

Improving
Sub-Seasonal to Seasonal
Precipitation Forecasting for
Water Management



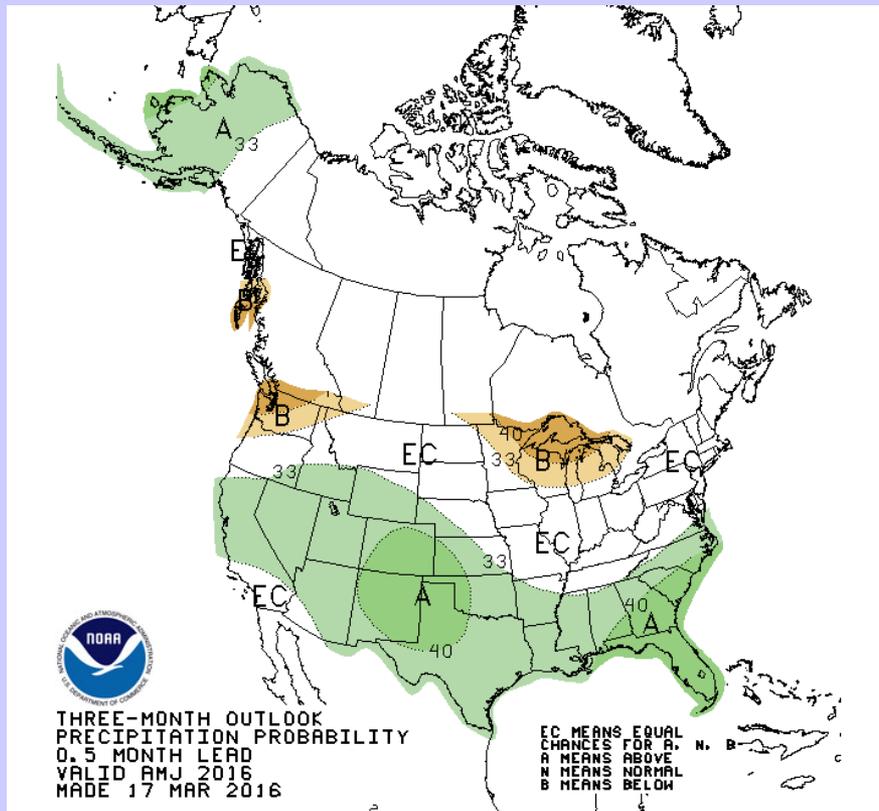
WESTERN
STATES
WATER
COUNCIL

WSWC/NOAA Workshops on S2S Precipitation Forecasting

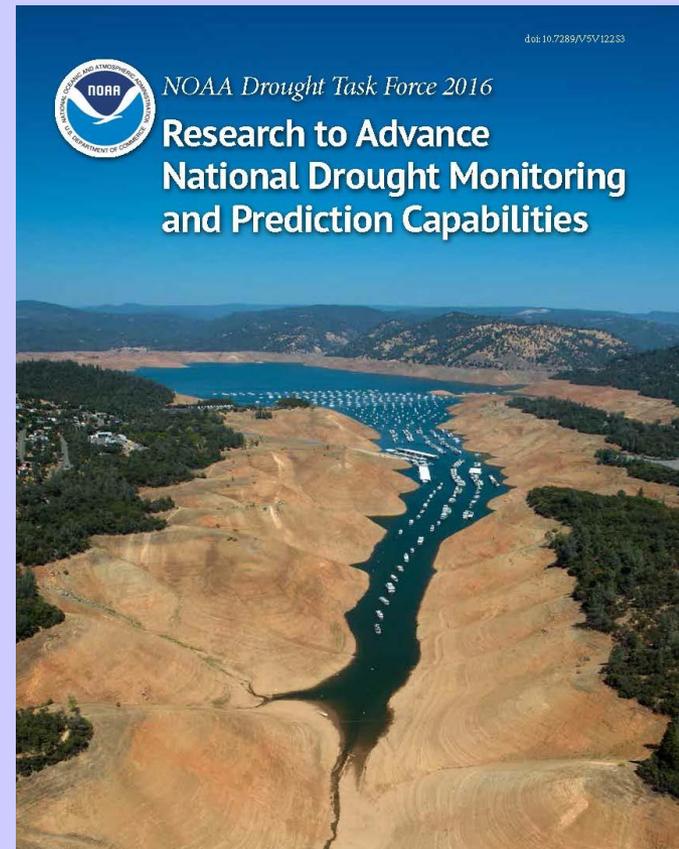
- San Diego, May 2015
- Salt Lake City at NWS Western Region HQ, October 2015
- Las Vegas at Colorado River Water Users Association, December 2015
- College Park, April 2016

