BACC II Chapter 3.3.2: Terrestrial cryosphere

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Author team

- Snow:

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- Ground frost:

Jan Boelhouwers, Kulturgeografiska institutionen, Naturgeografi, Uppsala University, Sweden

- Glaciers:
- **Ian Brown, Susanne Ingvander, Andrew Mercer**, Department of Physical Geography and Quaternary Geology, University of Stockholm, Sweden

Overview

- 13 pages + references, tables and figures
- 2 tables
- 7 figures
- Most emphasis on the seasonal snow cover
- Glaciers and frozen ground added
- Lake and river ice decided to be moved to the hydrology chapter

Structure of the chapter

- 1. Background
- 2. Recent and present changes in seasonal snow cover
  - 2.1 Snow cover formation, duration and melt
  - 2.2 Snow depth and snow water equivalent
  - 2.3 Snow cover extent
  - 2.4 Snow structure and properties
  - 2.5 Extreme events
- 3. Recent and present changes in glacier extent and mass balances
- 4. Recent and present changes in ground frost
  - 4.1 Seasonal ground frost
  - 4.2 Permafrost
- 5. Discussion

Points from reviewers I

- Prof. Vuglinsky, State Hydrological Institute, Russia:
  - Changes are presented for different countries, but discussion for the whole Baltic Sea basin mainly missing, but…
  - In many cases data on cryospheric components and their changes are given for areas much larger than the Baltic Sea basin (for example Europe)
  - Large extracts from BACC I should be avoided
  - Lake and river ice should be considered

Points from reviewers II

- Adj. prof. Vihma, Finnish Meteorological Institute, Finland:
  - recent results based on remote sensing results are missing (on snow extent and timing of snow melt).
  - it is not clear which changes have taken place in the Baltic Sea watershed. The previous publications (covering wider geographical area) should be studied in more detail to write a synthesis on the results that are valid for the Baltic Sea watershed.
  - the increase of greenhouse gas concentrations should be emphasized more, as a reason for the observed changes.
  - Heavy snow storm in winter 2010-2011 was left out when discussing the storminess...

1. Background (4p)

- The geography of the cryosphere
  - Based mainly on BACC I Appendix A.1.3.5
- Observations of the cryosphere
- About the chapter
  - Chapter structure
  - Short summary about the BACC I findings
  - Short summaries about the findings reported in Global outlook for snow and ice (UNEP, 2007), Fourth Assessment Report of the Intergovernmental Panel on Climate Change (AR4, 2007) and "Impacts of climate change on snow, ice, and permafrost in Europe" by Voight et al. (2010)

2. Recent and present changes in seasonal snow cover (5p)

- 2.1 Snow cover formation, duration and melt (~2p)
- 2.2 Snow depth and snow water equivalent (~1p)
- 2.3 Snow cover extent (~1p)
- 2.4 Snow structure and properties (1/2 p)
- 2.5 Extreme events (~1p)

Formation, duration and melt

- Snow cover duration has the highest sensitivity to climatic changes of all snow cover parameters
- Decrease in Northern Hemisphere / Eurasia snow cover duration during the period of 1966–2007 (satellites, snow surveys)
- During the last few decades snow cover period has been shortened in European Russian, Latvia, Lithuania, Poland, Estonia, and western Scandinavia
- Especially earlier snow melt.
- Also some contradicting references

Depth and water equivalent

- Large inter-annual variation is seen in the maximum snow depth and snow water equivalent time series
- Decreasing trends reported from southern and western part of Finland, Poland, Estonia, Lithuania, parts of Sweden
- Trends in the Baltic region of Russia more complicated
- In northern and eastern part of the watershed, and in mountain regions where both precipitation and temperature control the snow amounts, an increase in annual snow depth and snow water equivalent has been observed.

Table 1. Trends in monthly observations on surface air temperature (*T*), Precipitation (*Pr*), snow depth (*H*), snow water equivalent (*S*) for Russian part of Baltic region, during the periods of 1936-2008 and 1979-2006. (from Kitaev et al., 2007; 2010).

