Status of the current and future NOAA GOES Programs

Andrew Heidinger, GEO Senior Scientist

Contributions from Dan Lindsey, Pamela Sullivan, Jordan Gerth, Joel McCorkel, Alexander Krimchansky, Phil Driggers, Jemma Kline, Monica Coakley and Matt Seybold, Greg Frost, Shelly Tomlinson.

NOAA
National Environmental Satellite, Data, and Information Service

GOES-18

March 1st 2022: GOES-T Launched!

GOES Constellation with West Transition Plan

GOES-18 PLT Part 2: GOES-18 post-drift (June 7, 2022)

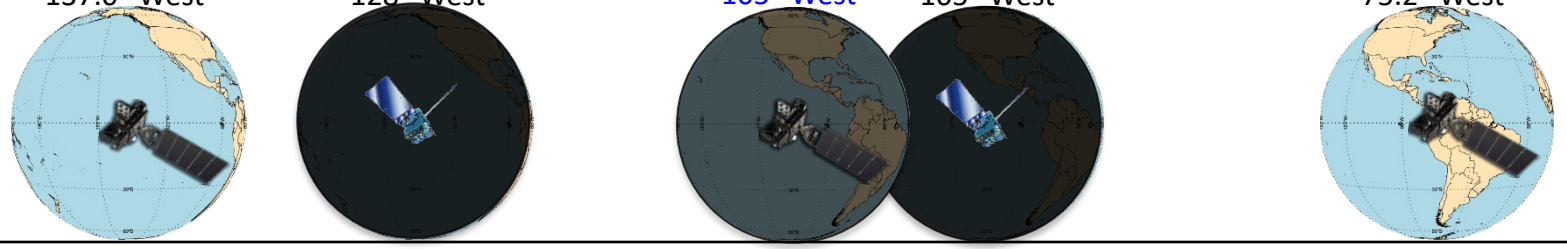
GOES-West	Checkout	Supp. Ops.	Standby	GOES-East
GOES-17	GOES-18	GOES-15	GOES-14	GOES-16
137.2° West	136.8° West	128° West	105° West	75.2° West

GOES-17 and GOES-18 orbit nudges (July, 2022)

GOES-West	Checkout	Supp. Ops.	Standby	GOES-East
GOES-17	GOES-18	GOES-15	GOES-14	GOES-16
137.3° West	137.0° West	128° West	105° West	75.2° West

GOES-18 as GOES-West, GOES-17 drift to Standby (January, 2023)

GOES-West	Storage	Standby	Storage	GOES-East
GOES-18	GOES-15	GOES-17	GOES-14	GOES-16
137.0° West	128° West	105° West	105° West	75.2° West



Changes by phase are indicated in blue

Note: GOES-18 PLT Part 1 was pre-drift checkout at 89.5°West

G18 ABI L1b/CMI Quality Status

Early observations show

- ***Loop Heat Pipes working well***
- Image navigation/registration stable and good for use in downstream applications
- Radiometric calibration performing well post-drift
- Reduced stray light compared to G16/G17
- Band 7 stray light noticeable within the Zone of Reduced Quality, as seen on G16 and G17

Accomplishments Thus Far

- Pre-drift PLT results are implemented and are already improving L1b/CMI quality
  - Line-of-sight corrections to align VNIR, MWIR, and LWIR images
  - Striping reduction for Bands 1 and 2
  - Radiometric parameter updates, including Planck and E_{Sun} values

Imminent Deliveries/Implementations

- IR mirror emissivity update (reduces PICA effect; LUT update)
- Further INR optimization (scan encoder scale factor error, possible Kalman filter tuning)

Issues in-work to be done by Provisional/Interleave

- ***Band 2 radiance biases will be measured (est. 7%) and corrected (LUT update)***
- ***Vertical banding in Band 7 (possibly coherent noise)***

G18 ABI L1b/CMI are on track for Provisional

GeoXO

GeoXO: Mission Needs Served

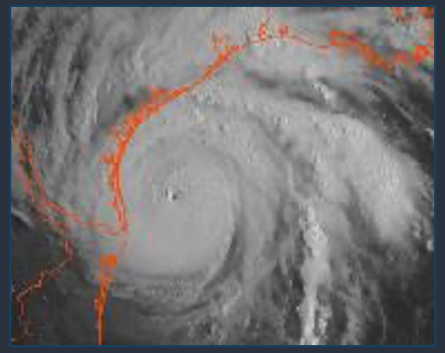
Ongoing Needs: Users require continuity of existing observations with improved performance

- **Data for short-range forecasting, severe weather watches and warnings, and monitoring hazardous environmental conditions** including tropical storms, severe storms with lightning and damaging winds, snow, ice, flooding, fog, fires, smoke, and volcanic ash.
  - ➢ Delivered by Imager and Lightning Mapper

Growing Needs: Users expect NOAA to meet new requirements with new observations:

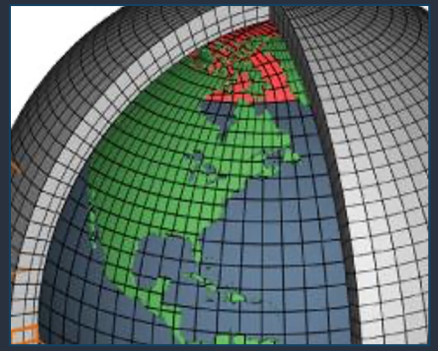
- **Improved numerical weather prediction and local nowcasting**
  - ➢ Delivered by Hyperspectral IR Sounder
- **Monitoring dynamic coast/ocean features, ecosystem change, water quality, and hazards**
  - ➢ Delivered by Ocean Color Instrument
- **Monitoring air quality and linkage with weather and climate**
  - ➢ Delivered by Atmospheric Composition Instrument

