Precipitation estimation and hydrologic simulations in cold mountainous basins using recent remote sensing observations

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GEWEX

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Mountain water cycle: very important topic

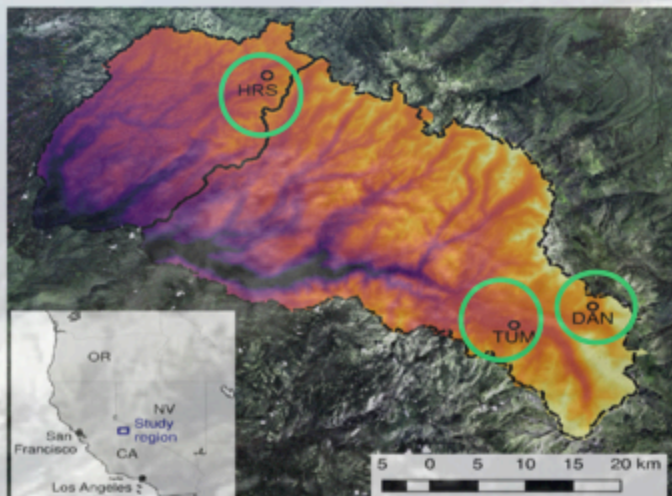
- Importance: Regional hydrology, economy, regional and global water budget.
- Growing interest: very important in a changing climate as cold mountains and high latitudes warm faster than other regions, more rain and less snow, loss of steady water resources…
- Challenge: Need to estimate Light rainfall, snowfall, precipitation over frozen land, orographic precipitation.
- Uncertainty: Largest uncertainties over cold mountains.
- Obs. limitation: Sparse and unreliable ground observation.
- Scale: very important due to topography …

- The University of Arizona
- NASA JPL

Scale: using ASO Very high resolution analysis of snowfall accumulation

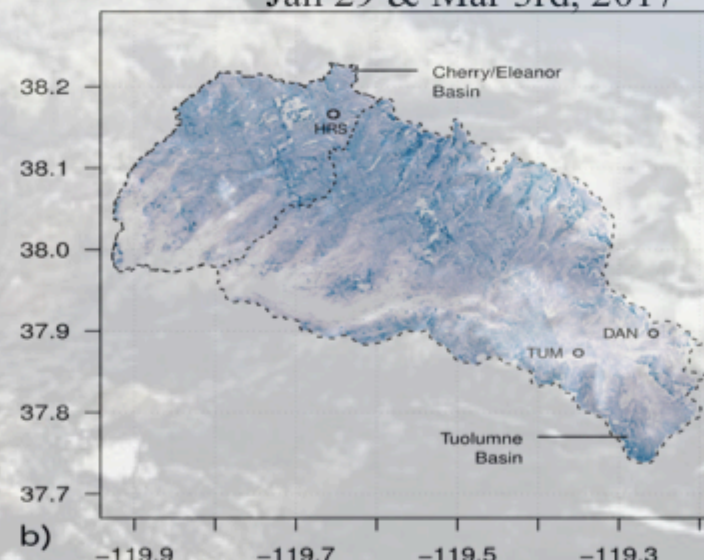
NASA Airborne Snow Observatory (ASO)

Tuolumne upstream of Hetch Hetchy reservoir and the adjacent Cherry/Eleanor basins



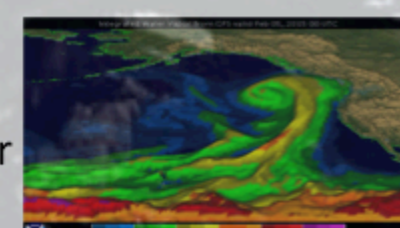
The locations of three in-situ snow within the basin

SWE accumulation during a 34-day period calculated by subtracting ASO 50m acquisitions on Jan 29 & Mar 3rd, 2017

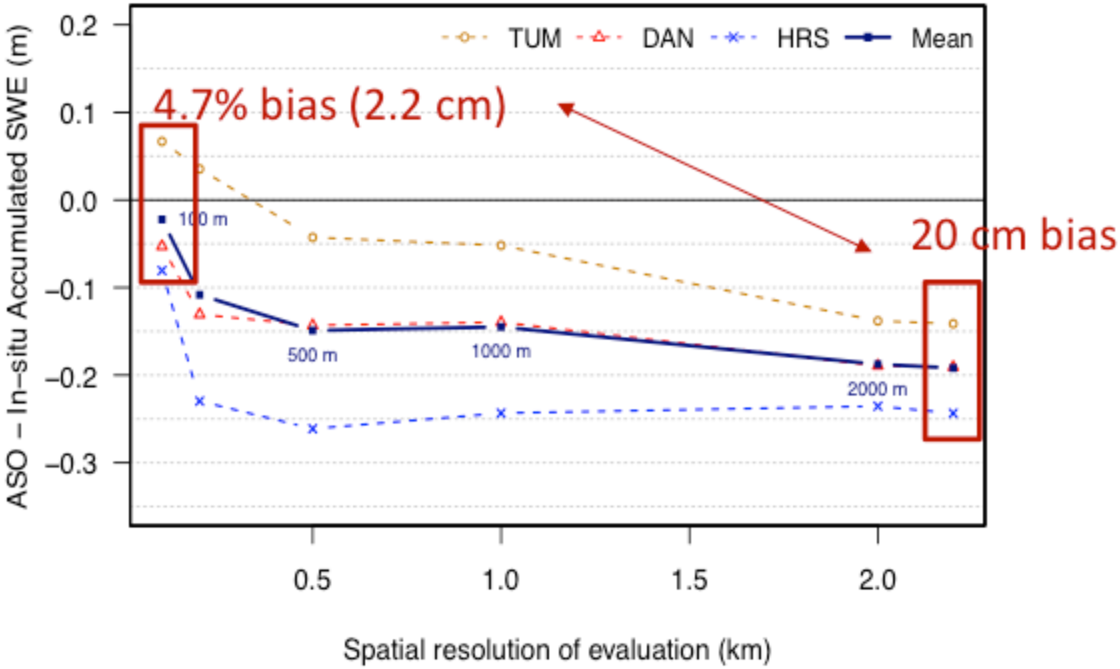


Behrangi et al. (in review)

