A Real-Time, High-Resolution Forecast System for the Gulf of Mexico

based on the Coupled Regional Climate Model

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GULF OF MEXICO RESEARCH INITIATIVE

SEA Software Engineering Conference 2013, Boulder, CO – April 2, 2013

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Calling for an accurate forecast system in the Gulf of Mexico

Two pressing cases

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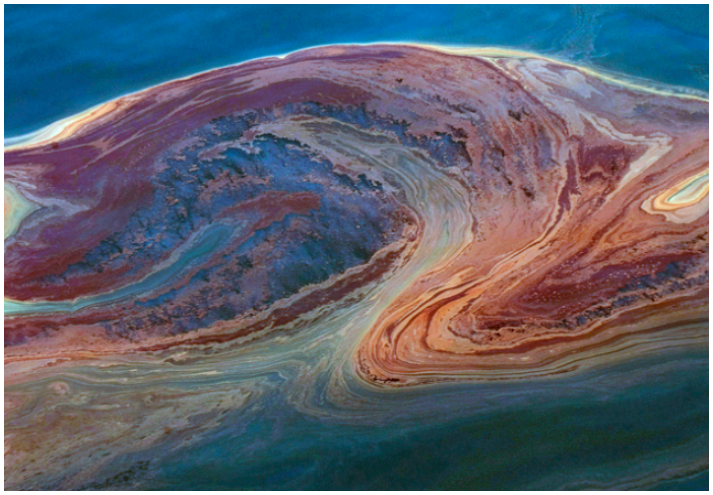
Calling for an accurate forecast system in the Gulf of Mexico

- Tropical Storms/Hurricanes forecast

- Oil spills tracking



Accurate forecast may help emergency response planning & management.

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Overview:
Designing a real-time forecast system

Defining forecasting model, strategy, and parameters

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Designing a real-time forecast system

Goals:

- **A**ccuracy
- **A**utomation
- **A**vailability

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Designing a real-time forecast system

Accuracy:

Use locally developed Coupled Regional Climate Model (CRCM)—couples WRF (3.4) and ROMS (3.5)

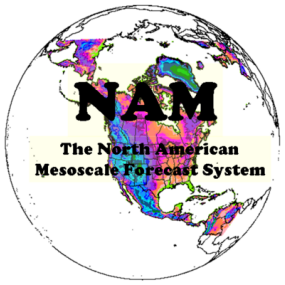
- CRCM should provide more accurate forecasts, since energy exchanges between the ocean and the atmosphere are being taken into account
- Energy exchange especially important when forecasting Tropical Storms/Hurricanes in the Gulf of Mexico
- Use of high-resolution grids (down to 1km) provides finer features in the output data.

Designing a real-time forecast system

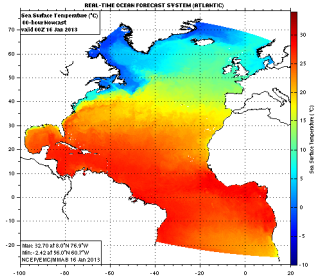
Accuracy:

Initialize forecast model **every other day**—or **every day** in case of Tropical Storms/Hurricanes—using:

- Latest 84-hour atmospheric forecast data from NOAA NCEP's North American Mesoscale Forecast System (NAM)—available every 3 hours at 12km resolution—to initialize atmospheric model (WRF)



- Latest 3-day ocean forecast data from NOAA NCEP's Real-Time Ocean Forecast System (RTOFS) for the Atlantic Ocean—provided daily at ~5km resolution—to initialize ocean model (ROMS)



Hourly coupling atmosphere/ocean

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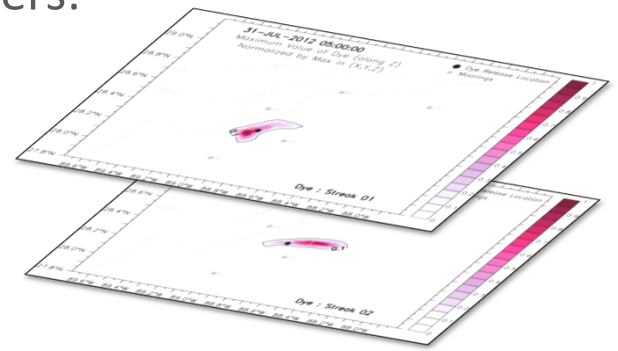
Designing a real-time forecast system

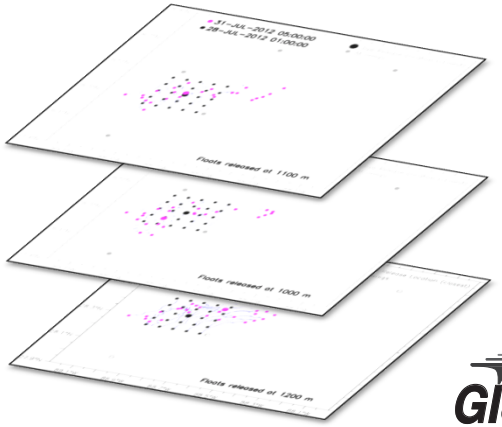
Accuracy:

For tracking of oil spills, use **passive** tracers:

- Dyes “released” at the spill site



- Lagrangian floats, distributed across a few depth levels around the spill site



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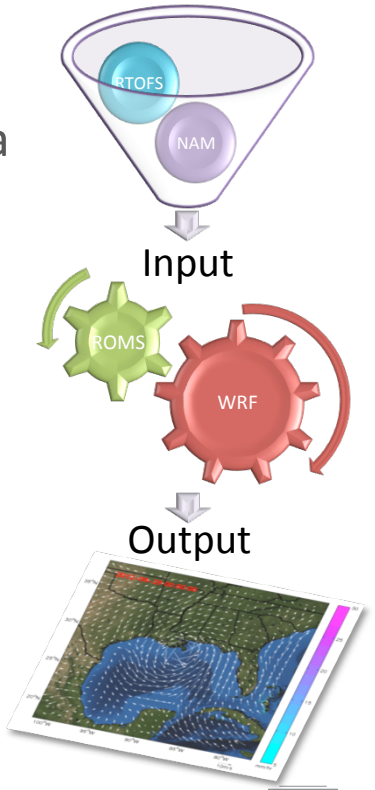
Designing a real-time forecast system

Automation:

Implement automatic scripts for:

- Preprocessing: download NOAA's data, remap data to CRCM grid, create initial and boundary conditions for CRCM
- Running CRCM
- Post-processing: Creating real-time forecast charts



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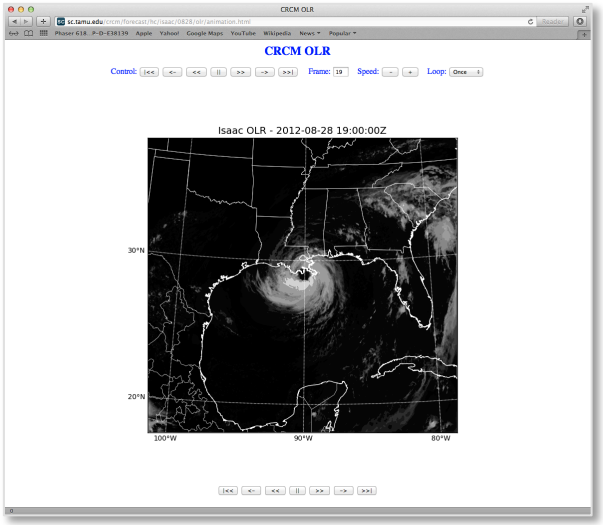
Designing a real-time forecast system

Availability:

Make available atmosphere/ocean forecasts as they are produced

- Analyze, plot, and publish CRCM output data to the World Wide Web:



http://sc.tamu.edu/crcm

- Post **hourly forecast** charts **every 15 minutes**

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The engine of the high-resolution forecast model: The Coupled Regional Climate Model

