Analyzing Multidimensional Scientific Data in ArcGIS

Sudhir Shrestha

Solution Engineer, Science Team

sshrestha@esri.com

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What we will cover today

- Scientific Multidimensional Data
- Ingesting and managing
- Visualizing and analyzing
- Disseminating and consuming
- Spatiotemporal Anomaly Detection

Scientific Data

Oceanographic

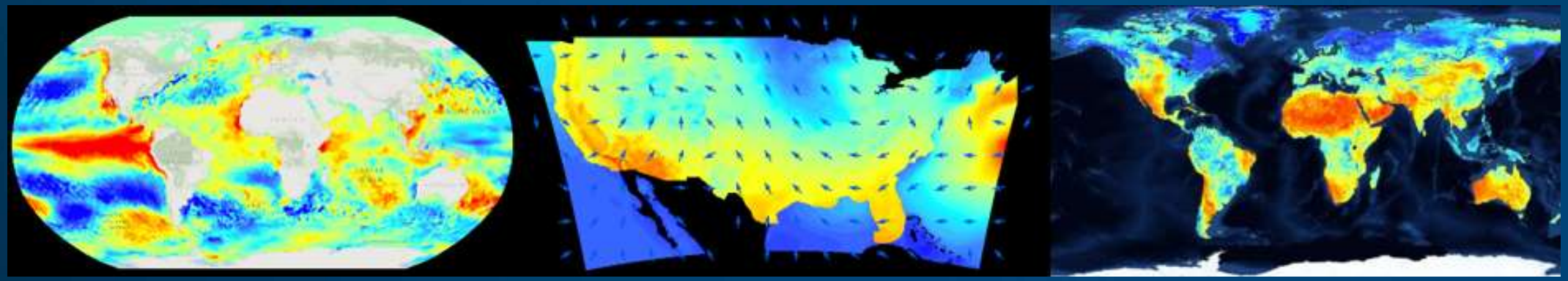
- Salinity
- Sea Temperature
- Ocean current

Meteorological

- Temperature
- Humidity
- Wind speed/direction

Terrestrial

- Soil moisture
- NDVI
- Land cover



Challenges

Manage

variety of formats

volume & velocity

redundancy

Analyze

portability

scalability

reproducibility

Share

integration

standards

accessibility

Multidimensional Rasters

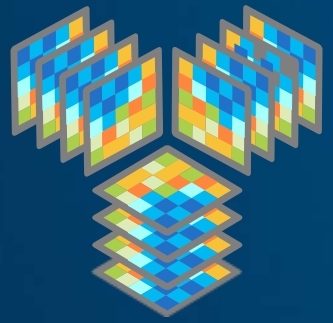
Gridded

Multidimensional

Multivariate

Ingesting and Managing Data

Multidimensional Mosaic Dataset



HDF

GRIB

netCDF

d-aware rasters

mosaic dataset

spatially-indexed catalog

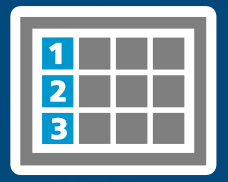
multi-resolution, multivariate, multidimensional

reduce storage redundancy & pixel resampling

defines information products

on-demand processing

mosaic

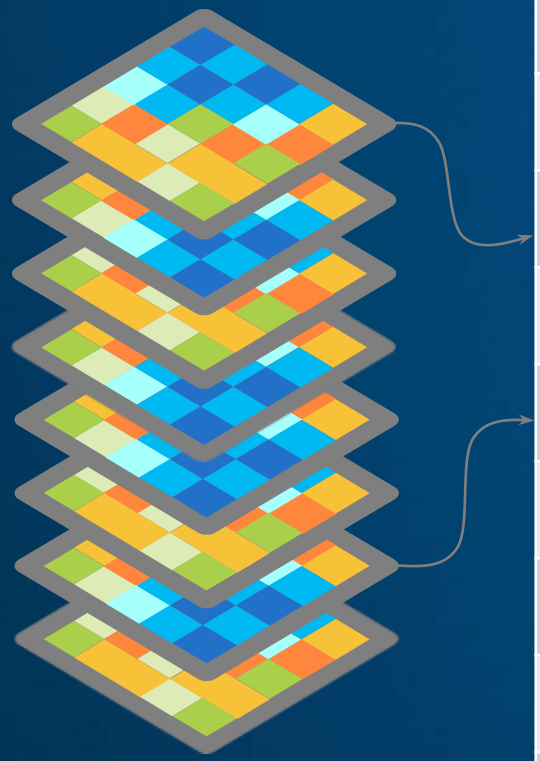


table

raster pixels

Representing multivariate collection of multidimensional rasters in ArcGIS

Tabular View

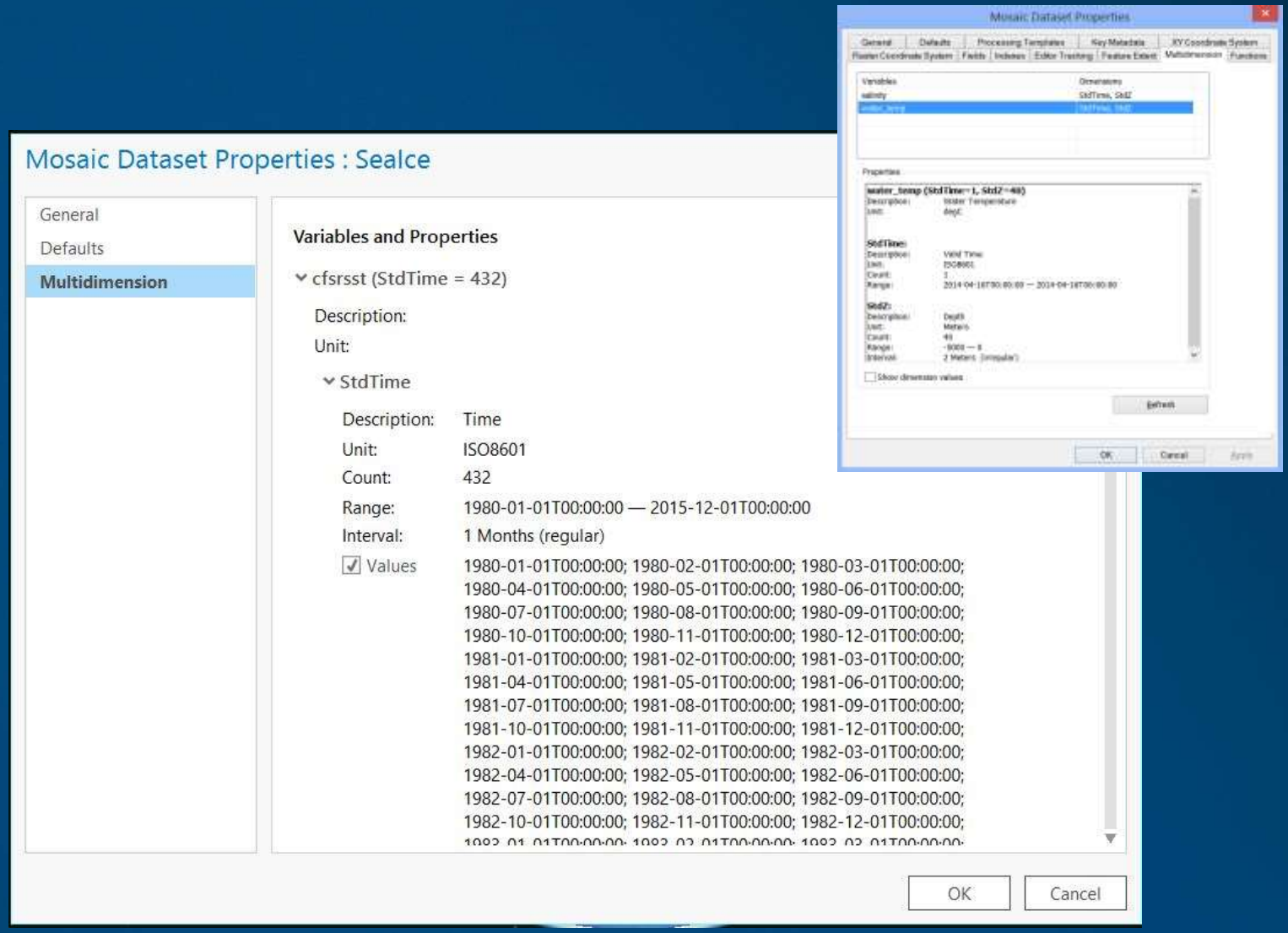


Raster	Shape	Variable	StdTime	StdZ
…	…	Temperature	3/22/2016	-10
…	…	Temperature	3/23/2016	-10
…	…	**Temperature**	**3/24/2016**	**-10**
…	…	Salinity	3/22/2016	-10
…	…	**Salinity**	**3/23/2016**	**-10**
…	…	Salinity	3/24/2016	-10
…	…	Temperature	3/22/2016	-20
…	…	Temperature	3/23/2016	-20
…	…	…	…	…

Tabular view of items in a multivariate multidimensional mosaic dataset

Metadata

- Variables
- Dimensions
- Values
- Statistics



Describing the structure of a multivariate multidimensional mosaic dataset

Raster Types

data on disk

netCDF

HDF

GRIB

d-aware rasters

raster type

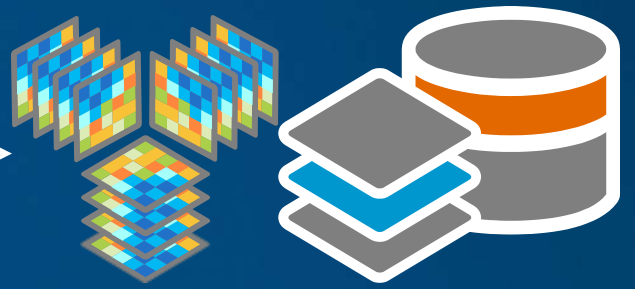
crawls disk

identifies rasters

extracts metadata

attaches processing

mosaic dataset



stores no pixels

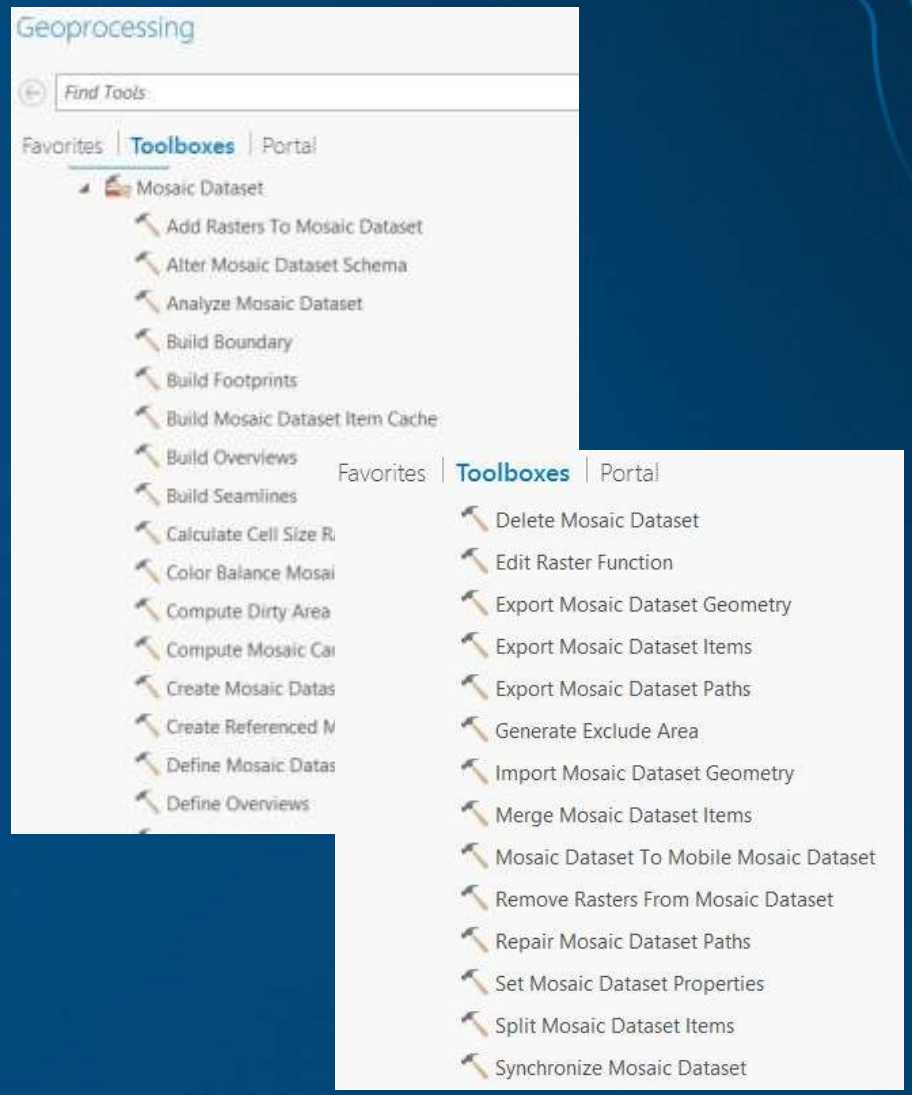
references rasters

stores processing & metadata

Format-agnostic direct ingestion of rasters into a mosaic dataset

Geoprocessing

- Tools—building blocks for managing data
- Data Management ≻ Raster ≻ Mosaic Dataset
- Intuitive UI for interactive workflows
- ModelBuilder: composite operations
- Python: automate or extend



Managing a mosaic dataset

Demo

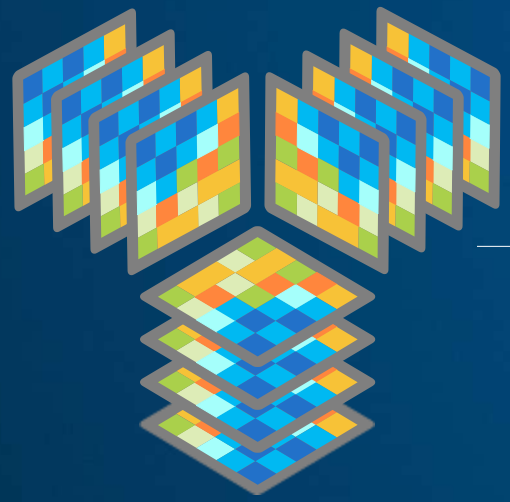
Make a netCDF raster layer

Populate a mosaic dataset using a raster type

Properties of a multidimensional mosaic dataset

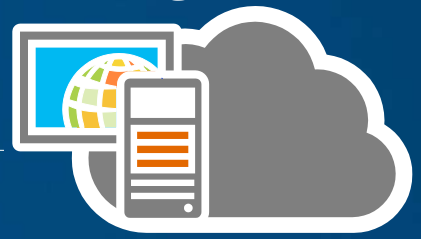
Attribute table of a mosaic layer

ArcGIS for Server



mosaic dataset

image service



dynamic, on-demand

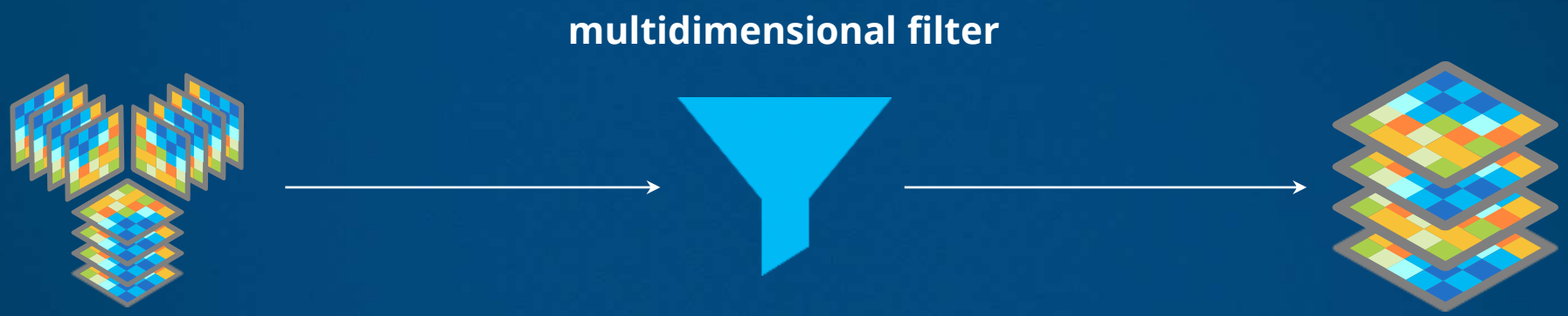
web-based access to data

rich information model

Make your mosaic dataset accessible to other users as a web-enabled dynamic image service