Vis/Near-IR Imagery

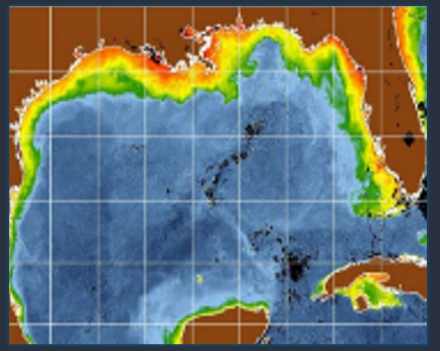


Lightning Mapping

IR Sounding



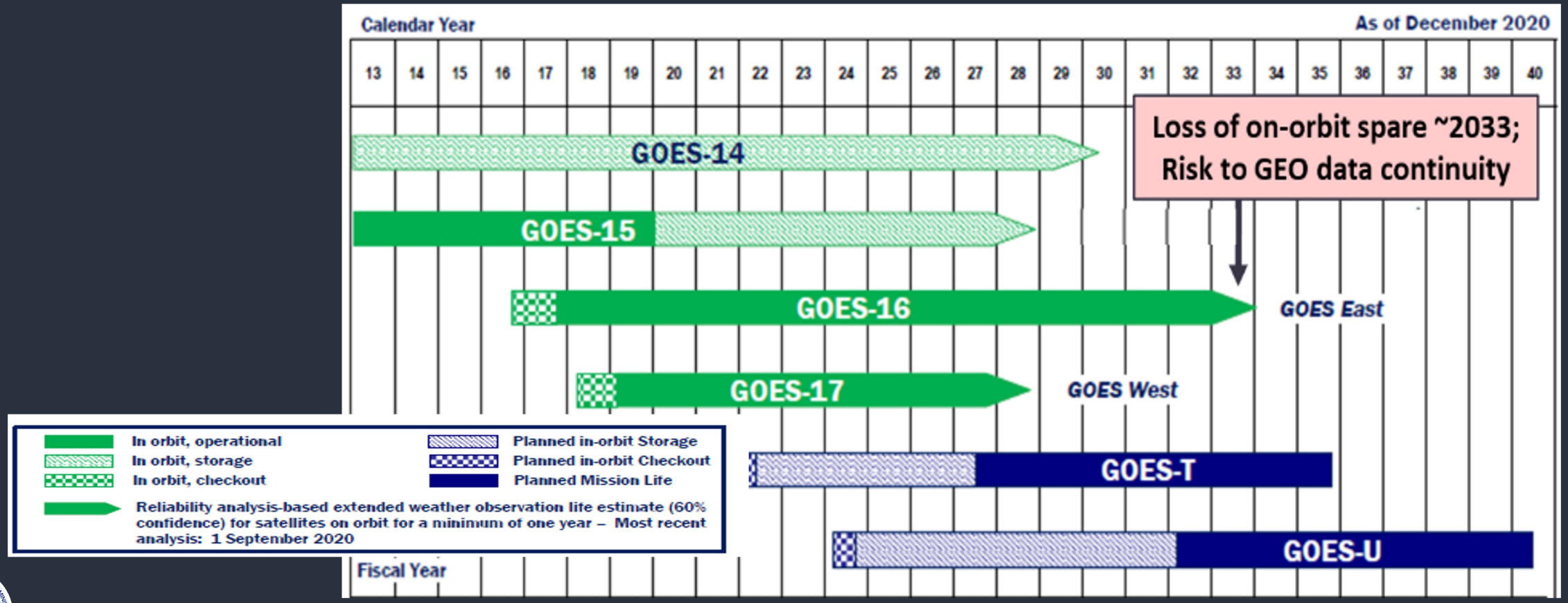
Ocean Color



Atmo. Composition

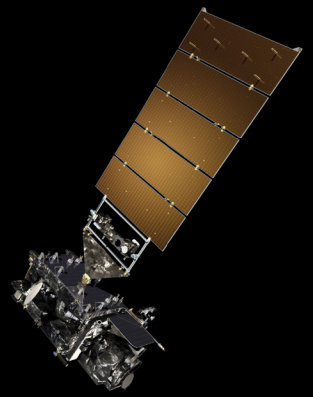
GeoXO will Provide that Continuity

- **NOAA is planning its next-gen GEO satellite system, Geostationary Extended Observations (GeoXO)**
- Need date for the 1st GeoXO launch is 2032, set by the projected loss of the on-orbit spare in ~2033



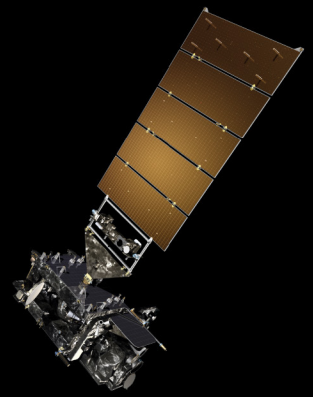
GeoXO Constellation

(Preliminary, pending program approval)



