Impact of autumn snow cover anomalies on the following winter atmospheric dynamics estimated from the INMCM4.0 and INMCM5.0 models output

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Introduction

There are different studies of the influence of autumn snow cover anomalies on atmospheric dynamics in the following winter (e.g. Allen R.J. and Zender C.S., 2011; Martynova Yu.V. and Krupchatnikov V.N., 2010). The mechanism of this effect is complex and largely affects stratospheric processes (Cohen J. et al., 2007). The snow cover rapidly increases exceeding normal values. Emerged diabatic cooling results in pressure increase over and temperature decrease under the normal value. Thus, in troposphere upward energy flux increases, and then it is absorbed in stratosphere. Strong convergence of wave activity flux causes geopotential heights increase, polar vortex slowdown and stratospheric temperature increase. Emerged geopotential and wind anomalies extend from stratosphere to troposphere up to surface. As a result, strong negative AO mode appears near the surface as surface air temperature increase (Figure 1).

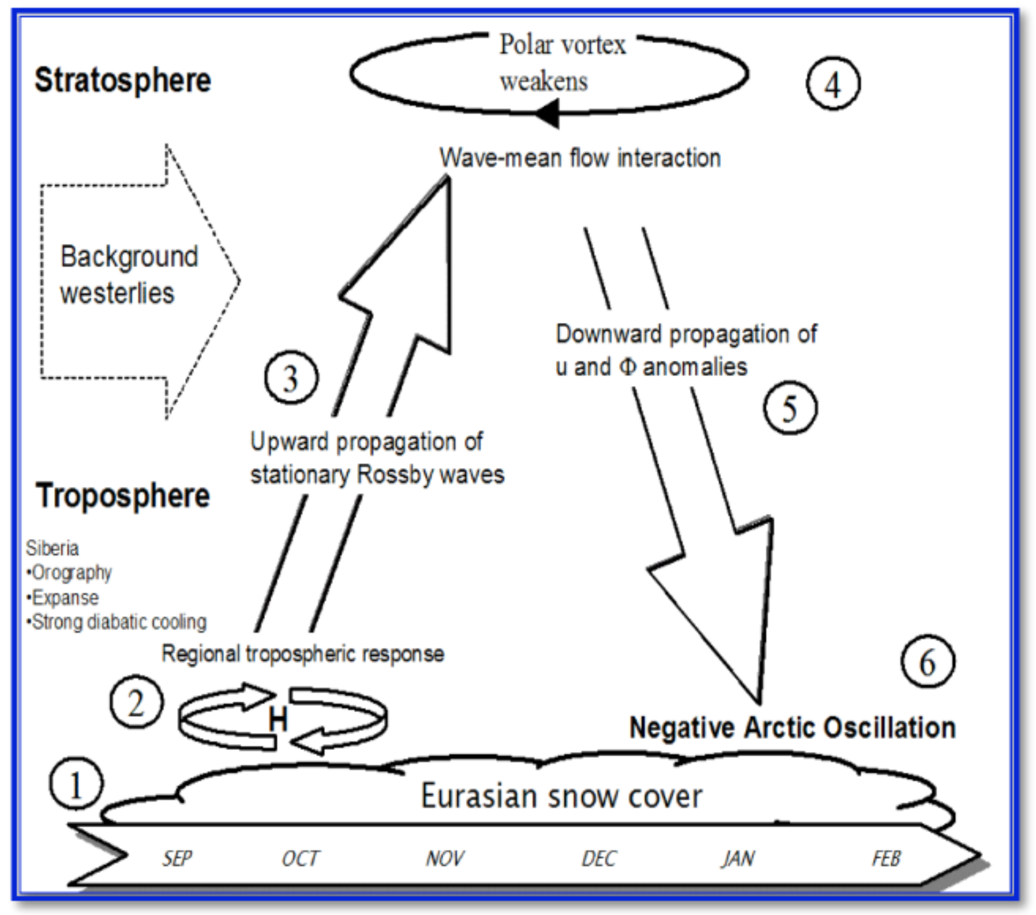

Figure 1. *Mechanism of the influence of autumn snow cover anomalies on atmospheric dynamics in the following winter (Cohen J. et al., 2007).*

Siberia plays important role in this mechanism. Firstly, the most extensive snow cover is formed there. Secondly, according to NOAA satellite observations this cover is generally formed in October (Figure 2) (Gong G. et al., 2003). As a result, Siberia is very interesting for investigations of the autumn snow cover anomalies influence on the atmospheric dynamics in the following winter.