A few details on theory and implementation

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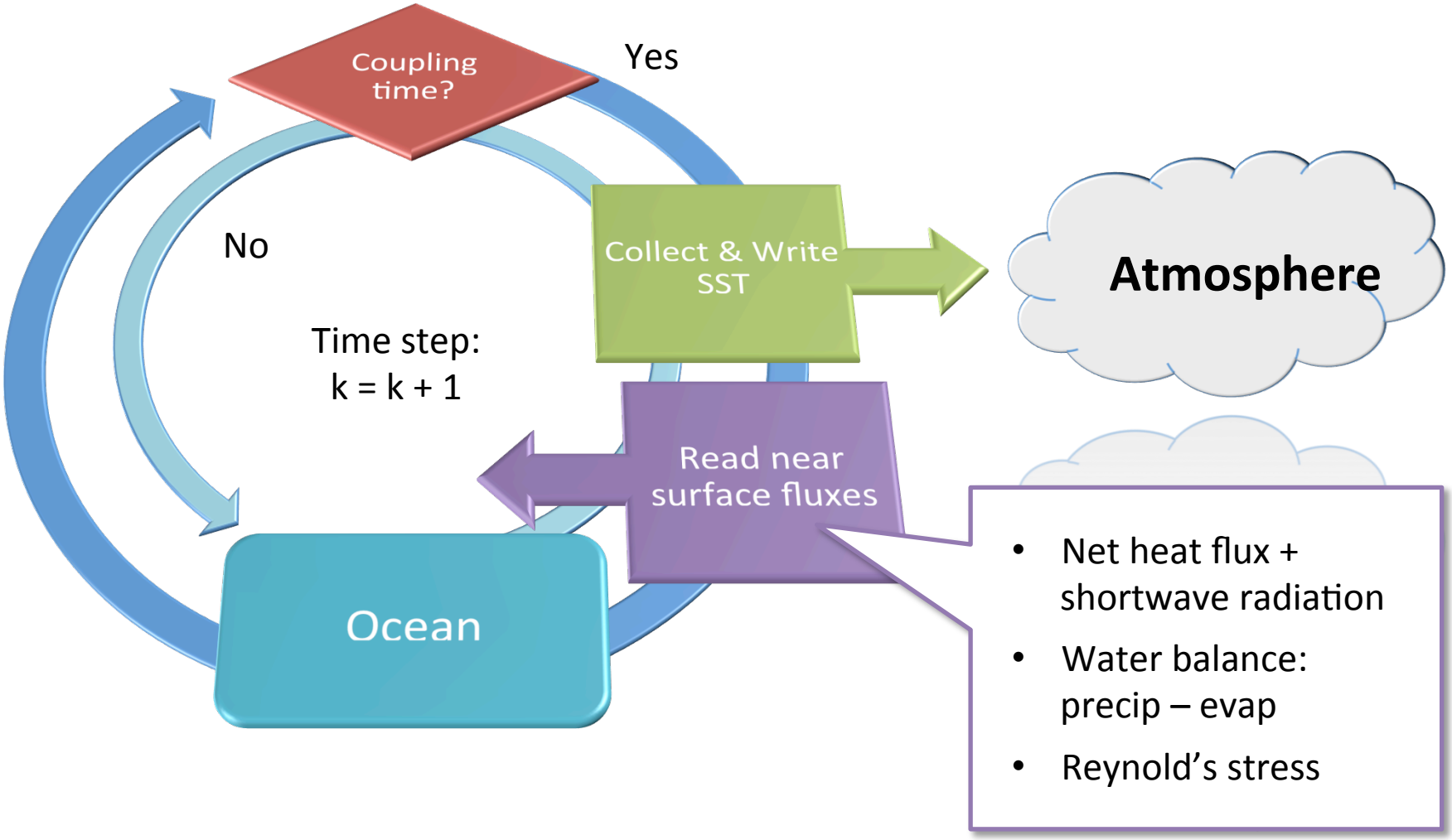
CRCM: The mechanics of coupling



CRCM: The starting point …

- **Regional Ocean Modeling System (ROMS) version 3.5**

  ROMS/TOMS Framework: September 21, 2011

  Snapshot:

  svn: $HeadURL: https://www.myroms.org/svn/src/trunk/ROMS/Version $

  svn: $LastChangedBy: arango $

  svn: $LastChangedRevision: 568 $

  svn: $LastChangedDate: 2011-09-21 15:57:11 -0500 (Wed, 21 Sep 2011) $

- **Weather Research and Forecast (WRF) Model Version 3.4**

  April 6, 2012

  http://wrf-model.org/users/users.php

- Only pure **distributed-memory** (MPI) versions used.

  No OpenMP/hybrid.

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A real-time framework

Implementation

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The Real-Time Forecast System Framework

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE
National Weather Service
NCEP Central Operations

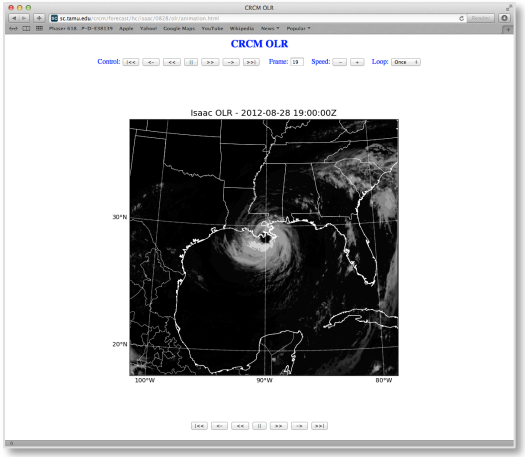
Real time: NAM/RTOFS
`ftp://ftp.ncep.noaa.gov`
`http://nomads.ncep.noaa.gov`

Archives:
- `http://nomads.ncdc.noaa.gov` (NAM-ANL)
- `http://data.nodc.noaa.gov` (OFS)

Preprocessing
✓Atmosphere
✓Ocean

Post-processing (plotting)

Coupled Regional Climate Model (CRCM)



`http://sc.tamu.edu/crcm`

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The ignition key

Main driver: `run_forecast.sh`

- Creates WRF initial & boundary condition
  `create_crcm_input.sh`
- Creates ROMS initial & boundary conditions
  `create_roms.sh`
- Add initial and boundary conditions for tracers, if needed
- Creates CRCM run directory and input files for the forecast run
- Starts forecast by submitting a batch job to a reserved run slot on Eos

Post-processing

Using:

- MATLAB to generate maps for wind, precipitation, SST, SSH, and storm intensity, and to upload them to the webserver

  `run_matlab.sh [YYYY-MM-DD]`

- Ferret to generate and upload tracer maps

  `run_ferret.sh [YYYY-MM-DD]`

- NCL for preprocessing

- NCO for postprocessing tasks

- Using GrADS/Python for further analysis

Forecast setup

Model parameters and strategy for real-time forecast

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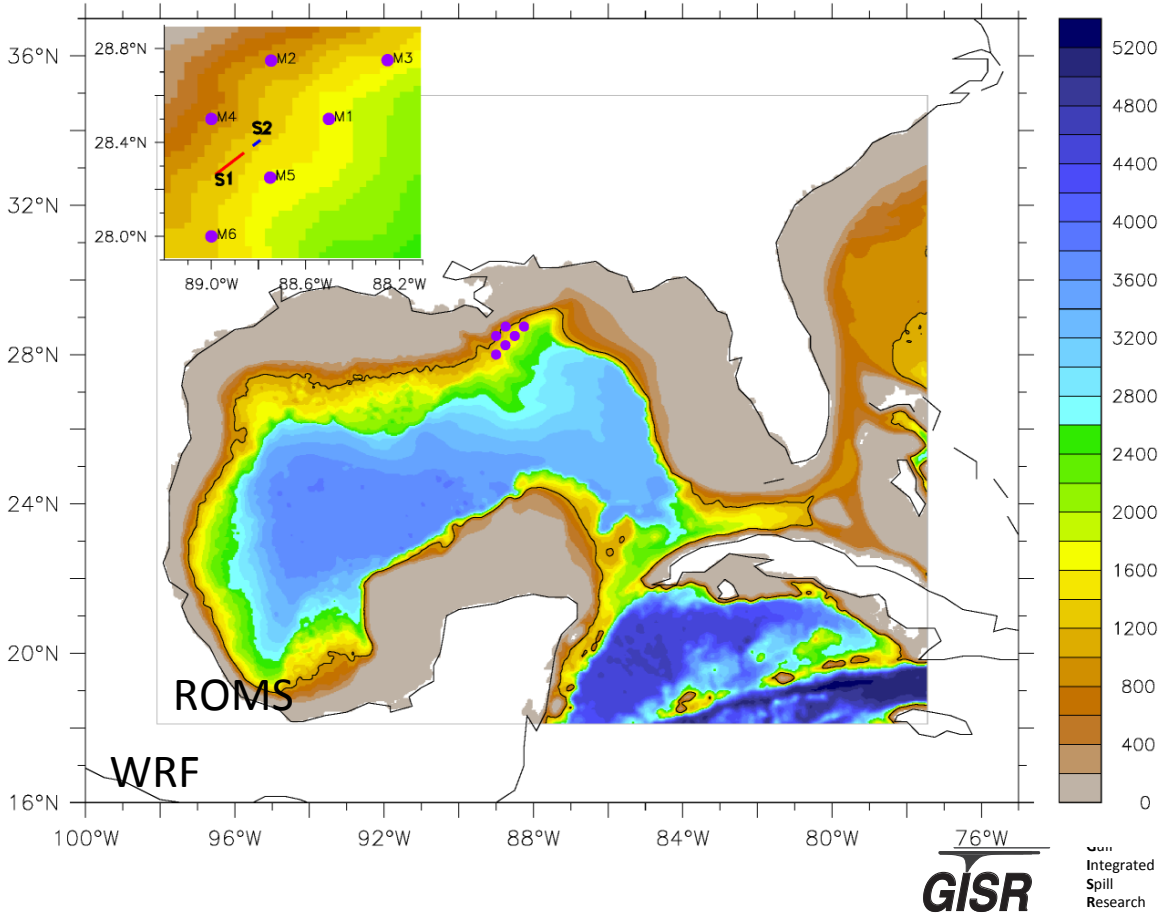
CRCM model setup

