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Inferring permafrost occurrence from surface energy balance and miniature temperature data (MTD) loggers in Cold-Arid Himalaya

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Cold-arid regions of the Himalaya is suspected to have significant permafrost cover. However, studies are in its infancy stage and characteristics, extent and governing energy regimes of Himalayan permafrost need to be established. Studies were initiated in a cryosphere experimental catchment of National Institute of Hydrology, Roorkee located in the upper Ganglass catchment, in Ladakh, India. The results of energy balance studies carried out from September 2015 to August 2016 are presented in this paper. The in-situ measurements of radiation components i.e. incoming and outgoing shortwave and longwave radiation and meteorological data such as air temperature, wind speed, and direction, relative humidity are used to estimate the surface energy balance (SEB) at a high elevation (4700m a.s.l.) cold-arid site. The SEB estimate is undertaken by the bulk aerodynamic method. The study has been further strengthened by installing 26 GeoPrecision miniature temperature data (MTD) loggers (24 M-Log5W simple in soil/debris and 2 M-Log5W cable in bedrock) between 4700 and 5600m a.s.l in the upper Ganglass catchment in August 2016.

For the period (Sep-2015 to Aug-2016) at 4700m a.s.l elevation, the net radiation component was dominant (76%) followed by sensible (14%) and latent heat fluxes (9%). The ground heat flux is limited to 1% of the total flux. The mean annual air temperature (MAAT) during the period was equal to -2.65°C. The total precipitation measured by non-recording rain gauge equals 99.4 mm w.e. during the study period and the precipitation dates were limited to 20 days in a year. A comparison of observed radiation and meteorological variables with other regions of the world show that the study site/ region at Ladakh have a very low relative humidity (RH) in the range of 40% compared to ∼70% in the Alps. This results in the reduced amount of incoming longwave radiation and strongly negative net longwave radiation e.g., an average of approximately (-)90 Wm-2 compared to (-)40 Wm-2 in the Alps. Hence, the high elevation cold-arid region land surfaces are overall colder than the locations with more RH such as the Alps. Further, it is appreciated that the increase in direct incoming shortwave radiation leads to more radiation received by sun-exposed slopes than shaded ones in comparable areas and wet places such as meadows, etc. experience increased cooling as a result of stronger evaporation. The logger data shows very low mean annual ground surface temperature (MAGST) for the period September 2016 to August 2017 and varies between -10.0°C and + 2.1°C. 21 loggers distributed across 15.7 km2 catchment recorded negative MAGST which suggest significant permafrost areas in the catchment. This study indicates that the permafrost is a significant cryospheric component in the region and highlight the need for further studies.