

Supplementary material for:

Evaluation of Greenland near surface air temperature datasets

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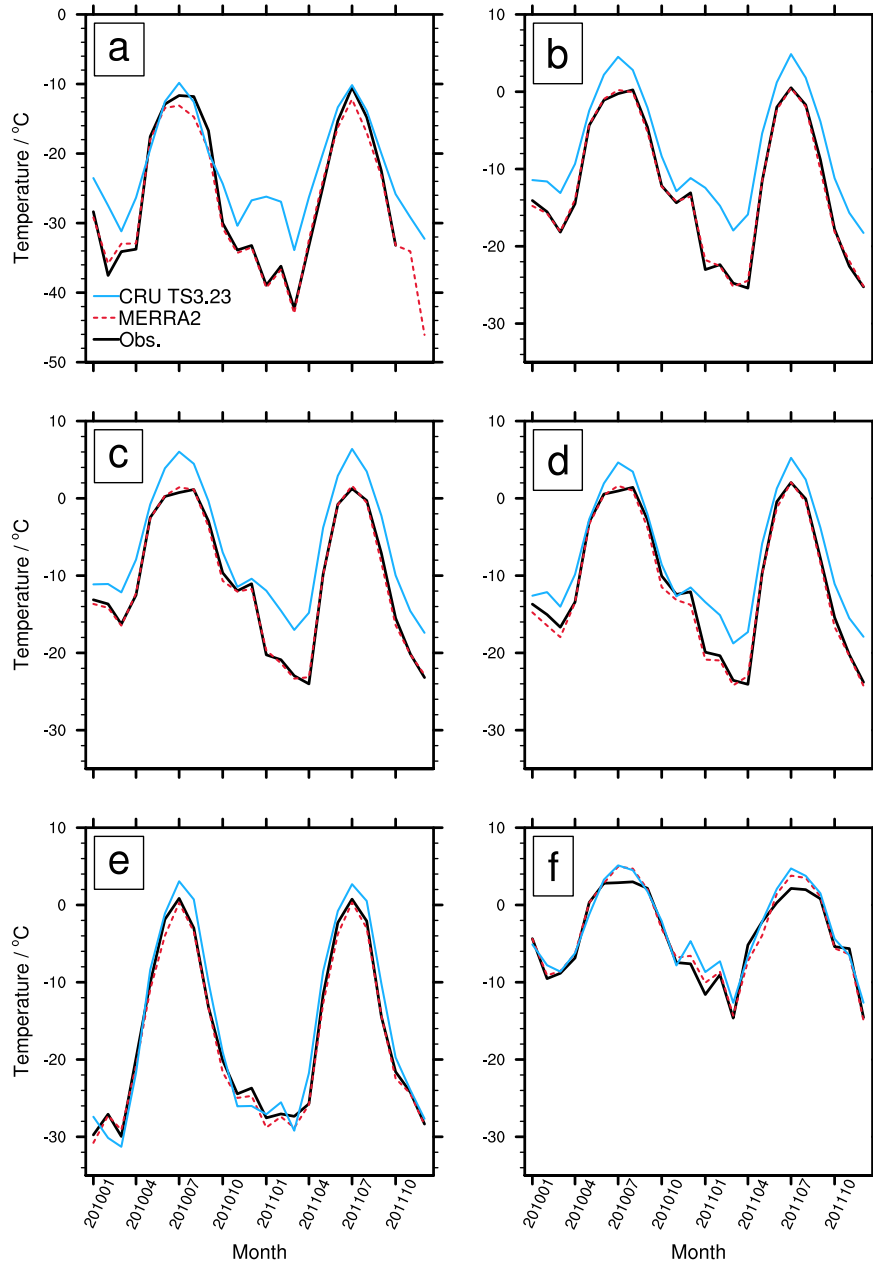
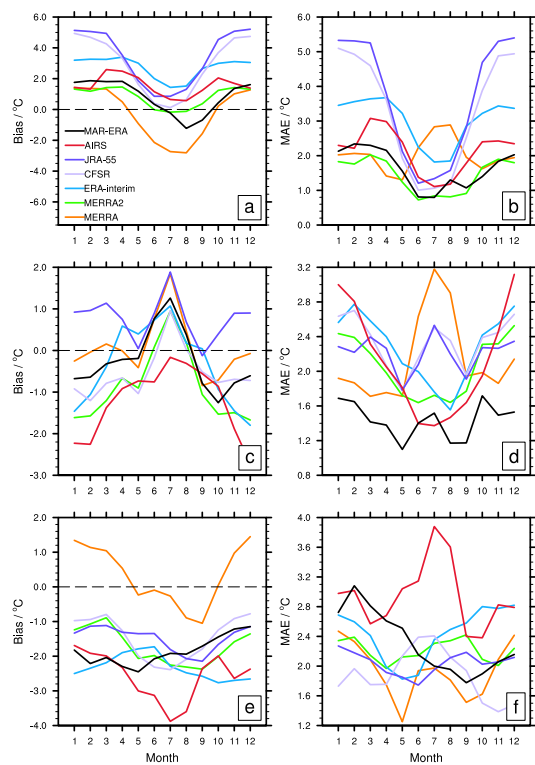


