Greenland Near Surface Air Temperature Datasets: What Should We Use to Evaluate CMIP6?

Jack Reeves Eyre & Xubin Zeng, University of Arizona, Tucson, AZ

Introduction

* Surface air temperature (SAT) is an important indicator of climate variability and change, and plays a major role in mass balance of ice sheets.

* SAT from some reanalyses has been evaluated over Greenland but many products, including global SAT analyses, remain untested in the region.

* We present an assessment of reanalyses, gridded temperature analyses, satellite and regional and global climate model data (Table 1), focusing on comparison with weather station data (Figure 1).

* We use one of the best-performing datasets to assess the Department of Energy's Energy Exascale Earth System Model (E3SM) over Greenland.

Data

	Dataset	Grid spacing	Time step	Period
Reanalysis	MERRA †	0.5 ° x 0.67 °	Hourly	1979-2015
	MERRA2 †	0.5 ° x 0.625 °	Hourly	1980-2015
	ERA-Interim †	0.75 ° x 0.75 °	3-hourly	1979-2015
	ERA-20C †	1 ° x 1 °	3-hourly	1900-2010
	CFSR †	0.5 ° x 0.5 °	Hourly	1979-2015
	20CR †	1.9 ° x 1.875 °	3-hourly	1851-2014
	JRA-55 †	0.56 ° x 0.56 °	3-hourly	1958-2014
Gridded temperature analysis	CRU TS3.23	0.5 ° x 0.5 °	Monthly	1901-2014
	Berkeley Earth	1 ° x 1 °	Monthly	1750-2015
	GISTEMP	2 ° x 2 °	Monthly	1880-2015
	NANSENSAT	2.5 ° x 2.5 °	Monthly	1900-2008
	Box 2013 (Incorporates RACMO output)	5 km polar stereographic	Monthly	1840-2014
Satellite	AIRS †	1 ° x 1 °	Monthly	2002-2015
Regional climate model	Modele Atmospherique Regional (MAR) †	5 km polar stereographic	Monthly	1958-2015
Global climate models	CMIP5 archive	Various	Monthly	1850-2005

Table 1. Datasets used in this study. Those marked with a (†) have been elevation-corrected by adding the product of elevation bias and lapse rate.

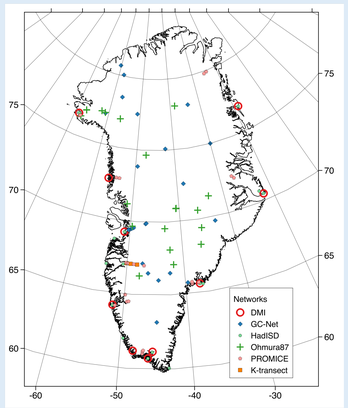

Figure 1. Map showing positions of weather stations used in this study: GC-Net, PROMICE and K-transect networks and DMI, HadISD and Ohmura (1987) datasets.

Dataset intercomparison

* Several reanalyses perform as well as MAR RCM in summer (Figure 2). MERRA2 performs as well as MAR in all months.

* Reanalyses generally perform better than gridded temperature analyses (Figure 3).

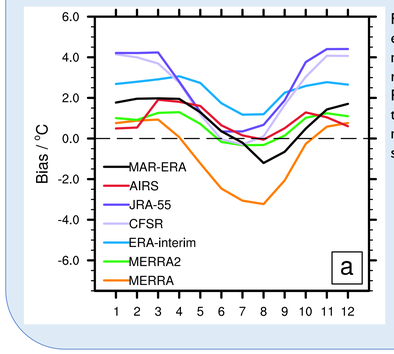

Figure 2. Mean bias of elevation-corrected monthly mean SAT from reanalysis, satellite and RCM products relative to high elevation (>1500 m) ice sheet weather station data since 1979.

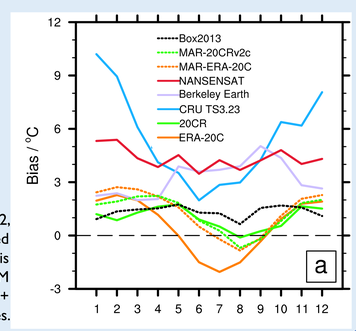

Figure 3. As in Figure 2, but for gridded temperature analysis products, long RCM runs and the two 100+ year reanalyses.

Conclusions

* Compared with in-situ observations, MERRA2 performs best in terms of mean bias and mean absolute error (averaged over seasons and glaciological regimes). RCMs perform better than most reanalyses, while gridded SAT analyses perform worse.

* Decadal variability and trends over the 20th century differ markedly between datasets. Time varying biases cast doubt on the realism of some trends. RCM variability is closely tied to variability in the forcing dataset.

