Understanding WRF-ARW Datasets with Interactive 3D Visualization

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Tutorial Overview

Purpose : Understand how to easily incorporate 2D and 3D visualization into understanding of WRF-ARW simulation

Utilizing **VAPOR** (A visualization and analysis package developed at NCAR):

On completion: You will be able to visualize WRF-ARW output, calculate and visualize Python-derived variables, use geo-referenced images, volume rendering, isosurfaces, and streamlines.

You will be able to interactively navigate and animate through 3D images of WRF output, and capture animation sequences.

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Supporting software and data

- Installed on classroom PC's:
  - VAPOR 2.1.0
  - Sample datasets at **C:/VaporTutorial/vapordata**
  - Sample images at **C:/VaporTutorial/images**
  - Sample Python scripts at **C:/VaporTutorial/python**
  - Cygwin at **C:\cygwin** (Windows version of Unix)
- On the web:

Vapor website is http://www.vapor.ucar.edu where you can get: installers, documentation, example data, image gallery

Tutorial data, examples, documentation are at

http://vis.ucar.edu/~alan/wrf2012/tutorial/

Tutorial Outline

- Set up a visualization session in VAPOR using a simulation of Typhoon Jangmi (Sept. 2008)
- *Apply georeferenced image* (Satellite image from Web)
- *Volume rendering*: Visualize the typhoon progress with QCLOUD
  - Build a *Transfer Function* (color/opacity map)
- Create and visualize derived variables using Python
- Visualize *Isosurfaces* of wind speed
- *Flow integration* (wind visualization)
  - *Streamlines:* observe how the air flows through the typhoon

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Obtaining images to use with VAPOR

- Geo-referenced satellite images can be retrieved from the Web, and VAPOR will insert them at the correct world coordinates.
  - VAPOR provides a shell script "getWMSImage.sh" that can be used to retrieve Web Mapping Service images for a specified longitude/latitude rectangle
- A geo-tiff terrain image for the typhoon data has been provided in the **C:/VaporTutorial/images** directory.
- Several useful images are installed with VAPOR, including a world-wide terrain image, and political boundaries of the U.S and the world. Apply these by clicking "Select Installed Image" in the Image panel.

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Optional: getWMSImage.sh exercise

- **`getWMSImage.sh`** will create a geo-referenced tiff file for a specified lon/lat rectangle. Due to NASA server limitations it often fails for some rectangles.
- Can obtain satellite images, political boundaries, rivers, etc.
- Default obtains an image from the NASA “blue marble” earth
- Requires Unix environment (Cygwin on PC will do)

- For Typhoon Jangmi,

  min: lon = 100, lat = 7

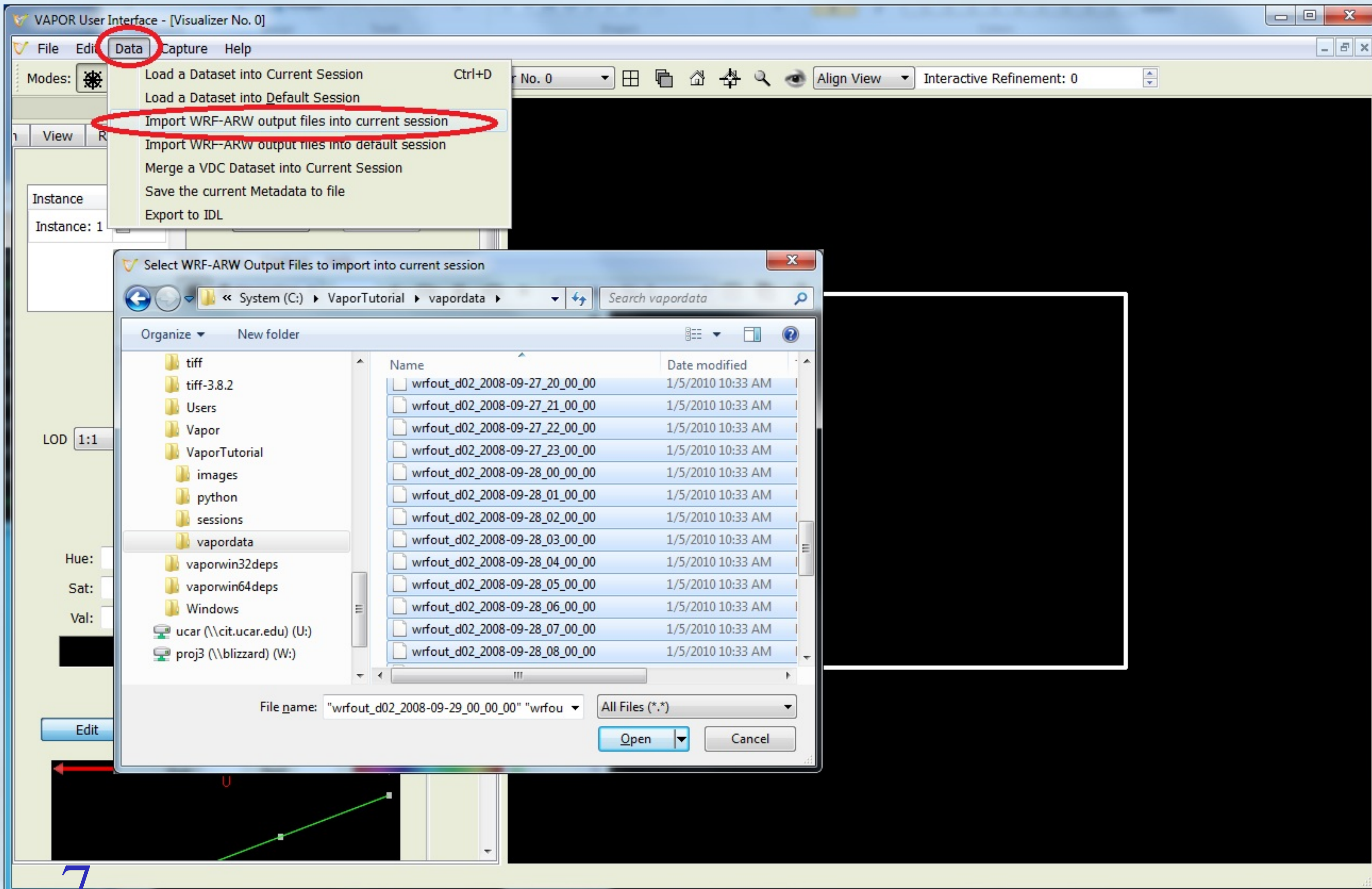
  max: lon = 148, lat = 40

- From a Cygwin (tcsh or bash) shell, issue the command:

```
getWMSImage.sh -o terrain.tiff  100 7 148 40
```

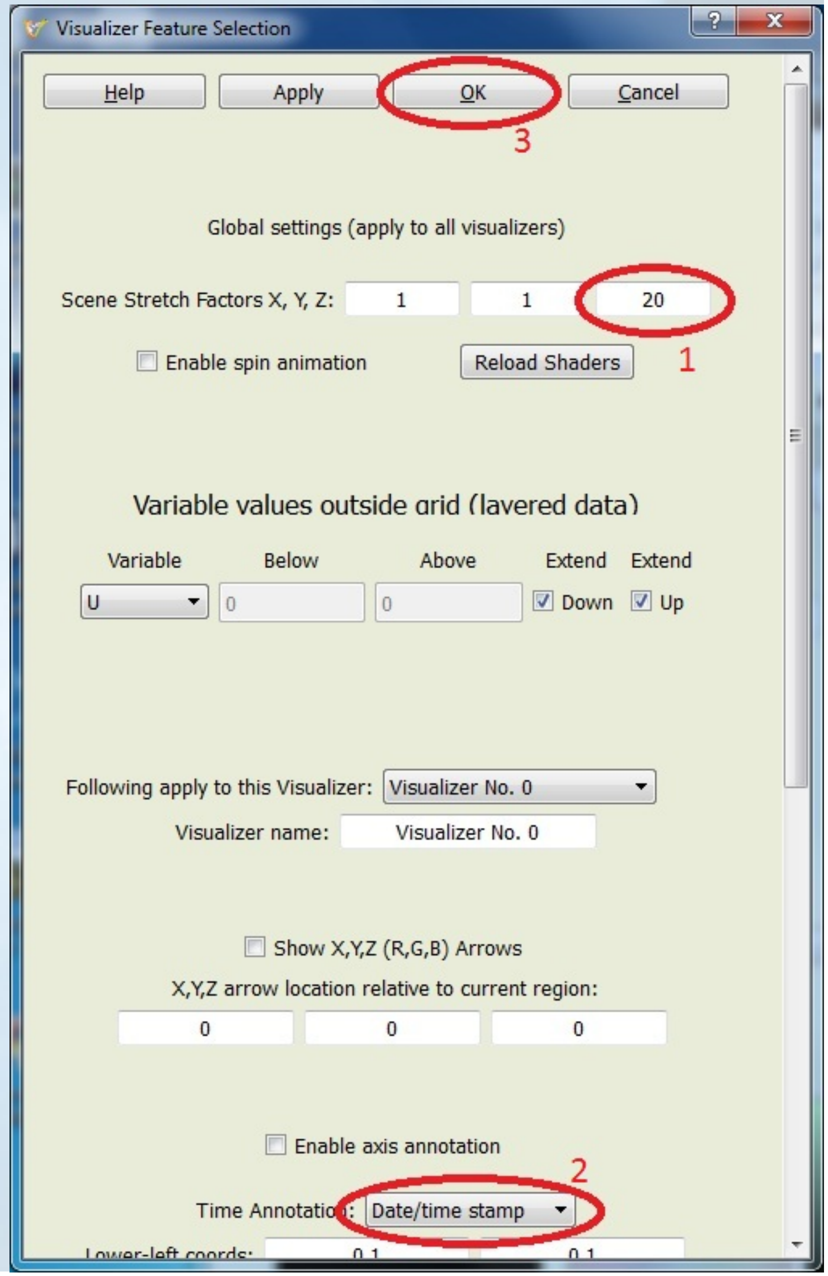
Set-up to visualize a WRF dataset (1)

- Launch 'vaporgui' (Desktop Icon: VAPOR)
- From Data menu: "Import WRF-ARW output files into current session": select all (60) **C:\VaporTutorial\vapordata\wrfout*** files to import



