Katrina and Beyond

Computational Challenges in Coastal Modeling

Ed Seidel

Center for Computation & Technology

Louisiana State University

Representing Louisiana, National Coastal Modeling Efforts

CLEAR

LSU HURRICANE CENTER

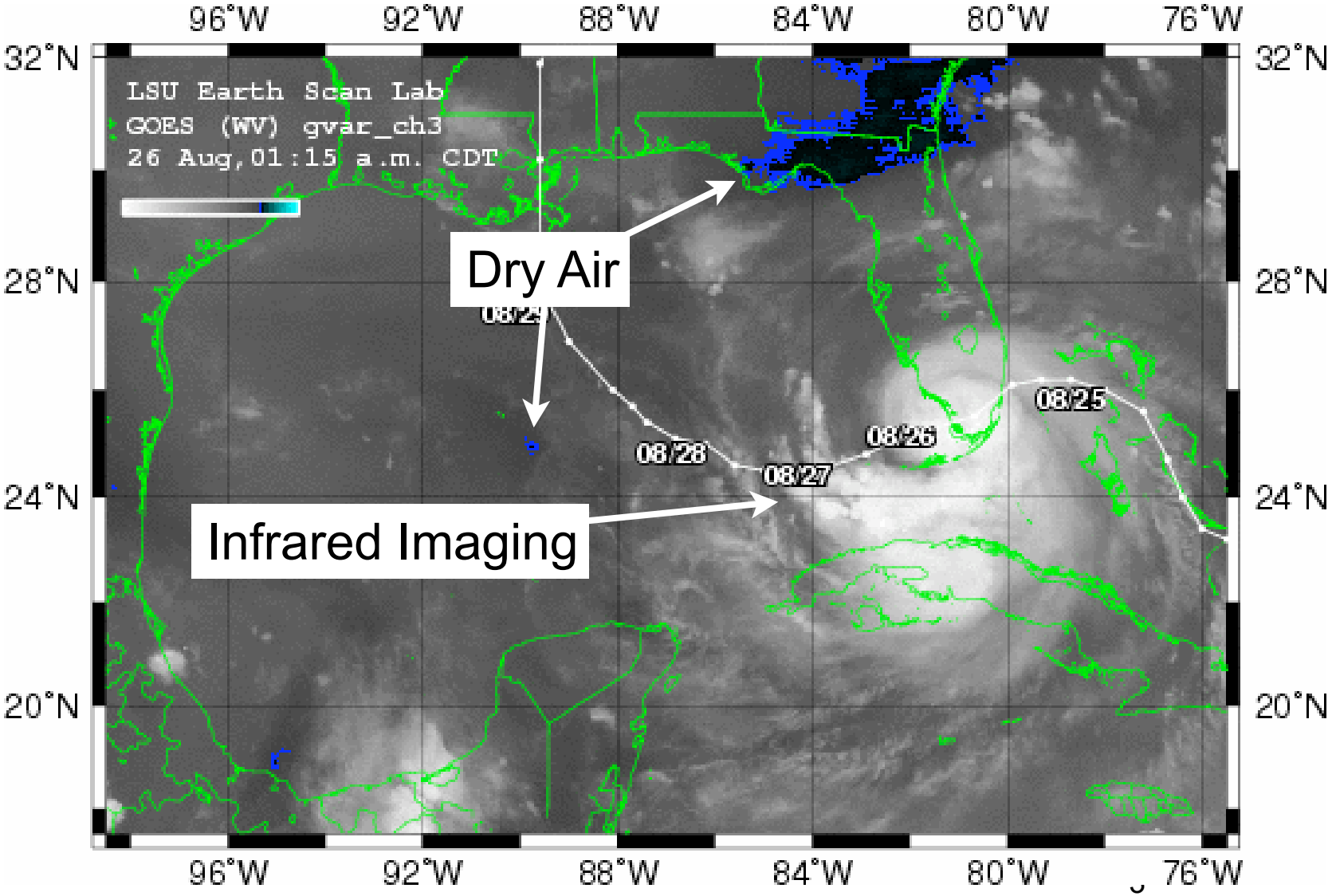
Addressing Hurricanes and Other Hazards and Their Impacts on the Natural, Built, and Human Environments

Center for the Study of PUBLIC HEALTH IMPACTS of Hurricanes

Louisiana Story

- 1927 flood, levees, loss of wetlands, growing crisis
  - Social impacts huge
- "Hurricane Pam", 2004
- Hurricane Katrina, 2005
  - 1.4M FEMA aid applications, 35K > 1000 miles away, 33K evacuations by coast guard alone (6x 2004)
  - 3 months later: much of N.O w/o power, homes abandoned, 80% gone, still finding bodies; today, parts still devastated
  - 20-50K homes may be destroyed: years to rebuild
  - Effects on State, Baton Rouge, LSU
    - 135K new residents, 4K new students, state crises
  - CCT devoted machines, staff
    - Lives of friends/families lost
- Role of HPC, Models, Grids

Actual Path of Katrina



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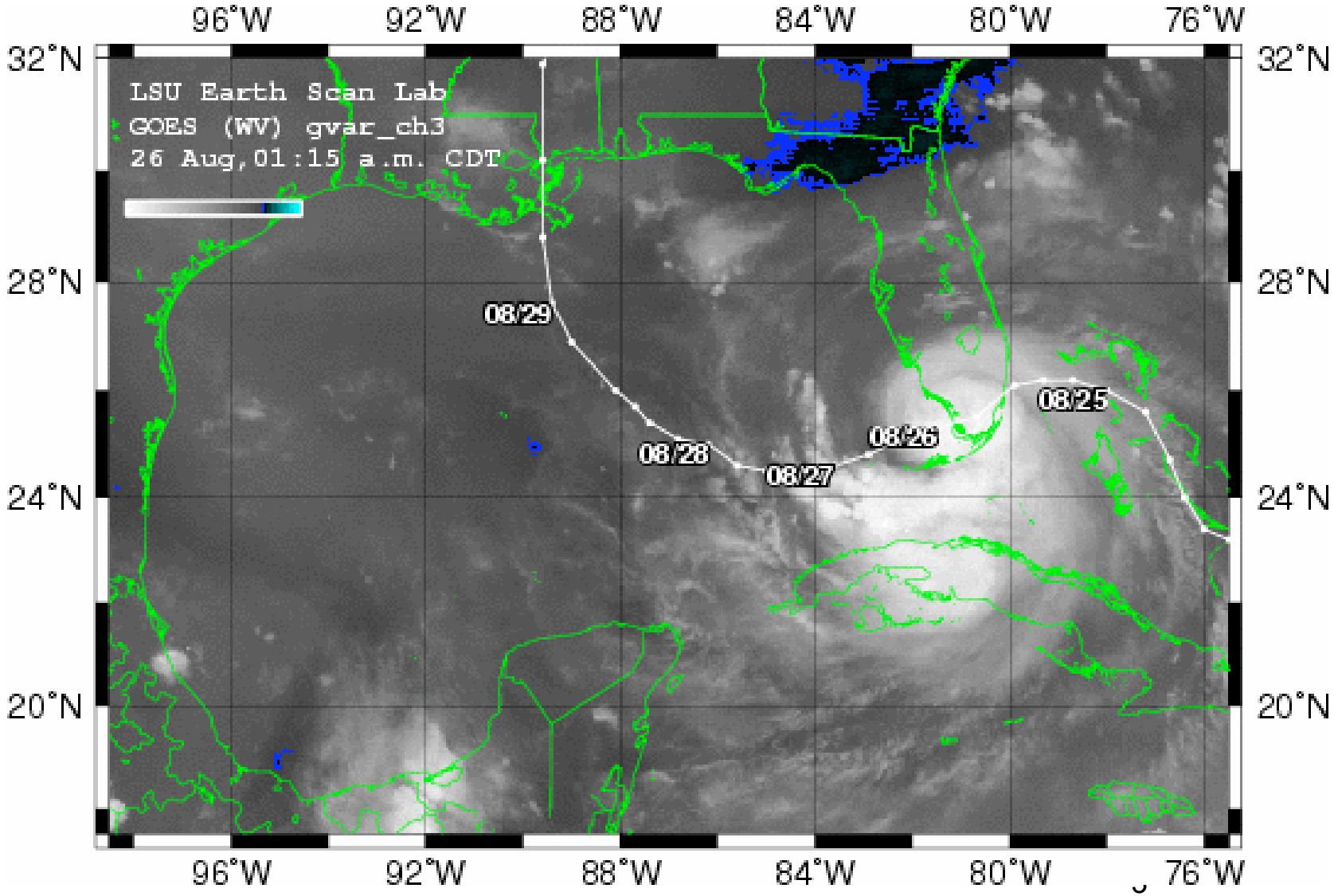
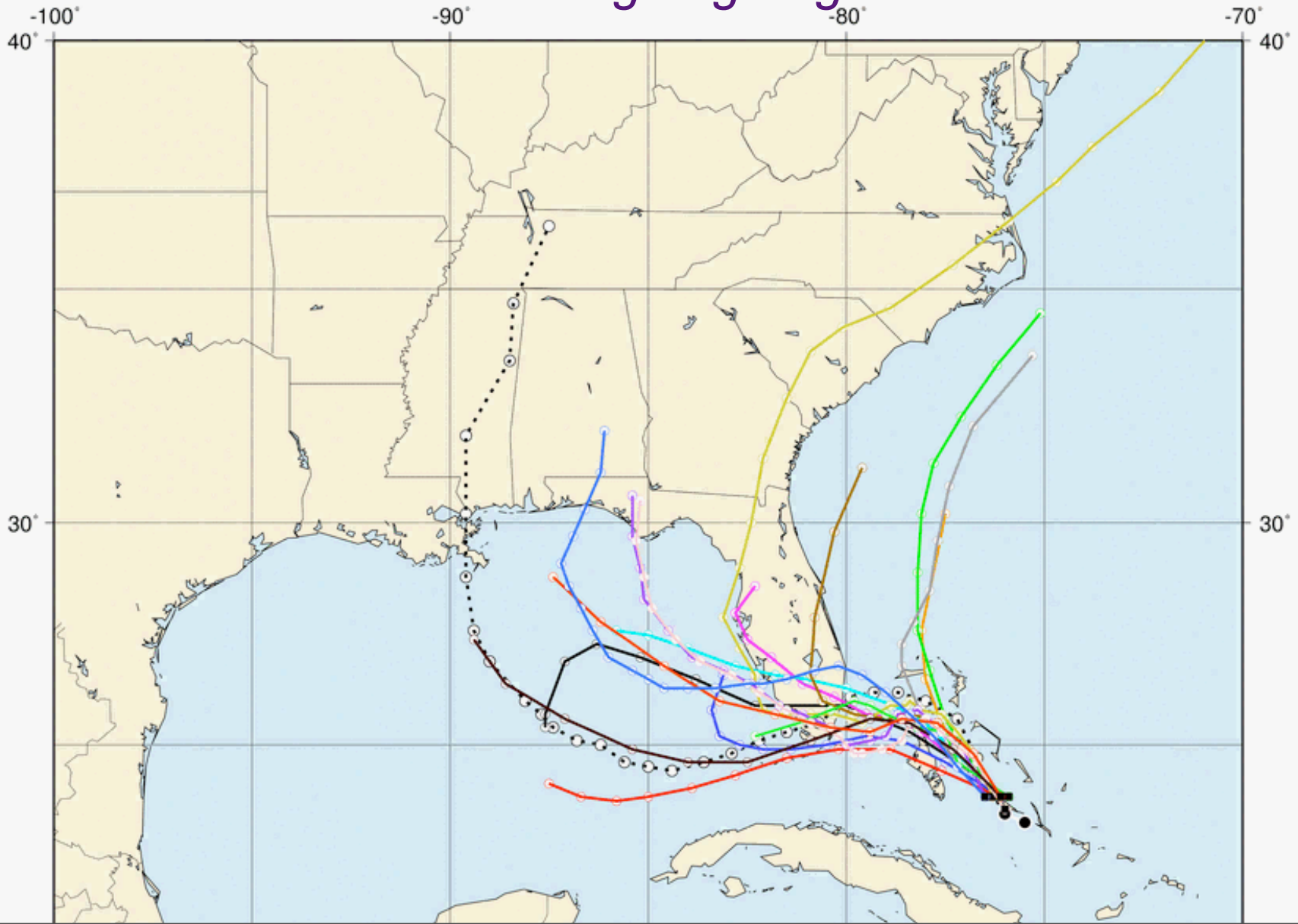