Specific Focus on S2S Precipitation Forecasting

This



Not This

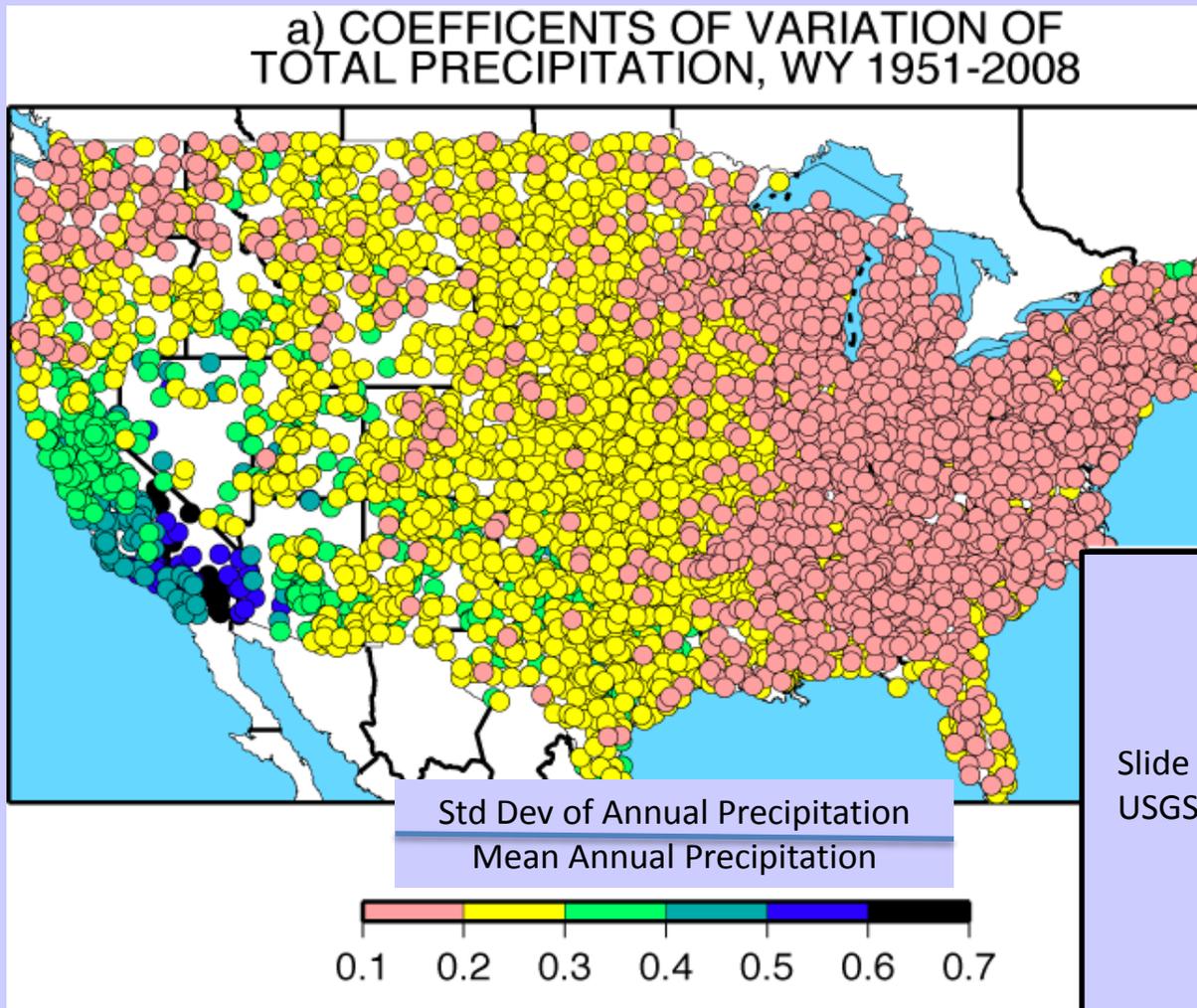


Why This Effort?

WSWC Perspective

- Importance of skillful sub-seasonal to seasonal precipitation forecasting for Western water management
- Lack of resources being directed to improving S2S precipitation forecasting
- Lack of resources being directed to Western precipitation prediction needs

Variability of Western Precipitation



Slide courtesy of Mike Dettinger,
USGS/Scripps



Motivation



- Opportunity for application of improved seasonal forecasts into water resource management is a long standing aspiration of both science and management communities.
 - Climate prediction literature from 1990s onward
 - Western water resources stakeholders (Colorado River in particular)
 - NOAA CA drought service assessment



Colorado Basin RFC Annual Stakeholder Meetings



Annual meetings of stakeholder agencies convened beginning in 2010 to discuss and document needs.

