Global CyberBridges: Hurricane Mitigation enabled by ICT

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Presentation Outline

- International Hurricane Research Center (IRHC) Hurricane Mitigation*
  - A Research Agenda Aimed at Mitigating Hurricane Hazards
- Global CyberBridges Hurricane Mitigation
  - Background and Motivation
  - Role of Cyberinfrastructure and Global CyberBridges
  - Hurricane Mitigation Project Overview
  - Project Status
  - Cyberinfrastructure Contributions
- Conclusion

*Slides for IRHC courtesy of Dr. Stephen Letterman, Director

Wind Damage

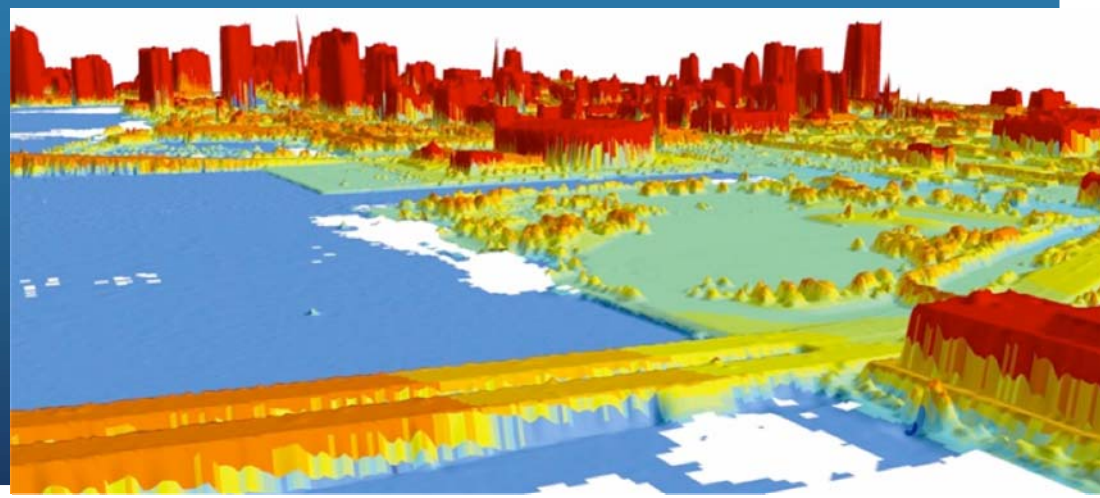
Storm Surge Inundation

Freshwater Flooding

Beach Erosion

IHRC Laboratories

- Insurance, Financial and Economic Research
- Dedicated to defining the hurricane threat to the economy
- Developed the first public catastrophe model to predict damage and insured losses
- Provides technical assistance to hurricane vulnerable stakeholders
- Quantitatively assesses vulnerability of coastal areas to storm-induced beach erosion and hurricane surges
- Utilizes advanced airborne laser mapping and computer animation (LIDAR) Coastal Research

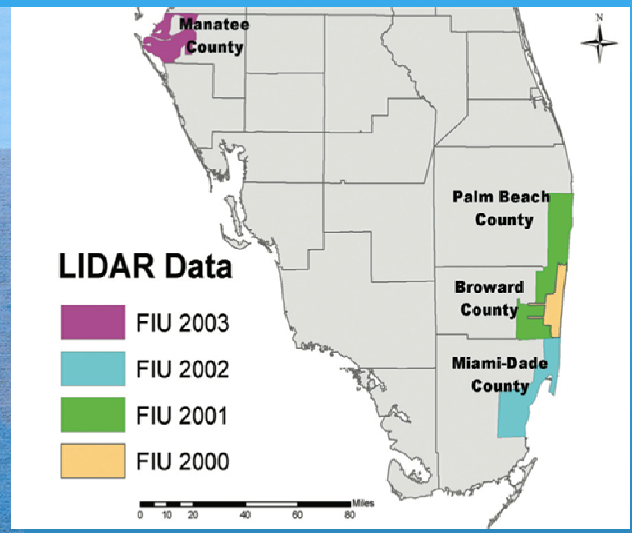


IHRC Laboratories

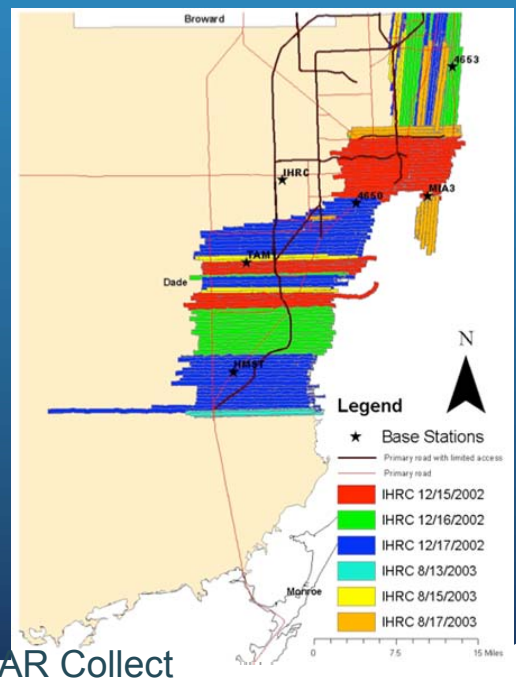
- Social Science Research
  - Studies how individuals and groups respond to hurricanes
  - Formulates methods to improve the resilience of communities
- Wind Engineering Research
  - Investigating solutions to making homes and buildings more hurricane resistant
  - Measuring hurricane surface winds with instrumented towers in actual storm landfalls
  - Conducting wind, pressure and impact testing

