# Orographic Precipitation Processes

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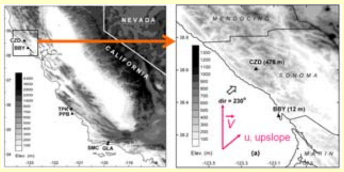
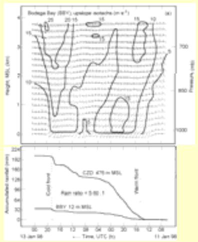
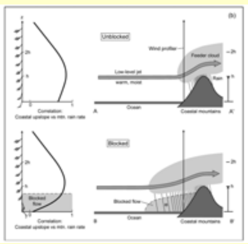
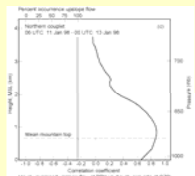
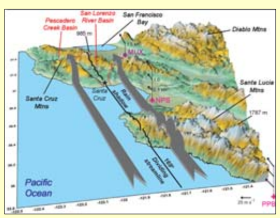
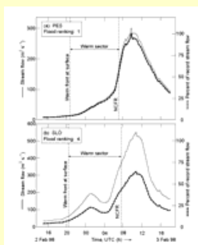
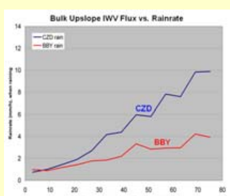
## Relationship between wind, water vapor, and orographic precipitation

- Rainrate in coastal mountains is directly correlated to upslope flow at coast, as measured by wind profilers and collocated rain gauges over multiple winters.
- Upslope flow at ~1 km is the best indicator of orographic rains.
- In blocked flow, near-surface winds do not provide useful rainrate information.

- Wind direction in the warm sector determined the location of a rain shadow.
- The rain shadow resided partially over a populated watershed.
- Small wind direction variations can modulate winter flooding in complex terrain.


- GPS receivers provide measurements of integrated water vapor (IWV).
- Integrated water vapor flux (upslope × IWV) correlates more strongly with mountain rain intensities than do either 1 km upslope flow or IWV separately.
- Rainrate and orographic rain enhancement increases with increasing water vapor flux.

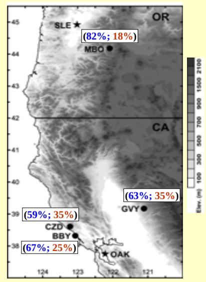
References:

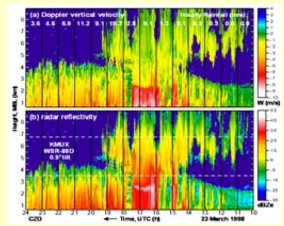
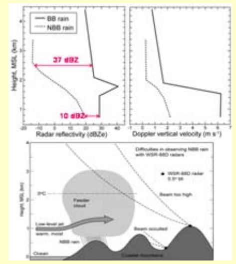
Neiman, P. J., F. M. Ralph, A. B. White, D. E. Kingsmill, and P. O. G. Persson, 2002: The statistical relationship between upslope flow and rainfall n California's coastal mountains: Observations during CALJET. *Mon. Wea. Rev.*, **130**, 1468-1492.

Ralph, F. M., P. J. Neiman, D. E. Kingsmill, P. O. G. Persson, A. B. White, E. T. Strem, E. D. Andrews, and R. C. Antweiler, 2003: The impact of a prominent rain shadow on flooding in California's Santa Cruz mountains: A CALJET case study and sensitivity to the ENSO cycle. *J. Hydrometeor.*, **4**, 1243-1264.

Neiman, P. J., A. B. White, F. M. Ralph, D. J. Gottas, and S. I. Gutman, 2009: A water vapour flux tool for precipitation forecasting. *Proc. Institution of Civil Engineers--Water Management (special issue on weather radar for water management)*, **162**, 83-94.

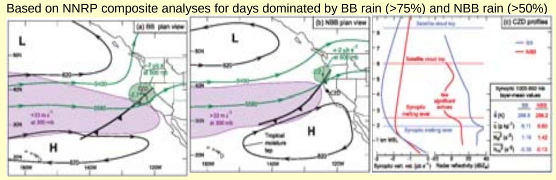
## Different types of rain associated with orographic precipitation


(%BB rain; %NBB rain)

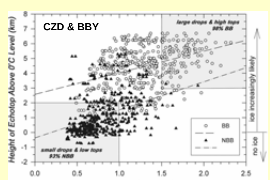
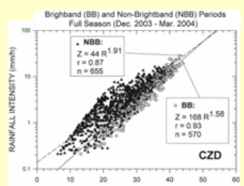



- Vertically pointing S-band radars documented a key shallow rain process without a brightband (NBB rain), as well as deep brightband (BB) rain.
- Rainrates in West Coast storms can exceed 20 mm $h^{-1}$ during NBB rain.
- For comparable rainrates, reflectivities were ~10 dBZ lower during NBB rain.
- NBB rain is common and hard to detect with NEXRAD due to its shallow character.
- 35% of rain in the 1997/98 winter season at CZD occurred without a brightband.
- NBB rain has also been observed by ESRL S-band profilers in the Sierra and Cascades.

