Using Satellite Data in GIS

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Adapted from Michael Soracco
NOAA Affiliate for NOAA CoastWatch
https://coastwatch.noaa.gov

Satellite Data & GIS Training

- Uses ESRI ArcGIS Pro, but techniques generally work with QGIS and other GIS software
  - ESRI has moved away from support for ArcMap
  - Using ArcGIS will generally require a license

- Updated from CoastWatch Satellite GIS training in 2021
  - EDC tool, developed for ArcMap, is not available for ArcGIS Pro

- This training was created using ArcGIS Pro 3.3.2

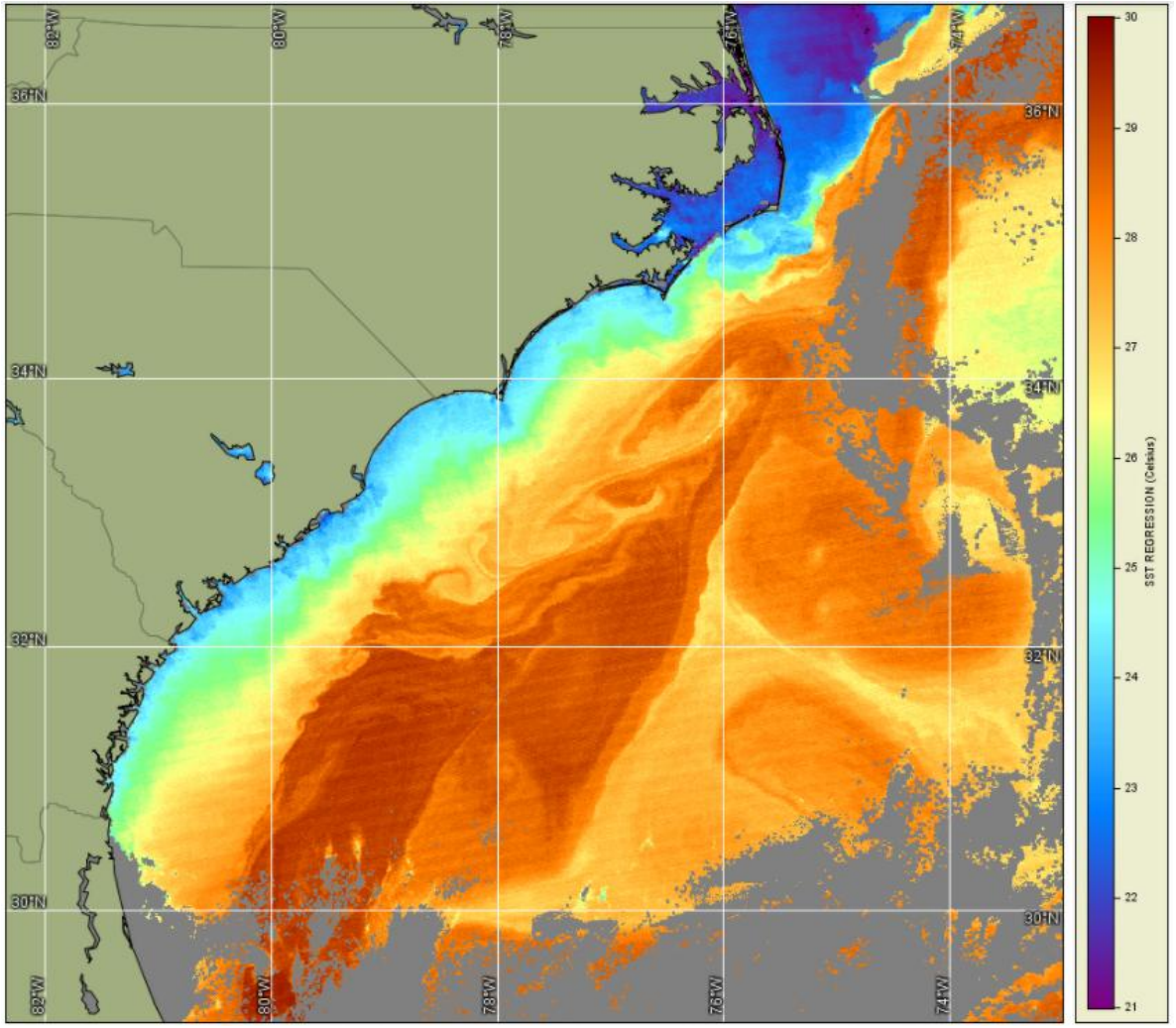
- The current version of ArcGIS Pro is 3.6 (+)

Data

Using Satellite Data in GIS

Overview

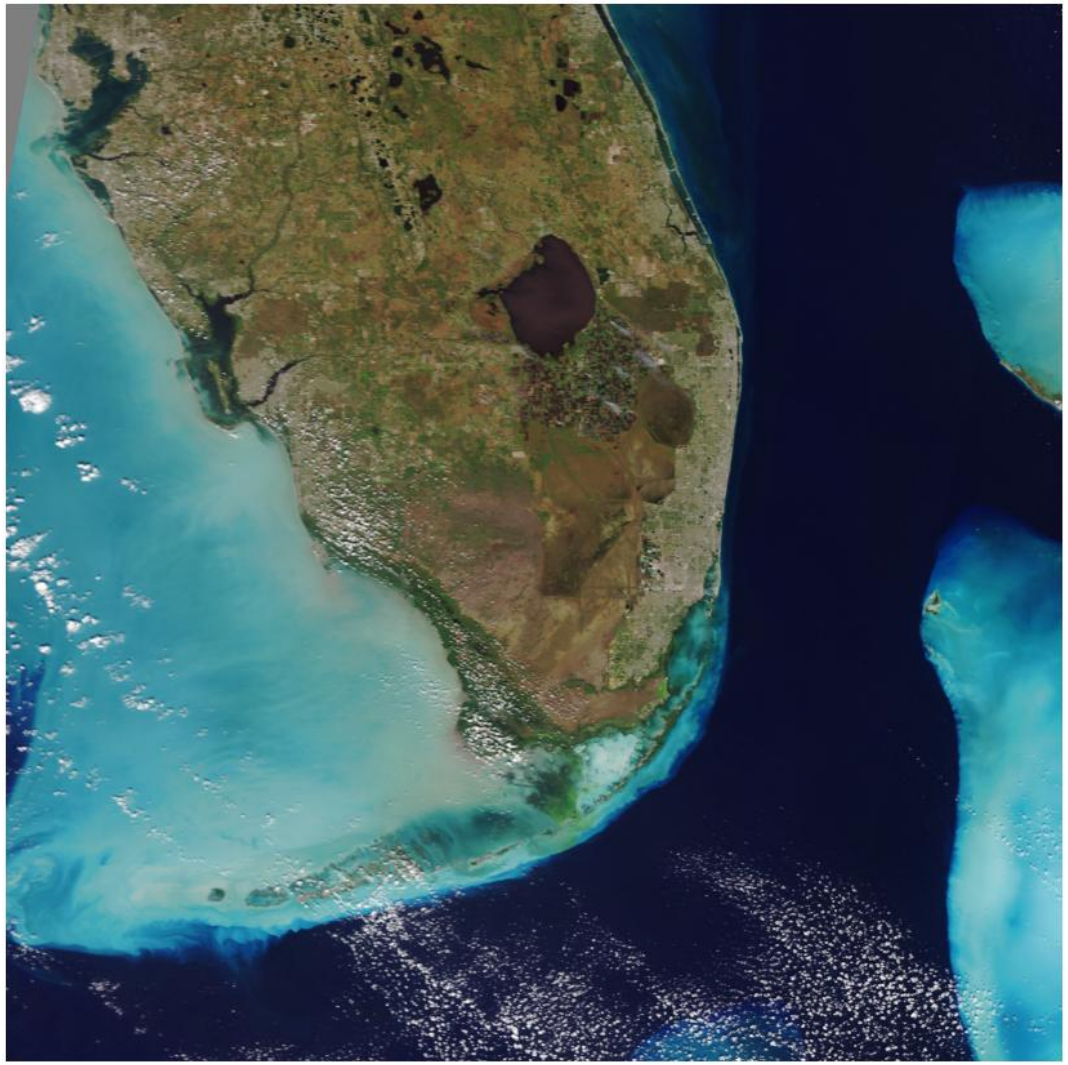
- Imagery
- Data
- Considerations and preparations



S-NPP VIIRS SST Image

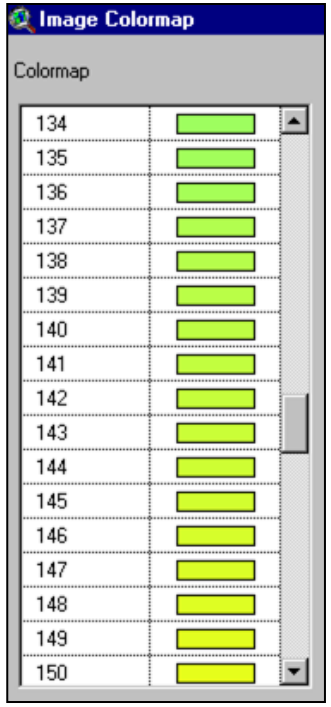
Satellite Imagery

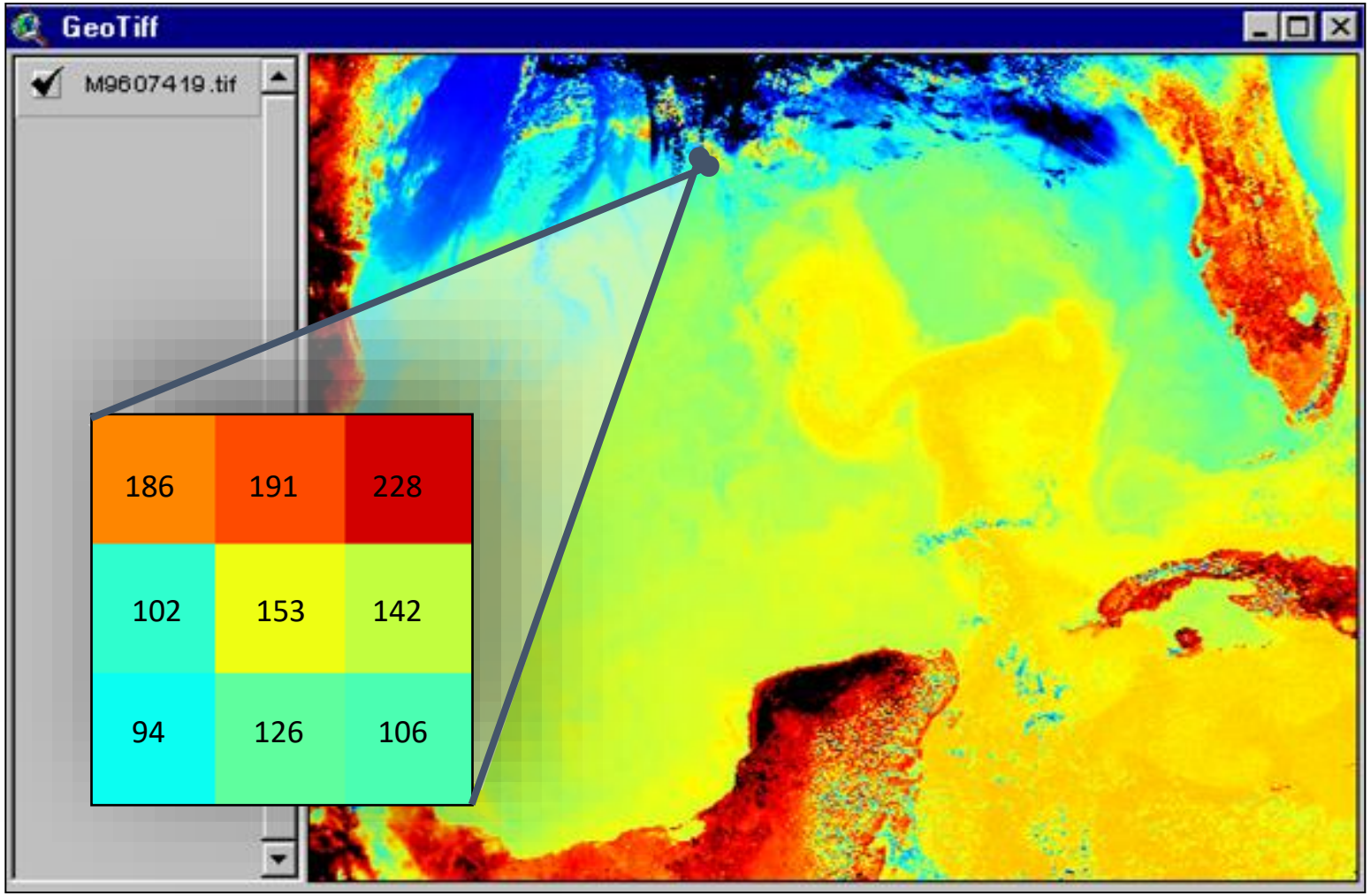
- Visualization
- Scaled data
- Formats
  - PNG, JPEG, GeoTIFF