Improvements to sub-seasonal and seasonal forecasts out to two years is a major recurring theme among stakeholder agencies



- 3 Day Event at CBRFC in August 2010
- Participants from all over CO basin attended
- Main focus on water supply and peak flow forecast needs in the basin
- Key requirements from forum:
 - Simple ways to communicate forecasts relative to important thresholds
 - More info on the 30 year average update
 - Objective water supply forecast system
 - Greater CBRFC participation in stakeholder meetings
 - 2 year forecast for Colorado
- Full report online (under papers and presentations -> reports)
 - Report has been used for driving both CBRFC development as well as NOAA and other research priorities

CBRFC 2010 Stakeholder Forum

Summary

The Colorado Basin River Forecast Center (CBRFC) held a stakeholder forum on August 17-19. The forum was organized around presentations from CBRFC staff on models, tools, and projects that the RFC uses to make forecasts. Presentations included a description and demonstration of most elements of the CBRFC forecast process, a review of the 2010 runoff and the forecasts for it, discussion on various CBRFC projects including improved evapotranspiration, peak flow forecasts, the community hydrologic prediction service, and an analysis of snow versus runoff for key basins. As part of NOAA, the CBRFC is a service organization and strives to be as relevant to its stakeholders as possible. To that end, active discussion and participation was facilitated throughout the forum. Participants included many of the major stakeholders in the Colorado Basin (see participant list in appendix 1). The forum generated significant ideas, actions, and requests for new and improved ways the CBRFC can meet stakeholder requirements in the basin. These are described below.

Feedback from both participants and NOAA staff was generally very positive. In particular, participants appreciated the openness of CBRFC to adjust to the stakeholder requirements and the service oriented mission of NOAA generally and the CBRFC in particular. The stakeholder forum model was largely endorsed appropriate mechanism for engaging with stakeholders on either an annual annual basis. Demonstrations of forecast tools and discussion of forecast skill, post-mortem event analyses were particularly well received. In the future, many of the stakeholders would appreciate any insight beyond the officially published forecasts that the CBRFC can provide. Complete, unedited feedback is in app

The workshop agenda is in appendix 3. Full presentations are available on the CBRFC website (www.cbrfc.noaa.gov).

Follow up items

The following items were identified during the forum:

- Identify a simple way to communicate forecasts relative to specific thresholds - Bill Hesterman requested participants and the DEP to think



Colorado River Stakeholders



In response to sustained interest and demand across the River Forecast Center community, a 2011 workshop was convened to tackle this problem



Welcome!

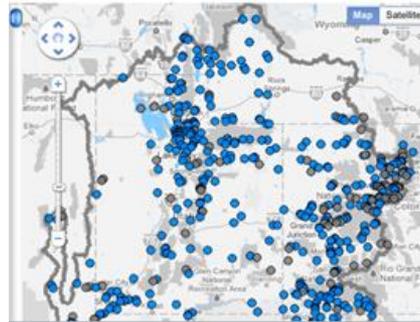


SI/Y2 Climate and Streamflow Forecasting Workshop

NOAA/NWS Colorado Basin River Forecast Center
Salt Lake City, UT – March 21-22, 2011

Organized by
CBRFC
USBR

Sponsored by
Colorado Water Conservation Board
NIDIS





2011 Colorado River Workshop



Where are we now?



- 15 years of applied climate and flow forecasting research pertaining to western US

