



# 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

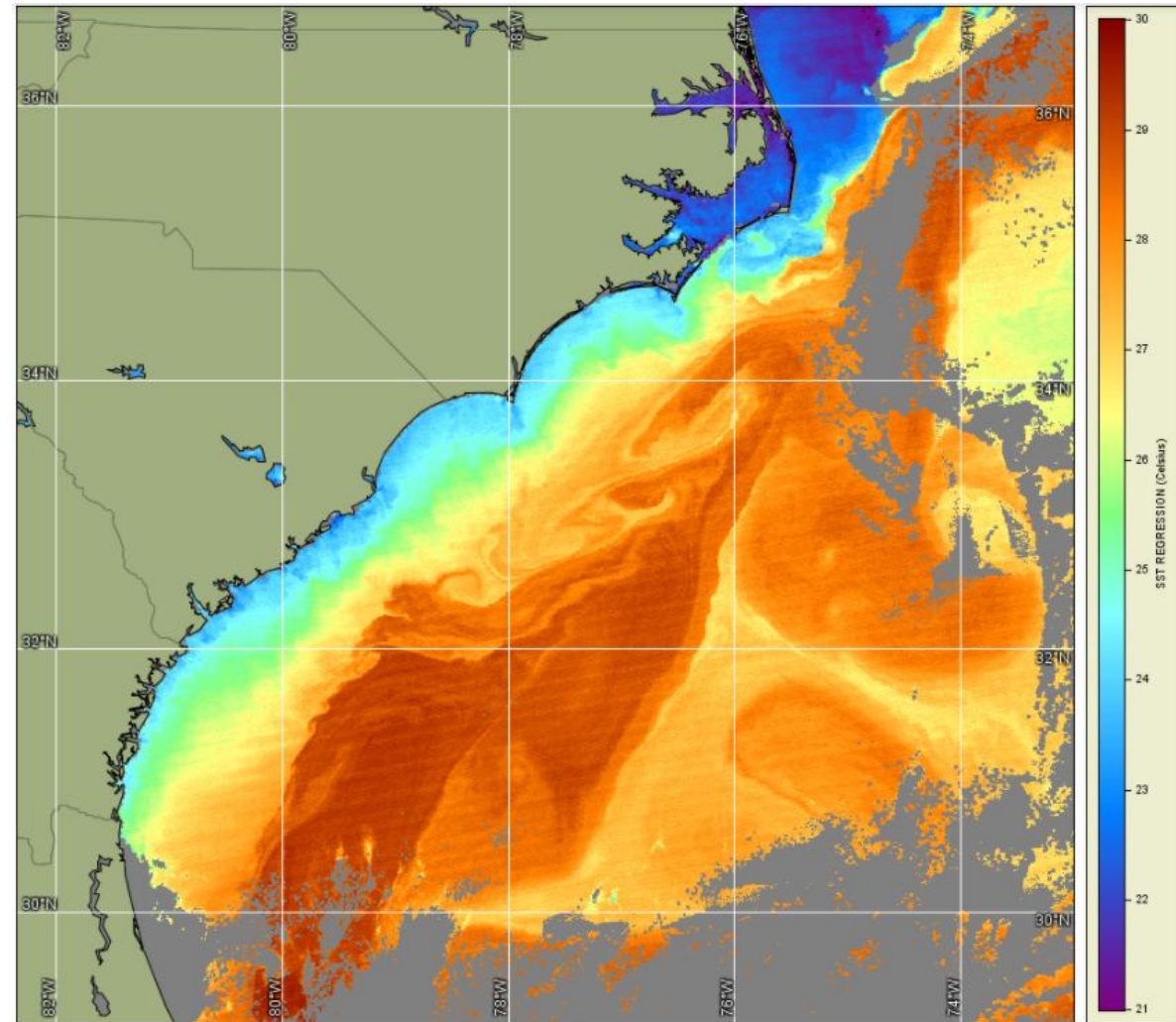
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Using Satellite Data in GIS



## Overview

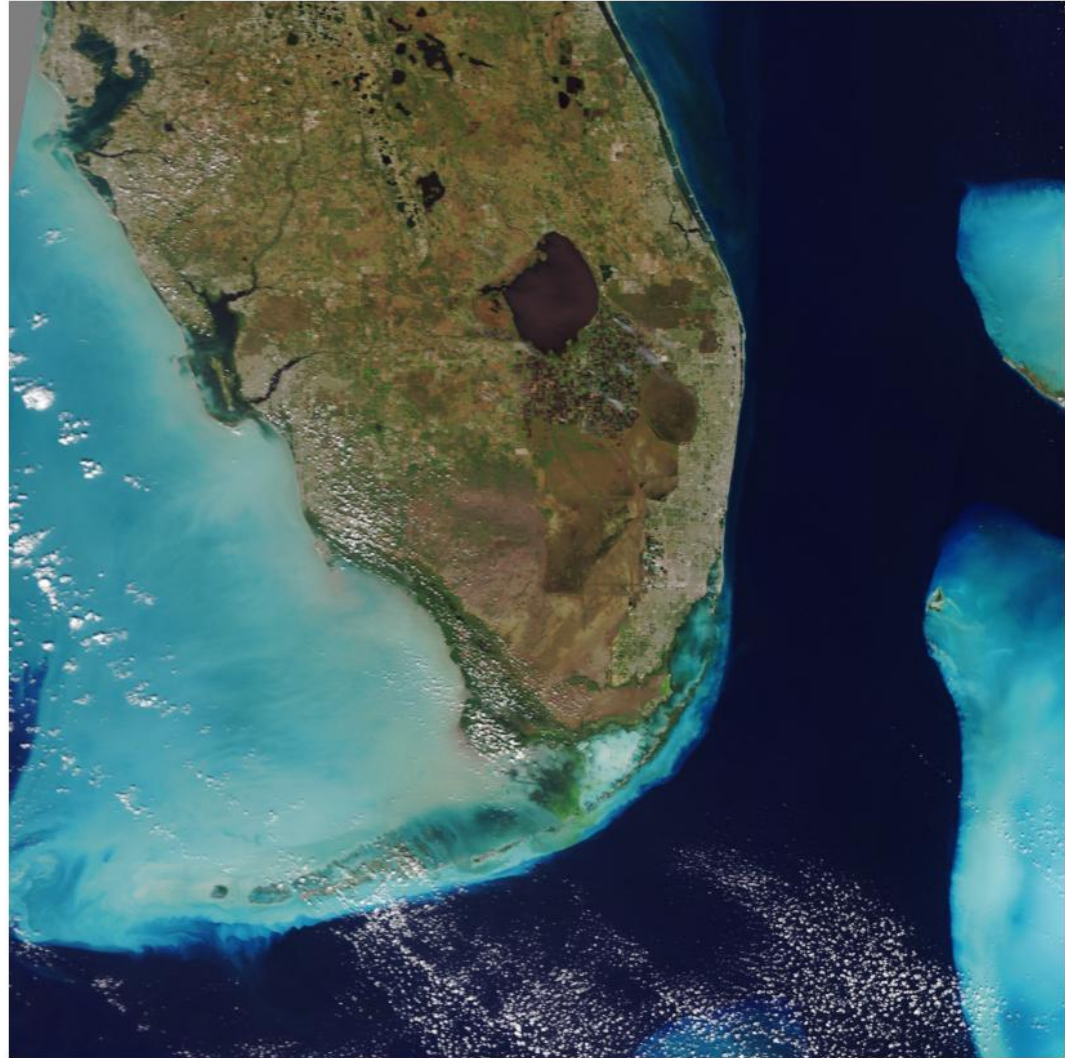
- Imagery
- Data
- Considerations and preparations



S-NPP VIIRS SST Image

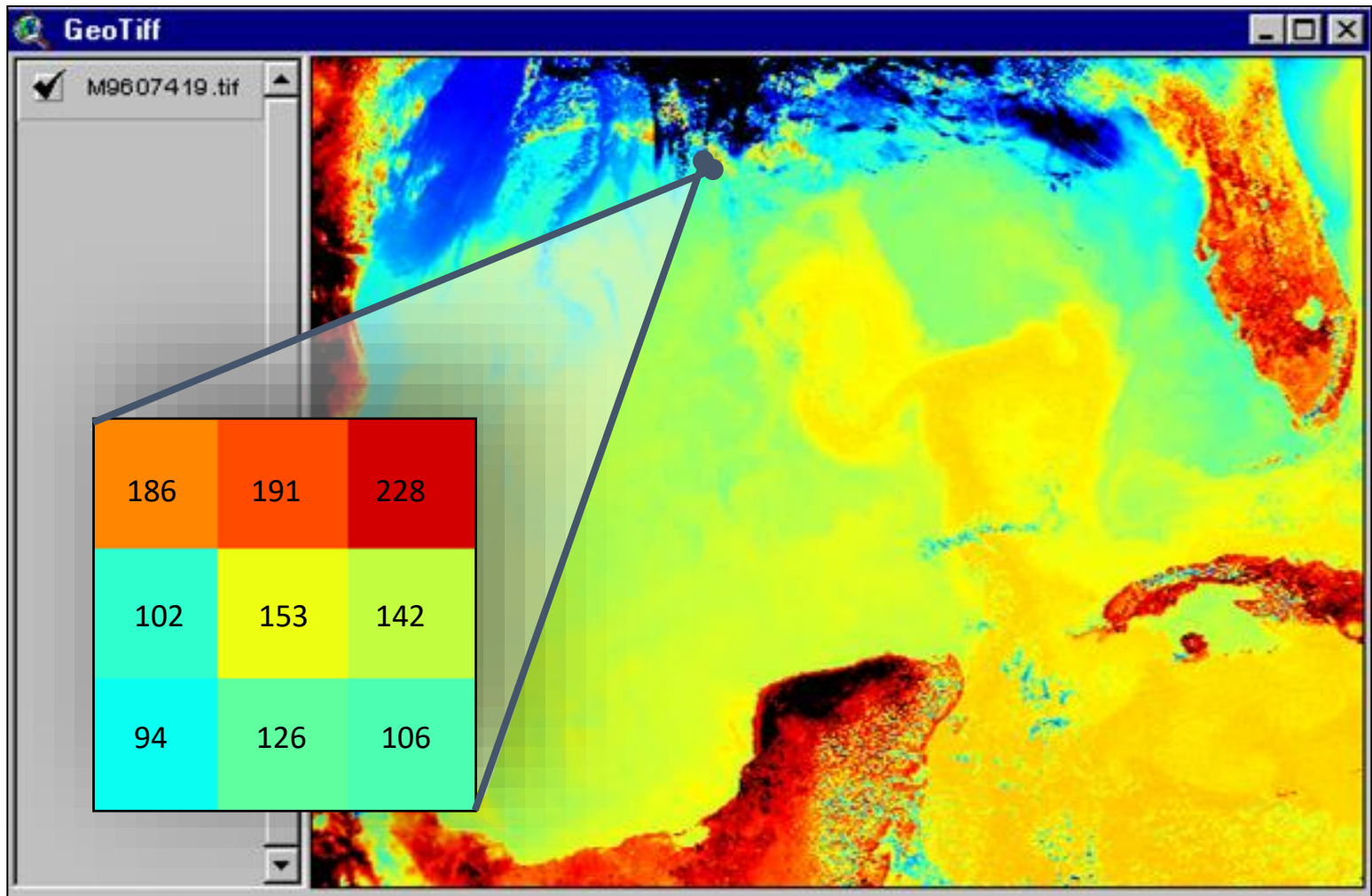
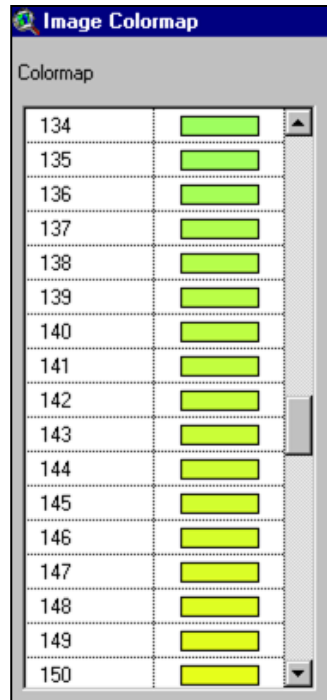
## Satellite Imagery