Predicting the Path

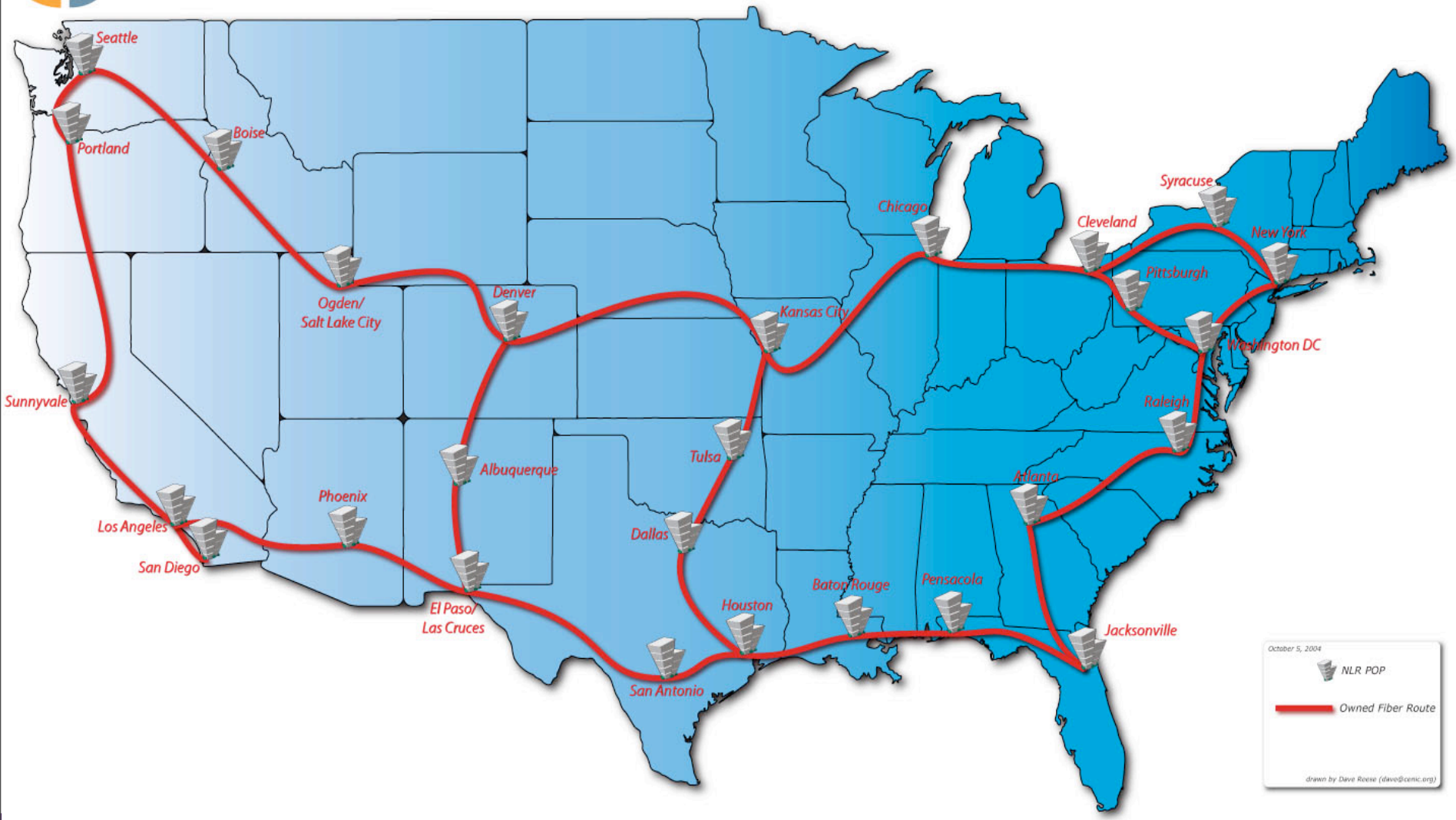
Where is it going to go?



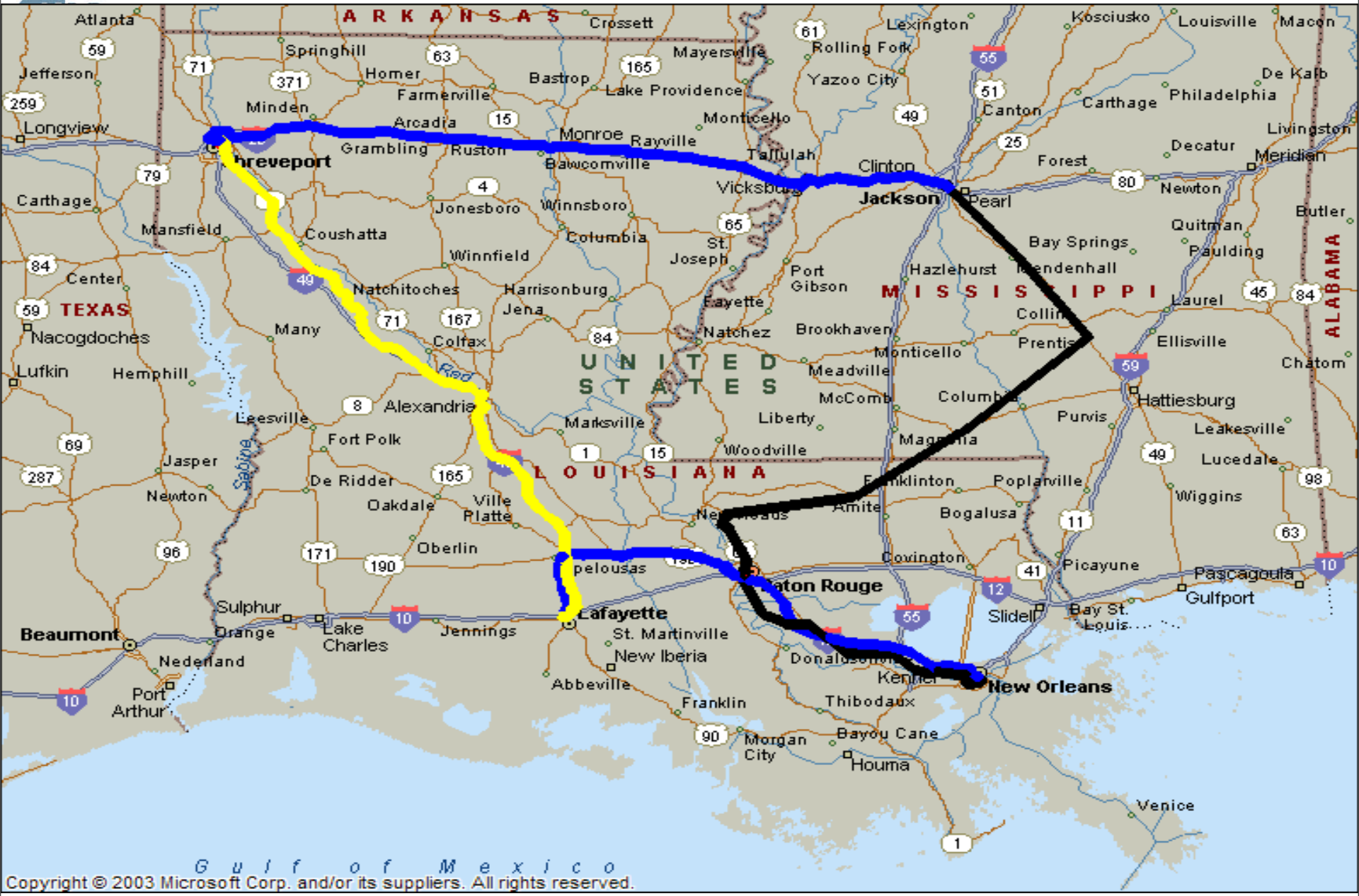
Optical Networks

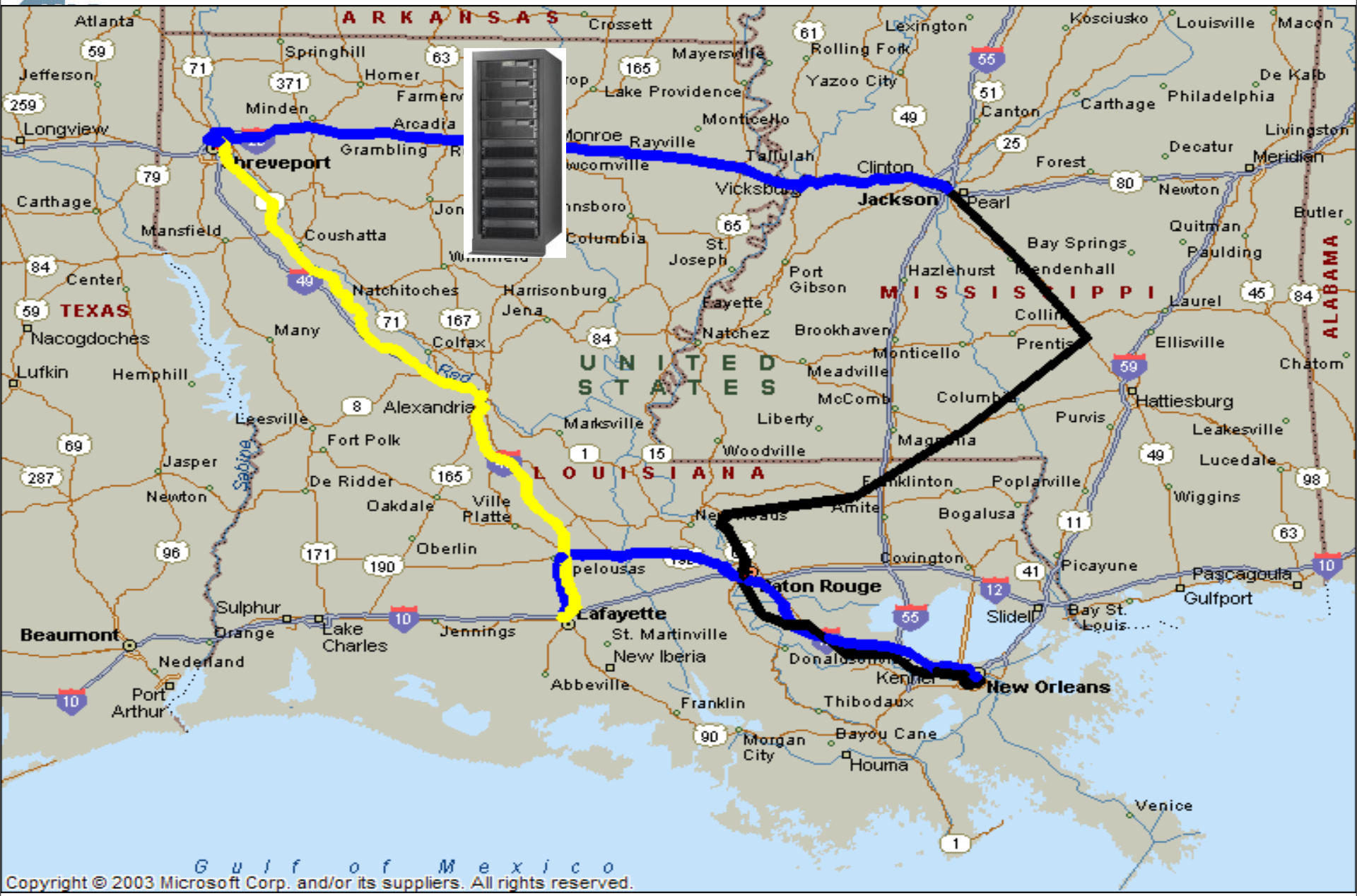
- New technology for decade. 1000x faster than typical regional networks: Louisiana LONI network
  - $40M state investment
  - Vision 20/20: $25M annual IT investment at 5 campuses
  - Dramatic effect on collaborations, funding across state
    - Example: HD video for education: requires 1.5 Gbit!
- National Lambda Rail
  - $100M USA Optical Network, backbone for next gen. research
  - Locally funded!! No Federal $$
- Other countries: $100'sM
  - Canada, Poland, Holland, Czech, etc; linked!
- Southern US states investing to be competitive for industry
  - Economic development, IT investment, Research linked

