Using satellite observations to evaluate model errors in environmental moisture around tropical cyclones

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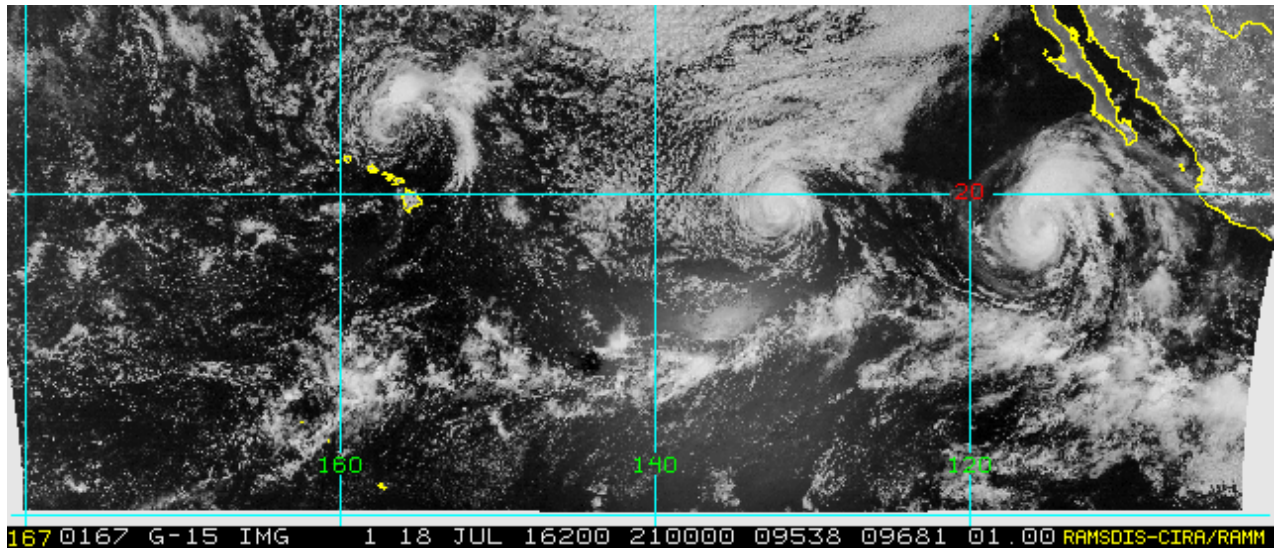
Fort Collins, CO

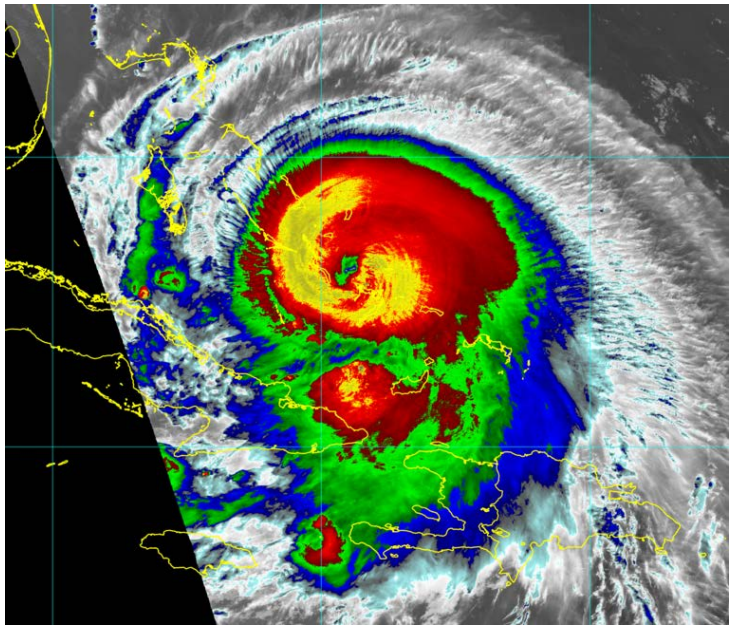
19 July 2016



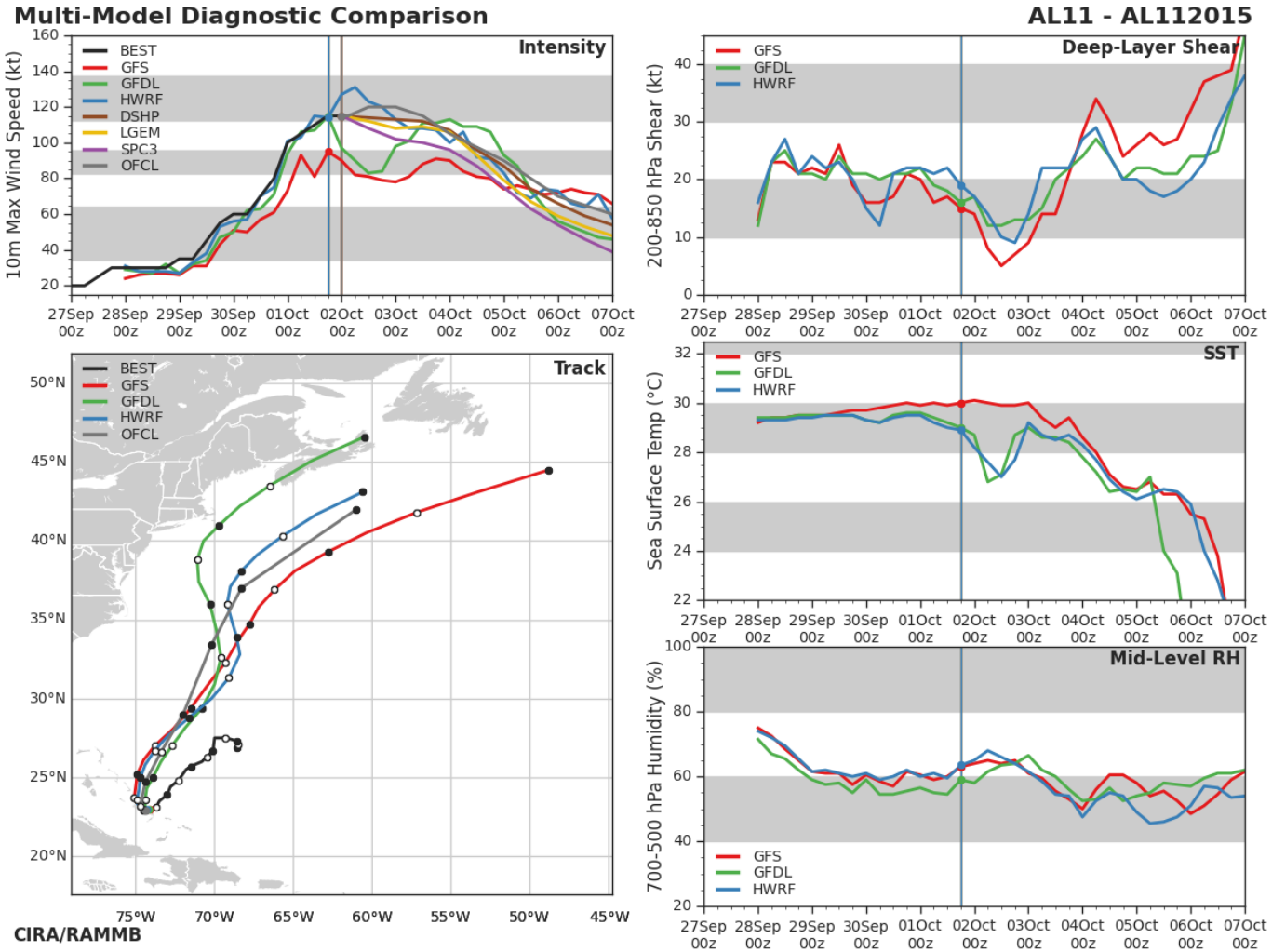
CIRA RAMMB NOAA HURRICANE FORECAST IMPROVEMENT PROJECT Colorado State University

