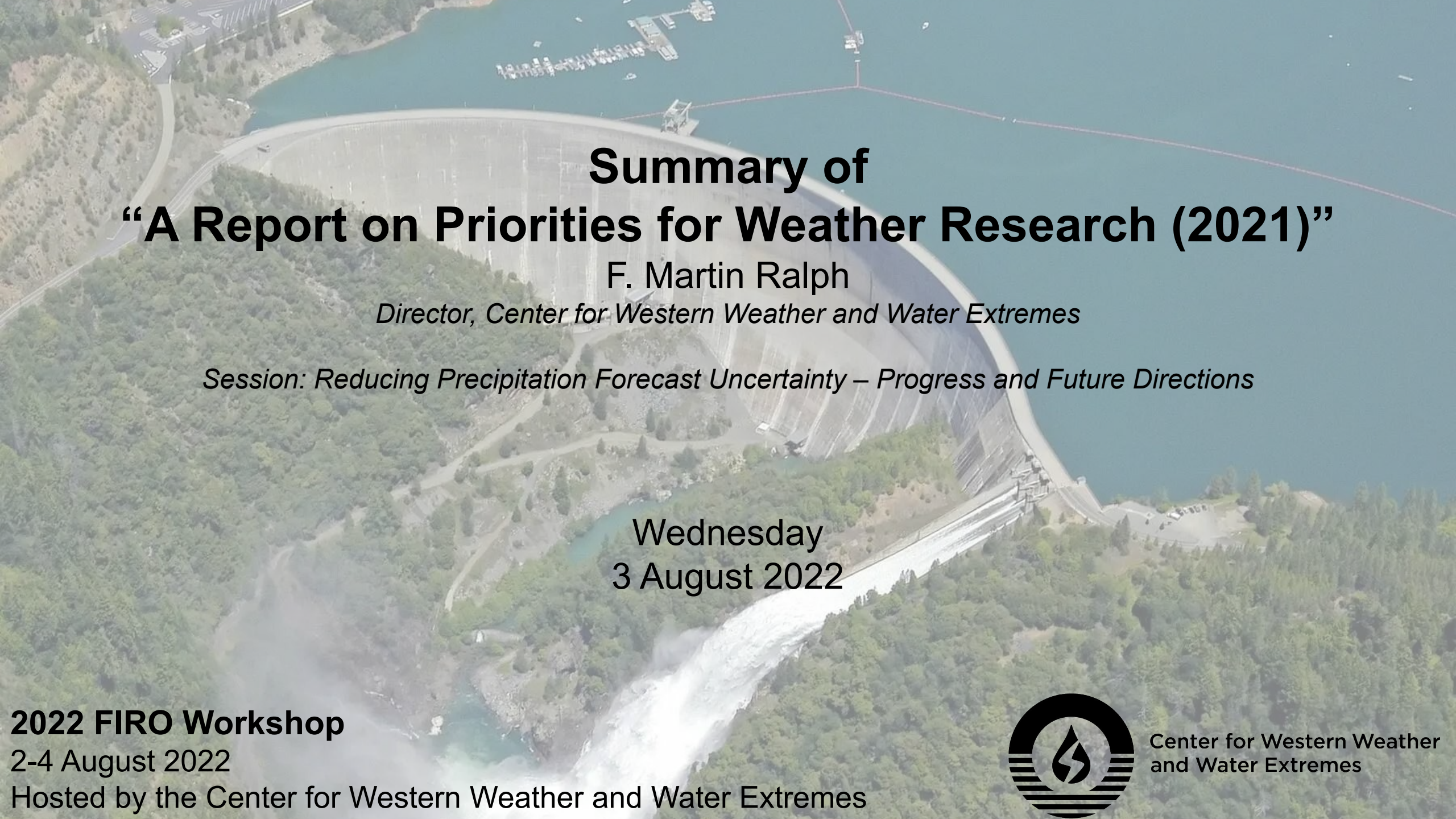


Summary of
"A Report on Priorities for Weather Research (2021)"

F. Martin Ralph
Director, Center for Western Weather and Water Extremes

Session: Reducing Precipitation Forecast Uncertainty – Progress and Future Directions

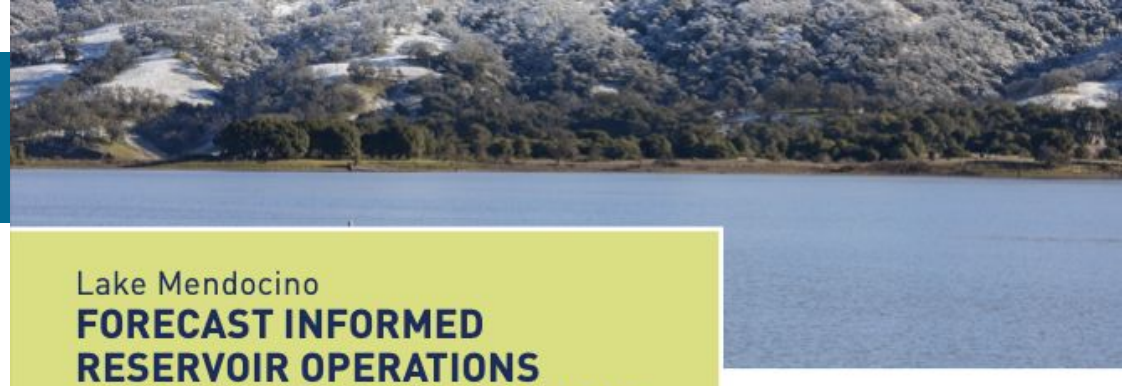
Wednesday
3 August 2022

2022 FIRO Workshop
2-4 August 2022
Hosted by the Center for Western Weather and Water Extremes

Center for Western Weather and Water Extremes

Objective

"FIRO is a flexible water management approach that uses data from watershed monitoring and improved weather forecasting to help water managers selectively retain or release water from reservoirs for increased resilience to droughts and floods. FIRO applies emerging science and technology to optimize water resources and adapt to climate change without costly infrastructure." – Feb 2021



Lake Mendocino
FORECAST INFORMED RESERVOIR OPERATIONS FINAL VIABILITY ASSESSMENT

February 2021

Executive Summary

The Final Viability Assessment (FVA) is the culmination of a six-year effort led by the Lake Mendocino Forecast Informed Reservoir Operations (FIRO) multi-agency Steering Committee. The FVA demonstrates the viability of FIRO and provides strong support for the U.S. Army Corps of Engineers (USACE) to approve and adopt FIRO-based operations at Lake Mendocino, located in the Russian River watershed in northern California.

What is FIRO?

FIRO is a flexible water management approach that uses data from watershed monitoring and improved weather forecasting to help water managers selectively retain or release water from reservoirs for increased resilience to droughts and floods. FIRO applies emerging science and technology to optimize water resources and adapt to climate change without costly infrastructure.

The Case for FIRO at Lake Mendocino

Lake Mendocino has experienced significantly reduced water supply reliability since diversions from the Eel River were decreased in 2006. The goal of FIRO at Lake Mendocino is to update the 1950s-era Water Control Manual by applying forecasting advancements to increase water supply reliability without reducing—and while possibly enhancing—the existing flood protection capacity of Lake Mendocino and downstream flows for fish habitat.

Read the full Final Viability Assessment at https://escholarship.org/uc/item/3b63q04n.

https://cw3e.ucsd.edu/FIRO_docs/LakeMendocino_FIRO_FVA_ExecutiveSummary.pdf

Origin of “Priorities for Weather Research”

FY21 Omnibus (Dec 2020) Appropriations (i.e., 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. – Dec 2020

Adapted from AMS Town Hall Jan 2022

Origin of “Priorities for Weather Research”

NOAA Science Advisory Board:

- Only NOAA Federal Advisory Committee to advise across all lines, strategic councils, and offices
- Provides strategic guidance on trends, issues and new areas of cutting-edge research that may impact NOAA mission in future
- Responds to requests for advice from external experts by NOAA and Capitol Hill
- Validates requirements and needs
- Identifies gaps in programs, expertise, funding

Adapted from AMS Town Hall Jan 2022

Origin of “Priorities for Weather Research”

NOAA Science Advisory Board:

US Undersecretary of Commerce for Oceans and Atmosphere (NOAA Administrator)

NOAA Chief Scientist

Federal Advisory Committee Act

SAB Staff

SAB

21 Current Members

Working Groups

- Climate
- Data Archive and Access Requirements
- Environmental Information Services
- Ecosystem Sciences and Management
- Tsunami Science & Technology Advisory Panel

