
CHENIERE ENERGY, INC.

Improving Forecasts: Fostering an Enterprise-Wide Dialogue on the Best Path Forward

99th American Meteorological Society Annual Meeting

January 8, 2019



Where can we go from here?

From the perspective of an operational forecaster

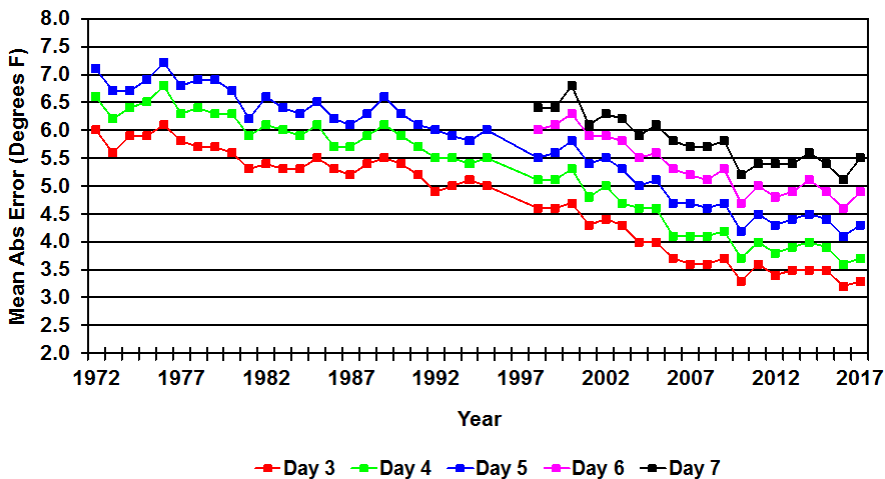
- Great progress made in reducing forecast error across all kinds of meteorological events.
- But societal impacts from forecasts with razor thin margins of error are still problematic.
- We've extinguished the bulk of the fire (forecast error), but can we now take the leap to put out the hotspots? (nagging errors that have socioeconomic impacts)
- Agenda
 - Success!
 - Tropics: Challenges remain
 - Winter storms: Riding the gradient
 - Rainfall (Harvey)

Success!

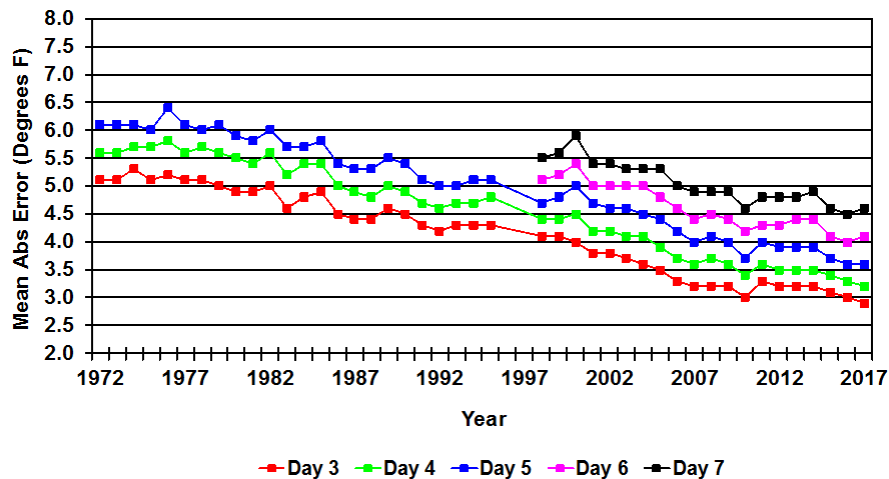
Forecasters getting better

- Using the National Weather Service (NWS) Weather Prediction Center (WPC) outlooks you can see steady, consistent improvements over time.
- A day 7 temperature forecast today has MAE that roughly matched those on day 3 in the late-80s.