- Define identical 3km rectangular lat/lon grids for both the atmosphere and ocean domains over the Gulf of Mexico
- 2 dyes at the experimental release sites: S1, S2
- 243 Lagrangian floats, uniformly distributed in square (9x9) patches at three depths: 1,000m; 1,100m; 1,200m



CRCM model details

- Atmosphere horizontal grid @ 3km resolution:
  - 856 (lon) x 811 (lat) = 694,216 points
  - 35 vertical levels
- Ocean horizontal grid @ 3km resolution:
  - 720 (lon) x 660 (lat) = 475,200 points
  - 50 vertical levels (stretched coordinate)
- Run forward for 84 hours simulated time on 704 cores (88 nodes) on Eos: 624 WRF + 80 ROMS
- Total downloaded data ~ 1.5 GB (NAM: 716.5 MB, OFS: 796.6 MB)
- Amount of data generated in one run (with tracers): 482 GB
- Wall clock time/run: ~7.5 hours / 14 hours (with tracers)

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Generated forecast

- Produce **hourly** forecast maps for:
  - Wind (10m) and precipitation rate
  - Sea Surface Temperature
  - Subsurface velocity at 1,100 m
  - Distribution of dye #1 & #2
  - Trajectories of Lagrangian floats at 1,000m, 1,100m, and 1,200m

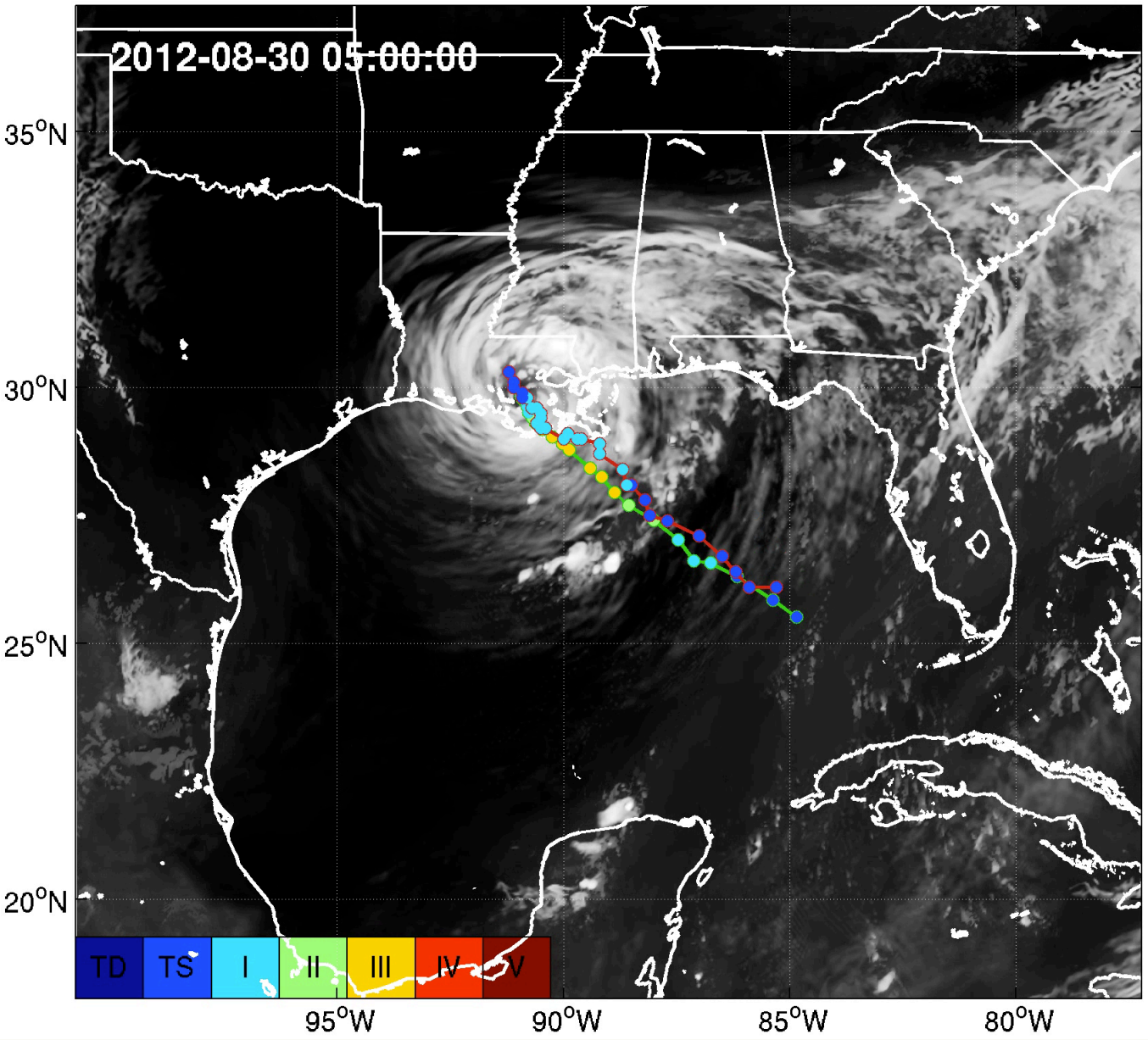
  Additionally:
  - Sea Surface Height
  - Storm Intensity

- Full dataset available through a THREDDS server:
  `http://pong.tamu.edu/thredds/catalog.html`

Results: Hurricane Forecast

Tracking Isaac

Hurricane forecast: Isaac, Aug 27 forecast



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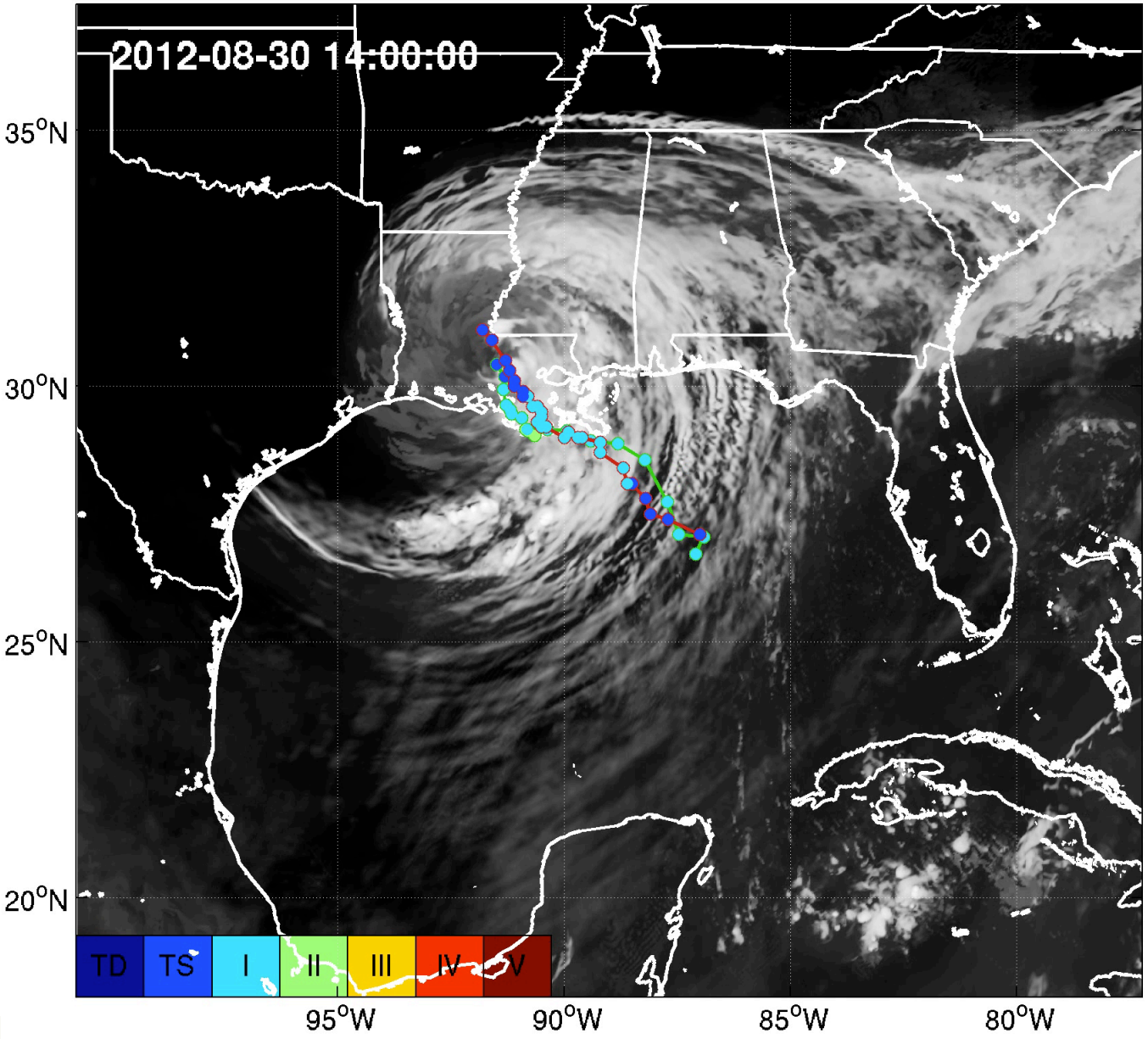
Hurricane forecast: Isaac, Aug 28 forecast



