Evaluation of Ocean Components in HWRF-HYCOM Model for Hurricane Prediction

Hyun-Sook Kim and Carlos J. Lozano

Marine Modeling and Analysis Branch, EMC
NCEP/NWS/NOAA
5200 Auth Road
Camp Springs, MD 20764

Hurricane Verification/Diagnostics Workshop
National Hurricane Center
Miami, FL
4-6 May 2009

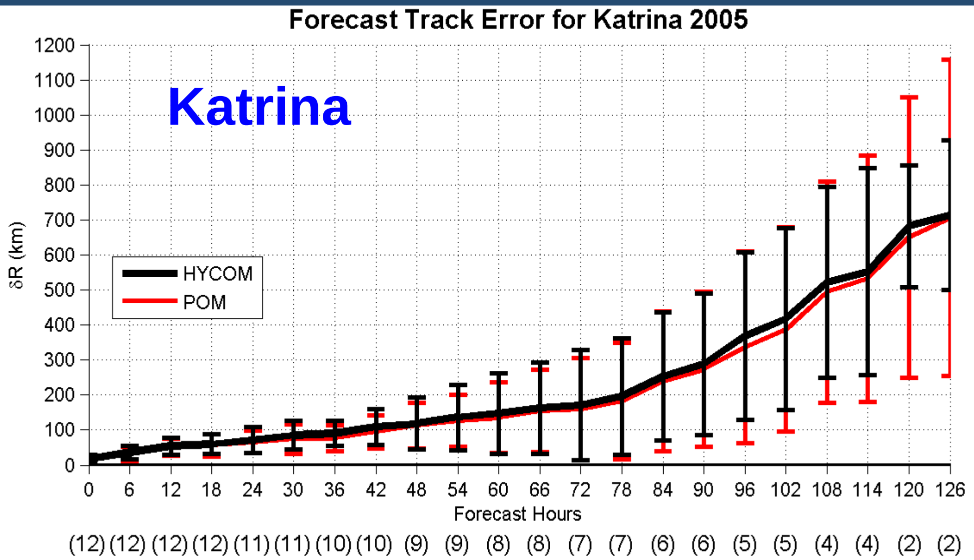
Objectives

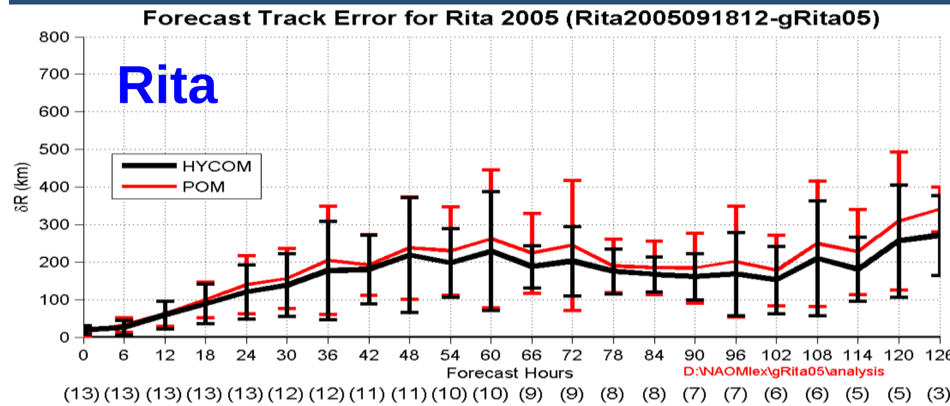
- Evaluate ocean model skill to accurately represent processes of interest.
- Evaluate hurricane forecast system to provide accurate air-sea fluxes.
- Evaluate the ability of observations and data assimilation to accurately represent initial conditions in regions and for state variables of interest.

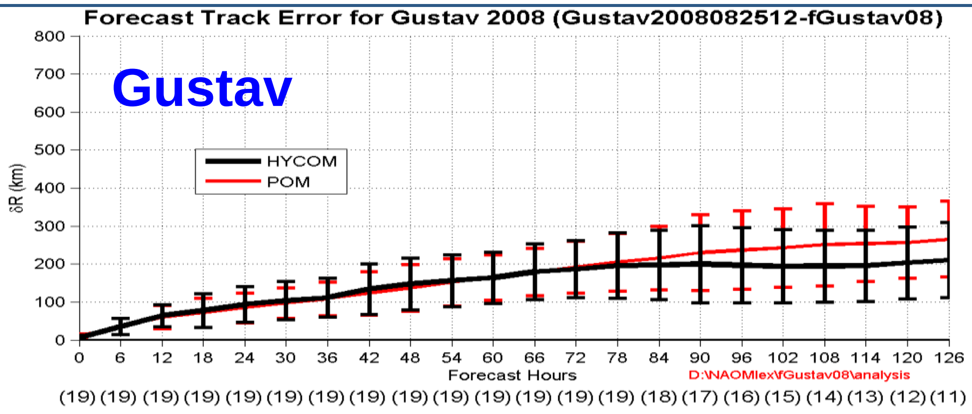
Track Forecast Skill Comparison

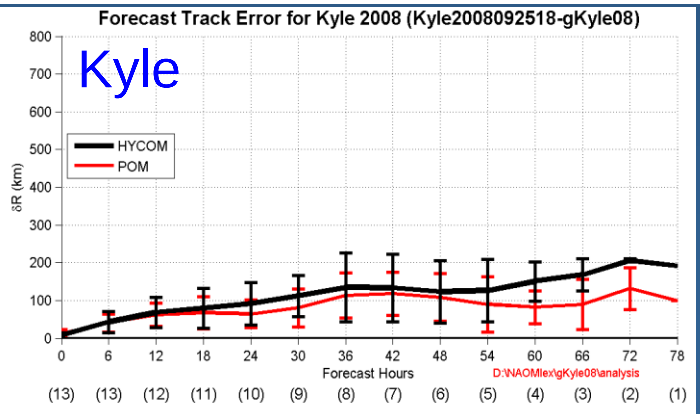
Black – HYCOM

Red – Op.









Summary:

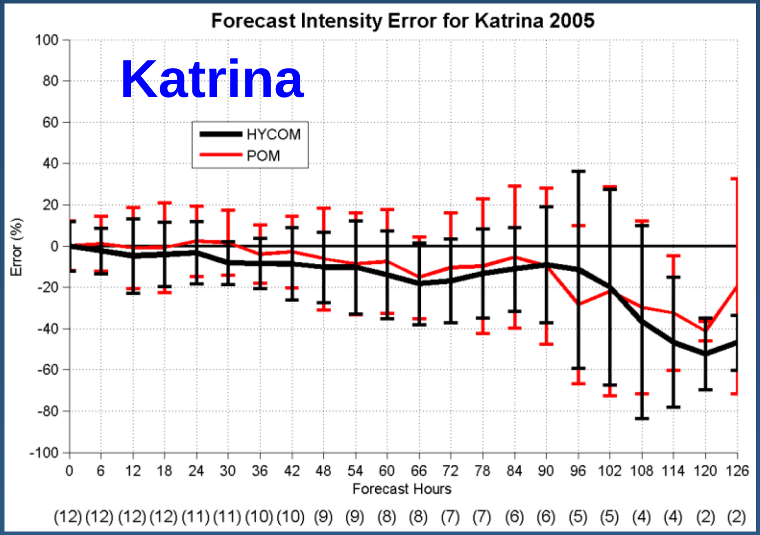
- Mean Difference is at the same order of magnitude;
- Variations are consistently smaller

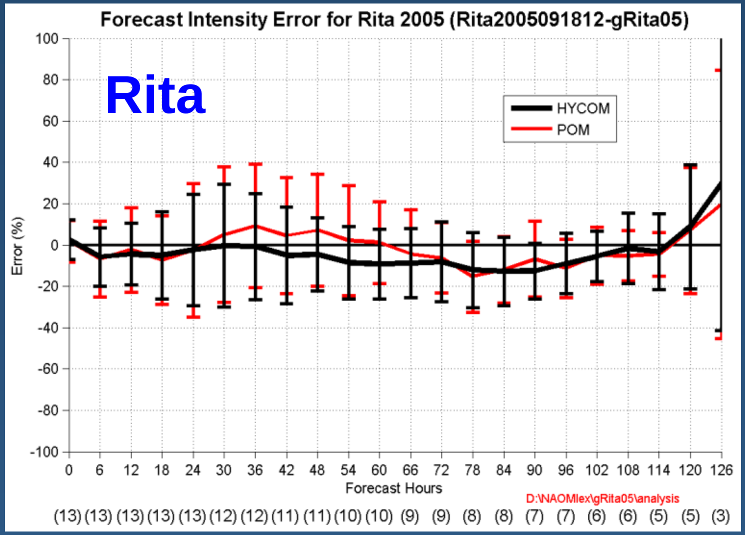
Remarks:

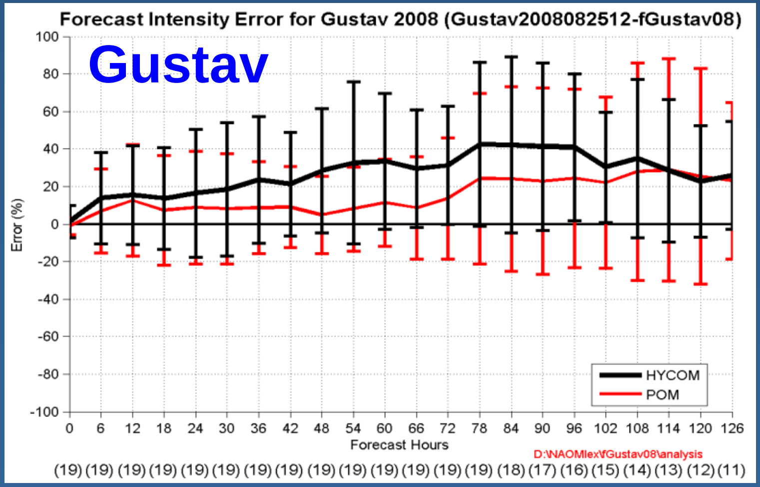
- **Comparable to Op.**
- **Coherent Forecast**

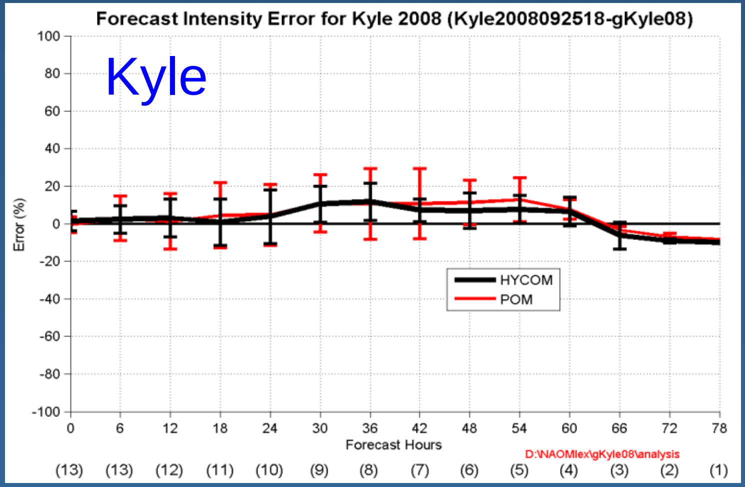
Intensity Forecast Skill Comparison

Black – HYCOM
Red – Op.









Summary:

- Mean Difference is at the same order of magnitude;
- Variations are consistently smaller

Remarks:

- ➢ **Comparable to Op.**
- ➢ **Coherent Forecast**

Critical Ocean Parameters for Hurricane-Ocean Interaction

- Sea Surface Temperature
  - modulate heat fluxes
  - contribute to overall hurricane heat engine efficiency
- Sea State
  - modulate flux-exchange coefficients
  - modulate momentum fluxes
- Currents
  - modulate surface gravity waves and internal waves
  - redistribute SST

3-way Coupling HWRF-HYCOM-WAVEWATCH III

Data Assimilation for HWRF-HYCOM

- Improve the estimate of **sub-surface ocean structures** for IC and nowcast, based on
  - remotely sensed observations of sea surface height (SSH), sea surface temperature (SST);
  - in situ temperature (T) and salinity (S); and
  - model estimates.
- Improve **the joint assimilation** of SSH, SST, T&S.

Data assimilation components (I)

- **Observations**
  - **SST**: in situ, remotely sensed (AVHRR, GOES)
  - **SSH**: remotely sensed (JASON1, JASON2, ENVISAT)
  - **T&S**: ARGO, CTD, XCTD, moorings.
  - **T**: AXBT, moorings

- **Climatology sources**
  - **SSH:** (global) MDT Rio-5 and Maximenko-Niiler
  - **SSHA**: Mean and STD from AVISO (global)
  - **SST**: Mean and STD from PATHFINDER version 5, Casey NODC/NOAA (global)
  - **T&S**: Mean from NCEP (Atlantic) and STD from Levitus

- **Quality Control**

  Observation accepted if
  - Anomaly from climatological mean is within xSTD; and
  - Anomaly from model nowcast is within STD. **It assumes there are no model biases.**

Data assimilation components (II)

- **Data Assimilation Algorithm**

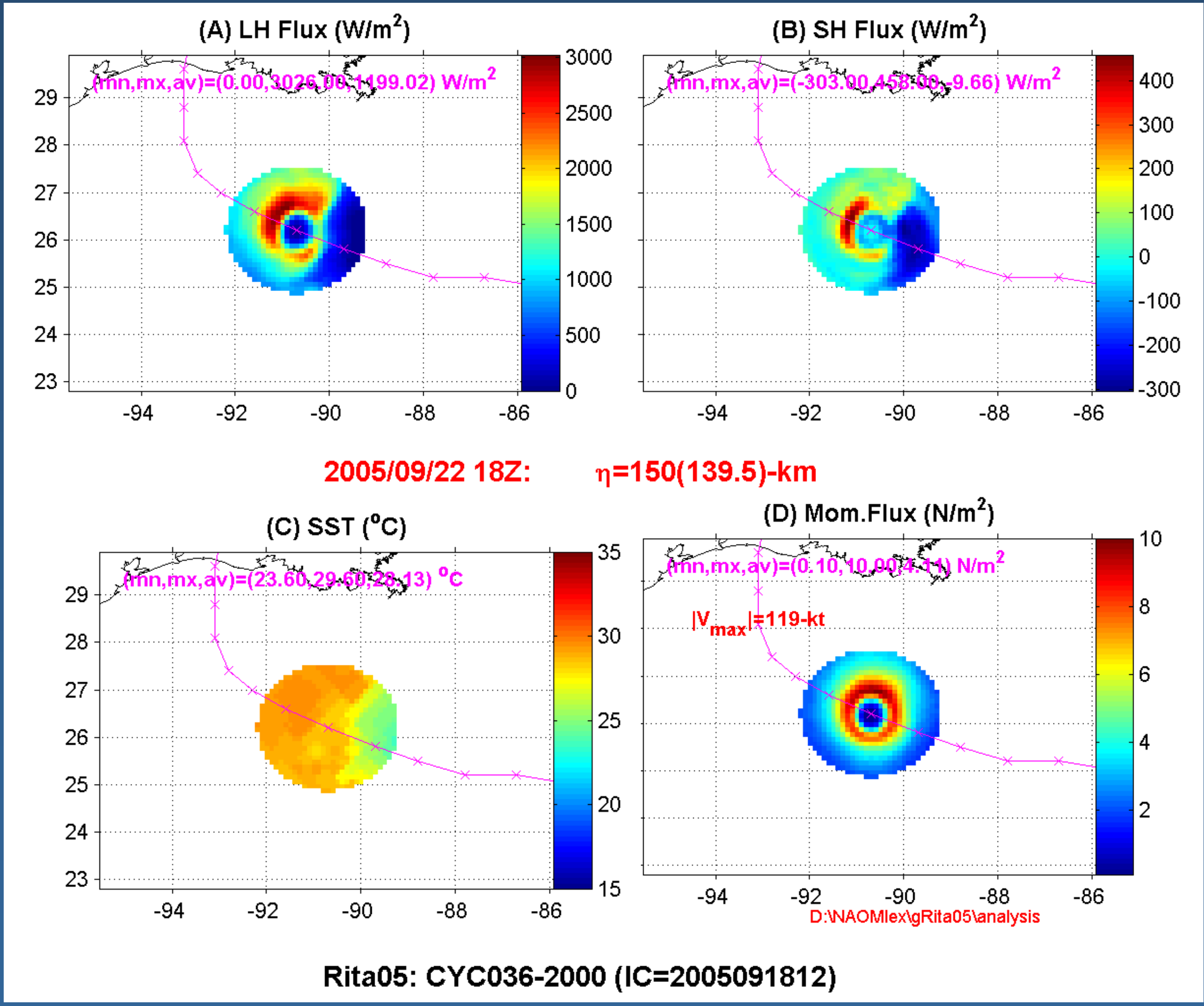
  3DVAR = 2D(model layers)x1D(vertical)

  - 2D assumes Gaussian isotropic, inhomogeneous
    - covariance matrix.
    - Jim Purser's recursive filtering.
  - 1D vertical covariance matrix.
    - Constructed from coarser resolution simulations.
    - **SST** extended to model defined mixed layer.
    - **SSH** lifting/lowering main pycnocline (mass conservation).
    - **T&S** lifting/lowering below the last observed layer.

