Overview of the U.S. EPA Remote Sensing Information Gateway (RSIG)

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EPA ARSET Training – RSIG Session
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RSIG Background

- The Remote Sensing Information Gateway (RSIG) grew out of research efforts to explore distributed data access ways to provide greater access to large volume data sets, including NASA and NOAA satellite data and EPA modeled data sets, for EPA applied research.

- Over the past several years RSIG has focused effort on extending access and increasing the use to several satellite (aerosol) and aircraft datasets to support EPA applied research.

- The result is a system capable of proving on-demand access to a variety relevant air quality/atmospheric composition data sets, with functionally to subset in time and space and re-grid on model relevant grids (including 3-D).

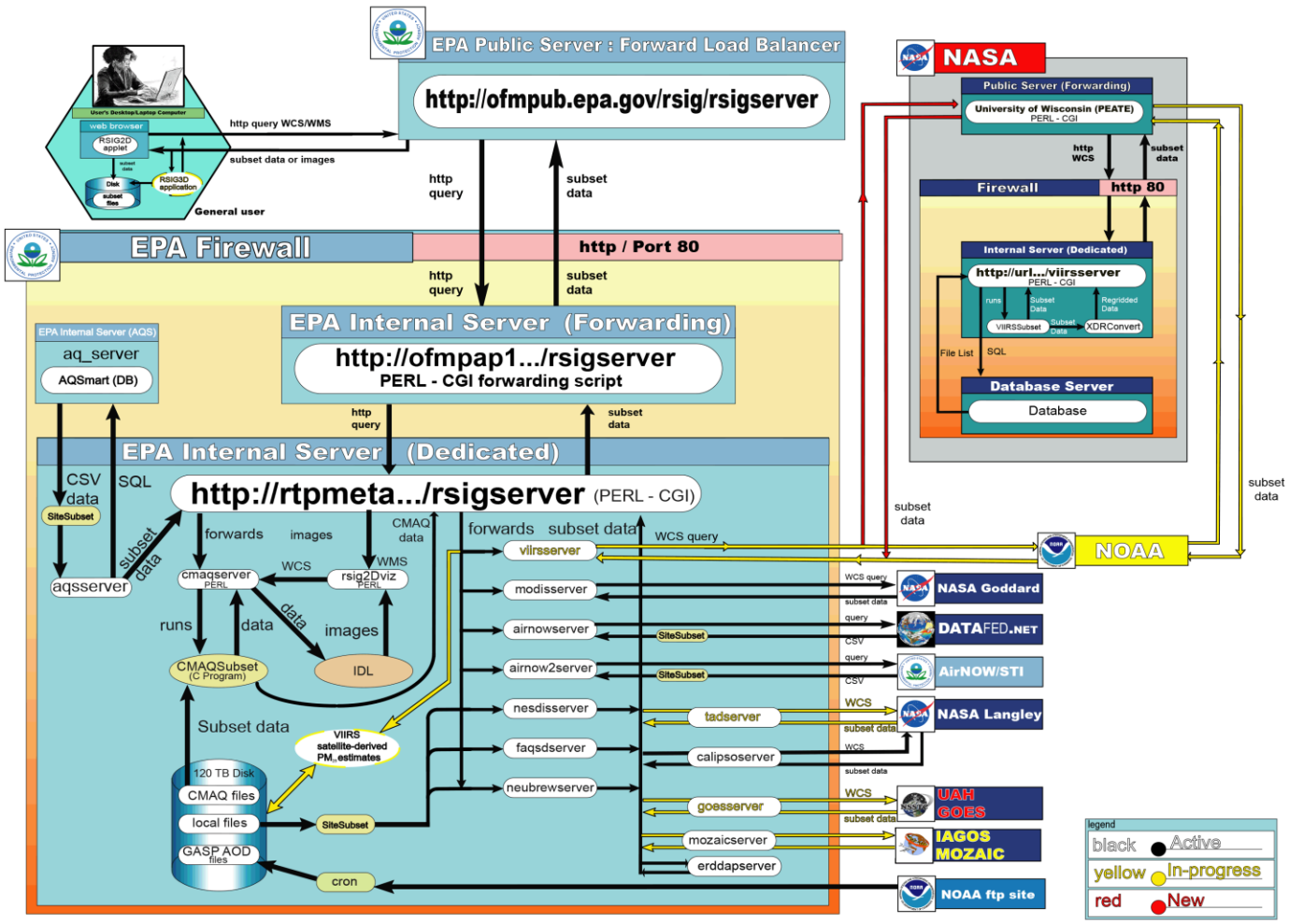
- Others Involved along the way include: U.S. EPA (ORD & OAQPS) Modeling Groups, NASA MODIS and CALIPSO Aerosol Science Teams, NOAA-NESDIS (GOES and VIIRS Aerosol Product(s)), MOZAIC/IAGOS PI's, NASA Airborne Data for Assessing Models (ADAM) Developers, and Several NASA AQAST members

Agenda

- RSIG Architecture
- RSIG Platform
  - Graphic User Interface (GUI) Overview - JAVA applet, JAVA application
- MODIS (and VIIRS)
  - 2D Regridding
- CALIPSO (CALIOP)
  - Preset Data Screening Criteria
  - 3D Regridding
  - Example Analysis
- Use of http WCS/WMS commands (Todd)
- New Platform - RSIG 3D application (Matt)

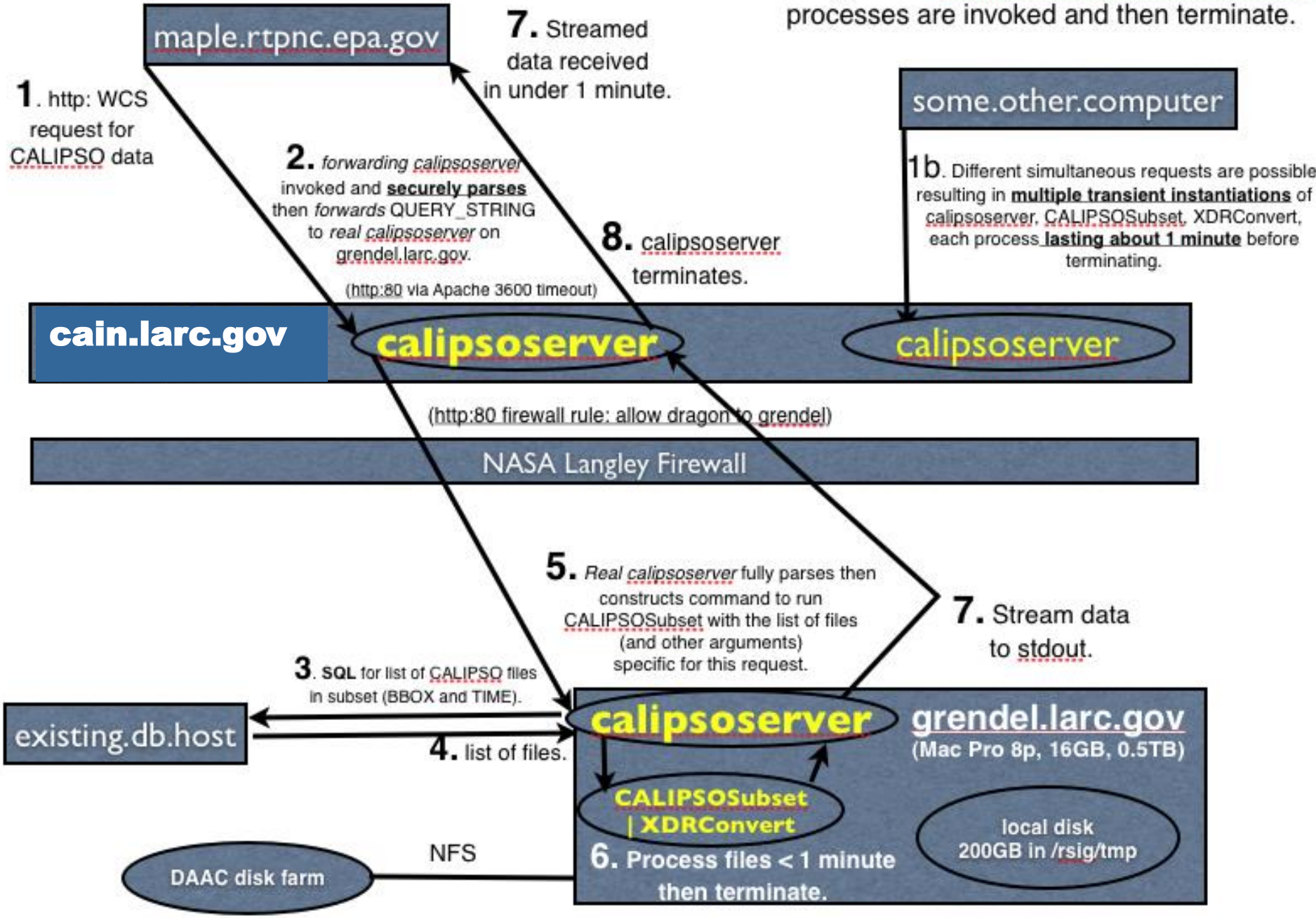
Remote Sensing Information Gateway Architecture

RSIG Data Flow Diagram



RSIG-CALIPSO Dataflow Diagram

Note: typical scenarios run for 1 - 5 minutes during which calipsoserver/CALIPSOSubset processes are invoked and then terminate.



Some Key Features

- Designed to assist in obtaining datasets relevant to air quality research and program analyses.
- Interoperable with other OGC-compliant systems.
- Accessible from computers outside the EPA network: (www.epa.gov/rsig).
- Subsets files at the source, allowing users to access most current data version.
- Aggregates data files in time and space within visualization and save functions.
- Allows for on-the-fly re-gridding of satellite data onto standard CMAQ model grid or user specified grid parameters.
- Provides many useful “Save As” formats for the data and images, such as XDR binary, ASCII, HDF, MPEG, NetCDF, and KMZ

Interoperability Standards Supported by RSIG

- OGC–WCS/XML
- OGC–WCS
- OGC–WMS
- ASCII
- IEEE–754
- XDR
- NetCDF
- NetCDF/COARDS
- NetCDF/IOAPI
- HDF
- HDF–EOS
- PNG
- MPEG
- KML/KMZ
- HTML
- PDF
- HTTP/80
- SI

Atmospheric Composition Data Sets served via U.S. EPA Remote Sensing Information Gateway

System name: EPA Remote Sensing Information Gateway (http://www.epa.gov/rsig)

Provider Type: Original source and intermediary broker

Types of atmospheric composition data:

Modeled: a subset of CMAQ/MCIP (conc., met., emissions) variables (2002-2008, *2009 & 2010 coming soon*)

Surface Observations: AIRNow: O_3 and $PM_{2.5}$ AQS: O_3, SO_2, NO_2, CO, and $PM_{2.5}$, NEUBrew total O_3 via v2.5 Umkehr Vertical Profiles

Satellite: (MODIS) L2 MOD04/MYD04 v5.1 variables, L2 MOD06/MYD06 v4.3.0 variables, (CALIOP) L1 CAL_LID_L1 – v3.01 variables, CAL_LID_L2_05kmAPro and 05kmCPro variables, (GOES-east) NOAA GASP, and *VIIRS EDR AOT in 2014.*

Aircraft: MOZAIC O_3, NO_y, (02-05), CO, T, P, WD, WS, and RH data (2002-2006) (***restricted to EPA access only under MOZAIC approved project AQ-ALOFT***)

Access: GUI (JAVA based applet) and web services (WCS/WMS)

Standard Web Services Implemented: OGC-WCS and OGC-WMS

Custom extension made to standards: yes

Type of data returned: original data returned- formats supported: binary (xdr), ascii, netcdf (coards & ioapi), and geotiff-float. Data can be regridded onto standard or custom CMAQ grids

Metadata standards used: Defined by project team

Data/Metadata catalogs used: hyperlink to original data provider(s)

Multiple years of U.S. EPA CMAQ (3-D) output is served via web services through RSIG

- US EPA:
  - CMAQ v4.7 (2002)
    - Eastern US and Western US 12 km (OAQPS runs) 14 layers
      - PM2.5, O3, NOy, AOD Bext, and all variables from conc, aconc, emis, metcro3d, aerodaim, aerovis, and wetdep1 & 2 –NetCDF-IO API.
  - CMAQ v4.7 (2002 to 2006)*
    - Eastern US 12 km (CDC runs) 24 layers
      - PM2.5, O3, NOy, AOD Bext, and subset of variables from conc, aconc, emis, and met – NetCDF-IO API.
  - CMAQ v4.7 (2007-10)
    - Extended CONUS 12km (CDC runs) 34 layers
      - PM2.5, O3, NOy, AOD Bext, and subset of variables from conc, aconc, emis, and met – NetCDF-IO API.
  - CMAQ v4.7 and v5.0 (2006)**
    - Extended CONUS 12km (AQMEII run) 34 layers (v5.0_final 35 layers)
      - PM2.5, O3, NOy, AOD Bext, and subset of variables from conc, aconc, emis, and met – NetCDF-IO API.
  - CMAQ v4.7 (2006)**
    - Northern Hemisphere 108 km (Development run) 35 layers
      - PM2.5, O3, NOy, AOD Bext, and subset of variables from conc, aconc, emis, and met – NetCDF-IO API.

Note: **restricted access, internal EPA use only

Remote Sensing Information Gateway Platform (main url: http://www.epa.gov/rsig)

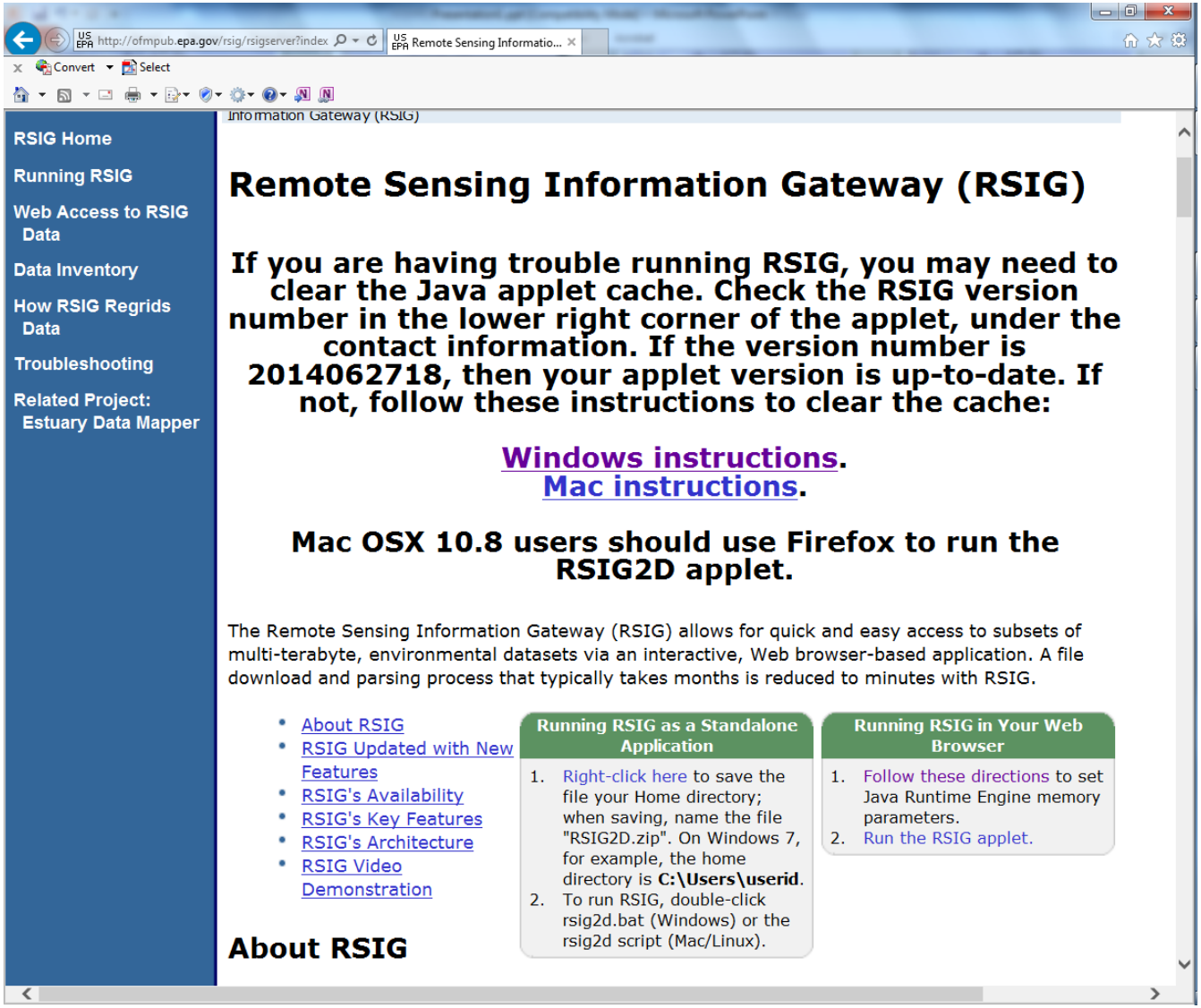
RSIG 2D GUI designed around JAVA (referenced to as RSIG2D)

- JAVA applet via web browser
  - Internet Explorer 7 (or later), Firefox 3 (or later, for Windows, Mac, and Linux). *Note:* Running RSIG on Safari 6 under OSX 10.8 is problematic.
  - Java runtime environment (JRE) 1.5 or greater. The JRE should be configured to use the following memory settings: -Xms64m -Xmx256m (see instructions below on configuring the JRE).

- JAVA standalone application
  - Same functionally as applet, but runs on users machine.
  - Tested and runs on MAC OSx and Windows 7

- Details on running platform(s) provided on RSIG website.

Remote Sensing Information Gateway (RSIG)
Main Access: http://www.epa.gov/rsig

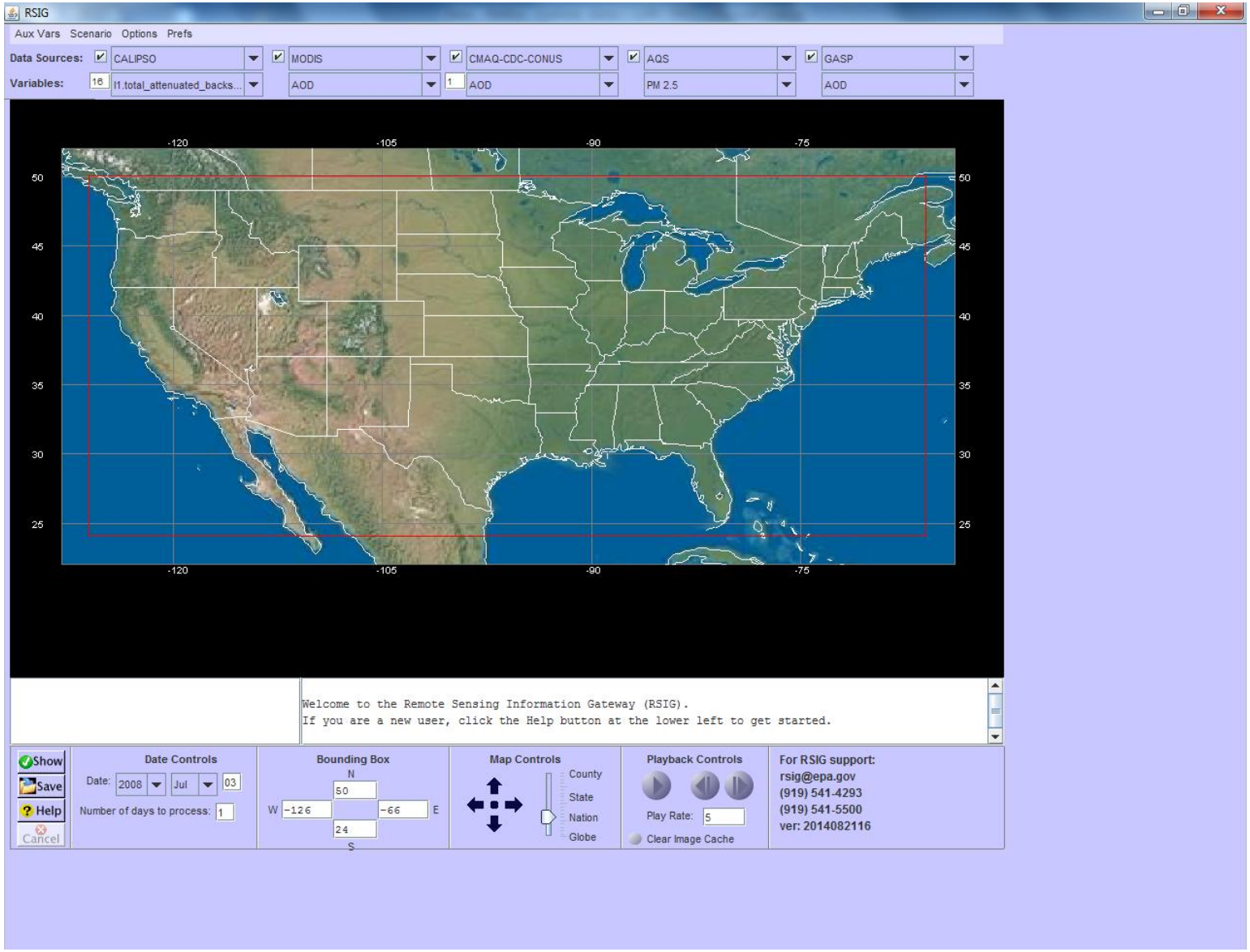


•RSIG Platforms:

1.) The RSIG applet:
✓IE 7, Firefox 3, Safari 4 (or any earlier versions) ,
✓ Java runtime environment (JRE) 1.5, or greater, configured with the following memory settings: -Xms64m -Xmx256m

2.) The RSIG application:
✓Rsig2d.bat (Windows) or rsig2d.script file saved to user home directory