Month	Period	T		Pr		H		S	
		b	R^2	b	R^2	b	R^2	b	R^2
Nov	1936-2008	0.10	1.9	3.87	30.0	1.3	20.9	-2.4	0.0
	1979-2006	0.12	3.2	2.05	3.5	8.4	1.9	3.1	5.1
Dec	1936-2008	0.10	1.4	7.52	30.5	1.3	20.1	1.2	0.0
	1979-2006	0.11	2.4	5.8	6.4	4.6	0.0	2.7	1.1
Jan	1936-2008	0.0	0.0	10.7	31.5	2.8	30.9	-1.6	0.0
	1979-2006	0.1	0.9	3.0	3.3	-2.9	6.2	0.9	0.4
Feb	1936-2008	0.13	1.3	14.6	33.2	4.2	36.3	-0.8	0.0
	1979-2006	0.19	1.8	6.2	5.6	-1.5	1.3	0.0	1.1
Mar	1936-2008	0.15	2.0	14.3	31.8	1.1	9.3	1.6	3.7
	1979-2006	0.38	2.2	6.2	1.8	-1.7	6.8	1.2	1.3

b – coefficients of liner trend: *T* C° /10 years; *Pr* mm /10 years; *H* cm /10 years; *S* mm /10 years;

R^2– coefficient of determination, %

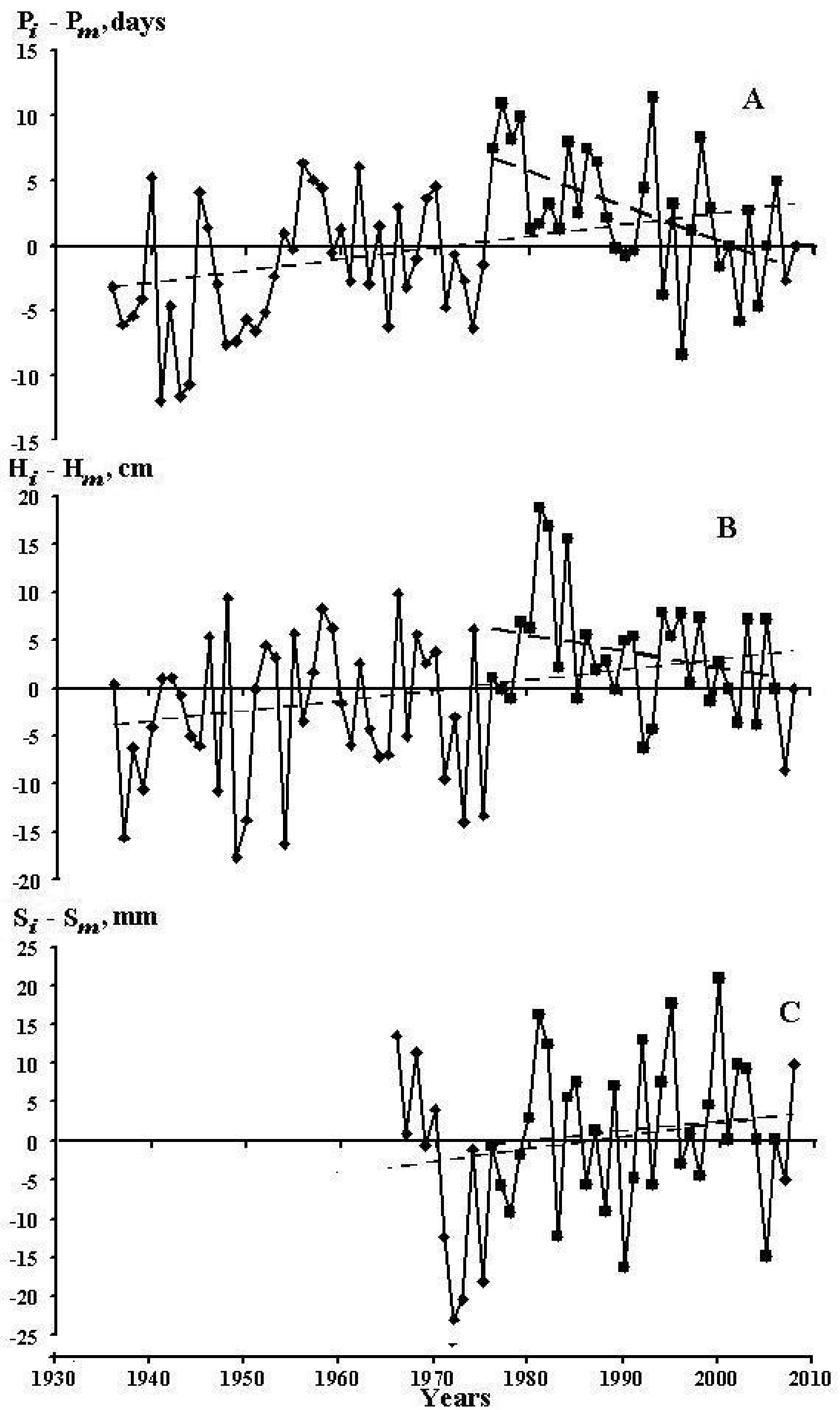
Table 2. Long-term trends (1976-2006) in surface air temperature (*T*), Precipitation (*Pr*), period of snow cover occurrence (*P*), snow depth (*H*), snow water equivalent (*S*) for Russian part of Baltic region and East European plain. (from Kitaev et al., 2007; 2010).

