# Estimating Greenland ice sheet surface mass balance contribution to future sea level rise using the regional climate model MAR

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Vienna, 10.04.2013

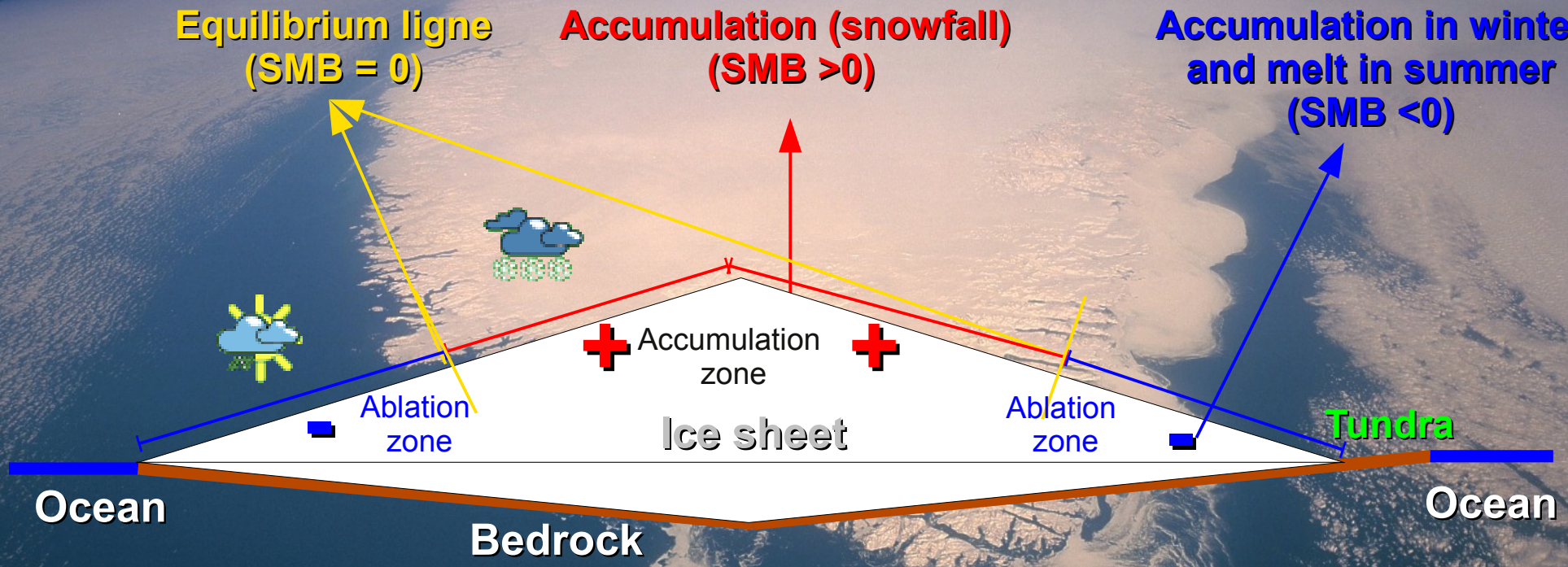
# Plan

1. Introduction
2. Current climate
3. Future climate
4. Feedback elevation ?
5. Atmospheric Circulation change ?

**Reference:**
Fettweis, X., Franco, B., Tedesco, M., van Angelen, J. H., Lenaerts, J. T. M., van den Broeke, M. R., and Gallée, H.: Estimating the Greenland ice sheet surface mass balance contribution to future sea level rise using the regional atmospheric climate model MAR, *The Cryosphere*, 7, 469-489, doi:10.5194/tc-7-469-2013, 2013.

# 1. Introduction

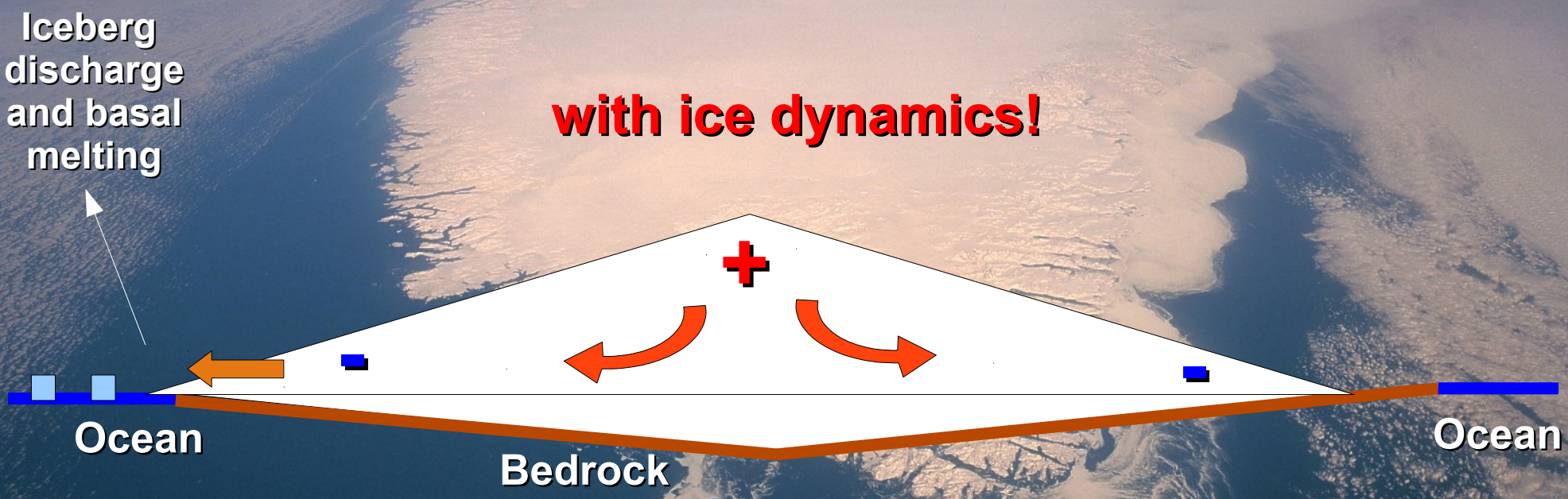
**Surface Mass Balance (SMB) ~ accumulation – meltwater run-off**



# 1. Introduction

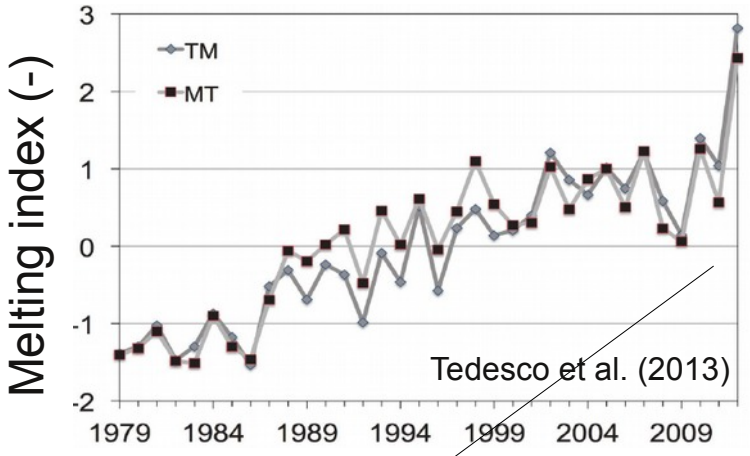
**Ice sheet Mass Balance (IMB) ≃ accumulation – runoff – iceberg calving**

