# WRF Modeling System Overview

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# What is WRF?

- WRF: Weather Research and Forecasting Model
  - Used for both research and operational forecasting
- It is an NCAR “community model”, i.e. a free and shared resource with distributed development and centralized support
- Its development is led by NCAR, NOAA/GSD and NOAA/NCEP/EMC with partnerships at AFWA, FAA, NRL, and collaborations with universities and other government agencies in the US and overseas

# What are ARW and NMM?

- The Advanced Research WRF (ARW) and Nonhydrostatic Mesoscale Model (NMM) are dynamical cores
  - Dynamical core includes mostly advection, pressure-gradients, Coriolis, buoyancy, filters, diffusion, and time-stepping
- Both are Eulerian mass dynamical cores with terrain-following vertical coordinates
- ARW support and development are centered at NCAR/MMM
- NMM support and development are centered at NCEP/EMC and NCAR/RAL/DTC
- This tutorial is for both dynamical cores
- Both are downloadable in the same WRFV2 tar file
- Physics, the software framework, and parts of data pre- and post-processing are shared between the dynamical cores

# What WRF does not include

- WRF does not include (yet) in its community release
  - WRF-Chem - coupled on-line chemistry
    - Available from NOAA
  - Coupled Ocean/Wave models
  - Adjoint model (4DVAR)

# WRF as a Community Model

- Version 1.0 WRF was released December 2000
- Version 2.0 May 2004 (ARW nesting released)
  - Version 2.0.1 Jun 2004
  - Version 2.0.2 Jun 2004
  - Version 2.0.3.1 Dec 2004
- Version 2.1 August 2005
  - Version 2.1.1 Nov 2005
  - Version 2.1.2 Jan 2006
- Current Version: Version 2.2 December 2006
  - NMM nesting released in 2007

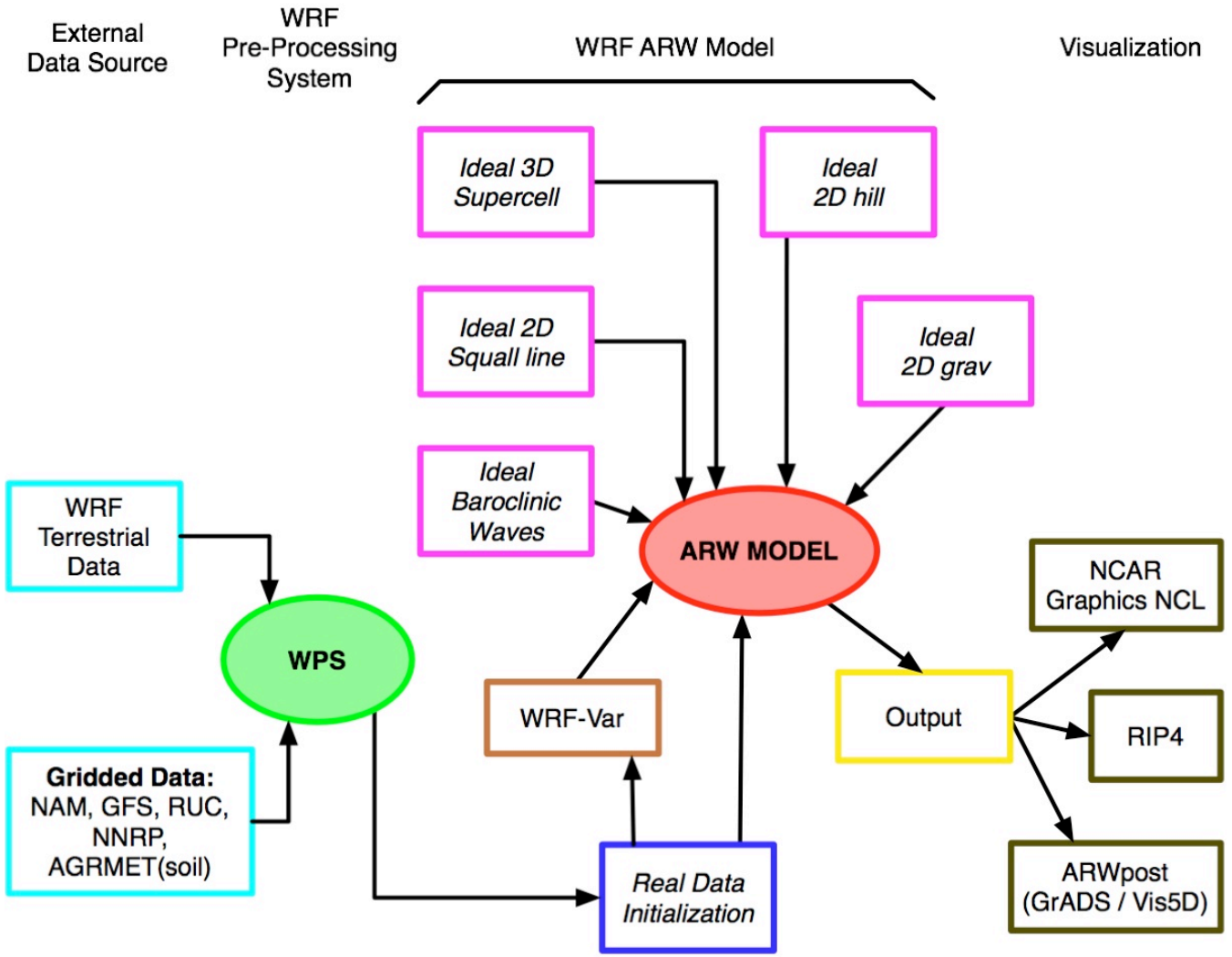
# What can WRF be used for?

