



Tropospheric Emissions:  
Monitoring of Pollution



Hourly Measurement of Pollution

60 minutes

# Synthetic TEMPO Data Products at NASA SPoRT for Air Quality and Public Health Communities

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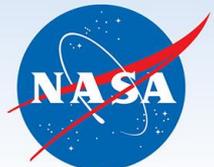
June 5-6, 2019

TEMPO Science Team Meeting

Madison, WI



Smithsonian





# Short-term Prediction Research and Transition (SPoRT)



**Mission:** Transition unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale

SPoRT prepares the *community* of *end users and mission scientists* for next generation satellite missions and capabilities through an interactive R2O/O2R paradigm

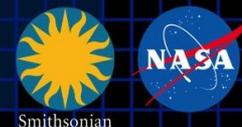
## **Current/Future Activities:**

- Successful partnerships to prepare NWS forecasters for GOES-R and JPSS through use of experimental proxy products
- Expanding partnerships to other government agencies and new NASA missions





# R2O/O2R Paradigm

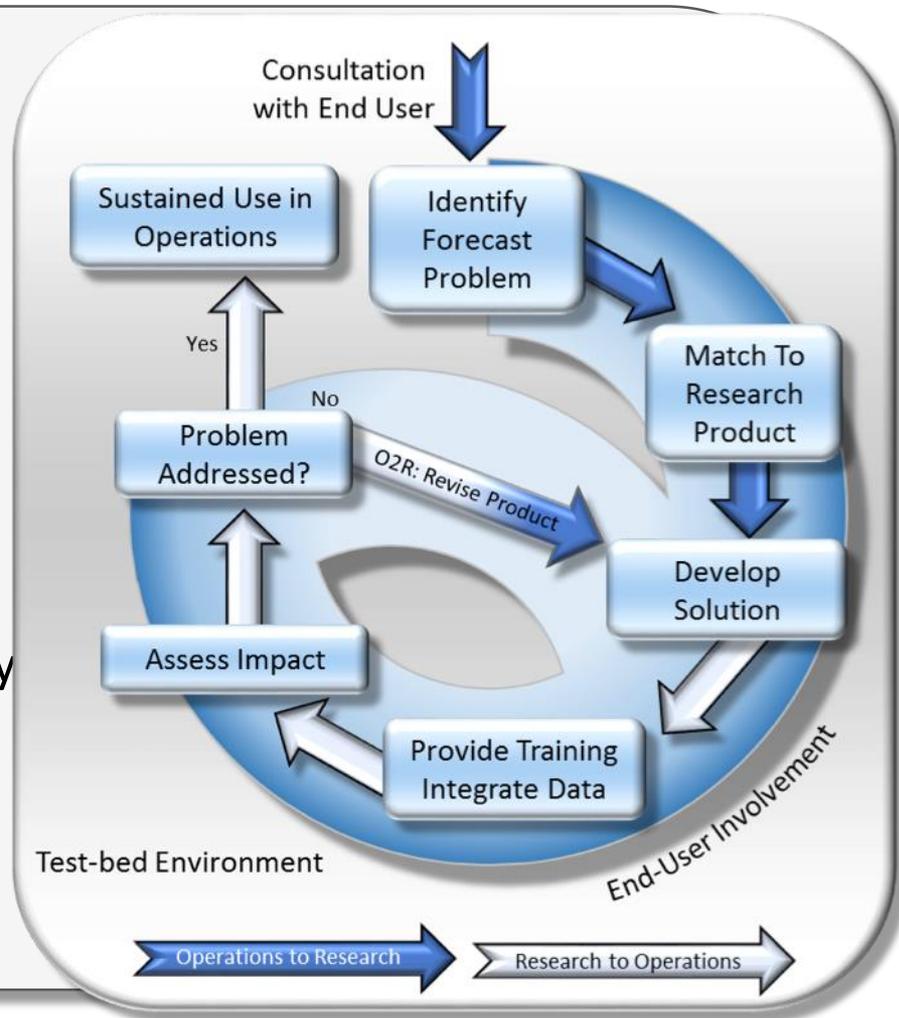


**Bridge the “Valley of Death”** through interactive partnership with end users and product or algorithm developers

- Integrate data into user decision support tools
- Create product training
- Conduct product assessments

Concept has been used to successfully transition more than 40 satellite datasets to operational users for nearly 15 years

Other groups in the community have adopted this paradigm





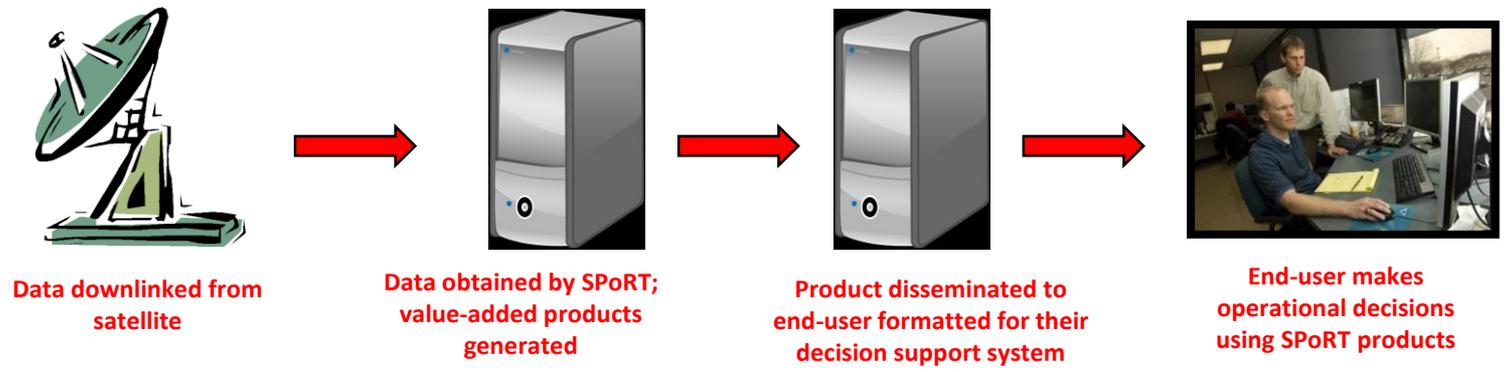
# Data Approach



SPoRT provides experimental data to end users by LDM, FTP, and WMS depending on the application

