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Microwave data and regional climate models for studying the Greenland ice sheet melt extent over 1958-2009

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Abstract. *Melt extent from two regional climate models (MAR [Fettweis et al., 2010] and RACMO [Ettema et al., 2009]) are compared with microwave brightness temperature-derived estimates to study the surface melt changes over the Greenland ice sheet (GrIS) since 1979. A simple algorithm (T19H>227K) is selected to retrieve the melt extent from the brightness temperatures and is sensitive to the production of surface meltwater. The models compare very well with the retrieving algorithm at both daily and yearly time scales. This suggests that the variability in the models is reliable and that the models can be used to detect melt changes over longer periods, when no satellite data are available. However, some disagreements still occur between the satellite-derived and model-simulated melt extent. This comparison helps us to identify biases in the models and limitations in the use of the microwave data for melt detecting. Finally, both models and satellite confirm the increase in GrIS surface melting since 1979. The melt extent area of the last years is unprecedented in the last 50 years. This works will be submitted soon in the Cryosphere Journal.*

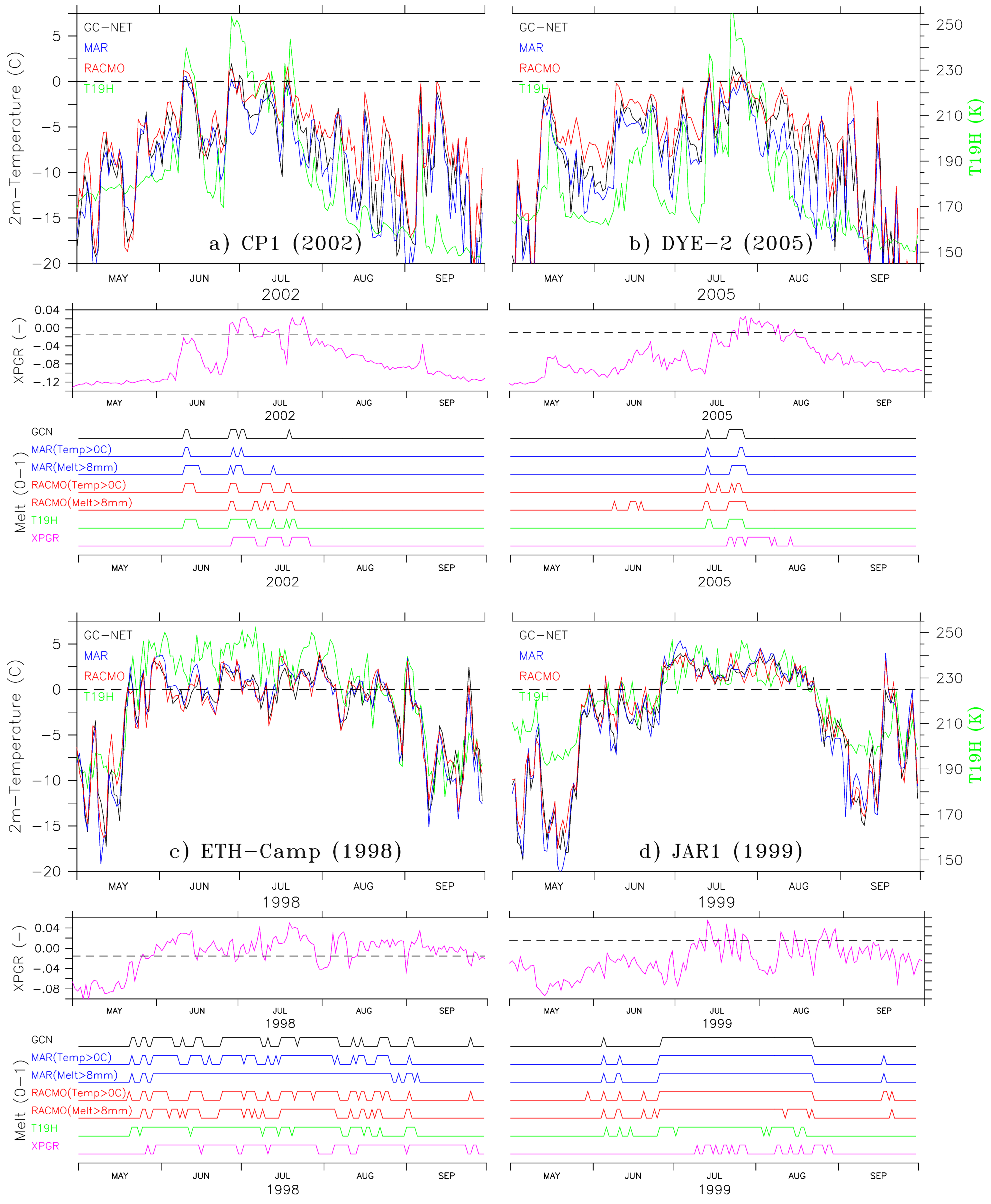

