

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

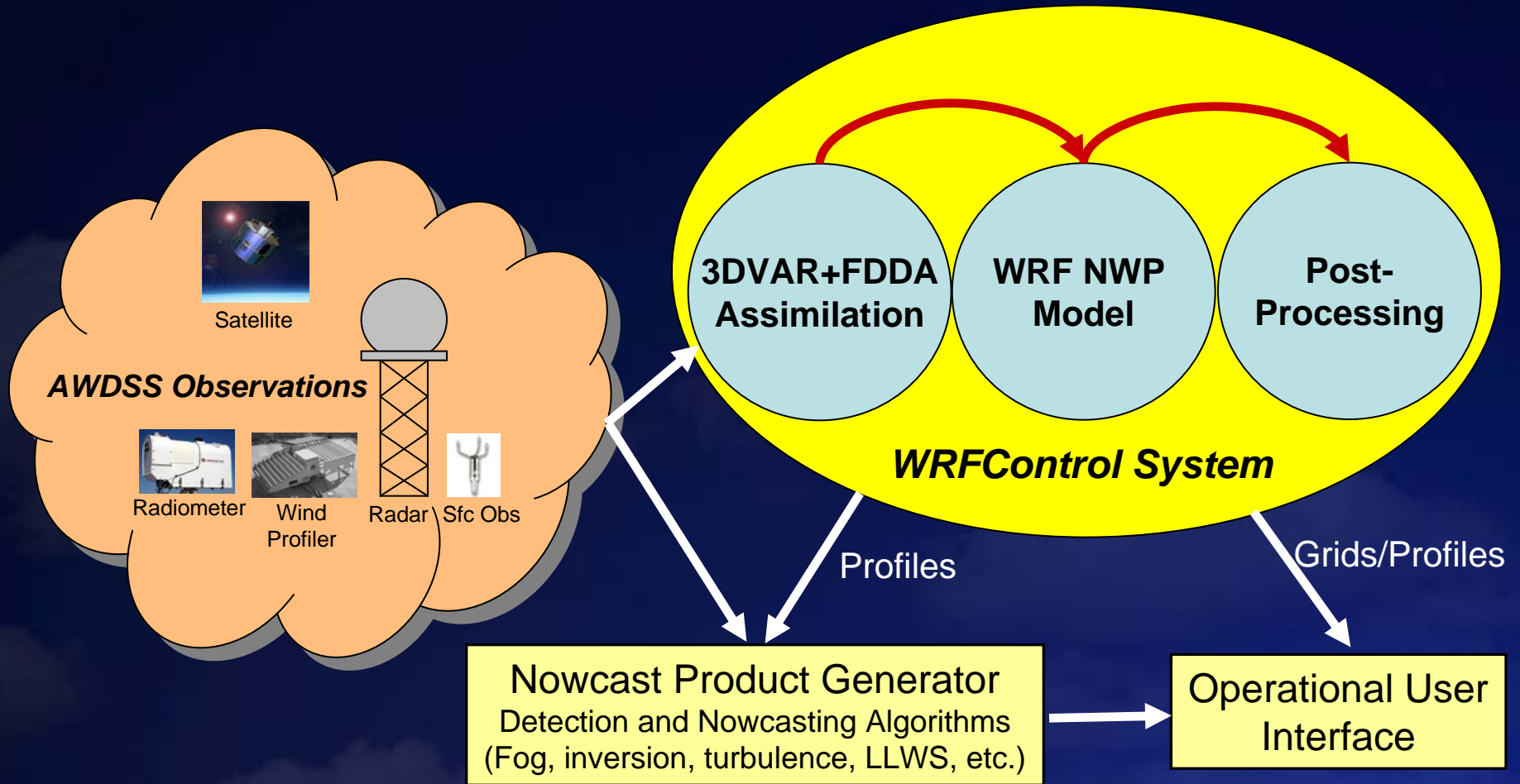


System Components

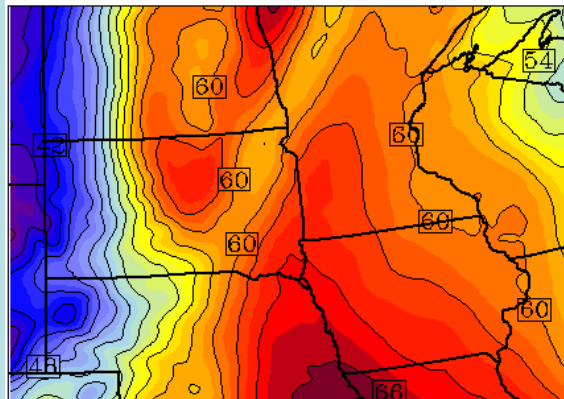
- **Public WRF Components**
 - WRF Domain Wizard
 - WPS
 - WRF-Var
 - WRF-ARW Version 2.2.1 with FDDA
 - WRF Post Processor (from WRF-NMM Distribution)
- **WDT Components**
 - WRFControl Package
