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Impacts of Atmospheric-River Landfalls on the Cold-Season Hydrology in California

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Background

- Atmospheric river (AR) landfalls are closely related with the occurrence of hydrologic extremes in California.
- Details on the impact of AR landfalls on California's hydrology remain to be identified & understood.
- Evaluation of RCMs is a key for projecting the climate change impacts on AR-related hydrology

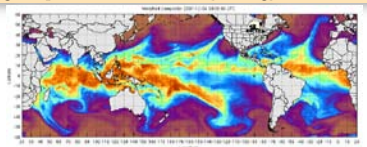


Figure 1. The PWV at 00UTC December 4, 2007 from space.

Atmospheric Rivers

- Narrow ($O[10^2 km]$) and elongated ($O[10^3 km]$) regions of intense water vapor fluxes
- PWV>20 mm within the core region.
- Typically located in the warm sector of extratropical cyclones
- Large amounts of poleward moisture transport

Goals

- Understand the impact of land-falling AR events on cold season water cycle in California
- Examine the performance of nested regional modeling in diagnostics/prediction of AR-related hydrology in California

Data

- NCEP-CPC daily precipitation datasets (0.25°) are analyzed for the 10 *cold seasons* (Oct-Mar) of WY2001-WY2010.
- SNODAS data are used for the AR-Δ*SWE* relationship for WYs2004-2010
- Land-falling AR inventory along the CA coast was developed *on the basis of satellite-retrieved PWV* (SSM/I and SSMIS) by P. Neiman & G. Wick
- *Select AR landfalls only in the California coast.*

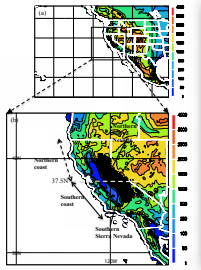
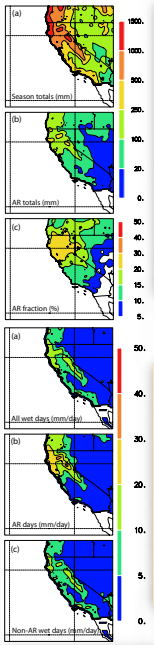


Figure 2. The nested model domain. The inner domain is also used in analyzing ODS data.

Modeling

- WRF version 3.1.1
- Outer domain covers the eastern north Pacific/WUS at a 0.36° resolution
- Inner domain covers CA at a 0.09° resolution
- 10 cold seasons (Oct-Mar) of water years 2001-2010.
- Large-scale forcing from 1°-resolution NCEP Final Analysis (NFA).



OBS Season-total Precipitation

- Geographical contrasts
  - North-south gradient
  - Terrain elevations/rain shadows

OBS AR precipitation

- Similar geographical characteristics as the season totals.
- Smaller contrasts between the so. coastal range & the Central Valley
- 10-30% of the cold-season total precipitation is during AR landfalls
- Much larger impacts in northern CA

Figure 3. Obs cold-season precipitation: (a) Season totals, (b) AR totals, and (c) AR totals as the %age of the season totals.

OBS Wet-day Precipitation

- Wet days: PR>0.1 mm/day
- Geographical contrasts
  - North-south gradient
  - High vs. low elevations.
- AR precipitation intensity shows strong north-south gradient over the CA coastal range.
- Non-AR precipitation intensity is similar over much of the coastal range

Figure 4. Obs cold-season wet-day precipitation: (a) Season totals, (b) AR totals, and (c) non-AR totals

OBS Precipitation in the Sierra Nevada Region

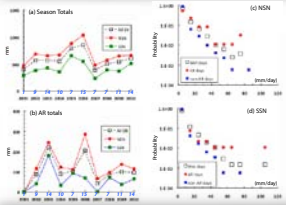


Figure 5. Obs cold-season precipitation in the Sierra Nevada: (a and b) Season totals in the 3 SN regions and the no. of AR landfalls (the numbers in blue fonts) for each year; (c and d) the wet-day precipitation intensity during AR (red) and no-AR storms in the NSN and SSN regions

Interannual Variations

- Large interannual variations in the number of AR landfalls
  - 1-15/year; mean=9.4/yr (*Fig. 5, and b*)
- Weak relationship between the number of AR landfalls and season-total precipitation in both *NSN* and *SSN*
- The number of AR landfalls are more closely related with the AR-totals than the season totals

OBS Daily Precipitation Intensity

- Higher frequency of heavy precipitation during the ARs (*Fig. 5, c and d*).

