Upgrades to the operational Monte Carlo wind speed probability program

A. Schumacher, CIRA/Colorado State University
NHC Points of Contact: M. DeMaria, D. Brown, M. Brennan, R. Berg, C. Ogden, C. Mattocks, and C. Landsea

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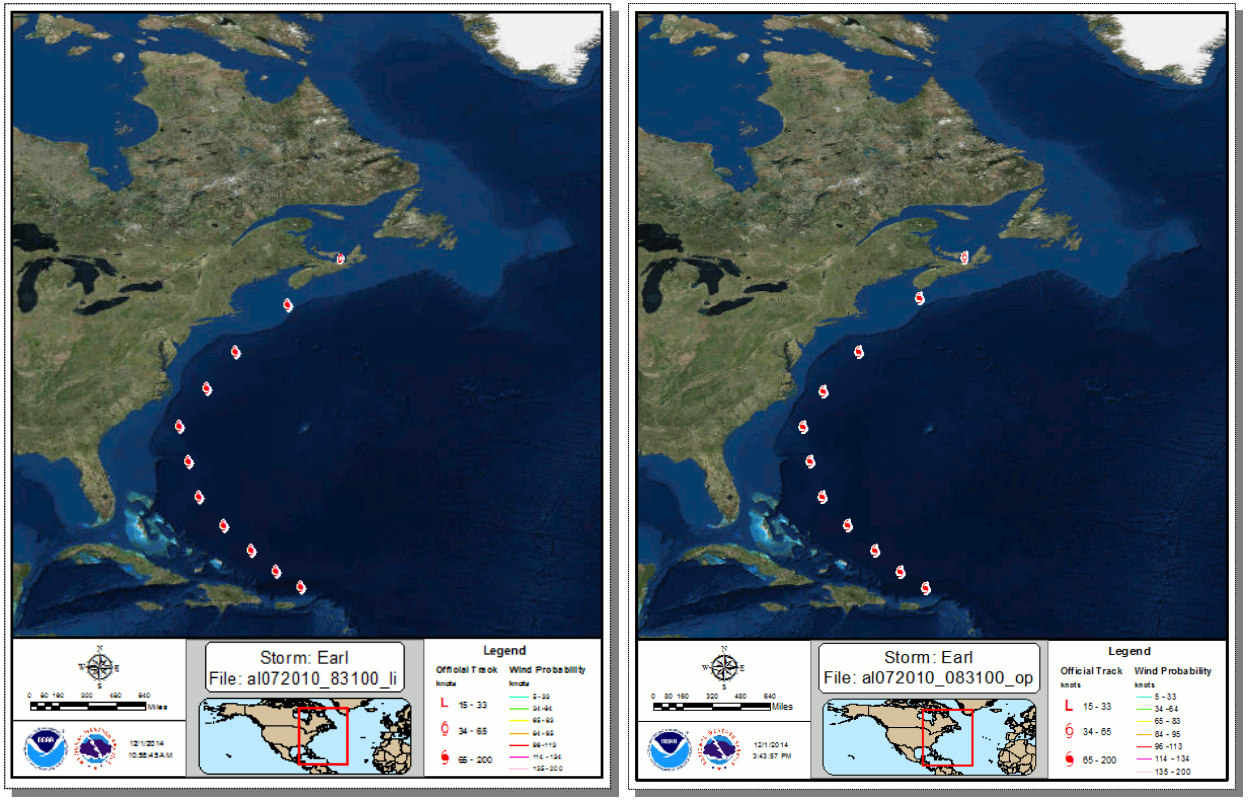
Presenter email: andrea.schumacher@colostate.edu

Outline

- Proposed 7 improvements / updates to MC model that reflect feedback from NHC forecasters
  - Improve time interpolation scheme
  - Apply bias-correction to model track error statistics
  - Apply bias-correction to radii-CLIPER model when official radii forecasts exist
  - Integrated GPCE guidance for NHC forecasters
  - Arrival and departure estimates of 34, 50, and 64-kt winds
  - Extend MC model to 7 days (April-May 2015)
  - Software upgrade (May-June 2015)
- Impacts on MC model performance
- Plans for 2015 season

1. Improve time interpolation scheme

- Linear interpolation between time steps introduces track errors
  - Slight eastward bias for recurving TCs
  - On order of ±1-5%
- Replaced with spline fit to generate smoother, more realistic tracks
- Spline interpolation option added for
  - official forecast
  - forecast realizations
- Implemented in 2015 operational MC model



