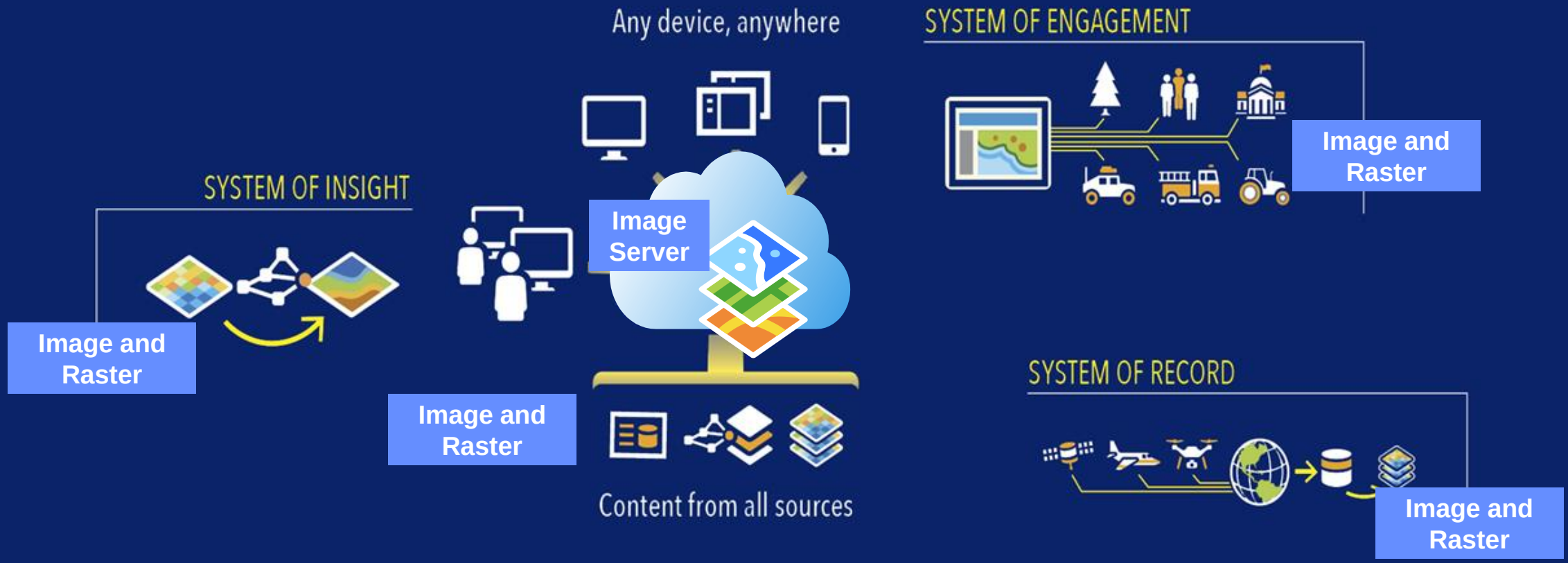
# Improved Cloud Raster Format for Multidimensional Raster Storage and Analysis

Hong Xu

Esri

# Imagery in the ArcGIS Platform



# Data and Requirements

## Oceanography

- Sea temperature
- Salinity
- Ocean currents
- Algal blooms

## Meteorology

- Air temperature
- Atmospheric moisture
- Wind speed

## Earth Observation System

- Landsat
- Sentinel
- Worldview
- Pleiades
- MODIS
- Etc.

## Climate

- Soil moisture
- Sea ice
- Snow cover

## Weather Forecasting

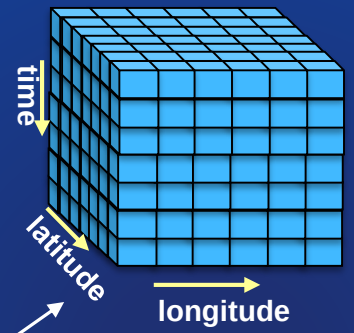
- Temperature
- Humidity
- Precipitation
- Dew point

Data volume is large spatially and long temporally
Require efficient data model and analytical methodology

