

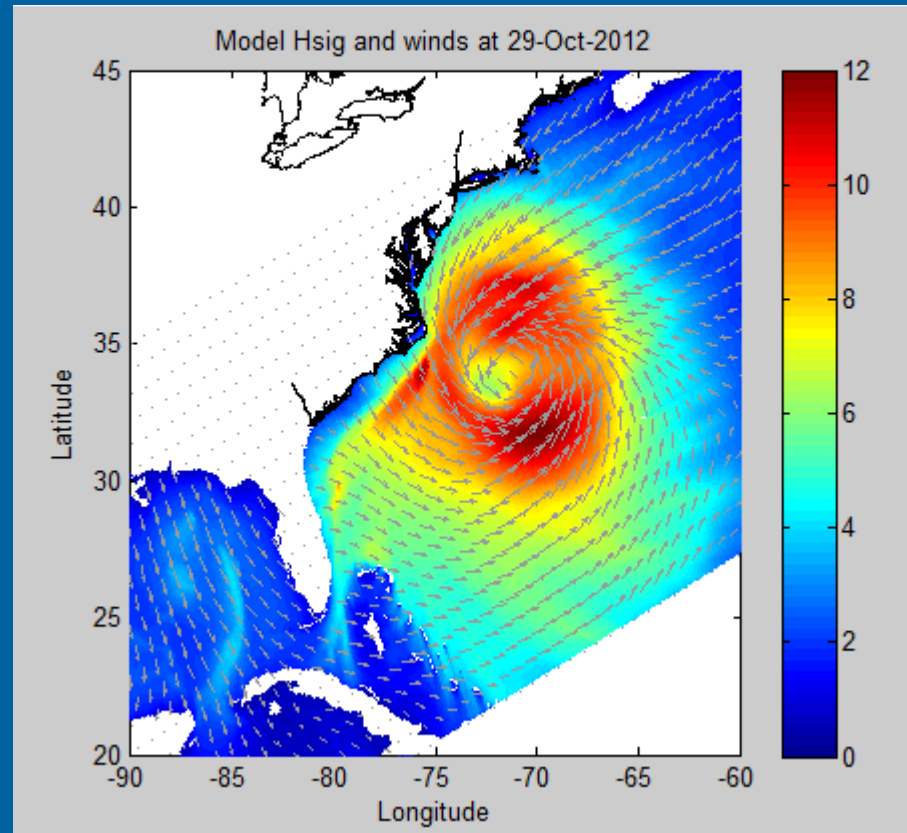
Using the Coupled-Ocean-Atmosphere-Waves-SedimentTransport (COAWST) Modeling System to Investigate Storm Dynamics

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US Geological Survey, Woods Hole, MA

Joe Zambon, Ruoying He
North Carolina State Univ

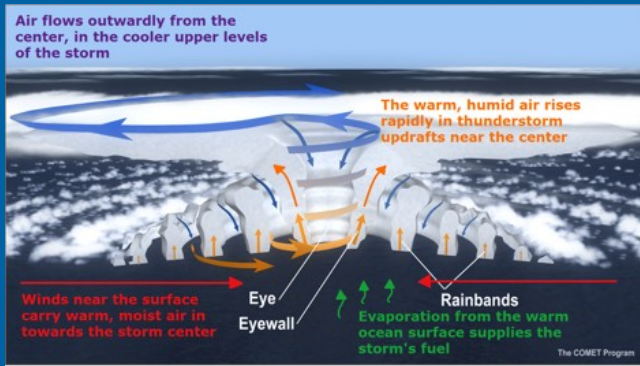
Maitane Olabarrieta
University of Florida

Christie Hegermiller
Woods Hole Oceanographic Institution



Coastal processes involve feedbacks between different physical processes.

Atmosphere

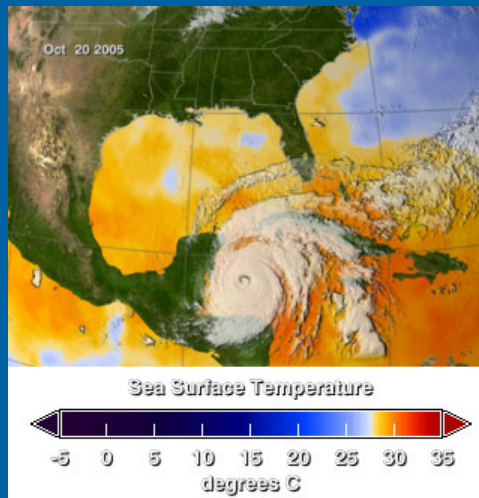


Usually treated independently but actually occur together

Coastal geomorphology



Ocean



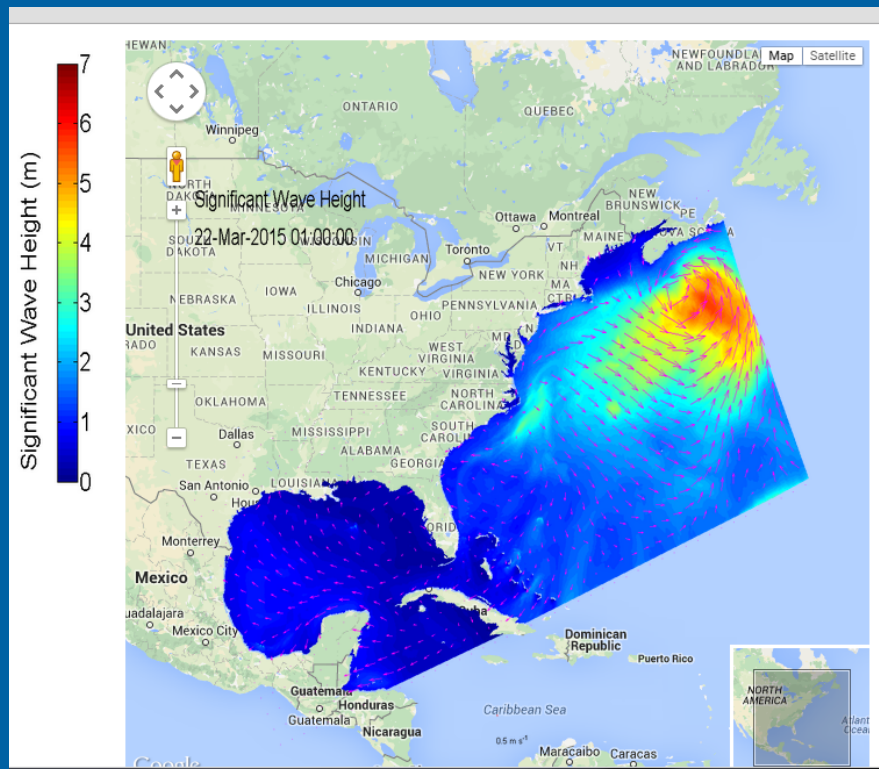
Wave



COAWST Numerical Modeling System

COAWST

Coupled Ocean – Atmosphere – Wave – Sediment Transport
Modeling System to investigate the impacts of storms on coastal environments.



