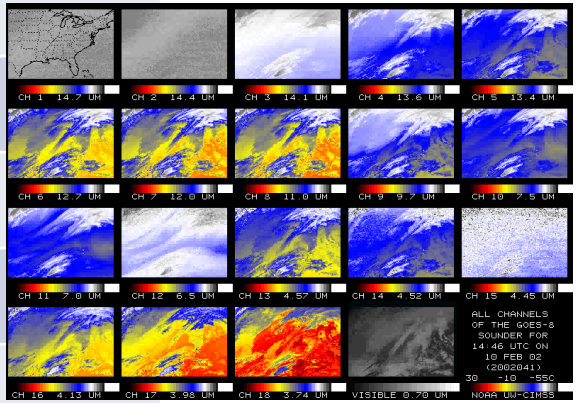
Improvement Factors:
ABI and Legacy geo Imagers



U.S. Geostationary Game-changers

Item	Imagery	Sounding
First of it's kind (experimental)	ATS-1 (1966)	VAS (1980)
First Operational	GOES-1 (1975)	GOES-8 (1994)
Orders of magnitude improvements	GOES-R series (2016)	High-spectral IR (203?)



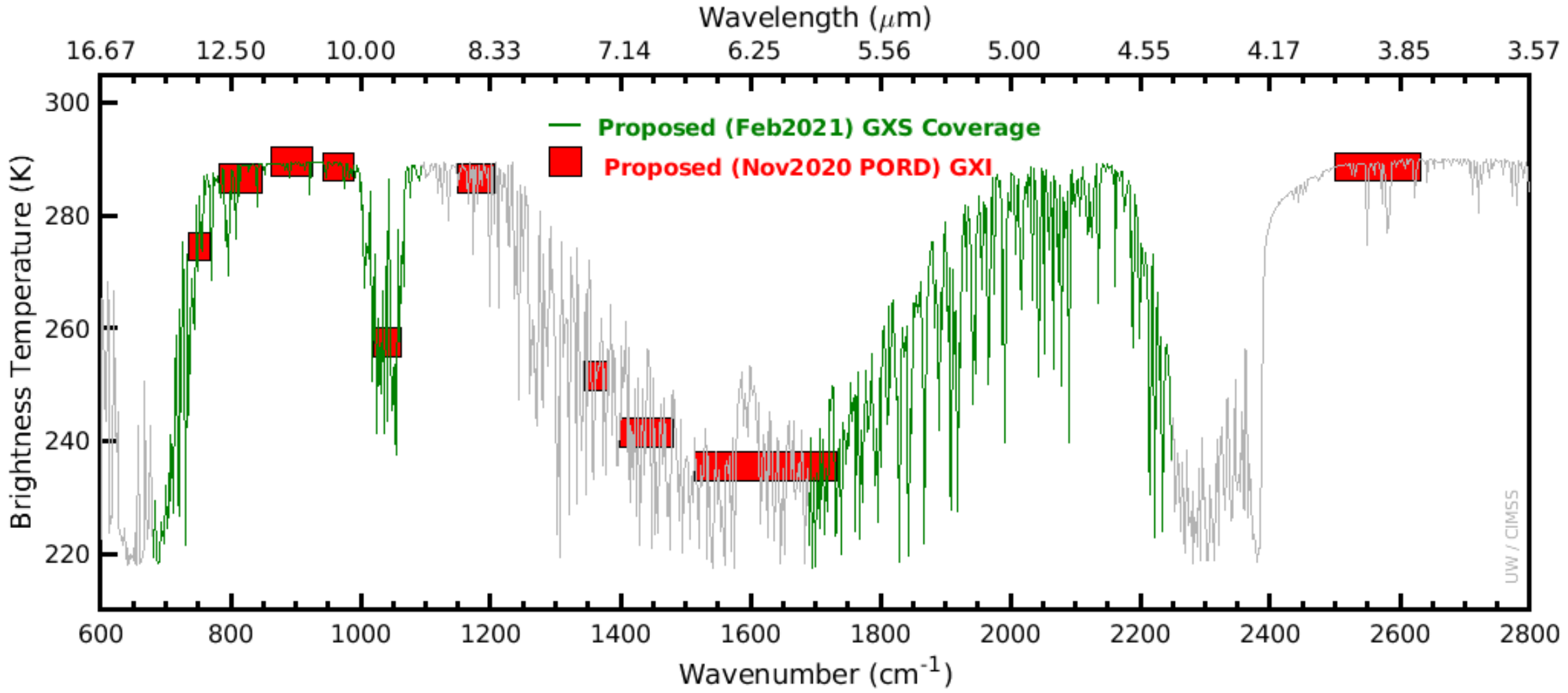


?