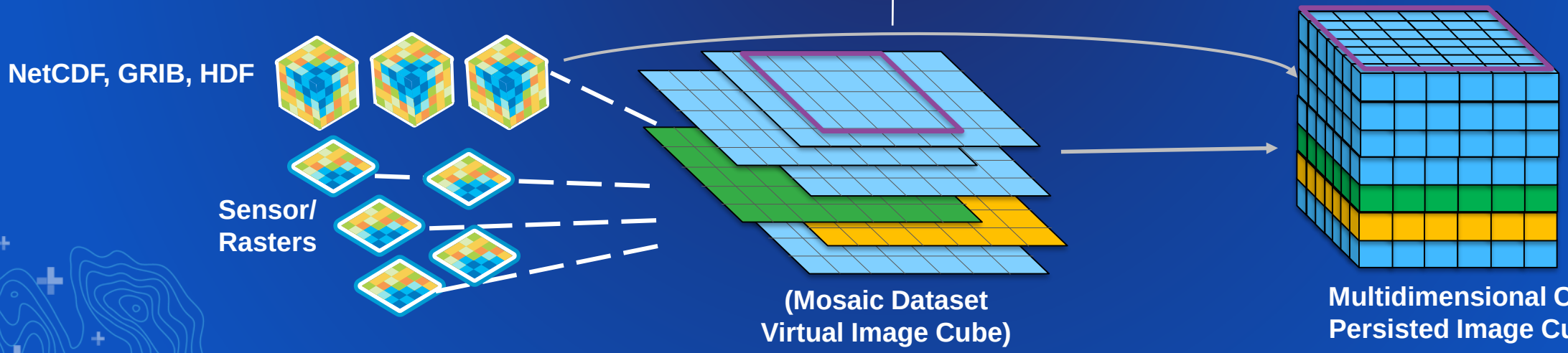
# Multidimensional Raster Data Model in ArcGIS

## Local or in cloud

- **Multidimensional raster object**
  - **One or more variables**
  - **Variable is 3D/4D (X, Y, time, depth)**
  - **Pixel can be one band or multiple bands**

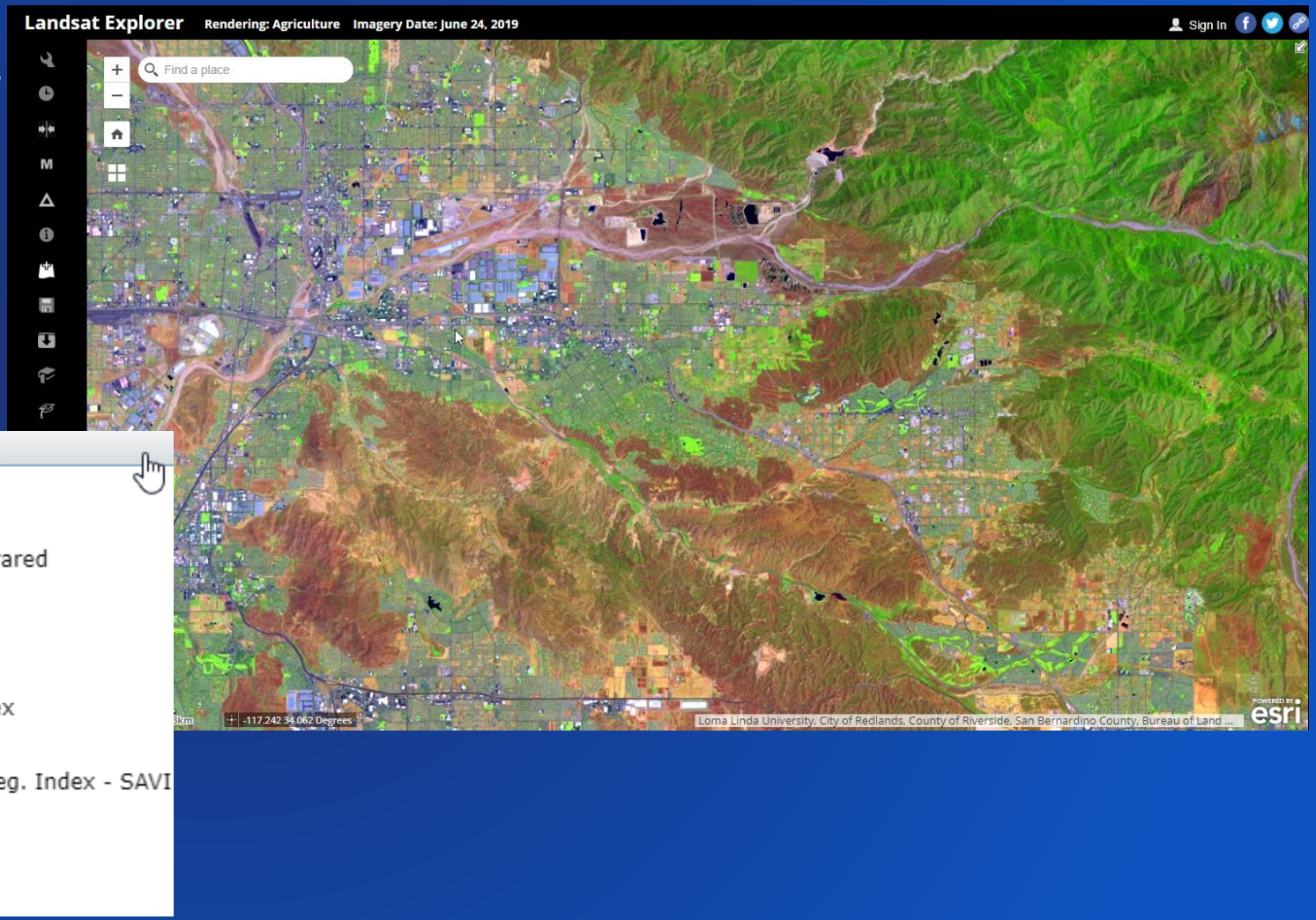



```
mdRaster = arcpy.Raster("temperature.nc", True)
mdRaster.mdinfo
mdRaster.save("c:/data/mdraster.crf")
```



