

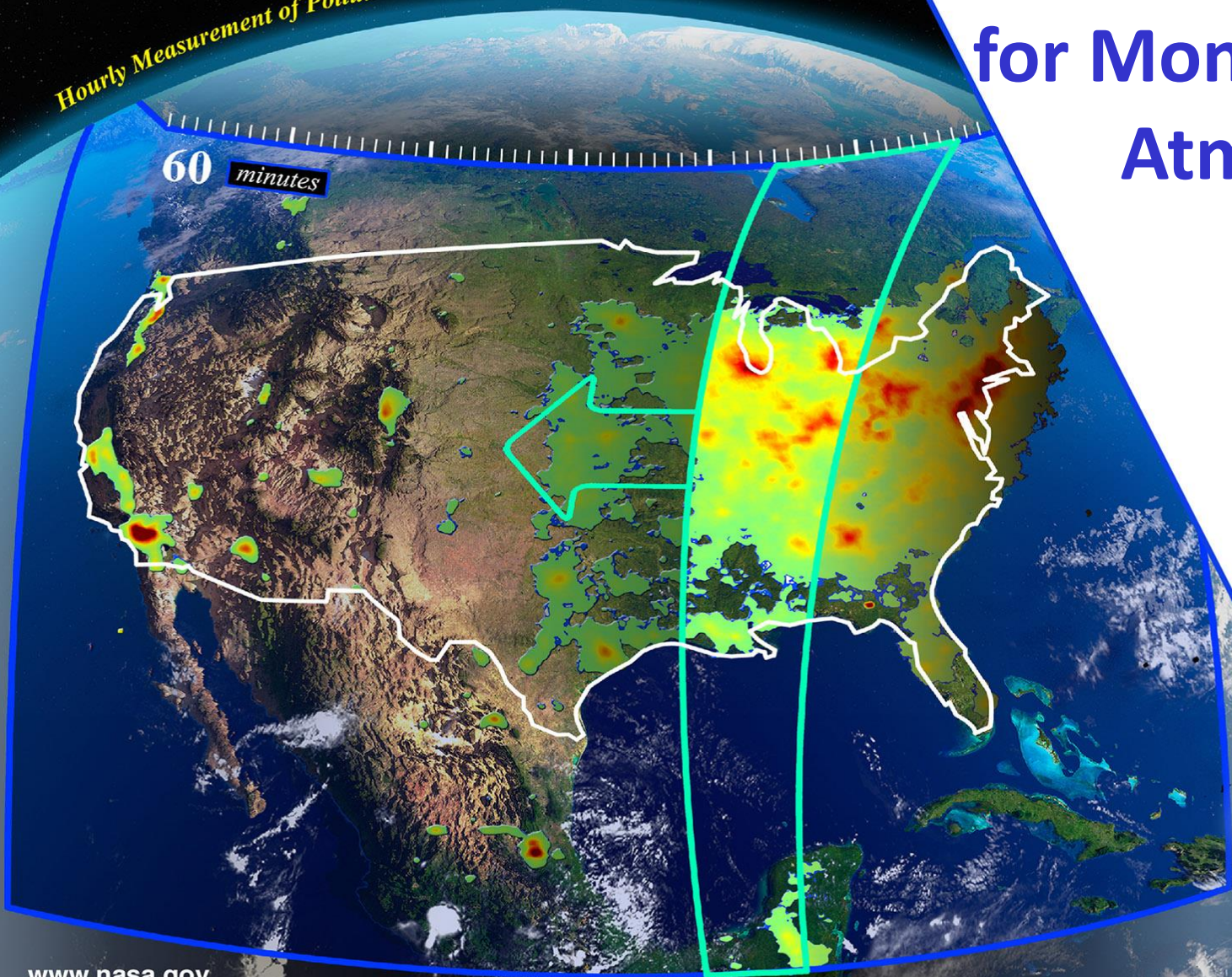
Tropospheric Emissions:  
Monitoring of Pollution



# Current and Future Geostationary Satellite Missions for Monitoring Air Quality and Atmospheric Composition

Hourly Measurement of Pollution

60 minutes



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2019 Joint Satellite Conference  
Boston, MA



# Spectral Bands

- Wealth of spectral bands onboard new geostationary sensors allows for enhanced aerosol algorithms
  - Robust cloud masking techniques
  - Improved aerosol classification
- Differences in channel combinations primarily in the VIS and NIR
  - 1.3  $\mu\text{m}$  on ABI, AMI for improved cirrus cloud detection
  - 2.3  $\mu\text{m}$  on AHI for improved land/cloud properties
- Temporal resolution – 10 to 15 min for Full Disk scan
- Spatial resolution – 0.5 to 2 km from VIS to IR
- Flexibility for regional area selection at higher temporal resolution ... down to 30 sec for GOES-R.

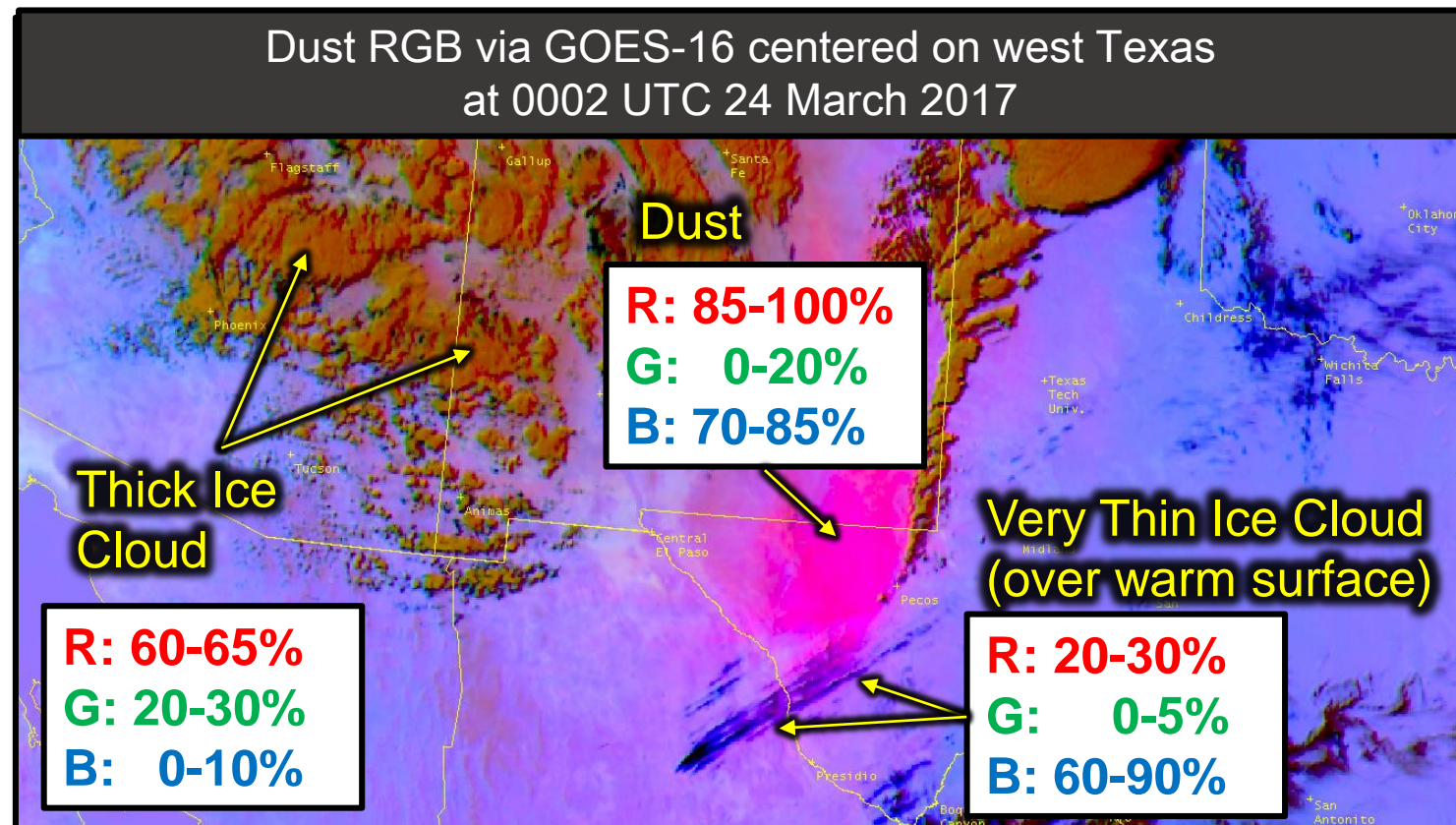
Bands	Resolution (km)	GOES-R (ABI)	Himawari-8 (AHI)	GK-2A (AMI)
VIS0.4	1	0.47	0.46	0.47
<b>VIS0.5</b>	<b>1</b>		<b>0.51</b>	<b>0.508</b>
VIS0.6	0.5	0.64	0.64	0.64
VIS0.8	1	0.865	0.86	0.863
<b>NIR1.3</b>	<b>2</b>	<b>1.378</b>		<b>1.374</b>
NIR1.6	2	1.61	1.6	1.609
<b>NIR2.2</b>	<b>2</b>	<b>3.35</b>	<b>2.3</b>	
IR3.8	2	3.9	3.9	3.832
IR6.3	2	6.185	6.2	6.21
IR6.9	2	6.95	7	6.94
IR7.3	2	7.34	7.3	7.327
IR8.7	2	8.5	8.6	8.59
IR9.6	2	9.61	9.6	9.62
IR10.5	2	10.35	10.4	10.35
IR11.2	2	11.2	11.2	11.23
IR12.3	2	12.3	12.3	12.37
IR13.3	2	13.3	13.3	13.29



