WRF Software

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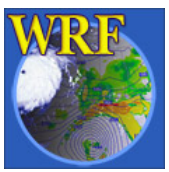
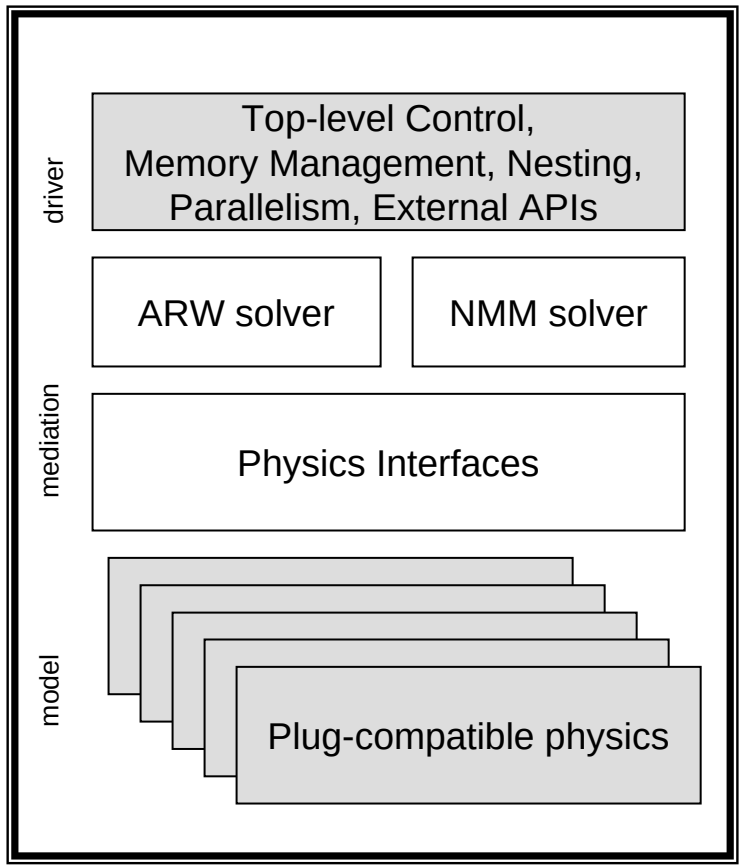
- Outline
  - Overview
  - New developments
  - Coupling



WRF Software Overview

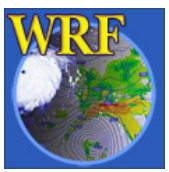
- Implementation of WRF Architecture
  - Hierarchical organization
  - Multiple dynamical cores
  - Plug compatible physics
  - Abstract interfaces (APIs) to external packages
  - Registry for managing model state
  - Portable/efficient for range of computers in community



