Performance Results for the Weather Research and Forecast (WRF) Model on AHPCRC HPC Systems

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Relevance of the Boundary Layer to the US Army

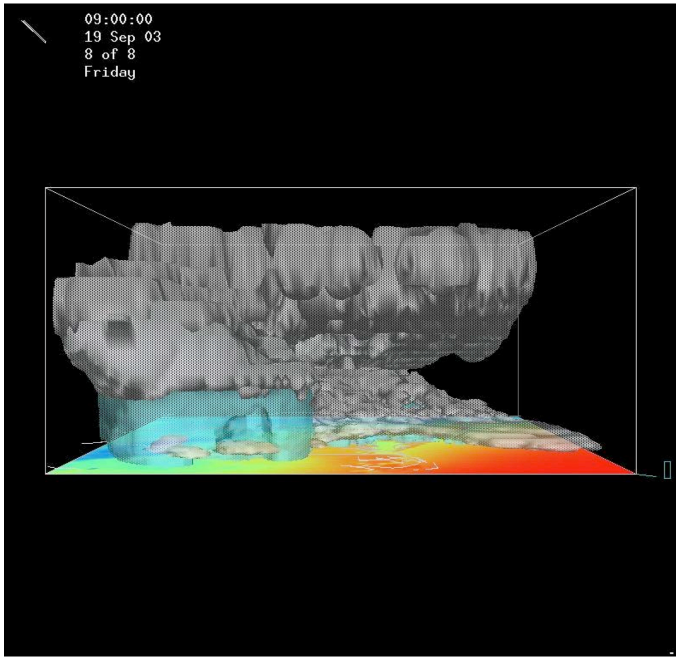
Example 1: Dust storms over Iraq
- surface visibility lost
- damage to equipment
- health issues
- operational problems

Source: (Army/AP Photo, ~ 4/27/05)

Example 2: Low level inversion with fog
- surface visibility intermittent
- interruption to transportation
- hard to predict ground level event
- seemingly benign … possibly fatal

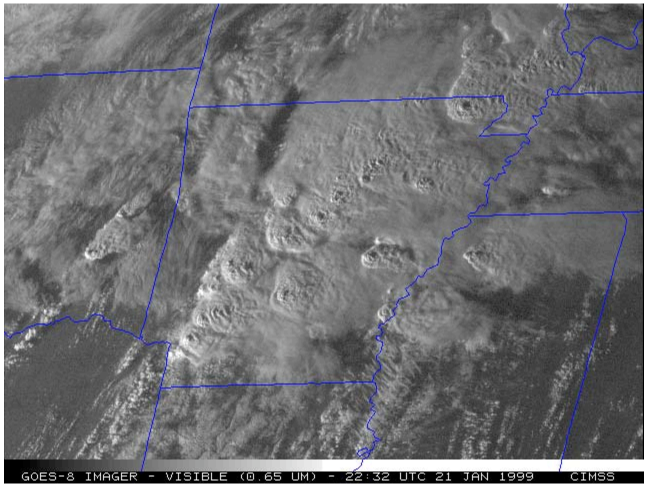
Source: (WDIO Tower Cam, 1/27/05)

Mesoscale Weather Model



- Domain over a limited geographical area (for example, the Midwest, Great Lakes, states bordering the Gulf of Mexico)
- Requires nesting in another model for lateral boundaries (usually, a regional model)
- Used to study small scale weather features like frontal thunderstorms (squall line), mesoscale convective complex, coastal land-sea forced winds, more complex topography
- Typical resolution is 15 km to 1 km

Some definitions:
mesoscale = a model with a resolution of 15 to 1 km
Mesoscale convective complex = a big storm comprise of many thunderstorm cells
Land-sea forced winds = localized winds caused by differential heating of land and sea



CIMSS

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AHPCRC X1E and Linux Opteron Cluster

Linux Cluster – 150 Opterons

Cray X1E – 256 MSP (1024 SSP)

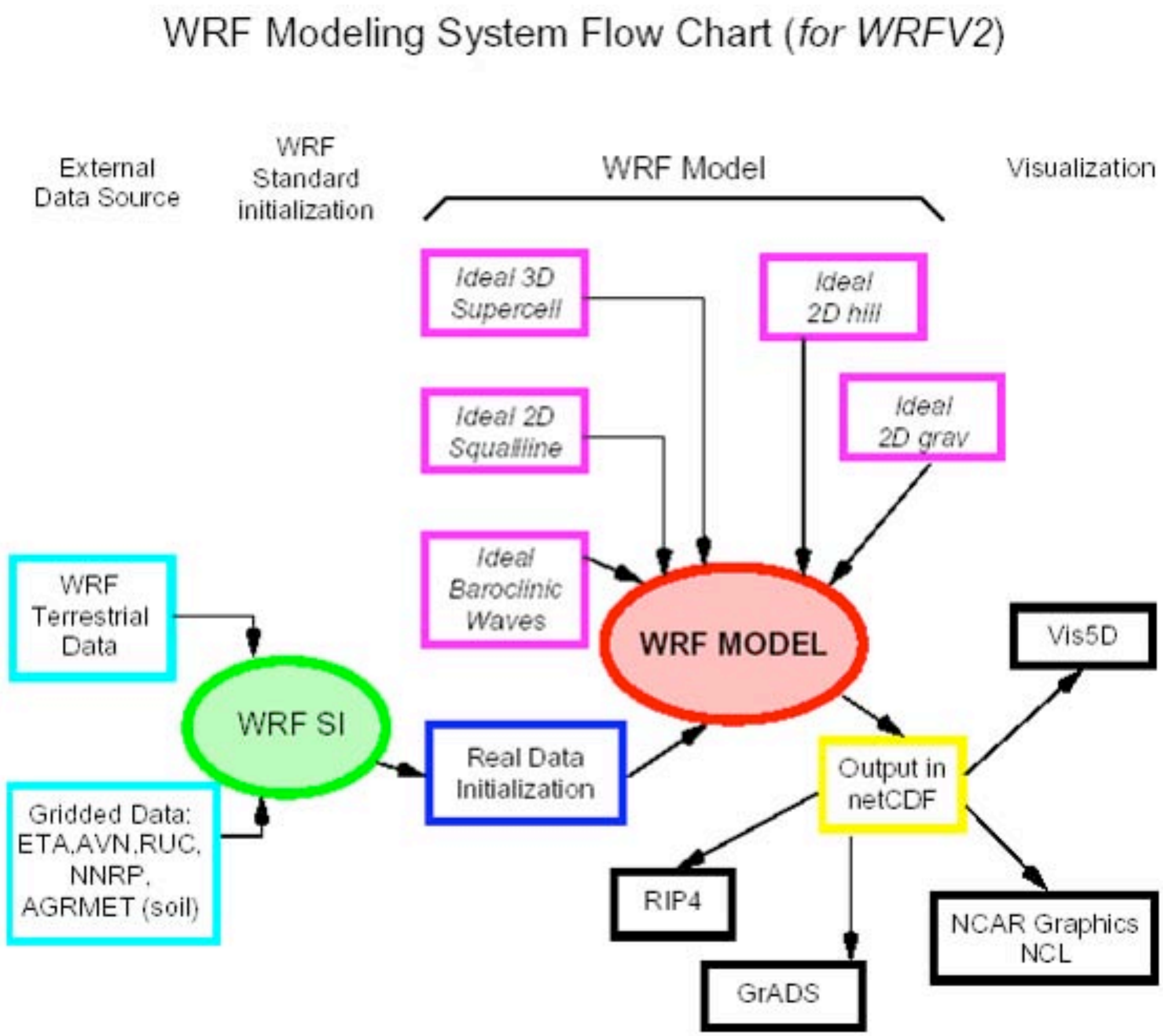
75 Nodes; Total Memory = 736 Gbytes
1 Node = Two 2.2 Ghz Opterons, 8/16 Gbytes
Interconnect: Myrinet
OS: Linux
Vendor: Atipa