Environmental ingredients for tropical cyclones

- Warm ocean waters
- Steep lapse rates
- Moist air to maintain convection
- Low vertical, deep layer shear



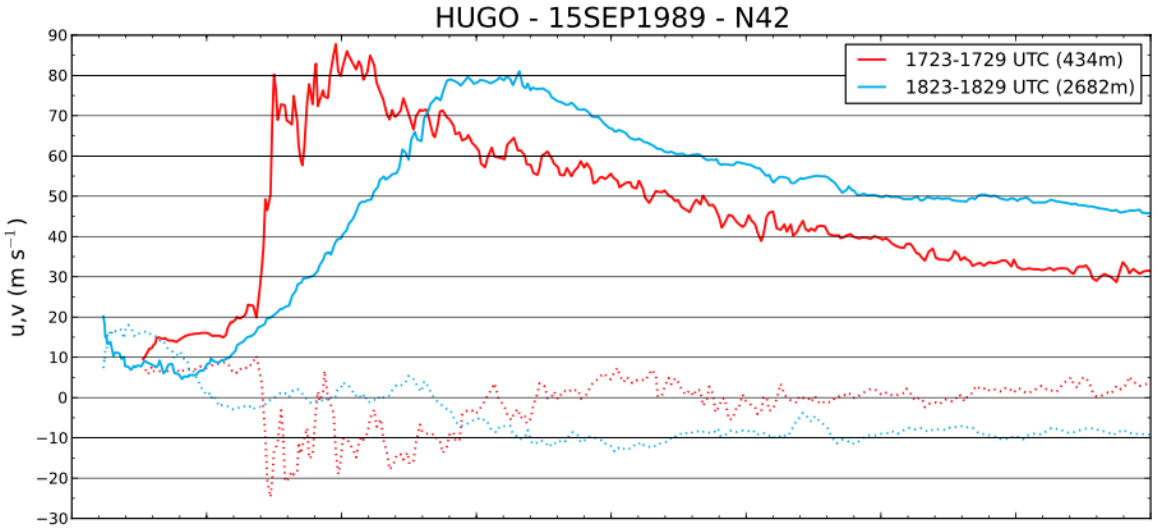
VIIRS IR 17:45 UTC 1 Oct 2015

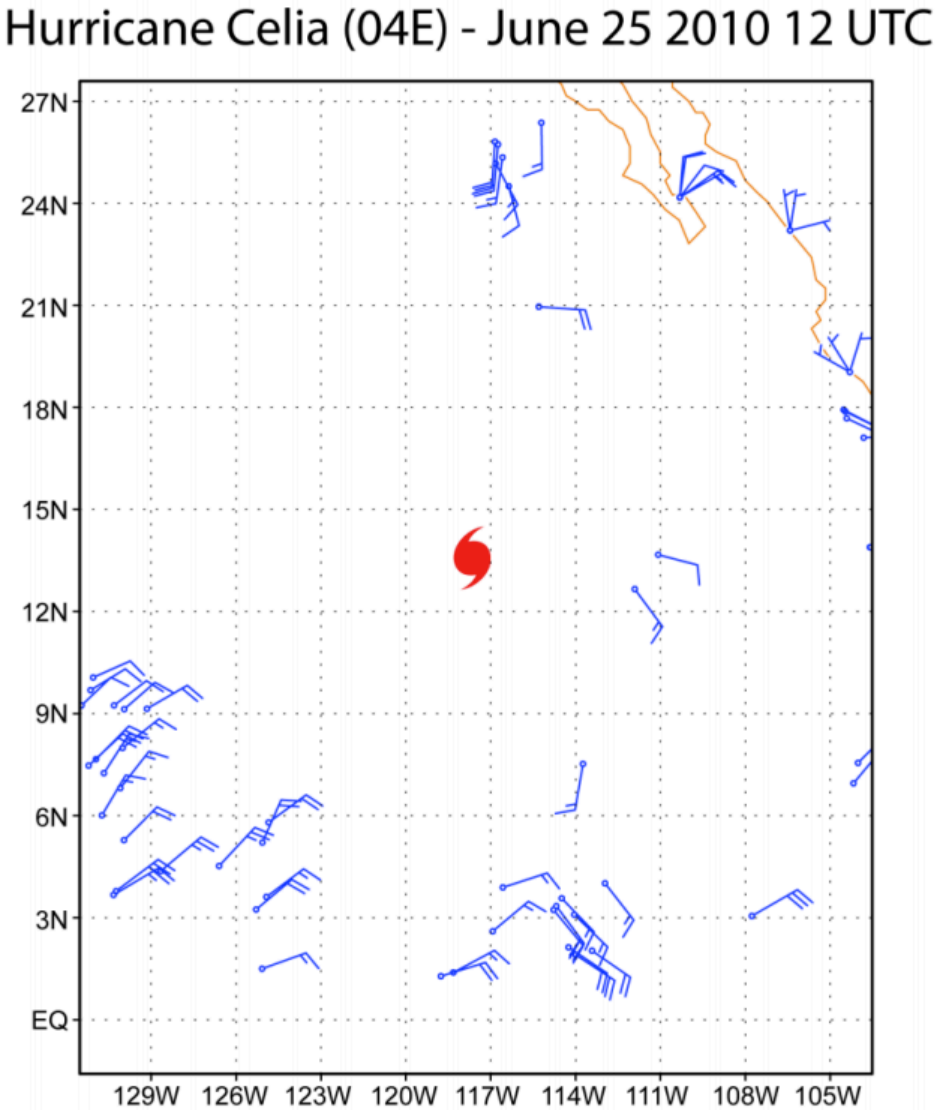


CIRA model environment diagnostics from 00:00 UTC 2 Oct 2015

How can you validate hurricane models?

