Applying satellite-derived ocean measurements for tropical cyclone intensity studies and forecasts

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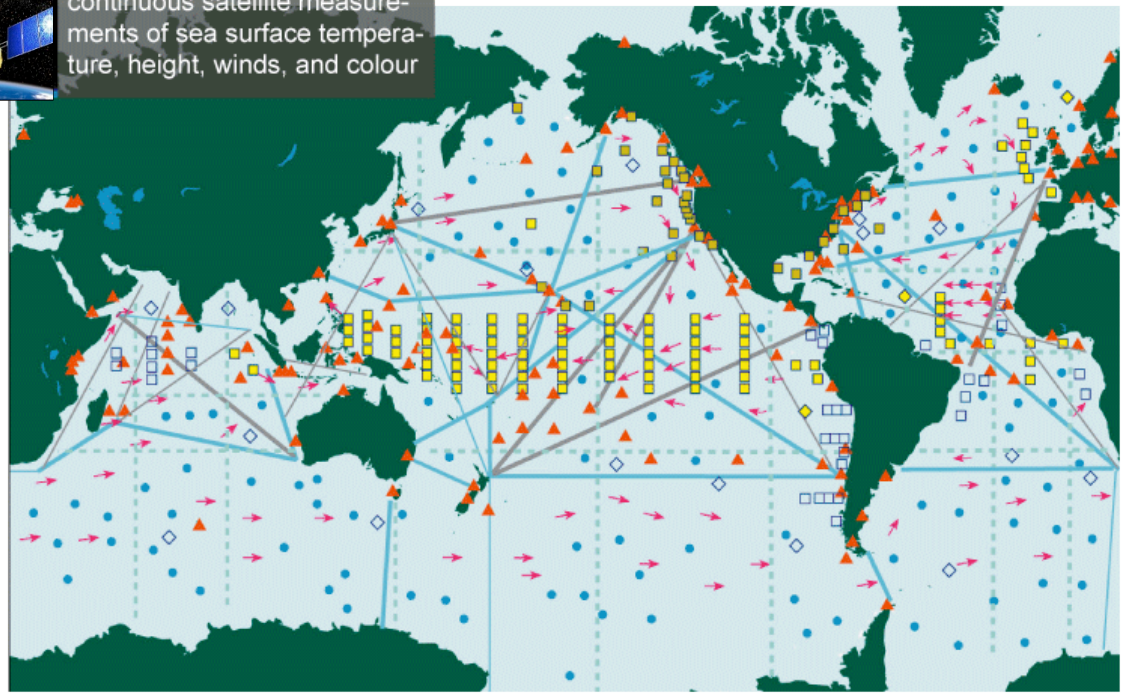
Initial Global Ocean Observing System for Climate

Status against the GCOS Implementation Plan and JCOMM targets

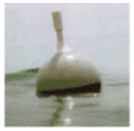
Total *in situ* networks **62%** January 2010

continuous satellite measurements of sea surface temperature, height, winds, and colour



100% **Surface measurements** from volunteer ships (VOSclim)

200 ships in pilot project



100% Global **drifting surface buoy** array

5° resolution array: 1250 floats

59% **Tide gauge** network (GCOS subset of GLOSS core network)

170 real-time reporting gauges

80% **XBT** sub-surface temperature section network

51 lines occupied

100% **Profiling float** network (Argo)