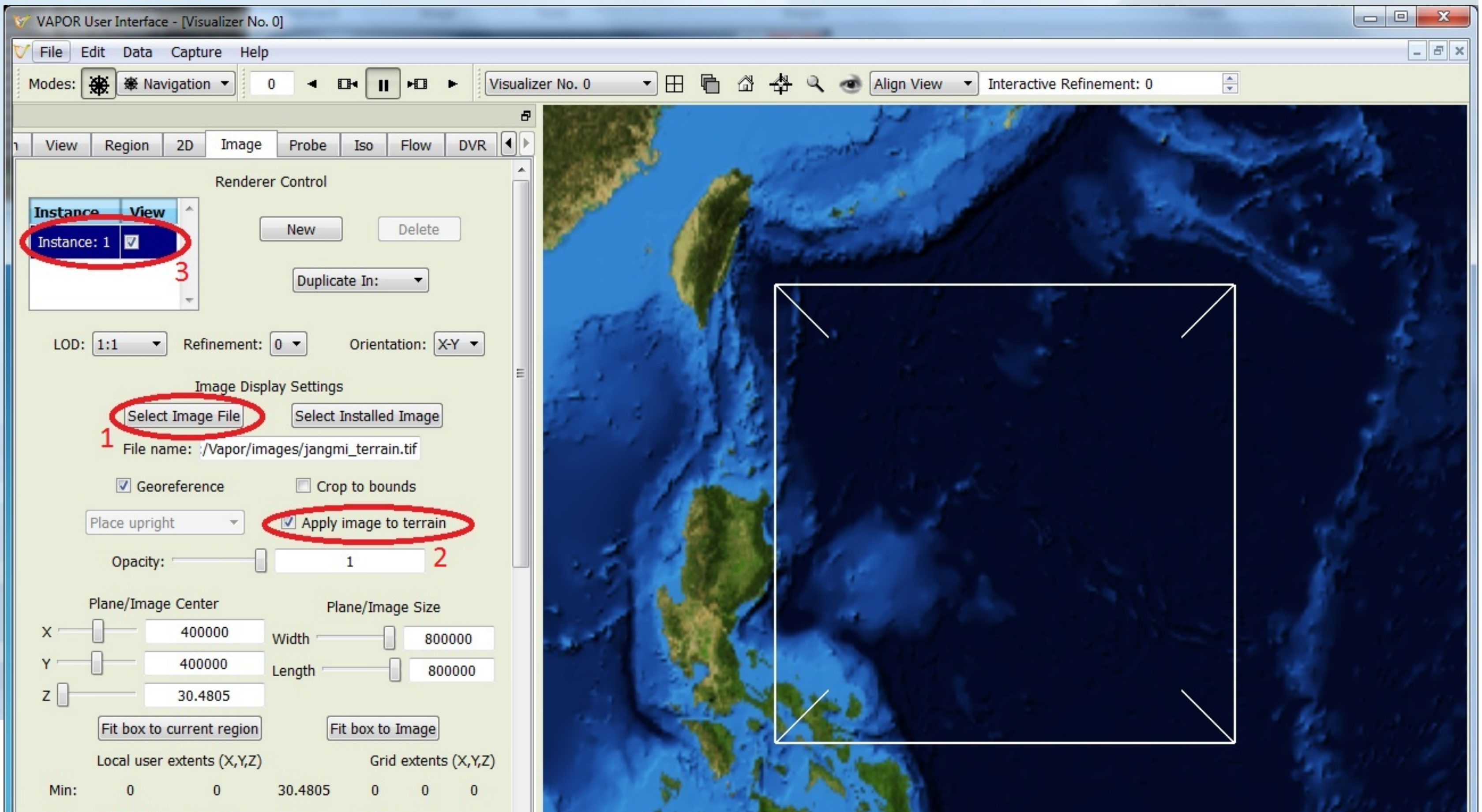
Set-up to visualize a WRF dataset (2)

- From Edit menu, click "Edit Visualizer Features" then:
  1. Stretch Z by factor of 20, press <enter> to confirm value
  2. Specify time annotation, "Date/Time stamp"
  3. Click "OK"



Set-up to visualize a WRF dataset (3)

- To include a terrain image: Click on the "Image" tab
  1. Click "Select Image File" and choose **"C:\VaporTutorial\images\jangmi_terrain.tif"**
  2. Check "Apply image to terrain"
  3. Check the "Instance: 1" checkbox at the top of the Image tab to view the terrain image.



Ways to Control the 3D Scene

- To navigate: Rotate, Zoom in, Translate by dragging in the scene with left, right and middle mouse buttons.

1. Click "Home" icon ( ) to return to starting viewpoint
2. Click "Eye" icon ( ) to see full domain
3. Use Edit→Undo if you make a mistake
4. Use the VCR controls at the top left of the window to animate through time (see where the WRF d02 domain is positioned over time)

- When you type in values, be sure to press <enter> to confirm the values.

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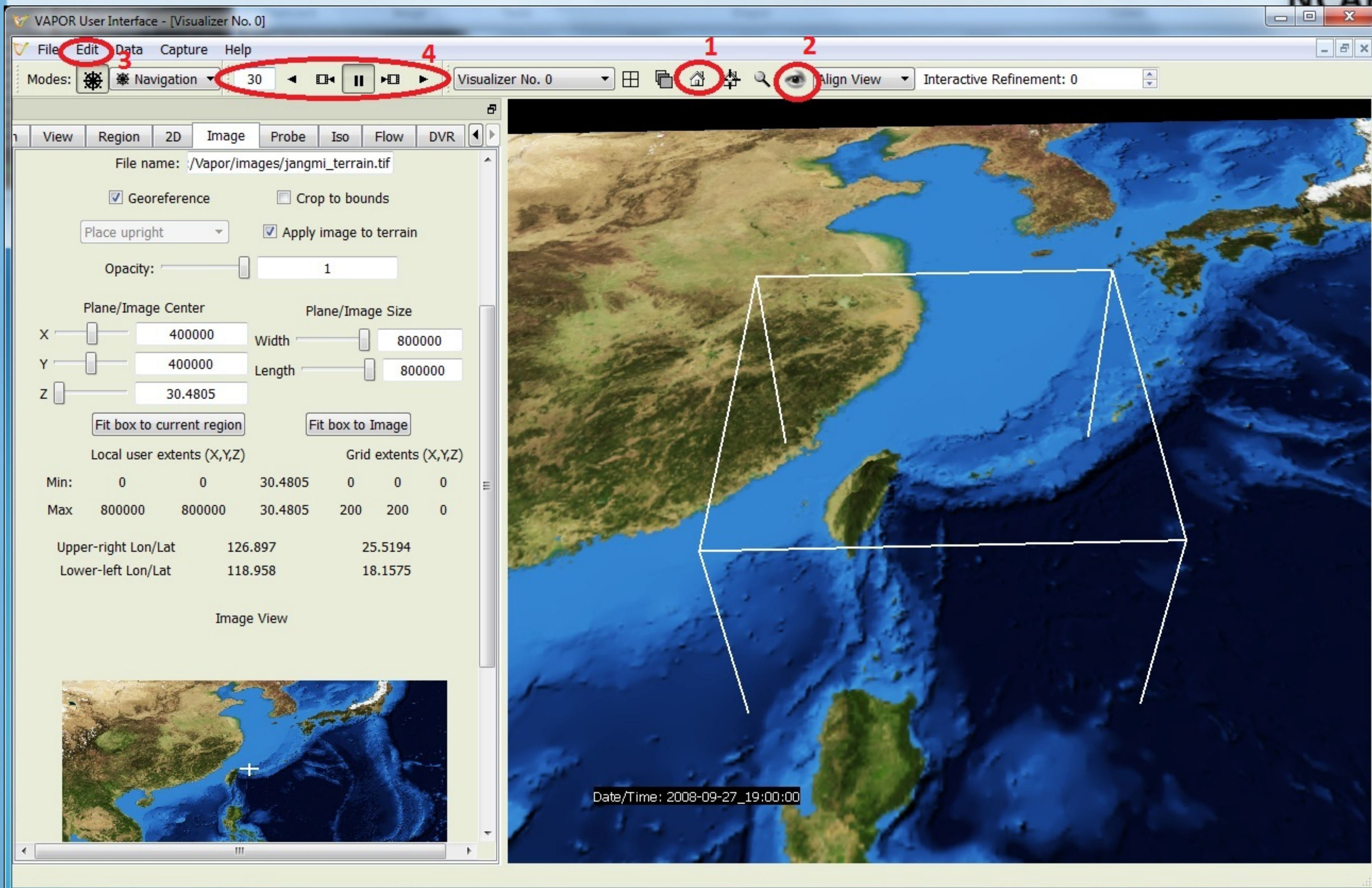
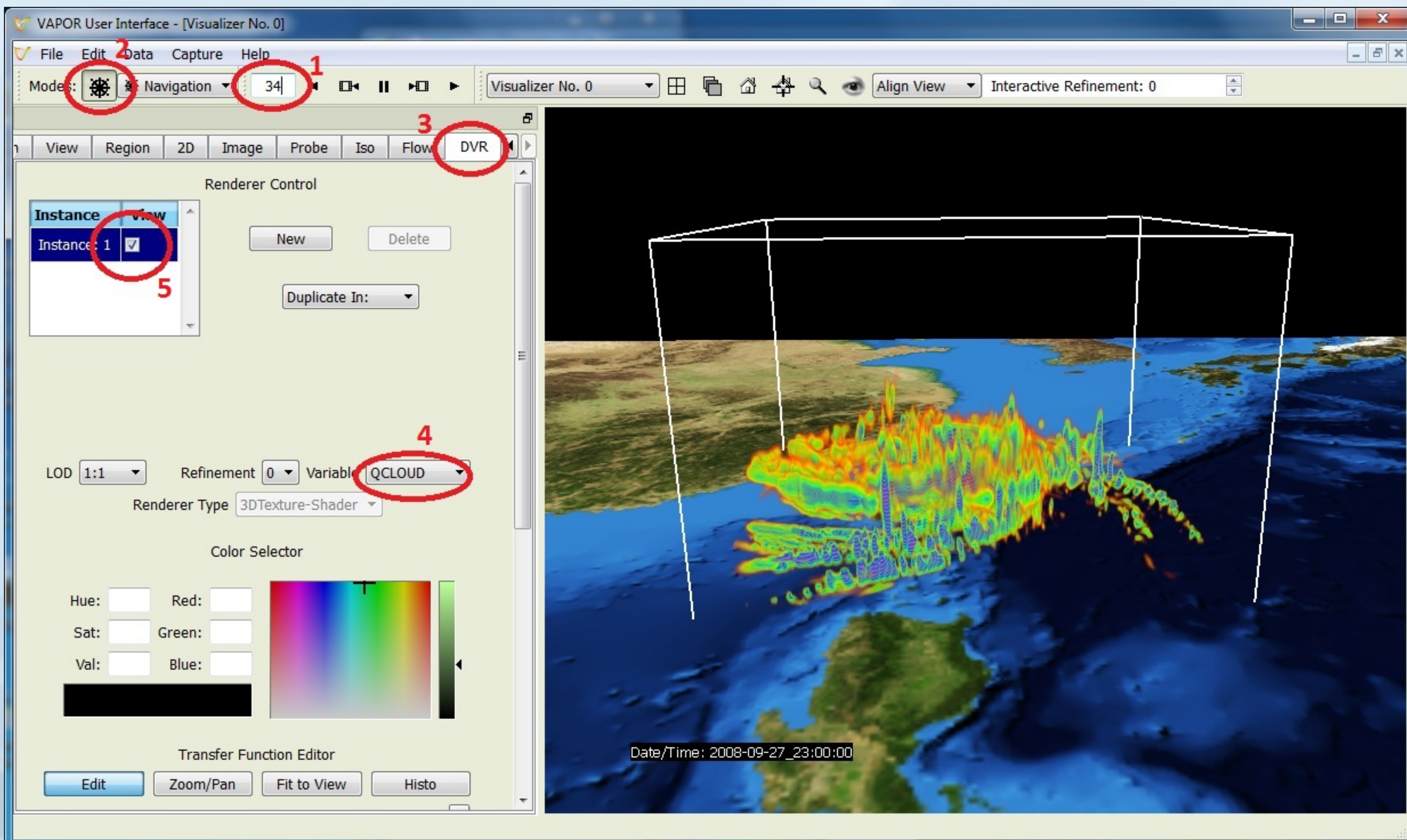
Navigation tools in VAPOR GUI