# Example: Landsat Explorer

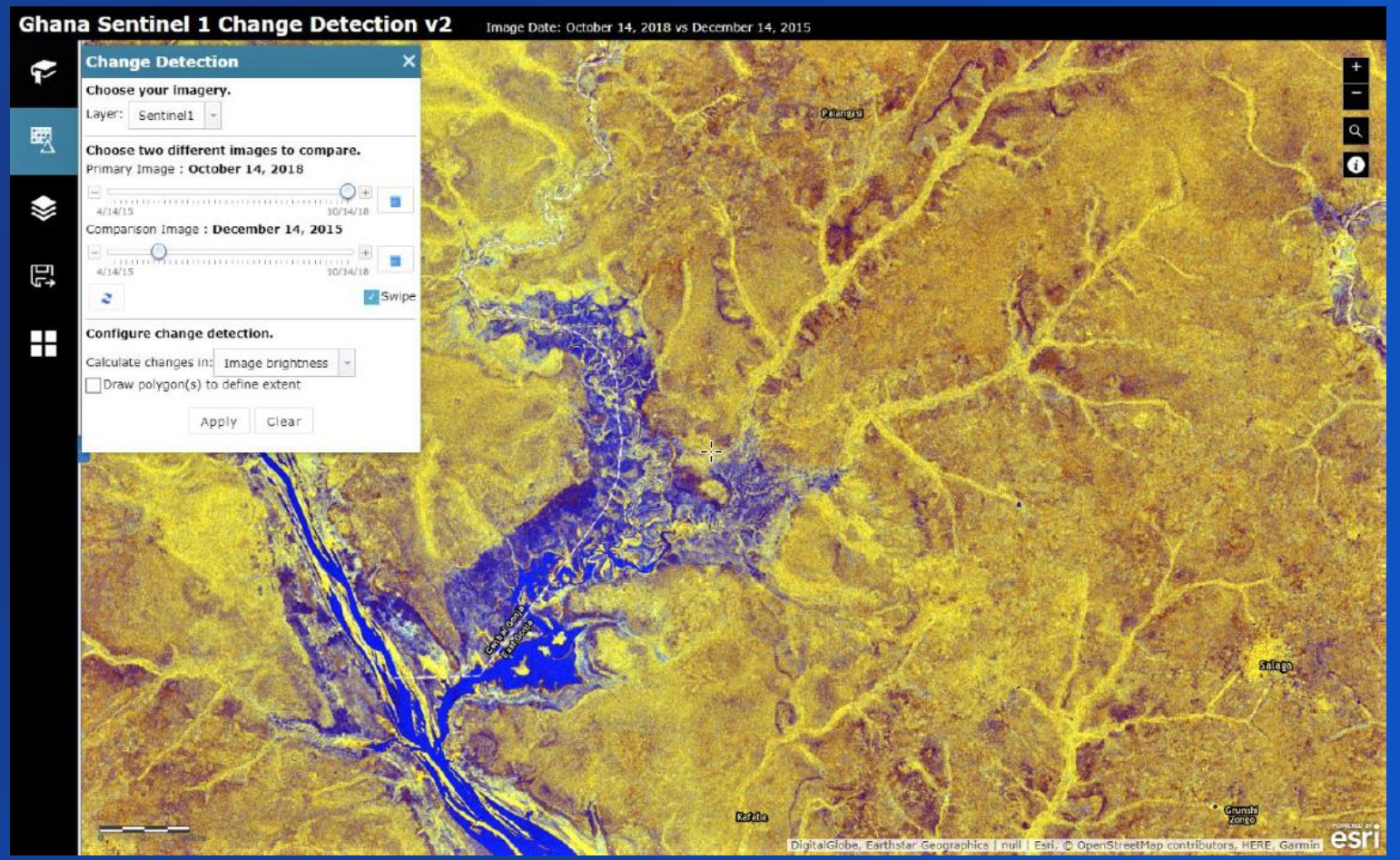
- Mosaic dataset to manage images
  - Reference pixels on disk
  - Support  Add, delete, update
- Support
  - Query with time
  - On demand processing