64 Nodes; Total Memory = 512 Gbytes
1 Node = 4 MSPs (16 SSPs), 8 Gbytes
Interconnect: Cray Proprietary
OS: UNICOS/mp

Modeling: WRF Description

Source:
www.mmm.ucar.edu

The MMM WRF Users Page, Modeling System Overview



Modeling: WRF Description

Source:
www.mmm.ucar.edu

The MMM WRF Users Page, Modeling System Overview, WRF Model Version 2

Model Solver

- fully compressible nonhydrostatic equations with hydrostatic option
- complete coriolis and curvature terms
- two-way nesting with multiple nests and nest levels
- one-way nesting
- mass-based terrain following coordinate
- vertical grid-spacing can vary with height
- map-scale factors for conformal projections:
  - . polar stereographic . Lambert-conformal
  - . Mercator
- Arakawa C-grid staggering
- Runge-Kutta 2nd and 3rd order timestep options
- scalar-conserving flux form for prognostic variables
- 2nd to 6th order advection options (horizontal and vertical)
- time-split small step for acoustic and gravity-wave modes:
  - . small step horizontally explicit, vertically implicit
  - . divergence damping option and vertical time off-centering
  - . external-mode filtering option
- lateral boundary conditions
  - . idealized cases: periodic, symmetric, and open radiative
  - . real cases: specified with relaxation zone
- upper boundary absorbing layer option (diffusion)

Modeling: WRF Description

Physics

-microphysics (Kessler / WRF Single Moment (WSM) 3, 5 and 6 class / Lin et al./ Eta Ferrier)
- cumulus parameterization (new Kain-Fritsch with shallow convection / Betts-Miller-Janjic, Grell-Devenyi ensemble)
- planetary boundary layer (Yonsei University (S. Korea) / Mellor-Yamada-Janjic)
- surface layer (similarity theory MM5 / Eta)
- slab soil model (5-layer thermal diffusion / Noah land-surface model / RUC LSM)
- longwave radiation (RRTM)
- shortwave radiation (simple MM5 scheme / Goddard)
- sub-grid turbulence (constant K diffusion / Smagorinsky / predicted TKE)
- land-use categories determine surface properties

Inputs for WRF initialization

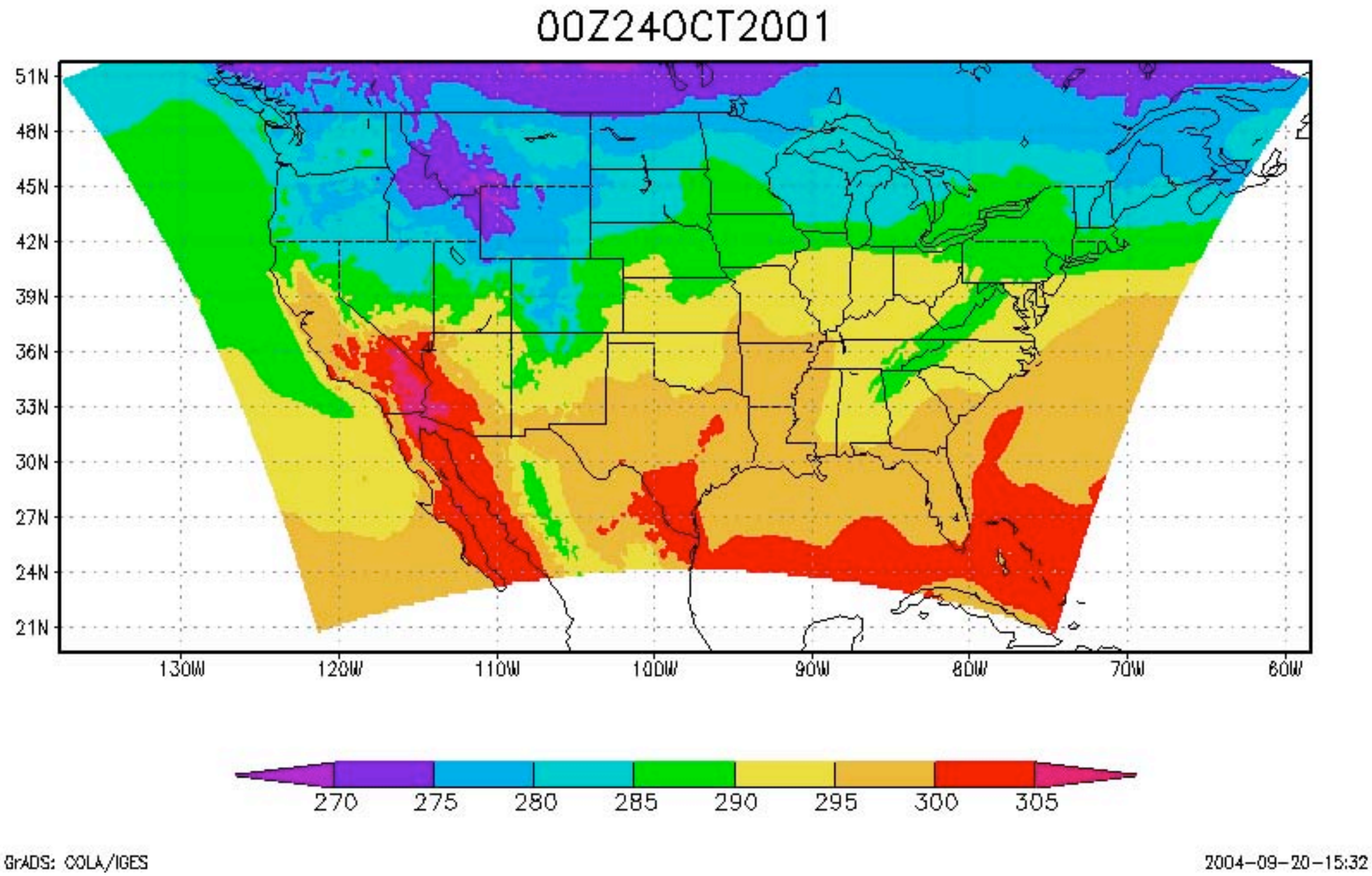
- idealized: several cases set up, both 2D and 3D
- real-data using Standard Initialization (SI) conversion from Grib files