Session file: slide11.vss

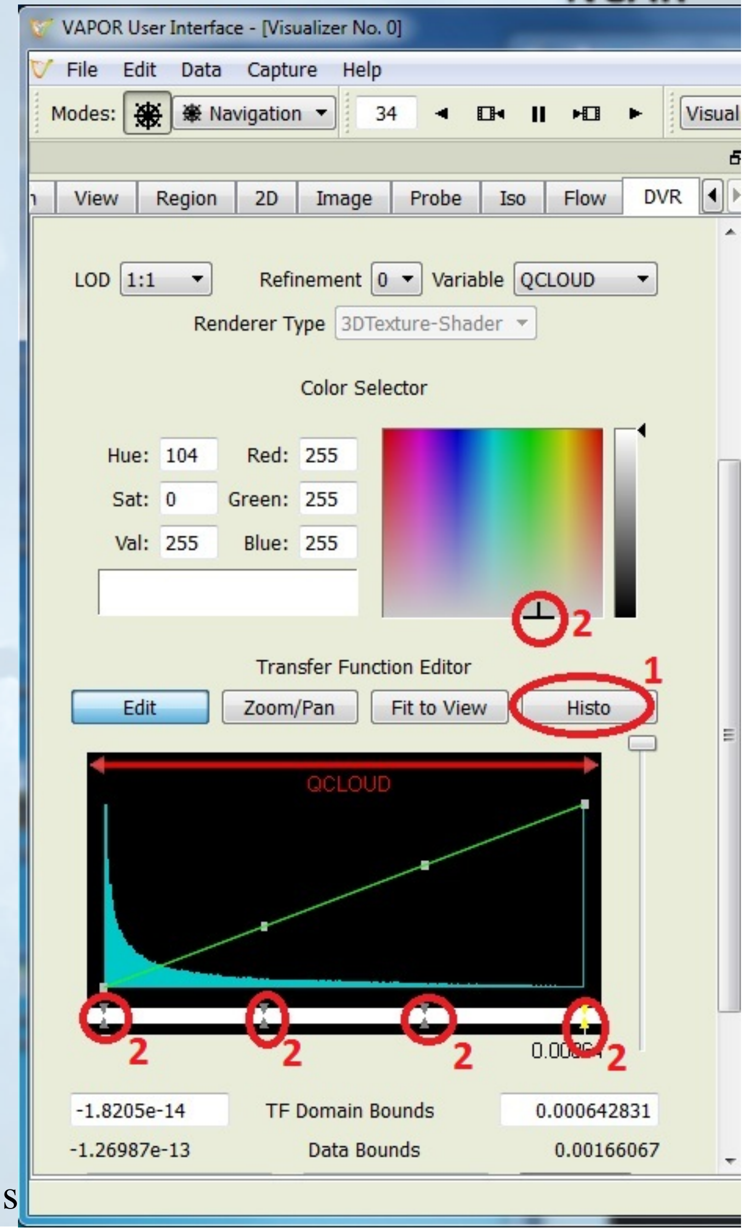
Volume Visualization of QCLOUD

1. Using VCR control, type in time step 34, press enter.
2. Click the “wheel” icon ( ) to set navigation mode
3. Select DVR panel (direct volume rendering)
4. Select variable “QCLOUD” (cloud water mixing ratio)
5. Check “Instance:1” to enable volume rendering



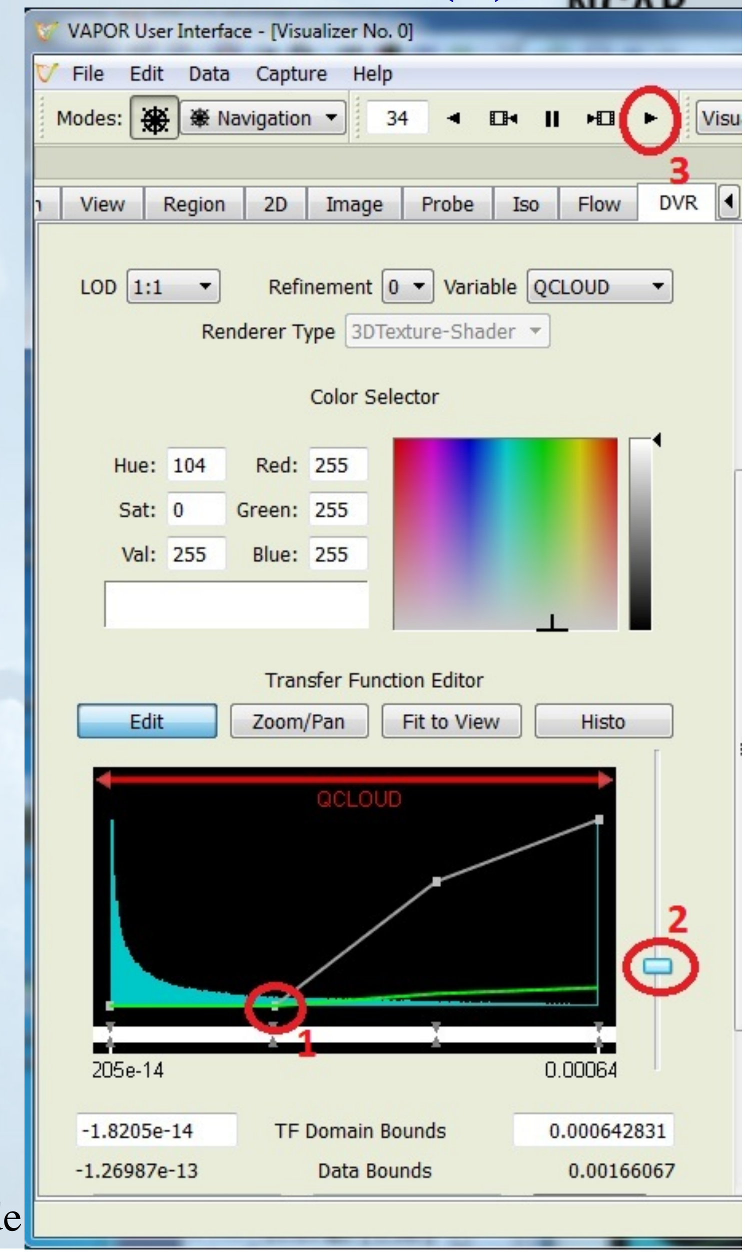
Volume Visualization: Edit Transfer function (1)

1. Click "Histo" to see histogram of data values of QCLOUD at current timestep
2. To make the clouds white, set 4 color control points to white
   – Either select/edit with right mouse button, or
   – Select point and then choose white color in color selector.

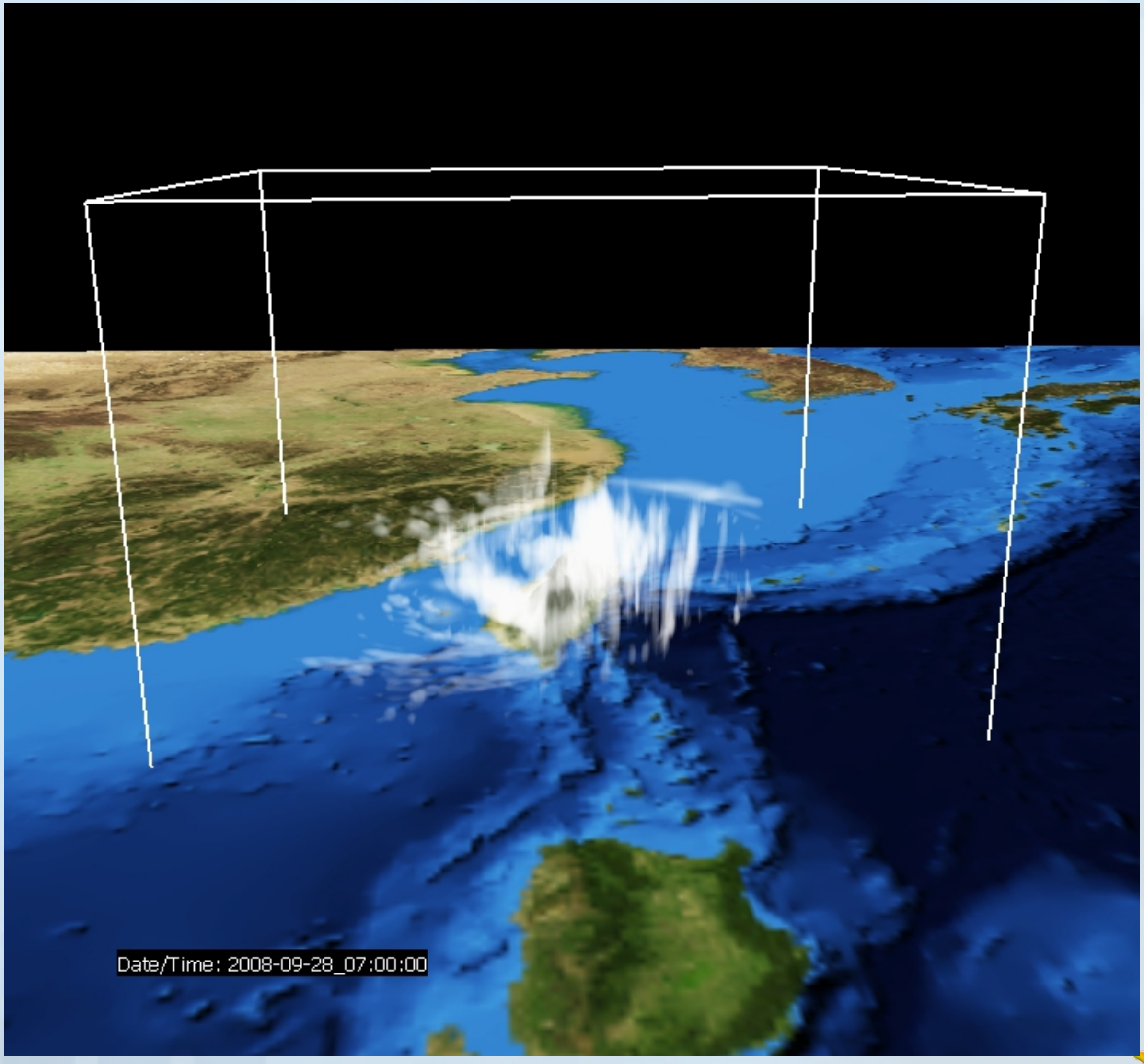


Volume Visualization: Edit Transfer function (2)

- To edit the transparency:
  1. Drag the 2nd control point down to make the lower values more transparent
  2. Use slider on the right to control overall transparency.
3. Click the play button "▸" to animate the clouds associated with the typhoon.



Visualization of typhoon: QCLOUD at time step 42



Session file: slide15.vss

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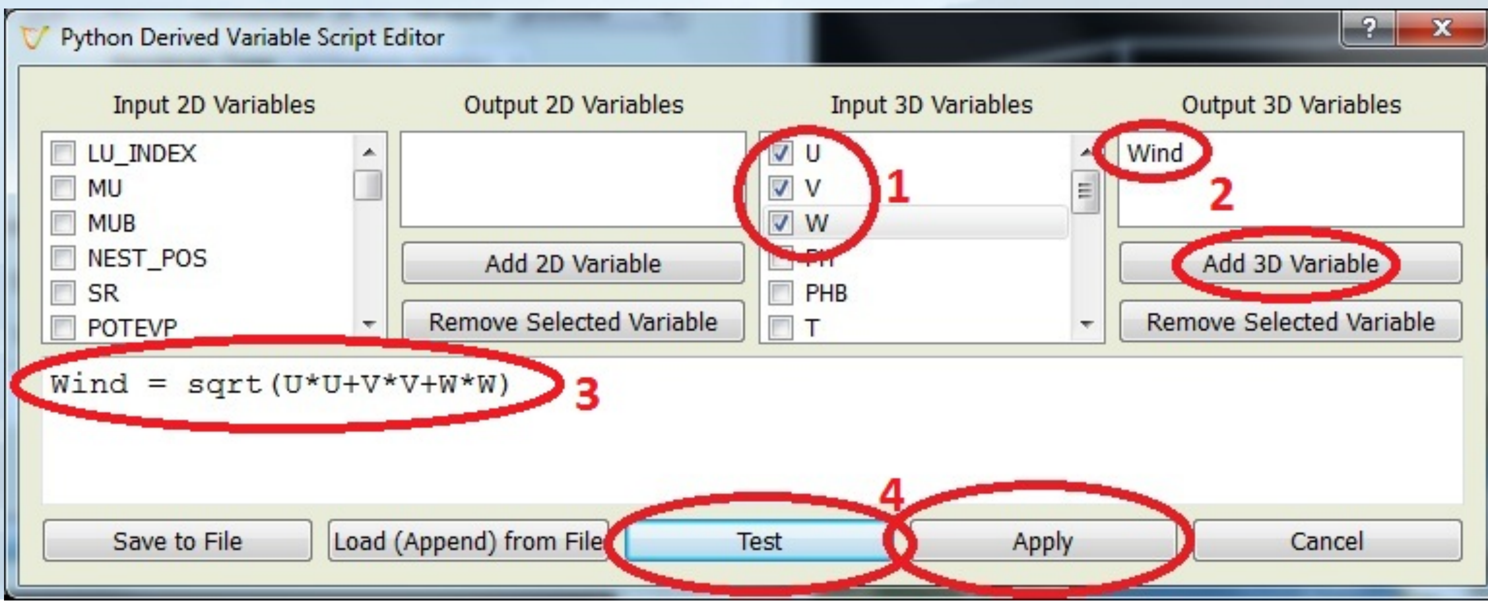
Define derived variable