Close Look at HWRF-HYCOM Hurricane-Ocean interaction

Under the footprint of a storm, **heat flux** can be modulated by <u>sea surface temperature (**SST**).</u>

Negative feedback between the SST response and the hurricane intensity (Change and Anthes, 1979)



Example: HWRF-HYCOM simulations for Rita

Oceanic Processes related to SST Cooling in the Near Field

- Heat flux across the air-sea interface
- Mixing in the upper ocean layer
- Upwelling/downwelling
- Horizontal advection

Processes of multi-spatial and temporal scales !

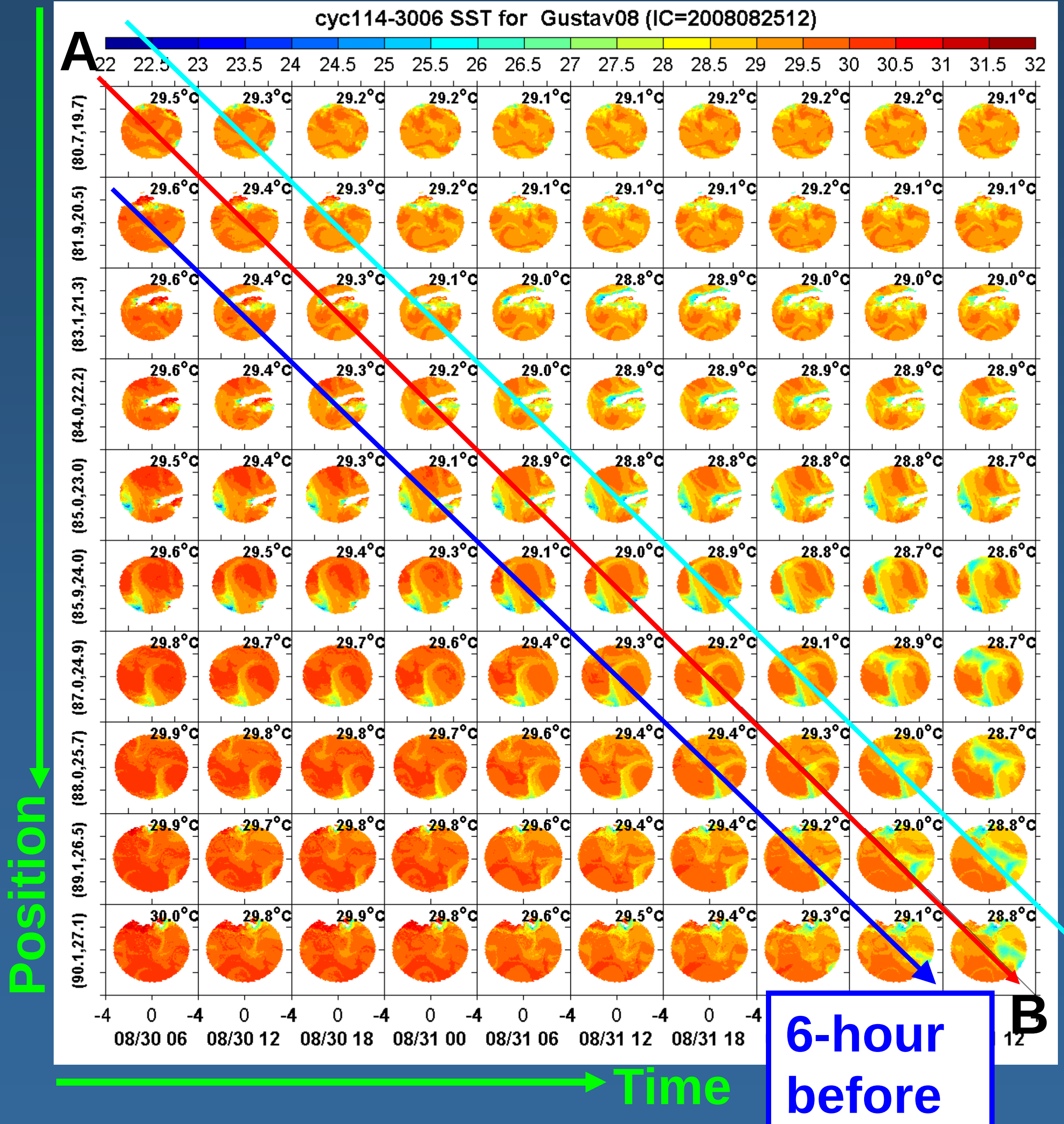
At the passage of a cyclone, large wind stress results in large SST cooling.

The upper ocean structure that matters for this change includes:

- **SST;**
- **MLD;** and
- **$\partial T/\partial Z$** (the strength of stratification) ~ Z_{26}

Sea Surface Temperature

Gustav



Size: 34-kt

Average SST cooling rate:

