

US EPA Remote Sensing Information Gateway: An introduction

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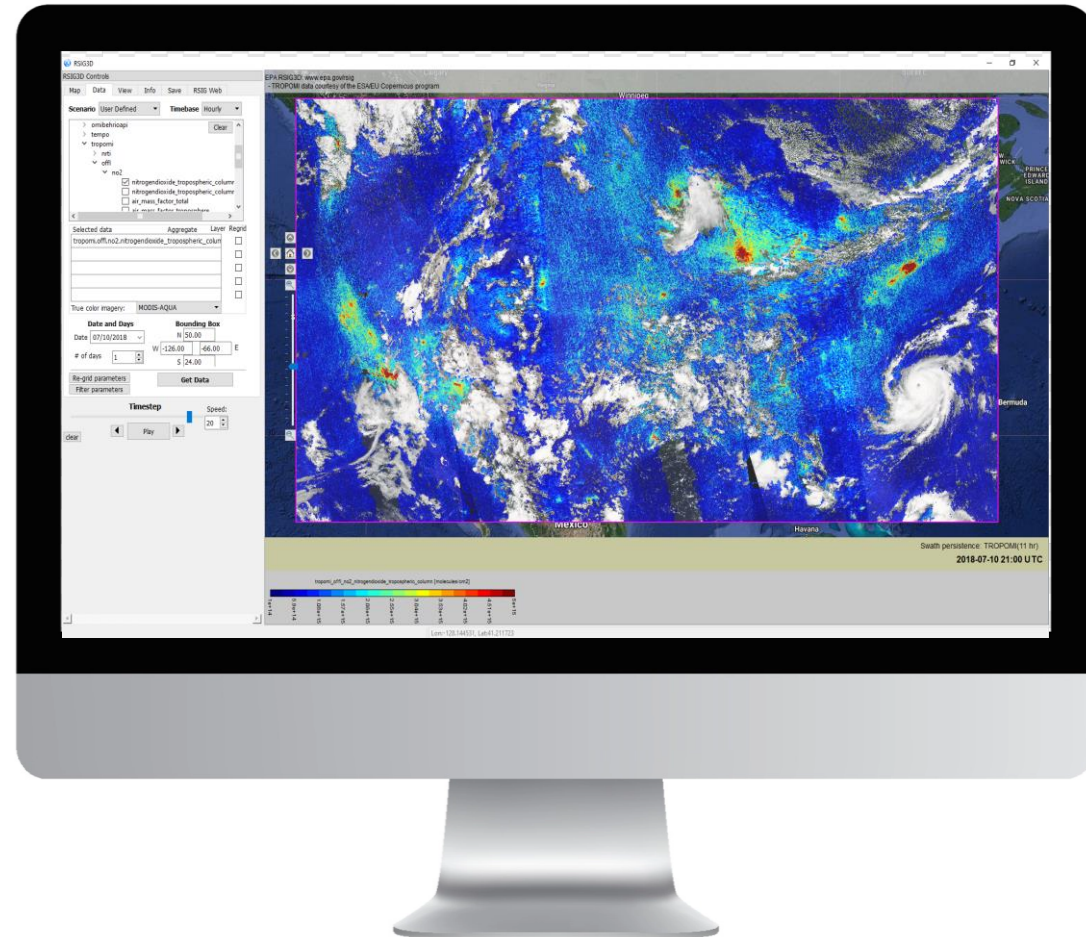
Applied Research Associates

Remote Sensing Information Gateway

- General Overview
- Popular Data Sets
- User Interface
- API/Python Case Studies

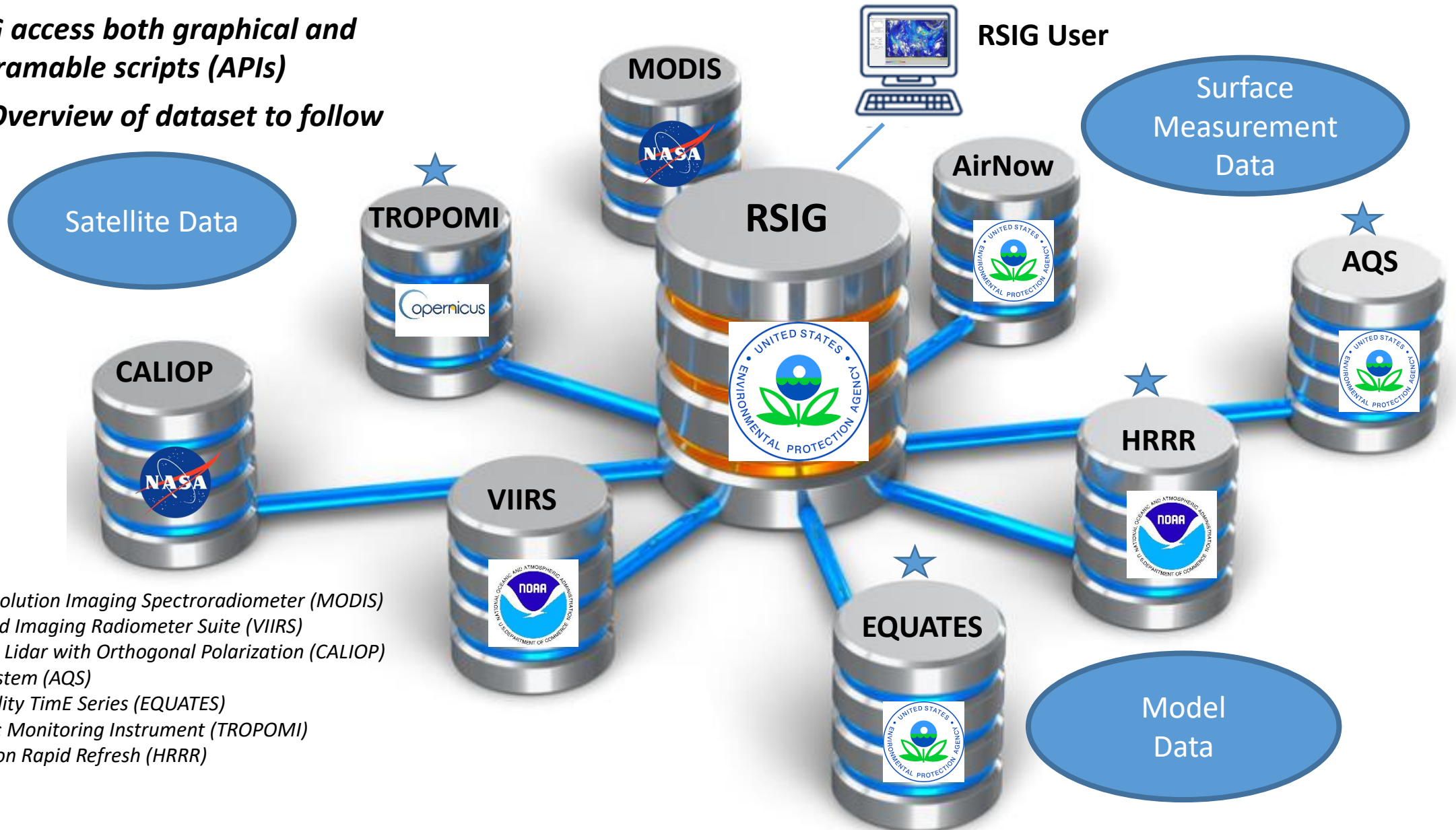
What is the Remote Sensing Information Gateway?

- Free multi-platform, scriptable software system which creates a consolidated access point to 100's of terabytes (TB) of air quality relevant model, measurement and satellite data sets
- Provides quick and easy ways of retrieving, visualizing and saving subsets of these selected geospatial atmospheric data
- Target users are air quality professionals, modelers, and researchers interested in historic and contemporary air-quality data



Popular Air Quality Datasets

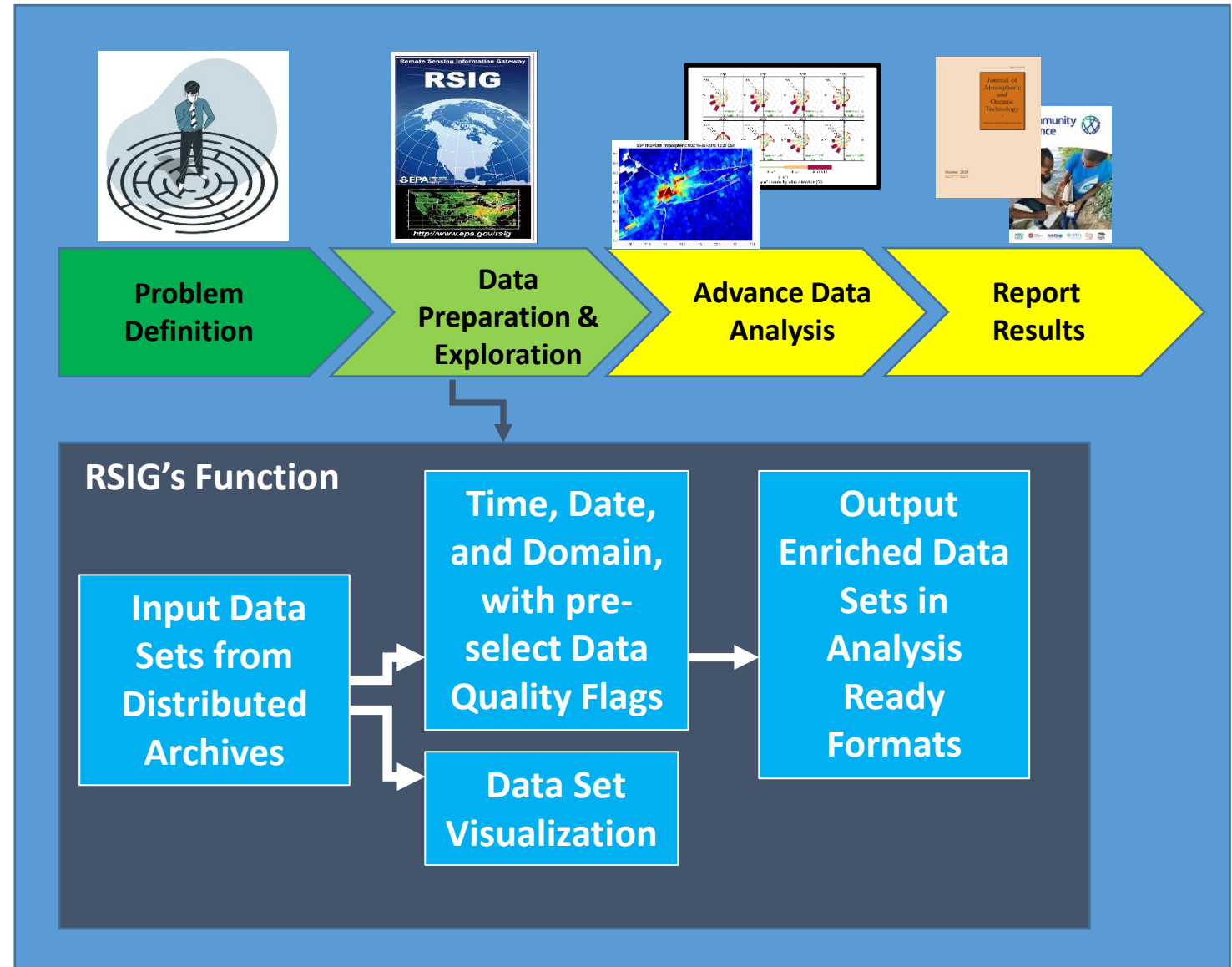
- RSIG access both graphical and programable scripts (APIs)
- ★ Overview of dataset to follow



Moderate Resolution Imaging Spectroradiometer (MODIS)
Visible Infrared Imaging Radiometer Suite (VIIRS)
Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)
Air Quality System (AQS)
EPA's Air QUALity Time Series (EQUATES)
TROPOspheric Monitoring Instrument (TROPOMI)
High-Resolution Rapid Refresh (HRRR)

Enabling Improved Data Access

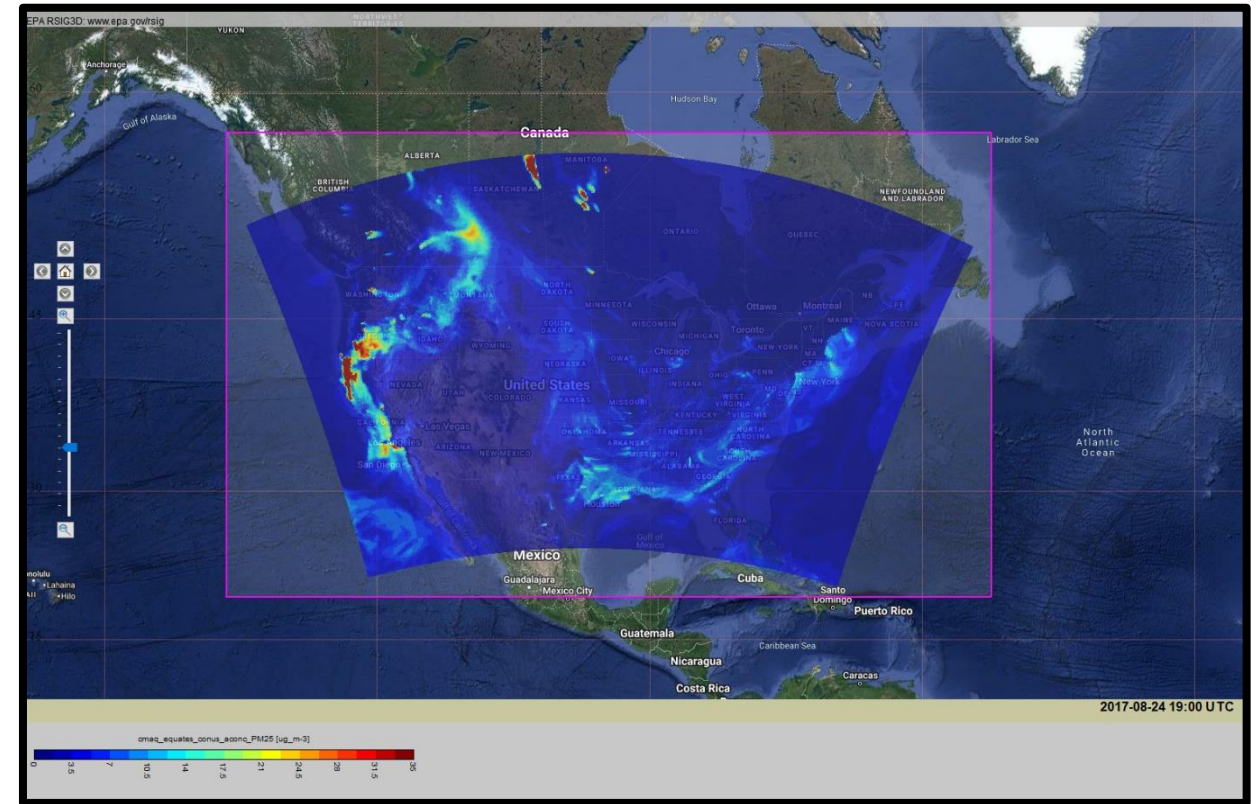
- Air quality management decisions required under the Clean Air Act are often informed through analyses of complex data
- RSIG facilitates access to complex data sets through web services and allow users to save data in an analysis-ready-format for further use in their own software, R, python, excel, etc.



