Legislative and Programmatic Drivers for Improving Sub-Seasonal to Seasonal (S2S) Precipitation Forecast Skill

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Outline

- It is Great to be Here and See Everyone in Person
- Overview
- Current Legislative and Programmatic Drivers Relevant to Improving Sub-Seasonal to Seasonal (S2S) Precipitation Forecast Skill:
  - S2S Weather Bill Report
  - NOAA Science Advisory Board (SAB) Priorities for Weather Research (PWR) Study
  - Opportunities for Expanding and Improving CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC
  - Precipitation Prediction Grand Challenge (PPGC)
  - NOAA Weather, Water, and Climate Strategy
  - Department of Commerce Strategic Plan
- Establishing an End-to-End Research to Operations Enterprise to Enable Progress on Tough Problems Like Improving S2S Precipitation Forecast Skill
- Possible Way to Leverage Alignment with the Drivers in Order to Increase Their Chance for Success
- Final Thoughts

Overview

- Currently, there are several legislative and programmatic drivers that explicitly recognize the need to improve precipitation prediction forecast skill, including for the sub-seasonal to seasonal (S2S) timescale. There are also more general programmatic drivers that have themes that would support this goal.
- All of these documents have several critical common themes that are expressed explicitly or implicitly:
  - Focus on stakeholder/customer needs
  - Focus on high-impact problems, i.e. extreme events
  - Critical role of research to make progress
  - Need to partner across the weather, water, and climate enterprise in order to make progress
- This talk will provide an overview of these drivers/themes and suggest a possible alignment between the initiatives that focuses on improving S2S precipitation prediction forecast skill. This will be based on the current landscape.

S2S Weather Bill History, Status, Definitions

Bill

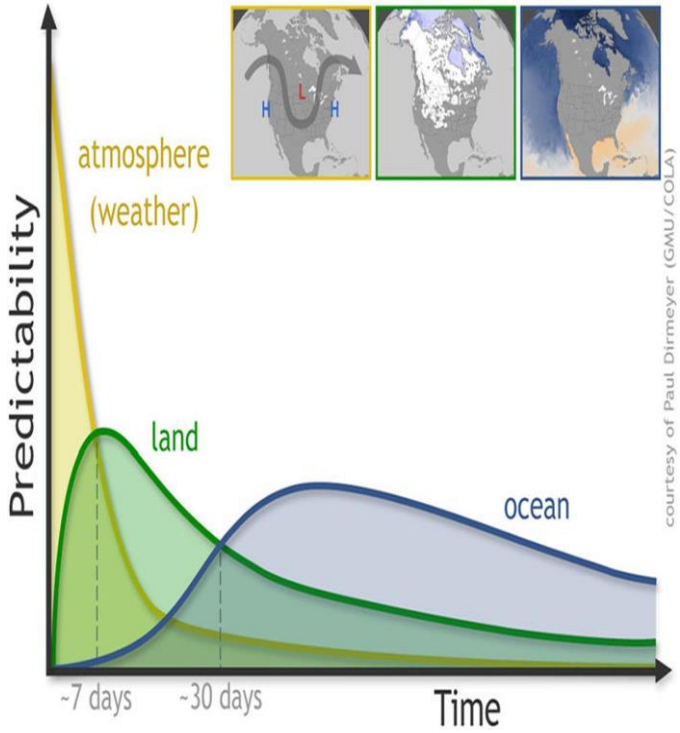
- **Required a report to Congress by October 2018.** Report was sent to Congress in early October 2020. The report is available here.
- **Defines sub-seasonal** as week two (day 8) to 3 months (first season), and seasonal as from 3 months to 2 years.
- **Bill was an authorization. To date there hasn't been an associated appropriation.**

Report to Congress

- **Serves as a guidepost for NOAA planning and execution**, as well as to inform the public and NOAA's stakeholders on its efforts on sub-seasonal and seasonal forecasting.
- **Two main goals of the report: Improve the skill of the S2S forecasts, and enhance the value of S2S products for stakeholders.**
- **One of the main themes of the report was need to improve S2S precipitation forecasts.** The goals of the report are in strong alignment with and superseded by the proposed Precipitation Prediction Grand Challenge (PPGC).