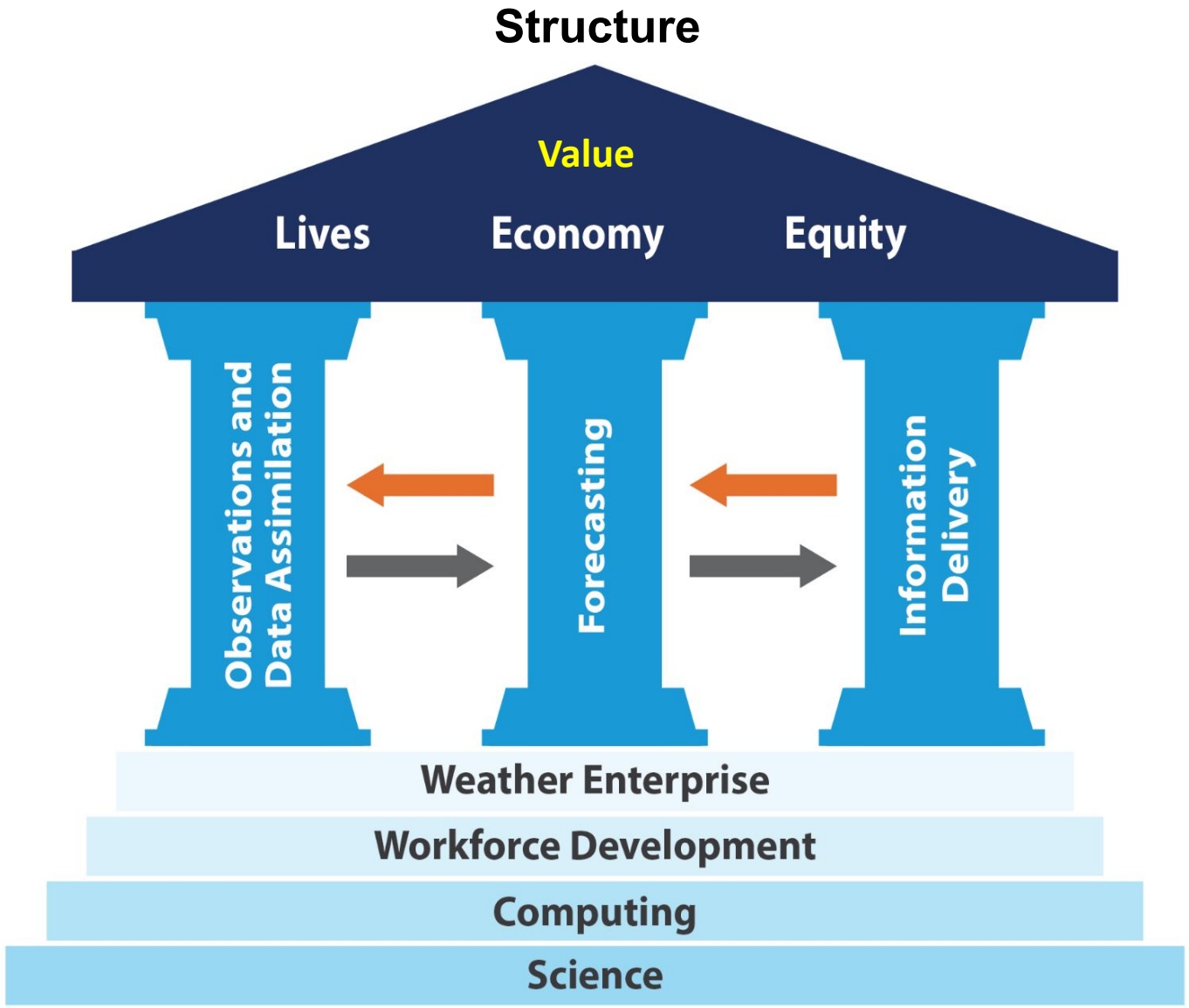
Network of Experts

Adapted from AMS Town Hall Jan 2022

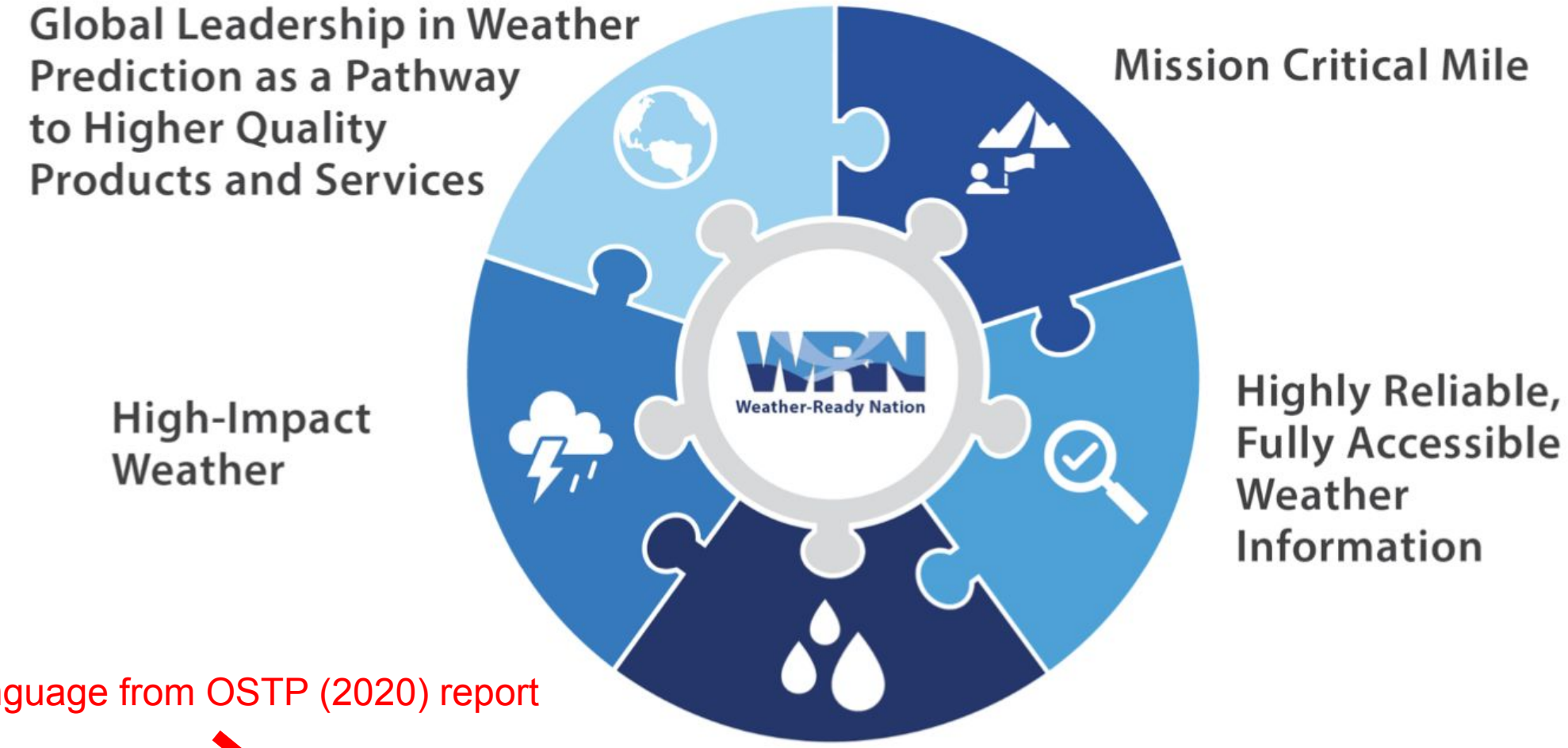
Priorities for Weather Research

- **SAB Chair**
  - John Kreider
- **PWR Co-Leads**
  - Scott Glenn & Brad Colman
- **Obs. & Data Assim. Co-Leads**
  - Xuguang Wang & **Marty Ralph**
- **Forecasting Co-Leads**
  - Christa Peters-Lidard & Fred Carr
- **Information Delivery**
  - Ann Bostrom & Mike Eilts

Priorities for Weather Research



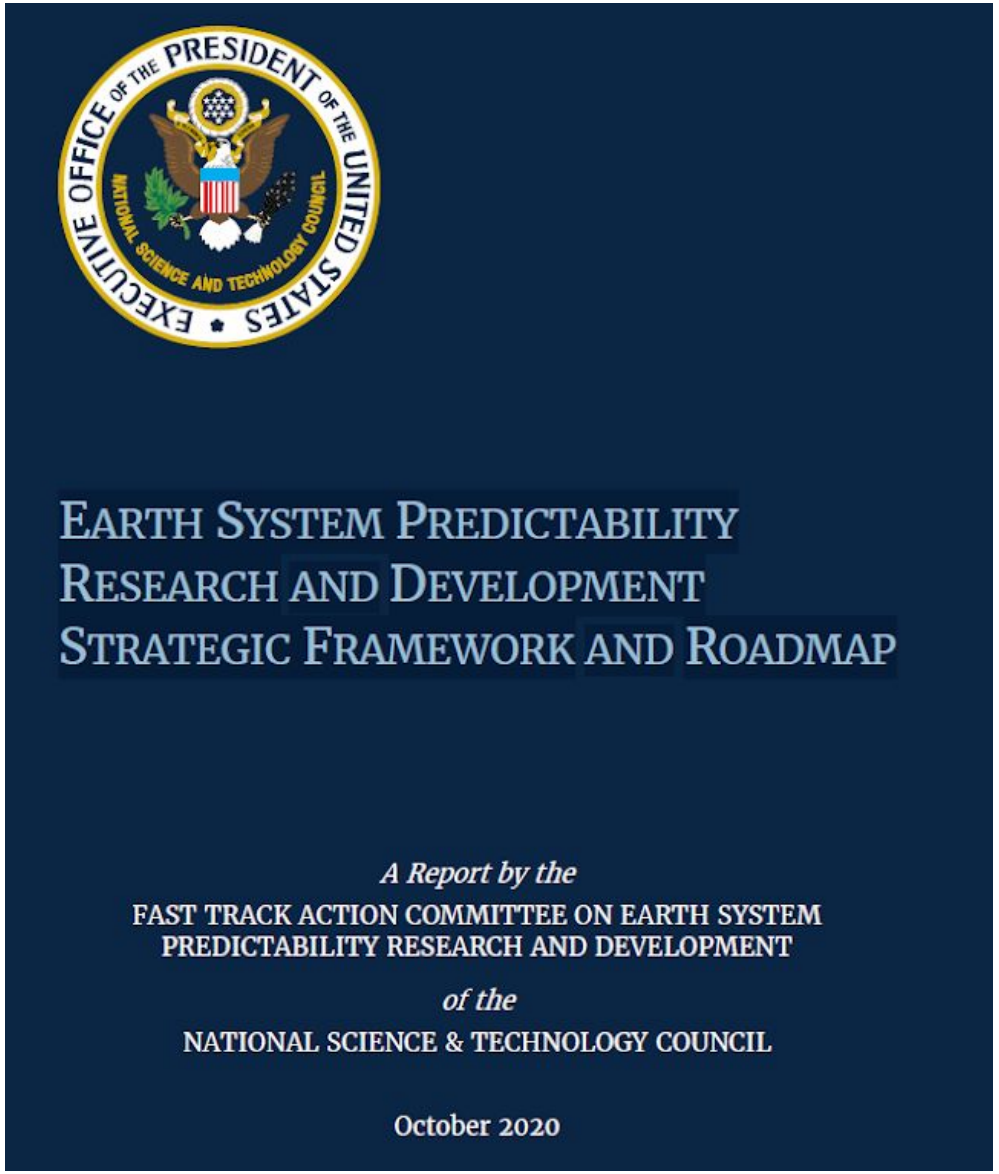
Connecting PWR to the “Weather-Ready Nation”