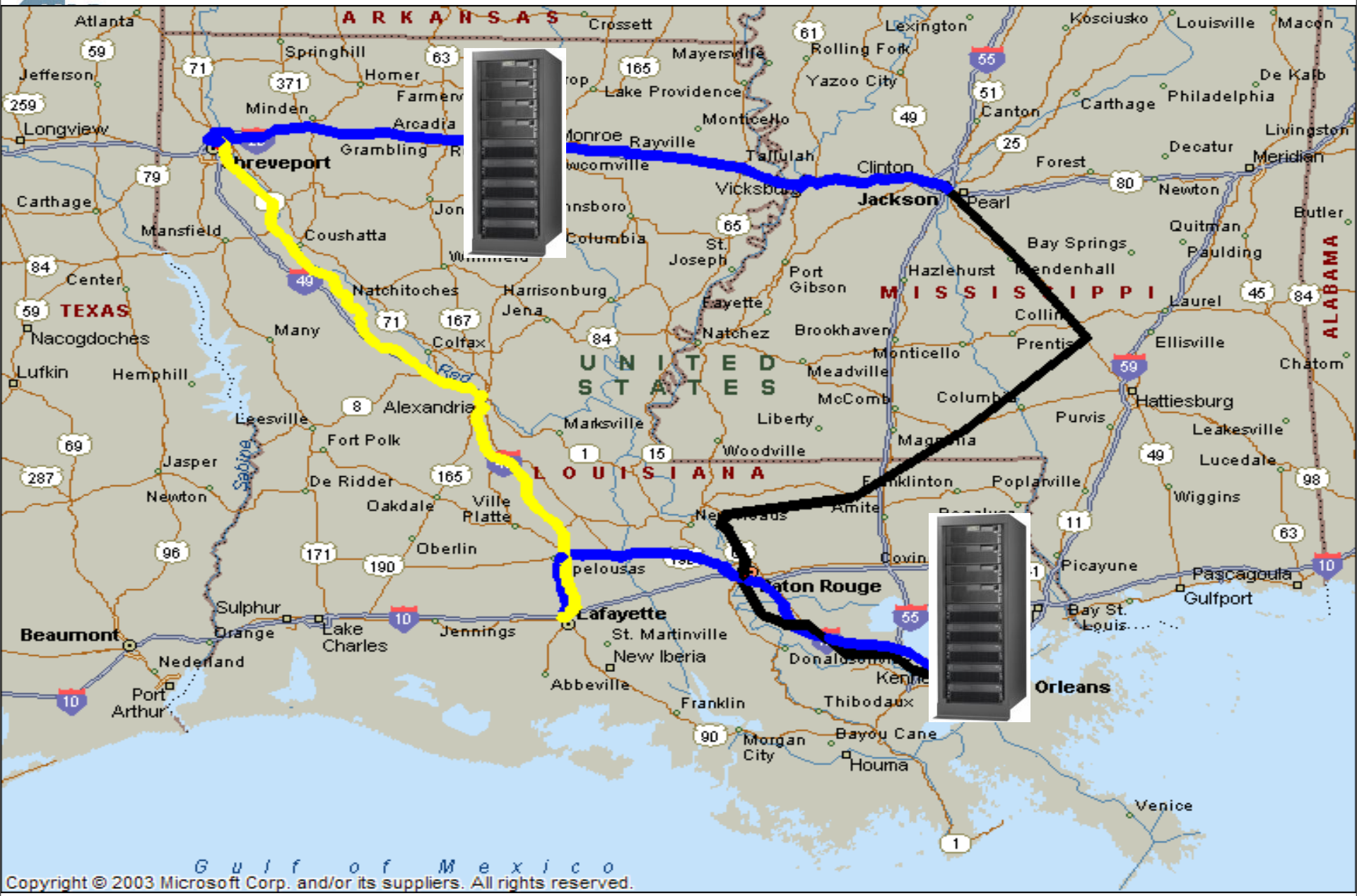
National LambdaRail Architecture

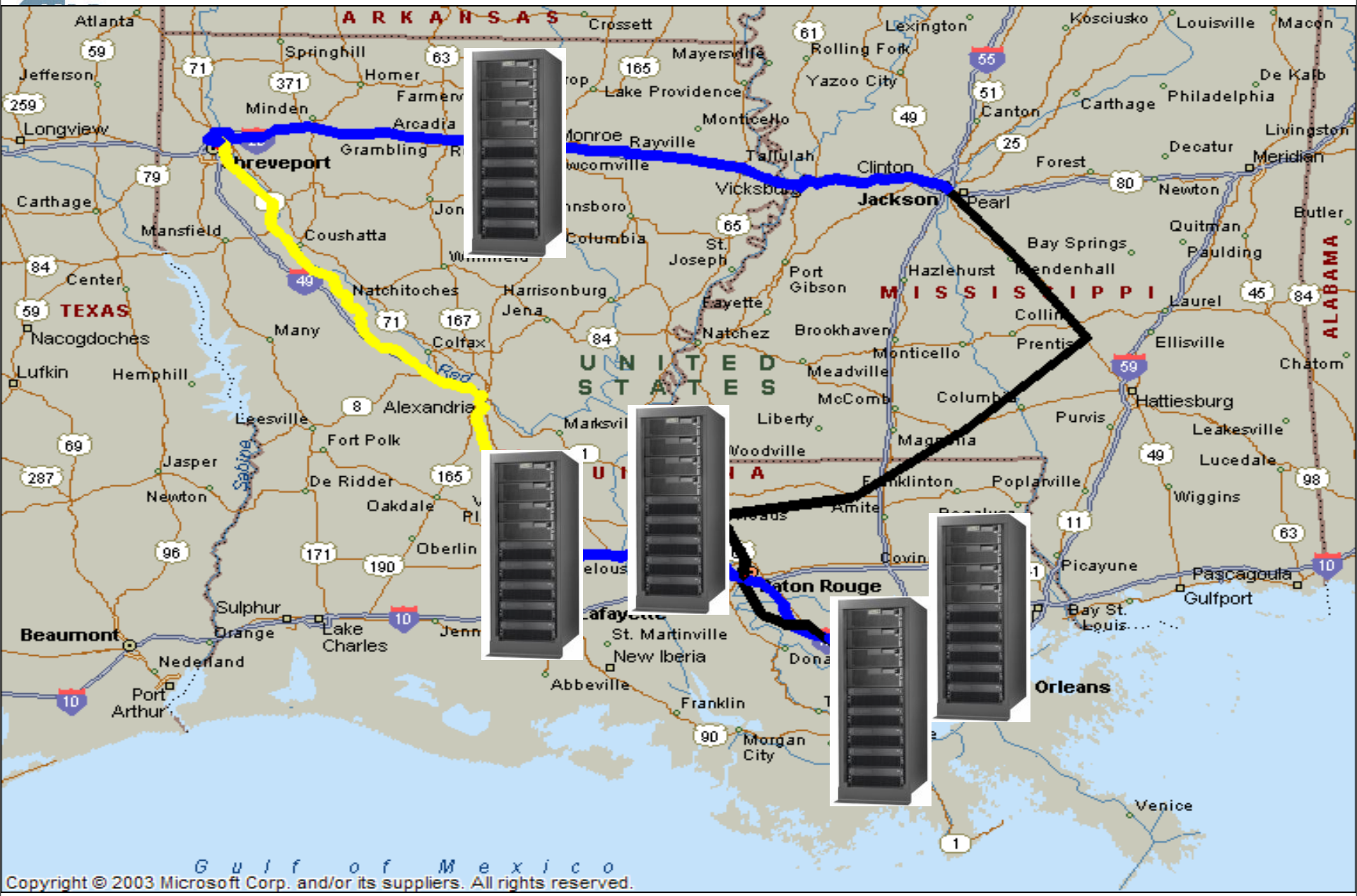


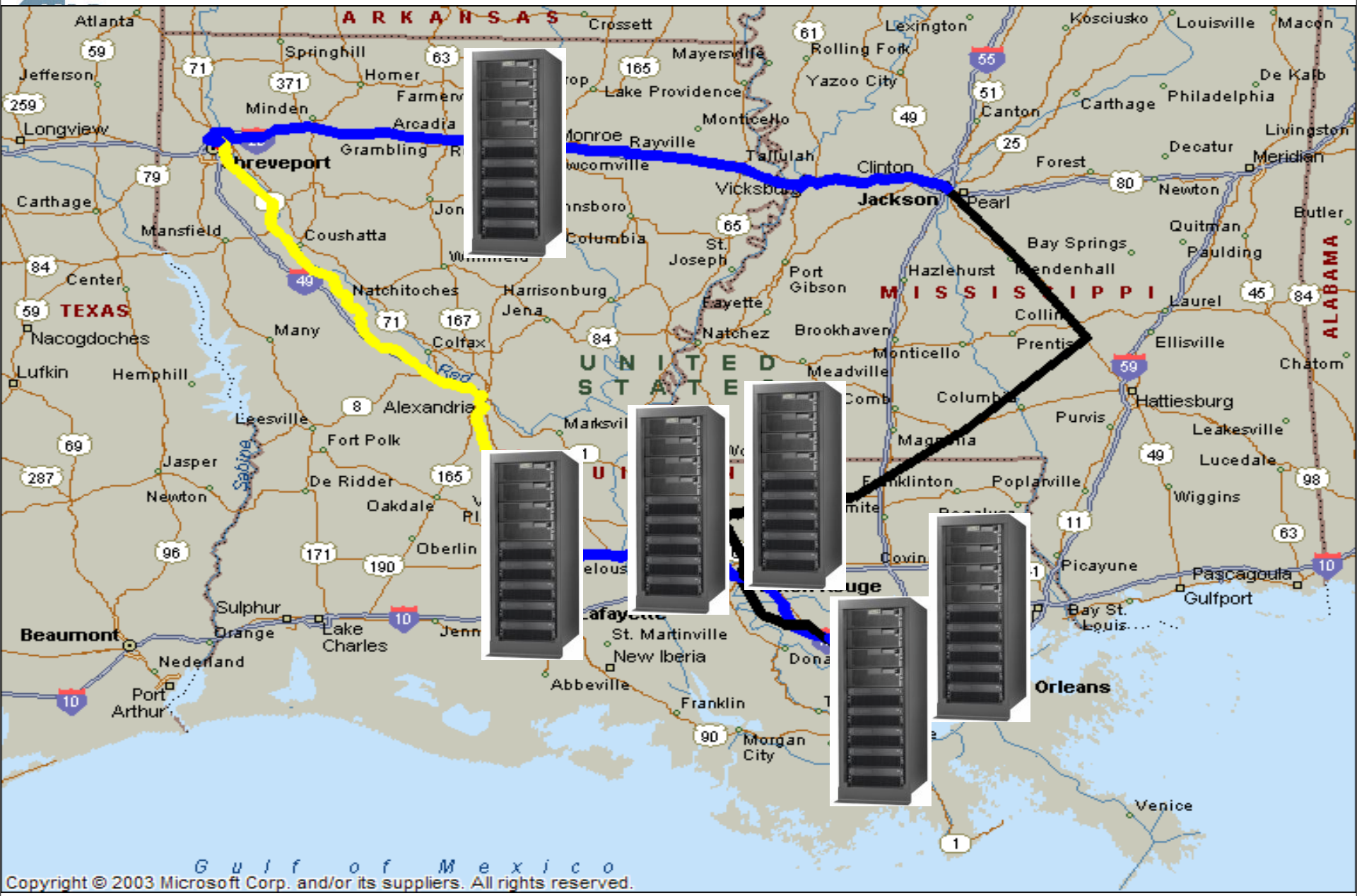
For more information regarding NLR see http://www.nlr.net or contact info@nlr.net