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



S-NPP VIIRS True Color Imagery

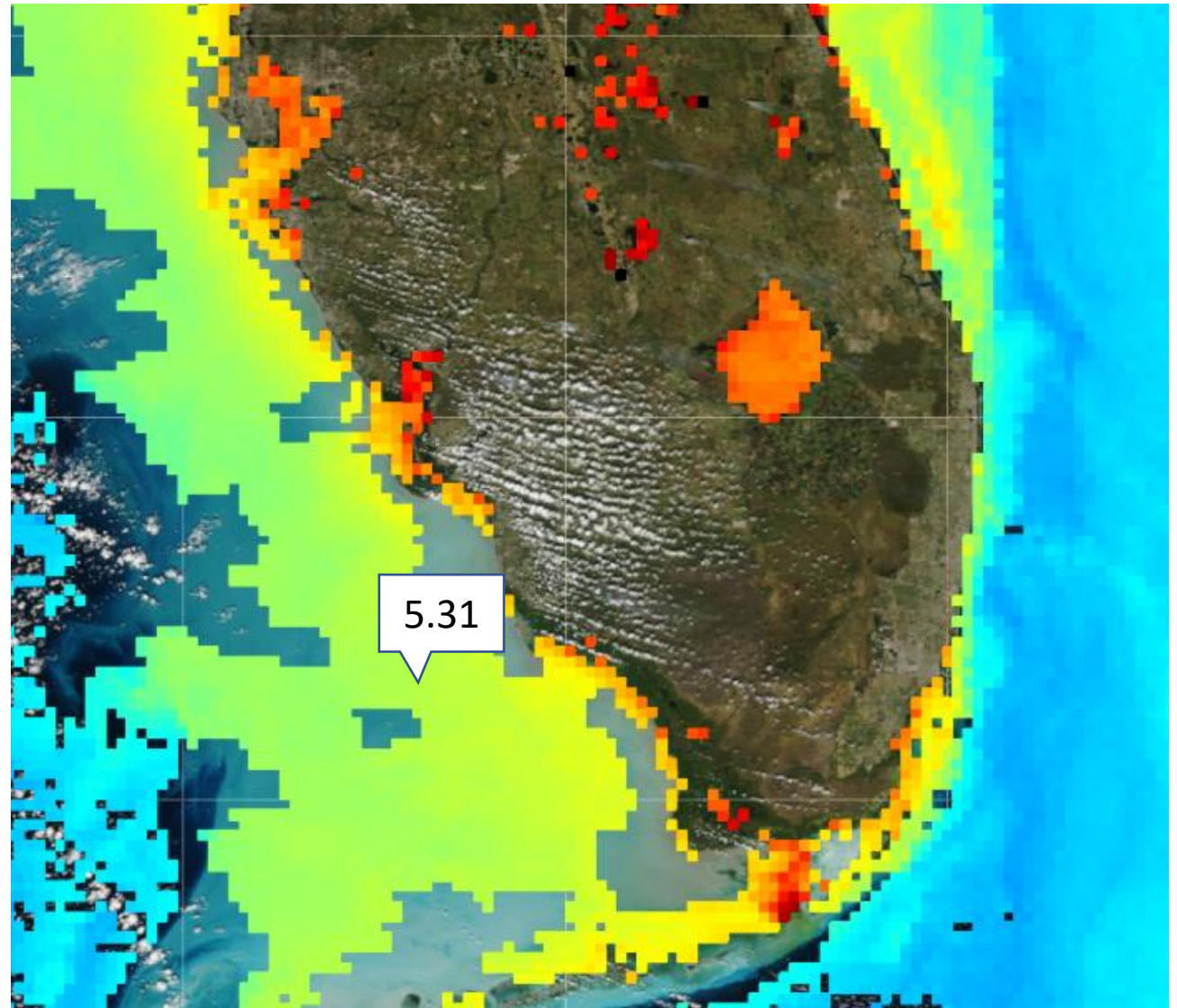
# 8-bit Image Example



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

## Satellite Data

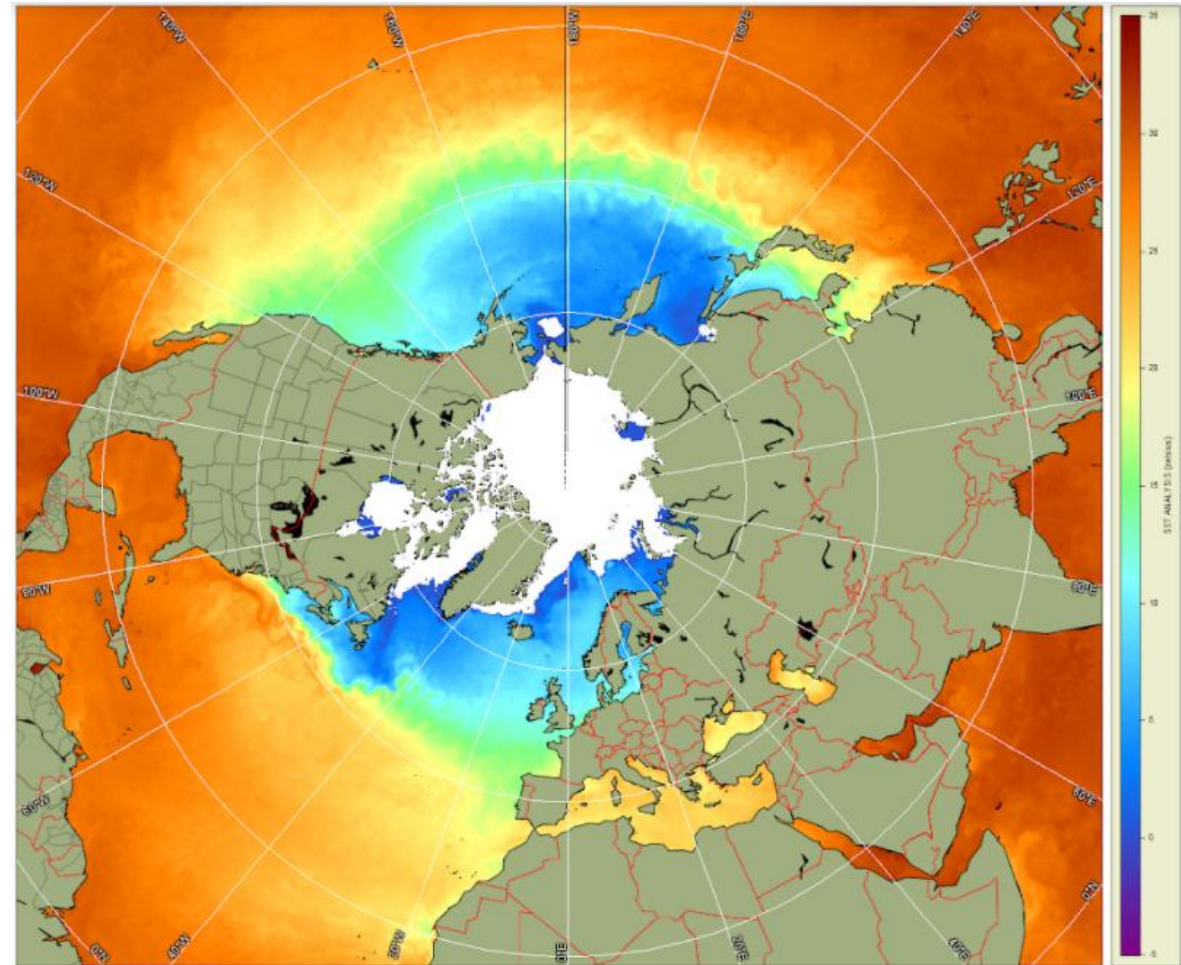
- Calculations
- Values
- Formats
  - HDF, NetCDF, 32-bit GeoTIFF



S-NPP VIIRS Chlorophyll-a Science Quality

## Data Considerations

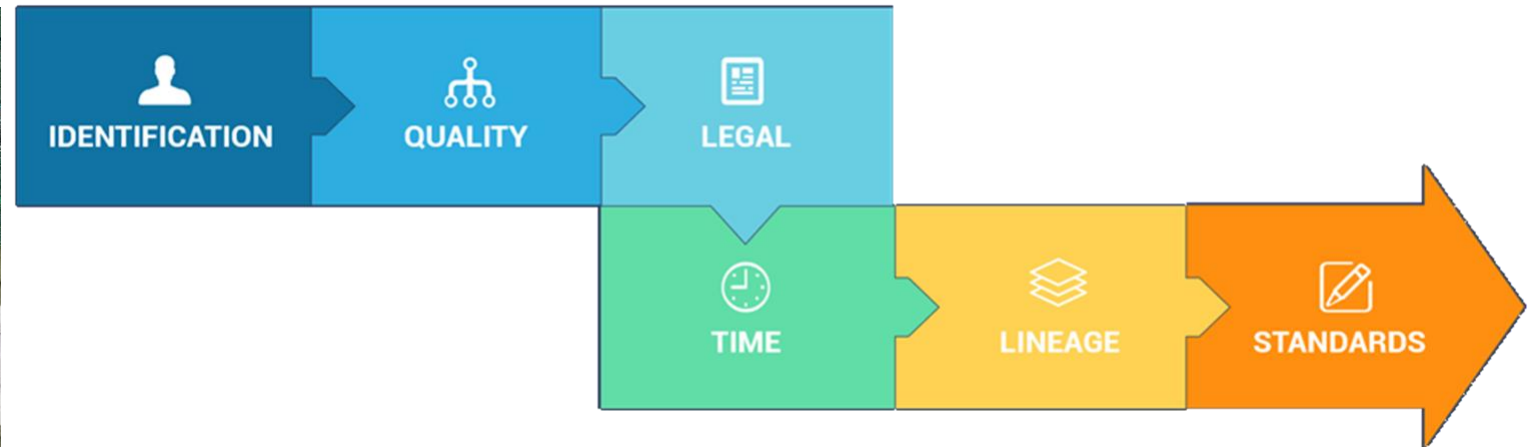
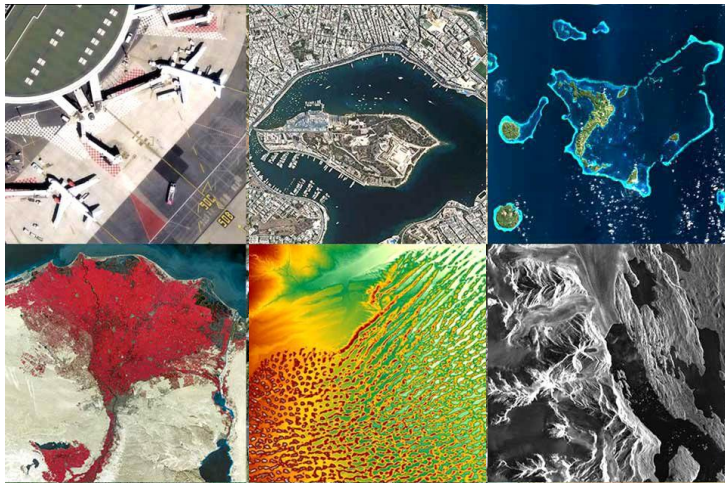
- Metadata
- Format
- Resolution
- Projection
  - Coordinate system
  - Datum
- Preparation