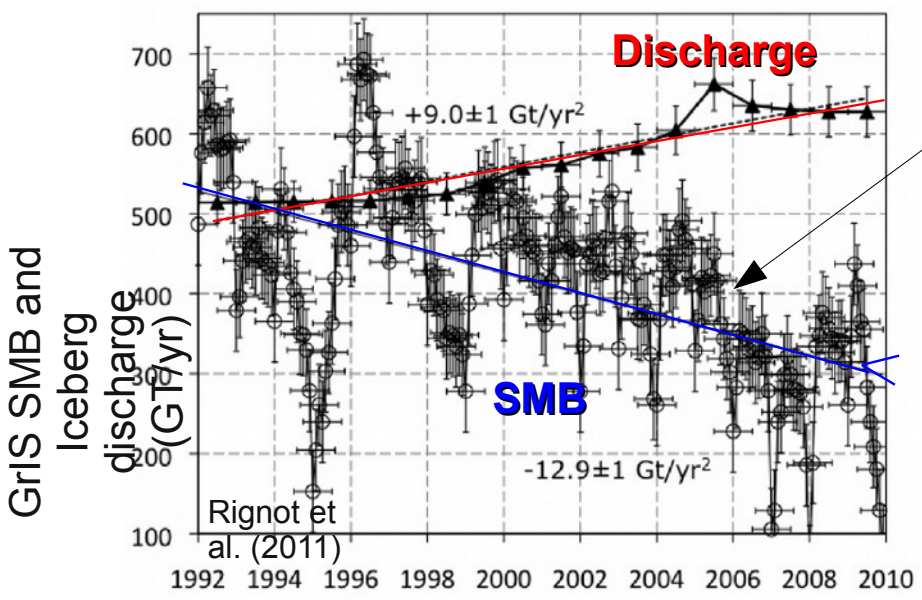
**IMB ~ 0 until the 90s !**



# 1. Introduction

**Since the 90s,** **Discharge ↗** **SMB ↘** ➡ **IMB < 0 !** **SLR > 0 !**



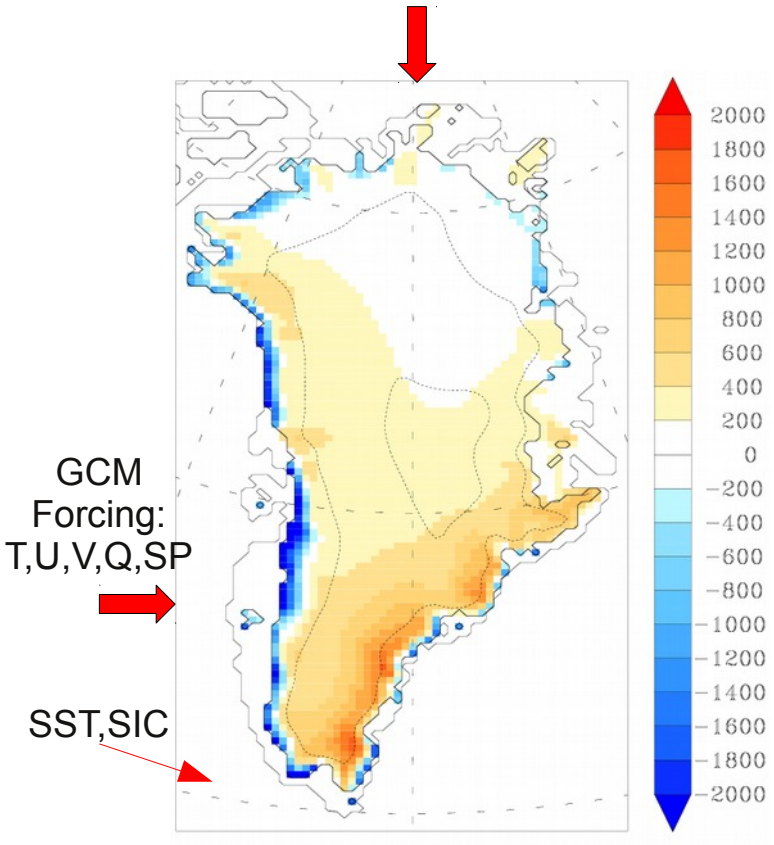

***360 GT ~ 1 mm sea level equivalent***

**Future projections of SMB ?**

**The current highest mass loss rates are observed over the Greenland ice sheet (GrIS) !**

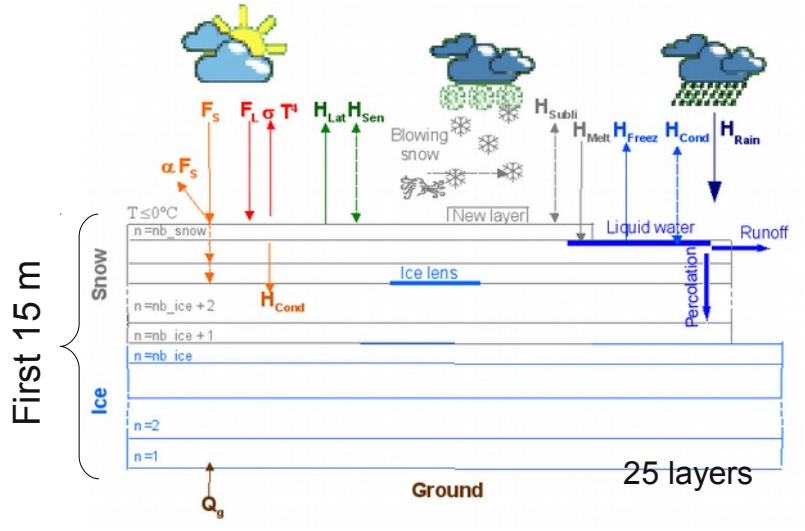
# 1. Introduction: MAR

Laboratoire de Glaciologie et Géophysique de l'Environnement
Hubert Gallée




*1980-1999 annual SMB (mmWE/yr)*
*at a resolution of 25 x 25 km*

## Regional climate model **MAR** full coupled with a snow energy balance model



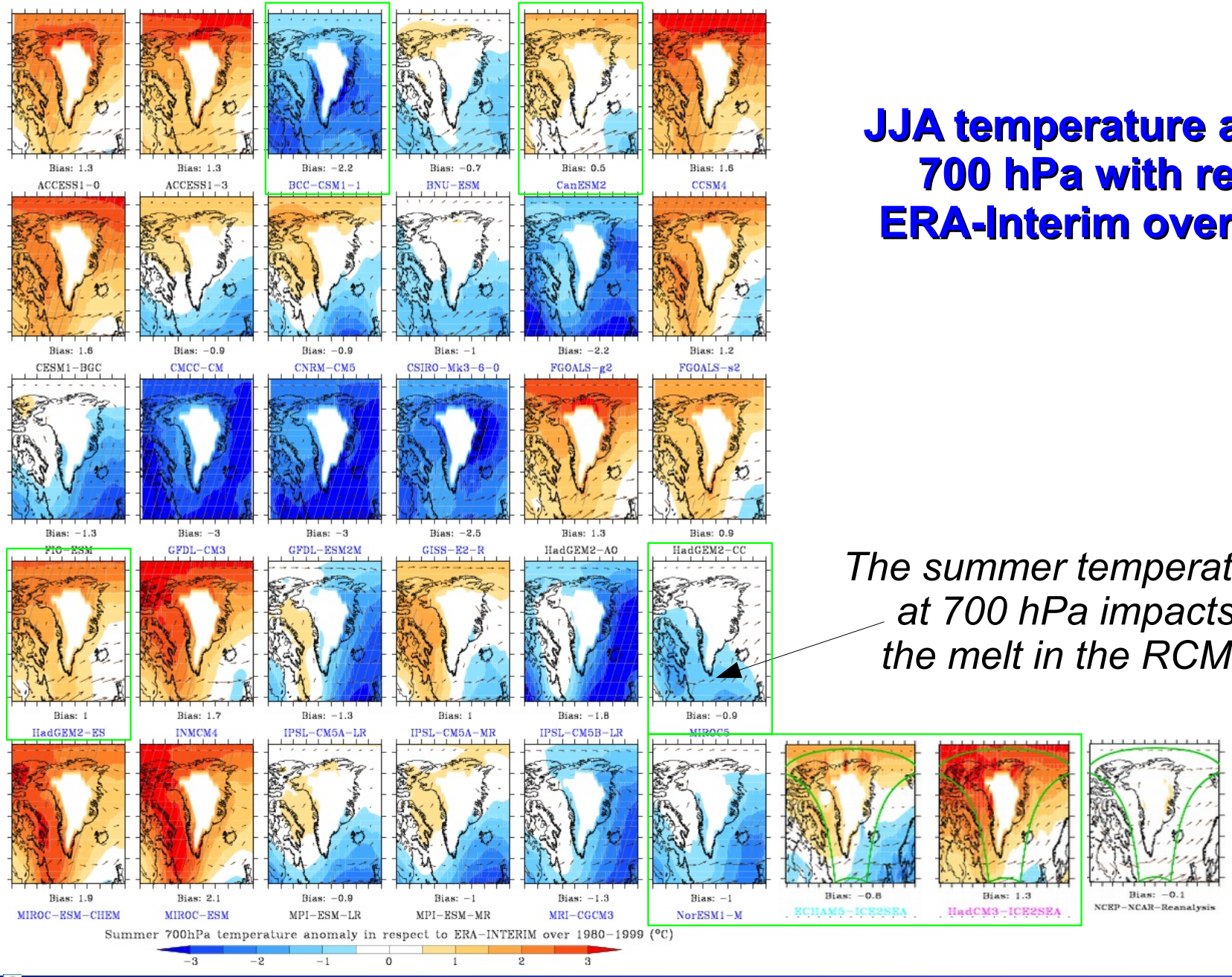

**Validation**

**SMB**: Tedesco et al. (2011), Franco et al. (2012), Rae et al. (2012), Vernon et al. (2013)
**Temperature**: Lefebre et al. (2005), Tedesco et al. (2012), Box et al. (2012),...
**solar radiation**: Box et al. (2012)
**melt extent**: Fettweis et al. (2006, 2007, 2011)
**Albedo**: Lefebre et al. (2003), Fettweis et al. (2005)

- MAR focuses only on the Surface Mass Balance (**SMB**) because it is not coupled with an ice sheet model (the topo is fixed)!
- MAR needs forcing from a GCM at its lateral boundaries + SST + sea ice.

