Delivering Usable and Scalable GIS Data and Services for Weather and Climate Information

Sudhir Shrestha (National Government Science and Civilian)

Matthew Rosencrans (NOAA Climate Prediction Center)

Adam Hartman (Innovim/ NOAA Climate Prediction Center)

Matt Tisdale (Booz Allen/ NASA Atmospheric Science Data Center)

Dan Pisut (Esri Living Atlas)

2019 ESRI
FEDERAL GIS CONFERENCE
WASHINGTON, DC

Exploiting scalable Imagery and Scientific Data: Weather and Climate Domain: How we go about it with ArcGIS Platform

What are the best practices on working with the scientific data and model output that can be enabled from Research to Operations and what are the current works, challenges and opportunities?

Web Services, Web enabling your data and services?

Current way to serve the data and information product that are consumed by large community of scientists, policy makers and industries?

Enabling the innovation through enabling the Scientific Data?

Interoperability ?

Build once and reuse?

GIS Technology at the Climate Prediction Center

Adam Hartman

Innovim, LLC / NOAA – NWS – NCEP Climate Prediction Center

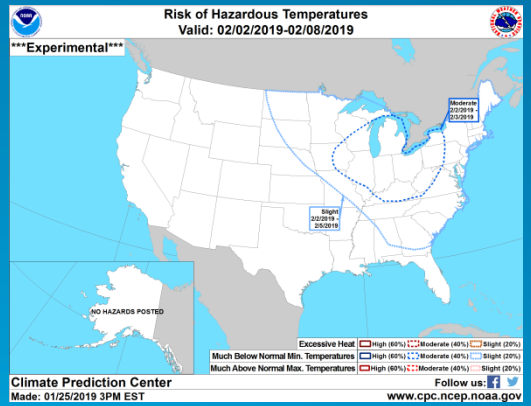
Matthew Rosencrans

NOAA – NWS – NCEP Climate Prediction Center

2019 ESRI
FEDERAL GIS CONFERENCE
WASHINGTON, DC

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Products with ESRI Tech



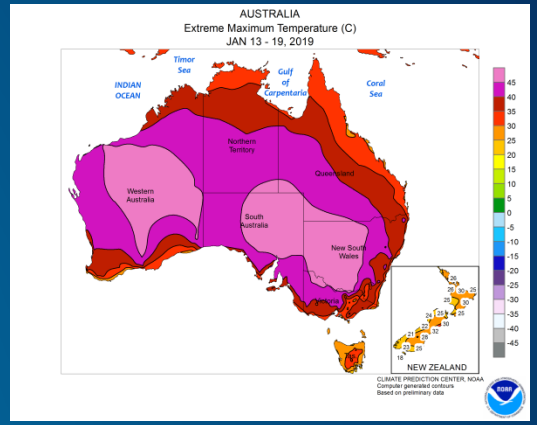
U.S. Hazards Outlook

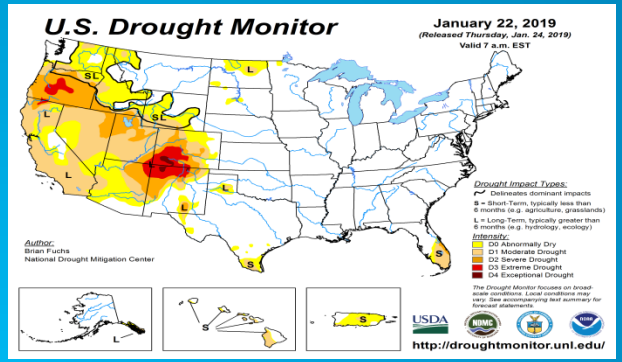
Drought Monitoring

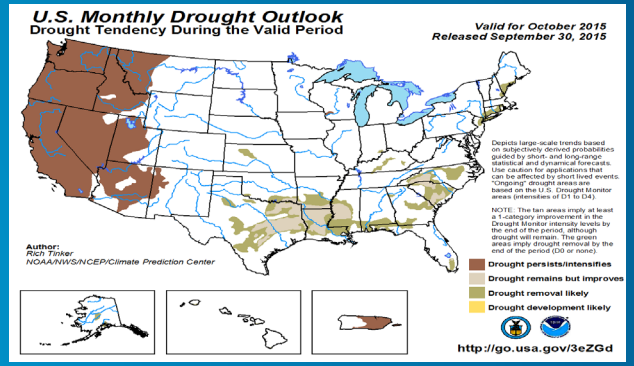
Drought Prediction

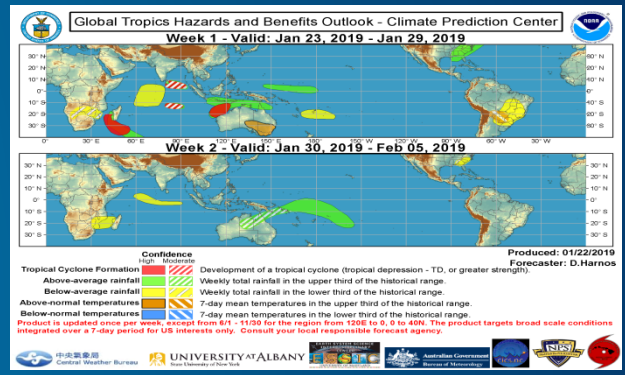
Tropical Cyclone forecasts

Climate Monitoring



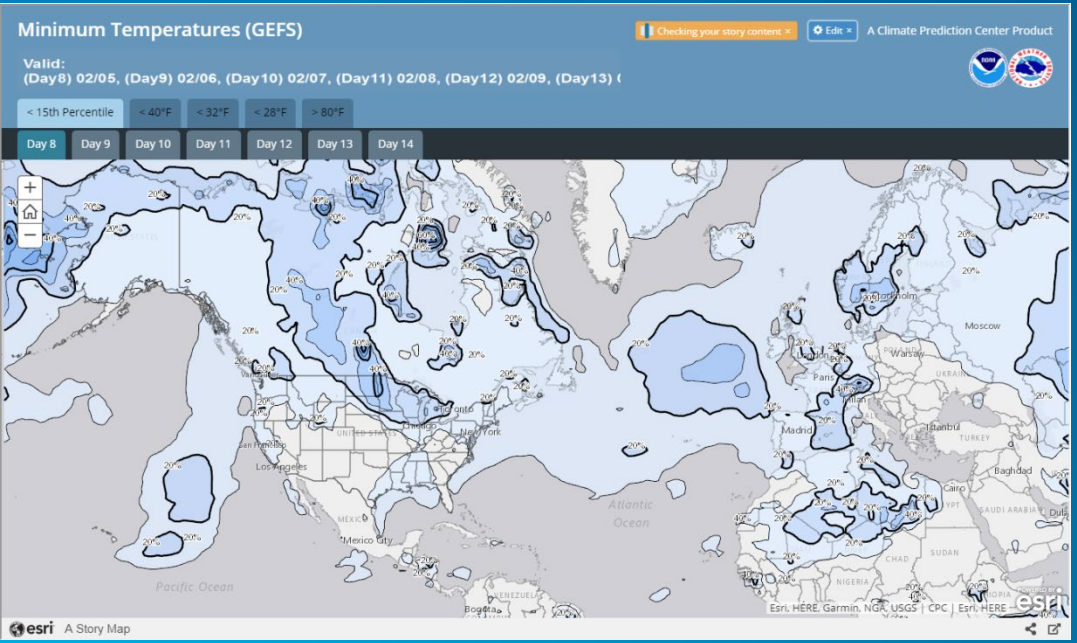


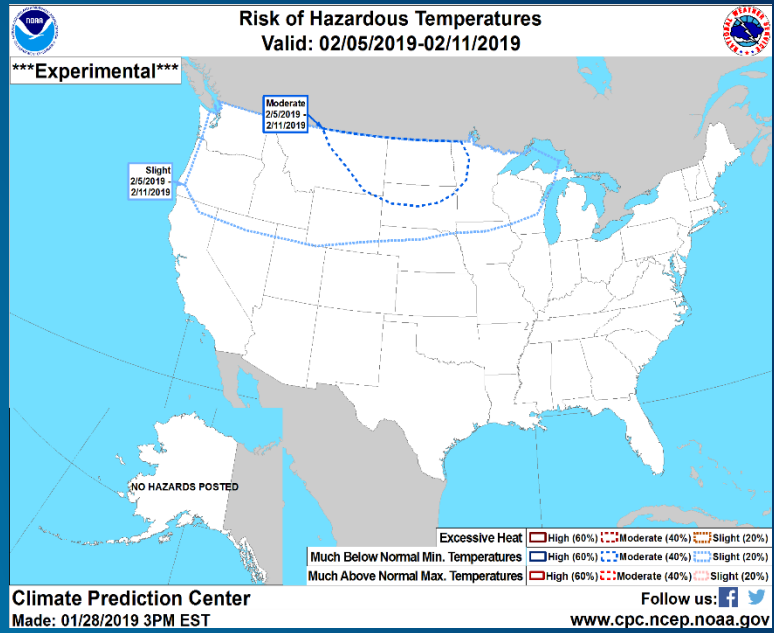




NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Extremes in Short-term Climate

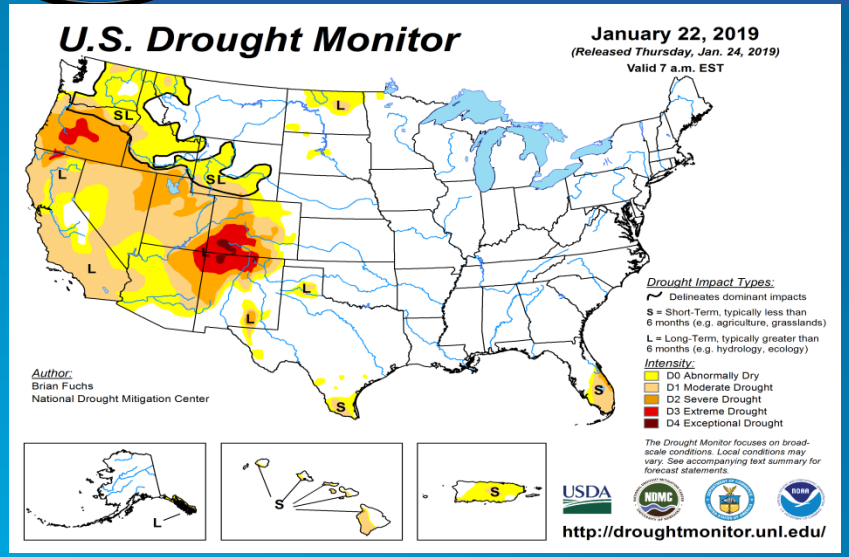




maximum temperature | minimum temperature | precipitation | wind

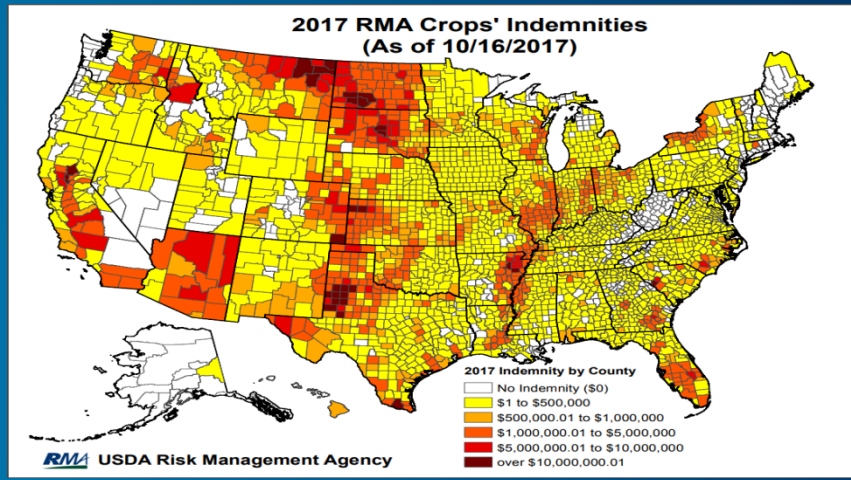
https://www.cpc.ncep.noaa.gov/products/predictions/threats/extremesTool.php?var=tmin

