Experimental S2S Forecasts for California: Wet/AR and Dry/Ridging Conditions

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In collaboration with
Center for Western Weather and Water Extremes (M. Ralph, A. Subramanian, etc.)
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CA Department of Water Resources (J. Jones)
NASA Energy and Water Cycle Research Program (J. Entin)

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Western U.S.: Wet or Dry?

Objective: Predict Western US Precipitation Conditions

Research Ingredients:
Global Perspective
AR Detection Algorithm
S2S Project Database (e.g. NCEP, ECMWF, EC)
Building blocks of western U.S. precipitation

- Atmospheric Rivers
- ENSO, MJO, etc
- West Coast Ridge Conditions
- Experimental Forecast Research
I. Tools and Resources
   • Global AR Detection Algorithm
   • WCRP/WWRP S2S Project & Forecast/Hindcast Database

II. AR Predictions
   • Weather predictions of Individual ARs (e.g. 0-15 days)
   • Subseasonal predictions (e.g. 2-4 weeks)
   • Experimental S2S Predictions

III. Ridging: Modulating Droughts and ARs
   • Early Considerations
Global AR Detection

I. Compute IVT

II. Map IVT globally

III. Apply AR Criteria

- IVT > 85th percentile
- Look for contiguous areas
- Length > 2000 km
- Length/Width > 2

Gives Long, Narrow Extreme Moisture Transports i.e. Rivers
Global AR Detection Algorithm

- Based on Integrated Vapor Transport (IVT) fields and a number of common AR criteria (e.g. Ralph et al. 2004).
- Developed for global studies and for observations/reanalysis and models.
- Applied to:
  - ERA-I, MERRA-2, CFSR, NCEP/NCAR
- Code and databases available at:
  - https://ucla.box.com/ARcatalog
- Databases include AR Date, IVT\textsuperscript{x,y}, Shape, Axis, Landfall Location, etc.
Algorithm Validation Support from CalWater
Guan, Waliser and Ralph (2018)

IVT Histograms Based On
5636 NE Pacific ARs from ERA-I
125-163W, 23-46N
Jan 15-Mar 25 1979-2016

Ralph et al. (2017)
21 AR Event Transects
4.7 +/- 1.9kg/s
Min 1.3; Max 8.3
Climate Patterns and ARs

El Niño Southern Oscillation (ENSO)  Madden-Julian Oscillation (MJO)

La Niña anomaly

El Niño anomaly

Guan and Waliser (2015)
Downloaded U,V,Q fields from all models’ multi-decade subseasonal hindcasts.
Computed Integrated Vapor Transport (IVT) and Applied AR Detection.
Examined global **AR event weather** and **AR activity subseasonal** forecast skill

Vitart, F., et al. (2017), The Sub-seasonal to Seasonal Prediction (S2S) Project Database, BAMS.
Atmospheric Rivers
ENSO, MJO, etc
Start with AR Forecasting
Predicting AR Events
Considering “Weather” Lead Times

How well do our global NWP models – ECMWF in this case - predict AR occurrence & position?

ECMWF Subseasonal to Seasonal (S2S) hindcasts include twice-per-week, 11 member ensembles, from 1996-2013.

1996–2013 ECMWF NDJFM % ensemble AR hits
7-day lead, 1000km threshold

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2018a)
Predicting AR Events
Considering “Weather” Lead Times

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2018a)
Predicting AR Events
Considering “Weather” Lead Times

ENSO Modulation: Better Skill During El Nino

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2018a)
Predicting AR Activity

Considering S2S Lead Times

“Observations”

For lead times > 2 weeks

Consider the 
# of ARs in a week

Model - 1 Week Forecasts

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2018b)
Predicting AR Activity

Considering S2S Lead Times

Some Model Prediction Skill over Western U.S. for Weeks 1, 2 and 3.

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2018b)
Predicting AR Activity
Considering S2S Lead Times

Intermittent Long-Lead Forecast Skill

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2018b)
Arctic Oscillation (AO) and Madden Julian Oscillation (MJO) modulates S2S AR forecast skill.
Experimental Synoptic and Subseasonal AR Forecasting for Winter 2017-18 and 2018-19

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Bin Guan

Marty Ralph
Aneesh Subramanian
Sasha Gershunov

Frédéric Vitart

Jay Cordeira

Jeanine Jones
Example of Experimental Atmospheric River Event Forecast*
Issued on Thursday, April 5, 2018

Contents:

Week 1 and 2: “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.

*This is an experimental activity for the 2017-18 and 2018-19 winters. Methodologies and hindcast skill are documented in DeFlorio et al. (2018a,b). 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.

POC: Michael J. DeFlorio (michael.deflorio@jpl.nasa.gov)
Experimental AR forecast issued on Thursday, April 5, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 51-member real-time ECMWF data for an Experimental AR Forecasting Research Activity sponsored by California DWR.