 - WRF Management Portal
 - Custom Post-Processing and Plotting
- **High-Performance Linux Cluster**
 - Built and managed with ROCKS, using Sun Grid Engine (SGE) for job control and Ganglia for system monitoring



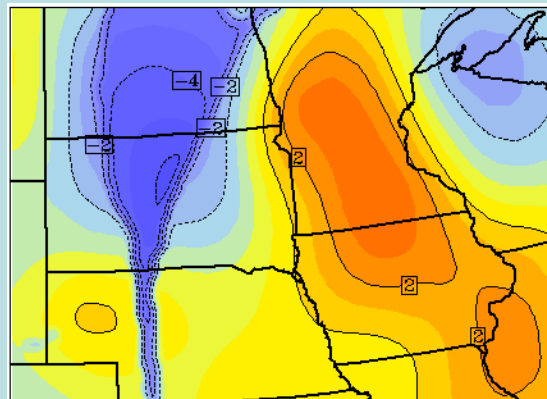
AWDSS WRF Integration



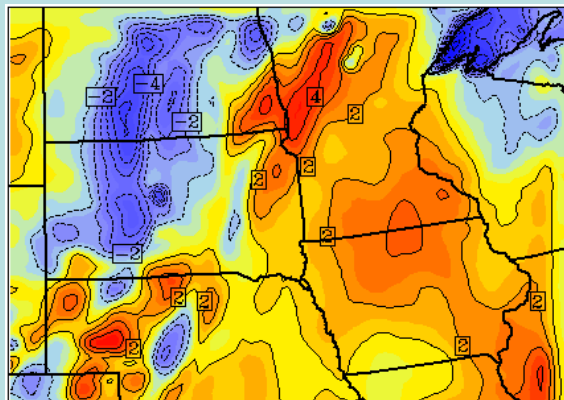
Data Assimilation: 3DVAR+FDDA Initialization