Visualizing and Analyzing

Filtering



variables

value range(s) per dimension

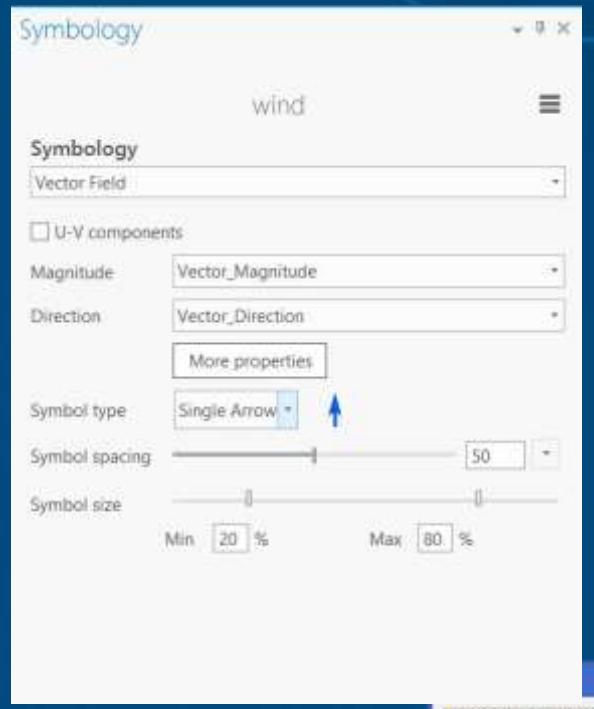
SQL WHERE clause

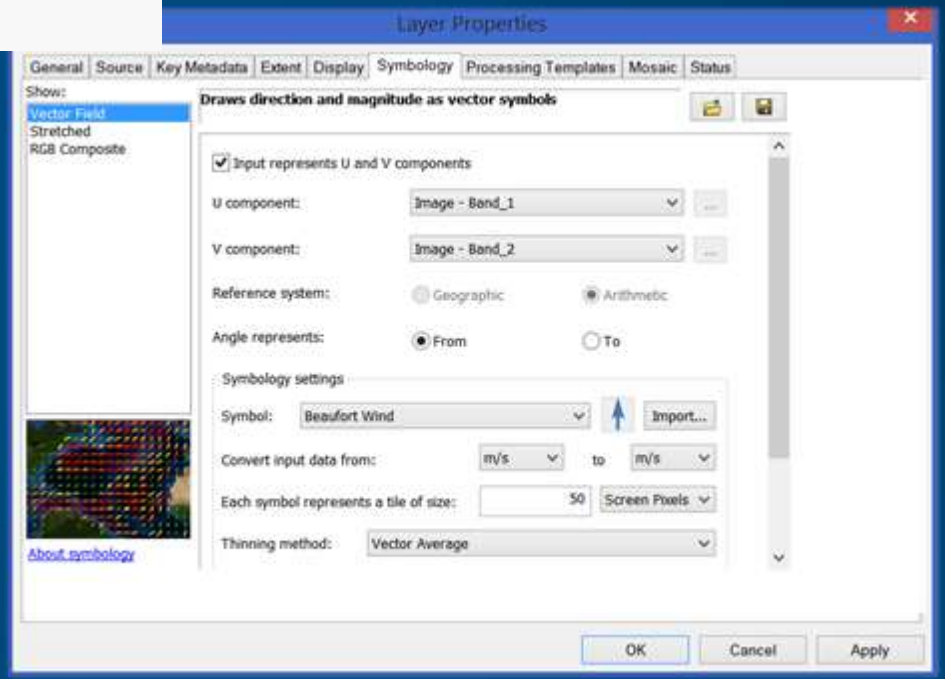
dimension-orthogonal cutting & chopping

slicing & dicing a multivariate multidimensional mosaic dataset

Rendering

- Choose and customize
- Scalar or vector field
- Export and reuse





Control how original or transformed data is presented on a map

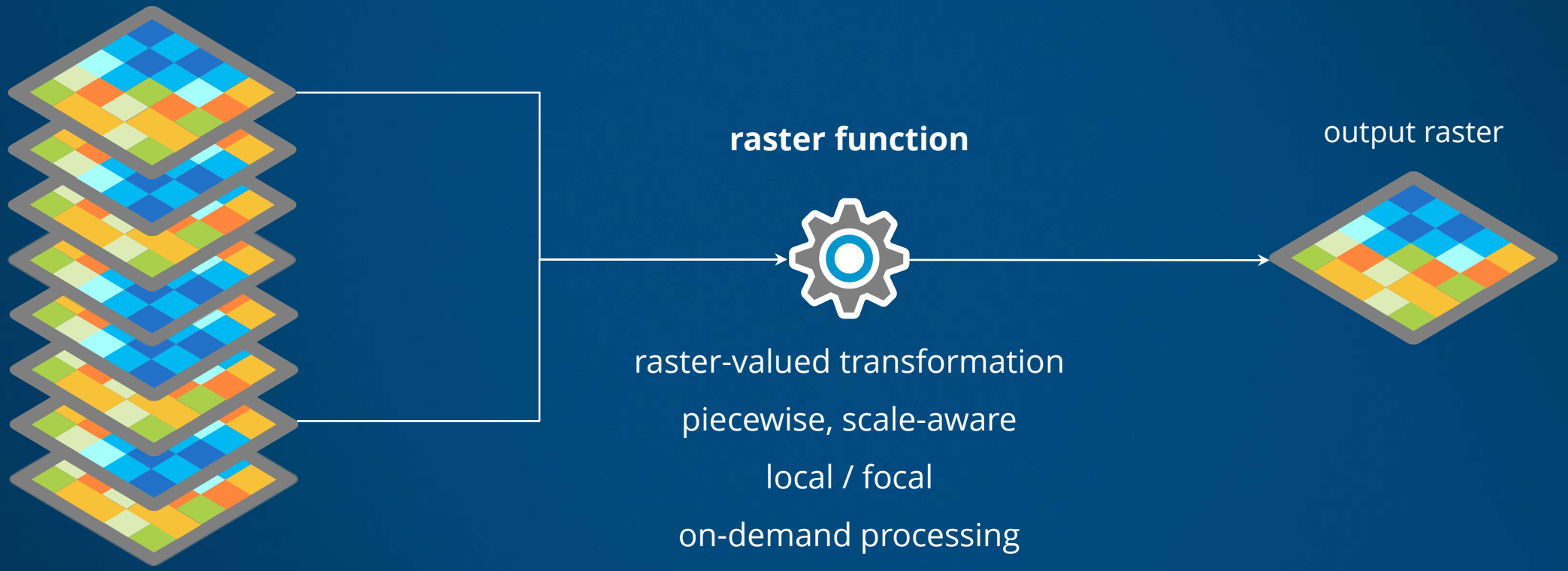
Demo

Vector-field mosaic dataset

Multidimensional mosaic layer on map

Dimensional slicing & animation

Raster Function: Transforming Raster Data



raster-valued transformation

piecewise, scale-aware

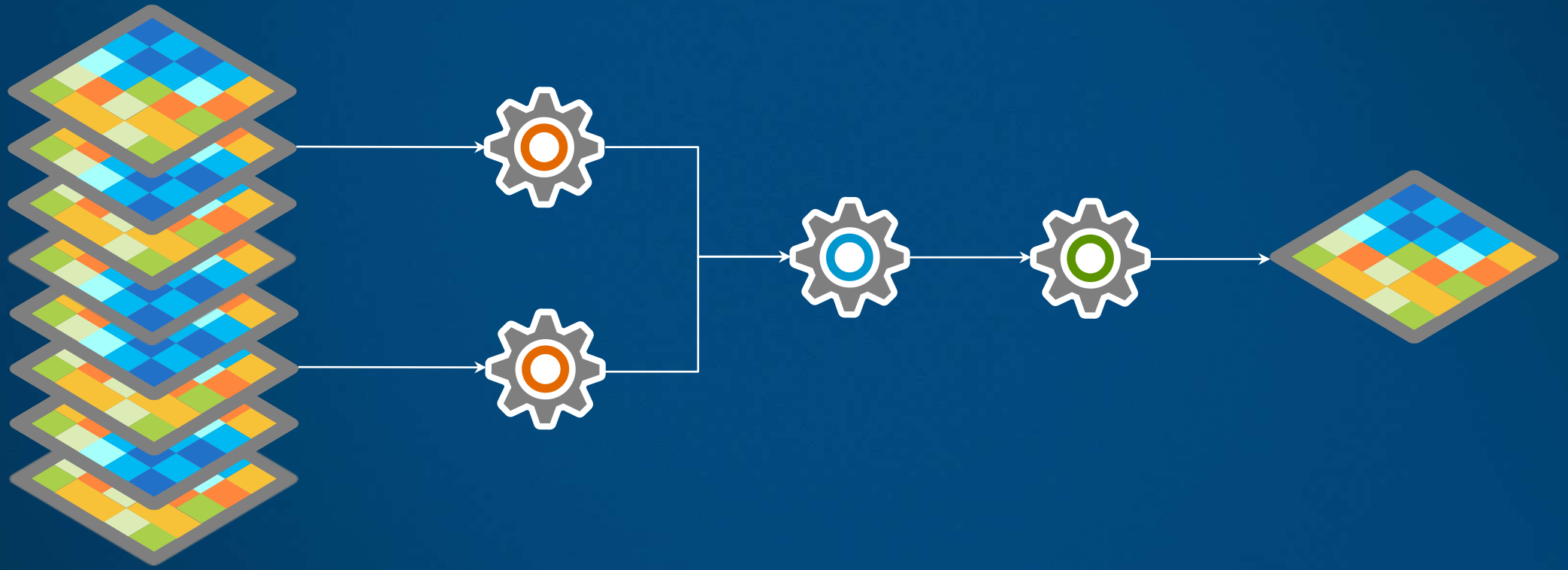
local / focal

on-demand processing

arity: unary, binary, ..., *n*-ary, polyadic

... using raster functions for on-the-fly processing

Chaining Raster Functions

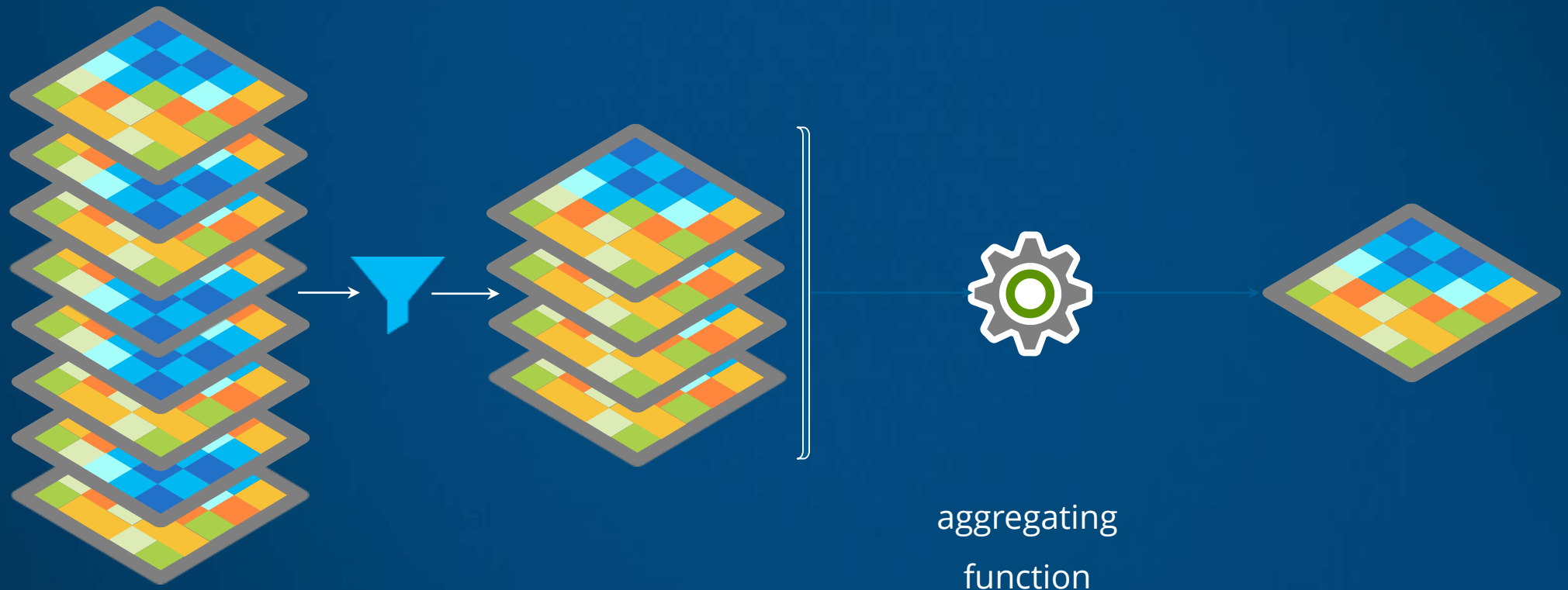


… to compose a complex analytic model

Demo

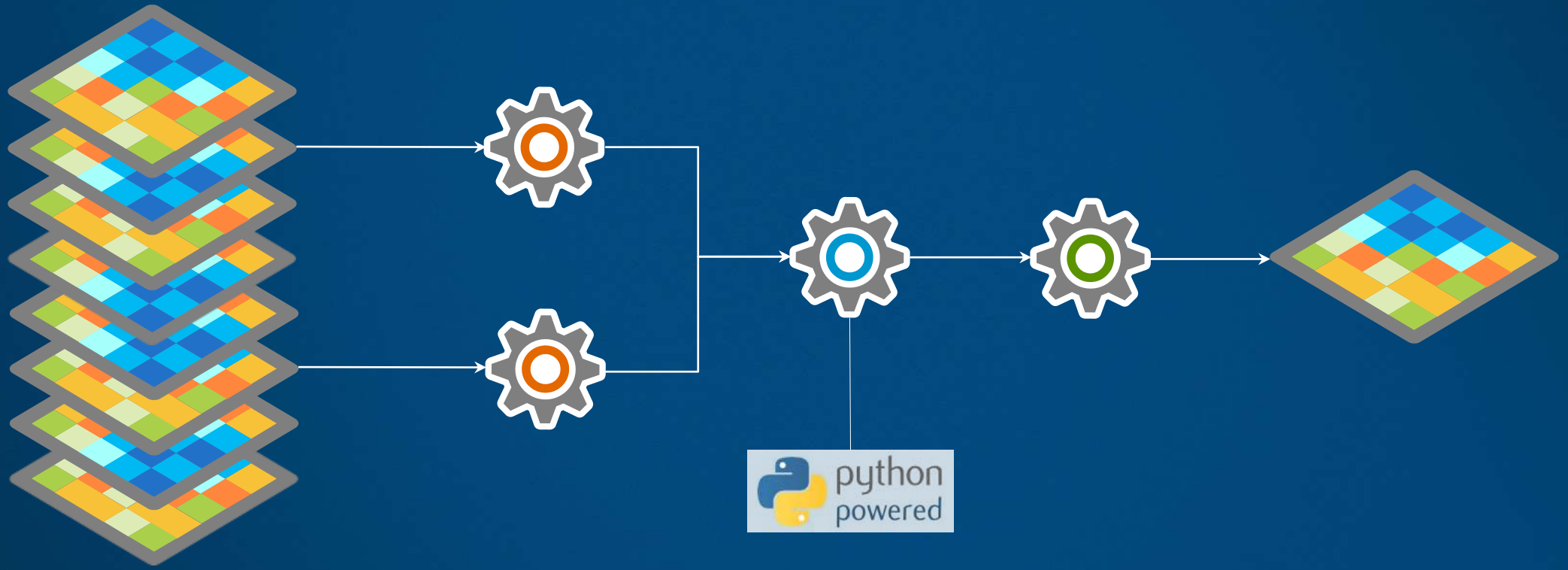
Applying a simple transformation

Dimensional Aggregation



