Supplementary material – The changing face of Arctic snow cover: a synthesis of observed and projected changes

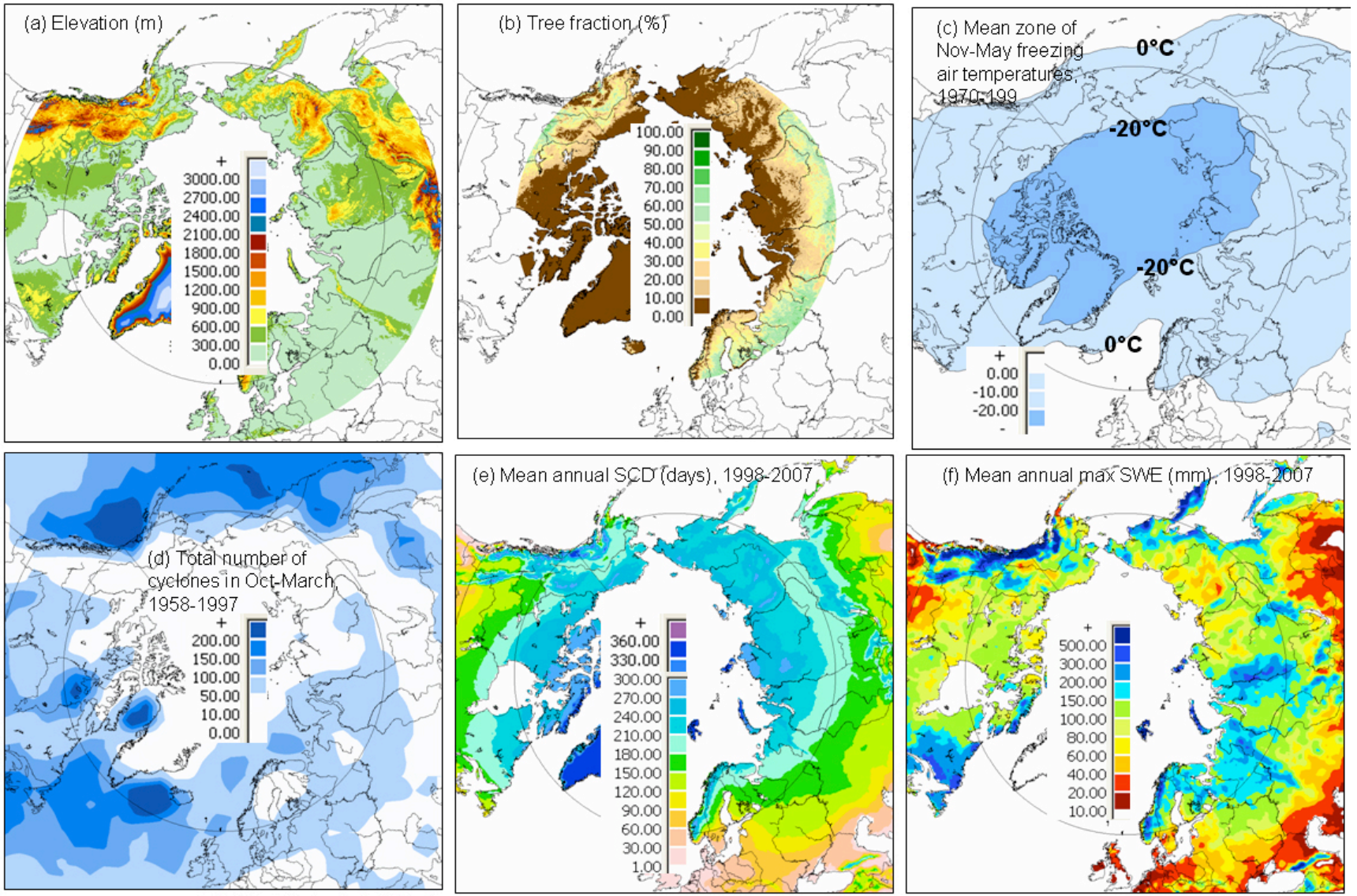
(a) Elevation (m)
+
3000.00
2700.00
2400.00
2100.00
1800.00
1500.00
1200.00
900.00
600.00
300.00
0.00
(b) Tree fraction (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(c) Mean zone of Nov-May freezing air temperatures, 1970-199
0°C
-20°C
-20°C
0°C
+
0.00
-10.00
-20.00
-
(d) Total number of cyclones in Oct-March, 1958-1997
+
200.00
150.00
100.00
50.00
10.00
0.00
(e) Mean annual SCD (days), 1998-2007
+
360.00
330.00
300.00
270.00
240.00
210.00
180.00
150.00
120.00
90.00
60.00
30.00
1.00
(f) Mean annual max SWE (mm), 1998-2007
+
500.00
300.00
200.00
150.00
100.00
80.00
60.00
40.00
20.00
10.00

