Multi-scale Comparison of Wintertime Mountain Surface Temperatures from GOES-R ABI, MODIS, ASTER, and Airborne TIR Observations

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Abstract

In situ surface temperature measurements of the upper Tuolumne River Basin in the Sierra Nevada, and of Grand Mesa in Colorado (both for Mar.-Apr. 2017) are compared against concurrent, ASTER (90 m), MODIS (1 km), GOES-16 ABI ("2 km"), and at Tuolumne, airborne (5 m) TIR observations. This multi-scale comparison helps to characterize the benefits and drawbacks of observations at each temporal and spatial scale, including addressing terrain parallax in the off-nadir view angle imagery from GOES. This work will help inform how GOES-16/17 can be used to measure the diurnal cycle of mountain surface temperatures, and how spatial patterns from finer resolution observations could be used to downscale GOES observations.

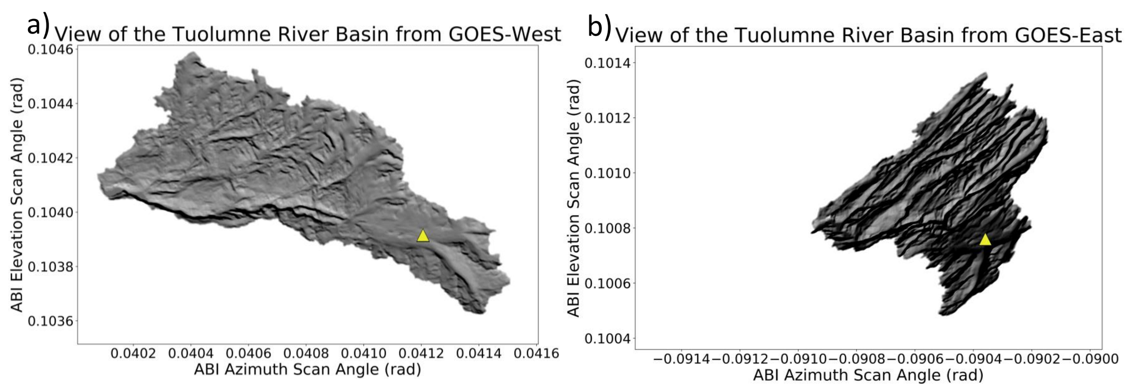

Figure 1. Two simulated views of the Tuolumne River Basin from the perspective of a) GOES-West and b) GOES-East demonstrating terrain parallax and occlusion effects. *(Generated with a 30 m resolution DEM.)*

Parallax Over Mountain Terrain

Map projections of GOES ABI imagery that do not consider the height of terrain relative to the reference ellipsoid (GRS 80) can be subject to significant foreshortening, parallax, and occlusion effects over mountain terrain. Orthorectification is needed to retrieve surface temperature measurements for precise ground locations from GOES ABI thermal infrared bands, especially for comparison with nadir-viewing polar orbiting satellites. Without orthorectification mountain locations can appear to be offset by several kilometers relative to their true locations, and low-lying areas can be obscured by adjacent ridgelines.

