WRF Modeling System Overview

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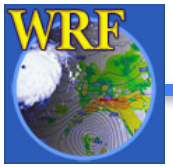
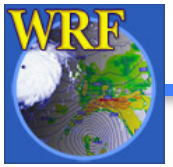
What is WRF?

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



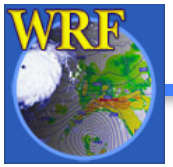
What is ARW?

- WRF has two dynamical cores: The Advanced Research WRF (ARW) and Nonhydrostatic Mesoscale Model (NMM)
  - 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 development is centered at NCEP/EMC and support is provided by NCAR/DTC; now HWRF only
- This tutorial is for only the ARW core
- Both are downloadable in the same WRF tar file
- Physics, the software framework, and parts of data pre- and post-processing are shared between the dynamical cores



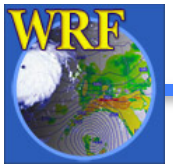
WRF as a Community Model

- Version 1.0 WRF was released December 2000
- Version 2.0: May 2004 (NMM added, EM nesting)
- Version 2.1: August 2005 (EM becomes ARW)
- Version 2.2: December 2006 (WPS released)
- Version 3.0: April 2008 (includes global ARW version)
- Version 3.1: April 2009
- Version 3.2: April 2010
- Version 3.3: April 2011
- Version 3.4: April 2012
- Version 3.5: April 2013
  - Version 3.5.1 September 2013 (bug-fix/minor release)
- Version 3.6: April 2014
  - Version 3.6.1 August 2014 (bug-fix/minor release, current version)
- Version 3.7: April 2015 (current version)
  - Version 3.7.1: August 2015 (bug fixes)
- Version 3.8: Expected release date in April 2016



What can WRF be used for?

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



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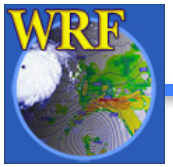
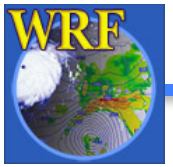
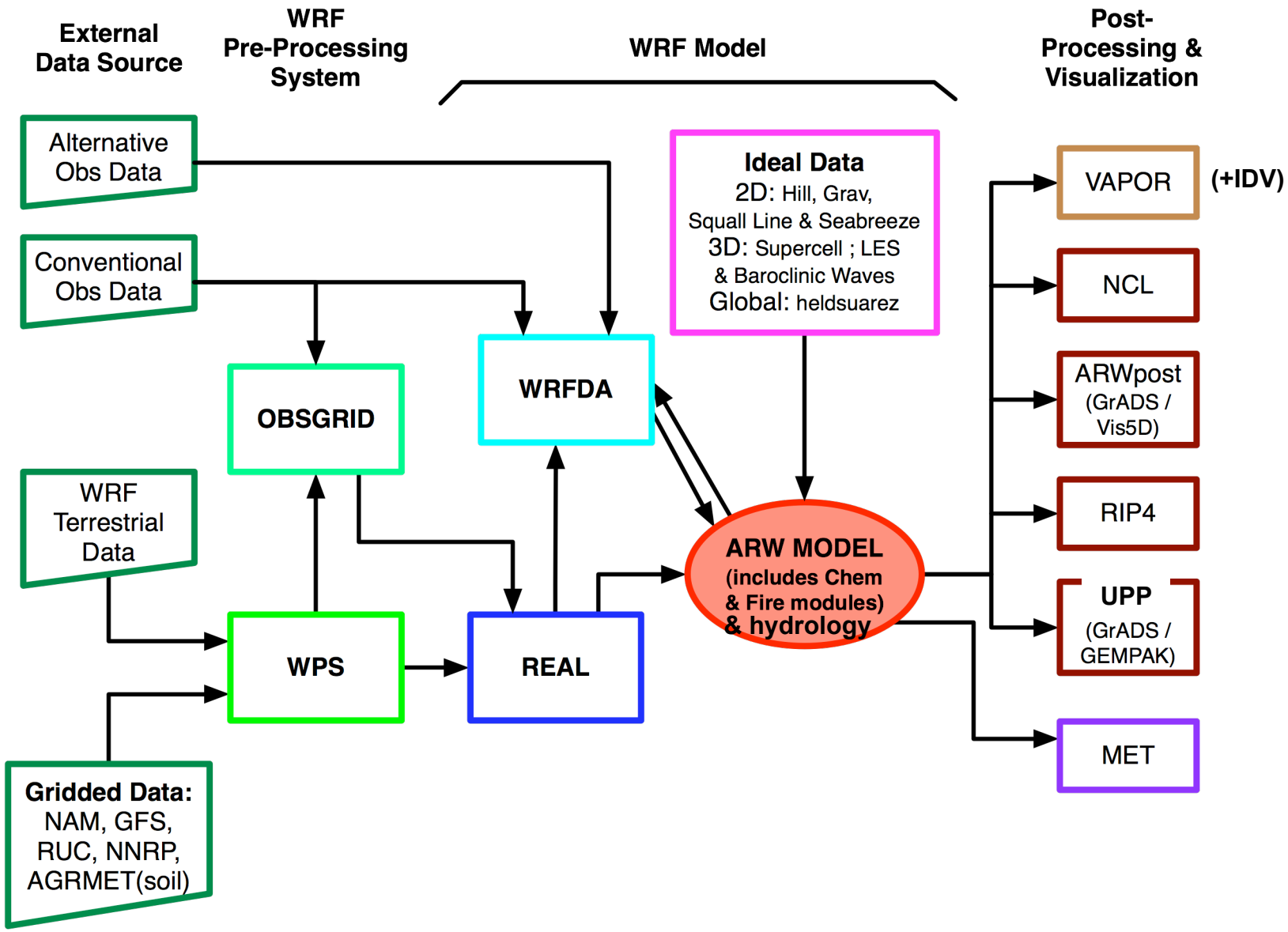


