Impact of Atlantic Multidecadal Oscillation on permafrost in the Northern Hemisphere estimated from idealized climate model simulations

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Considerable reduction of the permafrost area and thawing depth in the Northern Hemisphere (NH) with global warming is projected in the 21st century by climate models (IPCC 2013). The permafrost changes have considerable effect on infrastructure and may also feedback to global climate through an increase of greenhouse gases emission from soil to the atmosphere from the decaying organic matter. While there are a number of studies estimating externally forced changes of permafrost in scenario climate models simulations, there is not much known about a possible range of permafrost changes caused by internal climate variations. The major part of internal long-term climate variability in the northern extratropics is related to the Atlantic Multiecadal Oscillation (AMO). AMO is linked to quasi-periodical oscillation of sea surface temperature (SST) in the North Atlantic and possible Arctic sea ice area with 60-70 year period (e.g., Schlesinger and Ramankutty 1995). AMO, in particular, has a significant impact on temperature and precipitation over Eurasia on decadal to multidecadal time scale (e.g., Mokhov et al. 2008).

Here, estimates of AMO impact on permafrost area and thawing depth in the NH based on climate model simulations are presented. We employ the atmospheric general circulation model ECHAM5 of T31 (3.8°x3.8°) spatial resolution coupled with mixed layer (50m) ocean model (Roeckner et al. 2003). Two 500 years long simulations are analyzed. One is a control, with climatological oceanic heat convergence fluxes (OHCF) and another is with additional AMO related OHCF. AMO is represented by periodically (60 yrs) varying anomalous OHCF in the NA and the Arctic. The AMO related flux pattern is the same is the one used in Semenov et al. (2010). Such an idealized simulation does not represent a full spectrum of internal ocean dynamics but allow one to disentangle the AMO effect. Main characteristics of permafrost are obtained using numerical scheme of heat and moisture transfer in the atmosphere-underlying surface-soil accounting for dynamics of frozen and thaw layers boundaries with water phase changes (Arzhanov et al. 2008). As an AMO index, SST anomalies average over 40N-60N,50W-10E box are used.

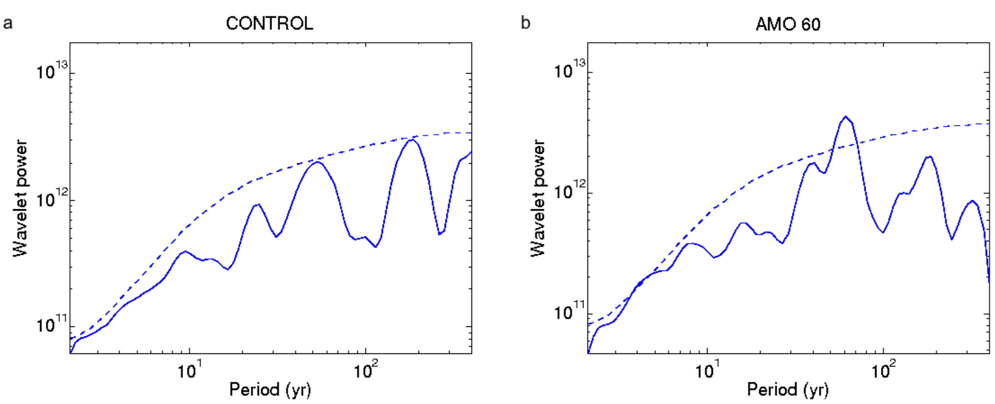

Fig.1. Wavelet spectra of NH permafrost area in control (a) and AMO-forced (b) simulations. Dashed lines show upper 95% confidence level of the fitted AR-1 process.

Variations of the NH permafrost area exhibit a statistically significant maximum at 60 yr period in the AMO-forced simulation that is absent in the control run (Fig.1). Amplitude of the NH area variations related to AMO transition from low to high phase amounts to 1.5 mln.km^2.

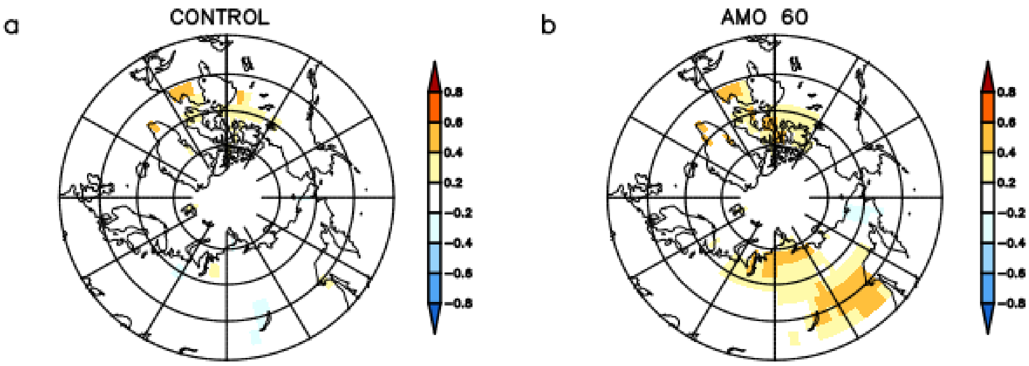

Fig.2. Correlation of the permafrost thawing depth with AMO index in control (a) and AMO-forced (b) simulations. All time series are smoothed with 11-yr running means.

AMO index in the AMO-forced simulations correlates with permafrost depth in the Eastern Eurasia and Canadian Archipelago with maximal correlations exceeding 0.4 (statistically significant at 90% confidence level) (Fig.2a). The control simulation does not reveal significant correlations over Eurasia despite comparable amplitude of internally caused AMO SST index variations (Fig.2a). Regression of the AMO index on thawing depth reaches 0.1m (not shown). Our analysis reveals a significant impact of AMO on the NH permafrost characteristics that is, however, considerably smaller than expected anthropogenically caused changes simulated by climate models to the end of the 21st century. The models project from 3 to 6 1.5 mln.km^2 area reduction depending on emission scenario (IPCC 2013)

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