Subseasonal-to-Seasonal (S2S) Forecasting of Atmospheric Rivers and Precipitation at CW3E

Mike DeFlorio[1], Marty Ralph[1], Luca Delle Monache[1], Duane Waliser[2,3], Bin Guan[2,3], Peter Gibson[2], Alexander Goodman[2], Zhenhai Zhang[1], Tamara Shulgina[1], Kristen Guirguis[1], Sasha Gershunov[1], Aneesh Subramanian[4], Frederic Vitart[5] … and others!

6th Annual FIRO Workshop; La Jolla, CA; 8 August 2019

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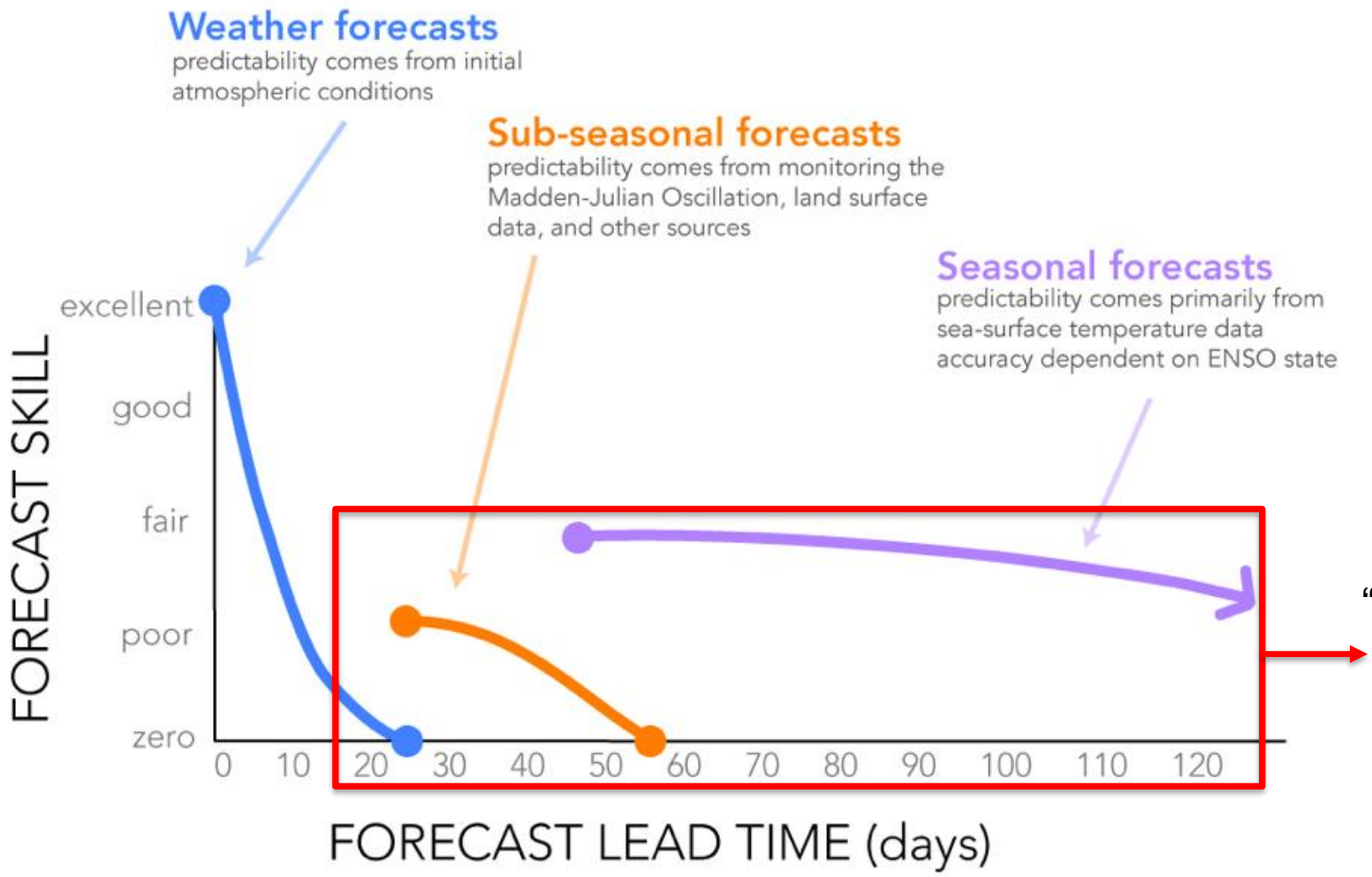
Mike, please help. What is the definition of S2S?

What is subseasonal-to-seasonal (S2S) forecasting?

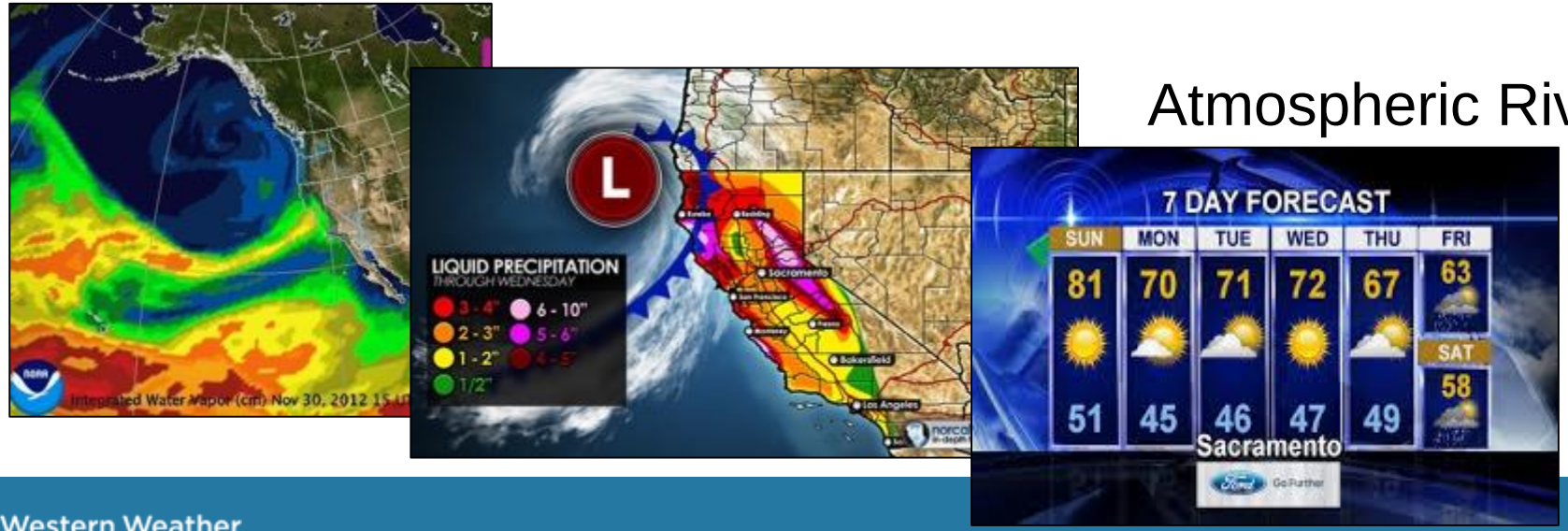


"S2S" lead time range: 2 weeks to ~3-4 months or longer. A critical decision-making window for many stakeholders.

