Diagnosing Large-scale Tropical Cyclone Model Moisture and Exploring Impacts on Track and Intensity

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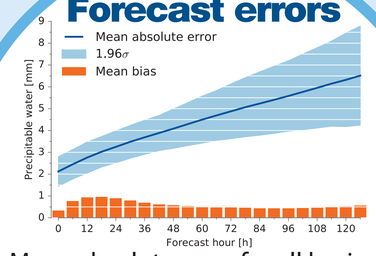
Background

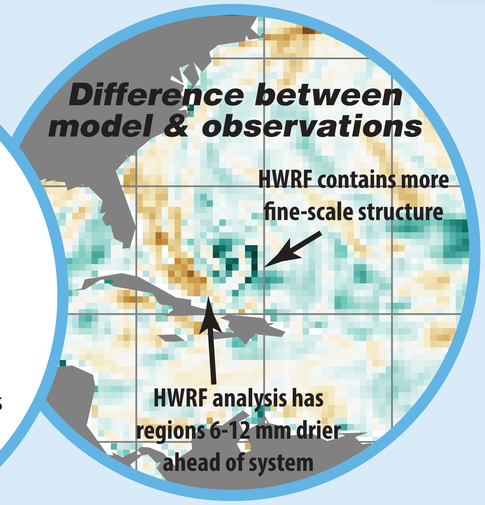
- Environmental moisture impacts vortex development by shaping
  - Storm track and intensity
  - Storm size and structure
- Moisture verification is potentially challenging
  - Lack of conventional observations near the storm
  - Limited aircraft reconnaissance depending on location
- Precipitable water, the vertical integral of water vapor, is a great comparison variable because it is produced by numerical models and is retrieved by polar orbiting satellites
- Statistical metrics are used to evaluate moisture in the 2015 operational Hurricane Weather Research and Forecast (HWRF) model
- Errors in the 48-hour moisture field are compared with 48-hour forecast track and intensity errors

Forecast errors



- Mean absolute error for all basins shows increase from 0-126 hours
- Bias spins-up in first 18 hours
- Metrics do not capture spatial variability

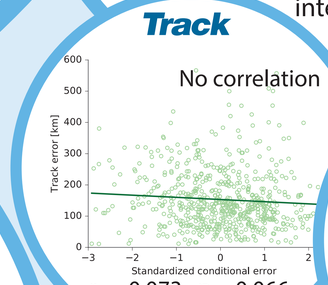
Difference between model & observations



Applications to track & intensity error

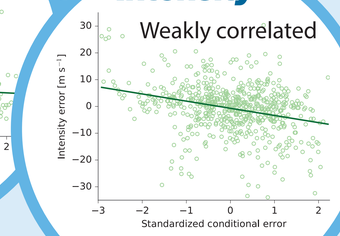
- Understanding how moisture errors reflect errors in track and intensity might help to improve model performance and forecasts
- Below are examples correlating the 48-hour standardized conditional bias component of the skill score to the track and intensity errors
- Results are basin dependent and are affected by the domain size used to compute the skill score
- The results illustrate how a single metric does not capture all the variance in track & intensity forecast errors

Track



r = -0.073 p = 0.066

Intensity



r = -0.292 p = 5e-14

Data & regridding

Forecast field

- Precipitable water from the HWRF parent grid (0.2 degree)
- 2015 Atlantic & Central and Eastern North Pacific Hurricane Season

Satellite observations

- NOAA NESDIS Operational Blended Total Precipitable Water Product

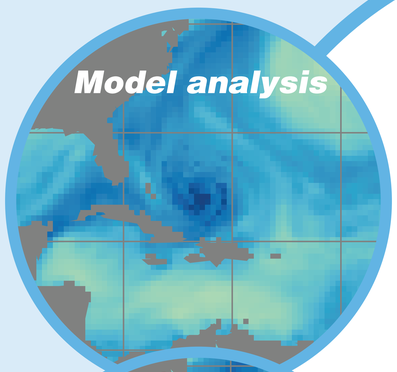
Climatology/reference state

- 5-day centered average for 2011-2014 satellite precipitable water observations
- Provides a reference state for skill score

