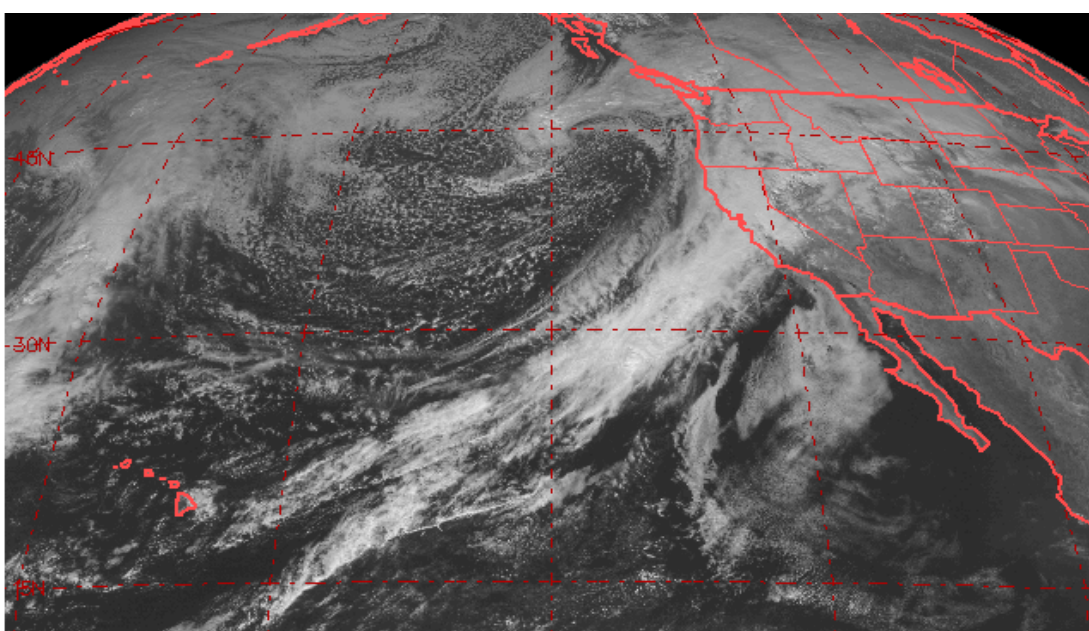


## Motivation

During the winter of 2016/2017, 34 atmospheric rivers (ARs) hit California's Russian River basin, many in quick succession of one another. Successive ARs were then defined as AR families based on their spatiotemporal characteristics.

This study aims to provide a formal definition of AR families, describe their characteristics, and begin to assess their predictability. The increased risk of higher impacts due to multiple AR events further motivated this study.



Visible satellite image of an atmospheric river over the Pacific Ocean taken from the GOES 15 satellite on February 9, 2017 at 2100 UTC.

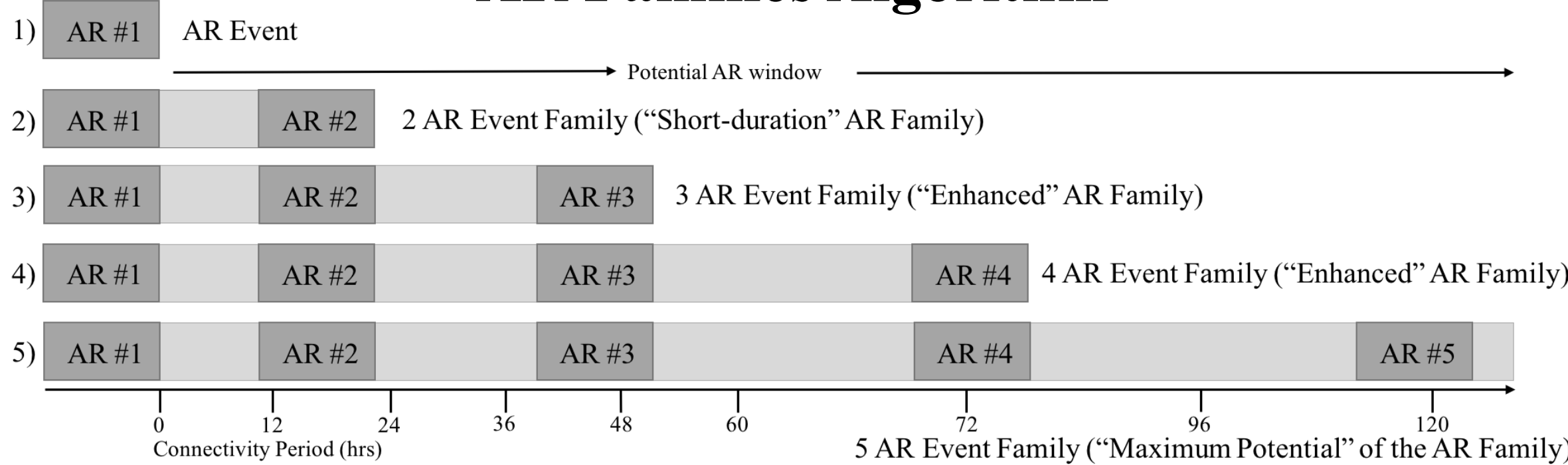
## Methodology

The Ralph et al., 2013 AR catalog at Bodega Bay, CA ARO was updated through water year 2017 using the following criteria:

- 8 hours of continuous:
  - Integrated Water Vapor  $\geq 2$  cm
  - Upslope Water Vapor Flux  $\geq 15$  cm (m s<sup>-1</sup>)