**RCM** = regional climate model , **GCM** = general circulation model

# 2. Current climate: GCM (1/3)



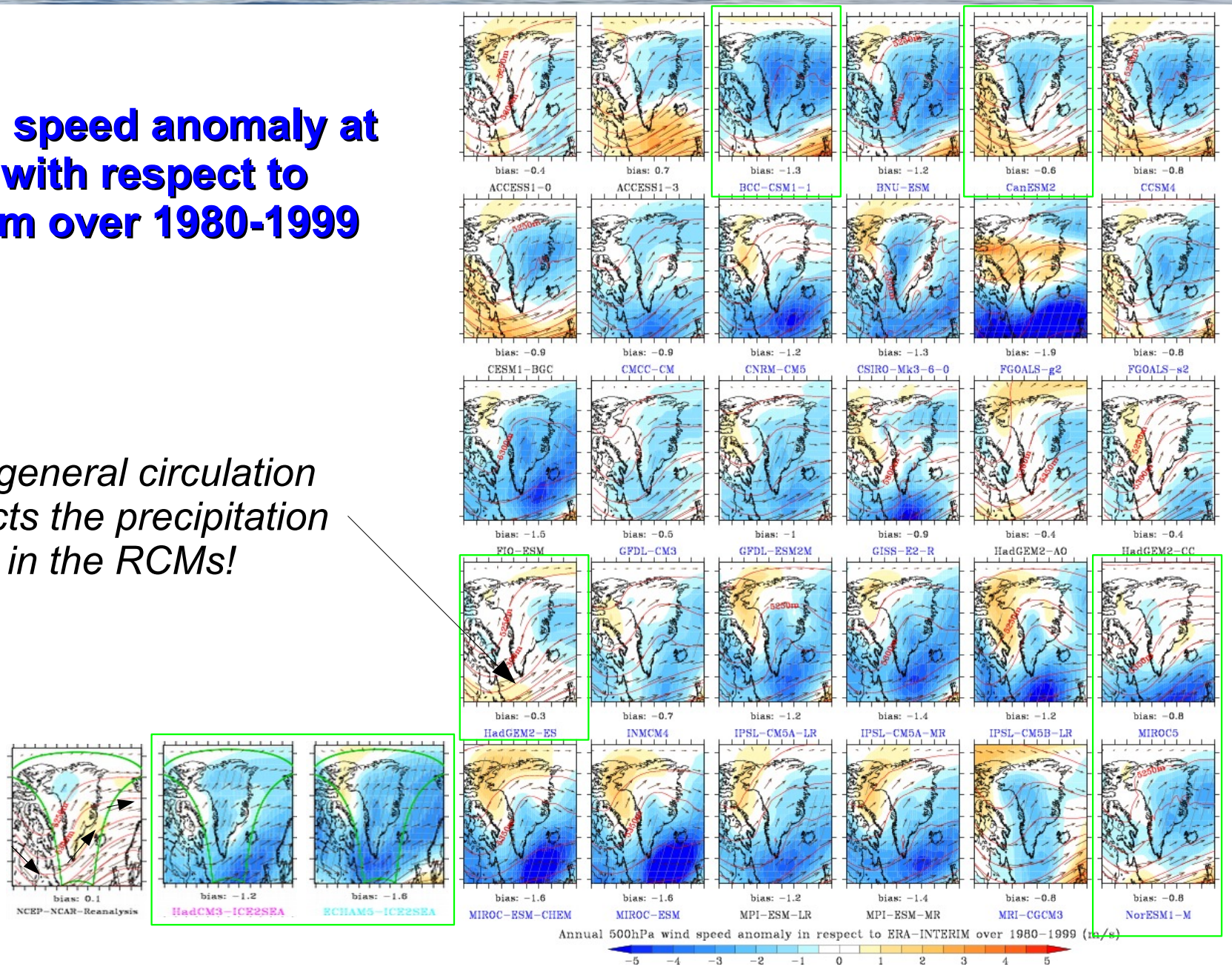

**JJA temperature anomaly at 700 hPa with respect to ERA-Interim over 1980-1999**

*The summer temperature at 700 hPa impacts the melt in the RCMs!*

# 2. Current climate: GCM (2/3)

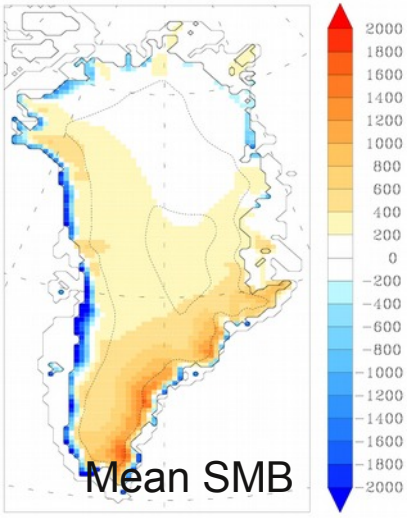
**Annual wind speed anomaly at 500 hPa with respect to ERA-Interim over 1980-1999**

*The general circulation impacts the precipitation in the RCMs!*

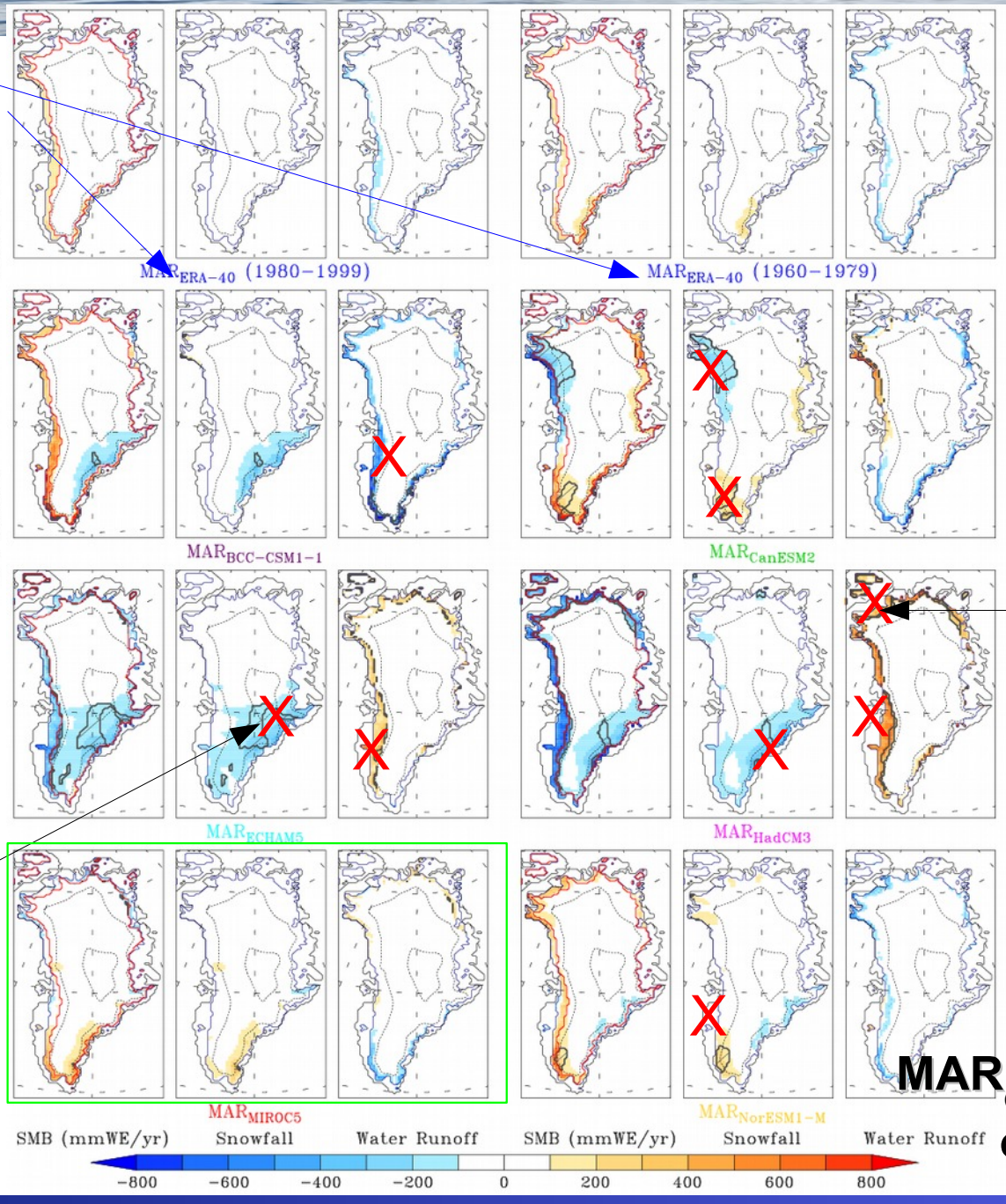


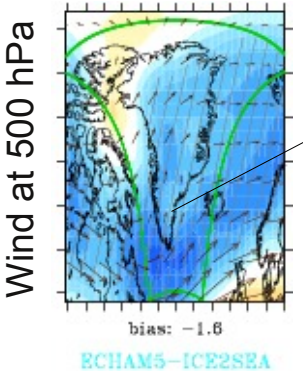
# 3. Current climate: MAR (3/3)

