THE WEATHER RESEARCH AND FORECAST MODEL VERSION 2.0

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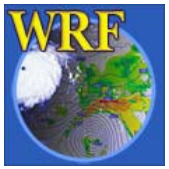
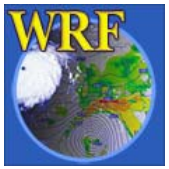
National Center for Atmospheric Research
Boulder, Colorado U.S.A.

11th ECMWF Workshop on Use of High Performance Computing in Meteorology
25-29 Oct. 2004



Outline

- WRF Overview and Status
- Performance
- New Developments in V2.0



Weather Research and Forecast Model

Goals: *Develop an advanced mesoscale forecast and assimilation system, and accelerate research advances into operations*

- Large collaborative effort to develop community model with direct path to operations
- Advanced numerics, data assimilation, and model physics
- Designed for 1-10km but must also perform at higher (LES; dx ~ 100 meter) and lower (synoptic scale; dx ~100km) resolutions
- Applicable to broad range of applications:
  - Large Eddy Simulation
  - Cloud modeling, storm simulation
  - Synoptic-scale research
  - Numerical Weather Prediction
  - Chemistry and air-quality research and prediction
  - Regional climate
- Portable and efficient on parallel computers

Signatory Partners:

- NCAR Mesoscale and Microscale Meteorology
- NOAA National Centers for Environmental Prediction
- NOAA Forecast Systems Laboratory
- OU Center for the Analysis and Prediction of Storms
- U.S. Air Force Weather Agency
- U.S. Naval Research Laboratory
- Federal Aviation Administration

Additional Collaborators:

- U.S. Department of Defense HPCMP
- NOAA Geophysical Fluid Dynamics Laboratory
- NASA GSFC Atmospheric Sciences Division
- NOAA National Severe Storms Laboratory
- CAMS Chinese Meteorological Academy
- EPA Atmospheric Modeling Division
- University Community

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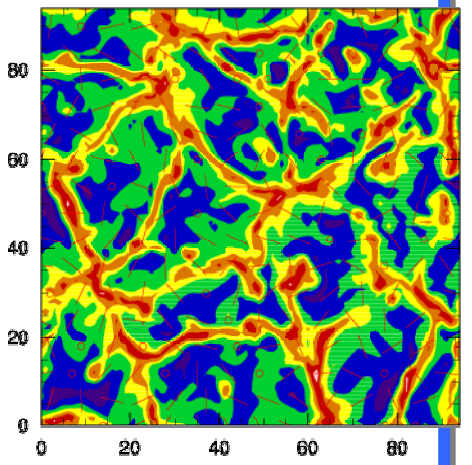
PBL LES, $\Delta x = 50$ m



(Chin-Hoh Moeng)

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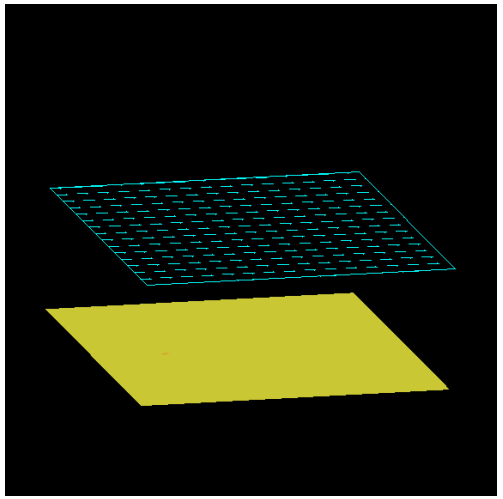
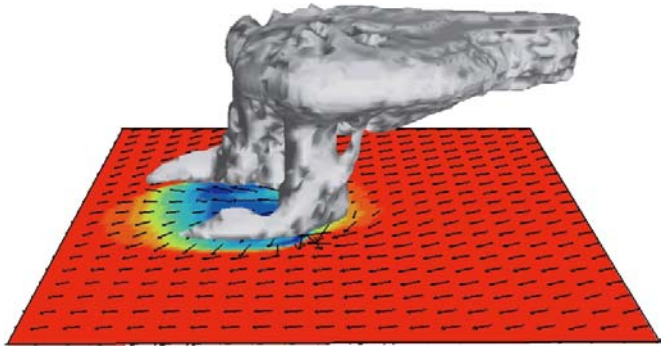