For a major Hurricane, e.g. Gustav

~0.3ºC/6-hr

For a weak storm, e.g. Kyle

~0.1ºC/6-hr

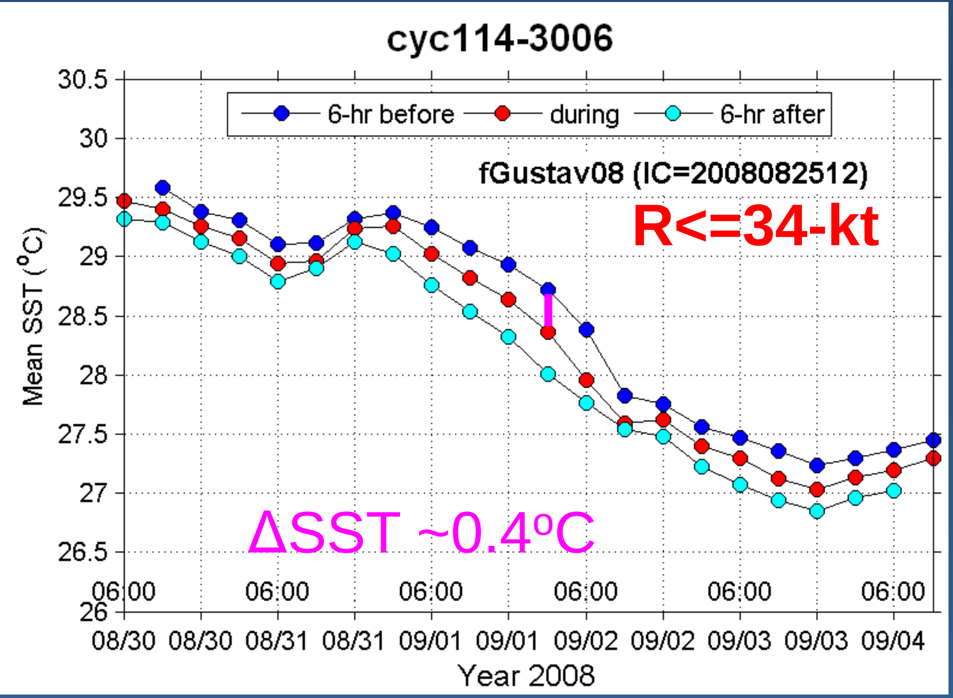
Metrics of Hurricane-Ocean interaction

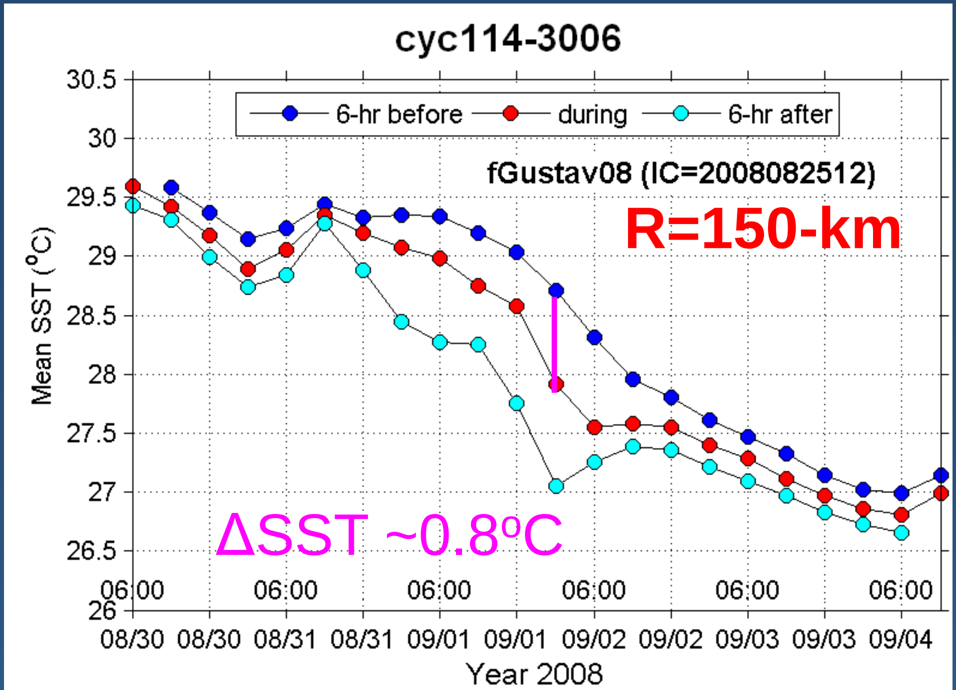
Choice would be:

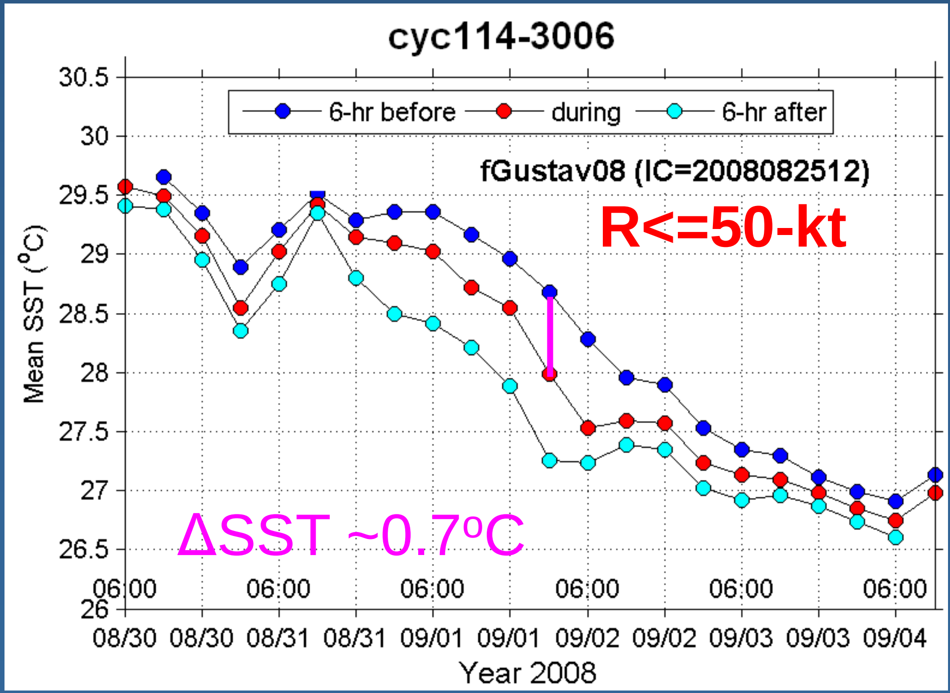
1. a **point** value;
2. an areal **averaged**; or
3. **integrated** value over the footprint of a storm.

Does the ***size*** *of the footprint matter?*

Example 1:



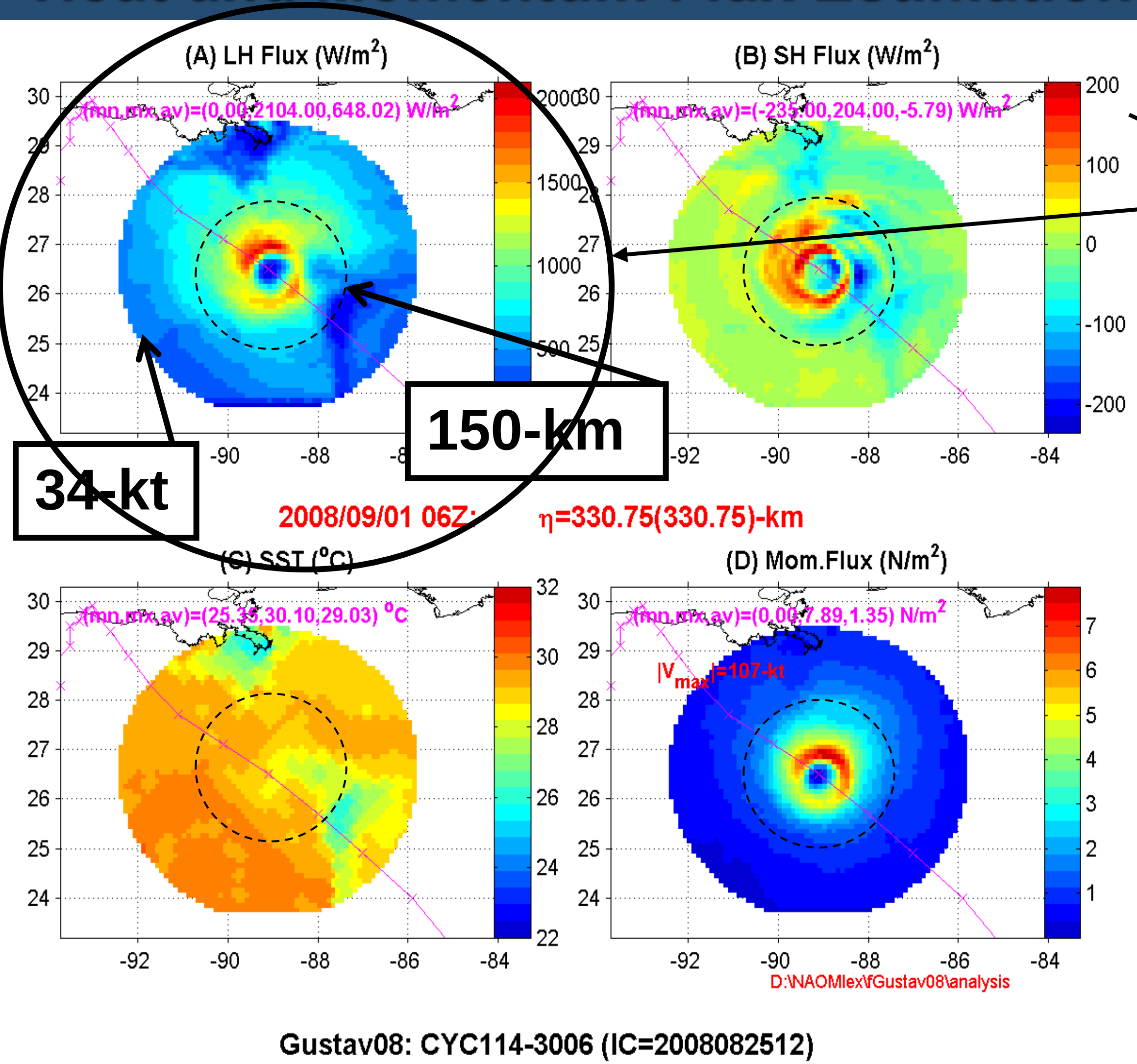




The Size of the footprint matters!

