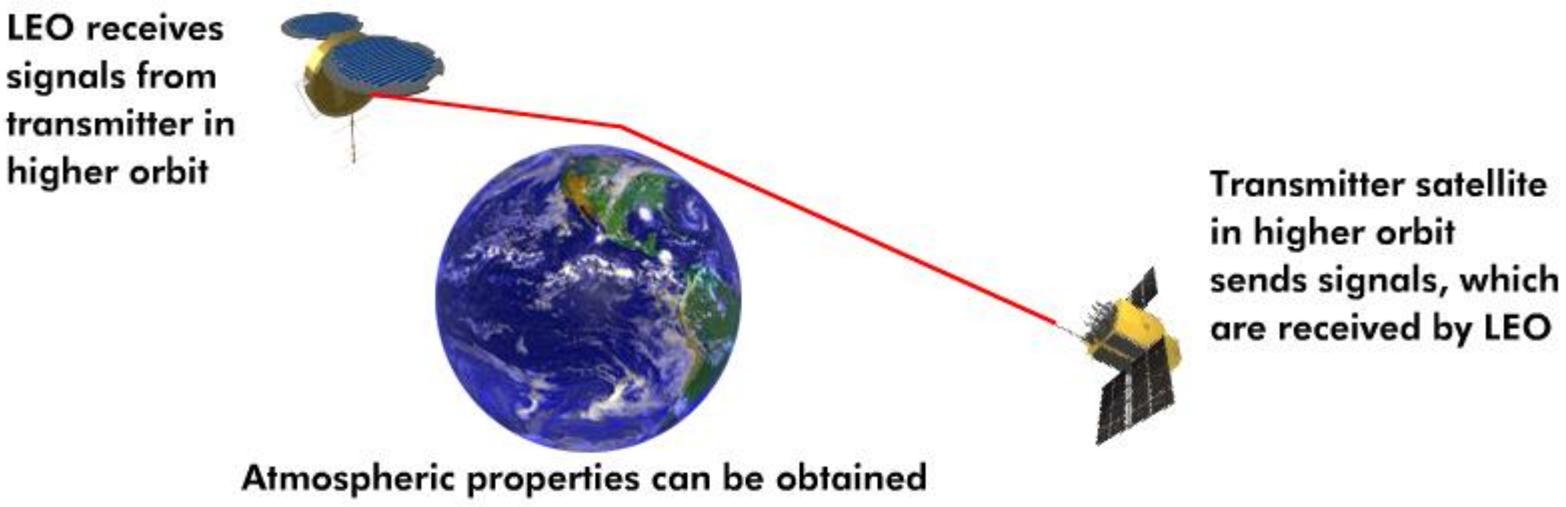
A review of MSU software tools and NOAA funded research applied to tropical cyclones

Pat Fitzpatrick, Mississippi State University

- Tropical Cyclone Tools
    - ❑ Probability of moist/dry air using refractivity data
    - ❑ R-CLIPER pdf equations
    - ❑ Model wind profile diagnostic tool in ATCF
    - ❑ Parametric wind scheme using NHC statements as a function of Vmax, Rmax, R34, and speed
    - ❑ Model validation tools (vector correlation, super-ranking)
    - ❑ Parallel coordinate visualization for multiple regression schemes
    - ❑ 0.5 km Surface reanalysis
- Recent tropical cyclone research
    - ❑ Storm surge (wetland impact, sensitivity studies, BP oil spill)
    - ❑ HWRF-HYCOM and HWRF-POM validation study of water profiles for Hurricane Isaac (2011)
    - ❑ Wave Glider 2014 Gulf of Mexico Field Program (2014)

Presentations on all topics available upon request, or for further discussions

Radio occultation (limb sounding) method



COSMIC (The Constellation Observing System for Meteorology, Ionosphere, and Climate):
Launched with 6 LEOs on April 14, 2006; joint Taiwan-U.S. project

CHAMP (CHAllenging Minisatellite Payload) :
Prototype for COSMIC, 1 LEO, launched on July 15, 2000; Germany project

Method can be coupled to refractivity equation

$$N(\mathrm{p},\mathrm{T},\mathrm{T_d}) = 77.6\frac{p}{T} + 3.73\times 10^5 \frac{e(\mathrm{T_d})}{T^2} + correction\ \ for\ ionospheric\ effects$$

$$\qquad\qquad [\text{dry term}]\ \ [\text{wet term}]$$

Advantages:

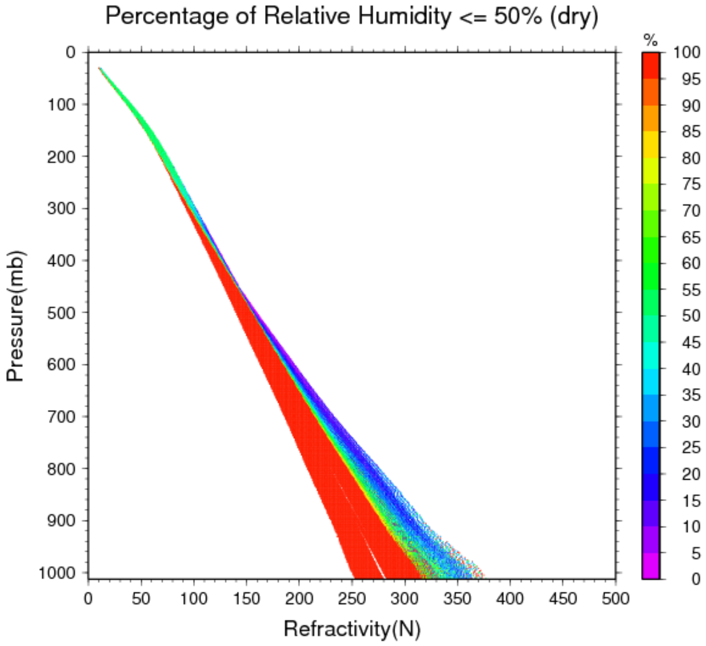
- *High vertical resolution (0.1 km)*
- *No calibration needed*
- *Not affected by clouds or rain*
- *Global coverage*

Disadvantages:

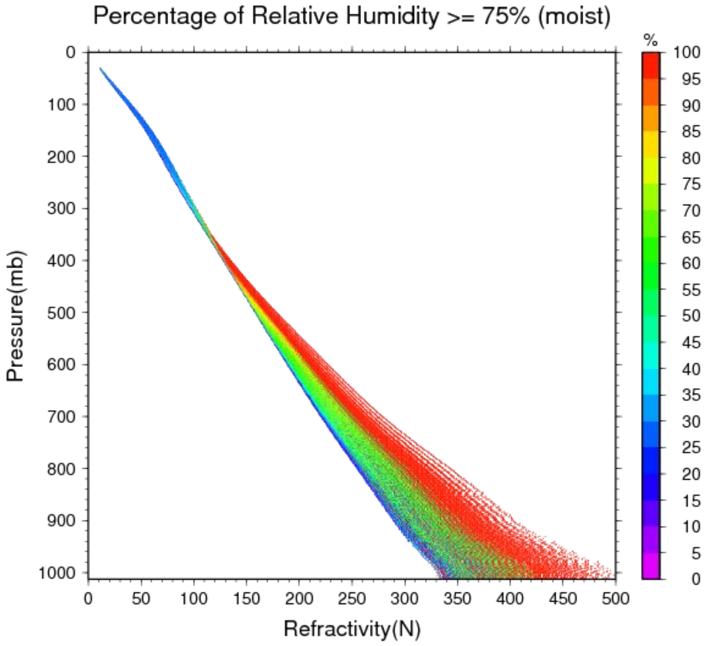
- *Horizontal resolution coarse (200 km)*
- *Refractivity equation an unclosed system where moisture abundant (lower troposphere).*

Diagnostic tool dry and moist air in hurricanes

Probability of dry air

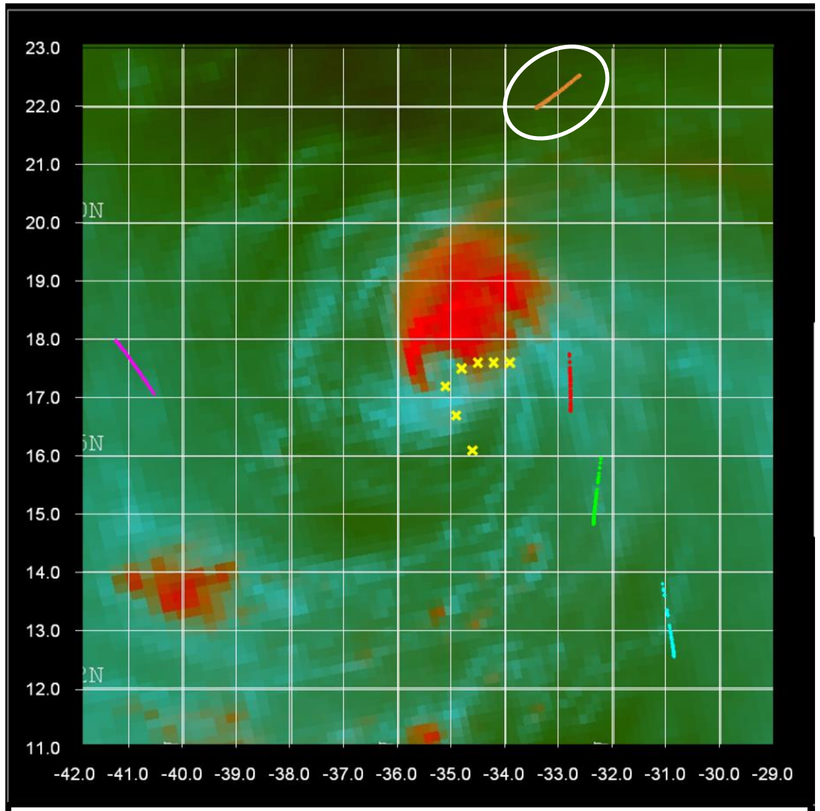


Probability of moist air

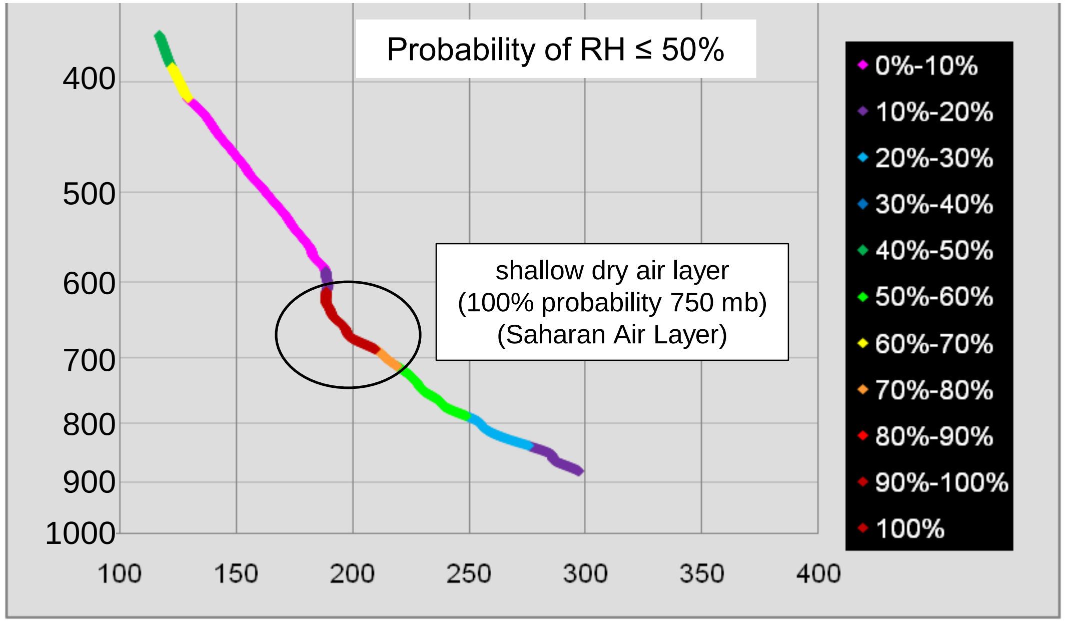


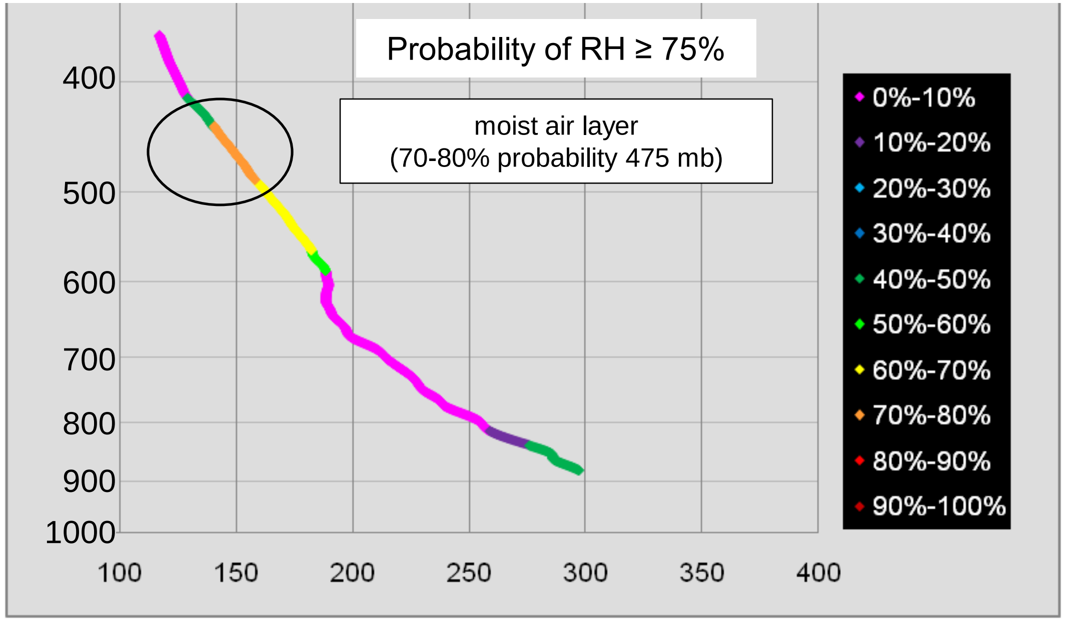
Understanding of optimum use of refractivity in hurricane models

Hurricane Fred 2009

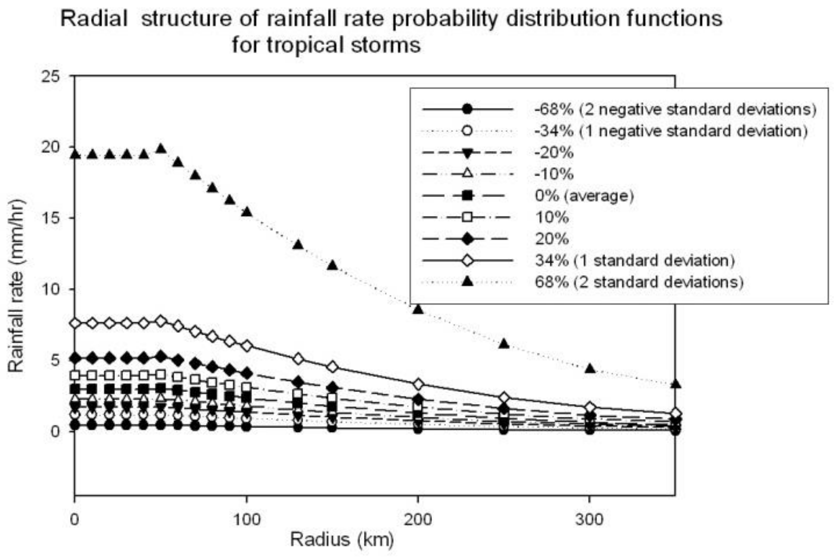


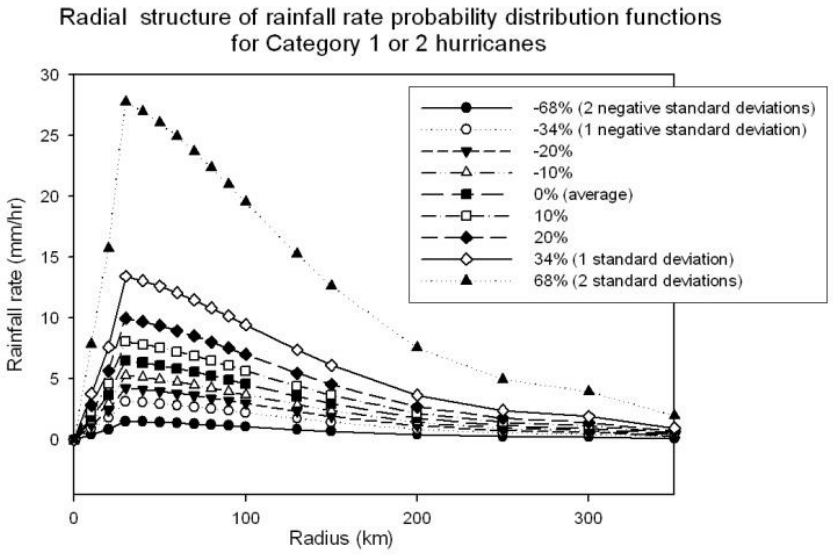
23:41 UTC 10 September 2009
AMSU-B image from METOP-A satellite
(image provided by NRL-Monterey)



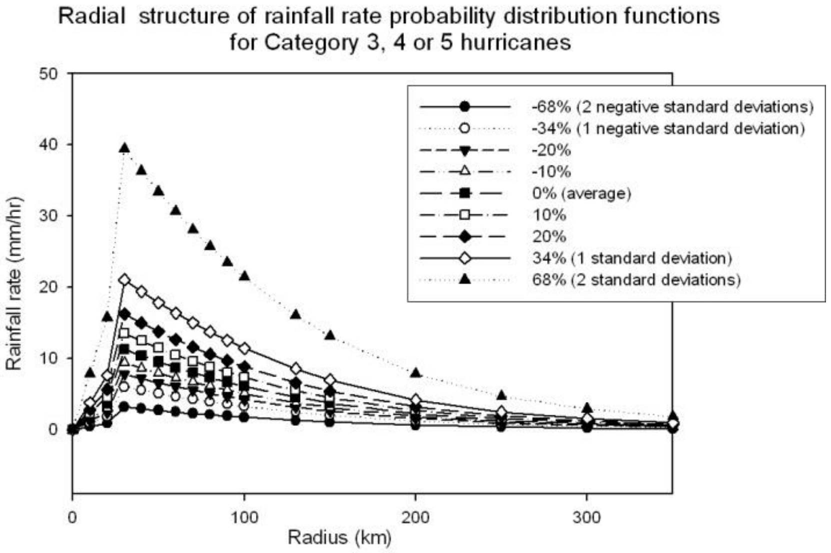


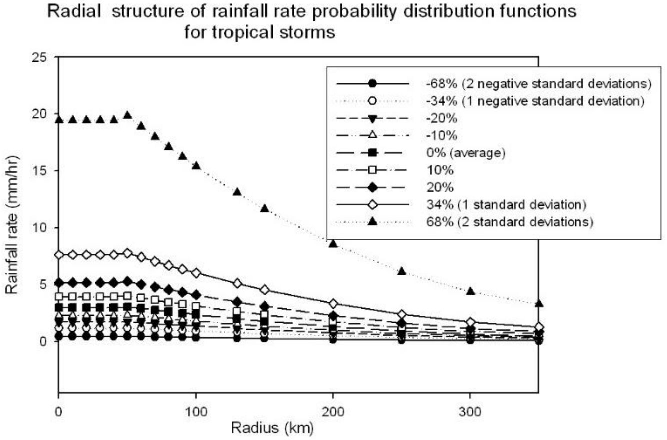
R-CLIPER for TS, Min Hurr, and Major Hurr, with avg, ± 10%, ± 20%, ± 34%, ± 68%,

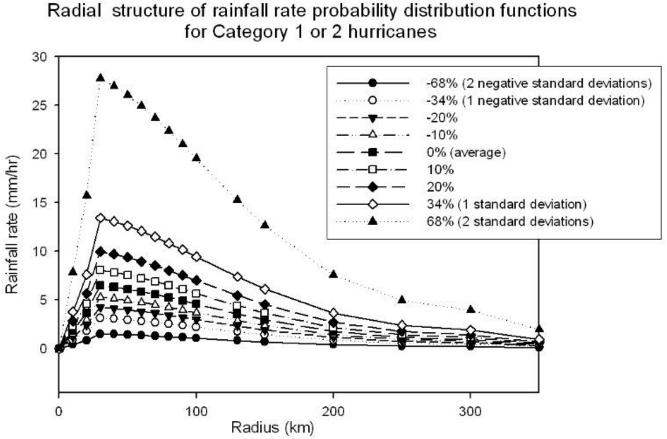


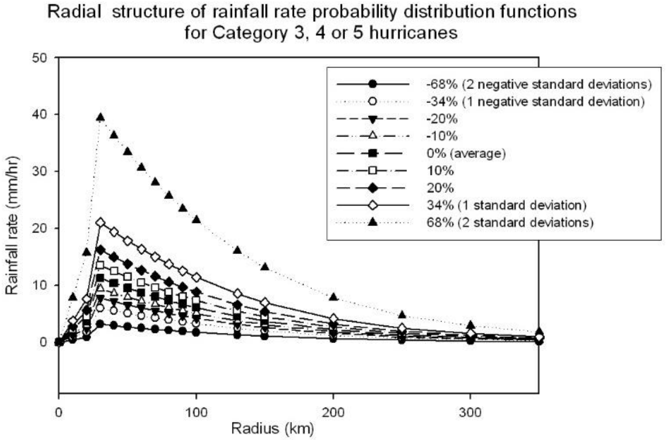


From Fitzpatrick and Lau (2011) Based on Lonfat et al. (2007)









R-Cliper PDF equations (-90% ≤ f ≤ 90%)

For tropical storms

$$R_{TS}(r,f) = A_{TS}\exp(B_{TS}\,f) \quad ; \qquad r \le 50$$

$$R_{TS}(r,f) = (2.05957684\times10^{-5}r^{2} - 1.672969851\times10^{-2}r + 3.838964806)\exp(B_{TS}\,f) \quad ; \qquad r > 50$$

$$A_{TS} = 2.995207,\ B_{TS} = 0.027499$$

For Category 1 and 2 hurricanes

$$R_{C12}(r,f) = A_{C12}\exp(B_{C12}\,f)\frac{r}{30} \quad ; \qquad r \le 30$$

$$R_{C12}(r,f) = (-2.474340293\times10^{-9}r^{4} + 1.935560971\times10^{-6}r^{3} - 4.444507808\times10^{-4}r^{2} + 6.840501651\times10^{-3}r + 6.656484399)\exp(B_{C12}\,f) \quad ; \qquad r > 30$$

$$A_{C12} = 5.539108,\ B_{C12} = 0.0213$$

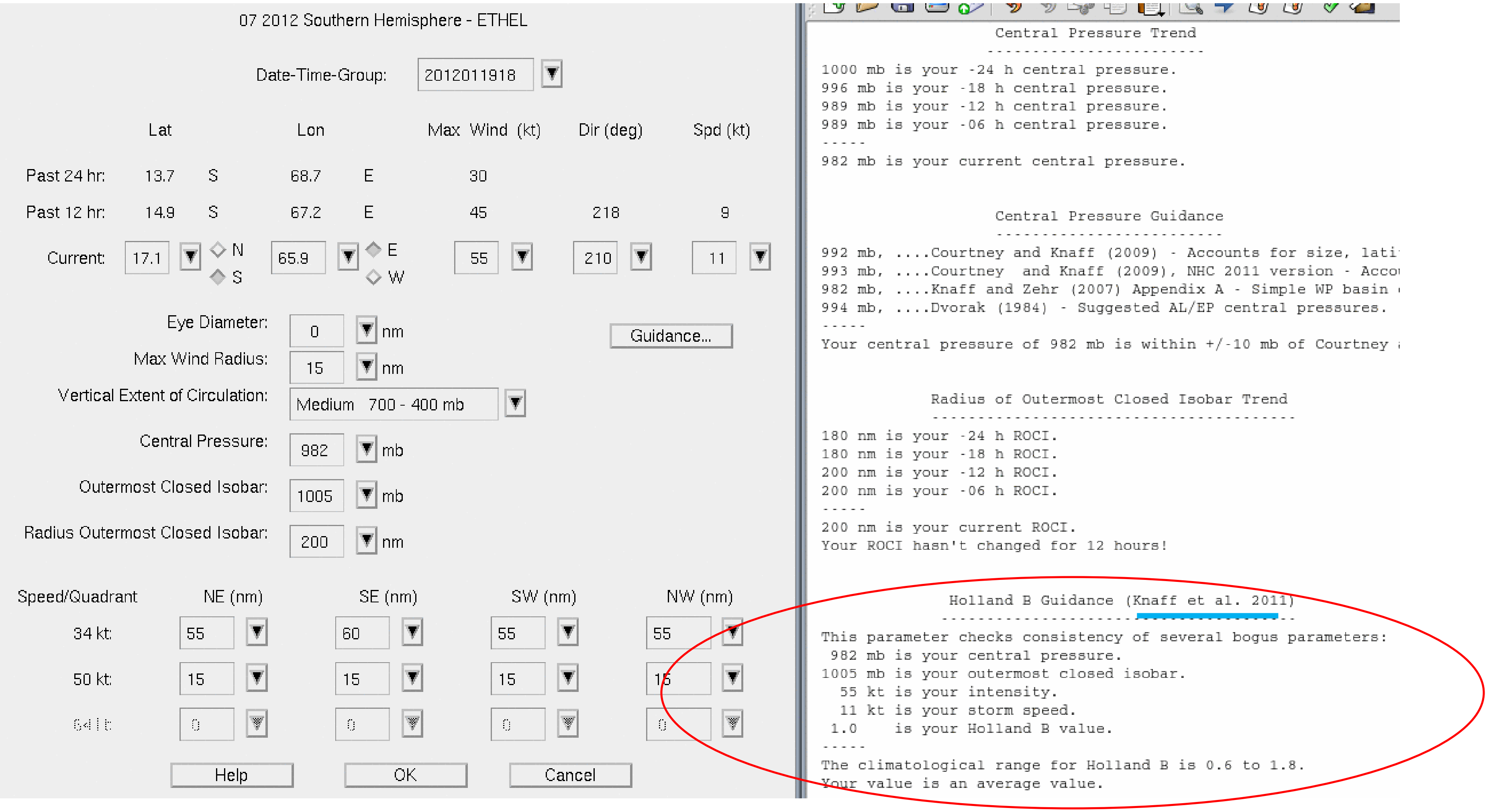
For Category 3, 4 and 5 hurricanes

$$R_{C35}(r,f) = A_{C35}\exp(B_{C35}\,f)\frac{r}{30} \quad ; \qquad r \le 30$$

$$R_{C35}(r,f) = (-2.984284245\times10^{-7}r^{3} + 3.033414728\times10^{-4}r^{2} - 1.088545019\times10^{-1}r + 14.25059433)\exp(B_{C35}\,f) \quad ; \qquad r > 30$$

$$A_{C35} = 10.94344,\ B_{C35} = 0.018433$$

Screen capture of wind profile scheme in the Automated Tropical Cyclone Forecasting System (ATCF)