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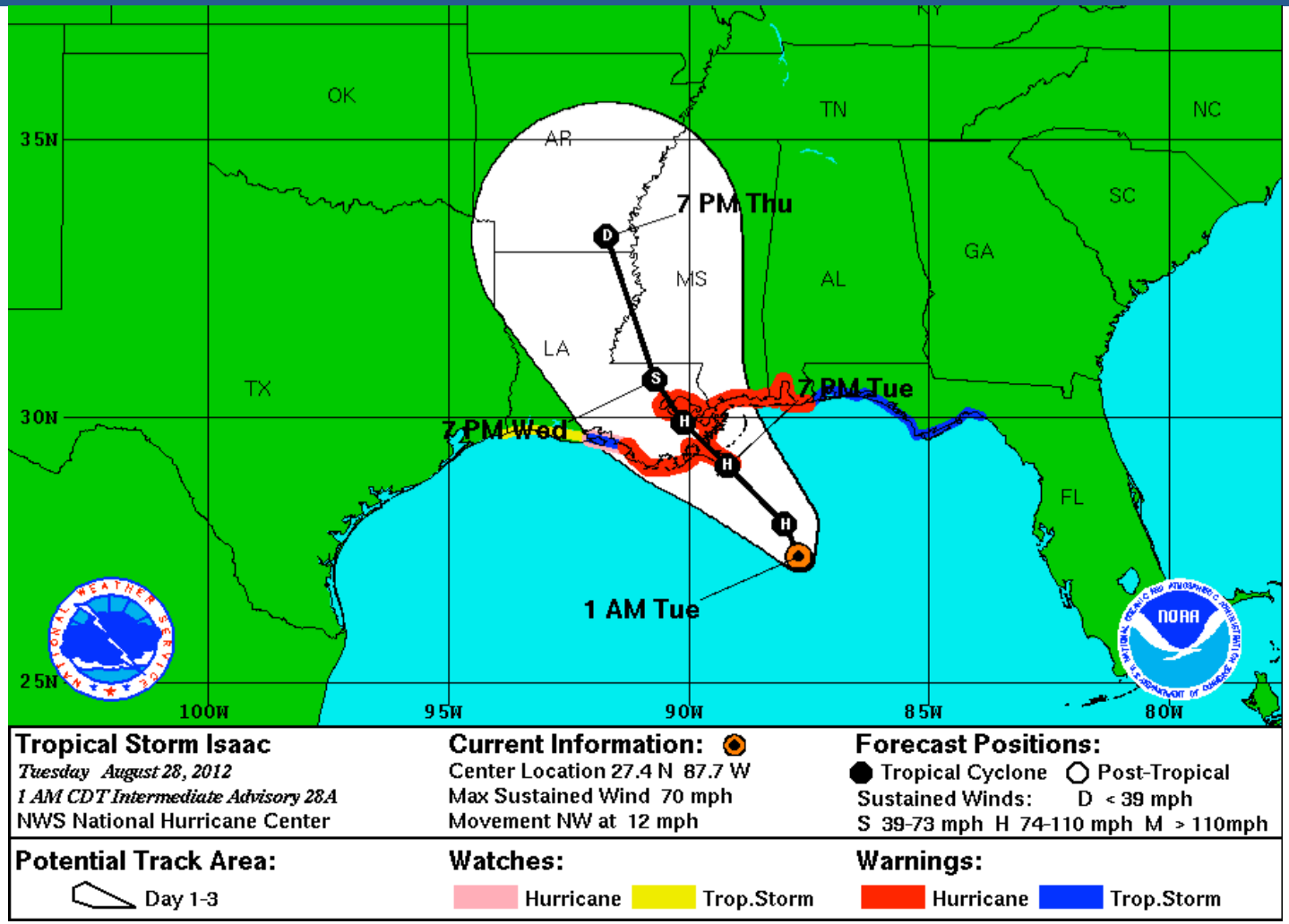
Hurricane forecast: Isaac



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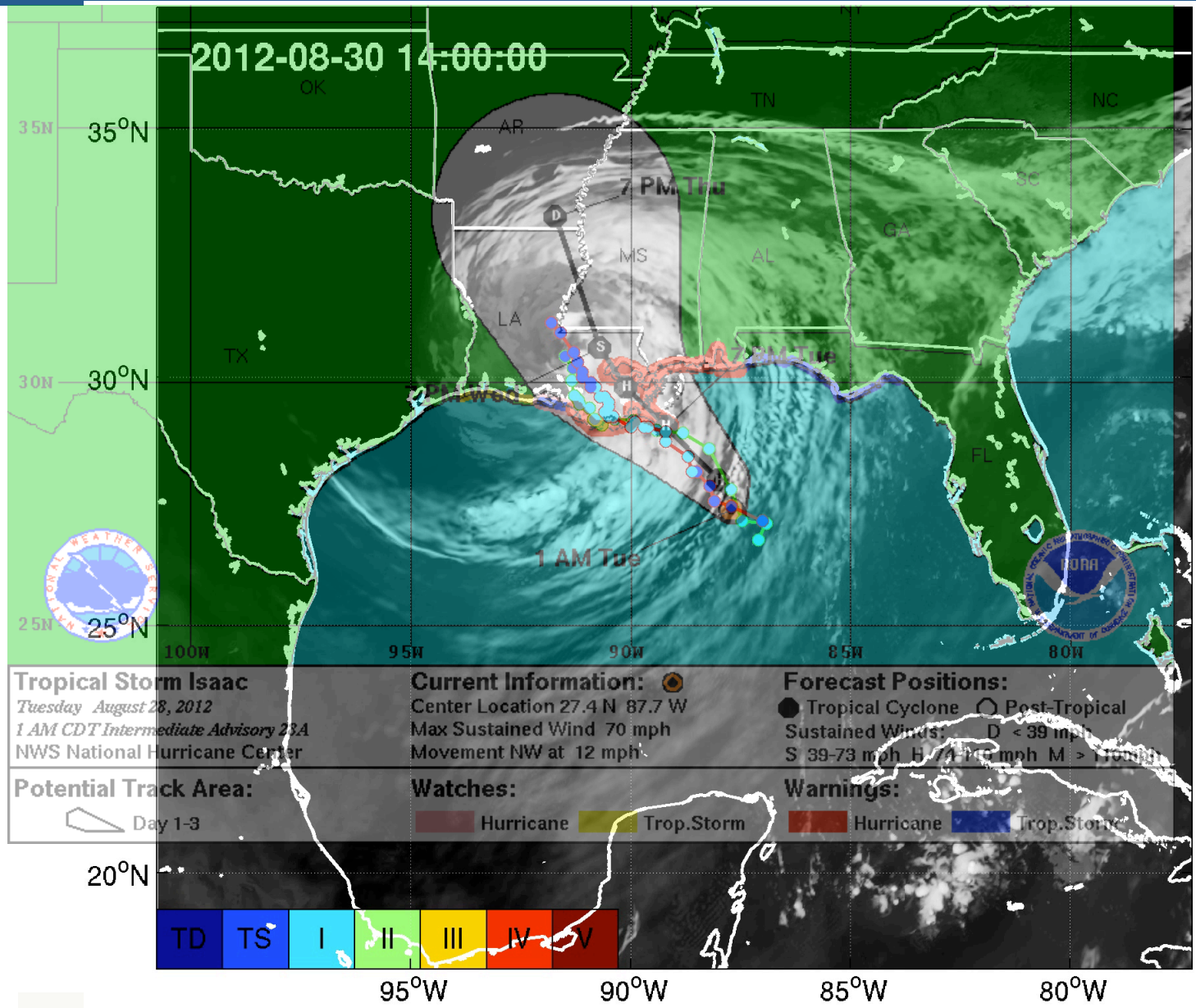
Hurricane forecast: Isaac, Aug 28 forecast