Select Data Sets Overview

EPA's Air QUALity Time Series (EQUATES) Project

- Data Set Type: Modeled datasets for the Conterminous U.S. (CONUS) at a 12km horizontal grid spacing and the Northern Hemisphere at a 108km grid spacing
- Dates: 2002-2017+ (future data to be added as model runs completed)
- Based on Weather Research and Forecasting (WRF) model v.4.1.1 for simulating weather conditions and EPA's Community Multiscale Air Quality (CMAQ) model v.5.3.2 for air quality modeling
- Types of variables: surface and upper model level gas and aerosol concentration, total column, deposition, metrological
- Typical Application Uses: air quality trends, epidemiological studies, critical loads analyses

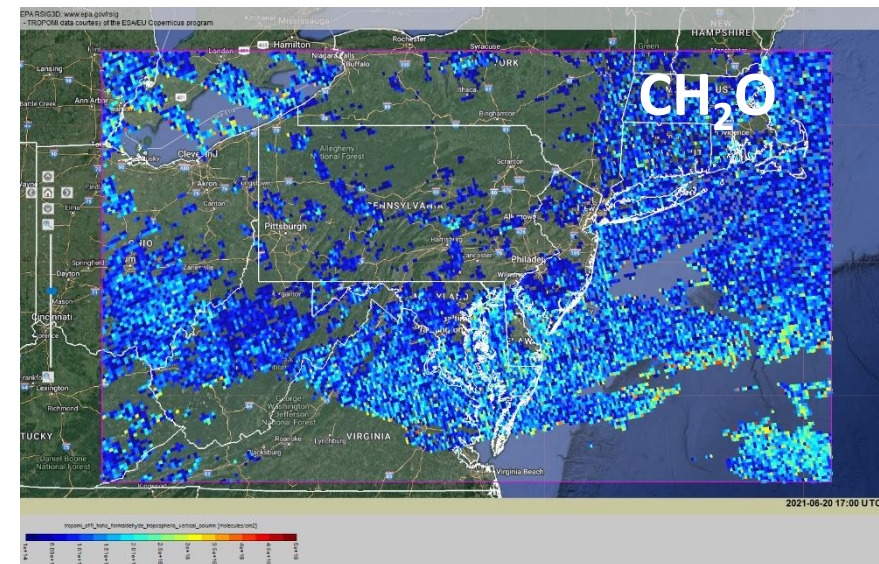
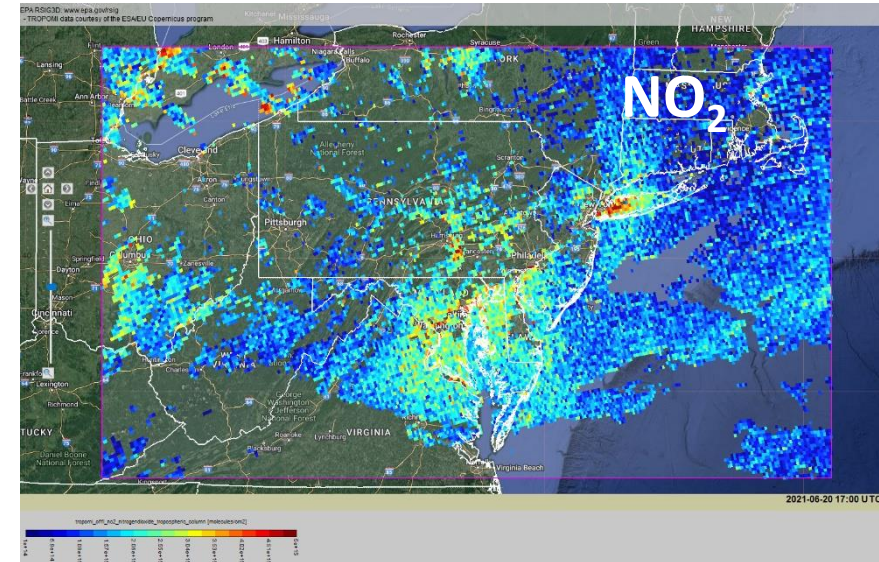


Metadata: <https://www.epa.gov/cmaq/equates>

Select Data Sets Overview

Copernicus (ESA) TROPospheric Monitoring Instrument (TROPOMI)

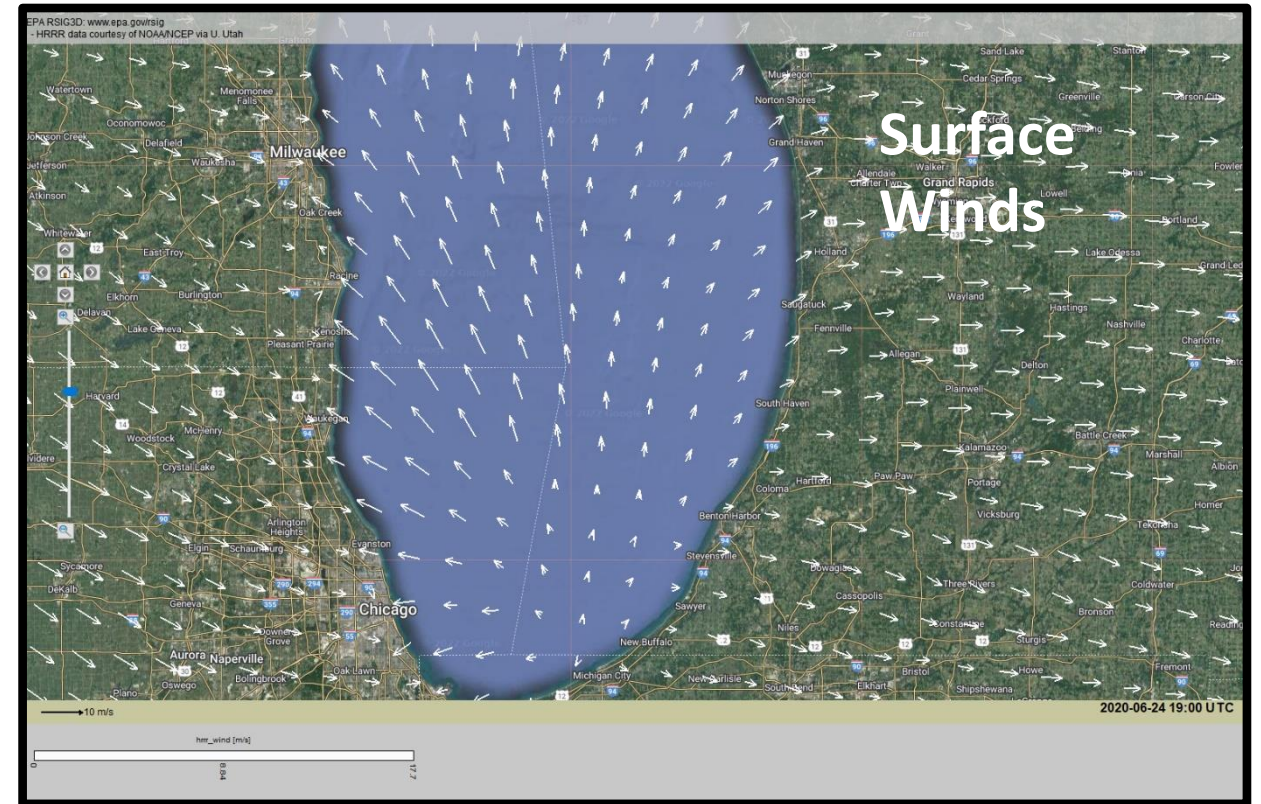
- Data Set Type: Satellite dataset from Copernicus Sentinel-5 Precursor satellite with daily global cover at various grid spacing
- Dates: June 2018-present
- Types of variables: Tropospheric Column Abundances of nitrogen dioxide, methane, carbon monoxide and formaldehyde with predetermined QA metrics
- Typical Application Uses: model evaluation, air quality event and trends analysis, pollutant emissions research, air pollutant exposure studies
- Typical Data Latency: Near-Real Time (NRT) vs Offline (OFFL) ~1 day to 2 weeks



Select Data Sets Overview

NOAA High-Resolution Rapid Refresh (HRRR)

- Data Set Type: Modeled datasets for the Conterminous U.S. (CONUS) at a 3km horizontal grid spacing
- Dates: 2014-present (future data to be added as model runs completed)
- Types of variables: surface winds (in the process of adding additional meteorological variables and altitudes)
- Typical Application Uses: assess frontal passages, sea or land breezes formation.
- Typical Data Latency: less than 4 hours

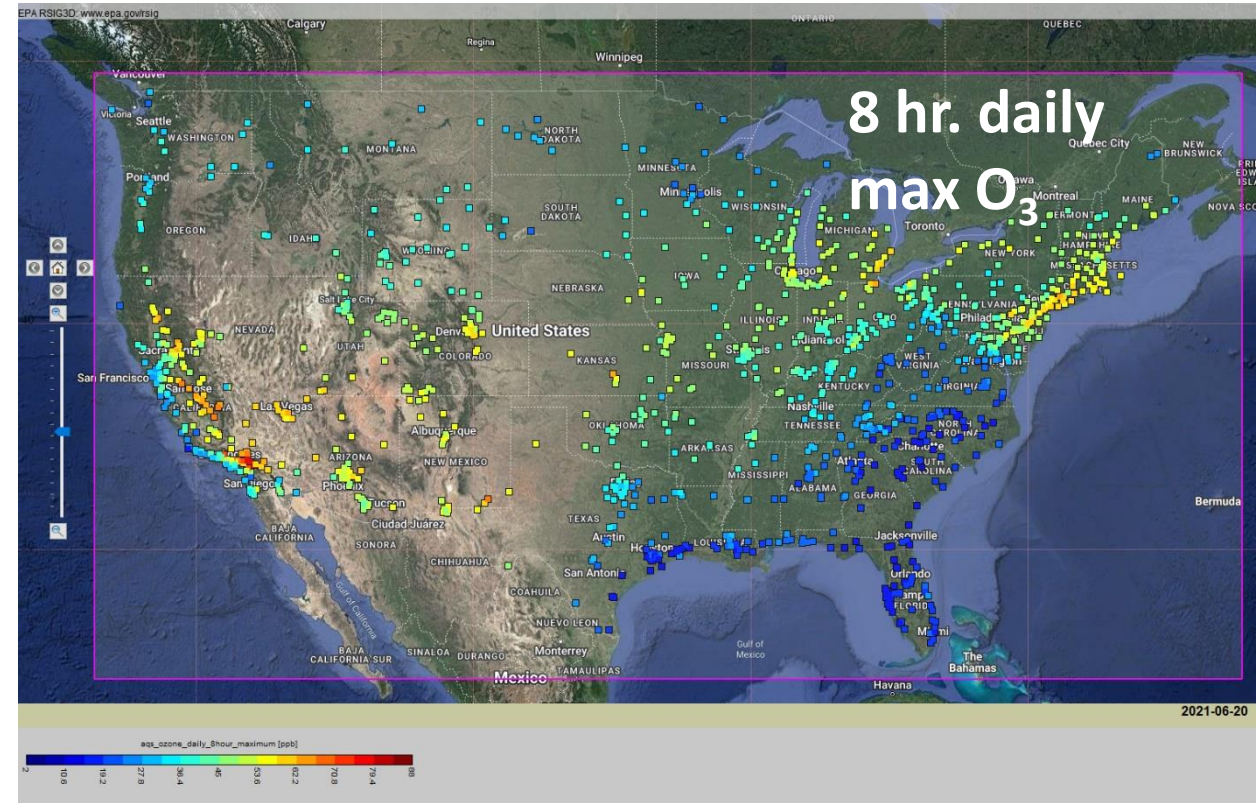


Metadata: <https://hive.utah.edu/concern/datasets/47429912h>

Select Data Sets Overview

EPA's Air Quality System (AQS) Database

- Data Set Type: Measurement - ambient air pollution data collected by EPA, state, local, and tribal air pollution control agencies from over thousands of monitors
- Dates: 1998 - present
- Types of variables: Major pollutants and meteorology (O_3 , $PM_{2.5}$, NO_2 , SO_2 , T, RH, WS, WD)
- Typical Application Uses: assist in attainment/non-attainment designations, model evaluation, air quality event and trends analysis, pollutant emissions research, air pollutant exposure studies
- Typical Data Latency: 6 months – use AirNow for more recent data



Metadata: <https://www.epa.gov/aqs>

Future Data Sets

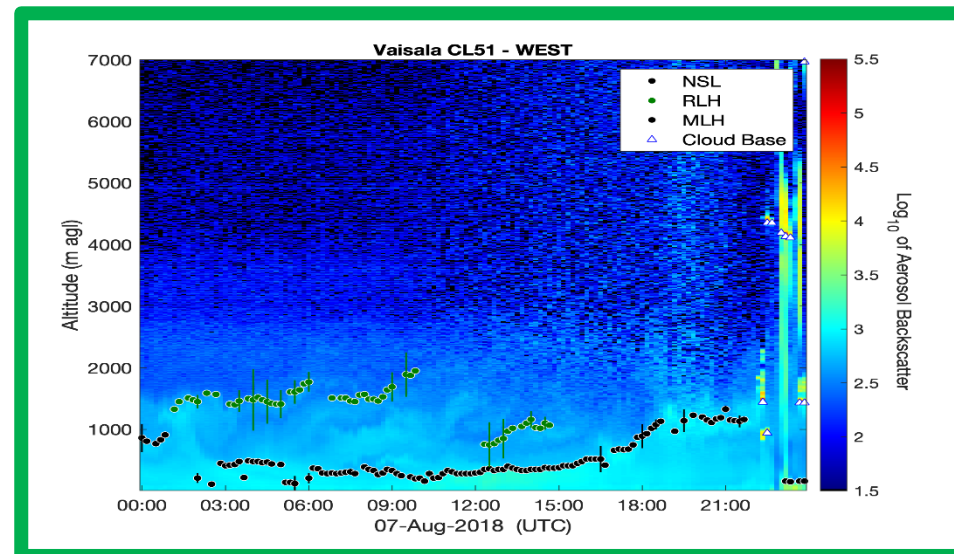
Tropospheric Emissions: Monitoring of Pollution –TEMPO

- The first space-based instrument to monitor major air pollutants across the North American continent every daylight hour at high spatial resolution
- Launch – Early 2023
- Public Release of Data Anticipated Late 2023




Unified Ceilometer Network–UCN

- The first operational ceilometer network focused on aerosol profiles and planetary boundary layer heights
- Developed by EPA, University of Maryland, Baltimore County (UMBC), NASA, state & local agencies
- Data Anticipated Late 2022