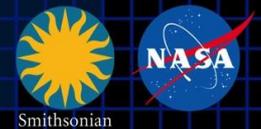
While NASA is not an “operational” data provider, team members strive to provide 24/7 data feeds, knowing that product reliability is key to use by operational forecasters and decision makers

Monitor our product ingest and status for all experimental products going to a customer





# Training Approach



## Targeted, applications based training

Multiple flavors of training are needed to reach all learning styles

- Site visits
- Microlessons
- User-based, interactive modules

## SPoRT Applications Library

- 1-minute examples
- Short videos
- 21 total cases (and counting)

Collaborate with end users for operational/decision maker perspective

**Night-time Microphysics RGB**

- Utilizes MODIS & VIIRS channels/channel differences:
  - 12.0µm-10.8µm (optical depth)
  - Thicker = more red
  - 10.8µm-3.9µm (particle size & phase)
  - Small water droplets = more green
  - 10.8µm (thermal)
  - Warmer = more blue

Labels in the image include: Low stratus (bluish green), Mid-level Cumulus, Cumulonimbus (tans, browns), Mid/Upper level stratus (purples), Fog in elevated valleys (grayish aqua), Fog in Sequatchie and TN valleys (grayish aqua), Mid/Upper level stratocumulus (red tones), and Upper level cirrus (dark blue tones).



**Application Library: Day Convective RGB**

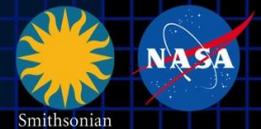
**Key Description:** A line of cold low-level frontal system... (text partially obscured)

**Figure 1:** GOES-16 Day Convective RGB, valid 1312 April 3, 2017





# Assessment Approach



Targeted product assessments with the end user to evaluate utility of product and give feedback to developers

## Methods for feedback

- Online form
- Email/phone calls
- Blog

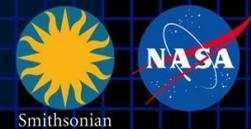
## Assessment follow-up

- Wrap-up telecon with participants
- Summarize results in a report for the developers





# Pre-launch R2O/O2R Activities



https://weather.msfc.nasa.gov/sandbox/tempo/

Home Research Applications Publications Team

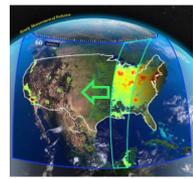
## Keys to successful day 1 readiness

- 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 data processors, mission scientists, algorithm developers, and guide baselining of products/capabilities

## Tropospheric Emissions: Monitoring of Pollution

### Introduction



The TEMPO mission is currently on-schedule and on-budget for an expected launch date in 2020 or 2021, and will be hosted on a commercial geostationary communications satellite with a Field of Regard (FOR) over North America for allowing hourly daytime monitoring capabilities. For each geospatial scene in the FOR, the TEMPO grating spectrometer instrument will measure the solar backscattered radiance in the ultraviolet (290-490 nm) and visible (540-740 nm) with a spectral resolution and sampling of 0.6 and 0.2 nm, respectively, for retrieving aerosol and cloud parameters, along with the major elements in tropospheric ozone (O<sub>3</sub>) chemistry cycle consisting of nitrogen dioxide (NO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), formaldehyde (H<sub>2</sub>CO), glyoxal (C<sub>2</sub>H<sub>2</sub>O<sub>2</sub>), water vapor (H<sub>2</sub>O), and UVB radiation. The high spatial resolution of 2.1 km x 4.7 km at the center of the FOR will allow for unprecedented air-quality monitoring at sub-urban scales.

### TEMPO Early Adopters

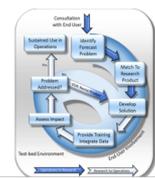
TEMPO Early Adopters are working towards identifying the myriad of capabilities and applications of TEMPO, recognizing the needs of the end-user community, and planning how these needs can be met prior to the TEMPO launch.

### Objectives

<b>1</b>	<b>2</b>	<b>3</b>
Identify key end users and end-user applications in the areas of air-quality modeling; planning and assessment; emissions; and health, agricultural, and environmental impacts to establish a feedback loop for the TEMPO Science Team to provide products to meet these end-user requirements.	Use current systems (space-borne, surface networks, model/synthetic calculations) to emulate future TEMPO capabilities, and better prepare the air quality agencies for the post-launch data, while also realizing the regional and local applications of the data.	Define processing and delivery needs from NASA for operational forecasting, episode analysis, and trend evaluation by air quality agencies.

### NASA SPoRT Collaboration

The SPoRT Center was established in 2002 for transitioning unique satellite observations and research capabilities to end users to improve short term forecasting and decision support. SPoRT team members work within a research to operations/operations to research paradigm to introduce experimental products to the operational environment via active involvement of end users. Involving the end users in the process ensures the products being developed by the researchers meet the end users' needs. This highly successful paradigm will be utilized for transitioning real-time TEMPO data products to end user communities in an effort to assess the impact on operations and develop end-user tailored products. Prior to TEMPO launch, SPoRT will apply the paradigm to (1) establish relationships with end users, and (2) deliver TEMPO proxy products in a format compatible with their decision support or display systems, and (3) gather feedback from the end users through targeted assessment of the products. These pre-launch activities will engage



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

Document Title





# Synthetic TEMPO data

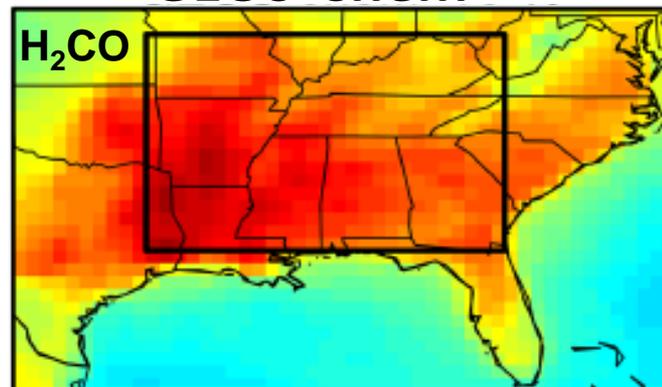


Synthetic TEMPO observations generated using simulated gaseous and aerosol composition from GEOS-NR