S-NPP VIIRS True Color Imagery

8-bit Image Example

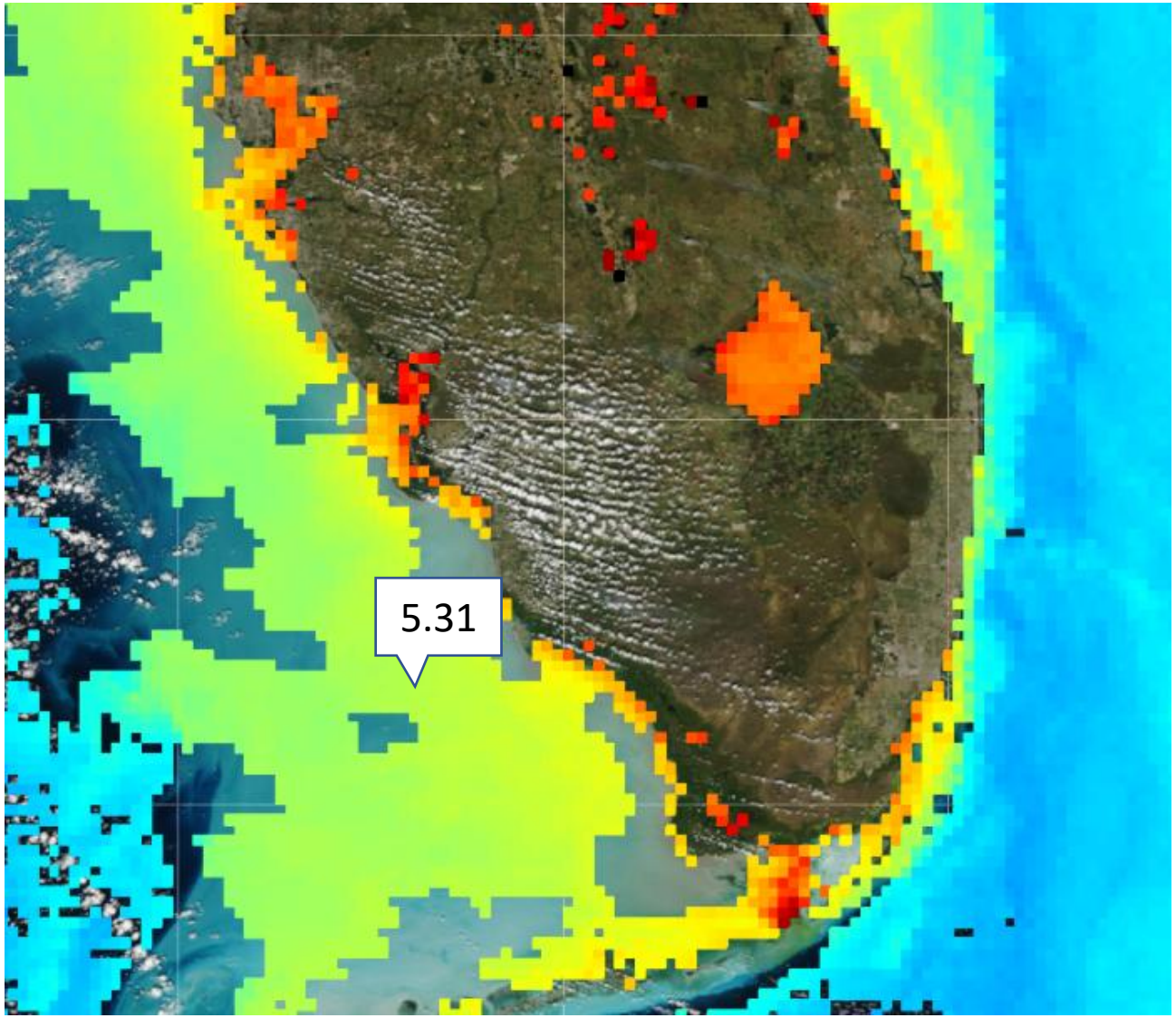




8-bit (0-255) image of Sea Surface Temperature stored in GeoTIFF

Satellite Data

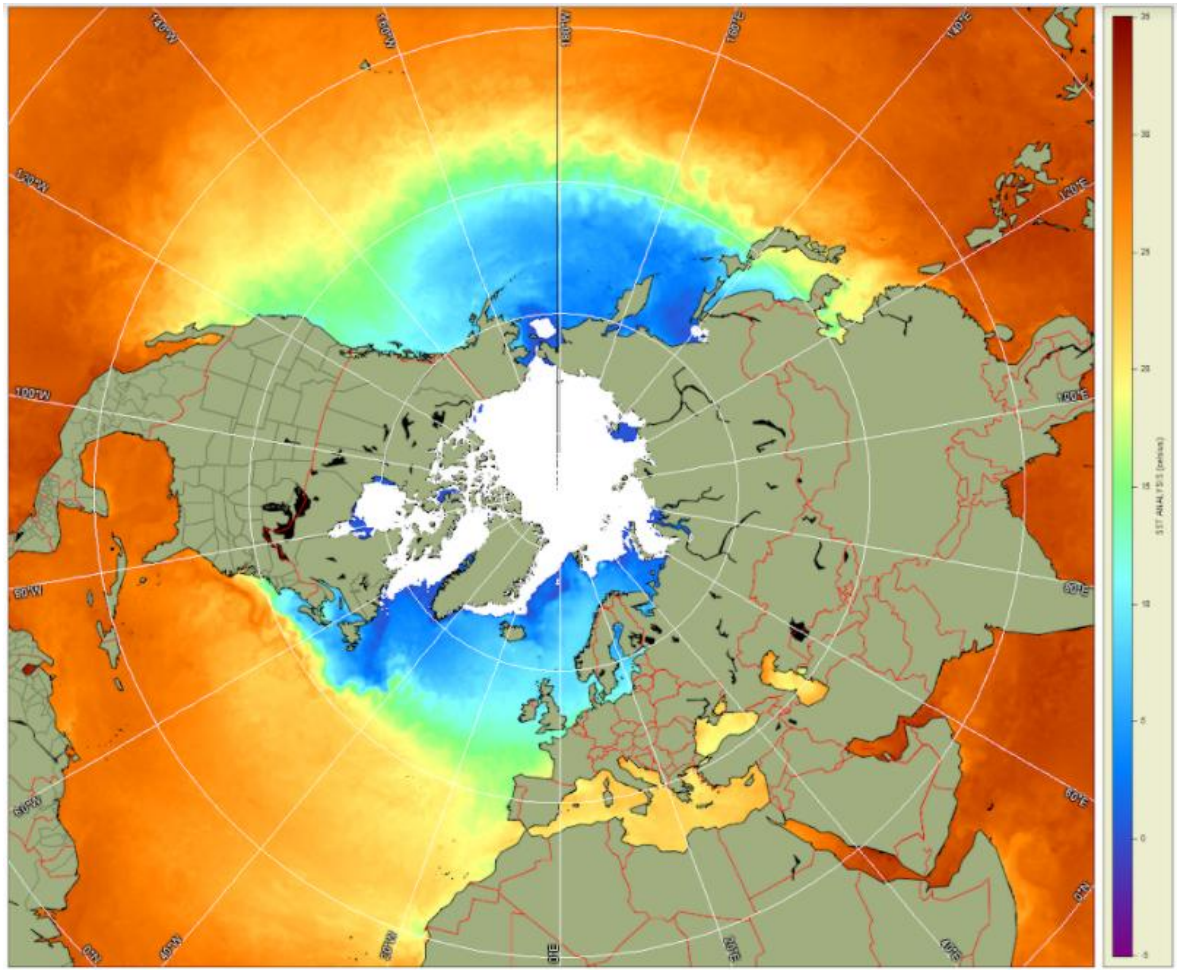
- Calculations
- Values
- Formats
  - HDF, NetCDF, 32-bit GeoTIFF



S-NPP VIIRS Chlorophyll-a Science Quality

Data Considerations

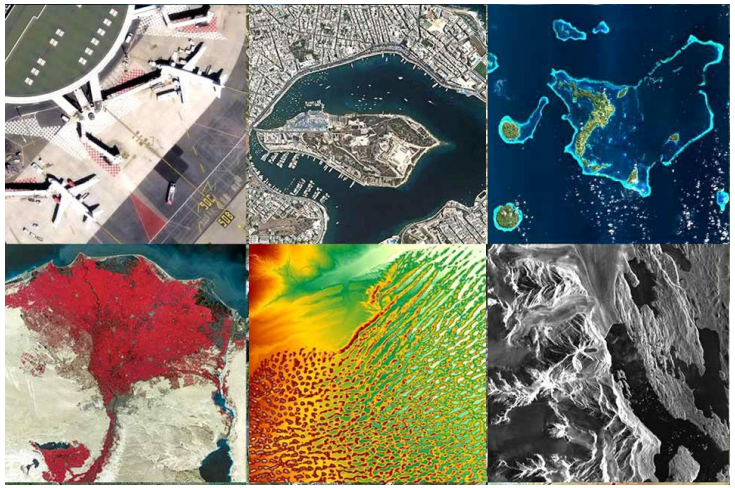
- Metadata
- Format
- Resolution
- Projection
  - Coordinate system
  - Datum
- Preparation

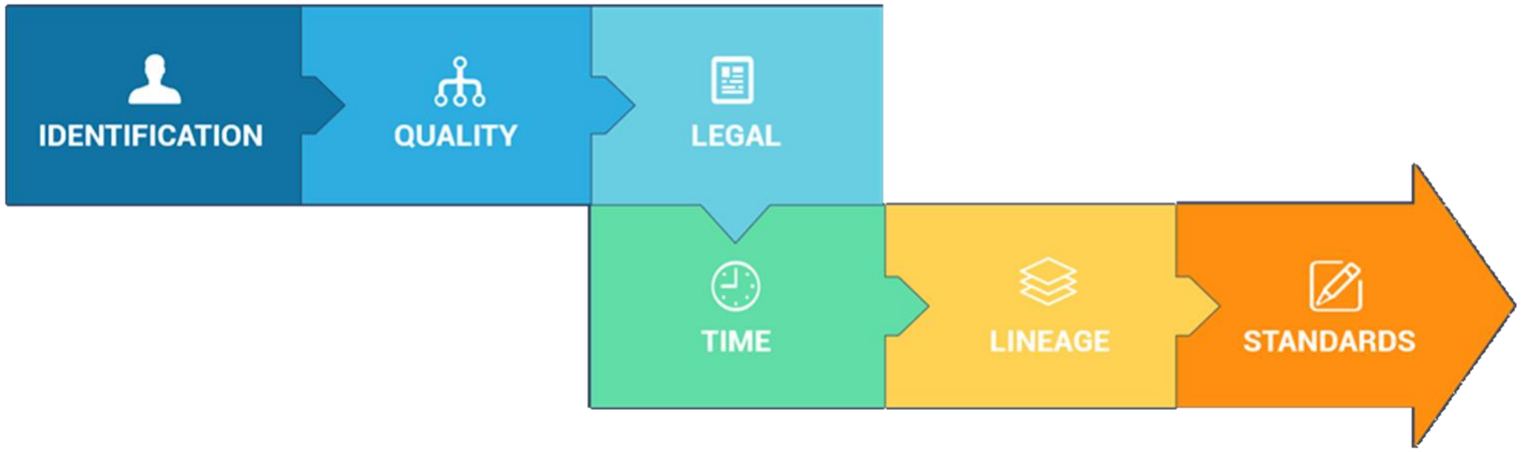


NOAA Blended SST in North Polar Stereographic Projection

Metadata

- Information about the data – usually standardized
- Methods used in collection / processing
- Custodian / Point-of-contact





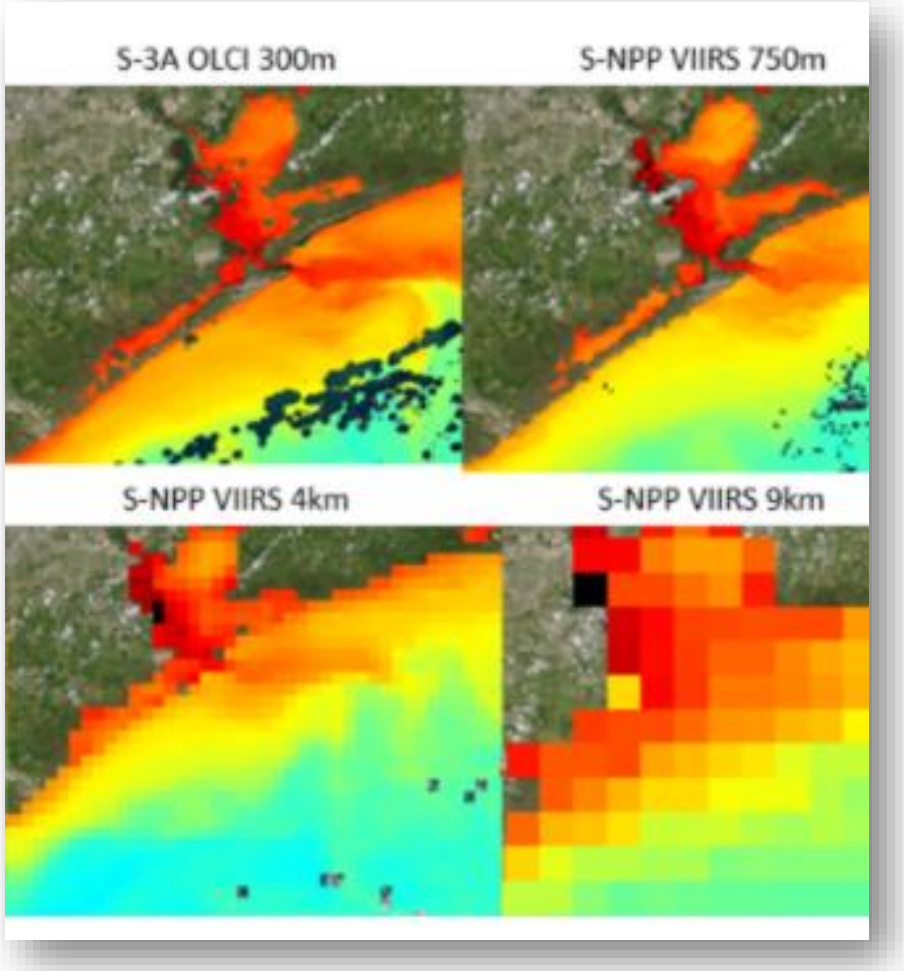
Data Formats

- Level of embedded metadata – ‘self-describing’
- Data storage
  - Scaling / Offset
  - Compression
- Geolocation Information
  - Tags
  - Attributes
- Complexity and Compatibility

HDF
NetCDF
TIFF
GeoTIFF
CSV
JPEG

Product Resolution

- Spatial resolutions
  - meters to hundreds of kilometers
- Temporal resolutions
  - minutes to days, weeks, or months
- How are data combined?