Annual WPC Mean Absolute Errors
Maximum Temperatures



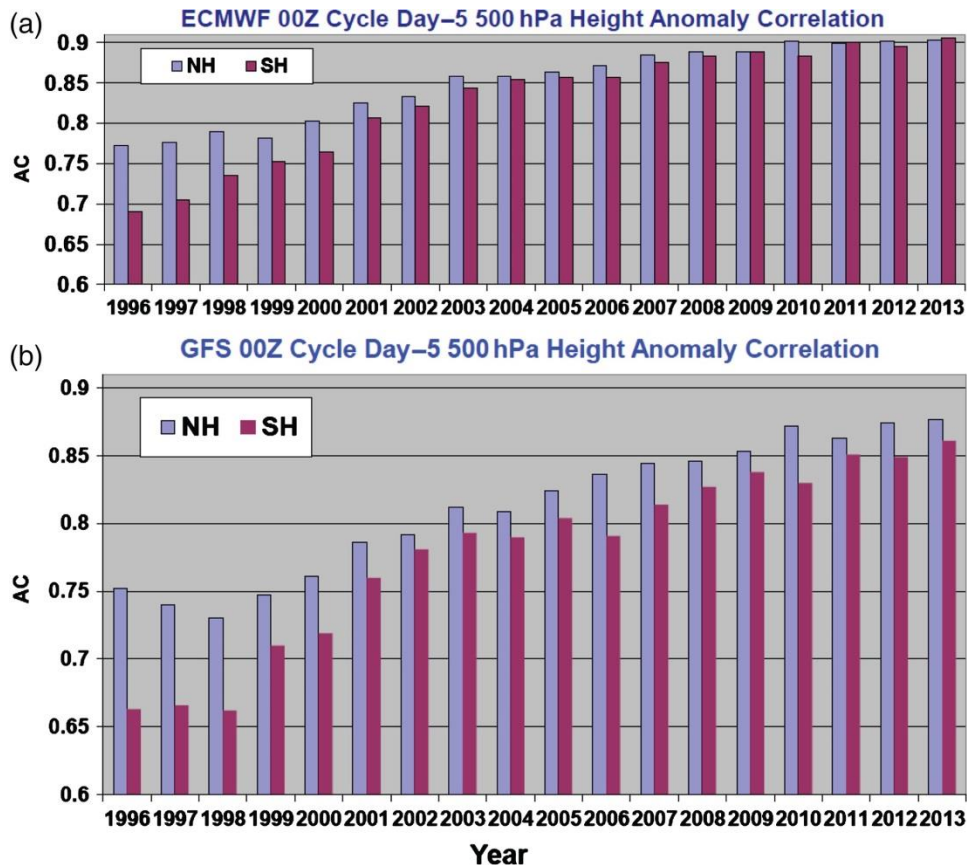
Annual WPC Mean Absolute Errors
Minimum Temperatures



Success!

