

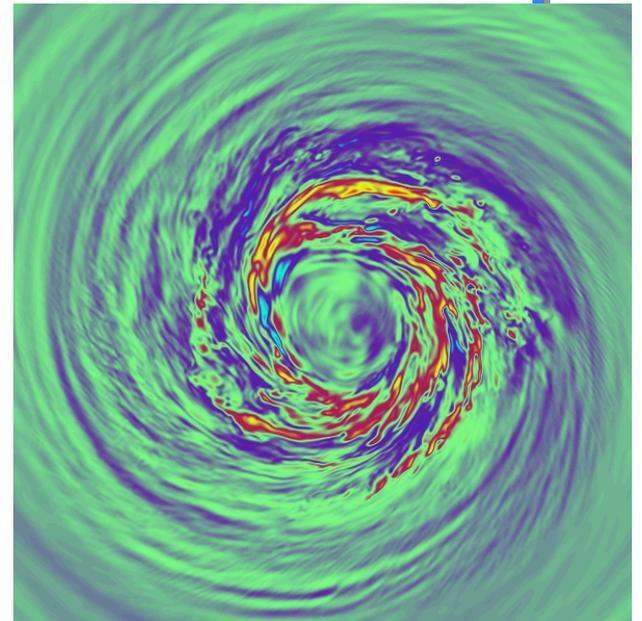
**Very High-Resolution Simulation of the
Hurricane Problem on the
ALCF Blue Gene/P**

John Michalakes
michalak@ucar.edu

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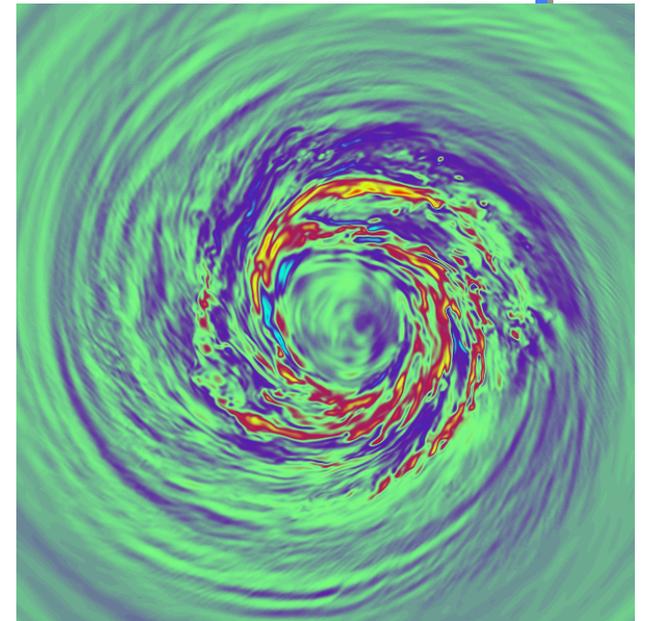
Introduction

- Can very large scale parallelism and high resolution be used to improve real-time hurricane prediction?



Outline

- The hurricane problem
- Why high-resolution?
- Hurricane WRF
- Results on Blue Gene/P
- Conclusion



The Hurricane Problem

- Worldwide, weather-related disasters outnumber other natural disasters 9 to 1
- Hurricanes cause more than half of all damage from weather hazards in U.S.
- \$36B losses per year; 2004-05: \$100B, 1450 deaths
- Half of U.S. population within 50 miles of a coastline

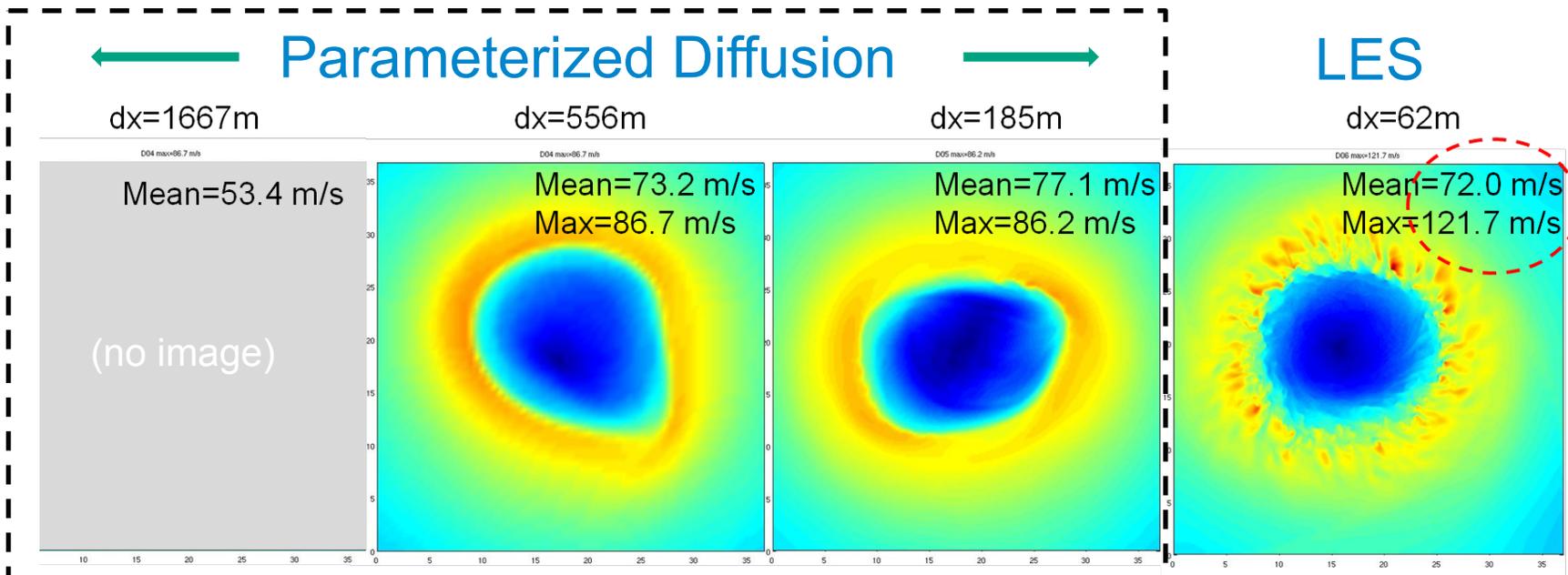


Improving Meteorology

- Prediction of hurricane track has improved to the point where the goals of the USWRP have been reached; progress with intensity prediction has been slower (Davis et al, MWR, 2008)
- Multi-scale problem:
 - Inner core dynamics
 - Interaction with underlying land and sea surfaces
- Can understanding of inner core dynamics (and thus prediction) be improved with higher resolution?