"Fitz" Holland B parametric scheme

The hurricane winds are based on a variant of the *Holland* (1980) wind profile:

$$p(r, B, p_{env}, p_c, R_{max}) = p_c + [p_{env} - p_c]e^{-Ar^{-B}}$$

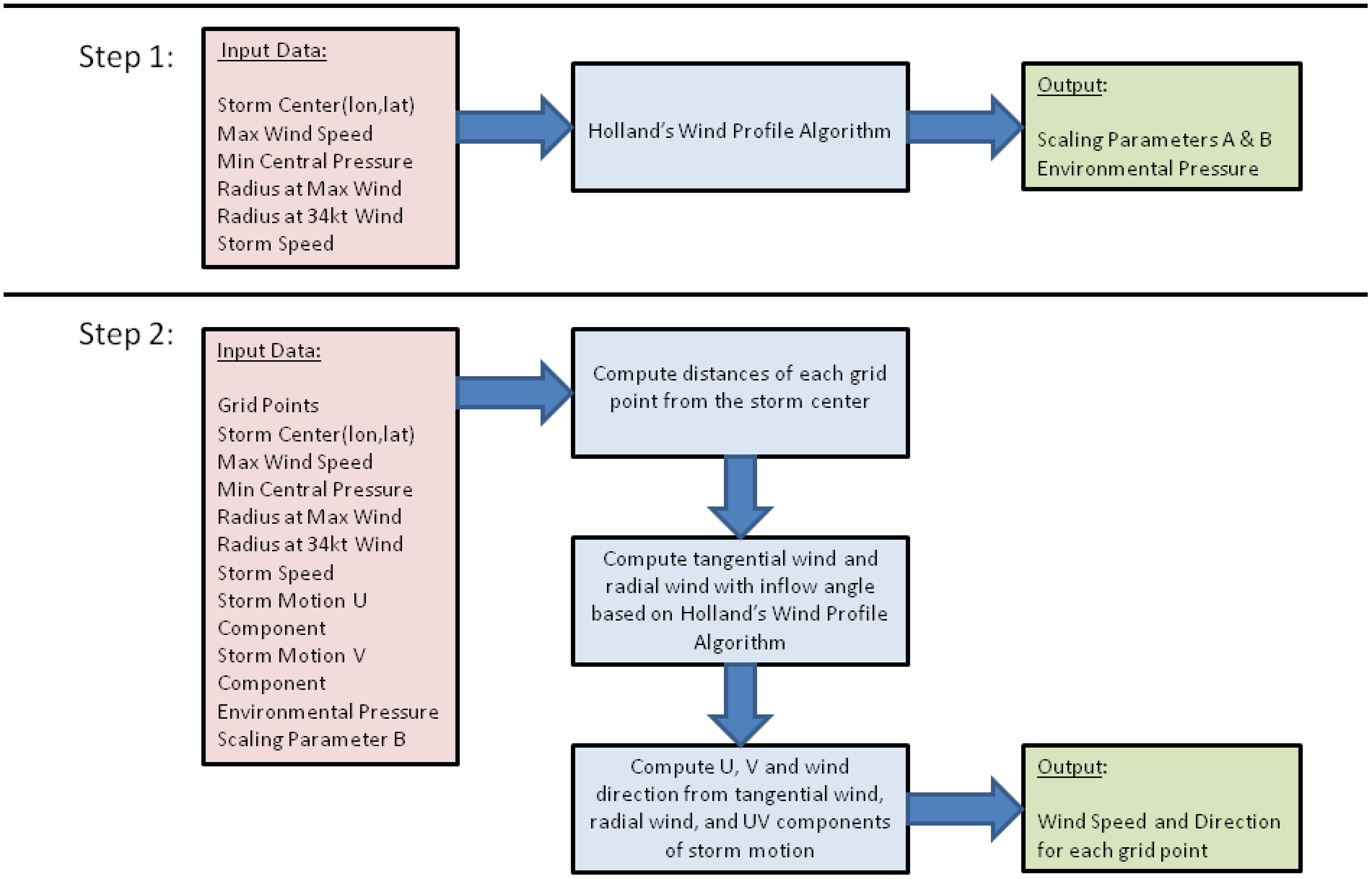
$$V(r, B, f, p_{env}, p_c, R_{max}) = \left[\frac{AB[p_{env} - p_c]e^{-Ar^{-B}}}{\rho r^B} + \left[\frac{rf}{2}\right]^2\right]^{0.5} - \left[\frac{rf}{2}\right]$$

$$V_{max}(B, p_{env}, p_c) = \left[\frac{B}{\rho e}\right]^{0.5} [p_{env} - p_c]^{0.5} \; ; \; A(R_{max}, B) = R_{max}^B$$

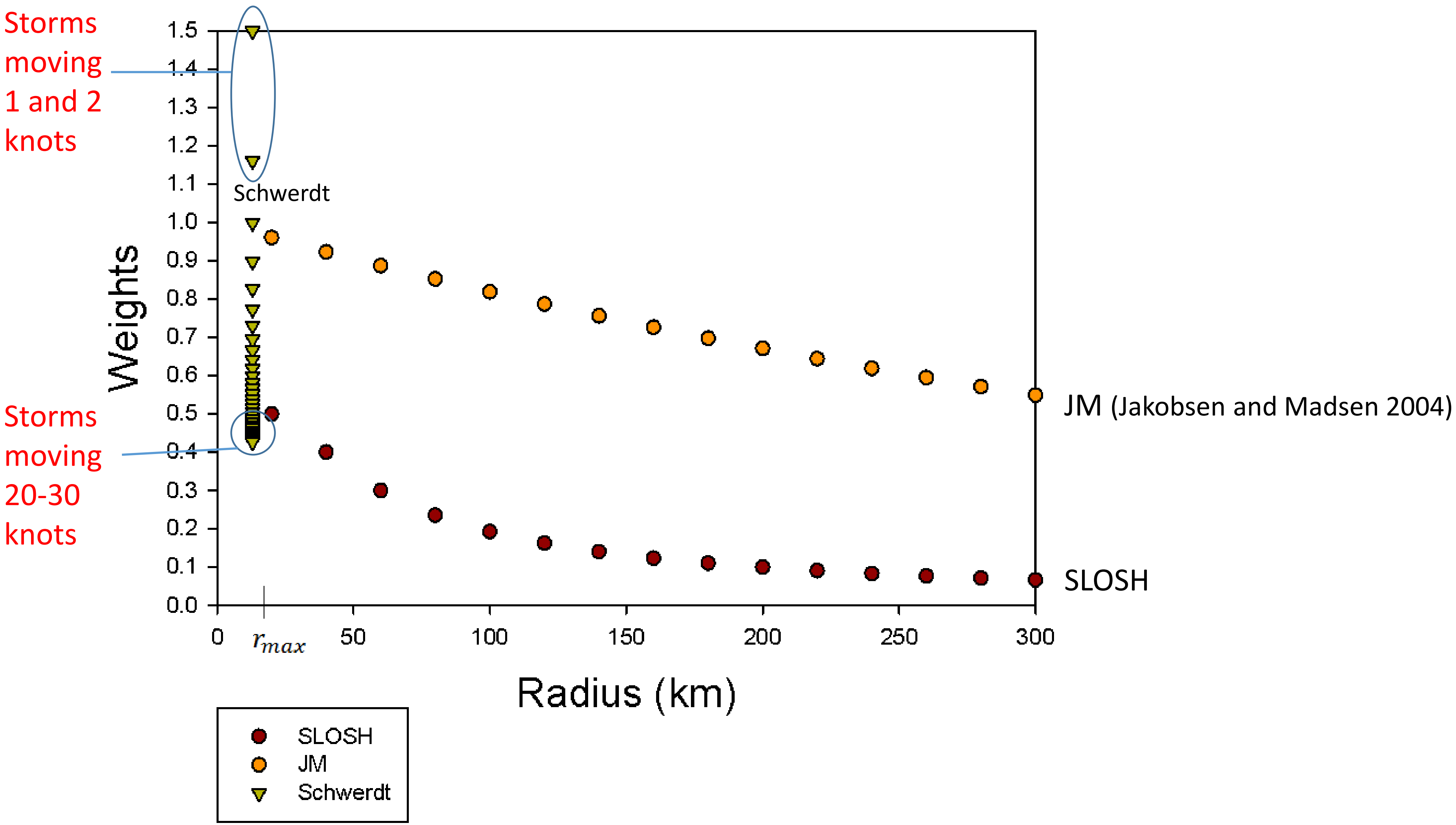
where f is the Coriolis parameter, p_c is the storm central pressure, p_{env} is the environmental pressure (set to 1013 mb), and e is Euler's number (the base of the natural logarithm, approximately 2.71828). A and B are scaling parameters which control the radial wind profile. This formulation includes storm motion in V. Given storm motion, V_{max}, R_{max}, p_{env} , and R34, the algorithm iterates for B and then calculates p_c.

Because these equations apply above the boundary layer, but V_{max} and V34 (34-kt winds at R34) are at 10-m height within the boundary layer, V_{max} and V34 are multiplied by 1.11 before the B iteration. On average, winds are 11% faster above the boundary layer (see http://www.nhc.noaa.gov/aboutwindprofile.shtml, and Powell and Black (1990)). However, little sensitivity in the B distribution was seen with this adjustment.

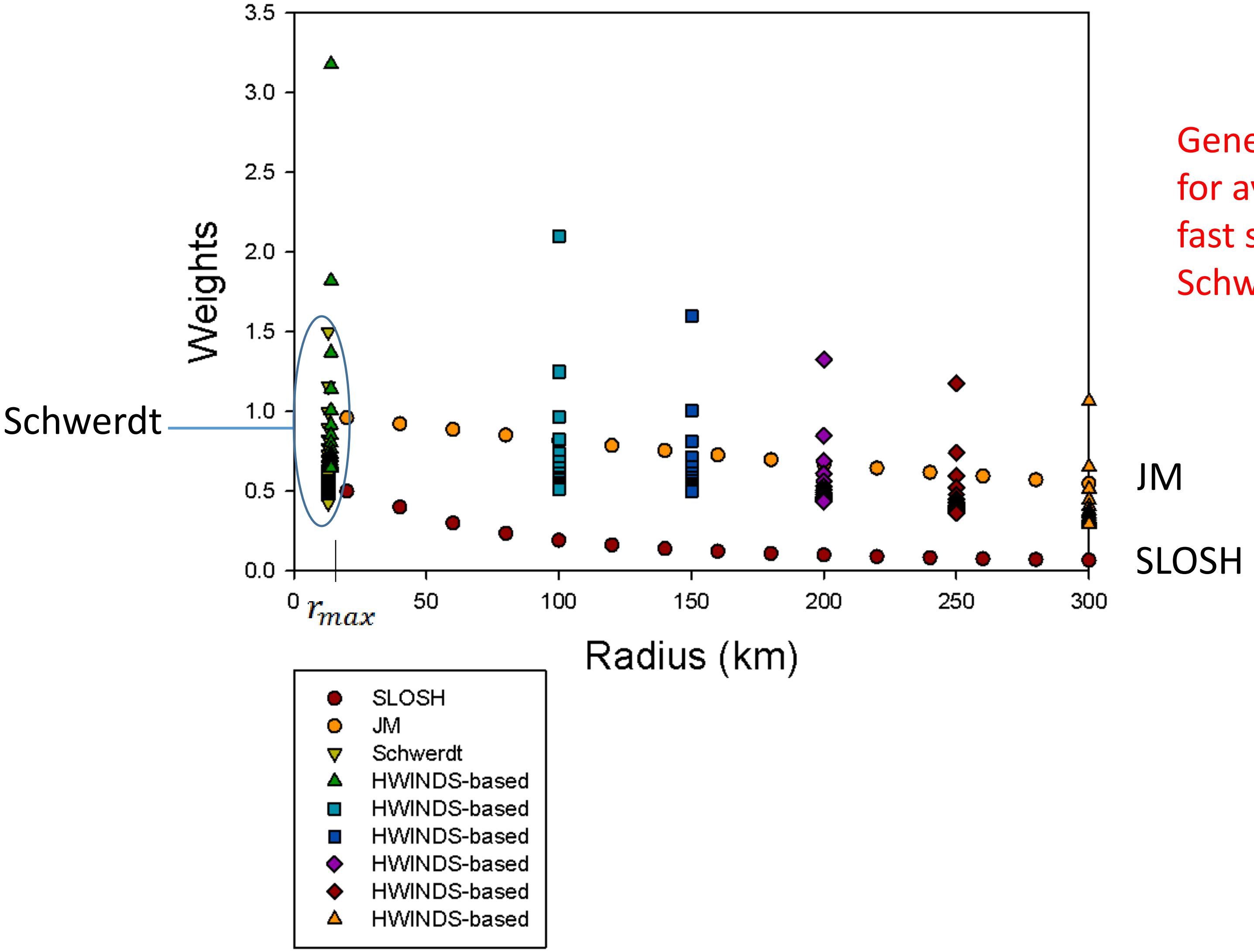
Parametric hurricane wind model flow chart



Summary, Asymmetry Weights



Summary, Assymmetry Weights Including HWINDS dataset



Generally matches JM for avg speeds. Slow and fast speeds follow Schwerdt correction

Snippets of code

```
w_rmax=(1.5*storm_speed_kts**0.63)/storm_speed_kts
w_r34=0.3*w_rmax
Vmax=Vmax-storm_speed*w_rmax
```

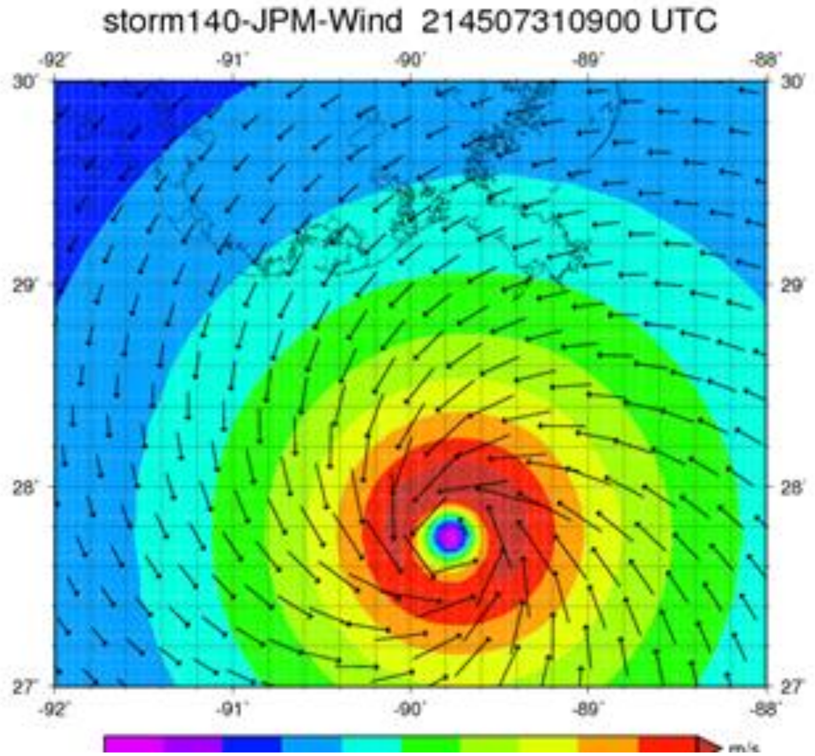
```
 function f(B,Vmax,storm_speed,Rmax,size,Coriolis,windF,w_r34)

 implicit none

 double precision  B, Vmax, Rmax, storm_speed, size, Coriolis
 double precision  Wind34ktInMeterPerSec, rho, f, ts, windF
 double precision w_r34
 parameter(Wind34ktInMeterPerSec=17.5, rho=1.15)

 ts = Wind34ktInMeterPerSec * windF - storm_speed*w_r34

 f=(sqrt((((Rmax**B)*B*(Vmax*Vmax/(B/(rho*2.71828))*
&   exp(-(Rmax**B)/(size**B))))/(rho*size**B)) +
&   ((size**2)*(Coriolis**2)/4.0)) - (size*Coriolis/2.0))
&   - ts

 end function f
```

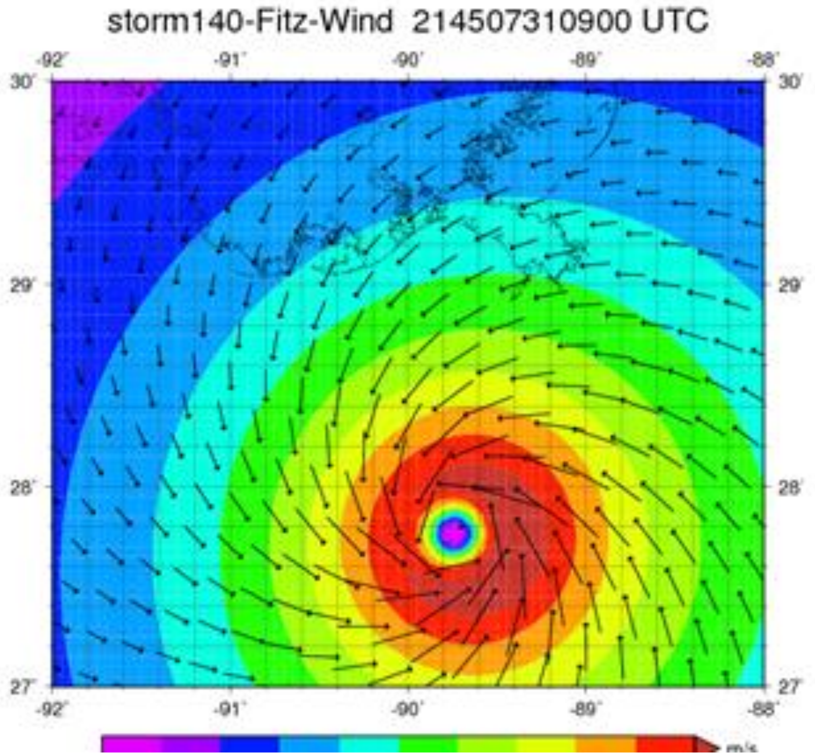
```
    slope=(w_r34-w_rmax)/(R34-Rmax)
    y_int=w_rmax-slope*Rmax
    w_asymm=slope*rad+y_int
    if(rad.lt.Rmax) w_asymm=slope*Rmax+y_int
    if(w_asymm.lt.0.0) w_asymm=0.0

    u(i,j) = -ur*dsin(angr)-tang*dsin(angt) + umot*w_asymm
    v(i,j) = -ur*dcos(angr)-tang*dcos(angt) + vmot*w_asymm

    wspd(i,j) = sqrt(u(i,j)**2 + v(i,j)**2)
    wdir(i,j) = dmod(dble(180.0)+
&                datan2d(u(i,j),v(i,j)),dble(360.))
```

Advantage of this method

- 10-meter surface winds **match** the observed peak **eyewall wind**
- 10-meter surface winds **match** the observed **radius of 34-knots winds**
- **Holland B an iterated solution**, not predetermined
- **Specification of wind direction** that can vary radially
- **Storm motion is included in the iteration, not added afterwards**
  - ➢ Vmax=storm speed plus hurricane vortex eyewall
  - ➢ V34=storm speed plus edge of hurricane vortex
- This allows a parametric model which:
  - ➢ **Matches the National Hurricane Center forecast**
  - ➢ Can **match hindcast hurricane data** for JPM studies, theoretical studies, risk modeling, etc.
  - **Correctly uses storm motion**. Many schemes superimpose storm speed translation. This is incorrect usage. Observed winds already include storm motion.
- Released 6/11/14 as open source. Its also now being incorporated into SMS software.

Comparison of hypothetical storm (left) fitted by Fitz Wind Model (right)





Super-ranking concept

<u>Philosophy</u>

Weighting multiple metrics and techniques provides clearer model validation comparison….especially for models of relatively close accuracy based only on bias and absolute error

Flexibility in weights if certain metrics are considered to be more important than others

Metrics were consolidated into three techniques

- Absolute error percentage – (single variable)
- Outlier metrics – (six variables)
- Validation metrics – (ten variables)

Variable details

- Absolute error percentage – percentage where speed errors are within 10 cm/s, and direction errors are within 20 deg (0 to 100%, 100% best)

- Outlier metrics of 10 cm/s or 20 deg (>=0, 0 best in all cases) –
  1) Positive outlier percentage
  2) Negative outlier percentage
  3) Number of occurrences with consecutive positive outliers
  4) Number of occurrences with consecutive negative outliers
  5) Maximum duration of consecutive positive outliers
  6) Maximum duration of consecutive negative outliers

Variable details (continued)

- Validation metrics –
  1) Model efficiency factor (<= +1, +1 best)
  2) Pearson correlation coefficient (-1 to +1, +1 best)
  3) Spearman correlation coefficient (-1 to +1, +1 best)
  4) Kendall’s Tau (-1 to +1, +1 best)
  5) Reliability index (>= +1, +1 best)
  6) Multiplicative bias (any number, +1 best)
  7) Normalized dispersion (any number, +1 best)
  8) Normalized bias (any number, 0 best)
  9) Root mean squared difference (>= 0, 0 best)
  10) Root centered mean square difference (>= 0, 0 best)

Super-ranking methodology

Step 1: After every variable of each metric is calculated for the models at each observation per month, a monthly variable rank is given to each model (1 to 4 for four models, for example) with rank 1 being the best.

Step 2: Assigning each monthly variable rank with points (0 pt for last place, 1 pt for 2nd-last, etc.), the sum of points for all months in the season determines the seasonal variable rank of each model at each observation.

Step 3: For each seasonal variable rank in each metric, points again are assigned as in Step 2. The sum of points for all seasonal variable(s) in the metric determines the overall seasonal metric rank of each model at each observation.

Step 4: To determine the final super-ranking of each model, averaging applied. The best model has the smallest averaged season model rank number.

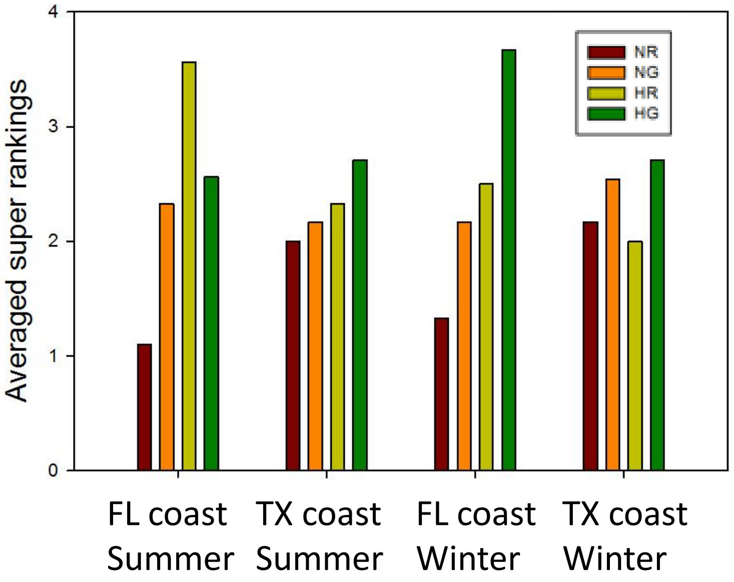
Vector correlation

- A methodology developed by Hanson et al. (1992) that describes the goodness-of-fit of a relationship between two sets of vectors that includes translation, scaling, and either rotational or reflectional dependency.
- Varies from -1 to +1. +1 best in terms of validation

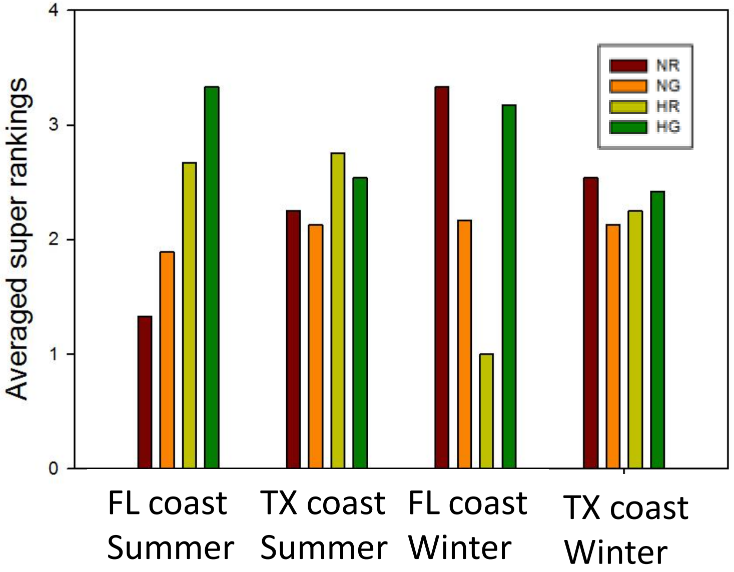
Example, ocean model currents, buoy validation, 0Z

- NCOM Regional (NR) for GOM, 1/30 deg, known as AMSEAS
- NCOM Global (NG), 1/8 deg
- HYCOM Regional (HR) for GOM, 1/25 deg
- HYCOM Global (HG), only available at 00Z, 1/12 deg