Models getting better

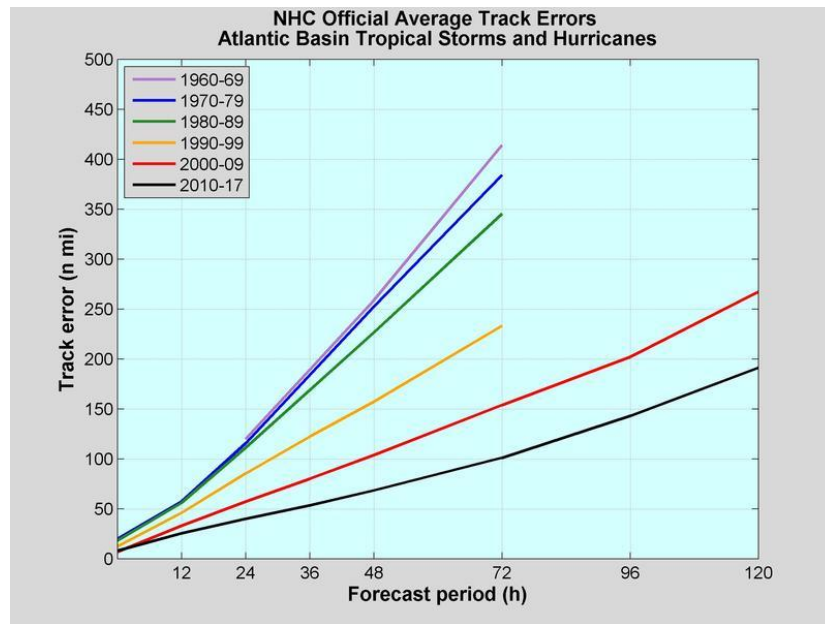
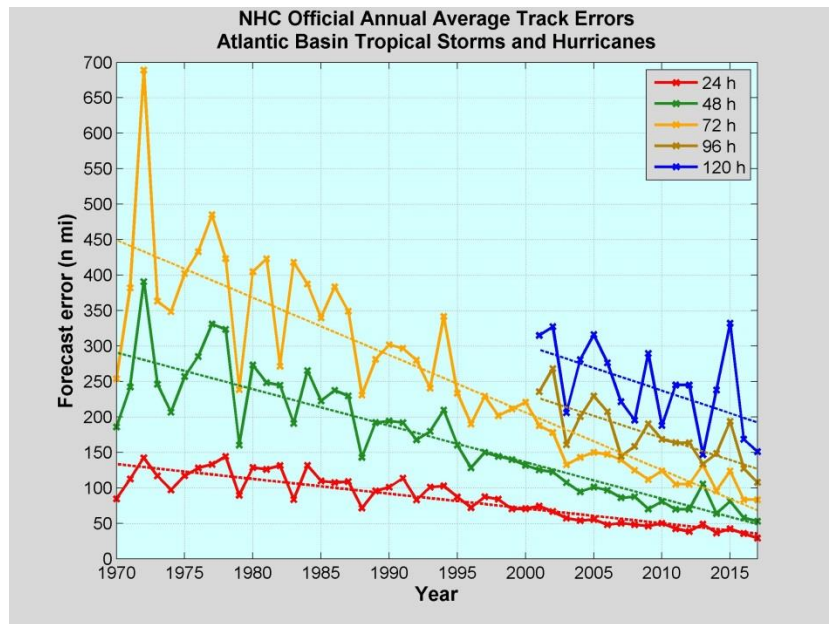
- 500 hPa height anomaly correlations show steady, consistent improvement over time also.
- Example at right shows day 5, but similar improvements also occurring at longer lead times too.
- Trends are positive in both ECMWF modeling, as well as the GFS model.
- We should appreciate:
 - Models are getting better.
 - Forecasters are getting better.
- We're living in a true golden age of weather prediction.



Tropics: Challenges Remain

First: Improvements have been substantial

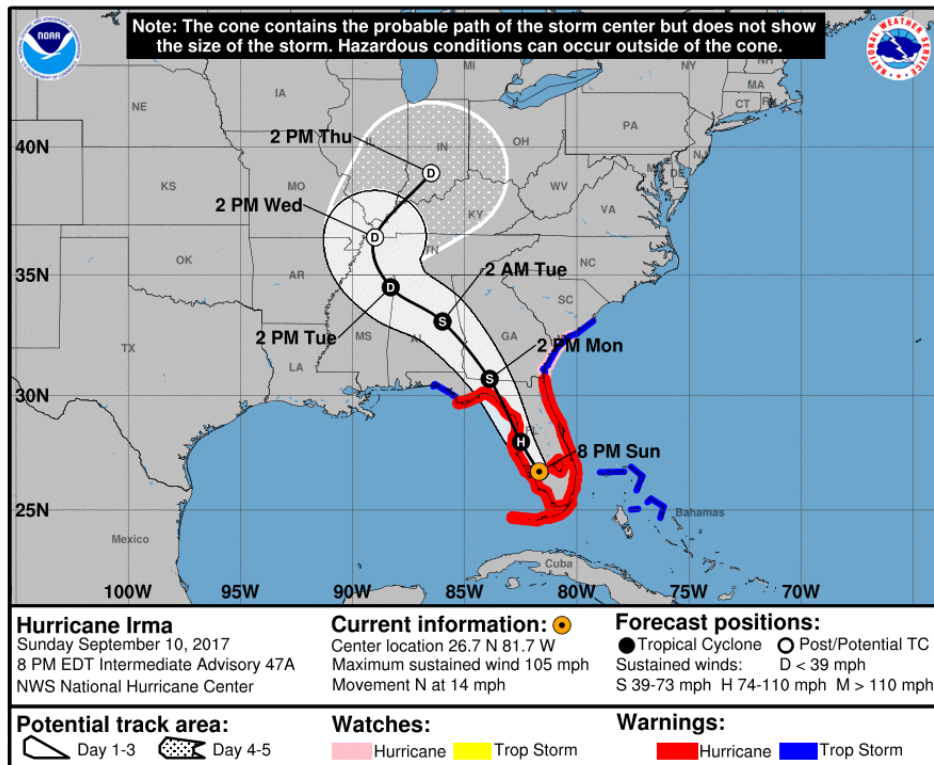
- Forecasts of tropical systems have shown similar improvements to other meteorological variables.
- National Hurricane Center (NHC) average day 5 track error is roughly equal to what day 2 track error was in the mid-to late-80s.