Much appreciated. Now: how does an S2S forecast differ from a weather forecast?

Weather Forecasts *(0-14 Days)*

Hurricanes



Atmospheric Rivers

… cold spells, heat waves, thunderstorms/tornados, Nor'easters, Santa Ana winds, etc

S2S Forecasts: Atmospheric Rivers (*2 –12 weeks)*

Atmospheric Rivers

- Rather than try to predict the occurrence or evolution of a single atmospheric river at such long leads, should we predict the likelihood of an atmospheric river or expected frequency of atmospheric rivers?
- Can we do that? How do we do that?

Fundamentally, the “S2S” lead time represents a transition from short-term weather forecasts, which aspire to predict individual, discrete events, towards probabilistic longer-term forecasts which still depend on initial conditions but are influenced by slower-varying modes of climate variability (e.g. MJO, ENSO, etc.).

Additionally, an S2S forecast is often compared to a climatological forecast in order to predict “above” or “below” normal conditions.

Weather forecast: “An AR will make landfall near Huntington Beach in 84-96 hours.”

S2S forecast: “There is a 20% chance for above-average AR activity in the vicinity of Prado Dam at week-3 (15-21 days) lead time.”

Wow, I think I'm starting to get it.

BUT… we already know that the limit of prediction skill of dynamical models in forecasting discrete AR events over the western U.S. within 500km accuracy is ~7-8 days (Wick et al. 2013; DeFlorio et al. 2018)!

So why might we think there is hope for predicting ARs/precipitation skillfully at lead times beyond 7-8 days?

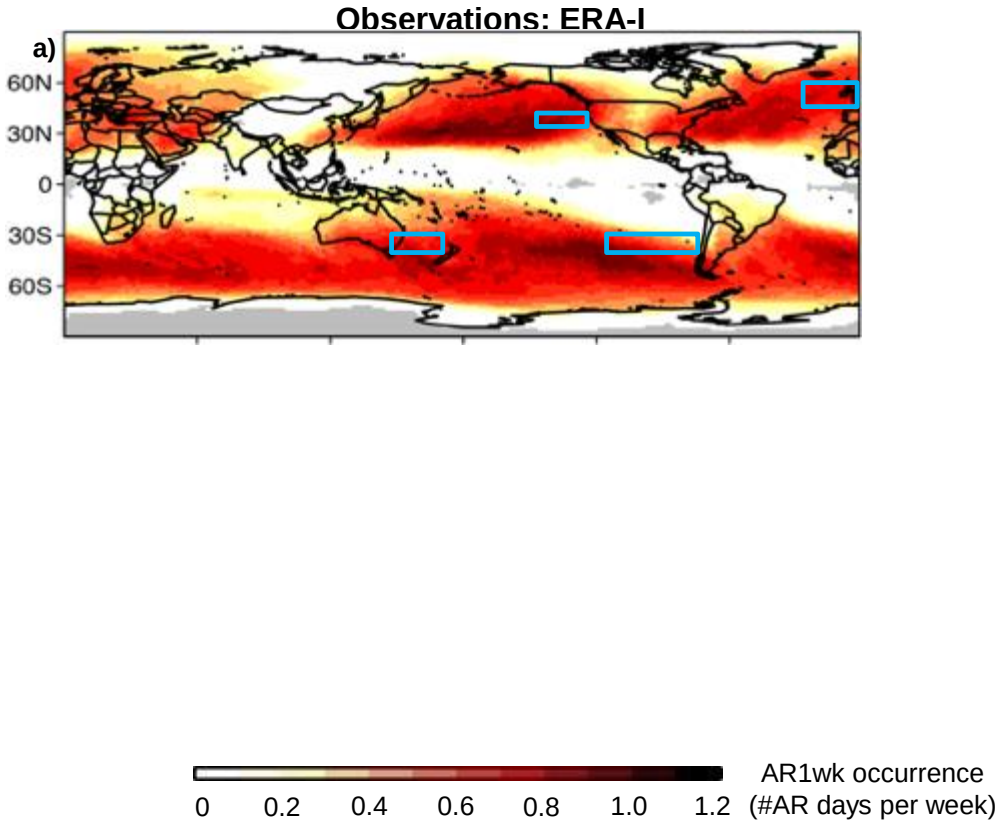
Answer: we don’t try to predict individual events at these longer lead times. Instead, we switch to evaluating forecasts at S2S lead times in a probabilistic framework.

i.e., trading forecast precision for increased lead time.

Global Evaluation of Atmospheric River Subseasonal Prediction Skill

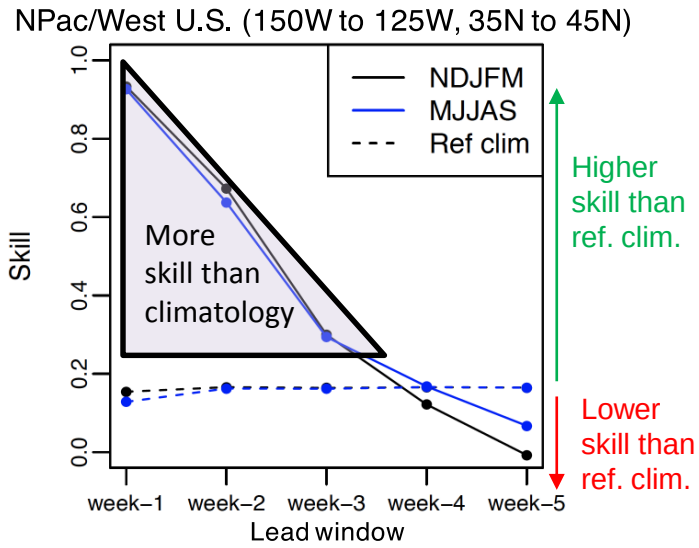
Michael J. DeFlorio[1], Duane E. Waliser[2,3], Bin Guan[2,3], F. Martin Ralph[1], and Frederic Vitart[4]; (*Climate Dynamics* 2019)
[1]UCSD/SIO/CW3E, [2]NASA JPL/CalTech, [3]UCLA, ECMWF[4]