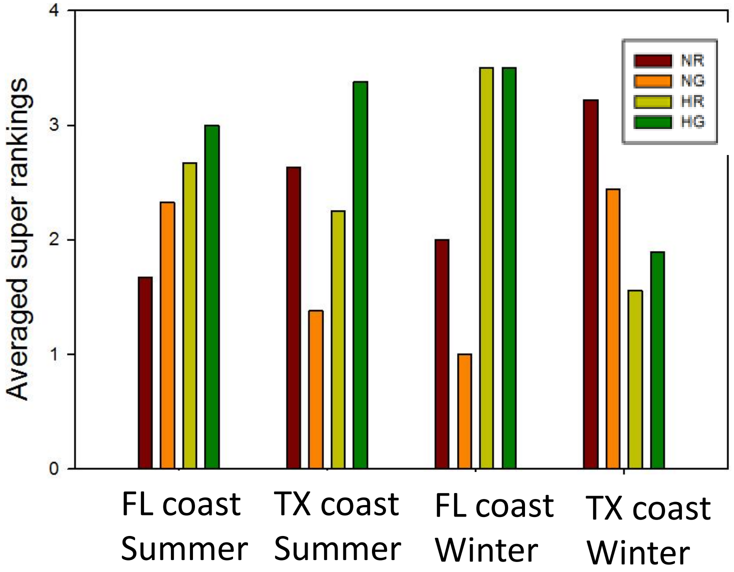
Comparison, 4 models, direction



Comparison, 4 models, speed

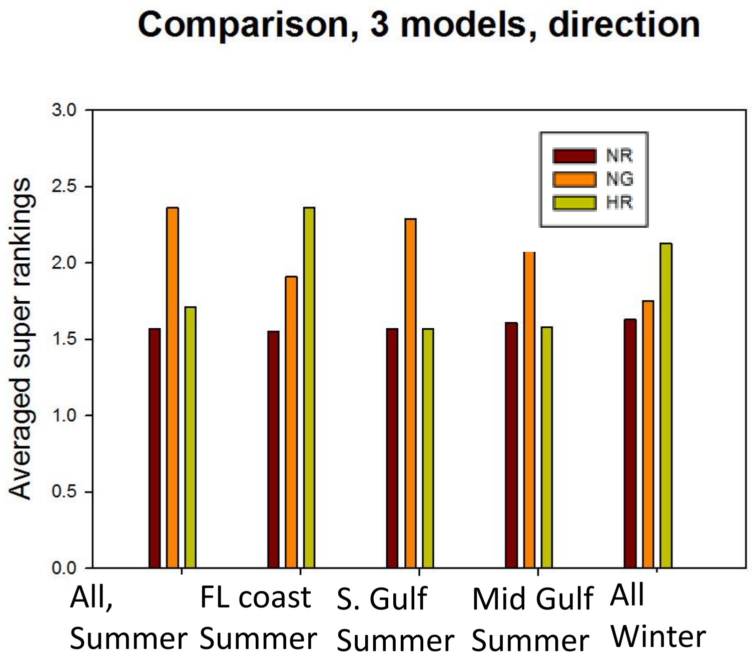


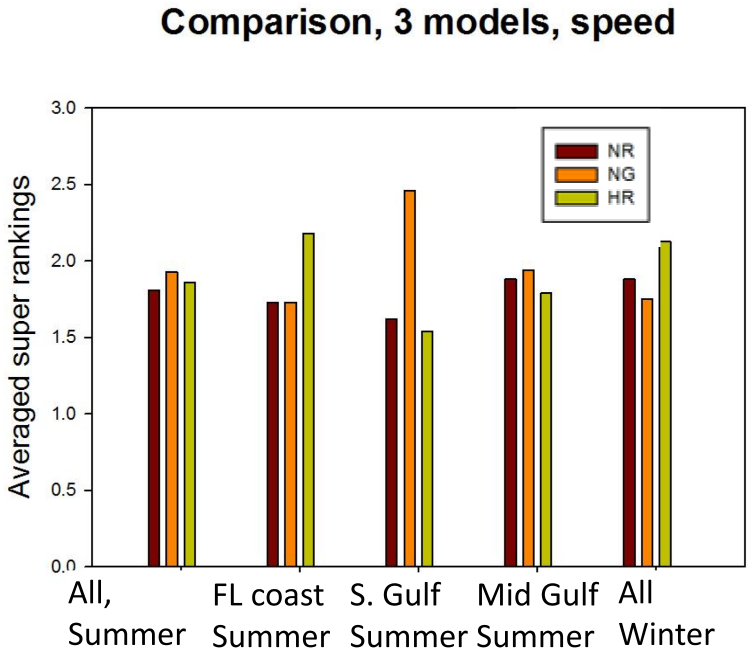
Comparison, 4 models, vector correlation

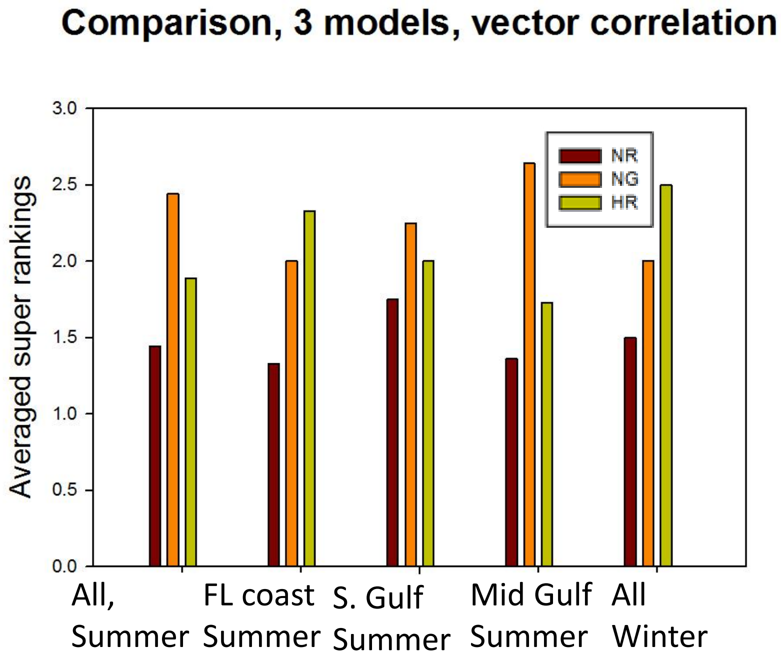


Example, ocean model currents, drifter validation, daily

- NCOM Regional (NR) for GOM, 1/30 deg, known as AMSEAS
- NCOM Global (NG), 1/8 deg
- HYCOM Regional (HR) for GOM, 1/25 deg

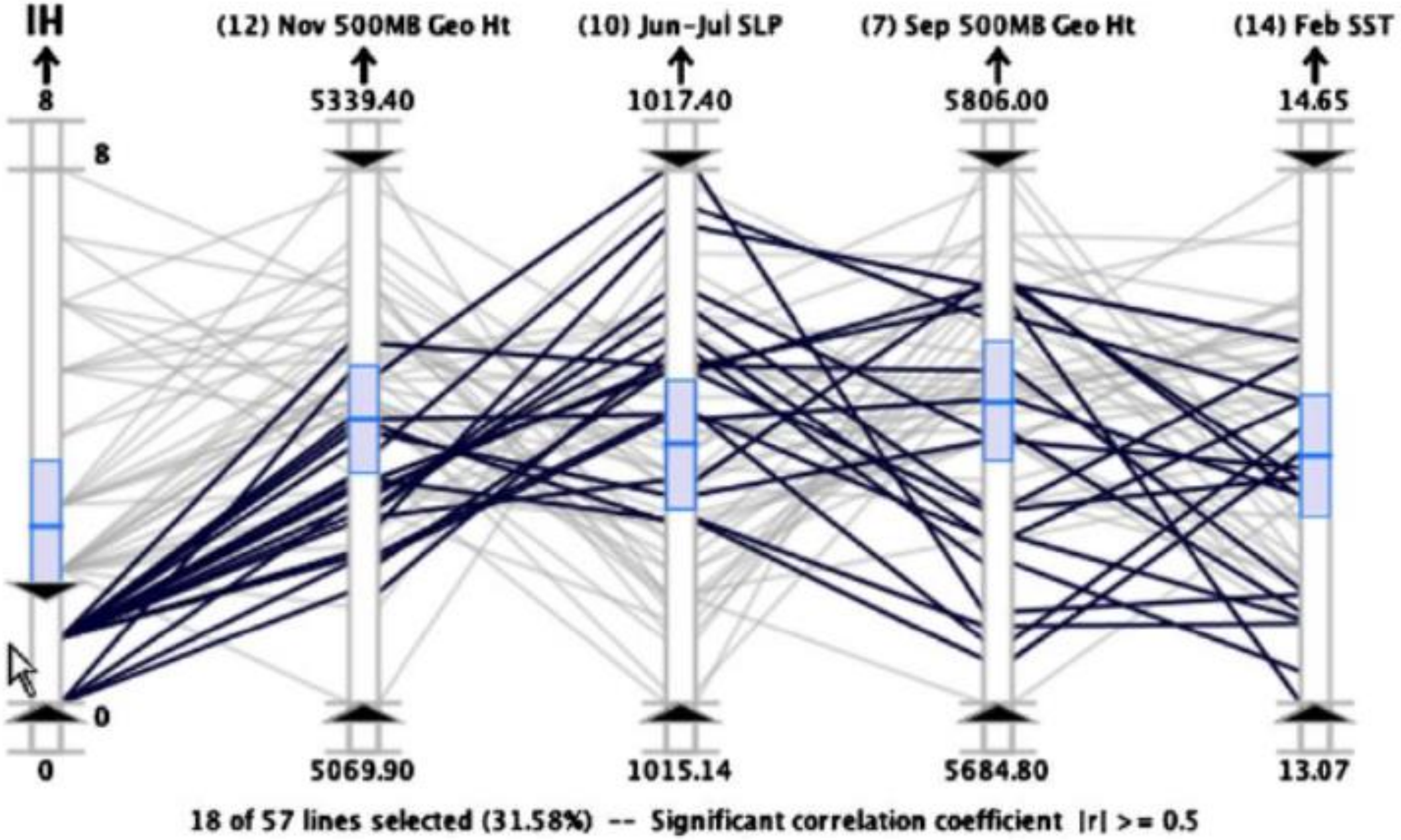






Parallel coordinates

- A visualization tool for visualizing multivariate relationships
- Draws *n* parallel lines as $y, x_1, x_2, x_3, \ldots x_n$ along an axis
- Can highlight lines to ascertain distinct relationships or patterns
- Patent number 8346682 issued on 1/1/13 for "Information Assisted Visual Interface, System, and Method for Identifying and Quantifying Multivariate Associations". Patent holders: C. A. Steed, P. J. Fitzpatrick, T. J. Jankun-Kelly, and J. E. Swan.
- Similar to multiple regression scheme SHIPS, with some changes from Fitzpatrick (1997), and rewritten into MATLAB by Steed.



Consortium for oil spill exposure pathways in Coastal River-Dominated Ecosystems (CONCORDE)

• Three-year BP-funded* consortium which addresses the question:

How do the complex fine-scale biological, chemical, and physical structure and processes in coastal waters - dominated by pulsed-river plumes – control the exposure, impacts, and recovery from offshore spills?

• MSU will provide hourly 0.5-km atmospheric forcing fields for ocean models in Mississippi Sound.

• These will be reanalyses datasets using the RTMA or NAM as a background fields from NOMADS archives, fluxes derived from COARE-Met algorithms, SSTs from AVHRR (AOML ERDAP site), and precipitation from Slidell radar (NCDC site).

• Observations from MADIS and WeatherFlow

• Currently testing Cressman, OI, 3DVAR-VAF, 3DVAR-VAN, 3DVAR-PSAS. Based on code by Xiang-Hu Yuang

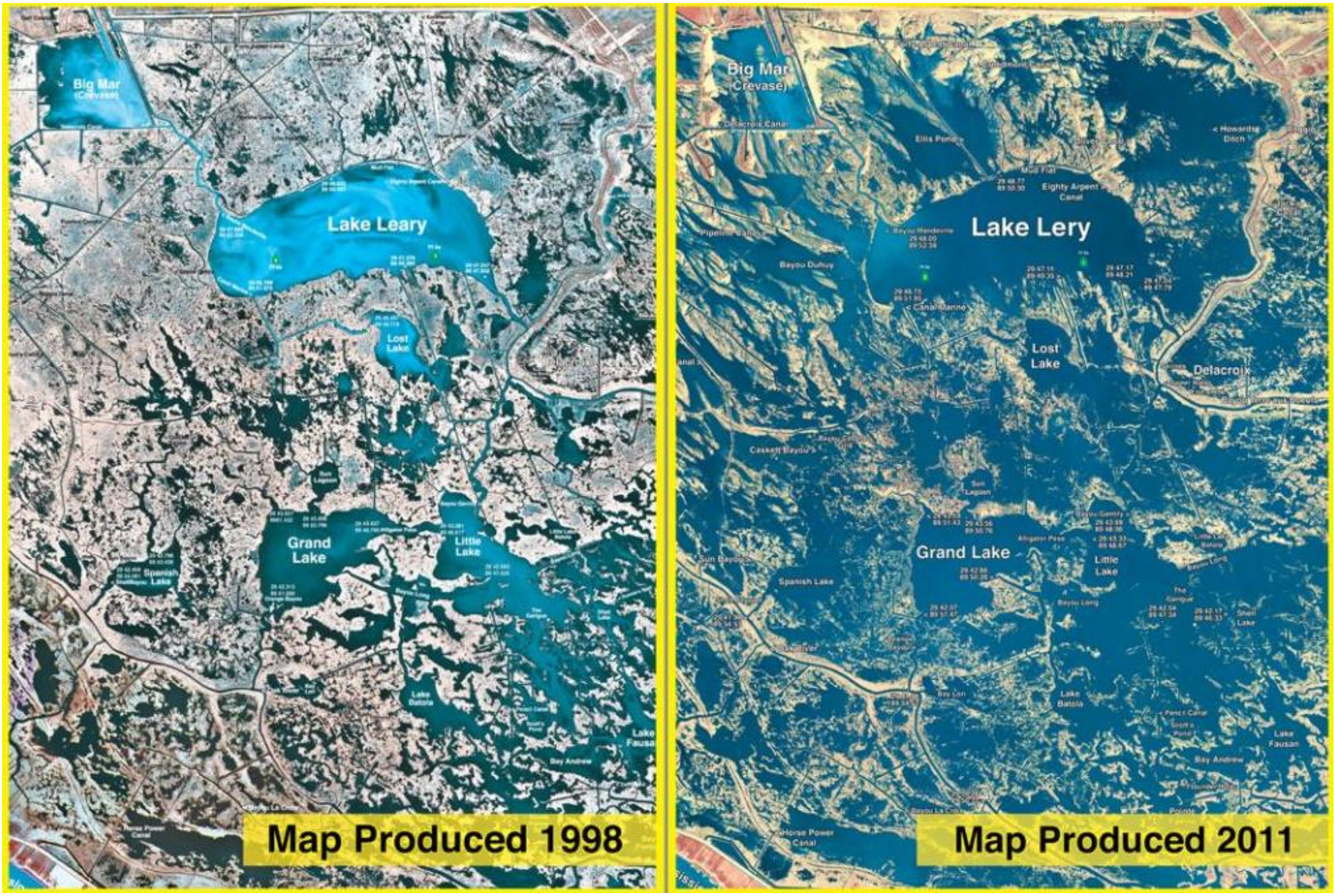
* *The Gulf of Mexico Research Initiative (GoMRI) is a ten-year $500 million commitment to study the effects of the Deepwater Horizon incident and the potential associated impact on the environment and public health. GoMRI's organization has overtones of an NSF structure.*

Wetland resilience to surge with Mississippi River water

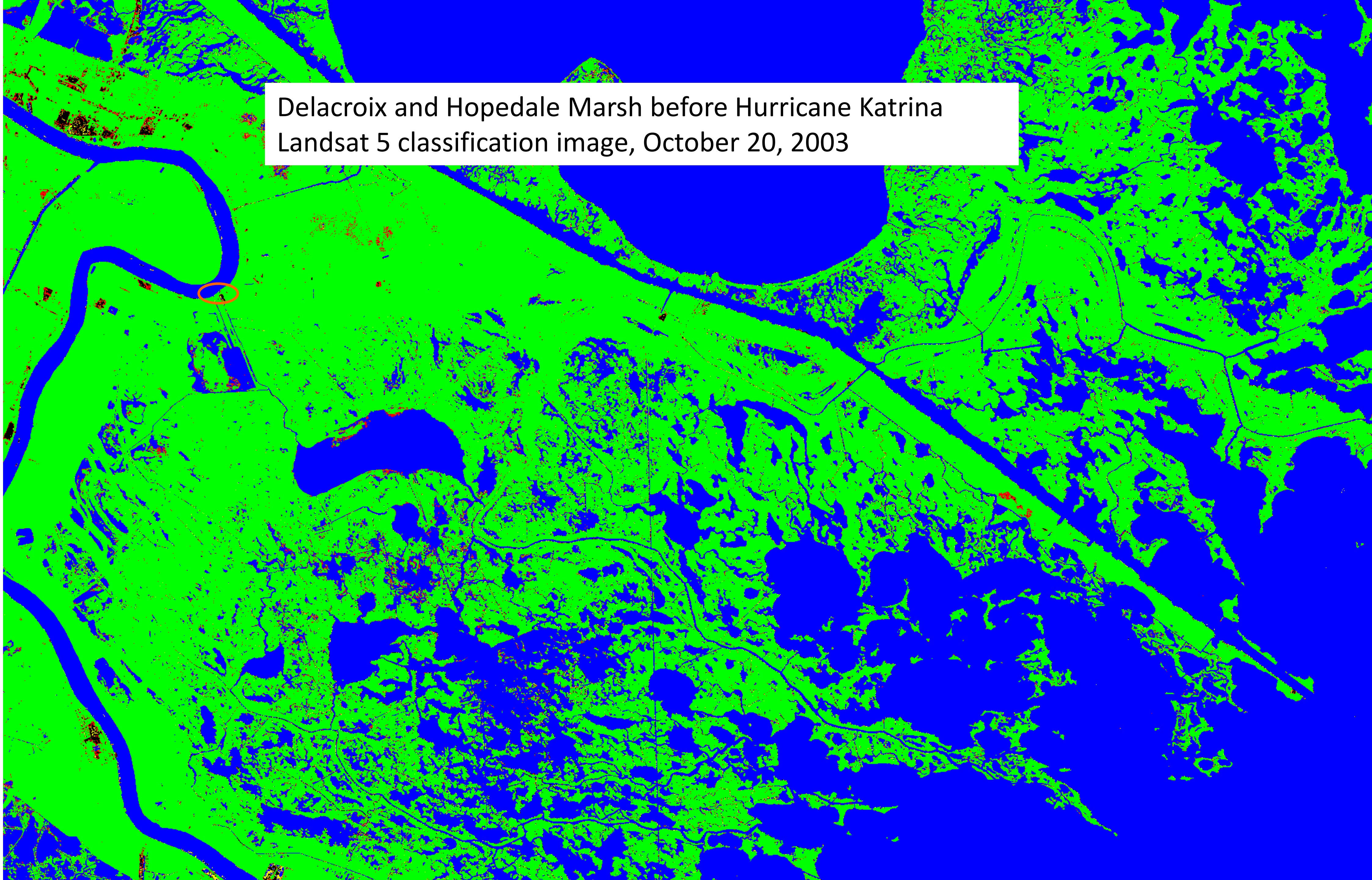
Issue – a marsh erosion issue exists near Caernarvon diversion

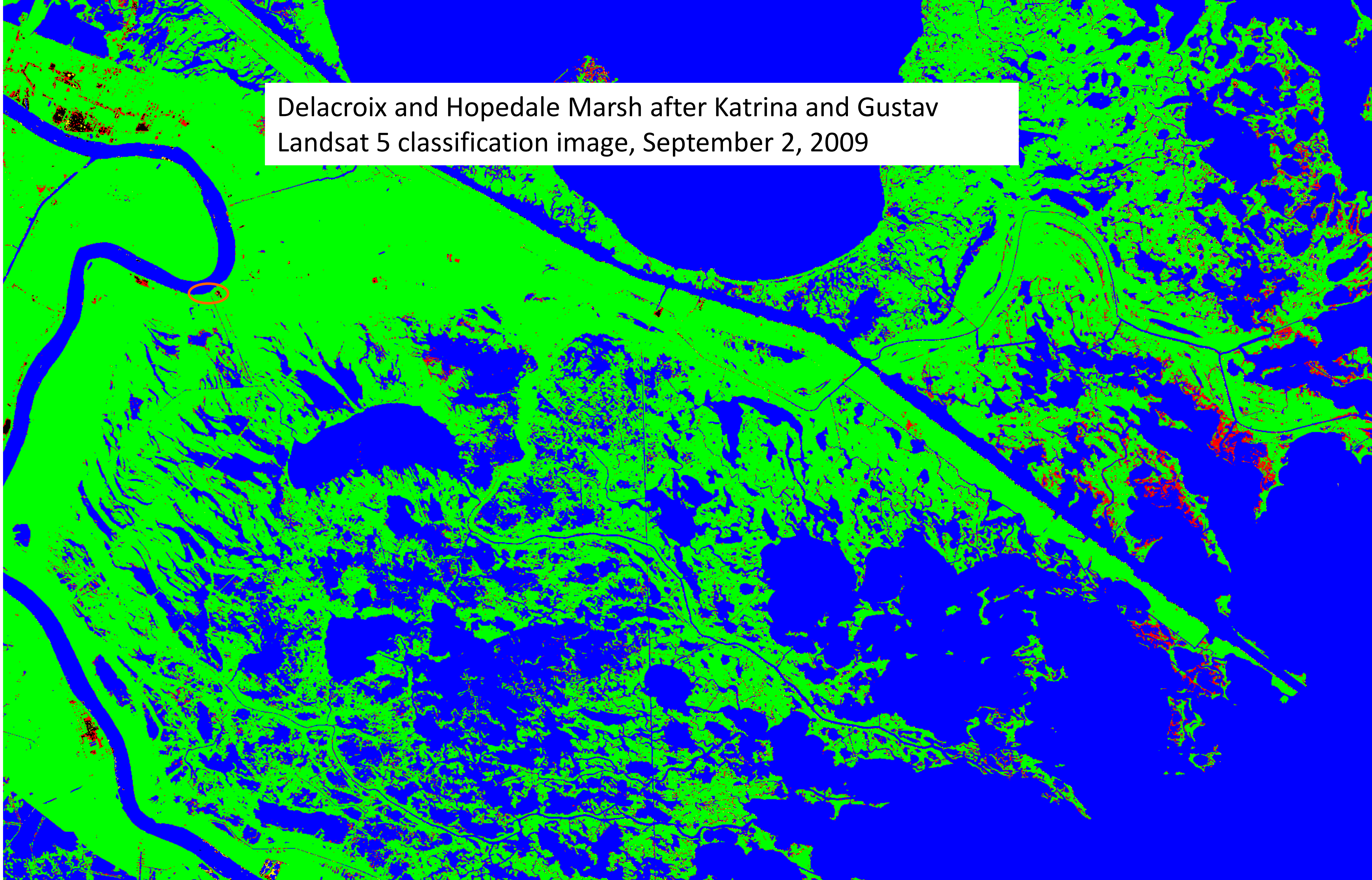
Erosion is pronounced after Katrina, Gustav, and Isaac: region is comparable in size to metro New Orleans!

Erosion in saline marsh east of Twin pipelines and in Hopedale was much less.

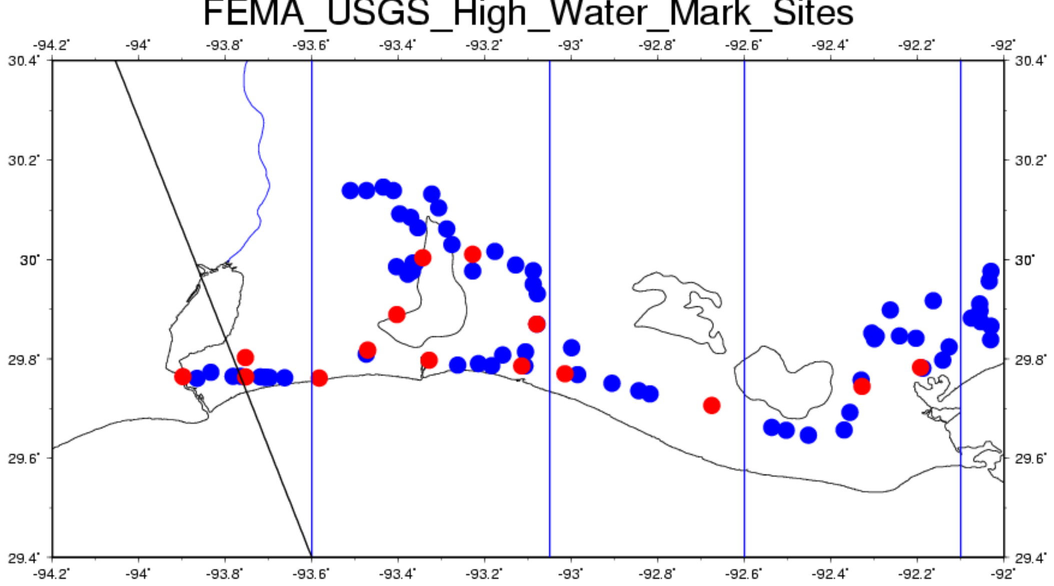


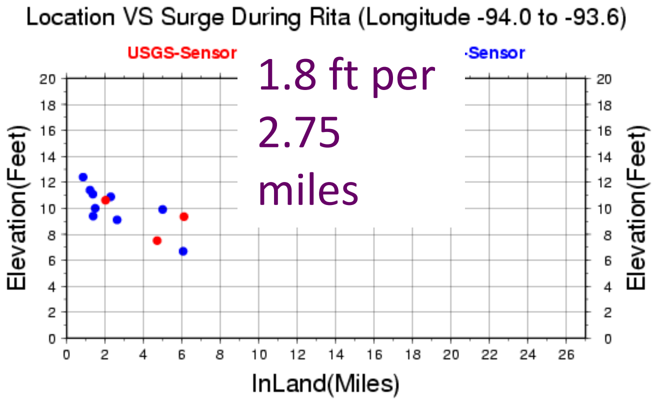
(Created by Standard Mapping)

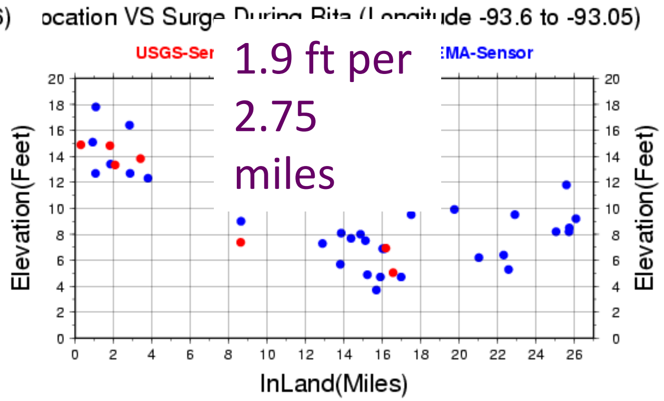

Delacroix and Hopedale Marsh before Hurricane Katrina
Landsat 5 classification image, October 20, 2003