Snow Accum. in the SN (*Figure 6*)

- 10-40% of Δ*SWE* during AR landfalls.
- Nearly no relationship between the number of ARs & the snow accumulation thru the cold season.
- ARs are more closely related with extreme daily Δ*SWE*

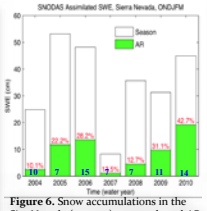


Figure 6. Snow accumulations in the Sier Nevada (>1500m), seasonal- and AR totals. The numbers in blue indicate the number of AR landfalls.

Cold-season Simulations

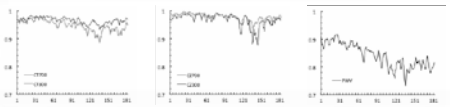


Figure 7. The pattern correlation btn the model and ERA reanalysis: (a) Temperatures at the 700 & 300hPa levels, (b) Geopotential heights the 700 & 300hPa levels, and (c) PWV.

Upper-air fields (*Figure 7*)

- The 10-season composite daily pattern correlation coefficients > 0.9 for both T & Z at 500 & 300hPa.
  - >0.8 for PWV
- Slight deterioration in Feb, but recovers in Mar.
- This indicates that the simulations do not drift from the large-scale forcing through the lateral boundaries over seasonal time scales.

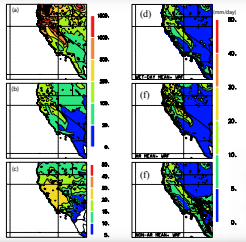


Figure 8. The simulated precipitation characteristics similarly as Figures 3 and 4: (a-c) cold season; (d-f) wet days.

Model Precipitation (*Fig. 8*)

- The simulation depicts the geographical variations in the season-total precipitation.
  - The most notable bias is over(under)estimation in the northern(southern) California region.
- AR precipitation and the percentage of AR precipitation in the season totals agree reasonably with the CPC analysis.
  - AR percentage is overestimated in the central CA coast.
- Precipitation intensity is also reasonable, except underestimation in the So. coastal range.

Simulated Interannual Variations (*Fig. 9*)

- Season totals agree well in both NSN and SSN regions
  - only 2 (2005 & 2010) out of 10 WYs differ notably from the CPC.
- Agreement between the simulated and observed AR totals is weaker than the season totals, but remains reasonable.

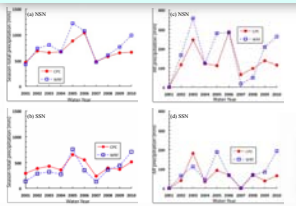


Figure 9. The observed and simulated cold-season and AR precipitation in the NSN and SSN regions.

Table 1. The cold-season average freezing level altitudes over the NSN and SSN regions derived from the ERA-Interim reanalysis (ERA) and simulation (WRF). The blue numbers represent the total number of wet days for the 10 cold seasons.

	NSN		SSN	
	ERA	WRF	ERA	WRF
AR Wet days	2746m (87)	3205m (74)	2949m (60)	3341m (50)
non-AR Wet days	2332m (792)	2753m (698)	2428m (603)	2998m (455)
Differences	+ 414 m	+ 272 m	+ 521 m	+ 316 m

Freezing-level altitudes (*Table 1*)

- Are systematically higher during the AR wet-days than the non-AR wet days
  - ERA reanalysis suggests 4-5K warmer low level temperature during AR storms.
- The simulated freezing level altitudes are higher than in the ERA-Interim reanalysis
  - Indicates *warm bias* in the low troposphere
- The simulated freezing level altitude differences are smaller than those from the reanalysis.

Summary

1. ARs afect precipitation more in the northern CA than the southern CA region.
2. The number of AR landfalls in California's coast is only weakly related with the season-total precip.
3. AR landfalls have clear impact on precipitation (and snow accumulation) intensity in California.
4. The WRF model appears to possess reasonable skill in simulating the impact of AR landfalls on the hydrology in California.
5. The most noticeable biases include:
   - Over-/under-estimation of precipitation in the northern/southern CA regions
   - General warm biases in the low troposphere during wet days.