Hurricane Irma

Small errors can still have huge impacts

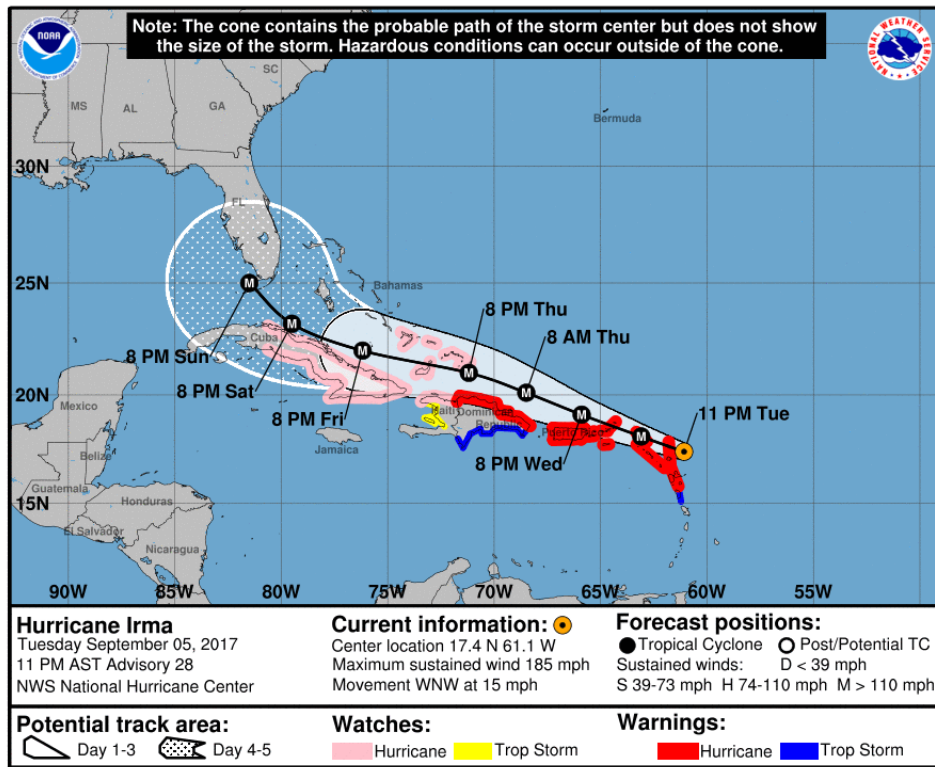
- 6.8 million residents, including 75% of the Florida Keys evacuated.
- Post-Irma survey finds 25% of South Florida residents will not evacuate ahead of a category 3 or 4 hurricane.
- It cost 60% of Irma evacuees more than \$300 to evacuate, 40% more than \$500.
- NHC 5 day track forecast for Irma's approach to Florida was nearly perfect.
- But what happened between then and landfall was tricky.



Sources: <https://www.nhc.noaa.gov/archive/2017/al11/> (NHC image), survey results from FAIR Foundation via: <http://weatherplus.blog.palmbeachpost.com/2018/09/11/hurricane-irma-6-8-million-evacuated-survey-finds-many-wont-next-time/>

Hurricane Irma

Five days of NHC cones: A pretty good forecast, but timing the turn...



