Experimental Subseasonal Forecasting of Atmospheric Rivers and Ridging Events to Benefit Western U.S. Water Management

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S2S RTP Workshop; 17 Nov 2022

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DWR supports a CW3E-JPL S2S Partnership, with key collaborating institutions

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CW3E S2S Advisory Panel

F. Martin Ralph[1] (Co-Chair), **Duane Waliser**[2] (Co-Chair), Dan Cayan[1], Bruce Cornuelle[1], Art Miller[1]





S2S Prediction Team

Mike DeFlorio (CW3E S2S Team Lead)[1], Alphan Altinok[2], Patrick Broxton[4], Christopher Castellano[1], Rachel Clemesha[1], Will Chapman[7], Luca Delle Monache[1], Michael Dettinger[1], Sasha Gershunov[1], Peter Gibson[8], Alexander Goodman[2], Bin Guan[6,2], Kristen Guirguis[1], Xianan Jiang[6,2], Julie Kalansky[1], Brian Kawzenuk[1], Hyemi Kim[9], Hai Lin[11], Wen-shu Lin[1], Andrea Molod[10], Ángel Muñoz[3], Ming Pan[1], Cody Poulsen[1], Andrew Robertson[3], William Scheftic[4], Agniv Sengupta[1], Bohar Singh[3], Aneesh Subramanian[5], Frederic Vitart[6], Jiabao Wang[1], Jing Yuan[3], Xubin Zeng[4], Zhenhai Zhang[1]

Affiliations: [1]CW3E, SIO-UCSD; [2]NASA JPL/CalTech; [3]IRI; [4]U. Arizona; [5]University of Colorado Boulder; [6]UCLA; [7]NCAR; [8]NIWA; [9]ECMWF, [9]Stony Brook University, [10]NASA Goddard, [11]ECCC

Motivation: Western U.S. water managers need better S2S forecasts of precipitation

From Days to [illegible] ... i-Scale Weather and

Water Management Decision Support Needs

- Reservoir
- Flood Em
  Response
- Situationa

Identify Vulnerabilities
Develop Adaptation Strategies
Prioritize Implementation

Physical Processes Impacting Predictability

"Wea ... nate"

daily to w ... decadal to century

Adapted from Merryfield [illegible]

The water level in Lake Oroville near Enterprise Bridge in Butte County, California, was 52% below its historical average level when this photograph was taken, on 23 October 2015. Credit: Zack Cunningham/California Department of Water Resources

Better Subseasonal-to-Seasonal Forecasts for Water Management

Emerging methods that improve precipitation forecasting over weeks to months could support more informed resource management and increase lead times for responding to droughts and floods.

By Michael J. DeFlorio, F. Martin Ralph, Duane E. Waliser, Jeanine Jones, and Michael L. Anderson

Image credits: Ralph et al. 2019; NOAA; NOAA; Josef Friedhuber

DeFlorio, M. J., F. M. Ralph, D. E. Waliser, J. Jones, and M. L. Anderson (2021): **Emerging methods supporting water management at subseasonal-to-seasonal (S2S) lead times.** *EOS, 102*, https://doi.org/10.1029/2021EO159749.

Overview of CW3E Subseasonal Research and Experimental Forecast Products

Forecast Product	Lead(s)	Predictands	Lead Times	Development stage	Associated Publication(s)
Weeks 1-3 AR activity outlooks	Mike DeFlorio[1]	AR frequency	Subseasonal	Public	DeFlorio et al. 2019a,b (Cli. Dyn., JGR-A)
Weeks 1-6 ridging outlooks	Peter Gibson[5]	Z500/ridge types	Subseasonal	Public	Gibson et al. 2020a,b (J. Clim., JGR-A)
Weeks 1-4 AR intensity outlooks	Zhenhai Zhang[1]	AR intensity	Subseasonal	Research/Internal	Zhang et al. 2022 (submitted, JGR-A)
Weeks 1-6 AR/IVT anomaly outlooks	Chris Castellano[1]	Total IVT and AR frequency	Subseasonal	Research	Castellano et al. 2022 (in revision, JGR-A); Wang et al. 2022b (in revision, JHM)
Weeks 1-6 weather regime outlooks	Andy Robertson[3], Juan Ying[3], Bohar Singh[3], Angel Muñoz[3]	Circulation regimes	Subseasonal	Public	Robertson et al. 2020 (MWR)

[1] *CW3E/SIO-UCSD;* [2] *NASA JPL;* [3] *IRI;* [4] *University of Arizona;* [5] *NIWA*

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Overview of CW3E Seasonal Research and Experimental Forecast Products