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

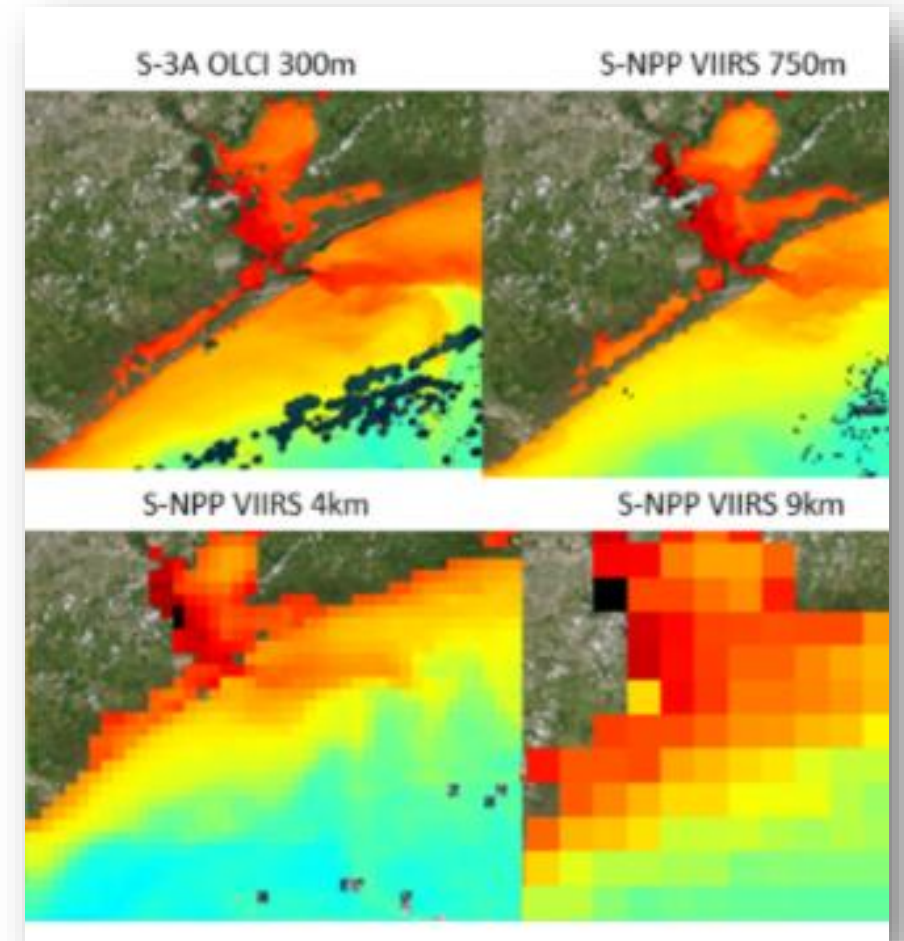
GeoTIFF csv

JPEG



# Product Resolution

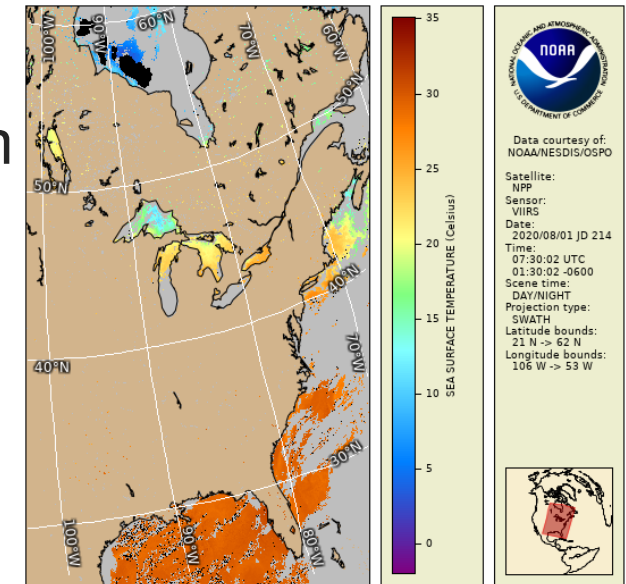
- Spatial resolutions
  - meters to hundreds of kilometers
- Temporal resolutions
  - minutes to days, weeks, or months
- How are data combined?



Resolutions from various  
chlorophyll-a products

# Projections

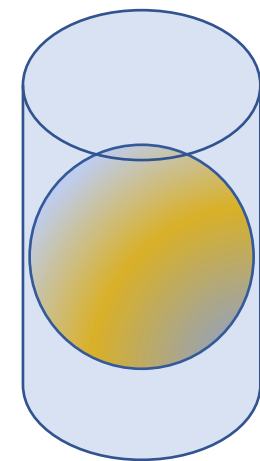
- Satellite sensor view (Swath / Level-2)
  - Irregularly/nonlinearly spaced
  - May include unique structure based on sensor
  - Geolocations with respect to Ellipsoid and Datum
- Mapped (Gridded / Level-3, -4)
  - Coordinate system
  - Locations with respect to Ellipsoid and Datum



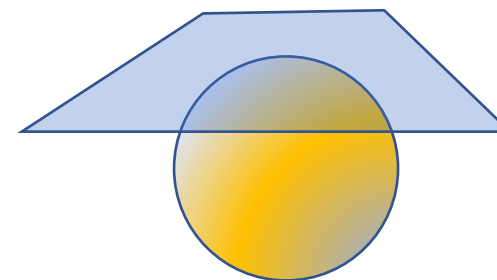
# Projections

- **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

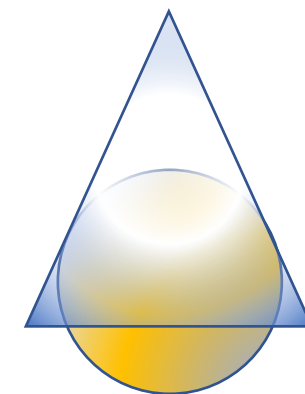
Map construct types  
(not all are shown)



