S2S Prediction Research at CPC
and
S2S Weather Bill (Public Law 115-25, Section 201)

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NOAA/NWS

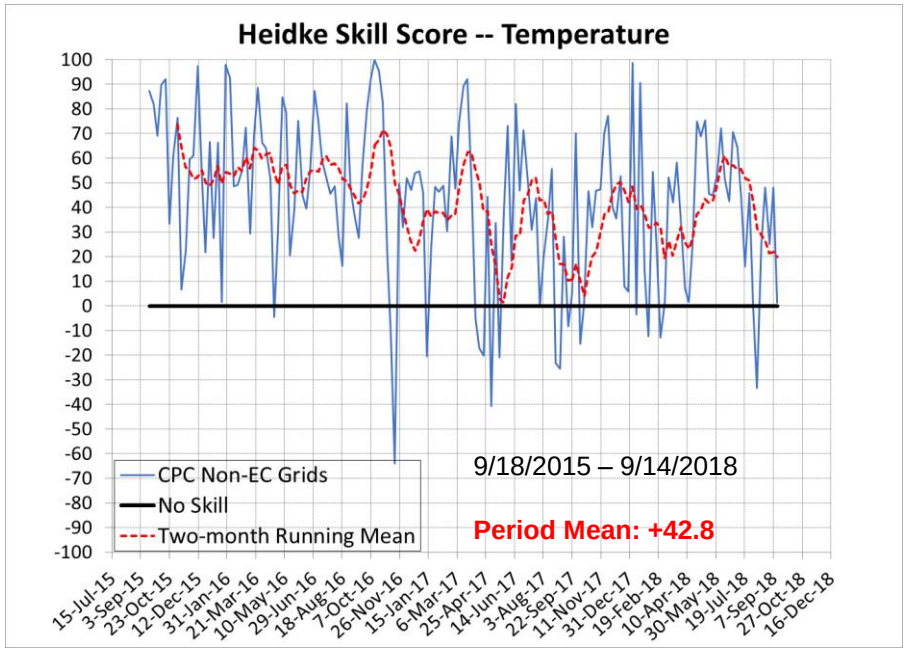
Outline

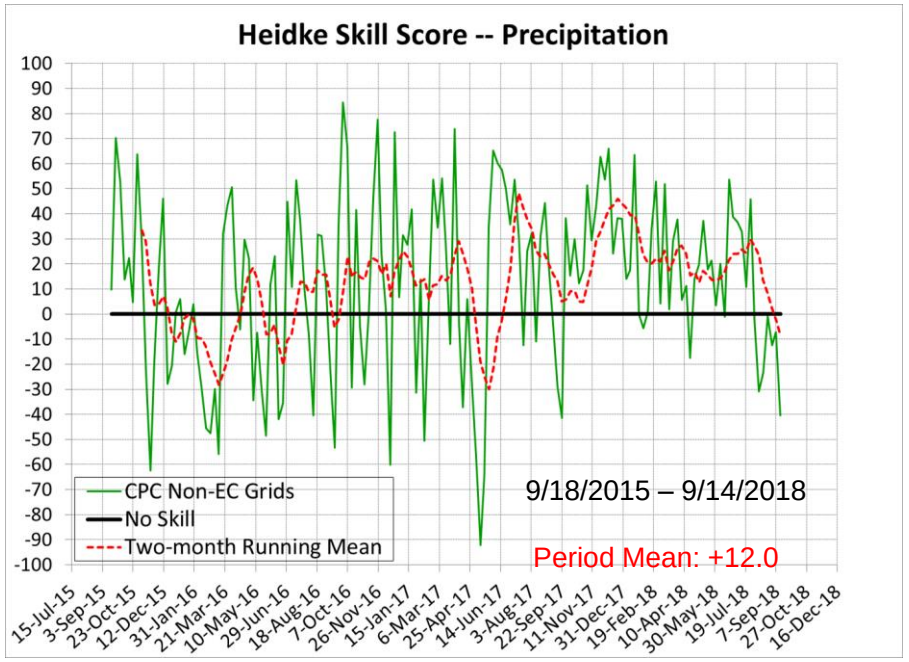
- CPC/EMC Efforts to Improve S2S Forecast Skill
  - Week 3-4 Outlooks
  - Statistical Tools Based on ENSO and MJO Phase
  - Long-Lead Consolidation
  - “Consistency Project” Leveraging Lead-Time Dependent Forecast Skill
  - Probabilistic Forecasts of ENSO Strength
  - Improving MJO forecast skill through improved physics
  - New NOAA community model
  - Diagnosing errors in El-Nino predictions
- S2S Weather Bill Report: Background and status
- Taking Stock of Current Status of S2S Forecast Skill and How to Improve it: A personal perspective
- Conclusions

Disclaimer: This talk will mix personal views with organizational positions. To ensure there is no confusion regarding which are my personal views these will be denoted by my initials in parenthesis (DGD).

Week Three-Four Temperature and Precipitation Outlook Skill

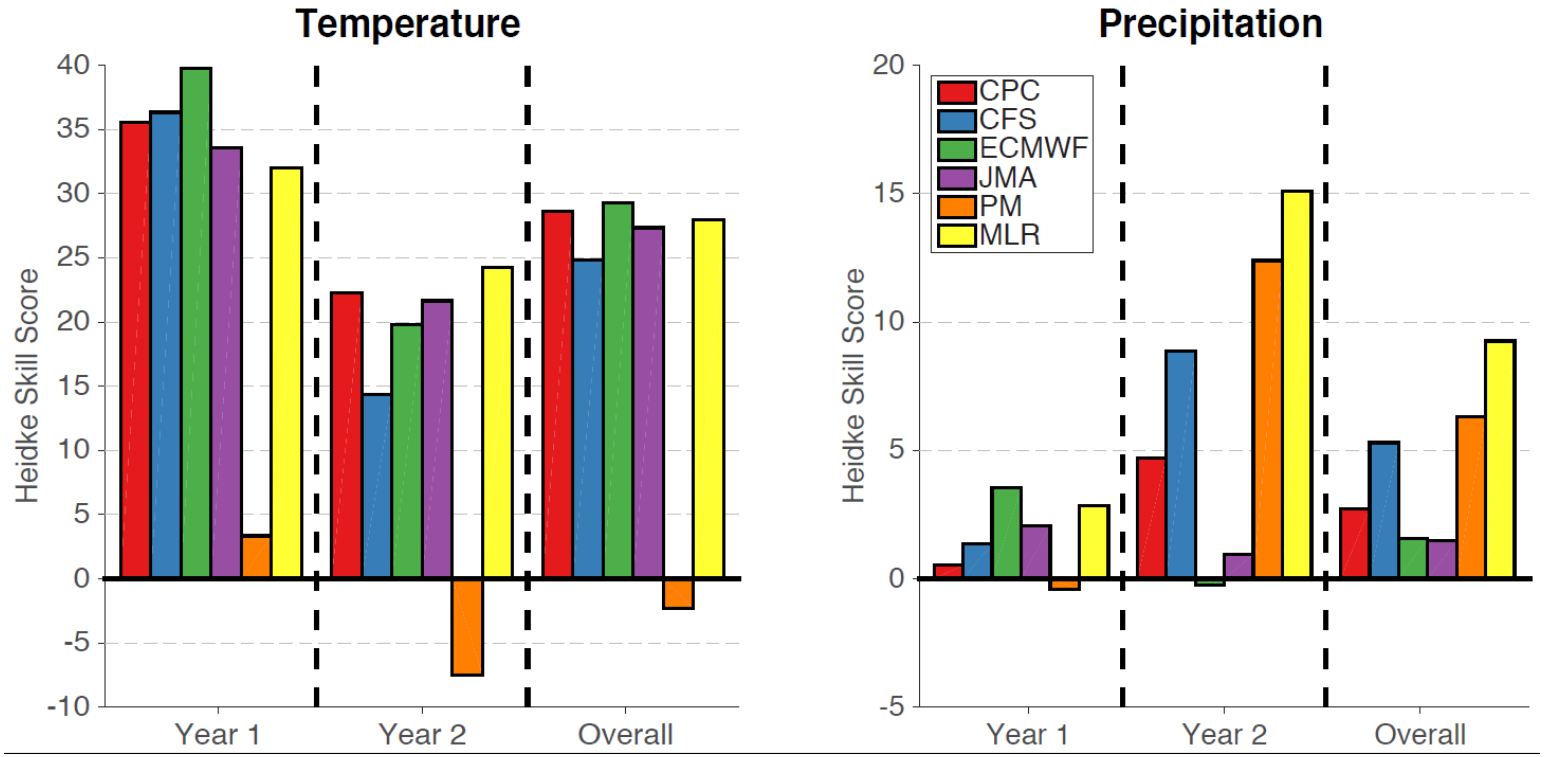
(Gottschalck, Allgood, Harnos, L'Heureux, Collins, Baxter, CPC OPB)





Comparing Performance of Statistical and Dynamical Week 3-4 Forecast Tools

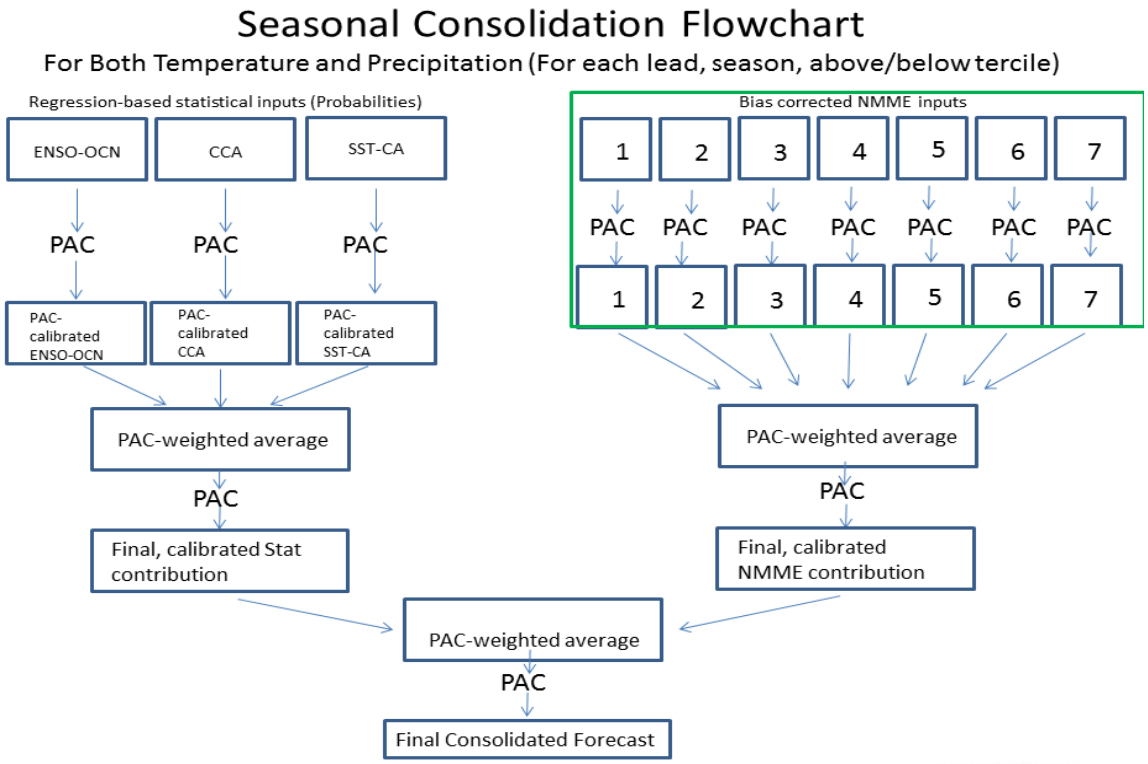
Harnos, Johnson, Baxter, L'Heureux, Ciasto



