Analyzing Multidimensional Scientific Data in ArcGIS

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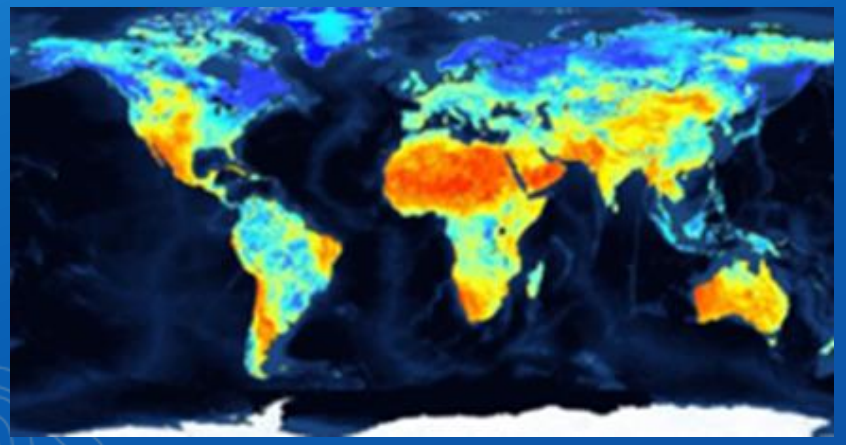
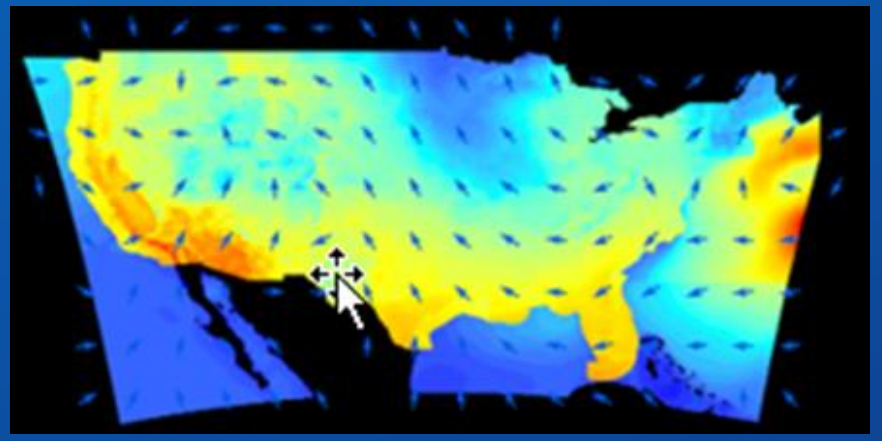
Take Away

- 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**

Ingest	Manage	Analyze	Visualize	Share
raster types	mosaic dataset	multidimensional filter	animate over slices	dynamic web services
crawl disk	geoprocessing tools	raster functions	sophisticated renderers	web maps & apps
link to pixels	optimization consumption	Interactive/dynamic	vector & scalar fields	web based analytics
		scalable/extensible		





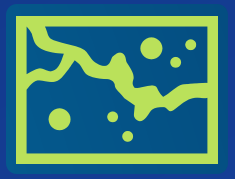
Data → **Service / Product**

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

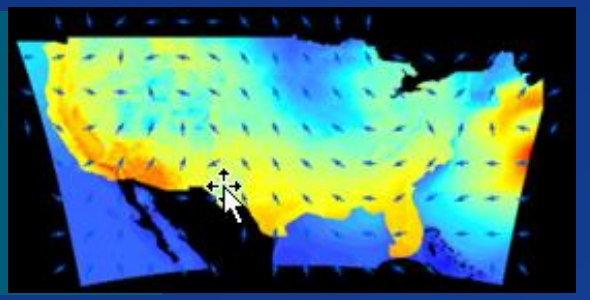
- Large volume (Volume)
- Many types of data (Variety)
- Grow rapidly (Velocity)

Multidimensional

- Time
- Depth
- Height

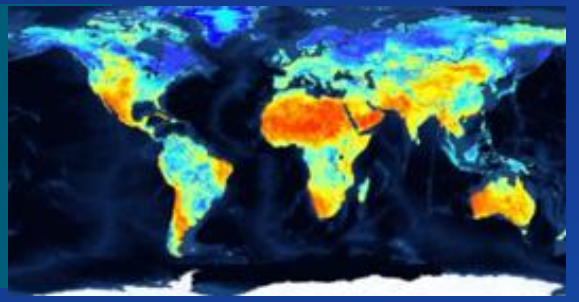
Meteorological

- Temperature
- Precipitation
- Wind speed



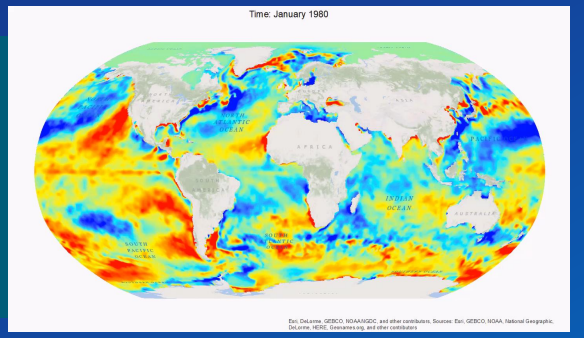
Terrestrial

- Soil moisture
- NDVI
- Land cover

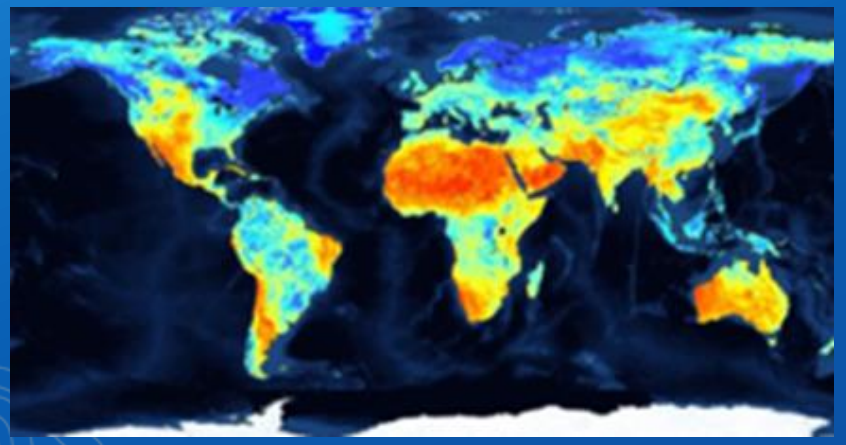


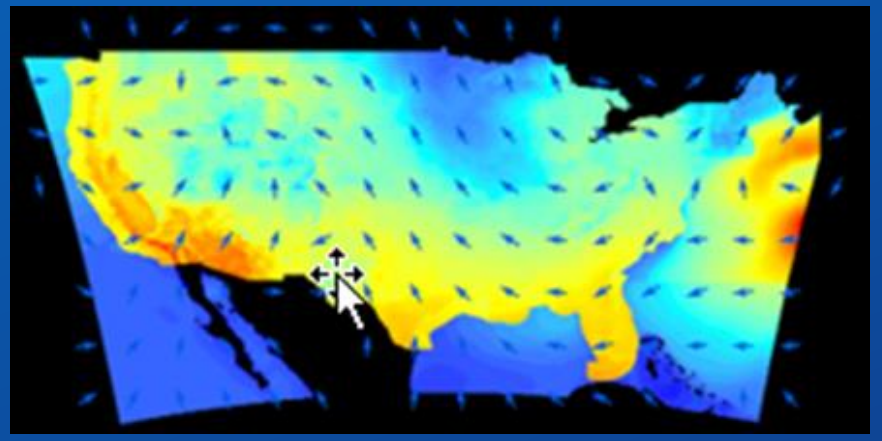
Oceanographic

- Salinity
- Sea Surface Temperature
- Ocean current



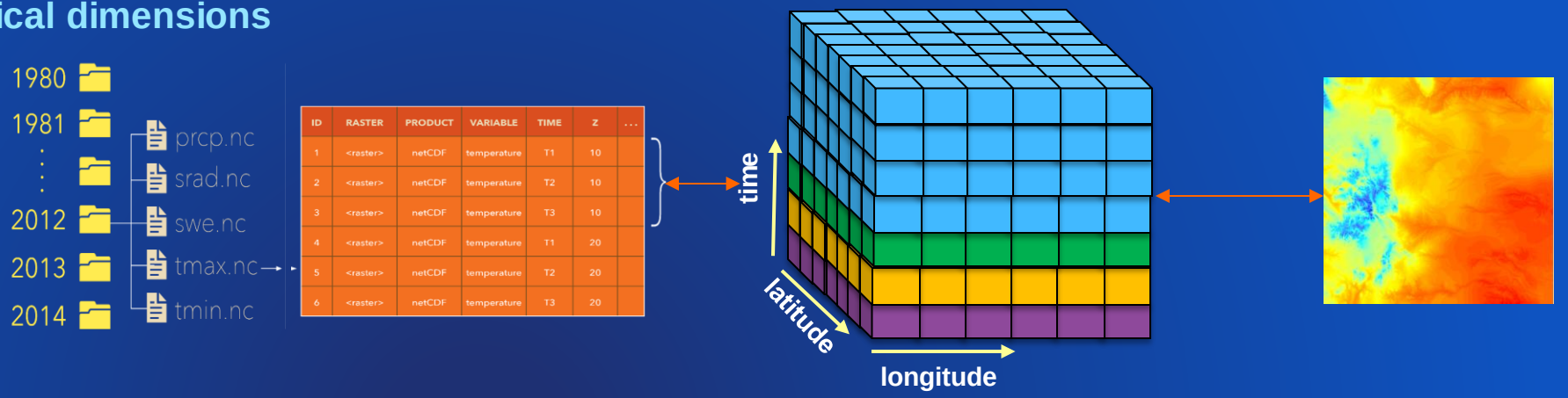
What is Multidimensional Data?





What is Multidimensional data?