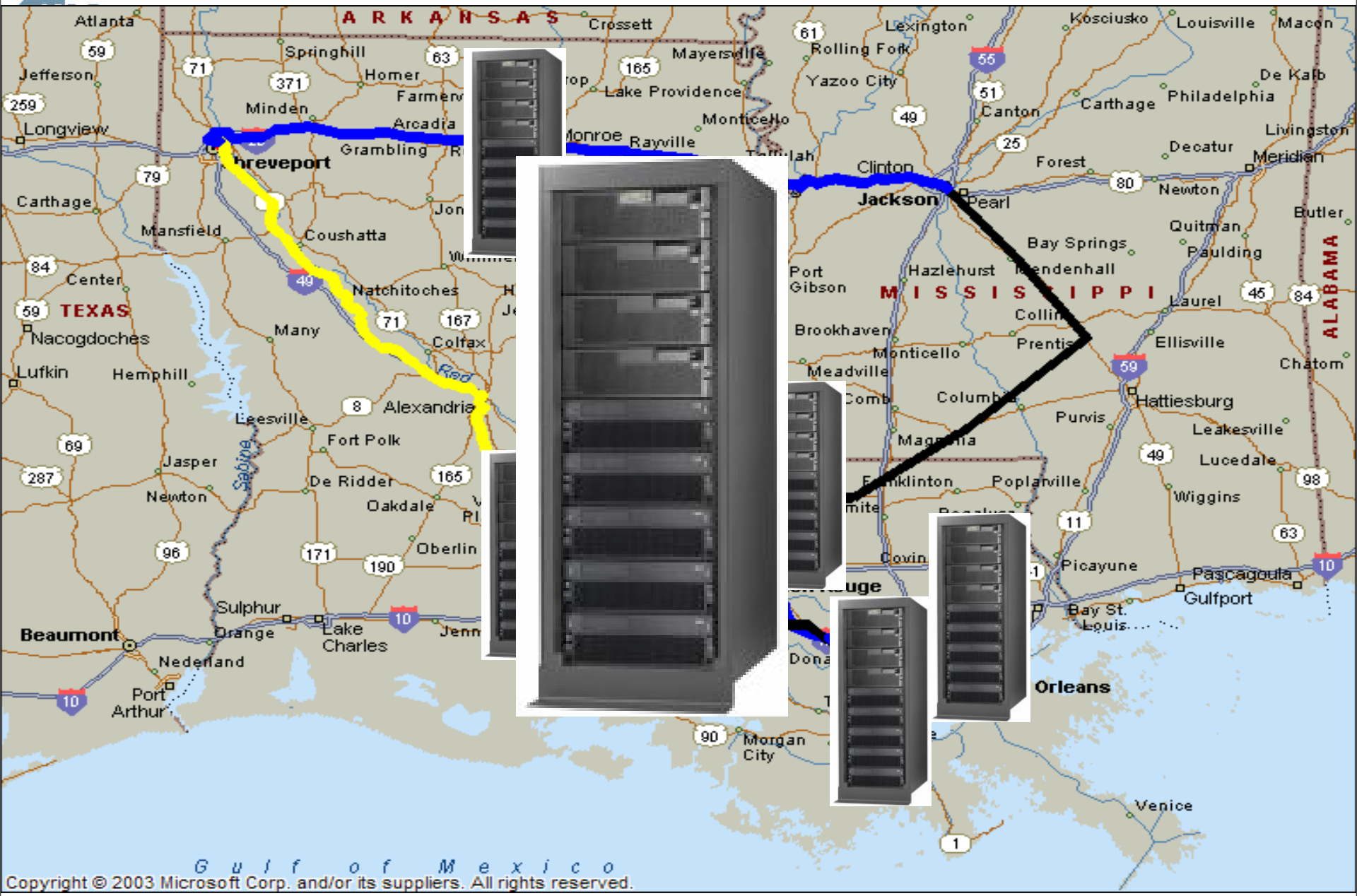




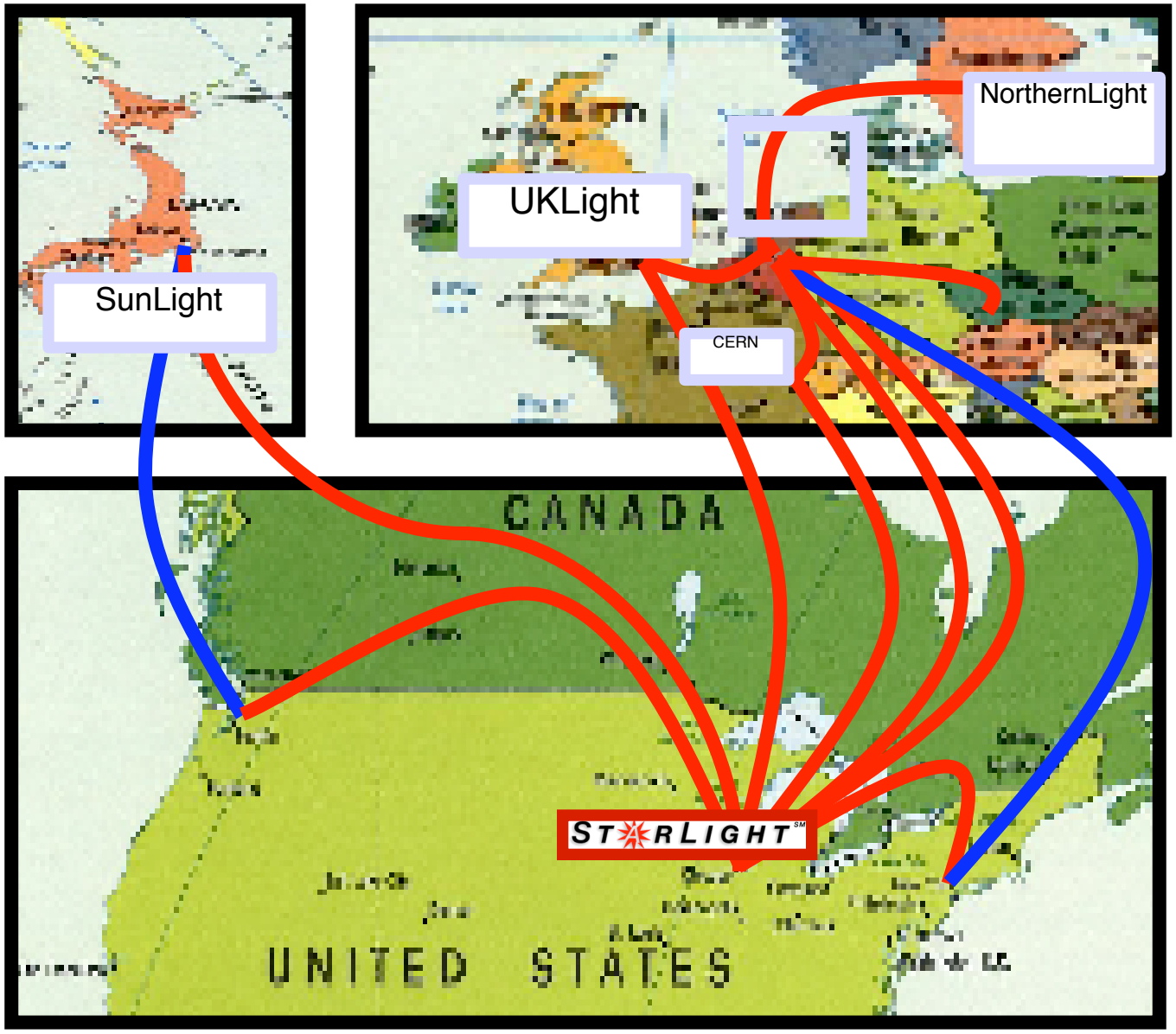








2004 International Lambdas



European lambdas to US
–10Gb Amsterdam—Chicago
–10Gb London—Chicago
–3Gb CERN — Chicago

Canadian lambdas to US
–10Gb Chicago-Canada-NYC
–10Gb Chicago-Canada-Seattle

US lambda to Europe
–7Gb Chicago—Amsterdam

US/Japan lambda
–10Gb Chicago—Tokyo

European lambdas
–10Gb Amsterdam—CERN
–2.5Gb Prague—Amsterdam
–2.5Gb Stockholm—Amsterdam
–10Gb London—Amsterdam

IEEAF lambdas (blue)
–10Gb NYC—Amsterdam
–10Gb Seattle—Tokyo

Source: DeFanti

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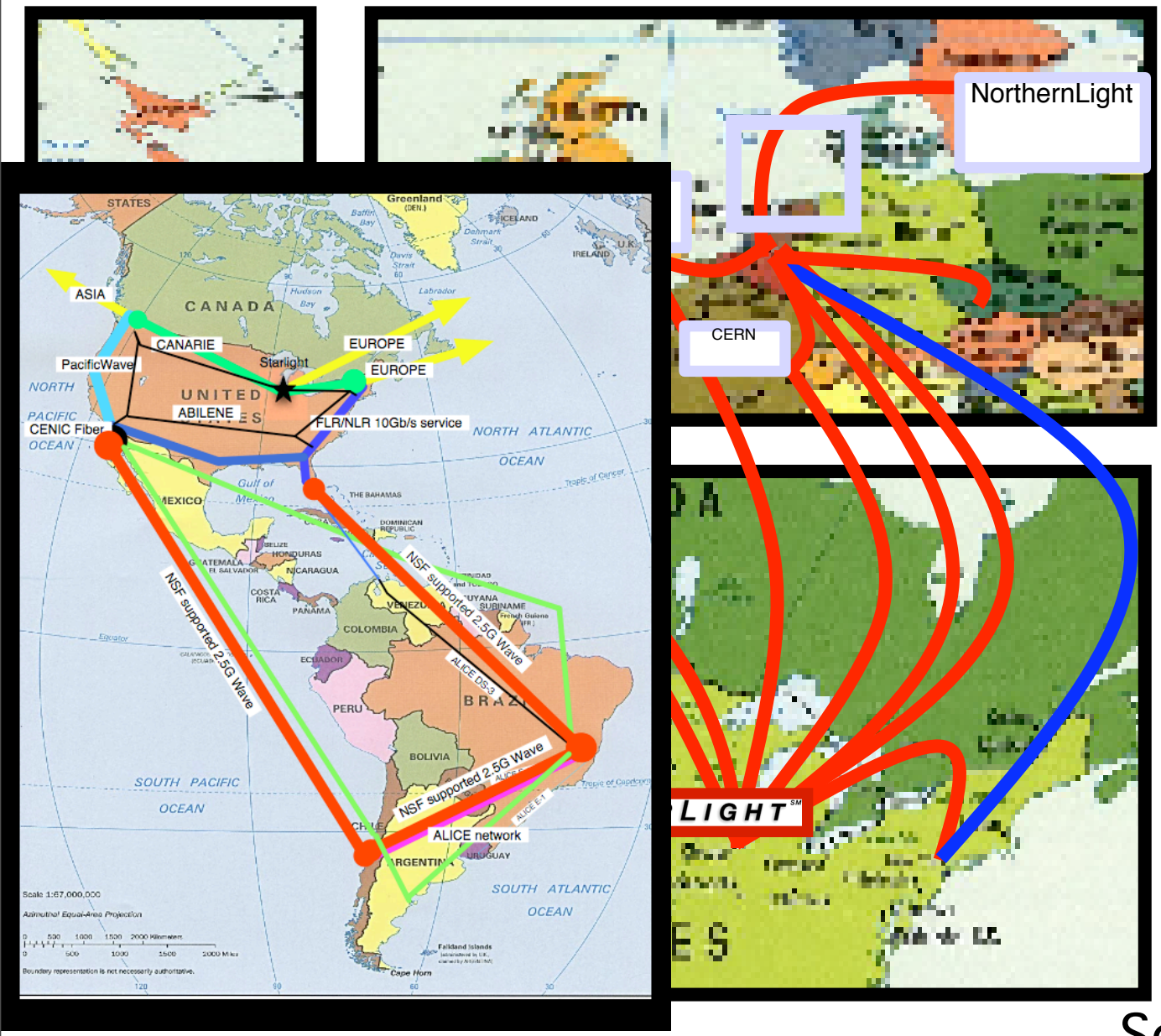

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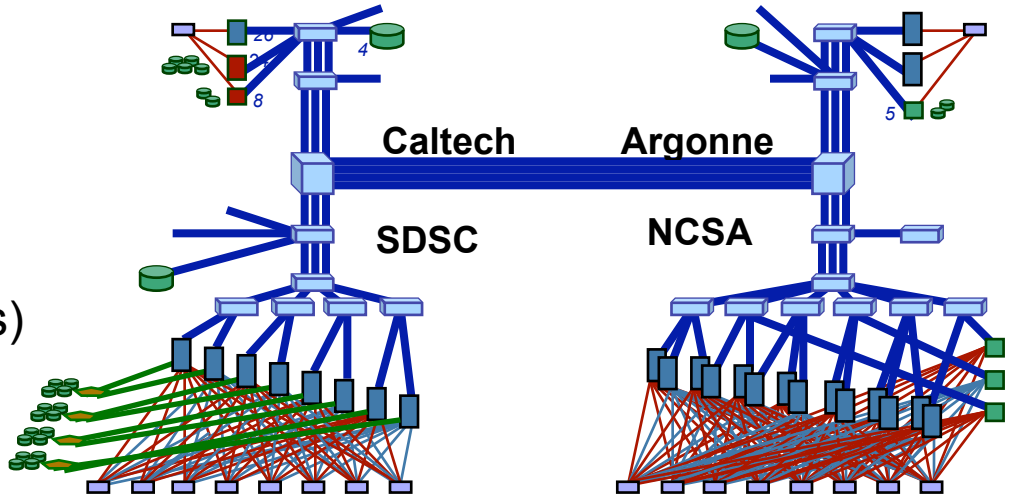
Grids: Bringing all Together