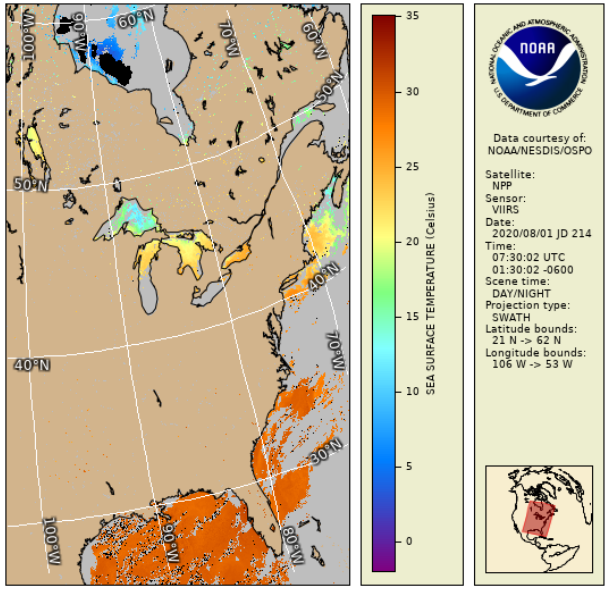


Resolutions from various chlorophyll-a products

Projections

- Satellite sensor view (Swath / Level-2)
  - Irregularly/nonlinearly spaced
  - May include unique structure based on sensor
  - Geolocations with respect to Ellipsoid and Datum

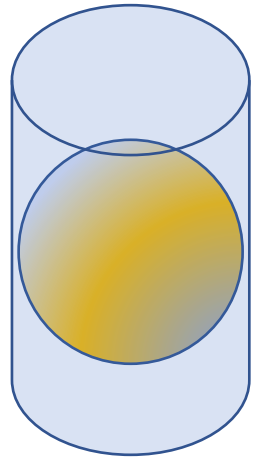
- Mapped (Gridded / Level-3, -4)
  - Coordinate system
  - Locations with respect to Ellipsoid and Datum



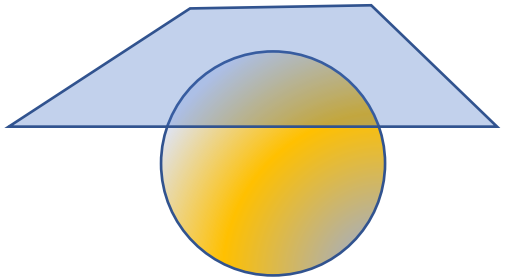
Projections

- Coordinate Systems
  - Projection constructs
  - Preserves one of the following (not all are listed):
    - Conformality (Shape)
    - Area
    - Direction
    - Distance
- Chosen based on application/scale
- Spatial distortion results from mapping

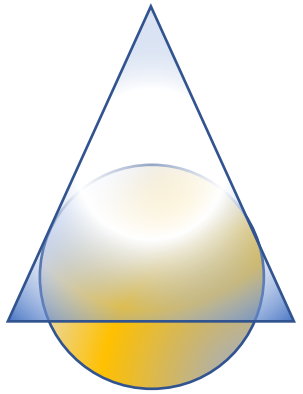
Map construct types
(not all are shown)



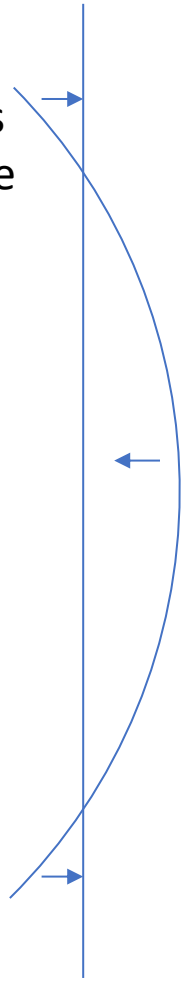
Cylindrical



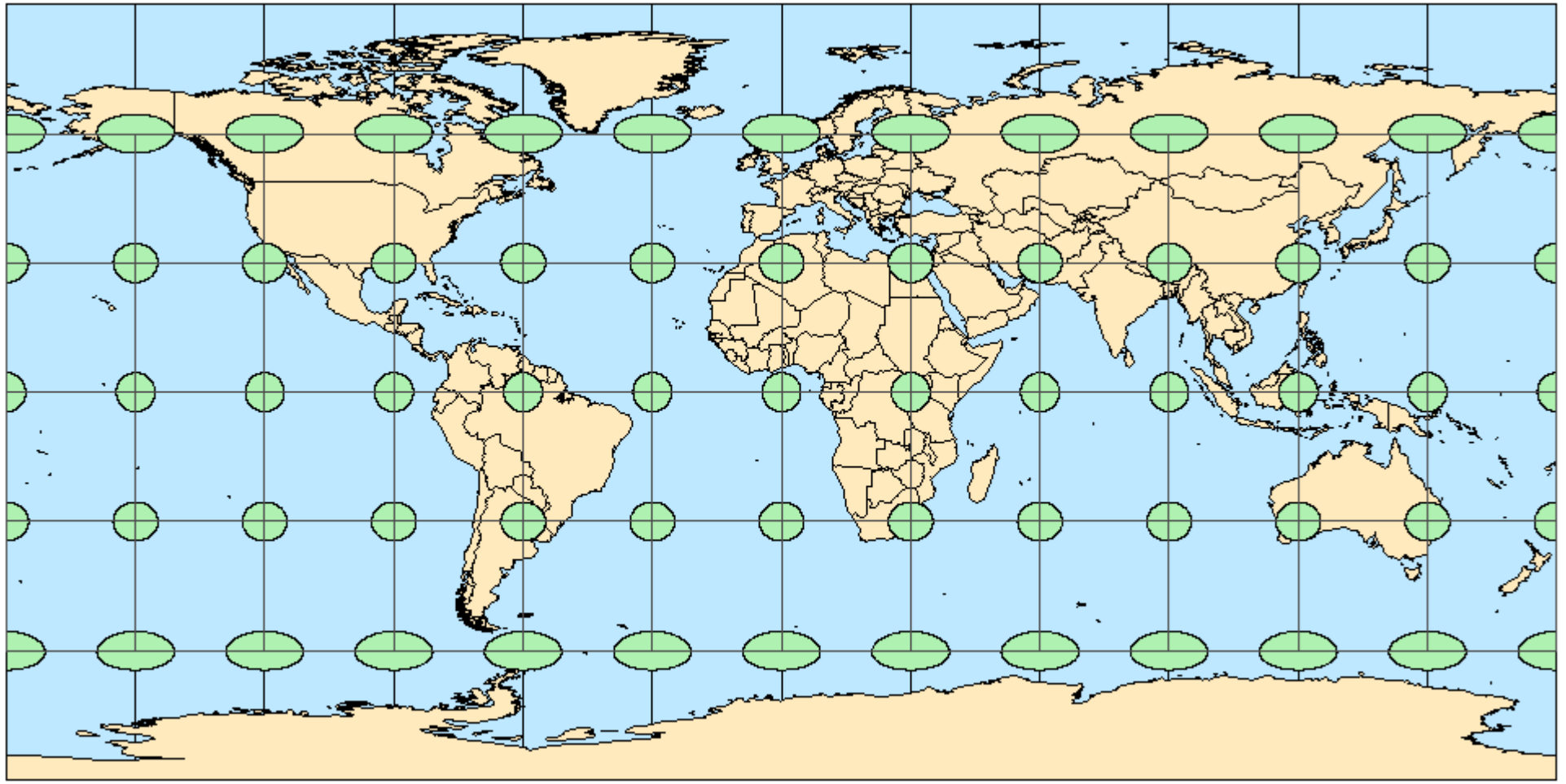
Azimuthal



Geographic (WGS84)

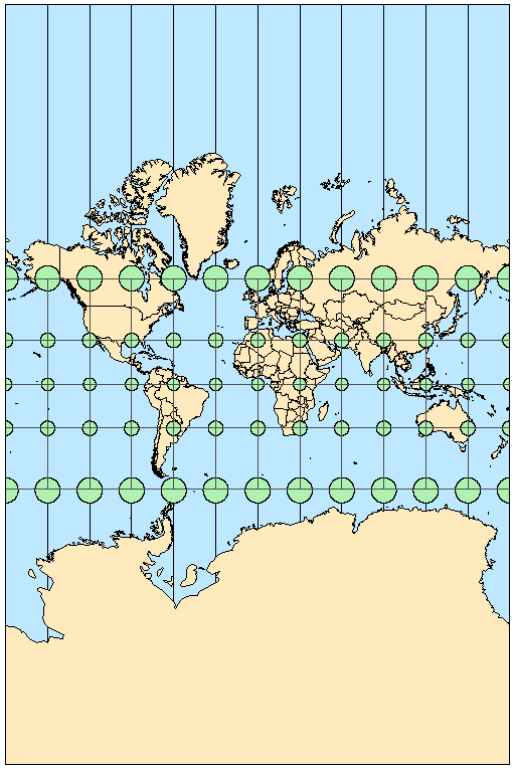


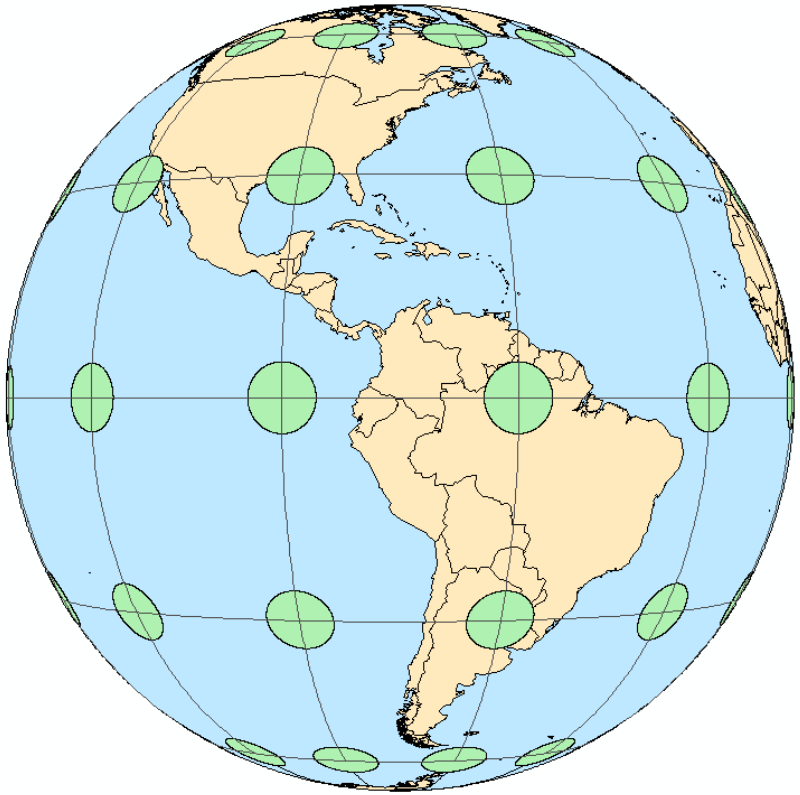
Projection Plane

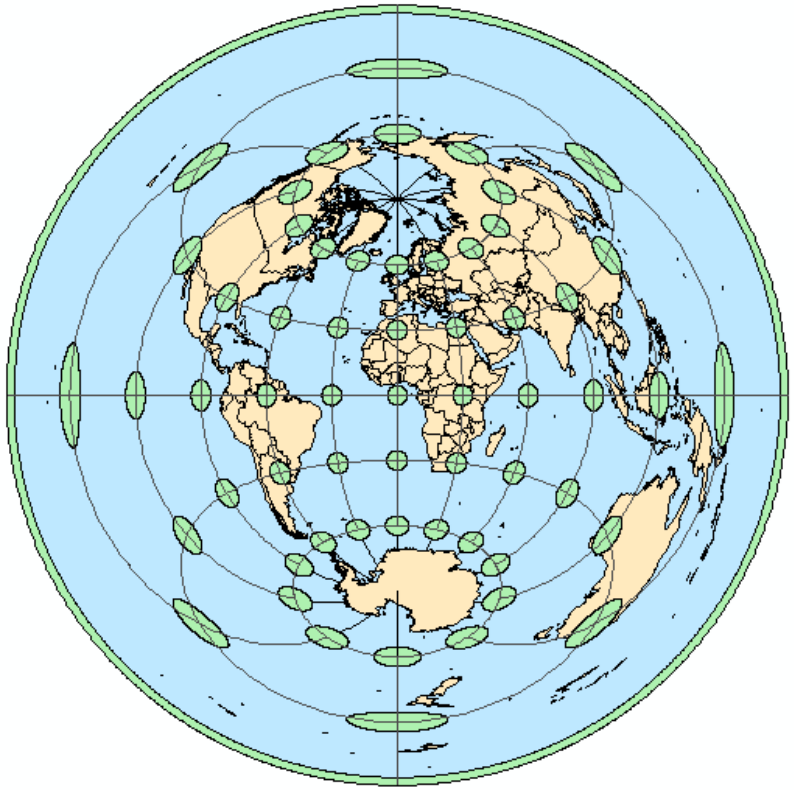


Tissot's indicatrix of circles illustrating distortion across a map

Mercator (WGS84) Equidistant GOES-16 (GRS80) Azimuthal



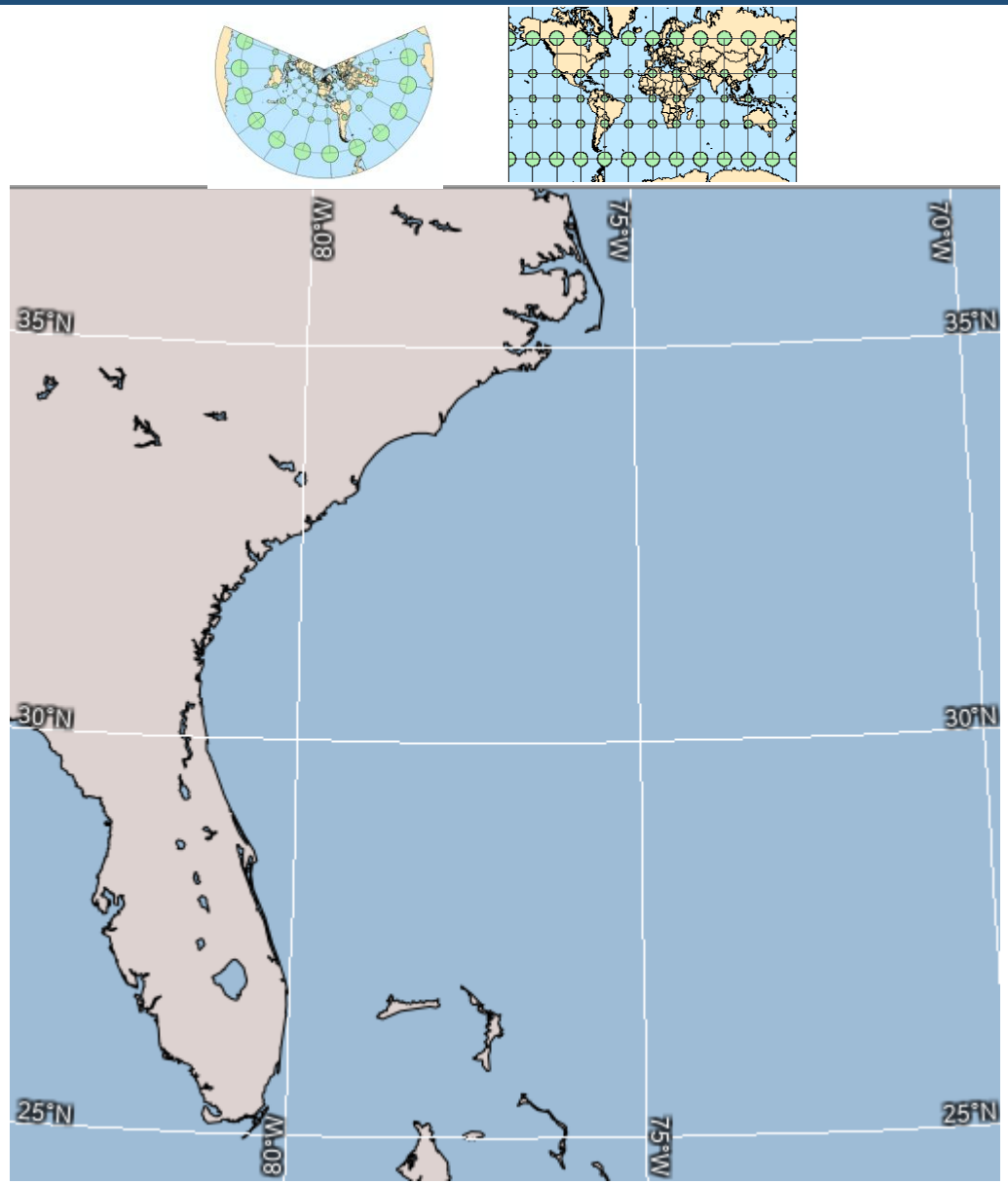




Tissot's indicatrix of circles illustrating distortion across a map

Projections - Conformality

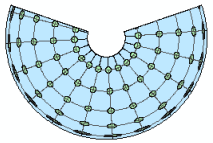
- Shape is preserved
- Representative of actual feature
- Useful for preserving shape
- Lambert Conformal Conic
- Mercator
  - Straight lines have constant bearing

