University of Liège
Geography Department
Laboratory of Climatology

Estimation of the 1900-2100 Greenland ice sheet surface mass balance

by

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Plan

1. Estimation of the Surface Mass Balance (SMB)
2. The SMB of the 20th century
3. Change in the 21th century
4. Conclusion

Reference:

Fettweis, X., Hanna, E., Gallée, H., Huybrechts, P., and Erpicum, M.: Estimation of the Greenland ice sheet surface mass balance during 20th and 21st centuries, *The Cryosphere Discuss.*, 2, 225-254, 2008. See: www.the-cryosphere.net

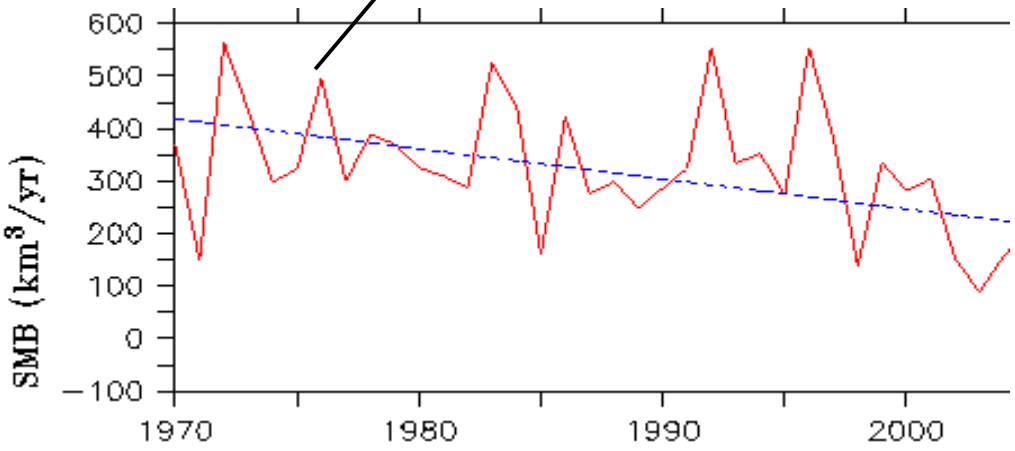
1. Method (1/3)

T_{jja} = JJA (June-July-August) 3-m temperature
P_{yr} = Annual precipitation

The variability of the Greenland ice sheet (**GrIS**) Surface mass balance (**SMB**) can be estimated with :

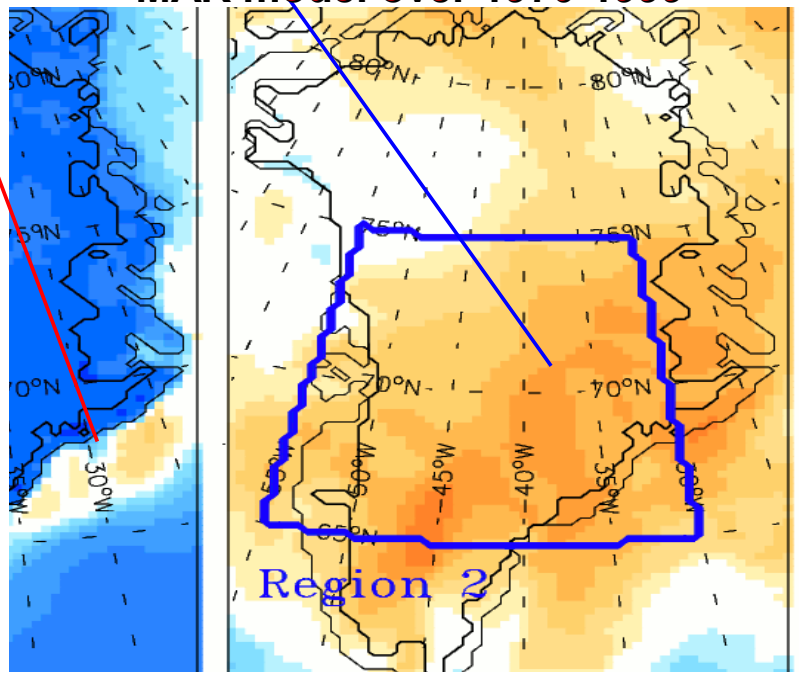
$$\Delta SMB \approx a\,\Delta T_{jja} + b\,\Delta P_{yr}$$

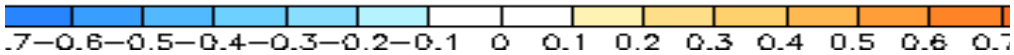
Corr. = 0.97 and RMSE = 25% of the stand. dev.