Key Contents of S2S Report to Congress

- Requirements for Improving S2S Products and Services
  - 4.1 Background
  - 4.2 Forecast Requirements
  - 4.3 Research Requirements
  - 4.4 Observational Requirements
  - 4.5 Monitoring Requirements
  - 4.6 Towards Improving S2S Capabilities, Usage, and Value
    - Unified Forecast System (UFS)
  - **4.7 Pilot Projects**



Innovation

To Address Key Areas Requiring Improvement from the S2S Report

- **Understanding/Estimating Limits of Predictability**
- **Drought Prediction Tools**
- **Unified Modeling Framework**
- **Madden-Julian Oscillation and Associated Teleconnections**
- **Coupled Data Assimilation**
- **Earth System Model Development**
- **Robust Community Participation: Earth Prediction Innovation Center (EPIC)**

The Earth Prediction Innovation Center – EPIC

Partnering with the Community for the Benefit of the Nation

Vision

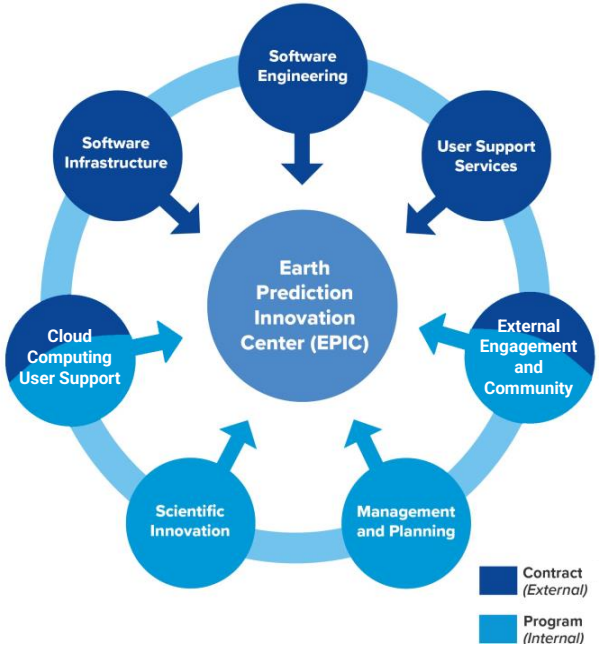
Enable the most accurate and reliable operational numerical forecast model in the world.

Mission

To be the catalyst for community research and modeling system advances that continually inform and accelerate advances in our nation's operational forecast modeling systems.

Strategy

- Modernize modeling infrastructure
- Provide Community Support
- Accelerate Community Innovations



FY21 Activities Include

- EPIC Community Center website
- 3rd Annual Cloud Workshop
- 2nd EPIC Community Workshop
- Community Modeling Symposium at AMS 102
- Documentation and release of cloud-based UFS code and Applications

S2S Modeling

- EPIC will provide infrastructure needed for UFS
  - Seasonal forecast system (SFS) and
  - Earth system components

Paradigm for S2S Pilot Projects (Strong Alignment with PPGC)

- Recognition of the difficulty of the problem and the fact that there is no single activity that will solve the problem.
  - Rather, compounding incremental improvement will lead to long-term measurable gains in forecast skill.
  - Increased investment addressing key skill and knowledge gaps (science challenges) will accelerate these improvements.

- Four regionally-focused pilot projects:
  - **Winter S2S precipitation forecasts for water management in the western United States**
  - **Spring and summer S2S precipitation forecasts in the central United States**
  - S2S forecasts of Arctic Sea Ice
  - S2S forecasts of tropical cyclone activity

Paradigm for Pilot Projects (continued)

- Well-defined metrics and timelines for evaluating success that are co-developed with the relevant stakeholder communities.
- Recognition of the need to focus on operational outcomes, i.e. not research for research's sake.
- **Sufficient sustained investment in all required aspects of the problem, including human resources, high-performance computing, observing systems, and transition of research innovations to operations.**
- **Leveraging the talents of all parts of the weather enterprise, including NOAA labs, other federal agencies, the research community, and relevant NWS operational centers.**
- **Recognition that making progress on this problem will require allowing some higher-risk, higher-reward research, i.e. allowing scientists to be more creative but still focused on operational outcomes. "Managing the tension between research push and operational pull."**
- Tying science priorities to key decision points for the relevant stakeholder communities.

Pilot Project Science Challenges

- Given the important role and deficiencies in current prediction systems, it was recognized that a deep-dive on tropical convection, oceanic and atmospheric boundary layers, and air-sea interaction was important to all of the pilot projects.
- **Specific science challenges for improving winter western precipitation forecast skill:**
  - Inadequate model resolution (horizontal and vertical) to resolve the mountainous terrain.
  - Fidelity in modeling of the atmospheric boundary layer in mountainous regions.
  - Inability to predict periods of blocked versus unblocked flow over the eastern Northeast Pacific Ocean and Western U.S. .
- **Specific science challenges for improving spring and summer precipitation forecast skill for the central US:**
  - Lack of observations and inaccurate modelling of the land surface and hydrologic cycle, especially soil moisture and the processes leading to flash drought.
  - Improved fidelity in modeling of warm season precipitation processes.
  - Understanding and prediction of large-scale upper-level dynamical flow anomalies that occur in this region at this time of year.

