



Hydrologic Secular Trends and Variations of the Eurasian and North American Permafrost Watersheds from GRACE, SSM/I and AMSR-E Observations

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The northern hemisphere permafrost regions compose the largest component by area of the cryosphere. Over the last century, substantial changes in storage and cycling of fresh water have been observed. Observations of the globally distributed hydrologic mass change from the Gravity Recovery and Climate Experiment (GRACE) mission offer to provide a greater understanding of the processes controlling redistribution of water mass. Using nominal monthly GRACE grids, complete to degree and order 40 (which act as a low-pass spatial-temporal filter) adjusted for post-glacial rebound we investigate the hydrologic mass change of the Eurasian and North American watershed regions. The extent of continuous permafrost in the watersheds in Eurasia varies from the Ob-Irtysh which has the least to the Lena (includes part of the Yedoma Ice Complex) which has the largest. The Mackenzie watershed contains the least extent of continuous permafrost in this study. GRACE-derived watershed region-average time series show strongly positive secular trends and seasonal variations. Watershed region-averaged time series were derived from the Special Scanning Microwave/Imager (SSM/I) and the Advanced Microwave Scanning Radiometer-for the Earth Observation System (AMSR-E) for snow water equivalent, soil moisture and vegetation water content respectively. The seasonal maxima and minima derived from SSM/I and AMSR-E occur one-to-two months ahead of those of GRACE. Secular trends of snow water equivalent, soil moisture and vegetation water content had neither significant gain nor loss over the time period. Partitioning the watershed regions into 5° by 5° sub-regions, showed GRACE sub-region secular trends varied from south-to-north and west-to-east, suggesting variation at the source of water equivalent mass change. SSM/I and AMSR-E sub-region secular trends showed no significant gains or losses of water (snow, soil moisture or vegetation content); however, mean water contents vary across sub-regions of each watershed. The Eurasian watersheds GRACE-derived water equivalent mass gains were $22.69 \pm 13.49 \text{ km}^3/\text{yr}$ for the Ob-Irtysh, $37.75 \pm 8.83 \text{ km}^3/\text{yr}$ for the Yenisei and $44.69 \pm 8.36 \text{ km}^3/\text{yr}$ for the Lena from August 2002 through March 2008. The Mackenzie watershed had a GRACE-derived water equivalent mass loss of $5.58 \pm 7.18 \text{ km}^3/\text{yr}$ (not significant) in the same time period. Therefore, the source of the GRACE 40 by 40 degree and order secular trends and variations of water equivalent mass changes must be occurring beneath the land surface and soil layer of the Eurasian and North American permafrost watershed regions.