MCT

<http://www-unix.mcs.anl.gov/mct/>

ROMS

<http://www.myroms.org/>

WRF

<http://www.wrf-model.org/>

SWAN

<http://vlm089.citg.tudelft.nl/swan>

WWIII

<http://polar.ncep.noaa.gov/waves/wavewatch/>

InWave infragravity wave

CSTMS

<http://woodshole.er.usgs.gov/>

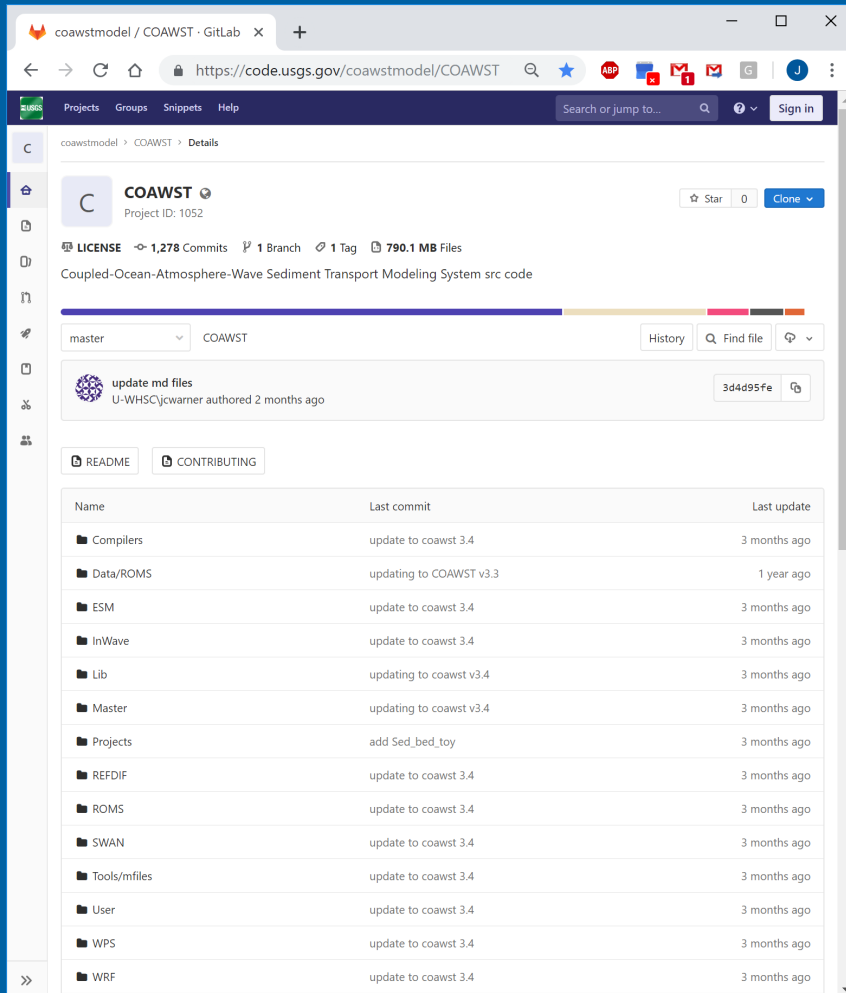


Daily forecast: <http://woodshole.er.usgs.gov/project-pages/cccp/public/COAWST.htm>

COAWST distribution

Github

<https://code.usgs.gov/coawstmodel/COAWST>

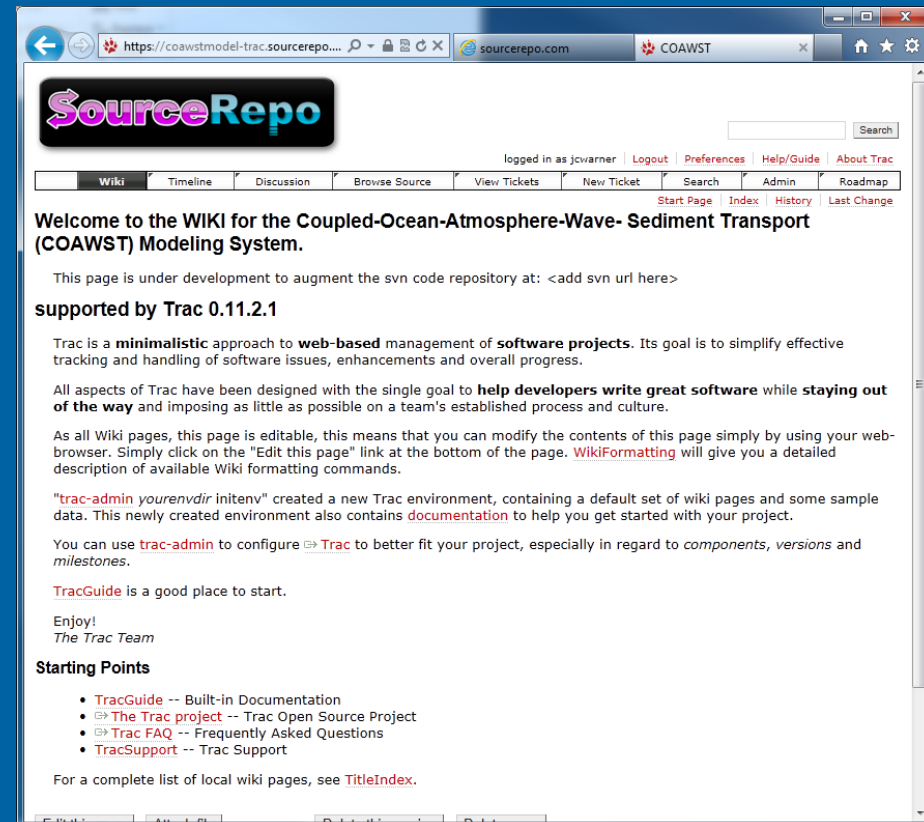


The screenshot shows the GitHub repository page for COAWST. The repository is named "COAWST" with Project ID: 1052. It has 1,278 commits, 1 branch, 1 tag, and 790.1 MB of files. The description is "Coupled-Ocean-Atmosphere-Wave Sediment Transport Modeling System src code". The current branch is "master". A recent commit "update md files" by U-WHSC\jcwerner is shown, dated 2 months ago. Below the commit list, there are links for "README" and "CONTRIBUTING". A table lists the repository's structure and the last update for each component.

Name	Last commit	Last update
Compilers	update to coawst 3.4	3 months ago
Data/ROMS	updating to COAWST v3.3	1 year ago
ESM	update to coawst 3.4	3 months ago
InWave	update to coawst 3.4	3 months ago
Lib	updating to coawst v3.4	3 months ago
Master	updating to coawst v3.4	3 months ago
Projects	add Sed_bed_toy	3 months ago
REFDIF	update to coawst 3.4	3 months ago
ROMS	update to coawst 3.4	3 months ago
SWAN	update to coawst 3.4	3 months ago
Tools/mfiles	update to coawst 3.4	3 months ago
User	update to coawst 3.4	3 months ago
WPS	update to coawst 3.4	3 months ago
WRF	update to coawst 3.4	3 months ago

svn

<https://coawstmodel.sourcerepo.com/coawstmodel/COAWST>



The screenshot shows the Trac Wiki page for COAWST. The page is titled "Welcome to the WIKI for the Coupled-Ocean-Atmosphere-Wave- Sediment Transport (COAWST) Modeling System." It states that the page is under development to augment the svn code repository. The page is supported by Trac 0.11.2.1. It describes Trac as a minimalistic approach to web-based management of software projects. It mentions that all aspects of Trac have been designed with the single goal to help developers write great software while staying out of the way. It also notes that the page is editable and provides a link to the WikiFormatting page. The page includes a section for "Starting Points" with links to TracGuide, The Trac project, Trac FAQ, and TracSupport. It also mentions that for a complete list of local wiki pages, see TitleIndex.

