NOAA's Precipitation Prediction Grand Challenge

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Precipitation Processes and Predictability Workshop
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Outline

- Why a “Precipitation Prediction Grand Challenge”?
- Ongoing NOAA planning activity
- Partnerships are required for success

Why: Every person and business in the United States at almost every timescale needs to know when, where, and how much it will rain

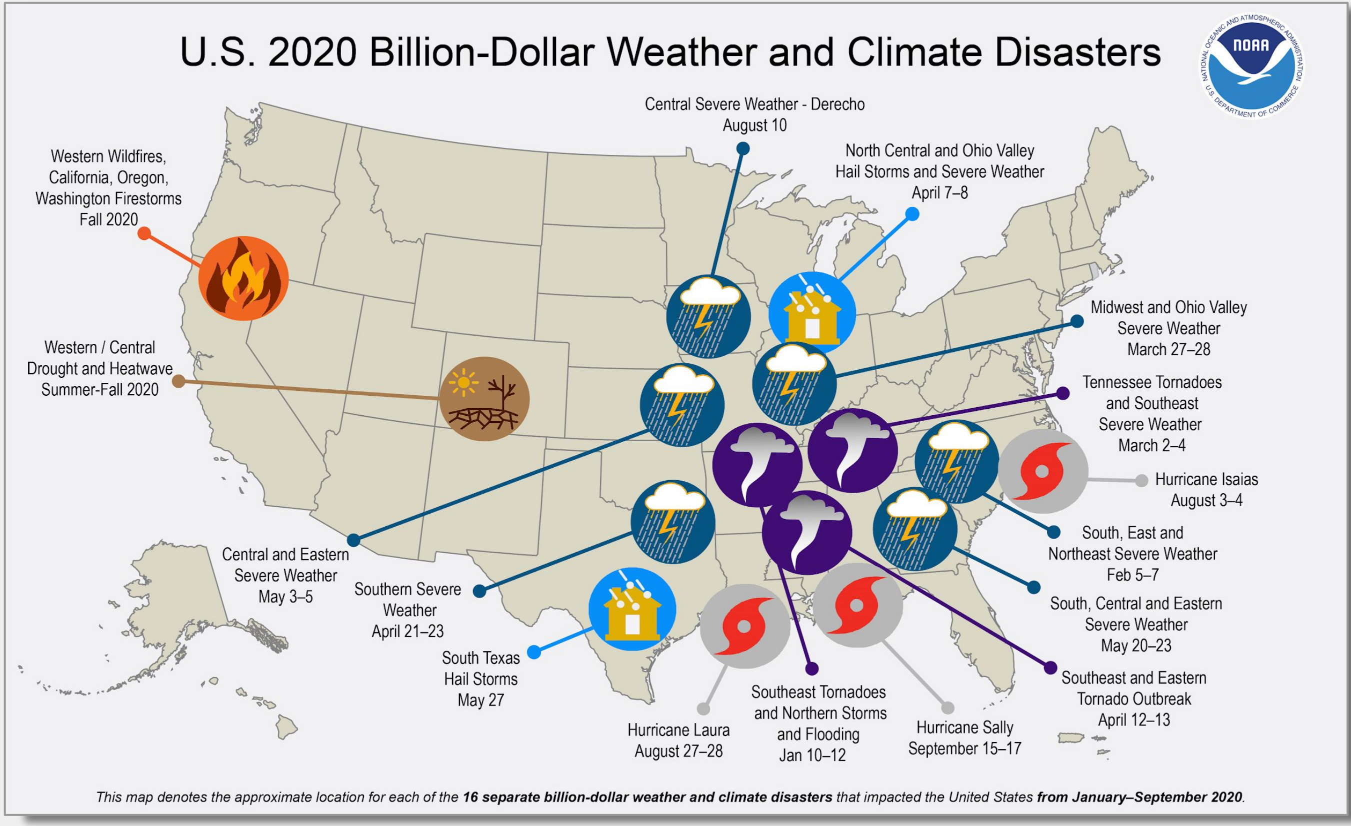
Why a Precipitation Prediction Grand Challenge?