Fig. A. Basic characteristics of the Arctic related to snow cover: (a) elevation distribution over the Arctic from the ETOPO2 dataset (United States Department of Commerce, National Oceanic and Atmospheric Administration and National Geophysical Data Center, 2006), (b) tree fraction from 500-m resolution MODIS Vegetation Continuous Field product (Hansen et al., 2003), (c) 0 °C and -20 °C mean winter isotherms (November–May) for the period 1970 to 1999, from the NCEP Reanalysis, (d) total number of cyclones in October to March from the NCEP Reanalysis over the 1958 to 1997 period from Key and Chan (1999), (e) mean annual snow cover duration for the period 1998 to 2007 from the NOAA IMS 24 km product (Ramsay, 1998), (f) mean annual maximum snow water equivalent for the period 1998 to 2007 from the Canadian Meteorological Centre snow depth analysis (Brasnett, 1999).

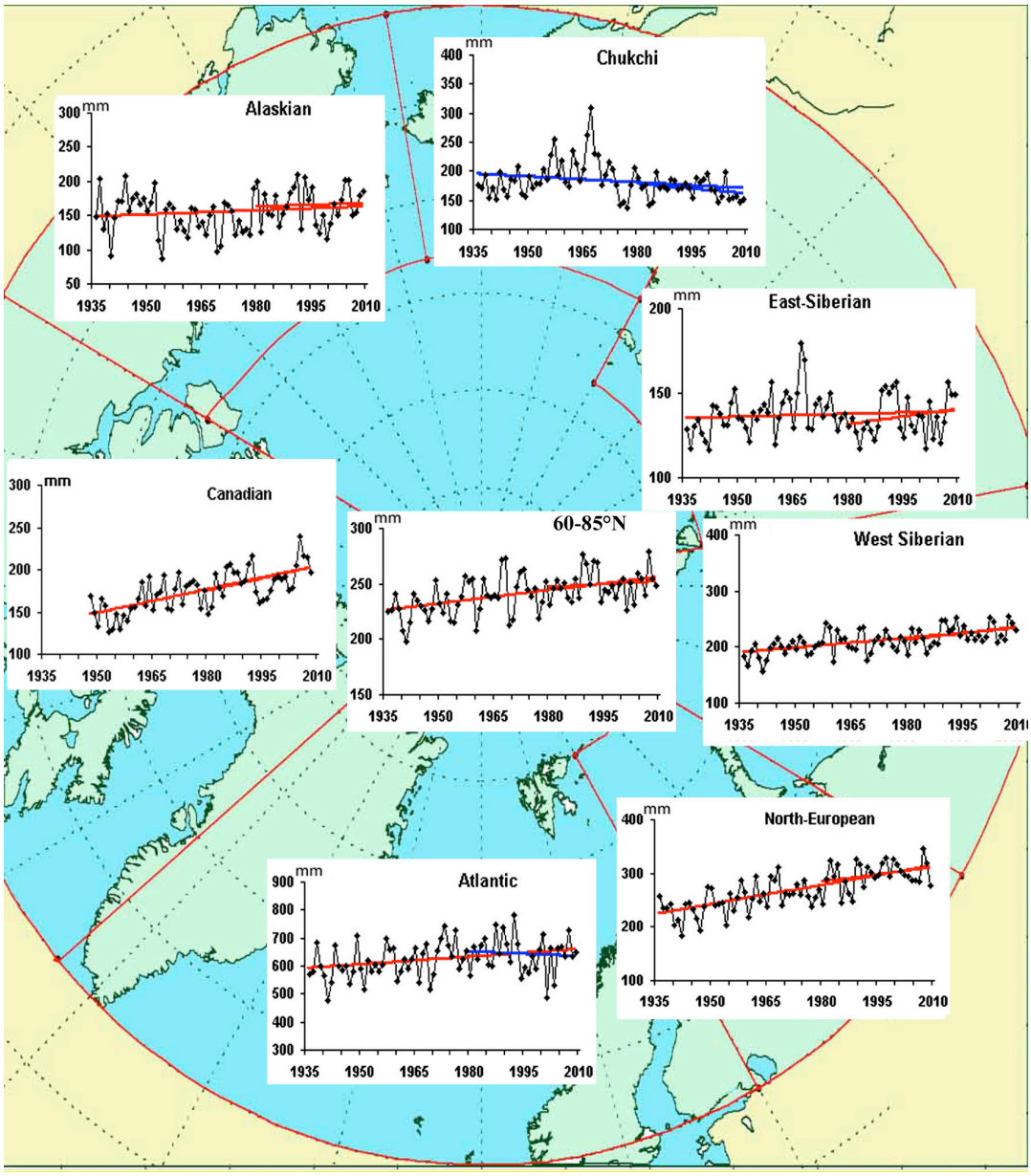

Fig. B. Long-term variability of total precipitation during the cold season (October to May when mean monthly temperature is below -2 °C) for inland stations in different sectors of the Arctic (see Figure 1 for definitions of sectors) together with their long-term-term (1936 to 2009) and short-term (1980 to 2009) linear trends. Precipitation amounts were calculated using a method of arithmetic averaging of total precipitation at all coastal and island meteorological

stations in each sector (Frolov, 2010). Results for Canada used the adjusted and homogenized precipitation dataset of Mekis and Hogg (1999) updated to 2008.