Source: <https://www.nhc.noaa.gov/archive/2017/al11/> (NHC)

Hurricane Irma

Weather models struggled to time that turn

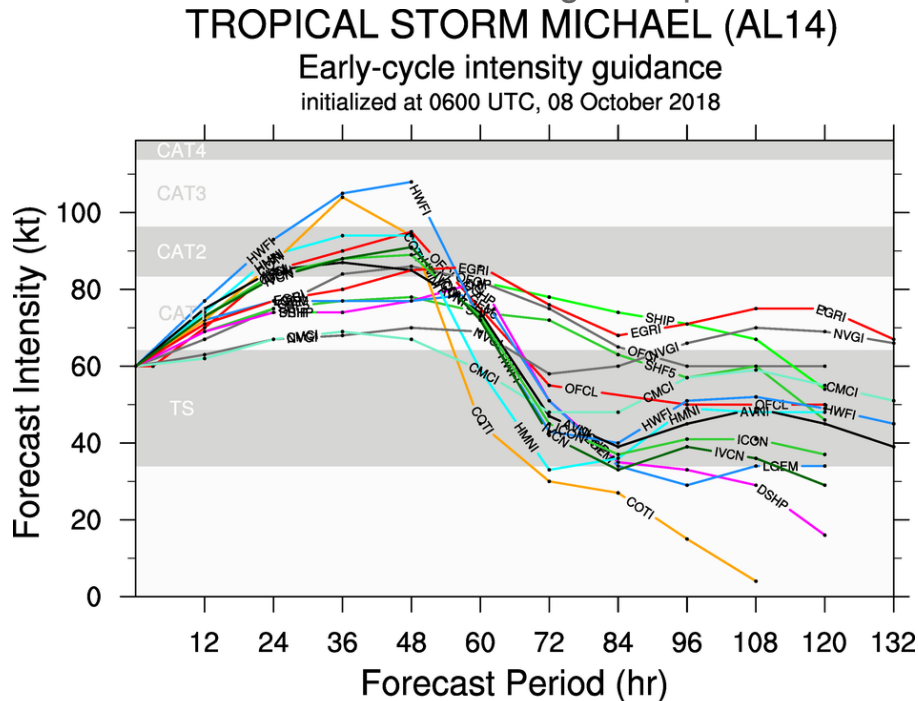
- Weather model forecasts between 1800 UTC on September 5th and 1800 UTC on September 9th kept the entire peninsula under risks.
- Also evidenced by the NHC cone.
- In model speak, a 50-100 mile 5 day forecast track error for a tropical system is a pretty good forecast...
- ...but when 10+ million people are in the way of varying possible impacts, the stakes are much, much higher.



Hurricane Michael

Weather models struggled with intensity

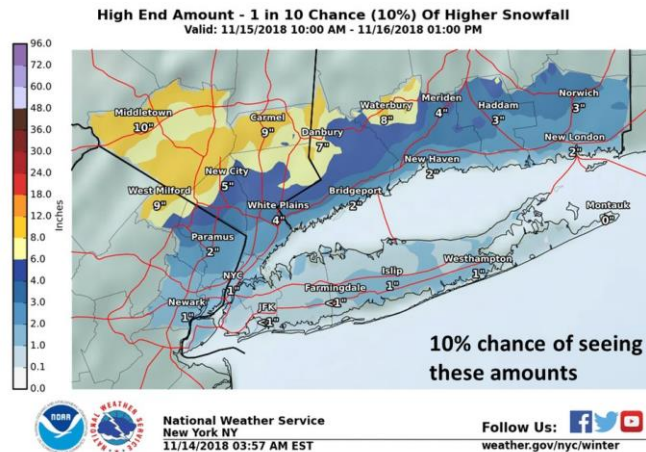
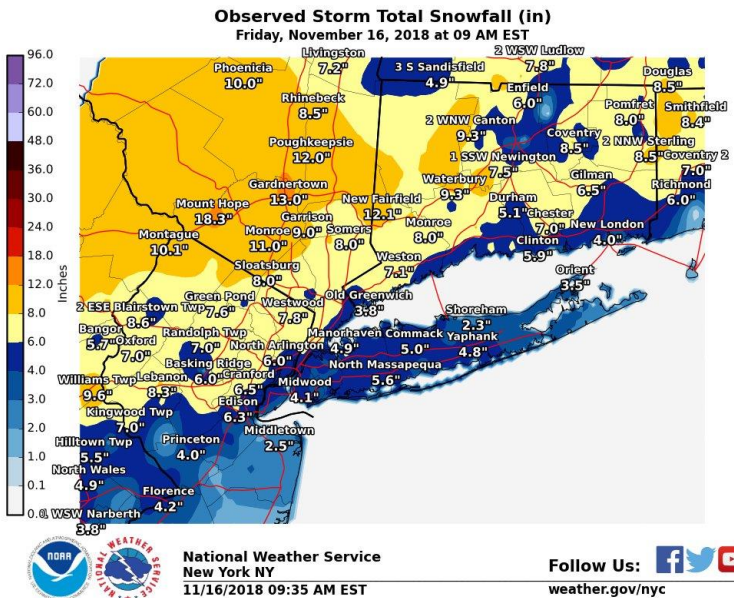
- Model data just about 48 hours before Hurricane Michael's landfall showed the strongest tropical model per UCAR selection of model output maxing out at around 105 kts. Consensus was less, around 85-90 kts. or so.
- NHC emphasized risks for potential rapid intensification and a stronger outcome than forecast on Monday morning.
- But with Michael maxing out around 135 kts. intensity, it's evident all these forecasts missed, in some cases by a substantial amount.
- Can we realistically improve this?



