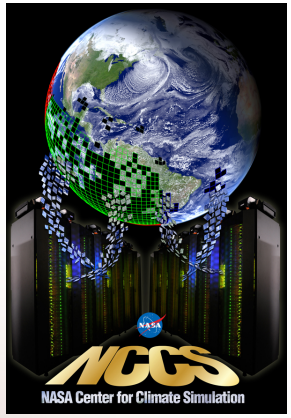
National Aeronautics and Space Administration

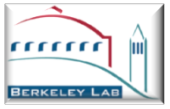


Exploratory Climate Data Visualization and Analysis

by

Thomas Maxwell, Jerry Potter & Laura Carriere, NASA NCCS

and the UVCDAT Development Consortium

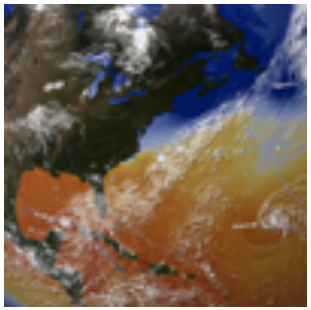
Scientific Visualization

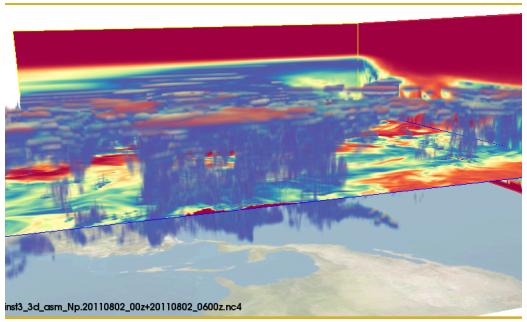
We process, understand, and analyze information visually.

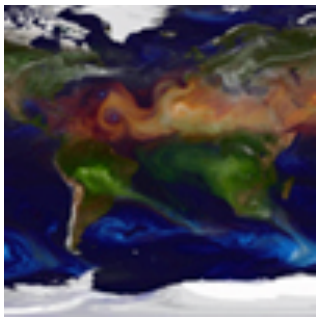
- 30% of the cerebral cortex is devoted to visual information processing.
- The brain's capacity to detect visual patterns is invaluable in data analysis and understanding.
- Extremely difficult to emulate using statistical and machine learning approaches alone.

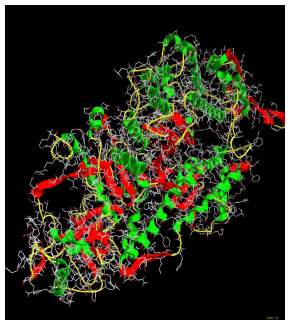
Visual representations are evolving

- Static 2D graphing and plotting => interactive 3D rendering.
- Driven by need to analyze complex multidimensional data.
- Calls for higher dimensional visuals and human perspective.
- Requires new tools for the scientific workbench.
- Must be seamlessly integrated and easy to use.



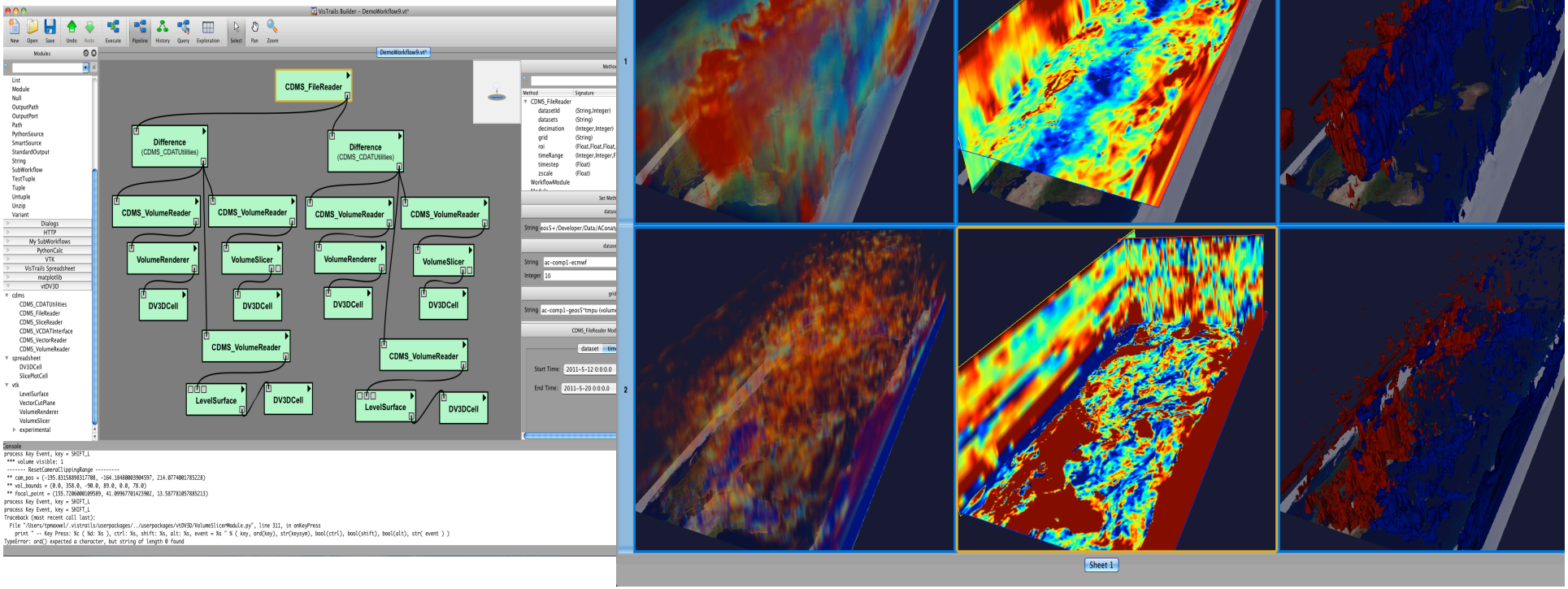






DV3D (vcs3D): Interactive 3D Visualization

- High level analysis and visualization modules for Vistrails and vcs.
- Encapsulates complex VTK visualization operations.
- Greatly simplified API (wrt raw VTK).
- Interactive configuration.
- Tight UVCAT integration.