Remote Sensing Information Gateway
Main Interface is a 2D GUI

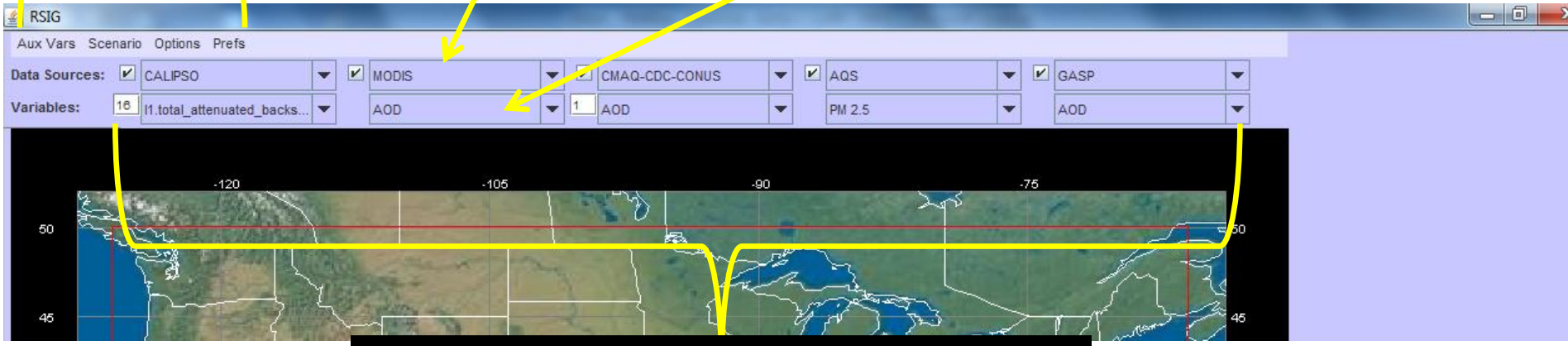


Remote Sensing Information Gateway

Additional RSIG data services on data display and screening criteria

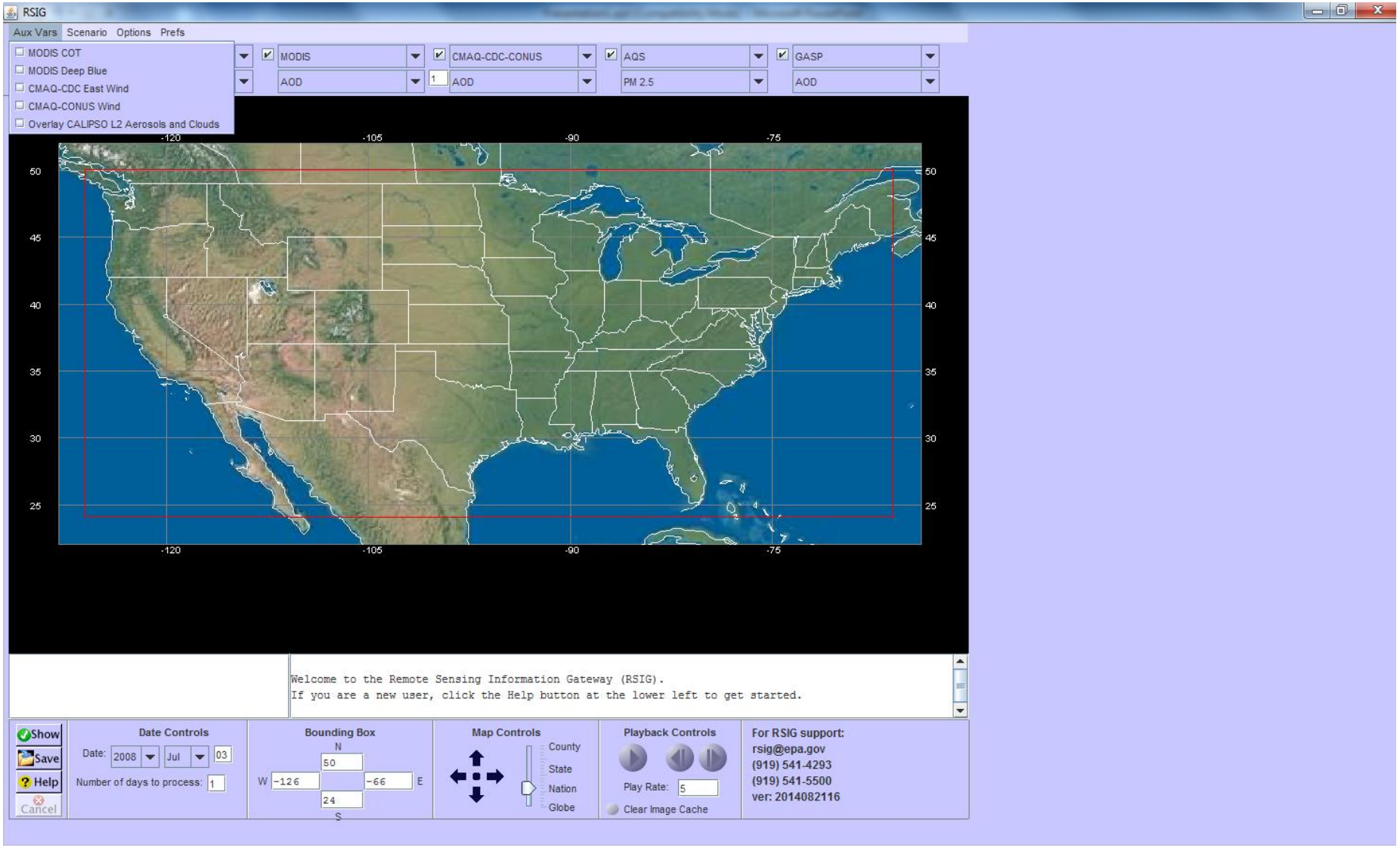
Data Source/Function Selection

Variable Source Selection

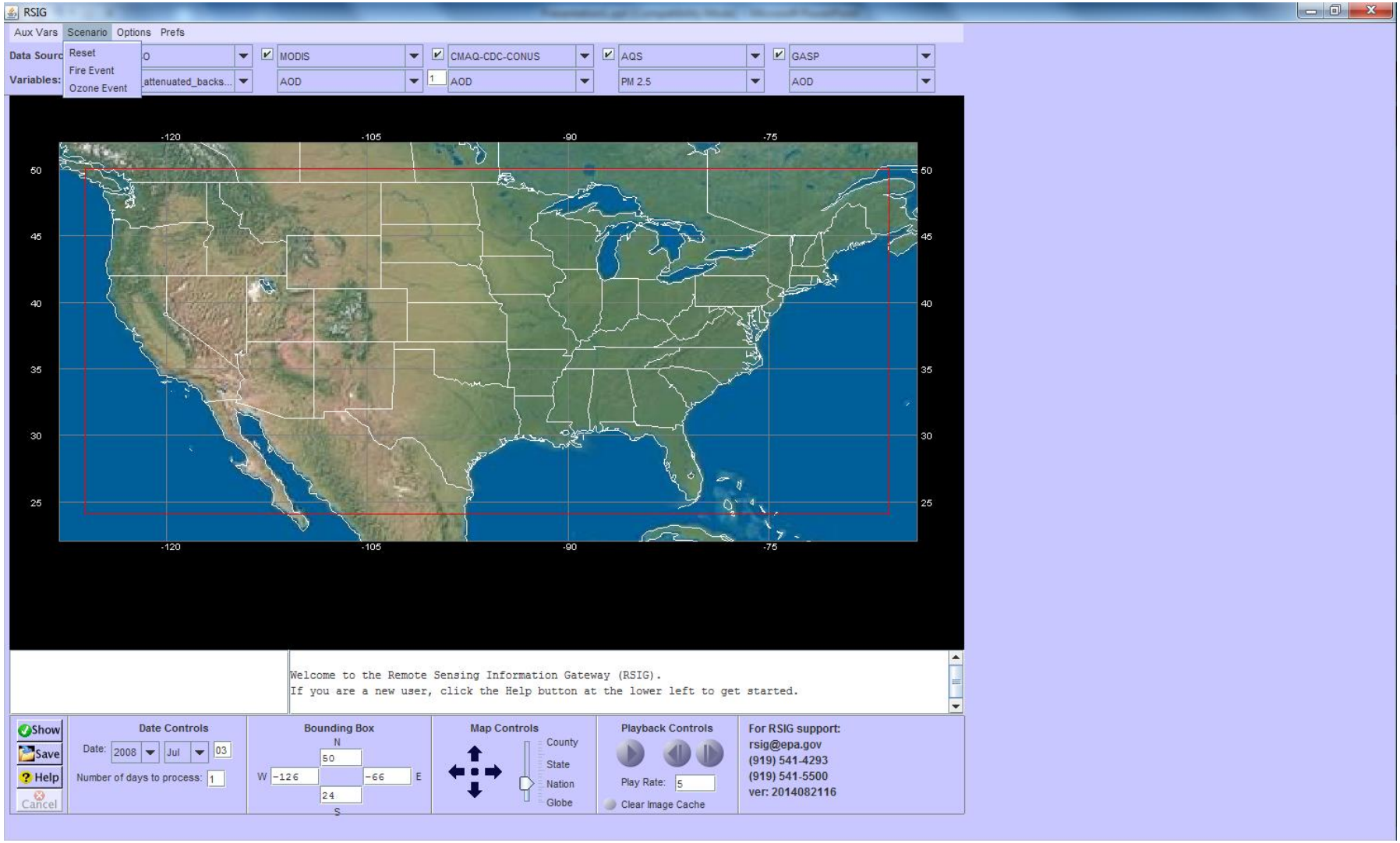


RSIG allows up to 5 concurrent data sources and variables to be selected

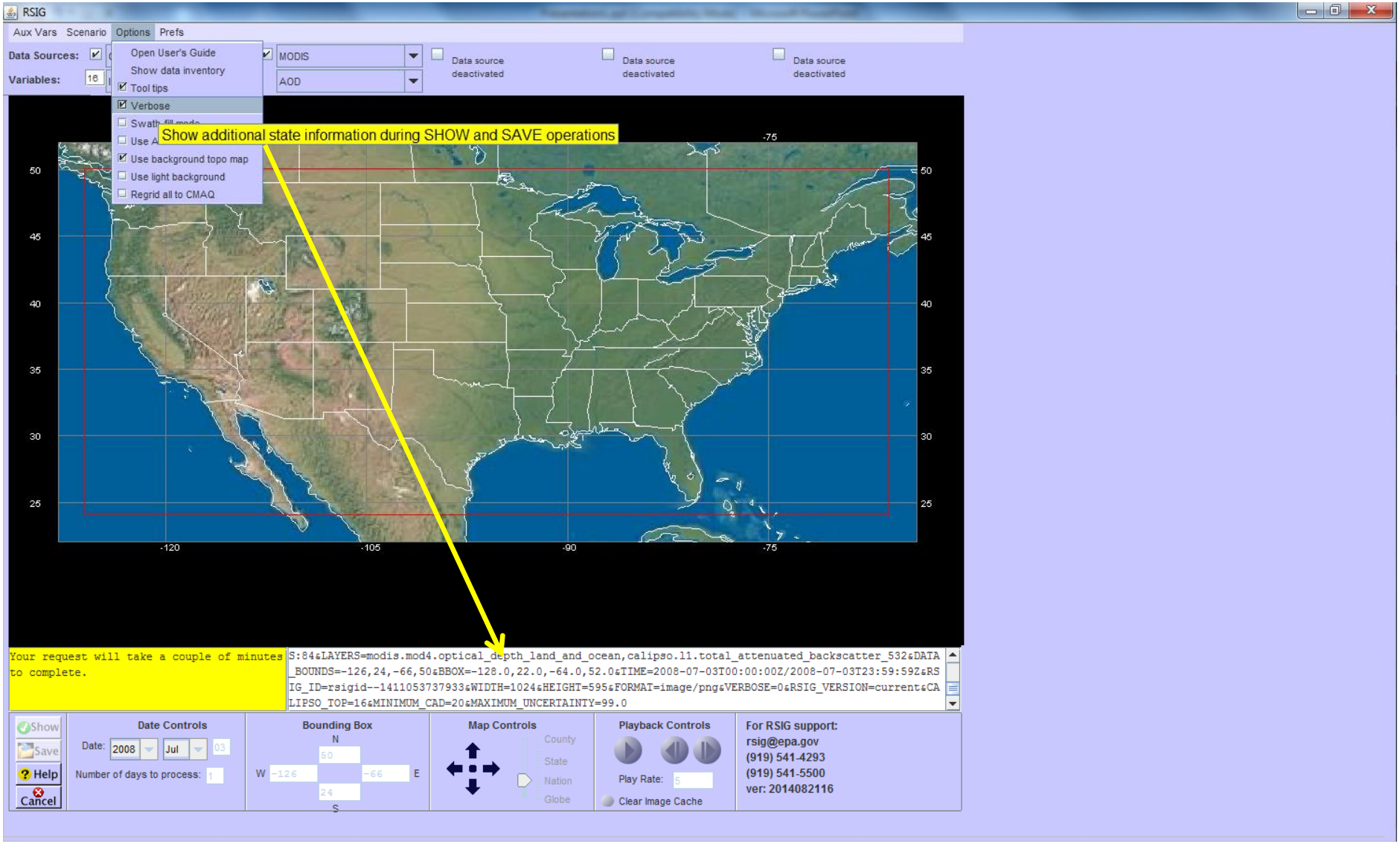
Remote Sensing Information Gateway



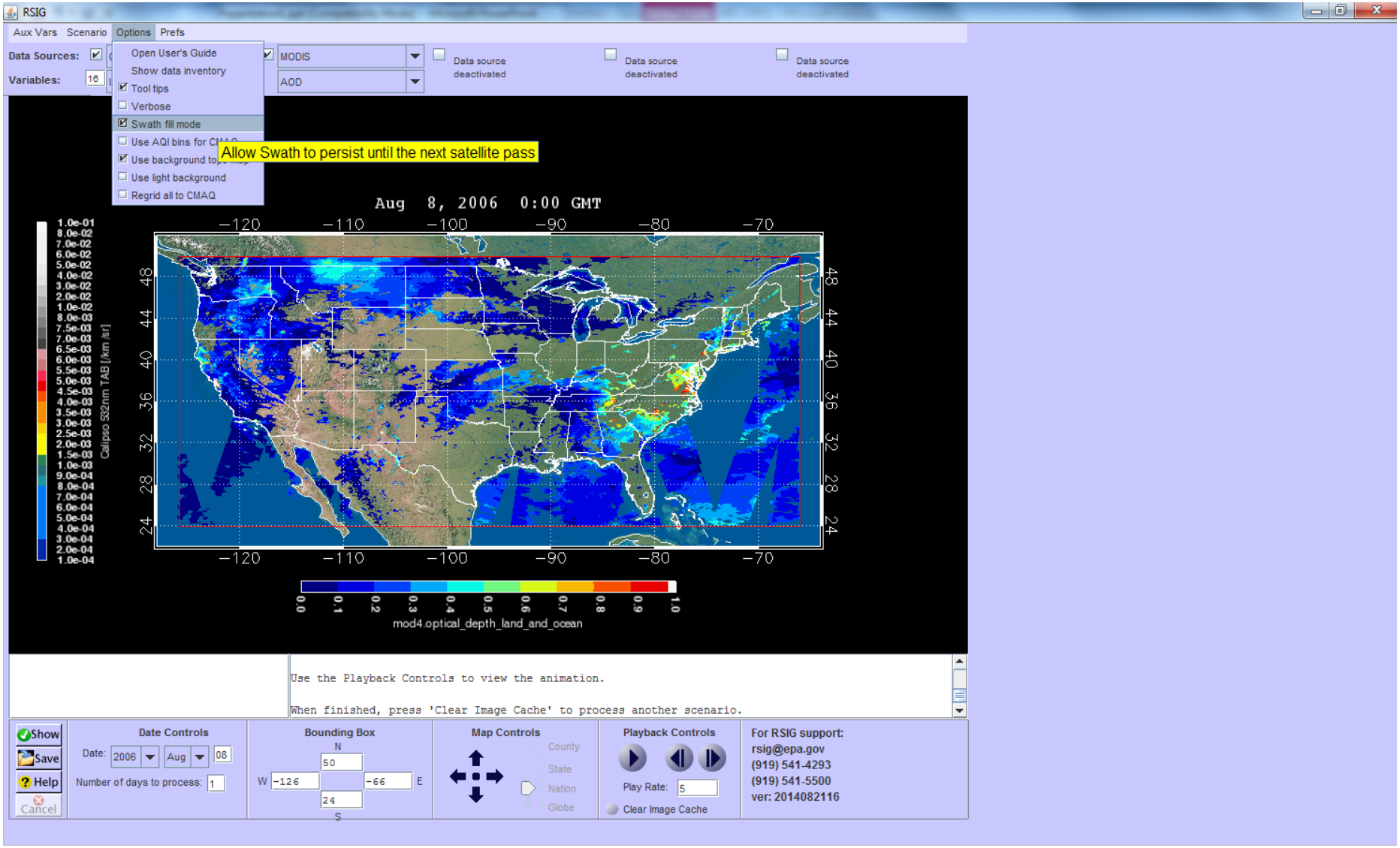
Remote Sensing Information Gateway



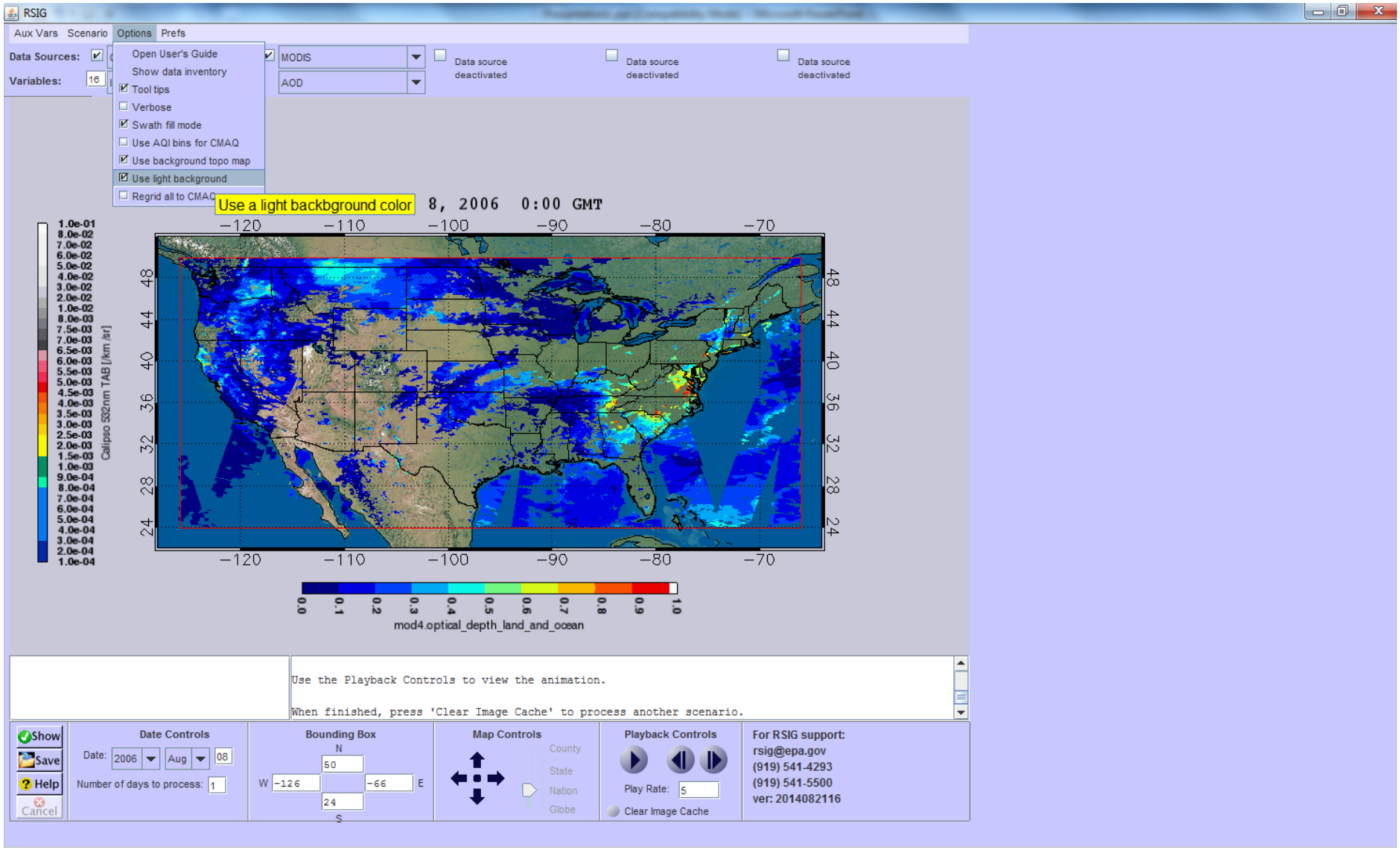
Remote Sensing Information Gateway



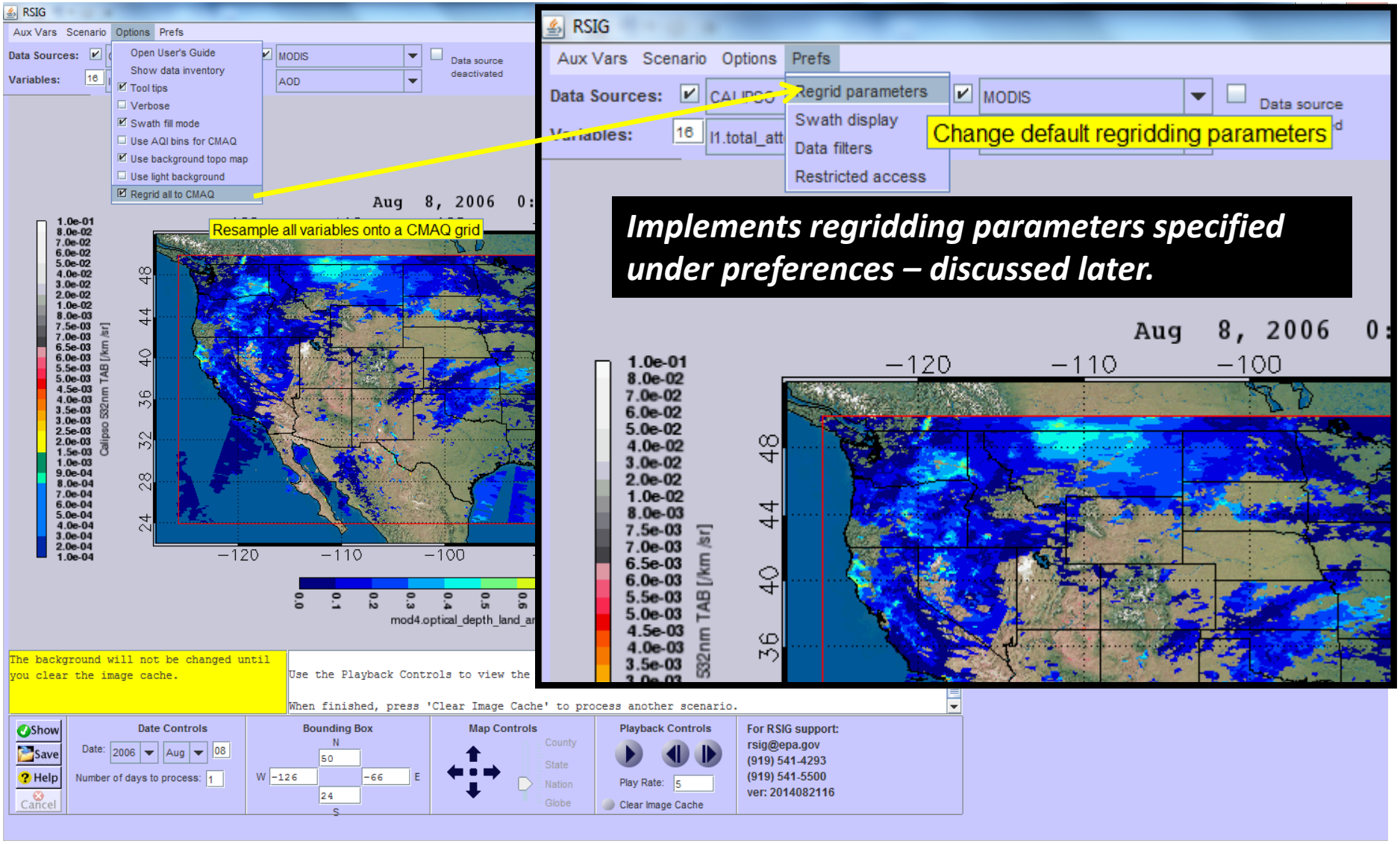
Remote Sensing Information Gateway



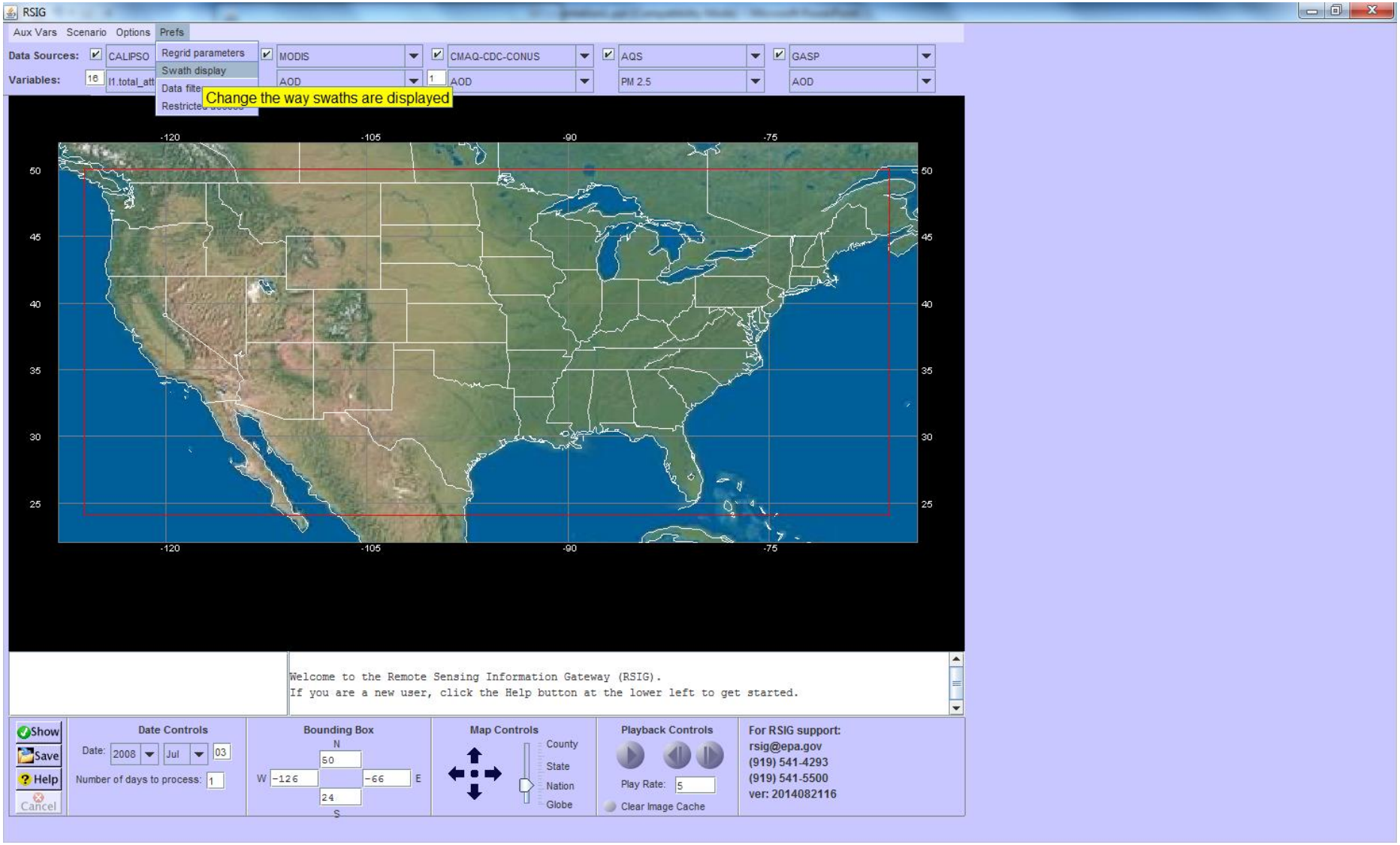
Remote Sensing Information Gateway

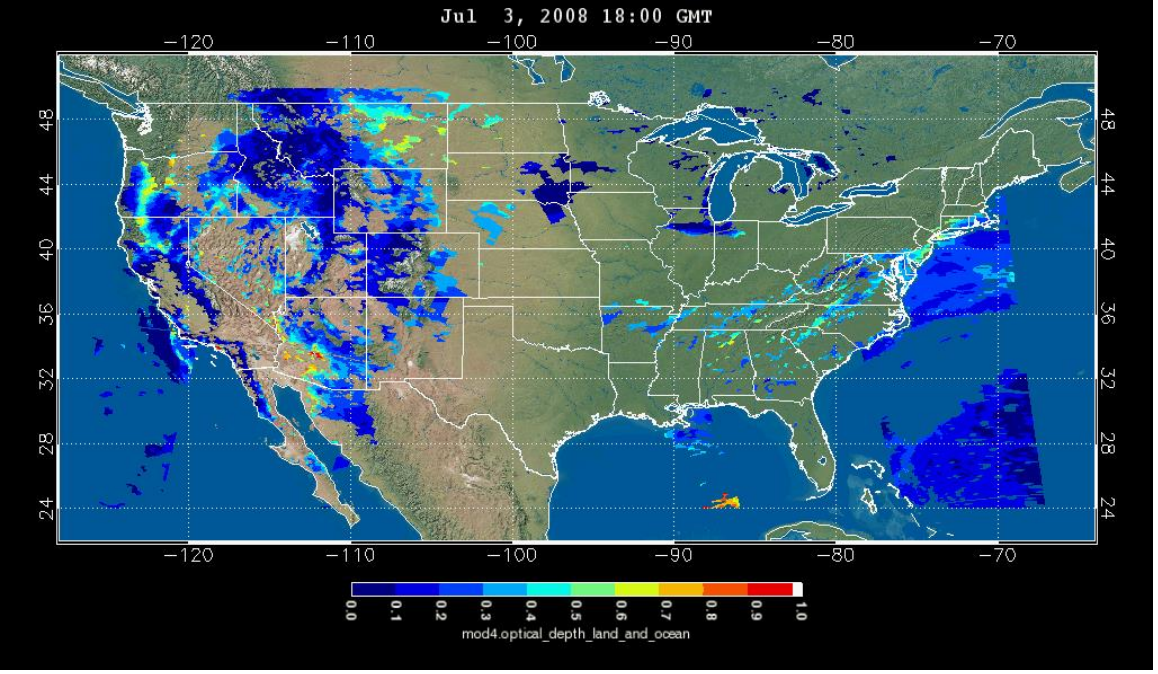


Remote Sensing Information Gateway



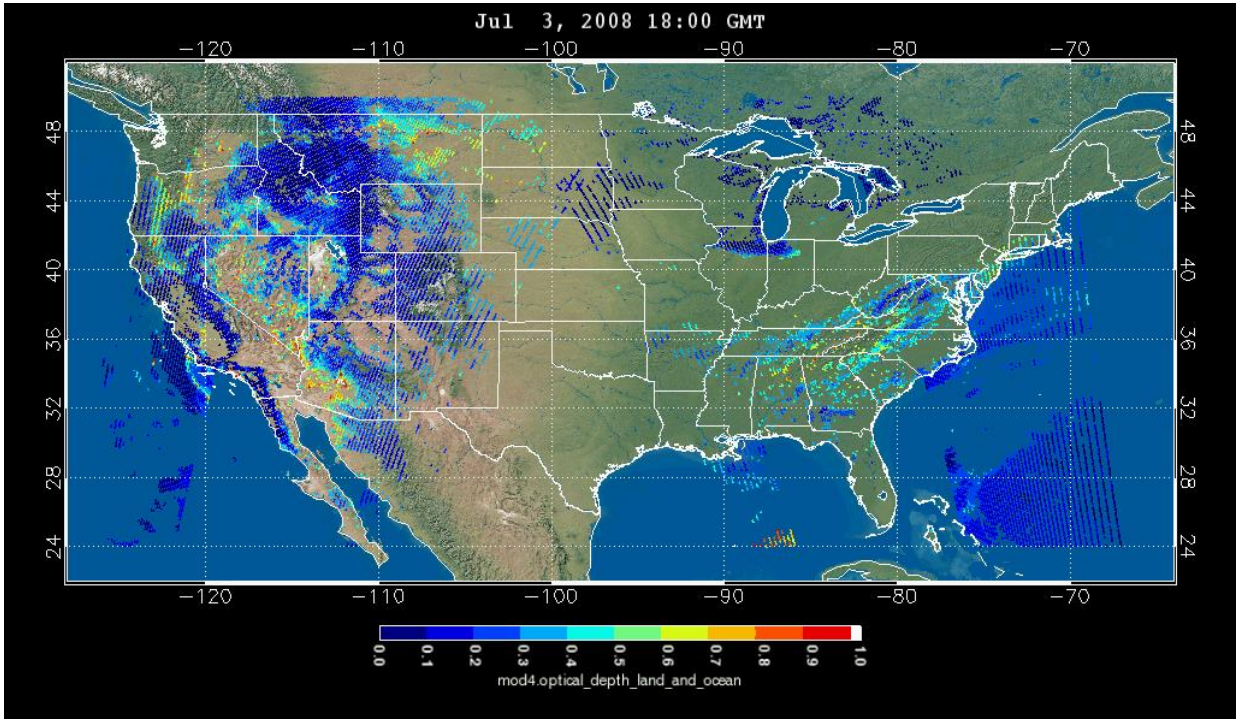
Remote Sensing Information Gateway



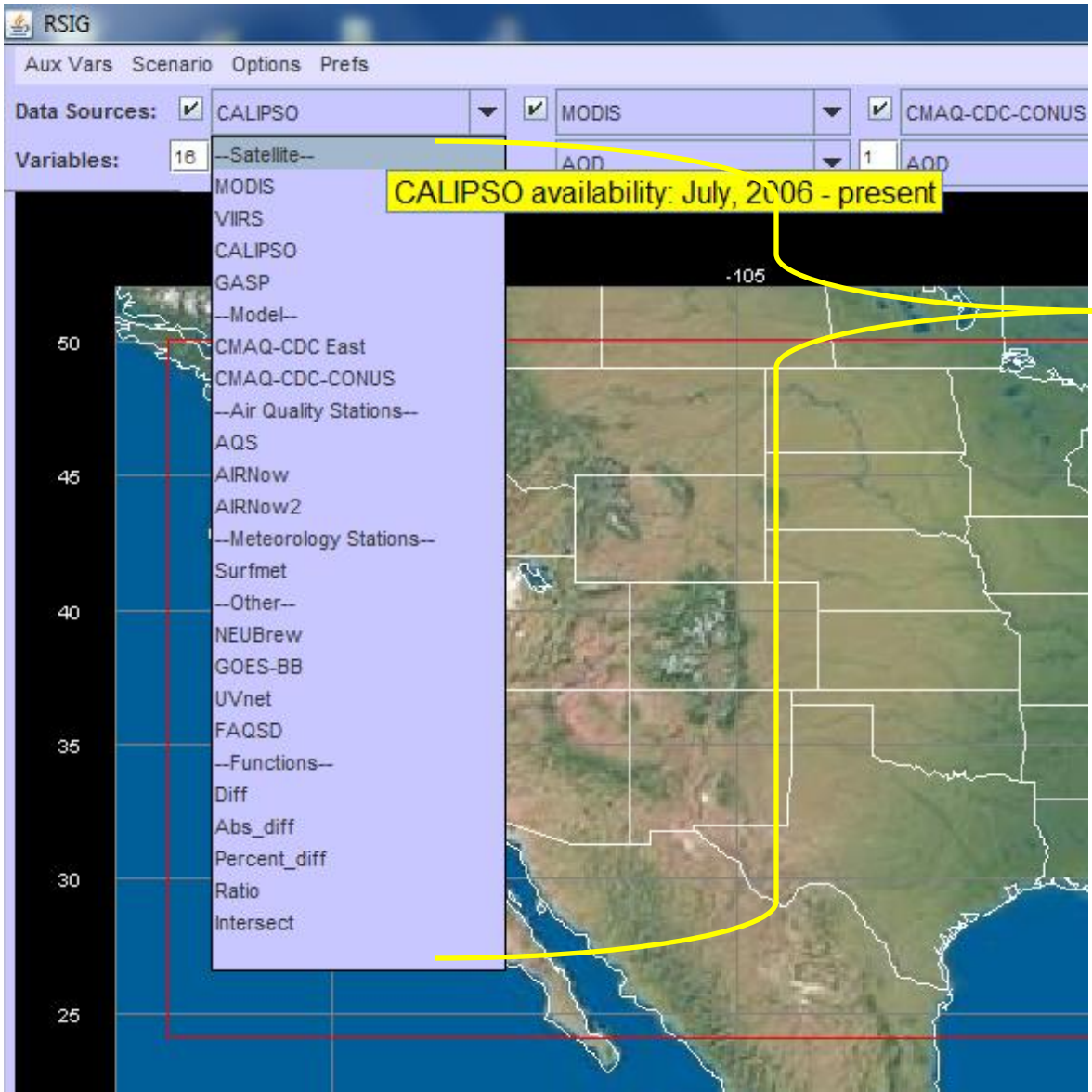


Contoured

Discrete points



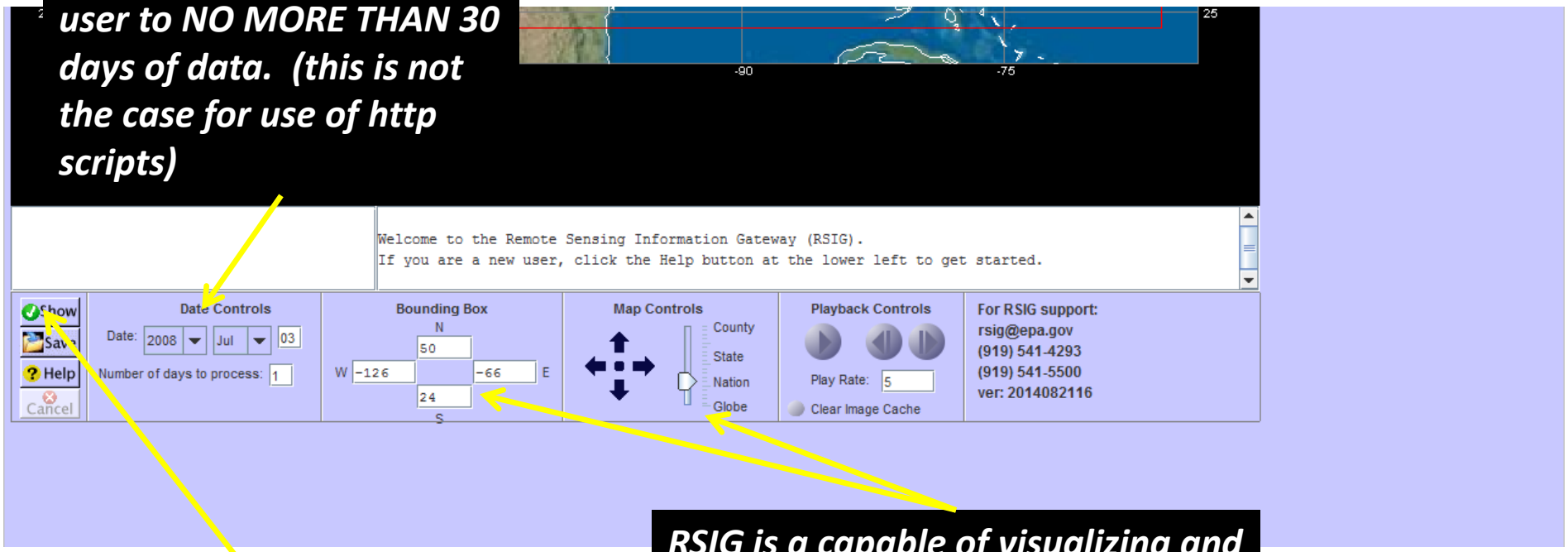
Remote Sensing Information Gateway
Data Source and Variable Selection



- Pull-Down Menu reveals Data Sources and Associated Variables for Selection