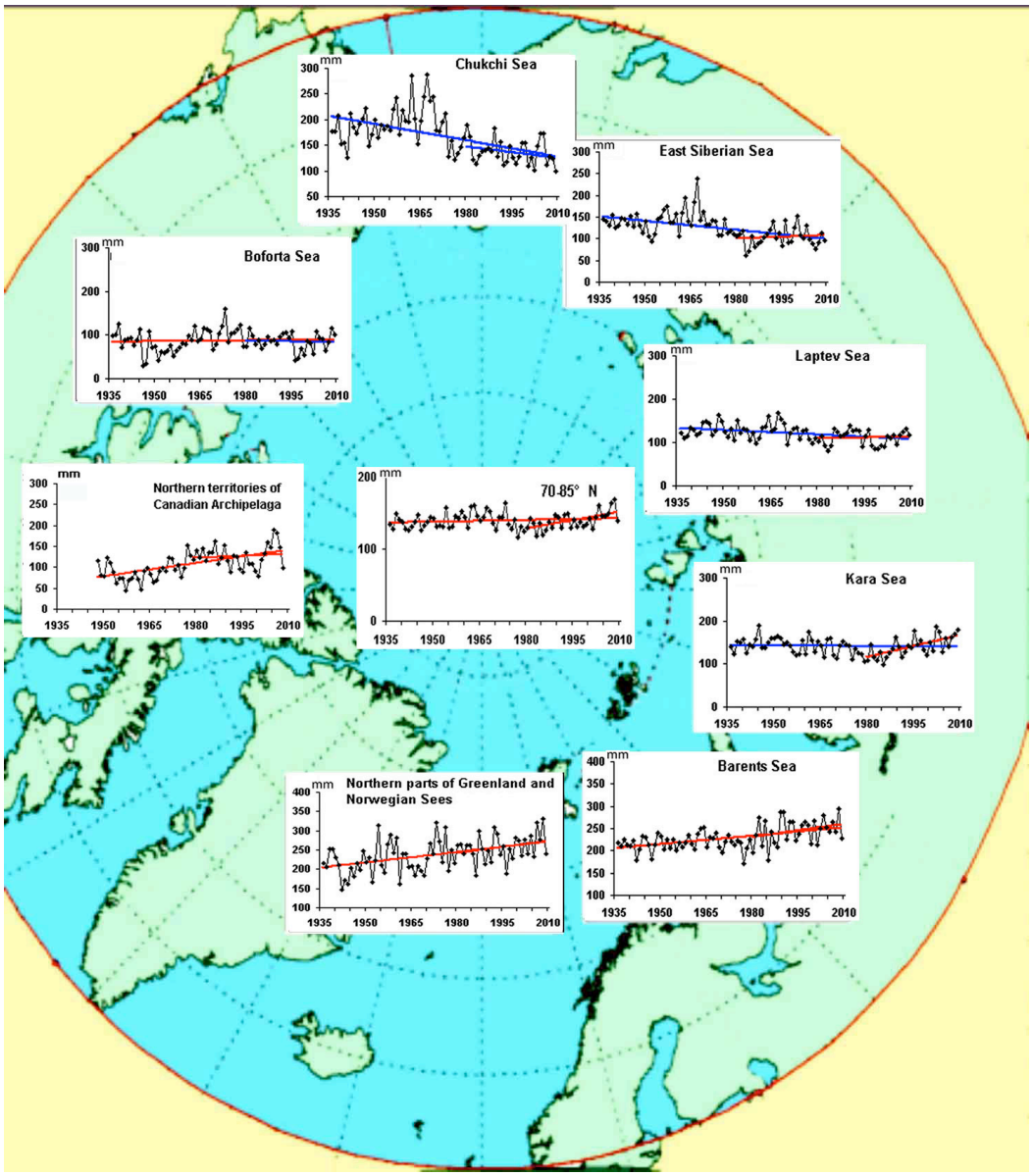

Fig. C. Long-term variability of total precipitation during the cold season (October to May when mean monthly temperature is below -2 °C) in the marginal Arctic seas, central Arctic basin, and northern territories of the Canadian Archipelago together with their long-term-term (1936 to 2009) and short-term (1980 to 2009) linear trends. Precipitation amounts over each sea were calculated using a method of arithmetic averaging of total precipitation at all coastal and