GOES-R series included the first geostationary lightning mapper

Geo advanced IR sounders are the next big step

Spectral



Imagers average out important vertical information

Spectral

Sounding Spectral Range Table

Band	Wavenumber (cm^{-1})	Wavelength (µm)
LWIR region (temperature, LWIR window, ozone, NH3, isoprene, HNO3, low level moisture)	680- 1095	14.7 – 9.13
MWIR region (vertical moisture, window and temperature, N_20 and CO)	1689 – 2250	5.92 – 4.44µm

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

From the posted PORD

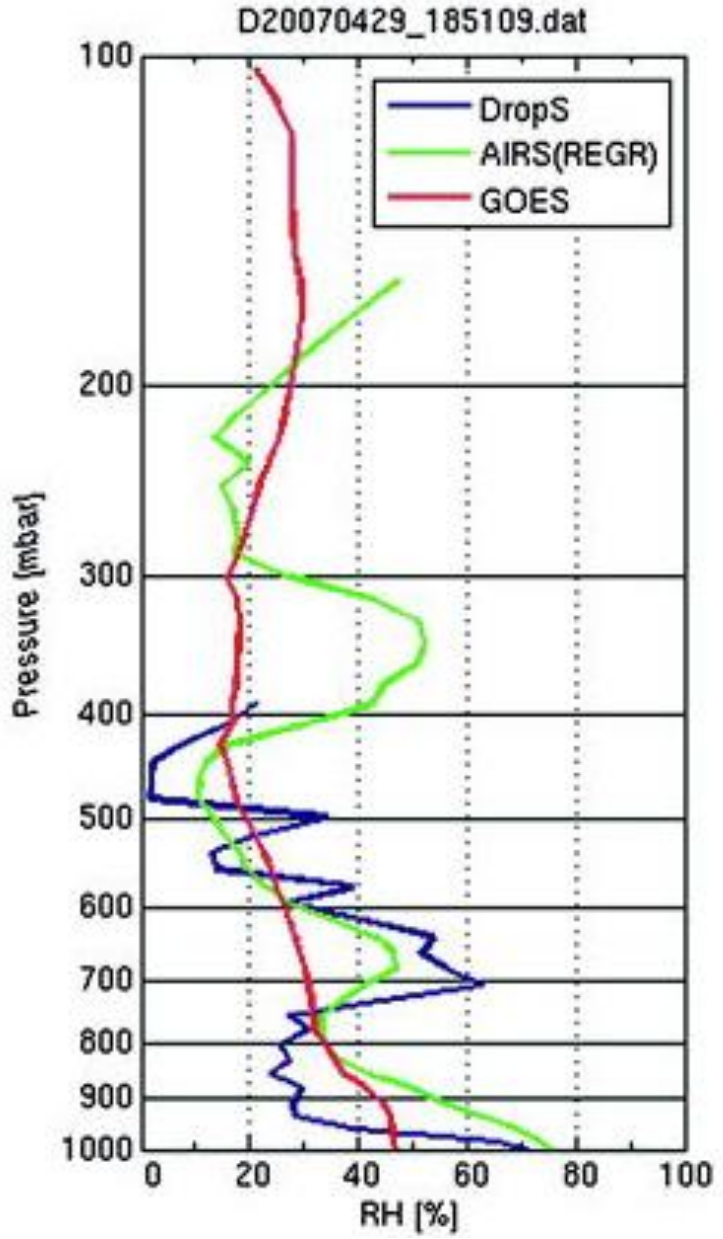
Spectral coverage and resolution is similar to Europe's planned geo Sounder

Improved Vertical Resolutions

Three RH soundings:

- Although legacy GOES Sounder [similar to ABI or GXI] (red) has reasonable men accuracy in general, it lacks vertical structures when compared with dropsonde (blue).
- The high-spectral-resolution observations of AIRS SFOV sounding (green) better depicts the fine structures in this case, which are close to those from the dropsonde.