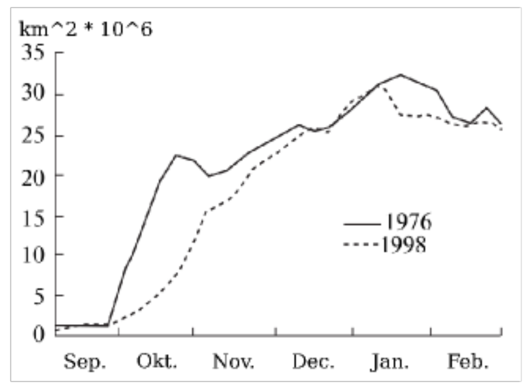

Figure 2. *Snow cover (Dymnikov V.P. et al., 2003).*

This study is devoted to detection and estimation of described mechanism in INMCM4.0 and INMCM5.0 data. INMCM5.0 model represents further development of INMCM4.0 model (Volodin E.M. et al., 2010; Volodin E.M., 2014). They are different both from physical (various physical processes) and numerical (spatial resolution) points of view.

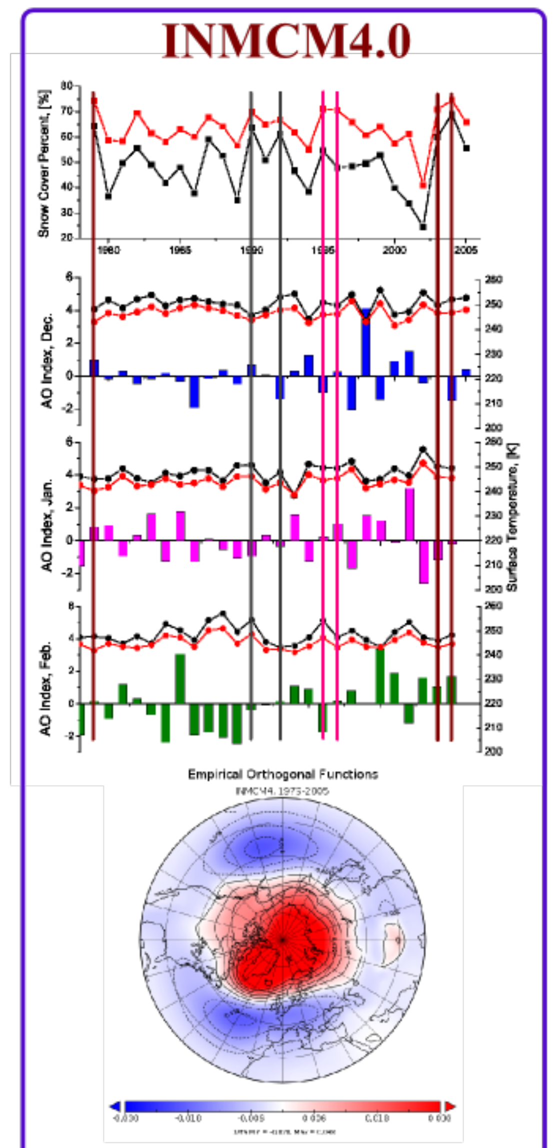

Figure 3.a.

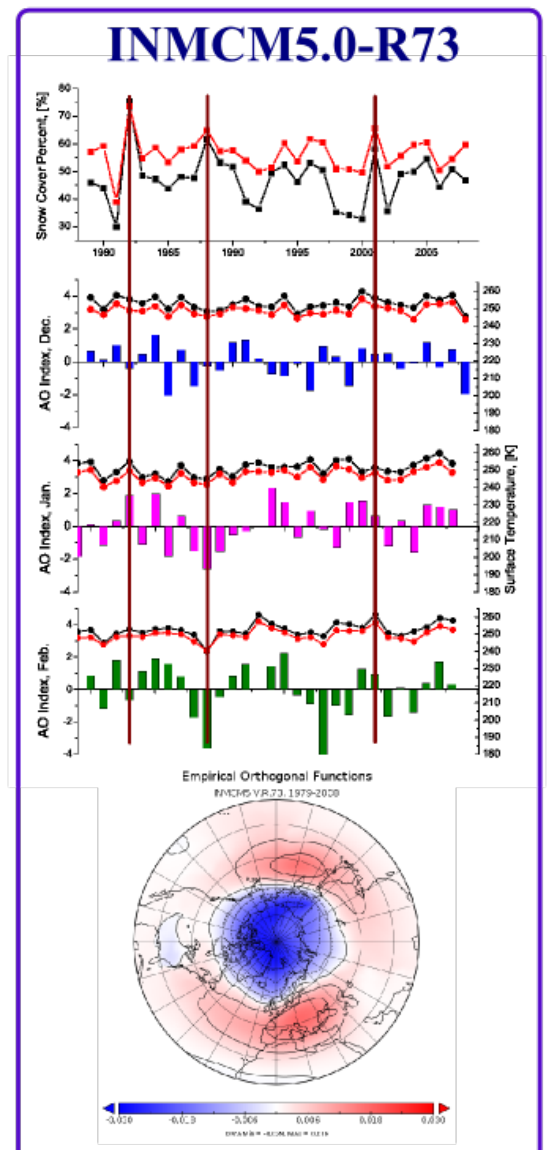

Figure 3.b.