Figure 1 *Daily mean near-surface temperature (in black) observed in summer 2002 at Crawford Point 1 (69.9°N, 47°W, 2022 m), 3 m-temperature simulated by the MAR model (in blue), 2 m-temperature simulated by the RACMO model (in red), and the T19H brightness temperature (in green on the left axe) for the pixel nearest CP1. Middle) the XPGR value as defined by Abdalati and Steffen (2001). Below) The Melt/no melt time series derived from observation (daily mean temperature >0°C), simulated by the RCMs, derived from the T19H temperature and using the XPGR algorithm. b) The same as a) but for DYE-2 (66.5°N, 46.3°W, 2165 m) in 2005. c) The same as a) but for ETH-Camp (69.6°N, 49.2°W, 1149 m) in 1998. d) The same as a) but for JAR-1 (69.5°N, 49.6°W, 962 m) in 1999.*

Abrv.	Melt if
MAR/RACMO (Temp)	Daily mean 3m-Temp > 0°C
MAR/RACMO (Melt)	Daily meltwater production > 8mm
T19H227K	T19H > 227K
XPGR	(T19H-T37V)/(T19H+T37V) > -0.0158

• The best agreement between the melt/no melt time series using observed daily mean temperature over 20 GC-NET AWS and the melt time series derived from T19H is obtained with T19H>227K with more than 95% of melt events detected over summers 1995-2005.

• The model results suggest that the T19H-based algorithm is sensitive to the production of surface meltwater, rather than the presence of liquid water in the snowpack as the algorithm XPGR developed by Abdalati and Steffen (2001).

• The most limiting approximation here is using a fixed T19H threshold over the whole SMMR-SSM/I data set (which is cross-calibrated here). However, the derived melt extent compares here very well with the RCM's results (which can be considered as quasi-homogeneous) over the full period.