Time series of the GrIS SMB simulated by the **regional climate model MAR**

Results (25kmx25km) from the MAR model over 1970-1999



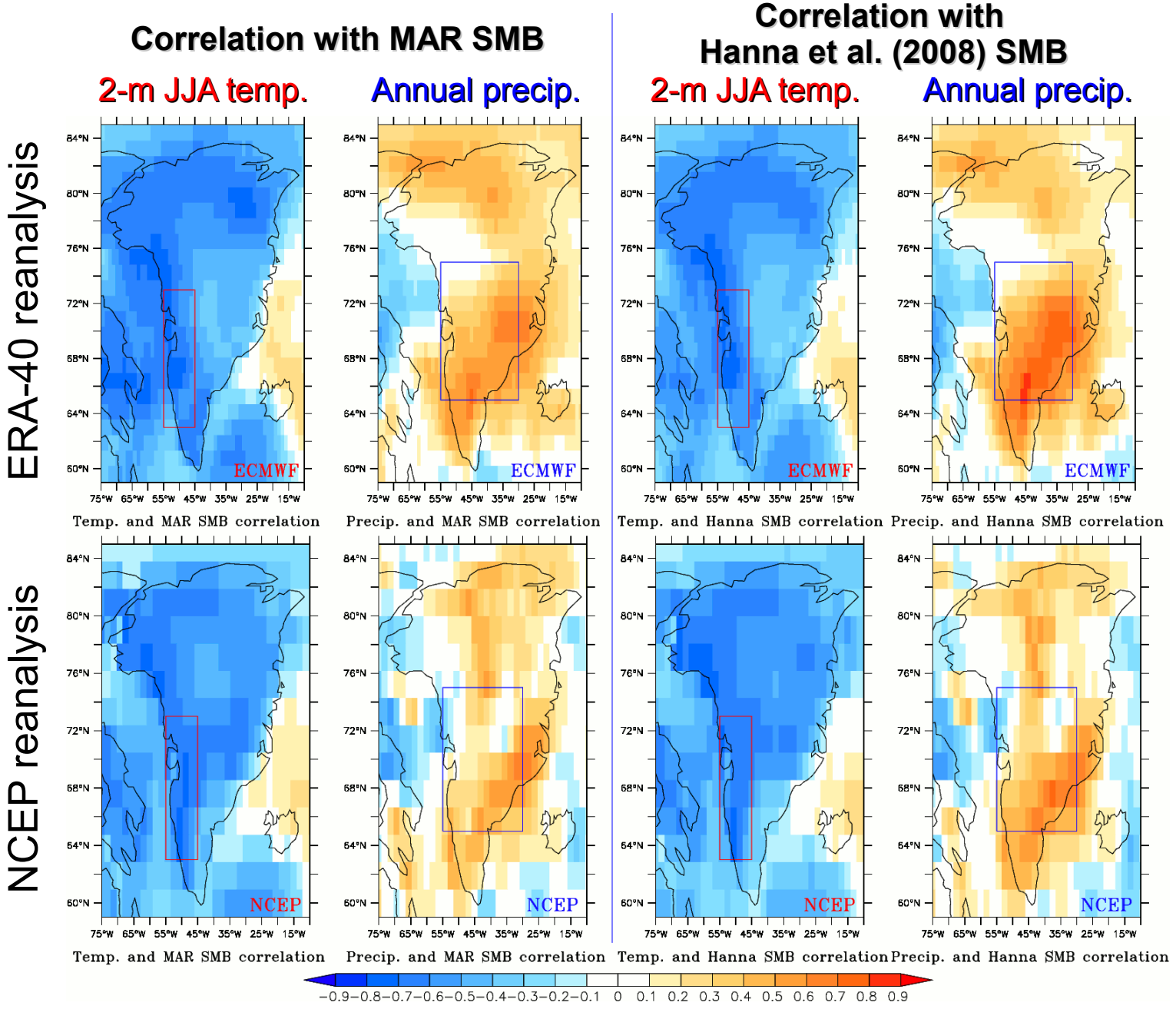


Correlation between the 3-m JJA Temp. and the whole GrIS SMB

Correlation between the annual precip. and the whole GrIS SMB

1. Method (2/3)

Reference period: 1970-1999

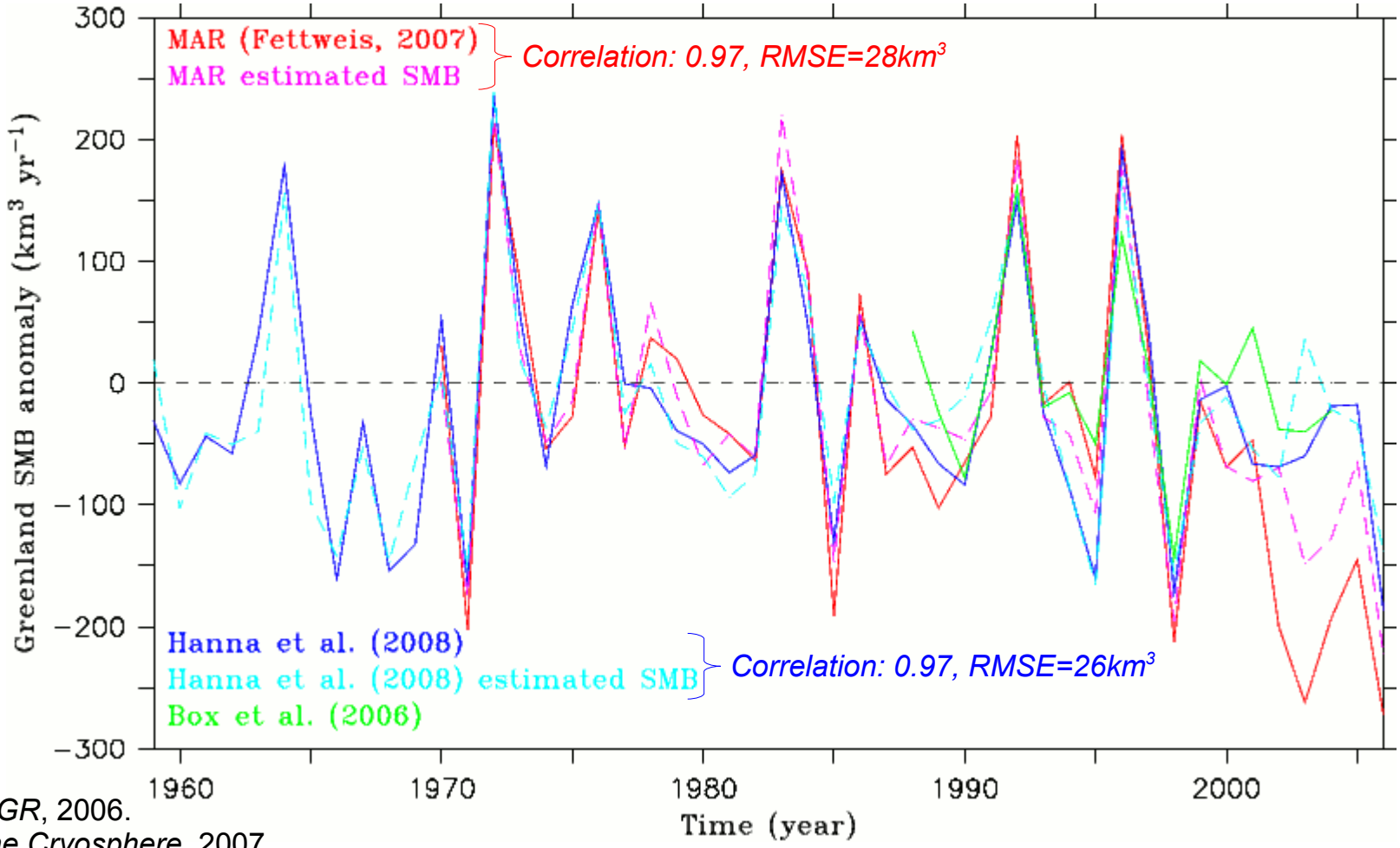


1. Method (3/3)

