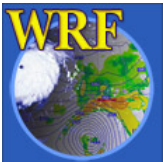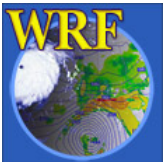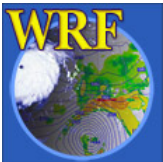# WRF Modeling System Overview

Jimy Dudhia

What is WRF?

- WRF: Weather Research and Forecasting Model
  - Now with ARW and NMM components
- Its development is led by NCAR/MMM, NOAA/GSD and NOAA/NCEP/EMC with partnerships at AFWA, FAA, NRL and collaborations with universities, other government agencies, and NCAR Divisions
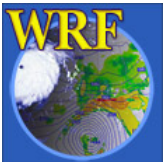- Includes research and operational models

What is ARW?

- Advanced Research WRF is a large sub-set of WRF
- It is a freely available community model
- Eulerian mass dynamical core
- ARW system includes modeling system components to go with this core
  - WRF Pre-Processing System (WPS), WRF-Var, graphics packages
- Its support and development are centered at NCAR/MMM
- This tutorial is for all the ARW components
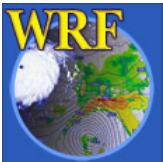- Physics and software framework (and soon WPS) are shared with NMM model

What ARW does not include

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

- NMM is separately supported and developed by NCAR/DTC and NOAA/NCEP/EMC
  - NMM has its own tutorial (in February)
  - However NMM is included in the same WRF tar file

ARW as a Community Model

- Version 1.0 WRF was released December 2000
- Version 2.0 May 2004 (nesting major release)
  - 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
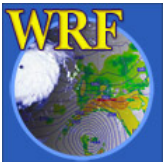- Current Version: Version 2.2 (December 2006)

What can WRF be used for?

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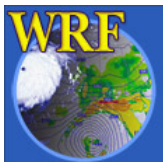- Coupled-model (e.g. ocean, chemistry) applications
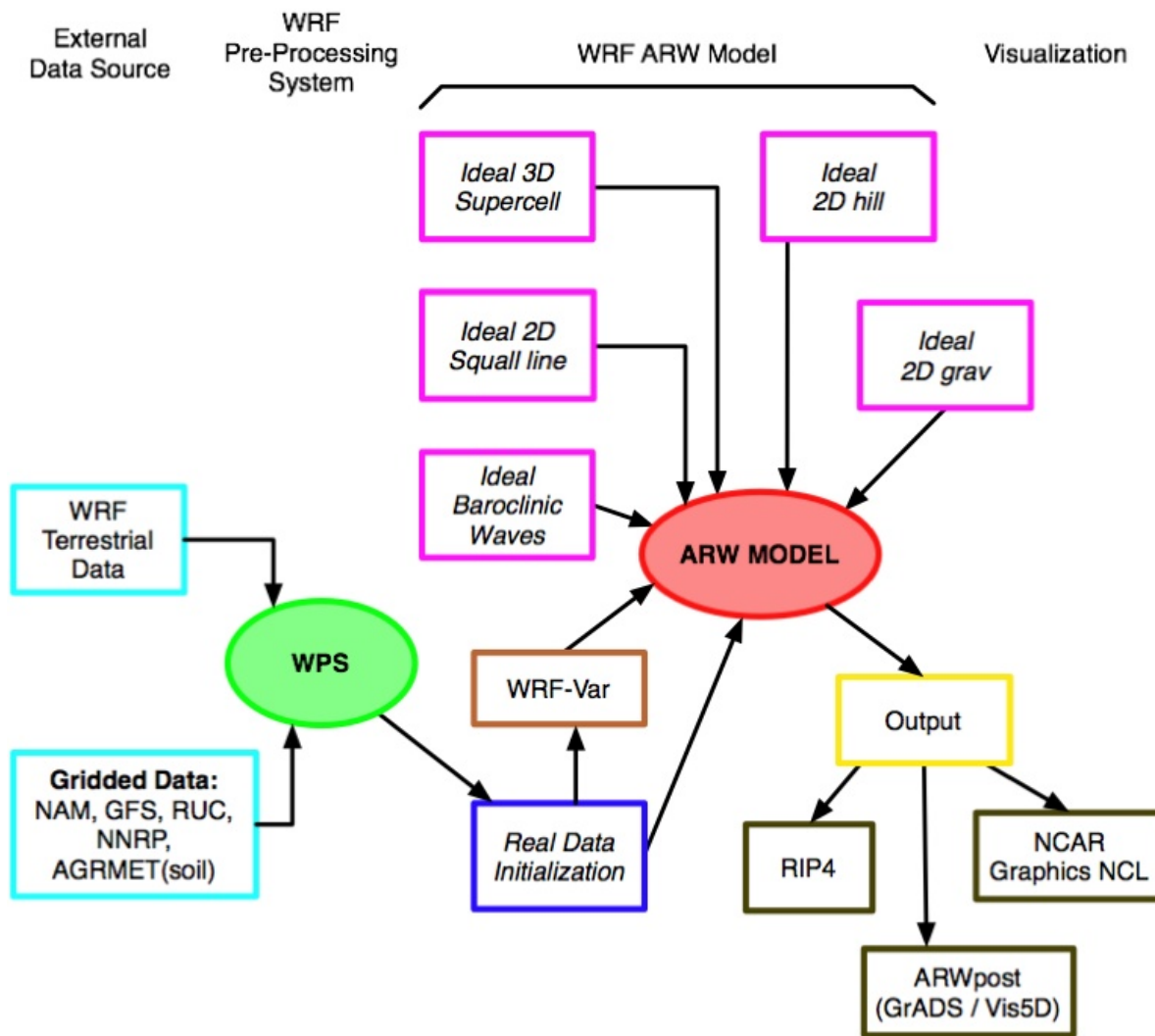- Teaching