- Computational Devices Scattered Across the World
  - Compute servers (double 18 months)
  - Networks (double each 9 months)
  - Sensors (exploding field)
- Experiments, feedback
  - DDDAS scenarios
- How to take advantage of this for science, engineering, business, art?
  - Harness multiple sites and devices
  - Deploy cyberinfrastructure: Globus, Unicore, many others
  - Increasingly application/community specific



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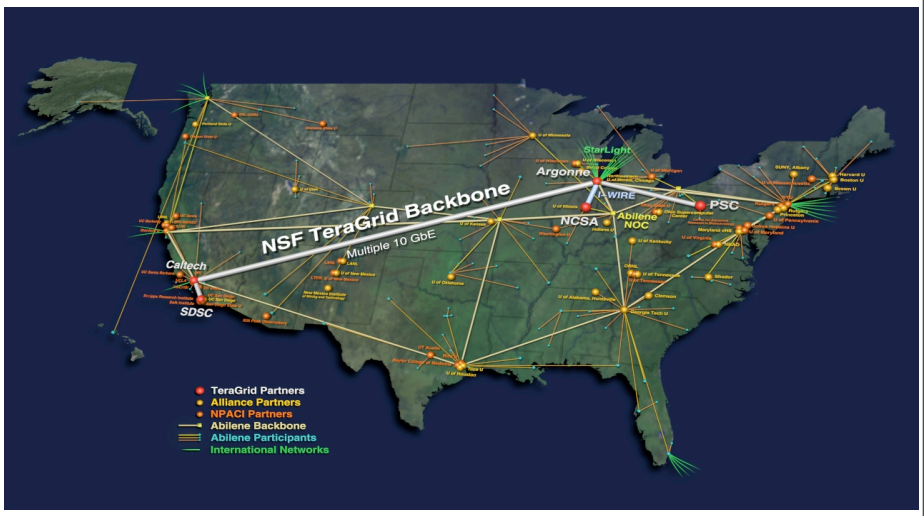

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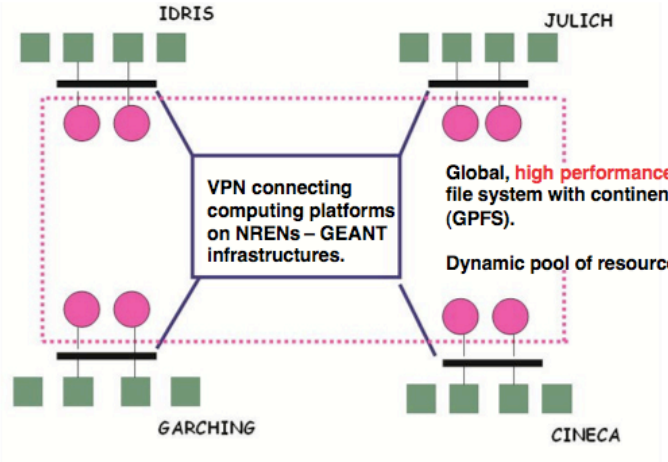
The DEISA super-cluster (phase 1)

Distributed European Infrastructure for Supercomputing Applications



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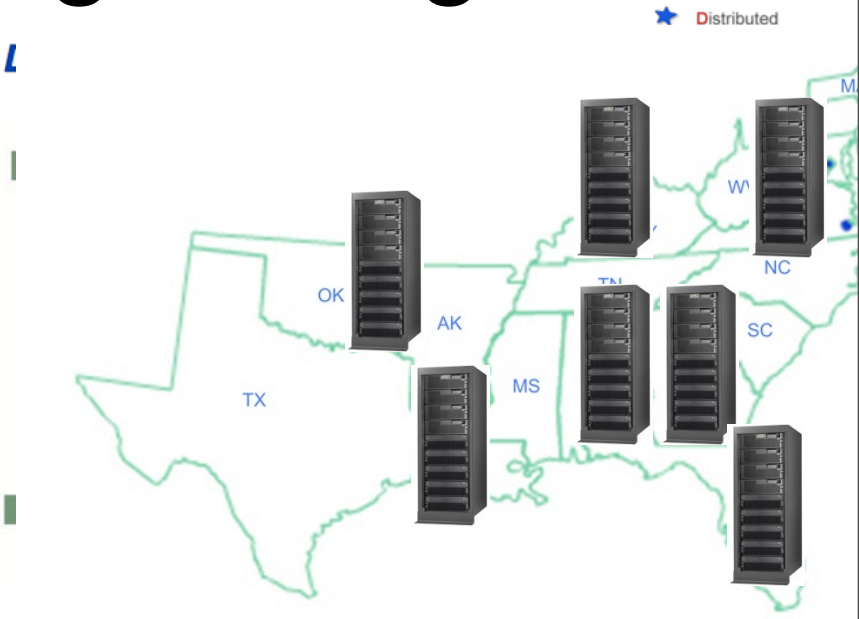
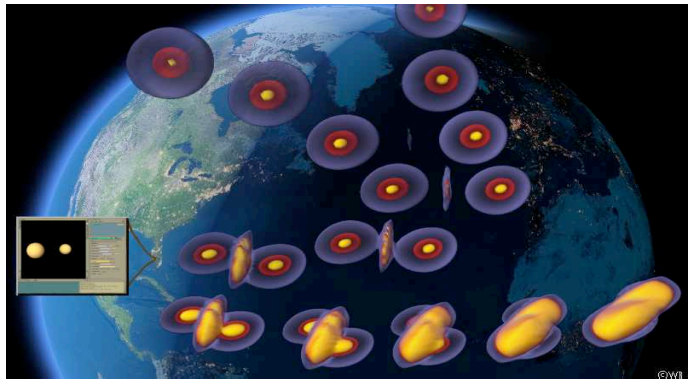
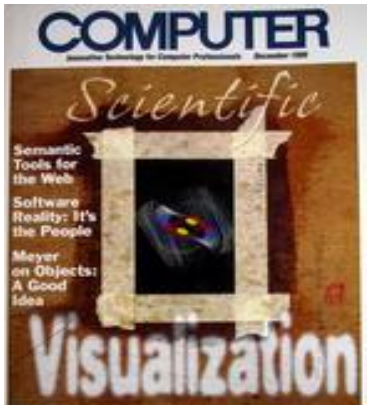




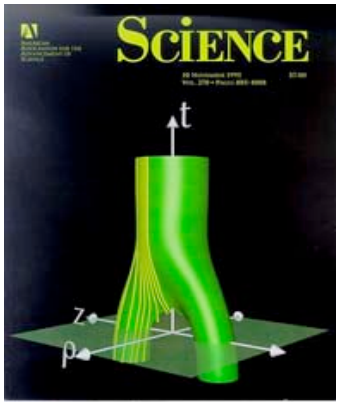
Gordon Bell Prize, 2001

Collaborations for Complex Problems



NASA Neutron Star Grand Challenge

- 5 US Institutions
- Attack colliding neutron star problem



NSF Black Hole Grand Challenge

- 8 US Institutions
- 5 years
- Attack colliding black hole problem

EU Astrophysics Network

- 10 EU Institutions
- 3 years
- Continue these problems

Examples of Future of Science & Engineering

- Require large scale data, simulations, beyond reach of any machine
- Require large geo-distributed cross-disciplinary collaborations
- These communities unified by common tools, infrastructure

Recommendations from PITAC

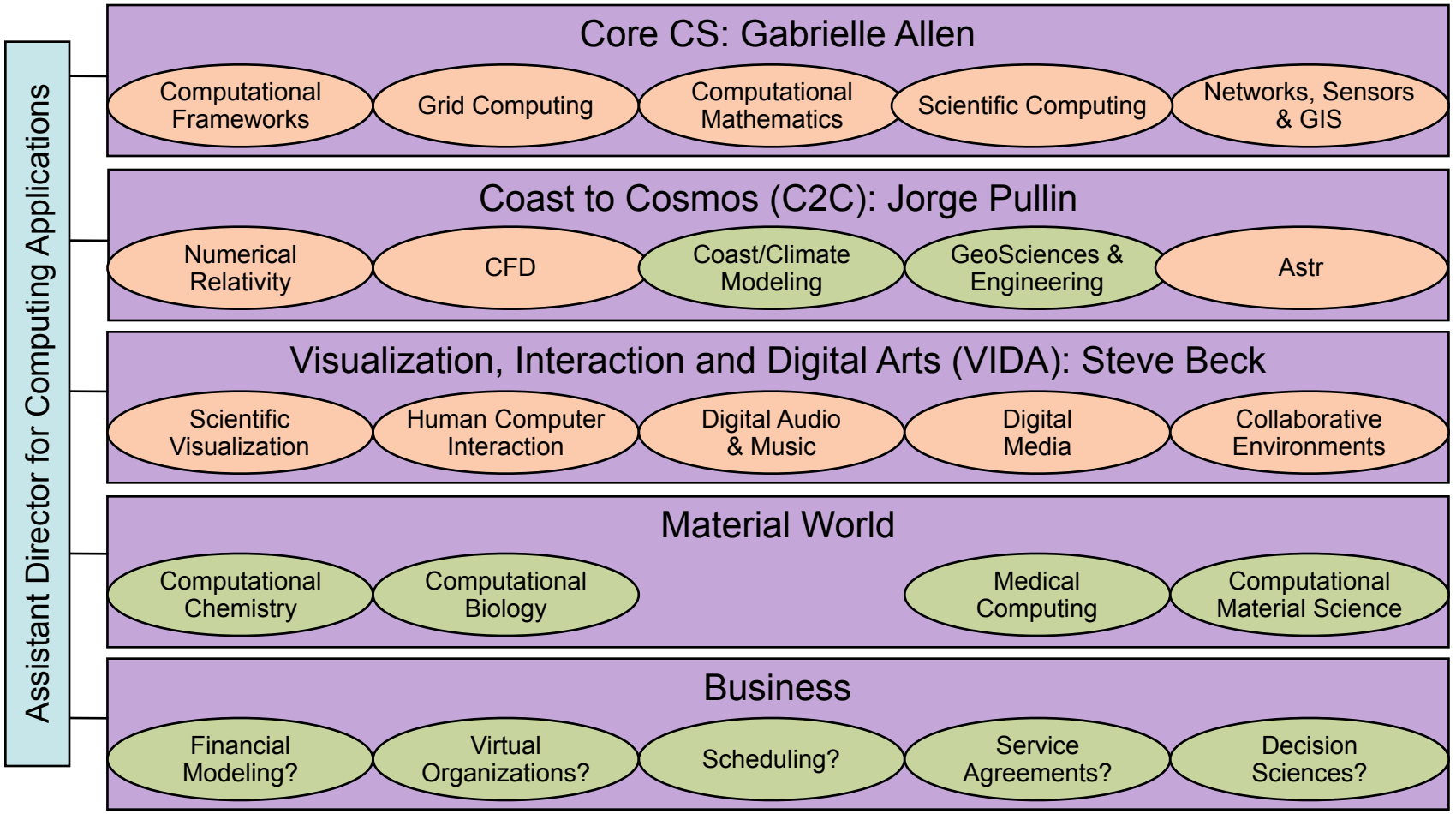
- Universities must significantly change organizational structures: multidisciplinary & collaborative research to remain competitive in global science.
- Federal investments must rebalance to:
  - *Software*: create reliable, easy to use, scalable software that will enable scientists to focus on discovery: Software *Crisis*
  - *Hardware*: develop, prototype, evaluate new hardware architectures to deliver larger peak and sustained performance at the petaflop level for scientific apps
  - *Data*: focus on data-intensive solutions to address the coming data explosion with advances in sensors and sensor networks

