

# Analyzing Multidimensional Scientific Data in ArcGIS

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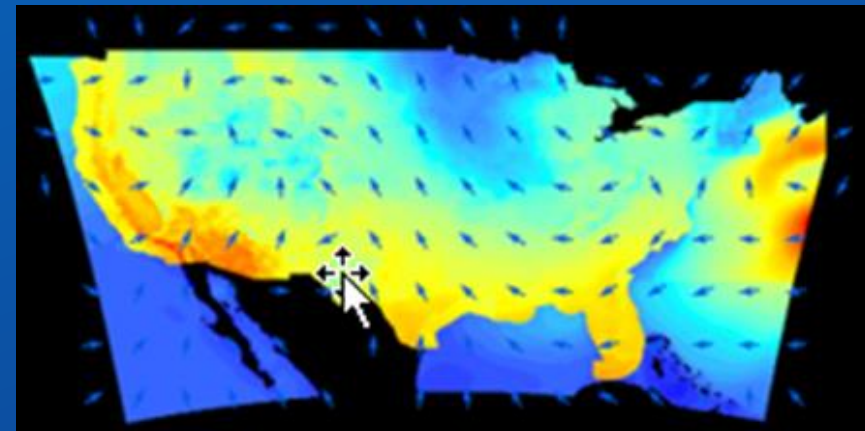
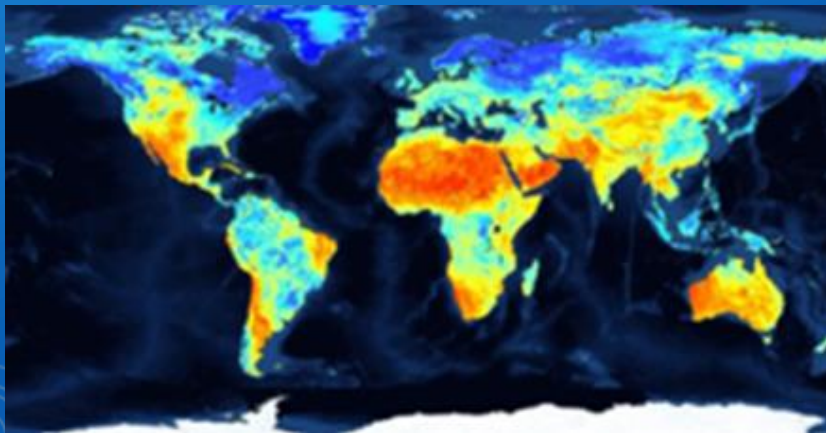
2020 FedGIS Conference  
February 12, 2020 | Washington DC

# Take Away

- The ArcGIS Platform has a robust data model and analytical tools for conducting analysis with Multidimensional Data
- Platform with a format agnostic enterprise framework to share your research result with a larger community
- Platform is extendable and Interoperable. Build Custom Apps to turn your Data into Actionable Information

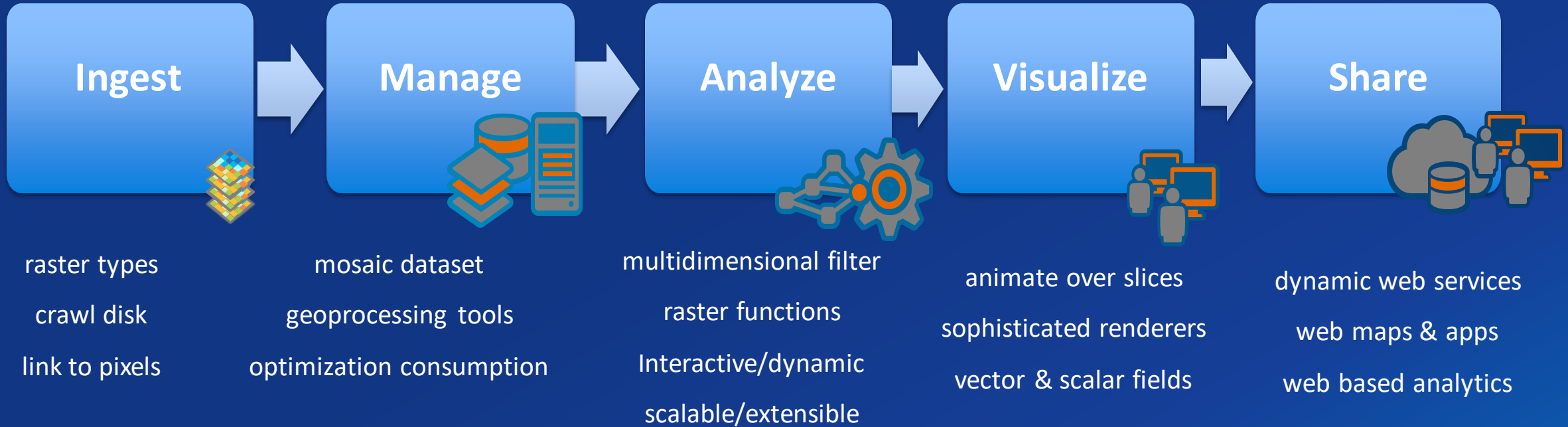


# Multidimensional Workflows Patterns within ArcGIS



# GIS Workflows that Scale

\* Scalable \* Automated



**Data**



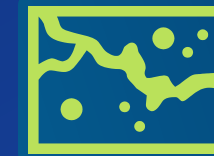
**Service / Product**

Data Sources

Analysis Framework

Relevant Tools

Data Products



Spatial  
Temporal  
Tabular  
Written Resource

ArcGIS Toolbox  
ArcPy  
ArcGIS API for Python  
Tensorflow  
PySAL  
R Packages

Hot Spot Analysis  
Deep Neural Network  
MaxEnt  
Mean Center  
Trends / Relationships

Map!  
Widget  
Web Applications

# Scientific and Multidimensional Raster Data

## Big data

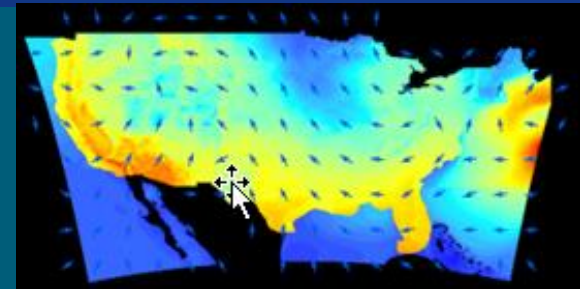
- Large volume (Volume)
- Many types of data (Variety)
- Grow rapidly (Velocity)

## Multidimensional

- Time
- Depth
- Height

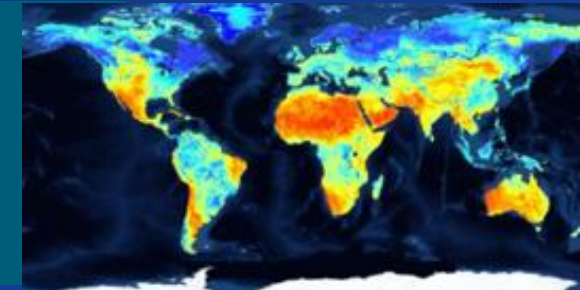
## Meteorological

- Temperature
- Precipitation
- Wind speed



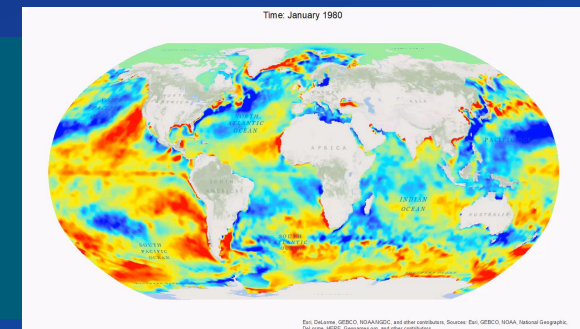
## Terrestrial

- Soil moisture
- NDVI
- Land cover

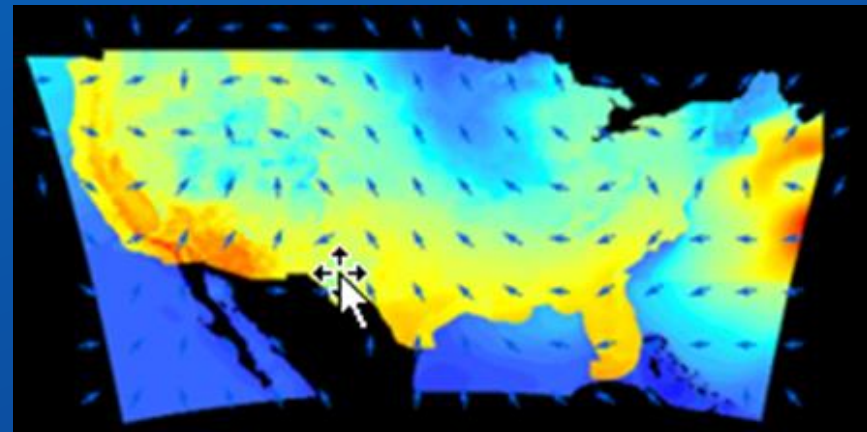
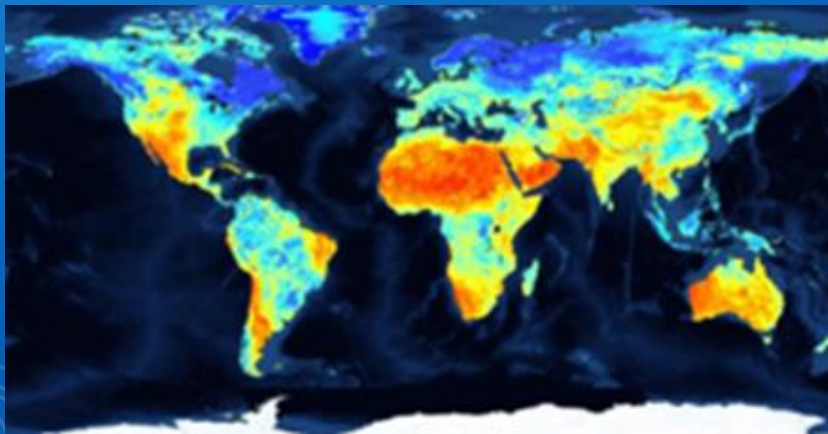