3° resolution array: 3000 floats

62% Repeat **hydrography** and **carbon inventory**

Full ocean survey in 10 years

Reference time series 48%

58 sites

34% Global **reference mooring** network

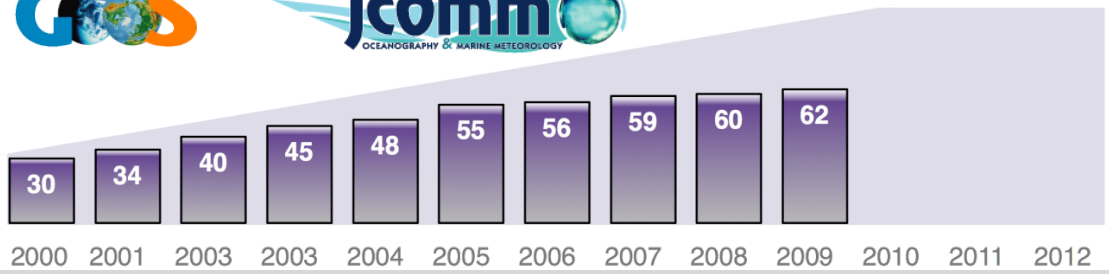
29 moorings planned

73% Global tropical **moored buoy** network

119 moorings planned

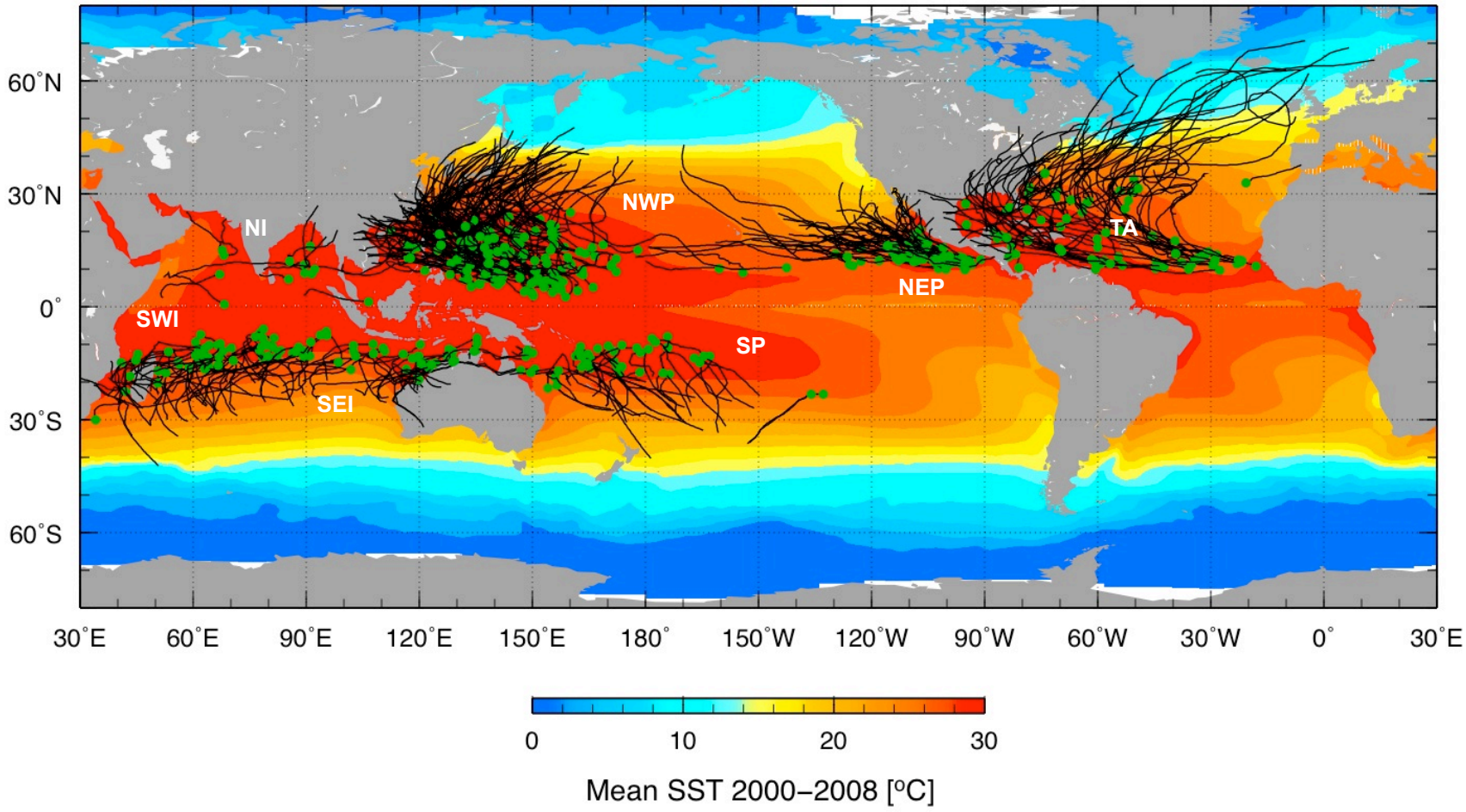
GCOS GOOS jcomm

System % complete



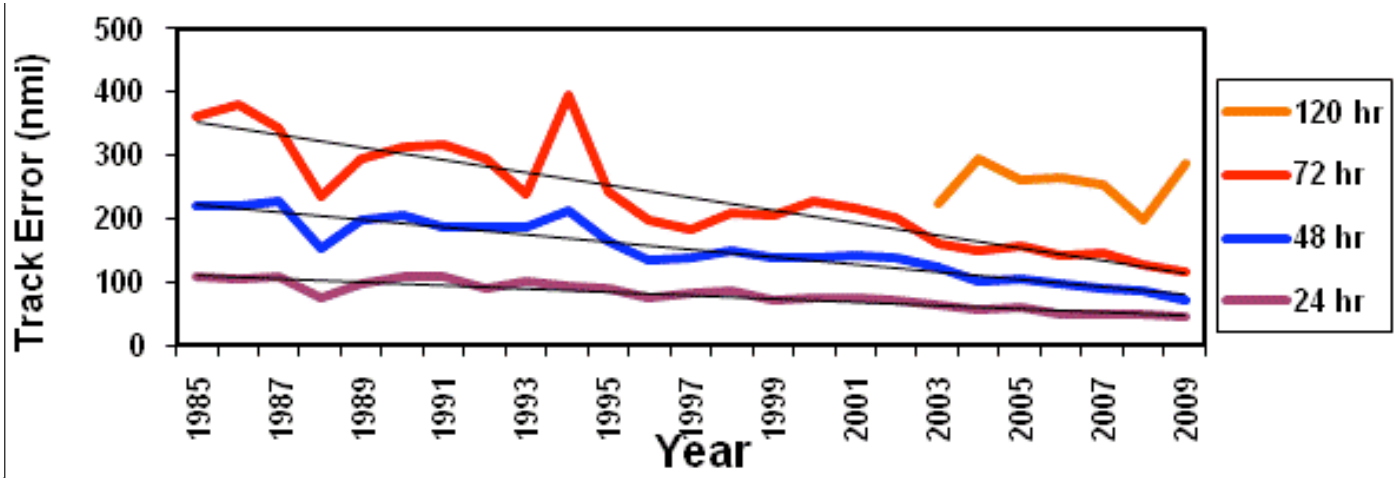
Original goal: Full implementation in 2010