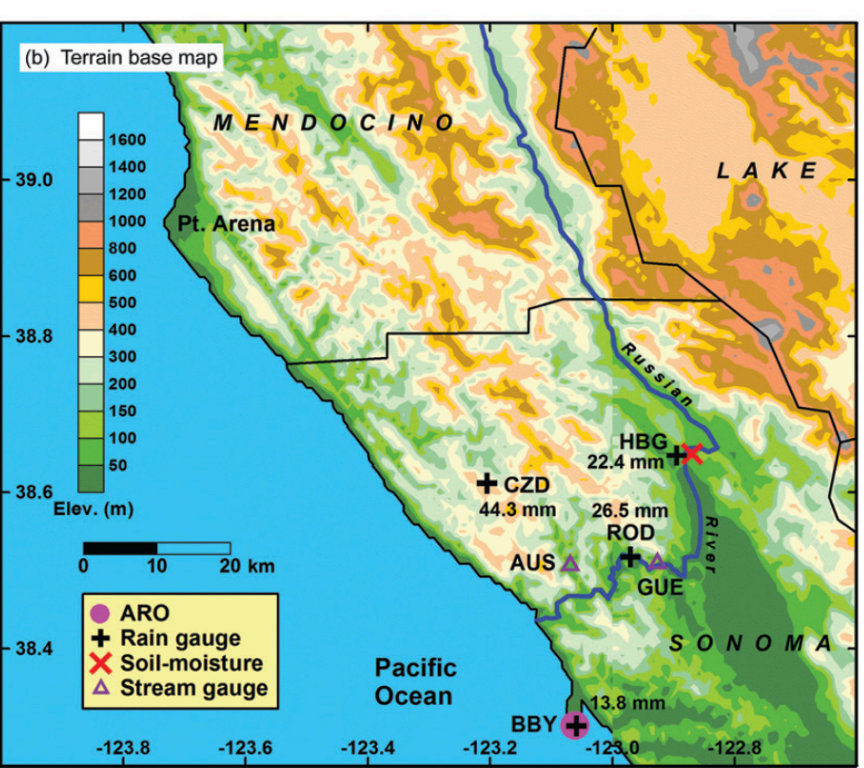
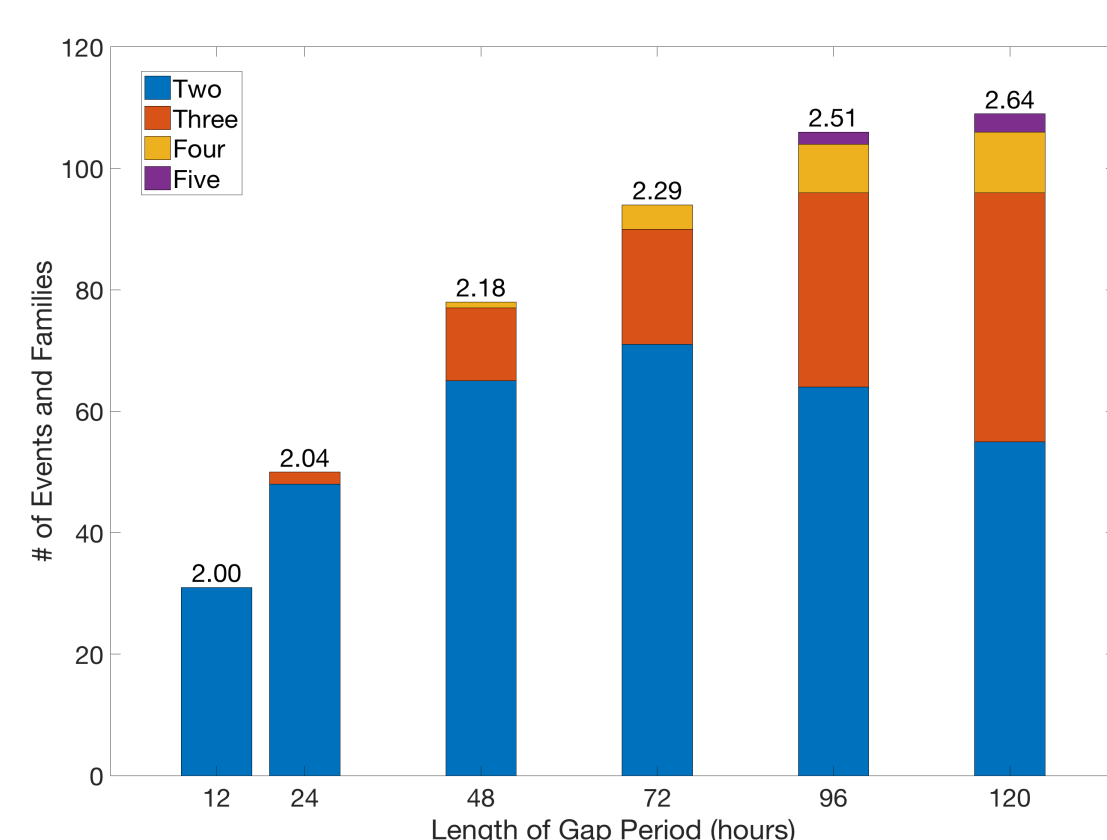
The MERRA-2 dataset was used to create a 30-year, 21-day running mean climatology (Grumm and Hart, 2001) from 1987-2016 on these relevant variables: 500hPa heights, 850hPa heights, 850hPa air temperature, 250hPa wind speed and integrated water vapor.

