Katrina and Beyond
Computational Challenges in Coastal Modeling

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Representing Louisiana, National Coastal Modeling Efforts
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: much of N.O w/o power, homes abandoned, 80% gone, still finding bodies
  - 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
Katrina’s Diaspora

The victims of Hurricane Katrina have filed for assistance from FEMA from every state. The map shows the distribution and number of the 1.36 million individual assistance applications as of Sept. 23.
Actual Path of Katrina

- **Dry Air**
- **Infrared Imaging**

Legend:
- LSU Earth Scan Lab
- GOES (WV) qvar_ch3
- 26 Aug, 05:15 a.m. CDT
Predicting the Path

Where is it going to go?
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 Lueettich, 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
Model-Model-Data Coupling

Global Forecast Models

Historical Data

Hurricane Models or Regional Forecast (e.g. NHC, MM5)

Data Assimilation

wind, velocity, pressure

Circulation & Surge (e.g. ADCIRC)

track, central pressure, storm speed, maximum winds

Wind Models (e.g. PBL)

wind velocity & pressure

Ocean Waves

wind velocities, pressure & temperature

Shallow Waves (e.g. SWAN)

water level, velocities

Emergency Response (e.g. evacuation, planning)
Computational domain with bathymetry (m)

Unstructured grid of the entire domain.
SCOOP Surge

SCOOP ADCIRC WANAF Ensemble MoM from 5d Forecasts starting 2005-08-24 06:00:00

Dr. Brian Blanton -- UNC
SCOOP Surge

SCOOP ADCIRC WANAF Ensemble MoM
from 5d Forecasts starting
2005-08-25 06:00:00

Dr. Brian Blanton -- UNC
SCOOP Surge

SCOOP ADCIRC WANAF Ensemble MoM
from 5d Forecasts starting
2005-08-26 06:00:00

Dr. Brian Blanton -- UNC
SCOOP Surge

SCOOP ADCIRC WANAF Ensemble MoM
from 5d Forecasts starting
2005-08-27 06:00:00

Dr. Brian Blanton -- UNC
SCOOP Surge

SCOOP ADCIRC WANAF Ensemble MoM
from 3a forecasts starting
2005-08-28 06:00:00

Dr. Brian Blanton -- UNC
Want Real Time! NLR!

- SC05 Streaming HD
  - Starlight/Chicago to SC showfloor
  - CaveWave/NLR optical network
  - SAGE (Scalable Adaptive Graphics Environment)
- Data size - 21G
- Bandwidth - 500Mbps
- Frame-rate - 12fps
Emergency response

- Run as many simulations as possible
  - High res, high throughput critical: HPC + Grids!
  - Presently 6 hours to convert NHC forecast to surge
    - 240 processors per run
  - Bracket official forecasts with different tracks
  - Create “MEOW” map

- Notify officials: FEMA, State, Governor’s Office
  - email, web, phone: can do better!
  - evacuation orders: based on this work!

- Continue forecast to inform emergency workers
Emergency Forecast
New Orleans
Surrounding Parishes
Holly Beach
(Hurricane Rita)
Land Loss

Critical contributor to problem

North Breton Island, La. looking Northwest. South and East of Mouth of Mississippi River

Isle Dernieres

After Katrina

CCT Faculty Meeting: 23/02/05
Post-Katrina Assessment

- Few water level gauges survived!
  - Manual surveys of high water marks validate computations
  - Combine data & models to establish hydraulic forces affecting entire coastal flood protection system
  - Work with US Army Corps to validate
    - Must agree on data to agree on causes, action to take
  - Use hindcast models to fill in data gaps where severe damage, overtopping, breaches occurred
  - Accuracy was good, but validations continue
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.
DynaCode: DDDAS framework for coast and environmental modeling

• Builds on SCOOP modeling expertise
• LSU (CCT, CS, LHC, CSI, WBI), Notre Dame (+ EU DROIDS)
• Two complimentary scenarios:
  – Coupling ocean circulation, storm surge, wave generation models for the Gulf
  – Coupling ecological, hydrodynamic, sediment transport models of the Mississippi River Delta
• Infrastructure & algorithms
  – Couple multi-models, data, external inputs from sensors, wind & databases
  – Optimize complex workflows on grids, invoking appropriate models, meshes, algorithms, depending on conditions.
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
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
  - Need comprehensive approach to modeling entire Gulf Coast region: hurricanes, oceans, surges, waves, erosion, levees, traffic: many communities
  - Model-model coupling, grids, HPC, optical nets, new algorithms all critical

- Looking to build national alliance of researchers
Credits

• LSU
  - CCT: Werner Benger, Shalini Venkataraman, Gabrielle Allen, Steve Beck, Chirag Dekate, Jon MacLaren, Cornelius Toole, Brygg Ullmer, Steve Brandt, Brian Ropers-Huilman, William Scullin, Sam White, ES
  - Hurricane Center: Ivor van Heerden, Paul Kemp, Hassan Mashriqui
  - Earth Scan Laboratory: Nan Walker, Sreekanth Balasubramaniam, Alaric Haag
  - WAVCIS: Greg Stone, XP Zhang
  - CLEAR: Carola Jesch, Robert Twilley, Karen Westphal
  - CSI: Dewitt Braud

• UNO Lake Pontchartrain Institute

• SURA SCOOP
  - Phil Bogden (Maine), Brian Blanton, Gerry Creager, Rick Lueuttich (UNC), Mesonet (Texas A&M)
Credits

- NCSA: Stuart Levy, John Towns
- EVL: Maxine Brown, Jason Leigh
- Notre Dame: Joannes Westerink
- NLR: Tom West
- Scripps Institution of Oceanography
- RSMAS-AMP - Miami: Hans Graber, Niel Williams
- USGS: John Barras, Brady Couvillion
- Zuse-Institut-Berlin: Stefan Prohaska
- National Science Foundation
  - Dynacode Project
- NOAA, ONR, SURA
  - SCOOP Project