Atmospheric River



Point versus areal BIAS

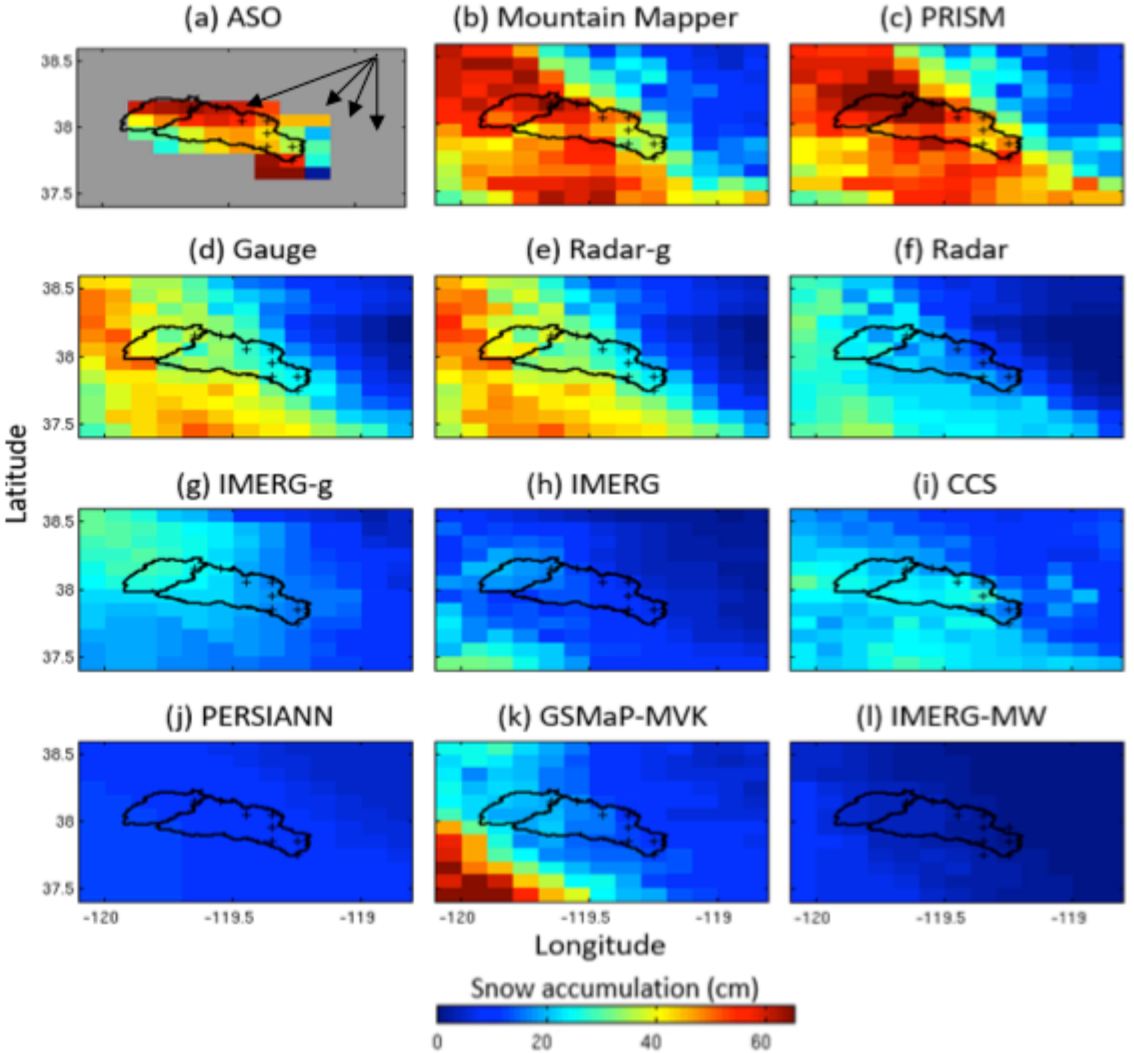


Bias increases an order of magnitude moving from 100m to 2.2 km scale

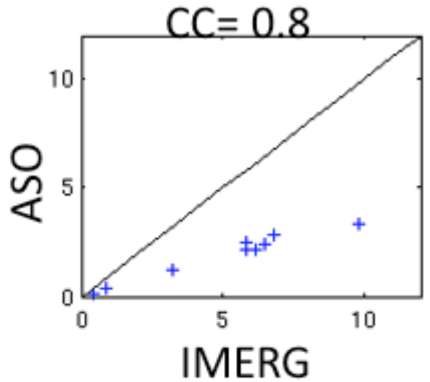
The spatial representation of in-situ snow accumulation measurements at point locations when compared to spatially aggregated snow accumulation data from ASO.

- The bias at 2.2 km is an order of magnitude larger than the ASO biases inferred at 100m even when the same data are simply coarsened.
- The use of alternative evaluation data that provide areal estimates (such as robust radar or ASO) are crucial in the robust evaluation of remote sensing products.