Source: www.mmm.ucar.edu

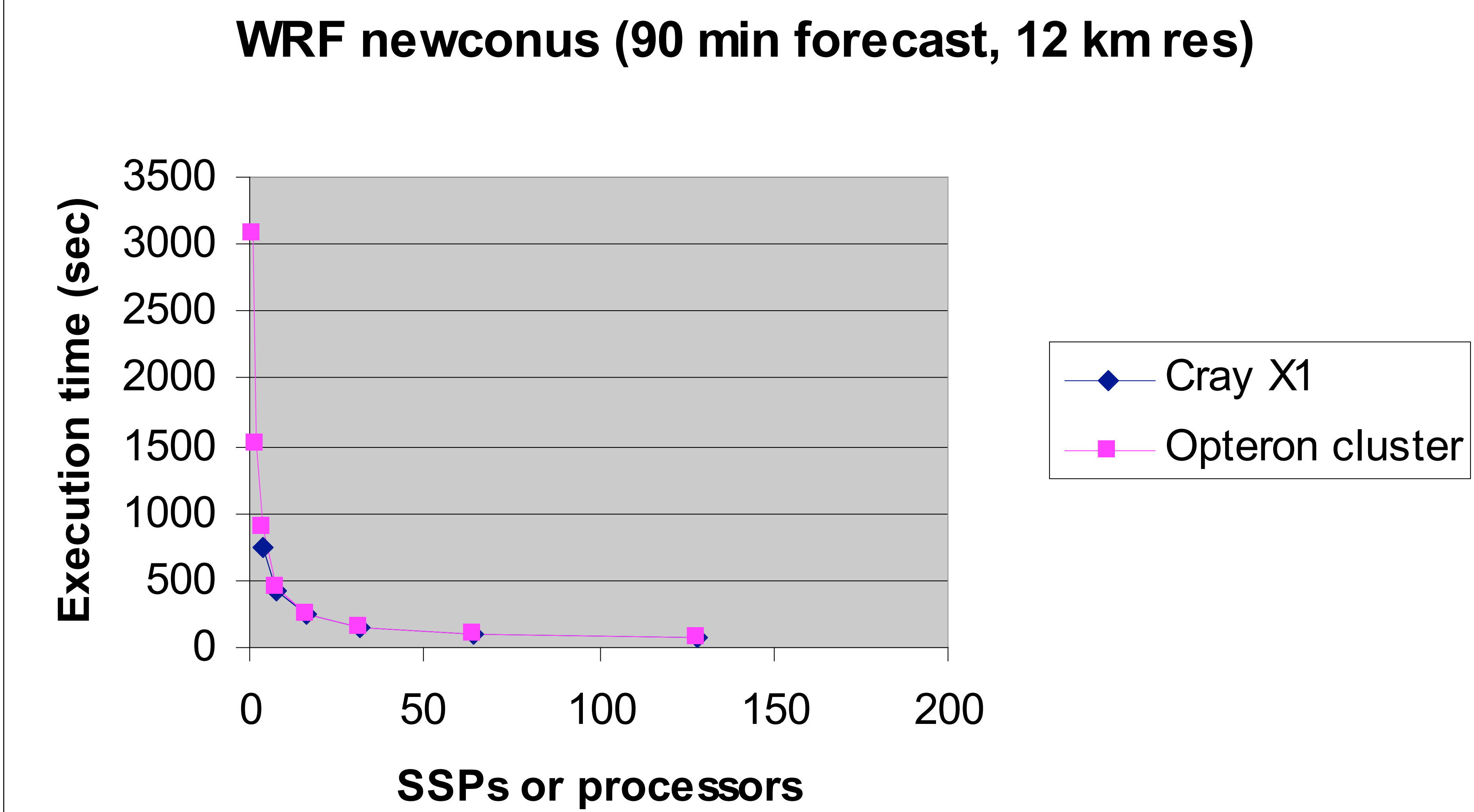
The MMM WRF Users Page, Modeling System Overview, WRF Model Version 2

Benchmark: newconus

1.5 forecast hours, 300x425x35, 72 sec time step, 12 km grid spacing

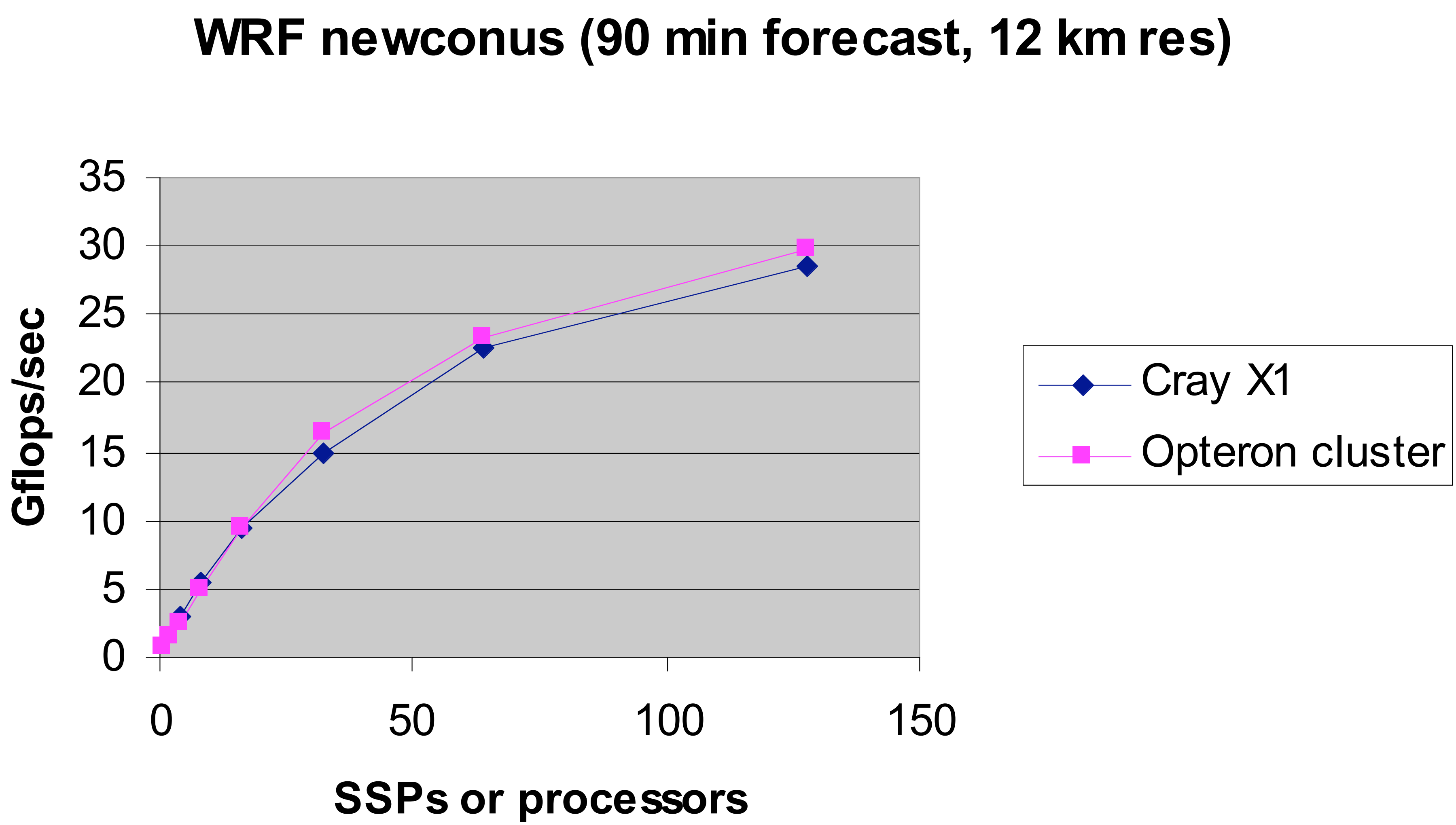


newconus: Execution Time



(Data points at 1, 2, 4, 8, 16, 32, 64 and 128 SSPs/processors.)

newconus: Performance



(Data points at 1, 2, 4, 8, 16, 32, 64 and 128 SSPs/processors.)