	T		Pr		P		H		S	
	b	R^2	b	R^2	b	R^2	b	R^2	b	R^2
Baltic region	0.38	2	6.2	1.8	-2.6[1]	24.2	-1.7	6.8	1.2	1.3
East European plain	0.68	7	0.61	4.2	-4.7	14	0.88	4.9	-1.5	2.7

b – coefficients of liner trend: *T* C° /10 years; *Pr* mm /10 years; *P* days /10 years; *H* cm /10 years; *S* mm /10 years;

R^2– coefficient of determination, %

[1]0.89 during the period of 1936-2008 (R^2=12.6%)



Variability of anomalies in Russian part of Baltic region, in the period of snow cover occurrence, days (A); snow depth in March, cm (B); snow water equivalent in March, mm (C), and the linear trends. (from Kitaev et al., 2007; 2010).

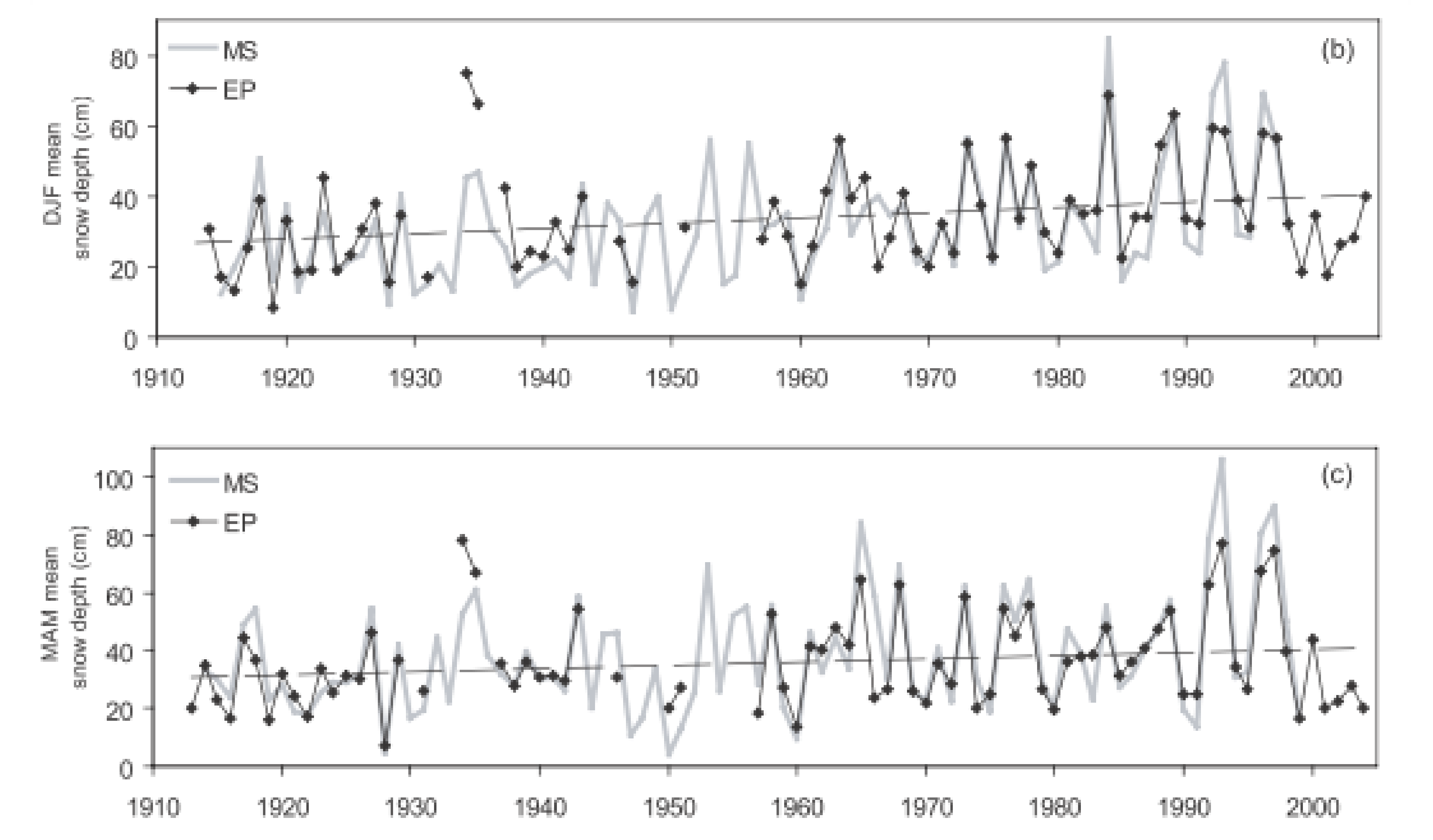