- Data Source Menu also contains some functions, such as difference between two data sets, ratios, and CMAQ intersections.
- Overview of data sets available on RSIG webpage

Remote Sensing Information Gateway

Data controls on GUI limit user to NO MORE THAN 30 days of data. (this is not the case for use of http scripts)

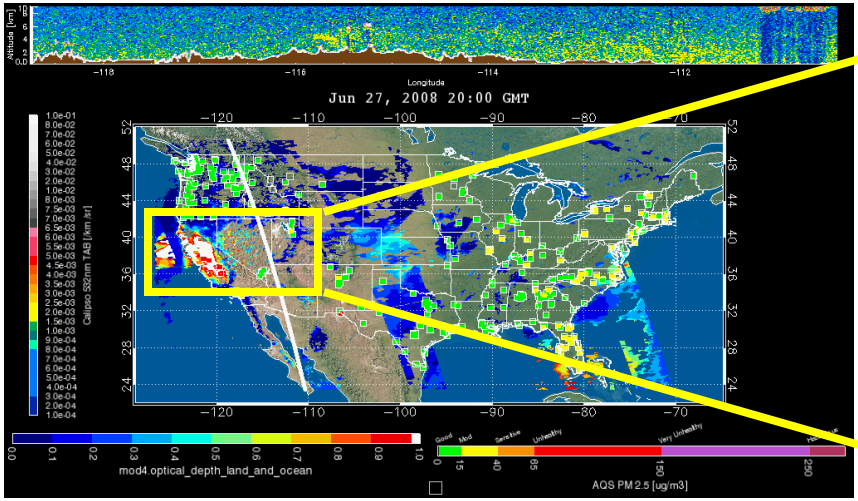


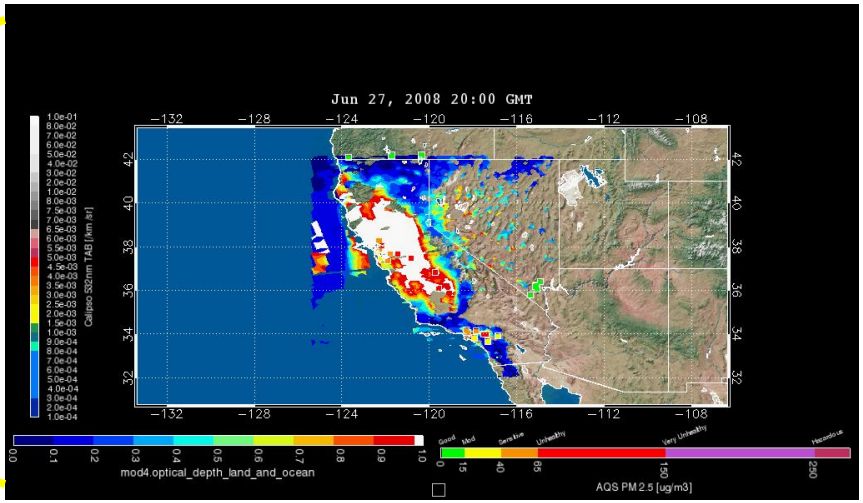
RSIG is a capable of visualizing and retrieving available global data, so Bounding Box and Map Controls allow for global data sets.

"Show" button - retrieves requested data to generate visualization via the GUI

RSIG bbox and date/time functions allow user to subset data source(s) to visualize and retrieve only data of interest

- **Time:** extract & transfer only data within hourly range (over many days)
- **Variable:** extract & transfer only variables of interest
- **Domain:** extract & transfer only data within a chosen lon-lat bbox



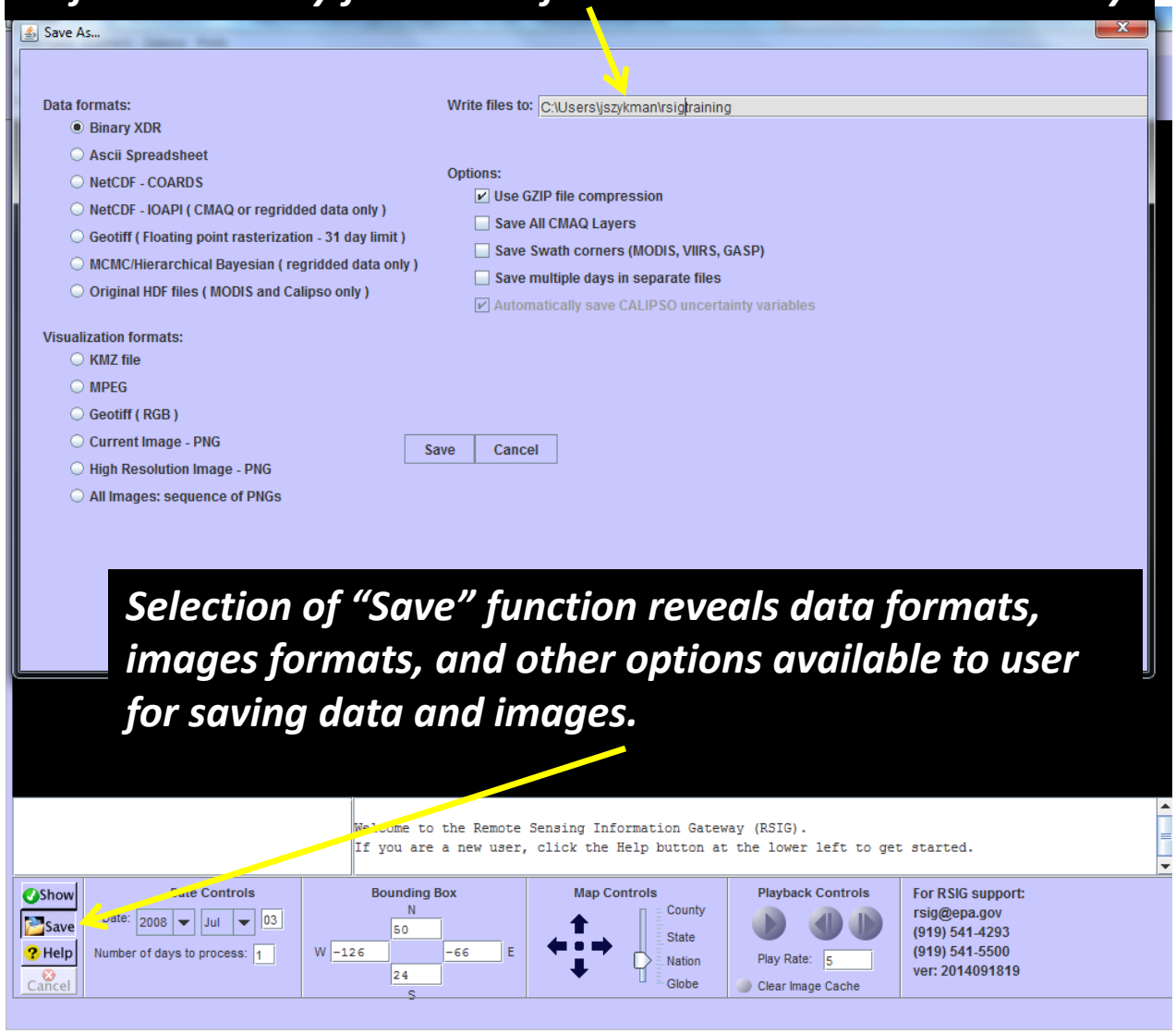


Direct download of daily L2 MODIS AOD granule file and L1 CALIOP TAB over CONUS = ~0.50 GB

The subsetted file over the region of interest is only 400 KB—1/8000th the source data size. Convenient, fast, and efficient to transmit across the network.