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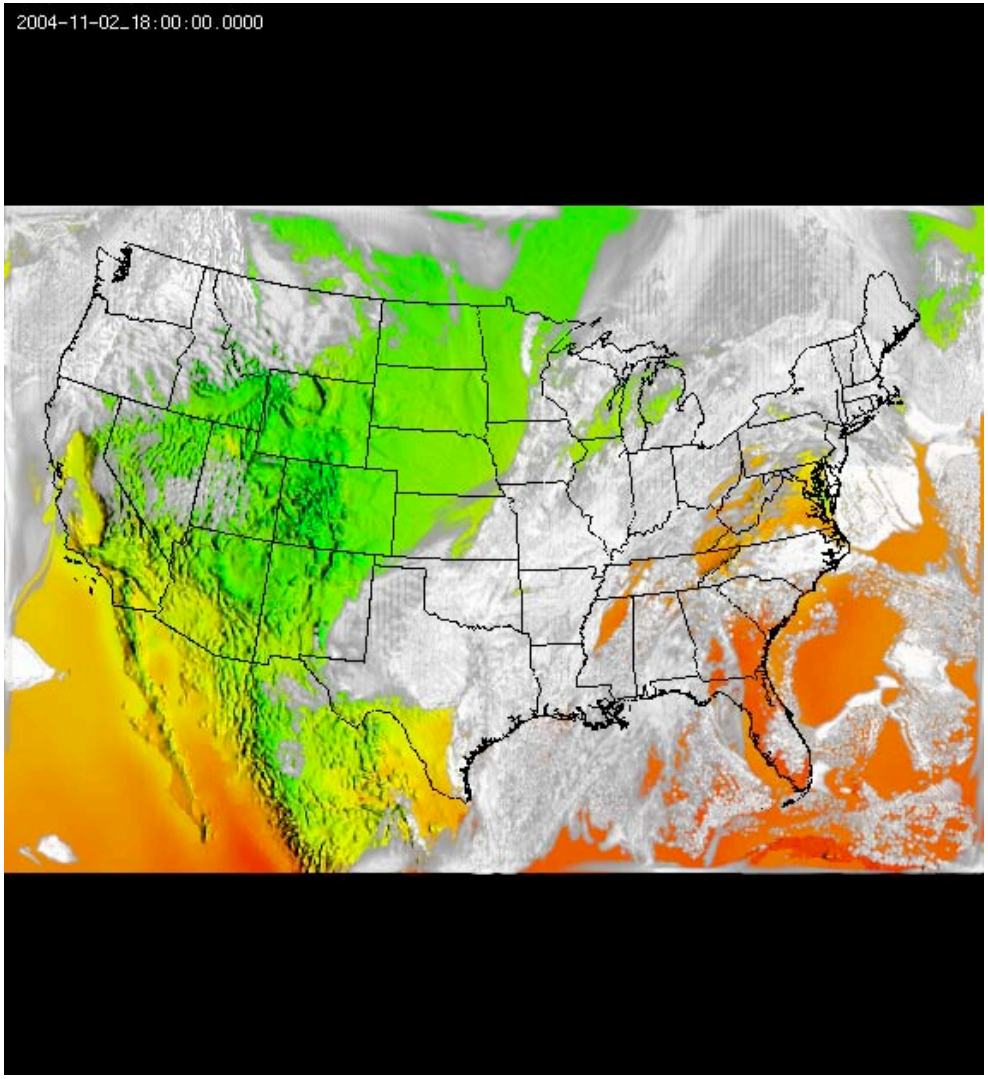
Benchmark: Basic Research Problem

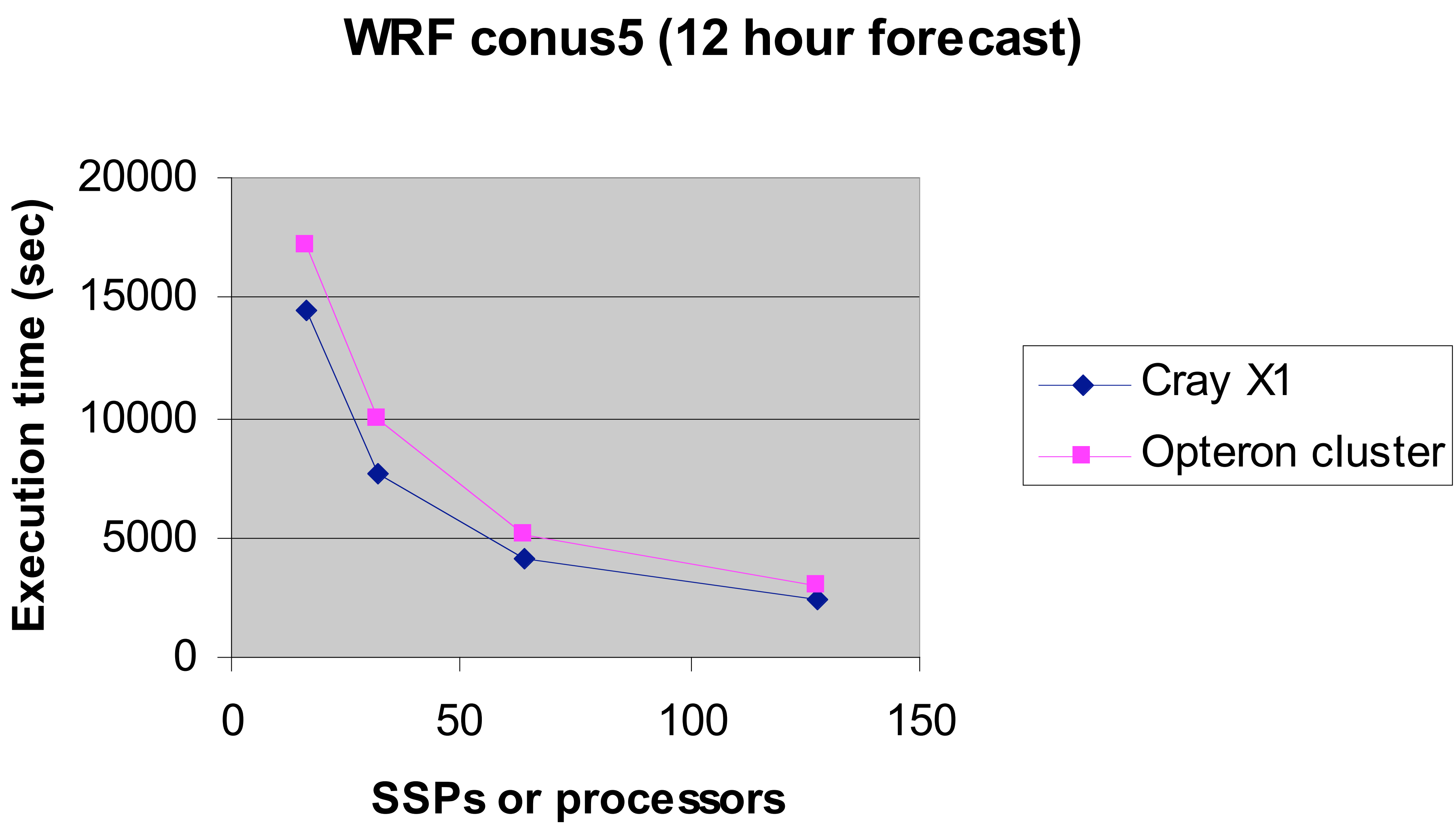
WRF test case:

680x1000
31 levels
5 km spacing
30 sec dt
12 hour fcst



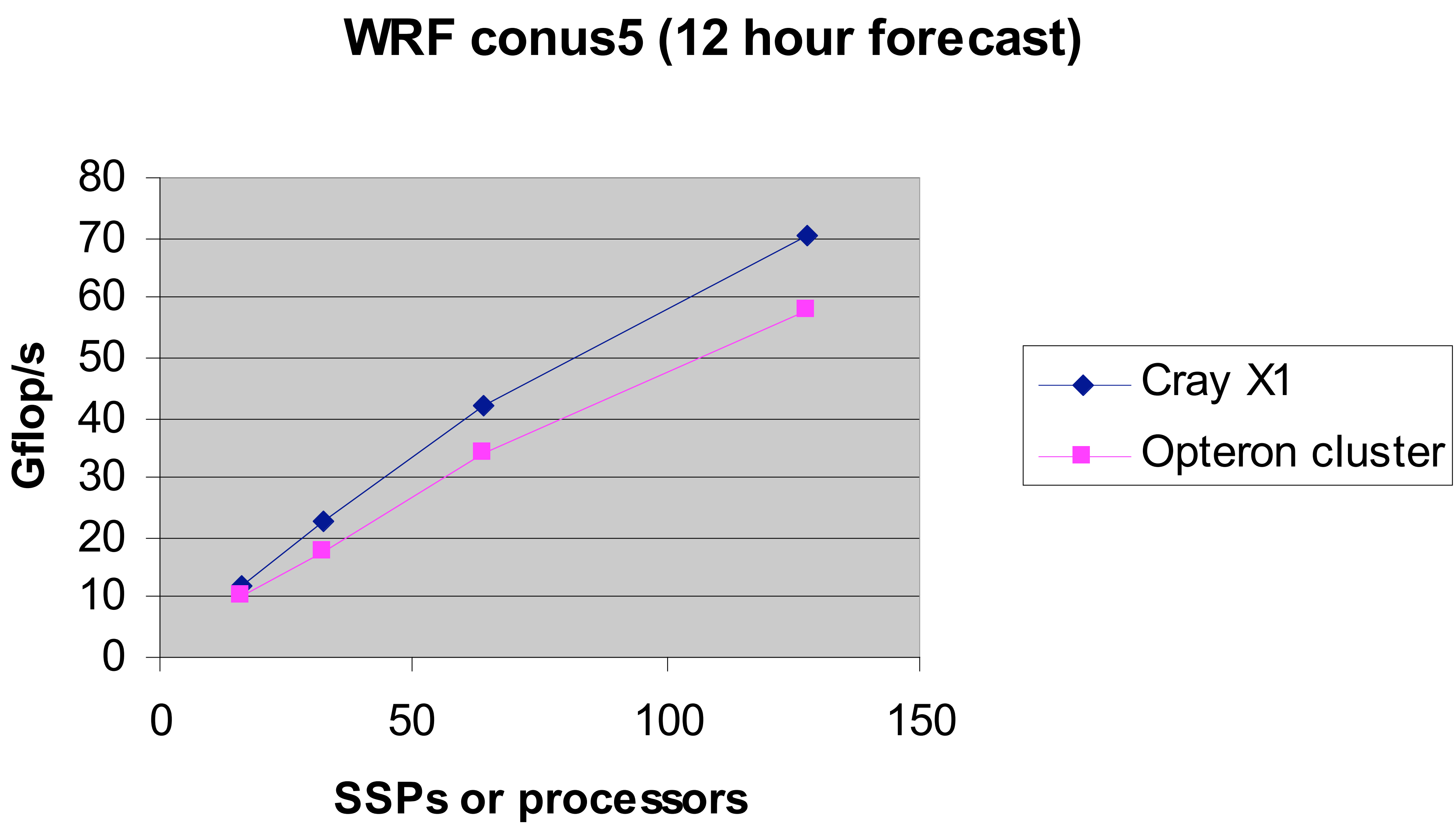
Cloud water and surface temperature

conus5: Execution Time



(Data points at 16, 32, 64 and 128 SSPs/processors.)

conus5: Performance



(Data points at 16, 32, 64 and 128 SSPs/processors.)

conus5: Performance

Cray X1E conus5 results for a 12 hour simulation.

MSPs (SSPs)	X1 (sec)	X1 GF/sec
004 (16)	14454	12
008 (32)	7658	23
016 (64)	4144	42
032 (128)	2466	70

Linux Opteron Cluster conus5 results for a 12 hour simulation.

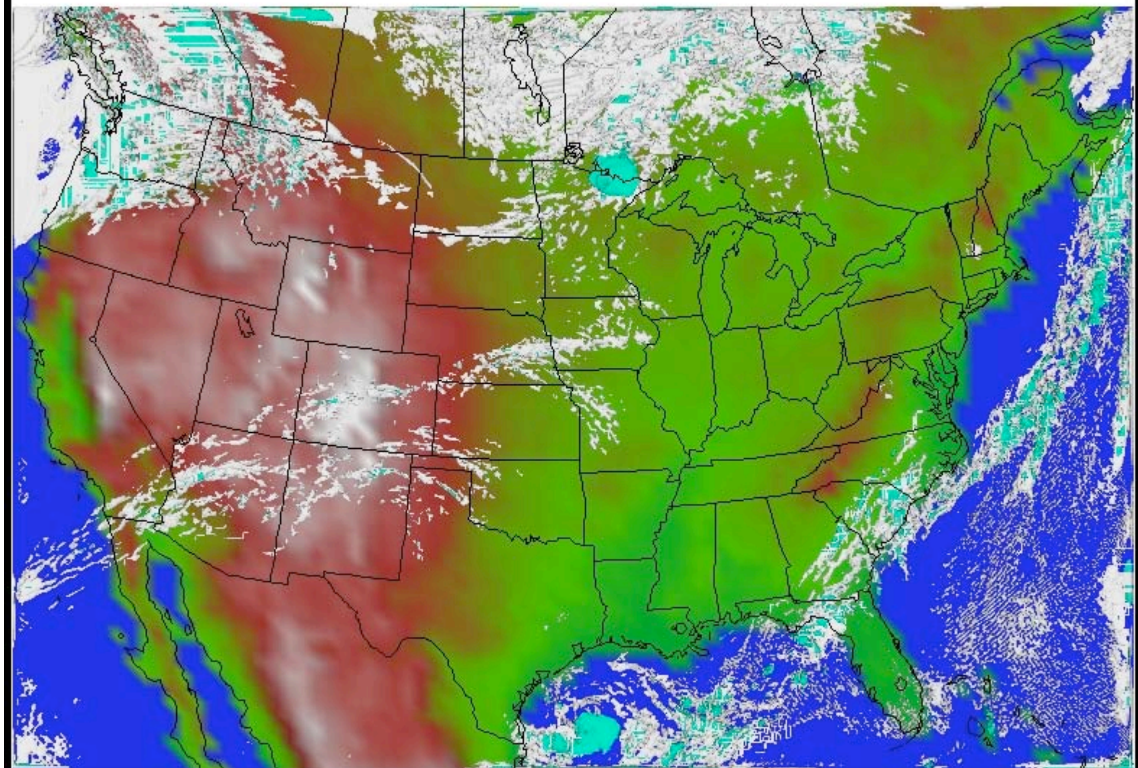
Opteron procs	Opteron (sec)	Opteron GF/sec
016	17230	10
032	9961	17
064	5109	34
128	2984	58

Benchmark: Large Benchmark Problem

WRF test case:

1000x1600
31 levels
3 km spacing
10 sec dt
3 hour fcst

Sample Image of the Domain



Cloud and rain water

conus 1000x1600x31: Performance

Cray X1E conus1000x1600x31 results.