### AR Families Algorithm

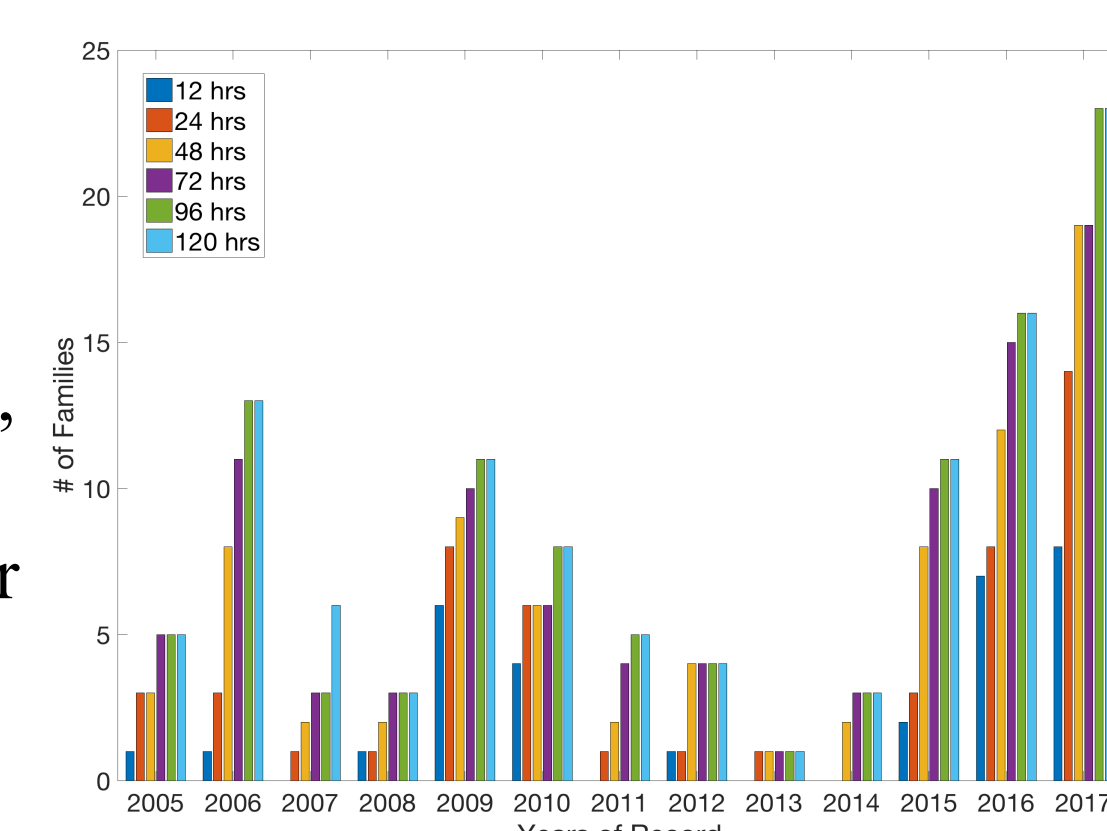


Above. Schematic of families algorithm. Connectivity periods begin at the end of the first AR, counting all AR events that occur within the connectivity period.

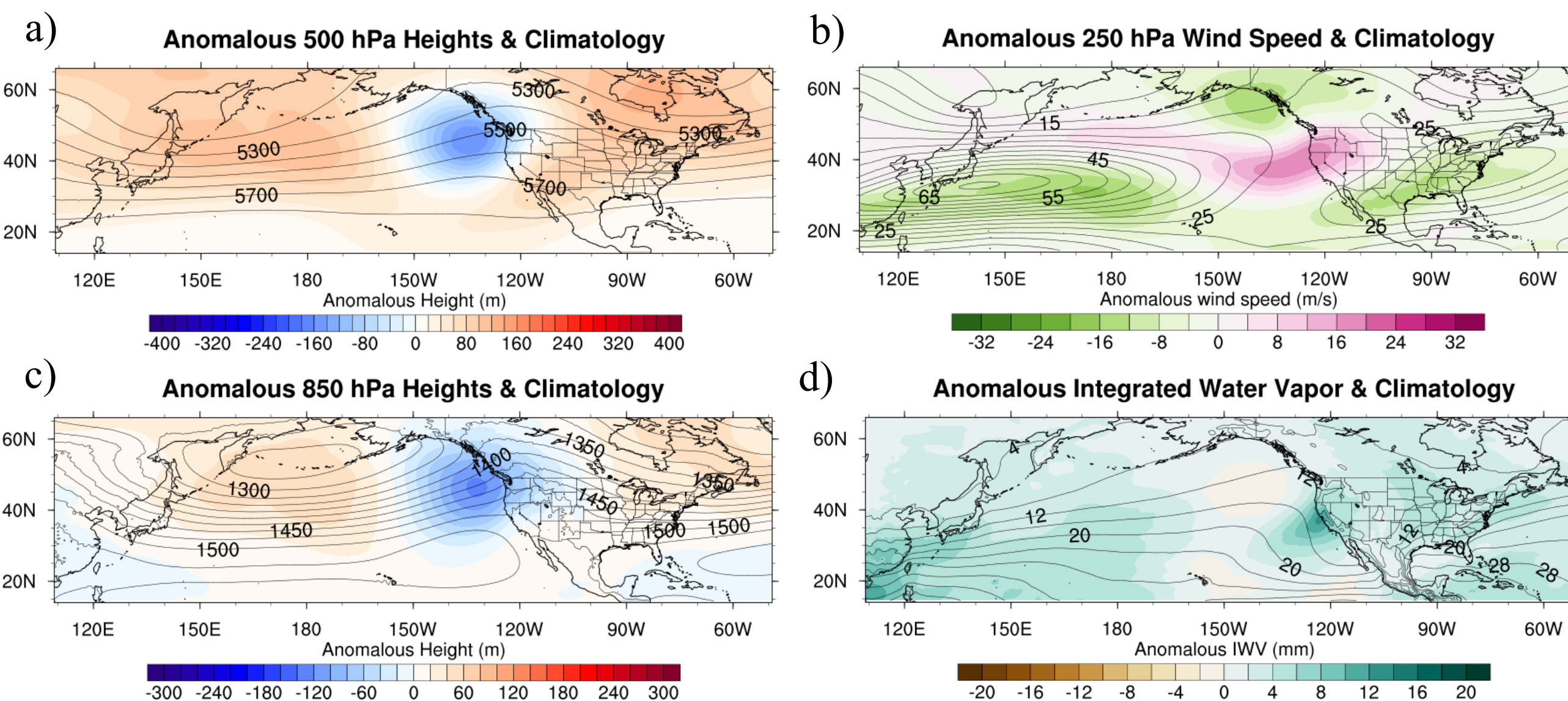
Top right. The number of AR families per connectivity period in total column height with the number of AR events per family dividing the bars. The value centered on each bar is the average number of AR events per family for each gap period. Bottom right. The number of AR families per water years 2005 – 2017 for each gap period (12, 24, 36, 48, 72, 96 and 120 hours).



Left. Map of coastal northern CA showing ARO, stream and rain gauges for Sonoma County, CA. Ralph et al., 2013