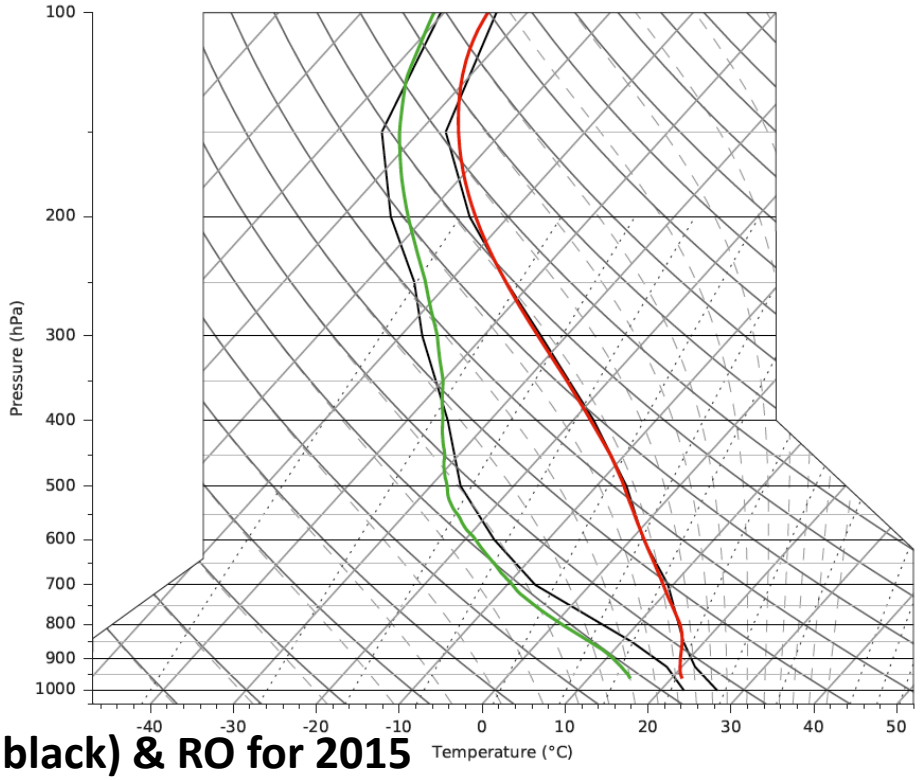
- Conventional observations
  - Aircraft reconnaissance
  - Surface stations
  - Buoys
  - Ships
  - Rawinsondes



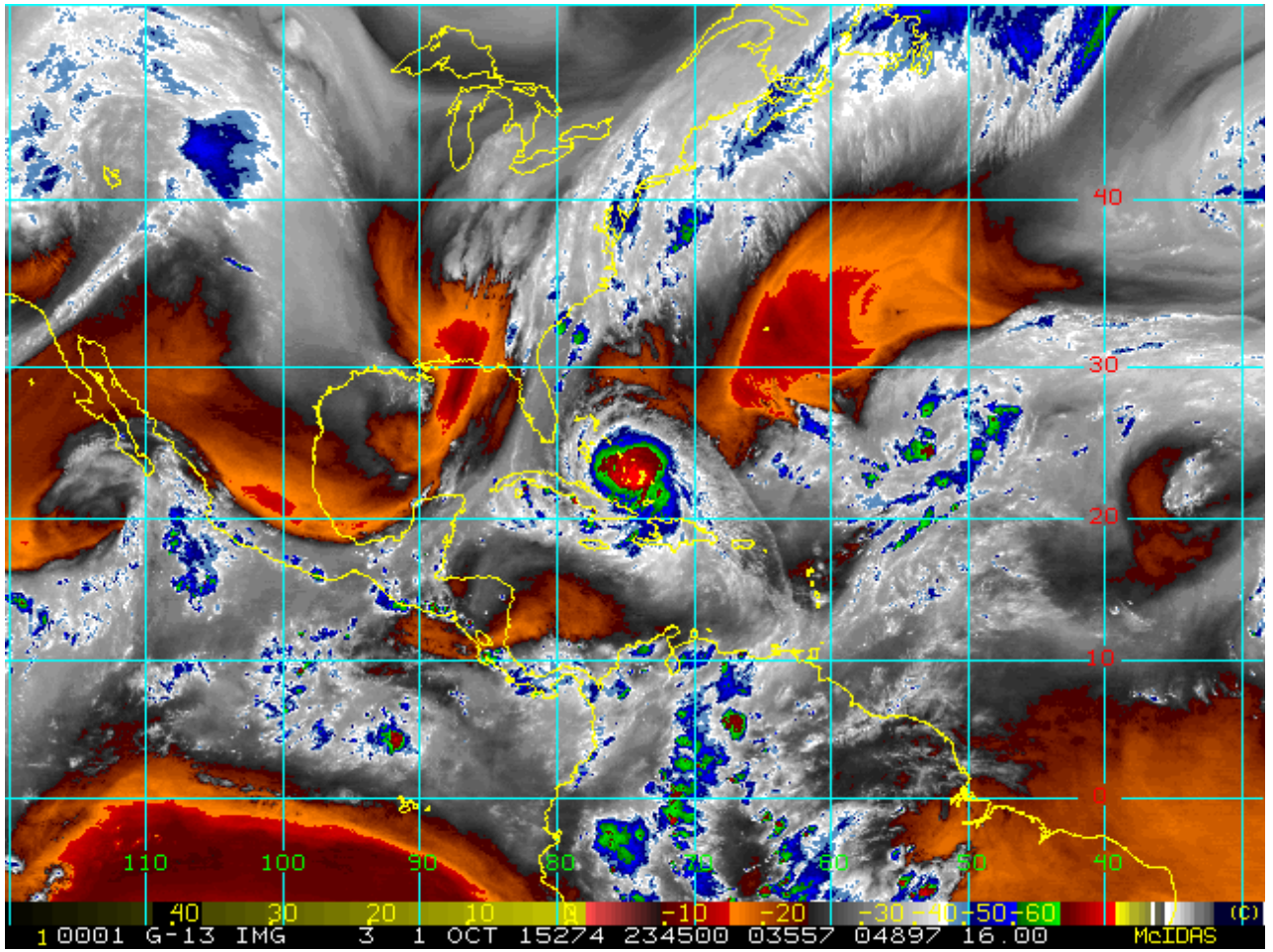


How can you validate hurricane models?