Who uses WRF?

- Academic atmospheric scientists
- Forecast teams at operational centers
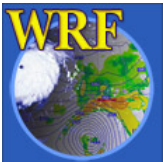- Air Quality scientists
- Others

WRF ARW Modeling System Flow Chart (for WRFV2)

External
Data Source

WRF
Pre-Processing
System

WRF ARW Model

Visualization

Ideal 3D
Supercell

Ideal
2D hill

Ideal 2D
Squall line

Ideal
2D grav

Ideal
Baroclinic
Waves

ARW MODEL

WRF
Terrestrial
Data

WPS

WRF-Var

Output

Gridded Data:
NAM, GFS, RUC,
NNRP,
AGRMET(soil)

Real Data
Initialization

RIP4

NCAR
Graphics NCL

ARWpost
(GrADS / Vis5D)

# Modeling System Components

- **WRF Pre-processing System (WPS)**
  - New real-data interpolation for NWP runs
  - Replaces Standard Initialization (SI) - still maintained
- **WRF-Var (including 3d-Var)**
- **WRF Model (Eulerian mass dynamical core)**
  - Initialization programs for real and 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)
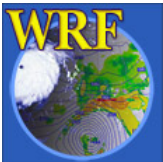
WPS

Function (cont)

- Support WRF nesting
- Three map projections:
  - Lambert conformal
  - Polar stereographic
  - Mercator
- Compile -> edit namelist -> run, methodology for each stage
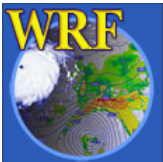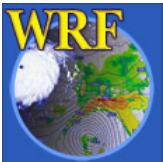
WRF-Var

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
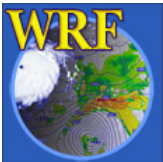
WRF 3DVAR

- 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 (new with WPS)
  - Does vertical dynamic (hydrostatic) balance
  - Does soil vertical interpolations and land-use mask checks

- IDEAL
  - Programs for setting up idealized case
  - Simple physics and usually single sounding
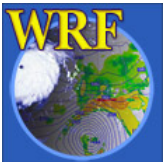 - Initial conditions and dynamic balance

WRF Model

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

$$\begin{array}{ccc} & v & \\ u & T & u \\ & v & \end{array}$$

WRF 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
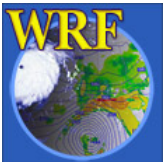
- Two-way and one-way nesting

WRF 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
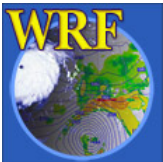- Grid-nudging and obs-nudging (FDDA)
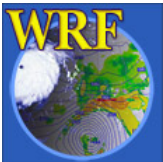
Graphics Tools

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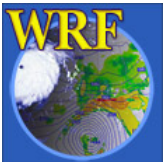- Conversion program for Vis5D

Software Requirement

- Fortran 90/95 compiler

- C compiler

- Perl

- netCDF library

- Public domain mpich for MPI
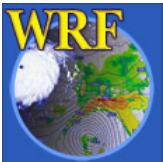
Portability