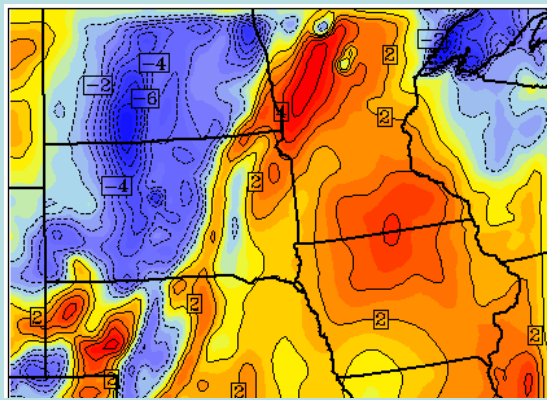
COLD Initialization



3DVAR - COLD



FDDA - COLD

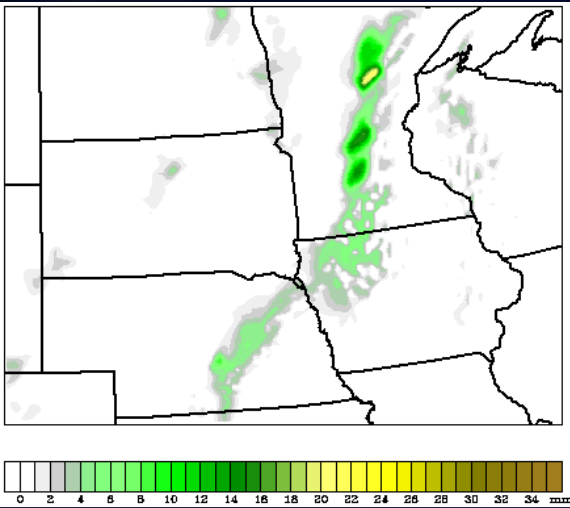


(3DVAR+FDDA) - COLD

**Comparison of 1200Z, 24 Sep 2007 WRF Initialization
2 m Dewpoint Temperature**

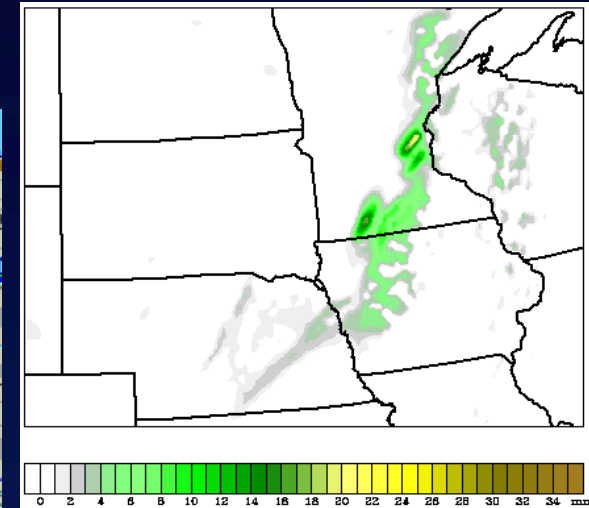
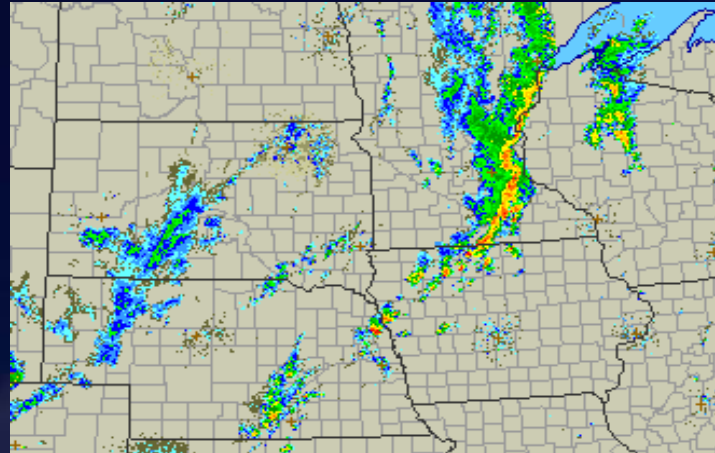
- **COLD**
 - Initialized from GFS forecast at 12Z
- **3DVAR**
 - 3DVAR analysis from GFS forecast + obs
- **FDDA**
 - 3-h Forecast initialized at T-3 with GFS, nudged with obs
- **3DVAR+FDDA**
 - Initialized with 3DVAR at T-3, FDDA from T-3 to T