## Oceanographic

- Salinity
- Sea Surface Temperature
- Ocean current

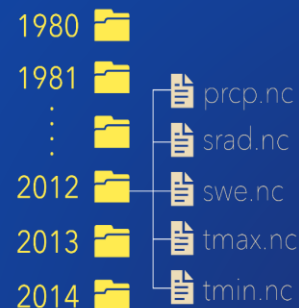


# What is Multidimensional Data?

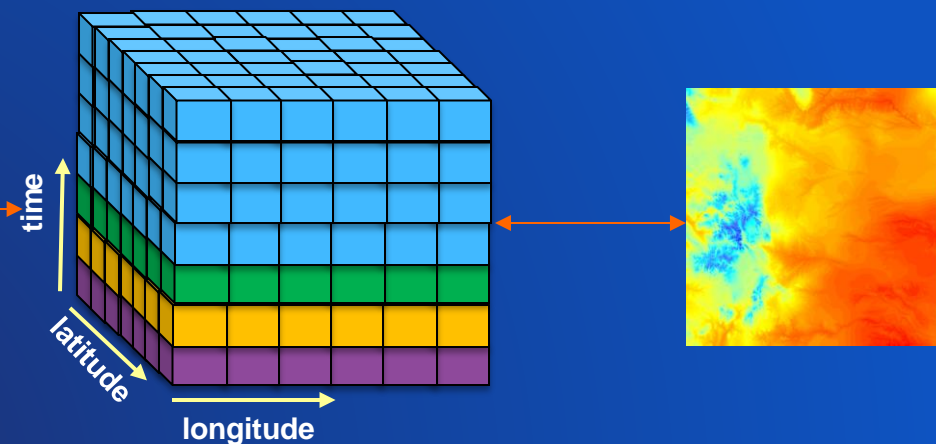


# What is Multidimensional data?

Spatial, temporal, and vertical dimensions



ID	RASTER	PRODUCT	VARIABLE	TIME	Z	...
1	< raster >	netCDF	temperature	T1	10	
2	< raster >	netCDF	temperature	T2	10	
3	< raster >	netCDF	temperature	T3	10	
4	< raster >	netCDF	temperature	T1	20	
5	< raster >	netCDF	temperature	T2	20	
6	< raster >	netCDF	temperature	T3	20	

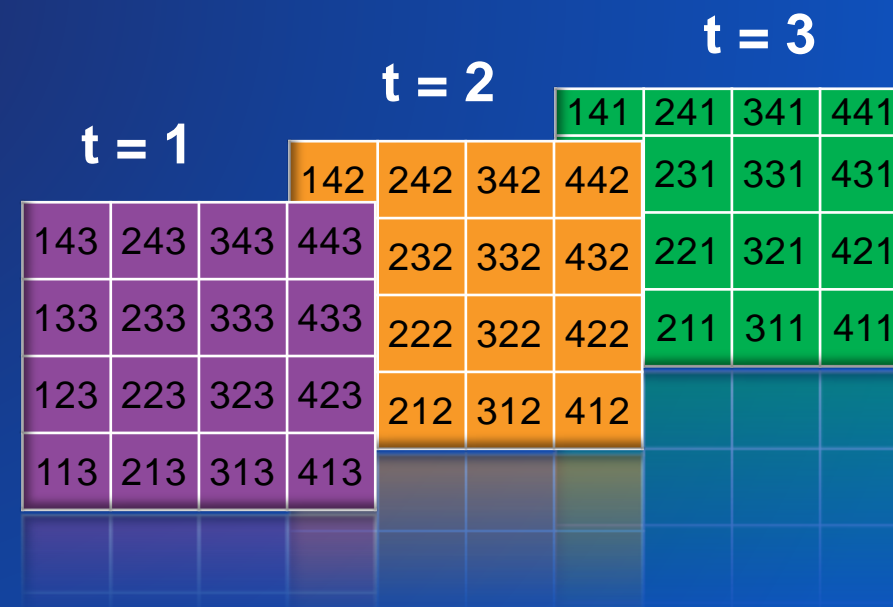


- **Contains one or multiple variables in one file**

- A variable is cube or cubes
- A variable has a time and/or depth
- Each slice is a 2D array