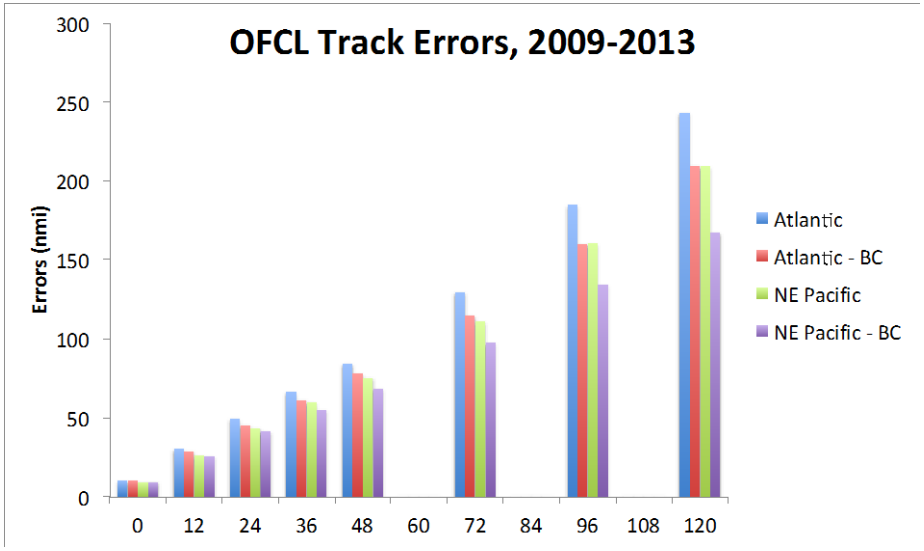
Earl on 31 Aug 2010 at 0Z – using linear interpolation (left) vs. spline (right)

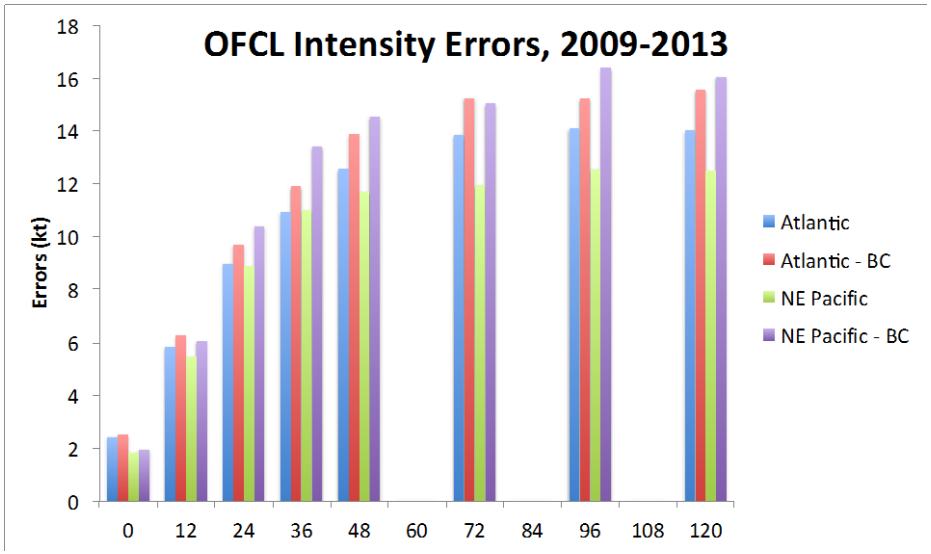
*Images courtesy of Casey Ogden, NHC

2. Bias correction to error statistics

- Error statistics used to develop wind speed probabilities are slightly different than the official NHC errors
  - Include non-tropical systems (extratropical, post-tropical)
- Updated MC model error statistics to match NHC errors statistics
- Benefits
  - Improve consistency between NHC uncertainty products
  - In future, can create cone that can increase and decrease based on GPCE parameter
- Serial correlation still introduces a small bias

How this effected MC model error statistics

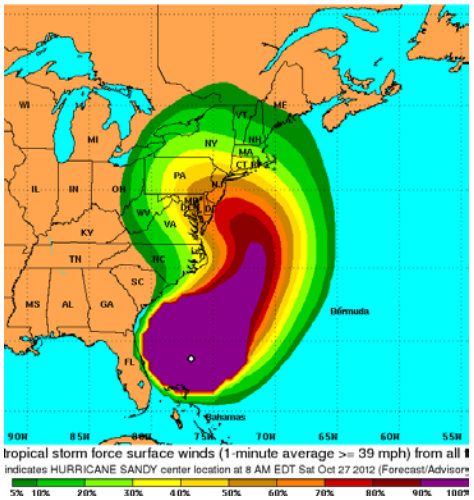




- Average track errors were decreased 10-15% at all forecast times in both basins
- Average intensity errors were increased ~10% in the Atlantic and 15-30% in the E. Pacific at all forecast times