Figure S1. SAT time series from six stations on the ice sheet for 2010 and 2011: (a) Summit (GC-Net) is at ~3200 m, close to the topographic summit of the ice sheet; (b) station S9 (K-transect) is at 1500m on the western flank of the ice sheet; (c) station KAN M (PROMICE) is at 1270 m, close to the K-transect stations; (d) Swiss Camp (GC-Net) is at ~1200 m, north of the K-transect; (e) KPC U (PROMICE) is at 870 m in the north-east of the ice sheet; (f) TAS U (PROMICE) is at 570 m in the south-east of the ice sheet.



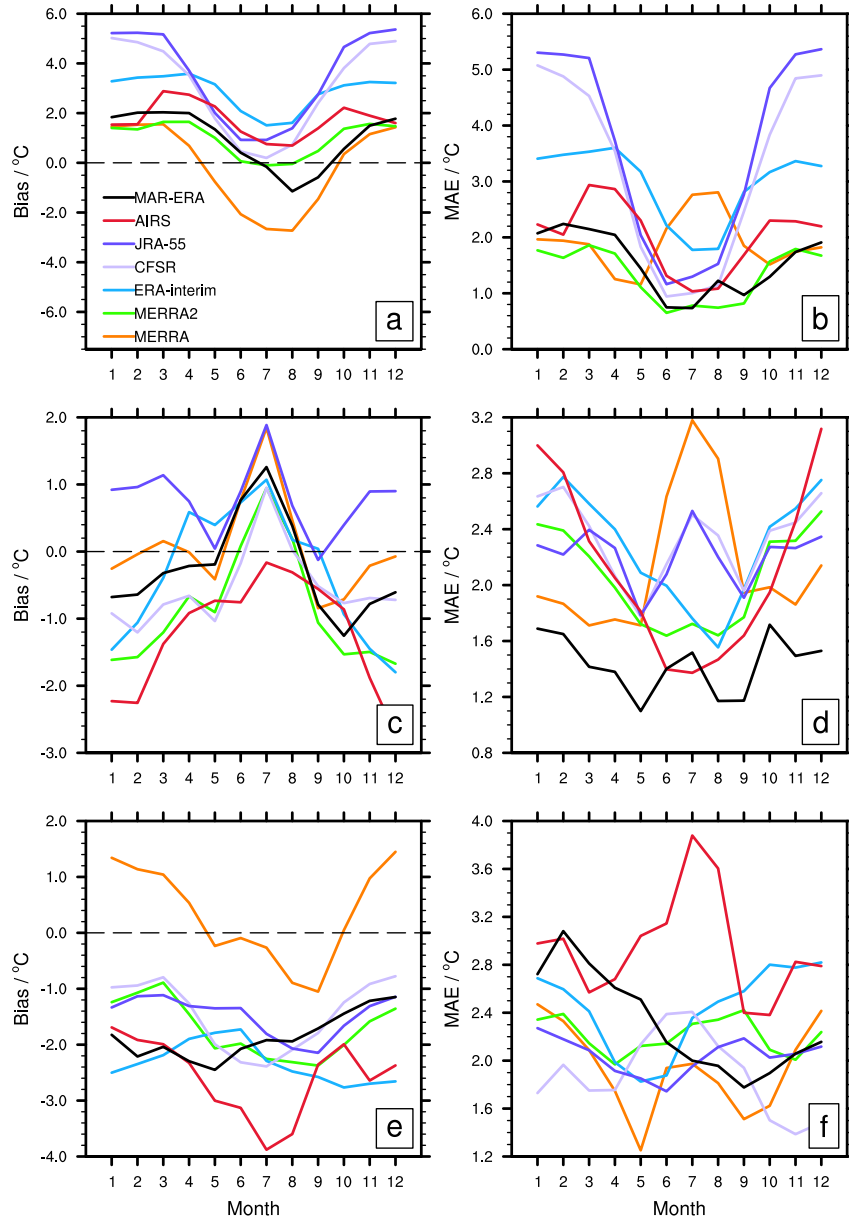
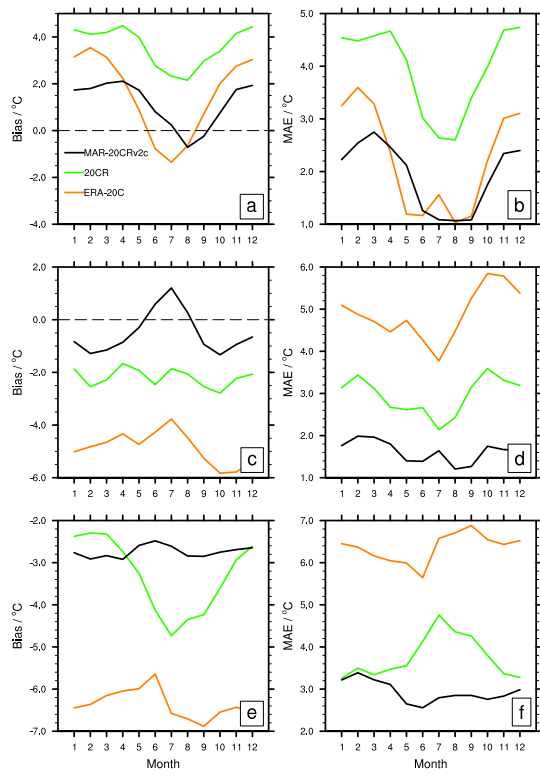