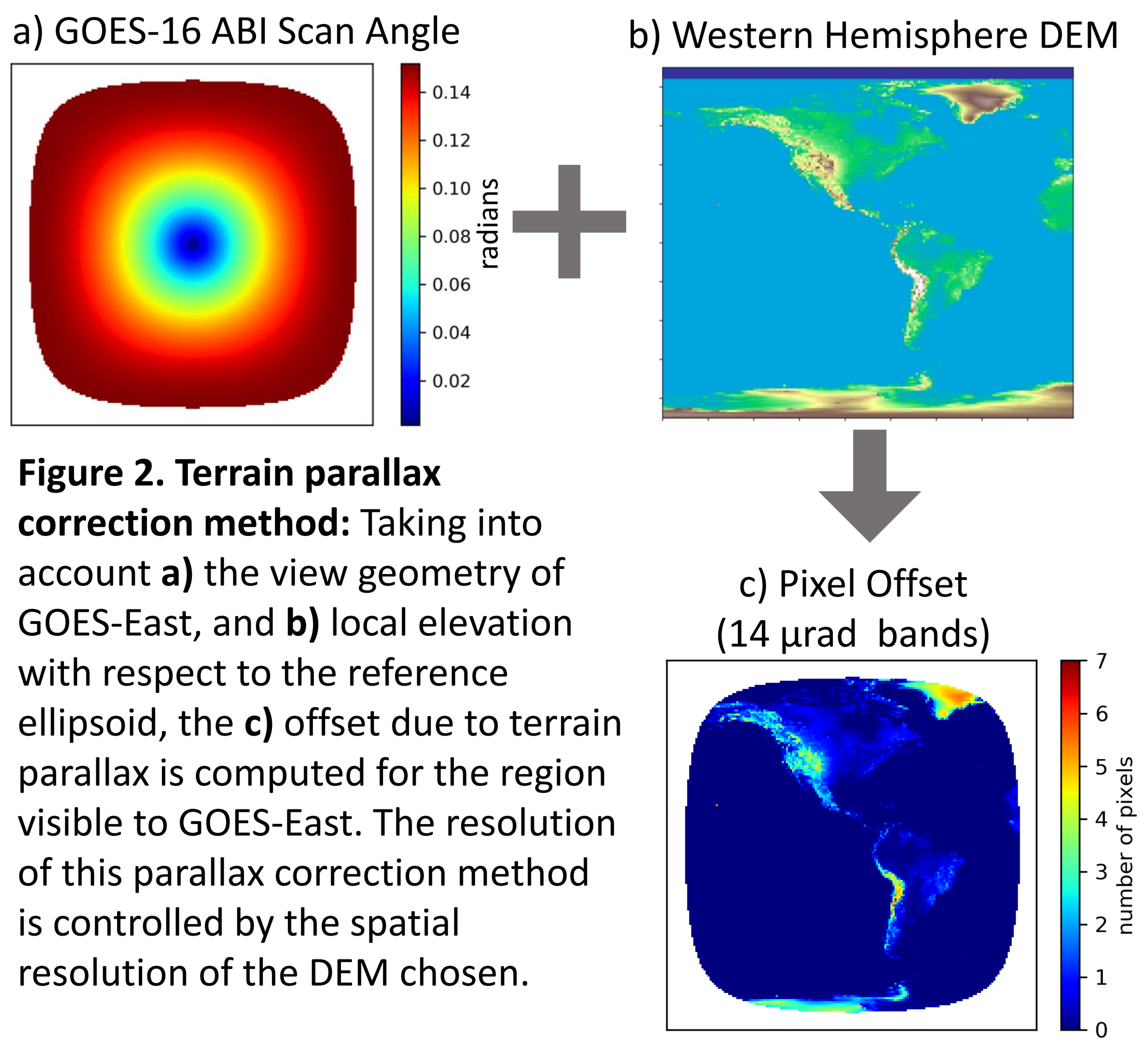

Figure 2. Terrain parallax correction method: Taking into account **a)** the view geometry of GOES-East, and **b)** local elevation with respect to the reference ellipsoid, the **c)** offset due to terrain parallax is computed for the region visible to GOES-East. The resolution of this parallax correction method is controlled by the spatial resolution of the DEM chosen.