Language from OSTP (2020) report

Improve Prediction of Water Cycle Extremes and Their Cascading Impacts

Office of Science and Technology Policy (OSTP) 2020 Report



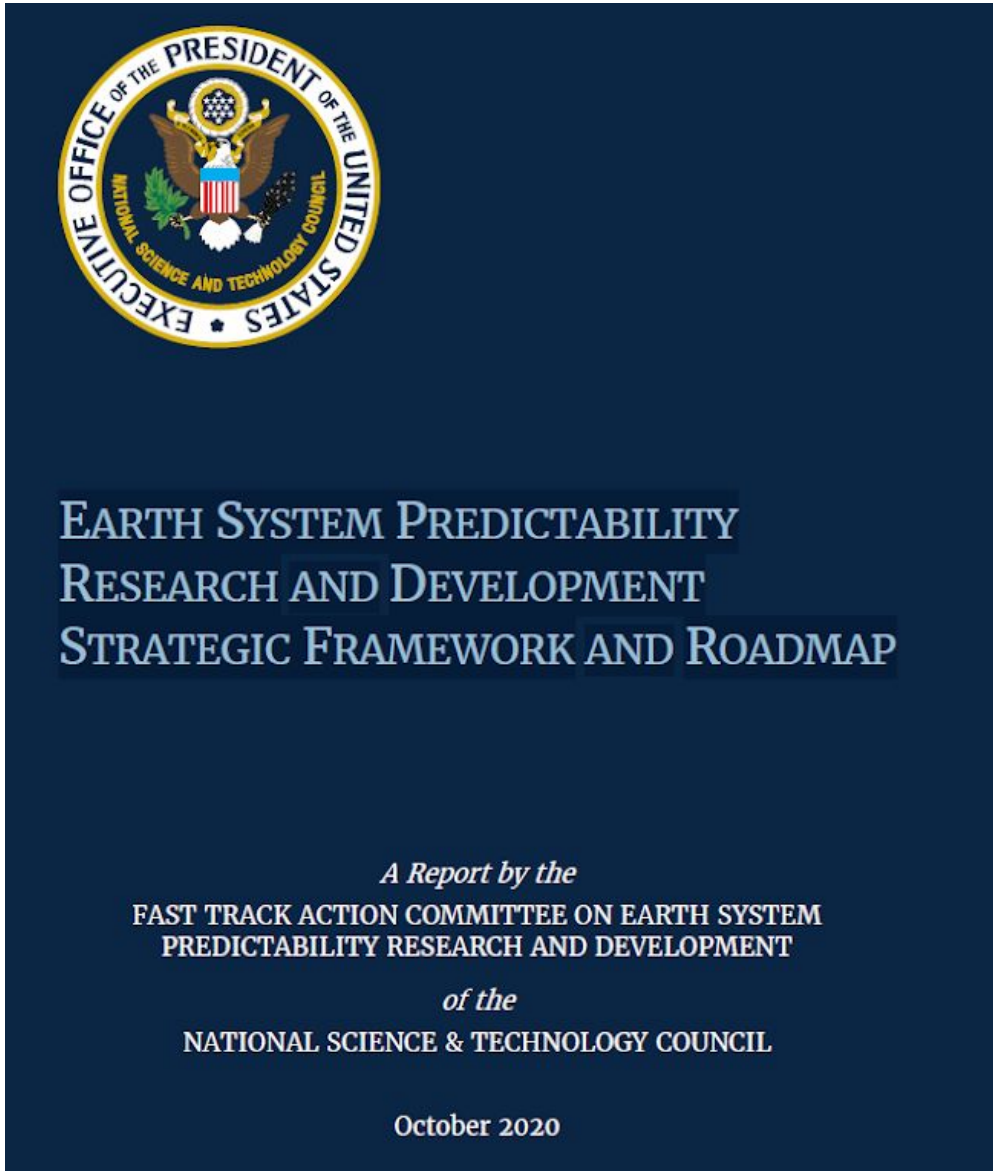
Executive Summary

From predictions of individual thunderstorms to long-term global change, enhanced Earth system predictions are crucial to inform societal resilience to extreme events such as droughts and floods, heat waves, wildfires and coastal inundation. However, in some cases, there is still a lack of clear understanding of whether, or under which conditions, extreme meteorological events and their cascading events are predictable and why. A better understanding of Earth system predictability (ESP) would help the Federal Government target investments to improve predictions and increase public benefit. To help address this gap, and facilitate Federal coordination, the National Science and Technology Council (NSTC) created a Fast Track Action Committee (FTAC) on ESP in February 2020. It was charged with identifying barriers to progress, as well as prioritizing opportunities for activities that could improve our understanding of ESP. Subsequently, the FTAC engaged with the public and the interagency prior to developing an R&D Strategic Framework and a Roadmap to guide the initial R&D activities that address urgent prediction needs within the framework.

The R&D Strategic Framework aims to increase the understanding of ESP to improve predictions through three primary goals that connect theory with observations, process research, and modeling. An additional four cross-cutting goals address these thrusts as well as emphasize advanced technologies, enhanced collaborations, partnerships, and training the next generation of talent. The Roadmap identifies five areas of R&D opportunity focusing on the predictability of Earth's water cycle and precipitation extremes and associated biosphere and human interactions as a springboard to strategically advance the ESP R&D priority. The goal of this R&D is to attain high-resolution predictions and projections of high impact water cycle events, their cascading impacts across the Earth system, and their coupling to human, ecological, and biogeochemical systems.

The Roadmap identifies five areas of R&D opportunity focusing on the **predictability of Earth's water cycle and precipitation extremes** and associated biosphere and human interactions…

Office of Science and Technology Policy (OSTP) 2020 Report



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Office of Science and Technology Policy (OSTP) 2020 Report

EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

EARTH SYSTEM PREDICTABILITY RESEARCH AND DEVELOPMENT STRATEGIC FRAMEWORK AND ROADMAP

A Report by the

FAST TRACK ACTION COMMITTEE ON EARTH SYSTEM PREDICTABILITY RESEARCH AND DEVELOPMENT

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

October 2020

Executive Summary

From predictions of individual thunderstorms to long-term global change, enhanced Earth system predictions are crucial to inform societal resilience to extreme events such as droughts and floods, heat waves, wildfires and coastal inundation. However, in some cases, there is still a lack of clear understanding of whether, or under which conditions, extreme meteorological events and their cascading events are predictable and why. A better understanding of Earth system predictability (ESP) would help the Federal Government target investments to improve predictions and increase public benefit. To help address this gap, and facilitate Federal coordination, the National Science and Technology Council (NSTC) created a Fast Track Action Committee (FTAC) on ESP in February 2020. It was charged with identifying barriers to progress, as well as prioritizing opportunities for activities that could improve our understanding of ESP. Subsequently, the FTAC engaged with the public and the interagency prior to developing an R&D Strategic Framework and a Roadmap to guide the initial R&D activities that address urgent prediction needs within the framework.