Mitigation Research Tools

- LIDAR Mapping



Areas of LIDAR Data Acquisition



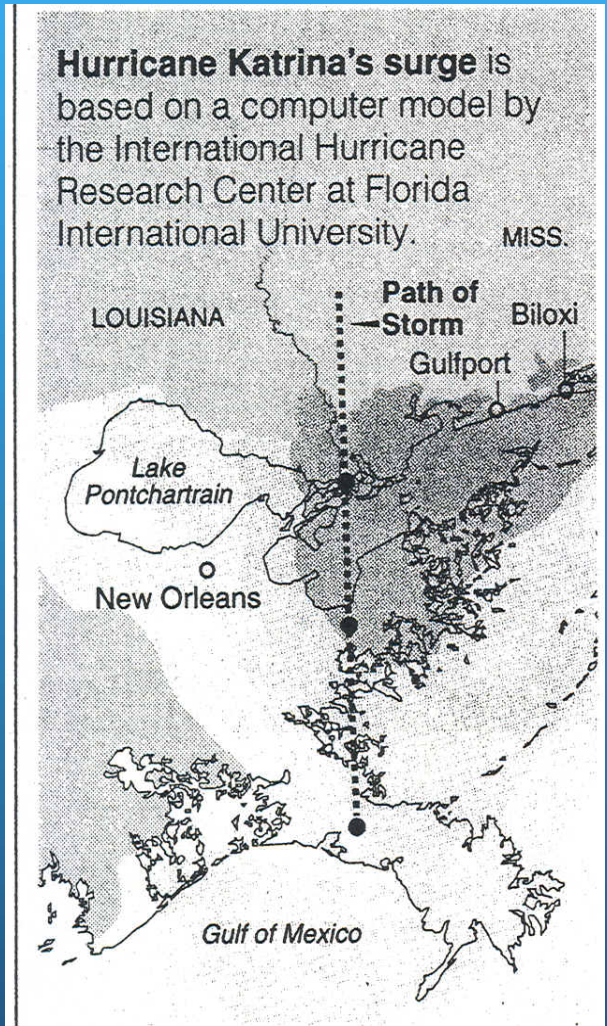
Miami-Dade LIDAR Collect

Case in Point: Hurricane Katrina

- Satellite view, Katrina

Wind Towers Team and Portable Doppler Radar Unit Coordinated Data Collection

IHRC Storm Surge Prediction



John and Rita Kennedy are shown, Tuesday, outside the collapsed second floor of a friend's house after it was destroyed by Hurricane Katrina on the beach in Biloxi, Miss *(AFP photo by Robert Sullivan) Posted Aug.30, 2005*
http://www.chicagotribune.com/news/nationworld/chi-0508310183aug31,1,5787808.story?coll=chi-newsnationworld-hed

Storm Surge Prediction

Hurricane Katrina's storm surge - the wall of water it pushed ashore when it struck the Gulf Coast on Monday - was the highest ever measured in the United States, scien-tists said yesterday.

Stephen P. Leatherman, director of the International Hurricane Re-search Center at Florida Interna-tional University, said the surge at Bay St. Louis, Miss., was 29 feet. Sci-entists from Louisiana State Univer-sity, using different mathematical models, said their estimate was low-er - 25 feet.

Either way, this hurricane easily surpassed the previous record, the 22-foot storm surge of Hurricane Camille, which struck in 1969 near Pass Christian, Miss., a few miles east of Bay St. Louis.

Dr. Leatherman said scientists from Florida International and the University of Florida gathered wind data from towers they set up along the hurricane's projected path just before it struck. They used this data and previous measurements of the topography of the ocean floor and the nearby land to calculate the height of the surge.

Current Wind Engineering Research

- IHRC Mitigation Research is taking on the problem of how to keep homes and businesses safer from damage caused by punishing hurricane winds

Wall of Wind: Phase I

- Fabricated by Diamondback Airboats
- Delivered in January 2005
- Presently developing the active control system that will be duplicated in Phase II

What is Global CyberBridges?

- Cyberinfrastructure Training, Education, Advancement, and Mentoring for Our 21st Century Workforce (CI-TEAM)
- Three year award (Oct. 2006 - Dec. 2009) for $765,000 total to CIARA at FIU
- The program expands on CyberBridges, which was initiated in 2005 to help FIU scientists and engineers advance their research through cyberinfrastructure (CI).

Global CyberBridges; Hurricane Mitigation Project Team

Advisors	Students
Dr. Heidi Alvarez, Director FIU Center for Internet Augmented Research and Assessment (CIARA), PI for GCB heidi@fiu.edu	Javier Delgado, FIU Global CyberBridges (GCB) Ph.D. Fellow Project Lead javier.delgado@fiu.edu
	Javier Figueroa, FIU
Dr. S. Masoud Sadjadi, FIU School of Computer and Information Science (SCIS), Co-PI for GCB sadjadi@cs.fiu.edu	Zhao "Wendy" Juan, Computer Network Information Center, Chinese Academy of Sciences (CNIC of CAS) GCB Master's Student Lead
Dr. Hugh Willoughby, FIU Earth Sciences Distinguished Research Professor	Bi Shuren, CNIC of CAS
Dr. Kai Nan, CNIC of CAS	Silvio Luiz Stanzani, UniSantos, Brazil
Dr. Esteban Walter Gonzalez Clua, Federal University Fluminense (UFF) Informatics Department	Mark Eirik Scortegagne Joselli, UFF, Brazil