Spatial, temporal, and vertical dimensions



- **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)

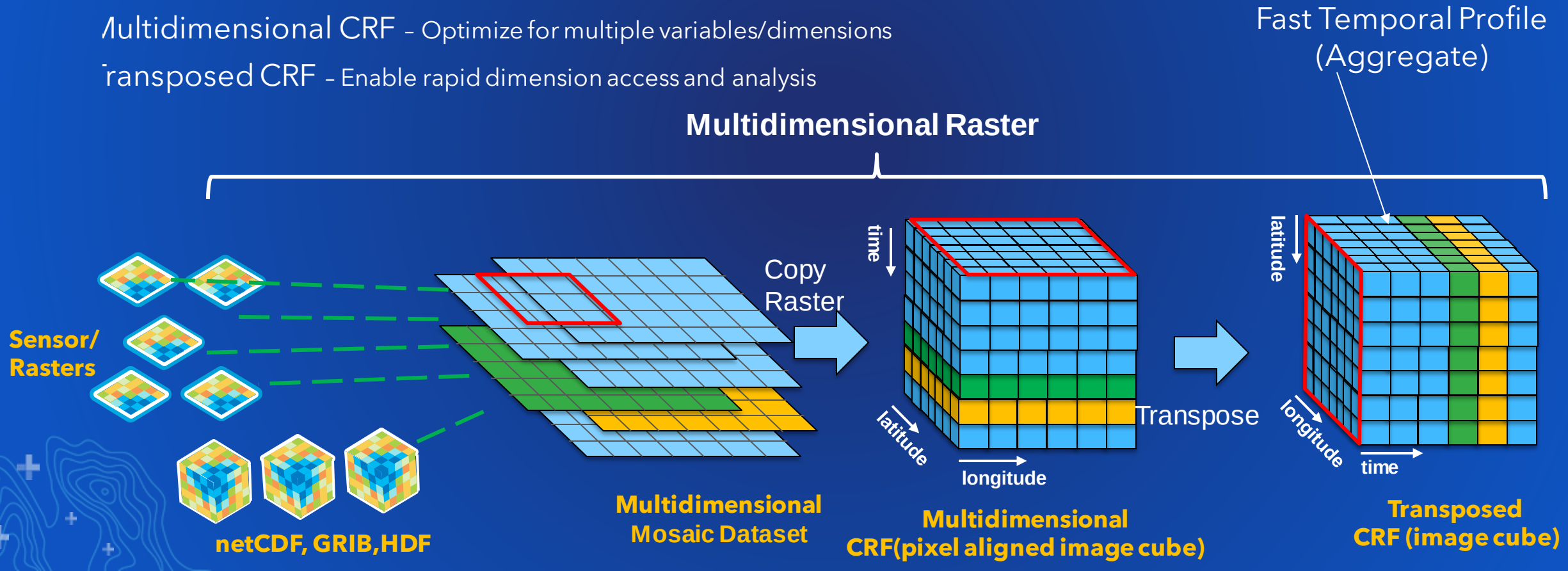
Mosaic Dataset

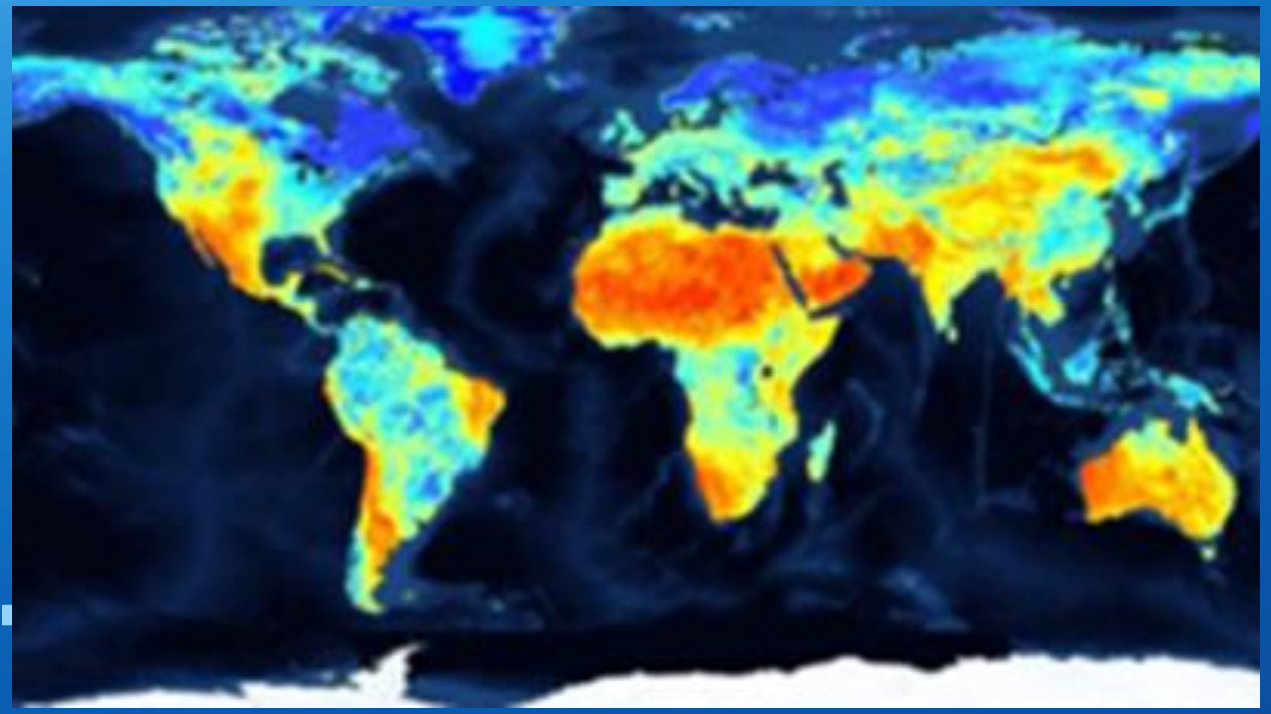
Multidimensional Mosaic Dataset

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

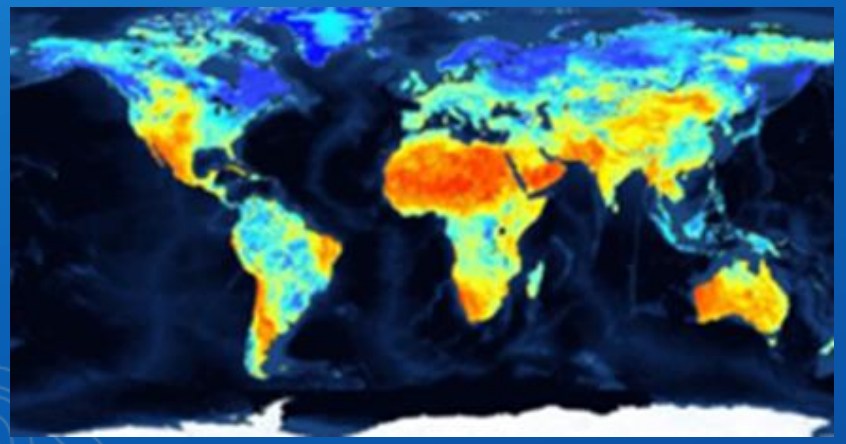


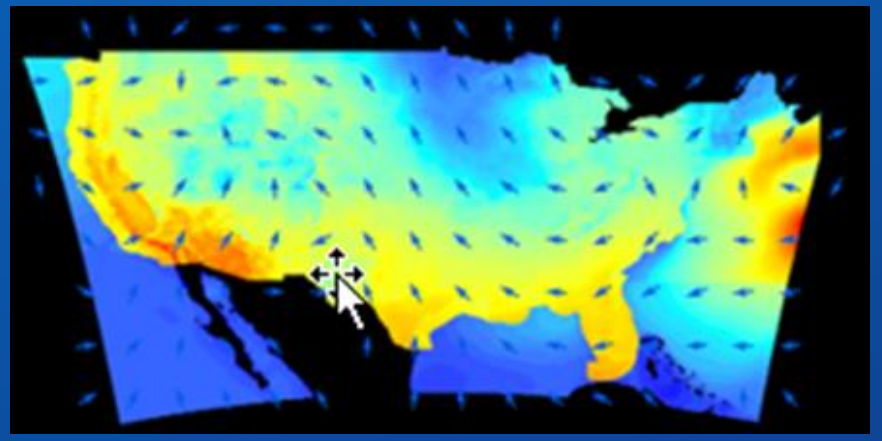


Ingesting Multidimensional Data

Intro Demo

Analyzing Multidimensional Data

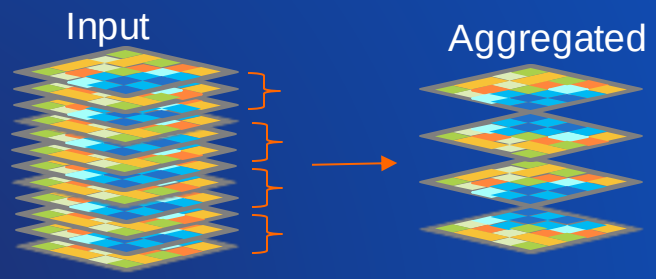




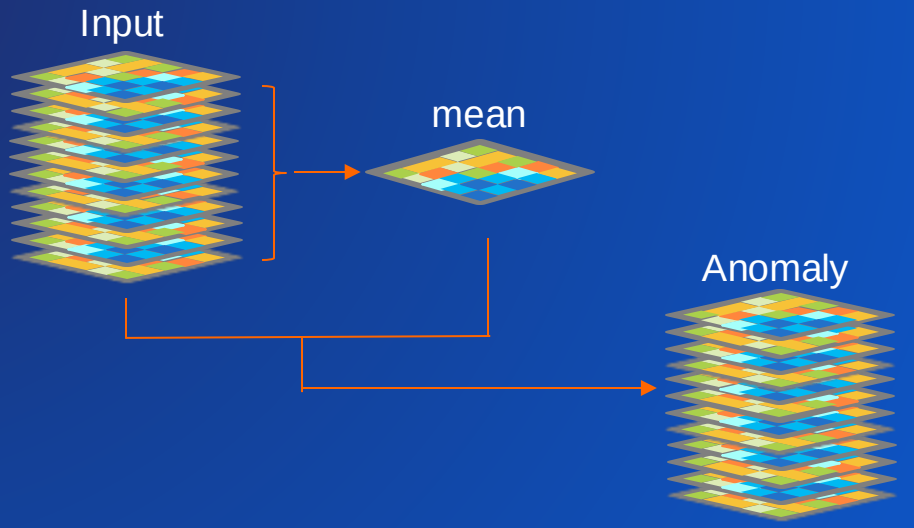
Multidimensional Raster Analysis – Using Geoprocessing Tools