Tropical cyclone basins genesis and SSTs

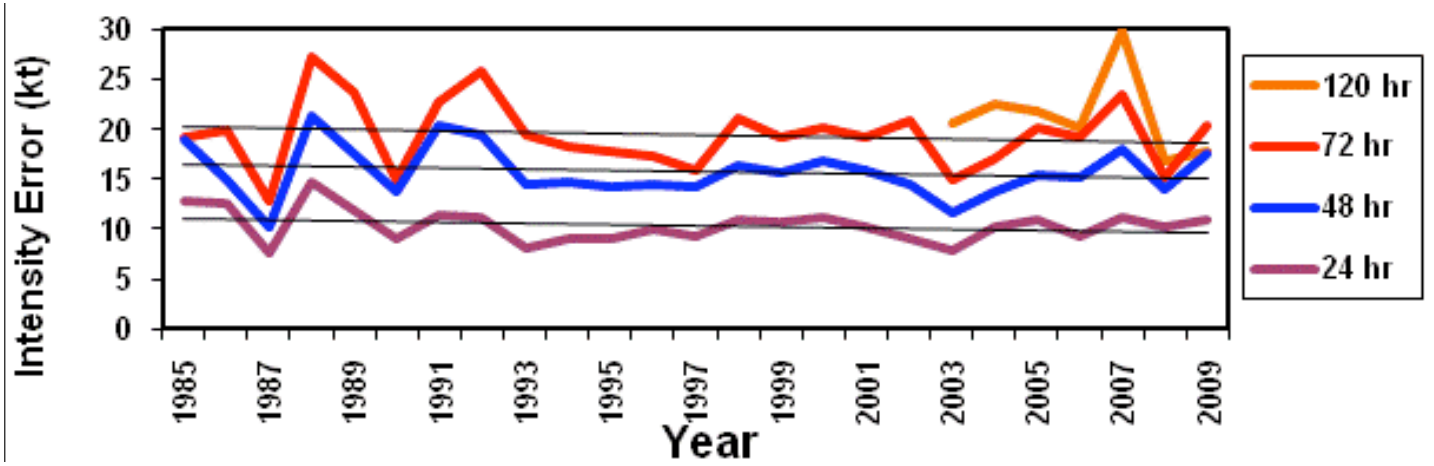


Goni et al 2009

Error reduction in TC track and intensity forecast Tropical Atlantic Ocean



48 hr track – 3.7% improvement per year

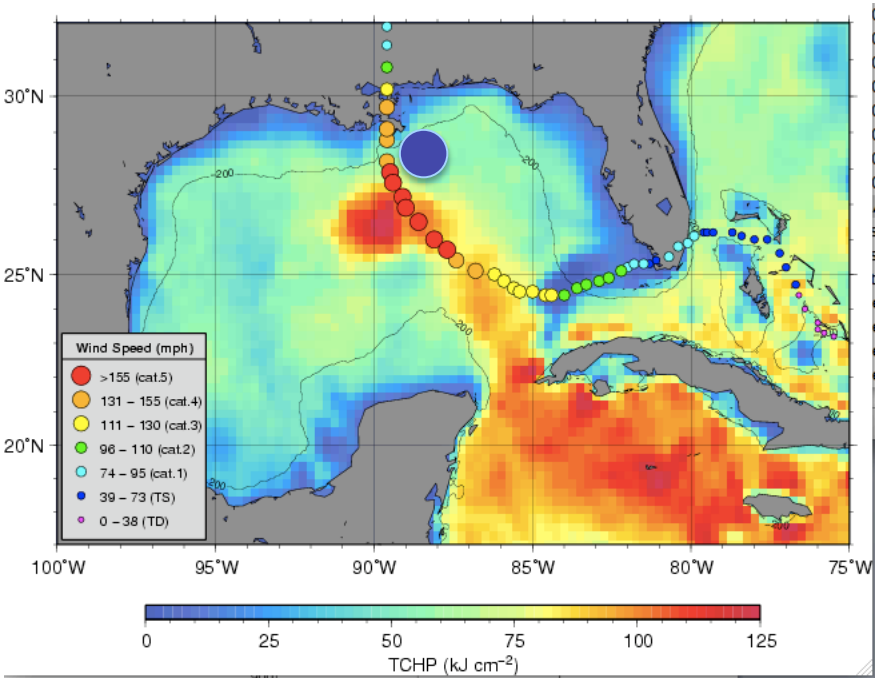


48 hr intensity 0.6% improvement per year

DeMaria, 2010

What studies in the tropical Atlantic have taught us

Mesoscale features and upper ocean thermal structure



Mainelli et al, 2008
Goni et al, 2009

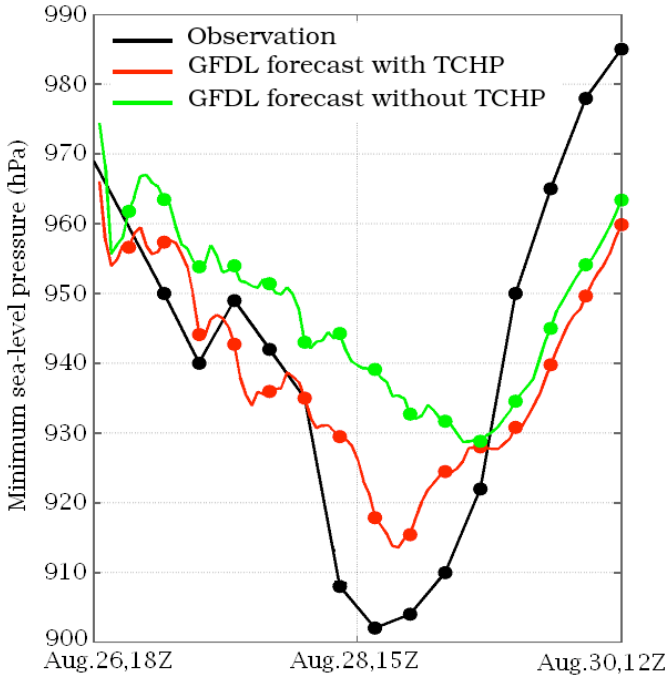
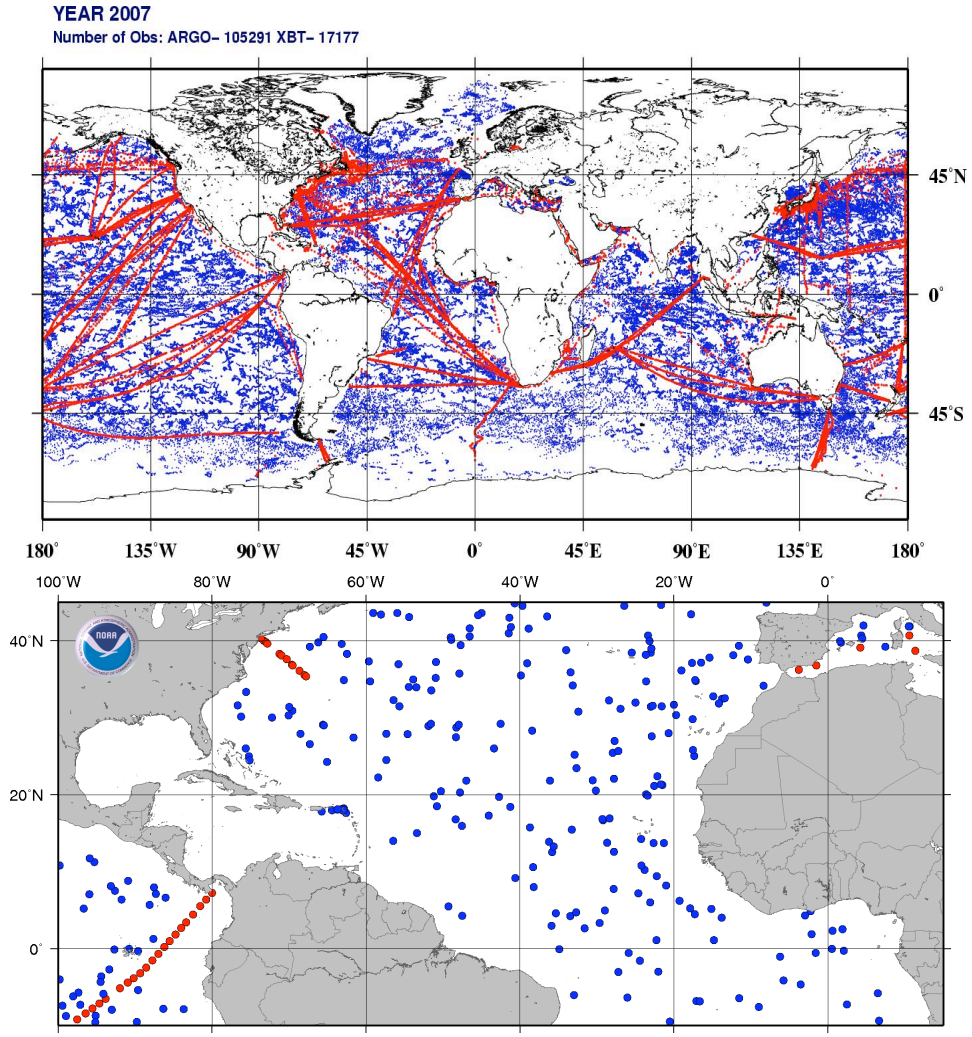