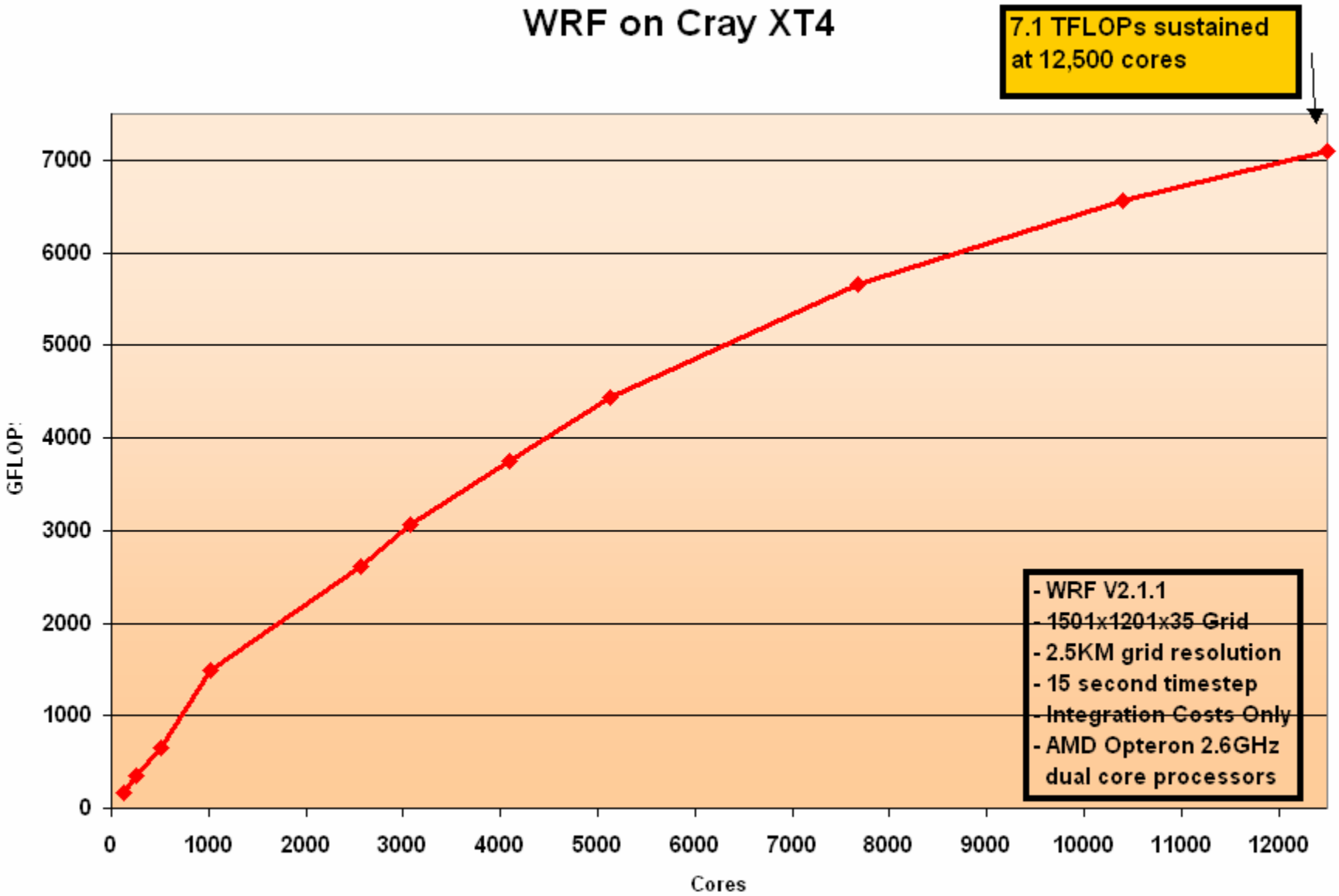
WRF Supported Platforms

Vendor	Hardware	OS	Compiler
Apple	G5	MacOS	IBM
Cray Inc.	X1, X1e	UNICOS	Cray
	XT3/XT4 (Opteron)	Linux	PGI
HP/Compaq	Alpha	Tru64	Compaq
	Itanium-2	Linux	Intel
		HPUX	HP
IBM	Power-3/4/5/5+	AIX	IBM
	Blue Gene/L	Linux	IBM
	Opteron		Pathscale, PGI
NEC	SX-series	Unix	Vendor
SGI	Itanium-2	Linux	Intel
	MIPS	IRIX	SGI
Sun	UltraSPARC	Solaris	Sun
various	Xeon and Athlon	Linux and Windows CCS	Intel, PGI
	Itanium-2 and Opteron		

