Anticipating Extreme Precipitation Events: Atmospheric Rivers and Scripps/CW3E Weather Modeling for the Bay Area

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BAFPA-C-HARG panel “Climate Change: The New Normal”
Oakland, California, 19 February 2015
What are Atmospheric Rivers (AR)?

ARs are “narrow” regions in the atmosphere that perform >90% of the water vapor transport in earth’s midlatitudes. They move with the larger storms they are part of and on average there are only 3-5 ARs in a hemisphere at one time.

ARs are narrow region of strong winds and large amounts of water vapor. On average they are 400 km wide. These regions provide the “fuel” (water vapor) for sometimes heavy rain or snow.
SSM/I satellite data shows atmospheric river

Stream gauge data show regional extent of high stream flow covers 500 km of coast

Flooding on California’s Russian River: Role of atmospheric rivers


ARs can CAUSE FLOODS and PROVIDE WATER SUPPLY

Atmospheric Rivers, Floods and the Water Resources of California

Mike Dettinger, M. Ralph, T. Das, P. Neiman, D. Cayan (Water, 2011)
"Angle of Attack" can determine flooding in the Bay Area.

AR et al. 2003
The greater the AR strength and duration, the greater the precipitation.

Other factors, e.g., aerosols, also important.

From Ralph et al. 2013, J. Hydrometeorology

\[ MV \text{ flux; } R^2 = 0.7453 \]
Key conditions during 91 ARs observed at the Earth’s surface and aloft north of San Francisco, WY2005-2010

The following attributes characterize the 10 longest-duration ARs, which produced the most extreme rainfall and streamflow:
- AR conditions persisted for > 31 h
- Coastal rainfall averaged 140 mm during AR conditions
- Wind direction between 180° to 240° at about 1 km MSL
- Storm-total Bulk Upslope IWV flux was > 1000 units
- Precursor soil moisture was > 36%
- Heavy rain was in DJF and transition seasons (SON, MAM)
- Extreme runoff was in December, January, February (DJF)

ARs that lasted TWICE as long as an average AR created SEVEN TIMES the runoff

From Ralph et al. 2013, *J. Hydrometeorology*
Mission

Provide 21st Century water cycle science, technology and outreach to support effective policies and practices that address the impacts of extreme weather and water events on the environment, people and the economy of Western North America

Goal

Revolutionize the physical understanding, observations, weather predictions and climate projections of extreme events in Western North America, including atmospheric rivers and the North American summer monsoon as well as their impacts on floods, droughts, hydropower, ecosystems and the economy
CW3E-SDSC Partnership

“West-WRF” Weather Model to Focus on Western U.S. Extreme Events

- Interdisciplinary team of SIO & SDSC Scientists, post-docs and grad students
- Working to an integrated research and operations plan
- West-WRF implemented in < 6 months now supporting Calwater2 mission planning

SDSC Director and UCSD Physics Professor Mike Norman is fully-supportive of CW3E

Contributing Staff time (J. Helly), computer time and disk storage on the Gordon supercomputer

CalWater Observations will be used to evaluate, explore and improve the physics in CW3E’s West-WRF Model from air-sea interaction, to mesoscale dynamics, aerosols and cloud microphysics and data assimilation.
CalWater-2* “Early Start” field campaign
3-25 February 2014

Summary Courtesy of Marty Ralph
UCSD/Scripps/Center for Western Weather and Water Extremes

This AR increased precipitation-to-date from 16% to 40% of normal in < 4 days in key Northern California watersheds, but runoff was muted due to dry soils.

Up to > 12 inches of rain – some drought relief

Flight area for NOAA’s G-IV aircraft on 8 Feb 2014
Goal: developing AR flight method to sample a “frontal wave” that can cause an AR to stall over one area at landfall (G-IV PI: Chris Fairall – NOAA; Mission Scientists: Marty Ralph – Scripps, Ryan Spackman – STC)

SSM/I satellite observations of water vapor on 8 Feb 2014 (Courtesy G. Wick, NOAA)

*CalWater-2 is a 5-year program (from 2015-2019) proposed to focus on West Coast precipitation processes and how a changing climate will affect them. It is led by UCSD/Scripps with partners from DWR, CEC, NOAA, NASA, DOE and others.
Flight 2, February 8-9th, 2014

Model Time: 21:00UTC

Sam Iacobellis
This slide and the next are pretty redundant. How can he clean this up so that it bogs down the flow less? Maybe hand-draw the WRF and GFS transects over this image? PPL will want to see all three transects in the context of the IWV imagery.

amartin, 9/22/2014
Water Vapor Flux Through Transect

Water Vapor Fluxes at 48hr Forecast

Water Vapor Flux (kg/s)

Drop: 3% 
WRF: 28% 
GFS: 28%

## Summary of Model Error

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<th>Flight</th>
<th>T1, T2, 1-9</th>
<th>T1, 1-10</th>
<th>T1, 4-33</th>
<th>T1, 1-10</th>
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<td>138%</td>
<td>138%</td>
<td>99%</td>
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\[
\frac{WVFlux_{obs} - WVFlux_{model}}{WVFlux_{obs}}
\]
Very good idea here, I would name this slide "Percent Error in Forecast WV Flux" I would also add a column which displays the length of forecast to validation time.

amartin, 9/25/2014
West-WRF and the Back-to-Back February ARs (02-05 through 02-08)

24 hour Precipitation ending Feb. 7, 2015 @ 4 am PST

24 hour Precipitation ending Feb. 9, 2015 @ 4 am PST
West Coast Focus and High Resolution Capture
Observed Heavy Precipitation

# Periods Exceeding 0.5 inch Rainfall

<table>
<thead>
<tr>
<th></th>
<th>Observed</th>
<th>West-WRF Hits</th>
<th>NAM Hits</th>
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West-WRF began running in mid-December 2014

Calwater2 Real-time Mission Support began 4-Jan-2015 and continues
An Atmospheric River-focused long-term observing network is being installed in CA as part of a 5-year project between CA Dept. of Water Resources (DWR), NOAA and Scripps Inst. Of Oceanography:
- Installed 2008-2014
- >100 field sites

$\frac{1}{4}$-scale 449-MHz wind profiler with RASS

GPS receiver for integrated water vapor

Soil Moisture and Temperature Probes

White et al. 2013 (J. Atmos. Oceanic Tech.)
CalWater 2
Precipitation, Aerosols, and Pacific Atmospheric Rivers Experiment
Scripps Inst. Oceanography Institutional Seminar – 12 Feb 2015

F. Martin Ralph
UC San Diego/Scripps Institution of Oceanography
Center for Western Weather and Water Extremes (CW3E)

Science Steering Committee
Marty Ralph, Kim Prather, Dan Cayan, Ryan Spackman, Paul DeMott, Mike Dettinger, Chris Fairall, Ruby Leung, Daniel Rosenfeld, Steven Rutledge, Duane Waliser, Allen White
Coordinated flights, February 5, 2015

1928 UTC
Thank You

See cw3.ucsd.edu for
• Real-time data and products
• Up-to-date science and projects
• The “AR Portal”

Also see hmt.noaa.gov for mirrored products and other information.