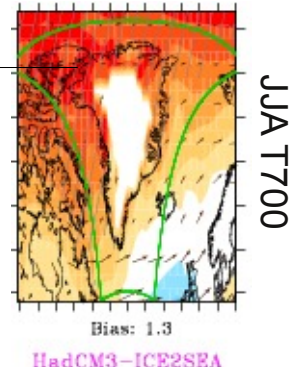
*Independence of the reference period*




$MAR_{ERA\text{-}INTERIM}$ over 1980-1999 (mmWE/yr)

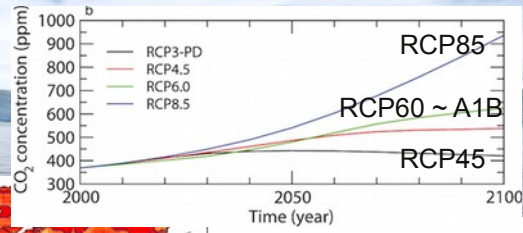


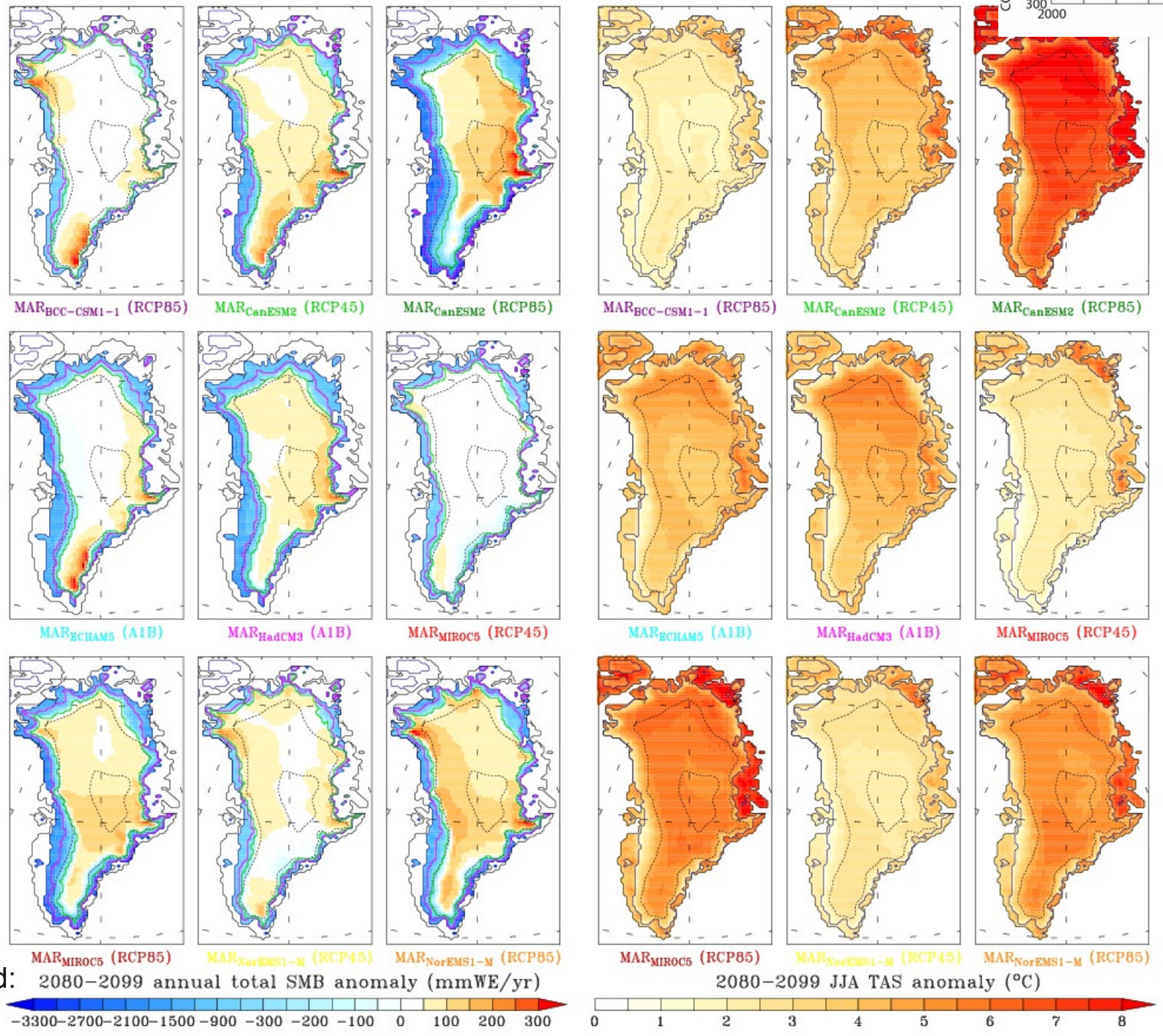

**$MAR_{GCM}$ vs $MAR_{ERA\text{-}INTERIM}$ over 1980-1999**

# 3. Future climate (1/5)




2080-2099 annual SMB anomaly (mmWE/yr)

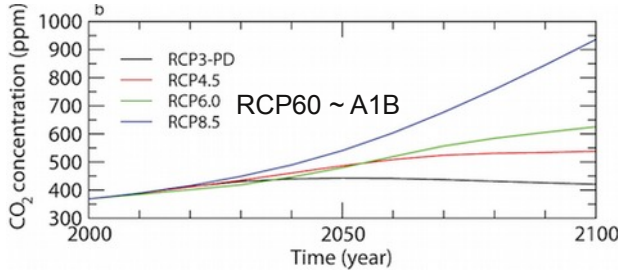
2080-2099 JJA near-surface temperature anomaly (°C)



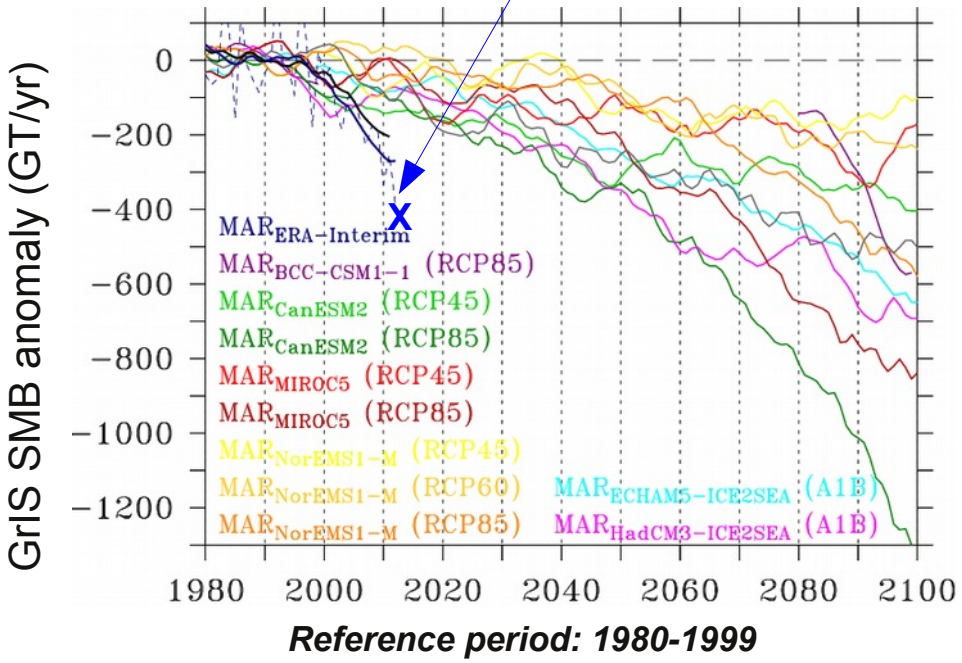

Reference period: 1980-1999

# 3. Future climate (2/5)

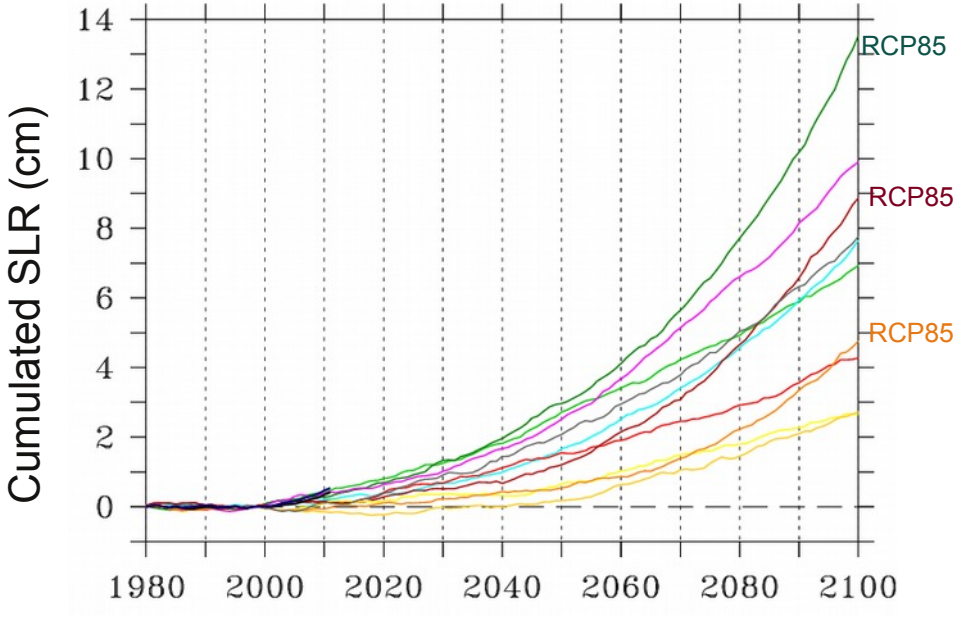
## GrIS SMB time series and corresponding SLR