island meteorological stations to the North of 70° N and at North Pole drifting stations (Frolov, 2010). Results for Canada used the adjusted and homogenized precipitation dataset of Mekis and Hogg (1999) updated to 2008.

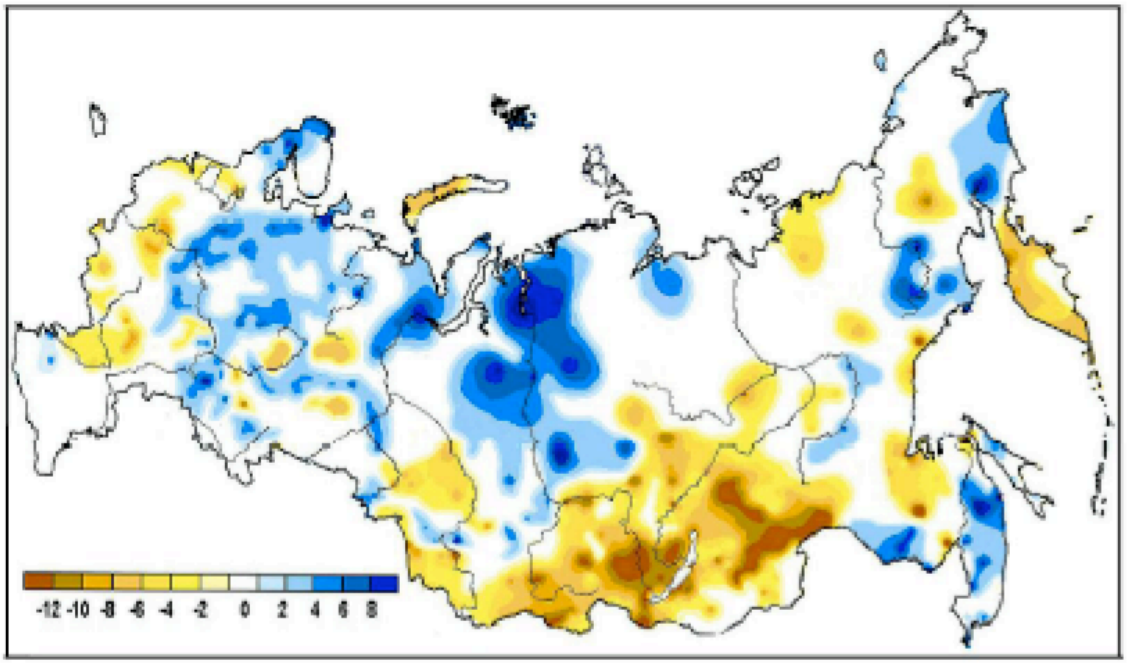

Fig. D. Spatial distribution of linear trend coefficients (cm per decade; 1% to 5% significance level) of maximum snow depth for permanent snow cover over the Russian Federation for the period 1966 to 2007. Source: Bulygina et al. (2009).