Drought Monitoring



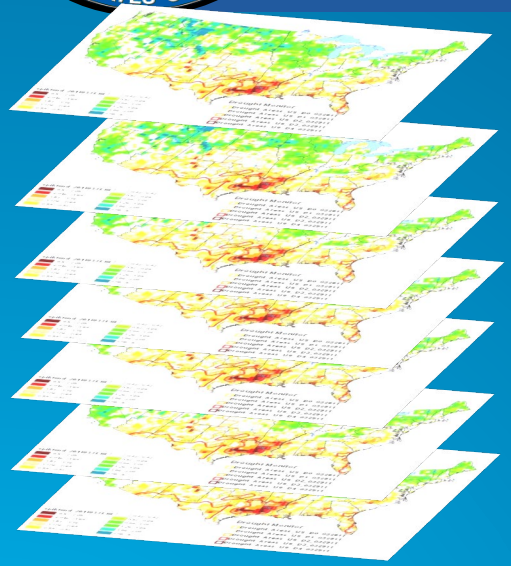
Weekly product – US
Monthly – North America

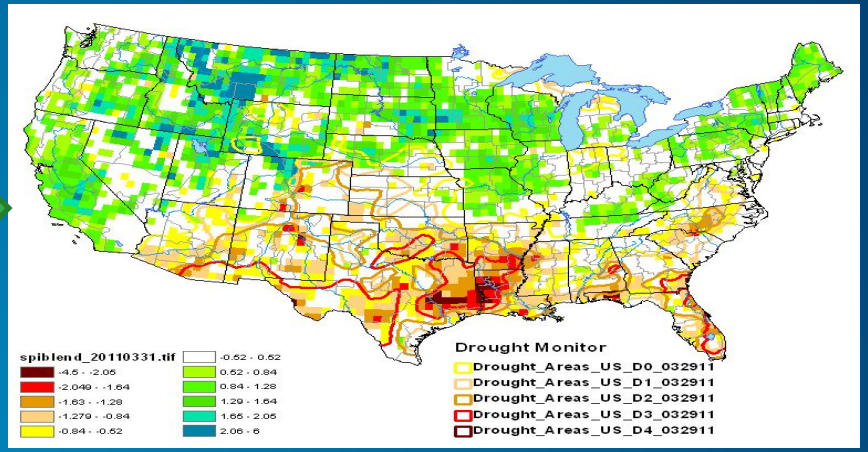
Established in 1999, Western Governors Association helped



Range of timescales used
5 year impacts out west
Impact of climatological wet and dry seasons also play a role

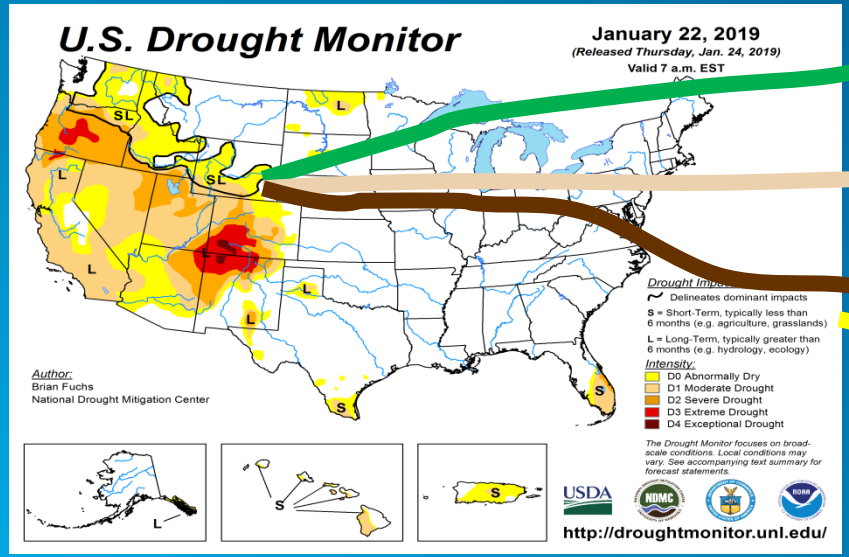
Data Consolidation

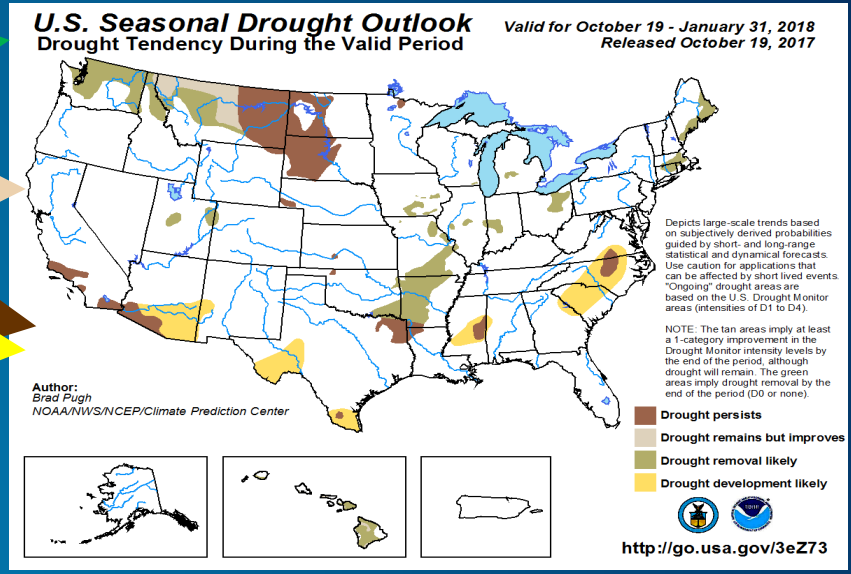




- How do we consolidate the data?
- Scripting is done with Python using ArcGIS Spatial Analyst

Drought Prediction





Applications for Agriculture

Station

Station data

1. Download and parse data
2. Import data into GDB as tables
3. QC data tables
4. Create point feature classes
5. Interpolate point feature classes
6. Contour raster datasets
7. Create maps
8. Forecasters QC and edit maps
9. Send maps to world

Blended Satellite & Station

Satellite data

QC'd station data

Blended gridded data

1. Download data and import to GDB
2. QC gridded data
3. Import to GDB and distribute
4. Create maps
5. Forecasters QC/edit data
6. Republish maps to world

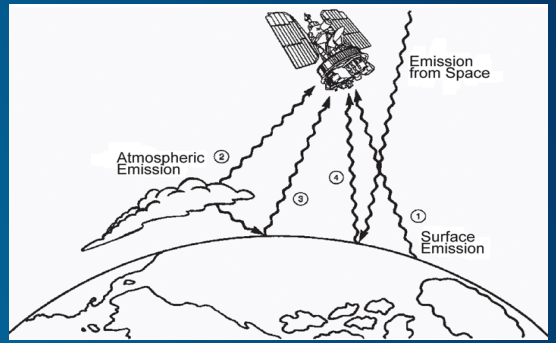
- Current Joint Agricultural Weather Facility (JAWF) maps use interpolated station data
  - Long processing times required to parse and interpolate station data (20-25 minutes)
  - Inaccurate representations of meteorological parameters in data-sparse regions
  - QC of data is done after map creation
    - Requires 2-3 forecasters per week
    - 2-3 days per week editing maps

- New gridded product suite for JAWF
  - Shorter processing times since data is already in gridded format (12-15 minutes)
  - Blended satellite and station products
  - QC of data is done prior to creation of maps
    - Requires only one forecaster
    - A couple hours of editing per week (maybe)

Imperfect Data Collection

Human Factor:

- Missed/incorrect reports
- Reuse of station IDs
- Degradation of stations



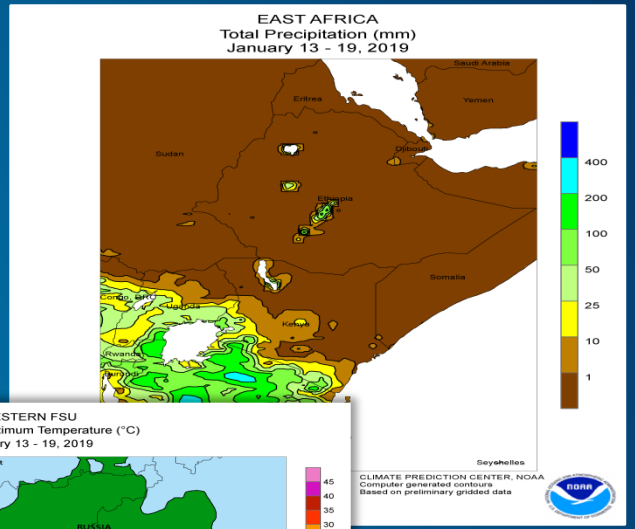
Swift and Cavalieri 1985

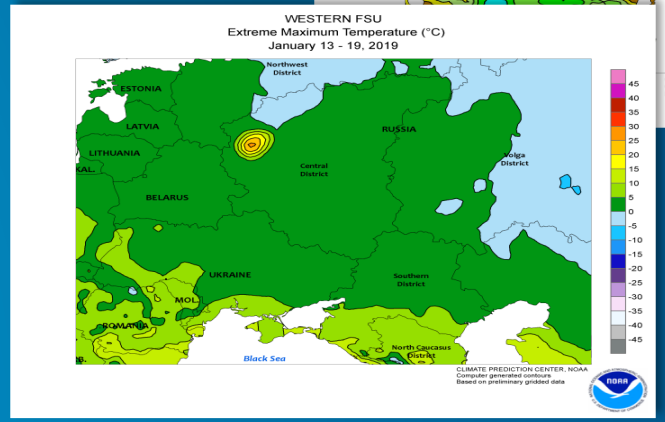
Satellites:

High Reflectivity = Low Emissivity = Anomalously Low Temperatures

Incorporation of Noisy Data

- Erroneous precipitation measurements
- **Unphysical** gradients (e.g. bullseyes)