- **Common formats**

- NetCDF, GRIB, HDF





# Multidimensional Raster Data Cube (Optimization)

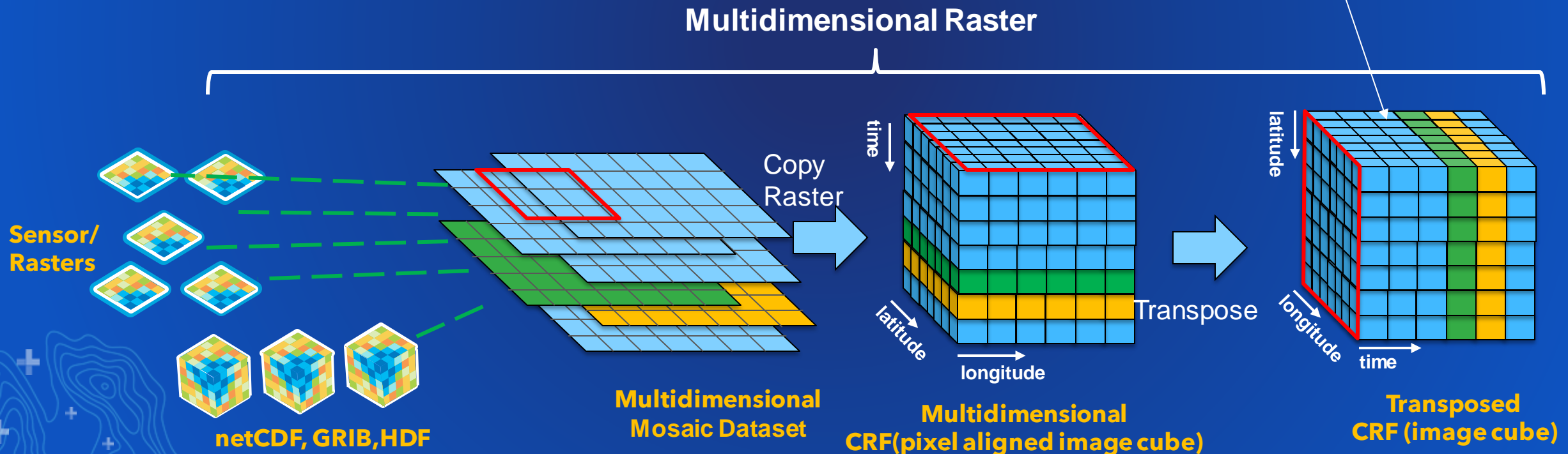
Mosaic Dataset

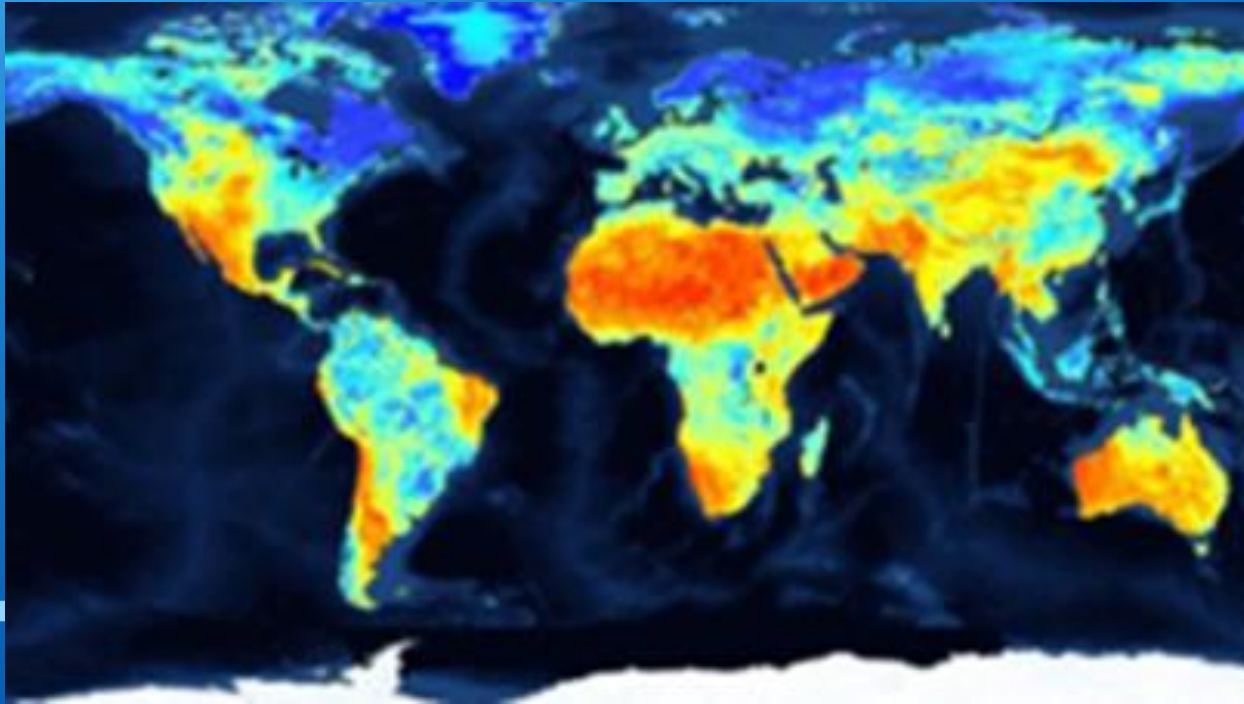
Multidimensional Mosaic Dataset

CRF - Optimized for cloud storage and processing - Output for Raster Analytics

Multidimensional CRF - Optimize for multiple variables/dimensions

Transposed CRF - Enable rapid dimension access and analysis



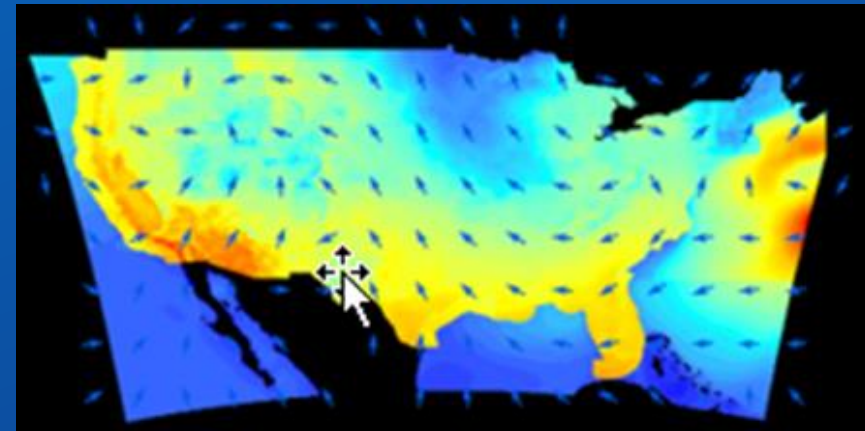
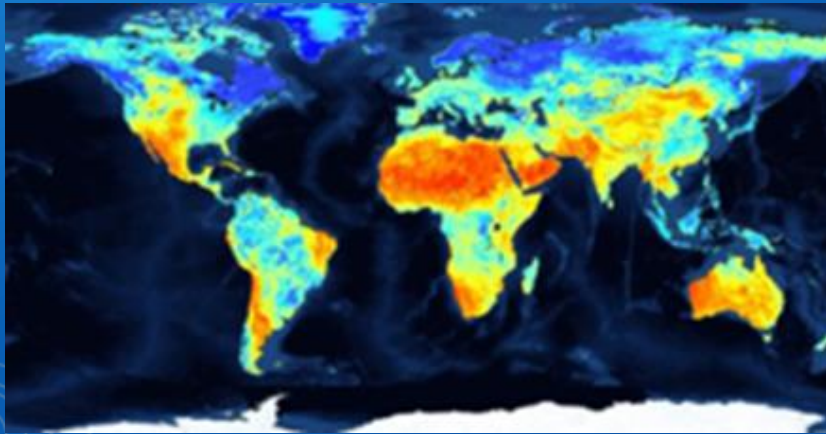


# Ingesting Multidimensional Data

Intro Demo



# Analyzing Multidimensional Data

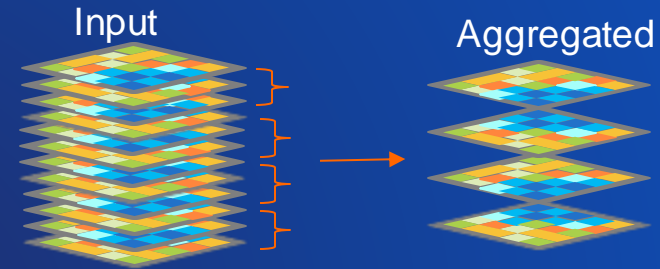


# Multidimensional Raster Analysis - Using Geoprocessing Tools

Require ArcGIS Image Analyst or Spatial Analyst license

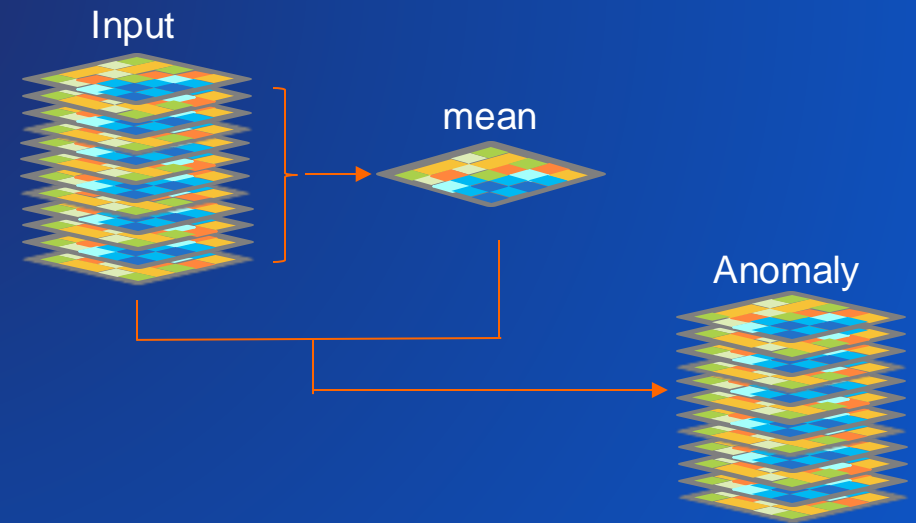
- **Aggregate Multidimensional Raster**

- Along a given dimension and interval
  - Yearly, monthly, daily etc.
- Output multidimensional CRF



- **Generate Multidimensional Anomaly**

- A long time series raster
- Output multidimensional CRF



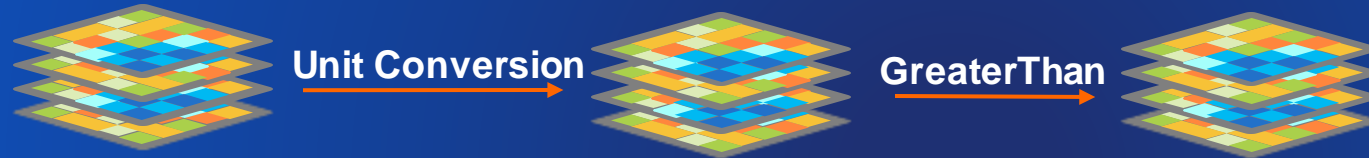
- **Trend and Prediction**



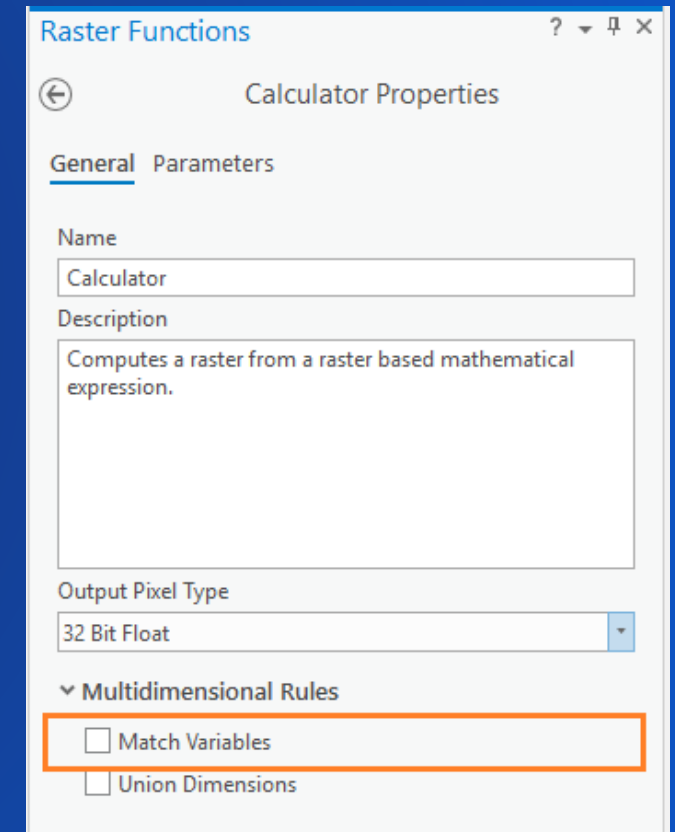
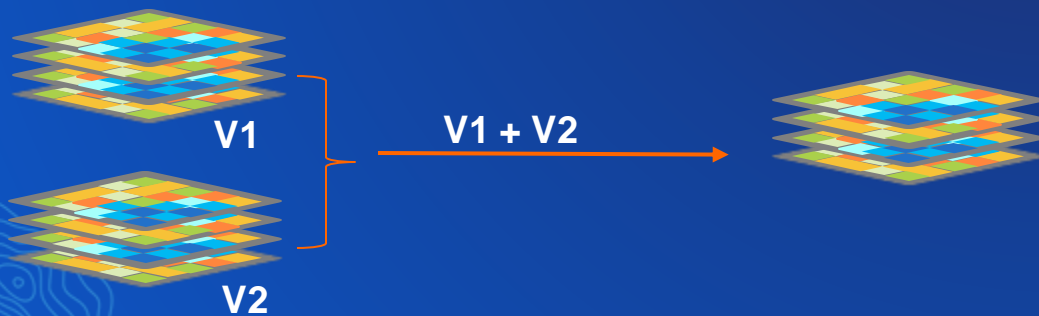
# Multidimensional Raster Analysis - Using Raster Functions