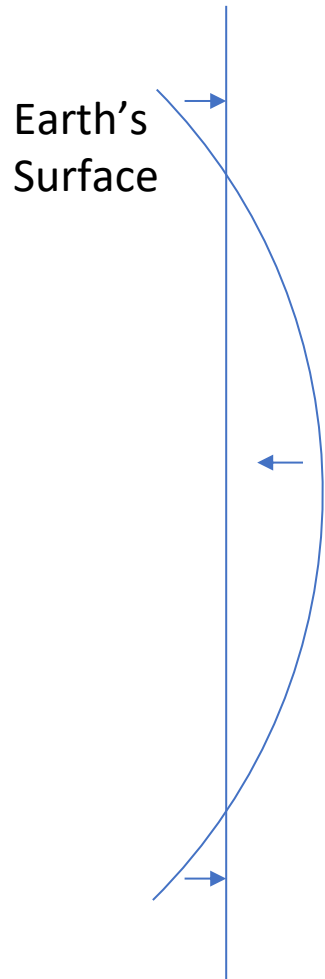
Cylindrical



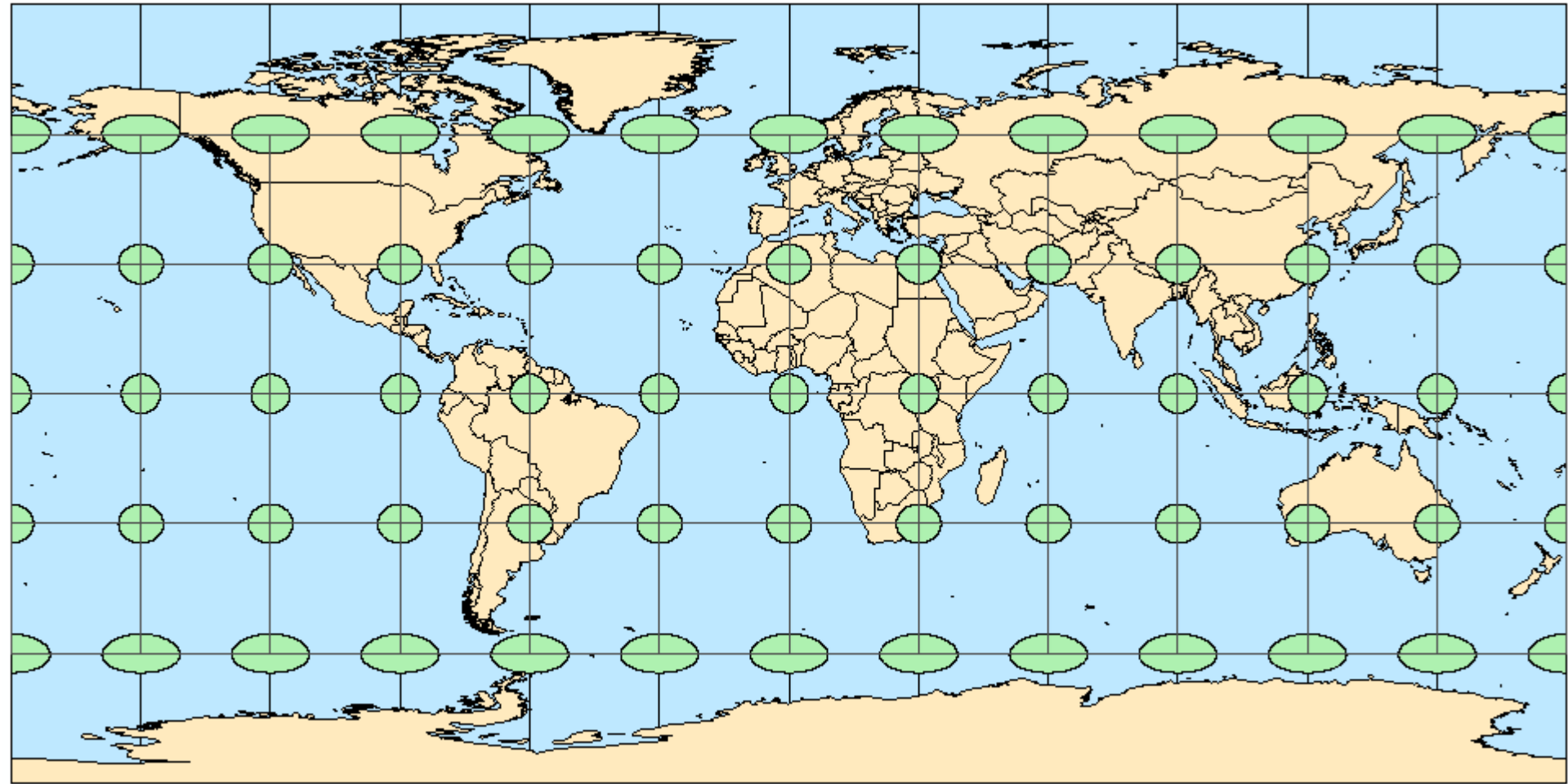
Azimuthal



# Geographic (WGS84)



Earth's  
Surface



Projection Plane

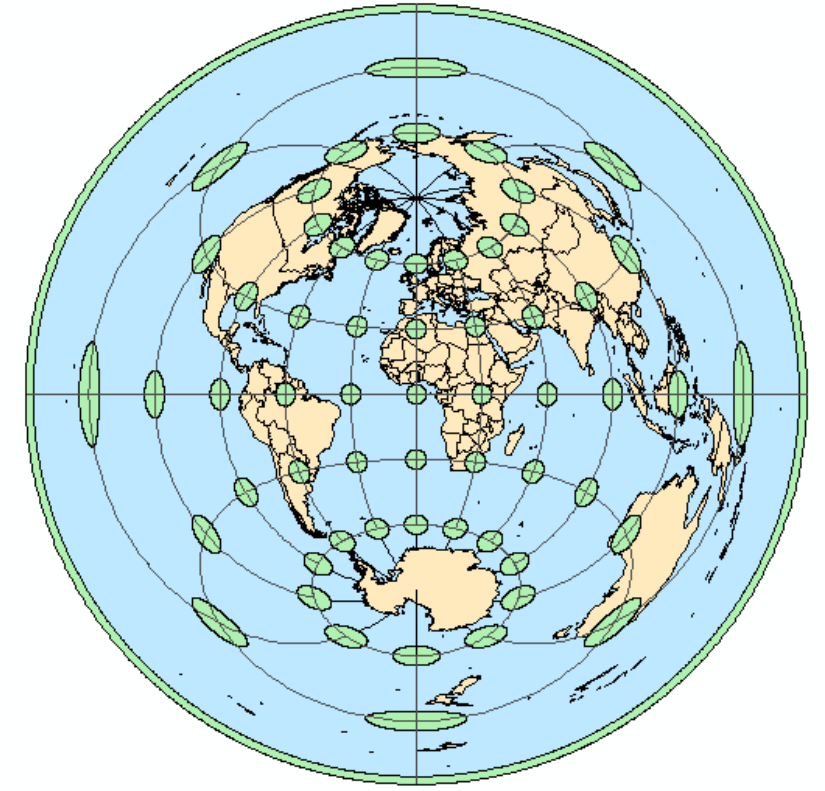
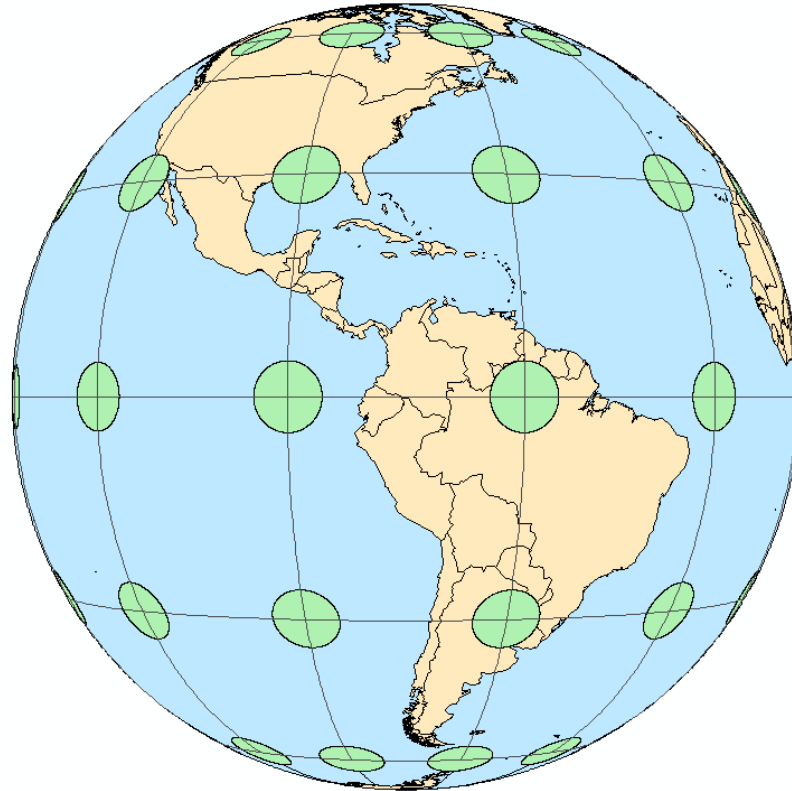
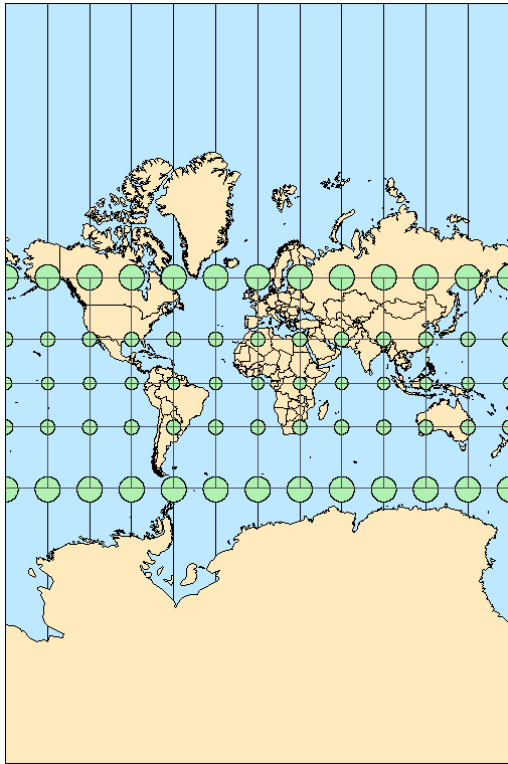
Tissot's indicatrix of circles illustrating distortion across a map



