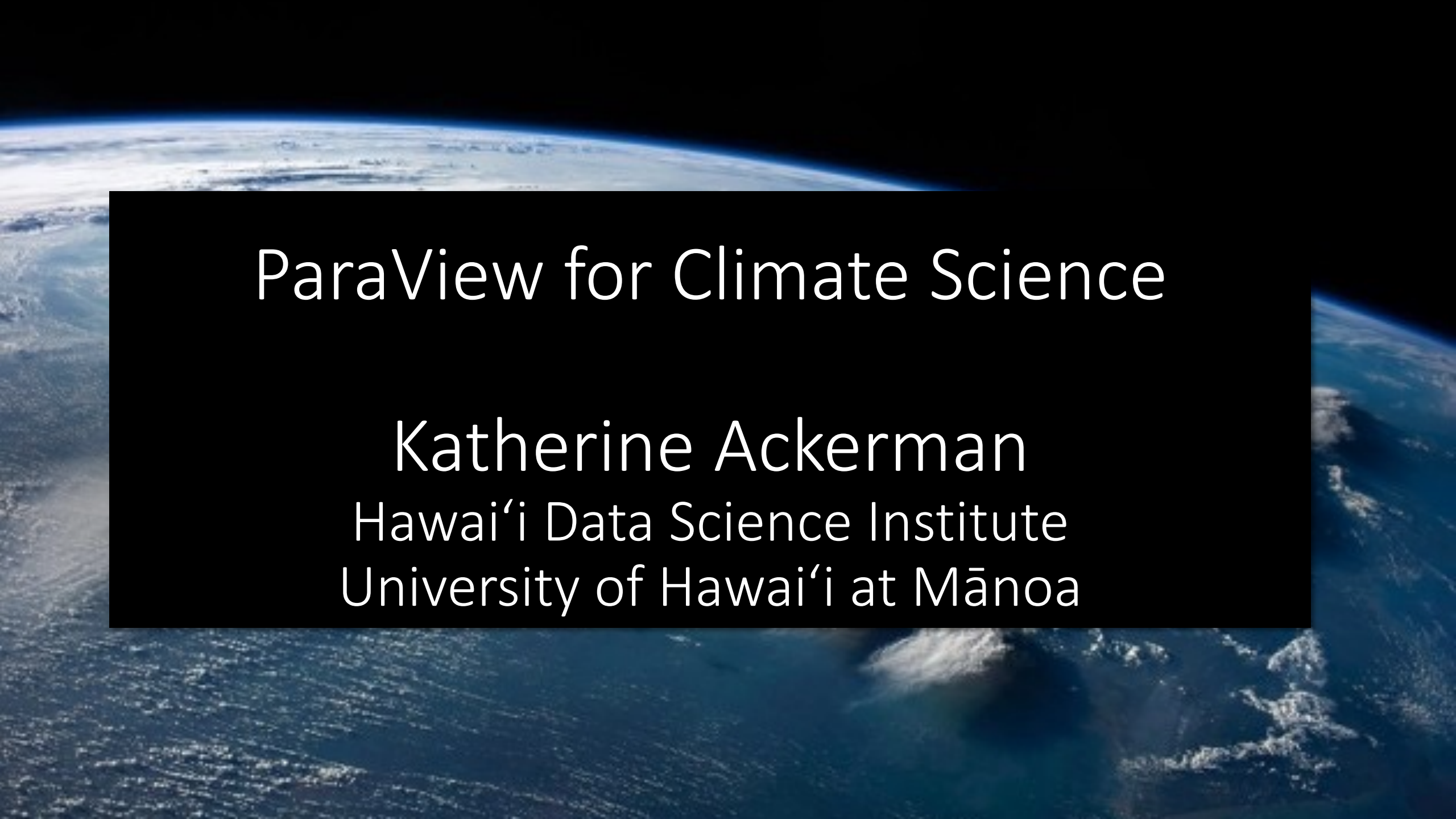

ParaView for Climate Science

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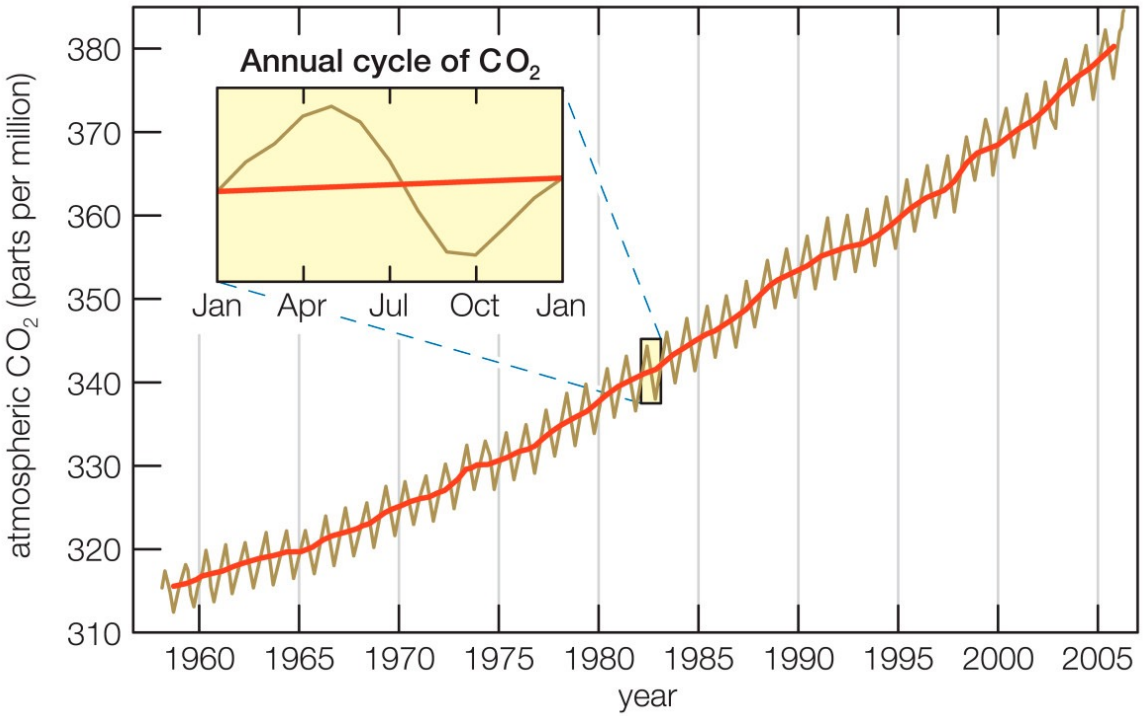
Climate Science

Climate Science: refers to the long-term and global scale study of Earth's average weather systems across different geographic regions, and can refer to regions of 10s km^2 to 1000s km^2

- Historical records are extremely important to our understanding of climate → help us determine cyclical patterns and changes to normal patterns

https://climate.nasa.gov/



Keeling Curve – Mauna Loa Observatory sampled CO_2 for decades, showing us:

1. An annual cycle of CO_2 changes, and
2. A rapid rise in global CO_2 concentrations

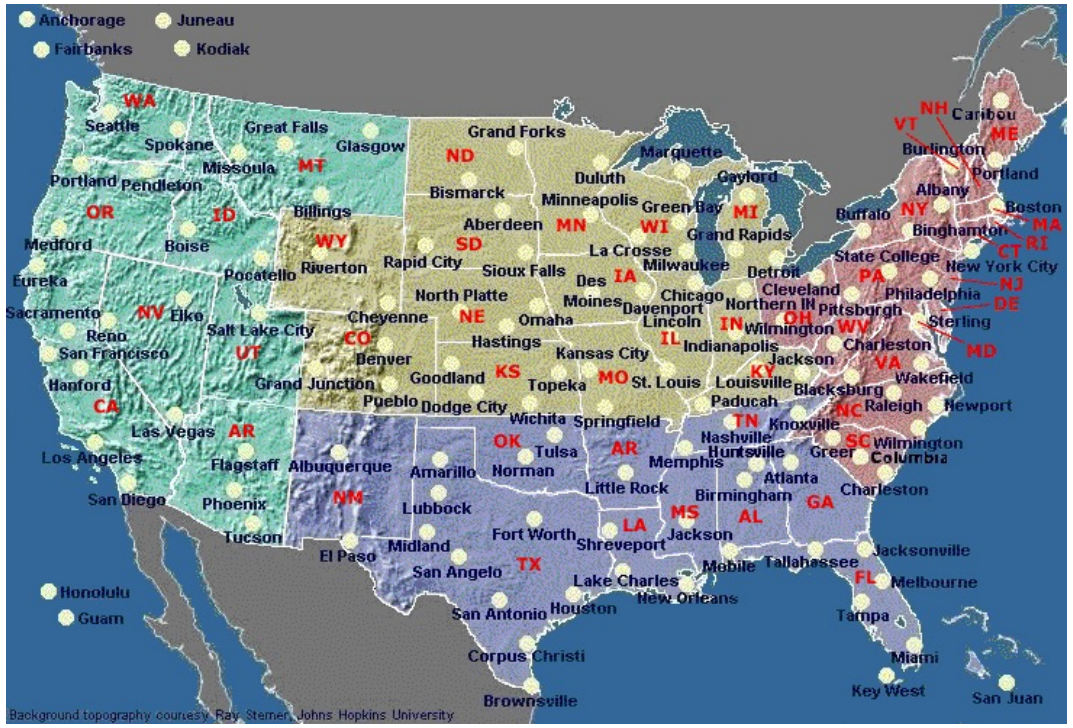
One of the most important climate records to date.

https://www.britannica.com/science/Keeling-Curve

Gaps in Historical Records

- Weather records at point locations (say, Honolulu Airport) have records of temperature, humidity, pressure, rain, etc, going back decades
- HOWEVER, these records only describe atmospheric conditions at single locations
- What about all area in between these stations?

Interactive Map of Weather Stations in the US
https://www.weather.gov/nwr/Maps

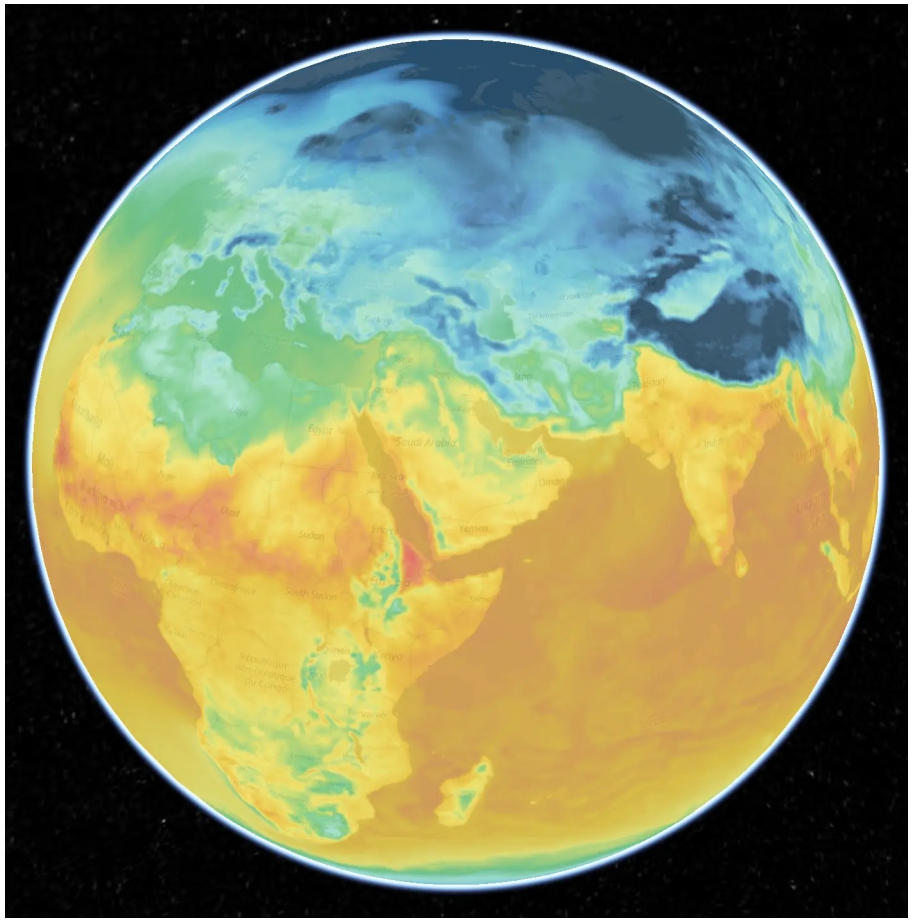


National Weather Service US Weather Stations
https://www.wrh.noaa.gov/wrh/forecastoffice_tab.php