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Hurricane Isaac's landfall: forecast vs. observation

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Hurricane Isaac's landfall: forecast vs. observation

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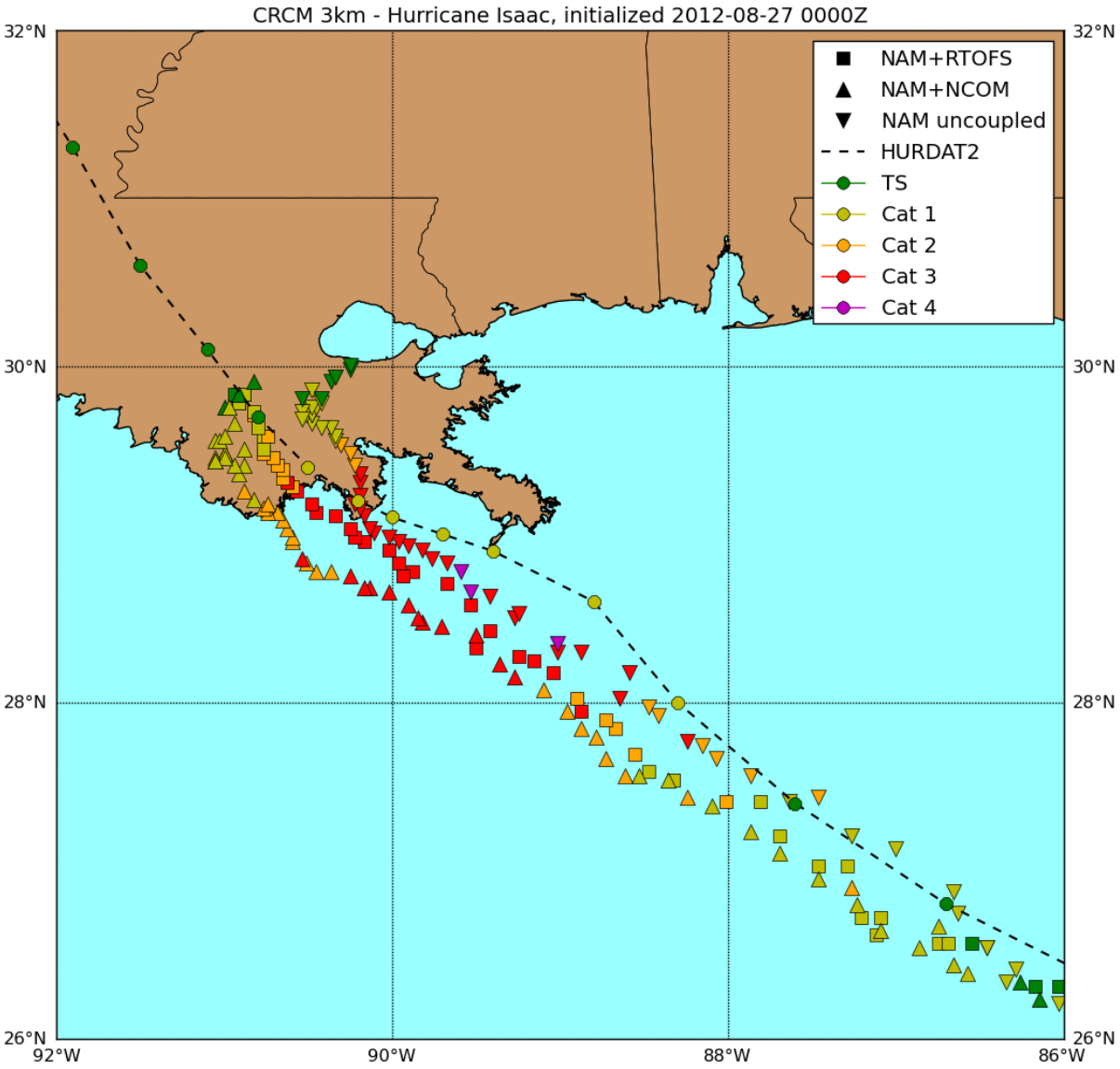
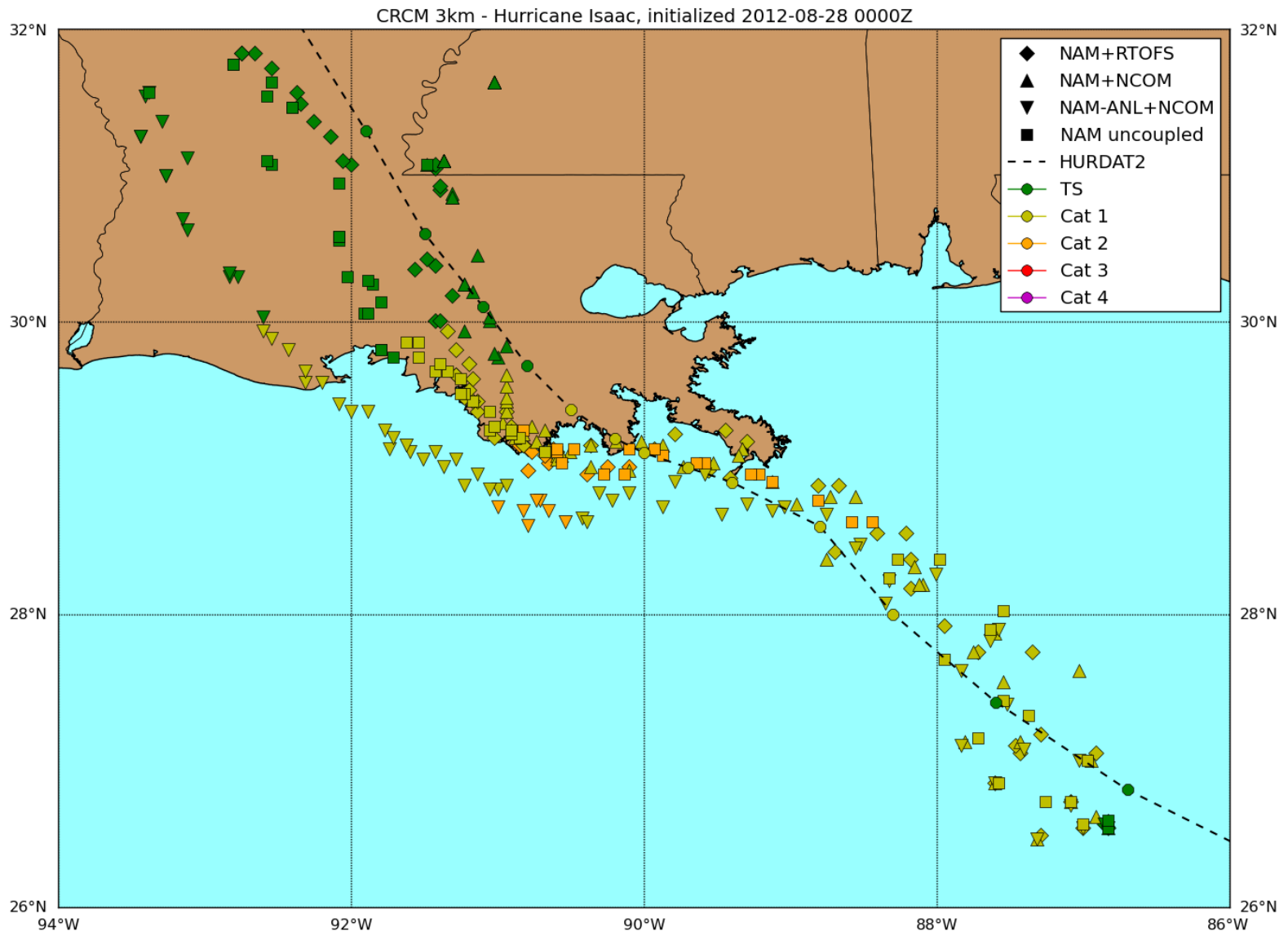
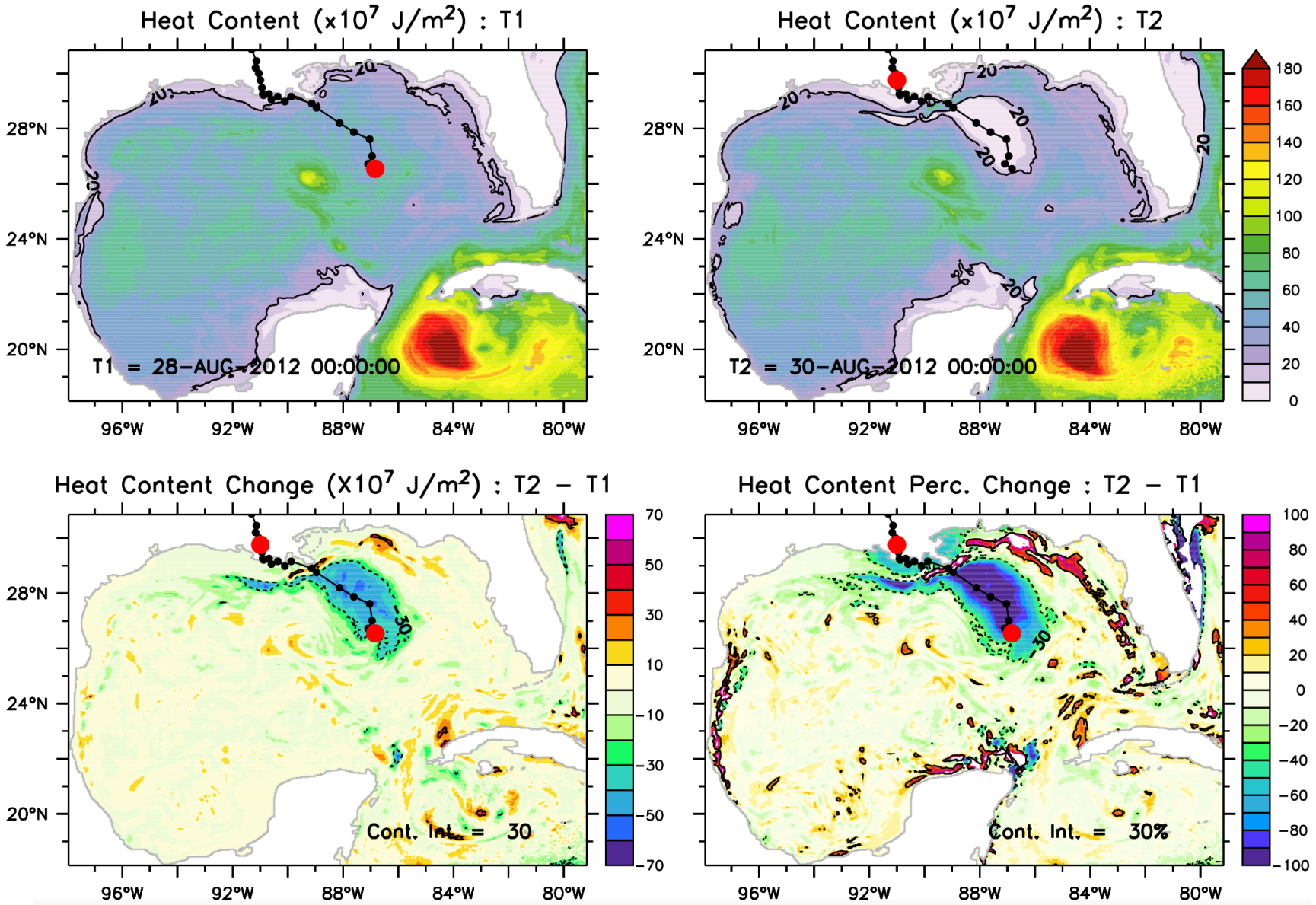
Hurricane Isaac: recent simulations