- ARW and NMM
  - Atmospheric physics/parameterization research
  - Case-study research
  - Real-time NWP and forecast system research
  - Teaching dynamics and NWP
- ARW only
  - Regional climate and seasonal time-scale research
  - Coupled-model (e.g. ocean, chemistry) applications
  - Idealized simulations at many scales (e.g. convection, baroclinic waves, large eddy simulations)
  - Data assimilation research

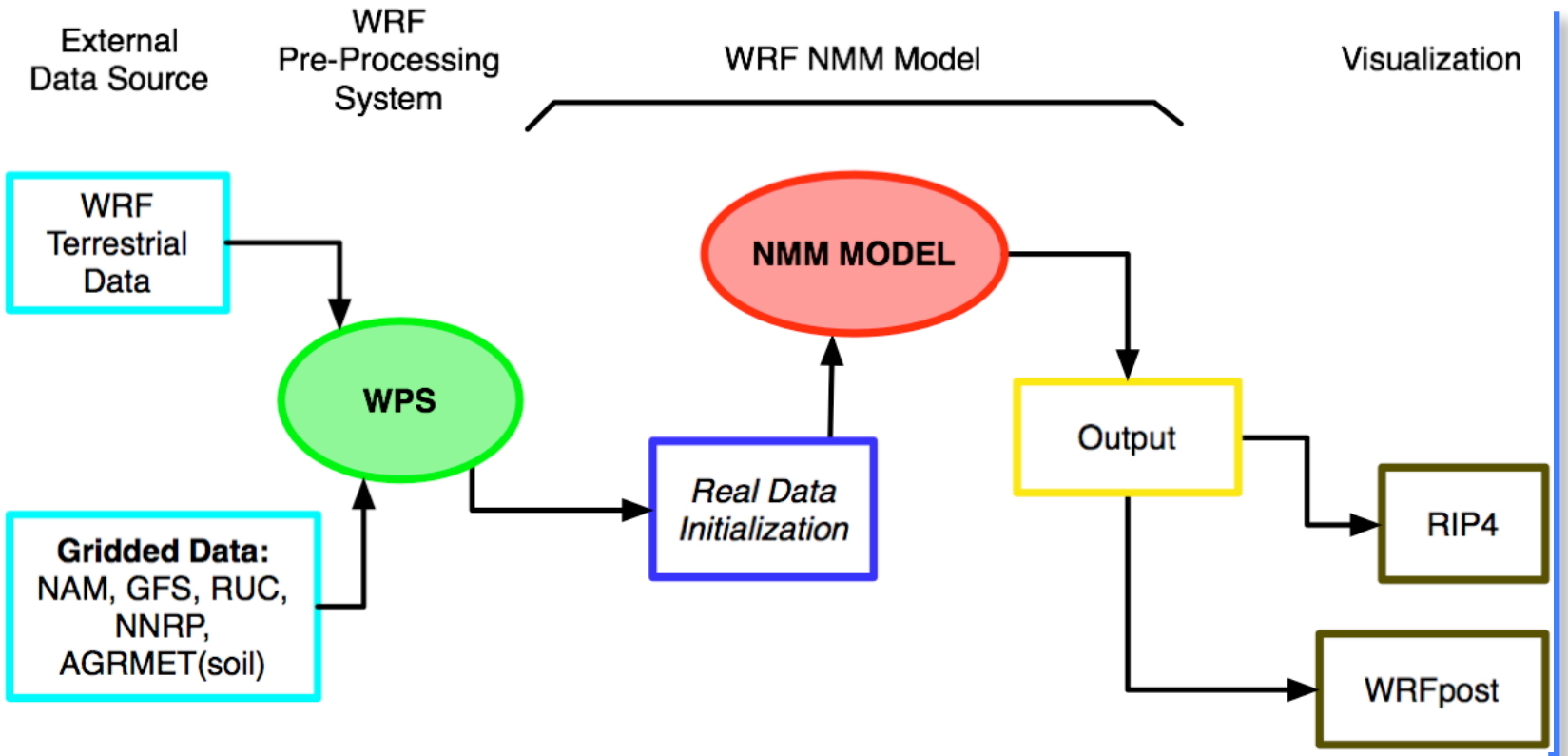
# Who uses WRF?