Forecast Product	Lead(s)	Predictors	Lead Times	Development stage	Associated Publication(s)
North Pacific circulation regimes (NP4 modes)	Kristen Guirguis[1], Alexander Gershunov[1], Tamara Shulgina[1]	Z500/SST	Subseasonal to seasonal	Research/Internal	Guirguis et al. 2020 (GRL); Guiguis et al. 2022 (in prep)
Seasonal precipitation anomaly (next three months and JFM)	Alexander Gershunov[1], Rachel Clemesha[1], Kristen Guirguis[1]	Pacific SST	Seasonal	Public	Gershunov and Cayan 2003
Seasonal precipitation anomaly clusters (NDJ and JFM)	Peter Gibson[1], Will Chapman[1], Alphan Altinok[2], Luca Delle Monache[1], Mike DeFlorio[1]	Tropical SSTs, VP200, U200, Z500	Seasonal	Research/Internal	Gibson et al. 2021 (Nat. Commun. Earth Environ.)
Seasonal precipitation	Agniv Sengupta[1], Duane Waliser[2]	Global SST	Seasonal	Research/Internal	Sengupta et al. 2022 (in prep)
Seasonal SWE, precipitation, and temperature forecasts	Xubin Zeng[4], Patrick Broxton[4], William Scheftic[4]	N/A (based on dynamical ensembles)	Seasonal	Research/Internal	Scheftic et al. 2022 (submitted, J. Clim.)
Odds of water year normal precipitation	Mike Dettinger[1]	Historical precipitation obs	Seasonal	Public	Experimental only

[1] *CW3E/SIO-UCSD;* [2] *NASA JPL;* [3] *IRI;* [4] *University of Arizona*

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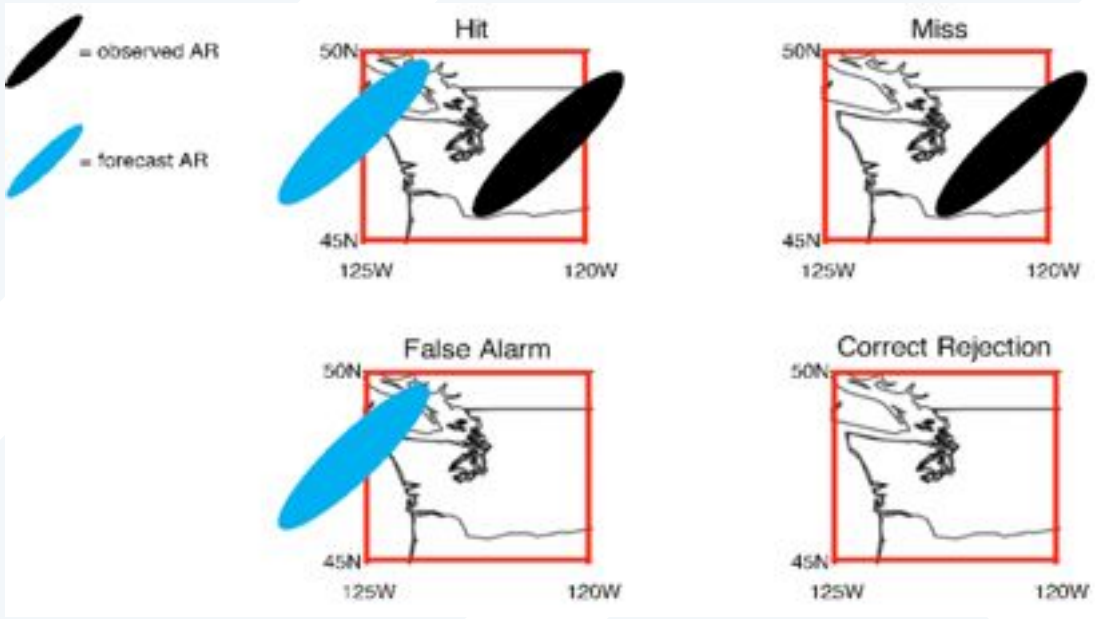
EXPERIMENTAL S2S FORECASTING OF ATMOSPHERIC RIVERS OVER THE WESTERN UNITED STATES