Supercell thunderstorm,
$\Delta x = 1$ km



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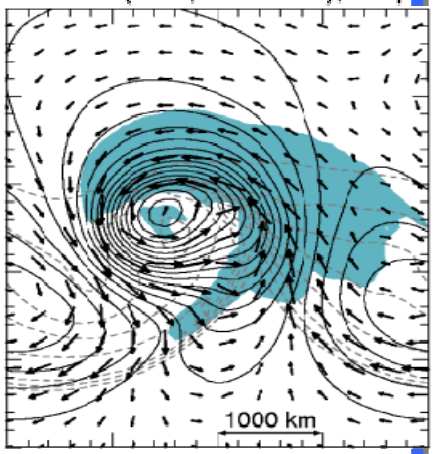
Baroclinic wave,
Δx = 100 km



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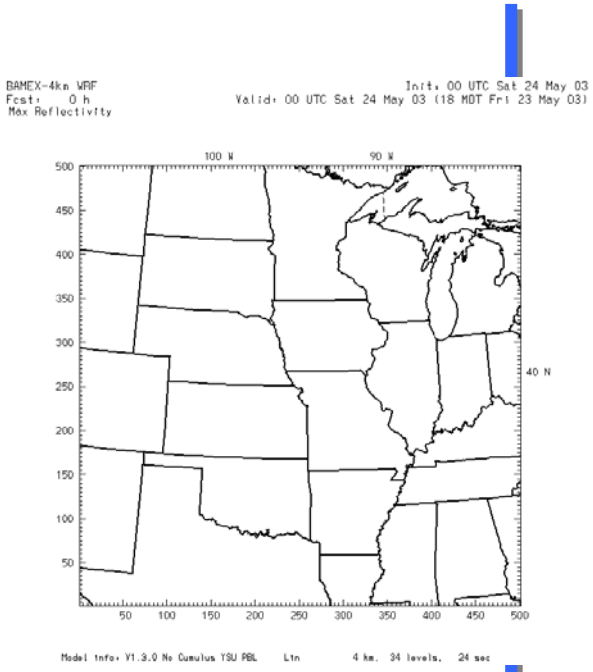
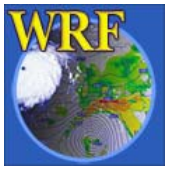


WRF 2.x Model Description

- Limited-area, regular grid, equally spaced horizontally
- Mass-based vertical coordinate system
- Non-hydrostatic, conservative formulation
- Explicit, time split numerics
- Multiple dycores (e.g. NMM), full physics
- Chemistry: dry deposition, biogenic emissions, photolysis, aerosols
- WRF Software Framework (ASF)



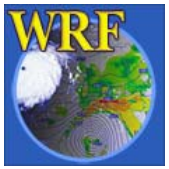
WRF Software

- Flexible, maintainable, extensible
  - Hierarchical, well-defined interfaces between layers and API's to external packages, algorithms
- Performance portability
  - Multi-level decomposition controlled at driver layer
- Other aspects

  F90, dynamic memory allocation

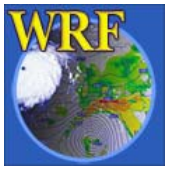
  Parallel nesting and moving nests

  ~165k lines, 40k of which automatically generated



WRF Status

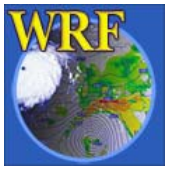
- Research release
  - WRF 2.0 released May, 2004
    - More than 2,200 registered users
    - June 2004 Users Workshop: 173 participants, 93 inst.
  - Model, preprocessors, and 3DVAR data assimilation system
  - Support for multiple dynamical cores
  - 2-way interactive moving nests
- Operational implementation underway
  - Air Force Weather Agency
  - National Centers for Environmental Prediction