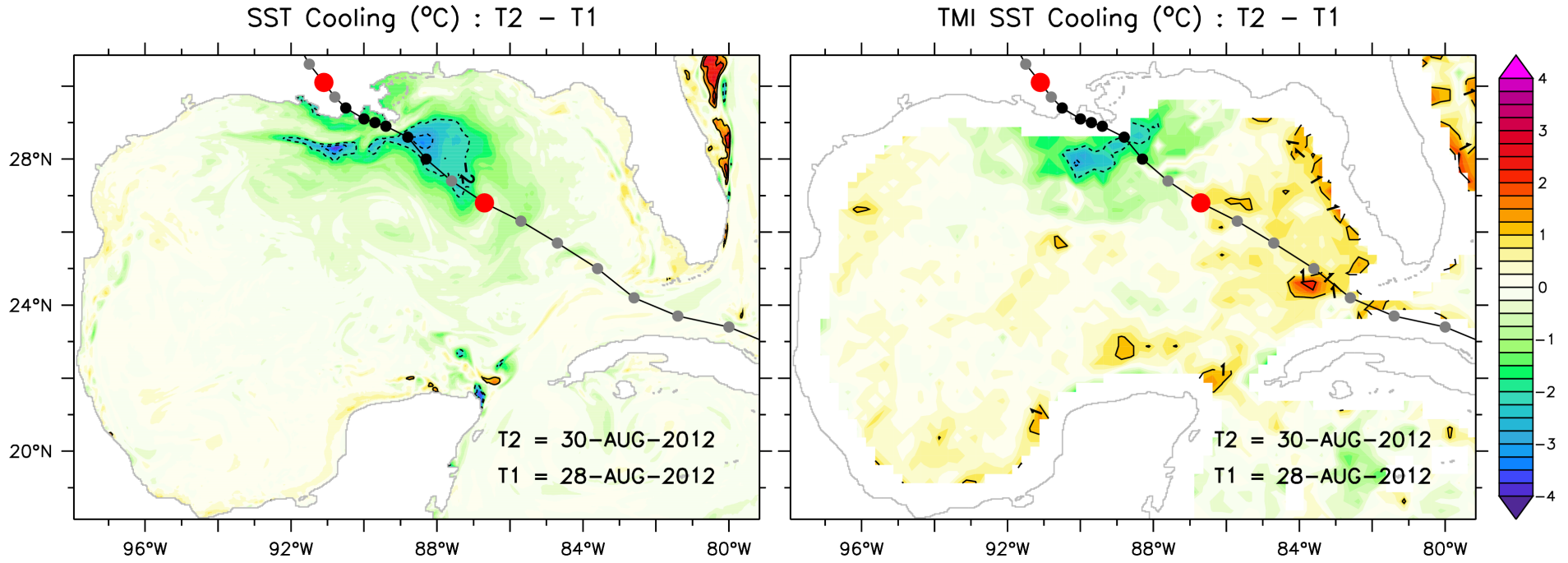
Hurricane Isaac: recent simulations



Hurricane Isaac: CRCM OHC (26 C isotherm)



Hurricane Isaac: CRCM SST vs TMI (daily averages)



Results: Deep Release Experiment

Tracking Oil Spills in the Gulf of Mexico

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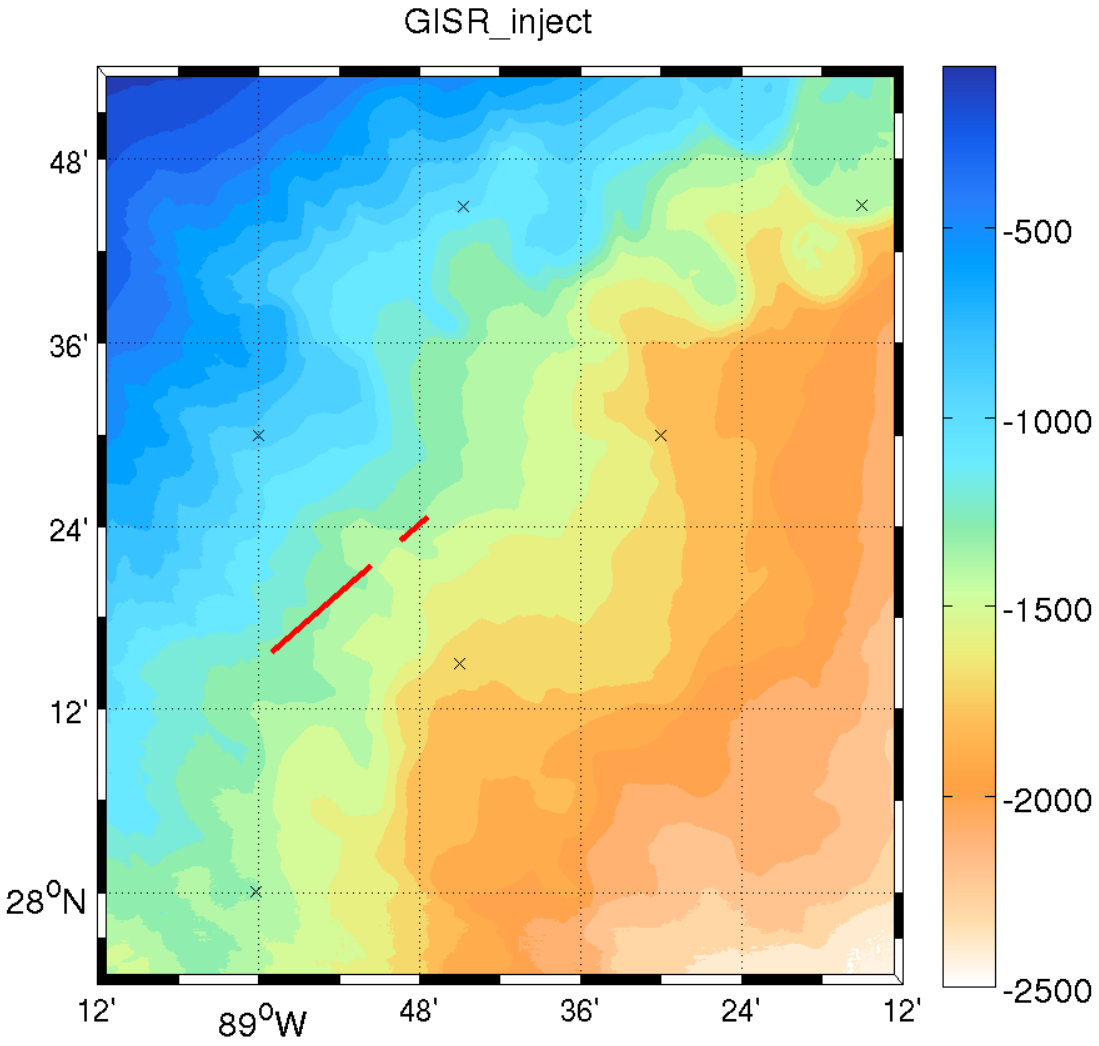
Deep Release Experiment: July 26-Aug 9