# Dust RGB Recipe & Product Basics

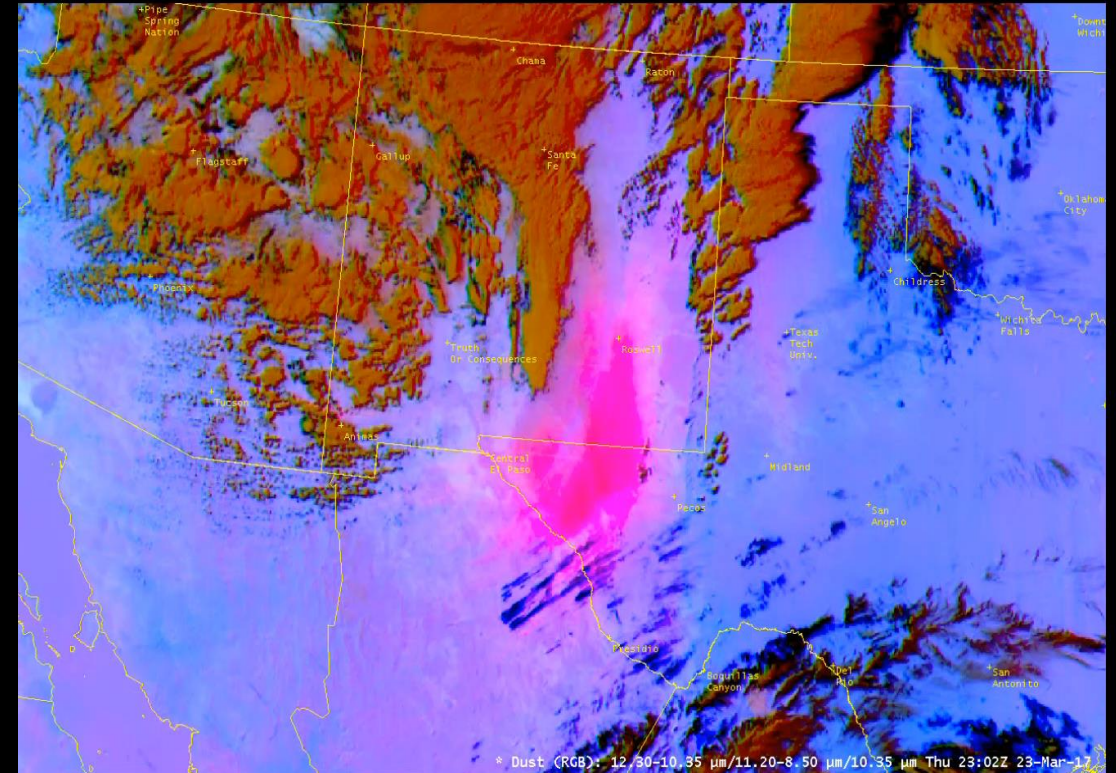
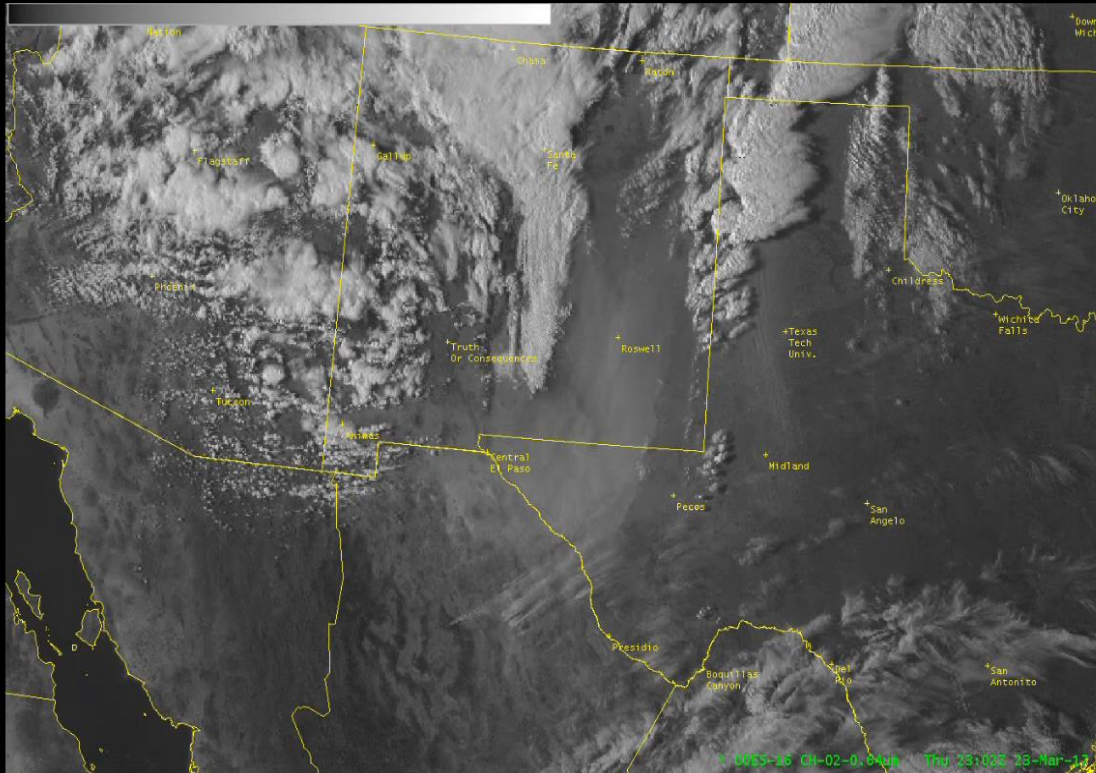
Color	Band/Band Diff. ( $\mu\text{m}$ )	Physically relates to...	Small contribution to pixel indicates...	Large contribution to pixel indicates...
Red	12.3-10.3	Optical depth/cloud thickness	Thin clouds	<b>Thick clouds, dust plume</b>
Green	11.2-8.4	Particle phase	Ice and particles of uniform shape (dust)	<b>Water particles or thin cirrus over deserts</b>
Blue	10.3	Surface temperature	Cold surface	<b>Warm surface</b>

- 12.3  $\mu\text{m}$  is semi-transparent to dust
  - large red intensity compared to clouds
- “Warm” dust at low levels
  - large blue intensity
- Dust plume **magenta** color
- Dust RGB valid day and night  
(benefit over typical use of visible or true color imagery to analyze dust plumes)



# Enhanced Dust RGB imagery

23 UTC 23 March – 02 UTC 24 March 2017



GOES-16 Visible band 2 (0.64  $\mu\text{m}$ )

GOES-16 Dust RGB

- Allows for enhanced capabilities for monitoring dust plumes, with some caveats including qualitative nature of the product and degradation of night