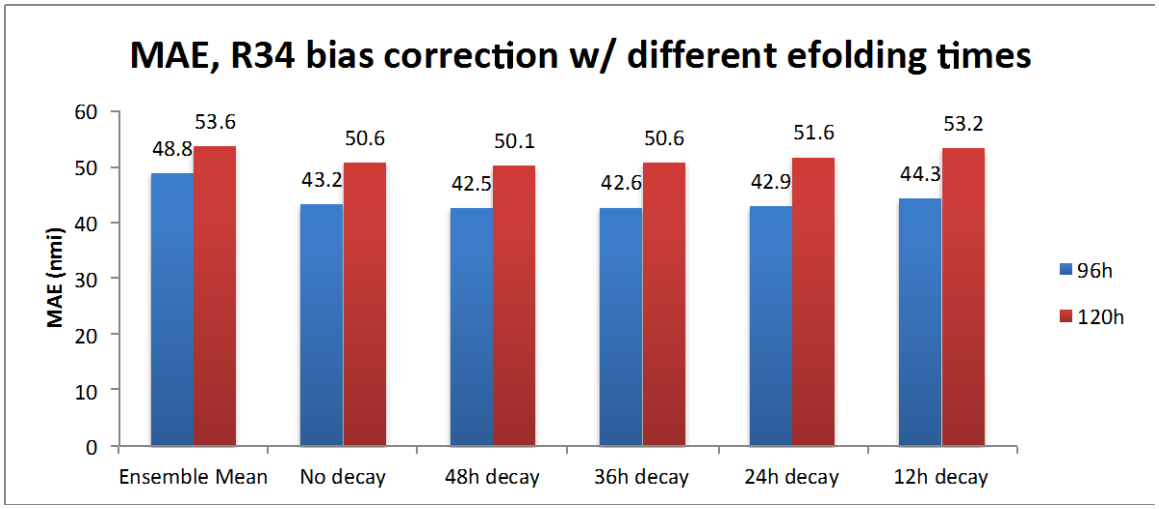
3. Radii bias correction

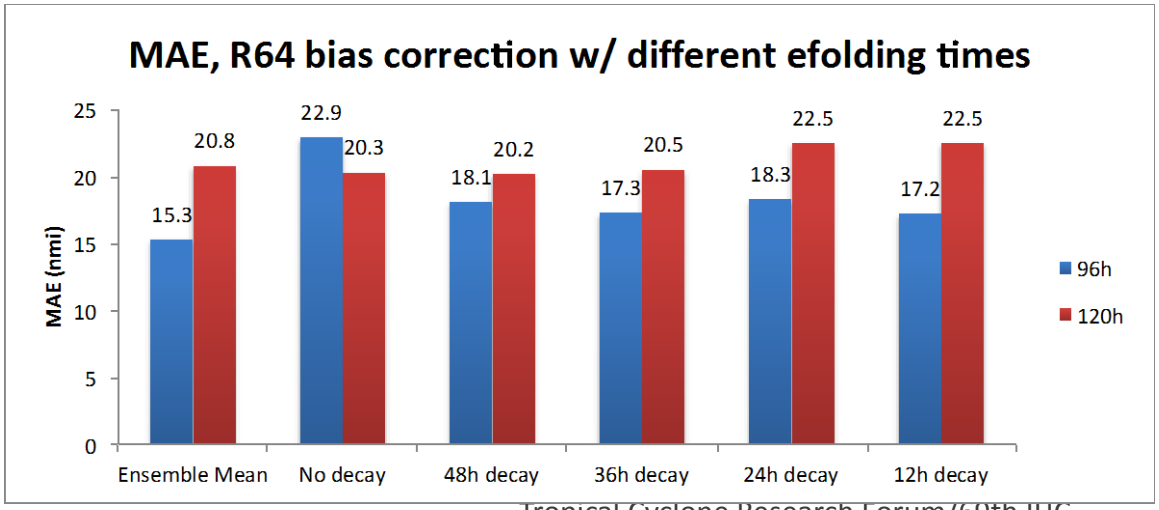
- Official wind radii not available for all forecast periods to 5 days
  - 72 h for R34 and R50
  - 36 h for R64
- MC model uses radii-CLIPER for 34, 50, and 64-kt wind radii estimates at all times
  - Contribution of persistence has e-folding time of 32 h (DeMaria et al. 2009)
  - For TCs much smaller (larger) than climatology, radii-CLIPER overestimates (underestimates) radii for t > 32 h
- Introduces bias to wind speed probabilities
  - Eg. Hurricane Sandy (right)
  - R34 much larger than climatology
  - Along NJ coast, probabilities 50-60% (left)
  - With bias correction, probs 70-80% (right)
- Fix (In Progress)
  - Develop method to use all available wind radii from NHC to consistently bias correct radii-CLIPER
  - Use error serial correlation to extend influence beyond NHC radii forecast



Sandy, 10/27/12 12Z

Proposed radii bias correction





For 34, 50, or 64-kt wind thresholds…

r_e = ensemble mean radius
r_o = official forecast radius
t_{last} = last time official radius forecast available

