3D Weather Visualization with VAPOR

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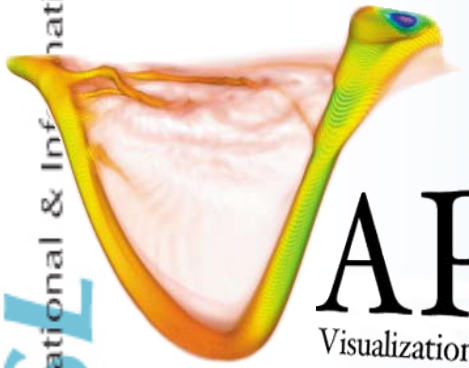

VAPOR
Visualization & Analysis Platform

ECMWF 14th Workshop on meteorological operational systems
Nov. 19, 2013

CISL Computational & Information Systems Laboratory

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KiSTi www.kisti.re.kr

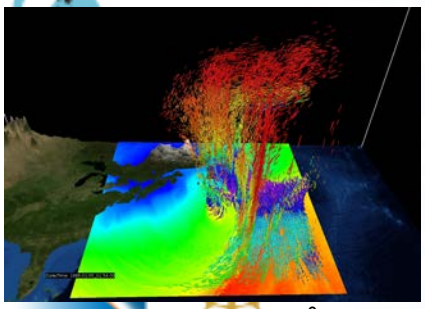
VAPOR

Visualization aided data analysis for the earth sciences

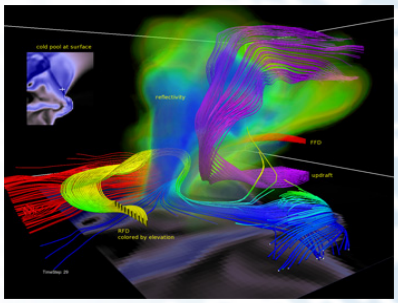
- A **domain-focused**, **open source** visual data analysis package targeted for researchers working in **numerical weather prediction**, **atmospheric, oceanic, and related sciences**
- By leveraging a wavelet-based *intelligent data storage* model VAPOR enables highly interactive exploration of the **largest numerical simulation** outputs using only **commodity computing** resources.
- A **community-driven** feature set guided by an **international steering committee** of domain scientists working in a broad gamut of earth science disciplines
- Metrics:
  - ~5000 new users since January, 2011
  - ~4000 unique VAPOR web site visitors per month in 2013 (up from 1000 in 2012, and 500 in 2011)
  - 20 scholarly citations for VAPOR in 2012, and 7 to date in 2013