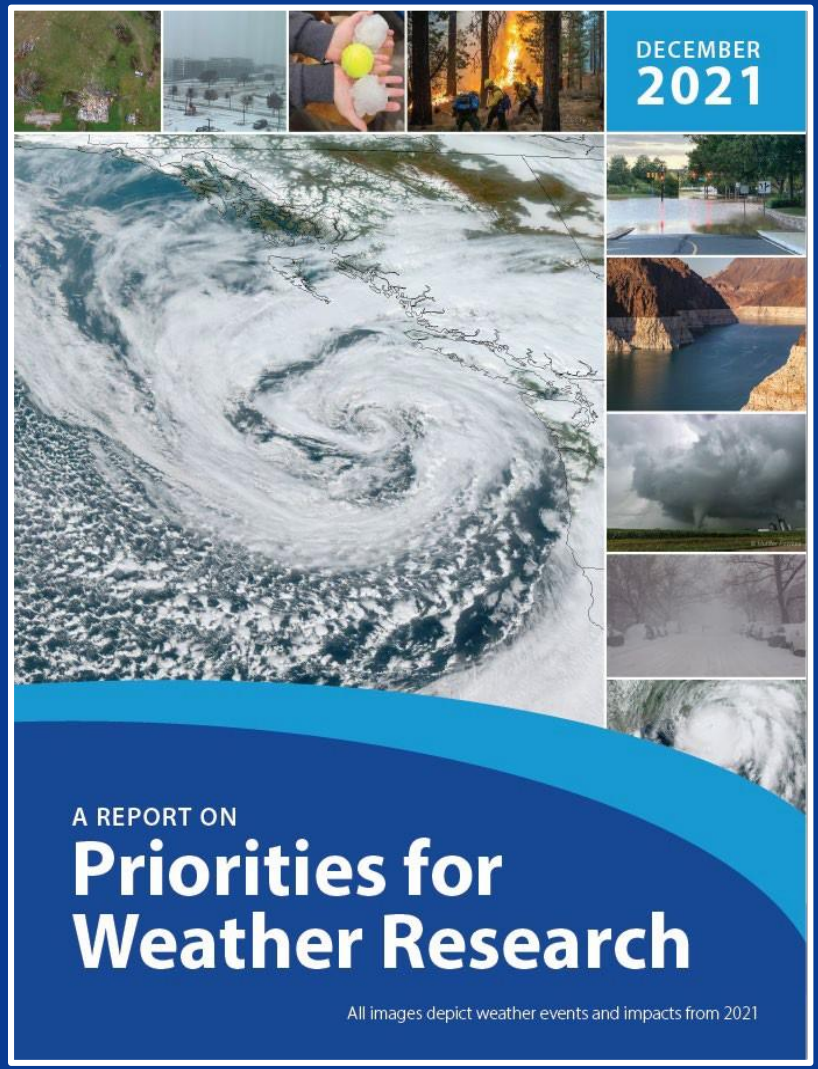
PWR Report Draft Posted on SAB Website

https://sab.noaa.gov/wp-content/uploads/2021/12/SAB_MtgPres_Dec2021_PWR_12_6_21_Final.pdf

Table of Contents

- Section 1: Executive Summary
- Section 2: Charge & Overview
- Section 3: Introduction
- Section 4: External World
- Section 5: Narrative Themes
- Section 6: Pillars
- Section 7: Foundational Elements
- Section 8: Immediate First Steps
- Section 9: Future Engagement
- Appendices I - VII