SMB ~ 0 GT/yr in 2012




*Reference period: 1980-1999*



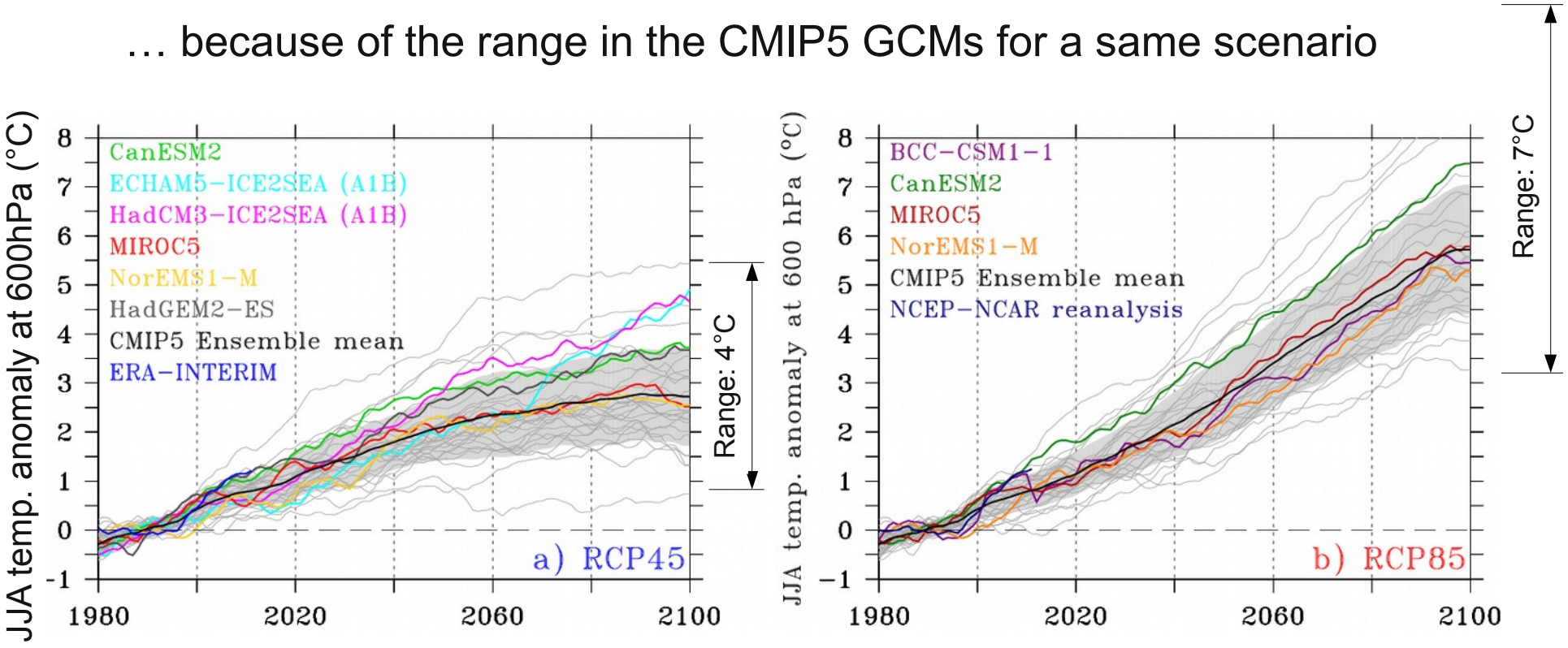

*- 361 GT/yr ~ + 1 mm SLR/yr*

***1. Why do these simulations fail to simulate the current SMB decrease ?***
***2. Why is the range for a same scenario so wide ?***

# 3. Future climate (3/5)

**Why are the MAR-based future projections so diverging ?**

… because of the range in the CMIP5 GCMs for a same scenario

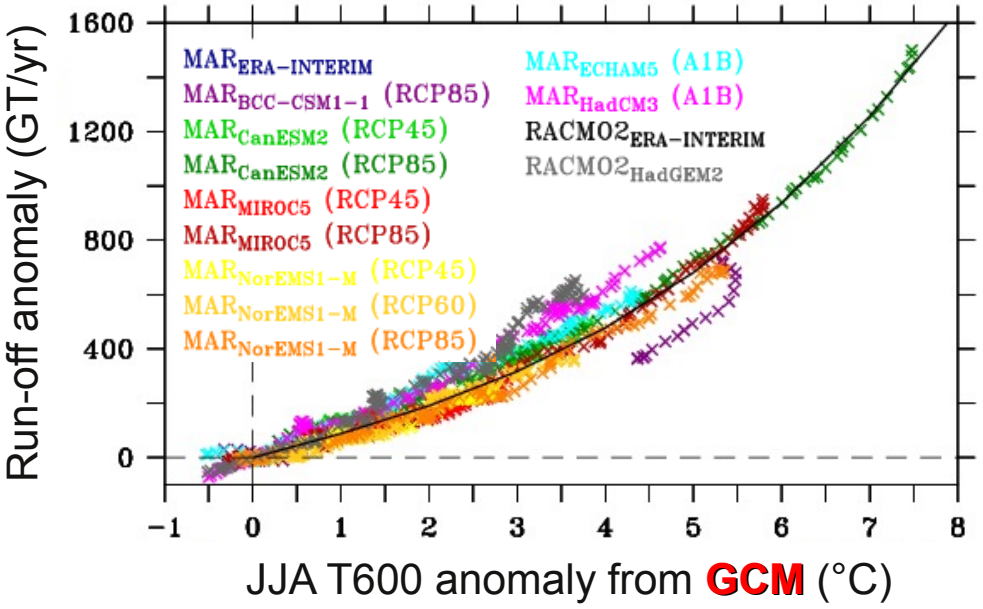



*The JJA temperature at 600 hPa above Greenland drives the surface melt variability.*

**Scatter plots of SMB vs temperature changes.**

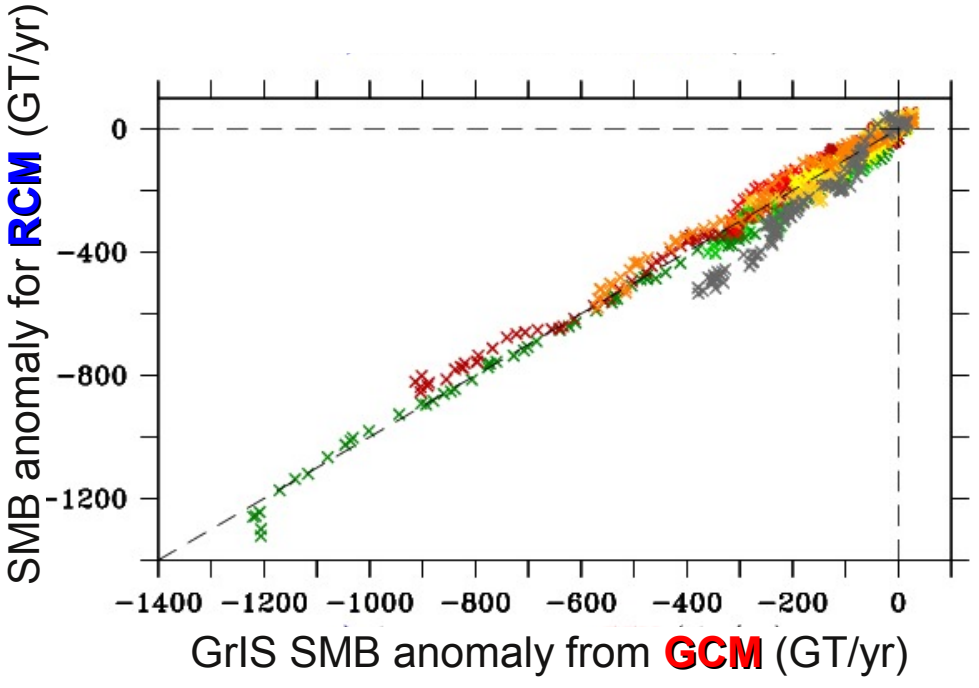
# 3. Future climate (4/5)