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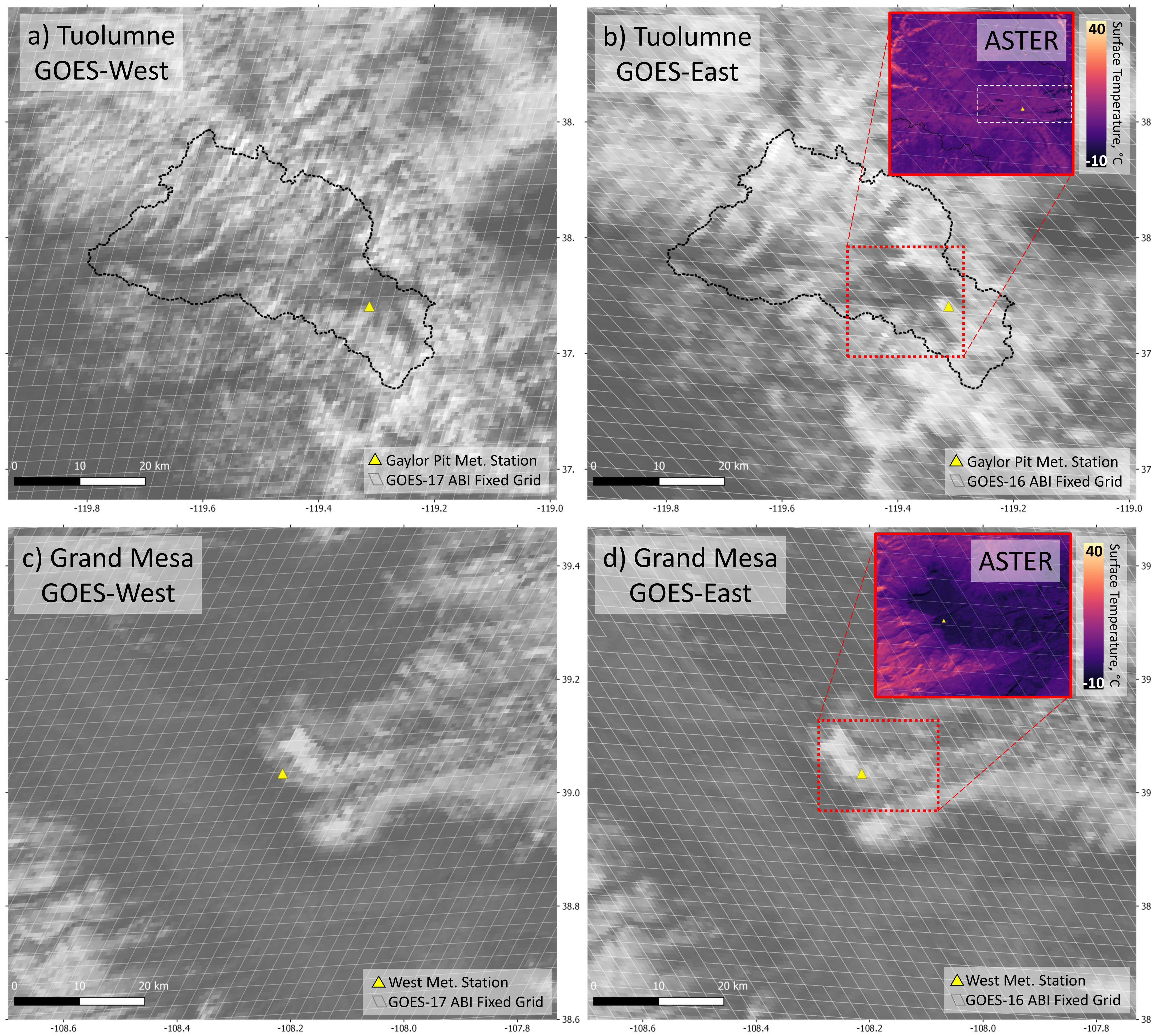

Figure 3. The apparent location of the in situ measurements sites appear to change between GOES-West and GOES-East imagery, demonstrating the parallax effect over mountain terrain. Example GOES-R ABI band 2 (0.64 μm, "500 m" resolution) imagery from April 2019: **a)** GOES-West, **b)** GOES-East, Tuolumne River Basin, California; **c)** GOES-West, **d)** GOES-East, Grand Mesa, Colorado. The GOES-R ABI Fixed Grids are shown for the "2 km" resolution (56 μrad) bands. The areas outlined in red boxes are shown in image subsets for each site with ASTER (90 m) TIR observations of surface temperatures (Tuolumne: Apr. 21, 2017; Grand Mesa: Feb. 15, 2017). Airborne TIR (5 m resolution; Apr. 21, 2017) imagery footprint outlined in white dotted line for Tuolumne.