- Builds off of the WMO 2010 call-to-action for the weather and climate disciplines to work together (see 3 BAMS Papers on Backup Slide)*
- The Weather Research and Forecasting Act of 2017 calls on NOAA to "collect and utilize information in order to make usable, reliable, and timely foundational forecasts of subseasonal and seasonal **temperature** and **precipitation**"
- Involves all of NOAA's Line Offices working together to address R&D challenges from mesoscale weather to global climate prediction
- The research activity is designed to transition into the operational modeling framework to support national services for societal benefits
- Includes the operational and research communities

Source: Weather Research and Forecasting Act of 2017

Driven by Extremes

- As of October 7, there have been 16 weather and climate disasters with losses exceeding $1B each
- The 1980–2019 annual average is 6.6 events (CPI-adjusted)
- Record number of landfalling tropical cyclones in the Atlantic basin (10 landfalling storms)
- 2020 is the most active fire year on record for the West Coast, with more than 5 million acres burned



Source: https://www.ncdc.noaa.gov/billions/

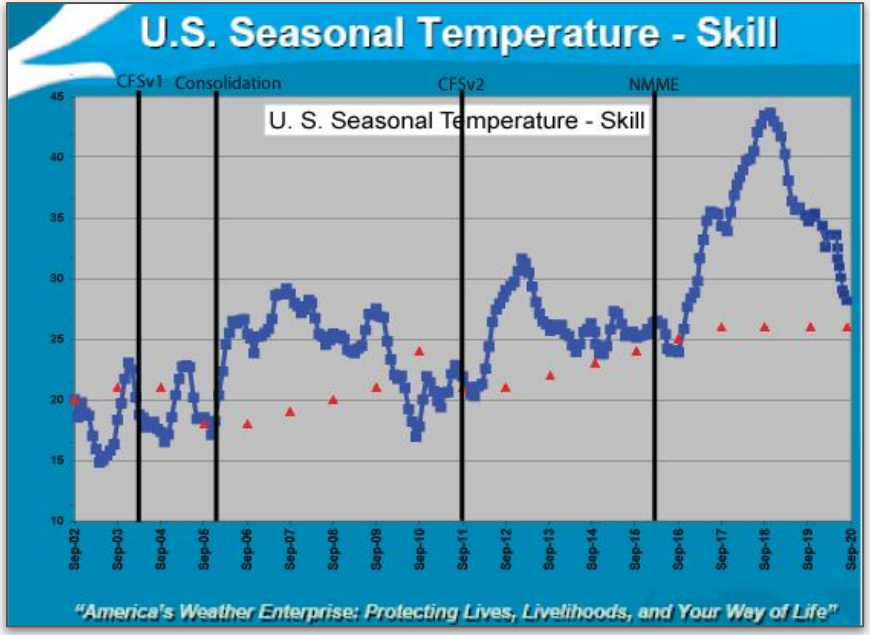
At Issue: Systematic Errors in Models

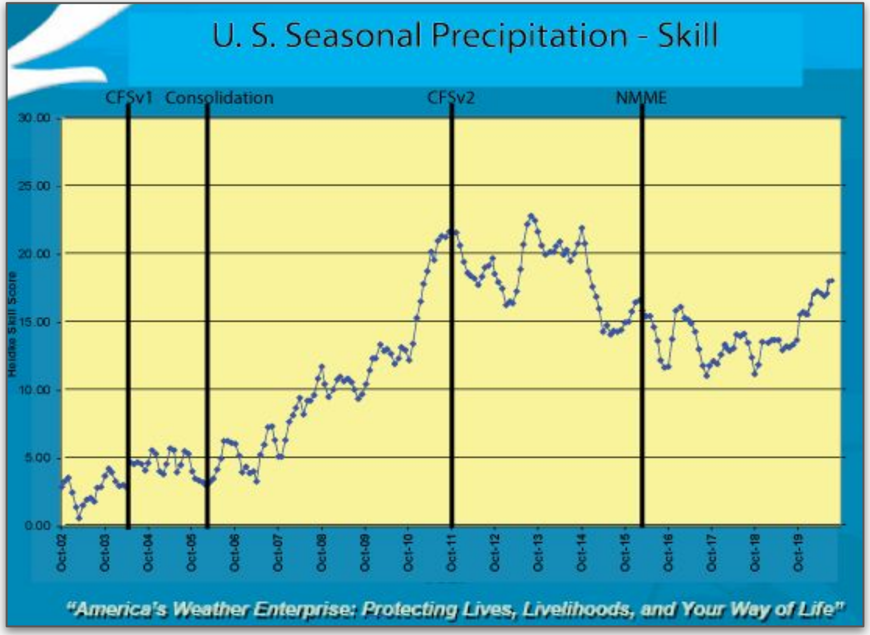
Today's state-of-the-art models exhibit systematic errors that are as large as the real precipitation signal NOAA is trying to model, and the magnitude of these errors (especially in global models) has remained essentially the same since the late 1990s.