High-spectral IR observations are critical to obtaining improved vertical moisture (and temperature and winds, not shown).



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.

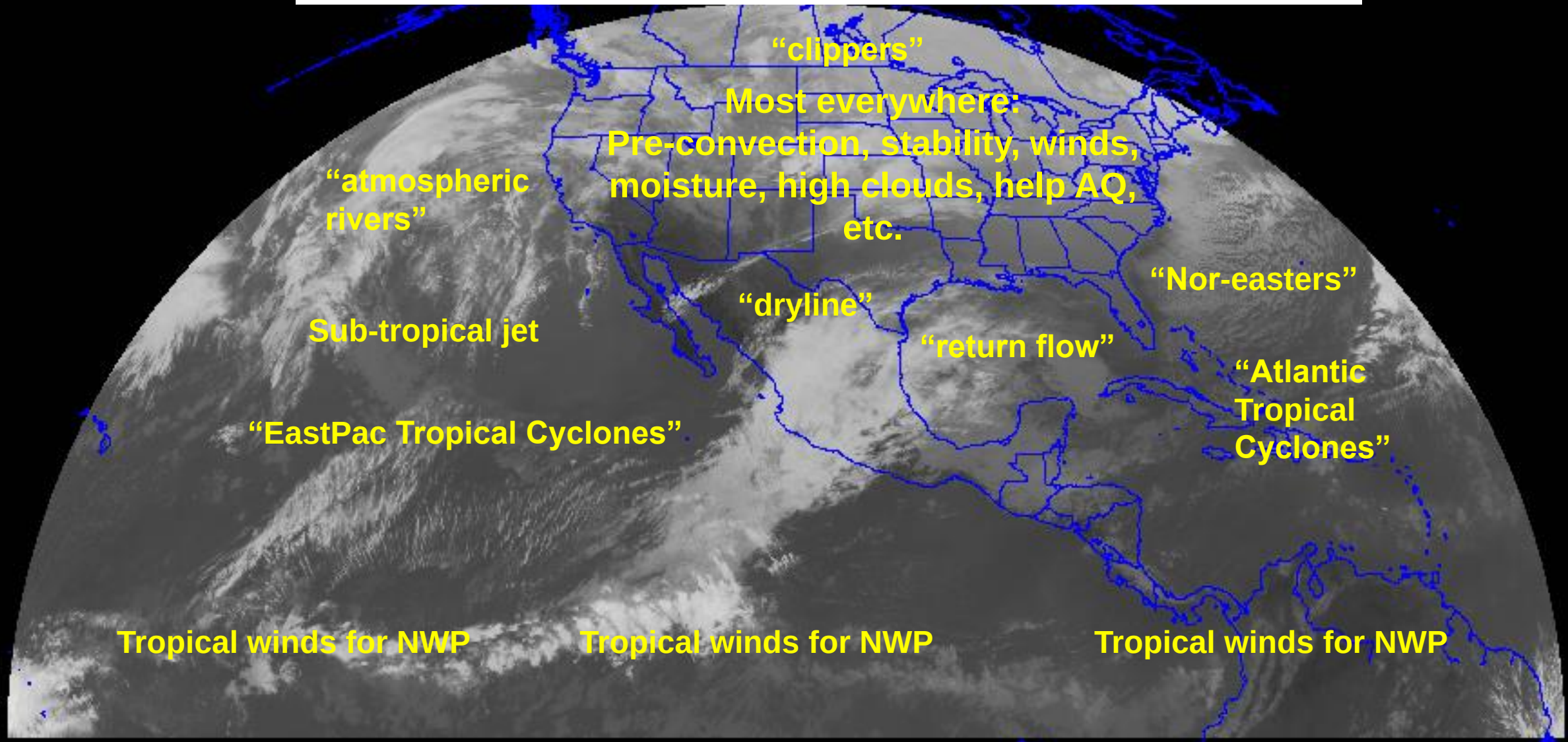
Applications in forecasting

- **The improved vertical resolution** allows for the critical vertical distribution of moisture to be monitoring (in clear skies)

