A Six-Year Climatology of Precipitation within Major Storms in Northern California

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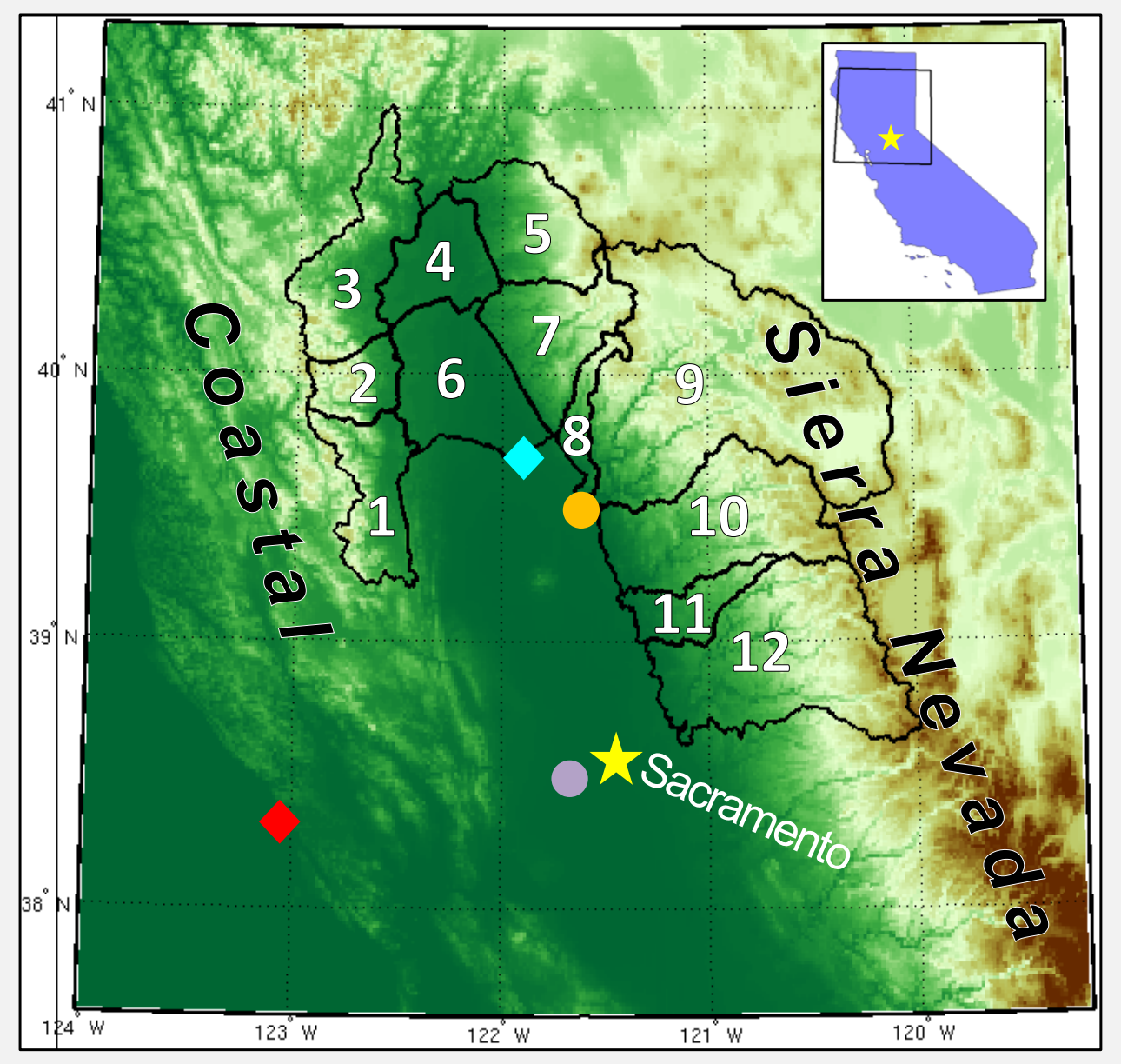
Introduction

Northern California's mountain ranges and proximity to the Pacific Ocean subject the region to major storms that are often difficult to forecast. This region also relies heavily on mountain snow produced by these major storms for its fresh water supply. To improve flood forecasts and fresh water supply planning, more accurate prediction of the spatial pattern of heavy precipitation, in terms of elevation and watershed, is needed.