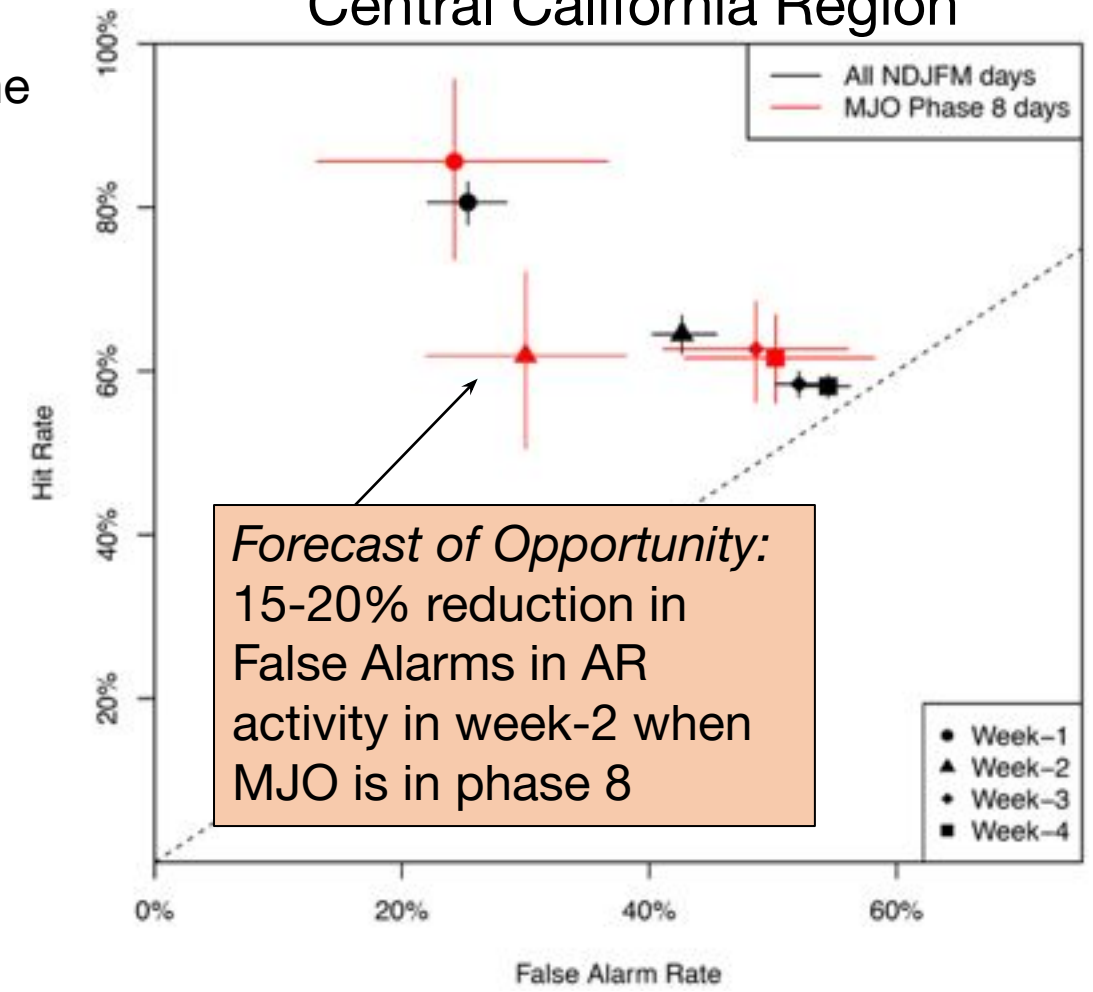
MIKE DEFLORIO, DUANE WALISER, MARTY RALPH, BIN GUAN, ALEX GOODMAN, PETER GIBSON, SHAKEEL ASHARAF, LUCA DELLE MONACHE, ZHENHAI ZHANG, ANEESH SUBRAMANIAN, FREDERIC VITART, HAI LIN, ARUN KUMAR (2019B, JGR-ATMOSPHERES)

Goal: multi-model assessment of S2S AR prediction skill

- Second approach: predict hits, misses, false alarms, and correct rejections of AR activity along western U.S. coastline in ECMWF hindcast system and composite skill of model prediction during strong ENSO/MJO periods



Central California Region



Forecast of Opportunity: 15-20% reduction in False Alarms in AR activity in week-2 when MJO is in phase 8

