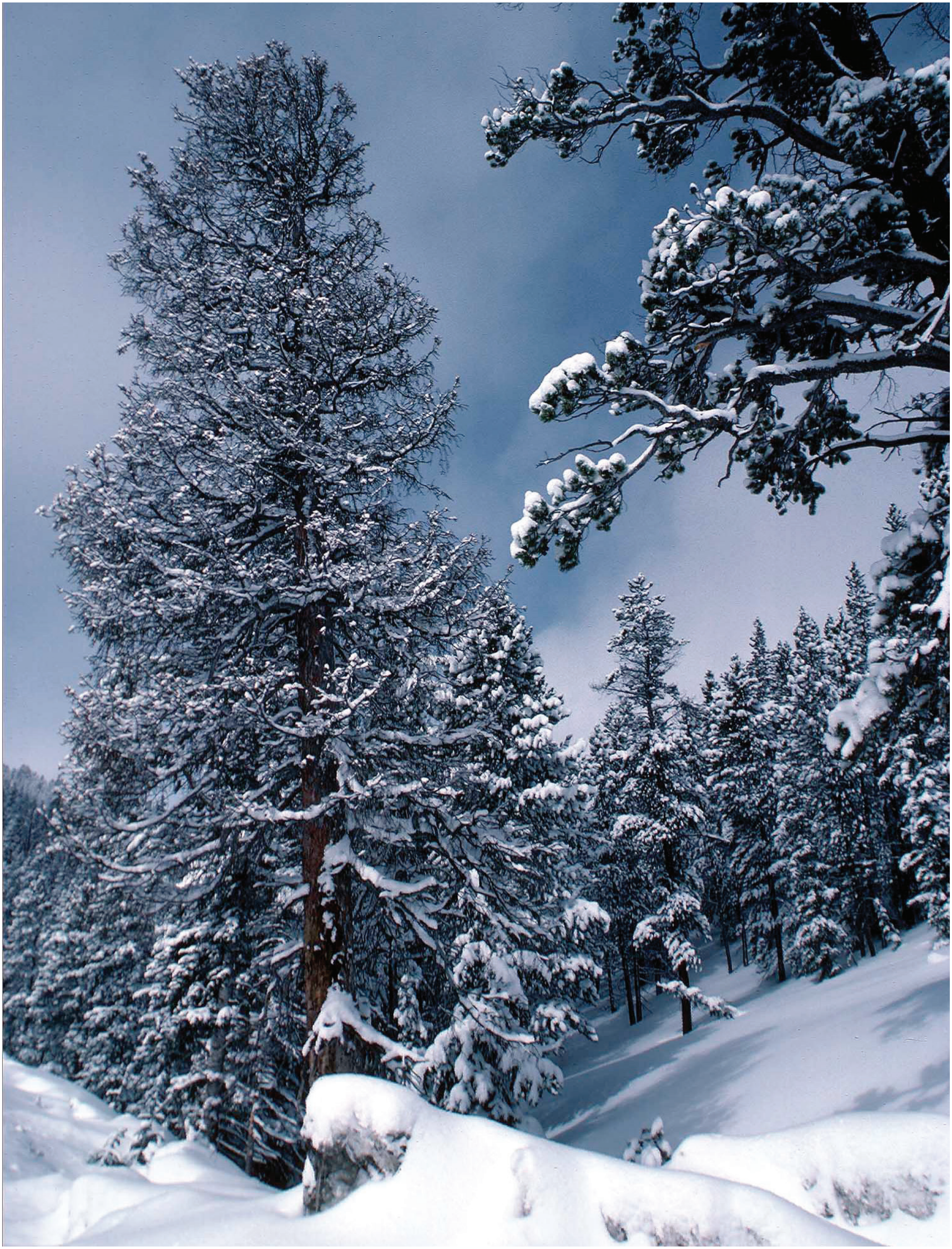
Understanding the Water Cycle

Findings from NOAA's Water Cycle Science Challenge Workshop

28 August – 1 September 2011, NOAA Earth System Research Laboratory, Boulder, Colorado

28 September 2012



Workshop Program Committee

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David Novak	NWS/NCEP/Hydrometeorological Prediction Center

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Submitted to the NOAA Research Council on behalf of the workshop participants and the Workshop Program Committee.