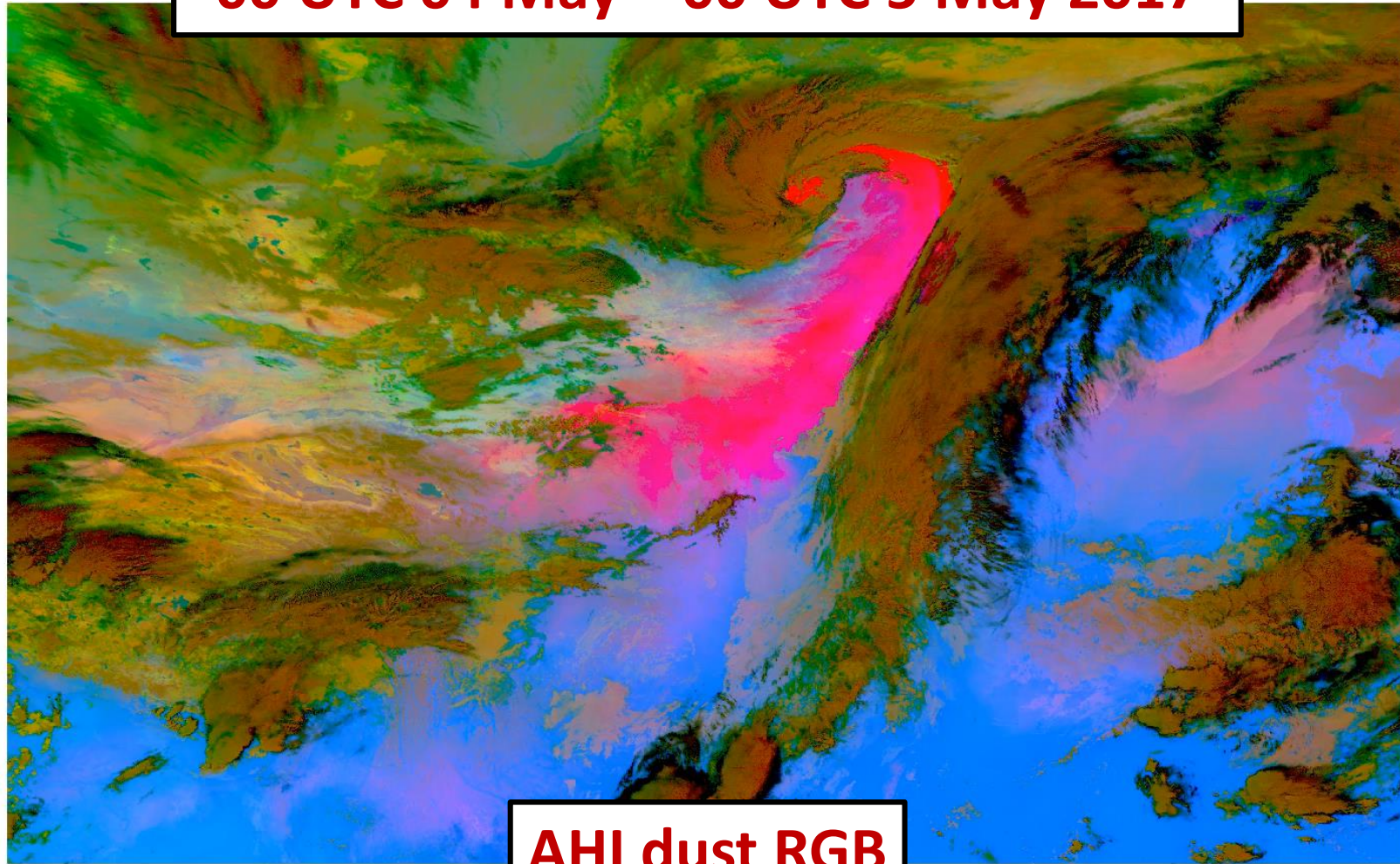


<https://weather.msfc.nasa.gov/sport/>



# Enhanced Dust RGB imagery

00 UTC 04 May – 00 UTC 5 May 2017



AHI dust RGB

- Similar spectral bands onboard Himawari AHI allows for robust monitoring of dust plumes over East Asia
- Combined use of AHI and GK-2A will monitor dust sources across most of Asia.

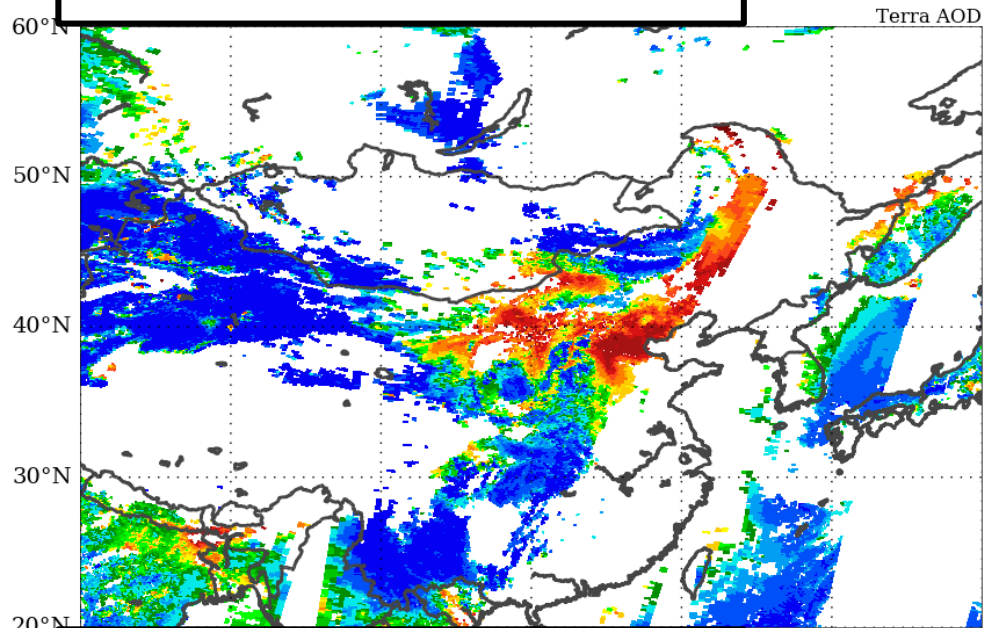


<https://weather.msfc.nasa.gov/sport/>

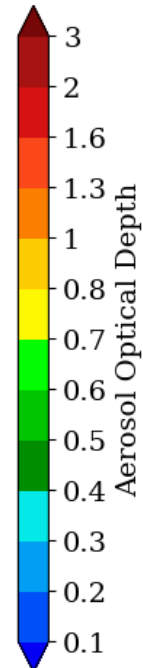
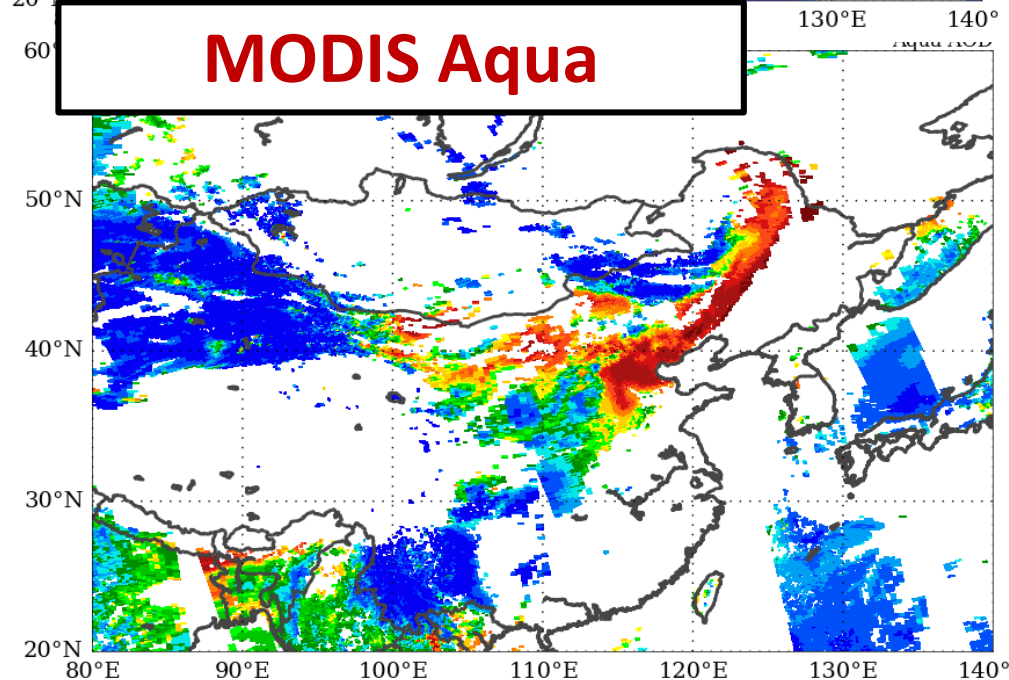
**SPORT**

# Geostationary AOD retrievals

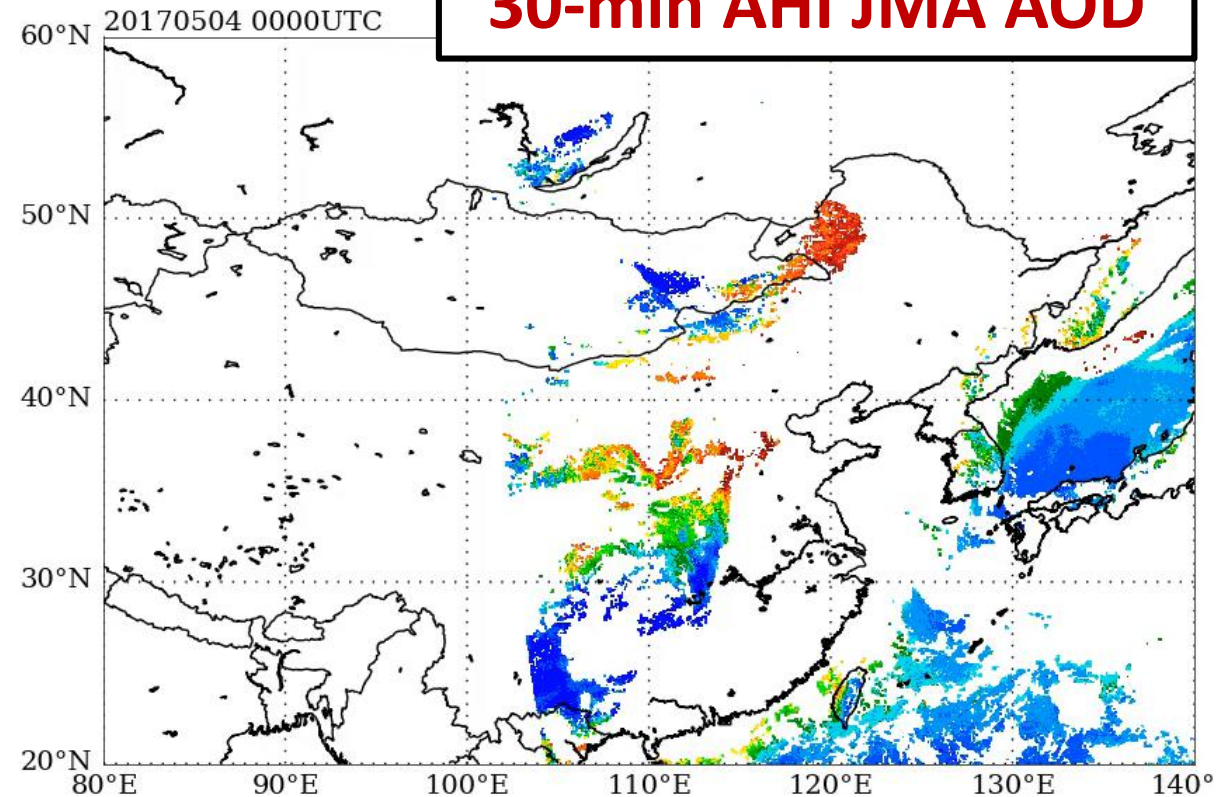
**MODIS Terra**



**MODIS Aqua**



**30-min AHI JMA AOD**



- New generation geostationary spectroradiometers allow for improved AOD retrievals at high temporal frequency
- Discrepancies still exist (cloud masking, anomalous AOD), so more work is needed to further refine the geostationary retrievals