Spatial distribution of snowfall : ASO & gridded precip. products

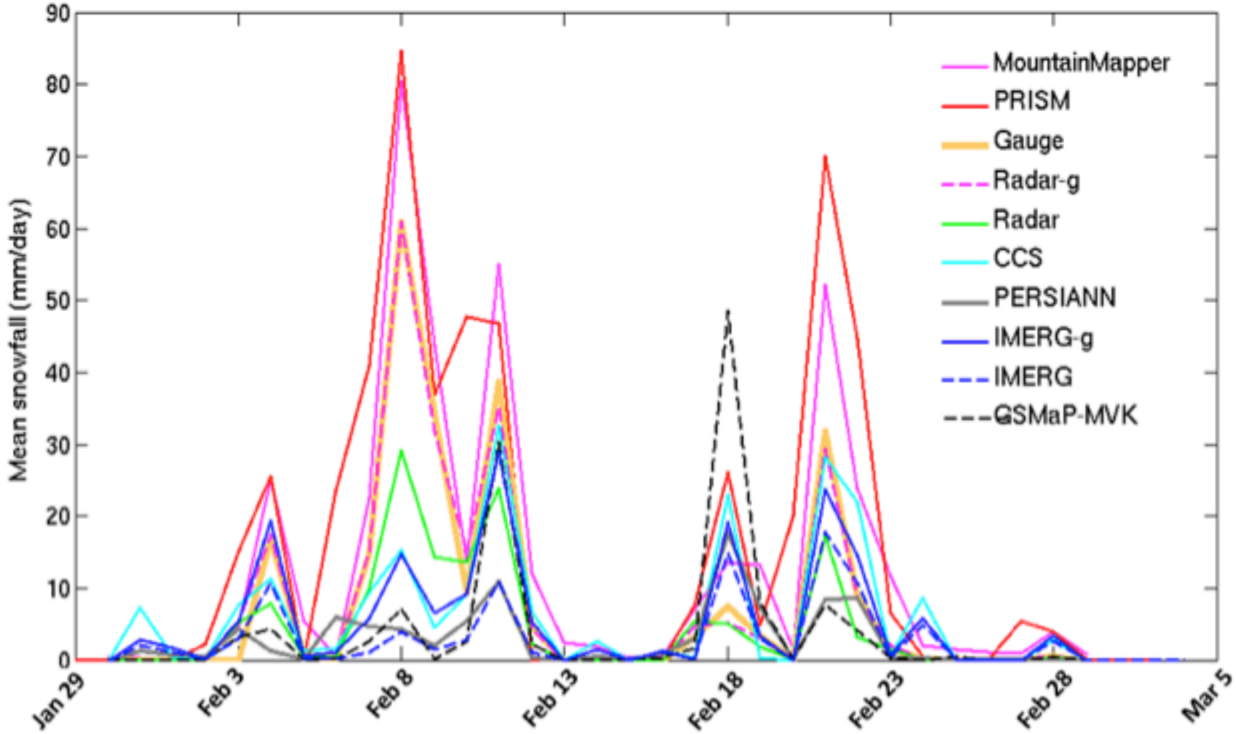


Comparison of Snow accumulation Jan 29 – March 3rd 2017 at 0.1 grid



- **Satellite/radar products significantly underestimate snowfall accumulation, but they generally present good correlations with ASO.**
- **Bias adjustment is effective.**

Time series of daily mean precipitation rate, averaged over snow grids



precipition estimation over cold mountains is challenging!

Long-term analysis of land falling Atmosphere river (2003-2012)