Figure S21: Mean over station-months of bias (a, c, e) and absolute error (b, d, f) relative to monthly mean SAT at: ice sheet stations above 1500 m (a and b); ice sheet stations below 1500 m (c and d); and coastal (DMI) stations (e and f). Ice sheet stations are from GC-Net, PROMICE and K-transect. All available station months from 1979 onwards are used. This figure is the same as Fig. 34 except that elevation corrections are not applied to any datasets.



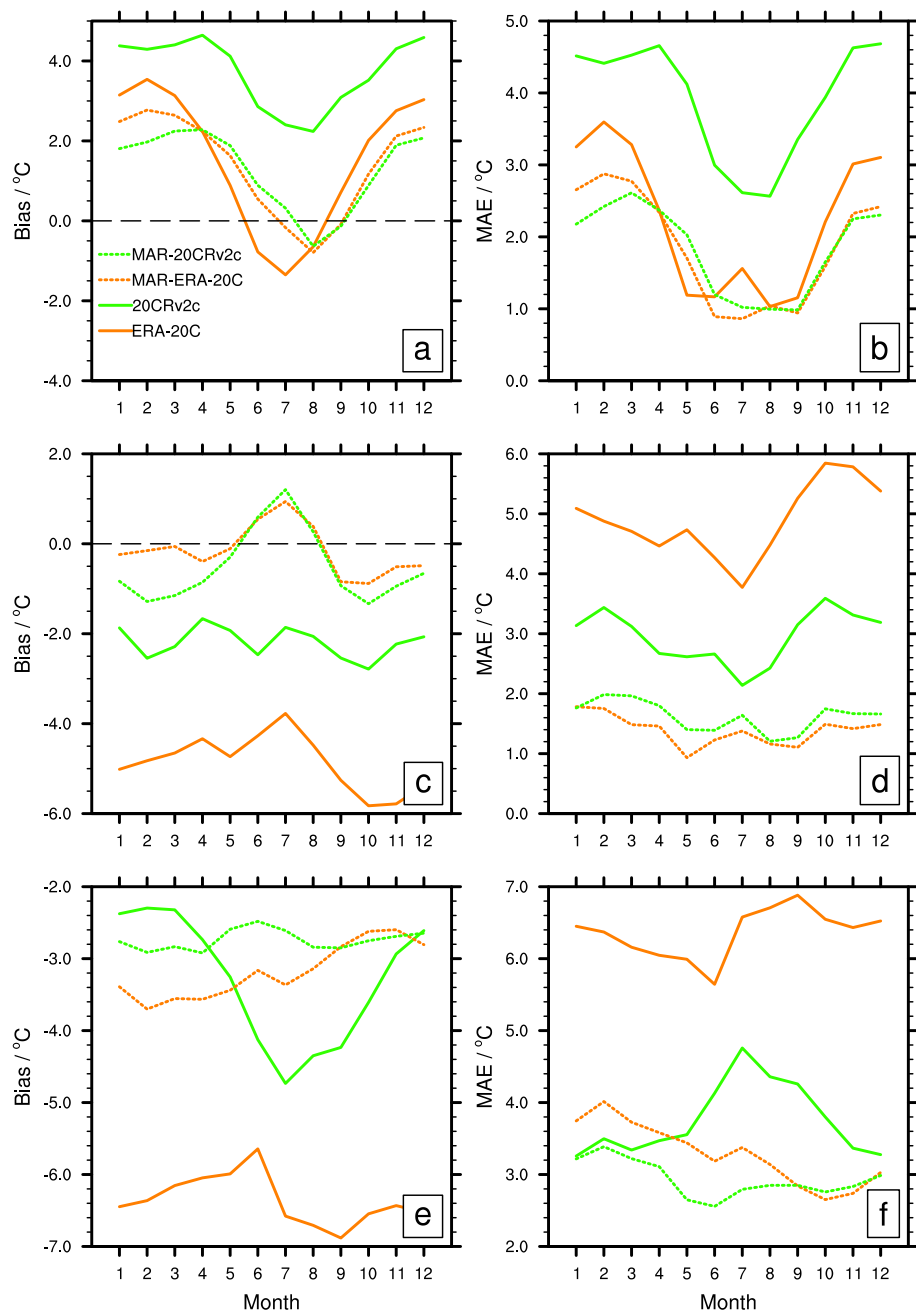


Figure S32: As Fig. S21 but for the two longer reanalyses, MAR-20CRv2c and MAR-ERA-20C.