MSPs (SSPs)	X1E (sec)	X1E GF/sec
032 (128)	2316	89
060 (240)	1500	138
128 (512)	905	230
192 (768)	769	270

Linux Opteron Cluster conus1000x1600x31 results.

Opteron procs	Opteron (sec)	Opteron GF/sec
128	3300	62

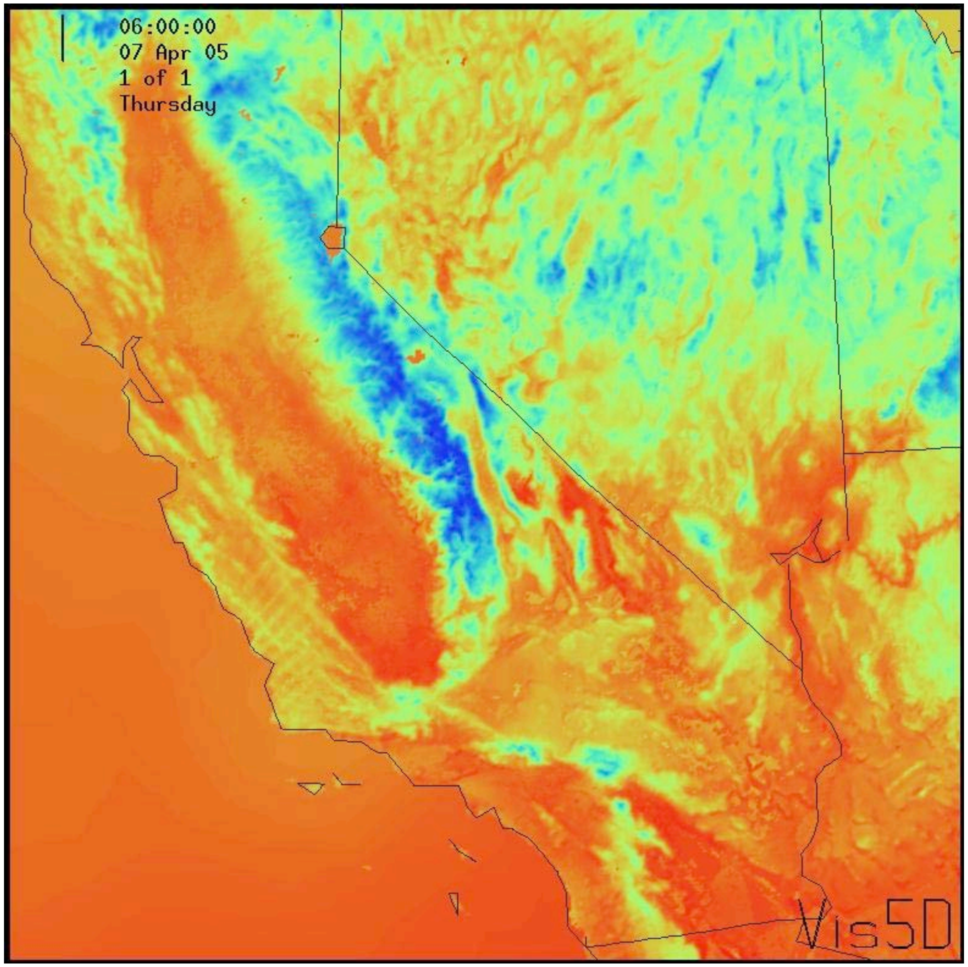
Case Study: Ensemble Experiment

Sample Image of the Domain

WRF test case:

512x512
45 levels
2 km spacing
10 sec dt
24 hour fcst

4 member
ensemble



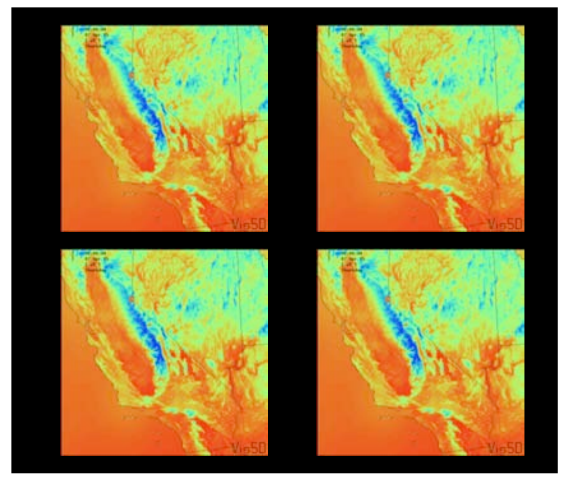
Surface temperature

Case Study: Ensemble Experiment

Run 4 WRF Models on X1E

GRIB Data
NAM 32 km

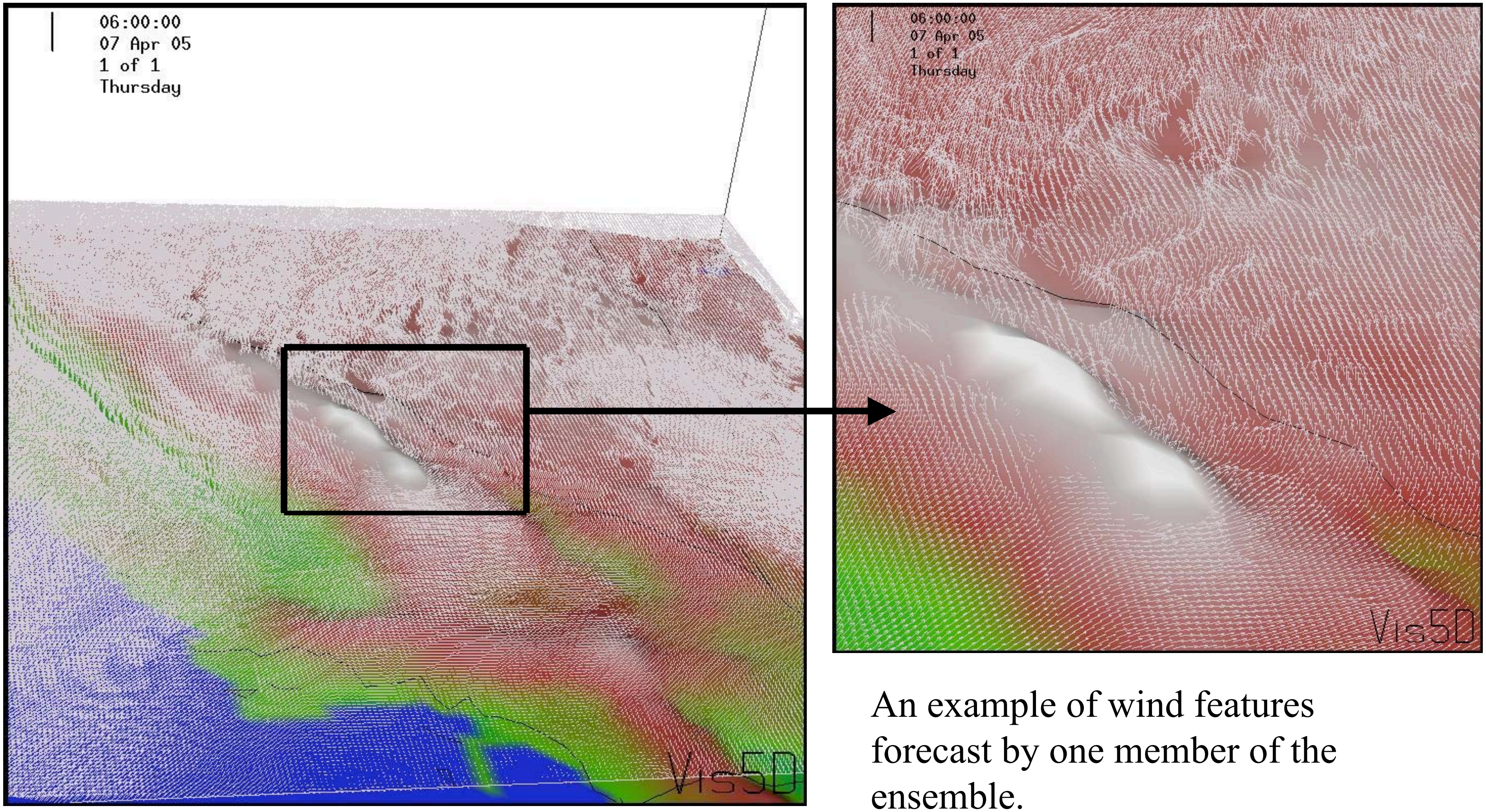
Domain Definition
Topography



Part of WRFSI and post-processing on Linux Cluster

Researcher's Workstation

Case Study: Ensemble Experiment



An example of wind features forecast by one member of the ensemble.

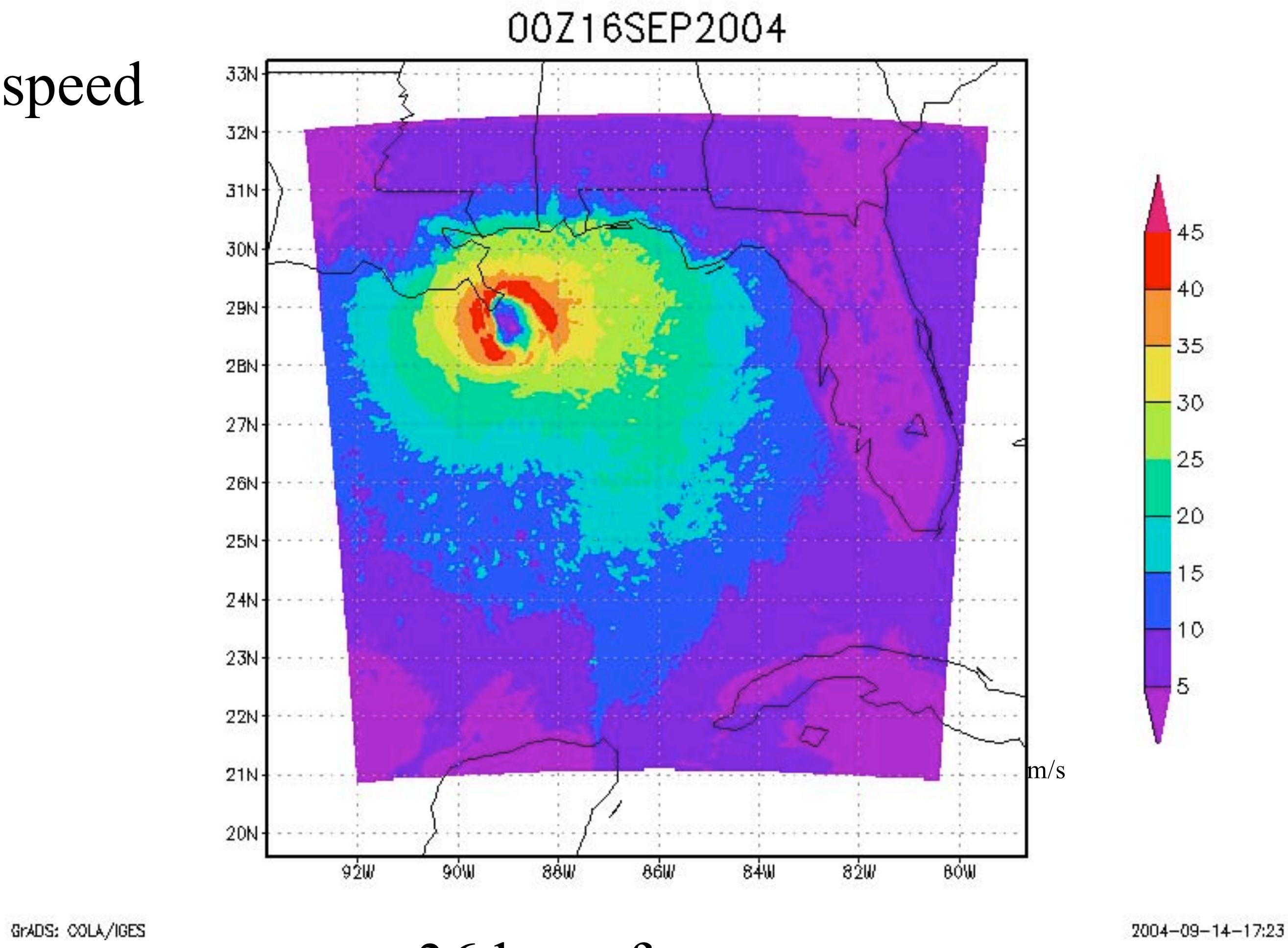
Post-processing: Dealing with Big Data

Dimensions	Gbytes/hr	Gbytes/48hr
100x80x31	0.013	0.6
512x512x45	0.7	35.4
680x1000x31	1.1	53.2
1000x1600x31	5.0	240.0

Problem size compared with WRF output data. Hourly output and total output after 48 simulation hours is shown above.