Participants Distribution 2009

- Weather Research and Forecasting “WRF” (only GCB students)
  - FIU (Miami): 3 students
    - 1 meteorology and 2 computer science
  - UFF (Brazil): 2 students
- Visualization platform
  - FIU: 4 students
  - CNIC: 2 students

Hurricane Mitigation Background

- Computationally Intensive
- Improvement requires cross-disciplinary expertise
- High Performance Computing
- Meta-scheduling
- Resource Allocation
- Work flow Management
- Weather Modeling
- Weather Research and Forecasting (WRF)

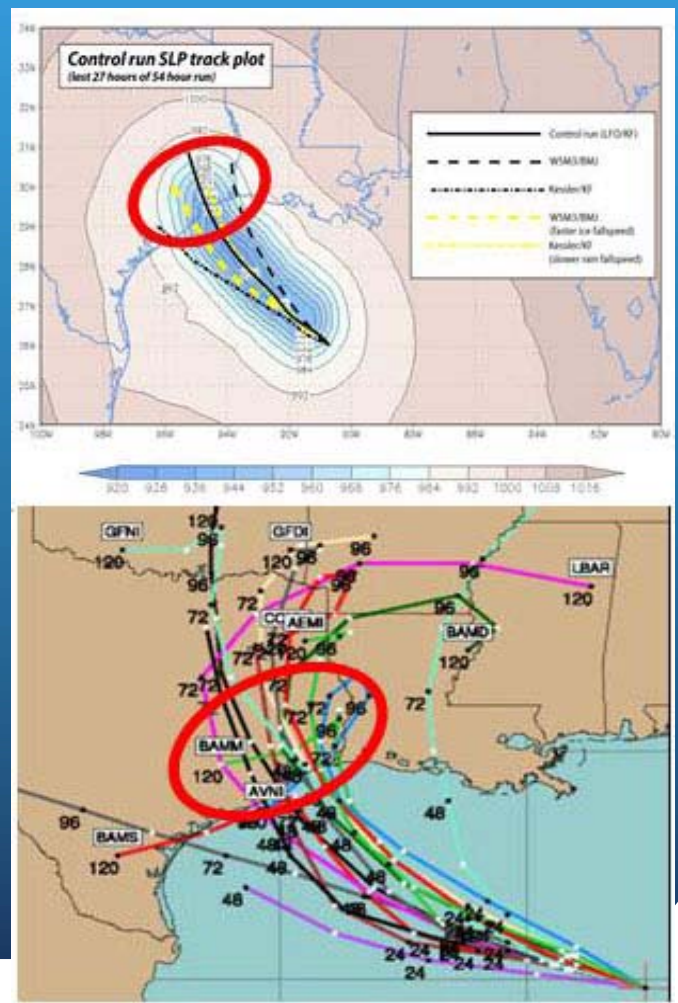


Image Source: http://mls.jpl.nasa.gov

Research Motivation

- Hurricanes cost coastal regions financial and personal damage
- Damage can be mitigated, but:
  - Impact area prediction is inaccurate
  - Simulation using commodity computers is not precise
- Alarming Statistics
  - 40% of (small-medium sized) companies shut down within 36 months, if forced closed for 3 or more days after a hurricane
  - Local communities lose jobs and hundreds of millions of dollars to their economy
  - If 5% of businesses in South Florida recover one week earlier, then we can prevent $219,300,000 in non-property economic losses

urricane Andrew, Florida 1992

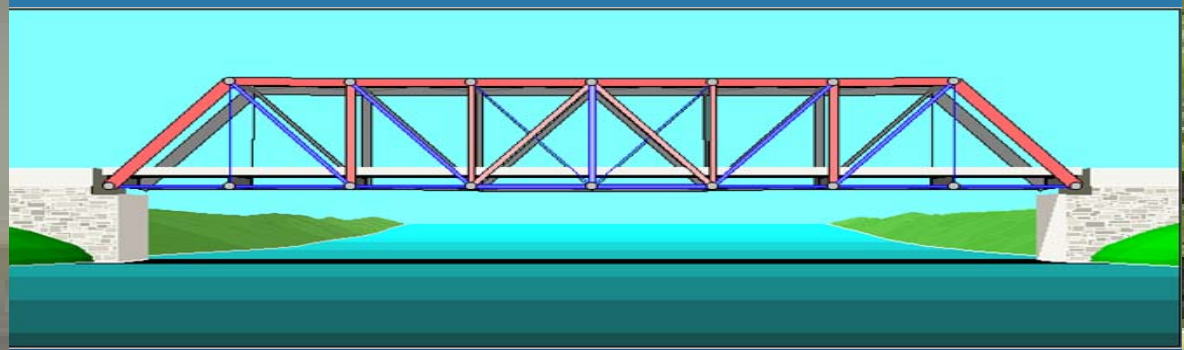
Ike, Cuba 2008

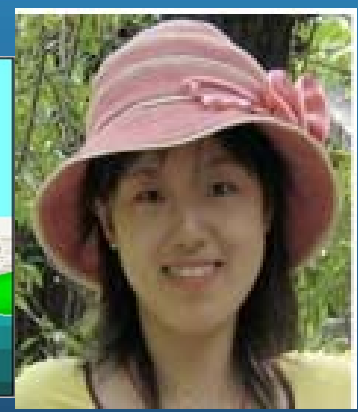
Katrina, New Orleans

Why Apply Cyberinfrastructure to Research & Learning?