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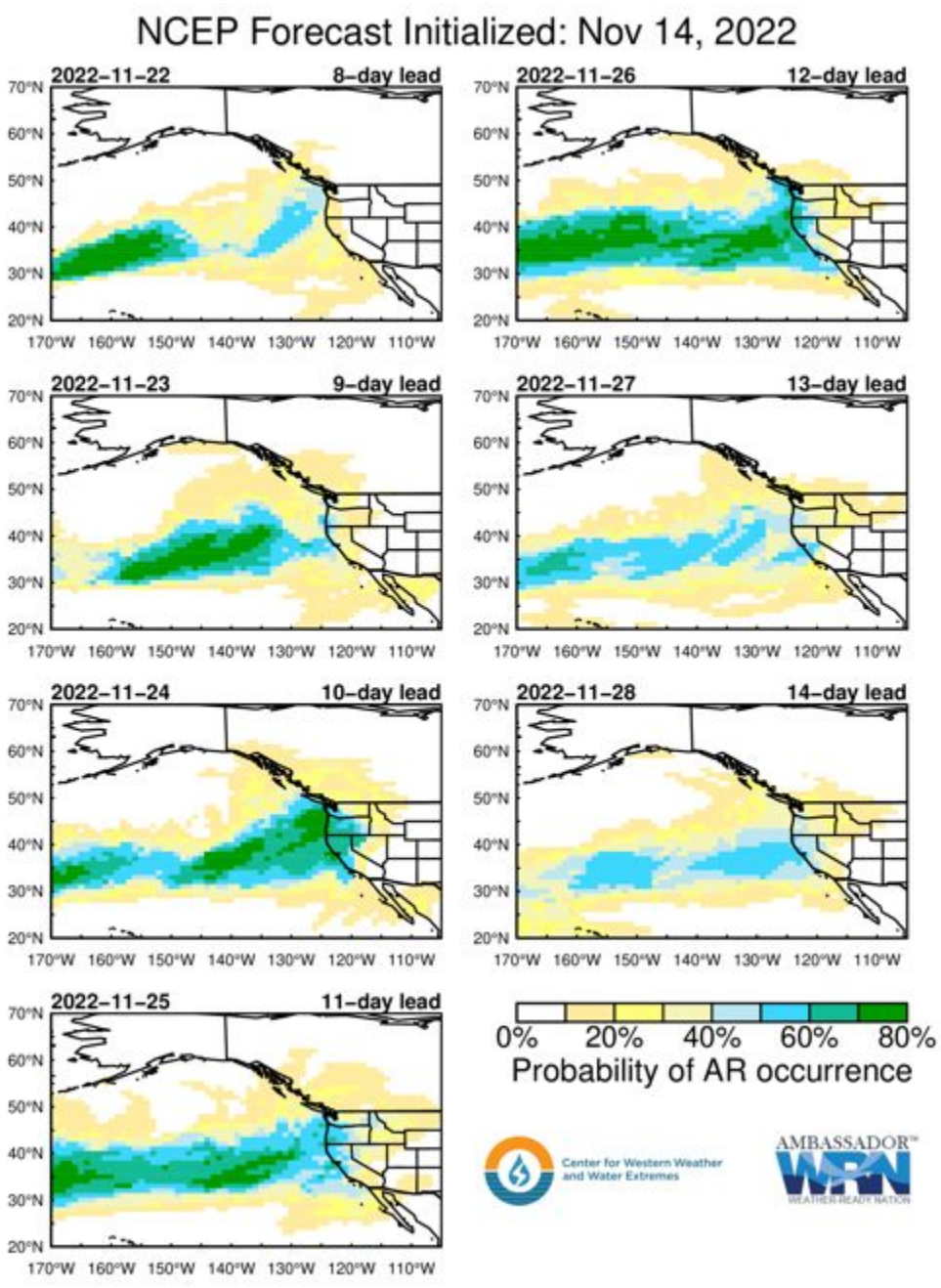
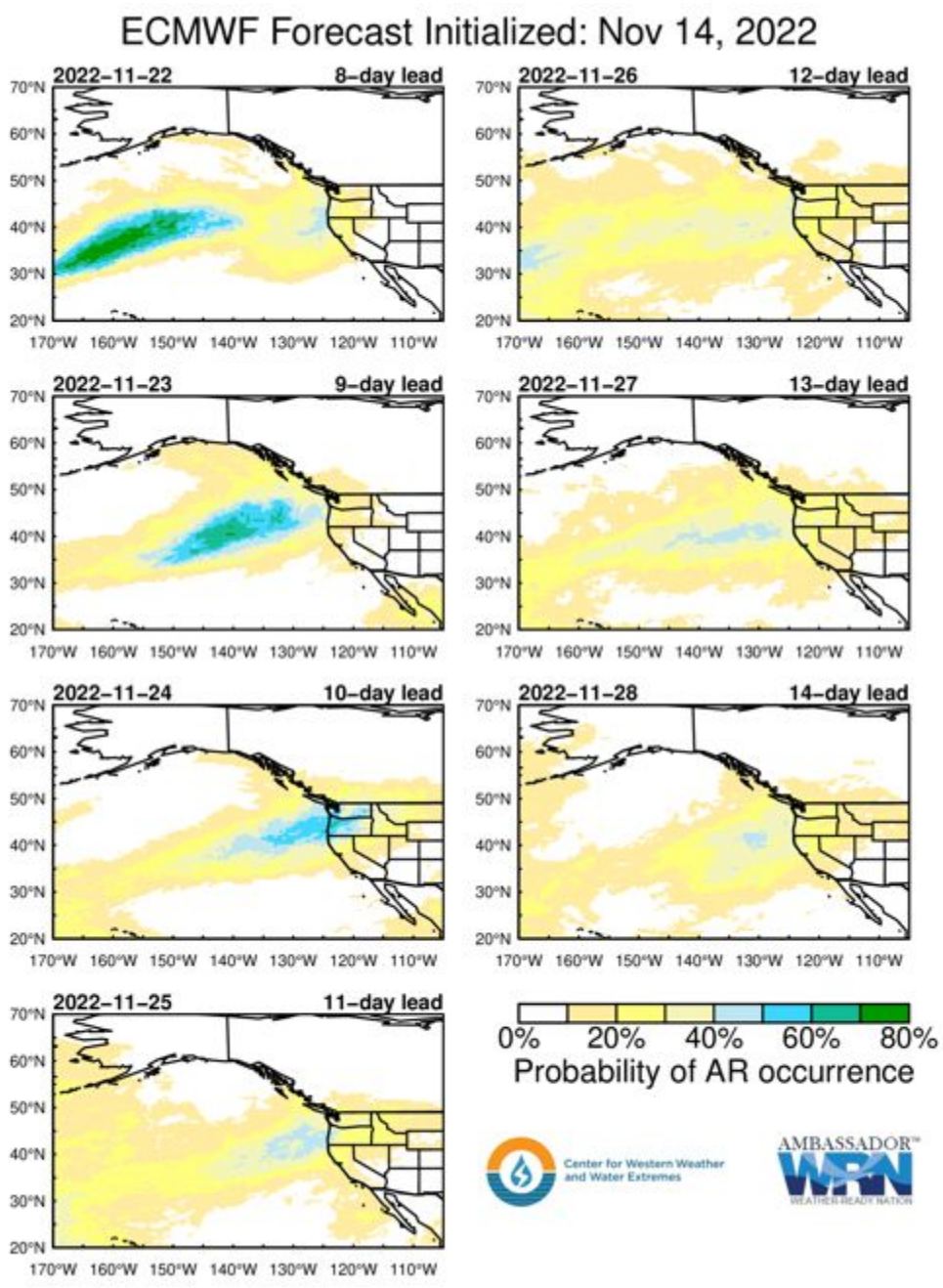
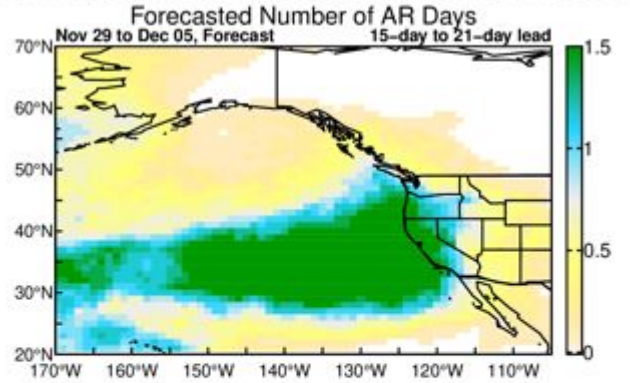
Week-2 AR Activity Outlooks - NCEP and ECMWF (Valid: 22-28 Nov 2022)