# Example: Sentinel-1 Africa Data Cube Application

Volta River area in center Ghana

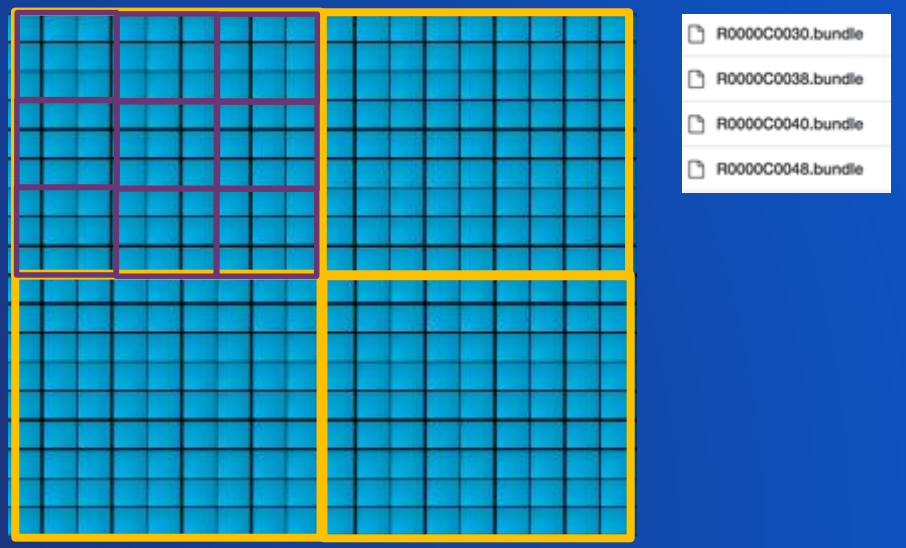
- Mosaic dataset points to Africa data cube
  - using custom python raster type
- RGB is created as VV, VH, VV/VH

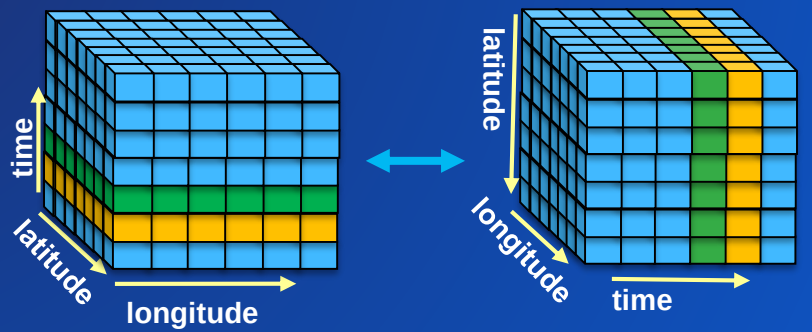


# Multidimensional CRF

## Support cloud storage and file system

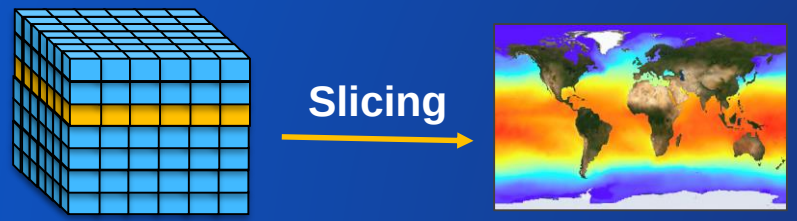
- Optimized format for distributed read/write
- CRF structure
  - Folder based and organized as bundles
  - A bundle contains many tiles
  - Compressed
    - LERC
- Multidimensional CRF structure
  - Each variable is a folder
  - Stores a transpose