$BC(t) = w(t) * [r_e(t) - r_o(t)]$

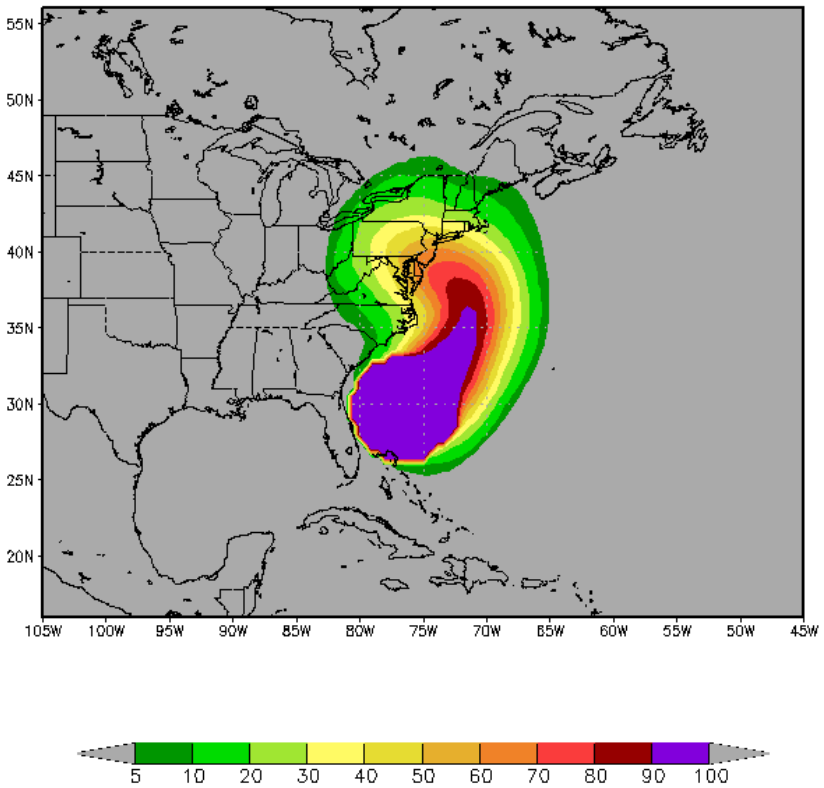
For $t \leq t_{last}$, $w(t) = 1.0$

For $t > t_{last}$,
$w(t) = e^{-[(t-tlast)/D]}$

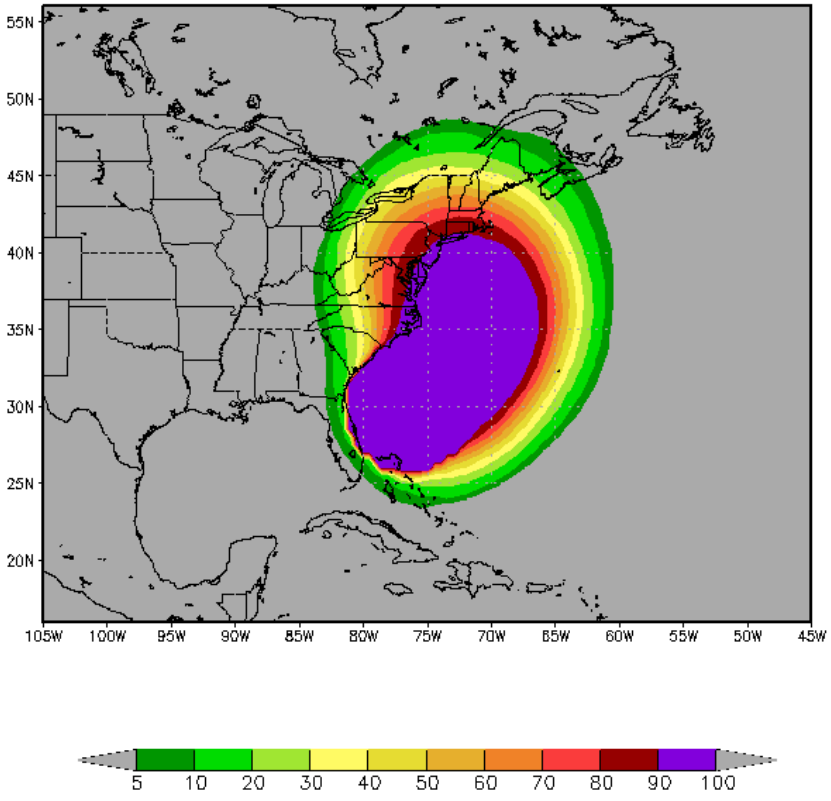
where D is the e-folding time

Example of radii bias correction incorporated into mc model

Current Algorithm



With Radii Bias Correction
e-folding time of 32 h



Sandy, 10/27/12 12Z

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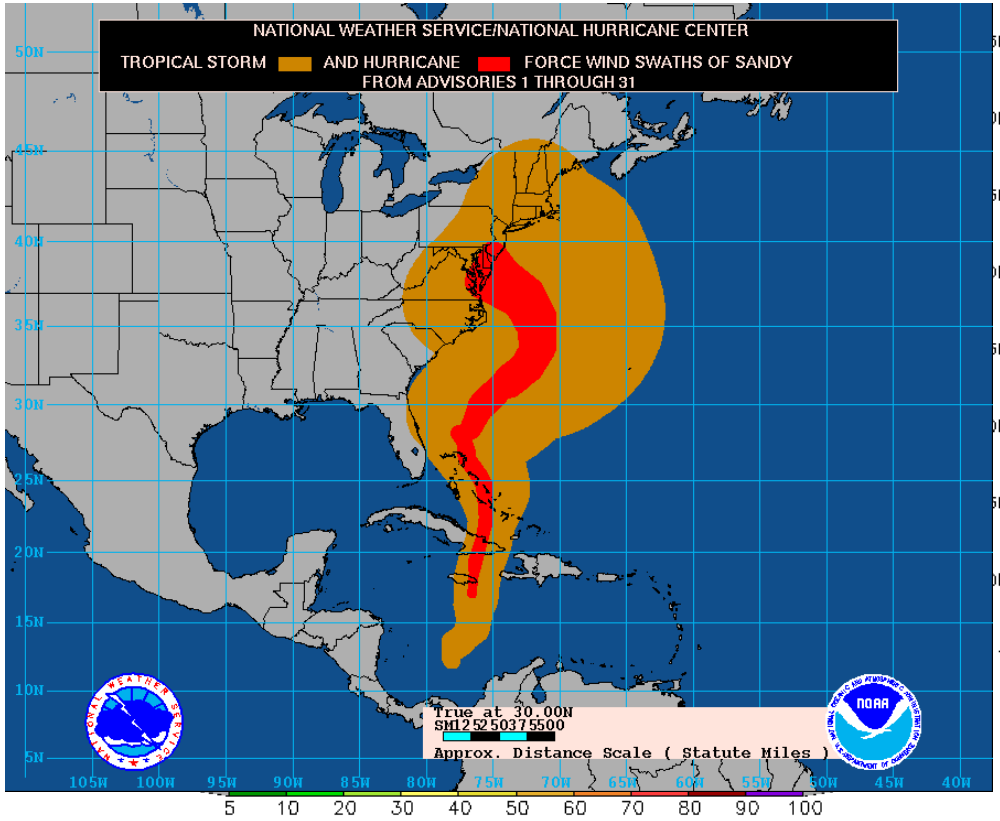