## Run-off vs Temperature anomalies




**1. Good consistence between the simulations because no circulation change is projected.**

**2. But depends on the ability to simulate the current melt.**

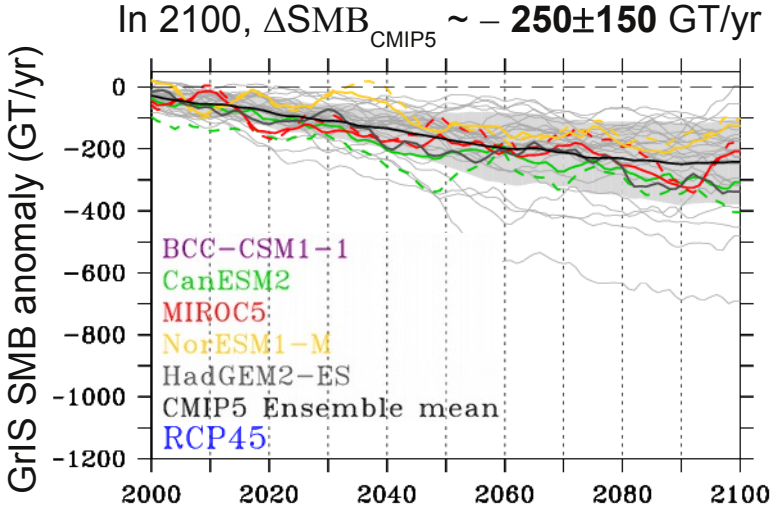


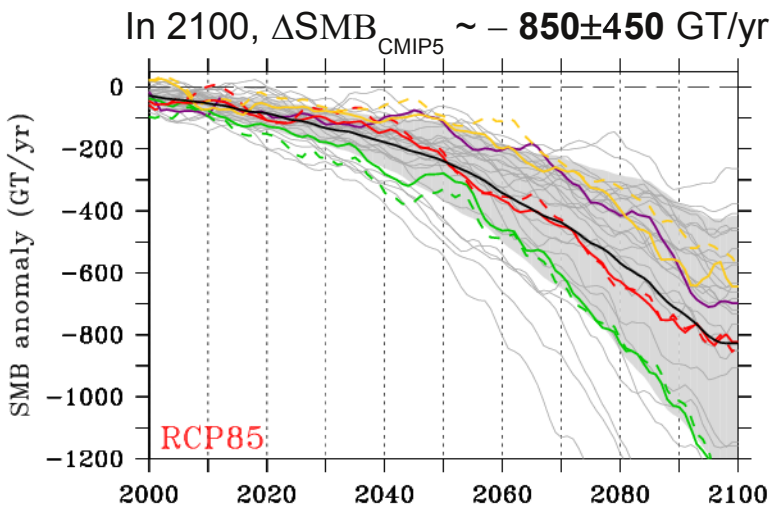

$$\Delta SMB_{CMIP5} \sim \Delta SF_{CMIP5} - \Delta RU(\Delta T600_{CMIP5})$$

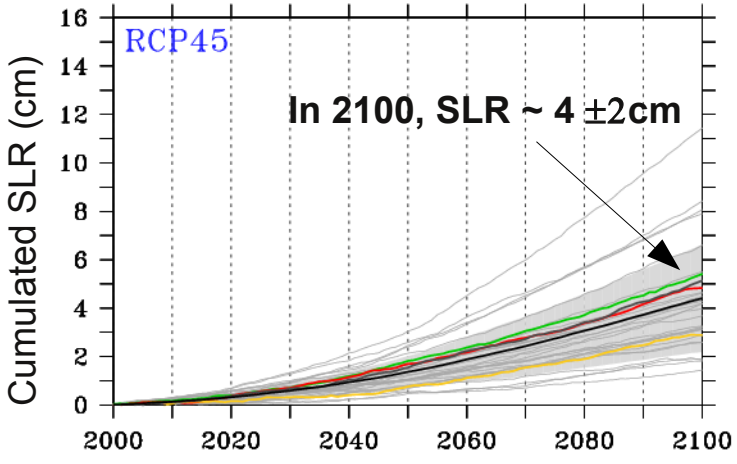
*where ΔSF and ΔT600 are taken in the area 60°N-80°N, 60°W-20°W covering the Greenland ice sheet.*

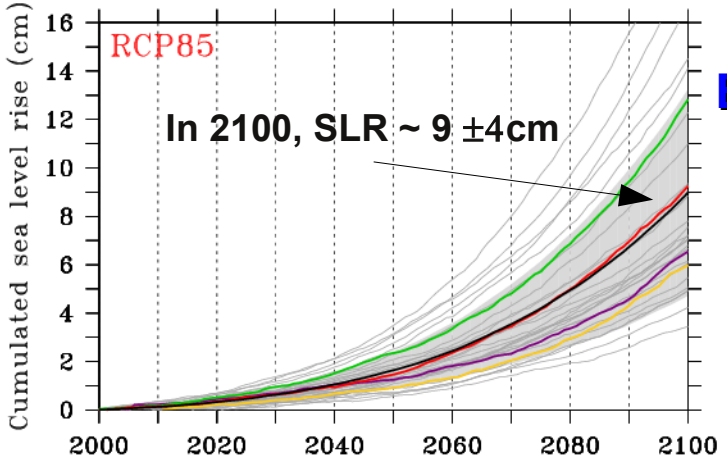
# 3. Future climate (5/5)

## Uncertainties in our future projections




**Uncertainties:**

**GCMs ~ 50 %**

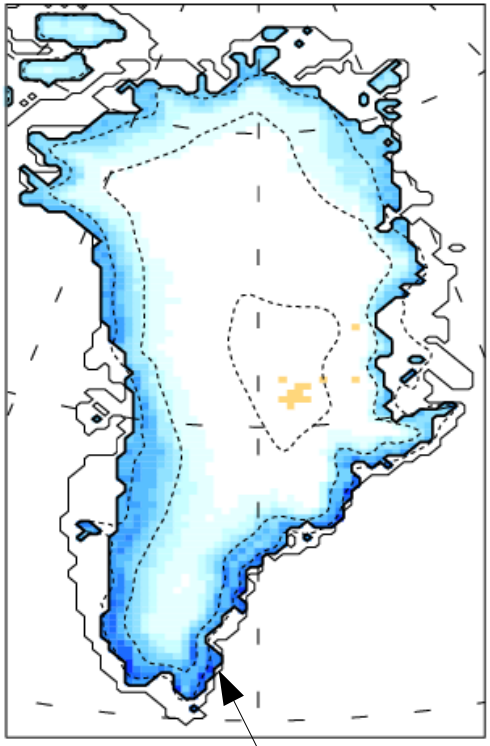
**MAR ~ 10%**
(Vernon et al., TC, 2013)

**Elev. feedback ~ - 10 %**

***GrIS SMB anomaly and SLR from all CMIP5 models***

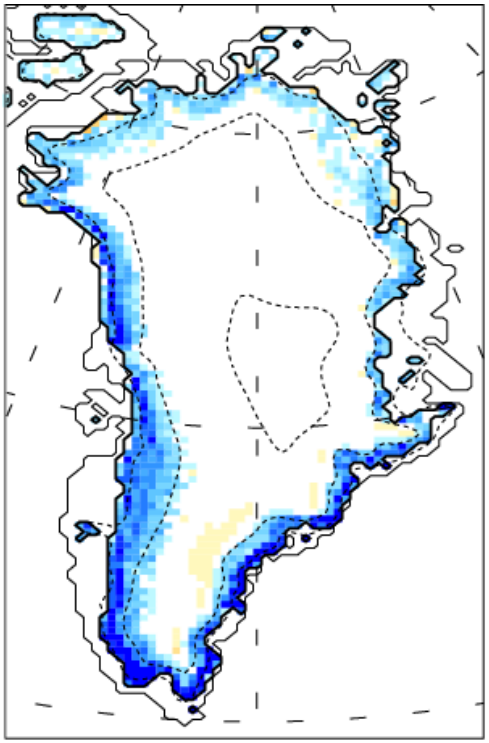
# 4. Elevation feedback ? (1/2)

## SMB changes over 2080-2099 using a perturbed topography

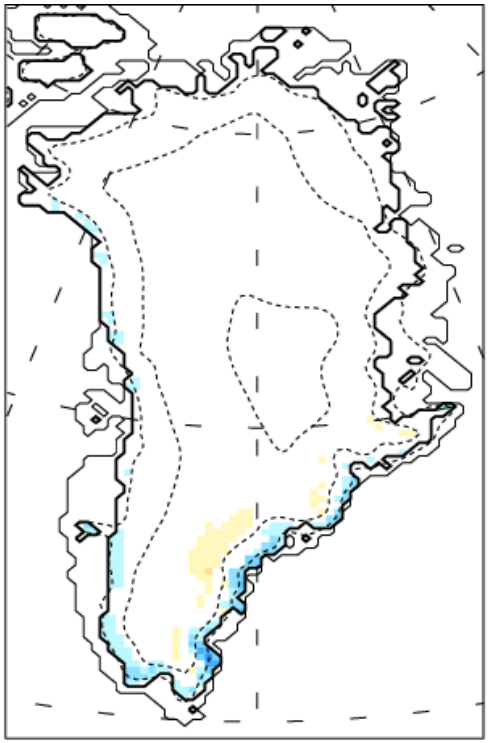


Topography changes (m)