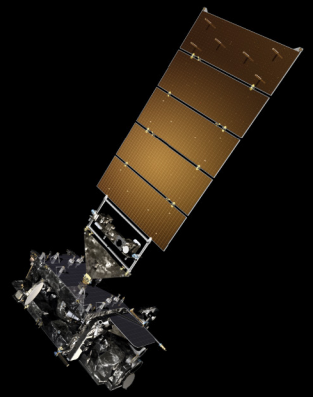
GEO-West

Visible/Infrared Imager
Lightning Mapper
Ocean Color



GEO-Central

Hyperspectral Infrared Sounder
Atmospheric Composition
Partner Payload



GEO-East

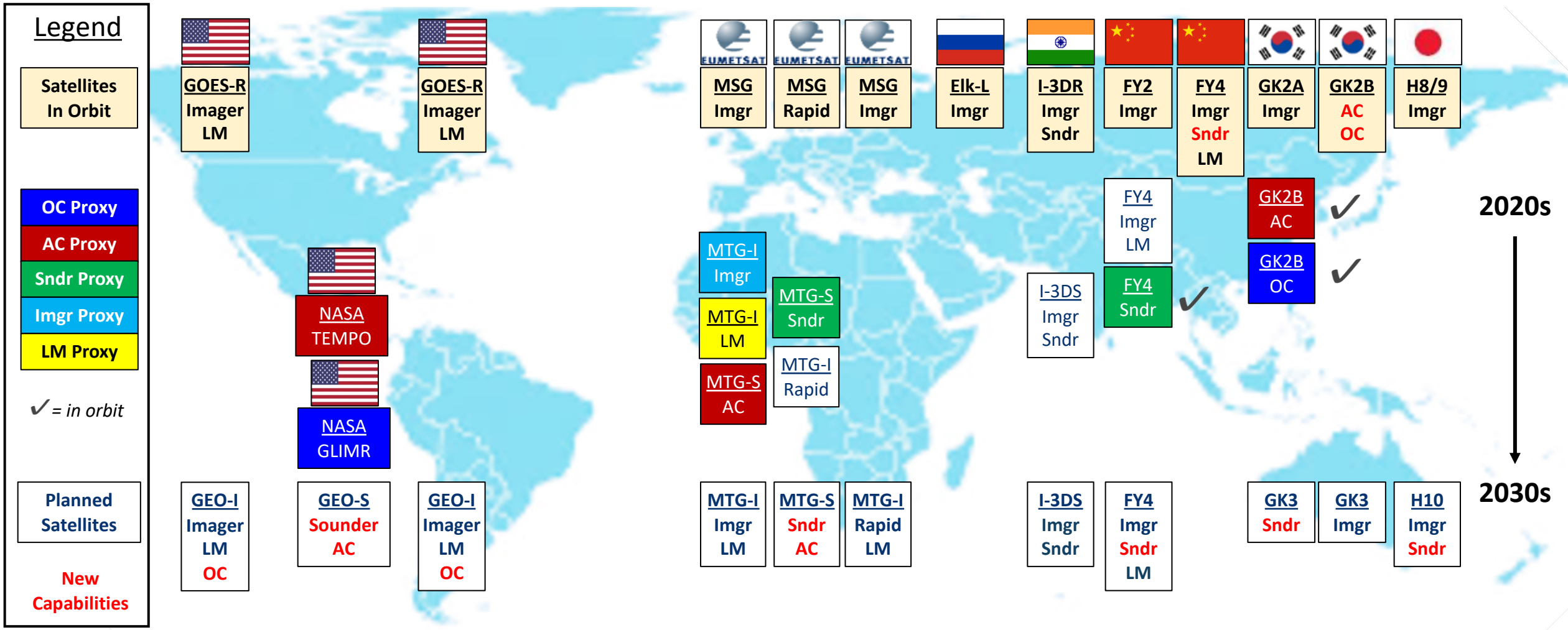
Visible/Infrared Imager
Lightning Mapper
Ocean Color

GeoXO Key Formulation Activities

GeoXO Formulation Event/Activity	Timeframe	Note
Imager Phase A Study Contracts Awarded	April 2021	L3Harris & Raytheon
Mission Concept Review	**June 2021**	
NOAA-NASA Key Decision Point A	**July 2021**	
Sounder Phase A Study Contracts Awarded	September 2021	Ball Aerospace & L3Harris
DOC Milestone 1 Review (DOC DepSec Approval)	**October 2021**	**Program Initiation**
Lightning Mapper Phase A Study Contracts Awarded	April 2022	Lockheed and Northrop
• AC Instrument Phase A Study Contracts Awarded	May 2022	Ball & Raytheon
• OC Instrument Phase A Study Contracts Awarded	May 2022	Ball & Raytheon
• Spacecraft Phase A Study Contracts Awarded	July 2022	
• **System Requirements Review**	**August 2022**	Requirements Baselined
• **DOC Milestone 2 Review (DOC DepSec Approval)**	**December 2022**	**Program Approval**
• Imager Implementation Phase Contract Awarded	January 2023	
• Other Implementation Phase Contracts Awarded	1Q – 3QFY24	

GeoXO within the GEO-RING

GeoXO User Readiness will rely heavily on non-NESDIS proxy data



GXI – Improvements over ABI

	Center Wavelength (μm)	50% Bandwidth (μm)	Nadir Pixel Size (km)	SNR/NEdT**
	0.47	0.04	0.5 (TBR)	250 (TBR)
	0.64	0.1	0.25***	125
	0.865	0.039	0.5 (TBR)	150 (TBR)
	0.91	0.02	1.0 (TBR)	300
	1.378	0.015	2.0	300
	1.61	0.06	1.0	300
	2.25	0.05	1.0 (TBR)	200 (TBR)
	3.9*	0.2	1.0	0.15 (TBR)
	5.15	0.2	1.0	0.15
	6.185	0.83	2.0	0.1
	6.95	0.4	1.0**** (TBR)	0.15 (TBR)
	7.34	0.2	2.0	0.1
	8.50	0.4	2.0	0.1
	9.61	0.38	2.0	0.1
	10.35	0.5	1.0**** (TBR)	0.1
	11.20	0.8	2.0	0.1
	12.30	1.0	2.0	0.1
	13.30	0.6	2.0	0.3

Two new channels – GXI will have 18.