I. Grooms, et al. 2010

S. Wedemeyer-Böhm, et al. 2012



M. Shapiro; S. Grønås, 2012



L. Orf, 2009

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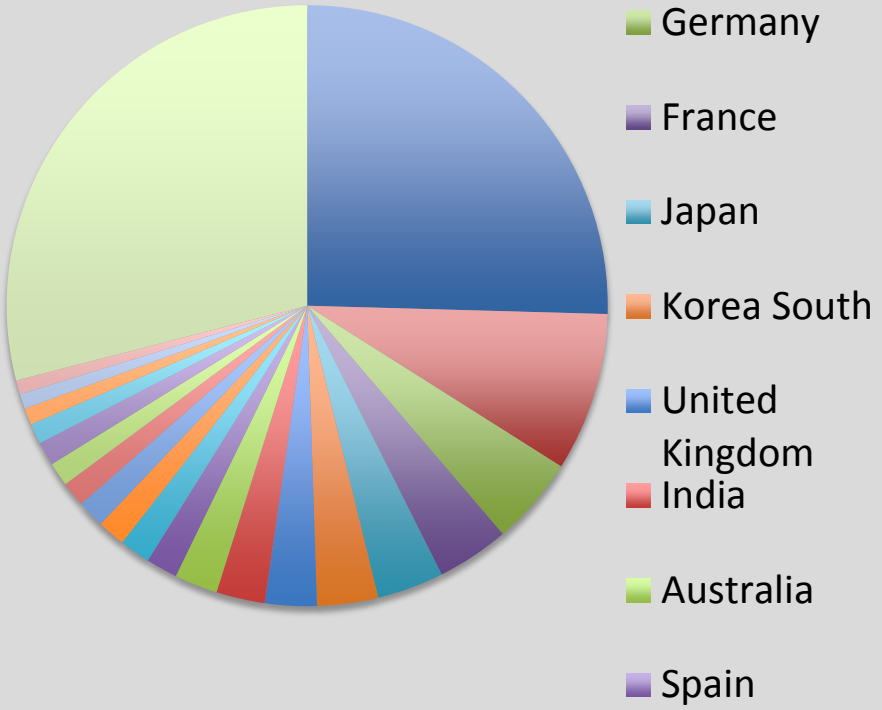
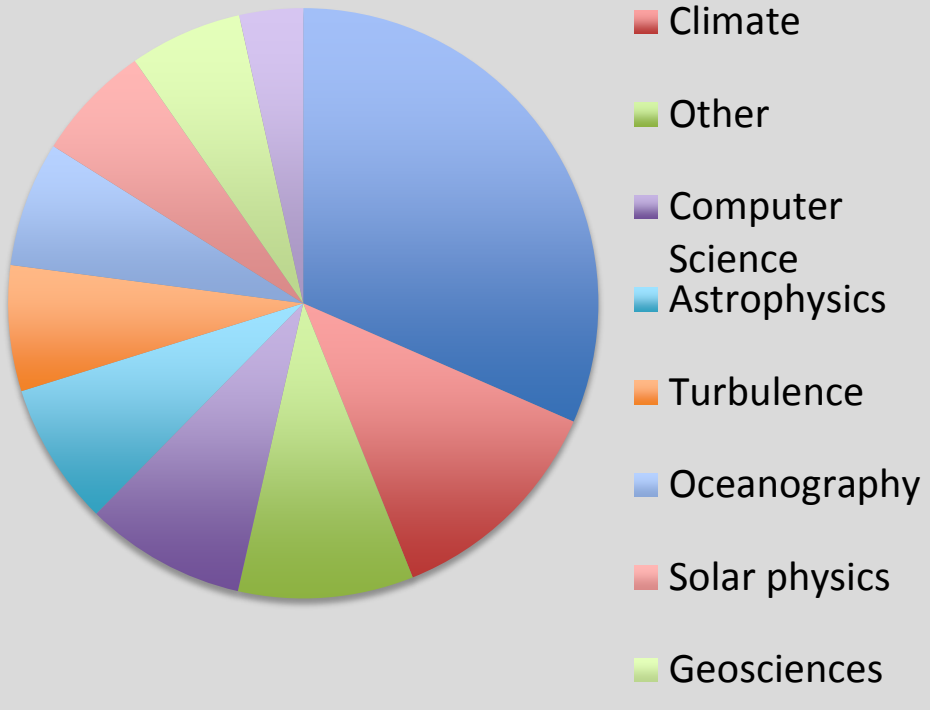
Who are the VAPOR users?