Gridded gauge

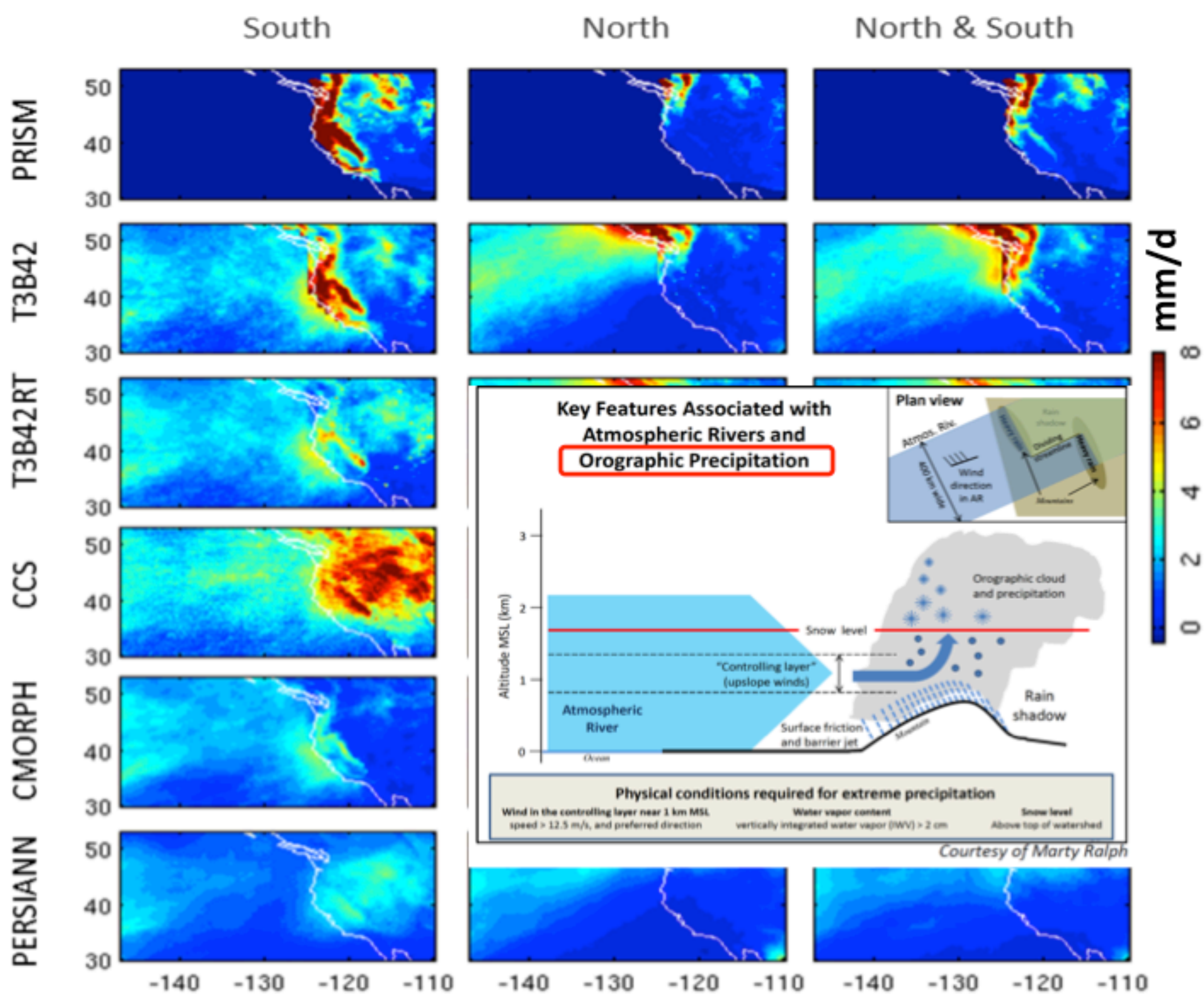
IR+MW
Gauge Corrected

IR+MW
Not corrected

IR
Not corrected

MW
Not corrected

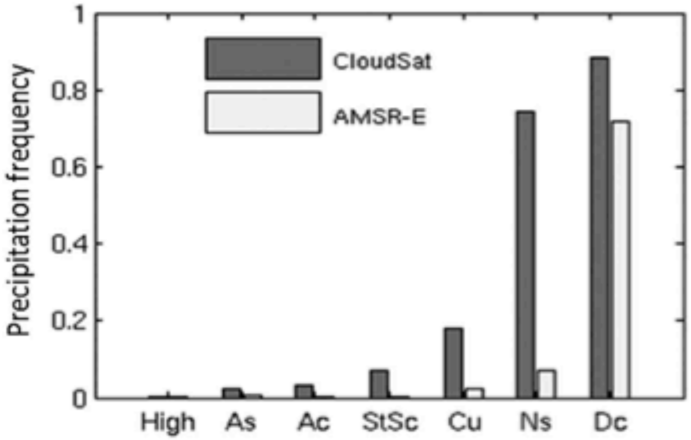
IR
Not corrected

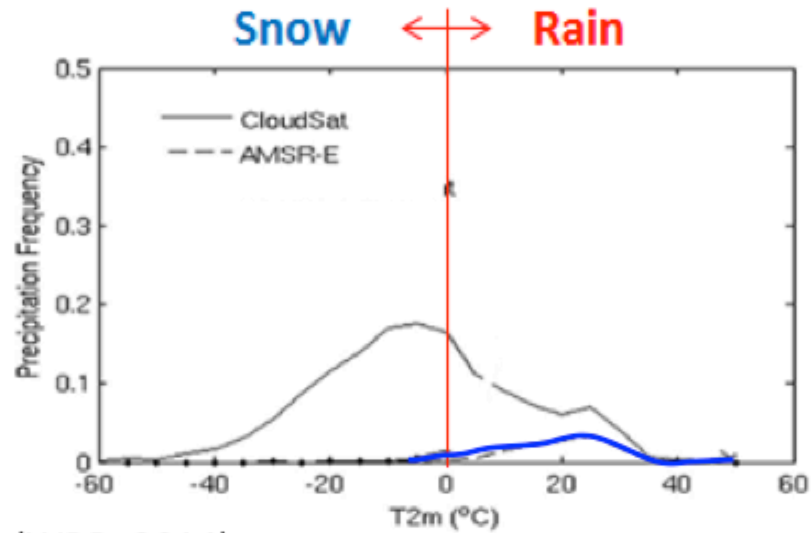


Behrangi et al. 2016 (JHM)

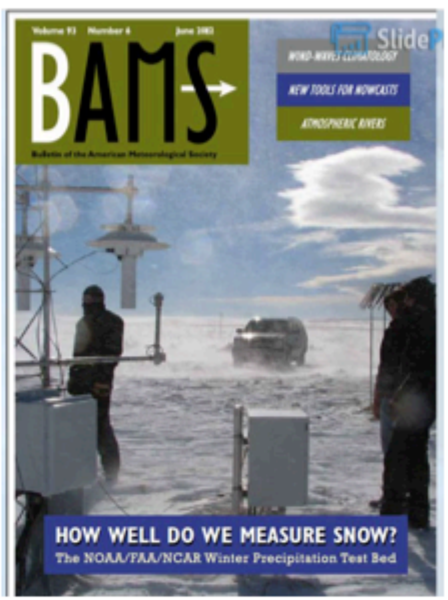
Other challenges ....