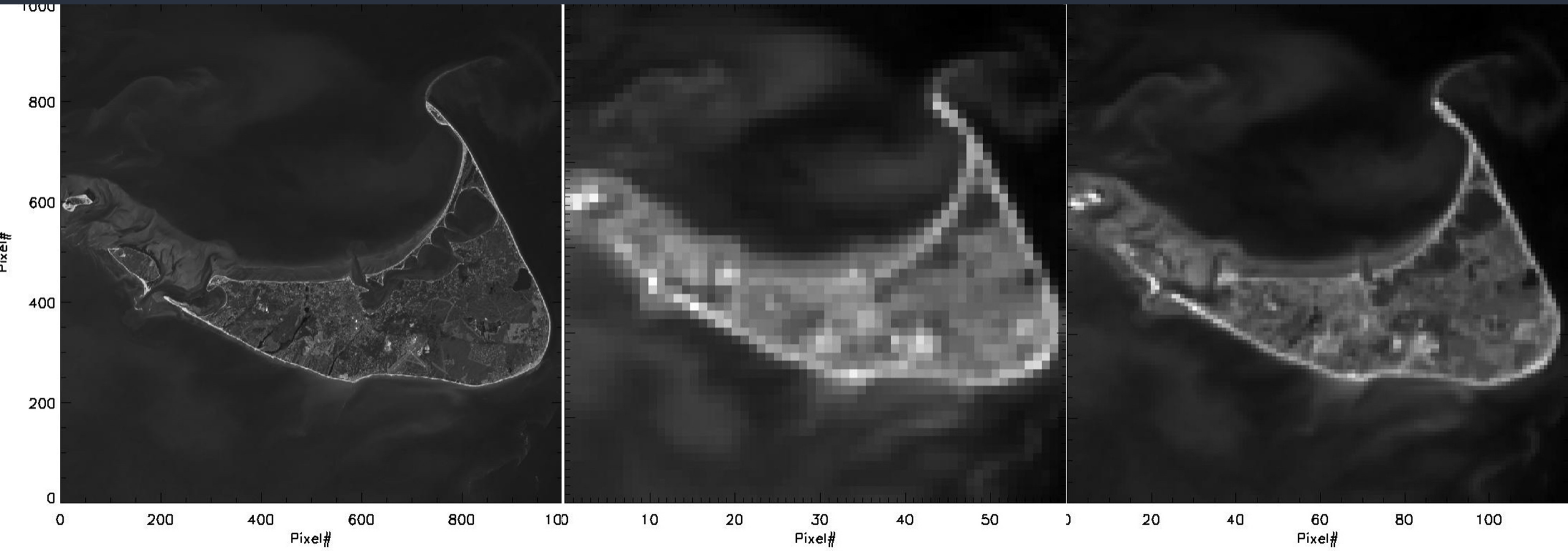
Improved spatial resolutions at several additional channels

In some cases, it may be not be possible to achieve these resolutions, but some in-between value (e.g., ~1.5 km at 10.35 μm) is achievable

Why no Green channel?

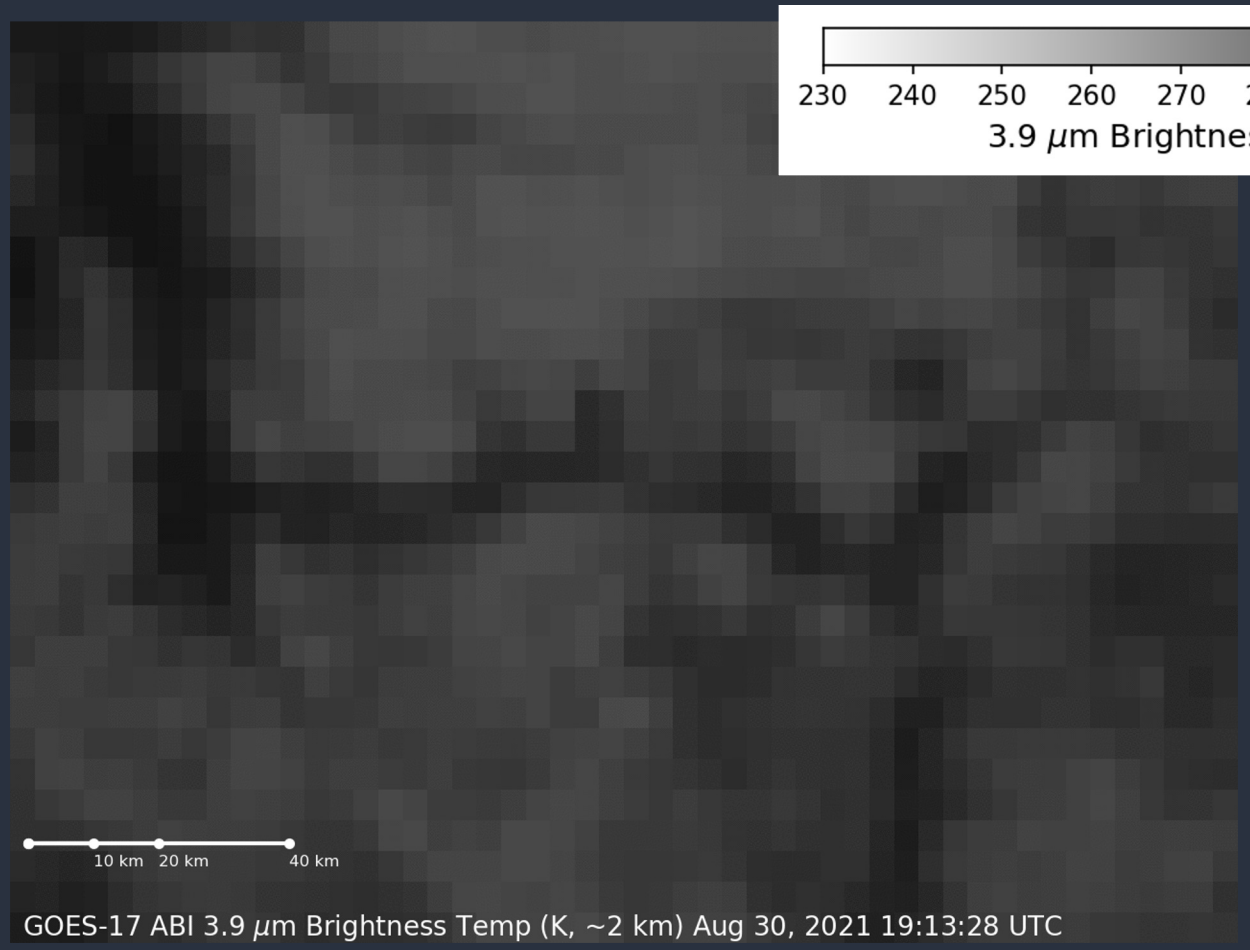
- We strongly considered including a “green” visible channel near 0.55 µm, so that true color imagery using red, green, and blue channels would be more accurate compared to ABI
- After discussions with NWS, the team concluded that the methods that have been developed to approximate the green channel, such as CIRA’s GeoColor product, are sufficiently accurate to prevent meteorological misinterpretation
- The primary operational use of true color imagery is for qualitatively identifying and tracking aerosols, such as smoke, and this is easily accomplished with GeoColor
- Instead of a green channel, GXI will include a water vapor absorption channel near 0.91 µm that will be used to track low-level moisture