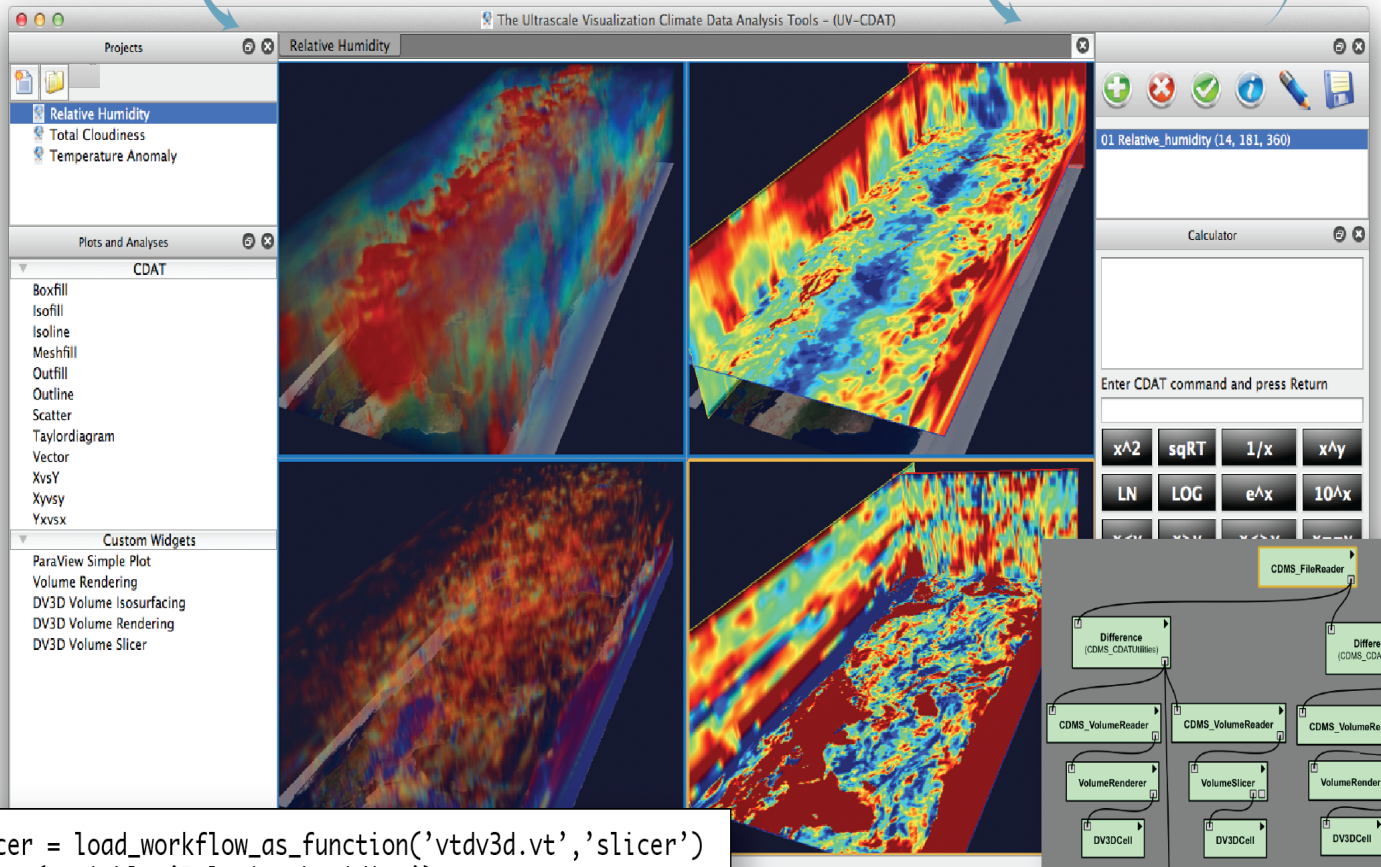
UVCDAT Interaction Layers

- Workflow
- Script
- GUI
- Remote

ESGF Data Archive

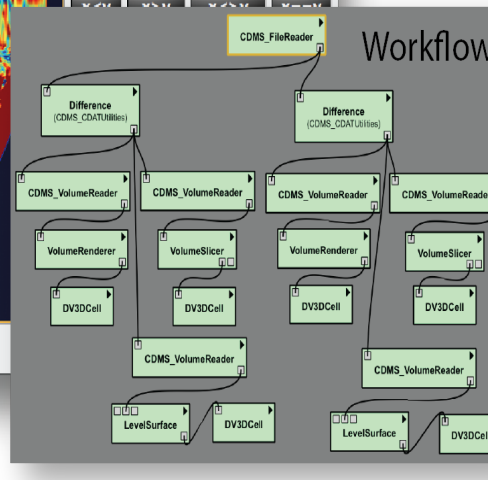
ParaView Cluster

parallel processing



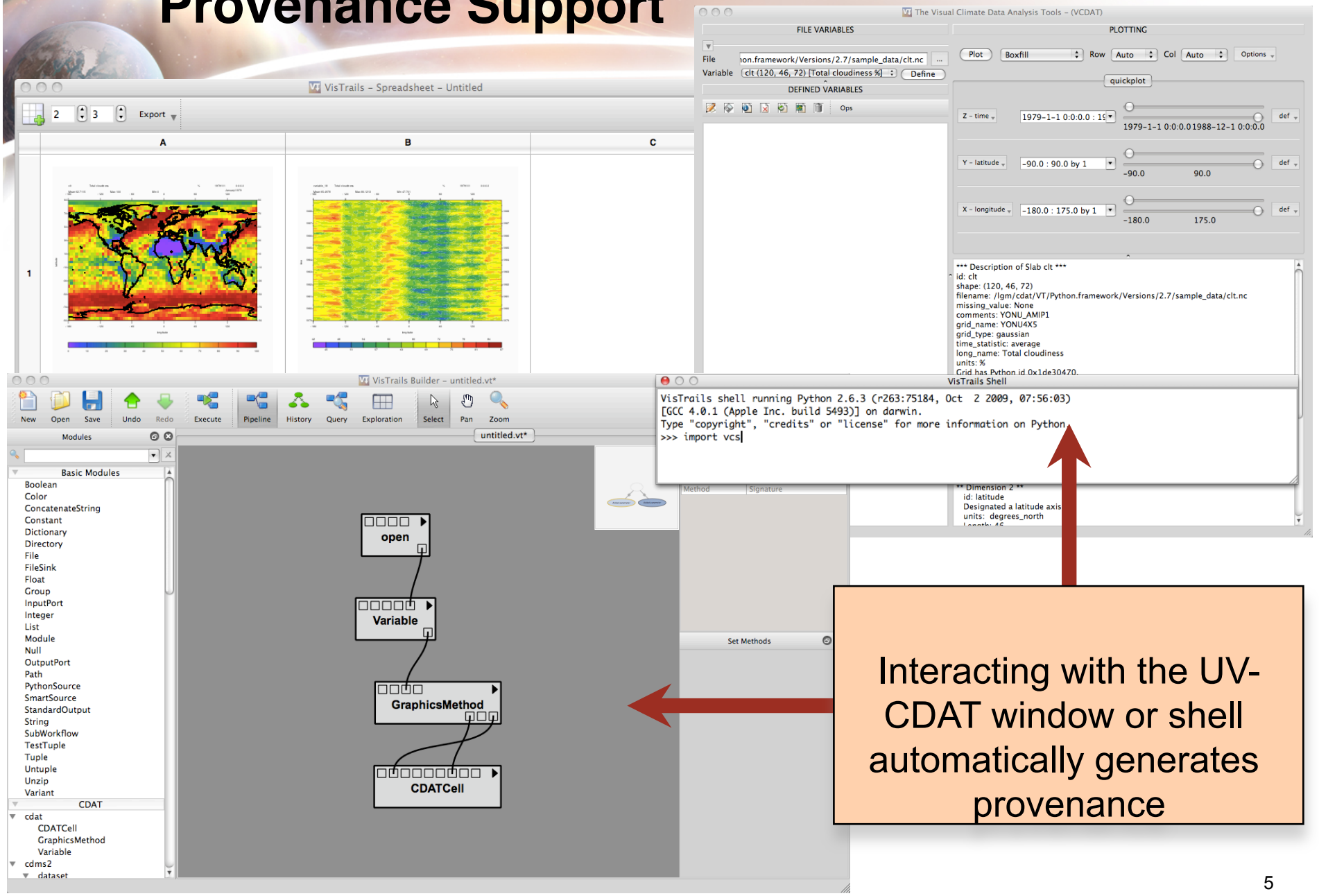

```
vslicer = load_workflow_as_function('vtdv3d.vt','slicer')
vslicer(variable='Relative_humidity')
vrender = load_workflow_as_function('vtdv3d.vt','vr')
vrender(variable='Relative_humidity')
```