Figure by I. Ginis
Goni et al, 2009

→Realistic detection of mesoscale features

→ Realistic monitoring of vertical thermal structure

Sustained ocean observations: Argo floats and XBTs



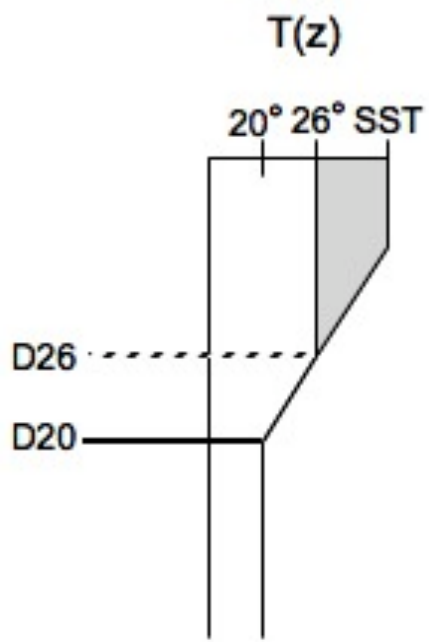
→ Cannot resolve mesoscale features

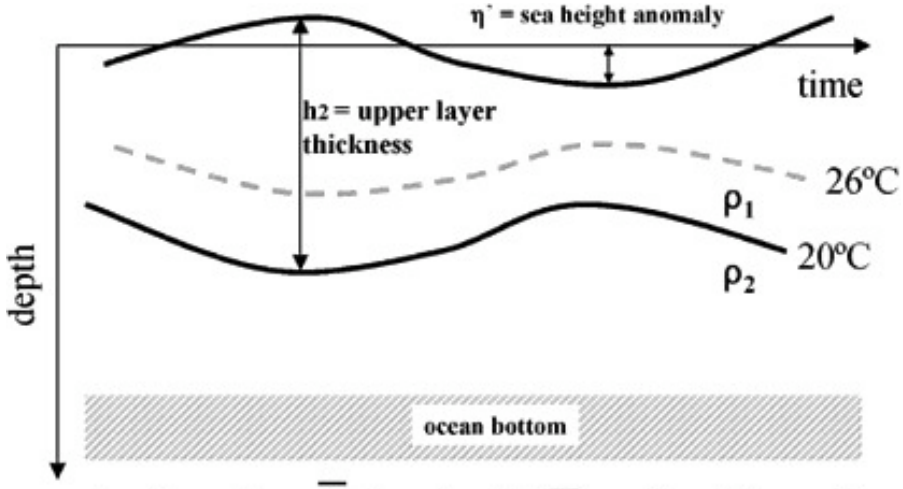
Tropical Cyclone Heat Potential (TCHP)

Hurricane Heat Potential (HHP), Ocean Heat Content (OHC)