NOAA SAB 2021



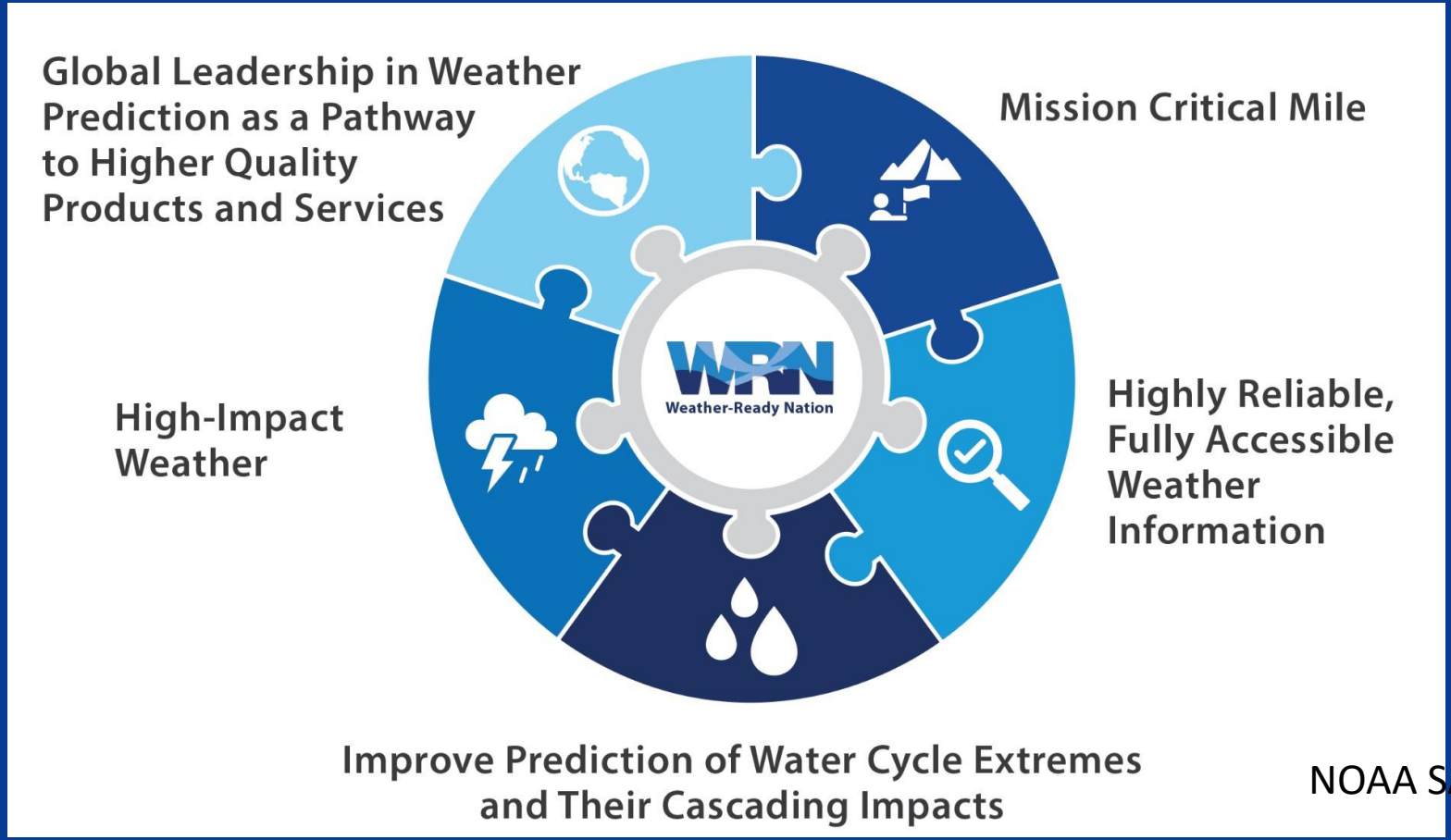
December 2020 - An Urgent Directive from Congress

Report on Weather Research Priorities - *In lieu of House language on a Weather Decadal, the agreement directs* ***NOAA's Science Advisory Board*** *to* ***publish a report****, not later than* ***one year*** *after enactment of this Act, that provides policymakers with the* ***relevant information necessary to prioritize investments*** *in weather forecasting, modeling, data assimilation, and supercomputing over the next ten years; and that* ***evaluates future potential Federal investments*** *in science, satellites, radars, and other observation technologies, to include surface and boundary layer observations so that all domestic users of weather information can receive data in the most efficient and effective manner possible.*

NOAA SAB 2021

- From the FY21 Omnibus (Dec 2020) Appropriations Act

Five Narrative Themes Illustrate Value



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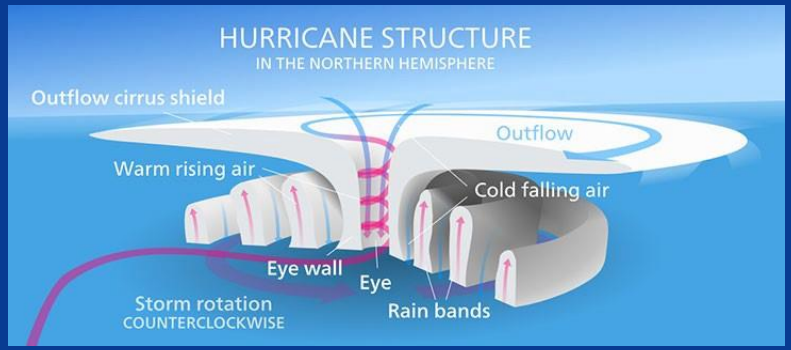
Actions and Impacts

Support **reanalysis and reforecasting** to support model evaluation and improvement, and for artificial intelligence (AI) product applications



Target **high-impact weather** to match the urgent need imposed by climate trends, population and infrastructure increases, and disproportionate impacts on vulnerable communities