Courtesy of D. Harnos

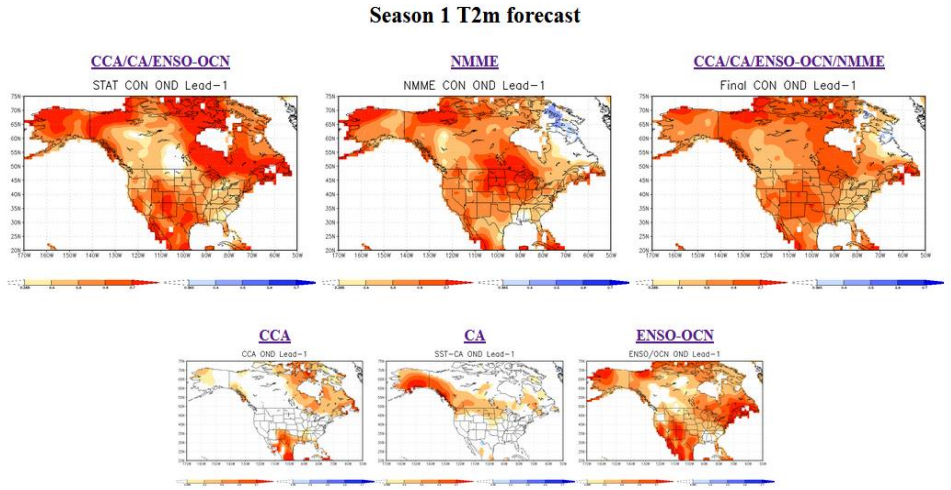
- Temperature: Statistical tools have comparable skill to dynamical and official forecasts
- Precipitation: Statistical tools outperforms dynamical tools and official forecasts

New Objective Seasonal Consolidation For NMME and Statistical Models (Baxter and Barandiaran)



Seasonal consolidation flowchart. The green box indicates process that currently executes operationally upstream of the consolidation. All other processes are included as part of this experimental consolidation process.

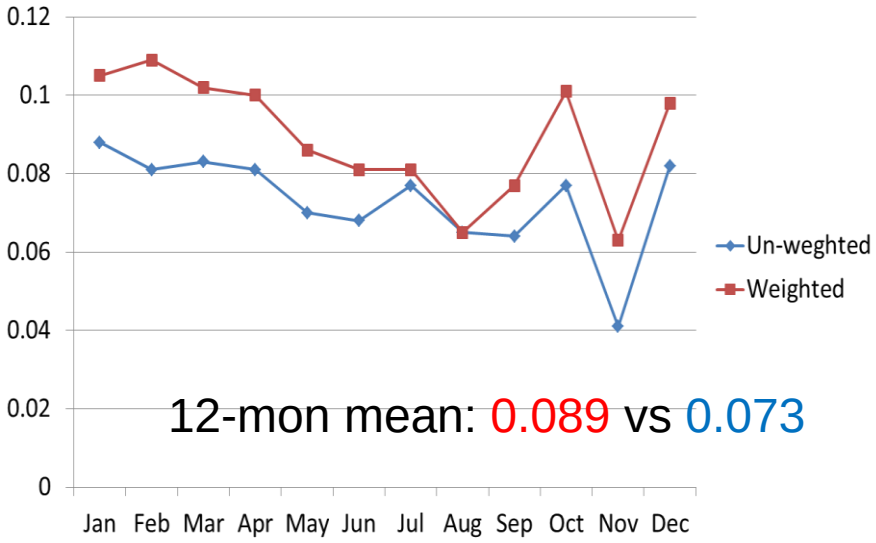
Sample output graphics available to forecasters for the Lead-1 temperature forecast (OND 2018).



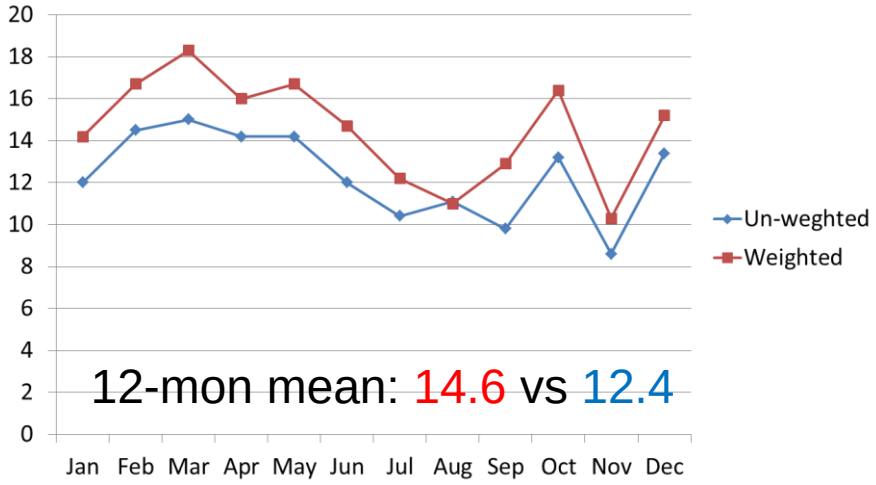
Consistency Project to Leverage Increased Skill from Shorter Lead Forecasts

(Baxter, Peng, Halpert, and Charles)

RPSS of Prec Days1-30 Forecast over CONUS



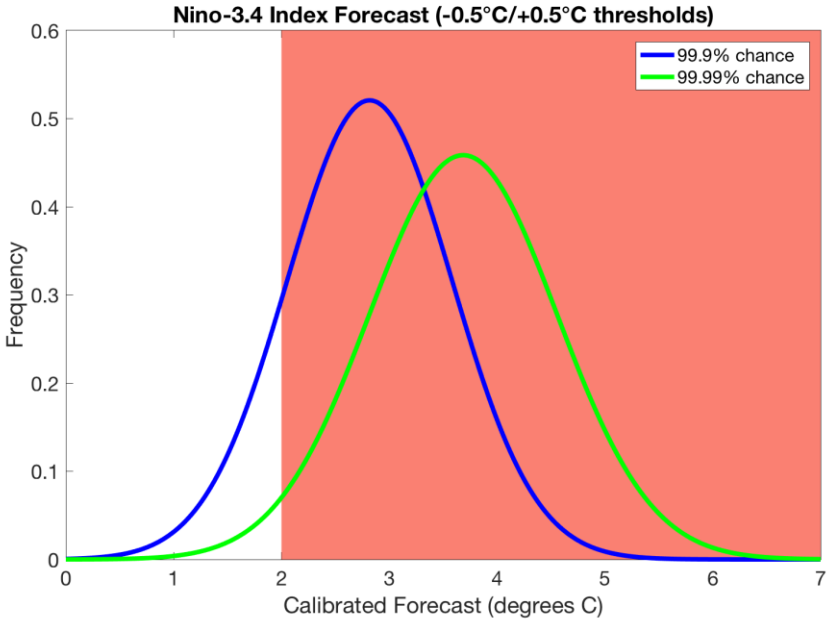
HSS of Prec Days1-30 Forecast over CONUS



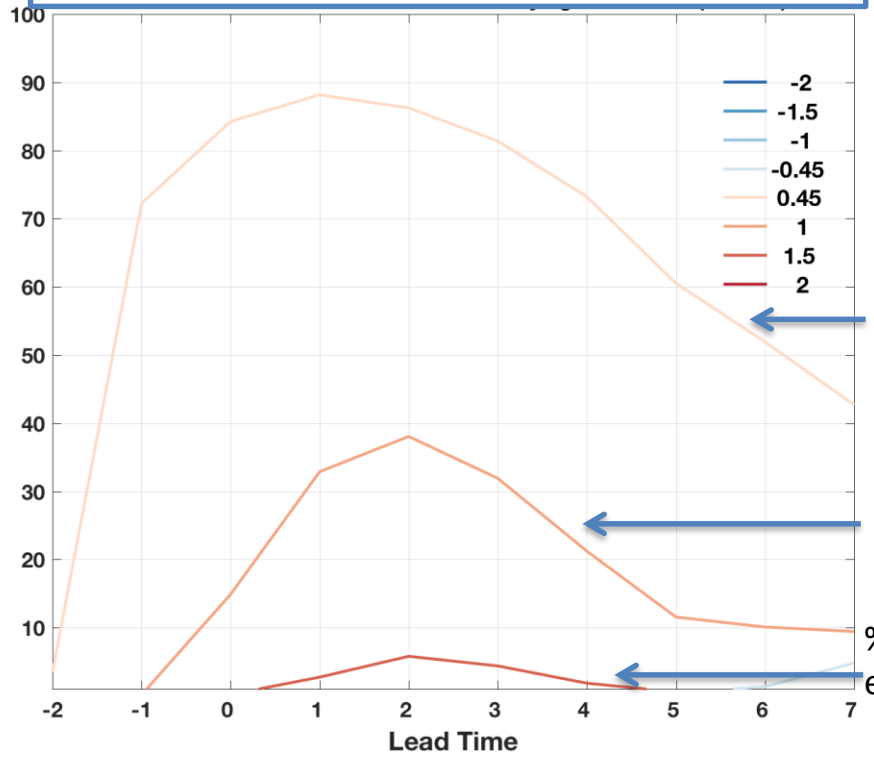
ENSO Strength Outlooks

(L'Heureux, Barnston, Takahashi, Tippett and CPC/IRI ENSO Team)

Goal: To provide the *full* distribution (POE) based on CPC's official ENSO outlooks.