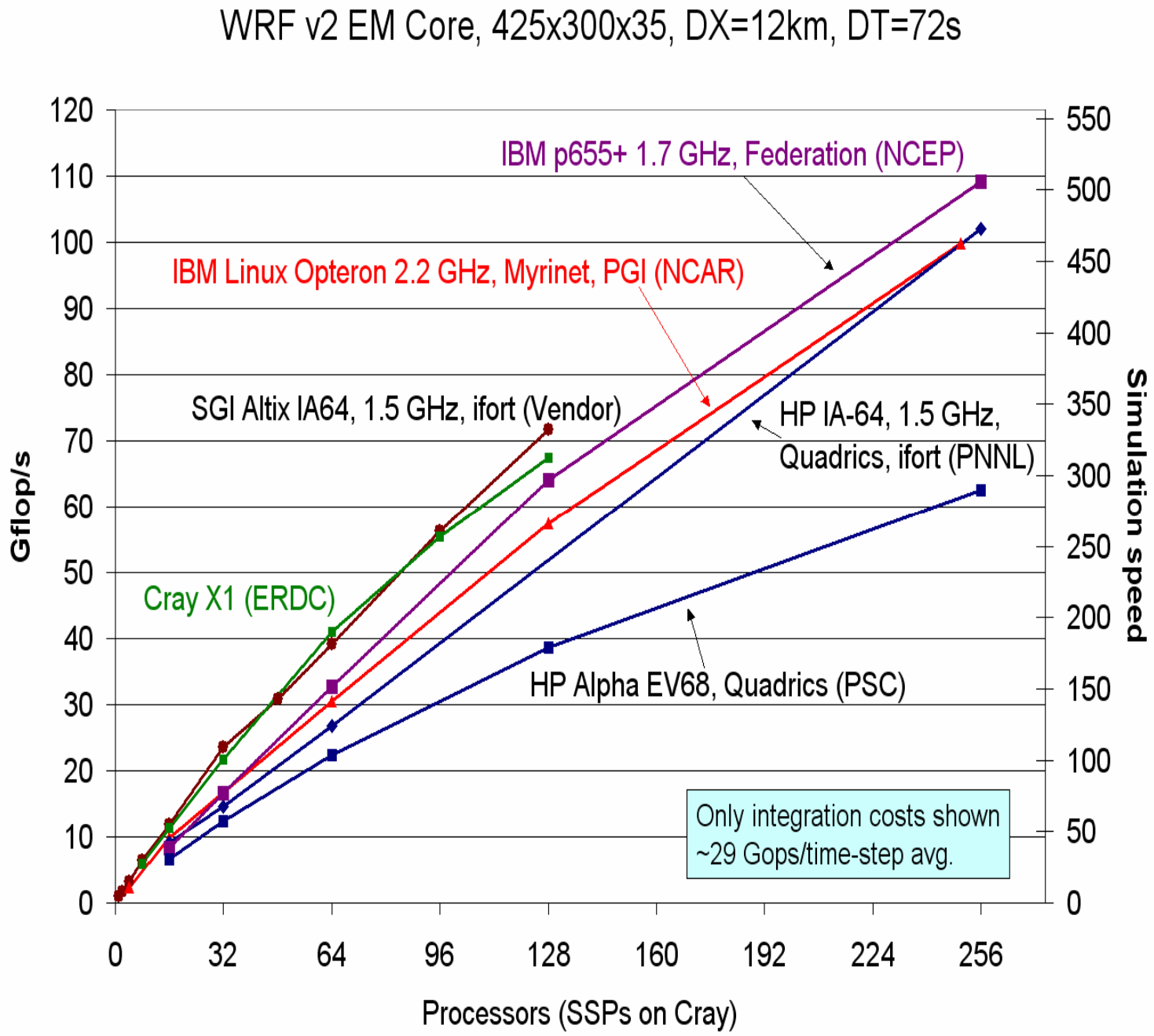
WRF Status

- Supported Platforms (alphabetical)

Vendor	Hardware	O.S.	Compiler
Cray Inc.	X1	UNICOS	vendor
HP/Compaq	Alpha	Tru64	vendor
	IA-64 (Intel)	Linux	Intel
		HPUX	vendor
IBM	SP Power-*x*	AIX	vendor
SGI	IA-64 (Intel)	Linux	Intel
	MIPS	Irix	vendor
Sun	UltraSPARC	Solaris	vendor
various	IA-32/AMD 32	Linux	Intel/PGI
	IA-64/Opteron	Linux	Intel/PGI