Petascale precursor systems



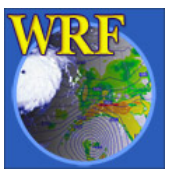
Performance



Courtesy: Peter Johnsen and John Levesque, Cray

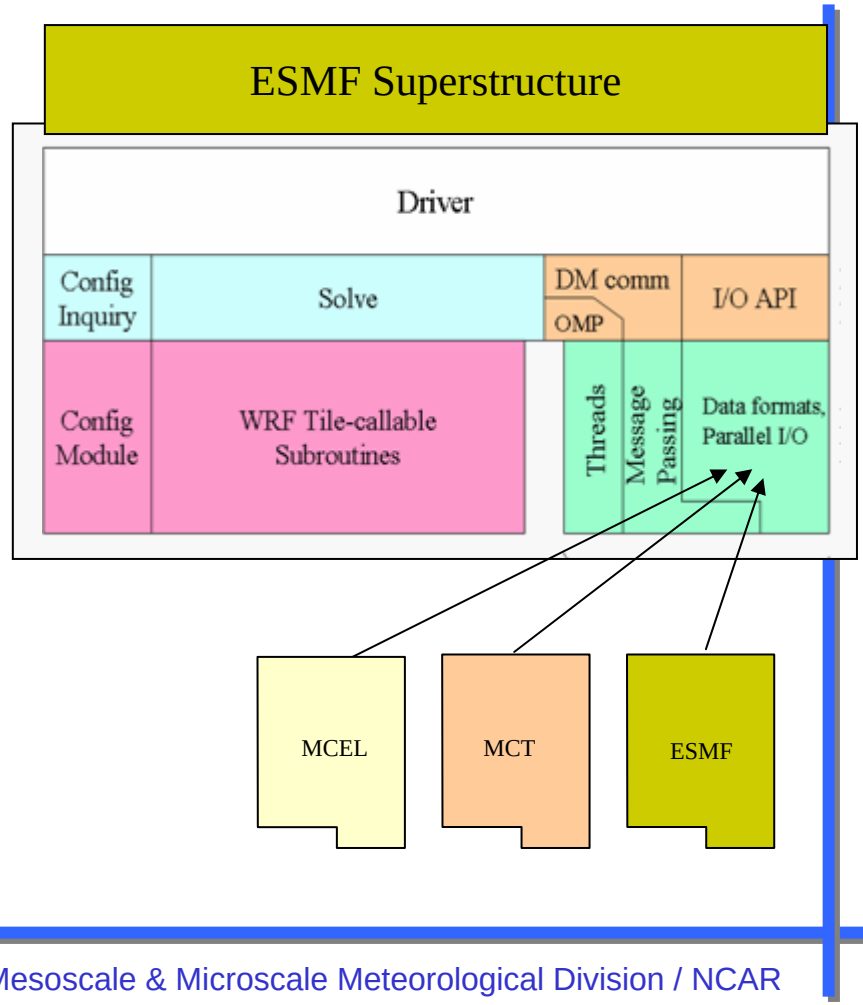
WRF Version 3.0

- 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



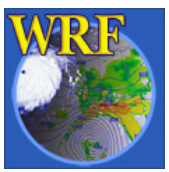
WRF Model Coupling

- 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



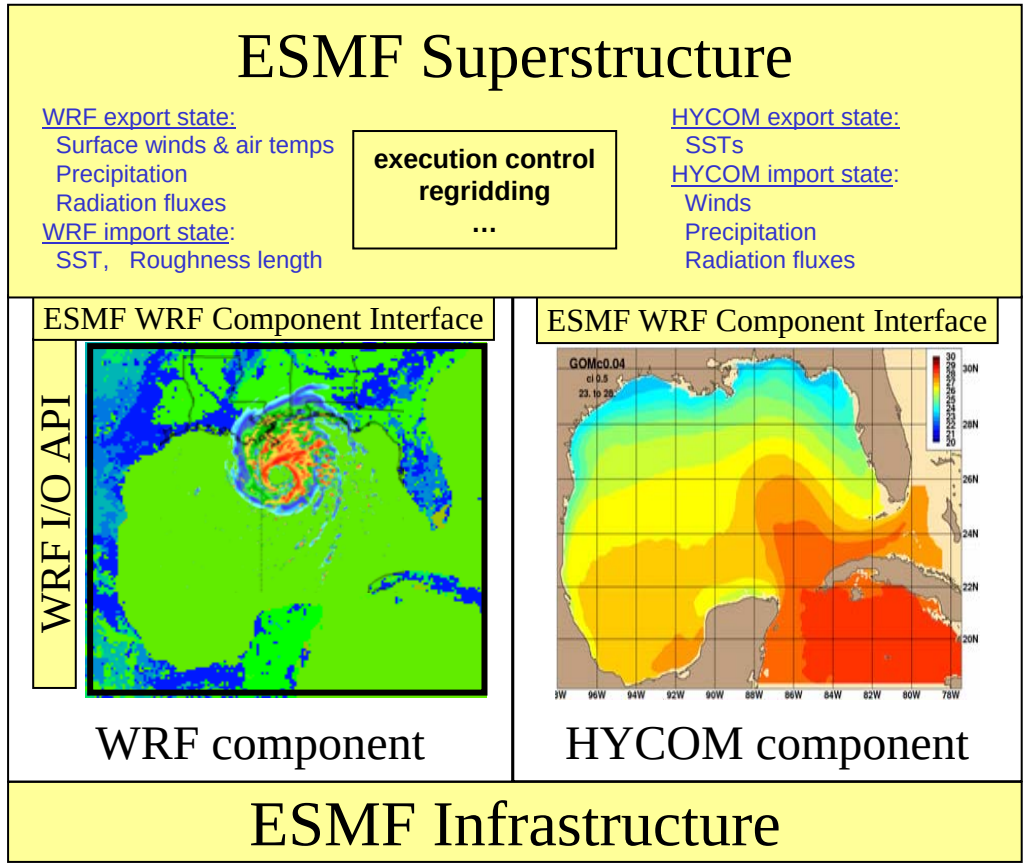