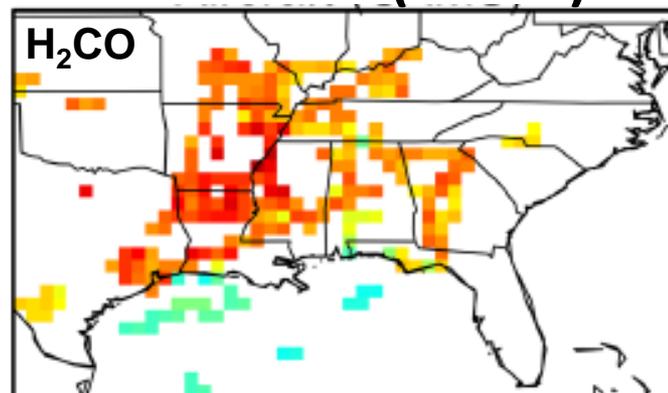
GEOS-NR spatial resolution of  $\sim 12 \times 12 \text{ km}^2$  spatiotemporally interpolated to finer TEMPO grid

Profiles and vertical column amounts of species obtained from interpolation

**GEOS-Chem**



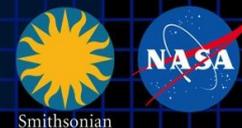
**Aircraft (CAMS)**



Zhu et al. (*ACP*, 2016)



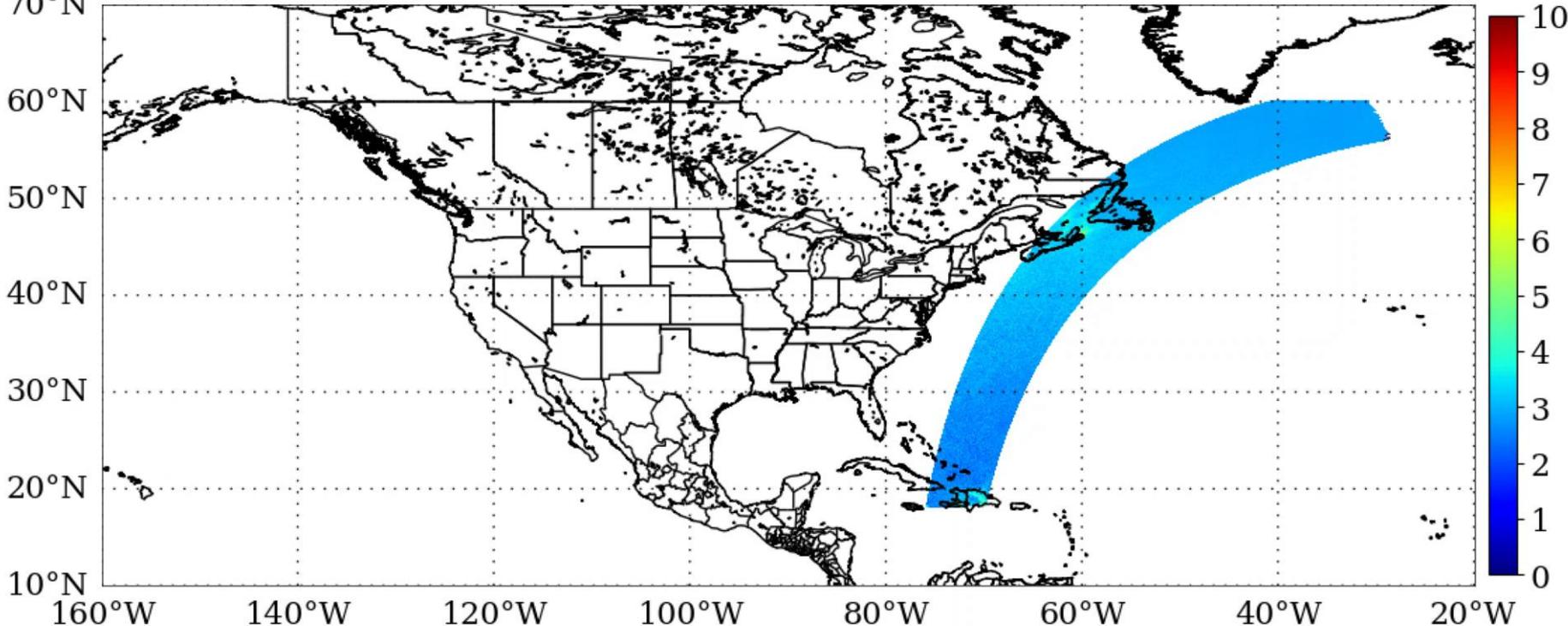
# Synthetic TEMPO data



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

20130908 1500UTC

TEMPO



NO<sub>2</sub> tropospheric column density (10<sup>15</sup> molec./cm<sup>2</sup>)

- Generating long-term archive of TEMPO proxy products
- Goal: Utilize TEMPO proxy data for applications to accelerate operational use of real TEMPO products after launch