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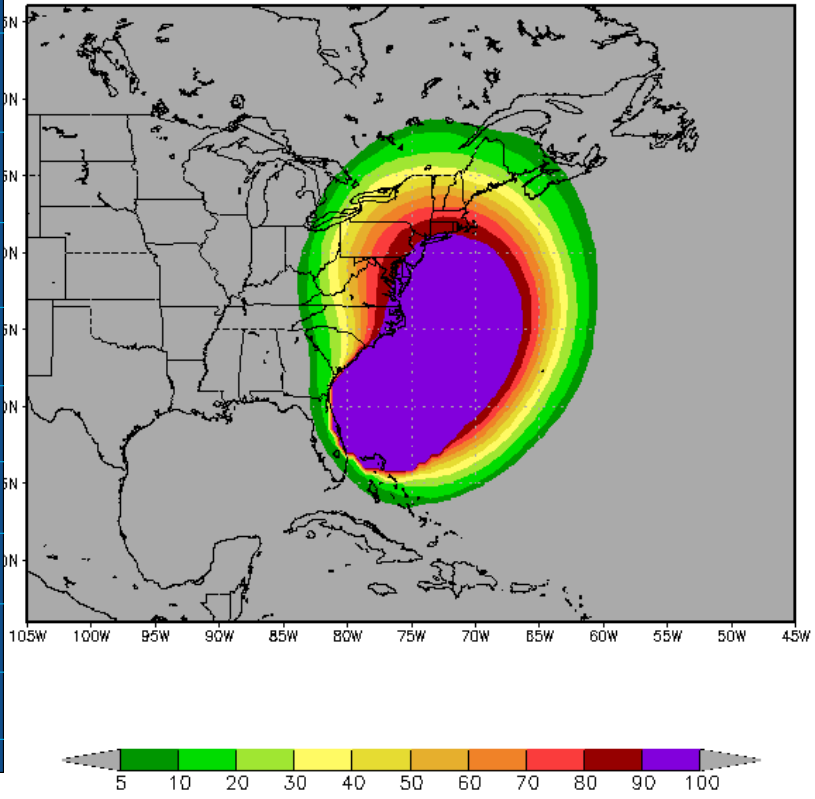
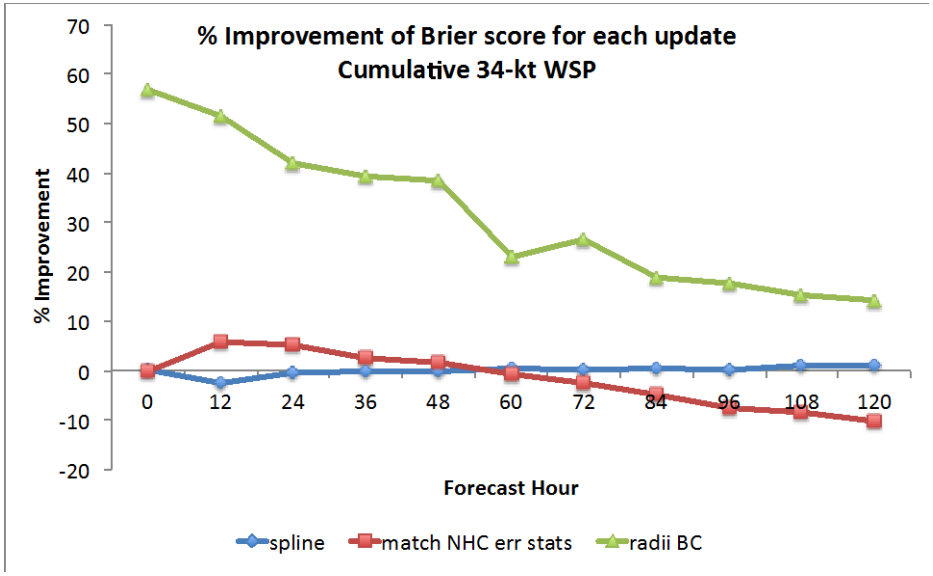
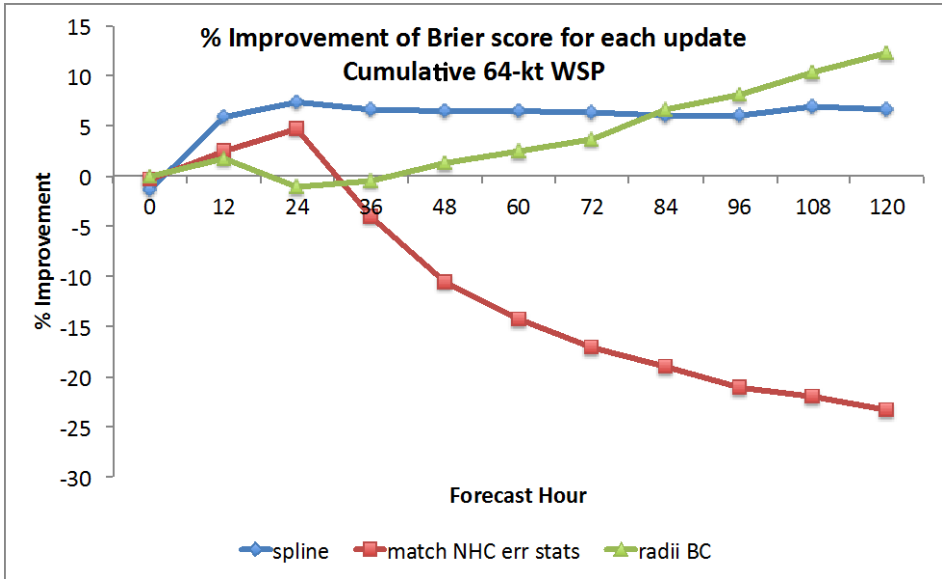