RSIG3D User Interface Orientation

www.epa.gov/rsig



“Getting started”
video tutorials

Web access to
RSIG data

Standalone/remote
CMAQ* file reader
tutorial

How RSIG re grids
data

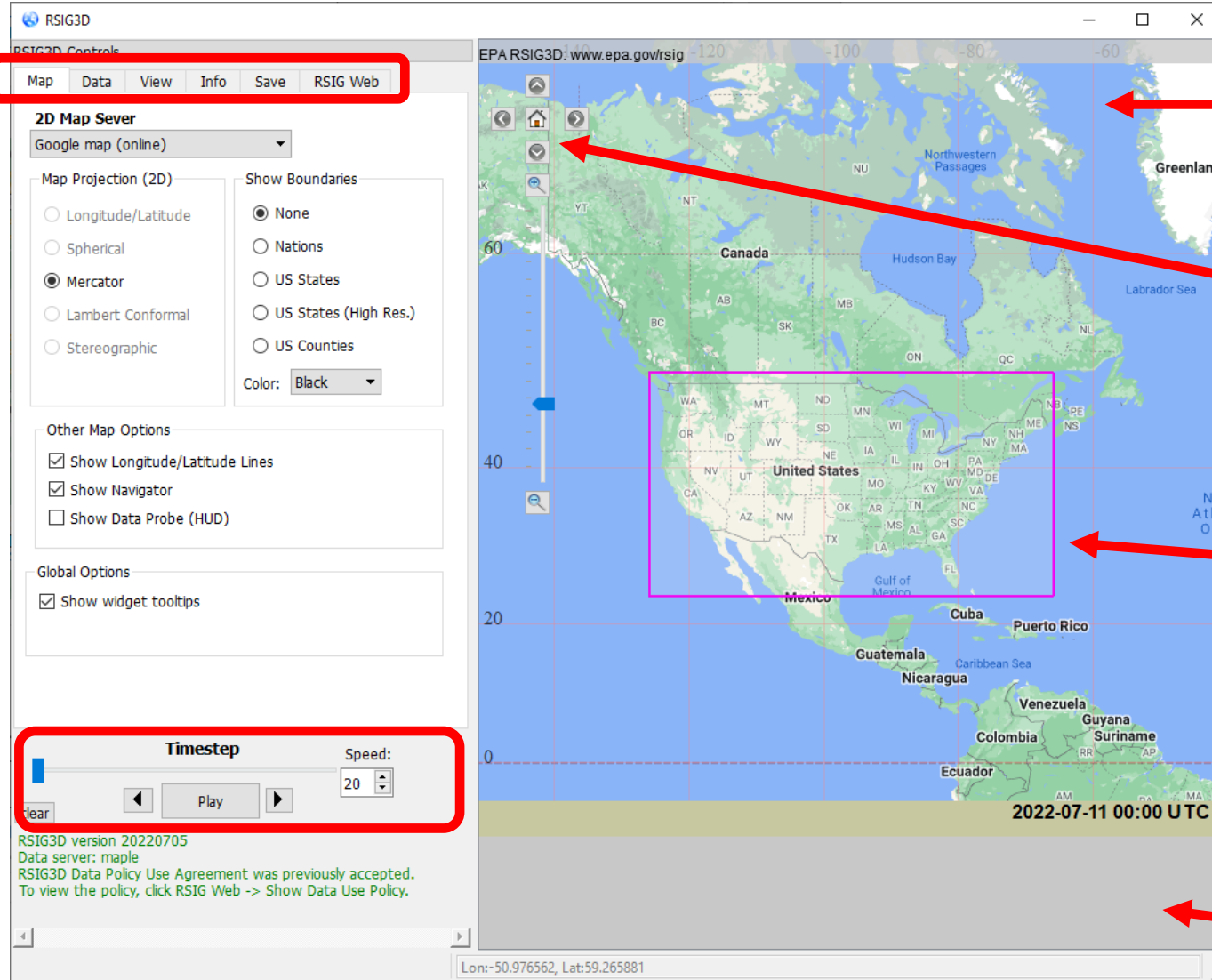
RSIG3D application
download

- Windows
- Mac
- Linux (RHEL7)

*Community Multiscale
Air Quality Modeling
System

RSIG3D User Interface Orientation

Control tabs



Map / data display

Map Controls

Bounding box for data retrievals

Time and date

Colorbar area

Tab specific controls

Animation controls

Useful info including full WCS string

RSIG3D User Interface – Map Tab

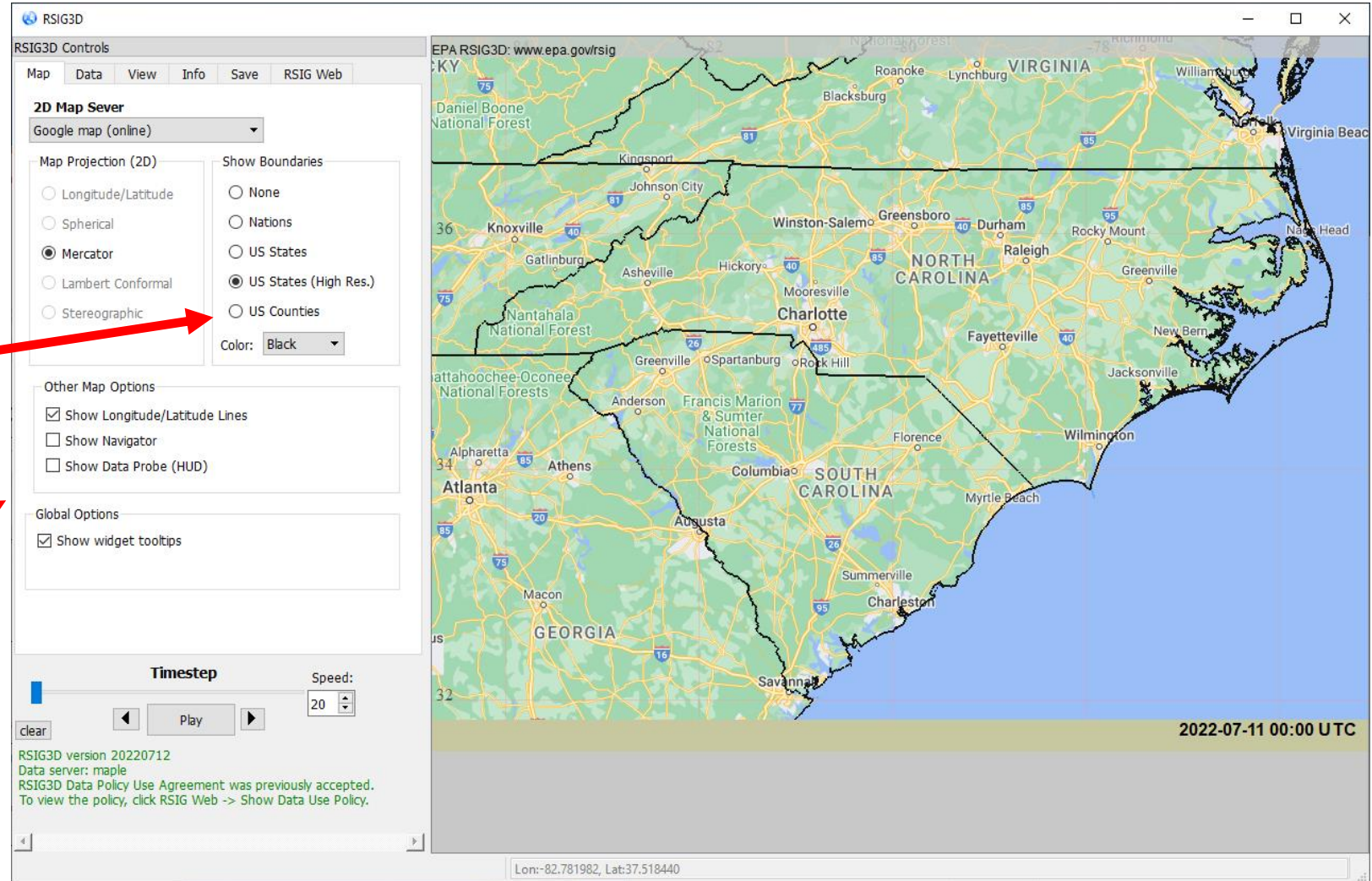
Basemap

Map
projection

Political
boundaries

Other options

- Grid lines
- Map navigator
- Data probe
- Tooltips



The screenshot displays the RSIG3D web application interface. On the left is a control panel with the following sections:

- 2D Map Server:** A dropdown menu set to "Google map (online)".
- Map Projection (2D):** Radio buttons for Longitude/Latitude, Spherical, Mercator (selected), Lambert Conformal, and Stereographic.
- Show Boundaries:** Radio buttons for None, Nations, US States, US States (High Res.) (selected), and US Counties. A "Color:" dropdown is set to "Black".
- Other Map Options:** Checkboxes for "Show Longitude/Latitude Lines" (checked), "Show Navigator", and "Show Data Probe (HUD)".
- Global Options:** A checkbox for "Show widget tooltips" (checked).
- Timestep:** A play button, a "Speed:" dropdown set to "20", and a "clear" button.
- Footer:** "RSIG3D version 20220712", "Data server: maple", and a link to the "RSIG3D Data Policy Use Agreement".

The main map area shows a satellite-style basemap of the Southeastern United States, including Virginia, North Carolina, South Carolina, and Georgia. Political boundaries are overlaid in black. The map includes labels for major cities like Atlanta, Charlotte, and Raleigh, as well as national forests. The bottom right corner of the map area shows the date and time: "2022-07-11 00:00 UTC". The bottom status bar displays coordinates: "Lon:-82.781982, Lat:37.518440".

RSIG3D User Interface – Data Tab

Time base (hourly, daily, or monthly)

Data selection tree

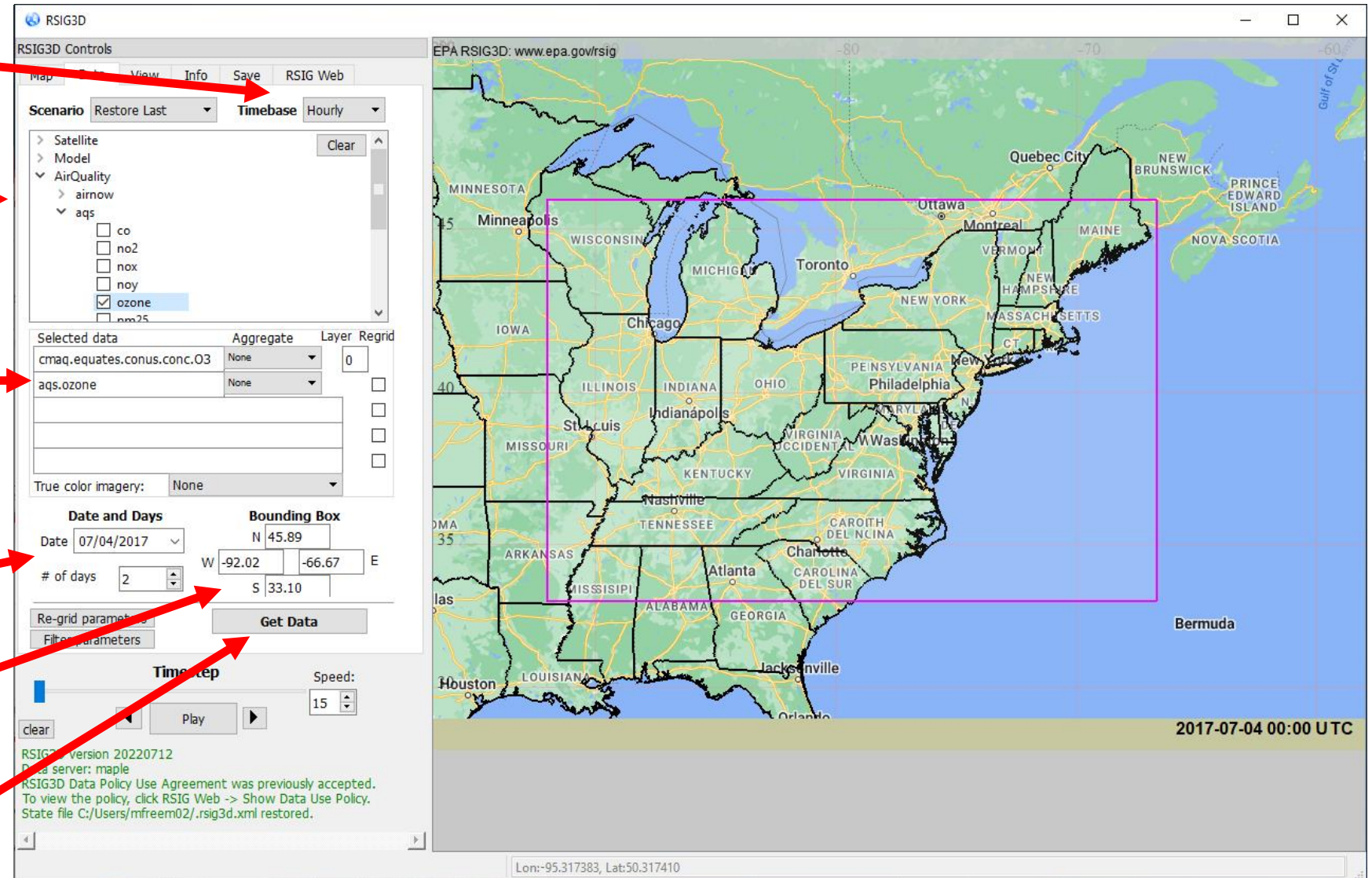
- 27 sources
- 4148 variables

Selected variables appear here (up to five)

Date and number of days to process

Bounding box (or draw with mouse)

Get Data!



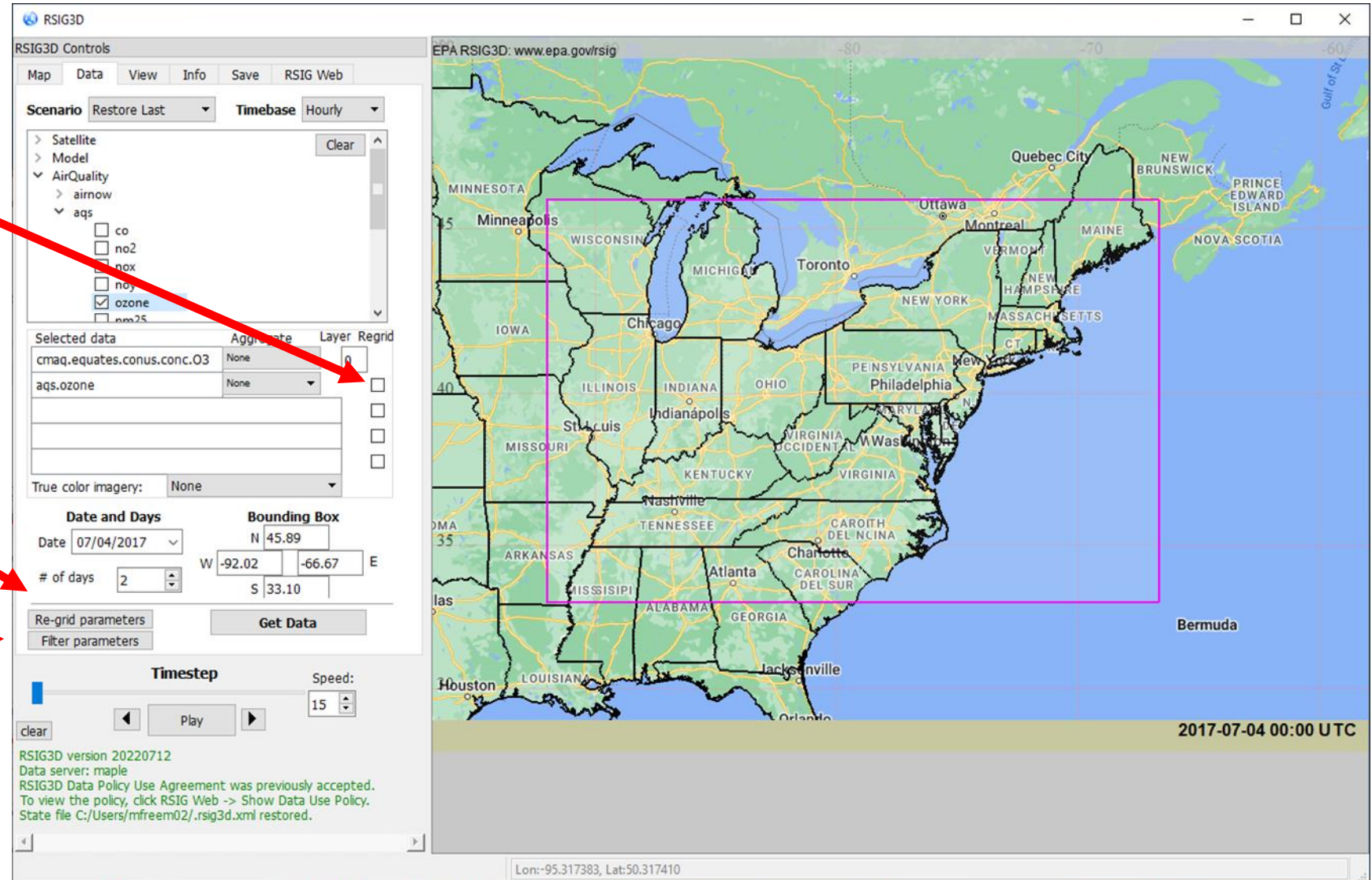
RSIG3D User Interface – Data Tab

Advanced options

Each data type can optionally be interpolated (regridded) to CMAQ or other grids

Regridding parameters can be specified here

Some data sources have filter or quality control parameters that can be specified here