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

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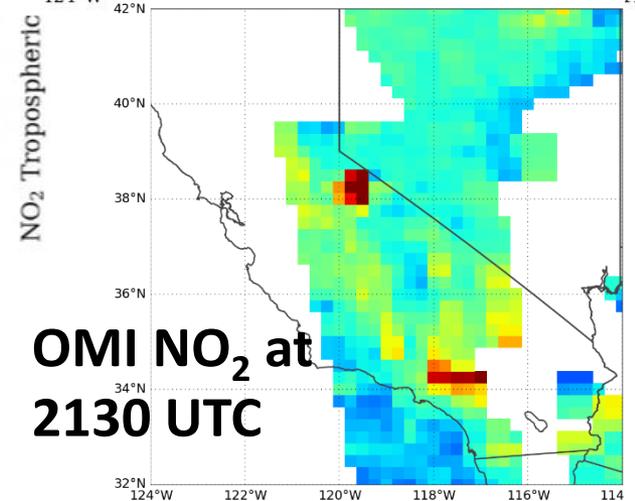
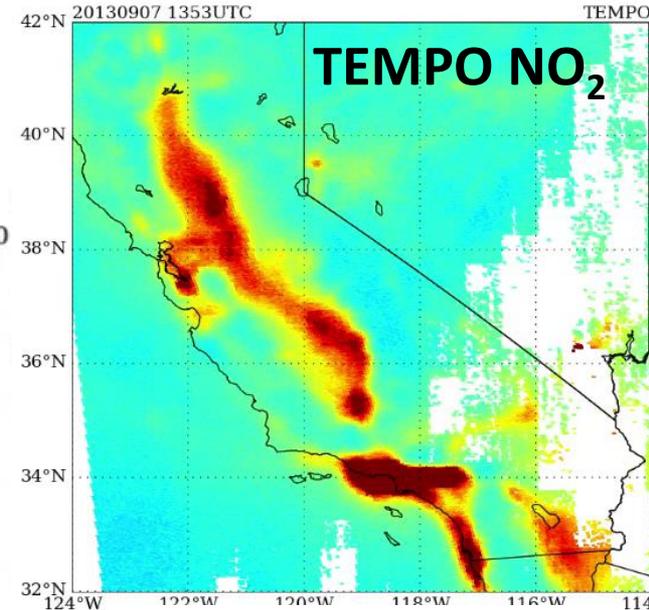
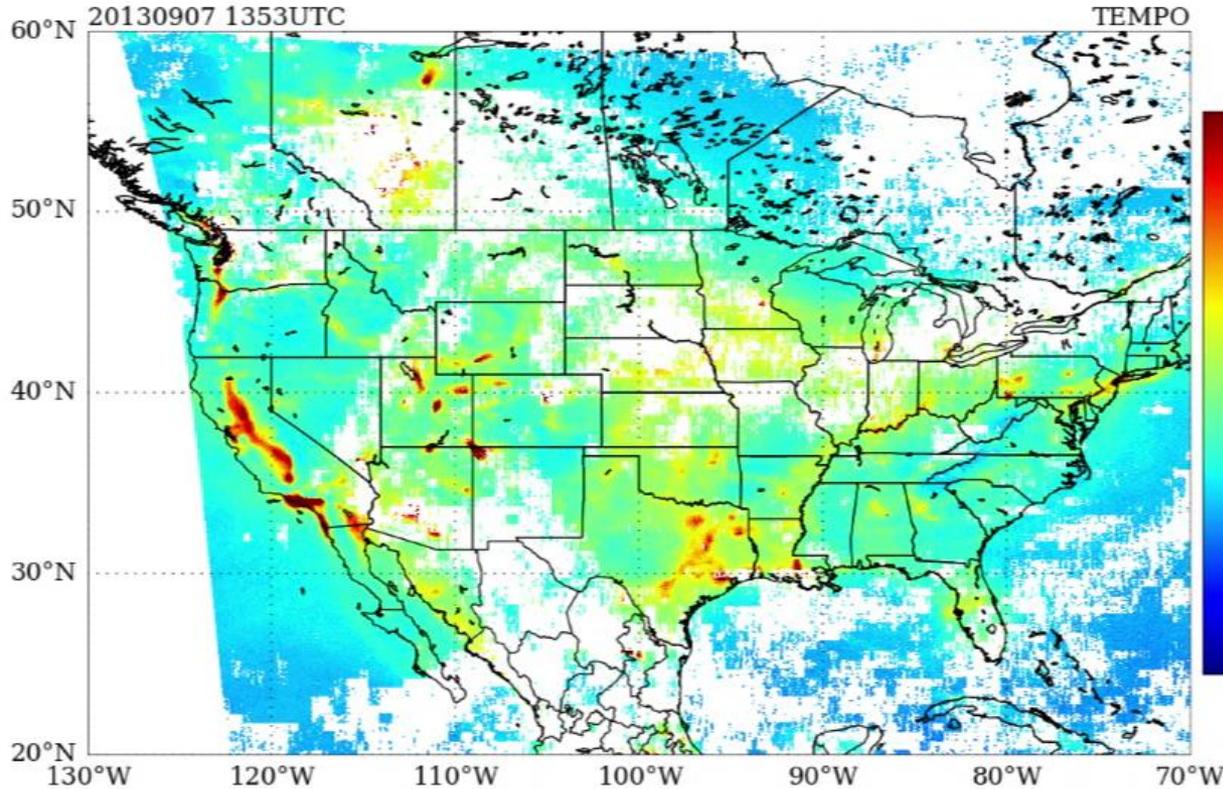




# Synthetic TEMPO data



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



- Diurnally varying mobile source emissions and smoke plumes shown in TEMPO proxy data



