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 construct visualizations of WRF-ARW output, using geo-referenced images, volume rendering, isosurfaces, data probing, and flow integration.

You will be able to interactively navigate through images of WRF output data with NCL imagery, and animate time-varying data.

Supporting software and data

- Installed on classroom PC's:
  - VAPOR 1.5.2
  - Sample vapor datasets at C:/VaporTutorial/vapordata
  - Sample WRF datasets at C:/VaporTutorial/wrfdata
  - Sample images C:/VaporTutorial/images
- 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/wrf2010/tutorial/

Tutorial Outline

- Data preparation process (command-line tools)
- Set up a visualization session in VAPOR using a simulation of Typhoon Jangmi (Sept. 2008)
- *Georeferenced images* (NCL plots and satellite images)
- *Volume rendering*: Visualize the typhoon progress with QCLOUD
  - Build a *Transfer Function* (color/opacity map)
- Visualize *Isosurfaces* of QRAIN
- *Flow integration* (wind visualization)
  - *Streamlines:* observe how the air flows through the typhoon
  - *Image-based flow visualization (IBFV)*: View and animate cross-sections of the flow
- *Data probing*
  - Accurate flow seed placement

Preparing WRF data for VAPOR

Two command-line utilities needed before you visualize WRF data; *this has already been done for this tutorial*

- **`wrfvdfcreate wrf_netcdf_files vaporfile.vdf`**
  - Examines the wrf netcdf files, determining the 3D variables, timesteps, and spatial extents of the data
  - Optionally specify other variables to be derived, e.g. wind speed (UVW_)
  - Creates a metadata file "vaporfile.vdf" describing the entire Vapor Data Collection to be created from the wrf data
- **`wrf2vdf vaporfile.vdf wrf_netcdf_files`**
  - Converts all of the WRF NetCDF files to files in the vapor data collection
  - By default, converts all timesteps, variables at full resolution
    - Optionally specify levels, timesteps, variables of data to be saved

To save time, the data used in this tutorial has already been converted (at lowered resolution), available in C:/VaporTutorial/vapordata or at http://vis.ucar.edu/~alan/wrf2010/tutorial/vapordata

Data preparation exercise

Open a command shell

- Double-click on Cygwin desktop icon for bash shell, or
- Start –> run –> cmd to get a DOS shell

Change directory to C:/VaporTutorial/wrfdata/

Create a vapor vdf file with following command:

```
wrfvdfcreate wrfout* vapordata.vdf
```

(note the lon/lat extents)

Convert the wrfout files in that directory with the command:

```
wrf2vdf vapordata.vdf wrfout*
```

Obtaining images to use with VAPOR

- Geo-referenced satellite images can be retrieved from the Web, and VAPOR will place 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 lon/lat rectangle
- NCL plots of WRF data can be inserted in the 3D scene.
  - Start with NCL scripts such as those provided by Cindy Bruyere at http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/)
  - These scripts can be converted to produce geotiffs (with one image per time-step) that VAPOR will insert in the correct time and place in the scene.
  - Instructions and examples for doing this conversion are available at: http://www.ncl.ucar.edu/Applications/wrfvapor.shtml
- Several geo-tiff images for the typhoon data have been provided in the C:/VaporTutorial/images directory.

getWMSImage.sh exercise

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- **`getWMSImage.sh`** will create a geo-referenced tiff file for any specified lon/lat rectangle

- Can obtain satellite images, political boundaries, rivers, etc.
- Default obtains an image from the NASA "blue marble" earth

- For Jangmi,

  min: lon = 117, lat = 18

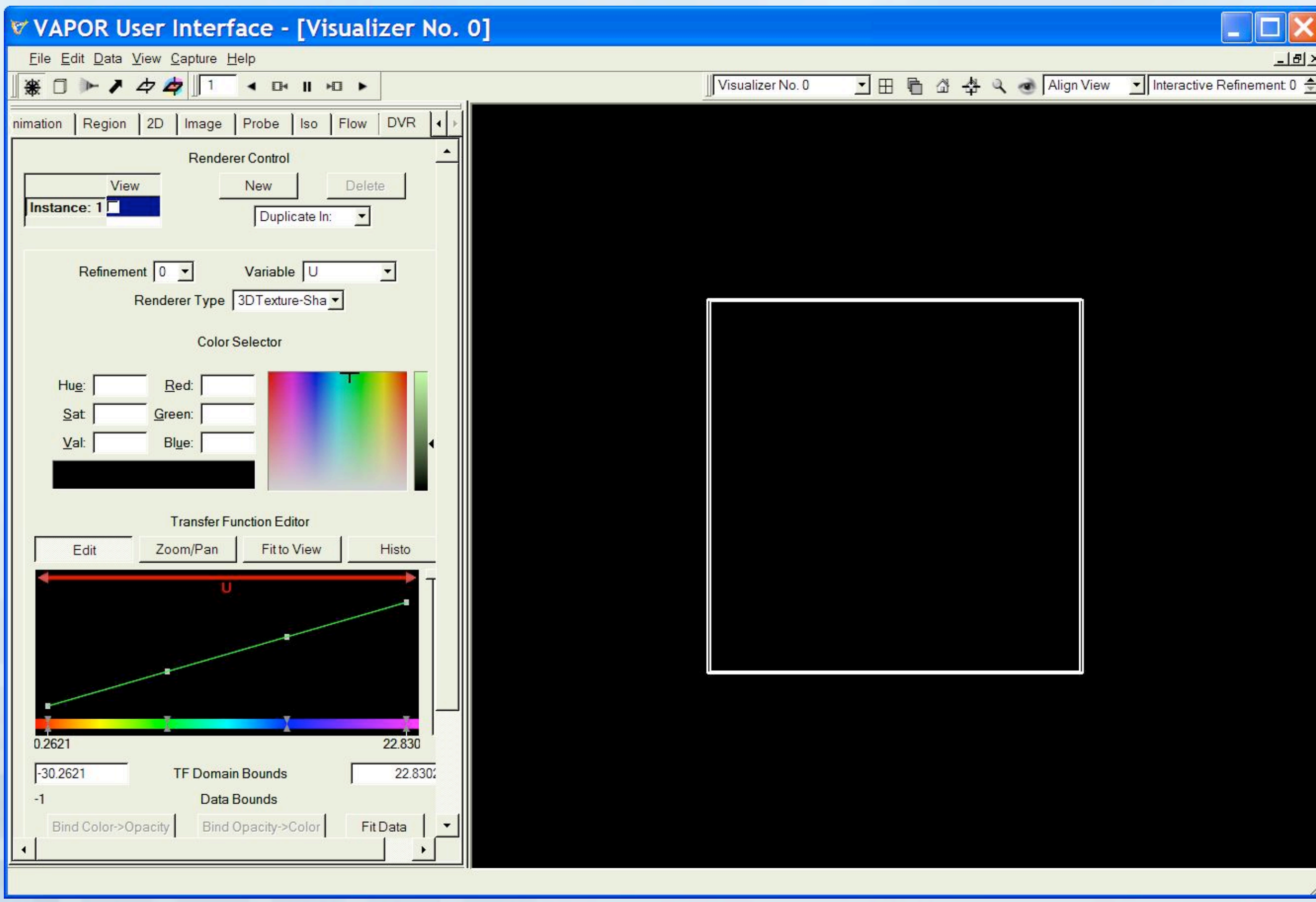
  max: lon = 127, lat = 28

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

```
getWMSImage.sh -o terrain.tiff  117 18 128 28
```

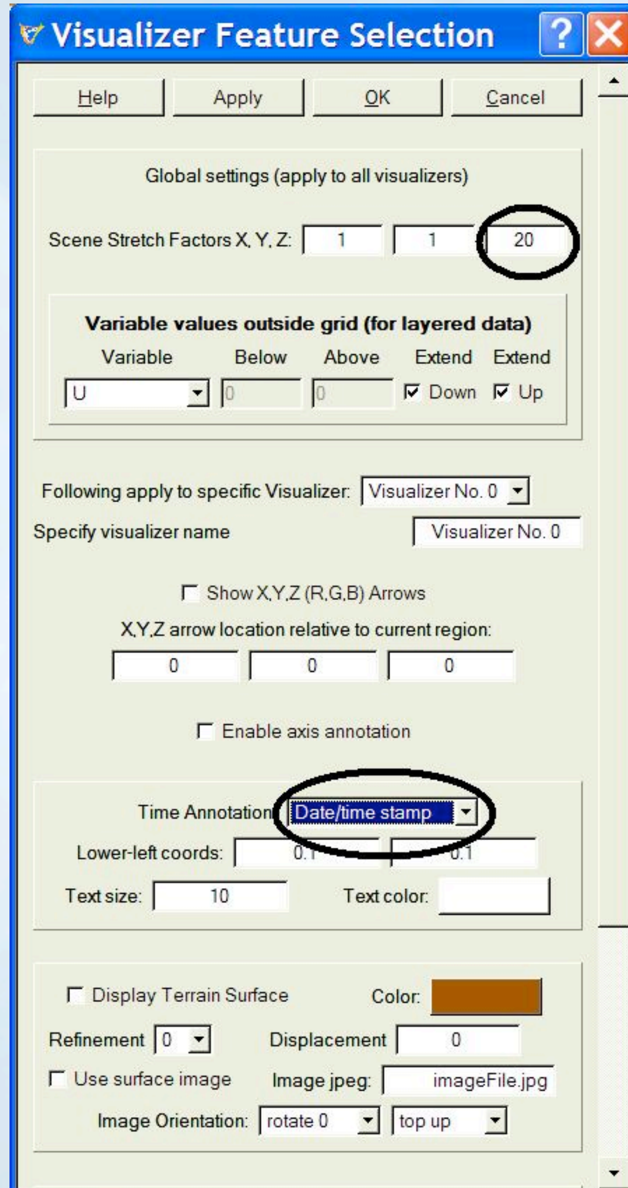
Set-up to visualize a WRF dataset (1)

- Launch 'vaporgui' (Desktop Icon:)
- From Data menu: Load a dataset into current session: select C:\VaporTutorial\vapordata\jangmi_lowres.vdf



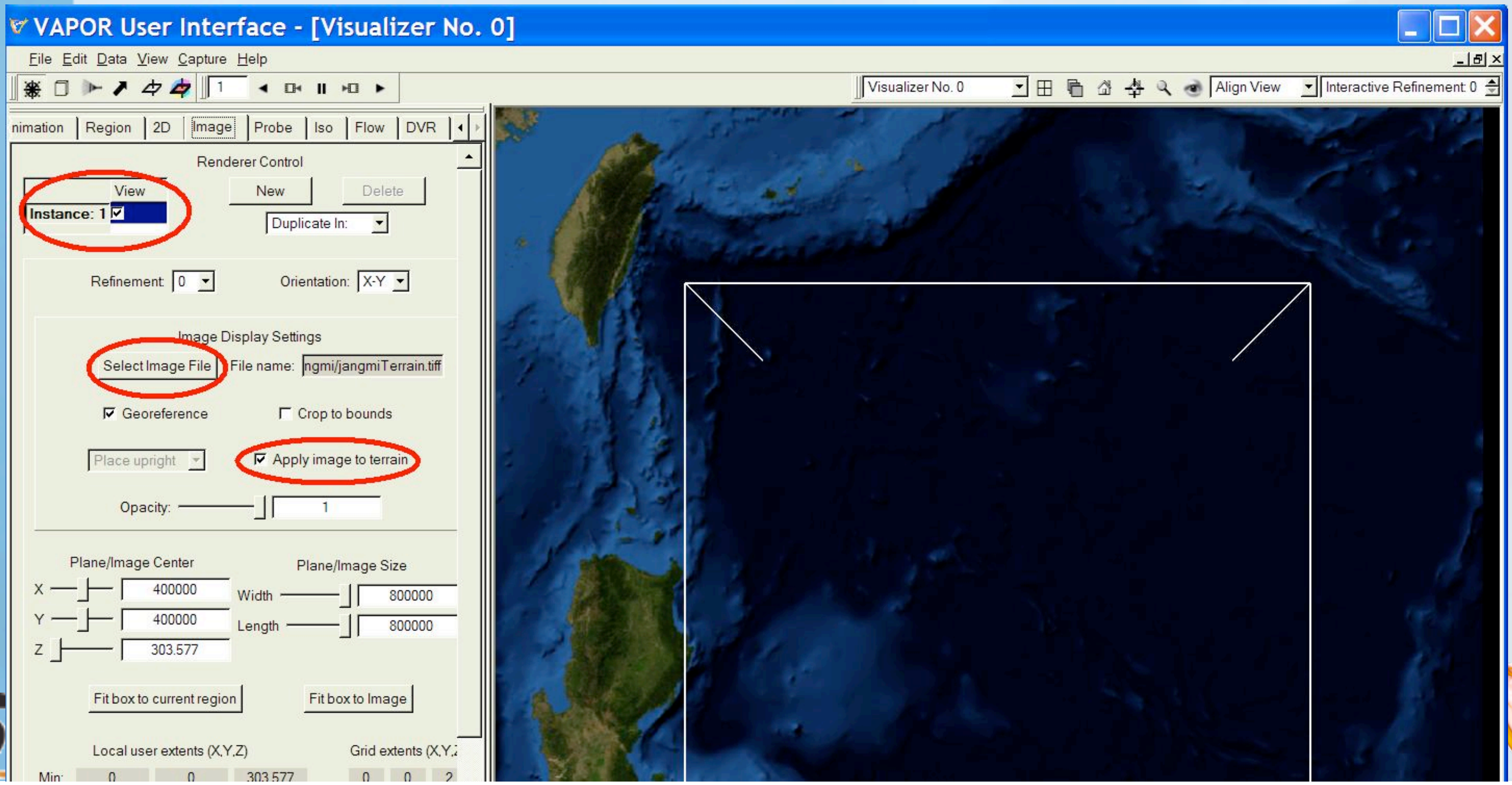
Set-up to visualize a WRF dataset (2)