Error characteristics are the same for **<u>all</u>** global models in the world, regardless of applications.

Source: Dr. David DeWitt, Director, Climate Prediction Center

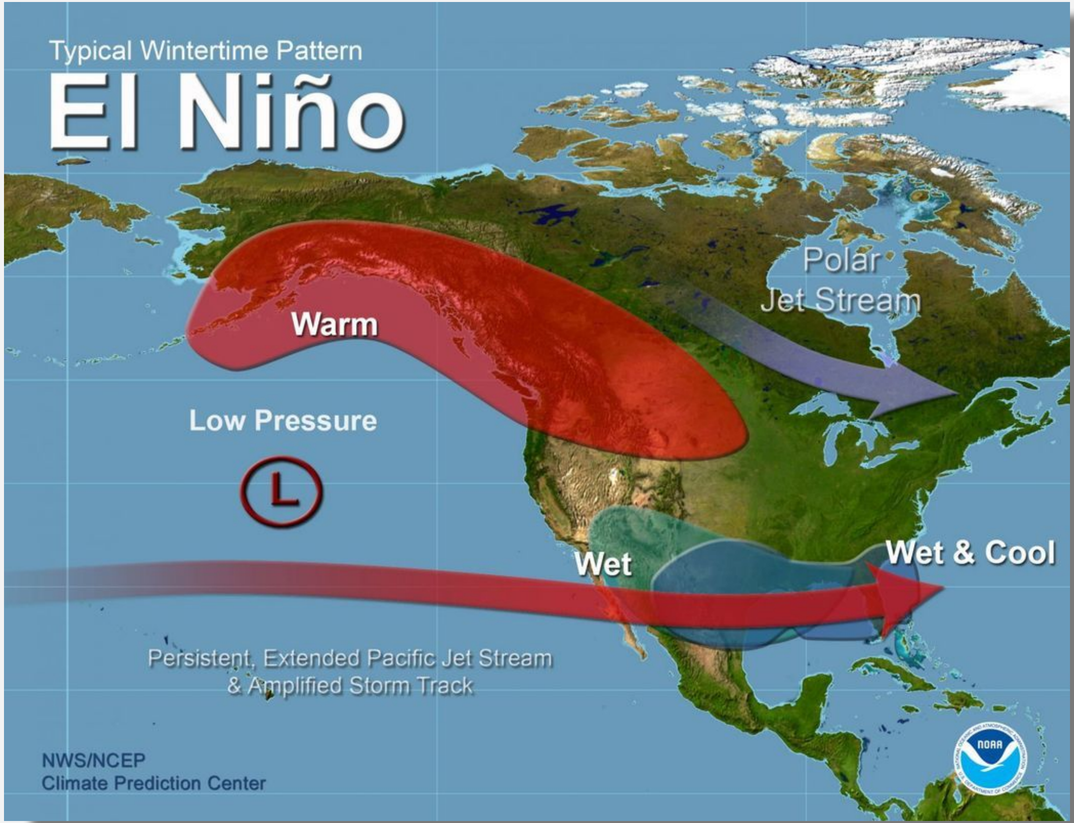
NWS GPRA Measures



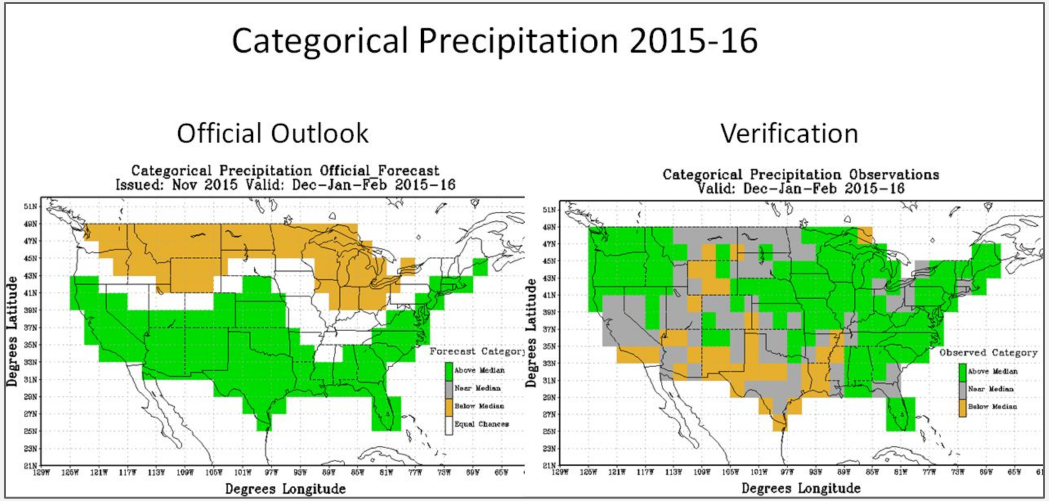


Source: NWS Climate Prediction Center

El Niño Ideal Scenario



2015-2016 El Niño Prediction



- **Winter Precipitation Prediction**: the major El Niño event of 2015/16 would lead to above normal (below normal) precipitation in the Southwest (Pacific Northwest) ameliorating the ongoing drought conditions in CA.