# Mercator (WGS84) Equidistant

# GOES-16 (GRS80)

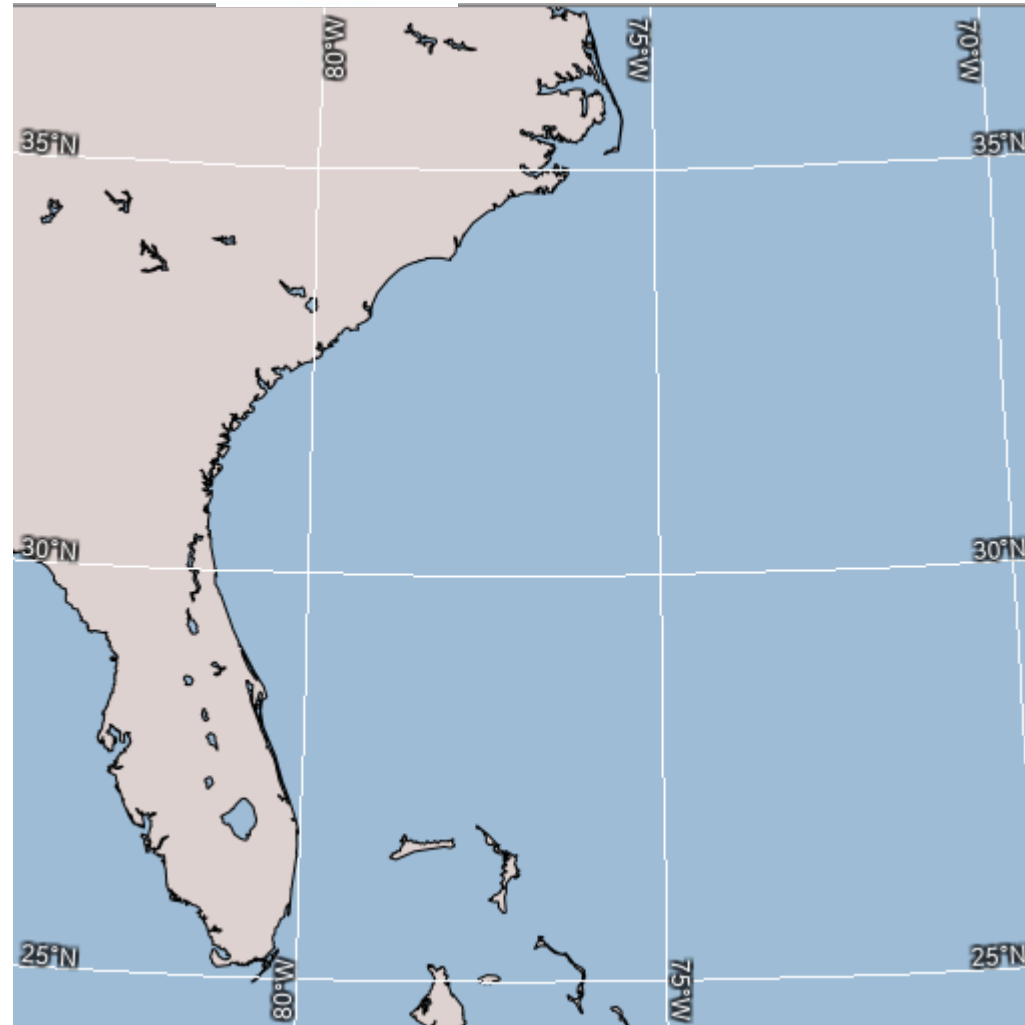
# Azimuthal



Tissot's indicatrix of circles illustrating distortion across a map

## Projections - Conformality

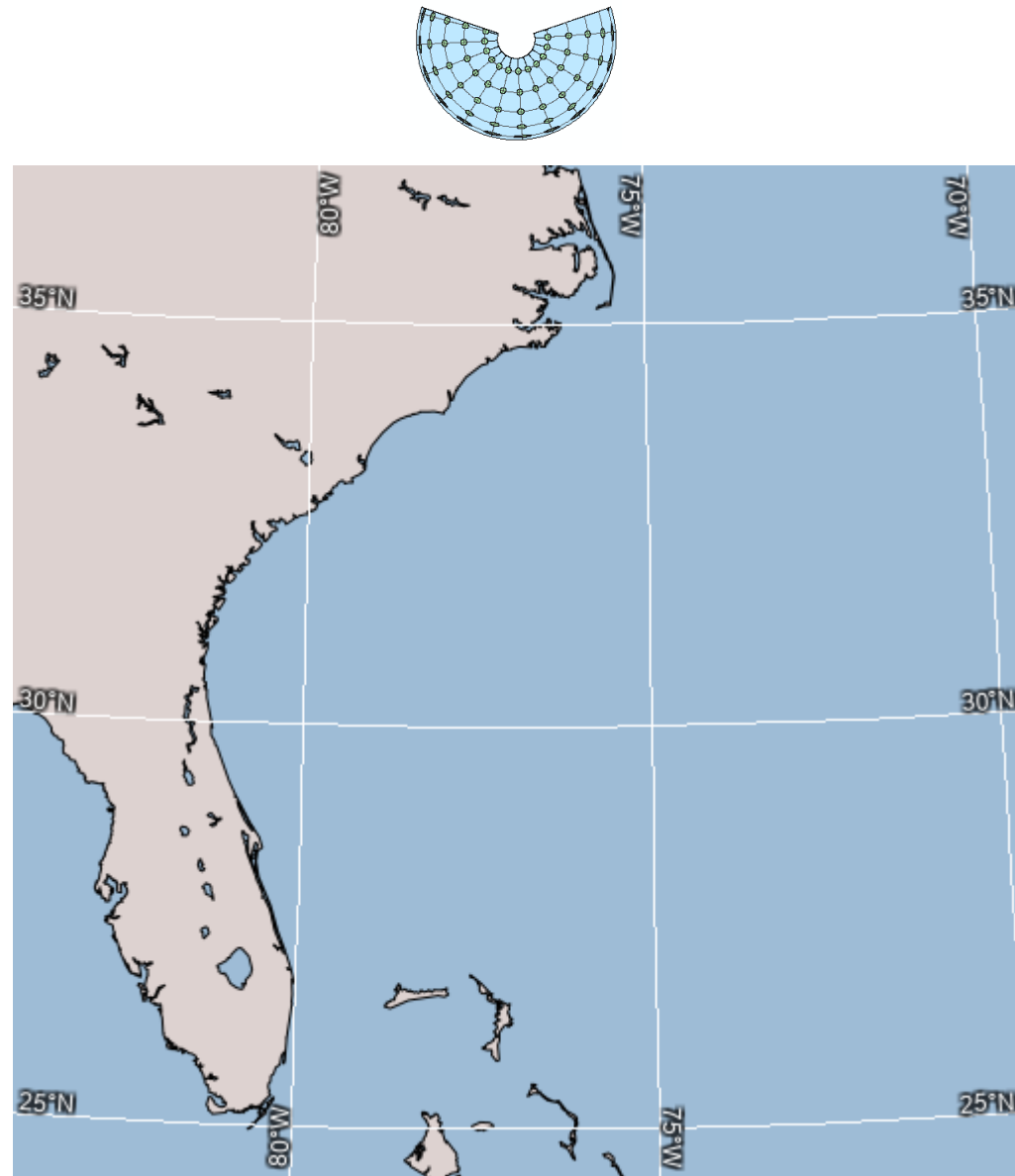
- Shape is preserved
- Representative of actual feature
- Useful for preserving shape
- Lambert Conformal Conic
- Mercator
  - Straight lines have constant bearing



Lambert Conformal Conic preserves shape

## Projections - Area

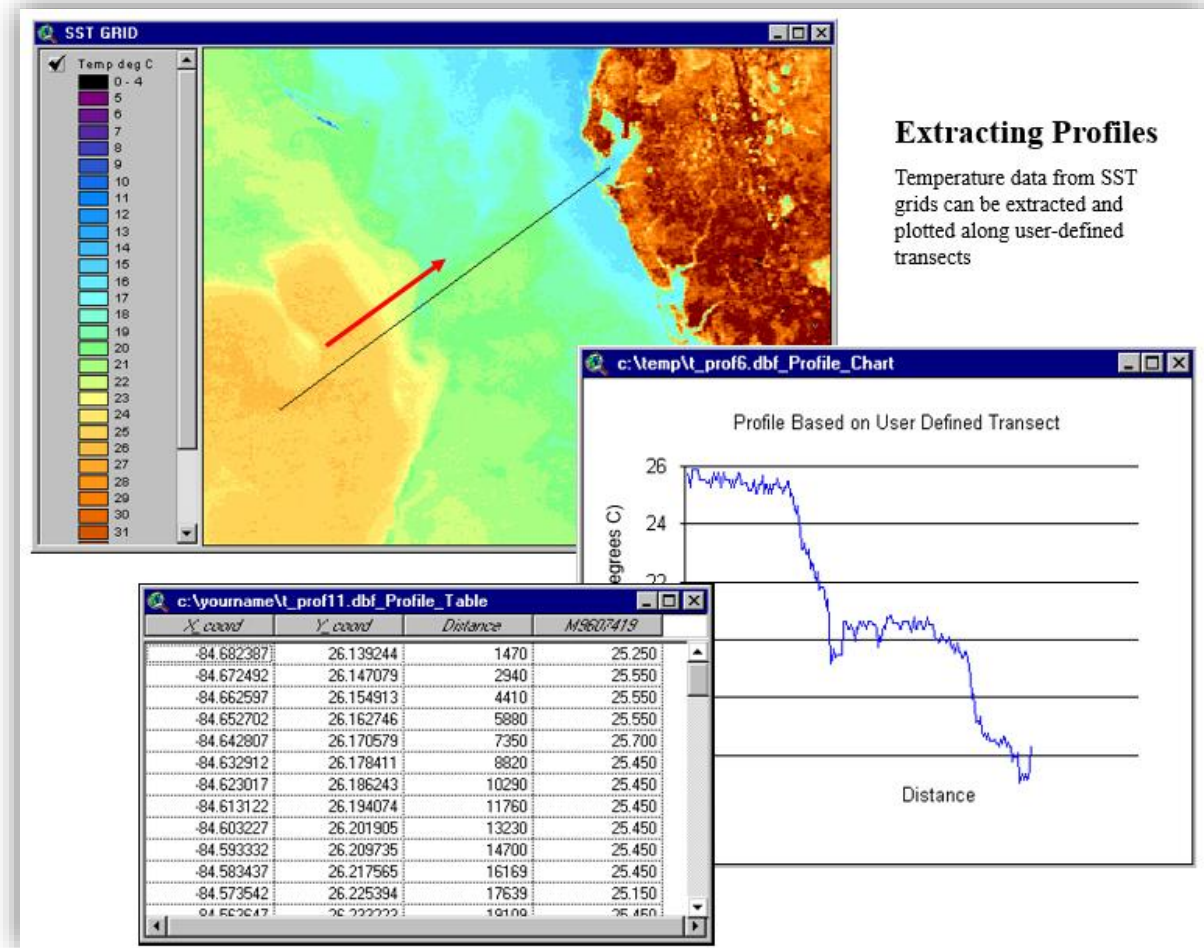
- Area is preserved
- Area measurements consistent across map
- Useful for comparison