Comparison of precipitation detectability as a function of cloud type





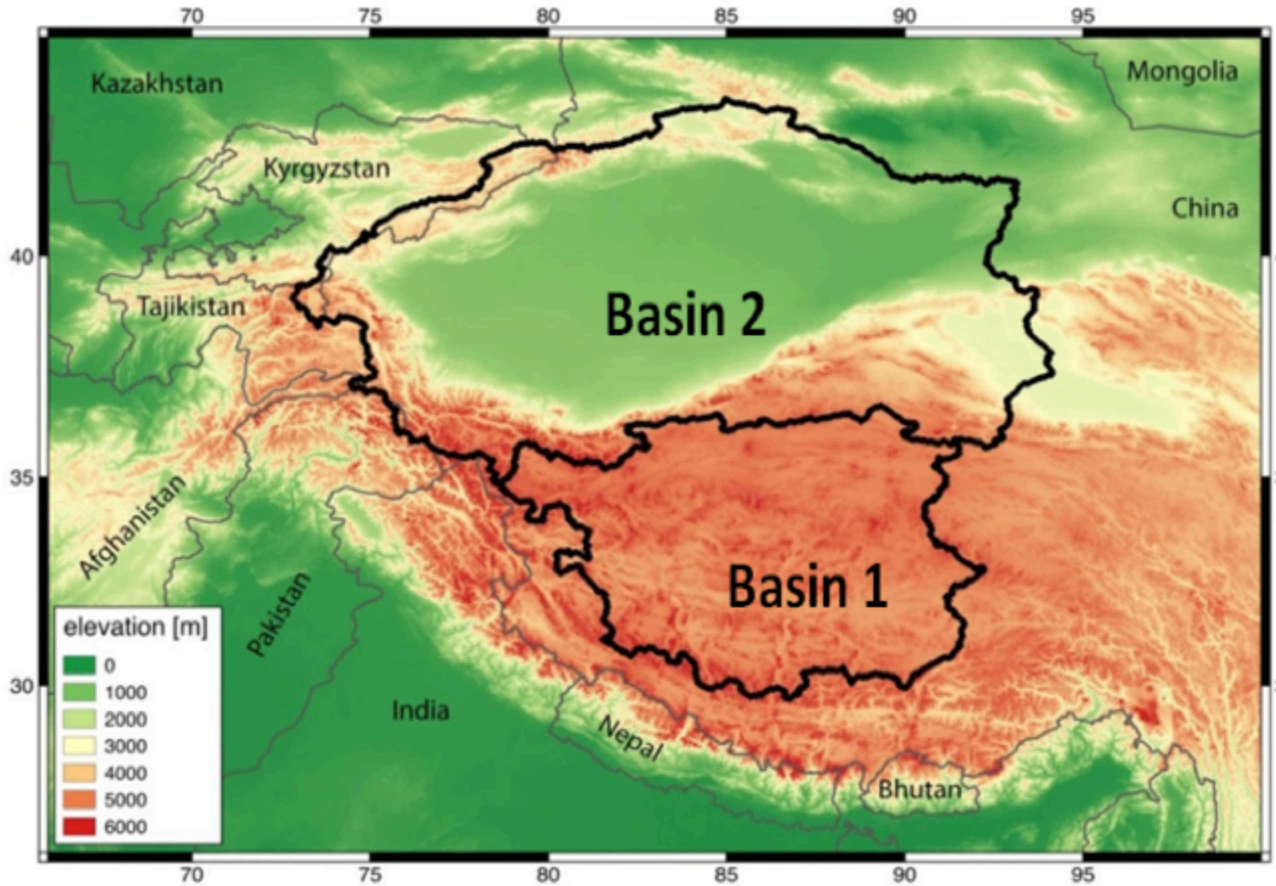
Behrangi et al. (WRR; 2014)



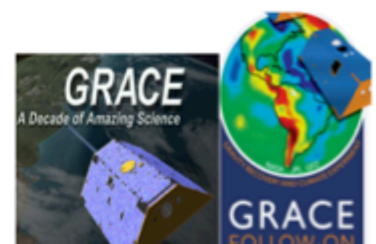
Challenges with measuring snowfall

Alternative methods ....

- Sparseness and inaccuracy of in situ. (with little if any areal representation)
- Challenges with satellite precipitation products



Behrangi et al. (2017; GRL)