- **Winter Precipitation Observed**: the opposite of the canonical El Niño pattern

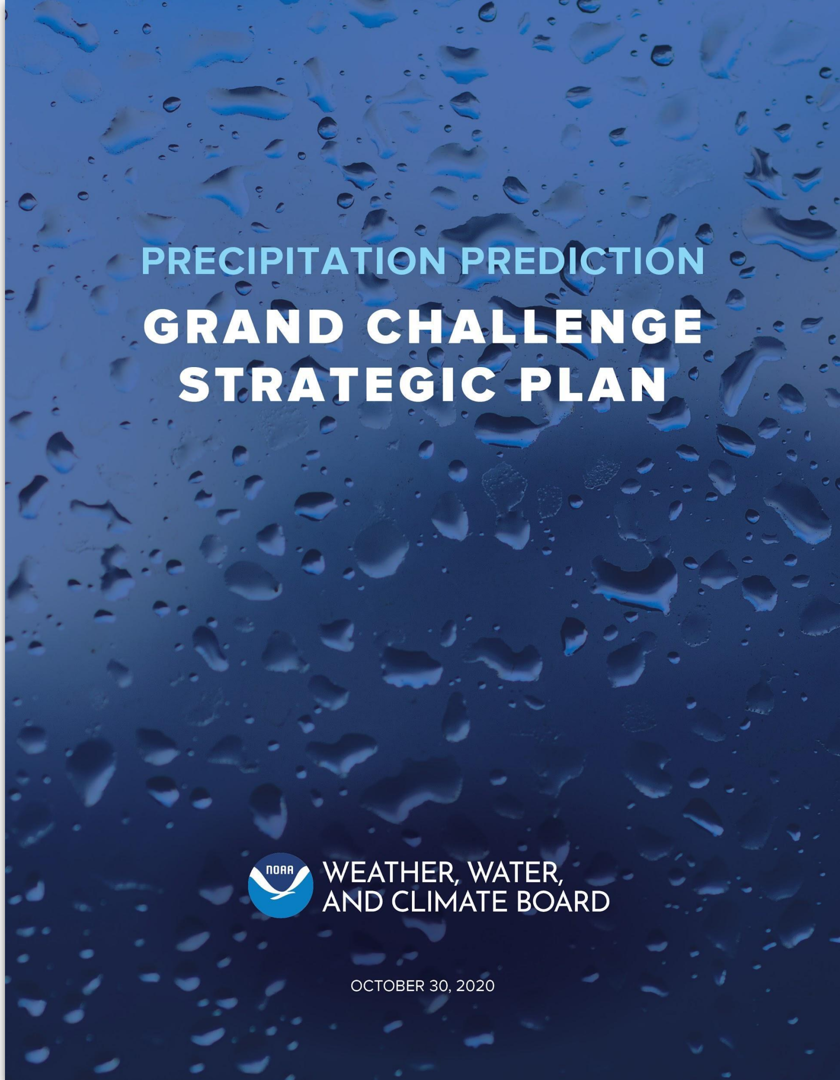
- Cash and Burls (2019) documented a statistically significant positive correlation between El Niño events and the Southern California and Pacific Northwest rainfall anomalies, but this relationship explains at most **one-third** of the observed variance
- Further, Cash and Burls found that much of the winter rainfall variability along the U.S. West Coast is dominated by unpredicted variations in the 200-hPa height field and that this same unpredicted variability was largely responsible for the unexpectedly dry conditions in 2015/16