Who uses WRF?

- Academic atmospheric scientists (dynamics, physics, weather, climate research)
- Forecast teams at operational centers
- Applications scientists (e.g. air quality, hydrology, utilities, wind/solar energy)

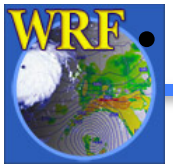


WRF Modeling System Flow Chart

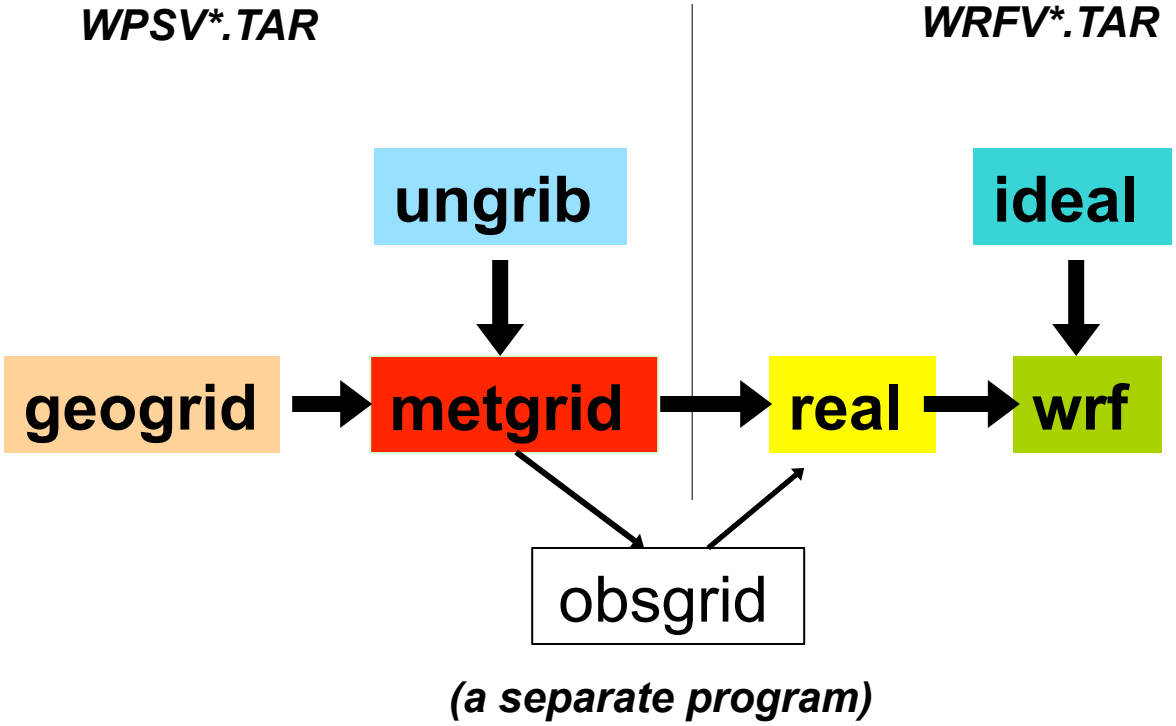


Modeling System Components

- WRF Pre-processing System
  - Real-data interpolation for NWP runs (WPS)
  - Program for adding more observations to analysis (obsgrid)
- WRF Model (ARW dynamical core)
  - Initialization programs for real and idealized data (*real.exe/ ideal.exe*)
  - Numerical integration program (*wrf.exe*)
- Graphics and verification tools including MET
- WRF Data Assimilation
- WRF-Chemistry
- WRF-Hydrology
- WRF-Fire – wildland model for forest fires

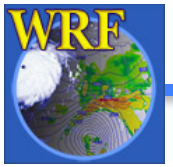


WPS and WRF Program Flow



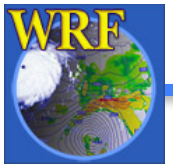
Real-Data Applications

- Numerical weather prediction
- Meteorological case studies
- Regional climate
- Applications: air quality, wind / solar energy, hydrology, etc.



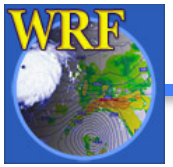
Real-Data Applications

- Need time-*independent* information for chosen *domain* (simulation grid area)
- Program *geogrid*:
  - Map projection information
    - 2d gridded latitude, longitude, Coriolis parameter, map-scale factors, etc.
  - Topographic information
    - 2d gridded elevation, vegetation and soil categories, etc.



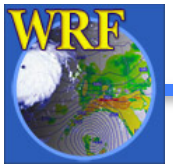