- NWS and other forecasters **have been using hyperspectral sounder data from LEO satellites for years** via the Hazardous Weather Testbed and NOAA Unique Combined Atmospheric Processing System (NUCAPS)

- However, a LEO sounder has a revisit time of 12 hours for a spot over the equator compared to the **GEO sounder that can revisit the same location in about 30 minutes**
  - The intrinsic nature of the geostationary orbit permits longer integration time of the detector over the same Earth scene and continuous data downlink. As a result, **GXS is expected to achieve a footprint on the Earth surface of 4 km** (subpoint)
    - **Doubling the clear-sky yields, comparted to LEO**

Sample GeoXO Sounder Uses



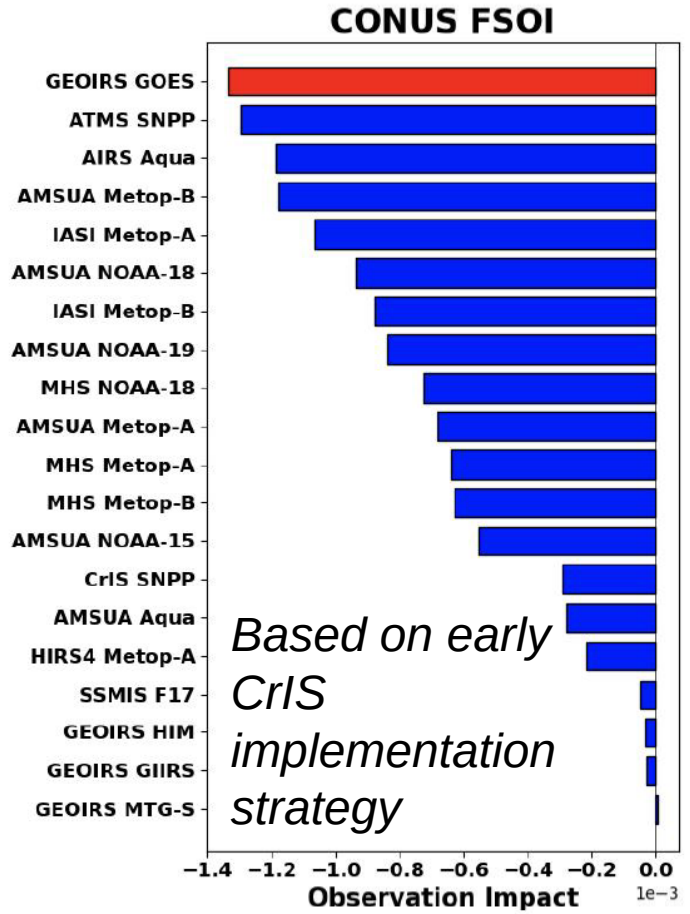
Benefits and Outcomes

- There are many additional applications from high temporal and spectral observations providing better cloud/thunderstorm/hurricane/etc. forecasts (in both **nowcasts** and **NWP forecasts**).
- High-spectral-resolution sounder observations would also **improve derived products with only advanced imager data** (and or with polar-orbiter and other data), volcanic ash, cloud detection, cloud-top properties, atmospheric motion vectors, dust detection, land and sea surface temperatures.
- **New areas** are possible, such as moisture flux, capping inversion, surface emissivity, and climate (especially the diurnal aspects).
- Information on several **trace gases** will also be possible, including ozone, HNO3, NH3, and isoprene (combined with ACX observations)
- GXS observations will allow for significant improvements in forecasting key parameters to better help **save lives**, **protect property** and provide **economic benefits**.