11-h Forecast of Valid 2300Z/24 Sep 2007 Total Precipitation from 2200-2300Z

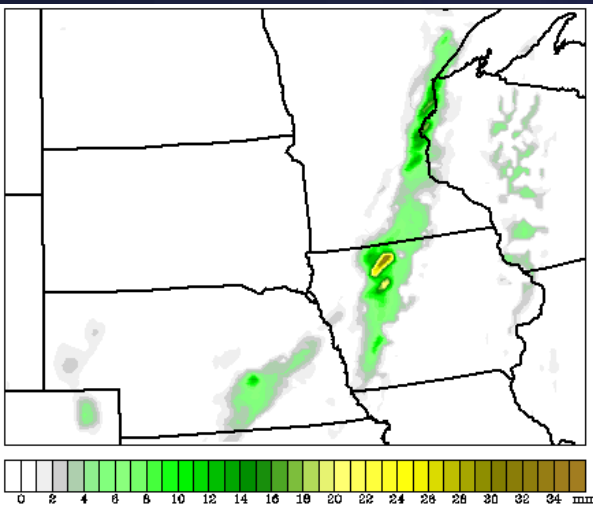


COLD

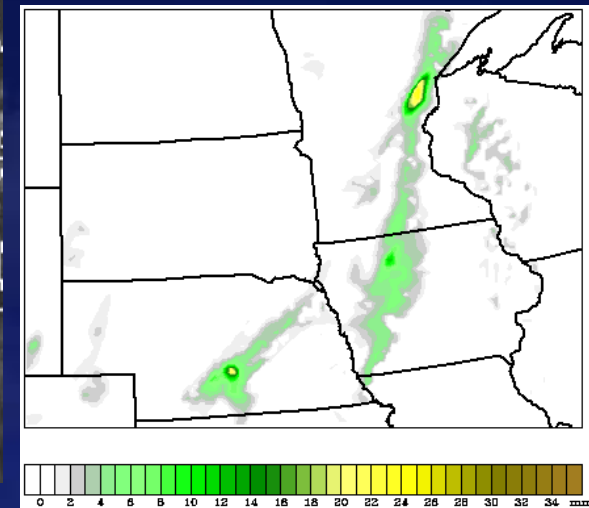
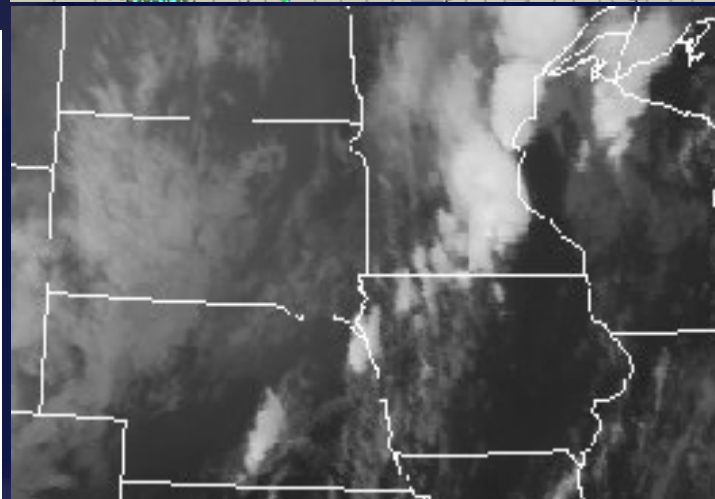
Radar/IR Satellite at 2300Z



