STATE OF THE CLIMATE IN 2012

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STATE OF THE CLIMATE IN 2012

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COVER CREDITS:

FRONT: Kate Stafford — 2012 RUSALCA Expedition, RAS-NOAA, Wrangel Island in the early morning

BACK: Terry Callaghan, EU-Interact/Sergey Kirpotin, Tomsk State University — Trees take hold as permafrost thaws near the Altai Mountains in Russia

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mean, winter (September 2011–May 2012) precipitation was significantly above normal in southern Alaska and Iceland (see Fig. 5.9) and near normal elsewhere in the Arctic. Summer air temperature anomalies (JJA 2012 mean at 700 hPa geopotential height, relative to the 1948–2008 mean) were again strongly positive (+1.4°C to +3.6°C) over the Canadian Arctic Islands (including Baffin Island), and positive over Severnaya Zemlya (+0.41°C) and Franz Josef Land (+0.48°C). They were close to normal in Svalbard, Iceland, and southern Alaska. These patterns are broadly consistent with the pattern of summer LST anomalies and glacier mass balance.

The region of strongly positive summer 700 hPa air temperature anomalies in 2012 over south and west Greenland, Baffin Island, and Canada's Queen Elizabeth Islands is associated with a region of anomalously high geopotential height at all levels of the troposphere that was centered over Greenland and Baffin Bay. (Figure 5.3b shows the anomalously high pressure in this region.) This is a feature that has persisted during summers of the last six years (Box et al. 2012a; Sharp et al. 2011). These positive anomalies point to another strong melt season on these ice caps in 2012, and it is worth noting that the extreme warm temperature event of 8–12 July 2012 that produced record melt extent on the Greenland Ice Sheet (Box et al. 2012a; section 5g) also affected the ice caps in Arctic Canada. In contrast, the near-normal summer air temperatures in Iceland and southern Alaska (where summer LST anomalies were negative), followed heavy winter precipitation in 2011/12, and may therefore have resulted in relatively low summer melt in those regions in 2012.

g. *Greenland Ice Sheet*—M. Tedesco, P. Alexander, J. E. Box, J. Cappelen, T. Mote, K. Steffen, R. S. W. van de Wal, J. Wahr, and B. Wouters

1) Satellite observations of surface melting and albedo

Melting at the surface of the Greenland Ice Sheet set new records for extent and melt index (i.e., the number of days on which melting occurred multiplied by the area where melting was detected) for the period 1979–2012, according to passive microwave observations (e.g., Tedesco 2007, 2009; Mote and Anderson 1995). Melt extent reached ~97% of the ice sheet surface during a rare, ice-sheet-wide event on 11–12 July (Fig. 5.13a; Nghiem et al. 2012). This was almost four times greater than the average melt extent for 1981–2010. The 2012 standardized melting index (SMI, defined as the melting index minus its average and divided by its standard deviation) was +2.4, almost twice the previous record of about +1.3 set in 2010 (Fig. 5.13b).

According to satellite observations, melting in 2012 began about two weeks earlier than average at low elevations, and lasted as much as 140 days (20–40 days greater than the mean value) in some areas of southwest Greenland (section 5e). Melting day anomalies (i.e., the number of melting days in 2012 minus the 1980–2010 average) were as much as +27 days in the south and +45 days in the northwest. Areas in northwest Greenland between 1400 m and 2000 m above sea level (a.s.l.), where melting is expected to be negligible or sporadic, experienced nearly two months longer melt duration in 2012 than the 1981–2010 reference period.

The area-averaged albedo of the ice sheet, estimated from spaceborne observations (MODIS), set a new record in 2012 (Fig. 5.14a). Negative albedo anomalies were widespread across the ice sheet, but were particularly low along the western and northwestern margins (Fig. 5.14b). The lowest albedo values occurred in the upper ablation zone and overlapped with the regions of extended melt duration.