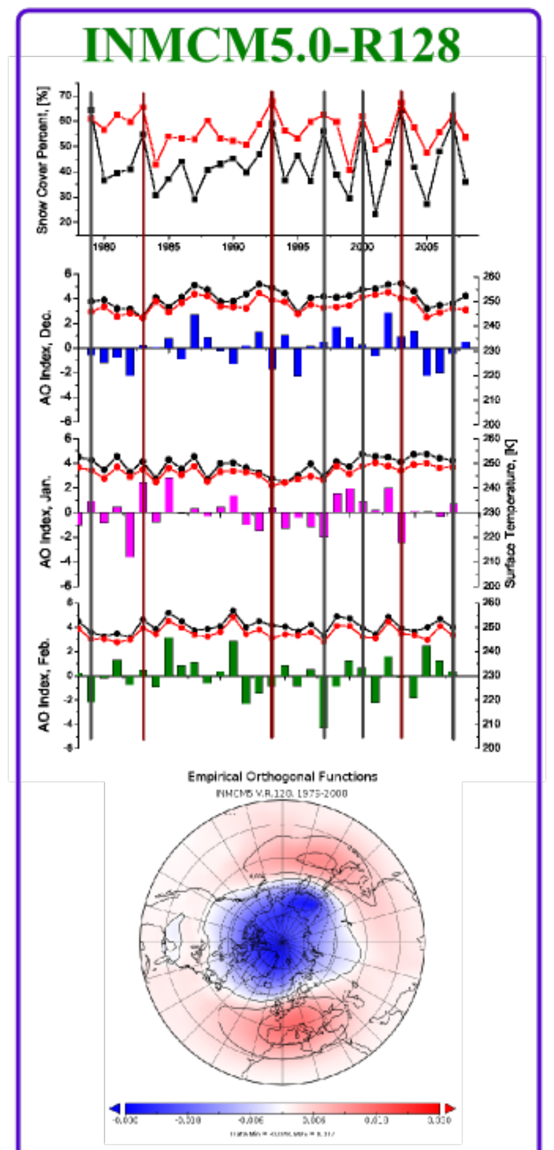

Figure 3.c.

Figure 3. *Top down: Snowcover percent, AO Index and surface temperature for Deceber, January and February, and leading mode of EOF analysis of monthly mean 1000 hPa geopotential height during 1979-2008(2005) period. Black line is values over Western Siberia; red line is values over Western and Eastern Siberia; bar charts are AO Index; vertical lines indicate the snow cover maxima.*

Figure 4. *Leading mode of EOF analysis of monthly mean 1000 hPa geopotential height during 1979-2000 period (NOAA).*

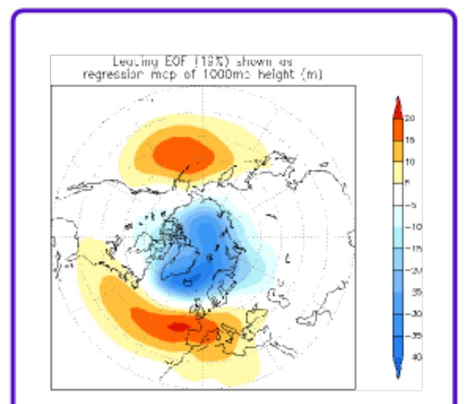

Figure 4.