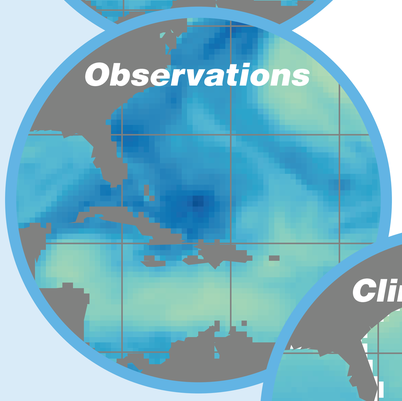
Common grid procedure

- Linear interpolation over ocean only
- Domain centered on HWRF forecast track
- 40˚x40˚ domain with 0.5˚ resolution

Model analysis



Observations



Climatology

Use QR-code to see an animation for Joaquin & basin specific statistics

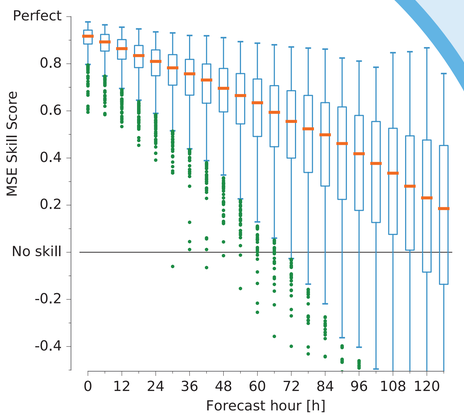
https://goo.gl/6uKcWq

Hurricane Joaquin (2015)
00 UTC October 01

Mean square error skill score

- Provides relative accuracy measures
- Climatology acts as a reference or control state
- Forecasts do not gain spurious skill

- HWRF's analysis has a median skill of ~0.93
- Skill drops below 0.50 by forecast hour 84



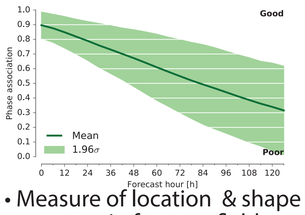
Skill score

$$SS_{Clim} \approx r_{f'o'}^2 - \left(r_{f'o'} - \frac{\sigma_{f'}}{\sigma_{o'}}\right)^2 - \left(\frac{\bar{f}' - \bar{o}'}{\sigma_{o'}}\right)^2$$

Phase association
Conditional bias
Unconditional bias

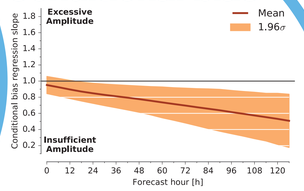
f = Forecast o = Observation $[\,]' = [\,] - \text{Clim}$

Phase association



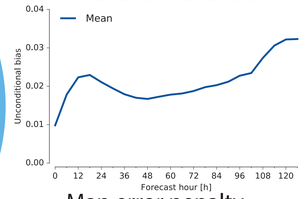
- Measure of location & shape errors in forecast field
- Relates to track errors

Conditional bias



- Penalty term for a deficiency in forecast field reliability
- HWRF has insufficient moisture amplitude

Unconditional bias



- Map error penalty
- Related to mean bias, which shows HWRF is too wet on average

Conclusions

- Mean absolute error and bias lack spatial data
- Skill score offers insight into the physical reasons behind precipitable water errors
- The HWRF model tends to be too moist
- HWRF displays insufficient moisture amplitude
- Skill quickly degrades after 48 hours
- Skill score components explain some variance in track and intensity errors
- More work needs to be done on applications

References

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This research was supported by the NOAA Hurricane Forecast Improvement Program under Grant NA14OAR4320125