Source: President's Information Technology Advisory Committee

www.nitrd.gov/pitac

Collaborations for Complex Problems

Building a Center on through Collaboration



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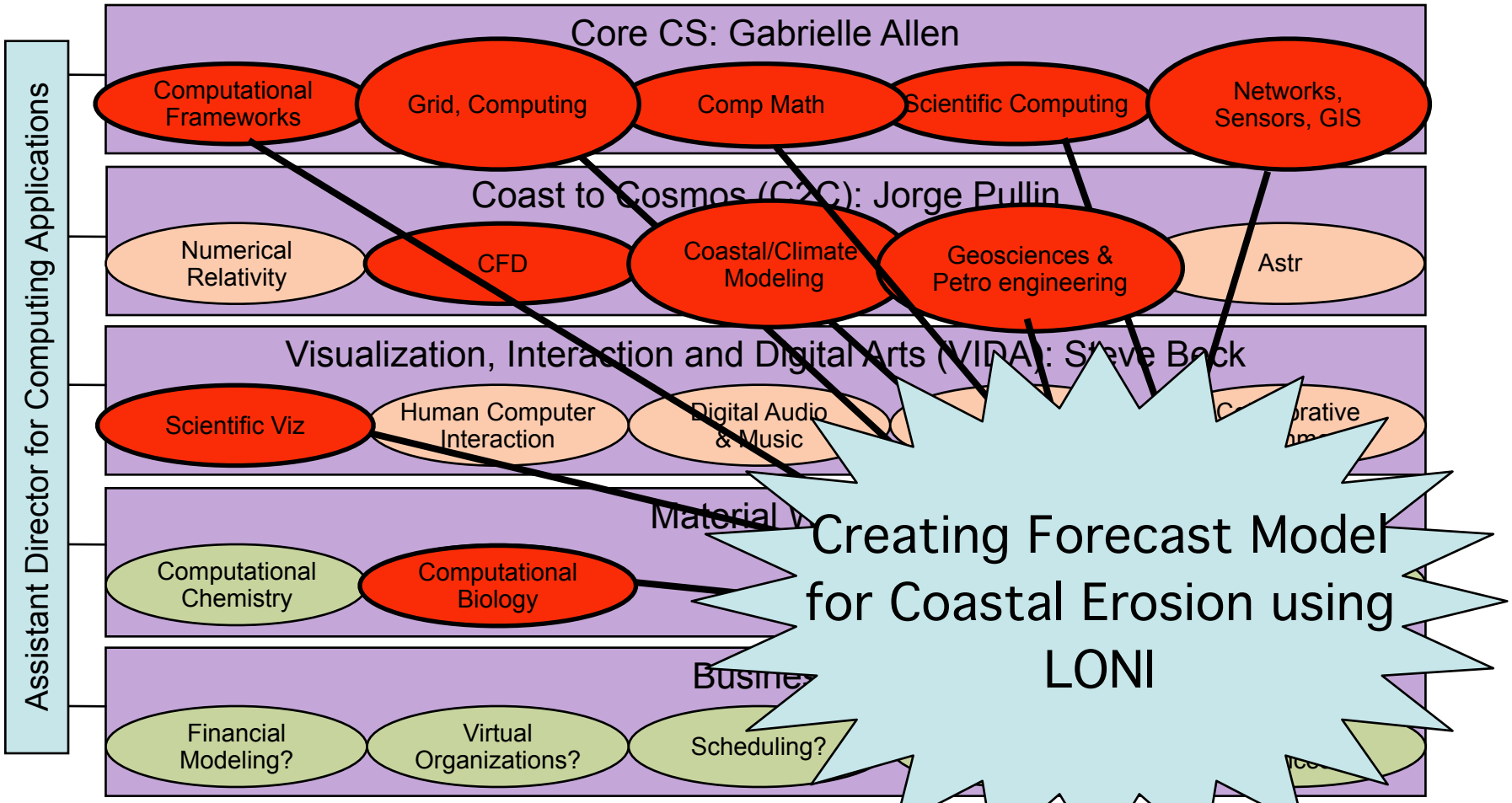

Storm Surges

ADCIRC: Unstructured Grid Shallow Water Model

- Storm surges: the worst part
  - ~ 25 ft for Katrina, kill far more people than winds
- ADCIRC: Joannes Westerink, Rick Luettich, Randy Kolar, Clint Dawson, et al
- Input 2D Unstructured Mesh, wind, pressure
  - 314K nodes, 85% near LA Coast
  - 50km resolution in deep ocean, 100m resolution
  - Smooth variation for 2nd order accuracy
- Time step = 2 sec: implies 43K steps/day
  - 6 seconds/time step implies < 1 hour per simulation-day on 128 processors
- Want: run dozens of simulations
  - Vary inputs, paths, strength

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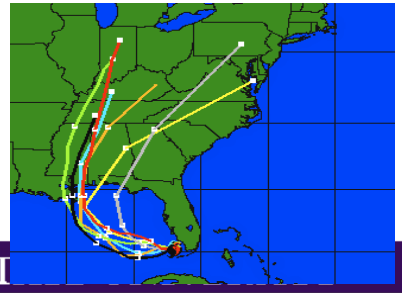
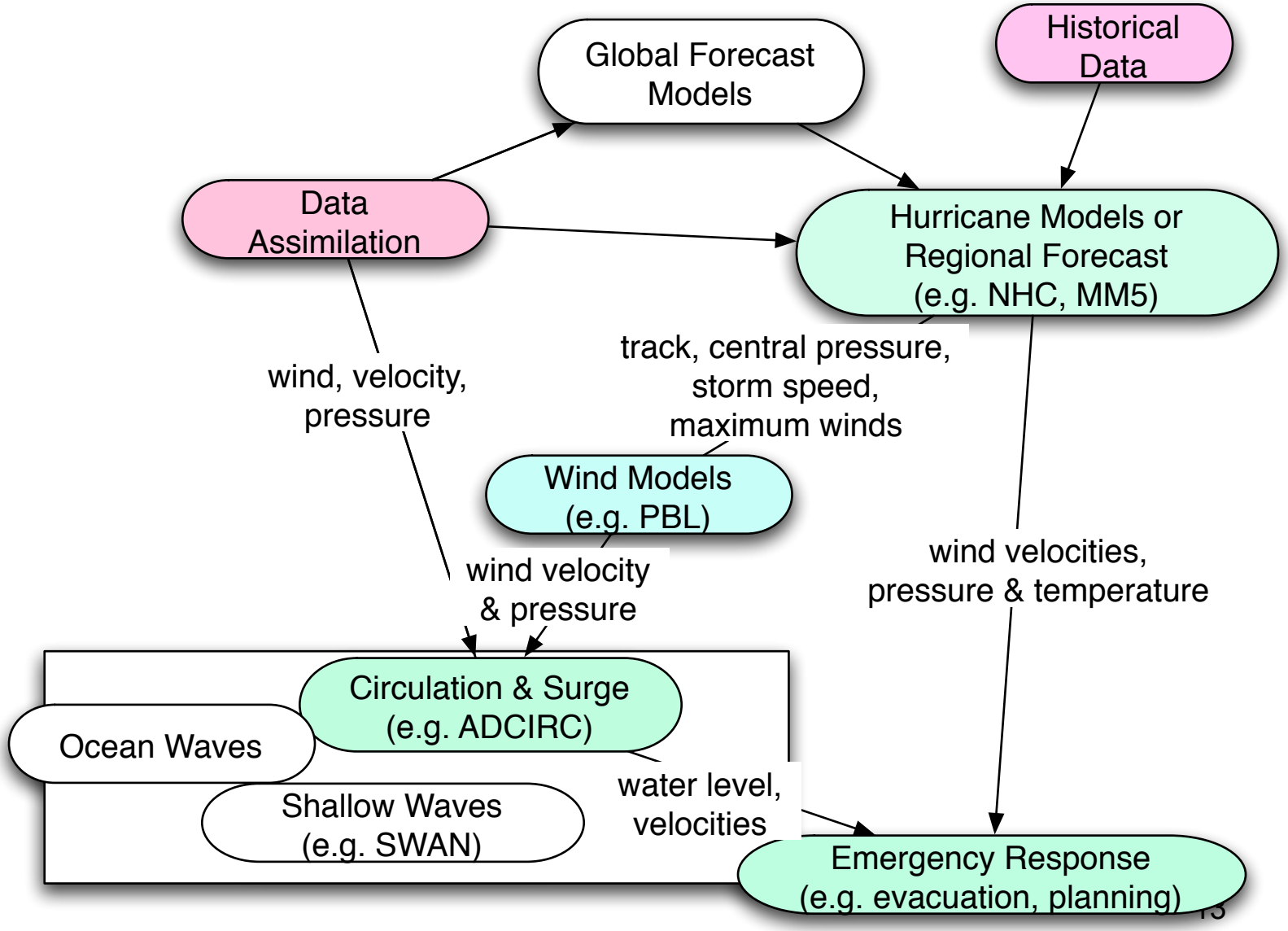
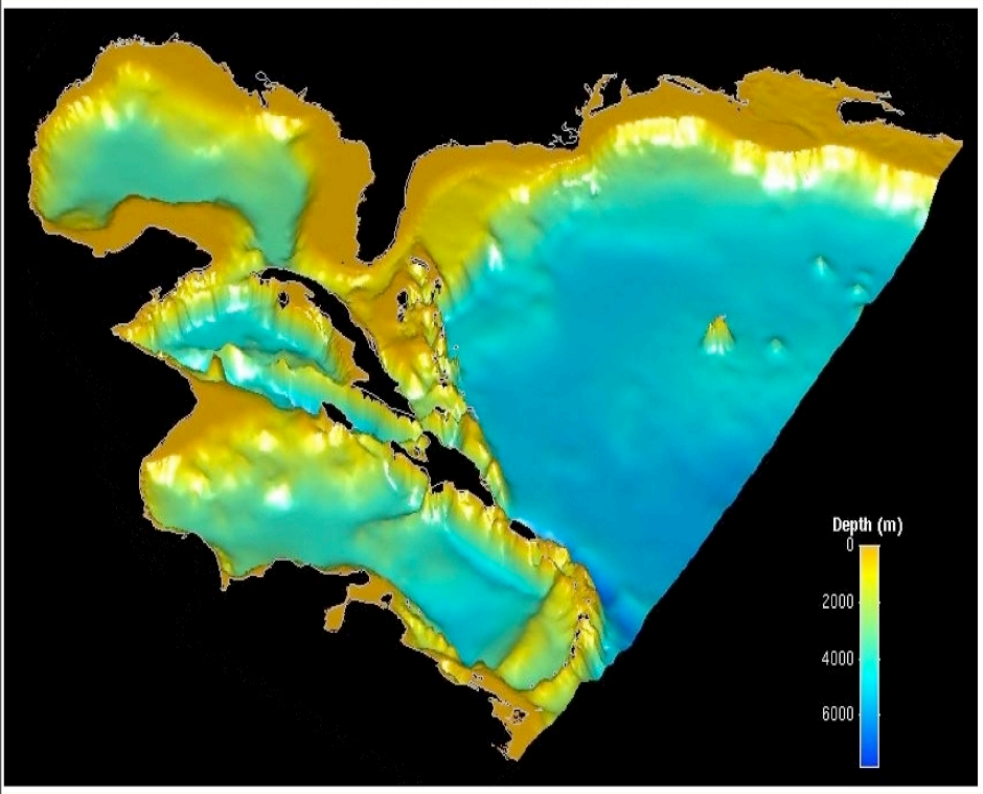