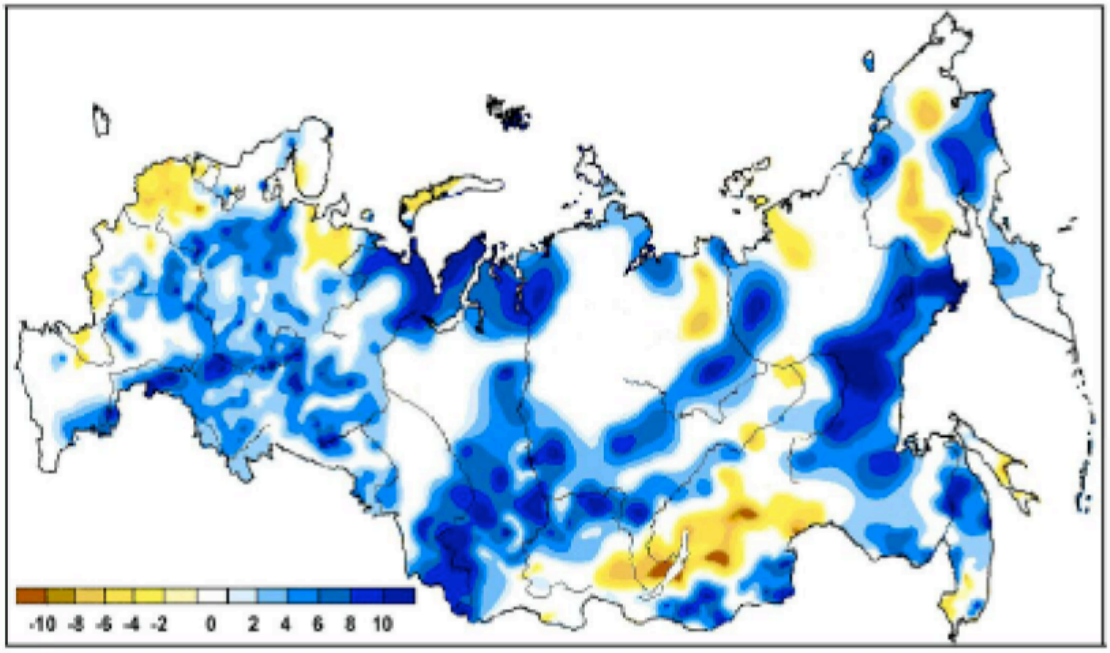

Fig. E. Spatial distribution of linear trend coefficients (days per decade; 1% to 5% significance level) in Russia showing the number of days with snow cover exceeding 20 cm for the period 1966 to 2007. Source: Bulygina et al. (2009).