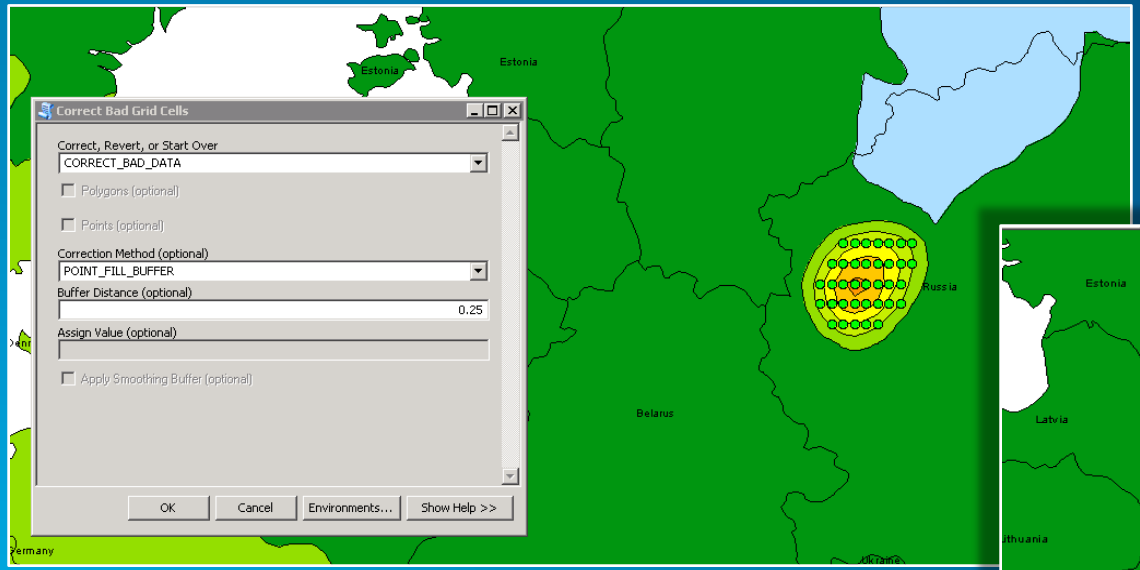
Challenges

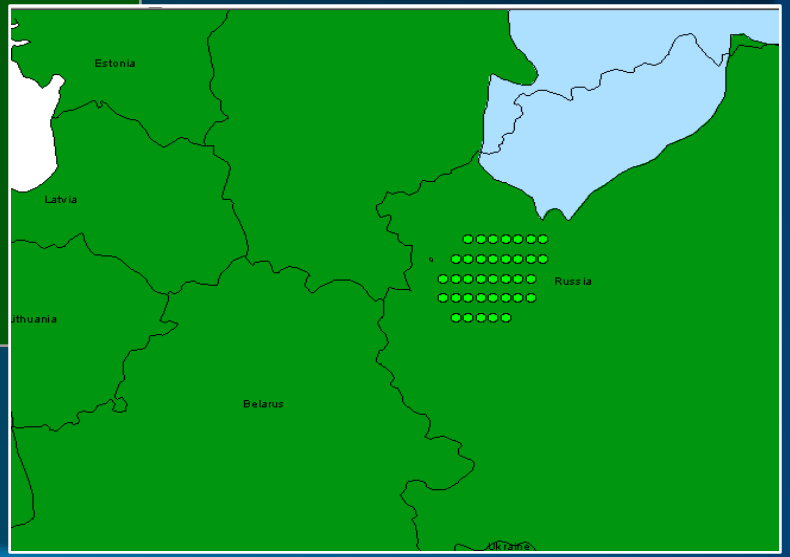
- Forecaster familiarity with ArcMap
  - Level of familiarity with ArcMap?
  - How to design a tool to fit that familiarity?

- Workflow and tool design
  - Performing QC of gridded data
    - How to directly interact with raster layers via GUI.
    - Workarounds - Used polygon and point feature layers.
  - Big data = slow/problematic rendering.
    - To vector (point) from raster (GDB) to save RAM.
    - Created buffers for point feature layers using Python.
  - Accounting for editors' changes or mistakes.
    - Centering points added by editors within grid cells of the underlying raster layer.
    - Creating a form of version control.

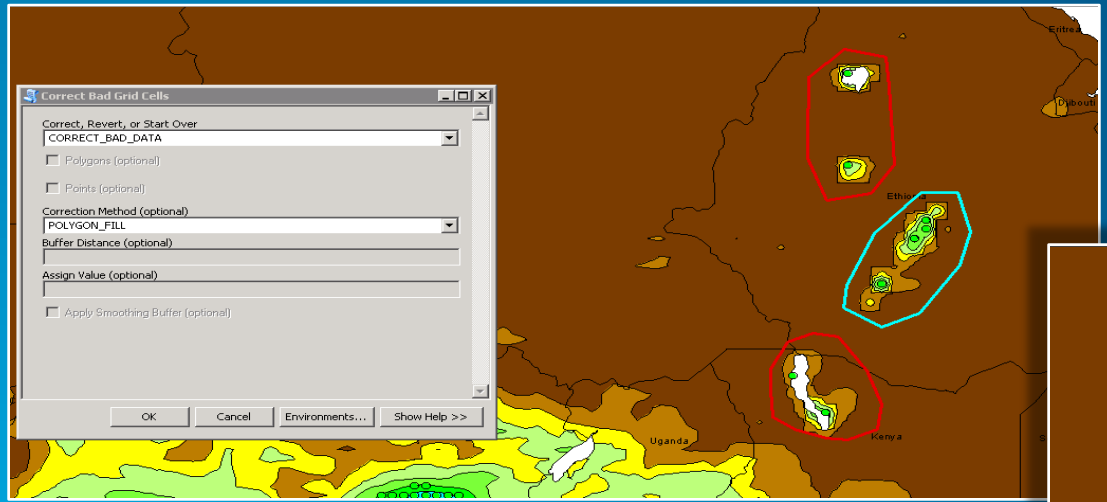
Examples

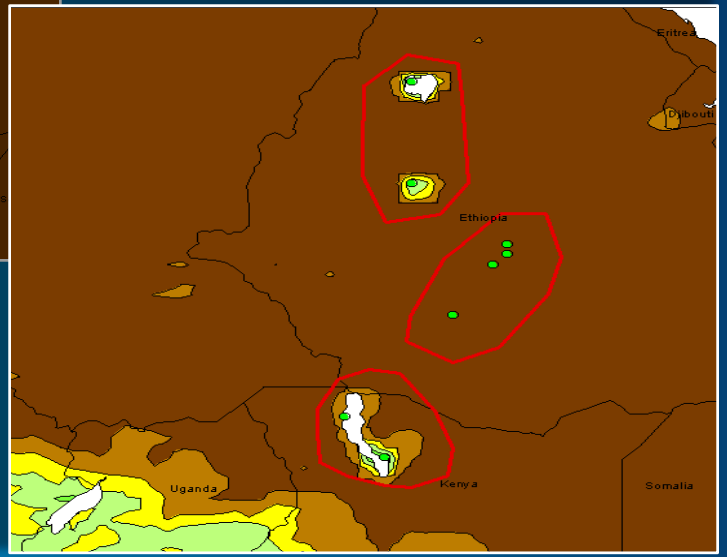
Using Points





Using Polygons





Conclusion

- **Blended satellite and station gridded data improves overall accuracy of measurements**
- **Upstream data QC reduces processing and editing time**
  - **Further reduced by new processing scripts and workflow practices**
- **New *JAWF Gridded Editing Tool* facilitates editing of new gridded products**
- **USDA receives higher-resolution maps with greater accuracy**

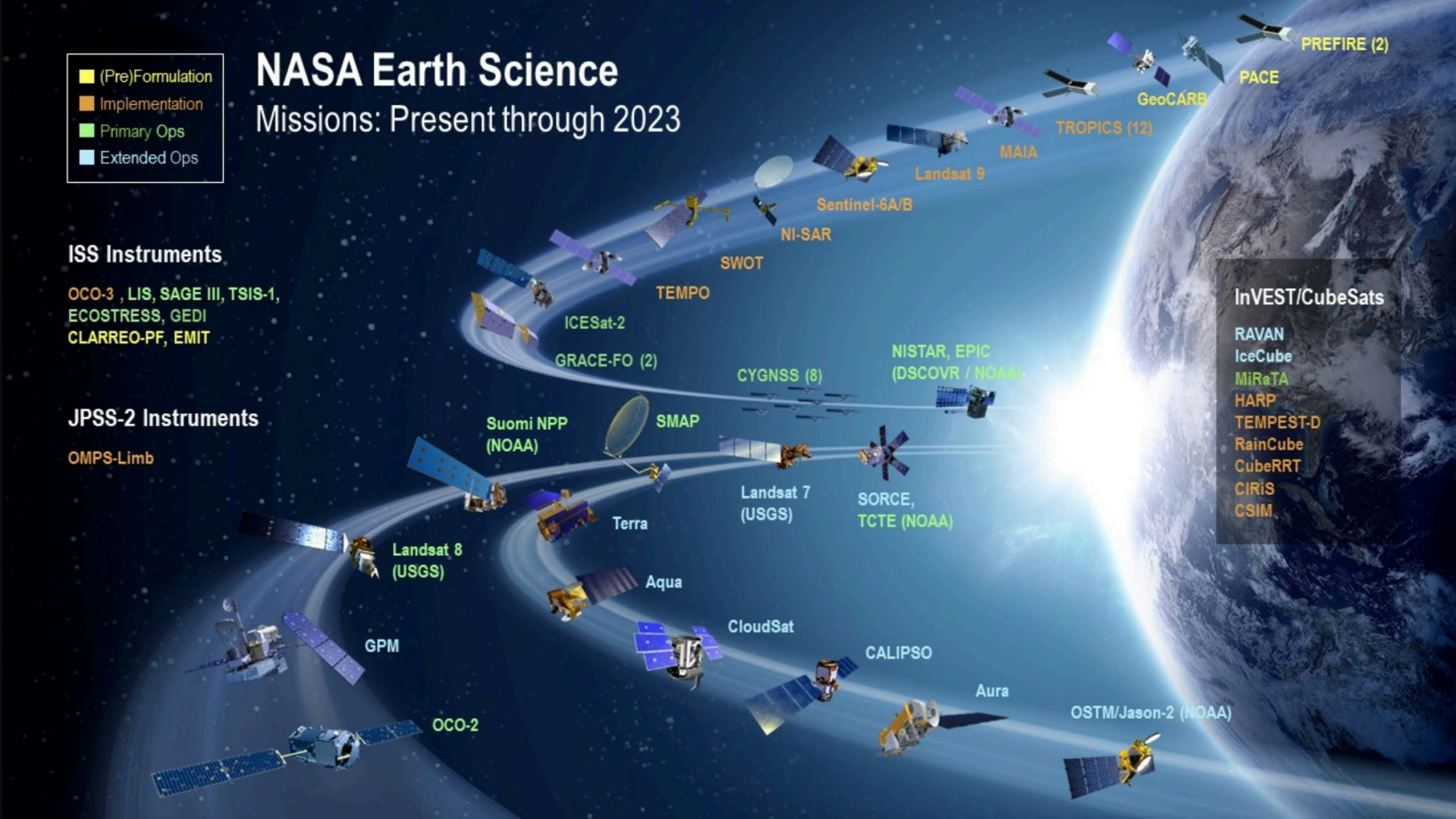
Improvements

- Reduce the number of MXDs used during map creation.
- Work with ESRI to determine feasibility of developing more direct methods for editing raster layers.
- Add functionality to editing tool that automates calculation of gradients for nested polygons.