Watershed Basins

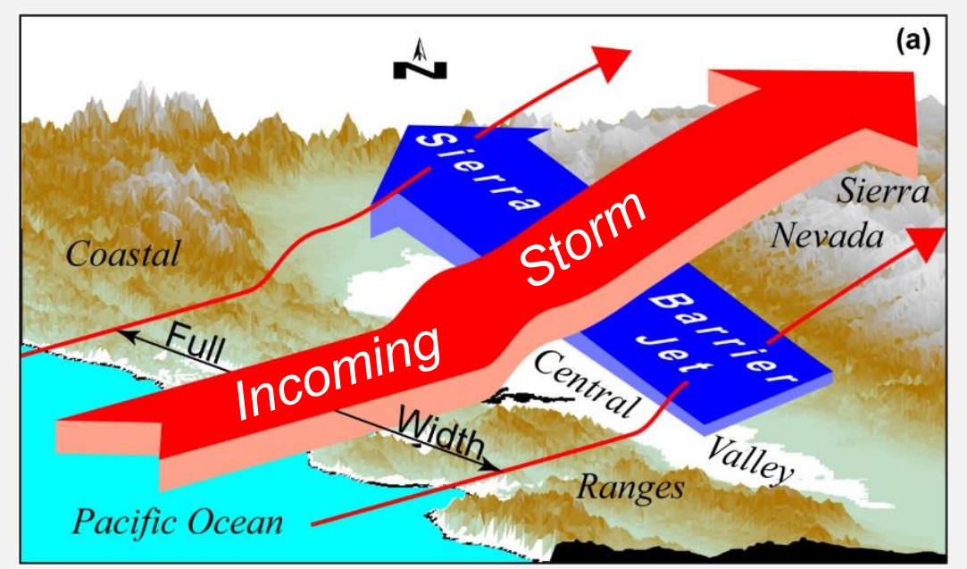
1. Stony Creek	7. Eastern Tehama
2. Ball Mountain	8. Butte Creek
3. Shasta Bally	9. Feather
4. Redding	10. Yuba
5. Whitmore	11. Bear
6. Tehama	12. American

Instruments

- ◆ Chico Wind Profiler
- ◆ Bodega Bay Wind Profiler
- ● Beale National Weather Service Radar
- ● Sacramento National Weather Service Radar