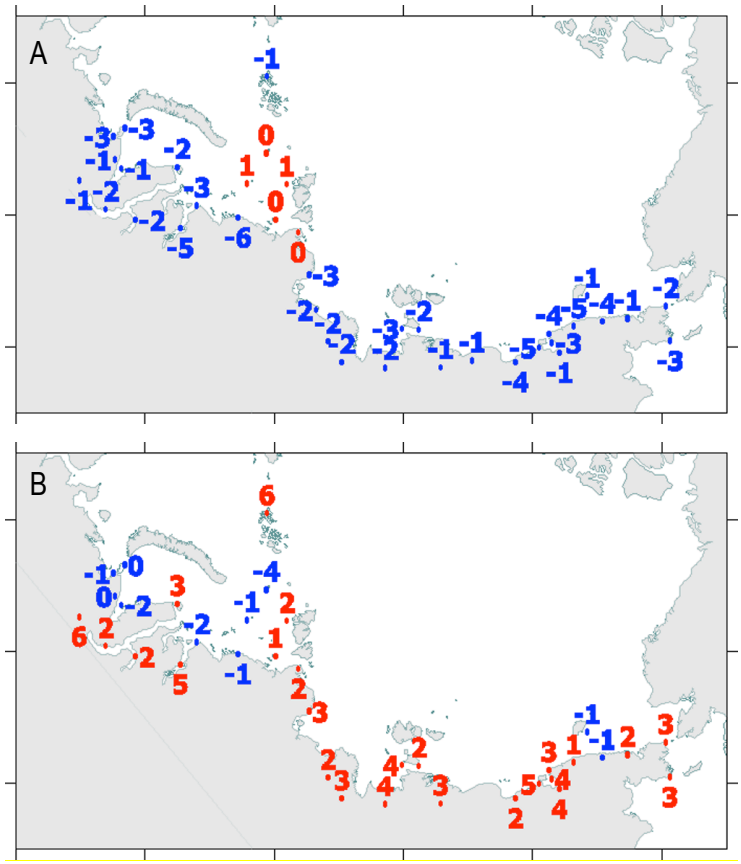

Fig. F. Linear trend (days per decade) in the formation (A) and decay (B) dates of continuous snow cover at Russian Arctic coastal stations for the period 1973-2010 (updated from Radionov et al., 2004)

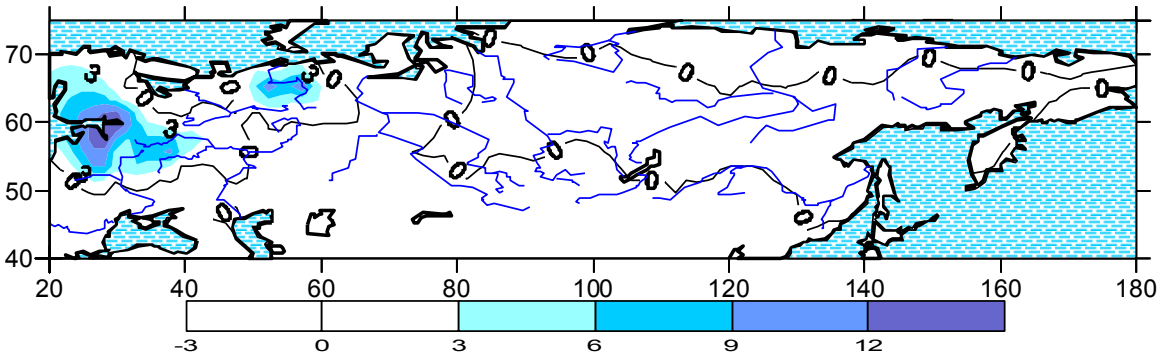

Fig. G. Sum of rain (mm) exceeding 4 mm per day falling on snow deeper than 3 cm, showing the change for 1989 to 2006 relative to 1951 to 1980. Source: Shmakin (2010).

