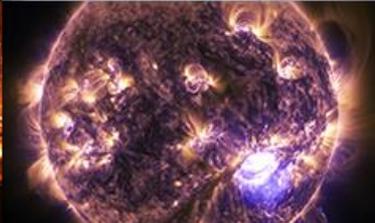
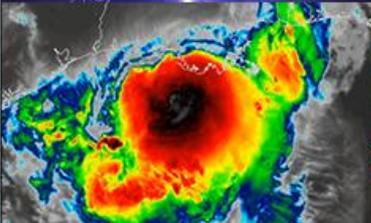
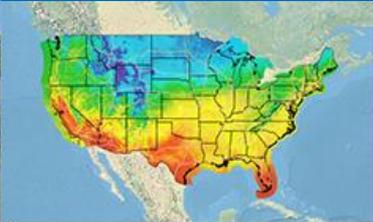




**NATIONAL
WEATHER
SERVICE**

Operational Forecasting of Precipitation: Regional Aspects

**Dr. David Novak
Weather Prediction Center Director**



Bottom Line Up Front



**Must improve accuracy,
think probabilistically, and
invest in all parts of the value chain**

Weather Prediction Center

MISSION: Provide national weather situational awareness and precipitation expertise to enable readiness for hazardous weather



National Weather Situational Awareness

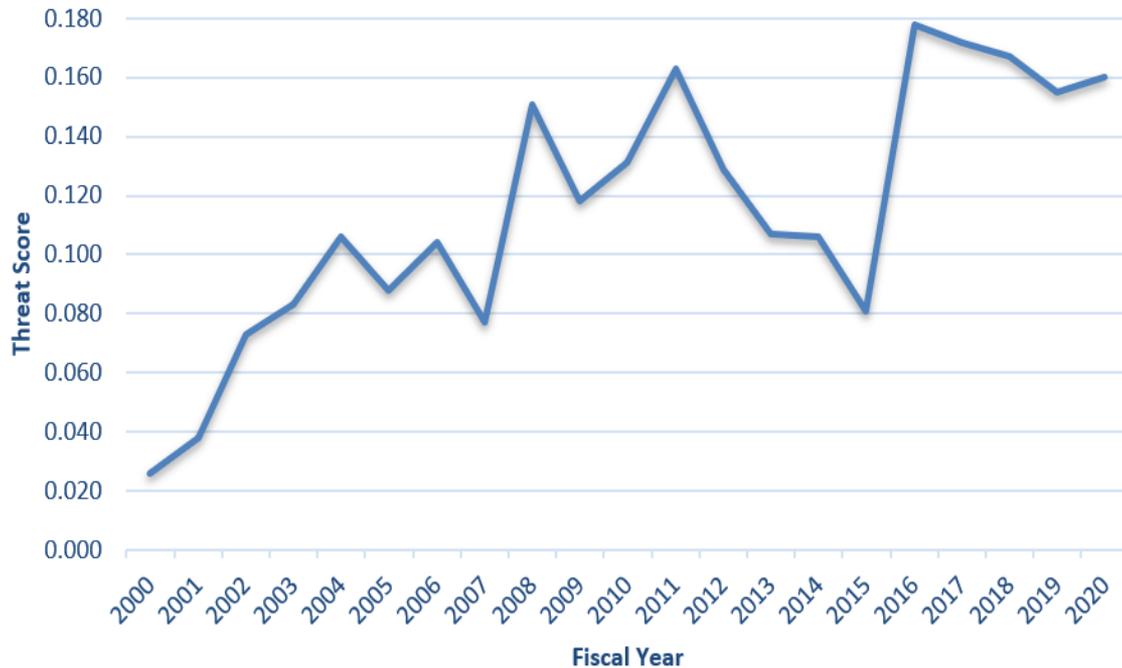
Heavy
Rainfall

Winter
Weather

Upcoming
Hazards

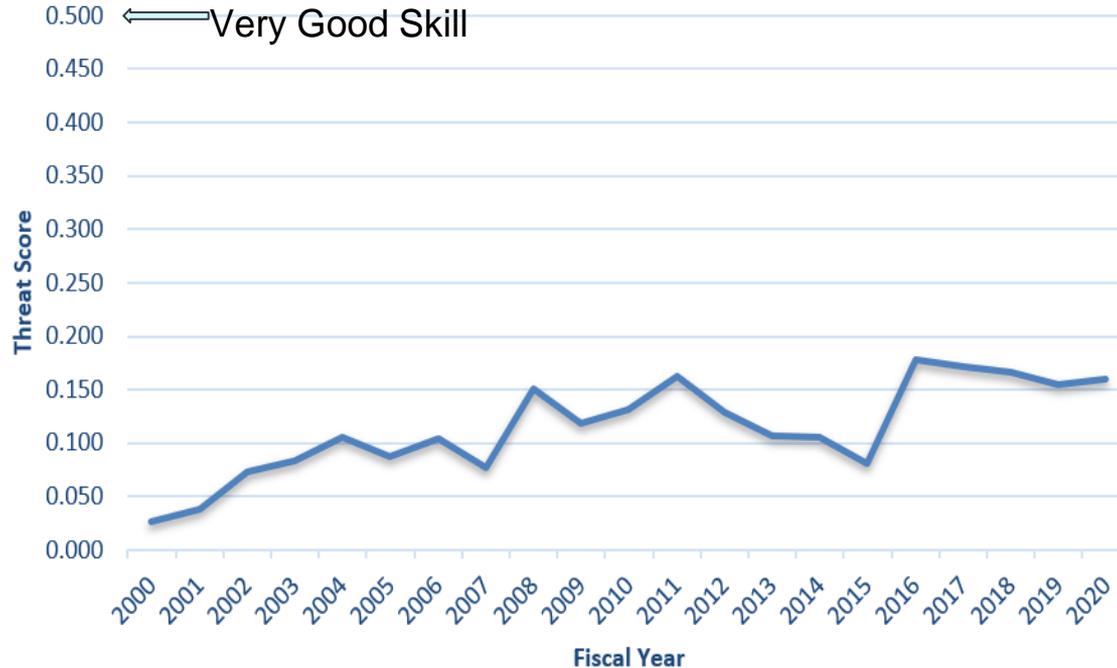
We are slowly getting better...