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

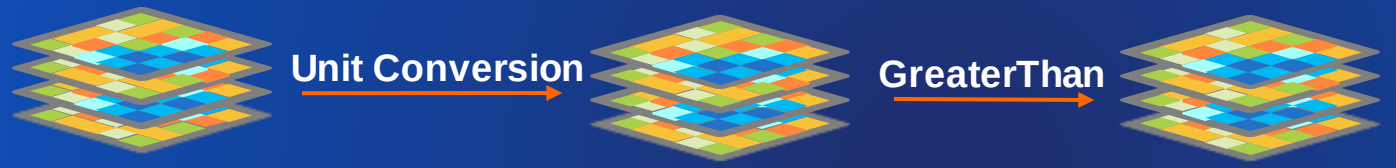


- **Trend and Prediction**

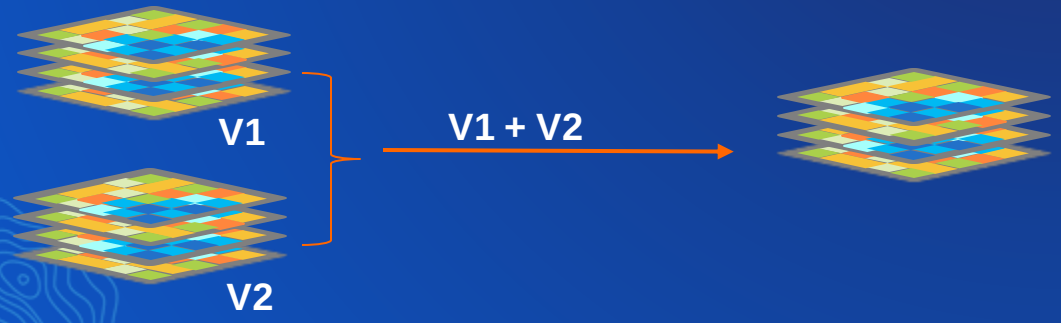
Multidimensional Raster Analysis - Using Raster Functions

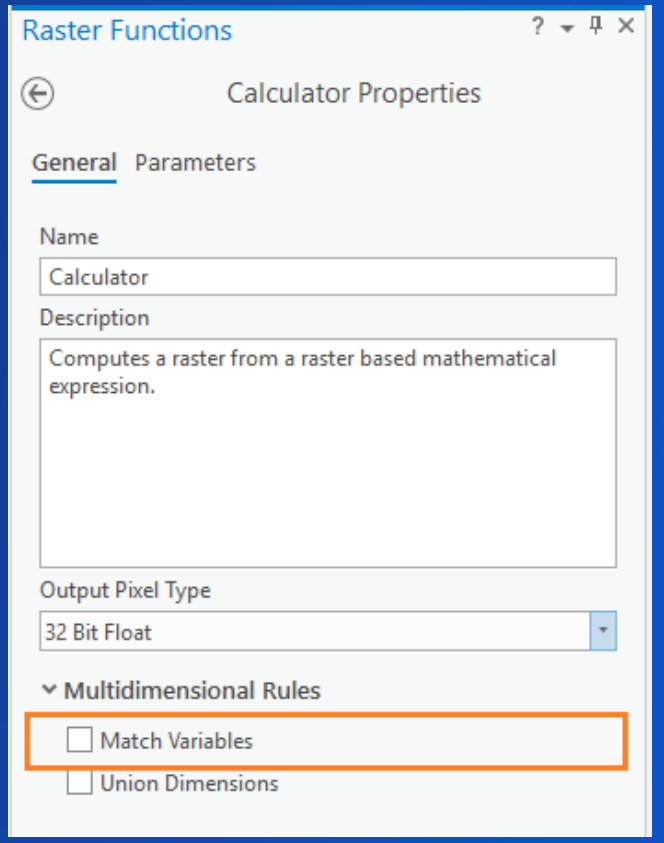
Cube based analysis / cube based map algebra

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



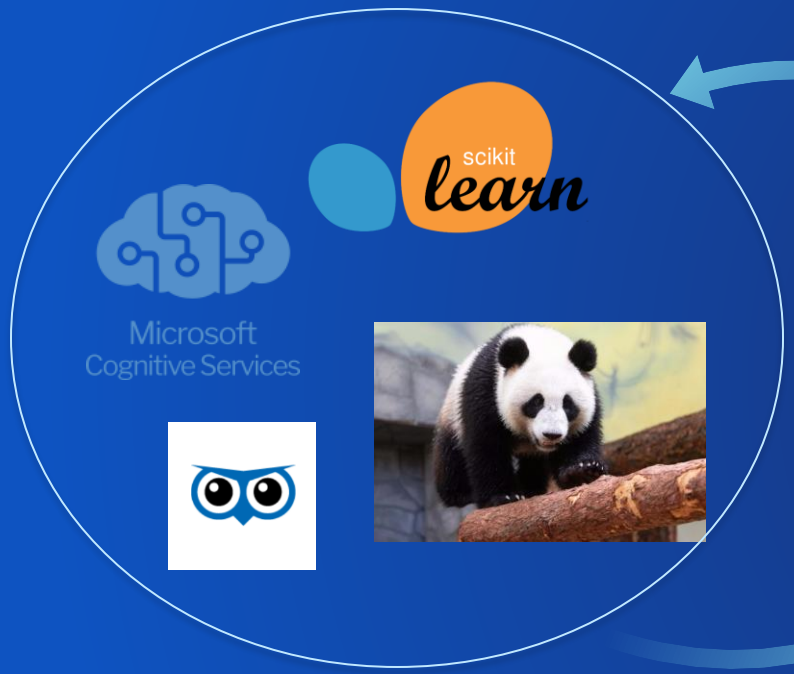
- **Functions with two or more inputs - rules**
  - **Variable names must match**
  - **Disable the Match Variables option**

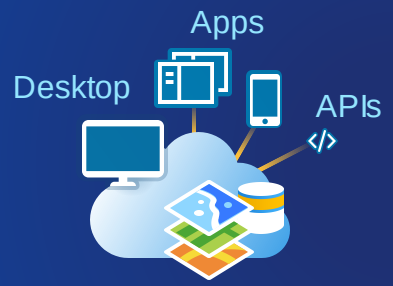


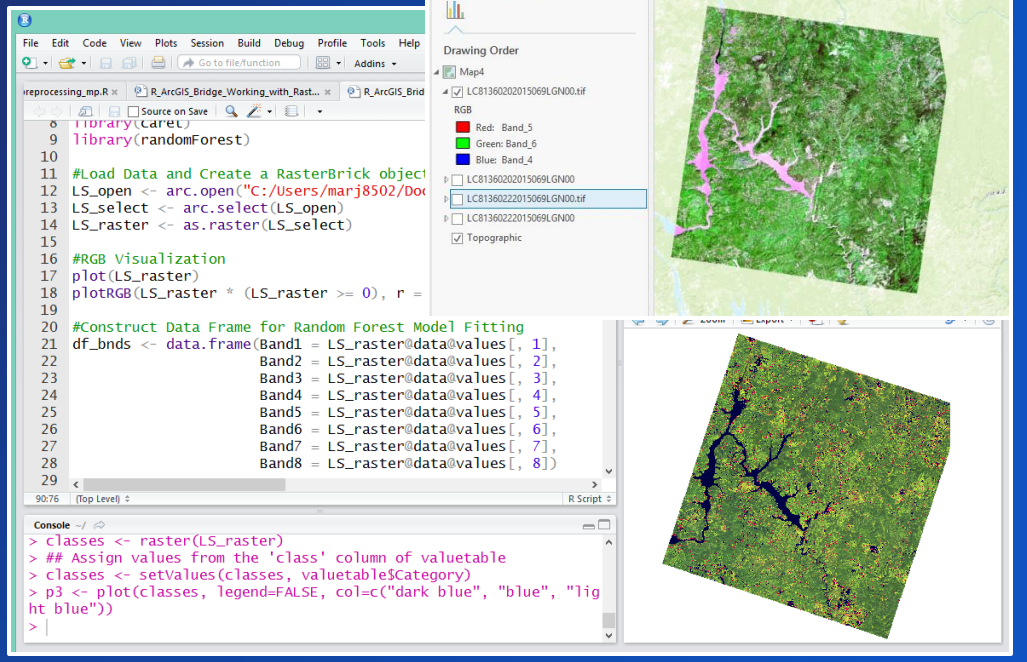


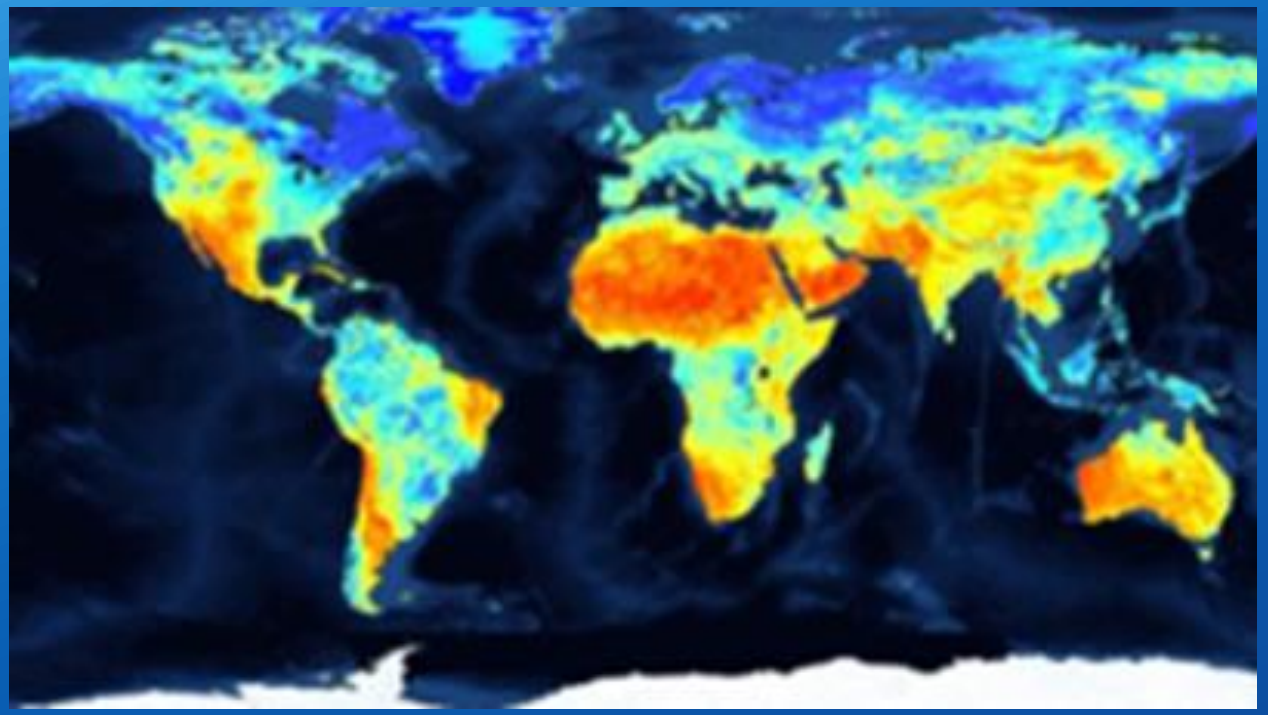
Multidimensional Raster Analysis – Open Platform