Distribution by country

4998 registered users

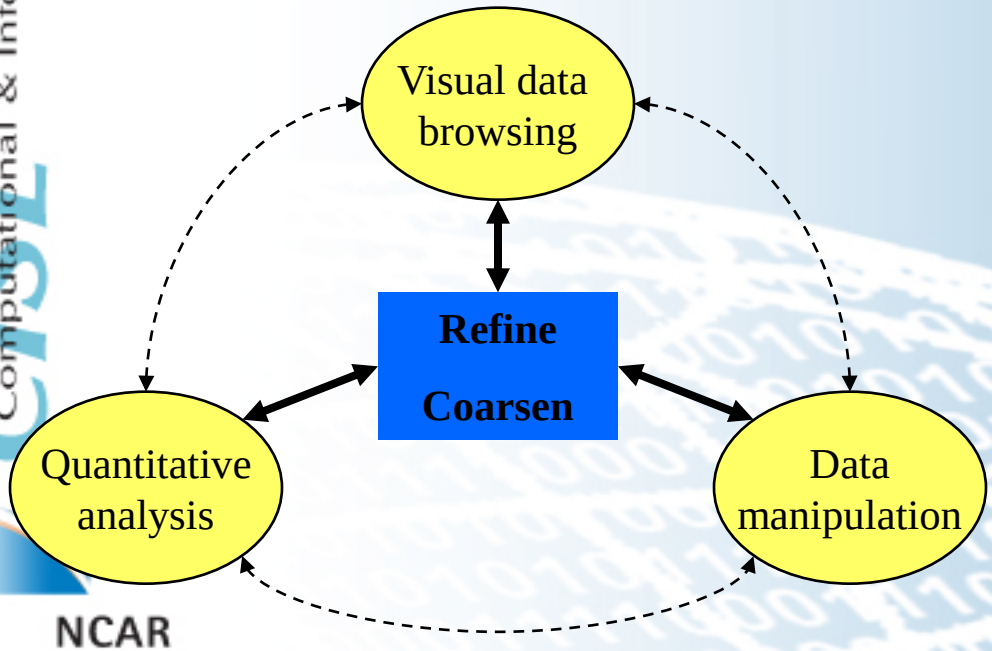


Field of Study



VAPOR Key Components
Terabyte data handling from a desktop PC (or laptop)

- Progressive access data model (VAPOR Data Collection)[Clyne 2013]
  - Permit speed/quality tradeoffs
  - Region of Interest (ROI) identification and isolation
- Two wavelet-based refinement models:
  1. *refinement level* (**grid coarsening**)
  2. *level-of-detail* (**wavelet coefficient prioritization**)

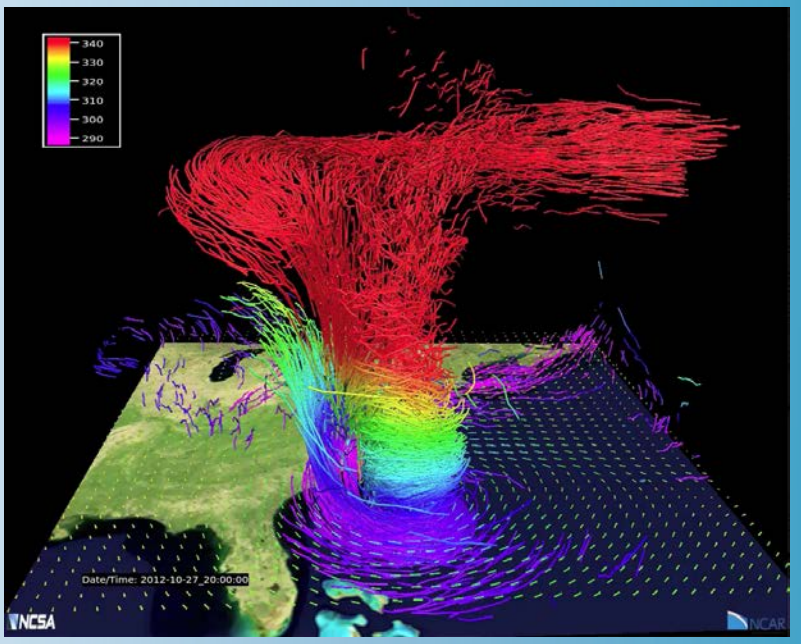


Combination of visualization, ROI isolation, and multiresolution data representation that provides sufficient **data reduction** to enable interactive work

Think *Google Earth*!!!

