

# Open and Free Community Resources for Environmental Research

## **Lower Mekong Initiative Workshop**

*August 18-22, 2014; Hanoi, Vietnam*

*Don Middleton, Chief Technologist for Data and eScience*

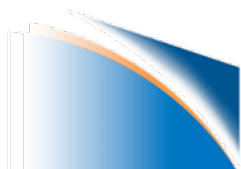
U.S. National Center for Atmospheric Research (NCAR)

Computational & Information Systems Laboratory

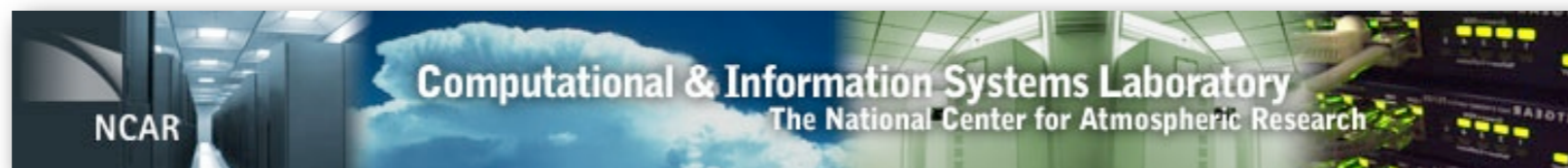
Technology Development Division (CISL/TDD)

Boulder, Colorado, USA

On behalf of many people and projects: NCAR Science Gateways, GIS Program, Climate Data Guide, CESM, WRF, DART, NCL/PyNGL, Vapor; UCAR's Unidata Program for IDV and the LDD/IDM; the global Earth System Grid Federation (ESGF); and the Globus Project



**NCAR**



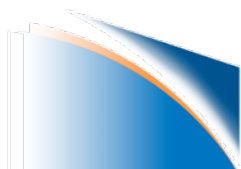


## **The National Center for Atmospheric Research**

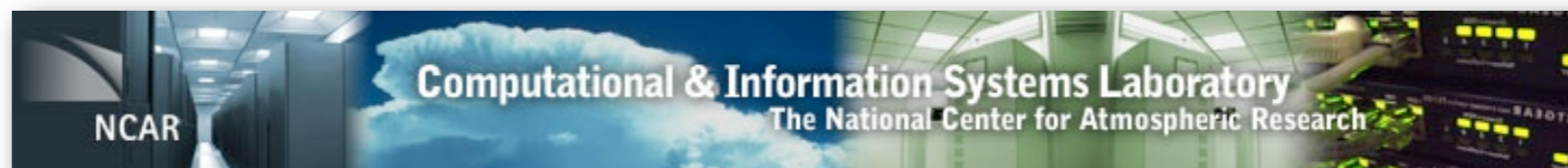
*Managed by the University Corporation for Atmospheric Research*

*A National Science Foundation FFRDC*

**Mesa Campus; Boulder, Colorado, USA**

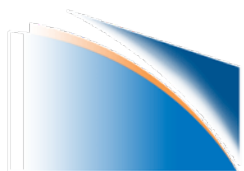


**NCAR**

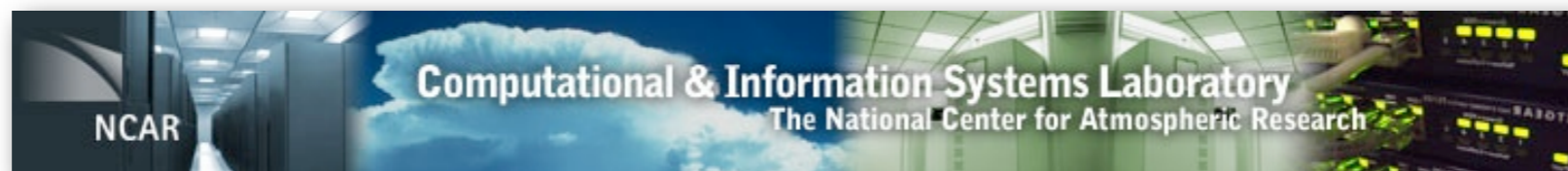


# Topics

- Data Resources
- Models and Data Assimilation
- Data Analysis, Visualization, and Transfer Tools
- NSF's EarthCube Program



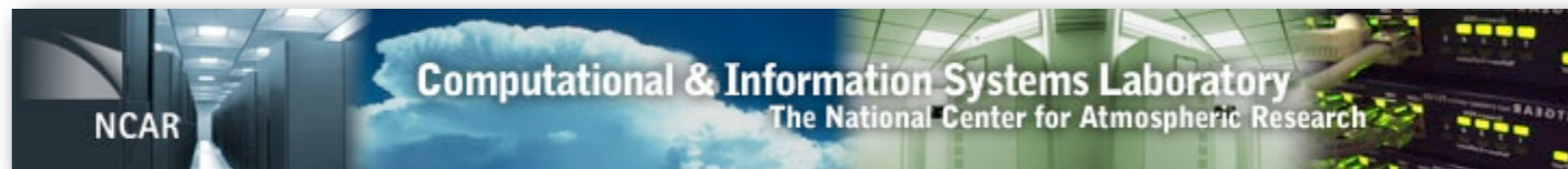
**NCAR**



# Data Resources



**NCAR**



ESG-NCAR Gateway

https://www.earthsystemgrid.org/home.htm

Financial Facebook Projects-Proposals BusWeatherTravel Events Google NCAR Netflix News Personal

ESG-NCAR Gateway

**Earth System Grid**

Home Search Data Account About Contact Us Login

### ESG Gateway at the National Center for Atmospheric Research

**Search Categories**

- **Type**
  - [Dataset](#) (9752)
  - [Software](#) (112)
- **Project**
  - [AMPS](#) (104)
  - [CCSM](#) (5513)
  - [CMIP5](#) (3048)
  - [COLA-SP-CCSM4](#) (25)
  - [GeoMIP](#) (63)
  - [NARCCAP](#) (132)
  - [NCL](#) (64)
  - [NMME](#) (82)
  - [PCM](#) (487)
  - [PMIP3](#) (9)
  - [PyNGL](#) (18)
  - [PyNIO](#) (20)
  - [TAMIP](#) (192)
  - [TraCE](#) (101)
  - [WHATCHEM](#) (2)
- + **Institute**
- + **Model**
- + **Experiment**
- + **Frequency**
- + **Product**
- + **Realm**
- + **CF Variable**


Search:

**Global Climate Models**

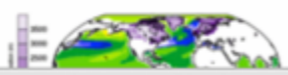
Community Earth System Model **Community Earth System Model (CESM)**


- [CESM1 CAM5 BGC 30-Member Large Ensemble](#)
- [CCSM 4.0 Model Output](#)
- [CCSM 3.0 Model Output](#)
- [Parallel Climate Model \(PCM\)](#)
- [High-resolution CESM simulation from the Accelerated Scientific Discovery phase of Yellowstone](#)
- [Simulation of the Transient Climate of the Last 21,000 Years \(TraCE-21ka\)](#)
- [CCSM4 30-Member Ensemble of 20th Century \(1970-2005\)](#)

**Regional Climate Models**

 [NARCCAP: North American Regional Climate Change Assessment Program](#)

**Analysis & Visualization Software**

 [NCL: NCAR Command Language](#)

 [PyNGL: Python Interface to the NCL Graphics](#)

**Quick Links**

- [Getting Started Guide](#)
- [Create Account](#)
- [Browse Catalogs](#)
- [Search for Data](#)

**Partner Data Centers**

- [ESG-ORNL](#)
- [NASA JPL](#)
- [PCMDI](#)

**Other Gateways**

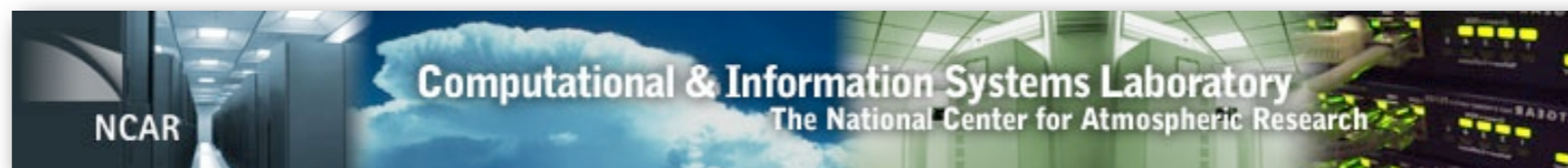
- [ACADIS](#) - Arctic Data

Go to # on this page

[www.earthsystemgrid.org](http://www.earthsystemgrid.org)



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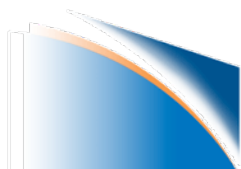


# A Few ESG Metrics

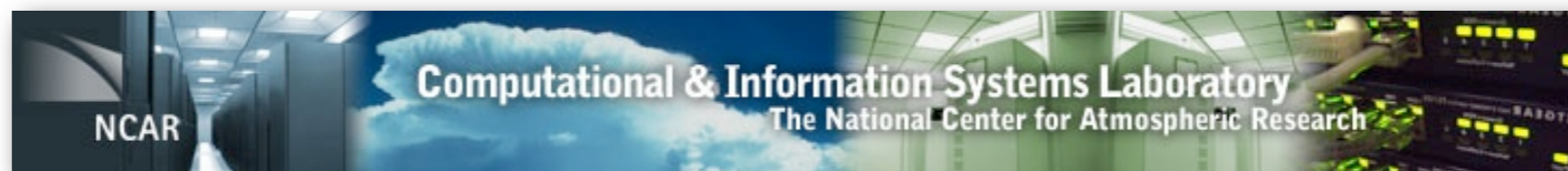
- Total registered users: ~40,000
- Average monthly registrations: 569
- Avg. monthly download volume: 110TB
- Avg. monthly download users: 1,190
- Est. 5 petabytes downloaded over time



NCAR's ESG Gateway feeds into the ESGF  
<http://pcmdi9.llnl.gov>



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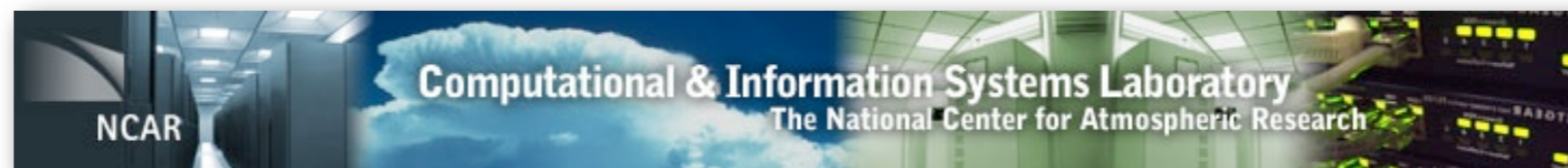


# Research Data Archive (RDA) at NCAR

- **Purpose:** Support climate & weather research
- **Collections:** Ocean & atmosphere observations, analyses, reanalyses, operational NWP outputs
- **Basic Metrics**
  - Established in 1960s
  - 600+ datasets, 8M files, 1.8 PB
  - +70 datasets growing daily to monthly
- **Science educated staff**
  - Expert consultants and data engineers
- **Free and open access**
- **Web Address:** <http://rda.ucar.edu/>



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GIS Climate Change Scenarios

https://gisclimatechange.ucar.edu

UCAR NCAR Closures/Emergencies Locations/Directions Find People

register login

# CLIMATE CHANGE SCENARIOS

GIS PROGRAM NCAR

HOME DATA CLIMATE INSPECTOR MORE RESOURCES FAQ CONTACT US

**Download NCAR Community Climate System Model (CCSM) projections in GIS formats**

New to the GIS Climate Change Scenarios site?

**Register Now**

Existing users log in here

**About this site**

Welcome to **NCAR's GIS Program** Climate Change Scenarios GIS data portal. This portal is intended to serve a community of GIS users interested in climate change. The free datasets of climate change projections can be downloaded as a shapefile, a text file, or as an image. Many 2D variables from modeled projected climate are available for the atmosphere and land surface. These climate change

Total Precipitation (mm) High: 5000 Low: 5

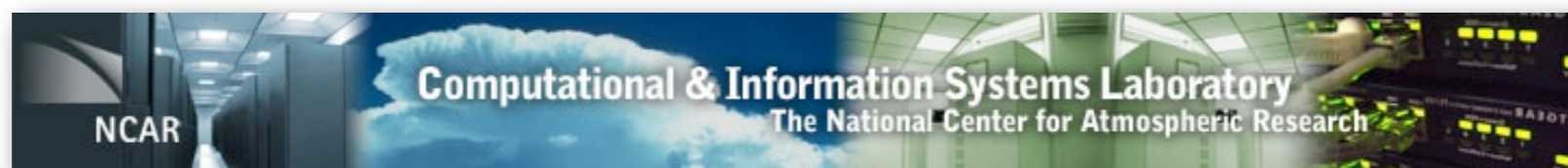
Annual total precipitation for 2030. Derived from CCSM monthly simulations emissions scenario B1.

Resources

<https://gisclimatechange.ucar.edu>



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NCAR - Climate Data Guide | Data Discovery Guided by Experts

https://climatedataguide.ucar.edu

UCAR NCAR Closures/Emergencies Locations/Directions Find People

# NCAR UCAR | ClimateDataGuide













inform • compare • discover

CLIMATE DATA | ANALYSIS TOOLS | MODEL EVALUATION | EXPERT CONTRIBUTORS | **ABC Site-wide Search >>**

## Data Discovery Guided by Experts >>

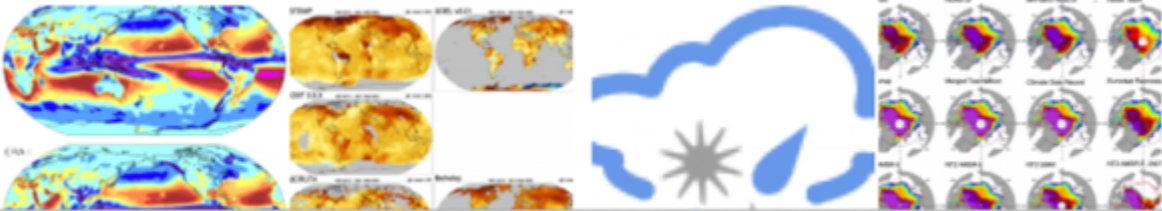
Search and access 167 data sets covering the Atmosphere, Ocean, Land and more. Explore climate indices, reanalyses and satellite data and understand their application to climate model metrics. This is the only data portal that combines data discovery, metadata, figures and world-class expertise on the strengths, limitations and applications of climate data. **Discover it now.**

See data pages with guidance from these experts:

<b>Randel, Bill</b> 	<b>Pendergrass, Angeline</b> 	<b>Mears, Carl</b> 	<b>Kimball, John</b> 	<b>Deser, Clara</b> 	<b>Meier, Walter</b> 
<b>von Schuckmann, Karina</b> 	<b>Hassler, Birgit</b> 	<b>Banzon, Viva</b> 	<b>Robinson, David</b> 	<b>Kay, Jennifer</b> 	<b>Huang, Boyin</b> 

## Data Set Overviews >>

Compare the attributes, strengths and limitations of multiple data sets.



### JOIN US

Multiply the impact of your work by announcing new data sets and sharing your knowledge of the strengths, limitations and applications of particular data sets.

**Ways to make an impact**

- [Become a registered user of this site](#)
- [Contribute a data set & assessment](#)
- [Post a simple announcement of a data set or product to Climate Data Trends](#)
- [Post a comment to any data set page](#)

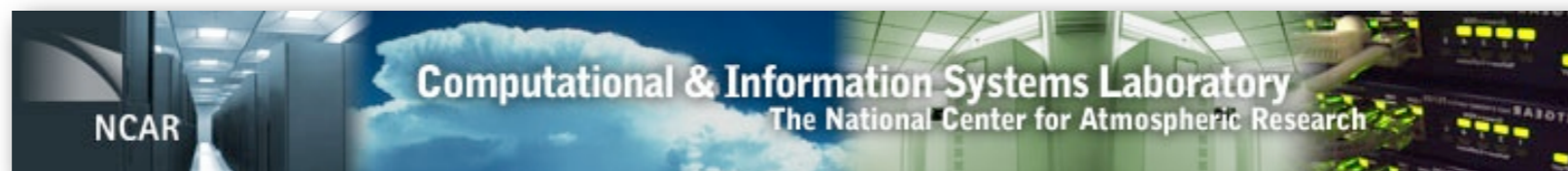
**SHARE CLIMATE DATA GUIDE**

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<https://climatedataguide.ucar.edu>



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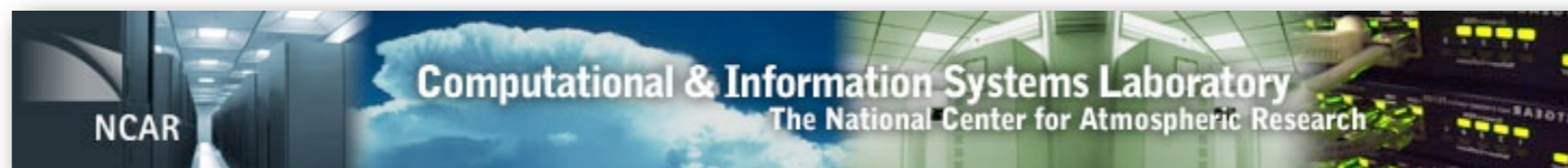


# Data Citation, and Related

- NCAR/UCAR have a Data Citation Initiative, led by the NCAR Library (with all major data providers)
- It's not just for data
- We want to form an interlinked web of citable data collections, tools, models, visualizations, and scholarly publications
- We're using DOI's via EZID/Datacite



NCAR

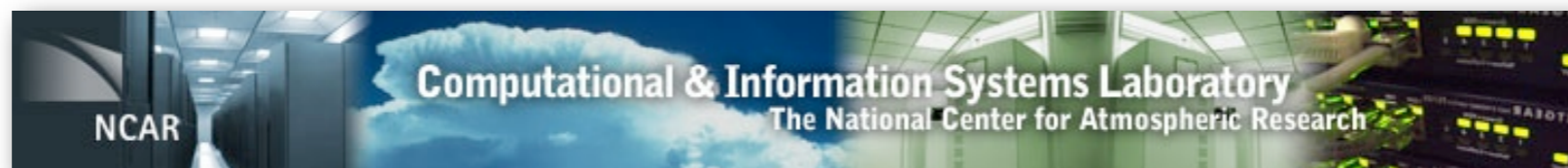


# Examples

- Mearns, L.O., et al., 2007, updated 2012. *The North American Regional Climate Change Assessment Program dataset*, National Center for Atmospheric Research Earth System Grid data portal, Boulder, CO. Data downloaded 2013-08-12. [[doi:10.5065/D6RN35ST](https://doi.org/10.5065/D6RN35ST)]
- Pelto, Mauri S. (2013). Juneau Icefield Glacier Mass Balance. UCAR/NCAR – CISL – ACADIS. <http://dx.doi.org/10.5065/D6NZ85N3>
- The NCAR Command Language (Version 6.1.1) [Software]. (2013). Boulder, Colorado: UCAR/NCAR/CISL/VETS. <http://dx.doi.org/10.5065/D6WD3XH5>



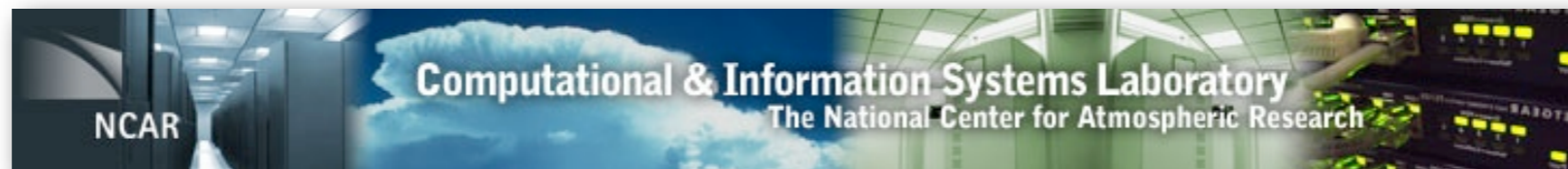
NCAR



# Models and Data Assimilation



**NCAR**



# WRF: The Weather Research and Forecast Model

The screenshot shows the homepage of the Weather Research & Forecasting Model website. The browser address bar displays [www.wrf-model.org/index.php](http://www.wrf-model.org/index.php). The website header features the WRF logo and the text "THE WEATHER RESEARCH & FORECASTING MODEL". A navigation menu includes links for Home, Working Groups, User Resources, Events, and Real-Time Forecasts. The main content area is titled "The Weather Research & Forecasting Model" and contains a detailed description of the WRF model, its capabilities, and its history. A sidebar on the left lists various resources like "WRF ARW Users' Page" and "WRF Administration". A right sidebar titled "Upcoming Events" states that there are no events currently scheduled.

**The Weather Research & Forecasting Model**

The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs. It features two dynamical cores, a data assimilation system, and a software architecture facilitating parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometers. The effort to develop WRF began in the latter part of the 1990's and was a collaborative partnership principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP) and the (then) Forecast Systems Laboratory (FSL)), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA).

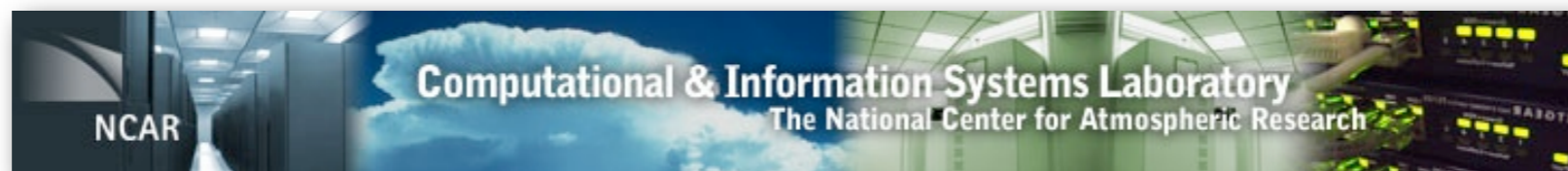
WRF allows researchers to generate atmospheric simulations based on real data (observations, analyses) or idealized conditions. WRF offers operational forecasting a flexible and computationally-efficient platform, while providing advances in physics, numerics, and data assimilation contributed by developers in the broader research community. WRF is currently in operational use at NCEP, AFWA, and other centers.