- From Edit menu, click "Edit Visualizer Features" then:
  - Stretch Z by factor of 20
  - Specify time annotation, "Date/Time stamp"
  - Click "OK"



Set-up to visualize a WRF dataset (3)

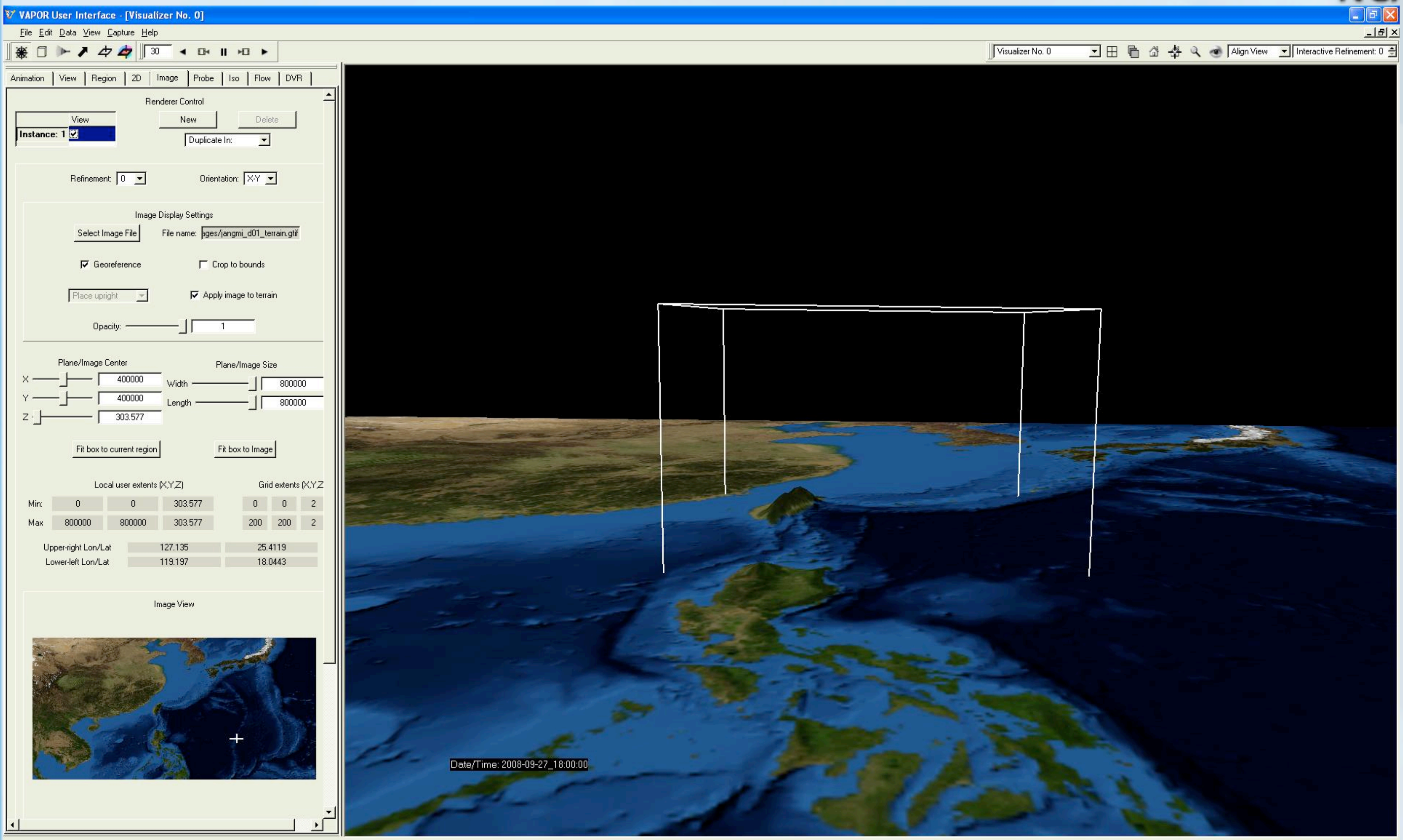
- To include a terrain image: Click on the "Image" tab
  - Click "Select Image File" and choose "C:\VaporTutorial\images\jangmiTerrain.tiff"
  - Check "Apply image to terrain"
  - Check the "Instance: 1" checkbox at the top of the Image tab to view the terrain image.



Ways to Control the 3D Scene

- To Navigate: rotate, zoom in, translate by dragging in the scene with left, right and middle mouse buttons.
- Click "Home" icon ( ) to return to starting viewpoint
- Click "Eye" icon ( ) to see full domain
- Use Edit→Undo if you make a mistake
- 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)

Terrain image with domain at timestep 30



Session file: fig1.vss

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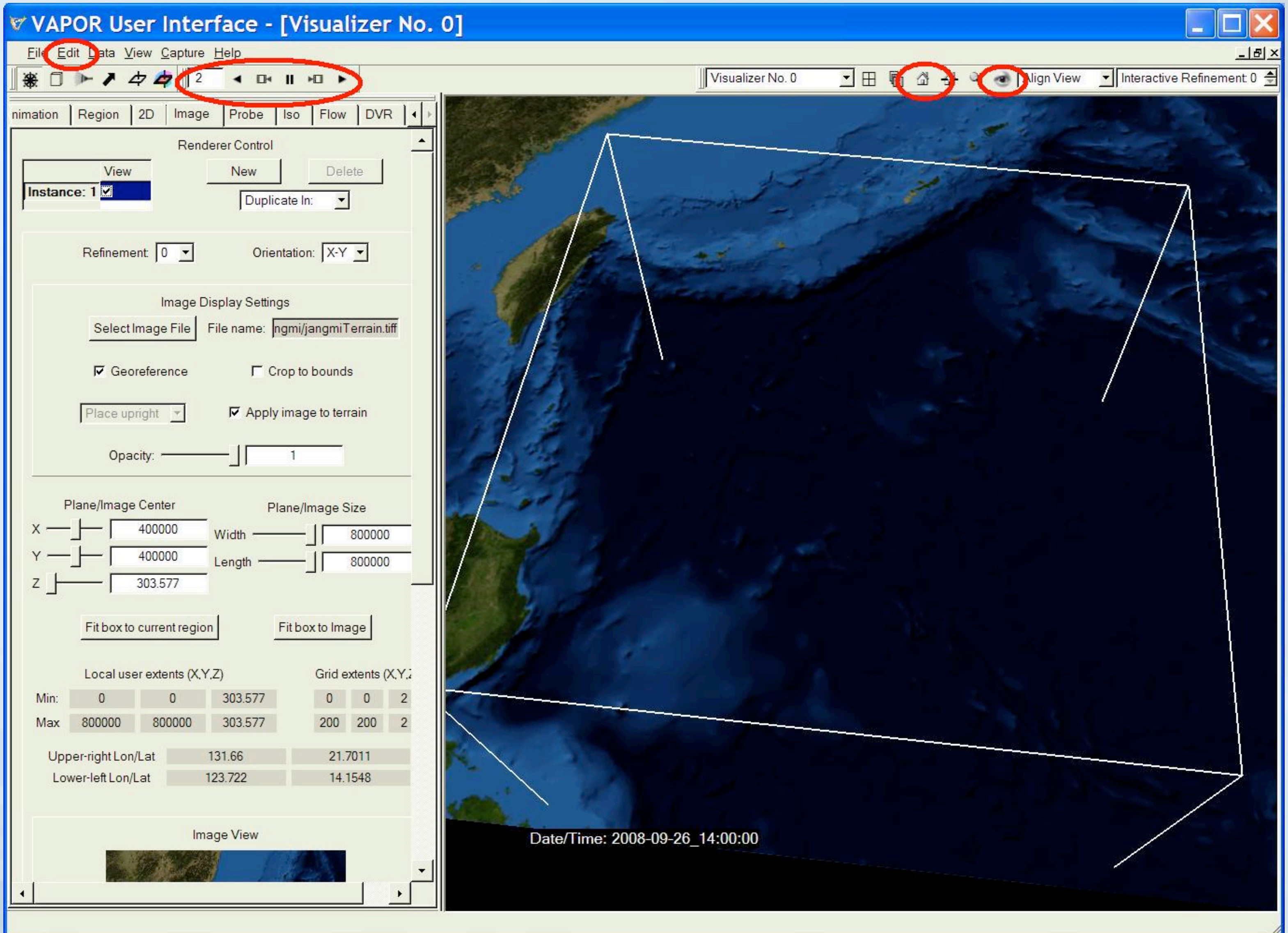
Navigation tools in VAPOR GUI

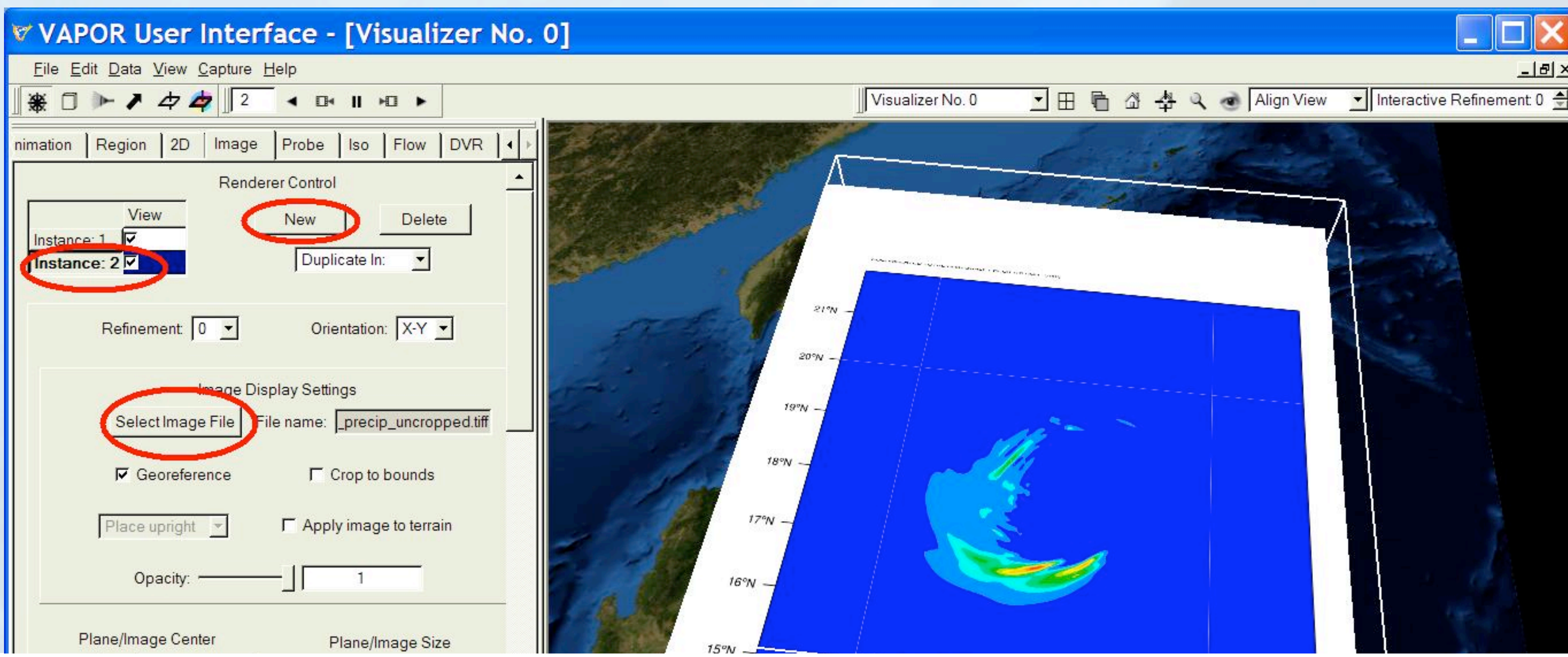


Using NCL plots with VAPOR

- Numerous examples of NCL scripts for plotting WRF data are available at: http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/
- With minor modification these plots can produce geotiffs that can be inserted into the VAPOR scene
- Such an NCL script is at C:/VaporTutorial/scripts/accumPrecip.ncl; It reads the typhoon data and outputs a plot of accumulated precipitation.
  - These plots are provided in the C:/VaporTutorial/images directory as **jangmi_precip_cropped.tiff** and **jangmi_precip_uncropped.tiff**
  - Sample wrf data for running these scripts is at: ftp://ftp.ucar.edu/vapor/data/jangmiWrfout.zip