3DVAR



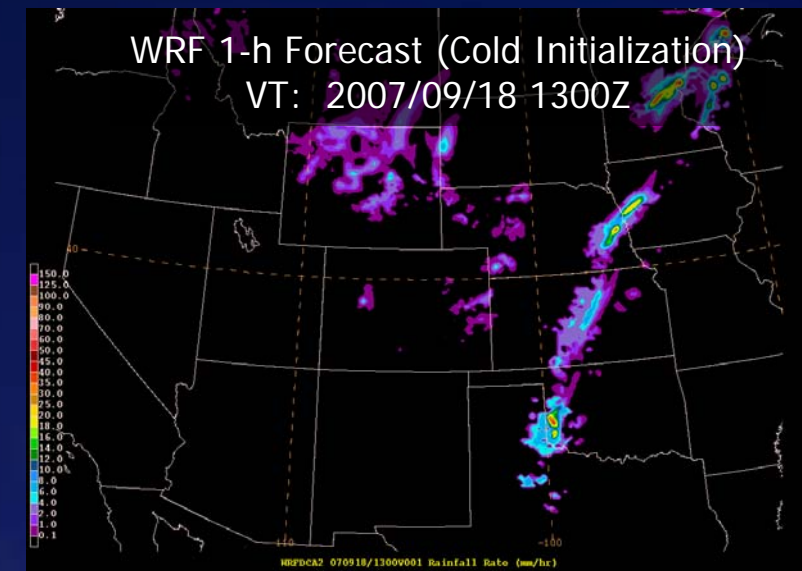
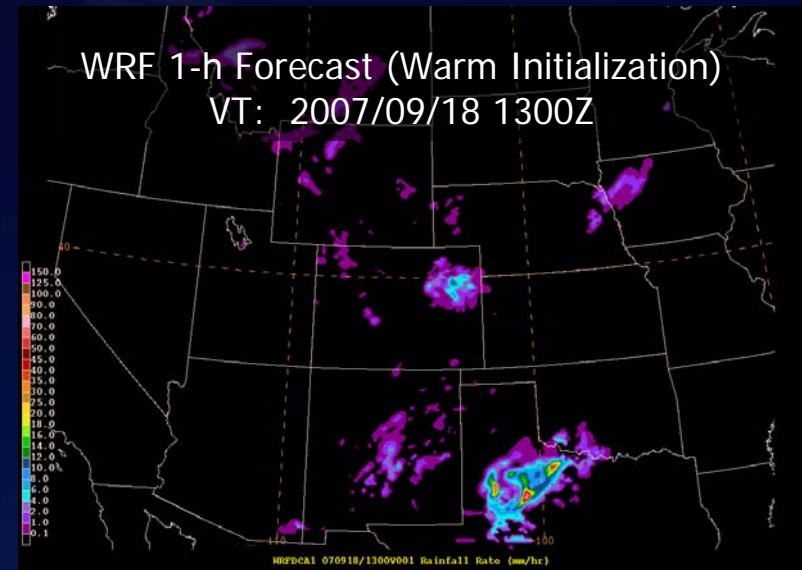
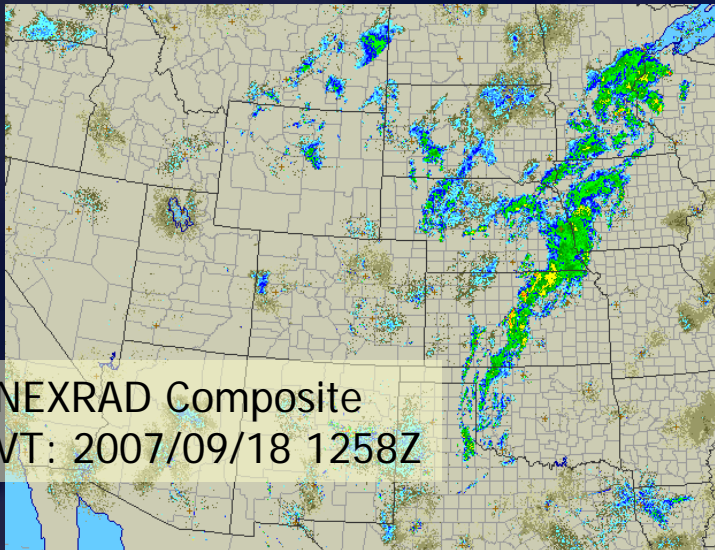
FDDA