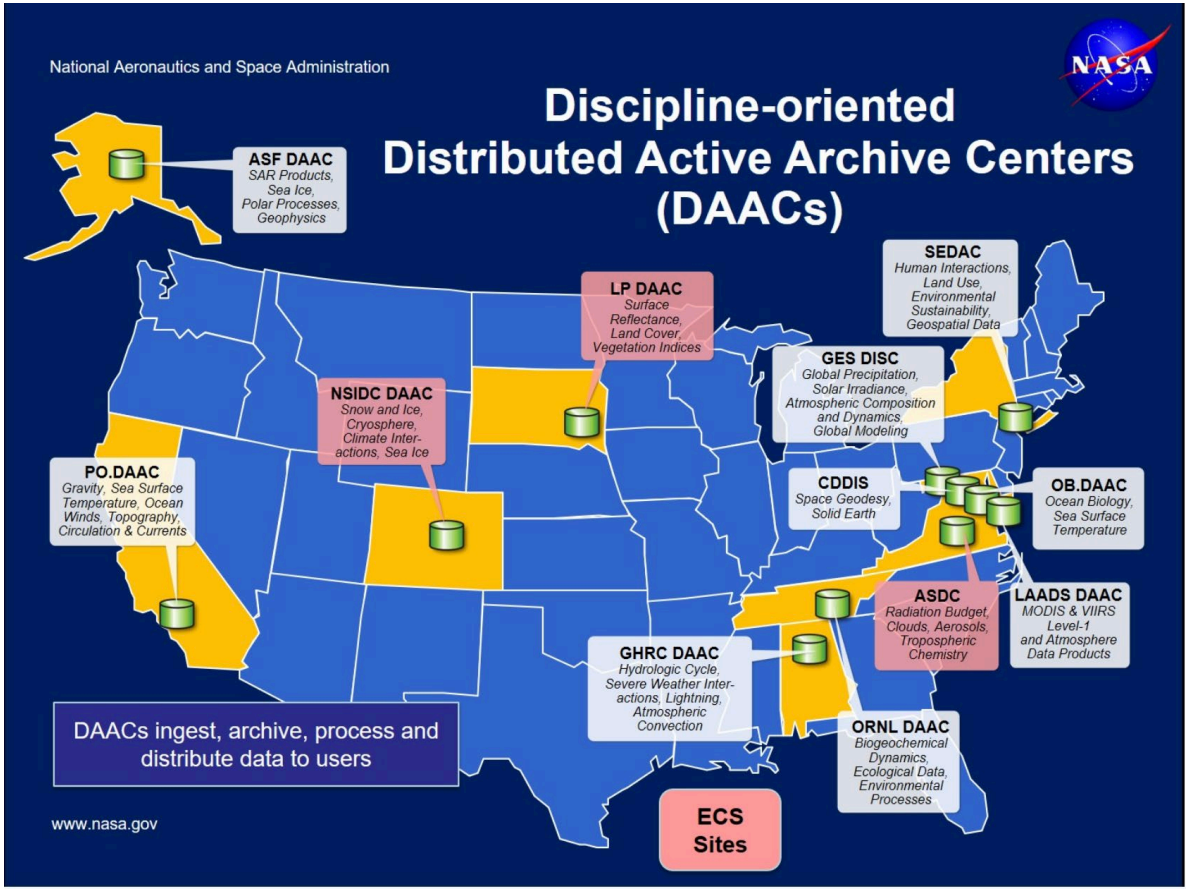
Delivering Usable and Scalable GIS Data and Services for Weather and Climate Information

NASA Atmospheric Science Data Center (ASDC)

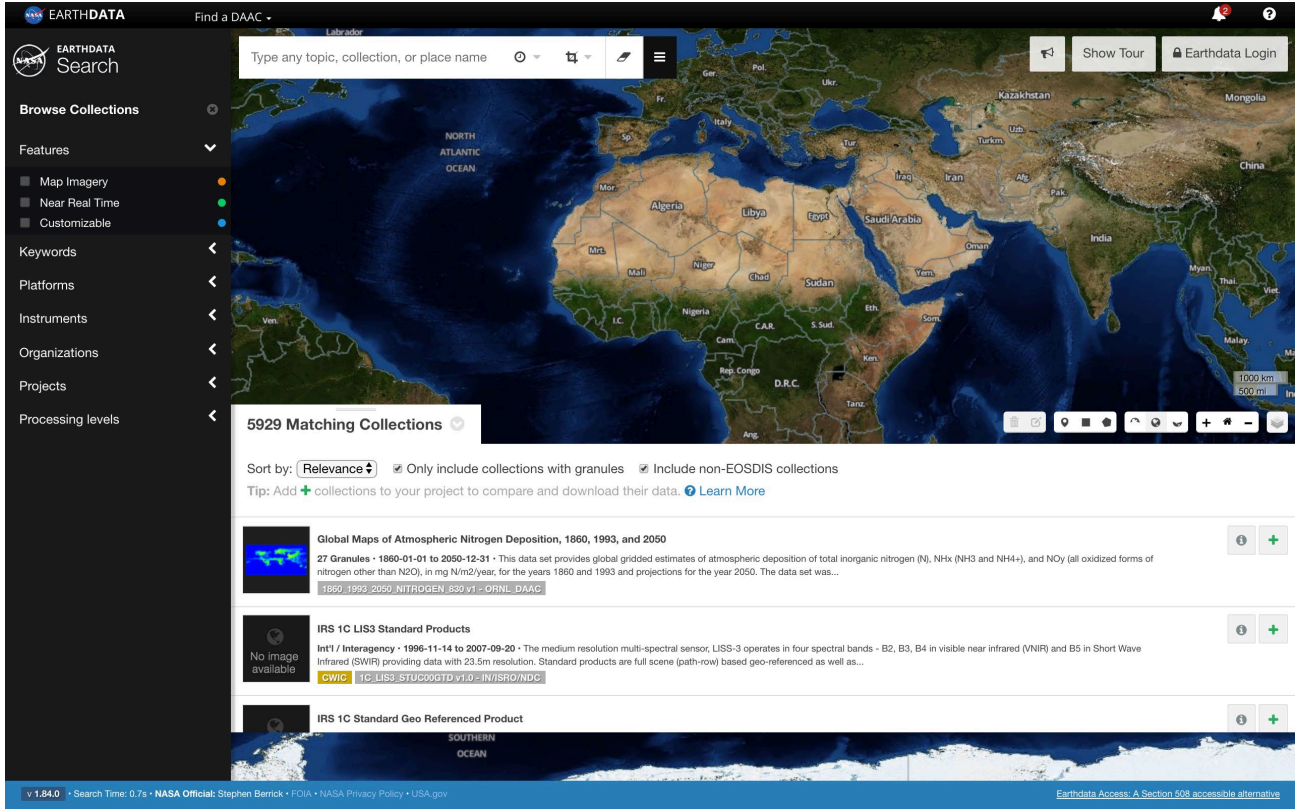
Matthew Tisdale, Booz Allen Hamilton (BAH), **matthew.s.tisdale@nasa.gov**


NASA Earth Science
Missions: Present through 2023
(Pre)Formulation
Implementation
Primary Ops
Extended Ops
ISS Instruments
OCO-3 , LIS, SAGE III, TSIS-1,
ECOSTRESS, GEDI
CLARREO-PF, EMIT
JPSS-2 Instruments
OMPS-Limb
PREFIRE (2)
PACE
GeoCARB
TROPICS (12)
MAIA
Landsat 9
Sentinel-6A/B
NI-SAR
SWOT
TEMPO
ICESat-2
GRACE-FO (2)
CYGNSS (8)
NISTAR, EPIC
(DSCOVR / NOAA)
Suomi NPP
(NOAA)
SMAP
Landsat 7
(USGS)
SORCE,
TCTE (NOAA)
Terra
Landsat 8
(USGS)
Aqua
CloudSat
GPM
CALIPSO
Aura
OCO-2
OSTM/Jason-2 (NOAA)
InVEST/CubeSats
RAVAN
IceCube
MiRaTA
HARP
TEMPEST-D
RainCube
CubeRRT
CIRiS
CSIM

DAACs

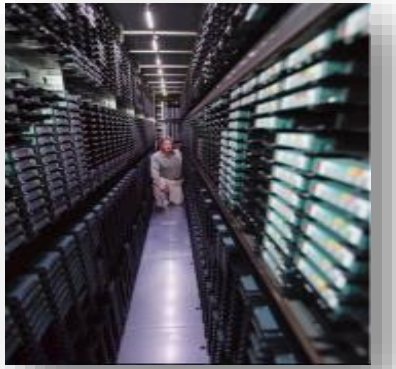

National Aeronautics and Space Administration
Discipline-oriented Distributed Active Archive Centers (DAACs)
ASF DAAC
SAR Products, Sea Ice, Polar Processes, Geophysics
LP DAAC
Surface Reflectance, Land Cover, Vegetation Indices
SEDAC
Human Interactions, Land Use, Environmental Sustainability, Geospatial Data
GES DISC
Global Precipitation, Solar Irradiance, Atmospheric Composition and Dynamics, Global Modeling
NSIDC DAAC
Snow and Ice, Cryosphere, Climate Inter-actions, 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 Inter-actions, 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

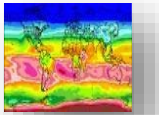


https://search.earthdata.nasa.gov

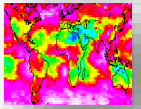
The NASA Atmospheric Science Data Center (ASDC) at a Glance



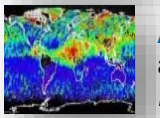
- Curates more than **300 unique science products** and provides data services for over **44 science projects**
- **4.65 Petabytes of data, over 58 million files,** are in the archive as of October 2017
- Data distributed to over **165,000** customers in **158** countries



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



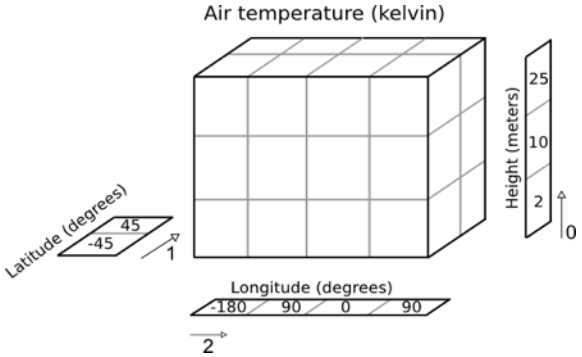
Clouds - A visible aggregate of minute water droplets and/or ice crystals in the atmosphere above the Earth's surface.
Instruments: CALIPSO, MISR



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

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%

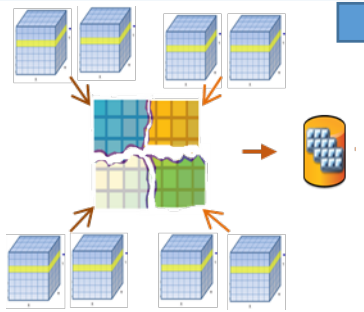
- GIS is utilized to support the delivery of priority data products, experiment with various geospatial technologies, and expand geospatial capabilities.