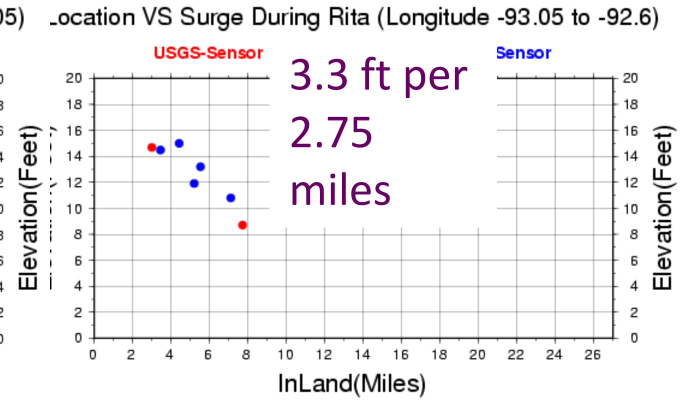

Delacroix and Hopedale Marsh after Katrina and Gustav
Landsat 5 classification image, September 2, 2009

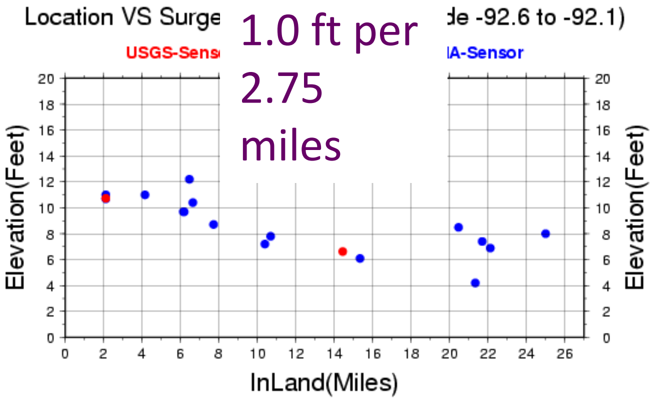
Surge reduction and wave reduction by wetlands

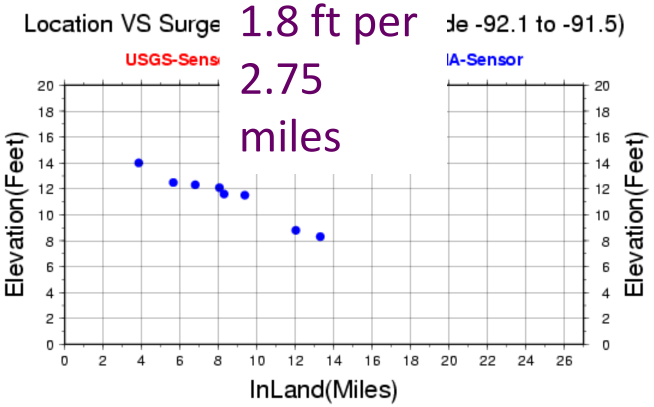

FEMA_USGS_High_Water_Mark_Sites


Location VS Surge During Rita (Longitude -94.0 to -93.6)
USGS-Sensor
Sensor
1.8 ft per 2.75 miles
Elevation(Feet)
InLand(Miles)

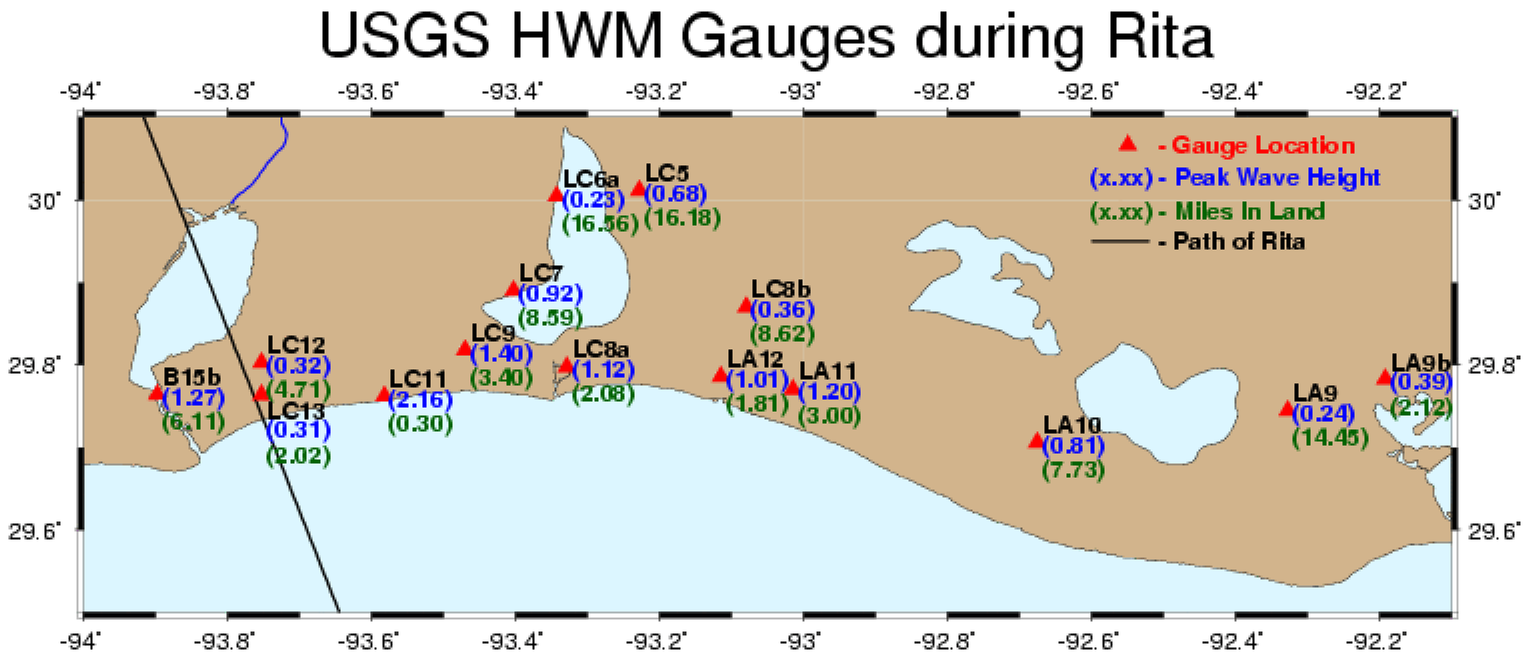

Location VS Surge During Rita (Longitude -93.6 to -93.05)
USGS-Ser
MA-Sensor
1.9 ft per 2.75 miles
Elevation(Feet)
InLand(Miles)


Location VS Surge During Rita (Longitude -93.05 to -92.6)
USGS-Sensor
Sensor
3.3 ft per 2.75 miles
Elevation(Feet)
InLand(Miles)


Location VS Surge
de -92.6 to -92.1)
USGS-Sens
IA-Sensor
1.0 ft per 2.75 miles
Elevation(Feet)
InLand(Miles)


Location VS Surge
de -92.1 to -91.5)
USGS-Sens
IA-Sensor
1.8 ft per 2.75 miles
Elevation(Feet)
InLand(Miles)

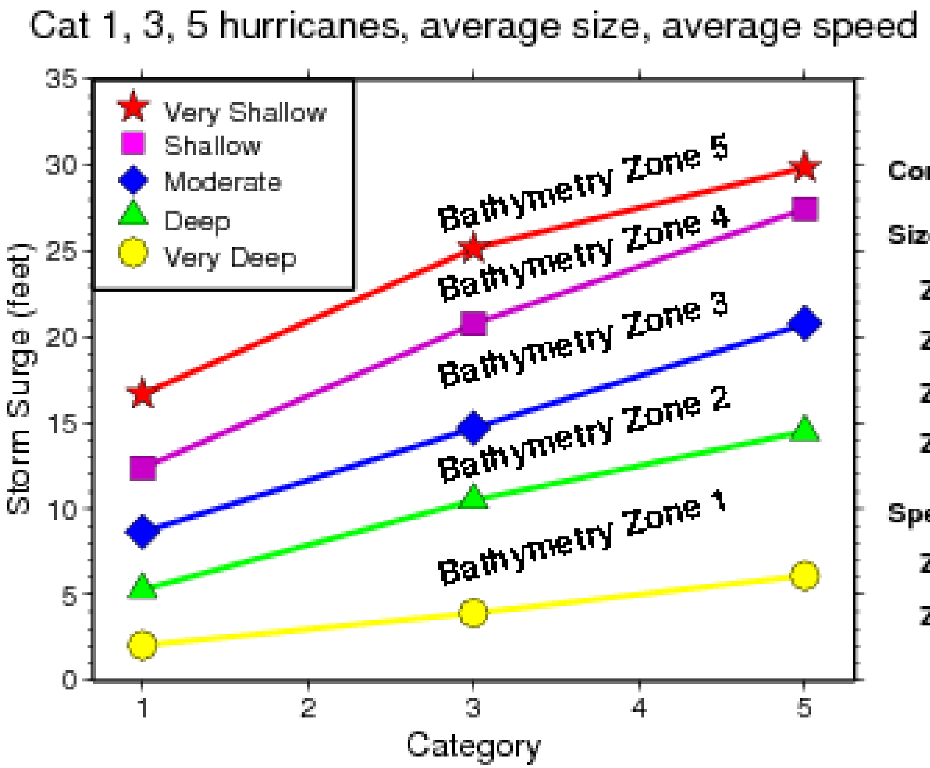
Wave height reduction significant



LC8b reduced 64-70% 5.5-6.8 miles inland (compared to LA12 and LA11)
LC8a reduced 48% 1.8 miles inland (compared to LC11)
LC9 reduced 36% 3.1 miles inland (compared to LC11)

Storm surge scale

Effect of hurricane intensity, size, and speed on storm surge



Correction factors for speed and size

Size

Zone 2: ± 1.5 (Cat 3–5)

Zone 3: ± 1.0 (Cat 1–2), ± 1.8 (Cat 3), ± 2.5 (Cat 4–5)

Zone 4: ± 1.6 (Cat 1–2), ± 2.5 (Cat 3), ± 3.6 (Cat 4–5)

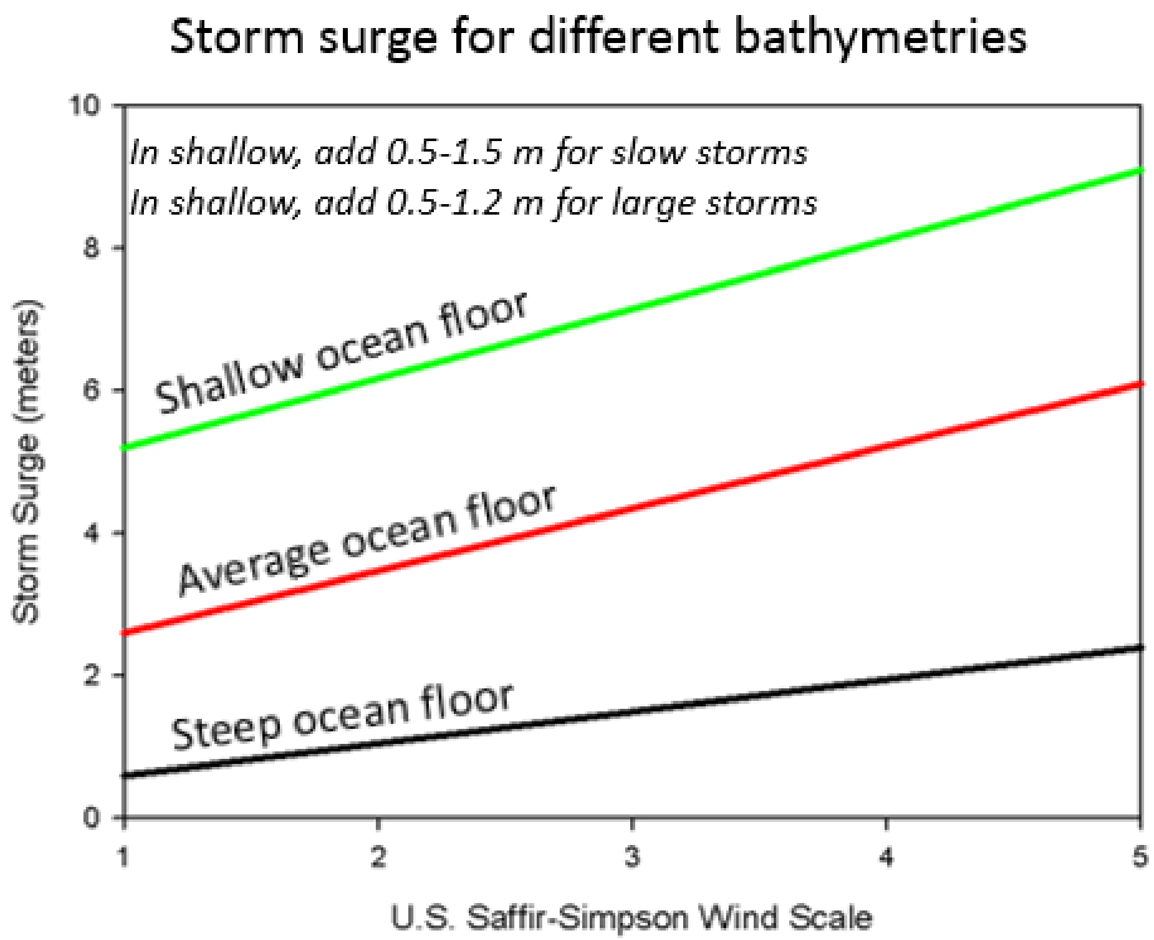
Zone 5: ± 2.3 (Cat 1–2), ± 3.3 (Cat 3), ± 4.3 (Cat 4–5)

Speed

Zone 4: ± 1.5 (Cat 1–2), ± 2.0 (Cat 3), ± 2.6 (Cat 4–5)

Zone 5: ± 3.0 (Cat 1–2), ± 3.9 (Cat 3), ± 5.2 (Cat 4–5)

General diagram for international encyclopedia article

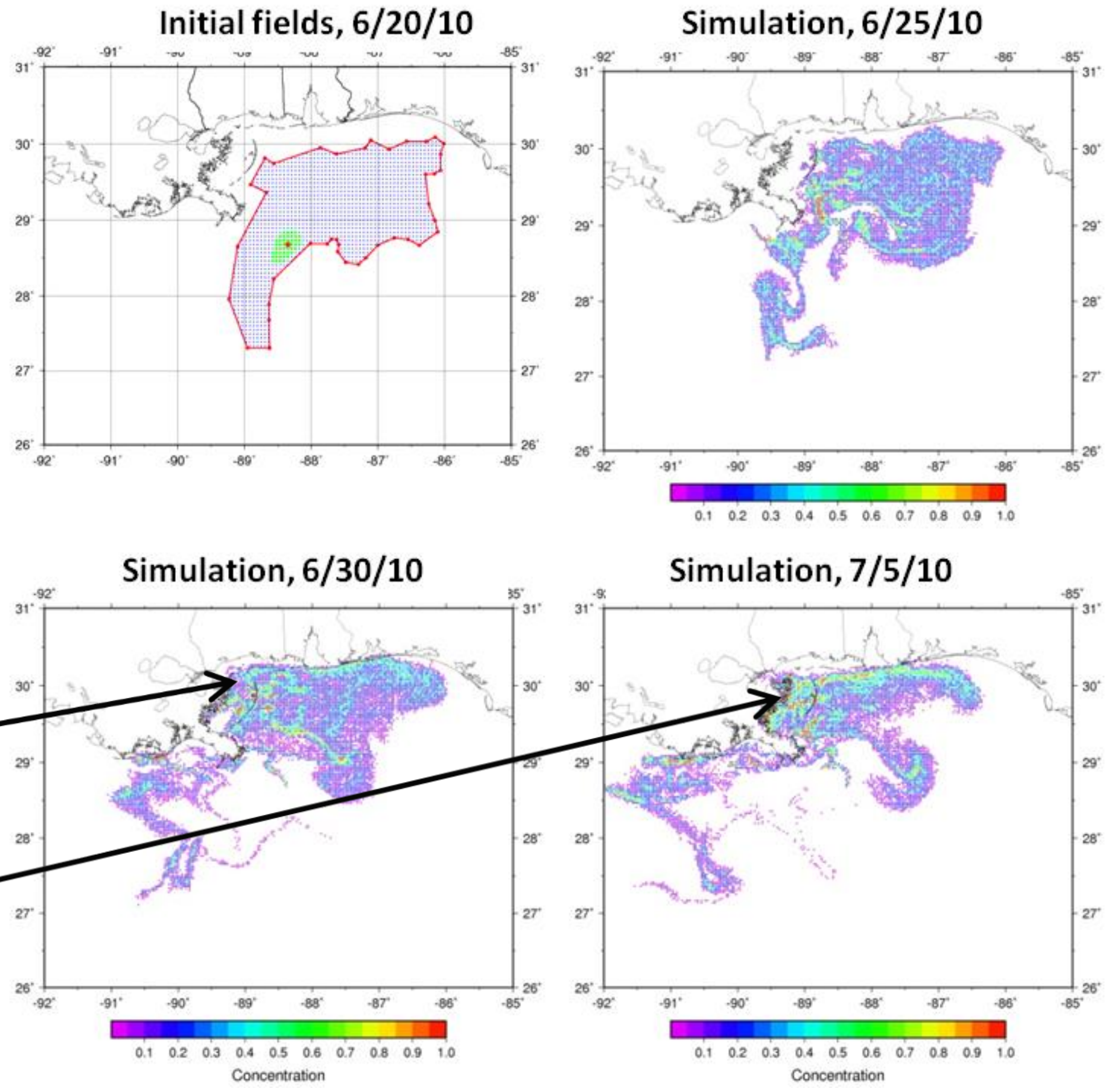


Influence of cyclones on Deepwater Horizon oil spill

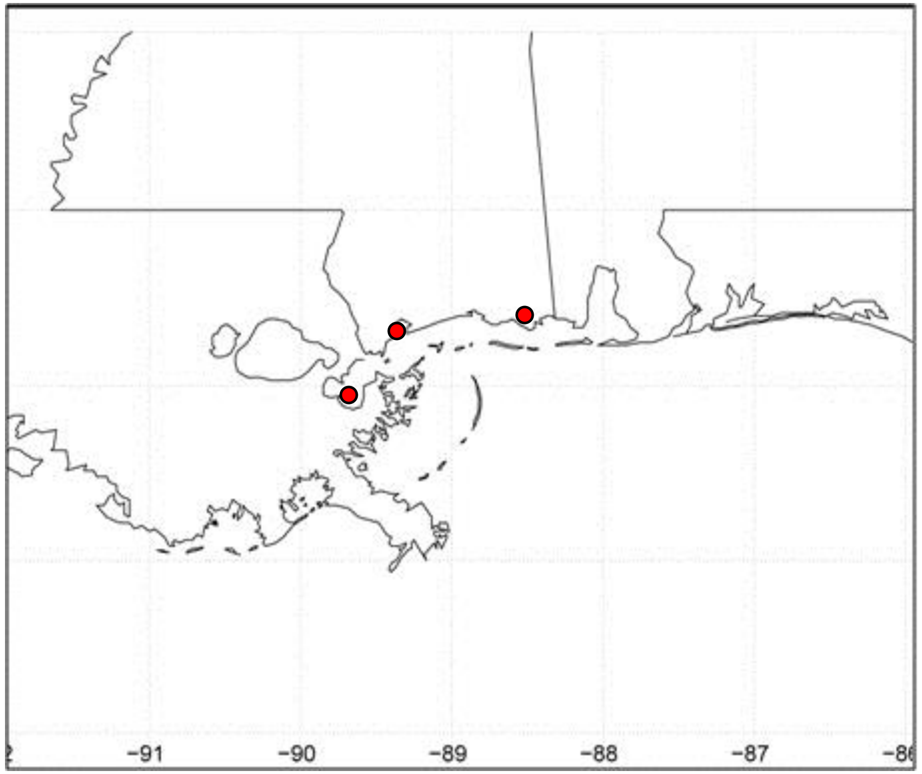
The influence of cyclones on the Deepwater Horizon oil spill

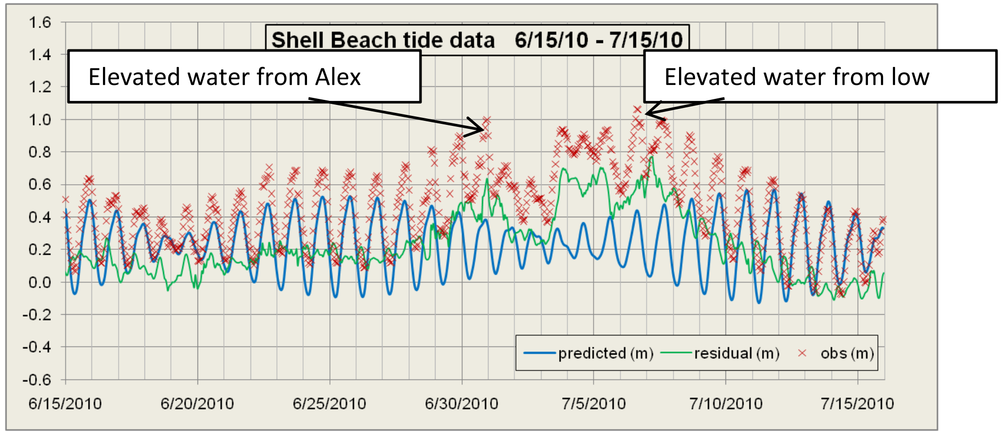
Pat Fitzpatrick, Yee Lau, Chris Hill, and Haldun Karan

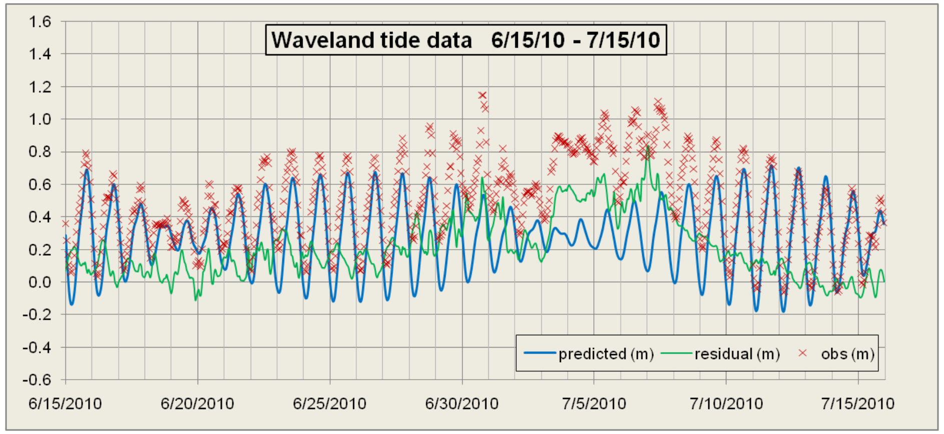
Oil spill simulation from 6/20/10-7/10/10 using AMSEAS NCOM data

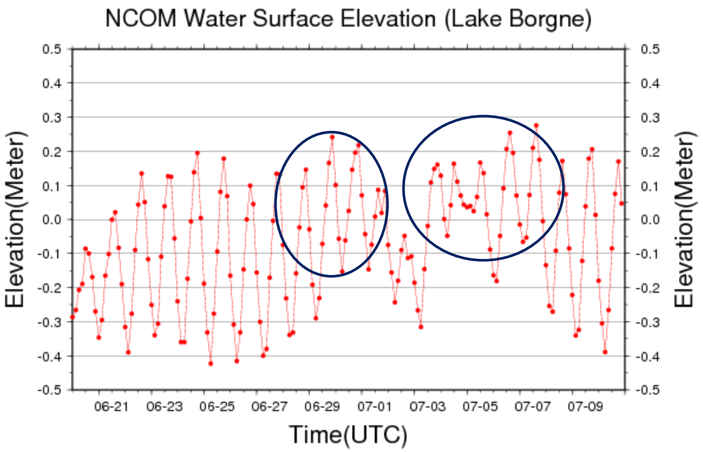


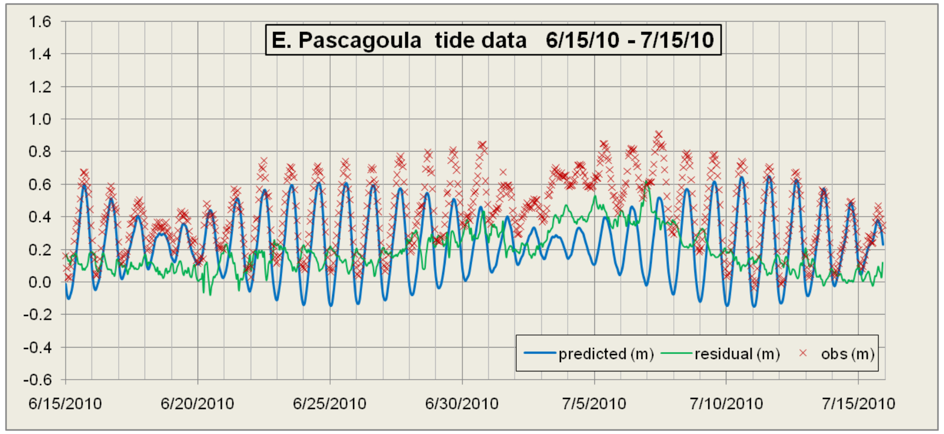
Note inshore movement of oil starting late June