Skill of Day 3 Forecast for 2" Events

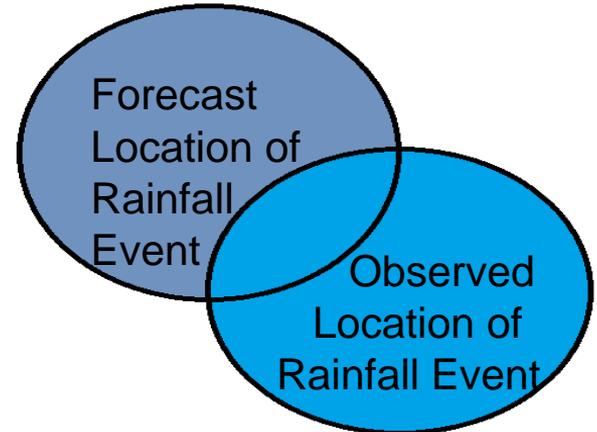


But...it's not that good

Skill of Day 3 Forecast for 2" Events

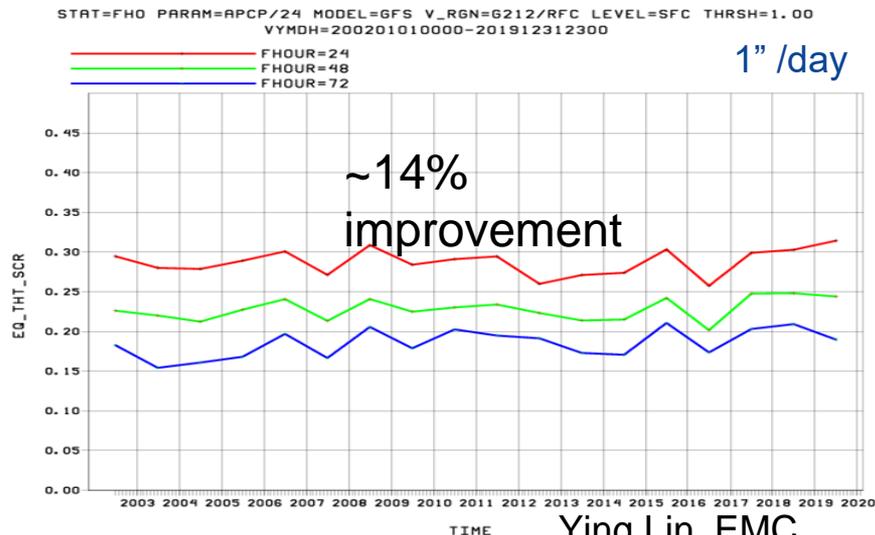
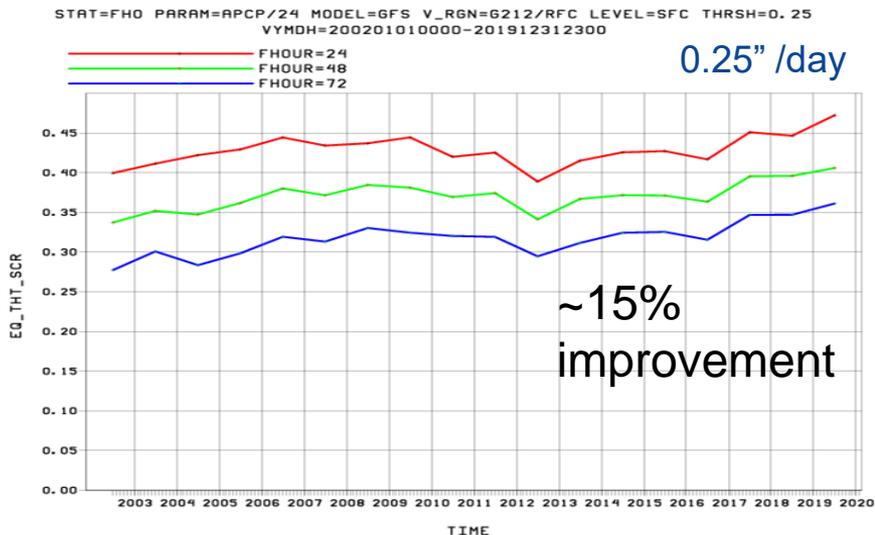


Average skill of heavy rainfall forecast 3 days out



AND...Precipitation Skill is Lagging

Over the past 17 years, the rate of improvement of GFS precipitation skill has **lagged** other phenomena, including Hurricane Track (30-50% improvement) and 500mb Anomaly Correlation (~20%). On par with Hurricane Intensity (~15% improvement).



GFS 24/48/72h annual Fractional Skill Score
2003-2019



Common Global Model Systematic Errors

- Underestimation of heavy rain & overestimation of light rain
- The diurnal cycle of precipitation, with maxima too early in the day
- Initiation of convective precipitation, often due to errors in representation of boundary layer & convective parameterizations
- Slow or non-physical propagation of convection
- Phase speed of mid-latitude troughs
- Sub-seasonal tropical variability (MJO representation)

**These Common Errors can lead to Ensemble Underdispersion
-TOO confident in the WRONG solution**

AND...the needs are tremendous

“Is it going to rain tomorrow?”

“How much is it going to rain tomorrow?”

“Will my city be immobilized?”

“Will my city be immobilized next week?”

