Extending the Operational Applicability of the Advanced Research WRF Model

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Or...NWP: It’s not just for meteorologists anymore!

The advent of “cheap” computing has allowed our NWP science to rapidly advance, changing the paradigm of how models are used for operational decisions.

NWP is often superior than any human forecast, depending on the parameter, region, and application.

Increasingly, our customers want and expect automated solutions to difficult and/or unique forecast problems. WRF is the best available engine for such applications, but can also benefit from “refinements” via add-on applications.

Overview of today’s talk:

• A brief description of our operational WRF system
• A quick survey of applications we are supporting with WRF
• Two unique “coupled” applications that enhance WRF’s intrinsic value for automated applications: ARMOR and USL

Also see poster of same title!
Operational WRF System

HPC Environment
- 40 Intel Xeon Cores
- 156 AMD Opteron Cores
- PGI Compilers+OpenMPI
- InfiniBand Interconnect
- ROCKS Cluster Tools
- SGE Job Management
- Tier 2 Data Center

Supports 100+ operational WRF Runs each day
We had been avoiding quad-core chips, using compute nodes with two dual-core AMD Opterons with great success. However, those are no longer available, so our last upgrade consisted of 10 new servers having dual Quad-Core AMD Opteron 2384 2.7 GHz CPUs. Fortunately, they seem to provide comparable performance to our older 3.0 GHz dual-core servers. But, performance is still better when fewer procs per server are used.

Performance Ratio (Sim Time:Wall Time) on AMD Opteron 2384 as a function of cores vs. servers. System uses OpenMPI+pgf90+gcc and InfiniBand. Processor and memory affinity set in OpenMPI.
Operational WRF System

**Data Assimilation**
- NAM/GFS for first guess and BC
- NOAAPort and MADIS Obs
- WDT Radar Mosaics*
- Geostationary Imagery*
- FDDA, 3DVAR, ADAS, LAPS

*Fall 2009

**Post Processing**
- Custom Algorithms
- GRIB-2 Data Feeds
- Point Data
- MET Verification

European 12 km

N. American 11 km

Hourly 10 km
Aviation

Icing

Turbulence

LLWS Hazard
WDT WRF Forecast for TC Nargis

43 h Forecast
2 May/1300 UTC

Left: WDT uses WRF to provide very high resolution (1 nm) wind forecasts for selected sailing venues around the world, delivered directly to a custom display application on the sailboat.

Right: WRF has demonstrated capability for forecasting strength and track of tropical storm systems.
Renewable Energy

Solar

WRF Incoming Solar Radiation

Wind

3-km WRF Winds

Decision Support Tools

- WindPredictor
  - Coupled USL+WRF
  - Microscale Winds
  - Rapid Updates
- SolarPredictor

Applications

- Micro-siting
- Prospecting
- Load Forecasting
- Energy Trading
- Hazard Monitoring

Incoming Solar Radiation for Norman, OK
WRF Forecast Initialized 2009/06/10 12:00
WDT has been providing high-resolution WRF forecasts for quantitative precipitation forecasts. GIS post-processing remaps the gridded QPF values to basin averages. These forecasts are used to plan cloud seeding operations. WRF performs particularly well in forecasting onset and duration of precipitation events.
Input for Point Forecast Services (WRF+USL)

Radar Precipitation Typing
• **Adjustment of Rainfall from Models using Radar**
• Developed by McGill University
• Provides short-range (0-10 h) QPF
• Applications:
  - Hydrometeorology
  - “Forecast Radar”
    • Media
    • Aviation
ARMOR specifications

• WDT has implemented the ARMOR algorithm with the following input data:
  – 10 km resolution Weather Research and Forecasting (WRF) model 15 minute accumulated precipitation field (run hourly)
  – 1 km resolution continental US low altitude radar mosaic at 5 minute frequency

• ARMOR is run every 15 minutes to produce a new 10 hour forecast of 15 minute average precipitation rate at 5 km resolution over the entire CONUS.
Details of the Methodology

1. Radar reflectivity mosaic is converted to precipitation rates and accumulated to 15 minute intervals.
2. Phase error is determined as vector field needed to overlap model and radar precipitation fields best at t0.
3. Phase errors are checked.
4. Precipitation features are tracked in both the verifying radar and model forecast to produce motion vectors for past hour.

5. Phase error is computed for all past times and trend is determined from those errors.

6. Vectors are computed for future model forecast times.
Example WRF forecast

**WRF**
remapped WRF model forecast avg precip rate 15 min model avg precip rate
150 min forecast valid at time 2009-04-20 18:30

**Verifying radar**
remapped radar low alt scan 15 min radar avg precip rate
radar valid at time 2009-04-20 18:15

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Weather Decision Technologies, Inc.
Example ARMOR forecast

ARMOR

ARMOR (intensity and phase corrected) forecast 15 min model avg precip rate

15 min forecast valid at time 2009-04-20 18:15

mm/hr

Verifying radar

remapped radar low alt scan 15 min radar avg precip rate

radar valid at time 2009-04-20 18:15

mm/hr
Statistical Evaluation

Critical Skill Index (Threat Score)

forecast time (hrs)
What’s next for ARMOR?

- Thresholding WRF precipitation field
  - reduces model noise
  - focuses motion of precipitation on stronger features

- ARMOR’s skill in tracking individual storms is bound by limitations of present-day NWP models.
  - ARMOR regional, high-resolution runs
    - Increase the dynamic range of precipitation patterns.
  - WRF regional, high-resolution runs
    - Increase dynamic range in the background model
    - Overall improvement of the mesoscale forecast (motion, etc.)
    - Better track individual storms
The Uncoupled Surface Layer (USL) Model

- A physics-based numerical prediction model designed to predict near-surface weather conditions at very fine scales. Developed and maintained by NanoWeather, Inc.

- The USL model can account for physical processes that are ignored or poorly resolved by standard models. In addition, the model is tuned to each grid point's microclimate using a combination of physical parameters and historical observations.

- Compared to standard models, the USL has been shown to be superior in predicting both winds and temperatures within the lower planetary boundary layer.

- When coupled with a mesoscale model such as WRF, USL provides superior forecasts of temperature and winds on small regional domains.

- The USL model outputs a wide variety of meteorological parameters including temperature, humidity, wind speed, and wind direction within the boundary layer.
USL Microscale Temperature Forecast
555 m USL 5 hr fcst based on 6 km WRF
USL Verification

- Won 2006 Collegiate Inventors Competition
- Superior to NWS NDFD point forecast and all model forecasts in national WxChallenge collegiate forecasting contest for the last two seasons


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<th>Parameter</th>
<th>MAE</th>
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<td>Temperature</td>
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<tr>
<td>Dewpoint</td>
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<tr>
<td>Wind Speed</td>
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Summary

- WRF has reached a level of reliability and trust that it can serve as an engine for automated content creation.
- Care still must be taken to apply it appropriately and educate the end users.
- Computationally efficient post-processing systems and techniques can provide significant improvements.