The parameter ***a*** and ***b*** are computed on the reference period (1970-1999).

$$\Delta SMB \approx a\,\Delta T_{jja} + b\,\Delta P_{yr}$$

The anomalies are taken in the 2 boxes defined earlier

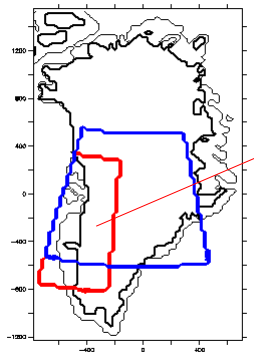


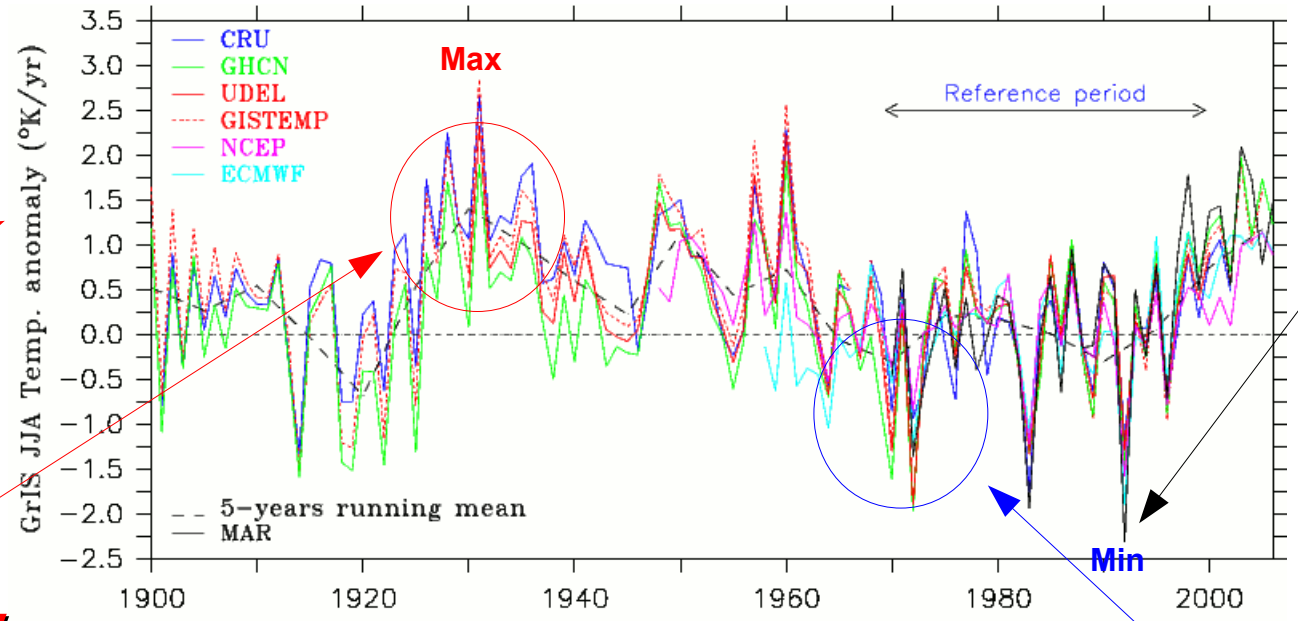
Reference period: 1970-1999

Reference:
Box et al., *JGR*, 2006.
Fettweis, *The Cryosphere*, 2007
Hanna et al., *J. of climate*, 2008.