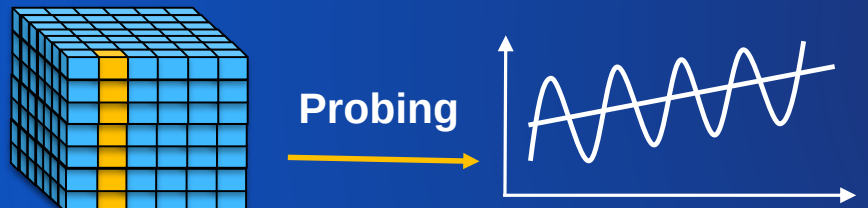


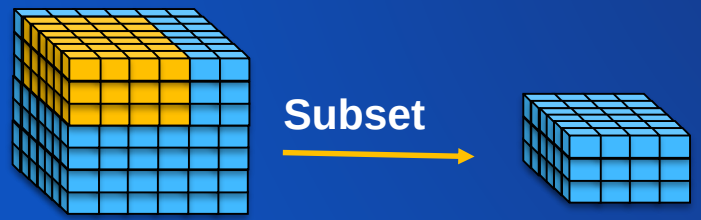



# Multidimensional Raster Computing

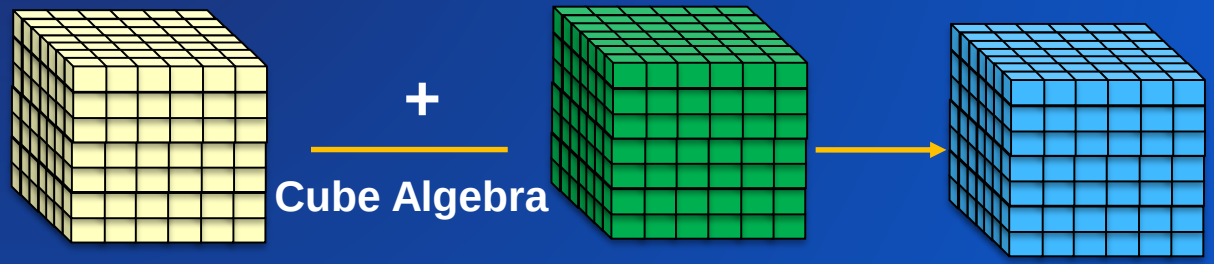
Analyze time series imagery and predict future