-91
-90
-89
-88
-87

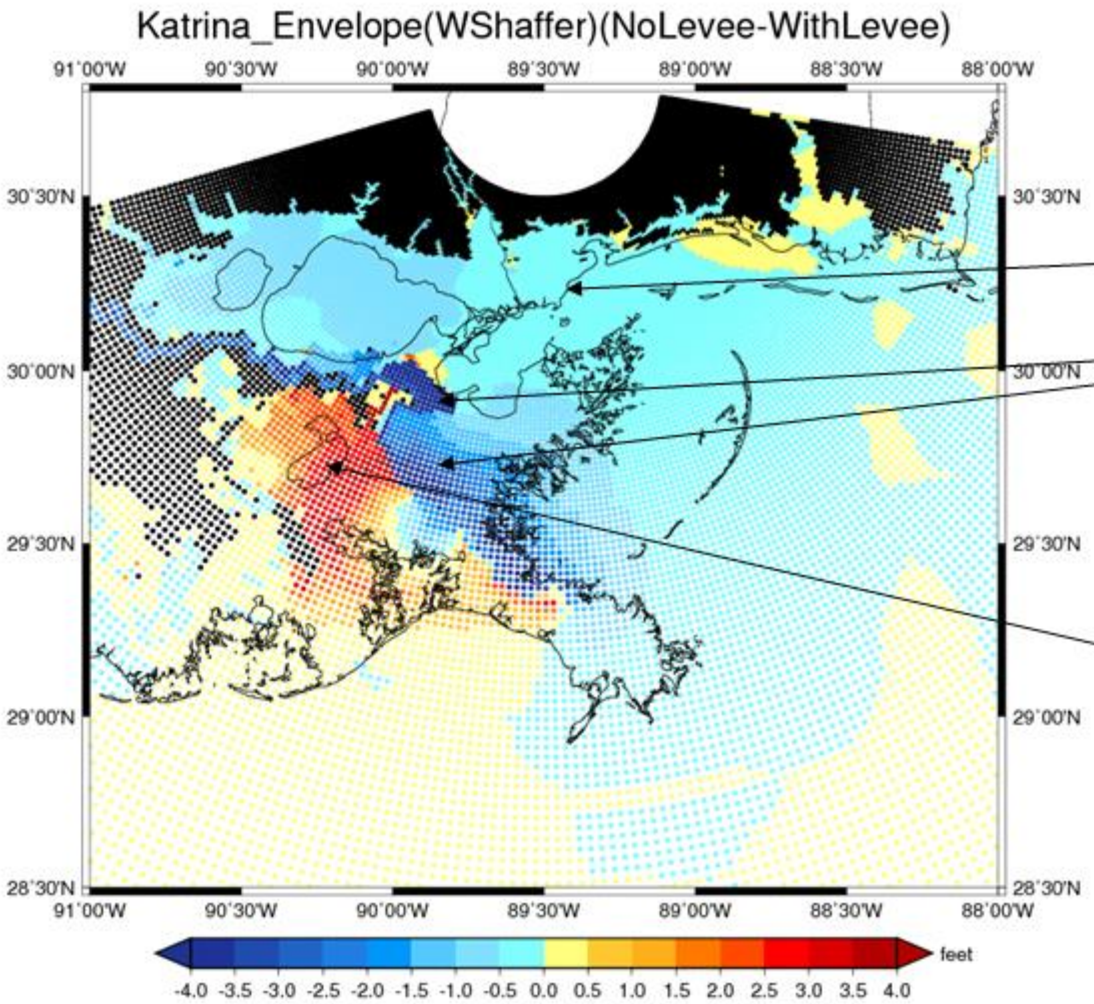

Shell Beach tide data 6/15/10 - 7/15/10
Elevated water from Alex
Elevated water from low
predicted (m)
residual (m)
obs (m)
6/15/2010
6/20/2010
6/25/2010
6/30/2010
7/5/2010
7/10/2010
7/15/2010


Waveland tide data 6/15/10 - 7/15/10
predicted (m)
residual (m)
obs (m)


NCOM Water Surface Elevation (Lake Borgne)
Elevation(Meter)
Time(UTC)
06-21
06-23
06-25
06-27
06-29
07-01
07-03
07-05
07-07
07-09


E. Pascagoula tide data 6/15/10 - 7/15/10
predicted (m)
residual (m)
obs (m)

Levee impact

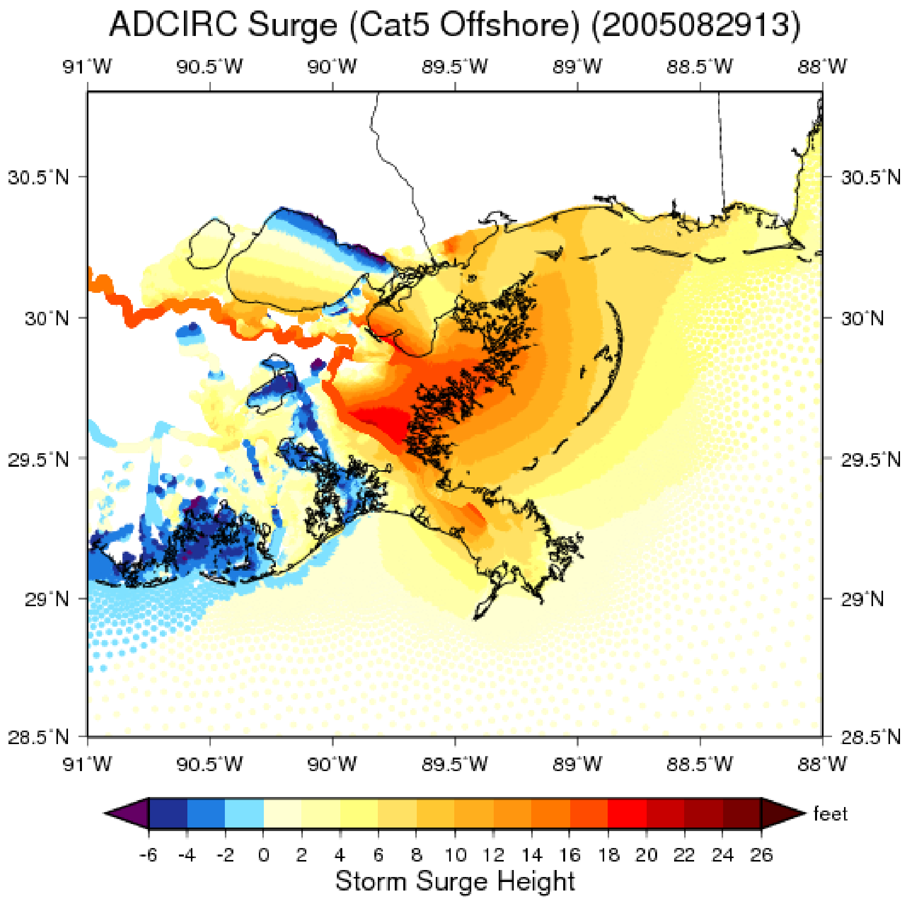


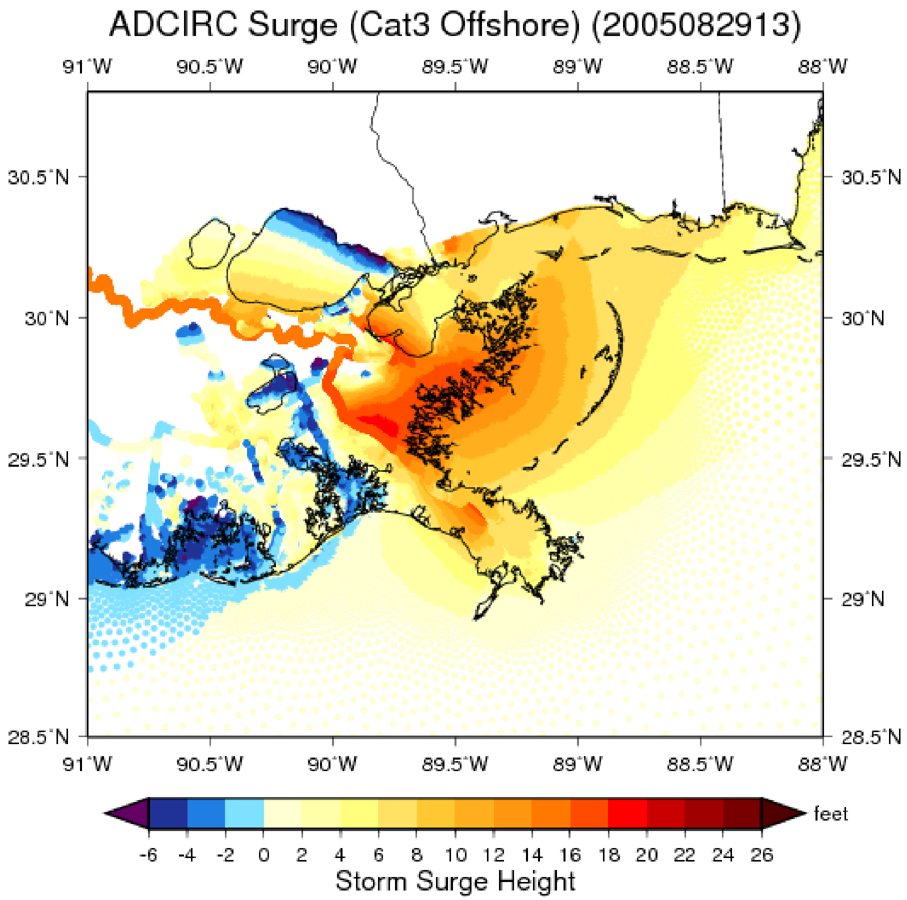
No impact

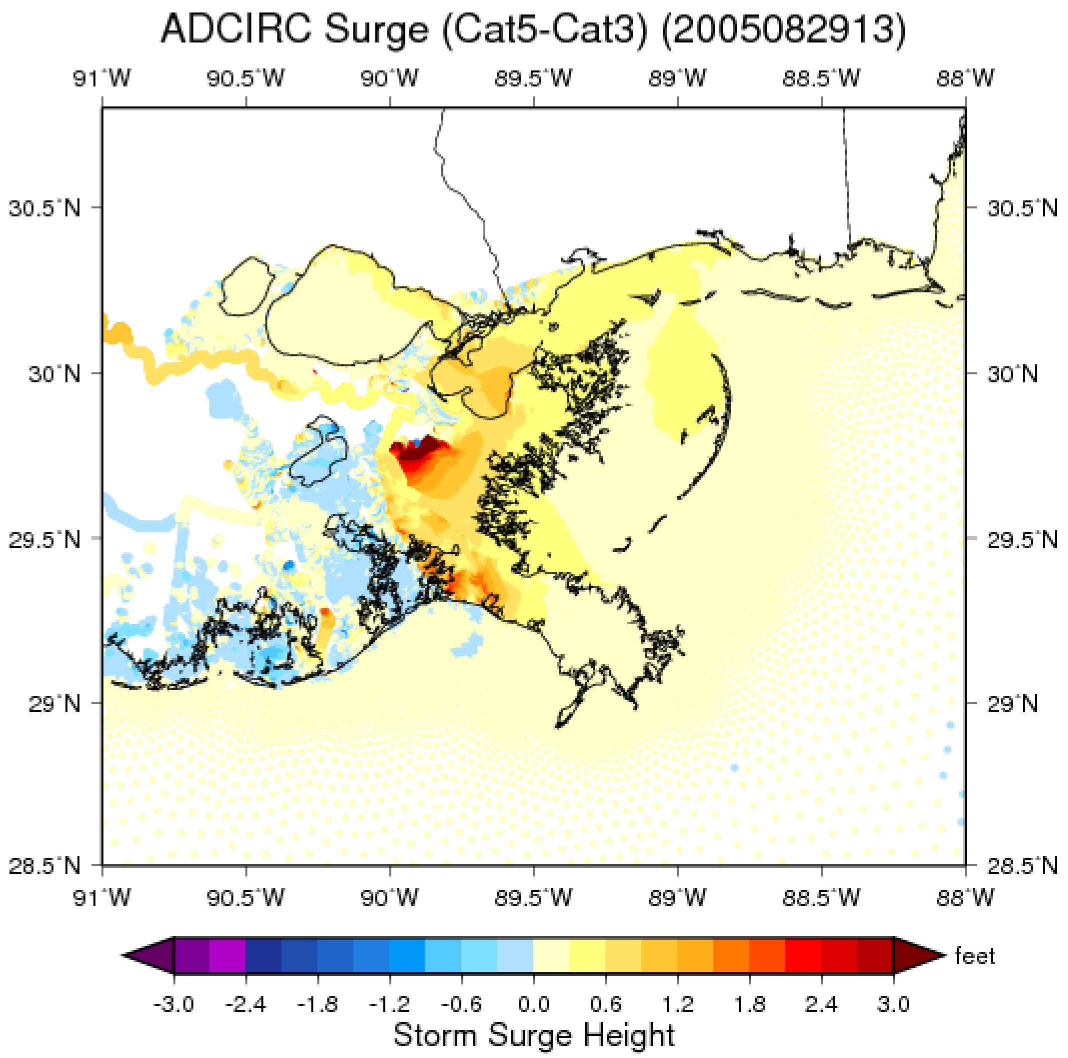
More surge, St. Bernard Parish & east

Less surge

Impact of Cat 5 Katrina offshore

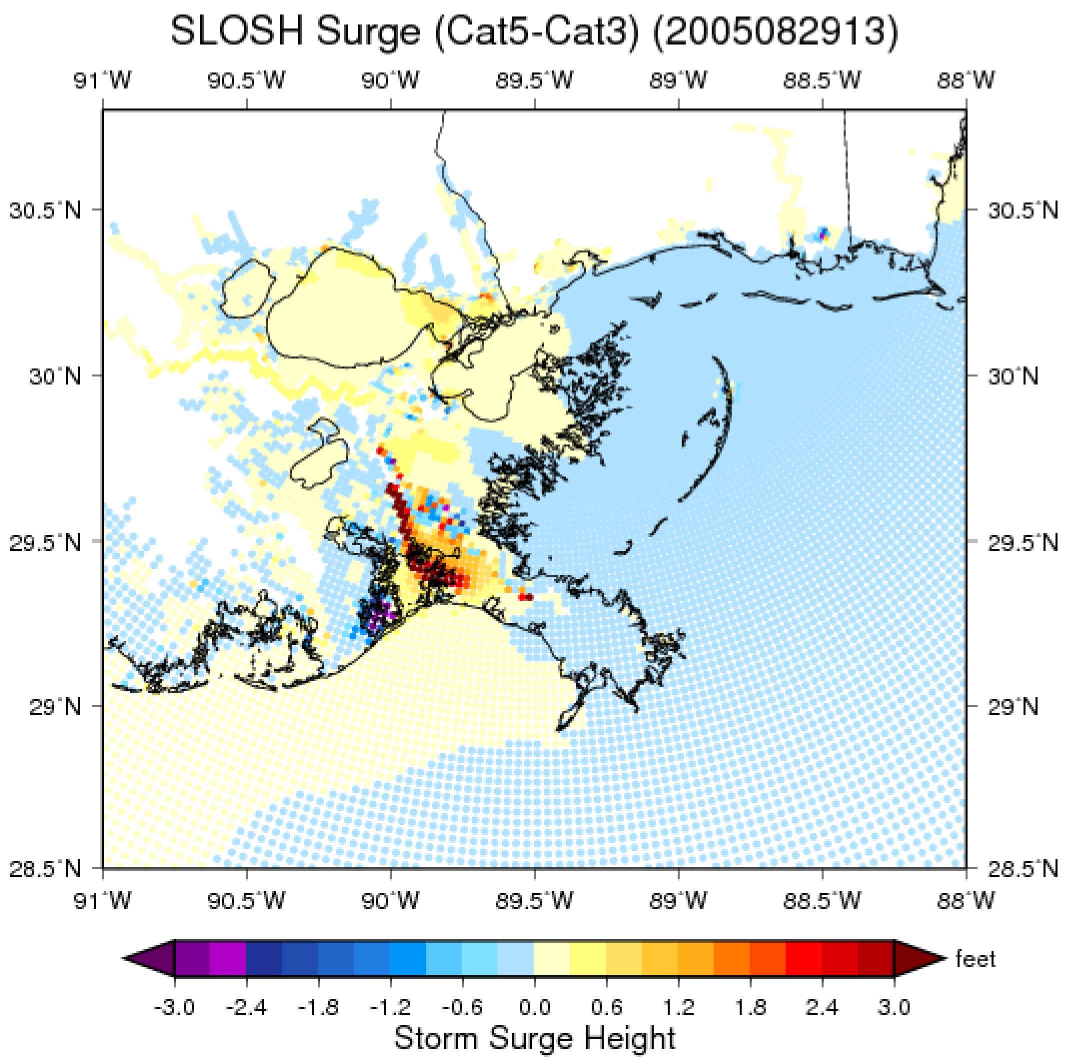

ADCIRC Surge (Cat5 Offshore) (2005082913)
91˚W 90.5˚W 90˚W 89.5˚W 89˚W 88.5˚W 88˚W
30.5˚N 30˚N 29.5˚N 29˚N 28.5˚N
-6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26
feet
Storm Surge Height


ADCIRC Surge (Cat3 Offshore) (2005082913)
91˚W 90.5˚W 90˚W 89.5˚W 89˚W 88.5˚W 88˚W
30.5˚N 30˚N 29.5˚N 29˚N 28.5˚N
-6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26
feet
Storm Surge Height



Katrina's offshore Cat 5 contribution less than 1 ft in most places

Similar results for SLOSH



Reason Surge is generated by wind stress on continental shelf

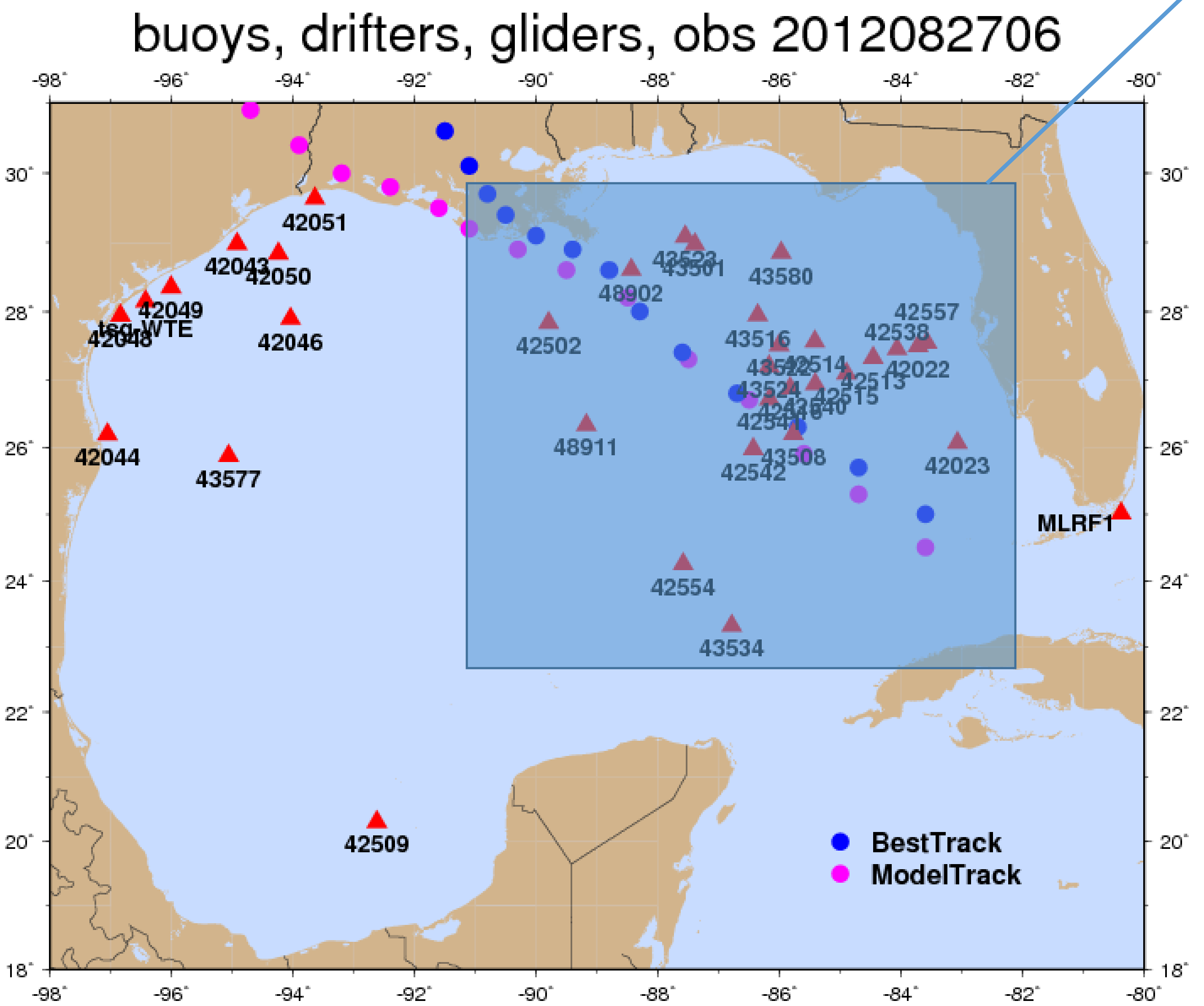
Case study validation of HWRF-HYCOM and HWRF-POM for Hurricane Isaac (2012)

Pat Fitzpatrick and Yee Lau, *Mississippi State University*

Hyun-Sook Kim, *Marine Modeling and Analysis Branch, NOAA/NWS/NCEP/EMC*

HWRF-HYCOM documented in:

Kim, H.-S., , C. Lozano, V. Tallapragada, D. Iredell, D. Sheinin, H. L. Tolman, V. M. Gerald, and J. Sims, 2014: Performance of ocean simulations in the coupled HWRF–HYCOM model. *J. Atmos. Oceanic Technol.*, **31**, 545–559.



Region of focus

<u>For water temperature</u>

- Data from buoys, drifters, and gliders. Isaac well-sampled from a combination of different field programs

- Some data is just 0m, or 1m. But have ten profile datasets down to 50-1000 m

- model values are interpolated to the exact depth where applicable. Otherwise, model's 1st layer value is used or last layer value may be used

<u>For surface wind speed</u>

- bilinear interpolation is used for both HWIND and model wind data at the observed locations

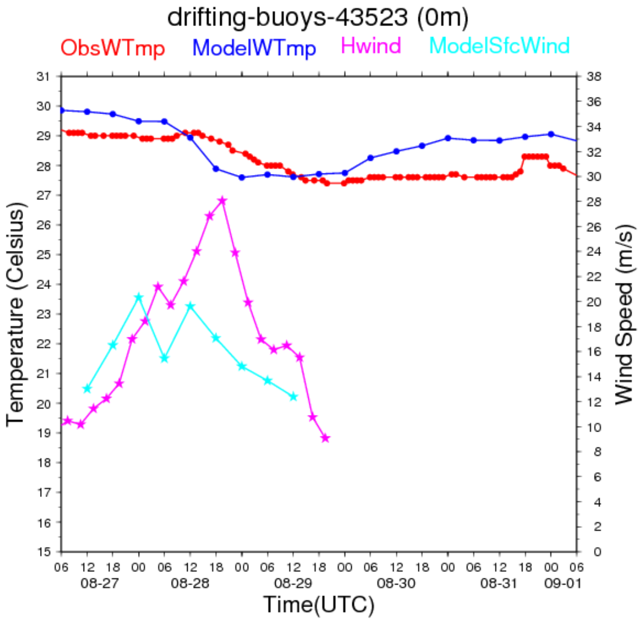
- Model wind data are 10-m winds from nested grid

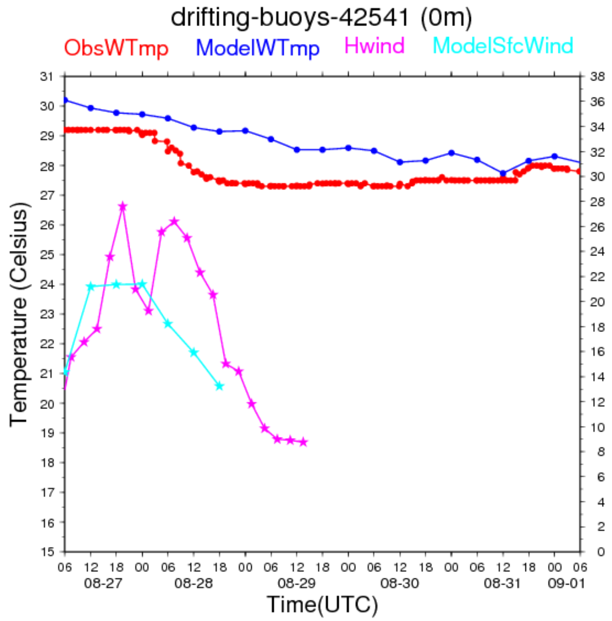
<u>Model runs</u>

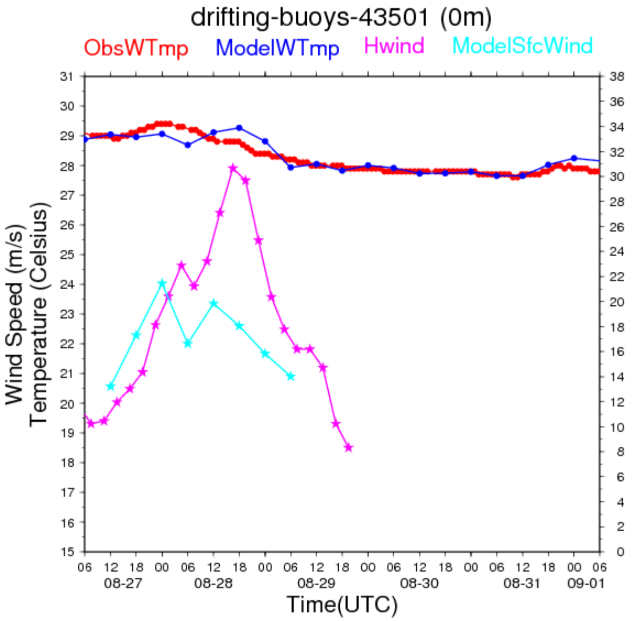
- Study done for 2014-version HWRF for Aug 27 00, 06, 12, 18Z runs, and Aug 28 00Z run. 00Z shown in next slides. Results are typical for all runs

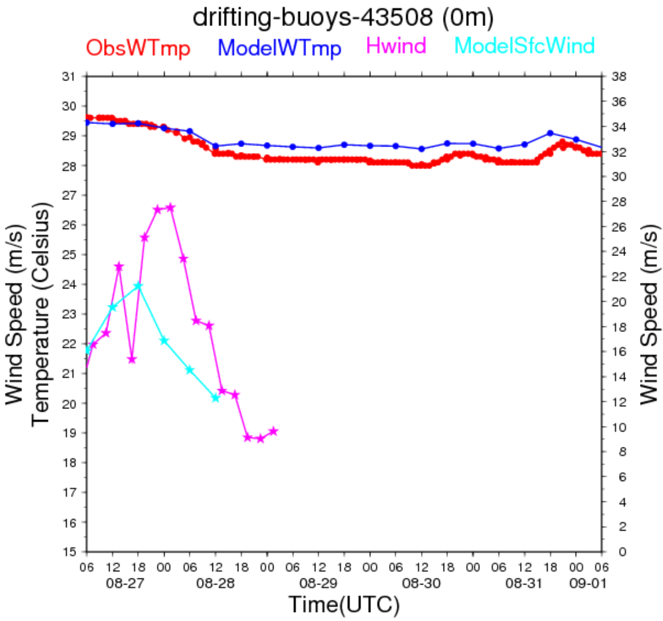
Surface water temperature comparisons

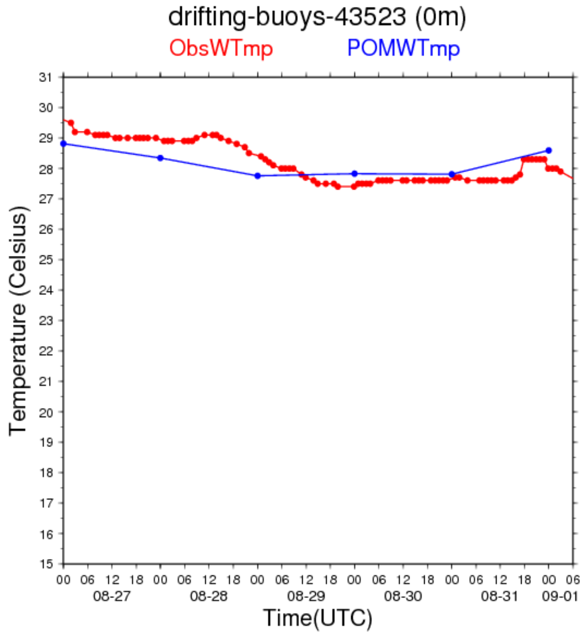
Times series comparison - east side near center; HYCOM (top) versus POM (bottom, if available)