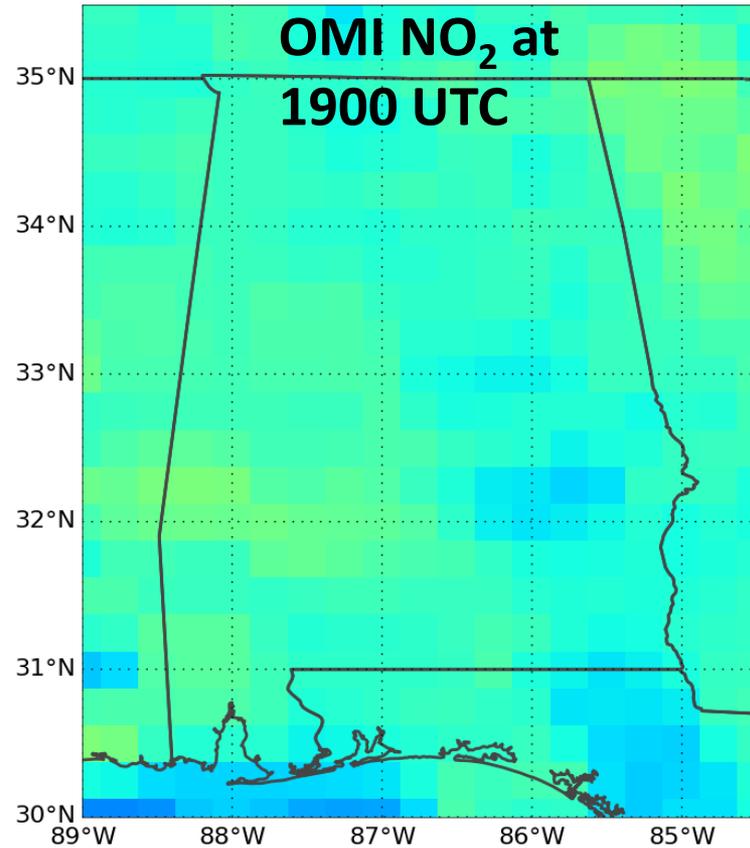
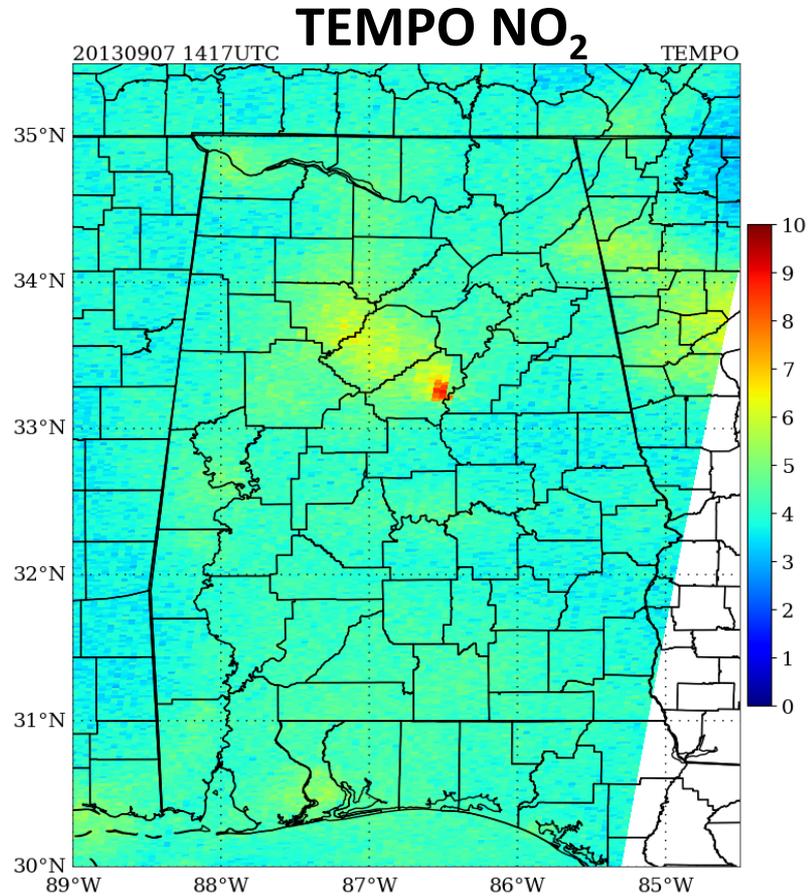
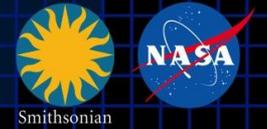
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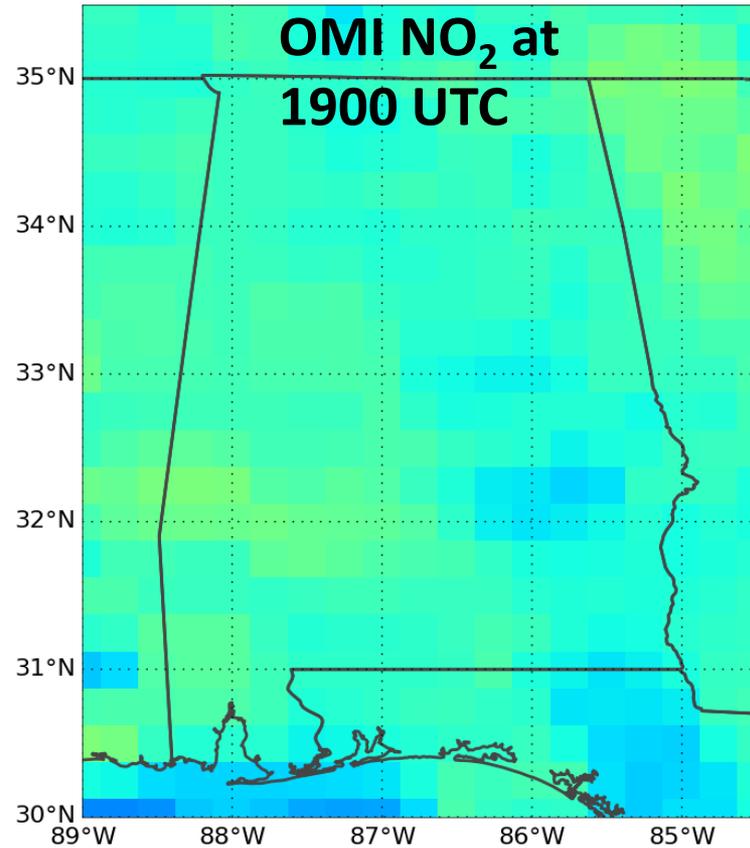
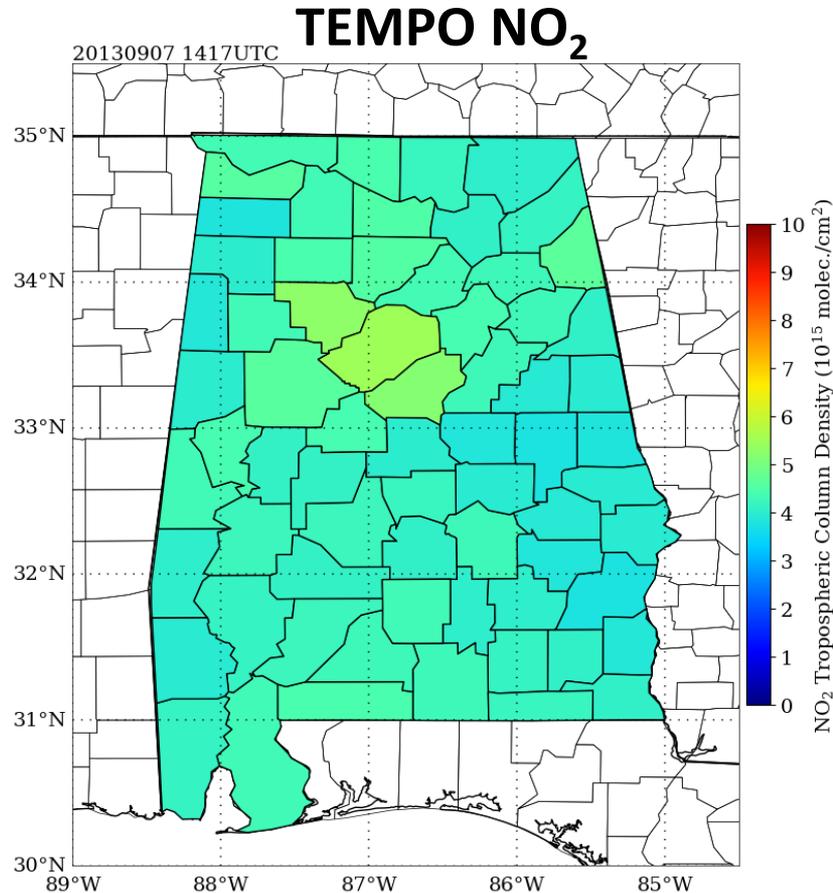
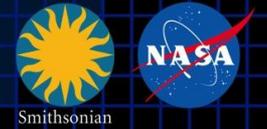