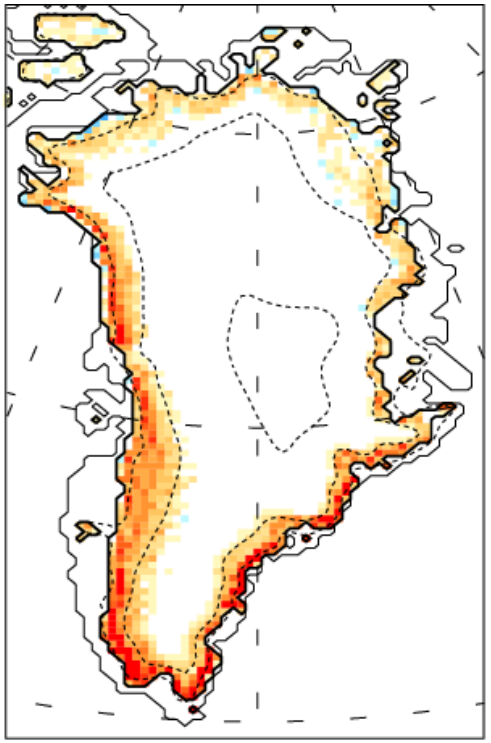
−100 −80 −60 −40 −20 0 20



SMB anomaly (mmWE/yr)



Snowfall anomaly



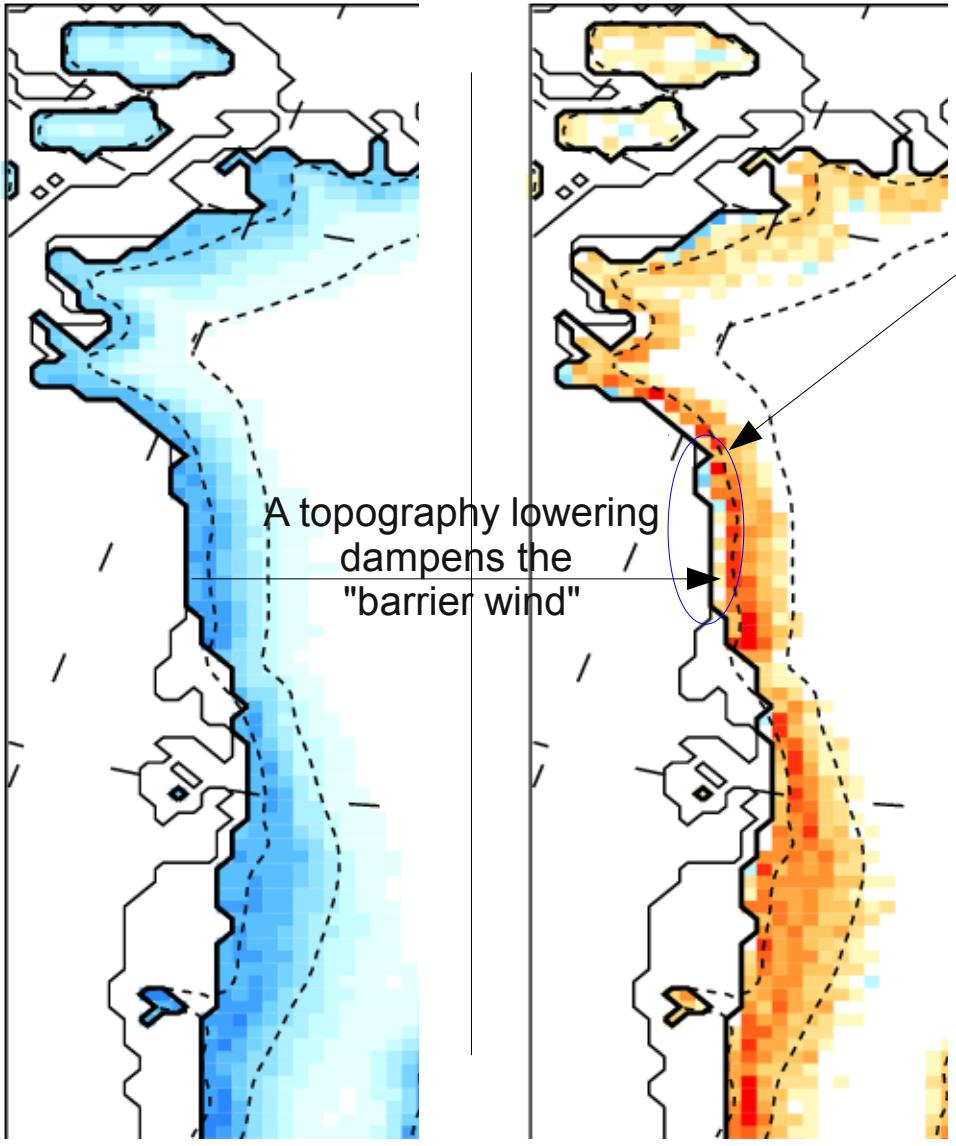
Run-off anomaly

−200 −160 −120 −80 −40 0 40 80 120 160 200

Topography changes equivalent to the cumulated surface height anomaly from 2000 to 2080 simulated by MAR forced by MIROC5 (RCP85)

**With elevation feedback**
**ΔSMB – 5-15 %**

# 4. Elevation feedback ? (2/2)




Topo anomaly

Run-off anomaly

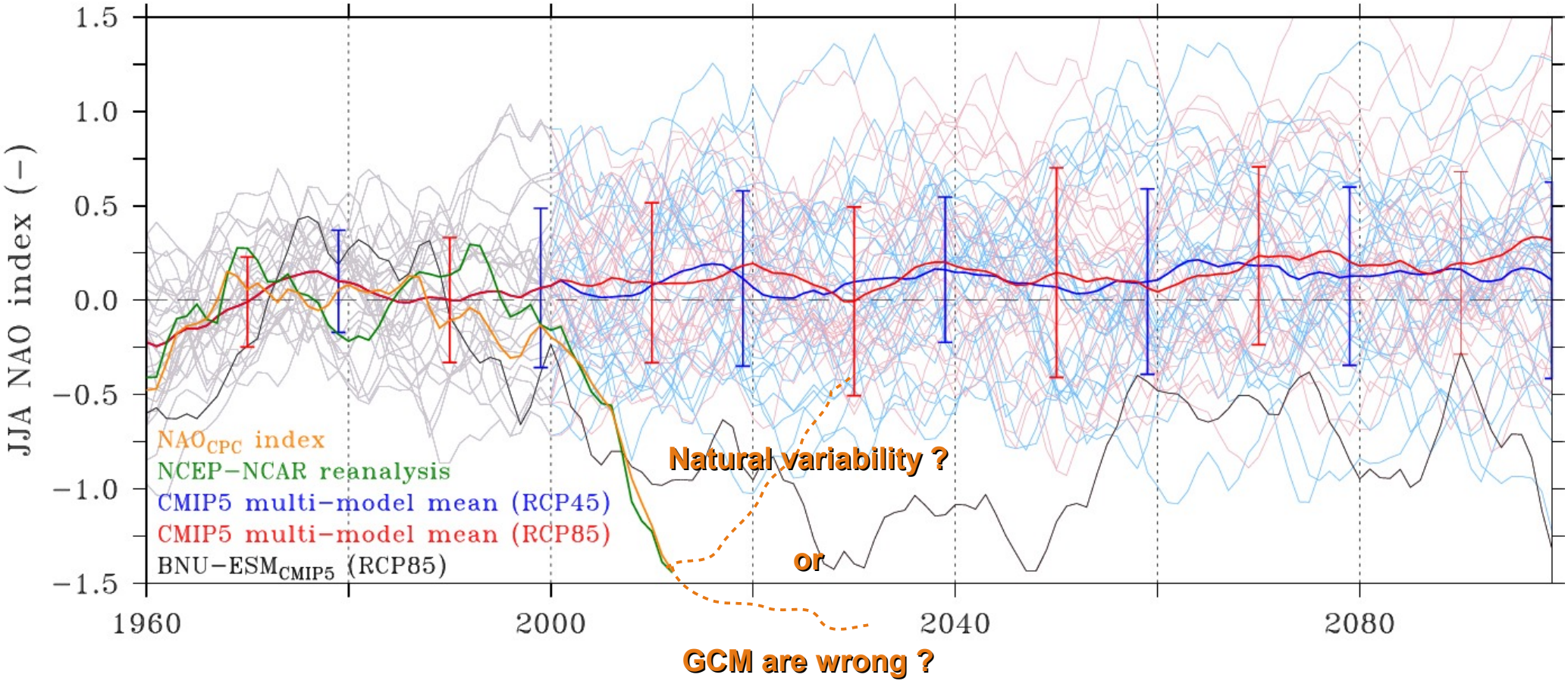
Run-off decrease !!

**Δ SMB vs Δ Topo**
**is highly non-linear !!**

**A coupling with an**
**ice sheet model is needed.**

# 5. Circulation changes ? (1/3)

Why don't our projections simulate the 2000's melt acceleration ?



