HYCOM and WAVEWATCH III ® for advancing hurricane guidance

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Overview

- Why coupling?
- Why HYCOM
- Why WAVEWATCH III.
- Progress at NCEP
  - HYCOM - HWRF.
  - HYCOM – WAVEWATCH III - HWRF.
- Computational costs.
- Risks.
- Outlook.

Why coupling

See many of the other presentations at this workshop !

Not just for hurricane guidance !

- Weather-ocean coupling proven concept:
  - Hurricanes (starting with GFDL-POM coupling).
  - Seasonal forecasting.
- Also potential benefit for many of other models.
  - Ocean circulation, waves, inundation (salt + fresh water), ecosystems, ….
  - NCEP, NOS, OAR, OHD, ….
  - Navy, USACE, USGS, ….

Why coupling

Wind waves are at the center of many of the physical processes at the water-air interface.

- Impact all fluxes, fluxes linked through sea spray.
- Waves as direct source to TKE in air and water.
- Non-local momentum transfer from atmosphere to ocean.
- Forcing inside boundary layers, not only at the interface.

This is not new:

- Decade of experience with impact on surface stresses for weather modeling (ECMWF).
- Decades of experience with impact of currents on waves.
- Decades of experience with wave-surge and wave-circulation linkage

GFDL-POM and HWRF-POM are proven systems. Why transition to HYCOM?

- Scientific / technical issues:
  - Use operational RTOFS-Atlantic model for IC and BC:
    - Realistic real-time ocean (previous TCs).
  - Full ocean model:
    - Separate support community.
    - Solid base for physics based improvement.
- Management of NCEP production suite:
  - No support (at NCEP) for further development of POM based system.
  - Cannot afford to maintain multiple systems (if not MME).

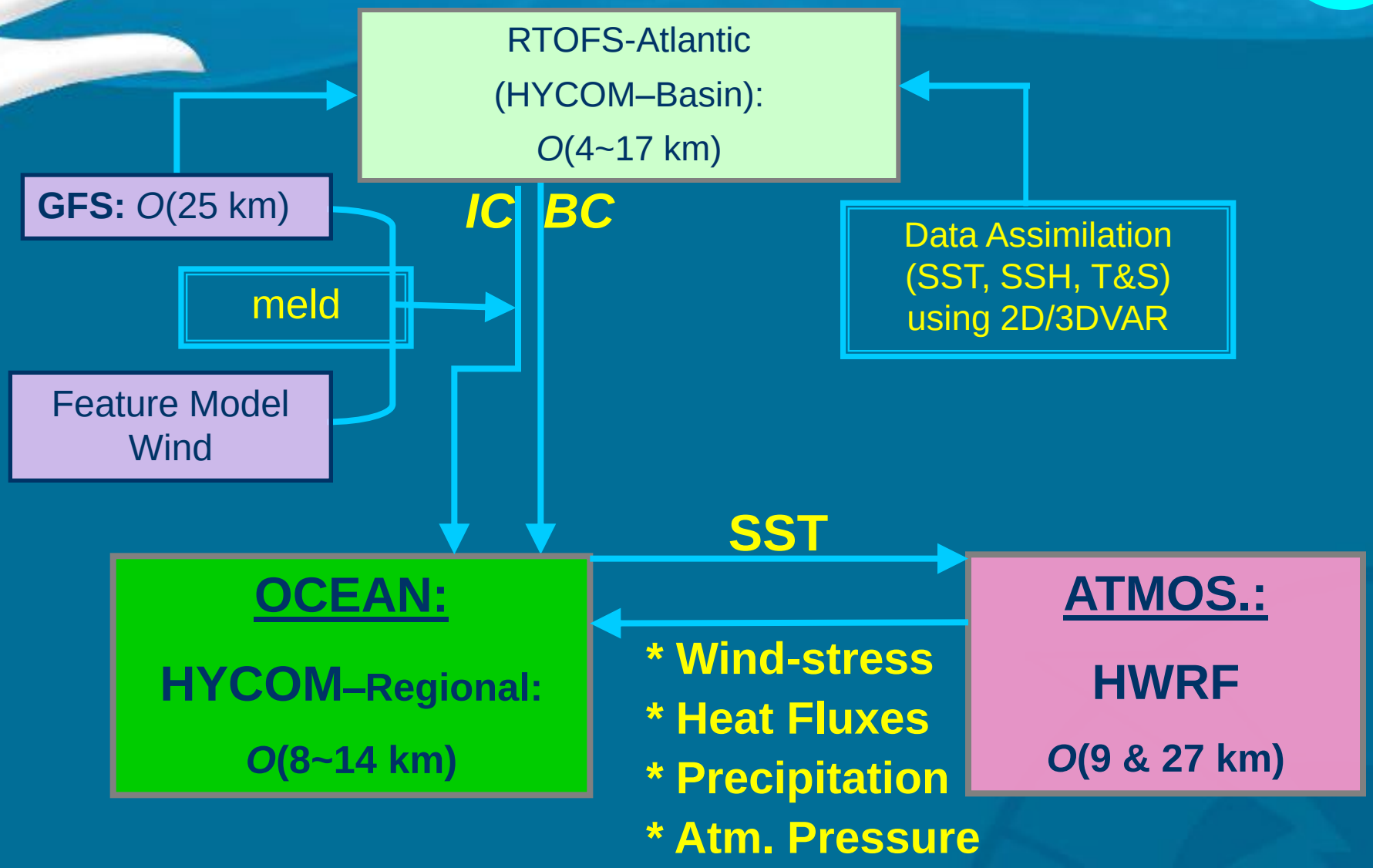
WAVEWATCH III is NCEPs main wave model:

- Consolidation of all wave modeling in single model since mid 1990's
  - Traditional deep ocean, applicable to surf zone.
  - Close to single wave scale.
- Has become a de-facto community operational and research model.
- Traditional use as a guidance model at NCEP, but also to be supported by NCEP for local applications at WFOs and any interested partner:
  - "Workstation WW III" under development.

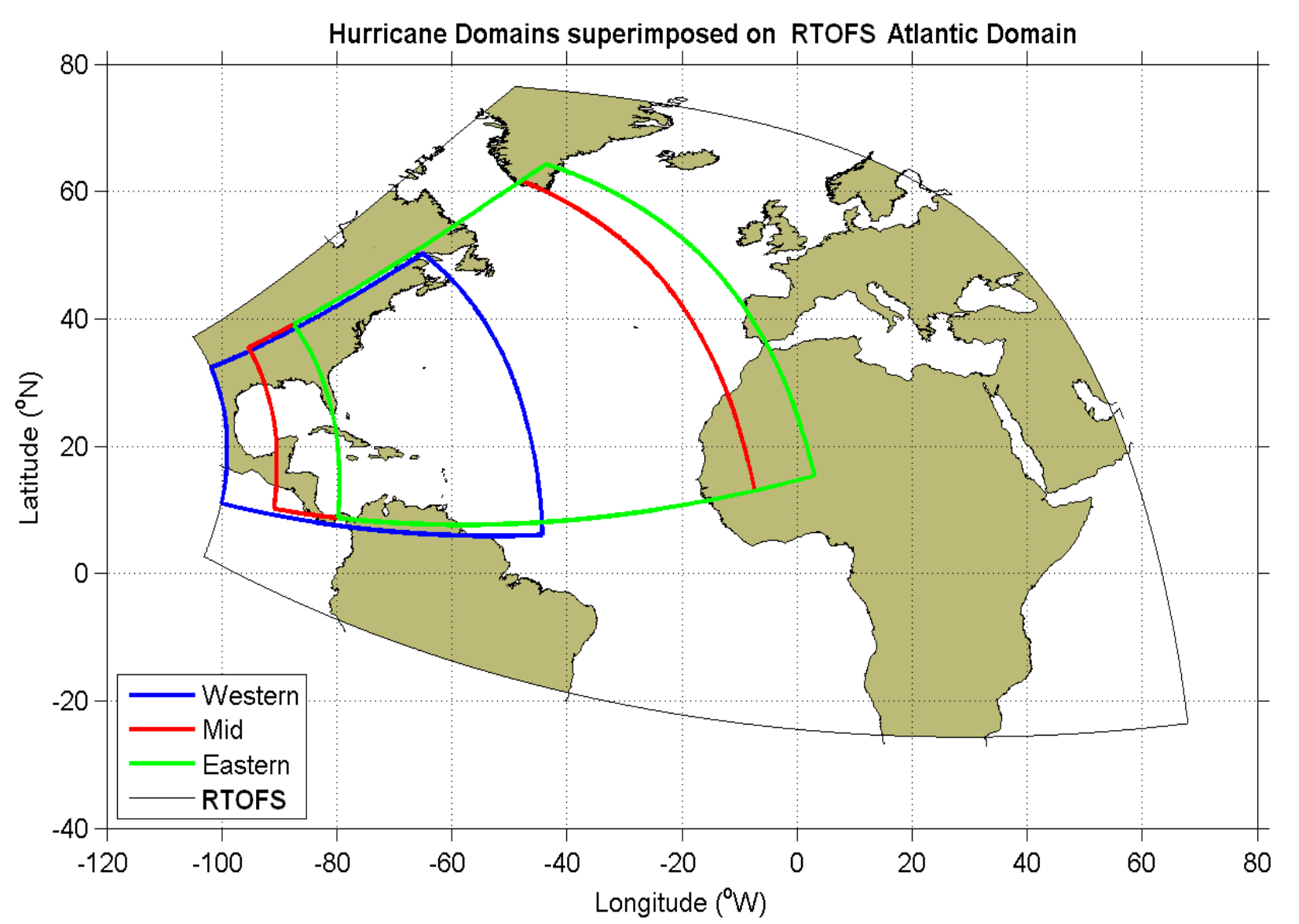
HYCOM – HWRF

- System reaching maturity at the end of 2008.
  - Initial development not with operational HWRF:
    - Needing H050 baseline for sensible coupling.
    - HR issues.
- Parallel testing with frozen system for 2009 Atlantic Hurricane Season:
  - Goal: Show potential impact of POM-HYCOM replacement.
  - Compare to operational HWRF.
- In pre-ops testing for possible 2010 operational implementation.
  - Fully integrated with HWRF development path.
  - Goal: Replacing POM with HYCOM should do no harm.