3DVAR+FDDA

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



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**

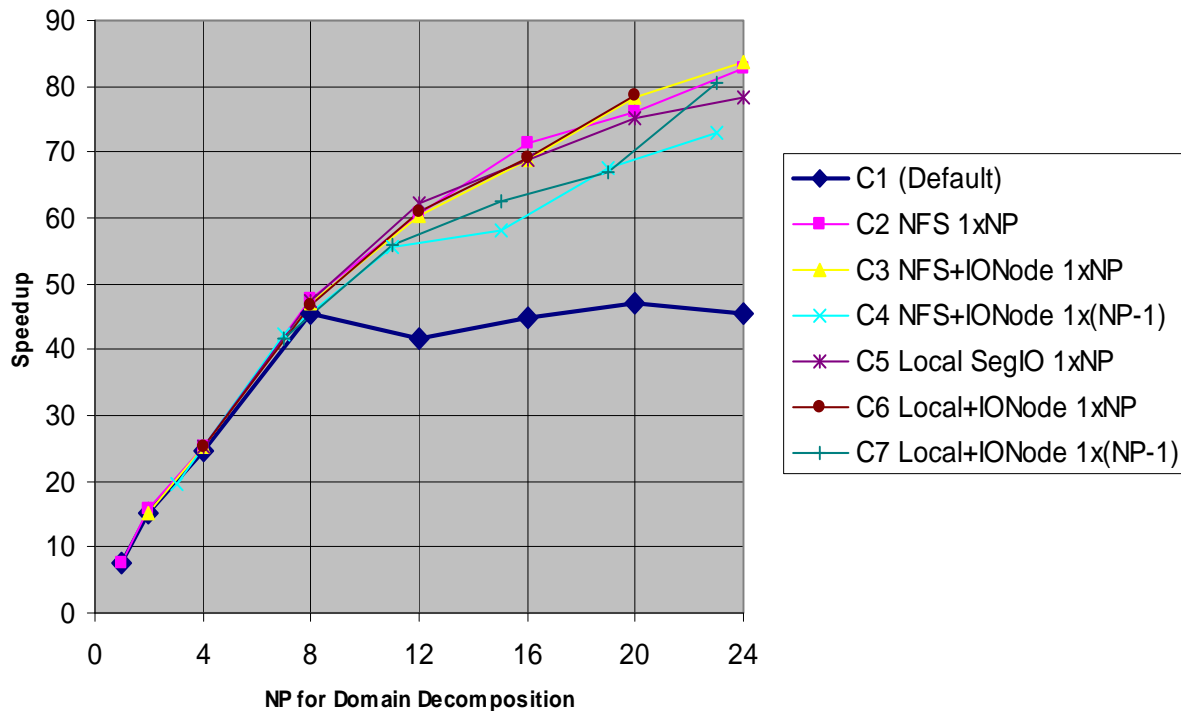


WRF
Nodes

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

4	4	4	4
3	3	3	3
2	2	2	2
1	1	1	1

Inter-node Interfaces: 30
Performance Ratio: 25.0

4	4
4	4
3	3
3	3
2	2
2	2
1	1
1	1

Inter-node Interfaces: 12
Performance Ratio: 27.6

3	3	3	3	4	4	4	4
1	1	1	1	2	2	2	2

Inter-node Interfaces: 24
Performance Ratio: 31.8

1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Inter-node Interfaces: 3
Performance Ratio: 29.4

1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Inter-node Interfaces: 3
Performance Ratio: 33.4



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



WRF Management Portal

Powered By



Home **Configure Domains** Schedule Monitor WRF Launch IDV Browse: Work Data Logs Monitor Cluster Cluster Info (ROCKS)

26 Oct 2007 18:35:37 UTC
Oct 26, 2007 1:35:37 PM

[Launch Domain Wizard](#)

Configure Domains

Portal User Guide

- Creating Forecast Domains
- Scheduling Forecasts
- Monitoring Forecasts
- View Output

All currently configured WRF domains for this system are shown below. Click on the thumbnail images to see the full resolution domain map.

To add a new domain, or to change or delete an existing domain, please click on the link above to launch the WRF Domain Wizard, ensuring that you complete the "Run Geogrid" step for each domain you edit. Click [here](#) to see the correct Domain Wizard settings

Note: Any changes made may take up to 10 minutes after the "Run Geogrid" step is completed before being made effective.

Domain Wizard

WRF Reference

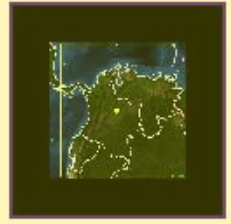
- WRF ARW Users Guide
- WRF ARW Technical Document
- WRF Model Homepage
- WRF Namelist
- Description of Forecast Products
- Selecting the Grid Spacing
- Troubleshooting WRF
- Technical Support
- Version history

Configured WRF Domains



Name	Projection	Standard Lon	TrueLat1	TrueLat2
Carib	Mercator	-70.0	17.0	0.0

Nest	Center Lat	Center Lon	Grid Spacing	Nx	Ny	Nz	Time Step
d01	17.00	-70.00	12.0 km	288	224	36	72.0 sec