Weather Models and Reanalysis Data

To fill in the gaps, we could:

1. Interpolate data between these weather stations (highly inaccurate, very coarse resolution between large gaps), or
2. Use historical observations at these locations in sophisticated weather models to reconstruct weather patterns across the globe



Reanalysis of Global Temperature
https://www.meteomatics.com/en/recent-developments/

Climate Science and Big Data

- Because reanalysis data is a product created by us, the temporal and spatial resolution can be as fine as you'd like it to be
- This means you can have 1-hourly global temperatures at 1 km^2 grid resolution if you'd like!
- 60 years of 1 hourly data for the entire globe is 2.68 x 10^{14} data points! (1/4 of a quadrillion)

Reanalysis data can be extremely large, making it computationally heavy and hard to visualize effectively

ParaView for Climate Science

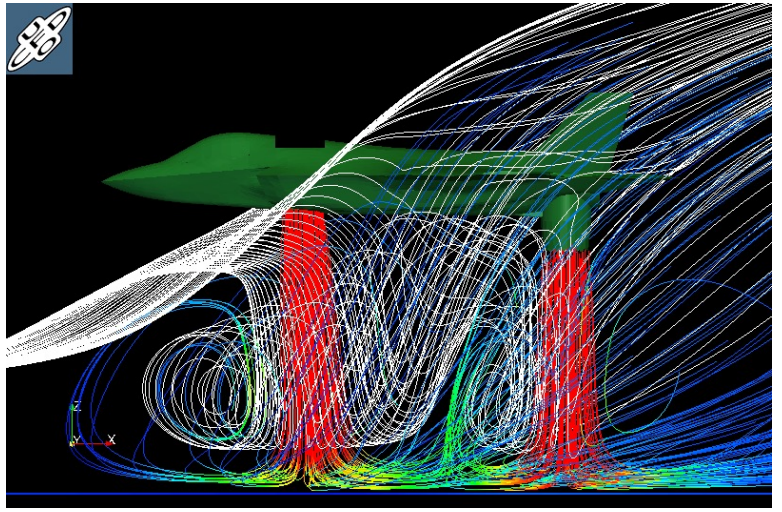
An open-source GUI for rapid and efficient data visualization

Parallel **Vi**sualization Application

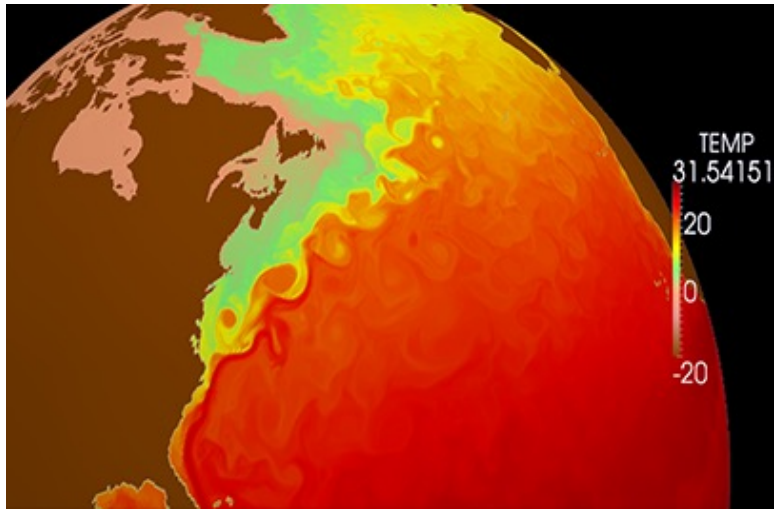
- Multi-platform visualization application
  - extensible architecture via plugins
  - rich scripting support through Python
  - binaries available for Window, OSX, and Linux