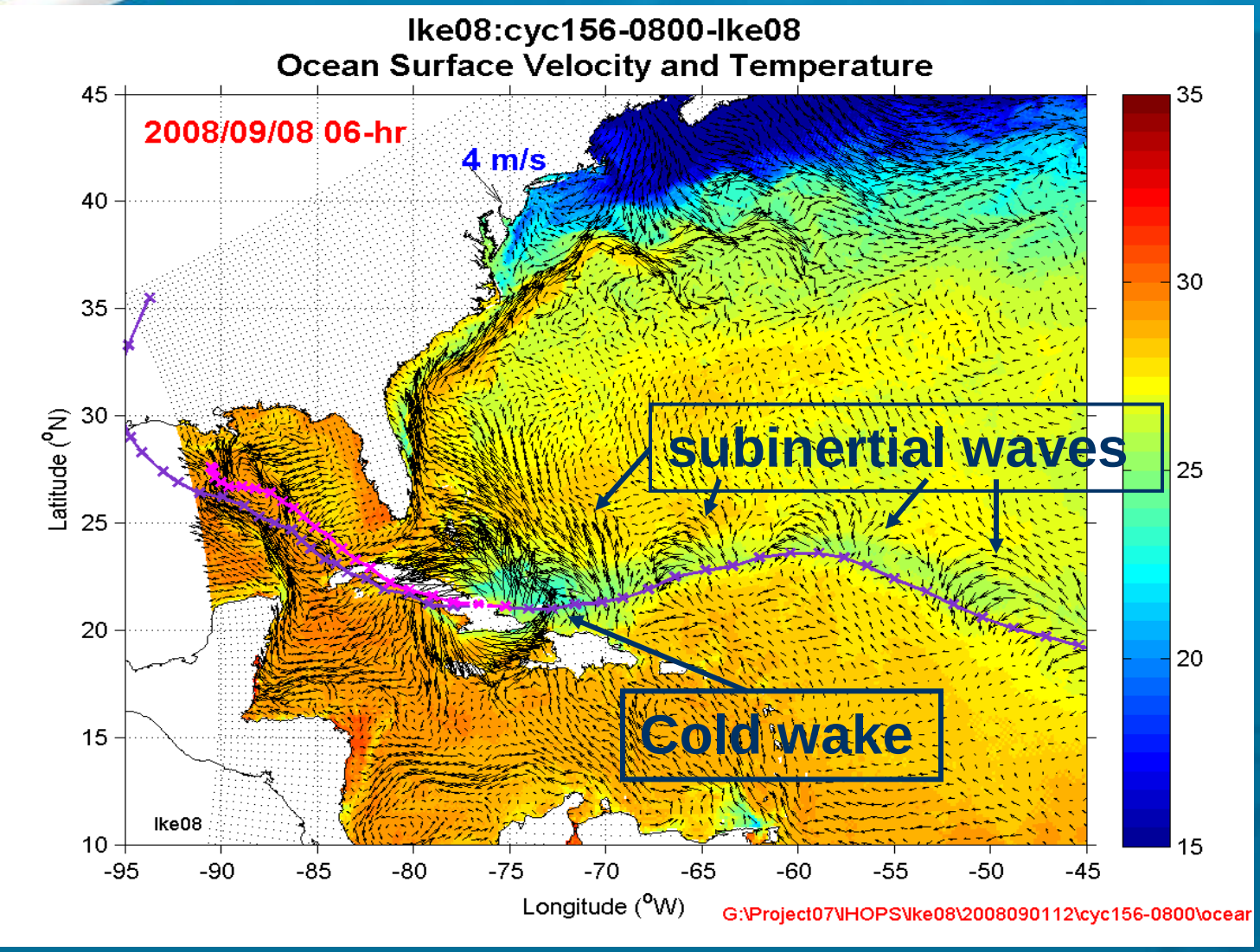
HWRF-HYCOM


RTOFS-Atlantic
(HYCOM–Basin):
O(4~17 km)
GFS: O(25 km)
meld
Feature Model
Wind
IC
BC
Data Assimilation
(SST, SSH, T&S)
using 2D/3DVAR
SST
OCEAN:
HYCOM–Regional:
O(8~14 km)
ATMOS.:
HWRF
O(9 & 27 km)
* Wind-stress
* Heat Fluxes
* Precipitation
* Atm. Pressure

HWRF-HYCOM


Hurricane Domains superimposed on RTOFS Atlantic Domain
Latitude (°N)
Longitude (°W)
80
60
40
20
0
-20
-40
-120
-100
-80
-60
-40
-20
0
20
40
60
80
Western
Mid
Eastern
RTOFS