2017 ACSI RESULTS – All DAACs

Tool(s) used to work with data~	2017 %	2017 N
ArcGIS	64%	2,349
Convert to Vector	4%	159
ENVI	32%	1,176
ERDAS/IMAGINE	21%	766
Excel	27%	980
Ferret	1%	26
Geomatica	4%	148
Global Mapper	15%	562
GrADS	3%	118
GRASS	12%	435
HDFLook	1%	51
HDFView	9%	311
HEG	2%	67
IDL	11%	400
IDV	1%	26
IDRISI	7%	248
MapReady	1%	41
MATLAB	18%	649
MODIS Reprojection Tool (MRT)	10%	355
NCL	3%	100
Panoply	5%	201
Quantum GIS (QGIS)	37%	1,344
R	19%	680
SeaDAS	3%	123
Other/open source	18%	676
Don’t know/Not applicable	1%	26
Number of Respondents	3,656	3,656

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

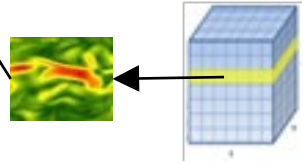
ArcGIS Multidimensional Mosaic Dataset Indexing HDF/netCDF/GRIB Data Warehouses



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

Mosaic Index

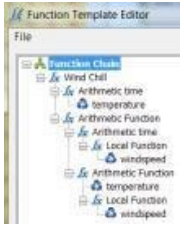
OBJ	Raster	Name	Variable *	Standard Time
1	<Raster	hycom_glb_regp01.nc:water_temp:0	water_temp	5/17/2013
2	<Raster	hycom_glb_regp01.nc:water_temp:1	water_temp	5/17/2013
3	<Raster	hycom_glb_regp01.nc:water_temp:2	water_temp	5/17/2013
4	<Raster	hycom_glb_regp01.nc:water_temp:3	water_temp	5/17/2013
5	<Raster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



Publish ArcGIS Image Service

Raster Functions

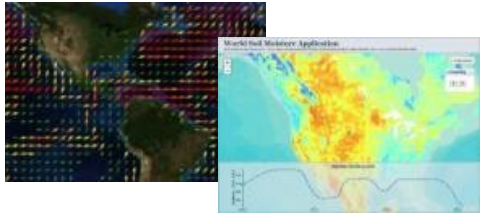
- On-the-fly Computing
  - Image Processing (NDVI, pansharpen, image classification, etc.)
  - Raster Calculator (Convert Celsius to Fahrenheit)
- Processes the pixels that are requested
- Can be chained and avoid intermediate results

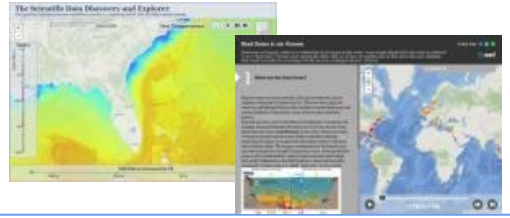


Usable by ArcGIS Platform

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) GIS - current

SSE GIS has merged into POWER GIS

- SSE-GIS capabilities merged into POWER GIS (https://power.larc.nasa.gov/)
- Includes all available parameters for climatological values
- Interactive maps with geospatial visualization tools
    - Time series slider and swiping tools, etc.

Mission Partner Driving Enhancements

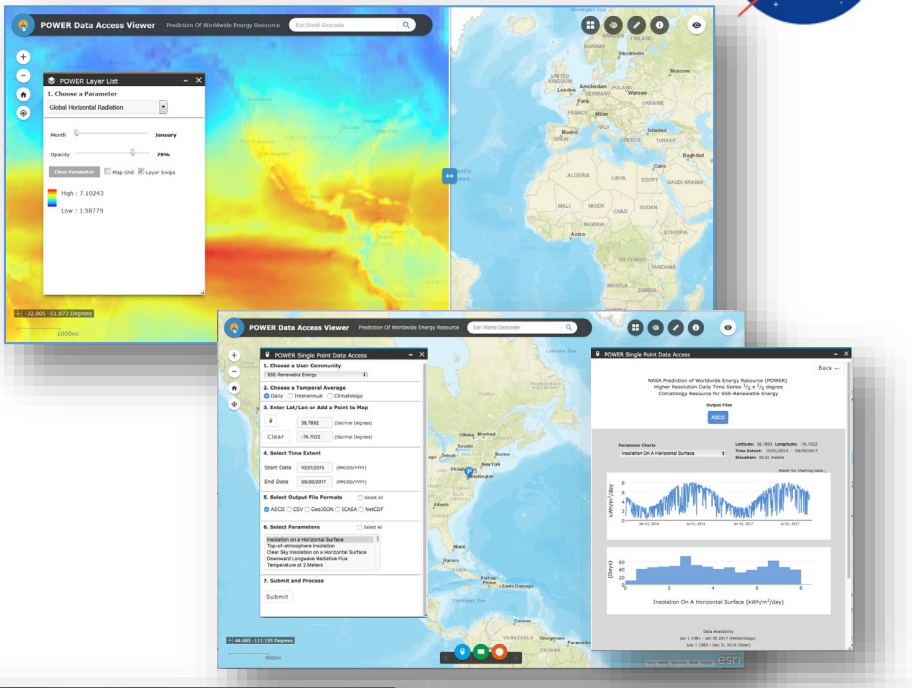
- RETScreen currently developing new web-based software using new POWER API with geoJSON response. (User base 500k+)

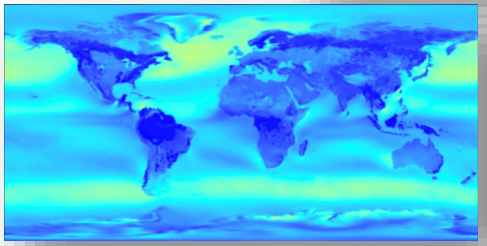
Graphical Data Access

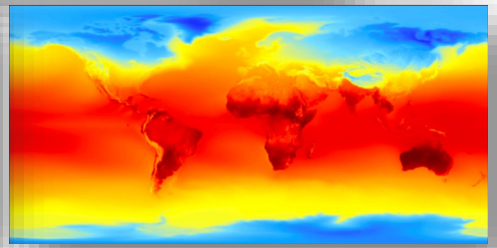
- ½ x ½ deg; within 5-7 days of observations
- Multiple parameters from FLASHFlux, GMAO, etc. available
- Parameters arranged by application community (i.e., renewable energy, buildings, agroclimatology)
- Multiple data output formats

Three Applications (initial version):

- Time series at a single point (daily, monthly, up to 30 years*)
- Regional times series (limited area)
- Global climatology (30 year*)