Improved resolution of the 0.64 µm channel



Nantucket Island Landsat 8 B3 image (left), degraded to *nadir* ABI B2-like resolution (middle), and *nadir* GXI-like 250-m resolution (right)

Improved resolution of the 3.9 µm channel



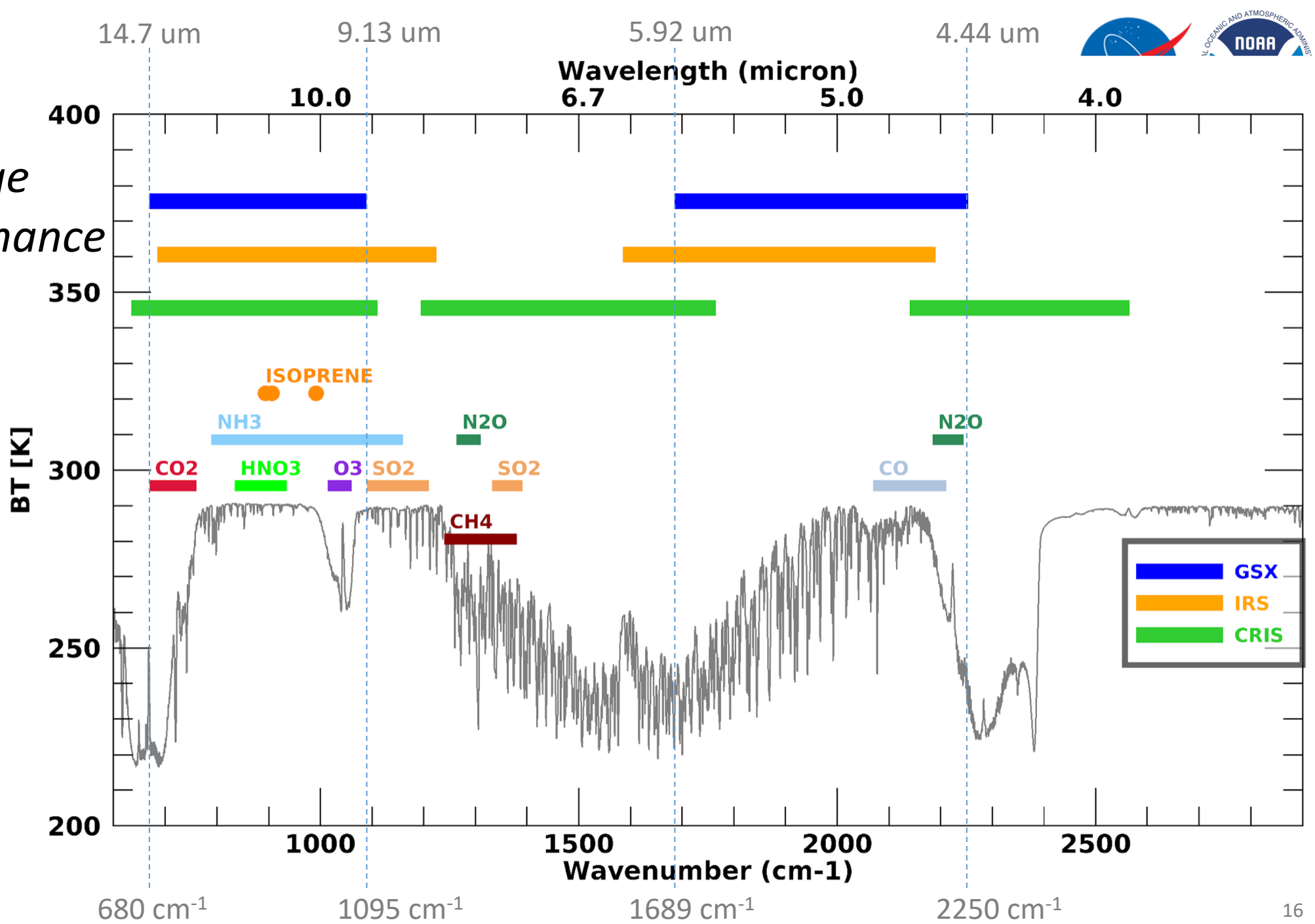
Observed GOES-17 ABI 3.9 µm channel from 8/30/2021 from the Meso sector over Idaho from 1913 – 2039 UTC

Simulated 3.9 µm 1 km resolution band from GXI for the same times as the ABI loop. It's based on VIIRS passes at 1913 (SNPP), 1959 (N20), and 2050 UTC (SNPP). Courtesy Jason Apke (CIRA)

Spectral coverage baseline performance

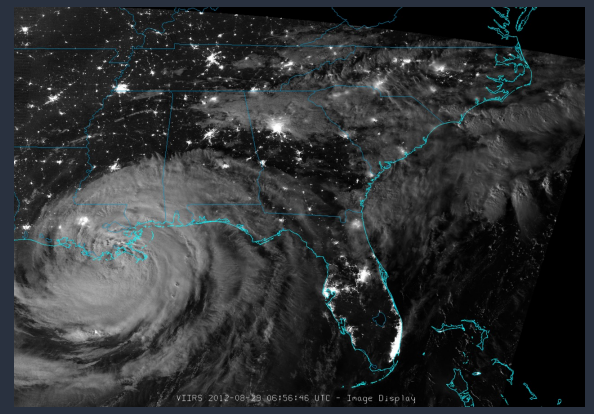
Spectral resolution reflects that of the CO_2 features that provide vertical temperature information.

Water vapor band resolution matches that of the European MTG-IRS instrument that will provide valuable test data to NOAA for future algorithm validation.