Real-Data Applications

- Need time-*dependent* information
- Initial conditions (initial model time)
- Lateral boundary conditions (later times)
  - except if running WRF globally
- Programs *ungrib* and *metgrid*:
  - 3d fields of horizontal wind, temperature, geopotential height, relative humidity
  - 2d fields of surface and/or sea-level pressure, surface temperature, relative humidity, horizontal winds
  - Time-sensitive land-surface fields: snow-cover, soil temperature, soil moisture



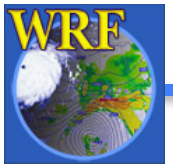
Real-Data Applications

- Regional domains need *specified* lateral boundary conditions at later times (e.g. every 3-6 hours) through forecast period
  - 3d fields of horizontal wind, temperature, geopotential height, water vapor
  - 2d field of surface pressure
- Long simulations (> 1 week) also need lower boundary condition at later times
  - 2d fields of sea-surface temperature, sea-ice, vegetation fraction



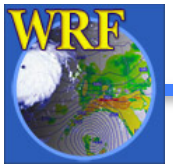
Real-Data Applications

- Lateral Boundary Conditions (linear in time)
  - The *wrfbdy* file contains later gridded information at model points in a zone (e.g.) 5 points wide around the domain
  - The boundary fields are linearly time-interpolated from boundary times to the current model time
  - This specifies the outer values, and is used to nudge the next (e.g) 4 interior points
- Lower Boundary Condition (step-wise)
  - New SSTs and a few others are read in and overwritten at each analysis time from *wrflowinp* file