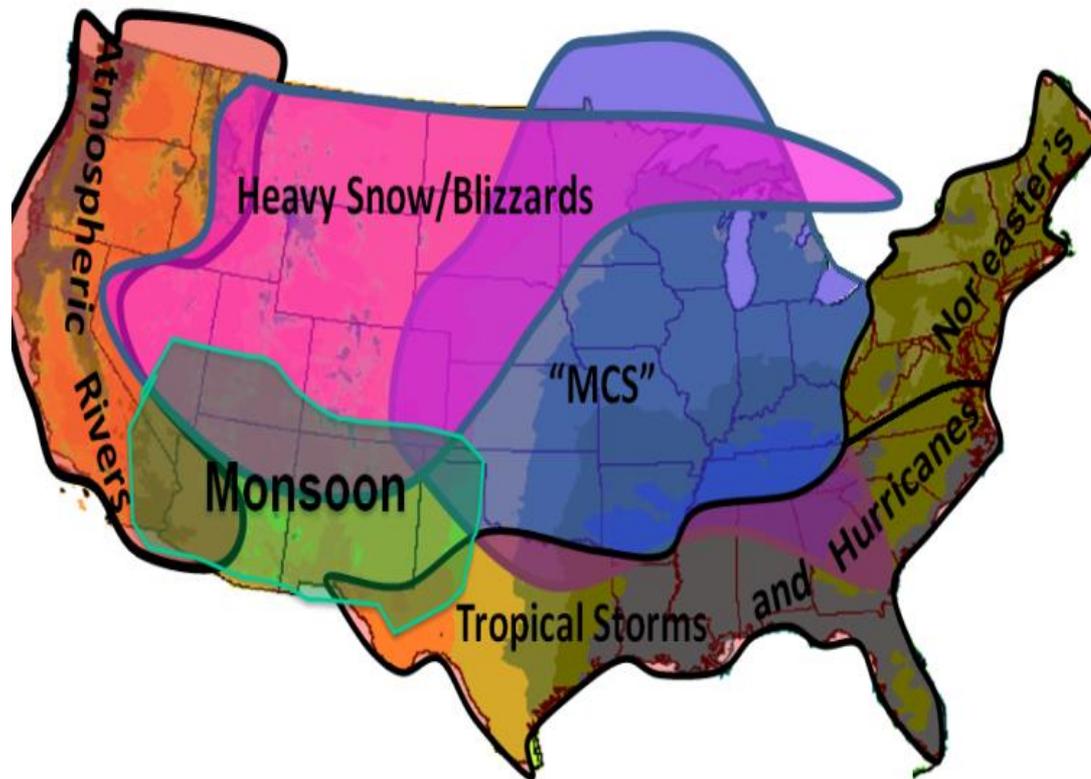
METEOROLOGY TO IMPACTS

More skill

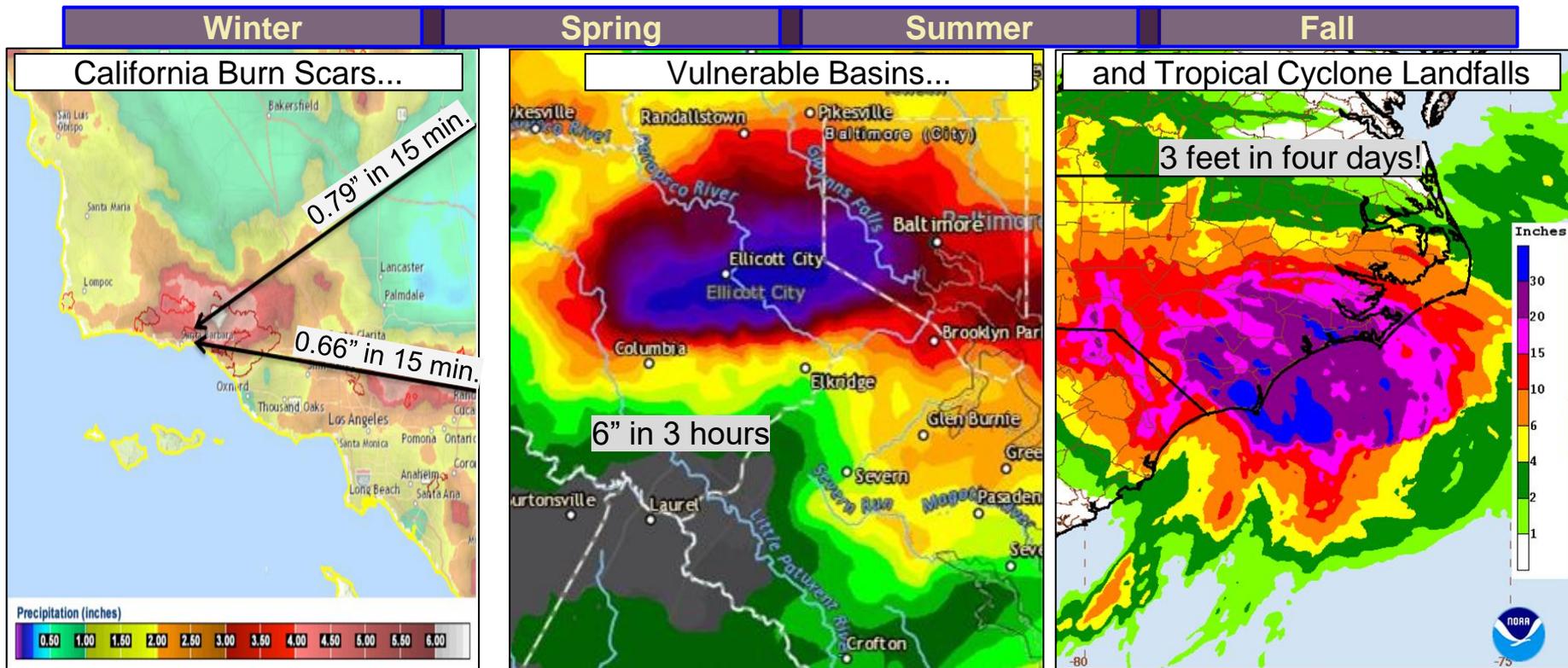
Less Skill



...We Have Various Precipitation Hazards



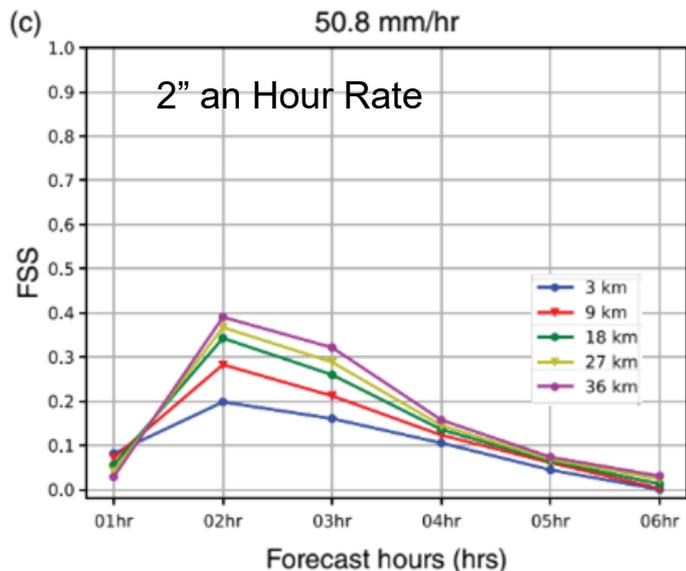
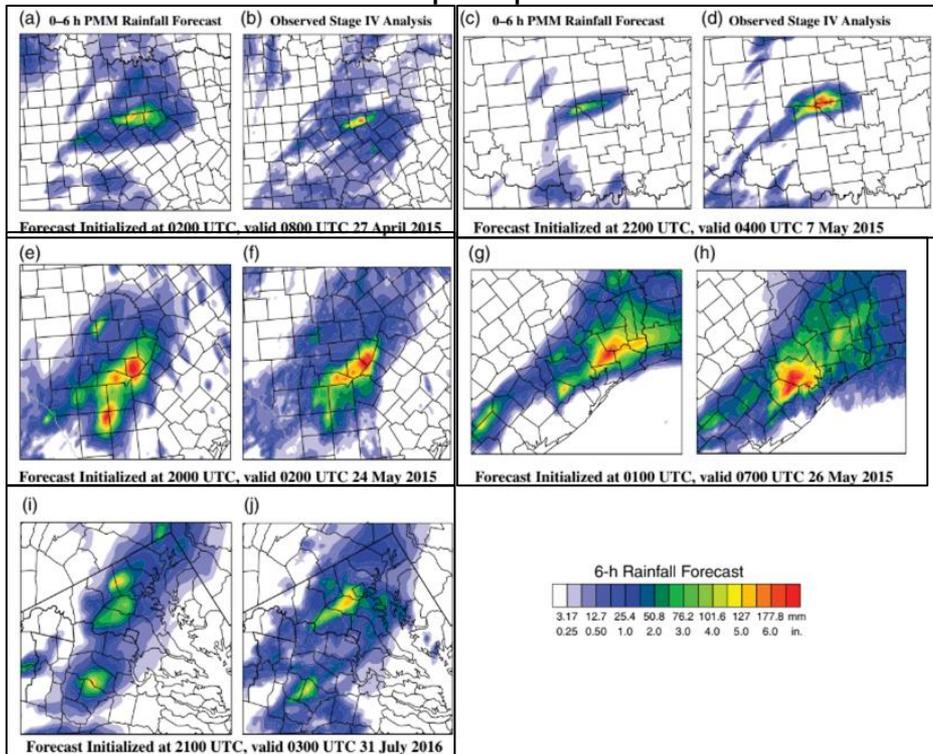
...Occuring on Different Time-scales



The Convection Challenge

State-of-the-art 36 member 3-km ensemble with rapid radar data assimilation run on 5 flash flood cases [Yussouf and Knopfmeier (2019)]