- From VAPOR Edit menu, choose “Edit Python Program defining a new variable”
- In the Python editor:
  1. Check U, V, and W as Input 3D Variables.
  2. Add “Wind” as Output 3D Variable.
  3. Type in the one-line python script:
     Wind = sqrt(U*U+V*V+W*W)
  4. Click “Test”; if response is “Successful Test” it’s OK; then click “Apply”



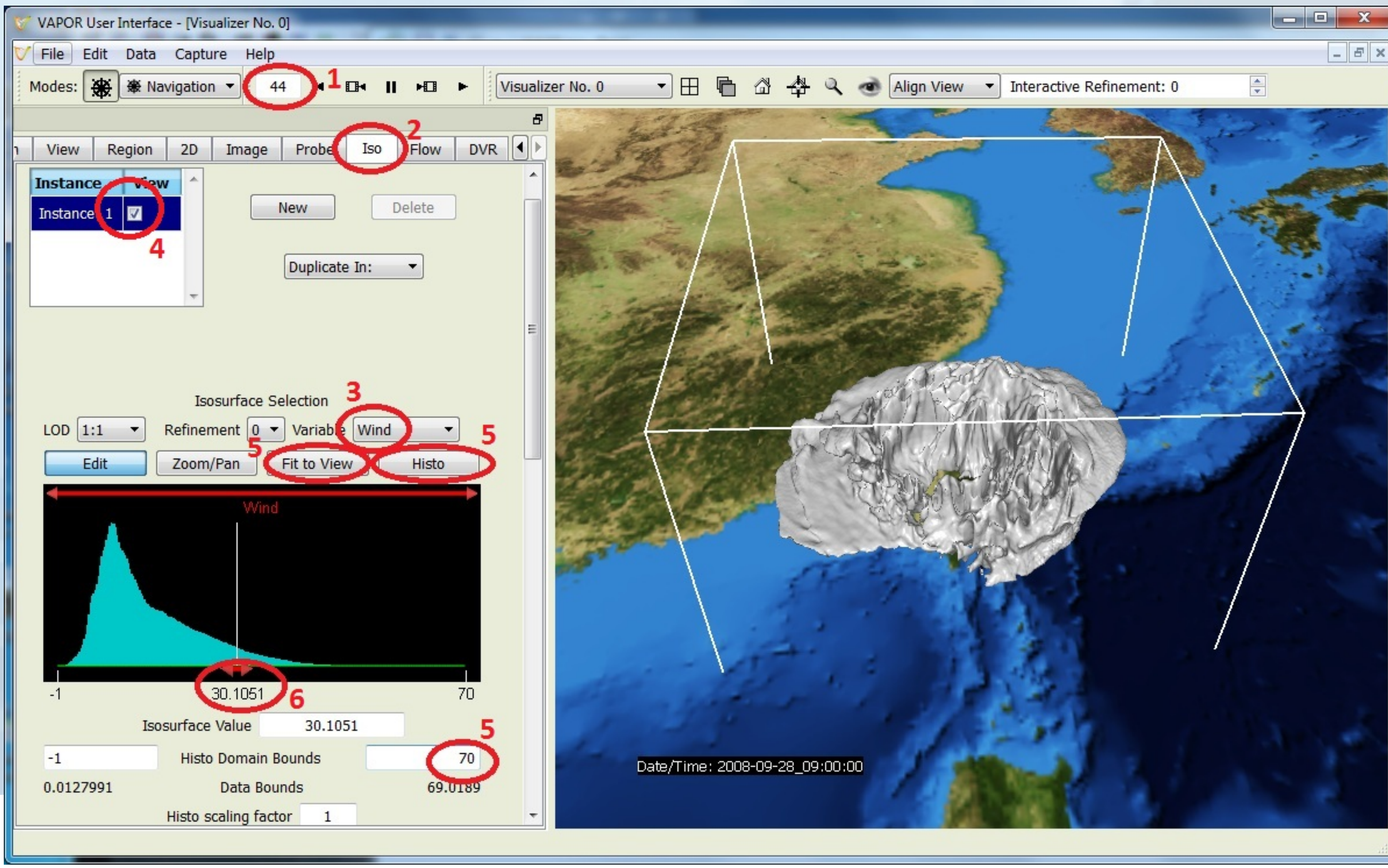
Isosurfaces of Wind (1)

- In the DVR tab: disable DVR (un-check Instance: 1)

1. Using VCR control:
   - Set current time step to 44
2. Click on Iso tab

In the Iso tab:

3. Set variable "Wind"
4. Check "Instance:1" to enable
5. Set histo right bound to 70, then "Fit to View" and "Histo" to see Wind histogram
6. Set the isovalue near 30 (use slider or type it in)

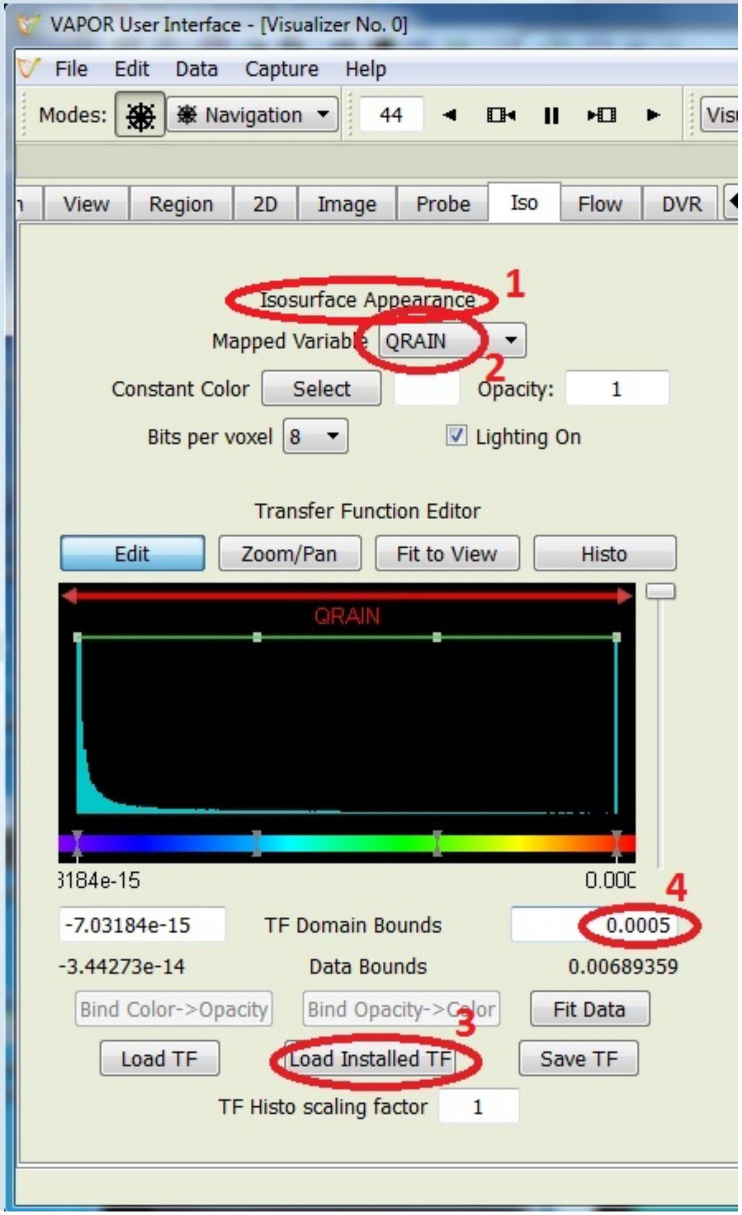


Isosurfaces of Wind (2)

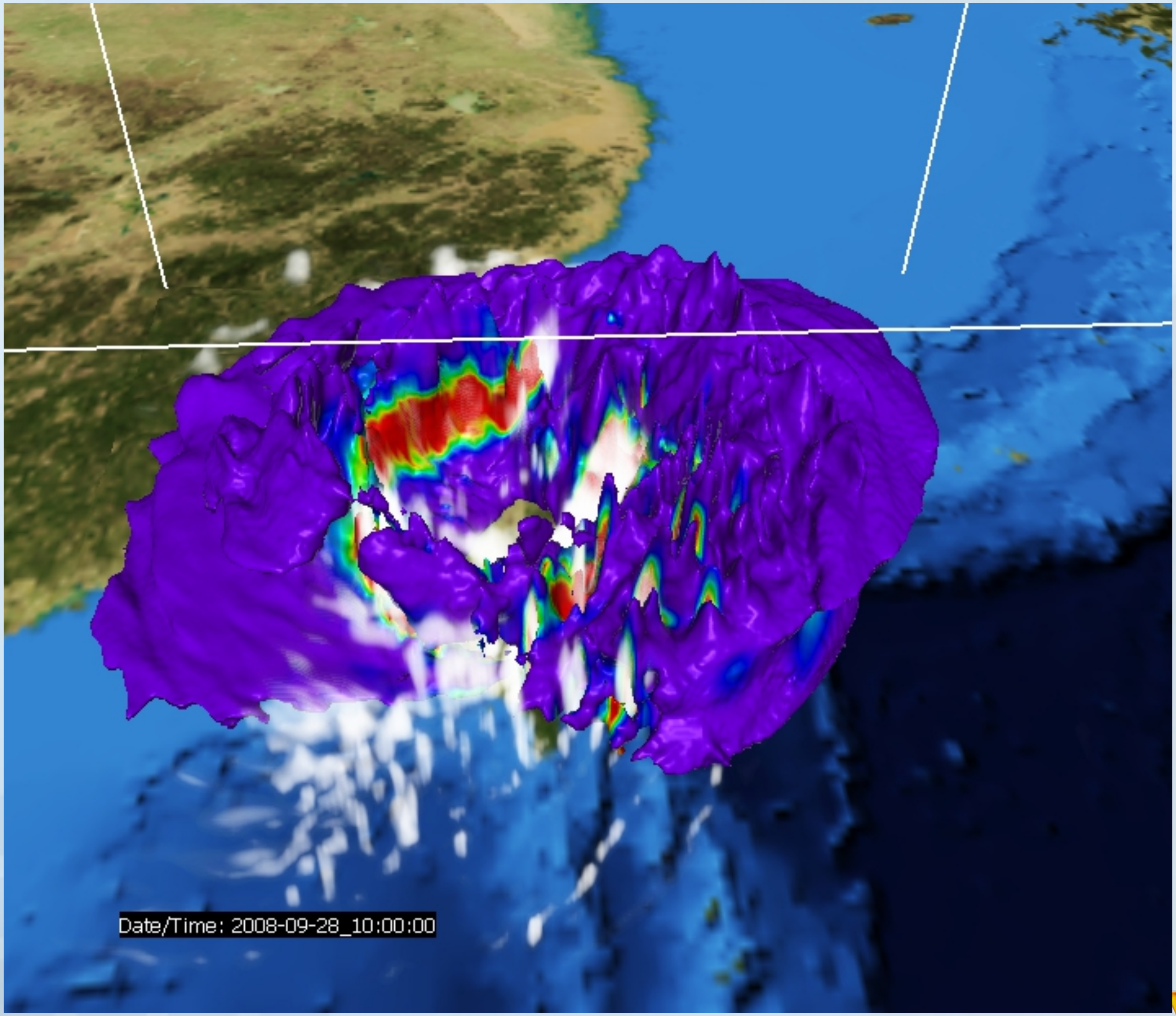
To color the isosurface of Wind by QRAIN (or other variable):

1. Scroll down in the Iso tab to the transfer function, under Appearance
2. Set the mapped variable to “QRAIN”.
3. Click the button “Load Installed TF” below the transfer function, and load “**reversedOpaque.vtf**”. This makes low values violet-blue, high values orange-red.
4. Set the right domain bound of the transfer function to 0.0005, so that the large values of QRAIN will show up as red in the isosurface.