Trac is a **minimalistic** approach to **web-based** management of **software projects**. Its goal is to simplify effective tracking and handling of software issues, enhancements and overall progress.

All aspects of Trac have been designed with the single goal to **help developers write great software** while **staying out of the way** and imposing as little as possible on a team's established process and culture.

As all Wiki pages, this page is editable, this means that you can modify the contents of this page simply by using your web-browser. Simply click on the "Edit this page" link at the bottom of the page. [WikiFormatting](#) will give you a detailed description of available Wiki formatting commands.

"[trac-admin yourenvidir initenv](#)" created a new Trac environment, containing a default set of wiki pages and some sample data. This newly created environment also contains [documentation](#) to help you get started with your project.

You can use [trac-admin](#) to configure [Trac](#) to better fit your project, especially in regard to *components*, *versions* and *milestones*.

[TracGuide](#) is a good place to start.

Enjoy!
The Trac Team

Starting Points

- [TracGuide](#) -- Built-in Documentation
- [The Trac project](#) -- Trac Open Source Project
- [Trac FAQ](#) -- Frequently Asked Questions
- [TracSupport](#) -- Trac Support

For a complete list of local wiki pages, see [TitleIndex](#).

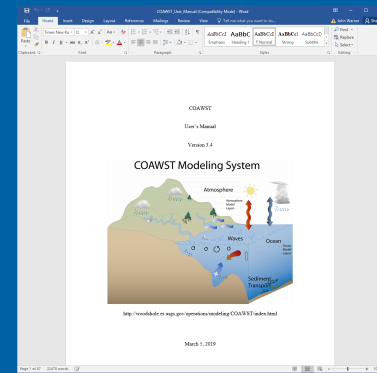
User base

- * Currently have ~ 800 registered users
- * User Manual for model setup, applications, m files, BCs ICs, etc.
- * Several Test Cases – Detailed steps to create coupled applications.
- * Forecast systems
- * Trainings (every 2 years)

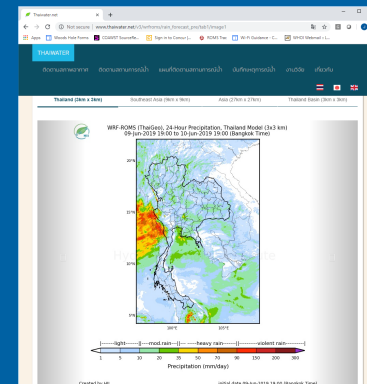
July 2012 USGS
Aug 2014 WHOI
Aug 2016 WHOI
Feb 2019 NCSU



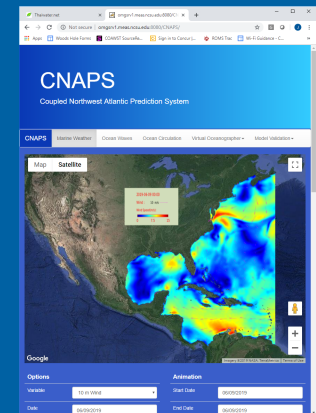
COAWST Modeling System training attendees at Hunt Library, North Carolina State University.
February 2019.



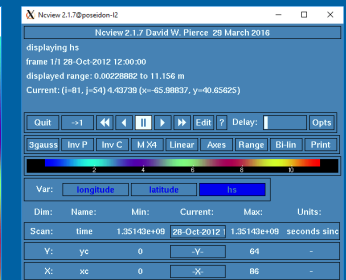
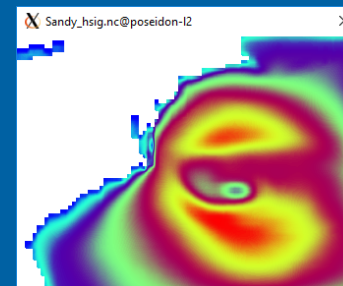
User Manual



http://www.thaiwater.net/v3/wrfroms/rain_forecast_pre/tab1/image1

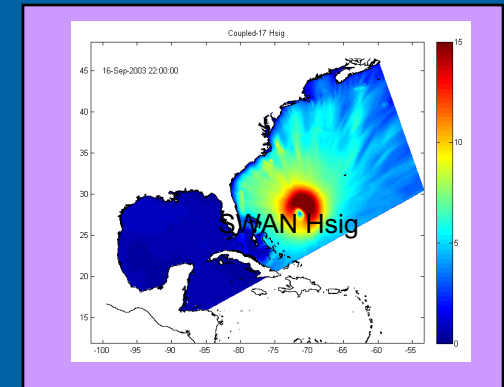
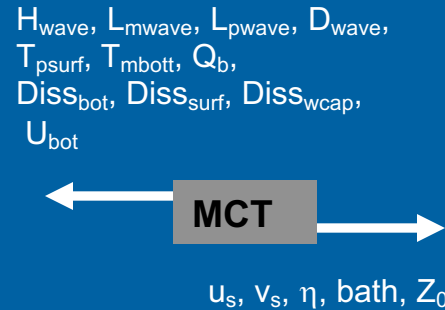
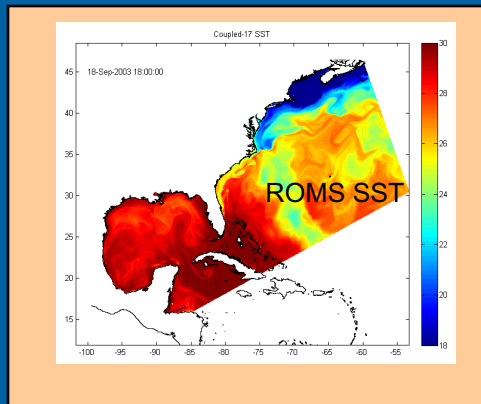
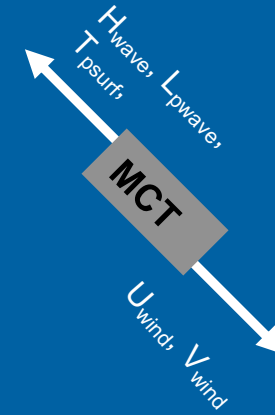
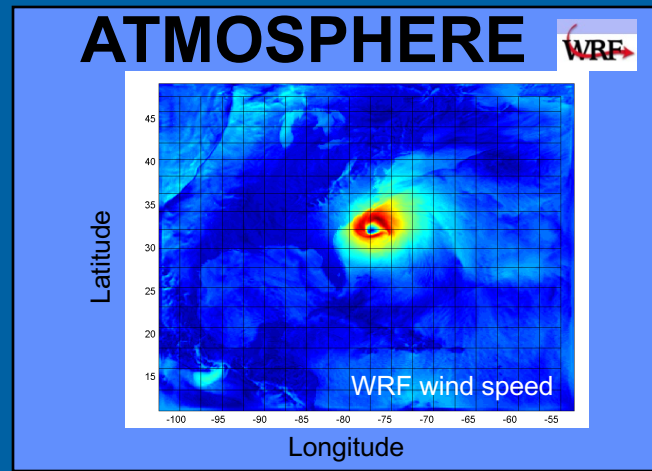