Script



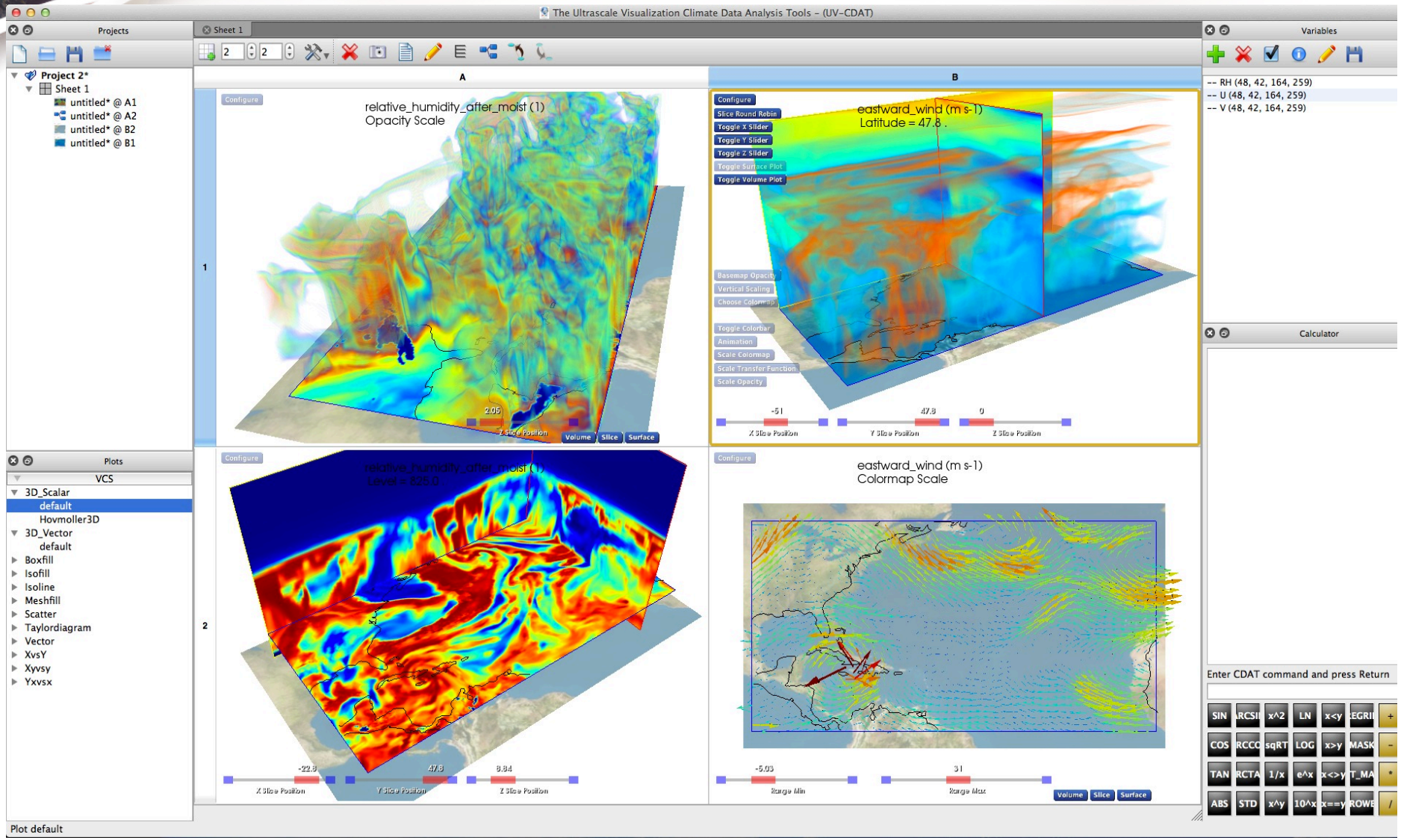
Provenance

Workflow and Provenance Support



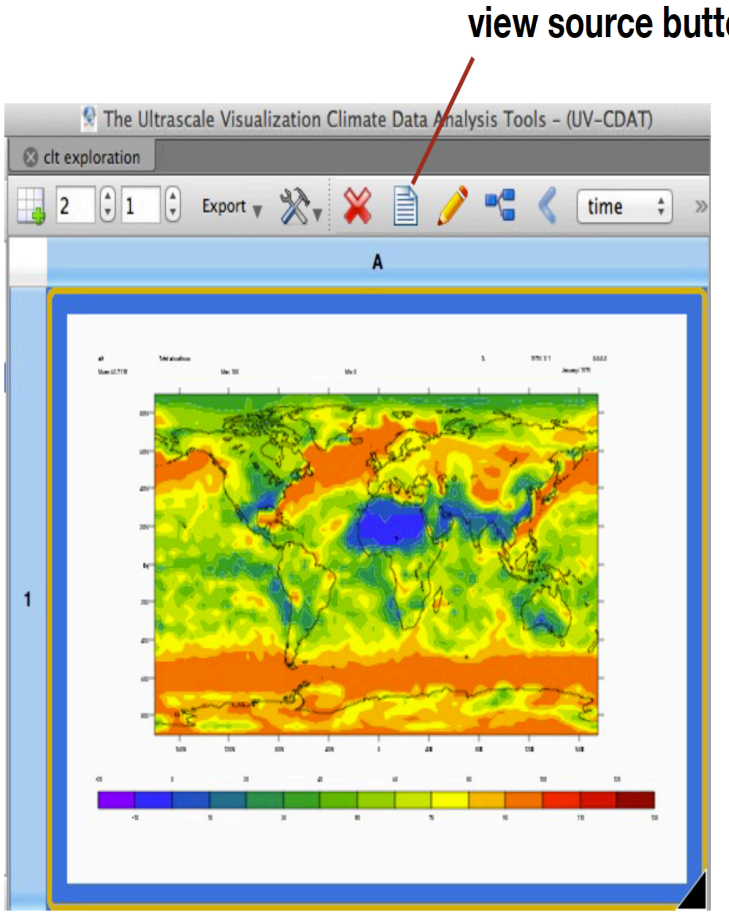
Interacting with the UV-CDAT window or shell automatically generates provenance

vcs3D in the UVCDAT GUI



Automating Workflows

- Workflows can be converted to python scripts
- Run outside of uvcdat in a python shell.



Visualization Source

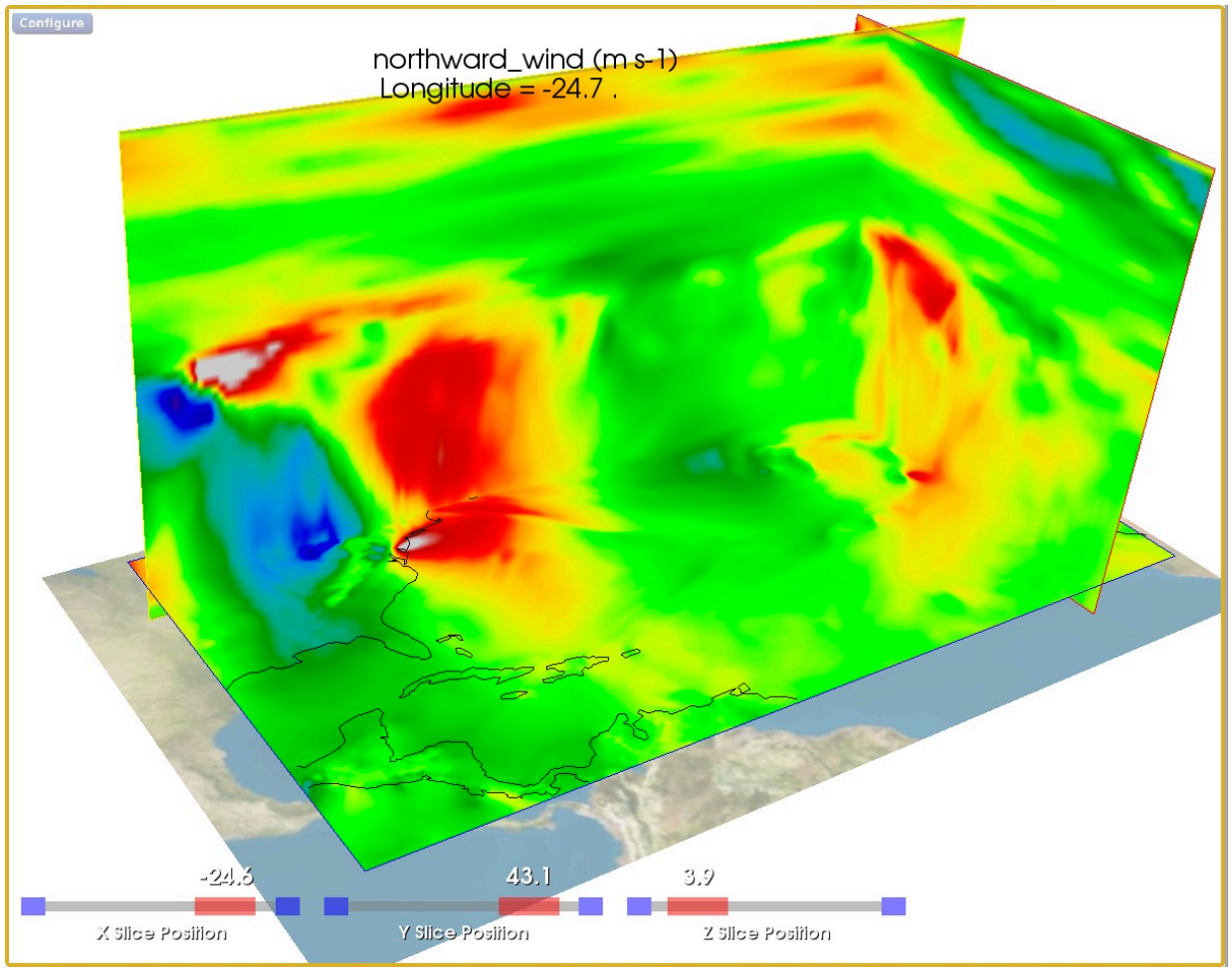
clt exploration @ A1

```
from PyQt4 import QtCore, QtGui
import cdms2, cdutil, genutil
import vcs

if __name__ == '__main__':
    import sys
    app = QtGui.QApplication(sys.argv)
    cdmsfile = cdms2.open('/Volumes/home/emanuele/Desktop/data/clt.nc')
    clt = cdmsfile('clt')
    clt = clt(latitude=(-90.0, 90.0),squeeze=1,longitude=(-180.0, 175.0)
    axesOperations = eval("{'latitude': 'def', 'longitude': 'def', 'time
    for axis in list(axesOperations):
        if axesOperations[axis] == 'sum':
            clt = cdutil.averager(clt, axis='(%s)'%axis, weight='equal'
        elif axesOperations[axis] == 'avg':
            clt = cdutil.averager(clt, axis='(%s)'%axis, weight='equal'
        elif axesOperations[axis] == 'wgt':
            clt = cdutil.averager(clt, axis='(%s)'%axis)
        elif axesOperations[axis] == 'gtm':
            clt = genutil.statistics.geometricmean(clt, axis='(%s)'%axis
        elif axesOperations[axis] == 'std':
            clt = genutil.statistics.std(clt, axis='(%s)'%axis)
    canvas = vcs.init()
    gmIsofill = canvas.getisofill('ASD')
    args = []
    args.append(clt)
    gmIsofill.datawc_calendar = 135441
    gmIsofill.datawc_timeunits = 'days since 2000'
    gmIsofill.datawc_x1 = 1.00000002004e+20
    gmIsofill.datawc_x2 = 1.00000002004e+20
```