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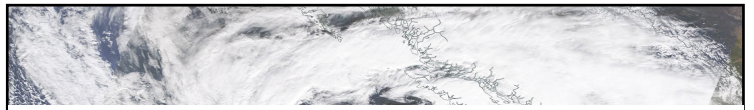
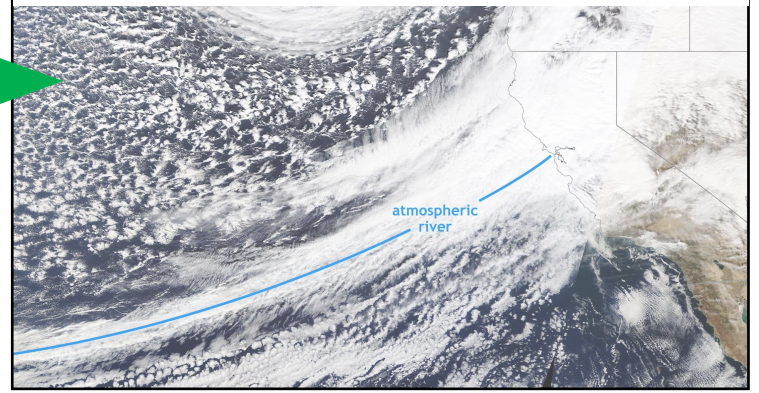
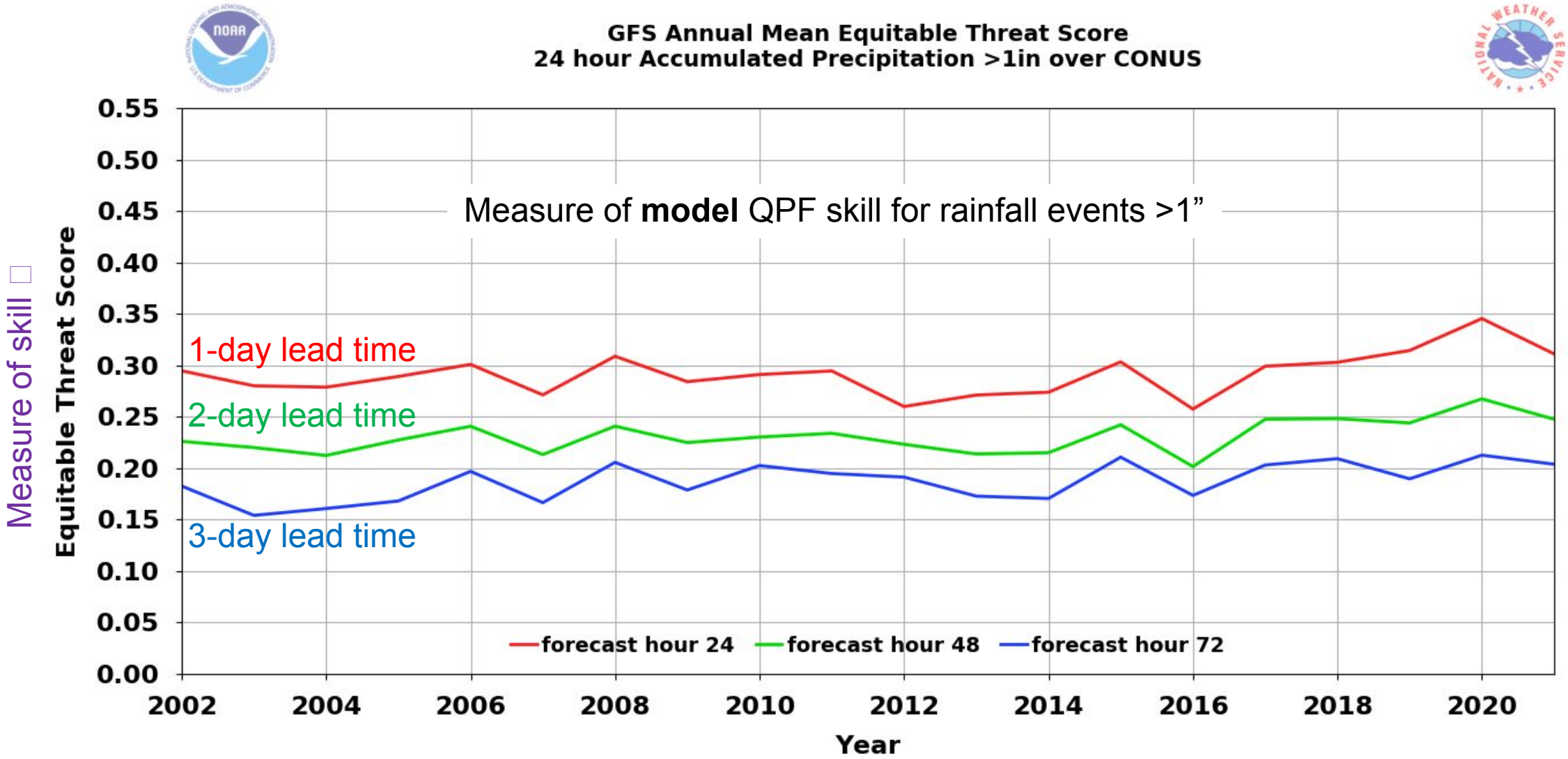


"Such as droughts, floods, hurricanes, extratropical cyclones, **atmospheric rivers**, and wildfires"



Predictability of Water Cycle Extremes

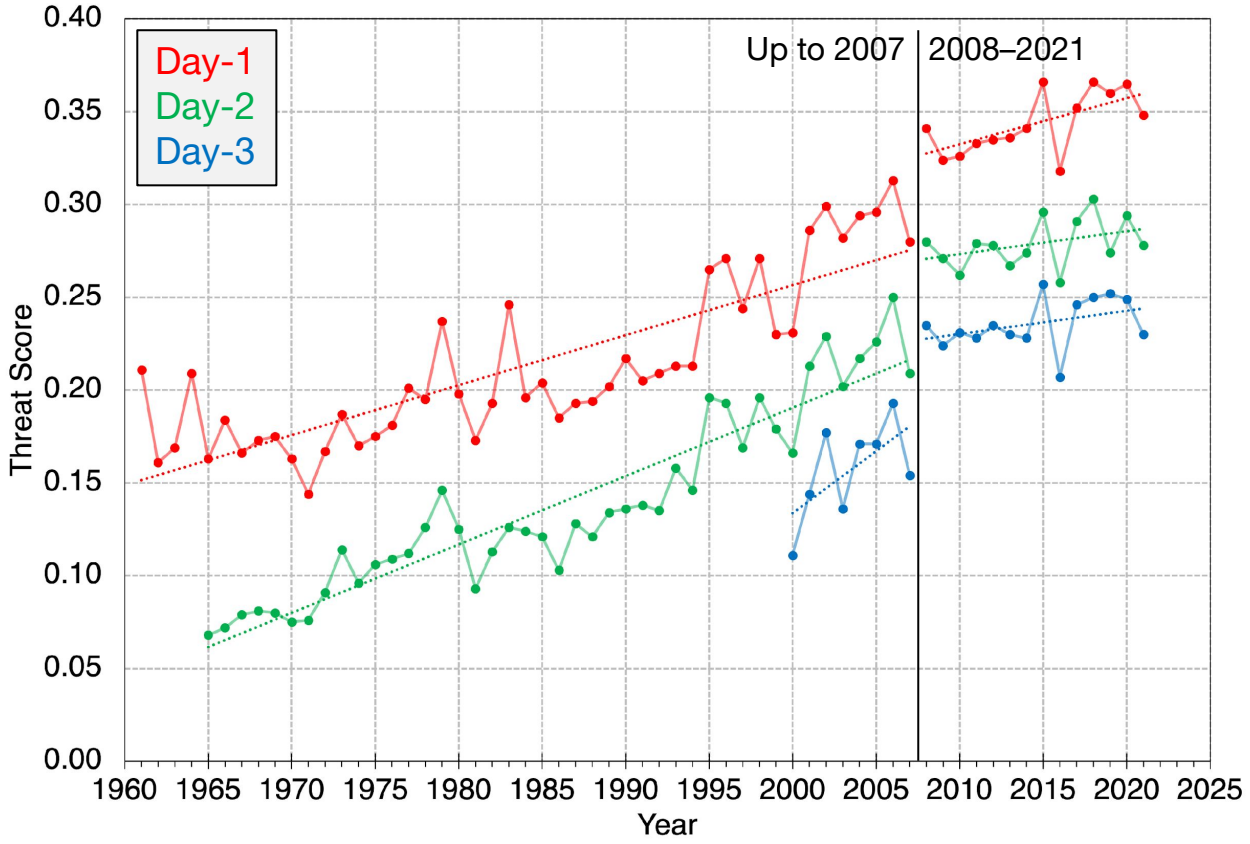


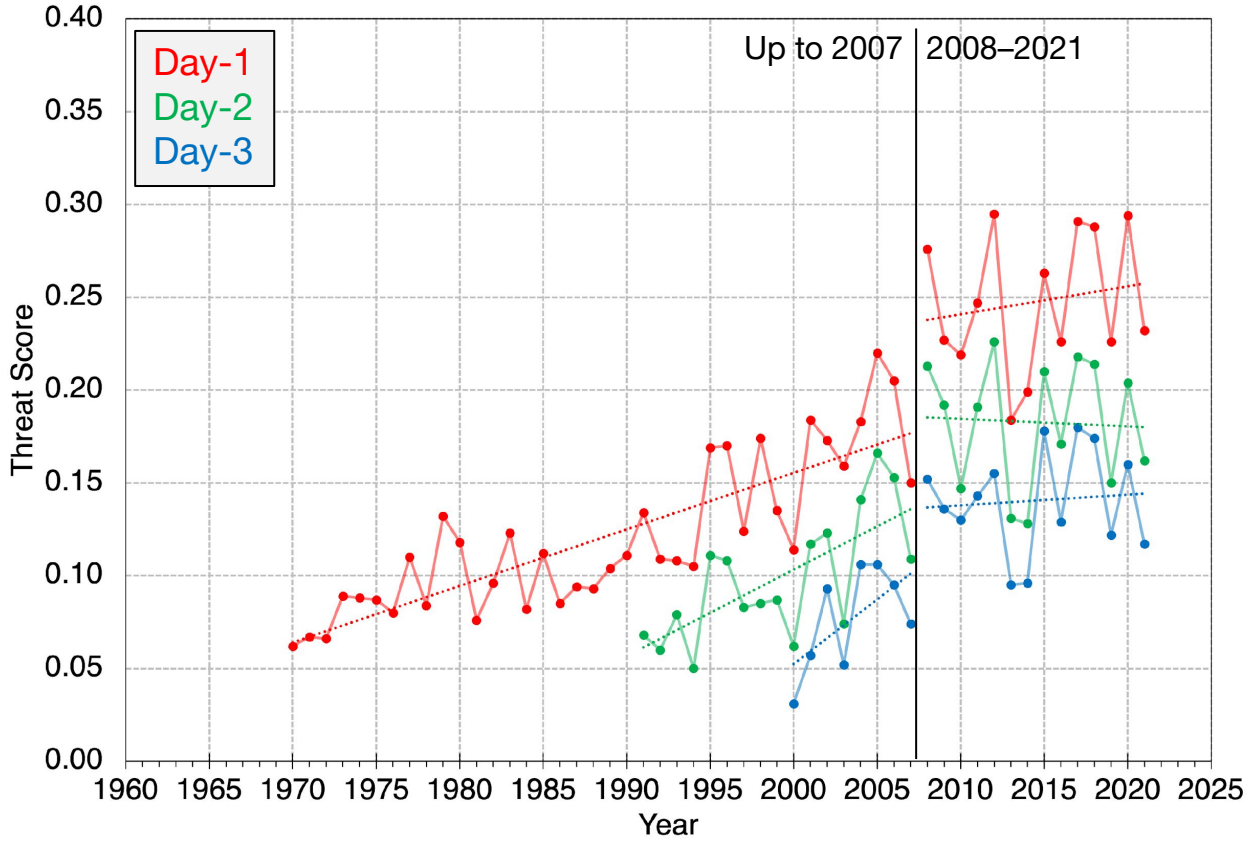
Evolution of precipitation forecast skill over the Continental United States (CONUS) in the GFS over the last 20 years. The equitable threat score is a metric that quantifies the skill of a forecast relative to random chance, with values ranging from 0 (no skill) to 1 (perfect skill). The 24-hour (red), 48-hour (green) and 72-hour (blue) forecasts all indicate minimal increases over this period.
(https://www.emc.ncep.noaa.gov/users/verification/headlines/gfs_precip/annual_gfs_precip_ets_1in.png)