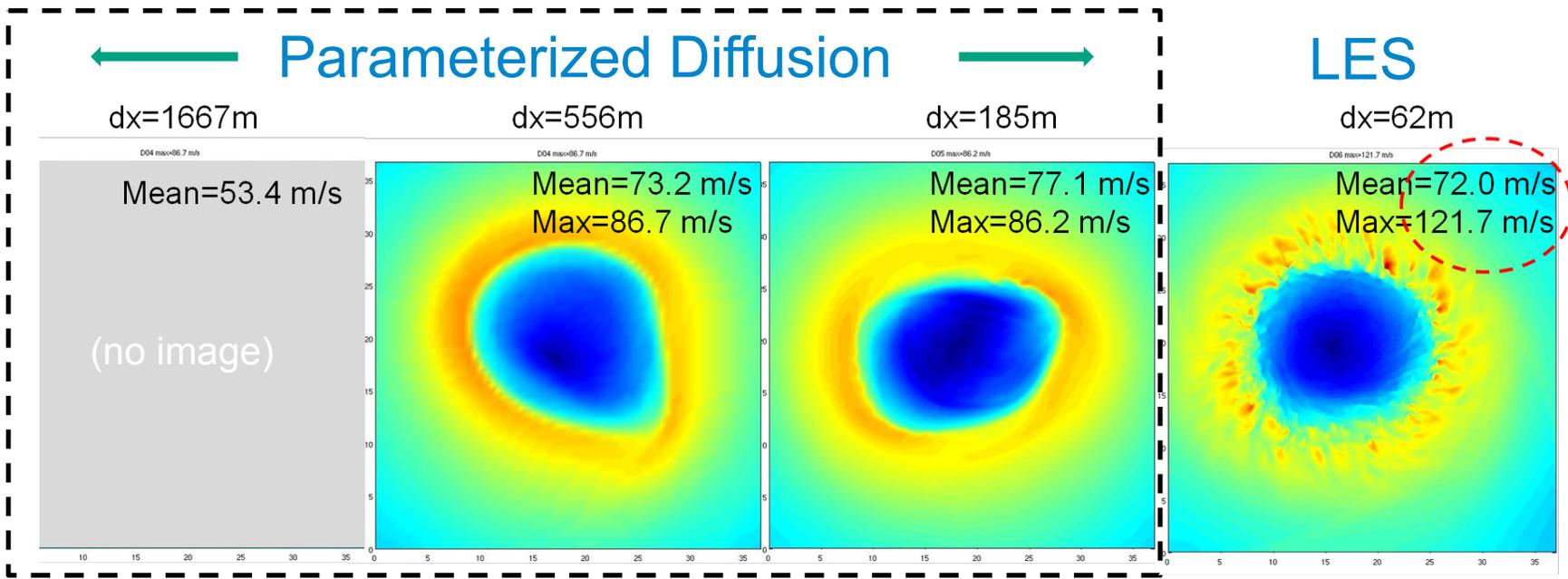
Improving Meteorology



- Parameterized diffusion from sub-grid turbulence is made to decrease with dx to prevent frontal collapse in conventional weather simulations
- However, for hurricane eyewalls, this causes spurious intensification as resolution is increased
- At LES resolution, diffusion is generated by explicitly resolved turbulence: both intensity and maximum winds exhibit behavior observed in real storms

Images and results from Rotunno, Chen, et al. LES of an idealized tropical cyclone, BAMS, 2009 (submitted)

Improving Meteorology

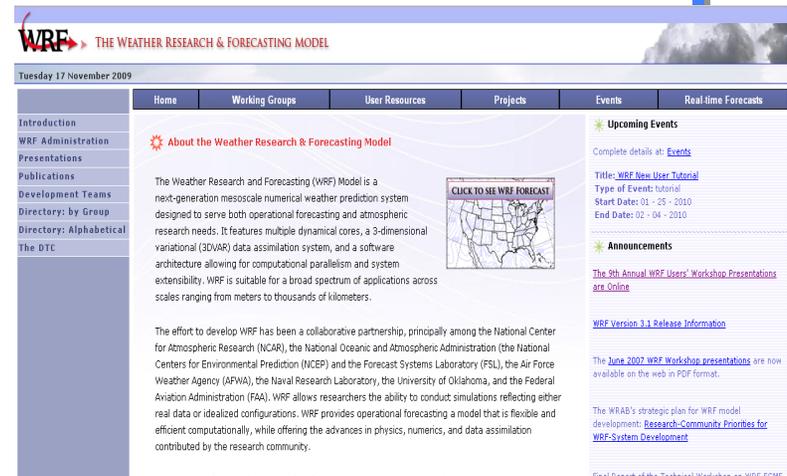


- These results are with an idealized hurricane and suggest that very high LES resolution may provide value both for improving understanding and for real-time prediction with real-data cases
- Meanwhile, use large-scale parallelism to extend our current Hurricane WRF simulations and provide meteorological and computational insight

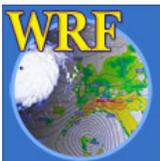
WRF Model for Hurricanes

- Weather Research and Forecast model
 - Community weather model supported by NCAR
 - Computational characteristics
 - Explicit finite difference on regular Cartesian grids, Single (32-bit) floating point precision
 - Designed for HPC: MPI, OpenMP, Hybrid, CUDA...
- Enhancements for hurricane simulation
 - Vortex following moving nests
 - Mixed-layer ocean
 - Physics and surface parameterizations