Multidimensional filtering followed by aggregation using a raster function

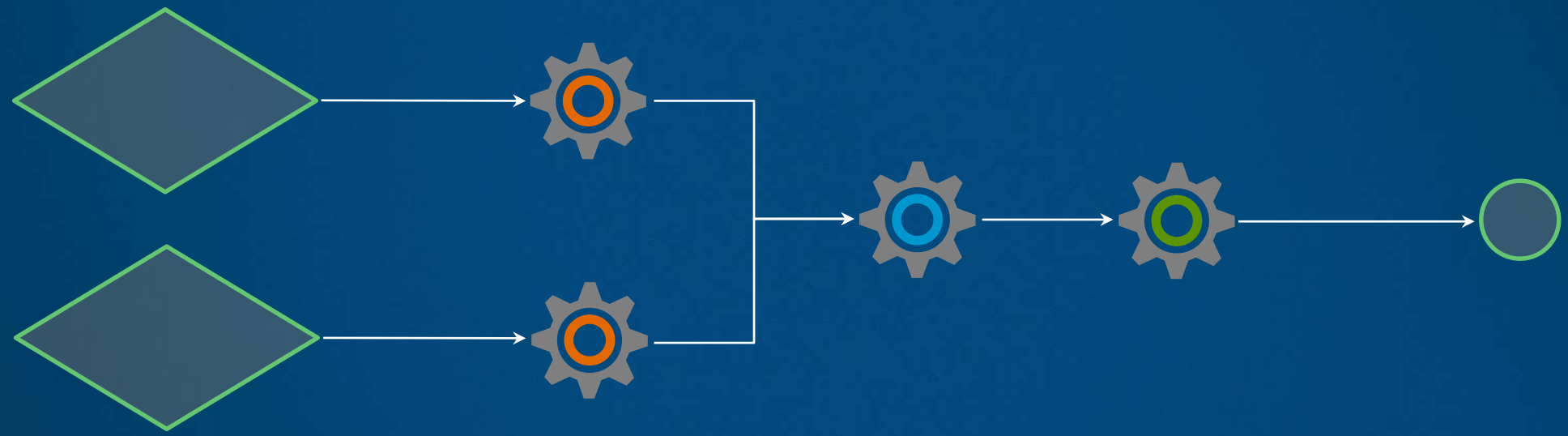
Python Raster Functions: Extending Analytic Capabilities



Learn more at: github.com/Esri/**raster-functions**

Choose from dozens of built-in functions or implement your own algorithm using Python

Raster Models: Raster Function Templates



raster ***variables***

A portable & reusable chain of raster functions

Demo

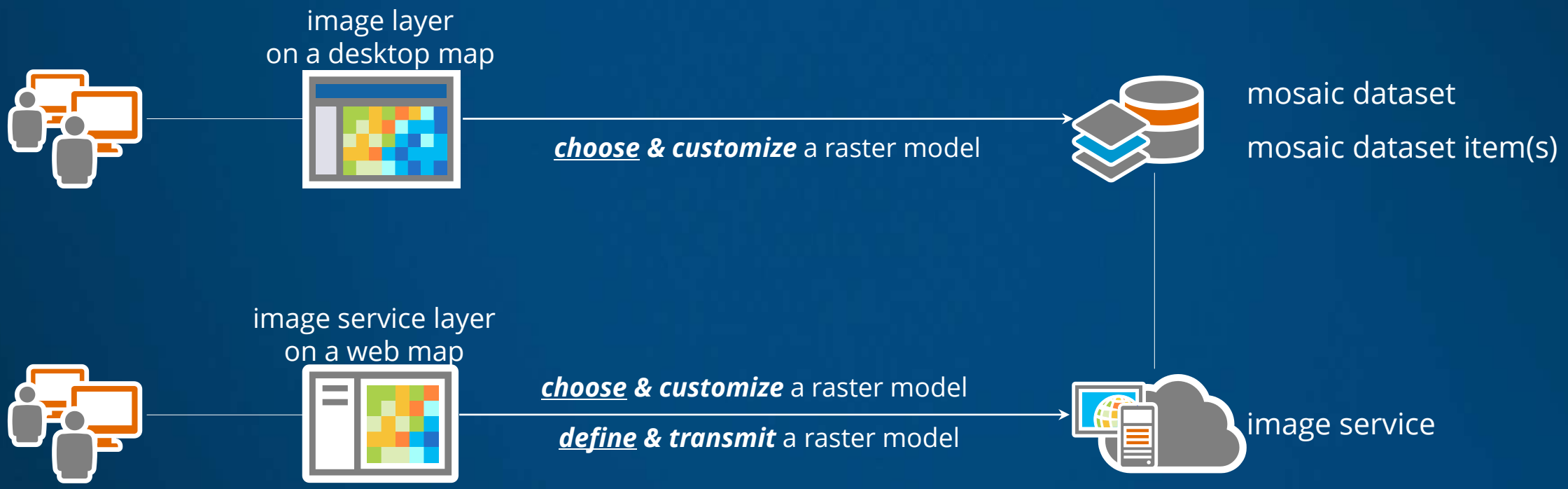
Combining variables using a raster model

Raster models on a mosaic dataset

Aggregating temporal slices

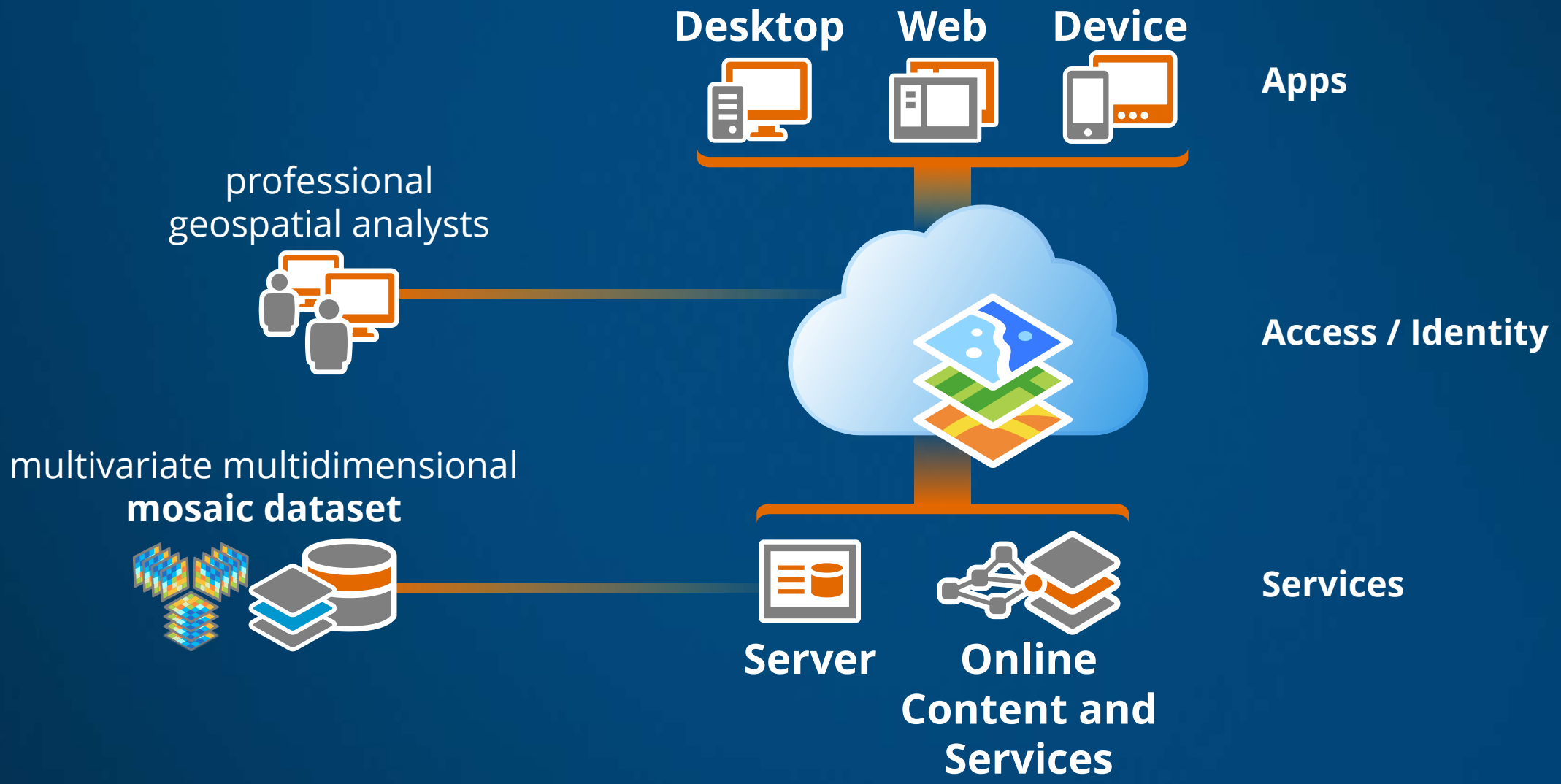
Difference of means

Applying a Raster Model



Disseminating and Consuming

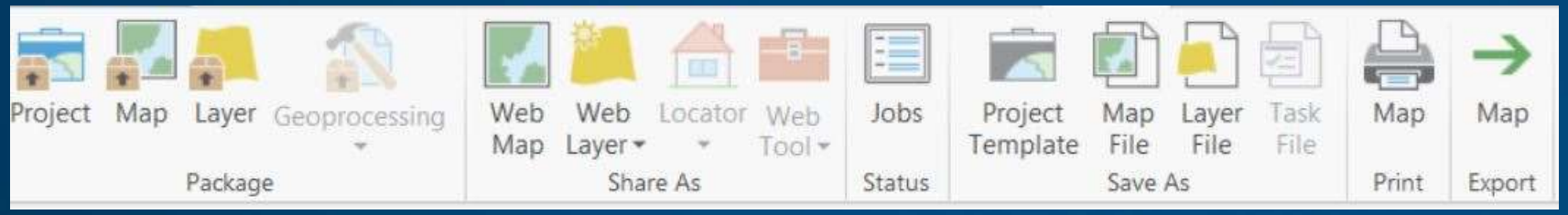
Disseminating



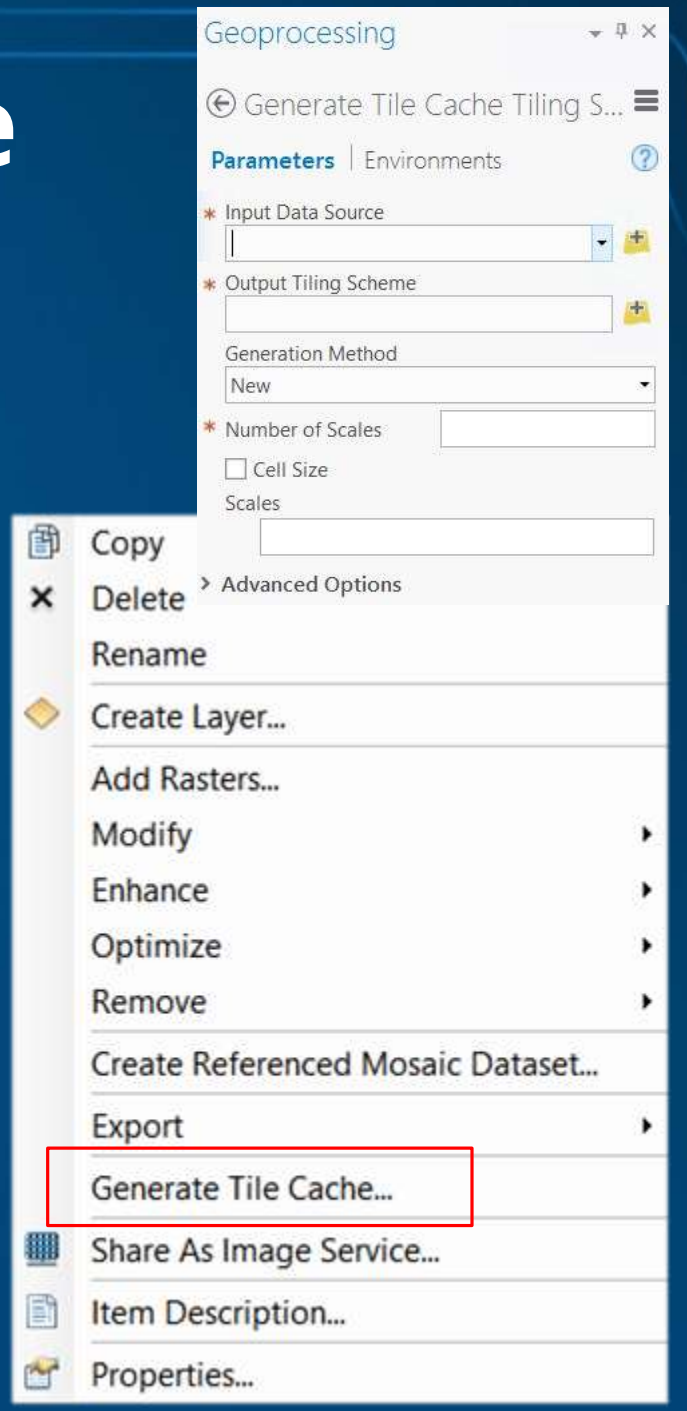
Dissemination Strategies

- Tiled map service
- Dynamic map service
- Dynamic image service

Sharing your data as an image



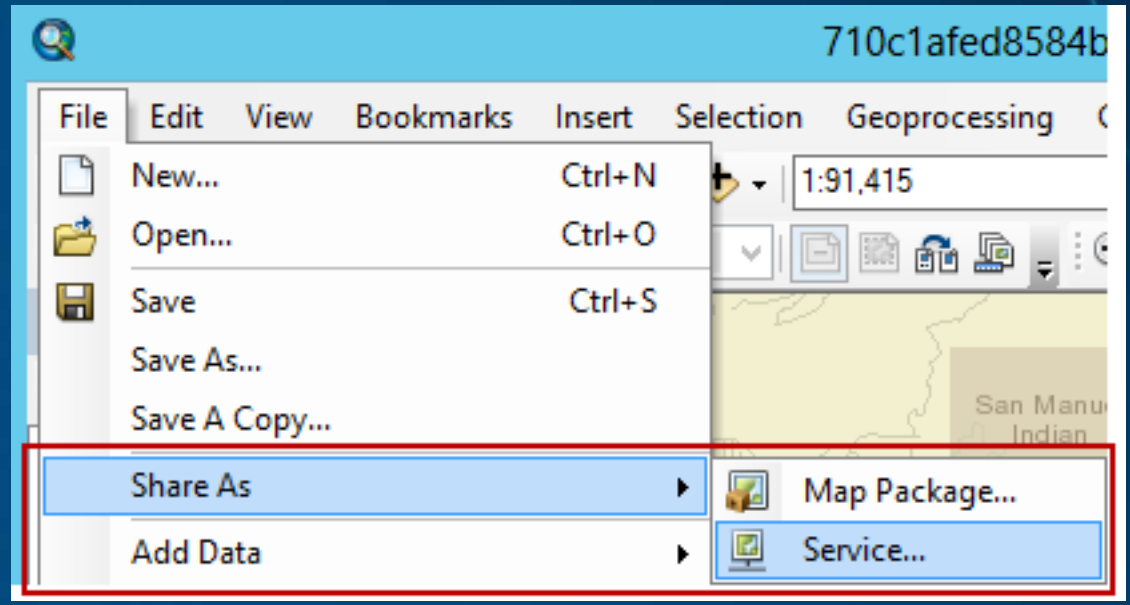
- Mosaic Dataset ≻ Generate Tile Cache
- Avoid copying source image to ArcGIS Online
- Cache tiles generated using ArcGIS for Desktop
- Accessed via **tiled map service**