Python / R / Other Sources



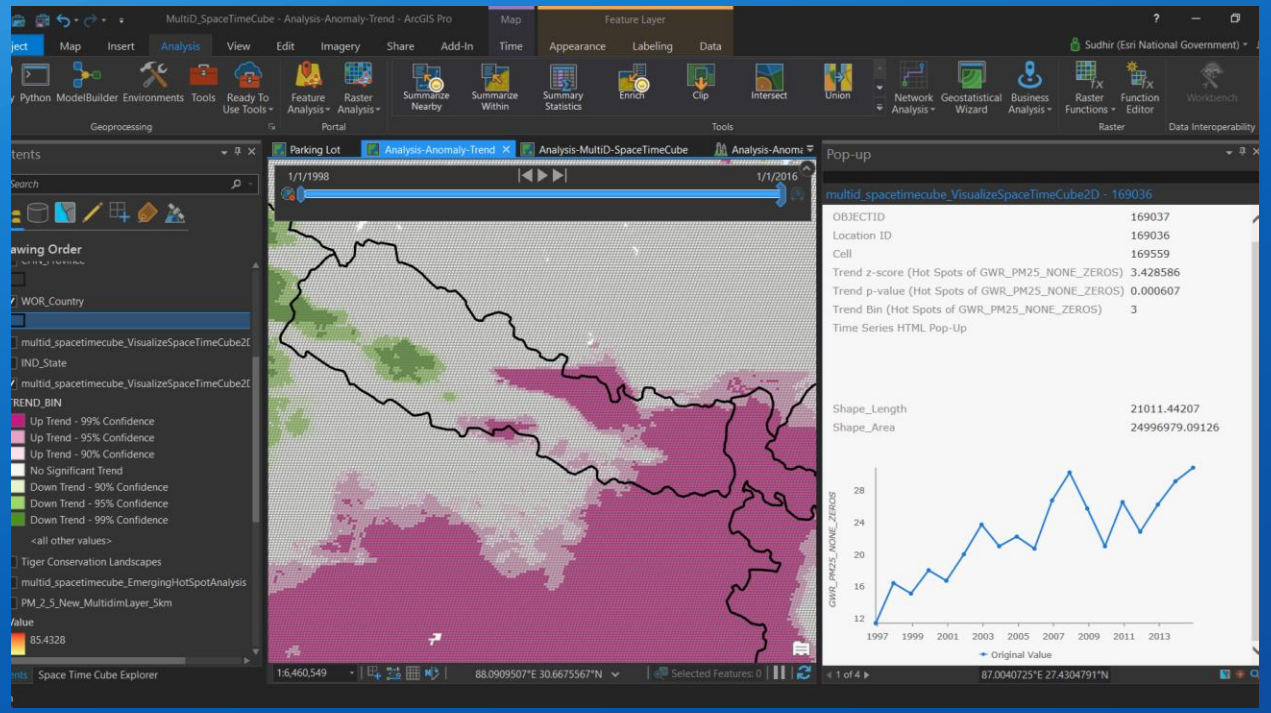






Precipitation Trends: Desertification / Expansion of Sub Saharan Africa

(Multidimensional Space Time Cube)



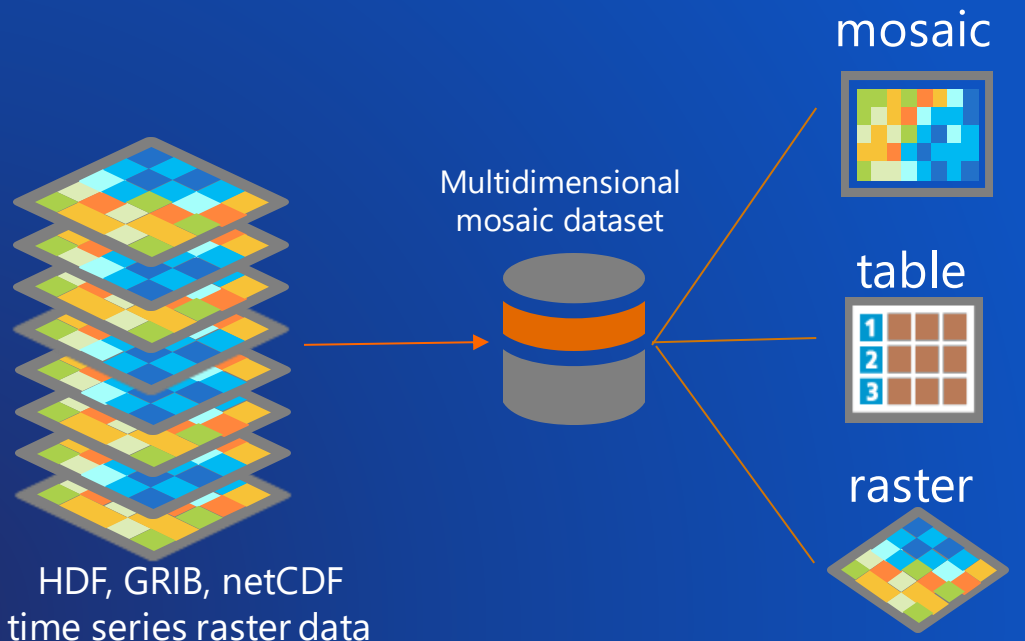
Quantifying spatial and temporal patterns of fine particulate matter (PM2.5) in Asia Pacific Region

(Multidimensional Space Time Cube)

