Climate Change from the in situ data

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Central Biosphere Forest Reserve
Fedorovskoe, RUSSIA
Cryosphere

Sea Ice
Glaciers
Permafrost
River and lake ice breakup
Snow cover (next week)
Sea Ice Extent Anomaly, Sept. 2002

Concentration anomaly (%) derived from DMSP SSM/I data relative to means for 1988-2000. (Fetterer et al. 2002)
Trend in sea ice

Since 1980, perennial sea ice in the Arctic has declined at a rate of 9.8% per decade (Comiso 2006).

Courtesy of National Snow and Ice Data Center,
http://nsidc.org/news/press/20050928_trendscontinue.html#fig1
Hemispheric Sea Ice Extent Anomalies

Northern Hemisphere Extent Anomalies Sep 2006

1979-2000 mean = 7.0 million sq km

slope = -8.6(+/-.29) % per decade

http://nsidc.org/cgi-bin/wist/wist/wist_nt.pl
Northern Hemisphere Extent Anomalies May 2007

1979-2000 mean = 13.6 million sq km

slope = -2.8 (+/-1.0) % per decade

Mean ice drafts at places where early cruises were (nearly) collocated with cruises in the 1990s.

Decrease in sea ice thickness

Sampling error issue not fully resolved
Meridional heat transfer

Ocean currents ~1/3 or ~ 0.5 \times 10^{15} W across 60°N
One of the first UCMO GCM sensitivity experiments with polar ice replaced by water at 273K

Changes in surface air temperature, K

Changes in glacier volume (km$^3$) since 1960

Source: http://www.nsidc.org
Impact on water supply...

When the millenium-old water storage will go, what to do?

Example. Central Asia. Example of a central Tien Shan glacier recession. Petrova Glacier in the Akshiyrak area, ASTER image, September 2002 (A), and instrumental topographic data (B) (Kuzmichonok et al. 2005)
Glacier contribution to sea level rise

Mass balance of mountain and subpolar glaciers with the aggregate area 785*10^3 km^2 and their contribution to the rise in sea level; observational results are weighted by sizes of individual glaciers (about 300 time series), primary systems (49 in the world) and by larger size systems (13); updated 10.10.04. Contribution increased in 1993-2002 decade from 0.40 to 0.73 mm/yr (M. Dyurgerov, 2004; results reported to NASA, NAG5-13691)

NSIDC: http://www.buscadores.info/ir\'nsidc.org

Dyurgerov 2004

... and the sea level rise
Circumpolar permafrost extent

J. Brown, O. J. Ferrains, Jr., J. A. Heginbottom, and E. S. Melnikov (1997)
Two possible scenarios after the permafrost thaw:

Wetlands

Steppe
Changes in Permafrost Temperature in Barrow, Alaska Between 2001 and 1950

From Romanovsky (2002)
## Changes in Permafrost Temperature

<table>
<thead>
<tr>
<th>Country</th>
<th>Region</th>
<th>Permafrost Temperature Trends</th>
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<tbody>
<tr>
<td>USA</td>
<td>Trans-Alaska pipeline route (20 m), 1983-2000</td>
<td>+0.6 to +1.5°C</td>
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<td></td>
<td>Barrow Permafrost Observatory (15 m), 1950-2001</td>
<td>+1°C</td>
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<tr>
<td>Russia</td>
<td>East Siberia (1.6-3.2 m), 1960-1992</td>
<td>+0.03°C/year</td>
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<td>North of West Siberia (10 m), 1980-1990</td>
<td>+0.3 to +0.7°C</td>
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<tr>
<td></td>
<td>European North of Russia, continuous permafrost zone (6 m), 1973-1992</td>
<td>+1.6 to +2.8°C</td>
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<tr>
<td></td>
<td>European North of Russia, discontinuous permafrost zone (6 m), 1970-1995</td>
<td>up to +1.2°C</td>
</tr>
<tr>
<td>Canada</td>
<td>Alert, Nunavut (15 m), 1995-2000</td>
<td>+0.15°C/year</td>
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<td>Northern Mackenzie basin, NWT (28 m), 1990-2000</td>
<td>+0.1°C/year</td>
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<tr>
<td></td>
<td>Central Mackenzie basin, NWT (15 m), 1985-2000</td>
<td>+0.03°C/year</td>
</tr>
<tr>
<td></td>
<td>Northern Quebec (10 m), late 1980’s – mid 1990’s</td>
<td>-0.1°C/year</td>
</tr>
</tbody>
</table>

Source: Romanovsky (2002)
Earlier Ice Breakup
Late Lake and River Freeze Up

- ~2 week increase in length of ice-free season

Magnusson et al. (2000)