WRF has a large worldwide community of registered users (over 25,000 in over 130 countries), and workshops and tutorials are held each year at NCAR. There are two dynamical core variants of WRF, each with its own web page. The Advanced Research WRF (ARW) is supported to the community by the

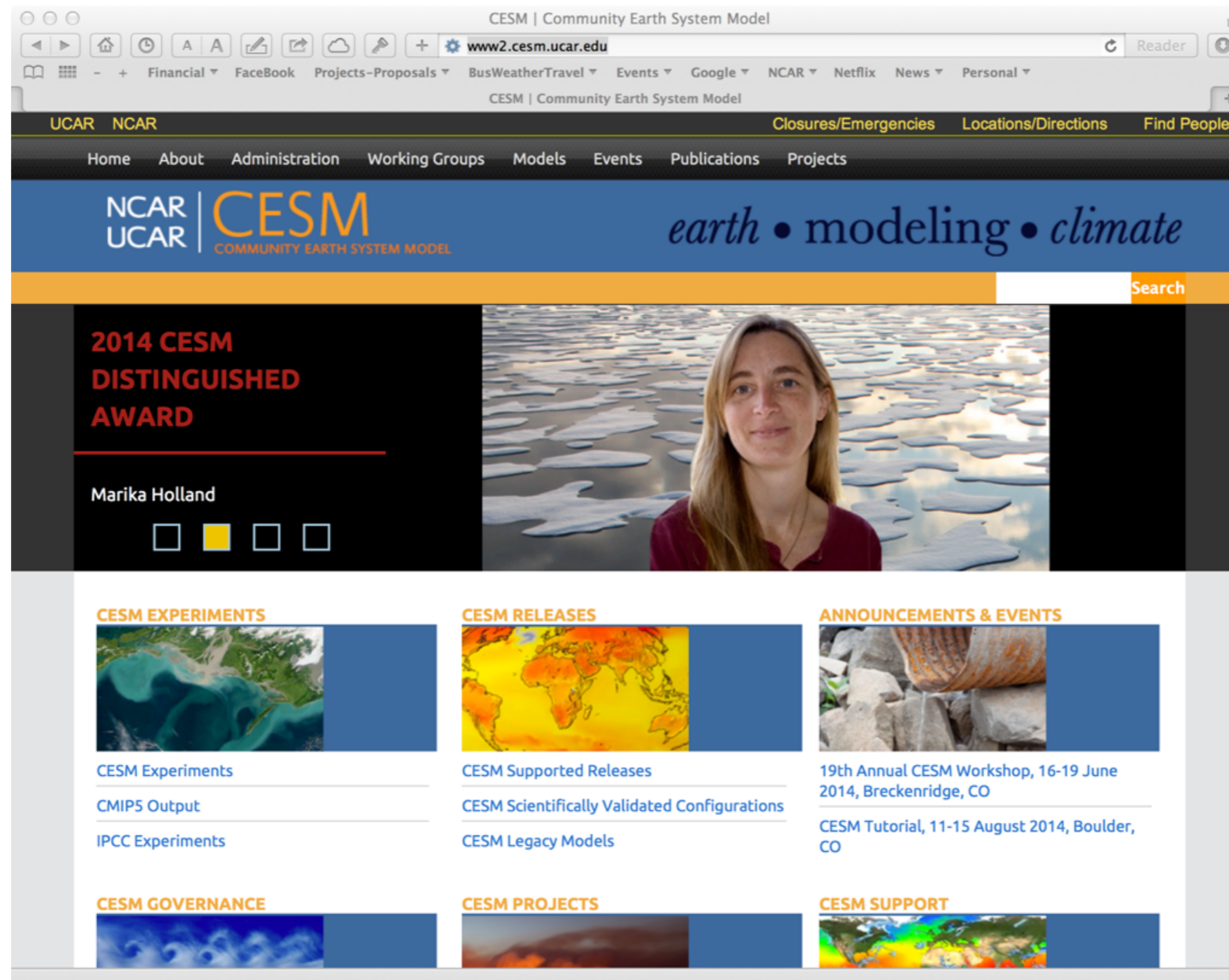
<http://www.wrf-model.org>



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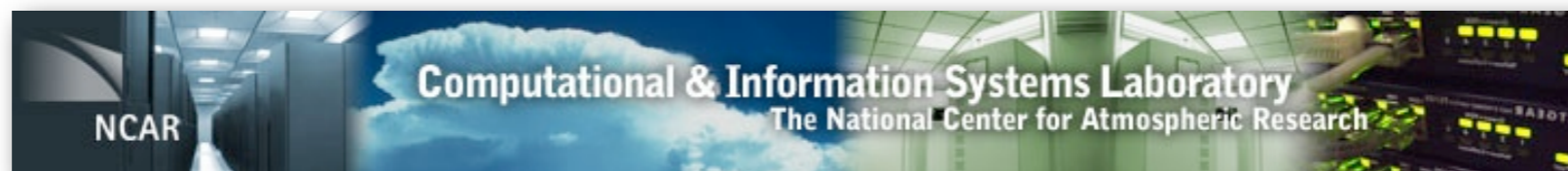
# CESM: The Community Earth System Model



<http://www2.cesm.ucar.edu>



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UCAR The Data Assimilation Research Testbed -- DART

www.image.ucar.edu/DAReS/DART/

UCAR The Data Assimilation Research Testbed -- DART

UCAR NCAR Find People Contact/Visit

CISL IMAGE DAReS DAREs Search advanced

NCAR IMAGE: Data Assimilation Research Section

DART Why DART? Research Getting Started Documentation Diagnostics Miscellany

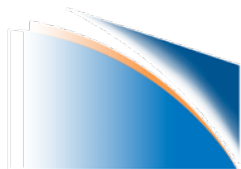
DART board

time series of 'total error'  
Quantify the effects of observations or parameter settings.

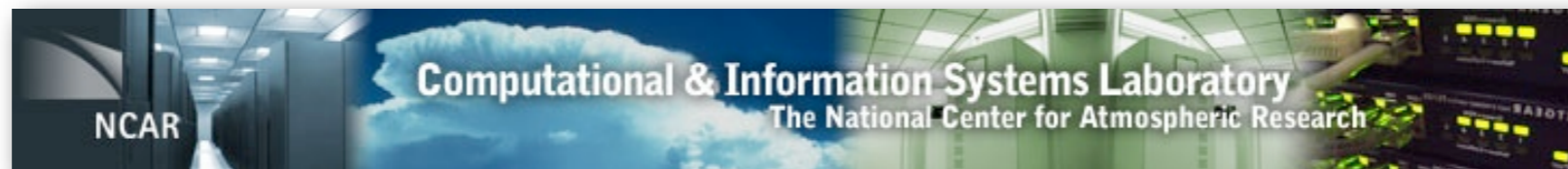
**Welcome to the Data Assimilation Research Testbed - DART**

DART is a community facility for ensemble DA developed and maintained by the Data Assimilation Research Section (DAREs) at the National Center for Atmospheric Research (NCAR). DART provides modelers, observational scientists, and geophysicists with powerful, flexible DA tools that are easy to implement and use and can be customized to support efficient operational DA applications. DART is a software environment that makes it easy to explore a variety of data assimilation methods and observations with different numerical models and is designed to facilitate the combination of assimilation algorithms, models, and **real** (as well as synthetic) observations to allow increased understanding of all three. DART includes extensive documentation, a comprehensive tutorial, and a variety of models and observation sets that can be used to introduce new users or graduate students to ensemble DA. DART also provides a framework for developing, testing, and distributing advances in ensemble DA to a broad community of users by removing the implementation-specific peculiarities of one-off DA systems.

<http://www.image.ucar.edu/DAReS/DART>



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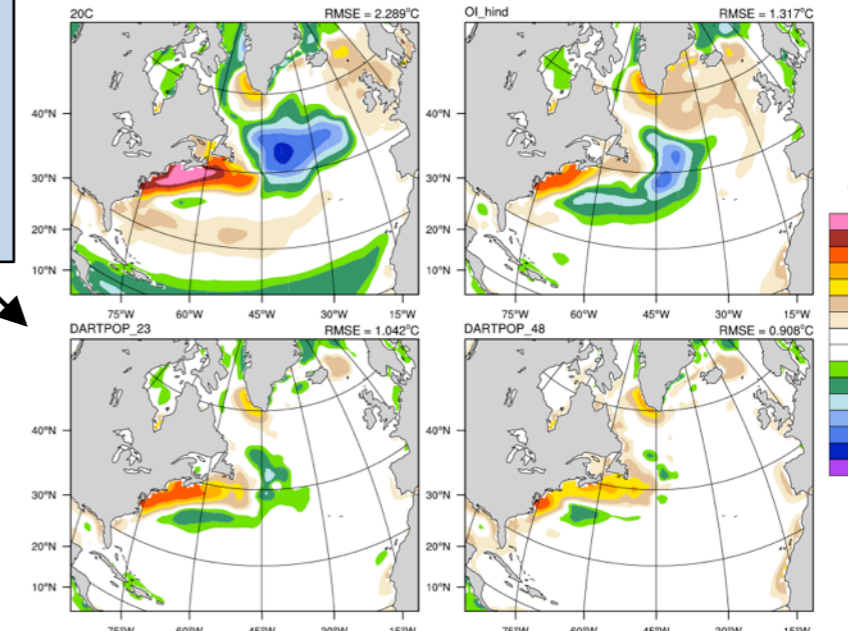


# Some Current DART Research Projects

DART/CAM  
Global DA

Ensemble of  
Boundary Conditions

DART/POP  
Coupled Ocean  
DA



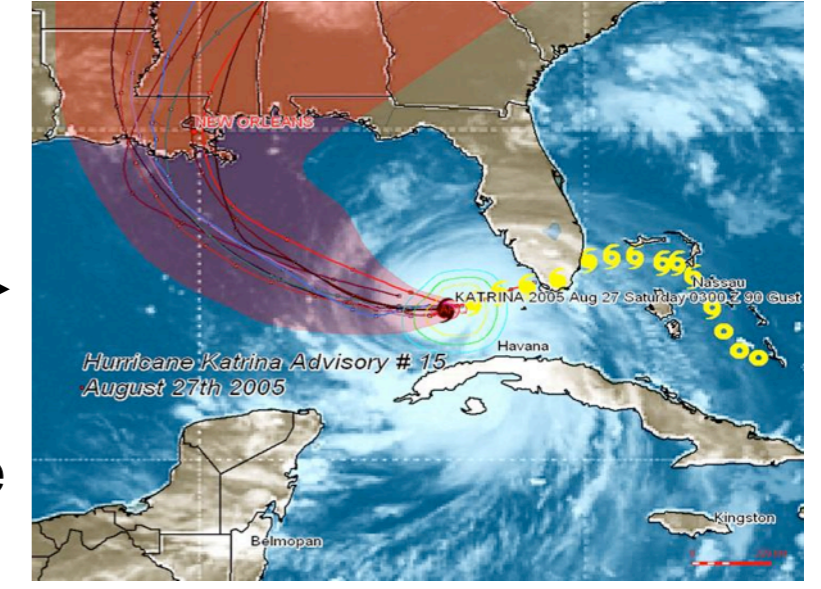
Ensemble Reanalysis Datasets  
(1998-2010 available)



Observations

DART/WRF  
Regional DA

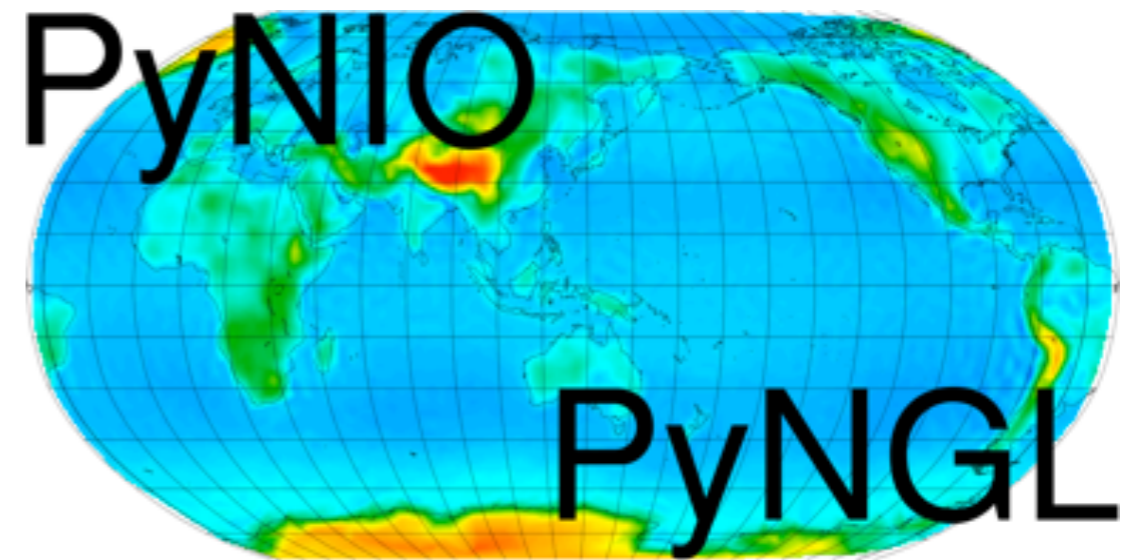
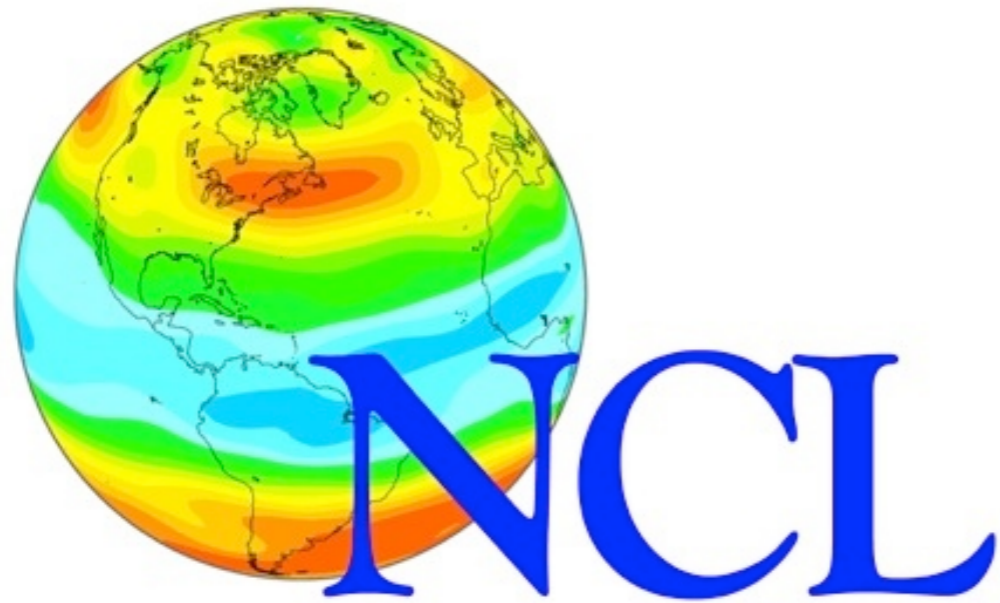
Hurricane and Severe  
Weather Prediction



# Data Analysis, Visualization, and Transfer Tools

NCL & Python material courtesy of  
Mary Haley, NCAR/CISL/TDD

# Community Tools for the Analysis and Visualization of Geoscientific Data



*The National Center for Atmospheric Research is sponsored by the National Science Foundation.*



Dennis Shea  
Science guy  
Data expert  
Trainer

Dave Brown  
NCL Tech Lead

Mary Haley  
Product owner  
Trainer

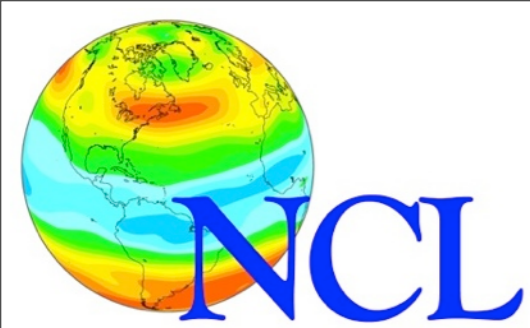
Rick Brownrigg  
Developer  
Research



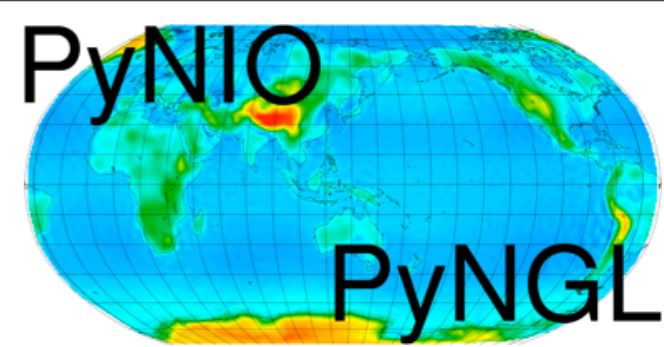
Wei Huang  
Developer  
Data Formats



Adam Phillips  
Science guy  
Graphical expert

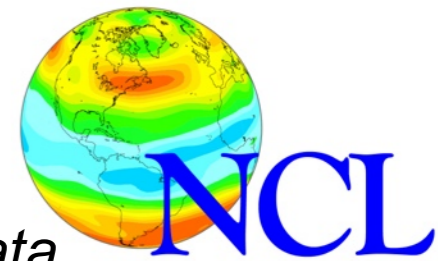


# What we do



- Develop geoscientific analysis and visualization software in close collaboration with NCAR scientists
- Document software and provide extensive examples
- Answer user questions on a daily (hourly!) basis
- Offer hands-on training workshops 4-6x a year
- *Collaborate with researchers world-wide to enhance software*

# NCAR Command Language (NCL)

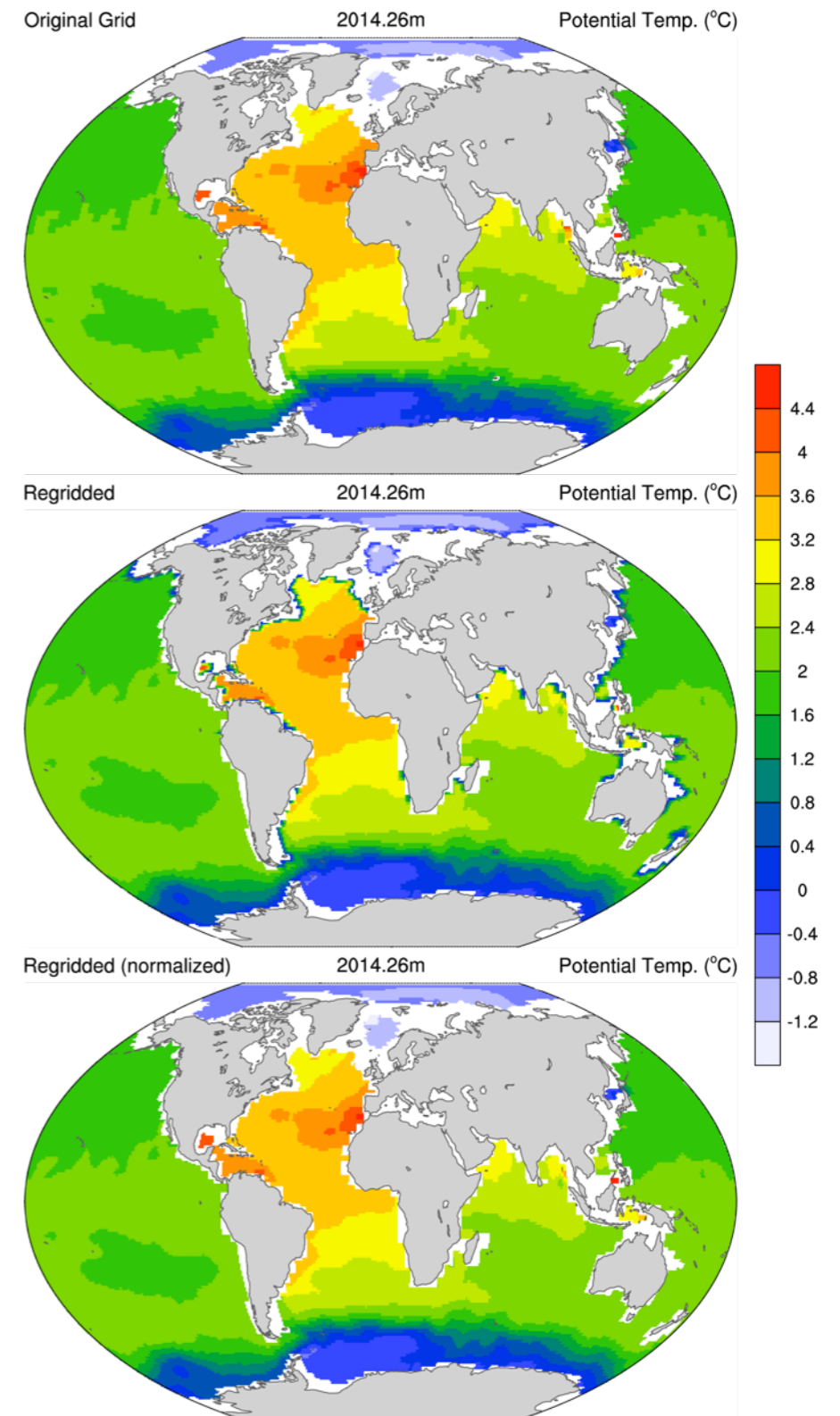


*A scripting language tailored for the analysis and visualization of geoscientific data*

- Simple, robust file input and output
  - Hundreds of analysis (computational) functions
  - Visualizations (2D) are publication quality and highly customizable
- 
- Users range from graduate students working on doctoral theses to programmers in scientific organizations working on large research projects
  - UNIX binaries & source available, free
  - Extensive website, **regular workshops**

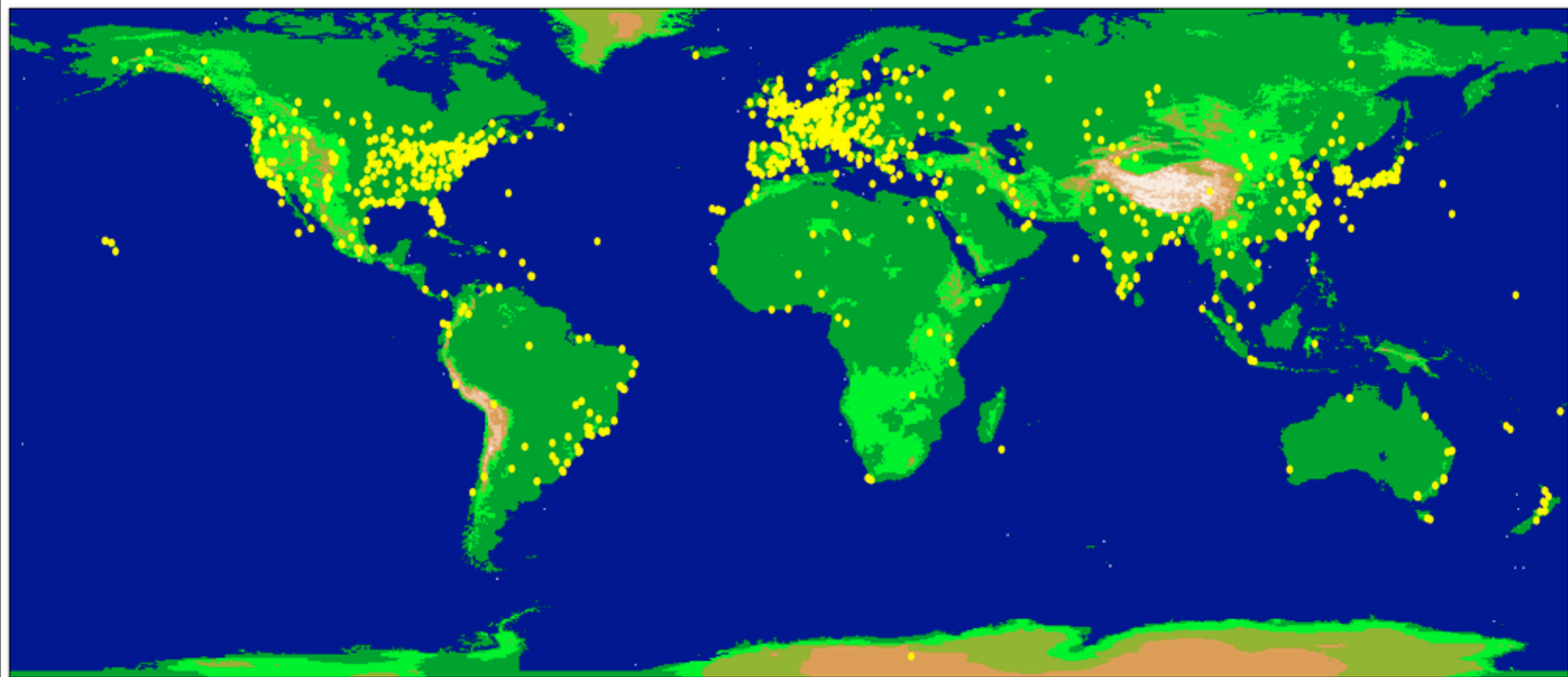
<http://www.ncl.ucar.edu/>

<http://dx.doi.org/10.5065/D6WD3XH5>



# Metrics and scope of software usage

- 20,000+ registered users in 127 countries
- Average of 1700 downloads a month
- Average of 300 emails a month on email list (includes responses)