2. The 1900-1999 SMB (1/2)

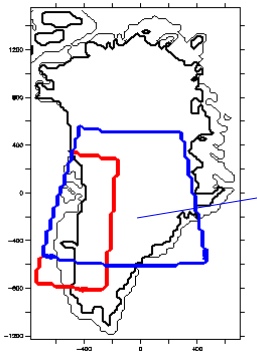
Reference period: 1970-1999

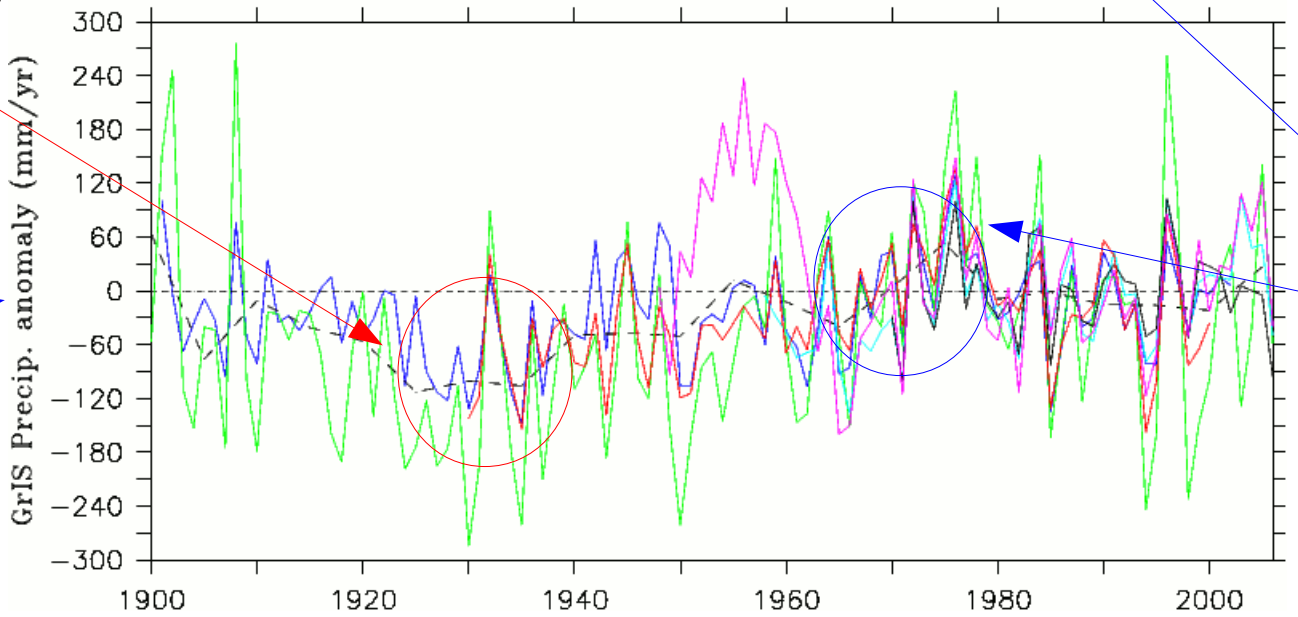




Mt. Pinatubo eruption

Warm and dry





Cold and wet

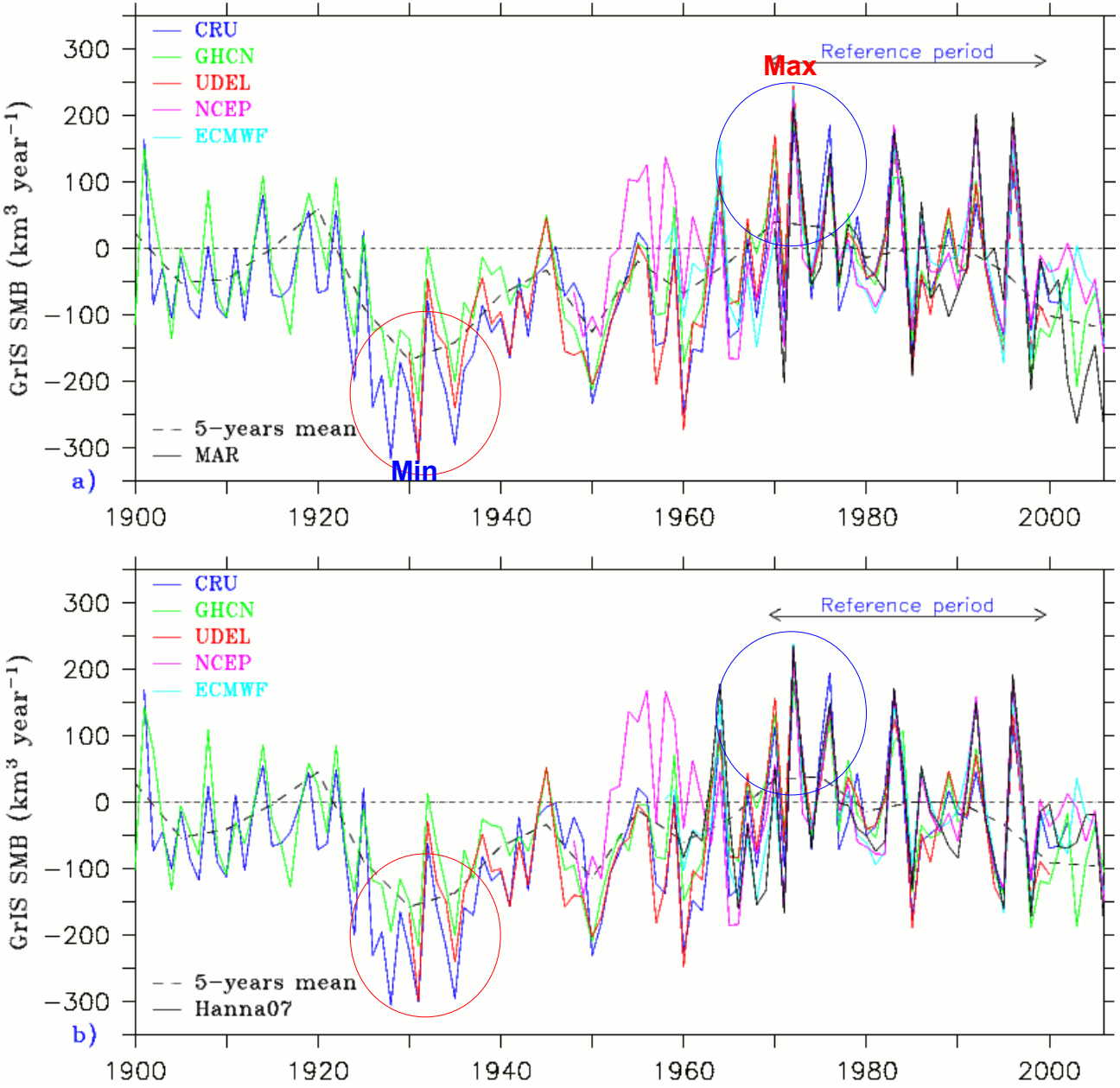
2. The 1900-1999 SMB (2/2)