Cube based analysis / cube based map algebra

- Support multidimensional raster (except global functions)
- Functions with one input - just works



- Functions with two or more inputs - rules
  - Variable names must match
  - Disable the Match Variables option



# Multidimensional Raster Analysis - Open Platform

Python / R / Other Sources



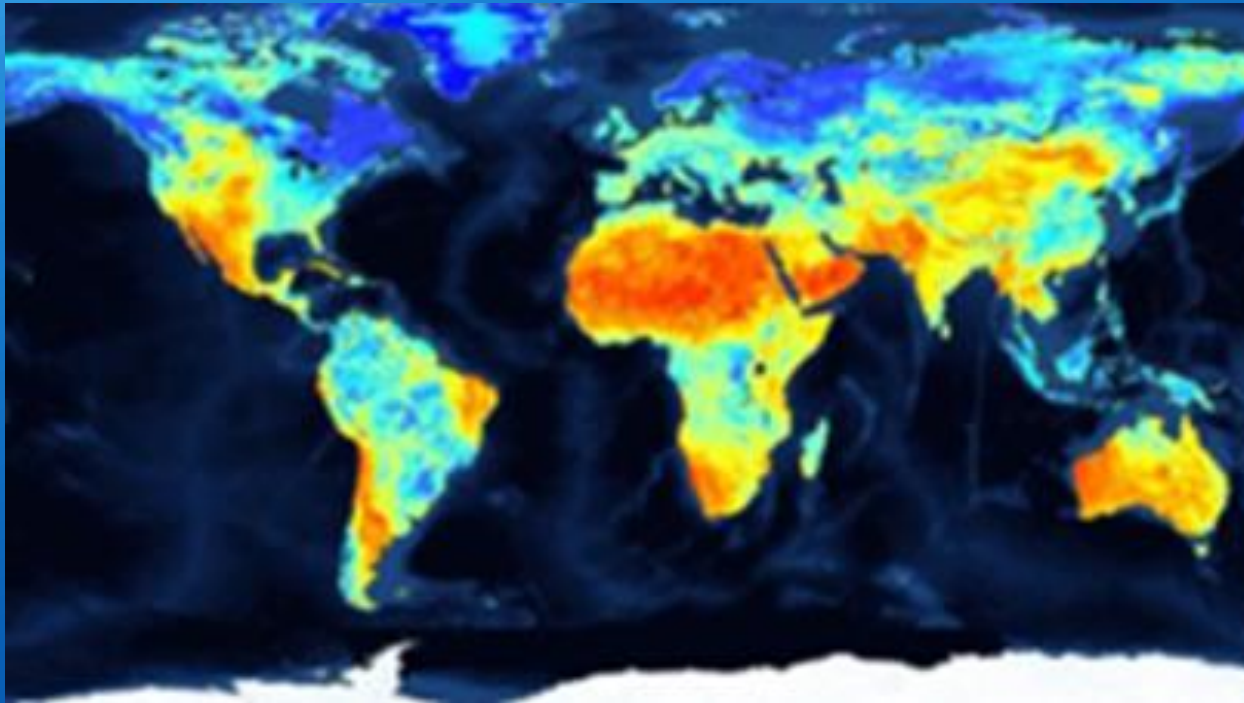
The right side of the slide contains two overlapping screenshots. The top screenshot shows the ArcGIS interface with a map of a forest area. The bottom screenshot shows an R script in an RStudio window. The script performs the following steps:

```
reprocessing_mp.R x R_ArcGIS_Bridge_Working_with_Rast... x R_ArcGIS_Brid
6 library(caret)
9 library(randomForest)
10
11 #Load Data and Create a RasterBrick object
12 LS_open <- arc.open("C:/Users/marj8502/Doc
13 LS_select <- arc.select(LS_open)
14 LS_raster <- as.raster(LS_select)
15
16 #RGB Visualization
17 plot(LS_raster)
18 plotRGB(LS_raster * (LS_raster >= 0), r =
19
20 #Construct Data Frame for Random Forest Model Fitting
21 df_bnds <- data.frame(Band1 = LS_raster@data@values[, 1],
22                      Band2 = LS_raster@data@values[, 2],
23                      Band3 = LS_raster@data@values[, 3],
24                      Band4 = LS_raster@data@values[, 4],
25                      Band5 = LS_raster@data@values[, 5],
26                      Band6 = LS_raster@data@values[, 6],
27                      Band7 = LS_raster@data@values[, 7],
28                      Band8 = LS_raster@data@values[, 8])
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```

The console output shows the following commands and results:

```
> classes <- raster(LS_raster)
> ## Assign values from the 'class' column of valuetable
> classes <- setValues(classes, valuetable$Category)
> p3 <- plot(classes, legend=FALSE, col=c("dark blue", "blue", "lig
ht blue"))
>
```

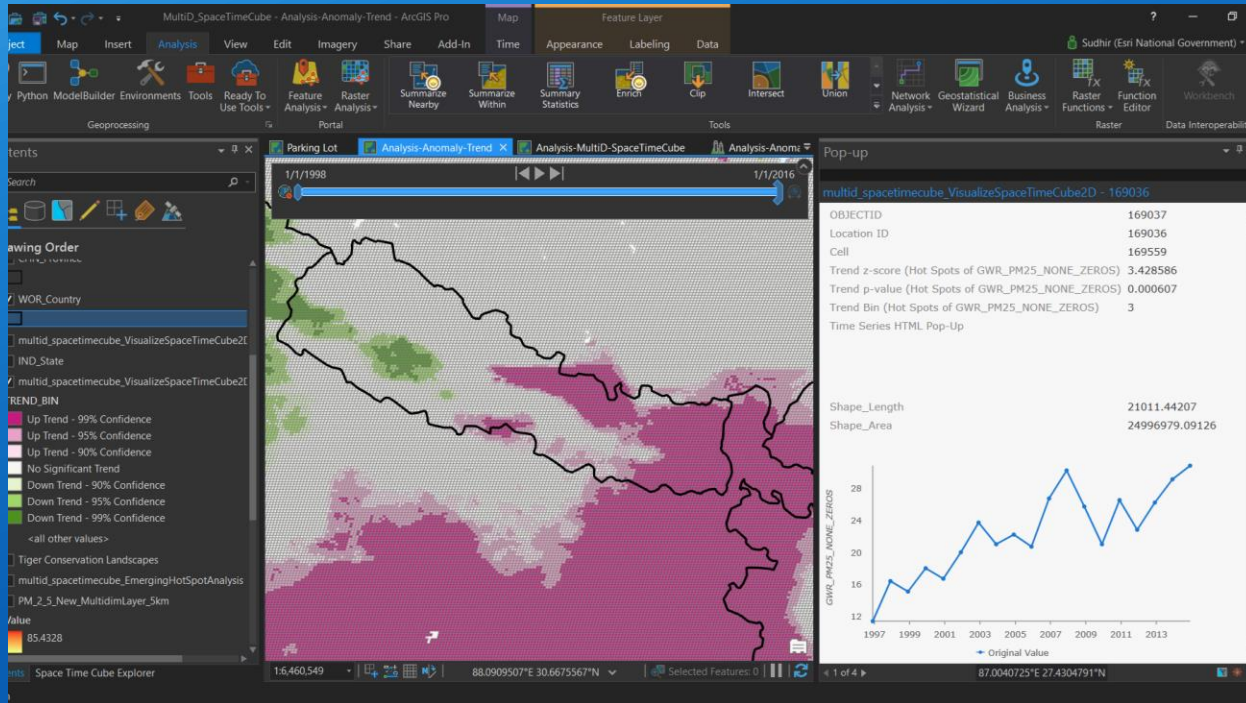




## Precipitation Trends: Desertification / Expansion of Sub Saharan Africa

(Multidimensional Space Time Cube)





## Quantifying spatial and temporal patterns of fine particulate matter (PM2.5) in Asia Pacific Region

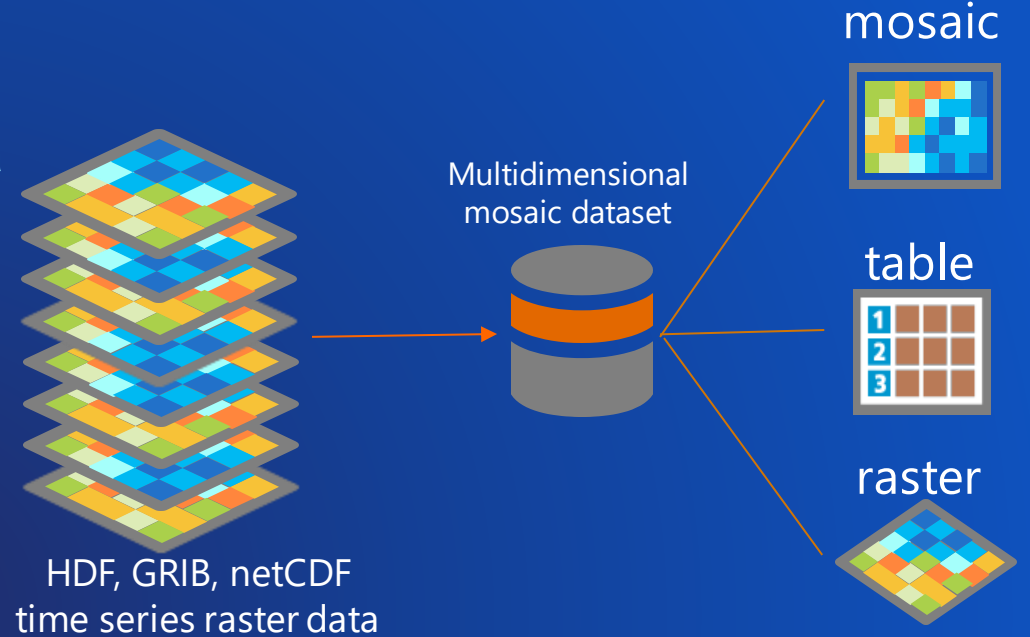
(Multidimensional Space Time Cube)



# Multidimensional Mosaic Dataset

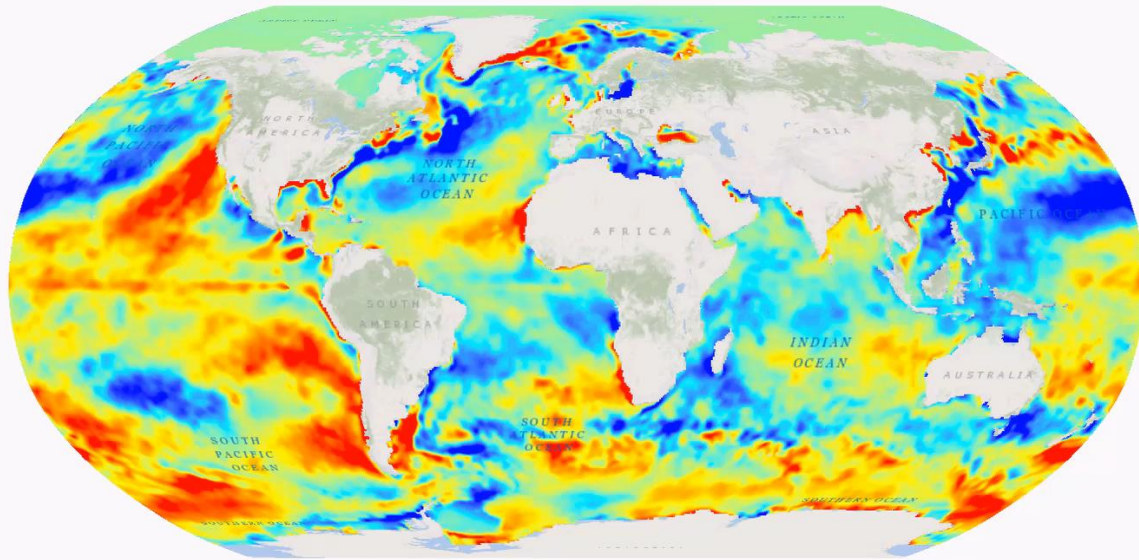
A mosaic dataset that manages multidimensional raster data

- **Mosaic dataset**
  - Catalog and index a collection of rasters
  - Process on-the-fly
- **Multidimensional mosaic dataset**
  - Manage variables and dimensions
  - Multidimensional Info



Raster	Shape	Variable	StdTime	StdZ
...	...	Temperature	3/22/2016	-10
...	...	Temperature	3/23/2016	-10
...	...	Temperature	3/24/2016	-10
...	...	Salinity	3/22/2016	-10
...	...	Salinity	3/23/2016	-10
...	...	Salinity	3/24/2016	-10
...	...	Temperature	3/22/2016	-20
...	...	Temperature	3/23/2016	-20
...	...	...	...	...

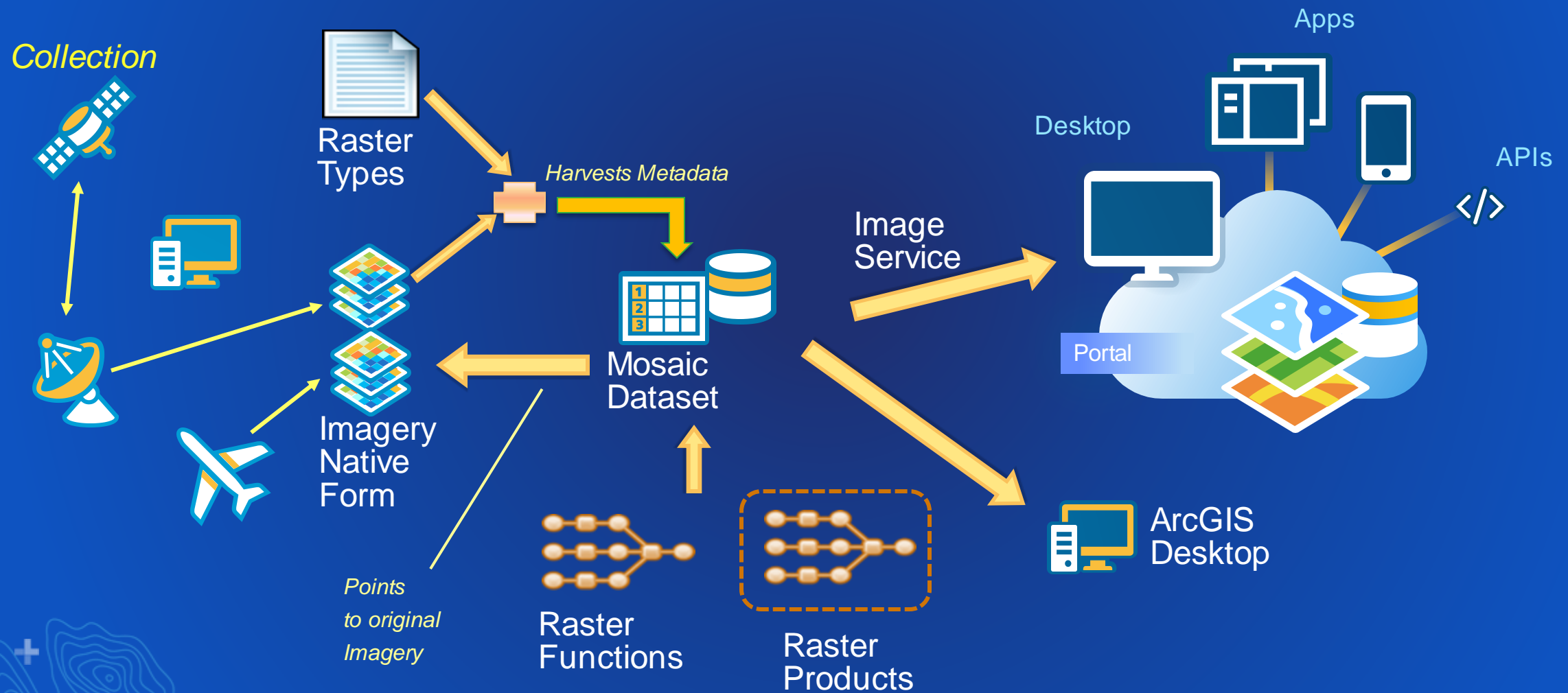
Time: January 1980

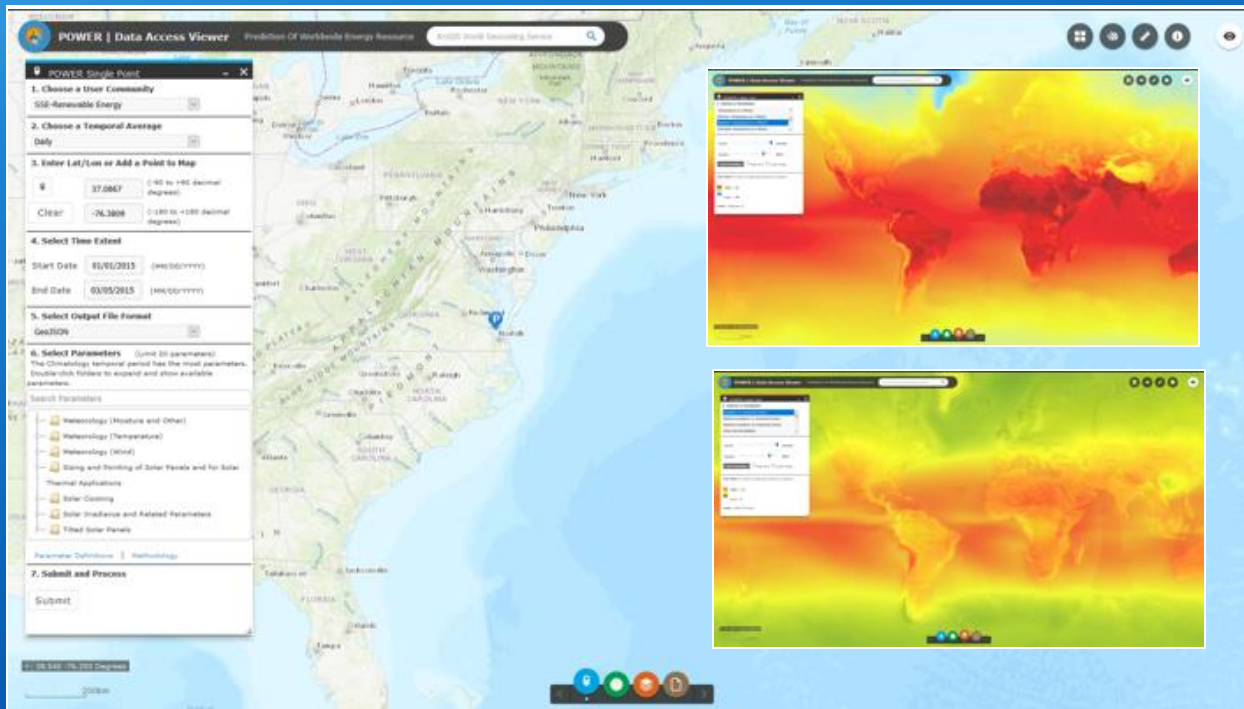


Esri, DeLorme, GEBCO, NOAA/NGDC, and other contributors, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

## MD Ingest and El Nino Detection demo

# Putting it all together: Open Interoperable Scientific Data Platform





# NASA Atmospheric Science Data Center (ASDC)

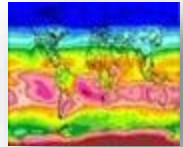
Matthew Tisdale  
NASA Langley Research Center  
(LaRC)

[matthew.s.tisdale@nasa.gov](mailto:matthew.s.tisdale@nasa.gov)

# The NASA Atmospheric Science Data Center (ASDC) at a Glance

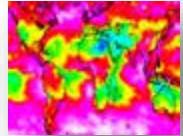


- Curates more than **1,000 unique science products** and provides data services for over **50 science projects**
- **5+ petabytes of data, over 58 million files**, are in the archive
- Data distributed to over **165,000** customers in **158** countries



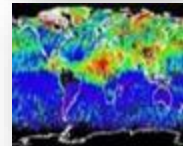
**Radiation Budget** - The radiation budget takes into account the sum of all radiation, transferred in all directions, through the Earth's atmosphere and to and from space.

*Instruments: CERES*



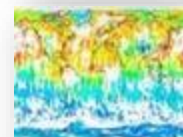
**Clouds** - A visible aggregate of minute water droplets and/or ice crystals in the atmosphere above the Earth's surface.

*Instruments: CALIPSO, MISR*



**Aerosols** - Suspension of particles of condensed matter (liquid, solid, or mixed) in a carrier gas (usually air).

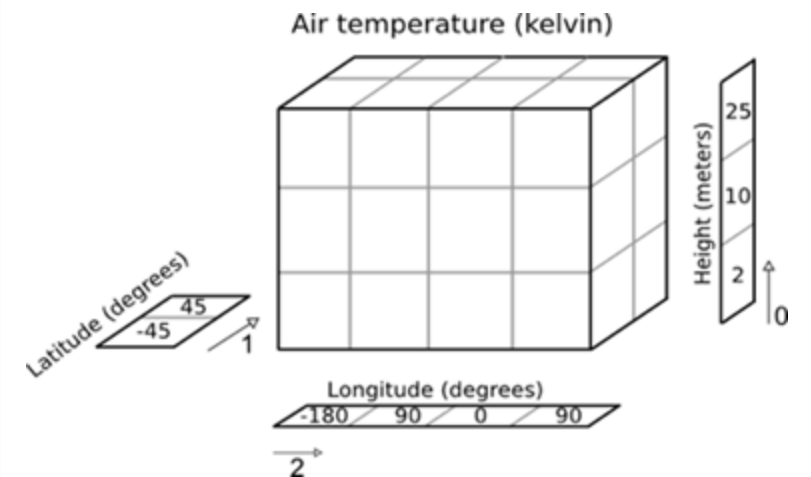
*Instruments: CALIPSO, MISR, SAGE III*



**Tropospheric composition** - Measurements of chemical constituents in the atmosphere including the major (non-H<sub>2</sub>O) greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, O<sub>3</sub>, N<sub>2</sub>O).

*Instruments: MOPITT, TES*

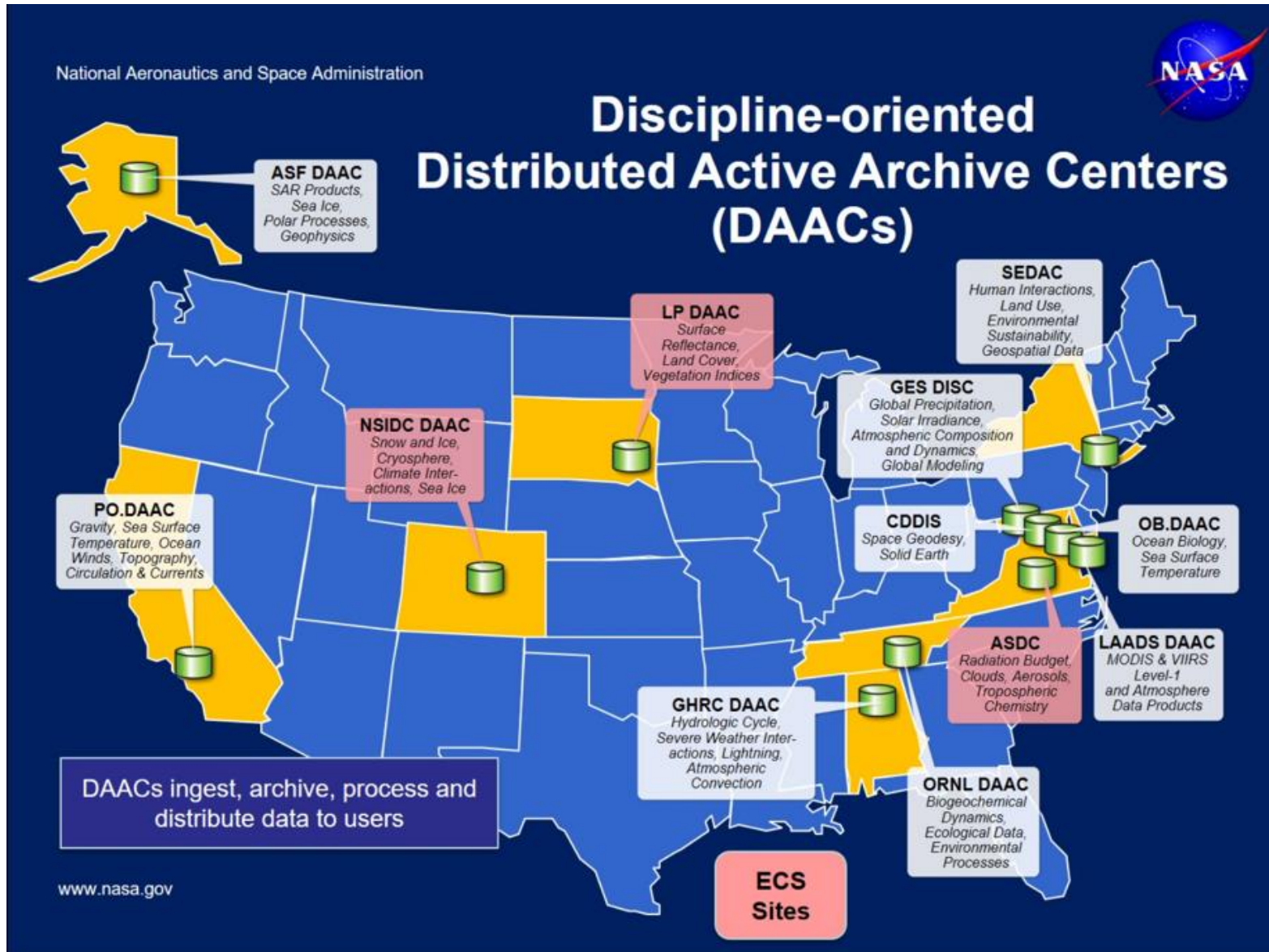
## Hierarchical Data Format (HDF)



Preferred container for NASA EOS data

<https://eosweb.larc.nasa.gov>