- Academic atmospheric scientists
- Forecast teams at operational centers
- Applications scientists (e.g. Air Quality, Hydrology, Utilities)

# WRF ARW Modeling System Flow Chart (for WRFV2)



# WRF NMM Modeling System Flow Chart (for WRFV2)



# Modeling System Components

- WRF Pre-processing System (WPS)
  - Real-data interpolation for NWP runs
  - Replaces old Standard Initialization (SI) - still maintained
- WRF-Var for ARW (including 3d-Var)
- WRF Model (ARW and NMM dynamical cores)
  - Initialization programs for real and (for ARW) idealized data (real.exe/ideal.exe)
  - Numerical integration program (wrf.exe)
- Graphics tools

# WPS

Function

- Define simulation domain area (and nests)
- Produce terrain, landuse, soil type etc. on the simulation domain (“static” fields)
- De-grib GRIB files for meteorological data (u, v, T, q, surface pressure, soil data, snow data, sea-surface temperature, etc.)
- Interpolate meteorological data to WRF model grid (horizontally)

# WPS

Function (cont)

- Support WRF nesting
- Map projections:
  - ARW
    - Lambert conformal, Polar stereographic, Mercator
  - NMM
    - Rotated lat/long
- Two grid-staggerings
  - ARW C-grid
  - NMM E-grid

# WPS and WRF

Running WPS

- Three executable stages with namelist input
  - geogrid.exe (interpolate maps and time-independent fields)
  - ungrib.exe (convert time-dependent Grib-formatted data to simple binary format)
  - metgrid.exe (interpolate time-dependent initial and boundary data)

Running WRF

- Two executable stages with namelist input
  - real.exe or real_nmm.exe (set up vertical model levels for model input and boundary files)
  - wrf.exe (run model)

# WRF-Var for ARW

Function

- Variational data assimilation
- Ingest observations into WRF input analysis from WPS
- May be used in cycling mode for updating WRF initial conditions after WRF run
- Also used for observation impact data studies

# WRF 3DVAR

- Supported data types
  - Conventional surface and upper air, wind profiler
  - Remote sensing data: Cloud-track winds, ATOVS thickness, ground-based GPS TPW, SSM/I, SSM/T1, SSM/T2, SSM/I brightness temp, Quikscat ocean surface winds, radar radial velocity
- Two background error covariance models
  - NCEP model
  - UK / NCAR