0-6 hour forecast precip & observed



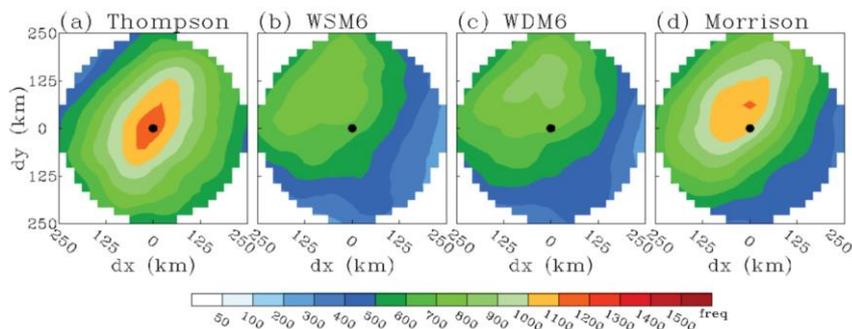
Skill limited to about 3 hours (!)

The Convection Challenge

Displacement Errors over the Central US

CONVECTION-ALLOWING MODELS

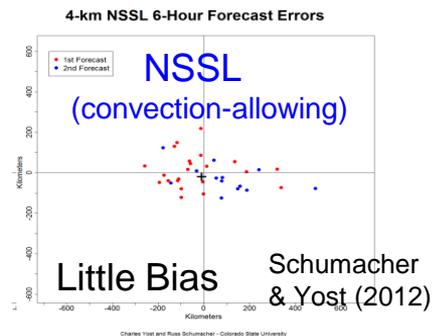
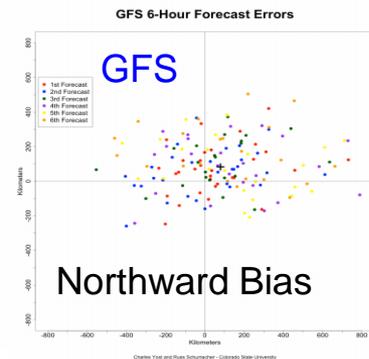
Placement sensitive to Microphysics Scheme



Clark et al. (2010)