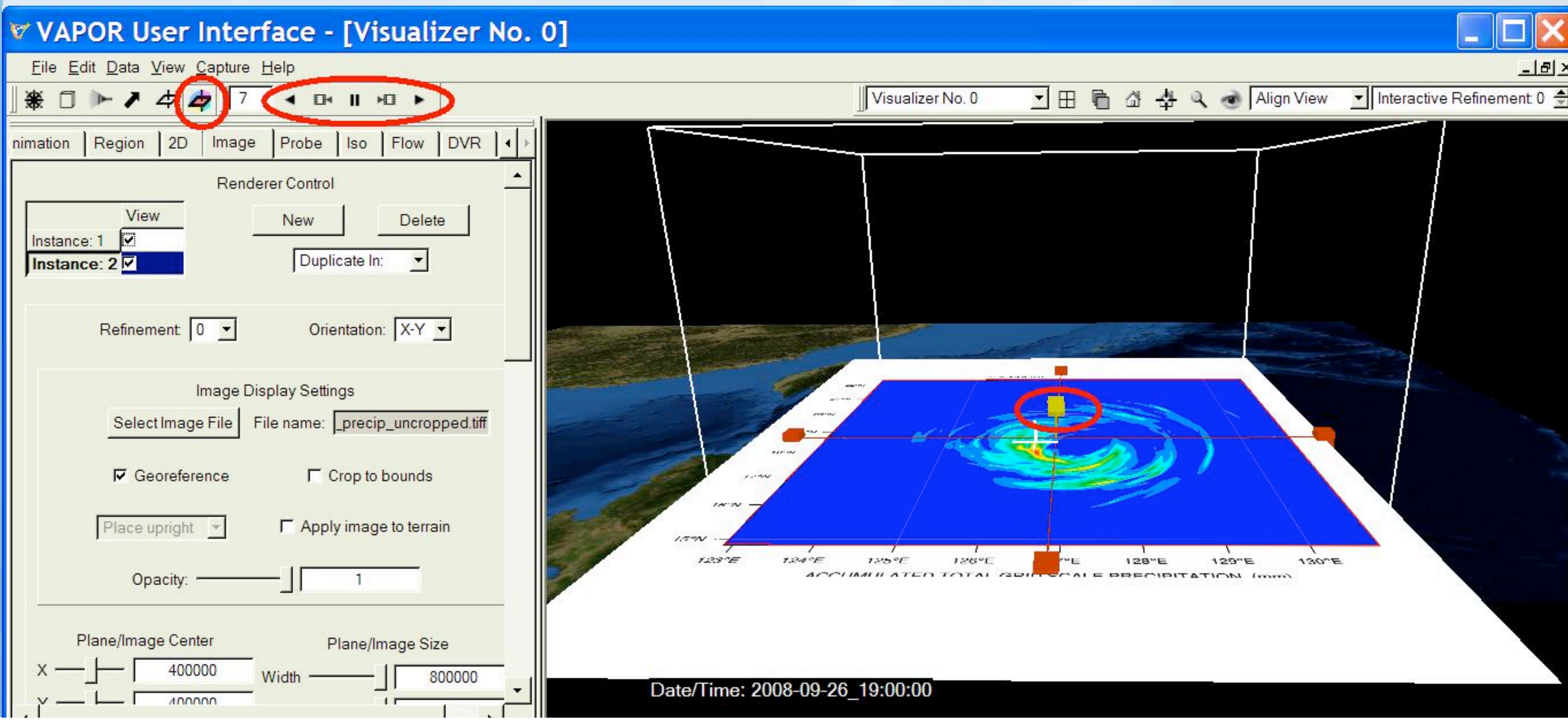
Inserting NCL plots into the scene(1)

- At the top of the the Image tab (in Renderer Control), click "New" to create a new Image renderer, and click on "Instance:2" to select renderer instance 2.
- Click "Select Image File" and select the file "jangmi_precip_uncropped.tiff".
- Check the "Instance: 2" checkbox to see an image of accumulated rainfall inserted into the scene.

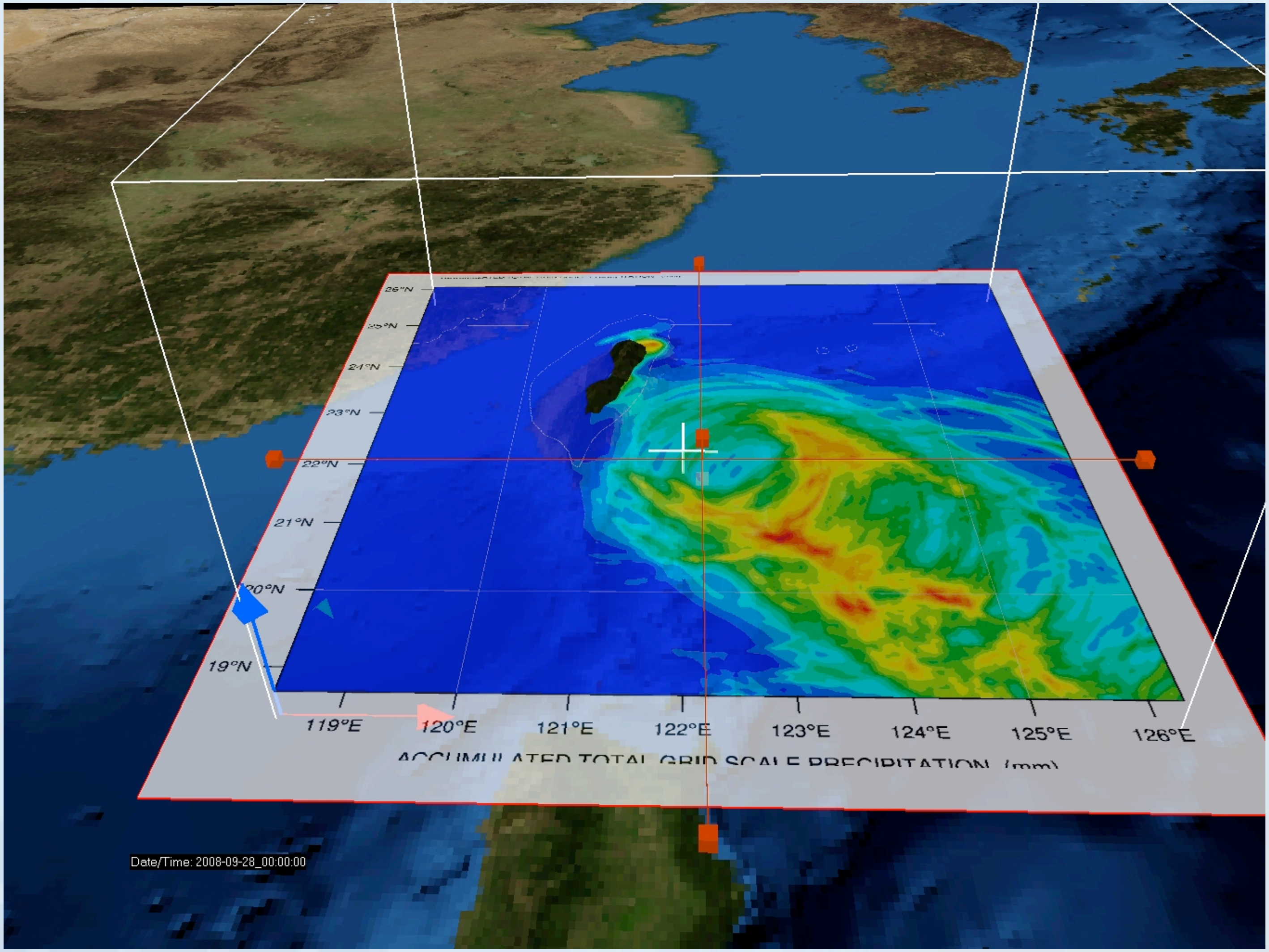


Inserting NCL plots into the scene (2)

- Rotate the scene to view it from the south side.
- Click on the colored "image mode" () icon at the top of the window, to enable a manipulator of the image location.
- Drag the left mouse button downward on the top red handle, placing the image near the bottom, but above the terrain.
- Animate forward and backward in time, using the VCR controls at the top of the window.



NCL accumulated precip plot at timestep 35



Session file: fig2.vss

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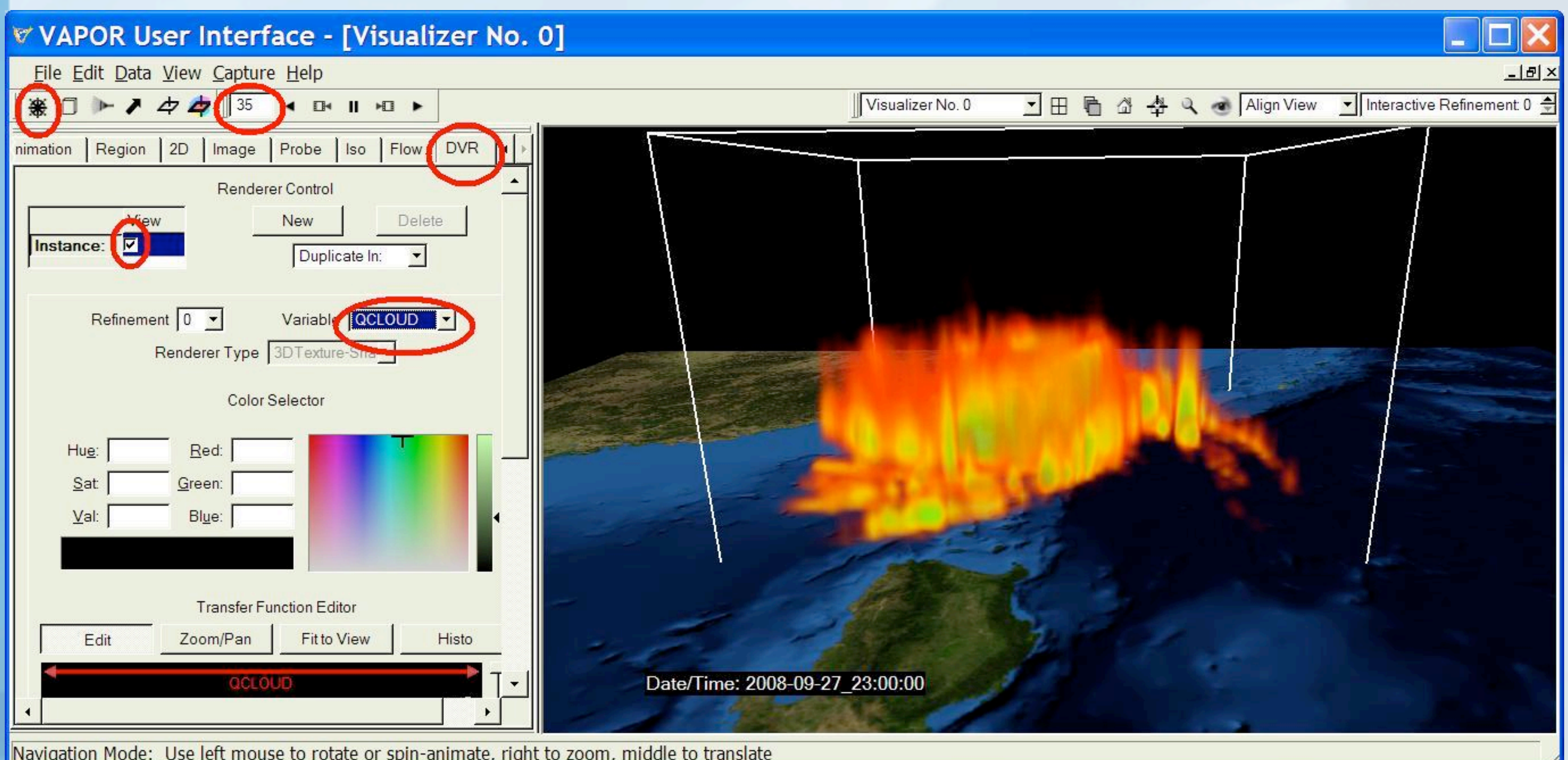
Volume Visualization of QCLOUD

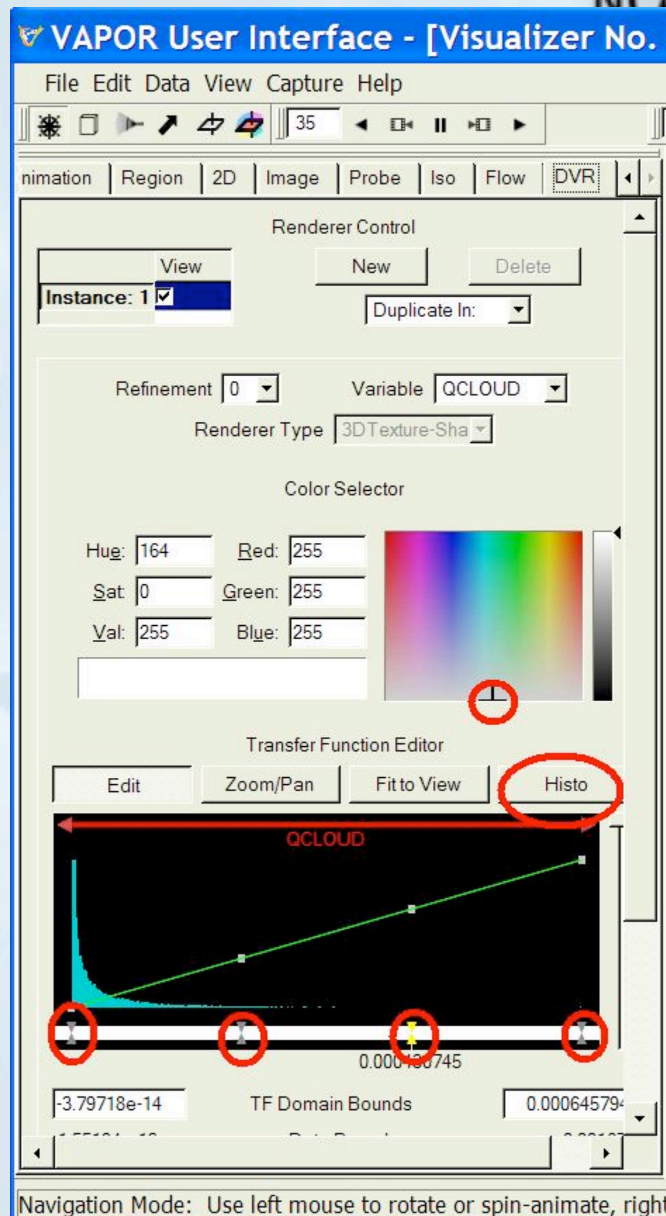
- Disable the 2^{nd} Image instance (uncheck the instance:2 box on Image tab)
- Using VCR control, type in time step 35, press enter.
- Click the “wheel” icon ( ) to return to navigation mode
- Select DVR panel (direct volume rendering)
- Select variable “QCLOUD” (cloud water mixing ratio)
- Check “Instance:1” to enable volume rendering