GeoXO Ocean Color (OCX) Instrument

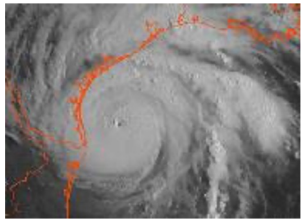
	Observation parameter	Science and operational rationale
Field of Regard	EEZ East (coastline out to EEZ plus Caribbean including Puerto Rico, Gulf of Mexico, plus Great Lakes) -or- EEZ West (coastline out to EEZ plus EEZ Hawaii plus southern Alaska)	Matches U.S. commercial fishing areas, protected species population areas, and regions for HAB forecasting and water quality monitoring associated with NOAA Mission Objectives.
Spatial Resolution	300 m at nadir	Allows specificity to HAB forecasts and ability of forecasts to perform in coastal areas. Detailed data on ocean color can match oceanographic features at that scale. Enhanced input for coupled ecosystem models.
Temporal Resolution	180 min *(Studying potential to improve to 120min)*	Multiple images per day allow mitigation of cloud cover in coverage area. Provides a more accurate depiction of bloom extent and movement. Enables dynamic ocean management predictions to become a "real-time" service. Better match to observe coastal ocean dynamics.
Spectral Coverage	Hyperspectral: • 20 nm resolution for 0.35-1.02 um • 10 nm resolution for 0.67-0.68 um *(Studying potential to improve to 10nm over full spectral range)*	Allows phytoplankton functional type products, and enhances HAB type identification. Allows compatibility with previous products and helps realize a multi-instrument, multi-mission, long-term time series for ocean color.



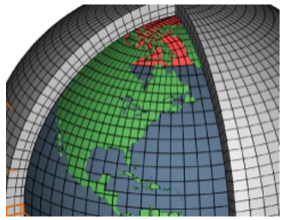
Addition of "Night Band" at 0.5 km is being studied

Atmospheric Composition: A Multi-Instrument Synergy

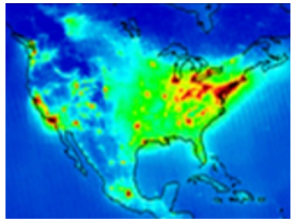
Vis/Near-IR Imagery



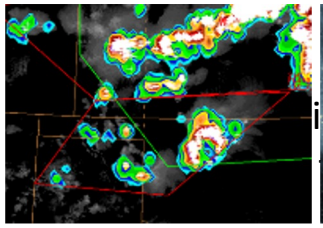
IR Sounding



Atmos. Composition

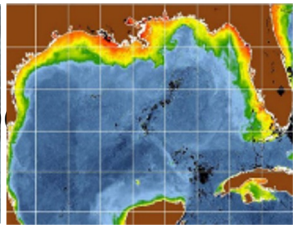


Lightning Mapping



Day/Night Imagery

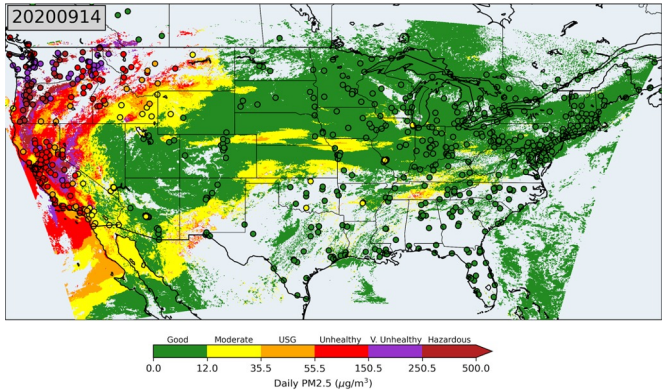
Ocean Color



Vis/IR Imager (GXI)

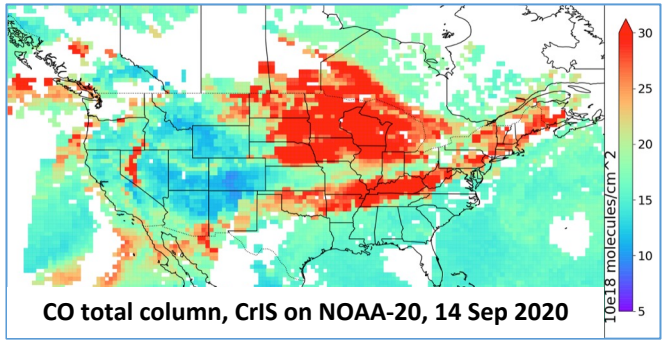
- Fire detection
- Fire radiative power
- Aerosol type
- Aerosol optical depth
- Aerosol concentration

PM2.5 derived from VIIRS AOD



IR Sounder (GXS)