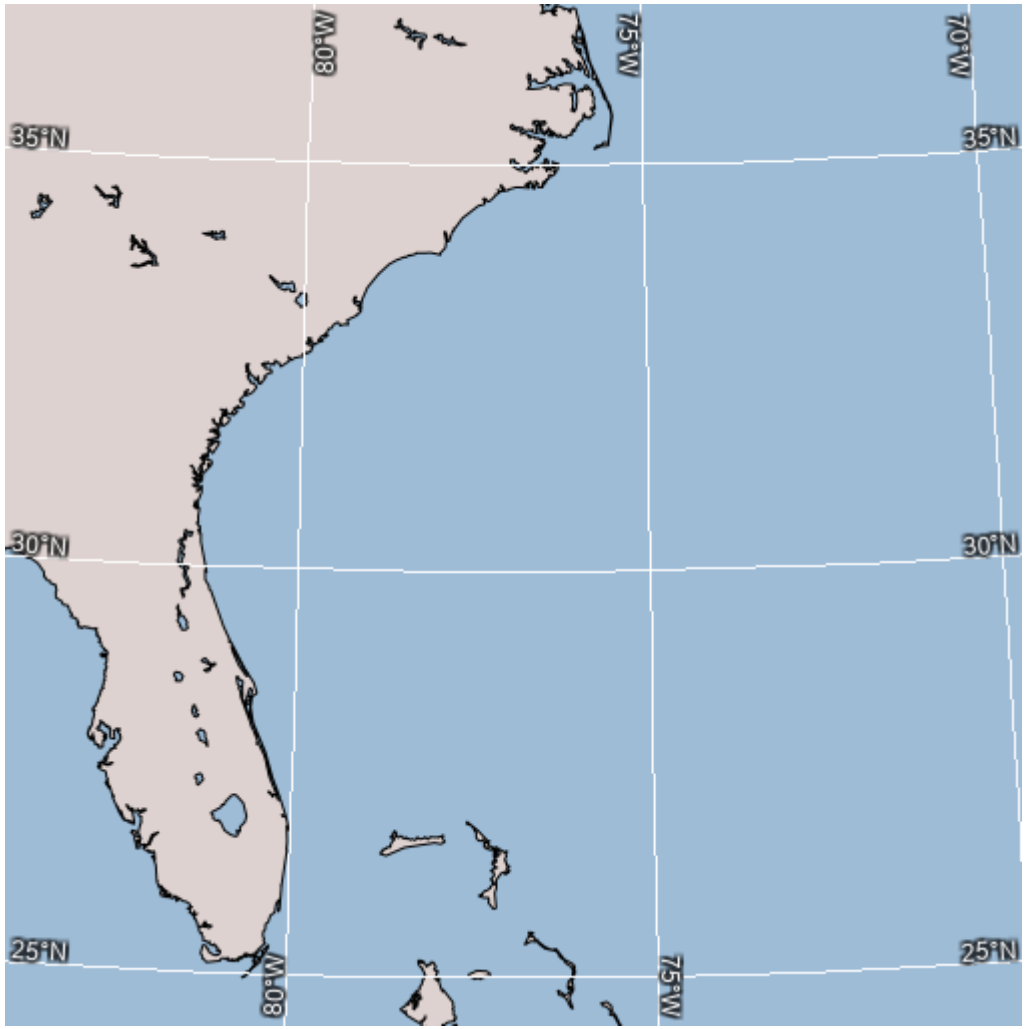


Lambert Conformal Conic preserves shape

Projections - Area

- Area is preserved
- Area measurements consistent across map
- Useful for comparison

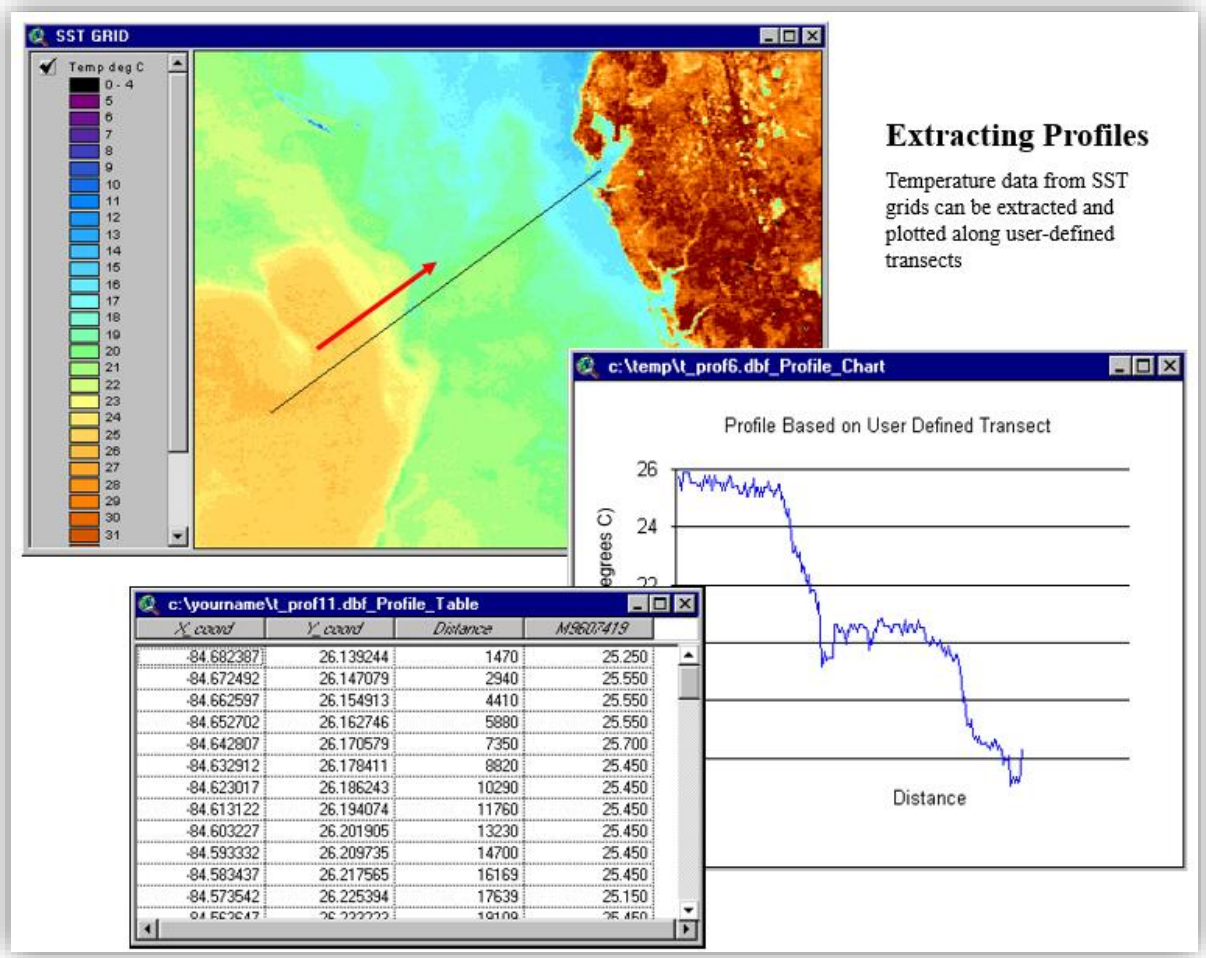




Albers Equal-area preserves area

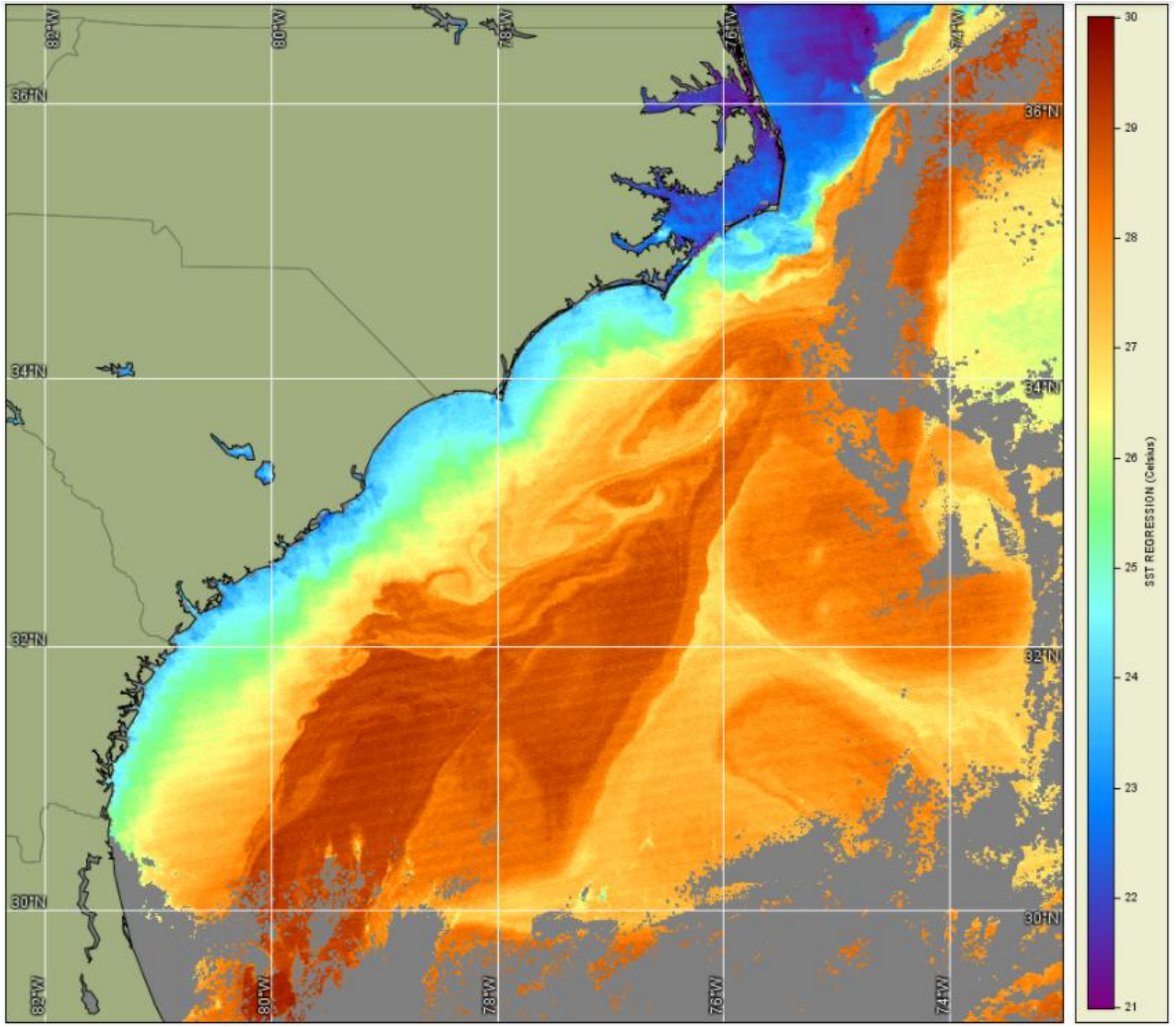
Data Preparations

- Reprojection required?
- Metadata complete?
- Values accessible?
- Compositing or binning required?



