Upgrades to the M-PERC and PERC Models to Improve Short Term Tropical Cyclone Intensity Forecasts

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74th Interdepartmental Hurricane Conference 2020
Lakeland, FL Feb 25-26

This work is sponsored by the NOAA Joint Hurricane Testbed

Radar image of Hurricane Maria approaching Puerto Rico courtesy of Brian McNoldy Univ. of Miami, Rosenstiel School)
ERC Onset Guidance: M-PERC

Goal – Make incremental improvements to short range forecasts by giving forecasters a tool that objectively identifies Eyewall Replacement Cycle (ERC) onset.

Microwave Probability of Eyewall Replacement (M-PERC) model

Existing microwave-based model M-PERC was developed using Atlantic data

- Baseline existing Atl-based model
- Create Eastern/Central Pacific data
- Create new model based on this basin-specific data
- Test model in near real-time
- Update web-based display to add SHIPS environment parameters (shear, sst, etc)
“The disparity between SHIPS forecasts and the observed intensity changes during ERCs is strongly suggestive that the typical environmental controls of intensity change, on which SHIPS is largely based, are temporarily countermanded while dynamic processes internal to the storm dominate the intensity evolution.” - Kossin
Matthew probably is near its peak intensity and will likely maintain a similar strength during the next 12 hours or so. Data from the reconnaissance plane show an incipient outer band of maximum winds, indicating that an eyewall replacement cycle could occur soon. This should result in fluctuations in intensity, and given that southwesterly shear is still affecting the cyclone, some weakening is anticipated.

ERC forecast tools available to forecasters currently

E-SHIPS – ERC adjustments to SHIPS forecast when ERC onset is known

PERC – Probability of ERC (based on environment, Vmax and infrared satellite information)

** PROBABILITY OF AT LEAST 1 SCANDRY EYEWAL FORMATION EVENT AL142016 MATTHEW 10/01/2016 00 UTC **

** DSHP FORECAST ADJUSTED RELATIVE TO ONSET OF ERC WEAKENING PHASE **

<table>
<thead>
<tr>
<th>TIME (HR)</th>
<th>&gt;24HR AGO</th>
<th>18HR AGO</th>
<th>12HR AGO</th>
<th>6HR AGO</th>
<th>NOW</th>
<th>IN 6HR</th>
<th>IN 12HR</th>
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<tr>
<td>24-36</td>
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** CLIMO(%) **

<table>
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<tr>
<th>TIME (HR)</th>
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<th>12-24</th>
<th>24-36</th>
<th>36-48</th>
</tr>
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<tbody>
<tr>
<td>CLIMO(%)</td>
<td>48</td>
<td>43(70)</td>
<td>28(79)</td>
<td>23(84)</td>
</tr>
</tbody>
</table>
**ERC Onset Guidance: M-PERC**

Secondary Eyewall Formation (SEF) – A nearly continuous spiral band that wraps more than 50% around an existing eyewall.

Eyewall Replacement (ERC) – The complete process of the replacement of the inner eyewall by an outer eyewall.

Secondary wind maxima can be observed by aircraft and radar velocity data.

In the absence of these sources, microwave imagery can be used as a proxy.
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M-PERC starts with Automated Rotational Center Hurricane Eye Retrieval (ARCHER)

Fixes TC position using 89 GHz imagery

Ring score is computed for all pixels thus the ring score can be used to determine primary and secondary ring “candidates”
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Ring scores can be displayed in hovemuller form to show time and space evolution of the features.

*ARCHER ring score plotted versus time shows a branching/merging pattern during ERCs
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Ring score profiles from 2 storms.

M-PERC Model

PCA on 1787 profiles from storms 1999-2011 to develop logistic regression predictors

Change in PCs over 6, 12, 18 and 24 hours added to set of predictors. Vmax and delta-Vmax also are used for a total of 18 predictors.

Two models are developed. Full model will all predictors and a Vmax-only model to provide some measure of comparison of the impacts of the microwave data

Model output does not start until best track Vmax > 65 knots
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Web page output for M-PERC
On CIMSS ARCHER page

Training Data 1999-2011 -> 41 storms with 84 ERC events

Verification

Verification data 2012-2019 -> 22 storms with 48 events

Evaluate performance of existing model in Atlantic

Using prob of >25% 37 hits and 11 misses
Using prob of >50% 22 hits and 24 misses

BSS for the sample (climatology of 13%) is 32%

Average delta-Vmax following SEF is -13 knots
Average forecast intensification was +4 knots
Though M-PERC runs for all storms globally the model was developed using Atlantic data.

Model is sensitive to radial distribution of the banding features. These features exhibit variability that has a basin dependence. IE storms tend to be smaller in the Eastern Pacific and larger in the Western Pacific than Atlantic storms.

Verify model performance in EPAC to test this potential size dependence.

Develop EPAC version of M-PERC.

Create three models: Vmax-only, microwave-only and full model to better evaluate contribution of the various terms.
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EPAC Example for Hurricane Fernanda
Reasonable performance, storm is similar in size to Atlantic training data.
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ERC process can aid in RW

SEF development

Erosion in NW quad

Entrainment of stable air into inner core interrupts ERC process. Core rapidly weakens

Hurricane Kenneth (13E) 2017

ERC process can aid in RW
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EPAC miss. Vmax is low compared to sample ERC events.

Microwave-only model might help with these cases.
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Hurricane Hector (10E) 2018 five ERC events

data gap
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Hurricane Edoaurd 2014

Many such cases exist in various best tracks (all basins). This impacts LMI, RI and RW data

Best Track does not reflect some ERC events. Obj estimates show steady state or weakening
M-PERC captures the majority of ERC events with lead time that can assist in intensity forecast decision process. In EPAC 22 hits for 27 events with 1 F/A using prob > 25%. Hits = 16 for prob > 50%

Moving Forward

Continue to identify EPAC/CPAC cases back to 1999

Develop new M-PERC model using basin-specific data. Compare results with Atlantic-based model to highlight differences if any.

Update web display to include wind shear, OHC and other environment parameters that impact ERC to allow forecasters to see if process will continue or possibly be disrupted.