Evaluation of summer Greenland blocking index of the CMIP6 models

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1. Introduction

An extreme melting event occurred this summer 2019 over Greenland as a result of abnormal anticyclonic conditions (Tedesco *et al.*, 2019).

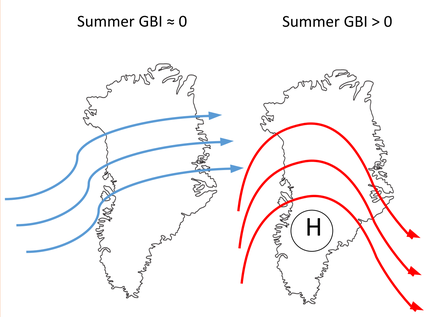

Figure 1. Representation of synoptique situation during summer over Greenland with a) GBI ≈ 0 and 2) GBI > 0

- Warm and moist air from W → N
- Solar radiation absoption
  → **melt-albedo feedback**

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- **Blocking events (Fig. 1)**
- More and more frequent over the past 20-years

- Reflect a change in the mean atmospheric summer circulation
- One of the main contributors to surface melt acceleration (Fettweis *et al.*, 2013).

←

- Circulation change is **not predicted by CMIP5** ESMs (Hanna *et al.*, 2018)
- Greenland SMB projections may be **underestimated by a factor of two** (Delhasse et al., 2018).

Goals : ability of CMIP6 Earth System Models (ESMs) 1) to represent the current increase of Greenland blocking and 2), to predict any circulation changes until 2100.

2. Methods

- The Greenland blocking index (**GBI**) is used to assess the representation in **CMIP6** (ssp585) and **CMIP5** (RCP85) simulations of the recent **summer (JJA)** blocking events compared to the NCEP/NCAR reanalyses :

$$\boldsymbol{GB1 = GBI = Z500\ (m)} \qquad (1)$$

- To avoid the influence of the global temperature increase (Fig. 2) and study only the dynamic changes that occur above Greenland, the **GB2** index is used:

$$\boldsymbol{GB2 = Z500_{GR} - Z500_{HN}} \qquad (2)$$

- The free-atmosphere temperature related to the GB2 region, **TA2** :

$$\mathbf{TA2} = \frac{(\mathbf{T850 + T700 + T500})_{GR}}{3} - \frac{(\mathbf{T850 + T700 + T500})_{NH}}{3} \qquad (3)$$

→ **TA1**

Where Z500 is the mean summer geopotential height at 500 hPa, Tx is the mean summer temperature at x hPa, GR means over Greenland (60–80 °N, 20–80 °W) and NH means over north hemisphere (60-80 °N).

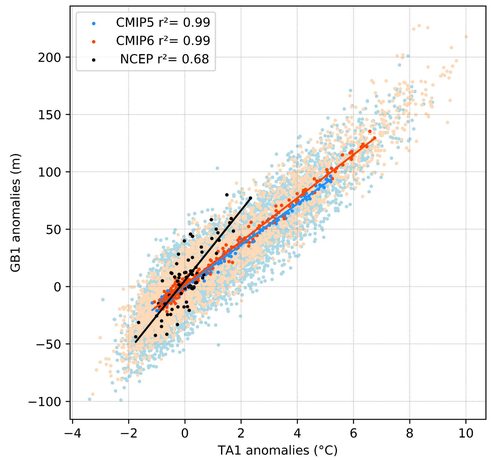

Figure 2. GB1 (m) versus TA1 (°C) anomalies (reference period: 1986 – 2005).

3. Results

NCEP **GB2 increases from 2000** (> 1.5 std, Fig. 3).

None of the CMIP5 and CMIP6 ESMs represents this increase.

Until 2020 two CMIP6 models (**(1)** MRI-ESM2-0 and **(2)** EC-Earth3) reach 1 standard deviation of GB2 and oscillate until the end of the century with a decreasing trend.

→ Idem **(3)** EC-Earth3-Veg and **(4)** NESM3 until 2040

Until **2100, GB2 of ESMs decrease** on average, without any circulation changes.

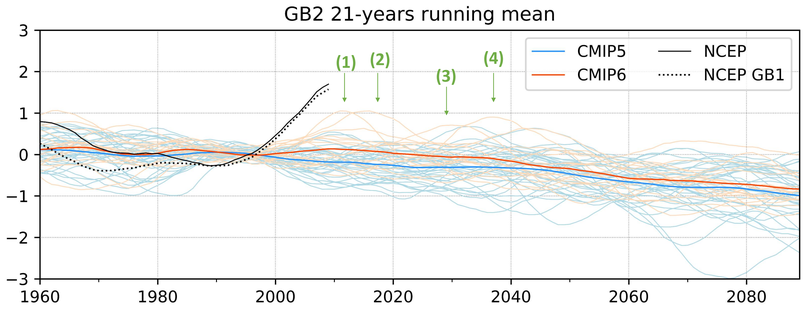

Figure 3. Time series of JJA GB1 (dashed black line, defined in Eq. 1) and GB2 (solid black line, defined in Eq. 2) indices over 1950–2100 as simulated by NCEP/NCAR Reanalysis 1 as well as by all the CMIP5 models (RCP8.5 scenario, blue lines) and the CMIP6 for which ssp585 scenario is available. For the CMIP5 and CMIP6-based time series, the historical scenario is used over 1900–2005 and RCP8.5 and ssp585 respectively afterwards. A 21-year running mean has been applied to smooth the time series, and values have been normalized (average = 0 and standard deviation = 1) using 1986–2005 as the reference period.

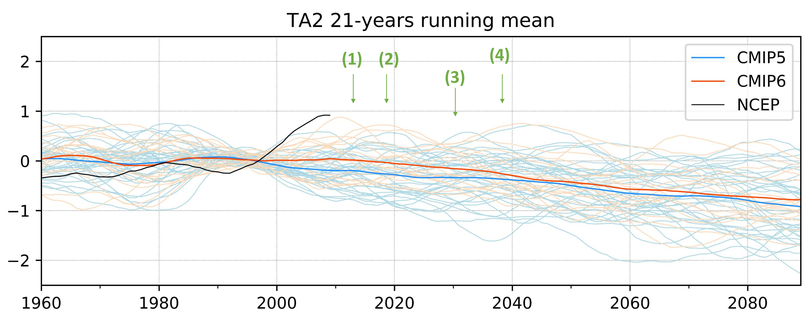

Figure 4. Similar to Fig. 3 but showing TA2 (defined in Eq. 3). Values are normalized to the 1986–2005 reference period.

Current TA2 increase (NCEP, Fig. 4) is mainly not represented by GCMs.

The Fig. 2 plots TA1 vs. GB1 and shows that the GBI variation in the **ESMs is driven by the temperature only.** This is not the case for the observed GBI (NCEP).

The part of the change in atmospheric dynamics causing the blocking events and therefore the rapid increase in GBI, is **not represented** by either the CMIP5 or the CMIP6 ESMs.

The largest GB2 oscillations (**1 → 4**, Fig, 3) are mainly due to temperature variability (**1 → 4**, same models in Fig. 4) and not to circulation changes.

The difference between CMIP5 and CMIP6 is **the higher CMIP6 warming rate** of TA1 at the end of the century (Fig. 2).

4. Conclusion

CMIP6 free atmospheric warming is more larger than CMIP5

No circulation change expected with CMIP6 ESMs

GBI changes in ESMs are fully driven by temperature variability

CMIP6, as CMIP5, could underestimate the Greenland ice sheet surface melt increase if the recent Greenland blocking occurrences persist.

References

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