Example 2:

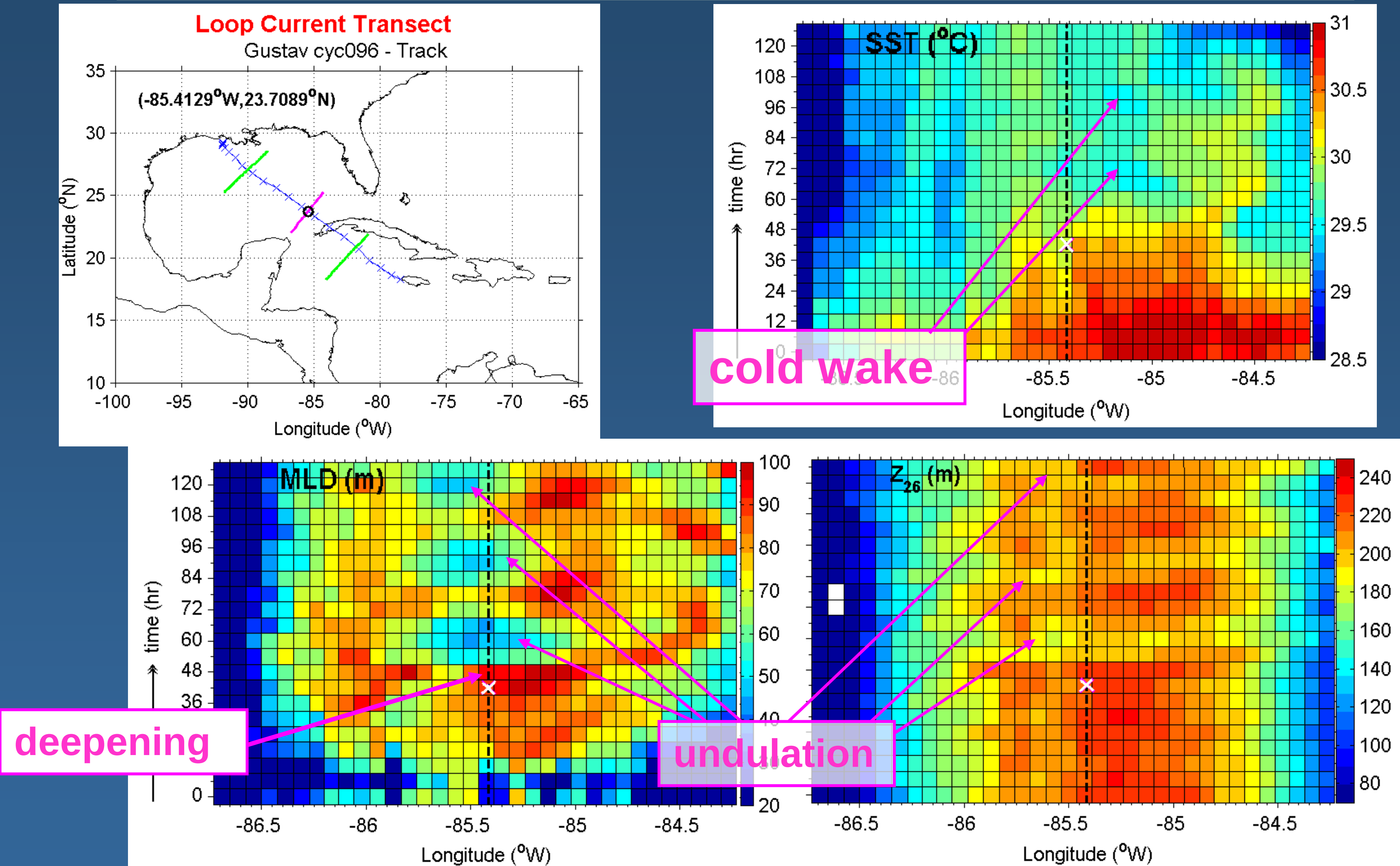
Heat and Momentum Flux Estimation



Latent Heat Flux estimates (W/m²)

M \ S	34-kt	150-km
Point	2,104	2,104
Ave.	648	1,056
Integr.	2.0×10^6	0.7×10^6

SST, MLD and Z26 Change at a Given Transect



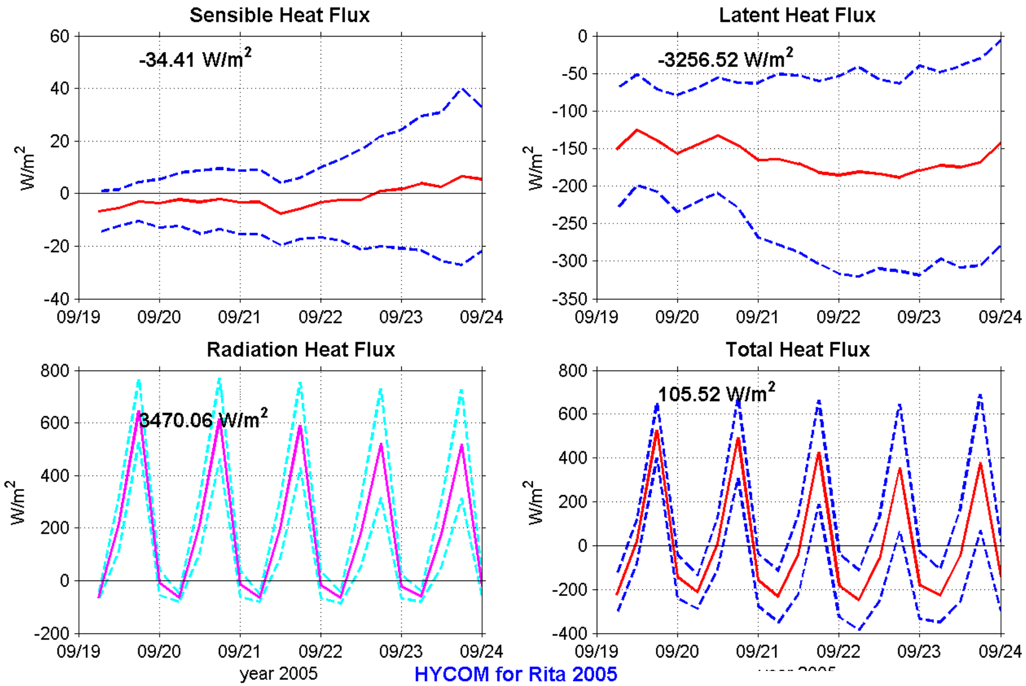
U_T ~ 5 to 4 m/s ➔ L_{6hr} ~108 to 86 km

Matter for the measure of Hurricane-Ocean Interaction:

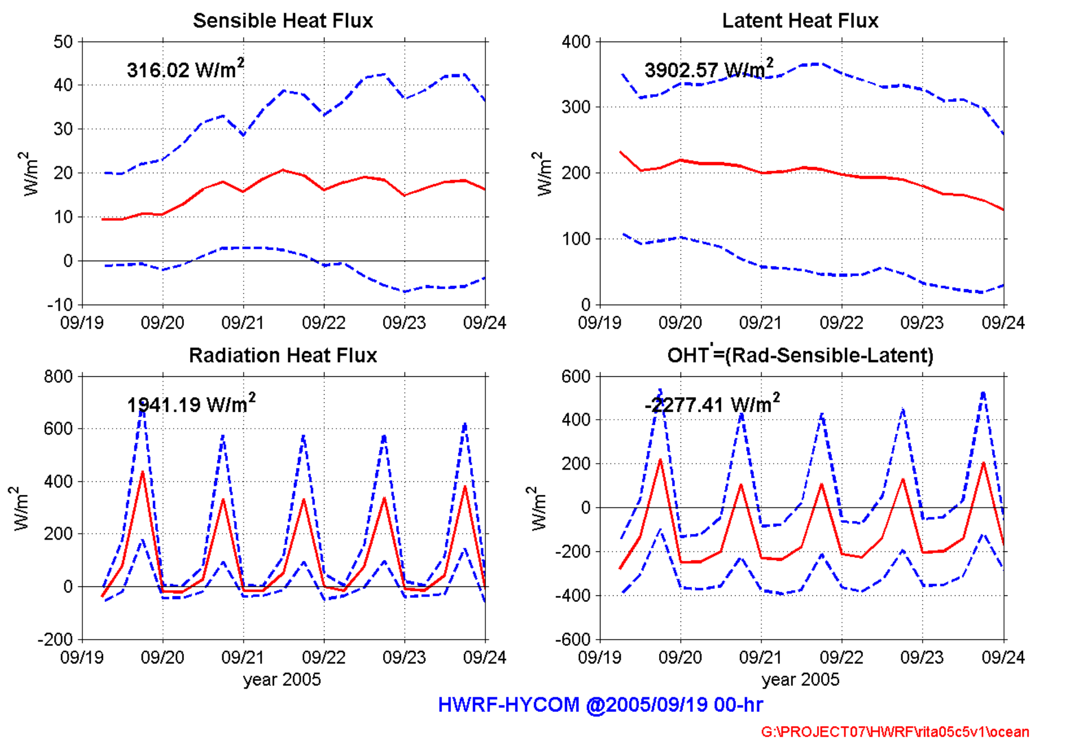
1. Metrics
2. The size of the footprint
3. Asymmetric distribution
4. Definition of Ocean Mixed Layer Depth/Thickness

Heat budget comparison between GFS and HWRF

GFS



HWRF



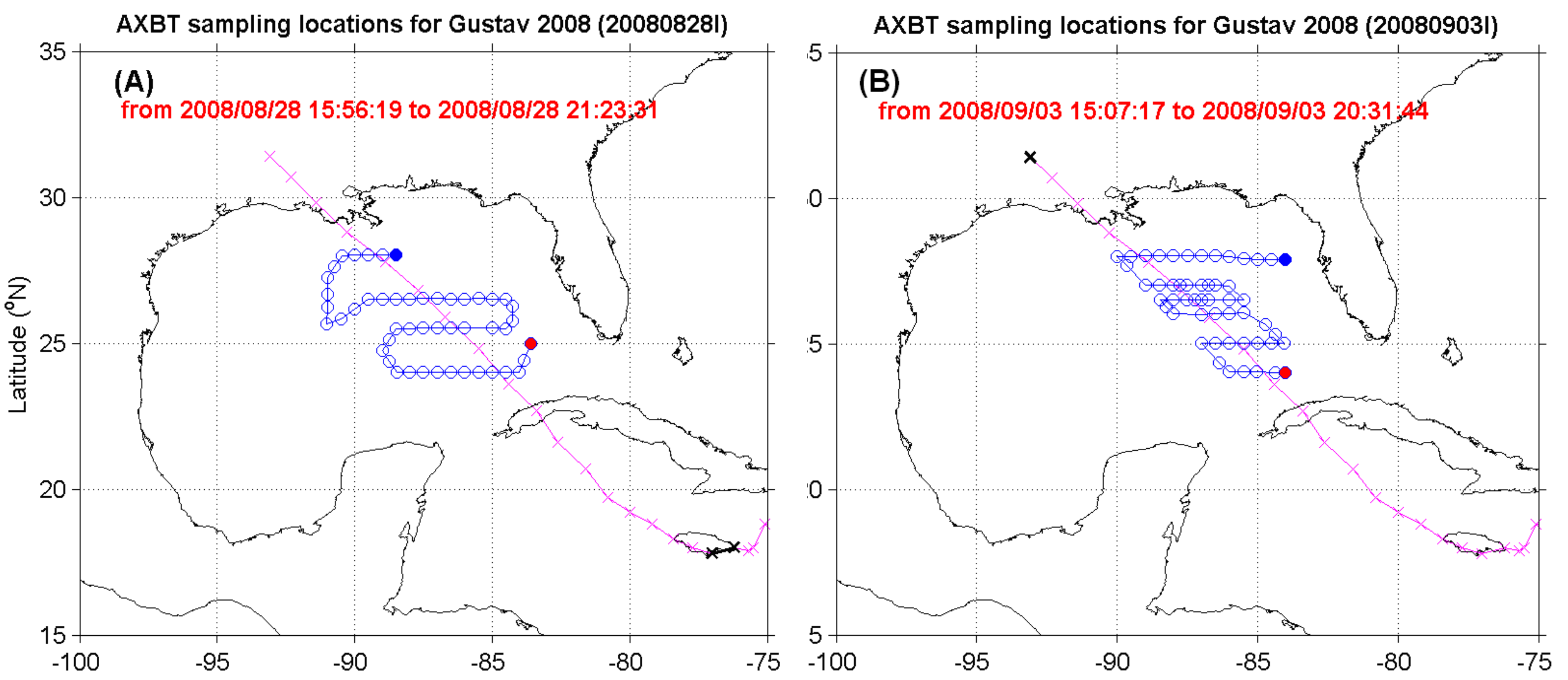
Observations (real-time)

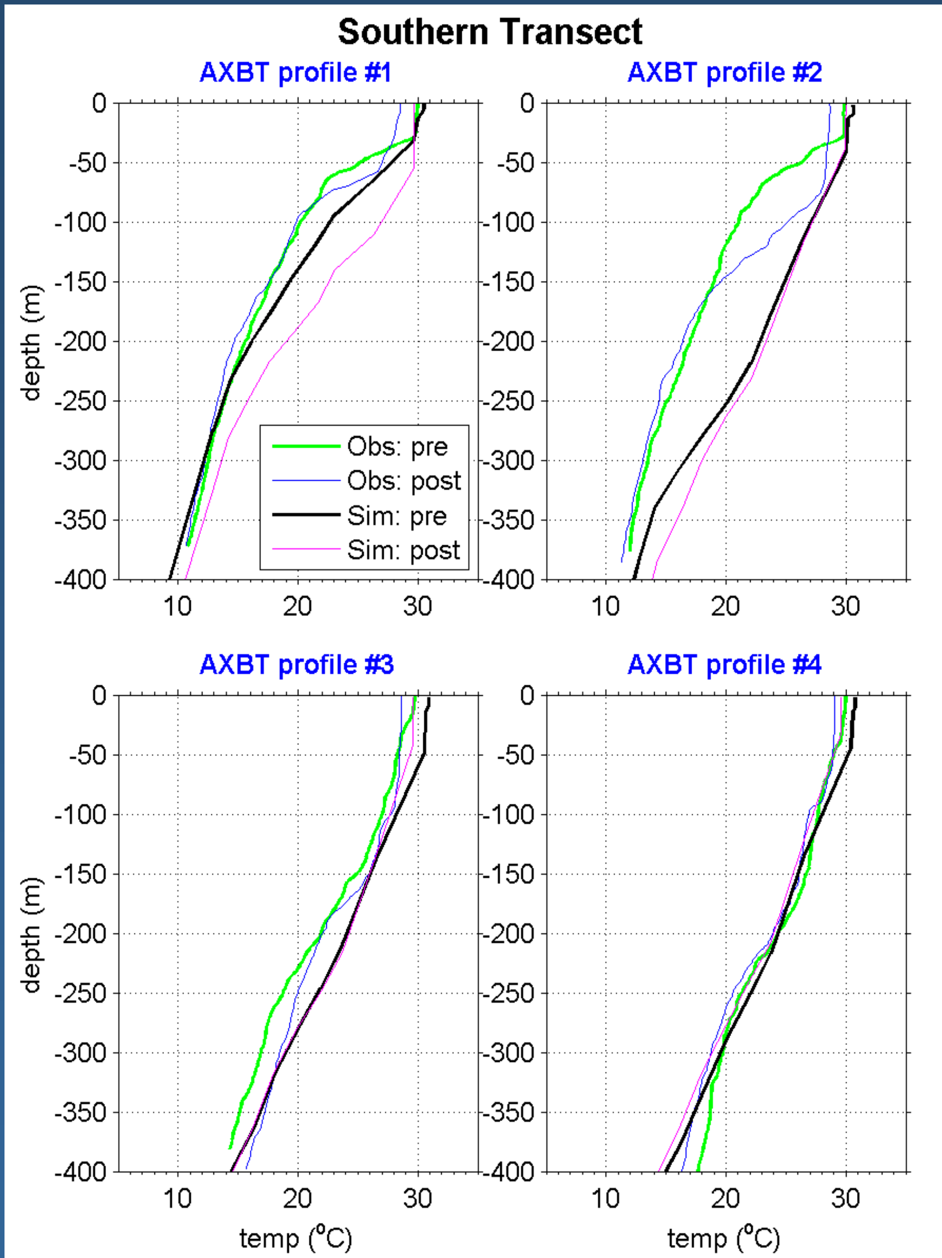
Data assimilation to improve IC – a pipe line set up and improved data assimilation method (real-time data assimilation for 2009 season)