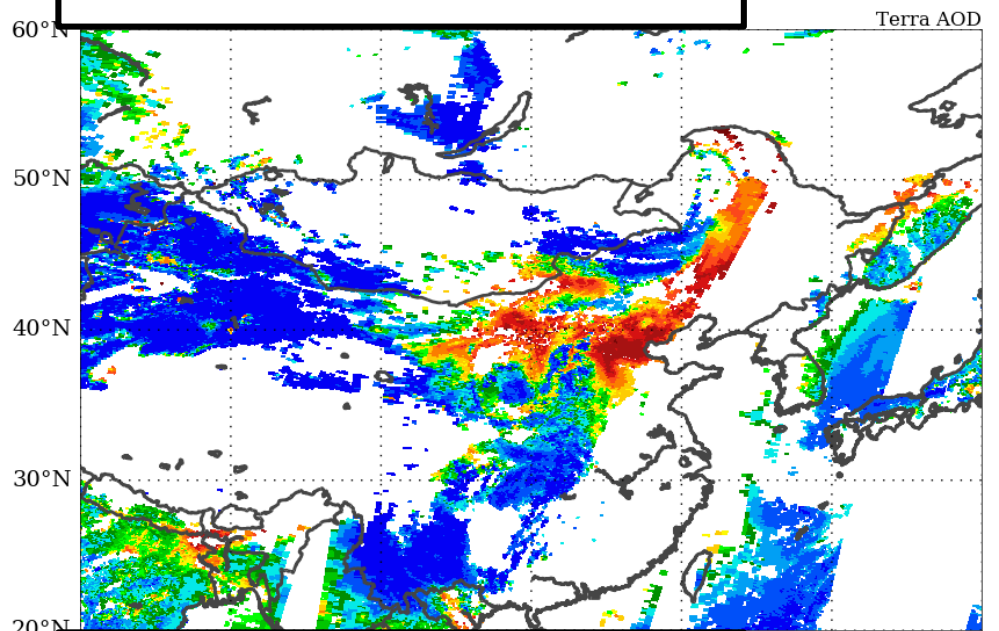


<https://weather.msfc.nasa.gov/sport/>

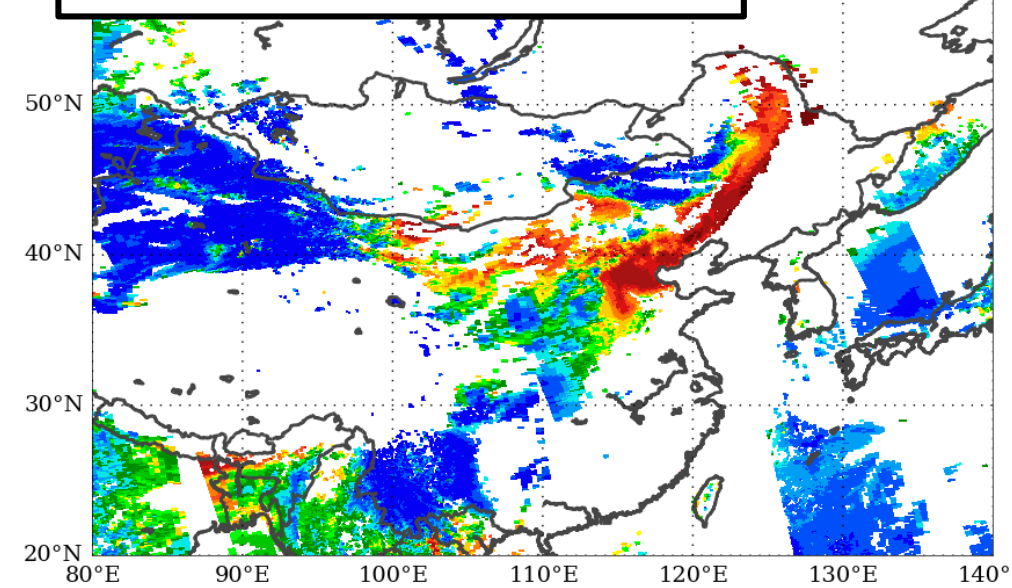


# Geostationary AOD retrievals

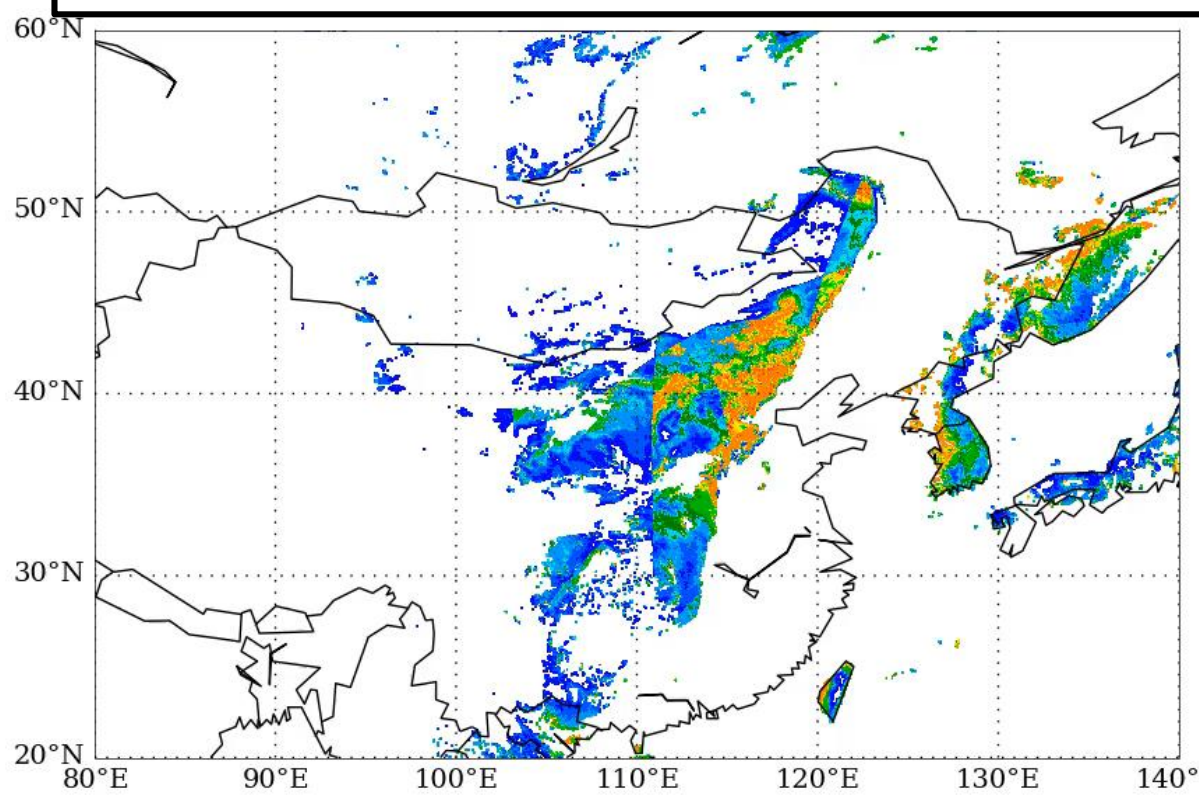
**MODIS Terra**



**MODIS Aqua**



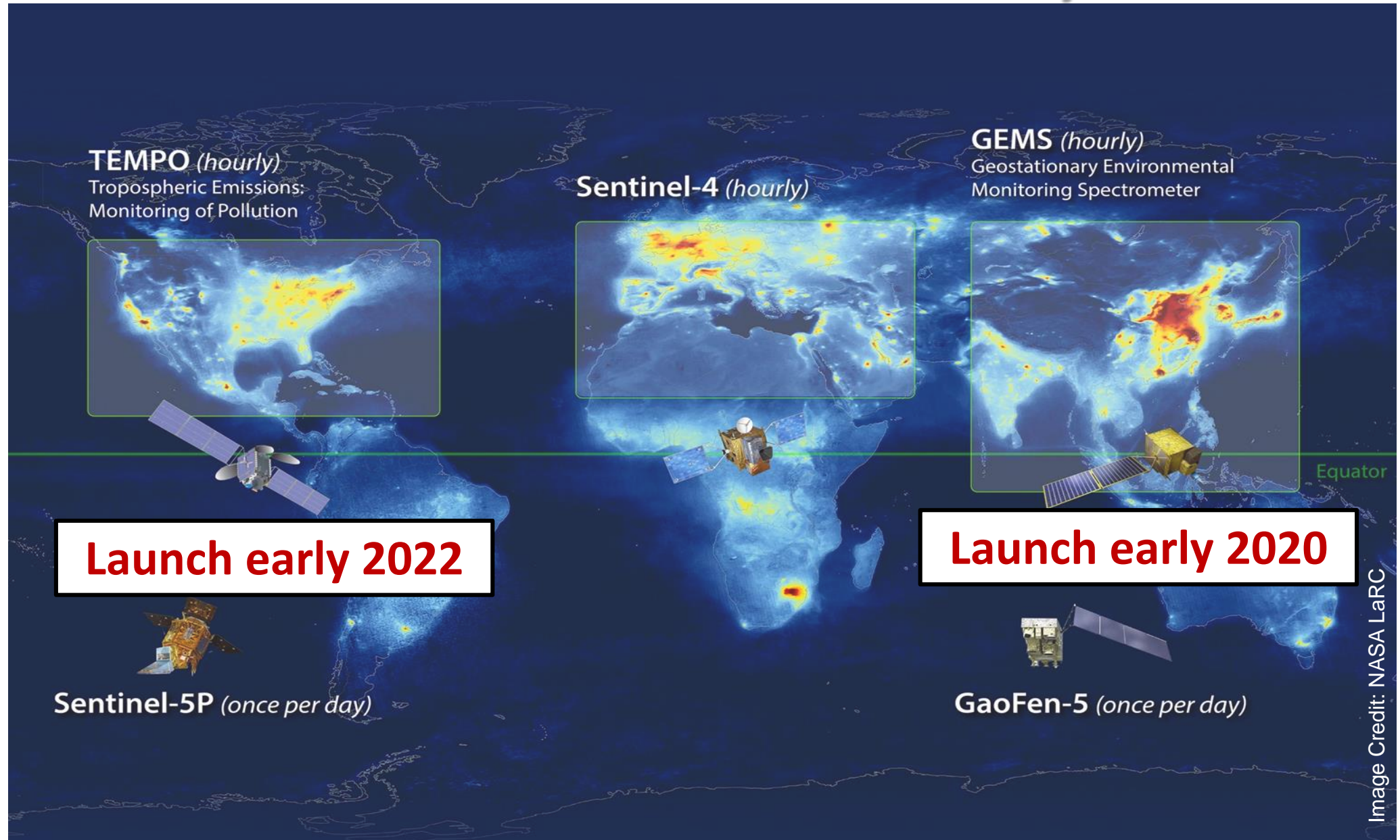
**30-min AHI SPoRT AOD (Preliminary)**



- Developing AHI AOD retrieval at NASA SPoRT using unique aerosol models and identification techniques, and surface parameterizations for Asia
- Implement version of SPoRT AHI AOD retrieval for GK-2 with an emphasis on South Asia



# Constellation of Geostationary Satellites



- Geostationary spectrometers aligned for unprecedented hourly monitoring of air quality



<https://weather.msfc.nasa.gov/tempo/>

**SPORT**



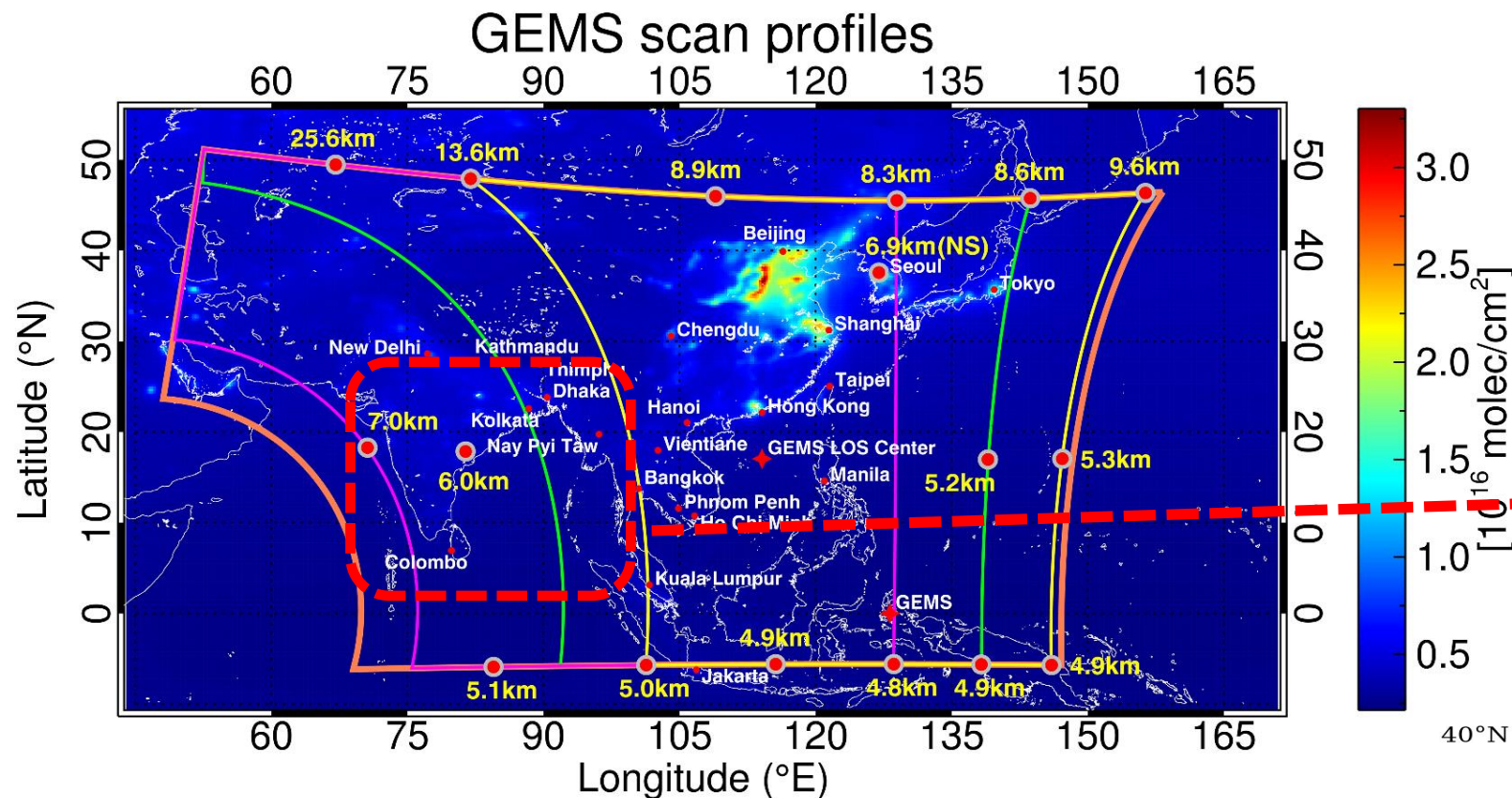