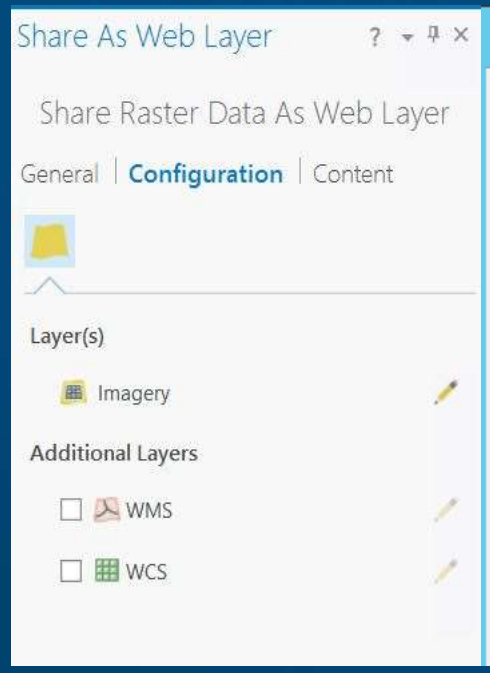


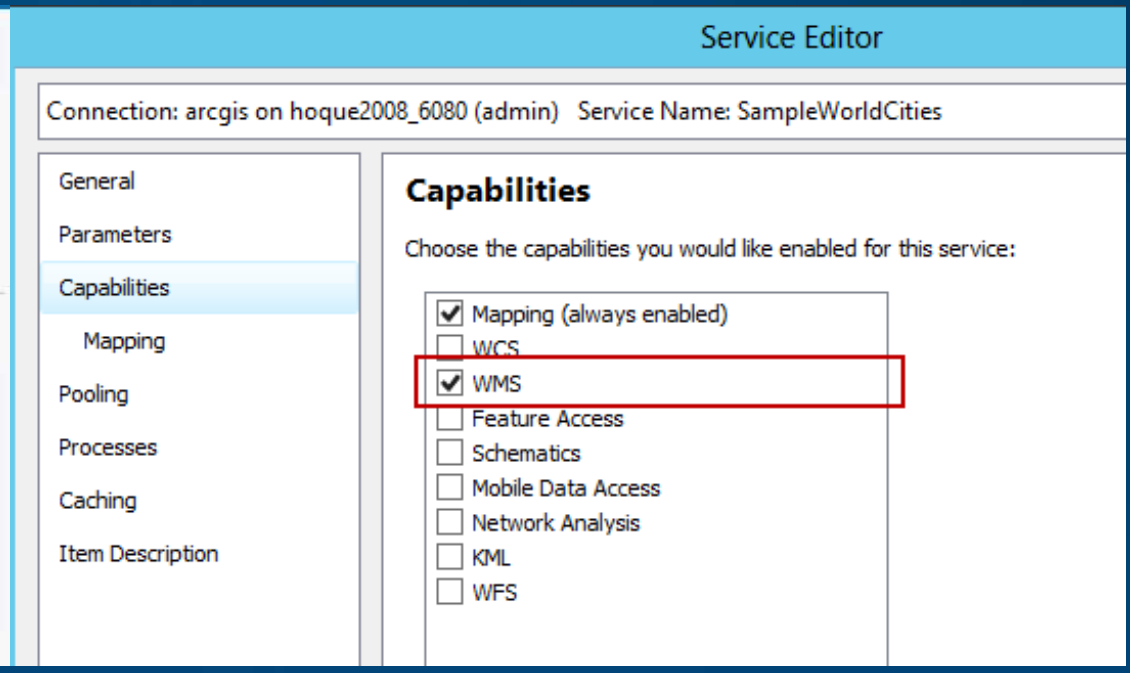
Enable access to a static representation of your data as a map service

Sharing your map

- File ≻ Share As ≻ Service
- Features overlaid on rasters
- Static vs Dynamic map service
- Multidimensional WMS

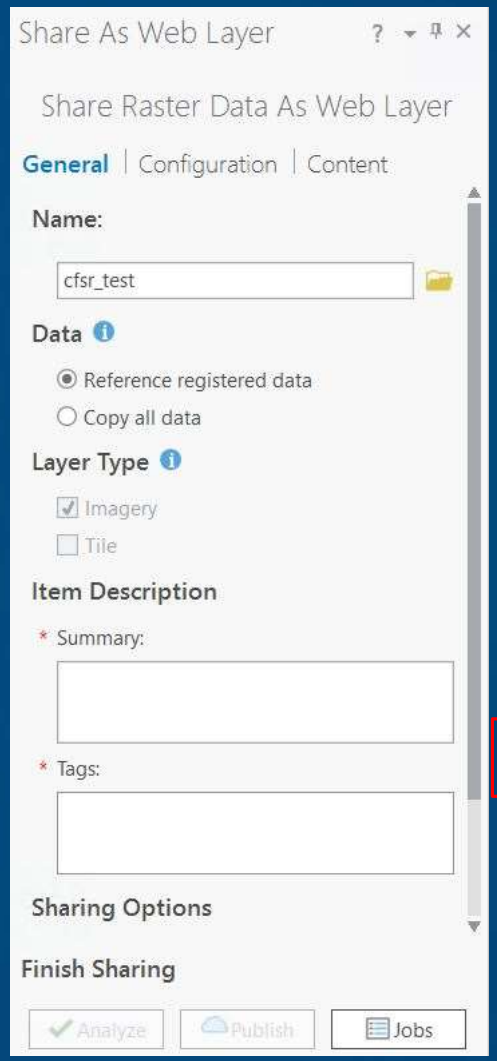


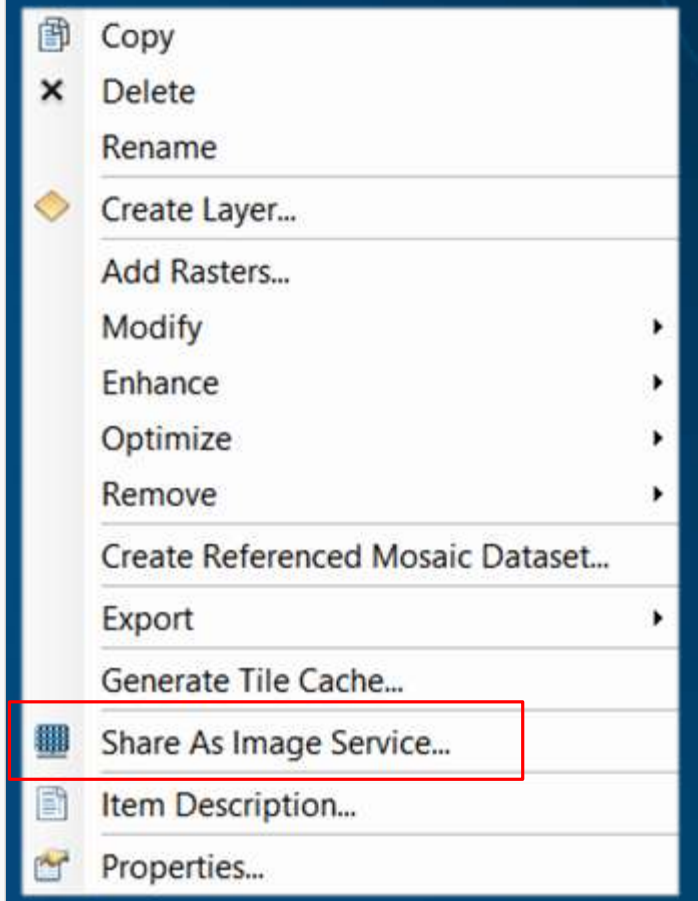




Sharing data & information products

- Mosaic Dataset ≻ **Share As Image Service**
- Pixels & item metadata
- On-demand server-side processing
- Raster models: predefined or client-specified
- multidimensional info, filtering, vector fields





Enable access to a dynamic representation of your information product as an image service

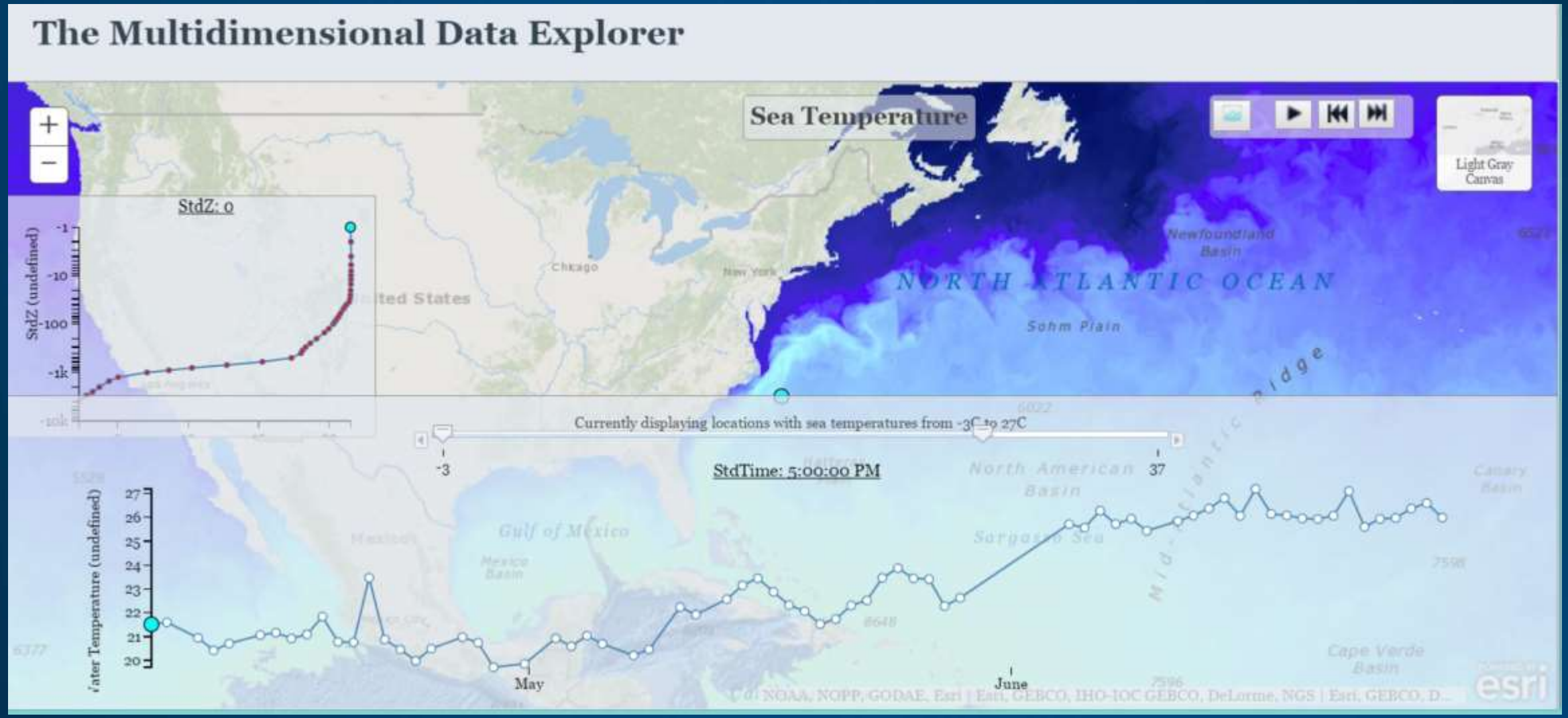
Demo

Publishing a multidimensional mosaic dataset

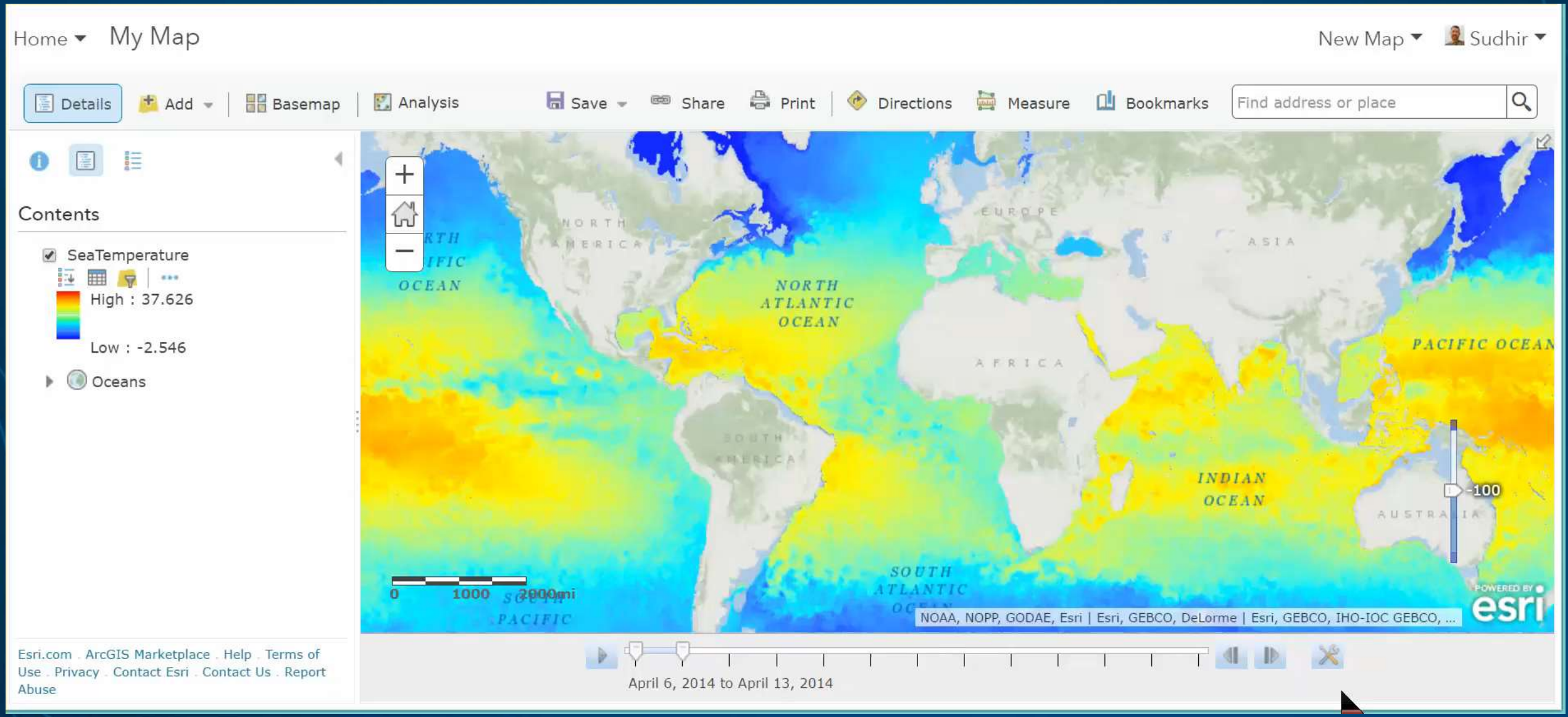
Consuming your services

- In any ArcGIS application or any WMS client
- In a web map 
  - Identify web services driven by maps or datasets
  - Bring service layers into a web map
- In a map-based application 
  - Configurable apps
  - Story Maps
  - Web AppBuilder
  - Custom web apps using ArcGIS API for JavaScript