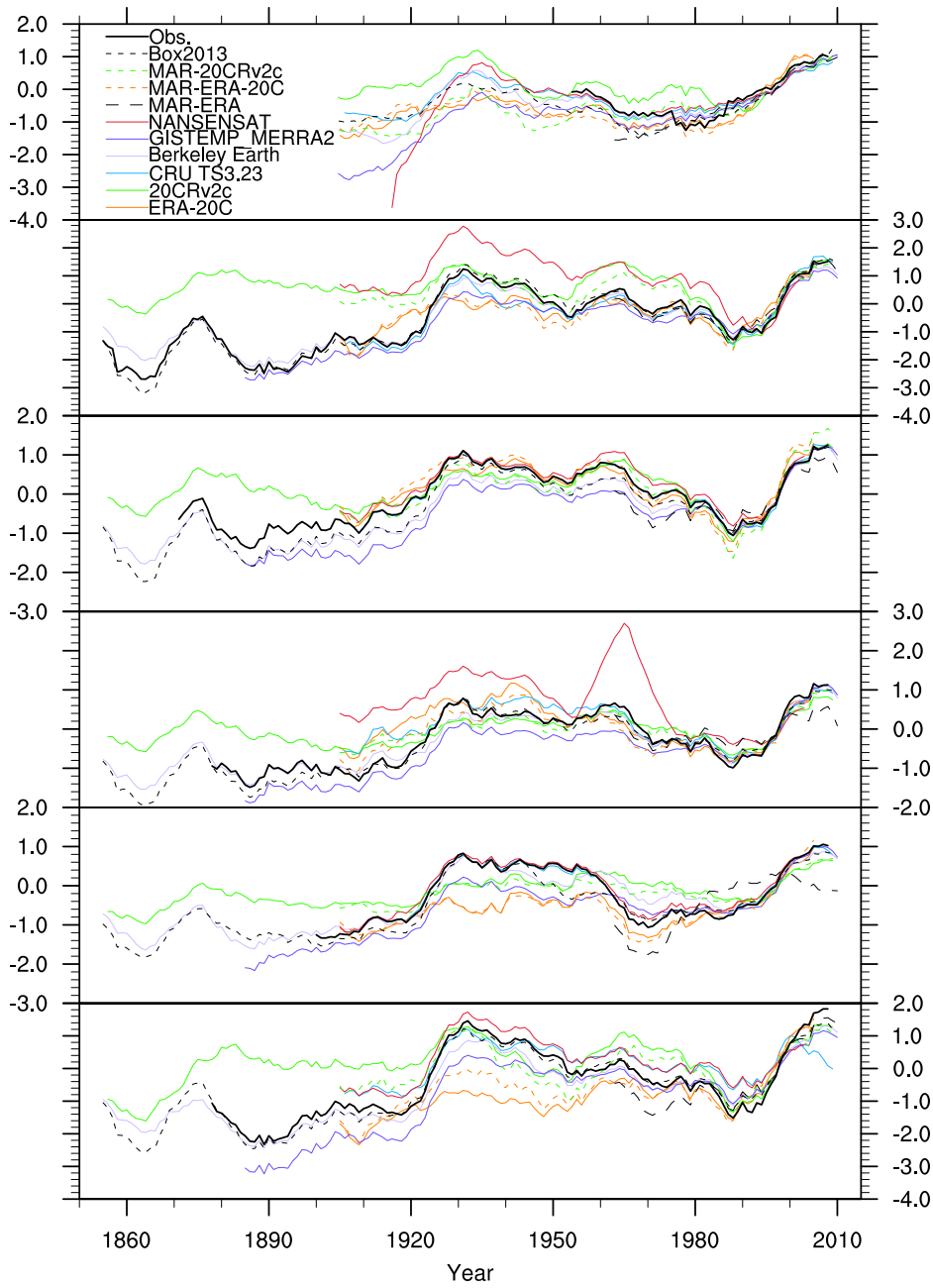


Figure S4. Annual mean SAT anomalies (°C; relative to 1981-2010) at six DMI stations from observations (solid black lines) and selected SAT datasets (nearest land grid point): from top to bottom Danmarkshavn, Ilulissat, Nuuk, Qaqortoq, Tasiilaq, Upernavik. All