Remote Sensing Information Gateway
Data, Image, and other Save Options

Default directory for "Save" function is users home directory

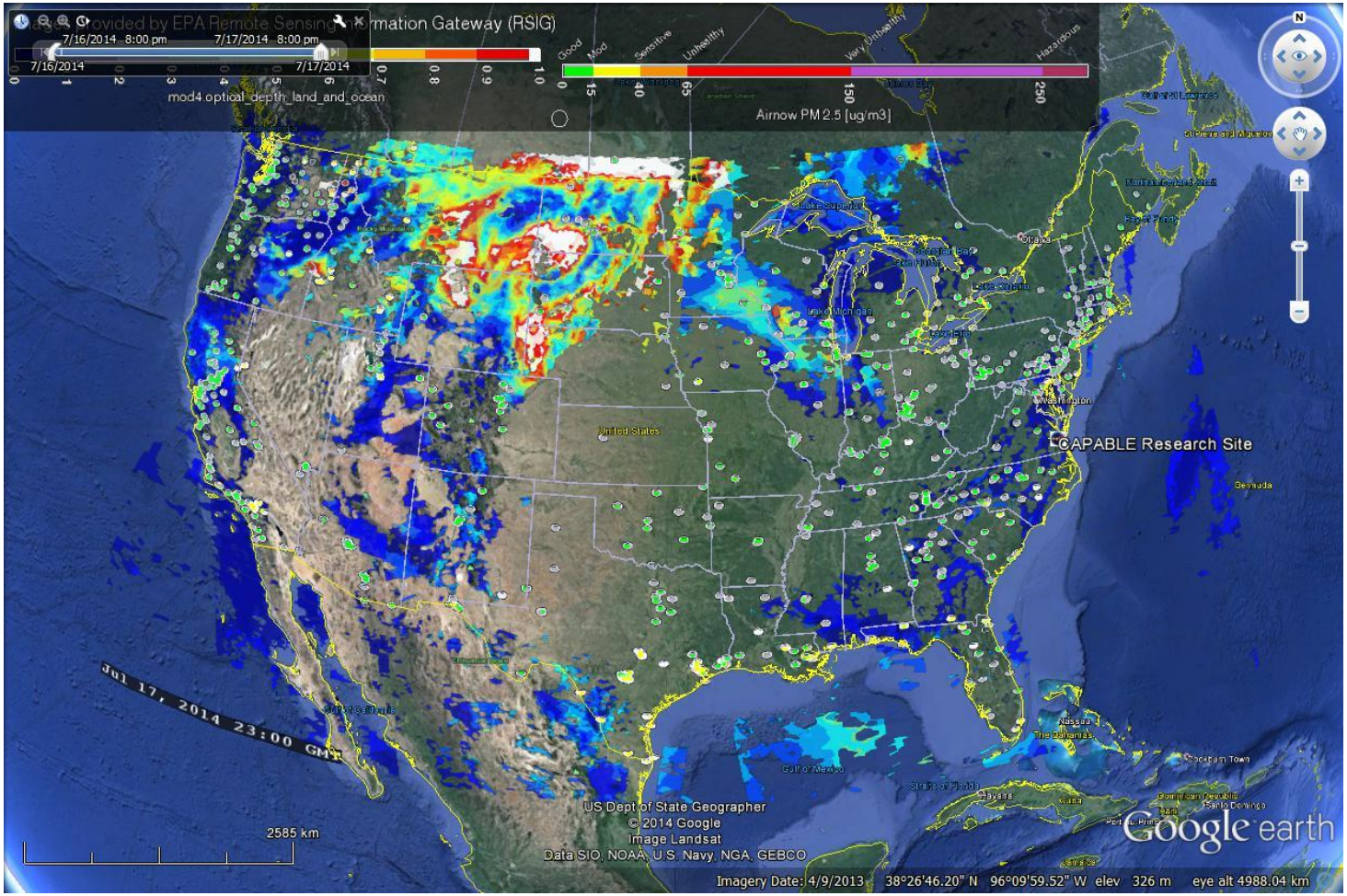


Selection of "Save" function reveals data formats, images formats, and other options available to user for saving data and images.

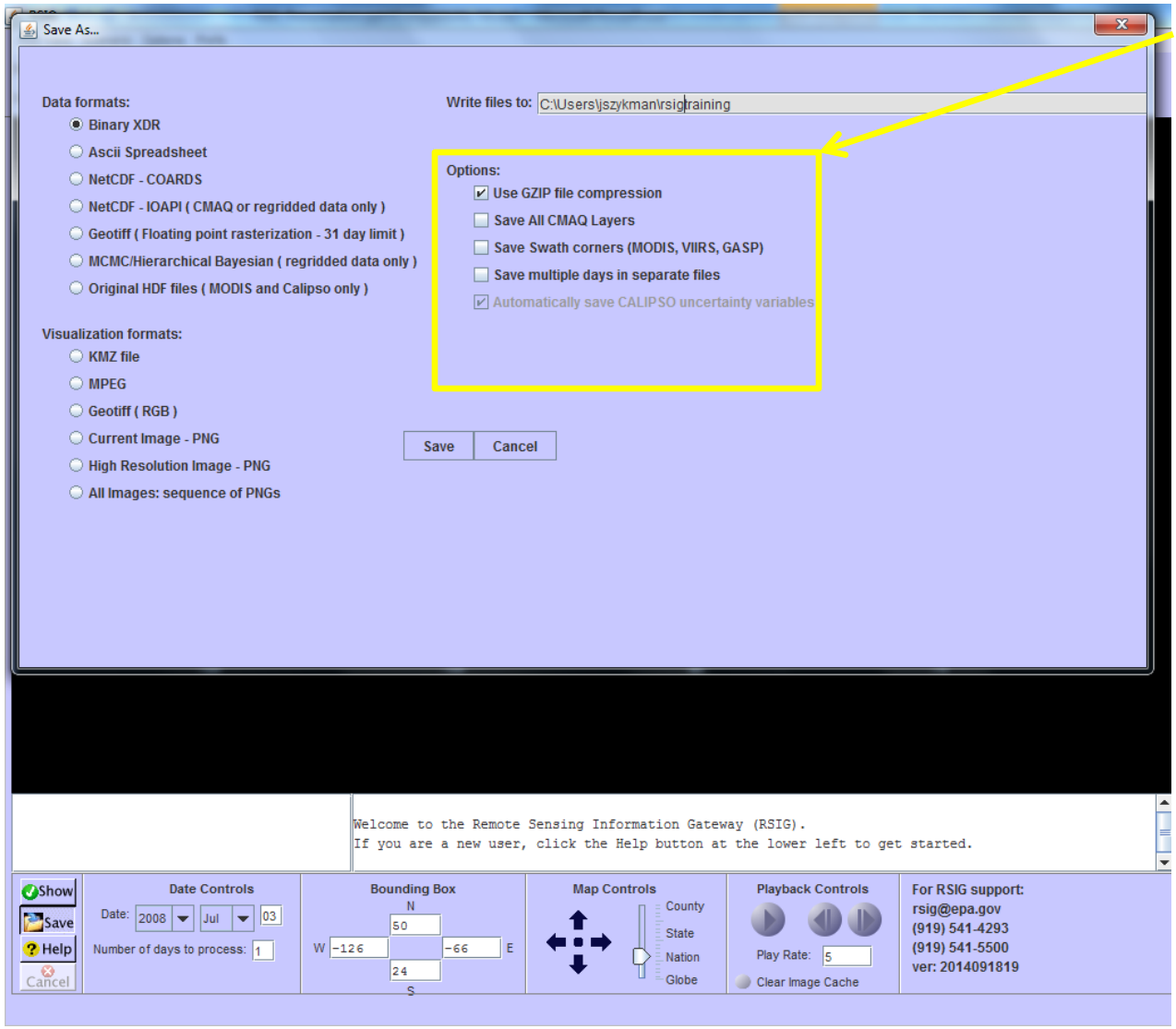
- Formats available via data save function:
  - Xdr
  - ascii
  - netCDF COARDs
  - netCDF IOAPI
  - Geotiff
  - Original hdf (CALIOP and MODIS)

- Formats available via Image save function:
  - kmz
  - mpeg
  - geotiff
  - png (single or image sequence)

Remote Sensing Information Gateway Data, Image, and other Save Options Example RSIG *.kmz file in Google Earth



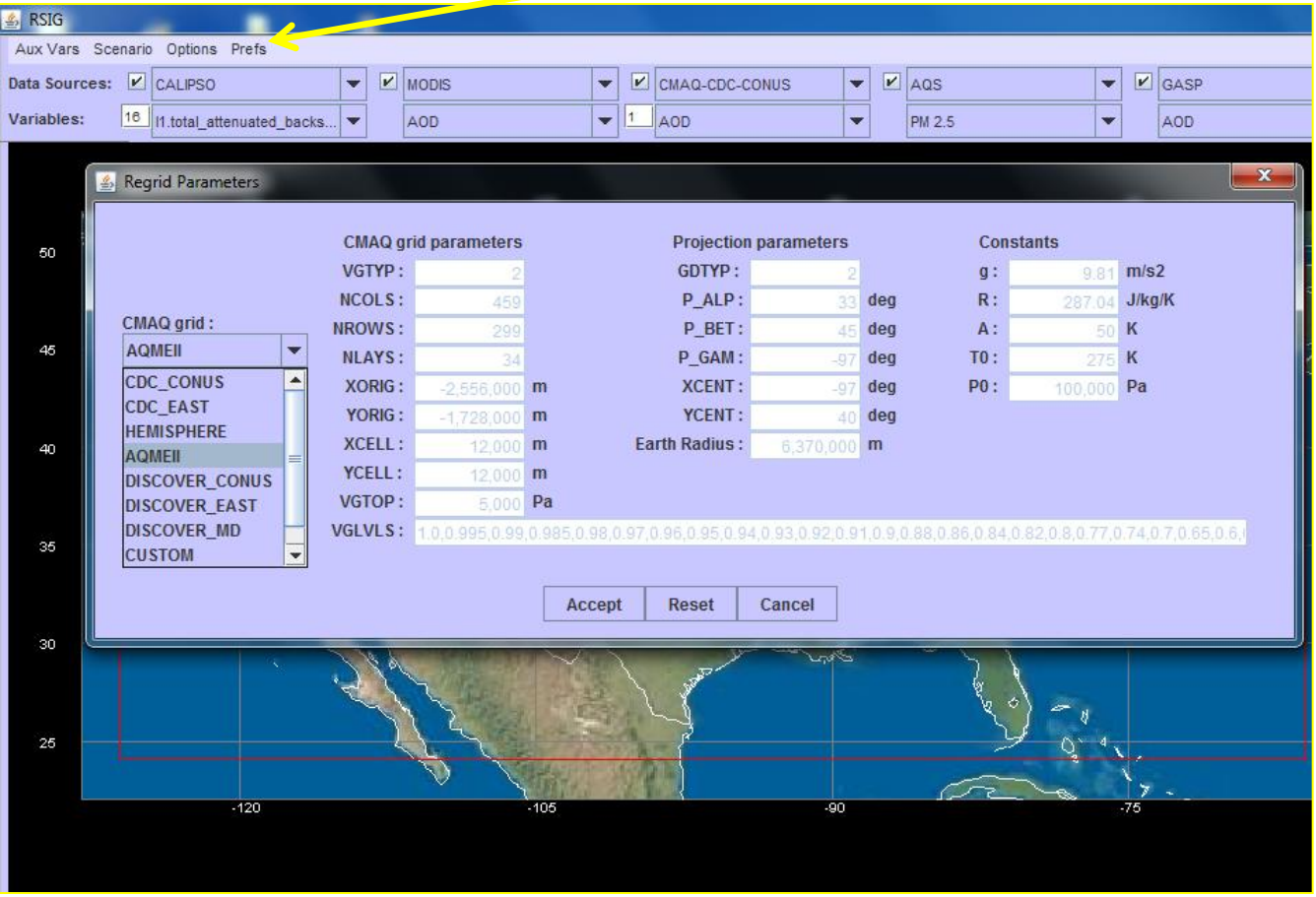
Remote Sensing Information Gateway
Data, Image, and other Save Options



- Additional options available under "Save":
  - File compression
  - Save all CMAQ layers for selected bbox and dates
  - Save pixel corners for satellite, in addition to center lat and lon
  - Save multiple days in one file per day

Remote Sensing Information Gateway
Regrid Function

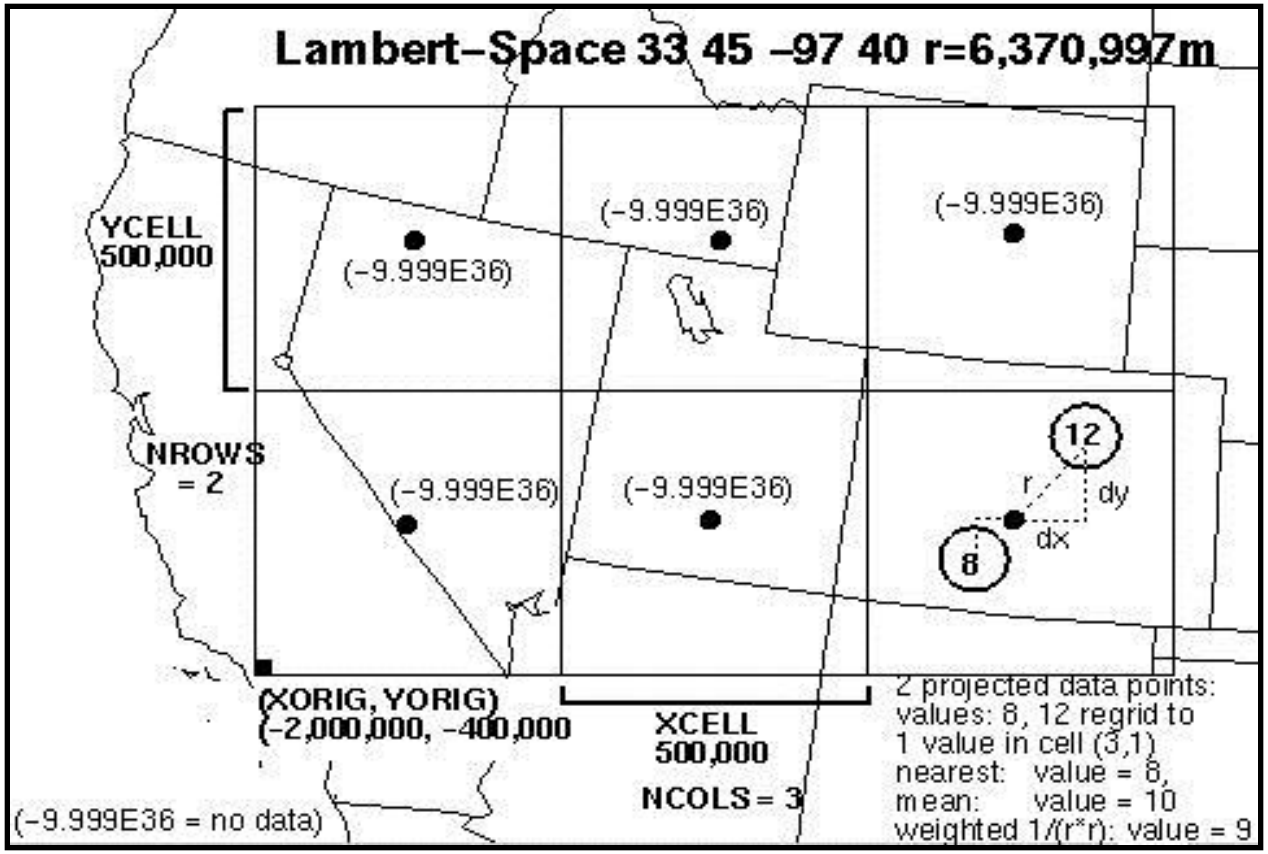
Selection of "Regrid Parameters" under the "Prefs" tab, reveals available grids along with CMAQ grid and Project parameters used for regridding.



- 2D Regridding allows the user to regrid any available surface data onto predefined CMAQ grids - CONUS grid (4km, 12km & 36km), hemispheric grid (108km), or input user specified parameters.

- User can select from 3 regridding methods :
  - Weighted (1/r2)
  - Mean
  - Nearest

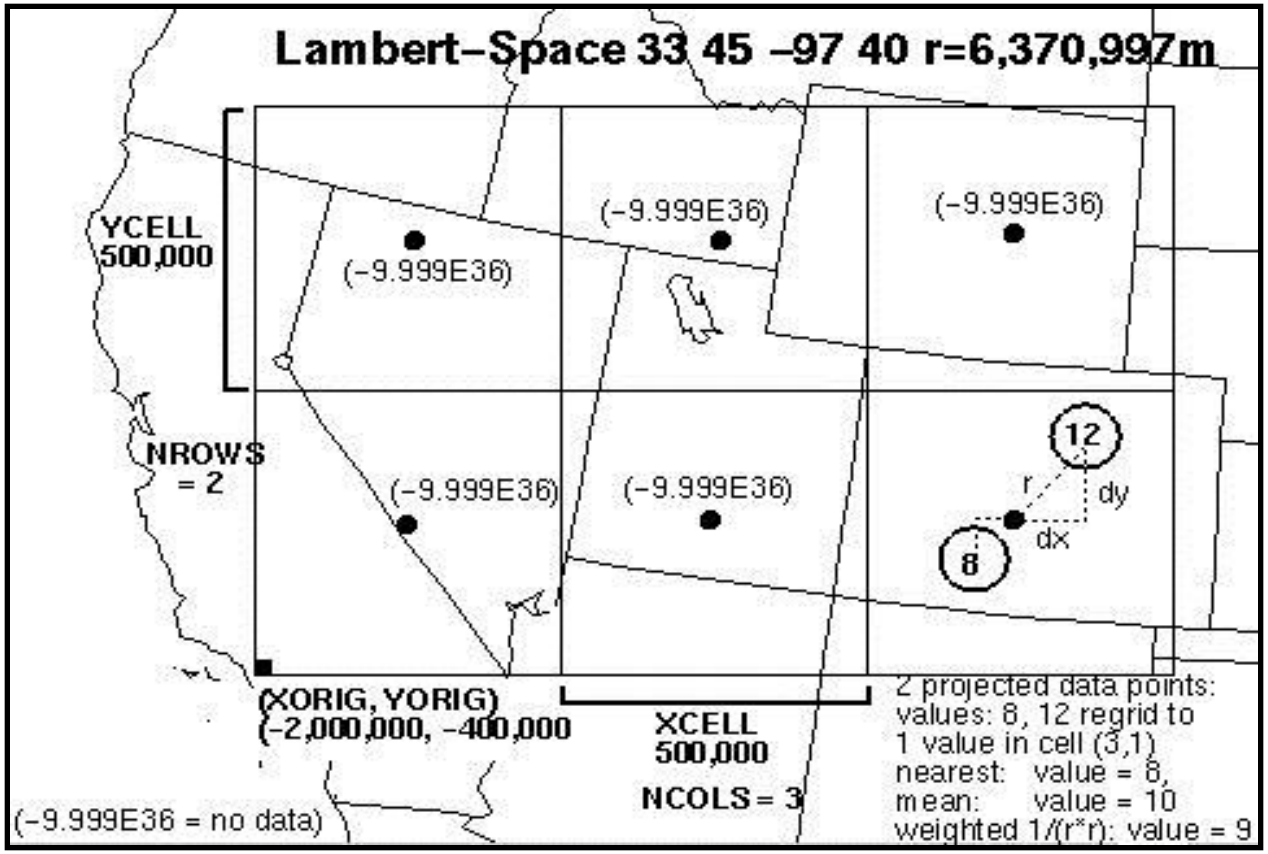
Remote Sensing Information Gateway
Regrid Function



•2D Regridding Steps:

- Data points (longitude, latitude) projected into the Lambert-space as defined by the CMAQ projection parameters
- Projected data points assigned to a CMAQ grid cell (column, row) based on CMAQ grid parameters
- Data points aggregated into one cell value based on regridding method selected

Remote Sensing Information Gateway
Regrid Function (timestamp)



- Since RSIG displays all data from HH:00 to HH:59 at hour HH, RSIG regridding aggregates all data for the hour - from HH:00 to HH:59 - into HH.
- Note: for satellite data, the timestamp is parsed from the file name (at 5-minute intervals).
- For MOZAIC, the timestamp is on the data line and is at sub-minute resolution.

MODIS data products available thru RSIG

- RSIG provides direct access to MODIS Level 2 (native resolution) Aerosol and Cloud Data files:
  - L2_MOD04/MYD04 v5.1 variables (including deep blue retrieval for bright surface)
  - L2_MOD06/MYD06 v4.3.0 variables

- Forthcoming additions in FY15:
  - Access to MODIS Collection 6 Aerosol Data Products (10 km, 3 km and DB)
  - NOAA VIIRS Environmental Data Record (EDR) AOT via NCDC (working prototype)
  - NASA VIIRS AOT (MODIS like retrieval) - funded thru NASA S-NPP Science Team

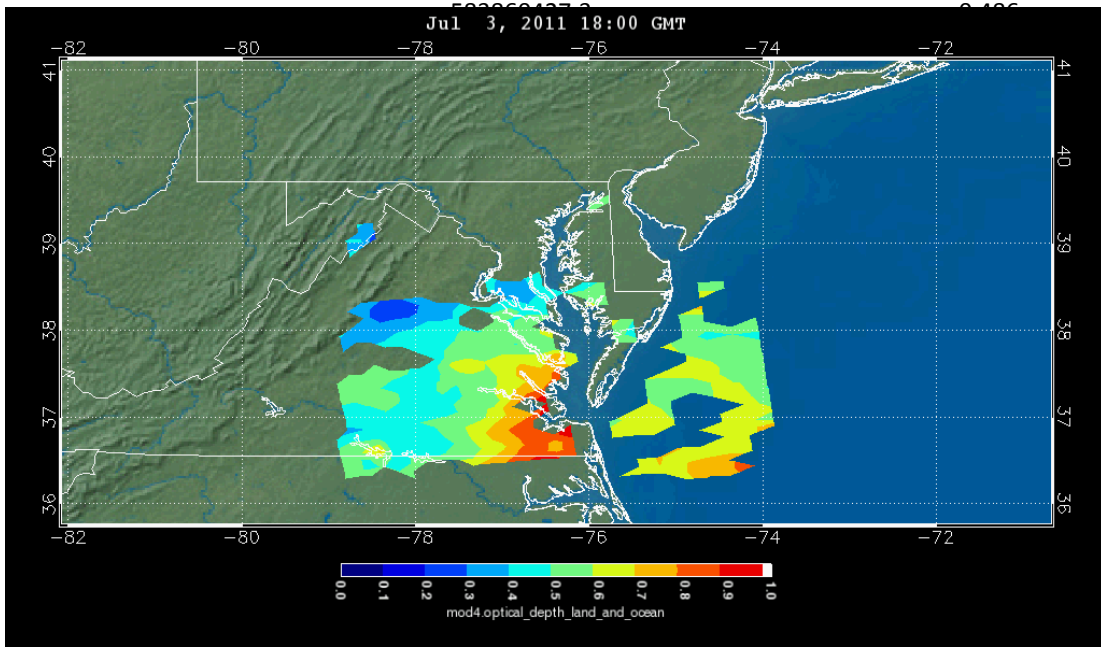
- When MODIS is selected as a Data Source you are access both Terra (MOD) and Aqua (MYD) data – Local overpass time (~10:30 am) and (~1:30 pm) should be used to determine which satellite.