# NCL's File Input and Output

- Handles many geoscientific data formats:
  - NetCDF (versions 3 and 4)
  - GRIB (versions 1 and 2)
  - HDF4, HDF5, HDF-EOS (versions 4 and 5)
  - ESRI Shapefiles
- OPeNDAP-enabled
- ASCII (text files, CSV files)
- Fortran and C binary



unidata



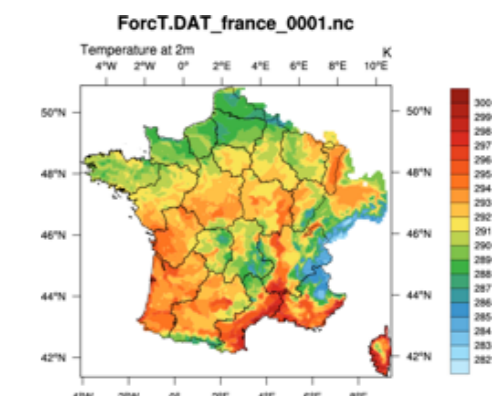
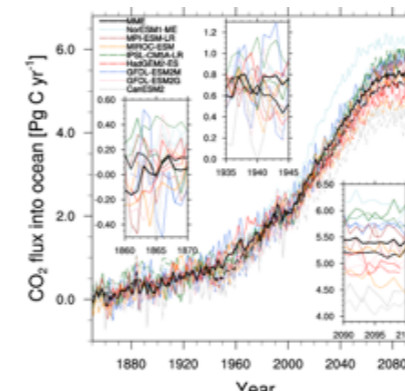
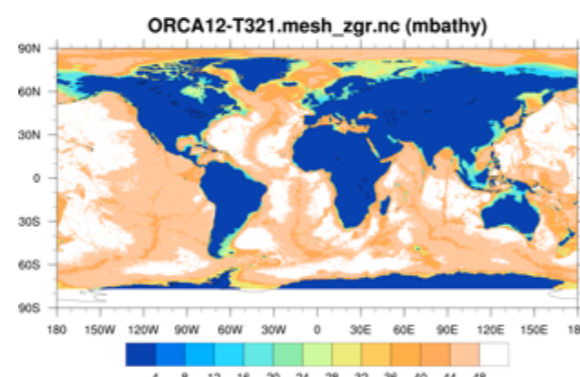
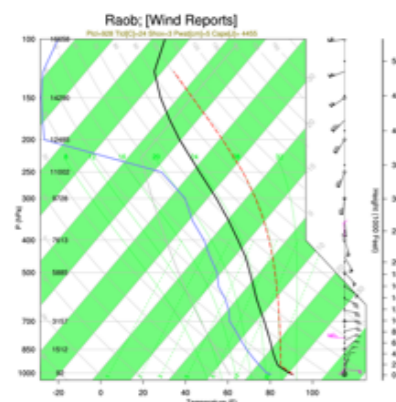
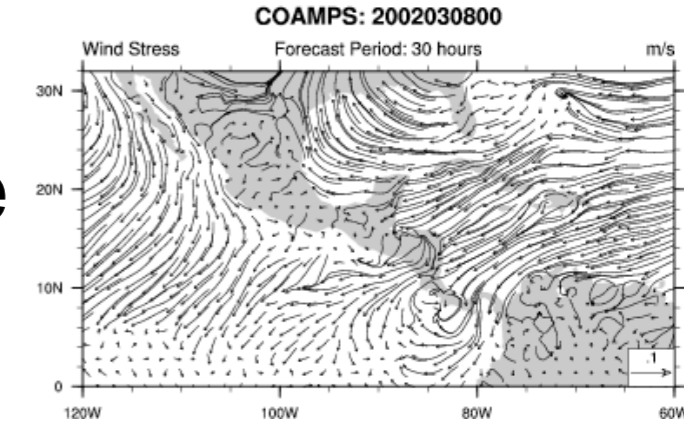
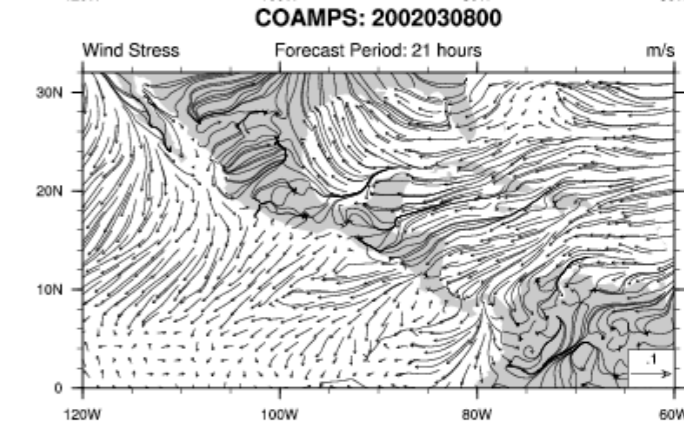
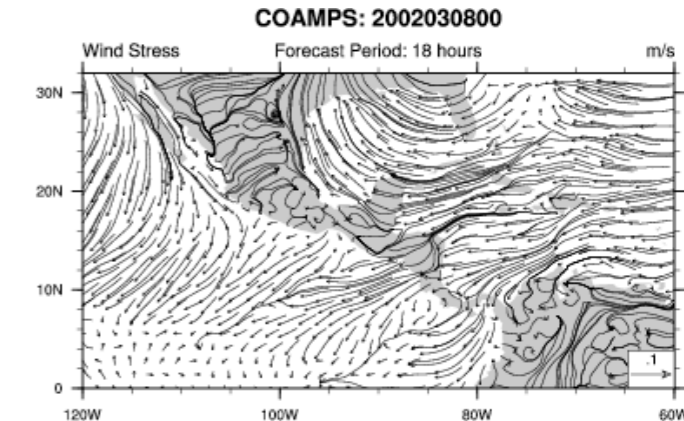
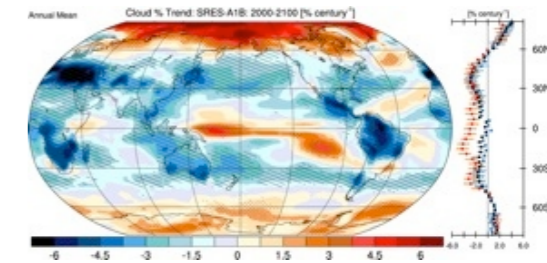


# NCL's computational analyses

- Array-based math (no need to loop across dimensions) – similar to Matlab, Python, IDL
- Hundreds of computational functions
  - Spherical harmonics, empirical orthogonal functions (EOFs)
  - Scalar and vector regridding
  - Interpolation
  - Climatologies
  - Functions specific to CESM and WRF models
- Many tailored to climate and weather
- Some are highly-specialized
- Most handle missing data
- Can call C and Fortran routines from NCL and PyNGL
- Many contributions from users, they drive priorities

# NCL Visualizations

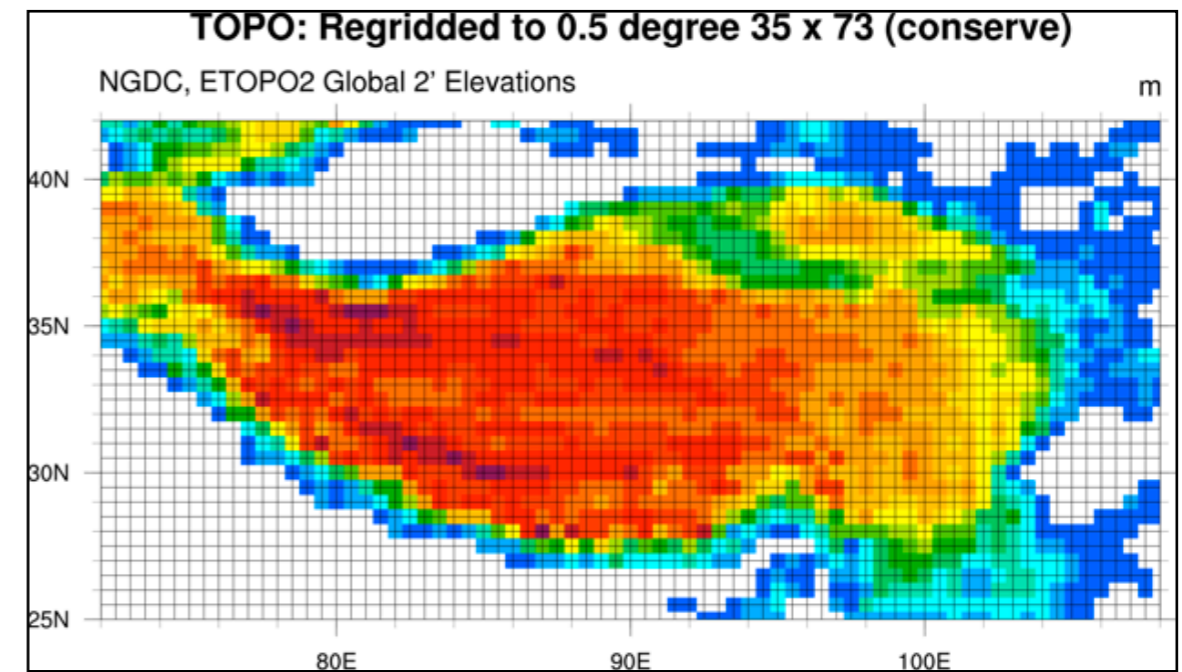
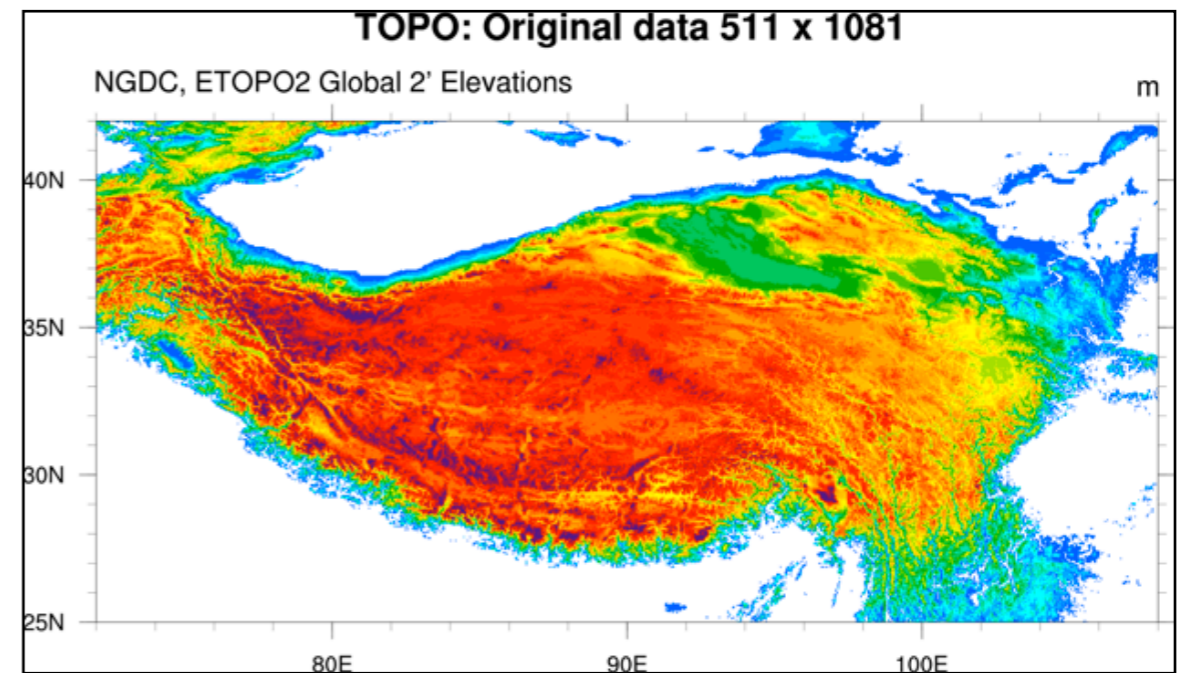
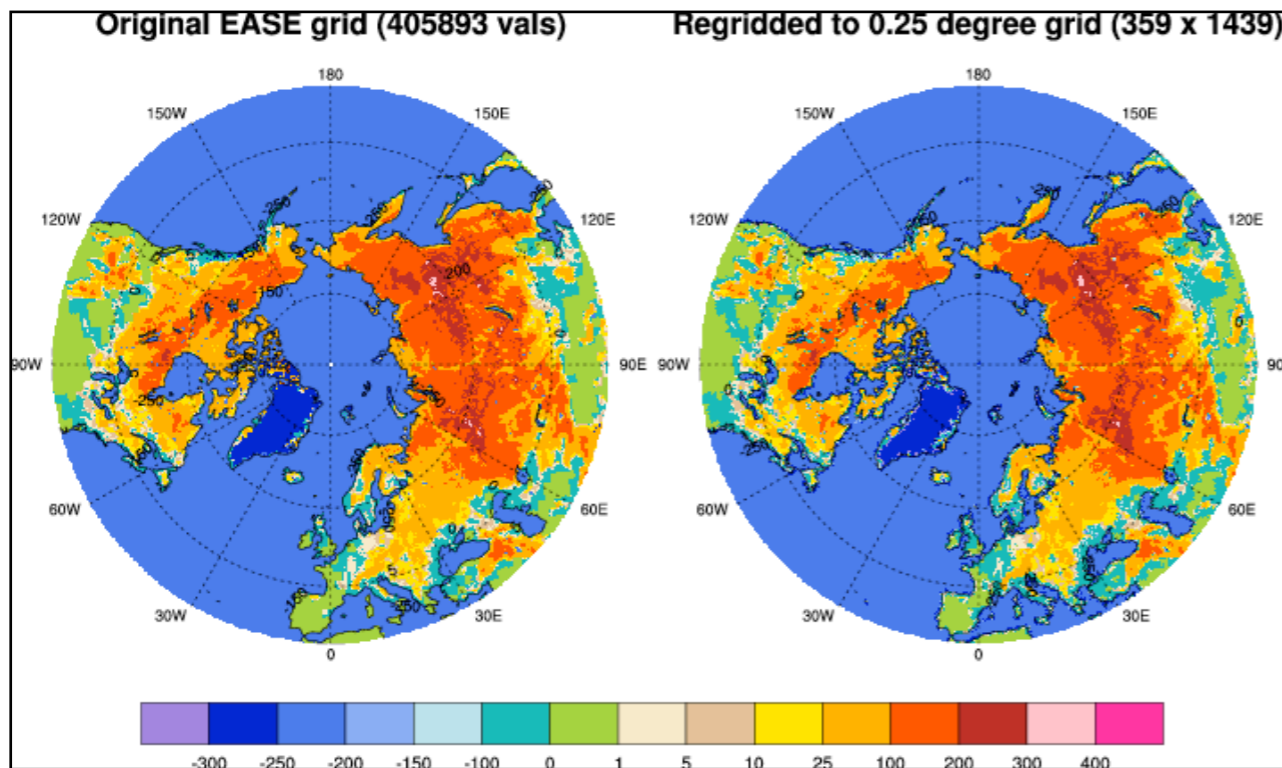
- High-quality and customizable visualizations
- Contours, XY, vectors, streamlines
- Maps with common map projections
- Handles data on regular and irregular grids, triangular meshes
- Specialized scripts for climate diagnostics, skew-T, wind roses, histograms, Taylor diagrams, panels, bar charts
- High-level interfaces: simplifies graphics code
- Over 1,400 visualization “options”



# ESMF regridding software

## built into NCL

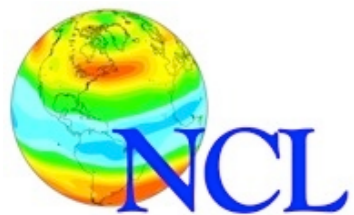
*Mohammad Abouali*, SIParCS intern  
*Dave Brown & Mary Haley*, mentors  
*Robert Oehmke*, collaborator  
ESMF Group, NOAA/ESRL/NESII



Regridding is the process of interpolating data from one grid (rectilinear, curvilinear, unstructured) to another while preserving the qualities of the original data.

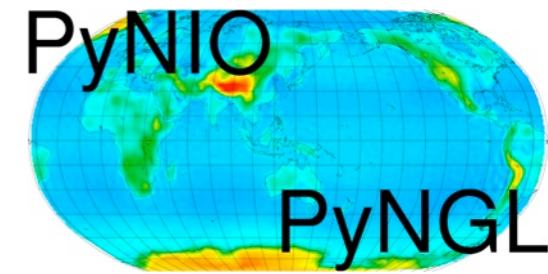
ESMF regridding has multiple interpolation methods; a crucial feature for climate model intercomparison.

<http://www.ncl.ucar.edu/Applications/ESMF.shtml>



# PyNIO and PyNGL

*Python modules based on a subset of NCL's capabilities*



## PyNIO

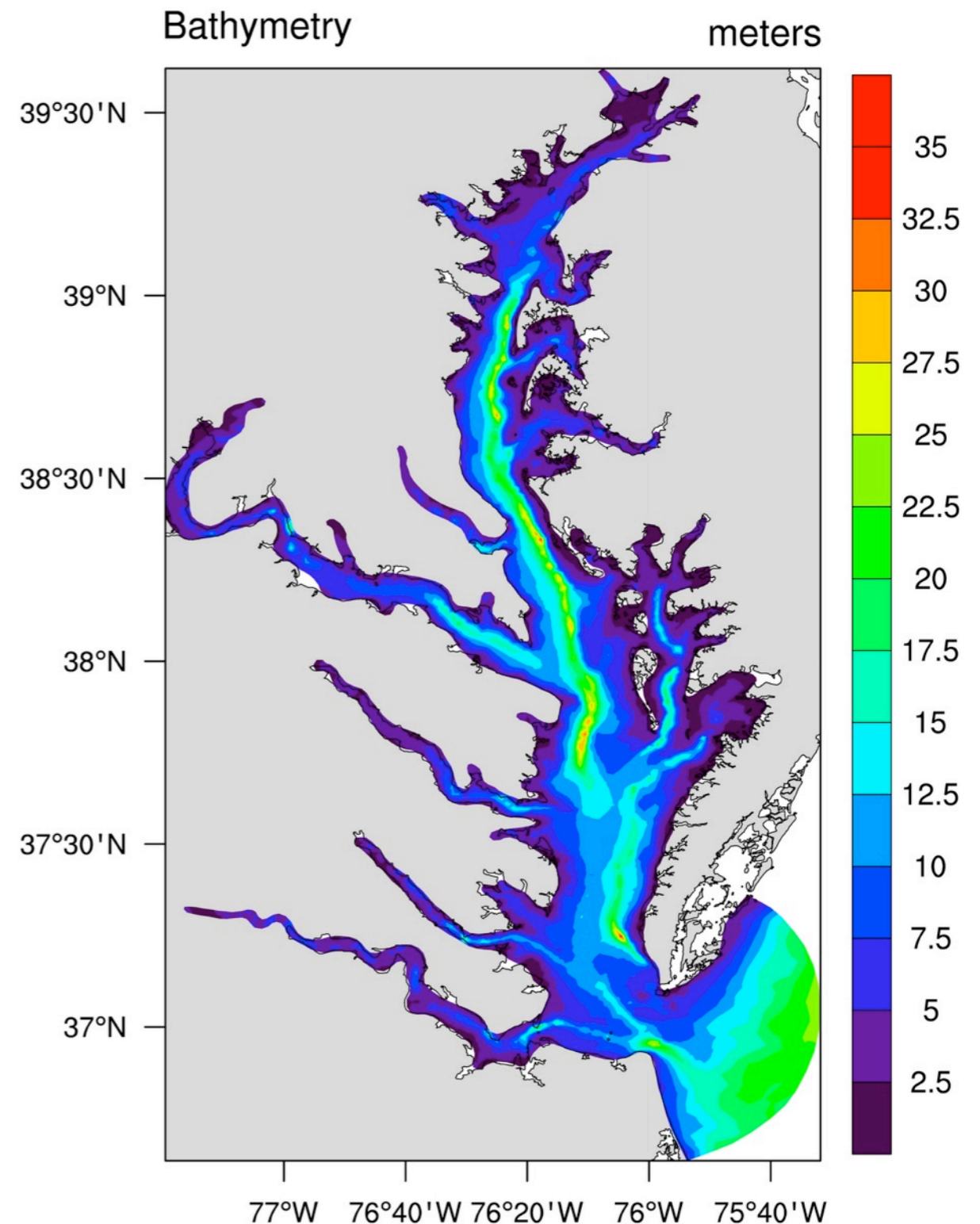
- Reads and writes same data formats as NCL
- Has special syntax for complex data subsetting (not available in NCL)

## PyNGL

- Same publication-quality graphics as NCL
- Utilizes existing Python modules and development tools (NumPy, swig, f2py, ScientificPython)
- Some climate-specific computations

<http://www.pyngl.ucar.edu/>

## Chesapeake Bay



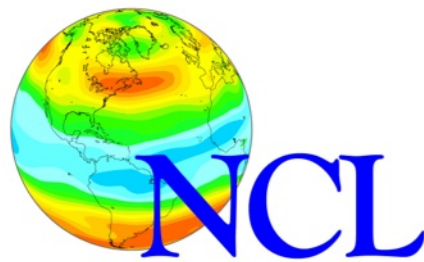
# pNetCDF



# parvis

*3-year joint DOE project with Argonne, Sandia, and Pacific Northwest National labs and UC-Davis to develop parallel analysis tools and new visualization techniques for ultra-large climate datasets.*

## MOAB



- High focus on Community Earth System Model data
- Special (and fast) algorithms for calculating vorticity/divergence on HOMME grids
- **ParGAL** (Parallel Gridded Analysis Library) - will vastly improve the speed of climate data analysis compared to the current serial tools.
- **ParNCL** – NCL with file I/O and computational components parallelized



swift → →

<http://trac.mcs.anl.gov/projects/parvis/wiki>



# NCL and PyNGL Visualizations

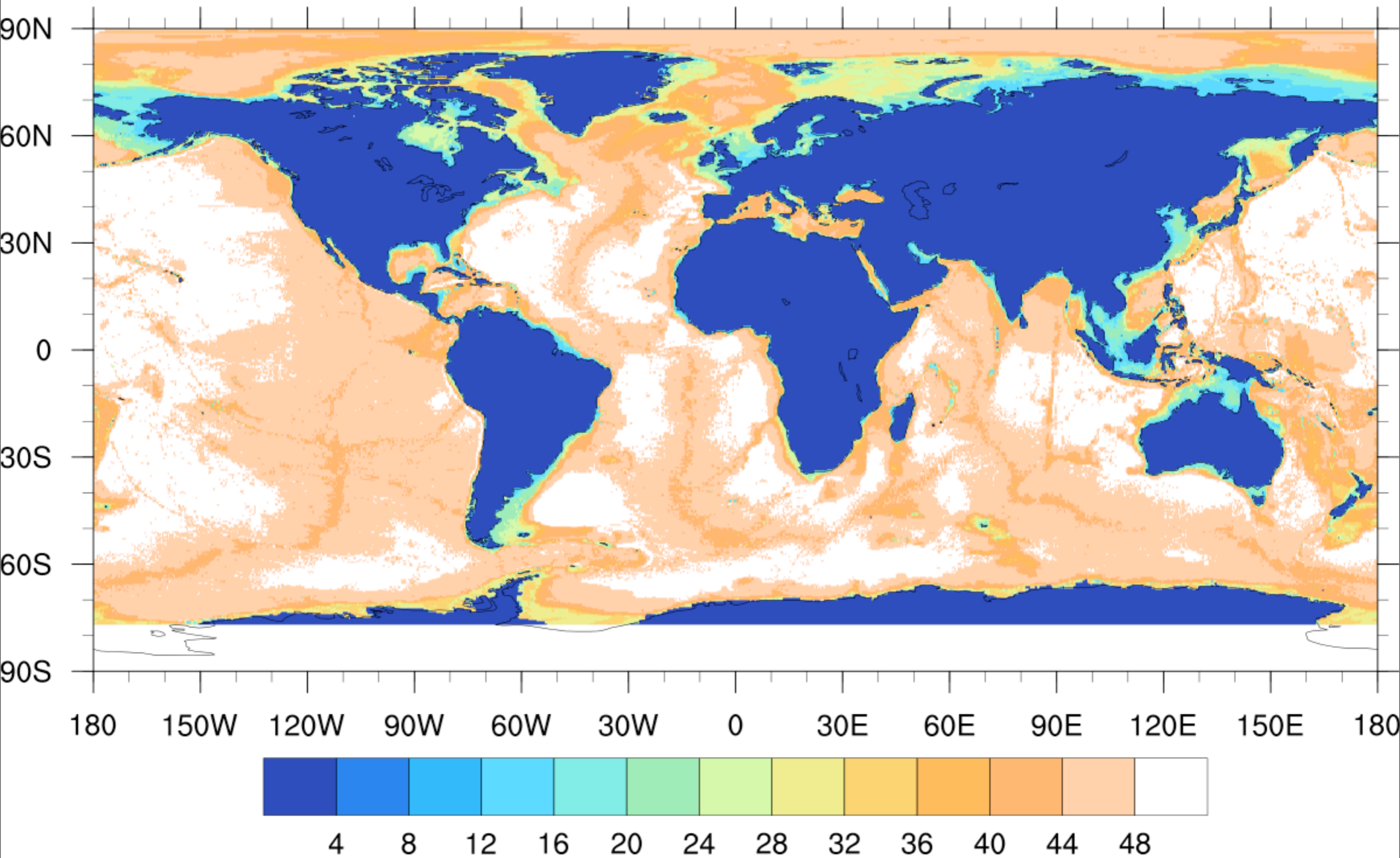
Hundreds of example and real world scripts available:

<http://www.ncl.ucar.edu/Applications/>

<http://www.pyngl.ucar.edu/Examples/gallery.shtml>

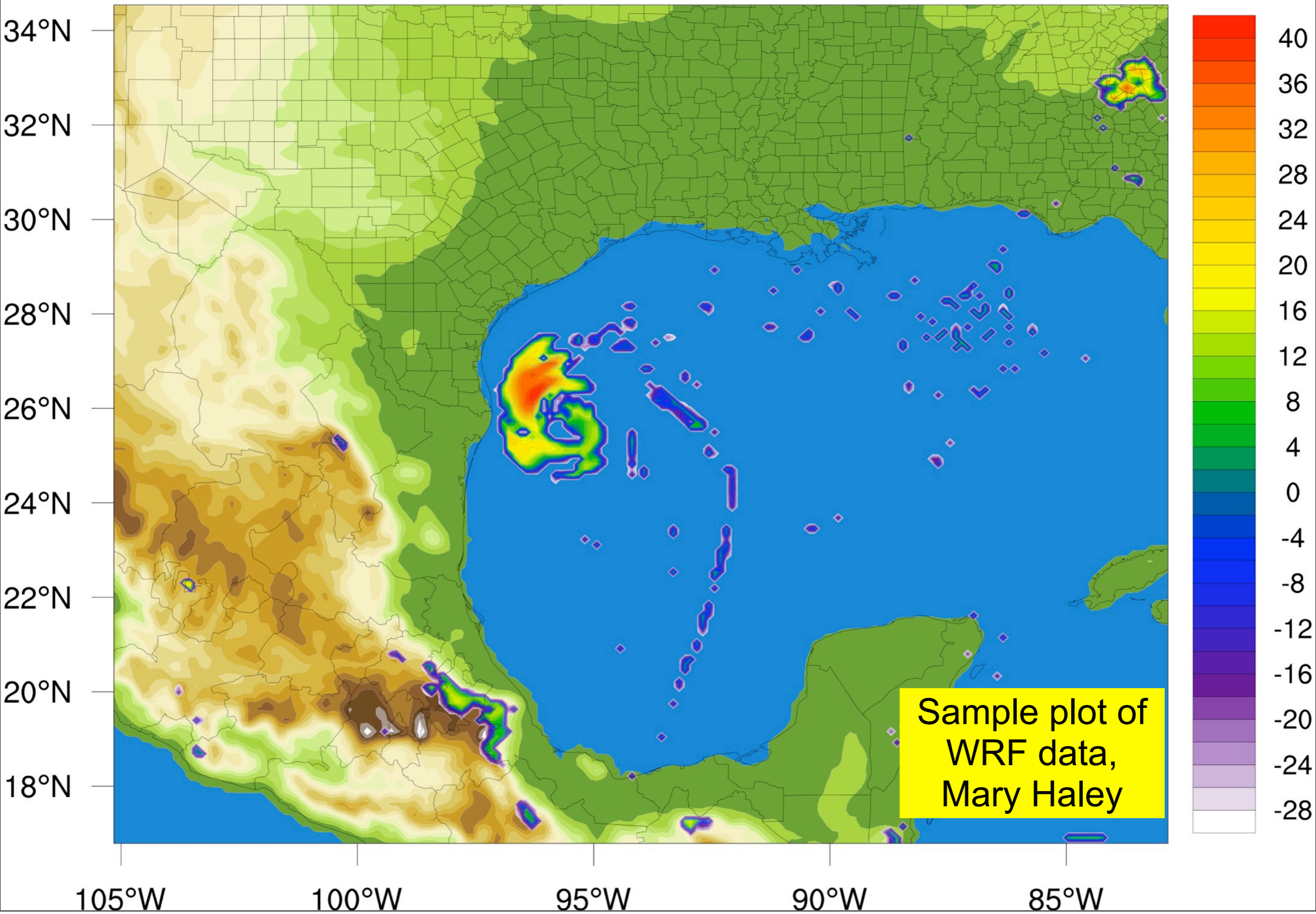
*Most visualizations that follow are taken from above URLs and have scripts you can download to generate them.*

# ORCA12-T321.mesh\_zgr.nc (mbathy)



Bathymetry from an ORCA12 grid file provided by Romain Bourdalle-Badie of Mercator Ocean. The variable is dimensioned 3059 x 4322

# Reflectivity (dBZ) at level = 0.996

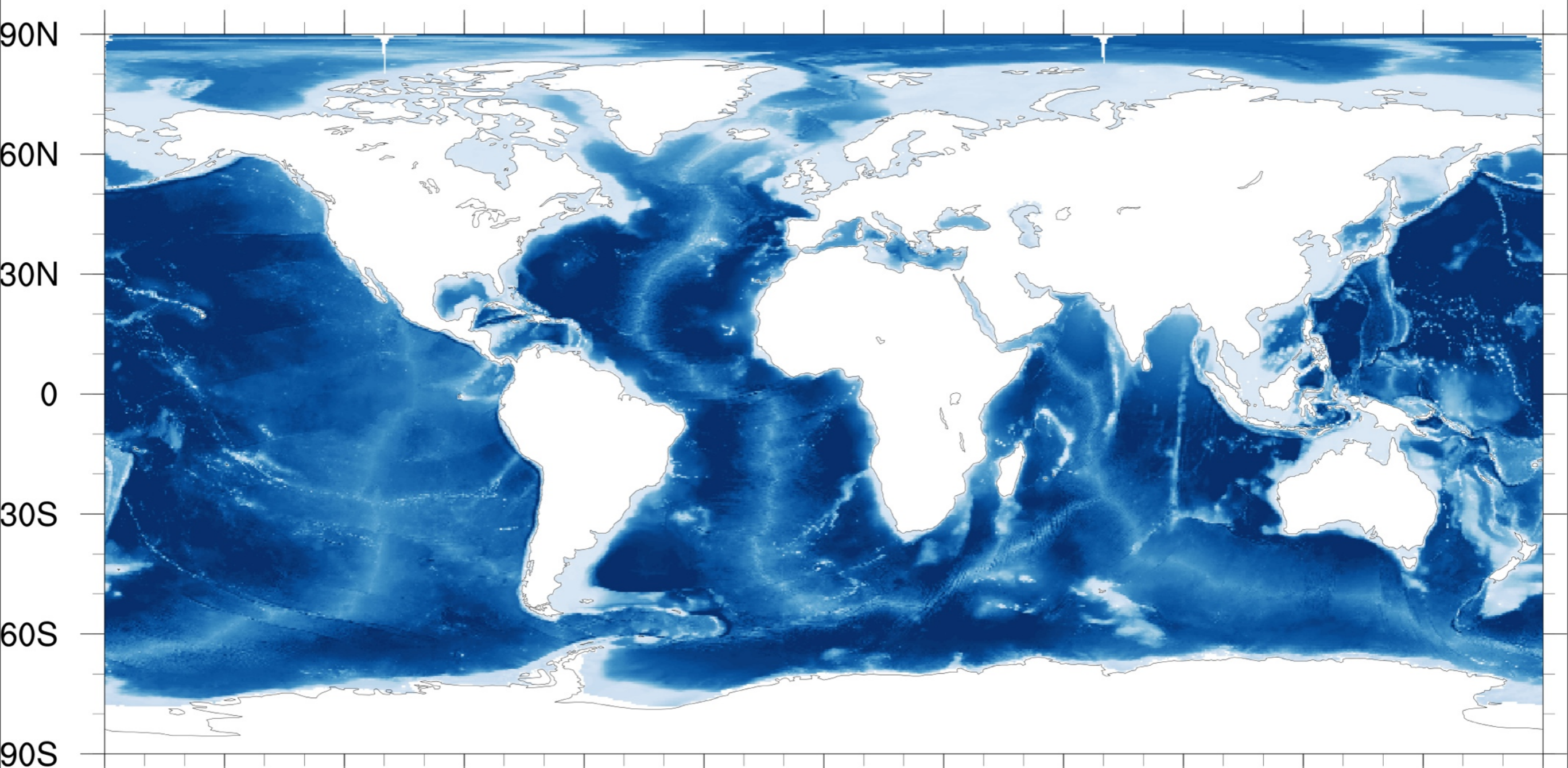




# grid.tx01\_62l.2013-07-13.nc (2400 x 3600, raster)

ocean depth at T points

centimeter

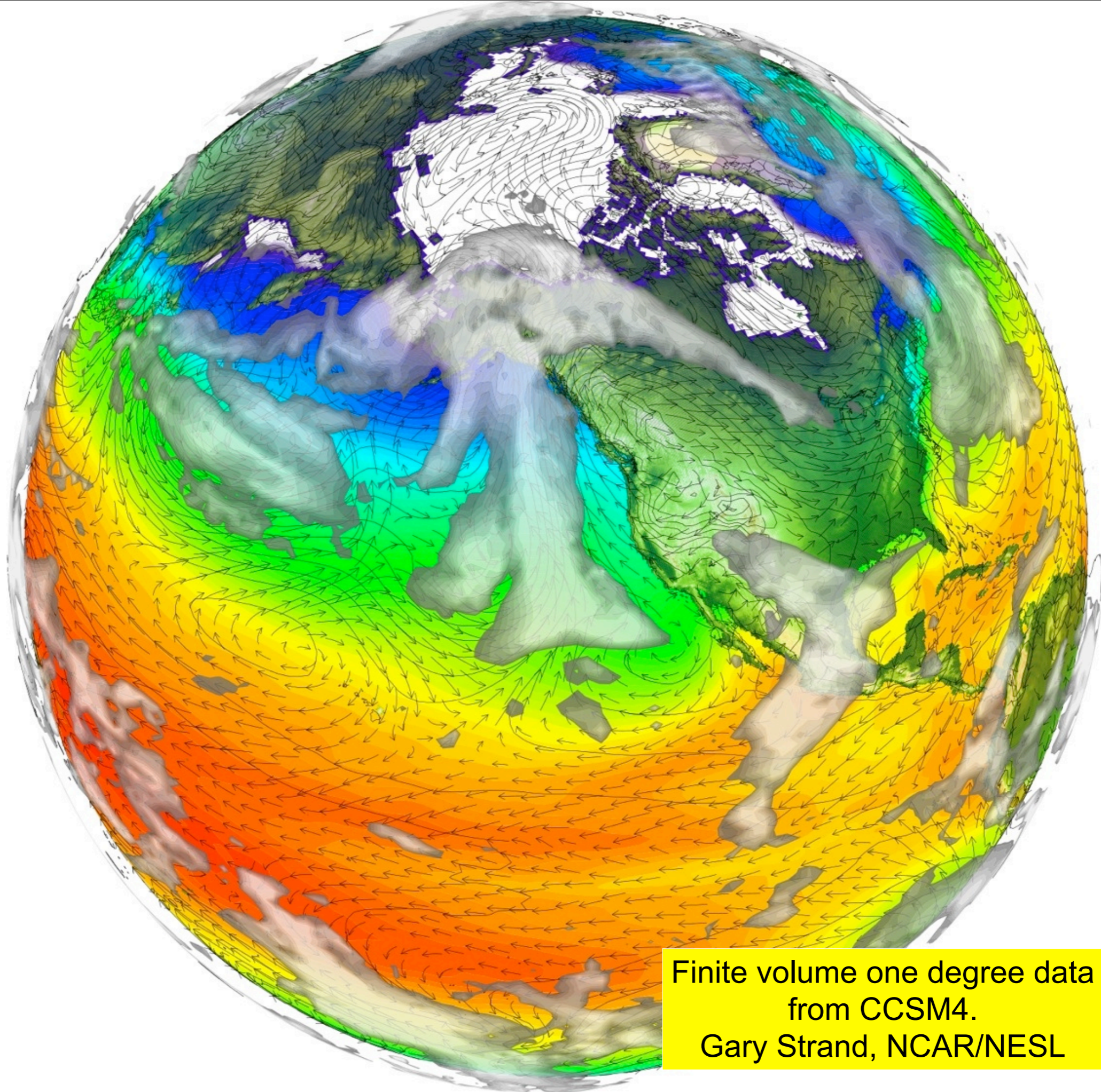


180 150W 120W 90W 60W 30W 0 30E 60E 90E 120E 150E 180



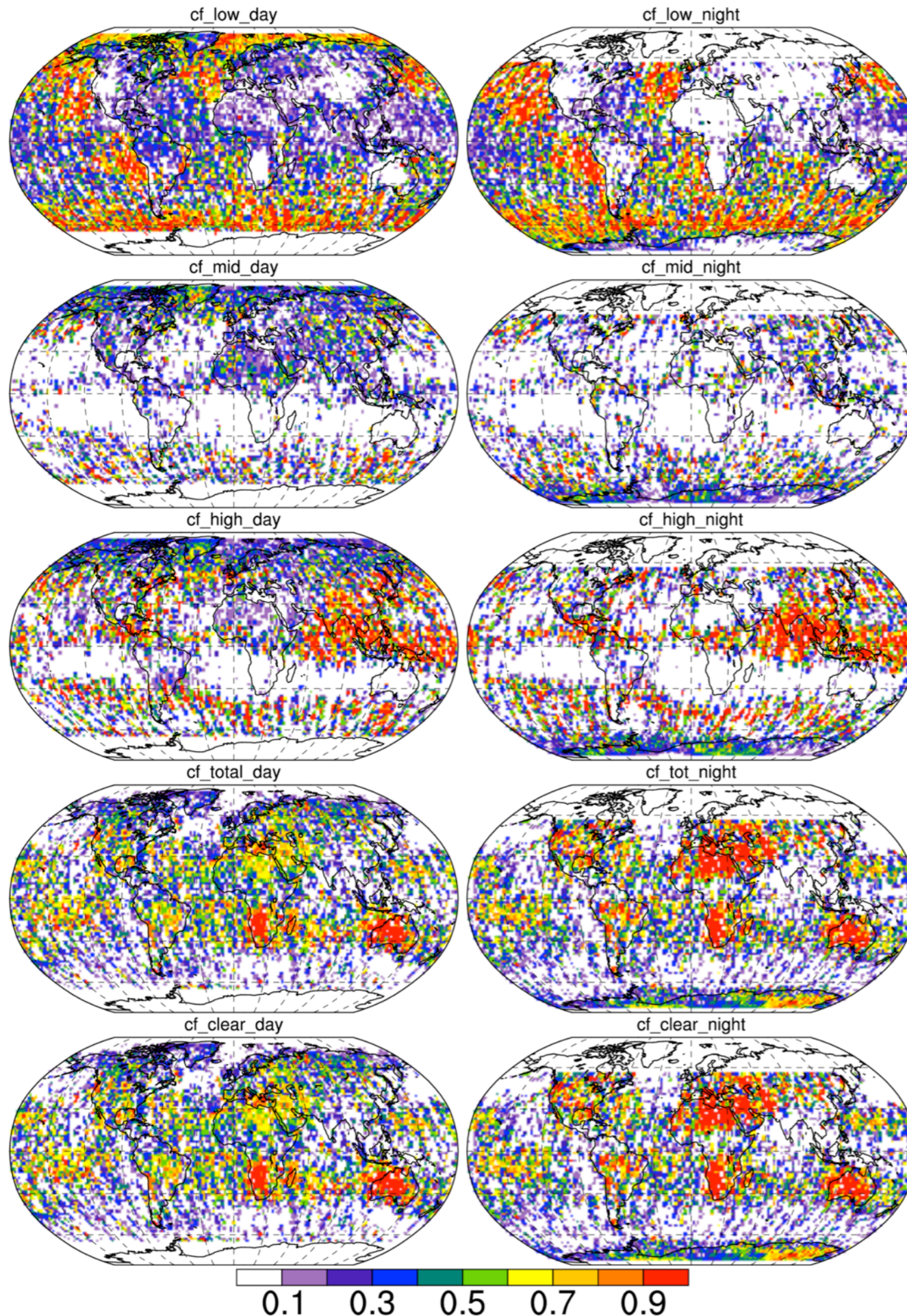
0 70000 140000 210000 280000 350000 420000 490000

High-resolution POP grid from Steve Yeager, NCAR/CGD, 44 CPU seconds



Finite volume one degree data  
from CCSM4.  
Gary Strand, NCAR/NESL

# CALIPSO: Cloud Fraction: calipso\_1: 20060615



**CALIPSO** was launched on April 28, 2006 to study the impact of clouds and aerosols on the Earth's radiation budget and climate.

It flies in formation with five other satellites in the international "A-Train" constellation for coincident Earth observations. The CALIPSO satellite comprises three instruments, the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), the Imaging Infrared Radiometer (IIR), and the Wide Field Camera (WFC).

CALIPSO is a joint satellite mission between NASA and the French Agency, CNES

# NCL/PyNGL visualizations of shapefile data

The ESRI Shapefile is a popular geospatial vector data format for geographic information systems software. It is developed and regulated by ESRI as a (mostly) open specification for data interoperability among ESRI and other software products.

Shapefiles describe a homogeneous set of geometrical features comprised of either points, polylines, or polygons.

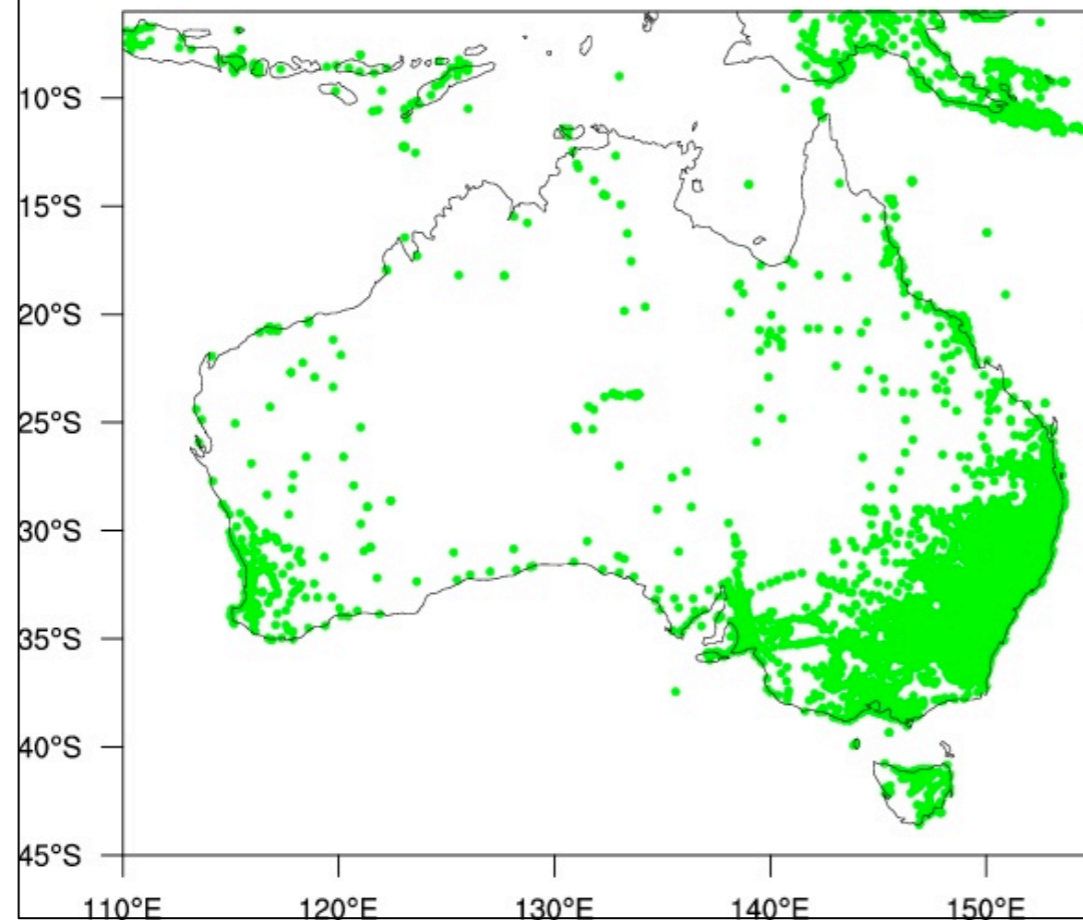
Numerous (and free) shapefiles can be found by googling on the web.

Global Administrative Areas database (<http://www.gadm.org>) offers consistent administrative boundaries at 3 levels. The level 0 database (nations) is good to use for global or mesoscale results, level 1 is the first level of sub-national administration (typically states/provinces and territories) while level 2 offers the second level of administration and is potentially useful for high-resolution plots. The global shapefiles are large but it's possible to download individual countries separately.

<http://www.ncl.ucar.edu/Applications/shapefiles.shtml>



## Places of interest



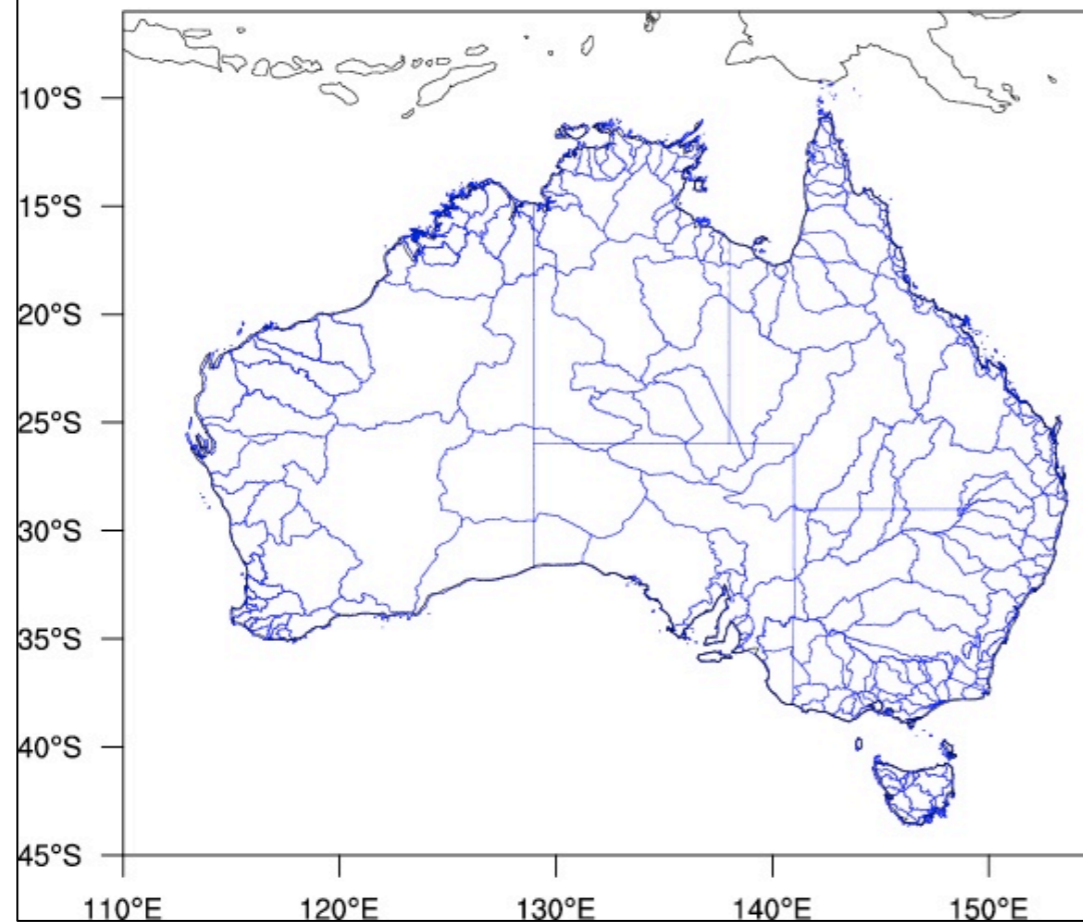
The three types of shapefiles supported by NCL:

