Geophysical Research Abstracts
Vol. 16, EGU2014-7533, 2014
EGU General Assembly 2014

Early 21st century climatology of snow cover for the western river basins of the Indus River System: effects of changes on hydrological balance and society.

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In this study we assess the snow cover and its dynamics for the western river basins of the Indus River System (IRS) and their sub-basins located in Afghanistan, China, India and Pakistan for the period 2001–2012.
Moderate Resolution Imaging Spectro-radiometer (MODIS) daily snow products from Terra (MOD) and Aqua (MYD) have been first improved and then analysed on seasonal and annual basis against different topographic parameters (aspect, elevation and slope). Our applied cloud filtering technique has reduced the cloud cover from 37% (MOD) and 43% (MYD) to 7%, thus improving snow cover estimates from 7% (MOD) and 5% (MYD) to 14% for the area of interest (AOI) during the validation period (2004).
Our results show a decreasing tendency for the annual average snow cover for the westerlies-influenced basins (Upper Indus Basin, Astore, Hunza, Shigar, Shyok) and an increasing tendency for the monsoon-influenced basins (Jhelum, Kabul, Swat and Gilgit).
Regarding the seasonal snow cover, decrease during winter and autumn and increase during spring and summer has been found, which is consistent with the observed cooling and warming trends during the respective seasons. Sub-basins at relatively higher latitude/altitude show higher variability than basins at lower latitude/mid-altitude. Northeastern and northwestern aspects feature larger snow cover.
The mean regional snow line altitude (SLA) zones range between 3000 and 5000 m a.s.l. for all basins. Our analysis provides an indication of a decrease in the regional SLA zone, thus indicating a change in the water resources of the studied basins, particularly for the Upper Indus Basin (UIB). Such results are consistent with the observed hydro-climate data, recently collected local perceptions and glacier mass balances for the investigated period.
Moreover, our analysis suggests some potential for the seasonal stream flow forecast as a significant negative correlation has been detected for the inter-annual variability of winter snow cover and value of the North Atlantic Oscillation (NAO) index of the previous autumn.