Marty Ralph and Bert Davis (Workshop Co-Chairs)

28 September 2012

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Executive Summary

A. Illustrative Motivations

Many motivations for advancing water-cycle science and services (Fig. 1) emerged from the workshop; a few of the most pressing were:

- "There is a collision in the Western US between 19th Century water law, 20th Century water infrastructure, and 21st Century population growth & climate change."
  —*Brad Udall, Western Water Assessment - Keynote*
- "Flood losses nationally have risen dramatically, even after being adjusted for inflation (Fig. 2). Flood losses averaged $4.7 billion/year in the 1980s, $7.9 billion/year in the 1990s and $10.2 billion/year in the 2000s."
  —*Don Cline, NOAA/NWS/Hydrology Laboratory - Invited*
- "Progress on predicting extreme precipitation seriously lags progress of other forecasts, and represents a major current gap."
  —*Dave Novak, NOAA/NCEP/HPC - Invited*

B. Background, Purpose, Planning

In August 2010 NOAA completed a report entitled "Strengthening NOAA Science," sponsored by Dr. Jane Lubchenco, the Undersecretary for Oceans and Atmospheres. The report (Sandifer and Dole 2010) identified 7 NOAA Science Grand Challenges, including "***Improve understanding of the water cycle at global to local scales to improve our ability to forecast weather, climate, water resources and ecosystem health."*** The topic was then selected by NOAA leadership for further development through engagement of external partners and stakeholders via the "Water Cycle Science Challenge Workshop" that is reported on below.

A key purpose of the workshop was to discuss and develop recommendations to NOAA Leadership that can be integrated into the next NOAA 5-Year Research Plan and into other NOAA science planning activities. The NOAA Research Council (RC) provided the following guidance for the workshop and is the formal recipient of this report. The workshop should "encompass the current state of understanding, identify gaps that can be addressed over the next five years, identify NOAA's role in filling those gaps in concert with external partners and other institutions over the next 5-years, and outline the expected benefits of filling the gaps."

An interagency program committee was formed. It selected the following overarching focus:

"Understanding and predicting conditions associated with either too much or too little water."

The program committee consisted of experts from several agencies and academia, with an emphasis on representing the spectrum of scientific and engineering knowledge required, and spanning weather and climate, as well as meteorology and hydrology. Ultimately 60 people participated in a 3-day workshop (Fig. 3; Appendix 1), roughly 30% of who were atmospheric-science oriented, 60% hydrology, and 10% other. Roughly 1/3 of participants were from other agencies, 1/3 from academia, and 1/3 from NOAA. Input was gathered through invited plenary presentations by experts, break-out sessions, and panel discussions (see Appendix 2 for the detailed agenda and Appendix 3 for findings from the breakout sessions). Relevant outputs of earlier planning efforts led by USGS, USBR, USACE, WGA, and WUCA were considered (e.g., Brekke et al. 2009; WSWC 2008; WUCA 2010; Reclamation & USACE 2011; Fig. 4), and a brief synopsis of these is provided in Appendix 4.