Name	Projection	Standard Lon	TrueLat1	TrueLat2
Colombia	Mercator	-72.0	5.0	0.0

Nest	Center Lat	Center Lon	Grid Spacing	Nx	Ny	Nz	Time Step
d01	5.00	-72.00	12.0 km	193	193	36	72.0 sec

Summary of Configured Domains

Home

Standard



26 Oct 2007 18:42:15 UTC
Oct 26, 2007 1:42:15 PM

- Portal User Guide**
- Creating Forecast Domains
- Scheduling Forecasts
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[Home](#)

Routine Forecast Schedule

Edit Existing Schedule

Domain	Frequency	First Run	Delay	Duration	Num Procs	Delete
Carib	6 hourly	00 UTC	1 hour(s)	3 hours	16	<input type="checkbox"/>

Add Routine Entry

Domain	Frequency	First Run	Delay	Duration	Num Procs
Carib	1 hourly	00 UTC	0 hour(s)	3 hours	1

Scheduled Forecasts (Next 6 Hours)

Domain	Base Time	Start Time	Run Length	# Procs
Carib	1800 UTC	19:15 UTC	3 h	16

Scheduler
After adding,
entries
appear on
schedule



WRF Monitor

WRF Management

Home Configure Domains Schedule **Monitor WRF** Launch IDV

26 Oct 2007 18:43:51 UTC
Oct 26, 2007 1:43:51 PM

Portal User Guide

Creating Forecast Domains

Color Key:

In Progress

Details of Job 20071026_1500.Colombia.23878

Domain/Init Time: Colombia 2007-10-26_15:00:00
Host/Master PID: dubai-nwp.wdtinc.com 23878
Working Directory: [/home/wdtnwp/wrfctl/work/wrf/Colombia/20071026_1500](#)
Final Output Directory: [/home/wdtnwp/wrfctl/data/wrf/Colombia/20071026_1500](#)
Processing began: 2007-10-26.18:15:01
Metgrid began: 2007-10-26.18:15:01
Metgrid end: 2007-10-26.18:17:02
Job began: 2007-10-26.18:17:05
Job end: 2007-10-26.18:18:05
Job start: 2007-10-26.18:18:05
Job end: 2007-10-26.18:20:45
File: [obs_gts.3dvar](#)
Job: 2007-10-26.18:20:45
Jobs: 16
Job: [6642](#)
Jobs: 3
File: [OBS DOMAIN101](#)
Job: 2007-10-26.18:25:45
Job: [6643](#)

ROCKS

Dubai-NWP Job 6642 Detail

Fri, 26 Oct 2007 18:44:32 +0000 [Back to Job Queue](#)

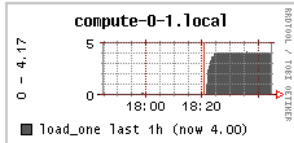
Name: wrf
Procs: 16
User: wdtnwp
Runtime: 0:23:37

Metric Graph:

load_one

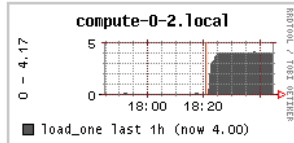
4: compute-0-1.local 4.00
cpu: 2.73G (4) mem: 7.85G

load_one



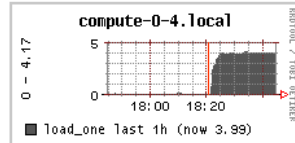
4: compute-0-2.local 4.00
cpu: 2.73G (4) mem: 7.85G

load_one



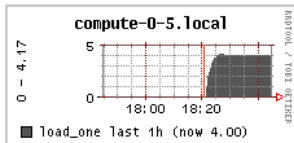
4: compute-0-4.local 3.99
cpu: 2.73G (4) mem: 7.85G