time series are smoothed using a centered, uniform-weighted 11-year window.

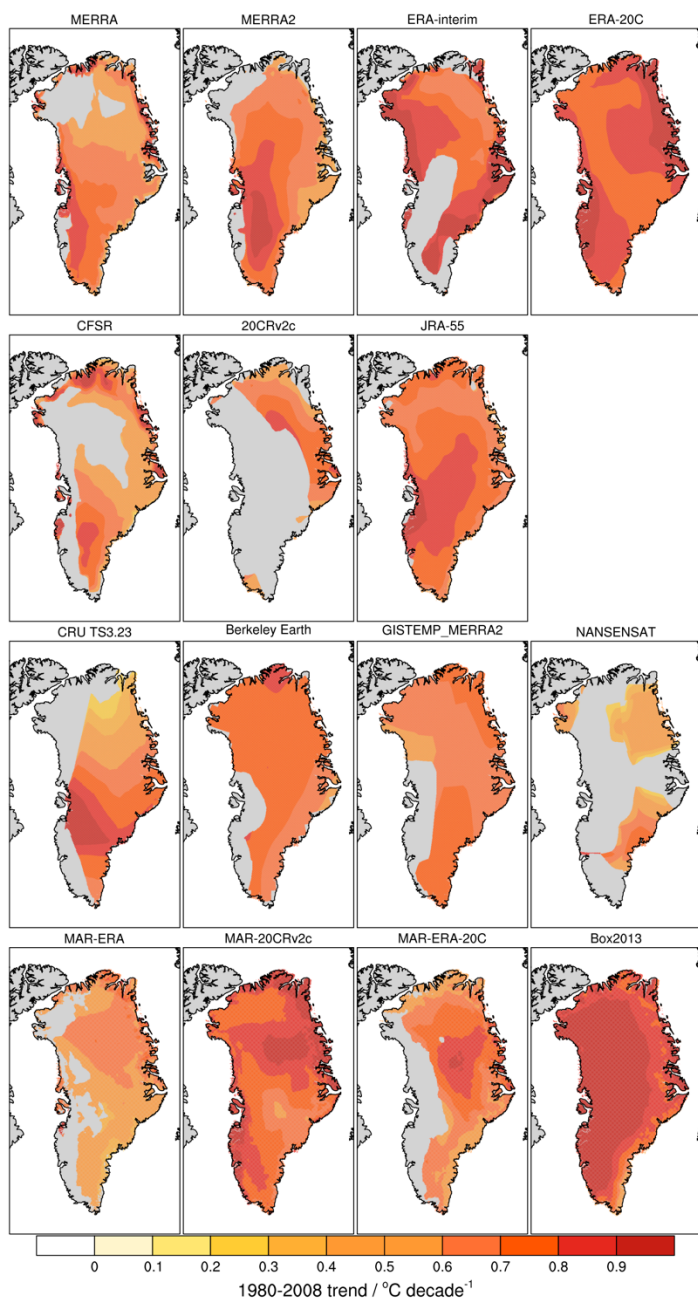


Figure 5. Grid point SAT trends over the period 1980-2008. Grid points where the trend is not significant (at the 0.05 level) have been masked out.