Benefits

- Hyperspectral infrared (IR) sounders
  - https://www.ssec.wisc.edu/geo-ir-sounder
- NOAA NESDIS Tech Report: Geostationary Extended Observations (GeoXO) Hyperspectral InfraRed Sounder Value Assessment Report
  - https://repository.library.noaa.gov/view/noaa/32921
- GeoXO
  - https://www.nesdis.noaa.gov/next-generation-satellites/geostationary-extended-observations-geoxo

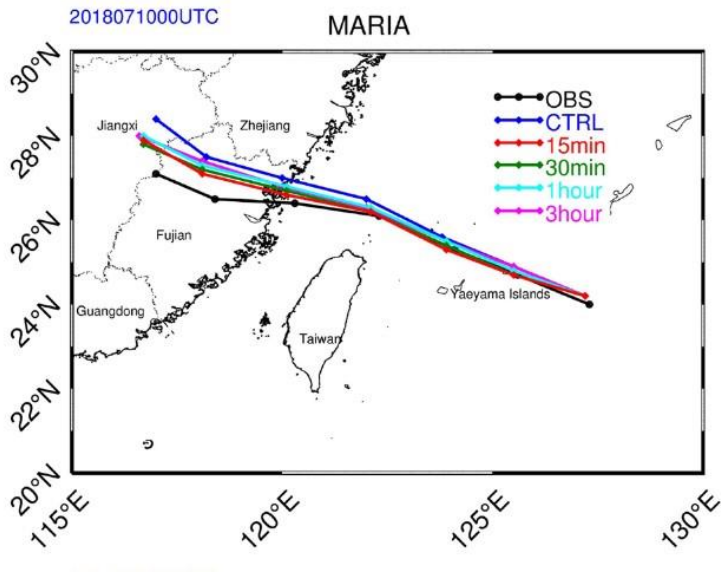
- Computer simulation of 24-hr Forecast Sensitivity Observation Impact ... for CONUS, for the four cycles (NASA GMAO):

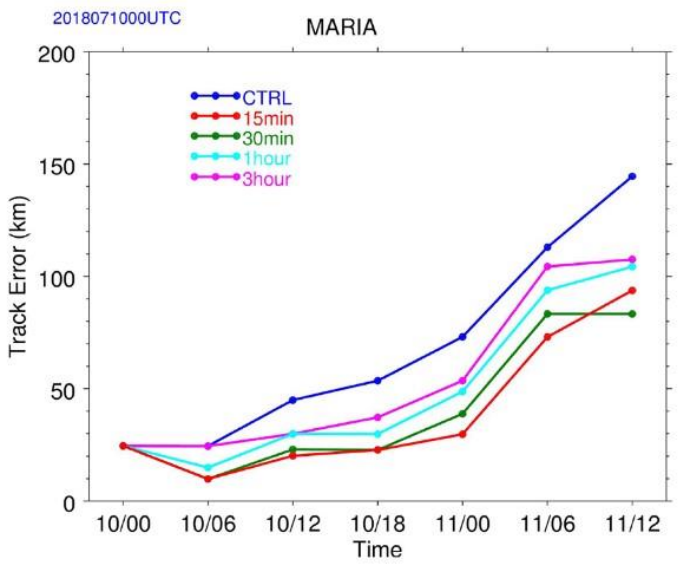


GeoXO : GXS Summary (What and Why)

Attribute	What	Why
Coverage	Ideally: Sounding Disk as seen from both GOES-East and –West positions; Central satellite position currently planned	The Atlantic for **hurricane development** and **model initializations**, CONUS for the **pre-convective environment monitoring** and the Pacific for both **upstream weather and monitoring moisture (and winds)** over the huge area with little conventional data.
Spatial Resolution	4 km (at the satellite subpoint)	Doubling the clear-sky yields, comparted to LEO, for a given time. Also for finer moisture gradients to be monitored.
Temporal Resolution	Sounding Disks (60 min), CONUS (~30 min) and mesoscale (5 min)	Sounding Disk upstream information and hurricane monitoring (**improved track and intensity**), CONUS for pre-convective monitoring and the targeted for regions of extremely active weather. Allows for clouds to move out and obtain more clear sky information.
Spectral Coverage / Resolution	680- 1095 cm-1 14.7 – 9.13 µm 1689 – 2250 cm-1 5.92 – 4.44 µm) @ ~0.6 cm-1	Spectral with information related to temperature, moisture and support select atmospheric compositions (ozone, NH3, isoprene, HNO3, N20 and CO). Need to resolve, not average out, the critical on/off spectral lines.
Other	Evolution of the radiances	Provides critical vertical information on atmospheric winds for both nowcasting and NWP applications.