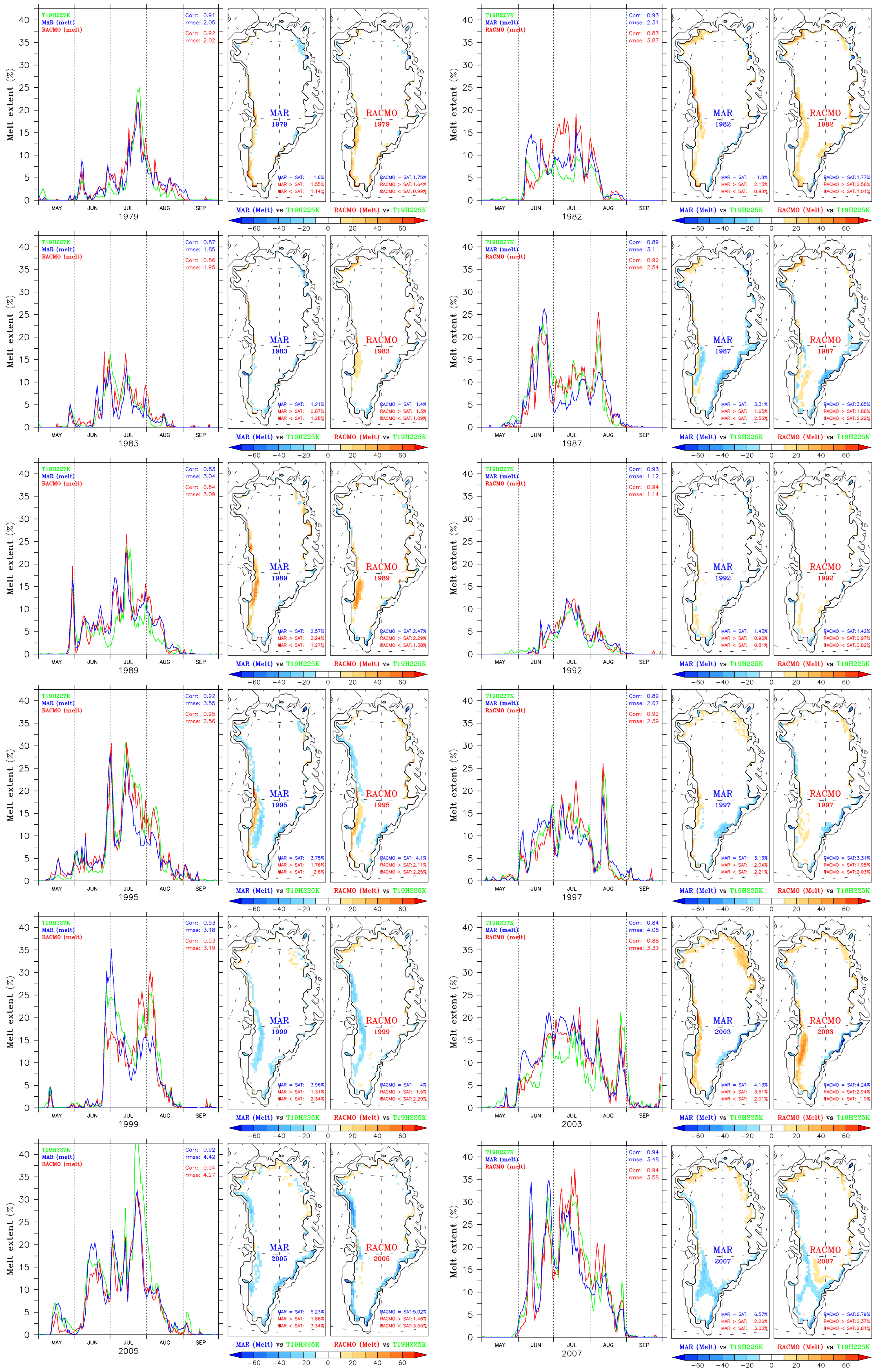

Figure 2 *1-D) Daily seasonal cycle of melt area (in % of GrIS area) simulated by MAR and RACMO as well as retrieved from the SMMR-SSM/I data set using T19H227K for 12 summers over 1979-2007. The statistics (i.e. the mean correlation coefficient as well as the mean Root Mean Square Error) between MAR (in blue)/RACMO (in red) and the T19H227K algorithm are also listed. 2-D) Difference between the total number of melt days by summer derived from SMMR-SSM/I data and simulated by the RCMs. The number of GrIS pixels when RCM and the algorithm detects melt (RCM=SAT), when RCM detects melt but the retrieving algorithm does not (RCM>SAT) and when RCM does not detect melt while the algorithm does (RCM<SAT) is also listed as a percentage of the number of GrIS pixels x summer days.*