<http://www.wrf-model.org>

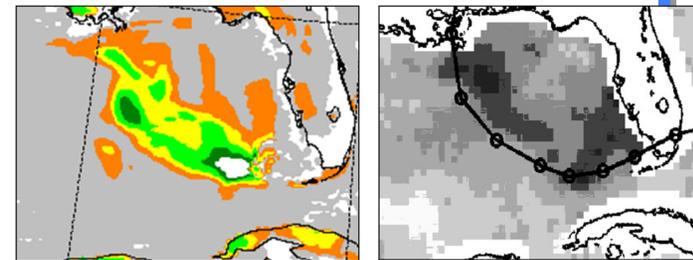
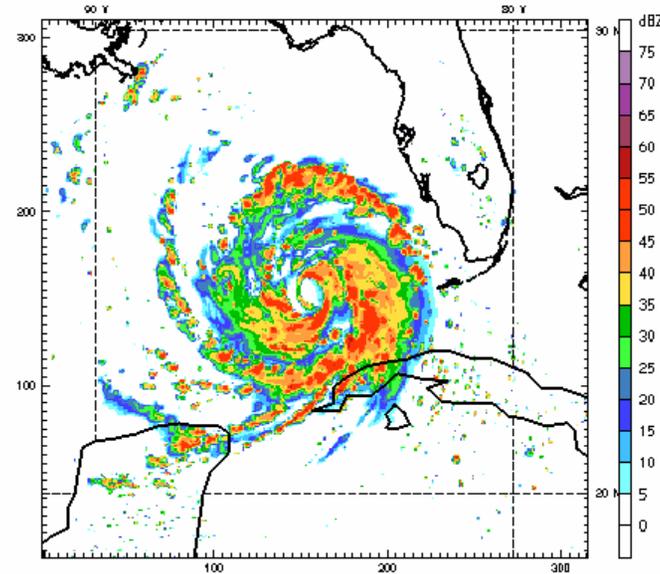


The screenshot shows the homepage of the Weather Research & Forecasting Model (WRF) website. The page features a navigation menu with links for Home, Working Groups, User Resources, Projects, Events, and Real-time Forecasts. The main content area includes an introduction to the WRF model, a link to see the forecast, and a list of upcoming events and announcements. The page is dated Tuesday, 17 November 2009.



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model

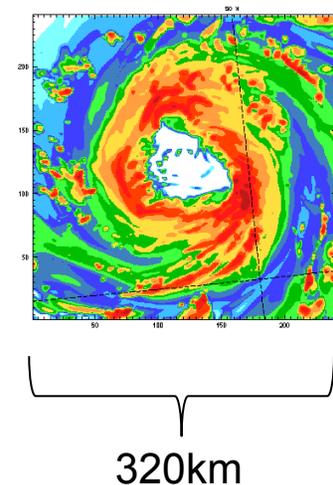
Observation

SST change (K)



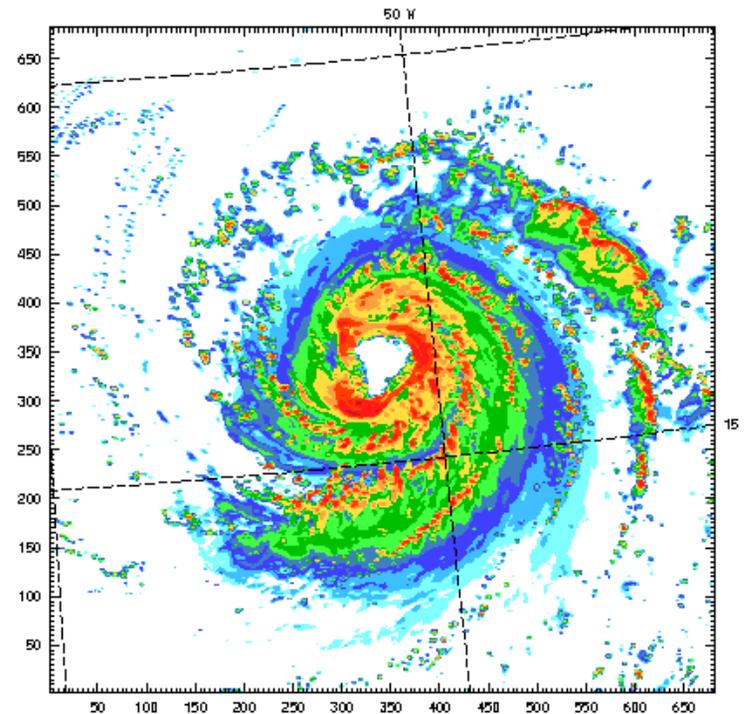
Case: Hurricane Bill (Aug. 18-23)

- Configuration from real-time hurricane forecast system running 2009 season on the NCAR Power6 system
 - Five-day nested simulations
 - 12km, 4km, and 1.33km vortex following nest
- Adapt to 4096 nodes (16K cores) on Blue Gene
 - Expand finest mesh to 1000km square to cover entire storm, not just eyewall
 - Also increase the outermost 12km domain to get improved large-scale forcing
 - Run on largest possible number of cores of BG/P (Intrepid.alcf.anl.gov) for five days and evaluate both model and computational performance