# Sensors & Baseline Products

Sensor Specs	TEMPO	GEMS
Wavelength Range (nm)	290-490 & 540-740 nm	300-500
Spectral Resolution (nm)	0.6	< 0.6
Spectral Sampling (nm)	0.2	< 0.2
Spatial Resolution (km <sup>2</sup> )	2.1 x 4.5	8 x 7
Baseline Products	O <sub>3</sub> , trop O <sub>3</sub> , 0-2 km O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , HCHO, CHOCHO, AOD, AAI	O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , HCHO, AOD, AI, AEH

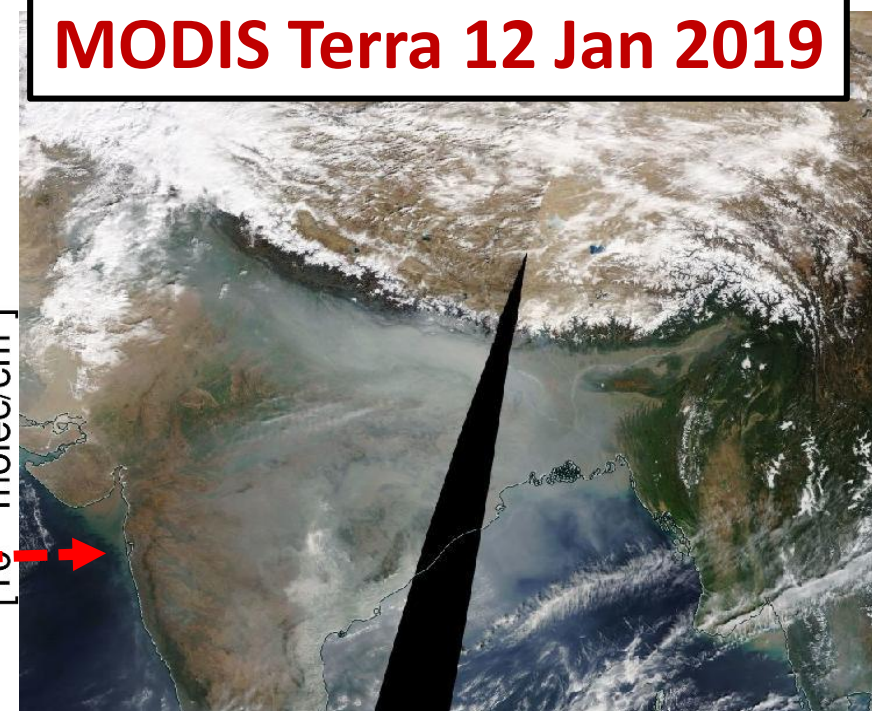
- Multi-band UV-VIS capabilities will provide revolutionary diurnal information on O<sub>3</sub> profile
  - 0-2 km O<sub>3</sub> profile for diagnosing AQ where people live
- Higher spatial resolution of TEMPO for enhanced monitoring of local emissions
- Larger Field of Regard (FOR) of GEMS, greater area coverage for monitoring AQ