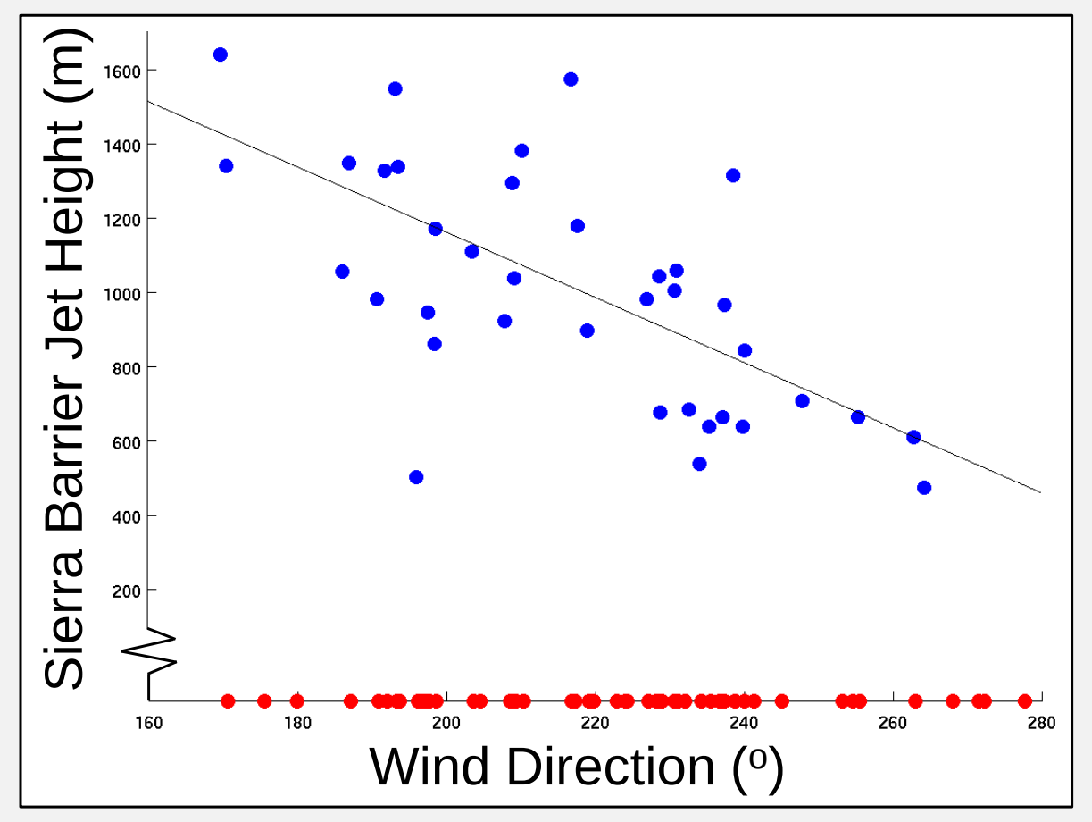
Dataset

We use data from the Beale and Sacramento weather radars to analyze the spatial patterns of precipitation within 12 watersheds in northern California for 64 major storms that occurred between 2005 and 2010. We examine wind direction at Bodega Bay as well as Sierra Barrier Jet occurrence and altitude at Chico to see if these factors have an effect on the spatial distribution of precipitation.



Adapted from Kingsmill et al. 2013

The Sierra Barrier Jet is a region of strong surface winds directed parallel to the ridge of the Sierra Nevada Mountains. It is generally associated with diverting precipitation northward.

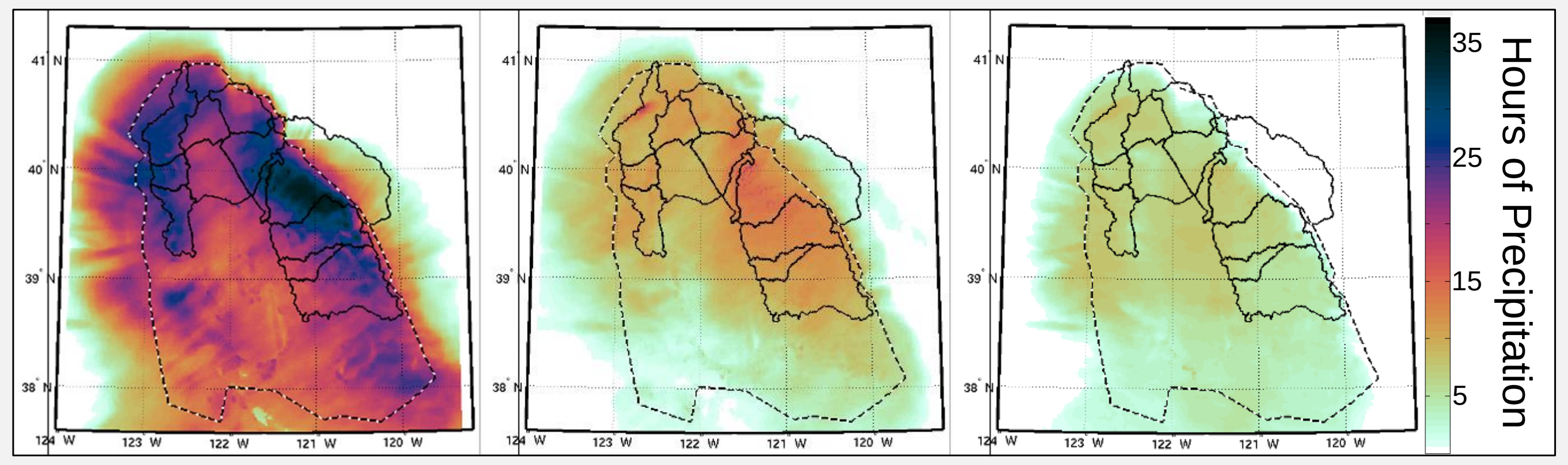


Relationship between wind direction and the Sierra Barrier Jet in the 64 storm dataset

- ● Storms with a Sierra Barrier Jet present
- ● Storms without a Sierra Barrier Jet present

Radar composite maps are made by counting the number of hours in one storm that the two radars in this study record precipitation.