Copy to clipboard | Save to file

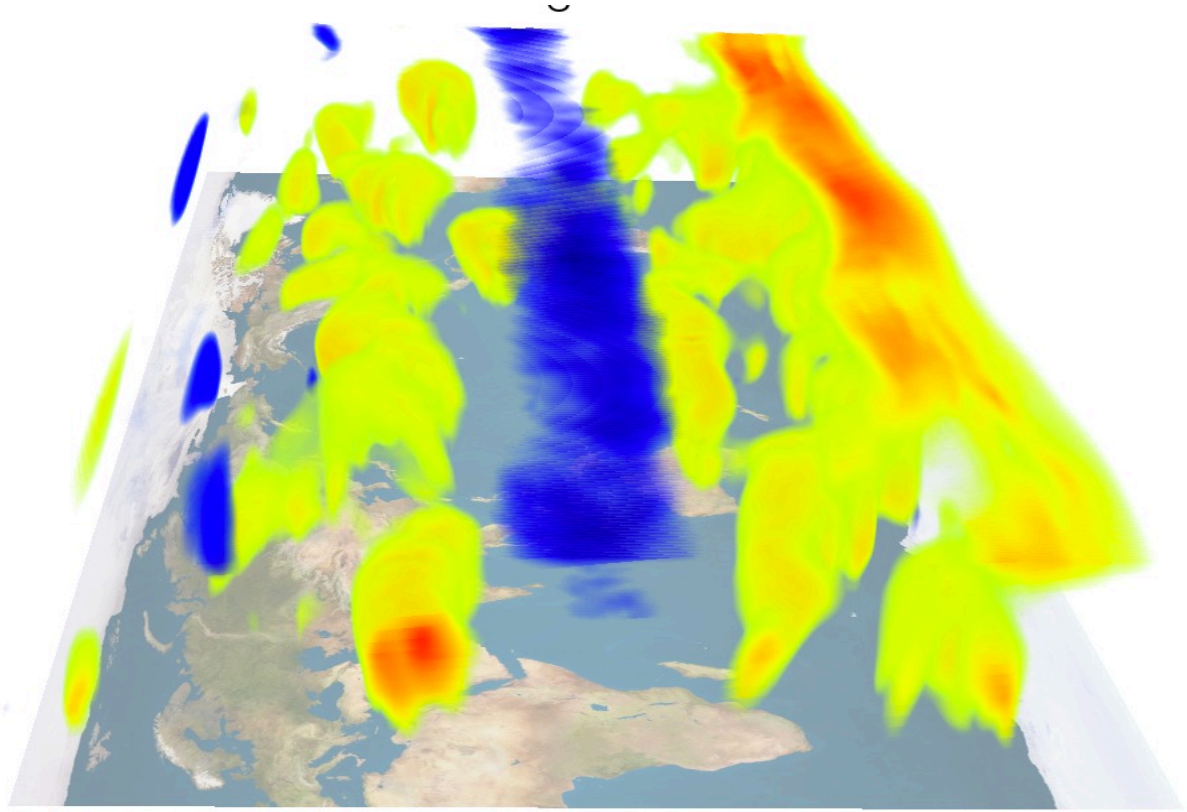
vcs3D Scripting: Slicing

```
import sys, vcs, cdms2

x = vcs.init()
f = cdms2.open( ”Sandy.xml″ )
dv3d = vcs.get3d_scalar()

dv3d.Camera={
        'Position': (-136,  -70, 86),
        'ViewUp': (.23, .46, .85),
        'FocalPoint': ( -57, 34, 7 ) }
dv3d.ScaleColormap= [ -45, 28 ]
dv3d.YSlider = ( 44, vcs.off)
dv3d.XSlider = ( -24, vcs.on )
dv3d.ZSlider = ( 0.07, vcs.on )
dv3d.ChooseColormap='spectral’

v = f[ "uwnd" ]
x.plot( v, dv3d )
x.interact()
```



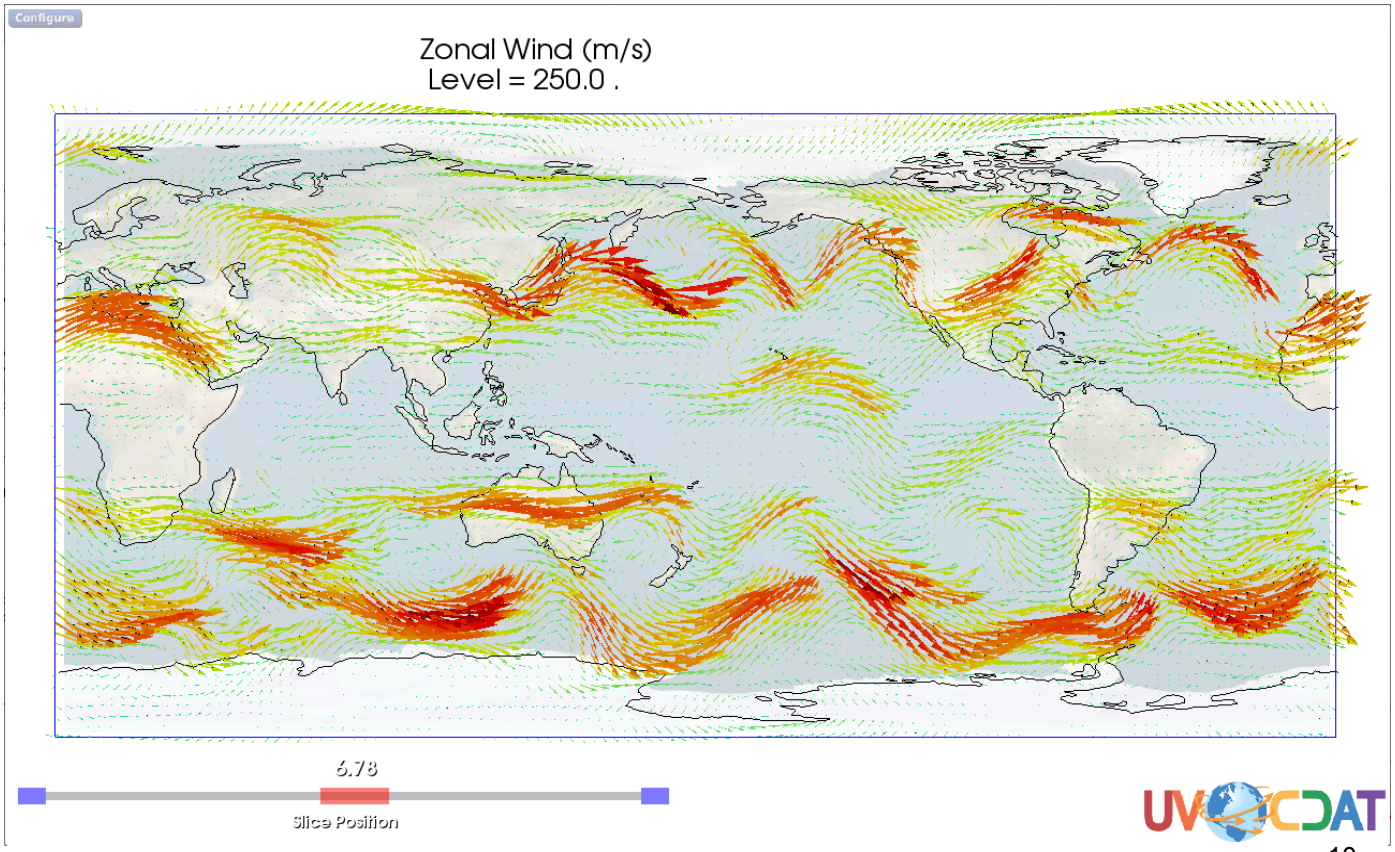
vcs3D Scripting: Simple Volume Render

```
import sys, vcs, cdms2

x = vcs.init()
f = cdms2.open( sys.prefix+"/sample_data/geos5-sample.nc"  )

dv3d = vcs.get3d_scalar()
dv3d.ToggleVolumePlot = vcs.on
dv3d.Camera={
            'Position': (-300, 0, 300),
            'ViewUp': (.3, .7, .7),
            'FocalPoint': ( 150, 0, 0 )}
dv3d.VerticalScaling = 4.0
dv3d.ScaleTransferFunction =  [10.0, 77.0]

v = f[ "uwnd" ]
x.plot( v, dv3d )
x.interact()
```