Sandy, 10/27/12 12Z

Impacts of updates on WSP Brier scores, 2011-2013 Atlantic sample





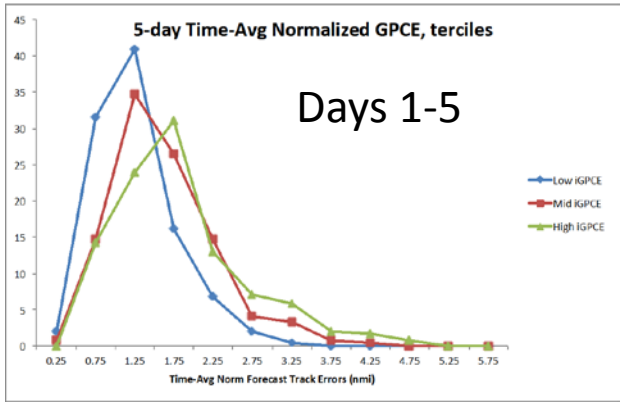
- Spline interpolation and radii bias correction improve WSPs at all forecast times
- Matching error statistics to NHCs improves WSP at early times but degrades verification after 1.5-2 days

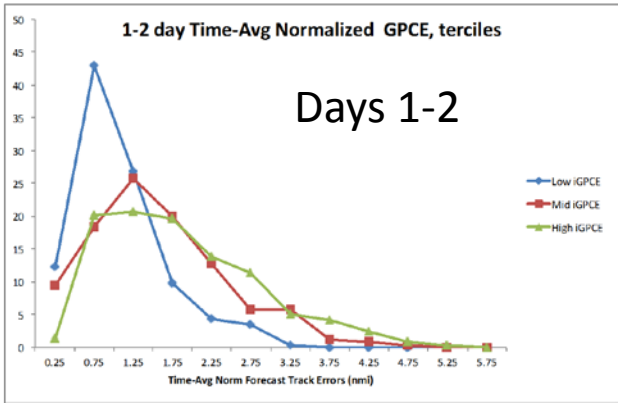
4. Time-Integrated GPCE Guidance

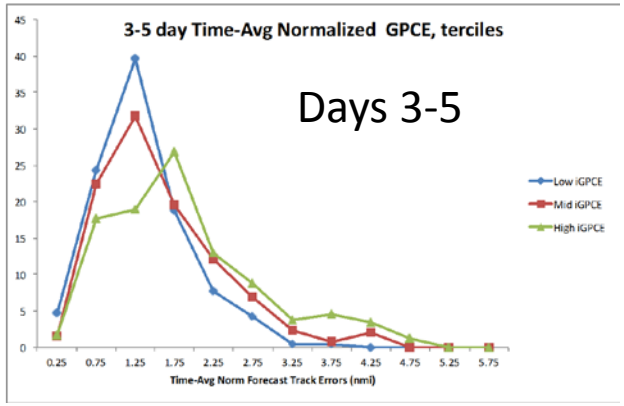
- DeMaria et al. 2013 showed relationship between GPCE terciles and track forecast error distribution
  - Low (high) GPCE values correspond to less (more) spread
  - Motivated use of GPCE parameter to modify MC model
- Developed time-integrated measure of GPCE information used in MC model
  - Provide forecasters 3-category measure of confidence for entire track forecast (low/med/high)
- Time-averaged normalization
  - Normalize all GPCE values and forecast error by their standard deviation at that forecast time
  - Then, average over selected range of time (here 0-5 days, 0-2 days, and 3-5 days)
- Examined 2008-2012 Atlantic cases
  - Both forecast errors and GPCE must be available to 5 days (N=718)

Time-Averaged Normalized GPCE (TANG) parameters, 2008-2012 ATL

Terciles (33/33/33)