The screenshot shows the RSIG3D web application interface. The main map displays the Eastern United States with a purple rectangular bounding box. The interface includes several control panels:

- Scenario:** Restore Last, Timebase: Hourly
- Data Selection:** A tree view showing 'Satellite', 'Model', and 'AirQuality'. Under 'AirQuality', 'airnow' is expanded to show 'aqc' with a list of pollutants: co, no2, nox, noy, ozone (checked), and pm25.
- Selected data table:**

Selected data	Aggregate	Layer	Regrid
cmaq.equates.conus.conc.O3	None		<input type="checkbox"/>
aqc.ozone	None		<input type="checkbox"/>
			<input type="checkbox"/>
			<input type="checkbox"/>
- Date and Days:** Date: 07/04/2017, # of days: 2
- Bounding Box:** N: 45.89, W: -92.02, E: -66.67, S: 33.10
- Buttons:** Re-grid parameters, Filter parameters, Get Data
- Timestep:** Speed: 15, Play button
- Footer:** RSIG3D version 20220712, Data server: maple, RSIG3D Data Policy Use Agreement was previously accepted. To view the policy, click RSIG Web -> Show Data Use Policy. State file C:/Users/mfrem02/.rsig3d.xml restored.

Regridding parameters

Regrid Parameters [?] [X]

CMAQ grid: CONUS (EQUATES) **Regrid method:** Weighted (1/r²) **Aggregation:** None

CMAQ grid parameters

VGTYPE:	Hemisphere	GDTYP:	2	m/s ²
NCOLS:	AQMEII	P_ALP:	33.00	deg
NROWS:	AQMEII_NA	P_BET:	45.00	deg
NLAYS:	AQMEII_EU	P_GAM:	-97.00	deg
XORIG:	DISCOVER-CONUS	XCENT:	-97.00	deg
YORIG:	DISCOVER-EAST	YCENT:	40.00	deg
XCELL:	DISCOVER-MD	Earth Radius:	6370000	m
YCELL:				
VGTOP:				
VGLVLS:				

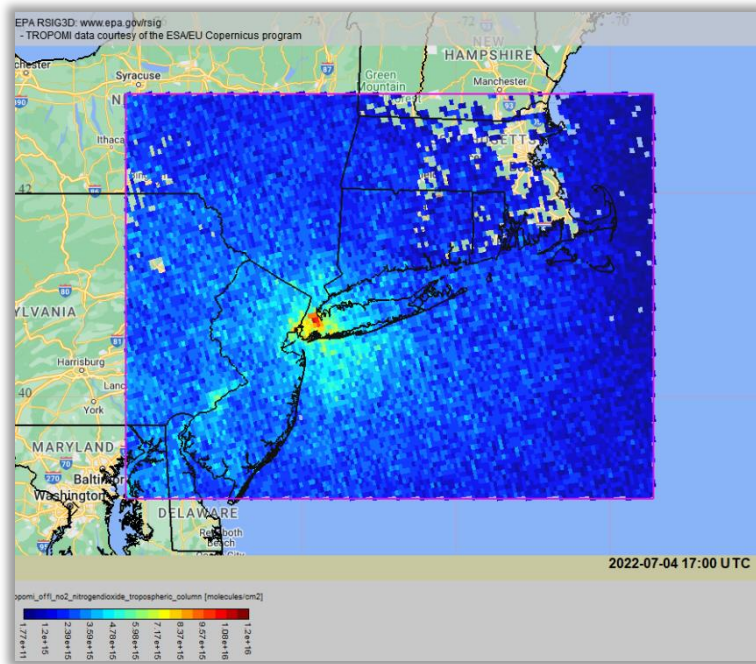
Constants

g:	9.81	m/s ²
R:	287.04	J/kg/K
A:	50.00	K
T0:	290.00	K
P0:	100000.00	Pa

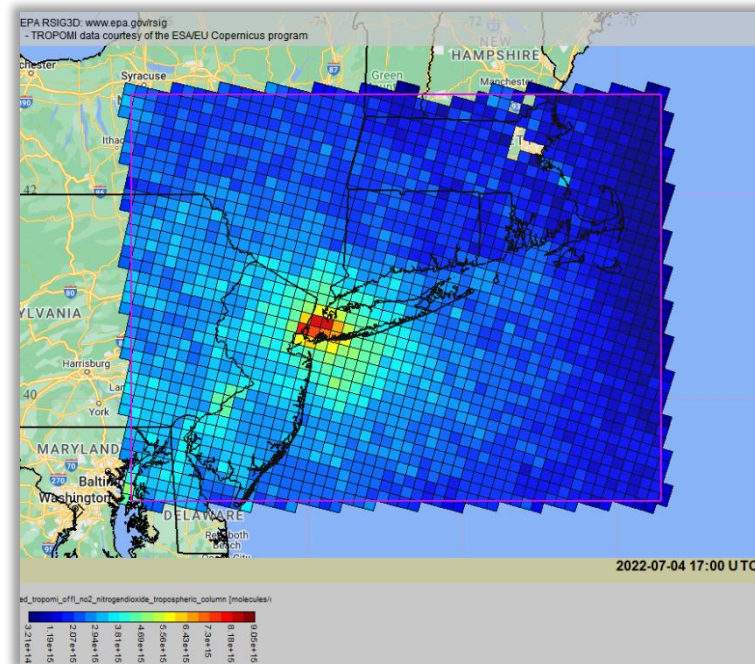
VGLVLS: .97, 0.96, 0.95, 0.94, 0.93, 0.92, 0.91, 0.9, 0.88, 0.86, 0.84, 0.82, 0.8, 0.77, 0.74, 0.7, 0.65, 0.6, 0.55, 0.5, 0.45, 0.4, 0.35, 0.3, 0.25, 0.2, 0.15, 0.1, 0.05, 0.0

[Reset] [Cancel] [Accept]

TROPOMI NO₂, native resolution



TROPOMI NO₂, regridded to CMAQ EQUATES 12km CONUS grid



RSIG3D User Interface – View Tab

Select the variable on which to operate

Visibility toggle

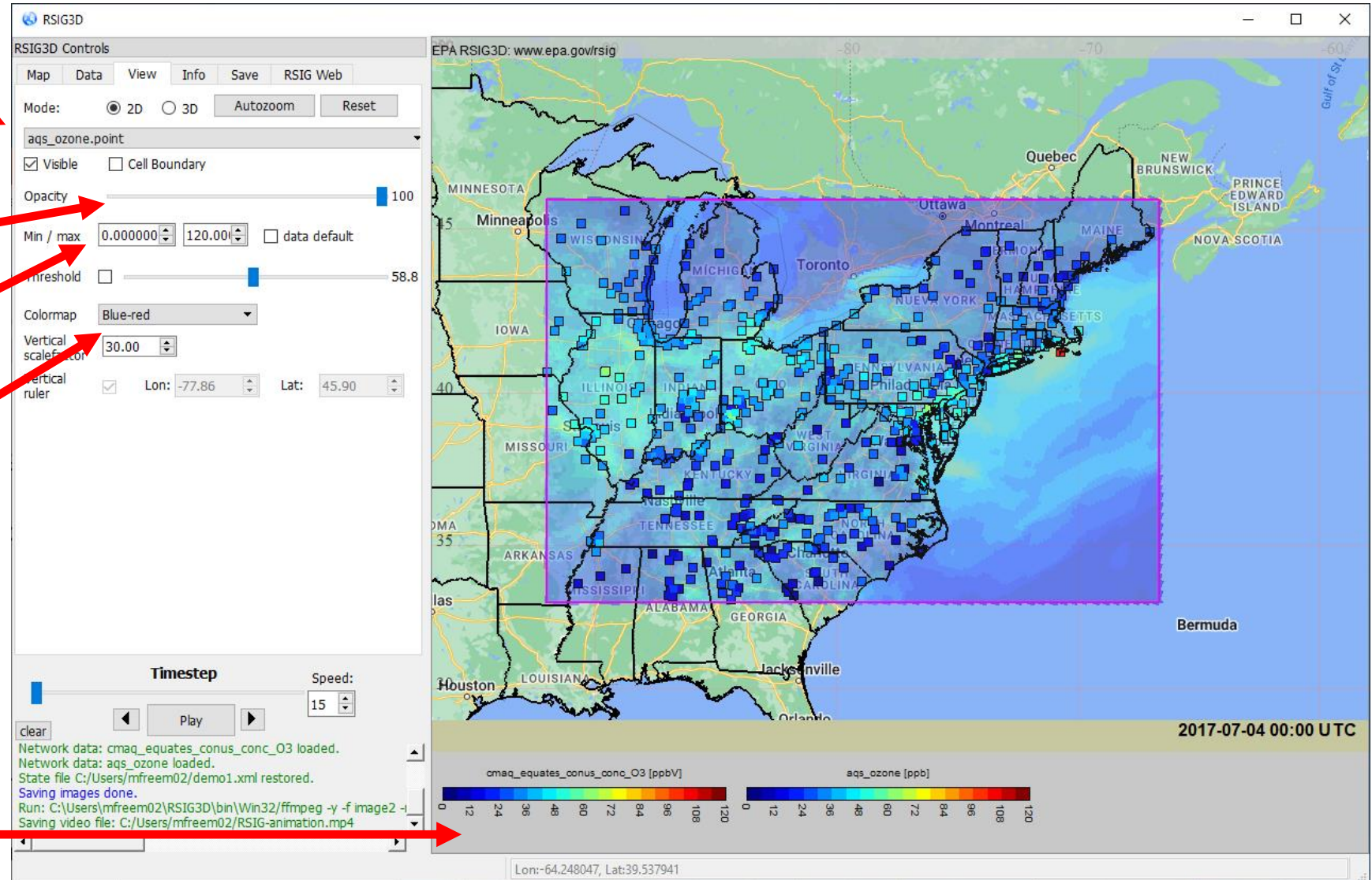
Opacity

Data range to display

Color map

Animation controls

Color bars for each variable shown here



RSIG3D Controls

Map Data View Info Save RSIG Web

Mode: 2D 3D Autozoom Reset

aq5_ozone.point

Visible Cell Boundary

Opacity: 100

Min / max: 0.000000 120.00 data default

Refresh: 58.8

Colormap: Blue-red

Vertical scale factor: 30.00

Vertical ruler: Lon: -77.86 Lat: 45.90

Timestep: [Slider] Speed: 15

clear [Play] [Stop]

Network data: cmaq_equates_conus_conc_O3 loaded.
Network data: aq5_ozone loaded.
State file C:/Users/mfreem02/demo1.xml restored.
Saving images done.
Run: C:/Users/mfreem02/RSIG3D/bin/Win32/ffmpeg -y -f image2 -i
Saving video file: C:/Users/mfreem02/RSIG-animation.mp4

2017-07-04 00:00 UTC

cmaq_equates_conus_conc_O3 [ppbV] aq5_ozone [ppb]