Table S1: Names and locations of weather stations used in this study. The DMI stations shown here represent the compilation of multiple stations at slightly different locations, with differing names (e.g., the Danish name for Ittoqqortoormiit is Scoresbysund). See Cappelen (2013) for more details.

| Station name | Latitude (North) | Longitude (West) | Elevation / m | Station name | Latitude (North) | Longitude (West) | Elevation / m |
|-------------------------|---------------------|---------------------|------------------|--------------|---------------------|---------------------|------------------|
| <i>Coastal</i> | | | | | | | |
| <i>DMI</i> | | | | | | | |
| Danmarkshavn | 76.77 | 18.67 | 11 | Nuuk | 64.18 | 51.73 | 80 |
| Ittoqqortoormiit | 70.48 | 21.95 | 70 | Pituffik | 76.53 | 68.75 | 77 |
| Ilulissat | 69.24 | 51.07 | 29 | Qaqortoq | 60.72 | 46.05 | 57 |
| Ivittuut | 61.20 | 48.18 | 30 | Tasiilaq | 65.61 | 37.64 | 54 |
| Narsarsuaq | 61.17 | 45.42 | 34 | Upernavik | 72.78 | 56.13 | 126 |
| <i>Ice sheet</i> | | | | | | | |
| <i>GC-Net</i> | | | | | | | |
| Swiss Camp | 69.56 | 49.33 | 1176 | South Dome | 63.15 | 44.82 | 2901 |
| Crawford Point | 69.88 | 47.00 | 2022 | NASA-E | 75.00 | 30.00 | 2614 |
| NASA-U | 73.84 | 49.51 | 2334 | Crawford P2 | 69.91 | 46.85 | 1990 |
| GITS | 77.14 | 61.04 | 1869 | NGRIP | 75.10 | 42.33 | 2941 |
| Humboldt | 78.53 | 56.83 | 1995 | NASA-SE | 66.48 | 42.50 | 2373 |
| Summit | 72.58 | 38.51 | 3199 | KAR | 69.70 | 33.01 | 2579 |
| Tunu-N | 78.02 | 33.98 | 2052 | JAR 2 | 69.41 | 50.09 | 507 |
| DYE-2 | 66.48 | 46.28 | 2099 | KULU | 65.76 | 39.60 | 878 |
| JAR 1 | 69.50 | 49.70 | 932 | JAR3 | 69.39 | 50.31 | 283 |
| Saddle | 66.00 | 44.50 | 2467 | | | | |
| <i>PROMICE</i> | | | | | | | |
| KPC_L | 79.91 | 24.08 | 370 | NUK_U | 64.51 | 49.27 | 1130 |
| KPC_U | 79.83 | 25.17 | 870 | NUK_K | 64.16 | 51.36 | 710 |
| SCO_L | 72.22 | 26.82 | 470 | NUK_N | 64.95 | 49.89 | 920 |
| SCO_U | 72.39 | 27.24 | 980 | KAN_B | 67.13 | 50.18 | 350 |
| MIT | 65.69 | 37.83 | 450 | KAN_L | 67.10 | 49.95 | 680 |
| TAS_L | 65.64 | 38.90 | 260 | KAN_M | 67.07 | 48.83 | 1270 |
| TAS_U | 65.70 | 38.87 | 570 | KAN_U | 67.00 | 47.02 | 1840 |
| TAS_A | 65.78 | 38.90 | 900 | UPE_L | 72.89 | 54.30 | 220 |
| QAS_L | 61.03 | 46.85 | 290 | UPE_U | 72.89 | 53.57 | 940 |