Three example radar composite maps from the 64 storm dataset



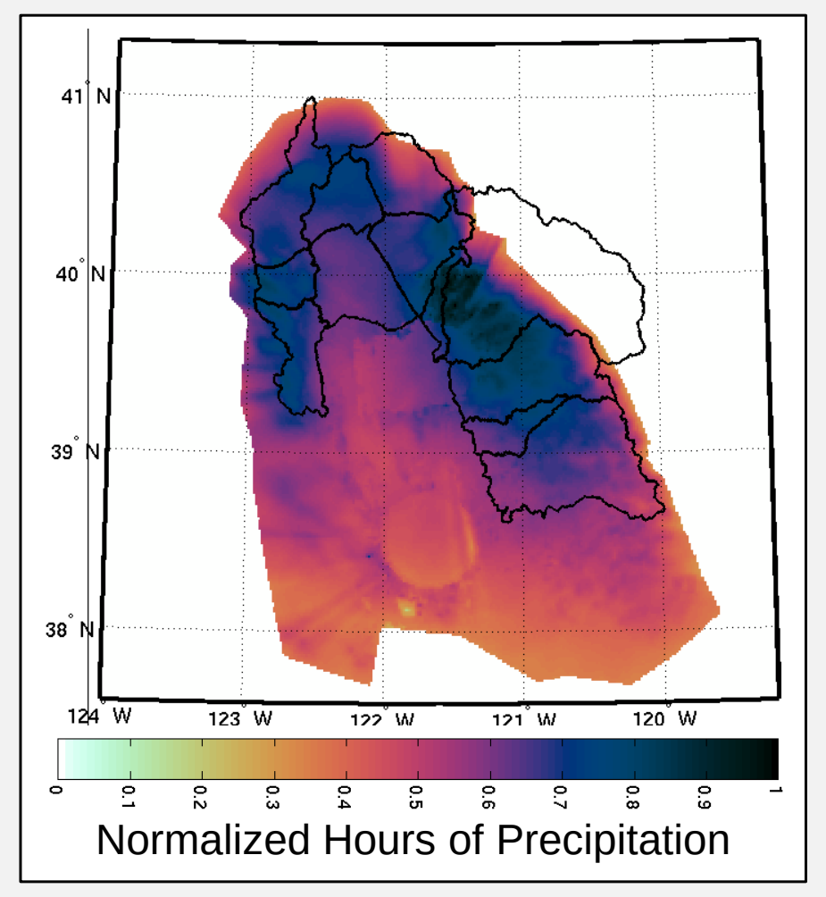
18 Dec 2005 | 03 Oct 2008 | 02 May 2009

Methods

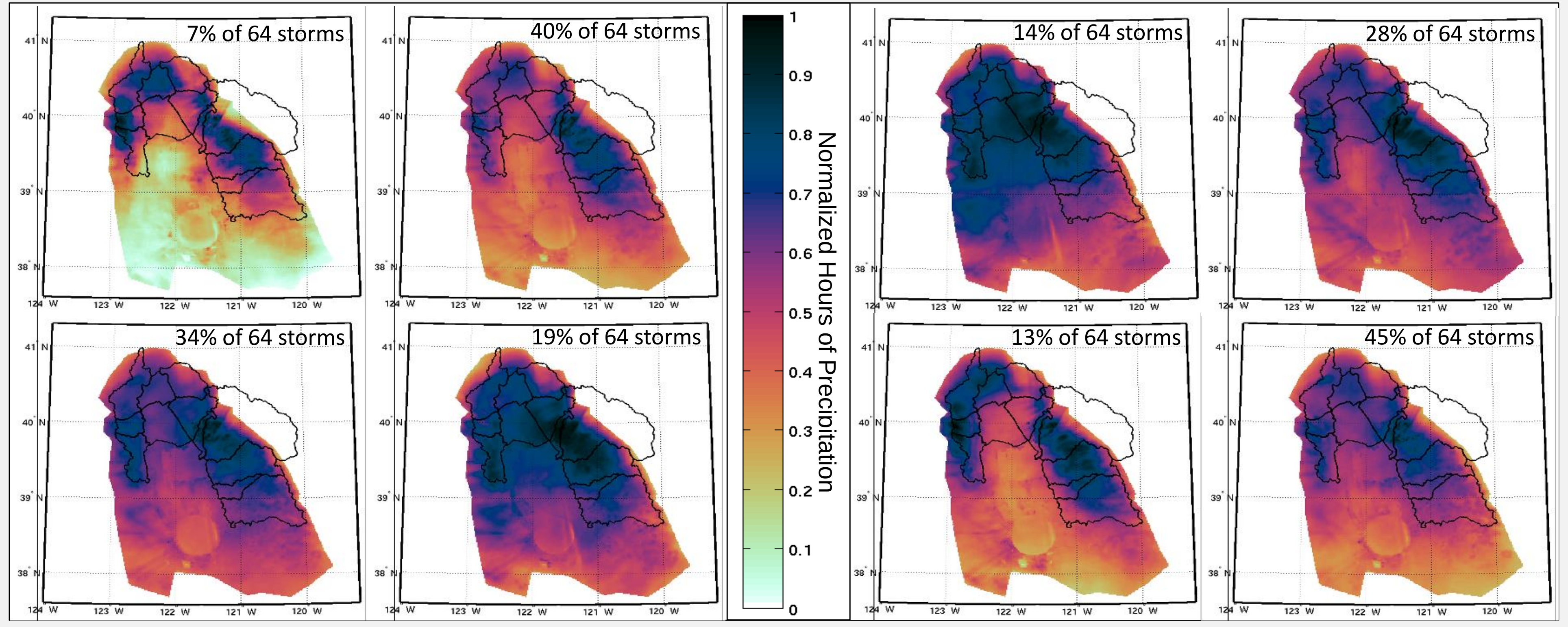
I. Group Composite Maps

1. The 64 radar composite maps are divided into 8 storm classes based on wind direction and Sierra Barrier Jet characteristics (shown below).
2. Radar composite maps from each storm are added together in each class.
3. The resulting maps are normalized by the maximum number of hours of precipitation in the map to allow comparisons to be made among storm classes while minimizing effects from sample size discrepancies.
4. Data obscured by mountain ranges are removed.