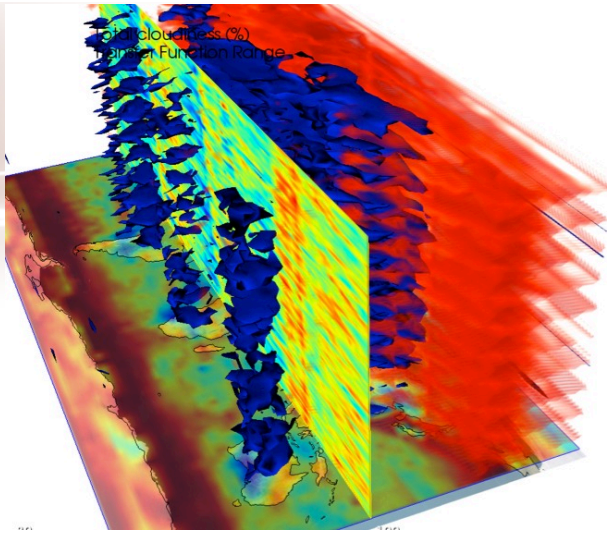


vcs3D Scripting: Vector Plots

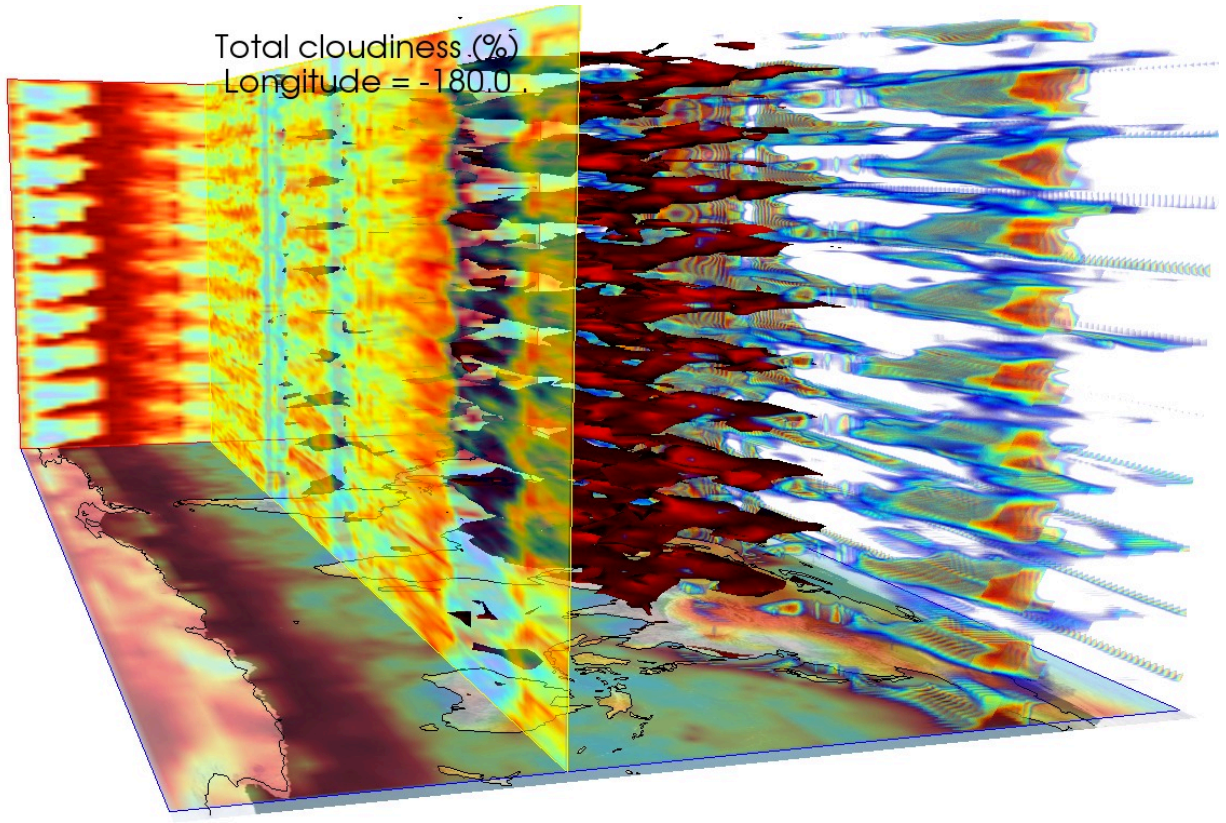
```
import vcs, cdms2, sys
x = vcs.init()
f = cdms2.open(sys.prefix+"/sample_data/geos5-sample.nc")
v = f["vwnd"]
u = f["uwnd"]
dv3d = vcs.get3d_vector()
dv3d.GlyphDensity = 3.5
dv3d.GlyphSize = 0.27
x.plot( u, v, dv3d )
x.interact()
```



vcs3D Scripting: Hovmoller Plots

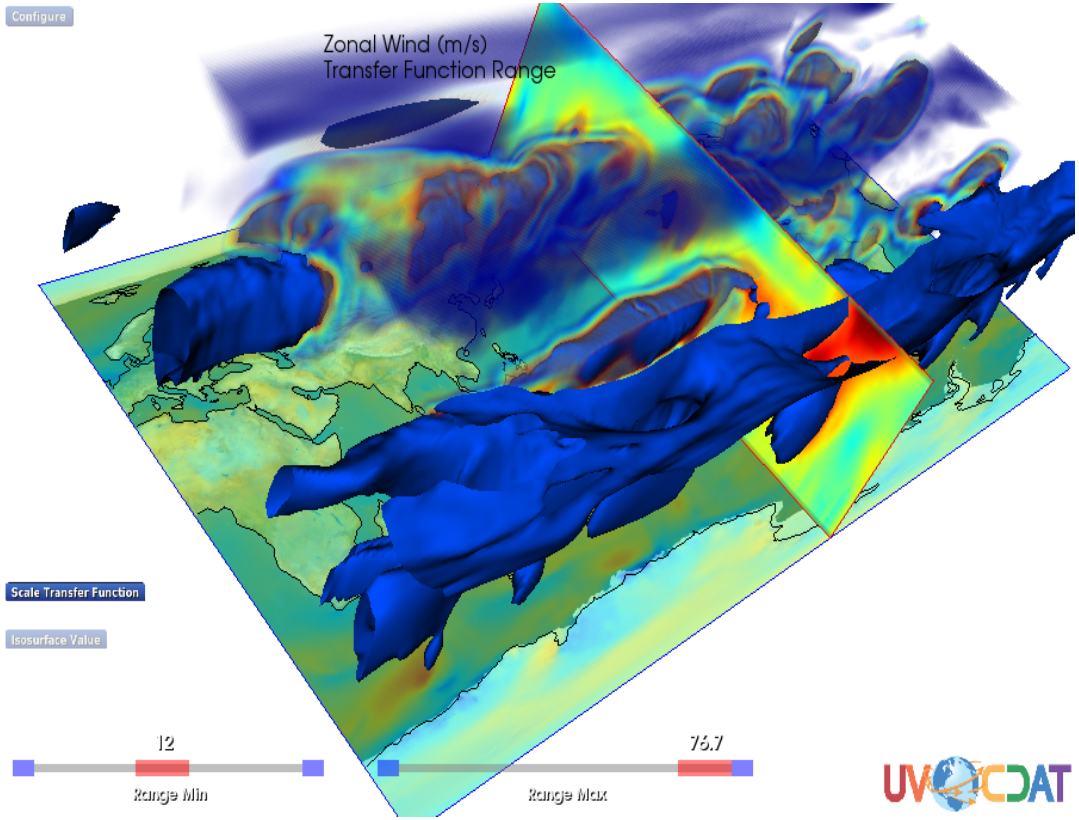


```
import vcs, cdms2, sys
x = vcs.init()
f = cdms2.open(sys.prefix+"/sample_data/clt.nc")
v = f["clt"]
dv3d = vcs.get3d_scalar('Hovmoller3D')
dv3d.ToggleSurfacePlot = vcs.on
dv3d.ToggleVolumePlot = vcs.on
dv3d.IsosurfaceValue = [ 10.0  ]
dv3d.ToggleClipping =
        [-180.0, 175.0, -22.0, 90.0,  0.0, 119.0 ]
dv3d.ScaleTransferFunction = [80, 100, 1]
dv3d.ScaleOpacity={ 'Volume': [0.0, 0.2] }
dv3d.YSlider = ( 20.0, vcs.on )
dv3d.Camera={
      'Position': (436.8, -126.3, 285.2),
      'ViewUp': (-0.5, 0.25, 0.83),
      'FocalPoint': (9.6, 19.9, -3.2) }
x.plot( v, dv3d )
x.interact()
```