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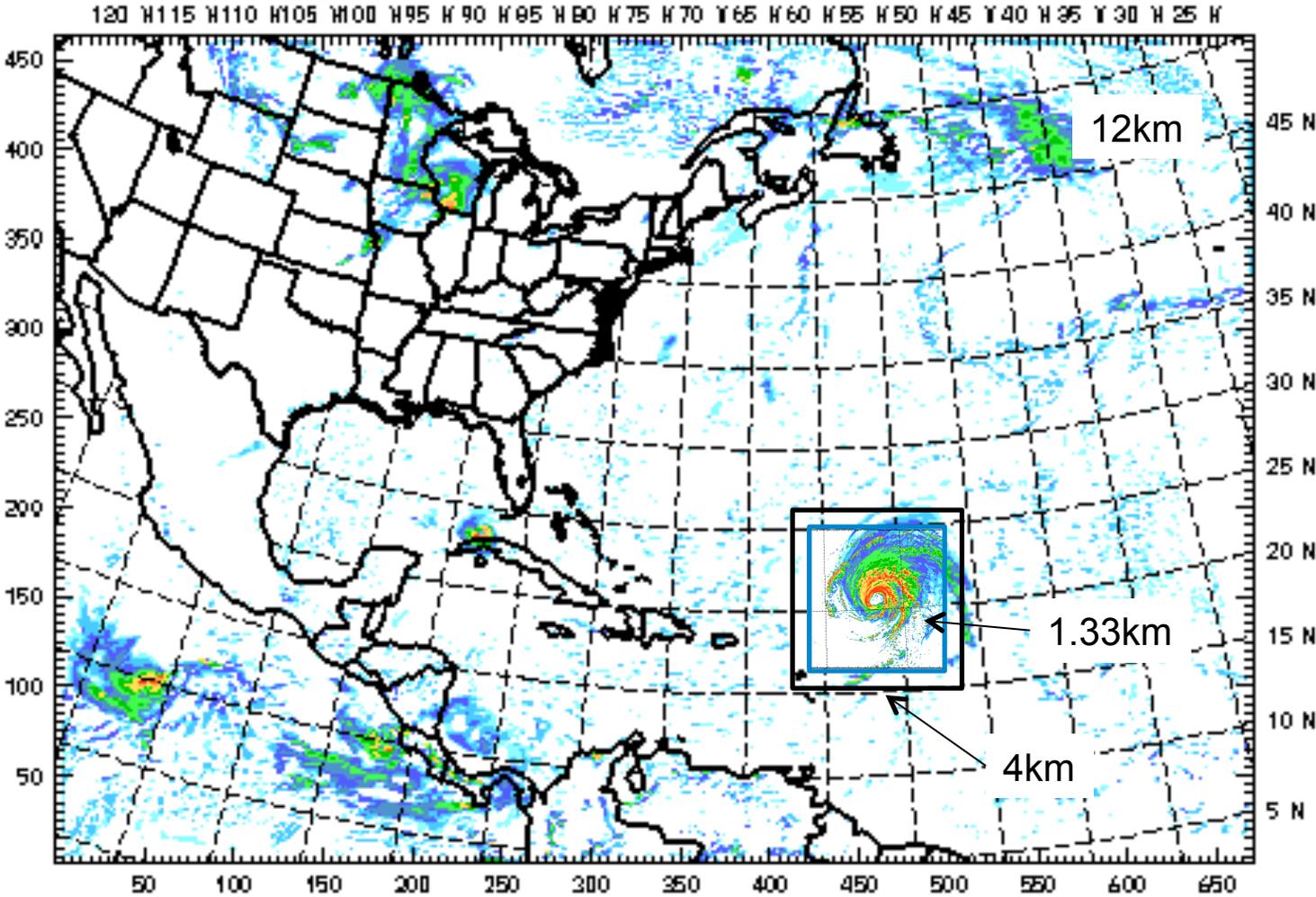
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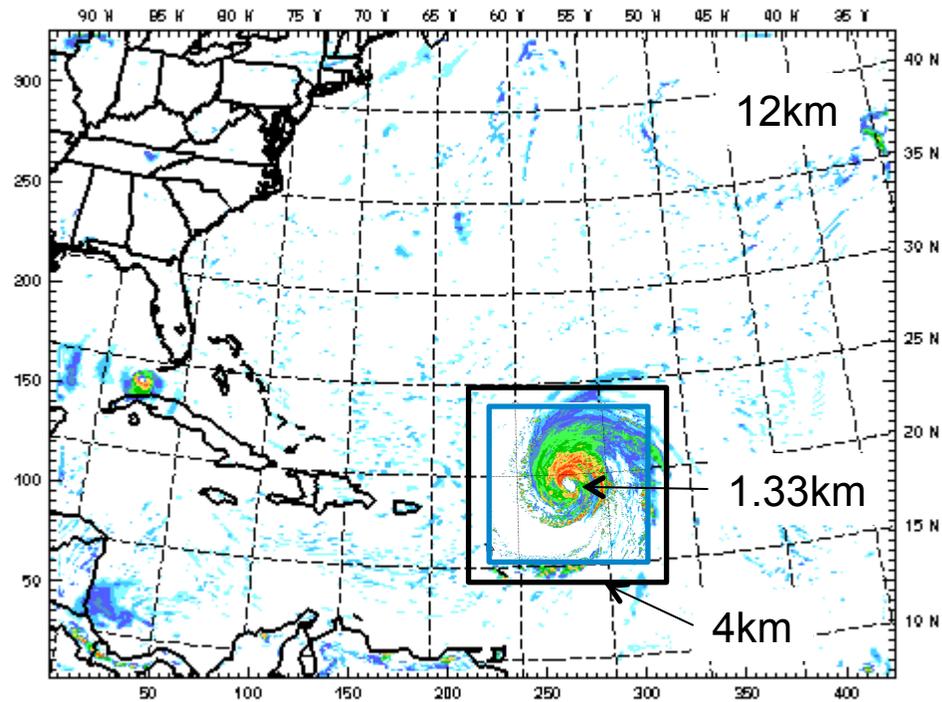
900 km