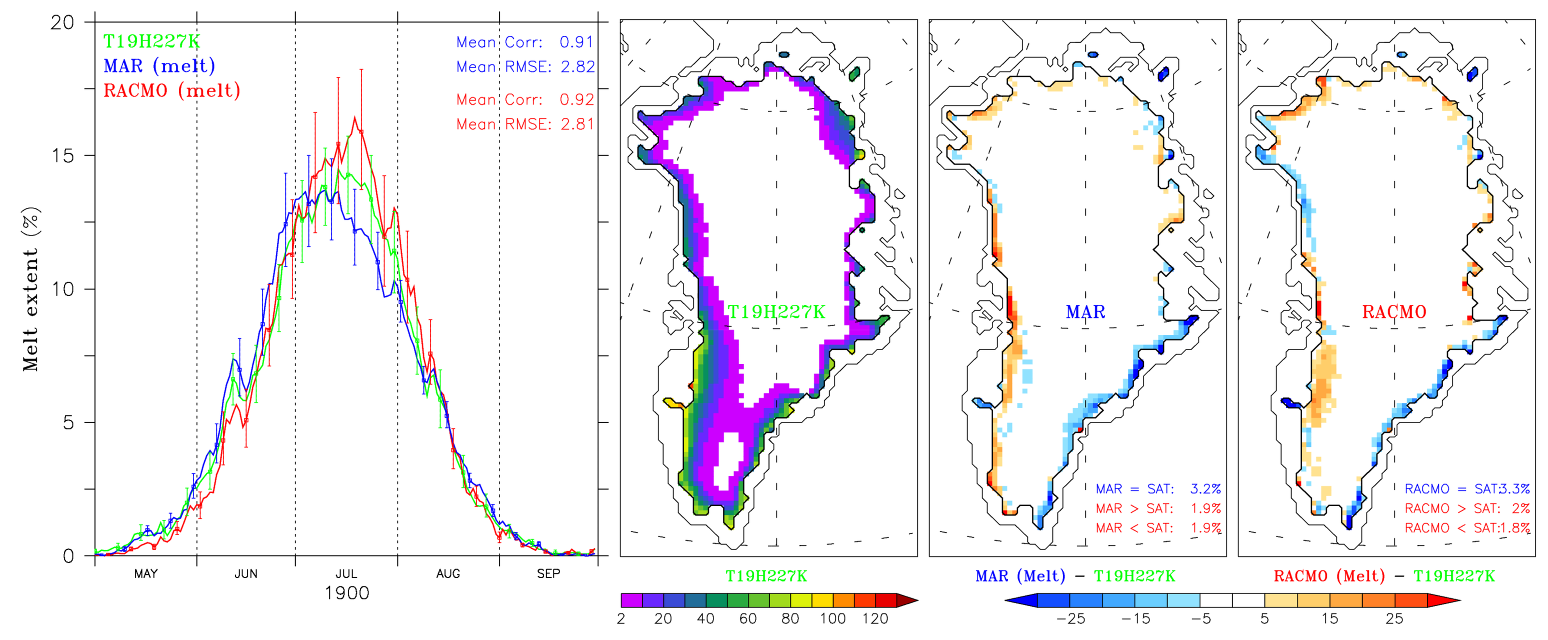

Figure 3 *The same as Figure 2 but for the average over the 30 summers of 1979-2008. The mean total number of melt days derived from SMMR-SSM/I data is also shown in the middle.*

• The timing of the melt season as well as the daily amplitude of the melt extent is well respected in the models. Moreover, the main ablation zones (lying below 70°N along the ice sheet margin and at the north-east of the ice sheet) are favourably simulated by the models.

• The bigest limitation of the microwave data is the real horizontal resolution of the data set which is closer to 50 km than 25 km. This may induce some biases along the ice sheet margin where the microwave signal could be biases by the nearby tundra or sea or when the ablation zone is very narrow.

• Both RCMs simulate less melt along the eastern and south-eastern mountainous regions of the ice sheet than the microwave-derived estimates. Possibly, the microwave brightness temperatures could be biased by rock outcrops found in these regions.

• Contrary to MAR, RACMO underestimates the melt area at the beginning of the melt season (from May to mid-June) and overestimates it in July until mid-August. The radiative scheme of the MAR model overestimates (resp. underestimates) the solar (infrared) flux. These biases induce a melting season peaking 10 days earlier in MAR compared to the satellite-derived data and RACMO. The longwave radiation should be reduced in RACMO to correct the melt extent overestimation occuring after mid-July.