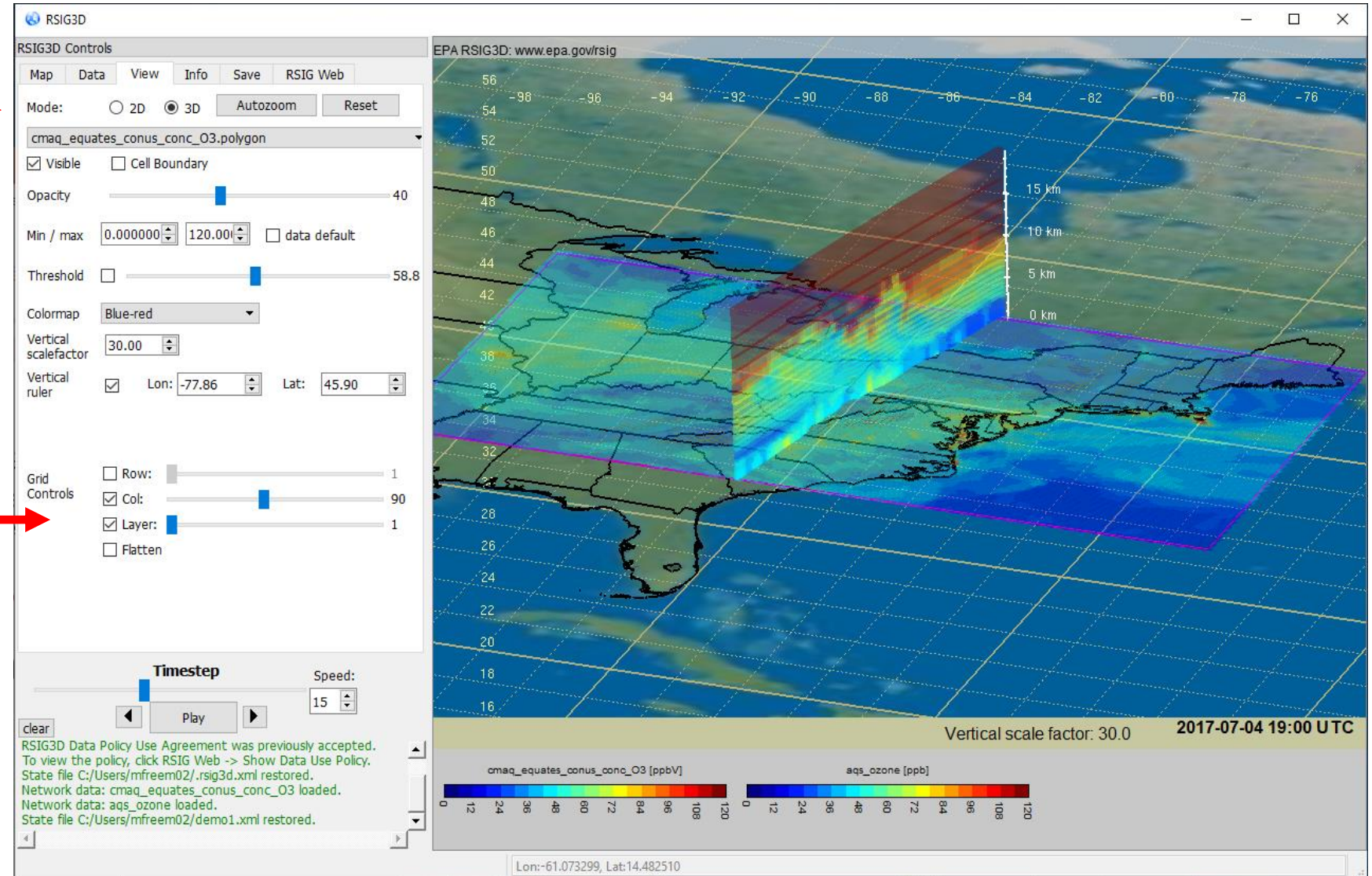
Lon: -64.248047, Lat: 39.537941

RSIG3D User Interface – View Tab

Advanced options

Visualization mode
(2D or 3D) →

Data specific controls
(here to manipulate
CMAQ “slice planes”) →



RSIG3D User Interface – Save Tab

Data formats

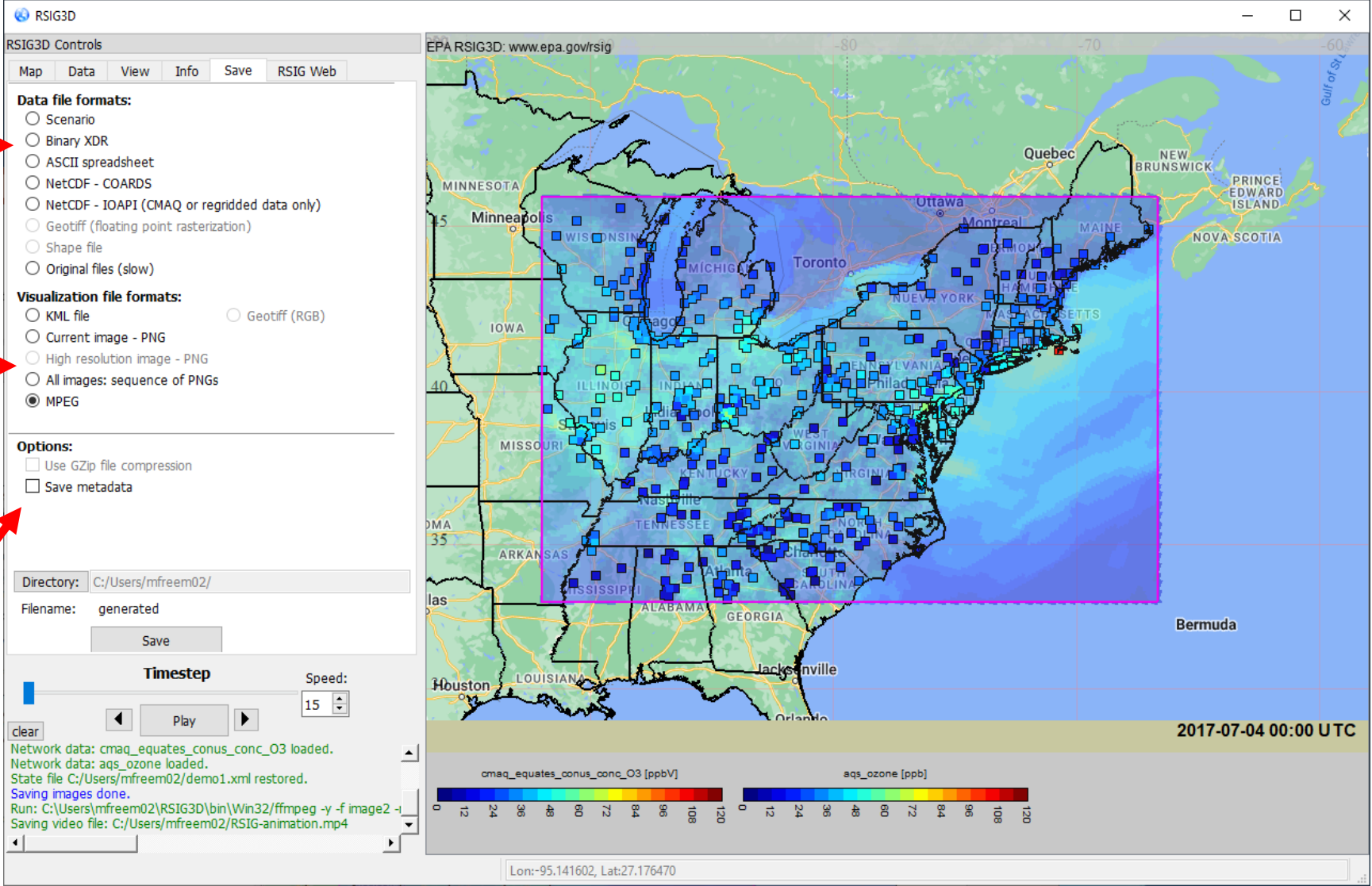
- Scenario
- Binary or ASCII
- NetCDF (2 kinds)

Visualization formats

- KML
- PNG
- Sequence on PNGs
- MP4

Options

- File compression
- Metadata



The screenshot shows the RSIG3D application window. The title bar reads 'RSIG3D'. Below it is a menu bar with 'Map', 'Data', 'View', 'Info', 'Save', and 'RSIG Web'. The 'Save' tab is active, displaying the following options:

- Data file formats:**
 - Scenario
 - Binary XDR
 - ASCII spreadsheet
 - NetCDF - COARDS
 - NetCDF - IOAPI (CMAQ or regridded data only)
 - Geotiff (floating point rasterization)
 - Shape file
 - Original files (slow)
- Visualization file formats:**
 - KML file
 - Current image - PNG
 - High resolution image - PNG
 - All images: sequence of PNGs
 - MPEG
- Options:**
 - Use GZip file compression
 - Save metadata

Below the options are fields for 'Directory: C:/Users/mfreem02/' and 'Filename: generated', with a 'Save' button. A 'Timestep' section includes a 'Speed:' dropdown set to '15', and 'Play' and 'Stop' buttons. A status bar at the bottom shows the current date and time: '2017-07-04 00:00 UTC'. Two color scales are visible: 'cmaq_equates_conus_conc_O3 [ppbV]' and 'aq5_ozone [ppb]'. The map shows a grid of data points over the eastern United States, with a purple rectangular selection box.

Overall Takeaways

- Designed to assist users in obtaining complex datasets relevant to the air quality research and application community.
- The RSIG application significantly reduces data processing time associated with air quality relevant high value data sets.
- Data can be downloaded using the RSIG user interface or users can issue cURL (client URL) scripts.
- RSIG visualization capabilities can be used to explore episodes of interest (case studies) and provide high quality graphics for re-use in reports and presentations.

Contacts

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Thank You!

Remote Sensing Information Gateway: <https://www.epa.gov/rsig>

Extra Slides

Bootleg Fire, July-August 2021

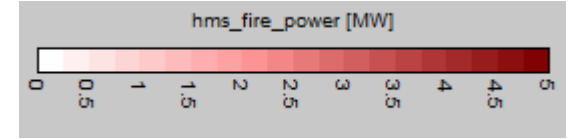
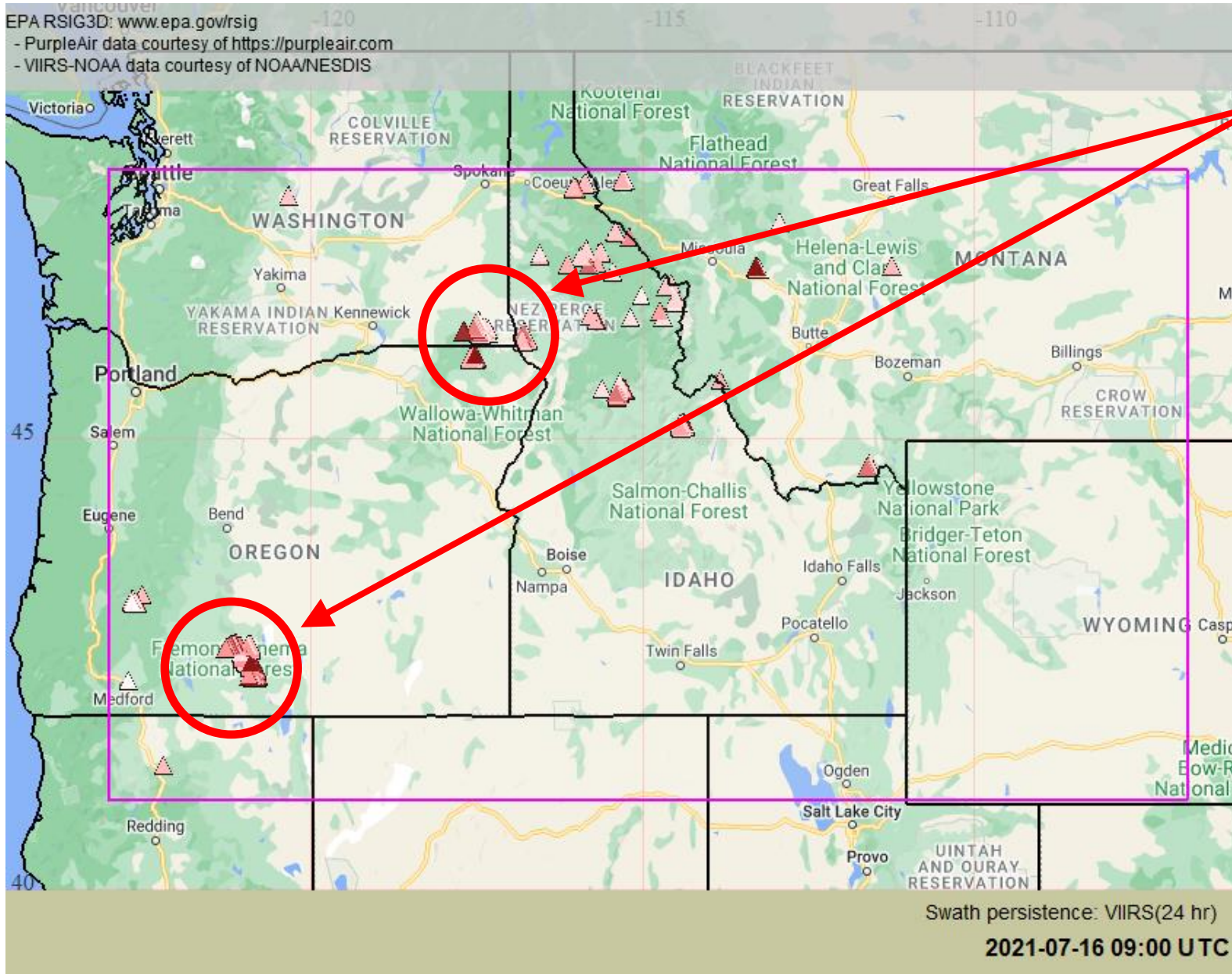
- Third largest fire in Oregon's history (since 1900)
- Second largest wildfire in the U.S. in 2021
- Over 400,000 acres burned
- Fastest growth: 1,000 acres per hour
- Over 2,200 personnel involved in containing the fire
- 408 buildings and 342 vehicles destroyed
- Affected ground level air quality across northern U.S. and Canada, including in NY, NC and Washington, DC