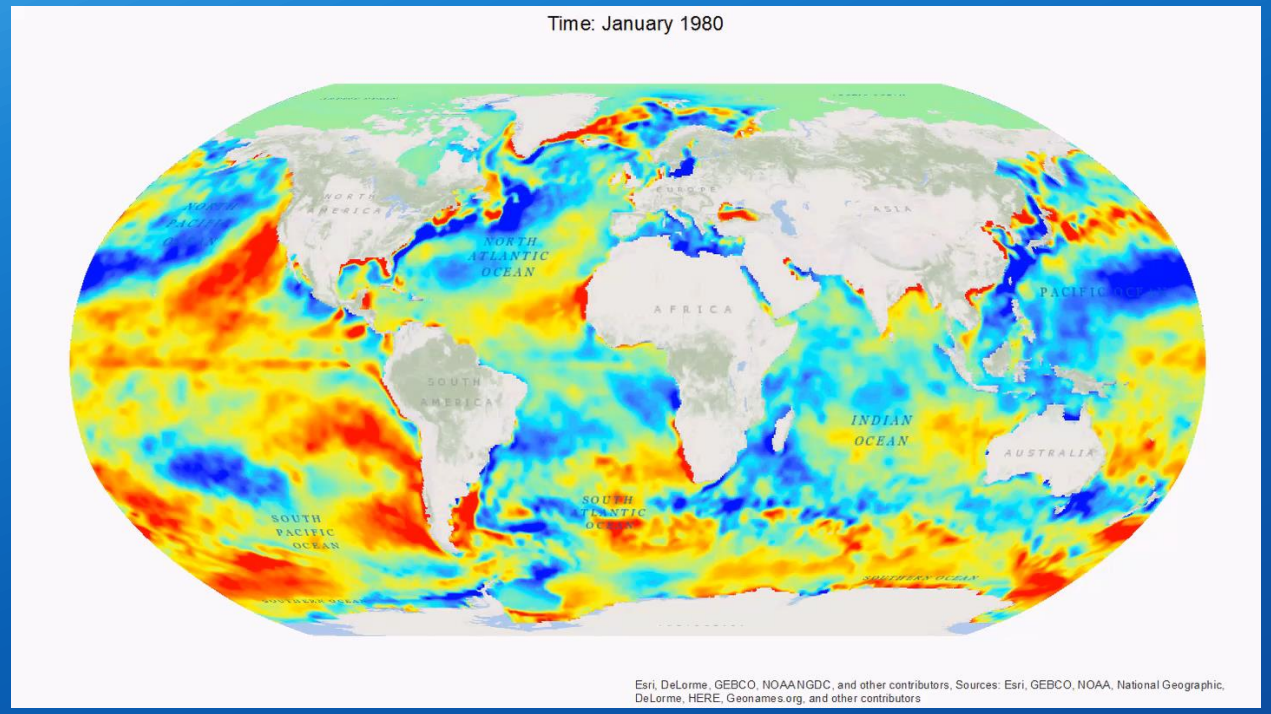
Multidimensional Mosaic Dataset

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

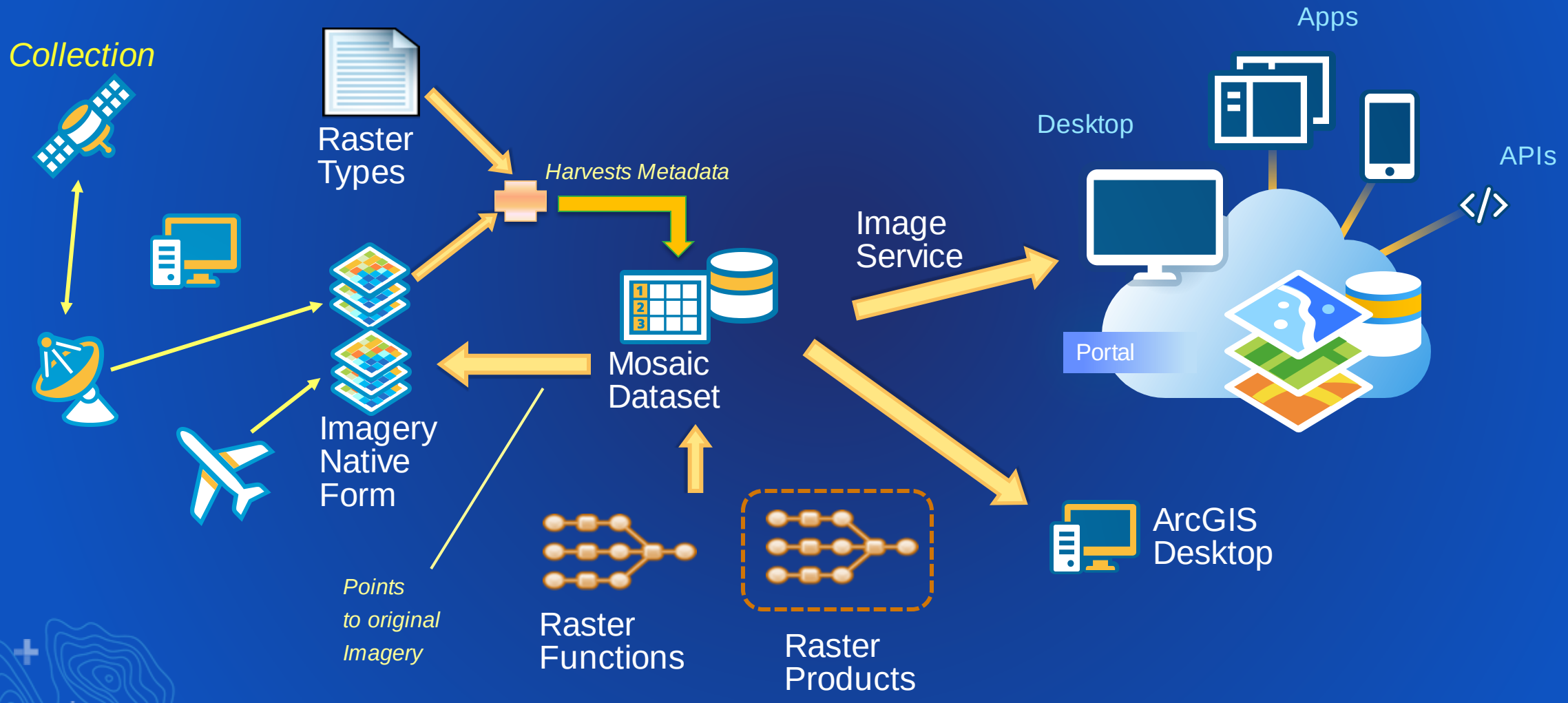


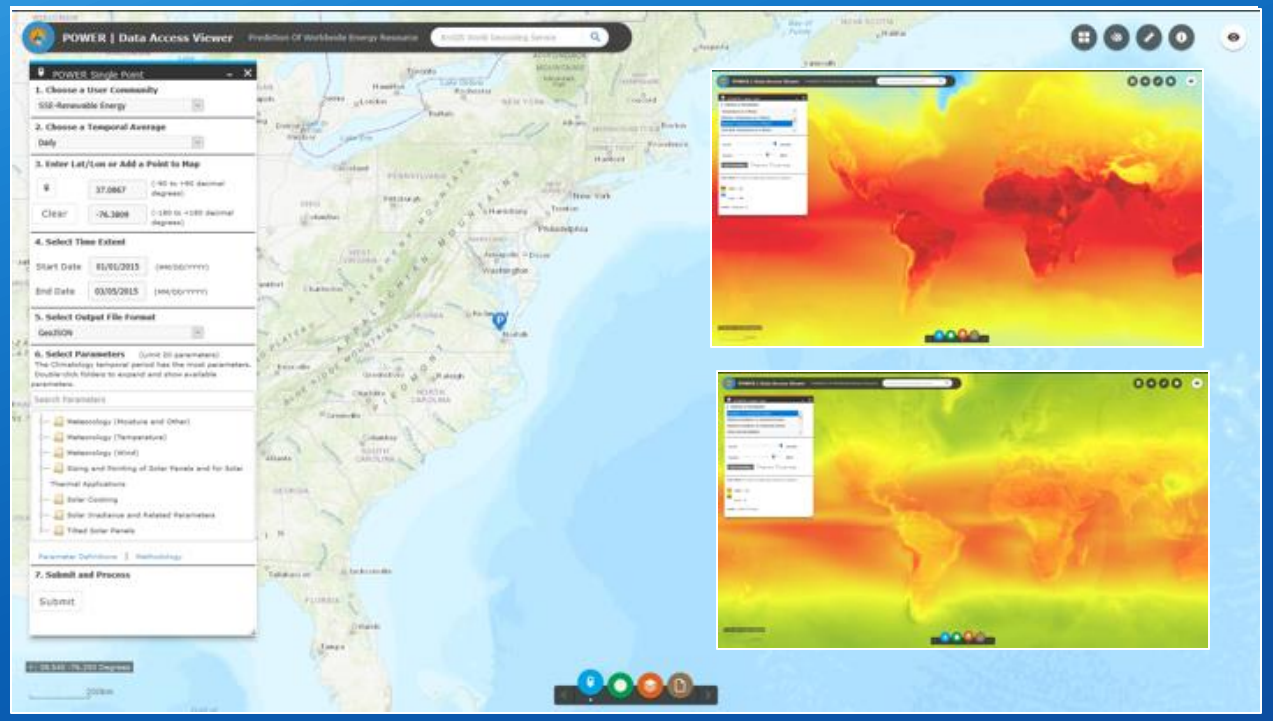
Raster	Shape	Variable	StdTime	StdZ
…	…	Temperature	3/22/2016	-10
…	…	Temperature	3/23/2016	-10
…	…	Temperature	3/24/2016	-10
…	…	Salinity	3/22/2016	-10
…	…	Salinity	3/23/2016	-10
…	…	Salinity	3/24/2016	-10
…	…	Temperature	3/22/2016	-20
…	…	Temperature	3/23/2016	-20
…	…	…	…	…



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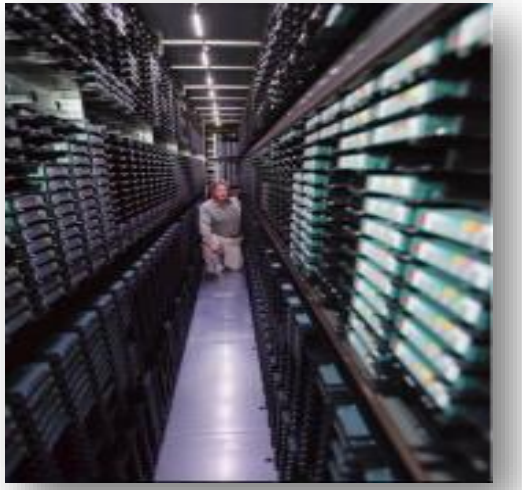
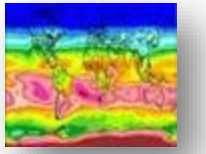
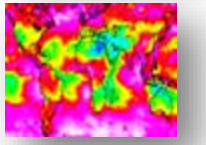
The NASA Atmospheric Science Data Center (ASDC) at a Glance



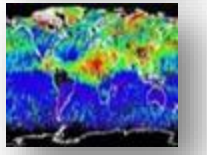
- Curates more than **1,000 unique science products** and provides data services for over **50 science projects**
- **5+ petabytes of data, over 58 million files,** are in the archive
- Data distributed to over **165,000** customers in **158** countries



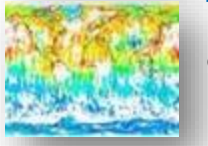
Radiation Budget - The radiation budget takes into account the sum of all radiation, transferred in all directions, through the Earth's atmosphere and to and from space.
Instruments: CERES



Clouds - A visible aggregate of minute water droplets and/or ice crystals in the atmosphere above the Earth's surface.
Instruments: CALIPSO, MISR

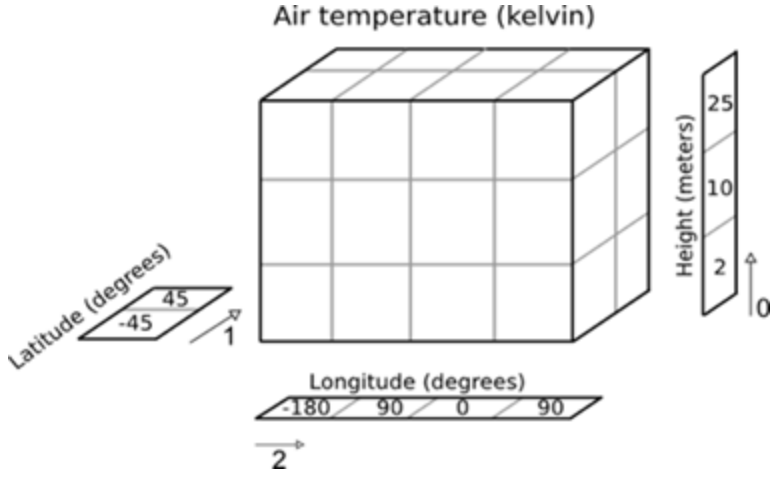


Aerosols - Suspension of particles of condensed matter (liquid, solid, or mixed) in a carrier gas (usually air).
Instruments: CALIPSO, MISR, SAGE III



Tropospheric composition - Measurements of chemical constituents in the atmosphere including the major (non-H_2O) greenhouse gases (CO_2, CH_4, O_3, N_2O).
Instruments: MOPITT, TES