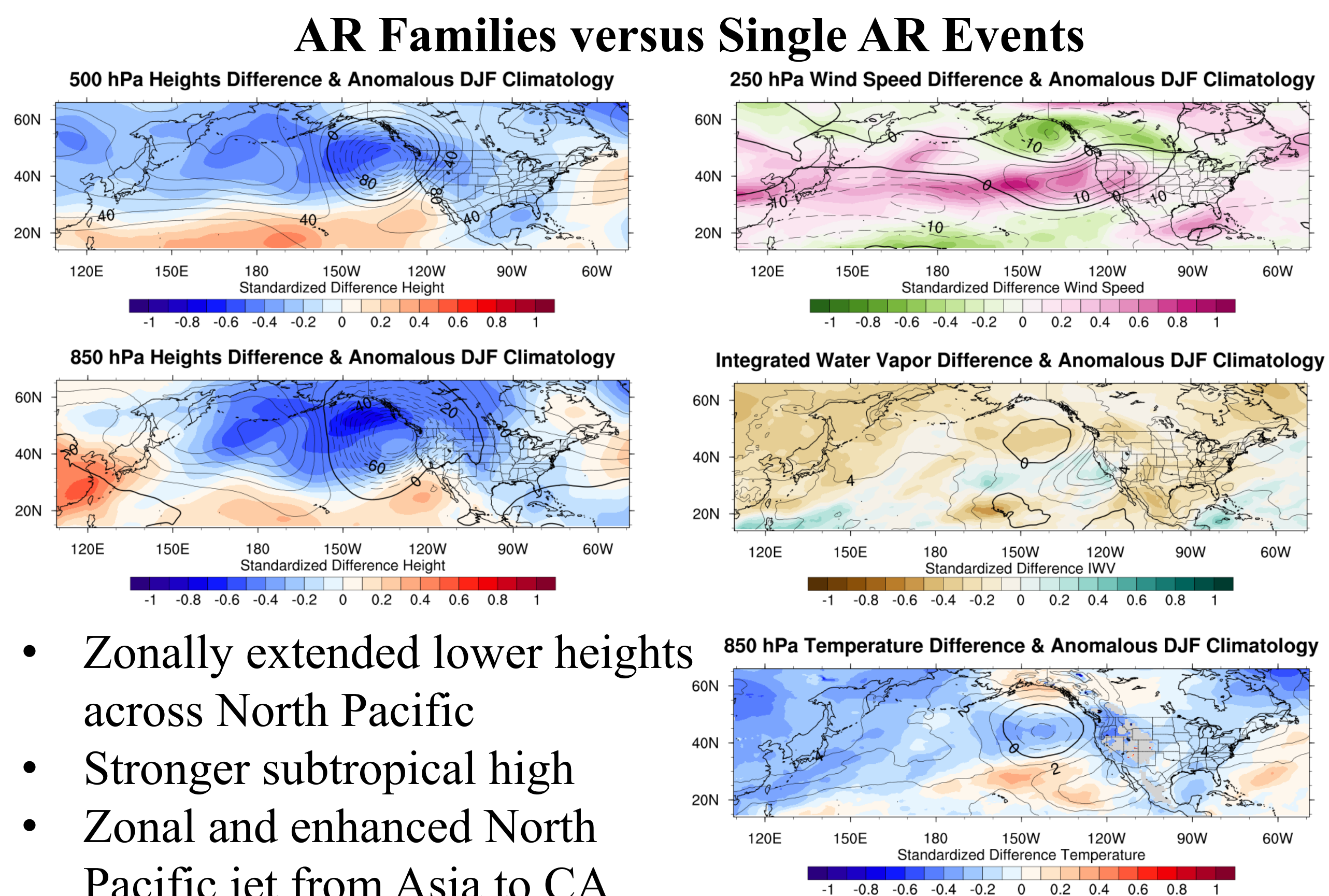
## Family Characteristics



Composites of all 120-hr AR families at BBY. a) Anomalous 500 hPa Heights (colored contour) and DJF climatology (contour), b) Anomalous 250 hPa Wind Speed, c) Average 850 hPa Heights, d) Average IWV.

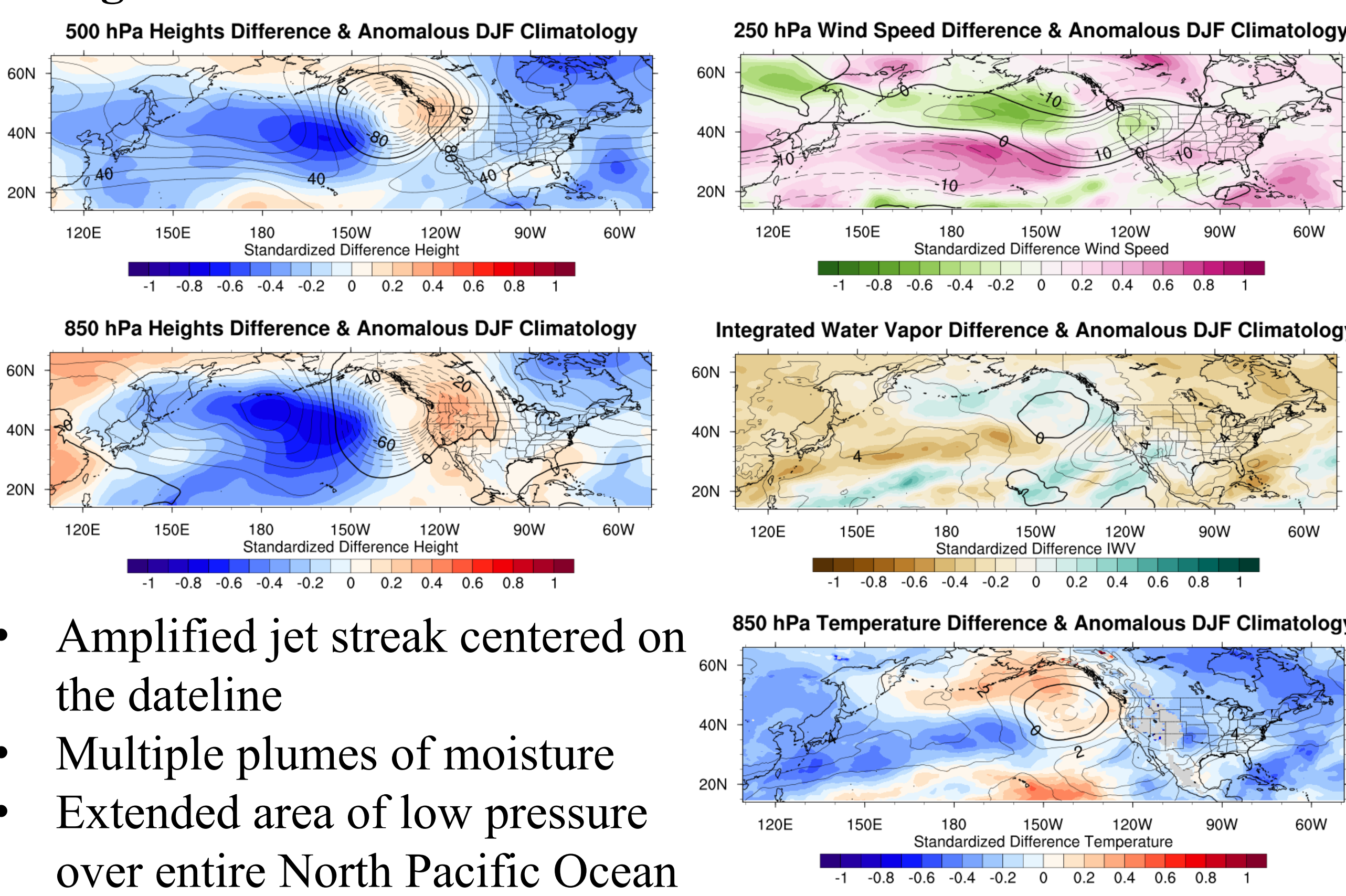
- Low central pressure off the coast of BC at 500hPa and 850hPa
- Enhanced jet streak centered around BBY, SW to NE tilt
- Higher IWV values from north of HI to CA coast