Supports distributed computation of large datasets

- runs on distributed and shared memory parallel systems
- also runs on single processor system
- Client/Server model



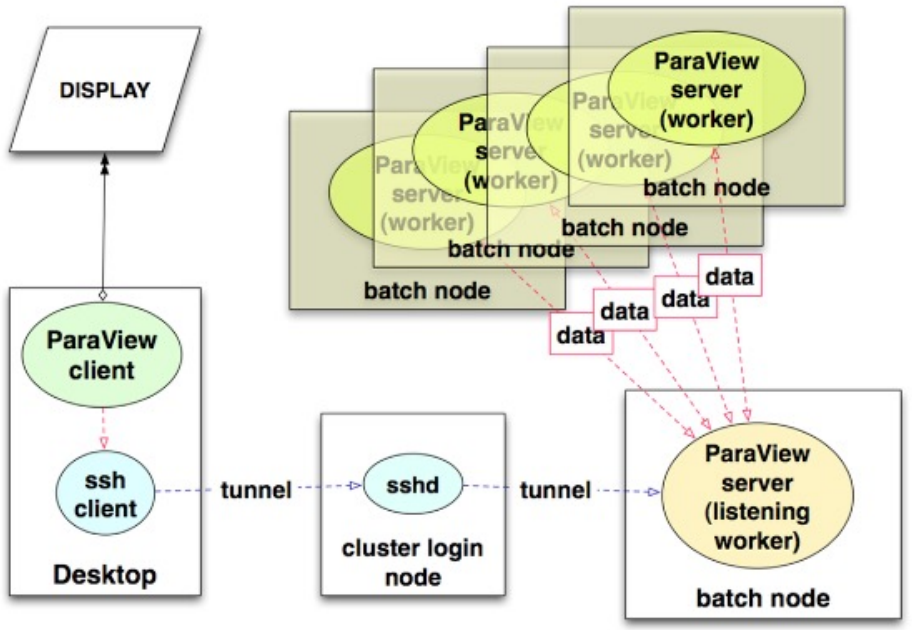
CFD Visualization on Paraview.org



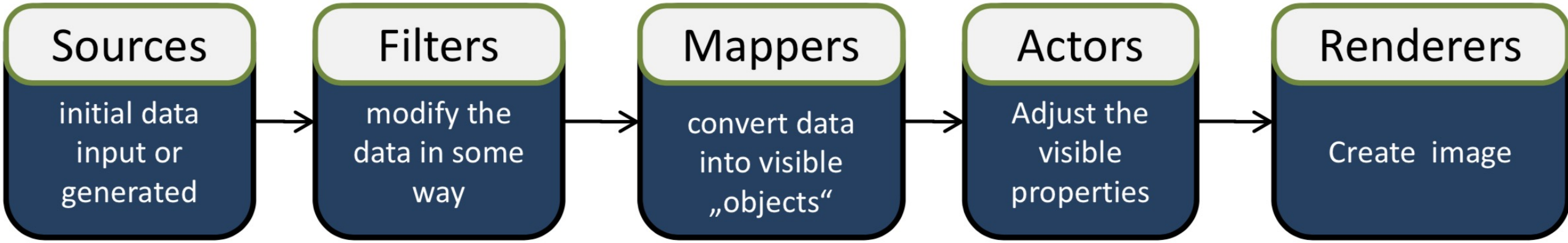
Climate Visualization on Paraview.org

Why use ParaView for Climate Data?