Example of variables saved in *.txt file for MODIS AOD

Timestamp(UTC)	LONGITUDE(deg)	LATITUDE(deg)	Scan_Start_Time(Seconds_since_1993-1-1_00:00:00.0_0)	Optical_Depth_Land_And_Ocean(-)
2011-07-03T15:25:00-0000	-75.014282	38.009335	583860425.8	-9999
2011-07-03			3860425.8	-9999
2011-07-03			3860425.8	-9999
2011-07-03T15:25:00-0000	-74.381775	37.953564	583860425.8	-9999
2011-07-03T15:25:00-0000	-74.183258	37.935333	583860425.8	-9999
2011-07-03T15:25:00-0000	-73.990273	37.917274	583860425.8	-9999
2011-07-03T15:25:00-0000	-73.802444	37.899384		-9999
2011-07-03T15:25:00-0000	-73.619476	37.881657		-9999
2011-07-03T15:25:00-0000	-79.164322	38.199299		0.571
2011-07-03T15:25:00-0000	-78.764175	38.178757		-9999
2011-07-03T15:25:00-0000	-78.399147	38.158829	583860427.3	0.404
2011-07-03T15:25:00-0000	-78.044556	38.138351	583860427.3	0.413
2011-07-03T15:25:00-0000	-77.707436	38.117886		
2011-07-03T15:25:00-0000	-77.387077	38.097515		
2011-07-03T15:25:00-0000	-77.080711	38.077206		
2011-07-03T15:25:00-0000	-76.787628	38.057014		
2011-07-03T15:25:00-0000	-76.507431	38.03701		
2011-07-03T15:25:00-0000	-76.237991	38.017128		
2011-07-03T15:25:00-0000	-75.978996	37.997417		
2011-07-03T15:25:00-0000	-75.72966	37.97789		
2011-07-03T15:25:00-0000	-75.48912	37.958538		
2011-07-03T15:25:00-0000	-75.257195	37.939396		
2011-07-03T15:25:00-0000	-75.032837	37.920433		
2011-07-03T15:25:00-0000	-74.815681	37.901657		
2011-07-03T15:25:00-0000	-74.60524	37.883064		

Both UTC date/time and TAI scan time are output.

MODIS AOD geolocation data is the center lon and lat of MODIS pixel

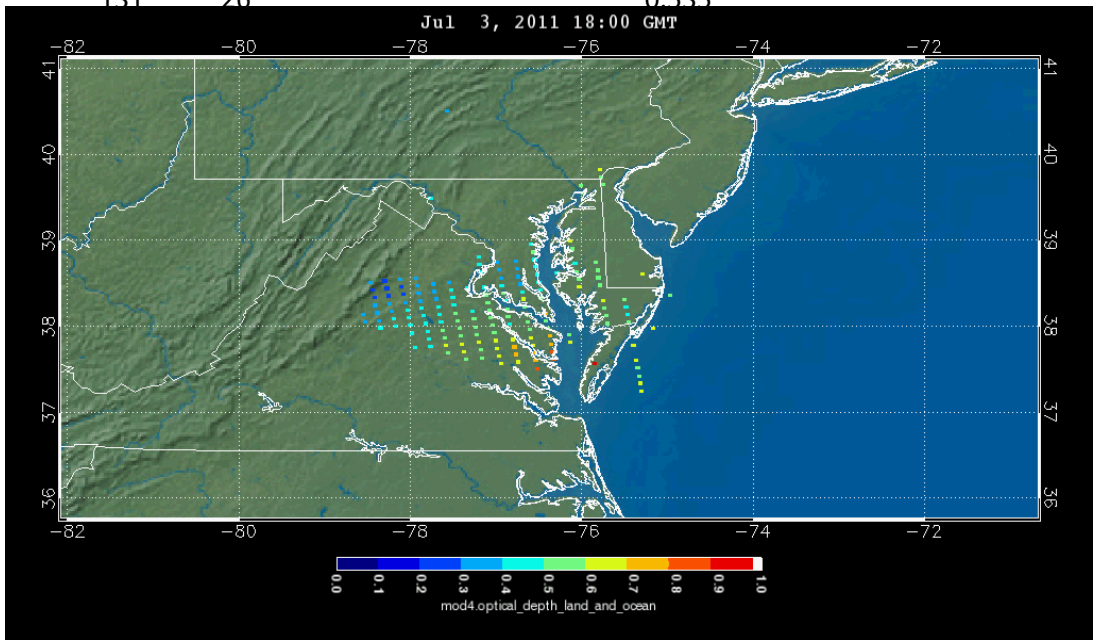


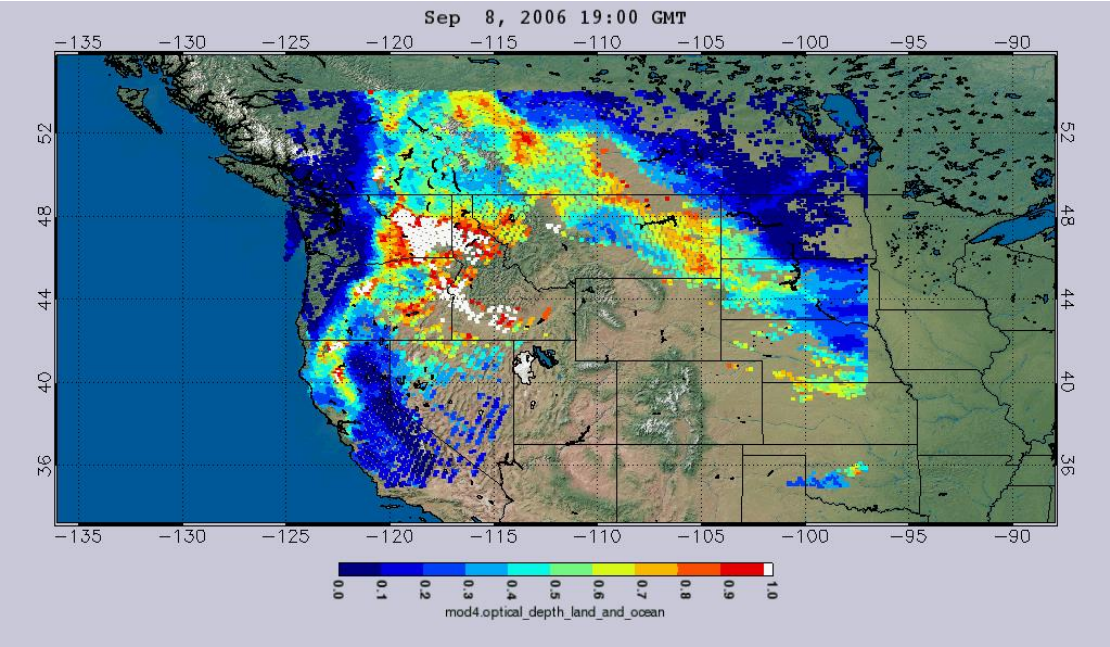
Example of MODIS AOD using Regrid Function
Example of variables saved in *.txt file for MODIS AOD

Timestamp(UTC)	LONGITUDE(deg)	LATITUDE(deg)	COLUMN(-)	ROW(-)	Optical_Depth_Land_And_Ocean(-)
2011-07-03T15:00:00-0000	-78.4865	37.8158	17	1	0.506
2011-07-03T15:00:00-0000	-77.4913	37.6573	106	2	0.511
2011-07-03T15:00:00-0000	-78.1308	37.7939	48	5	0.495
2011-07-03T15:00:00-0000	-77.1923	37.6421	132	6	0.493
2011-07-03T15:00:00-0000	-77.7976	37.7748	77	9	0.478
2011-07-03T15:00:00-0000	-78.1184	37.8844	[illegible]	[illegible]	0.513
2011-07-03T15:00:00-0000	-76.3455	37.5825	[illegible]	[illegible]	0.725
2011-07-03T15:00:00-0000	-77.7736	37.8633	[illegible]	[illegible]	0.541
2011-07-03T15:00:00-0000	-78.0948	37.973	[illegible]	[illegible]	0.506
2011-07-03T15:00:00-0000	-77.1541	37.8209	131	26	0.535
2011-07-03T15:00:00-0000	-76.331	37.6728			
2011-07-03T15:00:00-0000	-77.7632	37.9449			
2011-07-03T15:00:00-0000	-76.8681	37.798			
2011-07-03T15:00:00-0000	-78.4417	38.0767			
2011-07-03T15:00:00-0000	-75.83	37.6259			
2011-07-03T15:00:00-0000	-78.0847	38.0547			
2011-07-03T15:00:00-0000	-77.1405	37.9113			
2011-07-03T15:00:00-0000	-77.7503	38.0353			
2011-07-03T15:00:00-0000	-76.8541	37.8884			
2011-07-03T15:00:00-0000	-78.4297	38.1672			
2011-07-03T15:00:00-0000	-75.8148	37.7161			
2011-07-03T15:00:00-0000	-77.4273	38.017			

CMAQ cell column and row

Regridded MODIS AOD value(s)

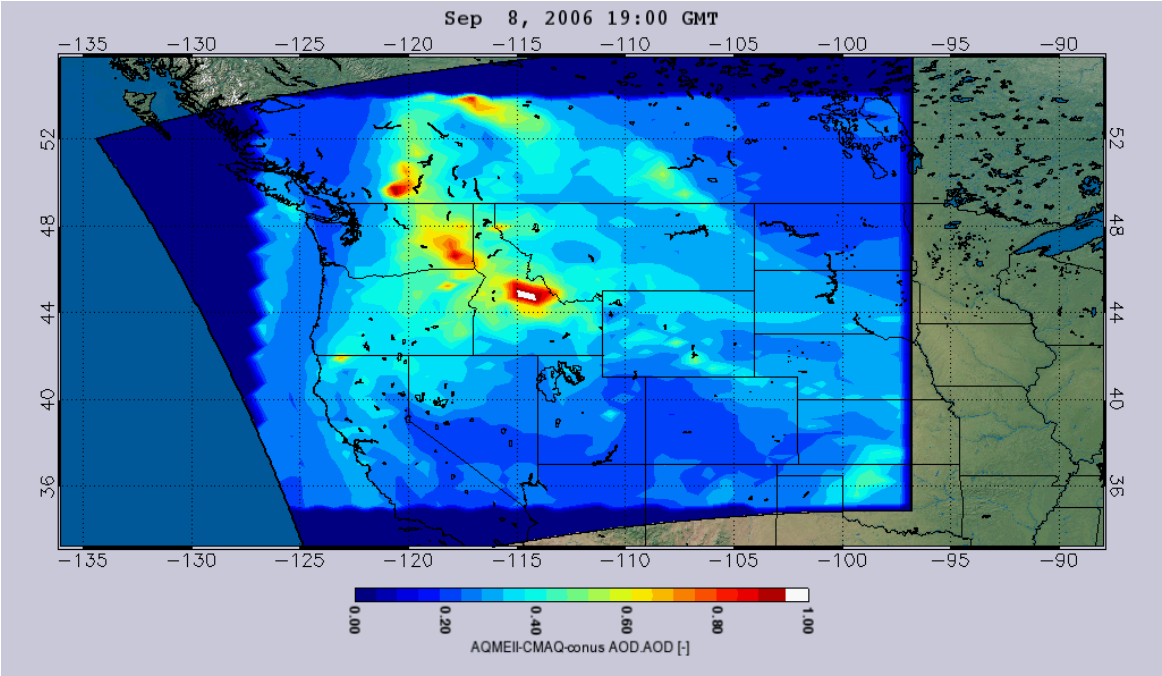




The RSIG-MODISserver regrid function allows the user to generate a regridded image for viewing <u>prior to downloading data</u>:

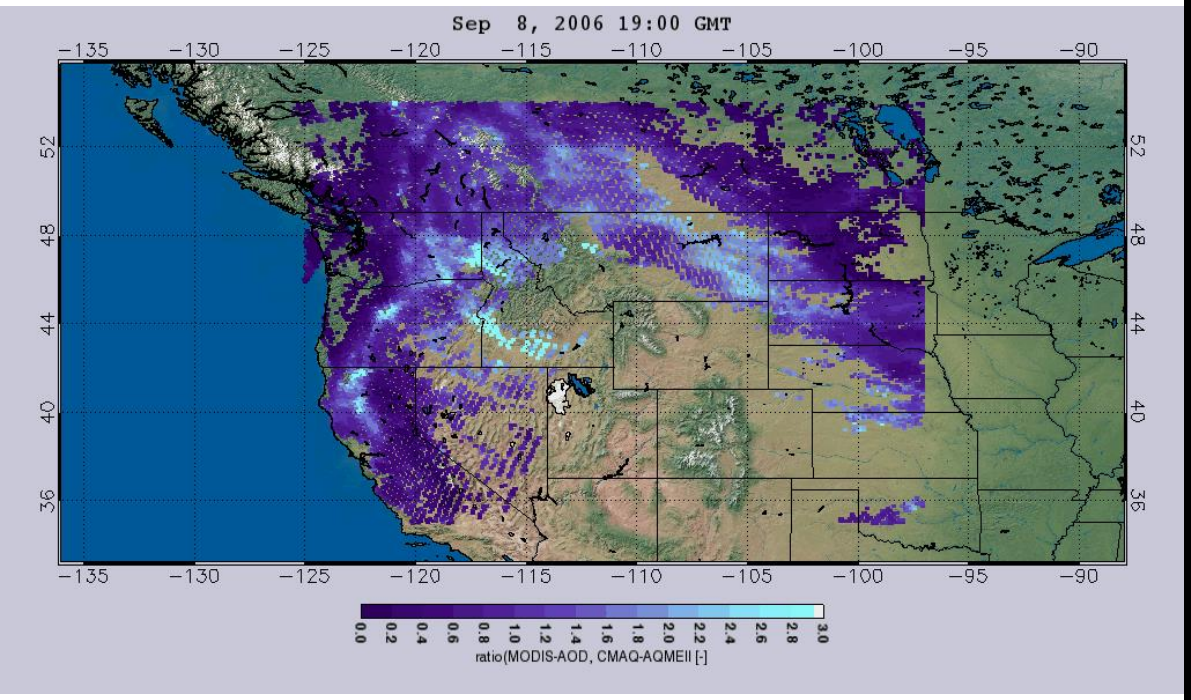
Left Image: MODIS AOD (Aqua) regridded onto the AQMEII CONUS 12km grid. (<u>less than mouse clicks</u>)

Bottom Image: CMAQ_AQMEII_4.7.1 AOD



Compare Feature for MODIS AOD

(and other datasets/variables)



Selection of a compare function under Data Source:

- ***Difference***
- ***Absolute Difference***
- ***Percent Difference***
- ***Ratio***

allows the user to generate an initial comparison with available CMAQ AOD.

Image: Ratio MODIS/CMAQ AOD from images on prior slide. This timeframe was associated with the Tripod Fire Complex Aug-Sept 2006.

CALIOP data products available thru RSIG*

Processing Level	Data Product Name	Primary Parameter	Data Maturity
Level 1	1B Profile	Total_Attenuated_Backscatter_532 Perpendicular_Attenuated_Backscatter_532	Validation Stage 1
Level 2	5 km Aerosol Profile	Extinction_coefficient_532 Column_optical_depth_aerosol_532 Total_backscatter_coefficient_532 Perpendicular_Backscatter_coefficient_532 Particulate_deplorization_ratio_532 Aerosol_layer_fraction_532	Validation Stage 1
	5 km Cloud Profile	Extinction_coefficient_532 Column_optical_depth_cloud_532 Total_backscatter_coefficient_532 Perpendicular_Backscatter_coefficient_532 Particulate_deplorization_ratio_532 Cloud_layer_fraction_532	Provisional

*RSIG-CALIPSOSERVER connection provides access to the full suite of CALIOP data products, but only the above data products have been revealed in the RSIG-GUI.

Remote Sensing Information Gateway
Overview of CALIOP data filtering criteria

- RSIG conservatively filters the CALIOP data using recommendations developed in conjunction with NASA Langley CALIPSO Team Members - Mark Vaughan and Jason Tackett)

- Objective was to implement filtering criteria to generate “best quality” data set for RSIG users which can be used of air quality related analysis.
  - Valid range of data - can include slightly negative (non-physical) values required to avoid bias in any subsequent aggregation.
  - Available/applicable QC flag data (only non-error bits accepted).
  - Available/corresponding absolute Uncertainty data (user adjustable).
  - CAD_Score (cloud-aerosol discrimination score) - a measure of the likely hood of correctly distinguished aerosol/cloud features. (User adjustable).

- CALIPSO data is filtered-out:
  - 1. If within 180m of the surface.
  - 2. If its corresponding QC flag(s) have error bits set.
  - 3. By user-specified maximum uncertainty (in absolute units).
  - 4. By user-specified minimum acceptable CAD score (>= 20 sign-adjusted).
  - 5. If it is outside the accepted value min/max range for the variable.

Remote Sensing Information Gateway
Overview of CALIOP data filtering criteria

min/max range values allowed for the variable

L1b:

Total_Attenuated_Backscatter_532 -0.075 2.5
Total_Attenuated_Backscatter_532 -0.075 2.5
Perpendicular_Attenuated_Backscatter_532 -0.075 1.5
Perpendicular_Attenuated_Backscatter_532 -0.075 1.5
Attenuated_Backscatter_1064 -0.075 2.5
Attenuated_Backscatter_1064 -0.075 2.5
Depolarization_Gain_Ratio_532 0.0 2.0

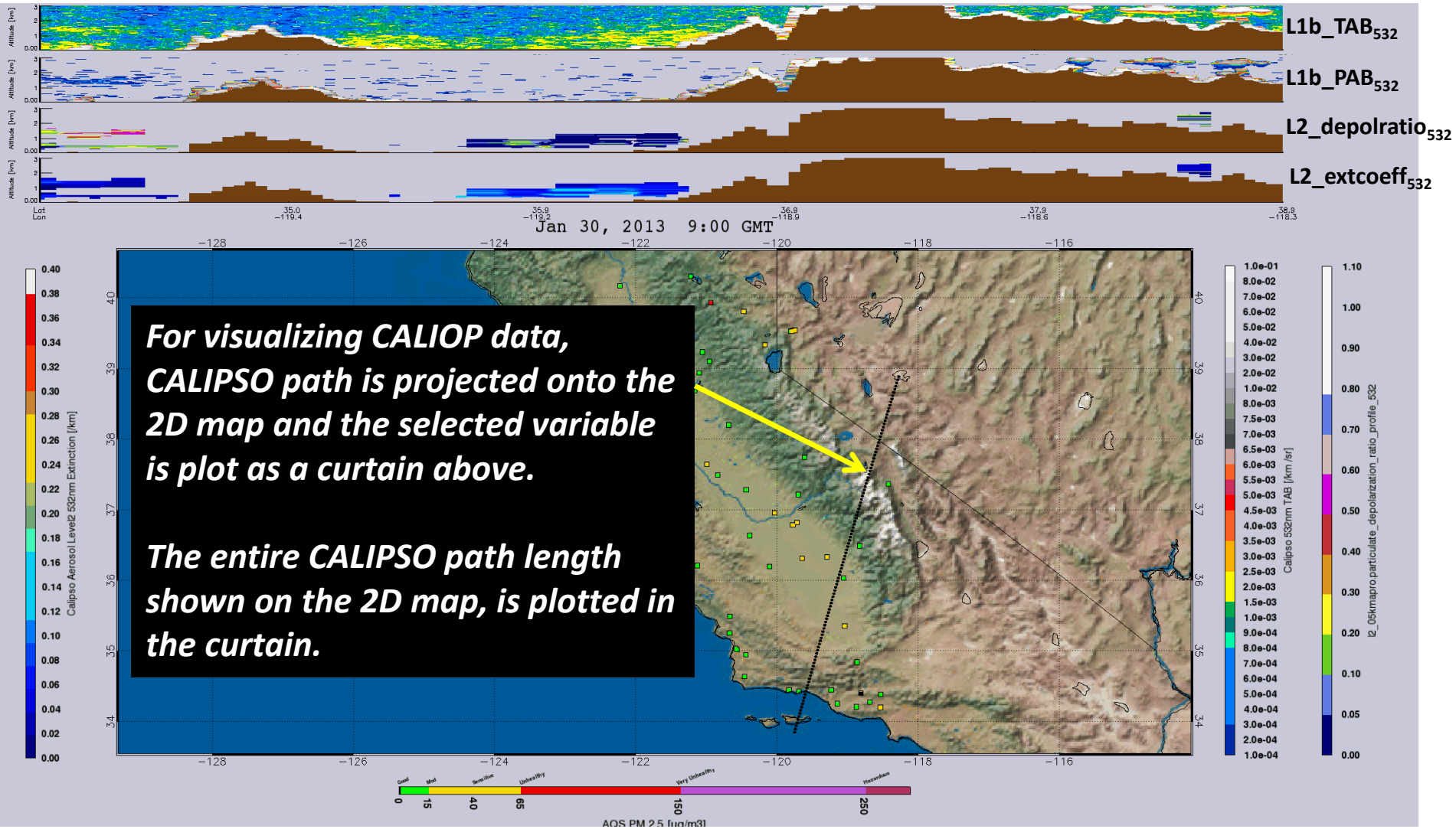
L2_05kmAPro:

Extinction_Coefficient_532 -0.2 2.5
Extinction_Coefficient_532 -0.2 2.5
Extinction_Coefficient_1064 -0.2 2.5
Extinction_Coefficient_1064 -0.2 2.5
Total_Backscatter_Coefficient_532 -0.01 0.125
Total_Backscatter_Coefficient_532 -0.01 0.125
Perpendicular_Backscatter_Coefficient_532 -0.01 0.025
Perpendicular_Backscatter_Coefficient_532 -0.01 0.025
Backscatter_Coefficient_1064 -0.01 0.075
Backscatter_Coefficient_1064 -0.01 0.075
Particulate_Depolarization_Ratio_Profile_532 -0.05 0.8
Particulate_Depolarization_Ratio_Profile_532 -0.05 0.8
Aerosol_Layer_Fraction 0.0 30.0
Cloud_Layer_Fraction 0.0 30.0
Column_Optical_Depth_Aerosols_532 0.0 5.0
Column_Optical_Depth_Aerosols_1064 0.0 5.0
Column_Optical_Depth_Cloud_532 0.0 5.0

L2_05kmCPro:

Extinction_Coefficient_532 -0.2 2.5
Extinction_Coefficient_532 -0.2 2.5
Total_Backscatter_Coefficient_532 -0.01 0.125
Total_Backscatter_Coefficient_532 -0.01 0.125
Perpendicular_Backscatter_Coefficient_532 -0.01 0.025
Perpendicular_Backscatter_Coefficient_532 -0.01 0.025
Particulate_Depolarization_Ratio_Profile_532 0.0 1.0
Particulate_Depolarization_Ratio_Profile_532 -0.05 0.8
Aerosol_Layer_Fraction 0.0 30.0
Cloud_Layer_Fraction 0.0 30.0
Column_Optical_Depth_Cloud_532 0.0 5.0
Column_Optical_Depth_Aerosols_532 0.0 5.0

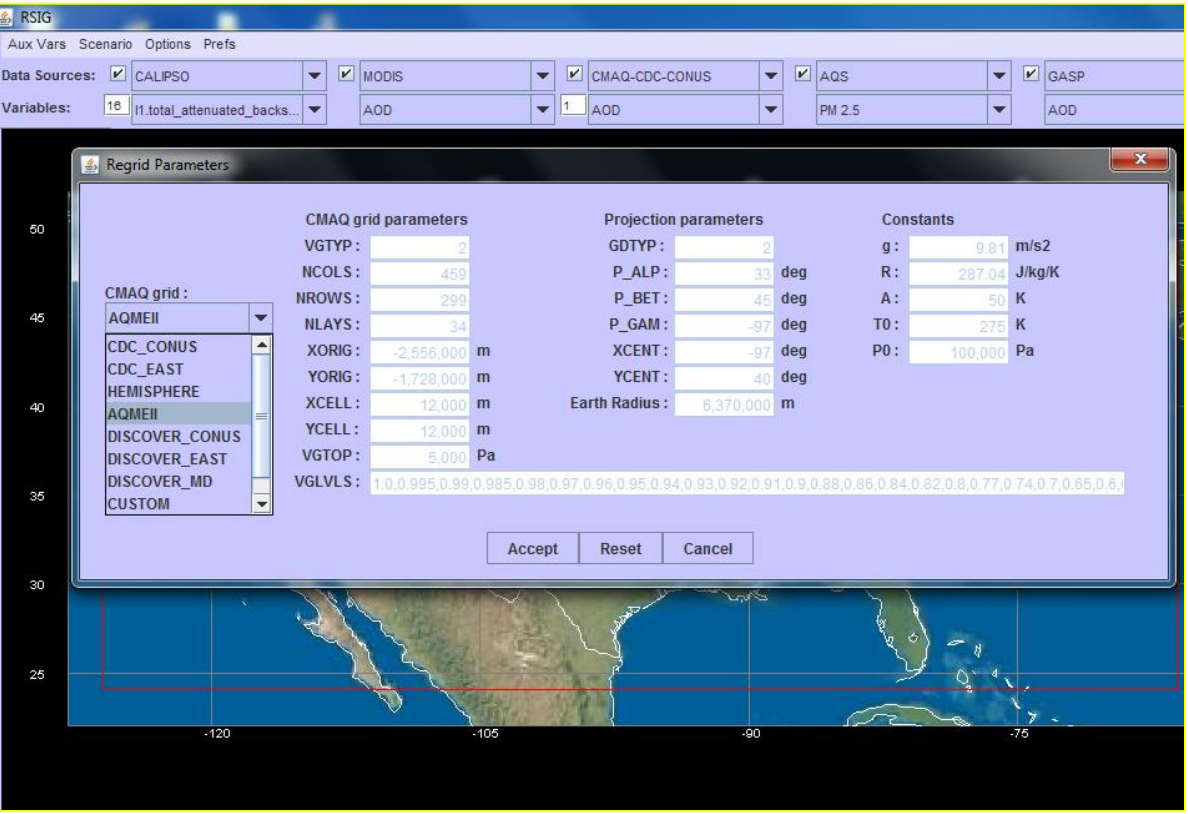
Visualizing CALIOP data in RSIG



For visualizing CALIOP data, CALIPSO path is projected onto the 2D map and the selected variable is plot as a curtain above.