| | | | | | | | |
|-------------------------|-------|-------|------|-------------------------|-------|-------|------|
| QAS_U | 61.18 | 46.82 | 900 | THU_L | 76.40 | 68.27 | 570 |
| QAS_A | 61.24 | 46.73 | 1010 | THU_U | 76.42 | 68.15 | 770 |
| NUK_L | 64.48 | 49.53 | 550 | | | | |
| <hr/> <i>K-transect</i> | | | | | | | |
| S5 | 67.10 | 50.12 | 490 | S9 | 67.05 | 48.24 | 1520 |
| S6 | 67.08 | 49.39 | 1020 | | | | |
| <hr/> <i>Ohmura87</i> | | | | | | | |
| North Ice | 78.07 | 38.48 | 2343 | Station Centrale | 70.92 | 40.63 | 2993 |
| Sierra | 77.23 | 62.33 | 1719 | Eismitte | 70.90 | 40.70 | 3030 |
| Camp Century | 77.18 | 61.15 | 1885 | Hiran 28 | 70.62 | 36.17 | 3139 |
| Site2 | 77.00 | 56.08 | 2128 | EGIG4 | 69.67 | 49.63 | 1004 |
| North Ice Cap Station 2 | 76.92 | 66.97 | 650 | Hiran 30 | 69.55 | 43.17 | 2558 |
| North Ice Cap Station 3 | 76.93 | 66.98 | 700 | Hiran 27 | 69.38 | 35.92 | 2755 |
| Tuto East | 76.38 | 67.92 | 801 | Hiran 26 | 68.25 | 36.50 | 2925 |
| Camp Watkins | 74.67 | 47.50 | 2659 | Hiran 29 | 68.07 | 42.33 | 2593 |
| Jarl Joset Dumont | 71.47 | 33.35 | 2867 | Ice Cap Station Watkins | 67.05 | 41.82 | 2440 |
| Weststation Wegener | 71.18 | 51.12 | 954 | Mint Julep | 66.28 | 47.77 | 1829 |

Table S2: Summary of CMIP5 models used in this work. Unless otherwise indicated in the first column, results are from historical and historical extended experiments. Average SAT is the 1901-2000 mean of ice sheet annual average; for reference, the same value calculated from MERRA2 climatology and GISTEMP anomalies is -21.85 °C.

| Model (experiment) | Institute | Period | Average SAT / °C |
|----------------------------|---|-----------|------------------|
| FGOALS-g2 | LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University | 1850–2005 | -16.47 |
| MIROC-ESM-CHEM | Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies | 1850–2005 | -16.69 |
| MIROC-ESM | | 1850–2005 | -16.74 |
| MIROC-ESM (ESM historical) | | 1850–2005 | -16.77 |
| MIROC5 | Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology | 1850–2012 | -19.13 |
| MIROC4h | | 1950–2005 | -19.17 |
| CMCC-CESM | Centro Euro-Mediterraneo per I Cambiamenti Climatici | 1850–2005 | -19.38 |
| CESM1-BGC | National Science Foundation, Department of Energy, National Center for Atmospheric Research | 1850–2005 | -19.53 |
| CCSM4 | National Center for Atmospheric Research | 1850–2005 | -19.71 |
| CESM1-FASTCHEM | National Science Foundation, Department of Energy, National Center for Atmospheric Research | 1850–2005 | -19.8 |
| GFDL-CM2p1 | Geophysical Fluid Dynamics Laboratory | 1861–2005 | -19.89 |
| INM-CM4 | Institute for Numerical Mathematics | 1850–2005 | -19.91 |
| GISS-E2-H | NASA Goddard Institute for Space Studies | 1850–2012 | -20.03 |
| CESM1-WACCM | National Science Foundation, Department of Energy, National Center for Atmospheric Research | 1850–2005 | -20.1 |
| GFDL-ESM2M | Geophysical Fluid Dynamics Laboratory | 1861–2005 | -20.52 |
| MPI-ESM-P | Max Planck Institute for Meteorology (MPI-M) | 1850–2005 | -20.64 |
| MPI-ESM-MR | Max Planck Institute for Meteorology (MPI-M) | 1850–2005 | -20.78 |
| IPSL-CM5A-MR | Institut Pierre-Simon Laplace | 1850–2005 | -20.92 |
| GISS-E2-H-CC | NASA Goddard Institute for Space Studies | 1850–2012 | -21.16 |
| GFDL-CM3 | Geophysical Fluid Dynamics Laboratory | 1860–2005 | -21.19 |
| GISS-E2-R | NASA Goddard Institute for Space Studies | 1850–2012 | -21.37 |
| GISS-E2-R-CC | NASA Goddard Institute for Space Studies | 1850–2010 | -21.43 |