**Point** – locations of cities, population data, election results ☺

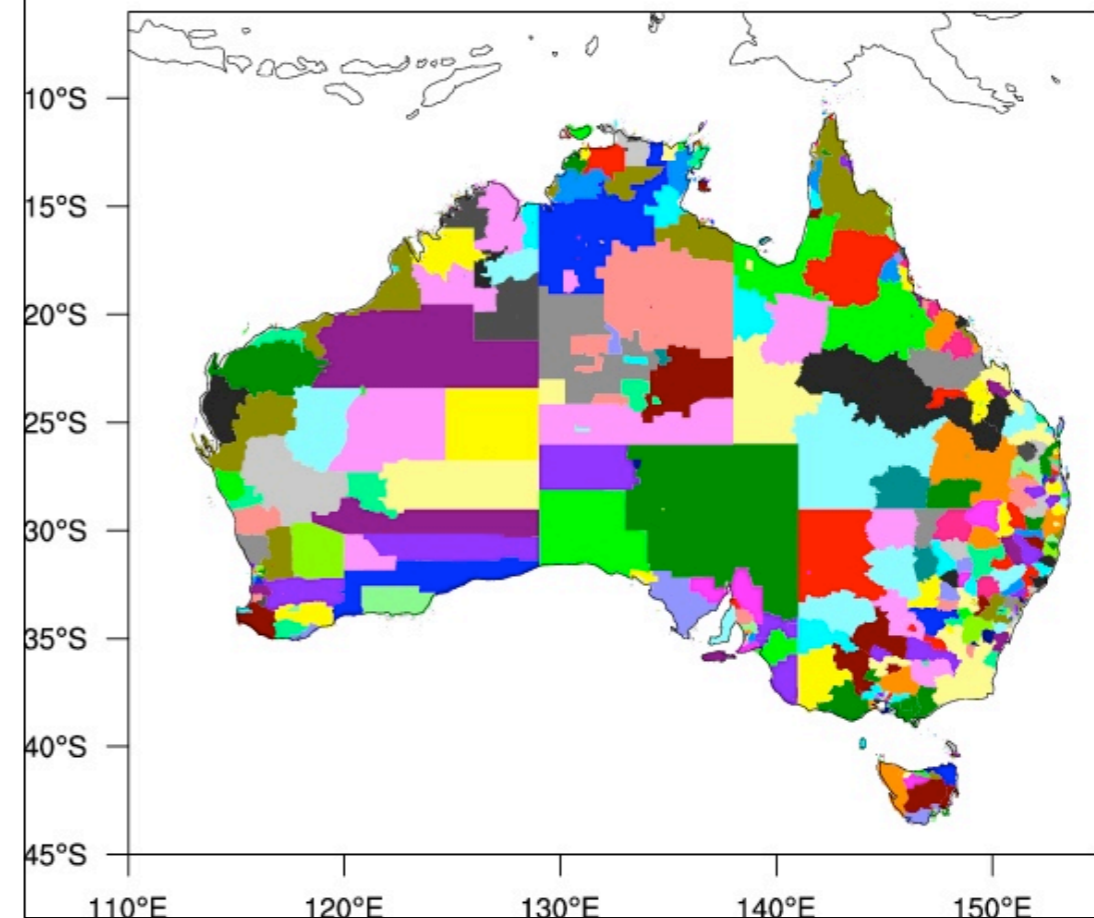
**Line** – rivers, roads, trails

**Polygon** – counties, lakes

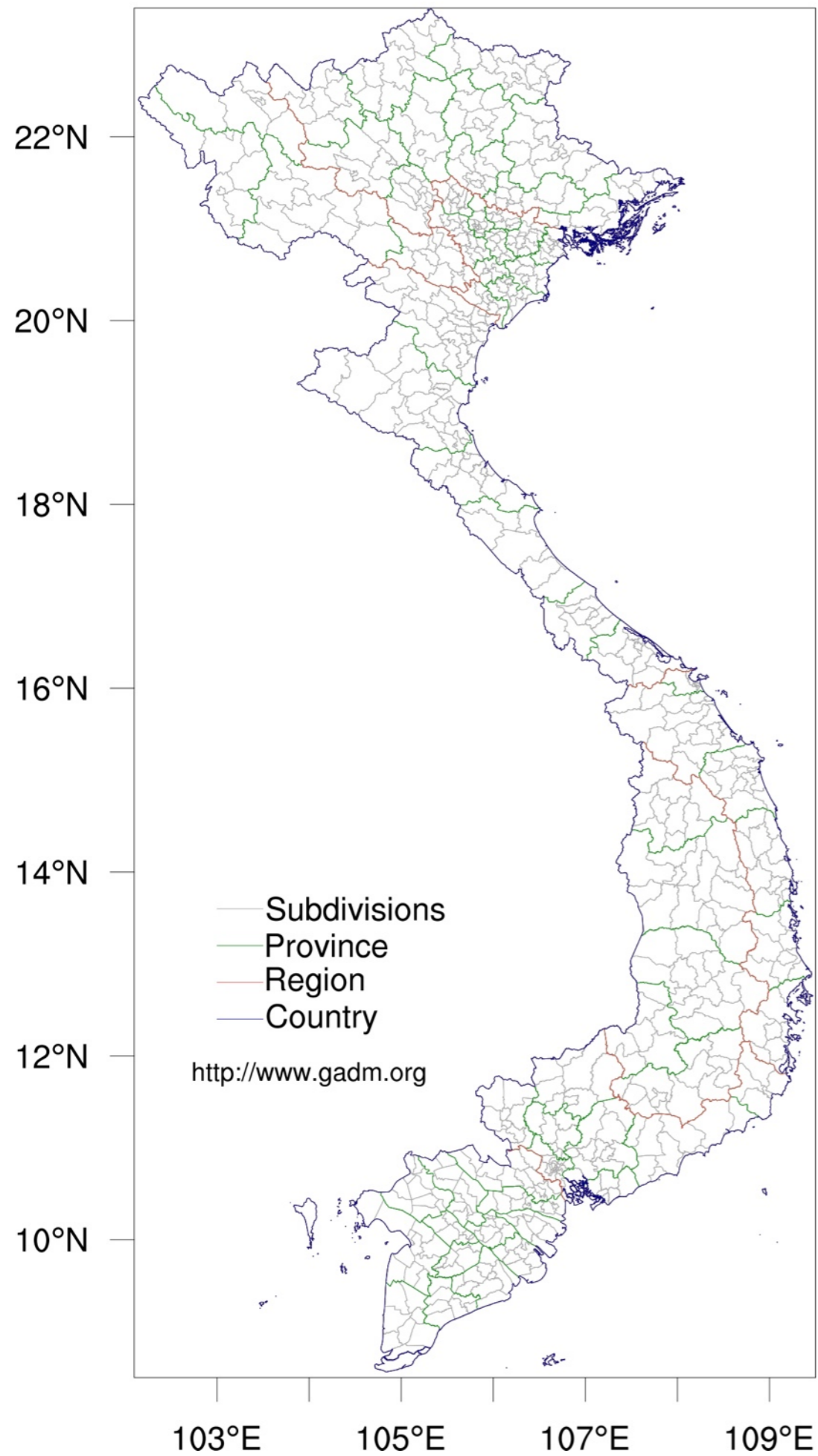
## River Basins



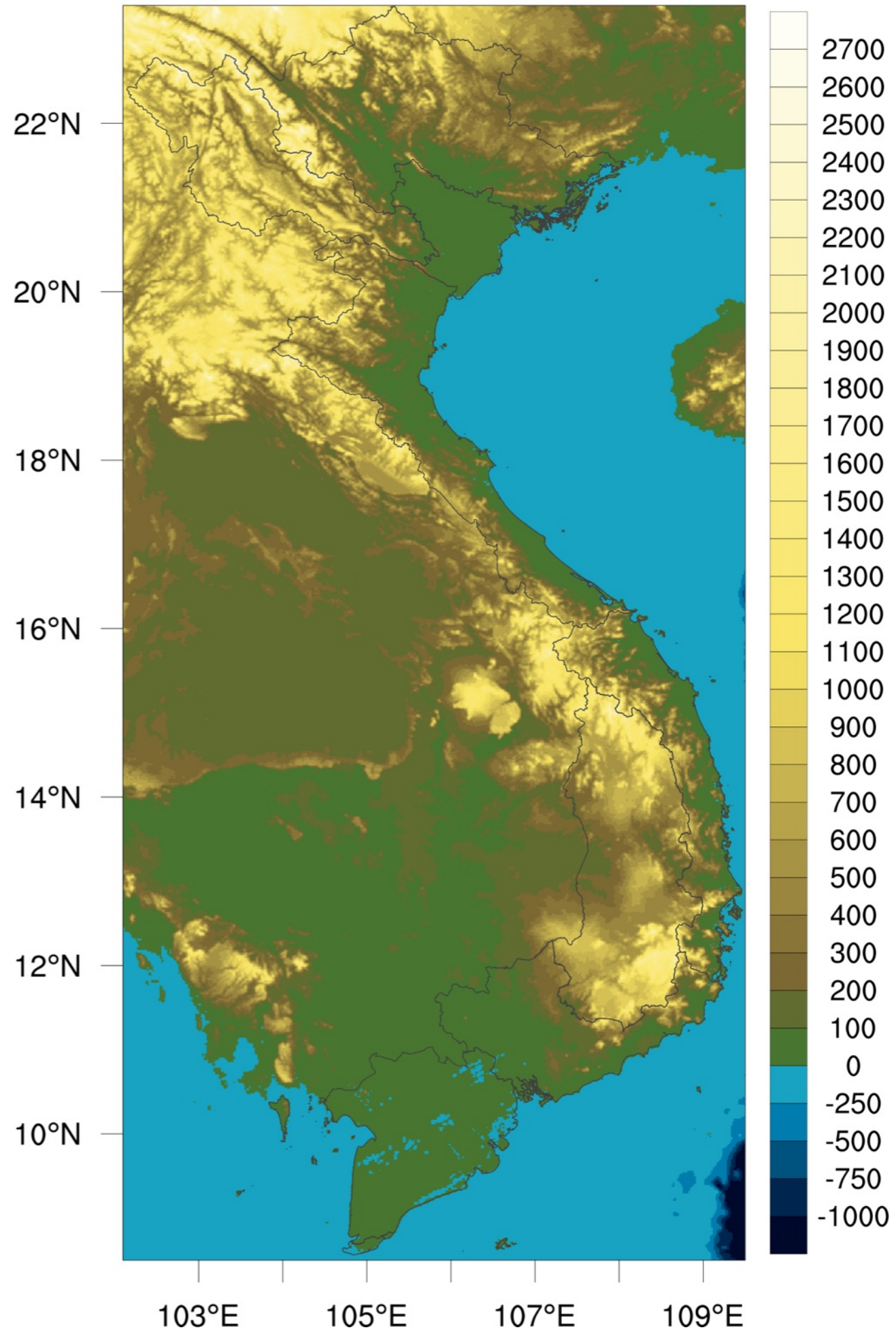
## Indigenous Areas



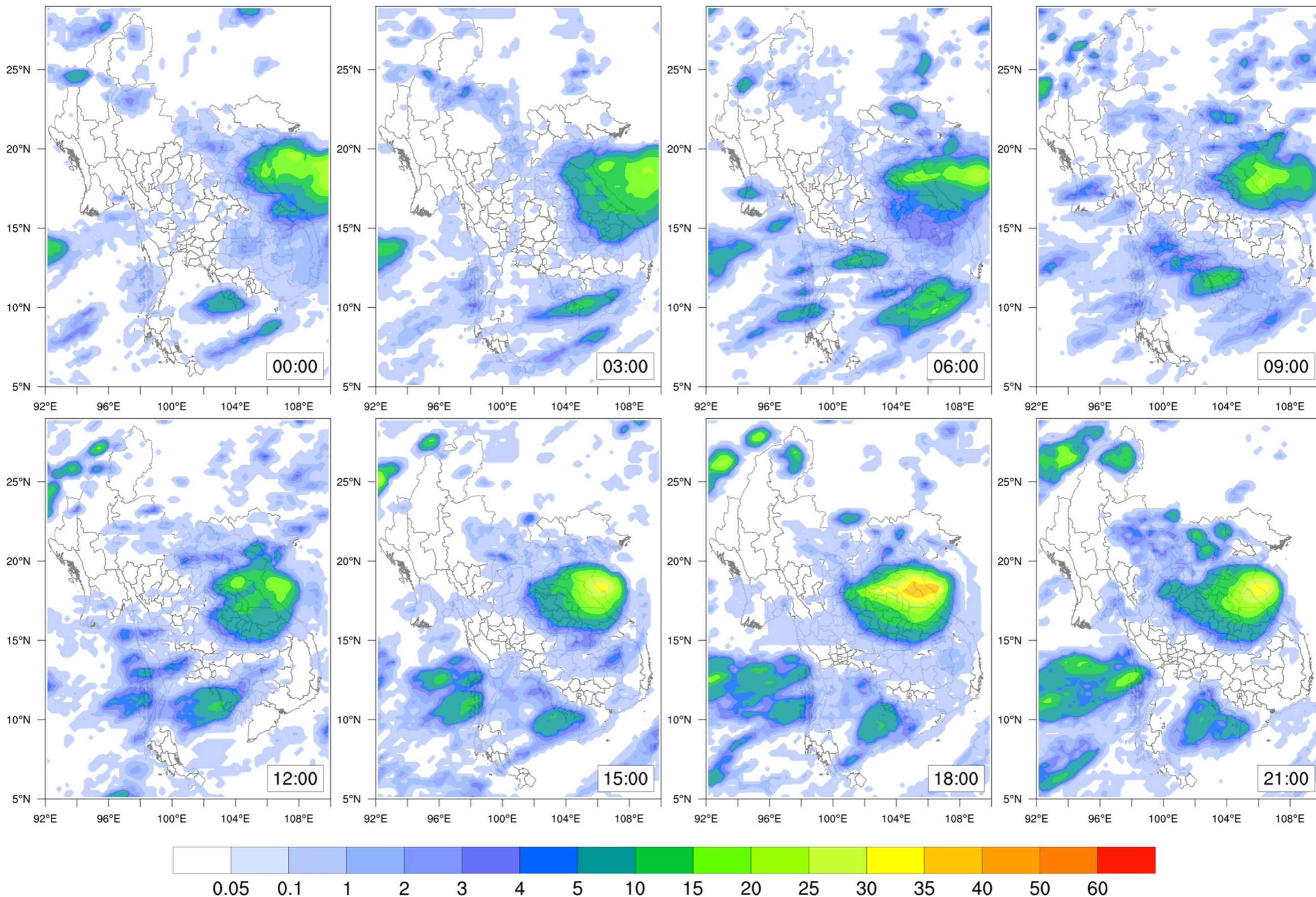
Administrative outlines for Vietnam



ETOPO1\_Bed\_c\_gmt4.grd.nc



# Lower Mekong: PERSIANN precipitation (mm/3hr) Jun 22, 2013



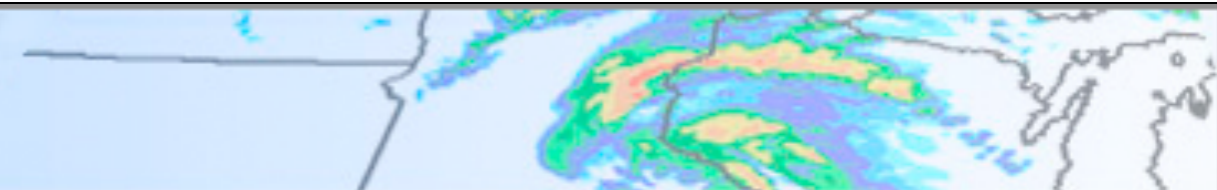
High-resolution precipitation data: <http://chrs.web.uci.edu/persiann/>  
Shapefile outlines: <http://www.gadm.org/country>

# NCL scripts for analyzing and visualizing WRF-ARW data (WRF-NCL)

The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs.

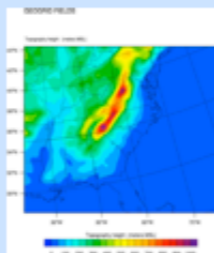
<http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/>





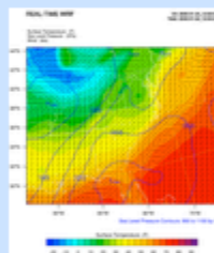
WRF-ARW online tutorial is maintained by Cindy Bruyère and Abby Jaye NCAR/MMM

## Basic Plots



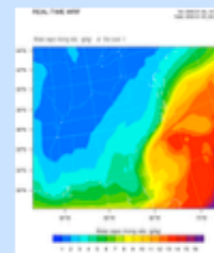
[Basic Plot Setup](#)  
*(This series of examples takes users through same basic steps in generating plotting scripts.)*  
[Get and plot a single field](#)  
[Multiple input files](#)

## Basic Surface Plots



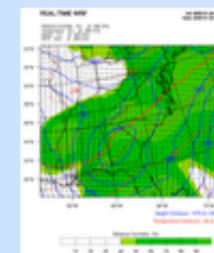
[Surface 1](#)  
[Surface 3](#)  
[Surface 2](#)

## Plots on Model Levels



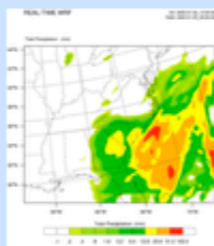
[Clouds](#)  
[Levels from wrfout files](#)  
[Levels from metgrid files](#)

## Plots on Interpolated Levels



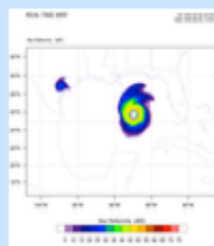
[Height Levels](#)  
[Pressure Levels](#)

## Plotting Precipitation



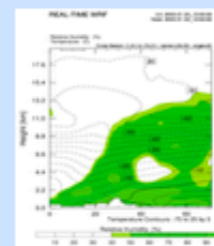
[Precipitation](#)

## Diagnostics



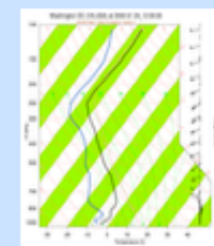
[CAPE](#)  
[dBZ](#)  
[Vorticity](#)  
*(More diagnostics are available, shown are only some newer/special diagnostics)*

## Cross-section Plots



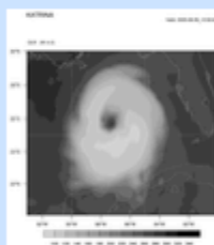
[Height - Through a Pivot Point](#)  
[Height - Point A to Point B](#)  
[Pressure](#)  
[Limited Vertical Extent](#)  
[For 2D fields](#)

## Skew\_T Plots



[Skew\\_T](#)

## Speciality Plots



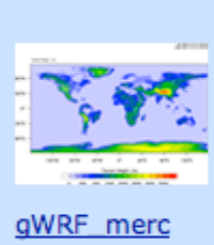
[Overlay](#)  
[Zoom](#)  
[Overlay & Zoom](#)  
[Panel 1](#)  
[Panel 2](#)  
[Metograms](#)  
[WRF Time Series data](#)  
[All fields in a file](#)

## Preview Domain



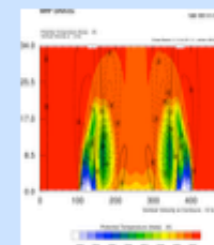
*This functionality, although available in NCL version 5.0.1, is still experiential.*  
[Preview](#)

## Global WRF



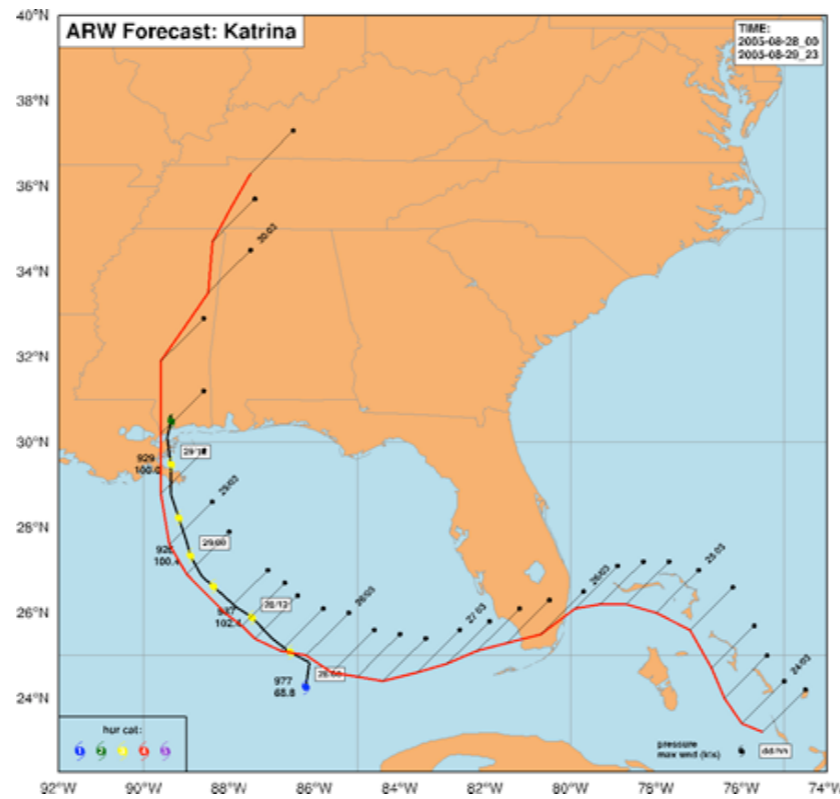
[qWRF\\_merc](#)

## Idealized cases



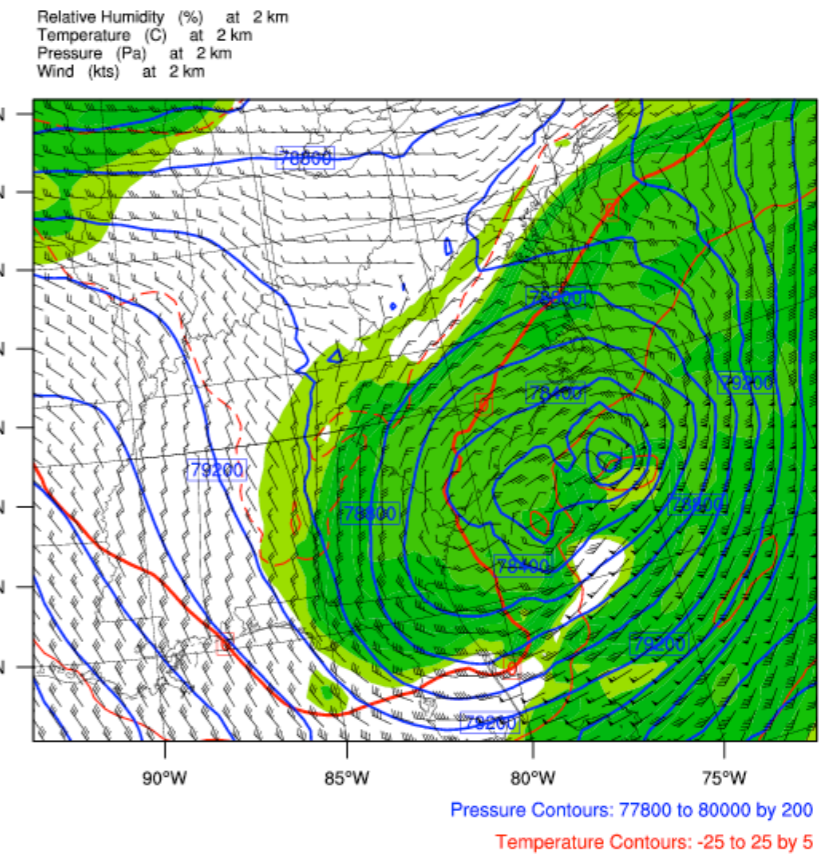
[wrf\\_Grav2x](#)  
[wrf\\_Hill2d](#)  
[wrf\\_Squall\\_2d\\_x](#)  
[wrf\\_Squall\\_2d\\_y](#)  
[wrf\\_Seabreeze2x](#)  
[wrf\\_BWave](#)  
[wrf\\_QSS](#)

# Sample WRF graphics generated by NCL



## REAL-TIME WRF

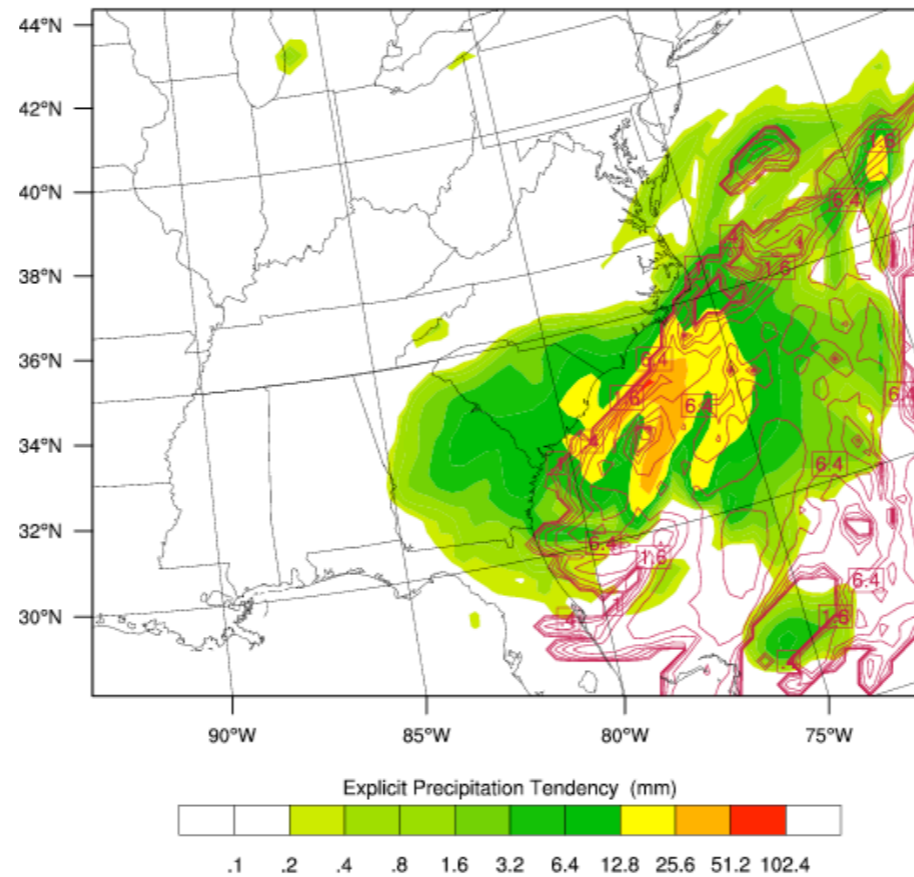
Init: 2000-01-24\_12:00:00  
 Valid: 2000-01-25\_00:00:00