Maps & Apps


The Multidimensional Data Explorer
Sea Temperature
Light Gray Canvas
StdZ: 0
StdZ (undefined)
-1
-10
-100
-1k
-10k
Chicago
New York
NORTH ATLANTIC OCEAN
Newfoundland Basin
Sohm Plain
Currently displaying locations with sea temperatures from -3C to 27C
-3
37
StdTime: 5:00:00 PM
Gulf of Mexico
North American Basin
Sargasso Sea
Canary Basin
Cape Verde Basin
Water Temperature (undefined)
27
26
25
24
23
22
21
20
May
June
esri

Maps & Apps


Home
My Map
New Map
Sudhir
Details
Add
Basemap
Analysis
Save
Share
Print
Directions
Measure
Bookmarks
Find address or place
Contents
SeaTemperature
High : 37.626
Low : -2.546
Oceans
NORTH ATLANTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
SOUTH ATLANTIC OCEAN
EUROPE
ASIA
AFRICA
NORTH AMERICA
SOUTH AMERICA
AUSTRALIA
-100
0 1000 2000mi
NOAA, NOPP, GODAE, Esri | Esri, GEBCO, DeLorme | Esri, GEBCO, IHO-IOC GEBCO, ...
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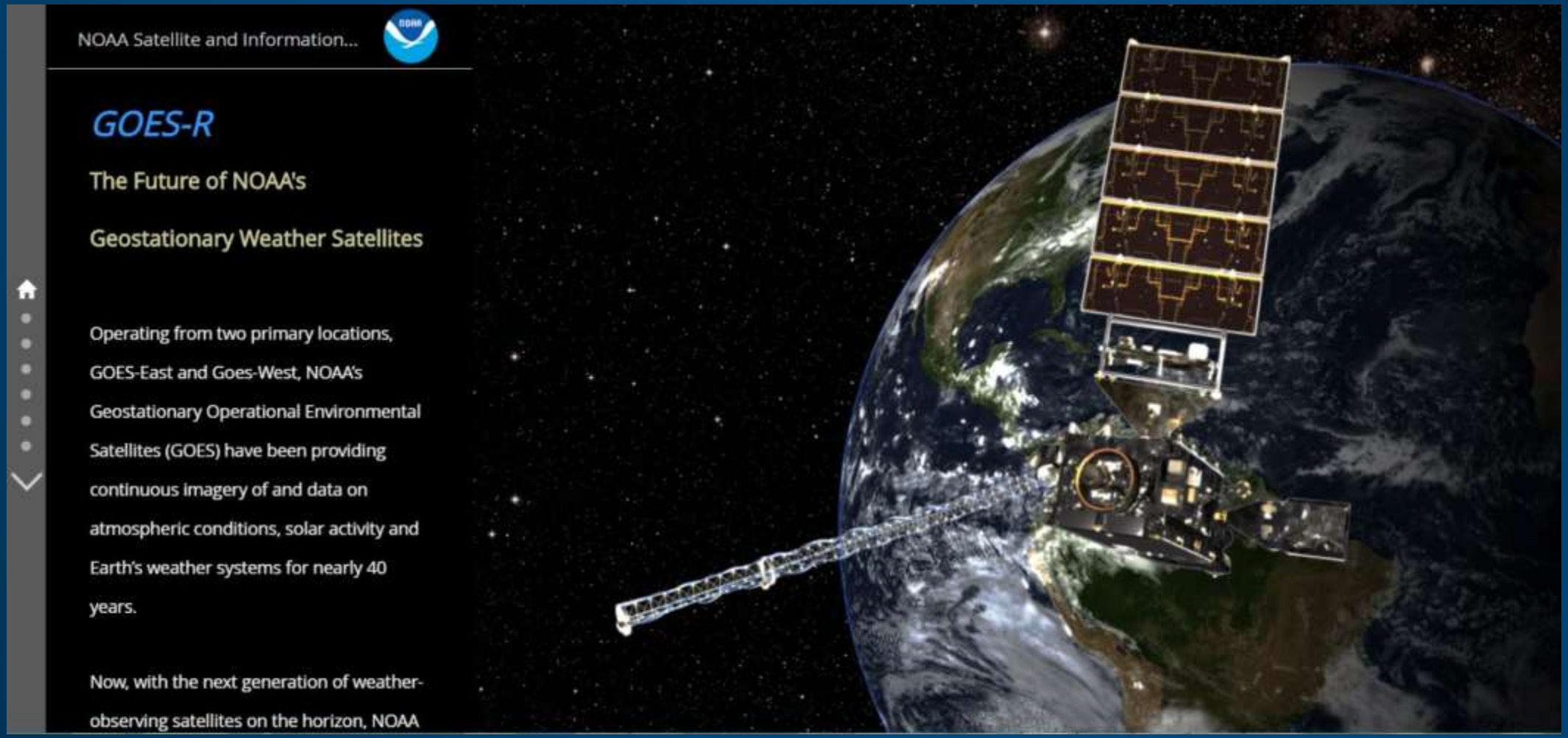
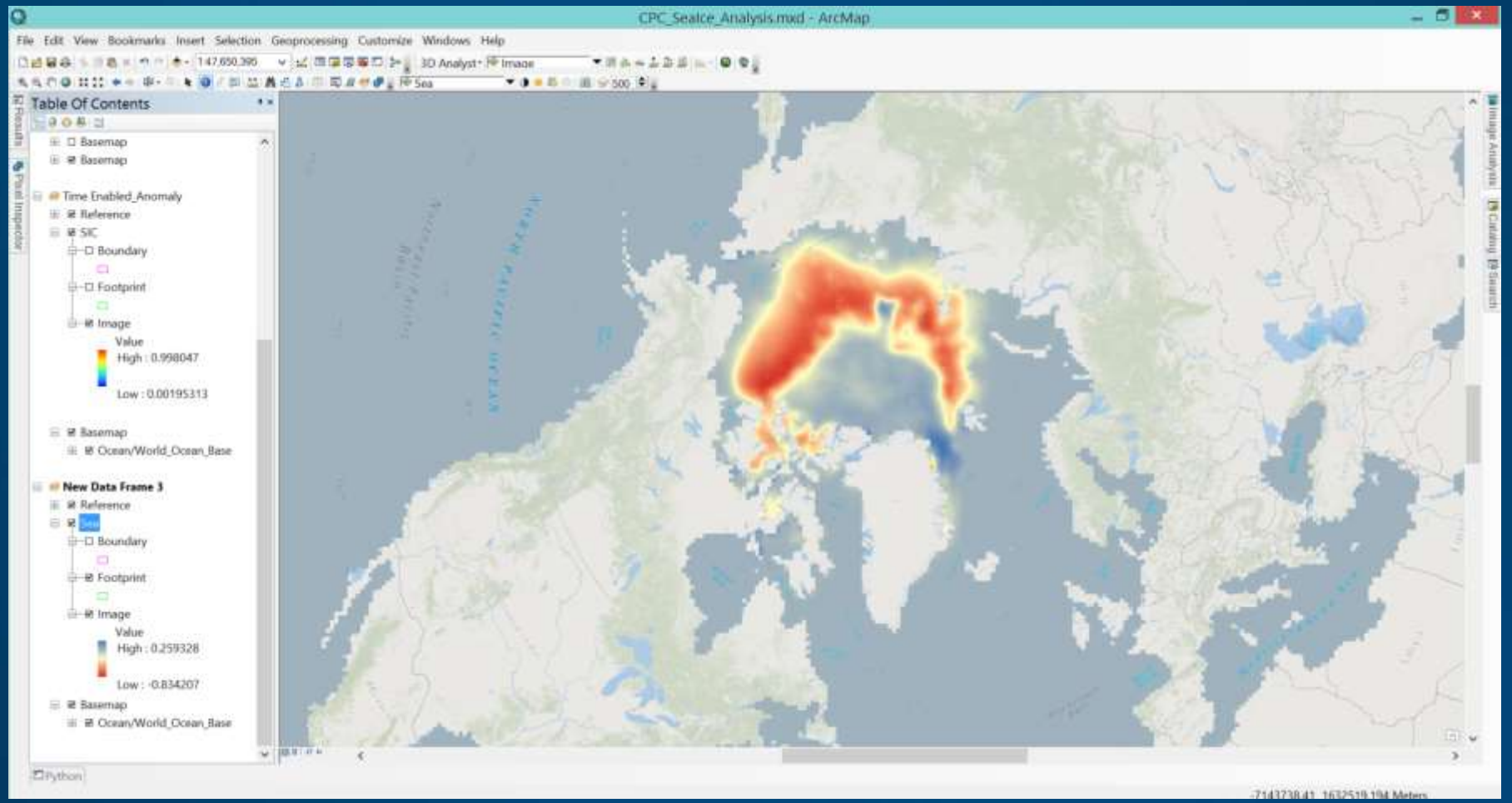
Maps & Apps


NOAA Satellite and Information...
GOES-R
The Future of NOAA's
Geostationary Weather Satellites
Operating from two primary locations, GOES-East and Goes-West, NOAA's Geostationary Operational Environmental Satellites (GOES) have been providing continuous imagery of and data on atmospheric conditions, solar activity and Earth's weather systems for nearly 40 years.
Now, with the next generation of weather-observing satellites on the horizon, NOAA

Demo

Looking at Scientific Data- CFSR Sea Ice and Sea Surface Temperature
Anomaly Detection and how to slice through the multidimensional data to understand this change

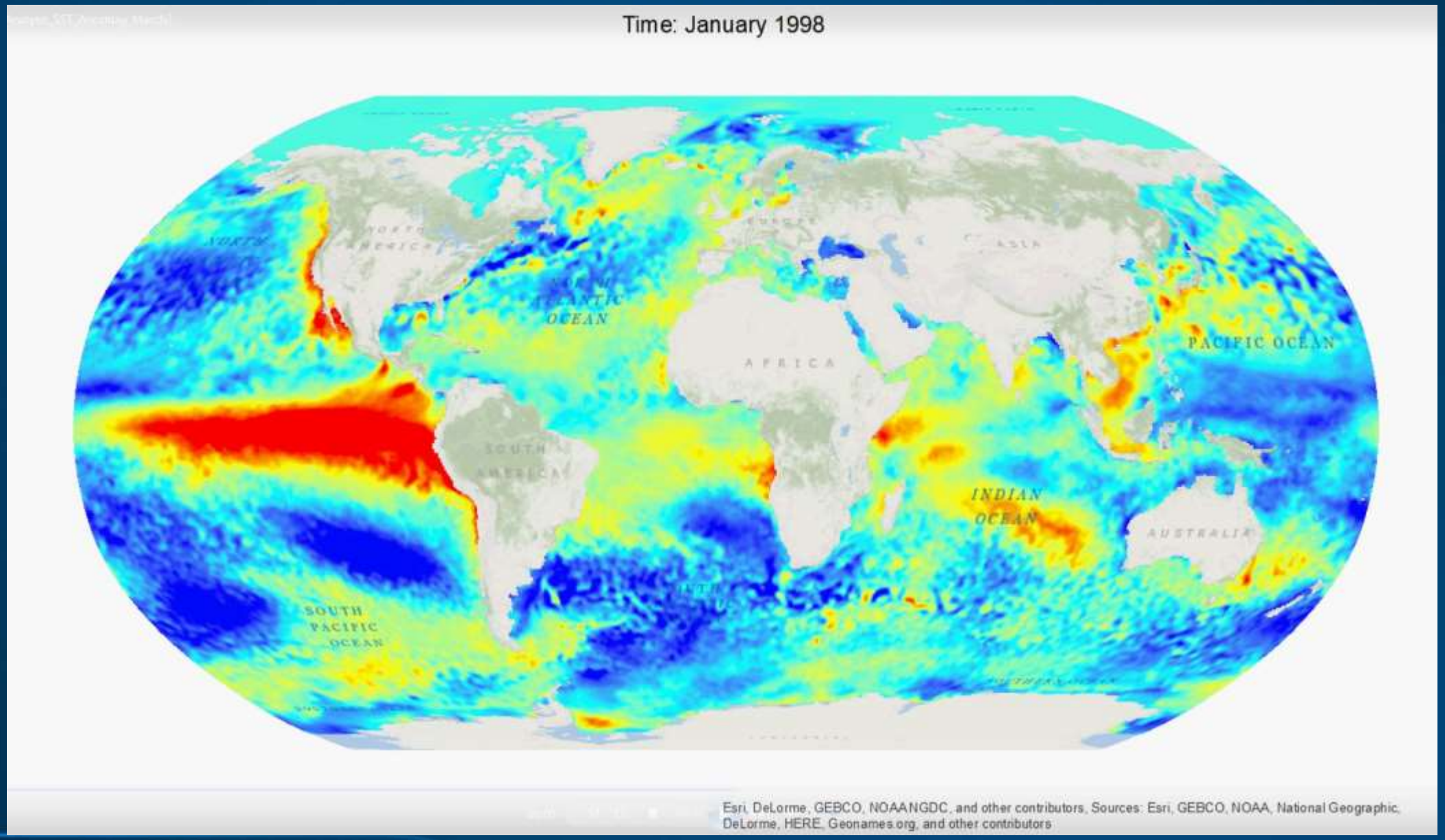
On the fly analysis using Raster Functions