www.aoml.noaa.gov/phod/cyclone

$$\mathrm{OHC} = c_p \int_0^{D26} \rho \left[T(z) - 26 \right] \, dz,$$

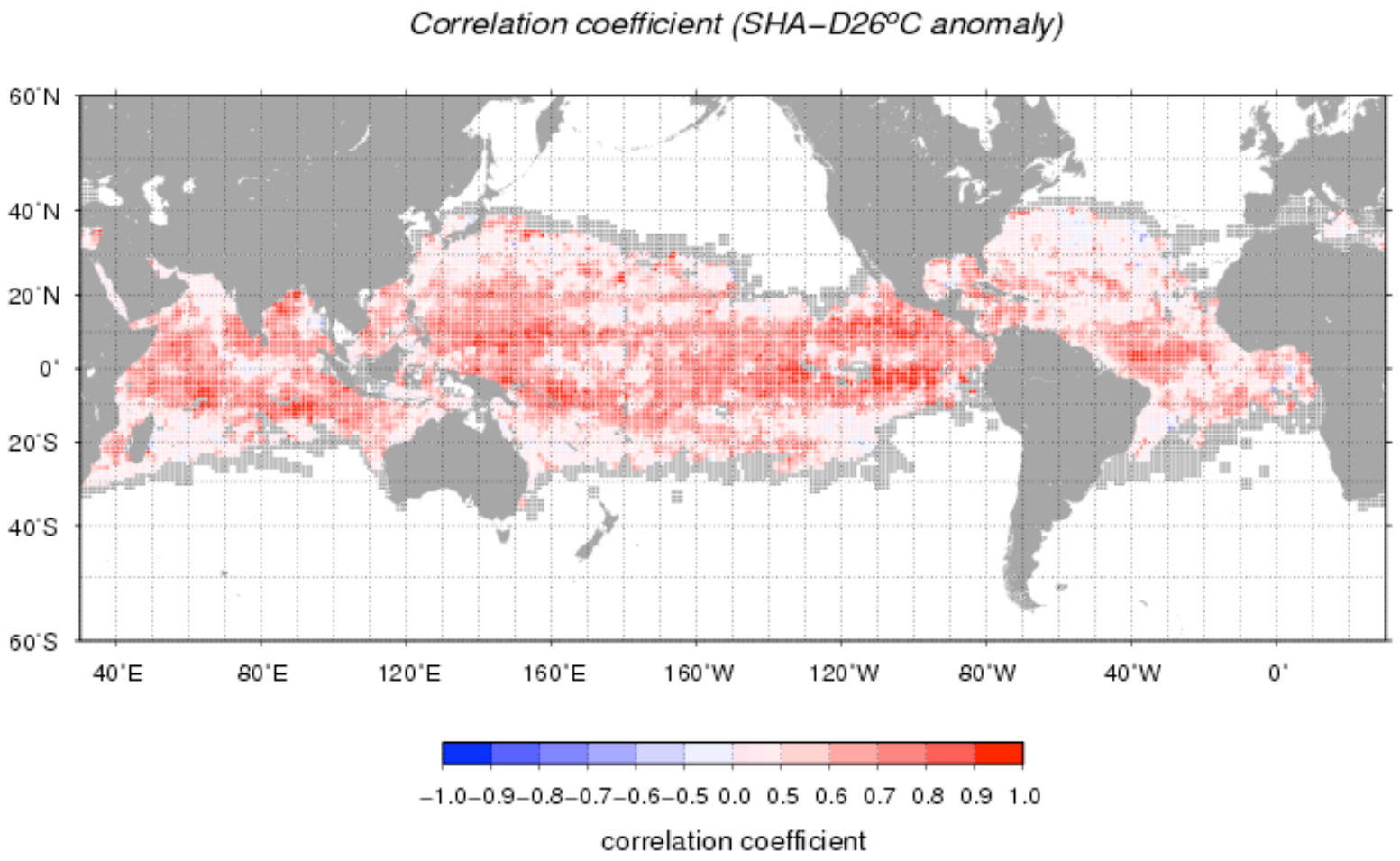




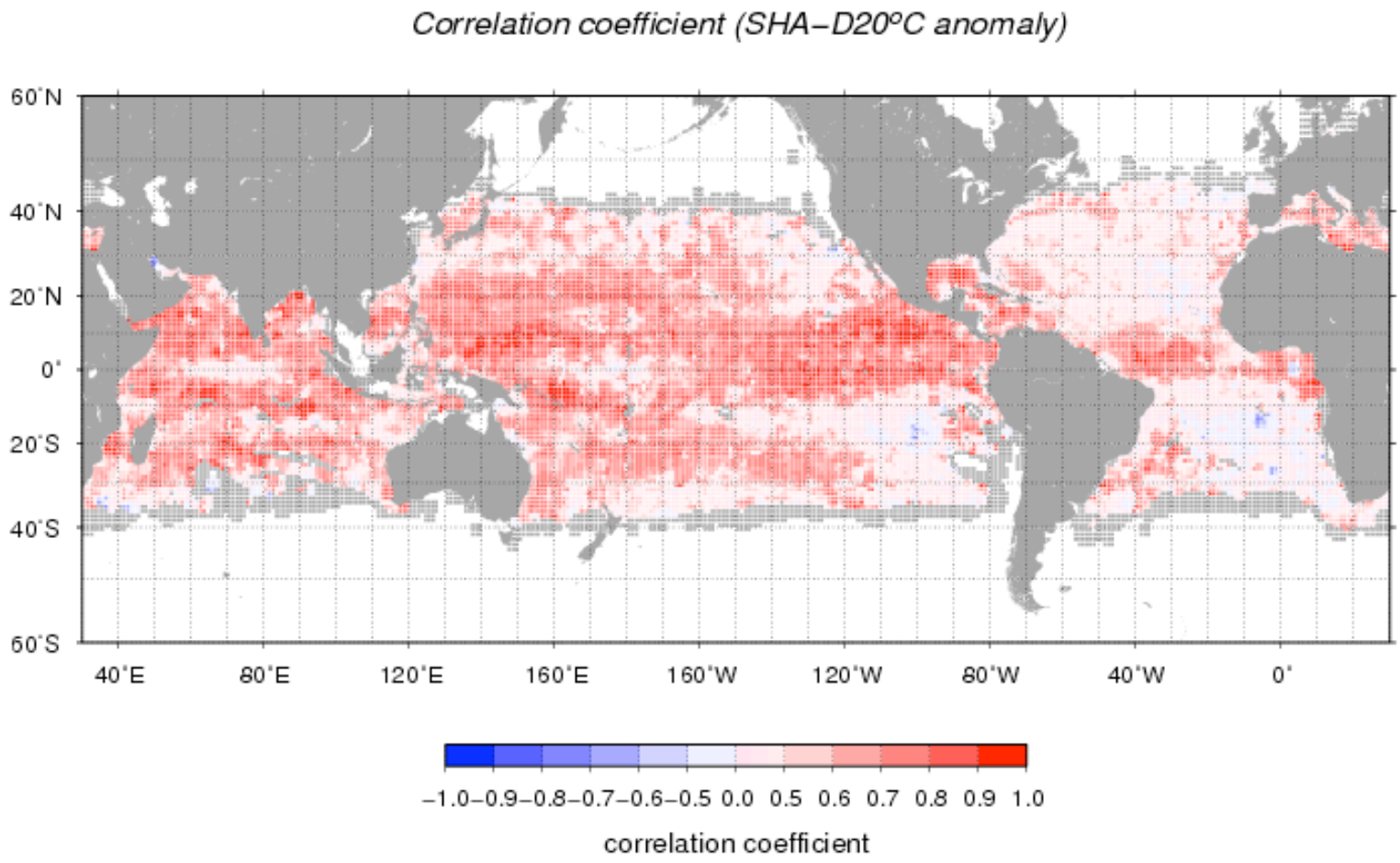
$$h_2(x,y,t) = \overline{h}_2(x,y) + [1/\overline{\epsilon}(x,y)]\ \eta'(x,y,t)$$

$$\overline{\epsilon}(x,y) = [\overline{\rho}_2(x,y) - \overline{\rho}_1(x,y)] \,/\, \overline{\rho}_2(x,y)$$

Depth of 26°C isotherm and sea height



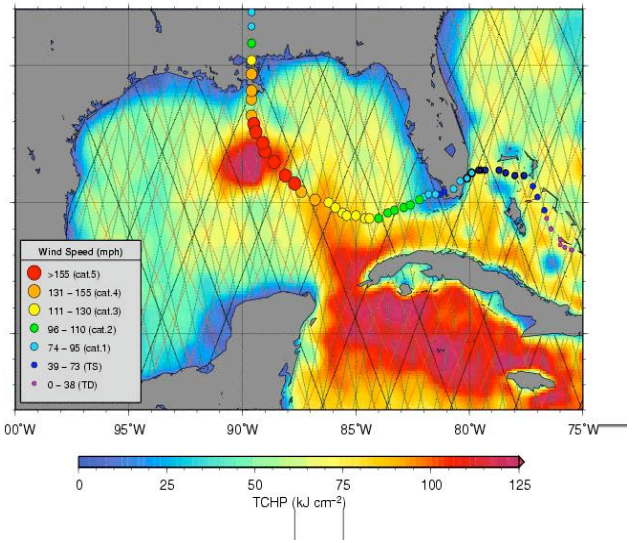
Depth of 20°C isotherm and sea height

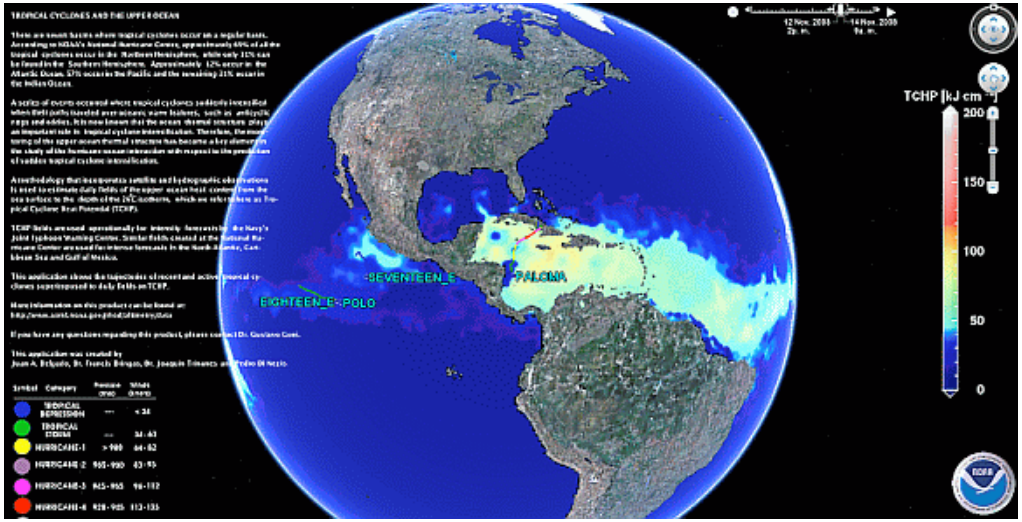


Tropical Cyclone Heat Potential (TCHP)

Hurricane Heat Potential (HHP), Ocean Heat Content (OHC)

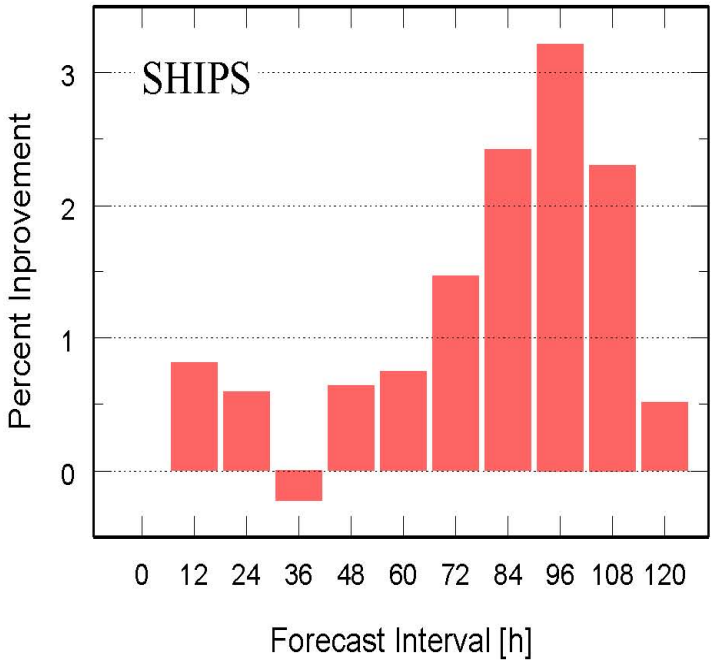
Data distribution:
www.aoml.noaa.gov/phod/cyclone