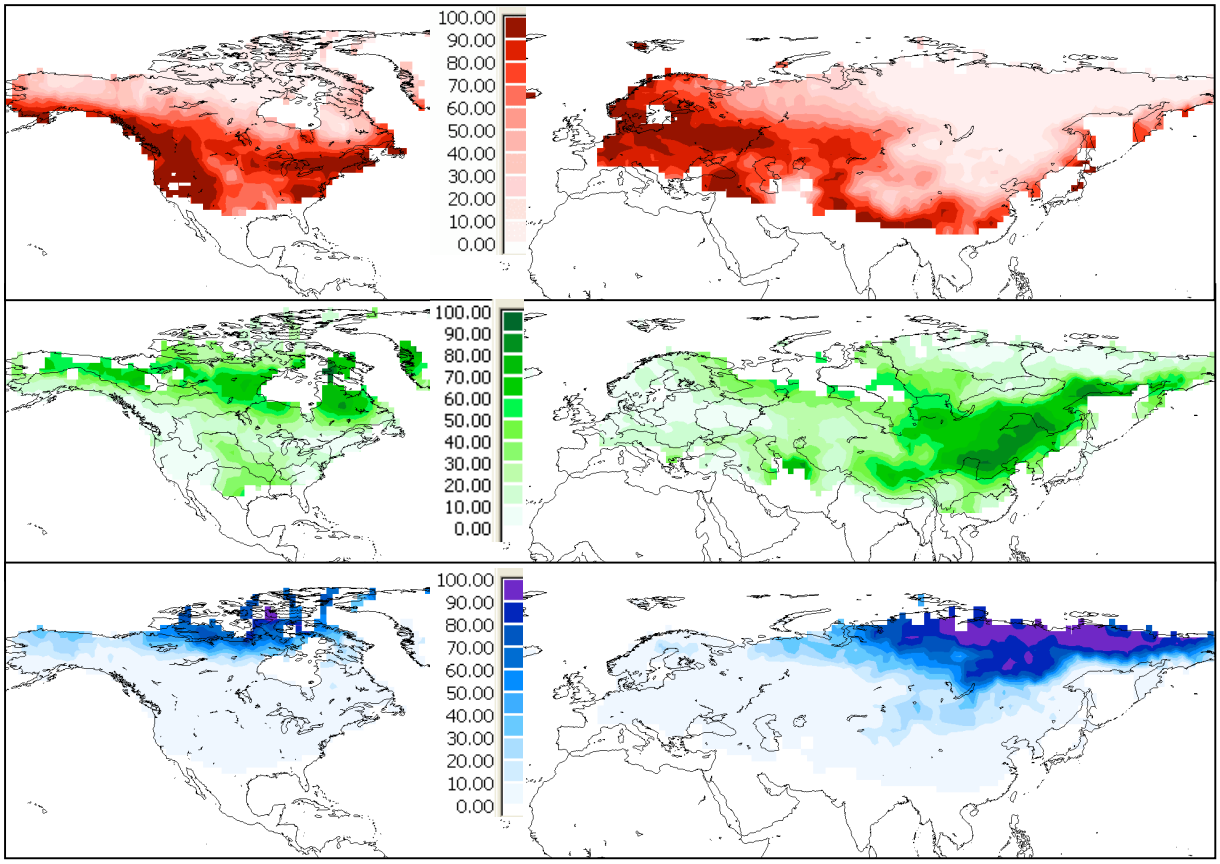

Fig. H. Percentage of 14 CMIP3 climate models showing significant decreases (top panel), no increases (middle panel) and significant increases (lower panel) in annual maximum snow water equivalent for the 2080 time horizon (2070–2099 minus 1970–1999) based on the A2 emissions scenario. Source: Brown and Mote (2009) © 2009 AMS.