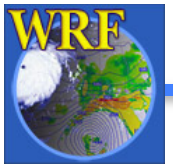
WPS Functions

- Program *geogrid*:
  - Define simulation domain area (and nests)
  - Produce terrain, landuse, soil type etc. on the simulation domain ("static" fields)
- Program *ungrib*:
  - De-grib GRIB files for meteorological data (u, v, T, q, surface pressure, soil data, snow data, sea-surface temperature, etc.)
- Program *metgrid*:
  - Interpolate meteorological data to WRF model grid (horizontally)
  - Optionally add more observations to analysis (separate *obsgrid* program)



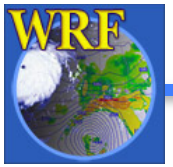
WPS Data

- *geogrid*:
  - We provide elevation, land-use, soil type data (static fields)
  - Or user can input own static data in same easy-to-write format
- *metgrid*: Supports input of time-dependent data (dynamic fields)
  - *ungrib* can provide these from GriB files
  - Or user can input own data in same "intermediate format" (simple binary files)



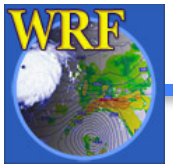
WRF real and ideal functions

- Program *real*:
  - Creates initial and boundary condition files for real-data cases; lower boundary conditions
  - Does vertical interpolation to model levels (when using WPS)
  - Calculates model variables
  - Does vertical dynamic (hydrostatic) balance
  - Does soil vertical interpolations and land-use mask checks
- Program *ideal*:
  - Programs for setting up idealized case
  - Simple physics and usually single sounding
  - Initial conditions and dynamic balance



WRF Model

- Program *wrf*:
  - Uses initial conditions from *real* or *ideal*
  - Real-data cases use lateral and lower boundary conditions from REAL
  - Runs the model simulation with run-time selected namelist switches (such as physics choices, timestep, length of simulation, etc.)
  - Outputs history and restart files



ARW Dynamics

Key features:

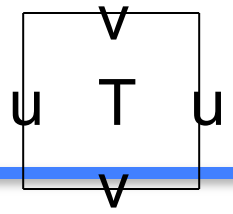
- Fully compressible, non-hydrostatic (with hydrostatic option)
- Mass-based terrain following coordinate, η

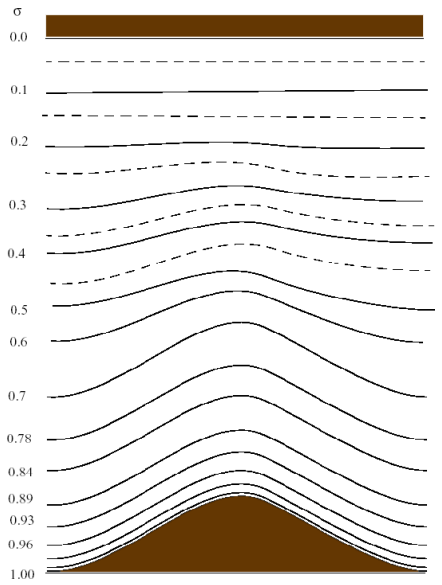
$$\eta = \frac{(\pi - \pi_t)}{\mu}, \qquad \mu = \pi_s - \pi_t$$

where π is hydrostatic pressure,

μ is column mass

- Arakawa C-grid staggering

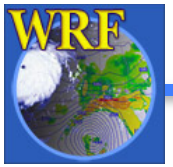




ARW Model

Key features:

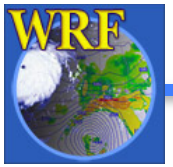
- 3rd-order Runge-Kutta time integration scheme
- High-order advection scheme
- Scalar-conserving (positive definite option)
- Complete Coriolis, curvature and mapping terms
- Two-way and one-way nesting