Group composite map of all 64 storms used in this study



Wind Direction Classes | **Sierra Barrier Jet Classes**



South-Southwesterly | Southerly | Low Altitude | No Sierra Barrier Jet

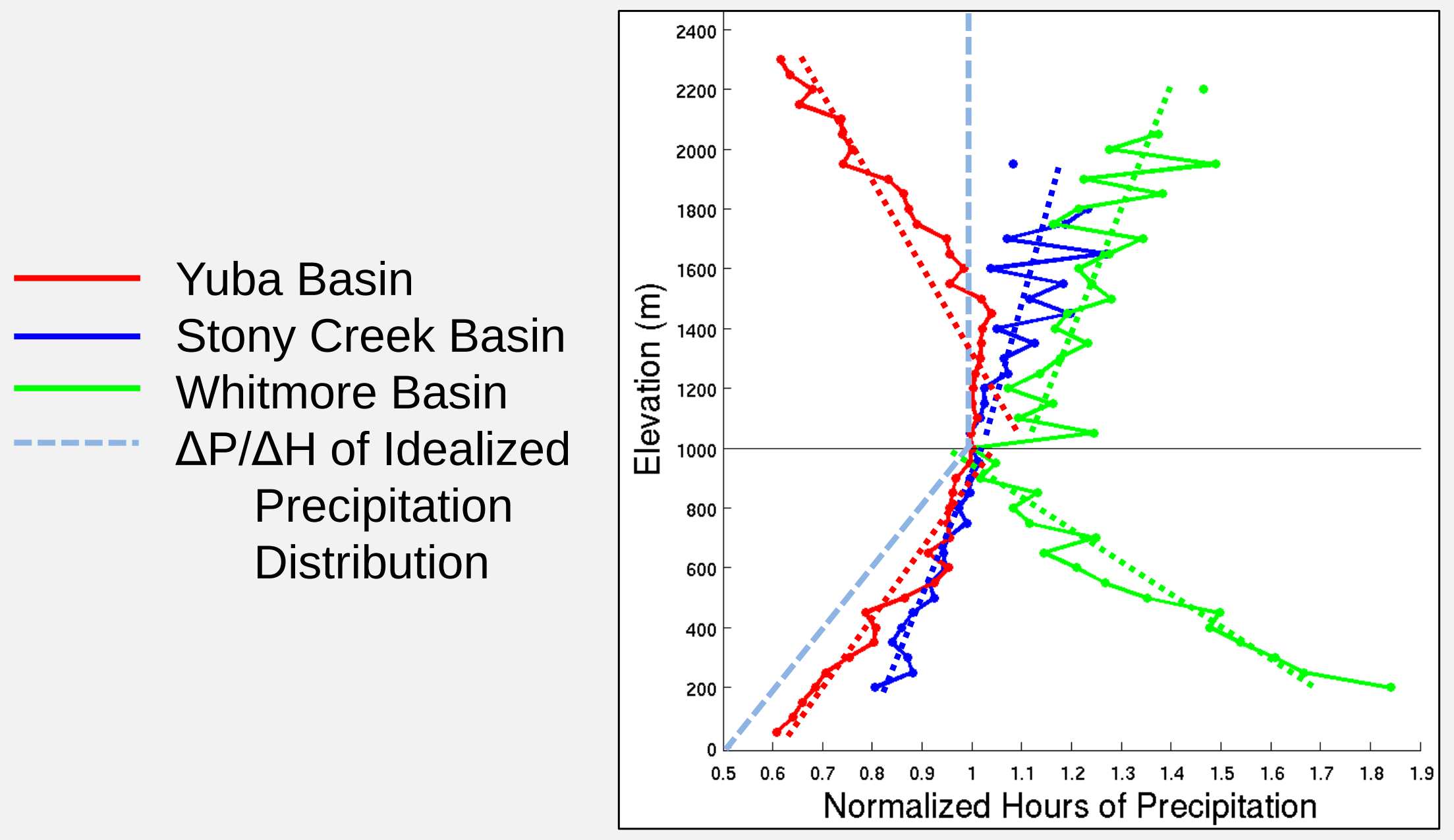
II. Change of Precipitation with Elevation

We examine how the normalized hours of precipitation in the 8 storm classes above changes with increasing elevation in all 12 basins. This information is summarized in terms of a best fit slope, ΔP/ΔH:

$$\frac{\Delta P}{\Delta H} = \frac{\Delta \text{ normalized hours of precipitation}}{\Delta \text{ elevation}}$$

Previous studies have found an idealized precipitation distribution for the Feather, Yuba, and American basins that shows an increase in precipitation up to 1000 m and constant precipitation above 1000 m.

Example Precipitation Change with Elevation within 3 Basins for Low Altitude Sierra Barrier Jet Storms