ESMF Support

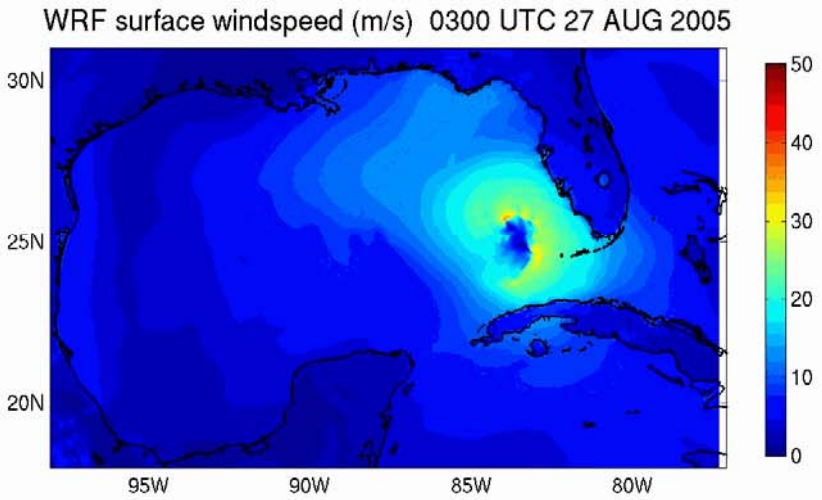
- WRFV2.2 fully interoperable as ESMF component
  - Runs stand-alone without ESMF, or
  - Fully integrated component in ESMF
  - Distributed with ESMF unit test coupled “data” ocean
- Infrastructure:
  - ESMF Time Manager using reference implementation or shared implementation with CCSM
- Superstructure: “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