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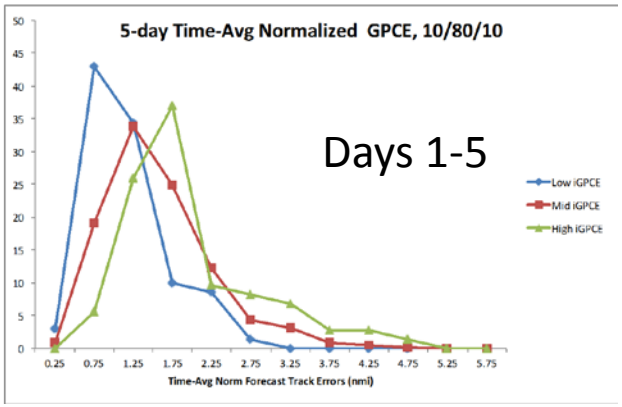
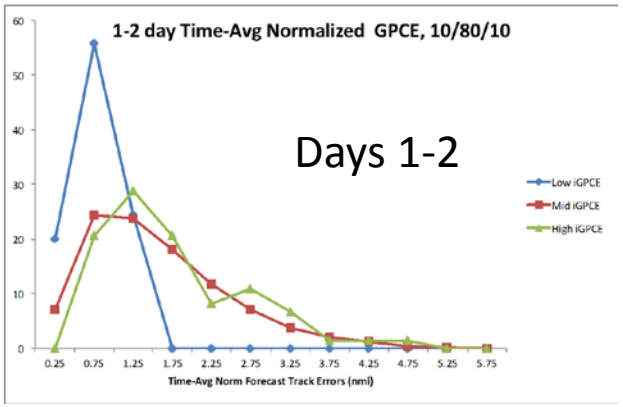
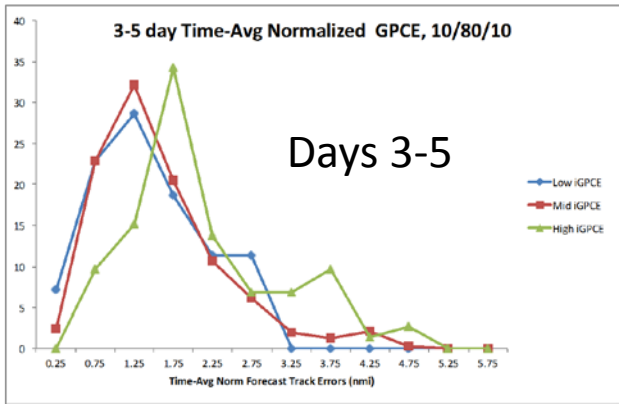






TANG classification examples

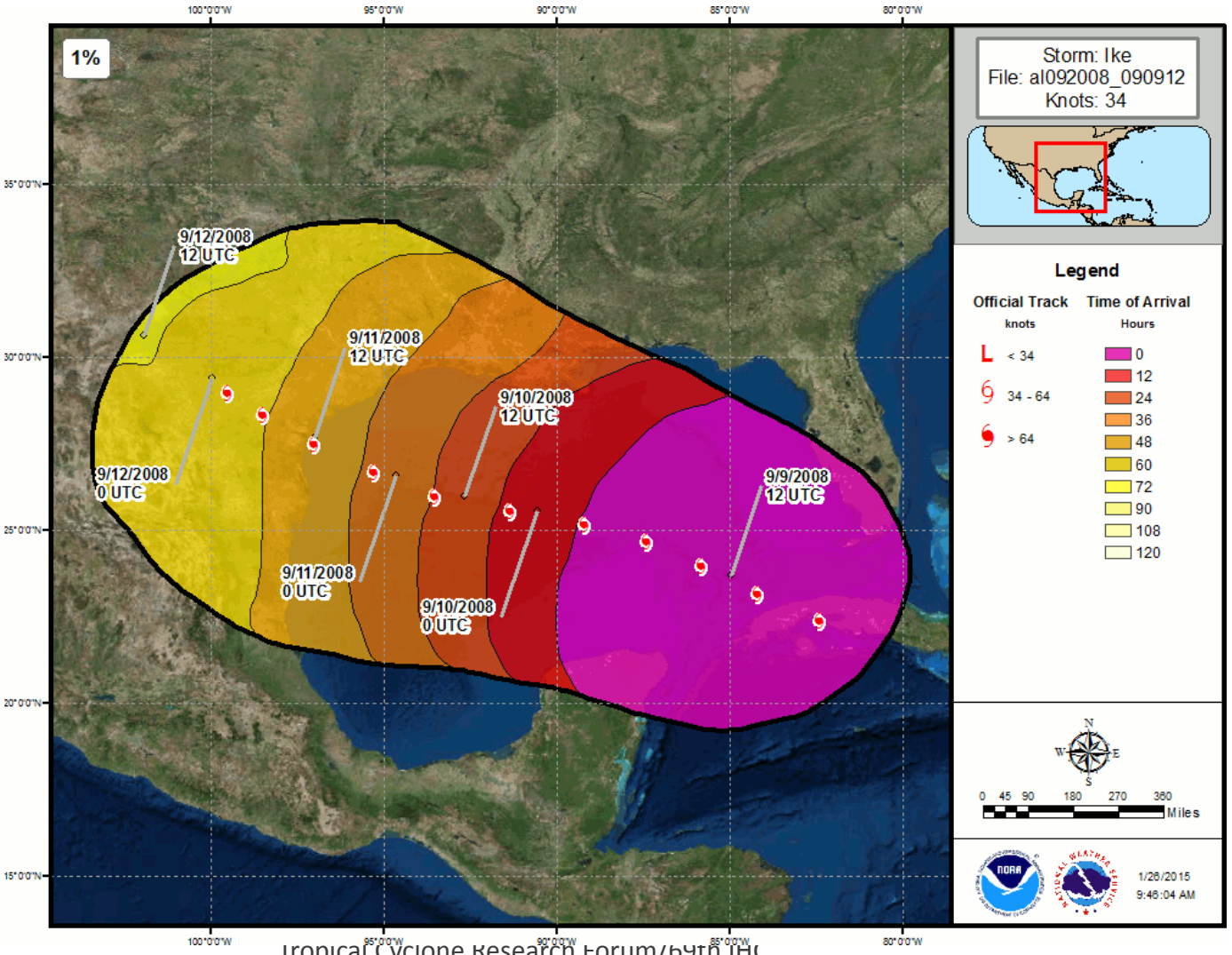
Low GPCE Days 1-2, High GPCE Days 3-5											TANG 1-2day		TANG 3-5day		TANG 0-5day	
Fcst Hr	12	24	36	48	60	72	84	96	108	120	10/80/ 10	33/33/ 33	10/80/ 10	33/33/ 33	10/80/ 10	33/33/ 33
AL172012 101512	33	54	69	86	130	174	240	306	382	458	M	L	M	H	M	H
AL182011 102606	23	42	66	97	154	211	333	455	607	759	L	L	H	H	H	H
AL162011 093006	26	46	71	100	148.5	197	279	361	427.5	494	M	L	H	H	M	H
AL062010 082706	21	42	65	100	137.5	175	226	277	328	379	L	L	M	H	M	M