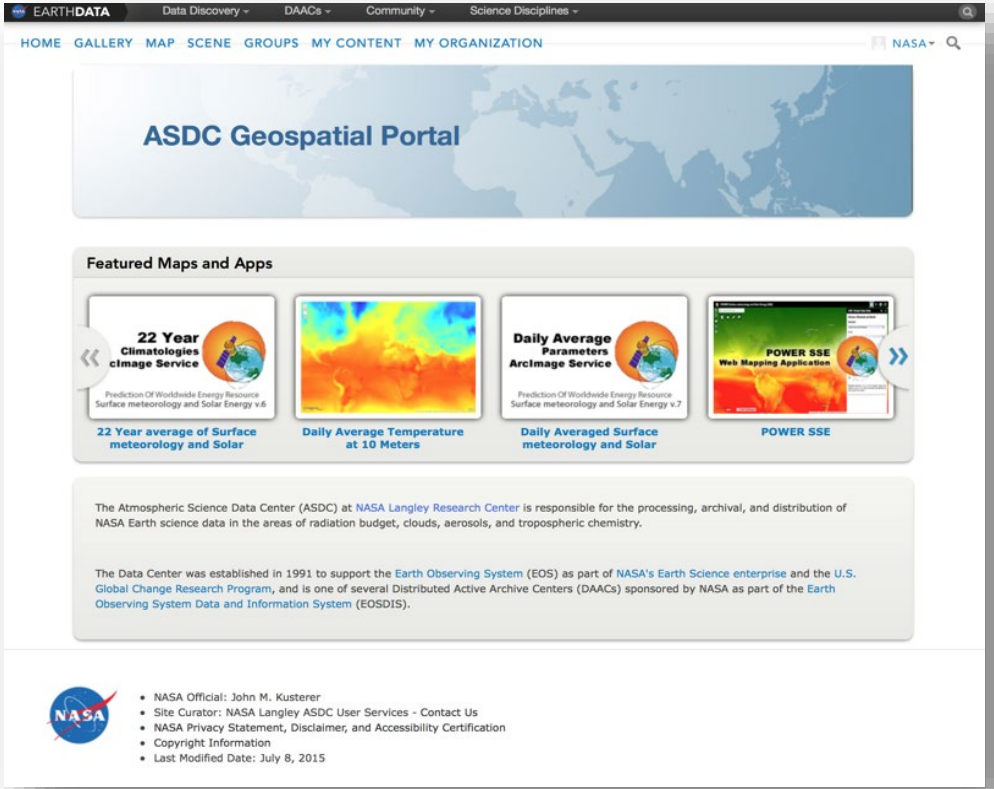






NASA ASDC ArcGIS Portal

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



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

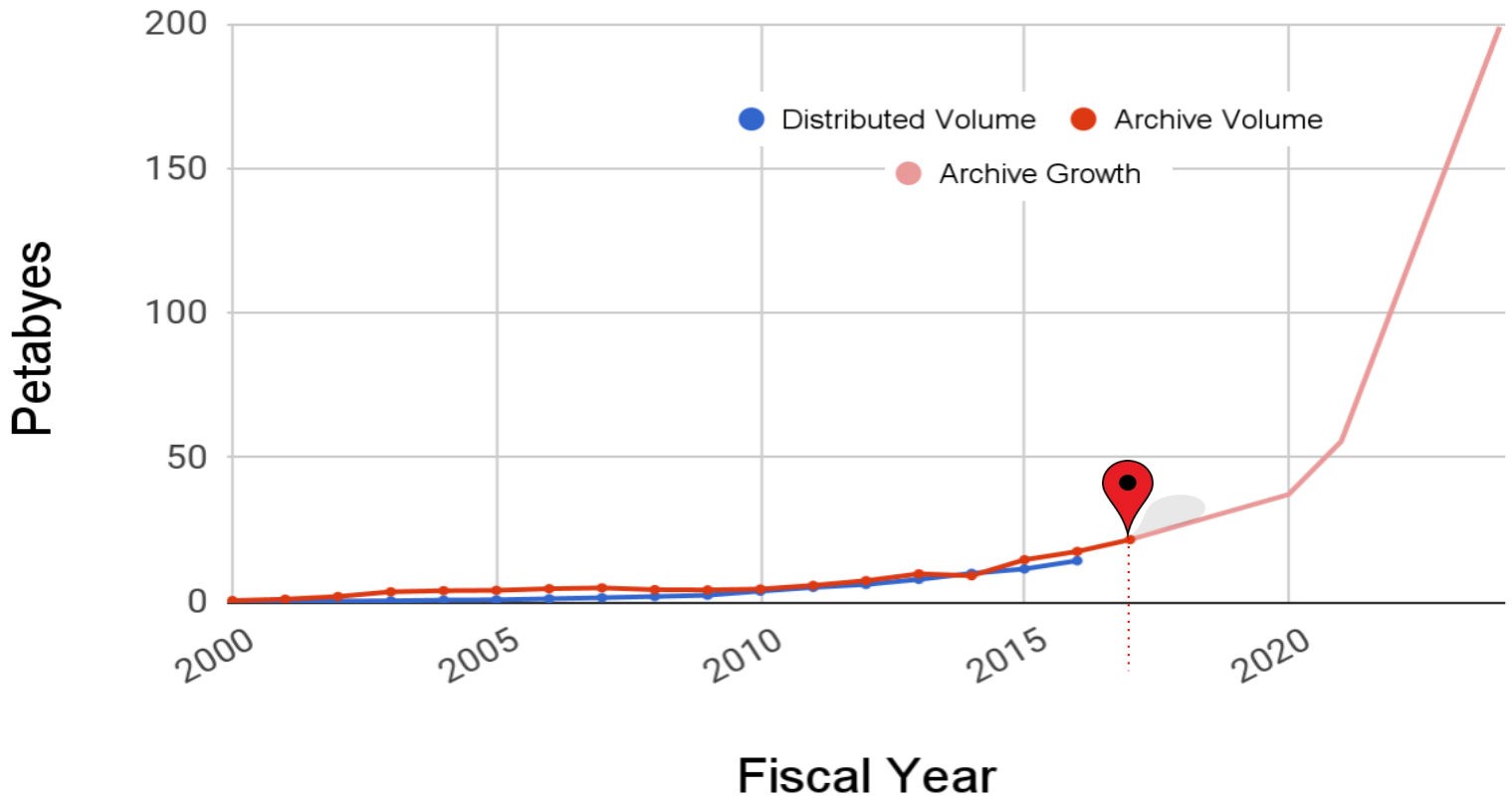
Examples of Variables Available for Initial Release (Daily and Long Term Averages over a 22 year Period):

- 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

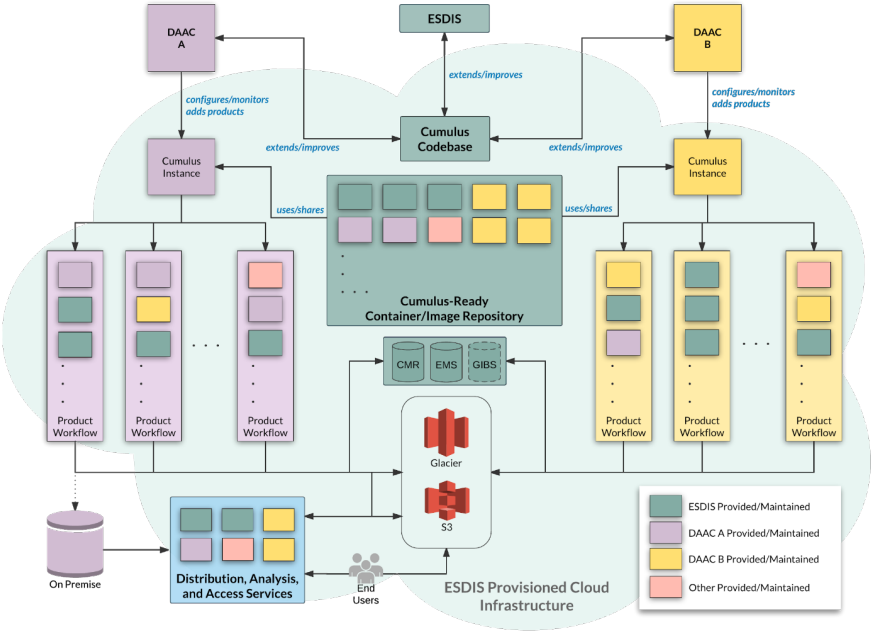
Data Rates Drive System Evolution



Moving to the Cloud

ASDC OpenShift and OpenStack On-Premise

EOSDIS CUMULUS in AWS



Next Steps

- Determining Best Formats for Cloud Storage (S3/CEPH):
  - Archive - HDF, NetCDF
  - Analysis - MRF, other?
- Deploying ArcGIS Enterprise in OpenStack
- Integrating services into NASA Common Metadata Repository (CMR), Earthdata Search, and ArcGIS Living Atlas
- Adding more data products to ArcGIS
- Additional Esri Story Maps and Apps

Delivering Usable and Scalable GIS Data and Services for Weather and Climate Information

NASA Atmospheric Science Data Center (ASDC)

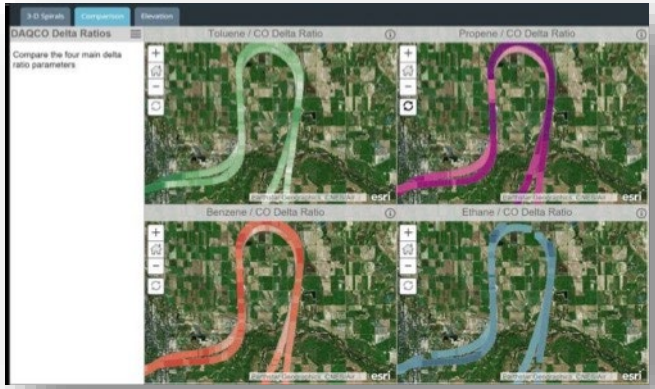
Matthew Tisdale, Booz Allen Hamilton (BAH), **matthew.s.tisdale@nasa.gov**

DISCOVER-AQ Proof of Concept

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

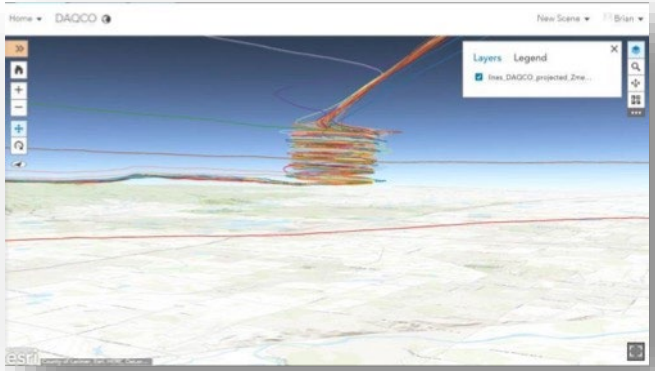
- NASA began a multi-year airborne field campaign in 2011 to distinguish between pollution high in the atmosphere and that near the surface where people live and breathe.

- 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.



Comparison Template

Story Map Journal



Web Scene

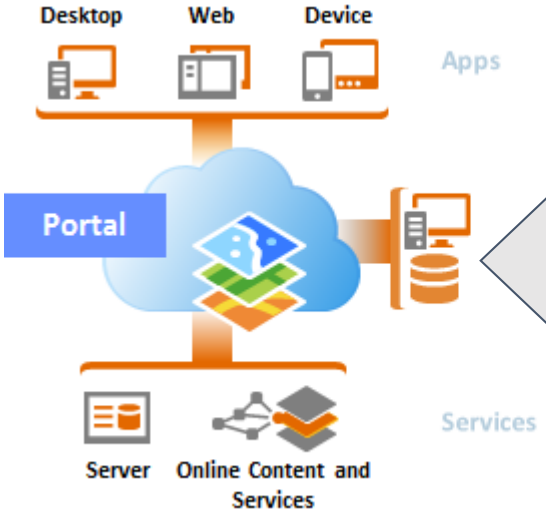
Addressing ASDC Geospatial User Driven Requirements

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 draft 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

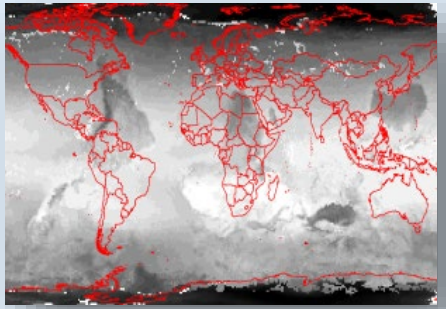
- Until recently, GIS applications were frequently unable to read EOS data product files or unable to properly interpret the internal data structures necessary to be visualized or analyzed.
- Many geospatial tools, including ArcGIS, GeoServer, MapServer, and Quantum GIS (QGIS), rely on GDAL, open source 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

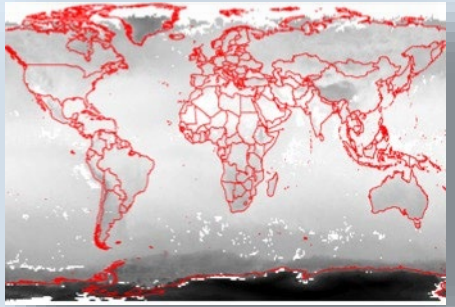
Image Displayed Inverted

MOP03TM.005 (HDF4): Retrieved Surface Temperature Night

Before



After



POWER/SSE GIS Lessons Learned Were Leveraged by New GIS Projects

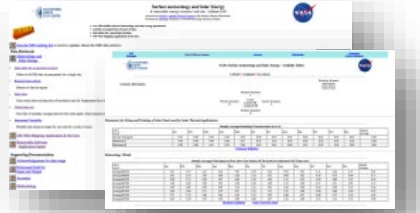
Prediction Of Worldwide Energy Resources (POWER) (https://power.larc.nasa.gov , https://eosweb.nasa.gov/sse)

- **COMMUNITIES**: Renewable Energy including Solar, Building Energy Efficiency and Sustainability, Agricultural
- **OBJECTIVE**: Integrate latest NASA-derived environmental data, analysis and modeling for enhanced management of energy production and energy efficiency systems.
  - *Target datasets for Electric Power, Renewable Energy, Energy-Efficient Building Design and Performance, and Biomass Crop Development Sectors*
- **GOALS**: Through partnerships, derive/validate/provide parameters relevant to industry needs, link to decision support, and transition capabilities when possible.