GLOBAL MODELS

Placement can be sensitive to Convective Parameterization



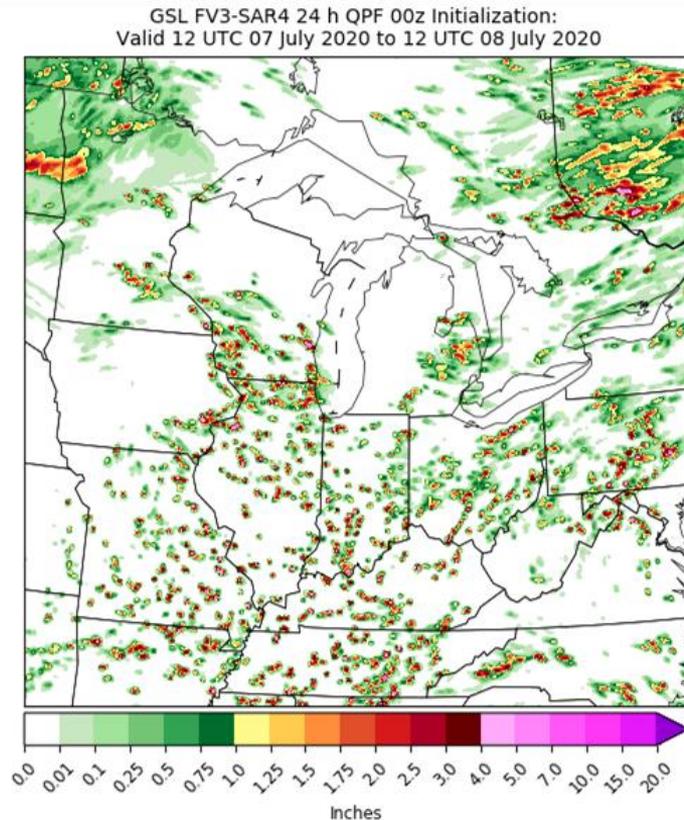
The Convection Challenge

Grid Scale Feedback

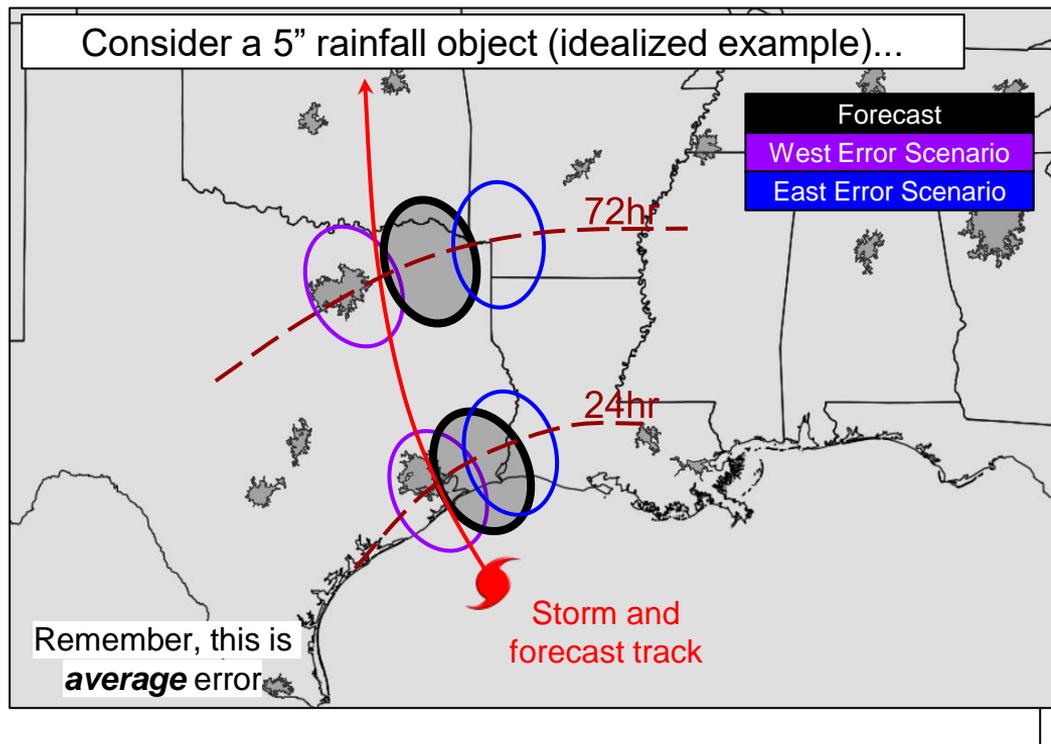
Grid-scale feedback largely solved in Global operational modeling systems through improved parameterizations.

However, problem reappearing in ongoing testing of FV3 at convection-allowing scales (right)

Example of the continuous challenge of convection



The Tropical Cyclone Rainfall Challenge

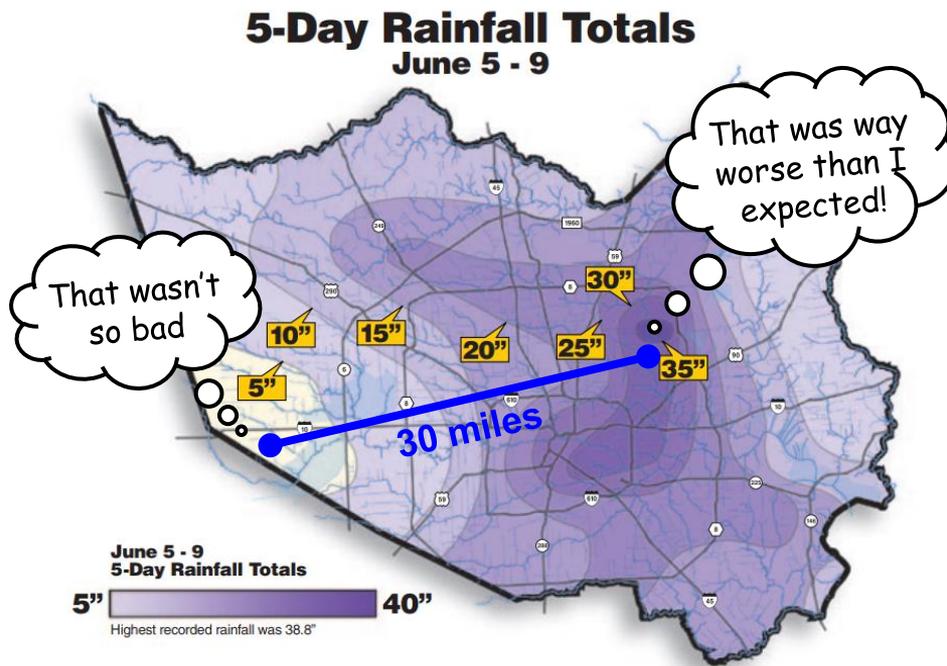


How far off are we with placement of higher amounts?