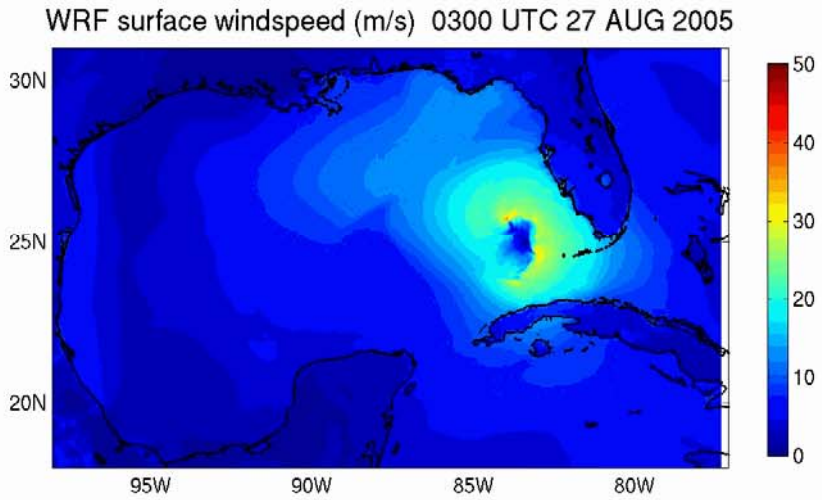
WRF/HYCOM Coupling (ESMF)

- 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)





Fixed Ocean



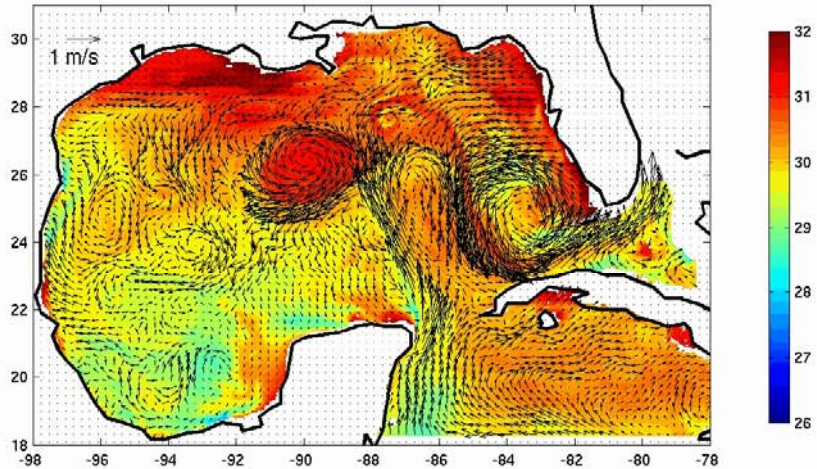
2-way Coupled Ocean

27-30 August 2005

4km WRF, 1/25° Hycom

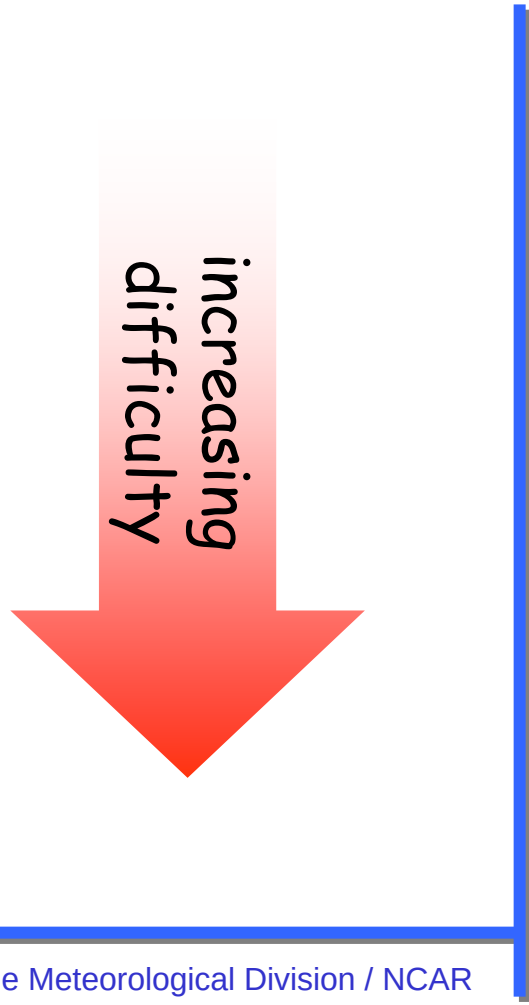
Uncoupled (left)