<http://omgsrv1.meas.ncsu.edu:8080/CNAPS/>

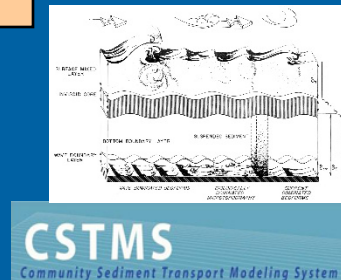


Test Cases

Model setup



SEDIMENT



Nesting in all the models

OCN interactions

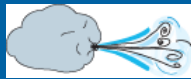
Use consistent stress
roms+wrf
#define
ATM2OCN_FLUXES



Ustress, Vstress, Swrad,
Lwrad, LH, HFX

or

Use wrf vars in
COARE
#define
BULK_FLUXES



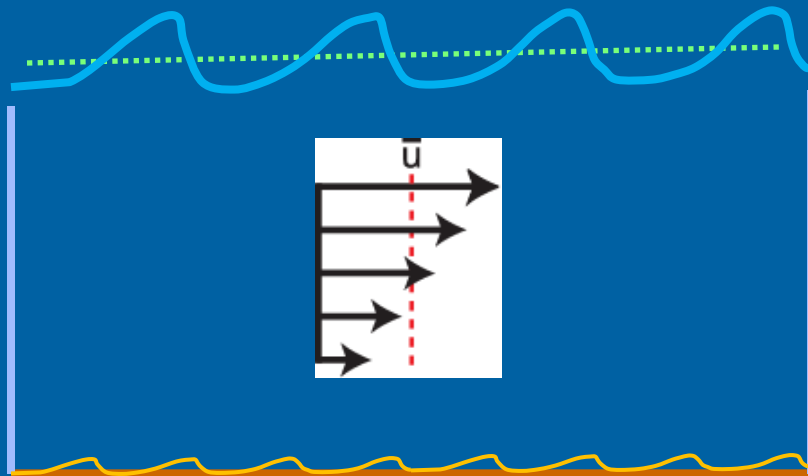
Uwind-ucur,
Vwind-vcur,
Swrad, Lwrad,
RH, Tair,
cloud



rain, evap

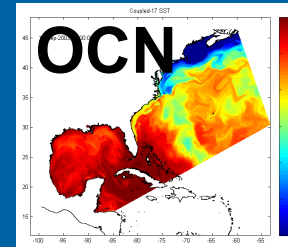


Patm



Integration and Application Network (ian.umces.edu/symbols/),
University of Maryland Center for Environmental Science.

ATM
Uwind, Vwind, Patm, RH, Tair,
cloud, rain, evap, SWrad, Lwrad,
LH, HFX, Ustress, Vstress



H_{wave}, L_{mwave}, L_{pwave}, D_{wave},
T_{psurf}, T_{mbott}, Q_b,
Diss_{bot}, Diss_{surf}, Diss_{wcap},
U_{bot}



WAVE

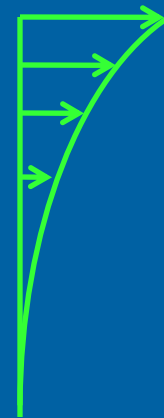
From the Waves

Water column

Surface

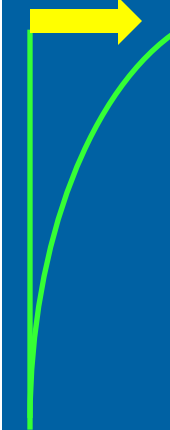
Bottom

Stokes + VF



H_{wave}, L_{mwave}, D_{wave},
T_{psurf}, Q_b,
Diss_{bot}, Diss_{surf},
Diss_{wcap},

$\tau_s = f(Z_{os})$



H_{wave}, L_{pwave},
D_{wave}, T_{psurf},

Zoa



$\tau_b = f(Z_{ob})$

H_{wave}, L_{mwave},
D_{wave},
T_{mbott}, U_{bot}

WAV interactions

$$\frac{\partial N}{\partial t} + \frac{\partial c_x N}{\partial x} + \frac{\partial c_y N}{\partial y} + \frac{\partial c_\sigma N}{\partial \sigma} + \frac{\partial c_\theta N}{\partial \theta} = \frac{S_w}{\sigma}$$

1) Generation

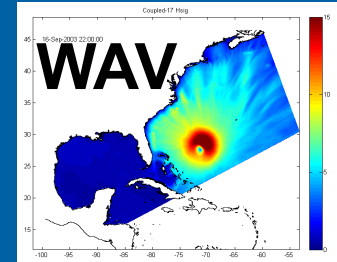
– wind speed is modified by ocean currents:

$$S(w) = f(U_{\text{wind}} - u_s ; V_{\text{wind}} - v_s)$$

$u_s, v_s, \eta, \text{bath}, Z_0$

OCN

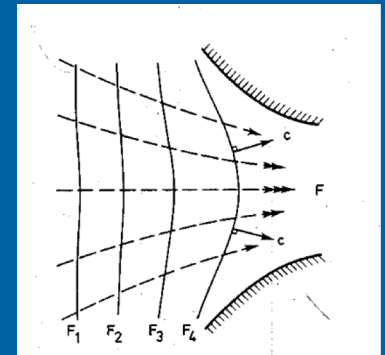
ATM
 $U_{\text{wind}}, V_{\text{wind}}$



2) Propagation

– wave celerity in geographic space is modified by ocean currents

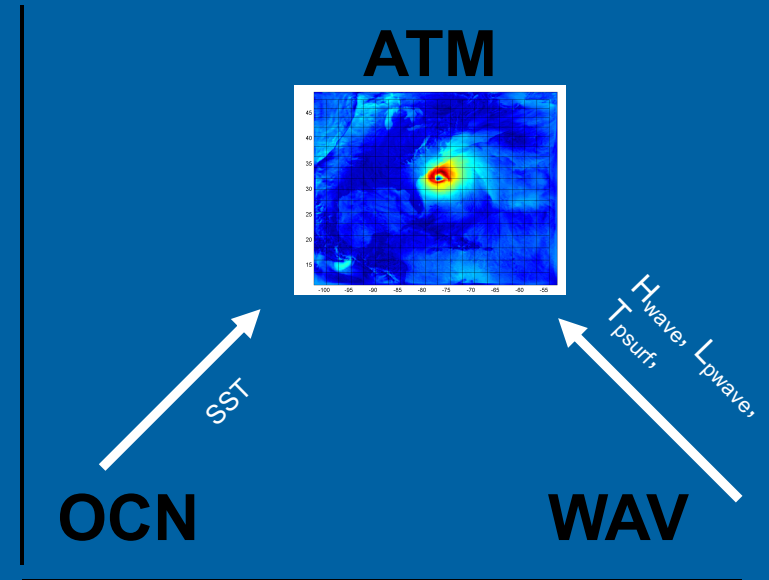
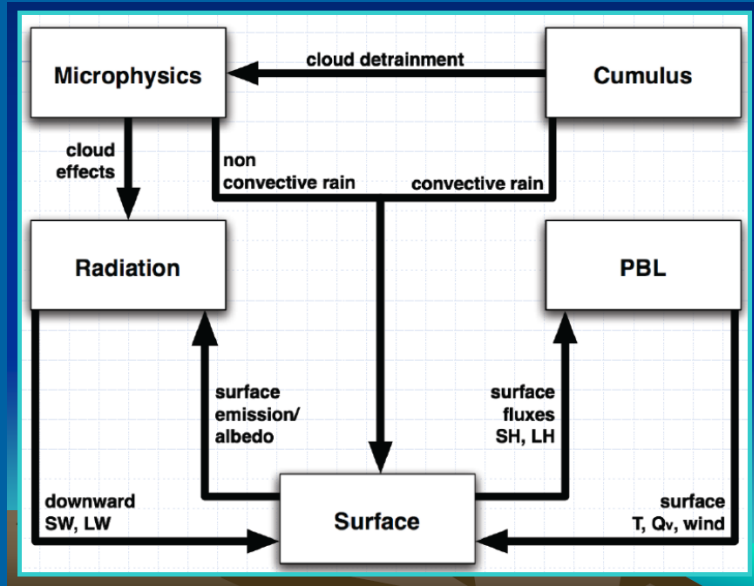
$$c_x = c_{gx} + u_s ; c_y = c_{gy} + v_s$$