Chance (%) that Niño-3.4 index exceeds various thresholds
(based on Oct. 2018 start)



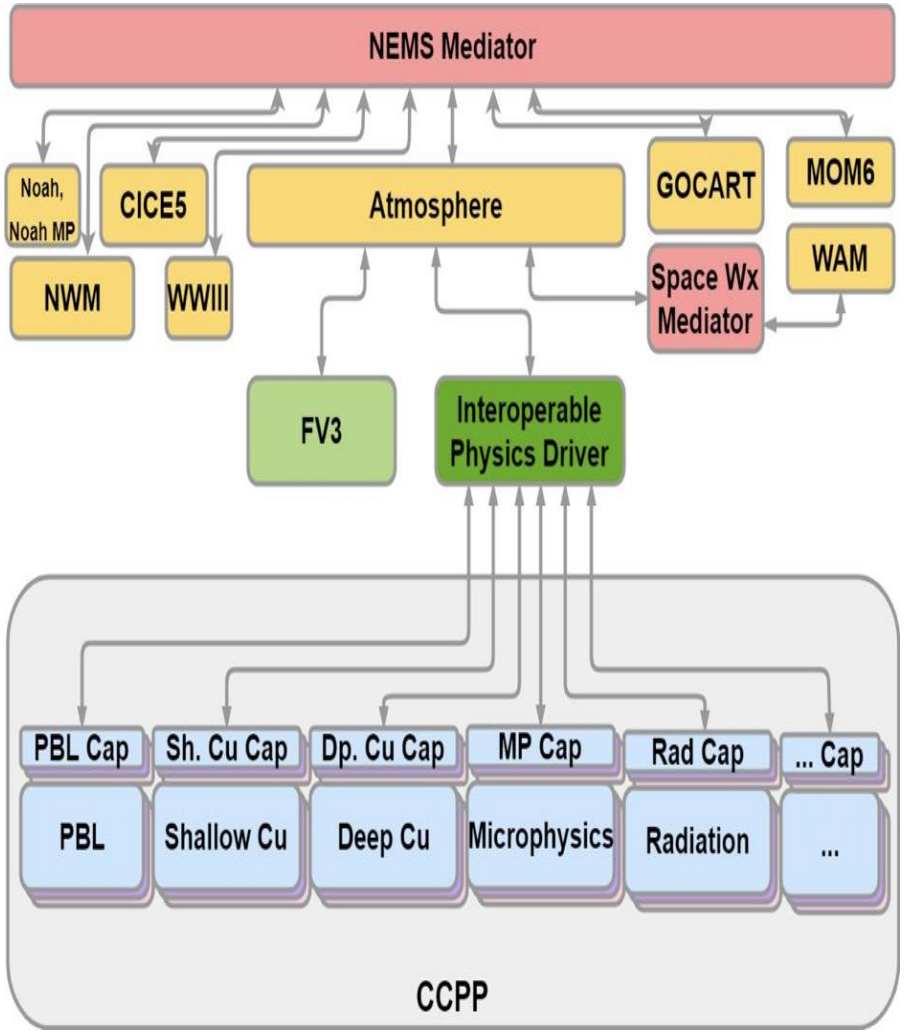
% chance in excess of +0.5C

% chance in excess of +1C

% chance in excess of +1.5C

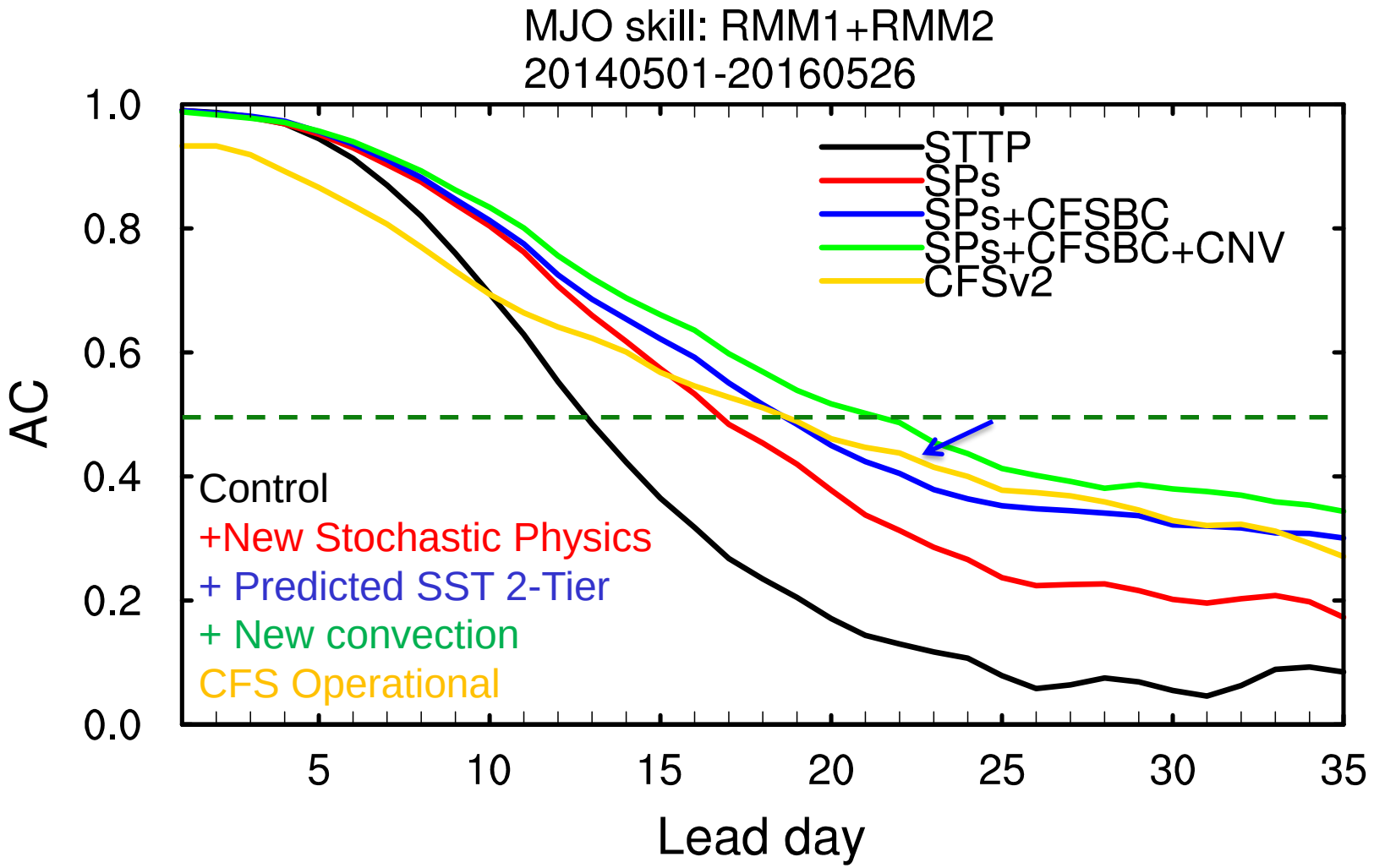
NOAA is Developing a Community-Based S2S Model

- Required elements of a successful community model:
  - Well-documented model
  - Funding to support community involvement
  - Community actively participating in model development



Increased MJO Forecast Skill from Focused Model Development

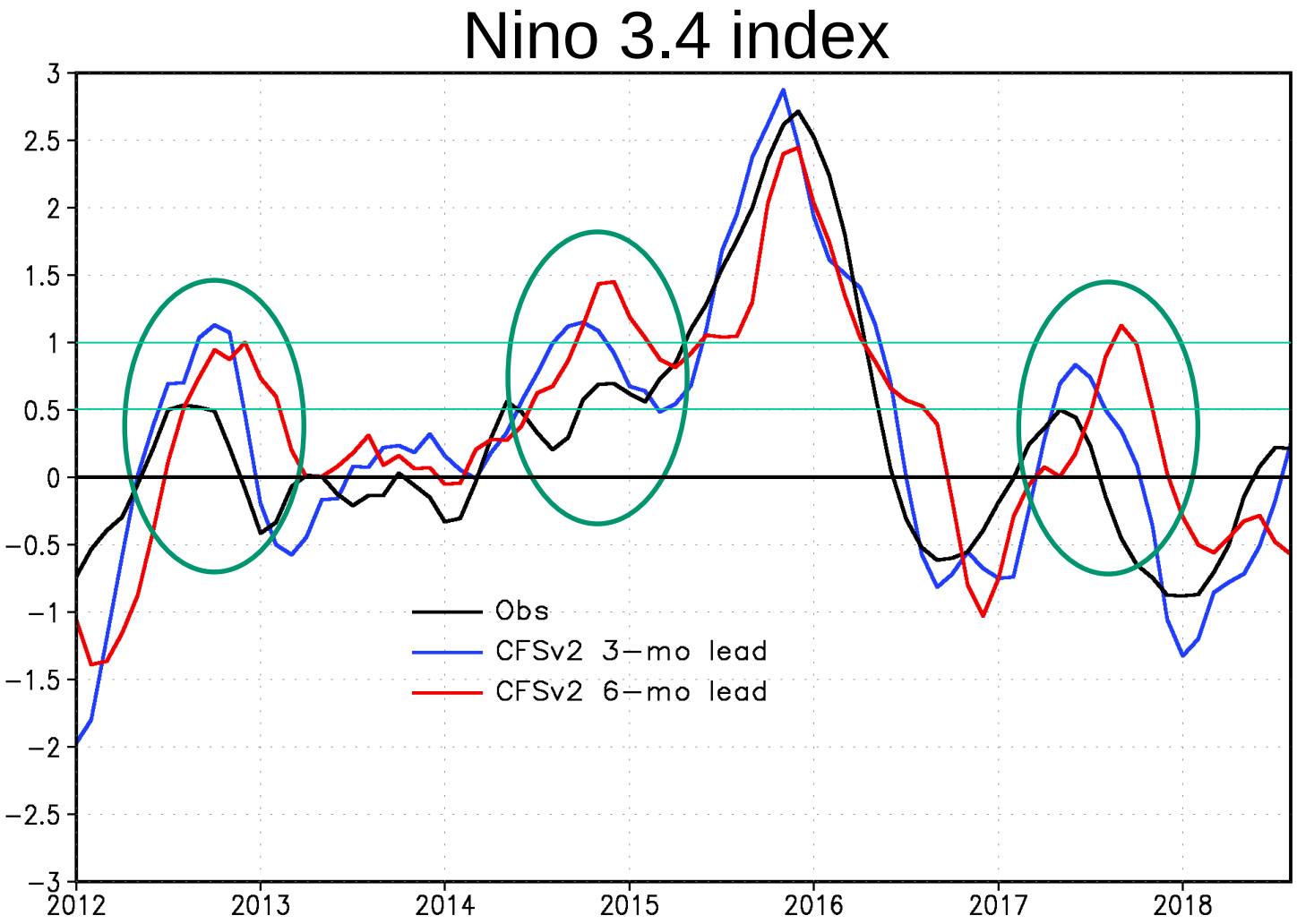
(Zhu and Tallapragada)



Dramatically increased skill of MJO from improved physics! Need to continue to improve teleconnections from MJO, i.e. precipitation forecast skill over California.

El Nino False alarms in CFSv2

(Wang)



False alarms occurred in 2012, 2014, and 2017 in CFSv2 real-time forecasts. This is related to incorrect modeling of the atmosphere-ocean coupling strength.