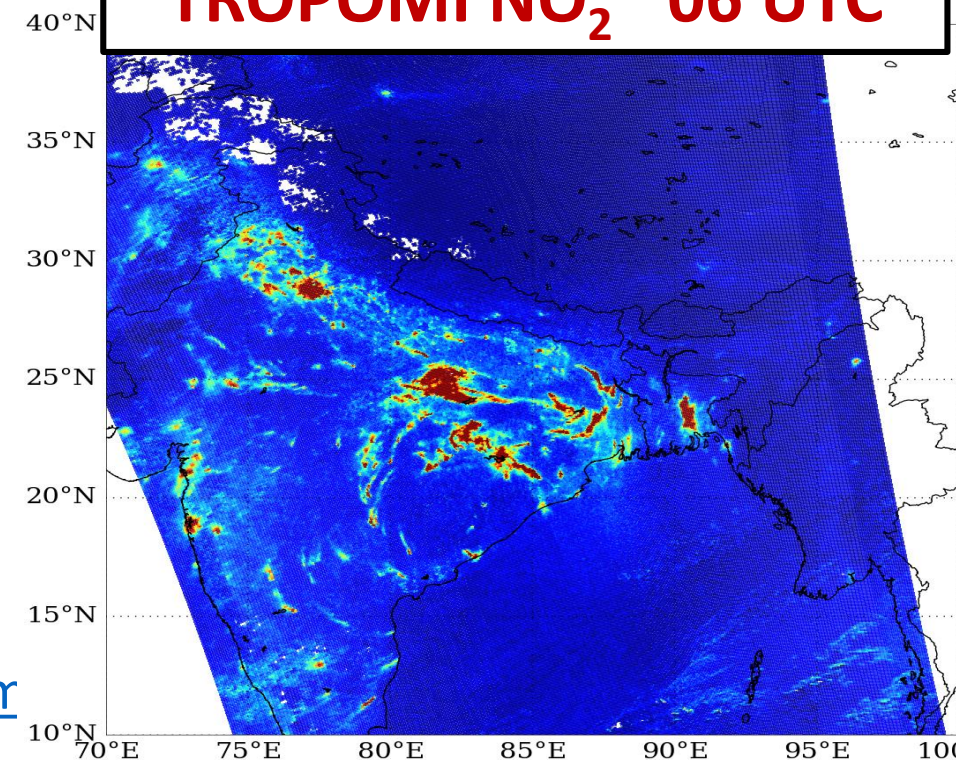
# Assimilation of GEMS data



MODIS Terra 12 Jan 2019



TROPOMI NO<sub>2</sub> ~06 UTC



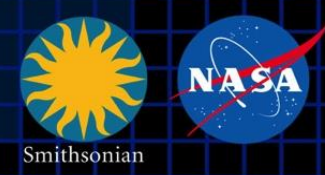
- High spatial resolution of TROPOMI helps better resolve emissions, but limited temporal resolution
- Assimilation of GEO (GEMS) trace gas products within regional modeling system over South Asia aims to improve AQ forecasting capabilities



<https://weather.msfc.nasa.gov/tem>



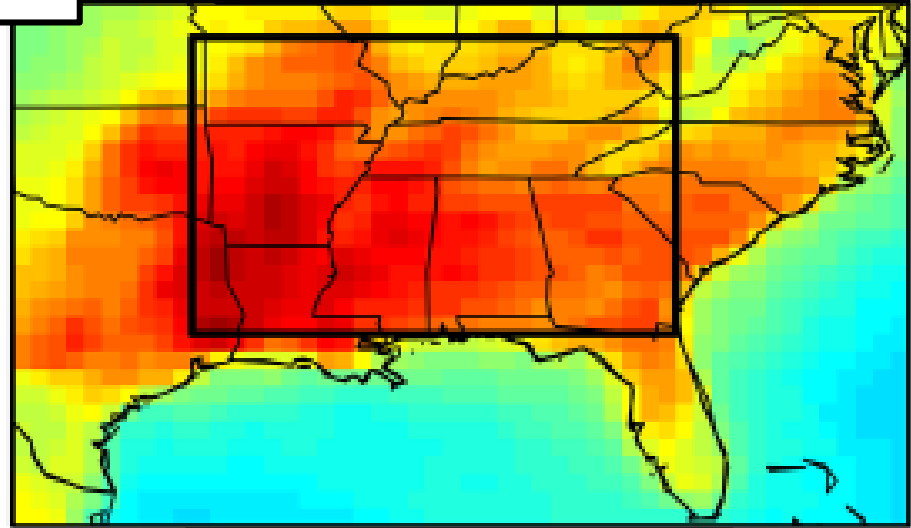
# Synthetic TEMPO data



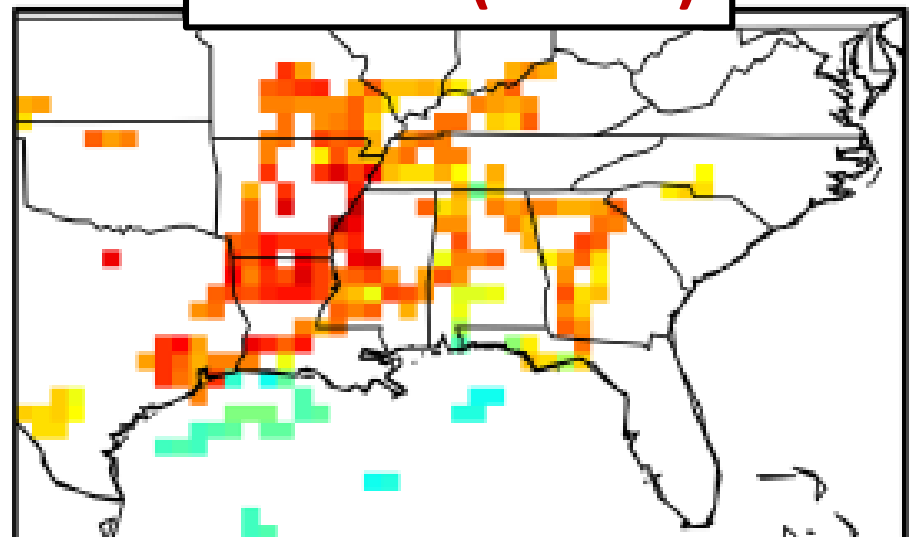
- Synthetic TEMPO data generated via spatiotemporal interpolation of simulated gaseous and aerosol composition from GEOS-NR (~12 x 12 km<sup>2</sup>)
- Accounts for instrument and algorithm effects
- **Generating 1-year of synthetic TEMPO data at NASA SPoRT from July 2013 – June 2014**
- Conducting analysis into possible extension of synthetic dataset for post-2017 period

**H<sub>2</sub>CO**

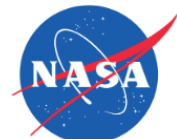
**GEOS-Chem**



**Aircraft (CAMS)**



Zhu et al. (ACP, 2016)

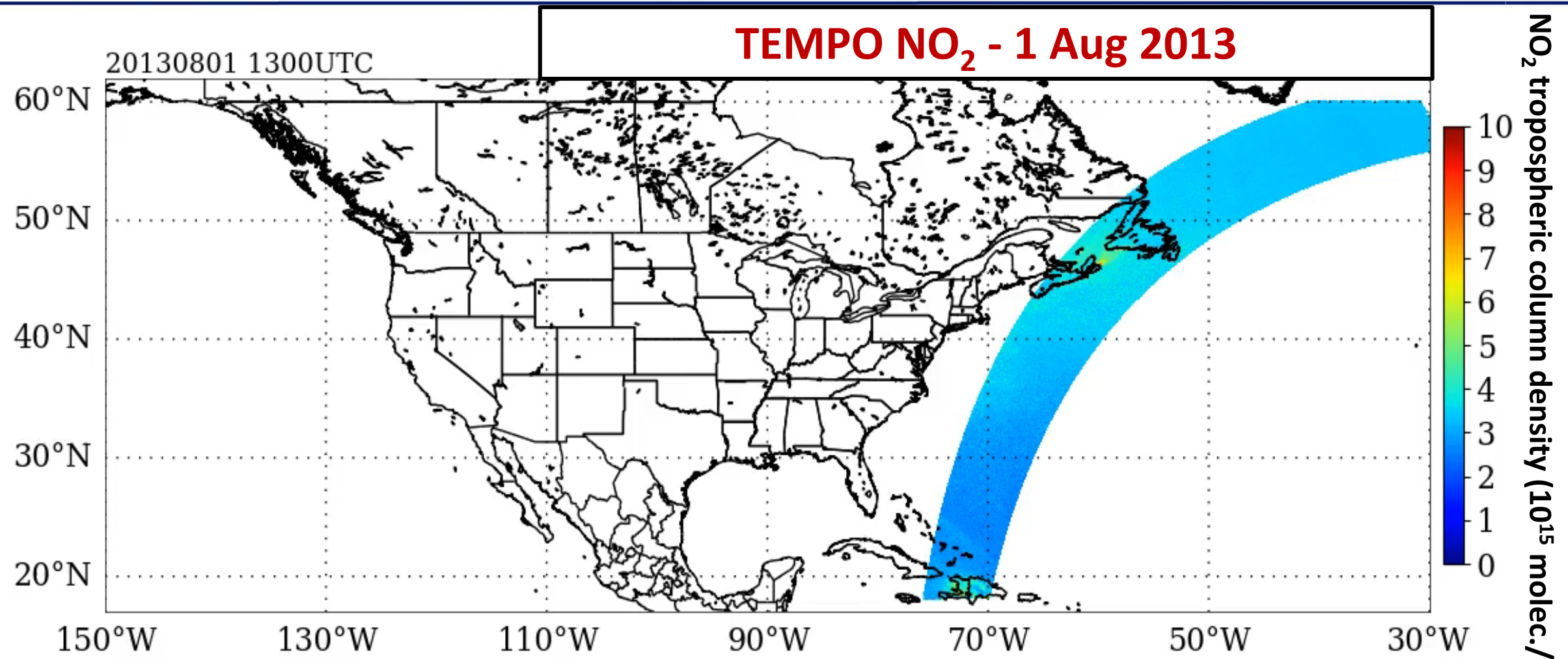
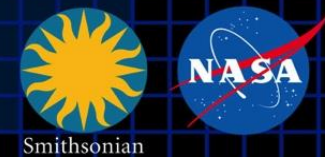