WRF simulation of Hurricane Sandy visualized with VAPOR

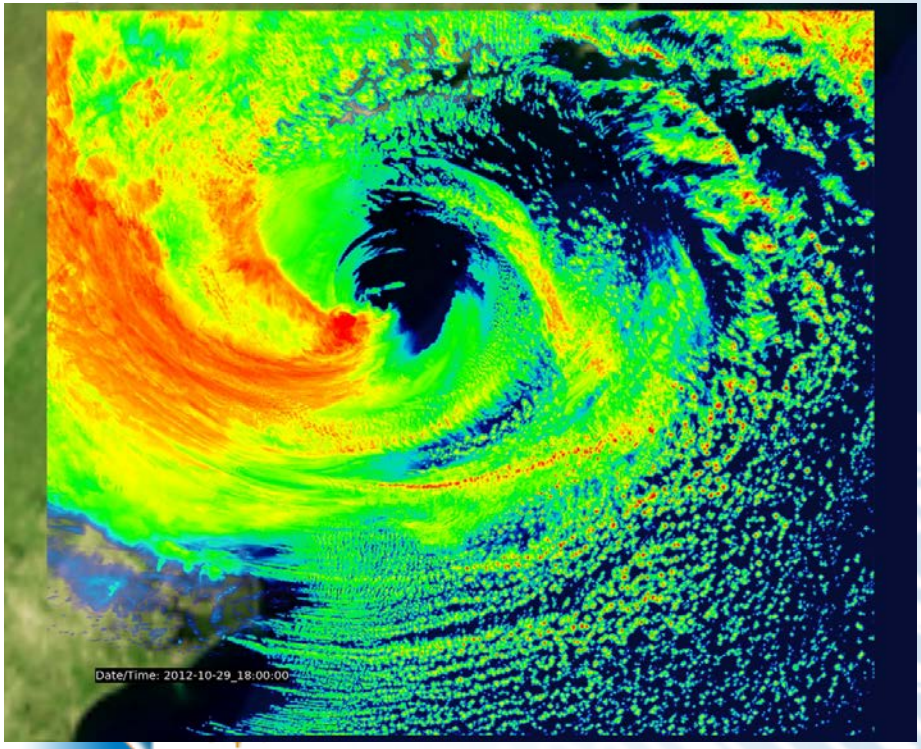
- Largest severe storm simulation to date [Johnsen, 2013]
  - 9120x9216x152 grid points
  - 0.5KM resolution
  - 48GBs/variable/time step
  - 100TBs total data
  - Computed on “Blue Waters” at NCSA
- Visualization platform:
  - Single node Linux workstation
  - nVidia Quadro 6000 GPU
  - 1TB RAM
  - 40 Intel Westmere cores
  - IB FDR storage interconnect



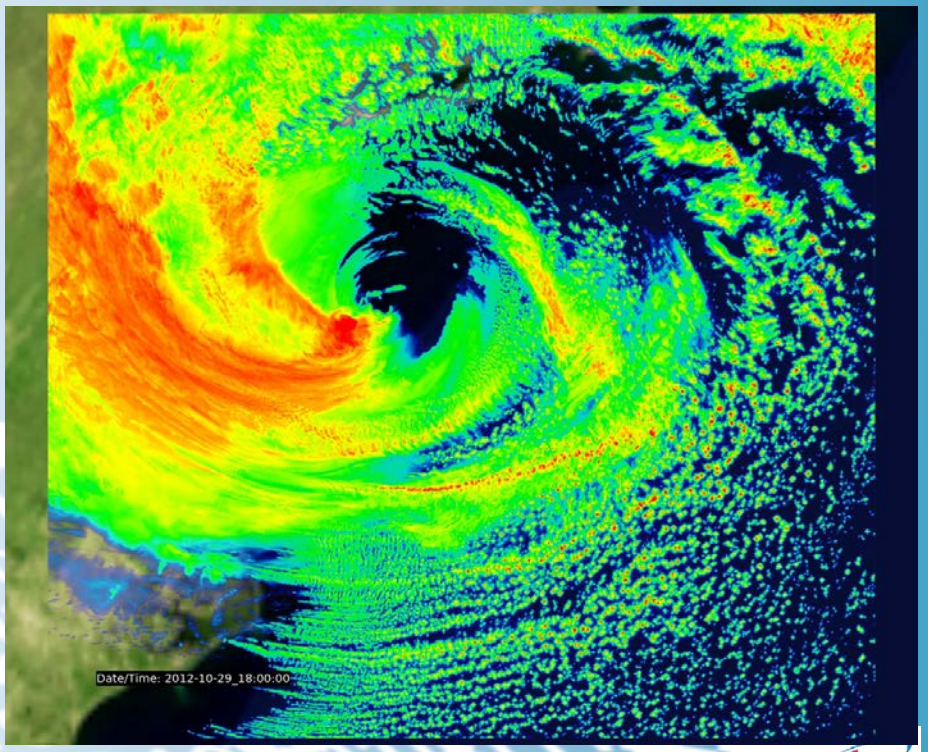
Data source: Mel Shapiro, NCAR

Radar reflectivity (DBZ) derived from a 500m Weather Research Forecast simulation of Hurricane Sandy[Johnsen 2013]