Improved track and intensity forecasts





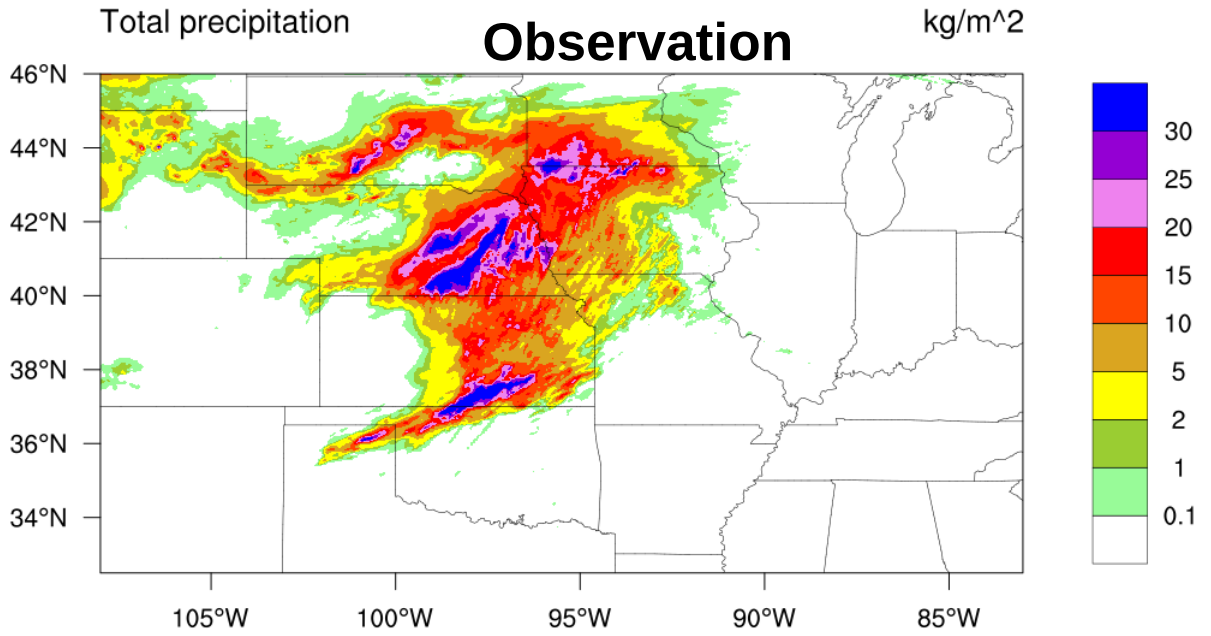
The 36 h track forecast for Typhoon Maria from 0000 UTC on July 10, 2018. The black, blue, red, green, cyan, and magenta lines indicate the Best Track, control experiment, 15 min, 30 min, 1 and 3 h, respectively.
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GL093672

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%).