Global climatology of wintertime AR1wk, 1996-2015



- AR1wk is largest in midlatitude storm track regions

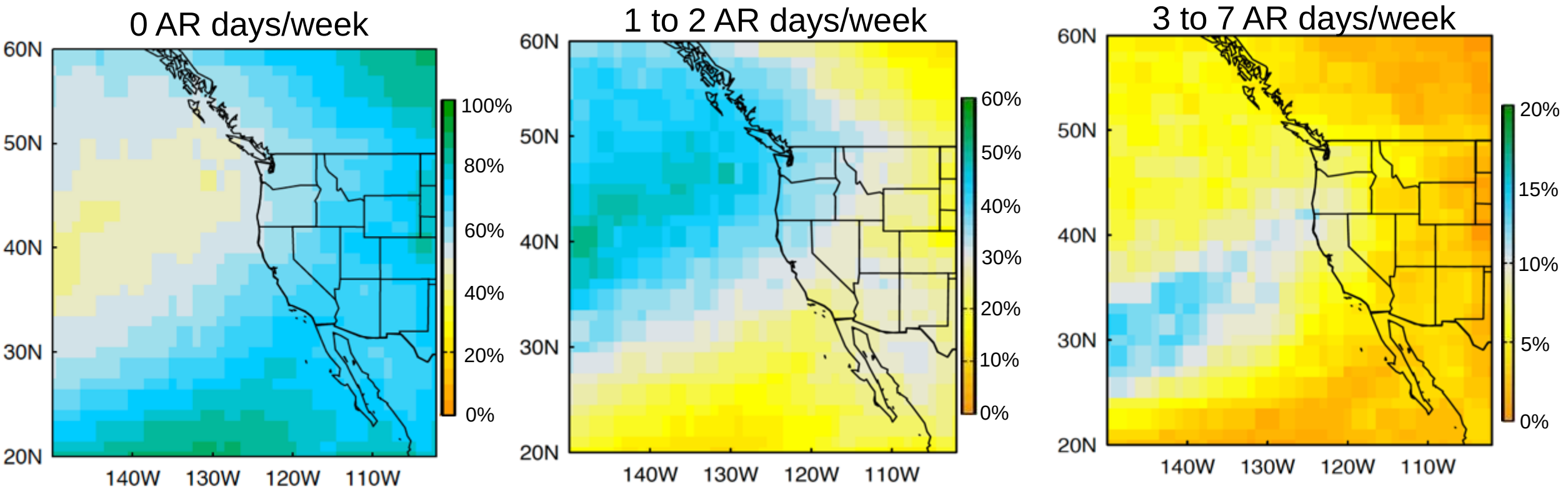
Does ECMWF AR1wk skill exceed climatological skill?
Is AR1wk skill modulated by large-scale climate mode activity during "forecasts of opportunity"?



- (left) ECMWF AR1wk occurrence forecast skill (ACC) outperforms a reference forecast based on monthly climatology of AR1wk occurrence at week-3 (14d-20d) lead over the North

Experimental S2S Forecasting of Atmospheric Rivers over the Western U.S.

Michael J. DeFlorio[1], Duane E. Waliser[2,3], F. Martin Ralph[1] et al. (2019, in revision)
[1]UCSD/SIO/CW3E, [2]NASA JPL/CalTech, [3]UCLA



ERA-I NDJFM 1996-2015 average number of AR days per week (“AR1wk”) for 0, 1-2, 3-7 AR days/week

Experimental S2S Forecasting of Atmospheric Rivers over the Western U.S.

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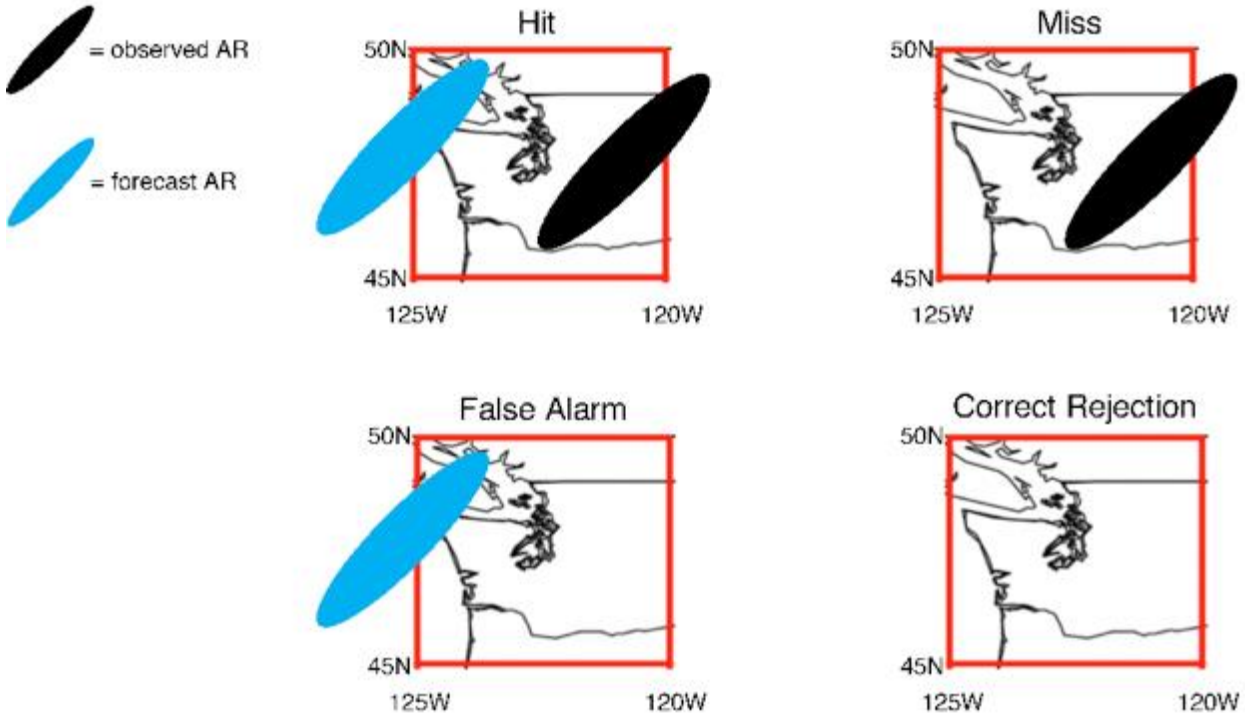
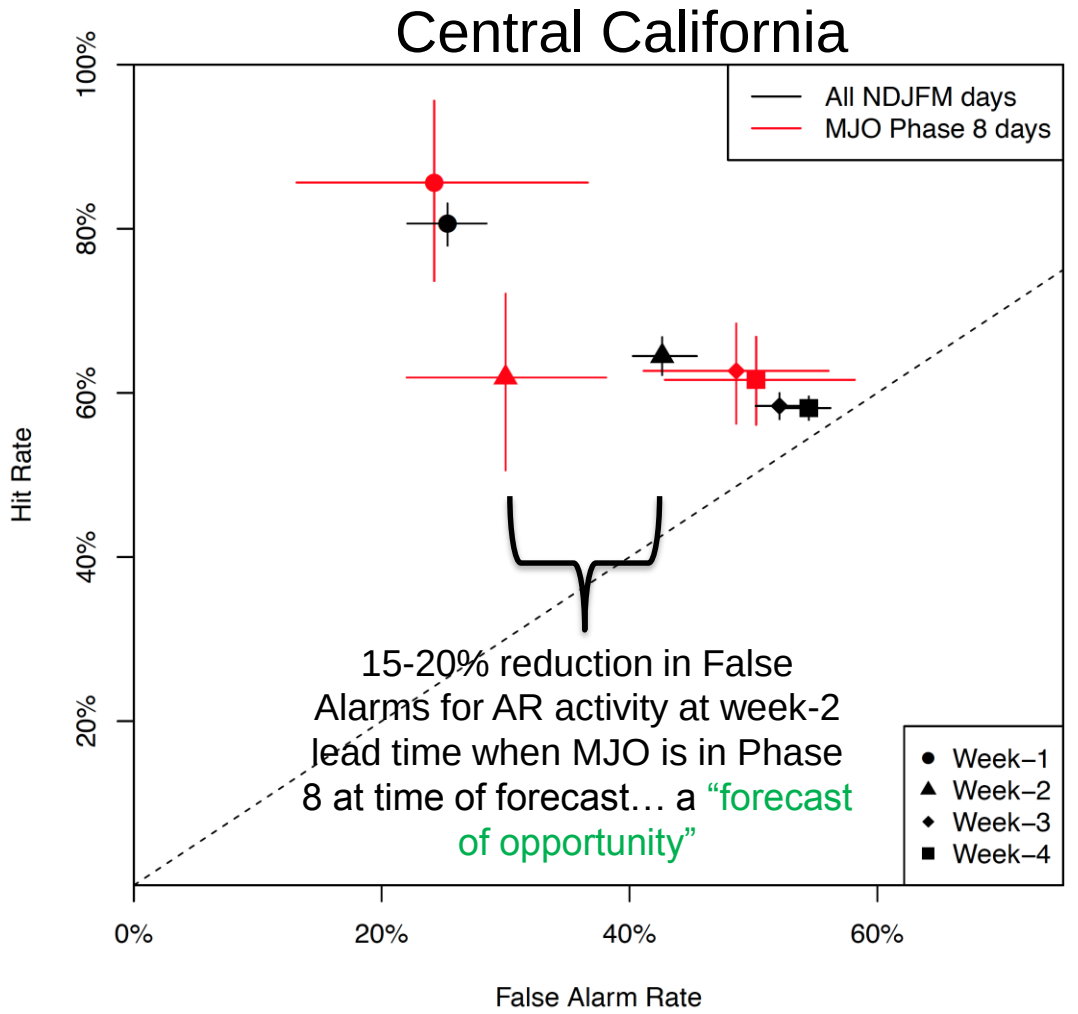