Session file: fig3.vss

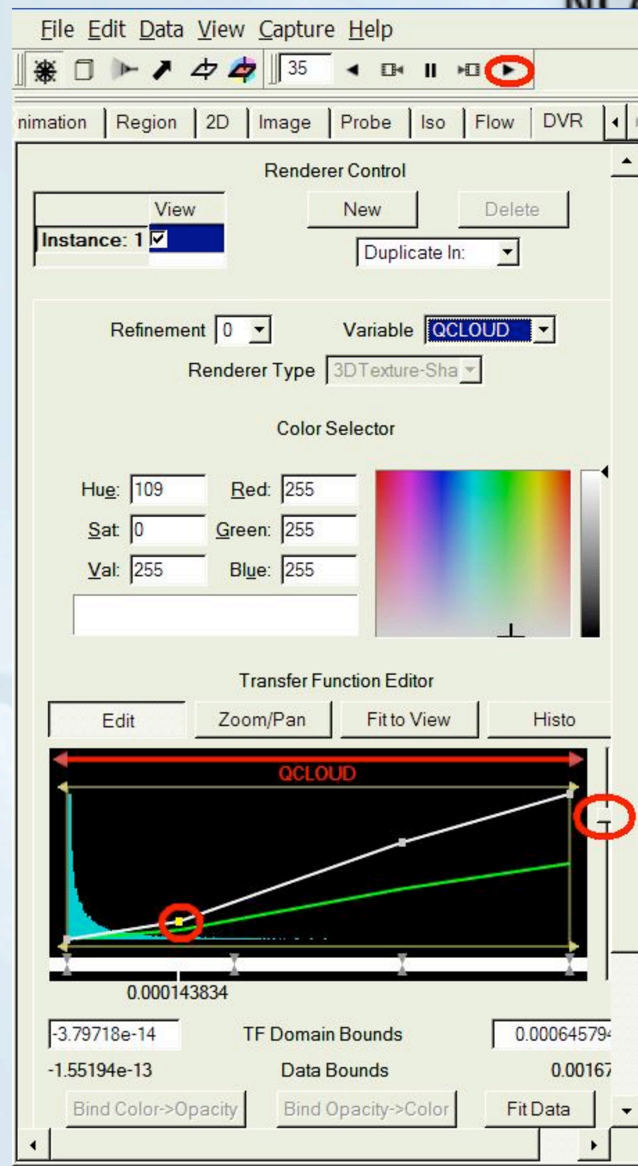
Volume Visualization: Edit Transfer function (1)

- Click "Histo" to see histogram of data values of QCLOUD at current timestep
- 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 color in color selector.



Volume Visualization: Edit Transfer function (2)

- To edit the transparency:
  - Drag the 2nd control point down to make the lower values more transparent
  - Use slider on the right to control overall transparency.
- Click the play button "►" to animate the typhoon
- In the Image panel, check "Instance:2" to see the accumulated rainfall with the typhoon.



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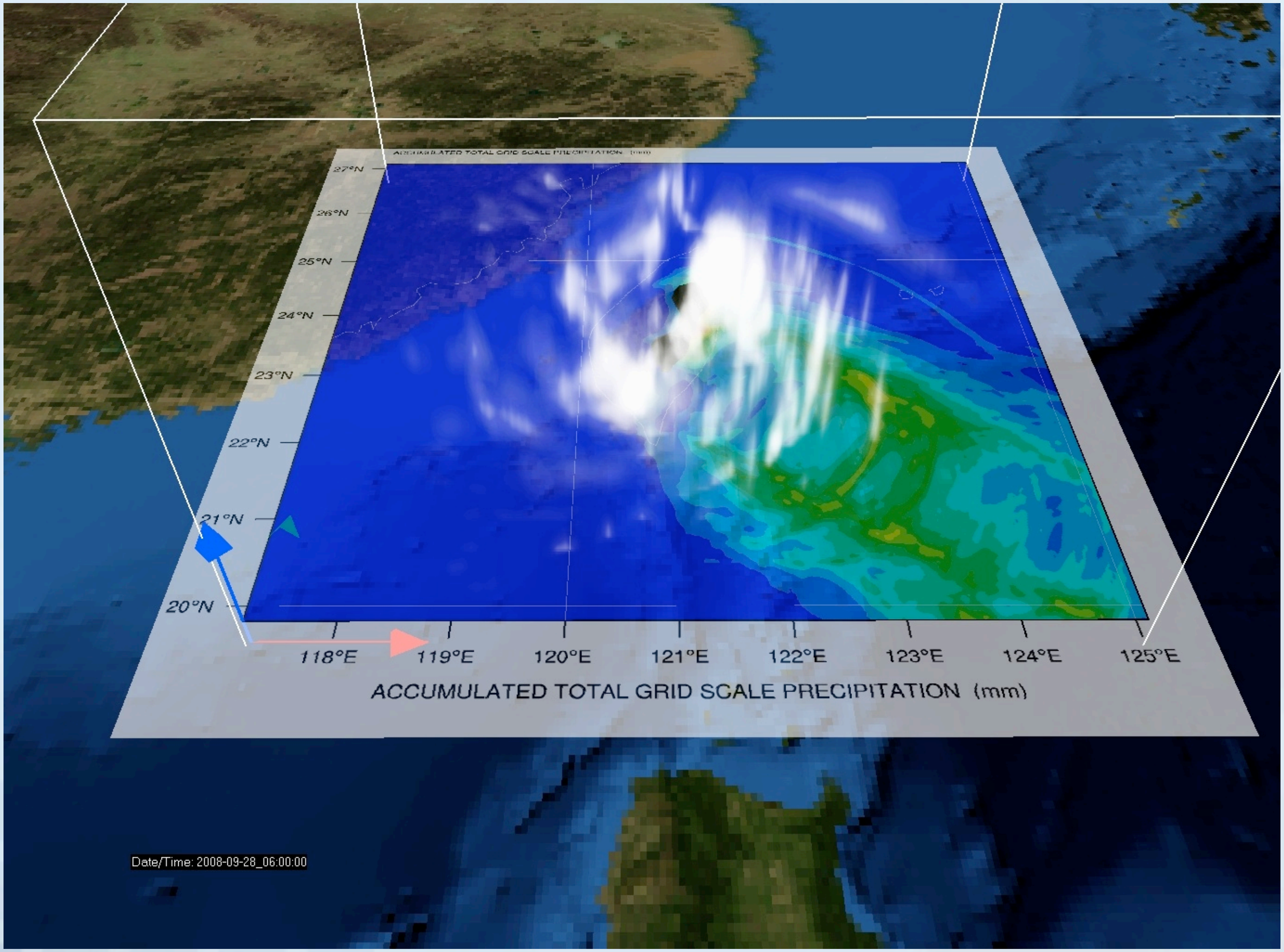
Visualization of typhoon: QCLOUD at time step 42, with plot of precip



Session file: fig4.vss

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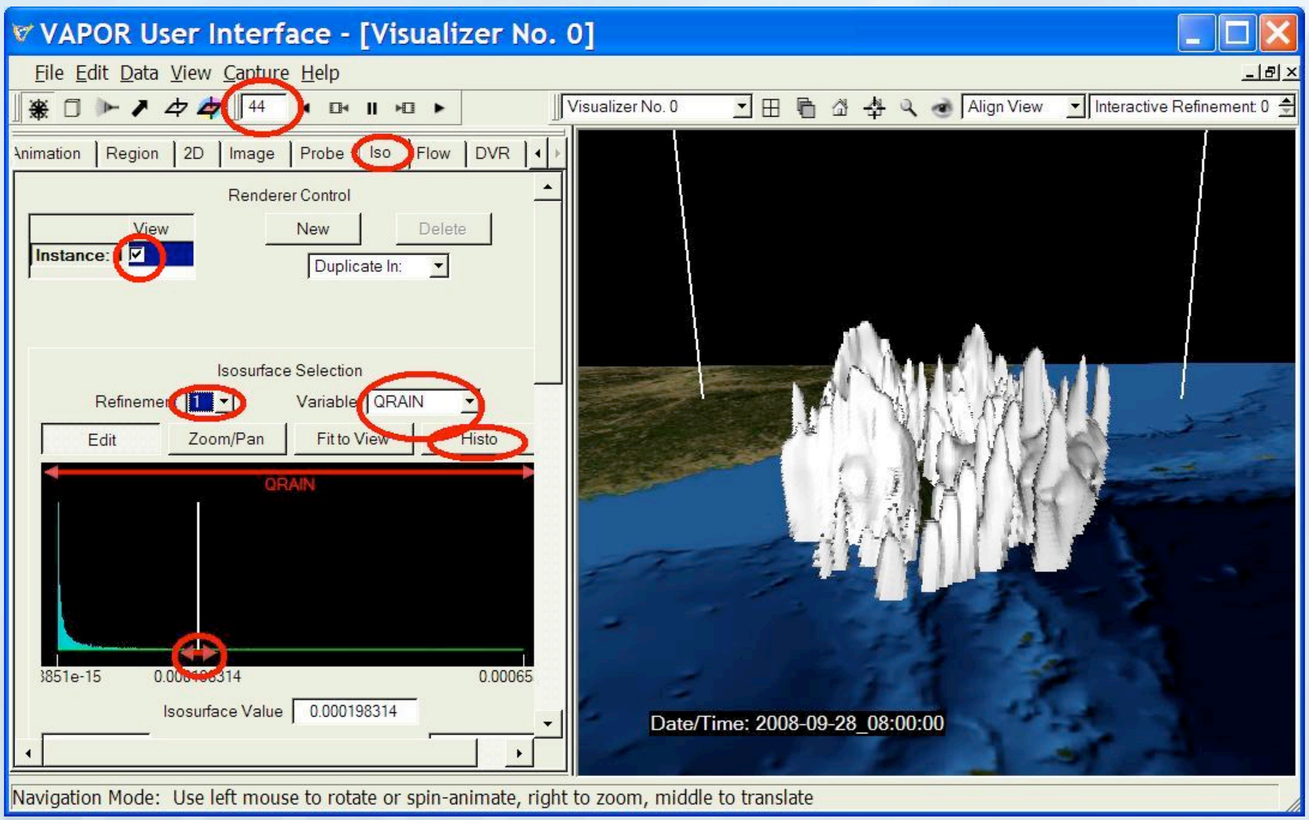
Isosurfaces of QRAIN (1)

- In the DVR tab: disable DVR (un-check Instance: 1)
- Disable second image instance.
- Using VCR control:
  - Set current time step to 44
- Click on Iso tab

In the Iso tab:

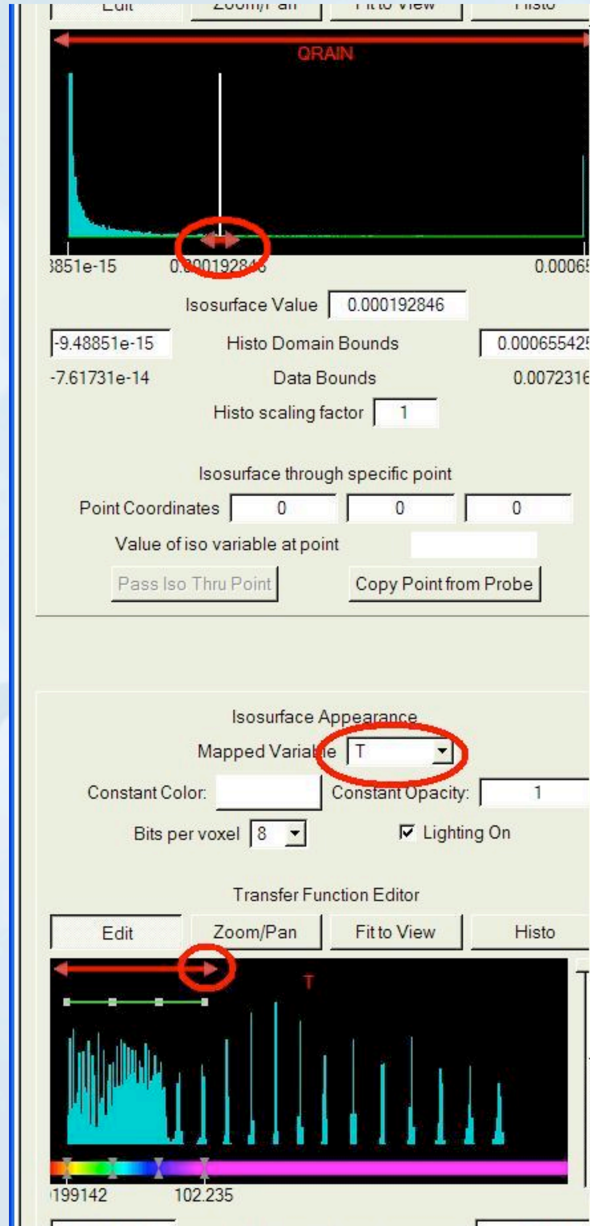
- Set variable “QRAIN” (rainwater mixing ratio)
- Check “Instance:1” to enable
- Click “histo” to see QRAIN histogram
- Set the isovalue near .0002 (use slider or type it in)