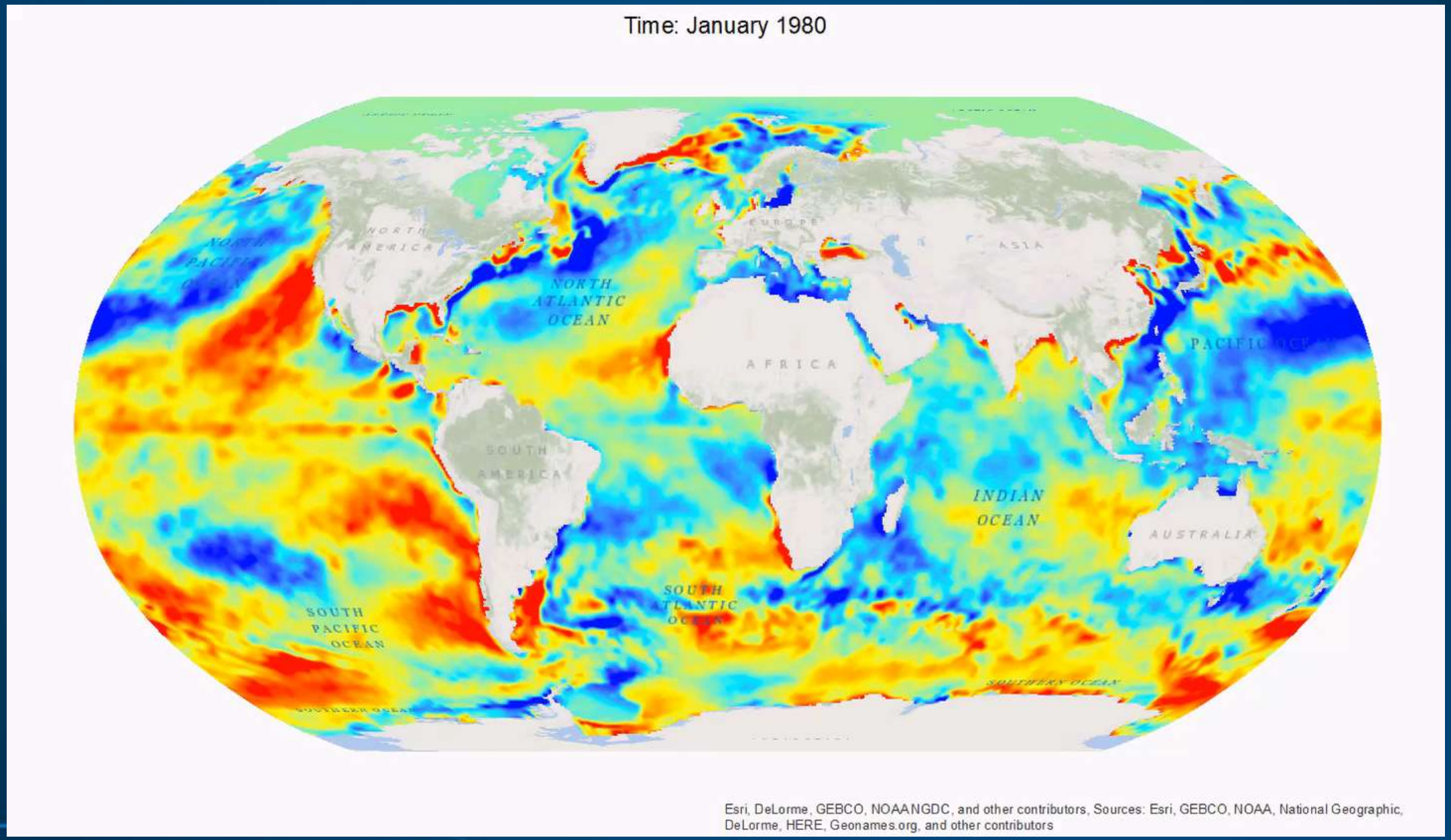
Sea ice concentration anomaly using NOAA CFSR data:
September 2012 anomaly with respect to 1980-2014 mean

Choose from dozens of built-in functions or implement your own algorithm using Python

Pronounced El Nino event: January 1998 sea surface temperature



On the fly processing: SST change over time using NOAA CFSR data



GIS workflows that scale

- mosaic dataset
- raster types
- geoprocessing tools

- multidimensional filter
- animation & rendering
- raster functions

- dynamic web services
- web maps & apps
- raster analytics

… built for the characteristics of multidimensional scientific data

Announcements and Follow up

Please join me for my another workshop tomorrow:

2:45 PM (Room #144C): Scientific Data Management and Dissemination
4 PM (Room # 144C): Analyzing Multidimensional Scientific Data in ArcGIS

Connect with us:

Twitter: @Sud_Shrestha @EsriScience

GeoNet: https://geonet.esri.com/groups/sciences/

Facebook: https://www.facebook.com/esrigis/
Email: sshrestha@esri.com

Announcements (Cont)

Join us and continue the conversation in the FedGIS 2017 group on GeoNet:

https://geonet.esri.com/community/events/fedgis

Print Your Certificate of Attendance

Print stations located in the 140 Concourse

Monday

12:30 PM – 6:30 PM

GIS Solutions Expo,
Hall B

5:15 PM – 6:30 PM

Expo Social,
Hall B

Tuesday

10:45 AM – 5:15 PM

GIS Solutions Expo,
Hall B

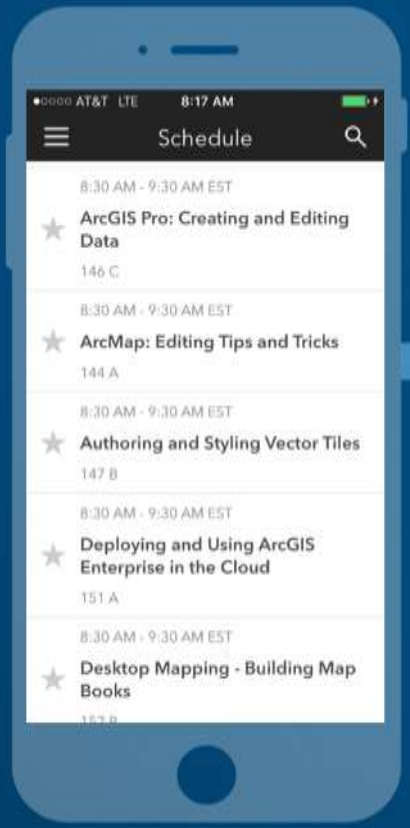
6:30 PM – 9:30 PM

Networking Reception,
Smithsonian National Air and Space Museum

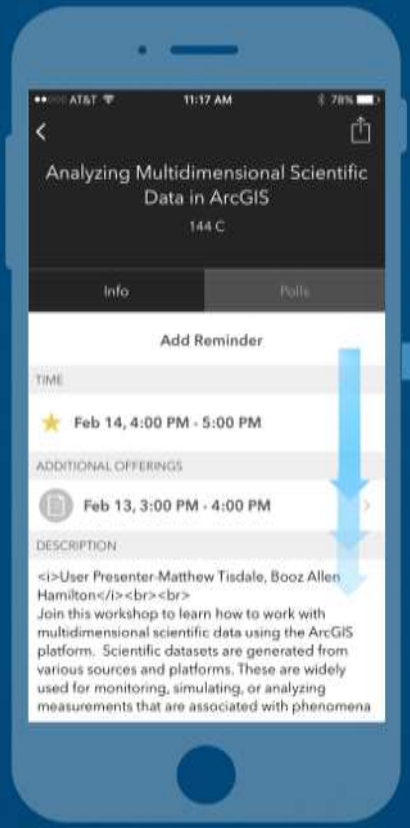
Please Take Our Survey on the **Esri Events App!**

Download the Esri Events app and find your event

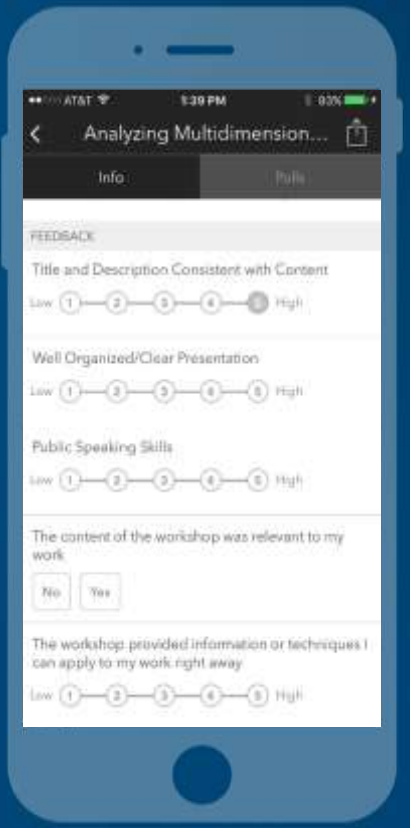
Select the session you attended



Scroll down to find the survey



Complete Answers and Select "Submit"




esri
THE SCIENCE OF WHERE

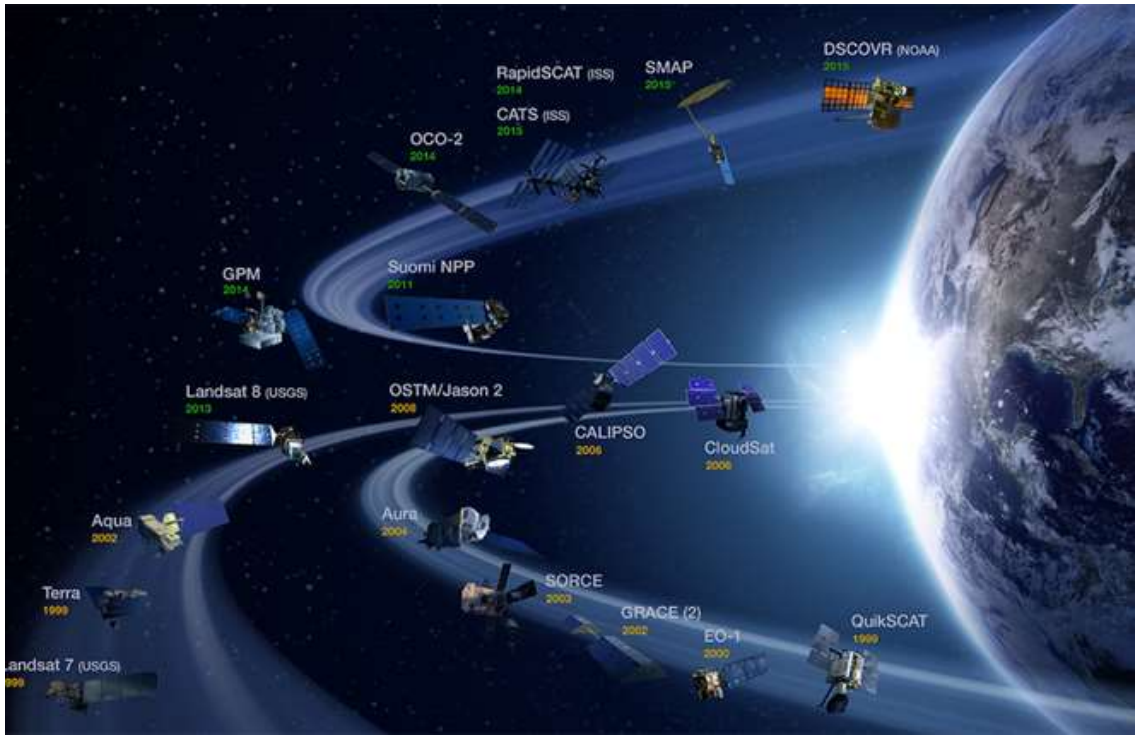
Increasing Accessibility and Use of NASA Earth Science Data in Geospatial Applications

NASA Atmospheric Science Data Center (ASDC)

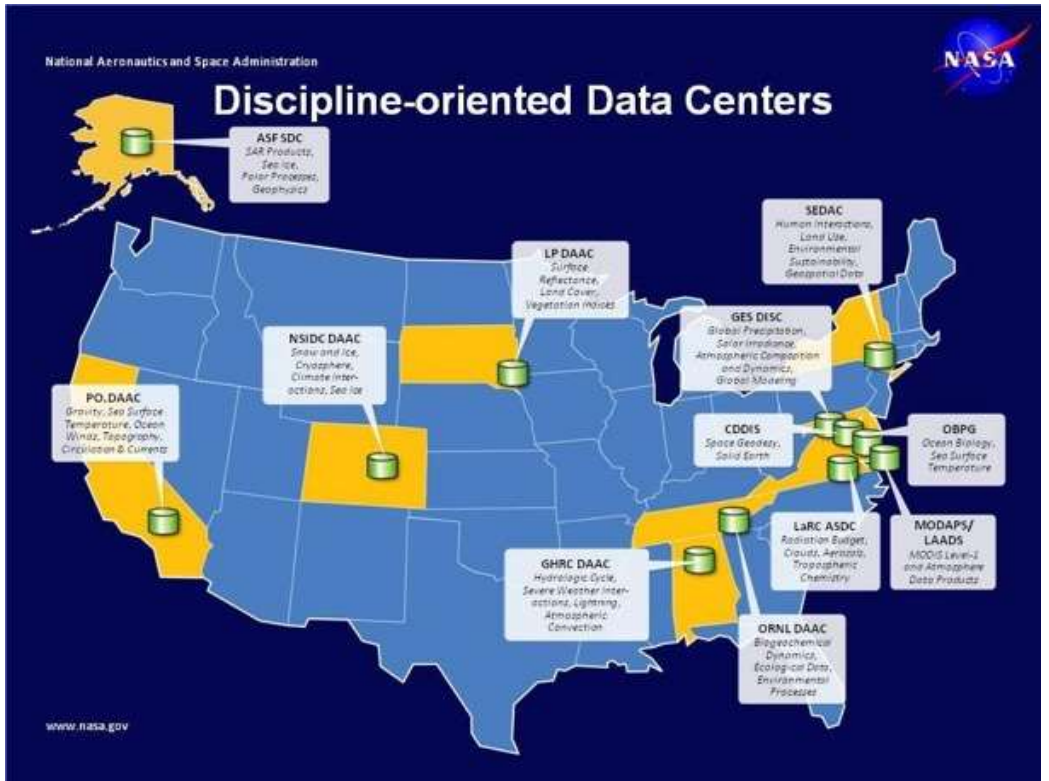
Matthew Tisdale, Booz Allen Hamilton (BAH), matthew.s.tisdale@nasa.gov

Atmospheric Science Data Center

NASA Earth Observing System Data and Information System (EOSDIS)



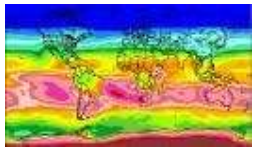
- Provides end-to-end capabilities for managing NASA's Earth science data from satellites, aircraft, field measurements, and various other programs.
- Twelve discipline-specific Distributed Active Archive Centers (DAACs), process, manage, archive (14.6+ PB), and distribute (32.1+ TB /day) a variety of Earth system science data.