Touché, touché. So what experimental S2S forecast products are available internally at CW3E that could be relevant to FIRO?

Experimental Multi-Model Atmospheric River Forecast*

Week-3: issued on February 7, 2019; Week-2: issued on February 14, 2019; Week-1: issued on February 21, 2019

Contents:

Slide 1: "week-3" - US west coast weather/precipitation forecast for week 3 considering the number of atmospheric river days predicted to occur in the given forecast week.
Novelty – an S2S forecast presented only in terms of AR likelihood - specifically for week 3, an extended/long-range or "subseasonal" prediction

Slides 2-3: "Weather" - Typical presentation of US west coast weather/precipitation forecast over lead times of 1 to 14 days considering only the likelihood of an atmospheric river (AR) occurring on a given forecast day. *Novelty – a weather forecast presented only in terms of AR likelihood.*

Ensemble Forecast Systems Used

ECMWF (European Centre for Medium-Range Weather Forecasts) forecast system
NCEP (National Centers for Environmental Systems) forecast system
ECCC (Environment and Climate Change Canada) forecast system

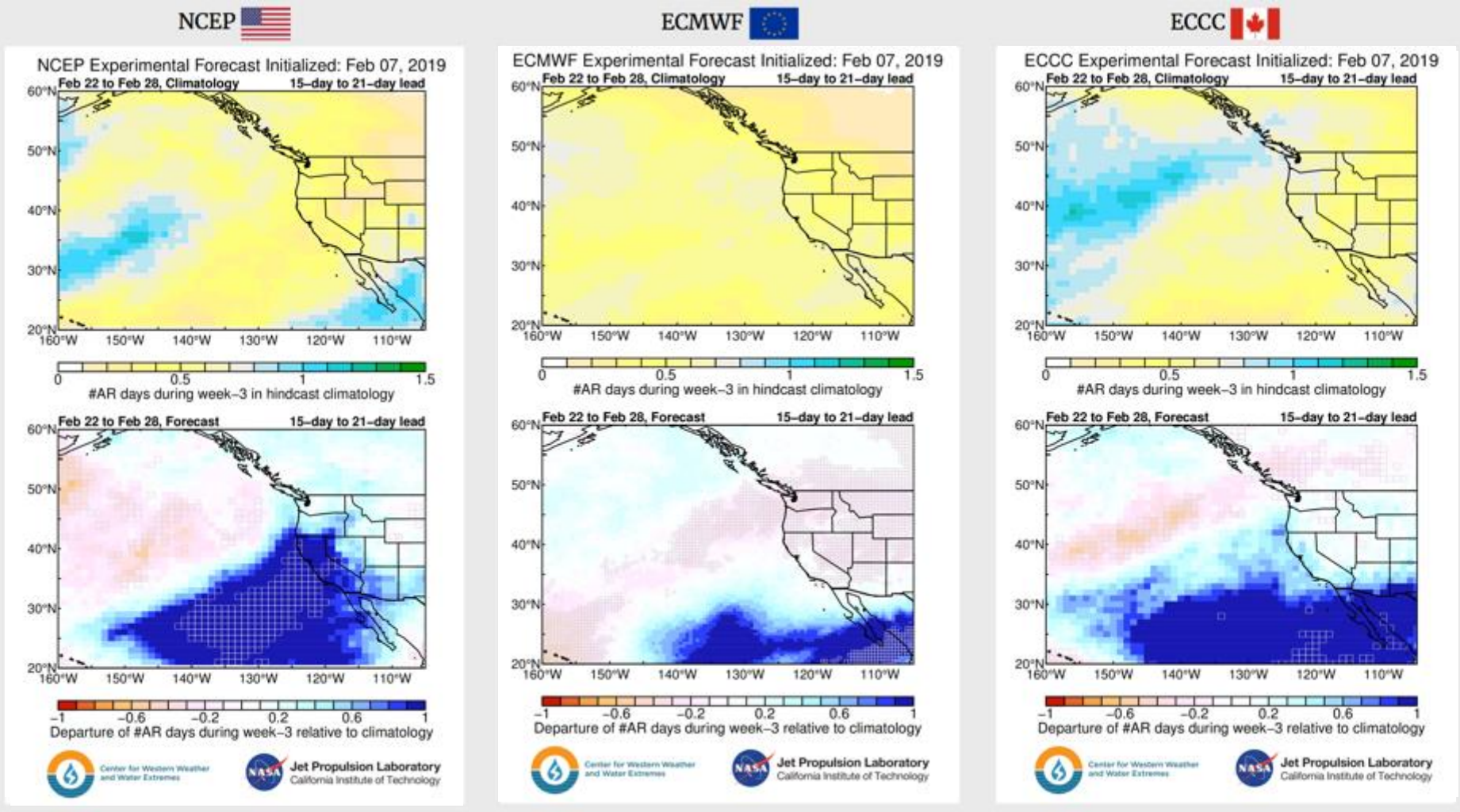
**This is an experimental activity for the 2017-18 and 2018-19 winters. Methodologies and hindcast skill are documented in DeFlorio et al. (2018,2019a,2019b). Further validation of the real-time forecast results is required and underway. This phase of the research includes gathering stakeholder input on the presentation of information – feedback is welcome.*

EXPERIMENTAL AR FORECAST

Week-3 (15-day to 21-day lead)

Hindcast Climatology

Forecast Minus Climatology



Experimental AR forecast issued on Thursday, February 7, 2019 by M. DeFlorio, D. Waliser, M. Ralph, A. Goodman, B. Guan, A. Subramanian, and Z. Zhang for an Experimental AR Forecasting Research Activity sponsored by California DWR