Figure 3. Mean snow depth for Abisko, Northern Sweden, during months December-February and March-May during the period of 1913-2004 (a) (from Kohler et al. 2006)

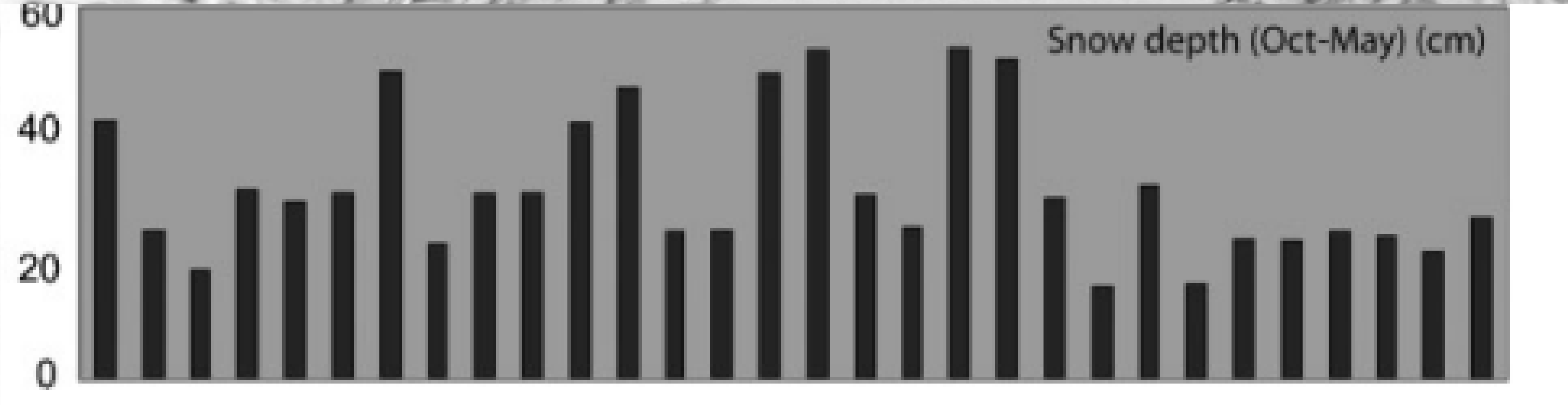


Figure 3. Mean snow depth for Abisko, Northern Sweden during the period of 1978-2006 (b) (from Åkerman and Johansson, 2008; updated from Kohler et al., 2006; data from the Abisko Scientific Research Station; Johansson et al., 2008).

Snow cover extent

- Snow cover extent has shown mostly decreasing trends in the area, with large decadal fluctuations.
- A fast decrease in spring snow cover (1972-2007) has been observed in Europe, especially in Scandinavia
- Snow cover extent decreased in Russia during the 1970s-1990s; this decrease has since ceased.