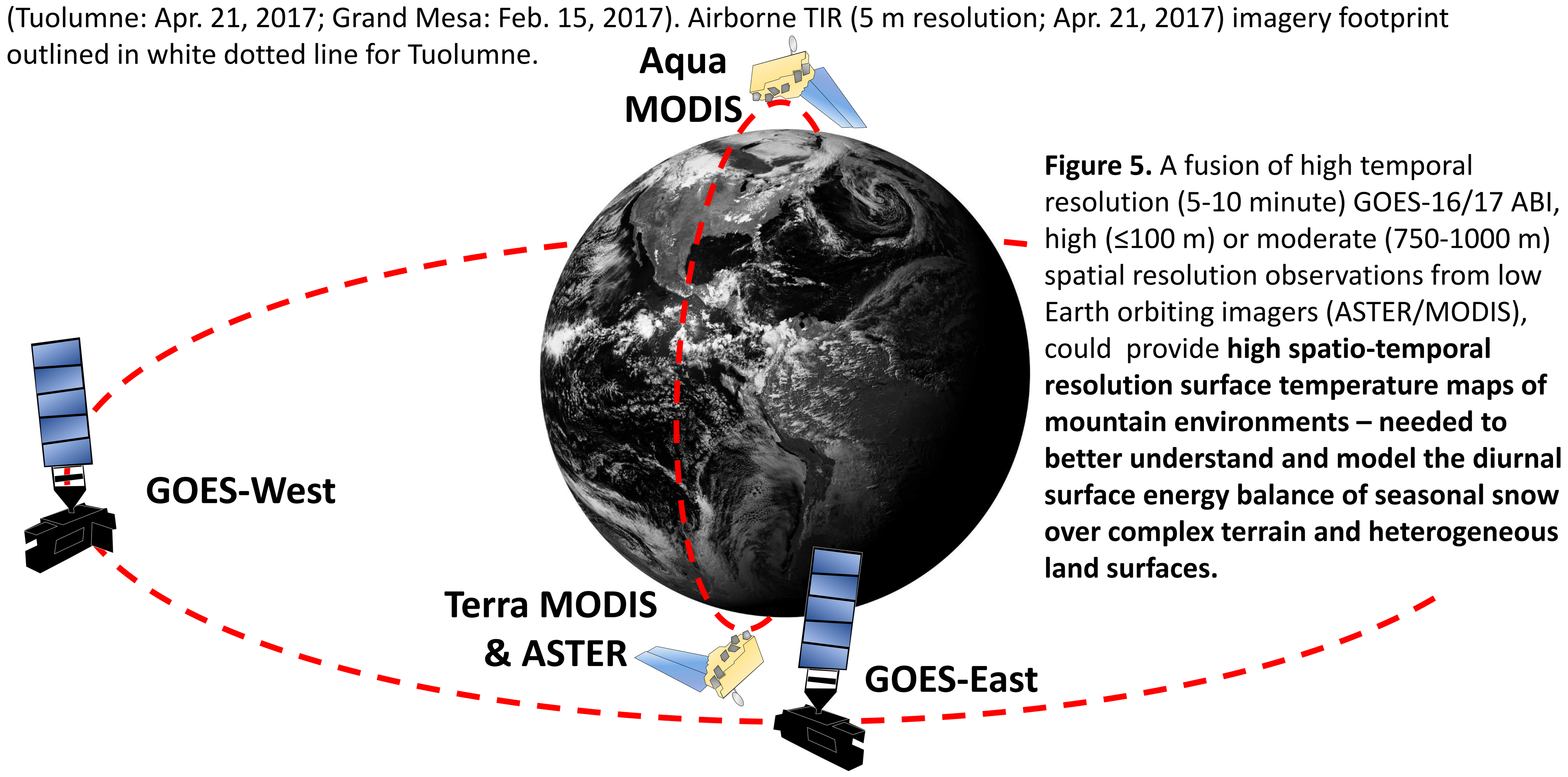

Figure 5. A fusion of high temporal resolution (5-10 minute) GOES-16/17 ABI, high (≤100 m) or moderate (750-1000 m) spatial resolution observations from low Earth orbiting imagers (ASTER/MODIS), could provide **high spatio-temporal resolution surface temperature maps of mountain environments – needed to better understand and model the diurnal surface energy balance of seasonal snow over complex terrain and heterogeneous land surfaces.**