## REAL-TIME WRF

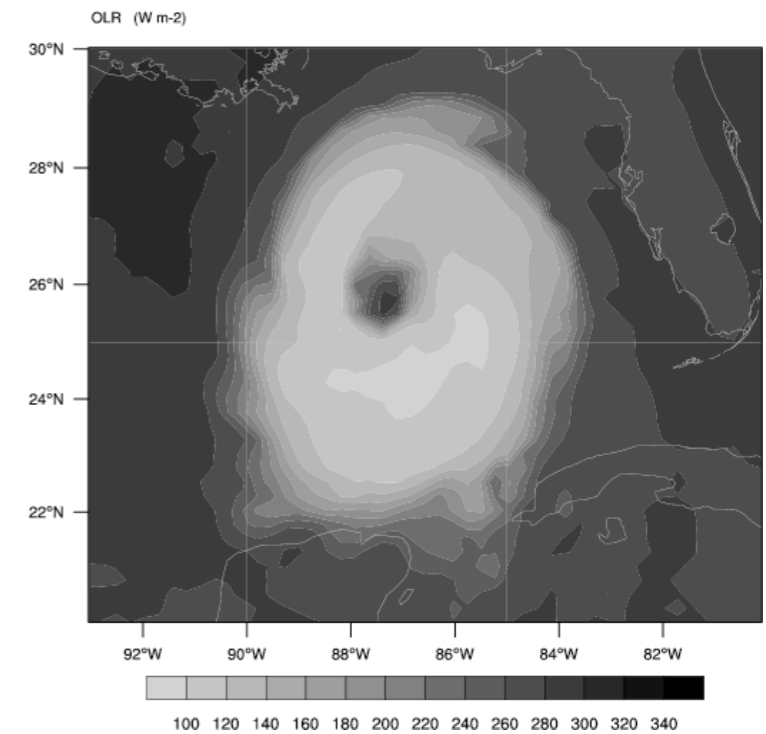
Init: 2000-01-24\_12:00:00  
 Valid: 2000-01-25\_00:00:00

Explicit Precipitation Tendency from 2000-01-24 18:00:00 to 2000-01-25 00:00:00 (mm)  
 Param Precipitation Tendency from 2000-01-24 18:00:00 to 2000-01-25 00:00:00 (mm)



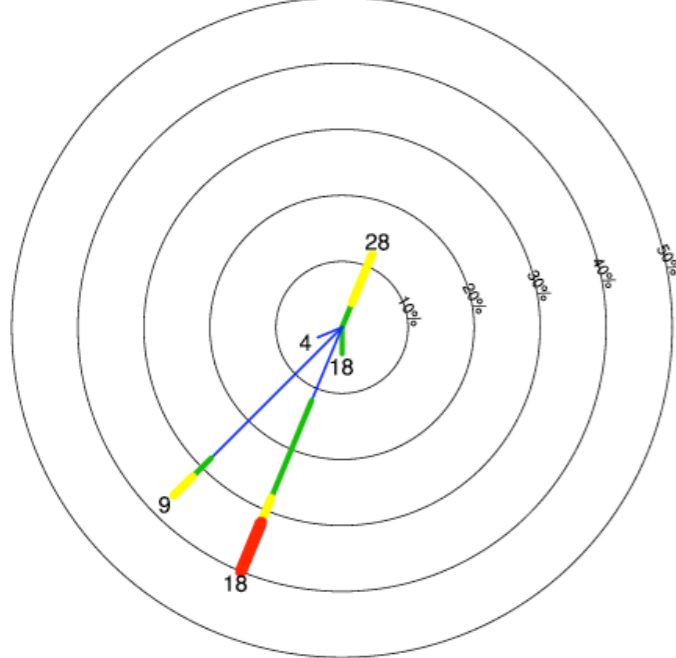
## KATRINA

Valid: 2005-08-28\_12:00:00



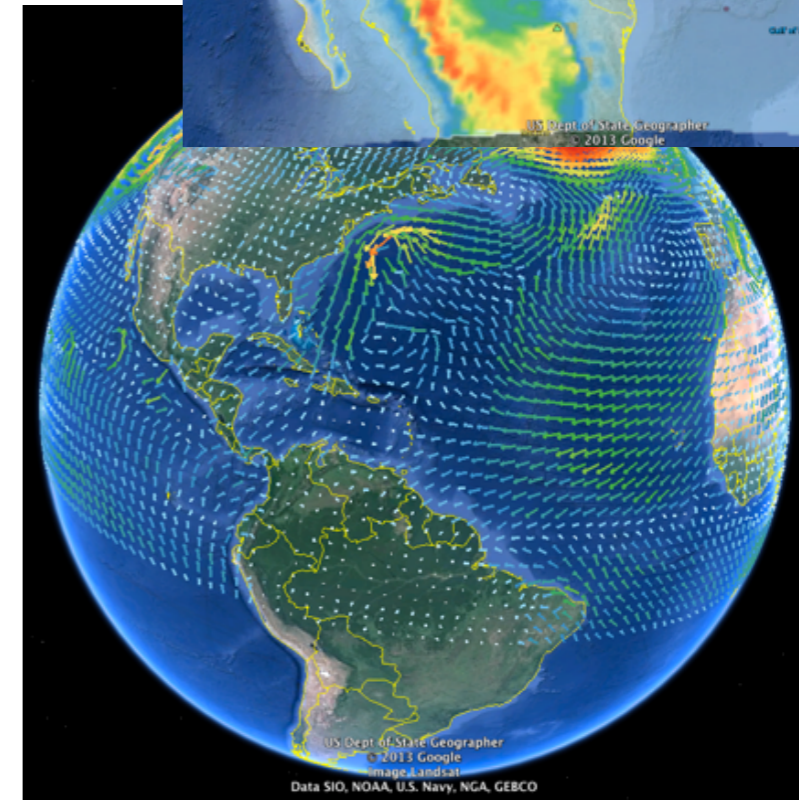
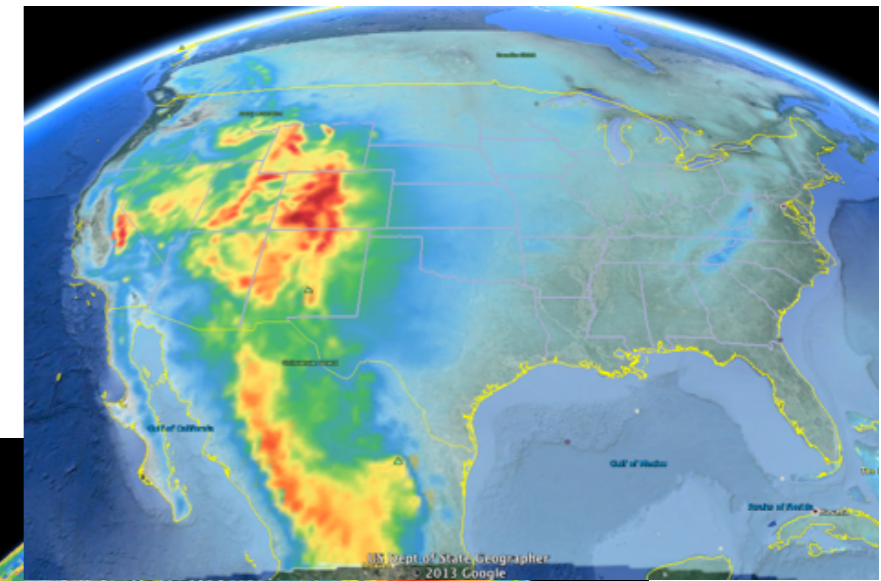
## WRF: All Times: grid point [25.65, -87.37]

SpdAve=16 SpdStd=11 DirAve=216 No Calm Reports Nwnd=25  
 Frequency circles every 10%. Mean speed indicated.



# NCL and GoogleEarth™

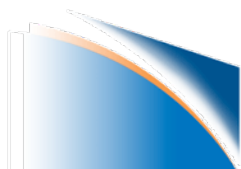
- Summer intern project in CISL
- Google Earth™ offers a highly intuitive and usable visualization environment for displaying Earth science data in its geospatial context.
- A library of NCL routines has been developed to enable earth scientists to easily convert geo-referenced model output and other data to KML for display in Google Earth.



Discovering, accessing, and analyzing diverse data sources can be difficult and time consuming! Training can be very beneficial.

*"The Complexities of individual data sources or models tend to absorb individual scientists and science teams. This limits the synergistic combination of data sources and science teaming."*

-- Chris Elvidge, earlier at this meeting

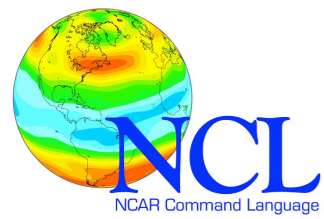


**NCAR**



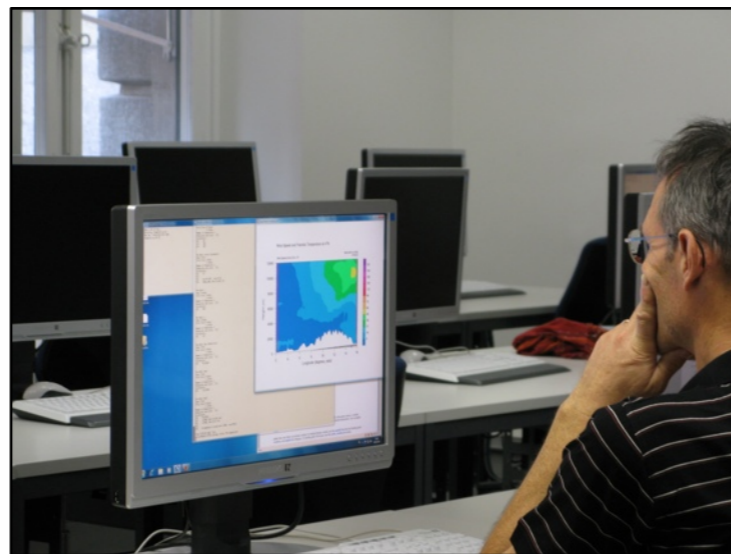
# NCL Data Analysis and Visualization Workshops

- Primarily for climate and weather researchers
- 3.5 days with lectures and intensive hands-on lab sessions
- Co-taught by NCAR scientific and engineering staff
- Students encouraged to BYOD (Bring Your Own Data)
- Free for all students; full funding provided for EPSCoR and MSI students; partial funding provided for U.S. universities
- Workshops given locally and at universities and research institutions world-wide
- 73 workshops taught to 1139 students since February 2000





MPI Hamburg 2008-2013



ETH Zürich 2010



UNSW Sydney 2011



BoM Melbourne 2011

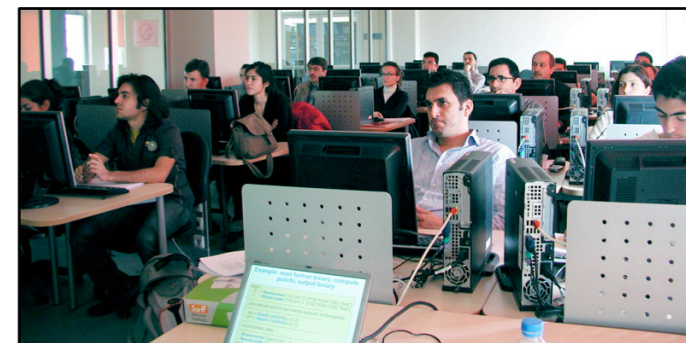


CERFACS Toulouse 2012



UFRN Natal 2013

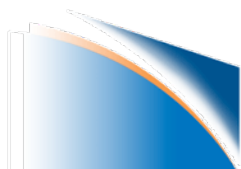
# International Workshops



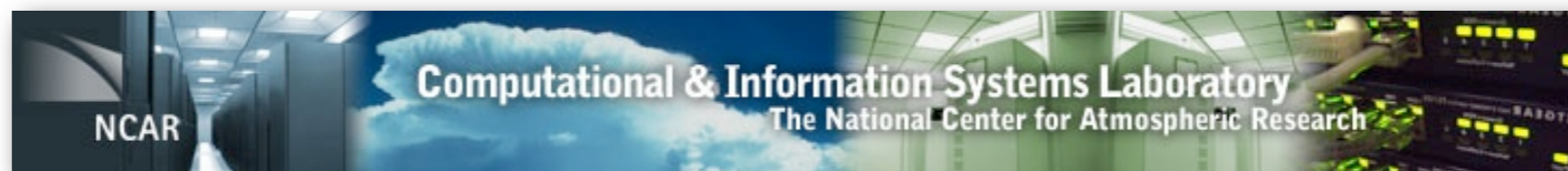
APEC Busan 2006

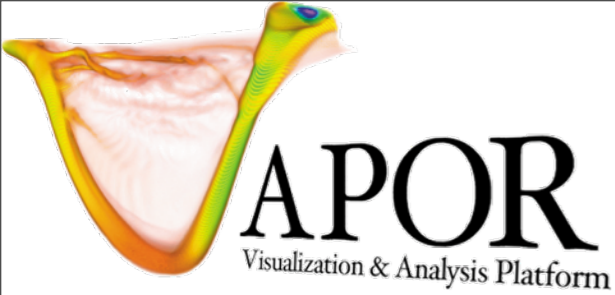
# VAPOR

Courtesy of John Clyne, NCAR/CISL/OSD



**NCAR**





# VAPOR

Visualization aided data analysis for the earth sciences

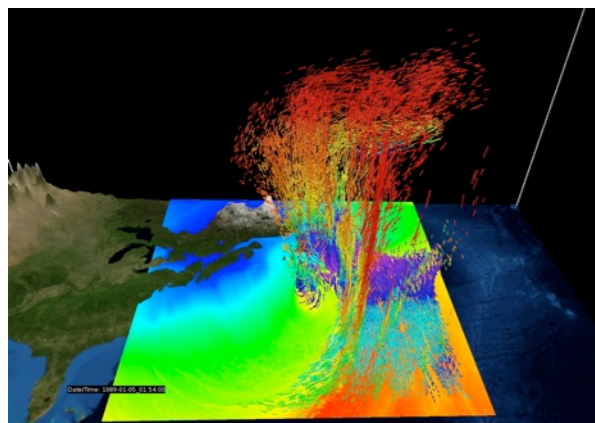
- A **domain-focused, open source** visual data analysis package targeted for researchers working in **numerical weather prediction, atmospheric, oceanic, and related sciences**
- By leveraging a wavelet-based *intelligent data storage* model VAPOR enables highly interactive exploration of the **largest numerical simulation** outputs using only **commodity computing** resources.
- A **community-driven** feature set guided by an international steering committee of computational scientists working in a broad gamut of earth science disciplines
- Metrics:
  - ~6000 registered users since January, 2011
  - ~4000 unique VAPOR web site visitors per month in 2013 (up from 1000 in 2012, and 500 in 2011)
  - ~100 scholarly citations for VAPOR



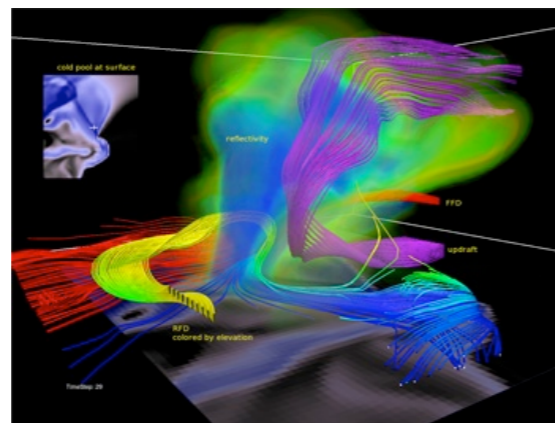
I. Grooms, et al. 2010



S. Wedemeyer-Böhm, et al. 2012



M. Shapiro; S. Grønås, 2012



L. Orf, 2009

[www.vapor.ucar.edu](http://www.vapor.ucar.edu)

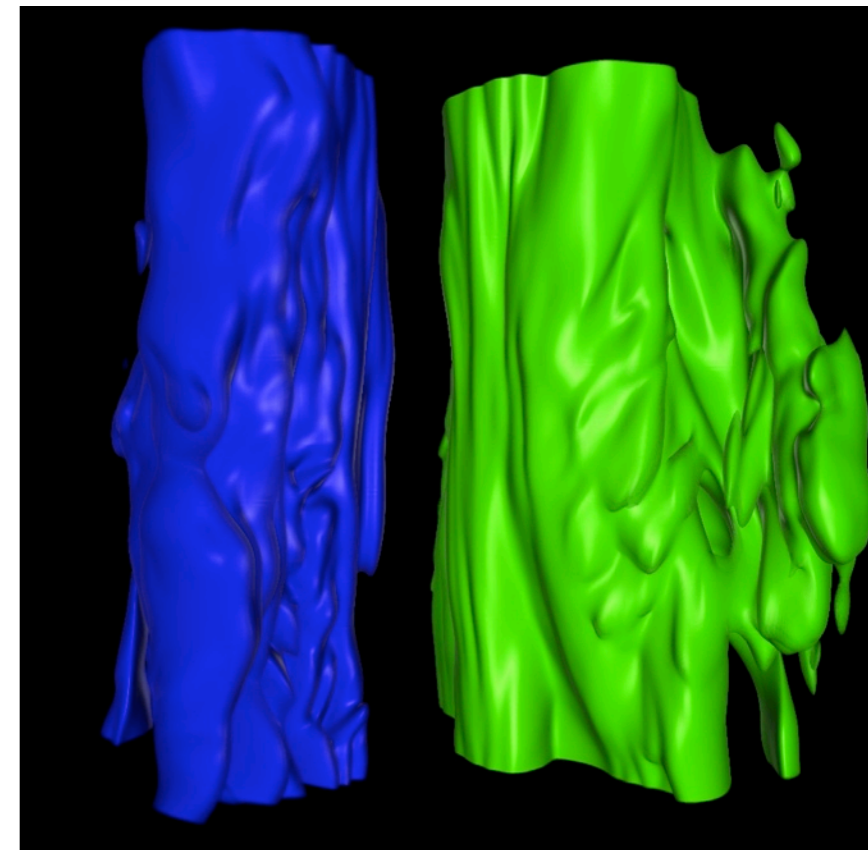
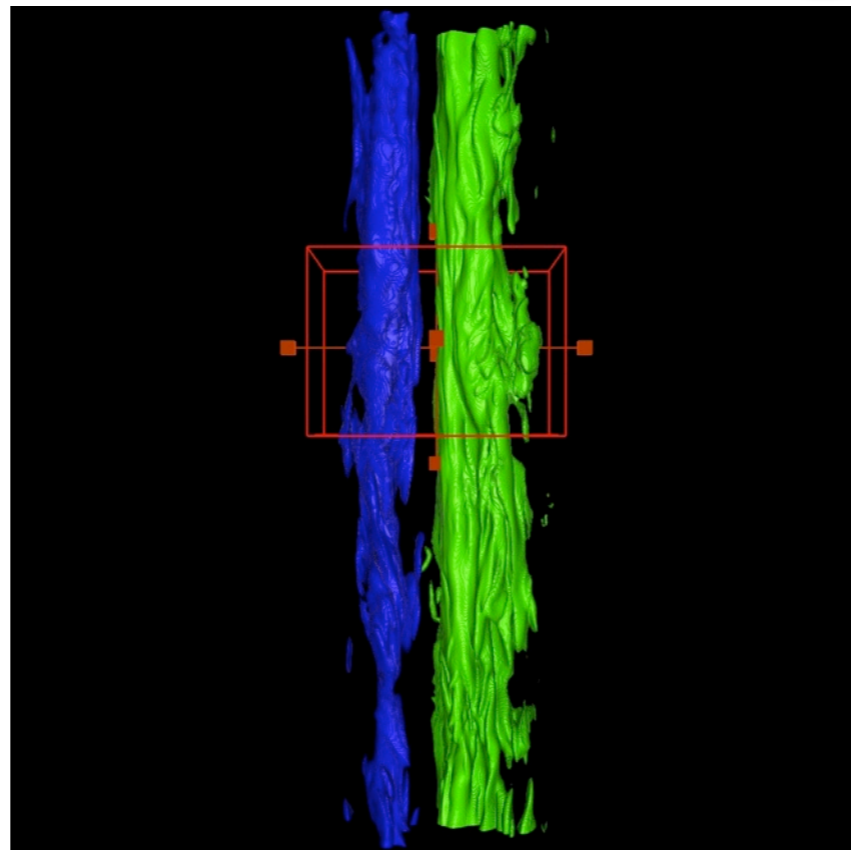
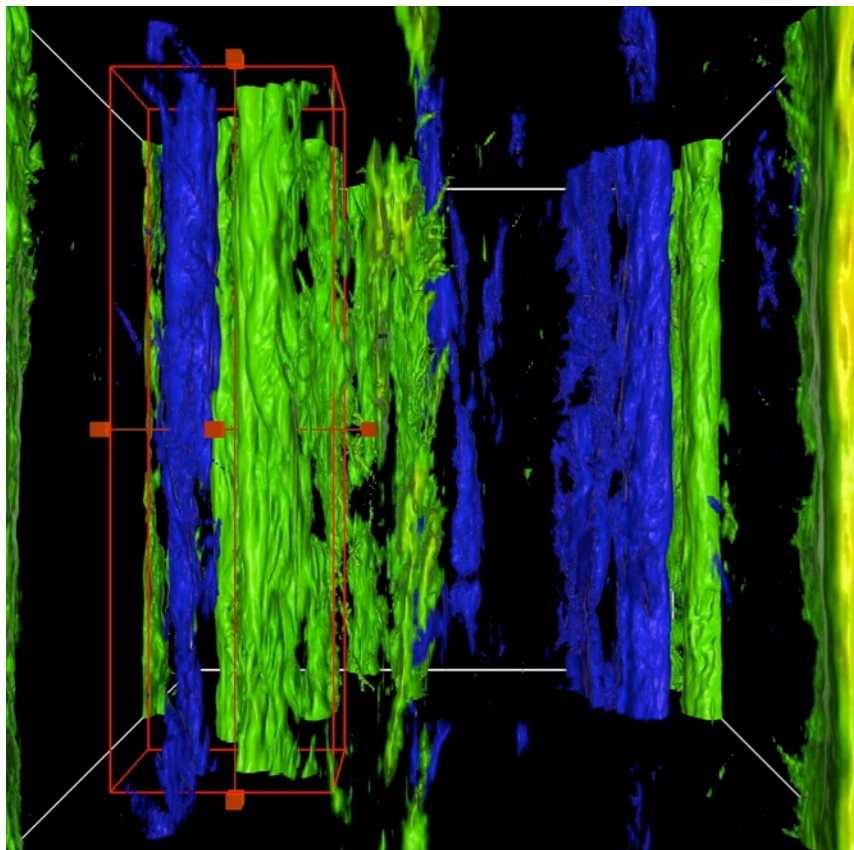
VAPOR is funded in part through U.S. National Science Foundation grants 03-25934 and 09-06379, 14-40412, a TeraGrid GIG award, and the Korean Institute for Science and Information Technology



# Wavelet Enabled Progressive Data Refinement

Exploring a  $1536^3$  simulation output on a laptop

Browse highly compressed data, subset, refine, repeat.