- 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)
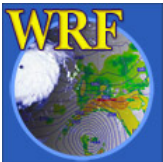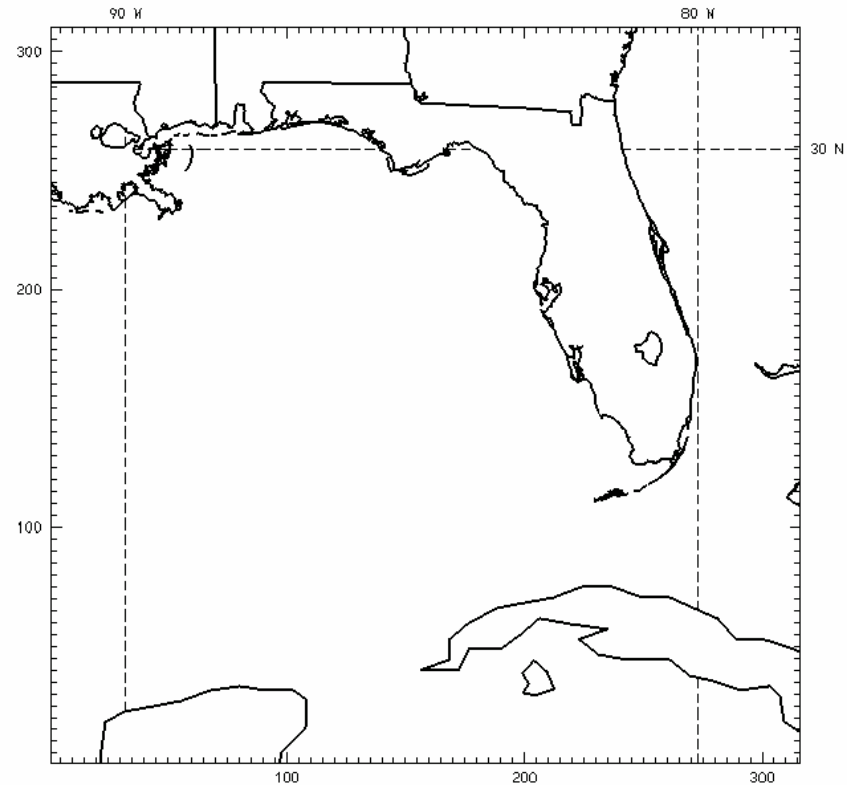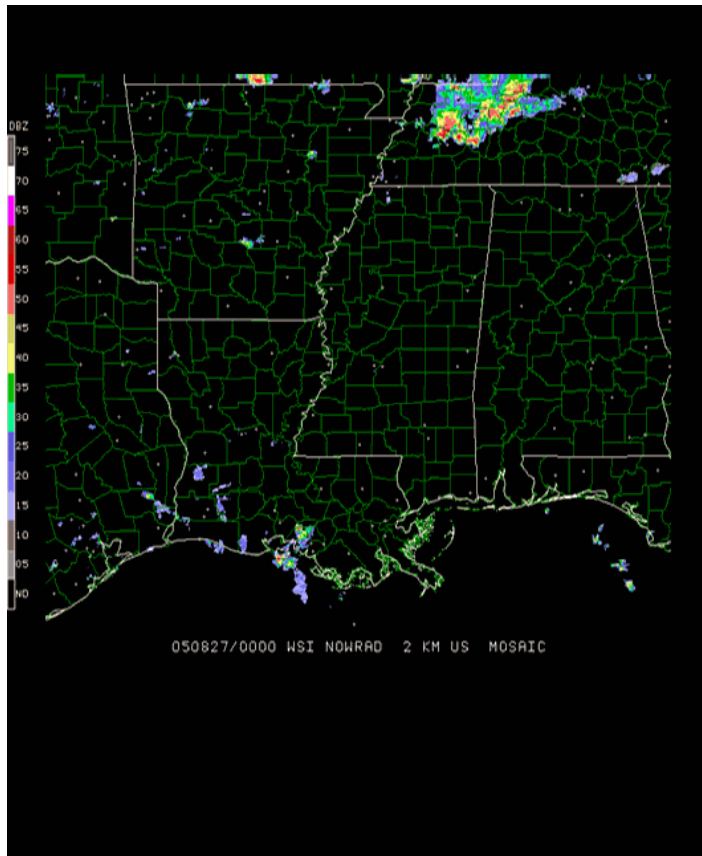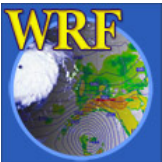 - Mac (xlf compiler, not nesting)