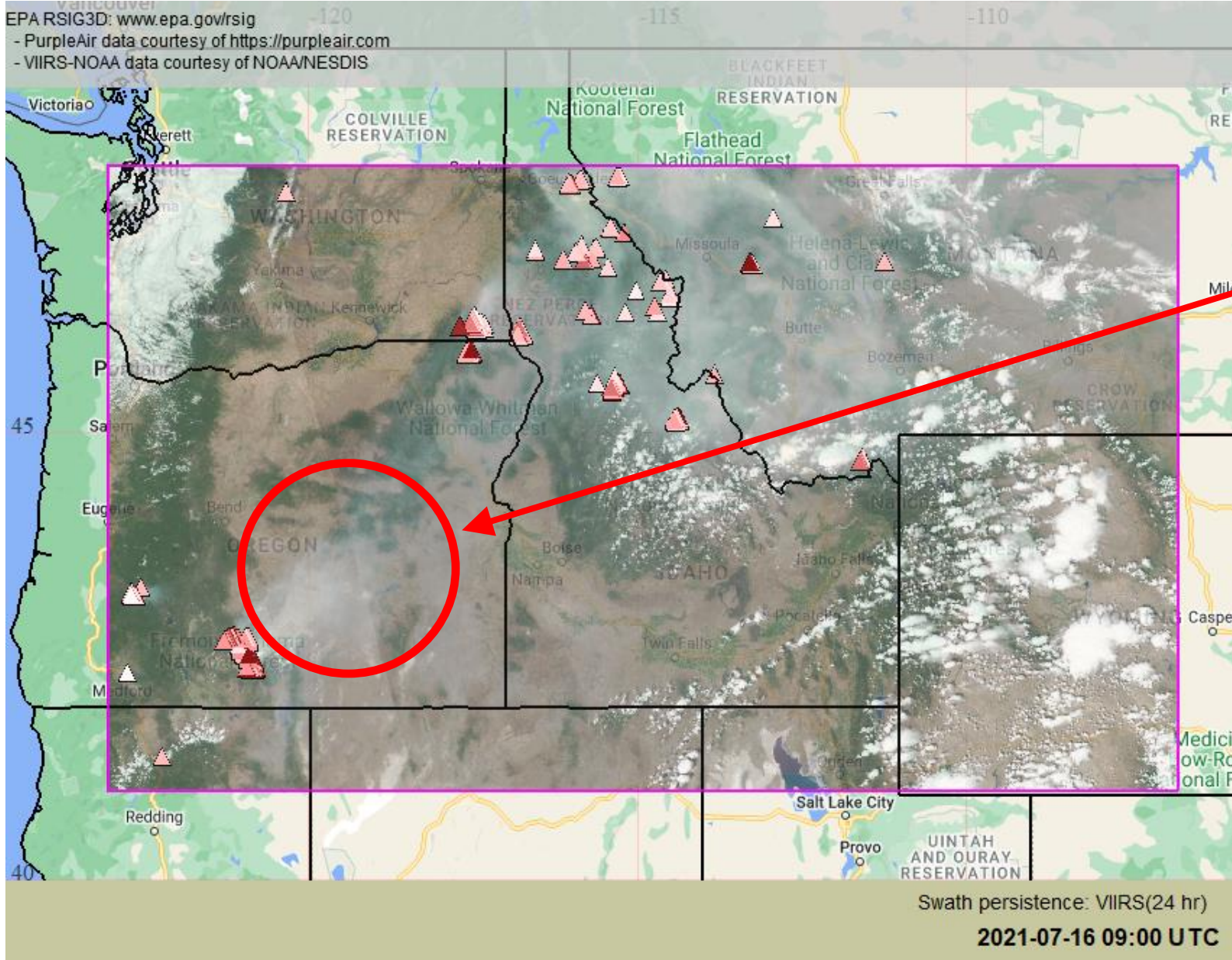


Photo credit: Freemont-Winema National Forest

Bootleg Fire, July 2021

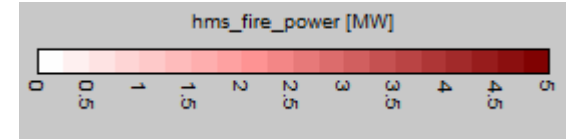
- Satellite fire detections



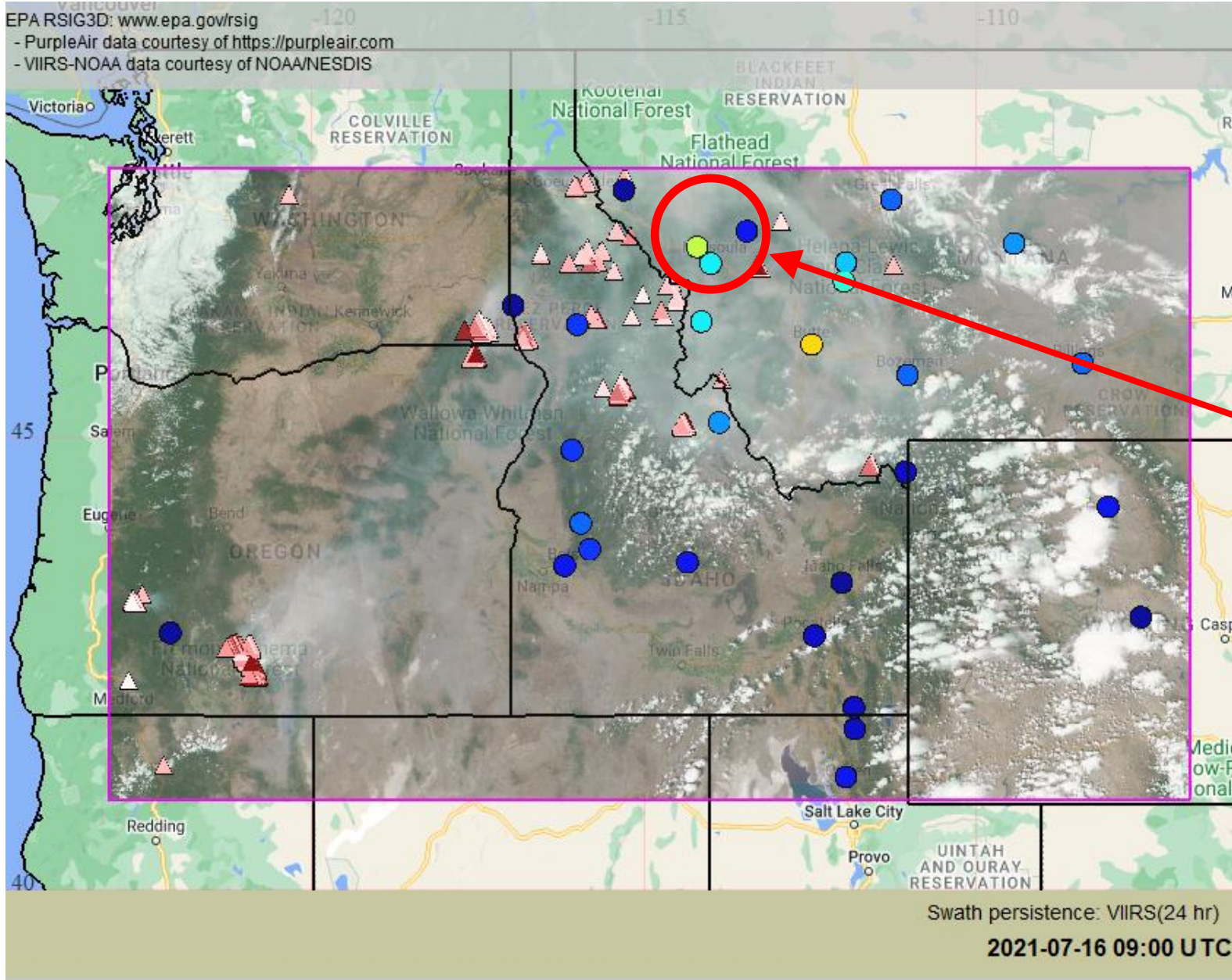


Bootleg Fire, July 2021

- Satellite fire detections

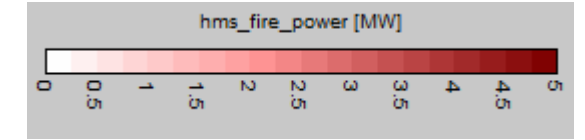


- VIIRS true color imagery showing smoke



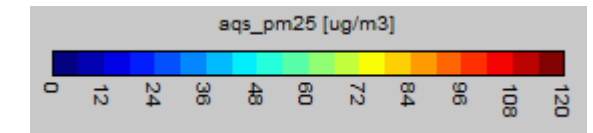
Bootleg Fire, July 2021

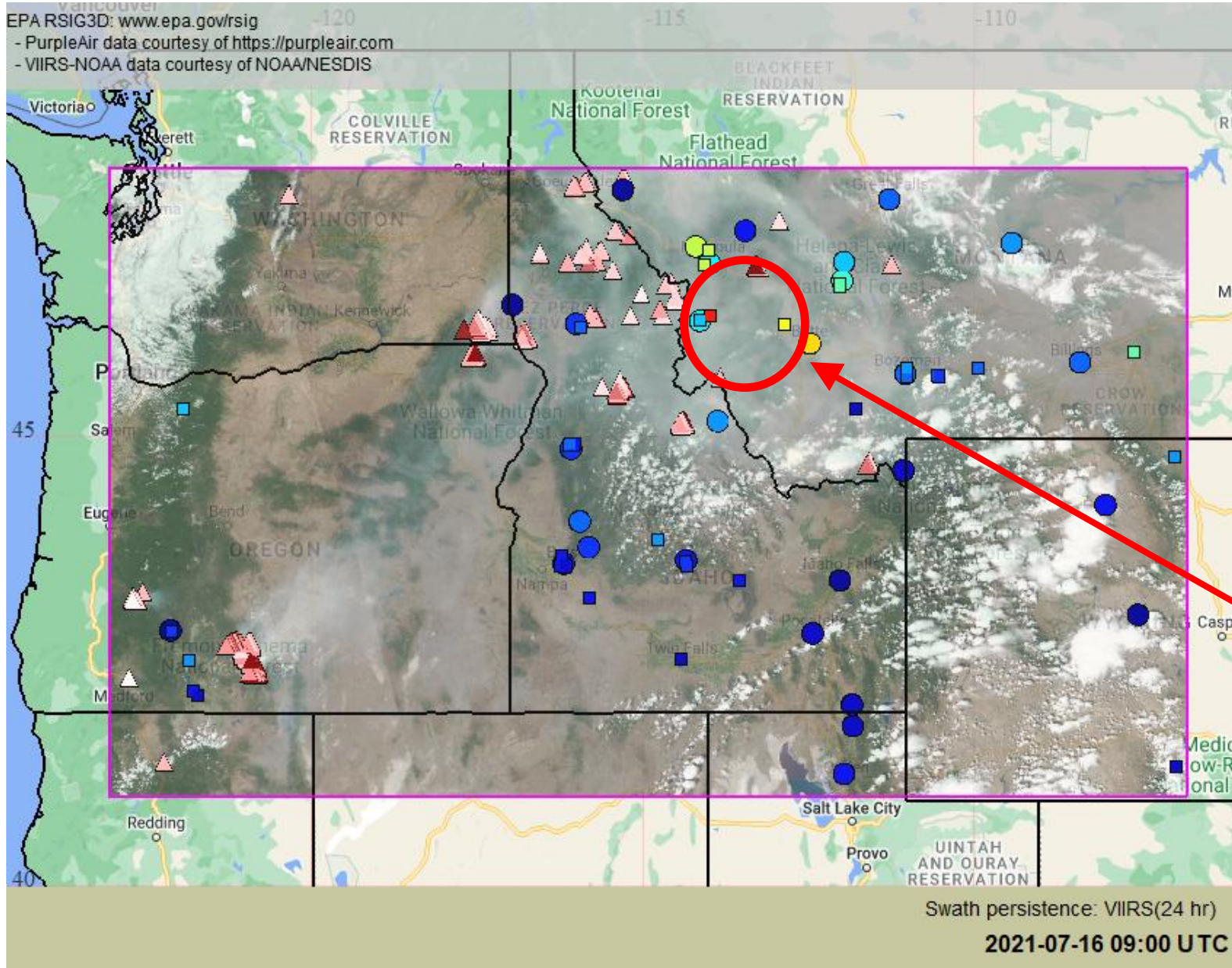
- Satellite fire detections



- VIIRS true color imagery showing smoke

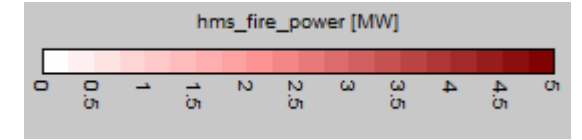
- AQS PM_{2.5} monitors





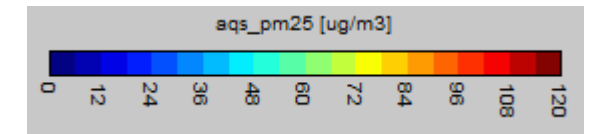
Bootleg Fire, July 2021

- Satellite fire detections

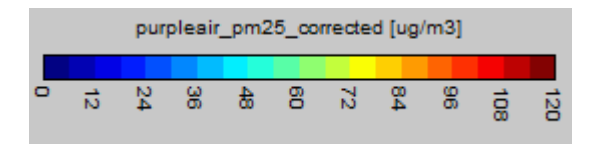


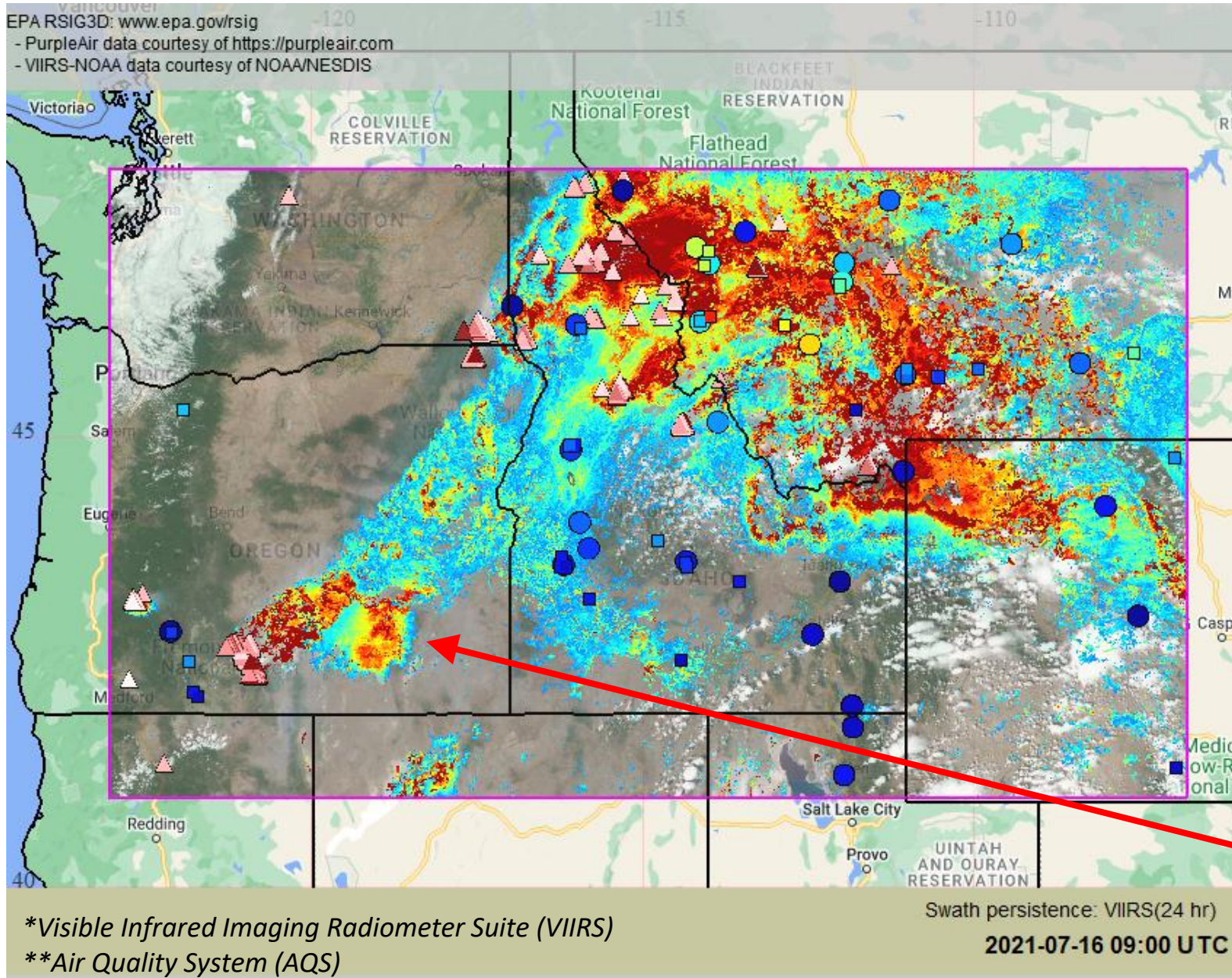
- VIIRS true color imagery showing smoke

- AQS PM_{2.5} monitors



- PurpleAir PM_{2.5} sensors

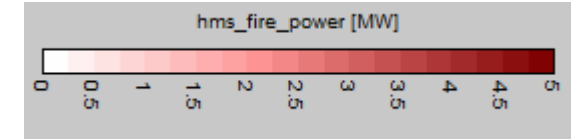




*Visible Infrared Imaging Radiometer Suite (VIIRS)
 **Air Quality System (AQS)