Source: [Journal of Climate]

“A frontier in forecasting involves extending the capability to skillfully predict environmental conditions and disruptive weather events to **several weeks and months** in advance, **filling what has long been a gap** between today’s short-term weather and ocean forecasting capabilities (within the next 14 days) and a growing ability to project the longer-term climate (on scales of years to decades or more).”

— National Academies, *Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts* (2016)

NOAA’s Response: The Precipitation Prediction Grand Challenge



Developing a NOAA Strategy

In November 2019, the **NOAA Weather, Water, and Climate Board established the Precipitation Prediction Grand Challenge (PPGC) Working Group** to develop a NOAA strategy for accelerating improvements to global models that will lead to increases in precipitation prediction skill, and that will translate these improvements into more effective decision support.

The PPGC Working Group has participation from across all of NOAA's Line Offices

- Oceanic and Atmospheric Research
- National Environmental Satellite, Data, and Information Service
- National Ocean Service
- National Marine Fisheries Service
- National Weather Service

Goal of the 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.

Expected Advancements from Achieving that Goal

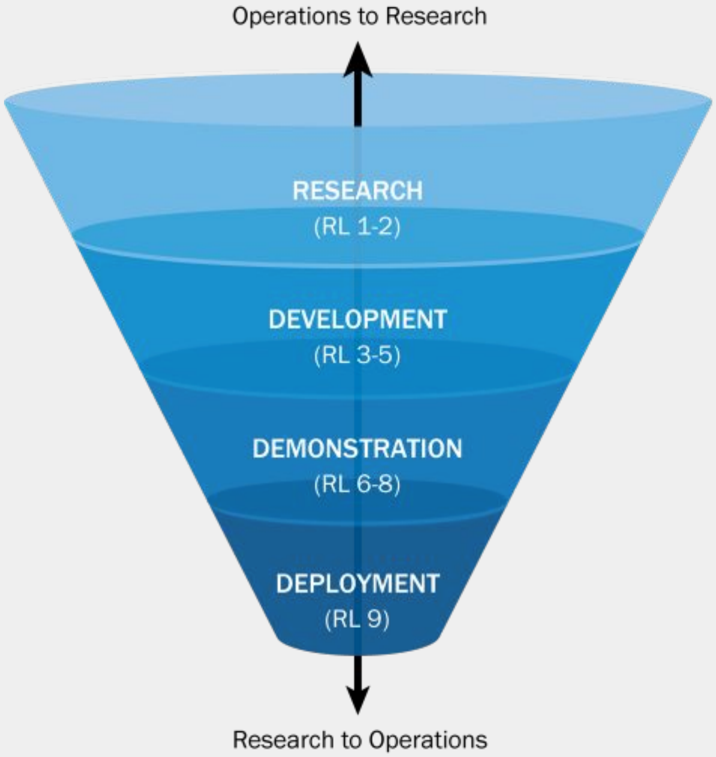
NOAA's research is aligned across all readiness levels (research, to operations, to services) and timescales (from mesoscale to S2S to S2D), resulting in:

1. Effective engagement, development, and delivery of decision-support tools and services based on this improved skill

2. Improved operational precipitation prediction skill

3. A significant reduction in systematic errors in NOAA global models

4. Improved process understanding



Why Now?