# Synthetic TEMPO data





# Synthetic TEMPO data



- TEMPO at county level, broader scale NO<sub>2</sub> field shows at county level, but NO<sub>2</sub> emission from Alabama Power Gaston Plant is no longer apparent





# Google Cloud Platform



← → ↻ https://console.cloud.google.com/storage/browser?folder=&organizationId=8

Google Cloud Platform TEMPO-HAQ

Browser CREATE BUCKET REFRESH DELETE

Filter by prefix...

Buckets

<input type="checkbox"/>	Name	Default storage class	Loc
<input type="checkbox"/>	tempo_al_county	Multi-Regional	Unit
<input type="checkbox"/>	tempo_I2	Multi-Regional	Unit

← → ↻ https://console.cloud.google.com/storage/browser/tempo\_I2?project=tempo-haq&folder=&organizationId

Google Cloud Platform TEMPO-HAQ

Bucket details EDIT BUCKET REFRESH BUCKET

tempo\_I2

Objects Overview Permissions Bucket Lock

Upload files Upload folder Create folder Manage holds Delete

Filter by prefix...

Buckets / tempo\_I2

<input type="checkbox"/>	Name	Size	Type
<input type="checkbox"/>	TEMPO_L2_V01_20130908T130001Z_S001G01.nc	55.49 MB	application/x-netcdf
<input type="checkbox"/>	TEMPO_L2_V01_20130908T130557Z_S001G02.nc	55.49 MB	application/x-netcdf
<input type="checkbox"/>	TEMPO_L2_V01_20130908T131153Z_S001G03.nc	55.49 MB	application/x-netcdf

← → ↻ https://console.cloud.google.com/storage/browser/tempo\_al\_county?project=tempo-haq&folder=&organizationId

Google Cloud Platform TEMPO-HAQ

Bucket details EDIT BUCKET REFRESH BUCKET

tempo\_al\_county

Objects Overview Permissions Bucket Lock

Upload files Upload folder Create folder Manage holds Delete

Filter by prefix...

Buckets / tempo\_al\_county

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<input type="checkbox"/>	TEMPO_HAQ_AL_20130908_1400.txt	3.66 KB	text/plain
<input type="checkbox"/>	TEMPO_HAQ_AL_20130908_1500.txt	3.64 KB	text/plain

Preparing and storing L2 products and formatted text files of gas concentrations and meteorology at county level for public health stakeholders (e.g., Alabama Hospital Association, Alabama Quality Assurance Foundation)



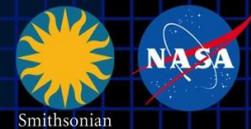
<https://weather.msfc.nasa.gov/sport/>

Document Title





# ESRI Visualization for TEMPO



← → ↻ https://msnswms.ndc.nasa.gov/portal/home/webmap/viewer.html?layers=94a1d1f5358e4a31b12a8fdac32825ca

Home ▾ tempo\_proxy

Details | Basemap | Print ▾ | Measure | Find address or place

Image Display

Set image display for: tempo\_proxy

**Renderer**

User Defined Renderer ▾

**Image Enhancement**

Symbology Type: ▾

Stretch: ▾

Apply contrast enhancements to improve the image display.

Stretch Type: ▾

Minimum and Maximum ▾

Stretch to the entire range of pixel values.