HWRF-HYCOM

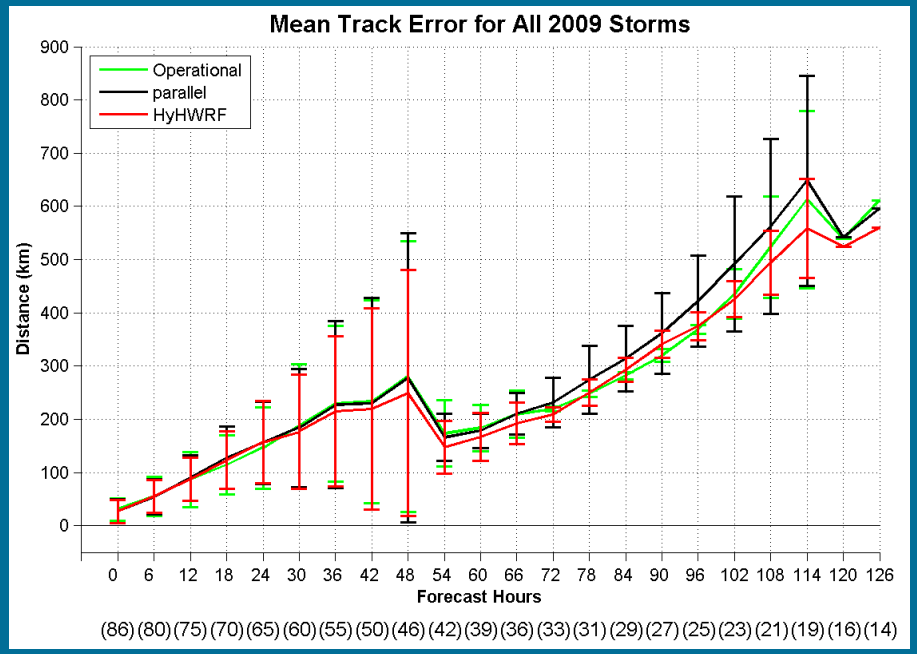


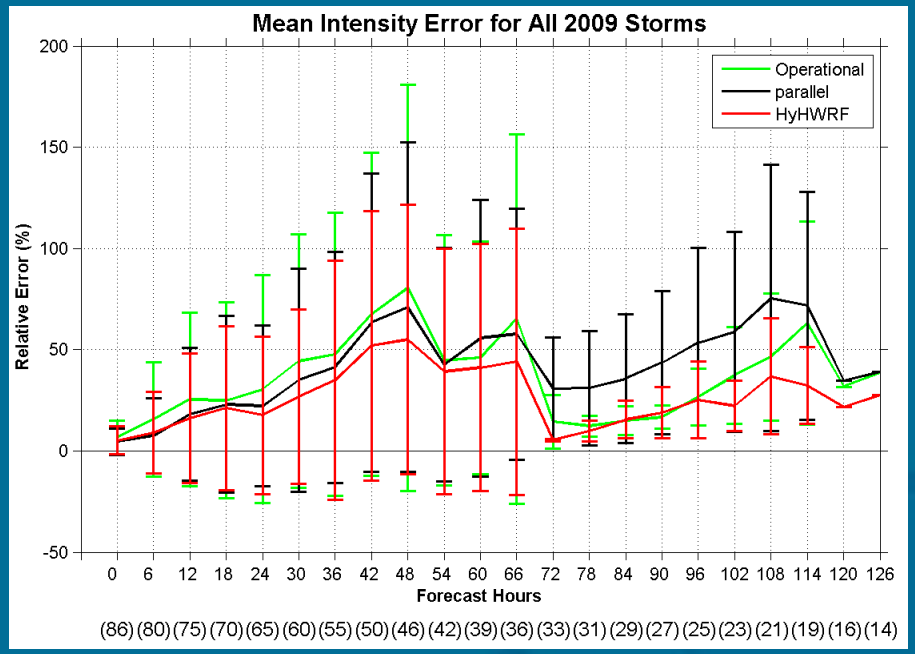
Real time testing for 2008 hurricane season (Ike).

Realistic Oceanic Simulation and Response to a Storm!