- Animate to see the typhoon vortex pass over Taiwan
- Enable the DVR to combine clouds, wind and rain in one visualization.



Isosurface of Wind = 30 at time step 45, colored by QRAIN, with volume render of QCLOUD



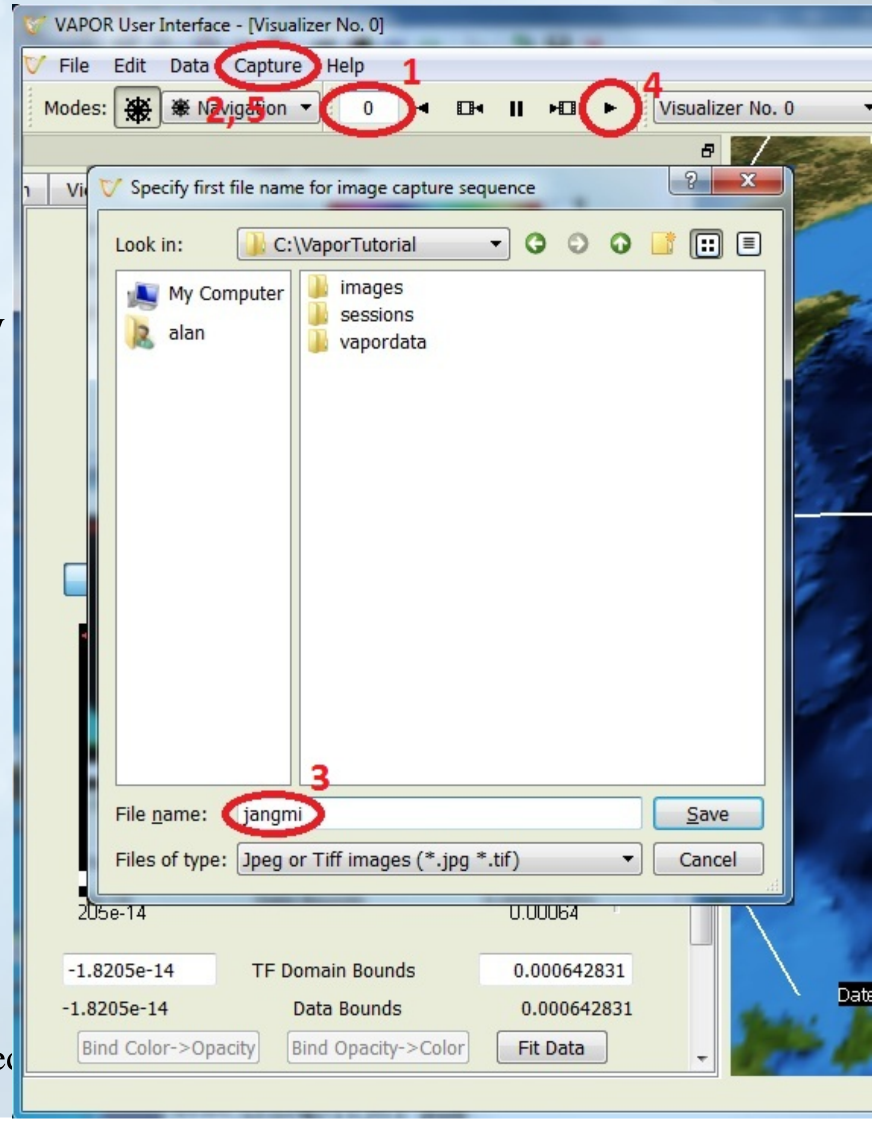
Capture an animation sequence

Save a sequence of jpeg files of your visualization:

1. Set the time step to 0
2. From Capture menu, choose “Begin image capture sequence…”
3. Choose a jpeg file name in a directory where you can write files.
4. Click the play (▶) button.
5. When animation is done, from the Capture menu, click “End flow capture sequence”

- (Use Quicktime Pro, ffmpeg, etc. to convert to movie file.)

See jangmi.mov in images directory



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Use VAPOR/WRF python support

Vapor includes several Python routines for various derived variables, such as radar reflectivity, relative humidity, sea-level pressure, cloud-top temperature, potential vorticity… (Documented on the VAPOR Website under “Data analysis with VAPOR”)

- Disable the DVR and the Isosurface
- Write a Python script to create a new variable “dbz” which represents the simulated radar reflectivity. The python script consists of the two lines:

```
import vapor_wrf
dbz = vapor_wrf.DBZ(P,PB,QRAIN,0,QSNOW,T,QVAPOR)
```

- Specify that dbz is an output 3D variable
- Specify that P, PB, QRAIN, QSNOW, T, and QVAPOR are input 3D variables.
- Visualize the DVR of dbz (click Fit Data and click “fit to view”)
- Compare this with rain, by creating an isosurface of QRAIN=5.e-05
- Animate this over time.

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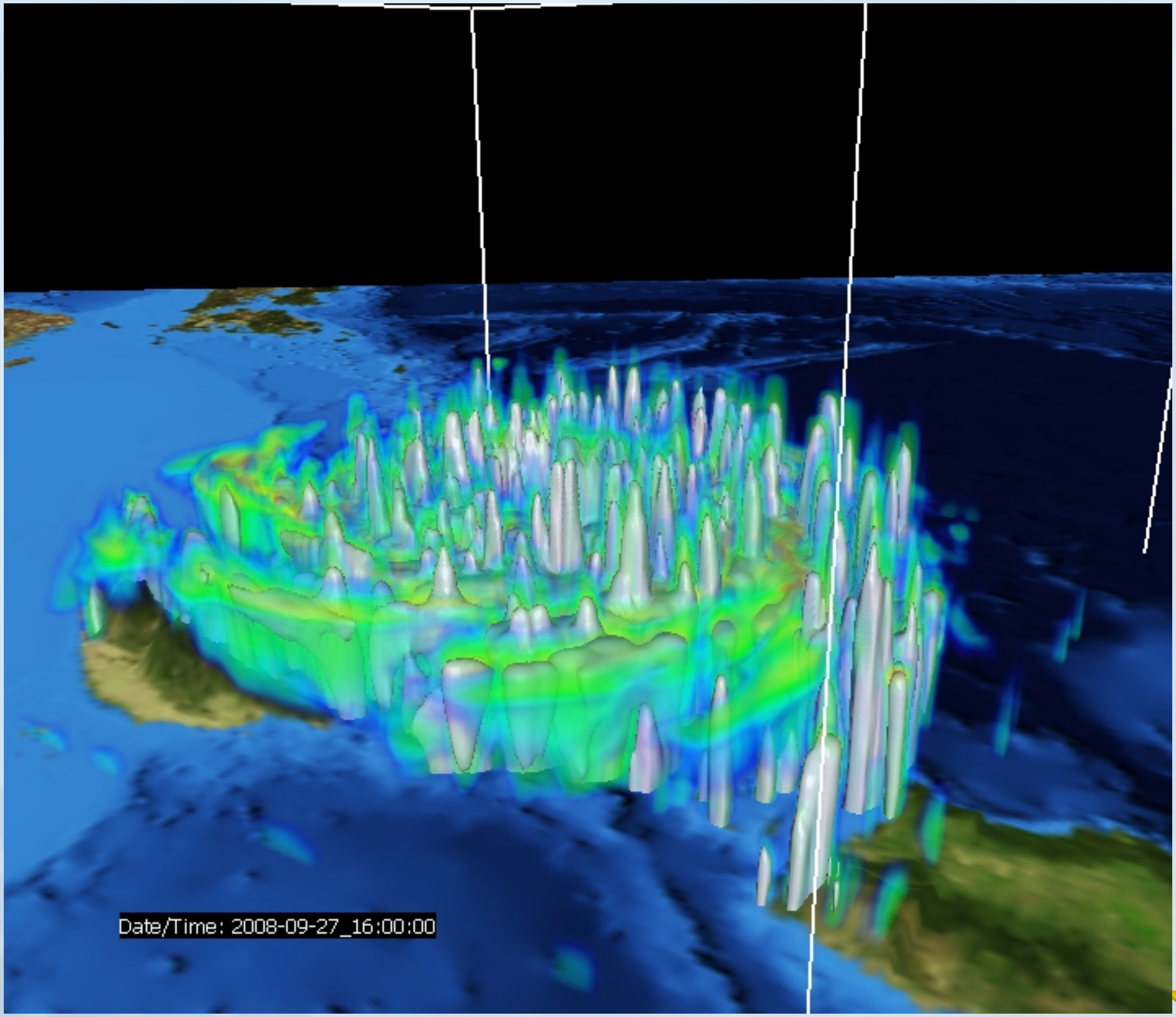
Radar reflectivity with isosurface of QRAIN as Typhoon Jangmi approaches Taiwan



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Flow Visualization Overview

- Vapor can display streamlines (***steady*** flow, constant time) and pathlines (***unsteady*** flow, showing particle paths over time)
- Flow can be illustrated in cross-section using the ***flow image*** capability in the Probe tab.
- Streamlines and path lines are established by ***seed points*** (starting points for flow integration)
- Seed points can be:
  - ***Random***: Randomly placed within a range of x, y, and z values, or
  - ***Nonrandom***: Evenly spaced in x, y, and z dimensions, or
  - ***Seed List***: Explicitly placed in the scene
- Vapor ***Rake*** tool is provided to specify a box for random or evenly spaced (nonrandom) seeds (looks like:)
- VAPOR ***Probe*** tool ( ) can be used to position flow seed points.