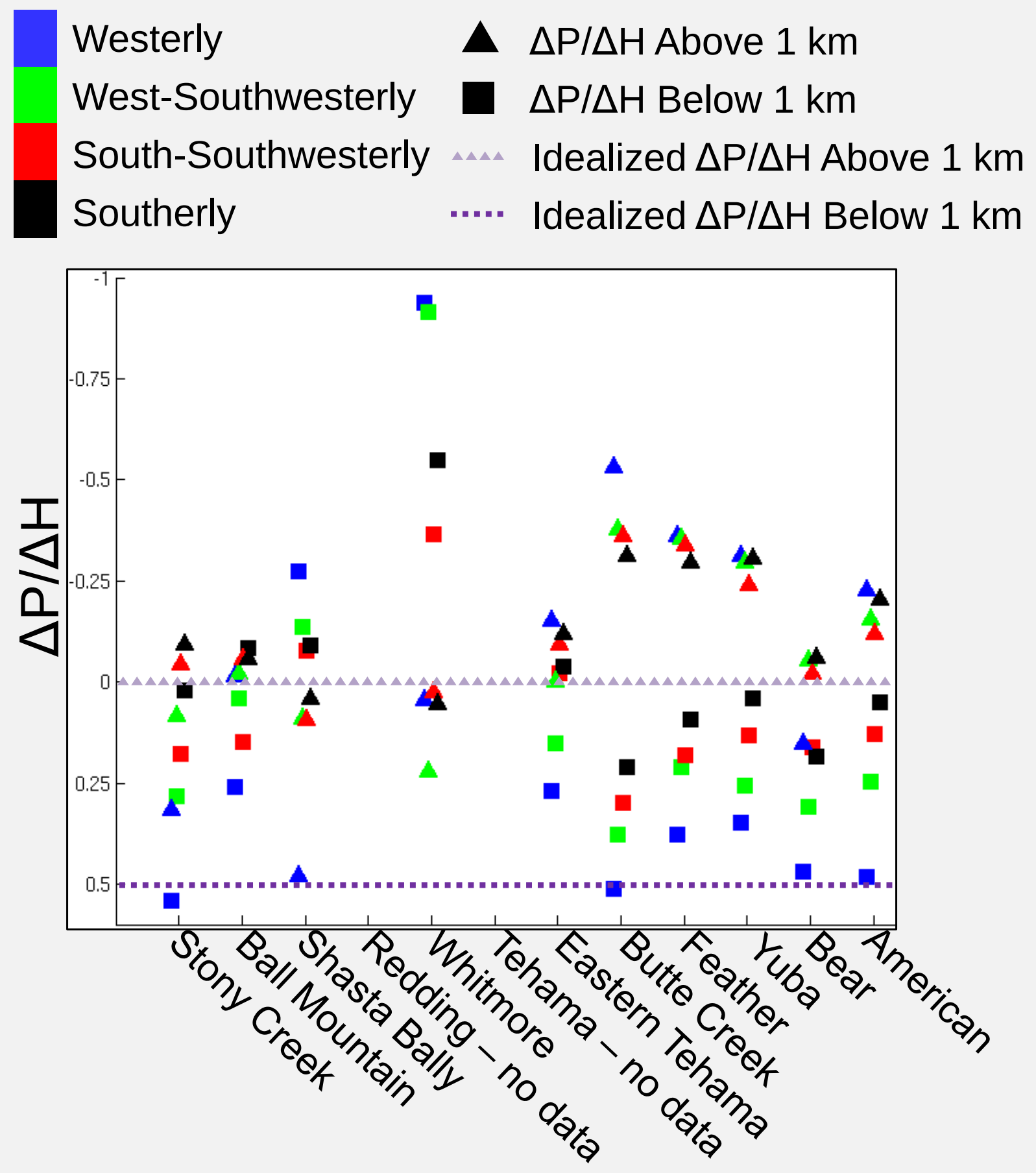


To make accurate comparisons among basins and minimize discrepancies in sample size, the number of hours of precipitation at every elevation is normalized by the value at 1000 m.