Gamma:  0.1 10

Dynamic range adjustment

Min	Max	Mean	Std. dev
0	10		

Color Ramp ▾

APPLY RESET CLOSE

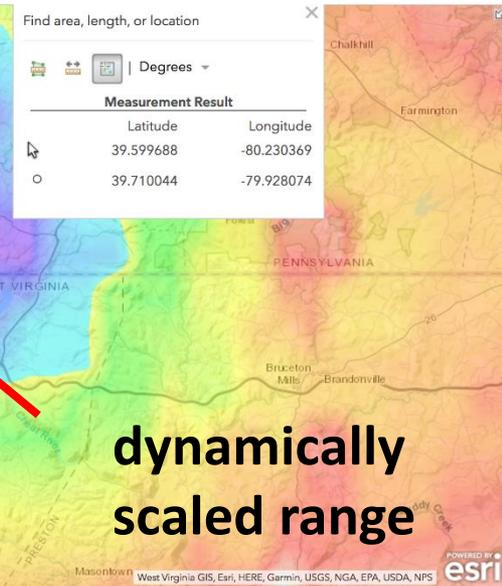
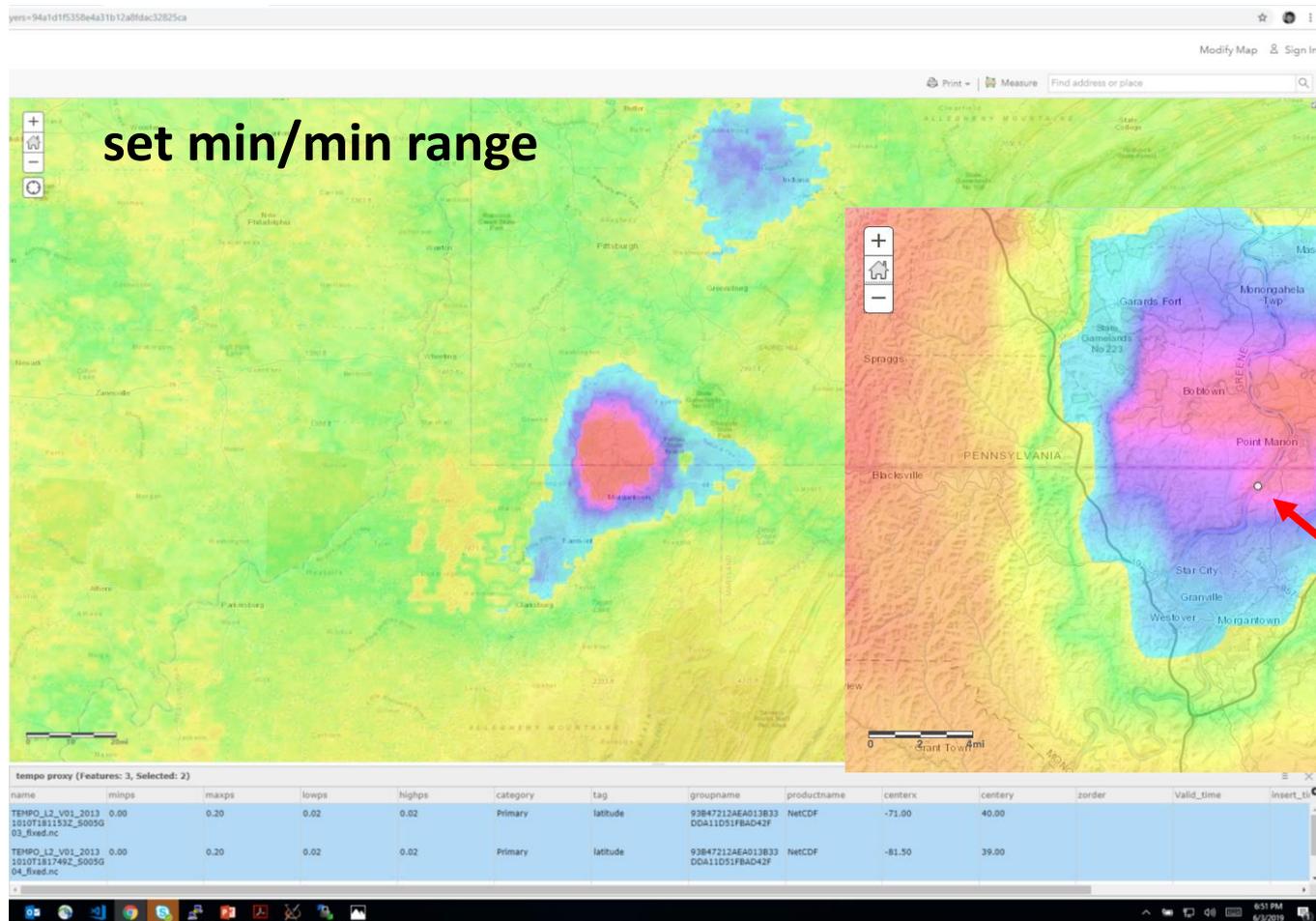
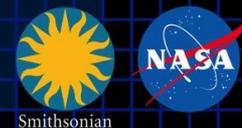
## Advantages of ESRI platform

- 1) Point and click feature for retrieving raw geophysical variables
- 2) Perform analysis via locally installed ArcGIS
- 3) Can ingest GRIB, NetCDF (CF compliant), GeoTIFF





# ESRI Visualization for TEMPO



Accurate geolocation of TEMPO data, high NO<sub>2</sub> associated with strong emissions from two active coal plants in area



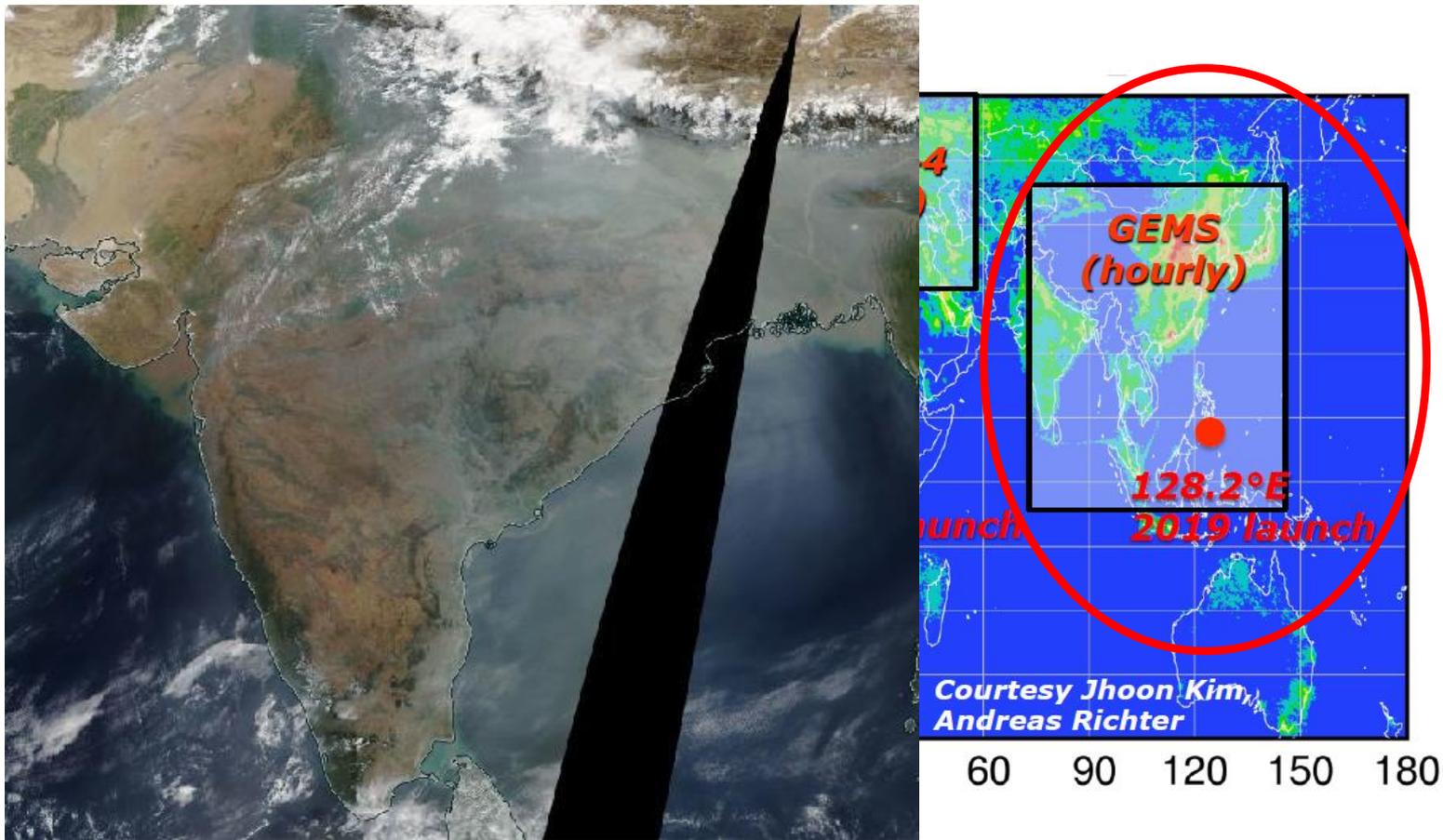
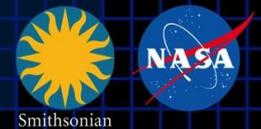
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Document Title





