*Extending Atmospheric River and Precipitation Forecasts along the U.S. West Coast into Subseasonal Lead Times using Consistency-based Forecasts derived from Numerical Models**

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MAPP
Modeling, Analysis, Predictions, and Projections

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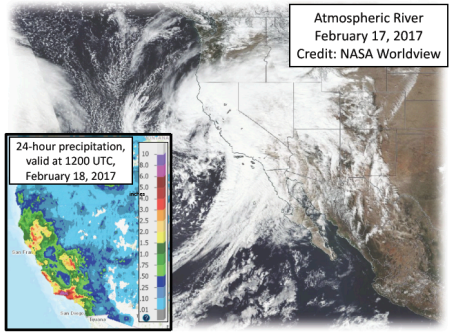
1. Motivation

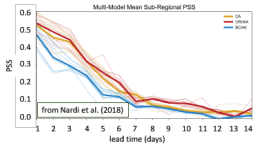
Precipitation along the U.S. West Coast is highly variable from year to year and is highly dependent on the presence of atmospheric rivers (ARs):

- Atmospheric rivers account for 20-50% of California's precipitation and streamflow (Dettinger et al. 2011)
- Atmospheric rivers break ~40% of California's droughts (Dettinger 2013)



Can state-of-the-art numerical weather models help us in forecasting atmospheric river and/or precipitation activity at subseasonal lead times (~3 to 6 weeks in advance)?

Apparently no. They have no skill at forecasting atmospheric river activity beyond a lead time of 10 to 14 days.



- Are the numerical models really that hopeless beyond 14 days?
- What if we look at variables associated with ARs, such as 500-hPa heights, precipitation, or vertically integrated vapor transport (IVT)?

Can a lagged ensemble approach based on model run to model run consistency be used to develop skillful deterministic forecasts of precipitation along the U.S. West Coast at subseasonal lead times?

2. Data & Methods

ECMWF Reforecast Ensemble System

- ECMWF Reforecasts from the S2S Project Database
- October-March reforecast target period over the years 1995 through 2017
- 3160 model runs spanning the 2015-2016, 2016-2017, and 2017-2018 model version suites
- Model runs occur twice per week, have a 46 day lead time, and contain 11 ensembles (1 control and 10 perturbed)

Forecast Variables and Verification

- Deterministic, weekly forecasts of above or below normal 500-hPa heights, vertically integrated vapor tranpsort (IVT), precipitation, and atmospheric river hits per week (Mundhenk et al. 2016) are derived from the ECMWF model with its bias removed.
- Forecasts are verified against ERA-Interim and quantified with the Heidke Skill Score.

Deterministic Forecast Setup (explain in panels 4 and 5)

- Type I Forecast – Current Ensemble Mean
- Type II Forecast – Current Ensemble Members
- Type III Forecast – Consistency Ensemble Mean
- Type IV Forecast – Consistency Ensemble Members

3. Composites based on Coastal Precipitation

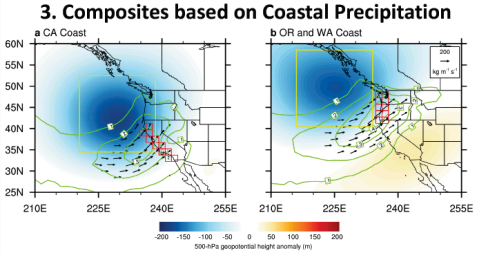


Fig. 1. Composites of anomalous 500-hPa heights (shading), anomalous vertically integrated vapor transport (IVT; vectors), and total atmospheric river frequency (green contours) based on days when precipitation averaged over the red grid boxes exceeds one standard deviation during October-March (1979-2017) for (**a**) the California and (**b**) the Oregon and Washington coasts.

4. Chiclet Plot of ECMWF Ensemble Mean Forecasts for Anomalous Weekly Precipitation along the CA Coast

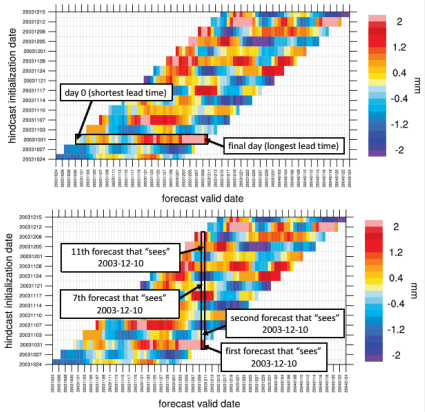


Fig. 2. Example of a chiclet plot derived from the ECMWF ensemble mean forecasts for anomalous weekly precipitation, area-averaged along the California Coast. Hindcast initialization dates range from 2003-10-24 through 2003-12-15 (y-axis). Forecast valid dates range from 2003-10-24 through 2004-01-24 (x-axis).

Is there consistent information in the suite of consecutive forecasts that see the same forecast valid date that can be harnessed to improve lead times beyond 10 to 14 days?