- Satellite
  - Geostationary
  - Radio occultation
  - Polar orbiting



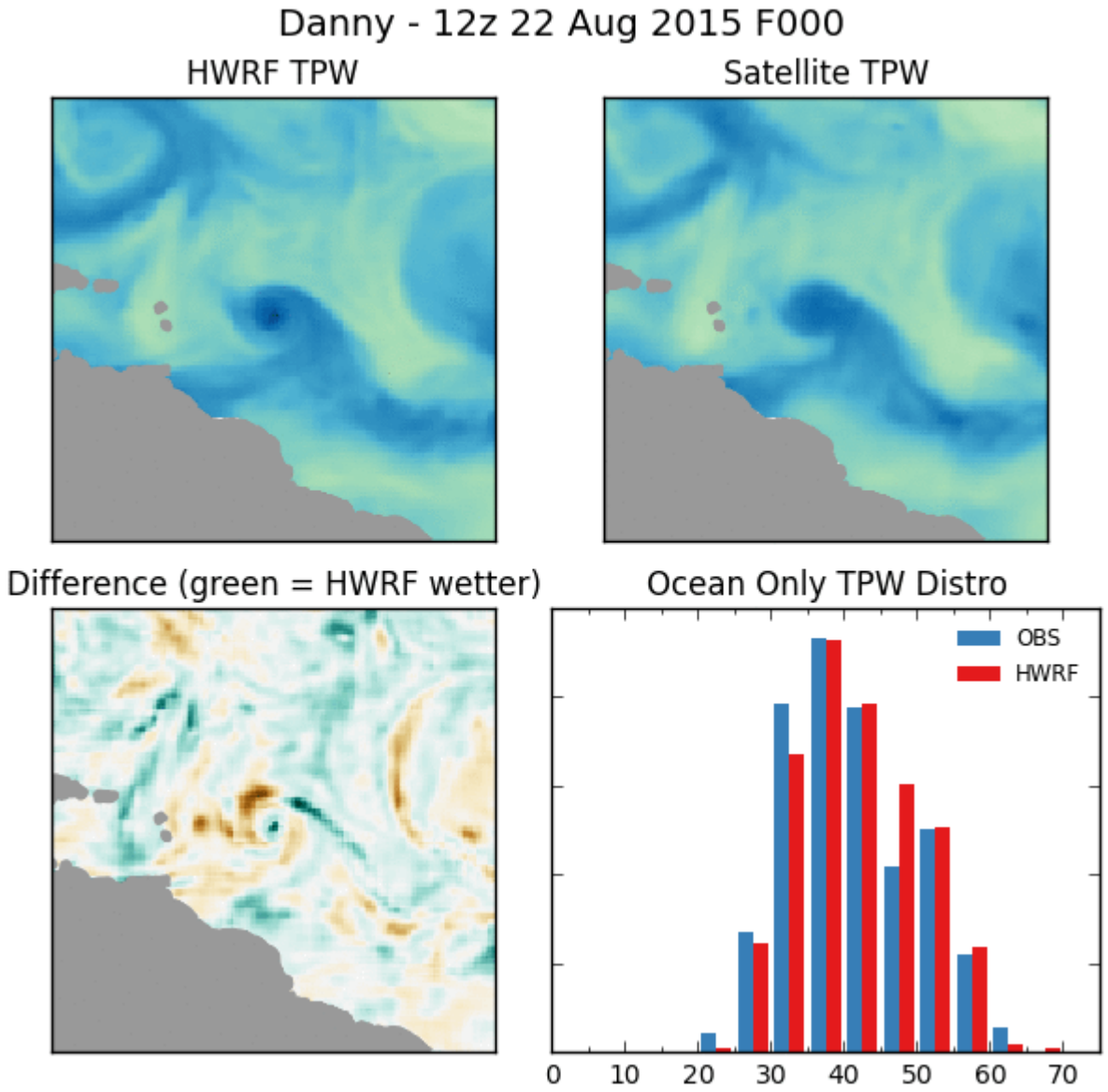
HWRF (black) & RO for 2015



Water vapor 00z 2 Oct 2015

Evaluating model precipitable water

- Precipitable water is an integrated quantity
- Weighted to the bottom of the atmosphere
- Directly output by numerical models
- Available from polar orbiting satellite retrievals



Comparison and difference plots and normalized histograms for each forecast.

Mean Square Error Skill Score with Climatological Reference

- MAE and bias do not provide insight into the divergence in observations and forecast
- Correlation is unbiased by construct but forecasts are not
- Adding climatology tames spurious skill given to a forecast predicting climatology

Phase association:

- Measure of forecast feature location, shape, and relative magnitude

Conditional bias:

- Amplitude error

Unconditional bias:

- Map error (bias)

$$SS_{clim} \approx r_{y'o'}^2 - \left[r_{y'o'} - \frac{s_{y'}}{s_{o'}}\right]^2 - \left[\frac{\bar{y'} - \bar{o'}}{s_{o'}}\right]^2$$

Phase

Conditional Bias

Unconditional Bias

y = forecast
o = *observation*
s = std dev
[ ]' = [ ] - clim

MSE SS: **1 = perfect**; **0 = no skill**; → – ∞

•Livezey, R. E., 1995a. Field intercomparison. In: H. von Storch and A. Navarra, eds., Analysis of Climate Variability. Springer, 159-176.
•Livezey, R. E., 1995b. The evaluation of forecasts. In: H. von Storch and A. Navarra, eds., Analysis of Climate Variability. Springer, 159-176.
•Murphy, A. H., and E. S. Epstein, 1989: Skill Scores and Correlation Coefficients in Model Verification. Mon. Wea. Rev., 117, 572–582.
•Wilks, D.S., 2011. Statistical Methods in the Atmospheric Sciences, 563-582.