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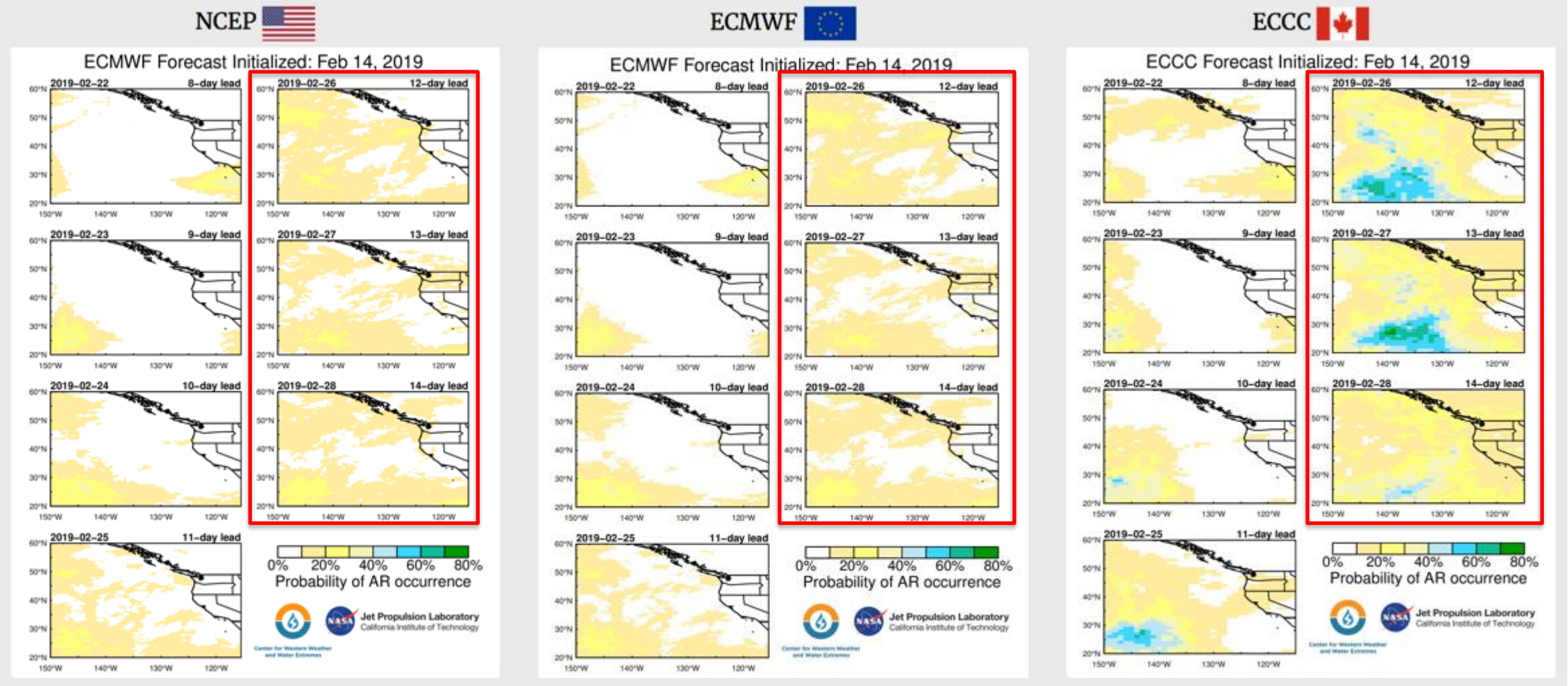
Jet Propulsion Laboratory
California Institute of Technology

EXPERIMENTAL AR FORECAST

Week-2 (8-day to 14-day lead)



Experimental AR forecast issued on Thursday, February 14, 2019 by M. DeFlorio, D. Waliser, M. Ralph, A. Goodman, B. Guan, A. Subramanian, and Z. Zhang for an Experimental AR Forecasting Research Activity sponsored by California DWR

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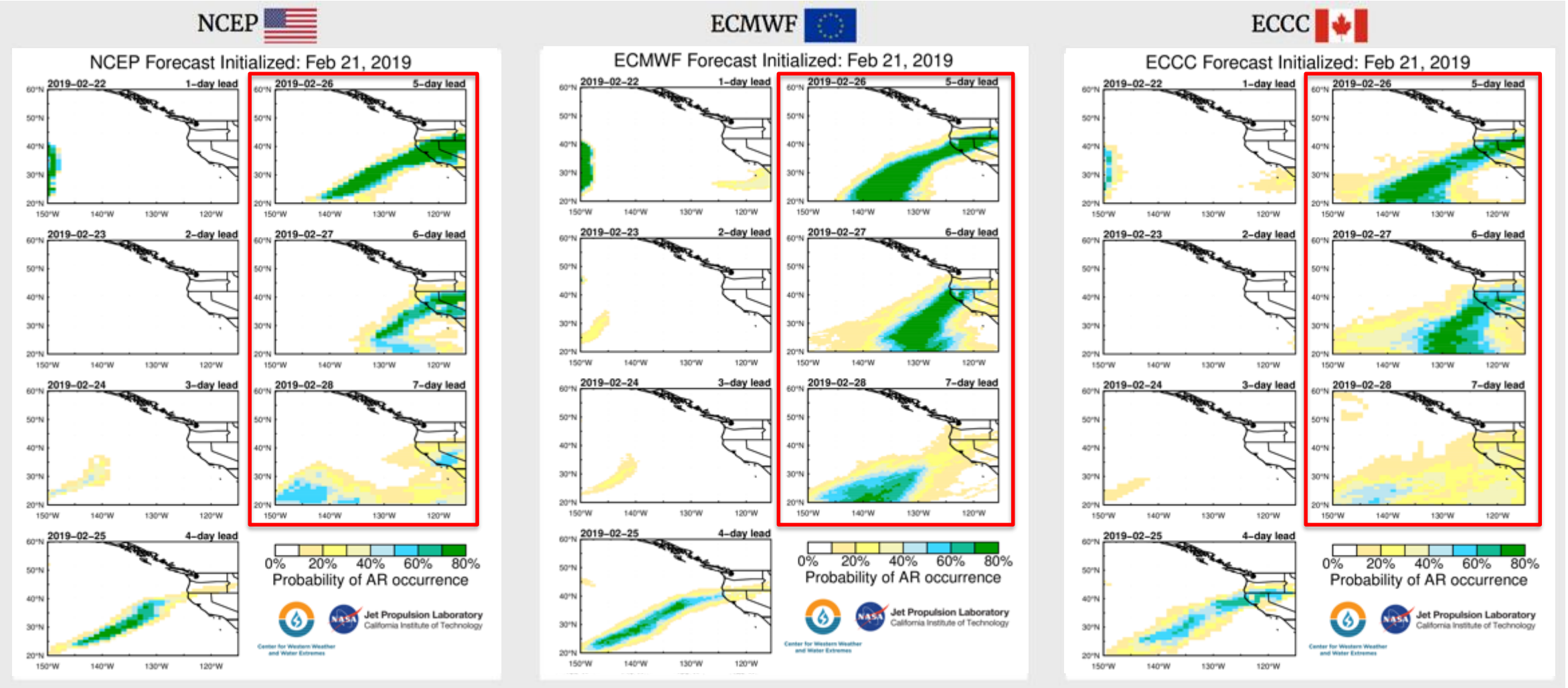
EXPERIMENTAL AR FORECAST

Week-1 (1-day to 7-day lead)



Experimental AR forecast issued on Thursday, February 21, 2019 by M. DeFlorio, D. Waliser, M. Ralph, A. Goodman, B. Guan, A. Subramanian, and Z. Zhang for an Experimental AR Forecasting Research Activity sponsored by California DWR

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Development of Statistically-Based Seasonal Prediction of Precipitation over the Western U.S.