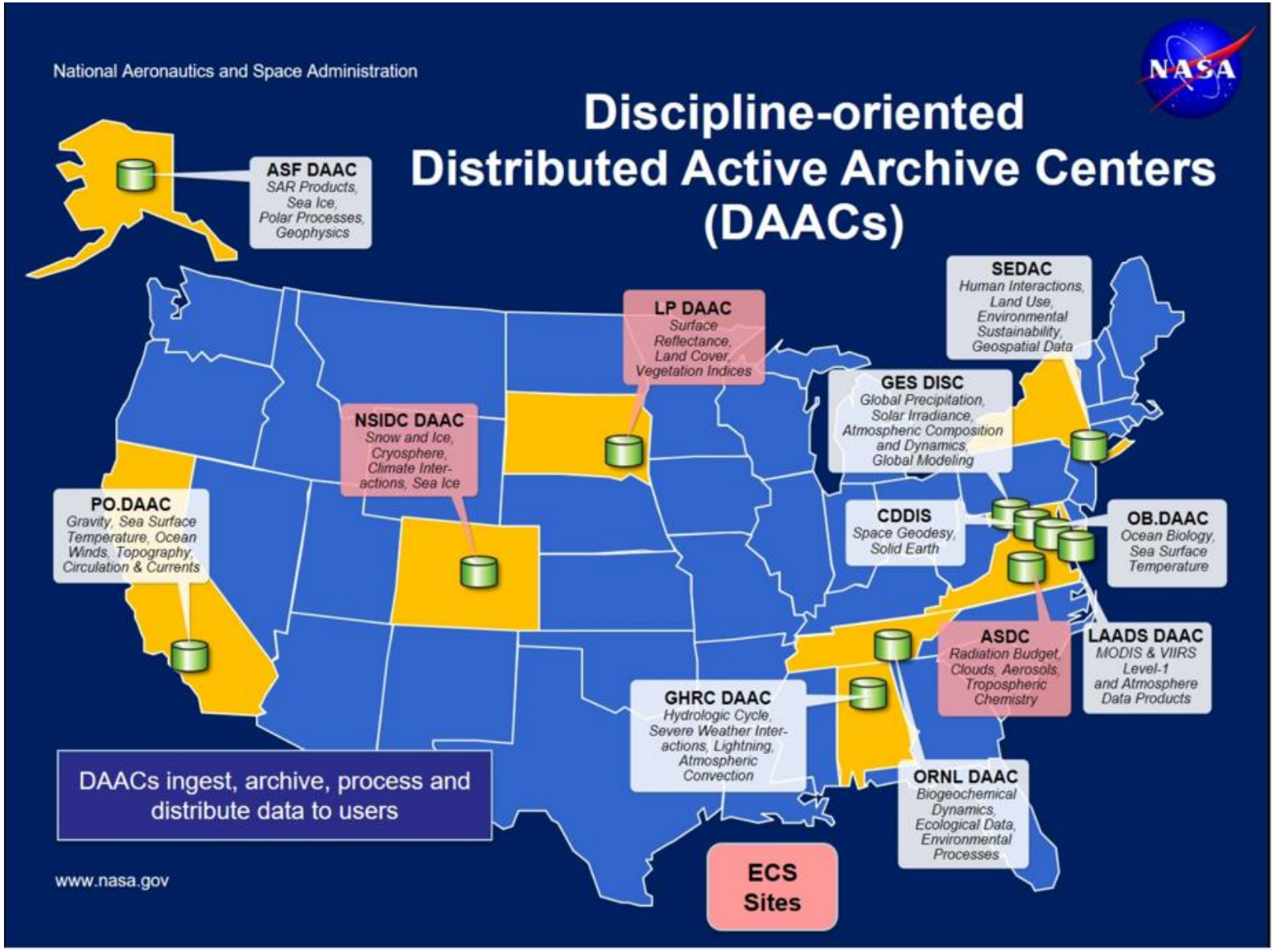
Hierarchical Data Format (HDF)



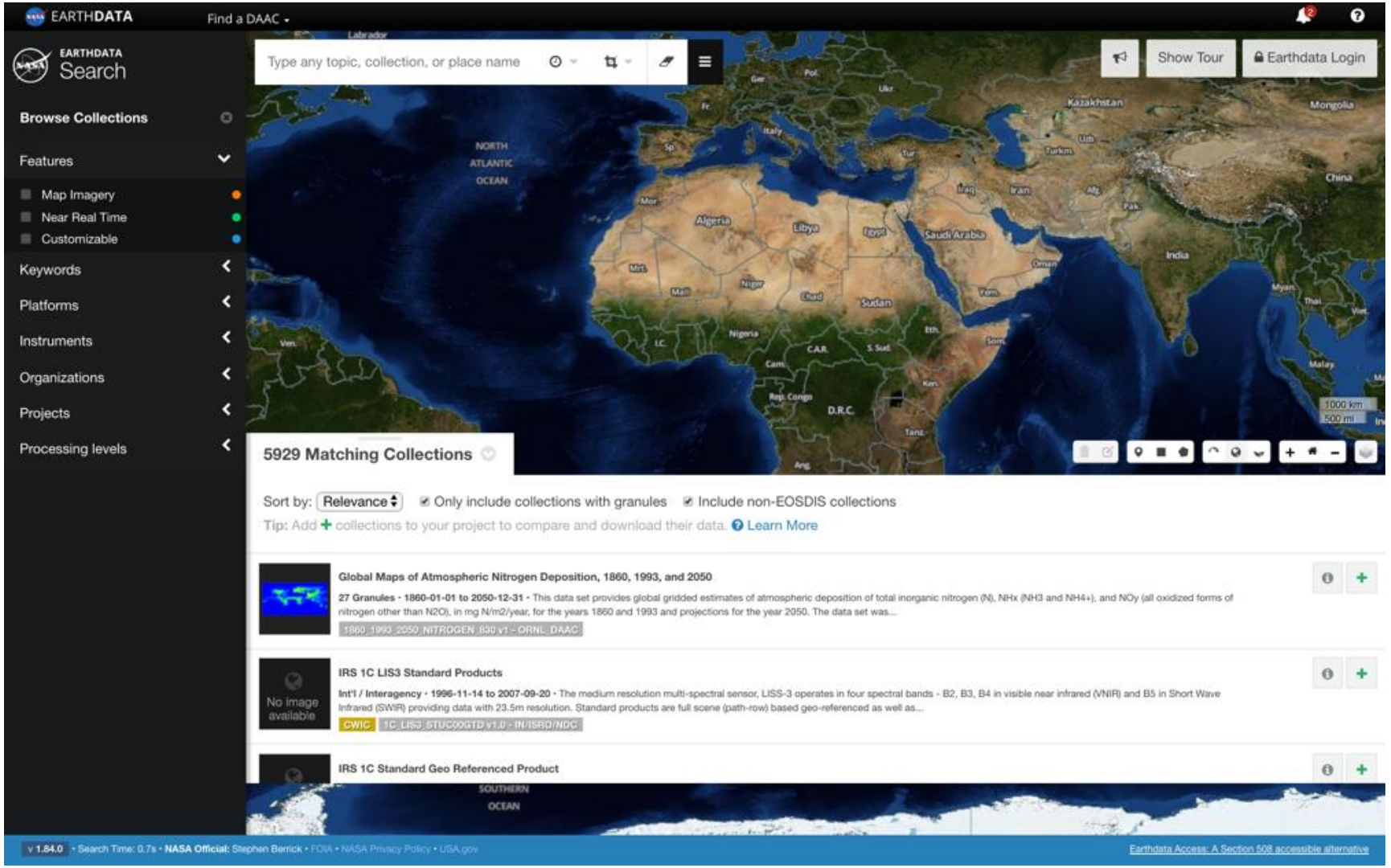
Preferred container for NASA EOS data

https://eosweb.larc.nasa.gov

DAACs


National Aeronautics and Space Administration
Discipline-oriented Distributed Active Archive Centers (DAACs)
ASF DAAC
SAR Products, Sea Ice, Polar Processes, Geophysics
LP DAAC
Surface Reflectance, Land Cover, Vegetation Indices
SEDAC
Human Interactions, Land Use, Environmental Sustainability, Geospatial Data
GES DISC
Global Precipitation, Solar Irradiance, Atmospheric Composition and Dynamics, Global Modeling
NSIDC DAAC
Snow and Ice, Cryosphere, Climate Interactions, Sea Ice
PO.DAAC
Gravity, Sea Surface Temperature, Ocean Winds, Topography, Circulation & Currents
CDDIS
Space Geodesy, Solid Earth
OB.DAAC
Ocean Biology, Sea Surface Temperature
ASDC
Radiation Budget, Clouds, Aerosols, Tropospheric Chemistry
LAADS DAAC
MODIS & VIIRS Level-1 and Atmosphere Data Products
GHRC DAAC
Hydrologic Cycle, Severe Weather Interactions, Lightning, Atmospheric Convection
ORNL DAAC
Biogeochemical Dynamics, Ecological Data, Environmental Processes
DAACs ingest, archive, process and distribute data to users
ECS Sites
www.nasa.gov

Earthdata Search



https://search.earthdata.nasa.gov

Tools Used with NASA Data Products

- 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.

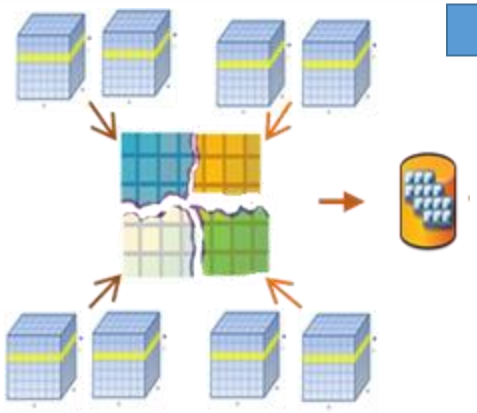
2018 ACSI RESULTS – All DAACs

	2018 %	2018 N
Tool(s) used to work with data~		
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
Number of Respondents	**3,656**	**3,656**

~ Multiple responses allowed

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

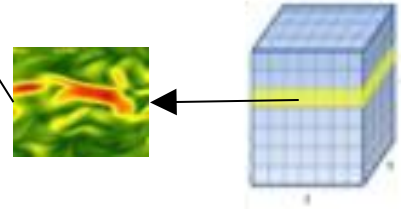
ArcGIS Multidimensional Mosaic Dataset Indexing HDF/netCDF/GRIB Data Warehouses