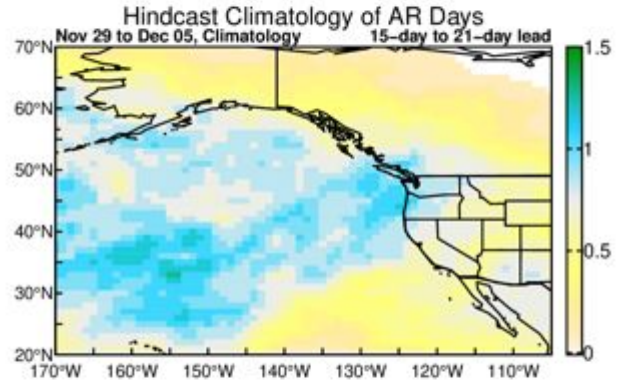


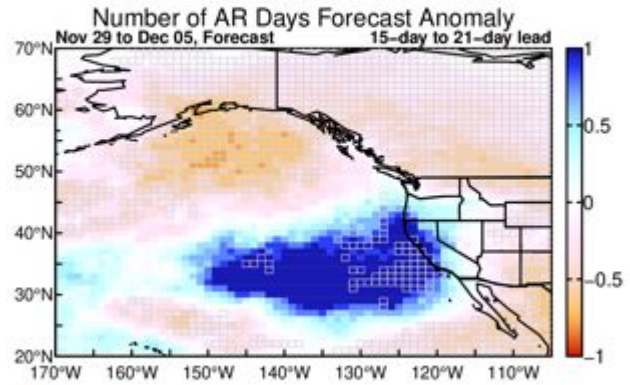


Week-3 AR Activity Outlooks - NCEP and ECMWF (Valid: 29 Nov – 5 Dec 2022)

NCEP Experimental Forecast Initialized: Nov 14, 2022







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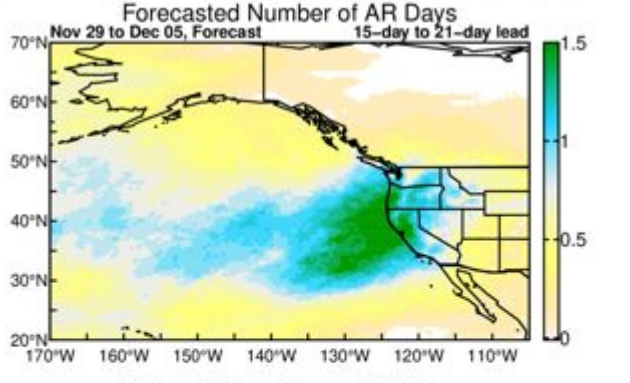
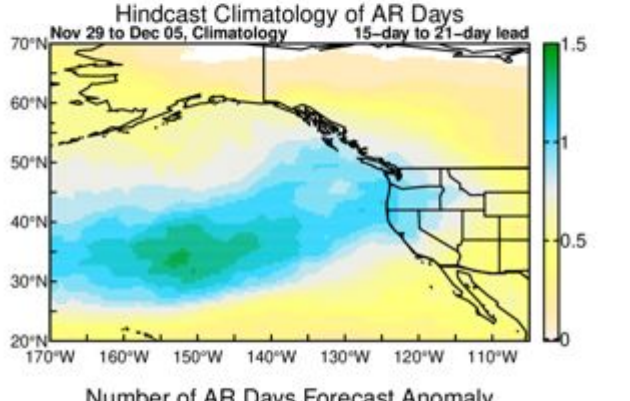
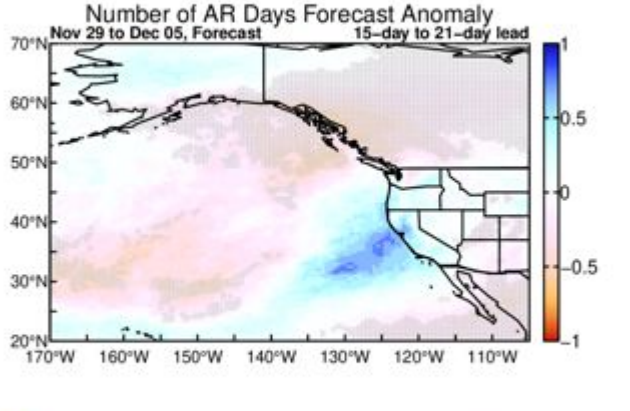
ECMWF Experimental Forecast Initialized: Nov 14, 2022