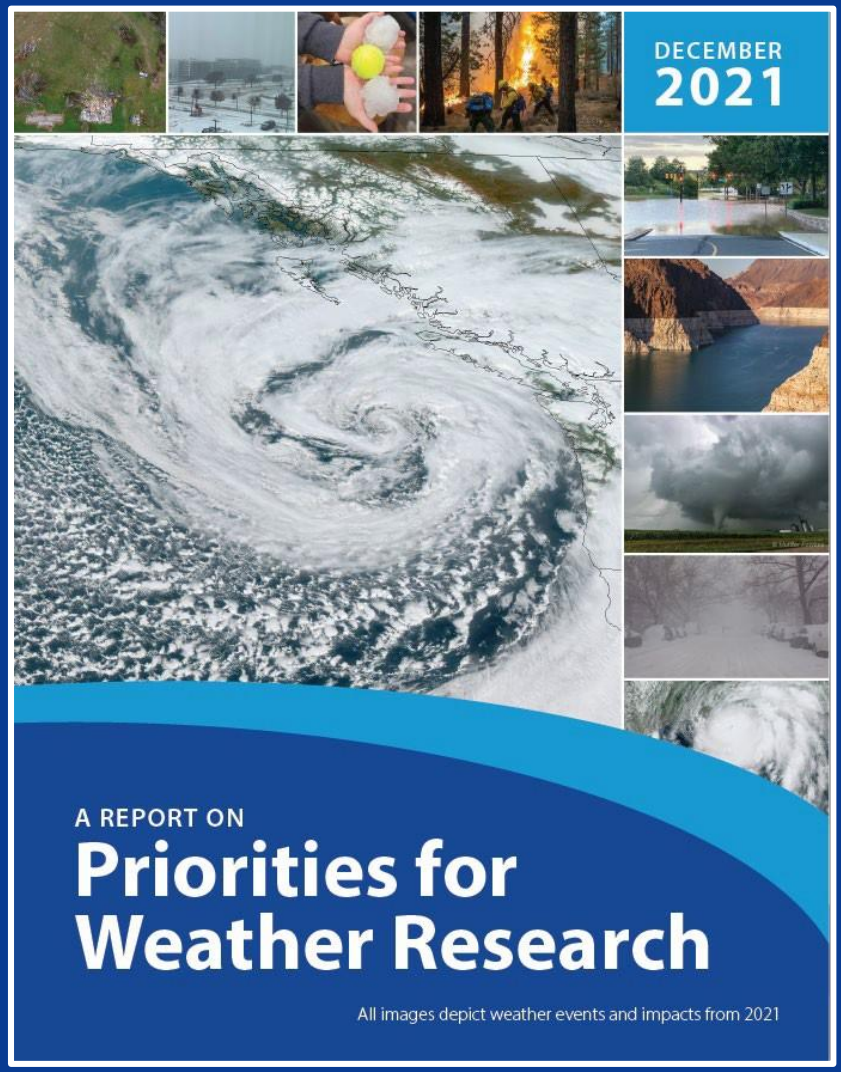
Target **water cycle extremes** to improve flood and drought prediction and to enable forecast-informed reservoir operations

NOAA SAB 2021

Summary Overview

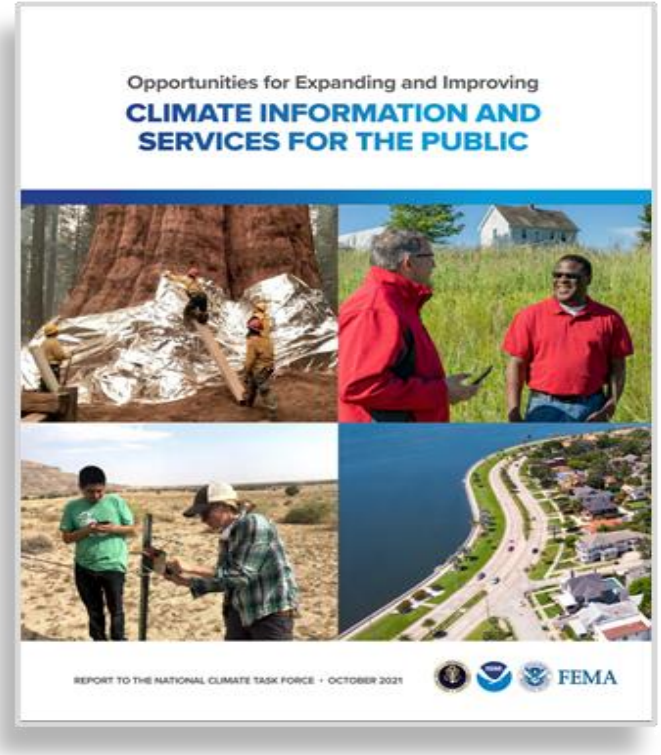
- PWR is a **comprehensive** report that is focused on decadal priorities and builds upon existing programs
- It is a **community consensus** that delivers the requested information
- Taken as a whole, the balanced investments will be **transformative**
- It is an urgent **call to action!**

NOAA SAB 2021



Inter-Agency (Cross-Government) Climate Services

- A report/white paper on a strategy for climate services was produced circa 2021 by senior officials from the White House (Office of Science and Technology (OSTP)), NOAA, and FEMA: "**Opportunities for Expanding and Improving CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC**"



US Climate Services: High-Level Strategy

- Cross-government (inter-agency) climate services will be a matrixed capability leveraging contributions from existing organizations.
- NOAA contribution to climate services will be a matrixed capability leveraging contributions from existing organizations.
- Collaboration across agencies and within NOAA is a foundational principal for developing and delivering climate services.