Contact: M. DeFlorio
(michael.deflorio@jpl.nasa.gov)
***EXPERIMENTAL AR FORECAST***

April 5, 2018 forecast: probability of AR occurrence during week-1

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

Experimental AR forecast issued on Thursday, April 5, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 21-member real-time ECCC data for an Experimental AR Forecasting Research Activity sponsored by California DWR

Contact: M. DeFlorio
(michael.deflorio@jpl.nasa.gov)
***EXPERIMENTAL AR FORECAST***

April 5, 2018 forecast: probability of AR occurrence during week-1

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

Experimental AR forecast issued on Thursday, April 5, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 51-member real-time ECMWF data for an Experimental AR Forecasting Research Activity sponsored by California DWR.

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***EXPERIMENTAL AR FORECAST***

April 5, 2018 forecast: probability of AR occurrence during week-1

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

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***EXPERIMENTAL AR FORECAST***

March 12, 2018 forecast: probability of AR occurrence during week-1

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

Experimental AR forecast issued on Monday, March 12, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 51-member real-time ECMWF data for an Experimental AR Forecasting Research Activity sponsored by California DWR

Contact: M. DeFlorio
(michael.deflorio@jpl.nasa.gov)
**EXPERIMENTAL AR FORECAST**

March 12, 2018 forecast: probability of AR occurrence during week-2

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

Experimental AR forecast issued on Monday, March 12, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 51-member real-time ECMWF data for an Experimental AR Forecasting Research Activity sponsored by California DWR

Contact: M. DeFlorio
(michael.deflorio@jpl.nasa.gov)
Example of Experimental Multi-model S2S Atmospheric River Activity Forecast*
Issued on Thursday, May 10, 2018

Contents:

Week 3: “Subseasonal” - 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

NCEP (National Centers for Environmental Systems) forecast system
ECMWF (European Centre for Medium-Range Weather Forecasts) 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. (2018a,b). 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.

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Jet Propulsion Laboratory
California Institute of Technology

Center for Western Weather and Water Extremes
**EXPERIMENTAL S2S AR FORECAST**

May 10, 2018 forecast: number of AR days during week-3

Top row: hindcast climatology (NCEP 1999-2010 data)
Bottom row: real-time forecast (NCEP 16-member ensemble)

Experimental AR forecast issued on Thursday, May 10, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 16-member real-time NCEP data for an Experimental AR Forecasting Research Activity sponsored by California DWR

Contact: M. DeFlorio
(michael.deflorio@jpl.nasa.gov)
May 10, 2018 forecast: number of AR days during week-3

Top row: hindcast climatology (ECMWF 1996-2015 data)
Bottom row: real-time forecast (ECMWF 51-member ensemble)

Experimental AR forecast issued on Thursday, May 10, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 51-member real-time ECMWF data for an Experimental AR Forecasting Research Activity sponsored by California DWR

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***EXPERIMENTAL S2S AR FORECAST***

May 10, 2018 forecast: number of AR days during week-3

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

Top row: hindcast climatology (ECCC 1995-2014 data)
Bottom row: real-time forecast (ECCC 21-member ensemble)

Experimental AR forecast issued on Thursday, May 10, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 16-member real-time NCEP data for an Experimental AR Forecasting Research Activity sponsored by California DWR

Contact: M. DeFlorio (michael.deflorio@jpl.nasa.gov)
**EXPERIMENTAL S2S AR FORECAST**

May 10, 2018 forecast: number of AR days during week-3

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**Week-3**

(Combined 15-day to 21-day lead)

Top row: hindcast climatology (NCEP 1999-2010 data)
Bottom row: real-time forecast (NCEP 16-member ensemble)

Experimental AR forecast issued on Thursday, May 10, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 16-member real-time NCEP data for an Experimental AR Forecasting Research Activity sponsored by California DWR

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Contact: M. DeFlorio (michael.deflorio@jpl.nasa.gov)
***EXPERIMENTAL S2S AR FORECAST***
May 10, 2018 forecast: number of AR days during week-3

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

Top row: hindcast climatology (ECMWF 1996-2015 data)
Bottom row: real-time forecast minus climatology (ECMWF 51-member ensemble)

Experimental AR forecast issued on Thursday, May 10, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 51-member real-time ECMWF data for an Experimental AR Forecasting Research Activity sponsored by California DWR

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May 10, 2018 forecast: number of AR days during week-3

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

Top row: hindcast climatology (ECCC 1995-2014 data)
Bottom row: real-time forecast (ECCC 21-member ensemble)

Experimental AR forecast issued on Thursday, May 10, 2018 by M. DeFlorio, A. Goodman, D. Waliser, B. Guan, A. Subramanian, and M. Ralph using 16-member real-time NCEP data for an Experimental AR Forecasting Research Activity sponsored by California DWR

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California Department of Water Resources is sponsoring research to explore subseasonal forecasts of AR activity.

The research is a collaboration between JPL and the University of California.

Near-term focus is on week-3 forecasts for AR activity for the winters of 2017-18 and 2018-19.

Experimental forecast suggests above average AR activity during 3rd week after forecast date.
Experimental results to date show some promise for intermittently being able to deliver skillful longer-lead (e.g. 3-week) forecast information for AR activity along the west coast of the US. Such forecasts will be valuable for flood, hazard and water decision support.