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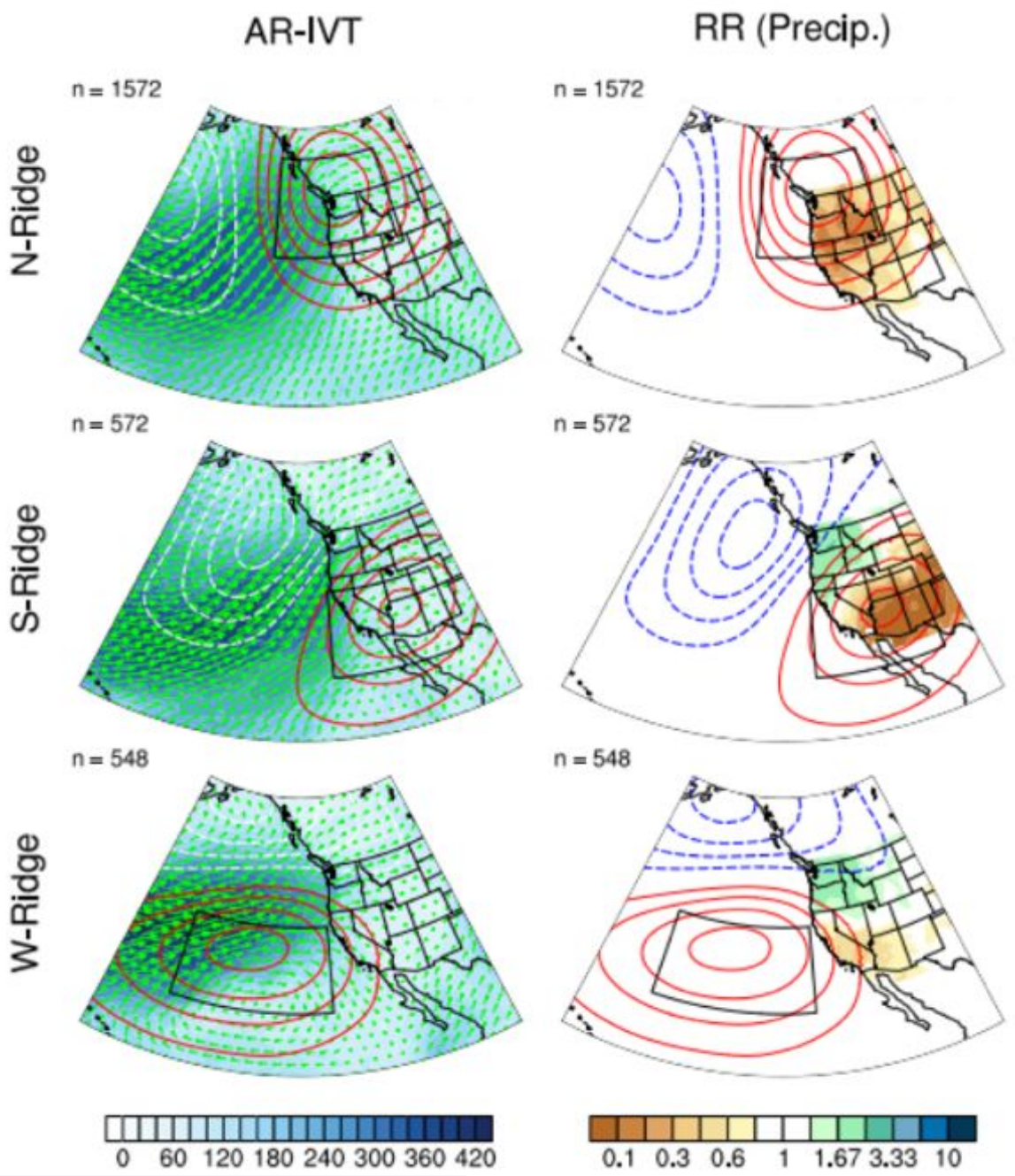
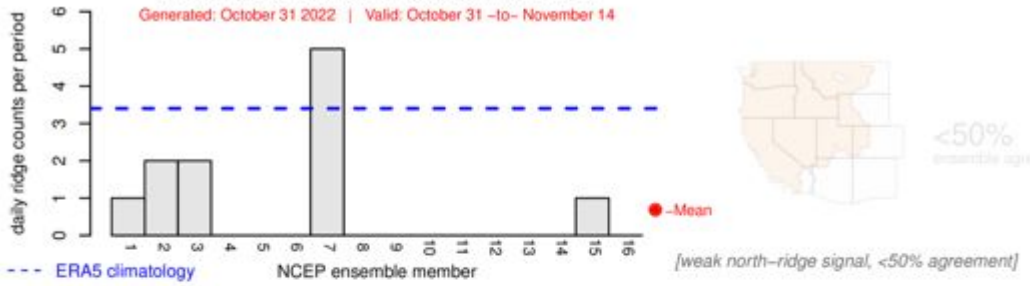
CW3E Ridging Outlooks – background methodology



Weeks 1-2 Ridging Outlooks - NCEP and ECMWF (Valid: 14 Nov – 28 Nov 2022)