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

Mosaic Index

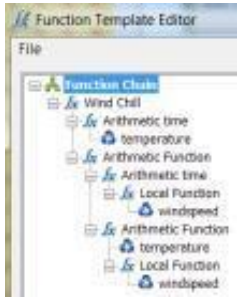
OBJ	Raster	Name	Variable *	Standard Time
	<Raster	hycom_glb_regp01.nc:water_temp:0	water_temp	5/17/2013
2	<Raster	hycom_glb_regp01.nc:water_temp:1	water_temp	5/17/2013
3	<Raster	hycom_glb_regp01.nc:water_temp:2	water_temp	5/17/2013
4	<Raster	hycom_glb_regp01.nc:water_temp:3	water_temp	5/17/2013
5	<Raster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



Publish ArcGIS Image Service

Raster Functions

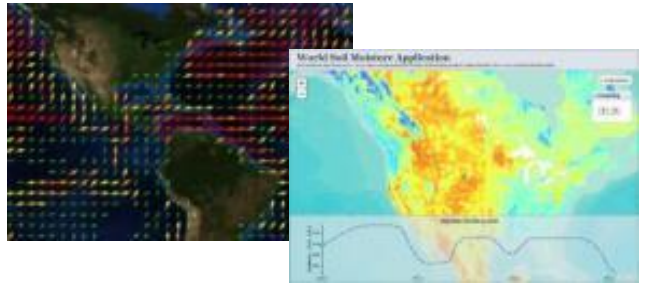
- On-the-fly Computing
  - Image Processing (NDVI, pansharpen, image classification, etc.)
  - Raster Calculator (Convert Celsius to Fahrenheit)
- Processes the pixels that are requested
- Can be chained and avoid intermediate results



Usable by ArcGIS Platform

Visualization

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

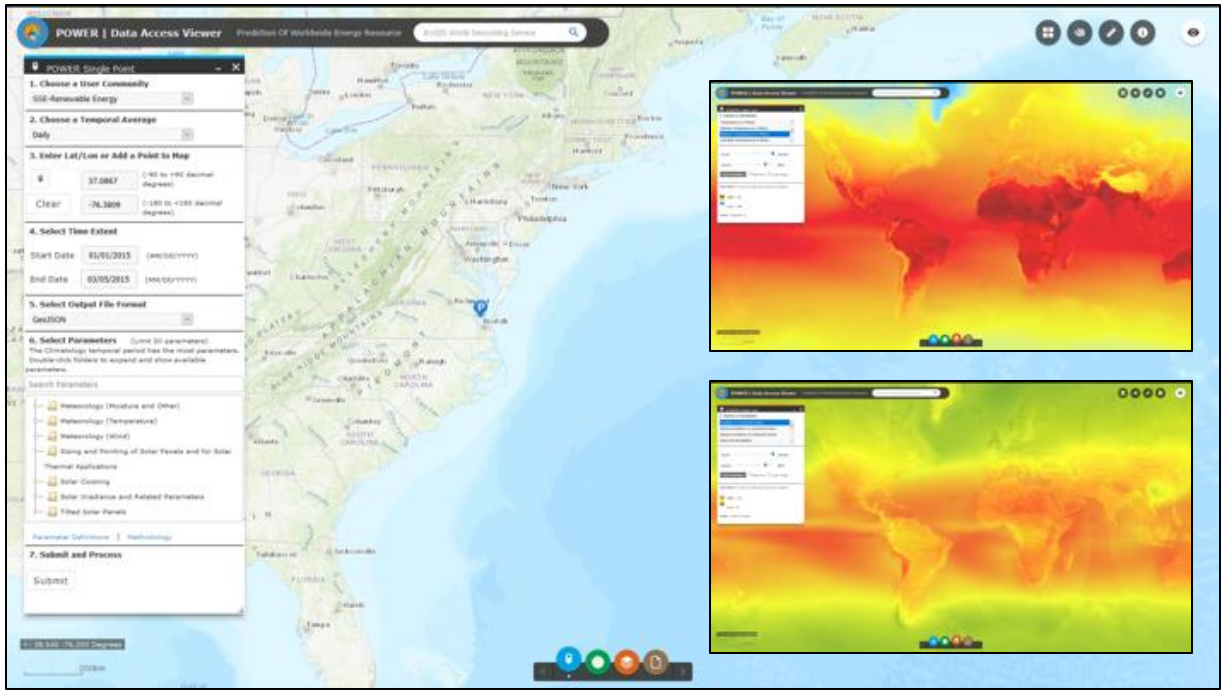


Prediction of Worldwide Energy Resources (POWER)

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 incudes 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).

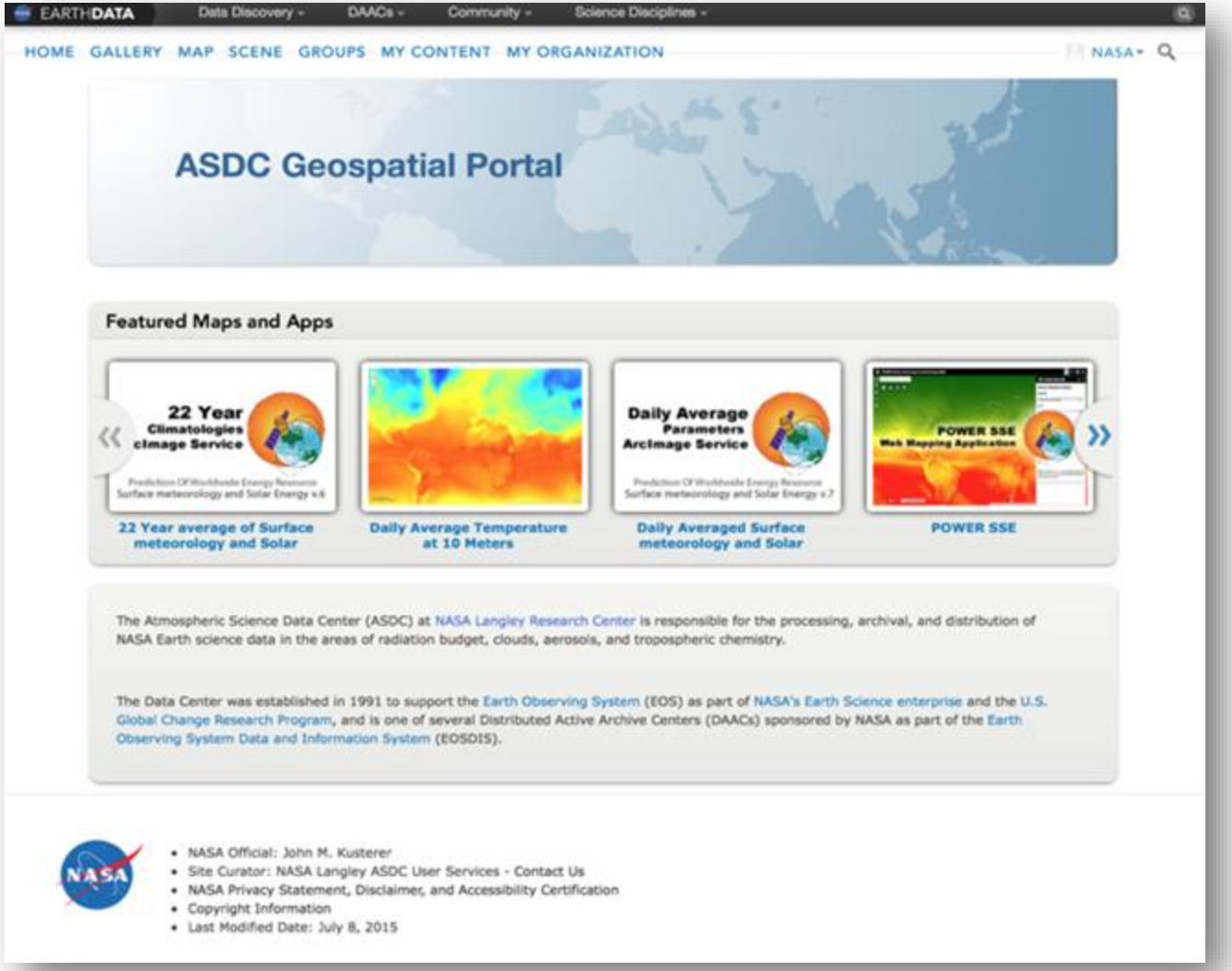
Meteorological parameters are derived from the NASA's GMAO MERRA-2 assimilation model (Jan. 1, 1981 to within a few months of real time) plus GEOS-5.12.4 FP-IT (End of MERRA-2 to within several days of real time).



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 Programing 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



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

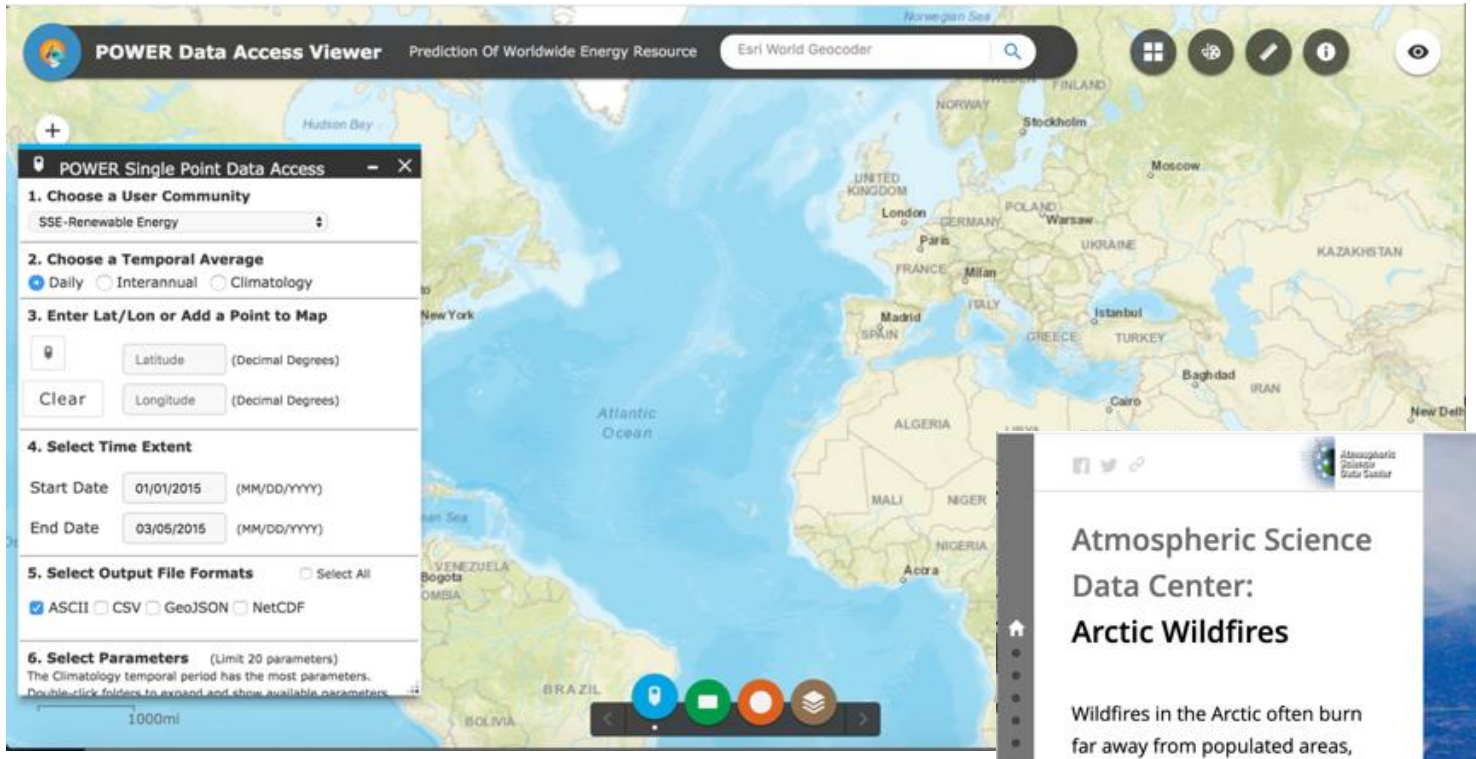
Examples of Variables Available for Initial Release (Daily and Long Term Averages over a 22 year Period):