# DAACs



# Earthdata Search



The screenshot displays the Earthdata Search web application. At the top, there is a search bar with the text "Type any topic, collection, or place name" and a "Find a DAAC" dropdown. To the right of the search bar are buttons for "Show Tour" and "Earthdata Login". Below the search bar is a map of the Middle East and North Africa region, showing countries like Algeria, Libya, Egypt, Saudi Arabia, and others. The map includes a scale bar for 1000 km and 500 miles. On the left side, there is a navigation menu with categories: "Browse Collections", "Features" (with sub-items: Map Imagery, Near Real Time, Customizable), "Keywords", "Platforms", "Instruments", "Organizations", "Projects", and "Processing levels". Below the map, a box indicates "5929 Matching Collections". Below this, there are sorting options: "Sort by: Relevance" and checkboxes for "Only include collections with granules" and "Include non-EOSDIS collections". A tip suggests adding collections to a project. Three search results are visible, each with a thumbnail, title, description, and a "Learn More" link. The first result is "Global Maps of Atmospheric Nitrogen Deposition, 1860, 1993, and 2050" with 27 granules. The second is "IRS 1C LIS3 Standard Products" with a note "No image available". The third is "IRS 1C Standard Geo Referenced Product". At the bottom of the page, there is a footer with version information (v 1.84.0), search time (0.7s), and various links including "NASA Official", "FOIA", "NASA Privacy Policy", and "USA.gov".

<https://search.earthdata.nasa.gov>

# Tools Used with NASA Data Products



2018 ACSI RESULTS – All DAACs

- Significant increase in the number of users interested in using NASA Earth Science data in a GIS
  - Per the ACSI survey results for “Top tools used to work with data”: ArcGIS ranked number 1 at 64%
- GIS is utilized to support the delivery of priority data products, experiment with various geospatial technologies, and expand geospatial capabilities.

Tool(s) used to work with data~	2018	2018
	%	N
ArcGIS	64%	898
Convert to Vector	6%	80
ENVI	32%	450
ERDAS/IMAGINE	20%	278
Excel	29%	409
Ferret	1%	10
Geomatica	4%	53
Global Mapper	15%	206
GrADS	3%	46
GRASS	12%	174
HDFLook	2%	27
HDFView	10%	138
HEG	1%	20
IDL	7%	100
IDV	1%	12
IDRISI	7%	96
MapReady	2%	22
MATLAB	18%	255
MODIS Reprojection Tool (MRT)	9%	126
NCL	3%	47
Panoply	9%	121
Quantum GIS (QGIS)	42%	587
R	22%	315
SeaDAS	3%	46
Other/open source	23%	320
Don't know/Not applicable	1%	8
<b>Number of Respondents</b>	<b>3,656</b>	<b>3,656</b>

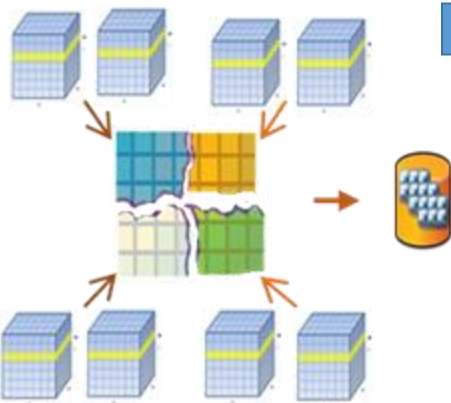
~ Multiple responses allowed



# Utilizing the ArcGIS Platform as an End-to-End Solution for Processing, Analyzing, and Visualizing NASA's Scientific Data



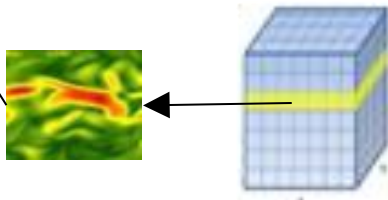
## ArcGIS Multidimensional Mosaic Dataset Indexing HDF/netCDF/GRIB Data Warehouses



- Aggregate (mosaic) spatial, time, and vertical dimensions

### Mosaic Index

OBJ	Raster	Name	Variable *	Standard Time†
1	<Raster	hycom_glb_regp01.nc.water_temp.0	water_temp	5/17/2013
2	<Raster	hycom_glb_regp01.nc.water_temp.1	water_temp	5/17/2013
3	<Raster	hycom_glb_regp01.nc.water_temp.2	water_temp	5/17/2013
4	<Raster	hycom_glb_regp01.nc.water_temp.3	water_temp	5/17/2013
5	<Raster	hycom_glb_regp01.nc.water_temp.4	water_temp	5/17/2013

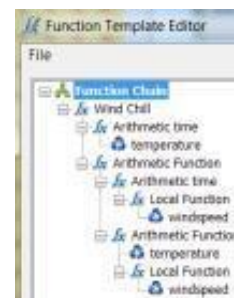


## Publish ArcGIS Image Service



### Raster Functions

- On-the-fly Computing