For 17 recent landfalling tropical events (2016-2020), we evaluated the offset between the centroid of our QPF “objects” and the observed “objects.”

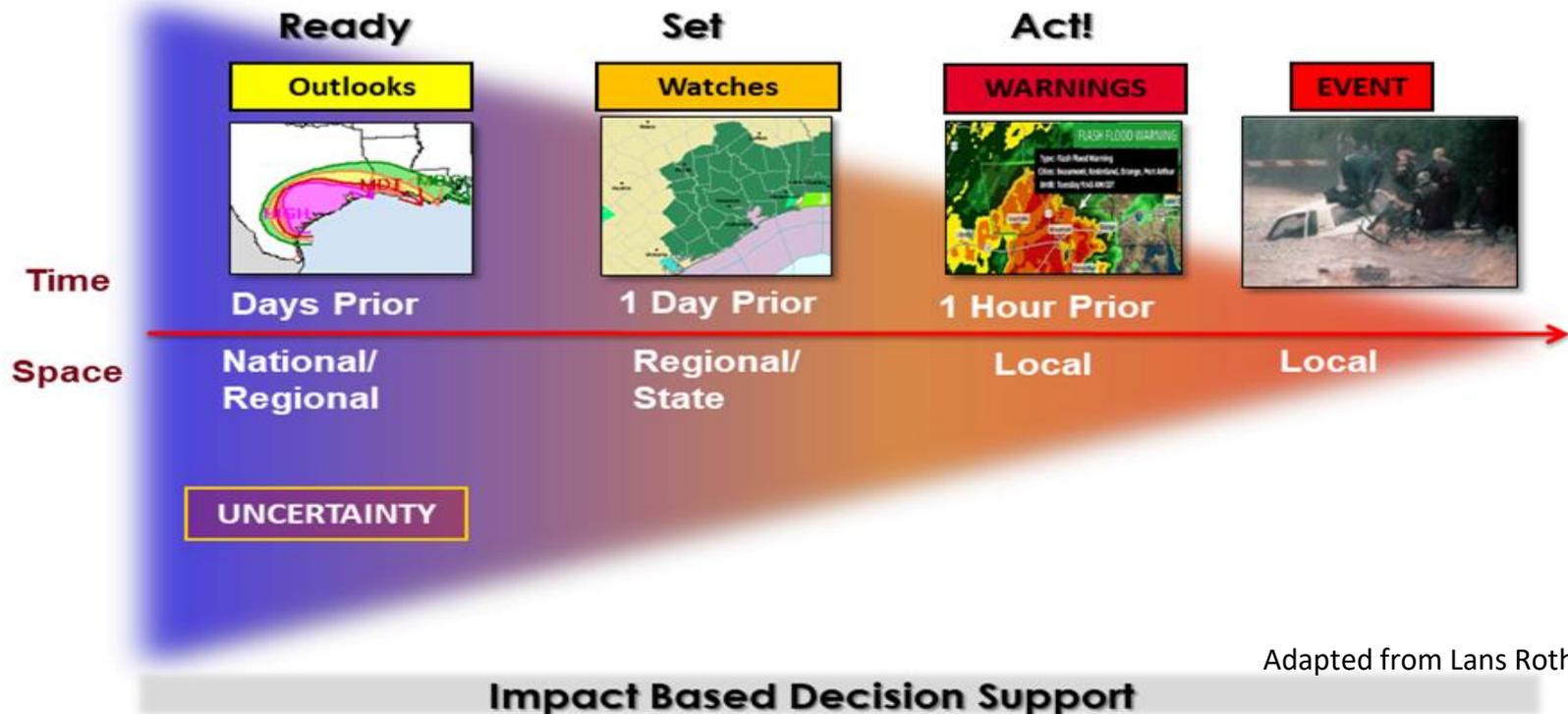
Forecast Hour	Avg QPF Error (2016-20)	NHC Track Error (2010-19)
24	56 mi.	41 mi.
72	86 mi.	101 mi.
120	157 mi.	186 mi.