load_one



4: compute-0-5.local 4.00
cpu: 2.73G (4) mem: 7.85G

load_one



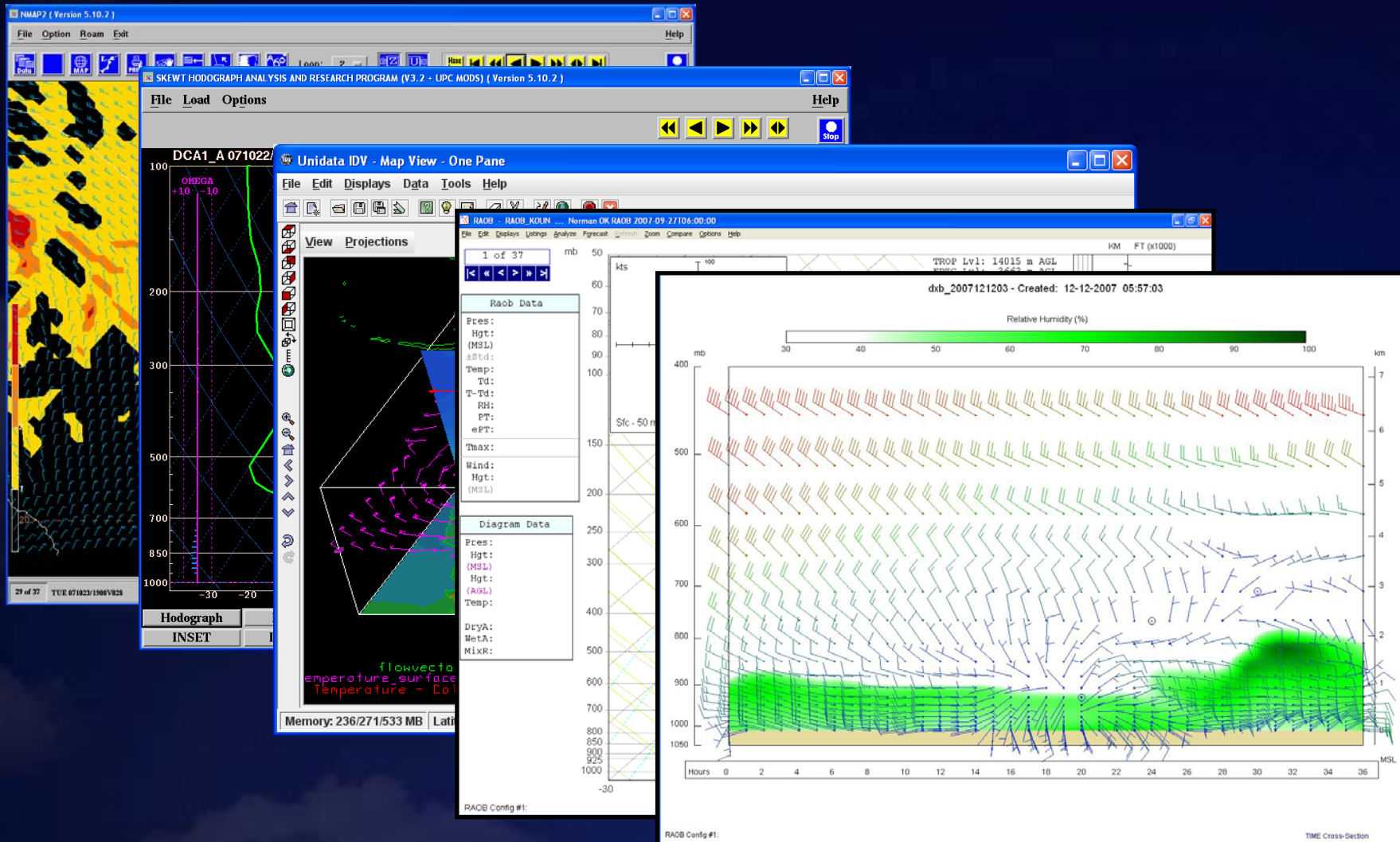
Stop this Forecast

924Z	100%	26/1007Z	39.6
921Z	100%	26/1001Z	41.3
824Z	100%	26/0907Z	38.5
821Z	100%	26/0903Z	39.9
724Z	100%	26/0806Z	39.8
721Z	100%	26/0802Z	40.9
623Z	100%	26/0706Z	38.9
621Z	100%	26/0701Z	41.6
524Z	100%	26/0607Z	38.4

Weather Decision Technologies, Inc.



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?