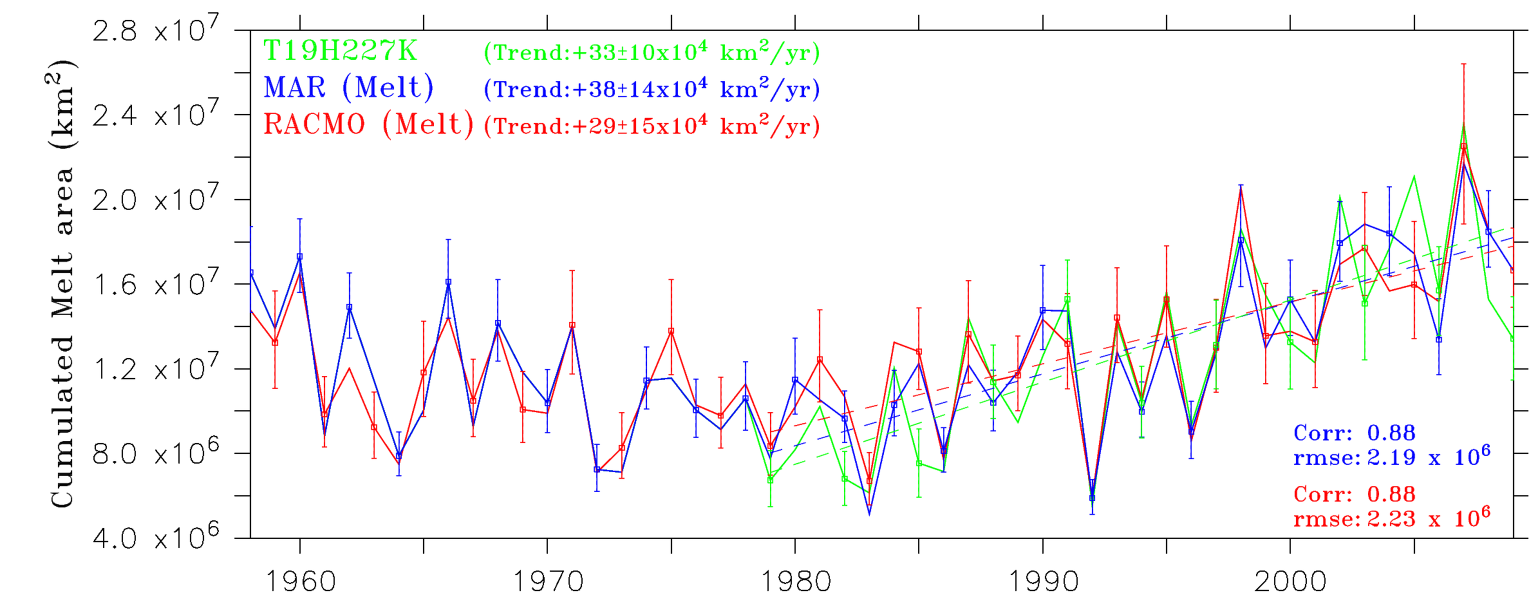

Figure 4 *Time evolution of the annual cumulated GrIS melt area simulated by the RCMs and retrieved from SMMR-SSM/I data set. The statistics are given over the period 1979-2008.*

• The maximum cumulated melt area occurs in 2007, followed by 1998. The minimum occurs in 1983 (resp. 1992) after the El Chichon (resp. Mont Pinatubo) eruption. The agreement between RCMs and microwave-derived melt over the full SMMR-SSM/I period suggests that i) using a linear regression to cross-calibrate the five sensors is sufficient to apply the same threshold through the whole period and that, ii) the model results can reliably be used to estimate the melt extent prior to 1979. The RCMs show the cumulated melt extent of 1998 and 2007 are unprecedented in the last 50 years.

• A period of of 2-3 years can be seen in the time series. This variability is likely due to the North Atlantic Oscillation for which Nicolay et al. (2008) found a period of 30 months.

Reference:

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