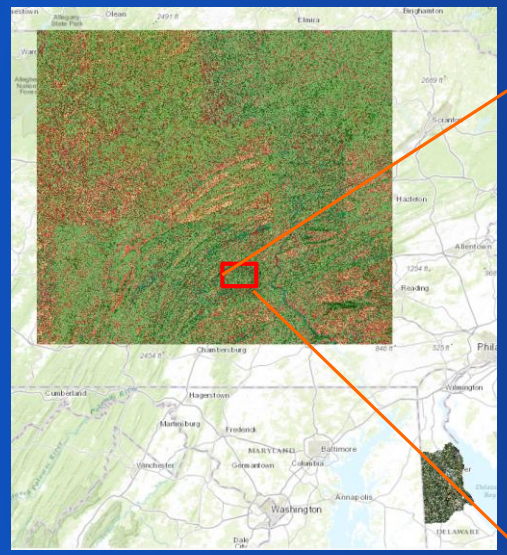


# CRF – Used in Raster Analytics in Cloud

## An example

### Input data Size 397GB




### Output: LandCover stored as CRF in Cloud

ArcGIS Enterprise on Amazon

**100 billion pixels!**

**1 hour 13 minutes**

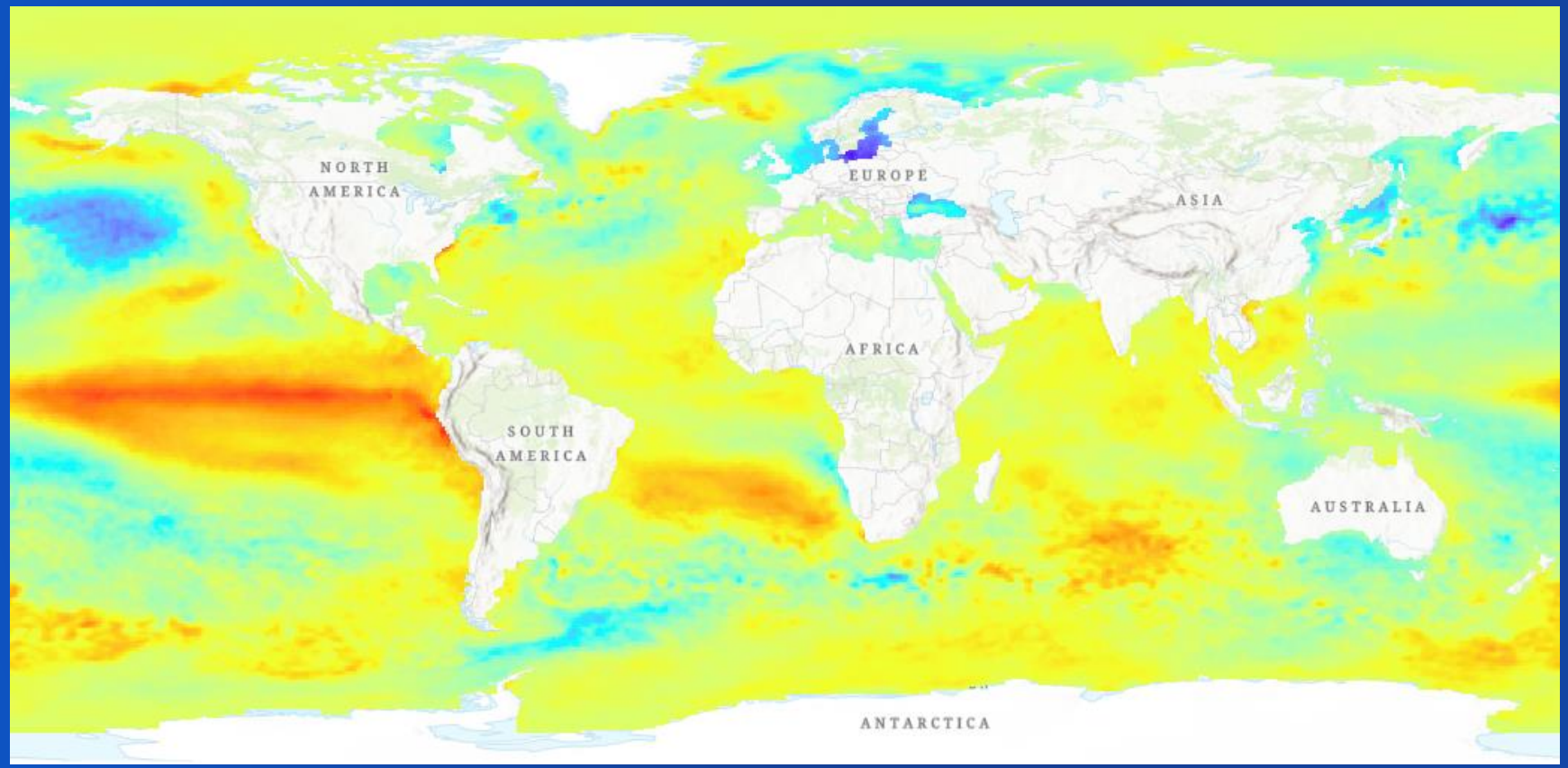
**10 – 20 core Amazon instances**

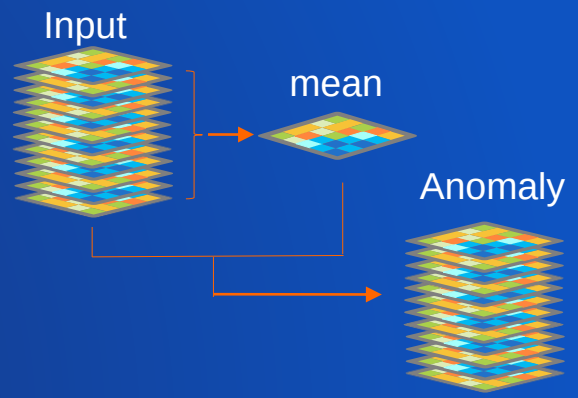
## Processing

Brightness/Veg Chromaticity → False color composite → Segmentation → Classification