Recommendations from White House Report on **Opportunities for Expanding and Improving CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC**

- **Recommendation 1:** Focus climate services on the challenges that pose the greatest risks and opportunities to society.
- **Recommendation 2:** Foster interagency coordination and strategic public-private partnerships to develop, deliver, and continually advance climate services.
- **Recommendation 3:** Enhance the usability, translation, and relevance of climate services to support use by all Americans.
- **Recommendation 4:** Strengthen core science capabilities needed to expand and improve climate services.

Implementation Guidance from White House Report on **Opportunities for Expanding and Improving CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC**

- Addressing these recommendations will require increased coordination across multiple Federal agencies to accelerate the development of new knowledge and more actionable services, and to deliver those services effectively and efficiently with a user-driven approach.
- A seamless spectrum of climate services, spanning different decision-relevant spatial scales and timescales, is needed to support preparedness for the next disaster and resilience to long-term climate-related impacts.
- There is also a need to improve the accessibility and utility of U.S. Government climate information, which can be difficult to navigate and is not always designed at the scale or in a format that enables effective decisions.
- Climate services should be based on the best-available science, developed in a way that is understandable, actionable, credible, relevant, and communicated clearly.

NOAA Strategy
Precipitation Prediction Grand Challenge

Provide more accurate, reliable, and timely precipitation forecasts across timescales, from mesoscale weather, through week 3-4, S2S, to S2D through the development and application of a seamless, fully coupled Earth System prediction model.

Interconnected Objectives

Enhance and sustain user engagement

Advance understanding of precipitation predictability

Improve process-level understanding and modeling

Sustain, enhance, and exploit observations

Improve prediction systems for precipitation

Improve precipitation prediction products and applications

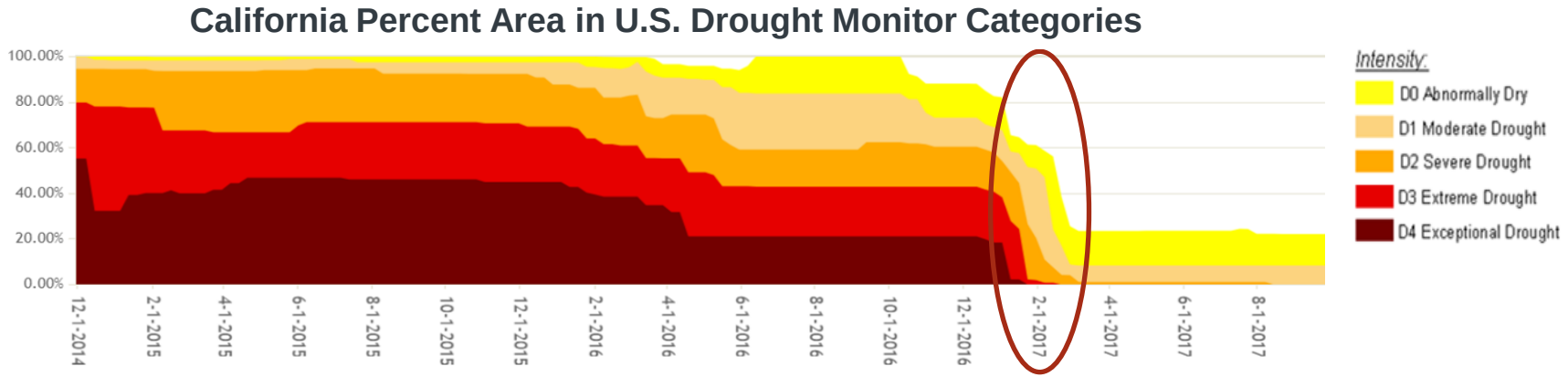
Users as the Driver

Key sectors that stand to benefit significantly from pursuing the PPGC, and related improvements in water prediction:[1]	Improved precipitation and water prediction will better inform decisions, across all time scales, related to challenges associated with:[2]
1. Emergency Management 2. Water Supply/Reservoir Management 3. Ecosystem Management 4. Agriculture 5. Hydropower 6. Recreation 7. Transportation	1. Floods 2. Droughts 3. Water availability 4. Water quality 5. Ice formation and melt* 6. Climate variability and change

Source[1]: U.S. Water Information in the 21st Century: A Conversation on Integrated Information and Services
Source[2]: 2012-2013 River Basin Commission Stakeholder Engagements and Regional Water Conversations

S2S Precipitation Prediction Challenge: Regime Transition

Failure to Predict Drought Amelioration



Transitioned from multi-year severe drought to near-normal conditions with record flooding over ~60 days