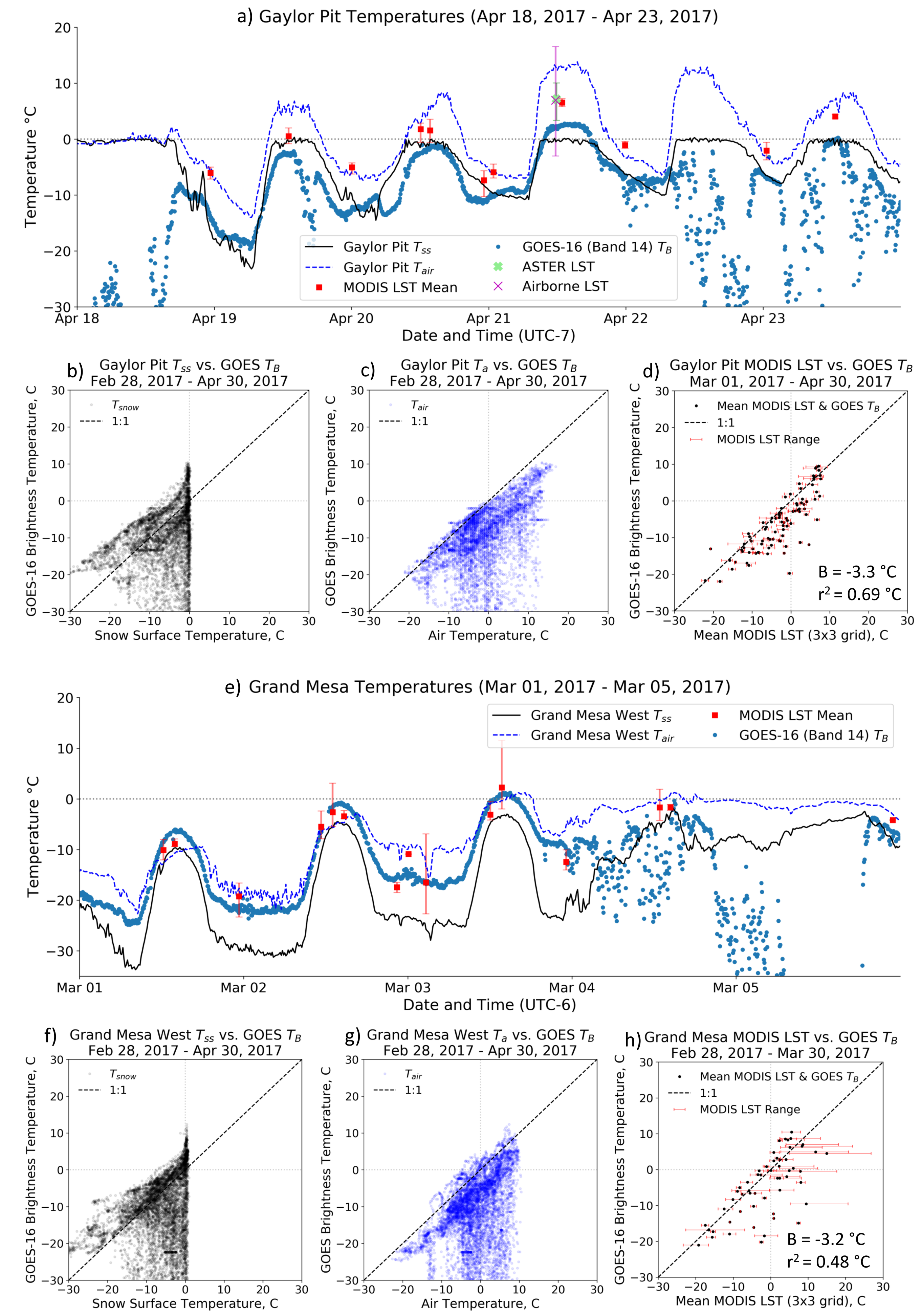

Figure 4. Following correction for terrain parallax, observations from GOES-16 captured the fine scale temporal patterns of surface temperature at each mountain study site. Comparisons of terrain-corrected GOES-16 ABI band 14 (11.2 μm) brightness temperature, MODIS (Terra & Aqua) Land Surface Temperature (LST), (airborne TIR over Tuolumne), and in situ snow and air temperature for **a-d)** Gaylor Pit meteorological station in the Tuolumne River Basin, California, and **e-h)** Grand Mesa West meteorological station at Grand Mesa, Colorado. *(Note that the coldest GOES brightness temperatures correspond to retrieving cloud-top temperatures and have not been filtered out)*

Future Work:

- **NASA SnowEx 2020** field campaign, providing ground and airborne TIR observations coincident with GOES-East, GOES-West, MODIS, ASTER, VIIRS, and Sentinel-3
- **Orthorectify GOES imagery** with parallax correction method
- **Compare TIR observations** at multiple spatial and temporal resolutions, and how well they capture surface temperature heterogeneities over mountain terrain
- **Test multi-satellite sensor fusion methods** including statistical downscaling models and spectral separation

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