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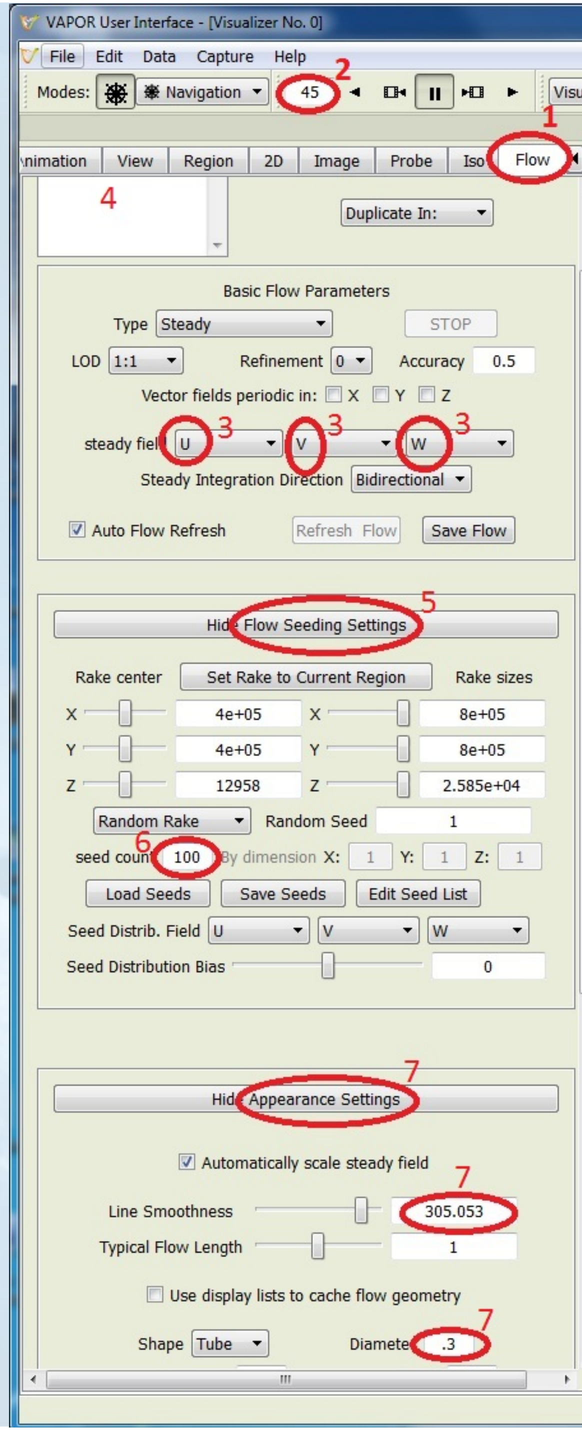
Random streamlines (1)

- Disable isosurface, DVR

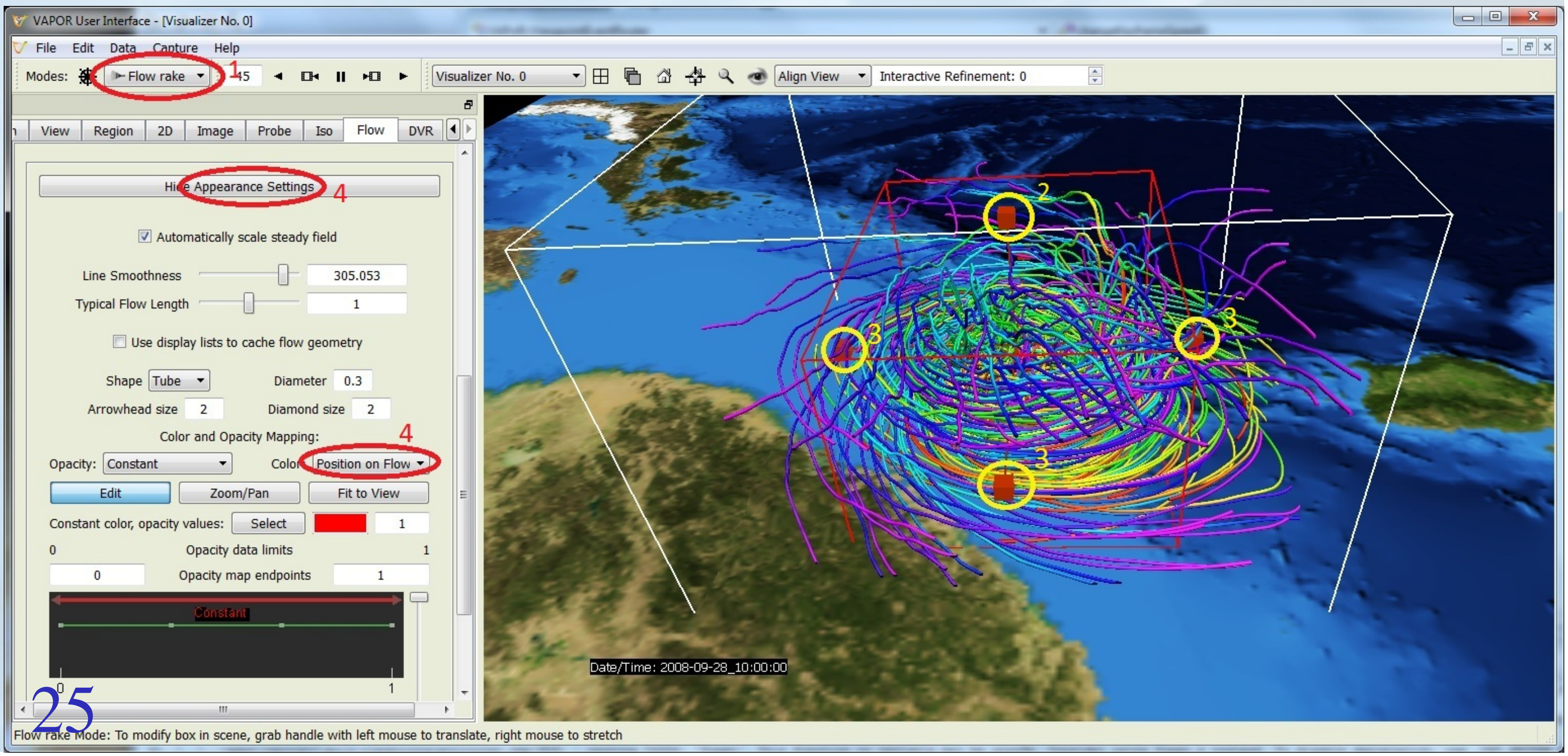
1. Click on Flow tab
2. Set time step to 45
3. In flow tab, select U, V, W as steady field variables.
4. Check "Instance: 1" to enable steady flow (streamlines). Ignore the warning message.
5. Click "Show Flow Seeding Settings"
6. Specify seed count 100 (random) for steady flow, press <enter> to set the value.
7. Under Appearance settings, adjust smoothness (~300) and diameter (~0.3)



Random streamlines (2), using Rake

1. Select flow rake at top left, Mode selector). Note box and handles.
2. Grab the top handle of the rake with the **right** mouse button, pull it down about 1/3 of the way down (the flow seeds will be nearer the ground.)
3. Using the **right** mouse button, shrink the rake to a smaller box enclosing the eye of the typhoon
4. Color flow lines according to “position on flow” (in Appearance settings)

See how the wind is drawn in at ground level and climbs through the eyewall

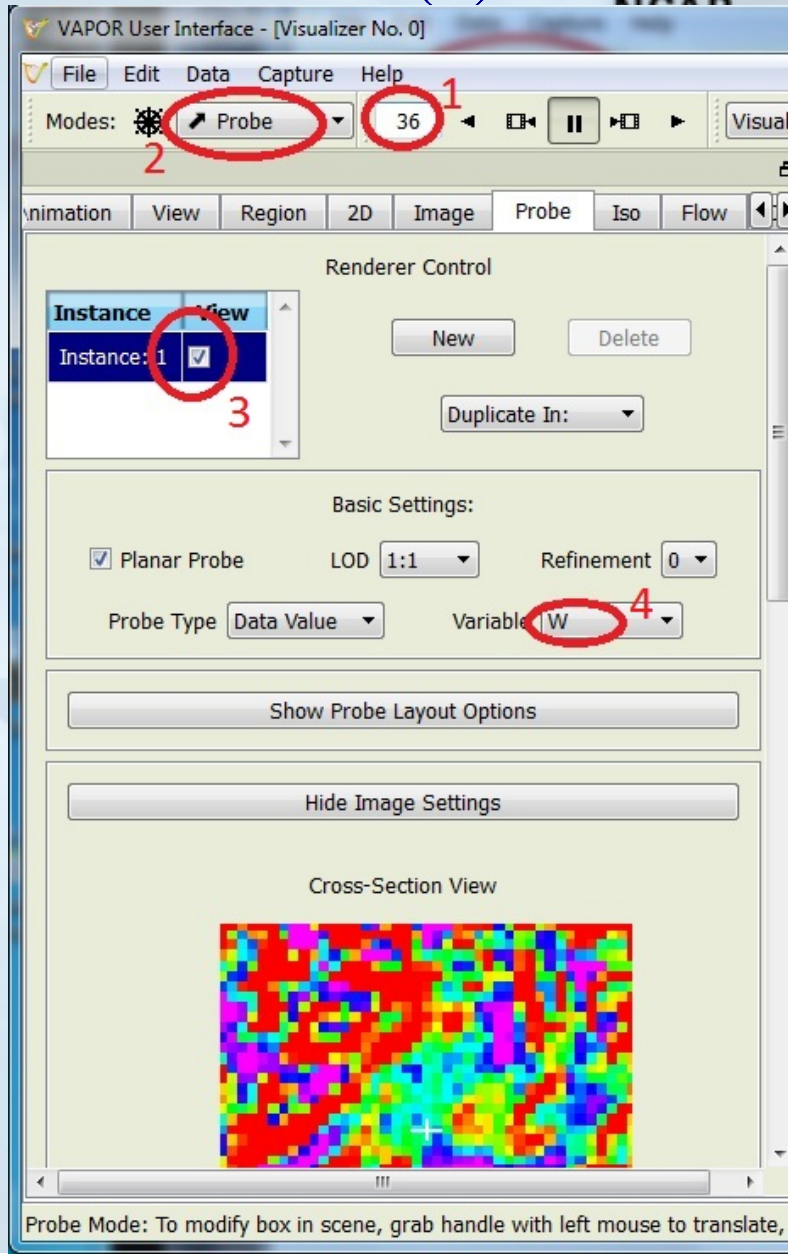


Use the probe to see a vertical slice of W (1)

Probe is useful to investigate the wind flow near the eye of the typhoon, by placing seed points where the W field is strongest

- Disable the flow (uncheck Instance:1 box in Flow tab)

1. Set the time step to 36
2. Select Probe mode( ) in the Mode selector at the top
3. Enable probe (check Instance:1 box in Probe tab)
4. Set the Probe variable to "W"



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Using the probe to see a vertical slice of W (2)

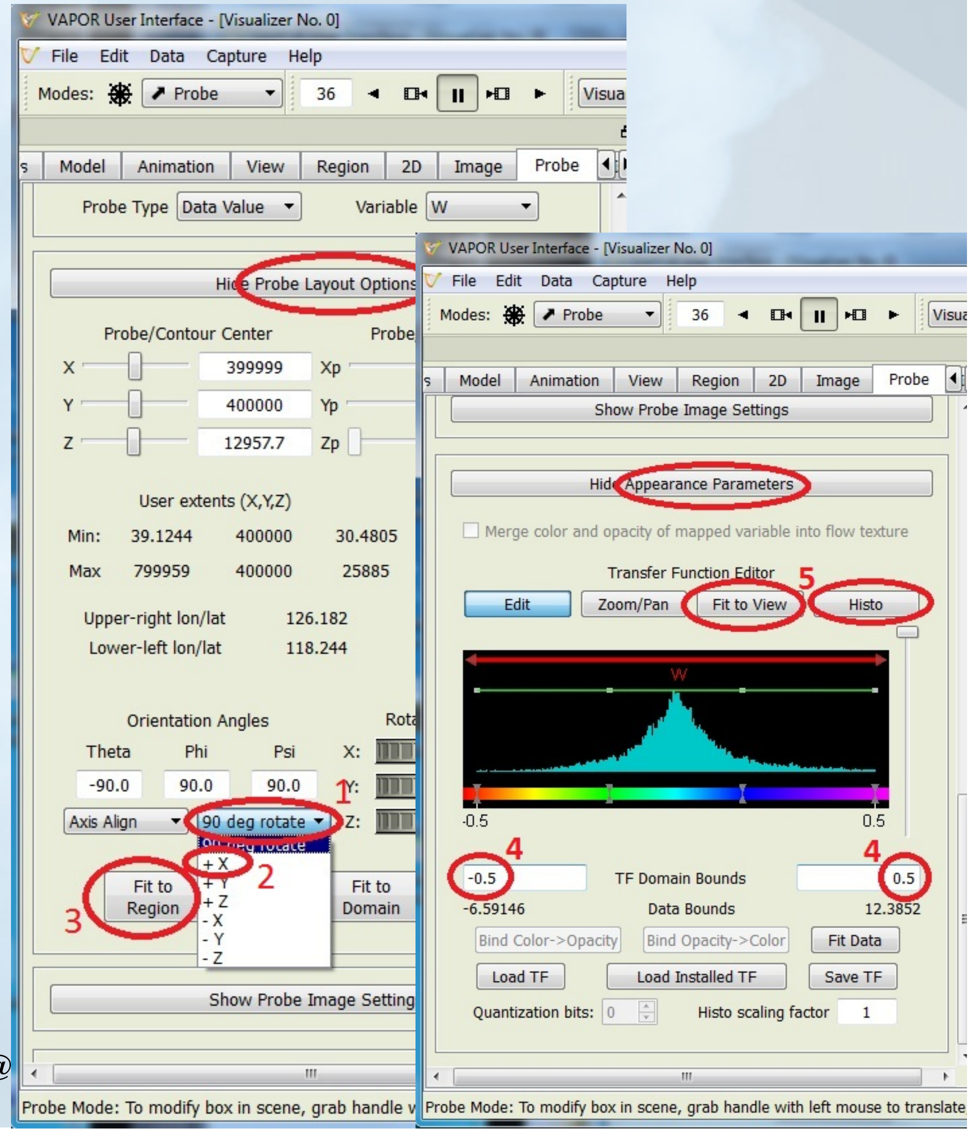
To view a vertical slice through the typhoon:

Under “Probe Layout options”:

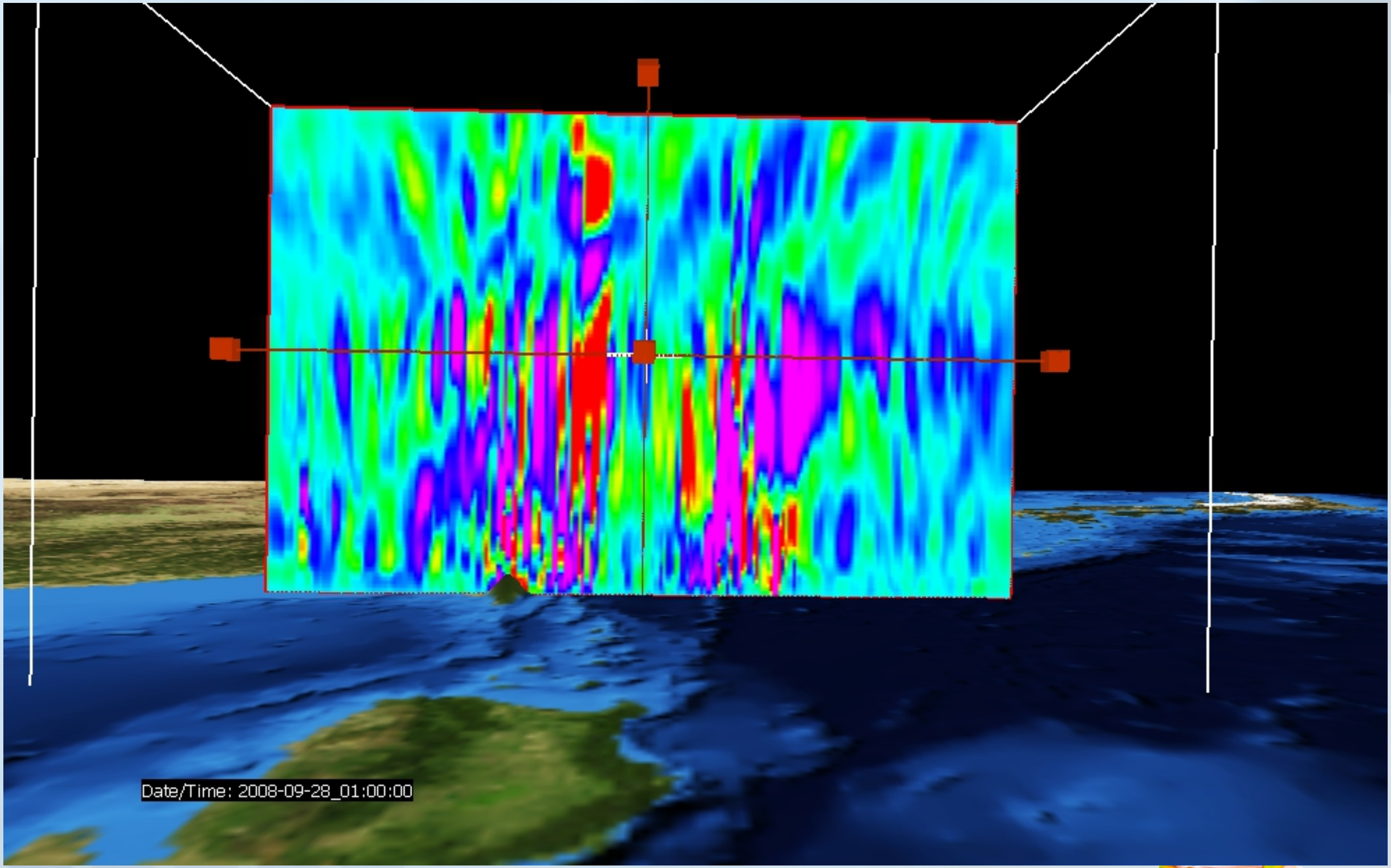
1. Click 90 degree rotate
2. Select “+X” to get a vertical slice.
3. Click “Fit to Region” button

In Appearance Parameters at the bottom of the probe panel:

4. Set the TF domain bounds to -.5 and 0.5
5. Click “Fit to view” and “Histo” to see the values of W in the probe



Cross section of typhoon (Probe of W)
Viewed from the south



 Session file: slide28.vss

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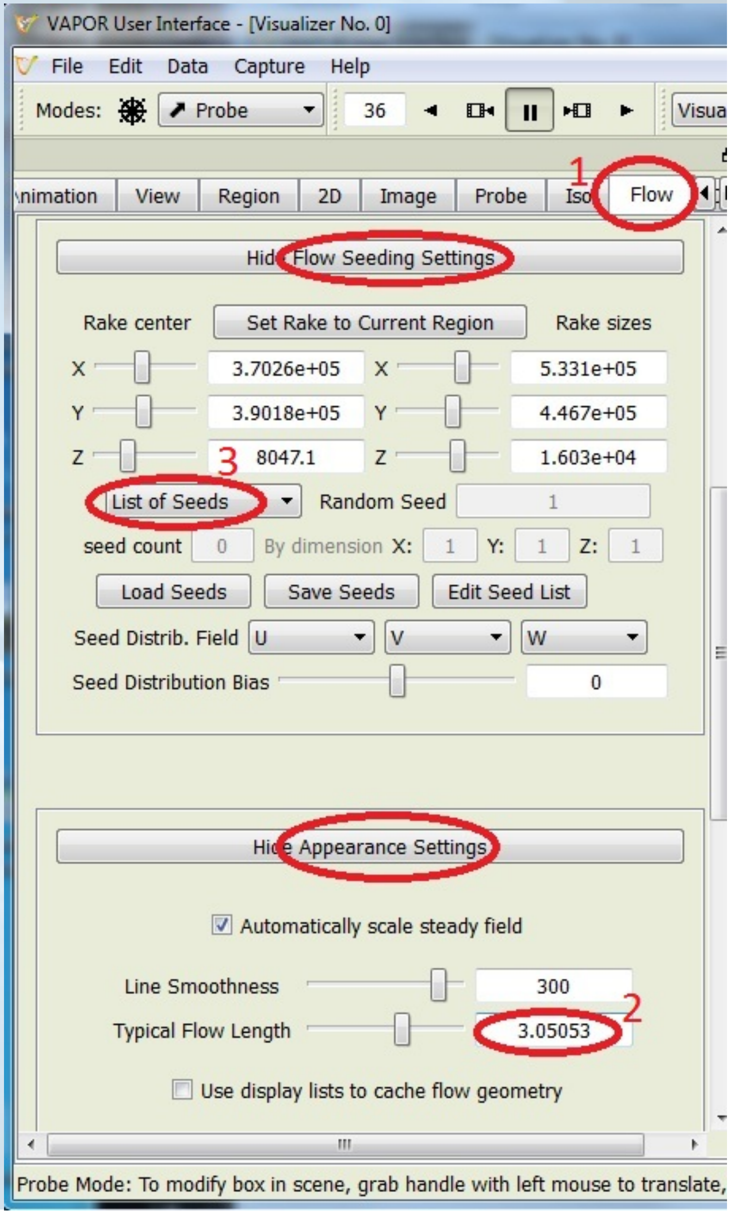
Using the probe to specify flow seed points (1)

1. Click on the Flow tab
2. Under Appearance Settings, set Typical Flow Length = 3
3. On the flow tab, under “flow seeding settings”, select “List of Seeds” instead of “Random Rake”.

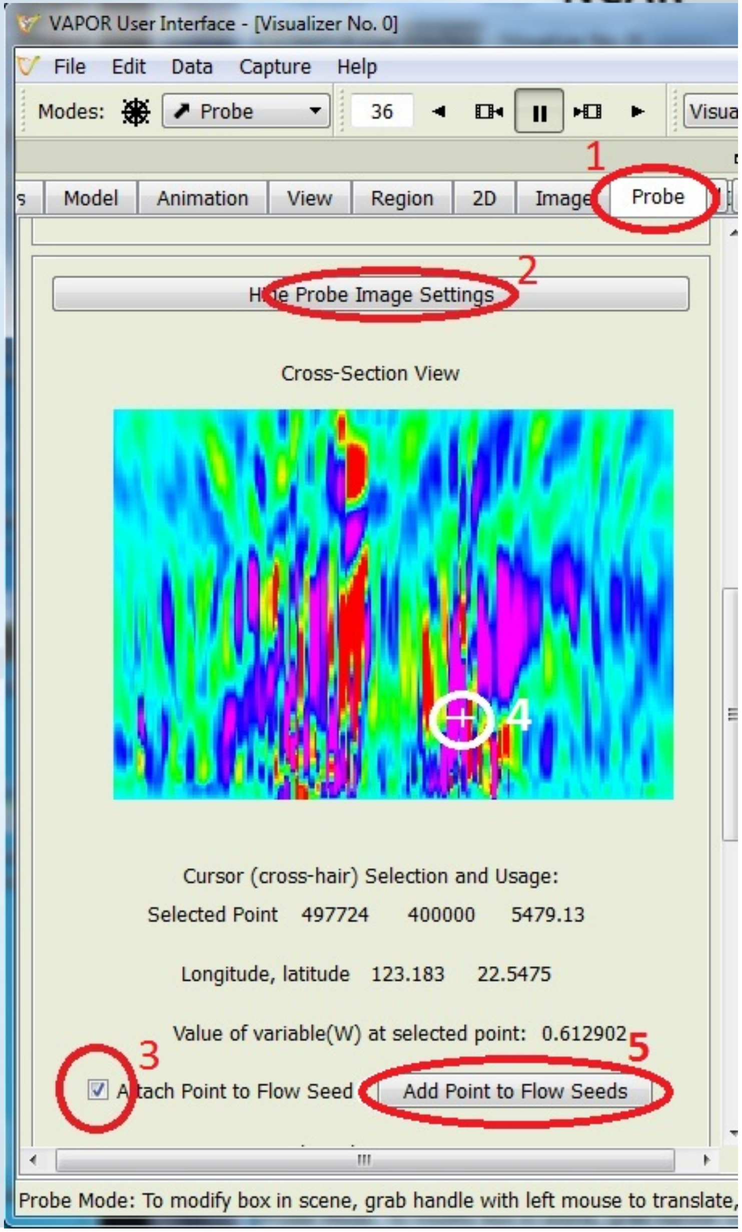
- Check “Instance:1” to enable the flow. Ignore the warning messages (there are no seeds in the list).