# WRF real and ideal

- REAL
  - Creates initial and boundary condition files for real-data cases
  - Does vertical interpolation to model levels (when using WPS)
  - Does vertical dynamic (hydrostatic) balance
  - Does soil vertical interpolations and land-use mask checks
- IDEAL (ARW only)
  - Programs for setting up idealized case
  - Simple physics and usually single sounding
  - Initial conditions and dynamic balance

# ARW Dynamics

Key features:

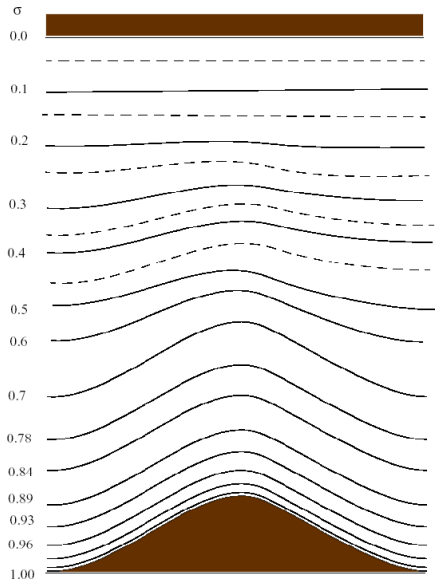
- Fully compressible, non-hydrostatic (with hydrostatic option)
- Mass-based terrain following coordinate, η

$$\eta = \frac{(\pi - \pi_t)}{\mu}, \qquad \mu = \pi_s - \pi_t$$

where π is hydrostatic pressure,
μ is column mass

- Arakawa C-grid staggering

v
u T u
v



# ARW Model

Key features:

- 3rd-order Runge-Kutta time integration scheme
- High-order advection scheme
- Scalar-conserving (positive definite option)
- Complete Coriolis, curvature and mapping terms
- Two-way and one-way nesting

# ARW Model

Key features:

- Choices of lateral boundary conditions suitable for real-data and idealized simulations
  - Specified, Periodic, Open, Symmetric, Nested
- Full physics options to represent atmospheric radiation, surface and boundary layer, and cloud and precipitation processes
- Grid-nudging and obs-nudging (FDDA)

# NMM Dynamics

Key features:

- Fully compressible, non-hydrostatic or hydrostatic
- Mass-based sigma-pressure hybrid terrain following coordinate
- Arakawa E-grid staggering

T **V** T
**V** T **V**
T **V** T

where **V** is u and v

# NMM Model

Key features:

- Adams-Bashforth and Crank-Nicholson time integration schemes
- High-order advection scheme
- Scalar and energy conserving
- Coriolis, curvature and mapping terms
- One-way nesting

# NMM Model

Key features:

- Lateral boundary conditions suitable for real-data and one-way nesting
- Full physics options to represent atmospheric radiation, surface and boundary layer, and cloud and precipitation processes

# Graphics Tools

- ARW and NMM
  - RIP4 (Read, Interpolate and Plot)
  - WRFpost
- ARW
  - NCAR Graphics Command Language (NCL)
  - Conversion program for GrADS
  - Conversion program for Vis5D

# Software Requirement

- Fortran 90/95 compiler
- C compiler
- Perl
- netCDF library
- Public domain mpich for MPI

# Portability

- Runs on Unix single, OpenMP and MPI platforms:
  - IBM
  - Linux (PGI and Intel compiler(?))
  - SGI Origin and Altix
  - HP/Compaq/DEC
  - Cray
  - Sun (not MPI)
  - Mac (xlf compiler, not nesting)