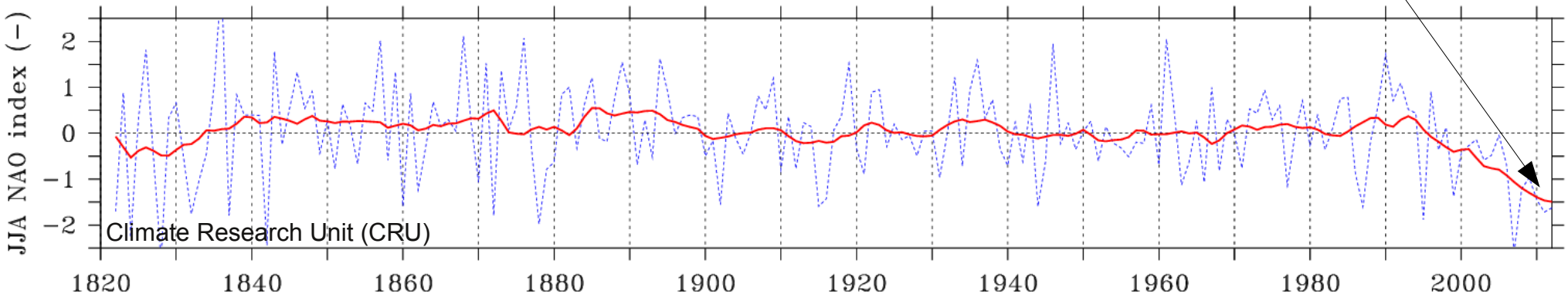

**The CMIP5 GSMs do not project changes in the general circulation/NAO!**

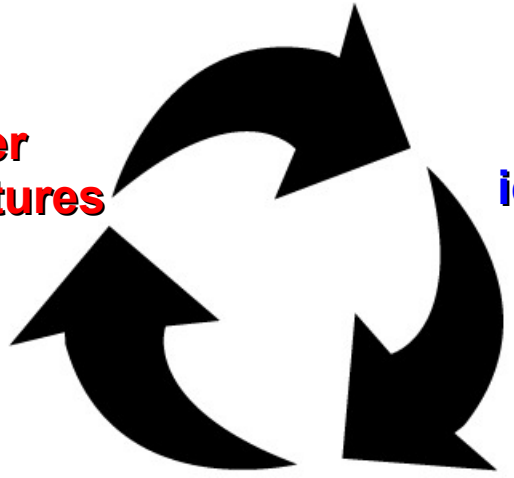
**Reference:** Fettweis, X., Hanna, E., Lang, C., Belleflamme, A., Erpicum, M., and Gallée, H.: Brief communication "Important role of the mid-tropospheric atmospheric circulation in the recent surface melt increase over the Greenland ice sheet", *The Cryosphere*, 7, 241-248, 2013.

More derails: see Poster CR3.2-B577 on Thursday (17h30-19h)

# 5. Circulation changes ? (2/3)

*The probability of such a succession is quasi null!*



**higher temperatures**

**higher SST**
**lower sea ice cover (SIC)**

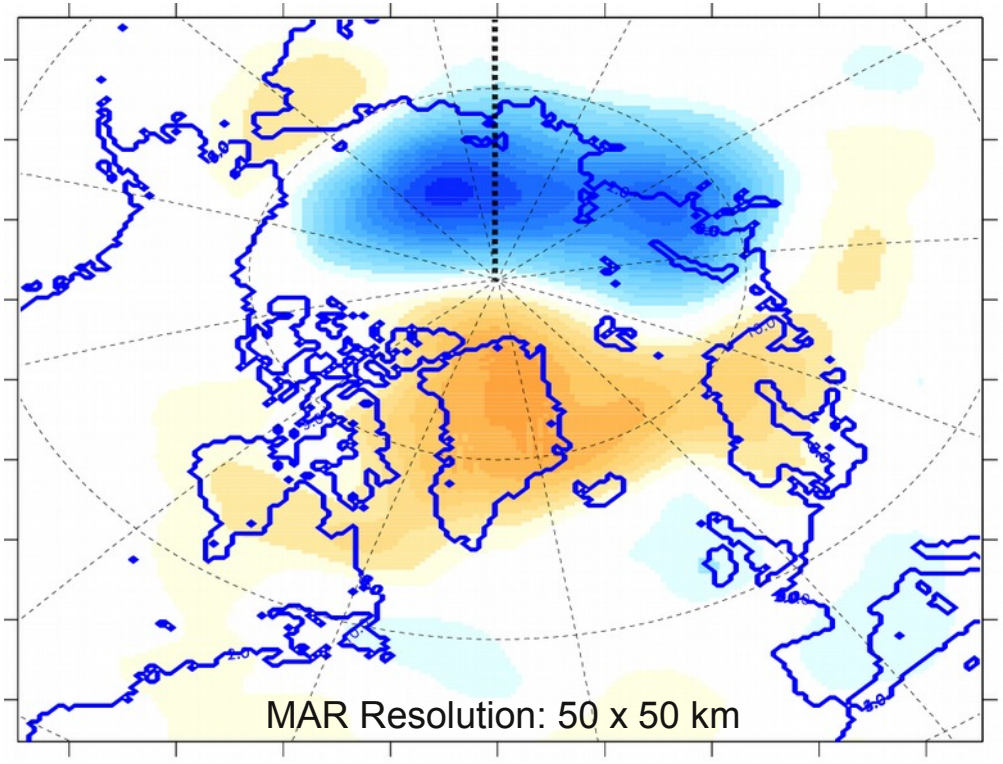
**circulation change (NAO < 0)**

***What about this positive feedback ?***

Pan (2005): Observed positive feedback between the NAO and the North Atlantic SSTA tripole, GRL.
Strong et al. (2009): Observed Feedback between Winter Sea Ice and the North Atlantic Oscillation, J. Climate.

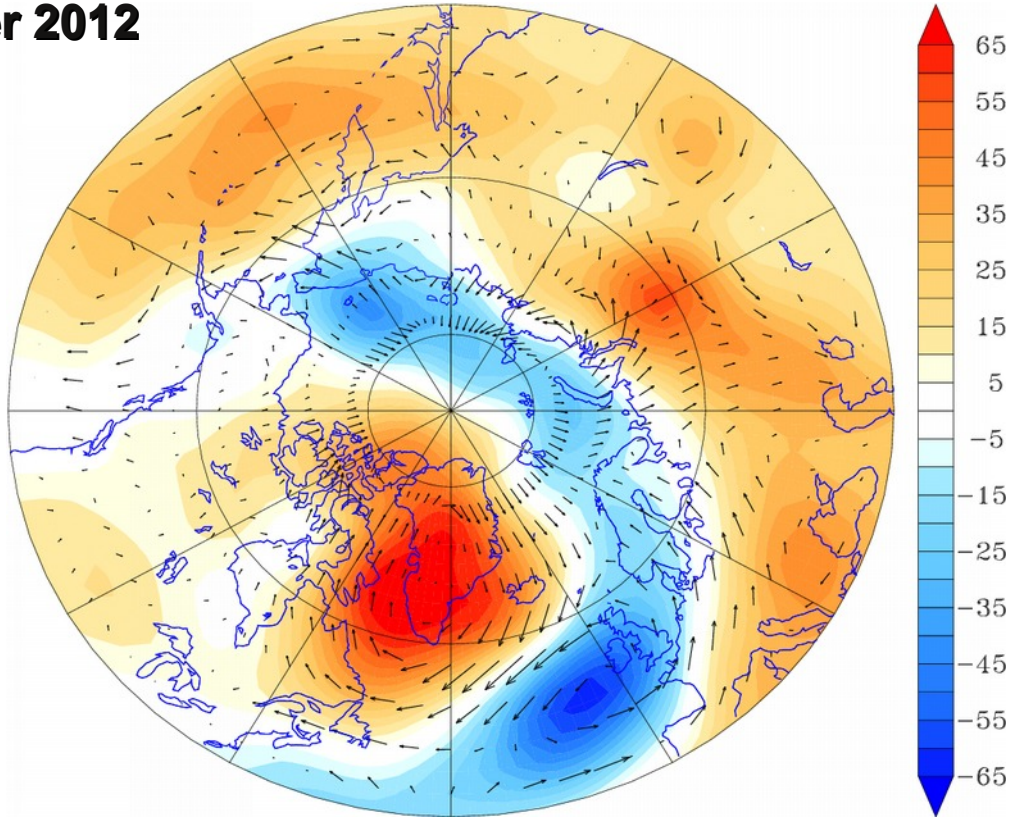
# 5. Circulation changes ? (3/3)

**MAR seems to suggest that this SST-NAO feedback played a role over last summer!**




*Geopotential height (Z500) anomaly at 500 hPa simulated by MAR with respect to a MAR sensitivity experiment using the 1980-1999 averaged SST/SIC.*

**Summer 2012**




*Summer 2012 Z500 anomaly with respect to 1980-1999.*

## Conclusions:

- Large range in the SMB future projections due mainly to CMIP5-based uncertainties. In 2100, SLR from GrIS SMB: 2-20cm!!
- Importance of well simulating the current climate.
- The elevation feedback needs to be taken into account explicitly because it is not a positive feedback along the ice sheet margin !
- The current climate changes over Greenland are underestimated by the GCMs.

## Next steps:

- Coupling MAR with ice sheet models (VUB, LGGE?, NASA-JPJ?) by using future scenario from MIROC5 for estimating ice sheet mass balance changes.
- More research is needed about the NAO-SST feedback.

# Thanks !