Evaluation of the present and future general circulation over Greenland simulated by the IPCC AR4/CMIP3 GCMs with the help of a circulation type classification

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Abstract

Greenland ice sheet climate projections using downscaling methods or not are based on General Circulation Model (GCM) circulation simulations. Therefore, it is essential to evaluate these simulations. Circulation type classifications offer an interesting approach to achieve that on a daily time scale by individualising a few main circulation types representing the best the circulation of Greenland. In this case, we use the daily geopotential height at 500 hPa to evaluate six GCMs proposed by the IPCC in its last report (AR4) (CMIP3 database).

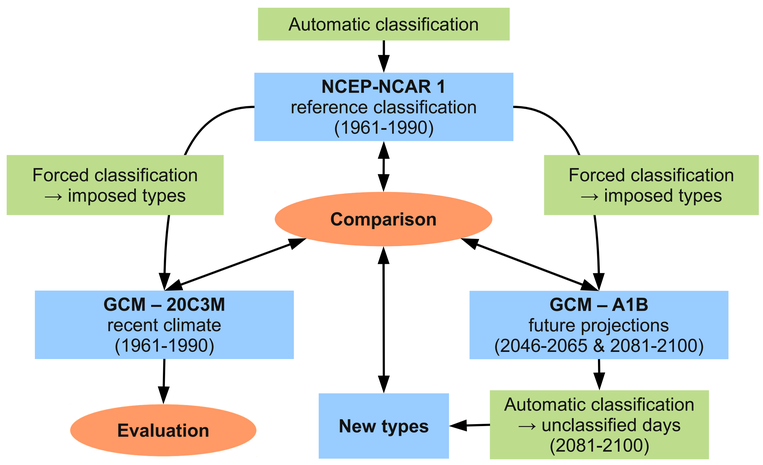
Firstly, the classification is done for the NCEP-NCAR 1 reanalysis data over 1961-1990 for summer (JJA) to individualise the main types. Then, these types are imposed to the GCM datasets for the 20C3M scenario over the same period.
It appears that most GCMs are not able to reproduce reliably recent climate circulation over Greenland. This is mainly due to systematic biases in the mean geopotential height and to an underestimation of its variability (standard deviation) by most GCMs.

The classification of future projections (A1B scenario) does not individualise really new circulation types but rather a general increase of the geopotential height over Greenland.

1. Interest

- Future projections simulate the most important warming in polar regions.
- Greenland ice sheet climate projections using downscaling methods or not are based on GCM simulations.
- **Atmospheric circulation**
  - is nearly independent from local features, topography …
  - is an important predictor variable for ground variables (e. g. temperature, precipitation)
  - is supposed to be better simulated by the GCMs, which have a coarse spatial resolution, due to its large-scale variations
  - its biases in GCM simulations can not be corrected by RCMs and other downscaling methods
- **Automatic circulation type classification**
  - uses the daily geopotential height at 500 hPa for summer (JJA)
  - groups the situations on the basis of a similarity index calculated between all pairs of days
  - individualises the 8 main circulation types over Greenland
  - allows a precise type per type analysis in contrary to monthly mean methods
  - focuses on the variability of the atmospheric circulation

2. Circulation type classification



3. NCEP-NCAR 1 classification

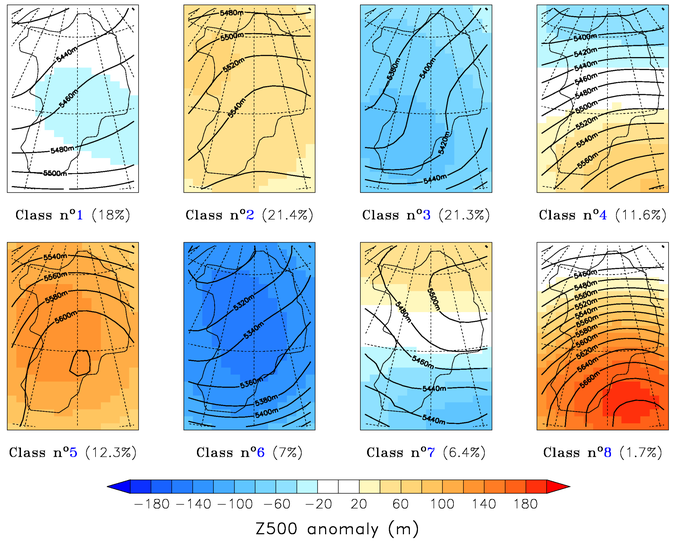


Fig. 1: Classification results for the NCEP-NCAR 1 reanalysis over the period from 1961 to 1990 for summer (JJA). The solid lines represent the mean geopotential height at 500 hPa for each class. The anomaly is calculated as the difference between the mean geopotential height of each class and the seasonal mean. The frequency of each class is shown in brackets.