Based on NNRP composite analyses for days dominated by BB rain (>75%) and NBB rain (>50%)



- BB rain is associated with stronger and deeper synoptic-scale ascent and colder (i.e., higher) cloud tops than NBB rain.
- Soundings associated with NBB rain showed warmer and moister low-level conditions than BB rain and had stronger upslope flow.

- NBB rain is characterized by greater concentrations of small drops and smaller concentrations of large drops compared to BB rain.
- Reflectivity-rainfall rate relations for NBB rain are dramatically different than those used by operational radars, which has implications for QPE.

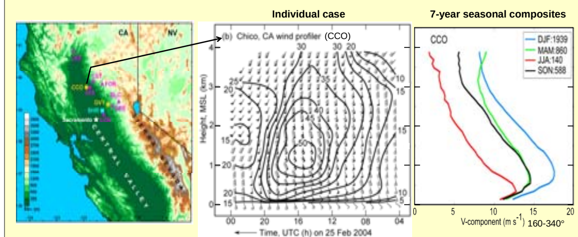
References:

White, A. B., P. J. Neiman, F. M. Ralph, D. E. Kingsmill, and P. O. G. Persson, 2003: Coastal orographic rainfall processes observed by radar during the California Land-Falling Jets Experiment. *J. Hydrometeor.*, **4**, 264-282.

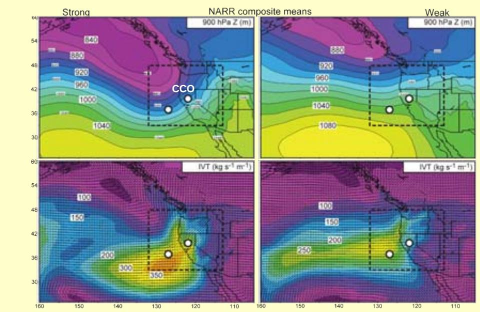
Neiman, P. J., G. A. Wick, F. M. Ralph, B. E. Martner, A. B. White, and D. E. Kingsmill, 2005: Wintertime nonbrightband rain in California and Oregon during CALJET and PACJET: Geographic, interannual, and synoptic variability. *Mon. Wea. Rev.*, **133**, 1199-1223.

Martner, B. E., S. E. Yuter, A. B. White, S. Y. Matrosov, D. E. Kingsmill, and F. M. Ralph, 2008: Raindrop size distributions and rain characteristics in California coastal rainfall for periods with and without a radar bright band. *J. Hydrometeor.*, **9**, 408--425

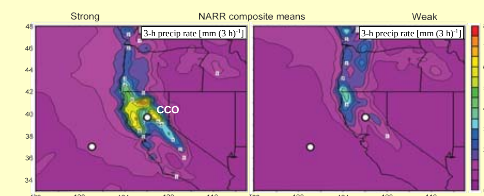
## Sierra barrier jet (SBJ) and its impact on precipitation distribution

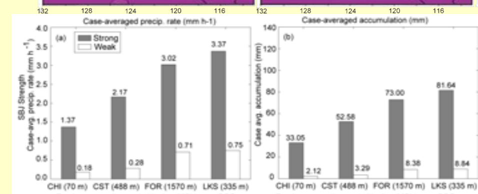



- Wind profilers provided a 7-y climatology of barrier jets in CA's northern Central Valley.
- SBJ cases are strongest, and occur most often, during the wet, cool season (Oct-Apr).
- SBJs are situated, on average, at ~1 km above ground level.
- Nearby rain gauges documented precipitation modulation by SBJs.




- The North American Regional Reanalysis (NARR) provides meteorological context for the 20 strongest vs. 20 weakest SBJ cases during the cool season at CCO (172 cases total).
- Strong SBJ cases are tied to deeper troughs located farther south than weak cases.
- Strong SBJ cases occur with larger, meridionally oriented, incoming vapor fluxes.





- The NARR also captures significant differences in precip. between strong vs. weak SBJs.
- Gauges reveal more intense precip. rates during strong SBJ cases.
- Total accumulations are far greater during strong SBJs (i.e., hydrologically significant).

References:

Neiman, P. J., E. M. Sukovich, F. M. Ralph, and M. Hughes, 2010: A seven year wind profiler-based climatology of the windward barrier jet along California's northern Sierra Nevada.. *Mon. Wea. Rev.*, In press.