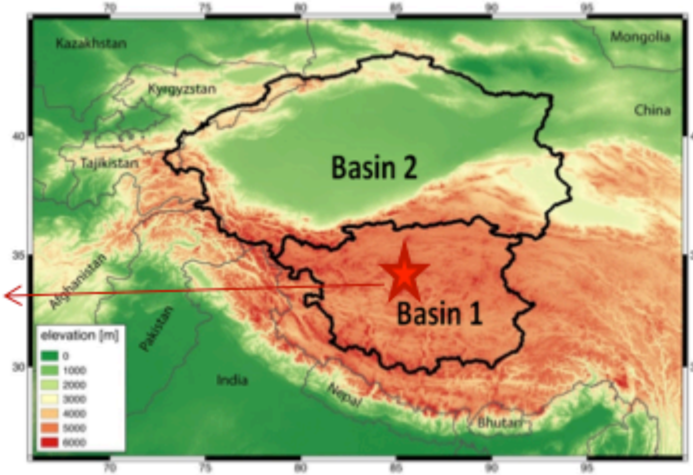


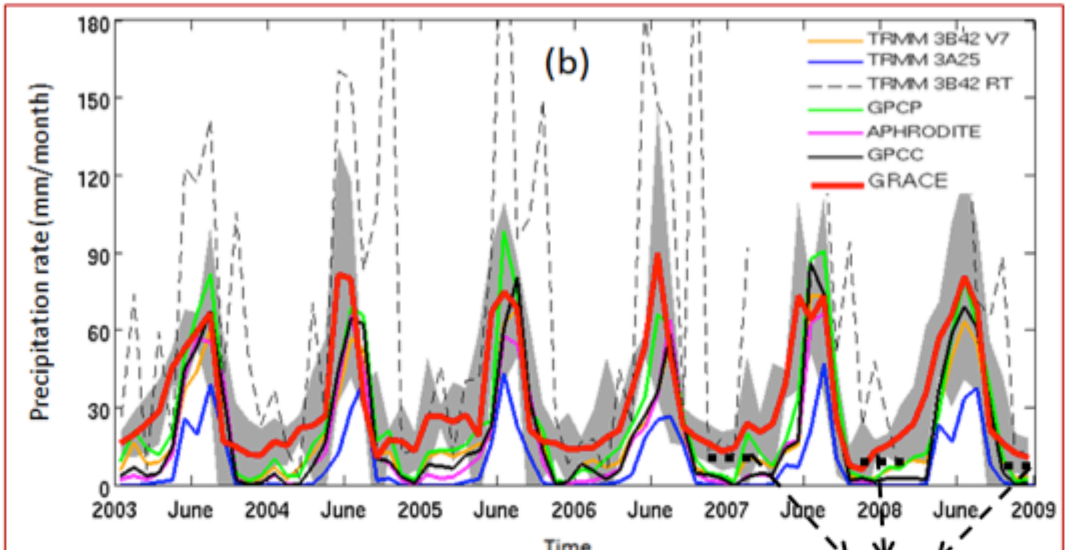
GRACE to constrain precipitation amount over mountainous cold basins

Endorheic basins => net lateral flux rate =0

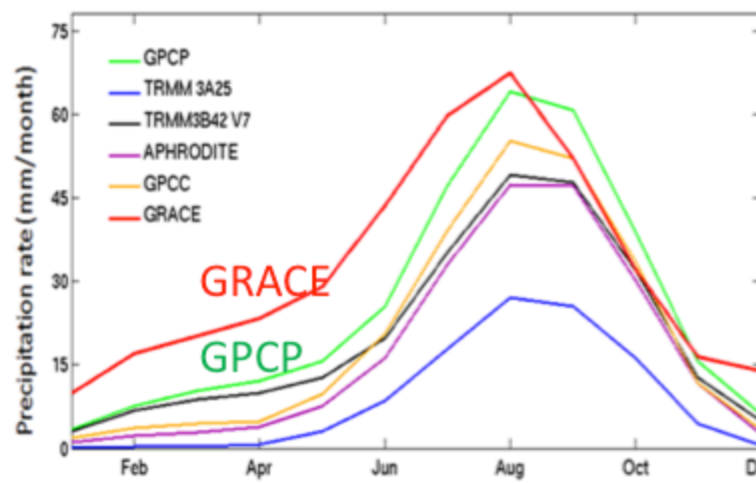
$$\Delta S = \int_{t_1}^{t_2} P(t)dt - \int_{t_1}^{t_2} ET(t)dt - \int_{t_1}^{t_2} Sub(t)dt - \int_{t_1}^{t_2} Q_{net}(t)dt$$

