An approach to analyse snow lines from MODIS data for Glaciers on the Tibetan Plateau

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In the remote areas of the Tibetan Plateau, very few measured glaciological, meteorological or hydrological data are available. In consequence, new methods to observe variations in energy and mass balance components of glaciers are necessary for a better understanding of atmosphere-cryosphere couplings. The variation of the equilibrium line altitude (ELA) of a glacier can be used as an indication of its mass balance variations. The end-of-summer snowline can be used as a proxy for the ELA.

We investigate the variability of the transient snow line altitude in several mountain ranges distributed along an east to west transect between the Nyainqentanglha Range in the east and the Gurla Mandhata mountain range in the southwest of the Tibetan Plateau, including also the Purogangri Ice Cap on the central Plateau. These regions are chosen in order to account for varying influences of large-scale atmospheric forcings such as the monsoon and the westerlies.

The snow line is derived from Moderate-resolution Imaging Spectroradiometer (MODIS) satellite imagery. For point by point validation and the generation of glacier masks Landsat Satellite Thematic Mapper data was used. Further we work with meteorological data from the High Asia Reanalysis (HAR) [1] to relate the ELA to atmospheric conditions.

We use datasets of the daily MODIS snow product to infer intra- and inter-annual transient snow line variability during 2001-2012 and to derive mean regional annual ELAs according to an approach similar to [2] but adapted to the Tibetan Plateau conditions. We apply techniques to minimize the data gaps due to clouds, such as combining Aqua and Terra Satellite Data. Using an albedo threshold, we can differentiate snow from ice. The 20th percentile of the snow-covered pixel altitude is chosen to derive the snow line altitude. The median of the three maxima snow line altitudes in the ablation period determines the annual ELA proxy.

The results are in good agreement with the few available observations and validated in detail by mapping snow lines within false colour visualizations. Averaged annual cycles suggest a strong impact of snow drift on albedo especially in winter. For the Purogangri Ice Cap correlation coefficients above 0.65 are found between the annual ELA and the mean temperature concurrent within the ablation period. This applies especially for the months with maxima positive degree days. Additionally, a significant correlation is obtained between the transient snow line altitude and the total precipitation in June, right before and in the beginning of the ablation period. Further, we investigate and present links between snow line altitude and the general large-scale atmospheric circulation. Thereby results at Gurla Mandhata, in the west of the Tibetan Plateau, show significant negative correlations between the annual ELA and the

North Atlantic Oscillation (NAO) Index in summer months. At Purogangri Ice Cap the same connection is stronger between the annual ELA and the NAO Index in winter months. Both suggest cooler summer and moister winter conditions associated with a positive NAO phase.

First comparisons with results of processed MODIS Level 1 radiance Swath Data are presented. The higher resolution of the latter of 250 m signifies an improvement of the accuracy whereas the effort of processing this data is disproportional higher.