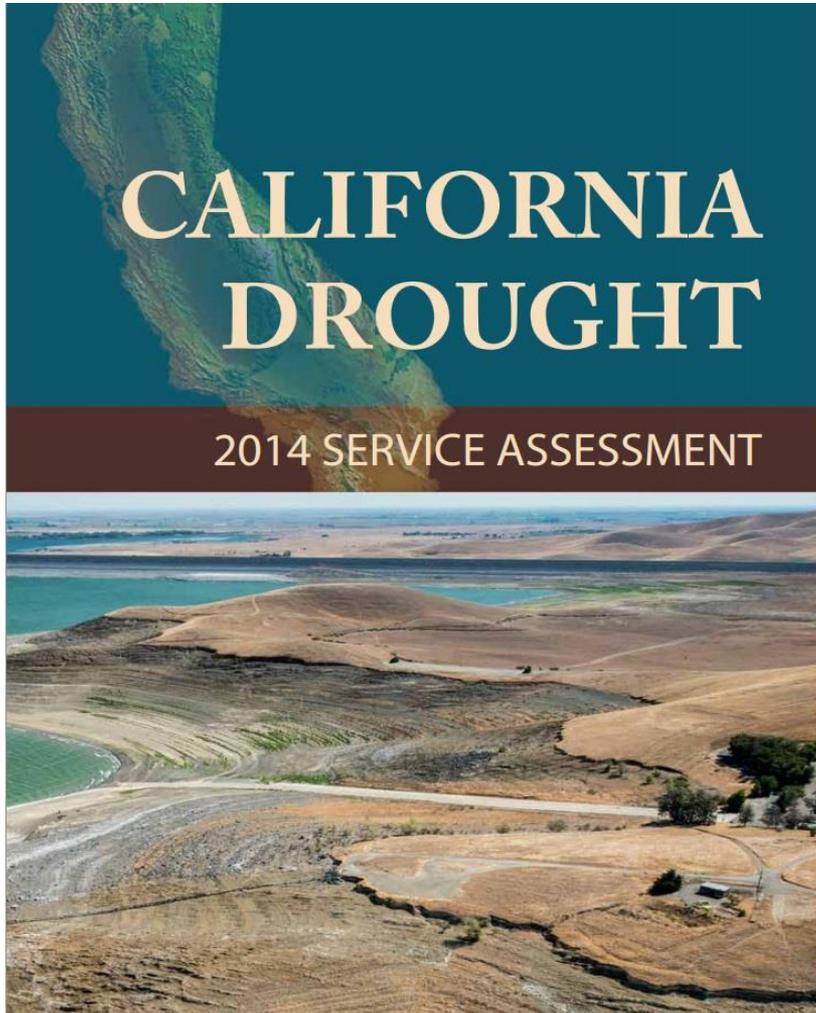
Barnston, A.G., et al: 1994, <i>Long-lead seasonal forecasts—where do we stand?</i> , BAMS	Trenberth, K. E. 1997. <i>The definition of El Niño</i> . BAMS
Wood, A. W., A. Kumar, and D. P. Lettenmaier (2005), <i>A retrospective assessment of National Centers for Environmental Prediction climate model-based ensemble hydrologic forecasting in the western United States</i> , <i>J. Geophys. Res.</i>	Piechota, T.C., J.A. Dracup, and R.G. Fovell, 1997. <i>Western U.S. Streamflow and Atmospheric Circulation Patterns During El Niño-Southern Oscillation (ENSO)</i> . <i>Journal of Hydrology</i>
Bracken, C., B. Rajagopalan, and J. Prairie (2010), <i>A multisite seasonal ensemble streamflow forecasting technique</i> , <i>Water Resour. Res.</i>	Piechota, T.C., Dracup, J.A., 1996, <i>Drought and Regional Hydrologic Variations in the United States: Associations with the El Niño/Southern Oscillation</i> . <i>Water Resources Research</i>
Ropelewski, C.F.; and M.S. Halpert. 1986. <i>North American precipitation and temperature patterns associated with the El Niño-Southern Oscillation (ENSO)</i> . <i>MWR</i>	Garen, D.C., 1992, <i>Improved Techniques in Regression-Based Streamflow Volume Forecasting</i> , <i>JWRPM</i>
Bracken, C; Rajagopalan, B; Prairie, J (2010), <i>A multisite seasonal ensemble streamflow forecasting technique</i> . <i>Water Resour. Res.</i>	Hamlet, A. F., Lettenmaier, D. P., 1999: <i>Columbia River Streamflow Forecasting Based on ENSO and PDO Climate Signals</i> , <i>JWRPM</i>
Grantz, K., B. Rajagopalan, M. Clark, and E. Zagona, 2005: <i>A technique for incorporating large-scale climate information in basin-scale ensemble streamflow forecasts</i> . <i>Water Resour. Res.</i>	Piechota, T. C. and Dracup, J. A., "Long-range streamflow forecasting using ENSO information: Application to the Columbia River Basin" (1997). <i>Faculty Publications (CEE)</i>
Grantz, K; Rajagopalan, B; Zagona, E; Clark, M (2007), <i>Water management applications of climate-based hydrologic forecasts: Case study of the Truckee-Carson River Basin</i> . <i>JWRPM</i>	Wang, S.-Y., R. R. Gillies, J. Jin, and L. E. Hipps (2009), <i>Recent rainfall cycle in the Intermountain Region as a quadrature amplitude modulation from the Pacific decadal oscillation</i> , <i>Geophys. Res. Lett.</i>
Najafi, M., Moradkhani H., and Wherry, S., "Statistical Downscaling of Precipitation using Machine Learning with Optimal Predictor Selection", <i>JHE</i>	Moradkhani, H., Meier, M., "Long-Lead Water Supply Forecast using Large-scale Climate Predictors and Independent Component Analysis", <i>JHE</i>
Switanek, Matthew B., Peter A. Troch, Christopher L. Castro, 2009: <i>Improving Seasonal Predictions of Climate Variability and Water Availability at the Catchment Scale</i> . <i>JHM</i>	Sankarasubramanian, A., U. Lall, N. Devineni and S. Espunueva, <i>Utility of Operational Streamflow Forecasts in Improving within-season Reservoir Operation</i> , <i>IACM</i>