Albers Equal-area preserves area

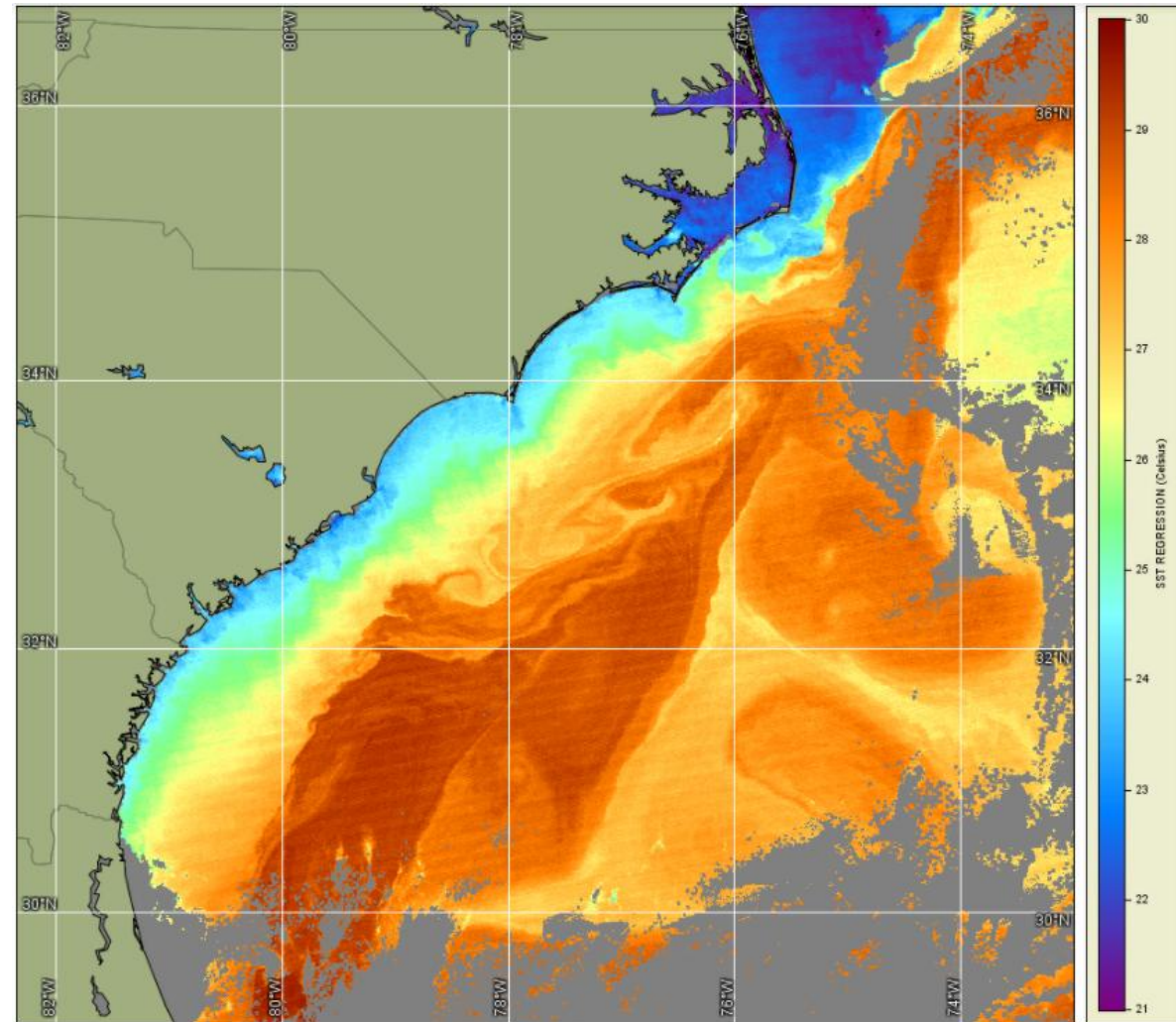
## Data Preparations

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



## Summary

- Imagery
- Data
- Considerations and preparations



S-NPP VIIRS SST Image



# GIS

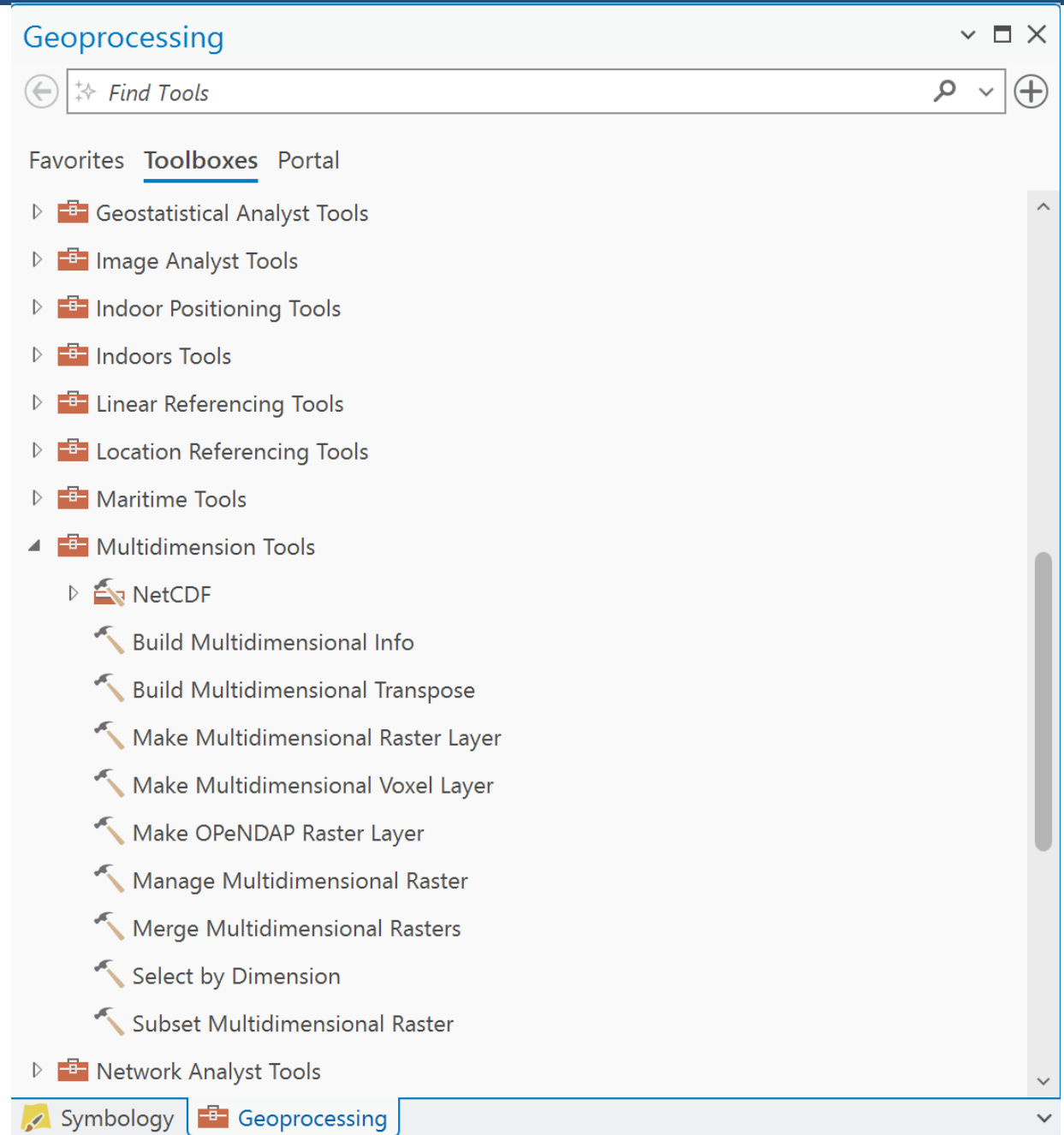
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Using Satellite Data in GIS



# Overview

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



## Useful Extensions / Add-ons

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


- CoastWatch Utilities

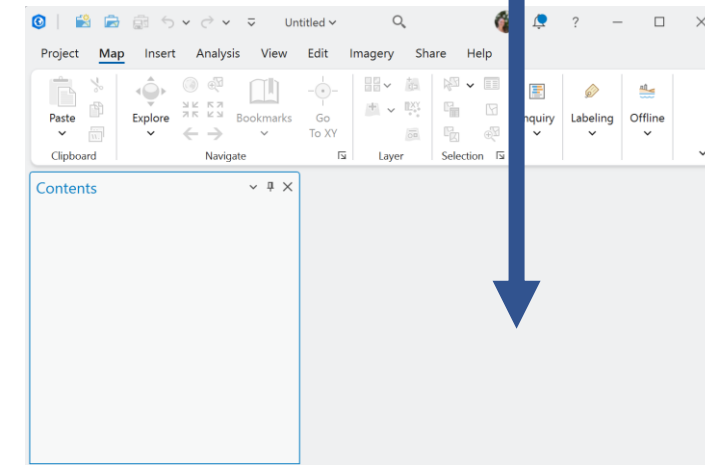
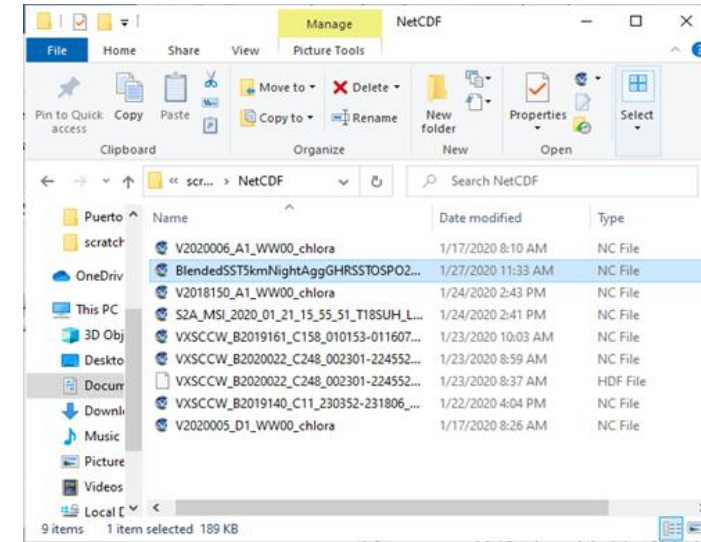
<https://coastwatch.noaa.gov/cwn/data-access-tools/coastwatch-utilities.html>

- Read data files (NetCDF and HDF format)
- Graphical tools for interactive data viewing
- Command line tools for data processing
  - cwexport, cwsample, cwrender



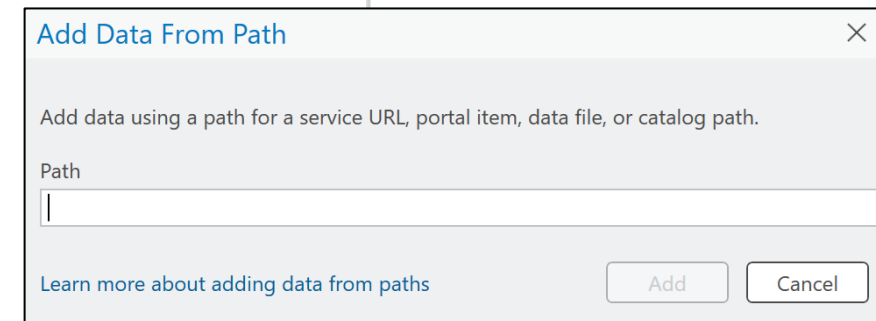
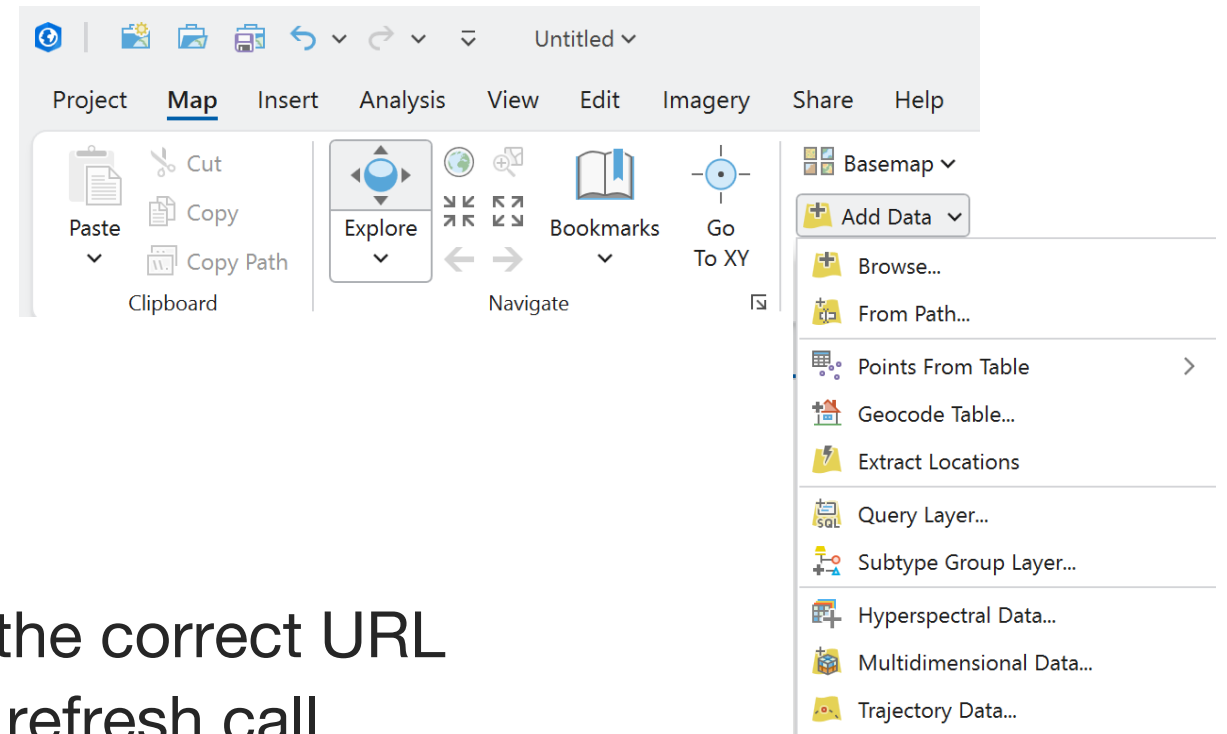
# Methods to add Satellite Data

- 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

URL:

Version:

Parameter	Value
-----------	-------

Server Layers

- STAR TDS Installation
  - STAR TDS Installation
    - Analysed blended sea surface temper
      - sea\_land\_ice\_bit\_mask
      - sea\_ice\_area\_fraction
      - estimated error standard deviation
      - sea\_surface\_foundation\_tempera