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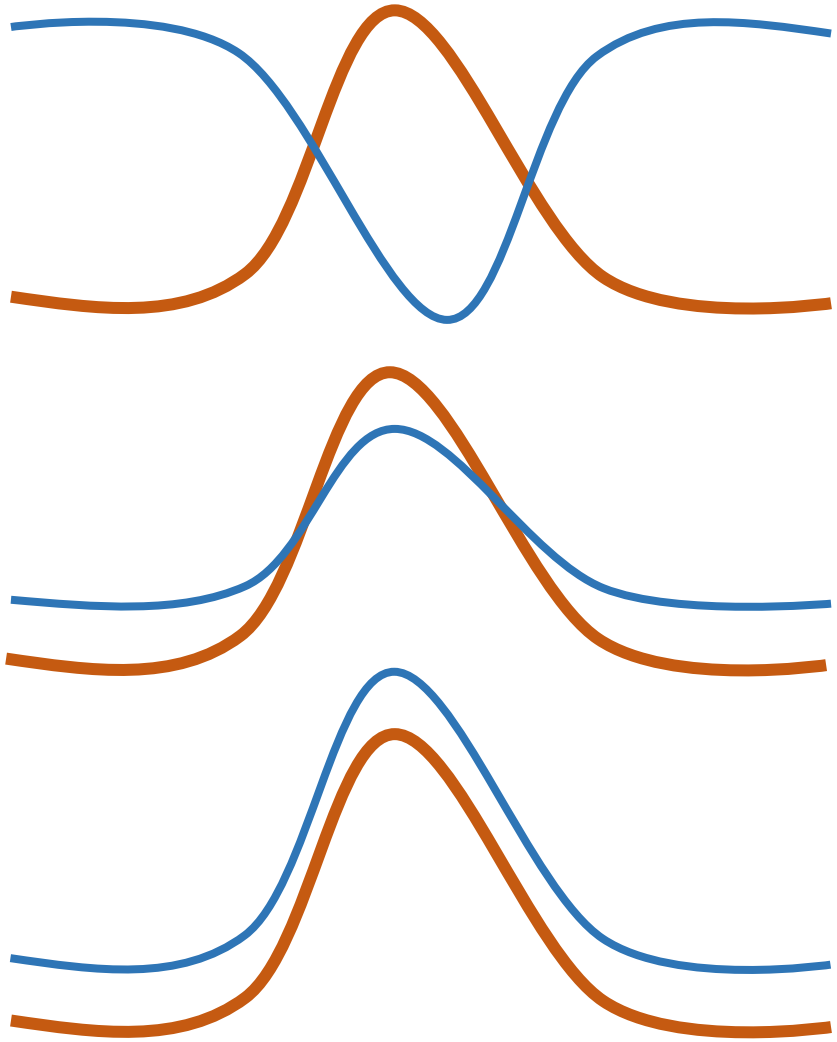


Observations Forecast

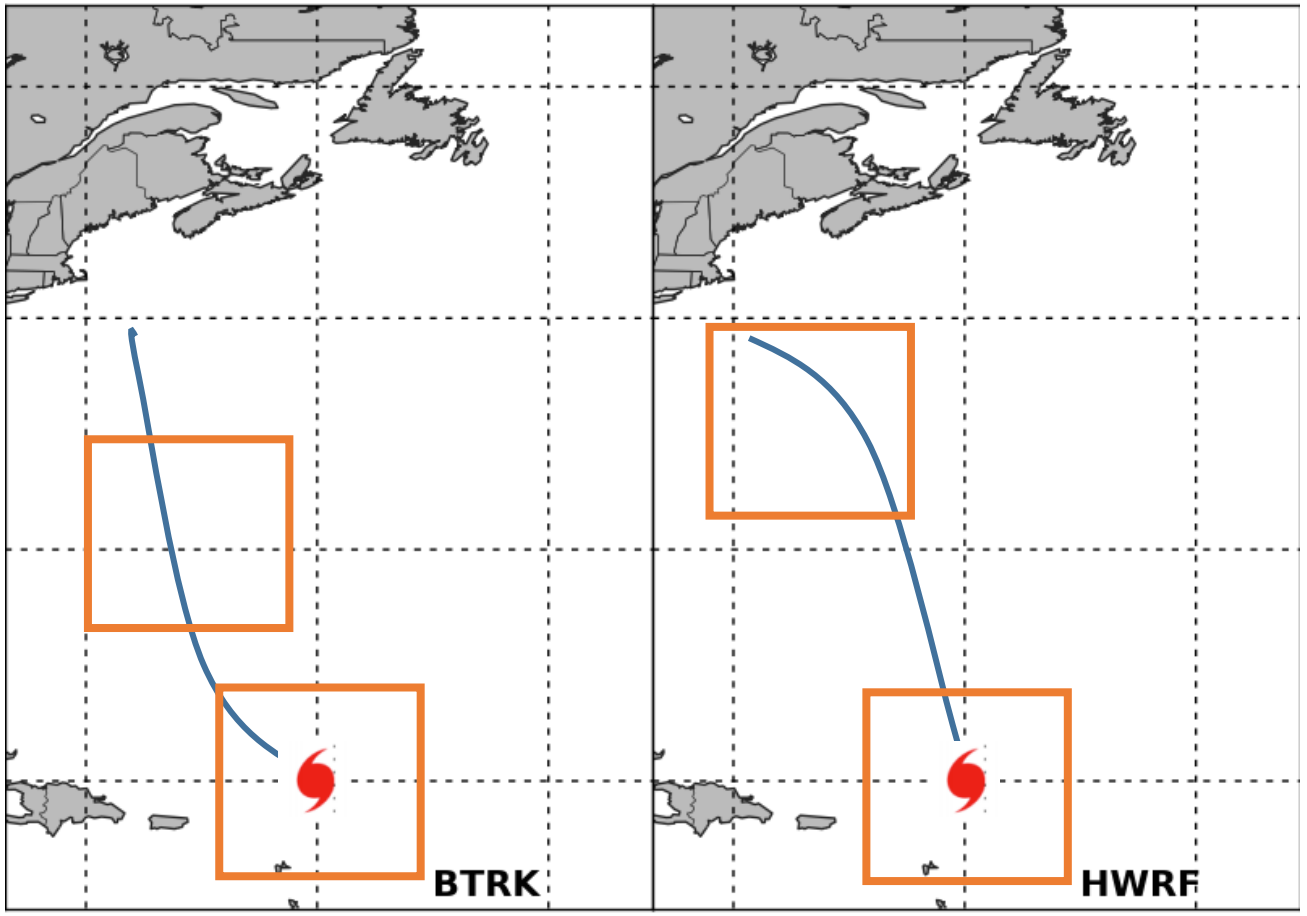
Applying MSE SS to hurricane models

Data:

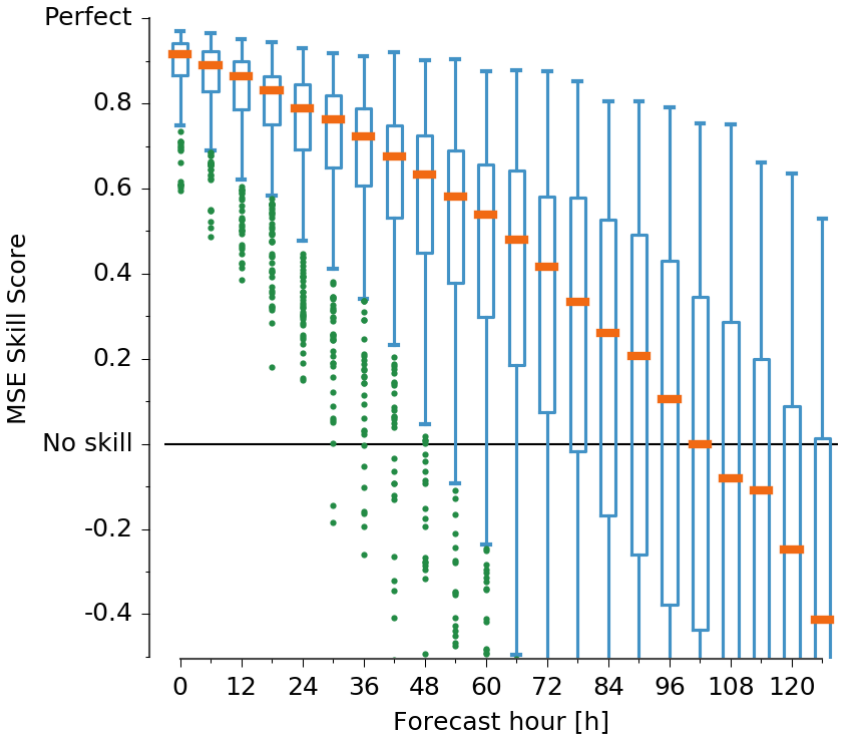
- Hurricane Weather Research & Forecast Model
- NOAA NESDIS operational blended precipitable water product

Analysis:

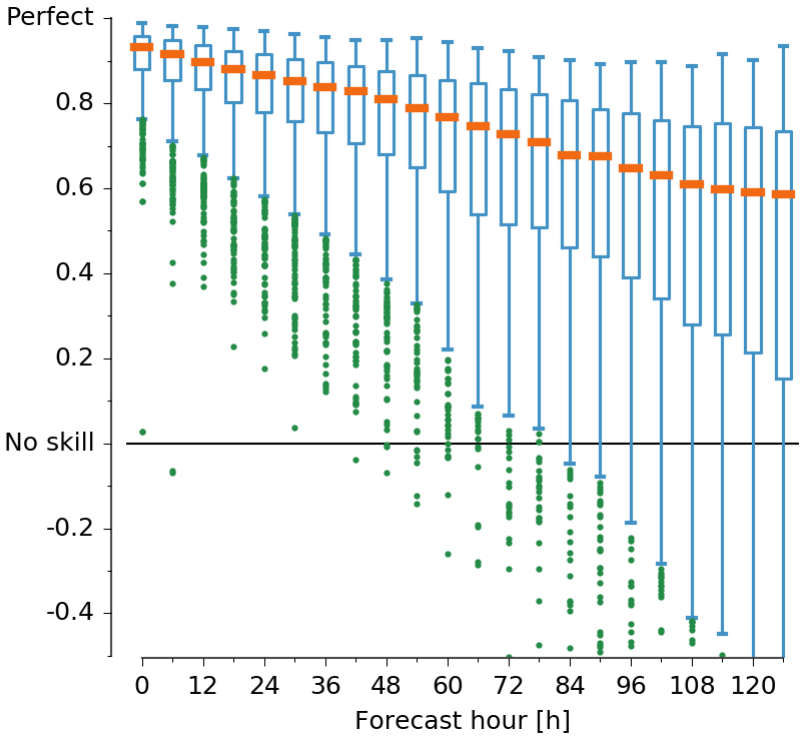
- Re-grid to 0.5 degree
- Synoptic scale - 20°x20°
- Storm scale - 5°x5°
- Centered on NHC best track data



Synoptic MSE SS for 2015 Hurricane Season



Atlantic



E. Pacific

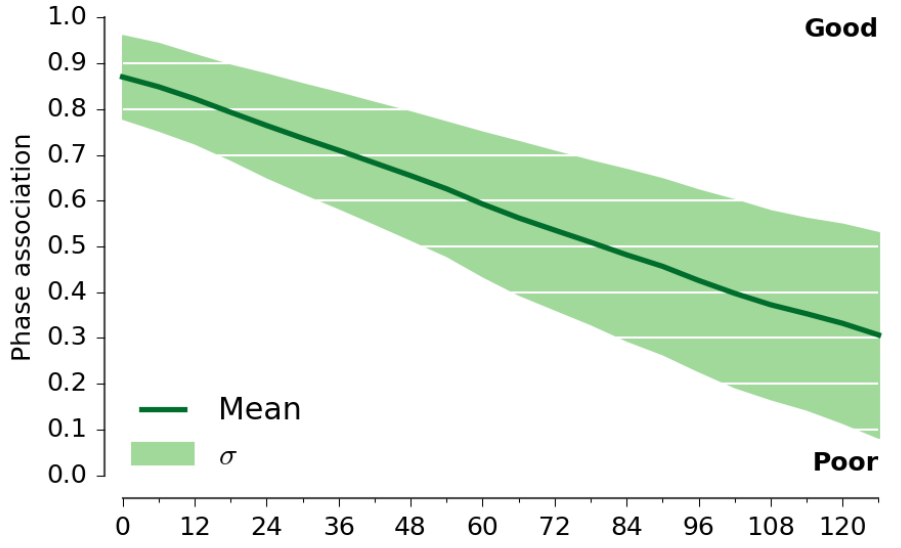
Atlantic:

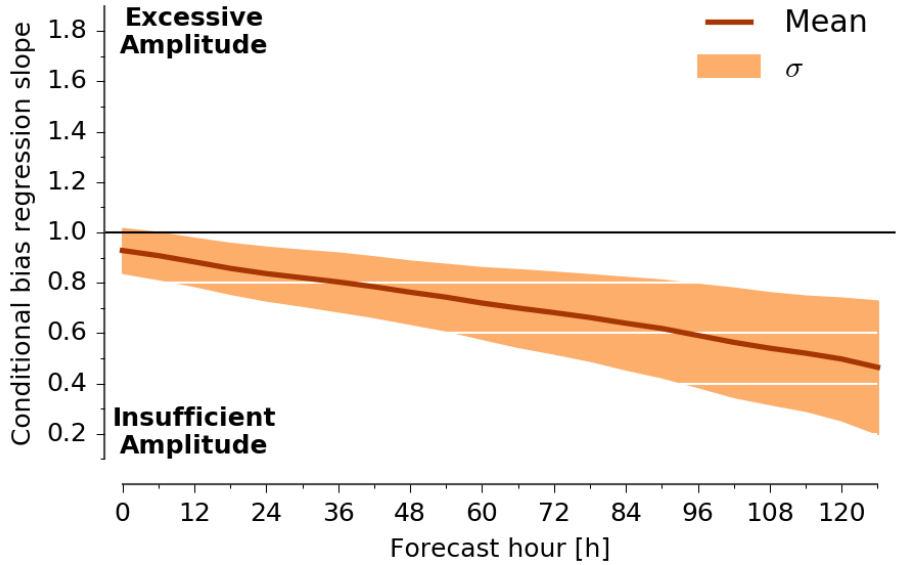
- MSE SS rapidly deteriorates
- By forecast hour 102, Mean MSE SS < 0
- Indication of more land influence and large track forecast deviations

Eastern Pacific:

- Mean MSE SS stays positive
- Less Mid-latitude interference

Synoptic MSE SS for 2015 Hurricane Season





Phase association:

- Drops over forecast period indicating shape, location, relative magnitude differences
- Mostly related to track errors

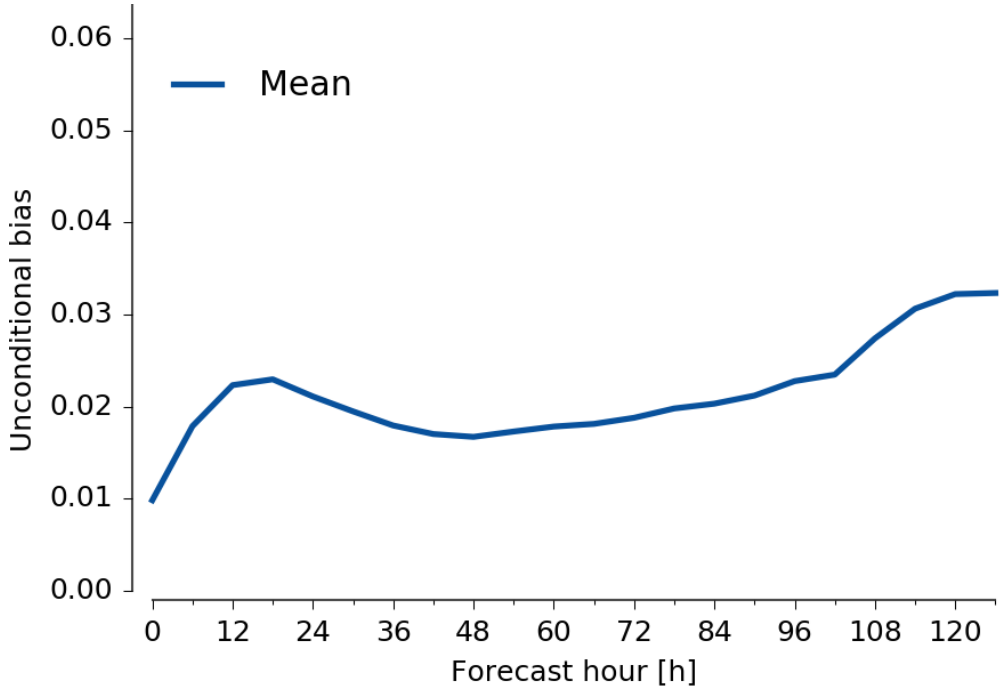
Conditional Bias:

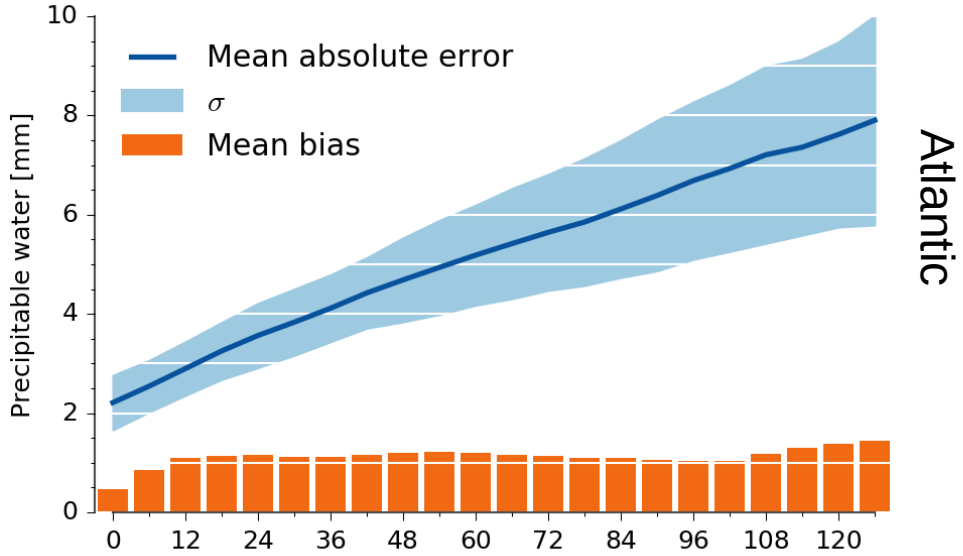
- Insufficient amplitude in HWRF
- Persistent from hour 0