Key CW3E-related personnel: Tamara Shulgina, Alexander Gershunov, Kristen Guirgius

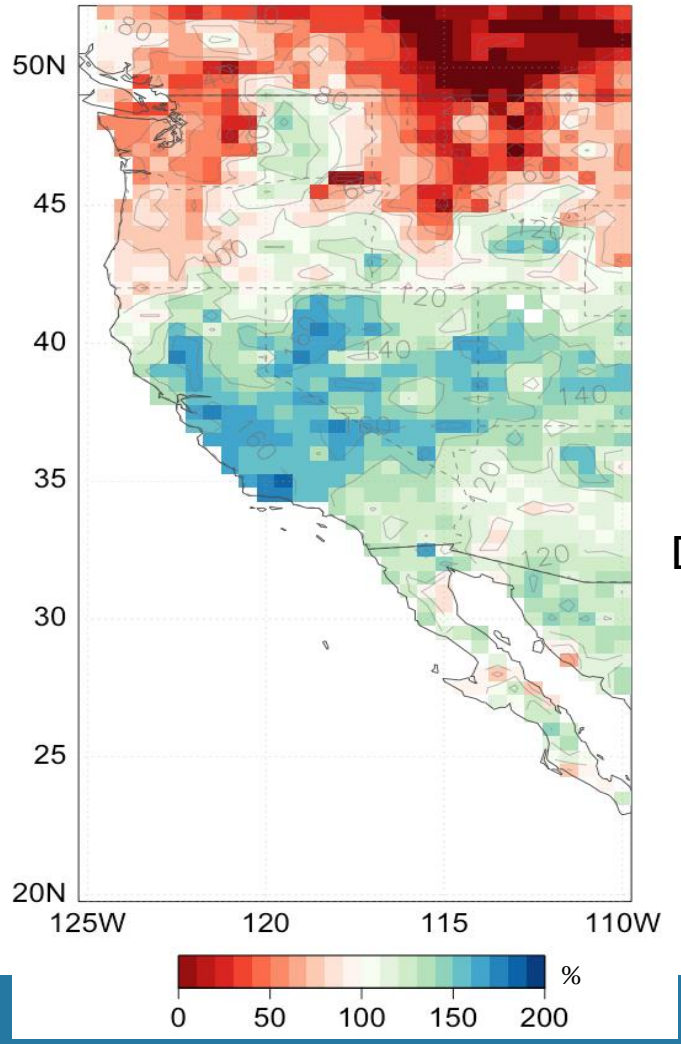
Predictand: **Precipitation** (PR): 1949 – 2012, 1/16°× 1/16°, [20-52N, 125-110W]

Predictor: **Sea Surface Temperature** (SST, NOAA Extended Reconstructed SST V4): 1948-2011, 2°× 2°, [20S-64N, 260-100W]

Method: **Canonical Correlation Analysis (CCA)** (Model training period: 1950 – 2012 (63 years)

Experimental Seasonal Forecast of January-March 2019 precipitation anomalies over the western US via December 2018 SST

Prediction of total precipitation anomalies, January-March, 2019

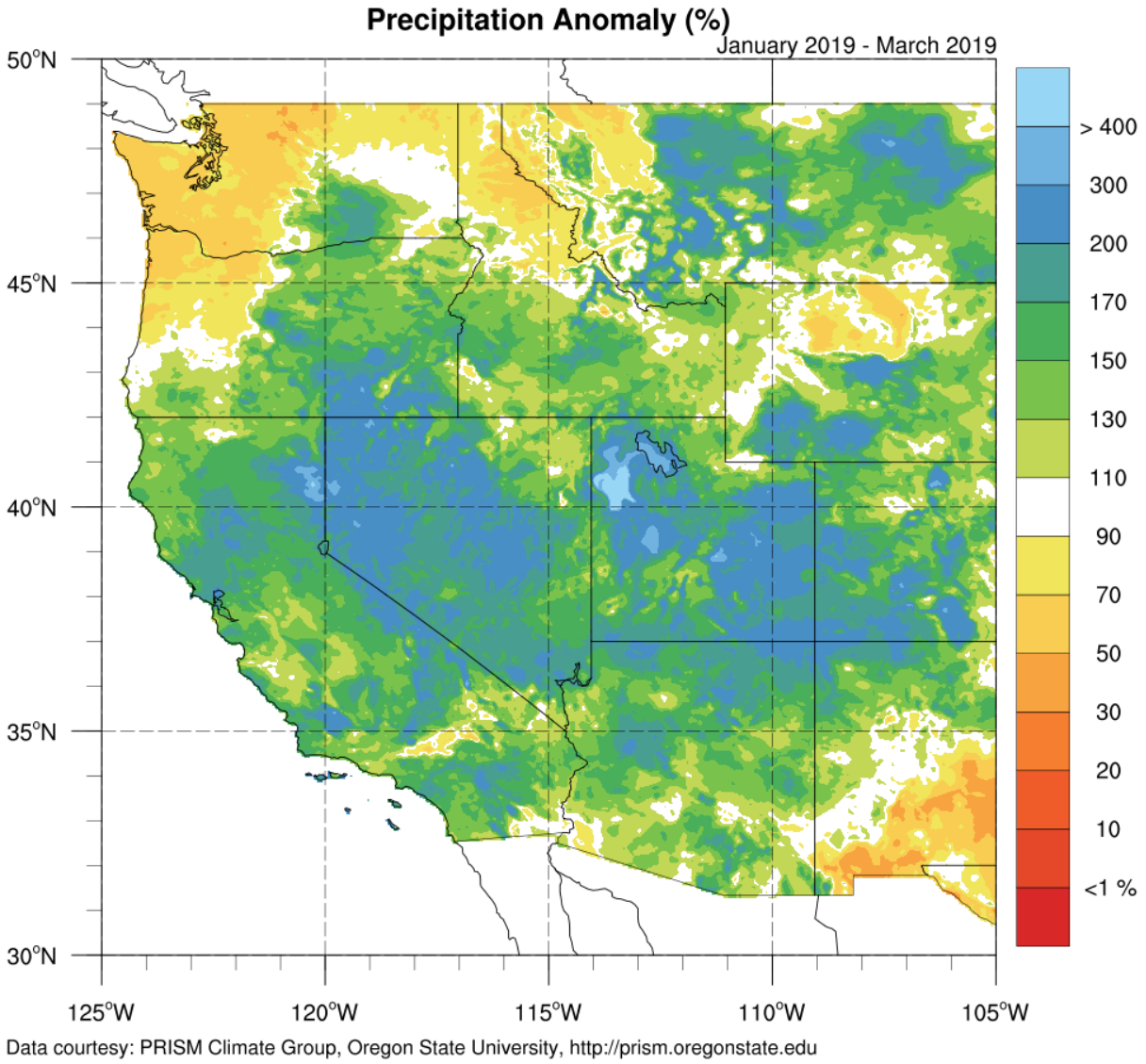


CCA prediction approach:
Predictor: December Pacific SST [20S – 65N]
Predictand: JFM precipitation anomalies (%)
Model training period: 1950 – 2012

EXPERIMENTAL SEASONAL FORECAST IN DECEMBER 2018 OF JFM 2019 PRECIPITATION BASED ON PACIFIC SST

Provided by T. Shulgina

Observed Precipitation Anomaly for January 2019 – March 2019



Data courtesy: PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu

Provided by B. Kawzenuk

Summary

- Atmospheric rivers occur globally and influence weather and water extremes.
- Total amount of annual California precipitation is uniquely variable from year to year and is strongly influenced by occurrence or absence of atmospheric rivers.
- S2S (here, week 3-4) forecasting of atmospheric rivers represents a critical decision-making time window for water resource managers.
- Real-time experimental AR occurrence forecasting effort using ECMWF, NCEP, and ECCC data is ongoing (CW3E/JPL partnership), with engagement from NCEP and addition of NASA GMAO data forthcoming
  - Pilot S2S Project for Applications
- NCEP and ECCC ensemble systems predicted above average AR activity for California at week-3 lead for Russian River flooding event. The signal diminished during week-2, but re-emerged at 5-6 day lead time.