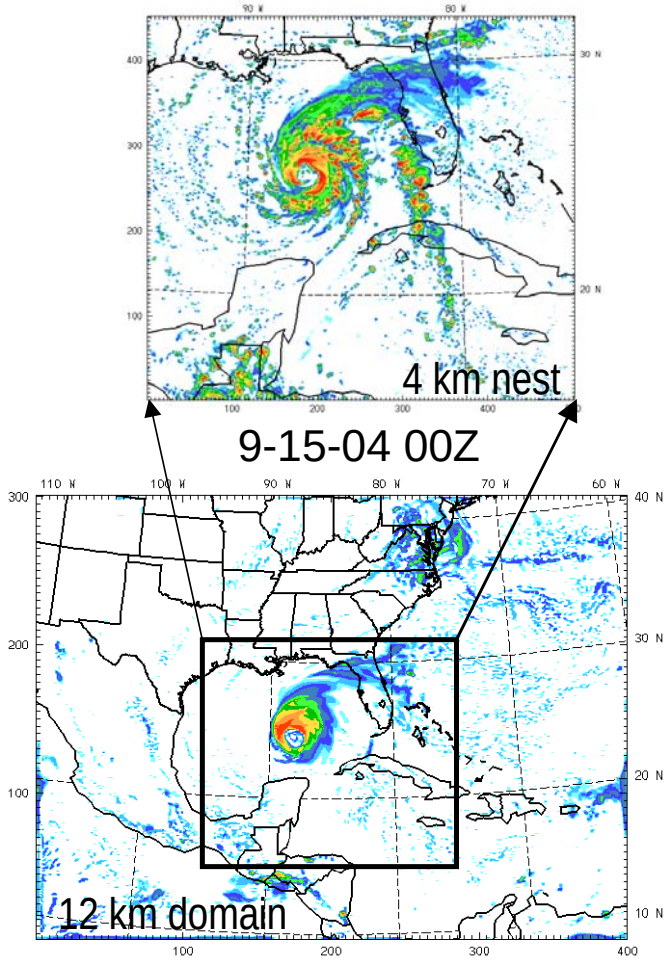
http://www.mmm.ucar.edu/wrf/bench



Nesting

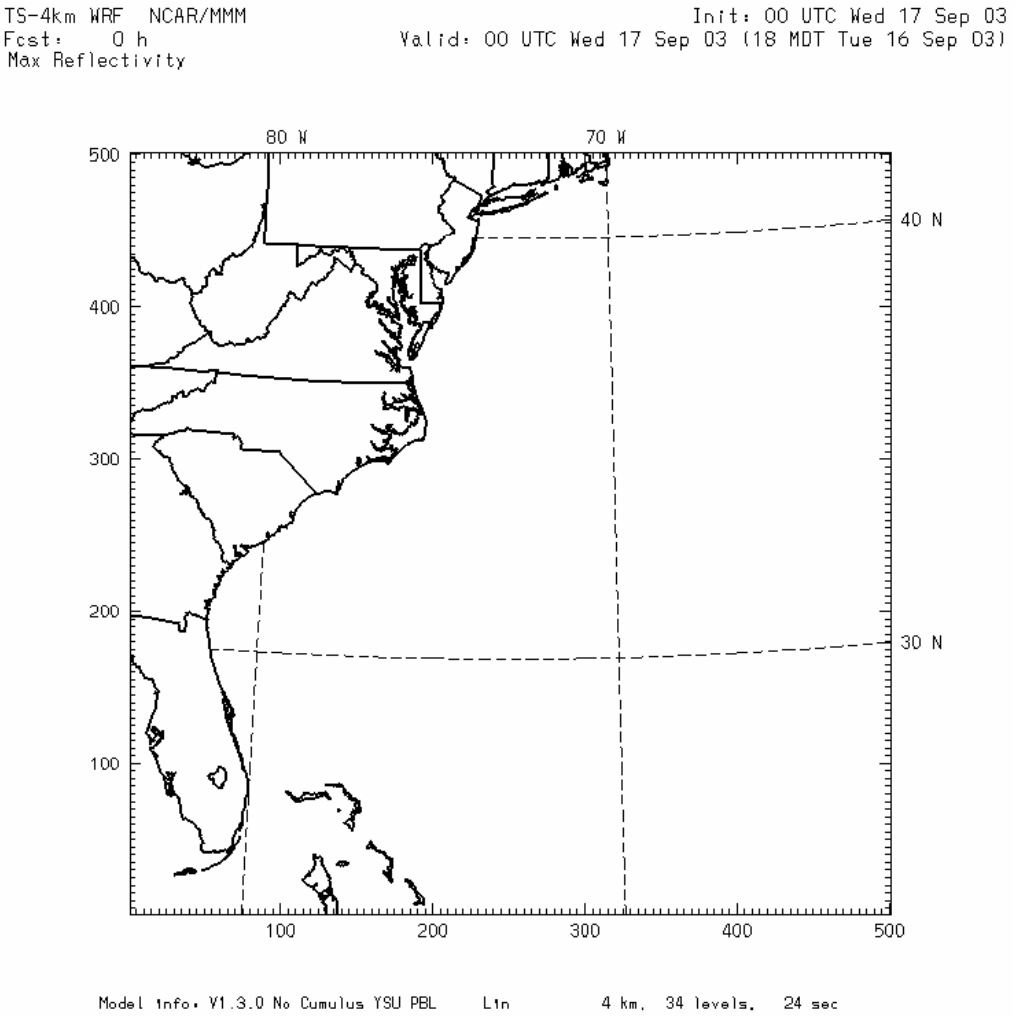
- WRF Nesting Features:
  - ✓ Fully parallelized, efficient
    - 5-8% overhead well within 15% target
    - Most of this is WRF's non-linear interpolation algorithm, not framework overhead
  - ✓ Two-way interacting
  - ✓ Dynamically instantiable
  - ✓ Telescoping to arbitrary depth
  - ✓ Moving (new) . . .