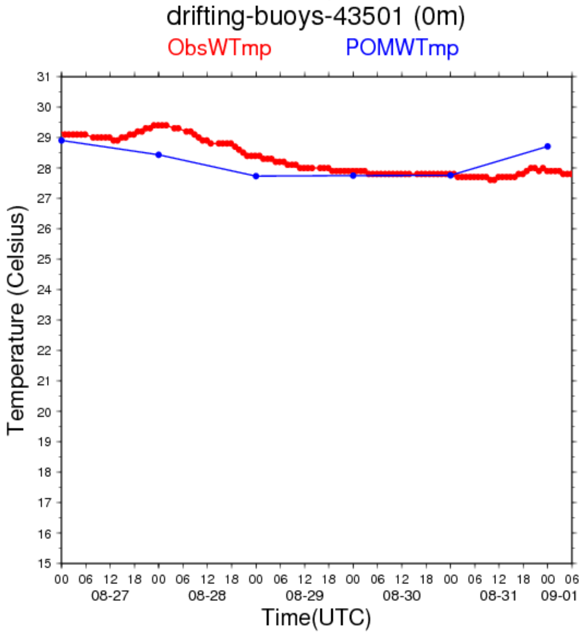




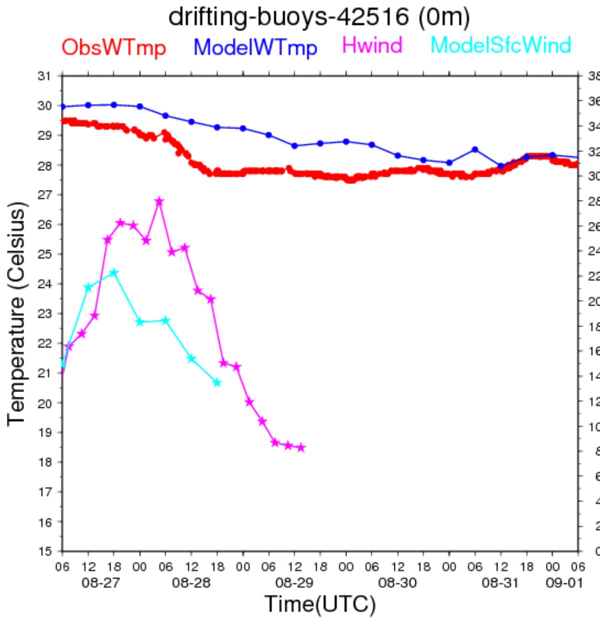


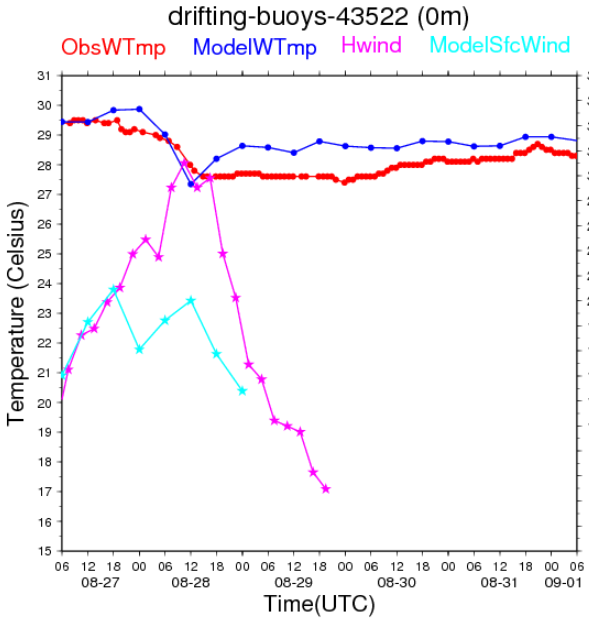


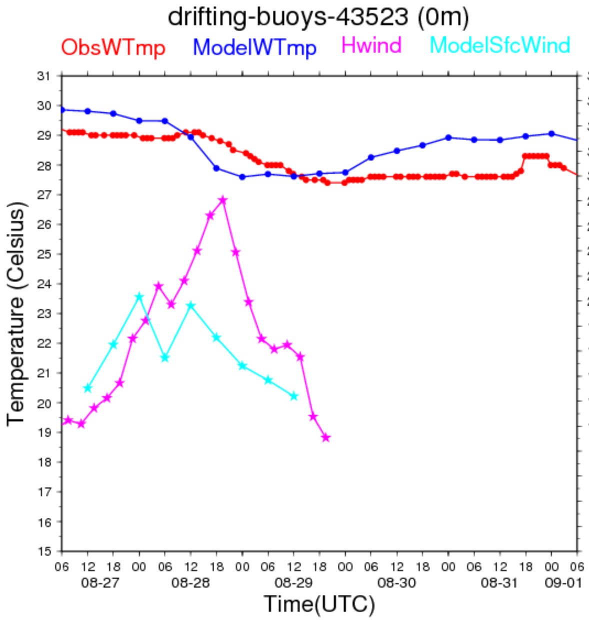


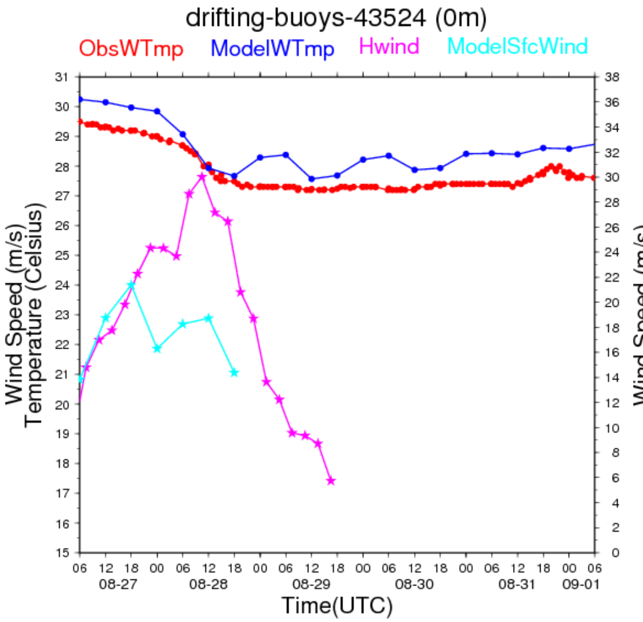


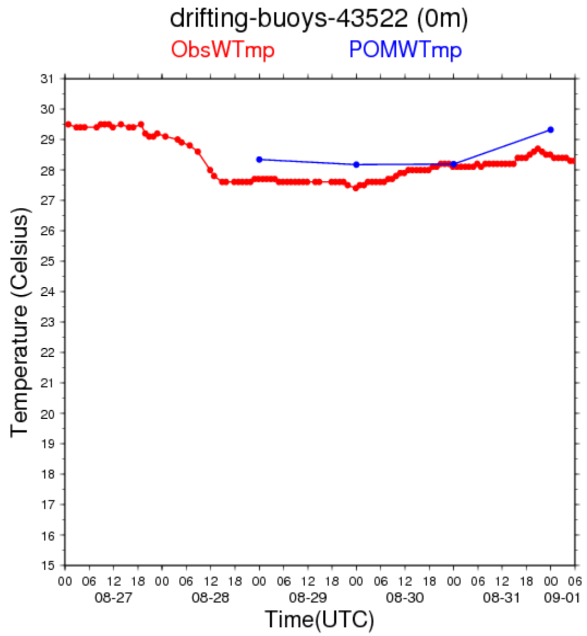
Times series comparison - east side near center; HYCOM (top) versus POM (bottom, if available)

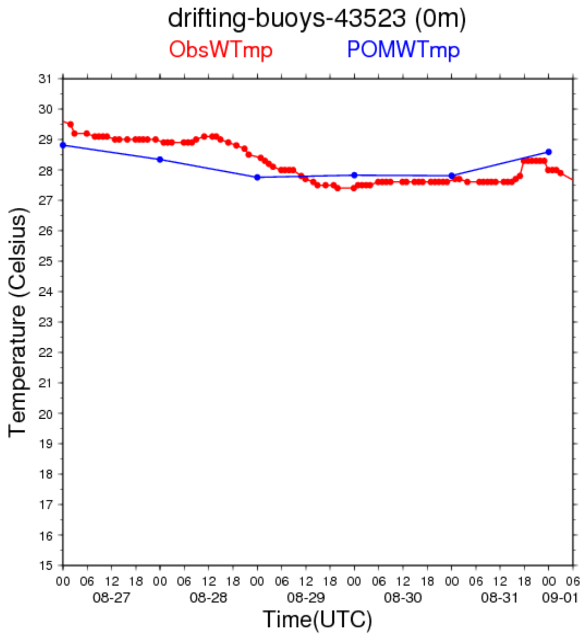




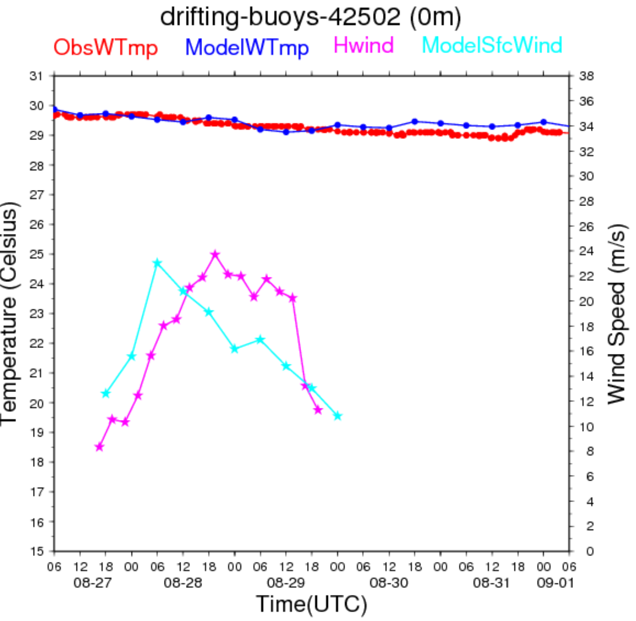


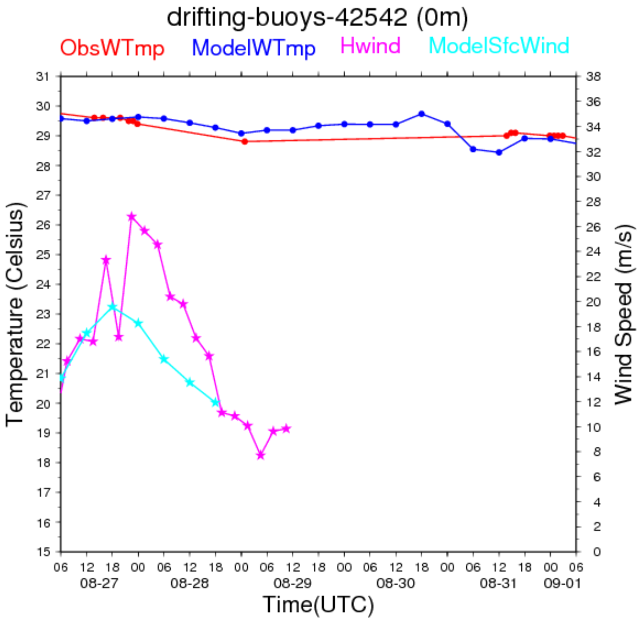


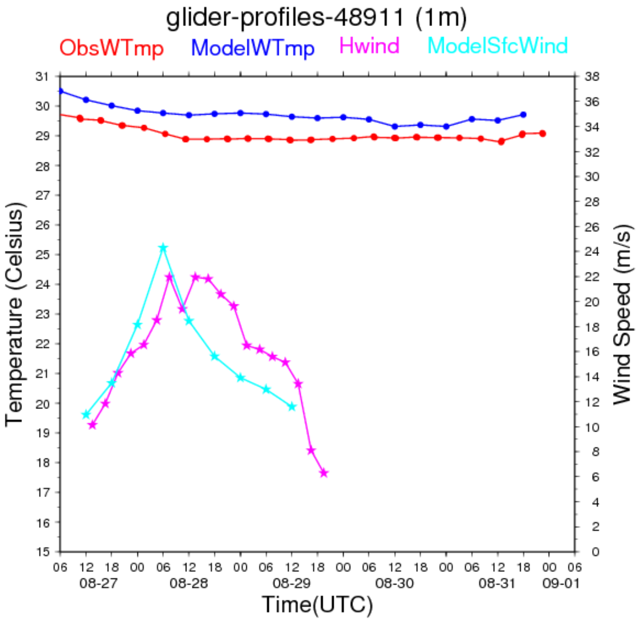


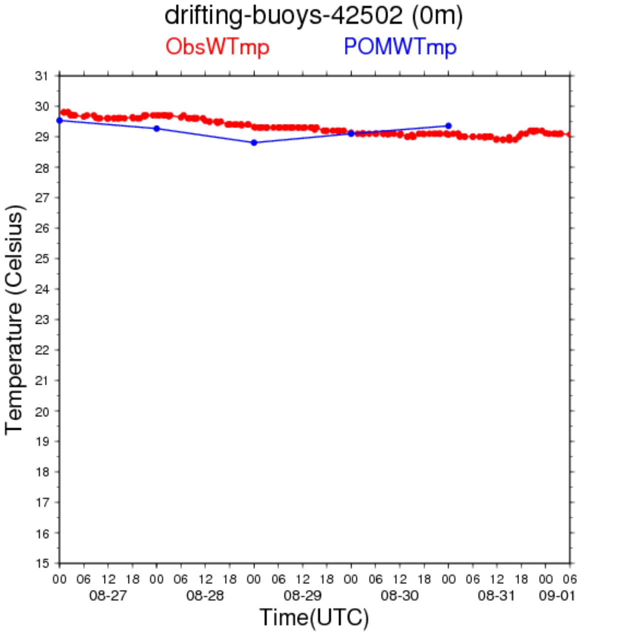


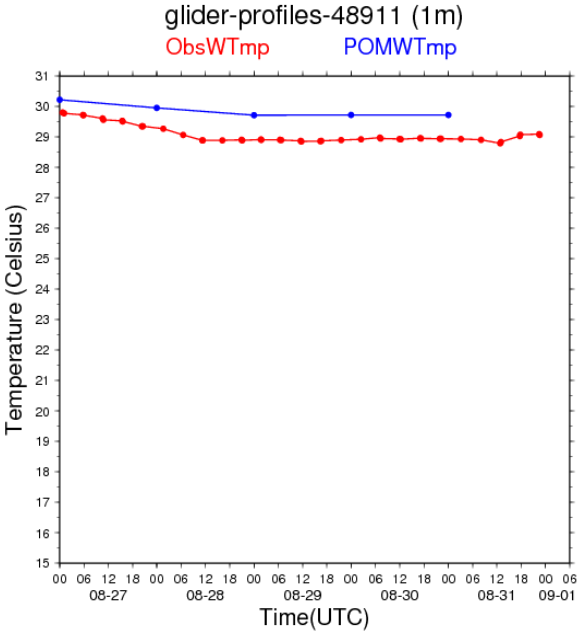
Times series comparison - west side near center; HYCOM (top) versus POM (bottom, if available)



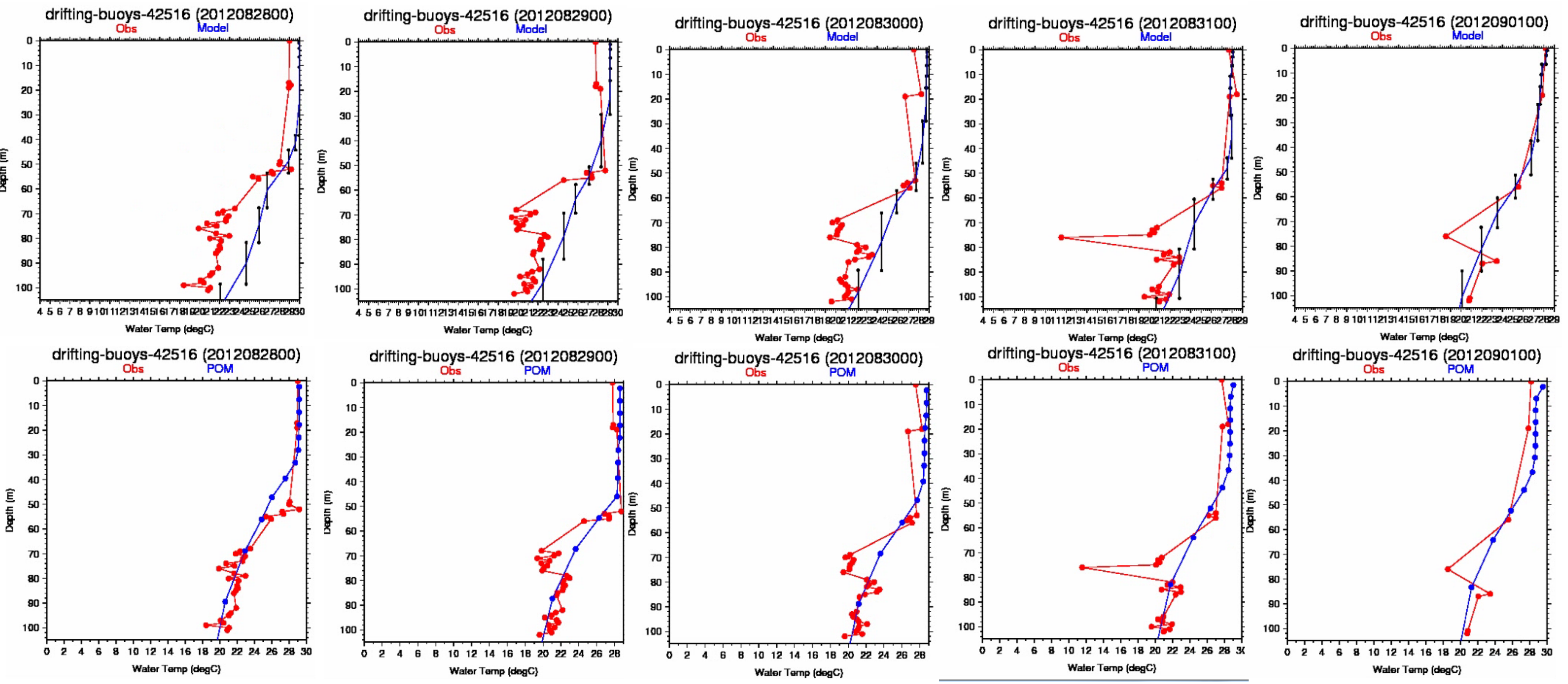








Profile comparison - drifting buoy 42516, east side of center, HYCOM (top) versus POM (bottom)



Preliminary conclusions

- HYCOM water temperature more responsive to TC forcing than POM, especially on eastern side "cold swath" region. This is a favorable attribute.
- POM response, in contrast, is rather stiff, perhaps by design to restrict temperature drift and for operational consistency:
  1. POM uses diffusive mixing, which means the shear-instability driven mixing is omitted.
  2. POM has weak diurnal signal; initial condition based on daily GFS SST
  3. POM mixed layer can be too thick due to coarser vertical resolution near ocean surface
- HYCOM exhibiting positive bias. There may also be a tendency to recover from mixing processes faster than observed. This could also be an artifact of seawater potential temperature computations and peak wind stress negative bias.

Future work will include atmospheric forcing from reanalysis package to remove track and wind structure uncertainties.

A Review of the 2014 Gulf of Mexico Wave Glider® Field Program

Pat Fitzpatrick, Yee Lau, Robert Moorhead, Adam Skarke

Mississippi State University

Daniel Merritt, Keith Kreider, Chris Brown, Ryan Carlon, Graham Hine, Teri Lampoudi

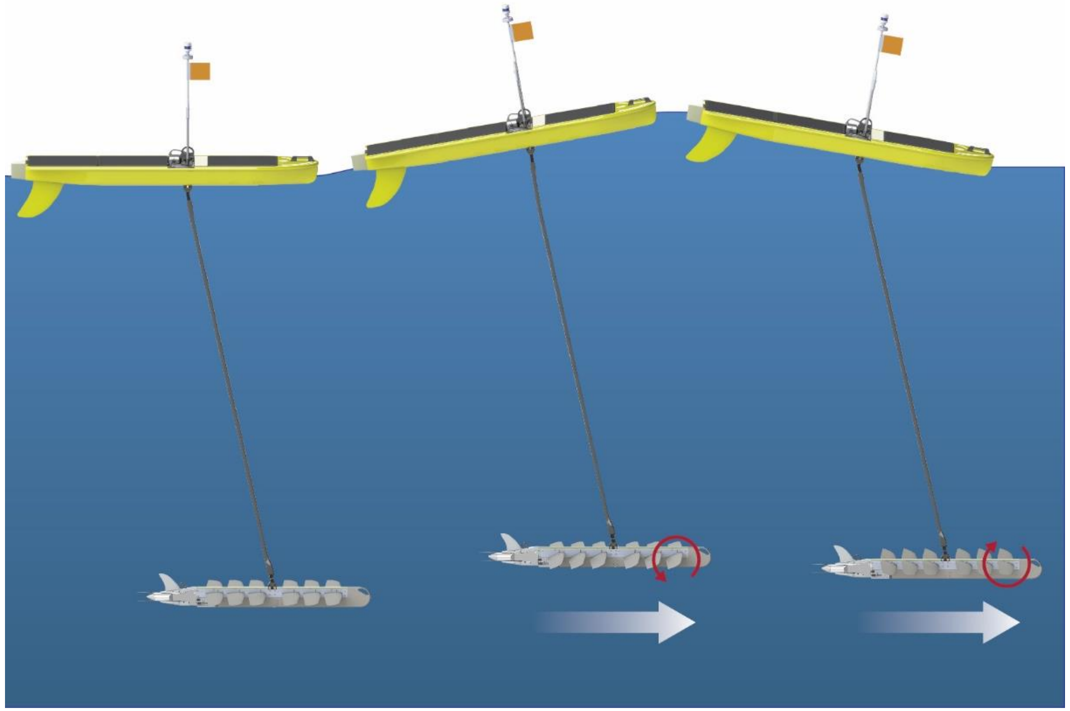
Liquid Robotics, Inc.