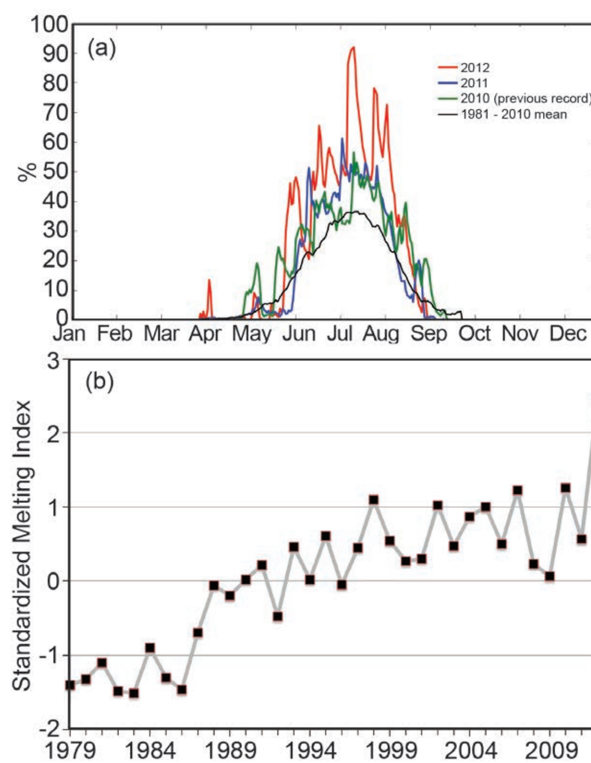

Fig. 5.13. (a) Surface melt extent, detected by the SSM/I passive microwave sensor, expressed as % of the total area of the Greenland Ice Sheet. (b) Standardized melt index (SMI) for the period 1979–2012 using the Tedesco (2009) algorithm.

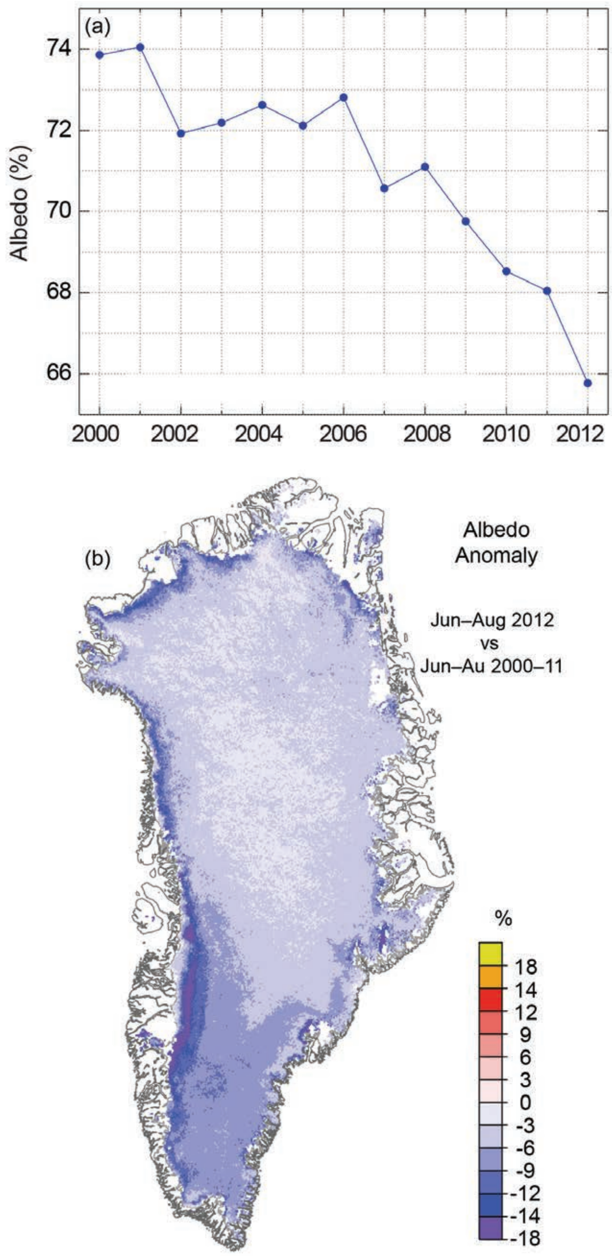

Fig. 5.14. (a) Area-averaged albedo of the Greenland Ice Sheet each Jul from 2000 to 2012, and (b) geographic variability of the Jun–Aug 2012 albedo anomaly expressed as % of the mean anomaly of the 2000–11 reference period. All data are derived from MODIS MOD10A1 observations. Figures are after Box et al. (2012b).

2) Satellite observations of ice mass loss

In 2012, new records for summertime and annual ice mass loss, as estimated from the GRACE satellite mission (e.g., Velicogna and Wahr 2006), occurred. Between June and August, the mass loss was -627 ± 89 Gt, 2 standard deviations below the 2003–12 mean of -414 Gt (Fig. 5.15; Tedesco et al. 2012). The previous record mass loss, -516 ± 89 Gt, 0.8 standard deviation below the mean, occurred in 2010. The trend of summer mass change during 2003–12 is -29 ± 11 Gt yr^{-1}. Excluding the mass loss in summer 2012, the trend is -20 ± 13 Gt yr^{-1}. The annual mass loss from mid-September 2011 to mid-September 2012, -575 ± 89 Gt, 2 standard deviations below the mean, also set a new record, exceeding the previous record, set only two years earlier, by +152 Gt.

