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Continental surfaces

Remotely-sensed high-latitude snow volume over the 1990-2006 period and its connection with climatic indices.

Etude du volume de neige aux hautes latitudes (1990-2006) et corrélation avec des indices climatiques.

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Abstract

Snow volumes over the 1990-2006 period from the Special Sensor Microwave/Imager have been computed for all continental surfaces above 50° N, except Greenland. Annual snow volume trend over Eurasia is positive (but not significant), whereas it is negative and significant over North America. These opposite trends can be explained by different regional climatic conditions. Snow volume trend over the study domain converted into sea level corresponds to a negligible contribution to sea level rise.

Le volume de neige sur la période 1990-2006 a été calculé à partir des données du Special Sensor Microwave/Imager pour les latitudes supérieures à 50° N, Groenland exclu. La tendance de ce volume de neige est positive sur l'Eurasie (mais non significative) et négative (et significative) sur l'Amérique du Nord. Ces tendances opposées peuvent s'expliquer par des conditions climatiques différentes. Il est aussi montré que la neige des hautes latitudes ne contribue pas à la montée des océans.

High-latitude regions are the most affected by the current climate change. Therefore their observation is a crucial issue to better understand how they respond to this change. Yet, few *in situ* snow observations are available for high latitudes, thus providing a poor knowledge of global or regional Snow Depth (SD) fields. While remote-sensing techniques offer a useful alternative to scarce *in situ* measurements, most analyses have focused on snow extent change. In this study, we use satellite-based microwave observations to derive global high-latitude Snow Volume (SV) change over the 1990-2006 period to analyze its temporal evolution. The correlation between SV and climate indices has also been investigated.

The algorithm used to estimate SD was developed by Mognar *et al.* (2002)[1] and takes into account the temporal evolution of the snow grain size. The inputs for this algorithm are respectively:

- the difference between 19.35 GHz and 37 GHz brightness temperature in horizontal polarization measured by the Special Sensor Microwave/Imager (SSM/I) [2] at a 25 km^2 × 25 km^2 spatial resolution averaged over a 5-day time period,
- the air/snow interface temperatures from the National Centers for Environmental Prediction (NCEP) global reanalysis,
- the snow/ground interface temperatures modeled by the "Interaction between Soil-Biosphere-Atmosphere" (ISBA) land surface scheme.

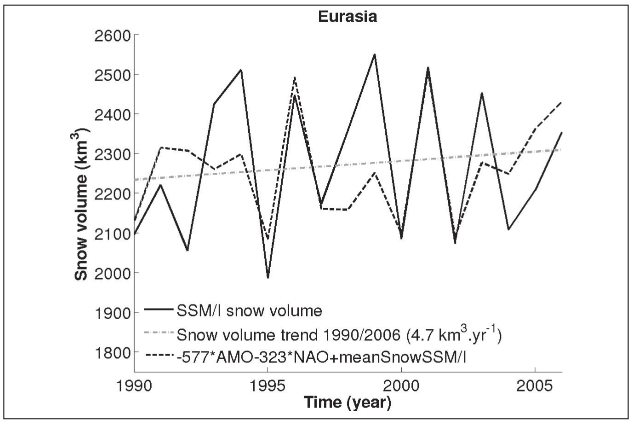
For this study, we consider all continental surfaces above 50° N, Greenland excluded.

Interannual total SV time series (seasonal signal removed) from SSM/I have been computed over the 1990-2006 period, for Eurasia (0° E < longitude < 191° E, Fig. 1) and for North America (191° E < longitude < 360° E, Fig. 2). SV over Eurasia displays a positive trend of 4.7 $km^3.yr^{-1}$ ± 9.6 $km^3.yr^{-1}$, whereas over North America, the trend is negative and amounts to -9.4 $km^3.yr^{-1}$ ± 4.2 $km^3.yr^{-1}$. While the trend over North America is statistically significant, over Eurasia it is not (the p-value, which is the probability to obtain this coefficient by random chance whereas the variables are uncorrelated, is equal to 0.63). The trend of the yearly SV averaged over the whole study domain is also not statistically significant (-4.7 $km^3.yr^{-1}$ ± 11.1 $km^3.yr^{-1}$ and p-value = 0.68). Converted into equivalent sea level, this trend is very small (-0.004 $mm.yr^{-1}$ ± 0.009 $mm.yr^{-1}$) compared to the global mean sea-level trend (3.3 $mm.yr^{-1}$ ± 0.4 $mm.yr^{-1}$ over the satellite altimetry period 1993-2009) [3], showing that high-latitude snow does not play any significant role in the global mean sea-level rise.