Future directions

- Implement post-processing methods (e.g. bias correction, superensemble prediction) into multi-model experimental forecast product pipeline (DeFlorio, Zhang, Delle Monache)
- Continue development of experimental seasonal precipitation forecasting model using Canonical Correlation Analysis based on Pacific SST and other variables (Shulgina, Guirguis, Gershunov)
- Extension of Chapman et al. (2019) methodology to S2S timescales, in combination with Analog Ensemble methods (Chapman, Gibson, Delle Monache)
- Evaluate intrinsic limit of S2S AR predictability in multimodel hindcast framework (DeFlorio, Waliser, Delle Monache et al.)
- … and many others!

Thank you!

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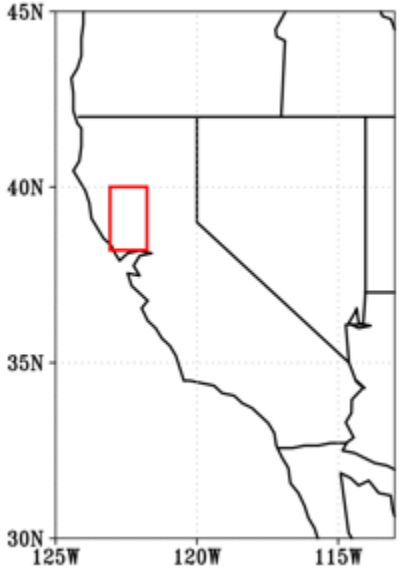
Extra slides

Verification of Week 1-3 AR Outlook for Russian River 2018-2019 Winter

From 2018 October to 2019 March
AR outlook issued every Thursday (**22 weeks/forecasts**)

Forecast and Verification Data

NCEP	16 ensemble members
ECCC	21 ensemble members
ECMWF	50 ensemble members
CLIM (**baseline**)	Climatology of 31 winters (1979-2009) from CFSR
CFSv2 (**OBS**)	CFSv2 reanalysis from NCEP



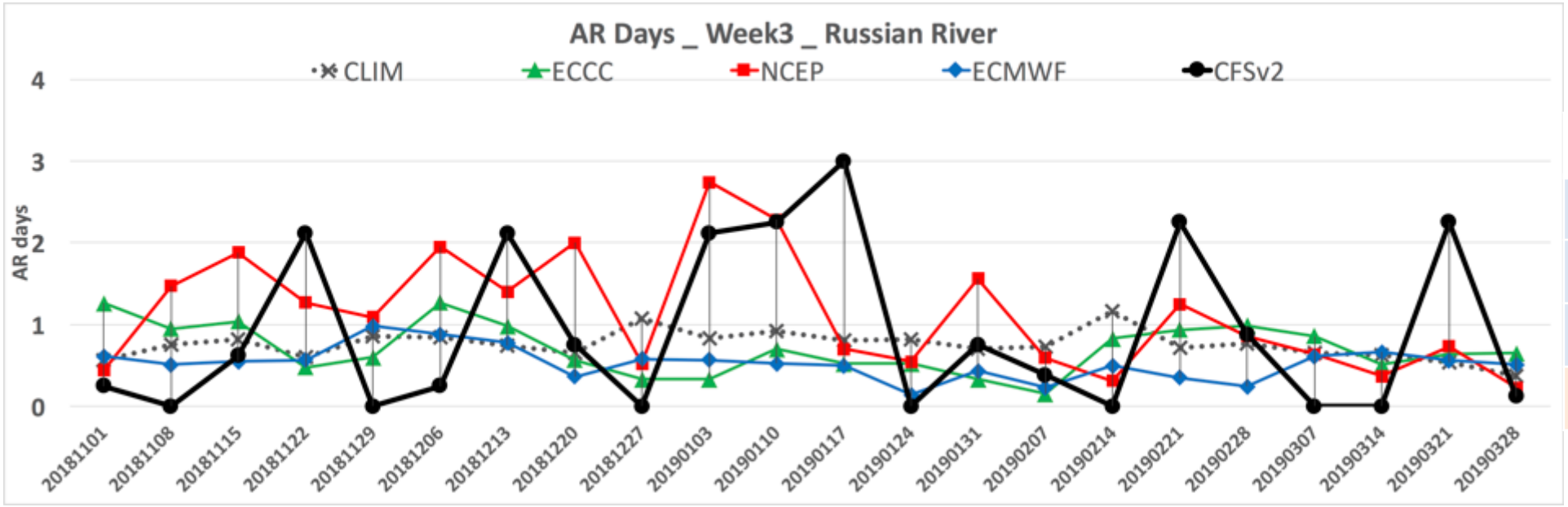
Russian River
2 grid cells
(1×1 degree resolution)

(More reanalysis data will be added as reference for the verification)

AR occurrence at Russian River Week-3 [15-21day lead]

2018-2019 winter (22 forecasts issued every Thursday)

(AR occurrence: number of AR days per week)



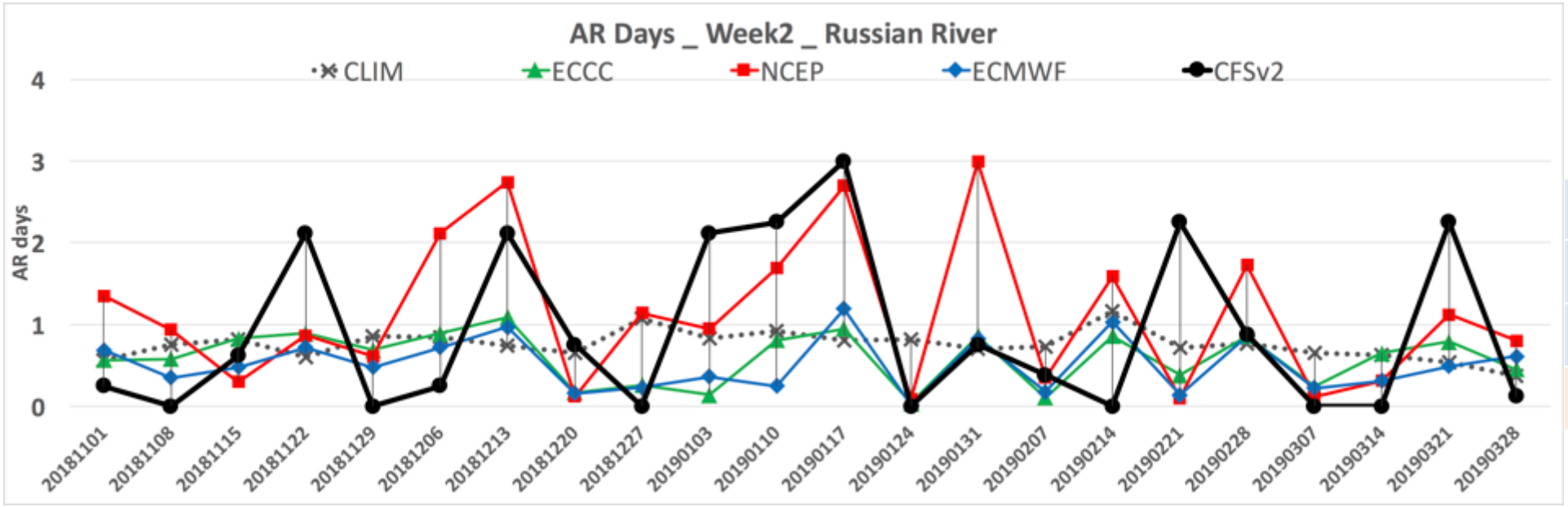
Forecasted Weeks

	CORR	RMSE
ECCC	-0.02	1.09
NCEP	0.16	1.06
ECMWF	0.04	1.09
CLIM	-0.01	1.12

AR occurrence at Russian River Week-2 [8-14day lead]

