Impacts of Atmospheric rivers on extreme snow events in the White-Yampa River Basin

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Introduction

The Colorado River Basin stretches over a vast majority of the western United States. The lower basin is situated over parts of Arizona, New Mexico, Nevada, and California. The upper basin is situated over parts of Colorado, Utah, New Mexico, Arizona, and Wyoming. For this study we focused on the White-Yampa River Basin (WYRB), a sub-region of the Upper Colorado River Basin located in the north-west corner of Colorado. Over half of the normalized stream flow in the Colorado River originates from water released by snow melt and therefore it is significant to understand how atmospheric rivers (ARs) can affect the snowpack in the basin (Xiao & Lettenmaier, 2021). ARs are commonly defined as corridors of concentrated water vapor transport in the atmosphere (Ralph et. al., 2018). In addition, ARs typically yield large amounts of snow accumulation when they make landfall during cold seasons. In this study, we examined the impacts of ARs on extreme snow events in the WYRB.

Data and methods

Snow Water Equivalent (SWE) is one of the primary measurements taken at Snow Telemetry (SNOTEL) and snow courses across the western United States. The SWE of the 21 SNOTEL stations in the WYRB during 31 water years (1990-2020) was used to examine the snow climatology and the extreme events in this basin. We first developed an algorithm that started with reading the CSV (comma-separated values) files which were created from the SNOTEL SWE data and limiting it to the water years from 1990 to 2020. We calculated the daily SWE at the 21 SNOTEL stations within the WYRB and identified snow days (positive SWE value) in the 31 water years. The extreme snow days were determined using the 99th percentile of daily SWE threshold for each station. In addition, we examined the inter-annual variabilities of the annual maximum SWE and the SWE from extreme snow days in the WYRB.

The integrated water vapor transport (IVT) calculated using NASA MERRA2 reanalysis and the AR catalog from Guan and Waliser (2015) were used to explore the AR conditions for the extreme snow days. In this catalog, ARs were detected using the 85th percentile threshold of IVT specific to each season and grid cell with a fixed lower limit of 100 $kg\ m^{-1}\ s^{-1}$, as well as some geometry requirements, including length >2000 km, length/width ratio >2, and the consistency of IVT direction (Guan and Waliser 2015).

Results

For the WYRB (averaged over the 21 stations in the WYRB), the mean annual maximum SWE is 28 inches, and the standard deviation is 4.96 inches in the 31 water years (Fig. 1). We did not find any statistically significant trend for the annual maximum SWE in the 31 water years for the WYRB, however there are large inter-annual variabilities. For example, in the water year 2011 it had nearly 37 inches of SWE; but in the next year, 2012, it had about 15 inches SWE, which was only about 40% of the 2011 SWE. These changes could have large impacts on the California water supply. The extreme SWE events throughout the 21 stations deliver 5.0%-6.5% of the total SWE a year in the WYRB (Fig. 1). They may play an important role in the inter-annual variability of the annual maximum SWE.