- Climate data is often extremely large
- Paraview is equipped to run on high performance computing systems, making it a low barrier application for viewing climate data
- Has readers for many geospatial data types:
  - NetCDF (most climate data stored this way, including reanalysis)
  - CAM Data (climate model)
  - MPAS Data (climate model)
  - NetCDF POP (ocean program data)
  - HDF5 converter (satellite data)
  - Good for animations



The Paraview Visualization Pipeline



Data reader

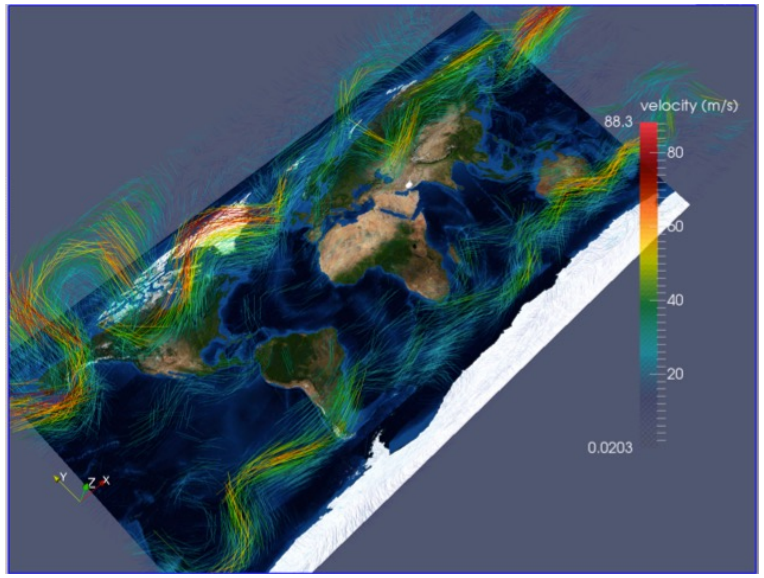
Select portion of the data

Map data to visual representation

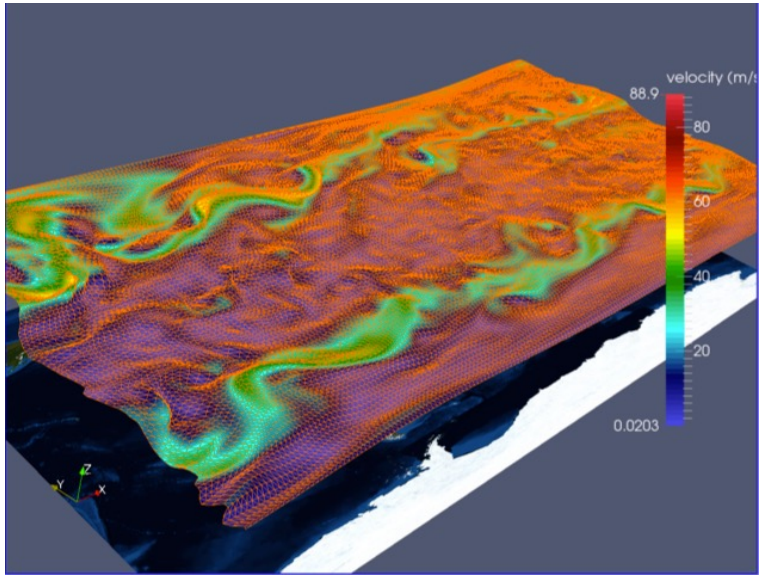
Present visual & enable interaction

Potential Applications – Data Vis. For Climate Science

- Color Mapping – Maps scalar data to color
  - Color panel in Display tab of object inspector of data → Color by → Edit Color Map
- Contour Plots – Construct boundaries between regions
- Scalar Generation – Extract scalars from parts of data → Elevation maps
- HedgeHogs – Oriented scaled line for vector representation; Wind Vectors
- Warping → Advect simple object to indicate flow; pressure contours