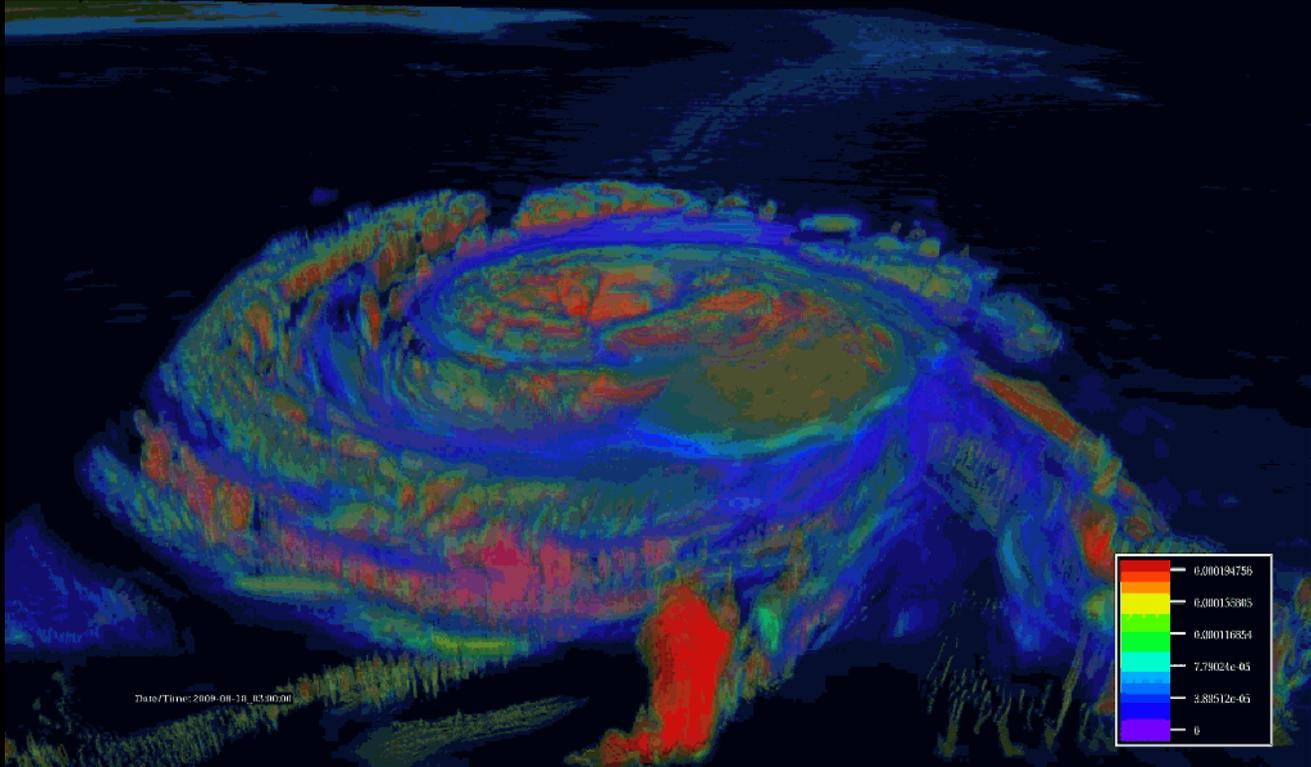
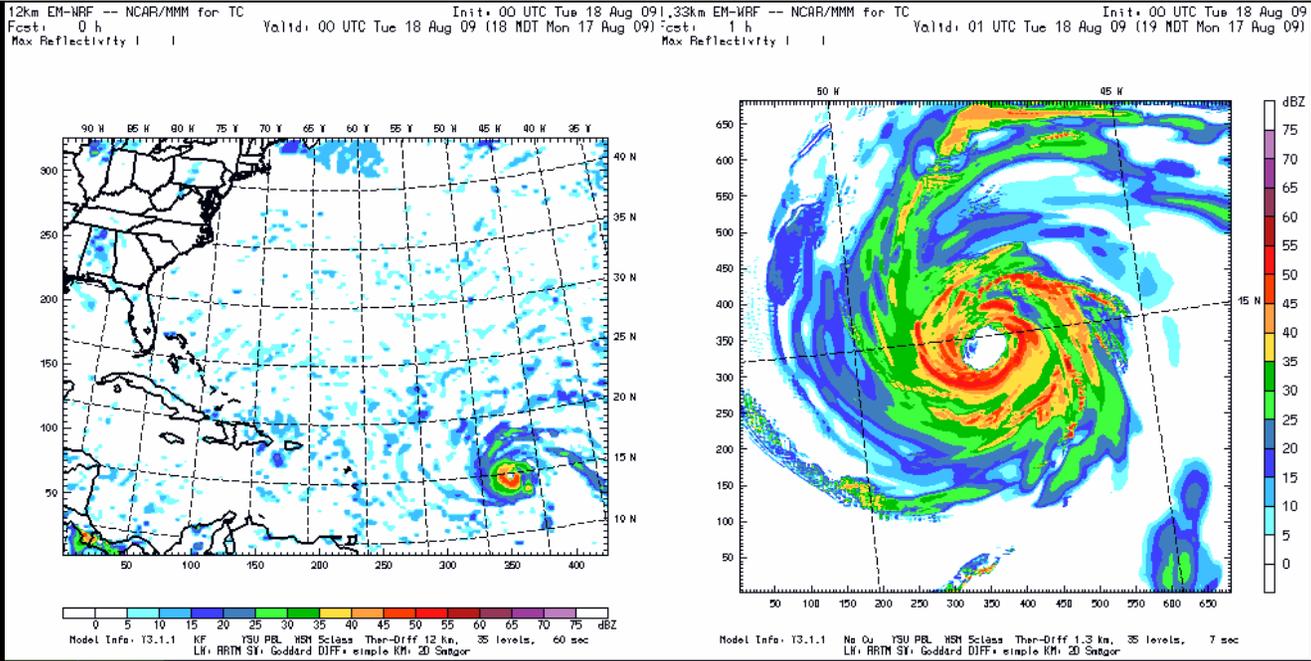
Hurricane Bill, Configuration 1:

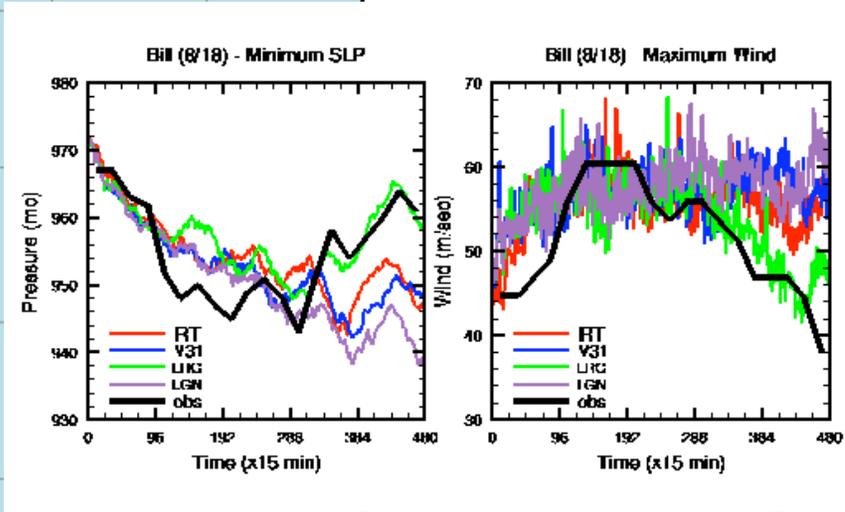
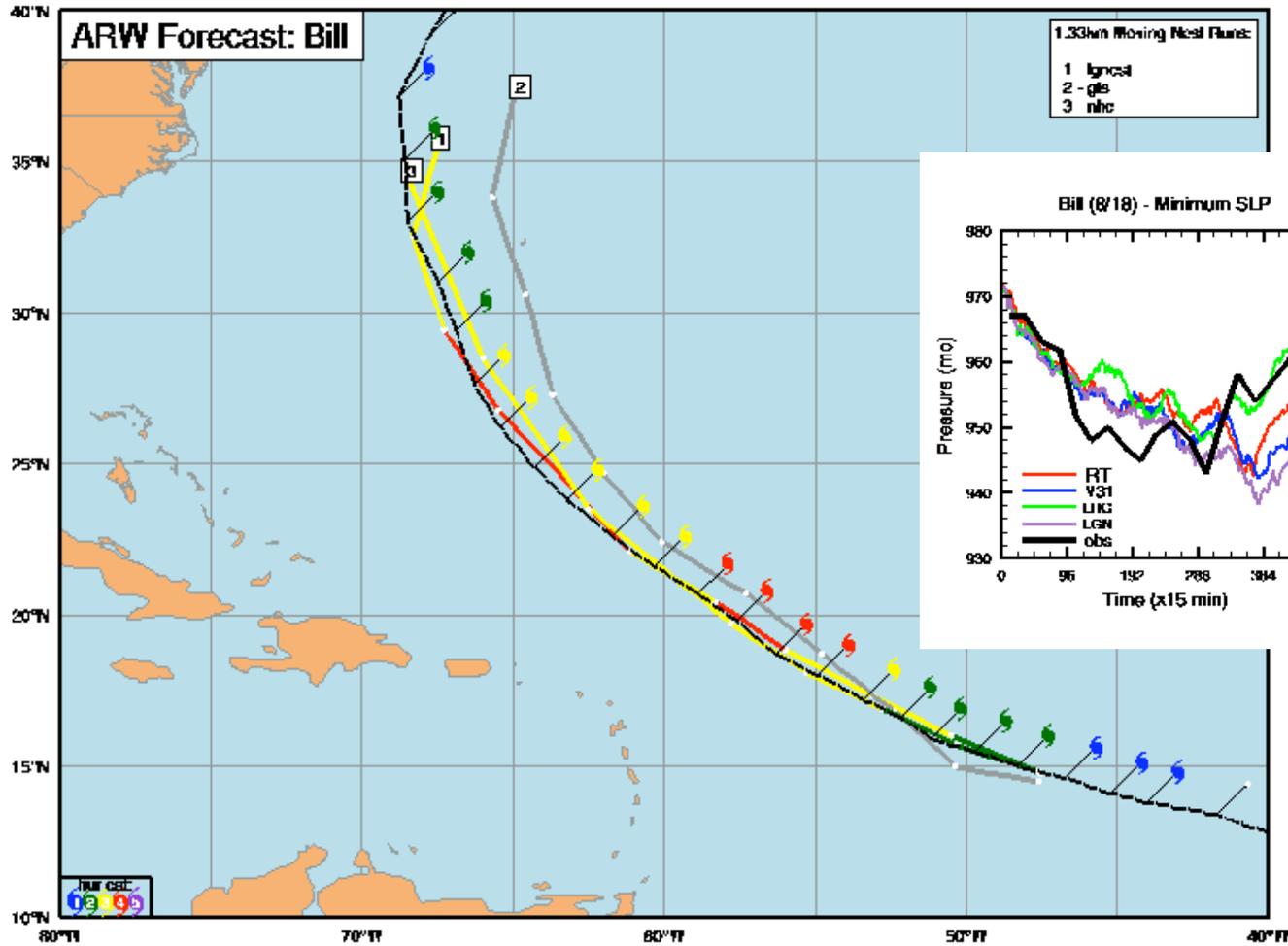


Hurricane Bill, Configuration 2: (subsequent to first set of runs)