Summary

- Imagery
- Data
- Considerations and preparations



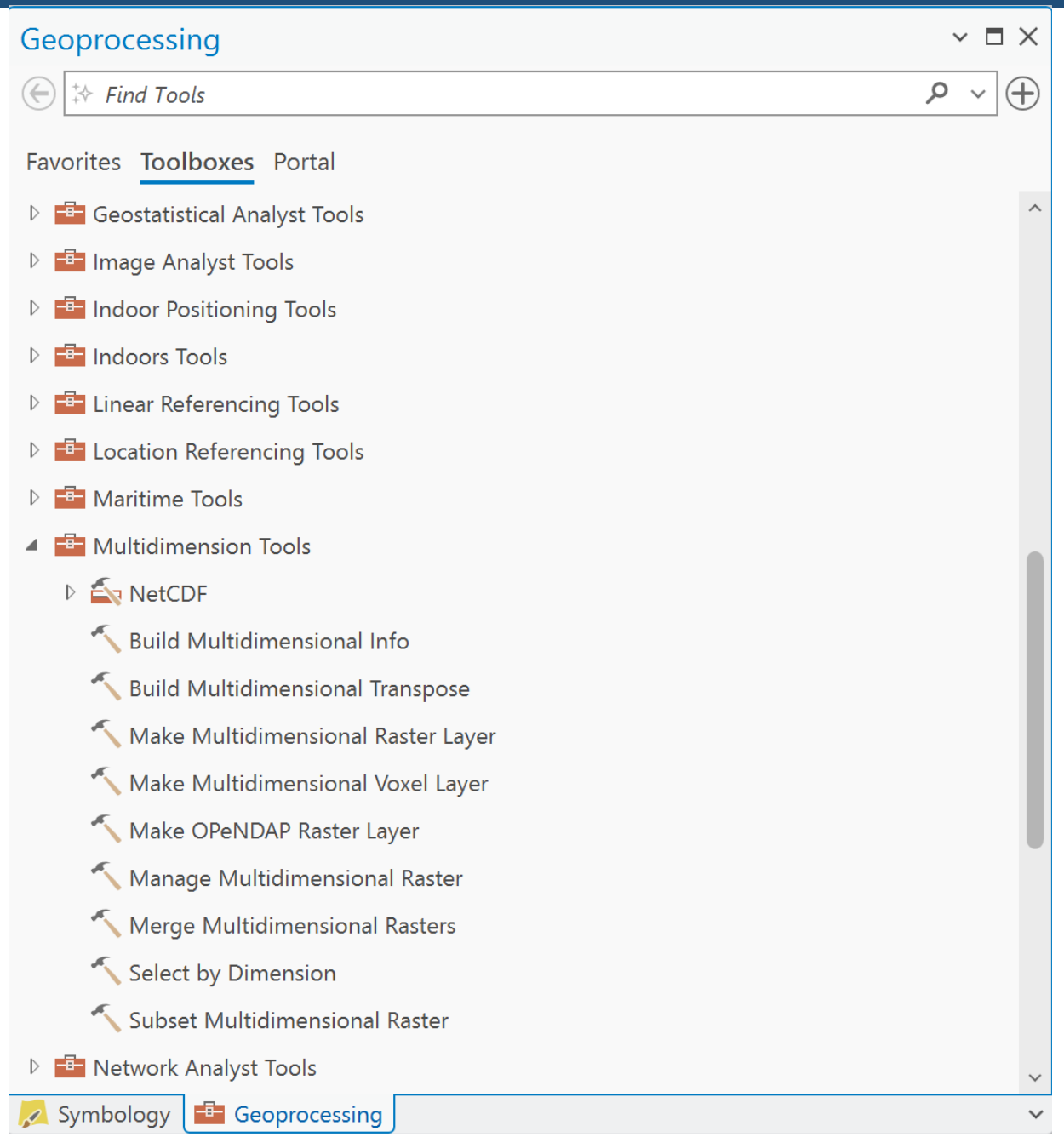
S-NPP VIIRS SST Image

GIS

Using Satellite Data in GIS

Overview

- Tools & methods
- ArcGIS built-ins & add-ons
- External utilities



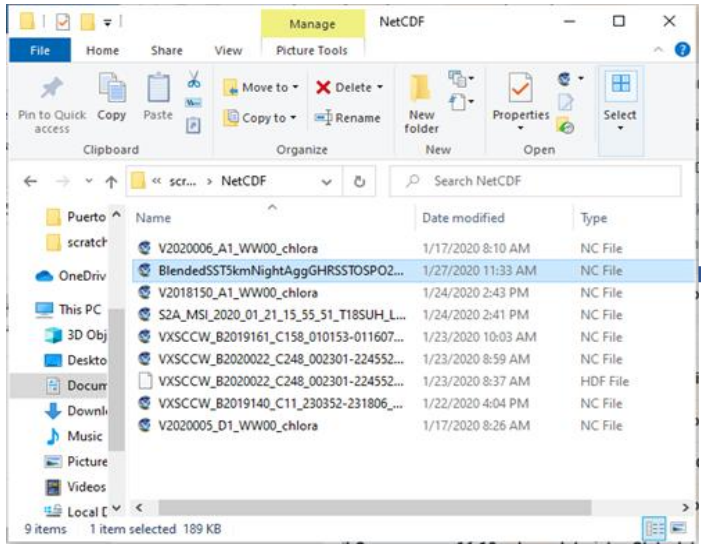
Useful Extensions / Add-ons

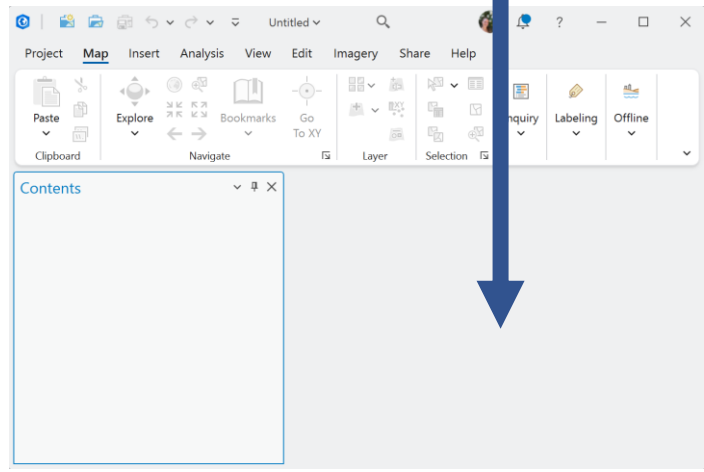
- ArcGIS Spatial Analyst (license) – ESRI
  - Raster tools

- CoastWatch Utilities
  https://coastwatch.noaa.gov/cwn/data-access-tools/coastwatch-utilities.html
  - Read data files (NetCDF and HDF format)
  - Graphical tools for interactive data viewing
  - Command line tools for data processing
    - cwexport, cwsample, cwrender

Methods to add Satellite Data

- WMS and WCS
- Drag-n-drop
  - GeoTIFF, HDF, NetCDF, JPEG2000
- Multidimension Toolbox
  - Make OpenDAP Raster Layer (Geoprocessing → Multidimensional Tools)
  - Make NetCDF Raster Layer (Geoprocessing → Multidimensional Tools)
- Programmatically
  - Python, Jupyter Notebooks

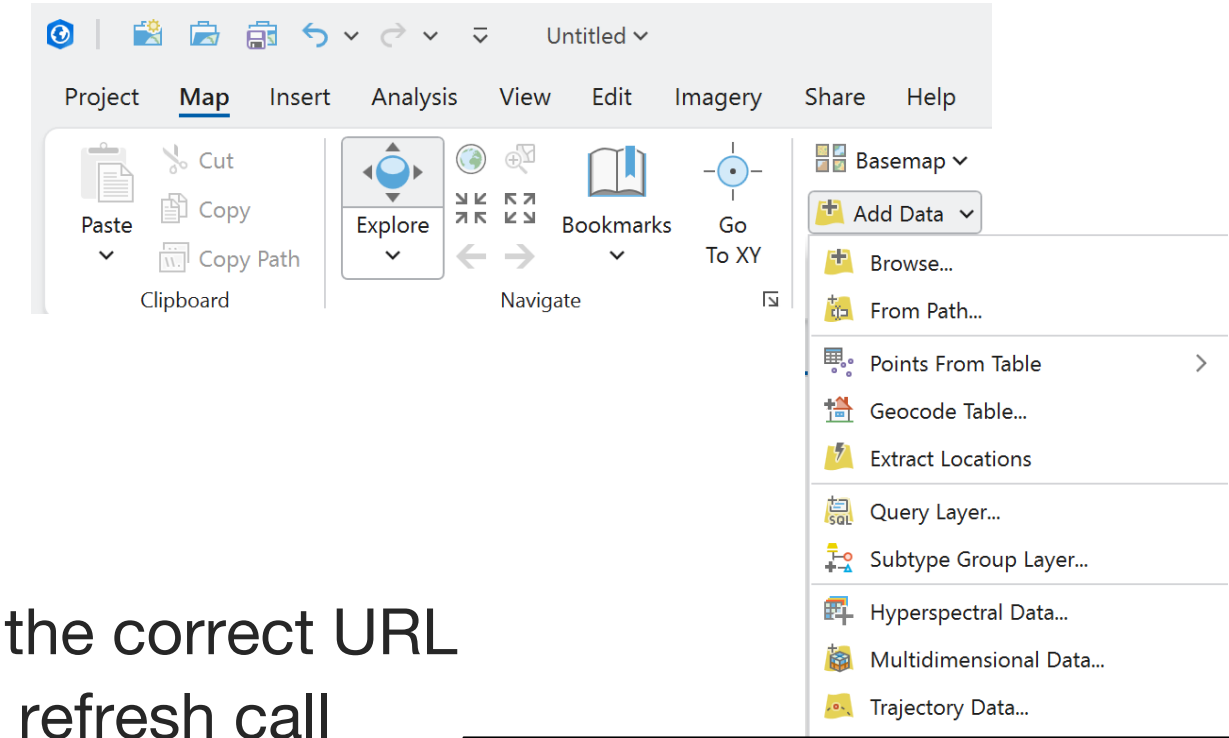


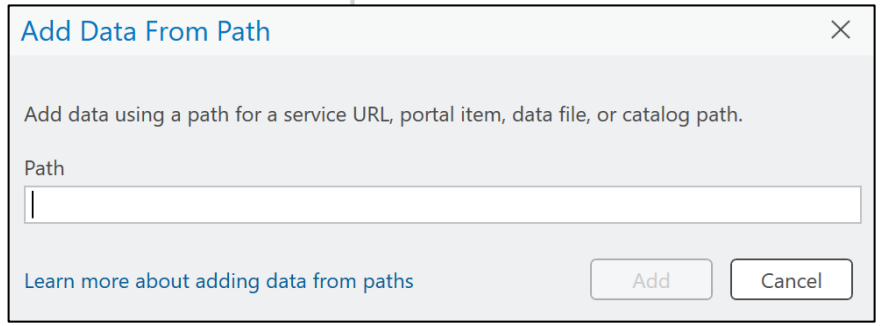


Web Mapping and Coverage Services (WMS and WCS)

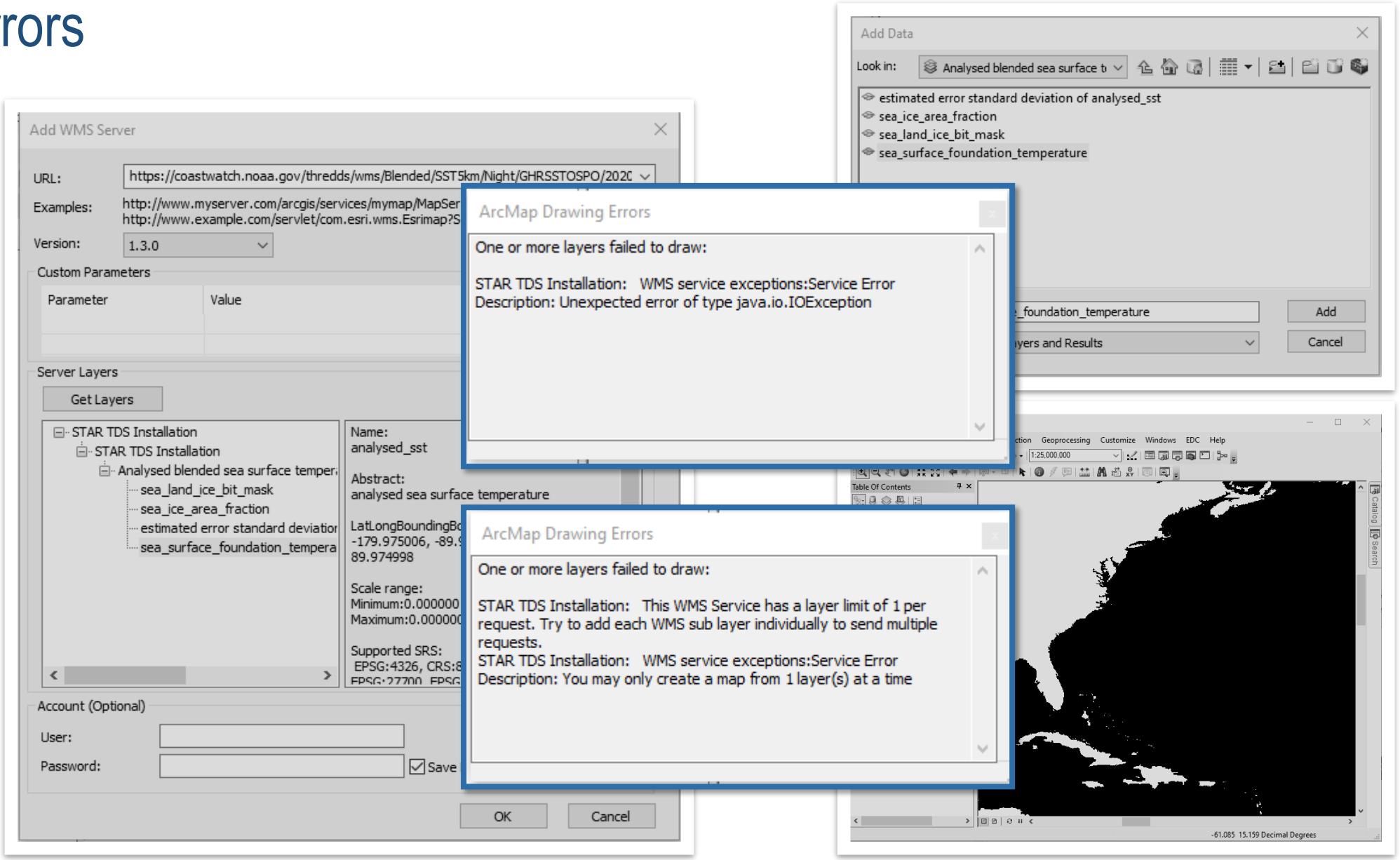
- Add data locally
- WMS: image
- WCS: data values

- Things to note:
  - OK for single time/place
  - Can be frustrating on finding the correct URL
  - Each change in PZI results in refresh call
  - And sometimes…





…errors


Add Data
Look in:
Analysed blended sea surface t
estimated error standard deviation of analysed_sst
sea_ice_area_fraction
sea_land_ice_bit_mask
sea_surface_foundation_temperature
Add
Cancel
Add WMS Server
URL:
https://coastwatch.noaa.gov/thredds/wms/Blended/SST5km/Night/GHRSSTOSPO/2020
Examples:
http://www.myserver.com/arcgis/services/mymap/MapSer
http://www.example.com/servlet/com.esri.wms.Esrimap?S
Version:
1.3.0
Custom Parameters
Parameter
Value
Server Layers
Get Layers
STAR TDS Installation
STAR TDS Installation
Analysed blended sea surface temper
sea_land_ice_bit_mask
sea_ice_area_fraction
estimated error standard deviatior
sea_surface_foundation_tempera
Name:
analysed_sst
Abstract:
analysed sea surface temperature
LatLongBoundingBo
-179.975006, -89.9
89.974998
Scale range:
Minimum:0.000000
Maximum:0.000000
Supported SRS:
EPSG:4326, CRS:8
Account (Optional)
User:
Password:
Save
OK
Cancel
ArcMap Drawing Errors
One or more layers failed to draw:
STAR TDS Installation: WMS service exceptions:Service Error
Description: Unexpected error of type java.io.IOException
ArcMap Drawing Errors
One or more layers failed to draw:
STAR TDS Installation: This WMS Service has a layer limit of 1 per request. Try to add each WMS sub layer individually to send multiple requests.
STAR TDS Installation: WMS service exceptions:Service Error
Description: You may only create a map from 1 layer(s) at a time
Table Of Contents
-61.085 15.159 Decimal Degrees

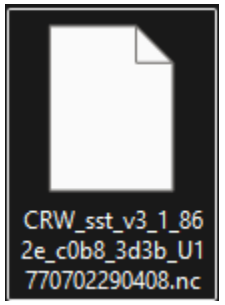
Drag-n-Drop

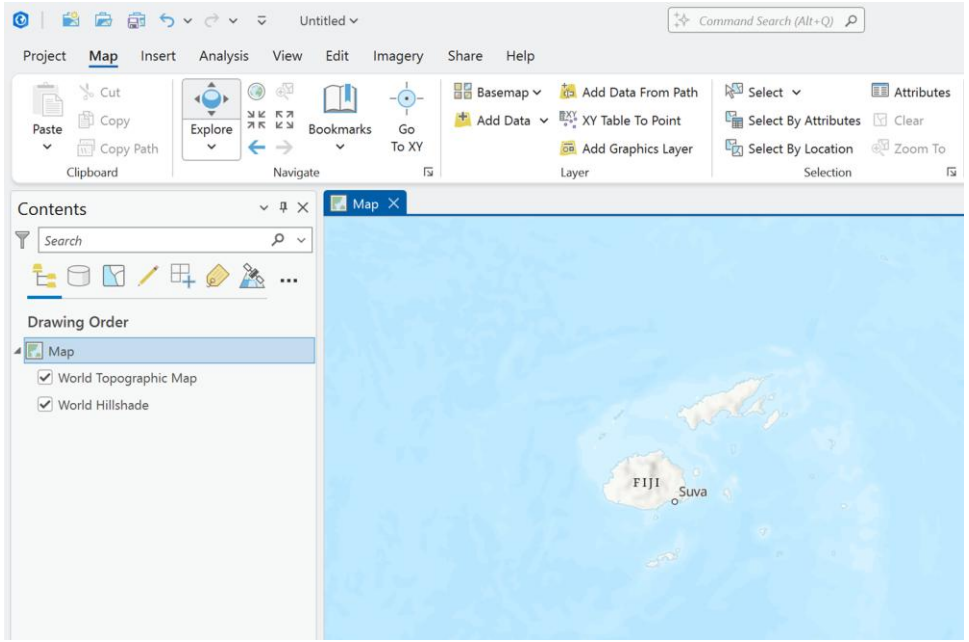
- Quick and easy

- Requires configuration
  - Symbology
  - NetCDF
  - Time/Time slider

- Things to note:
  - Defaults to first variable
  - Don’t always get what you want