Snowfall Forecasts

Different season, similar challenges

- November 15, 2018 snowstorm in the Mid-Atlantic/Northeast wreaked havoc.
- The *high-end* amount of snow forecast for New York City from NWS was 1" the day before. Over 6" fell.
- Snowfall gradients are often incredibly difficult to pin down.



Snowfall Forecasts

These are not the headlines you're looking for

Meteorologists were caught off guard by NYC snowstorm **NEW YORK POST**

By Natalie O'Neill

November 16, 2018 | 4:30pm

Under fire for snow chaos, Murphy blames 'lousy' forecasts **NEWS 12 NEW JERSEY**



Surprise winter storm cripples North Jersey

- And then this happens...
- Certain weather models may have “nailed” this forecast for one spot (NYC), but they’ve also been wrong before.
- Can we improve weather model consistency to a point where we can have fewer doubts when support for this output exists?
- Or will we ever even get to that point?

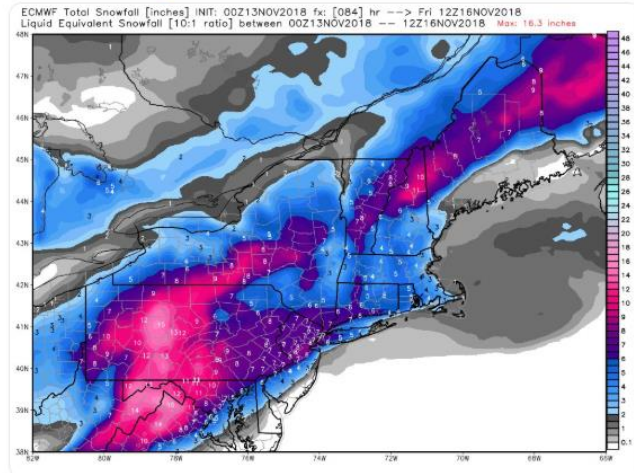
Source: Twitter, various news headlines



Jeff Berardelli
@WeatherProf

Following

Worth noting the European model has been incredibly consistent for days on approx. 6" snow for #NYC. This Image from Mon eve model run. Understandable forecasters had doubts as this breaks ~150 year Nov. record. But evidence was there to raise eye brows. #EuroIsKing #Snowvember