48 h Hurricane Ivan Forecast



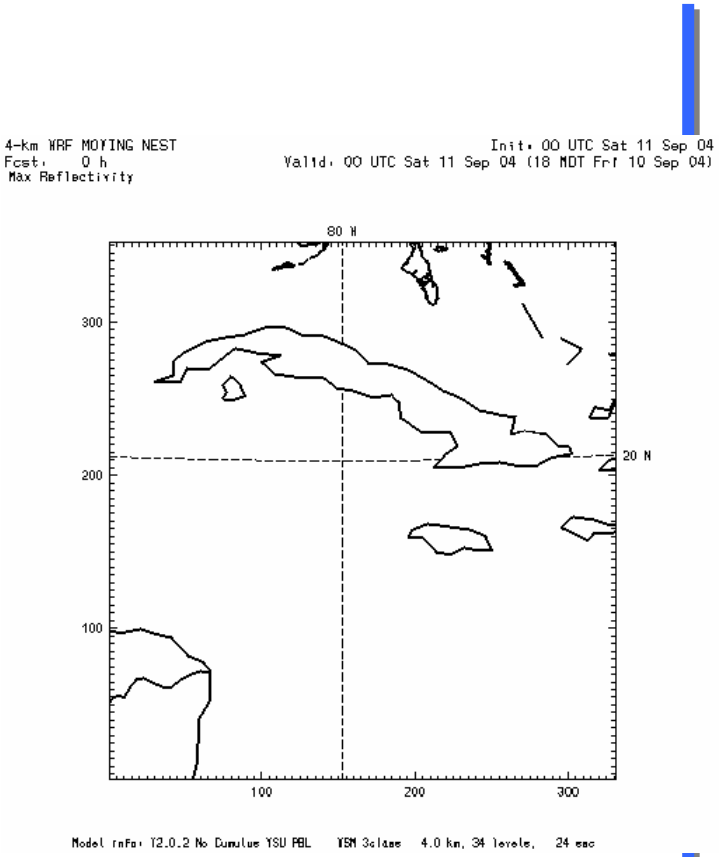
Static Nests

- A nest must be large enough to cover an entire feature: e.g. a storm track
- Hurricane Isabel, 16-17 Sept. 2003
  - Non-moving 4km nest:
    - Run off-line from 12km outer domain
    - 225,000 (450x500) points
    - 4 hr 10 min on 128 IBM processors



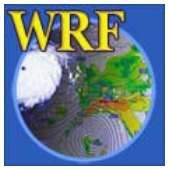
Moving Nests

- A nest must be large enough to cover an entire feature: e.g. a storm track
- Hurricane Isabel, 16-17 Sept. 2003
  - Non-moving 4km nest:
    - Run off-line from 12km outer domain
    - 225,000 (450x500) points
    - 4 hr 10 min on 128 IBM processors
- Hurricane Ivan, 11-13 Sept. 2004
  - Moving 4km nest:
    - 2-way interactive in 12km outer domain
    - 120,000 points
    - 3 hr 45 min on 80 IBM processors
    - 150 seconds overhead for 48 hourly moves (< 2%)



WRF

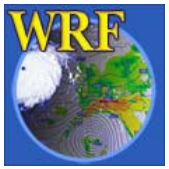
- Other WRF 2.0 features
  - Model Coupling as extension of WRF I/O
  - Web-based documentation generated automatically from source
- Ongoing work
  - Community support
  - 4DVAR, Atmospheric Chemistry, Hurricane WRF
  - ESMF integration



Ongoing Work

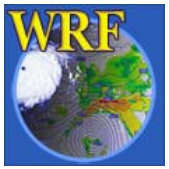
- Community/operational support
- WRF 4DVAR
- Coupling with moving nests
- ESMF integration

http://www.wrf-model.org



Summary

- WRF 2.0 release culminates six years effort to develop next generation mesoscale forecast system aimed at bridging operational and research communities
- WRF software aims to serve diverse communities on range of HPC architectures efficiently both in terms of computational performance and in terms of leveraging and preserving investment



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