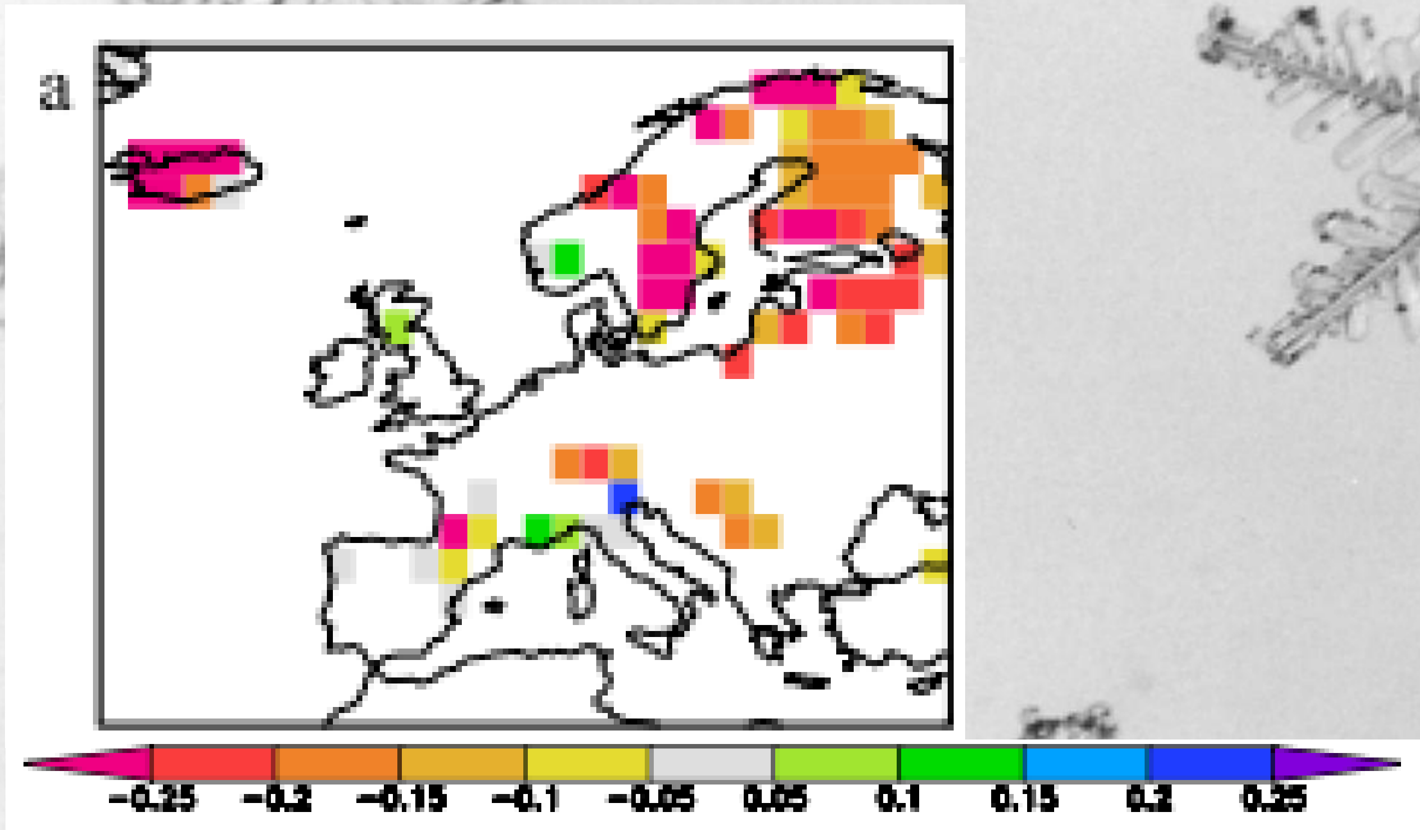


Figure 4. Trend in observed March-May snow cover (K^{-1}) during the period of 1972-2007. (from van Oldenburg et al., 2009).

Structure and properties

- Limited data is available on changes in snow structural properties.
- In the western half of Eurasian continent days with thaw have become more frequent
- In Fennoscandia the number of days with winter thaw increased by 6 days in 50 years.
- Some references show that there is a decrease in duration and maximum thickness of the ice basal ice layer in the European part of Russia since the year 1966.

Extreme events

- During the latest decade, an exceptionally warm winter 2007 was experienced, as well as two winters with high snow accumulation (2005/2006 and 2009/2010).
- Difficult to say anything on recent changes in frequency or severity of snow related extreme events.
- Fragmentary information from some countries: winter storms in Denmark, heavy winter precipitation and snow-induced forest damages in Finland, rapid snow accumulations and melts in Poland