Predictability of Water Cycle Extremes

Analyzing NOAA Weather Prediction Center QPF Skill

- Day-1, Day-2, and Day-3 QPF Threat Score for the Continental US at **1-inch** and **2-inch** thresholds
- QPF Threat Scores increased steadily at lead times of 1-3 days through early 2000s but have leveled off during the last 10-15 years.





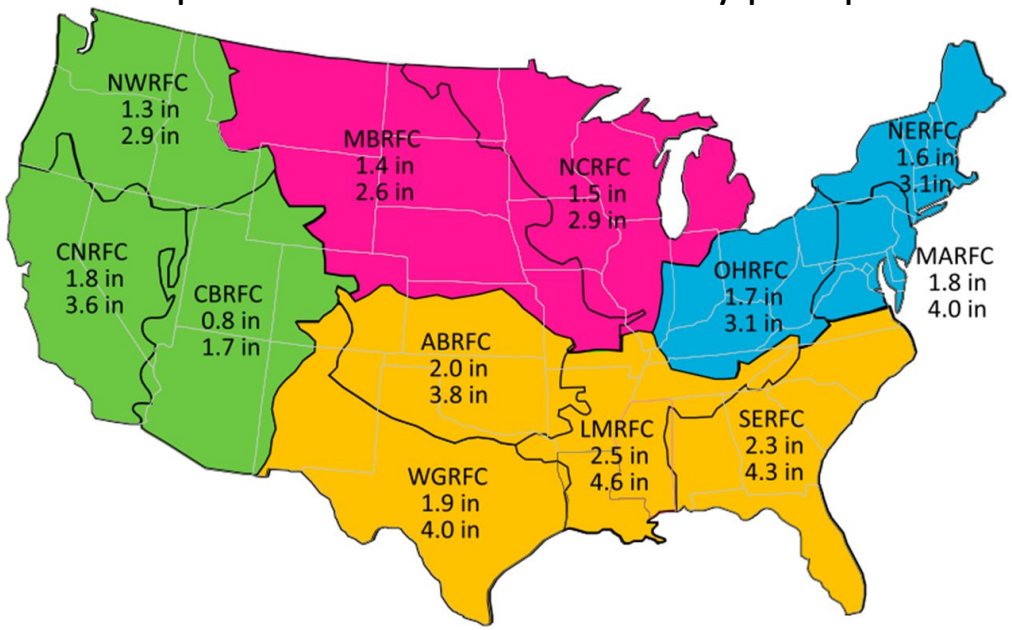
Data provided by the NOAA/Weather Prediction Center

Predictability of Water Cycle Extremes

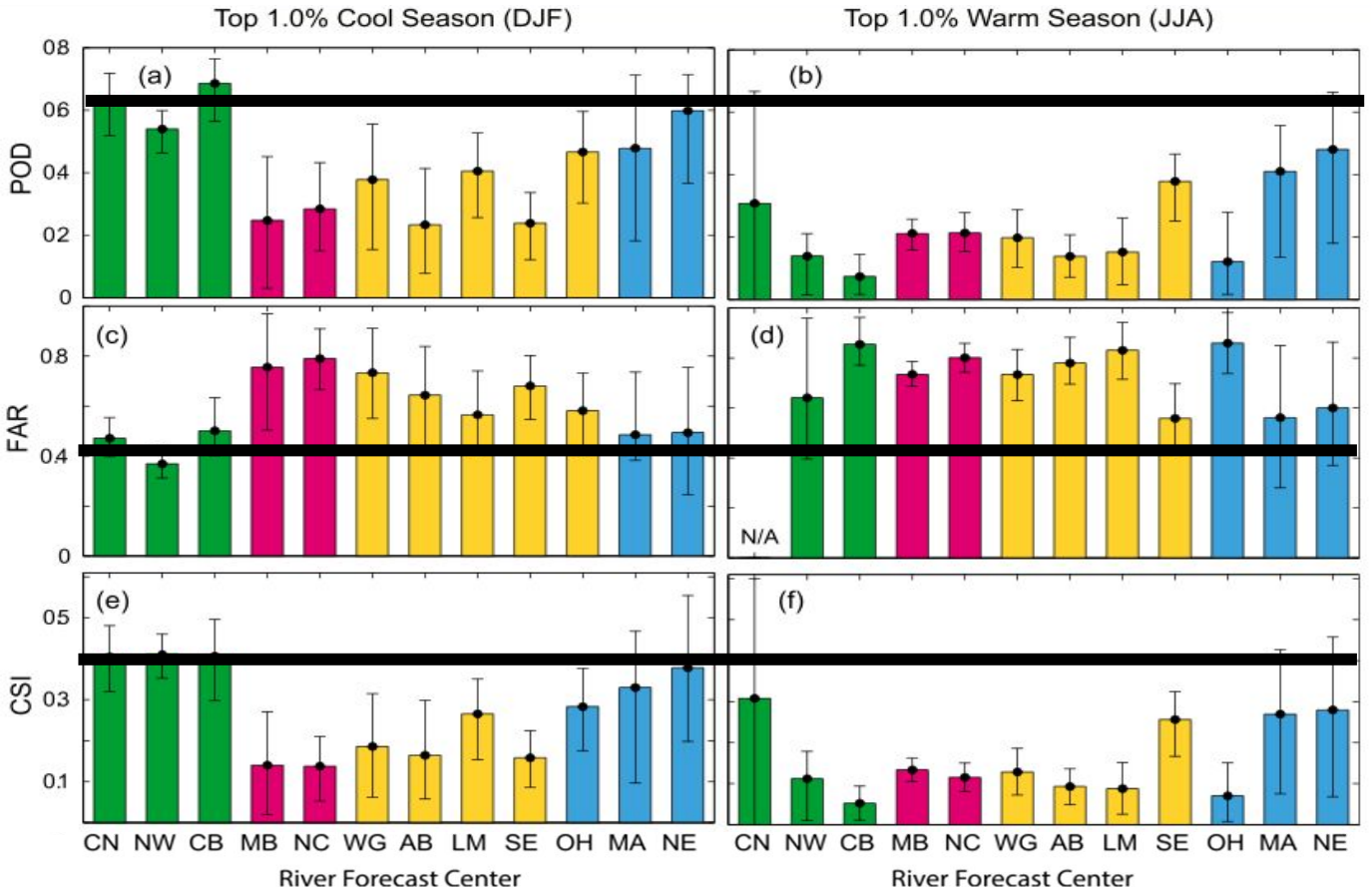
Extreme quantitative precipitation forecast performance at the Weather Prediction Center from 2001 to 2011
Sukovich, E. M., F. M. Ralph, F. E. Barthold, D. W. Reynolds and D. R. Novak; *Wea. Forecasting* (2014)

Contact: Marty Ralph; mralph@ucsd.edu

Regional thresholds for
Top 1% and 0.1% heaviest daily precipitation

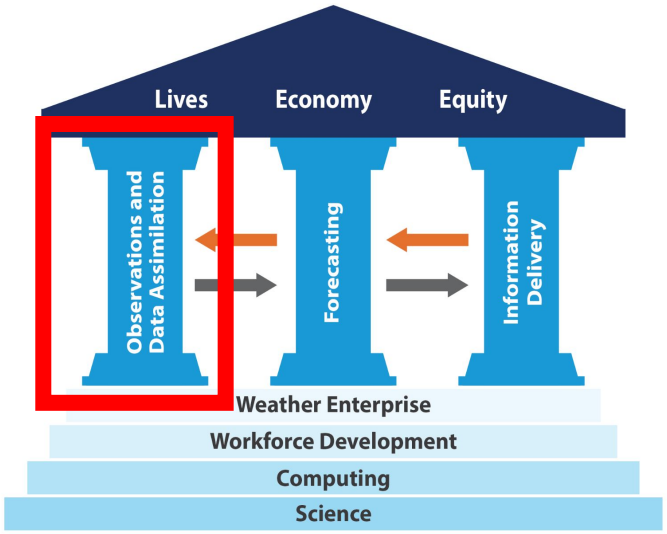


Used 32 km gridded NCEP/WPC QPE from 2001-2011
>12,000,000 wet days



Used 32 km gridded NCEP/WPC QPE/QPF from 2007-2011 for 1-d lead time.