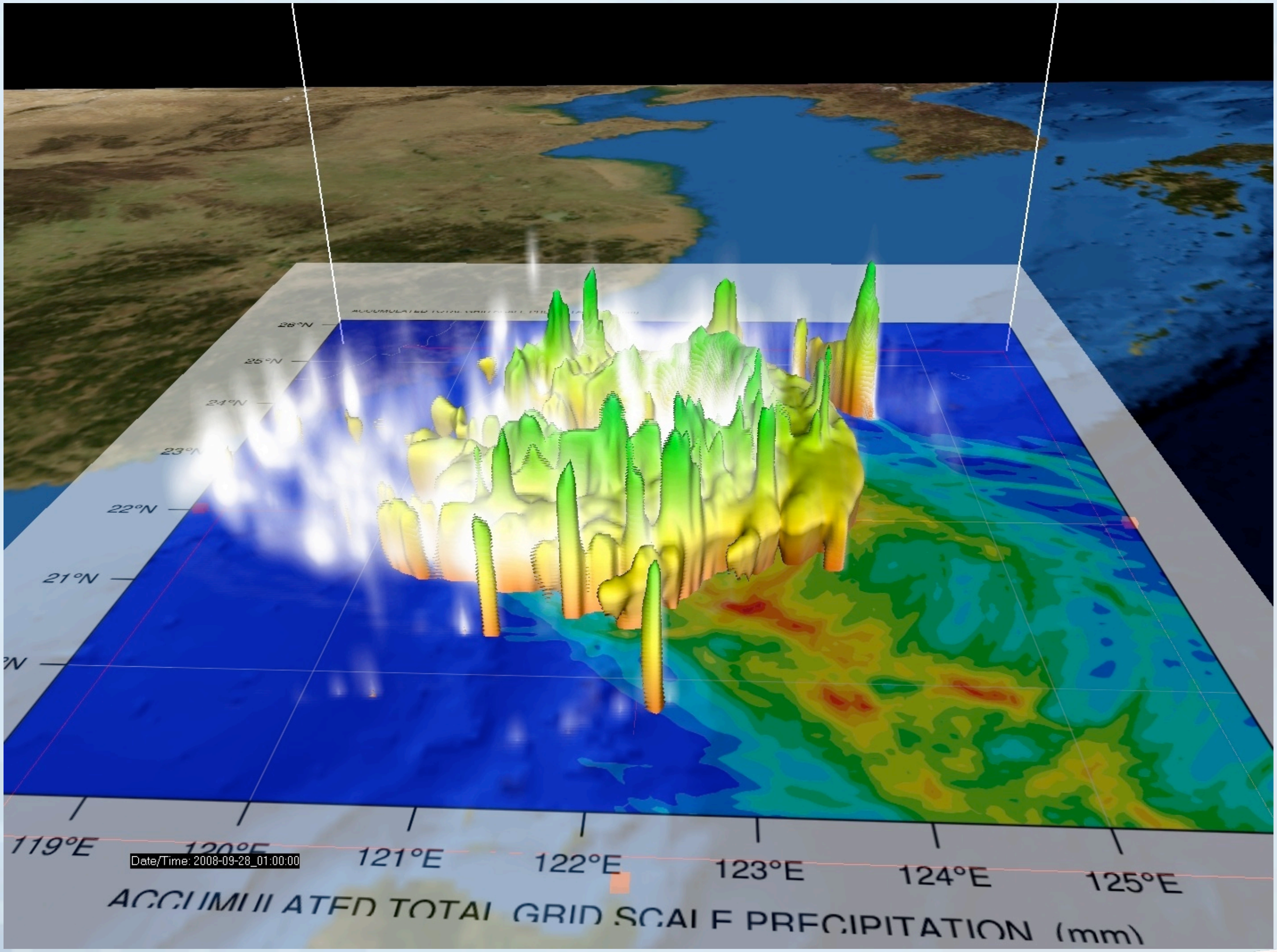
Session file: fig5.vss

Isosurfaces of QRAIN (2)

- Optional Iso tab settings:
  - Slide iso slider to vary isosurfaces
  - Scroll down in the Iso tab to the transfer function
  - Set the mapped variable to “T”.
  - Grab the handle above the transfer function with the left mouse, and slide it to the left, to make the large values of T map to green.



Isosurface of QRAIN = .00025 at time step 37, colored by T, with volume render of QCLOUD



Session file: fig6.vss

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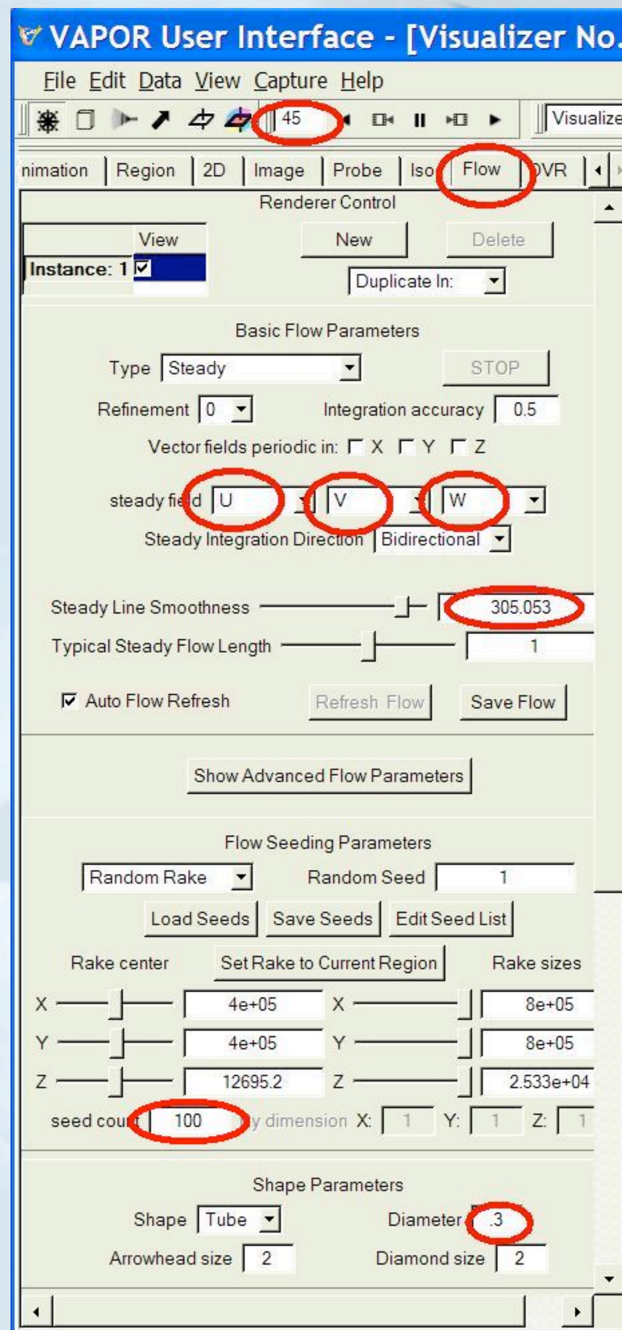
Flow Visualization Overview

- 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.

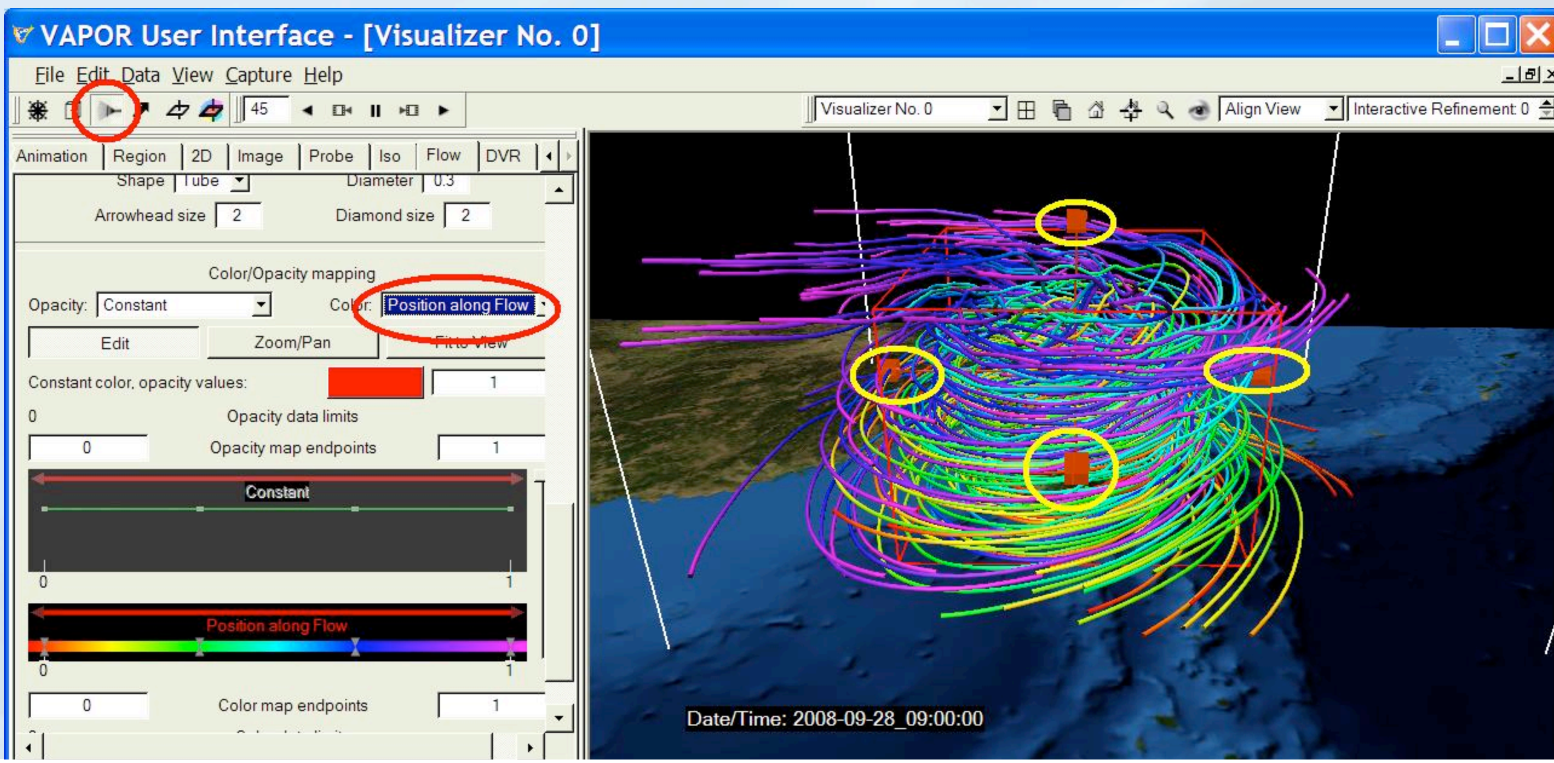
Random streamlines using Rake (1)

- Disable isosurface, DVR, second image instance.
- Click on Flow tab
- Set time step to 45
- Select flow tab, select U, V, W as steady field variables.
- Check "Instance: 1" to enable steady flow (streamlines). Ignore the warning message.
- Specify seed count 100 (random) for steady flow
- Adjust smoothness (~300) and diameter (~0.3)



Random streamlines using Rake (2)

- Click on rake button (at top left, above the tabs)
- Grab the top handle of the rake with the right mouse button, pull it down about halfway to the terrain (so the flow seeds will be near the ground.
- Using the right mouse button, shrink the rake to a small box enclosing the eye of the typhoon
- Color flow lines according to "position along flow"
- See how the wind is drawn in at ground level and climbs into the eye