DBZ computed from original data (203 GBs)



DBZ computed from data compressed 10:1 (20.3 GBs)



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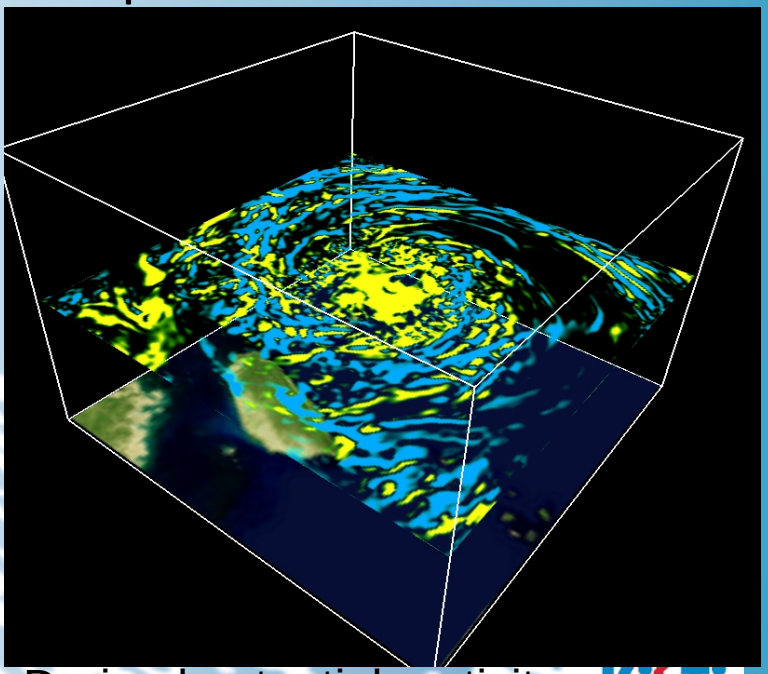
VAPOR Key Components
NumPy/SciPy integration

- Integration with python interpreter (NumPy/SciPy) provides data operators with array syntax:
  - E.g. `windspeed = sqrt(U*U + V*V + W*W)`
- Complex new variables can be derived on-the-fly as needed
- A library of **weather-specific** functions is provided
  - Cloud top temp.
  - Radar reflectivity
  - Equivalent potential temperature
  - Potential vorticity
  - Relative humidity
  - Etc.
- New functions can be easily added