# Constellation of satellites

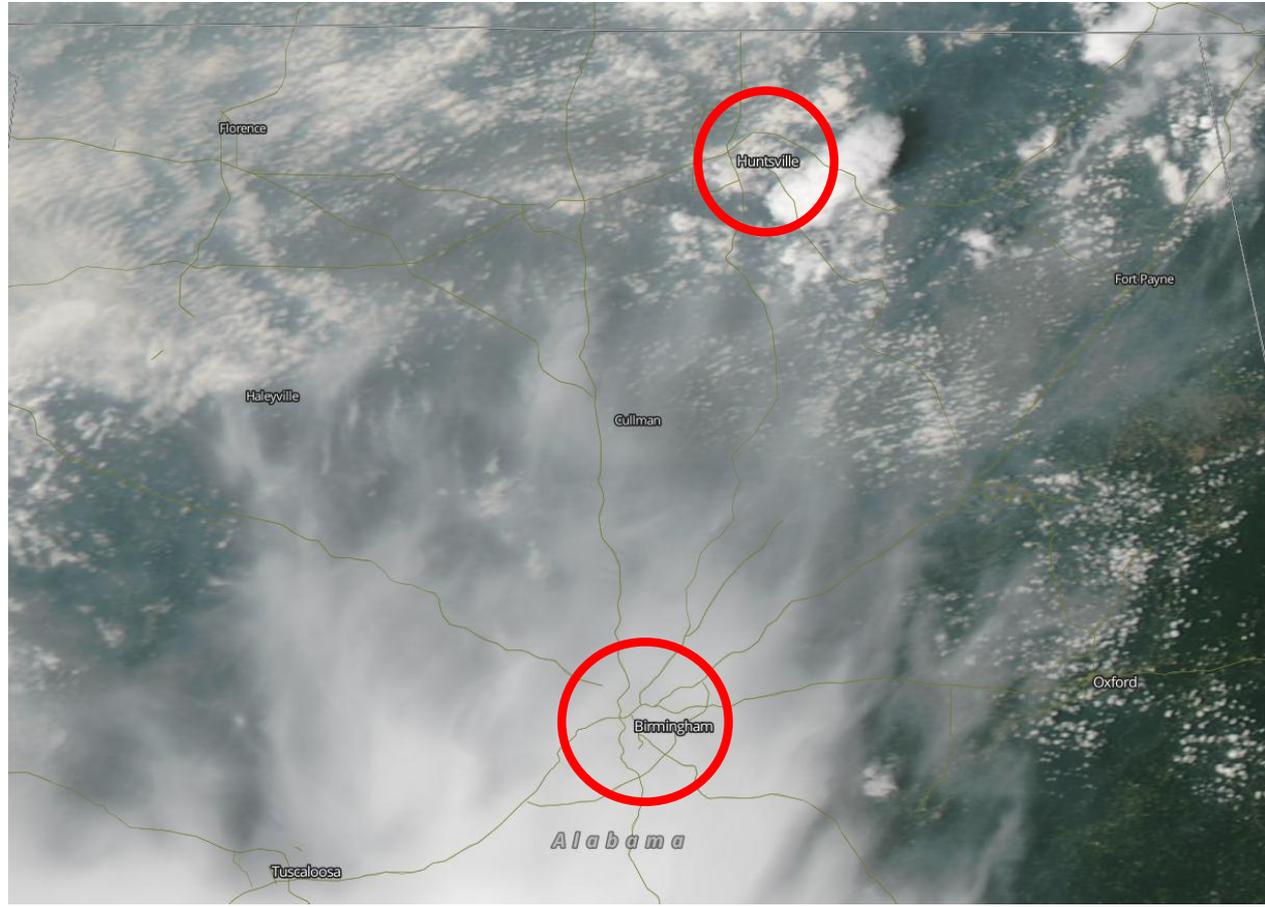
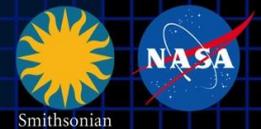


Proposed activity to start ingesting upcoming GEMS data into WRF-Chem modeling system over South Asia, which will help recognize future capabilities of TEMPO





# Pilot Health Study over AL



Deployment of 20 low-cost AQ sensors measuring  $O_3$ , CO, NO,  $NO_2$  and  $PM_{2.5}$ , along with surface meteorology in Madison County, AL by summer 2019

Additional 20 sensors to be deployed in Birmingham

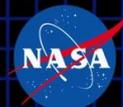
Hospital claims data for state of Alabama at county and zip code level

Combine health and AQ (TEMPO) data over AL to build a readmission rate model for reducing hospital costs related to readmissions





# TEMPO Activities at SPoRT



Our pre-launch activities can provide input to the Science Team on valuable fields/products to be accessible via Lance/Worldview

Fully ingest TEMPO proxy dataset from July 2013-June 2014 into ESRI platform for allowing effective analysis of L2 products

Compare to current WMS at SPoRT and interact with end users/stakeholders on preferred solution for real data

Setup FTP server for distributing proxy data to community, LDM solution for future real-time data

Plan to utilize TEMPO data along with hospital claims data over AL for public health study, begin building prediction system with proxy data

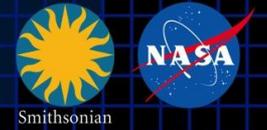
Proposed activity to start ingesting upcoming GEMS data into modeling system over South Asia, which will help identify future capabilities of TEMPO

**TEMPO public health conference at University of Alabama in Huntsville with conference date of 10/11/19, ARSET training sessions preceding the conference date**





# Thanks!



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