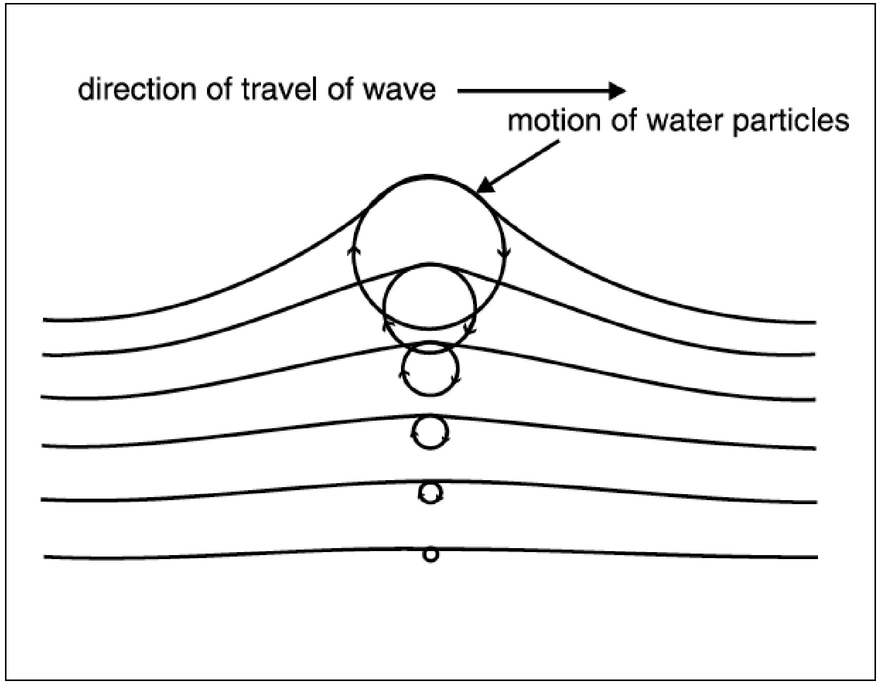
Alan Leonardi

NOAA/OAR/ Ocean Exploration and Research

Funded by the Sandy Supplemental Internal Competition for Instruments and Observing Systems under NOAA Grant NA14OAR4830128

Propulsion mechanism



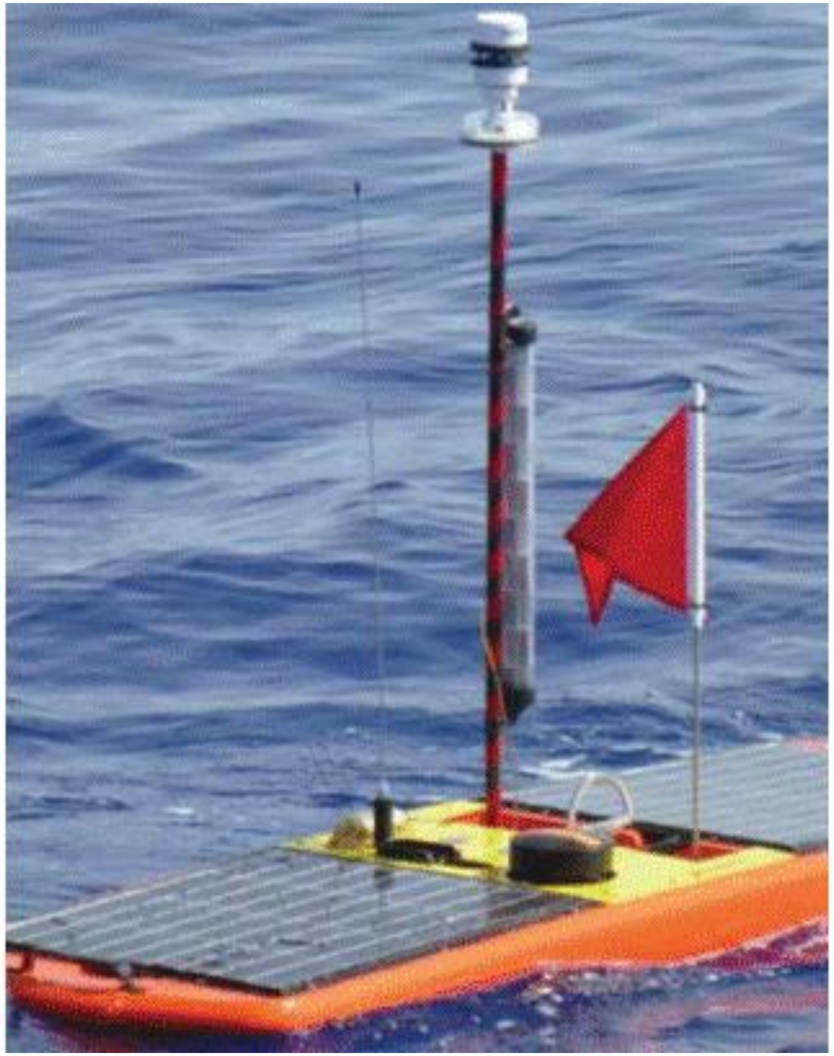


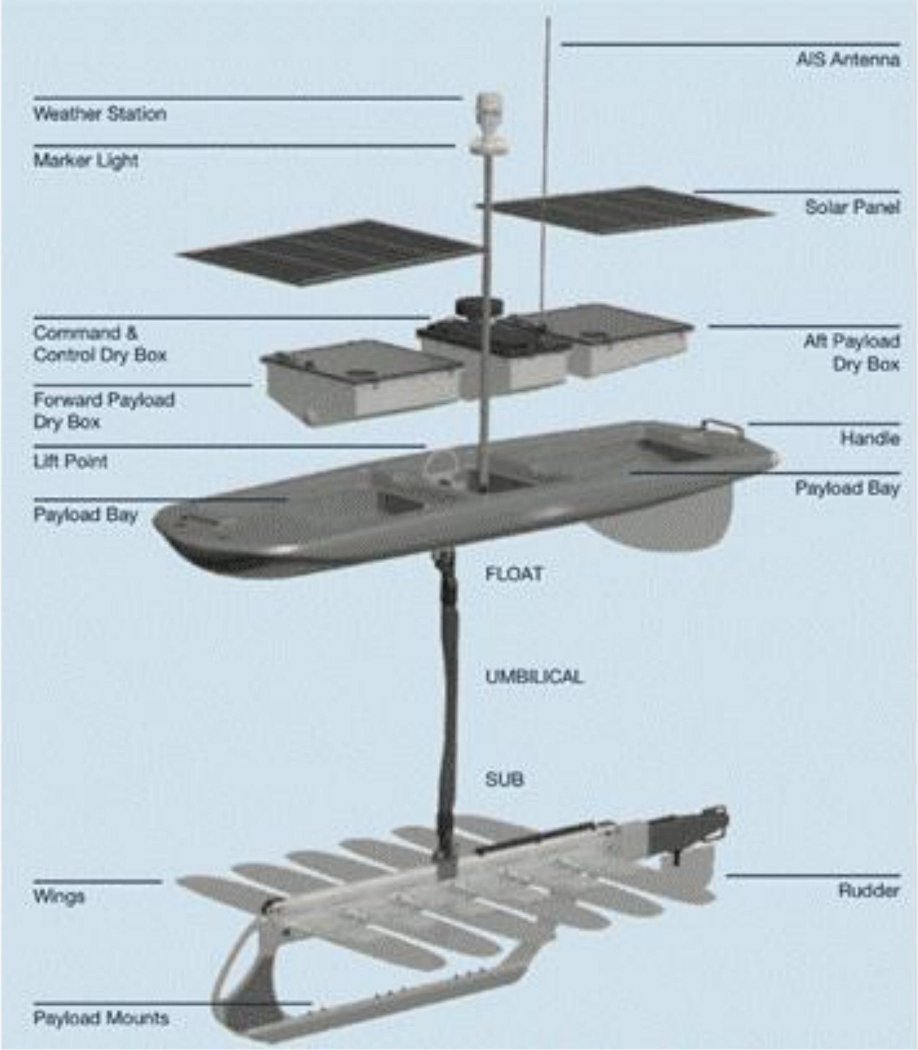
The propulsion works off of the buoyancy of a surface float tethered to a wing rack, the smaller amplitude of the wave motion 6 m below, and a switch on the wings from the wave crests rising and falling. The up and down motion of the wing system creates propulsion, pulling the float by its tether, in a synergistic feedback.

Typical translation speed range was 0.25-1 ms^{-1}, with an average of 0.5 ms^{-1} . Proportional to buoyancy force, generally faster for higher waves. Propulsion of 0.25 ms^{-1} happens even with low-wind “ripples”, but drifting can occur if calm.

Also need to consider and monitor currents, because forward motion can be challenging around currents faster than 1 ms^{-1}

Wave Glider SV2





Loitering periods

G10

42040: 8/28-8/29
42039: 9/2-9/5
42036: 9/15-9/23; 10/11-11/21
42099: 11/28-11/29

G11 (renamed G14 on 9/11)

42040: 9/1-9/5

G12 (discontinued 10/24, duties assumed by GOM1)

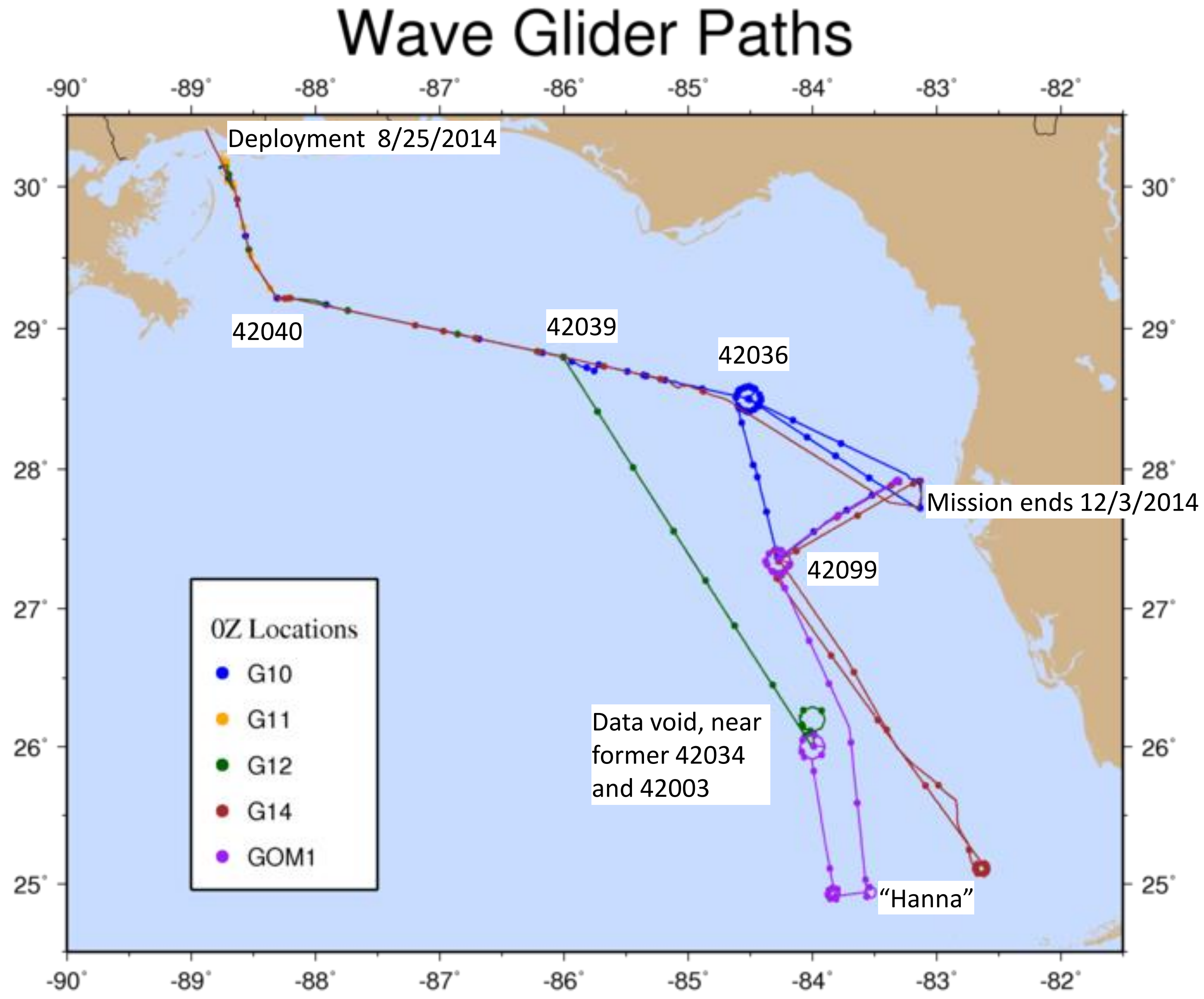
42039: 9/1-9/2
84W, 26N: 9/9-10/23

G14

42040: 9/14-9/19
42099: 10/10-10/21
"Hanna" 82.6W 25.1N: 10/25-11/18
42099: 11/28-11/29

GOM1

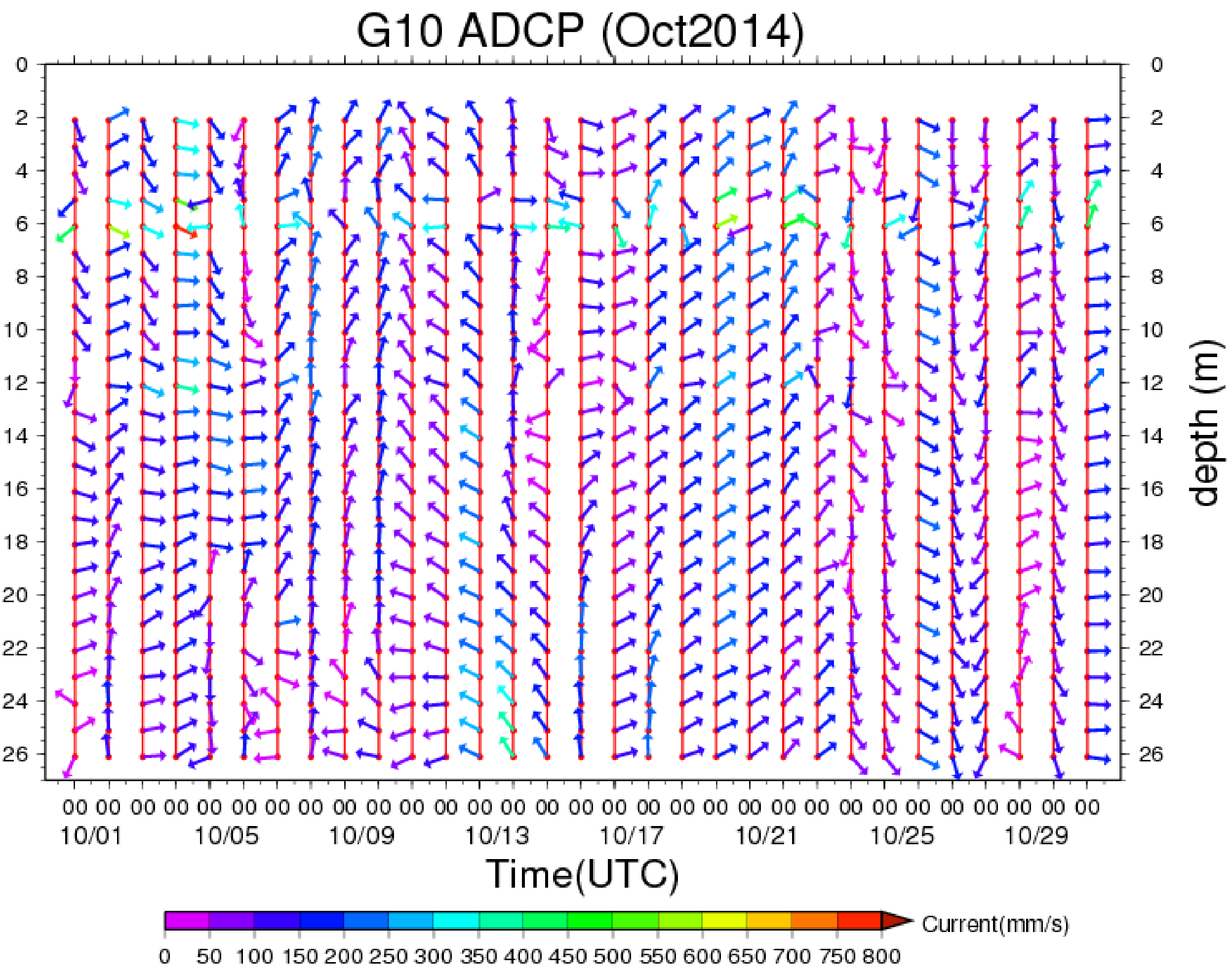
84N, 26W: 10/14-10/21
"Hanna" 83.8W 24.9N: 10/23-10/31
"Hanna" 83.5W 24.9N: 11/1-11/3
42099: 11/9-11/29

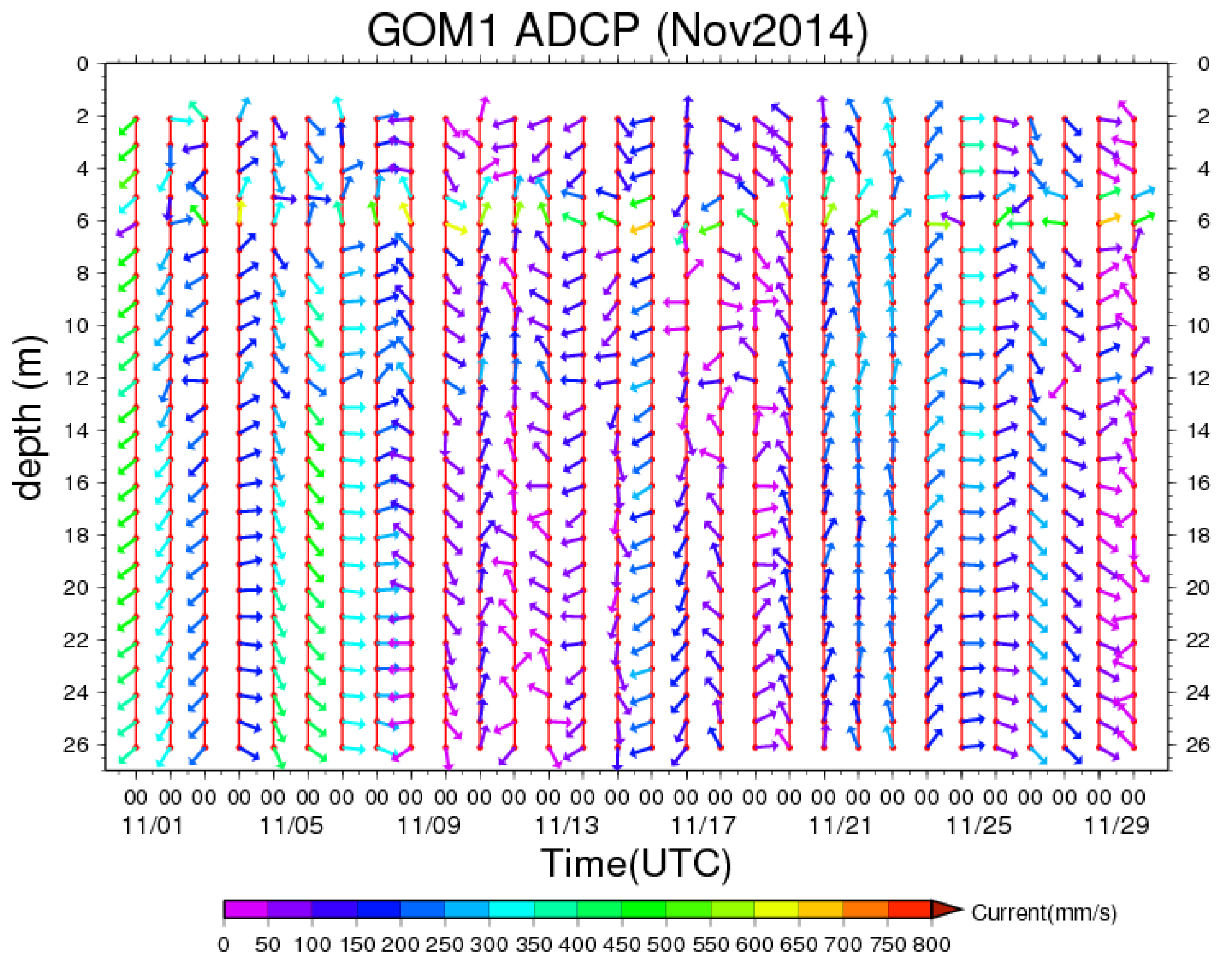


"Hanna" connotes northern fringe of tropical system

Example data plots

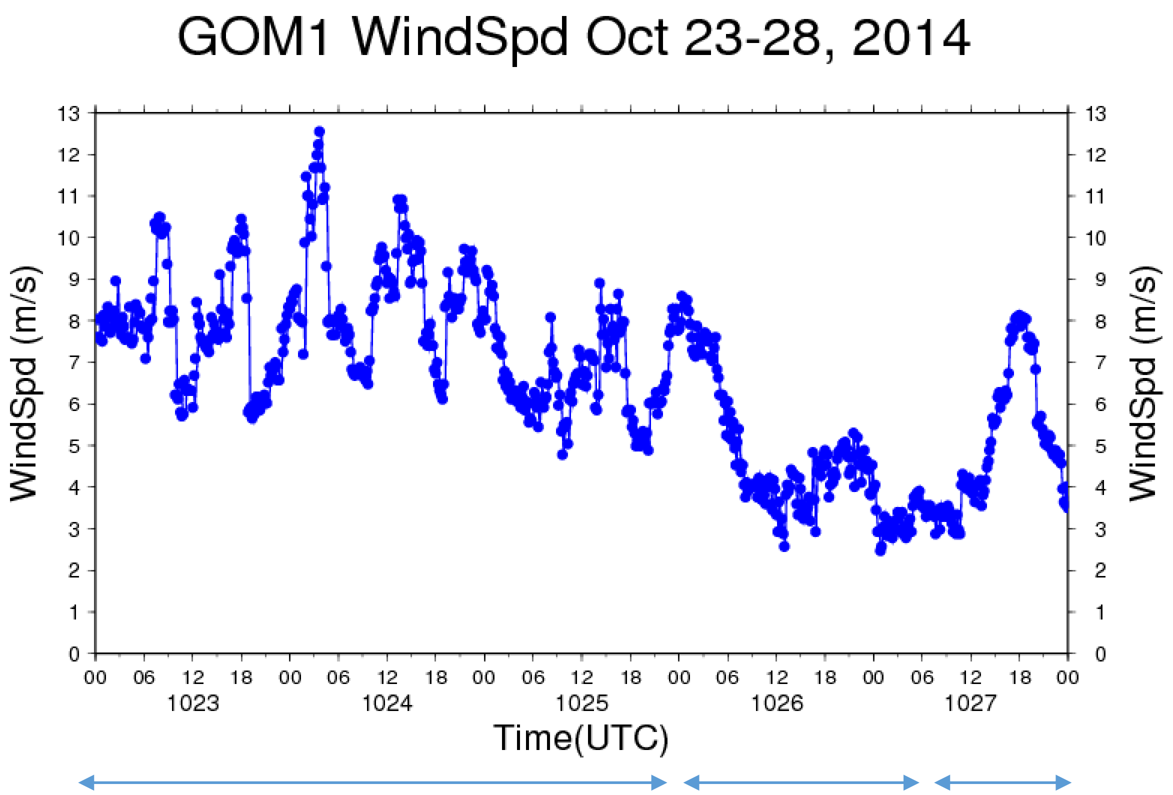
Example monthly plots of ADCP at 00Z – no validation possible

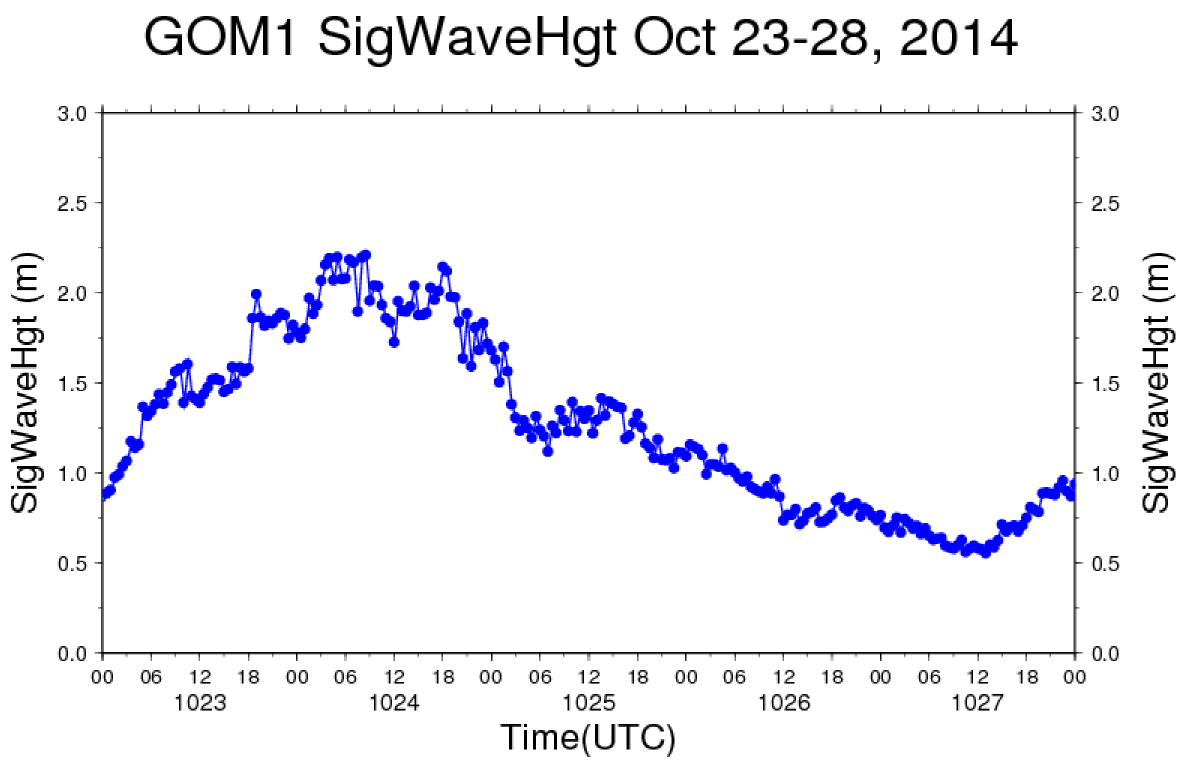




Real-time data available every 30 min

Northern fringe of Hanna lifecycle



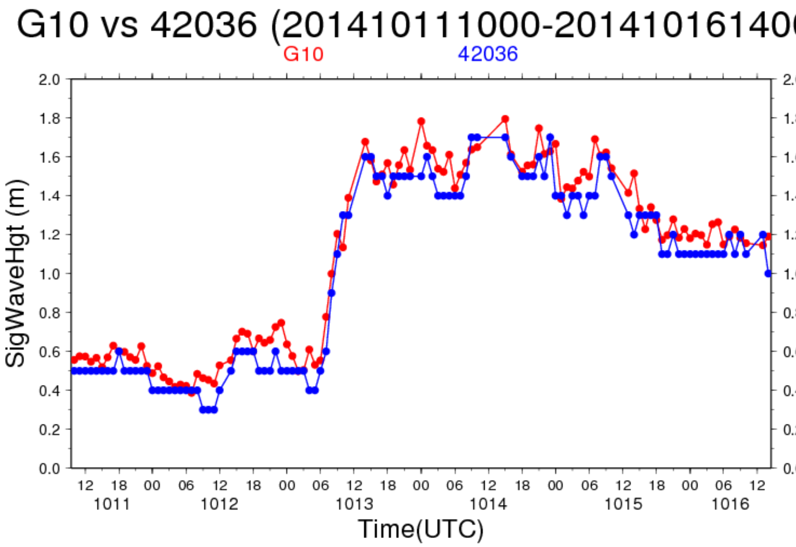


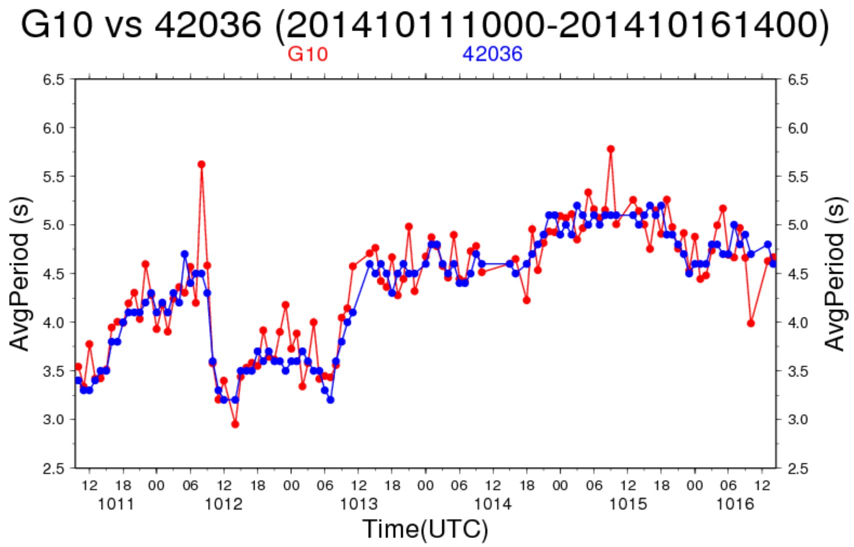
Front and circulation interaction

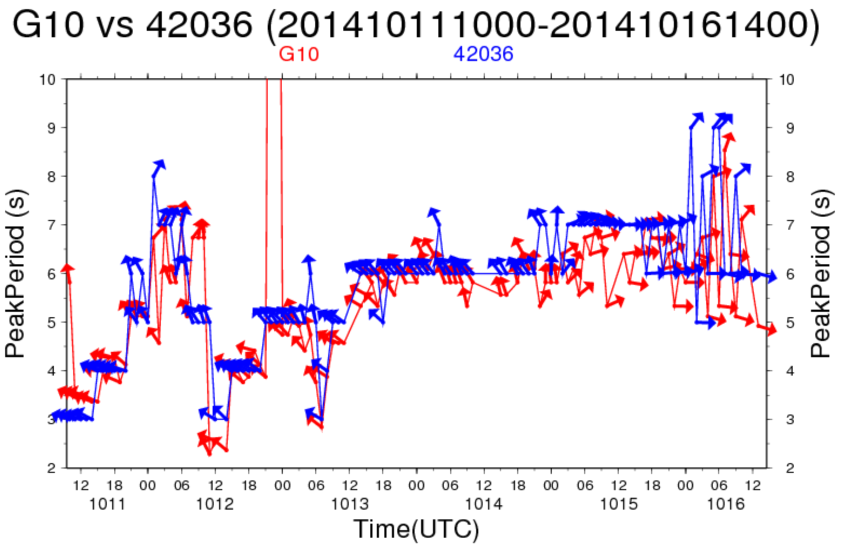
Front dissipates

Genesis then landfall

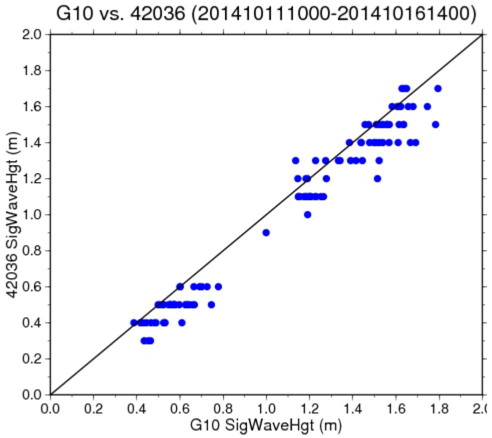
Loitering validation examples - wave data