Requires a Probabilistic Approach



Operational Approach

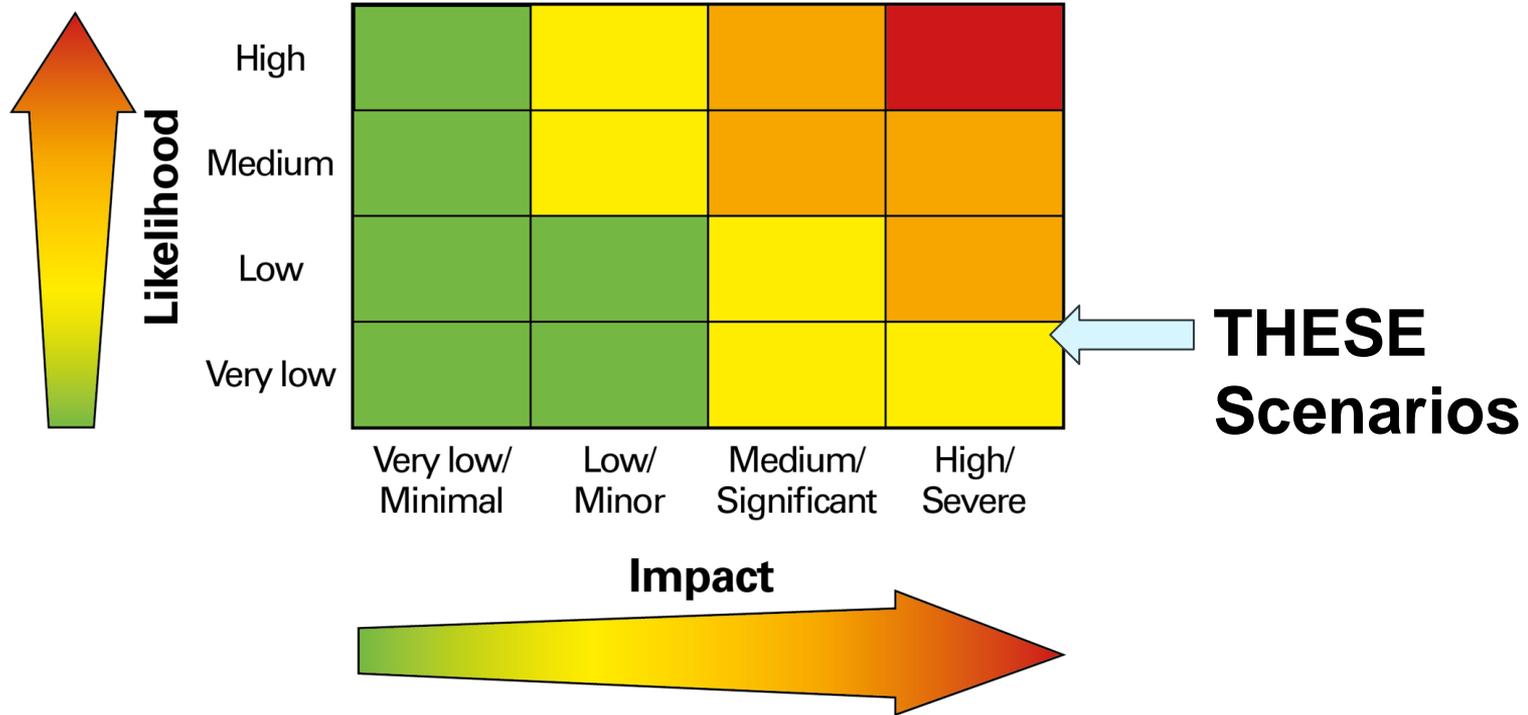
Products & Language Triggered by Level of Certainty



Adapted from Lans Rothfus

Operational Challenge

Communicating unlikely, but high impact scenarios



Operational Nightmare

Outside the Envelope Event with Short Lead

High				
Medium				
Low				
Very low				
NONE				
	Very low/ Minimal	Low/ Minor	Medium/ Significant	High/ Severe

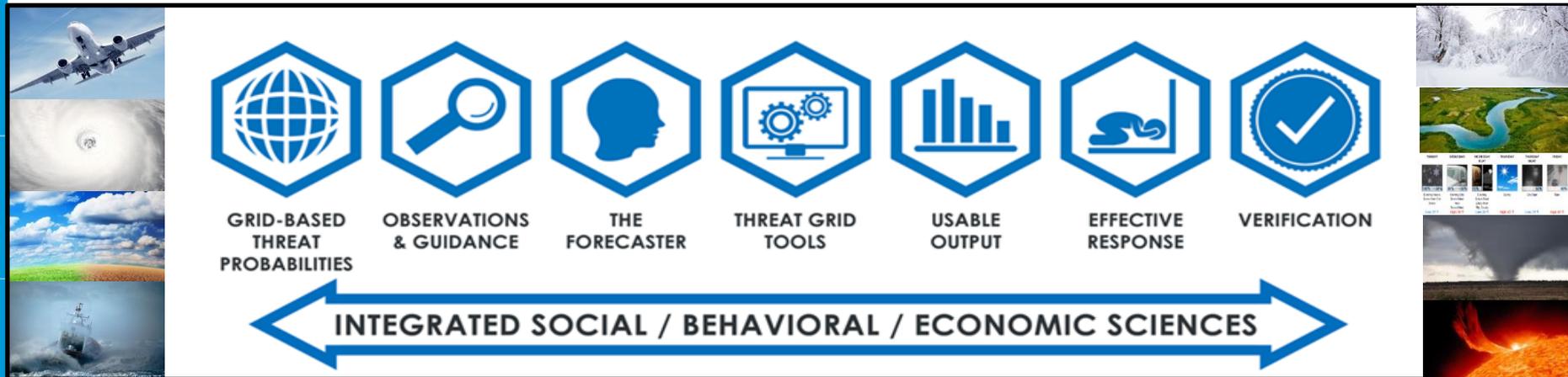


November 15, 2018 in New York City



An End-to-End View

Address all facets of the forecast process end-to-end for multiple users, threats, and timescales to enable effective response.





HMT Flash Flood & Intense Rainfall Experiment



Serve as forum to bring meteorologists, hydrologists, modelers, and academics together to improve forecasts



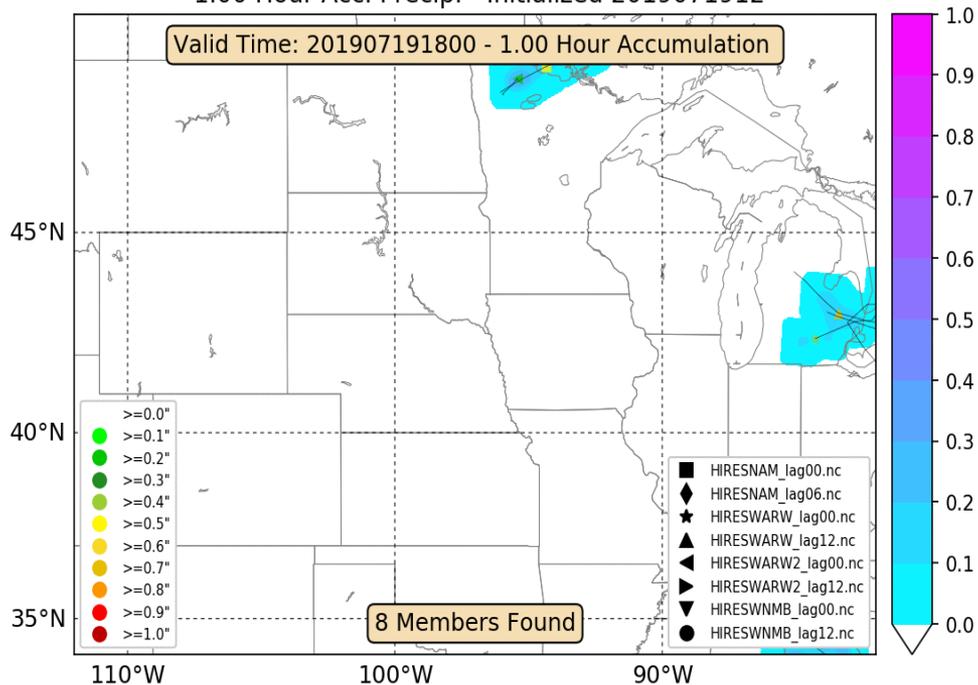
- Test new forecasting and verification techniques
- Test new ways to identify regions of concern
- Evaluate deterministic and ensemble models
- Examine ways to better represent the hydrological aspect of flash flooding