- Variable use of findings within operational water prediction and management
- One of the biggest usage gaps: the upper Colorado River Basin
- Motivation: Increasing scrutiny of Colorado River water management

Credit: Andy Wood



NOAA's CA Drought Service Assessment



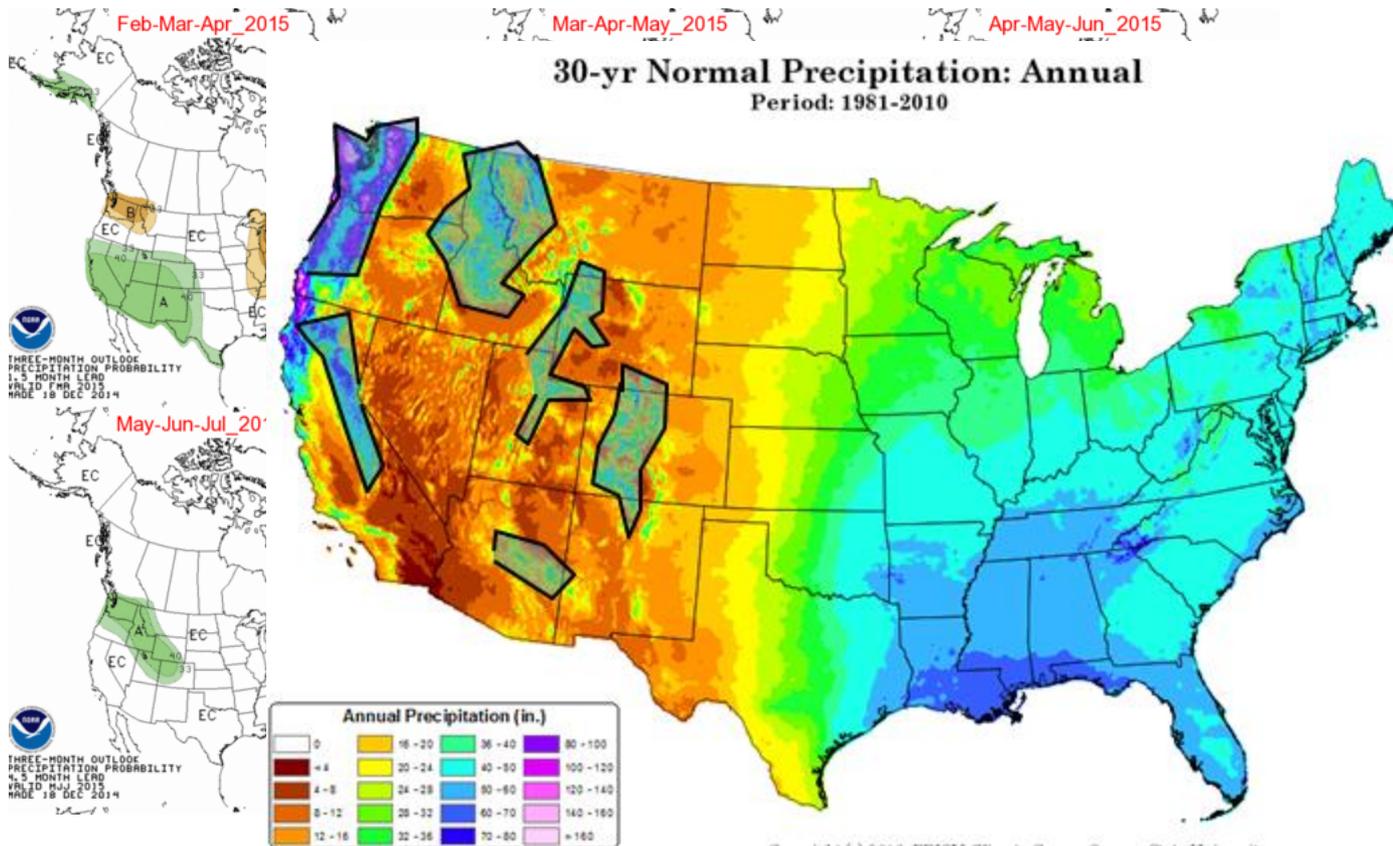
- 10 team members
- 43 recommendations
- 100+ interviews
- 40+ reviewers
- 400+ comments
- 62 pages
- 10 months
- 3 focus sectors
- 1 really bad drought



