Geophysical Research Abstracts
Vol. 18, EGU2016-15018, 2016
EGU General Assembly 2016
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Interaction between temperature, precipitation and snow cover trends in Norway

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Northern latitudes are experiencing faster warming than other regions, partly due to the snow–albedo feedback. A reduction in snow cover, which has a strong positive feedback on the energy balance, leads to a lowering of the albedo and thus, an amplification of the warming signal. Norway, in particular, can be considered a "cold climate laboratory" with large gradients in geography and climate that allows studying the effect of changing temperature and precipitation on snow in highly varying regions. Previous research showed that during last decades there has been an increase in air temperature for the entire country and a concurrent reduction in the land surface area covered by snow. However, these studies also demonstrate the sensitivity of the trend analysis to the period of record, to the start and end of the period, and to the presence of extreme years.
In this study, we analyse several variables and their spatial and temporal variability across Norway, including mean, minimum and maximum daily temperature, daily precipitation, snow covered area and total snow water equivalent. Climate data is retrieved from seNorge (http://www.senorge.no), an operationally gridded dataset for Norway with a resolution of 1 km2. Analysis primarily focused on three overlapping 30-year periods (i.e. 1961-1990, 1971-2000, 1981-2010), but also tested trend sensitivity by varying period lengths. For each climate variable the Theil-Sen trend was calculated for each 30-year period along with the difference between 30-year mean values. In addition, indices specific to each variable were calculated (e.g. the number of days with a shift from negative to positive temperature values). The analysis was performed for the whole of Norway as well as for separate climatological regions previously defined based on temperature, precipitation and elevation.
Results confirm a significant increase in mean daily temperatures and accelerating warming trends, especially during winter and spring (mainly November, January and April). This accelerated warming occurs at the critical beginning and end of the snow cover season, where a notable decrease in snow cover also is found. This suggests a positive land-atmosphere feedback between increased air temperatures and reduction in snow cover. The last decade (2000 – 2010) features the smallest snow covered area and lowest values of snow water equivalent. The regional analysis clearly shows a stronger increase in the temperature trend in Northern Norway: in the first 30-year period the trends are negative or around zero, while in the end they are around 1.5 °C/30 years. In the other regions a positive trend is seen in the first period ($\sim$1 °C/30 years) increasing to around 1-1.5 °C/30 years in the two last 30-year periods). Finally, precipitation increases in winter, spring and summer (with a lower intensity in the most recent 30-years periods), and decreases in autumn. This contributes to a lower snowfall in the beginning of the snow season, suggesting that the reduced snow cover is due to both a reduction in precipitation as well as an increase in temperature. This study provides an important contribution to the understanding of the driving forces of changes in snow cover.