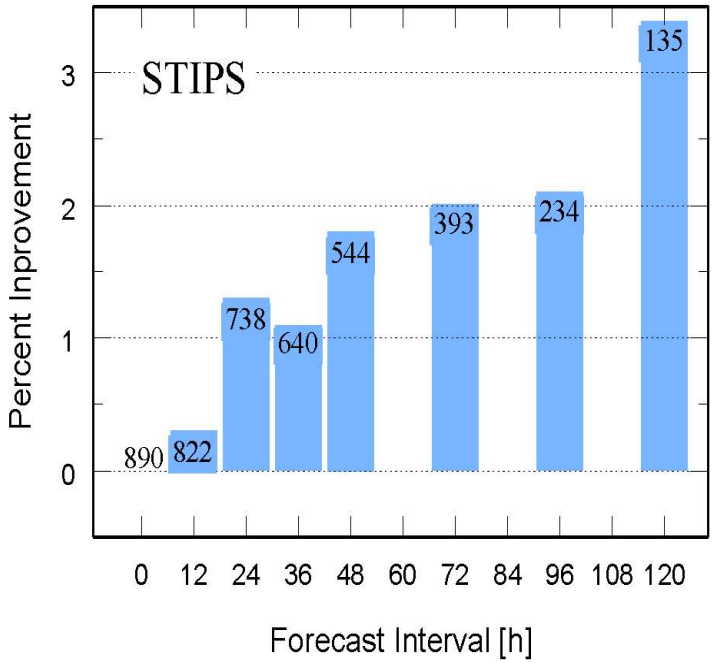




Upper ocean thermal structure in individual TC forecasts:

Mean results for the Atlantic (SHIPS) and the NE Pacific (STIPS)

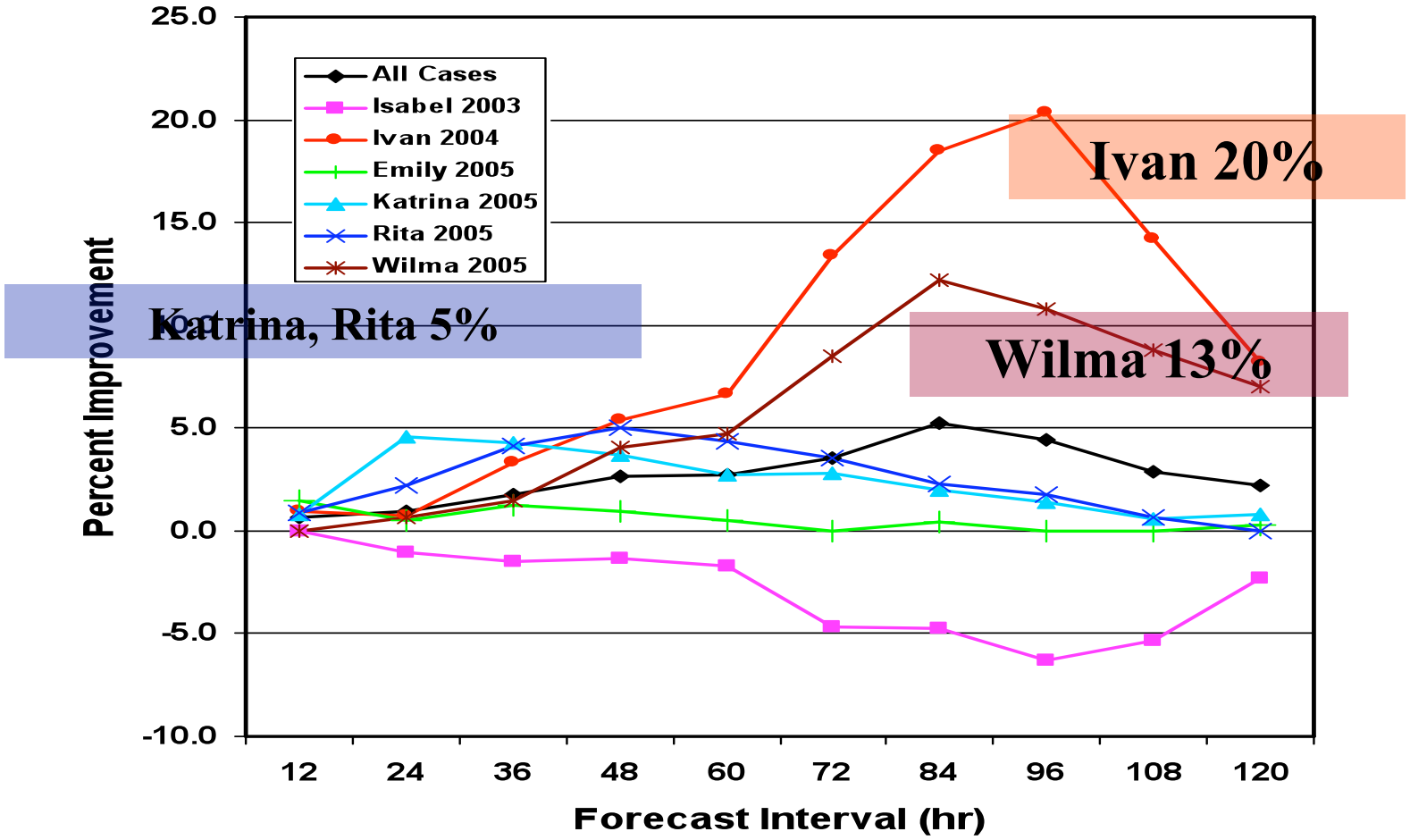




Is this really a good improvement ?

Goni et al, 2009

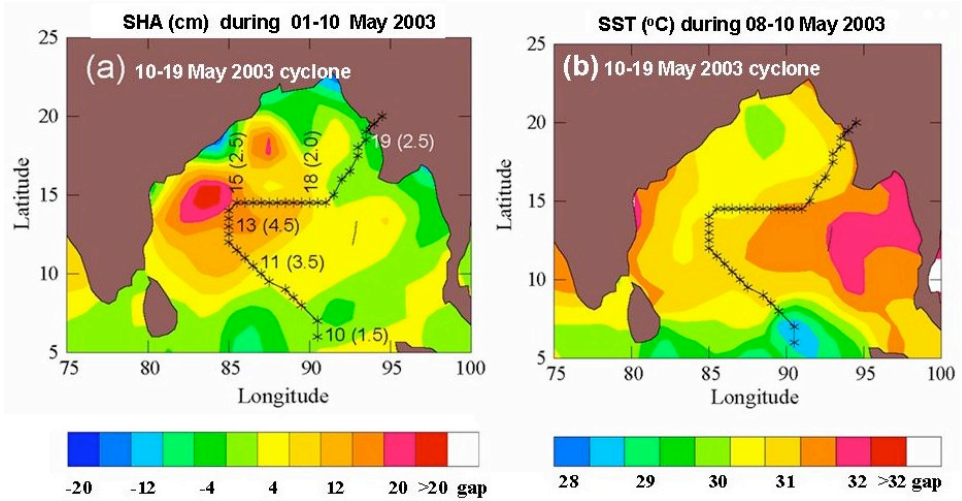
Upper ocean thermal structure
And individual TC forecasts