* Choice of validation dataset and comparison methods plays an important part in assessing earth system models over Greenland. We recommend combining MERRA2 with GISTEMP and applying elevation-corrections where appropriate.

E3SM assessment

* An E3SM control run shows a warm bias over most of the ice sheet, but a cold bias in coastal regions, when compared to elevation-corrected MERRA2 (Figure 4).

* Part of the warm bias is caused by bias in E3SM's surface elevation, and when this is corrected for (in the same way as MERRA2), the pattern is different.

* The same issues occur when comparing against other high resolution observation-based datasets, e.g., MAR, RACMO. Elevation corrections should be applied to ESMs where possible.

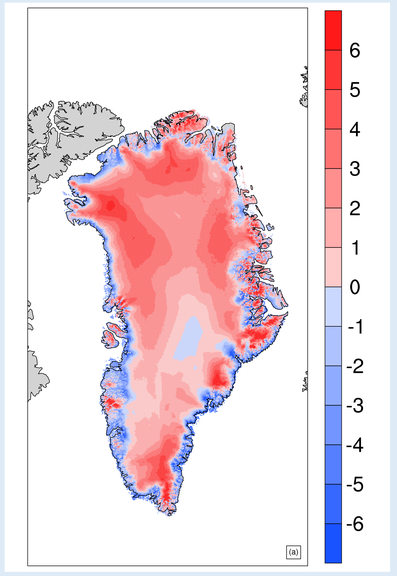

Figure 4. Map of long term annual mean SAT bias: E3SM control run minus elevation-corrected MERRA2. Both datasets have been interpolated to a 5 km grid. Units are °C.

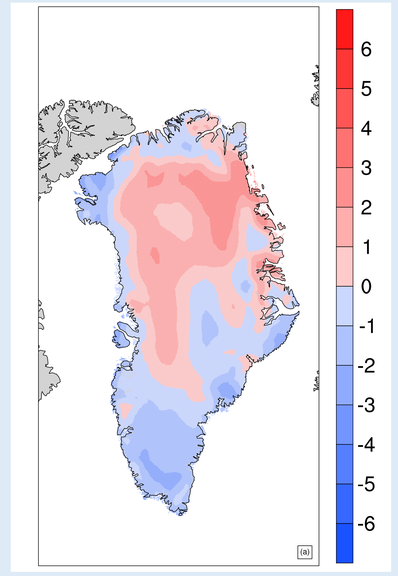

Figure 5. As in Figure 4, but with elevation correction applied to E3SM as well as MERRA2. Note that both are still on the 5 km grid.

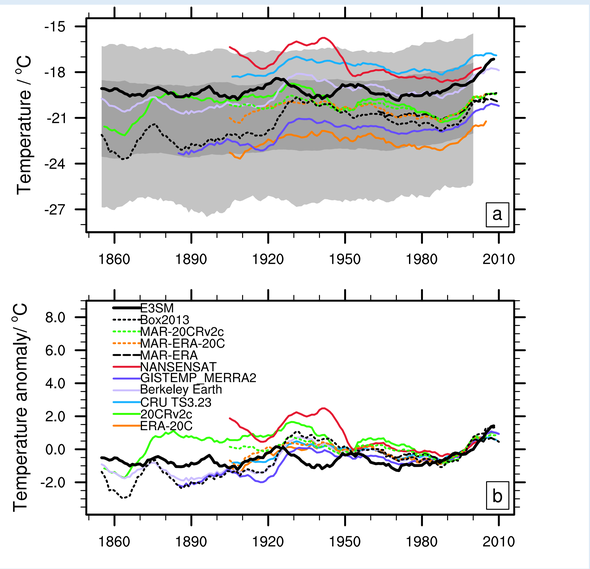

Figure 6. Time series of Greenland ice sheet areal average annual mean temperature with 11-year smoothing for selected datasets and CMIP5 models (grey shading). Panel (a) shows absolute values and panel (b) shows anomalies. The E3SM run shown in the bold black lines is a historical run using CMIP6 forcings. Elevation corrections have not been applied to E3SM or CMIP5 models.

* The choice of "validation" dataset is important when assessing ESMs, both for the absolute value (Figure 6a) and long term variability and trends (Figure 6b).

* The homogeneity of long reanalyses (and RCMs based on them) is questionable, so we recommend combining them with gridded SAT analyses for a more thorough assessment of long term variability and trends.

Reference:
Reeves Eyre, J. E. J. and X. Zeng, 2017: Evaluation of Greenland near surface air temperature datasets. *The Cryosphere*, **11**, 1591-1605, https://doi.org/10.5194/tc-11-1591-2017.

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Contact: jeyre@email.arizona.edu