Improved Seasonal Prediction for Water Resources



- #1 Stakeholder request: What is the forecast for the upcoming winter's precipitation?





NOAA's CA Drought Service Assessment



- ***Finding 5.3:*** Accumulated precipitation—typically snow—in the key watersheds of the Cascade, Sierra Nevada, southern California mountains, and groundwater recharge areas are the primary source for water resources in California and the western states, yet no focused seasonal forecast capacity exists for this all-important resource in order for agencies to make effective planning decisions and water allocations.
- ***Recommendation 5.3a:*** NOAA (including CPC, RFCs, NWC, NCDC, and CPO) should invest in developing and operationalizing seasonal forecast techniques targeted at accumulated cool-season precipitation, specifically snowpack accumulation and snowmelt runoff, in the watersheds important for water resources.



NOAA's CA Drought Service Assessment



- **High Level Finding (HLF) 1:** Great interest exists for seasonal prediction products and ENSO discussions (monthly), especially for cool-season precipitation. These forecasts, however, typically have very low skill and confidence, rendering them near-useless for most decision makers interviewed. Further, the CPC forecast products were often prone to misinterpretation by both NOAA field offices and external stakeholder agencies.
- **Recommendation HLF 1a:** NOAA should acknowledge the major importance of cool-season precipitation in providing water not only for California but for the western United States. As such, Office of Oceanic and Atmospheric Research (OAR) should synthesize the state of research on predictability of accumulated cool-season precipitation in the mountains and scope an operational forecasting capability that is closely linked to supporting the water resource management community.
- **Recommendation HLF 1b:** The Climate Prediction Center (CPC) should work more closely with front line offices, especially the RFCs and WFOs in the National Weather Service, to understanding local uses of and needs for seasonal prediction and how to more effectively communicate them to the public. Additionally, the effectiveness of internal education on seasonal prediction products should be assessed. To address this recommendation, NWS should develop a plan for improving two-way communications between CPC and field offices, documenting stakeholder use cases and requirements for seasonal prediction, and assess the effectiveness of internal education on seasonal prediction.

Member states:



WESTERN STATES
WATER COUNCIL

Importance of Improved Forecasting for Water Management

Lead Time Very Important for Water Management

- Public health & safety decisions
- Balancing risk/cost trade-offs
- Increasing water management efficiency
- Operating within legal & regulatory frameworks
- Reducing impacts of extreme events
- Responding to increased competition for resources

Will the Rest of This Winter be Wet or Dry?

Example Sub-Seasonal Decisions

- How much water will we be able to provide to our water users? When can we make the announcement?
- Will we hit hydrologic shortage triggers that require extraordinary conservation measures, or the need to negotiate contracts or adopt regulations?
- Is an elevated flood risk likely this spring? Should we pre-position resources?
- If the rest of this winter looks dry, can we use reservoir flood control space to store water for allocation to users?
- Will we have to curtail diversions on intensively used rivers? How early in the season?

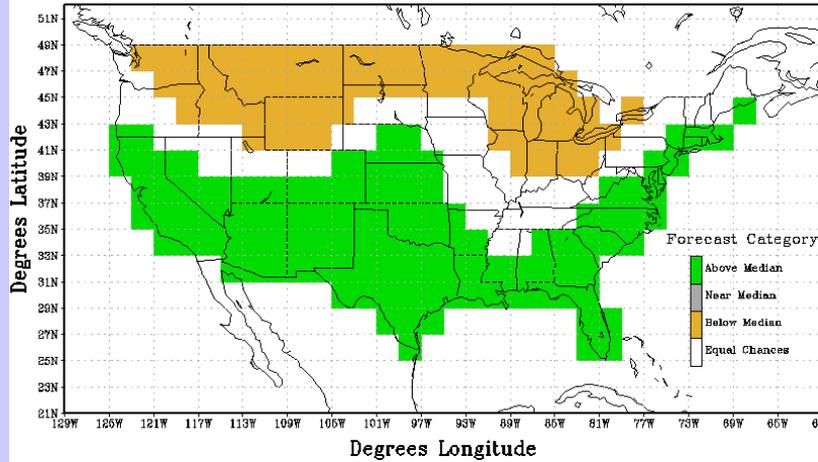
Will This Winter be Wet or Dry?