Coral Reef Watch
USCRTF | CRCP | NCRMP | CoRIS



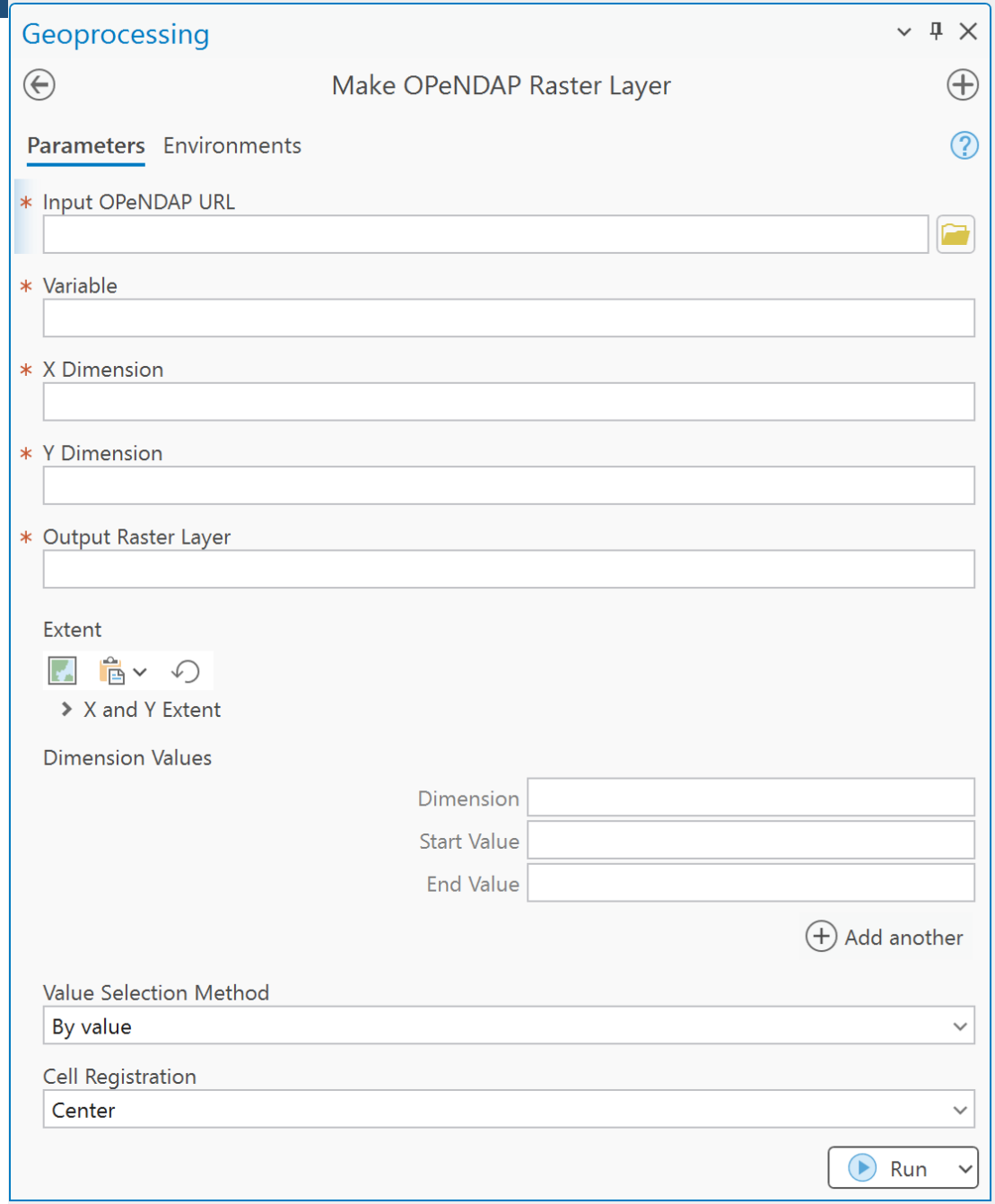


Make OpenDAP Raster Layer

Analysis → Geoprocessing → Multidimension Tools → Make OpenDAP Raster Layer

- A few clicks
- Menu-driven configuration to maximize usefulness
- Handles file or aggregates
  - Enter URL without extension
- Requires additional configuration to maximize usefulness

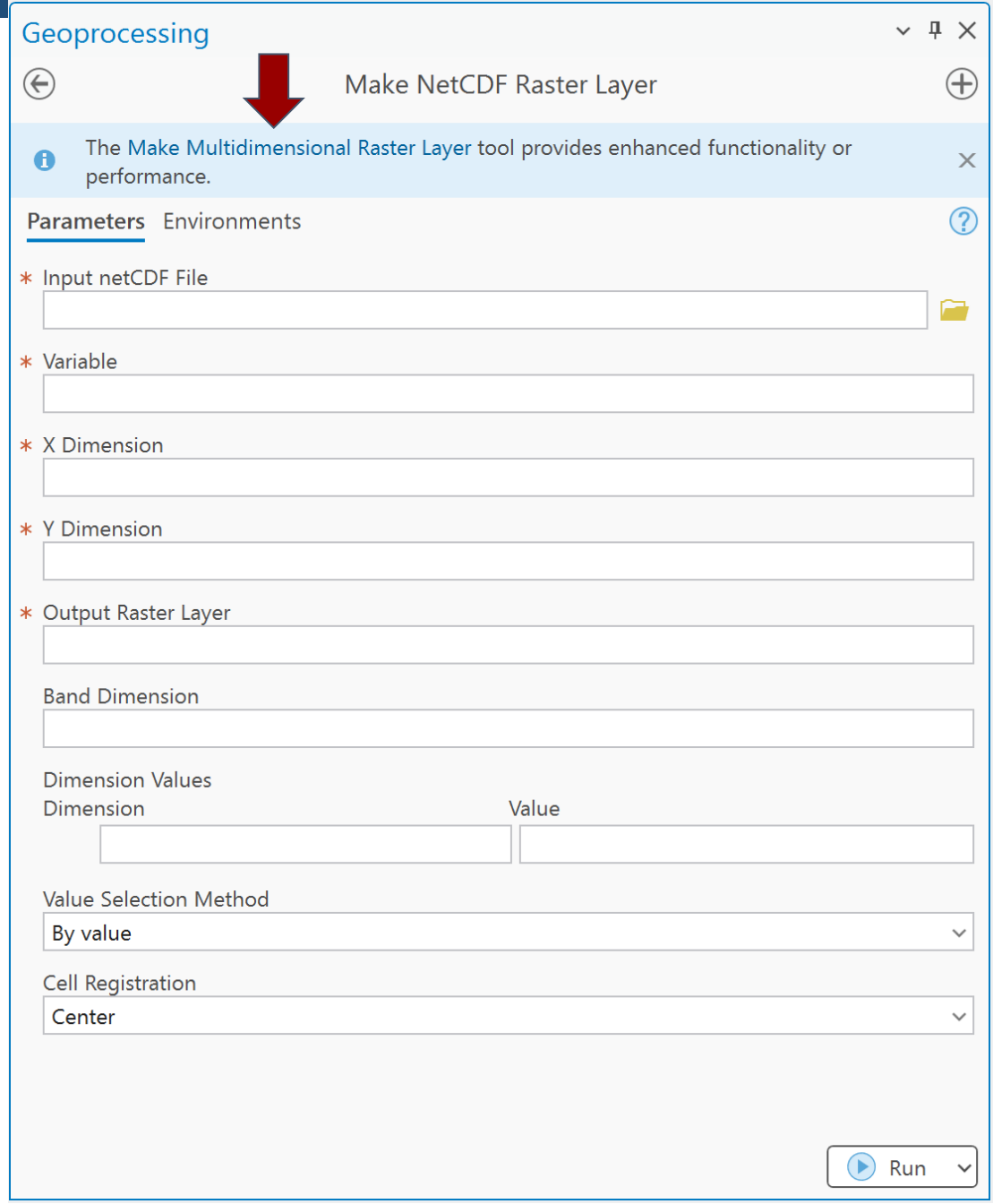
- Things to note:
  - Unexpected Errors
  - Results may vary



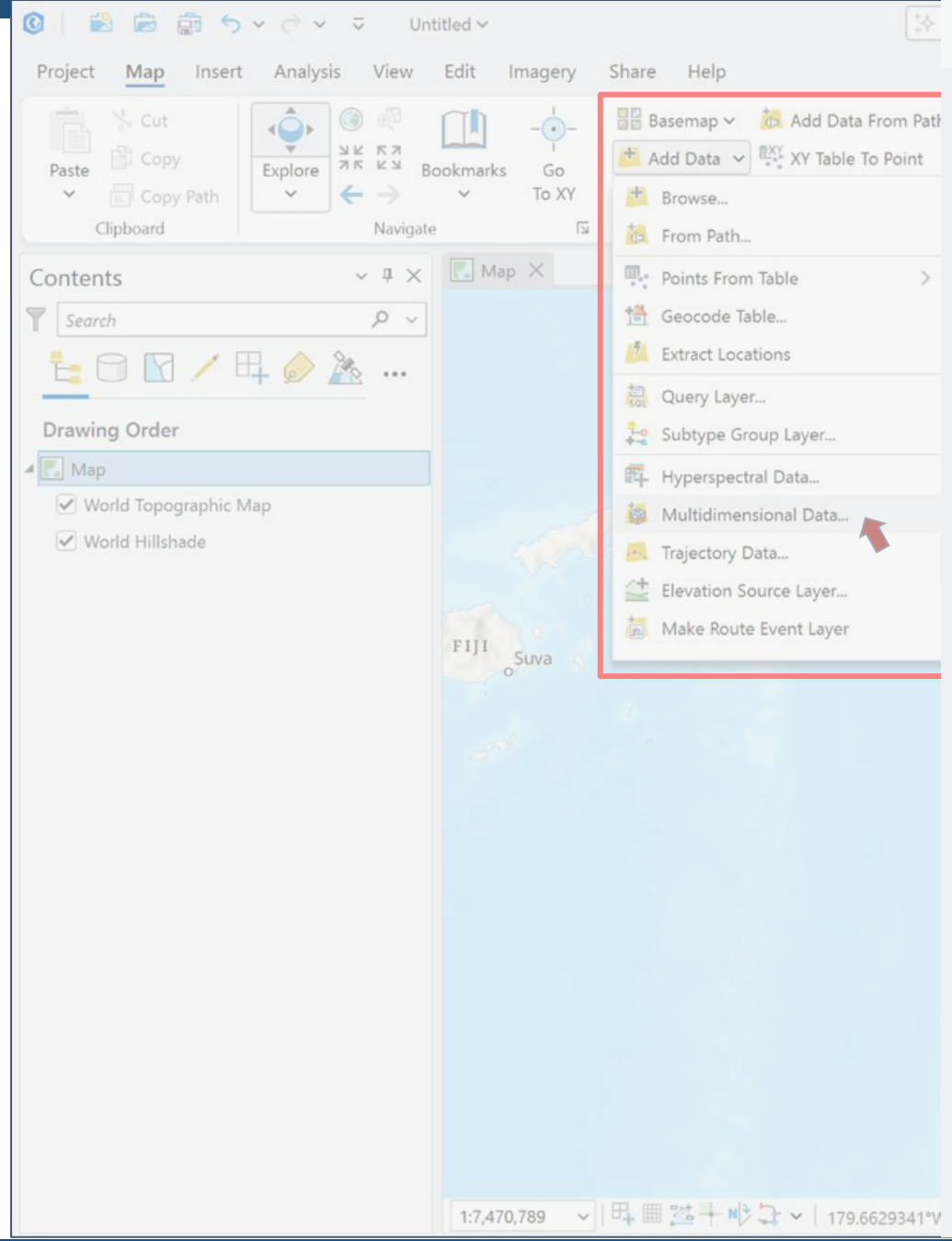
Make NetCDF Raster Layer

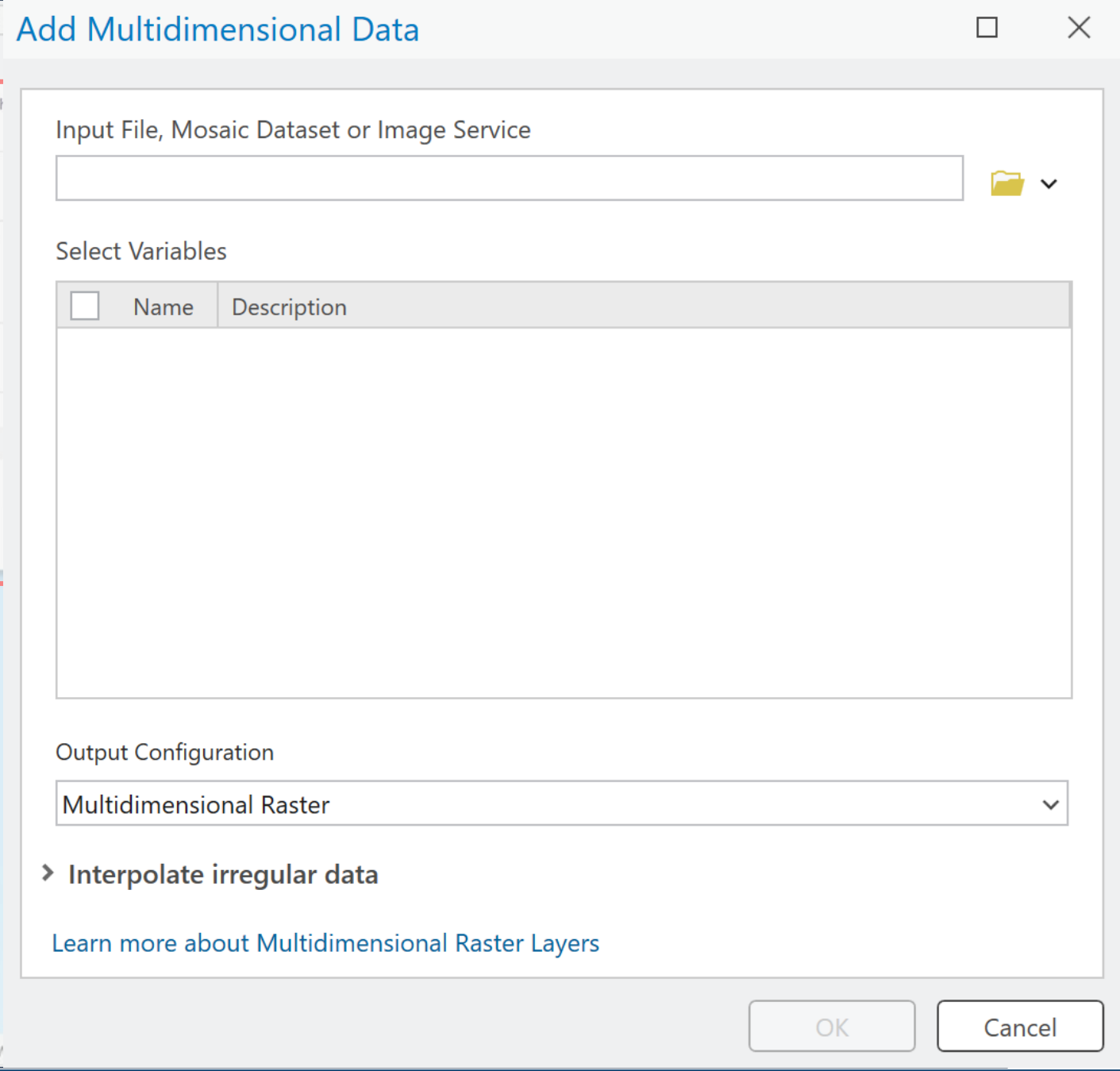
Analysis → Geoprocessing → Multidimension Tools → NetCDF → Make NetCDF Raster Layer