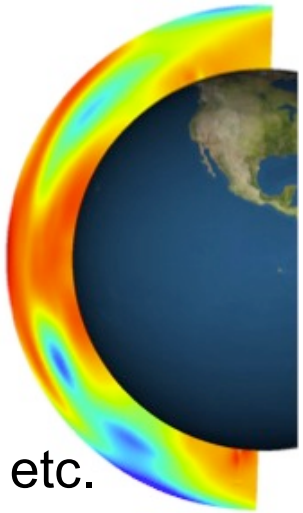


vcs3D Scripting: Combined Plots

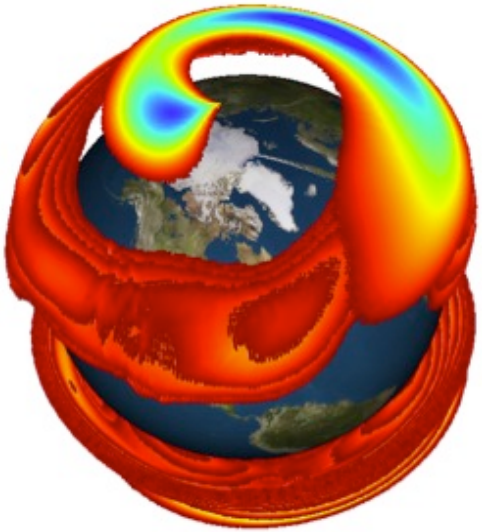
```
import vcs, cdms2, sys
x = vcs.init()
f = cdms2.open( sys.prefix+"/sample_data/geos5-sample.nc" )
v = f["uwnd"]
dv3d = vcs.get3d_scalar()
dv3d.ToggleClipping = ( 40, 360, -28, 90 )
dv3d.YSlider = ( 0.0, vcs.off)
dv3d.XSlider = ( 180.0, vcs.on )
dv3d.ZSlider = ( 0.0, vcs.on )
dv3d.ToggleVolumePlot = vcs.on
dv3d.ToggleSurfacePlot = vcs.on
dv3d.IsosurfaceValue = 31.0
dv3d.ScaleOpacity = { 'Volume': [0.0, 0.3] }
dv3d.BasemapOpacity = 0.5
dv3d.Camera={   'Position': (-161, -171, 279),
                'ViewUp': (.29, 0.67, 0.68),
               'FocalPoint': (146.7, 8.5, -28.6)  }
dv3d.VerticalScaling = 5.0
dv3d.ScaleColormap = [ -46.0, 48.0 ], {
            'Volume': [ 16.0, 30.0 ],
            'Surface': [ 30.0, 35.0 ] }
dv3d.ScaleTransferFunction =  [ 12.0, 77.0 ]
x.plot( v, dv3d )
x.interact()
```

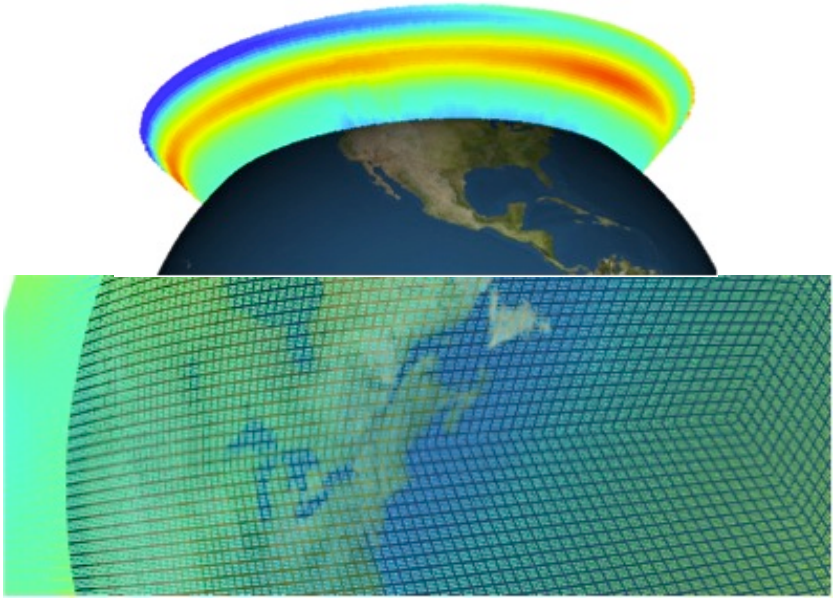


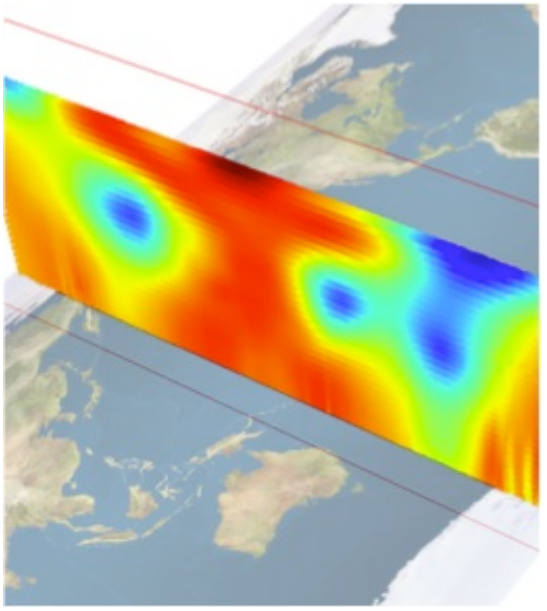
Unstructured Grid Visualization



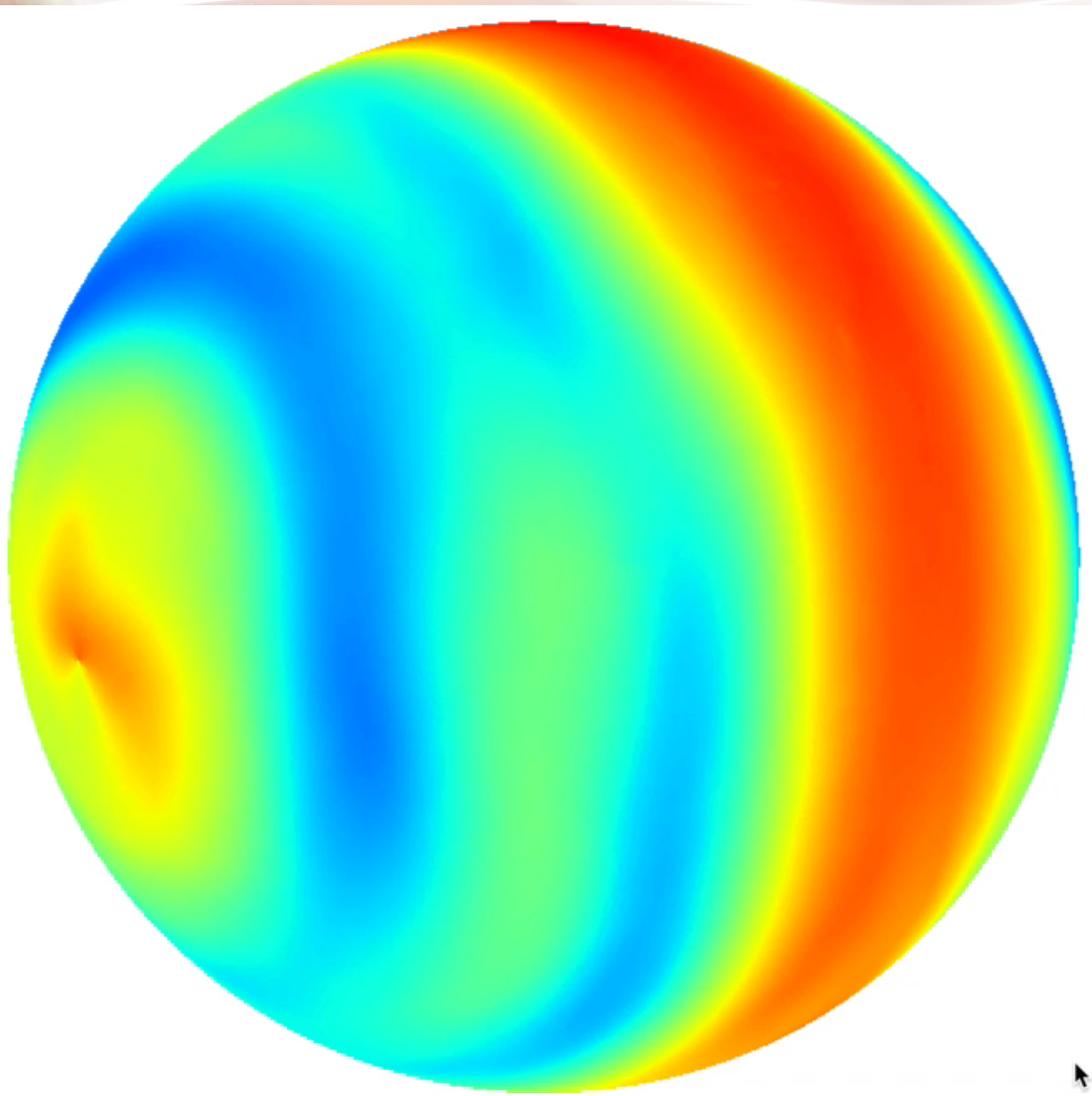
- Regridding to rectangular arrays is undesirable:
  - Computationally expensive.
  - Distorts data- may mask features of interest.
- vcs3D plots raw data without regridding:
  - Renders point clouds- requires no geometry.
  - Subsetting operation generates slices, surfaces, volumes, etc.
  - Multi-resolution, multi-core operations enable responsivity.
  - Easily switch between different projections & vertical coordinates.