Overall 2009 real-time parallel results

Two populations due to several short weak systems





Green: NCO operational POM-HWRF

Black: parallel POM-HWRF

Red: parallel HYCOM-HWRF

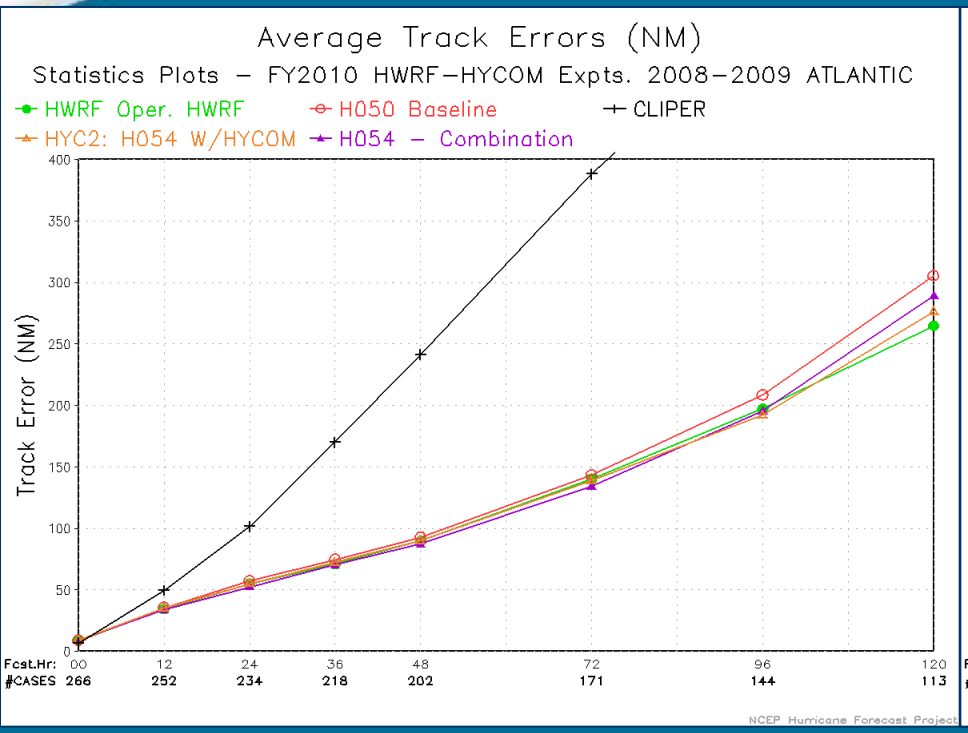
Identical HWRF

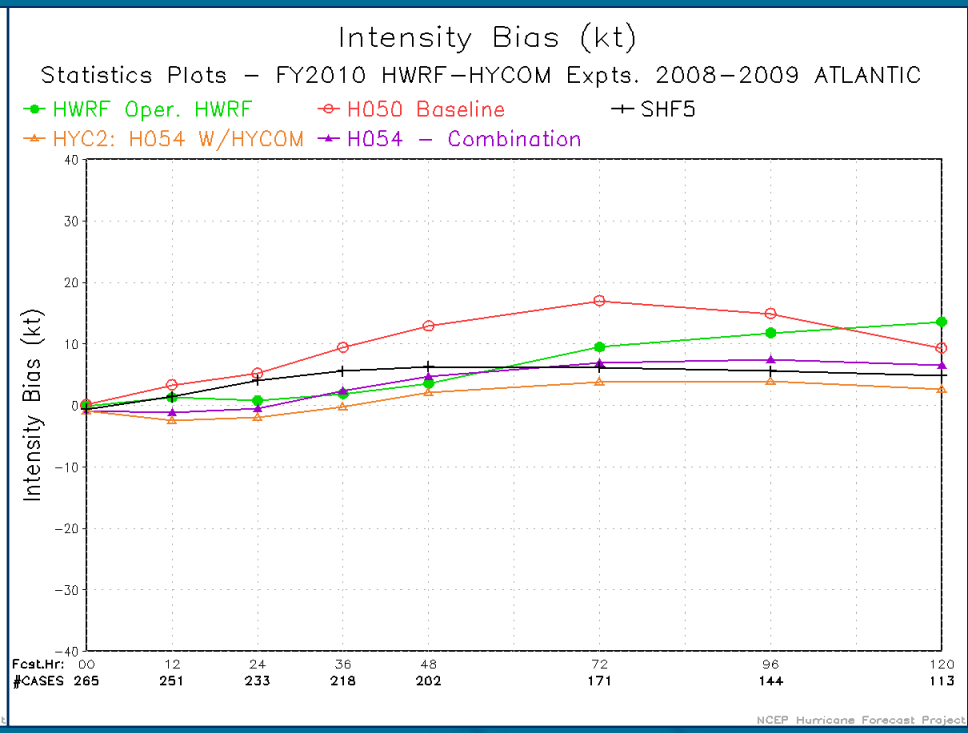
HWRF-HYCOM pre-ops testing

Name	Date	Wind	Pressure	Category
Fay (06L)	15 – 24 Aug. 2008	60	985	TS
Gustav (07L)	25 Aug. – 1 Sep. 2008	135	940	4
Hanna (08L)	28 Aug. – 7 Sep. 2008	75	977	2
Ike (09L)	1 – 14 Sep. 2008	125	935	4