The Program Committee identified the following four themes for the workshop and organized the meeting and this report around these themes:

- Next generation hydrologic modeling
- Hydrometeorological forcings for hydrologic models
- Physical processes underlying the water cycle, and
- Climate dimensions

C. Goals and Recommendations

- Increase hydrologic forecasting skill for low-to-high stream flow conditions to be as good as the skill afforded by weather and climate predictions

Fig. 1. Examples of several key drivers for improved understanding and prediction of the water cycle. (Courtesy of Don Cline, NOAA)

  - Develop systems using strengths of both "lumped" & "physically-based" hydrologic models
  - Develop a unified large-scale hydrological modeling system allowing integrated and multi-scale predictions, projections and analyses
  - Foster efforts to bridge the historical disconnect between hydrology and meteorology
- Improve representations, understanding and forecasting of key hydrometeorological forcings to rival those of other non-water-cycle variables and forcings in the weather-climate system
  - Develop a National water cycle reanalysis, including key components and fluxes that close the water balance
  - Fill major gaps in observations of water cycle parameters (water vapor transport, precipitation, snow, surface energy budget terms including evapotranspiration, aerosols)
  - Integrate in situ, radar, satellite and numerical model guidance to construct high-resolution data-assimilation products that directly link atmosphere and land-surface processes and depict the full water cycle over the US with high fidelity
  - Implement a "moon-shot" style effort to improve extreme precipitation information
- Identify and diagnose physical processes key to extreme events (storms and floods) and document their roles in forecast errors
  - Identify "emergent" behavior in watershed dynamics and quantify associated thresholds
  - Understand and diagnose variability of water vapor transport, including atmospheric rivers which conduct >90% of the water vapor transport in mid-latitudes
  - Explore the role of aerosol variability in modulating cloud microphysics and precipitation
  - Diagnose, understand and quantify the characteristics of extreme precipitation and precursor land surface conditions that amplify or reduce drought and flood severity.
- Explicitly characterize key uncertainties in climate and hydrologic models (and their couplings)

- Establish NOAA "tiger teams" to evaluate selected real-world extreme events aiming to dissect causes and antecedents, assessing forecast skill and utility from hours to weeks
- Understand and describe the distributions of seasonal-to-interannual climate oscillations and their impacts on drought and flood risks
- Develop a global water cycle reanalysis and applications tools to better quantify uncertainties in water cycle trends in climate models and to meet user needs, e.g., for long-term infrastructure decisions for flood control, water supply, endangered species, etc.
- Analyze and identify landscape changes and water scape changes (e.g., irrigation, ice cover, lake levels), including human-caused, that must be factored into hydroclimate projections.

Fig. 2. Examples of recent flooding impacts associated with extreme precipitation, and a recommendation after a formal service assessment. (Courtesy of Don Cline (top) and Dave Novak (bottom); both of NOAA)

D. Proposed Implementation Strategies

- Elevate the priority of water cycle science and services in NOAA to levels comparable to that of weather and climate, building on MOUs between USGS, USACE & NOAA and between WGA & NOAA.
- Fully support the "National Water Center" (NWC) in the NWS to advance hydrologic services.
- Fully support NOAA's HMT in OAR to develop innovative solutions to providing the necessary hydrometeorological "forcings" to drive future hydrologic prediction systems across agencies.
- Implement the "Western US Observing Systems Vision for Extreme Events" requested by the WSWC to improve monitoring, prediction and climate trend detection of extreme events.
- Carry out and coordinate hydrological (e.g., via CUAHSI) and hydrometeorological (e.g., HMT) field studies.
- Develop a Hydroclimate Testbed building on NIDIS, HMT, RISAs, Laboratories and CUAHSI that would link hydroclimate science to services and user needs, and would emphasize extremes.

The following quote from a resolution passed in July 2011 by the Western States Water Council as a recommendation to the Western Governors Association (WGA) illustrates the existence of policy-maker support to move forward on implementation of key elements of this report's recommendations.

- "BE IT FURTHER RESOLVED, that the Western States Water Council (WSWC) supports development of an improved observing system for Western extreme precipitation events, to aid in monitoring, prediction, and climate trend analysis associated with extreme weather events; and, … urges the federal government to support and place a priority on research related to extreme events, including research on better understanding of hydroclimate processes, paleoflood analysis, design of monitoring and change detection networks, and probabilistic outlooks of climate extremes; and … the WSWC will work with NOAA in supporting efforts on climate extremes, variability, and future trends as called for in the WGA-NOAA memorandum of understanding.