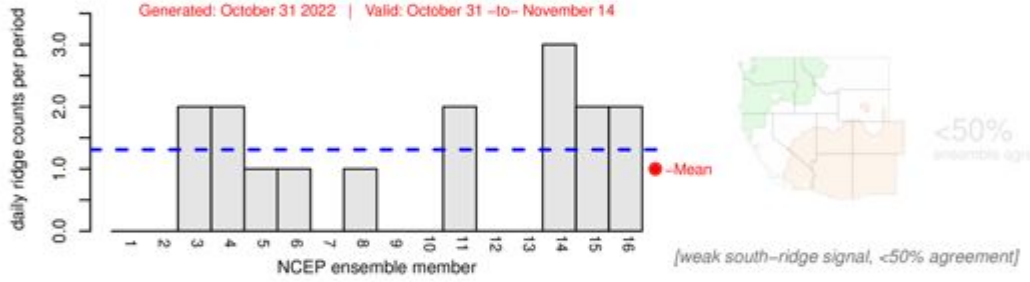
CW3E Subseasonal Ridging Forecast
(Uses NCEP CFSv2 model)

North–ridge type (lead time: weeks 1 & 2)



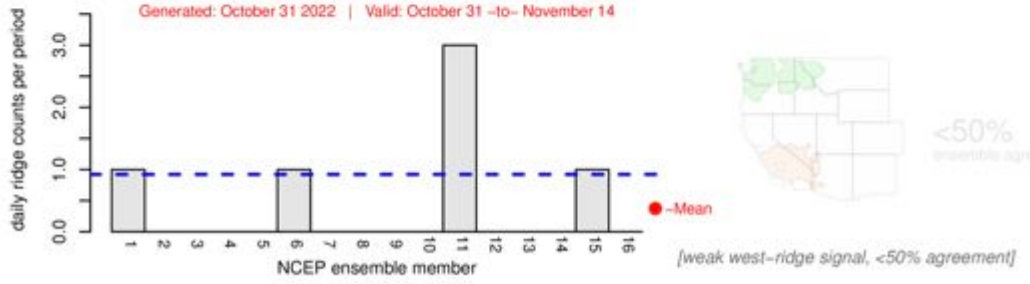
[weak north–ridge signal, <50% agreement]

South–ridge type (Lead time: weeks 1 & 2)



[weak south–ridge signal, <50% agreement]

West–ridge type (Lead time: weeks 1 & 2)



[weak west–ridge signal, <50% agreement]

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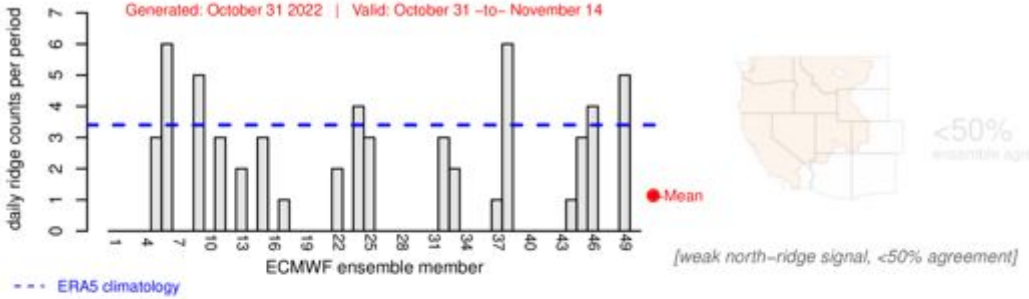
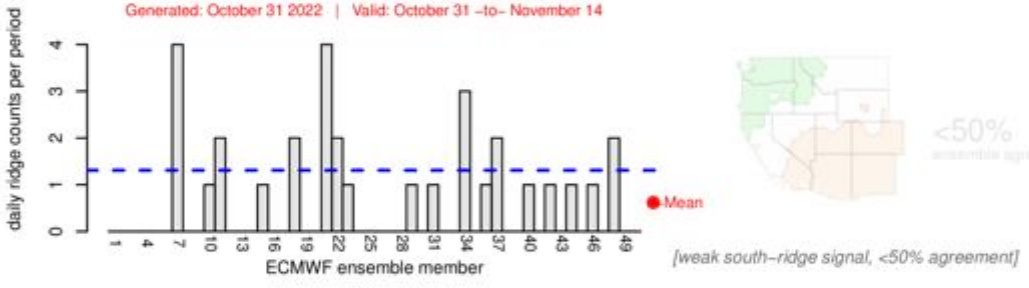
CW3E Subseasonal Ridging Forecast
(Uses ECMWF model)

North–ridge type (lead time: weeks 1 & 2)



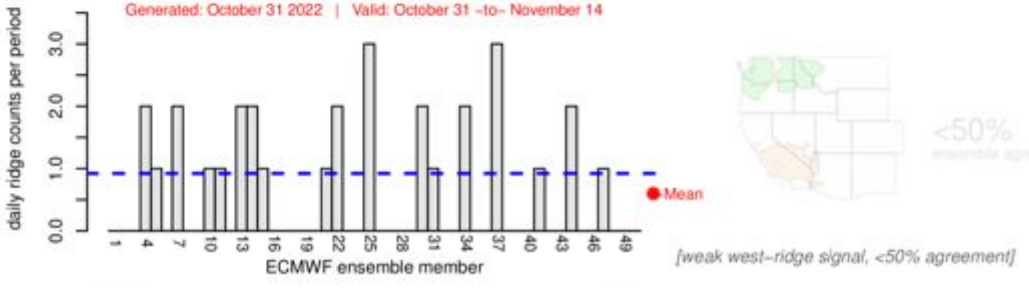
[weak north–ridge signal, <50% agreement]

South–ridge type (Lead time: weeks 1 & 2)



[weak south–ridge signal, <50% agreement]

West–ridge type (Lead time: weeks 1 & 2)