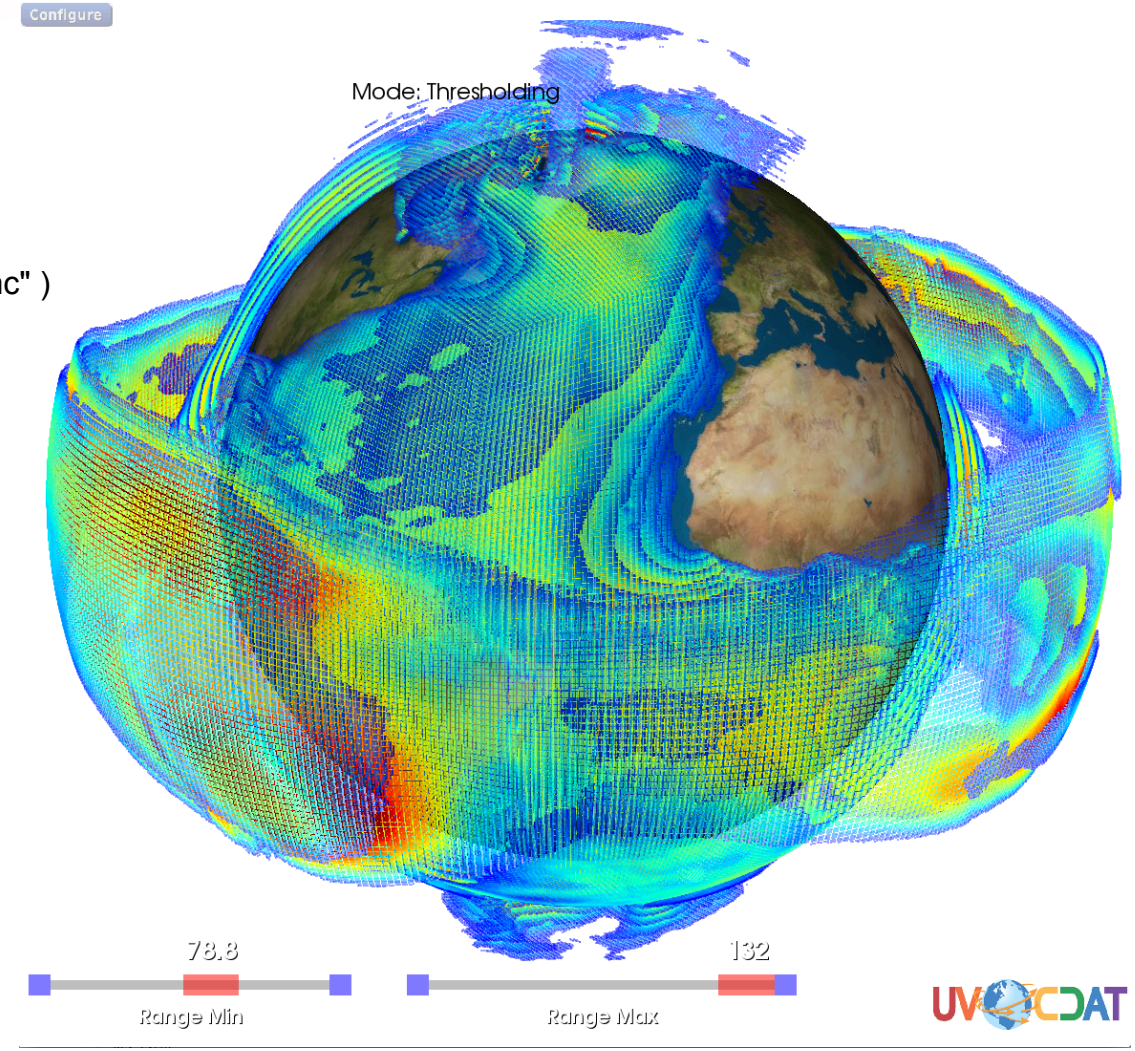
Point Cloud Visualization



Unstructured Grid Plot

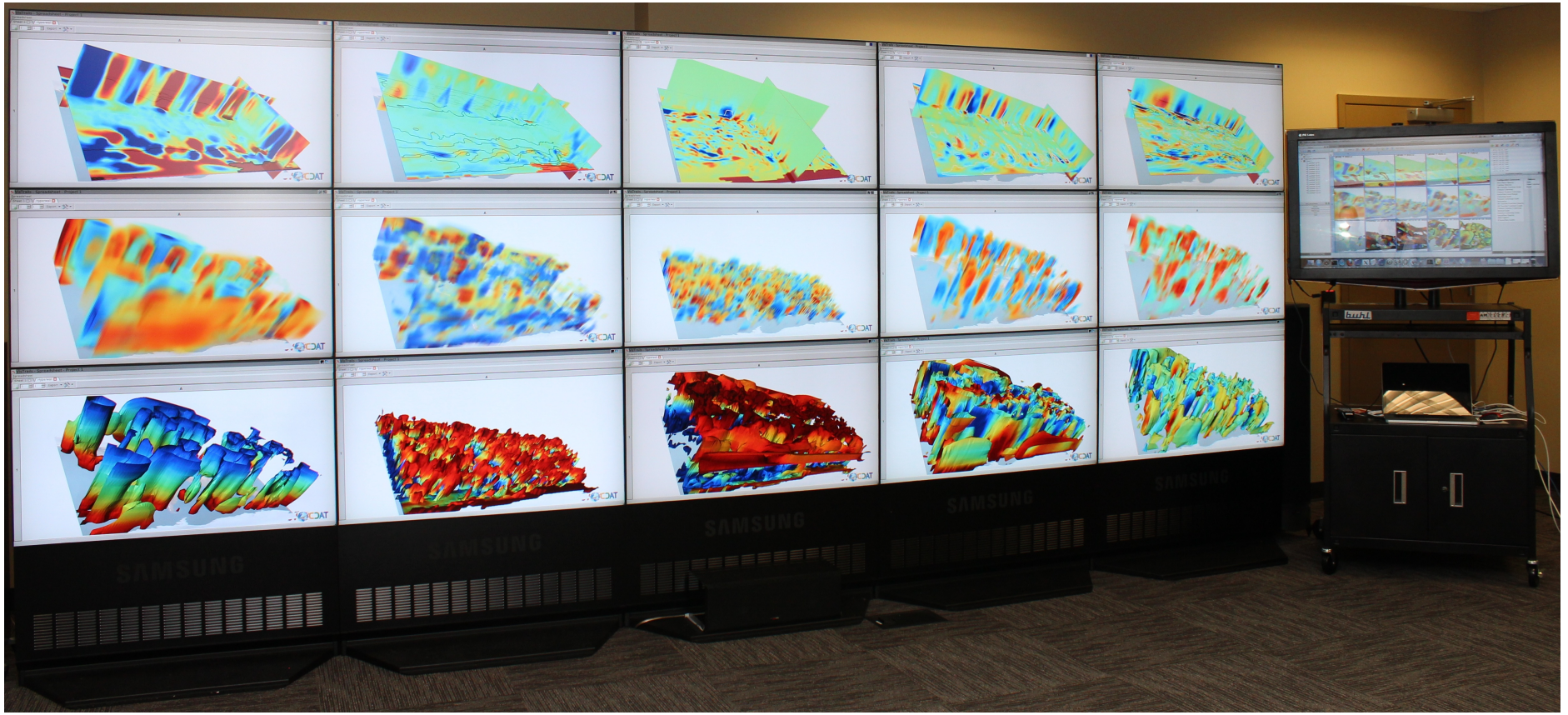
Plotting CAM cubed sphere data without regridding.

```
import vcs, cdms2, sys

x = vcs.init()
f = cdms2.open( "f1850c5_t2_ANN_climo-native.nc" )
v = f["RELHUM"]
dv3d = vcs.get3d_scalar()
dv3d.ScaleTransferFunction = [ 78.7, 132.0 ]
dv3d.ScaleColormap = [ 75.4, 100.0 ]
dv3d.ScaleOpacity = [0.27, 1.0]
dv3d.PointSize = [5, 2]
dv3d.VerticalScaling = [ 1.7 ]
dv3d.ToggleVolumePlot = vcs.on
dv3d.ToggleSphericalProj = vcs.on
dv3d.Camera = {
      'Position': (-108, -477, 85),
       'ViewUp': ( 0.0, 0.0, 1.0),
       'FocalPoint': (0, 0, 0)  }
x.plot( v, dv3d, grid_file="ne120np4_latlon.nc" )
x.interact()
```