Derived potential vorticity, Typhoon Jangmi

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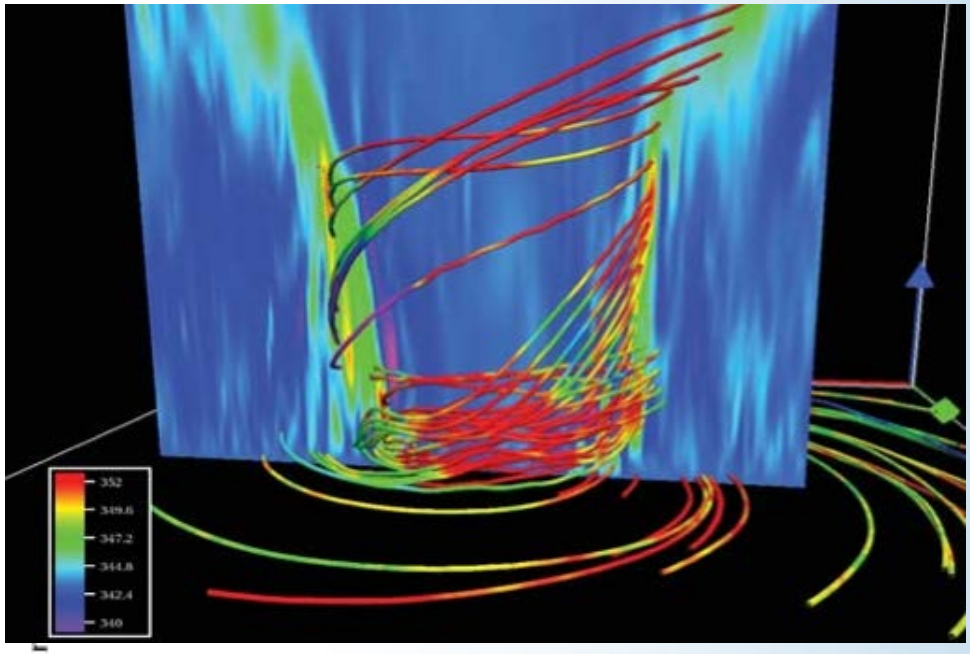
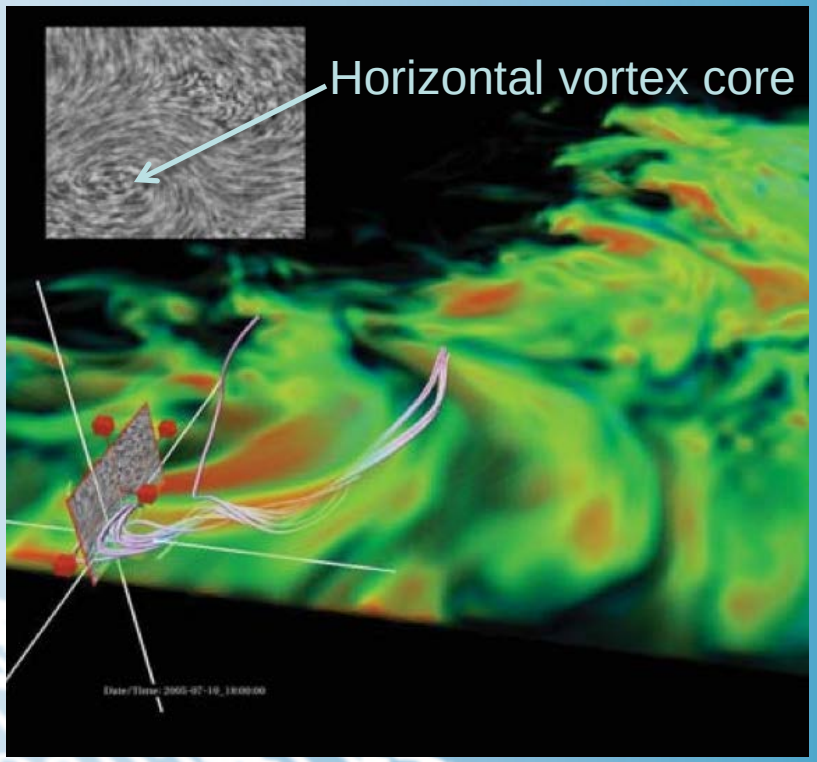
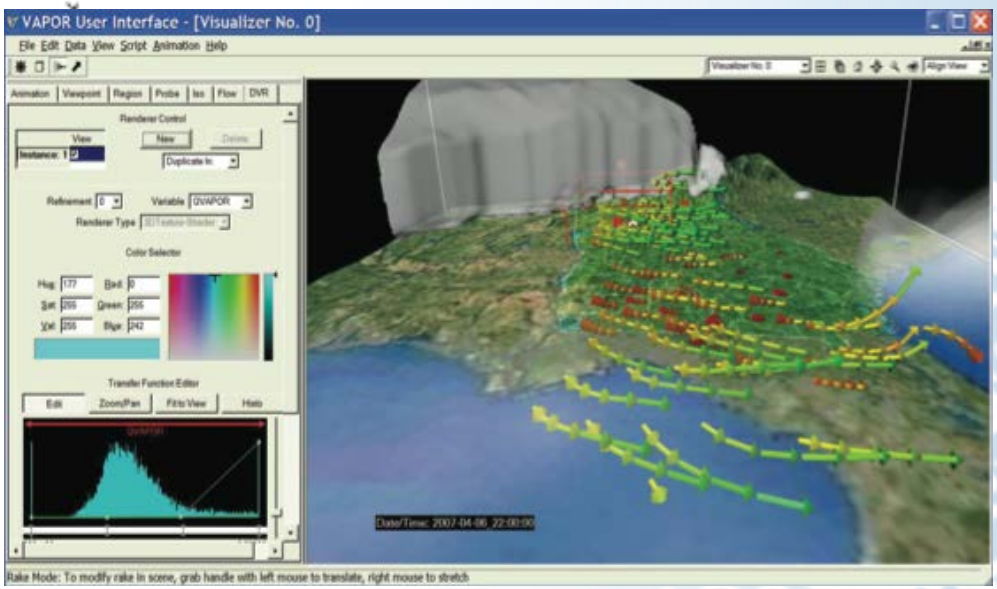
VAPOR Key Components
Flow visualization and analysis