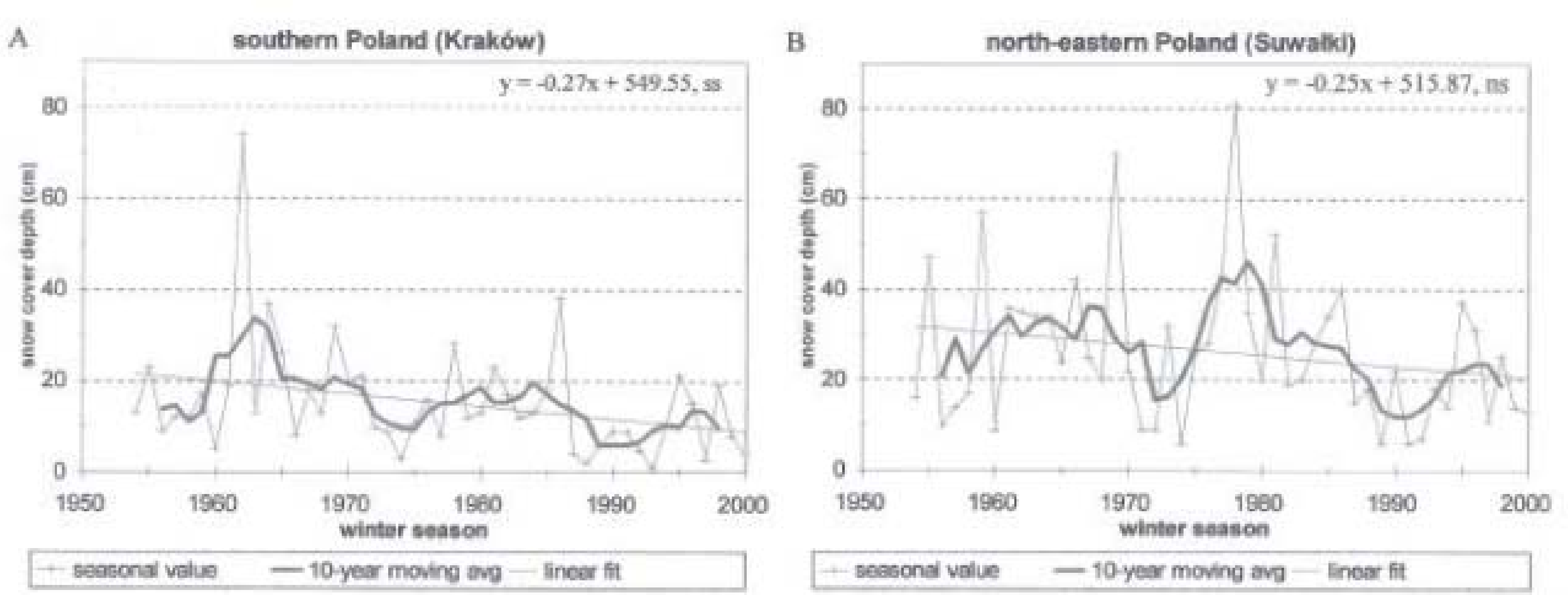


Figure 5. The 90th percentile of the daily snow cover depth (cm) for the period from Dec 1st to Feb 28th in: A) southern Poland, B) north-eastern Poland (1954/55-2000/01). Denotations: ss – statistically significant, ns – not statistically significant (from Falarz 2008).

3. Recent and present changes in glacier extent and mass balances (1p)

- The mass balance record for Storglaciären, the longest continuous mass balance record in the world, shows a fluctuating pattern in net balance
- Since 1992 the net mass balance trend has been largely negative with no positive mass balances reported since 1995/6
- The frontal positions measured in Tarfala show retreat rates from -1 to -14 meters per year between 1915 and 1994
- Decrease of glacier coverage in Sweden of 24.6% over 35 years
- In inland Scandinavia, a cumulative loss in glacier ice thickness has been reported by World Glacier Monitoring Service during period 1967-2008