Account (Optional)

User:

Password:   Save

Look in:

- estimated error standard deviation of analysed\_sst
- sea\_ice\_area\_fraction
- sea\_land\_ice\_bit\_mask
- sea\_surface\_foundation\_temperature

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

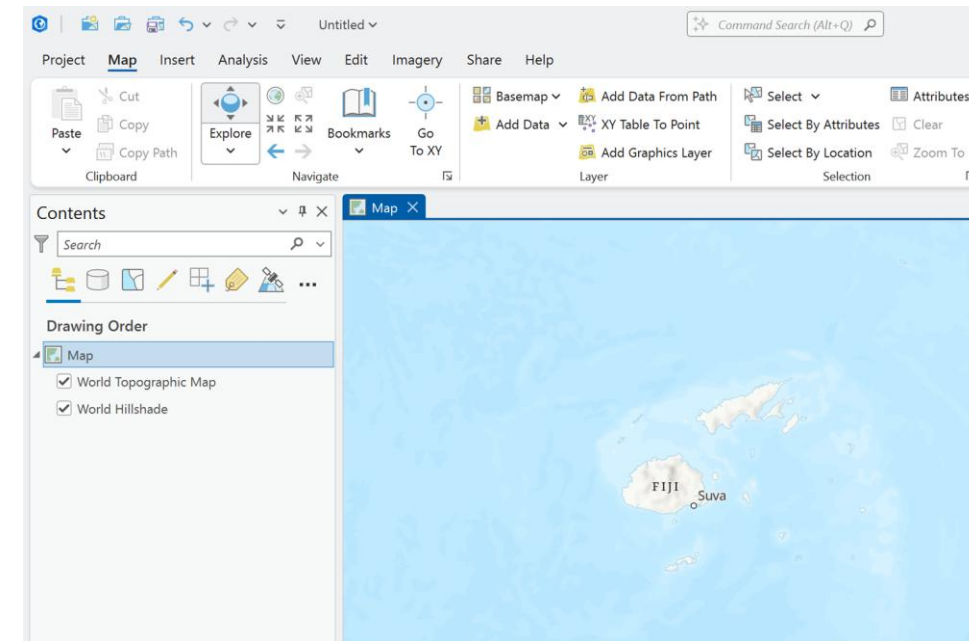
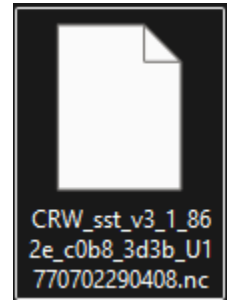
One or more layers failed to draw:

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



# ⊘ Drag-n-Drop

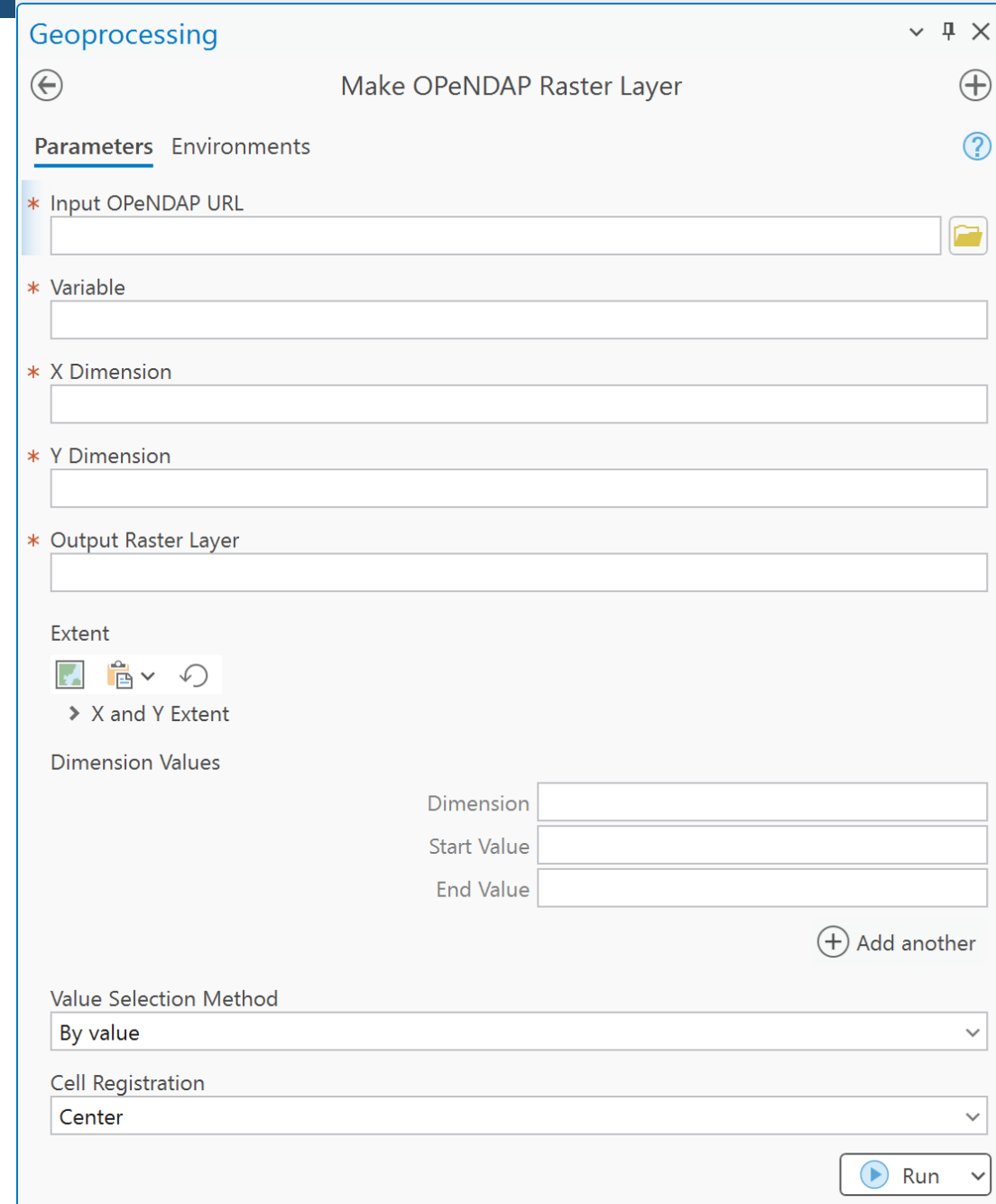
- Quick and easy
- Requires configuration
  - Symbology
  - NetCDF
  - Time/Time slider
- Things to note:
  - Defaults to first variable
  - Don't always get what you want



# 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



The screenshot shows the 'Make OPeNDAP Raster Layer' tool interface in the ArcGIS Geoprocessing environment. The window title is 'Geoprocessing' and the tool name is 'Make OPeNDAP Raster Layer'. The interface is divided into 'Parameters' and 'Environments' tabs. The 'Parameters' tab is active and contains several required fields marked with a red asterisk: 'Input OPeNDAP URL', 'Variable', 'X Dimension', 'Y Dimension', and 'Output Raster Layer'. Below these fields is the 'Extent' section, which includes a map icon, a dropdown menu, and a refresh icon, with a sub-section for 'X and Y Extent'. The 'Dimension Values' section contains three input fields for 'Dimension', 'Start Value', and 'End Value', along with an 'Add another' button. The 'Value Selection Method' is set to 'By value' and the 'Cell Registration' is set to 'Center'. A 'Run' button is located at the bottom right of the tool interface.



# 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

Geoprocessing

Make NetCDF Raster Layer

The Make Multidimensional Raster Layer tool provides enhanced functionality or performance.

Parameters Environments

\* Input netCDF File

\* Variable

\* X Dimension

\* Y Dimension

\* Output Raster Layer

Band Dimension

Dimension Values

Dimension	Value

Value Selection Method

By value

Cell Registration

Center

Run



# Add NC Data

The screenshot shows the ArcGIS Desktop interface. The 'Add Data From Path' menu is open, and 'Multidimensional Data...' is highlighted with a red arrow. The 'Contents' pane on the left shows 'World Topographic Map' and 'World Hillshade' checked. The map view shows a satellite image of Fiji with Suva marked.

## Add Multidimensional Data

Input File, Mosaic Dataset or Image Service

Select Variables

<input type="checkbox"/>	Name	Description
--------------------------	------	-------------

Output Configuration

Multidimensional Raster

> Interpolate irregular data

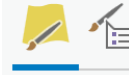
[Learn more about Multidimensional Raster Layers](#)

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



## Primary symbology

Stretch

Choose how to symbolize your raster layer.



Stretch

Stretches values along a color ramp.



Discrete

Groups data based on a selected number of colors and applies a color scheme.



Classify

Assigns a color for each group of values.



Unique Values

Assigns a color for each value.



Shaded Relief

Creates a 3D representation of the surface, with the sun's relative position.



Vector Field

Displays values as vector symbols.

Statistics

Mask

Advanced Labeling

Statistics

Dataset

Options

Min

-2

Max

50

Mean

0

Std. dev

-1

# 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

The screenshot shows the 'Layer Properties: CRW\_sst\_v3\_MultidimLayer' dialog box with the 'Time' tab selected. The 'Visibility using time' section has the checkbox 'Show the layer when the map is within a fixed time extent' unchecked. The 'Visible Time Extent' is set to two empty date-time fields. The 'Filter using time' section has the radio button 'Filter layer content based on attribute values' selected. The 'Layer Time' dropdown is set to 'Layer has time as a dimension', and the 'Time Dimension' dropdown is set to 'StdTime'. The 'Time Extent' is set to '7/10/2023 12:00:00 PM' to '7/10/2023 12:00:00 PM'. The 'Calculate' button is visible. The 'Data is a live feed' checkbox is unchecked. The 'No pre-defined time interval' radio button is selected, with a 'Step' of '10' and 'Seconds' selected. The 'View using unique times within the data' radio button is also visible. The 'Time Zone and Time Offset' section has the 'Time Zone' dropdown set to '<None>' and the 'Adjust For Daylight Saving' checkbox unchecked. The 'Time Offset' is set to '0' and '0'. A 'Learn more about time properties' link is at the bottom. The 'OK', 'Cancel', and 'Apply' buttons are at the bottom right.