- A few clicks
- Menu-driven configuration to maximize usefulness
- Requires configuration
  - time, time slider



Add NC Data


Untitled
Project
Map
Insert
Analysis
View
Edit
Imagery
Share
Help
Paste
Cut
Copy
Copy Path
Clipboard
Explore
Navigate
Bookmarks
Go To XY
Basemap
Add Data From Path
Add Data
XY Table To Point
Browse...
From Path...
Points From Table
Geocode Table...
Extract Locations
Query Layer...
Subtype Group Layer...
Hyperspectral Data...
Multidimensional Data...
Trajectory Data...
Elevation Source Layer...
Make Route Event Layer
Contents
Search
Drawing Order
Map
World Topographic Map
World Hillshade
FIJI
Suva
1:7,470,789


Add Multidimensional Data
Input File, Mosaic Dataset or Image Service
Select Variables
Name
Description
Output Configuration
Multidimensional Raster
Interpolate irregular data
Learn more about Multidimensional Raster Layers
OK
Cancel

Layer Properties: Symbology

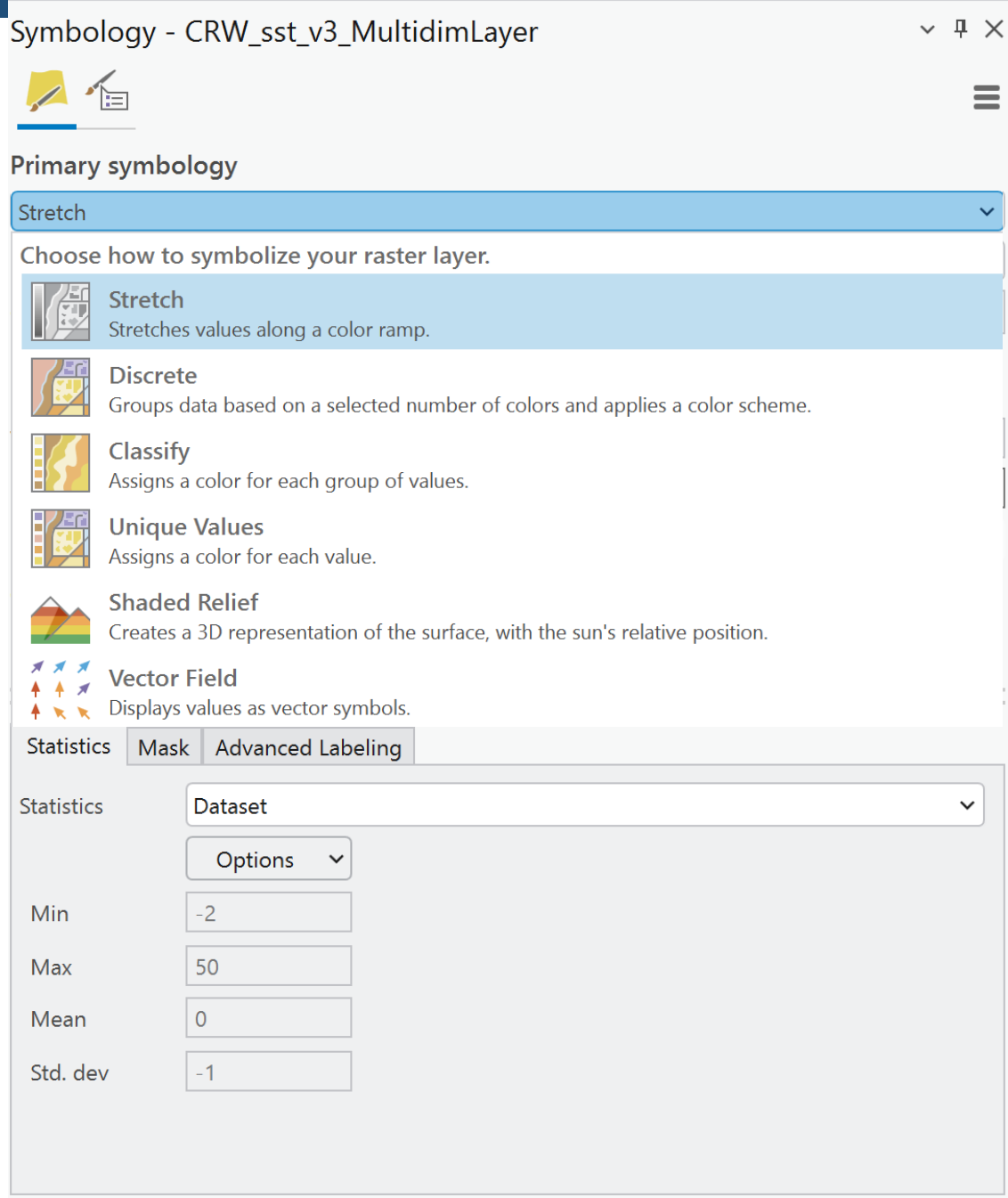
- Format raster layer appearance
  - Color scheme / invert
  - Edit min/max values / classes

- Right-Click Layer → Symbology

  – OR –

- Raster Layer → Symbology

- Menu-driven configuration to maximize usefulness



Layer Properties: Time

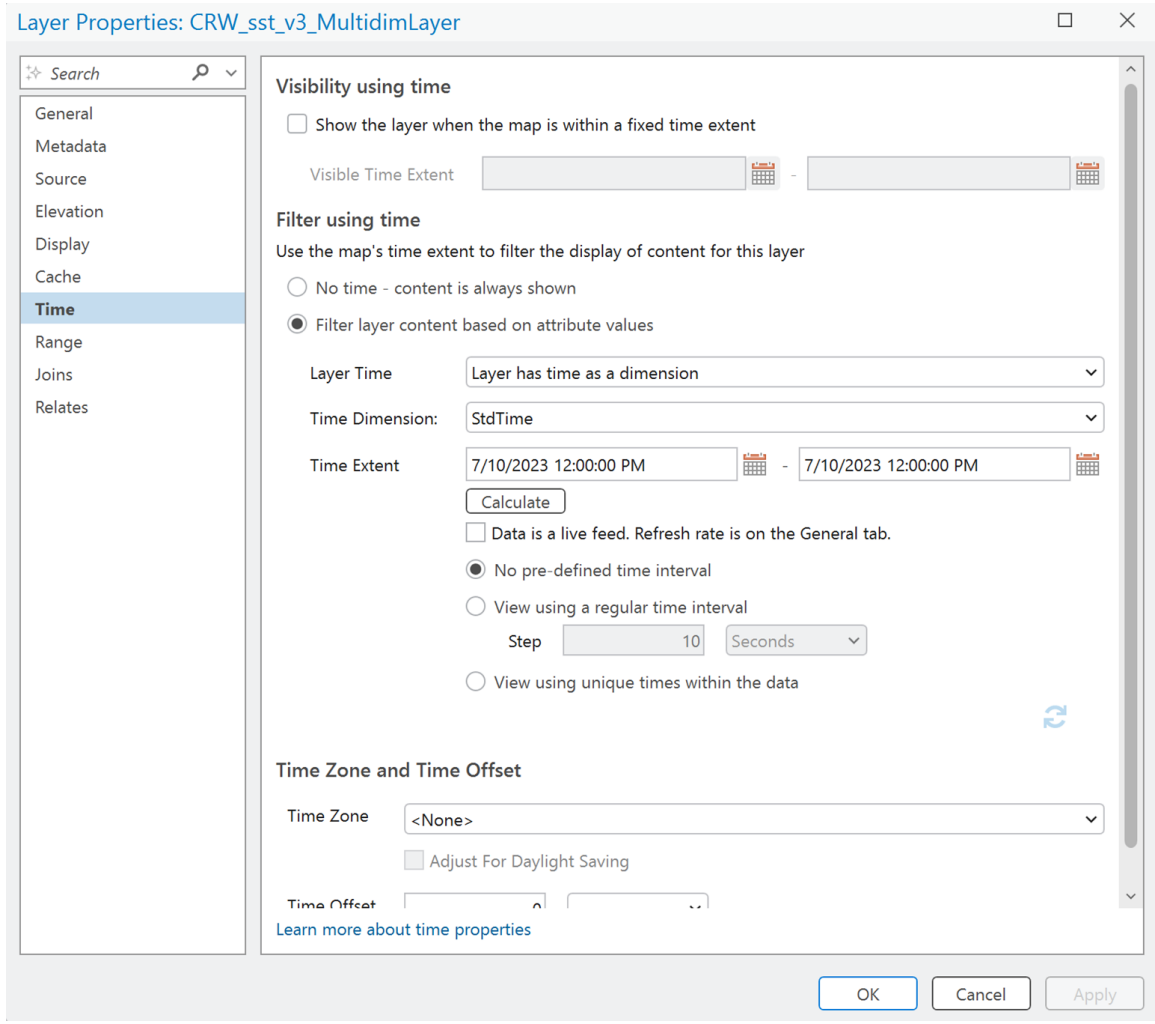
- Format raster layer appearance
  - Time extent / interval / step

- Right-Click Layer → Properties

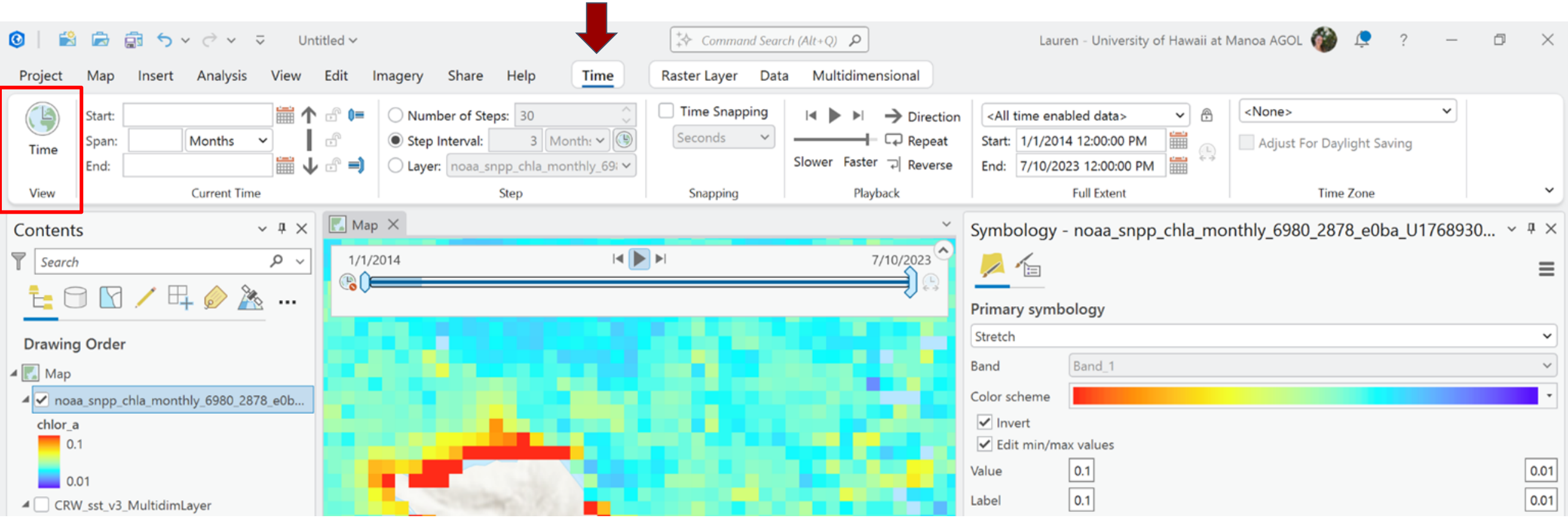
  – OR –

- Raster Layer → Multidimensional

- Menu-driven configuration to maximize usefulness



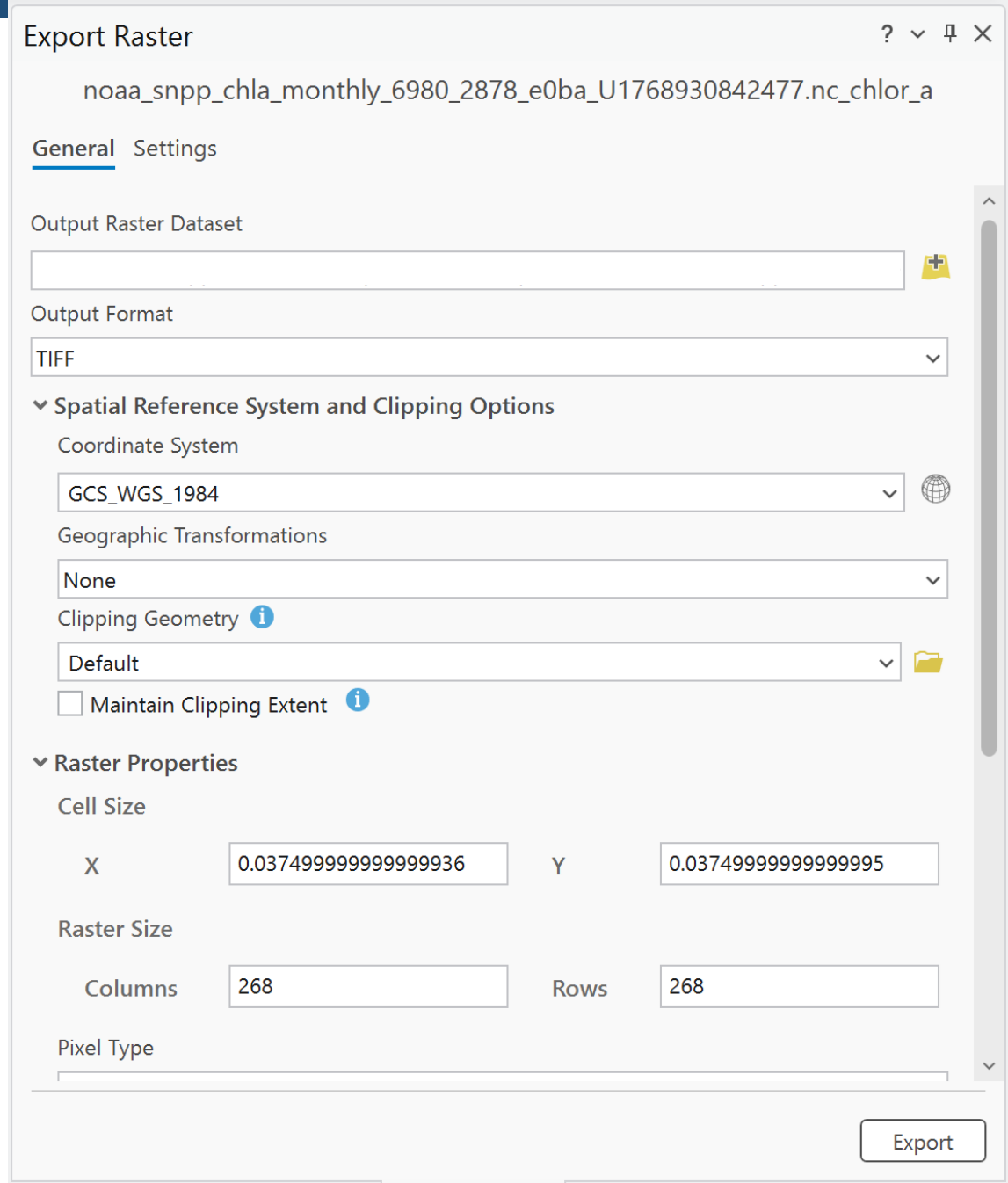
Enable Time Slider



- And sometimes… ERRORS!