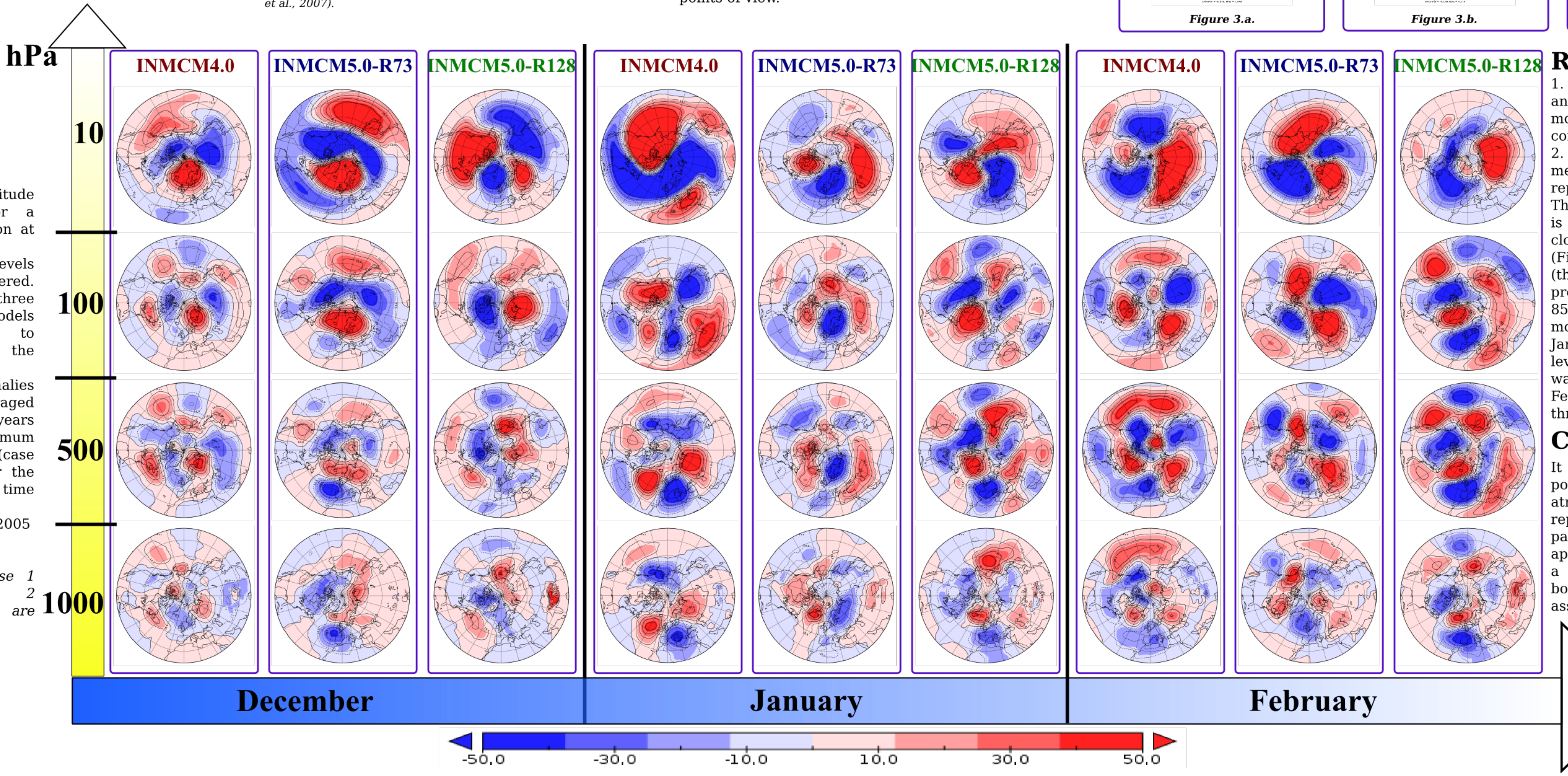

Figure 5. Geopotential height latitude anomaly for a winter season at different pressure levels was considered. Outputs of three different models were used to calculate the anomalies. These anomalies were averaged over the years with maximum snow cover (case 1) and over the whole time period (1979-2008/2005) (case 2). *Differences between case 1 and case 2 averages are presented.*

Results

1. It wasn't found explicit dependence between positive anomaly of snow cover in Oktober and both negative AO mode appearance and surface temperature anomalies in all considered outputs of models.

2. The sign of the leading mode of EOF analysis of monthly mean 1000 hPa height during 1979-2005 period wasn't reproduced correctly in INMCM4.0 dataset (Figure 3.a). There is opposit situation in INMCM5.0 datasets. The sign is correct but maximum and minimum areas are shifted clockwise relative to the leading mode obtained by NOAA (Figure 3.b, 3.c, 4).3. Significant changes of wave activity (the intensification) in the case of snow anomalies are present only at altitudes above the boundary layer (above 850 hPa) for all considered datasets. In December, all models show increased activity only in the stratosphere. In January, INMCM4.0 and INMCM5.0-R128 (128 vertical levels during the simulation) demonstrate the beginning of wave anomalies propagation down to the troposphere. In February, all three models show the propagation down through troposphere.

Conclusion

It has been shown that the mechanism of the effect of positive snow cover anomalies in October on the atmospheric dynamics in following winter is not reproduced fully in all the considered outputs of models. In particular, it can be seen in the case of negative AO mode appearence at the surface. One of possible reasons may be a suppression of wave processes by turbulence in the boundary layer. However, at this stage of research, this assumption has not been tested.

Acknowledgements

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