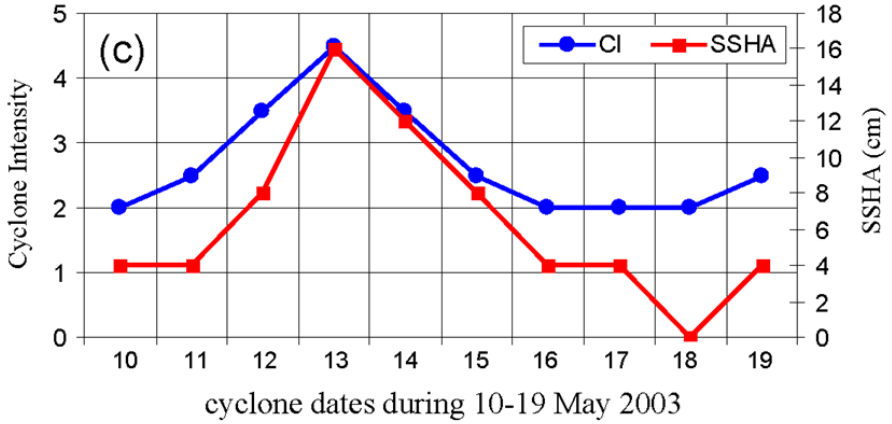


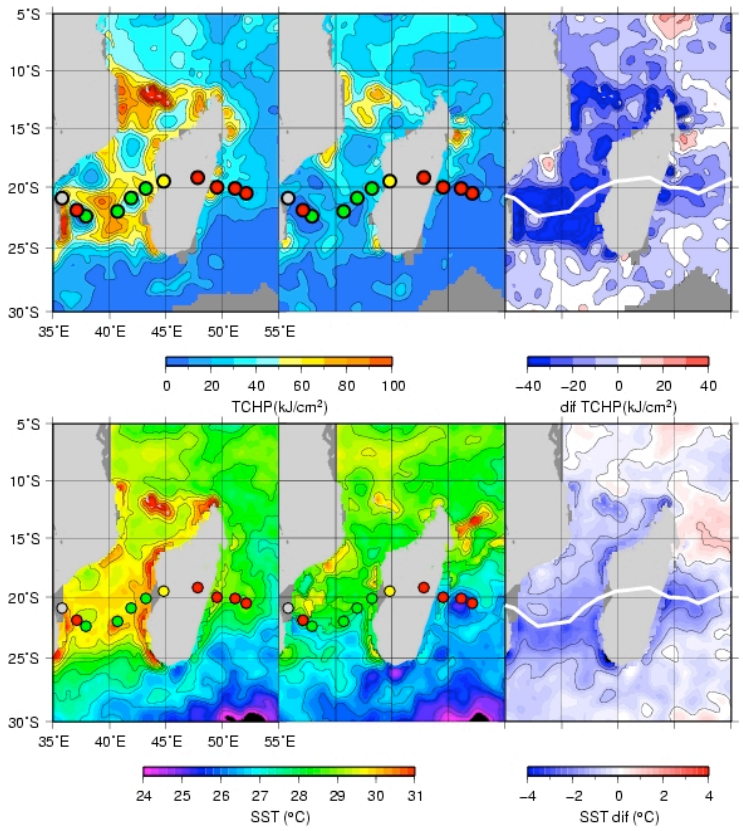
Maineli et al, 2008

Upper ocean thermal structure in individual TCs

Indian Ocean







Goni et al, 2010

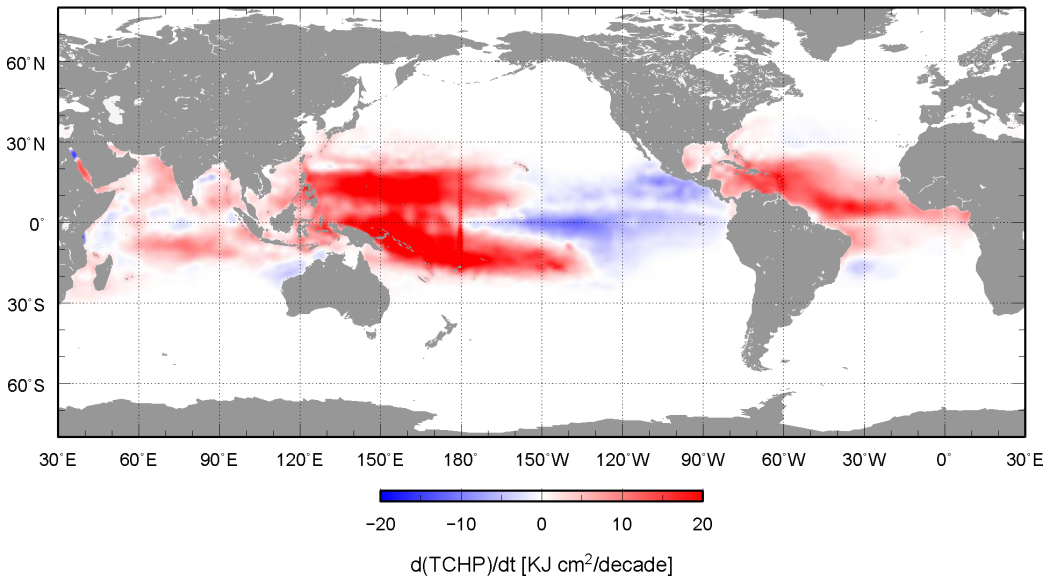
Figure by M.M. Ali
Goni et al, 2009

Current efforts in different basins

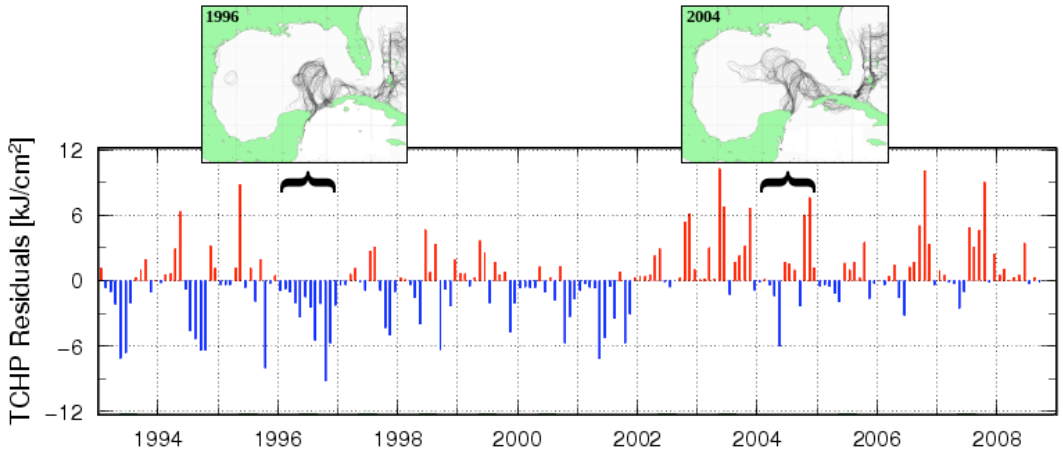
basin	agency	effort	mode
Atlantic	NOAA/NWS	SHIPS (statistical)	operational/research
	NOAA/GFDL	HYCOM + HWRF	research
	NOAA/NCEP	HYCOM + HWRF	operational
	U Miami and NOAA	HYCOM + HWRF	research
	NOAA	Ocean TCHP	To operational/analysis
	Mercator	Global upper ocean forecast	operational
NW Pac.	Nat. Taiwan Univ.	Ocean TCHP	Research/analysis
NE Pac.	US Navy and NOAA	STIPS (statistical)	operational
N Indian	Nat. Remote Sensing Center	Upper ocean monitoring	research/analysis
SW Pac. SW Indian	BOM	CLAM/blue Link	Operational Ocean
		TCLAPS	Research/analysis
SE Indian	UCP and NOAA	TCHP	research/analysis

Adapted from a more complete table from Goni et al, 2010; some current efforts may be incomplete and/or missing

Tropical Cyclone Heat Potential (non-secular) Trends (1993-2008)



Goni et al, 2009



Goni et al, 2009

Sustained *global* ocean observing system for TC intensification studies and forecasts

The current system was not designed for this type of studies.