- Ozone
- Methane
- Carbon monoxide
- Carbon dioxide
- Ammonia

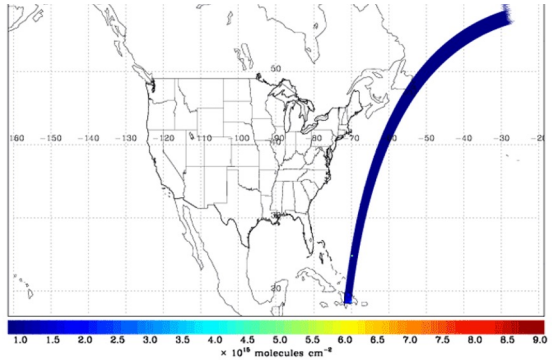


CO total column, CrIS on NOAA-20, 14 Sep 2020

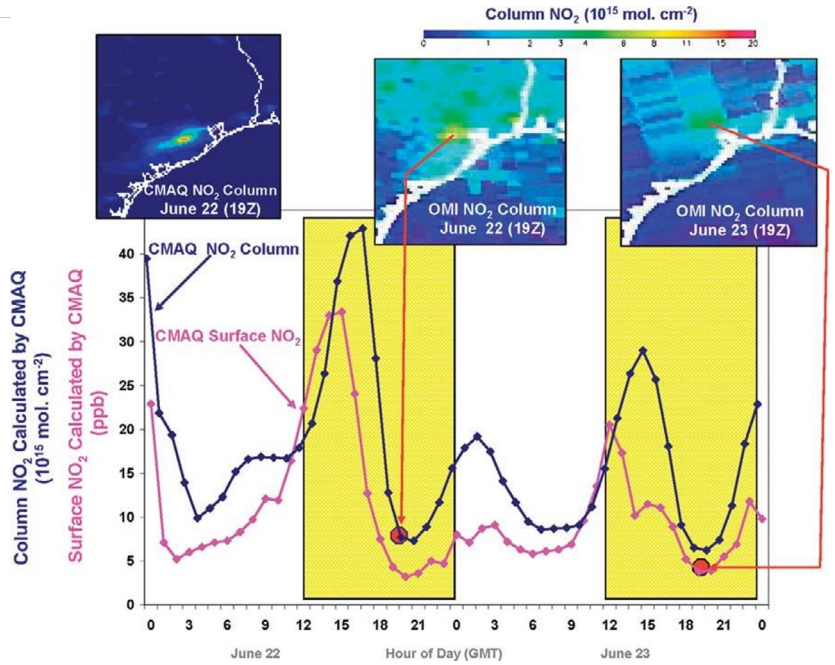
UV/Vis Spectrometer (ACX)

- Ozone
- Nitrogen dioxide
- Sulfur dioxide
- Formaldehyde
- Aerosol layer height

OMI NO_2 over TEMPO field of regard



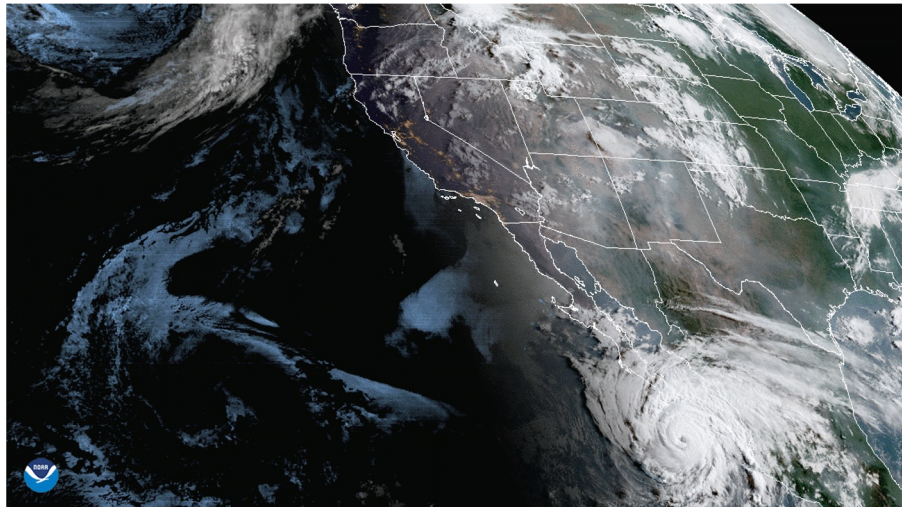
Advantages of GEO AC Observations



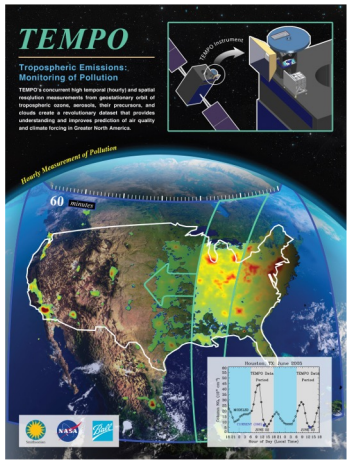
Fishman et al., BAMS, 2008

GEO Atmospheric Composition data will be indispensable to NOAA's future air quality, wildfire, and hazards observation and prediction efforts:

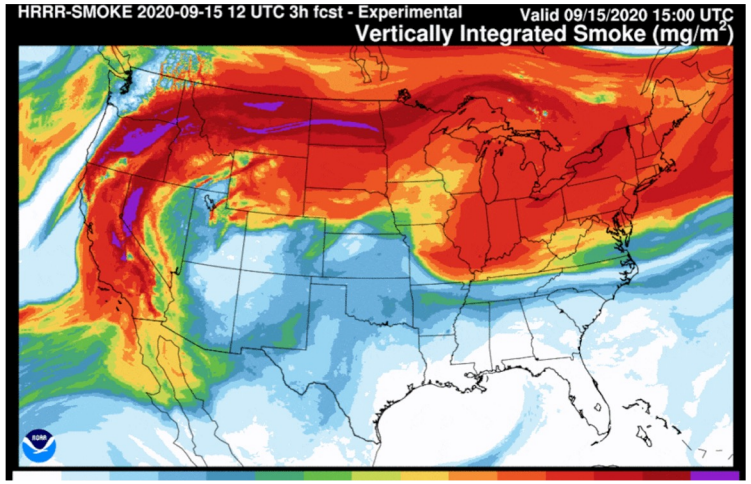
- Monitoring hourly variations
- Detecting episodic events
- Selecting cloud-free conditions



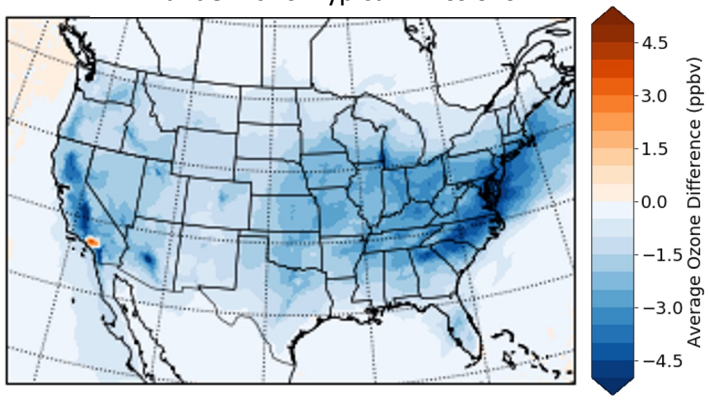
Once TEMPO data are available, NOAA's forecasting systems will become reliant on these data and will improve accordingly.