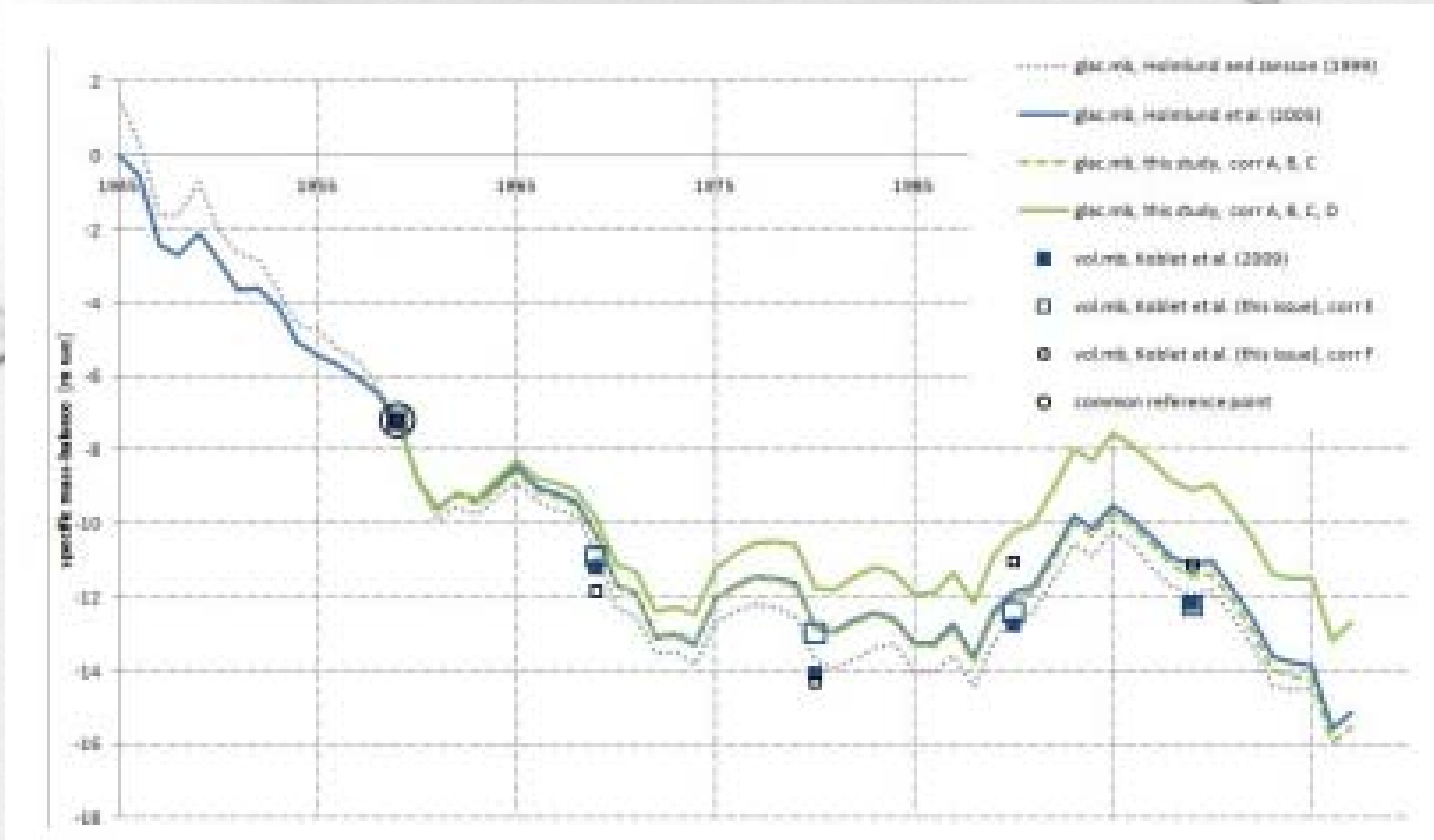


Figure 6. Cumulative glaciological and volumetric mass balance series of Storglaciären (from Zemp et al., 2010).

4. Recent and present changes in ground frost (2p)

- 4.1 Seasonal ground frost (1 page)
- 4.2 Permafrost (1 page)

4.1 Seasonal ground frost

- Current understanding of the spatial patterns of frequency- intensity-duration characteristics of ground frost cycles in the Baltic region remains poor and has not been subject to systematic study.
- In Sweden small warming trend in the ground temperatures, decrease in seasonal frost duration with later freeze-up and earlier spring thaw and increase of intensity of short-term frost cycles in the upper 20cm
- Duration and depth of frozen ground decreased in Lithuania