Full domain, compressed 500:1  
14GBs -> 29MBs

Region of interest (ROI), 100:1  
800MBs -> 8MBs

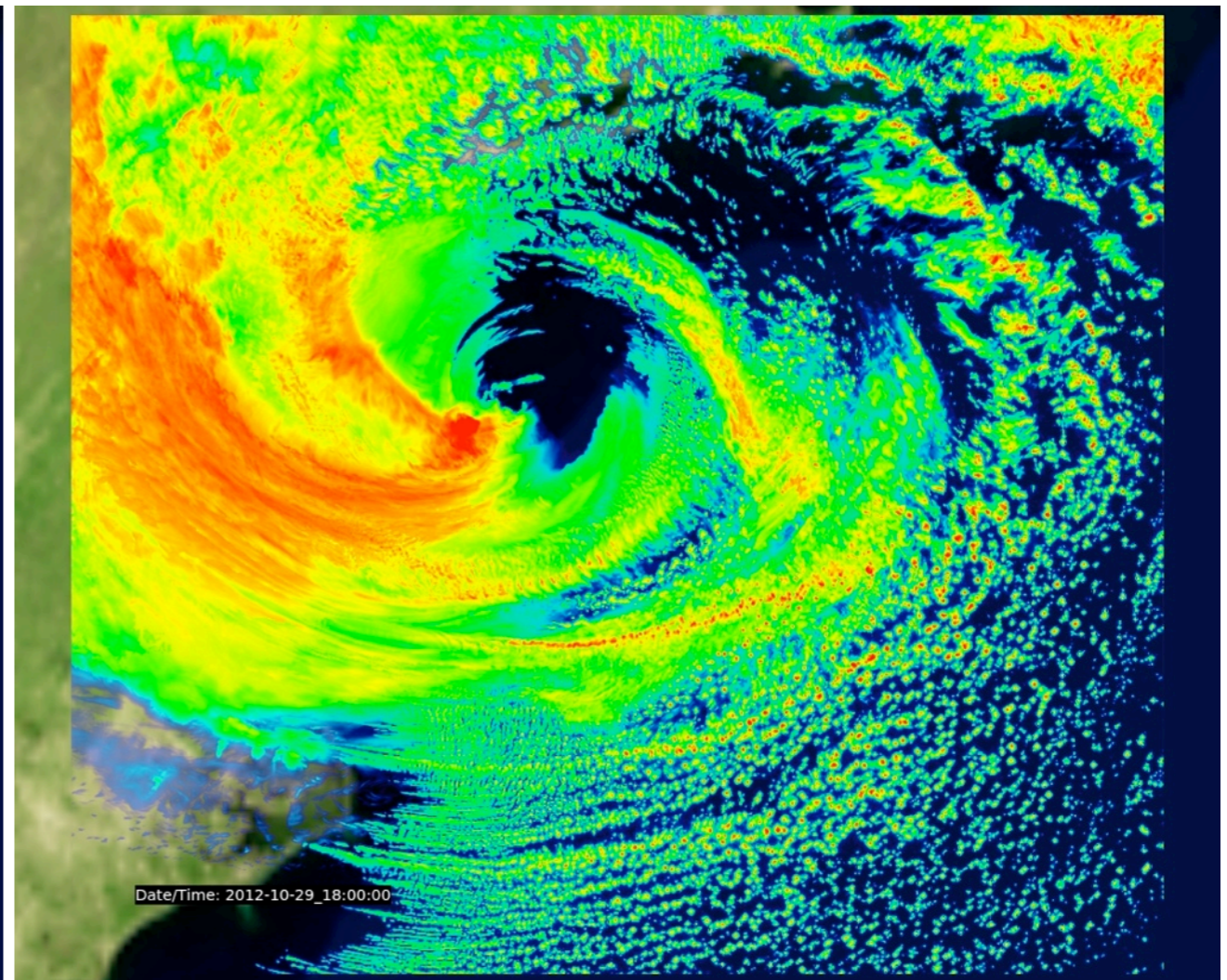
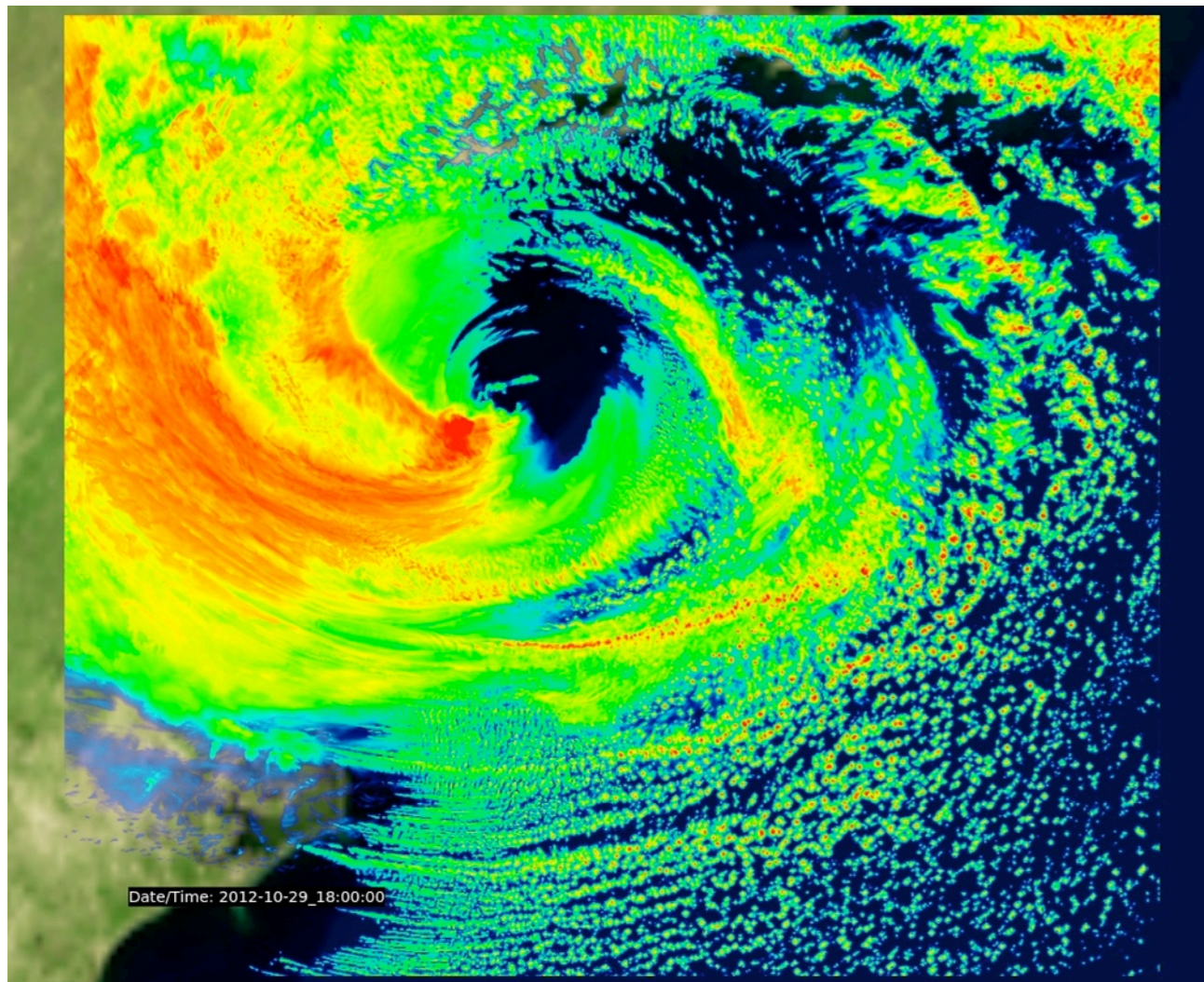
ROI, No compression  
182MBs



# Radar reflectivity derived from a 500m Weather Research Forecast simulation of Hurricane Sandy, the largest NWP model ever run [Johnsen 2013]

DBZ computed from original data (203 GBs)

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



## Supported file formats & model outputs

- Climate Forecast (CF) convention NetCDF files
  - MOM4
  - POP
  - ROMS
  - CAM
- WRF outputs
- NetCDF (structured grid data)
- Flash AMR
- Raw (binary) data

## Features

GPU enabled volume rendering and isosurfaces

Cutting planes

Isolines

Flow visualization

Streamlines (steady flows)

Pathlines (unsteady flows)

Image Based Flow Vis.

Hedgehog plots (wind barbs)

Geo-referenced data support

NumPy/SciPy calculation engine

Key-frame animation

Quantitative analysis

Probes

Statistics

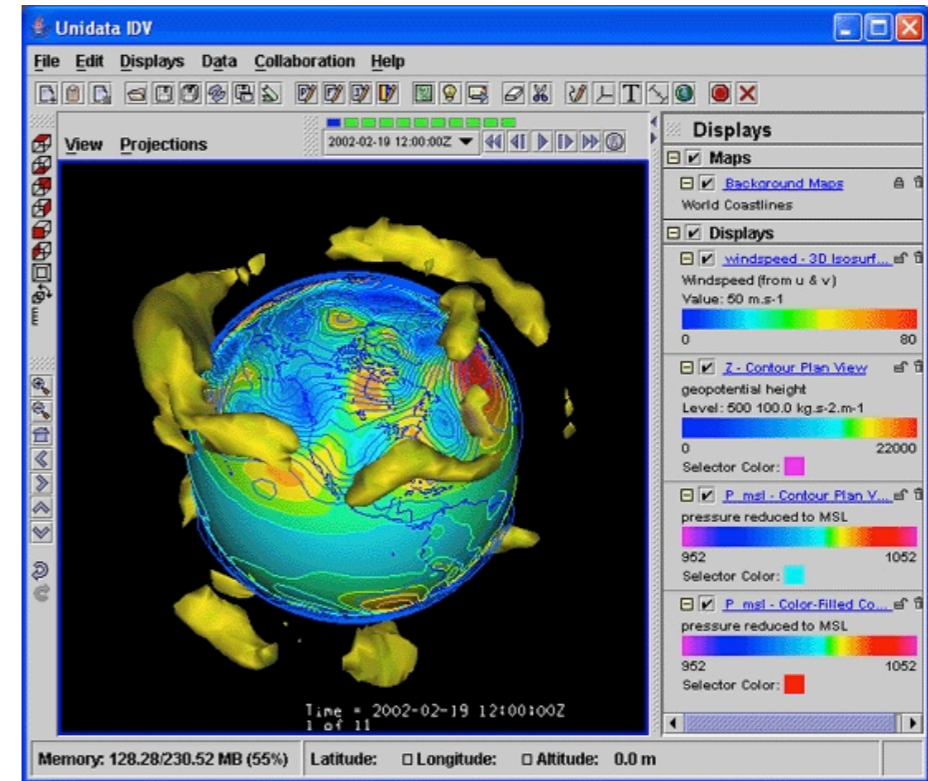
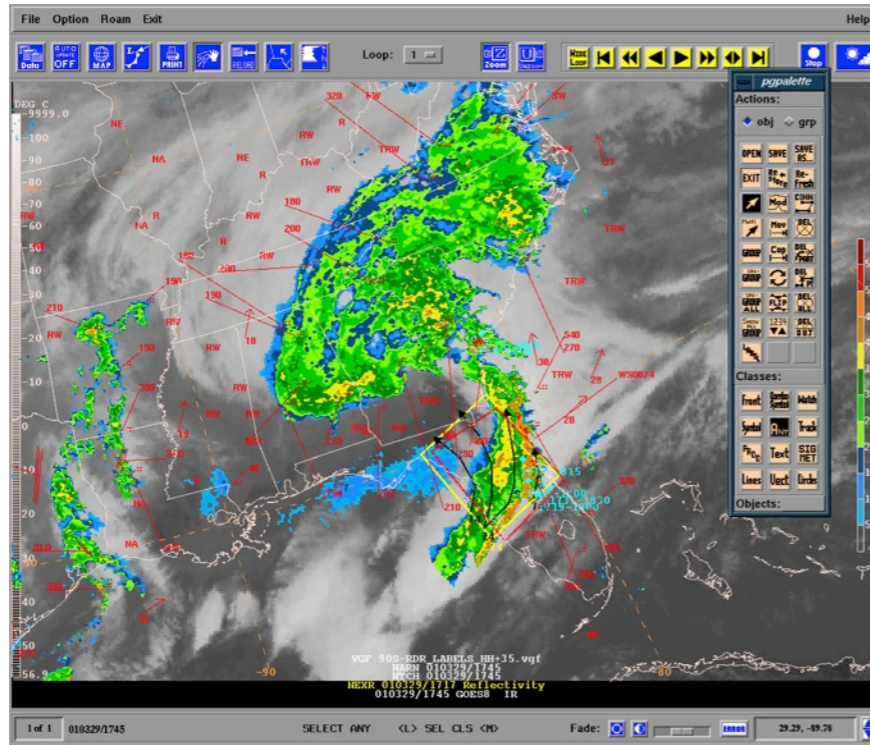
# UCAR/Unidata Tools

Courtesy of Mohan Ramamurthy, UCAR/Unidata

<http://www.unidata.ucar.edu>

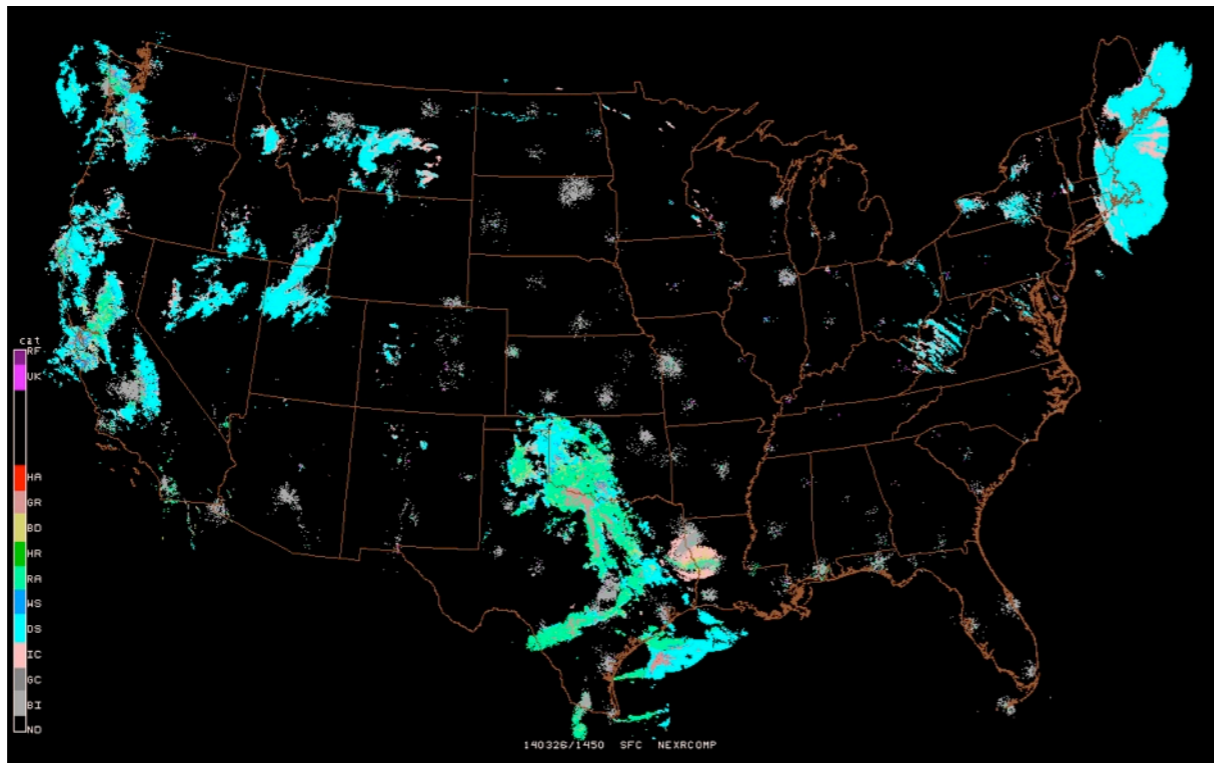
# Unidata Visualization Software

**GEMPAK**

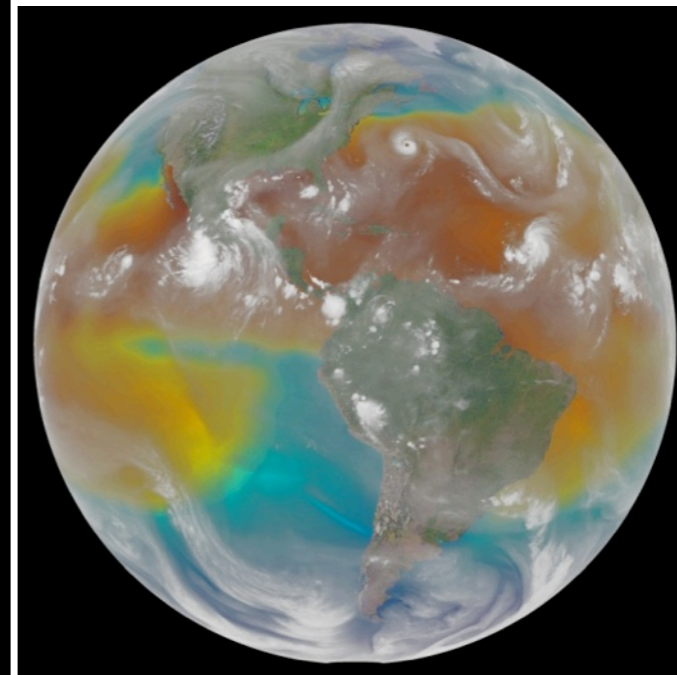


**IDV**

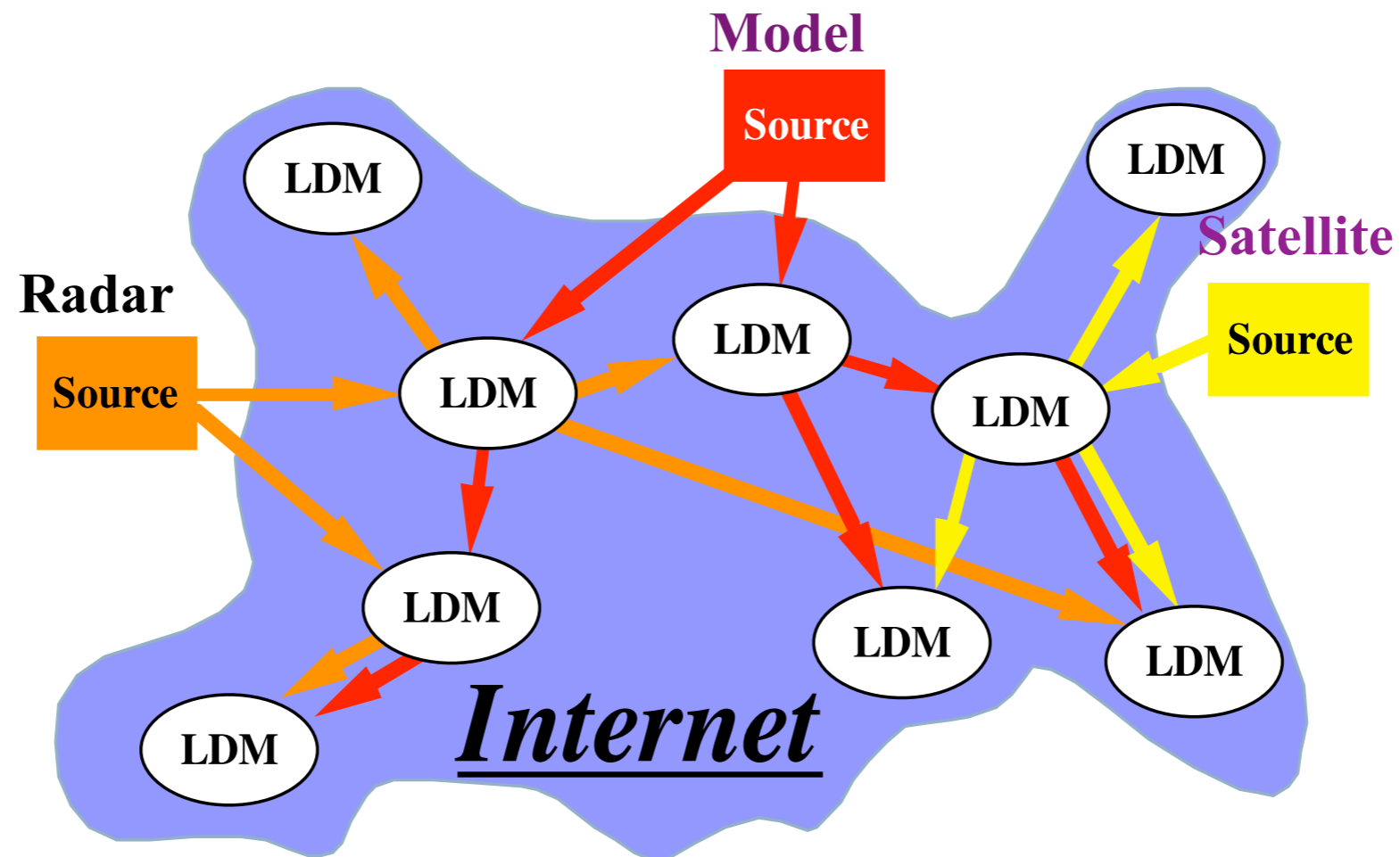
**AWIPS II**



**McIDAS-X**



# Real-time Data Distribution



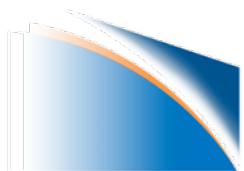
About 30 different streams of real-time weather data from diverse sources are provided to a global community.

Unidata systems move more data (~30 Terabytes/week) via Internet 2, more than any other advanced application.

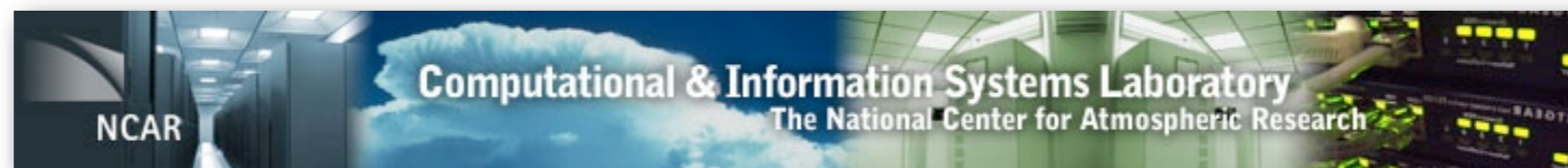
# Globus Transfer

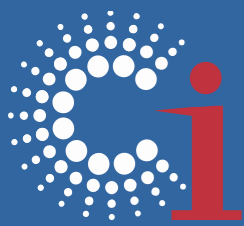
Courtesy of Rachana Ananthakrishnan and Ian Foster,  
Computation Institute, Univ. of Chicago

<https://www.globus.org>

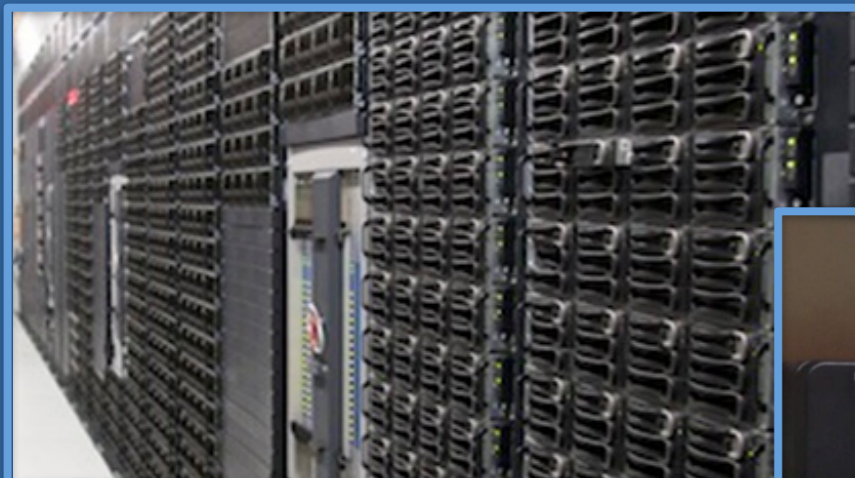


**NCAR**

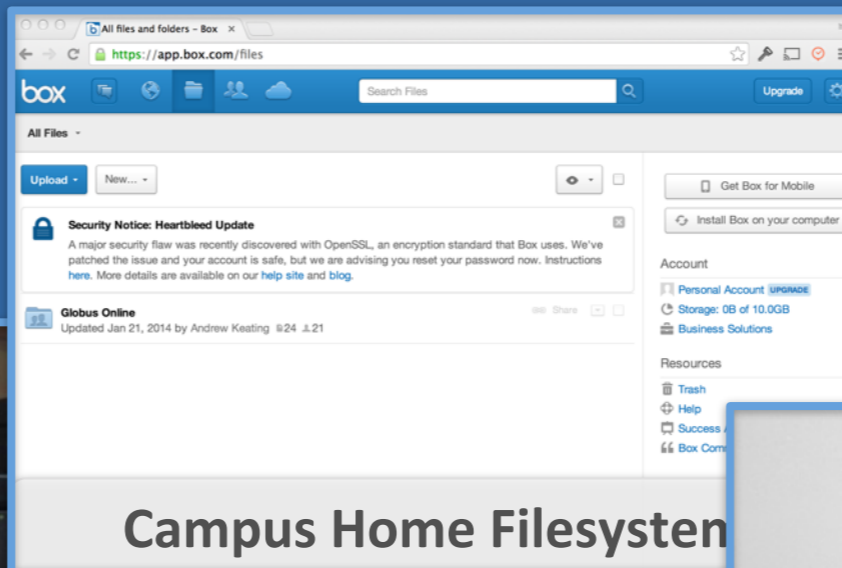




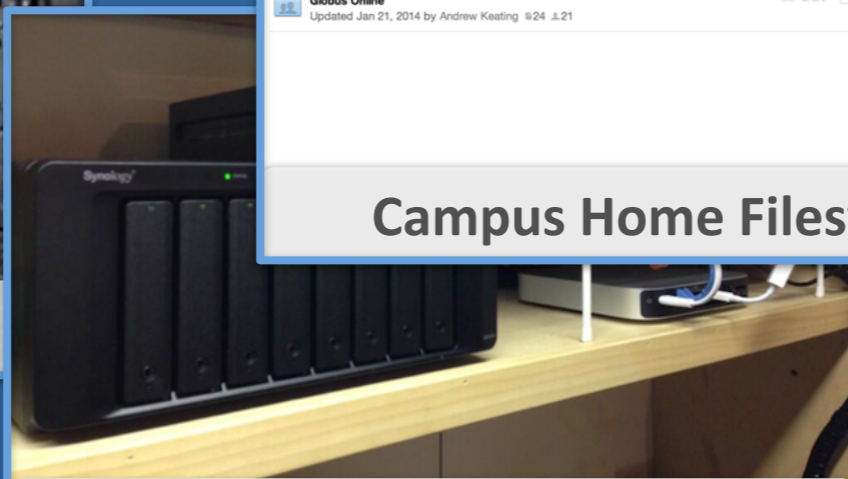
“I need to easily, quickly, & reliably move or mirror portions of my data to other places.”