– change of wave direction (refraction) due to η , bathy, and currents:

$$C_{g,\theta} = \frac{\sigma}{\sinh(2kh)} \left(\frac{\partial h}{\partial x} \sin \theta - \frac{\partial h}{\partial y} \cos \theta \right) + \cos \theta \left(\frac{\partial U}{\partial x} \sin \theta - \frac{\partial U}{\partial y} \cos \theta \right) + \sin \theta \left(\frac{\partial V}{\partial x} \sin \theta - \frac{\partial V}{\partial y} \cos \theta \right)$$

ATM interactions



Surface fluxes

Momentum
Heat
Moisture

$$\begin{aligned}
 F_m &= C_m |\vec{V}_{SL}|^2 \\
 F_h &= \rho_1 c_p C_{hq} (\theta_{sk} - \theta_1) \\
 F_q &= \rho_1 L C_{hq} M (q_{vsk} - q_{v1})
 \end{aligned}$$

$$|\vec{V}_{SL}|^2 = u^2 + v^2$$

C_m is the exchange coefficient for momentum and is expressed as

$$C_m = \frac{u_*^2}{|\vec{V}_{SL}|^2}$$

C_{hq} is the exchange coefficient valid for both heat and water vapor as

$$C_{hq} = u_* t \left[\psi_h \left(\frac{z}{L_{MO}} \right) - \psi_h \left(\frac{z_{0T}}{L_{MO}} \right) + \ln \left(\frac{z}{z_{0T}} \right) \right]^{-1}$$

SST

OCN

u_* is the friction velocity and is expressed as

$$u_* = \kappa |\vec{V}_{SL}| \left[\psi_m \left(\frac{z}{L_{MO}} \right) - \psi_m \left(\frac{z_{0m}}{L_{MO}} \right) + \ln \left(\frac{z}{z_{0m}} \right) \right]^{-1}$$

$$z_{0m} = f(H_{\text{wave}}, L_{\text{pwave}}, T_{\text{psurf}})$$

WAV

OCEAN SURFACE ROUGHNESS CLOSURE MODELS

CHARNOCK 1955

$$z_{0m} = \frac{0.011(u_*)^2}{g}$$

TAYLOR & YELLAND 2001: TY2001

$$\frac{z_{0m}}{H_s} = 1200 \left(H_s / L_p \right)^{4.5}$$

DRENNAN 2003: DGQH

$$\frac{z_{0m}}{H_s} = 3.35 \left(u_* / C_p \right)^{3.4}$$

OOST 2002: OOST

$$\frac{z_{0m}}{L_p} = \frac{25.0}{\pi} \left(u_* / C_p \right)^{4.5}$$

H_s = significant wave height

z_0 = ocean surface roughness

u_* = wind friction velocity

C_p = peak wave celerity

L_p = peak wave length

$\frac{u_*}{C_p}$ = wave age

- Wave steepness based parameterization.
- Based on three datasets representing sea-state conditions ranging from strongly forced to shoaling.

- Wave age based formula to characterize the ocean roughness.
- They combined data from many field experiments representing a variety of condition and grouped the data as a function of the wind friction velocity.

- Wave age dependent formula but it also considers the effect of the wave steepness.

MCT

Model Coupling Toolkit

Mathematics and Computer Science Division Argonne National Laboratory

<http://www-unix.mcs.anl.gov/mct/>

MCT is an open-source package that provides MPI based communications between all nodes of a distributed memory modeling component system.

Download and compile as libraries that are linked to.



Model A running on M nodes.

Model B running on N nodes.

Model C

.....



MCT provides communications between all models.

(it also works here)

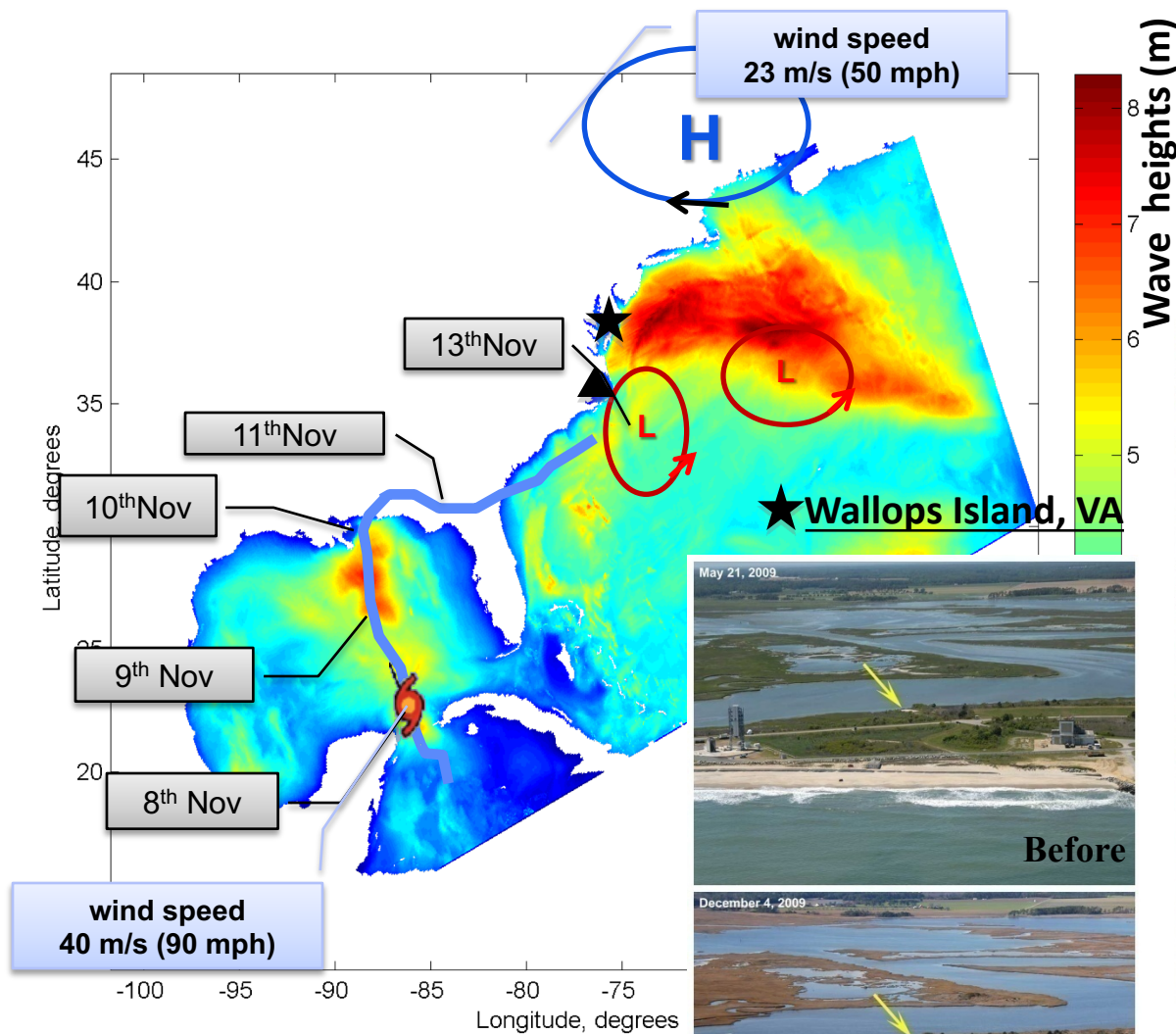


Warner, J.C., Perlin, N., and Skillingstad, E. (2008). Using the Model Coupling Toolkit to couple earth system models. Environmental Modeling and Software