High GPCE Days 1-2, Low GPCE Days 3-5											TANG 1-2day		TANG 3-5day		TANG 0-5day	
Fcst Hr	12	24	36	48	60	72	84	96	108	120	10/80/ 10	33/33/ 33	10/80/ 10	33/33/ 33	10/80/ 10	33/33/ 33
AL032012 062100	41	66	122	154	153	152	177.5	203	229.5	256	H	H	M	L	M	H
AL162011 092112	42	70	96	122	127.5	133	162.5	192	230.5	269	M	H	M	L	M	M
AL052011 080706	52	97	149	165	152.5	140	166.5	193	216	239	H	H	M	L	M	H
AL062010 082118	63	112	146	168	160	152	168	184	189	194	H	H	M	L	M	H

5. Time of wind arrival / departure estimates

- Realizations created by MC model can be used to provide estimates of the time of arrival & departure of 34, 50, and 64-kt winds for various threshold (e.g., 10^{th}, 50^{th}, 90^{th}, 95^{th} percentiles)
- TOA/TOD estimates currently available in Hurricane Landfall Probability Application (HuLPA), with limitations
  - Computed at single breakpoints
  - Accessible via GUI after MC model has run (inefficient)
- Numerous uses for TOAs/TODs
  - Emergency managers (e.g., road closures, evacuation timing)
  - Utilities (e.g., response planning)
- NHC POCs (e.g., M. DeMaria, C. Ogden, R. Berg) have taken the lead on developing and refining this upgrade

Example: TOA - Ike



Remaining updates

- #6 (April-May 2015) – Extend wind speed probabilities to 7 days
  - Create developmental dataset of 7-day forecasts
    - 2012, 2013, 2014 – NHC forecasts
    - Prior to 2012 – GFS tracks and trajectory-CLIPER intensity
- #7 (May-June 2015) – Software update
  - Consolidate code and scripts for seasonal updates

Plans for the rest of Year 2

- By August 2015
  - Finalize updates based on NHC POC feedback
  - Implement all upgrades (Atlantic and N.E. Pacific) into experimental MC model
  - Run experimental MC model for the 2015 Atlantic & N.E. Pacific seasons
  - Display wind speed probabilities and difference plots
    - http://rammb.cira.colostate.edu/realtime_data/nhc/mc_model/

Thank you! Questions?

References:

- Goerss, J. S., 2007: Prediction of consensus tropical cyclone track forecast error. *Mon. Wea. Rev*., **135**, 1985–1993.
- Knaff, J. A., C. R. Sampson, M. DeMaria, T. P. Marchok, J. M. Gross, and C. J. McAdie, 2007: Statistical tropical cyclone wind radii prediction using climatology and persistence. *Wea. Forecasting*, **22**, 781–791.
- DeMaria, M., J.A. Knaff, R.D. Knabb, C.A. Lauer, C.R. Sampson, and R.T. DeMaria, 2009: A New Method for Estimating Tropical Cyclone Wind Speed Probabilities. *Wea. Forecasting*, **24**, 1573–1591.
- DeMaria.M., J.A. Knaff, M.J. Brennan, D. Brown, R.D. Knabb, R.T DeMaria, A. Schumacher, C.A. Lauer, D.P. Roberts, C.R. Sampson, P. Santos, D. Sharp, and K.A. Winters, 2013: Improvements to the operational tropical cyclone wind speed probability model. Submitted to *Wea. Forecasting*.