Weather Act of 2017 (PL 115-25)
Section 201

- Short Title - Weather Research and Forecasting Act of 2017
- TITLE II – Addresses “Sub-seasonal and Seasonal Forecast Innovation”
  - Section 201 “Improving Sub-seasonal and Seasonal Forecasts” is the only section in TITLE II
  - Section 201 Amends Food Security Act of 1985
- Scope: Defines and authorizes NOAA’s Sub-seasonal and Seasonal (S2S) forecast responsibilities
- Authorizes $26M in each of the years 2017 and 2018 for the NWS to meet the provisions of the Act
- *Subseasonal* is defined as the period from 2 weeks to 3 months; *Seasonal* ranges from 3 months to 2 years

S2S Report to Congress

§ h. “Reports”, calls for…

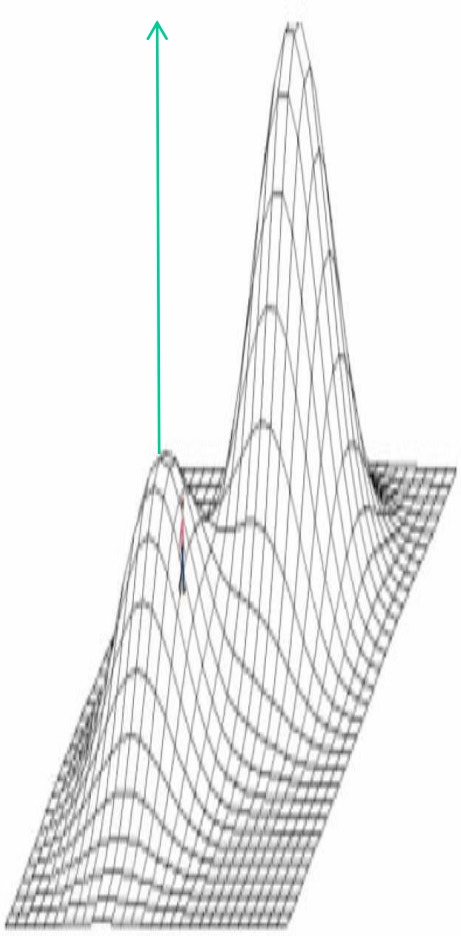
- Not later than 18 months after date of enactment (18 Oct 2018), the Undersecretary shall submit to Congress (relevant House and Senate Committees) a report including:
  1. An analysis of how NOAA’s S2S forecasts are used for public planning and preparedness,
  2. NOAA plans for the continued improvement of an S2S forecasting capability, including products to meet the need described in 1, and
  3. An identification of the needed research, monitoring, observing and forecasting requirements for number 2
- The Undersecretary shall consult with relevant Federal, regional, State, tribal, local government agencies, research institutions, and the private sector in the development of this report.
  - 64 replies were received during the public comment period with 28 of them from Western Water. Second largest group of respondents was state climatologists.
  - My personal apologies if you were part of that process, which changed at the last minute

NOAA's Report

"Subseasonal and Seasonal Forecasting Innovation: Plans for the Twenty-First Century"

- Will serve as a guidepost for NOAA planning and execution, as well as to inform the public and NOAA's stakeholders on its efforts on subseasonal and seasonal forecasting
- This document traces the continuum of effort from S2S products and services to the innovations needed to enable and improve them
- Two main goals: (i) improving the skill of the S2S forecasts, and (ii) enhancing the value of S2S products for stakeholders

Draft Weather Bill Report Recommends Accelerating S2S Forecast Skill Through a Few Regionally -Focused Pilot Projects. One of these is Winter Precipitation for the Western US



What is essential in order for us to go from current limit of predictive skill to one that is substantially higher (assuming that is possible)?:

-Fostering and nurturing an entrepreneurial (risk-taking culture). Examples from weather community :S2S TOGA decade, HFIP, FACETS.

- Recognition of the difficulty of the problem and the fact that there is no single silver bullet that will solve the problem. Rather, compounding incremental improvement will lead to long-term measureable gains in forecast skill.

-Well-defined metrics and timelines for evaluating success that are co-developed with the relevant stakeholder communities and are operationally-oriented.

- Sufficient sustained investment in all required aspects of the problem, including human resources, high-performance computing (currently a strongly limiting factor), observing systems, and transition of research innovations to operations.

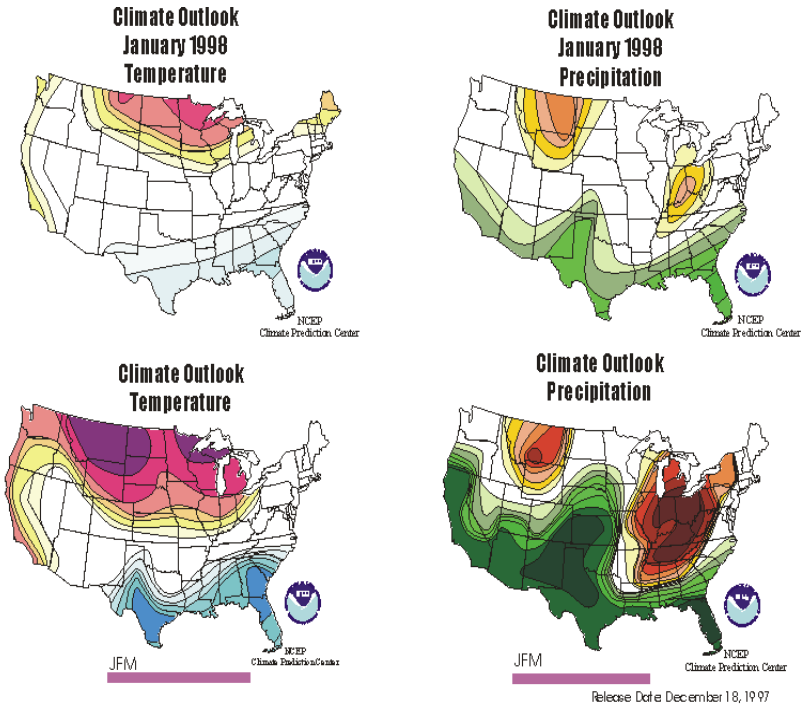
-Leverage the talents of all parts of the weather enterprise, including NOAA labs, other federal agencies, the research community, and relevant NWS.

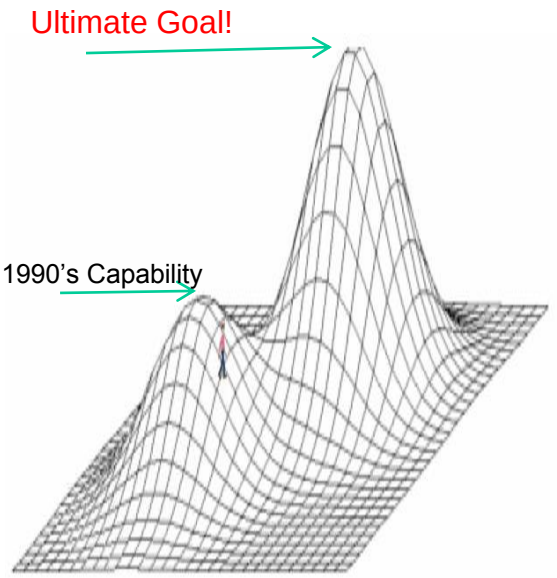
”Weather Bill” Report Status

- Currently under final review within NOAA
- Next to be routed to DOC and then to relevant Congressional Committees. Likely early in the next Congress.
- Personal (DGD) views on the Weather Bill report:
  - Unique (once in a generation) opportunity to communicate to Congress what we do, why it is important, and what our challenges (needs) are.
  - Report will have minimal impact if it doesn’t result in action.
  - Open question is: Will we as a community seize the opportunity that this represents?

Personal Reflections on Status of S2S Prediction and Changes Needed to Accelerate Skill Improvement

View on Seasonal Forecasting: Is it a solved problem or was late 1990s success a False Summit and we have more work to do to?





Hard work and higher-risk research by the S2S enterprise in the late 1980s through the 1990's led to tremendous success in forecasting the 1997-98 El Nino and 1998-99 La Nina. That led some to conclude that this was a solved problem (or equivalently we had reached the limits of predictability). I (DGD) believe that shaped our research investment decisions and our focus, not necessarily for the better.

Complementary Value of Dynamical and Statistical Tools

Human Forecasters Use Various Tools To Develop Seasonal Predictions:

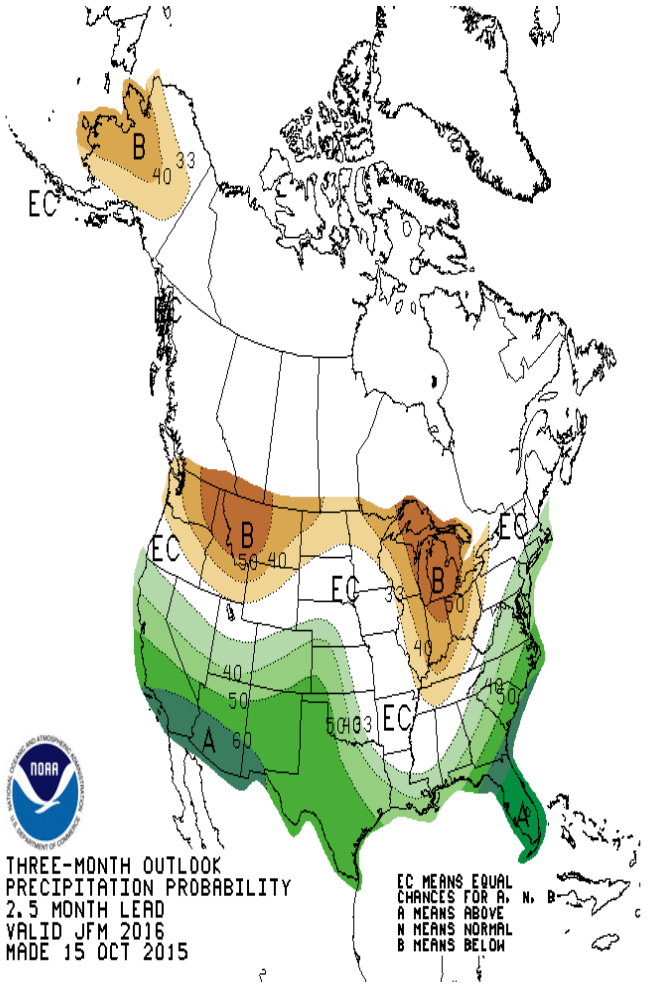
- Dynamical Models
- Statistical Models
- Historical Analogs
- Historical Composites

Goal is to leverage complementary skill between the tools.