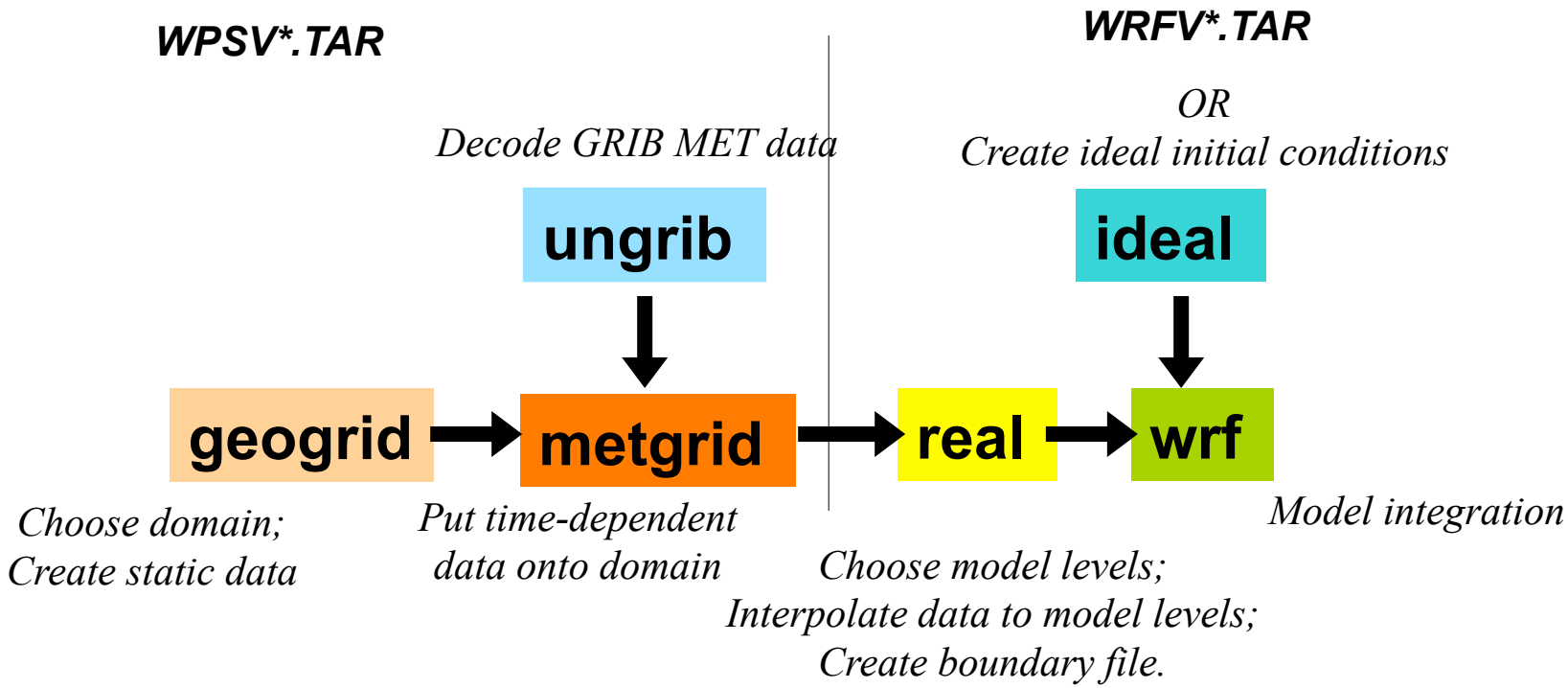
ARW Model

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)
- Digital Filter Initialization option

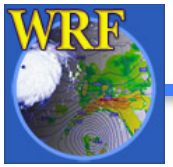


Summary of WPS and WRF Programs



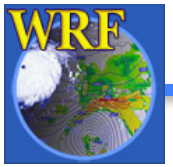
Graphics and Verification Tools

- RIP4 (Read, Interpolate and Plot)
- ARWpost
  - Conversion program for GrADS
- Unified Post-Processor (UPP)
  - Conversion to GriB (for GrADS and GEMPAK)
- MET (Model Evaluation Toolkit)
- NCAR Graphics Command Language (NCL)
- VAPOR (3D visualization tool)
- IDV (3D visualization tool)



Basic Software Requirement

- Fortran 90/95 compiler
  - Code uses standard f90 (very portable)
- C compiler
  - "Registry"-based automatic Fortran code generation (for argument lists, declarations, nesting functions, I/O routines)
- Perl
  - configure/compile scripts
- netcdf library
  - for I/O (other I/O formats semi-supported)
- Public domain mpich for MPI
  - if using distributed memory option