Research Computing HPC Cluster



Campus Home Filesystem



Lab Server



Personal Laptop



Desktop Workstation

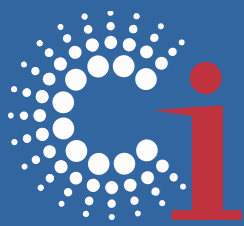


XSEDE Resource



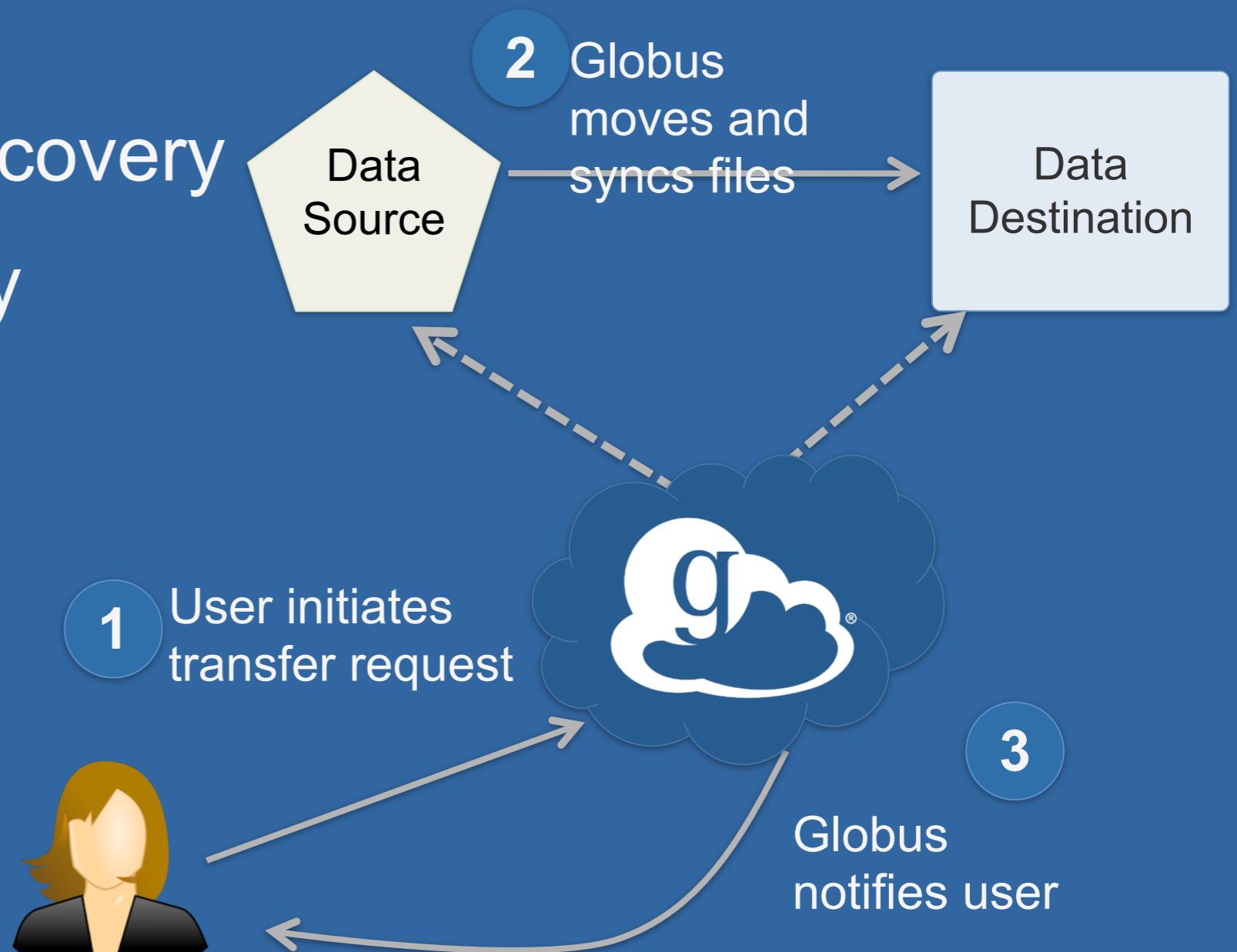
Public Cloud

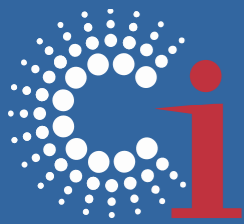




# Reliable, secure, high-performance *file transfer* and *synchronization*

- “Fire-and-forget” transfers
- Automatic fault recovery
- Seamless security integration
- Powerful GUI and APIs





# Transfer Files



Manage Data

Groups

Support

ranantha

Transfer Files

Activity

Manage Endpoints

Dashboard

Flight Control

## Transfer Files

Get Globus Connect Personal

Turn your computer into an endpoint.

Endpoint  ... Go

Path  Go

Endpoint  ... Go

Path  Go

select all | none   up one folder   refresh list

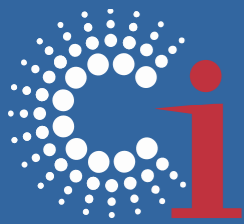
scratch-midway	Folder
share	Folder

select all | none   up one folder   refresh list

user2	Folder
vytas	Folder
CASC Registration Form - April 2014-Rachana.docx	13.16 kB
NAMD_2.9_Linux-x86_64-multicore.tar.gz	2.75 MB
test2.txt	28 b
test3.txt	32 b

more options   Label This Transfer

This will be displayed in your transfer activity.



# Transfer Options

▲ less options

Label This Transfer

This will be displayed in your transfer activity.

Transfer Settings

- only transfer new or changed files where the
- delete files on destination that do not exist
- preserve source file modification times ?
- verify file integrity after transfer ?
- encrypt transfer ?

- checksum is different
- file does not exist on destination
- file size is different
- modification time is newer

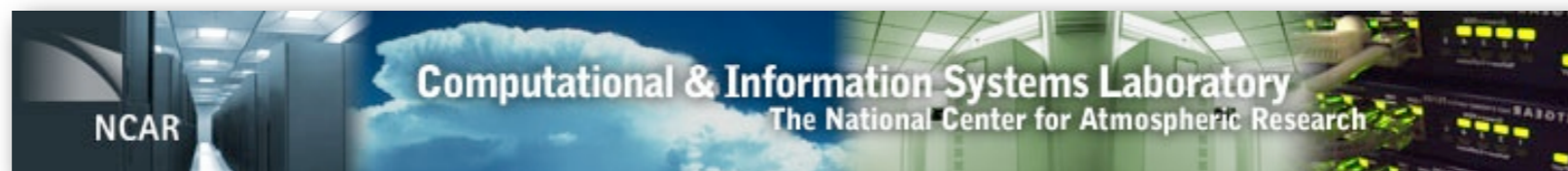


# NSF's EarthCube Initiative

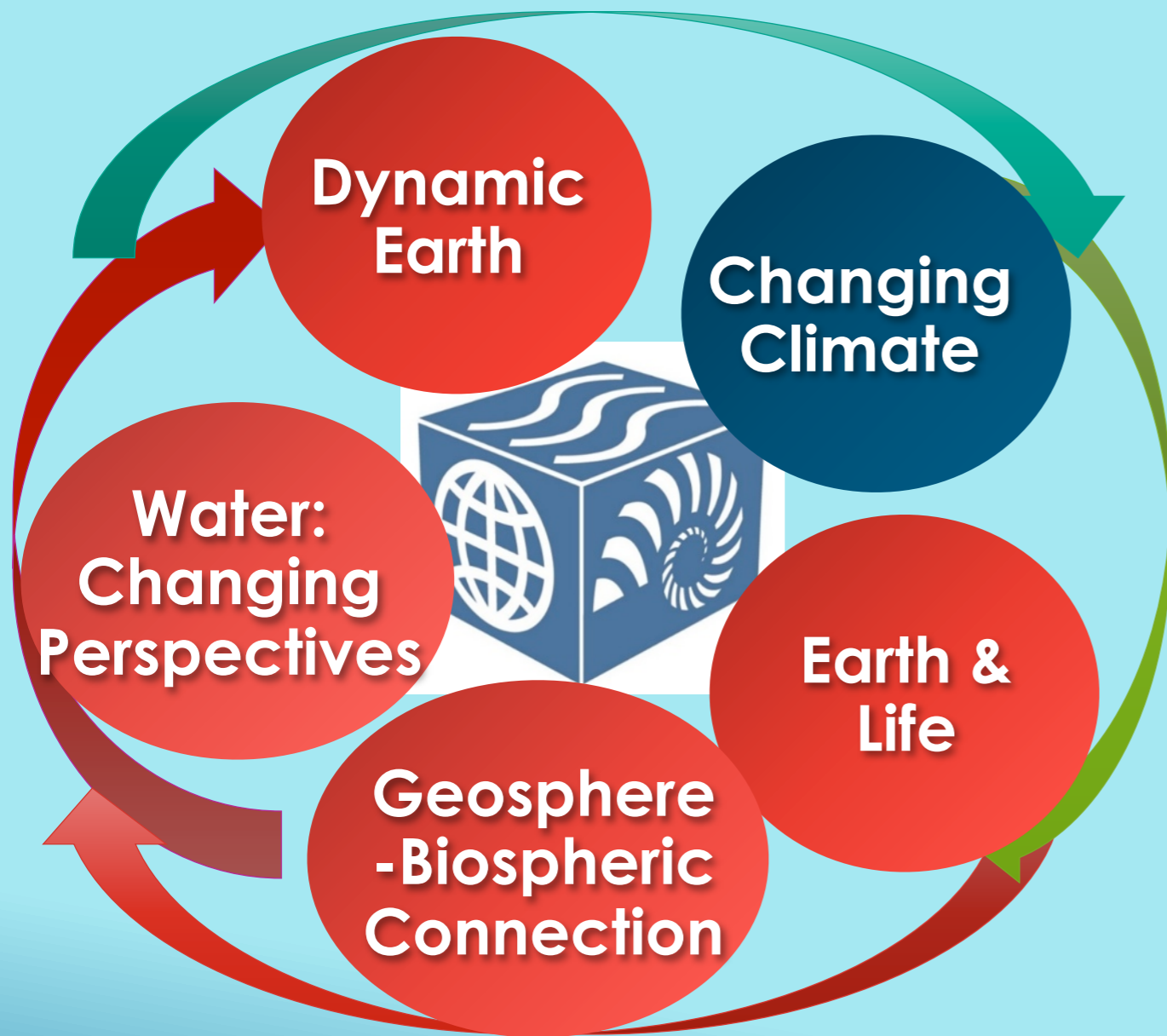
Courtesy of Rachael Black, Lee Allison, and others from the Arizona Geological Survey, serving EarthCube's Governance effort. Search for "EarthCube".



**NCAR**



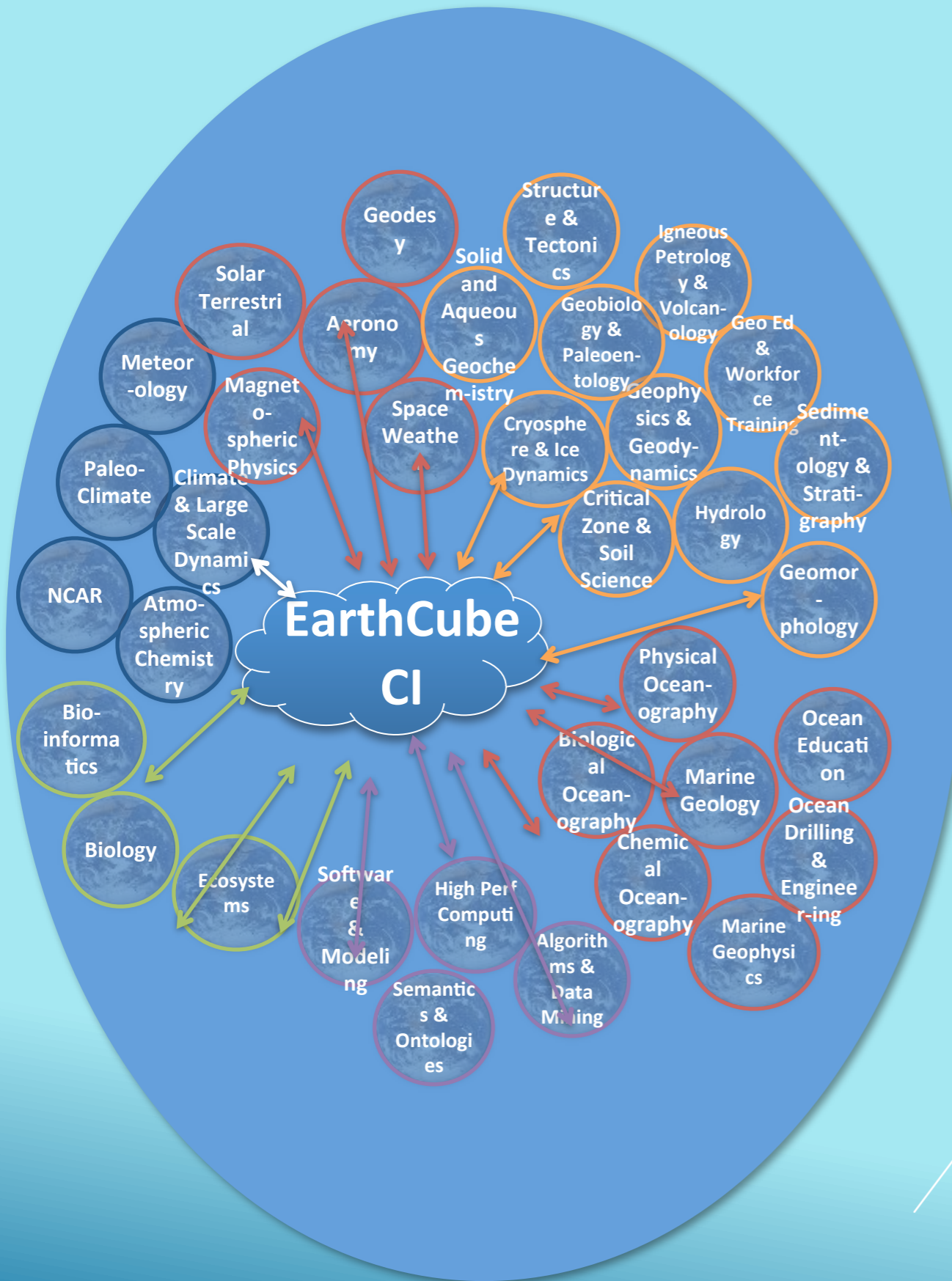
# EARTHCUBE VISION



- ▶ **Transform** the **conduct** of data-enabled geoscience-related **research**
- ▶ Create effective **community-driven cyberinfrastructure**
- ▶ Allow **global data discovery** and **knowledge management**
- ▶ Achieve **interoperability** and data integration **across disciplines**



# Who is EarthCube?



*Enables transformative geoscience by fostering a community committed to providing unprecedented discovery, access, and analysis of geoscience data.*

## Academic Geoscience Researchers in

- **Earth**
- **Oceans**
- **Atmosphere**
- **Polar**

# The EarthCube

Present

2011

Dear Colleague Letter & Charrettes

2012

White Papers & Expressions of Interest  
(Geo & CI)

2013

Roadmaps & Concept Designs (*technical roadmaps and small prototype designs*)

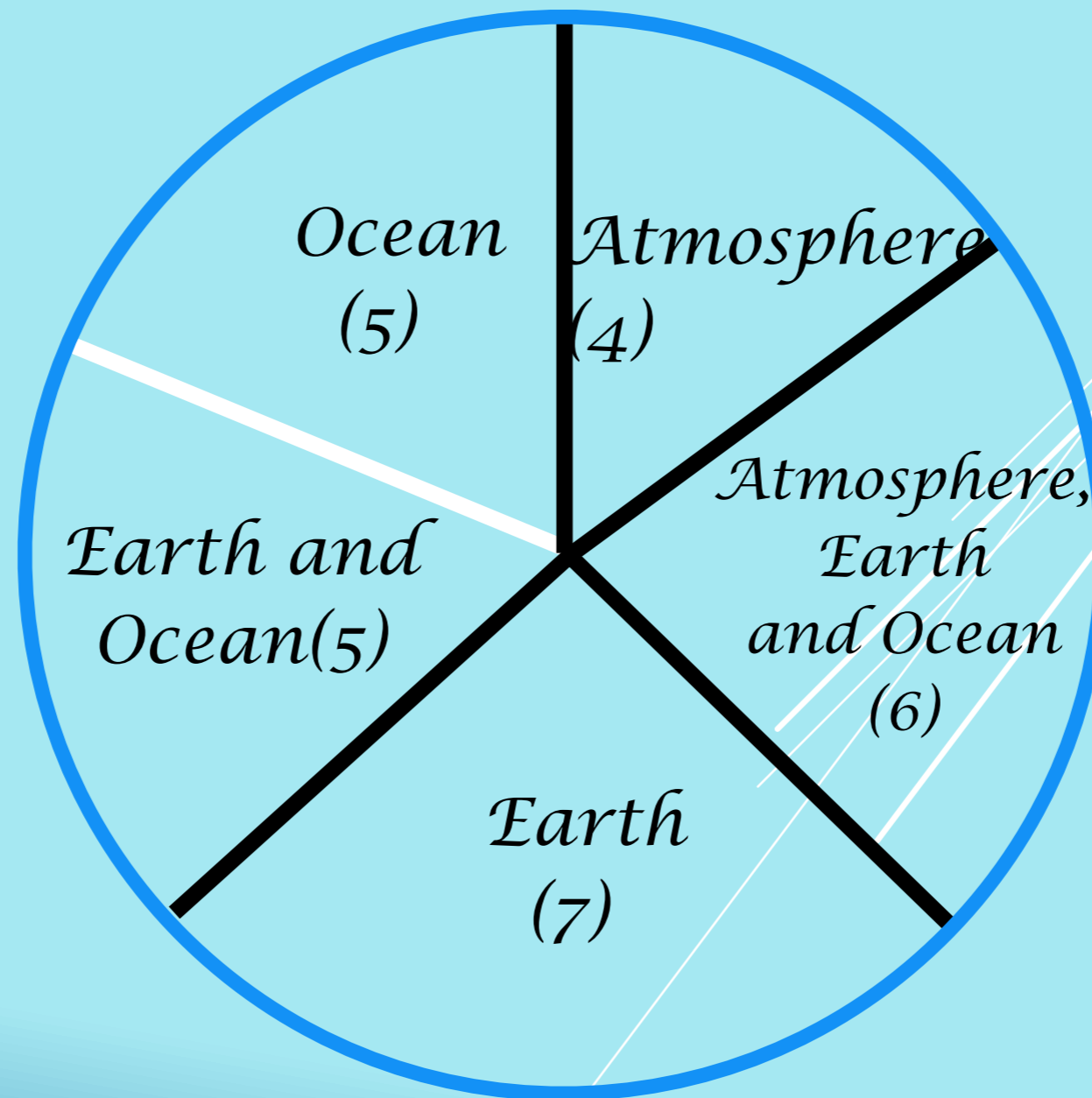
End-User Workshops & Stakeholder Alignment

Building Blocks, RCNs, and Conceptual Design Awards (*current funded projects*)

Full List of Awards at: <http://earthcube.org/page/earthcube->

# 27 End-User Workshops: 2 pending

~2,000 participants, multiple agencies (NOAA, NASA, USGS, USDA, NRL, +)



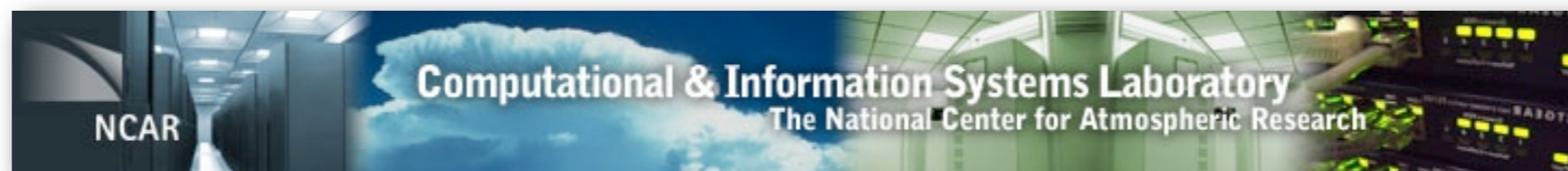


# Questions?

[don@ucar.edu](mailto:don@ucar.edu)



**NCAR**



# How we reach our users

## Workshops

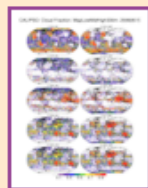


## Hundreds of website examples

<http://www.ncl.ucar.edu/Applications/>

**CALIPSO** (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations ) was launched on April 28, 2006 to study the impact of clouds and aerosols on the Earth's radiation budget and climate. It flies in formation with five other satellites in the international "A-Train" constellation for coincident Earth observations. The CALIPSO satellite comprises three instruments, the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), the Imaging Infrared Radiometer (IIR), and the Wide Field Camera (WFC). CALIPSO is a joint satellite mission between NASA and the French Agency, CNES

CALIPSO data are available as **Level-2** and as part of the **CFMIP-OBS** (Cloud Feedback Model Intercomparison Program) a protocol to evaluate clouds in climate and weather prediction models based on satellite observations has been designed.



**calipso\_1.ncl**: CALIPSO cloud fractions (low, middle, high, total and clear) for June 6, 2006.

The file used in this example was obtained from:  
[ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/3D\\_CloudFraction/grid\\_2x2xL40/](ftp://ftp.climserv.ipsl.polytechnique.fr/cfmip/goccp/3D_CloudFraction/grid_2x2xL40/)

## One-on-one correspondence with users



## Active email lists

I am regridding a 12km by 12km lambert conical conformal grid of sparse emissions over the U.S. To a 1/2 by 2/3 degree grid over the same domain. If I choose the grid corners to be rounded to zero decimal places, I get a slightly different answer in my final emissions than if I round the grid corner to 2 decimal places which is actually slightly (1%) less than the original emissions. Why would this occur, and what is 'best practices' in choosing the grid corners for this scenario?