Coupled with MCEL (right)

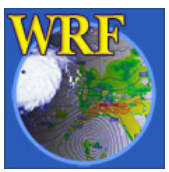


Model Coupling

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

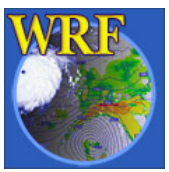


extras



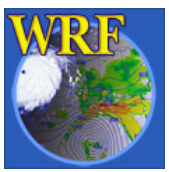
Petascale Challenges

- 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



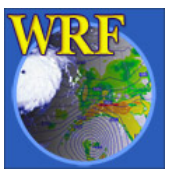
Code Management

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



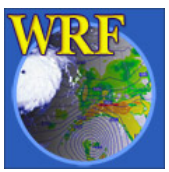
WRF/LIS Coupling through ESMF

- 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

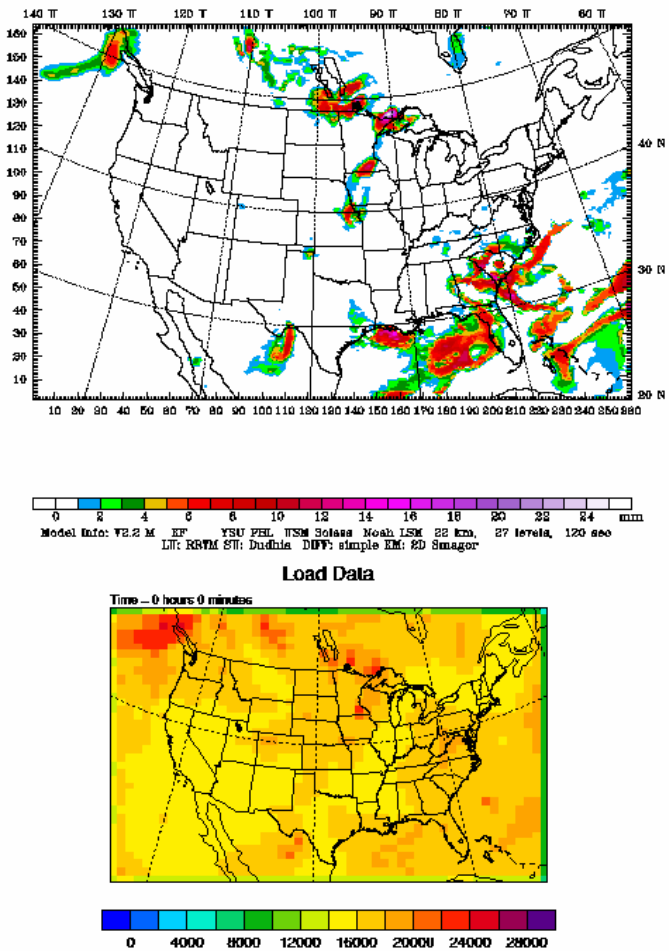
- Share goals with Earth System Curator
  - Similar approaches may apply to forecast V&V, managing ensembles, etc.
    - Earth System Curator-Numerical Model Metadata (NMM) standard
      - http://ncas-cms.nerc.ac.uk/NMM/index.php
      - Full specification of an “experiment”
    - Automatic testing of component compatibility



