Experimental S2S Forecasting of Atmospheric Rivers Over the Western United States

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Contains key figures/concepts from:
3. DeFlorio et al. 2019b, Multi-model hindcast skill assessment of atmospheric river prediction skill over the Western U.S., in prep
Overview of S2S AR Team

S2S AR Prediction Team
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Atmospheric rivers and their associated flood and hazard risks occur globally and influence climate and water extremes.

Over 90% of poleward moisture transport at midlatitudes is by ARs that take up only ~10% of the zonal circumference.

In the west, ARs account for ~40% of annual precipitation and most floods.

Zhu and Newell 1998
Ralph et al. 2004
Atmospheric rivers:

- can carry as much as water as *25 Mississippi Rivers*, and can provide up to 50% of West Coast precipitation
- are about *500 miles wide* (Ralph et al. 2017, Guan et al. 2018) and are located above the lowest mile of the atmosphere
- sometimes tap *tropical moisture* near Hawaii, transporting concentrated water vapor for thousands of miles

Source: NASA JPL
Why are our water challenges so unique in California?
Precipitation is uniquely variable year-to-year in the western U.S.

Relative to the rest of the U.S., southern California experiences the largest year-to-year swings in annual precipitation totals relative to its average values.

Caption: Map shows the ratio of the year-to-year variability in precipitation divided by the long-term mean precipitation (based on TRMM, 1998-2016). Thus, the eastern half of the country vary rarely experiences a significant variation from their typical precipitation totals (~1-1.5 m), about +/- 20% of the mean. Uniquely, in southern California, the year-to-year variations are nearly as big as the total annual precipitation (~0.2-0.3 m), i.e. +/- 70% of the mean.

Calculation using Tropical Rainfall Measuring Mission (TRMM) data, as originally performed by Dettinger et al. 2011 with station data.
Potential Predictability of IVT vs. Precipitation

- 31 years of NCEP GEFS hindcast data (1984-2015) during DJF
- 30N-50N, 125-120W
- Potential predictability method treats each ensemble member as a surrogate observed realization (Waliser et al. 2003)
- Potential predictability of IVT exceeds that of precipitation at lead times of 1-15 days

Lavers, Waliser, Ralph and Dettinger, 2016 (GRL)
Key Research Question

What is the limit of global subseasonal-to-seasonal (S2S) (here, 1-week to 1-month) prediction skill of atmospheric river occurrence, and how does it vary as a function of season, region, and certain large-scale climate conditions?

Key Applications Question

Can present-day subseasonal-to-seasonal (S2S) forecast systems provide benefit to CA water resource management decision makers?
A global, objective algorithm for AR identification
(Guan and Waliser 2015)

- AR detection involves thresholding 6-hourly fields of ERA-I IVT based on the 85th percentile specific to each season and grid cell and a fixed lower limit of 100 kg/ms and checking for the geometry requirements of length >2000 km, length/width ratio >2, and other considerations indicative of AR conditions

- Applied to global hindcast/forecast systems and reanalysis datasets (code and databases available at: https://ucla.box.com/ARcatalog)

- Parameter space AR Date, IVT$_{x,y}$, Axis, Landfall Location, etc.

- Used for GCM evaluation (Guan and Waliser 2017), comparison to dropsonde data (Ralph et al. 2017, Guan et al. 2018), climate change projections (Espinoza et al. 2018), extratropical and polar vapor transport (Nash et al. 2018), & hindcast/forecast skill assessment (DeFlorio et al. 2018, 2019a; and DeFlorio et al. 2019b [in prep])
• Suite of real-time forecasts and several decades of hindcasts from 11 operational forecast models
• Maximum lead time ranging from 32 days to 60 days
• Hindcast ensemble size ranging from 1 to 33
• Variety of forecasting configurations and other model parameters (heterogeneity amongst models) – “dataset of opportunity”

Vitart et al. 2017
Global Evaluation of Atmospheric River Subseasonal Prediction Skill

Michael J. DeFlorio¹, Duane E. Waliser²,³, Bin Guan²,³, F. Martin Ralph¹, and Frederic Vitart⁴; (Climate Dynamics 2019)

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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?

- (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 Pacific/Western U.S. region.

- Higher forecast skill is evident during Phase 8 of the Madden-Julian Oscillation at week-2 (7-day to 13-day) lead.
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ERA-I NDJFM 1996-2015 average number of AR days per week (“AR1wk”) for 0, 1-2, 3-7 AR days/week
AR1wk NDJFM Brier Skill Scores:
“0 AR days/week” category
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ROC Diagram; Central Cal; MJO Phase 8 IC (red) vs. all NDJFM days (black), ECMWF
Experimental Multi-Model Atmospheric River Forecast*
Issued on Thursday, March 28, 2018

Contents:

Slide 1-2: “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.**

Slide 3-5: “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**

**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.

POC: Mike DeFlorio (mdeflorio@ucsd.edu)
Experimental AR forecast issued on Thursday, March 28, 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 issued on Thursday, March 28, 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.
• 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

• Verification of S2S hindcasts of AR1wk (bias, BSS, ROC) is nearly complete (DeFlorio, Waliser, Ralph, Subramanian et al. 2019 in prep), and can be used as skill benchmarks for winter 2017-2018 and 2018-2019 experimental forecasts.

• Examining sources of increased prediction skill at longer lead times – e.g. atmospheric ridging events (Peter Gibson, Duane Waliser, Bin Guan, Alex Goodman et al., NASA JPL)
Thank you!

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