Example Seasonal Decisions

- Should we begin negotiating contracts for one-time sale of surplus wet-weather water? Can we set up a temporary groundwater banking program to take advantage of wet conditions?
- Do we need to seek additional drought response funding or raise water rates? Do we need to budget for enhanced water conservation activities?
- Should we make plans and adopt regulations for adopting a drought water bank?
- Should we intensify flood preparedness activities in vulnerable areas?

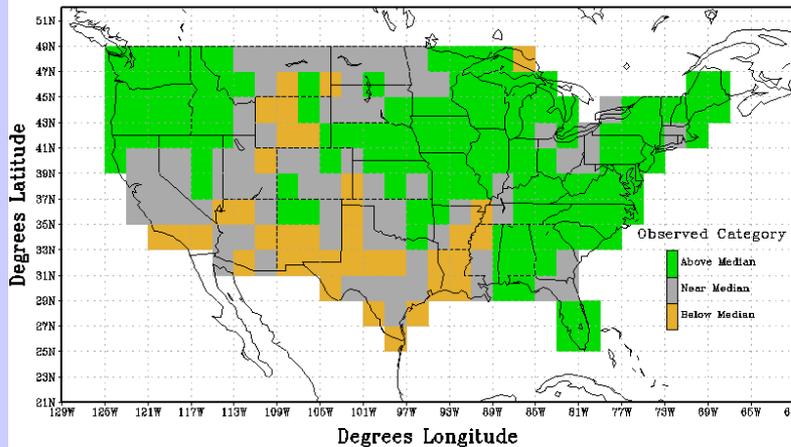
Present Forecasting Skill Not Useful for Water Management

Categorical Precipitation Official Forecast
Issued: Nov 2015 Valid: Dec-Jan-Feb 2015-16



Precipitation Forecast Heidke Skill Scores :
Non-Equal Chance(non EC) forecasts: -7.87
All forecasts: -6.03
% coverage not Equal Chance forecasts : 76.72