Priorities for Weather Research pertinent to FIRO



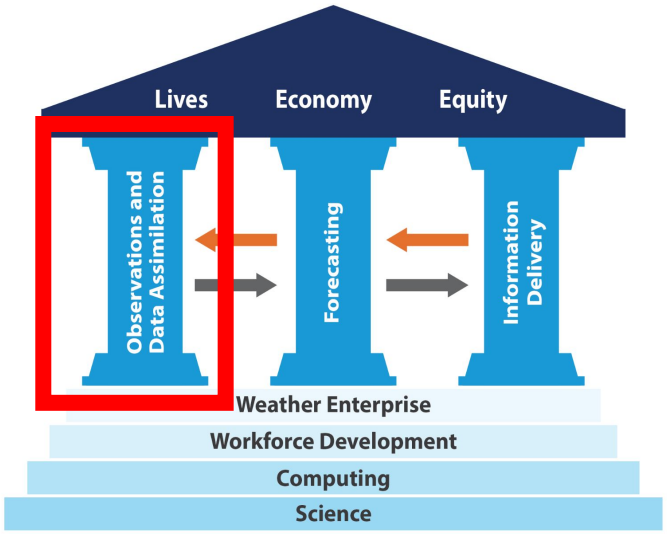
Pillar: Observations & Data Assimilation (OD)

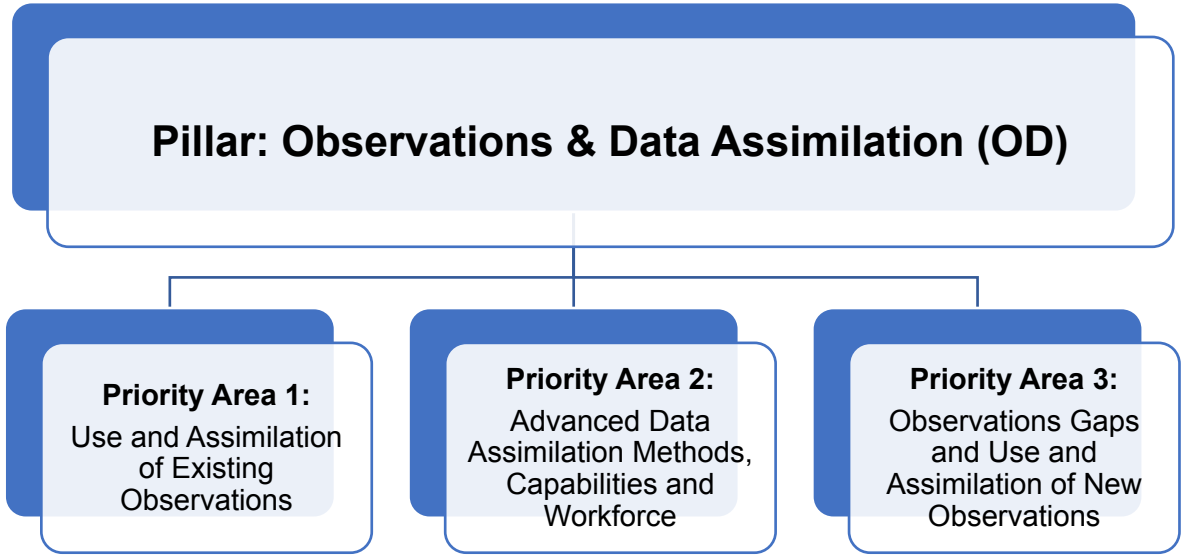
Priority Area 1:
Use and Assimilation of Existing Observations

Priority Area 2:
Advanced Data Assimilation Methods, Capabilities and Workforce

Priority Area 3:
Observations Gaps and Use and Assimilation of New Observations

Priorities for Weather Research pertinent to FIRO





Example Action Items		
	Priority Area 1	**Use and Assimilation of Existing Observations**
	OD-1	Maximize use and assimilation of underutilized ground, airborne & marine observations - *to ensure maximum value is derived from the full suite of observations in the Earth system model*
	Priority Area 3	**Observations Gaps and Use and Assimilation of New Observations**
	OD-8 (see next slide)	Implement a multi-phase program to improve the forecasting of atmospheric rivers - *to better anticipate and mitigate water cycle extremes and their cascading impacts*
	OD-9	Fill radar gaps using diverse weather radars and data assimilation - *to better detect significant precipitation and severe weather over a greater area and more equitably across the population*

OD-8: Recommendation and Findings (re: ARs)

OD-8 Recommendation: Leverage and expand atmospheric river (AR) observations to improve flood and drought prediction and to enable forecast-informed reservoir operations.
Water and emergency managers often cope with too much or too little water and require better information on storms that produce extreme precipitation. However, precipitation prediction skill has not improved substantially in the last 20 years. The multi-agency, OSTP-led Earth System Prediction Roadmap (2020) identified expanded research, observations and communication needed to better anticipate and mitigate water cycle extremes and their cascading impacts, including atmospheric river type storms.

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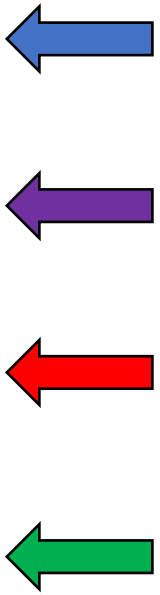
Findings

1. NOAA has articulated the need for improved precipitation forecasts in the form of a Grand Challenge developed jointly with the Department of Energy (DOE). It highlights very slow gains in precipitation forecast skill over the past two decades. A key recommendation from this report, which incorporated substantial community input, was to focus on predicting the storm types that are most responsible for extreme precipitation.[43]

2. The United States Army Corps of Engineers (USACE)-led Forecast-Informed Reservoir Operations pilot studies have identified atmospheric river (AR) storms as the leading cause of extreme precipitation and flooding in the west (84% of all flood damages in the western United States are due to atmospheric river storms, based on forty years of FEMA data[44]); Major impacts across other key U.S. regions also occur. The Fourth National Climate Assessment added ARs as a fourth type of extreme storm to track as the Earth's climate changes[45].

3. Improved skill in predicting rainfall, and this storm type in particular, would enable more flexible reservoir operations, which can mitigate drought and flood impacts. The more skillful the AR forecast, the more flexibility there can be to hold water after a storm, or to release it ahead of a storm. This expands the potential usefulness of existing dams to create greater resilience to the increasing swings between drought and flood that is already being seen, simultaneously supporting the economy, public safety and the environment.

4. A pilot program to improve predictions of ARs and their extreme precipitation and impacts ("AR Recon") recently demonstrated success. It used aircraft (Figure 13), additional buoy data and airborne radio occultation (from GPS satellites), combined with novel data assimilation techniques. An initial operational capability has been established as a Research And Operations Partnership (RAOP) between universities, NWS, OMAO, the United States Air Force and others. Profound gaps in current weather observations have been found that AR Recon fills, and improvements in prediction skill at one to four days lead time has been demonstrated[46-50].



"focus on predicting storm types that are most responsible for extreme precipitation"

"USACE-led FIRO pilot studies have identified AR storms as leading cause of extreme precipitation and flooding" in the west

"Improved skill in predicting rainfall, and [ARs], would enable more flexible reservoir operations"

AR Recon fills profound gaps in observations and improves prediction skill at 1-4 days lead time

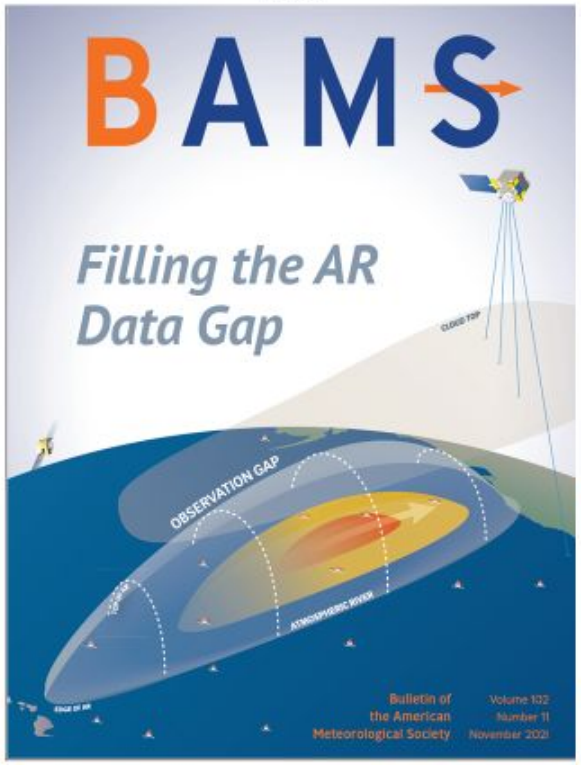
OD-8: Critical Actions

OD-8.1. Implement a multi-phase program to improve the understanding and forecasting of ARs that leverages current and future aircraft, buoy, and satellite capabilities. The program should build upon existing capabilities and programs to expand coverage in space and time and improve forecasts through advanced data assimilation (OD-3), as well as integration of ocean surface and mixed layer observations (OD-7).

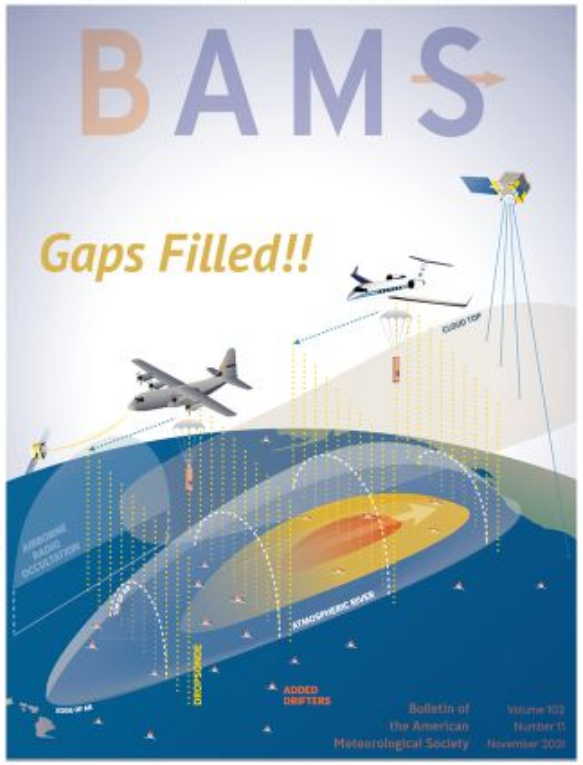
OD-8.2. Adopt a research and operations partnership approach, including engagement of the international and academic communities.