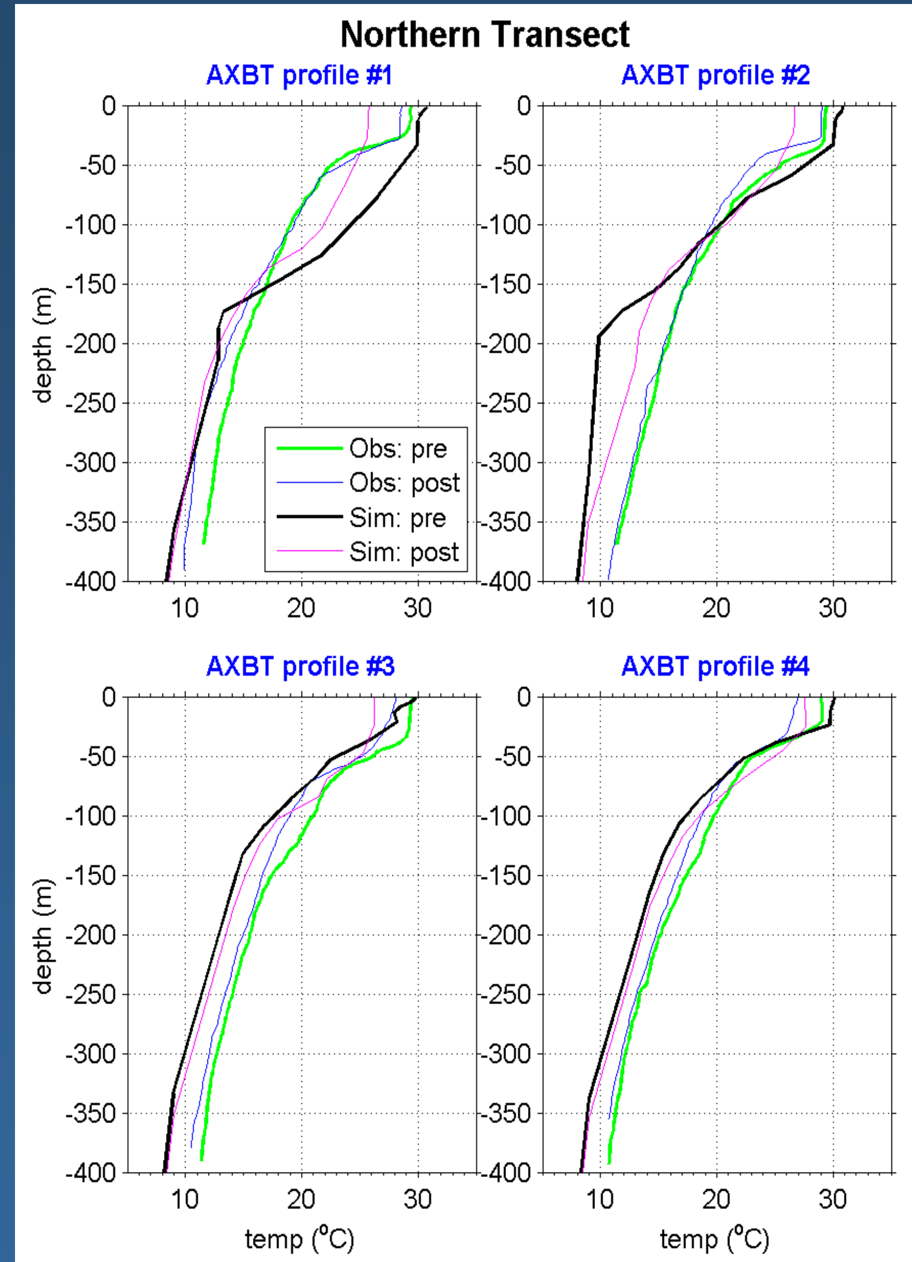
(also Model verification)

AXBT Observations for Gustav

Total 7 Surveys, Including pre- and post-storm samplings.