… - 2014

SSE Web Apps

- HTML Based web applications with manual latitude/longitude input, copy/paste HTML Tables, ASCII Downloads.
- Surface Radiation Budget (SRB) – Solar; GMAO GEOS 4 – Meteorology; 1x1 Spatial Resolution, 1983-2005; 22 Year Climatologies
- ***End Users requesting higher resolution, near real time daily time series and longer climatological products in formats other than ASCII***



2014-2016

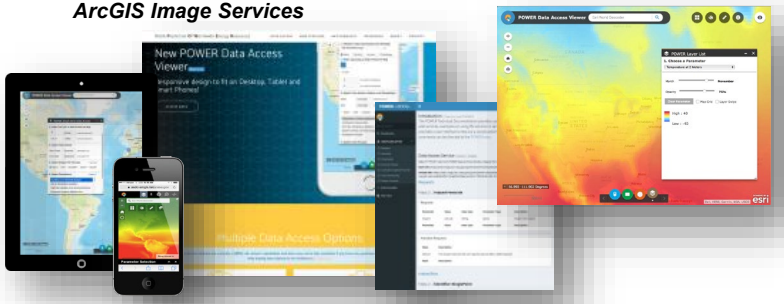
SSE GIS - ACCESS 36

- ***POWER/SSE continues project, collaborating with the ASDC, to provide direct access to source data sets, add GIS capabilities and web services for updated data products including low latency time series.***
- LaRC ASDC stood up "Web services" used to make the application platform and technology independent by following standards (i.e. DAP, WCS, WMS, etc.), promoting interoperability

2016 - …

POWER GIS (beta)

- **Implementing lessons learned and ArcGIS architecture put in place by A36** to geospatially enable entire POWER data archive for access to growing Applied Science users.
- Increased spatial/temporal resolutions: SRB, CERES FLASHFLUX – Solar, GMAO MERRA-2/GEOS 5.12.4; ½ x ½ Spatial resolution, Near Real Time Daily Time Series, 30 Year Climatological Averages
- ***(Phase 1) Beta product providing data in ASCII, CSV, geoJSON, NetCDF4, ICASA, GeoTiff and (Phase 2) ArcGIS Image Services***



Atmospheric Science Data Center

NASA POWER Data Processing & Distribution

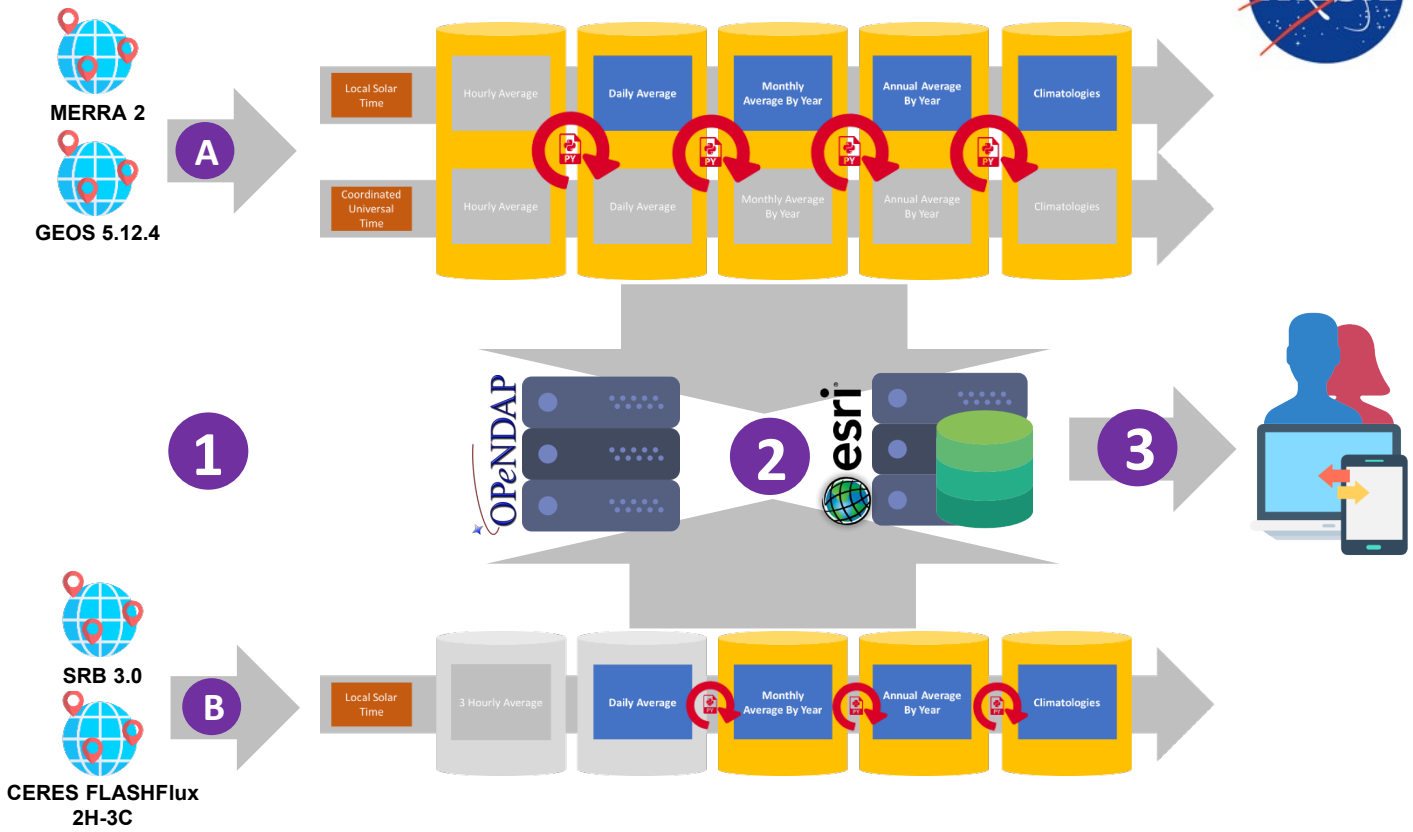
1

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)

Delivering Usable and Scalable GIS Data and Services for Weather and Climate Information:

Esri Living Atlas of the World

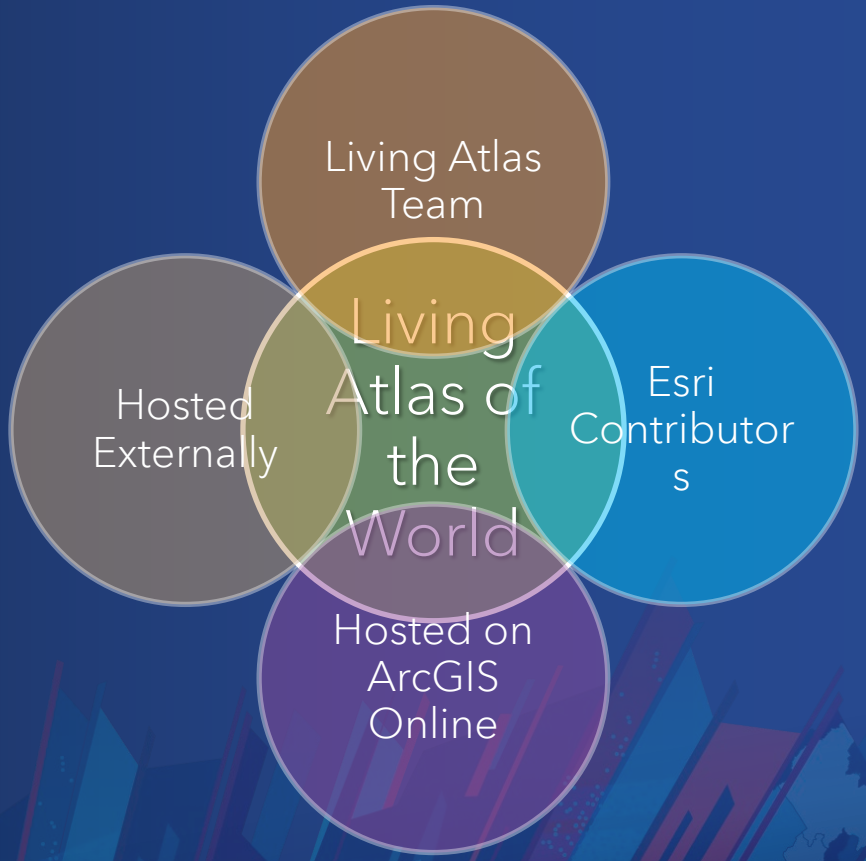
Dan Pisut

dpisut@esri.com

2019 ESRI
FEDERAL GIS CONFERENCE
WASHINGTON, DC

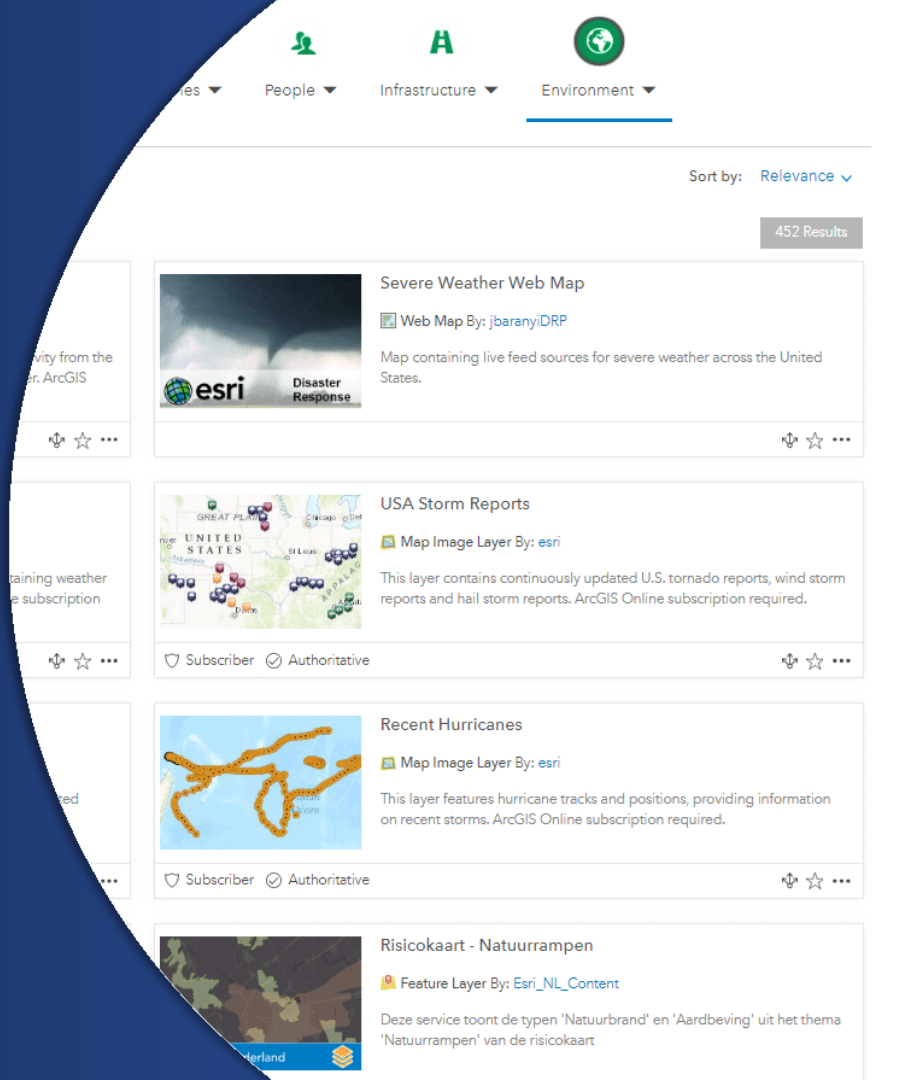
The Living Atlas of the World receives content and nominations from a variety of sources, including Esri, those hosting services in ArcGIS Online, and those running their own ArcGIS servers.