- Preparation for a globalized workforce
- Innovation is now driven by global collaboration
- Diverse (and complementary) expertise
- Enable transparent cyberinfrastructure
- In Global CyberBridges, students are the bridges

Javier Delgado, FIU





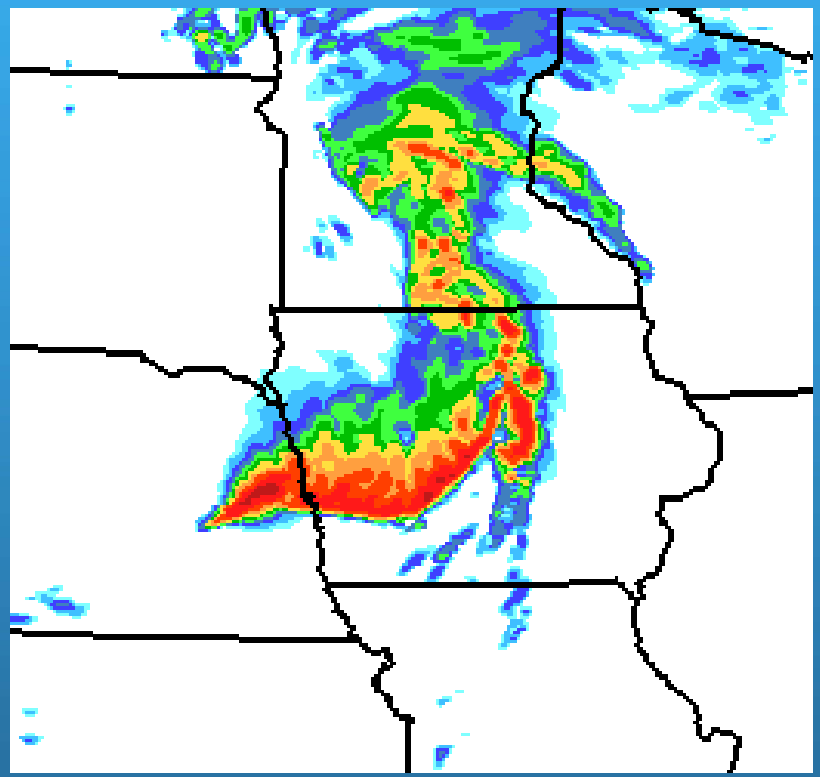
Zhao “Wendy” Juan, CNIC

Hurricane Mitigation Project Overview

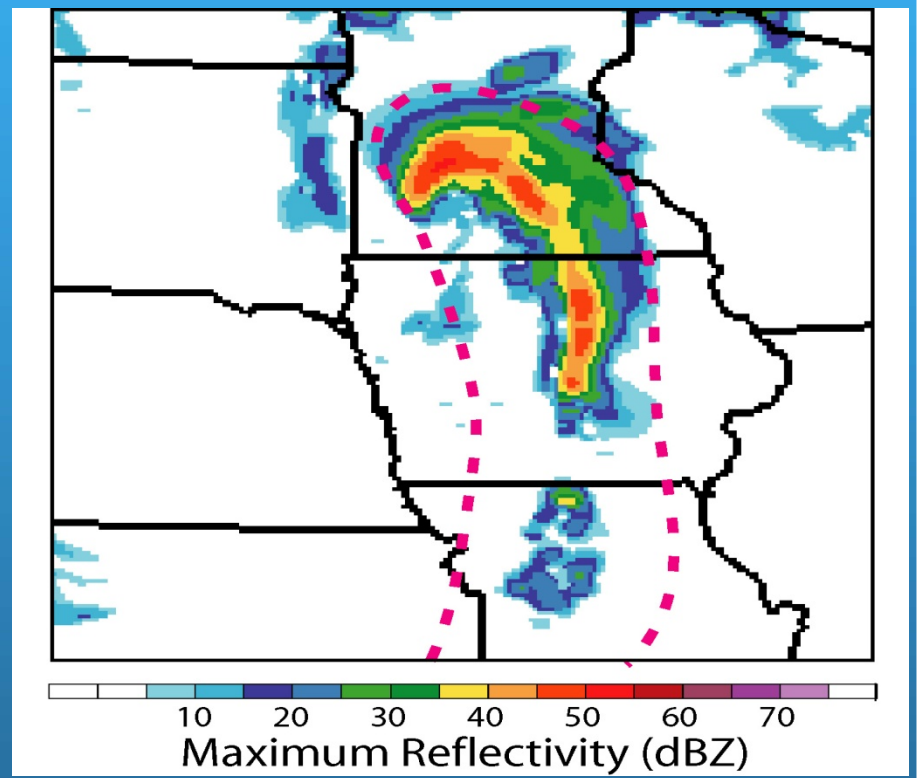
- Goals
  - High-resolution forecasts with guaranteed simulation execution times
  - Human-friendly portal
  - High-resolution visualization modality
  - High Resolution Hurricane Forecasting
- We create:
  - A distributed software model that can run on heterogeneous computing nodes at multiple sites simultaneously to improve
    - Speed of results
    - Resolution of the numerical model
    - Scalability of requests by interested parties
    - In other words, we need to grid-enable Weather Research and Forecasting (WRF) software system
- WRF Information: http://wrf-model.org/index.php

Why So Many Processors?