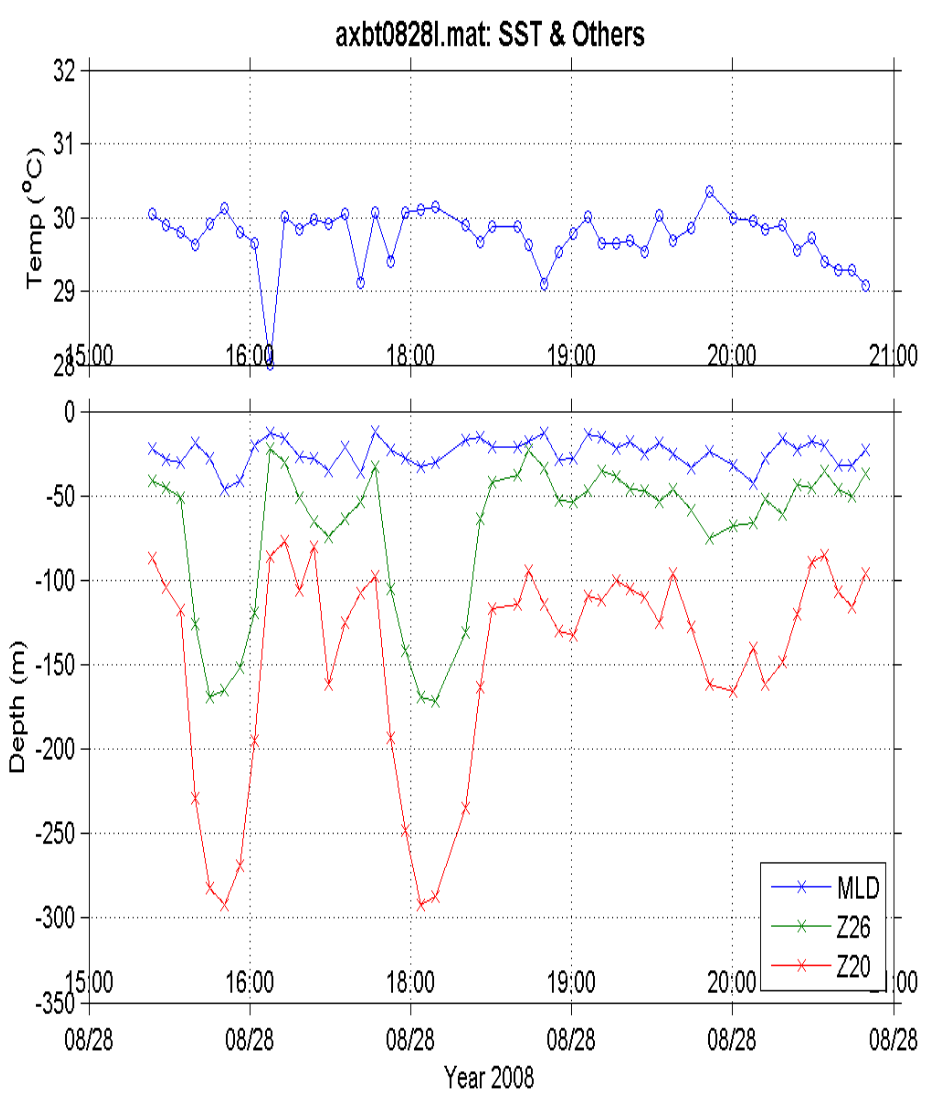




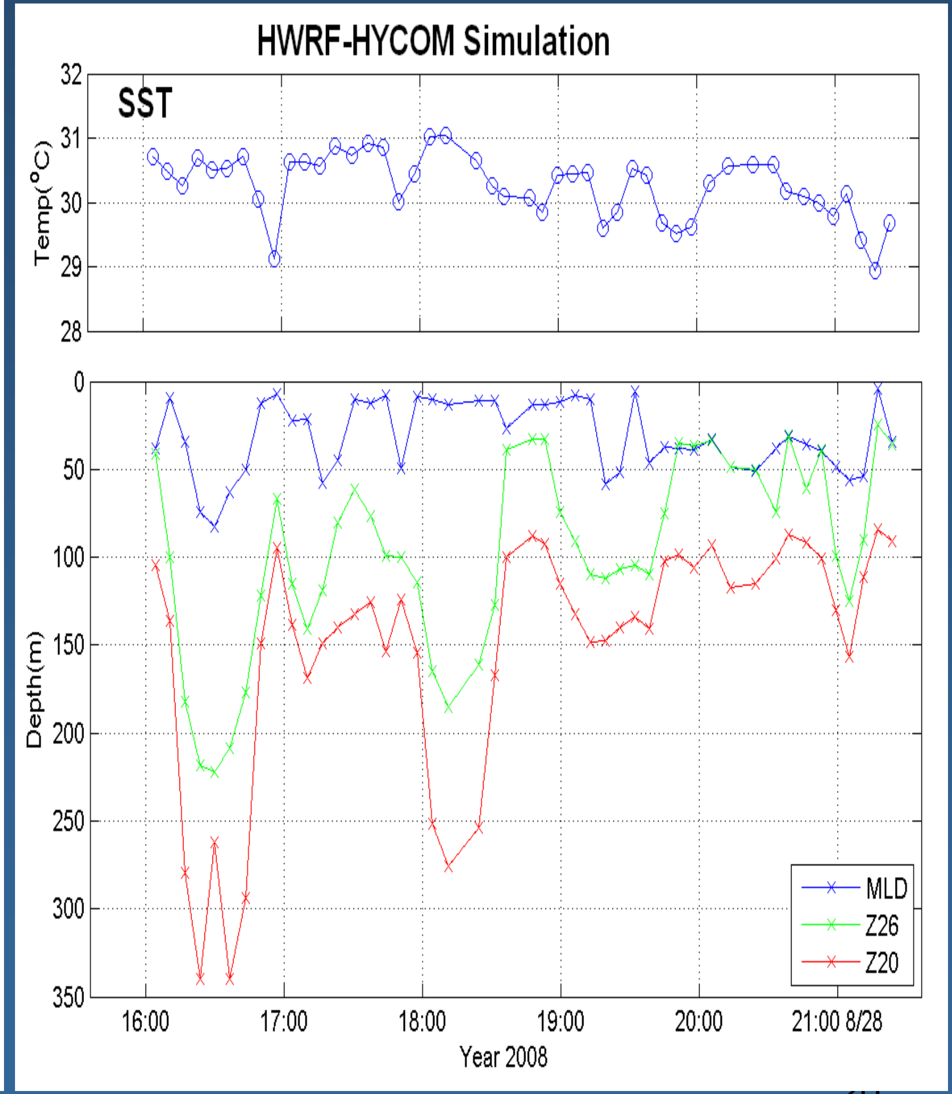
Model verification – Gustav (pre- and post-storm conditions)

Pre-storm survey (Gustav)

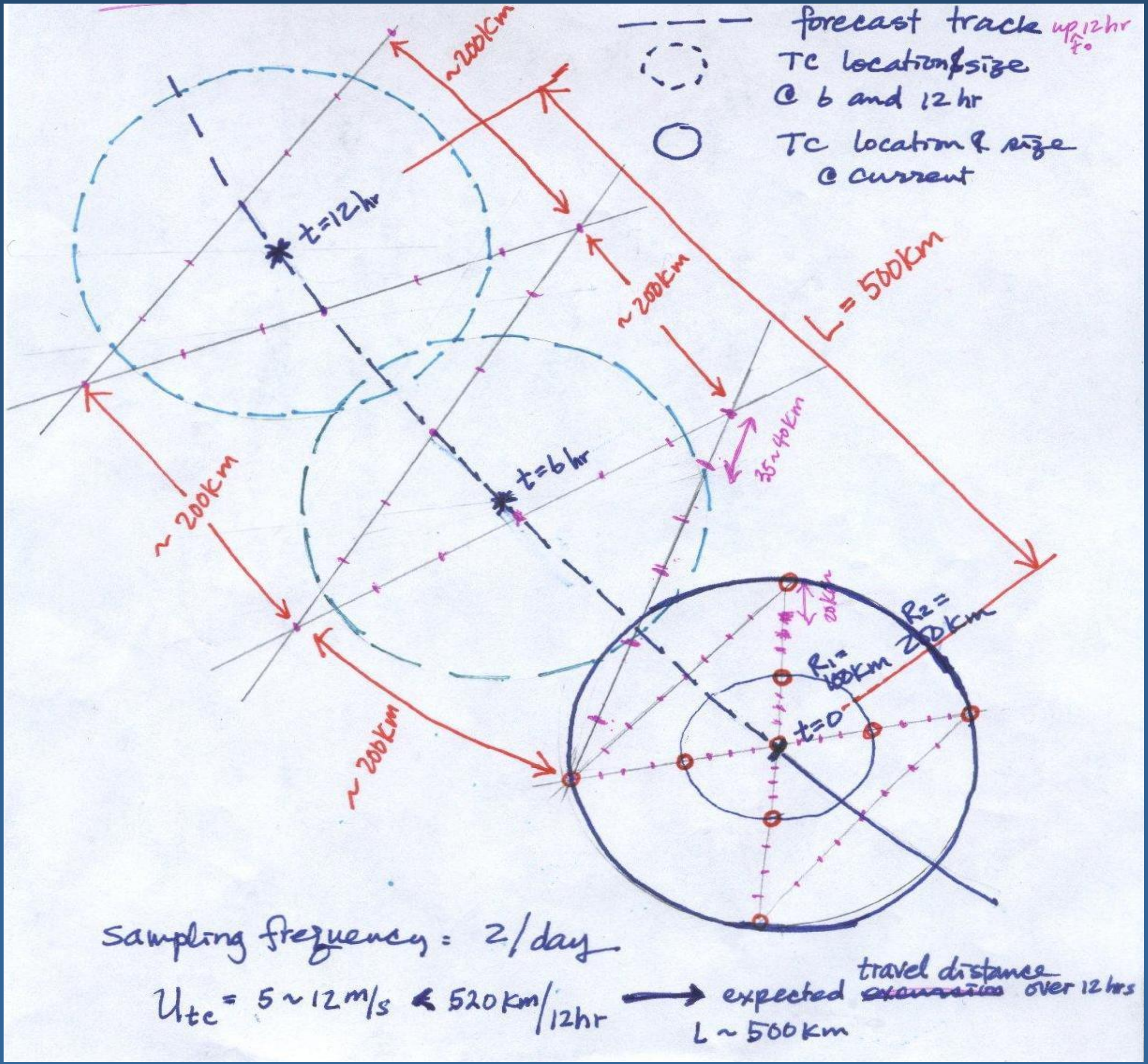
Observation



Simulation



Sampling Strategy



Matter for the measure of Hurricane-Ocean Interaction:

1. Metrics
2. The size of the footprint
3. Asymmetric distribution
4. Definition of Ocean Mixed Layer Depth/Thickness

Sampling Strategy for AXBT, e.g.

MMAB monitoring of Hurricane Ocean Parameters

- Hurricane track and intensity records
- In situ/remotely sensed observations:

  XBT,moorings, CTD, current meters
  SST & Altimeter (analysis)

- Model nowcast and forecast fields of

  a. Sea Surface Temperature
  b. Mixed Layer Depth
  c. Z_{26}

http://polar.ncep.noaa.gov/ofs/hurr/NAOMIex/ocean_parameters.shtml

User protected URL:

Acknowledgement

Eric Ulhorn,

Rick Lumpkin,

Peter Black,

Pearn P. Niiler,

Jan Morzel,

HWRF/EMC team,

HYCOM/EMC team