The entire CALIPSO path length shown on the 2D map, is plotted in the curtain.

Regridding CALIOP data in RSIG



- 3D regridding:
  - Applied to CALIOP L1b and L2 (apro & cpro) data products which exist as a column of points.
  - CALIOP data points are regridded into the CMAQ layers by using the CMAQ vertical grid description parameters NLAYS, VGTOP, VGLVLS (sigma pressures), etc. to compute the CMAQ levels in meters above mean sea level.
  - Multiple points are aggregated within a single CMAQ grid cell.

Remote Sensing Information Gateway
C Routine to compute elevations from sigma pressures

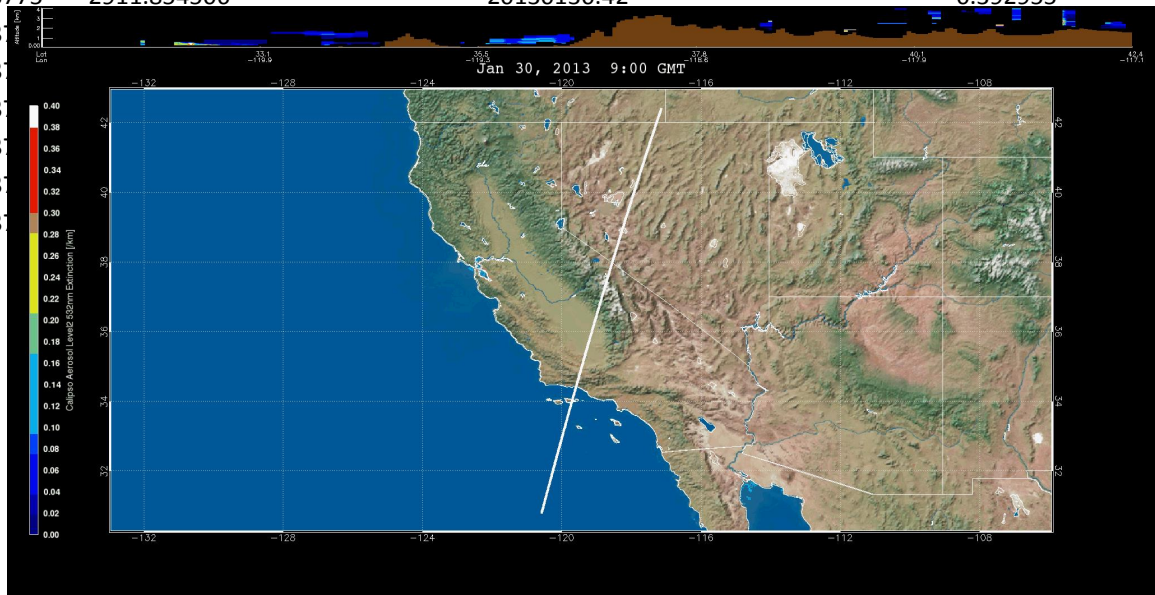
http://ofmpub.epa.gov/rsig/rsigserver?regridding.html

Example of variables saved in *.txt file(s) for CALIOP data

Timestamp(UTC)	LONGITUDE(deg)	LATITUDE(deg)	ELEVATION(m)	Profile_UTC_Time(yyyymmdd.f)	Extinction_Coefficient_532(km^-1)
2013-01-30T09:47:00-0000	-117.190536	42.263775	2133.462429	20130130.42	0.032142
2013-01-30T09:47:00-0000	-117.190536	42.263775	2193.338633	20130130.42	0.025898
2013-01-30T09:47:00-0000	-117.1905				0.047449
2013-01-30T09:47:00-0000	-117.1905				0.038186
2013-01-30T09:47:00-0000	-117.1905				0.046509
2013-01-30T09:47:00-0000	-117.190536	42.263775	2432.843924	20130130.42	0.092854
2013-01-30T09:47:00-0000	-117.190536	42.263775	2492.720366	20130130.42	0.004341
2013-01-30T09:47:00-0000	-117.190536	42.263775	2552.596569	20130130.42	0.057184
2013-01-30T09:47:00-0000	-117.190536	42.263775	2612.473011	20130130.42	0.077705
2013-01-30T09:47:00-0000	-117.190536	42.263775	2672.349215	20130130.42	0.125766
		775	2732.225657	20130130.42	0.254137
		775	2792.10186	20130130.42	0.297647
		775	2851.978302	20130130.42	0.612941
		775	2911.854506	20130130.42	0.392955

Both UTC date/time from HDF file timestamp and profile time are output

In profile CALIPSO files (l1 and l2_*pro), elevation (per data point, e.g., TAB, EXT) is computed from the HDF variable, Surface_Elevation (which is per ground point, like Longitude) and one of the fixed VData metadata arrays: Met_Data_Altitudes or Lidar_Data_Altitudes



Example of CALIOP data using Regrid Function
Example of variables saved in *.txt file(s) for CALIOP data

Timestamp(UTC)	LONGITUDE(deg)	LATITUDE(deg)	ELEVATION(m)	COLUMN(-)	ROW(-)	LAYER(-)	Extinction_Coefficient_532(km^-1)
2013-01-30T09:00:00-0000							-9999
2013-01-30T09:00:00-0000							-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	95.2311	32	92	3	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	133.6995	32	92	4	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	172.3193	32	92	5	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	230.5937	32	92	6	0.0838
2013-01-30T09:00:00-0000	-120.2455	31.9609	308.759	32	92	7	0.1378
2013-01-30T09:00:00-0000	-120.2455	31.9609	387.5539	32	92	8	0.149
2013-01-30T09:00:00-0000	-120.2455	31.9609	466.9897	32	92	9	0.1036
2013-01-30T09:00:00-0000	-120.2455	31.9609	547.0777	32	92	10	0.119
2013-01-30T09:00:00-0000	-120.2455	31.9609	627.8298	32	92	11	0.2499
2013-01-30T09:00:00-0000	-120.2455	31.9609	709.258	32	92	12	0.4079
2013-01-30T09:00:00-0000	-120.2455	31.9609	791.3748	32	92	13	0.2226
2013-01-30T09:00:00-0000	-120.2455	31.9609	916.1397	32	92	14	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	1084.6753	32	92	15	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	1256.2086	32	92	16	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	1430.8584	32	92	17	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	1608.7505	32	92	18	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	1836.4358	32	92	19	-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	2116.3911				-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	2454.7374				-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	2908.6028				-9999
2013-01-30T09:00:00-0000	-120.2455	31.9609	3438.8899				-9999

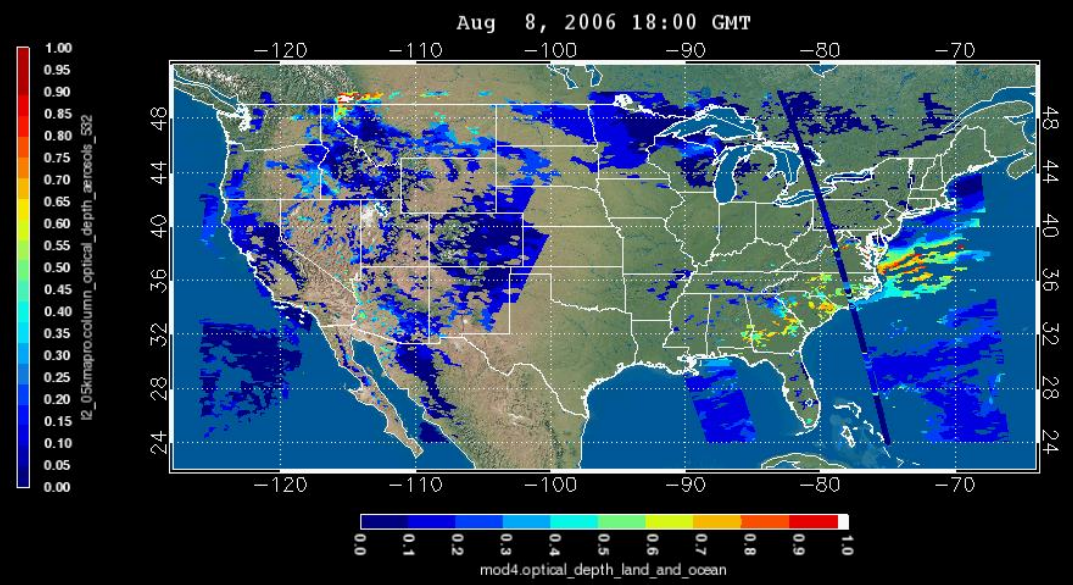
CALIPSO data aggregated within CMAQ hour.

Regridded CALIOP value(s)

CMAQ cell column, row, and layer index (1-based)

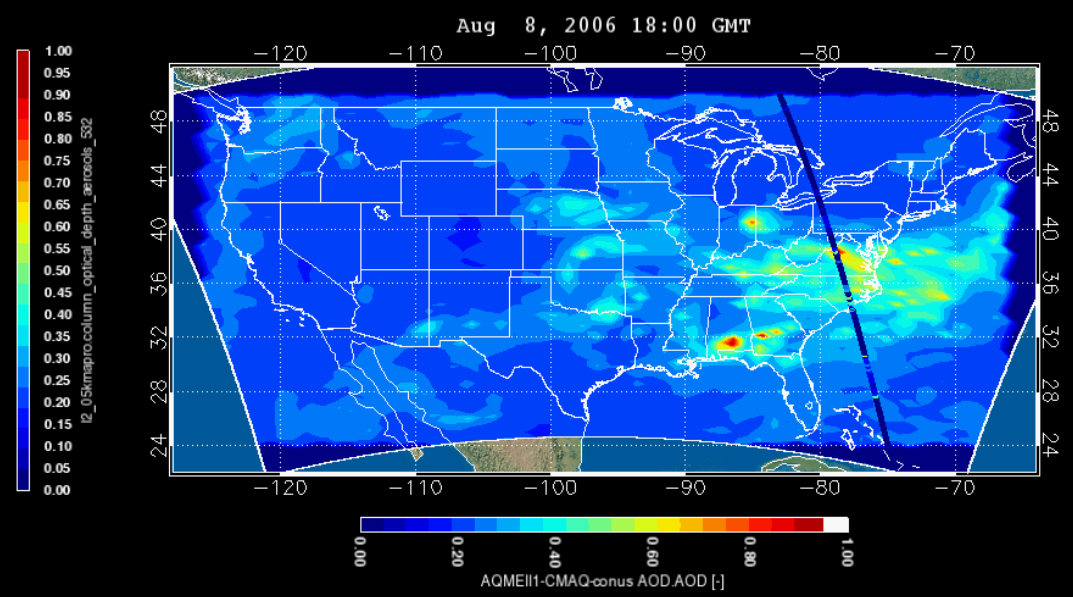
No CALIPSO profile for this variable

MODIS L2_AOD (550nm) and CALIOP L2_AOD (532 nm)

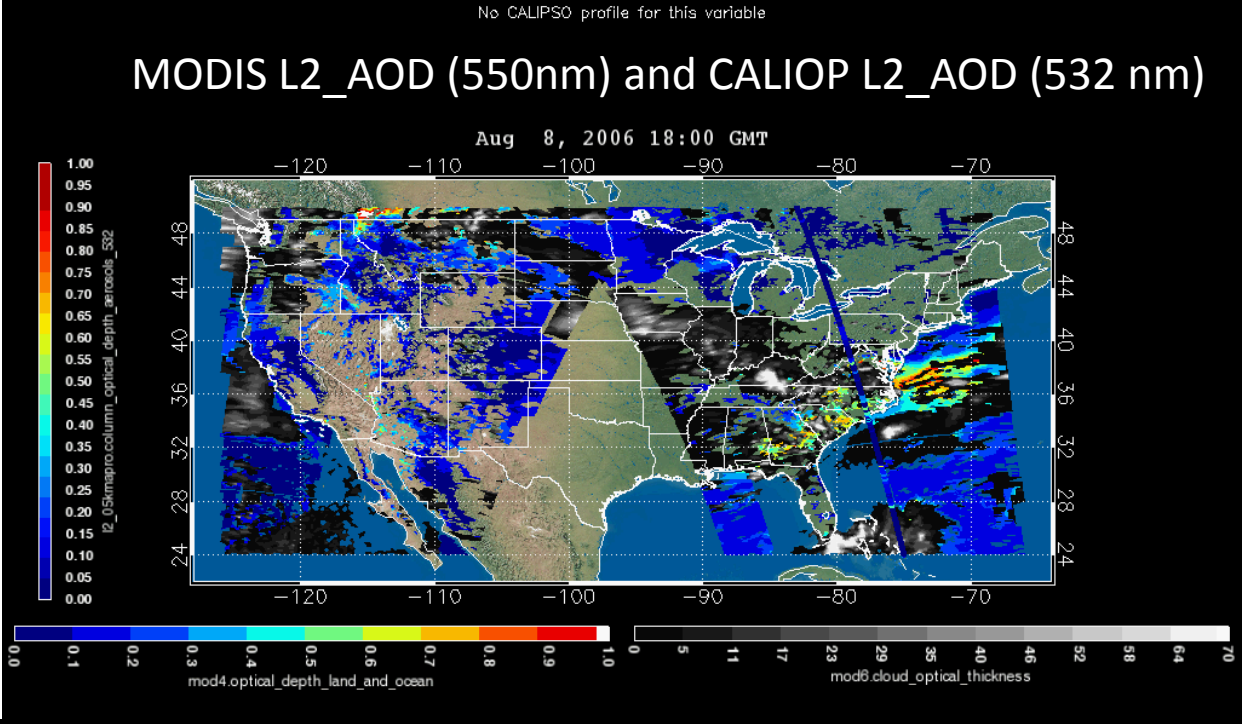


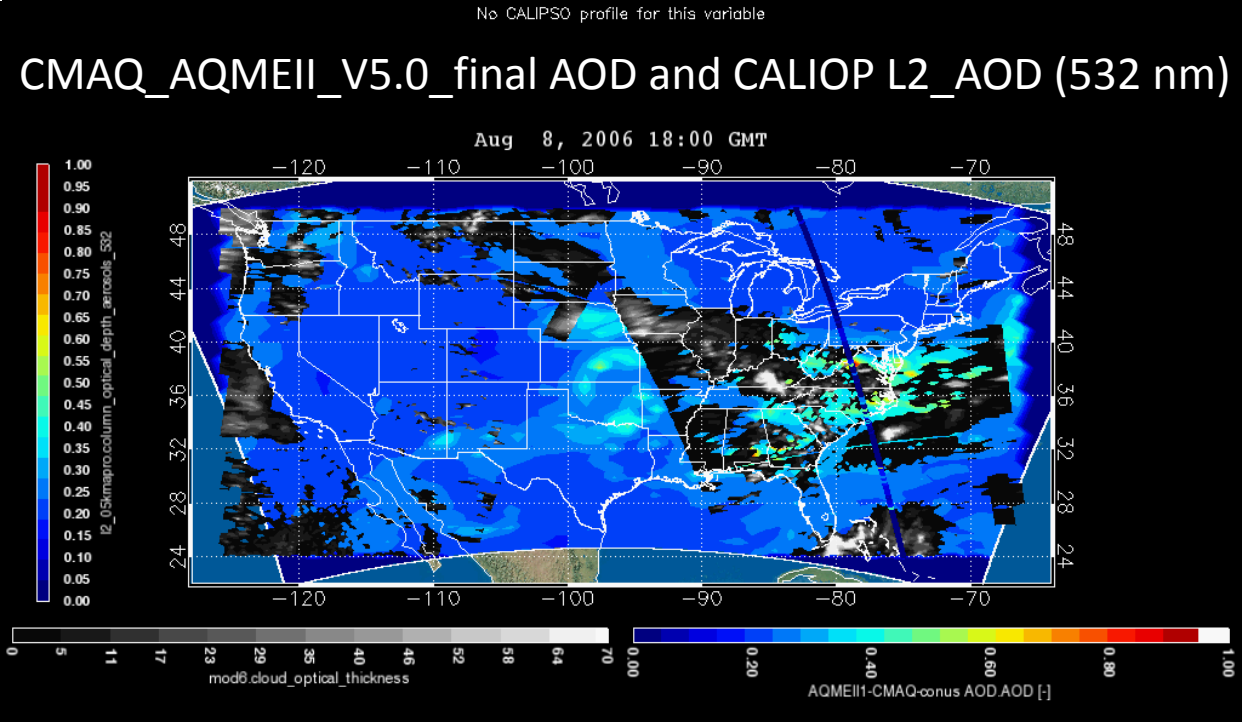
No CALIPSO profile for this variable

CMAQ_AQMEII_V5.0_final AOD and CALIOP L2_AOD (532 nm)

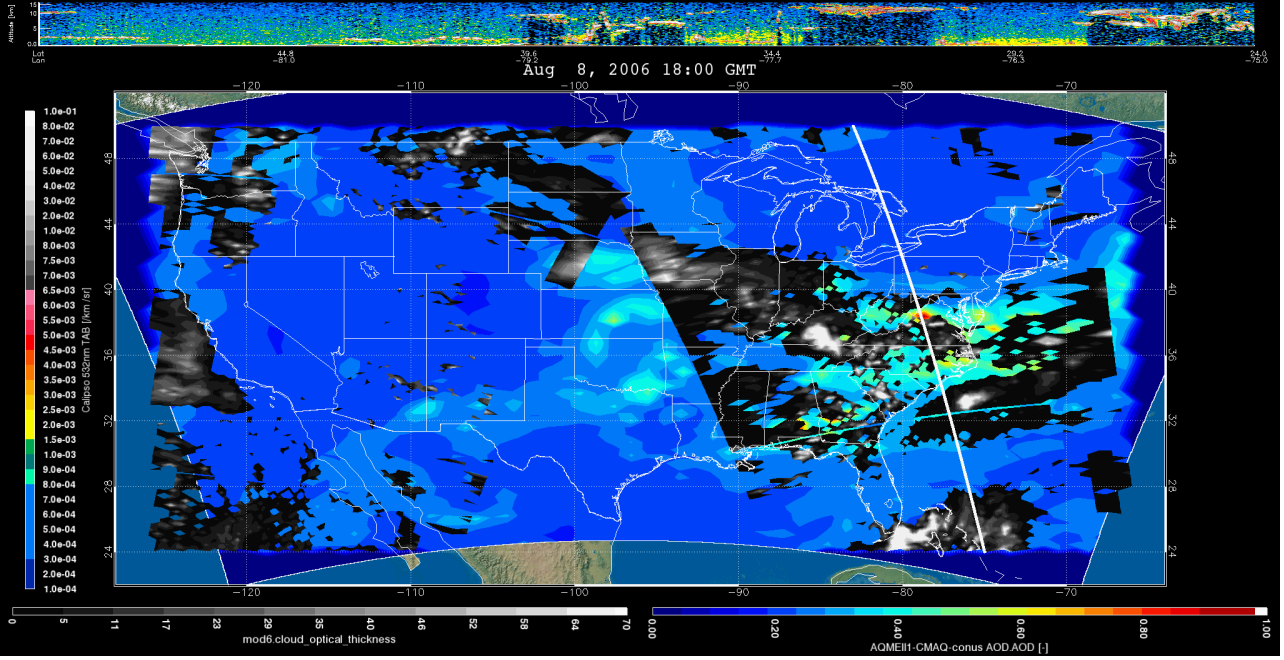


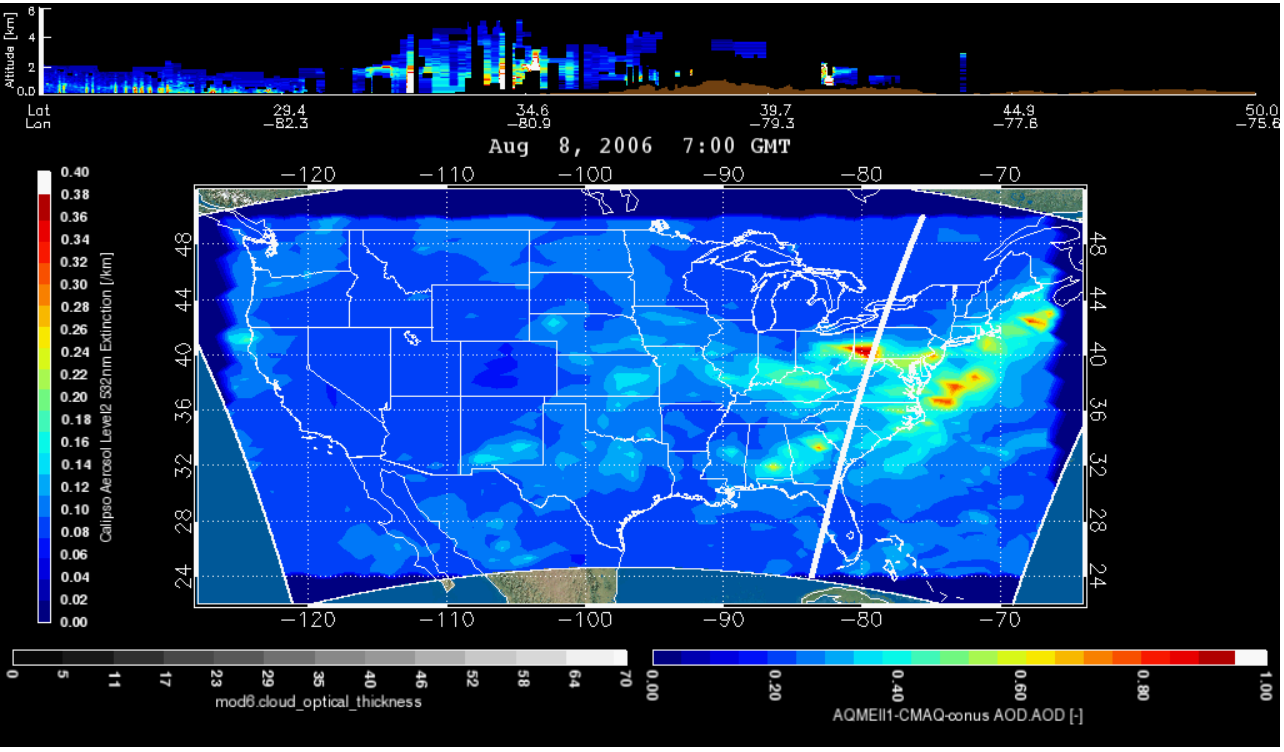
- RSIG server currently hosts several password protected CMAQ runs from AQMEII and DISCOVER-AQ
- RSIG visualization capabilities can provide quick access to CMAQ runs for internal EPA users via password protection to explore data for further analyses.