1) An ocean observing system able to resolve mesoscale features

2) An ocean observing system able to resolve their vertical thermal structure.

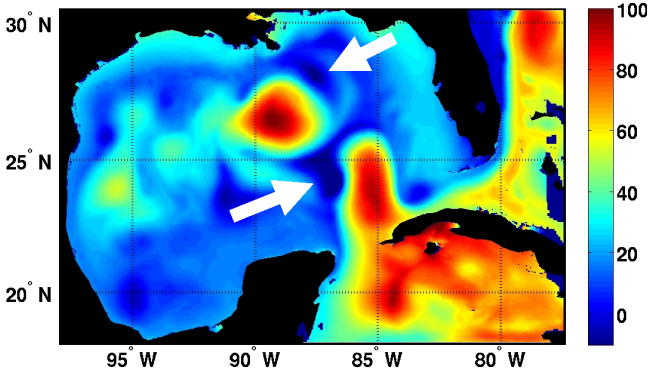
*** Implementing such a system could be impossible.**

3) From what is already in place, satellite altimetry appears to be the most adequate tool, since resolve mesoscale and since the parameter that measures is linked to the upper ocean thermal structure.

*** In situ systems continue to play a critical role in process studies, to assimilate in numerical models, and to validate model outputs.**

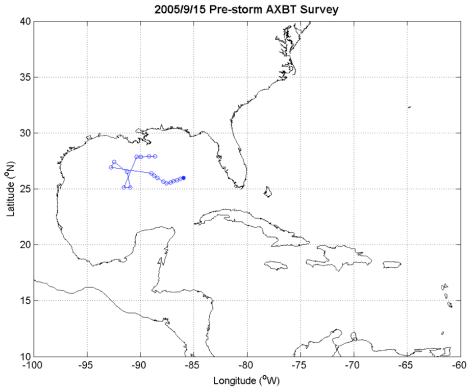
→ Is TCHP this the right ocean parameter ?

One modeling effort (HYCOM-HWRF) NOAA/AOML and NCEP

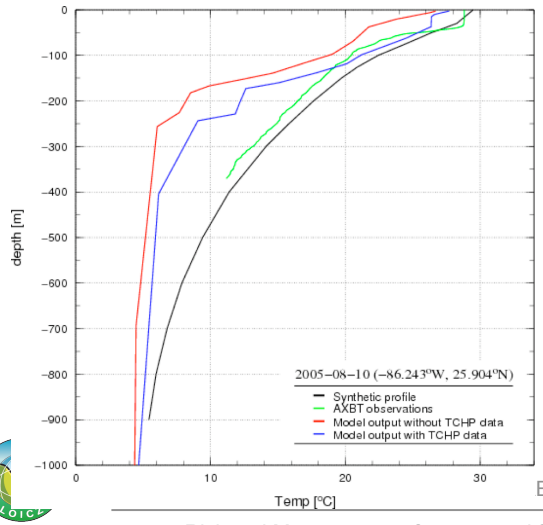


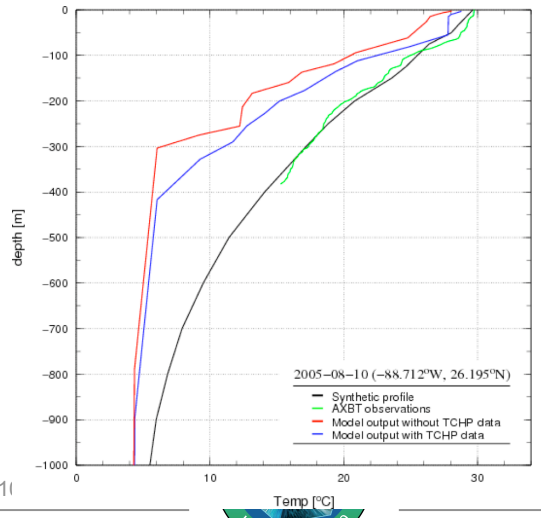
Goni et al, 2009

The features are approximately right, but the vertical thermal structure needs improvement.



AXBT survey pre-hurricane Rita (AUG 2005)





Green = AXBT
Black = altimetry
Red and blue = HYCOM

HYCOM has a colder ocean in the GOM.

Figures by Avichal Mehra

Ocean Obs'99 Recommendations

THE OCEAN OBSERVING SYSTEM FOR TROPICAL CYCLONE INTENSIFICATION FORECASTS AND STUDIES

Gustavo Goni [1], Mark DeMaria [2], John Knaff [2], Charles Sampson[3], James Price[4], Avichal Mehra[5], Isaac Ginis[6], I-I Lin [7], Paul Sandery [8], Silvana Ramos-Buarque [9], M. M. Ali[10], Francis Bringas[11], Sim Aberson[1], Rick Lumpkin[1], George Halliwell[1], Chris Lauer[12], Eric Chassignet[13], Alberto Mavume[14], K. Kang[15]

1) Continue and support the international efforts to evaluate the role that the ocean plays in tropical cyclone intensification,

2) Support the creation and maintenance of an in-situ component of the ocean observing system, which is a complement to the current system, able to resolve mesoscale features and their upper ocean thermal structure for tropical cyclone intensification studies,

3) Support operational altimetry with a suit of satellites able to resolve mesoscale features,

4) Carry out upper ocean observations from airborne platforms, such as AXBTs and AXCTDs, before and after the passage of tropical cyclones,

Ocean Obs'99 Recommendations

6) Support new observations of other ocean parameters, such as salinity, to improve estimates of mixed layer depth properties,

7) Encourage the transmission of all observations into real-time data bases to allow immediate access to these data,

8) Support the validation efforts and improvement of ocean models that are used in TC studies,

9) Initiate an ocean Observing System Simulation Experiment, to optimize the observations made for TC studies and forecasts, and

10) Continue the strong presence of scientific presentations at international meetings and workshops.

Take Home Message

• Some sustained ocean observations performed for climate are adequate to investigate the link of TC intensification and the ocean.

•The only current *global* observations useful for TC intensity forecasts come from satellites, mainly altimetry.

• For TC intensity studies there is a wide range of observations available for process studies, including process studies using AXBTs, dropsondes, etc.

• Improvement in our understanding the physics of air-sea interaction in extreme weather events will be critical.

• International collaboration is key to advance in our understanding of the problematic in each region where TCs occu