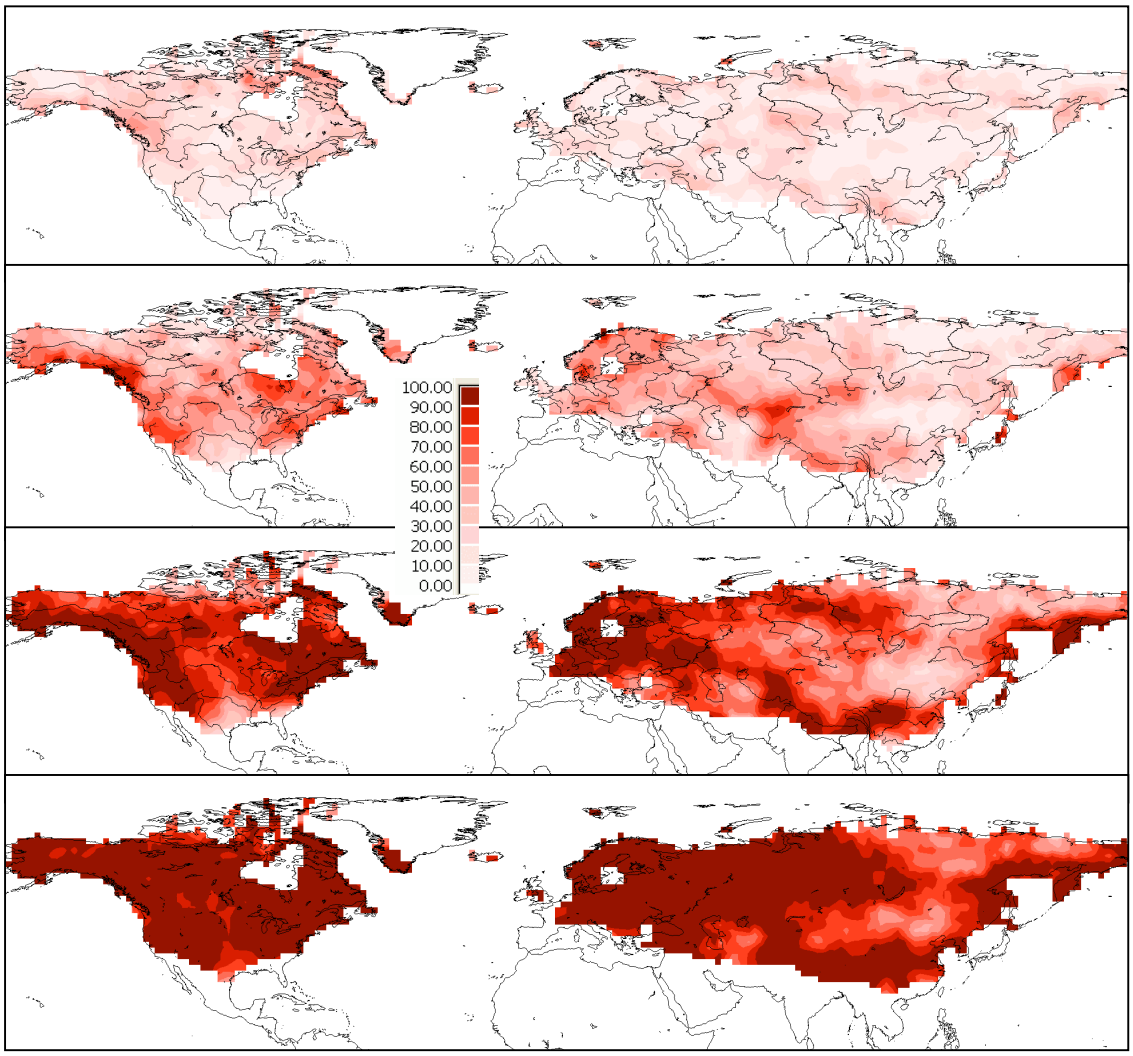

Fig. I. Evolution of the climate-warming signal in annual snow cover duration from eight CMIP3 climate models (showing the percentage of models that show statistically significant local decreases in annual snow cover duration). The top panel results are for 1970–1999 versus 1900–1929 from 20C3M simulations, while the three lower panels are computed from 30-year averages centered on the indicated date from the A2 emissions scenario with respect to a 1970–1999 reference. There is no model consensus for significant increases in SCD. Source: Brown and Mote (2009)

References

Brasnett, B. 1999. A global analysis of snow depth for numerical weather prediction. *Journal of Applied Meteorology* 38:726-740.

Brown, R.D. and P.W. Mote. 2009. The Response of Northern Hemisphere Snow Cover to a Changing Climate. *Journal of Climate* 22: 2124-2145.

Bulygina, O.N., V.N. Razuvaev and N.N. Korshunova. 2009. Changes in snow cover over Northern Eurasia in the last few decades. *Environmental Research Letters* 4: 045026.

Frolov, I.E. (Ed.) 2010. Review of the Hydrometeorological Processes in the Arctic Ocean, 2009 [in Russian]. 136 pp. St. Petersburg. AARI Publishing. www.aari.ru/main.php

Hansen, M.C., R.S. DeFries, J.R.G. Townshend, M. Carroll, C. Dimiceli and R.A. Sohlberg. 2003. Global Percent Tree Cover at a Spatial Resolution of 500 Meters: First Results of the MODIS Vegetation Continuous Fields Algorithm. *Earth Interactions* 7:15.

Key, J.R. and A.C.K. Chan. 1999. Multidecadal global and regional trends in 1000 mb and 500 mb cyclone frequencies. *Geophysical Research Letters* 26:2053-2056.

Mekis, E. and W.D. Hogg. 1999. Rehabilitation and analysis of Canadian daily precipitation time series. *Atmosphere-Ocean* 37: 53-85.

Radionov, V.F., E.I. Aleksandrov, V.R. Bayborodova, N.N. Bryazgin and A.A. Dement'ev. 2004. Long-term changes of snow cover period in the Arctic. *Data of Glaciological Studies* 97:136-142. [in Russian with English summary].

Ramsay, B.H. 1998. The interactive multisensor snow and ice mapping system. *Hydrological Processes* 12:1537-1546.

Shmakin, A.B. 2010. Climatic characteristics of snow cover over North Eurasia and their change during the last decades. *Ice and Snow* 1: 43-57.

United States Department of Commerce, National Oceanic and Atmospheric Administration and National Geophysical Data Center. 2006. 2-Minute Gridded Global Relief Data (ETOPO2v2). http://www.ngdc.noaa.gov/mgg/fliers/06mgg01.html. Accessed: 7 October 2010.