Hurricane Bill (18-23 August 09) Simulations on ALCF Blue Gene/P





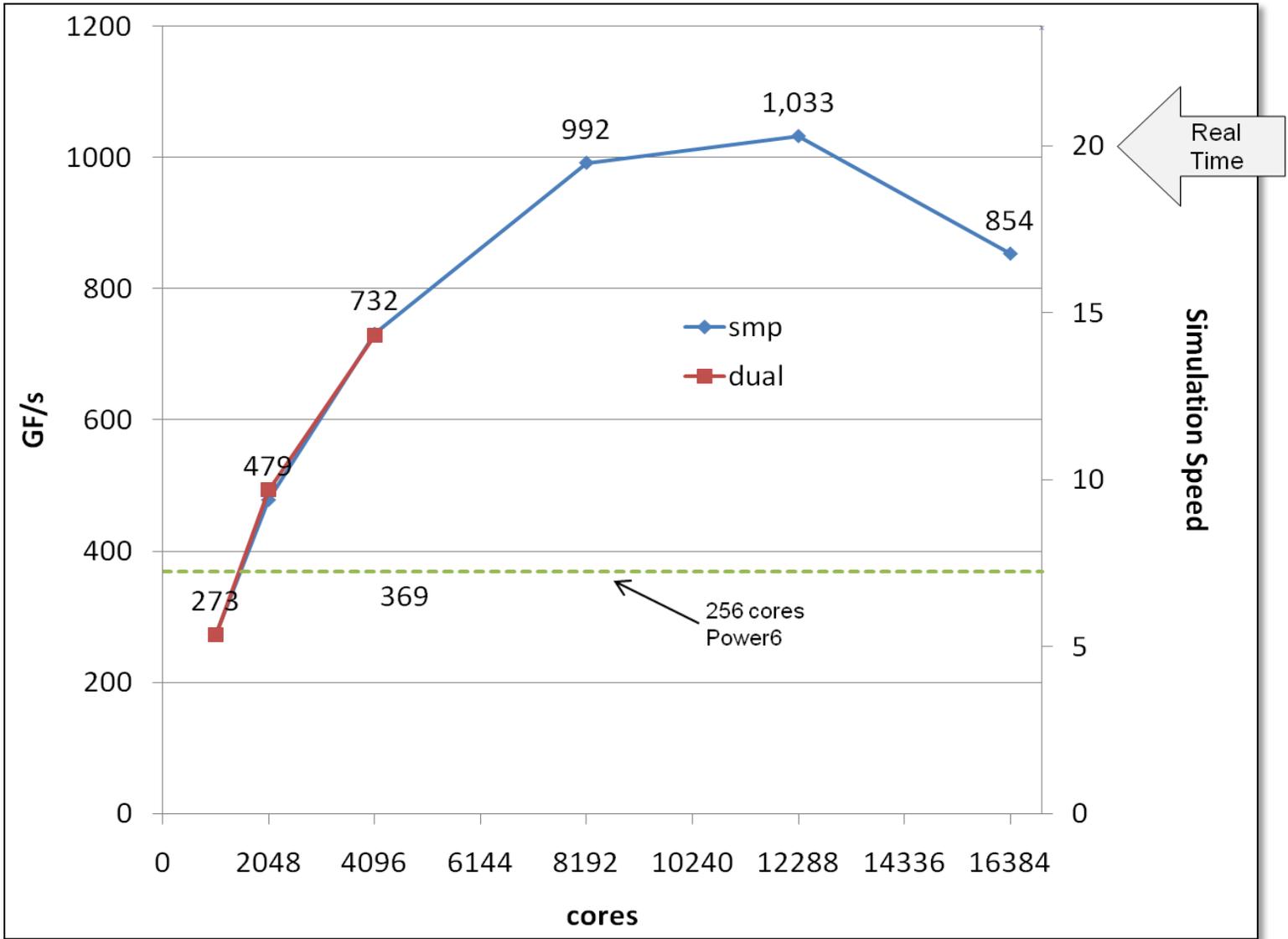
Results

- Configuration 1
 - Track is too far east but within typical uncertainty for 5 day forecast
 - Intensity is better than any other forecast of Bill, but may be because the track took it over colder water
- Configuration 2
 - Track is very good
 - The intensity is over predicted, as with most other runs for this case
- Difficult to draw conclusions based on initial runs of a single case; more study at high resolution needed