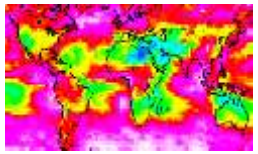
https://earthdata.nasa.gov
https://search.earthdata.nasa.gov

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

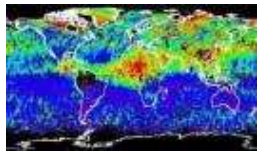
- **4.1 Petabytes of data, over 58 million files,** are in the archive as of January 2016
- **Over 624 Terabytes of data** were distributed to over **165,000** customers in **158** countries



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



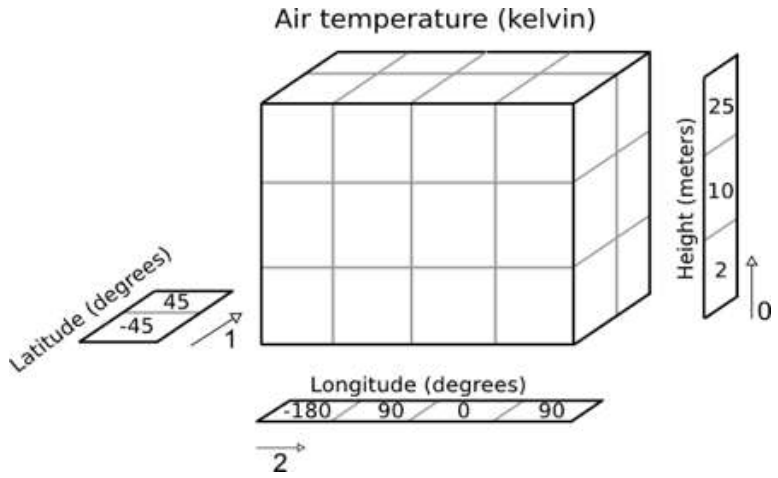
Clouds - A visible aggregate of minute water droplets and/or ice crystals in the atmosphere above the Earth's surface.
Instruments: CALIPSO, MISR



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

Tropospheric Chemistry - 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

Addressing ASDC Geospatial User Driven Requirements

Continuously receive request from users for data in "GIS format"

Developed one-off "Data Recipes" for how to extract, transform and load data into traditional GIS formats (Shapefiles and GeoTIFFs)

Esri announces support for HDF/NetCDF/GRIB

Developed proof of concept to determine if NASA EOS data, in its native formats, can be used in ArcGIS Platform

Leveraging ArcGIS Platform [Server, Portal Desktop, Pro] to meet guidelines of the White House's Common Framework for Earth-Observation Data (CFEOD) Data-Access Services

- OGC Web Map Service (WMS), OGC Web Map Tile Service (WMTS), OGC Web Coverage Service (WCS), OGC Web Feature Service (WFS)
- Data Access Protocol (DAP), Web Processing Service (WPS)

Geospatial Application Support for Multidimensional Data Proof of Concept

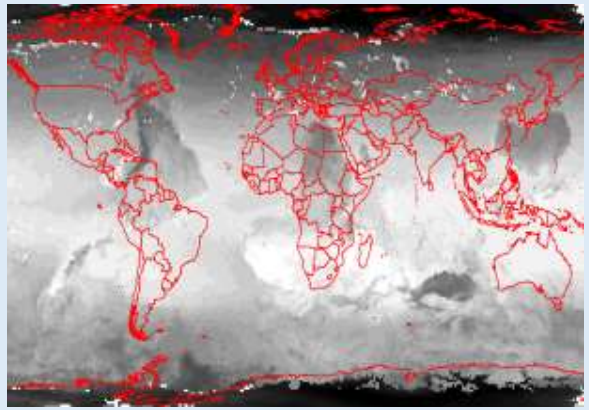
- Until recently, GIS applications were frequently unable to read EOS data product files or unable to properly interpret the internal data structures necessary to be visualized or analyzed.
- Many geospatial tools, including ArcGIS, GeoServer, MapServer, and Quantum GIS (QGIS), rely on GDAL, open source translator library, to present a single raster abstract data model to the calling application.
- Developing an extensible GDAL augmentation framework, that can be leveraged by data consumers and producers, to properly interpret EOS data products in GIS applications.
- Project known as **GDAL Enhancements for ESDIS (GEE)**, in support of the Big Earth Data Initiative (BEDI)

EXAMPLE

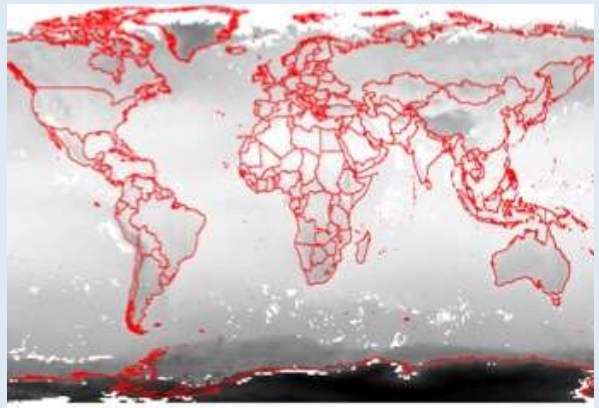
Image Displayed Inverted

MOP03TM.005 (HDF4): Retrieved Surface Temperature Night

Before



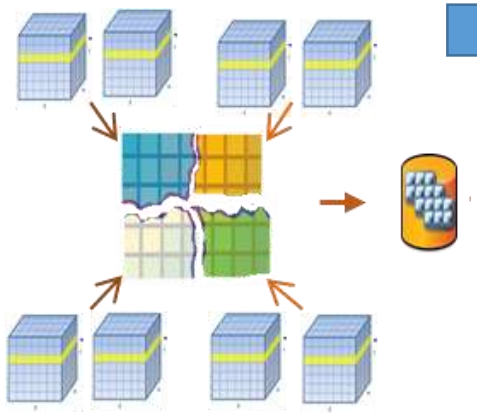
After



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

Atmospheric Science Data Center

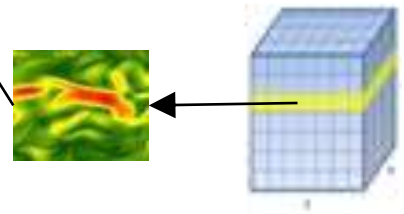
ArcGIS Multidimensional Mosaic Dataset Indexing HDF/netCDF/GRIB Data Warehouses



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

Mosaic Index

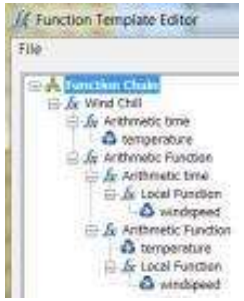
OBJ	Raster	Name	Variable *	Standard Time
1	<Raster	hycom_glb_regp01.nc:water_temp:0	water_temp	5/17/2013
2	<Raster	hycom_glb_regp01.nc:water_temp:1	water_temp	5/17/2013
3	<Raster	hycom_glb_regp01.nc:water_temp:2	water_temp	5/17/2013
4	<Raster	hycom_glb_regp01.nc:water_temp:3	water_temp	5/17/2013
5	<Raster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

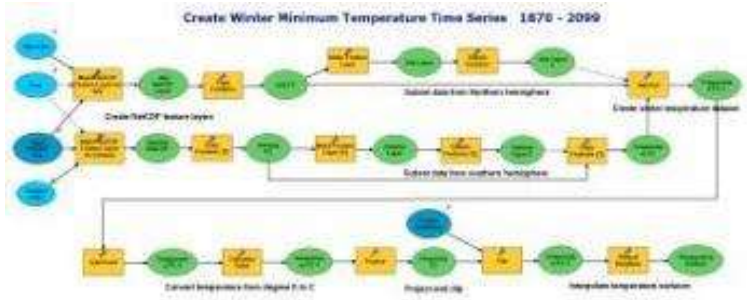


Publish ArcGIS Image Service

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

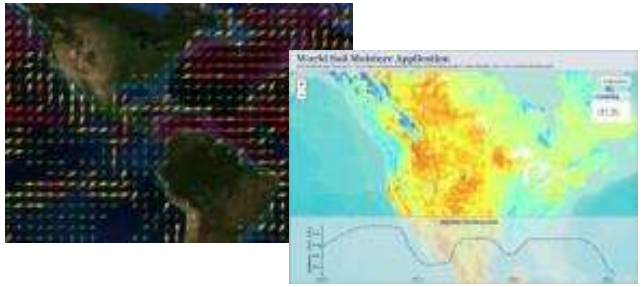




Usable by ArcGIS Platform

Visualization

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

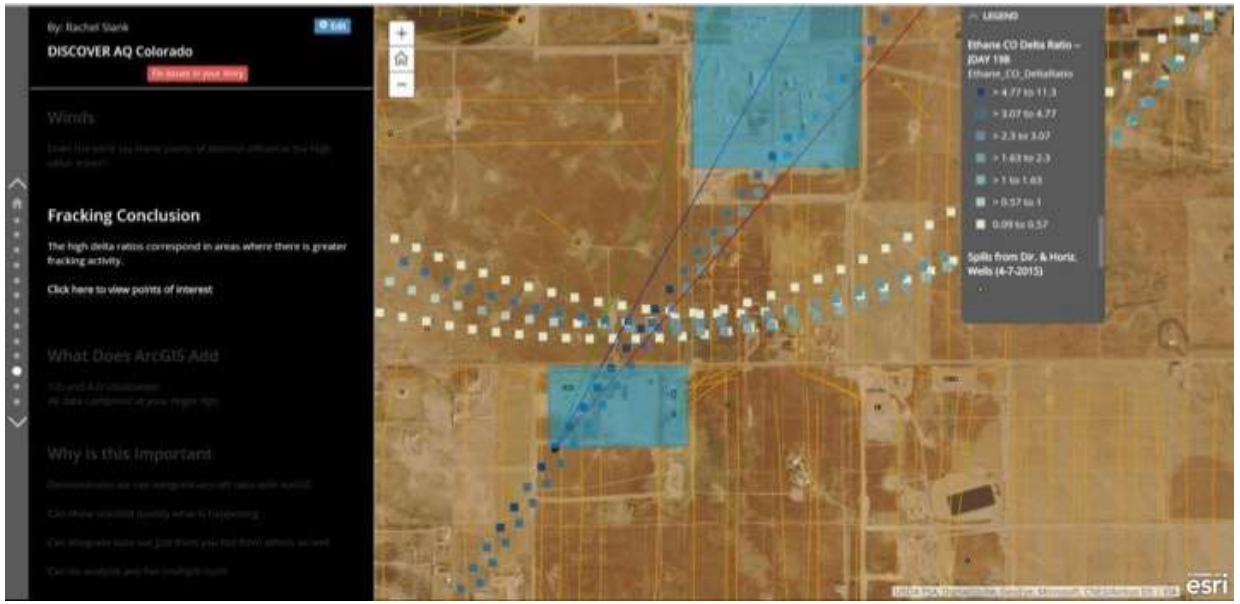


DISCOVER-AQ Proof of Concept

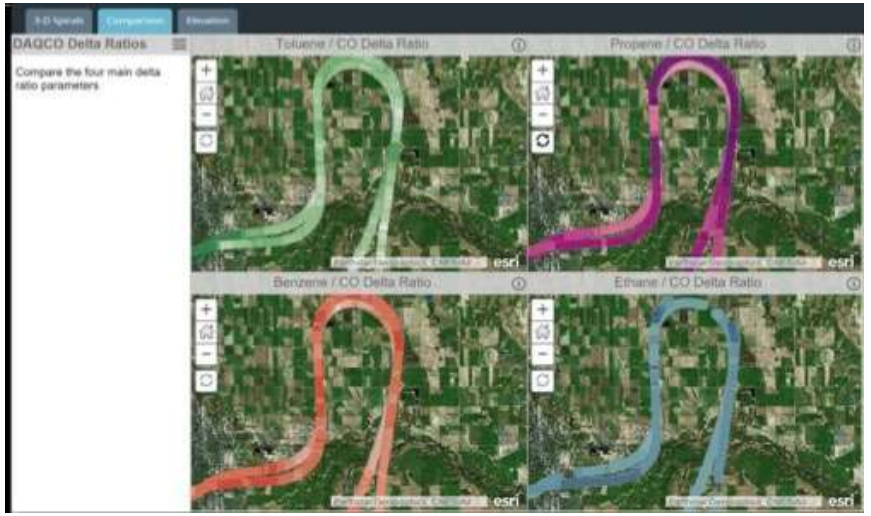
- **Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ)**

- NASA began a multi-year airborne field campaign in 2011 to distinguish between pollution high in the atmosphere and that near the surface where people live and breathe.

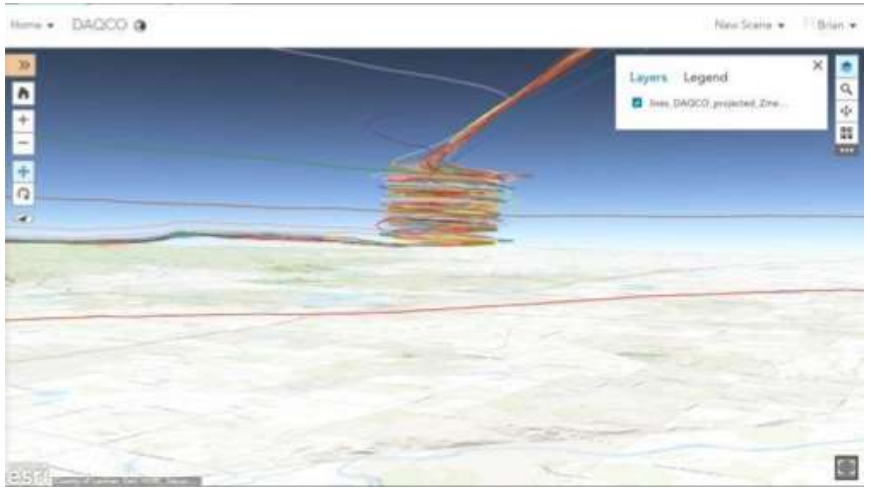
- Detailed observations of air pollution from the surface up into the atmosphere will help improve the capability of future satellites to monitor air quality around the world.



Story Map Journal



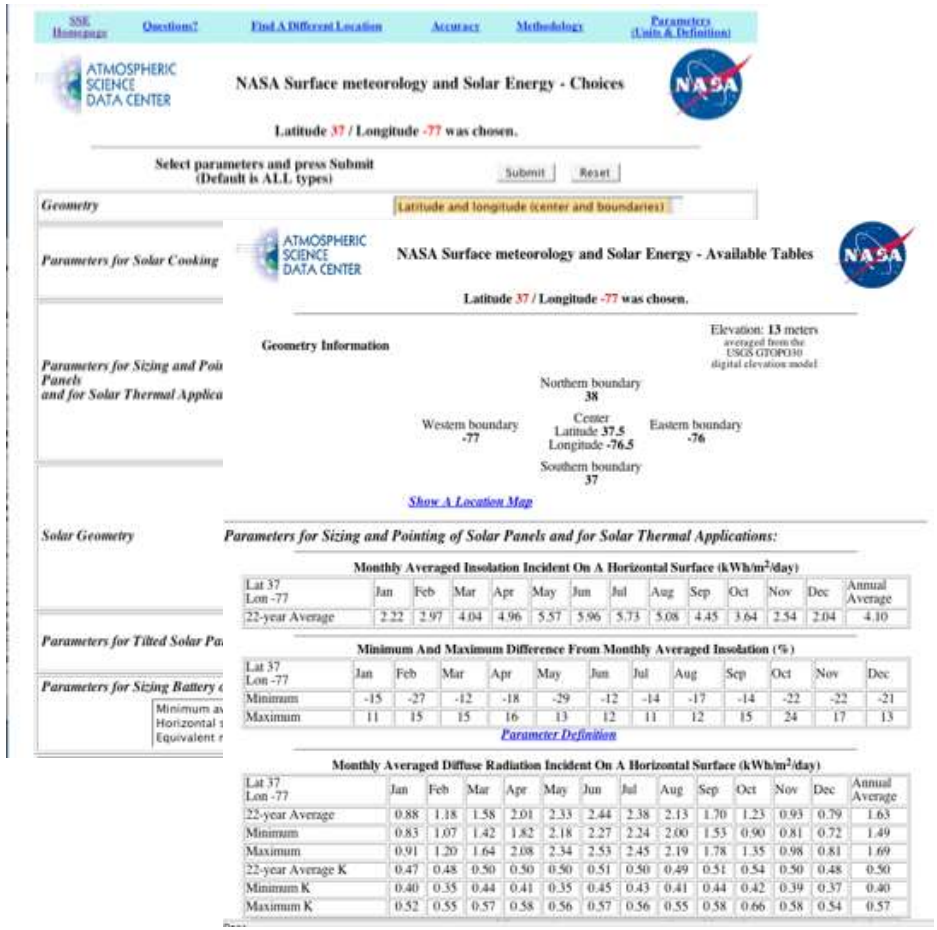
Comparison Template



Web Scene

Predication Of Worldwide Energy Resources (POWER) GIS

Experience Being Phased Out



SSE Homepage | Questions? | Find A Different Location | Accuracy | Methodology | Parameters (Units & Definition)

ATMOSPHERIC SCIENCE DATA CENTER

NASA Surface meteorology and Solar Energy - Choices

Latitude 37 / Longitude -77 was chosen.