[weak west–ridge signal, <50% agreement]

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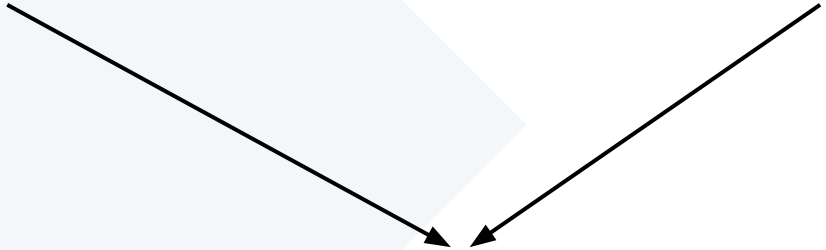
Summary

The western U.S. region, and in particular California, experiences the highest interannual variability of wintertime precipitation in the country relative to average conditions.

In addition, water managers across the western U.S. are in need of more skillful predictions of precipitation at S2S lead times.



This combination, along with increasing demand by other end users in the applications community for more skillful longer-lead precipitation forecasts, has led to increased international investment for S2S research, with a focus on better understanding of physical mechanisms related to predictability, and an end goal of creating experimental S2S forecast products to meet end user needs.

The California Department of Water Resources has funded a research and operations partnership led by the Center for Western Weather and Water Extremes and the NASA Jet Propulsion Laboratory to create experimental S2S forecast products for precipitation, atmospheric rivers, and ridging.

These experimental S2S products are necessarily supported by peer-reviewed hindcast skill assessments, and are designed in tandem with stakeholders to best meet their needs.

Selected CW3E S2S Publications: 2021-2022

Cao, Q., S. Shukla, M. J. DeFlorio, F. M. Ralph, and D. P. Lettenmaier (2021), Evaluation of the subseasonal forecast skill of floods associated with atmospheric rivers in coastal Western U.S. watersheds. *Journal of Hydrometeorology,* https://doi.org/10.1175/JHM-D-20-0219.1.

DeFlorio, M. J., F. M. Ralph, D. E. Waliser, J. Jones, and M. L. Anderson (2021), Better subseasonal-to-seasonal forecasts for water management. *EOS, 102*, https://doi.org/10.1029/2021EO159749.

Gibson, P. B., W. E. Chapman, A. Altinok, L. Delle Monache, M. J. DeFlorio, and D. E. Waliser (2021), Training machine learning models on climate model output yields skillful interpretable seasonal precipitation forecasts. *Nature Communications Earth & Environment*, 2, 159. https://doi.org/10.1038/s43247-021-00225-4.

Guirguis, K., A, Gershunov, B. J. Hatchett, T. Shulgina, M. J. DeFlorio, A. C. Subramanian, J. Guzman-Morales, R. Aguilera, R. Clemesha, T. W. Corringham, L. Delle Monache, D. Reynolds, A. Tardy, I. Small, and F. M. Ralph (2022), Winter wet-dry weather patterns driving atmospheric rivers, and Santa Ana wind events provide evidence for increasing wildfire hazard in California. *Climate Dynamics*, https://doi.org/10.1007/s00382-022-06361-7.

Wang, J., H. Kim, and M. J. DeFlorio (2022), Future changes of PNA-like MJO teleconnections in CMIP6 models: underlying mechanisms and uncertainty. *Journal of Climate*, 1-40, https://doi.org/10.1175/JCLI-D-21-0445.1.

Wang, J., M. J. DeFlorio, B. Guan, and C. M. Castellano (2022), Seasonality of MJO impacts on precipitation extremes over the western U.S. *Journal of Hydrometeorology*, in press.

White, C. J., D. I. V. Domeisen, N. Acharya, E. A. Adesfsian, M. L. Anderson, S. Aura, A. A. Balogun, D. Bertram, S. Bluhm, D. J. Brayshaw, J. Browell, D. Büeler, A. C-Perez, X. Chourio, I. Christel, C. A. S. Coelho, M. J. DeFlorio, L. Delle Monache, F. Di Giuseppe, A. M. García-Solórzano, P. B. Gibson, L. Goddard, C. González-Romero, R. J. Graham, R. M. Graham, C. M. Grams, A. Halford, W. T. K. Huang, K. Jensen, M. Kilavi, K. A. Lawal, R. W. Lee, D. MacLeod, A. Manrique-Suñén, E. S. P. R. Martins, C. J. Maxwell, W. J. Merryfield, A. G. Muñoz, E. Olaniyan, G. Otieno, J. A. Oyedepo, L. Palma, I. G. Pechlivanidis, D. Pons, F. M. Ralph, D. S. Reis Jr., T. A. Remenyi, J. S. Risbey, D. J. C. Robertson, A. W. Robertson, S. Smith, A. Soret, T. Sun, M. C. Todd, C. R. Tozer, F. C. Vasconelos Jr., I. Vigo, D. E. Waliser, F. Wetterhall, and R. G. Wilson (2021), Advances in the application and utility of subseasonal-to-seasonal predictions. *Bulletin of the American Meteorological Society*, 1(aop), 1-57. https://doi.org/10.1175/BAMS-D-20-0224.1.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cw3e.ucsd.edu/s2s_forecasts
Thank you!
mdeflorio@ucsd.edu
Photo credit of Lake Mead: Oakley Originals