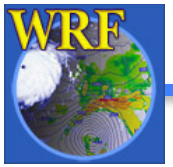


WRFDA (Data Assimilation)

- Variational data assimilation (3D-Var and 4D-Var)
- Ensemble DA
- Hybrid variational/ensemble DA

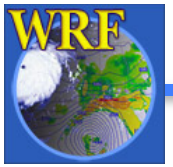
Function

- Ingest observations to improve 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



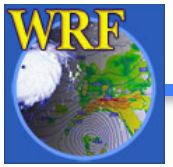
WRF-Chem

- Supported by NOAA/ESRL
- Includes chemistry species and processes, many chemistry options
- Also needs emissions data
- Included in WRF tar file, but requires separate compilation option



Portability

- Runs on Unix single, OpenMP and MPI platforms:
  - IBM SP AIX (xlf)
  - Linux (PGI, Intel, gfortran, Pathscale compilers)
  - SGI Altix (Intel)
  - Cray XT (PGI, Pathscale)
  - Mac Darwin (PGI, Intel, gfortran compilers)
  - Others

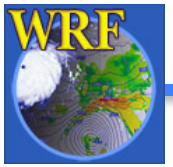


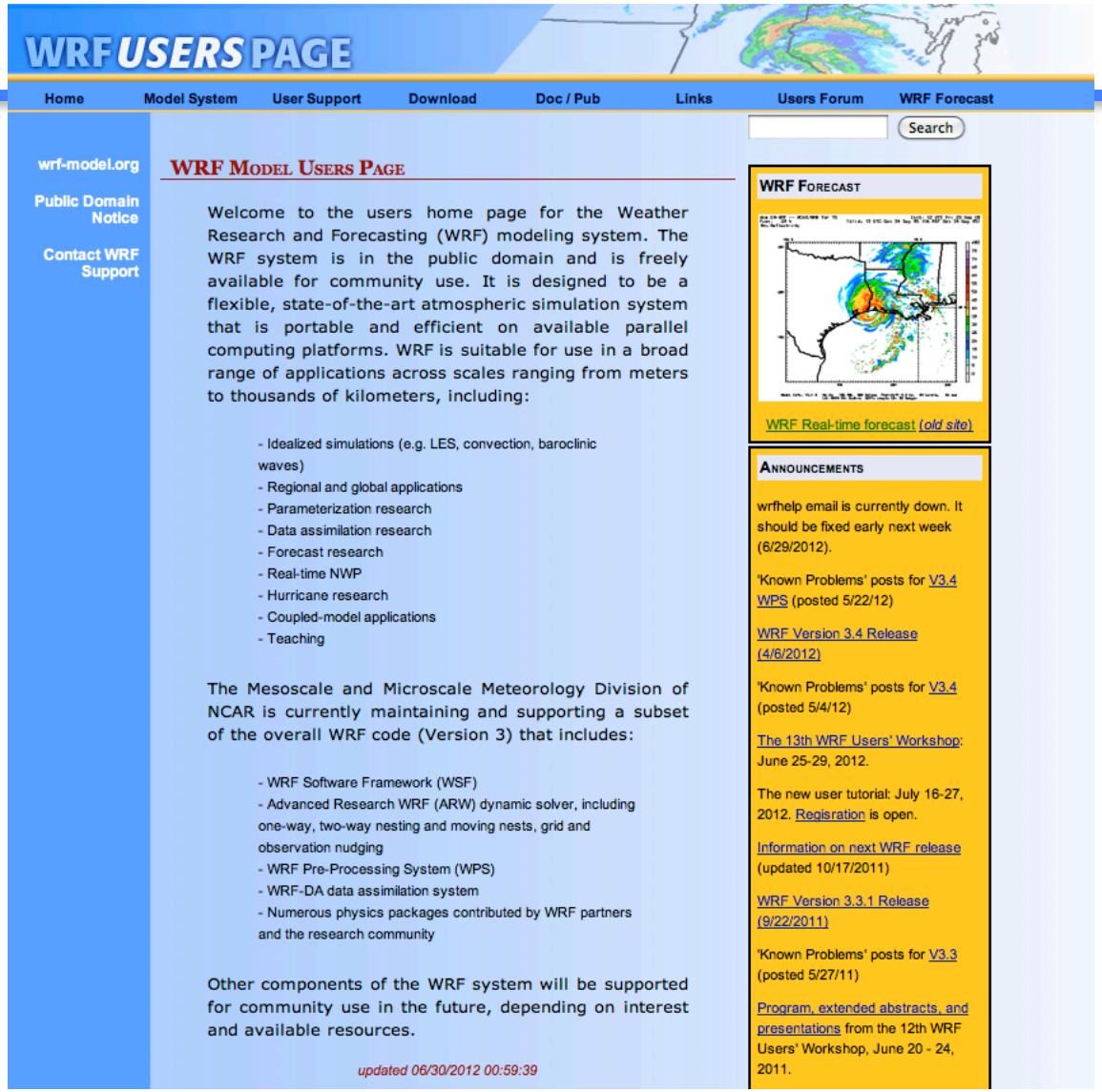
User Support

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

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

  – Latest update for the modeling system
  – WRF software download
  – Various documentation
    - Users' Guides (both cores)
    - Technical Note (ARW Description)
    - Tutorial presentations

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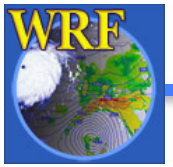
WRF Model Users Page
Welcome to the users home page for the Weather Research and Forecasting (WRF) modeling system. The WRF system is in the public domain and is freely available for community use. It is designed to be a flexible, state-of-the-art atmospheric simulation system that is portable and efficient on available parallel computing platforms. WRF is suitable for use in a broad range of applications across scales ranging from meters to thousands of kilometers, including:
- Idealized simulations (e.g. LES, convection, baroclinic waves)
- Regional and global applications
- Parameterization research
- Data assimilation research
- Forecast research
- Real-time NWP
- Hurricane research
- Coupled-model applications
- Teaching