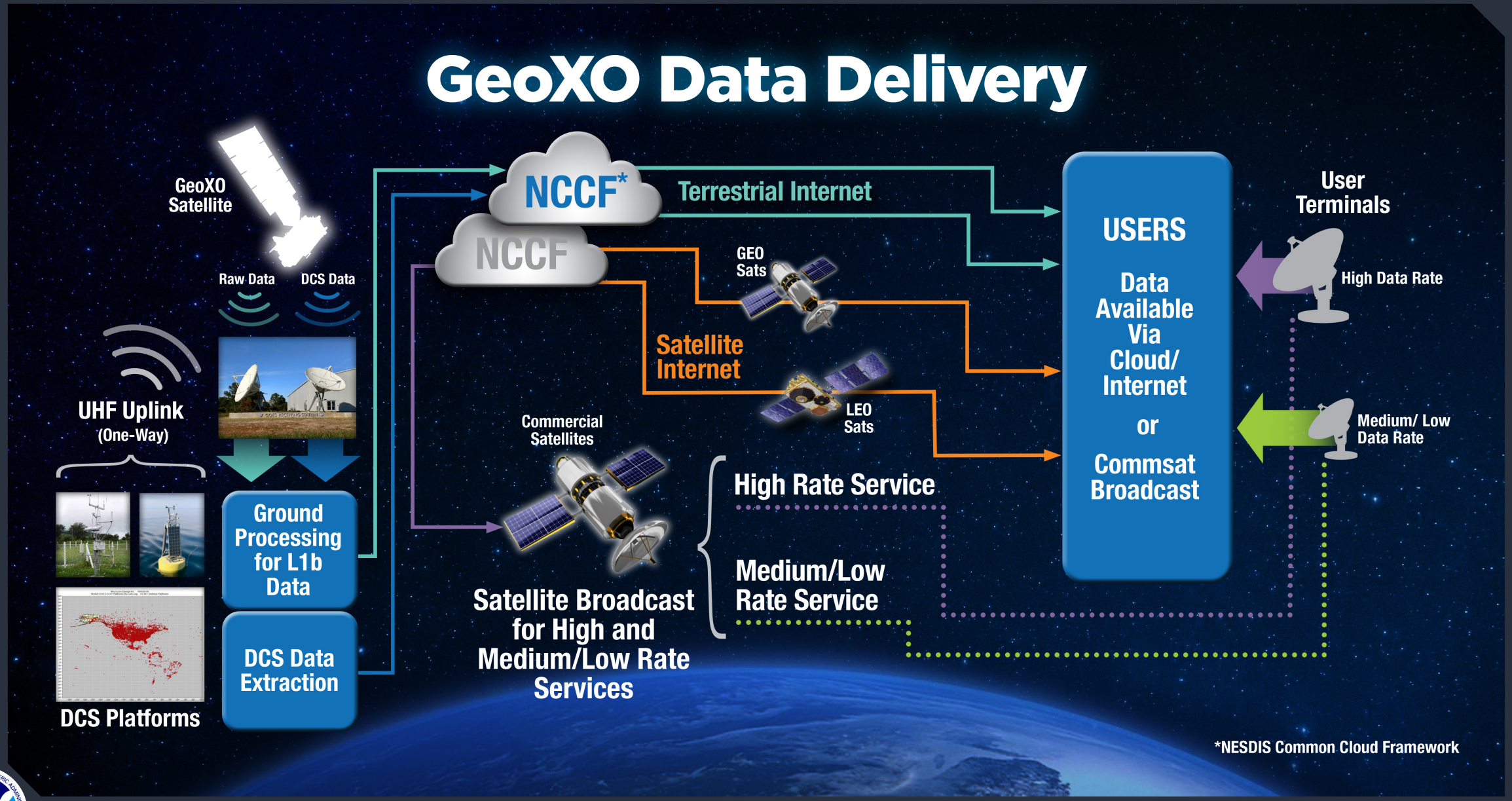
NASA's TEMPO Atmospheric Composition instrument will provide geostationary data over CONUS for research applications after it launches in 2022.



Change in Near-Surface Ozone, Pandemic vs. Typical Emissions



GeoXO Data Delivery



GeoXO Data Plans

- GeoXO will provide data to users in two main ways, through ***NOAA cloud services*** (and from the cloud to the internet (terrestrial, cell, and satellite)) and by ***NOAA-funded commercial communications satellite RF broadcast.***
- ***We expect most users will access the data through the cloud/internet path***, for a few reasons: that is where all the GeoXO data and products will be available, that is where other NOAA and non-NOAA data will be that users will want to use with GeoXO data, and it will be easier to access (i.e. you don't need to buy an antenna receive station to get it).
- The commercial RF data delivery will be provided for those that do not wish to rely on the cloud option. Because of the new instruments and improved resolution of GeoXO, the data rate will increase significantly and therefore an ***RF broadcast cannot practically include all the GeoXO data***. We intend that the GeoXO RF broadcast will be a similar data rate and similar content to the current GRB. In coming years, we will reach out to users to help define the content: we expect it will include the highest priority imagery/data for real time needs.
- Other factors that are driving us from government-satellite-RF to commercial satellite RF are: ***the expectation that we will use commercial services where available and the sale of L-band spectrum.***

Conclusions

- GOES-18's transition to GOES-West is on schedule for January 2023
- GeoXO has begun and is looking for to Milestone 2 in December 2023.
- GeoXO is planning to have 5 instruments (Imager, LI, Sounder, AC and OC) and be relevant to all NOAA Mission Service Areas (Weather, Oceans, Coasts and Climate).
- GeoXO data distribution will rely heavily on the NESDIS Common Cloud Framework (NCCF) and GRB will be handled by a Commercial Service and all data will not likely be served by GRB (as was case with GOES-R).

Questions for CSPP

- Which of the GeoXO Sensors and Data make sense for GRB?
- Will CSPP-GEO support the data in the cloud? Will CSPP provide a service like the EUMETSAT NWCSAF?
- Will CSPP-GEO support the MTG sensors which are excellent GeoXO Proxy?

Thank You