  - Image Processing (NDVI, pansharpen, image classification, etc.)
  - Raster Calculator (Convert Celsius to Fahrenheit)
- Processes the pixels that are requested
- Can be chained and avoid intermediate results

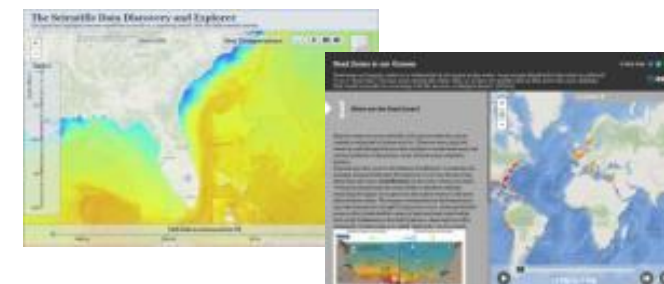
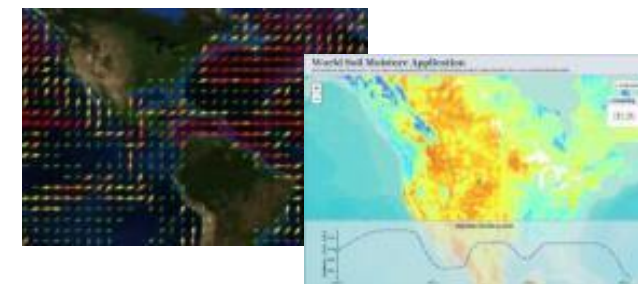


## Usable by ArcGIS Platform



### Visualization

- Visualize temporal change of a variable
- Visualize a variable at any vertical dimension
- Visualize flow direction and magnitude variables



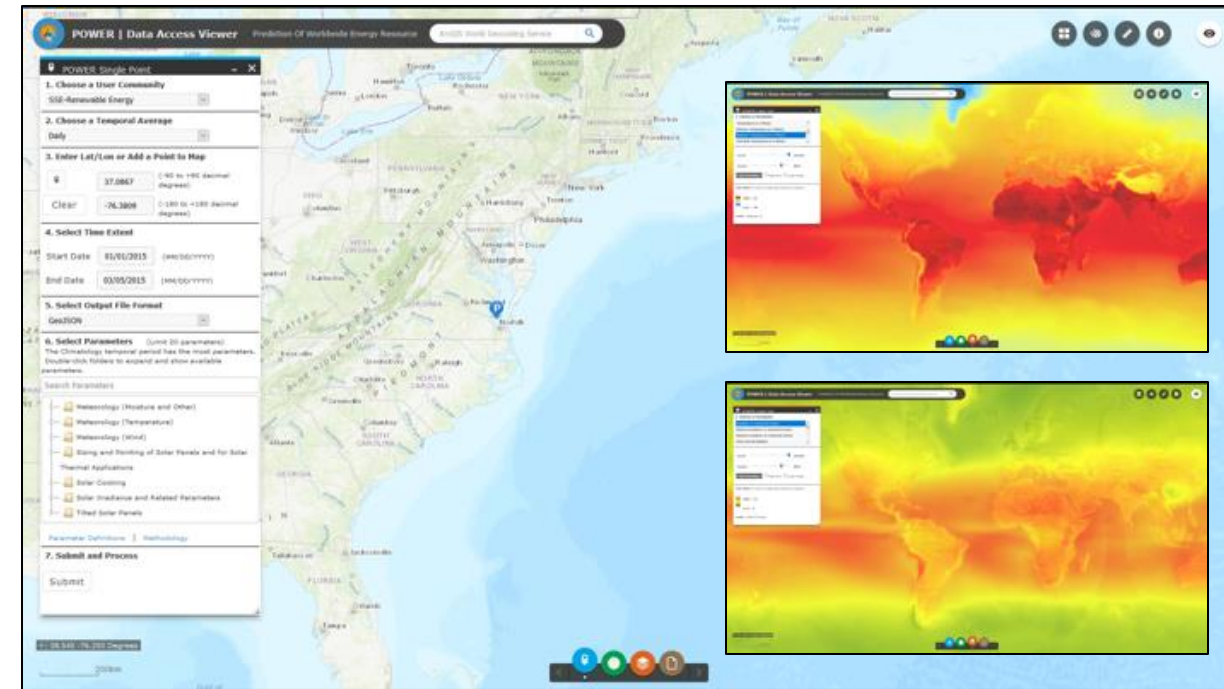
# Prediction of Worldwide Energy Resources (POWER)



The Prediction of Worldwide Energy Resources (POWER) Project's objective is to integrate environmental data, analysis and modeling from NASA research, and customize it to enhance decision support in energy production and usage, as well as agricultural applications. To support this, POWER targets three user communities: Renewable Energy (denoted as Surface meteorology and Solar Energy or SSE), Sustainable Buildings (SB), and Agroclimatology (AG) with geospatially enabled Analysis Ready Data (ARD). The POWER Communities are provided ARD outputs in formats, naming conventions, and units that are commonly employed in each user community; all derived from the same underlying solar and/or meteorological data in the POWER Data Archive. The POWER Data Archive includes a total of 275 parameters available on a 0.5° x 0.5° latitude and longitude global grid, and are available at four temporal levels - hourly, daily, interannual, and climatological. The POWER project can provide time series data ranging from January 1, 1981, to within 4-7 days of a given current date.

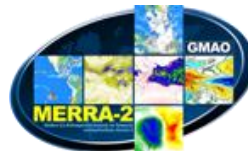
**Solar parameters** are derived from NASA's GEWEX/SRB release 3.0 archive (July 1, 1983 – Dec. 31, 2007) and NASA's CERES FLASHFlux project (Jan. 1, 2008 – to within about 7-days of real time).

**Meteorological parameters** are derived from the NASA's GMAO MERRA-2 assimilation model (Jan. 1, 1981 to within a few months of real time) plus GEOS-5.12.4 FP-IT (End of MERRA-2 to within several days of real time).



The POWER Project's Data Access Viewer (DAV) uses the Esri Web Appbuilder to host a series of widgets to support download of POWER data products from the POWER's ArcGIS Image Services and Application Programming Interface (API) via a simplified user interface. These include single point and global data download, image services viewer, and temporal reports exports.

This can be accessed at: <https://power.larc.nasa.gov/data-access-viewer/>



# NASA ASDC ArcGIS Portal



Increasing the discoverability of data, services, maps, and apps

**ASDC Geospatial Portal**

**Featured Maps and Apps**

- 22 Year Climatology Image Service
- Daily Average Parameters ArcImage Service
- POWER SSE Web Mapping Application

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center is responsible for the processing, archival, and distribution of NASA Earth science data in the areas of radiation budget, clouds, aerosols, and tropospheric chemistry.

The Data Center was established in 1991 to support the Earth Observing System (EOS) as part of NASA's Earth Science enterprise and the U.S. Global Change Research Program, and is one of several Distributed Active Archive Centers (DAACs) sponsored by NASA as part of the Earth Observing System Data and Information System (EOSDIS).