Bill (03L)	15 – 24 Aug. 2009	115	945	4
Danny (05L)	26 – 29 Aug. 2009	50	1005	TS
Erika (06L)	1 – 4 Sep. 2009	50	1004	TS
Fred (07L)	7 – 12 Sep. 2009	105	958	3
Henri (10L)	6 – 8 Oct. 2009	45	1005	TS
Ida (11L)	4 – 10 Nov. 2009	90	978	2

HWRF-HYCOM

2010 pre-ops testing





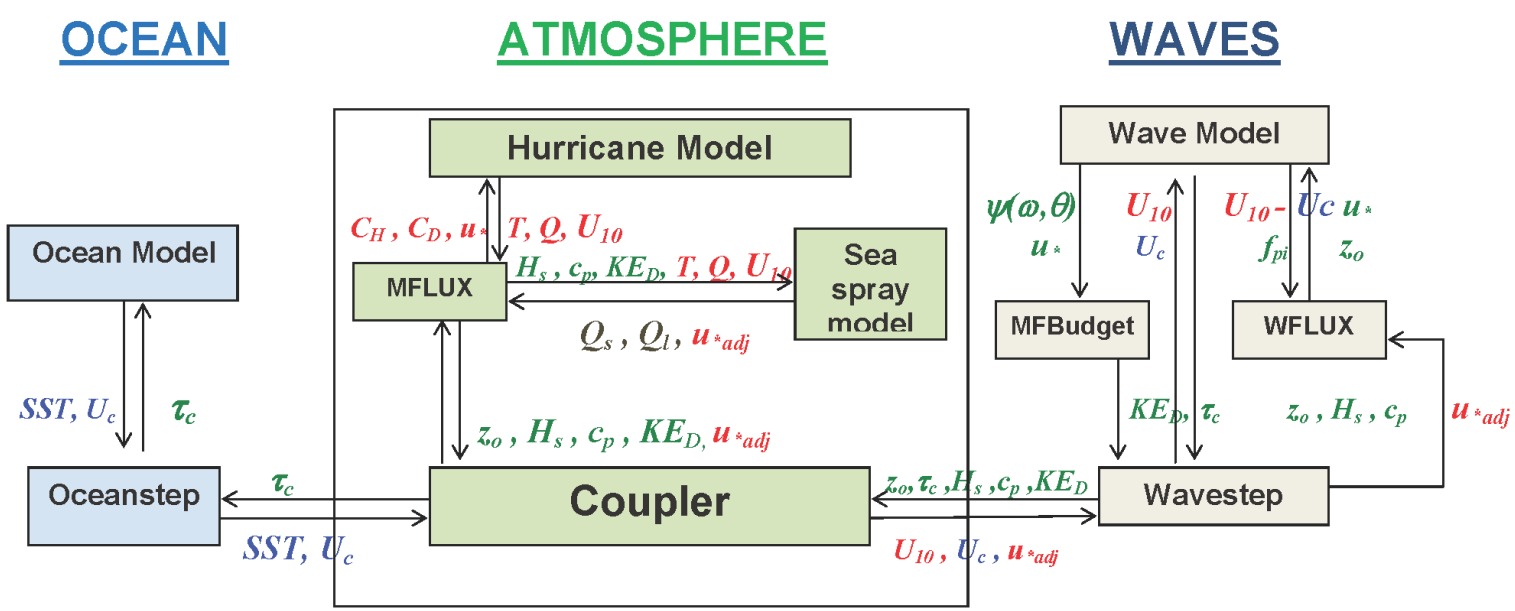
Green:	Operation 2009 HWRF model.	
Red:	New baseline HWRF model	(H050)
Purple:	2010 test package (POM)	(H054)
Orange:	2010 test package (HYCOM)	(HYC2)

No GFS res. incr.