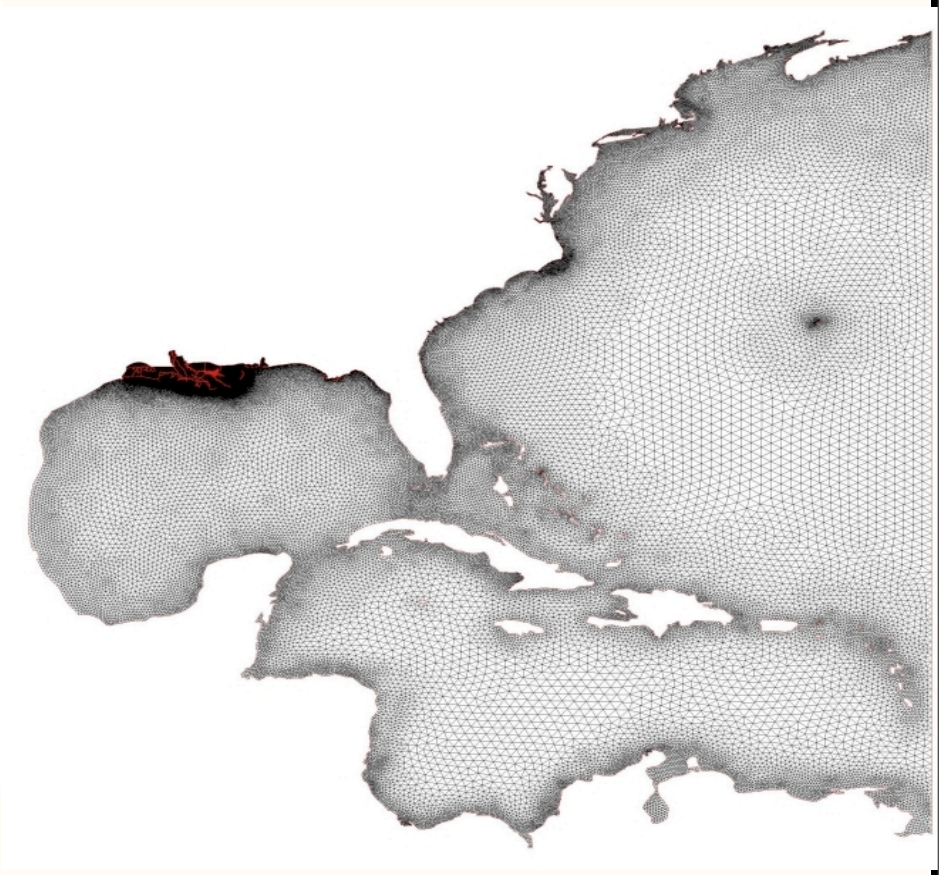
Model-Model-Data Coupling



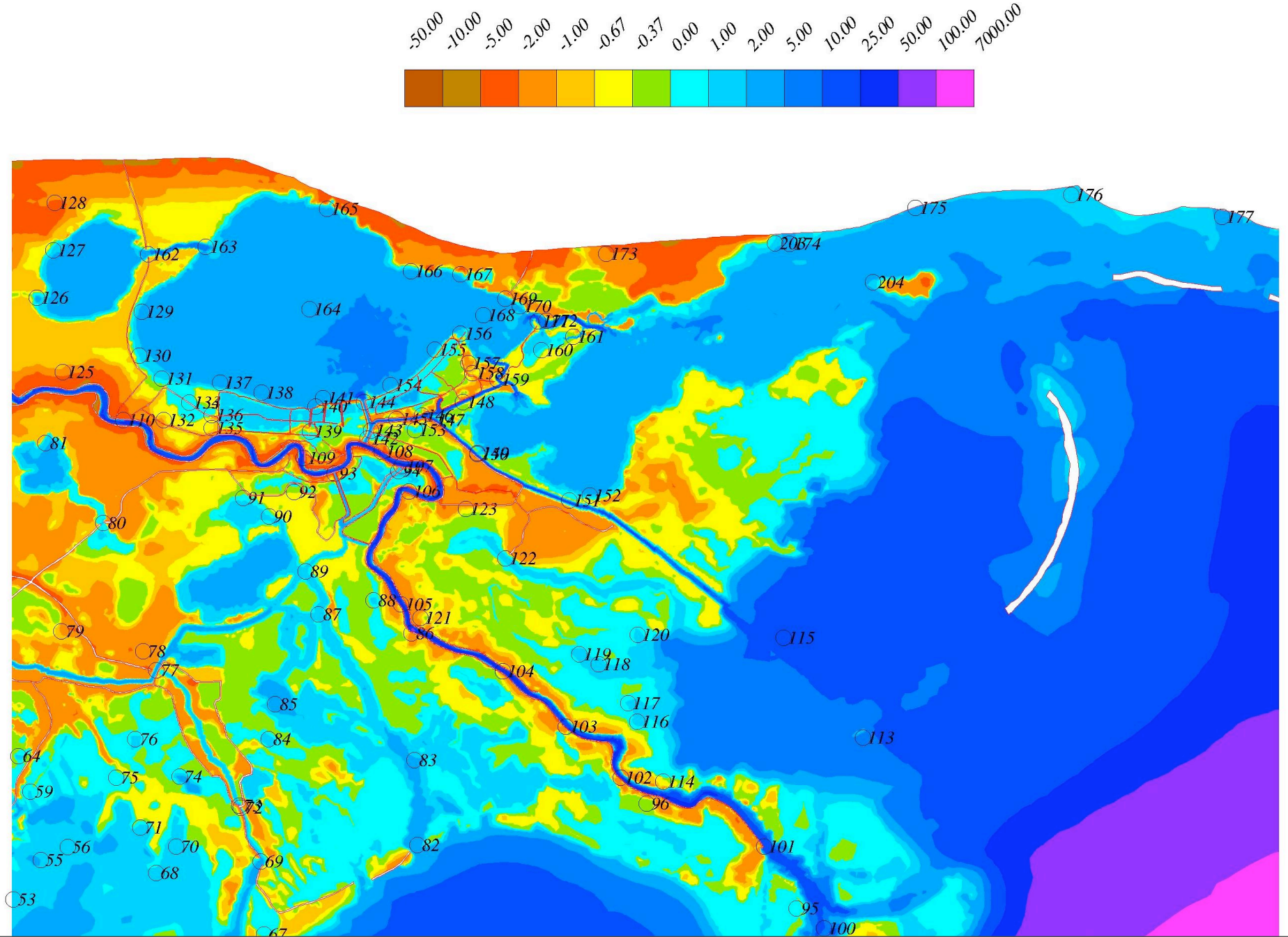
ADCIRC : Computational Mesh (used for Hurr. Katrina)
Source: http://www.nd.edu/~adcirc/



Computational domain with bathymetry (m)



Unstructured grid of the entire domain.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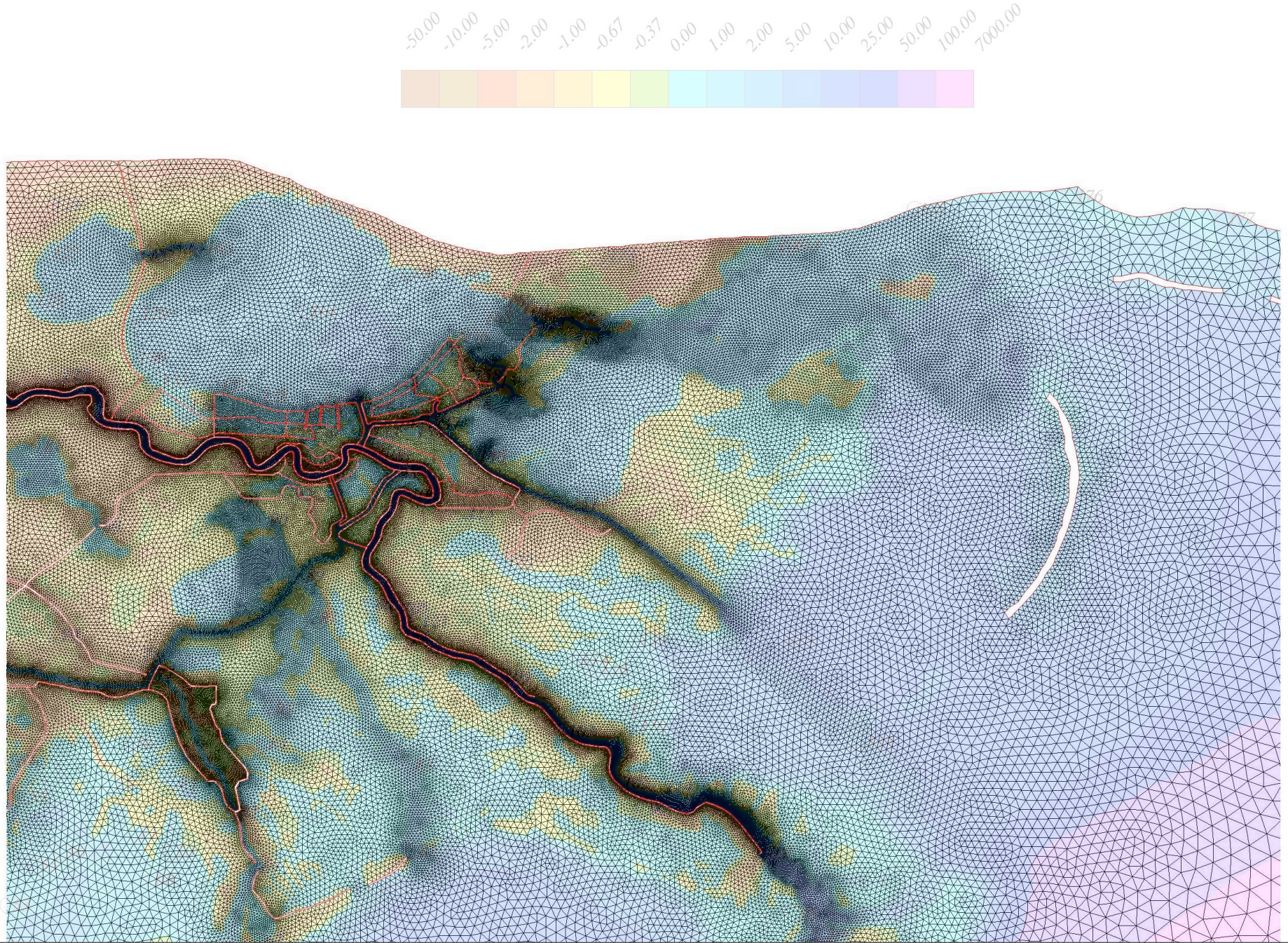
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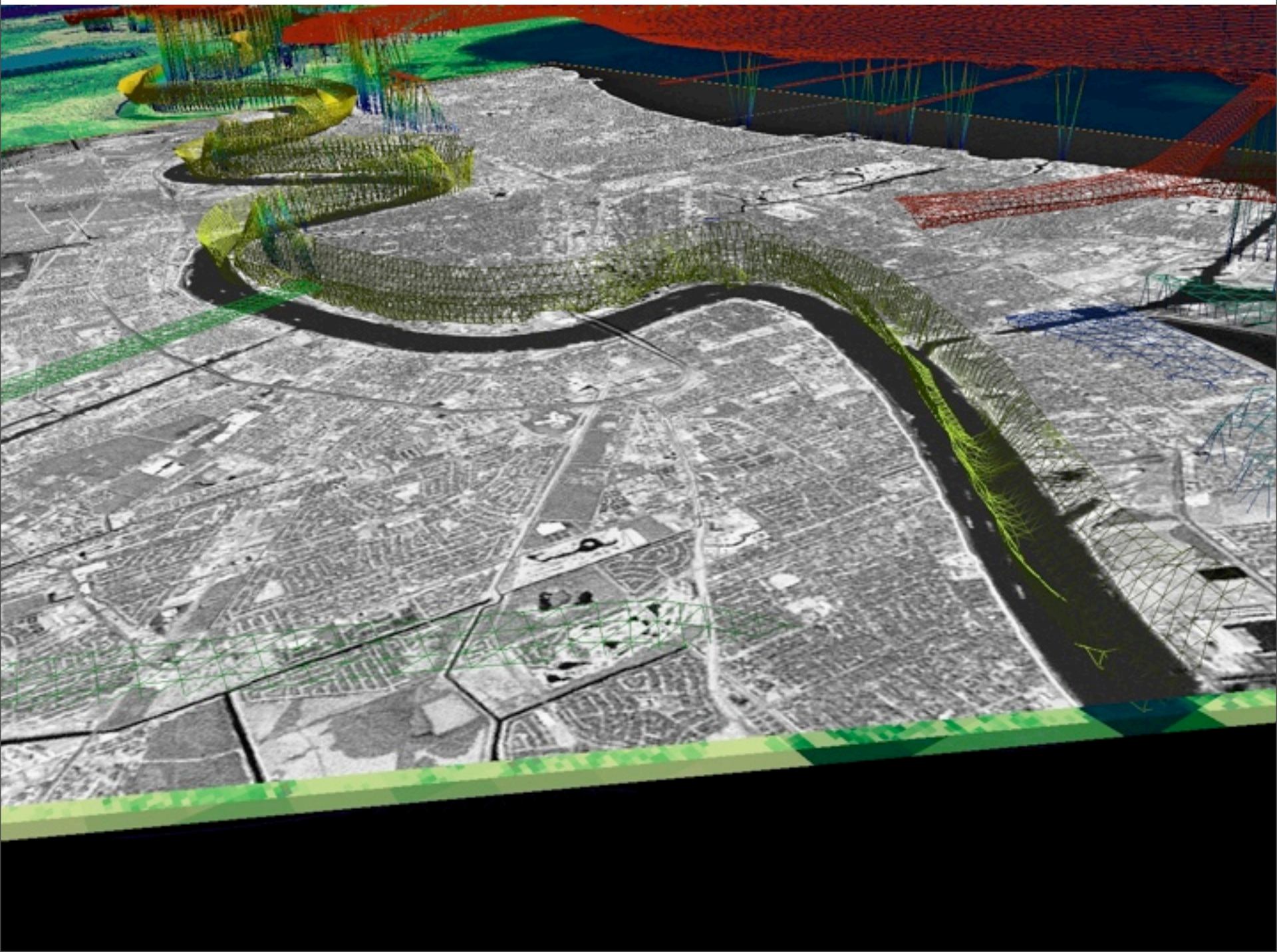
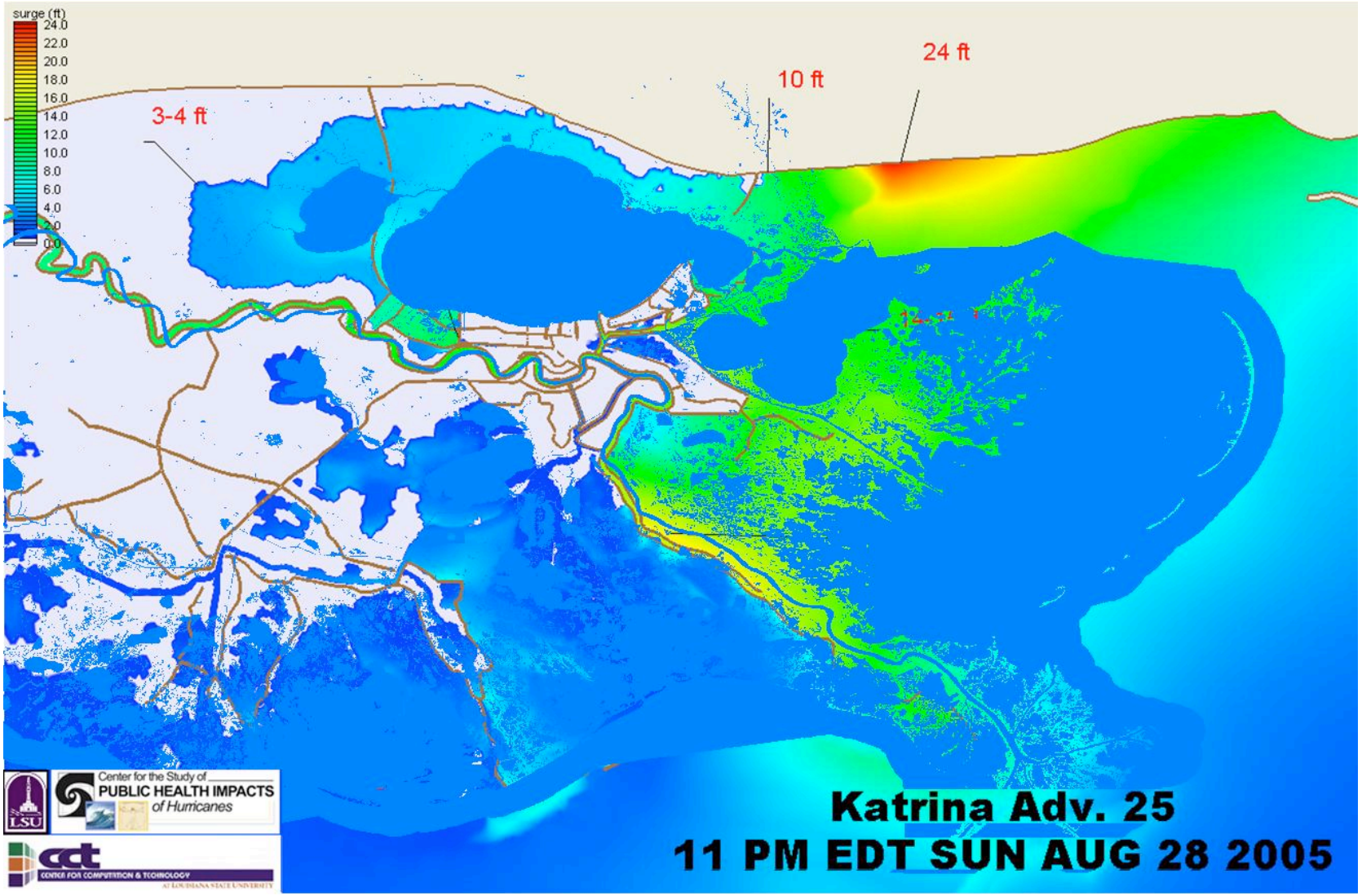