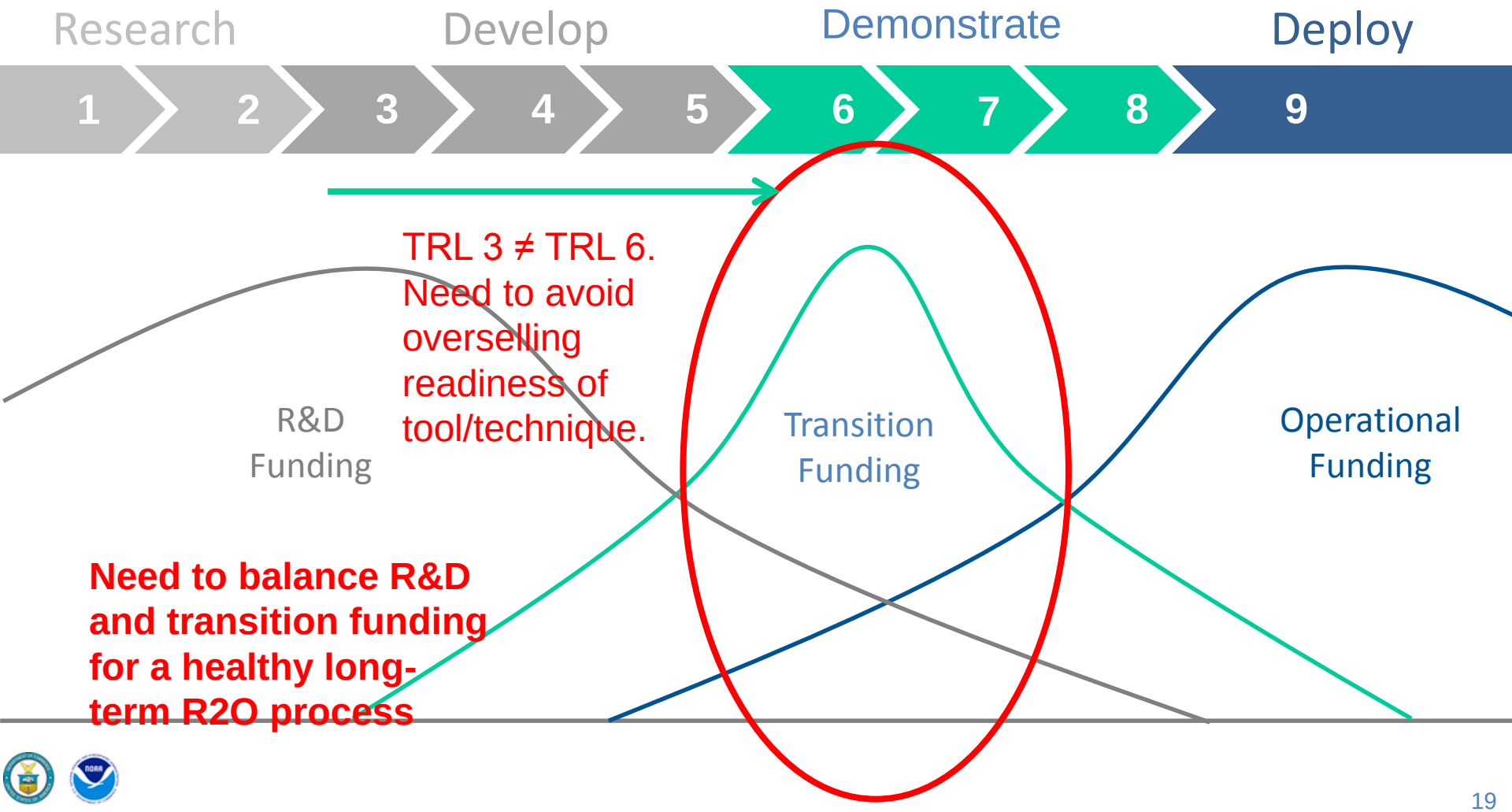
Ultimately, skill of seasonal forecast depends on skill of tools made available to the forecaster.

Need to improve skill of all forecast tools.

Need to invest in development of statistical tools.



Need to have a balanced funding portfolio to ensure sufficient high-risk, high-reward funding that enables cutting edge development and eventual transition. Development Work/Improved Understanding Are Critical to Ultimate Success (DGD)

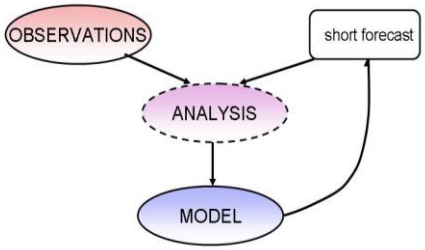


Personal Perspective on Challenges to Improving S2S Forecasting Skill (DGD)

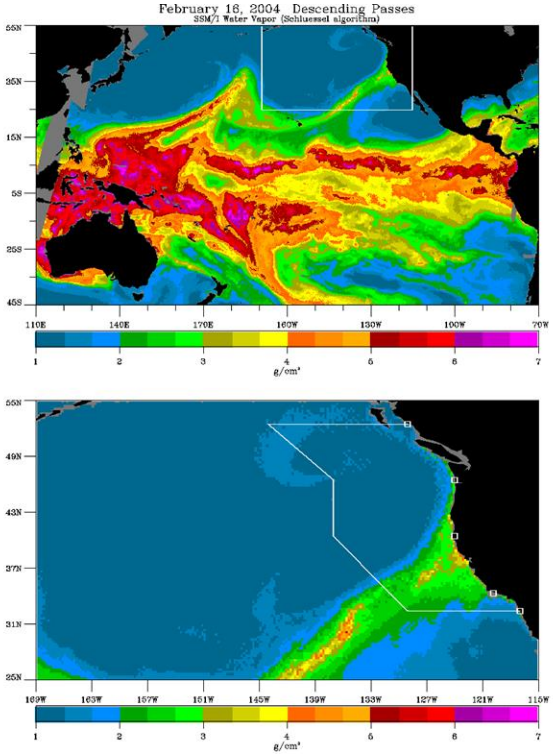
- This isn't about needing to work harder or lack of intellectual ability. People have worked hard and make some great progress but we we need to acknowledge that there are strong constraints in the system that are limiting progress. These include but are not limited to:
  - Persistent systematic errors that are as large as the signal we are trying to model. The magnitude of these errors has remained the same since the late 1990's.
  - Due to HPC limitations we are not sufficiently resolving the phenomena of interest, i.e. transients (either horizontally or vertically), which means that it is highly unlikely that we can adequately capture their mean statistics.
  - Incredibly talented but poorly organized and aligned community. This means we are not efficient nor effective. Just within NOAA the following organizations work on some aspect of S2S product development, interpretation, and delivery: RCC, RCSD, NCEI, ESRL PSD, ESRL GSD, GFDL, CPO, NCEI, CPC, EMC, OWAQ, RISA, CSB, CSPM, CFP.

Improved Skill Will be Achieved Due to Strengthening Key Building Blocks of Forecast System

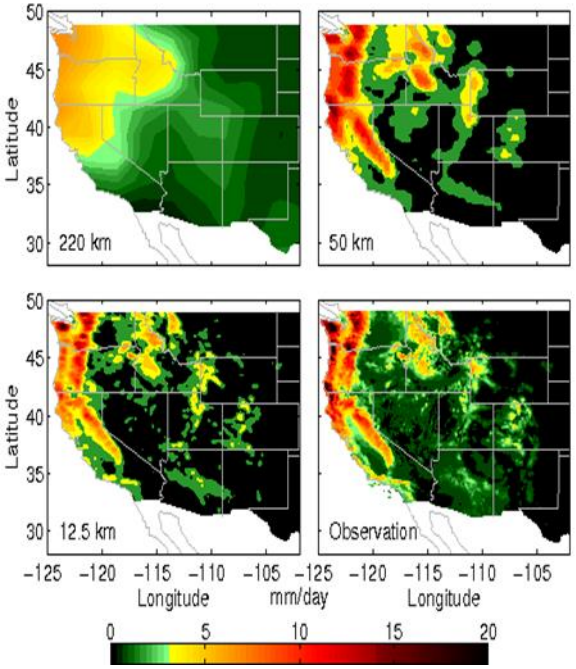
Improve data assimilation system and observations, and calibration/post-processing



Improve model physics to better represent physical processes and reduce error, i.e. tropical/extra-tropical interactions.

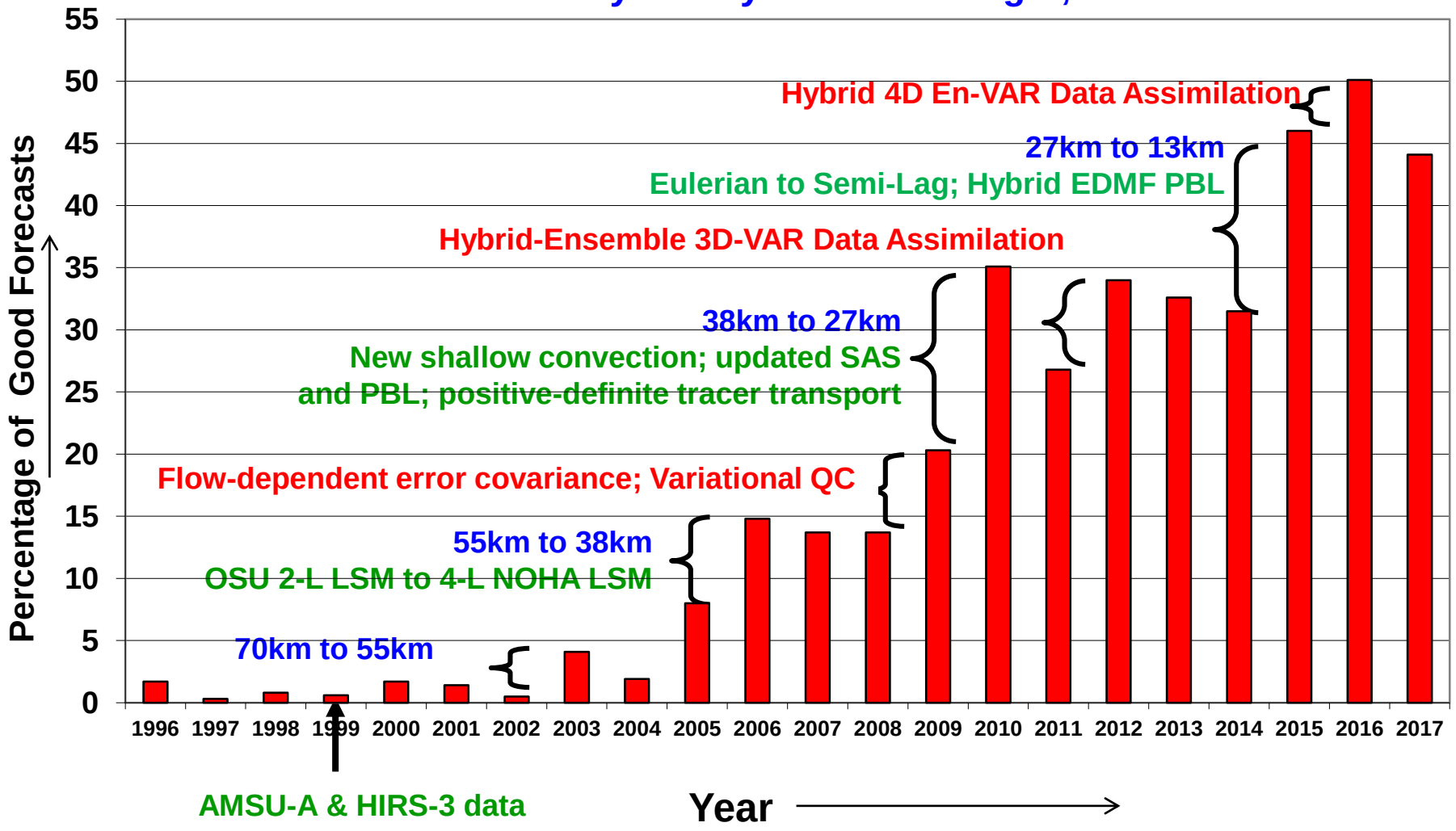


Reduce model errors through enhanced-resolution to better resolve key phenomena. This is computationally expensive!!!!!!!!!!!