Streamlines at time step 45 in the typhoon eye, with QCLOUD and QRAIN

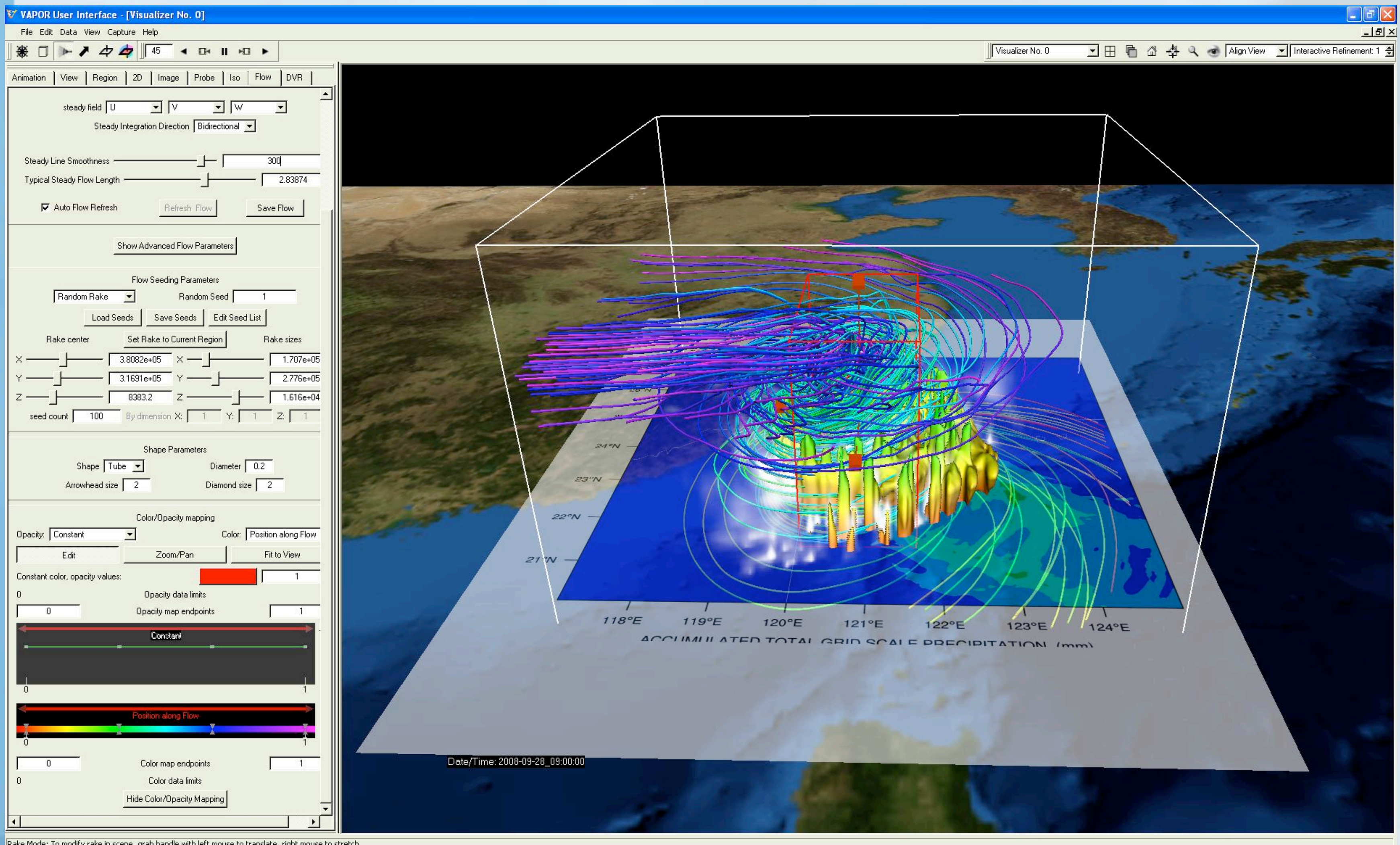


fig7.vss

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Image-based flow visualization(1): Pictures of flow motion

- Set time step = 40
- Disable the flow, Iso, and DVR
- Click on the Probe mode button ()
- Click “Fit to region” in the probe tab
- Set “Probe Type” to be “Flow Image”
- Check the “Instance:1” checkbox to enable the probe of flow image

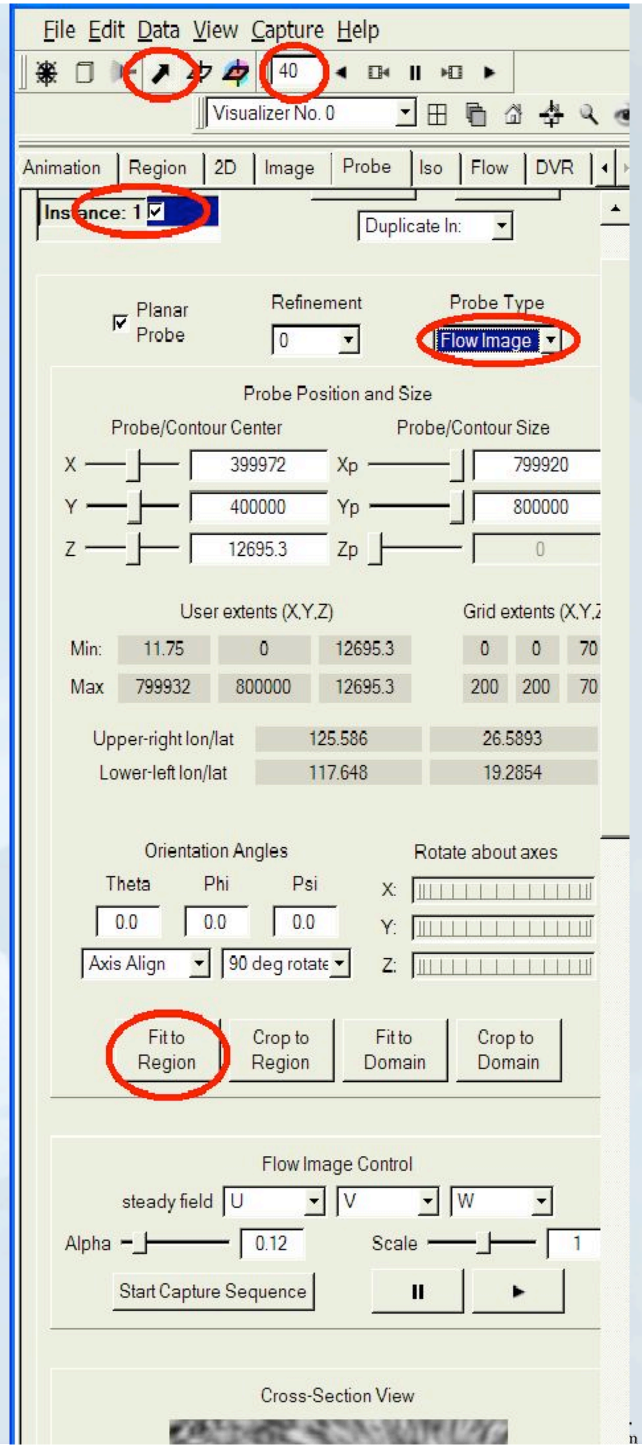

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Image-based flow visualization (2): Animation of flow

- Using the left mouse button in the scene, drag the probe tool down near the ground
- Click the "▸" (play) button above the probe image to animate the flow images.
- Slide the probe up and down in the scene to see how the wind varies with elevation.
- Optional: Check "merge color and opacity…" to color the flow images with another variable.

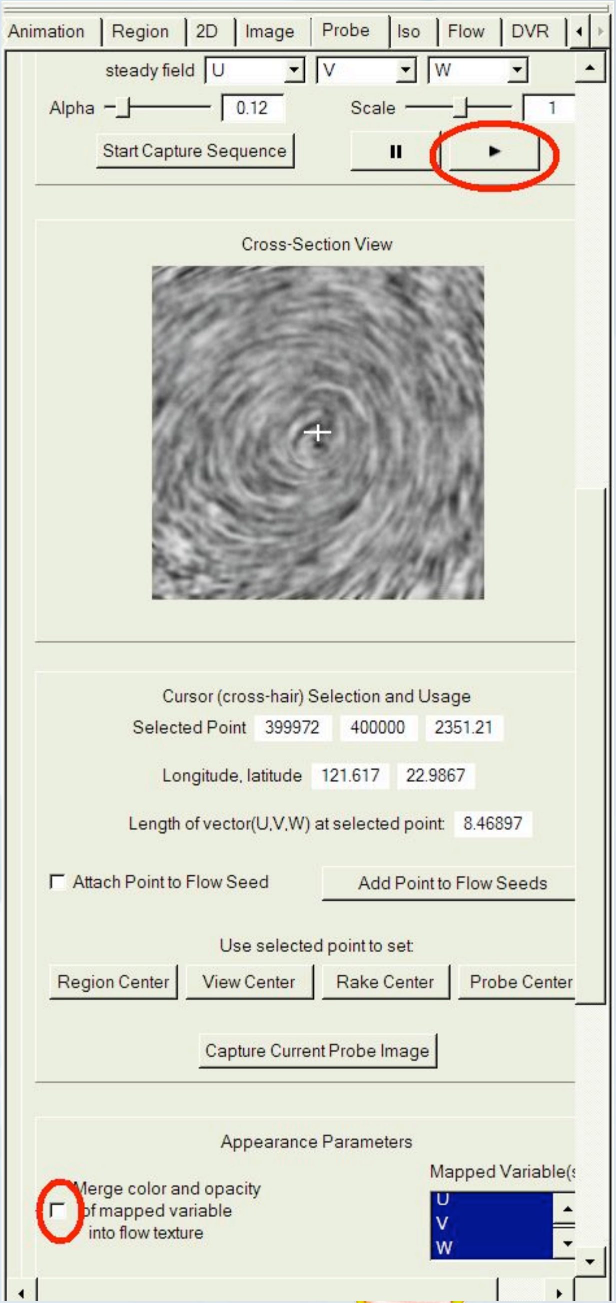
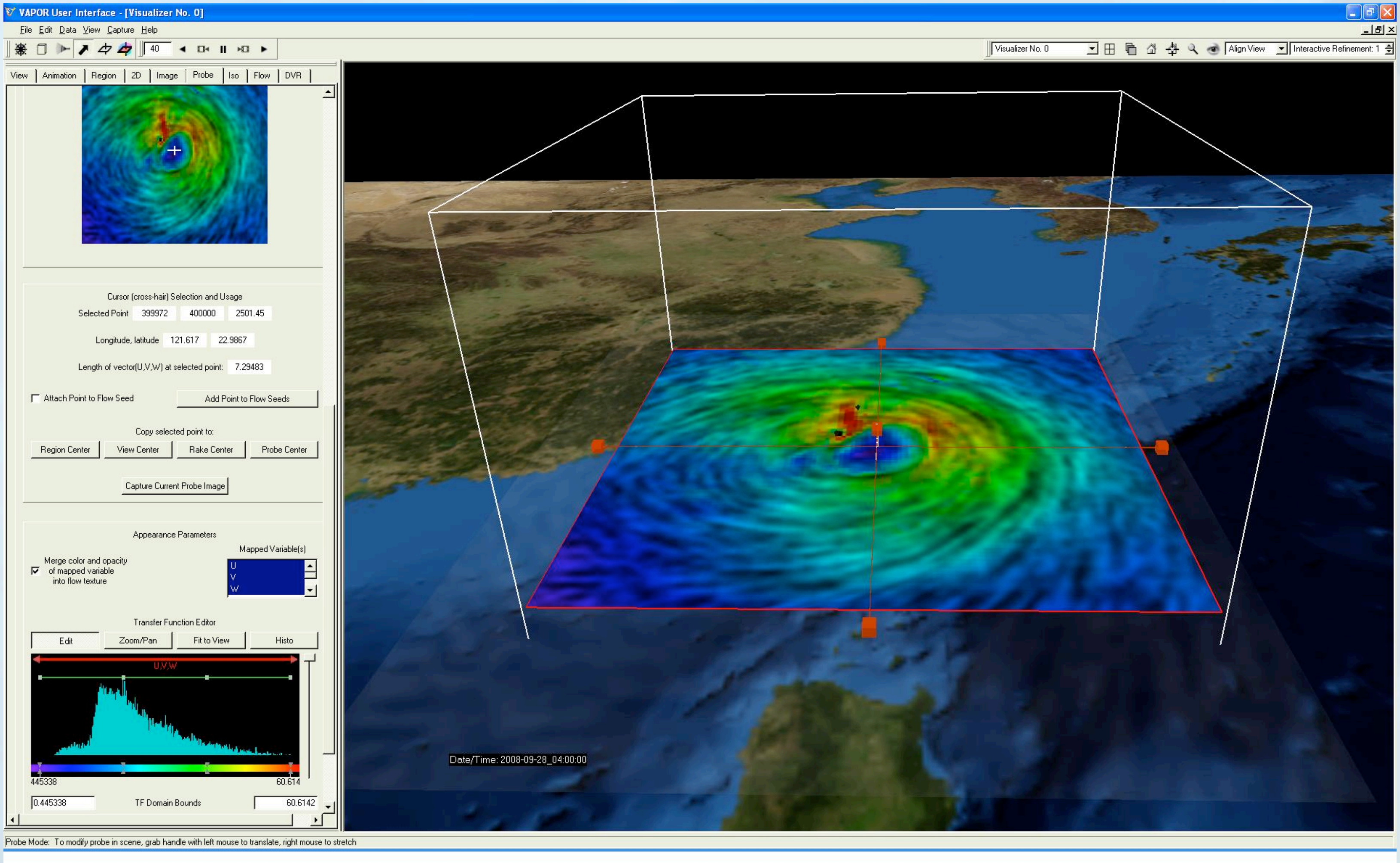