HYCOM – WAVEWATCH III – HWRF

- Framework for three-way coupling build at NCEP.
- Transitioned to URI for insertion of coupling physics.
- Intended for real-world testing at end of year.

Coupled Hurricane-Wave-Ocean Framework



(from Isaac Ginis)

- Implemented in GFDL model in a research mode.
- Being implemented in HWRF-WW3-HYCOM.

"Workstation WW III"

- Coupled ADCIRC-WW III capability, integrated in operational WW III, can be run locally.
  - Adding NOS ADCIRC models to NCO operation.
- HFIP funding through NOS.
  - Work now starting, test version available 2011.

- First as stand-alone coupled model.
- Could become blueprint for coupled wave-surge modeling in coupled HWRF.

Is coupling too expensive for operations ?

- HYCOM requires significantly less resources than HWRF.
- POM typically is run on only one process:
  - HYCOM much more expensive than POM, but
  - this does not mean that HYCOM dominates resource requirements.
- Adding the wave model later requires only 20% of HYCOM resources or 7% of HWRF resources

assigned resources in test setup

model	processes
HWRF	91
HYCOM	30
WW III	6

But this is not the whole story, what is the run time ?

Is coupling too expensive for operations ?

- There are 20 nodes available for operational HWRF model.
- We believe we can fit HYCOM-HWRF on 4 nodes fitting in the allotted time window.
  - HYCOM-HWRF and a fifth storm as requested by TPC can be implemented operationally.

- Still working on optimization of HYCOM-HWRF.
  - Significantly less efficient than POM-HWRF (2 nodes).
  - Mostly related to different hardware optimization approaches needed for the two models.
  - By 2011, we expect to be able to run on 3 instead of 4 nodes, generating space for new model additions in 2011 (requires < 15% speed up).

Computational costs (future)

HYCOM

- 1/12° resolution should be sufficient for foreseeable future,
  - Consistent with present reduced RTOFS grid.
  - Consistent with planned RTOFS-Global (NE Pacific or even global coupled modeling capability).
- Relative need for resources likely to be reduced.

WAVEWATCH III

- 3x speed up possible with true relocatable grid.
- 2.5x – 5x slow down expected for physics optimization.
- Scaling like HWRF expected when adding grids.
- Highly optimized on various architectures / resources.
- Likely to remain small part of needed effort.
- Workstation WW III alows for efficient landfall coupling.

Adding WAVEWATCH III

- Minor risk, since this is a forced and damped system without chaotic behavior or a need for initialization.
- Comparable to adding new BL parameterization to HWRF.

Replacing POM with HYCOM

- HYCOM (with RTOFS-Atlantic) is a much more complex system than POM without real-time continuous initialization.
  - Risk: previous issues with quality of RTOFS-Atlantic.
  - Mitigation: New procedures are in place to rapidly resolve spurious behavior in operations.
  - Mitigation; Adding Jason-2 to SSH data to better constrain model.
  - Mitigation: growing support group for RTOFS.
  - Possible mitigation: Fallback to other SST in coupler.

HYCOM cont'ed

- HYCOM-HWRF coupling is more complex:
  - Risk: Small support group for coupled system.
  - Mitigation: Dedicated group expanded from 1 to 3.
  - Mitigation: Community support (FSU, AOML, …).
  - Risk: Complexity of system may make it more prone to failure.
  - Reality: This system will be fully supported in-house, the present POM base system is not.
  - Reality: This system was robust in parallel testing.
  - Possible mitigation: Fallback to other SST in coupler.

Coupling in hurricane guidance excites me because:

- It provides road to potential improvement of hurricane guidance with solid roots in physics.
- It constrains the underlying physical problems by linking flux parameterizations.
- It provides a road to improvement for “secondary” hurricane issues related to ocean circulation, wind waves, inundation etc.
  - Will these remain “secondary” (e.g., inundation) ?

- It fosters collaborations.
- It helps NOAA to focus more on oceans.

Thank you!