# User Support

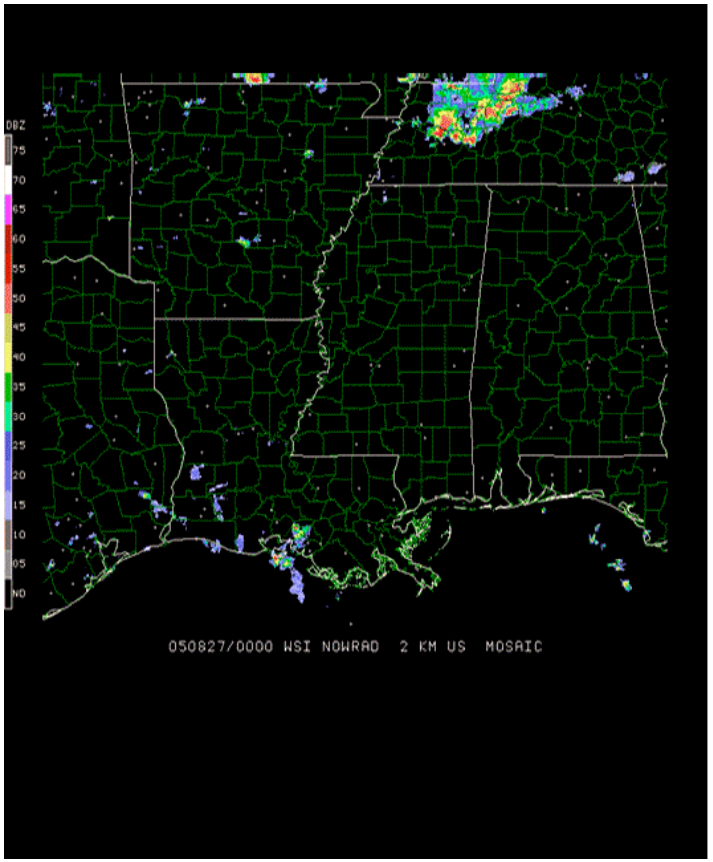
- Email: wrfhelp@ucar.edu
- User Web pages:

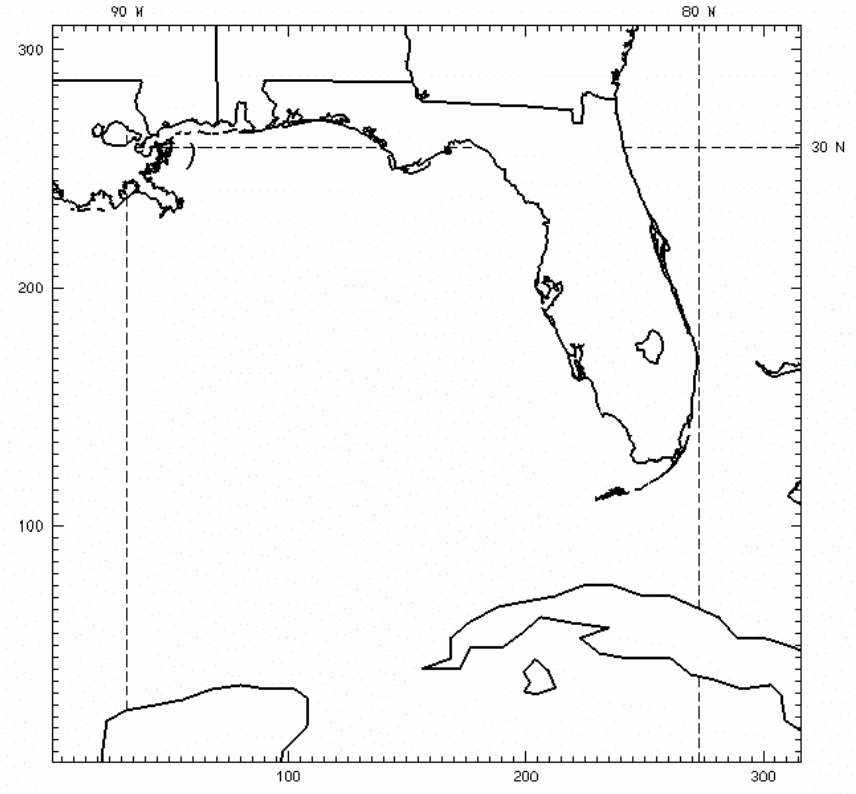
  ARW:http://www.mmm.ucar.edu/wrf/users/