- Multiple tools and techniques for exploring flow (wind) fields
- Streamlines, pathlines, particle advection
- Seeding options
  - Traditional *rake*
  - Random or gridded
  - External sources (CSV file)
  - Data guided methods
    - Automated (e.g. regions of high wind speed)
    - Interactive (e.g. using the mouse)
- Image Based Flow Visualization [Van Wijk, 2003]

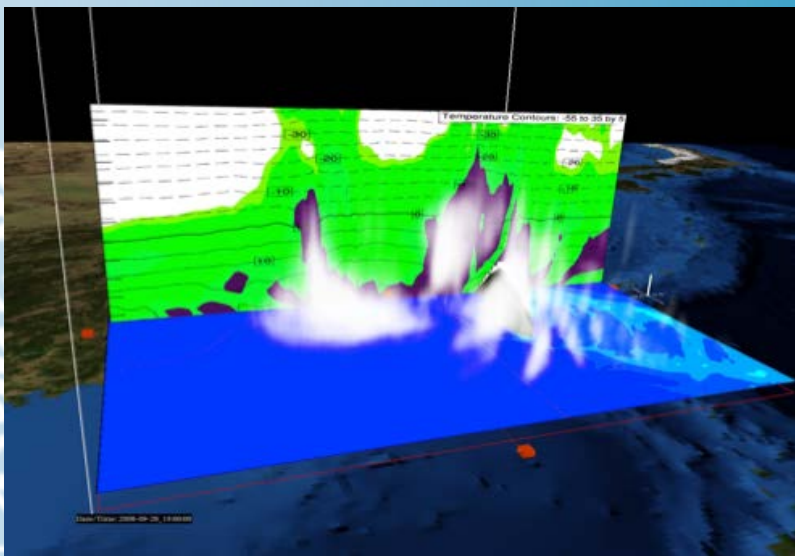

352
349.6
347.2
344.8
342.4
340


Horizontal vortex core


VAPOR User Interface - [Visualizer No. 0]
File Edit Data View Script Animation Help
Animation Viewpoint Region Probe Iso Flow DVR
Renderer Control
Color Selector
Transfer Function Editor
Edit Zoom/Pan Fit to View Histo
Rake Mode: To modify rake in scene, grab handle with left mouse to translate, right mouse to stretch

Key Components
Geo-referenced image support with GeoTIFF

- Support for GeoTiff (Geographical Tagged Image File Format)
- VAPOR uses PROJ4 to transform between various map projections (e.g. Lambert Conformal Conic, Mercator, etc.)
- Geo-referenced images can be correctly registered in space and time in scene
- GeoTiff sources:
  - NCAR Command Language (NCL)
  - Web Mapping Services (e.g. NASA Big Blue Marble)



Data source: Bill Kuo, NCAR

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Limitations of current VAPOR design

