The Impact of Atmospheric Rivers on the Cold Season Hydrology in California

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Atmospheric Rivers: Characteristics

- Narrow \(O[10^2 \text{km}]\) and elongated \(O[10^3 \text{km}]\) regions of strong water vapor fluxes
- PWV > 20 mm within the core region
- Typically located within the warm sector of extratropical cyclones
- Large amounts of poleward moisture transports
- Frequently cause extreme hydrologic events in California
Major Goals/Methodology of this Study

- 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
- 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-ΔSWE 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
- **AR-related ongoing/planned studies at JIFRESSE and JPL:**
  - Numerical modeling of regional water cycle and circulation for California
  - The origins/pathways of moisture using a trajectory model (Ryoo et al.)
  - Assimilation of the Sierra Nevada SWE (Guan et al.)
  - The relationship with tropical convection, MJO, and AR (Guan et al.)
  - The impact of climate change on ARs and water cycle in California
The season-total and AR-related Precipitation

- AR precipitation closely resembles the geographical distribution of the season-total precipitation except the absence of precipitation maximum over the southern CA Coast Range that is clearly distinguished from the Central Valley.

- 10-30% of cold season precipitation totals is related with ARs.

- ARs affect cold season precipitation mainly in the northern CA region.
Daily-mean Precipitation Intensity

Daily-mean precipitation intensity for the WYs 2001-2010 from the CPC data

- **Wet days**: Days with $PR > 0.1$ mm

- Larger precipitation intensities occur in the mountainous regions (the Coast Range, Sierra Nevada, and northern CA region).

- **Precipitation intensity for AR days show contrasts between the northern and southern CA regions that are characterized by**:
  - Larger daily-mean precipitation intensity during AR/non-AR days in the northern/southern CA region
Precipitation and SWE in the Sierra Nevada region are closely related with water resources and flooding.

The Sierra Nevada region is sub-divided into northern and southern regions across the 37.5N.
Interannual variations

- The number of AR events undergoes a large interannual variations (mean=9.4)
- The relationship between the number of ARs and the seasonal precipitation total is not clear, especially in the SSN
- Correlation Coefficients:
  - All SN=0.55, NSN=0.57, SSN=0.44

- The NSN region generally receives more AR precipitation than the SSN region
- The number of ARs and the AR-total precipitation are more closely correlated
- Correlation Coefficients:
  - All SN=0.83, NSN=0.85, SSN=0.56
For the relationship between AR and daily precipitation extremes, the PDF of wet-day precipitation intensity in the three SN regions are examined for:

- Wet days
- AR days
- non-AR days

AR days generally show much higher frequency of heavy precipitation events than non-AR days in all three SN regions.
Snow accumulations in the SN (above 1.5km) Season totals and AR portions

- 10-40% of the cold season snow accumulation in the SN region has occurred during AR events; however, interannual variation is large.
  - On average, ARs generate four times as much daily ∆SWE as non-AR storms
- The relationship between the number of AR events and ∆SWE is not clear
- ARs are more closely related with extreme daily ∆SWE
  - AR contribution was dominated by just two events in WY2005 and a single event in WY2008 and WY2010
Evaluate RCM performance in simulating AR-related cold season hydrology for the CA region for extended-range forecasts and climate change impact assessment studies

- **Model and Domain**
  - WRF3.1.1
  - 27 sigma layers in the vertical
  - Physics schemes: Kain-Frisch convection, YSU PBL, WSM-5 microphysics, Dudhia SW, RRTM LW, NOAH LSM
  - One-way nested EP-CA domain.
  - Ten cold season (Oct-Mar) runs for the Water Years 2001-2010
  - Large-scale forcing data from $1^\circ \times 1^\circ$ NCEP Final Analysis
AR-total Precipitation in the Sierra Nevada Region

- The model well simulates AR precipitation in the all three Sierra Nevada regions.
- The most notable model errors are the general overestimation of the AR precipitation especially for the WYs 2005 and 2010.
The hindcast reasonably simulates reasonably the daily precipitation intensity PDFs related with AR events

- Good agreement in the all and northern SN region

- Peak precipitation values are overestimated, especially in the NSN region.
Summary and Conclusions

- The impact of land-falling ARs on California’s hydrology is investigated for the cold season (Oct-Mar) of 10 water years 2001-2010.
- NCEP CPC data show 10-30% of the season-total precipitation falls during AR events with large interannual variations in the number of AR events and AR precipitation.
- ARs affect precipitation more in the northern CA than in the south; similar for the Sierra Nevada region.
- ARs are more closely related with heavy precipitation events than the season-total precipitation.
- Similar to precipitation, ARs are more closely related with large snow accumulation events than the season-total snow accumulation.
- The cold season hindcast reasonably simulates several features in the AR-related precipitation in the Sierra Nevada region.
- One of the most noticeable biases in the model simulation is overestimation of daily precipitation extremes and their frequencies.
• Additional posters on AR studies:
  
  • Winter storm trajectory analysis: Ryoo et al. A53B-0208
  
  • MJO vs. AR frequency/precipitation in California: Guan et al. A53B-0212