4-km WRF



10-km WRF



Parameterized convection (on the 10 km grid) cannot differentiate different mode of convection

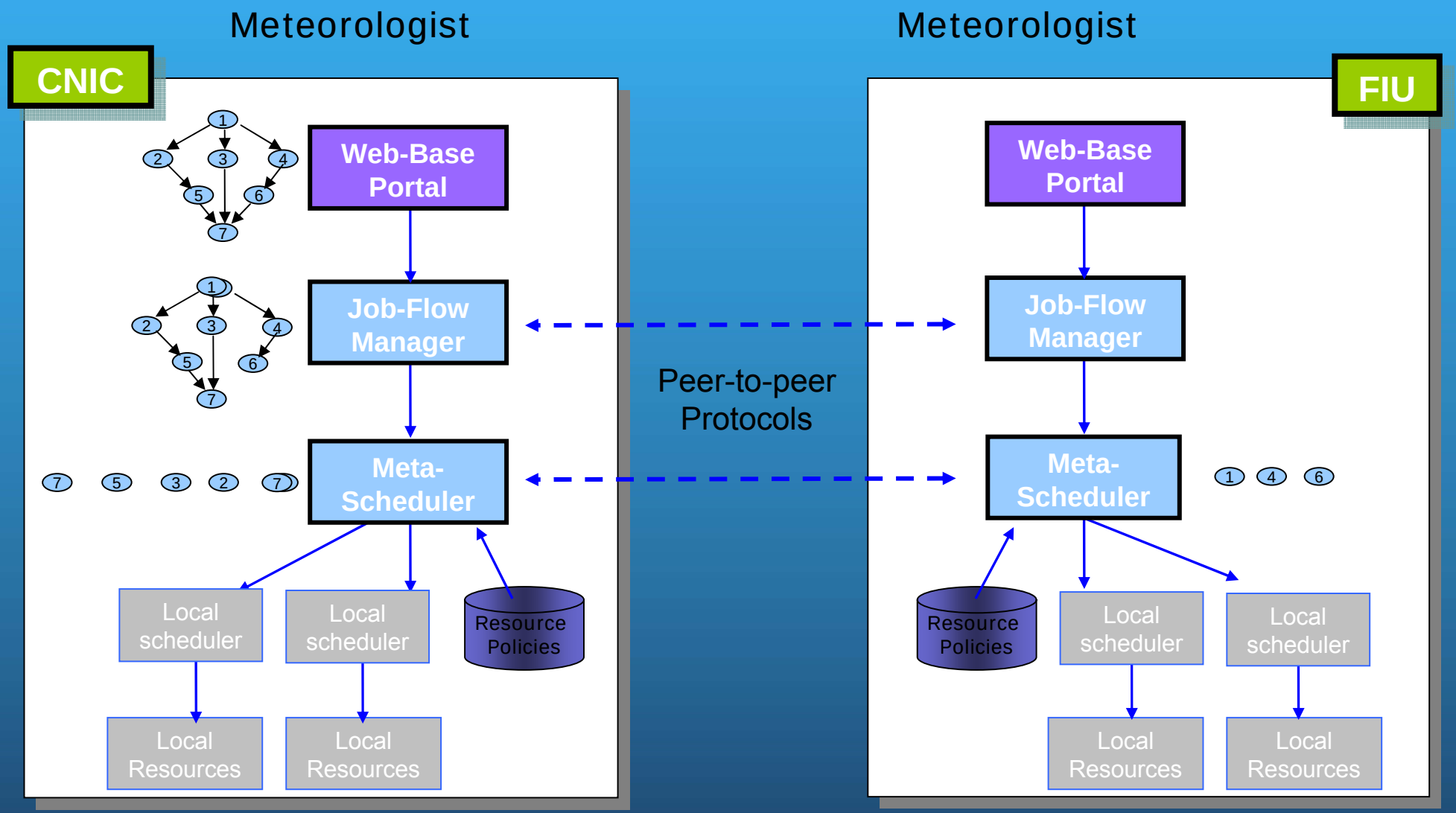
Dashed magenta indicates approximate area of rainfall

Produced by convective parameterization

Source: NCAR

(www.ncep.noaa.gov/nwp50/Presentations/Thu_06_17_04/Session_9/Kuo_50th_NWP/Kuo_50th_NWP.ppt)