HedgeHogs for Wind vectors

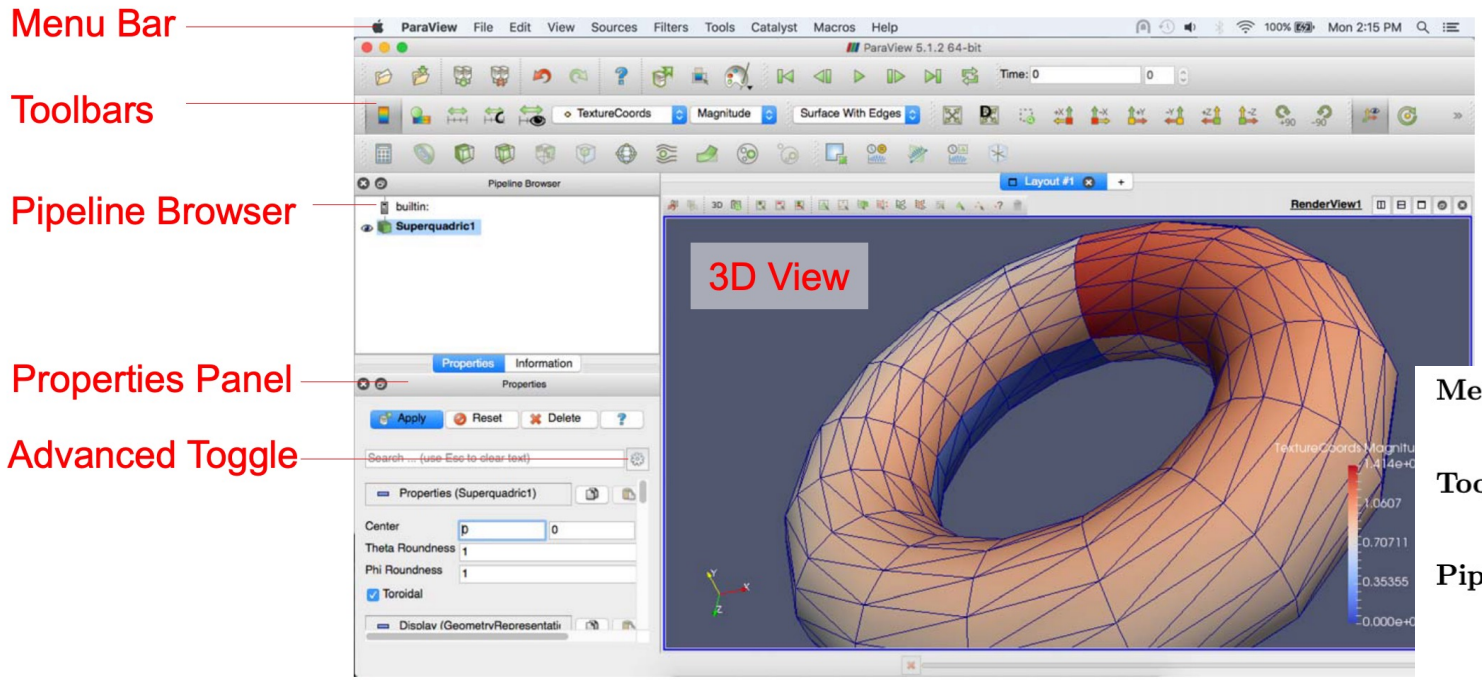


Warping for Pressure Contours

Where to get Climate Data?

- Weather Forecasts and Reanalysis Data:
  Copernicus: https://cds.climate.copernicus.eu/cdsapp#!/home
  LLNL: https://esgf-node.llnl.gov/search/esgf-llnl/
- Paleoclimate reconstructions:
  NOAA NCEI: https://www.ncei.noaa.gov/access/paleo-search/
- Satellite Data:
  GOES-R: https://www.goes-r.gov/multimedia/dataAndImageryImagesGoes-17.html
  LAADS: https://ladsweb.modaps.eosdis.nasa.gov/search/

Overview of the Interface



** Pipeline Browser and Properties Panel are most important to Visualization

Menu Bar As with just about any other program, the menu bar allows you to access the majority of features.

Toolbars The toolbars provide quick access to the most commonly used features within ParaView.

Pipeline Browser ParaView manages the reading and filtering of data with a pipeline. The pipeline browser allows you to view the pipeline structure and select pipeline objects. The pipeline browser provides a convenient list of pipeline objects with an indentation style that shows the pipeline structure.

Properties Panel The properties panel allows you to view and change the parameters of the current pipeline object. On the properties panel is an advanced properties toggle that shows and hides advanced controls. The properties are by default coupled with an **Information** tab that shows a basic summary of the data produced by the pipeline object.

3D View The remainder of the GUI is used to present data so that you may view, interact with, and explore your data. This area is initially

Extensive ParaView for Climate Science Tutorial: https://www.dkrz.de/mms/pdf/vis/paraview.pdf

Example