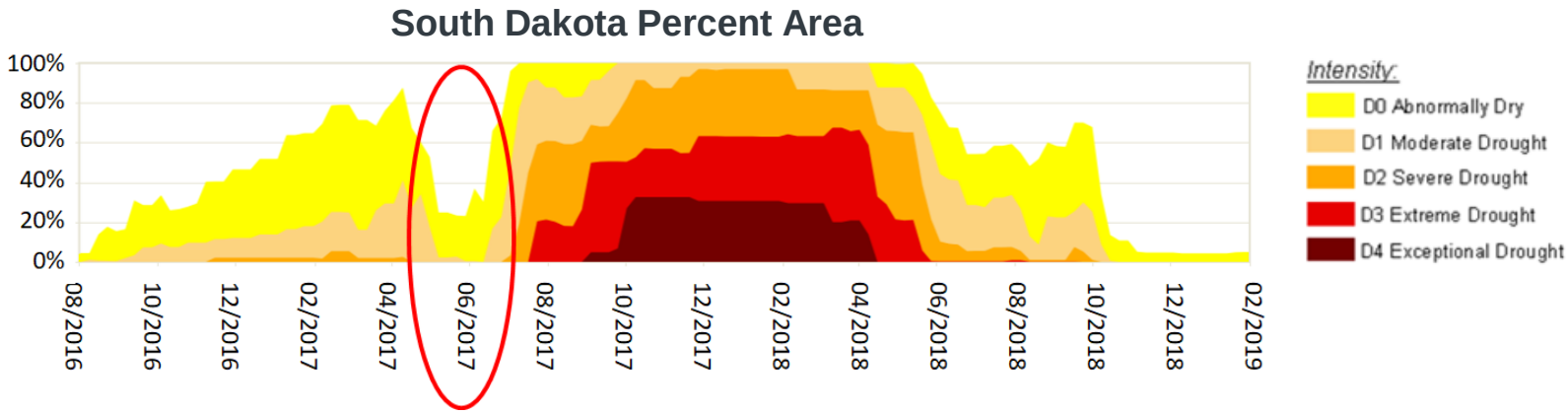
Science challenges for improved winter precipitation in this case for the southwest US include:

- Understanding why the persistent west coast ridge broke down despite La Nina conditions
- Potential role of other tropically-forced teleconnections.

All models failed to predict this transition of the large scale atmospheric state and subsequent heavy rains beyond about two weeks lead.

S2S Precipitation Prediction Challenge: Regime Transition

Failure to Predict Flash Drought Onset



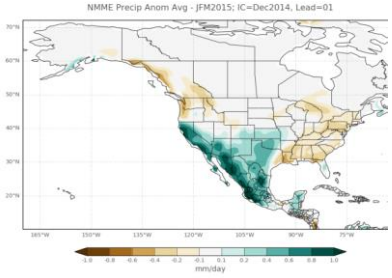
Transitioned from near normal conditions to severe drought over a ~60 day period.

Science challenges in this case for improved spring/summer precipitation for the Northern Plains include:

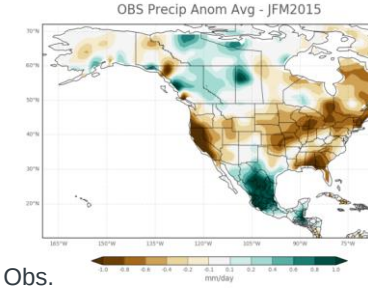
- Land-atmosphere interactions
- Warm-season continental convection

All models failed to predict the onset of this drought beyond about two weeks lead-time.

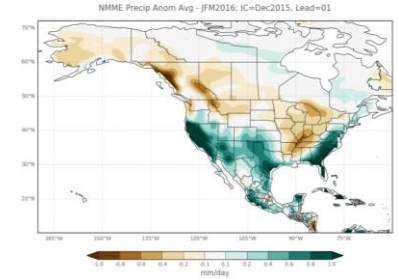
Key Science Gap: Inability to Predict Seasonal Variability Beyond the Canonical ENSO Response