Operational Innovations

Feature-based Perspectives

HREF Ensemble Object Probabilities - Precip. ≥ 0.1 "
1.00 Hour Acc. Precip. - Initialized 2019071912



- Probability of being inside a heavy precipitation object (blue shading), with object centroid location (marker)
- User can assess model consistency with regard to placement, intensity and timing.

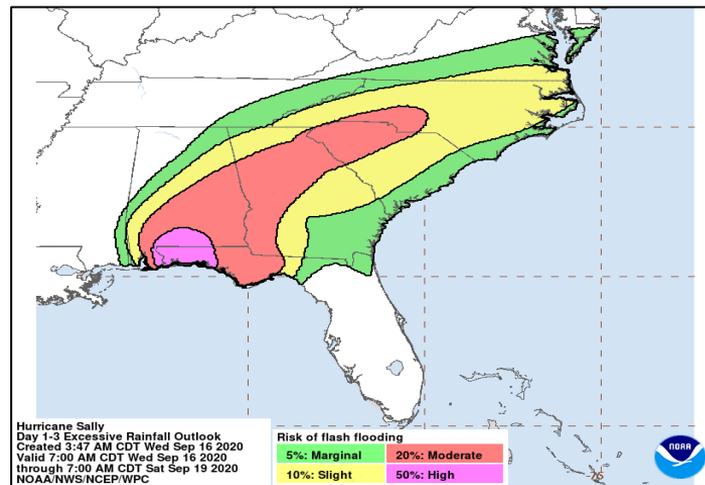
Operational Innovations

Excessive Rainfall Outlook

Raises situational awareness that conditions are favorable for impactful rainfall.

Calibrated probability of flash flood event within 40 km of a point. Verified by proxies of

- Rainfall exceeding flash flood guidance
- Flash Flood LSRs
- Rainfall exceeding 5yr recurrence interval



Machine-Learning First-Guess (based on GEFS reforecast)

“High” risk forecast days have been correlated to events with fatalities and large damages.

Operational Innovations

Communicating What is Possible

10th Percentile

Most Likely

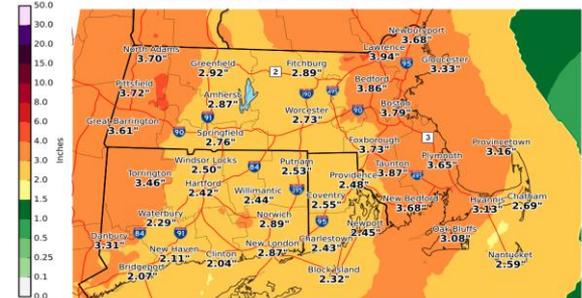
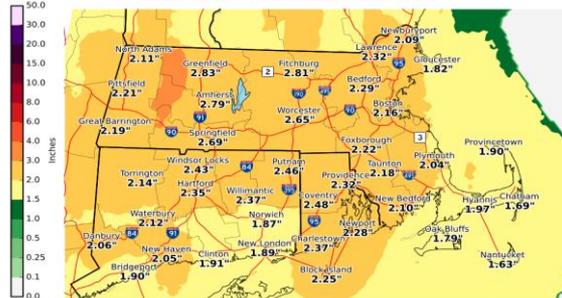
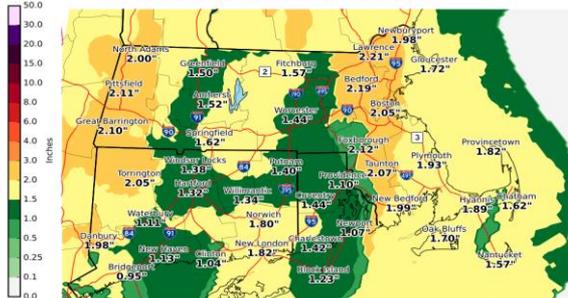
Mode...not the 50th Percentile

90th Percentile

Low End Amount - 9 in 10 Chance (90%) of Higher Liquid Precipitation
Valid: 10/14/2019 03:00 PM - 10/18/2019 03:00 AM EDT

Expected Liquid Precip - Official NWS Forecast
Valid: 10/14/2019 03:00 PM - 10/24/2019 03:00 PM EDT

High End Amount - 1 in 10 Chance (10%) of Higher Liquid Precipitation
Valid: 10/14/2019 03:00 PM - 10/18/2019 03:00 AM EDT



National Weather Service
Boston/Norton, MA
10/14/2019 03:45 PM EDT

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National Weather Service
Boston/Norton, MA
10/14/2019 03:45 PM EDT

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weather.gov/Boston

Low End Amount –
9 in 10 Chance (90%) of Higher Rainfall

Expected Rainfall –
Official NWS Forecast

High End Amount –
1 in 10 Chance (10%) of Higher Rainfall

Wording based on Eastern Research Group study of the
understanding/interpretation of descriptive wording (for probabilistic snowfall)



NOAA Precipitation Prediction Grand Challenge



GOAL

To provide more accurate, reliable, and timely precipitation forecasts across timescales from weather to subseasonal-to-seasonal (S2S) to seasonal-to-decadal (S2D) timescales through the development and application of a fully coupled Earth system prediction model

Bottom Line



**Must improve accuracy,
think probabilistically, and
invest in all parts of the value chain**