Example: Nor'Ida Nov 2009

Olabarrieta, M., Warner, J.C., and Armstrong, B. (2012). "Ocean-atmosphere dynamics during Hurricane Ida and Nor'Ida: an atmosphere-ocean-wave coupled modeling system application." *Ocean Modelling*, 43-44, pp 112-137.



▲ Bodie Island, NC



SST

Before

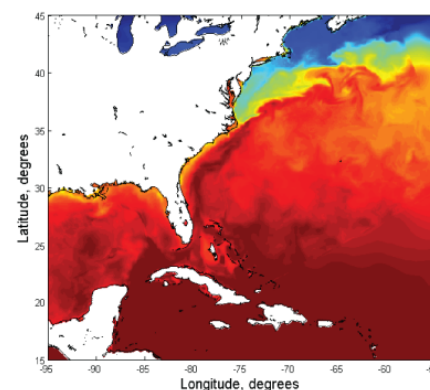
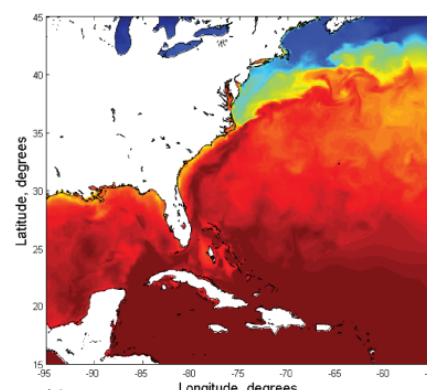
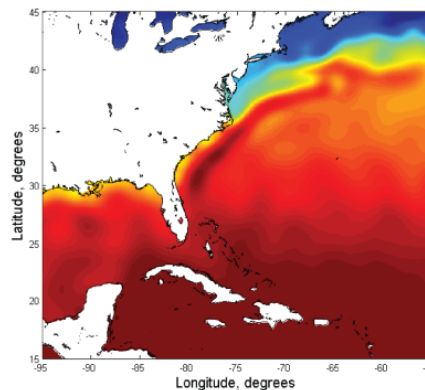
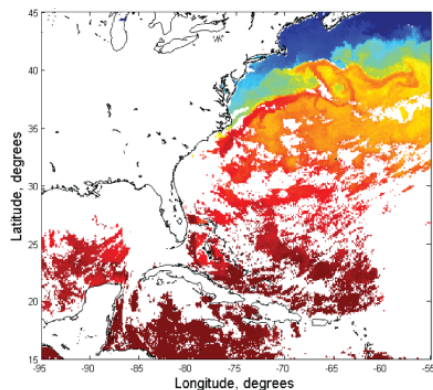
09-Nov-2009 18:00 UTC

GOES

WRF

WRF + ROMS

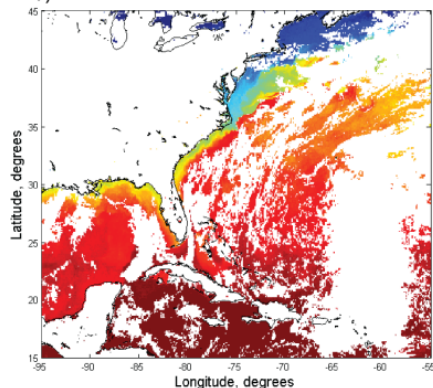
WRF + ROMS + SWAN



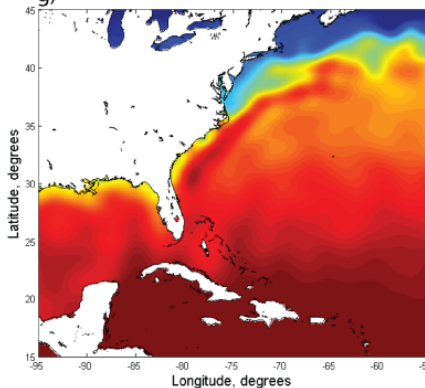
After

16-Nov-2009 21:00 UTC

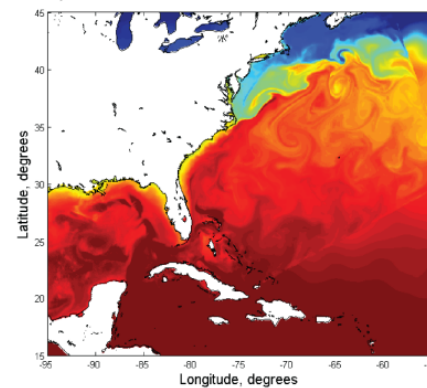
f)



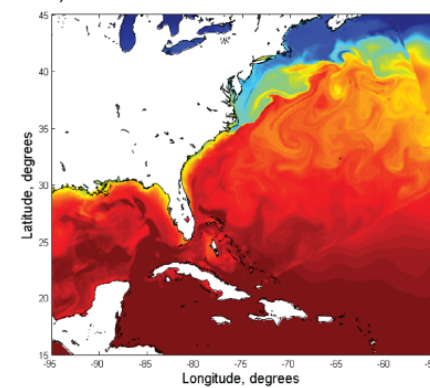
g)



h)



i)