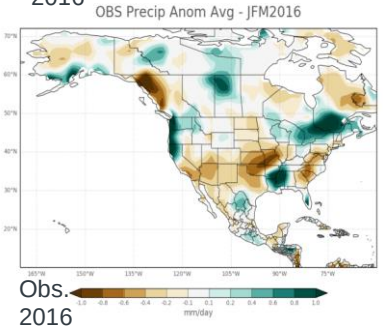
NMME 2015



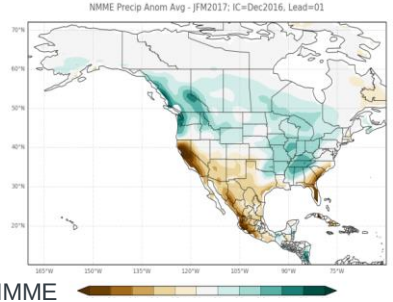
Obs. 2015



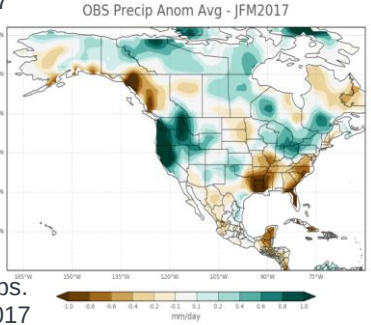
NMME 2016



Obs. 2016



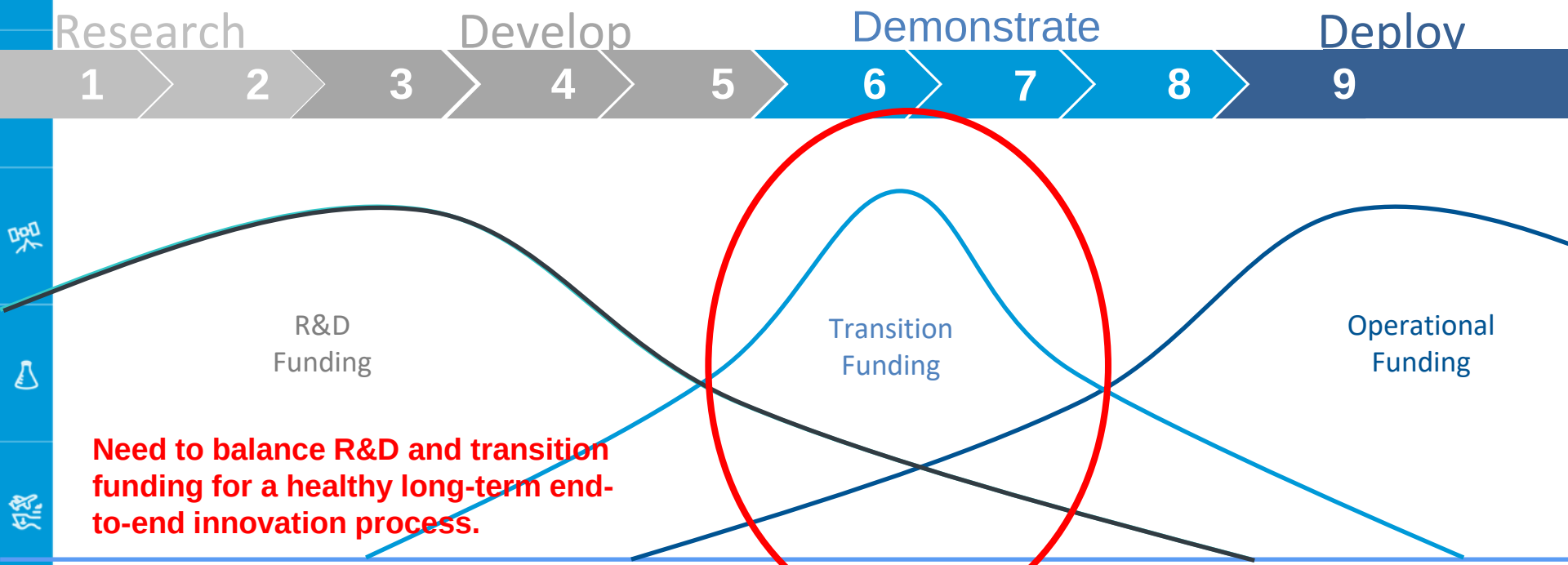
NMME 2017



Obs. 2017

State of the art NMME first season precipitation forecasts for winters of 2014-2017 were consistently of wrong sign over California and most of the west as they were dominated by a canonical ENSO response.

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)



Need to balance R&D and transition funding for a healthy long-term end-to-end innovation process.

Possible Way to Leverage Alignment with the Drivers in Order to Increase Their Chance for Success

- All the legislative/programmatic documents emphasize the following priorities:
  - Focus on stakeholder/customer needs
  - Focus on high-impact problems, i.e. extreme events
  - Critical role of research to make progress
  - Need to partner across the weather, water, and climate enterprise in order to make progress
- Currently the drivers receiving the most attention and internal support are the Precipitation Prediction Grand Challenge (PPGC) and the PWR Study. Therefore, it makes sense to show how any proposed activities map into the specific language of these initiatives.

Final Thoughts/Personal Perspective

- Improving S2S precipitation forecast skill will require the following:
  - Compounding incremental improvement, i.e. there is unlikely to be a single, highly transformative technological innovation.
  - Sufficient sustained investment in all required aspects of the problem, including human resources, high-performance computing, observing systems, and transition of research innovations to operations.
  - Recognition that making progress on this problem will require allowing some higher-risk, higher-reward research, i.e. allowing scientists to be more creative but still focused on operational outcomes. "Managing the tension between research push and operational pull."
  - Close coordination with stakeholders and collaboration across the weather, water, and climate enterprise.