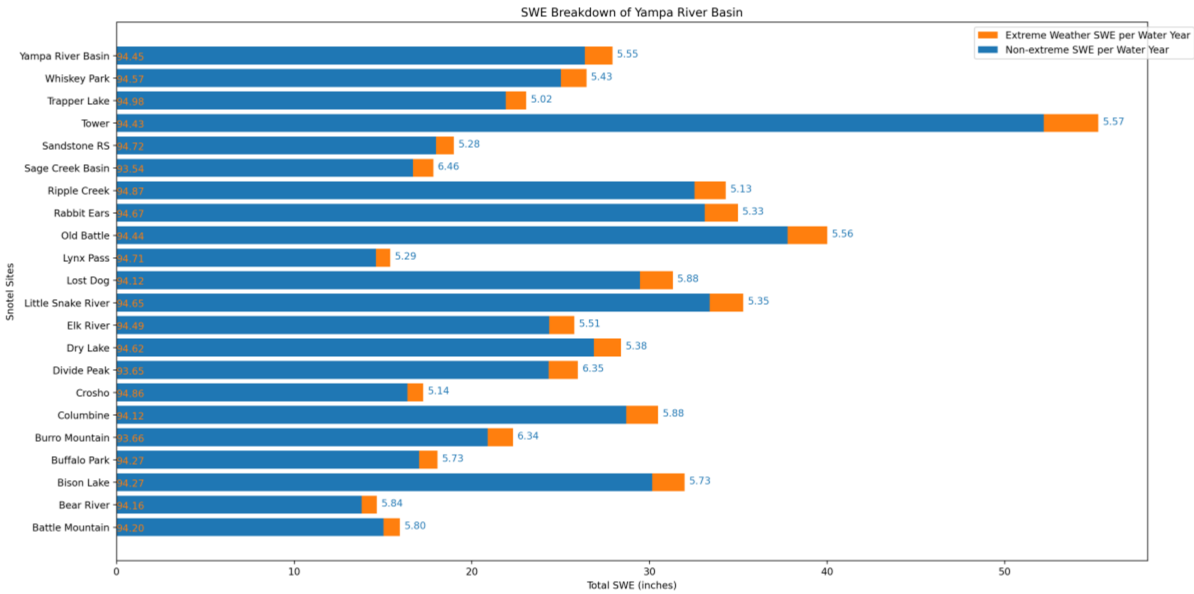

Figure 1. Annual maximum SWE for the WYRB and the 21 SNOTEL stations averaged over the 31 water years (1990-2020). Bar graph in orange is SWE from extreme snow days and bar graph in blue is SWE from non-extreme days. Values in each bar are the percentages of the extreme and non-extreme SWE to the total SWE.

We are interested in the impacts of ARs on the extreme snow events in the WYRB, so we examined the IVT field as well as the detected AR conditions on those extreme snow days. If there is a detected AR covering any part of the blue box (105°W-114°W and 36°N-44°N) on an extreme snow day, it will be defined as an extreme snow day associated with an AR (Fig. 2). The blue box is larger than the WYRB because a nearby AR (within the blue box) may have a great impact on the snow in the WYRB although the AR does not directly hit this basin. We found that out of the 37 extreme days 12 days (32%) were associated with ARs.

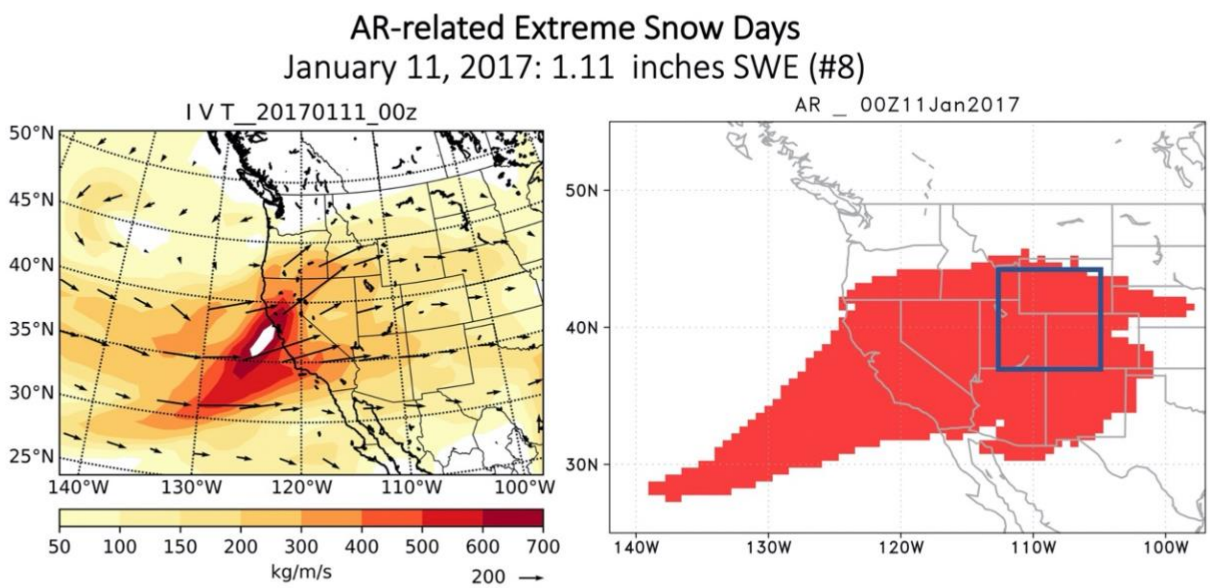

Figure 2: An example of extreme snow day associated with an AR: the IVT (left panel) and the detected AR shape (right panel) at 00z 11/1/2017. The blue box around the WYRB in the right panel is used to determine the association between the extreme snow day and the AR.

Conclusion and future work

We examined the snow within the WYRB in the water years 1990-2020 and selected the extreme snow events using the 99th percentile SWE threshold. For the WYRB, the mean annual maximum SWE of the 21 SNOTEL stations was about 28 inches. The 37 extreme snow days contributed about 5.6% of the total SWE in the 31 water years. Out of the 37 extreme snow days we found that 12 days (32%) were associated with ARs. The ARs can have large impacts on those extreme snow events in the WYRB. More research is needed to deepen our understanding of the impacts. For example, we can use the 95 percentile SWE thresholds for selecting extreme snow days in 1990-2020, examine AR catalog for 1-3 days before the extreme snow days, examine AR characteristics related to extreme snow events.

Reference

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