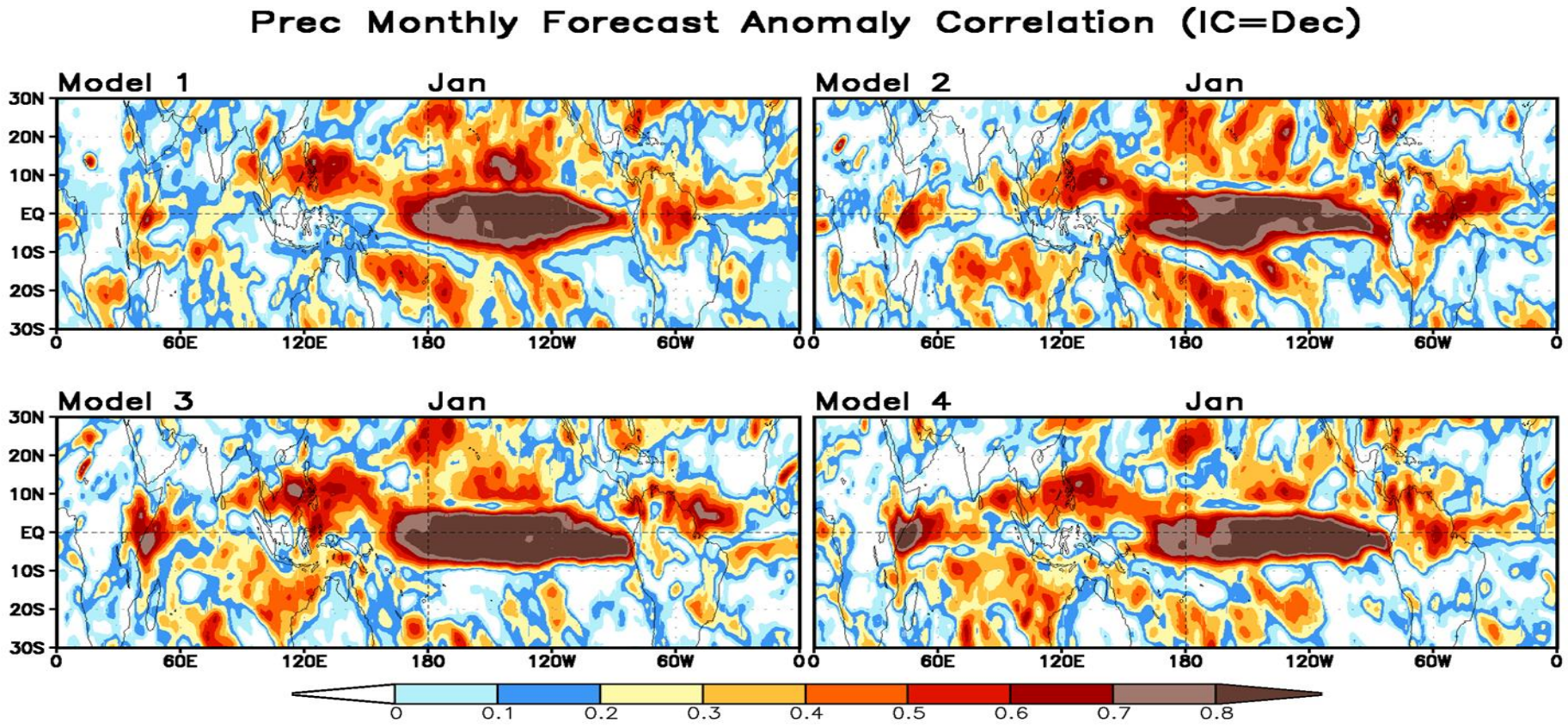


GFS Skill Improvement Due to Increased Resolution, Data Assimilation and Physics Upgrades

Percent Anomaly Correlations Greater Than 0.9
GFS 00Z Cycle Day-5 500hPa Height, NH

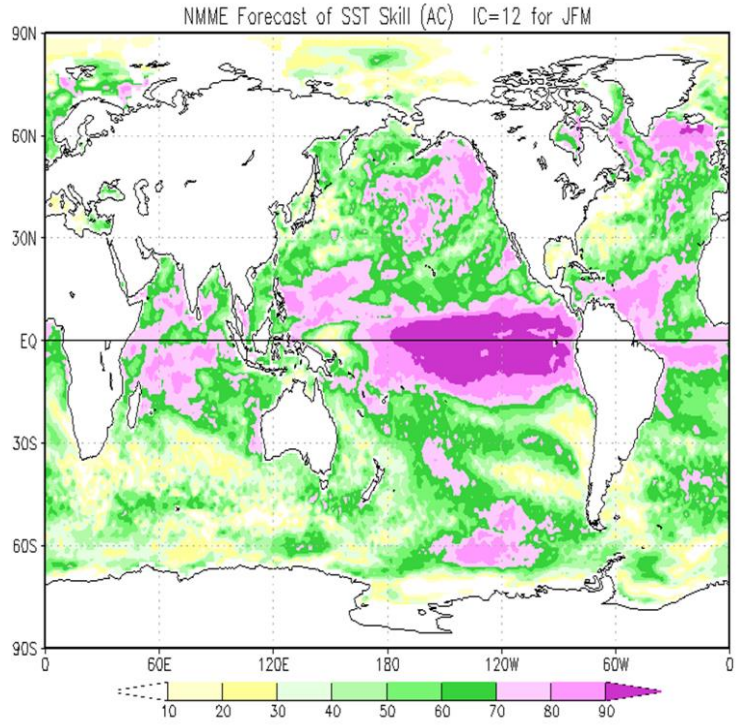


Large Scale Model Errors Leading To Limited Precipitation Forecast Skill for US Beyond Week Two

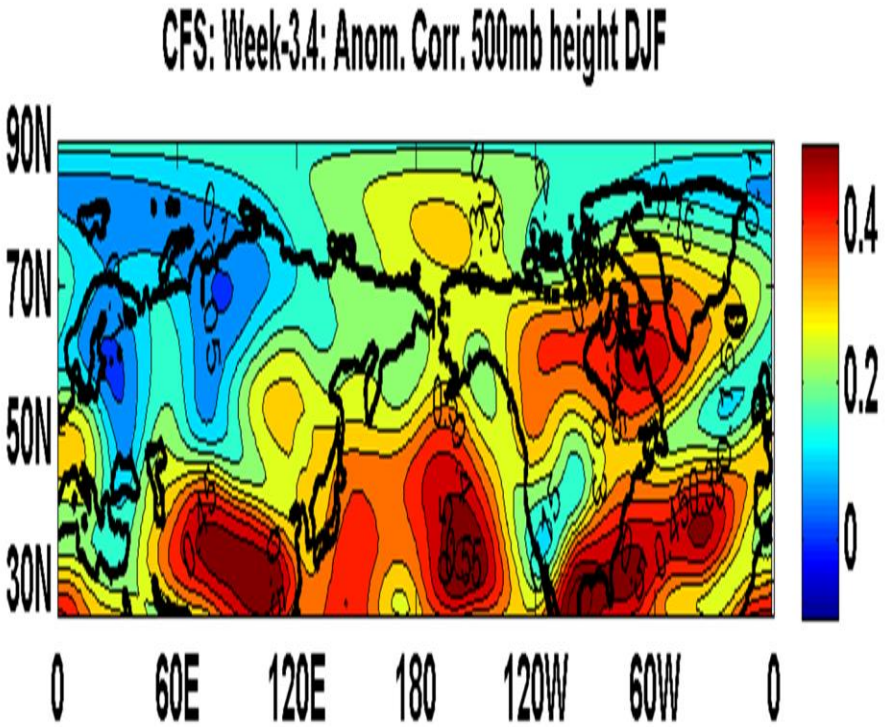


State of the art coupled models from NMME have very little skill in predicting tropical precipitation outside of near-equatorial central and eastern Pacific.

Large Scale Model Errors Leading To Limited Precipitation Forecast Skill for US Beyond Week Two



Inability of dynamical models to predict tropical SST variability beyond a few weeks outside central/eastern Pacific



Inability of dynamical models to predict upper-level flow for western half of the US.

Personal Perspective on Way Forward to Accelerate Improvements to S2S Forecasting Skill (DGD)

- Obtain sufficient HPC so that we can adequately resolve relevant physical phenomena.
- Rebalance funding portfolio to ensure sufficient funding to allow an entrepreneurial culture, but focused on operational outcomes.
- Establish an organizational structure within NOAA to ensure sufficient but not stifling coordination that maximizes efficiency, effectiveness, and alignment toward the highest priority goals. We need an S2S coordination framework. Please note that this should learn lessons on what not to do from the previous attempt by NOAA to stand up a climate service, which was poorly planned, poorly executed, and tone-deaf to concerns from important stakeholders.
- Need some crazy people who think differently(Famous Apple commercial: https://www.youtube.com/watch?v=QjvrBzYt3d8

Final Thoughts

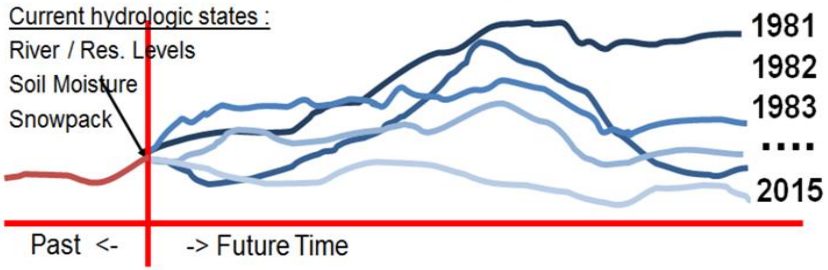
- Despite the challenges we face and the difficulty of the problem I am optimistic that we can accelerate improvements in S2S forecast skill. Please note that I didn't say it would be easy nor likely fast. This optimism is based in three factors:
  - A new generation of diverse scientists who haven't bought into the dogma of can't, won't, and don't associated with S2S prediction and its prospects.
  - Weather modelers are moving into the S2S space and they don't look at these systematic errors as insurmountable obstacles but rather as interesting science challenges. Remember that they have been working on and succeeding at improving tornado and hurricane forecasts, which are not exactly easy problems.
  - An engaged and organized stakeholder community that wants to help us help them. Western water is such a community.
- The weather bill is the vehicle that we can use to achieve these ends and I hope that people stay engaged and are willing to work together toward a greater good for all of us.