OD-8.3. The program development and implementation should create new forecast skill metrics targeting extreme precipitation prediction in the west and the phenomenon, ARs, that produces it. It should target socio-economic impact considerations including for use in reservoir operations to mitigate drought and flood impacts.

Cover



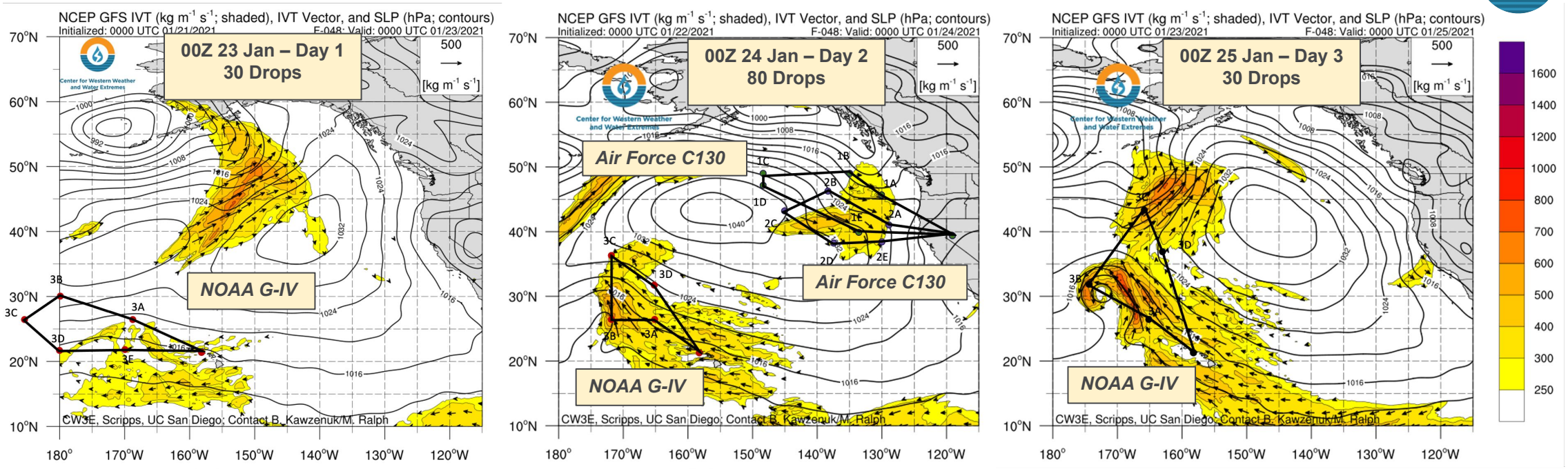
Inside front Cover – first ever for BAMS



Atmospheric River Reconnaissance 2021 Sequence-1 (23– 28 Jan)

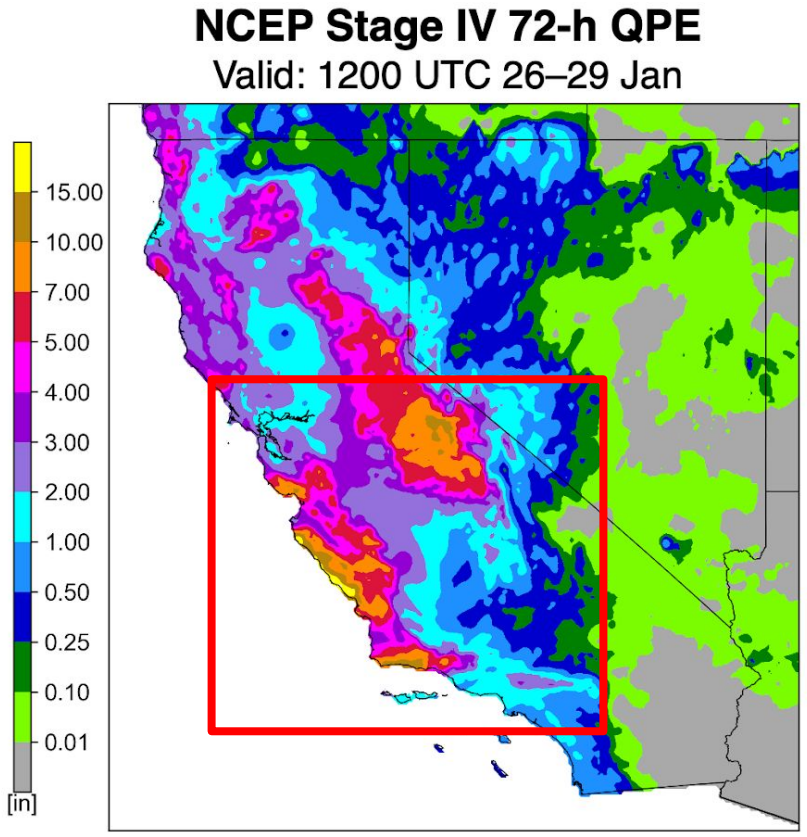
PI: Marty Ralph

Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO



U.S. AIR FORCE

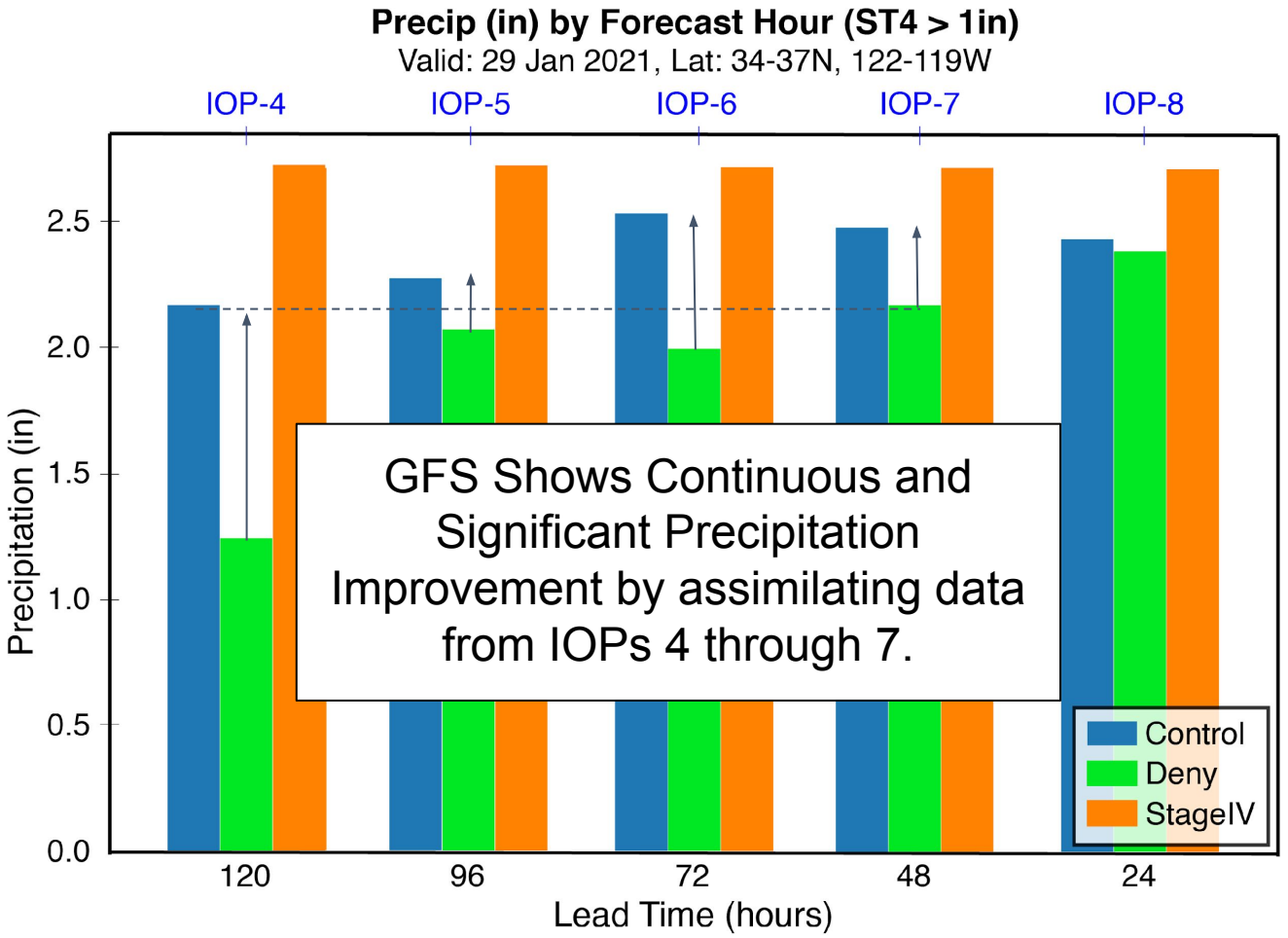
AR Recon Success: 21 – 26 January 2021



GFS precipitation forecast error at 120h (5-day) lead time *with drops* is equivalent to the 48h (2-day) error without drops.