- James R. Ledwell - *Woods Hole Oceanographic Institution Woods Hole, MA*

R/V Brooks McCall, Pensacola, July 26

Deep Release Experiment: July 26-Aug 9



- Released 16.8kg CF_3SF_3 in two streaks at 1,090 to 1,180 dbar on July 28, 2012
- Released RAFO floats
- Moorings (×) set in previous cruise (Steve Di Marco) guided tracer release
- Accurate numerical simulations requested to predict tracer dispersion
- Simulation model will help responses to accidental oil spills in the Gulf

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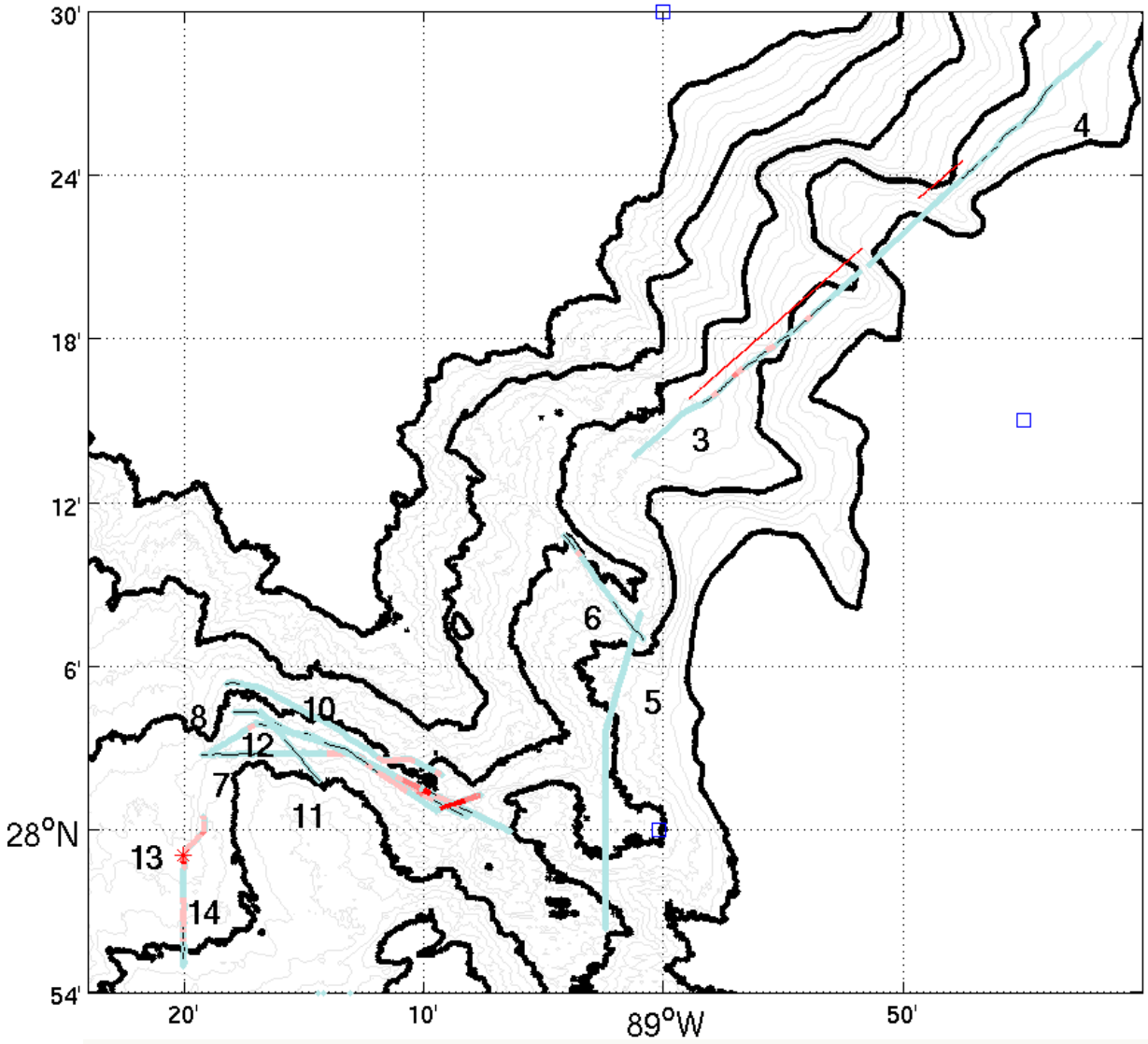
Deep Release Experiment: July 26-Aug 9



Sampling tows

Tracer < 5 pM

Tracer > 5 pM

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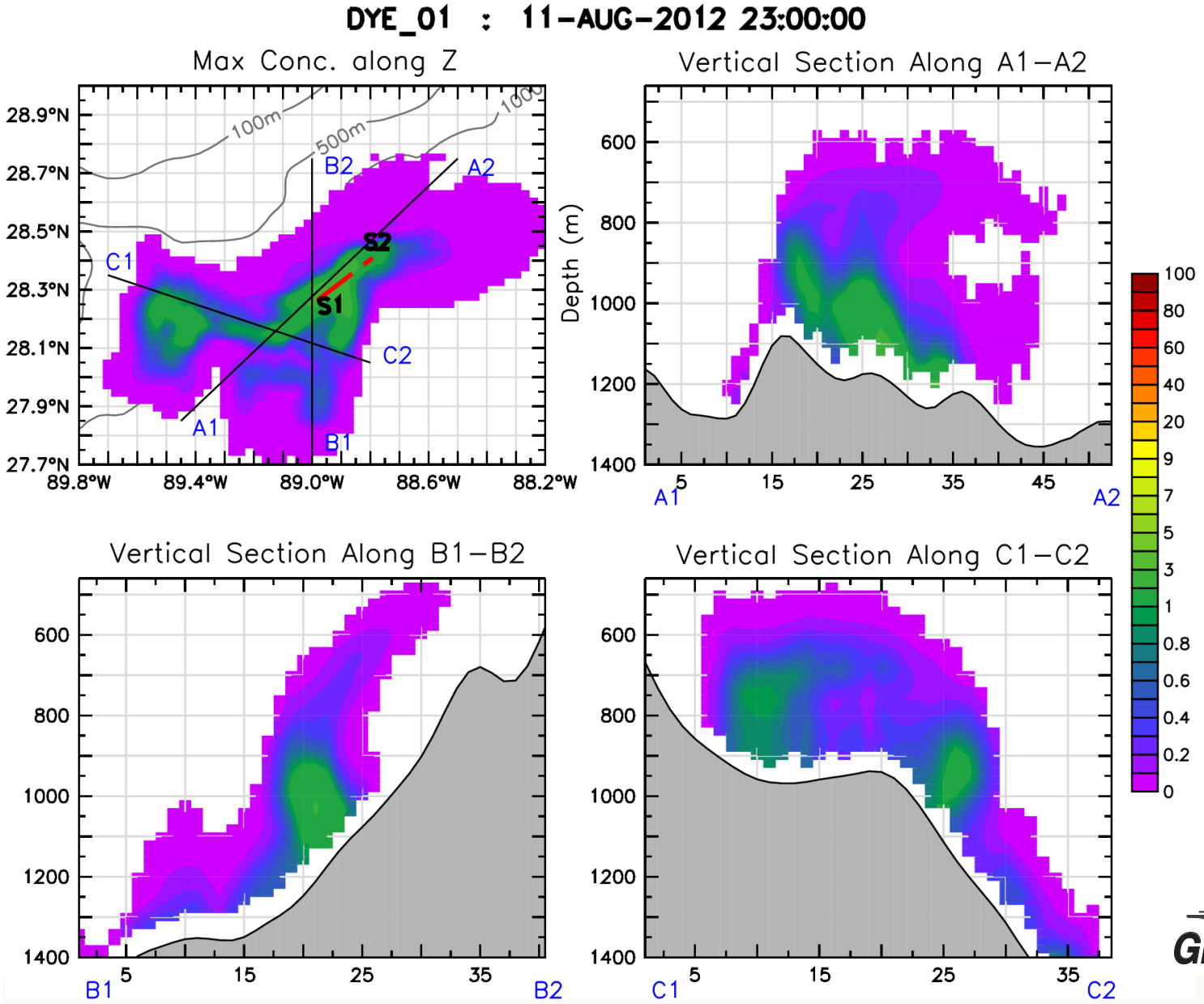
Deep Release Experiment: July 26-Aug 9