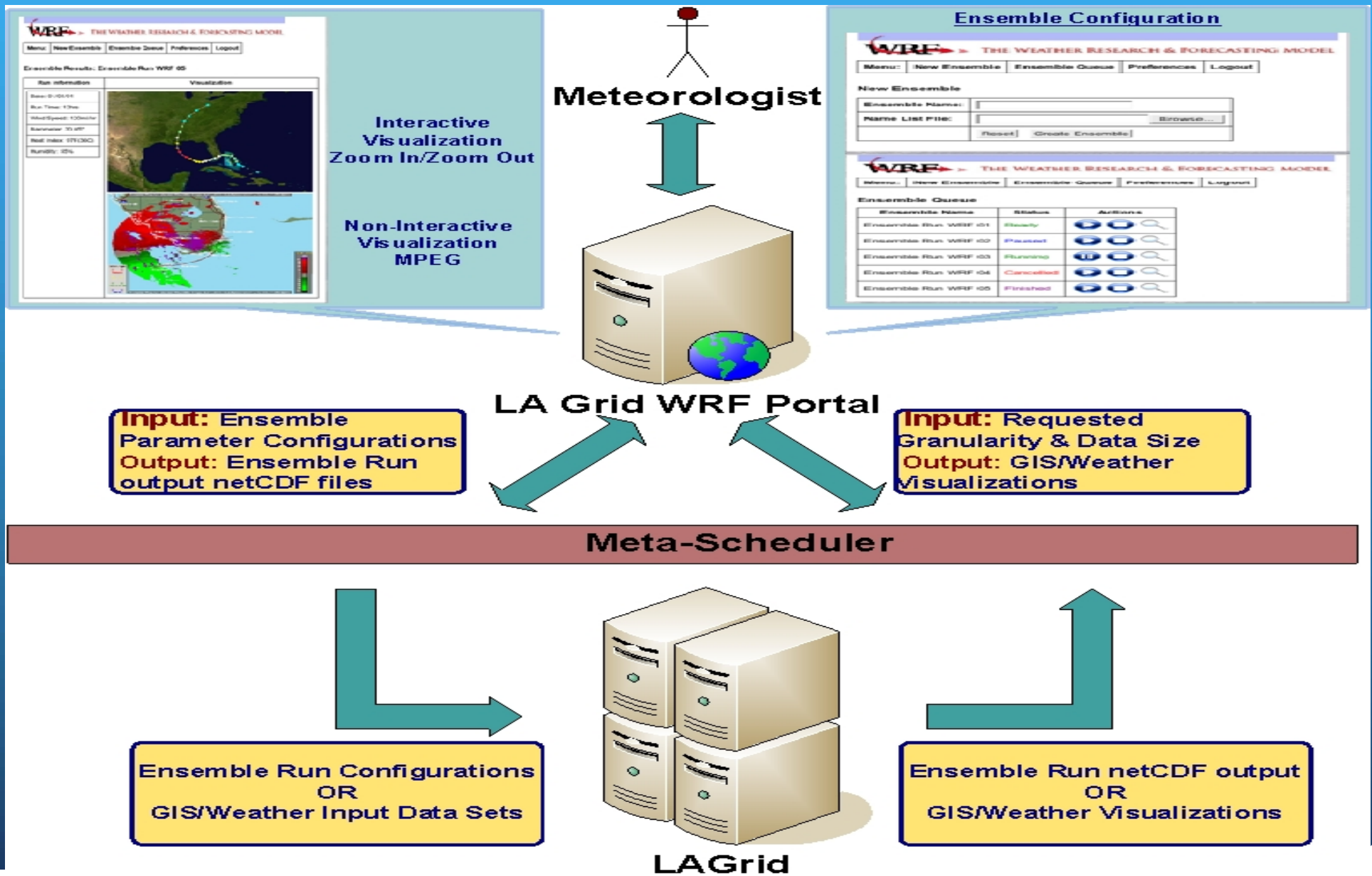
Interaction of the Components



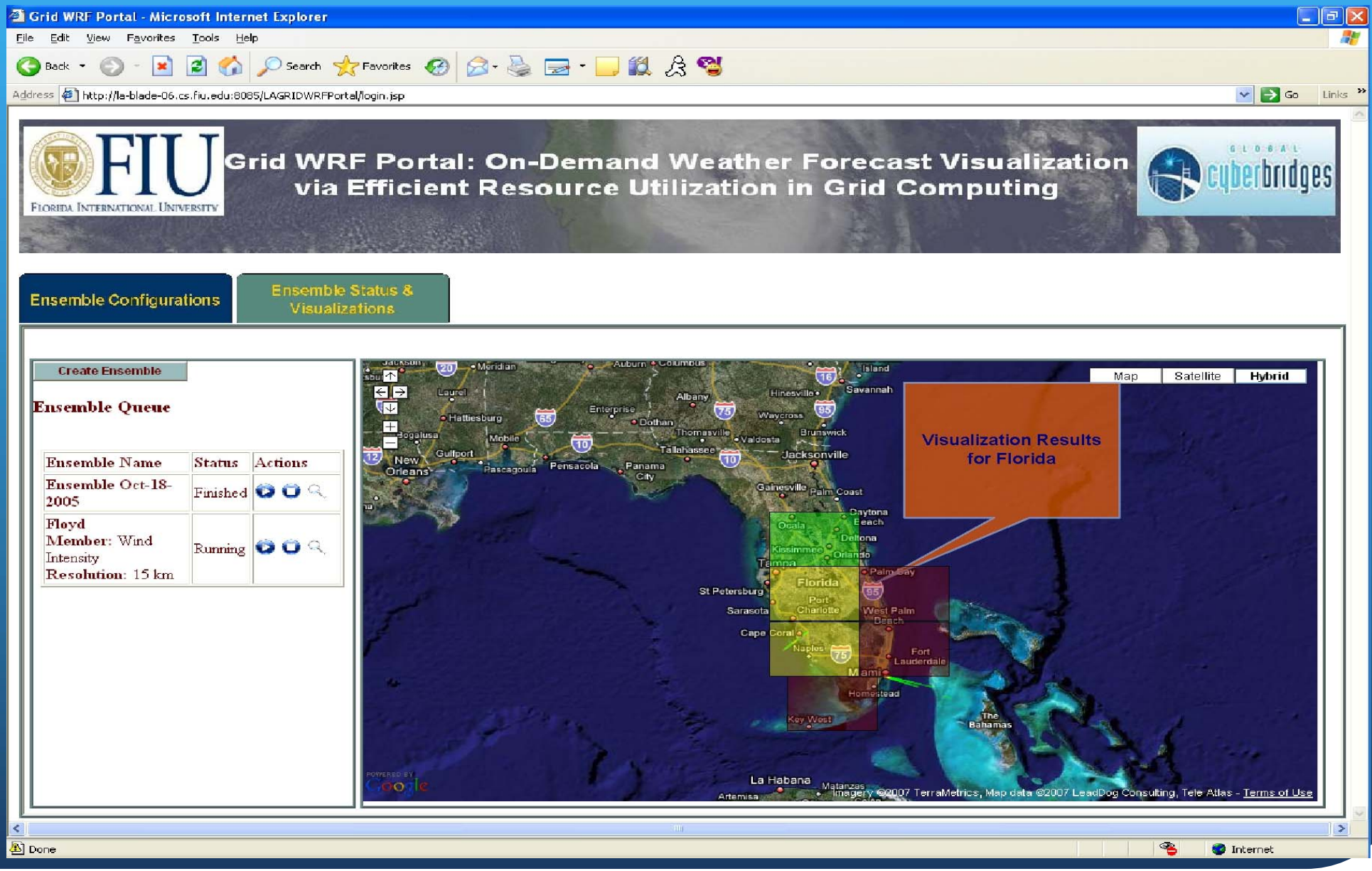
WRF Data

- 3-Layer Nested Domain that covers Florida
- Distributing WRF over a WAN slows performance due to high input/output
- Communication across the WAN occurs before and after the job run
  - Before: Send domain input. There are three stages documented at http://www.mmm.ucar.edu/wrf/users/docs/user_guide/users_guide_chap3.htm
- Domain Resolutions:
  - 1.7km for the inner domain
  - 5km for the middle domain
  - 15km for the outer domain
- For the input data:
  - Static Geographical Data for the domain + Other geographical data: About 250 MBs.
  - MET Data: 35MB/time step (of simulation).
    - We use a time step of 6hours, so for a 3 day forecast the total size is 210MBs. Real Data: 101MB (for a 3 day forecast)
- For the output data:
  - About 215MB per time step (of simulation) is generated.
  - Time step of 1 hour.
  - 3-day forecast, 215*24*3 = 15.4 GB of data without compression