# Enable Time Slider

The screenshot displays the ArcGIS Pro software interface. A red arrow points to the 'Time' tab in the top menu bar. The 'Time' tab is active, showing various settings for time-based data. The 'Current Time' section includes 'Start', 'Span' (set to 'Months'), and 'End' fields. The 'Step' section includes 'Number of Steps' (30), 'Step Interval' (3), and 'Layer' (noaa\_snpp\_chla\_monthly\_69...). The 'Snapping' section has 'Time Snapping' checked and 'Seconds' selected. The 'Playback' section includes 'Direction', 'Repeat', 'Slower', 'Faster', and 'Reverse' options. The 'Full Extent' section shows 'Start' (1/1/2014 12:00:00 PM) and 'End' (7/10/2023 12:00:00 PM). The 'Time Zone' section has '<None>' selected and 'Adjust For Daylight Saving' unchecked. The 'Contents' pane on the left shows a map layer named 'noaa\_snpp\_chla\_monthly\_6980\_2878\_e0ba...' with a color scale for 'chlor\_a' ranging from 0.01 to 0.1. The 'Map' view shows a time slider from 1/1/2014 to 7/10/2023 over a satellite image. The 'Symbology' pane on the right shows 'Primary symbology' set to 'Stretch' with 'Band\_1' selected and a color scheme ranging from red to blue.

- 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”

Export Raster

noaa\_snpp\_chla\_monthly\_6980\_2878\_e0ba\_U1768930842477.nc\_chlor\_a

General Settings

Output Raster Dataset

Output Format

TIFF

▼ Spatial Reference System and Clipping Options

Coordinate System

GCS\_WGS\_1984

Geographic Transformations

None

Clipping Geometry

Default

Maintain Clipping Extent

▼ Raster Properties

Cell Size

X 0.03749999999999936 Y 0.03749999999999995

Raster Size

Columns 268 Rows 268

Pixel Type

Export



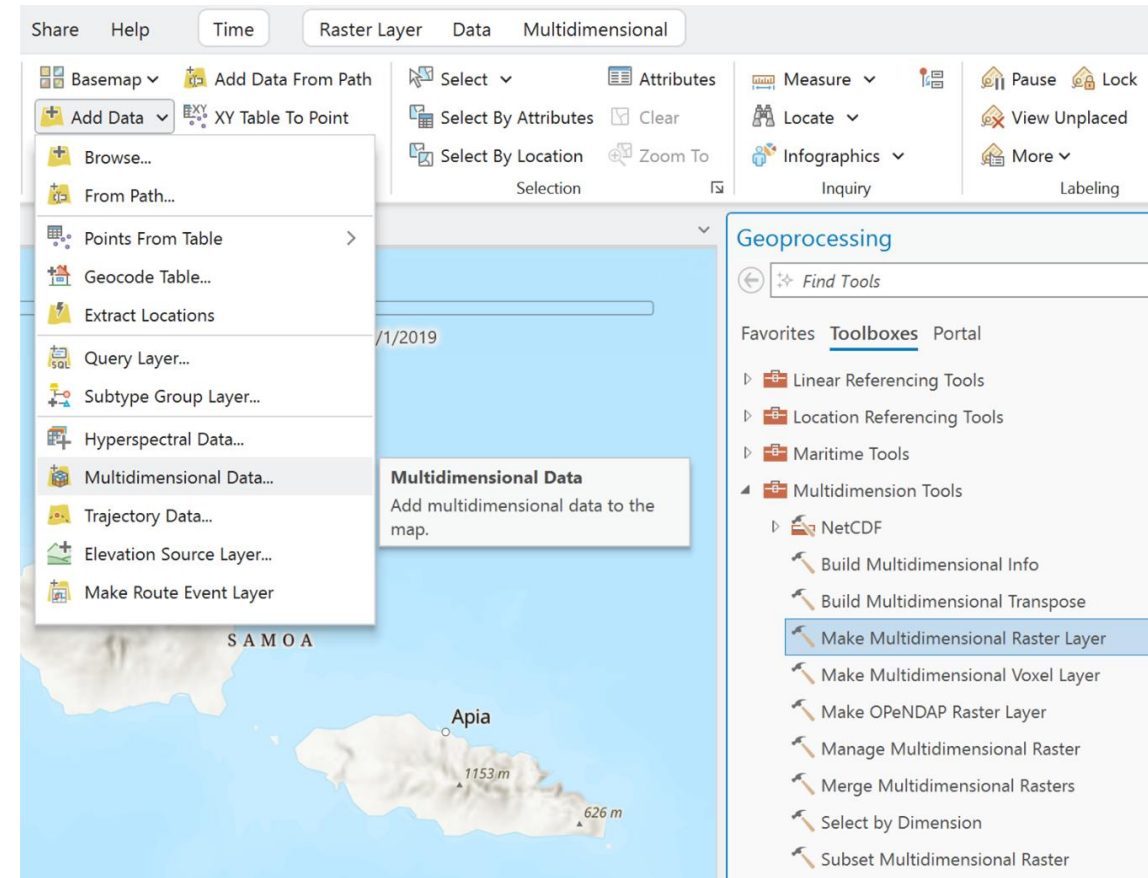
# Recap Methods to add Satellite Data



- **Add Data**
  - Multidimensional Data...
  - From Path...
  - Browse...



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

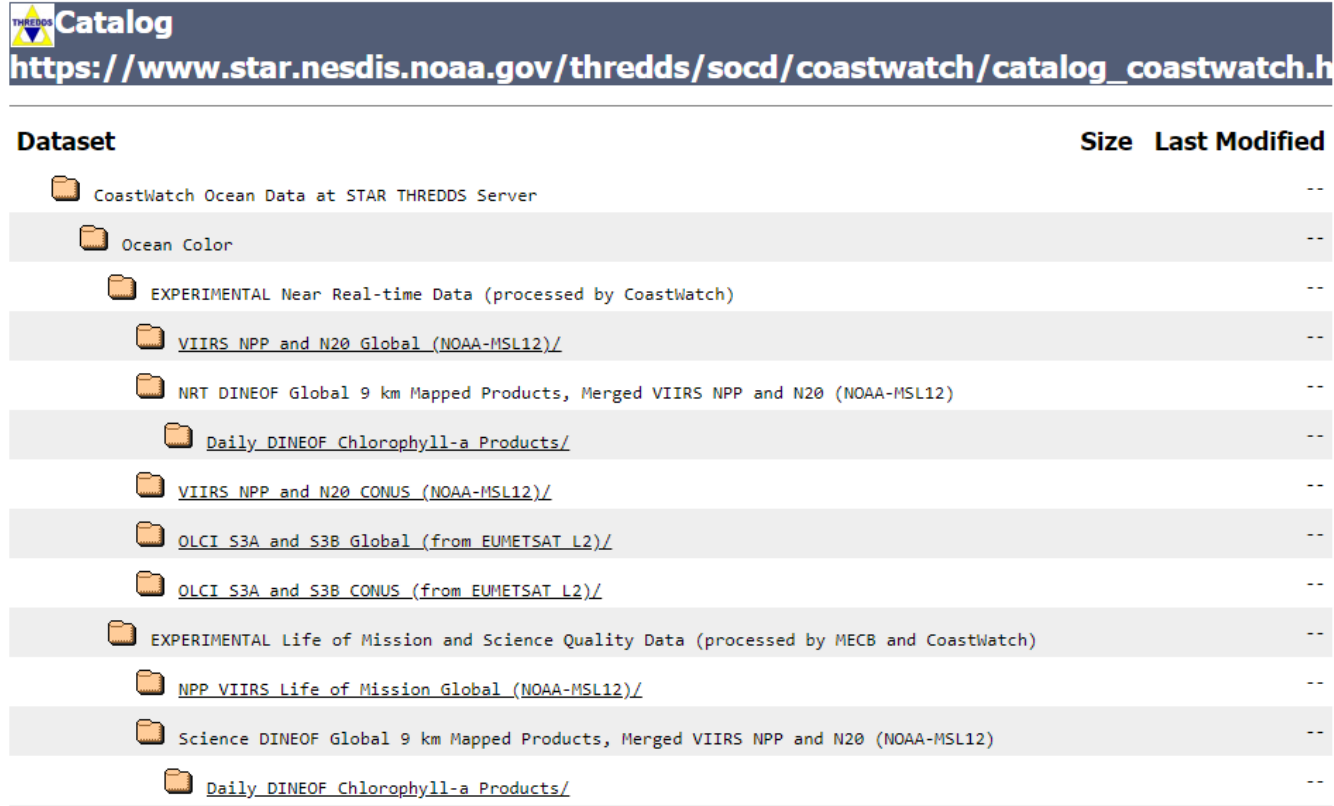


- *Drag-n-Drop and EDC no longer recommended*



# Additional Services to Obtain Data

- OpenDAP
- THREDDS
- ERDDAP



The screenshot shows the THREDDS Catalog interface. At the top, it displays the THREDDS logo and the URL: [https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/catalog\\_coastwatch.h](https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/catalog_coastwatch.h). Below the header, there is a table with columns for 'Dataset', 'Size', and 'Last Modified'. The table lists several datasets, including 'CoastWatch Ocean Data at STAR THREDDS Server', 'Ocean Color', and various experimental and science data products.

Dataset	Size	Last Modified
CoastWatch Ocean Data at STAR THREDDS Server		--
Ocean Color		--
EXPERIMENTAL Near Real-time Data (processed by CoastWatch)		--
VIIRS NPP and N20 Global (NOAA-MSL12)/		--
NRT DINEOF Global 9 km Mapped Products, Merged VIIRS NPP and N20 (NOAA-MSL12)		--
Daily DINEOF Chlorophyll-a Products/		--
VIIRS NPP and N20 CONUS (NOAA-MSL12)/		--
OLCI S3A and S3B Global (from EUMETSAT L2)/		--
OLCI S3A and S3B CONUS (from EUMETSAT L2)/		--
EXPERIMENTAL Life of Mission and Science Quality Data (processed by MECB and CoastWatch)		--
NPP VIIRS Life of Mission Global (NOAA-MSL12)/		--
Science DINEOF Global 9 km Mapped Products, Merged VIIRS NPP and N20 (NOAA-MSL12)		--
Daily DINEOF Chlorophyll-a Products/		--

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)

The screenshot shows the ERDDAP interface for NOAA CoastWatch. The header includes the NOAA logo and the text "ERDDAP at NOAA CoastWatch" with the tagline "Easier access to scientific data". The dataset title is "Sea-Surface Temperature, NOAA Geo-polar Blended Analysis, GHR SST, Near Real-Time, Global 5km, 2002-Present, Daily". The institution is NOAA NESDIS STAR. The form allows for subsetting data by time, latitude, and longitude. The "Dimensions" section shows time (UTC) from 2020-09-06T12:00:00Z to 2020-09-06T12:00:00Z, latitude from -89.975 to 89.975, and longitude from -179.975 to 179.975. The "Grid Variables" section includes checked options for analysed\_sst, analysis\_error, mask, and sea\_ice\_fraction. The "File type" dropdown is set to ".htmlTable". A "Submit" button is at the bottom.

Dimensions	Start	Stride	Stop	Size	Spacing
<input checked="" type="checkbox"/> time (UTC)	2020-09-06T12:00:00Z	1	2020-09-06T12:00:00Z	6575	1 day 0h 1m 19s (uneven)
<input checked="" type="checkbox"/> latitude (degrees_north)	-89.975	1	89.975	3600	0.05 (even)
<input checked="" type="checkbox"/> longitude (degrees_east)	-179.975	1	179.975	7200	0.05 (even)

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?

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Using Satellite Data in GIS