Post-processing: GrADS

Ivan –
surface wind speed



36 hour forecast

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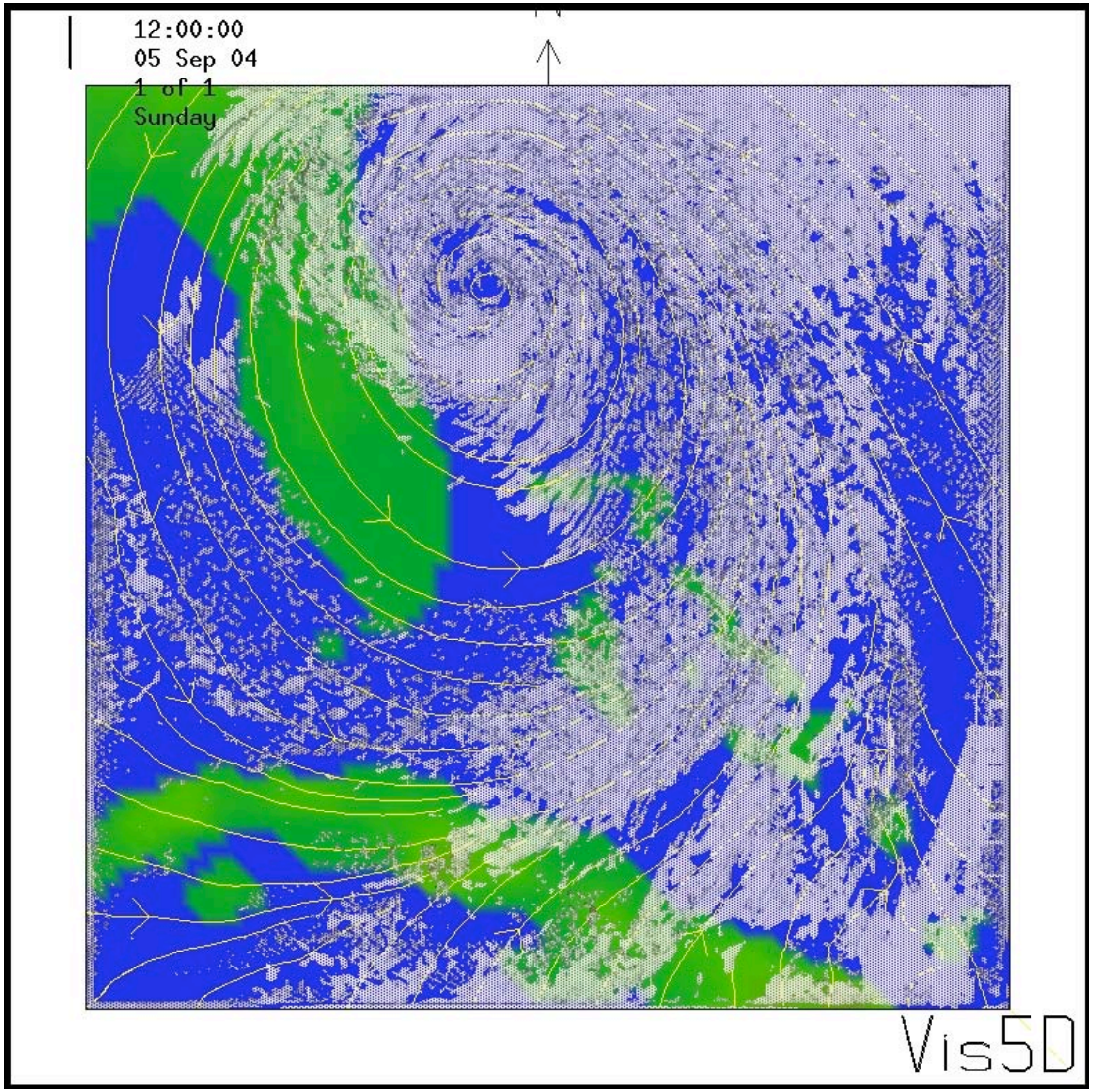
Post-processing: Vis5D

Hurricane Frances example.

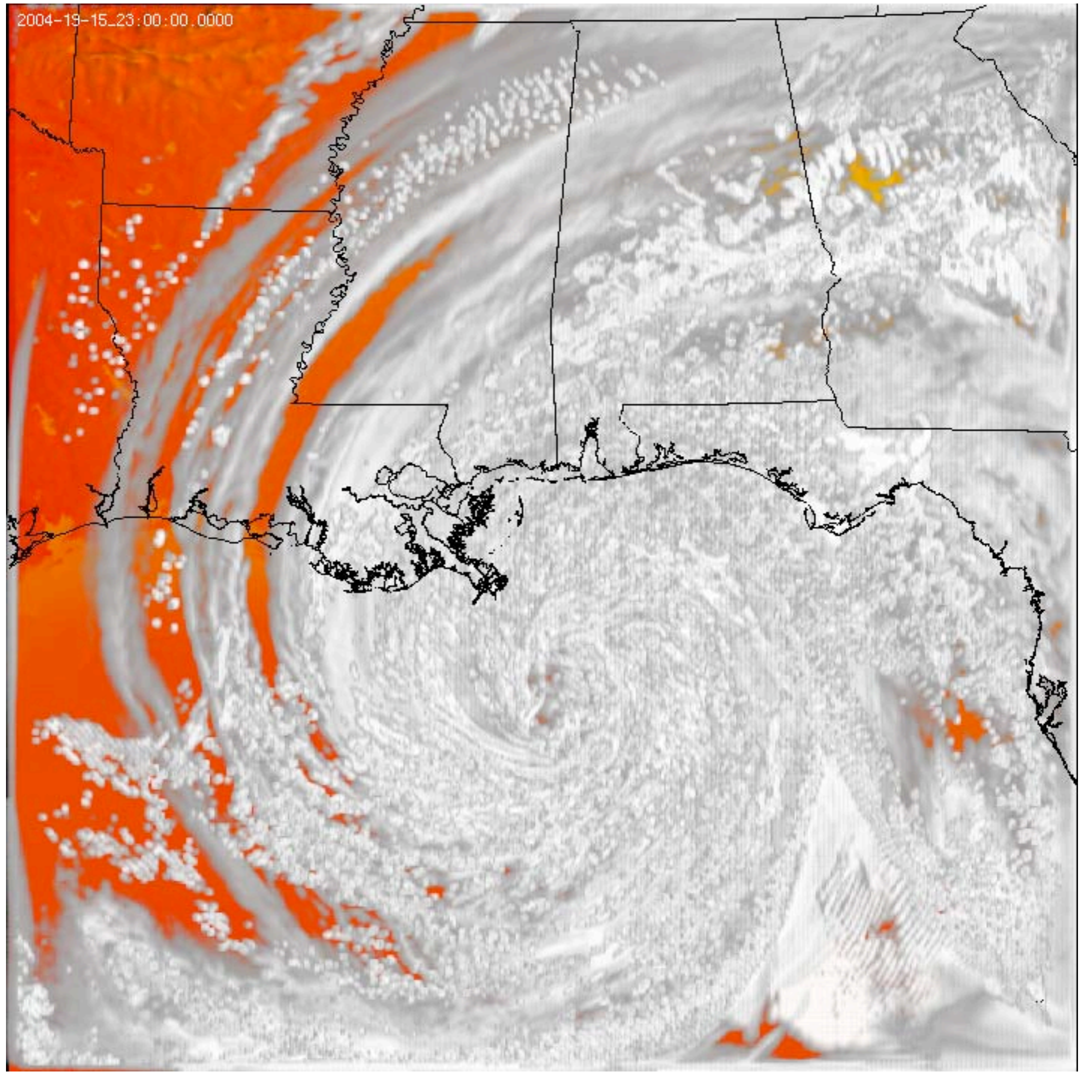
Streamlines of wind flow and cloud water are shown.



Post-processing: Vivendi

Hurricane Ivan example.

Surface temperature and cloud water are shown.



Conclusion

- Cray X1E and Linux Opteron Cluster both demonstrated to run WRFSI and WRF

- AHPCRC Linux Cluster shows strengths in pre-processing and post-processing

- AHPCRC Cray X1E machine of choice for mid-size to large WRF Model runs

- Comparisons of WRF with larger Linux Cluster would be of interest

- Diversity of HPC Architectures: There are still pros and cons to platforms

- Common HPC Problem: Dealing with big data (analysis and visualization)

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