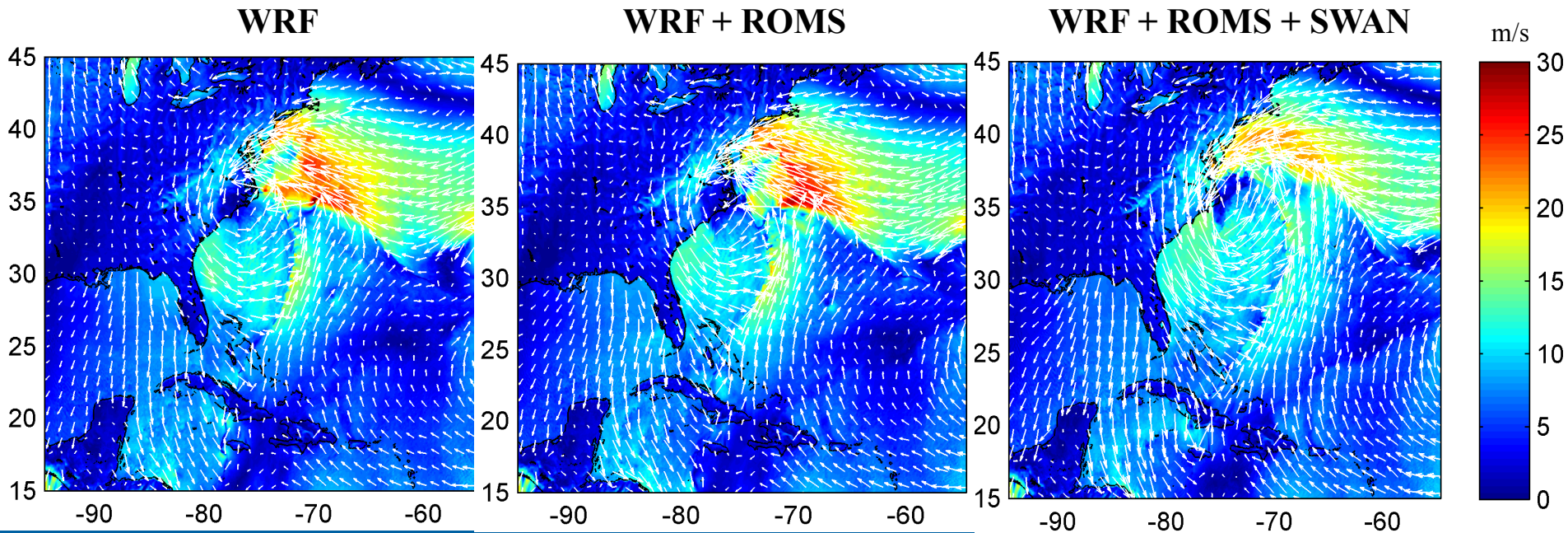


From WRF alone to WRF+ROMS. the SST structure increases.

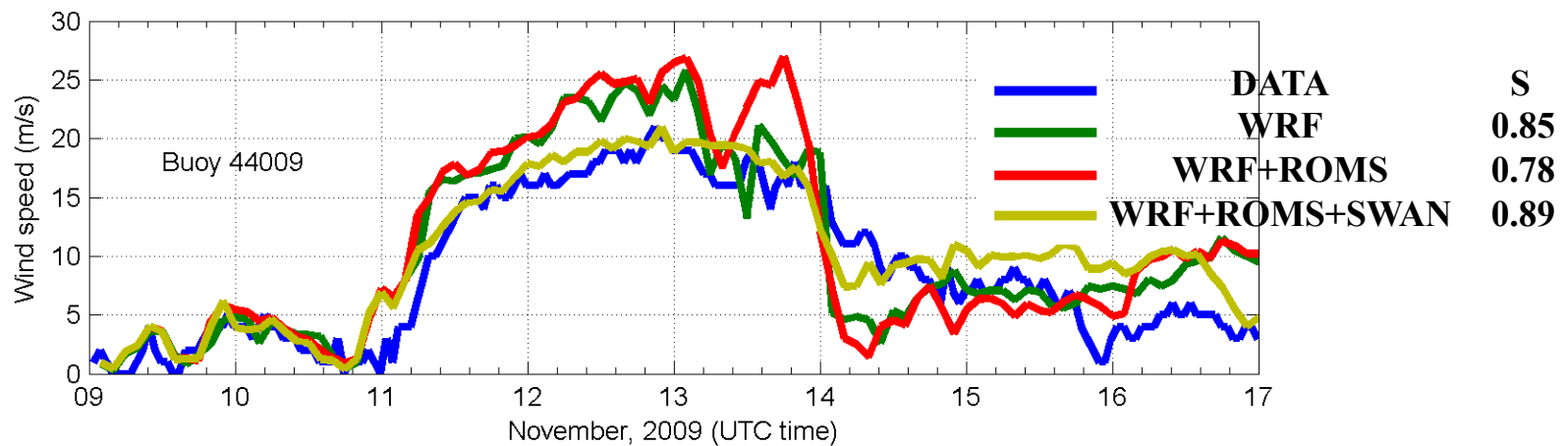
Adding SWAN does not alter the SST that much.

(This was a rather stationary storm!)

WINDS



Reduced wind speed with waves coupling.