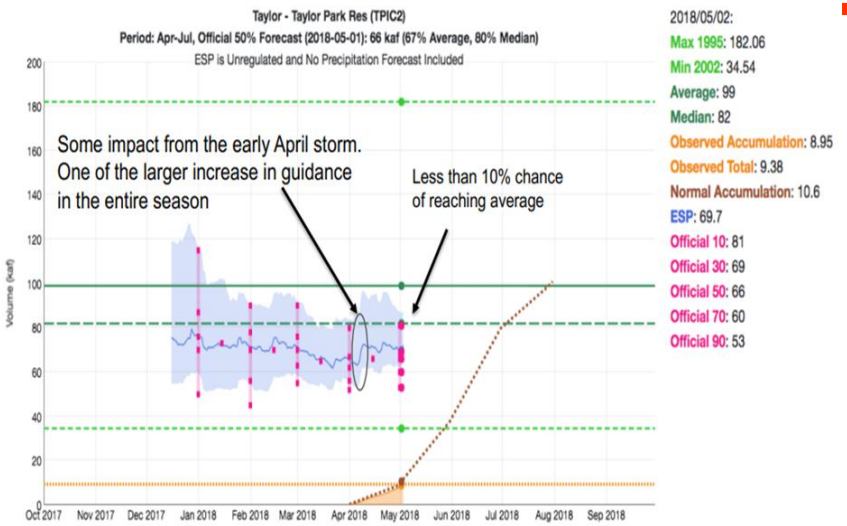
Extra Slides

High-Level Overview of "Evaluation Of CPC Prediction Tools by RFC"

ESP Probabilistic Forecasts

- Start with current conditions (from the daily model run)
- Apply precipitation and temperature from each historical year (1981-2015)
- A forecast is generated for each of the years (1981-2015) *as if, going forward,* that year will happen
- This creates 35 possible future streamflow patterns. Each year is given a 1/35 chance of occurring





My view on this is to enable the RFC to use the following tools:

Probabilistic threshold NMME (Kumar and Chen) for Months 1 to N

CPC Calibrated, Consolidated Week 3-4 Prediction Tool

CPC Week Two Calibrated, Consolidated Prediction Tool

To evaluate the following question: Do these tools provide skill enhancement for HEFS/ESP (or NWM) for various watersheds ? At what lead? How much is skill improvement? This is a pretty rich space of possibilities based on lead and forcing variable.

Intent is for us to provide data and consultation for RFC (possibly NWC) to perform

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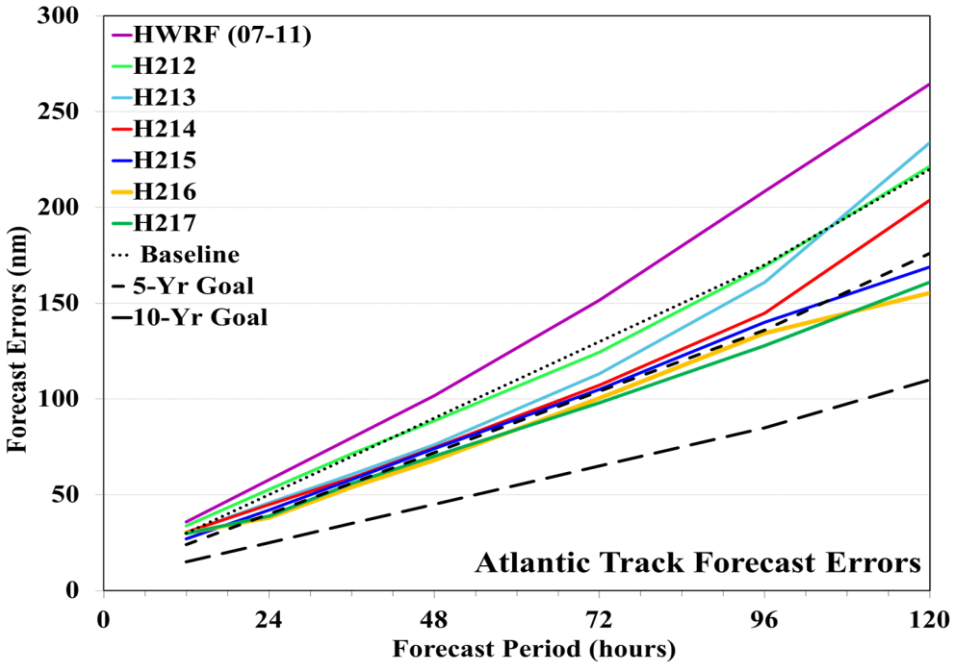
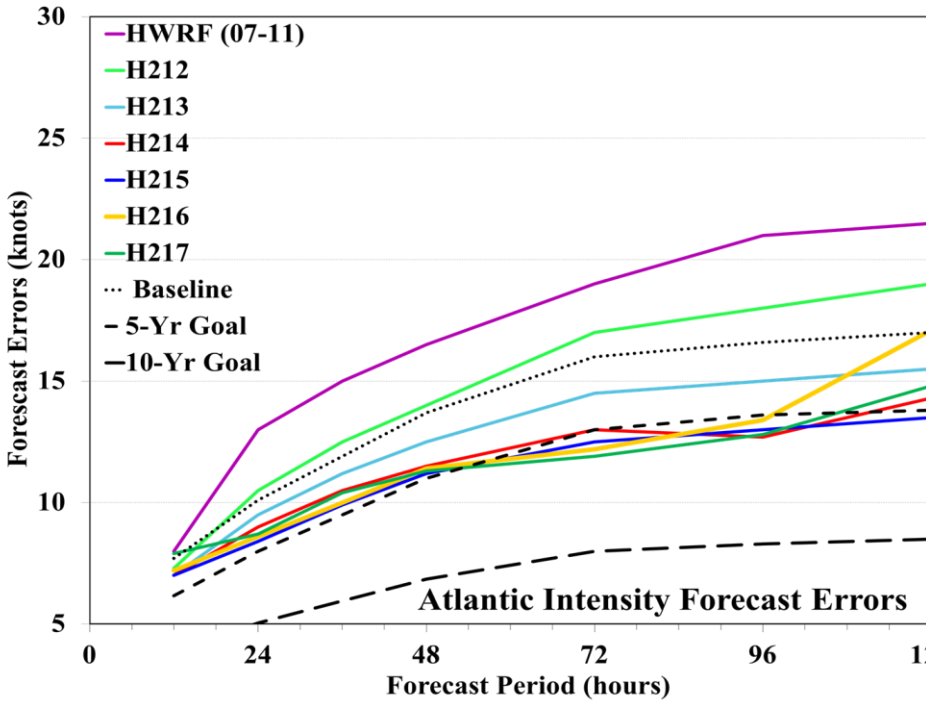
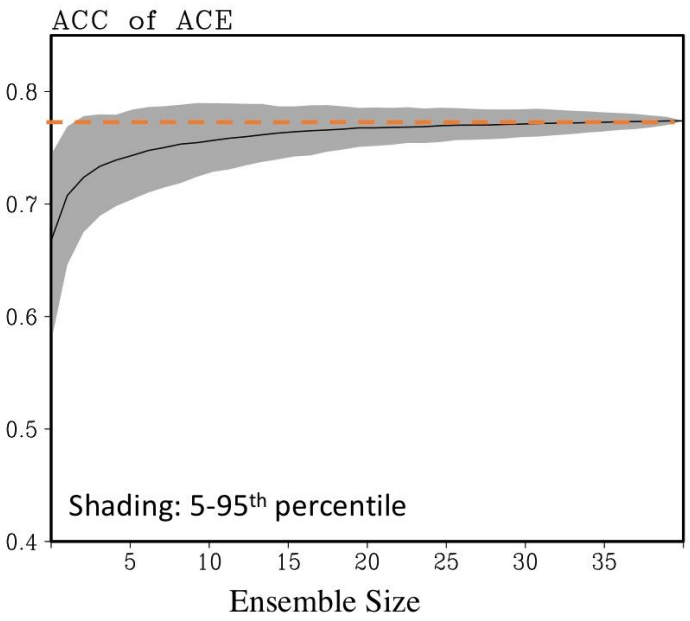
HFIP as a Successful Paradigm to Improve Forecast Skill Through Targeted Research



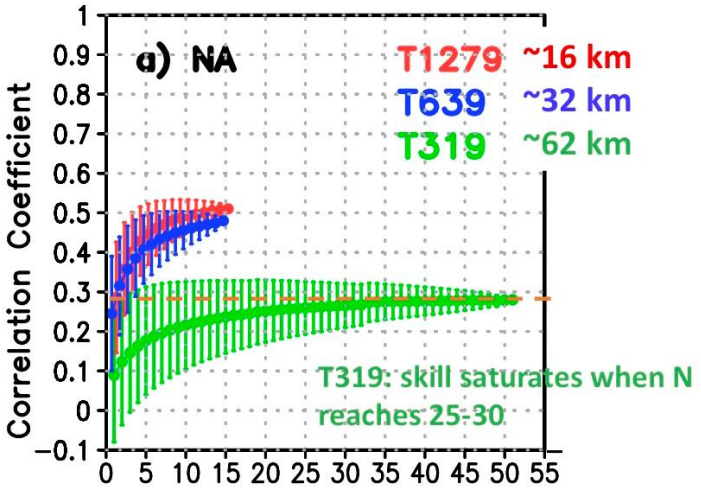


Characteristics of HFIP that led to its success with aggressive goals despite much slower progress before its inception and skepticism from some that it could succeed: Focus on operational outcomes, well-defined targets/metrics, recognition of the difficulty of the problem and realization that there was no single silver bullet that would meet these goals, leveraging the talents of all parts of the weather enterprise, and sufficient and sustained investment to enable progress.

Prediction Skill as a Function of Ensemble Size



Dynamical seasonal prediction using ECMWF System 4



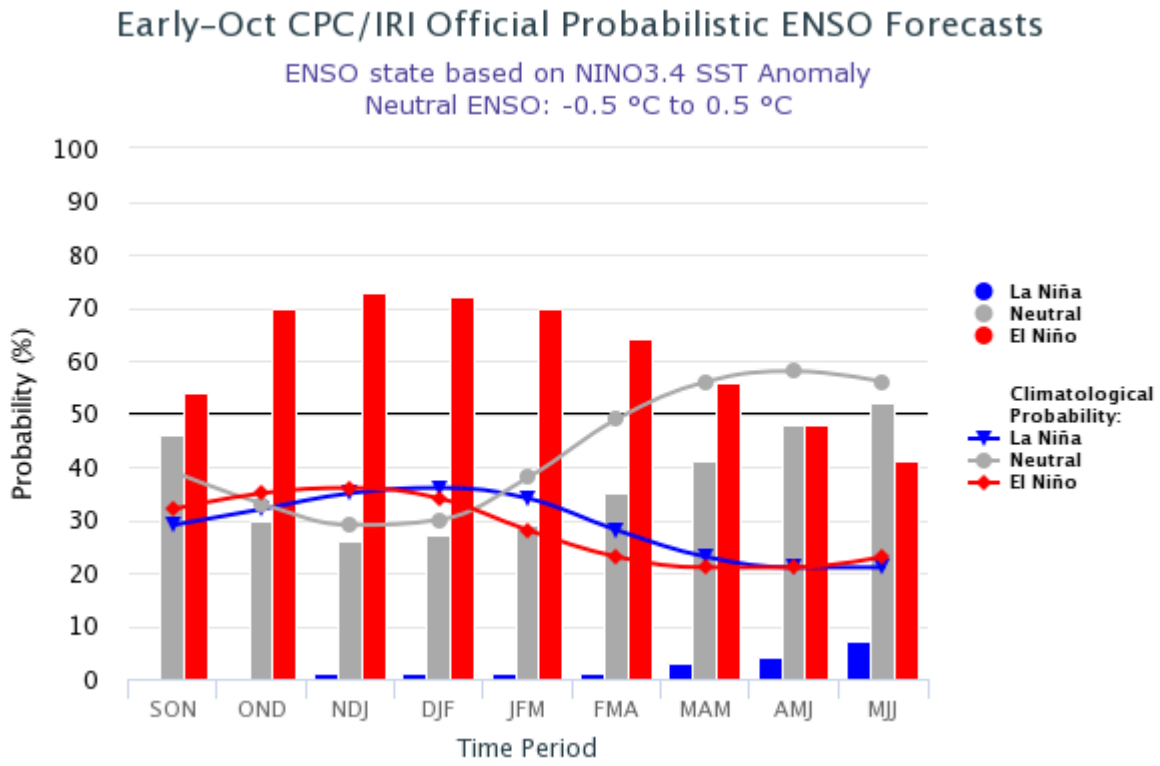
Manganello et al. (2016): Seasonal forecasts starting from May 1 for 1980-2011

The model skill increases sharply when the ensemble size is increased from 1 to 5, and saturates when the ensemble size is 15-20. The behavior is similar to the dynamic prediction by HR models.