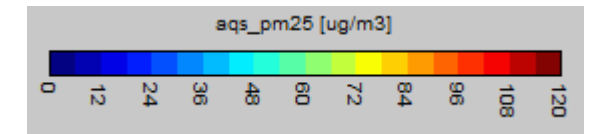
Bootleg Fire, July 2021

- Satellite fire detections

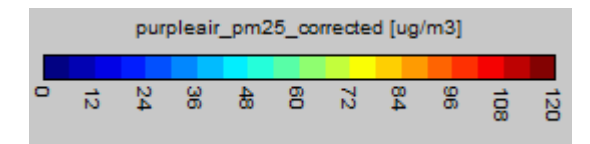


- VIIRS* true color imagery showing smoke

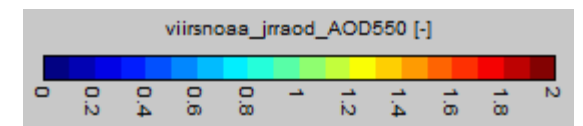
- AQS** PM_{2.5} monitors



- PurpleAir PM_{2.5} sensors



- VIIRS* satellite AOD



Bootleg Fire, July-August 2021

VIIRS Aerosol Optical Depth (AOD) data saved in ASCII format

Timestamp

Location of polygon centroid

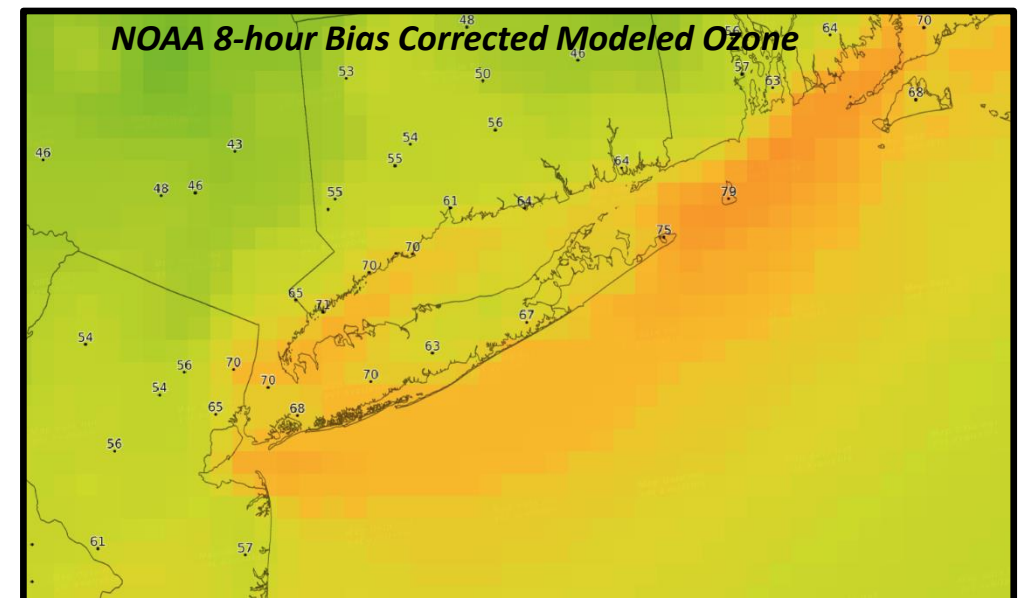
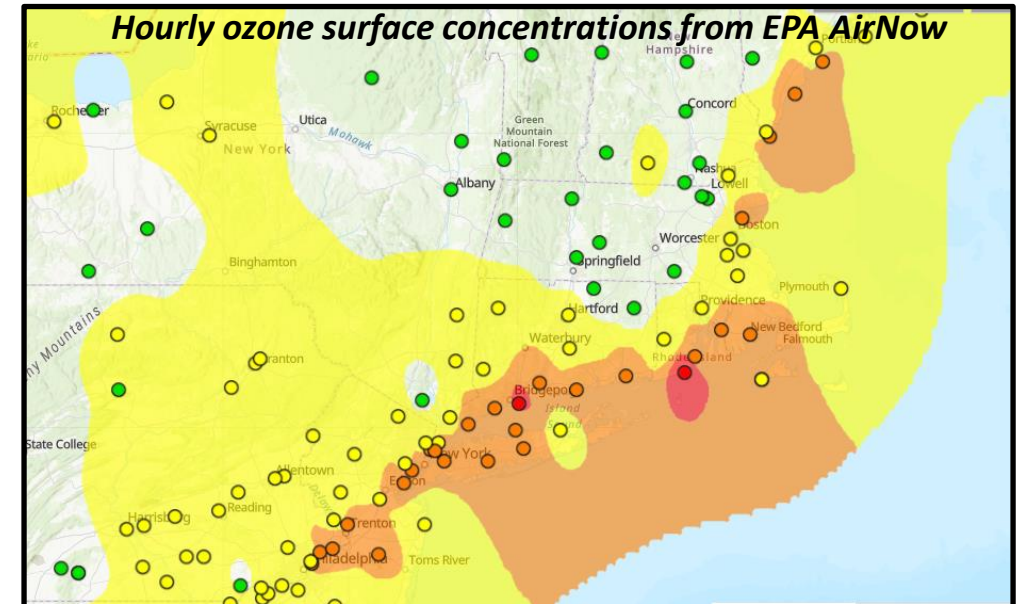
Data value

Locations of polygon corners

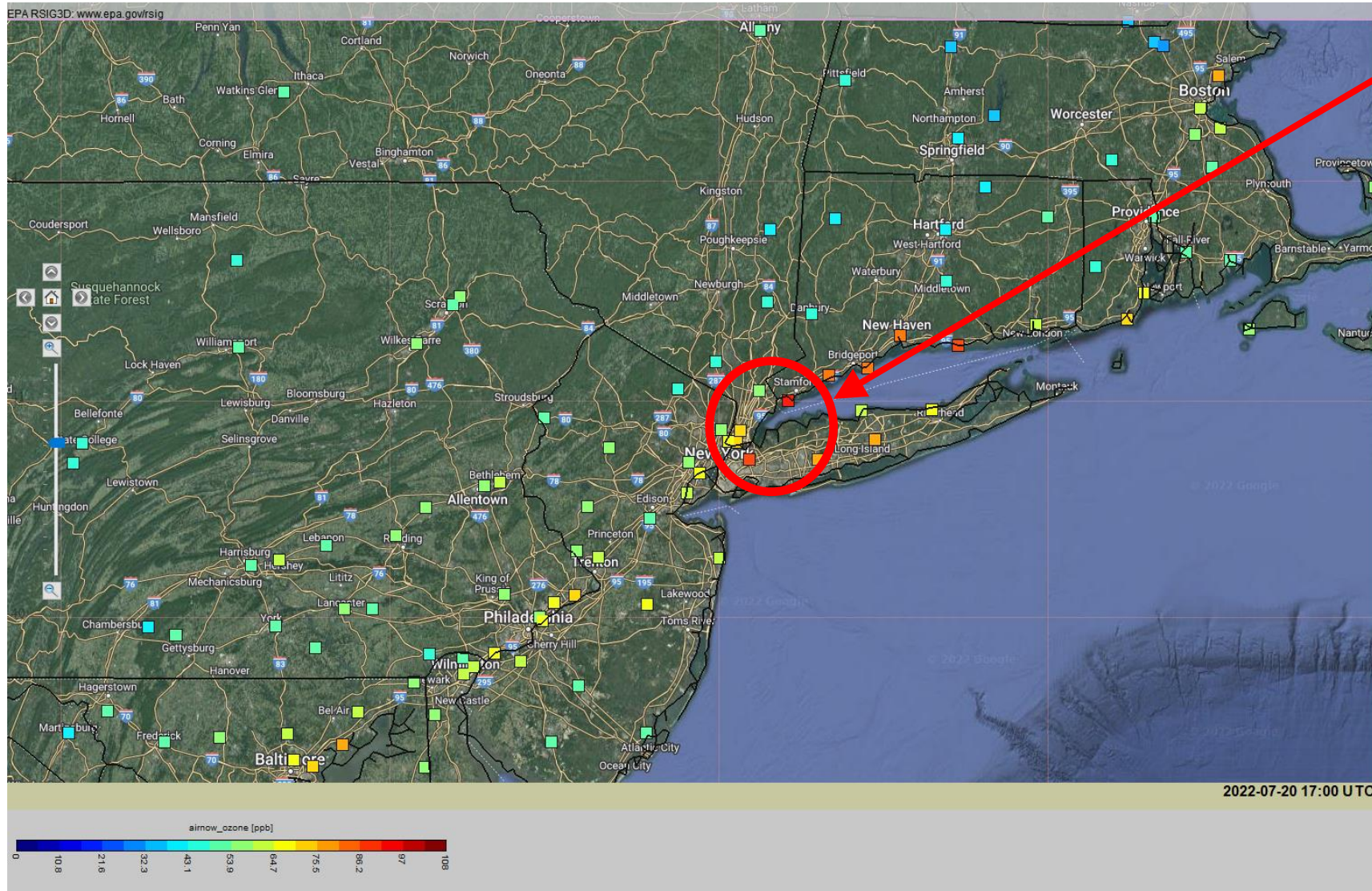
	A	B	C	D	E	F	G	H	I	J	K	L
	Timestamp(UTC)	Longitude(deg)	Latitude(deg)	AOD550nm	Longitude_SW(deg)	Longitude_SE(deg)	Longitude_NW(deg)	Longitude_NE(deg)	Latitude_SW(deg)	Latitude_SE(deg)	Latitude_NW(deg)	Latitude_NE(deg)
2	2021-07-15T18:35:00-0000	-106.81219	44.32335	0.94197	-106.79886	-106.81483	-106.80918	-106.82588	44.32008	44.31421	44.33282	44.32669
3	2021-07-15T18:35:00-0000	-106.82256	44.33637	0.89462	-106.80918	-106.82588	-106.81922	-106.83594	44.33282	44.32669	44.34566	44.33954
4	2021-07-15T18:35:00-0000	-106.81689	44.35477	0.78322	-106.80343	-106.81922	-106.81422	-106.8307	44.35144	44.34566	44.364	44.35798
5	2021-07-15T18:35:00-0000	-106.83321	44.3448	0.78311	-106.81922	-106.83594	-106.8307	-106.84697	44.34566	44.33954	44.35798	44.35203
6	2021-07-15T18:35:00-0000	-106.8355	44.3534	0.78332	-106.81188	-106.82794	-106.82306	-106.83914	44.35003	44.34405	44.36243	44.35646
7	2021-07-15T18:35:00-0000	-106.84164	44.34724	1.08382	-106.82794	-106.84468	-106.83914	-106.8548	44.34405	44.33782	44.35646	44.35064
8	2021-07-15T18:35:00-0000	-106.81969	44.37196	0.78312	-106.80644	-106.82306	-106.81623	-106.83303	44.36859	44.36243	44.38151	44.37529
9	2021-07-15T18:35:00-0000	-106.836	44.36571	0.78384	-106.82306	-106.83914	-106.83303	-106.84879	44.36243	44.35646	44.37529	44.36945
10	2021-07-15T18:35:00-0000	-106.85162	44.36011	0.8114	-106.83914	-106.8548	-106.84879	-106.86377	44.35646	44.35064	44.36945	44.3639
11	2021-07-15T18:35:00-0000	-106.81249	44.39115	0.7941	-106.79919	-106.81623	-106.80873	-106.82583	44.38781	44.38151	44.4008	44.39449
12	2021-07-15T18:35:00-0000	-106.82937	44.38442	0.78355	-106.81623	-106.83303	-106.82583	-106.84239	44.38151	44.37529	44.39449	44.38837
13	2021-07-15T18:35:00-0000	-106.84544	44.37817	0.78311	-106.83303	-106.84879	-106.84239	-106.85754	44.37529	44.36945	44.38837	44.38277
14	2021-07-15T18:35:00-0000	-106.86044	44.37311	0.77199	-106.84879	-106.86377	-106.85754	-106.87167	44.36945	44.3639	44.38277	44.37754
15	2021-07-15T18:35:00-0000	-106.82178	44.40445	0.74341	-106.80873	-106.82583	-106.81792	-106.83464	44.4008	44.39449	44.41393	44.40777
16	2021-07-15T18:35:00-0000	-106.83848	44.39839	0.75338	-106.82583	-106.84239	-106.83464	-106.85106	44.39449	44.38837	44.40777	44.40171
17	2021-07-15T18:35:00-0000	-106.8544	44.39211	0.72376	-106.84239	-106.85754	-106.85106	-106.86661	44.38837	44.38277	44.40171	44.39598
18	2021-07-15T18:35:00-0000	-106.86926	44.38612	0.76347	-106.85754	-106.87167	-106.86661	-106.88119	44.38277	44.37754	44.39598	44.3906
19	2021-07-15T18:35:00-0000	-106.81384	44.42338	0.819	-106.80067	-106.81792	-106.80972	-106.82703	44.42027	44.41393	44.43344	44.42708
20	2021-07-15T18:35:00-0000	-106.83085	44.41712	0.76904	-106.81792	-106.83464	-106.82703	-106.84383	44.41393	44.40777	44.42708	44.42091

Retrospective Analysis on Air Quality Forecast July 20, 2022

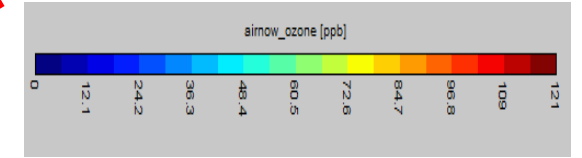
- Over the Greater NY City Metro area July 20th was the most widespread ozone event of the season, with 2 sites (CT & RI) exceeding 85 ppb for the maximum 8-hr ozone average
- The usually reliable NOAA National Weather Service Bias Correct forecast model, grossly under-estimated the ozone on this day (lower image)
- Use of RSIG data sets help explain evolution of this event to understand the differences between observations and the air quality the NOAA forecast model



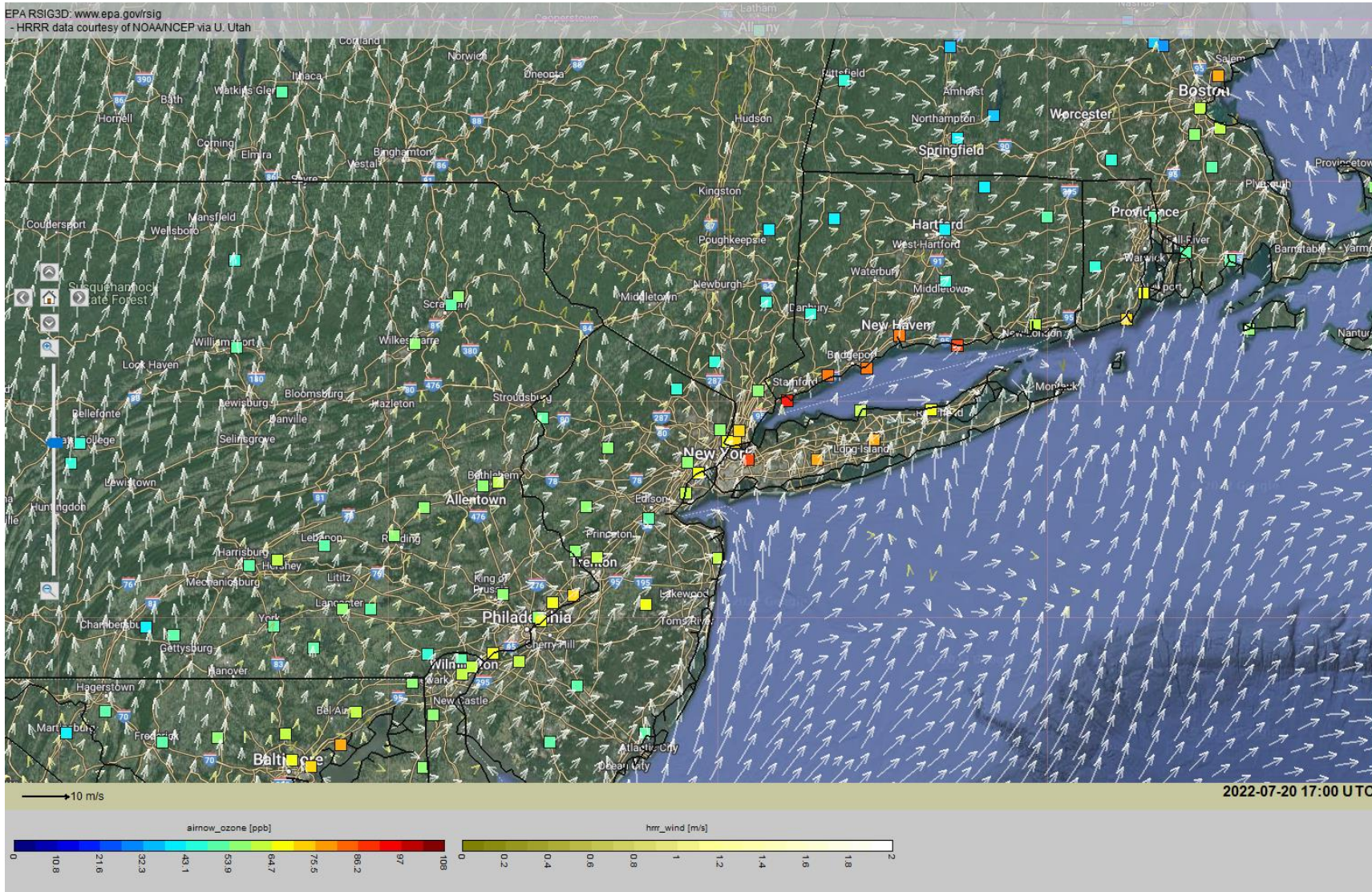
July 20, 2022 - Northeast U.S. Ozone Episode