4. Deterministic Forecasts of Above or Below Normal Precipitation based on the Ensemble Means

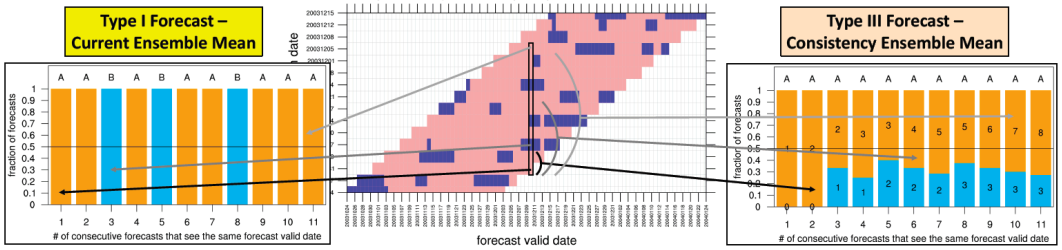


Fig. 3. (**left**) Above normal (A; shaded in orange) and below normal (B; shaded in blue) precipitation forecasts are based solely on the current model run's ensemble mean.

Fig. 3. (**center**) As in Fig. 2, but the ensemble mean has been shaded in red when it is greater than the climatological October-March median and in blue when it is less than the median

Fig. 3. (**right**) Above normal (A) and below normal (B) precipitation forecasts are based on the ensemble means of consecutive model runs. E.g., forecasts are issued for above normal precipitation if more than half of the consecutive ensemble means agree.

Precipitation verified above normal. In this example, the Type I Forecast incorrectly predicted below normal precipitation three times while the Type III Forecast consistently predicted above normal precipitation correctly.

5. Deterministic Forecasts of Above or Below Normal Precipitation based on Individual Ensemble Members

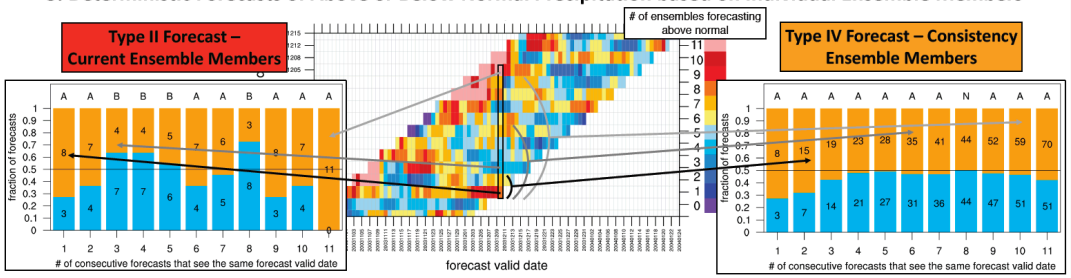


Fig. 4. (**left**) Above normal (A) and below normal (B) precipitation forecasts are based on the current model run's individual ensemble members. E.g., forecasts are issued for above normal precipitation if more than half of the current model run's individual ensemble members agree.

Fig. 4. (**center**) As in Fig. 2, but the shading indicates the number of individual ensemble members that forecast greater than the climatological October-March median.

Fig. 4. (**right**) Above normal (A) and below normal (B) precipitation forecasts are based on the ensemble members of consecutive model runs. E.g., forecasts are issued for above normal precipitation if more than half of the consecutive ensemble members agree.

In this example, the Type II Forecast incorrectly predicted below normal precipitation four times while the Type IV Forecast consistently predicted above normal precipitation correctly except in one instance when no forecast was issued.

6. Heidke Skill Scores by Forecast Type and Consistency Threshold

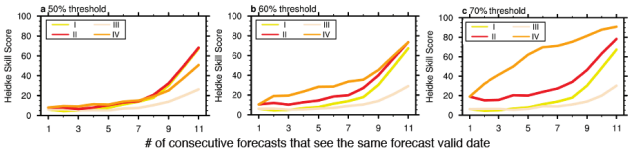


Fig. 5. Aggregated Heidke Skill Scores (HSS) for each forecast type. Forecast are only issued for consistency thresholds of 50% (**left**), 60% (**center**), and 70% (**right**). E.g., for Type IV Forecasts, a 60% threshold implies that 60% of the ensemble members from consecutive model runs agree on the sign of the precipitation anomaly.

As the consistency threshold is increased, Type IV Forecasts have the highest HSS – meaning that information derived from ensemble members from consecutive forecasts that see the same forecast valid date offers more skill than using the current forecast alone. However, the number of issuable forecasts decreases.

7. Ranking of the Forecast Types by Heidke Skill Score and Variable

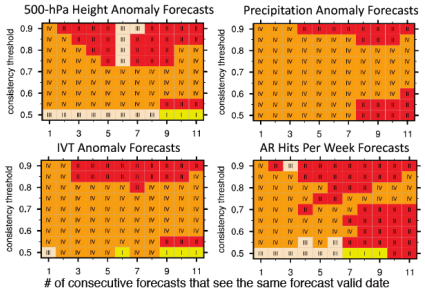


Fig. 6. Ranking of the forecast types by Heidke Skill Score as a function of consistency threshold and the number of consecutive forecasts that see the same forecast valid date for the prediction of AR-related variables along the CA Coast.

Using a lagged ensemble approach, model run to model run consistency offers improved skill scores at subseasonal lead times for variables related to precipitation along the CA Coast. Similar results (not shown here) are found for the OR to WA Coast.

8. References & Acknowledgements

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