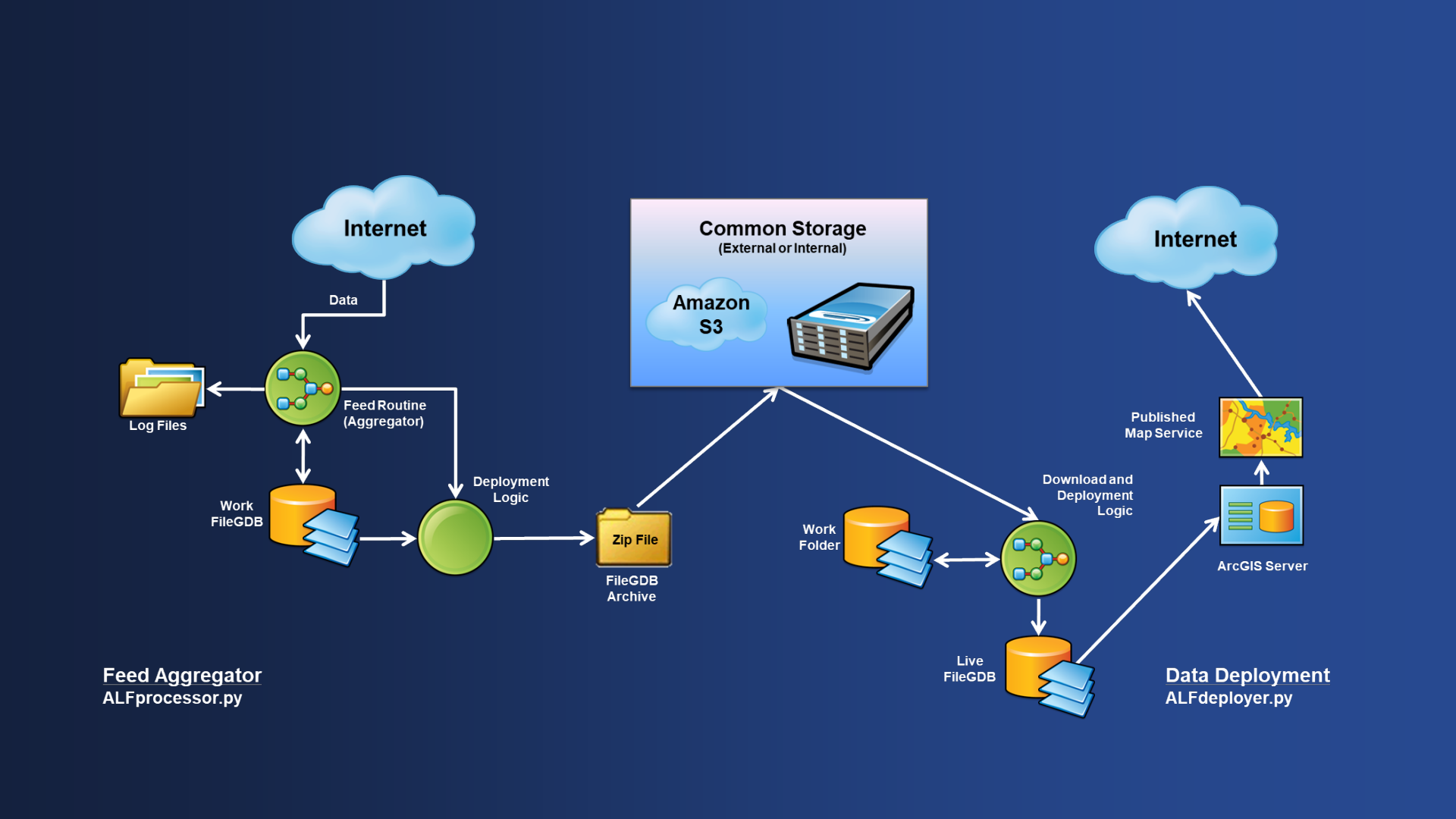
Contributing data the Living Atlas not only improves the findability of your data, but also creates added value by allowing it to be merged with related data from other sources.



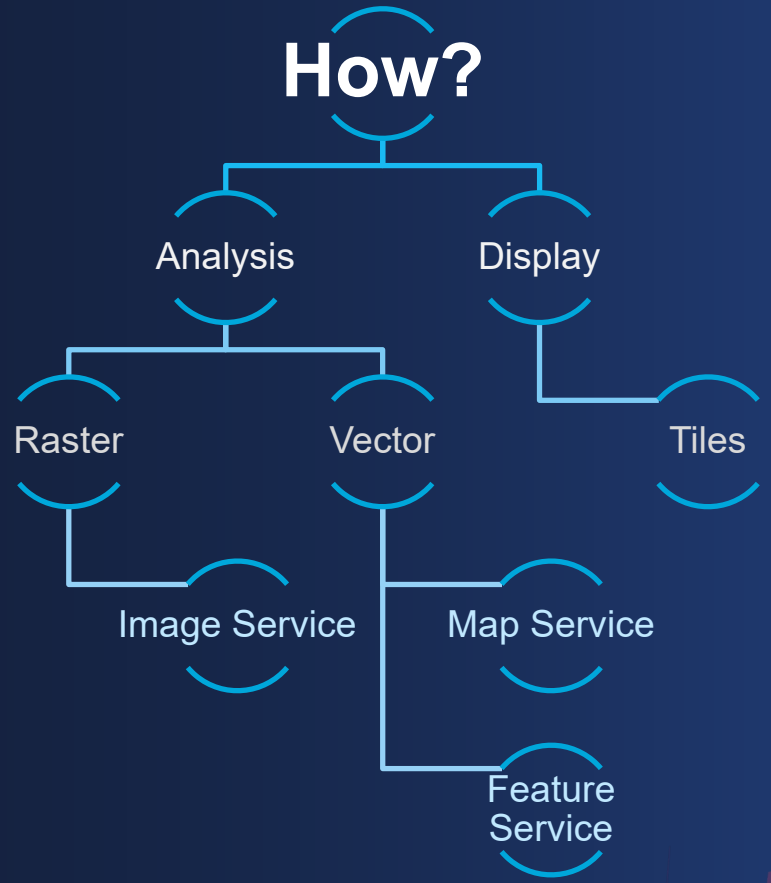
- Live Feeds: real-time updating
  - National Weather Service layers
  - Earthquakes
  - Wildfire
- National Water Model
- GLDAS monthly hydrology reanalysis
- National Drought Monitor
- Sea Surface Temperature
- HYCOM
- Stream Gauges

- CMIP5 temperature and precipitation
- GHCN-M




Internet
Data
Log Files
Feed Routine
(Aggregator)
Work
FileGDB
Deployment
Logic
Zip File
FileGDB
Archive
Common Storage
(External or Internal)
Amazon
S3
Internet
Published
Map Service
Download and
Deployment
Logic
Work
Folder
ArcGIS Server
Live
FileGDB
Feed Aggregator
ALFprocessor.py
Data Deployment
ALFdeployer.py

How?



Plan out the How, Where, and Who of each service to optimize the output

You may need more than one output to satisfy the demands

Vector

	Feature Service	Map Service	Tile Service
Multiple Layers	✓	✓	✓
Pop-Ups	✓	✓	
Change Symbology	✓	✓	✓
Geoprocessing	✓		
Editing	✓		
Hosted	✓		✓

Increasing Performance

But are you really ready to publish the service?

- How optimized are the fields? Is floating point necessary? Can you convert to an integer? Realistic resolution/tolerance?
- Are there meaningful field aliases?
- Did you enable query?
- Did you enable editing symbology?
- Did you enable copying?
  - Copy Feature or Copy Raster geoprocessing tools
- Is the symbology intuitive?

Water Wells (CWI Wadena County): NEWHOUSE, ARCHIE

RELATEID	0000530686
COUNTY_C	80
UNIQUE_NO	00530686
WELLNAME	NEWHOUSE, ARCHIE
TOWNSHIP	138
RANGE	34
RANGE_DIR	W
SECTION	23
SUBSECTION	CBBBAD
MGSQUAD_C	255C

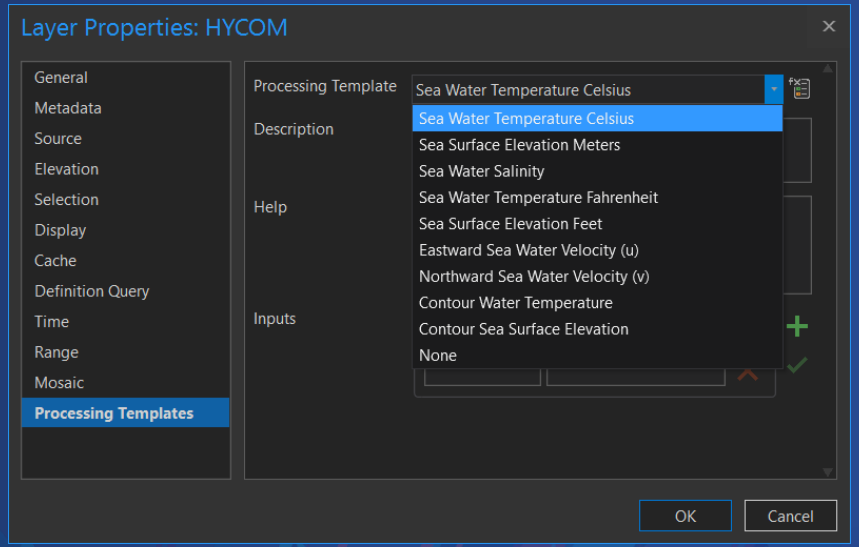
Raster

	Image Service	Tile Service
Multiple Layers		✓
Pop-Ups	✓	
Change Symbology	✓	
Geoprocessing	✓	
Editing	—	
Hosted		✓

Increasing Performance

Optimizing the Raster

- Does the intended use match the projection?
- Is the projected resolution and tolerance realistic?
- Enable query or just use a tile service
  - Scientific (value) vs cartographic renderers (RGB)
- Have you tried using Raster Templates?
  - Multiple variables
  - Pre-build time aggregation
  - Multiple symbologies



Exploiting scalable Imagery and Scientific Data: Weather and Climate Domain: How we go about it with ArcGIS Platform

What are the best practices on working with the scientific data and model output that can be enabled from Research to Operations and what are the current works, challenges and opportunities?

Web Services, Web enabling your data and services?

Current way to serve the data and information product that are consumed by large community of scientists, policy makers and industries?

Enabling the innovation through enabling the Scientific Data?

Interoperability ?

Build once and reuse?

esri

THE SCIENCE OF WHERE