## Unique Family Signals



- Zonally extended lower heights across North Pacific
- Stronger subtropical high
- Zonal and enhanced North Pacific jet from Asia to CA

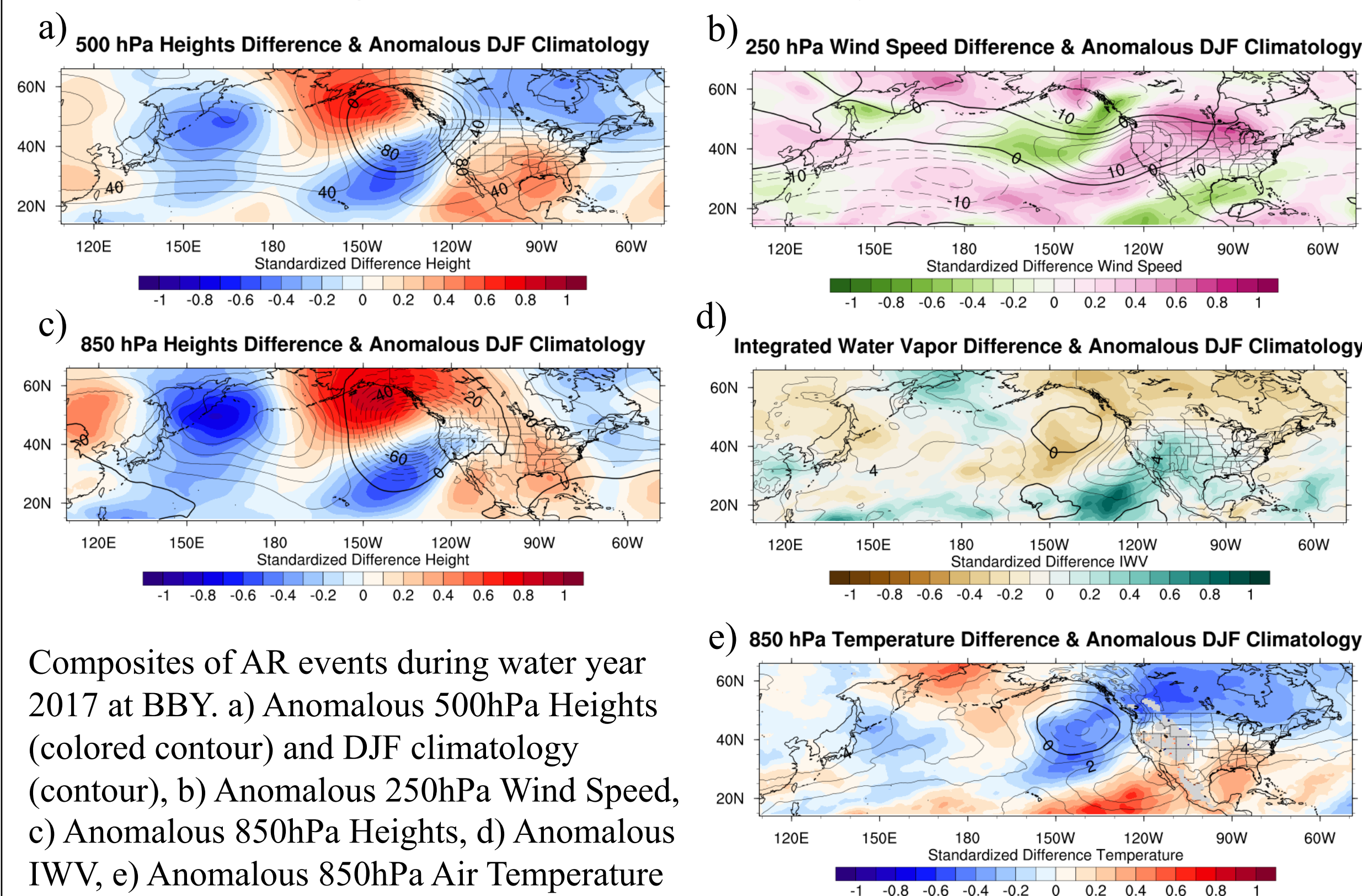
### Long-duration AR Families versus Short-duration AR Families