Emergency Forecast



New Orleans

New Orleans

New Orleans

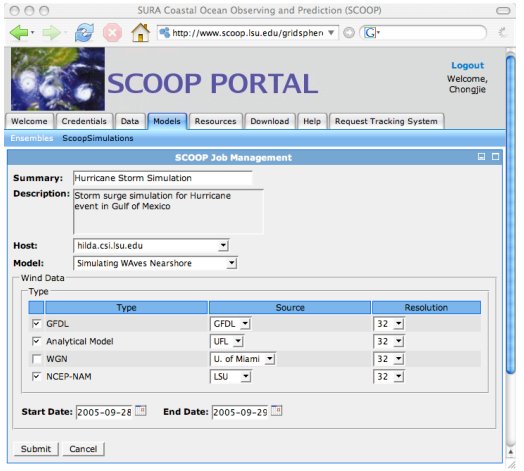
New Orleans

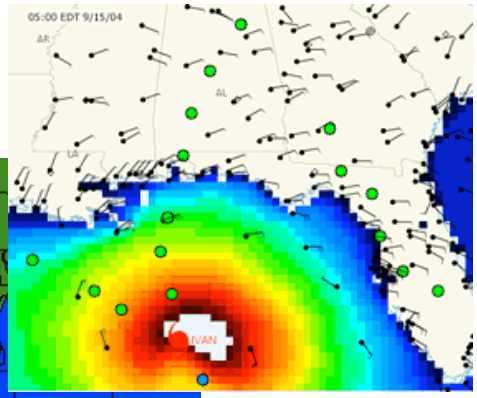
New Orleans

New Orleans

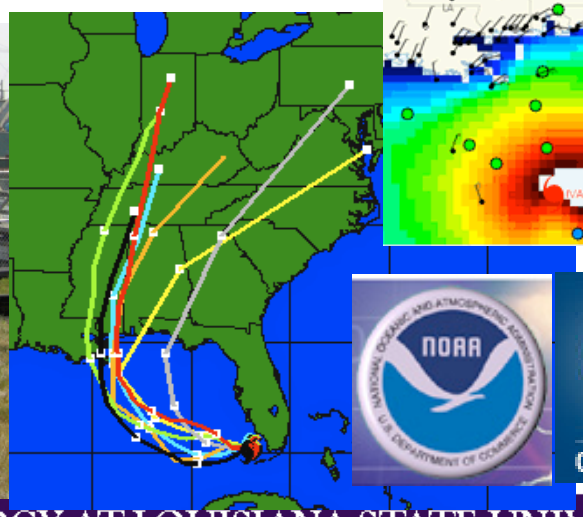
SURA Coastal Ocean Observing Program (SCOOP)

- Integrating data from regional observing systems for realtime coastal forecasts in SE
- Coastal modelers working closely with computer scientists to couple models, provide data solutions, deploy ensembles of models on the Grid, assemble realtime results with GIS technologies.





University of Alabama at Huntsville, University of Florida, GoMOOS, Louisiana State University, University of Miami, University of Maryland, University of North Carolina, Texas A&M, Virginia Inst of Marine Sciences



NOAA

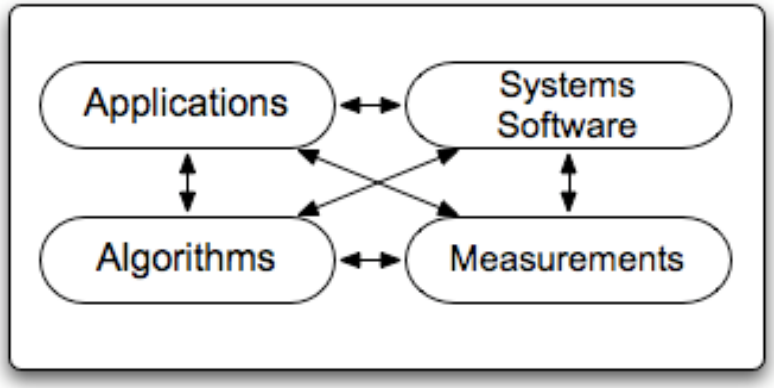
Office of Naval Research

DynaCode: DDDAS framework for coast and environmental modeling

- New capabilities:
  - dynamically invoke more accurate models and algorithms as hurricane approaches coast
  - choose appropriate computing resources for needed confidence levels
  - compare model results with observations to feedback into running simulations
  - realtime data assimilation
  - adaptive multi-scale simulations
  - dynamic component recomposition
  - simulation requirements can steer sensors and data input

Cyberinfrastructure

High End Computing



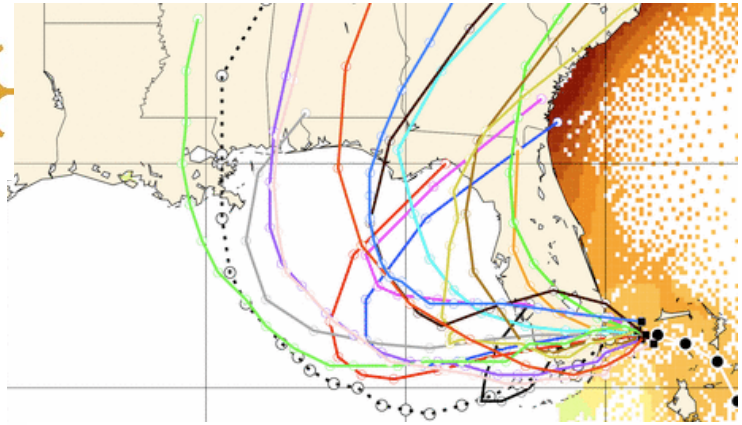
Computer Science

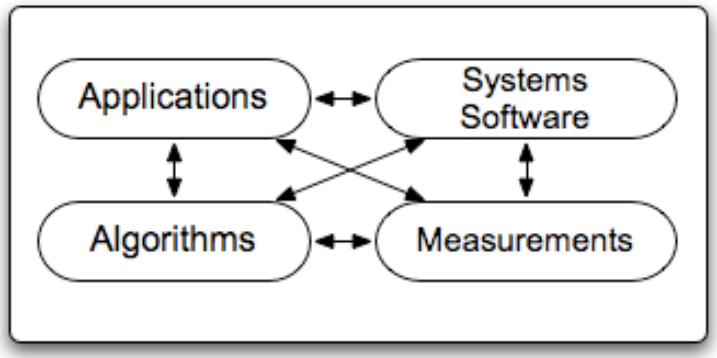
Applied Math

Application Domains

DynaCode

- Focus on scenarios:
  - Hurricane ensemble modeling
    - Coupling ocean circulation, storm surge, wave generation models for the Gulf
    - Notifications from NHC trigger customized ensemble hurricane models (surge/wind/ wave), sensors verify, guide dynamic ensembles
    - Event driven, dynamic component framework with algorithm selection, optimization tools, workflow, data assimilation, result validation with sensor/ satellite.
  - Ecological restoration and control
    - Breton Sound diversion, control structure to allow Mississippi to flow into wetlands
    - Coupled models (hydrodynamic, salinity, geomorphic, sediment) control diversion, sensors/wind fields inject real time data.





More Complexity

Land Loss at Isle Dernieres

More Complexity

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The Times-Picayune

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River's mud could mold coast

Pipeline to marshes seen as fast track

Sunday, April 02, 2006

By Matthew Brown
West Bank bureau

Stack Louisiana's coastal wetlands gains against the losses during the past century, and a sobering picture of unchecked decline emerges.

- $500M to restore 250 sq. miles since 1986
  - 12 sq. miles/year, but losing 2x this per year!
- How to catch up? $14B dollars later...
  - floods? diversions? pipelines of mud? many ideas!
- Complex processes: comprehensive approach needed to understand competing forces. *But there is a quantitative answer!*

Summary/Discussion

- HPC already impacts emergency response
  - operational pipeline in place from researcher to governor
- Much more sophisticated DDDAS approaches needed: very rich computational science!!
  - SCOOP, DDDAS programs started: just a beginning
  - Comprehensive approach to modeling entire Gulf Coast region: hurricanes, oceans, surges, waves, erosion, levees...
  - Model-model coupling, grids, HPC, optical nets, new algorithms all critical
- Collaborative computational science for complex problems
  - Looking to build international alliance of researchers