Dynamic Load Balancing

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

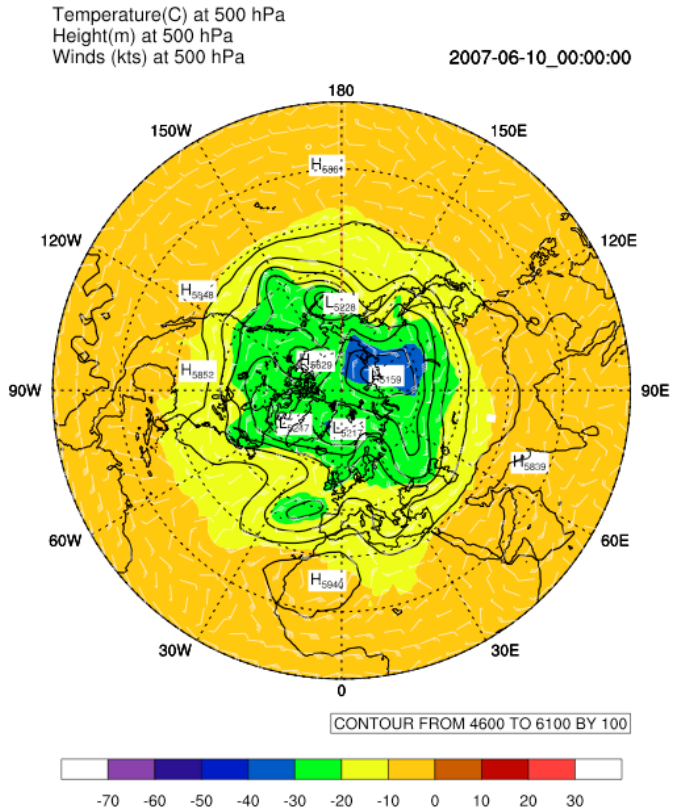
- Key obstacle for Petascale; opportunity for new approaches, e.g. PGAS languages
- Instrument WRF using PAPI
- Generated high-resolution traces over 8 day period in July ’05
- Characterize dynamic load from microphysics as functions of
  - Decomposition
  - Sizes, trajectories, other characteristics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



Global WRF Parallelization

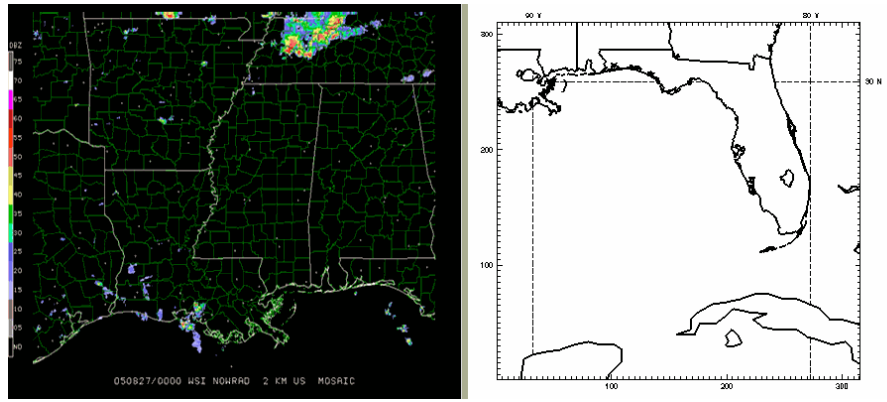
- FFT-based polar filters
  - Parallelized using Registry XPOSE (transpose) operation
  - Distributed FFTs (?)
- Periodic BCs
- Polar BC