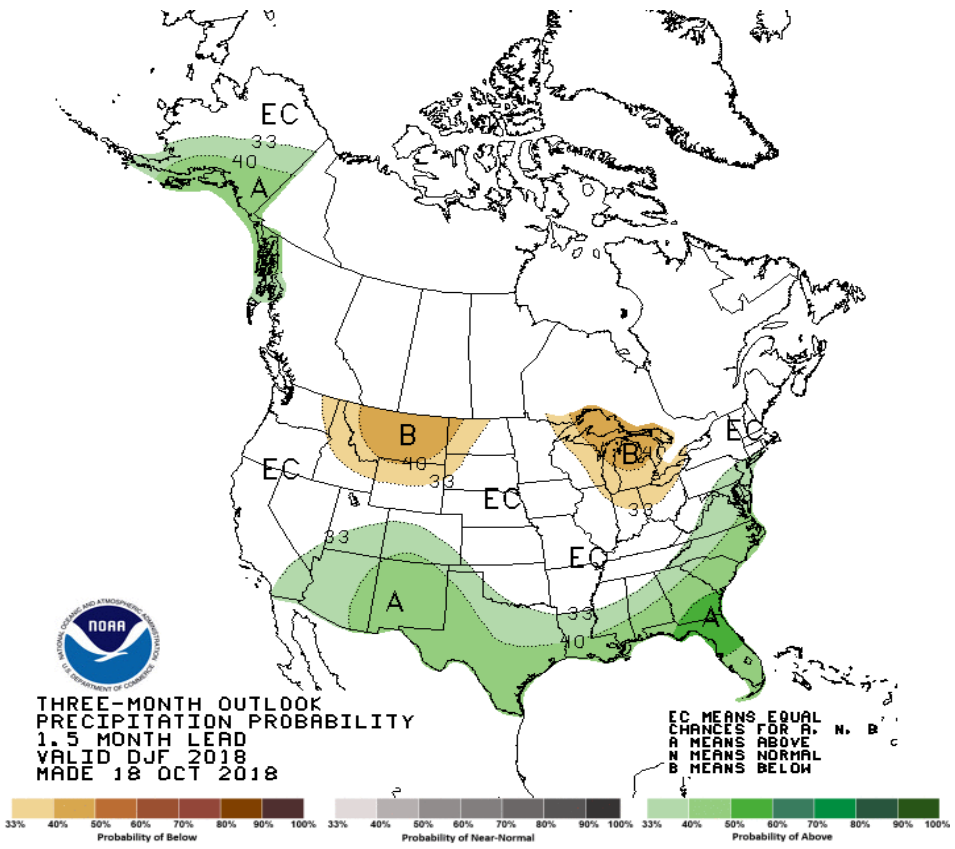
From Zhou Wang

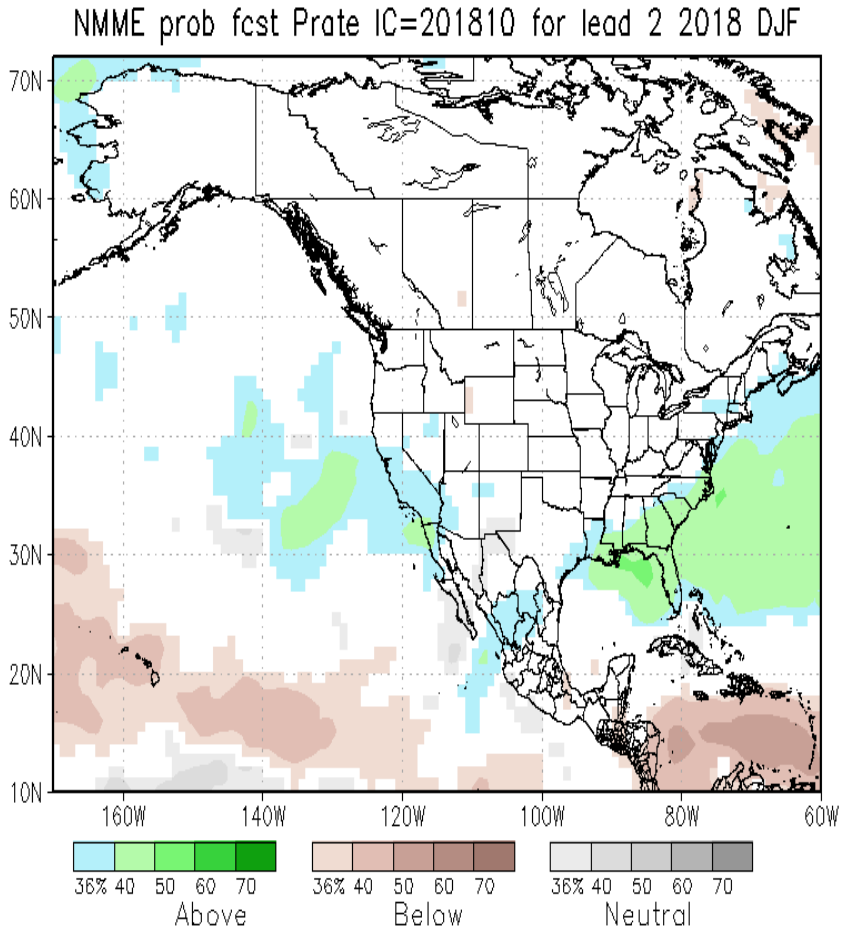
Hot Topics (October 29, 2018)

El Nino conditions are favored (~75%) during the Northern Hemisphere Fall. Current status is: El Nino Watch.



CPC DJF (Winter) Outlook for Precipitation

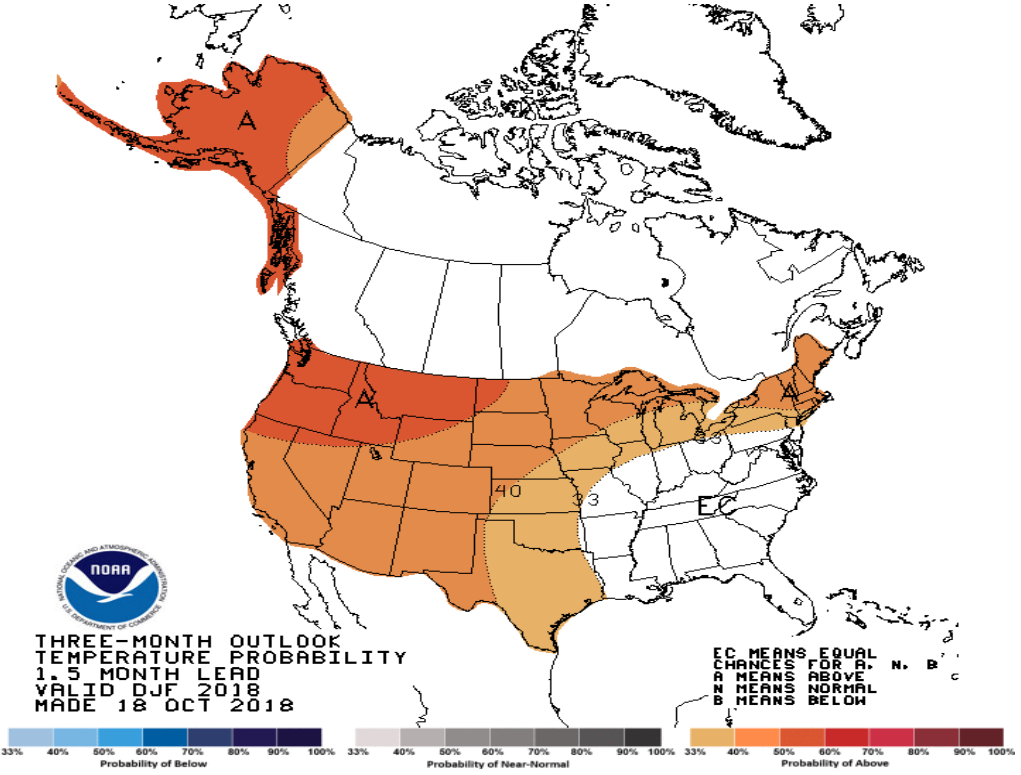


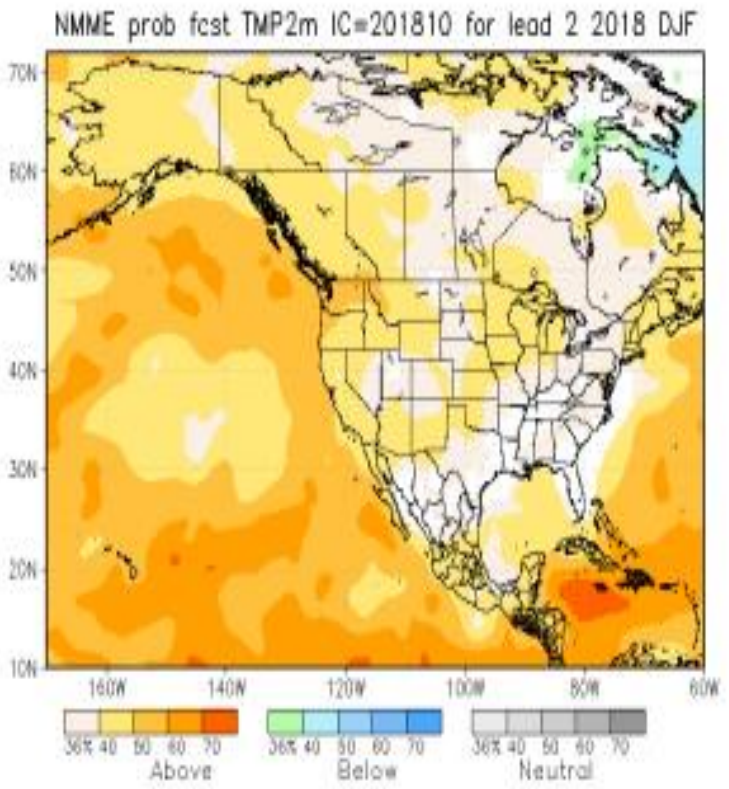


CPC Outlook

Calibrated NMME

CPC DJF (Winter) Outlook for Temperature





CPC Outlook

Calibrated NMME