User Support

- Email: wrfhelp@ucar.edu

- User Web page:

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

    – Latest update for the modeling system

    – WRF software download

    – Various documentation
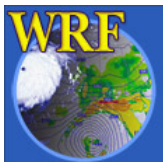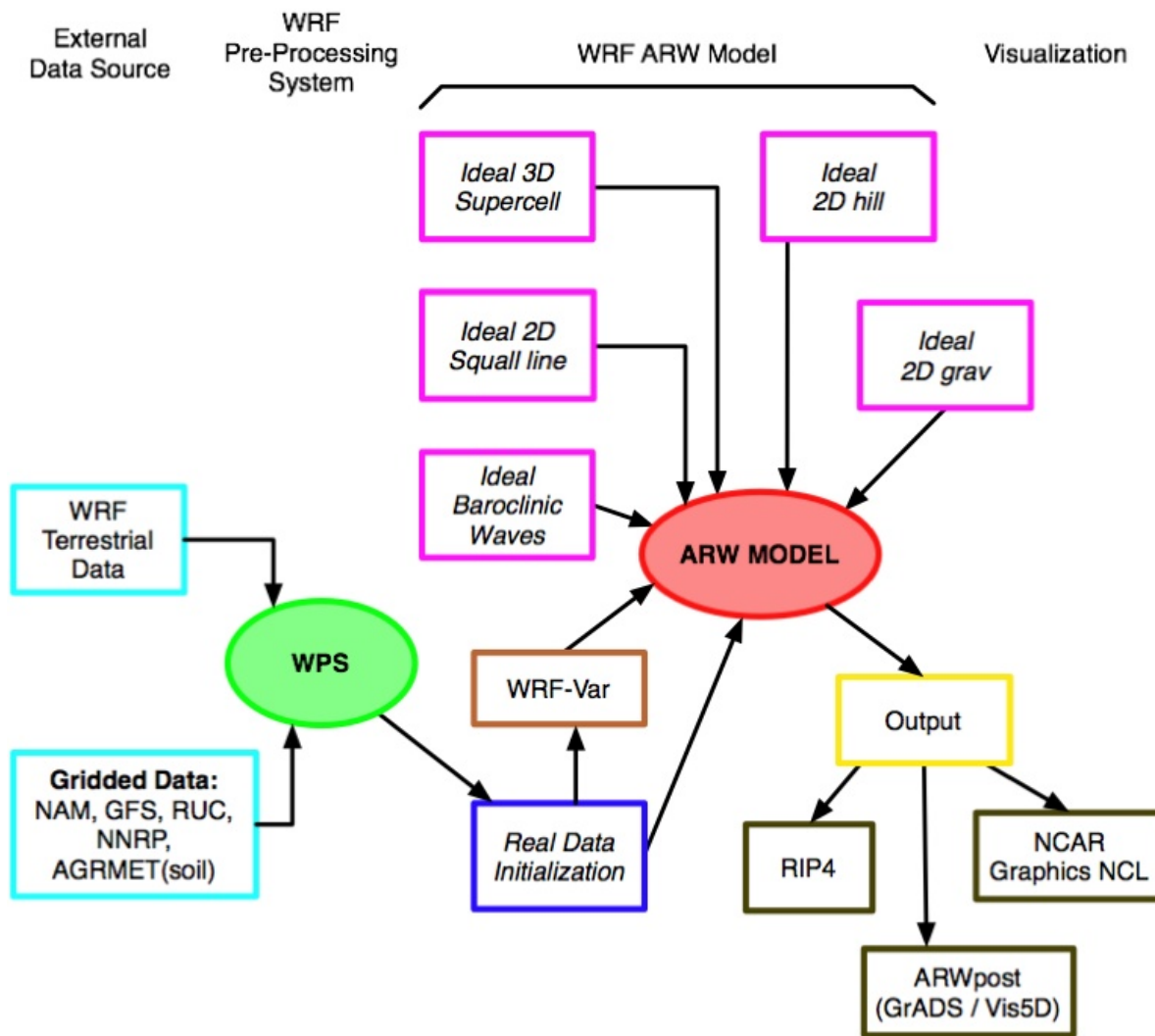
    - Users' Guide

    - Technical Note (ARW Description)

Hurricane Katrina Simulation (4km)

050827/0000 WSI NOWRAD 2 KM US MOSAIC

Convective-scale Forecasting (4km)

00 h forecast 00 UTC 04 June 2005

WRF ARW Modeling System Flow Chart (for WRFV2)