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

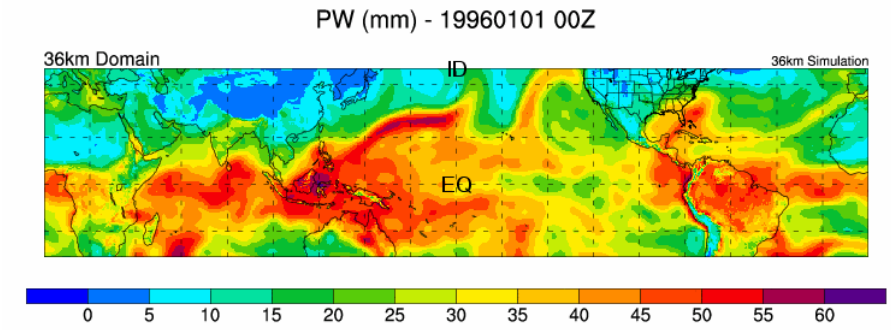


WRF Software Overview

- 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



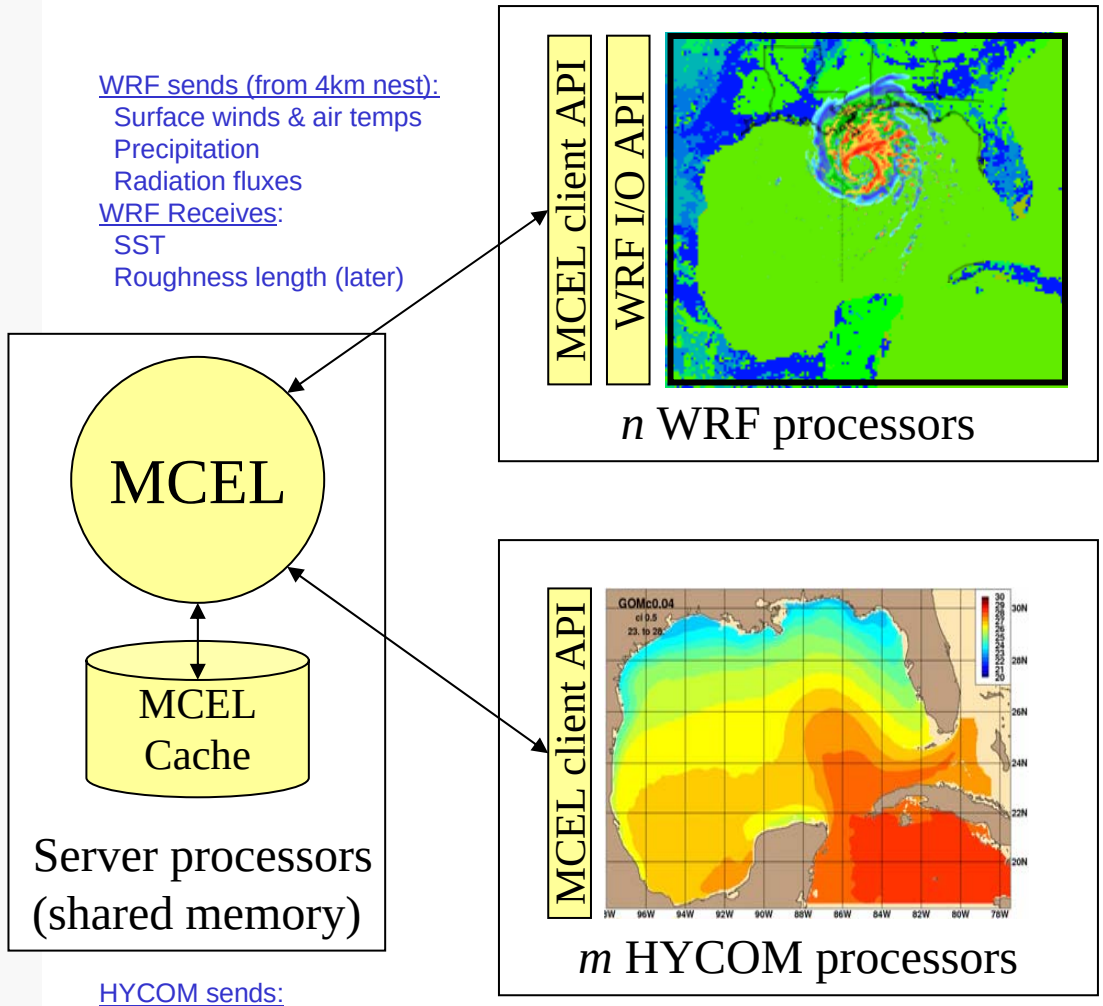
4km Hurricane Katrina Moving Nest (right) with Composite radar (left)



Precipitable H^2O, 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



***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)