0





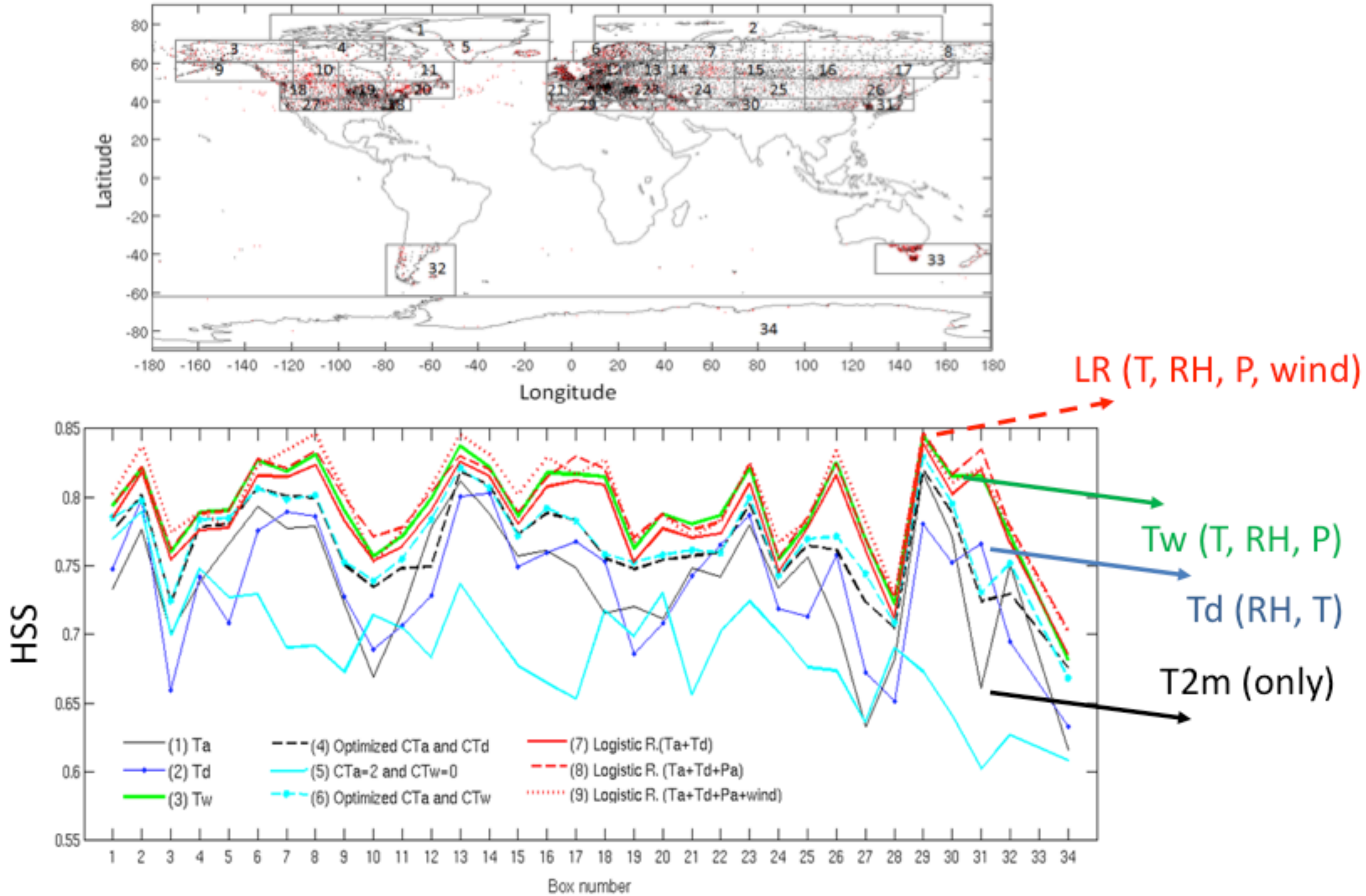
CloudSat snowfall



Behrangi et al. (2017; GRL)

While typical remote sensing products may have major issues, there are alternative ways that can really help

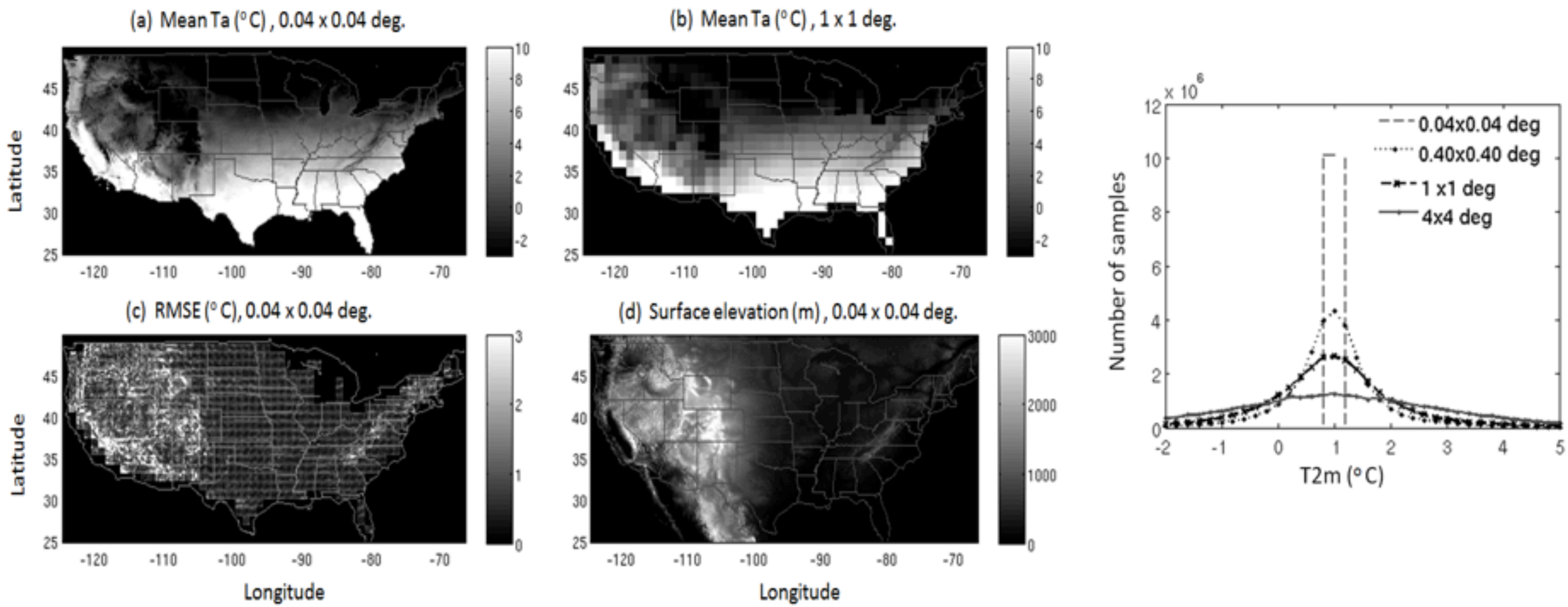
Another uncertainty source : snow-rain delineation metric