Reference period: 1970-1999

The **MAR SMB time series** is used to determine the parameters *a* and *b*.
k = a/b ~ -1.5 if Δt_{jja}, $\Delta p_{yr} \in [-1,1]$

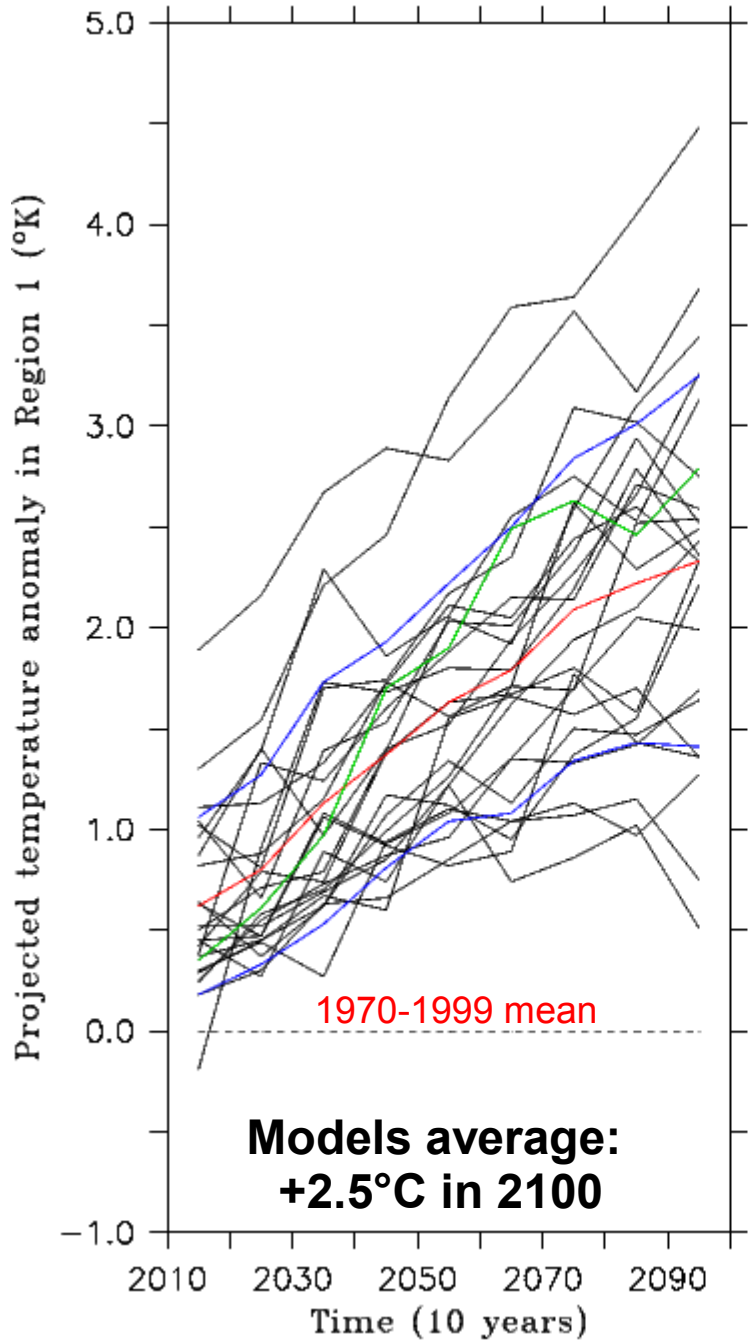
$$\Delta SMB \approx a\,\Delta T_{jja} + b\,\Delta P_{yr}$$