- The patchwork approach is not working
- Legislative mandate // 2017 Weather Act
- FY2022 OSTP/OMB Guidance
- User Needs

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

Working Group Writing Teams

Writing Team	Lead
Team 1: User Needs	Ellen Mecray (NESDIS)
Team 2: Model Limitations	Dave DeWitt (NWS)
Team 3: Research Questions	Jin Huang (OAR)
Team 4: Accelerating R2O2S	Dave McCarren
Team 5: Observation Systems	Howard Diamond (OAR)
Team 6: Post Processing	Dave Novak (NWS)

Key Questions

1. What are the major systematic errors in precipitation prediction systems?
2. What are the key physical processes imprinting on model biases?
3. How can systematic errors in precipitation forecasts be fixed/reduced?
4. Which systematic errors should be fixed first?
5. What are lessons learned from previous successes and mistakes?
6. What major gaps persist regarding precipitation processes and prediction?
7. What new capabilities may reduce systematic errors and improve precipitation prediction?
8. How can NOAA best organize activities within the agency, and across the federal, academic and private research enterprise to make significant progress?

Addressing Systematic Errors

- Timing and magnitude of the precipitation diurnal cycle
- Mid-latitude warm surface temperature simulation
- Predicted precipitation amount
- Phase speed of mid-latitude troughs
- Propagation errors of convection
- Sub-seasonal tropical variability
- West coast winter steering flow on sub-seasonal timescales
- Regime transition: Predicting flash drought onset
- S2S sea surface temperature forecasts
- Time Mean Statistics of Large-Scale Precipitation Forecasts
- Double ITCZ
- El Niño Southern Oscillation false alarms
- Sea ice prediction
- Quasi-Biennial Oscillation
- S2D variability

Specific objectives detailed in the Precipitation Prediction Strategic Plan:

- Enhance and sustain user engagement
- Improve precipitation prediction products and applications
- Improve prediction systems for precipitation
- Sustain, enhance, and exploit observations
- Improve process-level understanding and modeling
- Advance understanding of precipitation predictability

Biggest Pushes

1. Improve end-user products through continuous user engagement and social science to more effectively communicate the forecast
2. Assimilate and integrate data, then regularly produce supporting datasets, including reanalyses and reforecasts
3. Address global model systematic errors
4. Establish traceability of error sources
5. Change the paradigm and target regions around the globe that host sources of prediction predictability
6. Improve global water vapor and boundary layer observations

The Impact: Improved process understanding and operational precipitation prediction skill; reduction in systematic errors; better decision-support tools and services

Next Steps

- NOAA's Precipitation Prediction Grand Challenge has been reviewed by its Science Advisory Board and approved by NOAA and is ready for broader review
- At NOAA's Line Office level, the WWCB will work towards preparing a budget plan for this effort
- Is the time right to develop a Global Earth System Science Research Program?

Next Steps

- **USGCRP** // Activities to support Earth System Predictability are in development following the 2020 USGCRP Annual Meeting, especially as part of the Integrated Water Cycle Group workstreams (e.g., US GEWEX; IHTM, etc.).
- **USGCRP-WCRP** // A North American Consultation between USGCRP and the World Climate Research Program (WCRP) is in development and precipitation prediction is a likely topic of discussion.
- **U.S Climate and Earth Modeling Summit** // The theme for the 2021 U.S Climate and Earth Modeling Summit is predictability. This may focus on linking modeling and observations to improve S2S prediction.
- **Earth System Predictability Fast Track Action Committee** // Activities to support the Earth System Predictability Fast Track Action Committee are in development to pull together interagency commitments, and develop commitment to using the R2O2R approach.