The Mesoscale and Microscale Meteorology Division of NCAR is currently maintaining and supporting a subset of the overall WRF code (Version 3) that includes:
- WRF Software Framework (WSF)
- Advanced Research WRF (ARW) dynamic solver, including one-way, two-way nesting and moving nests, grid and observation nudging
- WRF Pre-Processing System (WPS)
- WRF-DA data assimilation system
- Numerous physics packages contributed by WRF partners and the research community
Other components of the WRF system will be supported for community use in the future, depending on interest and available resources.
updated 06/30/2012 00:59:39
WRF Forecast
WRF Real-time forecast (old site)
Announcements
wrfhelp email is currently down. It should be fixed early next week (6/29/2012).
'Known Problems' posts for V3.4 WPS (posted 5/22/12)
WRF Version 3.4 Release (4/6/2012)
'Known Problems' posts for V3.4 (posted 5/4/12)
The 13th WRF Users' Workshop: June 25-29, 2012.
The new user tutorial: July 16-27, 2012. Regisration is open.
Information on next WRF release (updated 10/17/2011)
WRF Version 3.3.1 Release (9/22/2011)
'Known Problems' posts for V3.3 (posted 5/27/11)
Program, extended abstracts, and presentations from the 12th WRF Users' Workshop, June 20 - 24, 2011.

Tutorial Schedule

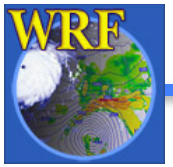
- Lectures for WRF: Mon – Wed
- Practice and Q&A for WRF: Mon – Wed

  ~ 5 – 6 pm
- Lectures for WRF-Chem: Wed – Thur



Scope of Tutorial

- What's in the modeling system
  - Pre-processing programs and model
- How to run the modeling system
- Hints on choosing options
- Advanced usage
  - Adding your own input or output data
  - Making changes to the code
  - Tips on making best configuration



Scope of Tutorial

- Note: we cover a wide range of topics in much detail due to having a wide range of new users
  - New users can focus on areas of their own interest
  - Don't feel you have to learn everything in the lectures now
  - Minimum you need to learn is how to run the programs and what they do
    - Daily practice sessions (~1 hr) are a basic part