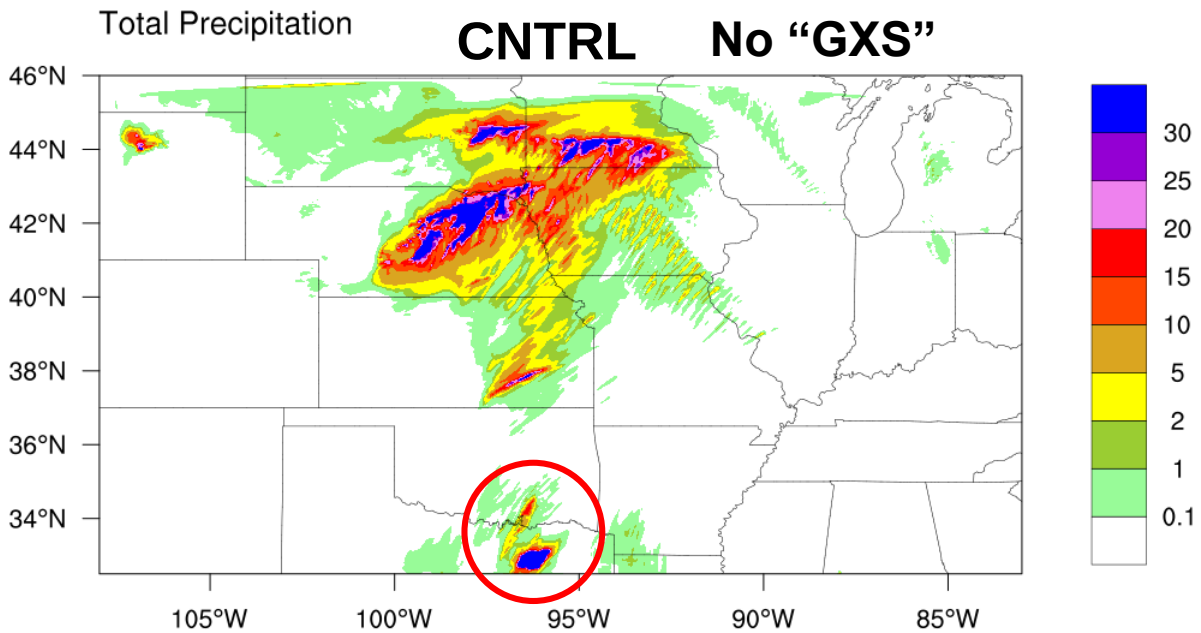
Precipitation forecasts also improved.

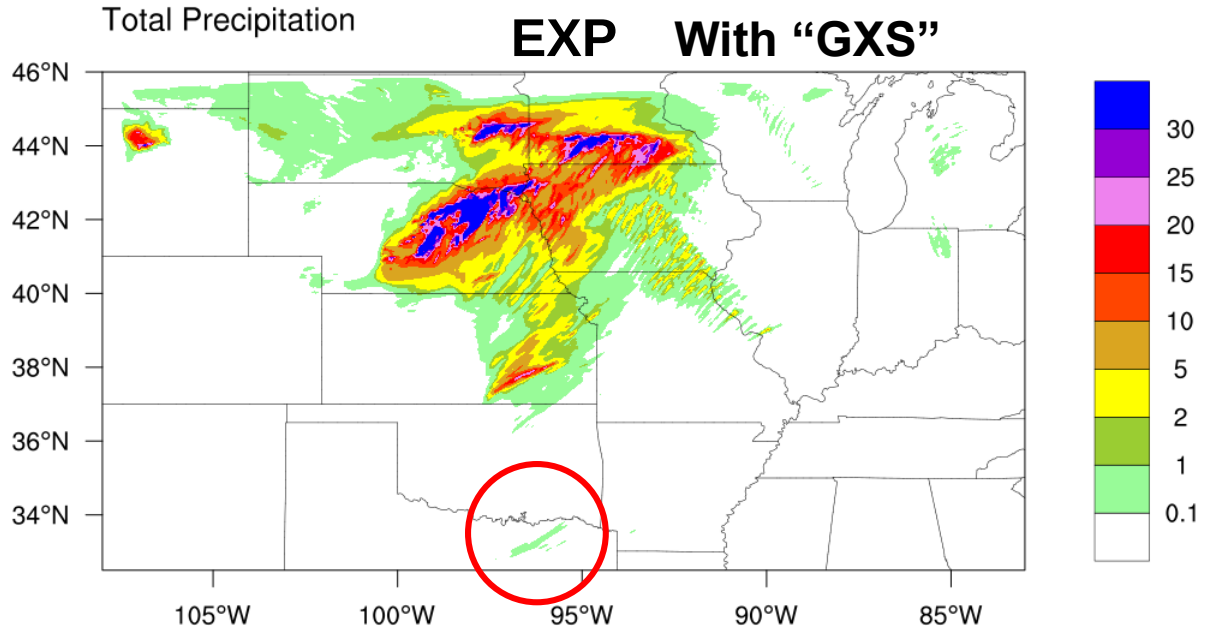
Hybrid OSSE: Precipitation Impact Verification