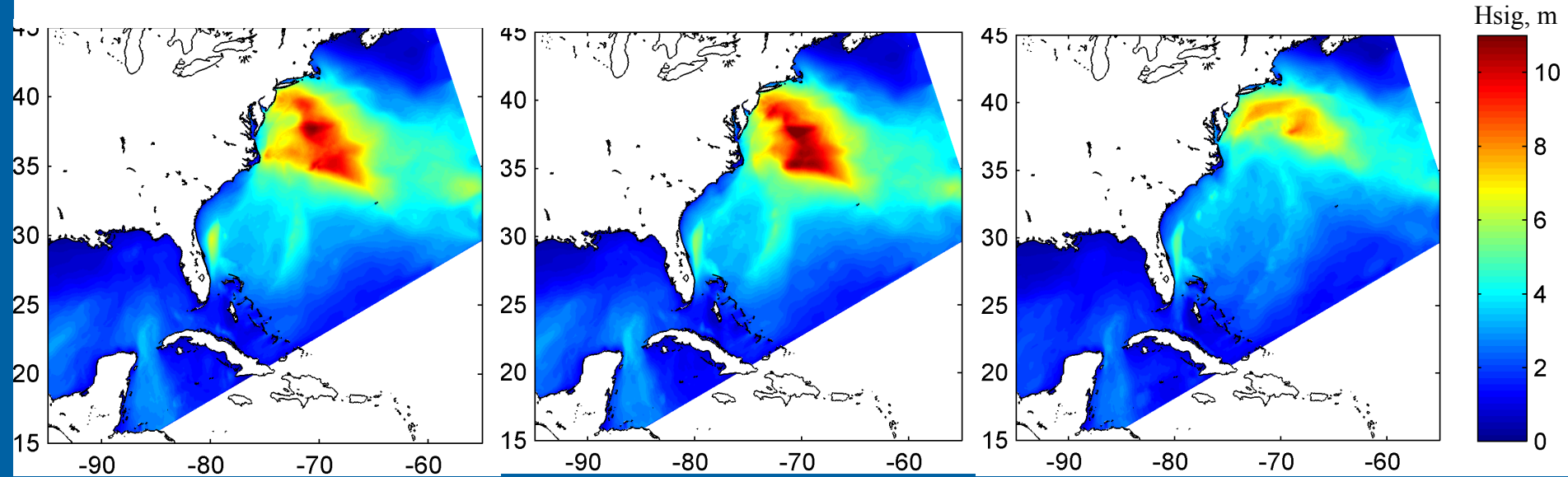


WAVES

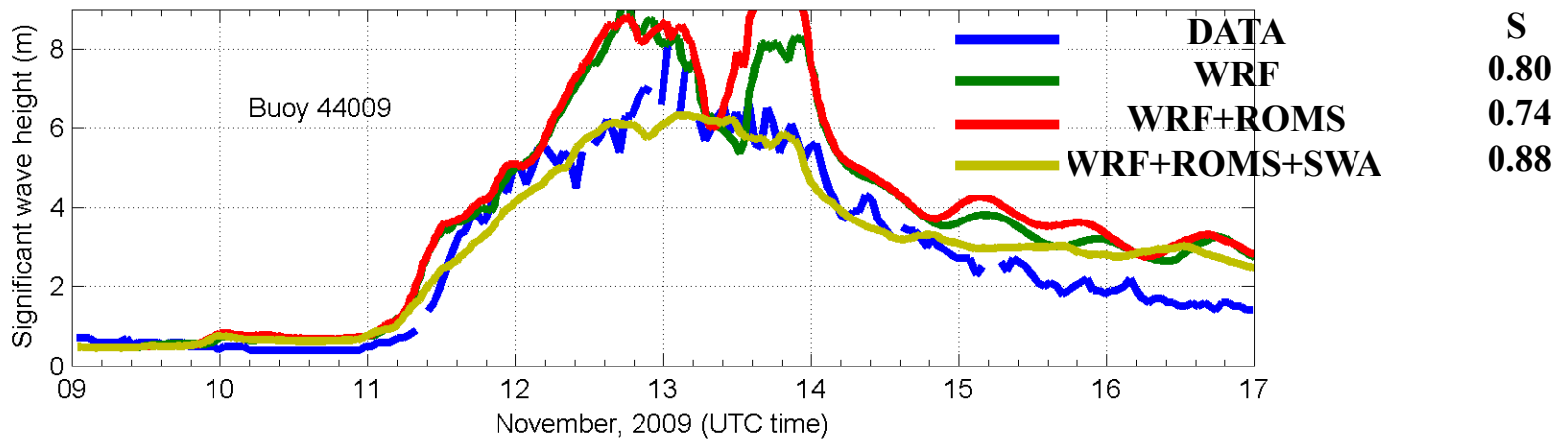
WRF

WRF + ROMS

WRF + ROMS + SWAN



Reduced waves with waves coupling.



PRECIPITATION

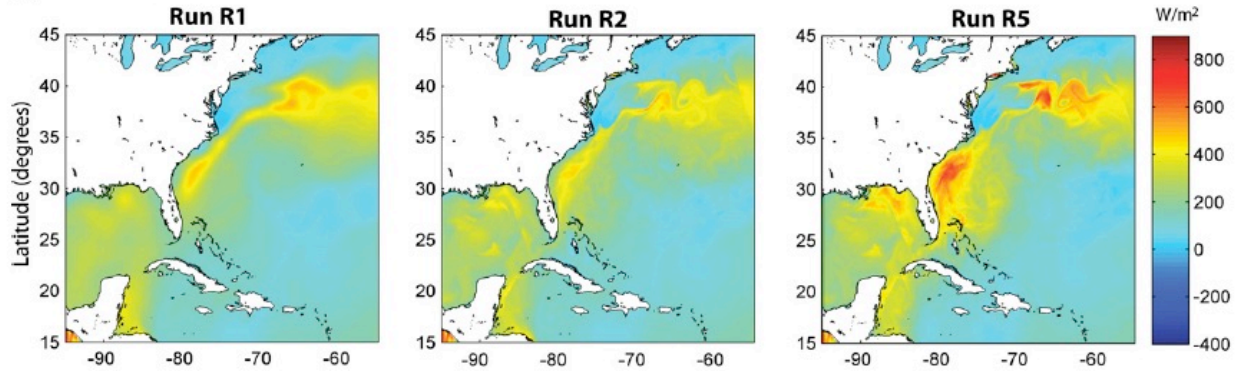
Waves increased heat fluxes and moisture fluxes to atm, leading to increased max precipitation and location closer to measured area.

WRF

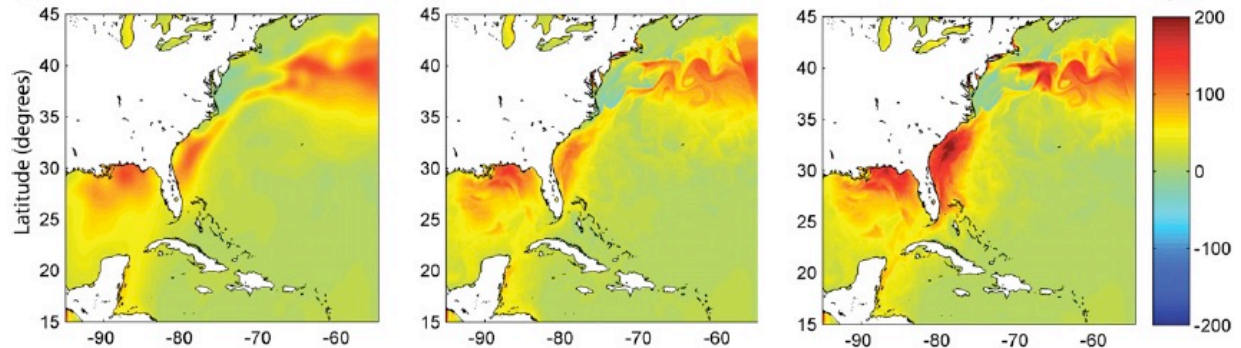
WRF + ROMS

WRF + ROMS + SWAN

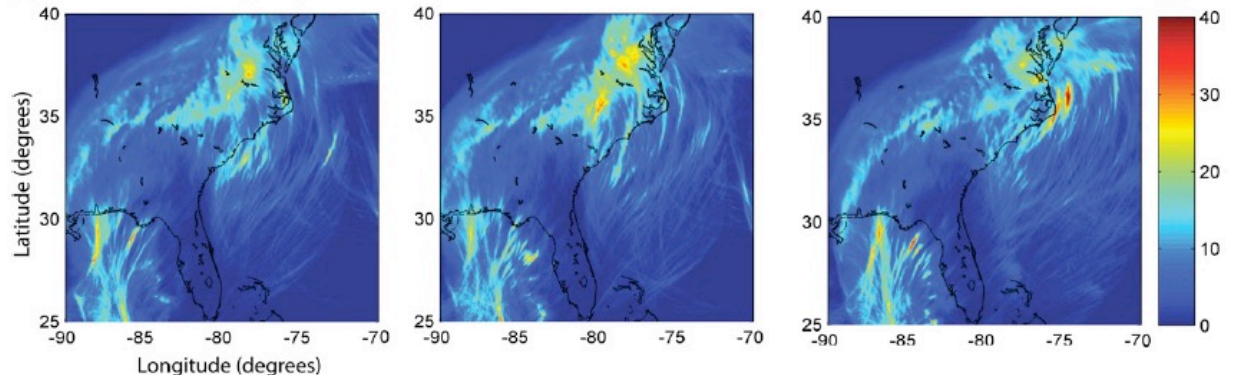
(a) Mean Latent Heat flux



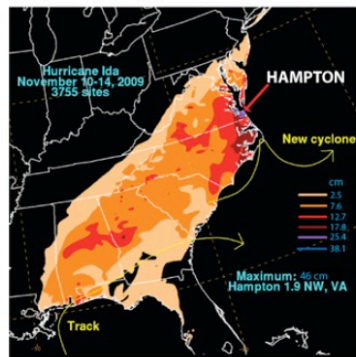
(b) Mean Sensible Heat flux



(c) Accumulated total precipitation



(a) Measurements



<http://www.hpc.ncep.noaa.gov/tropical/rain/crainfall.html>

Summary

- Developed a Coupled Ocean – Atmosphere - Wave – Sediment Transport Modeling System
- ~ 800 International Users, Trainings, Documentation, Test Cases
- Sensitivity tests of a strong Nor'Easter identified:
 - Coupling of atm-ocn led to slightly increased storm intensity due to SST updating.
 - Coupling of waves caused increase surface stress that reduced storm strength.
 - Waves also increased moisture flux to atm leading to increased precipitation.

Processes in one model propagate to other models and cause feedbacks !

Have ~ 50 publications listed in User Manual of other applications. If you are interested please let us know!.