2018-2019 winter (22 forecasts issued every Thursday)

(AR occurrence: number of AR days per week)



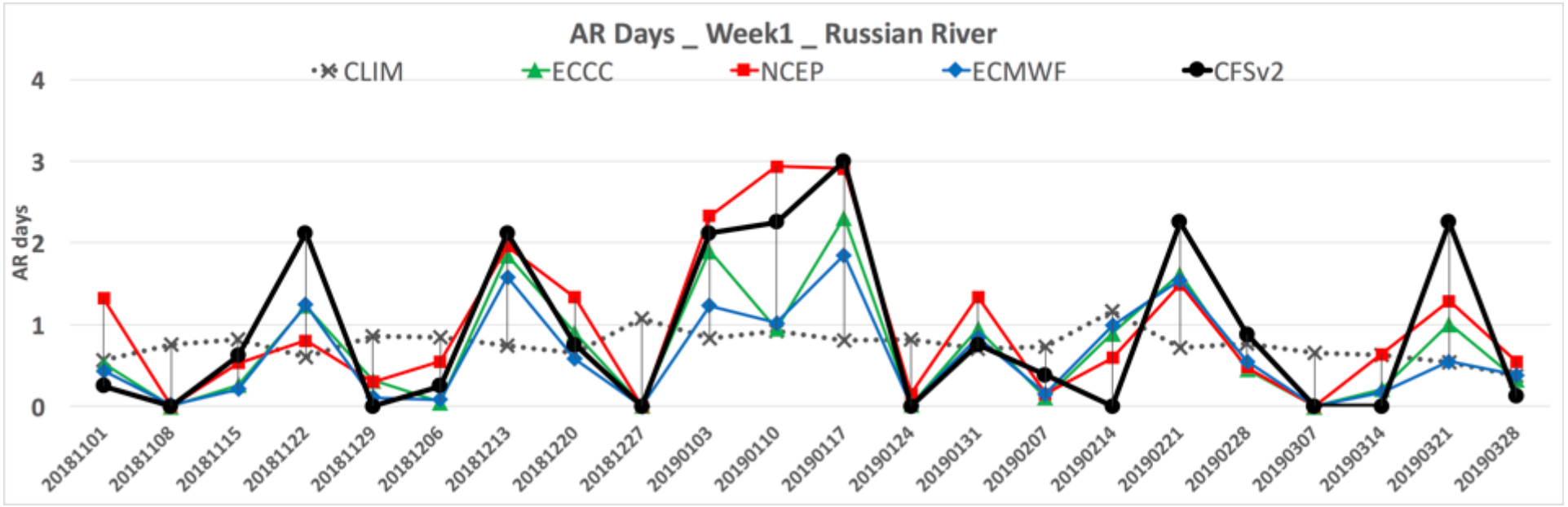
Forecasted Weeks

	CORR	RMSE
ECCC	0.34	0.99
NCEP	0.35	1.04
ECMWF	0.27	1.04
CLIM	-0.01	1.12

AR occurrence at Russian River Week-1 [1-7day lead]

2018-2019 winter (22 forecasts issued every Thursday)

(AR occurrence: number of AR days per week)



Forecasted Weeks

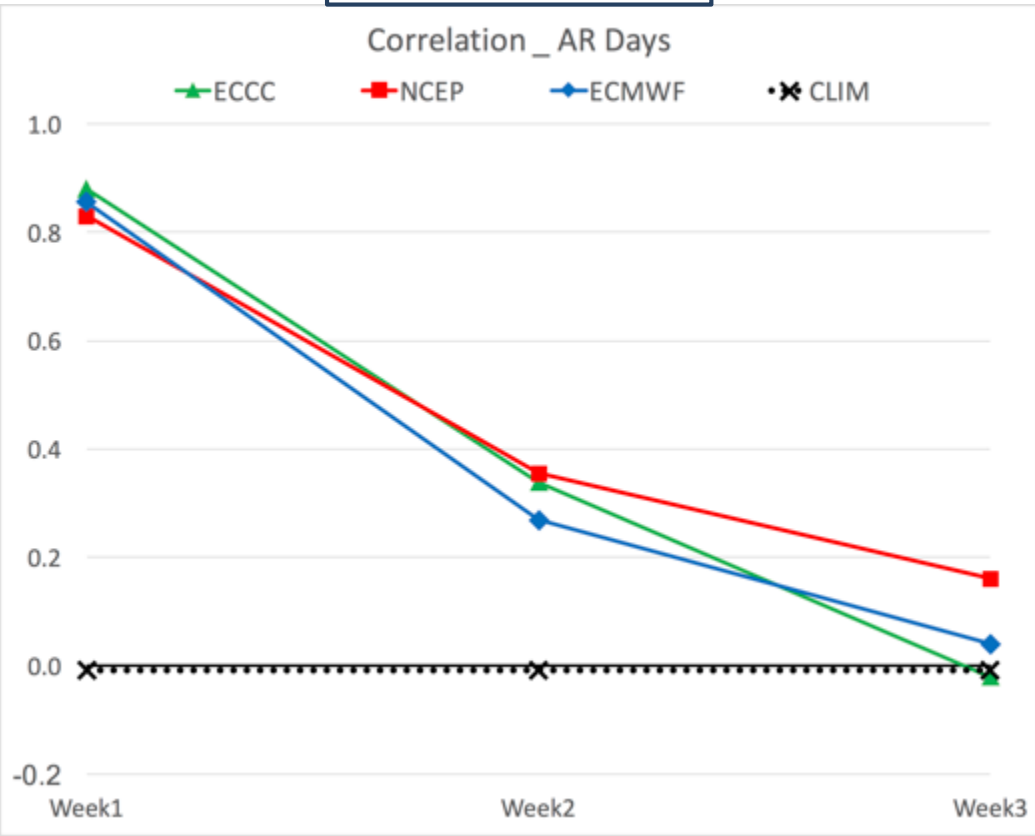
	CORR	RMSE
ECCC	0.88	0.55
NCEP	0.83	0.56
ECMWF	0.86	0.66
CLIM	-0.01	1.12

Verification of AR Occurrence in 2018-2019 Winter (22 weeks/forecasts)

Correlation and RMSE of AR Occurrence for Russian River the changes with lead time (week1 - week3)

Statistics also computed for AR-related IVT

Correlation



RMSE