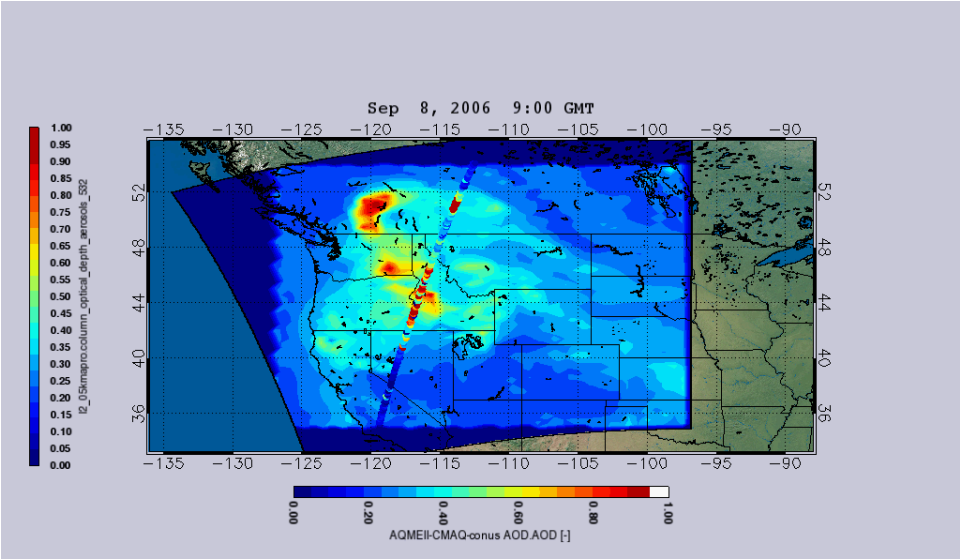


- Same images shown on previous slide, but MODIS-L2_COT is now over plotted on both images.

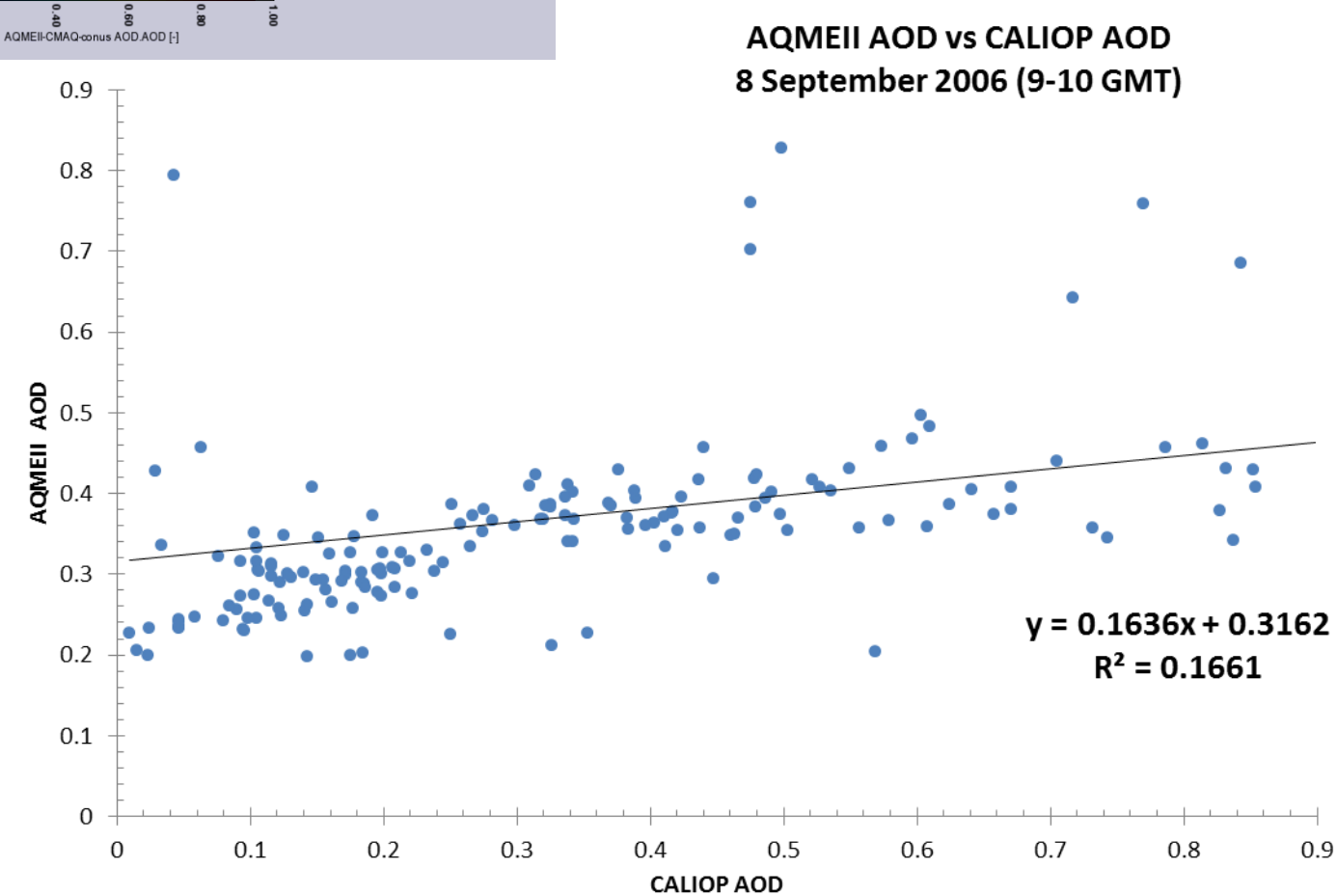


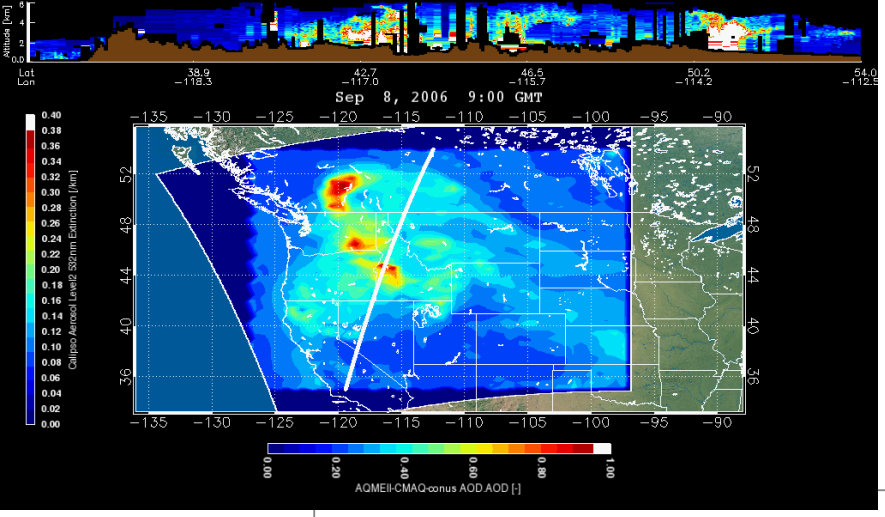


- Top image: CALIOP L1b_total attenuated backed (532), MODIS L2_COT (Aqua), CMAQ_AQMEII_v5.0final AOD
- Bottom image: CALIOP L2_extinction_coefficient (532) and CMAQ_AQMEII_v5.0final AOD



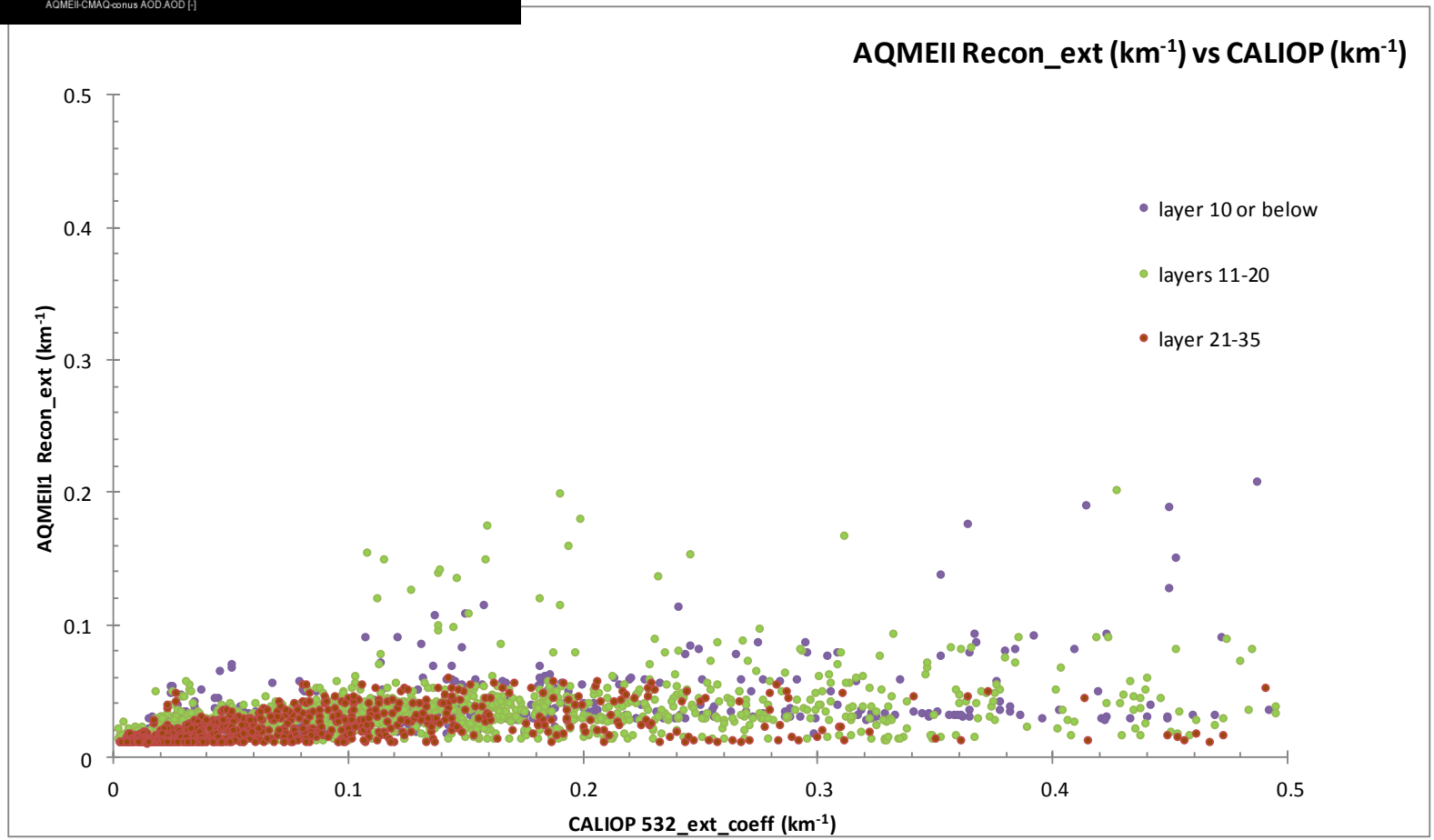
Use of RSIG for Episode Analysis: With a few clicks RSIG provides the user with quick access to several CALIOP data products regridded onto relevant CMAQ grids. Left Image: CMAQ_AQMEII_4.7.1 AOD over-plotted with CALIOP AOD regridded onto the AQMEII CONUS 12km grid.



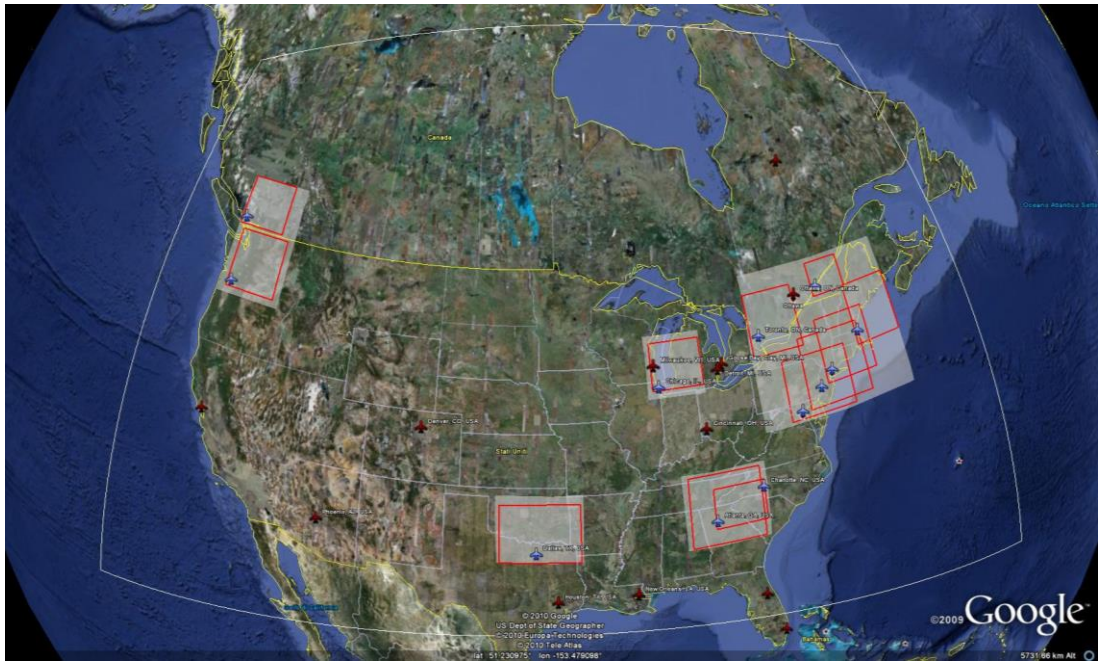


Left Image: CMAQ_AQMEII_4.7.1 AOD shown with CALIOP extinction coeffient 532 nm (original resolution)

Plot below: AQMEII recon-ext vs. CALIOP ext. coeff. 532nm



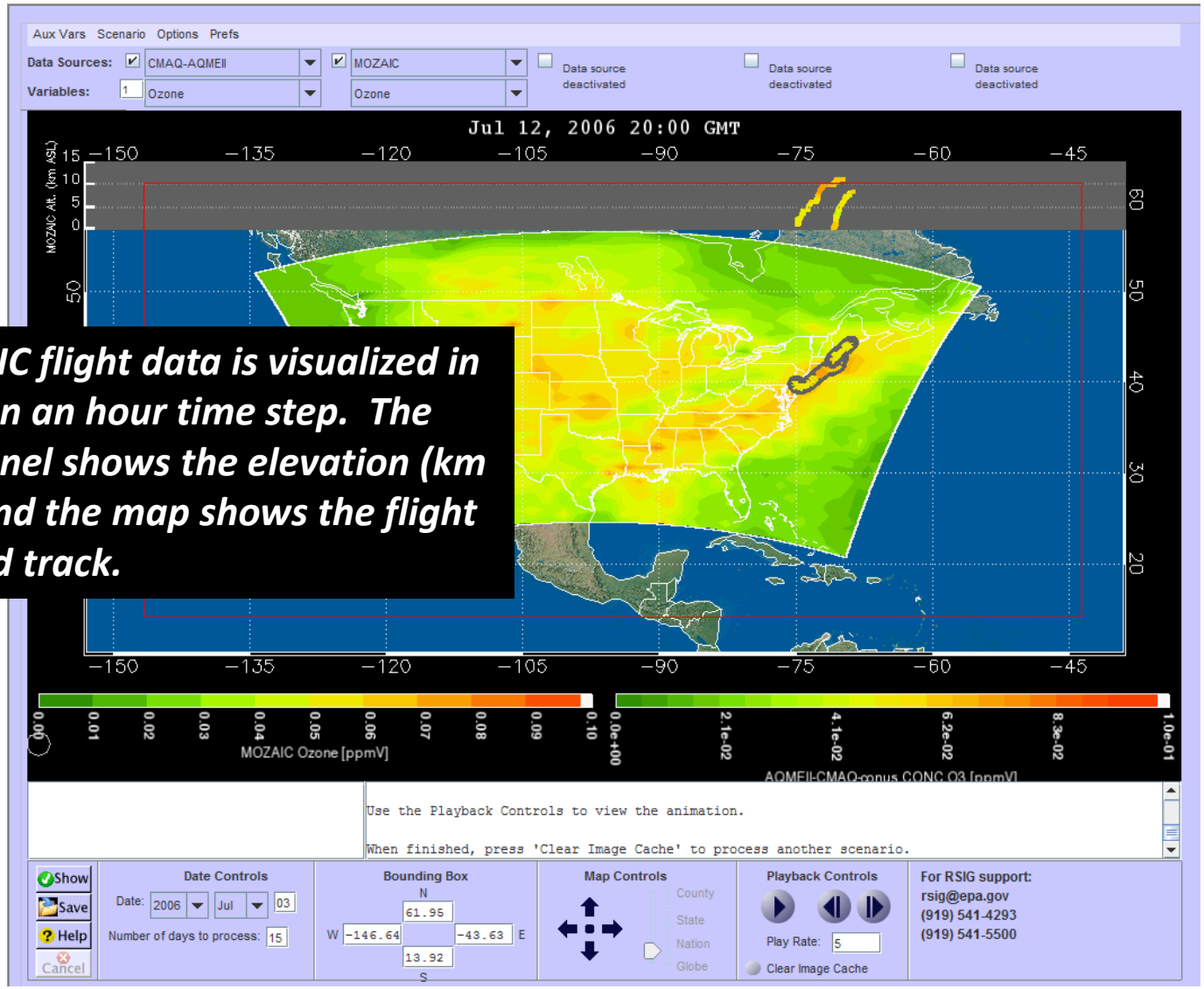
Measurement of OZone, water vapour, carbon monoxide and nitrogen oxides by AIrbus in-service airCraft



North American Airports with available MOZAIC vertical profiles of trace gases

- For <u>internal EPA users only</u> RSIG currently contains MOZAIC flight data (worldwide) from 2002-2006.
- The MOZAIC program flew 5 long-haul aircraft with trace gas and meteorological measurements of O_3, CO, NO_y, T, P, RH, wind speed and direction.
- MOZAIC is now part of IAGOS (In-Service Aircraft for the Global Observing System), a new European initiative to measure tropospheric and lower stratospheric air quality and greenhouse gases with instruments based on commercial aircraft.

Visualizing MOZAIC data in RSIG



MOZAIC flight data is visualized in RSIG on an hour time step. The top panel shows the elevation (km asl) and the map shows the flight ground track.

Remapping MOZAIC observations to CMAQ cell values

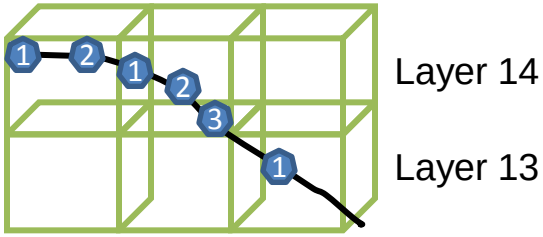
•MOZAIC observations can be regridded to CMAQ layers using CMAQ vertical grid description parameters NLAYS, VGTOP, VGLVLS (sigma pressures), etc. to compute the CMAQ levels in meters, similar to the regridding of CALIOP data.