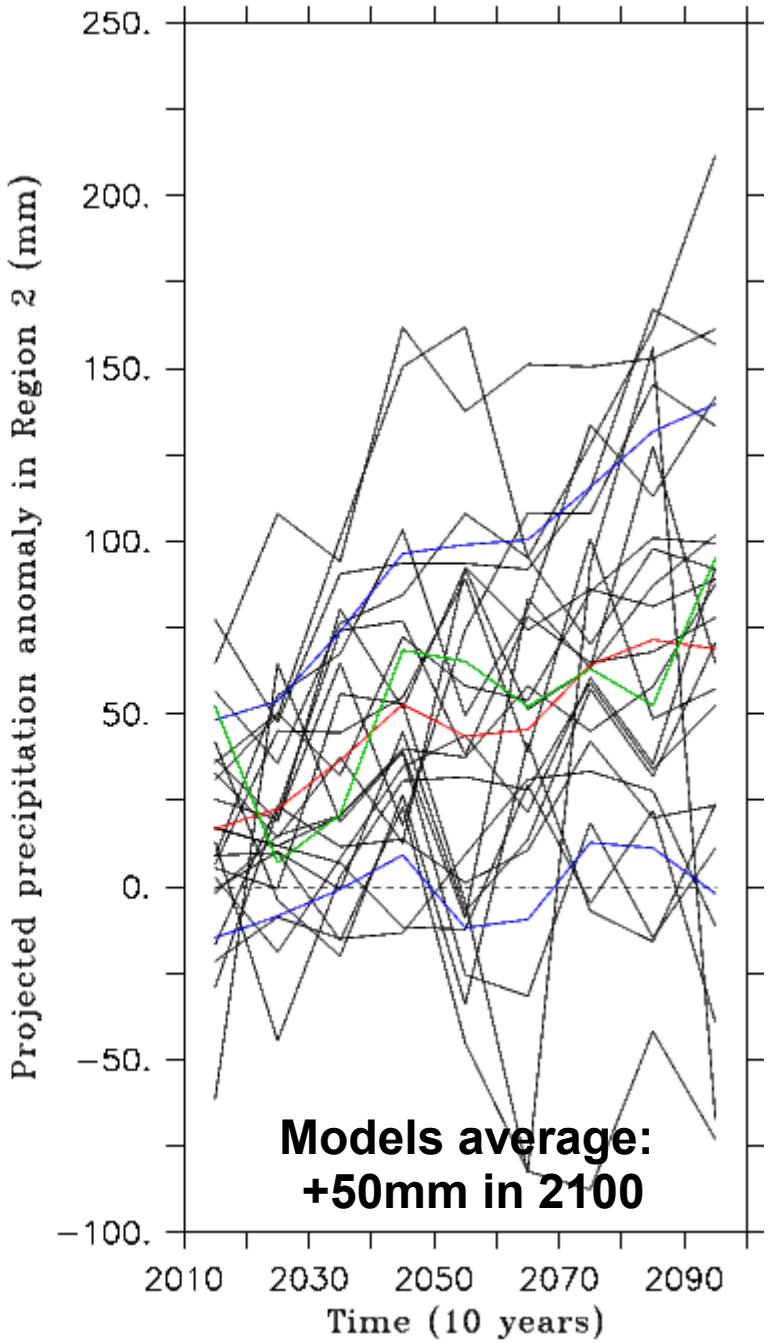
The **Hanna et al. (2008) SMB time series** is used to determine *a* and *b*.
k = a/b ~ -1 if Δt_{jja}, $\Delta p_{yr} \in [-1,1]$



3. The 21th century SMB changes (1/2)

Results from AOGCM's of the IPCC AR4





3. The 21th century SMB changes (2/2)

From the 20C3M experiment

$$\Delta SMB \approx a\,\Delta T_{jja} + b\,\Delta P_{yr}$$

1.

$$\overline{\Delta T} = \frac{1}{30}\sum_{i=1970}^{1990} \Delta T_i = \overline{\Delta P} = 0$$

$$\Delta T_i, \Delta P_i \in [-1,1]$$

2.