External Data Source | WRF Pre-Processing System | WRF ARW Model | Visualization

- Ideal 3D Supercell
- Ideal 2D hill
- Ideal 2D Squall line
- Ideal 2D grav
- Ideal Baroclinic Waves
- WRF Terrestrial Data
- WPS
- ARW MODEL
- WRF-Var
- Output
- Gridded Data: NAM, GFS, RUC, NNRP, AGRMET(soil)
- Real Data Initialization
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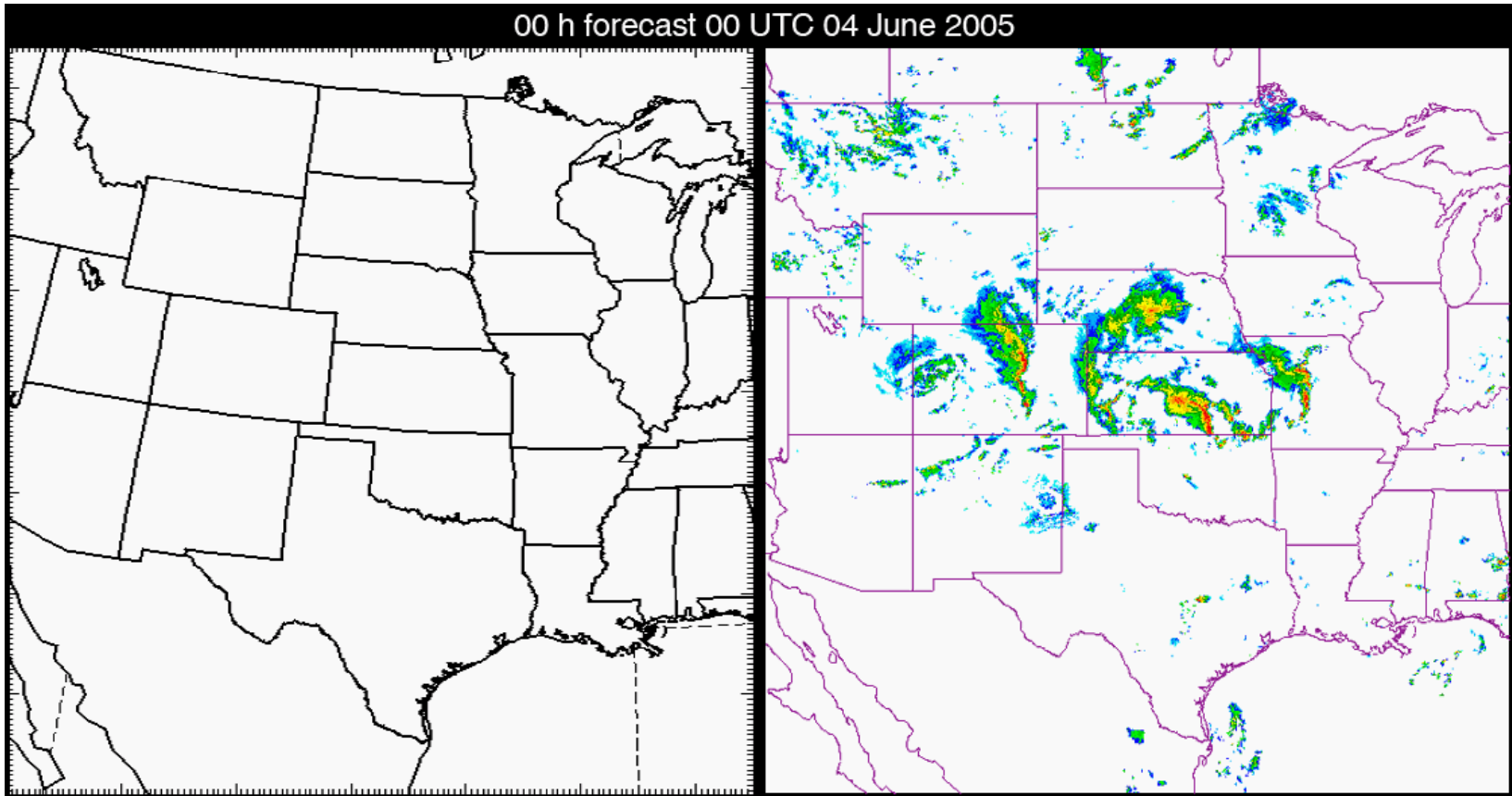
Tutorial Schedule

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