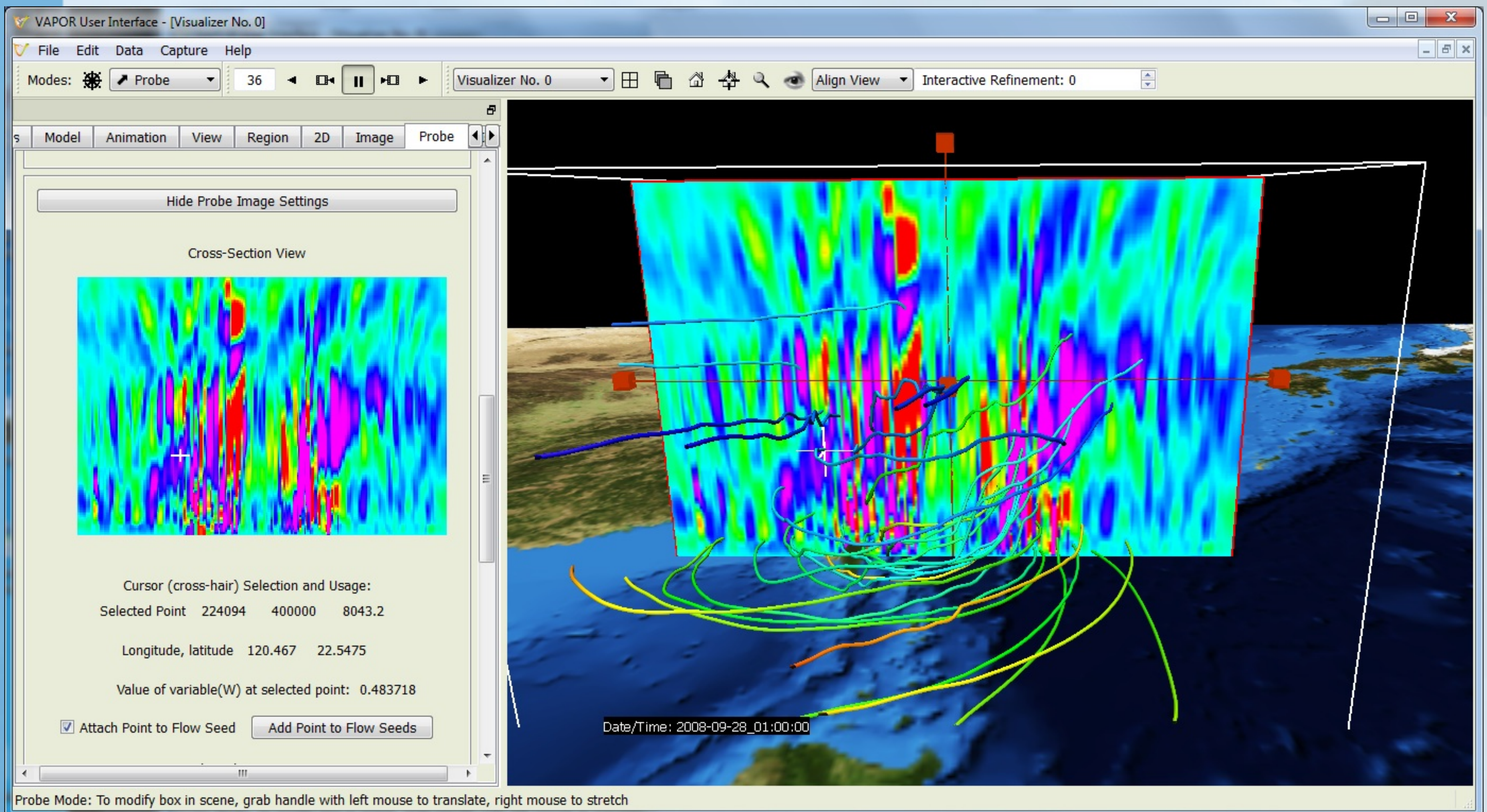
Using the probe to specify flow seed points (2)

1. Click on the probe tab.
2. Scroll down to the probe image settings, where you see an image of the cross-section of the data
3. Check "Attach point to flow seed". You should see a streamline associated with a seed point at the cursor position.
4. Click mouse in the image, at positions with large (purple) W values, and see the streamlines associated with the eye wall.
5. Click "Add Point to Flow Seeds" for streamlines that you want to keep.

With 10-15 flow seeds you can visualize the wind flow pattern near the eye wall.



Streamlines placed with the probe



Session file: slide31.vss

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Other useful capabilities of VAPOR

Some features we haven't shown you

(more info at http://www.vapor.ucar.edu/):

- Convert WRF output to VAPOR data format
  - Visualization will be much more interactive, especially on large grids.
- Use NCL with VAPOR: Embed NCL plots in the 3D scene
- Sample Python scripts for deriving variables from WRF output are available at http://vis.ucar.edu/~alan/wrf2012/tutorial/python
- Other flow visualization capabilities
  - Particle traces
  - Wind barbs
  - Image-based flow visualization

Where to go from here

To visualize the output of your WRF-ARW simulation:

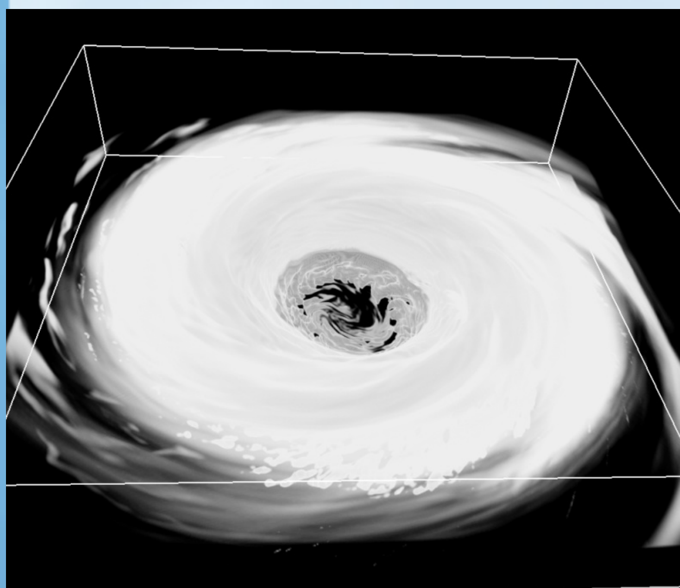
- Install VAPOR on your computer (or use vapor installed at NCAR) (Instructions at http://www.vapor.ucar.edu/)
- For faster visualization, convert your data to VAPOR using wrfvdfcreate and wrf2vdf
- Various python scripts are available for WRF analysis
- Use NCL to create 2D data plots to put in the scene
- Additional tutorials and user guides are available at http://www.vapor.ucar.edu/
- E-mail vapor@ucar.edu with questions, suggestions, bugs.
- Let us know if you have additional needs – That's how we select and prioritize new features!

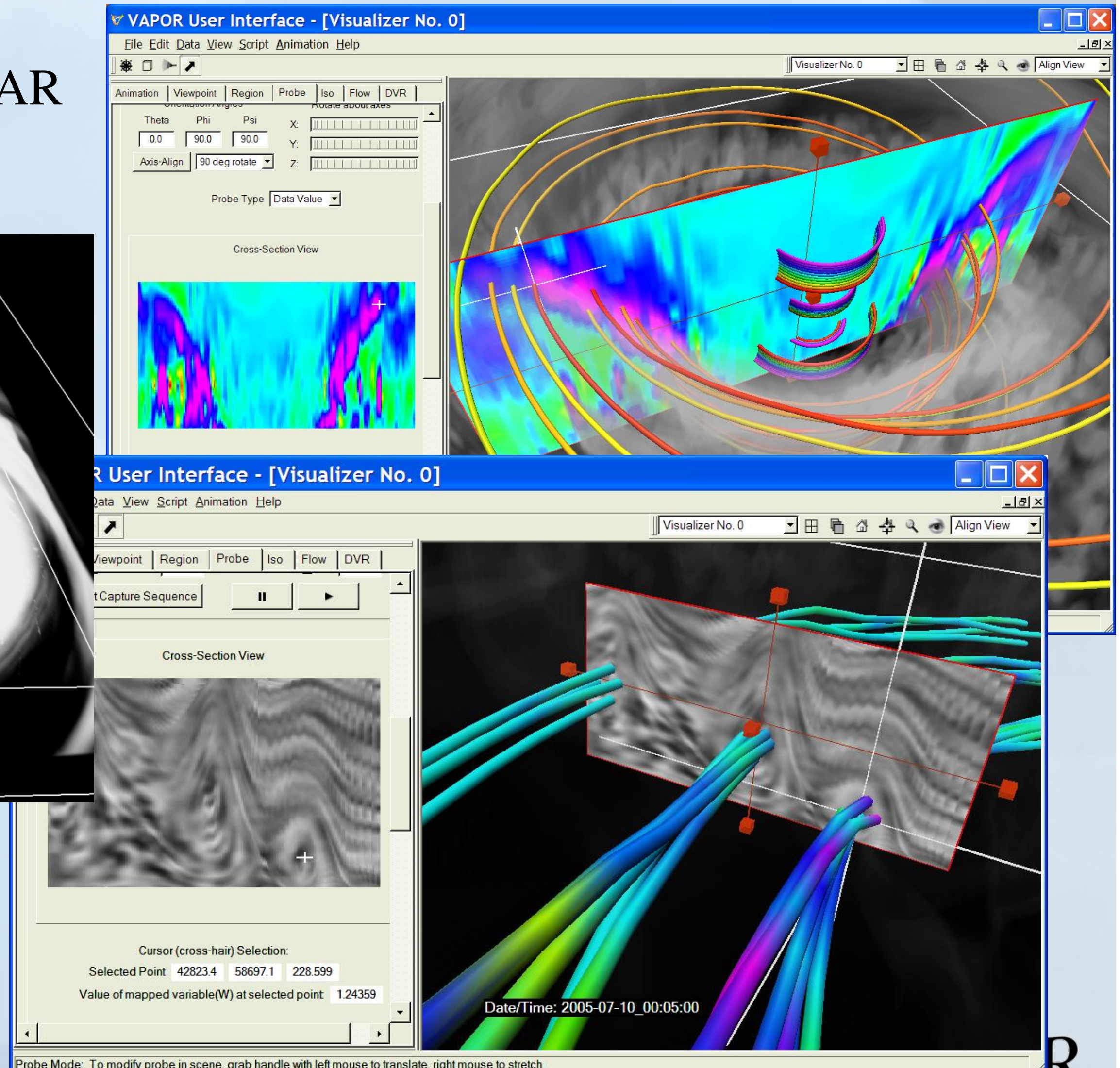
Tutorial supplement:
An analysis of high-res hurricane data

http://vis.ucar.edu/~alan/wrf2012/tutorial/docs/WRFVaporTutorialSupplement.ppt

Data provided by:

Yongsheng Chen, MMM/NCAR





VAPOR Availability

- Version 2.1.0 software is available
- Runs on Linux, Windows, Mac
- System requirements:
  - a modern (nVidia or ATI) graphics card (available for about $200)
  - ~1GB of memory
- Supported in NCAR visualization/analysis systems
- Software dependencies:
  - IDL® http://www.ittvis.com/ (only if you need IDL)
- Contact: vapor@ucar.edu
- Executables, documentation available (free!) at http://www.vapor.ucar.edu/

Thanks!

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