Image-based flow in the typhoon, colored by wind speed



Session file: fig8.vss

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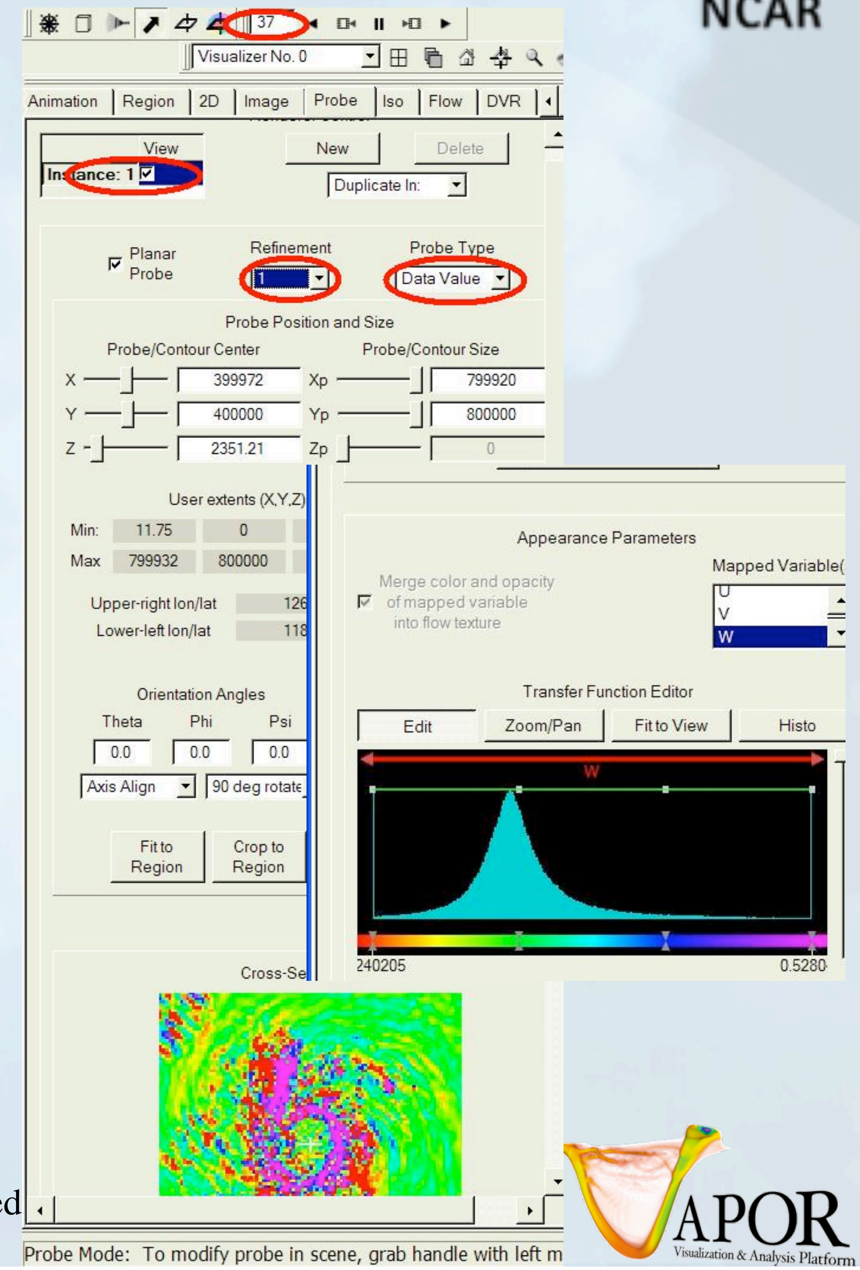
Use the probe to see a vertical slice of W (1)

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

- Set the time step to 37
- Set the Probe Type to “Data Value”
- Enable probe (check Instance:1 box)
- Set refinement level to 1
- Scroll down to the bottom of the probe panel and set the Mapped Variable to “W”



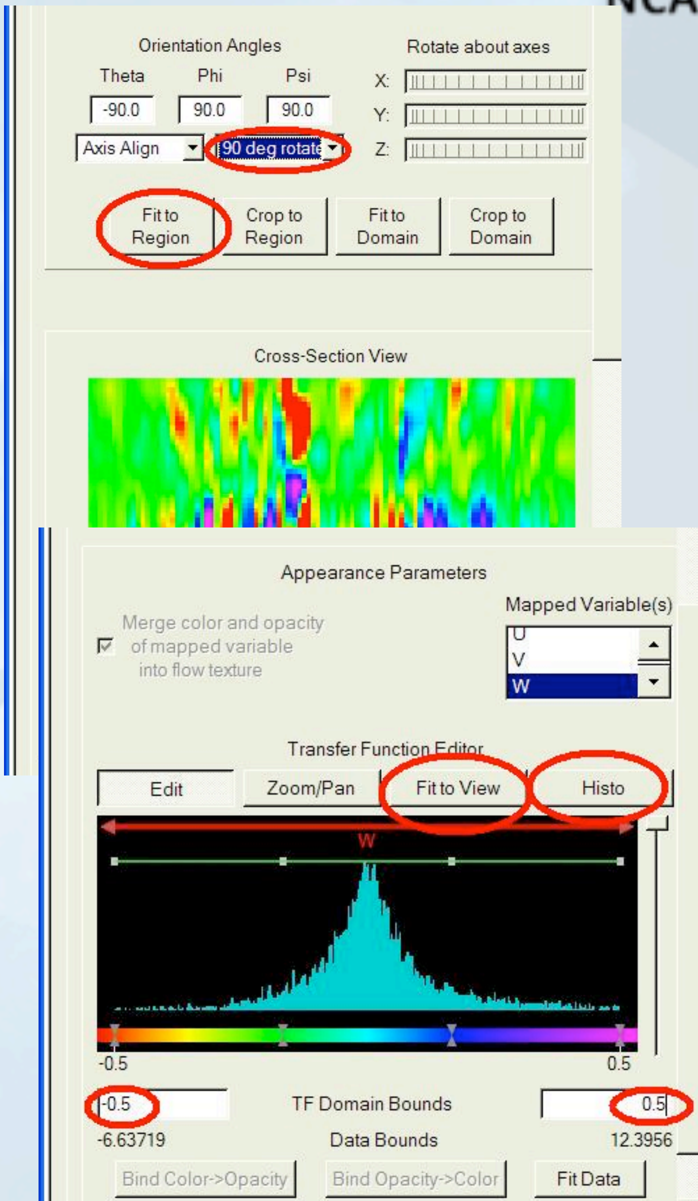
Using the probe to see a vertical slice of W (2)

To view a vertical slice through the typhoon:

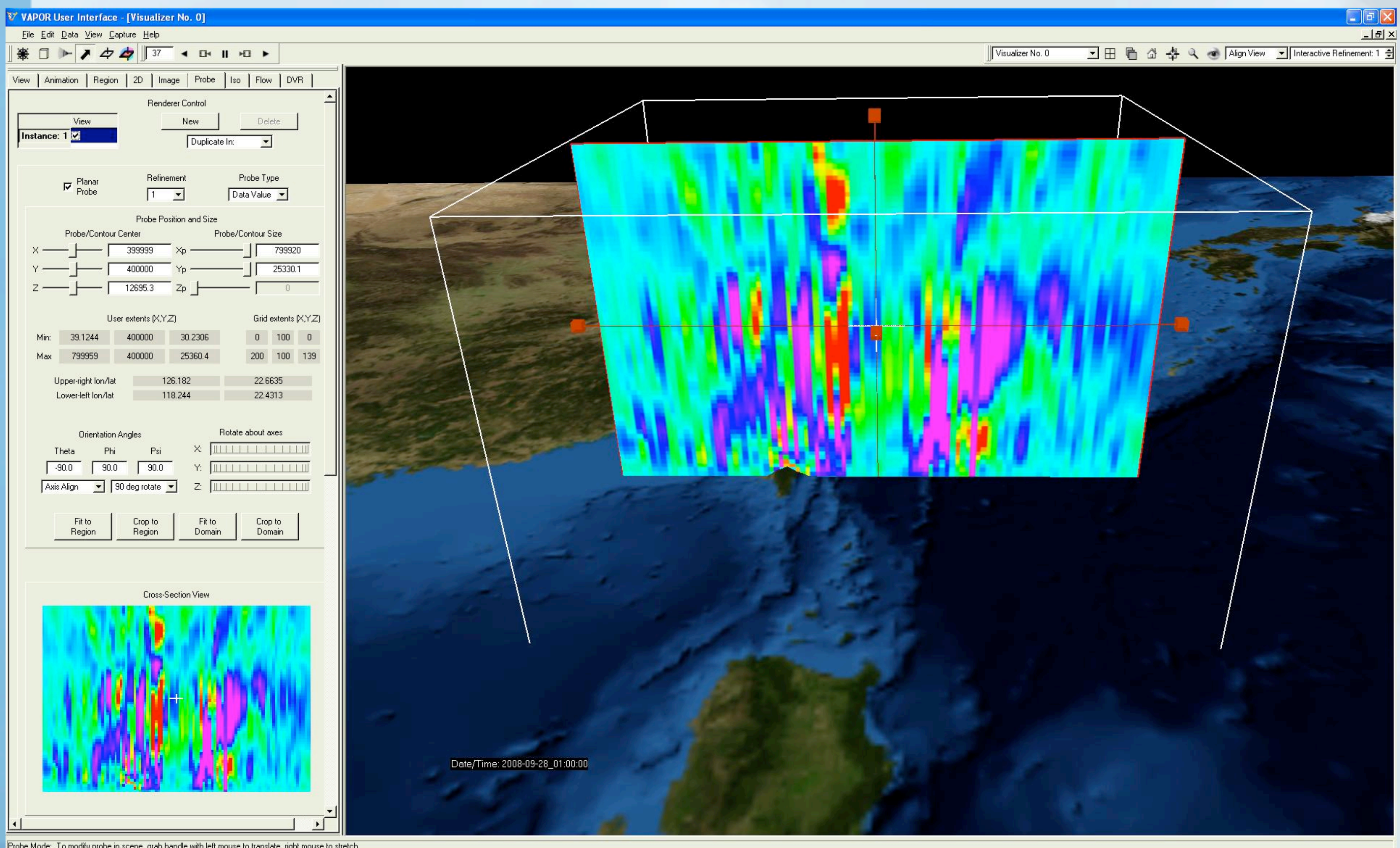
- Click 90 degree rotate and select "+x" to get a vertical slice.
- Click "Fit to Region"

Above the histogram at the bottom of the probe panel:

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



Cross section of typhoon (Probe of W)



Session file: fig9.vss

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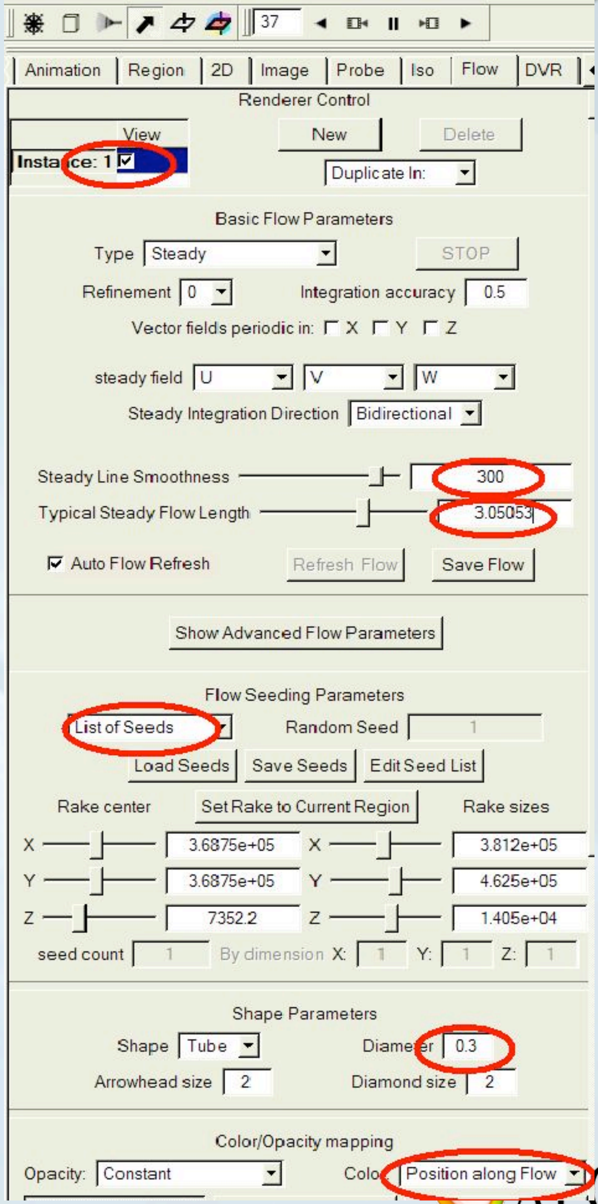
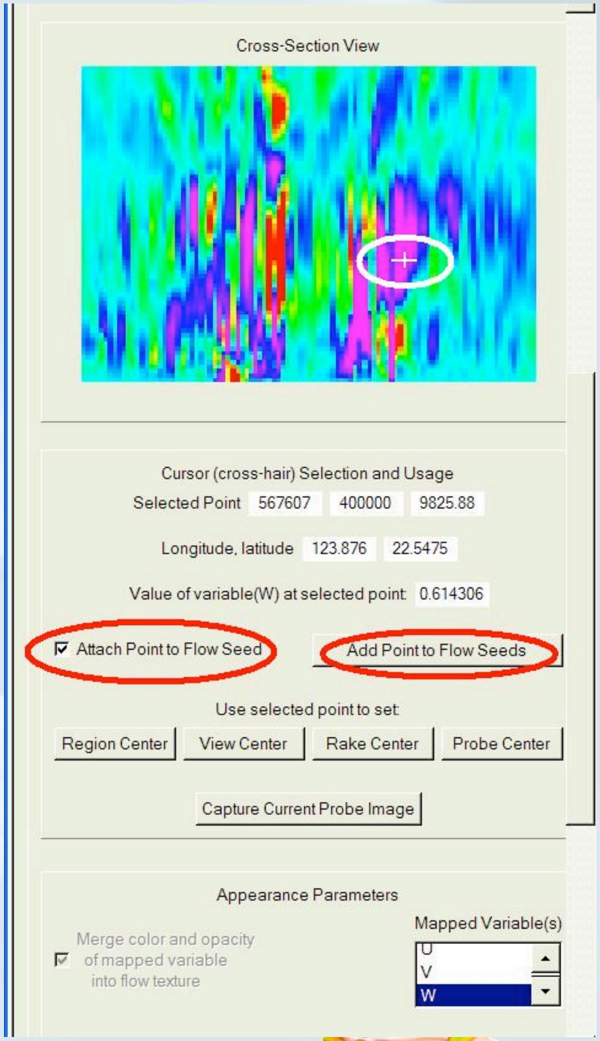
Using the probe to specify flow seed points (1)

- Click on the Flow tab
- Set the flow tab with the same settings as before (smoothness = 300, diameter = 0.2, color=position along flow)
- Set Typical Steady Flow Length = 3
- On the flow tab, under “flow seeding parameters”, 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).