Select parameters and press Submit (Default is ALL types)

Submit | Reset

Geometry — Latitude and longitude (center and boundaries)

Parameters for Solar Cooking

Parameters for Sizing and Poi... Panels and for Solar Thermal Applica...

Solar Geometry

Parameters for Tilted Solar Pa...

Parameters for Sizing Battery ...

Minimum a... Horizontal s... Equivalent ...

ATMOSPHERIC SCIENCE DATA CENTER

NASA Surface meteorology and Solar Energy - Available Tables

Latitude 37 / Longitude -77 was chosen.

Geometry Information

Elevation: 13 meters averaged from the USGS GTOPO30 digital elevation model

Northern boundary 38

Western boundary -77 | Center Latitude 37.5 Longitude -76.5 | Eastern boundary -76

Southern boundary 37

Show A Location Map

Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications:

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	2.22	2.97	4.04	4.96	5.57	5.96	5.73	5.08	4.45	3.64	2.54	2.04	4.10

Minimum And Maximum Difference From Monthly Averaged Insolation (%)

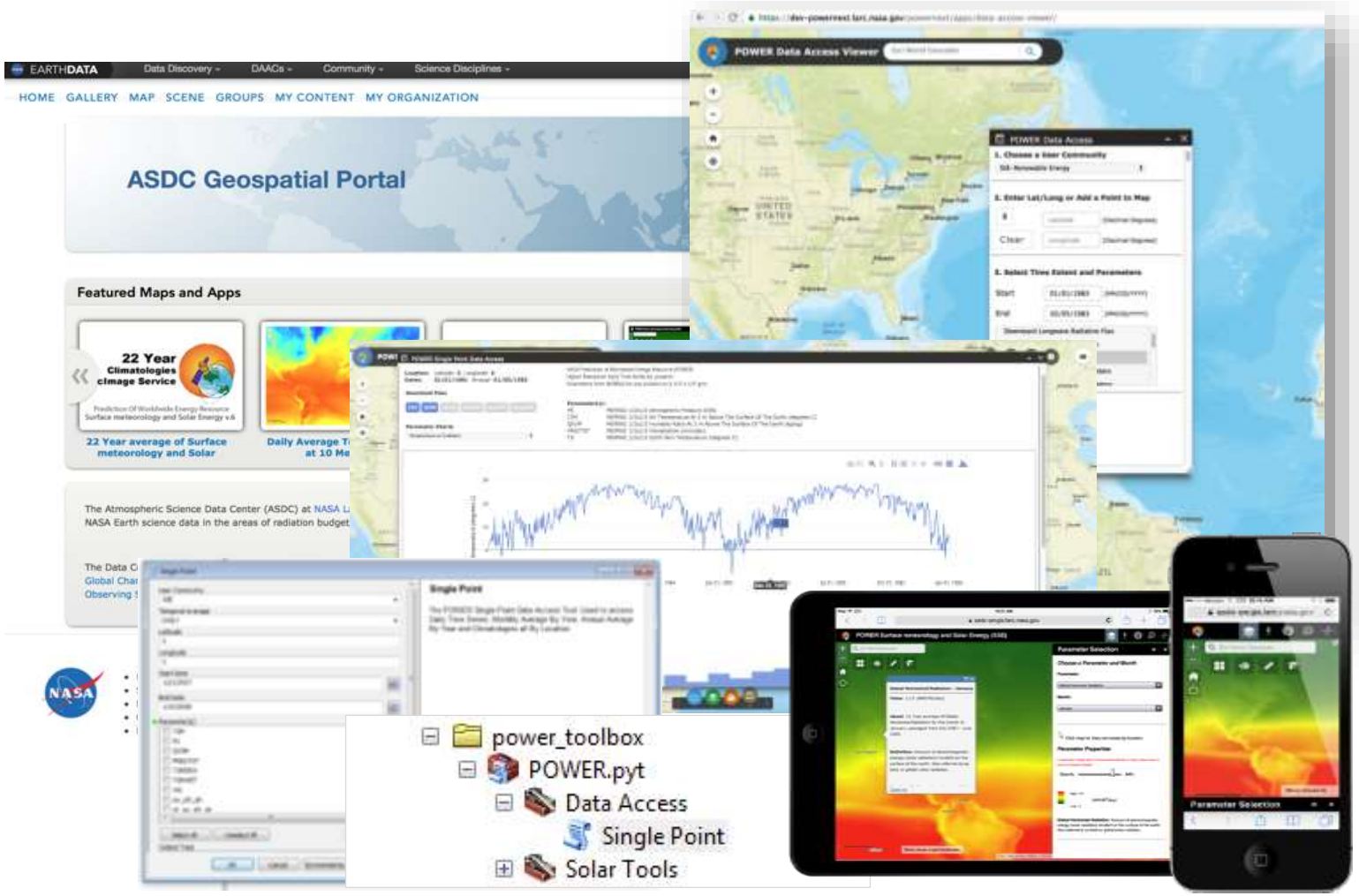
Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	-15	-27	-12	-18	-29	-12	-14	-17	-14	-22	-22	-21
Maximum	11	15	15	16	13	12	11	12	15	24	17	13

Parameter Definition

Monthly Averaged Diffuse Radiation Incident On A Horizontal Surface (kWh/m²/day)

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	0.88	1.18	1.58	2.01	2.33	2.44	2.38	2.13	1.70	1.23	0.93	0.79	1.63
Minimum	0.83	1.07	1.42	1.82	2.18	2.27	2.24	2.00	1.53	0.90	0.81	0.72	1.49
Maximum	0.91	1.20	1.64	2.08	2.34	2.53	2.45	2.19	1.78	1.35	0.98	0.81	1.69
22-year Average K	0.47	0.48	0.50	0.50	0.50	0.51	0.50	0.49	0.51	0.54	0.50	0.48	0.50
Minimum K	0.40	0.35	0.44	0.41	0.35	0.45	0.43	0.41	0.44	0.42	0.39	0.37	0.40
Maximum K	0.52	0.55	0.57	0.58	0.56	0.57	0.56	0.55	0.58	0.66	0.58	0.54	0.57

Experience Being Phased In



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

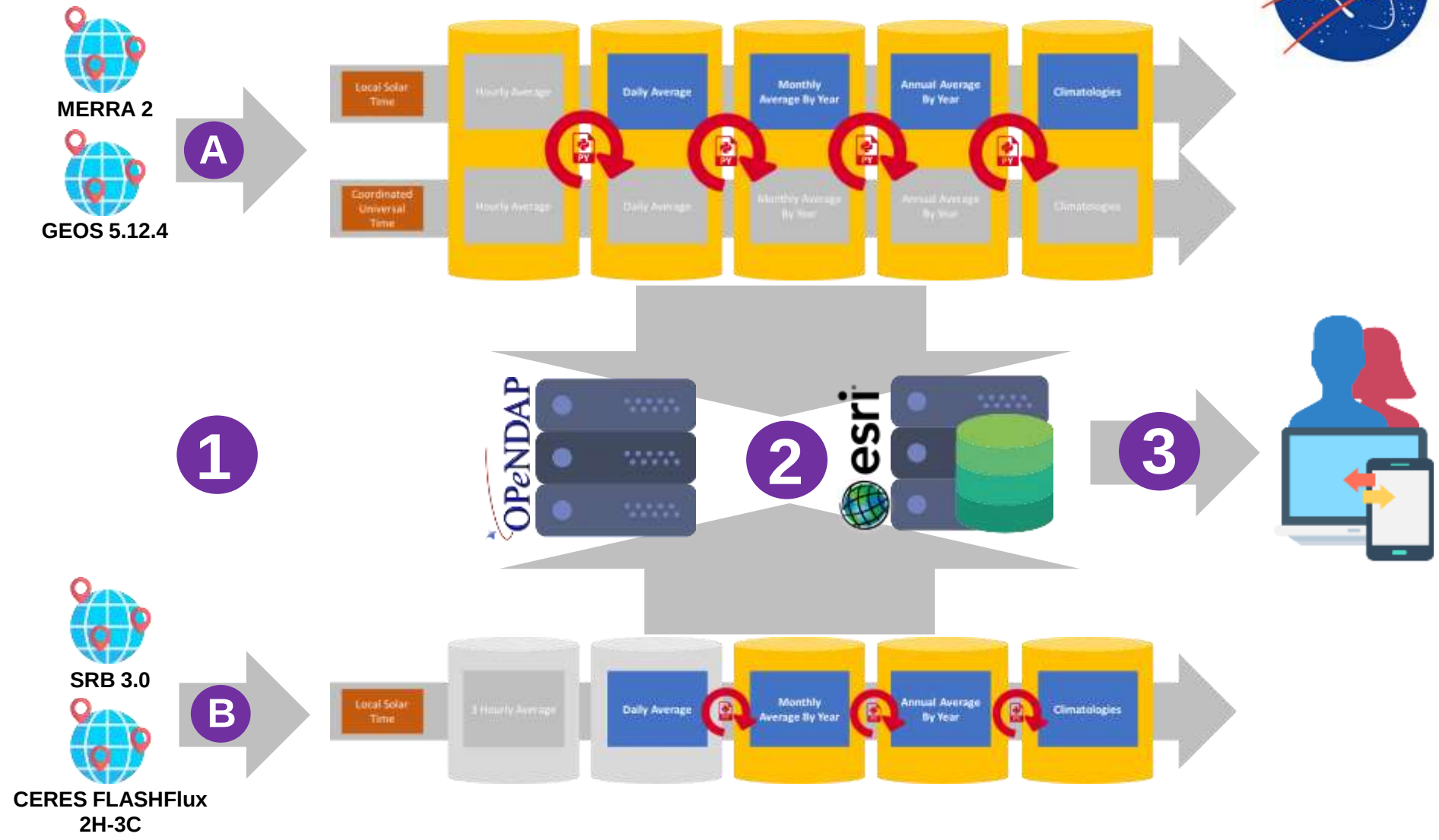
NASA POWER Data Processing & Distribution

Atmospheric Science Data Center

1
- A: Native meteorological model data is ingested and processed on a recurring cycle and stored.
- B: Native solar model data is ingested on a recurring cycle and averages greater than daily are processed and stored.

2 Data is served to users via OPeNDAP and Esri ArcGIS Server (Image Services, Geoprocesing Services).

3 Users can access the data in commercial and custom applications via Desktop, Tablet and smartphone technologies.



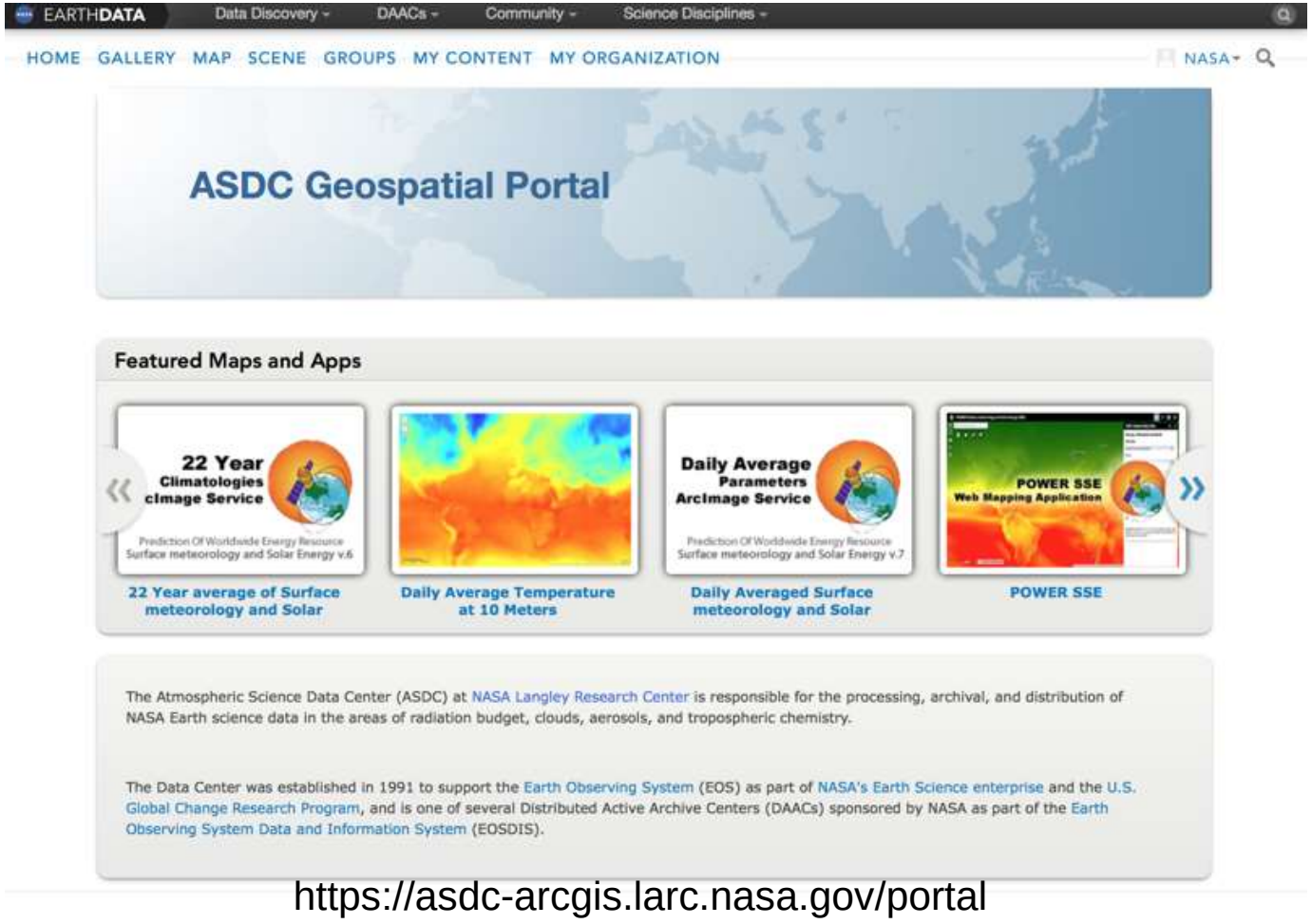
Native Gridded Model Data | Data Not Distributed* | Data Distributed | Data Stored | Recurring Python Scripts | Server with Enterprise GeoDatabase | Web Server | Users Access On Responsive Platform

* Data may become available in future depending on resources and user requirements.

Icons Source: http://www.flaticon.com (Creative Commons 3.0)

NASA ASDC ArcGIS Portal

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



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

- 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

DATA.GOV

Increasing Accessibility and Use of NASA Earth Science Data in Geospatial Applications

NASA Atmospheric Science Data Center (ASDC)

Matthew Tisdale, Booz Allen Hamilton (BAH), matthew.s.tisdale@nasa.gov