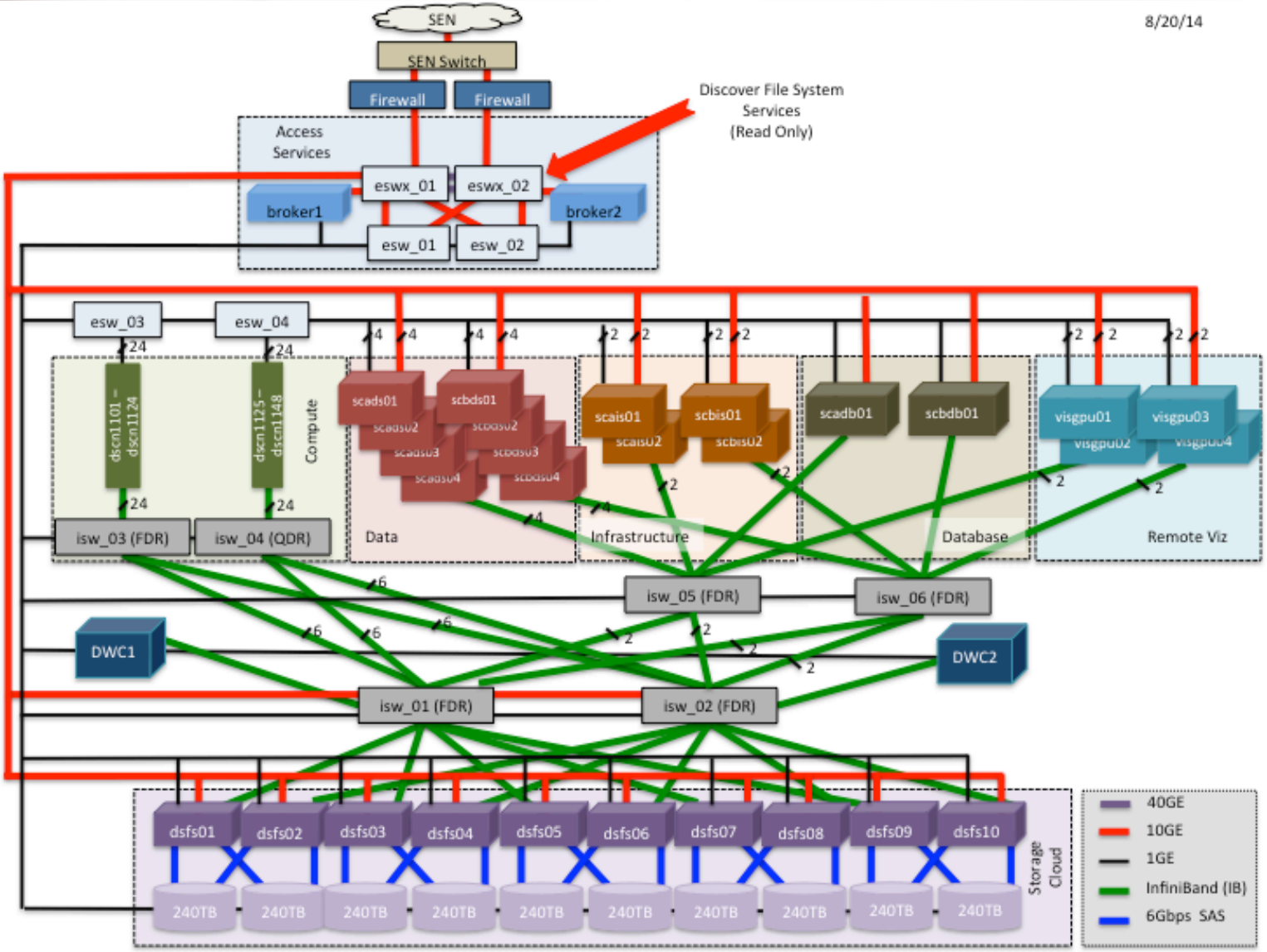


Interactive Hyperwall Visualization

- Uses parallelism to address data complexity
- UVCDAT runs on each display node (full-res 1-cell hyperwall display)
- UVCDAT runs on control node (low-res 15-cell touchscreen display)
- Control node interactions broadcast to all hyperwall nodes

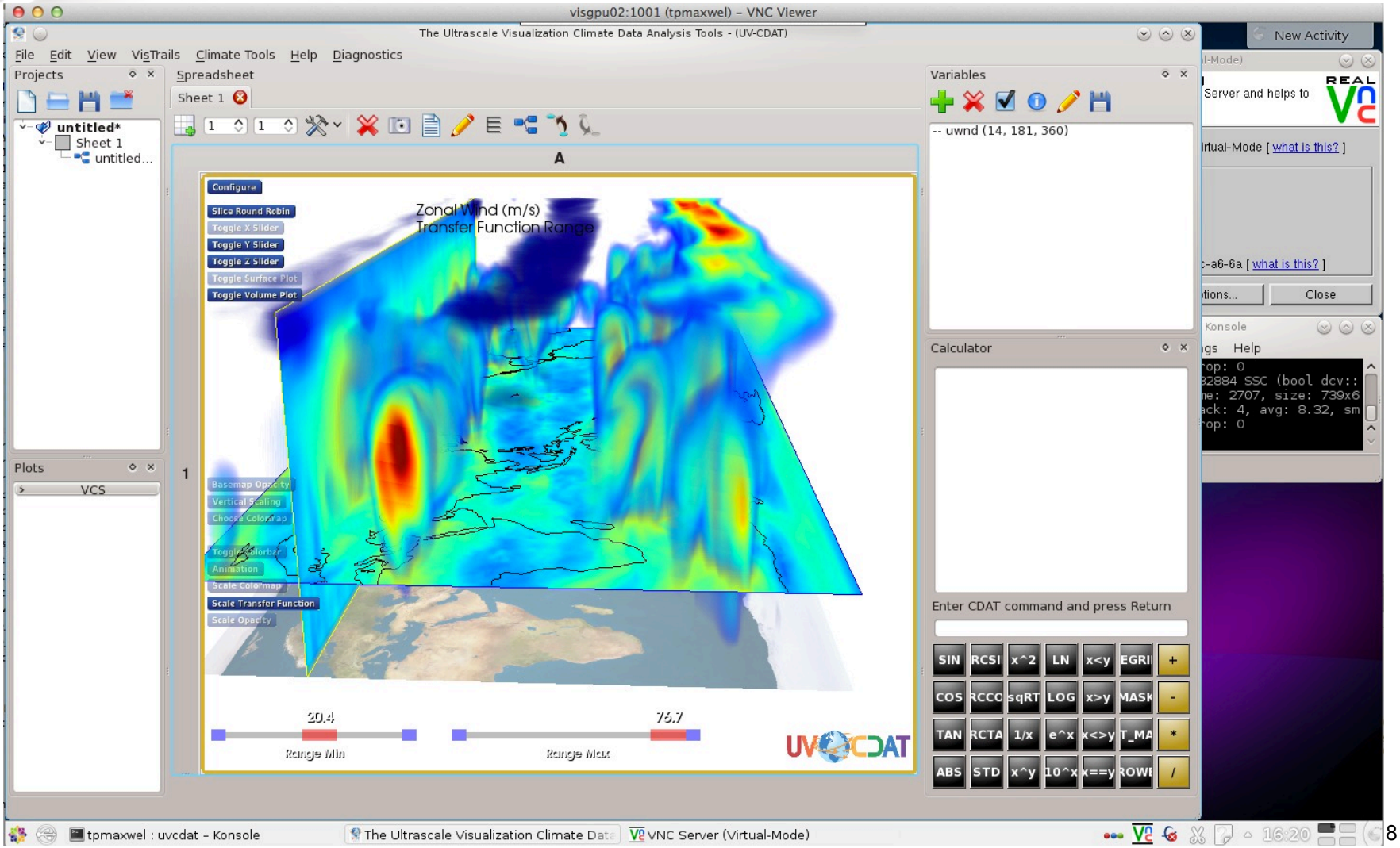


Remote Visualization
UVCDAT in NCCS Science Cloud



Remote Visualization Deployment

Utilize NICE Visualization (VNC) software for interactive remote visualization.



Advantages of Feature Rich Higher Dimensional Visualization

- Provides a more expansive window into the dataset.
- Many layers simultaneously visible “at a glance”.
- Interactivity enables iterative exploration.
- Provides overviews facilitating gestalt understanding.
- Facilitates serendipitous discoveries:
  - Unexpected features can “pop out”.