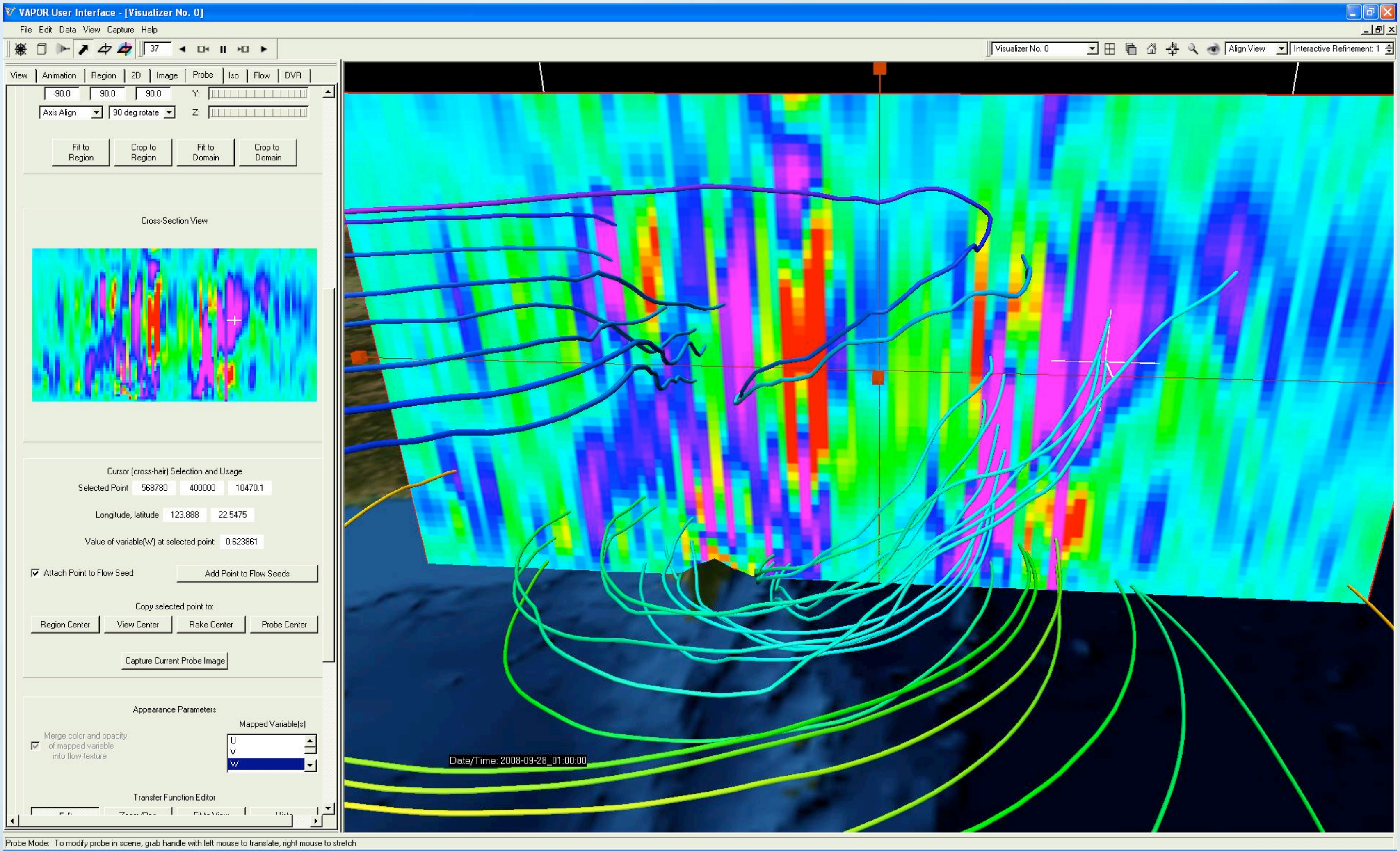


Using the probe to specify flow seed points (2)

- Click on the probe tab., scroll down to the cross-section view
- Check "attach point to flow seed". You should see a streamline associated with a seed point at the cursor position.
- Try various cursor positions with large (purple) W values to see the resulting streamlines. 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: fig10.vss

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Other useful capabilities of VAPOR

Some features we haven't shown you

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

- Combining analysis and visualization:
  - Calculate derived variables in NCL or in IDL. Insert these variables into the VAPOR scene
- Visualization of 2D variables
  - 2-dimensional WRF variables can be visualized in the scene alongside the 3D variables and images, and can be applied as terrain images
- Unsteady flow visualization
  - Particle traces can be visualized and animated.
  - Field line advection can be used to visualize fieldlines and streamlines moving over time
- Wind arrows
- Animation capture
  - A sequence of images can be captured to jpeg files, and converted into a movie file

VAPOR plans

We are preparing a new release for later this year

Some features under consideration:

- 64-bit on Mac
- Fast streamline rendering
- Interactive calculation of new variables (using Python)
- Import VAPOR data into VisIt and Paraview
- Insert Cartesian-gridded data into WRF scene (e.g. radar data)
- Direct reading of WRF output (not requiring a conversion step)
- Easy placement of wind arrows
- Website improvements

Where to go from here

To visualize the output of WRF-ARW simulation:

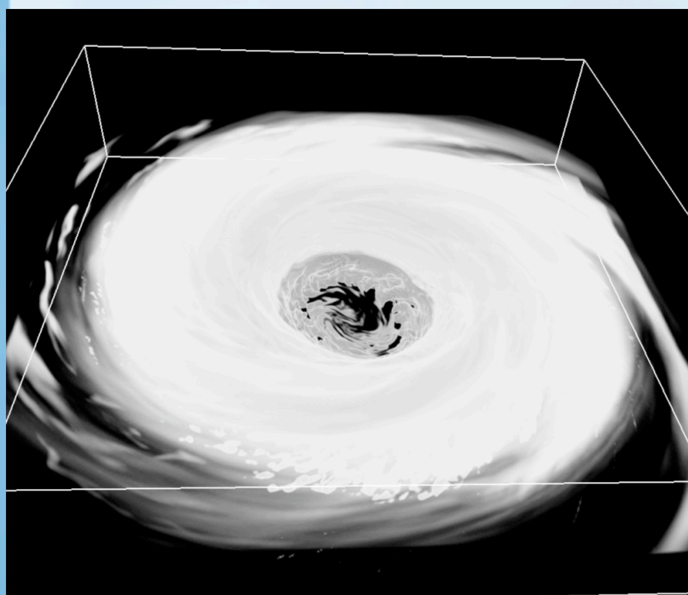
- Install VAPOR on your computer (or use vapor installed at NCAR) (Instructions at http://www.vapor.ucar.edu/)
- Convert your data to VAPOR using command-line utilities
- Use NCL to create 2D data plots to put in the scene
- Additional tutorials and user guides are available at http://www.vapor.ucar.edu/
- 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!

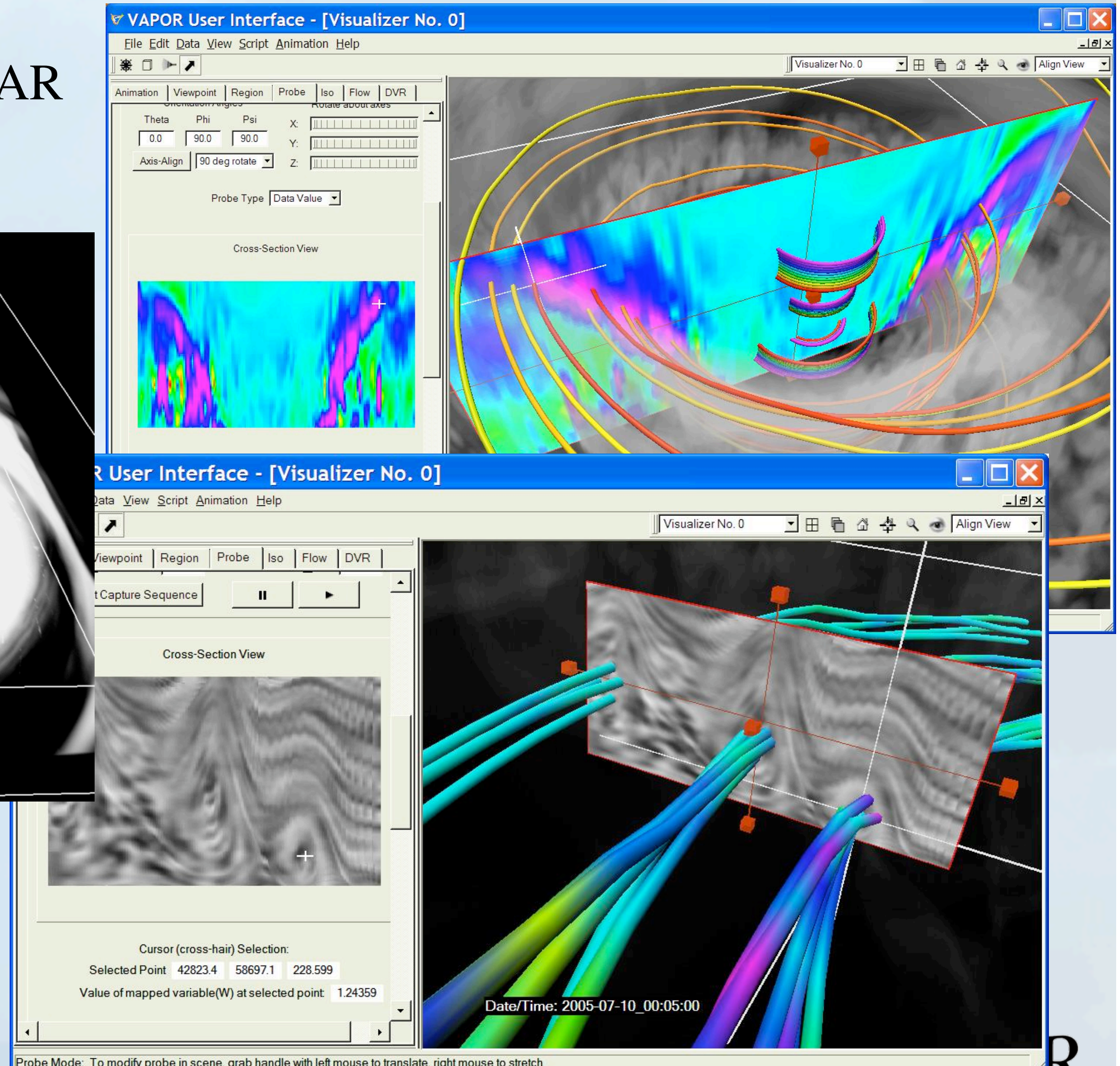
Tutorial supplement:
An analysis of high-res hurricane data

http://vis.ucar.edu/~alan/wrf2010/tutorial/docs/WRFVaporTutorialSupplement.ppt

Data provided by:

Yongsheng Chen, MMM/NCAR





VAPOR Availability

- Version 1.5.2 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 for interactive analysis)
- Contact: vapor@ucar.edu
- Executables, documentation available (free!) at http://www.vapor.ucar.edu/

Thanks!

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Acknowledgements

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  - Pablo Mininni, NCAR, IMAGe
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  - Helene Politano - Observatoire de la Cote d'Azur
  - Yannick Ponty - Observatoire de la Cote d'Azur
  - Annick Pouquet - NCAR, ESSL
  - Mark Rast - CU
  - Duane Rosenberg - NCAR, IMAGe
  - Matthias Rempel - NCAR, HAO
  - Geoff Vasil, CU
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  - Wei Wang – NCAR, MMM
  - Cindy Bruyere –NCAR, MMM
  - Yongsheng Chen-NCAR,MMM
  - Thara Prabhakaran-U. of Ga.
  - Wei Huang – NCAR, CISL
  - Minsu Joh - KISTI
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  - Alan Norton – NCAR/CISL
  - Dan LaGreca – NCAR/CISL
  - Pam Gillman – NCAR/CISL
  - Kendall Southwick – NCAR/CISL
  - Markus Stobbs – NCAR, CISL
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