"Earth system science is bigger than any particular agency, it's bigger than any single nation, it's bigger than any single continent and I surely hope, because humanity requires it, that we make some significant progress in understanding."

— Mike Freilich, Director of NASA's Earth Science Division
(*Tribute to NASA Earth Trailblazer*, August 5, 2020)

QUESTIONS?

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Backup Slides

October 2010

The 2010 BAMS articles are available here.

BAMS

Bulletin of the American Meteorological Society

VOLUME 91, NUMBER 10, OCTOBER 2010

IN BOX

1357 **EC-Earth**
A Seamless Earth-System Prediction Approach in Action
W. HAZELEGER ET AL.

ARTICLES

1365 **Verifying Forecasts Spatially**
E. GILLELAND ET AL.

1377 **An Earth-System Prediction Initiative for the Twenty-First Century**
M. SHAPIRO ET AL.

1389 **Addressing the Complexity of the Earth System**
C. NOBRE ET AL.

1397 **Collaboration of the Weather and Climate Communities to Advance Subseasonal-to-Seasonal Prediction**
G. BRUNET ET AL.

1407 **Toward a New Generation of World Climate Research and Computing Facilities**
J. SHUKLA ET AL.

Media-enhanced article available in the BAMS Digital Edition (www.ametsoc.org/digitalbams).

ON THE COVER

Four papers in this issue together make a case for an international Earth-System Prediction Initiative: Shapiro et al., Nobre et al., Brunet et al., and Shukla et al.

READINGS

1413 **ESSAY**
Is Science Fiction a Genre for Communicating Scientific Research? A Case Study in Climate Prediction

1414 **NEW PUBLICATIONS**

1417 **BOOK REVIEWS**
Stochastic Physics and Climate Modeling…
Atmospheric Science for Environmental Scientists

A supplement, "Sunrise" by T. N. Palmer, is available online at http://journals.ametsoc.org.

Enhance and sustain user engagement

- **Action 1.1** Strengthen existing user engagement entities to continuously engage with internal and external end-users
- **Action 1.2** Champion co-production of precipitation applications between user engagement entities and product development teams
- **Action 1.3** Develop and sustain region-specific networks to understand users and their needs

Improve precipitation prediction products and applications

- **Action 2.1** Revamp precipitation products and services to effectively communicate uncertainty
- **Action 2.2** Post-process raw coupled model precipitation forecasts to calibrate for bias and other deficiencies and to quantify prediction uncertainties
- **Action 2.2** Translate precipitation output into actionable visualizations and data that help forecasters more directly make a forecast decision
- **Action 2.4** Establish reforecasts and high quality multi-decadal analyses of precipitation to support more statistically advanced precipitation post-processing techniques
- **Action 2.5** Design prediction verification metrics based on physical reasoning and user applications

Improve prediction systems for precipitation

- **Action 3.1** Improve Unified Forecast System (UFS) precipitation forecasts by addressing errors from initialization
- **Action 3.2** Improve UFS precipitation forecasts by addressing errors in model biases
- **Action 3.3** Improve physics in coupled models by emphasizing co-development of all model components, focusing on UFS

Sustain, enhance, and exploit observations

Extend, enhance and sustain observations needed to:

- **Action 4.1** Advance understanding of precipitation predictability
- **Action 4.2** Advance understanding of physical processes key to precipitation prediction
- **Action 4.3** Improve initial conditions for precipitation prediction
- **Action 4.4** Improve calibration, verification, and uncertainty quantification of precipitation prediction products

Improve process-level understanding and modeling

- **Action 5.1** Support synthesizing analysis of existing observations
- **Action 5.2** Identify and fix key model deficiencies and processes that contribute the most to error growth
- **Action 5.3** Conduct targeted field experiments to obtain intensive observations
- **Action 5.4** Conduct a hierarchy of modeling-observational integrated studies
- **Action 5.5** Target extremes (flooding and drought)

Advance understanding of precipitation predictability

- **Action 6.1** Modernize observational and modeling tools for the study of predictability
- **Action 6.2** Understand precipitation predictability, its sources and barriers
- **Action 6.3** Expand the definition of predictability to be directly applicable to users