| | | | |
|----------------------------------|---|-----------|--------|
| GFDL-ESM2G | Geophysical Fluid Dynamics Laboratory | 1861–2005 | -21.55 |
| CESM1-CAM5 | National Science Foundation, Department of Energy, National Center for Atmospheric Research | 1850–2005 | -22.07 |
| CMCC-CMS | Centro Euro-Mediterraneo per I Cambiamenti Climatici | 1850–2005 | -22.59 |
| IPSL-CM5A-LR | Institut Pierre-Simon Laplace | 1850–2005 | -22.69 |
| IPSL-CM5A-LR (ESM historical) | Institut Pierre-Simon Laplace | 1850–2005 | -22.81 |
| CNRM-CM5 | Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique | 1850–2012 | -23.15 |
| CMCC-CM | Centro Euro-Mediterraneo per I Cambiamenti Climatici | 1850–2005 | -23.33 |
| CNRM-CM5-2 | Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique | 1850–2005 | -24.86 |
| IPSL-CM5B-LR | Institut Pierre-Simon Laplace | 1850–2005 | -26.29 |

Data availability

DMI weather station data (Cappelen, 2014) were downloaded from the DMI website (DMI, 2015). GC-Net weather station data (Steffen and Box, 2001) were obtained from the Cooperative Institute for Research in Environmental Sciences (CIRES, 2015). Data from the Programme for Monitoring of the Greenland Ice Sheet (PROMICE) and the Greenland Analogue Project (GAP) were provided by the Geological Survey of Denmark and Greenland (GEUS) (PROMICE, 2016).

20CR v2c data (Compo et al., 2011) were downloaded from the NOAA Earth System Research Laboratory Physical Sciences Division (ESRL PSD, 2015) website. Support for the Twentieth Century Reanalysis Project version 2c dataset is provided by the U.S. Department of Energy, Office of Science Biological and Environmental Research (BER), and by the National Oceanic and Atmospheric Administration (NOAA) Climate Program Office. MERRA (Rienecker et al., 2011) and MERRA2 (Molod et al., 2015) data were produced by the NASA Global Modelling and Assimilation Office (GMAO) and obtained from the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC; GMAO 2011, 2015). ERA-Interim (Dee et al., 2011) and ERA-20C (Poli et al., 2016) data are produced by and obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF, 2011, 2016). CFSR (Climate Forecast System Reanalysis; Saha et al., 2010) and CFSv2 (Climate Forecast System version 2; Saha et al., 2014) datasets were produced by NCEP and downloaded from the Research Data Archive (RDA) at the National Center for Atmospheric Research (NCAR), Computational and Information Systems Laboratory (CISL) (NCEP 2010, 2014). JRA-55 data (Kobayashi et al., 2015) were also obtained from the NCAR RDA (Japan Meteorological Agency/Japan, 2013). JRA-55 data are from the Japanese 55-year Reanalysis project carried out by the Japan Meteorological Agency (JMA).

GISTEMP (Hansen et al., 2010) was obtained from the NASA Goddard Institute for Space Studies (GISTEMP Team, 2016). Berkeley Earth data (Rohde et al., 2013) were downloaded from the Berkeley Earth website (Berkeley Earth, 2016). CRU TS3.23 data (Harris et al., 2014) are from the University of East Anglia Climatic Research Unit (UEA CRU, 2016) and were downloaded from the British Atmospheric Data Centre (BADC). NANSENSAT data (Kuzmina et al., 2008) were provided by the Nansen Centers in St. Petersburg (Russia) and Bergen (Norway) (Nansen Centers, 2015). The Box2013 data (Box, 2013) were downloaded from the website of the Byrd Polar and Climate Research Center at The Ohio State University (BPCRC, 2017).

AIRS data were obtained from GES DISC (AIRS Science Team/Joao Texeira, 2013). MAR version 3.5.2 data (~~both~~ all three forcings) were downloaded from the Laboratory of Climatology at the University of Liège (Fettweis, 2017~~6~~). We acknowledge the World Climate Research Programme's Working Group on Coupled Modelling, which is responsible for CMIP, and we thank the climate modeling groups (listed in Table S2) for producing and making available their model output. For CMIP the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison (PCMDI) provides coordinating support and led development of software infrastructure in partnership with the Global Organization for Earth System Science Portals. CMIP5 data were downloaded from the PCMDI portal (PCMDI, 2016).

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