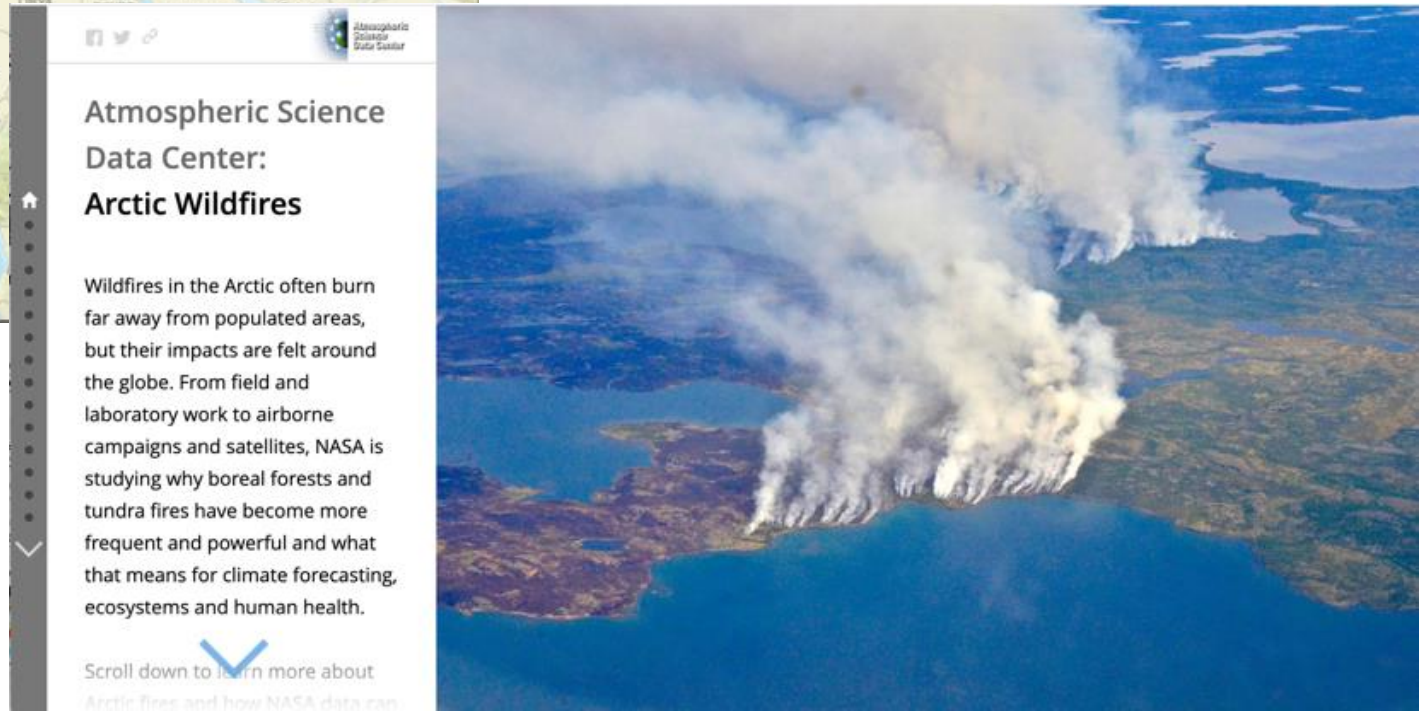
- Global Horizontal Radiation
- Diffuse Radiation
- Direct Normal Radiation
- Latitude Tilt Radiation
- Clear Sky Insolation
- Top-of-Atmosphere Insolation
- NO-SUN or BLACK Days
- Air Temperature
- Relative Humidity
- Atmospheric Pressure
- Earth Skin Temperature
- Heating Degree Days Below 18C
- Cooling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

GEOPLATFORM.gov ArcGIS Living Atlas

DATA.GOV

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.
1000mi
Atlantic Ocean
Stockholm
Moscow
London
Paris
Warsaw
Madrid
Istanbul
Baghdad
Cairo
Accra
Bogota
BRAZIL
BOLIVIA


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

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

Tonight

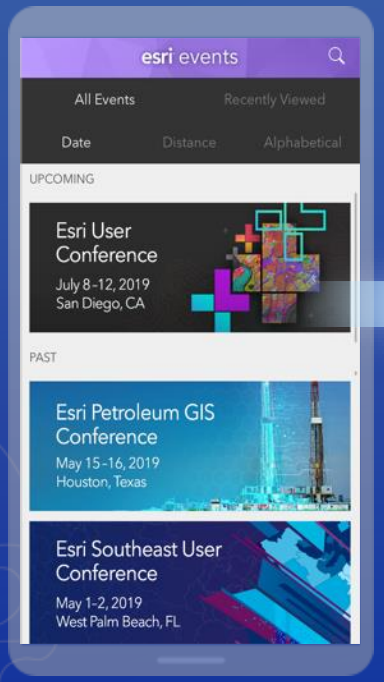
6:30 pm – 9:00 pm

Networking Reception

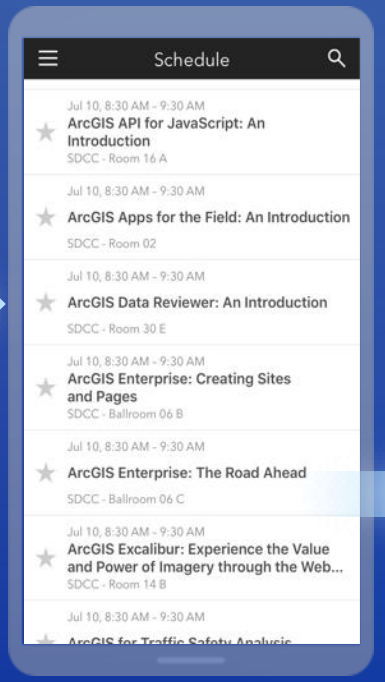
Smithsonian National Museum of Natural History

Please Share Your Feedback in the App

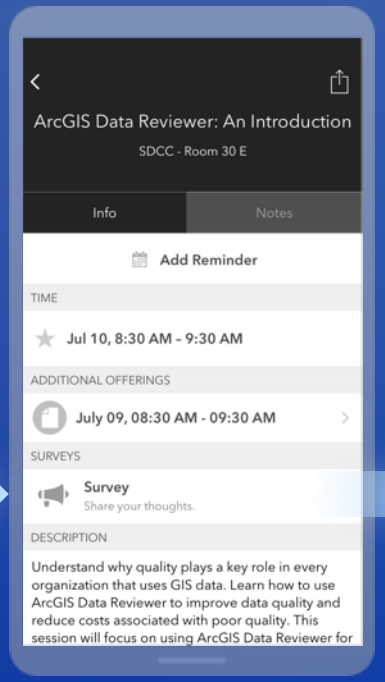
Download the Esri Events app and find your event



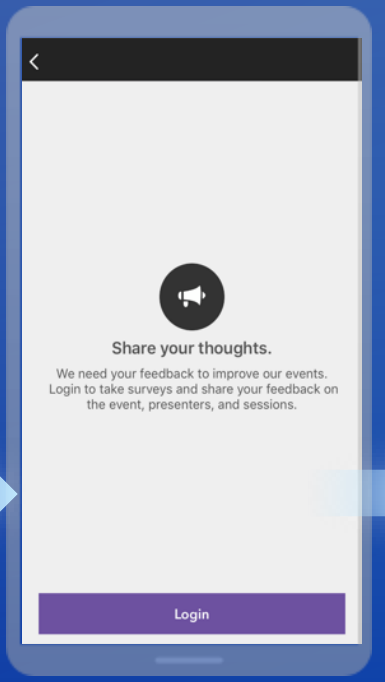
Select the session you attended



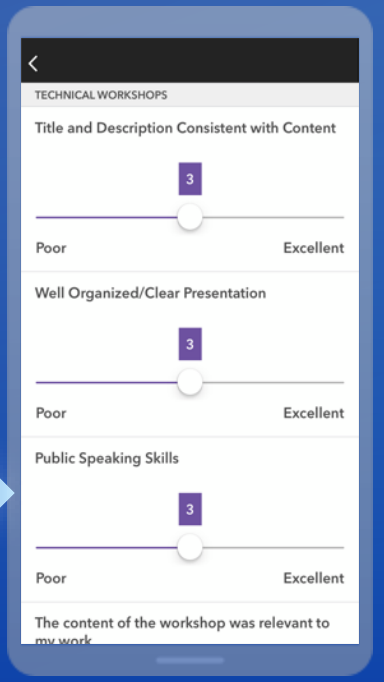
Scroll down to "Survey"



Log in to access the survey



Complete the survey and select "Submit"



Questions ?

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