**NASA Official:** John M. Kusterer  
**Site Curator:** NASA Langley ASDC User Services - Contact Us  
**NASA Privacy Statement, Disclaimer, and Accessibility Certification**  
**Copyright Information**  
**Last Modified Date:** July 8, 2015

## Examples of Variables Available for Initial Release (Daily and Long Term Averages over a 22 year Period):

- Global Horizontal Radiation
- Diffuse Radiation
- Direct Normal Radiation
- Latitude Tilt Radiation
- Clear Sky Insolation
- Top-of-Atmosphere Insolation
- NO-SUN or BLACK Days
- Air Temperature
- Relative Humidity
- Atmospheric Pressure
- Earth Skin Temperature
- Heating Degree Days Below 18C
- Cooling Degree Days Above 18C

 **GEOPLATFORM.gov** ArcGIS Living Atlas



<https://asdc-arcgis.larc.nasa.gov/portal>

# Demos



**POWER Data Access Viewer** Prediction Of Worldwide Energy Resource Esri World Geocoder

**POWER Single Point Data Access**

1. Choose a User Community  
SSE-Renewable Energy

2. Choose a Temporal Average  
 Daily  Interannual  Climatology

3. Enter Lat/Lon or Add a Point to Map  
Latitude (Decimal Degrees)  
Clear Longitude (Decimal Degrees)

4. Select Time Extent  
Start Date 01/01/2015 (MM/DD/YYYY)  
End Date 03/05/2015 (MM/DD/YYYY)

5. Select Output File Formats  Select All  
 ASCII  CSV  GeoJSON  NetCDF

6. Select Parameters (Limit 20 parameters)  
The Climatology temporal period has the most parameters.  
Double-click folders to expand and show available parameters.

Atmospheric Science Data Center

## Arctic Wildfires

Wildfires in the Arctic often burn far away from populated areas, but their impacts are felt around the globe. From field and laboratory work to airborne campaigns and satellites, NASA is studying why boreal forests and tundra fires have become more frequent and powerful and what that means for climate forecasting, ecosystems and human health.

Scroll down to learn more about Arctic fires and how NASA data can



# Take Away

- The ArcGIS Platform has a robust data model and analytical tools for conducting analysis with Multidimensional Data
- Platform with a format agnostic enterprise framework to share your research result with a larger community
- Platform is extendable and Interoperable. Build Custom Apps to turn your Data into Actionable Information



# Relevant Upcoming Sessions

- **Working with Multisensor Imagery and Raster Data**
  - 143C | 4:00 - 5:00 pm



# Print Your Certificate of Attendance

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**Tonight**

6:30 pm – 9:00 pm

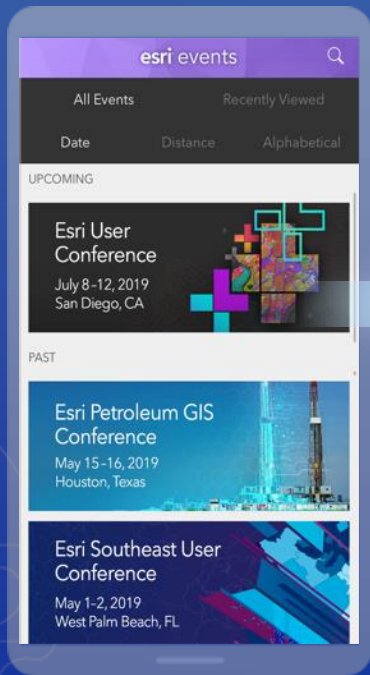
**Networking Reception**

**Smithsonian National Museum of Natural History**

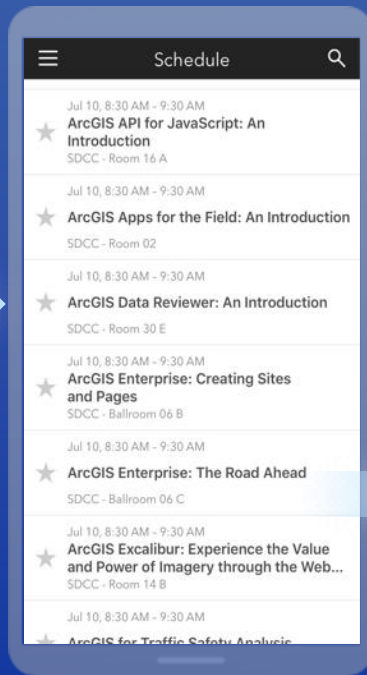


# Please Share Your Feedback in the App

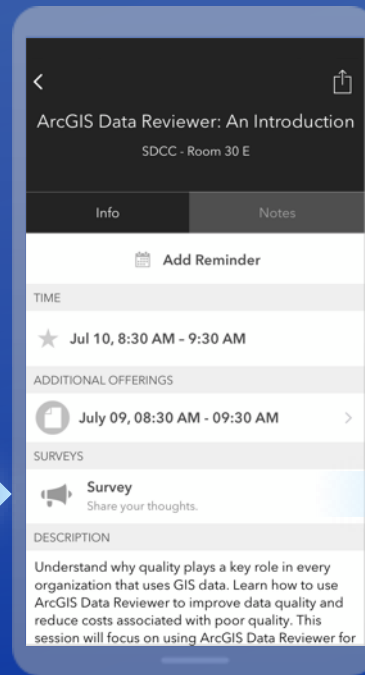
Download the Esri Events app and find your event



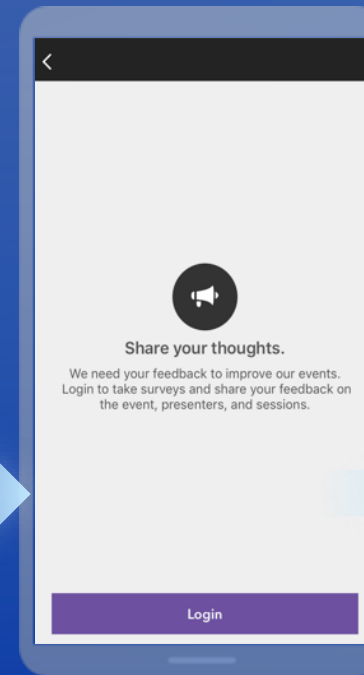
Select the session you attended



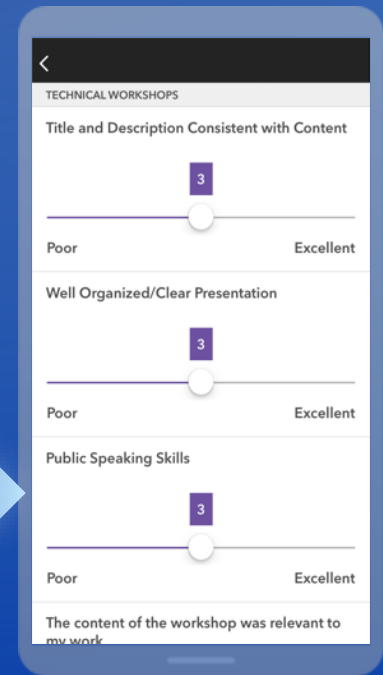
Scroll down to "Survey"



Log in to access the survey



Complete the survey and select "Submit"





# Questions ?

[SSHRESTHA@ESRI.COM](mailto:SSHRESTHA@ESRI.COM)

[L.ZHANG@ESRI.COM](mailto:L.ZHANG@ESRI.COM)