# Multidimensional CRF Example - Sea Surface Temperature Anomaly

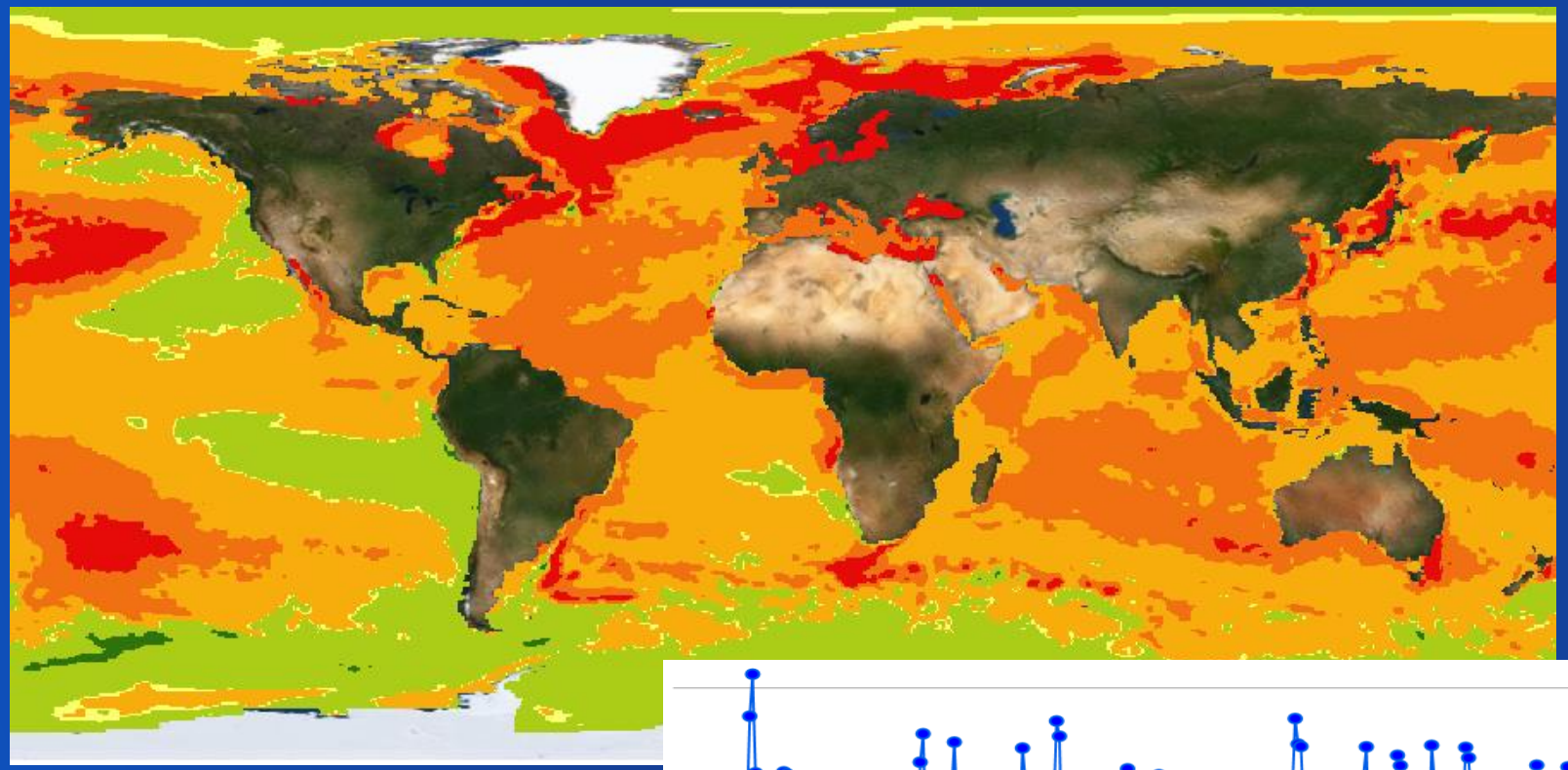
Computed from 35 years SST (420 slices)



