WRF Software

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• Outline
  – Overview
  – New developments
  – Coupling
WRF Software Overview

- Implementation of WRF Architecture
  - Hierarchical organization
  - Multiple dynamical cores
  - Plug compatible physics
  - Abstract interfaces (APIs) to external packages
  - Registry for managing model state
  - Portable/efficient for range of computers in community
# WRF Supported Platforms

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Hardware</th>
<th>OS</th>
<th>Compiler</th>
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<tbody>
<tr>
<td>Apple</td>
<td>G5</td>
<td>MacOS</td>
<td>IBM</td>
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<tr>
<td>Cray Inc.</td>
<td>X1, X1e</td>
<td>UNICOS</td>
<td>Cray</td>
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<td></td>
<td>XT3/XT4 (Opteron)</td>
<td>Linux</td>
<td>PGI</td>
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<td>Itanium-2</td>
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<td>Opteron</td>
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<td>PGI</td>
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<td>Unix</td>
<td>Vendor</td>
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<td>Linux</td>
<td>Intel</td>
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<td>MIPS</td>
<td>IRIX</td>
<td>SGI</td>
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<tr>
<td>Sun</td>
<td>UltraSPARC</td>
<td>Solaris</td>
<td>Sun</td>
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<tr>
<td>various</td>
<td>Xeon and Athlon</td>
<td>Linux and Windows</td>
<td>Intel, PGI</td>
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<tr>
<td></td>
<td>Itanium-2 and Opteron</td>
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Petascale precursor systems

Mesoscale & Microscale Meteorological Division / NCAR
Performance

WRF on Cray XT4

7.1 TFLOPs sustained at 12,500 cores

- WRF V2.1.1
- 1501x1201x35 Grid
- 2.5KM grid resolution
- 15 second timestep
- Integration Costs Only
- AMD Opteron 2.6GHz dual core processors

Courtesy: Peter Johnsen and John Levesque, Cray
WRF Version 3.0

- New/improved platform support
  - Linux (PGI, Ifort, G95, Gfortran)
  - Windows and WindowsCCS (PGI)
  - Mac OSX (PGI and G95)
  - Blue Gene
- High performance I/O: Parallel NetCDF
- Coupling support
  - MCT, MCEL, ESMF
- General cleanup, streamlining, simplification, and documentation
- Possible:
  - Run-time specification of I/O
  - WRF-Var/WRF-Model integration
WRF Model Coupling

• Extension of WRF I/O API
  – MCEL (U. Southern Miss.)
  – MCT (Argonne NL)
  – ESMF

• Projects
  – WRF/ROMS, WRF/ADCIRC/SWAN/LSOM
  – Very high resolution urban airflow modeling (Fei Chen, NCAR; CFD Corp.)
  – Coupled WRF/HYCOM Katrina simulation
ESMF Support

• WRFV2.2 fully interoperable as ESMF component
  – Runs stand-alone without ESMF, or
  – Fully integrated component in ESMF
  – Distributed with ESMF unit test coupled “data” ocean

• Infrastructure:
  – ESMF Time Manager using reference implementation or
    shared implementation with CCSM

• Superstructure: “Wrapperized”
  – Top level init-run-finalize convention
  – ESMF conforms to “coupling as I/O” and is integrated with
    WRF Registry

• Planned – “bottom-up coupling” to ESMF-ized components
WRF/HYCOM Coupling (ESMF)

- WRF and HYCOM two-way coupled through ESMF to improve modeling of hurricane intensification
- Synchronization is through successive calls to components by ESMF top-level driver
- Status:
  - WRF an ESMF component (NCAR),
    - Init-run-finalize at top level
    - Import/export through WRF I/O API
    - ESMF Time Manager
    - WRF I/O in ESMF
  - HYCOM-ESMF (NRL)
WRF/HYCOM Coupling (MCEL*)

2-way Coupled Ocean

27-30 August 2005
4km WRF, 1/25° Hycom
Uncoupled (left)
Coupled with MCEL (right)
Model Coupling

- **Challenges**
  - **Software**
    - Data exchange, interpolation
    - Control
    - Code modification
  - **Scientific**
    - Model setup
    - Representation
    - Assumptions
    - Tuning
  - **Other/non-technical**

Increasing difficulty
extras
Petascale Challenges

- Multi-core performance
  - Increasing number of cores will further aggravate imbalance between compute power and bandwidth (both memory and interprocessor)
  - Message passing within a socket may not be efficient
  - L3 cache will be too small to hide latencies
- Load imbalance
- I/O
- Management, analysis, and visualization at petascale
- Maintaining community models on pScale systems
Code Management

- **WRF Developers Committee**
  - Representation: NCAR, DTC, NCEP, GSD, others
  - Manage Subversion code repository and update process
- **Draft plan for formalizing process under review**
WRF/LIS Coupling through ESMF

- LIS = Land Information System
  - NASA GSFC (lis.gsfc.nasa.gov)
  - Incorporates CLM, Noah, and VIC land surface models
- Initial WRF-LIS prototype by Sujay Kumar (GSFC)
  - Coupled via WRF surface driver using ESMF
  - All ESMF objects manufactured by LIS
- Planned
  - WRF provides ESMF_State objects to LIS
  - Extend to allow different grids
Interoperability

• Share goals with Earth System Curator
  – Similar approaches may apply to forecast V&V, managing ensembles, etc.
  • Earth System Curator-Numerical Model Metadata (NMM) standard
    – Full specification of an “experiment”
• Automatic testing of component compatibility
Dynamic Load Balancing

Workload Characterization of Physics-Induced Load Imbalance in WRF (draft NCAR TM, 2007)

- Key obstacle for Petascale; opportunity for new approaches, e.g. PGAS languages
- Instrument WRF using PAPI
- Generated high-resolution traces over 8 day period in July ’05
- Characterize dynamic load from microphysics as functions of
  - Decomposition
  - Sizes, trajectories, other characteristics of load features
Global WRF Parallelization

- FFT-based polar filters
  - Parallelized using Registry XPOSE (transpose) operation
  - Distributed FFTs (?)
- Periodic BCs
- Polar BC

Status: gWRF prototype parallelized and bit-for-bit with single-threaded prototype
WRF Software Overview

- Characteristics, Features, & Capabilities
  - Flexible, extensible to range of WRF applications
  - Movable, feature following nested grids
  - Coupling to other models
  - Parallel, efficient on range of computers in WRF community

Precipitable H$_2$O, Year 2 of Nested Regional Climate Model
WRF/HYCOM Coupling (MCEL*)

- Components run concurrently as separate applications
- “Coupling as I/O” through existing I/O modules
- Application “clients” synchronize and exchange data through connections to MCEL server
- Server provides interpolation between arbitrary component grids, both structured and unstructured, using geolocation data provided by components
- Caching on server allows easy switching between off-line and on-line coupling

HYCOM sends:
- SSTs

HYCOM Receives:
- Winds
- Precipitation
- Radiation fluxes

WRF sends (from 4km nest):
- Surface winds & air temps
- Precipitation
- Radiation fluxes

WRF Receives:
- SST
- Roughness length (later)

*M Model Coupling Environment Library, M. Bettencourt, AFRL
HYCOM image courtesy A. Wallcraft, NRL
HYCOM/MCEL courtesy P. Fitzpatrick & N. Tran, MSU
Interoperability

- Supported metadata formats: NetCDF+parallel, HDF+parallel, GRIB[1&2]
- Participating in continuing refinement of Climate and Forecast metadata convention
  - Participate in GOESSP meetings to discuss conventions (go-essp.gfdl.noaa.gov)