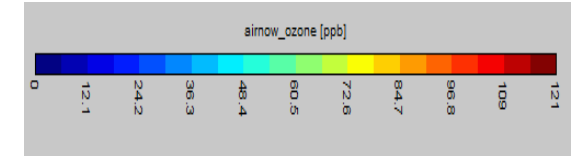
• AirNow Surface Ozone



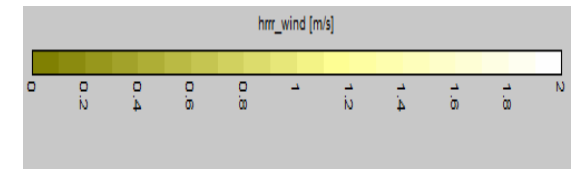
July 20, 2022 - NE U.S. Ozone Episode



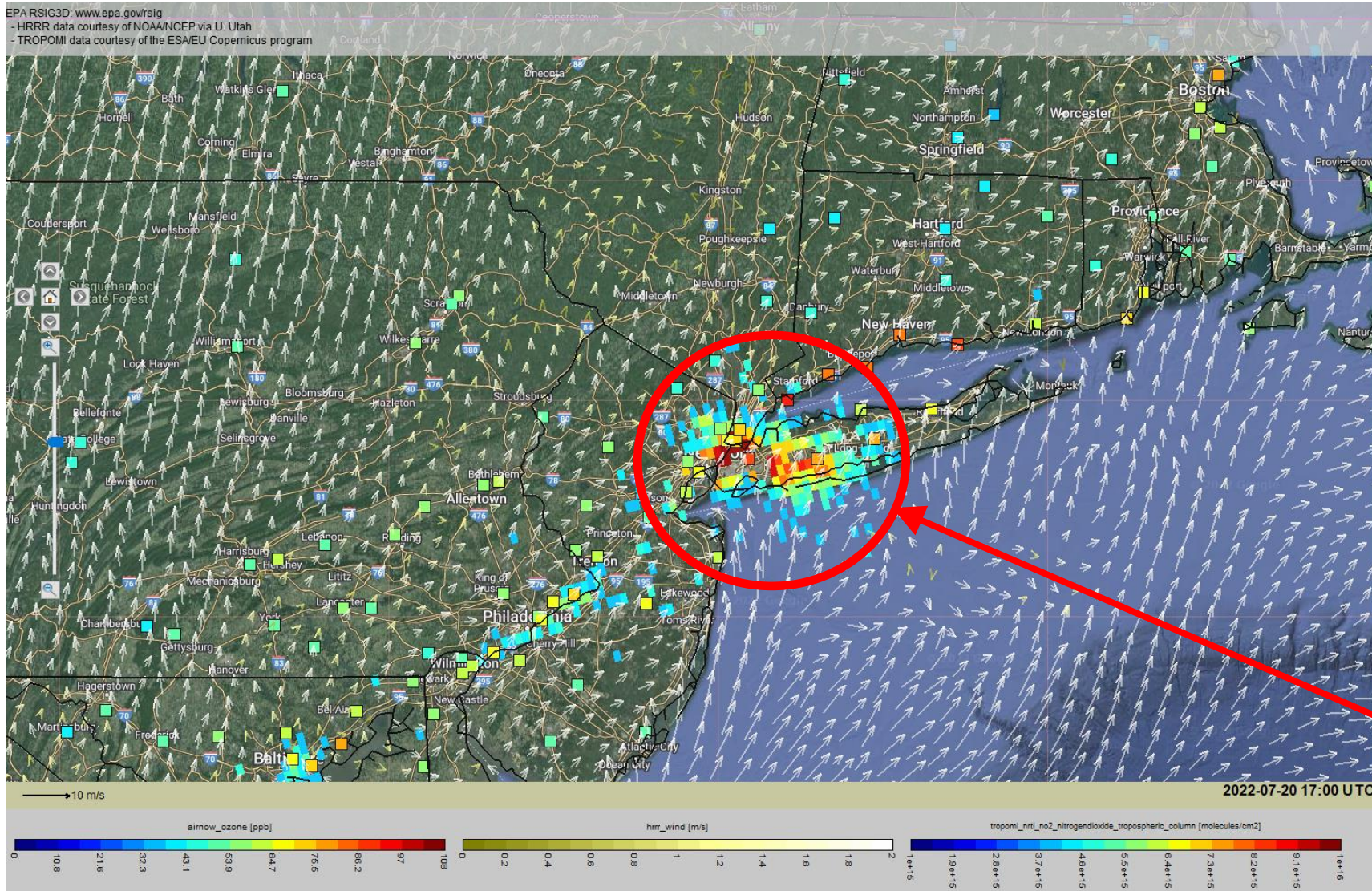
- AirNow Surface Ozone



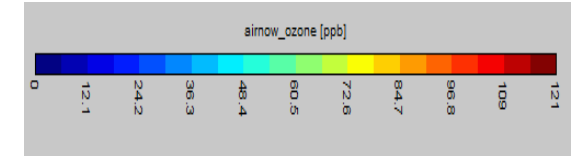
- HRRR* model surface winds (wind speed and direction)



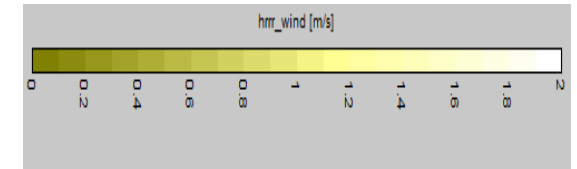
July 20, 2022 - NE U.S. Ozone Episode



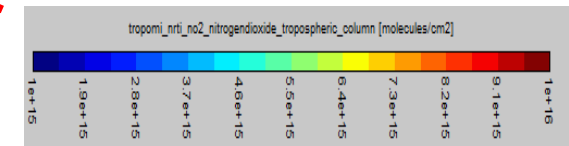
- AirNow Surface Ozone



- HRRR model surface winds (wind speed and direction)

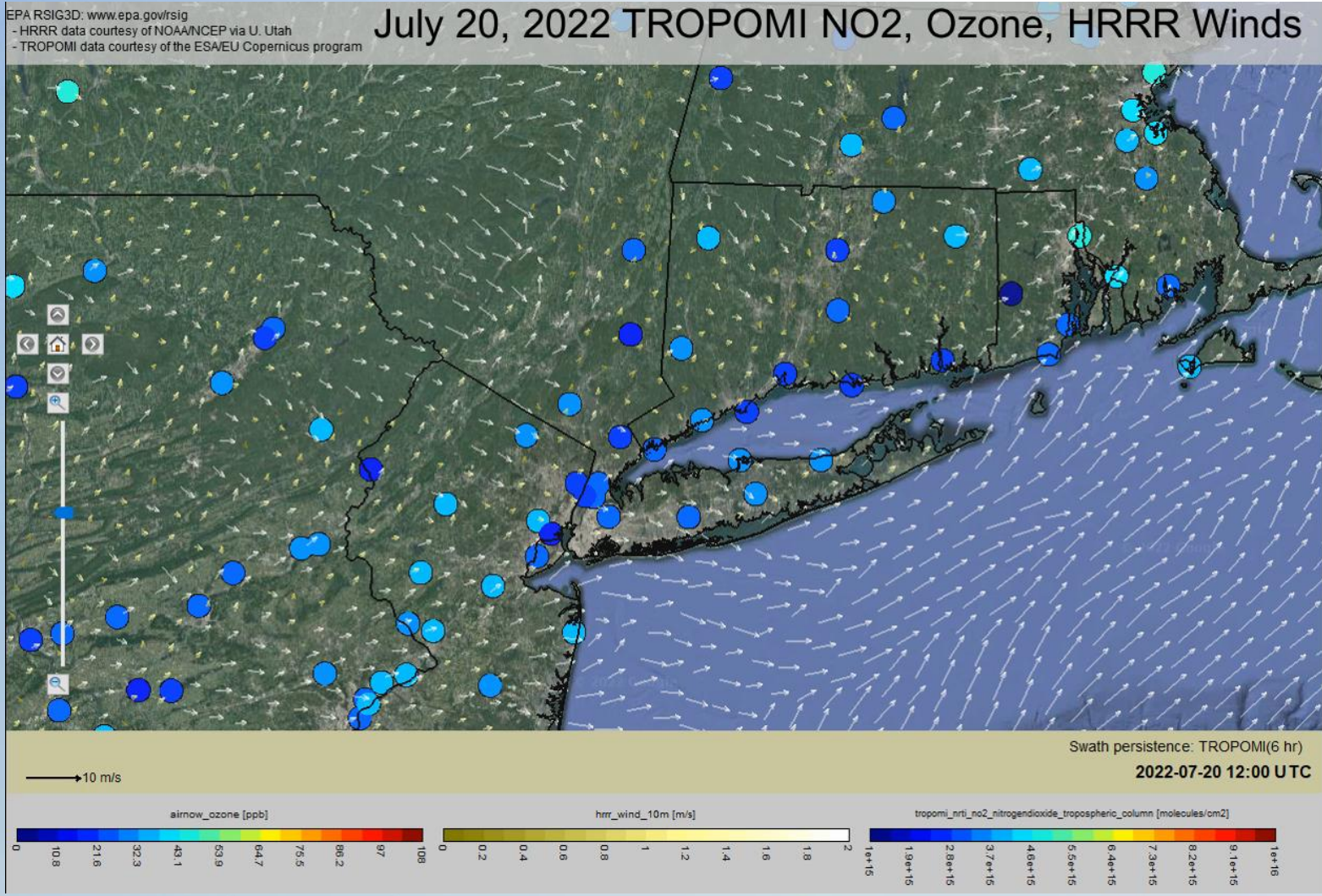


- TROPOMI Tropospheric Column NO₂ abundances



RSIG3D Animation

RSIG Case Study provided by:
Michael Geigert
Air Pollution Control Engineer
Bureau of Air Management



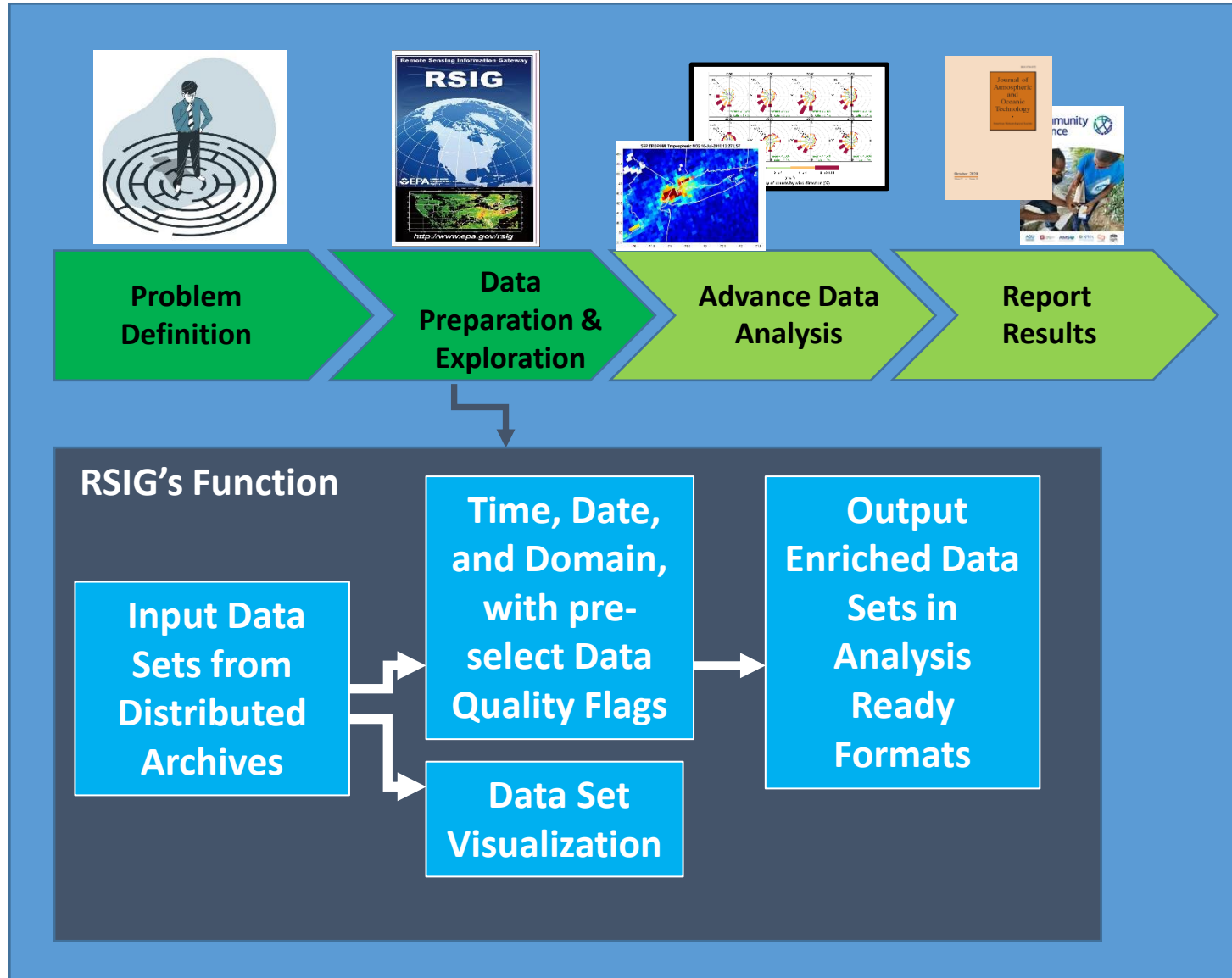
The RSIG3d animation, which layers the HRRR winds, hourly ozone and the afternoon TROPOMI satellite NO2 column, shows the ozone formation occurring further north than modeled

Case Study Takeaways

- Fire Case Study: Not all smoke reaches the surface – routine, accessible visualization of satellite and surface in situ datasets enable air quality managers to gain insights into what factors affect surface-level smoke impacts.
- Air Quality Forecast Case Study: The full spatial coverage of satellite data and higher resolution of NWS meteorological modeling show where 12 km resolution air quality modeling falls short, in this case by not resolving mesoscale features associated with Long Island Sound.

Impact

End Users – RSIG Used to Support



Air Quality Modelers

- Model Evaluation
- Case Study Analysis

Air Quality Forecasters

- Retrospective Analysis

Scientists & Researchers

- Exposure studies
- Inverse modeling studies
- Improving air quality models

Students

- Thesis/Dissertation Research