<https://weather.msfc.nasa.gov/tempo/>

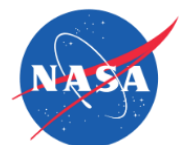




# Synthetic TEMPO NO<sub>2</sub>



- 10 granules compose hourly scan over TEMPO Field of Regard
- Goal: **Utilize TEMPO proxy data to assess and adopt applications in pre-launch phase and accelerate operational use of TEMPO products after launch**

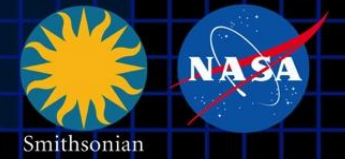


<https://weather.msfc.nasa.gov/tempo/>

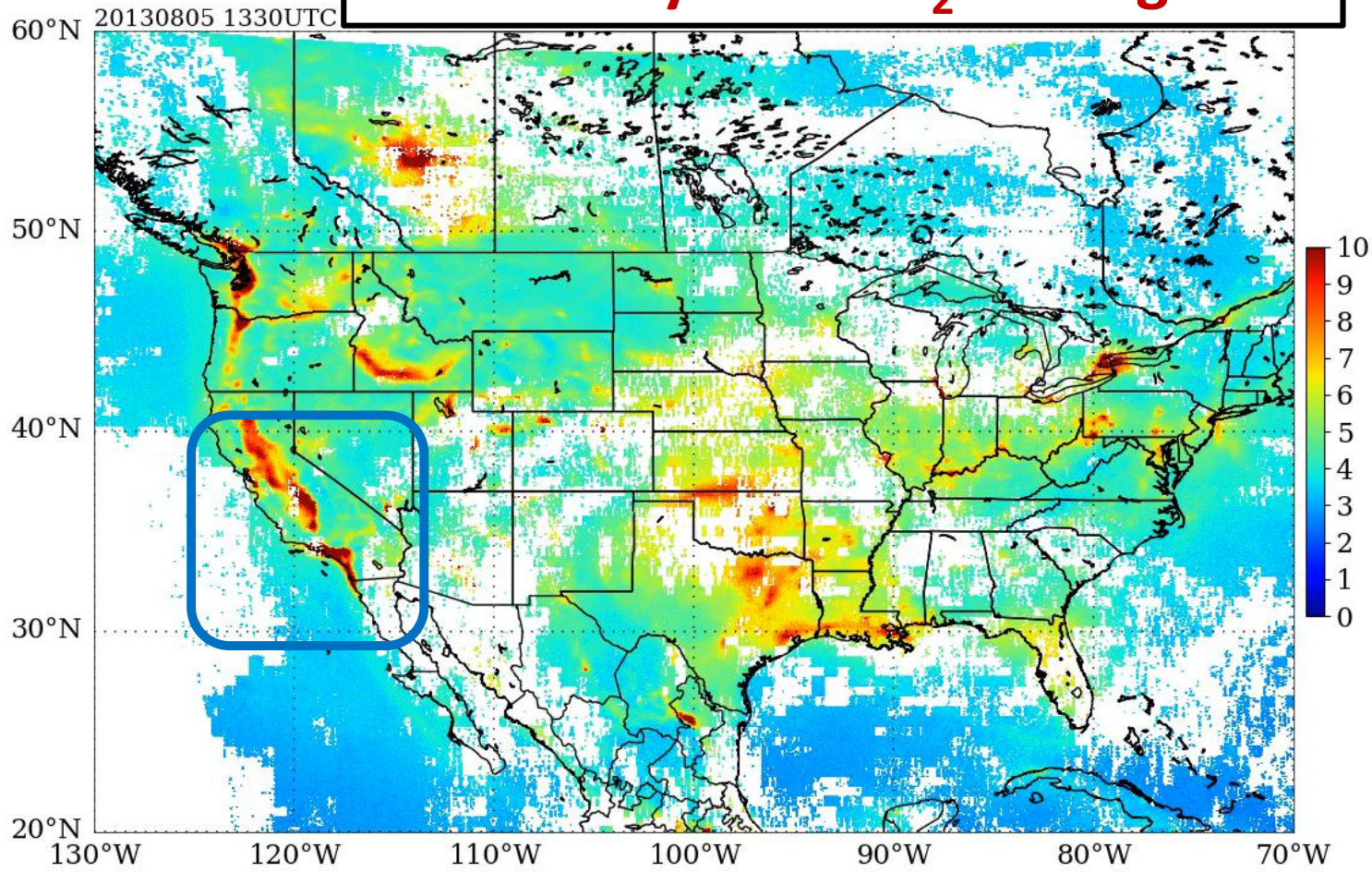




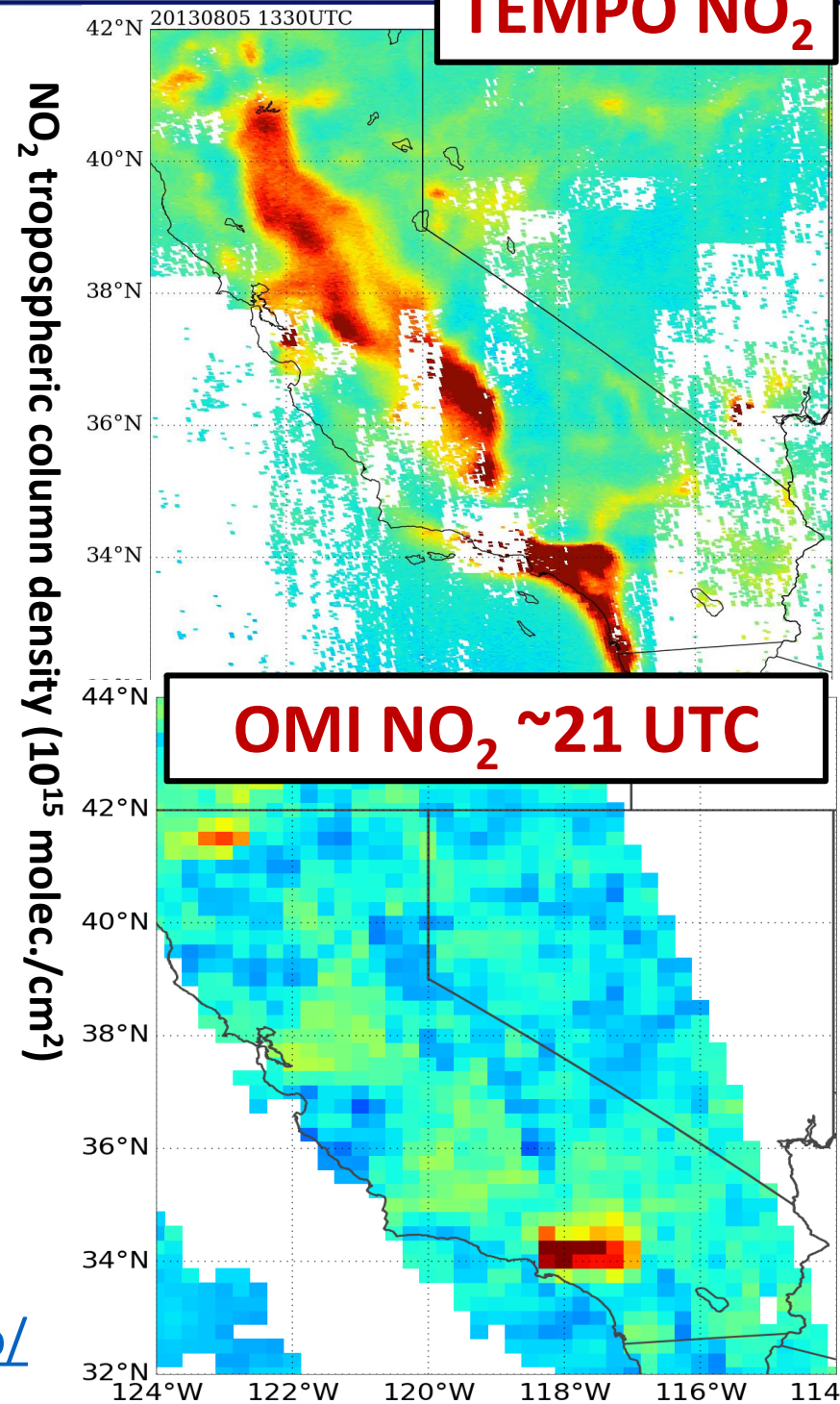
# TEMPO vs OMI NO<sub>2</sub>



**TEMPO daytime NO<sub>2</sub> - 5 Aug 2013**



**TEMPO NO<sub>2</sub>**



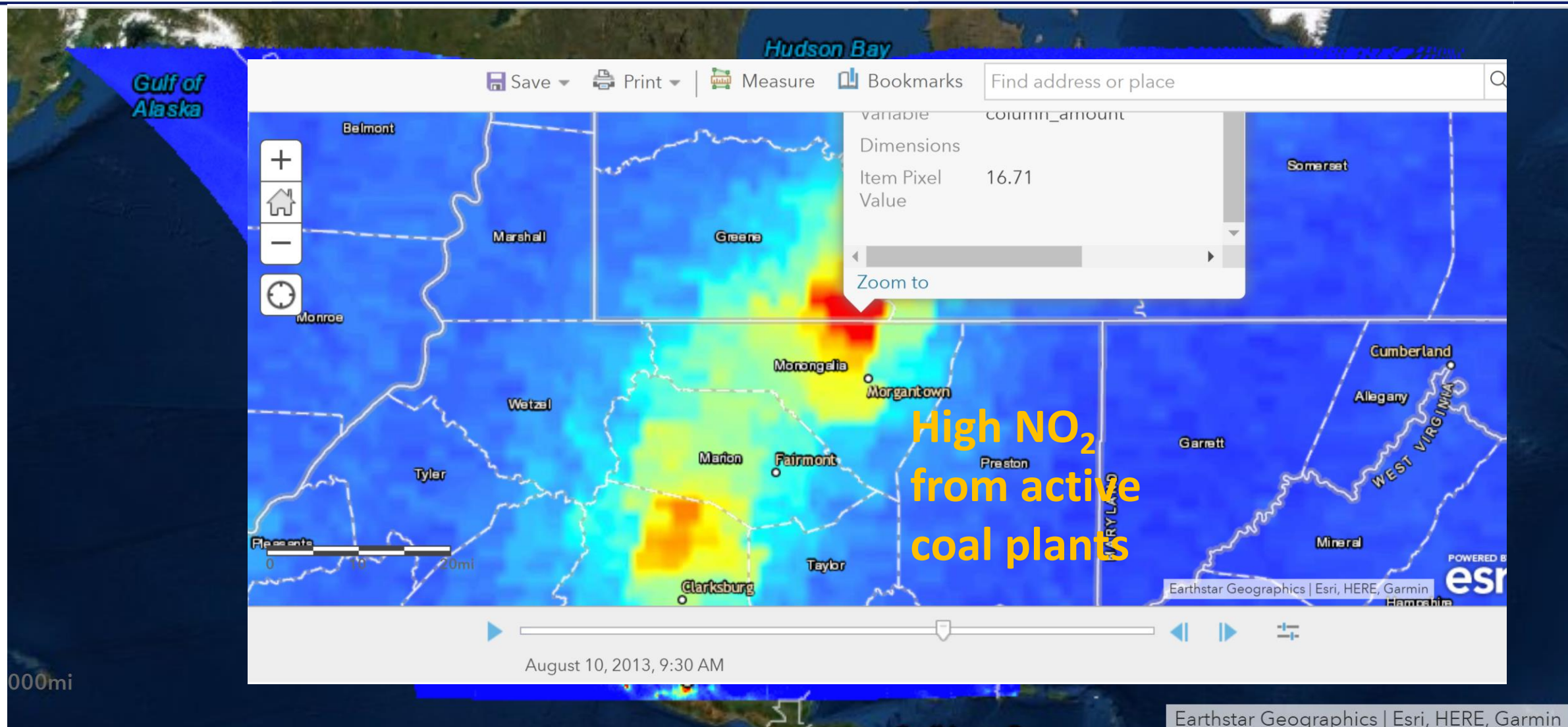
- TEMPO will observe diurnally varying mobile source and smoke emissions



<https://weather.msfc.nasa.gov/tempo/>



# ESRI Visualization for TEMPO



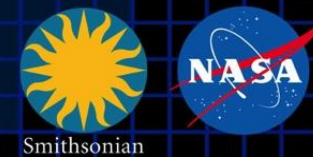
- ESRI includes point and click feature for retrieving raw geophysical variables at pixel level for on-the-fly analysis



<https://weather.msfc.nasa.gov/tempo/>



# Pre-launch R2O/O2R Activities

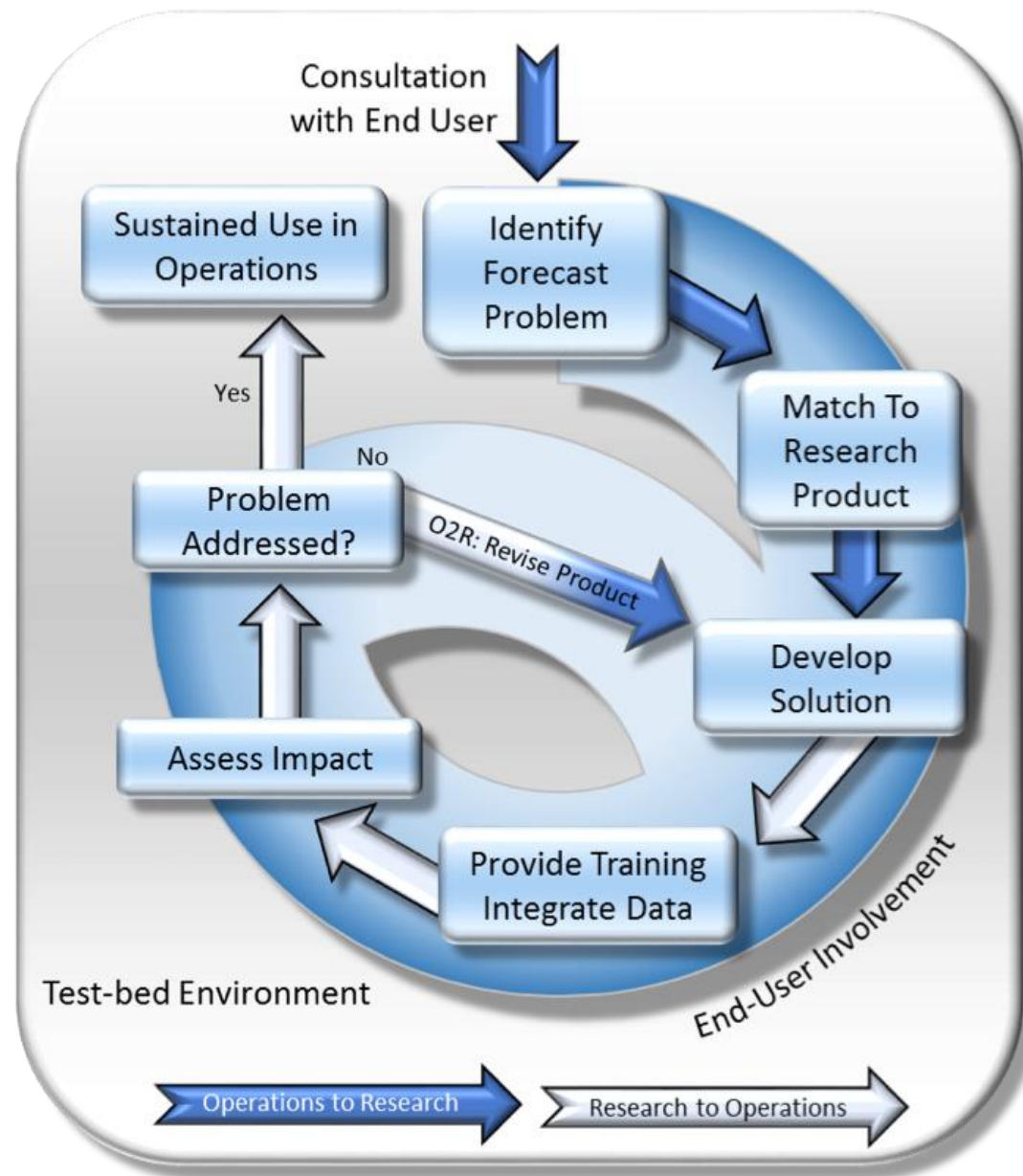


## Keys to successful day 1 readiness

- Data in the end users' display system
- Targeted training