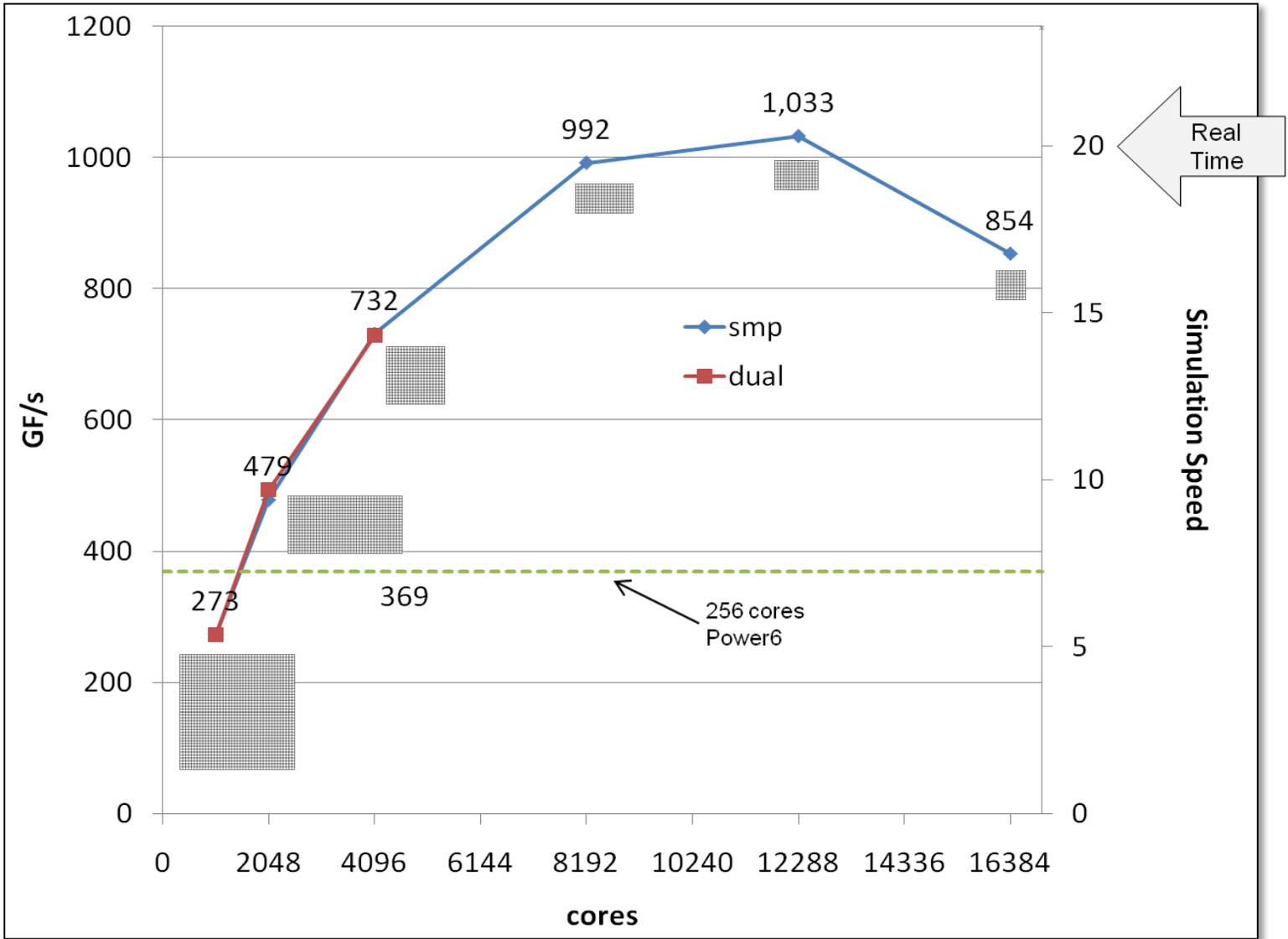


Computational results





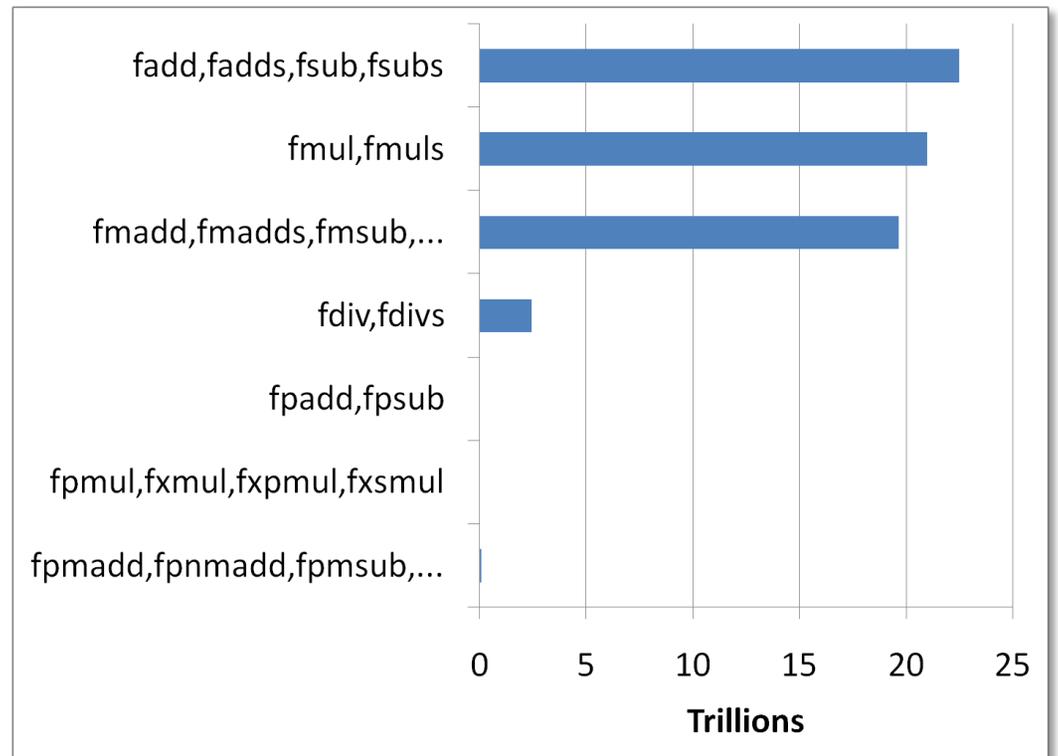
3061 Gigaflop per outer time step



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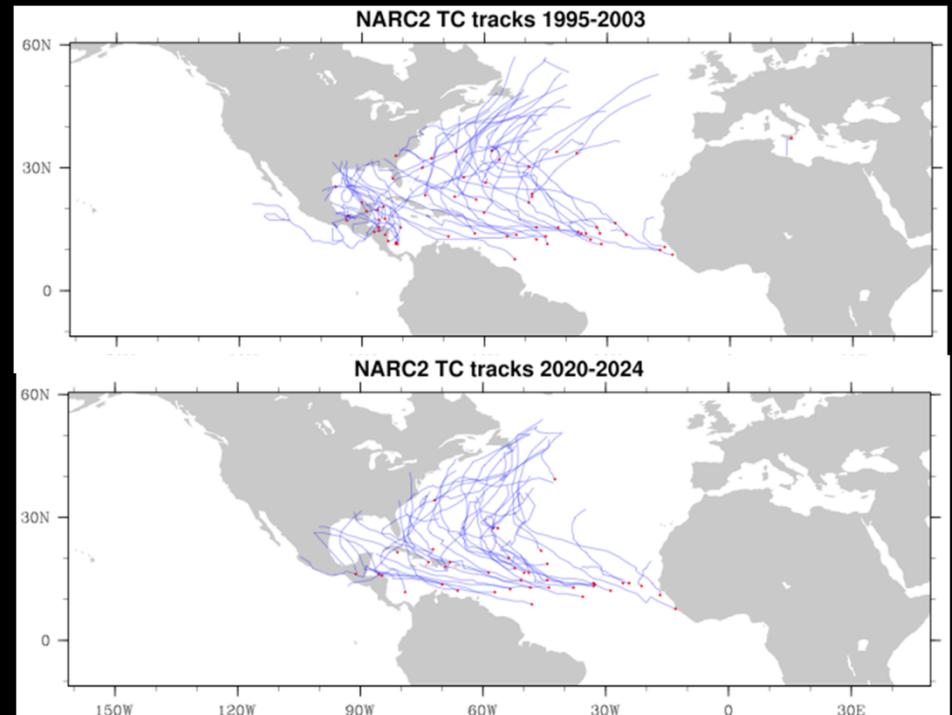
Real time?

- Regardless of domain size we won't do better than 20x real time with this domain – just barely real-time capable
- Detailed instruction count from UPC version of HPM
 - Almost no use of the SIMD double precision units
 - WRF can be run double precision but it isn't a win
- Blue Gene/Q will have single precision SIMD capability



Conclusions

- Large-scale parallelism can be used efficiently, if high resolution is justified
 - Understanding of inner storm dynamics
 - Eliminate need for parameterized diffusion in real-time runs
- Real-time speed is attainable, especially once BG/Q arrives
- Efficient I/O and other scaling issues to be addressed
- Other research: Use of high resolution for climate effects on number and intensity of hurricanes
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