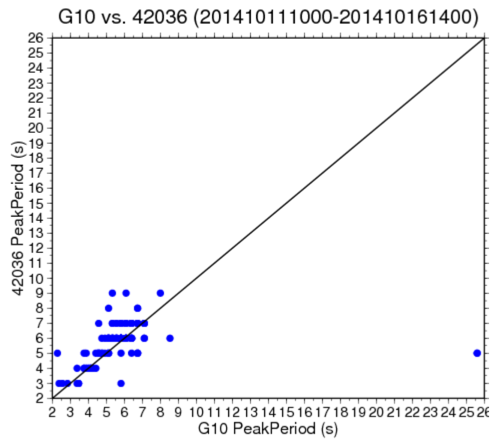


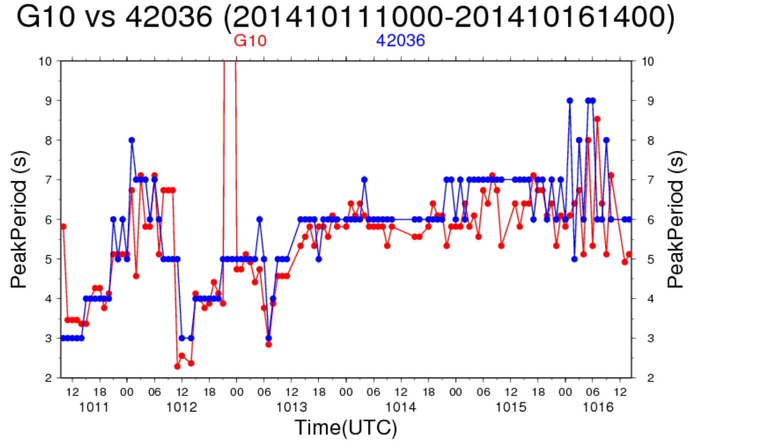


Sig Wave Hgt
Bias Err = 0.08
Abs Err = 0.09

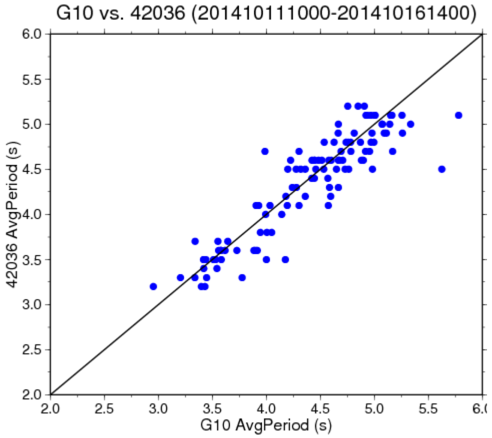


Peak Period
Bias Err = 0.05
Abs Err = 1.06

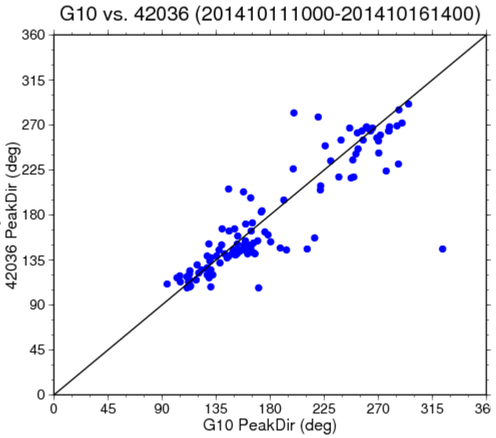


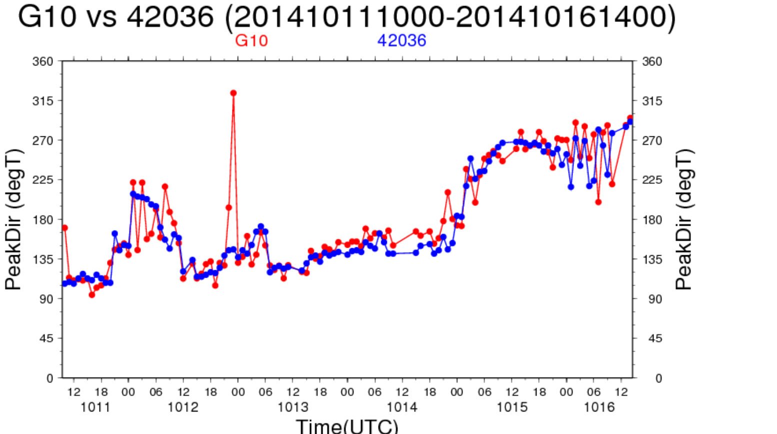


Average Period
Bias Err = 0.05
Abs Err = 0.19



Peak Direction
Bias Err = 5.19
Abs Err = 17.27

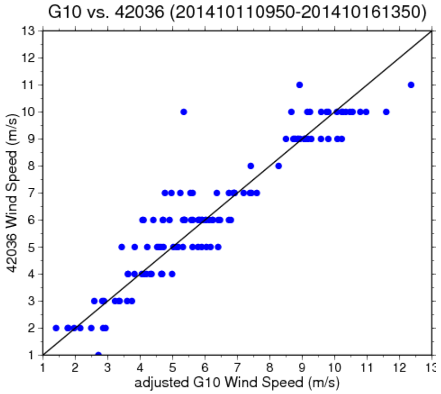


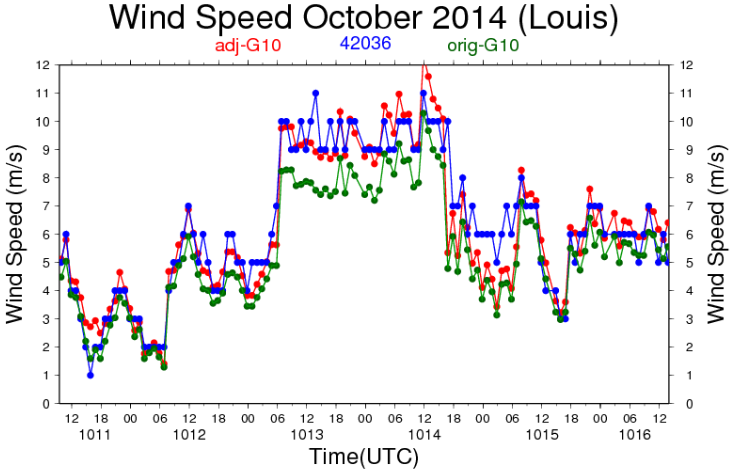


Loitering validation examples – meteorology data

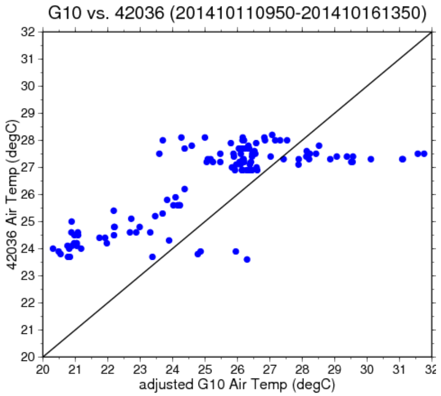
Results preliminary

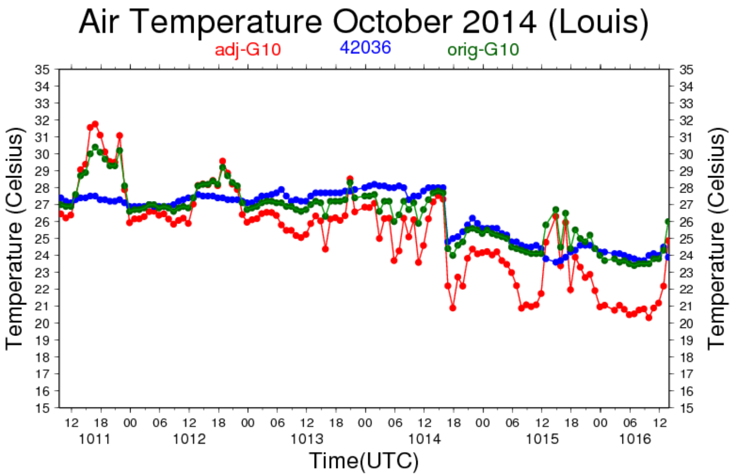
G10 adjusted to 4m for AirTemp and 5m for WindSpd (42036) using 42036's water temperature in calculation



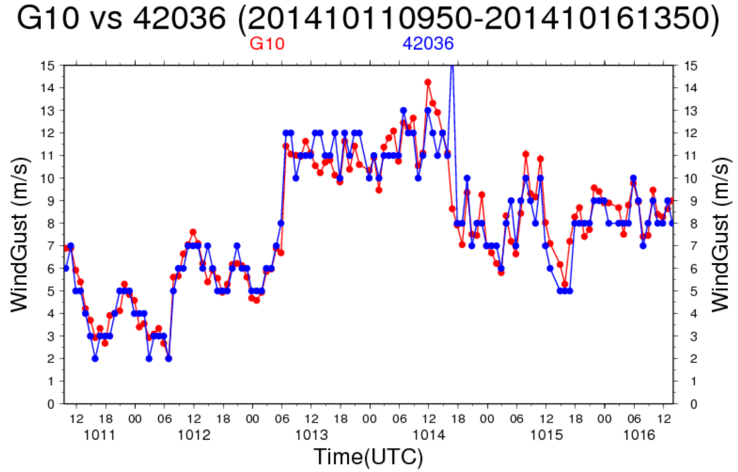


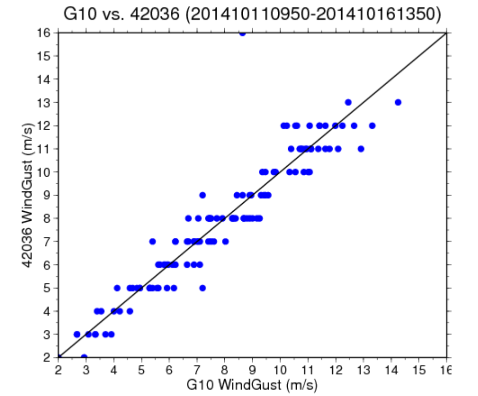
Bias Err = -0.09
Abs Err = 0.63



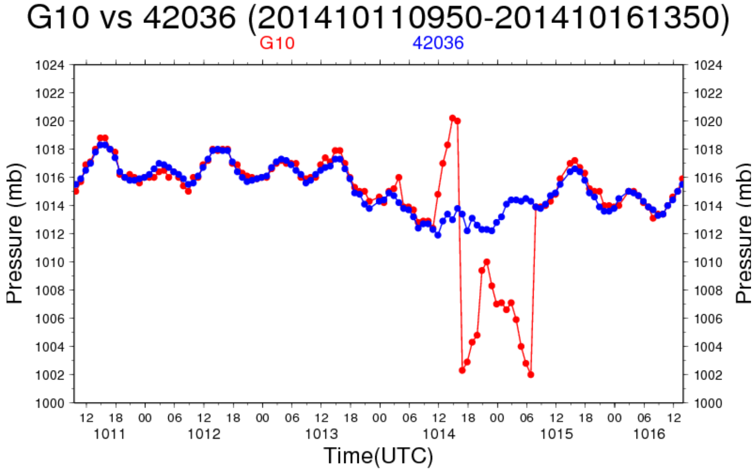


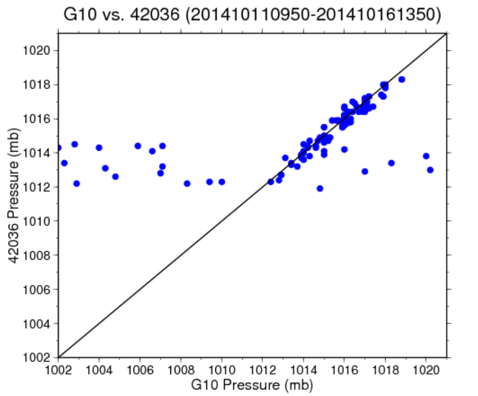
Bias Err = -1.14
Abs Err = 1.86



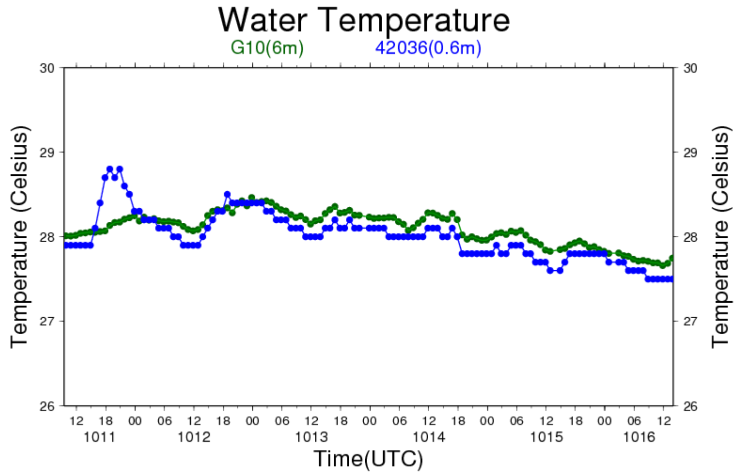


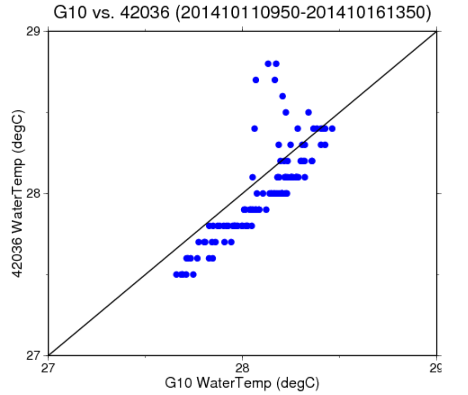
Bias Err = 0.03 Abs Err = 0.62





Bias Err = -0.63 Abs Err = 1.4





Bias Err = 0.10 Abs Err = 0.16

Validation of WG surface water temperature

Loitering platform, radii proximity, and period	r	Bias (WG - buoy)	Absolute error	Bias σ	Absolute error σ	Sample size
G10 vs 42036 (Large radius) 10/16-11/15	.98	.14	.24	.27	.19	664
G10 vs 42036 (Small radius) 10/11-10/16	.97	.15	.15	.07	.07	126
G10 vs 42036 (Small radius) 9/15-9/23	.98	.18	.18	.07	.07	192
G10 vs 42039 (Small radius) 9/2-9/5	.95	.07	.09	.09	.07	76
G10 vs 42040 (Small radius) 8/28-8/29	.76	.12	.21	.20	.10	26
G11 vs 42040 (Small radius) 9/1-9/6	.94	.20	.28	.24	.14	64
G12 vs 42039 (Small radius) 9/1-9/2	.98	.12	.12	.06	.06	16
G14 vs 42099 (Small radius) 11/25-11/28	.94	-.15	.16	.08	.07	152
G14 vs 42099 (Large radius) 10/16-10/21	.62	-.03	.23	.30	.19	243
G14 vs 42099 (Small radius) 10/10-10/16	.99	-.05	.06	.04	.04	308
G14 vs 42040 (Small radius) 9/14-9/19	.91	.22	.30	.25	.14	133
GOM1 vs 42099 (Small radius) 11/22-11/28	.88	-.24	.27	.25	.21	315
GOM1 vs 42099 (Large radius) 11/9-11/22	.84	-.02	.22	.32	.23	610

Buoy	Depth (m)
42036	0.6
42039	0.6
42040	1.0
42099	0.46

Conclusion

- WGs show a capacity for short–term to seasonal targeted sustained observations in data-void regions and possibly tropical cyclones.
- Demonstrated that SV2 WGs retain maneuverability in currents up to approximate 1 ms^{-1} .
- Preliminary results indicate reasonable buoy agreement with wave, pressure, and SST. Height-adjusted wind promising but have outliers that require more study. Instruments may also deteriorate with time (under study).
- Needs an improved air temperature sensor in warm season.
- Validation of WGs against each other planned.
- Surface (float), 6-m water temperature data (glider), salinity, dissolved oxygen, and ADCP will facilitate excellent mixing layer studies.
- Paper in upcoming May/June MTS journal

Issues

- Tampering or collisions need to be addressed by:
  - Better boater education and better signage
  - Increased distance from buoys during loitering. Buoys attract fish and fishermen.
- Require plans for international maneuvering
- Fast currents (i.e., “Loop Current”) should be examined with new SV3, which has more thrust
- Tropical cyclone intercept studies still needed to examine data viability

Extra slides

SLOSH methodology – three steps

1) V_{max} computed from p_c-p_{env} using an empirical equation similar to gradient wind balance

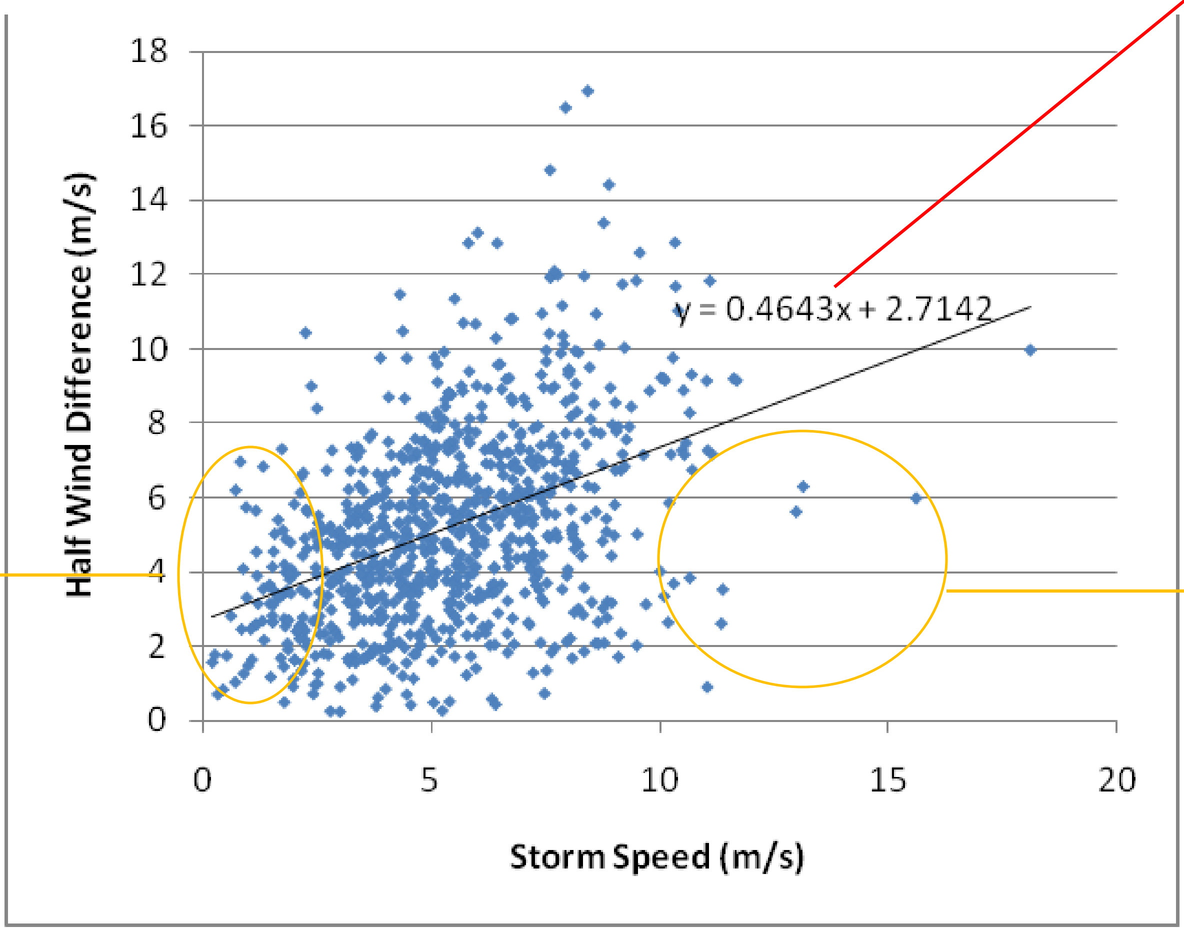
2) $$V_{sym}(V_{max}, r_{max}, r) = V_{max}\frac{2r r_{max}}{r^2 + r_{max}^2}$$

3) Asymmetry added using equation similar to V_{sym} format

Deficiencies with wind forcing:

- Not based on observed wind observations
- Storm size information, such as radius of 34 knots winds, not considered. In fact, storm size only a function of r_{max}, which has nothing to do with storm size
- Storm motion probably inflating intensity
- Storm motion asymmetry not based on observations. In fact, original paper even states it's a "gross correction" which provides a reasonable asymmetry

Scatterplot, asymmetry versus V_{SPD} at r_{max}
Explained variance = 19%

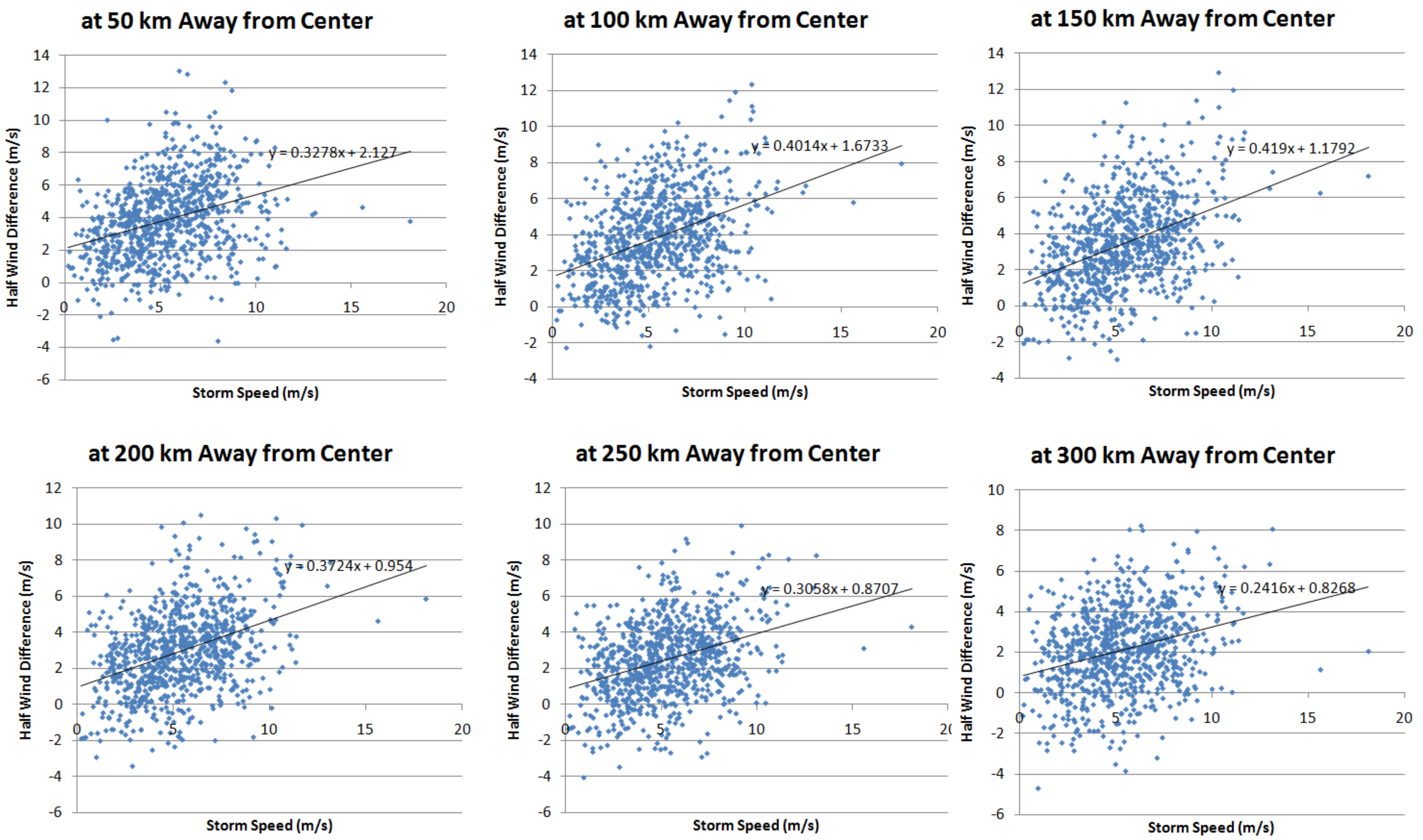


Slope of 0.46 at r_{max} plus y intercept indicates > 0.5, more than SLOSH formulation

Large asymmetry relative to slow motion, consistent with Schwerdt

Consistent with Schwerdt for fast storms. Cluster indicates more reduced inner-core asymmetry factor for fast storms may be needed

Scatterplots at different radii, asymmetry versus V_{SPD}
Explained variance ranges from 9% to 18%



- Storm speed dependence still seen. Outliers for fast storms decrease outside of 100 km.
- Slope and y intercept decreases out to 300 km, indicating asymmetry decreases radially