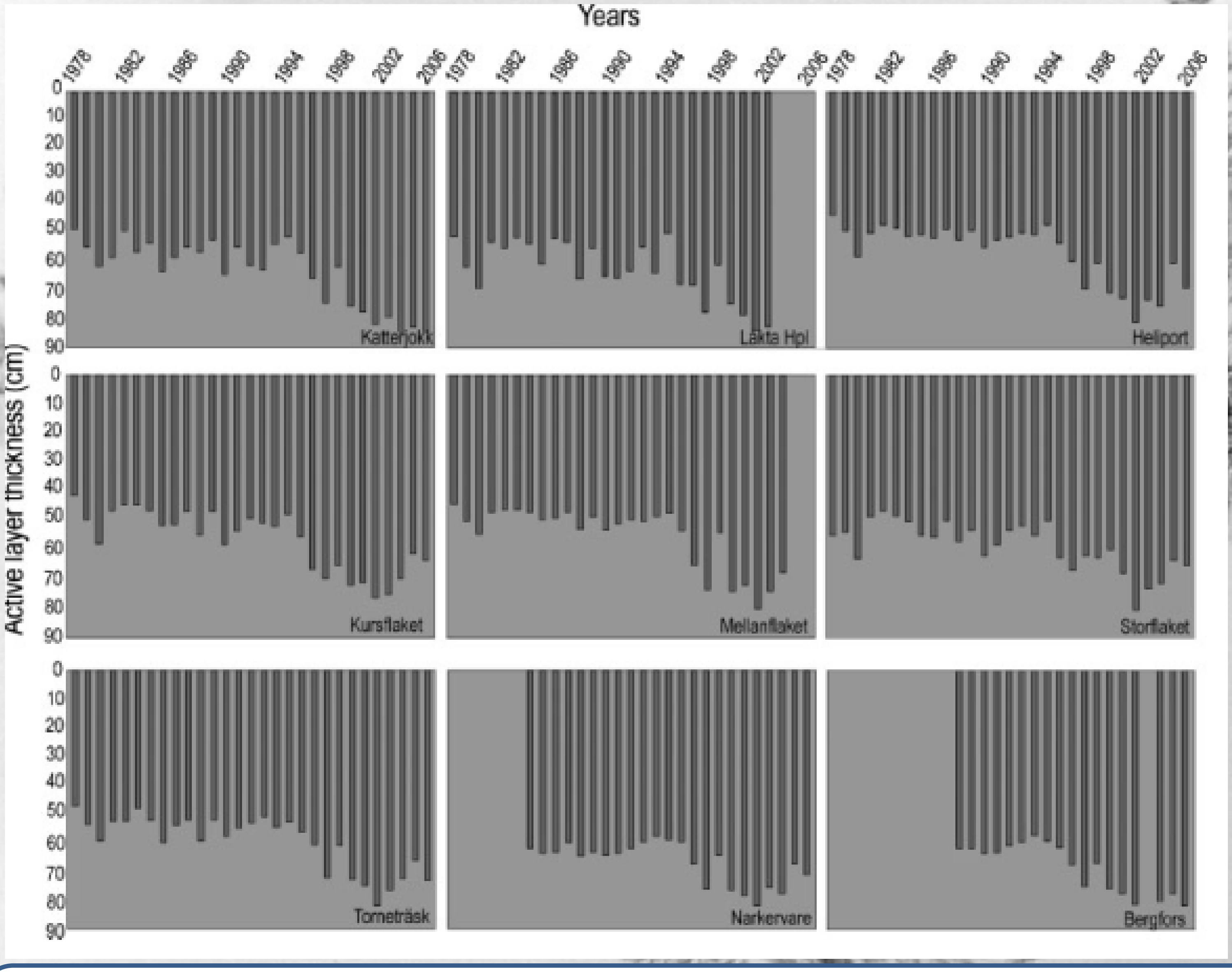


Figure 7. Active-layer thickness from 1978 to 2006 at the nine sites in sub-arctic Sweden. The active layer has become thicker over the monitoring period, especially during the last decade (from Åkerman and Johansson, 2008).

4.2 Permafrost

- Recent warming trends in permafrost observed, with greatest warming at higher latitudes.
- Rise in ground temperature in European Russia and in sub-Arctic Sweden
- 20-50km shift northward of patchy near-surface permafrost during latest decades in European Russia
- Thawing permafrost and thicker active layers in sub-Arctic Sweden

5. Discussion (3p)

- Some climatic reasons for the changes
- Roles of the cryosphere in the global climatic system
- Interactions between the terrestrial cryosphere components and other biotic and abiotic systems
- Some consequences of changes in seasonal snow cover, glacier mass balance and frozen ground on society functions, traditional livelihoods, building, tree growth, forestry, hydrological regime are discussed…
- …but this information can be used by authors of chapter 5, if they so decide.

References

- 113 references at the moment
- Also some references emphasizing the socio-economical, ecological and traditional knowledge included
- Some older than 2007 (for subjects not included in BACC I)

Conclusions

- Recent literature reinforces the findings of BACC I
- In some cases new, longer time series show different types of trends than during the BACC I

Concerns from our team

- Ian Brown did language editing, but more of that is needed - There should be consistent language all through the report
- Eastern European colleagues noticed that many of the names and locations are not spelled correctly in the papers we refer to, and may be in wrong format also in the BACC chapters.
- The most recent references should be included before the report goes to print

Other thoughts

- Part of the information of the current state of the Baltic area snow cover (in attachment of BACC I) is now in the introduction. This part could be taken out of the chapter and put once again as an attachment.
- We are ready to formulate some information also to table form, if this is needed
- Clear need to do more synthesis about changes in Baltic watershed area

About figures…

- Amount and selection of figures per chapter?
- Our selection ia now too much concentrating on Scandinavia
- Report would benefit if there were some figures produced just for this reason, giving better synthesis than already published figures…
- We suggest a map of the Baltic Sea watershed area, with glaciers, permafrost areas, and mean extents of the seasonally frozen ground and the seasonal snow cover as a figure 1 - or inclusion of distribution of some cryospheric components into some other map / figure.


Thank you !