AR Recon Data Denial Experiments

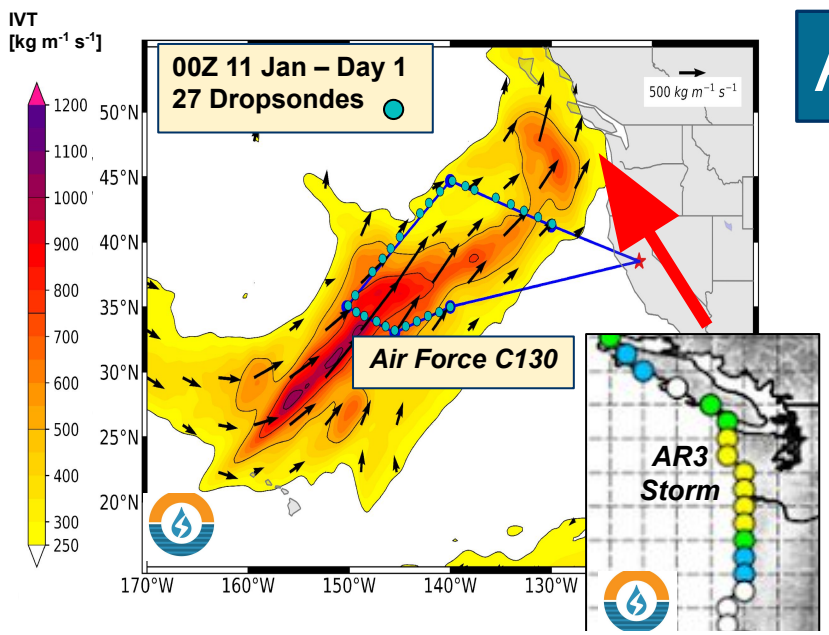
V. Tallapragada, F.M. Ralph, X. Wu, M. Zheng



Center for Western Weather and Water Extremes

Research And Operations Partnership
F. Martin Ralph (UCSD/SIO/CW3E) - PI
Vijay Tallapragada (NWS/NCEP) - Co-PI

AR Recon Success: 11 – 13 January 2022



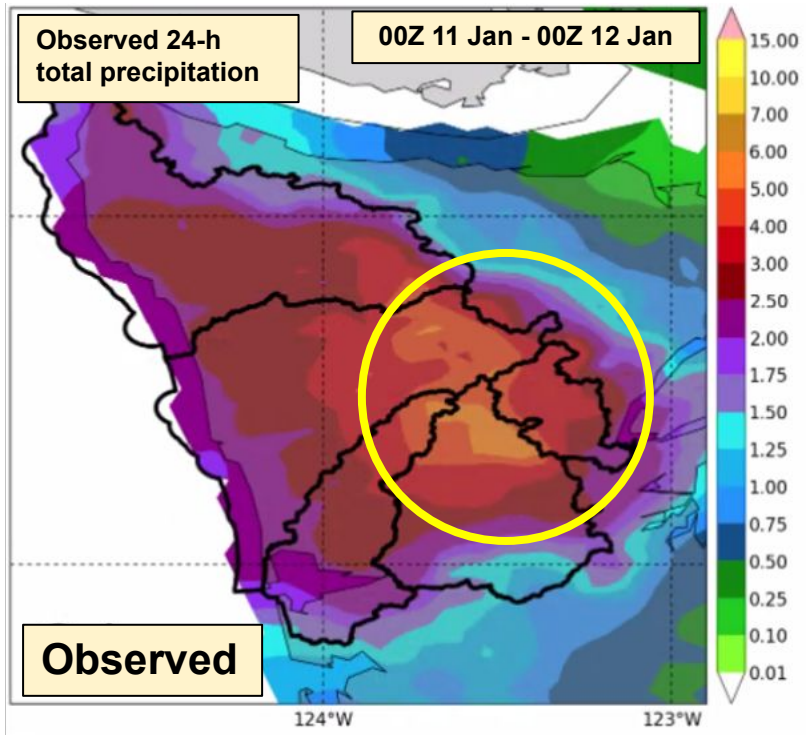
AR Recon flight substantially reduced errors in 1–2-day lead-time forecast of heavy precipitation from an AR3 storm

The region had been experiencing flooding already this winter, and WA had requested a Presidential Disaster Declaration for earlier AR storms that had hit in Nov-Dec 2021, before AR Recon season began on 11 Jan 2022.

Center for Western Weather and Water Extremes

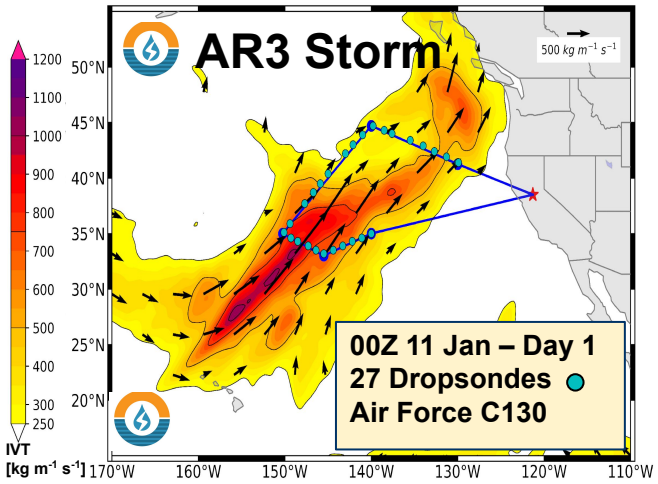
Research And Operations Partnership
F. Martin Ralph (UCSD/SIO/CW3E) - PI
Vijay Tallapragada (NWS/NCEP) - Co-PI

Max > 6 inches in 1 day

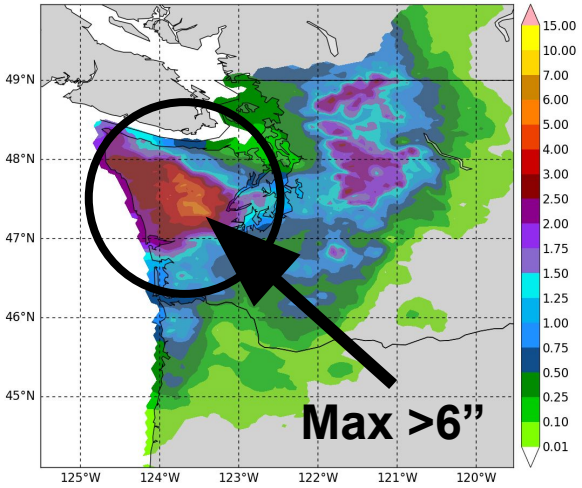


AR Recon Success: 11 – 13 January 2022

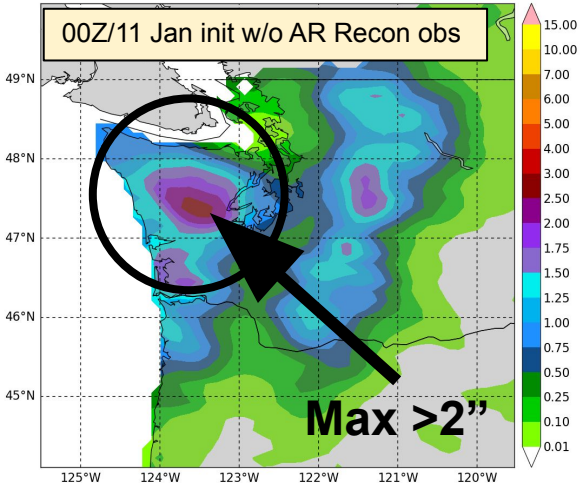
a. IVT at 00Z 11 January 2022



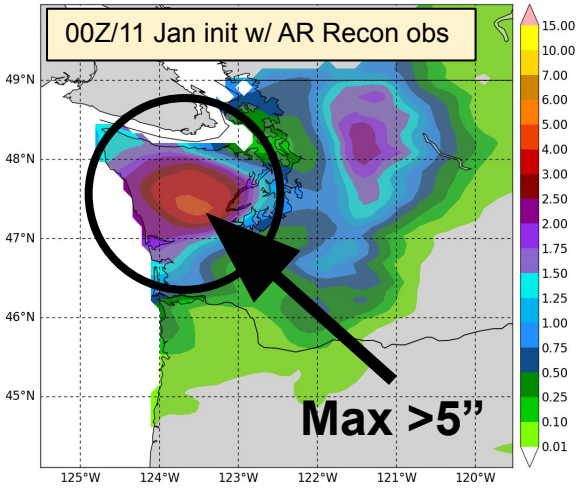
b. 24-h observed precip



c. 24-h GFS forecast (denial)



d. 24-h GFS forecast (AR Recon)



Preliminary Assessment of Impact on Heavy Precipitation Forecast in GFS During the Sequence of 3 days of AR Recon flights from 11-13 Jan 2022

The region had been experiencing flooding already this winter, and WA had requested a Presidential Disaster Declaration for earlier AR storms that had hit in Nov-Dec 2021, before AR Recon season began on 11 Jan 2022.

AR Recon flight substantially reduced errors in the 1-2-day lead-time forecast of heavy precipitation from an AR3 storm

Center for Western Weather and Water Extremes

Research And Operations Partnership
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Summary

Congress directed NOAA to create a report the relevant information necessary to prioritize investments in weather forecasting, modeling, data assimilation, and supercomputing over the next ten years

Emphasis placed on prediction of water cycle extremes and their cascading impacts, including droughts, floods, and ARs

Action items focused on improved observations, data assimilation including development of multi-phased program to improve AR forecasting and to enable FIRO

RAOPs such as AR Recon and FIRO are leading examples of achieving the goals set forward by the NOAA PWR report