WRF Web Portal



WRF Portal Hi-Res Visualization

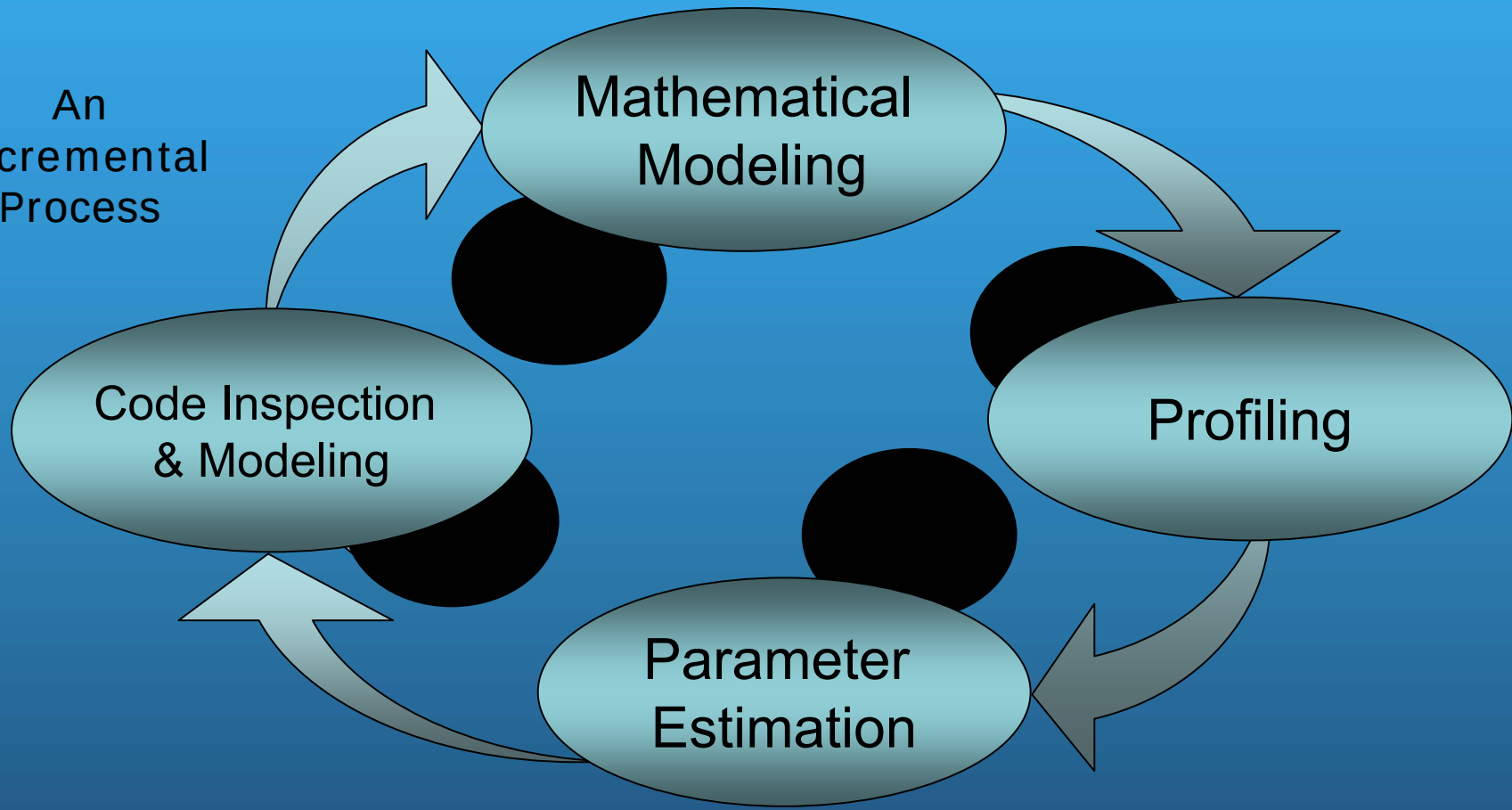


Modeling WRF Behavior

- Paradox of computationally-intensive jobs:
  - Underestimated execution time = killed job
  - Overestimated execution time = prohibitive queue time
- Grid computing drawbacks
  - Less reliable than cluster computing
  - No built in quality assurance mechanism
  - **Hurricane prediction is time-sensitive, so it needs to work around this**
- Meta-scheduler addresses the quality assurance issue
- To predict execution time, model the software
  - Pick a representative simulation domain
  - Execute it on various platforms with various configurations
  - Devise a model for execution time prediction and implement it in software
  - Test model
  - Adjust until prediction accuracy is within 10 percent

Modeling WRF Behavior

An Incremental Process



Current Execution Prediction Accuracy

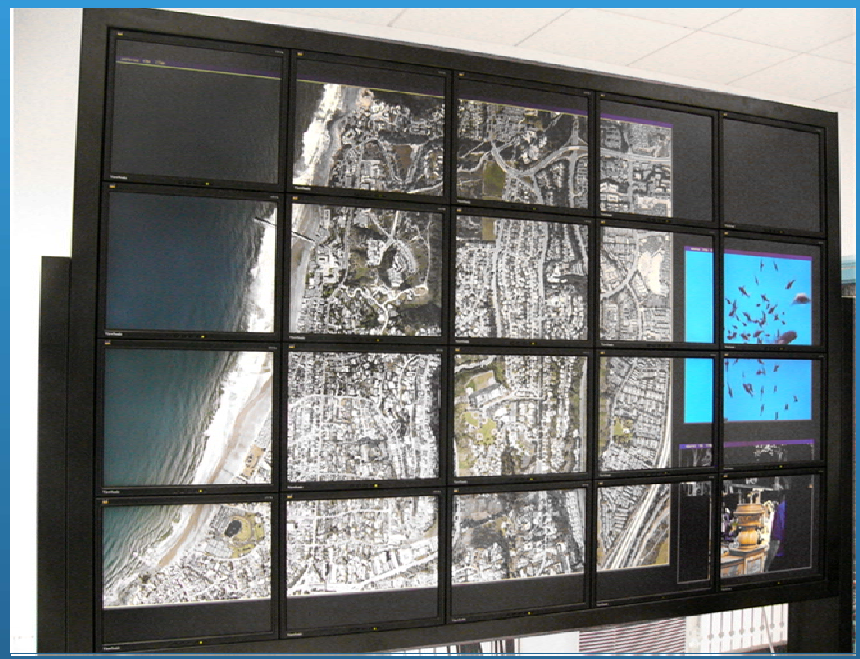
- Adequate accuracy on multiple platforms
- Cross-cluster:
  - 8-node, 32-bit Intel Cluster
  - 16-node, 64-bit Intel Cluster
  - Different (simulated) CPU speed and number-of-node executions
- Inter-cluster on MareNostrum Supercomputer of Barcelona Supercomputing Center
  - Up to 128-nodes

MareNostrum Info: http://www.top500.org/system/8242

Visualization Platform for Hurricane Mitigation Scalable Adaptive Graphics Environment (SAGE)

- Scalable
  - Hundreds of Screens can be used
  - Built with high-performance applications in mind
- Extensible
  - Provides API for creating custom SAGE applications
- Porting an application is not trivial

4 by 5 SAGE Display Wall at CNIC



SAGE is developed by UIC Electronic Visualization Laboratory.
NSF SCI-0225642 & ANI-0225642

Enhancements to SAGE

Remote Desktop Enhancement

- A responsive remote desktop modality is essential for collaboration and e-Learning
- Users can share their display for all collaborators to see
- Non-portable applications can also be displayed

Wii Remote input interface

- A traditional mouse makes it difficult to work with a large display

Global CyberBridges Overall Contributions

- Weather Forecasting
  - Students in different scientific fields from 3 different continents exposed to the problem through a remote class
  - Grid-computing related methodologies for addressing these problems have been presented
  - Collaborative publications in progress
- Visualization
  - Based on the difficulties we had in the class, we are trying to implement a cutting-edge e-Learning environment based on SAGE
  - Publication: Javier Delgado, Mark Joselli, Silvio Stanzani, S. Masoud Sadjadi, Esteban Clua, and Heidi Alvarez. A learning and collaboration platform based on SAGE. In Proceedings of the 14th Western Canadian Conference on Computing Education (WCCCE 2009), Simon Fraser University, Vancouver, Canada, May 2009. (Accepted for publication.)

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- NSF research assistance grants: HRD-0833093, CNS-0426125, CNS-052081, CNS-0540592, IIS-0308155

- For more information: www.cyberbridges.net and heidi@fiu.edu

Thank You!