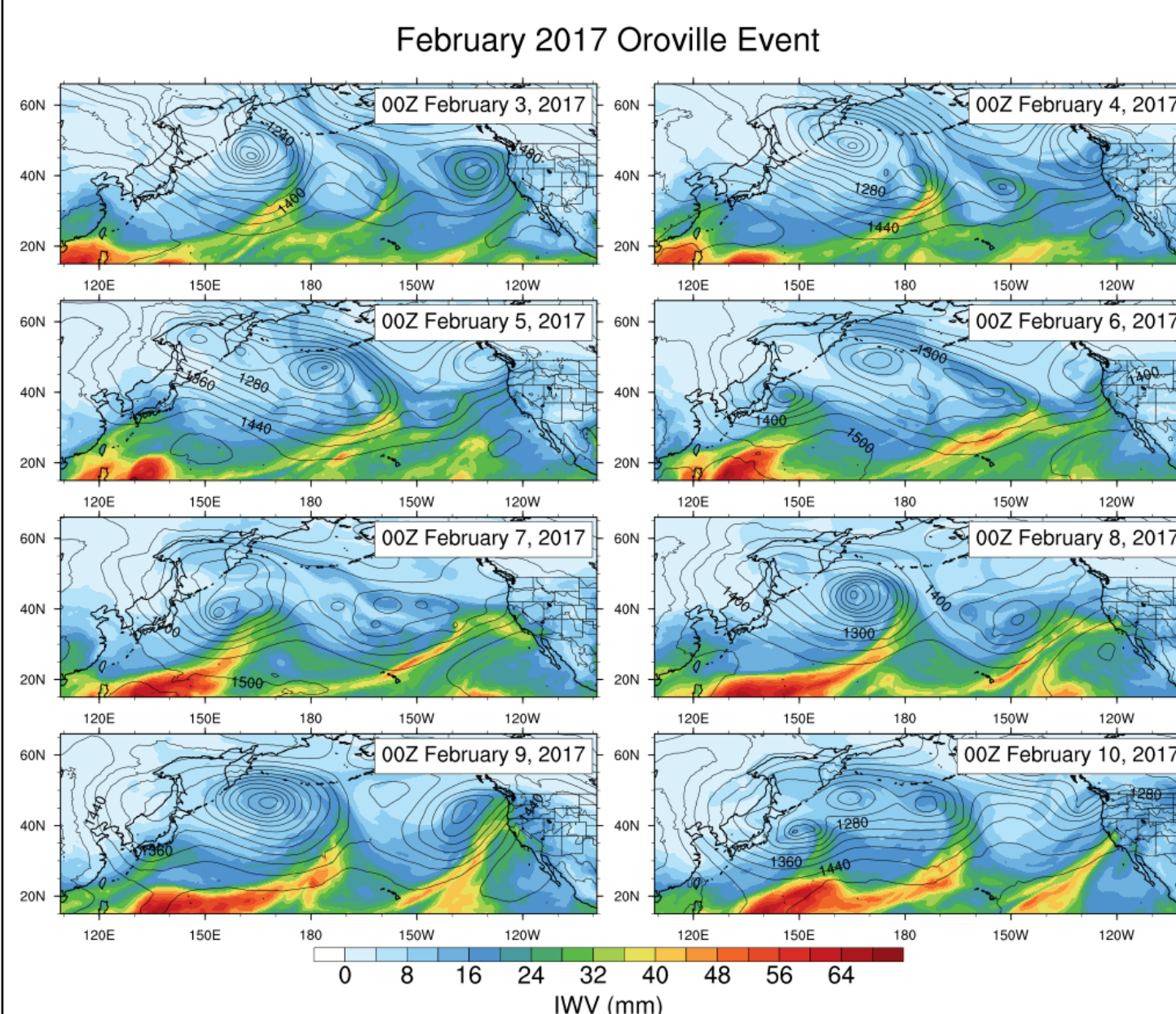
- Amplified jet streak centered on the dateline
- Multiple plumes of moisture
- Extended area of low pressure over entire North Pacific Ocean

## Water Year 2017 Case Study

A total of 23 families hit California's Russian River basin in WY 2017 using the 120-hr connectivity period.

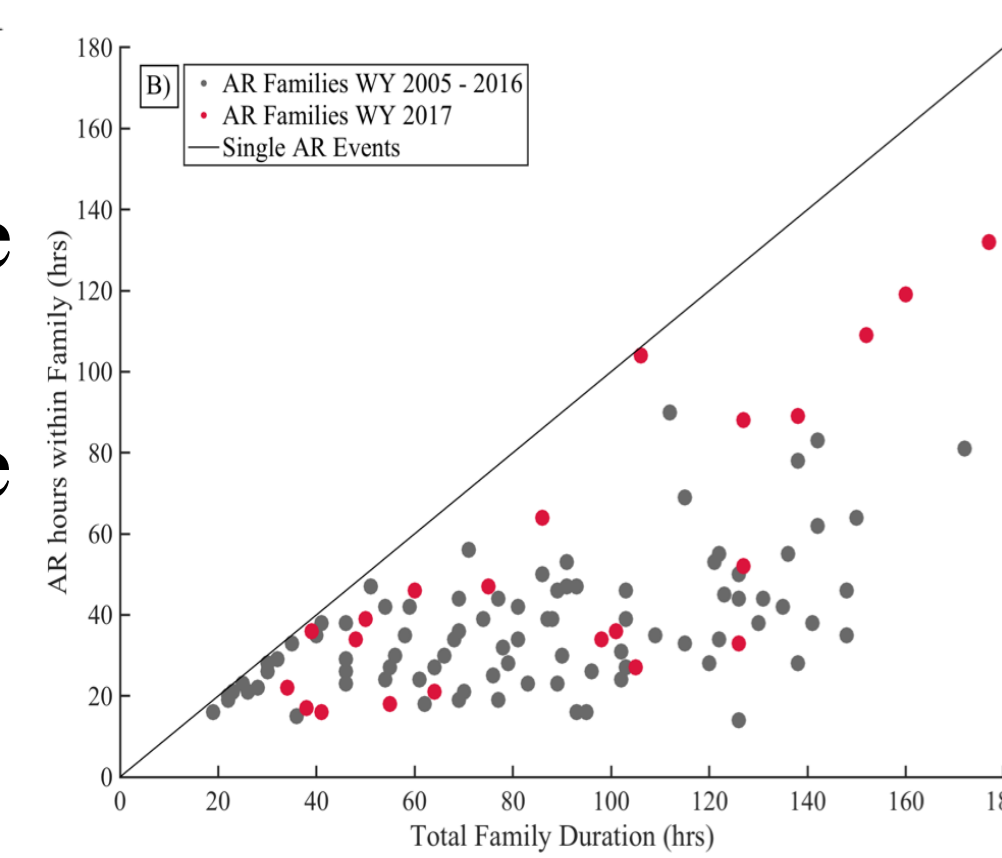


Composites of AR events during water year 2017 at BBY. a) Anomalous 500hPa Heights (colored contour) and DJF climatology (contour), b) Anomalous 250hPa Wind Speed, c) Anomalous 850hPa Heights, d) Anomalous IWV, e) Anomalous 850hPa Air Temperature



Left. Time evolution of February 2-8, 2017 AR events showing the eastward propagation of multiple low pressure centers and associated ARs.

Below. The ratio of total family time to the number of AR hours within the AR family. Red dots highlight WY 2017 events.



Between Feb 2 – 10, five ARs hit the Northern CA, including the Russian River. The cumulative effect of these ARs worsened the problems caused by infrastructure issues at Oroville Dam in Northern CA.