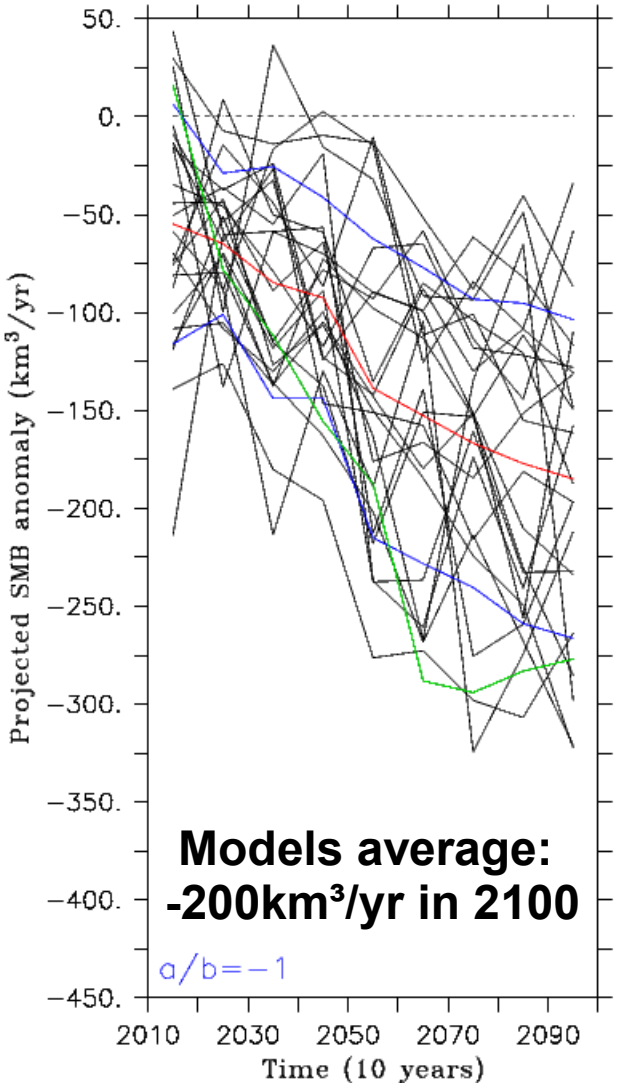
$$\sqrt{\sum_{i=1970}^{1990} a(\Delta T_i - \overline{\Delta T}) + b(\Delta P_i - \overline{\Delta P})}$$

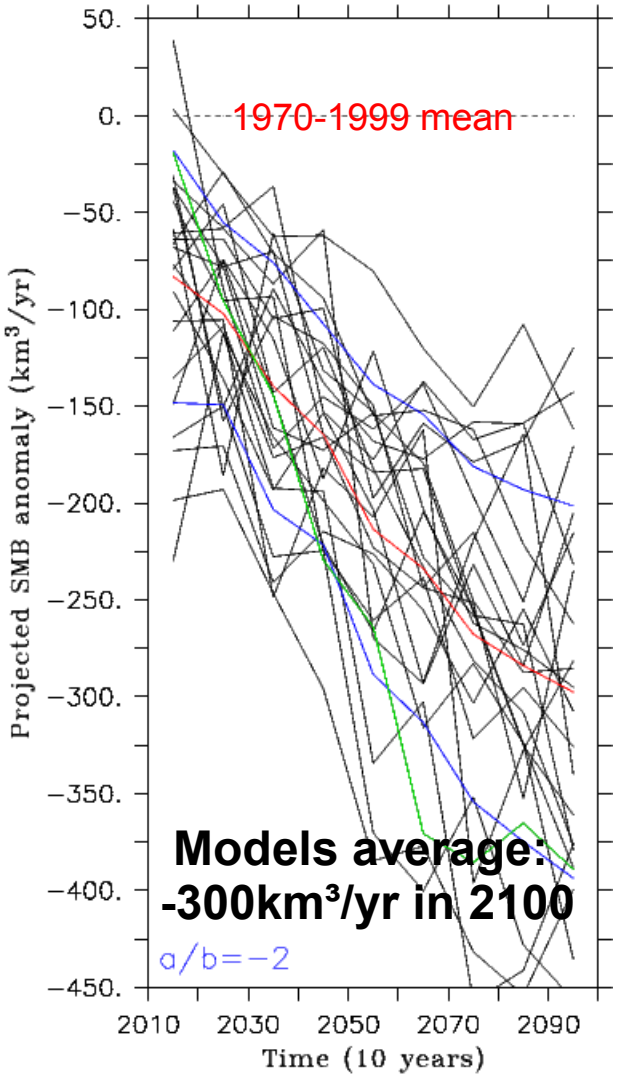
$$= a\sqrt{\sum_{i=1970}^{1990} (\Delta T_i + \frac{1}{k}\Delta P_i)}$$

= 100 km³/yr with **k=a/b**

3. The normalized factor as well as the parameter *a* computed for the 20C3M time series is used after with the A1B temp./precip. Anomalies time series.