- Grids
  - All data are assumed to reside on a single computational grid
    - Model data must therefore be re-gridded to single grid
  - Most general form of grid currently supported is Rectilinear
    - More generally structured model data must be re-gridded
- VAPOR Data Collection (VDC)
  - API supports only subset of capabilities found in other formats
    - Attribute information not supported
  - API very different from other scientific data format (e.g NetCDF)
    - Difficult to support VDC with other tools
- Extensibility by 3rd parties
  - Code base was not designed for extensibility
    - Very difficult for 3rd parties to add new capabilities to VAPOR
    - Sometimes difficult even for knowledgeable developers

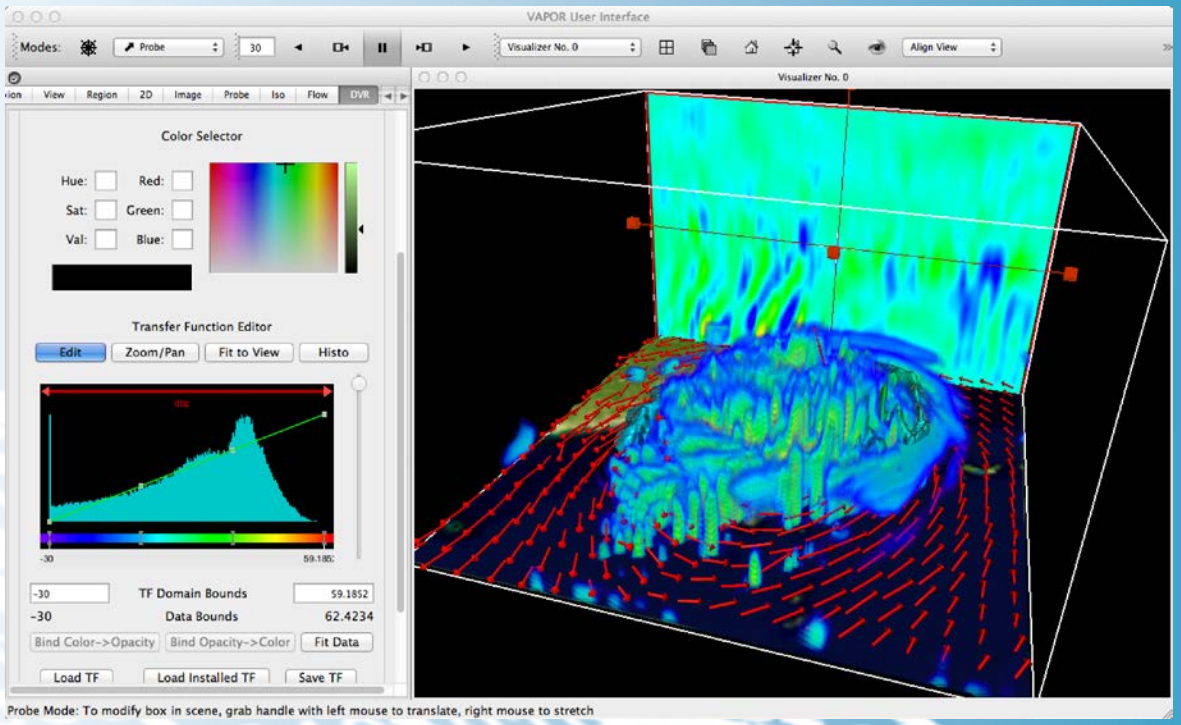
Future development plans
VAPOR 3.X

- Re-factor VDC:
  - General structured grids (e.g. curvilinear)
  - Unstructured grids (e.g. MPAS)
  - Multiple grids within a single VDC
  - Specification of user-defined metadata (attributes)
  - Facilitate supporting other model outputs (e.g. GRIB)

- Re-factor vaporgui
  - Support new VDC capabilities (i.e. more general grids, no "single-grid" constraint
  - Facilitate 3rd party extension
  - Facilitate new UI's (e.g. scripting, web-based)

Misc.

- Easy to use
  - Graphical User Interface
  - No programming required
- Free
- Runs on Mac, Linux, Windows
  - Binary distribution – no building necessary
- System requirements
  - GPU
  - More memory the better



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Questions???

Live demo at Exhibition and Reception today

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