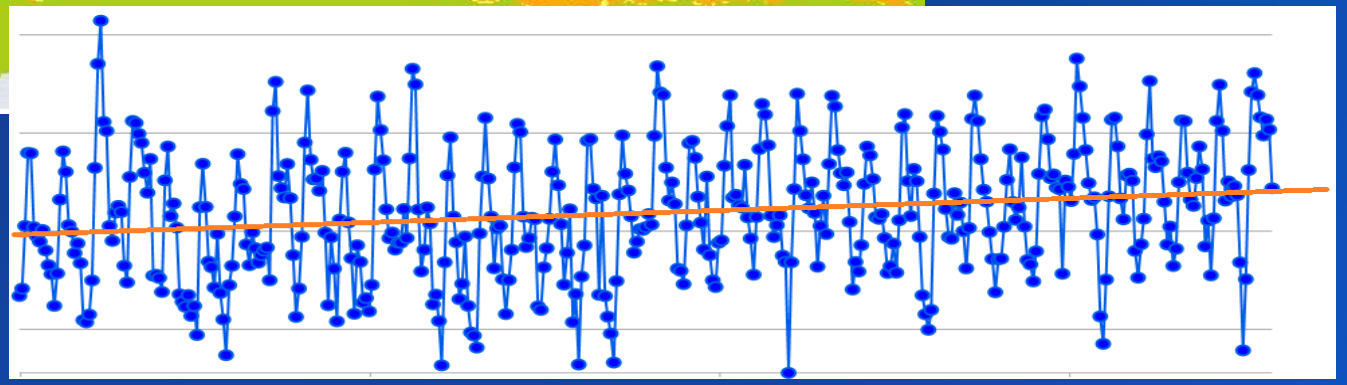



# Multidimensional CRF Example - Sea Surface Temperature Trend Map

Computed from 35 year monthly SST data using harmonic regression method



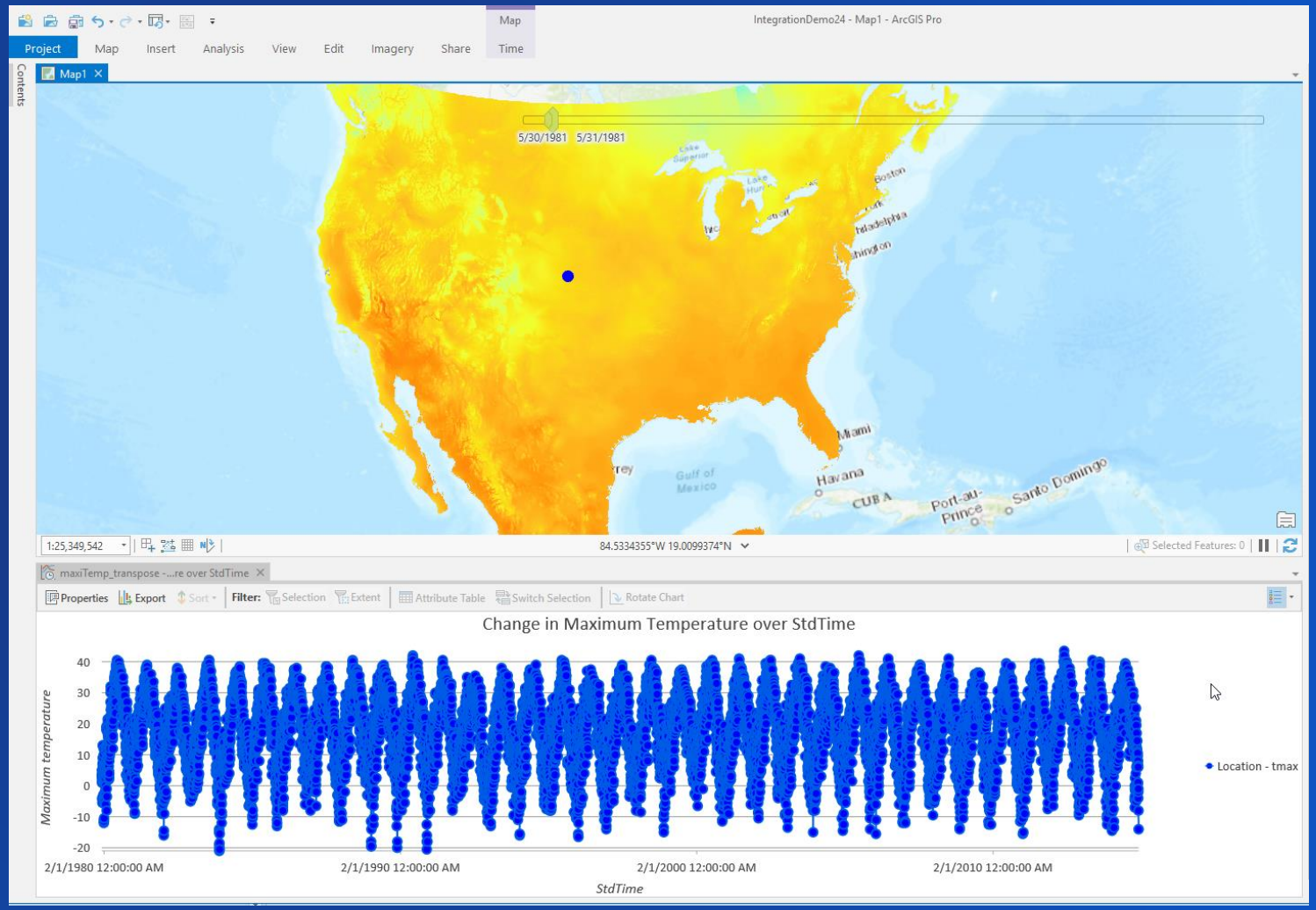
- **Mean: 0.003**

# Multidimensional CRF Example – Daymet 35 Year Daily Temperature

created from 35 netCDF files, each contains 365 slices, total 12775 slices

- CRF with transpose
- Temporal profile
  - 3 seconds on local file
  - 6 seconds on S3



# Thank you!