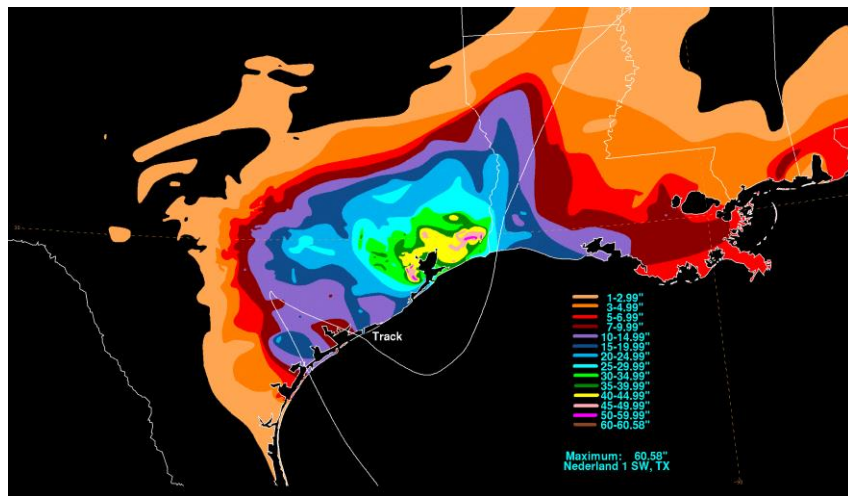
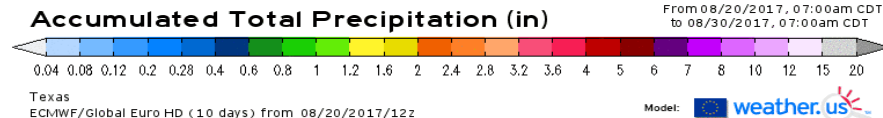
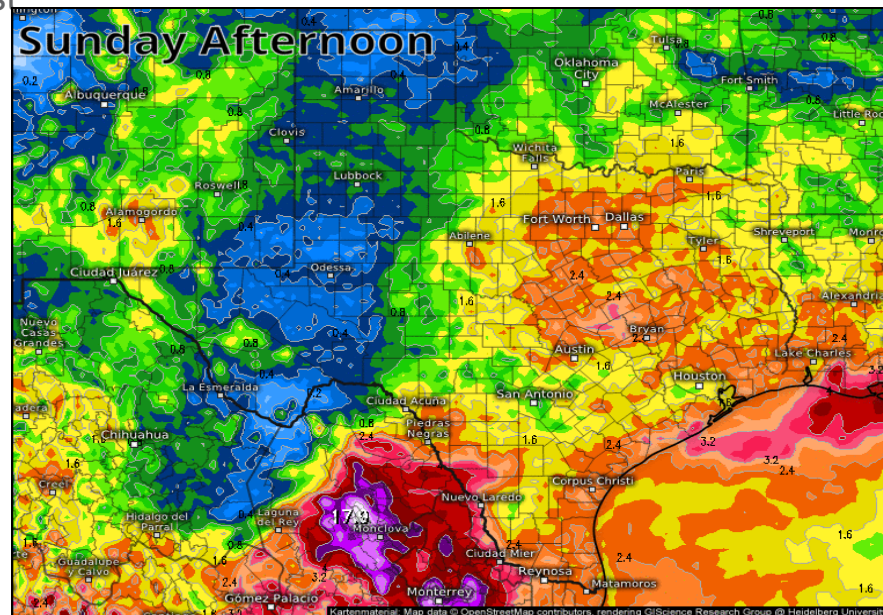


8:40 PM - 15 Nov 2018

QPF Forecasts

Hurricane Harvey

- ECMWF operational model QPF output through August 30th ahead of Hurricane Harvey showed increasingly high rainfall totals, but significant fluctuations in the bullseye's placement.
- Forecast on Friday afternoon showed 50"+ bullseye between Corpus Christi & Victoria.



Source: weather.us

Improving Forecasts

Having a conversation

- Tremendous success in recent decades leads to continued and increased pressure to further and expand those successes.
- We're now fighting trench warfare style battles. We've made great overall improvement, but now we have seemingly minor details that have huge impacts to deal with: A tropical storm track miss by 75 miles over 5 days, a snowstorm that has a gradient of 15-20" over 15-20 miles, a rainfall forecast that misplaces a maxima by 50 miles.
- What can we do to win these battles?
- Being honest: Are they even winnable? Does the public and do operational forecasters expect too much sometimes?
- What can operational forecasters fighting these battles in the trenches every day do to help modelers and researchers and vice versa?
- How do we make this an enterprise-wide discussion rather than keeping everyone trapped in their niches?

Thank you!

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