Analysis

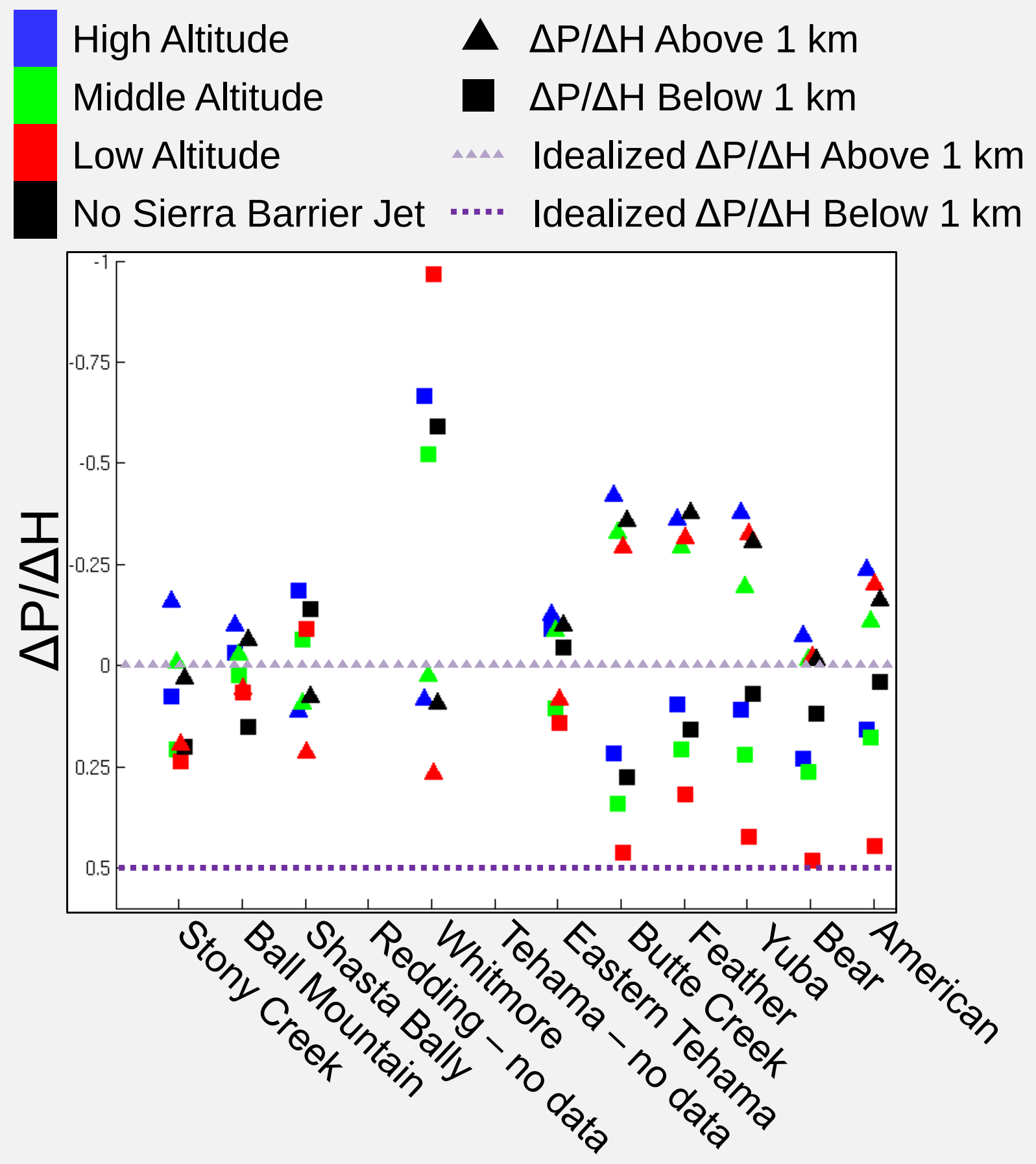
How does ΔP/ΔH vary among storm classes and watershed basins?

Wind Direction Classes



- ΔP/ΔH in the lowest 1 km tends to decrease as winds become more southerly in basins along the Sierra Nevadas.
- Westerly storms in the Sierra Nevada basins most closely match the lowest 1 km idealized ΔP/ΔH.
- Basins along the Coastal mountains show no clear association between ΔP/ΔH and wind direction class.

Sierra Barrier Jet Classes



- ΔP/ΔH in the lowest 1 km tends to decrease as Sierra Barrier Jet Altitude increases in basins along the Sierra Nevadas.
- Low altitude Sierra Barrier Jet storms in the Sierra Nevada basins most closely match the lowest 1 km idealized ΔP/ΔH.
- Basins along the Coastal mountains show no clear association between ΔP/ΔH and Sierra Barrier Jet class.

Conclusions

1. Sierra Barrier Jet height tends to be lower when wind direction is westerly.
2. The geographic distribution of hours of precipitation significantly varies from storm to storm and among storm classes.
3. Basins along the Coastal mountains show no clear association between ΔP/ΔH and storm class.
4. The only clear pattern among ΔP/ΔH and storm class is in the lowest 1 km of basins along the Sierra Nevadas.

References:

- Kingsmill, D., P. Neiman, B. Moore, M. Hughes, S. Yuter, F. M. Ralph, 2013: Kinematic and Thermodynamic Structures of Sierra Barrier Jets and Overrunning Atmospheric Rivers during a Landfalling Winter Storm in Northern California. *Mon. Wea. Rev.*, **141**, 2015–2036.
- Lundquist, J., J. Minder, P. Neiman, E. Sukovich, 2010: Relationships between Barrier Jet Heights, Orographic Precipitation Gradients, and Streamflow in the Northern Sierra Nevada. *J. Hydrometeor*, **11**, 1141–1156.

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