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

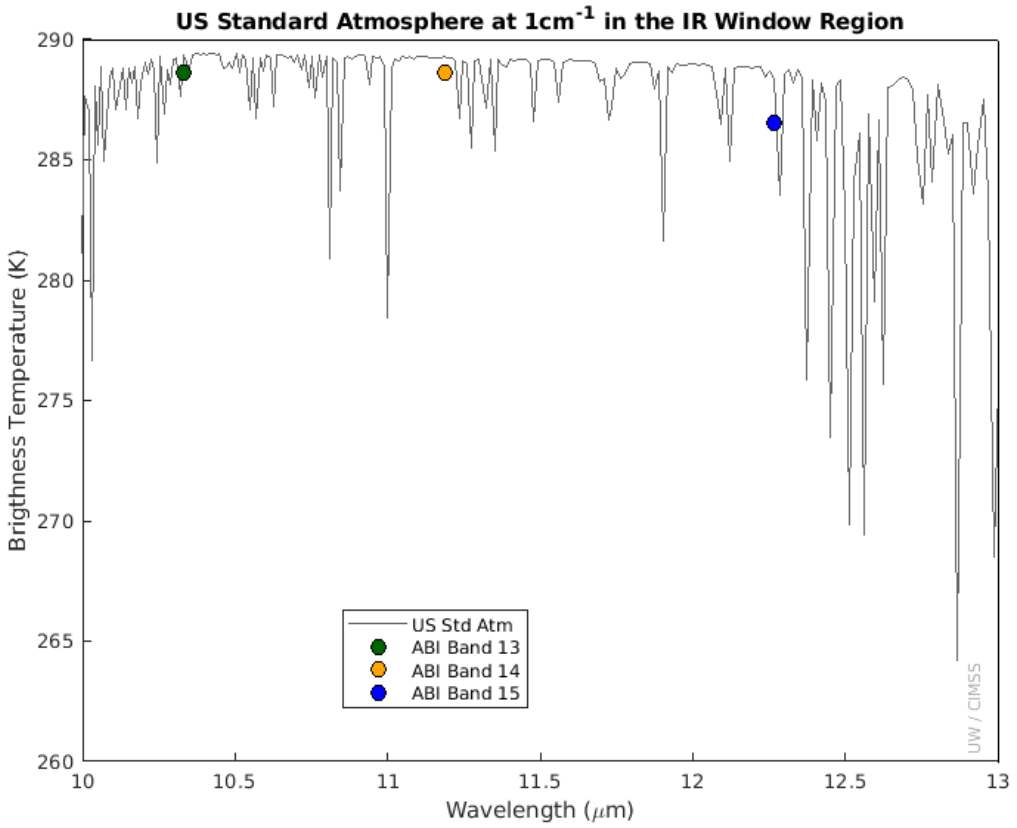




Need for high spectral/temporal observations

- **High-spectral-resolution observations provide much more information**
  - Imagers average out important vertical information; GEO offers time evolution
- Forecasting Applications – fill in critical gaps wrt vertical moisture, wind and temperature
  - **Nowcasting** and **Numerical weather prediction**, especially on the regional/mesoscales
- Additional applications
  - High-spectral-resolution sounder observations would also **improve derived products with only advanced imager data** (and or with polar-orbiter and other data)
    - volcanic ash, cloud detection, cloud-top properties, atmospheric motion vectors, dust detection, land and sea surface temperatures.
  - **New areas**
    - trace gases, moisture flux, capping inversion, surface emissivity and climate
- **Economic impacts** ("in the billions"…) More with the benefits of 4dvar analysis … and cloudy radiances
- **Critical Component of the Global Constellation**

Questions ?



Advanced sounders have much more temperature and moisture vertical information (Images: Mat Gunshor, CIMSS)

"Geostationary satellites are essential for monitoring weather and storms across the Pacific Basin. **If we could add one instrument to our toolkit for weather surveillance, it would be a geostationary hyperspectral infrared sounder.** Such observations would dramatically increase confidence in forecasts of hurricanes and other storms that originate over the ocean and head towards U.S. interests."

Eric Lau
Environmental and Scientific Services Division Chief
NWS Pacific Region Headquarters, Honolulu, Hawaii

Thanks to many who have contributed, especially Ed Grigsby and the geoXO Hyperspectral InfraRed Sounder value assessment team and the geoXO sounder working group

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

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