<table>
<thead>
<tr>
<th>City</th>
<th>Cumulative Precipitation (inches)</th>
</tr>
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<tbody>
<tr>
<td>Oroville Dam</td>
<td>0.01</td>
</tr>
<tr>
<td>San Francisco</td>
<td>0.01</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>Trace</td>
</tr>
<tr>
<td>San Diego</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Drought image credit: LA Times
Review of
Winter 2017-2018 Activities &
Winter 2018-2019 Goals

Winter 2017-2018: what we did

- Create an automated pipeline to:
  - Calculate IVT fields from ECMWF, ECCC, and NCEP forecast systems
    - Twice-a-week for ECMWF
    - Weekly or bi-monthly for ECCC, NCEP
  - Apply Guan and Waliser 2015 AR detection algorithm to IVT fields
  - Calculate AR1wk forecasts for week-1, week-2, and week-3 lead windows
- Developing strategy for calculating verification statistics - compare to hindcast skill benchmarks [DeFlorio et al. 2018b]
- Disseminate experimental forecasts and solicit feedback from sponsor, CW3E S2S weekly teleconferences, meetings, etc.

Winter 2018-2019: what we’ll do

- Continue to produce near-real time experimental week-3 AR1wk occurrence forecasts for ECMWF, ECCC, and NCEP forecast systems, stratified by mean AR intensity (>250 kg/ms, >500 kg/ms)
- Calculate verification statistics for week-3 forecasts in real-time during winter 2018-2019
- Refine forecast products/metrics with stakeholders
- Turn useful parts of product pipeline into CW3E web products
Add Focus on West Coast Ridging

Atmospheric Rivers

West Coast Ridge Conditions

ENSO, MJO, etc.
Project Goal
Improve our predictive capabilities of U.S. west coast drought conditions on S2S for improved water resource management.

Project Objectives

• Develop a US West Coast Drought Ridging Index (WC-DRI) that is closely tied to U.S. west coast drought
• Quantify subseasonal to seasonal (S2S) prediction skill of atmospheric ridging conditions relevant to western U.S. water resources in hindcasts of current generation weather/climate models.
• Identify sources of S2S predictability of ridging conditions relevant to U.S. west coast water resources and quantify their predictability characteristics.
• Develop and implement real-time operational S2S monitoring and prediction products related to ridging relevant to U.S. west coast water resources.
Standard Precipitation Index (SPI) over Western US

First 2 EOFs of SPI-3 in ONDJFM

- CPC-Unified gauge-based precipitation (0.25 deg.) 1950-2016

- *Drought definition may be modified in terms of region (e.g. Colorado vs. Western USA vs. CA only) to improve immediate relevance for stakeholder*
Defining a west coast ridge index:

‘Ridging’ is a general term describing the pattern of relatively high atmospheric pressure that influences the storm track.

Swain (2015, GRL)
Candidates for a West Coast (drought) Ridge Index (WC-DRI) relevant to U.S. west coast Drought

**3 month gpt. Height anomaly (500hPa)**

- Area-weighted 500 hPa height anomaly
- % of > 0 anomalies for size/consistency

Based on MERRA-2 6-hourly data
WC-DRI as an AR blocker

When the WC-DRI >100m very few ARs make landfall over CA (16 in total, or <1% of all ARs between 1980-2016)

Those that do are very weak IVT at land fall (and even weaker precip.) and the AR has still been strongly affected by ridge
Case 1: Big ridge in position

Gray shading indicates ridge object (> +50m contour)

Ridge centroid (red dot) lies in critical boxed region

MERRA-2 6hrly ridge index tracker: 1983011012

Stats returned from tracker

WCRI = 136.53m
WCRI (% positive) = 89.95%

Ridge position critical? YES
Persistence (n. 6hr steps) = 4
n. of ridge objects = 1
Area (km^2) = 7.36705e+06
max lat. span (km) = 2650.47
max lon. span (km) = 3187.8
Ridge Effects on ARs

- grey line = median
- blue lines = 10/90 percentile range
- blue dots = 99th percentile

Over 90% of ARs that make landfall over CA (red region) are associated with negative Ridge intensities

Only a tiny fraction of ARs (<1%) make landfall over CA associated with Ridge intensity ~+100m
Ridge Effects on ARs

British Columbia = more ARs under positive ridge

CA = less ARs under positive ridge

Mexico = unaffected by positive ridge?
Summary

• We’re leveraging global AR detection algorithm and databases, S2S Predictions (e.g. NCEP, EC, ECMWF), and climate variations to explore/quantify AR prediction capabilities.

• We’re quantifying skill in the present-day S2S forecasts for:
  • Individual AR Events
  • Subseasonal AR Activity (# ARs in 1 week)

• We’re exploring prediction and predictability characteristics of U.S. west coast ridging conditions and impacts on ARs

• We’re leveraging this research to help develop experimental forecast products relevant to U.S. west coast precipitation & water resource management.