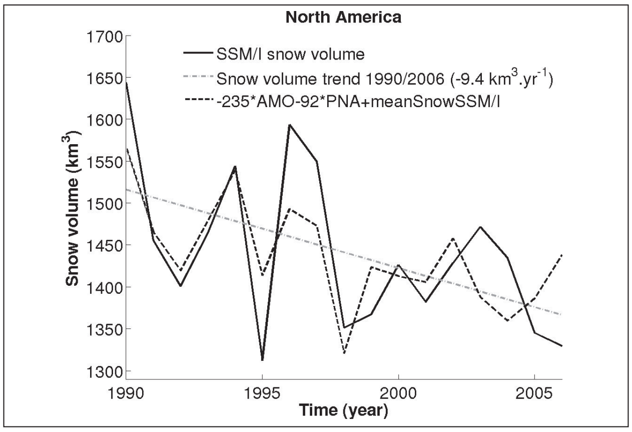
Each climatic index used in this section has been downloaded from the UNESCO website* and has been averaged from January through March for each year. The Arctic Oscillation index (AO, leading mode from the Empirical Orthogonal Function analysis of monthly mean height anomalies at 1000-hPa, poleward of 20° N) is relatively well correlated with SV over North America (correlation = 0.51 and p-value = 0.03) and anti-correlated with SV over Eurasia (correlation = -0.57 and p-value = 0.01). Thus, the climatic conditions represented by the AO index (which is the dominant mode of interannual variability in the Northern Hemisphere) play a significant and opposite role over the two continents. It is worth mentioning that SSM/ISV over Eurasia and North America are not correlated (correlation = -0.07 and p-value = 0.80). Similar results are found for the North Atlantic Oscillation (NAO, the sea-level pressure difference between Iceland and the Azores), which is commonly seen as a regional manifestation of AO (over North America the correlation is 0.42 with p-value = 0.08 and over Eurasia the correlation is -0.58 with p-value = 0.01). Atlantic Multidecadal Oscillation (AMO, North Atlantic mean sea-surface temperature anomaly north of the Equator) and Pacific North American pattern (PNA, second component of the Northern Hemisphere extra tropical sea-level pressure anomalies) are anti-correlated with SV over North America (correlation = -0.59 with p-value = 0.01 and correlation = -0.66 with p-value < 0.01, respectively) and not, or only weakly, correlated with SV over Eurasia (correlation = 0.04 with p-value = 0.87 and correlation = 0.30 with p-value = 0.22, respectively).

The correlation coefficients between the yearly mean SV anomaly and all possible linear combinations of two different indices have also been computed. For Eurasia, the best correlation coefficient (0.69) is obtained for a linear combination between NAO and AMO (-577.AMO-323.NAO, dotted black curve in Fig. 1), whereas for North America the best correlation coefficient (0.75) is obtained for a linear combination between PNA and AMO (-235.AMO-92.PNA, dotted black curve in Fig. 2). Thus, these indices represent regional atmospheric processes influencing the most the two continents.

From satellite passive microwave data, it has been shown that over Eurasia the trend in the high-latitude mean annual SV is positive, but not statistically significant. Over North America the SV trend is negative and highly significant. This difference could be due to the influence of AO which correlates with North American SV and anti-correlates with Eurasian SV. These differences are also linked to regional climatic conditions as SV anomaly over Eurasia better correlates with a linear combination of the NAO and AMO indices, whereas over North America it better correlates with a linear combination of the PNA and AMO indices.



[Fig. 1]



[Fig. 2]

***Fig. 1**: Spatial mean (solid black curve) and trend (gray dotted line) of the annual snow volume from SSM/I over Eurasia. The dotted black curve corresponds to the linear combination of two climatic indices which best correlates with snow volume (the mean snow volume has been added to the linear combination).*

***Fig. 2**: Spatial mean (solid black curve) and trend (gray dotted line) of the annual snow volume from SSM/I over North America without Greenland. The dotted black curve corresponds to the linear combination of two climatic indices which best correlates with snow volume (the mean snow volume has been added to the linear combination).*

References

* http://ioc3.unesco.org/oopc/state_of_the_ocean/atm

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