  NMM:http://www.dtcenter.org/wrf-nmm/users/

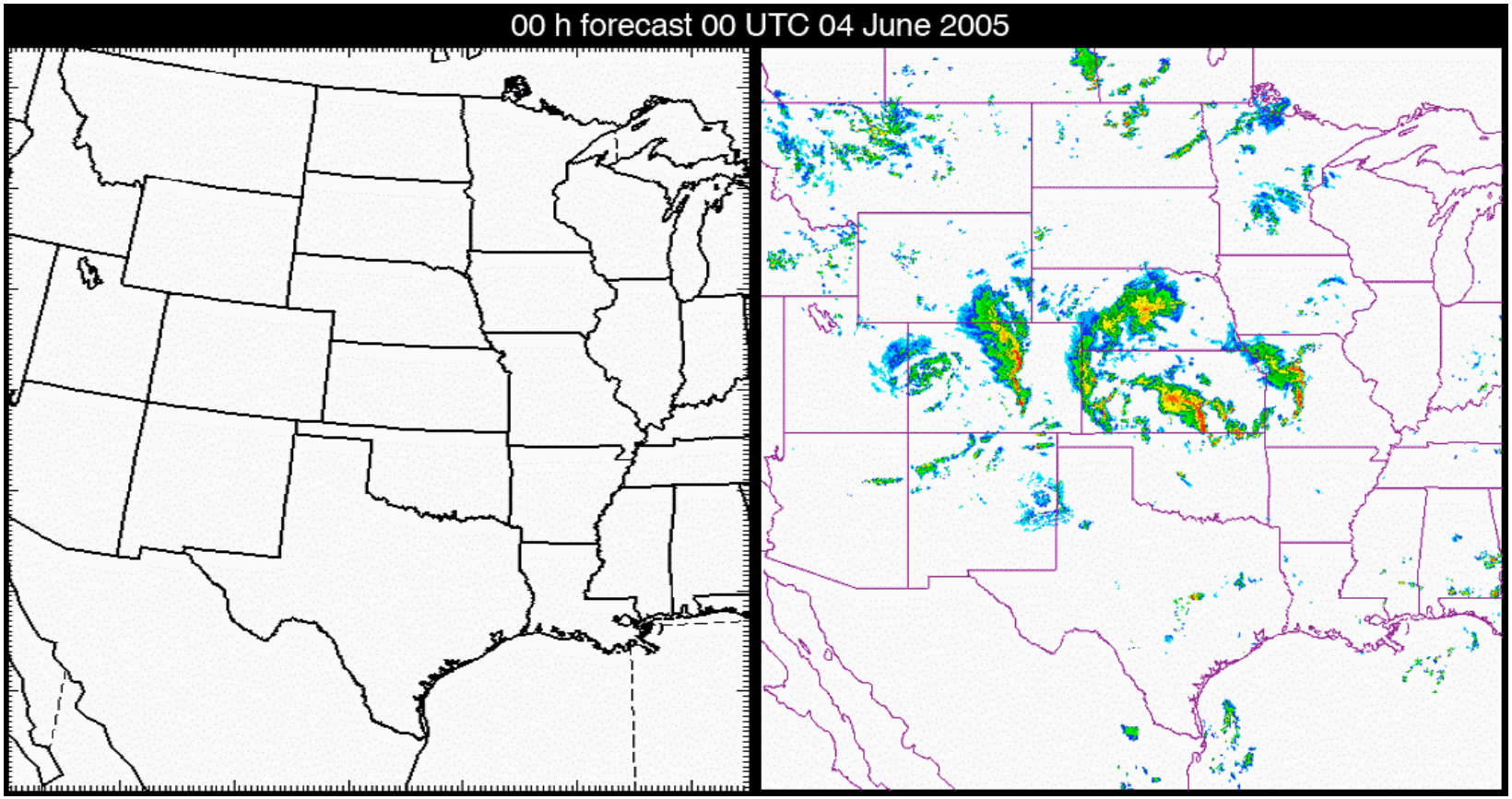
  – Latest update for the modeling system
  – WRF software download
  – Various documentation
    - Users' Guide
    - Technical Note (ARW Description)

# Hurricane Katrina Simulation (4km)



# Convective-scale Forecasting (4km)



# Tutorial Schedule

- Lectures for WRF: Mon.-Fri.
- Practice for WRF: Tue., Wed., Thu.
  - 2 Groups (a.m./p.m.)
- Lectures for WRF-Var: Thu.
- Practice for WRF-Var: Thu., Fri.
  - 2 Groups (Thu./Fri.)
- Ends Friday mid-day