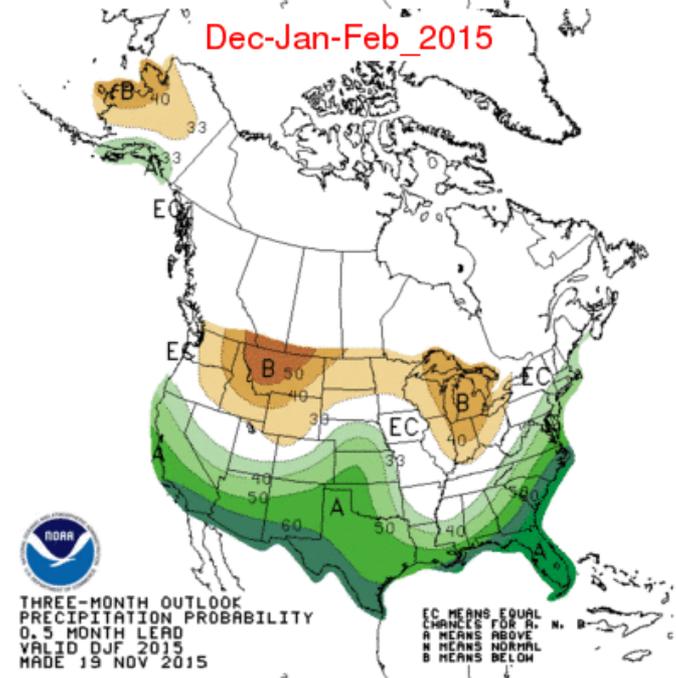
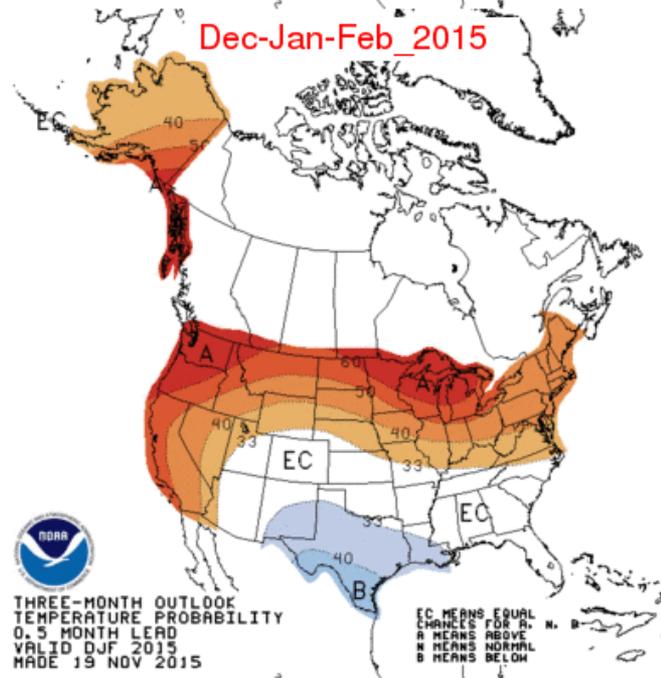
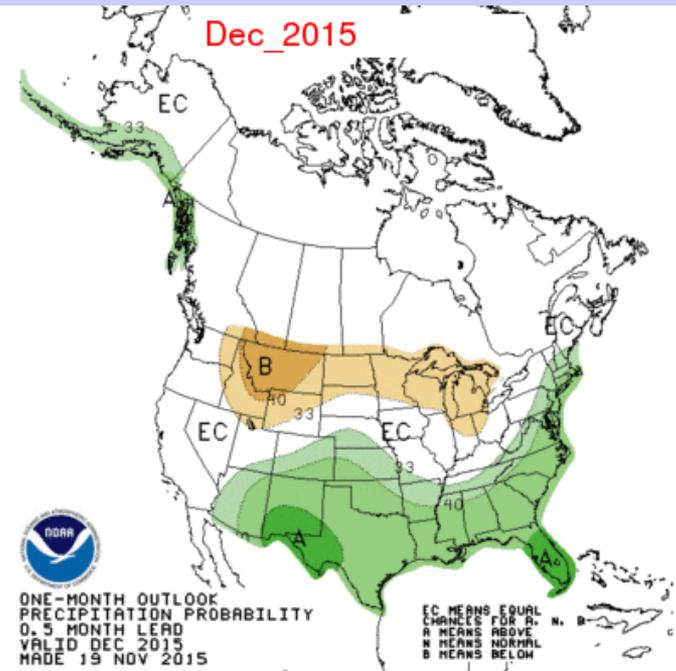
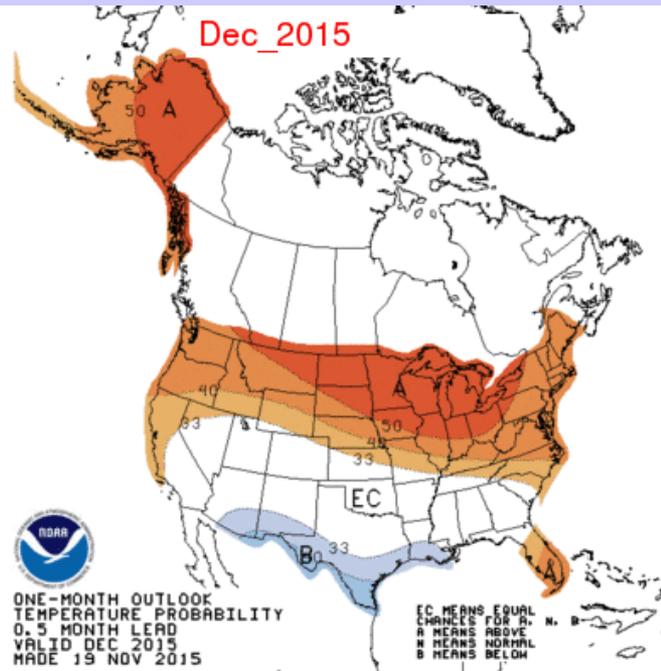
Categorical Precipitation Observations
Valid: Dec-Jan-Feb 2015-16



Sources of NOAA Forecast Skill

- 1. ENSO
- 2. Trends (difference between 10yr temp mean or 15yr precip mean & 30yr climatology)
- 3. MJO
- 4. NAO
- 5. PDO
- 6. Soil moisture/snow cover
- 7. Statistical forecast tools
- 8. Dynamical forecast models
- 9. Consolidation of trends & forecasts





Water Year 2016 – What Actually Happened

Snoqualmie, WA in November 2015



Meanwhile in Southern California