- Assessments to gather feedback from users for the mission scientists

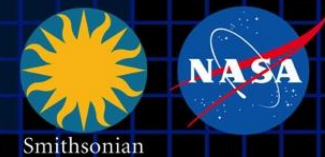
Pre-launch R2O/O2R activities can provide valuable input to mission scientists, algorithm developers, and guide products/capabilities

**Accelerate operational use of products after launch!**





# Much more to come!



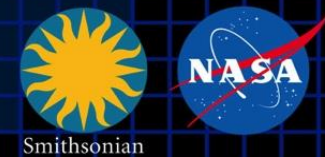
- Actively engage with end users/stakeholders during pre-launch phase of TEMPO mission
- Utilize GEMS for demonstrating potential applications of TEMPO mission
- Design tailored TEMPO products/files for fulfilling needs of end users/stakeholders
- Assess Data Fusion and Machine Learning techniques



- Synthesize TEMPO and MAIA measurements to develop unprecedented merged products for AQ and health applications
- Synthesize health, low-cost AQ sensors, and satellite data to build advanced exposure models







# Thanks!

## Questions/Comments

**Aaron Naeger**

**Deputy Program Applications (DPA) Lead of TEMPO Mission**

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**TEMPO Health Applications Workshop in Huntsville, AL**

October 10, 2019

<https://weather.msfc.nasa.gov/tempo/meetings.html>



<https://weather.msfc.nasa.gov/tempo/>