CMAQ cell value = (MOZAIC value1 x $1/r1^2$) +
(MOZAIC value2 x $1/r2^2$) + ... +
(MOZAIC valueN x $1/rN^2$) / W

where W = ($1/r1^2 + 1/r2^2 + ... + 1/rN^2$)

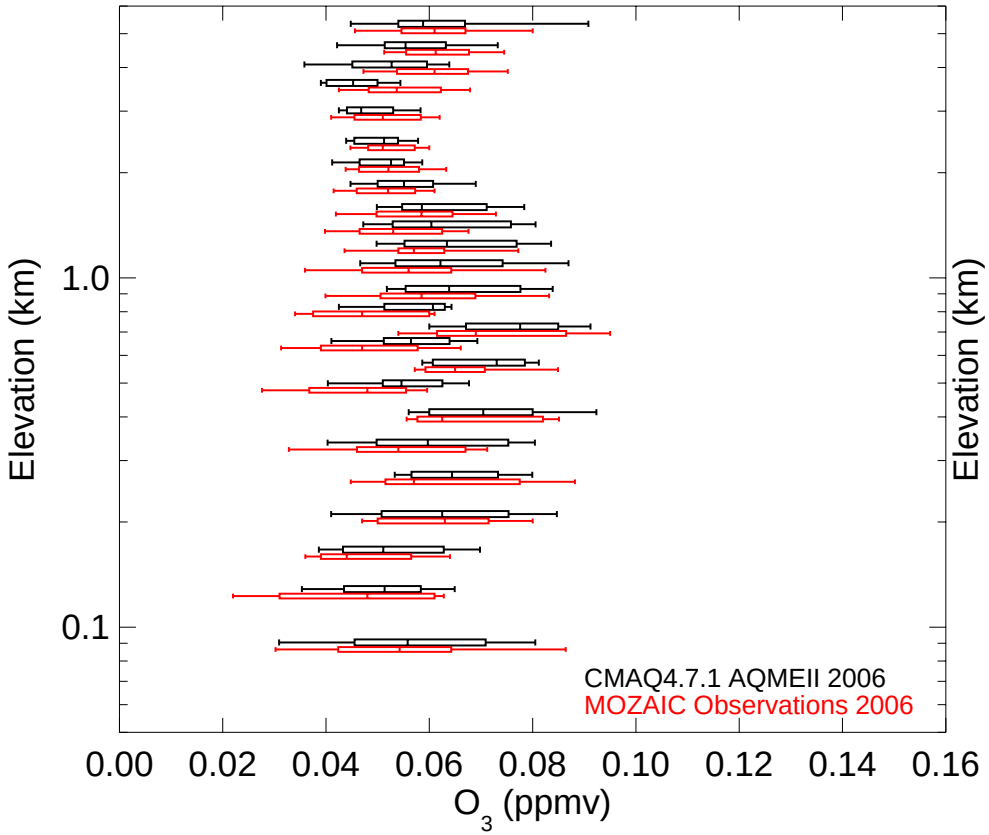
MOZAIC valuei = value of the ith projected data point that lies in the given CMAQ cell

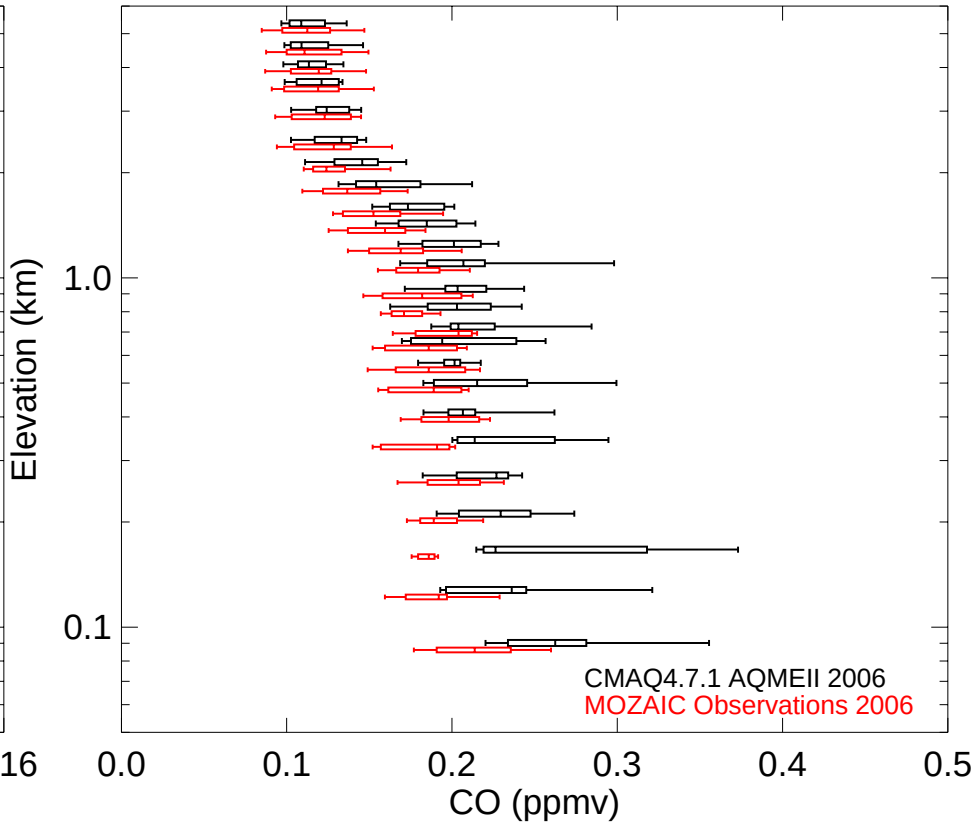
ri = distance between MOZAIC point and CMAQ grid cell center



MOZAIC and CMAQ O_3 (51) and CO (55) Profiles
Summer 2006 (J,J,A) Descending Flights Philadelphia Airport (PHL)

35% 3pm, 53% 4pm



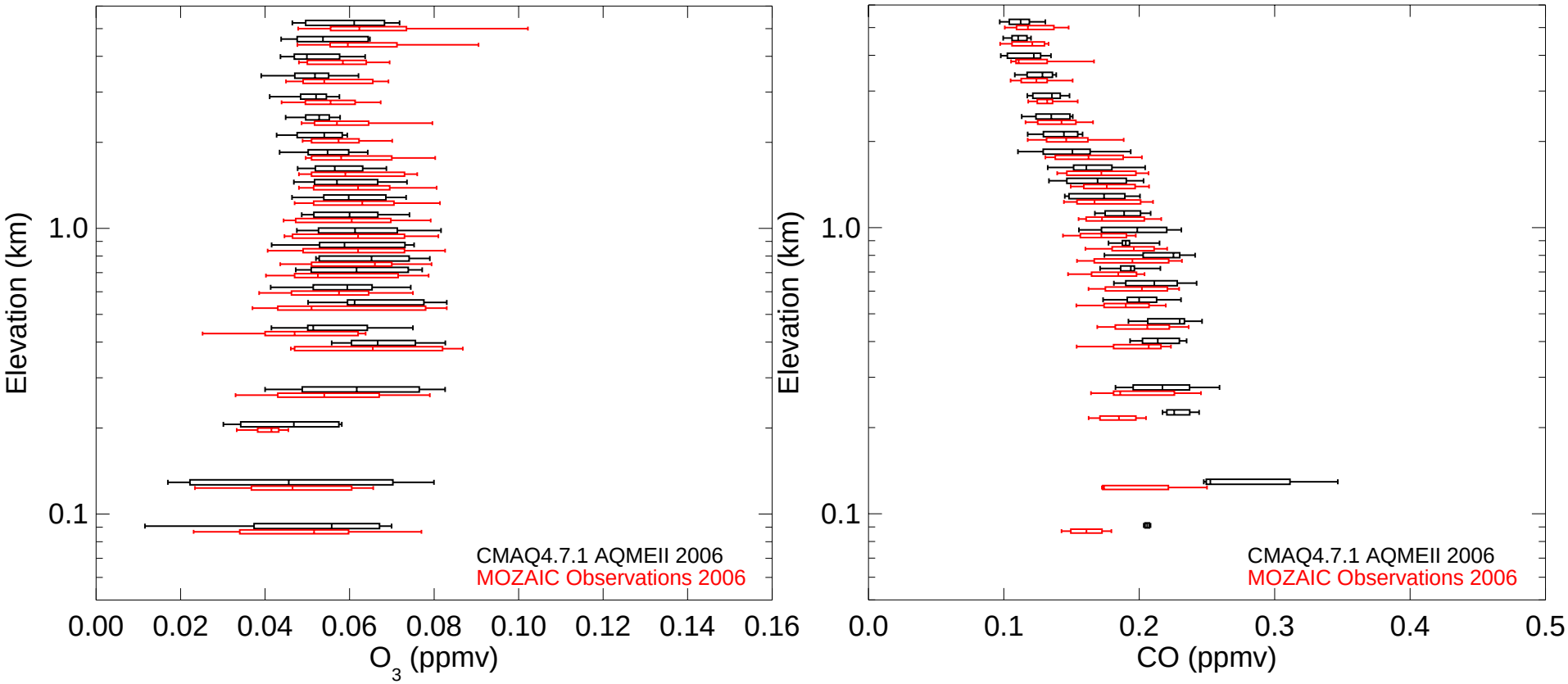


- CMAQ [O_3] distributions are low ~3-5 km as compared to MOZAIC and become higher than MOZAIC as the [CO] concentrations increase below 2 km.
- CMAQ and MOZAIC [O_3] distributions in the lowest few 100 meters agree well.
- [CO] overestimated in CMAQ and greater variability in the BL versus MOZAIC [CO].

Source: Silverman et al., CMAS 2012

MOZAIC and CMAQ O_3 (52) and CO (50) Profiles
Summer 2006 (J,J,A) Ascending Flights Philadelphia Airport (PHL)

38% 6pm, 43% 7pm



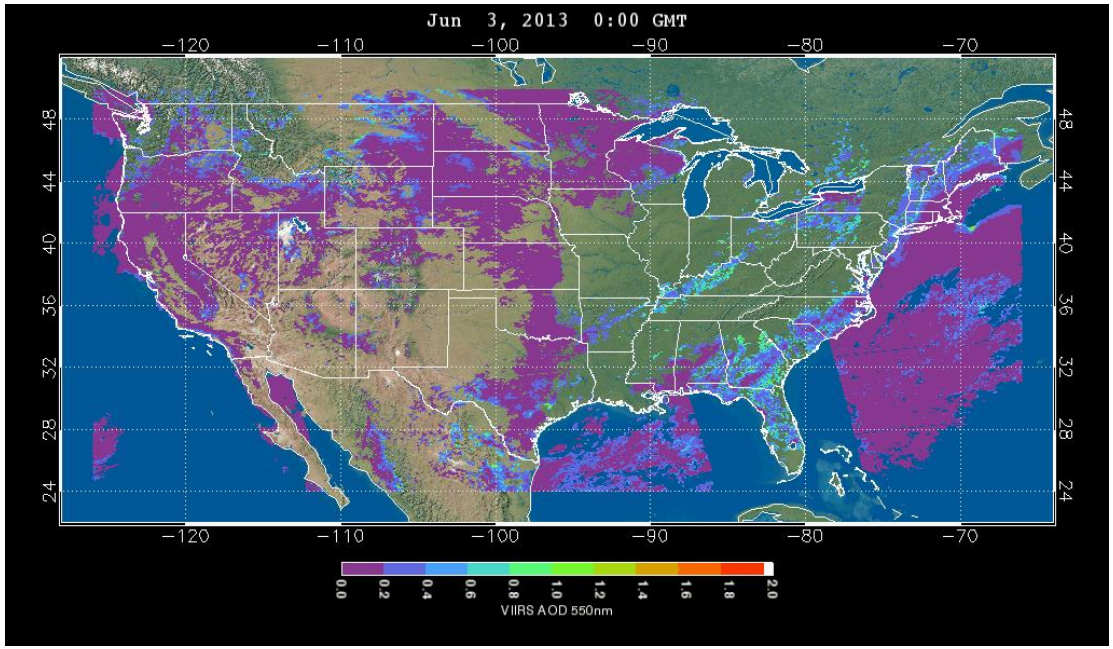
- CMAQ [O_3] distributions low ~3-5 km compared to MOZAIC, but to a lesser degree than descending flights.
- CMAQ and MOZAIC [O_3] distributions in the lowest 2 km agree well but a bit high closer to the surface.
- CMAQ [CO] distributions better aligned with variability seen in MOZAIC [CO].

Source: Silverman et al., CMAS 2012

Using Web Server Scripts to Obtain Data and Images

Example WMS command:

WMS_url: http://ofmpub.epa.gov/rsig/rsigserver?
SERVICE=wms
&VERSION=1.3.0
&REQUEST=GetMap
&STYLES=CMAQ_USEAQI,USETOPO,SWATH_PAINT
&CRS=CRS:84
&LAYERS=viirs.vaooo.aerosolopticaldepth_at_550nm
&DATA_BOUNDS=-126,24,-66,50
&BBOX=-128.0,22.0,-64.0,52.0
&TIME=2013-06-03T00:00:00Z/2013-06-03T23:59:59Z
&WIDTH=1024&HEIGHT=595
&FORMAT=image/png



Using Web Server Scripts to Obtain Data and Images

WCS (Web Coverage Service) is a standard syntax for retrieving subsets of data streamed from another computer over the Internet. Pasting the following (one-line, no space) query string into a web browser:

http://ofmpub.epa.gov/rsig/rsigserver?SERVICE=wcs&VERSION=1.0.0&REQUEST=GetCoverage&TIME=2008-07-03T00:00:00Z/2008-07-03T01:59:59Z&BBOX=-79.76,40.48,-71.78,45.01&COVERAGE=airnow.pm25&FORMAT=ascii

produces the following tab-delimited spreadsheet of Airnow PM25 data:

Timestamp(UTC)	LONGITUDE(deg)	LATITUDE(deg)	STATION(-)	pm25(ug/m3)
2008-07-03T00:00:00-0000	-79.3853	43.6619	000060424	14.0000
2008-07-03T00:00:00-0000	-78.3500	44.3000	000061104	14.0000

…

The query string consists of the following parts:

- URL:http://ofmpub.epa.gov/rsig/rsigserver?
- (or rtpmeta.epa.gov/cgi-bin/rsigserver? if inside the EPA network) is the web service being invoked.
- SERVICE=wcs&VERSION=1.0.0& Specifies WCS service version 1. WMS serves images.
- REQUEST=GetCoverage Request data. GetCapabilities lists available data.
- TIME=2008-07-03T00:00:00Z/2008-07-03T01:59:59Z& UTC date-time range subset.
- BBOX=-79.76,40.48,-71.78,45.01& Lon-lat bounds subset.west,south,east,north.
- COVERAGE=airnow.pm25 Name of data variable. E.g., gasp.aod, mozaic.co, etc.
- FORMAT=ascii ASCII format. Only use ascii for tiny data.
- E.g., xdr, netcdf-coards, netcdf-ioapi, image/tiff32-

Using Web Server Scripts to Obtain Data and Images

To retrieve data to a file or stream into a program, use a command-line utility such as wget or curl and enclose the one-line, no-space query string in single quotes and redirect the data stream to a file (or pipe into a program):

```
# Example: One day of MODIS AOD over New York:

curl --silent --retry 0 --max-time 120 -L 1 --tcp-nodelay
'http://rtpmeta.epa.gov/cgi-bin/rsigserver?
SERVICE=wcs&VERSION=1.0.0
&REQUEST=GetCoverage
&TIME=2008-07-03T00:00:00Z/2008-07-03T23:59:59Z
&BBOX=-79.76,40.48,-71.78,45.01
&COVERAGE=modis.mod4.optical_depth_land_and_ocean
&FORMAT=xdr' > modis_aod.xdr

head -15 modis_aod.xdr
Swath 1.0
2008-07-03T00:00:00-0000
# Dimensions: variables timesteps swaths:
4 24 6
# Variable names:
Longitude Latitude Scan_Start_Time Optical_Depth_Land_And_Ocean
# Variable units:
deg deg Seconds_since_1993-1-1_00:00:00.0_0 –
# Domain: <min_lon> <min_lat> <max_lon> <max_lat>-79.76 40.48 -71.78 45.01
# MSB 64-bit integers (yyyydddhhmm) swath_timestamps[swaths] and
# IEEE-754 64-bit reals swath_bounds[swaths][2=<lon,lat>][2=<min,max>] and
# MSB 64-bit integers swath_dimensions[swaths][2=<rows,columns>] and
# IEEE-754 64-bit reals swath_data_1[variables][rows_1][columns_1] ... swath_data_S[variables][rows_S][columns_S]
```

Using Web Server Scripts to Obtain Data and Images

RSIG supports custom options such as data-filtering and regridding onto CMAQ:

```
curl --silent --retry 0 --max-time 120 -L 1 --tcp-nodelay
'http://rtpmeta.epa.gov/cgi-bin/rsigserver?SERVICE=wcs&VERSION=1.0.0
&REQUEST=GetCoverage
&TIME=2008-07-03T00:00:00Z/2008-07-03T23:59:59Z
&BBOX=-79.76,40.48,-71.78,45.01
&COVERAGE=gasp.aod
&aod_range=-0.5,2.05 &std_range=0,2.55 &cls_range=0,25 &sfc_range=-0.1,0.41 &ch1_range=0,0.425
&sig_range=-0.5,0.52 &mos_range=0,0.425 &sca_range=0,255
&REGRID=weighted
&LAMBERT=33,45,-97,40
&ELLIPSOID=6370000,6370000
&GRID=459,299,-2556000,-1728000,12000,12000
&FORMAT=netcdf-coards' > regridded_gasp_aod.ncf
```

Using Web Server Scripts to Obtain Data and Images

```
ncdump regridded_gasp_aod.ncf | more

netcdf regridded_gasp_aod {
dimensions:
	points = 6026 ;
variables:
	int column(points) ;
		column:units = "none” ;
	int row(points) ;
		row:units = "none" ;
	float longitude(points) ;
		longitude:units = "degrees_east" ;
	float latitude(points) ;
		latitude:units = "degrees_north" ;
	float aod(points) ;
		aod:units = "none" ;
		aod:missing_value = -9999.f ;
	float time(points) ;
		time:units = "hours since 2008-07-03 10:15:00.0 -00:00" ;
// global attributes:
		:Conventions = "COARDS" ;
		:history = "http://www.ssd.noaa.gov/PS/FIRE/GASP/gasp.html,GASPSubset,XDRConvert"
```

Using Web Server Scripts to Obtain Data and Images

Regridding of CALIPSO extinction onto CMAQ 12km CONUS 24-layer grid,formatted as an IOAPI file (like CMAQ output):

```
curl --silent --retry 0 --max-time 120 -L 1 --tcp-nodelay
'http://rtpmeta.epa.gov/cgi-bin/rsigserver?
SERVICE=wcs&VERSION=1.0.0
&REQUEST=GetCoverage
&TIME=2008-07-03T00:00:00Z/2008-07-03T23:59:59Z
&BBOX=-79.760000,40.480000,-71.780000,45.010000
&COVERAGE=calipso.l2_05kmapro.extinction_coefficient_uncertainty_1064
&minimum_cad=20
&maximum_uncertainty=99
&REGRID=weighted
&LAMBERT=33,45,-97,40
&ELLIPSOID=6370000,6370000
&GRID=459,299,-2556000,-1728000,12000,12000
&LEVELS=24,7,5000,1.0,0.995,0.99,0.98,0.97,0.96,0.94,0.92,0.9,0.88,0.86,0.84,0.82,0.80,0.77,0.74,0.7,0.65,0.6,0.5,0.4,0
.3,0.2,0.1,0.0,9.81,287.04,50.0,290.0,100000
&FORMAT=netcdf-ioapi' > regridded_calipso_ext.ncf
```

Using Web Server Scripts to Obtain Data and Images

```
ls -l regridded_calipso_ext.ncf
 -rw-rw-r--  1 plessel  staff  58287293 Sep 24 15:50 regridded_calipso_ext.ncf
ncdump regridded_calipso_ext.ncf | more
netcdf regridded_calipso_ext {
dimensions:
        TSTEP = 24 ;
        DATE-TIME = 2 ;
        LAY = 24 ;
        VAR = 4 ;
        ROW = 299 ;
        COL = 459 ;
variables:
        int TFLAG(TSTEP, VAR, DATE-TIME) ;
                TFLAG:units = "<YYYYDDD,HHMMSS>" ;
                TFLAG:long_name = "TFLAG          " ;
                TFLAG:var_desc = "Timestep-valid flags:  (1) YYYYDDD or (2) HHMMSS                                " ;
        float LONGITUDE(TSTEP, LAY, ROW, COL) ;
                LONGITUDE:units = "deg" ;
                LONGITUDE:long_name = "LONGITUDE      " ;
                LONGITUDE:var_desc = "Longitude at the center of each grid cell                                   " ;
        float LATITUDE(TSTEP, LAY, ROW, COL) ;
                LATITUDE:units = "deg" ;
                LATITUDE:long_name = "LATITUDE       " ;
                LATITUDE:var_desc = "Latitude at the center of each grid cell                                     " ;
        float ELEVATION(TSTEP, LAY, ROW, COL) ;
                ELEVATION:units = "m" ;
                ELEVATION:long_name = "ELEVATION      " ;
                ELEVATION:var_desc = "ELEVATION                                                                   " ;
        float EXTINCTION_COEFF(TSTEP, LAY, ROW, COL) ;
                EXTINCTION_COEFF:units = "km^-1" ;
                EXTINCTION_COEFF:long_name = "EXTINCTION_COEFF" ;
                EXTINCTION_COEFF:var_desc = "EXTINCTION_COEFF                                                     " ;
```

```
// global attributes:
        :IOAPI_VERSION = "1.0 1997349 (Dec. 15, 1997)" ;
        :EXEC_ID = "????????????????                                                    " ;
        :FTYPE = 1 ;
        :CDATE = 2014267 ;
        :CTIME = 1948 ;
        :WDATE = 2014267 ;
        :WTIME = 1948 ;
        :SDATE = 2008185 ;
        :STIME = 0 ;
        :TSTEP = 10000 ;
        :NTHIK = 1 ;
        :NCOLS = 459 ;
        :NROWS = 299 ;
        :NLAYS = 24 ;
        :NVARS = 4 ;
        :GDTYP = 2 ;
        :P_ALP = 33. ;
        :P_BET = 45. ;
        :P_GAM = -97. ;
        :XCENT = -97. ;
        :YCENT = 40. ;
        :XORIG = -2556000. ;
        :YORIG = -1728000. ;
        :XCELL = 12000. ;
        :YCELL = 12000. ;
        :VGTYP = 2 ;
        :VGTOP = 10000.f ;
        :VGLVLS = 1.f, 0.995f, 0.99f, 0.98f, 0.97f, 0.96f, 0.94f, 0.92f, 0.9f, 0.88f, 0.86f, 0.84f, 0.82f, 0.8f, 0.77f, 0.74f, 0.7f, 0.65f, 0.6f, 0.5f,
                  0.4f, 0.3f, 0.2f, 0.1f, 0.f ;
        :GDNAM = "M_02_99BRACE    " ;
        :UPNAM = "XDRConvert      " ;
        :VAR-LIST = "LONGITUDE       LATITUDE        ELEVATION       EXTINCTION_COEFF" ;
        :FILEDESC = "http://eosweb.larc.nasa.gov/PRODOCS/calipso/table_calipso.html,CALIPSOSubset,XDRConvert
```

Using Web Server Scripts to Obtain Data and Images

Using WCS queries to retrieve data from RSIG:

1. First contact Todd Plessel 919-541-5500, plessel.todd@epa.gov for guidance. If you need to retrieve large amounts of data, Todd can create and run a script which will get the data to you quickest and most efficiently.
2. To learn the syntax and options, simply use the RSIG applications (2D/3D)and copy the WCS calls to rsigserver that are printed when retrieving or saving data.
3. Try retrieving a small amount of data first and see if that is feasible before launching a script to retrieve lots of data.
4. When using a script to get many days of data, retrieve one day at a time and run the script serially to avoid overloading the (three modest) servers at NASA Goddard, NASA Langley and EPA.
5. Retrieval requests will time-out in about 30 minutes.

RSIG-3D Application
(Currently Under Development)

- Cross platform stand-alone application focused on exploiting use of RSIG available data sets (current and future) for air quality analysis applications.
- Interactive 3D visualization capability.
- RSIG3D retrieves **data** as opposed to images (as in RSIG2D), allowing user interaction. Initial focus is on application of data sets to model evaluation.
- Allows for application/analysis functions of relevant 3-D data (CMAQ, CALIPSO, Aircraft, etc…).
- Possibility to connect to relevant externally-developed web services (e.g., HTAP).
- Initial release targeted for late 2014.

RSIG-3D Application
(Currently Under Development)

- Initial development (2014/2015) focused on:
  - Provide access to all datasets and functionality currently available via RSIG 2D.
  - Add the ability for users to read model data files (for MM5, WRF, CMAQ and CAMX) for analysis, regridded, and display.
  - Incorporate the use of the EPA/NASA developed Spatial Allocator to run under script control via RSIG.
  - Develop and install external WCS and Subsetter for NOAA S-NPP VIIRS AOT (NOAA/NESDIS) and airborne field campaign data sets from the NASA-LaRC ASDC Toolset for Airborne Data (TAD).
  - Incorporate satellite-measurement model evaluation methods developed in support of TF HTAP under NASA AQAST efforts.

For more information contact

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- Developer: Todd Plessel, Lockheed Martin, (919) 541-5500, plessel.todd@epa.gov
- Developer: Matt Freeman, Lockheed Martin, (919) 541-4293, freeman.matt@epa.gov
- Project Manager: Heidi Paulsen, EPA/OEI, (919) 541-1834, paulsen.heidi@epa.gov