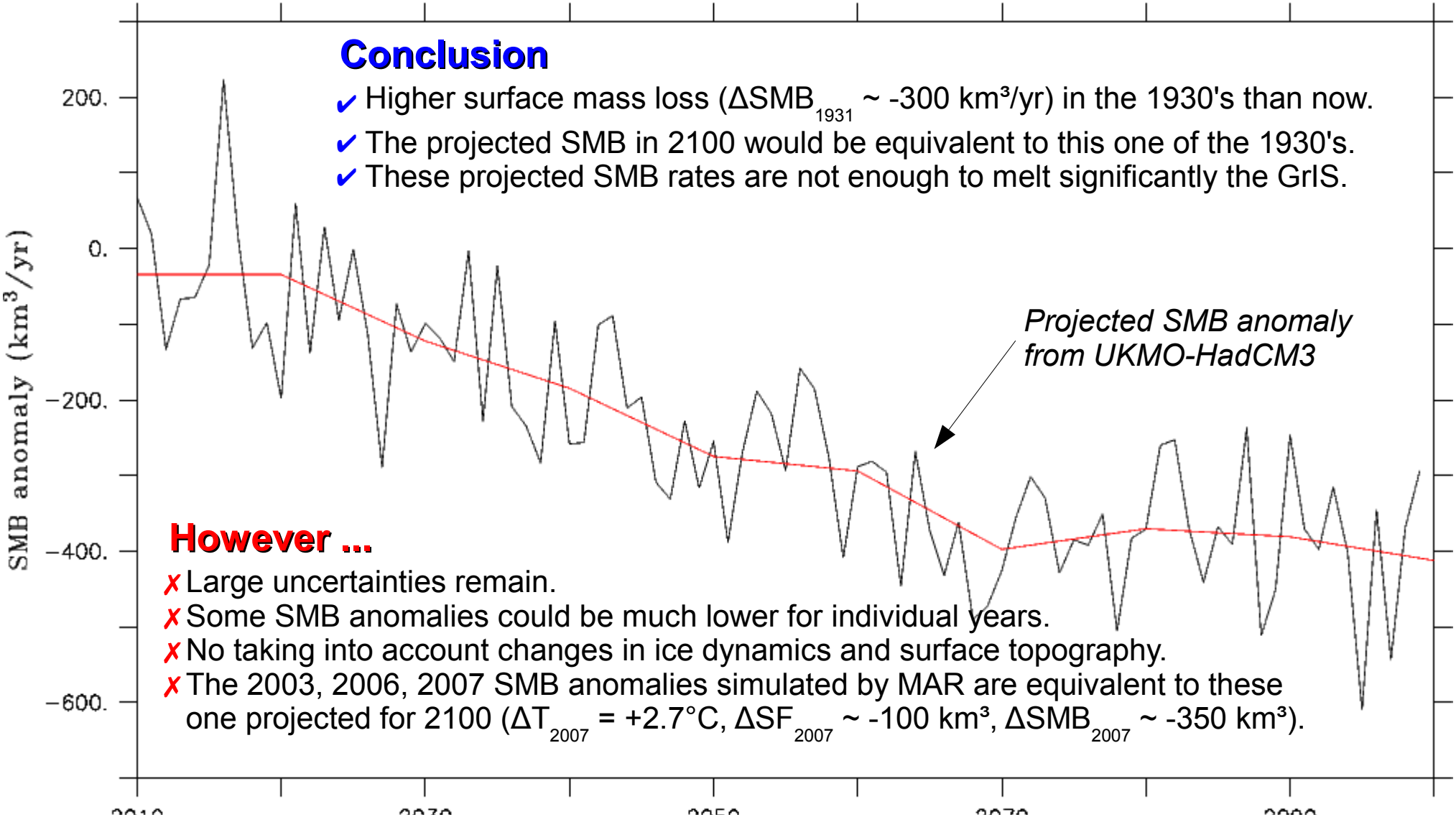
From the SRES A1B scenario





$$\Delta SMB_{1931} = -300 km^3/yr$$

4. Conclusion



Conclusion

- ✔ Higher surface mass loss (ΔSMB_{1931} ~ -300 km³/yr) in the 1930's than now.
- ✔ The projected SMB in 2100 would be equivalent to this one of the 1930's.
- ✔ These projected SMB rates are not enough to melt significantly the GrIS.

However ...

- ✗ Large uncertainties remain.
- ✗ Some SMB anomalies could be much lower for individual years.
- ✗ No taking into account changes in ice dynamics and surface topography.
- ✗ The 2003, 2006, 2007 SMB anomalies simulated by MAR are equivalent to these one projected for 2100 (ΔT_{2007} = +2.7°C, ΔSF_{2007} ~ -100 km³, ΔSMB_{2007} ~ -350 km³).

Further investigations are needed ...
(e.g. with a regional climate model)

Thanks for your attention !

Poster CR2-A0026 (Hall A, 10:30-12:00): Fettweis, X.; Gallée, H.; Tedesco, M.; Hanna, E.: Erpicum, M.
A record negative Greenland ice sheet surface mass balance rate in 2007.

Poster CR10-A0053 (Hall A, 17:30-19:00): Fettweis, X.
Impacts of ice sheet mask and resolution on estimating the surface mass balance of the Greenland ice sheet.