4. Mean and standard deviation of the geopotential height

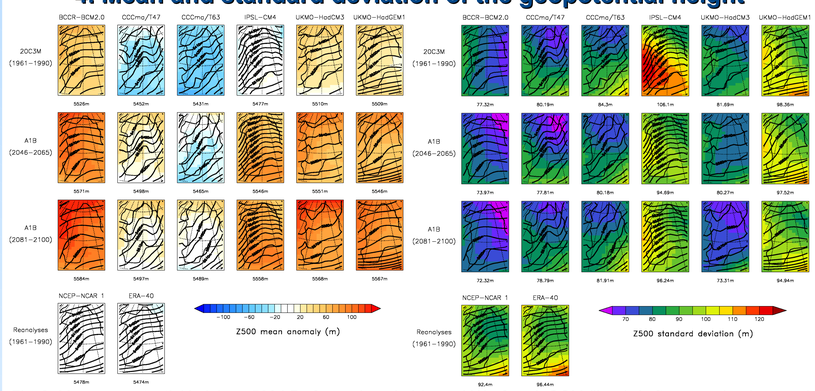


Fig. 2: Mean geopotential height at 500 hPa for each period (over JJA) of each GCM (lines). Left : anomaly wit regard to the NCEP-NCAR 1 reanalysis. Right : mean standard deviation over the same period.

5. Recent climate and future projections

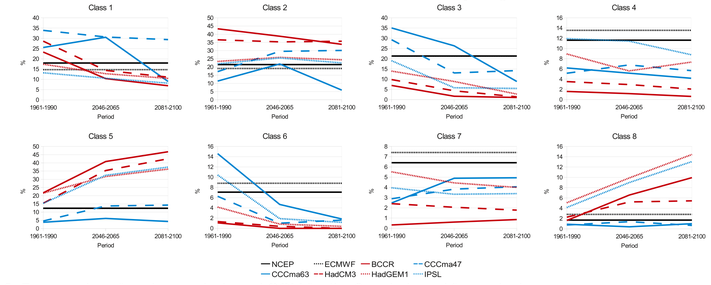


Fig. 3: Frequencies of each reanalysis and GCM for the 3 periods and for each class.

Recent climate

- Over or under-representation of the classes mainly due to :
  - systematic positive/negative biases in the geopotential height
  - the under-estimation of the variability of the circulation by most GCMs

→ Most GCMs are not able to reproduce reliably the circulation of the last decades over Greenland. The best matching GCMs are UKMO-HadGEM1 and IPSL-CM4.

Future projections

- For all GCMs
  - increase of the classes with a positive anomaly
  - decrease of the classes with a negative anomaly
  - other classes : remain constant
- Classification of the days of the last class : 2 new main types similar to classes 4 and 5 but with a higher geopotential height

→ General increase of the geopotential height over Greenland similar for all GCMs.

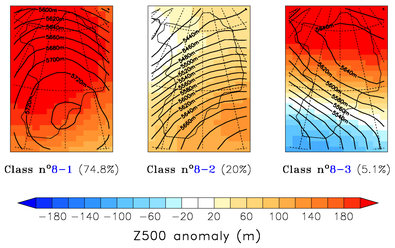


Fig. 4: Classification results for the IPSL model over the period 2081-2100, only for the elements of the last class. The anomaly is calculated with regard to the NCEP-NCAR 1 seasonal mean as in figure 1 and the frequency is calculated with regard to the total number of elements in class 8 for IPSL.

6. Conclusion

- **The classification of circulation types is useful for evaluating GCM simulations and particularly their ability to reproduce the variability of atmospheric circulation.**
- **GCMs have difficulties for simulating reliably recent circulation over Greenland, due to systematic biases and an underestimation of the variability of the circulation.**
- **Future projections show a general increase of the geopotential height for all GCMs leading to the emergence of two new types.**
- **Projected future change is of the same order than uncertainty for recent climate.**

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