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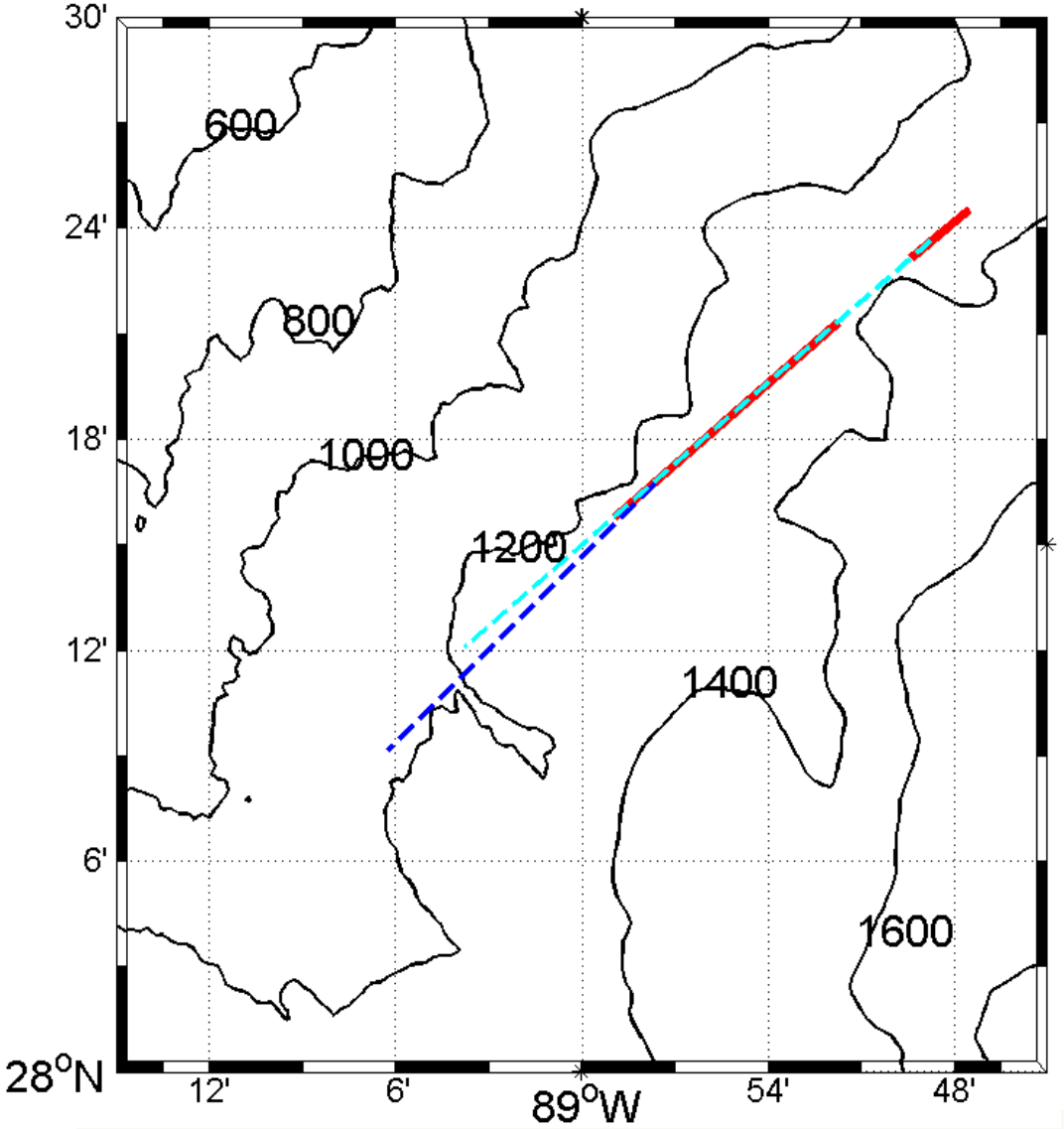

Injection streaks

1st RAFOS float

2nd RAFOS float

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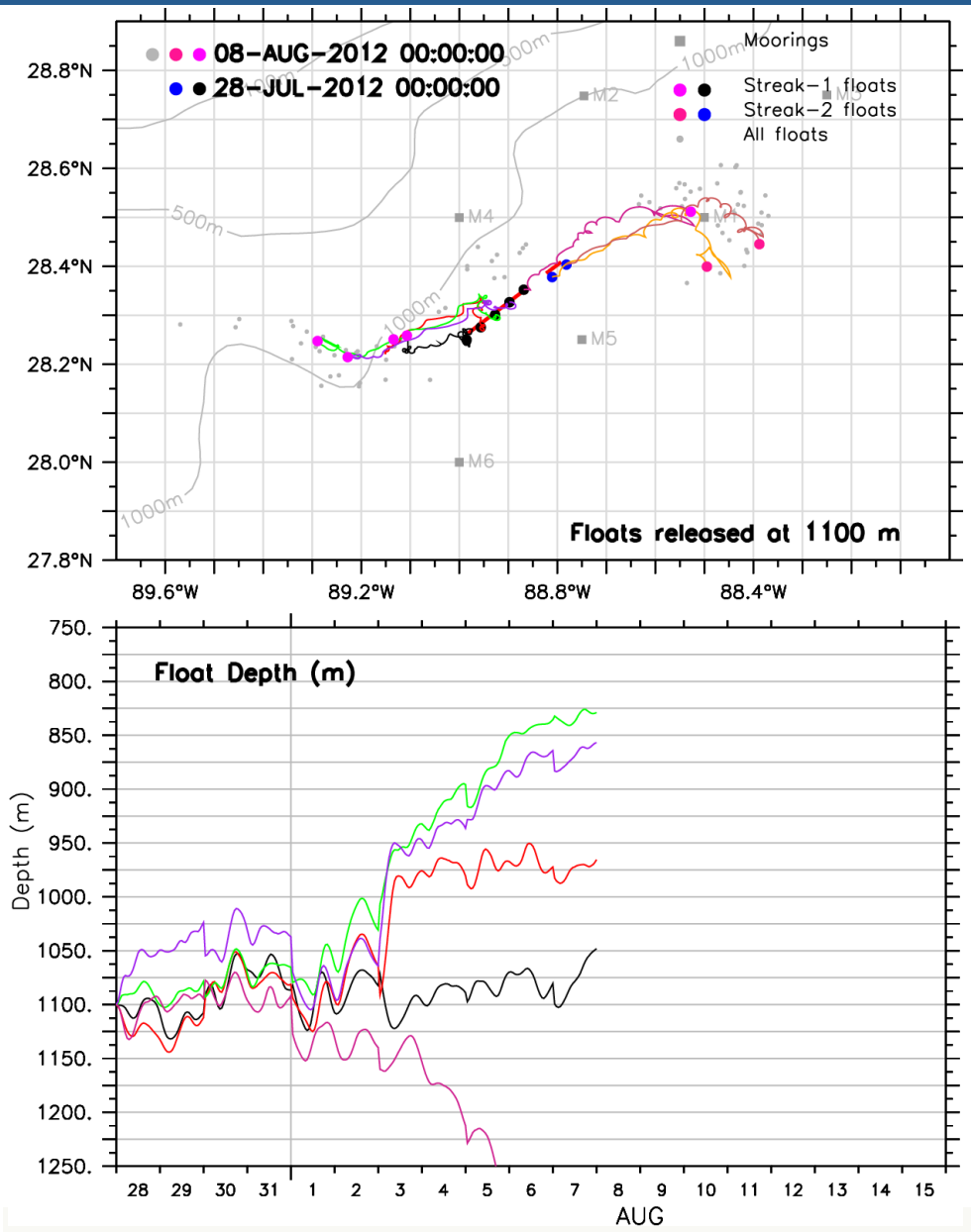
Deep Release Experiment: July 26-Aug 9



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Summary

- A Real-Time, High-Resolution forecast system is available for the ocean and atmosphere over the Gulf of Mexico
- Based on a 3km-resolution Coupled Regional Climate Model (WRF/ROMS)
- Used to predict Tropical Storms/Hurricanes and to track oil spills via passive tracers
- Results available to the community through the Web
- Validation still underway, but early results look promising

Questions?