~ 20 % increase in rain/snow delineation skill due to use of proper metric

- The University of Arizona
- NASA JPL

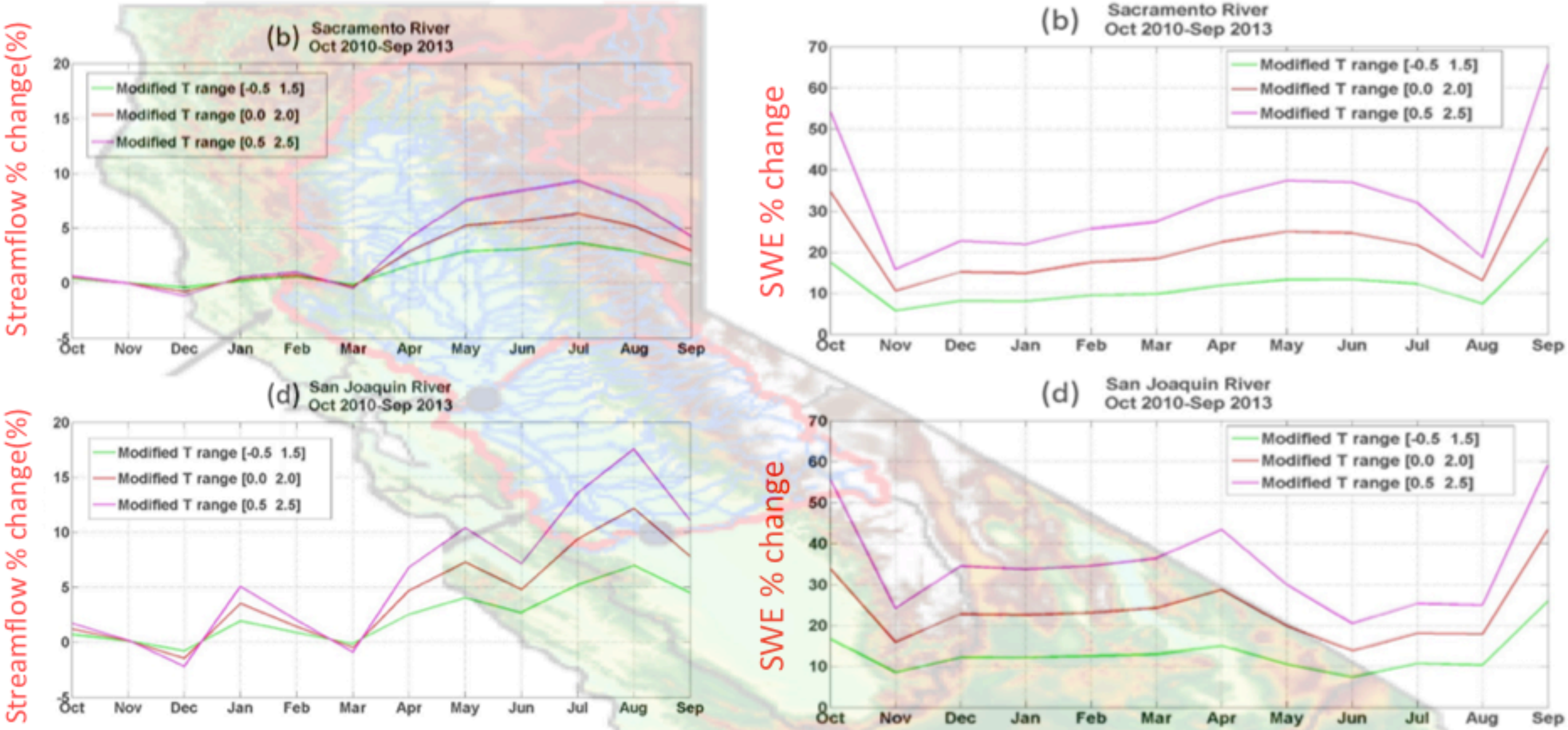
Uncertainty source : Spatial Resolution



Behrangi et al. (2016; WRR)

Moving from 0.4 deg. resolution (typical resolution of reanalyses) to 0.04 deg. can result in about 3°C or higher error in temperature in topographically complex regions. The impact is critical for many applications including snow-rain separation.

Hydrologic sensitivity to rain/snow separation



Behrangi et al. (2018)

2^0C error in T => uncertainties due to inaccurate snow/rain delineation threshold => up to 10% for streamflow and 40% for SWE !

Final slide

GEWEX **MOUNTerrain**?

The papers referred to:

- **Behrangi, A.,** X. Yin, S. Rajagopal, D. Stampoulis, and H. Ye, **2018**: On distinguishing snowfall from rainfall using near-surface atmospheric information: comparative analysis, uncertainties, and hydrologic importance. *Quarterly Journal of the Royal Meteorological Society*.
- **Behrangi, A.,** A. S. Gardner, J. T. Reager, and J. B. Fisher, **2017**: Using GRACE to constrain precipitation amount over cold mountainous basins. *Geophysical Research Letters*, **44,** 219-227.
- **Behrangi, A.,** B. Guan, P. J. Neiman, M. Schreier, and B. Lambrigtsen, **2016**: On the Quantification of Atmospheric Rivers Precipitation from Space: Composite Assessments and Case Studies over the Eastern North Pacific Ocean and the Western United States. *Journal of Hydrometeorology*, **17,** 369-382.
- **Behrangi, A.,** Y. Tian, B. H. Lambrigtsen, and G. L. Stephens, **2014**: What does CloudSat reveal about global land precipitation detection by other spaceborne sensors? *Water Resources Research*, **50,** 4893-4905.
- **Behrangi, A.,** K. Andreadis, J. B. Fisher, F. J. Turk, S. Granger, T. Painter, and N. Das, **2014**: Satellite-Based Precipitation Estimation and Its Application for Streamflow Prediction over Mountainous Western U.S. Basins. *Journal of Applied Meteorology and Climatology*, **53,** 2823-2842.
- **Behrangi, A.,** K. J. Bormann, and T. H. Painter Using the Airborne Snow Observatory to assess remotely sensed snowfall products in the California Sierra Nevada, *Water Resources Research* **(in review).**
- Zhang, G., et al.**, 2017:** Lake volume and groundwater storage variations in Tibetan Plateau's endorheic basin, *Geophysical Research Letters*, 44(11), 5550-5560, doi: 10.1002/2017gl073773.

Thanks to funding sources:

NASA NEWS
NASA GRACE/-FO
NASA Weather

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