Export Data to Geospatial Database

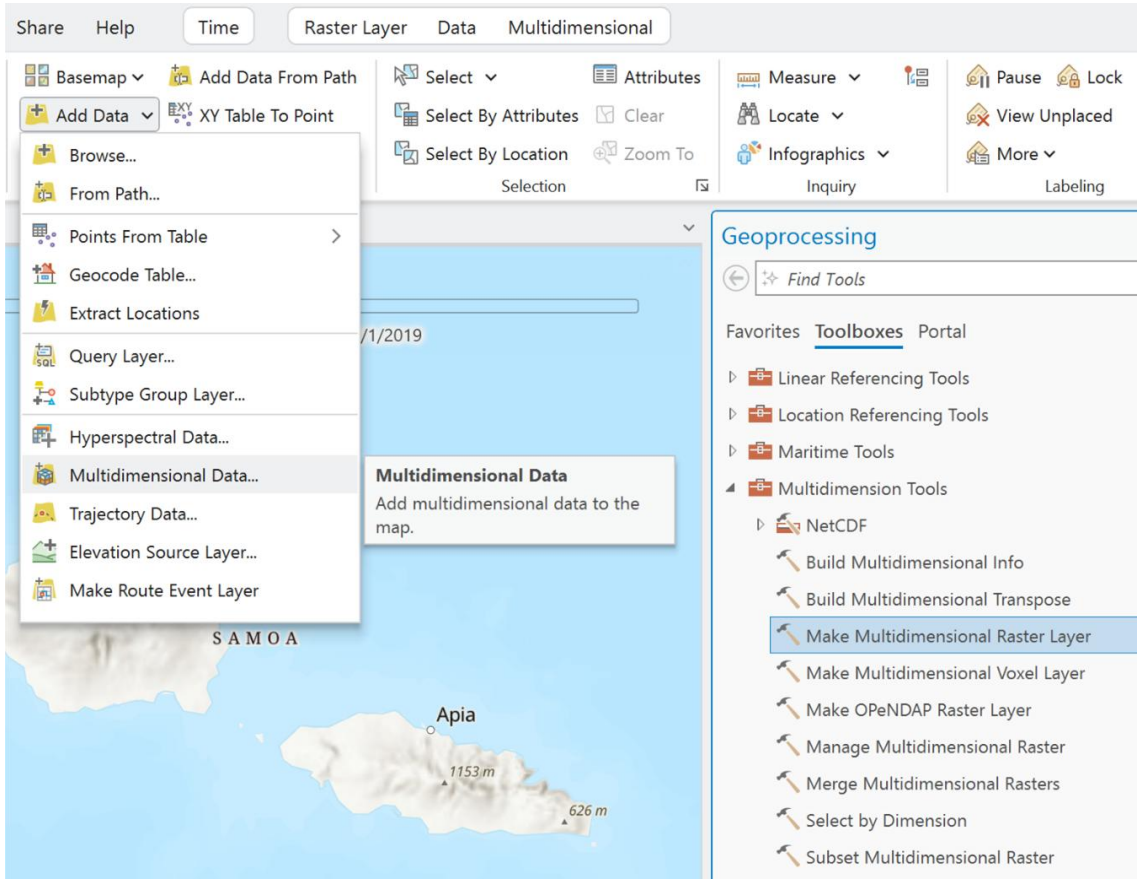
- Right-Click Layer → Data → Export Raster
- Input general settings
  - Output Raster Dataset
  - Output Format
  - …and more
- Click “Export”



Recap Methods to add Satellite Data

- Add Data
  - Multidimensional Data…
  - From Path…
  - Browse…

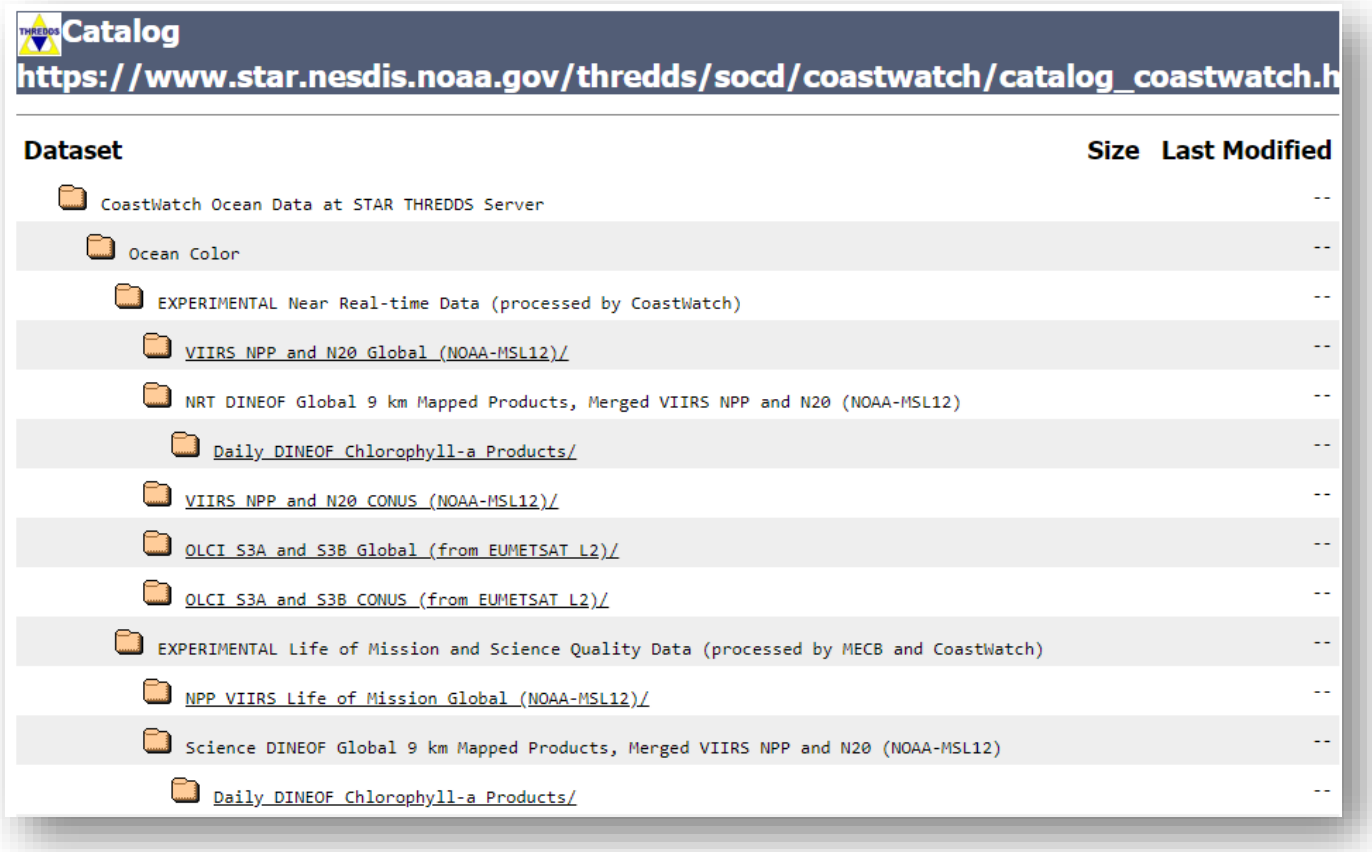
- Analysis → Geoprocessing → Multidimension Tools →
  - Make OPeNDAP Raster Layer
  - NetCDF → Make NetCDF Raster Layer



- *Drag-n-Drop and EDC no longer recommended*

Additional Services to Obtain Data

- OpenDAP
- THREDDS
- ERDDAP



Example of THREDDS Catalog

OpenDAP (Open Data Access Protocol)

- Data model
- Application Program Interface (API)
- Dataset Descriptor Structure (DDS)

https://coastwatch.noaa.gov/erddap/griddap/noaacwBLENDEDsstDaily.dds

- Dataset Attribute Structure (DAS)

https://coastwatch.noaa.gov/erddap/griddap/noaacwBLENDEDsstDaily.das

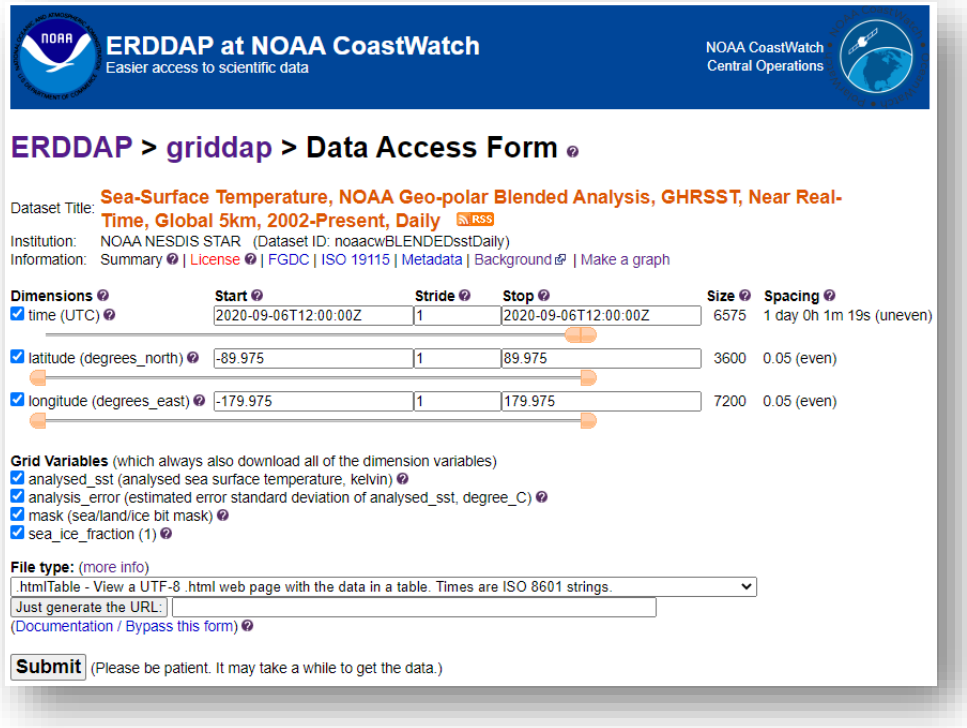
- Used within THREDDS / ERDDAP

```
Dataset {
  Float64 time[time = 6575];
  Float32 latitude[latitude = 3600];
  Float32 longitude[longitude = 7200];
  GRID {
    ARRAY:
      Float32 analysed_sst[time = 6575][latitude = 3600][longitude = 7200];
    MAPS:
      Float64 time[time = 6575];
      Float32 latitude[latitude = 3600];
      Float32 longitude[longitude = 7200];
  } analysed_sst;
  GRID {
    ARRAY:
      Float32 analysis_error[time = 6575][latitude = 3600][longitude = 7200];
    MAPS:
      Float64 time[time = 6575];
      Float32 latitude[latitude = 3600];
      Float32 longitude[longitude = 7200];
  } analysis_error;
  GRID {
    ARRAY:
      Byte mask[time = 6575][latitude = 3600][longitude = 7200];
    MAPS:
      Float64 time[time = 6575];
      Float32 latitude[latitude = 3600];
      Float32 longitude[longitude = 7200];
  } mask;
  GRID {
    ARRAY:
      Float32 sea_ice_fraction[time = 6575][latitude = 3600][longitude = 7200];
    MAPS:
      Float64 time[time = 6575];
      Float32 latitude[latitude = 3600];
      Float32 longitude[longitude = 7200];
  } sea_ice_fraction;
} noaacwBLENDEDsstDaily;
```

Example of Dataset Descriptor Structure

THREDDS and ERDDAP

- Provide additional means to obtain data
- Temporal and spatial subsetting
- Useful services
  - OpenDAP (THREDDS)
  - NetCDF Subset Service (THREDDS)
  - GRIDDAP (ERDDAP)
  - TableDAP (ERDDAP)



ERDDAP (GRIDDAP) Data Access Form

Things To Note…

- Data Units
  - SST may come in Kelvin or degrees Celsius (rarely Fahrenheit)
  - Chl comes in several units that do not necessarily change the values
- Time
  - Check the time zones for data – likely UTC
- Dateline
  - Most satellite data composited daily products and may span 180W-180E
  - May introduce a mismatch in data collection time across the dateline
- Projection / Map Units
  - Note units as usually the first data loaded sets projection and units
  - Ellipsoids/Datum – satellite data is most likely WGS84, land/coastal data may be NAD83

Additional ESRI Resources

- ArcGIS Pro quick-start tutorials
  - introduces you to many aspects of ArcGIS Pro
  - https://pro.arcgis.com/en/pro-app/latest/get-started/pro-quickstart-tutorials.htm
- ArcGIS Pro Basics WebCourse
  - introduces you to the powerful capabilities of ArcGIS Pro and how to integrate, visualize, analyze, and share your data
  - https://www.esri.com/training/catalog/5cad02469b1f4010cad9ac46/arcgis-pro-basics/
- ArcGIS Pro Resources
  - build your expertise through documentation, tutorials, and more
  - https://www.esri.com/en-us/arcgis/products/arcgis-pro/resources

Questions?

Using Satellite Data in GIS