Commercial Implementation of WRF with Efficient Computing and Advanced Data Assimilation

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Motivation

• Dubai International Airport Project
  – Incorporate WRF in the Aviation Weather Decision Support System (AWDSS)
  – Need for an operationally reliable turn-key system that can run without an on-site NWP expert
  – Incorporation of data assimilation and rapid refresh

• Refresh of WDT’s internal infrastructure
  – Replacement of older WRF+ADAS system
  – Hardware nearing end-of-life

• Develop a shared code base for deployable and internal WRF-based systems
System Components

• Public WRF Components
  – WRF Domain Wizard
  – WPS
  – WRF-Var
  – WRF-ARW Version 2.2.1 with FDDA
  – WRF Post Processor (from WRF-NMM Distribution)

• WDT Components
  – WRFControl Package
  – WRF Management Portal
  – Custom Post-Processing and Plotting

• High-Performance Linux Cluster
  – Built and managed with ROCKS, using Sun Grid Engine (SGE) for job control and Ganglia for system monitoring
AWDSS WRF Integration

3DVAR+FDDA Assimilation

WRF NWP Model

Post-Processing

AWDSS Observations

Satellite

Radiometer

Wind Profiler

Radar

Sfc Obs

WRFControl System

Profiles

Grids/Profiles

Nowcast Product Generator
Detection and Nowcasting Algorithms (Fog, inversion, turbulence, LLWS, etc.)

Operational User Interface
Data Assimilation: 3DVAR+FDDA Initialization

- **COLD**
  - Initialized from GFS forecast at 12Z
- **3DVAR**
  - 3DVAR analysis from GFS forecast + obs
- **FDDA**
  - 3-h Forecast initialized at T-3 with GFS, nudged with obs
- **3DVAR+FDDA**
  - Initialized with 3DVAR at T-3, FDDA from T-3 to T

Comparison of 1200Z, 24 Sep 2007 WRF Initialization
2 m Dewpoint Temperature
11-h Forecast of Valid 2300Z/24 Sep 2007
Total Precipitation from 2200-2300Z

Radar/IR Satellite at 2300Z
Data Assimilation Issues

- Cycling of 3DVAR Problematic
- Numerous Data Formats
- Observation QC in FDDA
- Availability of Documentation
  - I/O Formats
  - Obs. Types and Usage
  - GenBE Code

NEXRAD Composite
VT: 2007/09/18 1258Z

WRF 1-h Forecast (Warm Initialization)
VT: 2007/09/18 1300Z

WRF 1-h Forecast (Cold Initialization)
VT: 2007/09/18 1300Z
Computational System

• **Linux Cluster**
  – 2 dual-core AMD Opteron CPUs per node
  – 8 GB RAM per node
  – Dual power supplies
  – High-availability network attached storage

• **ROCKS Cluster Software**
  – Built with Red Hat Linux
  – Sun Grid Engine (SGE) Job Management
  – Ganglia Web Monitor

• **PGI Fortran and Gnu C Compilers**

• **Functional Partitioning for Reliability**
  – Primary/backup headnode
  – Separate queues for serial vs. parallel jobs

• **No single point of failure**
Optimizing Parallel WRF Performance
System Tuning on Small Clusters without Interconnect

Execution Performance Ratio (Excludes I/O Steps)

Key Results

- Decomposition matters!
- MPICH2 better than MPICH1
- OpenMPI may be even better
- Multi-core systems present new challenges

NOTE: All issues above are mitigated if high-speed interconnect is used!
## Optimizing Parallel WRF Performance

### Decomposition Tuning via NPROC_X and NPROC_Y

<table>
<thead>
<tr>
<th>NPROC_X</th>
<th>NPROC_Y</th>
<th>Inter-node Interfaces</th>
<th>Performance Ratio</th>
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</table>
Operationalization

• Efficiency
  – Computational system optimizations
  – Separation/parallelization of WPS ungrib process

• Reliability
  – Elimination of single failure points
    • Enterprise-class servers and OS
    • Dual head nodes using SGE “shadow master”
    • Extra compute nodes
    • NetApp file server
  – Fault tolerance
    • Handling of missing data, 3DVAR problems, etc.
    • Dynamic resource allocation via SGE to handle failed servers
    • Configurable e-mail alerting levels

• Usability
  – Turn-key system with flexible user configuration options
  – Web-based WRF Management Portal
  – Standardized output formats for easy integration into operations
Configure Domains

Domain Wizard

Summary of Configured Domains
After adding, entries appear on schedule.
Post-Processing and Integration
Future Plans

• WDT Internal System Implementation
  – Hourly update CONUS 0-9 h forecast (10 km)
  – 6-hourly CONUS 0-72 h forecast (10 km)
  – 6-hourly Europe 0-72 h forecast (10 km)
• Test and upgrade to WRF v3.0
• Radiance and Radar Assimilation
• Address Cycling (Digital Filter?)
• Automate 3DVAR GenBE
• New Post-processing (GRIB-2)
• Deliverable Systems
Community Recommendations

• Add/Improve Documentation
  – I/O Format Specifications for 3DVAR & FDDA
  – Explanation of observation usage/limitations
  – Optimizing

• Continue Software Architecture Improvements
  – Liberal use of inline comments
  – Integration of related software packages
  – Other decomposition options?