## Conclusions & Future Work

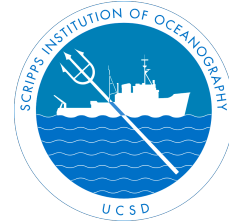
- Compared to single AR events, AR families have zonally extended low pressure areas and are influenced by the Pacific high off of Baja CA, Mexico
- AR families exhibit multiple plumes of moisture across the Pacific Ocean originating from the western Pacific to Baja
- What are the associated impacts (i.e., precipitation, streamflow, soil moisture) of AR families?
- Are any parameters of families predictable? And if so, how many days in advance can we spot these trends?
- How do Rossby wave breaking and wave number analysis influence family development?

Ralph, F.M., T. Coleman, P.J. Neiman, R.J. Zamora, and M.D. Dettinger, 2013: Observed impacts of duration and seasonality of atmospheric-river landfalls on soil moisture and runoff in coastal northern California. *Journal of Hydrometeorology*, 14, 443-459.  
Grumm, R. H. and R. Hart, 2001: Standardized Anomalies Applied to Significant Cold Season Weather Events: Preliminary Findings. *Weather and Forecasting*, 16, 736-754.  
This project was supported by the United States Army Corps of Engineers.





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and Water Extremes

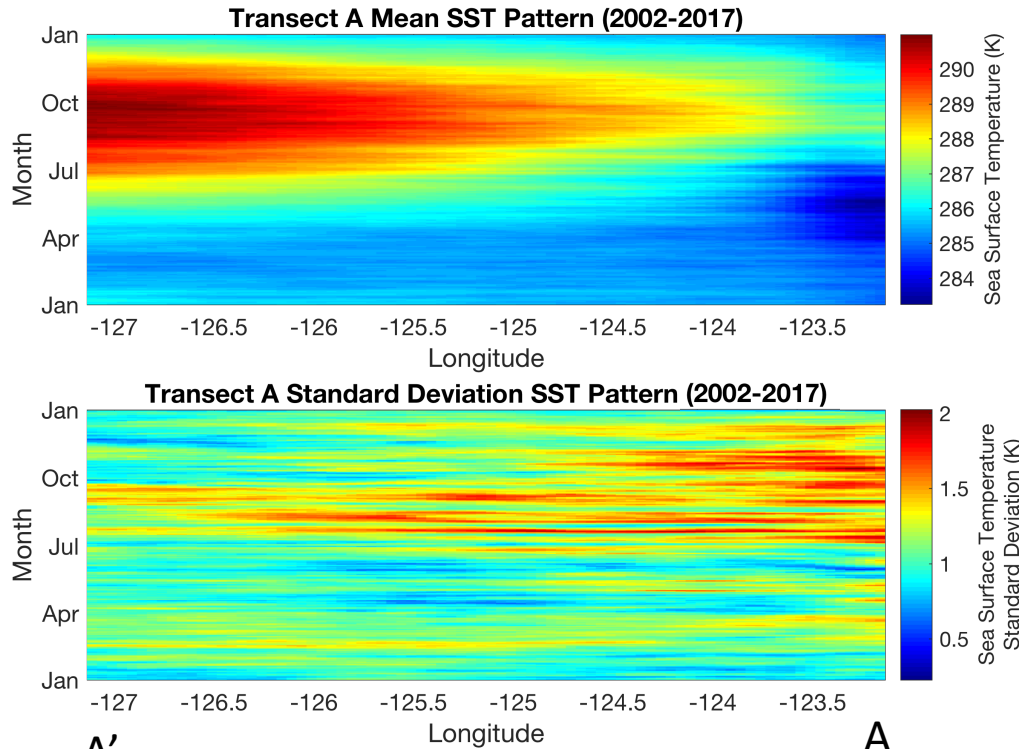


# Coastal sea surface temperature variability in Northern California during landfalling atmospheric rivers

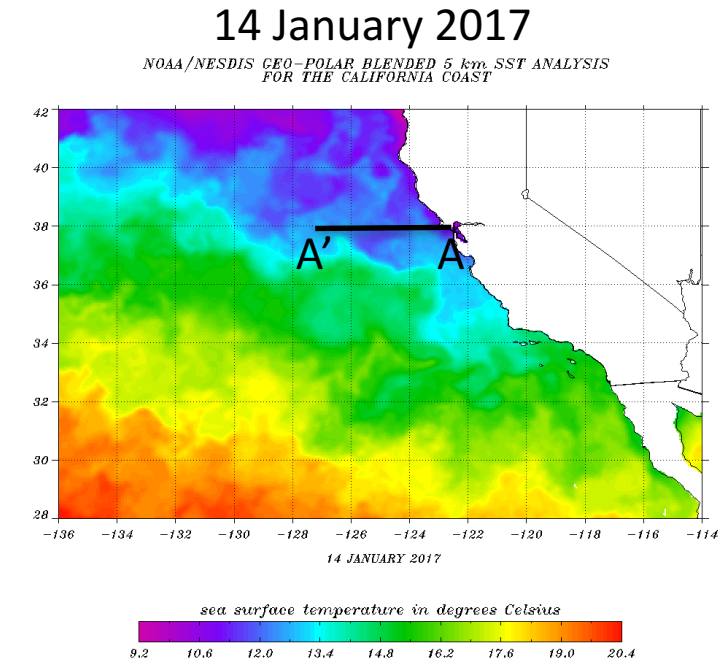
Meredith A. Fish, Rachel Weihs, F. Marty Ralph