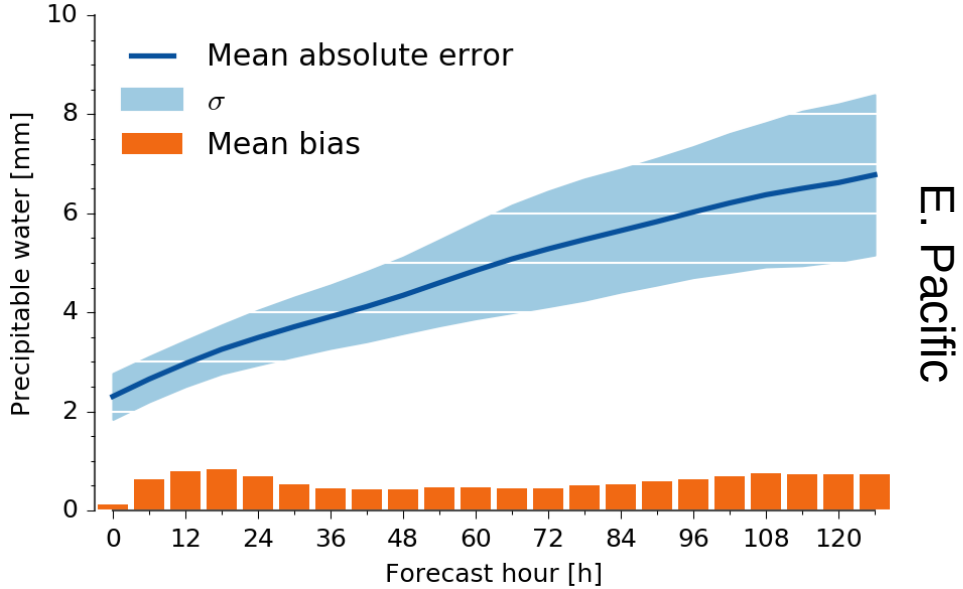
Synoptic MSE SS for 2015 Hurricane Season

Unconditional Bias:

- Small contribution to the skill score
- Relatively constant positive bias
- Bias ramps up during first 18 hours







Storm scale error applications

6 hr intensity error:

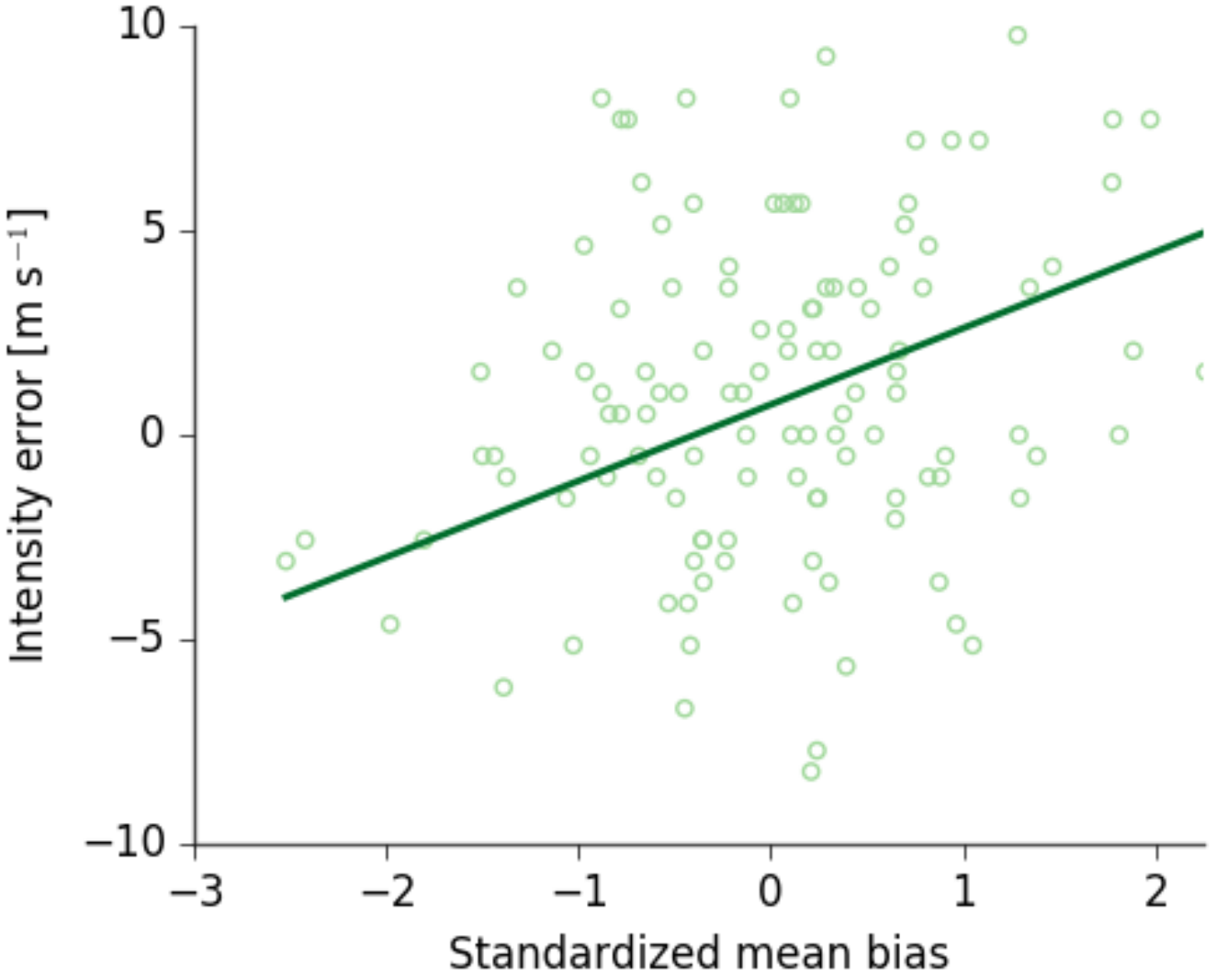
- Storm scale has strongest link to intensity error
- Track errors related to synoptic scale
- Can provide forecasters Information about quality of forecast

Skill score:

- Tells you error, but not sign
- Less physical
- more of a signal

Mean bias:

- Sign included and has
- More physical



Conclusions & future work

- Skill score provides insight to the type of error
- Amplitude errors exist and persist in forecast fields
- Bias ramps up in first 18 hrs
- Bias not largest error but has the most application
- Calculated MSE SS with CIRA layered water vapor product
  - Applications to intensity error (500-700 hPa)
  - Avoids issues surrounding surface emissivity for land & ocean
- Use radio occultations & Caribbean rawinsondes to evaluate boundary layer depth as a source of ~1 mm moisture bias
  - Limited spatial & temporal coverage
  - Provides vertical structure of moisture
- Split track error to along & cross track error