July 10, 2018

# Coastal SST seasonal variability

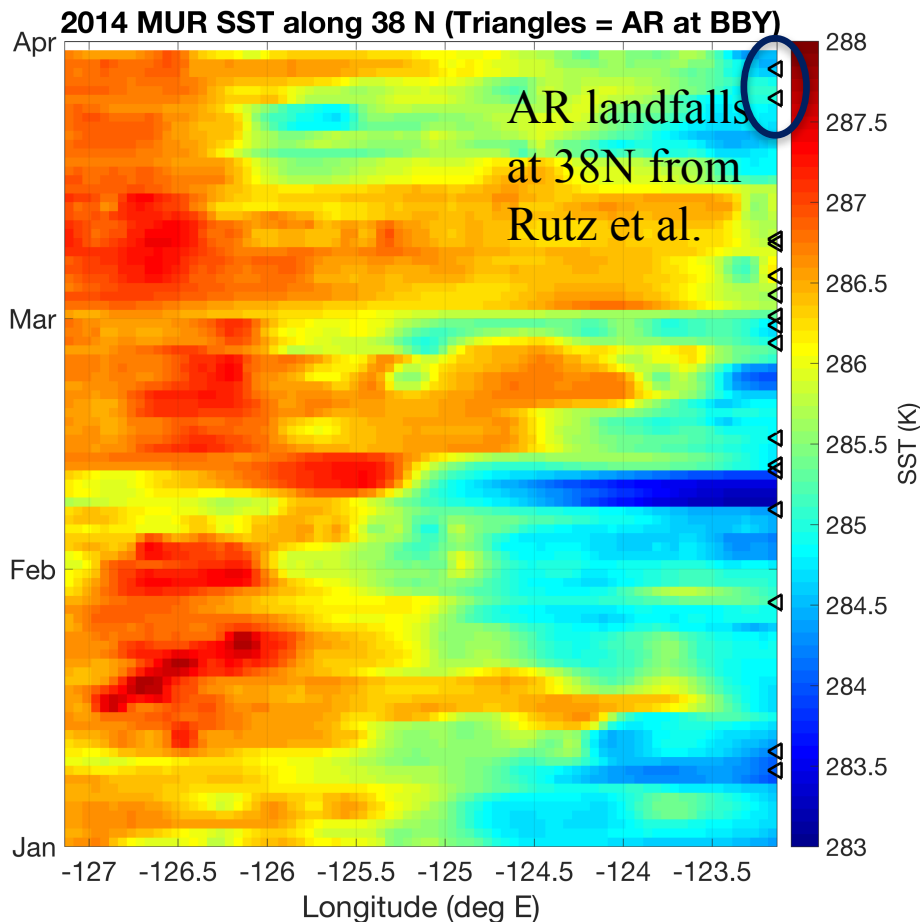


A'  
Multi-scale Ultra-High Resolution SST; NASA PO-DAAC



- Mean SST coastal variability dominated by summertime upwelling
- Large variance in SST during early cool season ( $> 1^{\circ}\text{C}$  on average) especially during spring/fall transition period

# Coastal SST variability

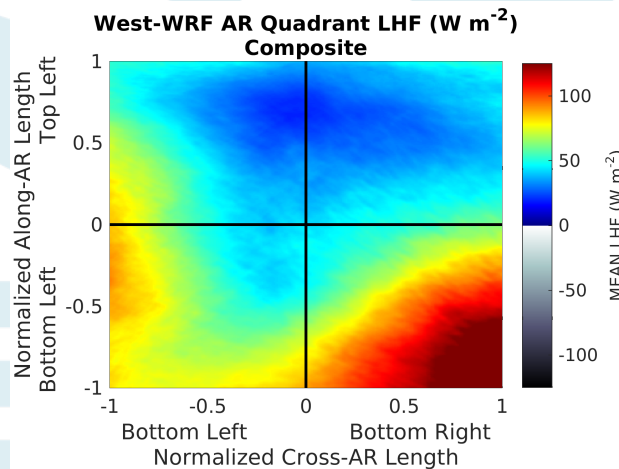
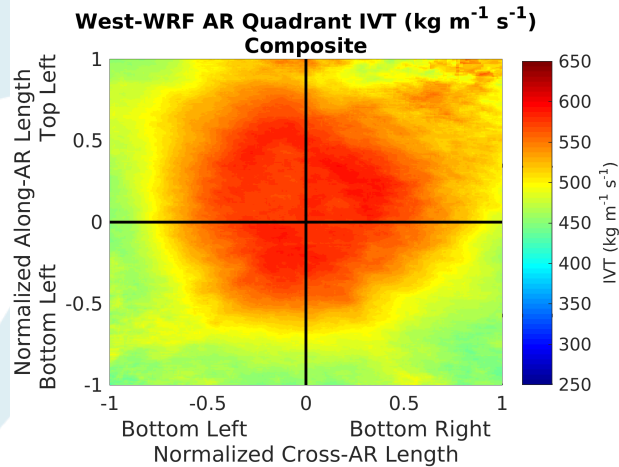


- Change in SST ( $\sim 1\text{-}2$  K) during or after AR
- If SST variations due to post-cold front heat flux loss, what are time scales of SST “rebound”?
- Could heat flux loss affect next storm? What spatial scales and magnitude would affect the AR?



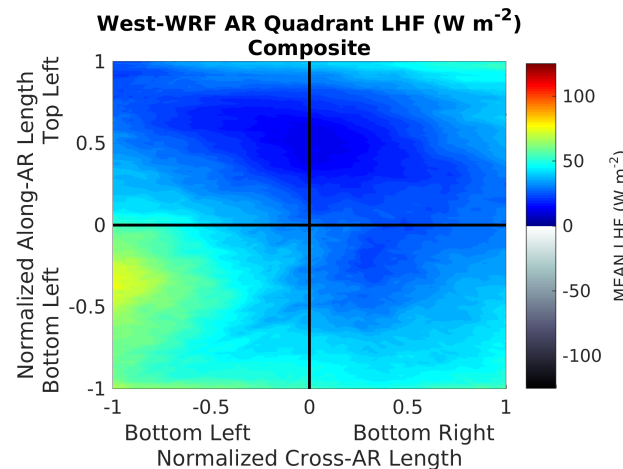
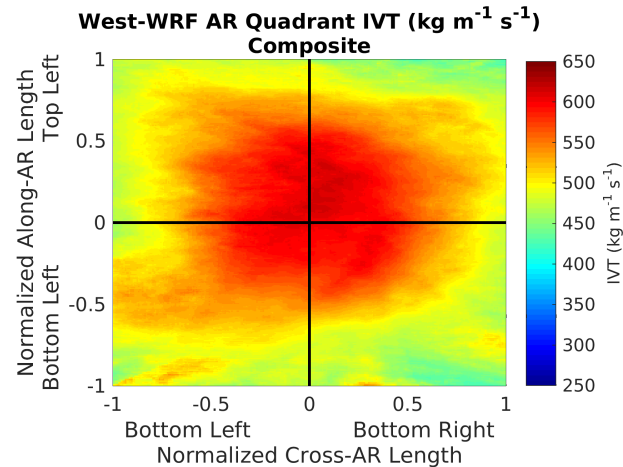
# West-WRF AR Composites

WY2017



WY2017 E Pac Mean LHF =  $100.31 \text{ Wm}^{-2}$

WY2018



WY2018 E Pac Mean LHF =  $90.53 \text{ Wm}^{-2}$

Quadrant orientation