3) Surface mass balance observations along the K-Transect

The original K-Transect is located in western Greenland near Kangerlussuaq at 67°N and between 340 m and 1500 m a.s.l. (van de Wal et al. 2005). During the period 1991–2012, 1500 m a.s.l. was the average equilibrium line altitude (ELA; i.e., the highest altitude at which winter snow survives). In 2012, the ELA reached 2687 m a.s.l., 3.7 standard deviations above the mean (van de Wal et al. 2012). The surface mass balance in 2012, between 340 m and 1500 m a.s.l., was the second lowest since measurements began in 1991. However, a weighted mass balance that includes a site above the former 1500 m ELA indicates that the 2011/12 mass balance year was the most negative in 21 years. At the highest station in 2012, 1847 m, almost 350 m higher than the former ELA, the surface mass balance was estimated to be -0.74 m water equivalent. Below 1500 m elevation, surface mass balance values decreased gradually to normal values near the ice margin.

4) Surface air temperature observations

The extensive surface melting and ice mass loss observed in 2012 occurred in conjunction with record summer (June, July, and August: JJA) air temperatures. The ice sheet-wide JJA surface temperature estimated from space by MODIS increased

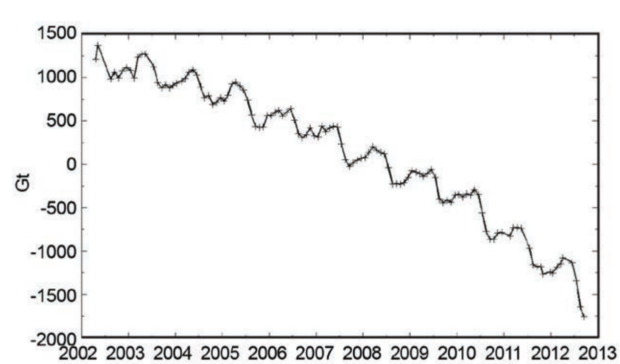

Fig. 5.15. Cumulative mass anomaly in Gt of the Greenland Ice Sheet derived from GRACE satellite data between April 2002 and September 2012.

3.4°C between 2000 and 2012, from an average value of -9°C in 2000 to -5.6°C in 2012 (Tedesco et al. 2012). Applying a linear fit, this suggests an increase in ice sheet-wide surface temperature of +0.16°C yr^{-1}. Other than Tasiilaq, in southeast Greenland, where June 2012 was the coldest it had been since records began in 1895, record-setting warm JJA surface air temperatures occurred at long-term meteorological stations (records began in 1873) along the western and southern margins of the island and at the ice sheet summit. The Greenland Climate Network (GC-Net) automatic weather station at Summit (3199 m a.s.l.) measured hourly-mean air temperatures above 0°C for the first time since measurements began in 1996. Such a melt event is rare; the last significant event occurred in 1889, according to the analysis of ice core data (Nghiem et al. 2012).

Seasonally-averaged upper air temperature data available from twice-daily radiosonde observations show anomalous warmth throughout the troposphere in summer 2012 (section 5f). This is consistent with an overall warming pattern near the surface between 850 hPa and 1000 hPa. The recent warming trend is seen in the long-term air temperature reconstruction for the ice sheet, which also shows that mean annual air temperatures in all seasons are now higher than they have been since 1840 (Box et al. 2012a).

5) Marine-terminating glaciers

Forty marine-terminating glaciers have been surveyed daily since 2000 using cloud-free MODIS visible imagery (Box and Decker 2011; http://bprc.osu.edu/MODIS/). The net area change of the 40 glaciers during the period of observation has been -1775 km^2, with the 18 northernmost (>72°N) glaciers alone contributing to half of the net area change. In 2012, the northernmost glaciers lost a collective area of 255 km^2, or 86% of the total net area change of the 40 glaciers surveyed. The six glaciers with the largest net area loss in 2012 were Petermann (-141 km^2), 79 glacier (-27 km^2), Zachariae (-26 km^2), Steenstrup (-19 km^2), Steensby (-16 km^2, the greatest retreat since observations began), and Jakobshavn (-13 km^2). While the total area change was negative in 2012, the area of four of the forty glaciers did increase relative to the end of the 2011 melt season. The anomalous advance of these four glaciers is not easily explained, as the mechanisms controlling the behavior of individual glaciers are uncertain due to their often unique geographic settings.

h. *Permafrost*—V. E. Romanovsky, A. L. Kholodov, S. L. Smith, H. H. Christiansen, N. I. Shiklomanov, D. S. Drozdov, N. G. Oberman, and S. S. Marchenko

Systematic observations of permafrost temperature at many sites in Alaska, Canada, and Russia since the middle of the 20th century provide several decades of continuous data, which allow decadal changes in permafrost temperatures to be assessed. A general increase in temperatures has been observed during the last several decades in Alaska, northern Canada, and Siberia (Smith et al. 2010; Romanovsky et al. 2010a,b). During the last four to five years, all these regions show similar temporal and spatial variability of permafrost temperature. As illustrated for selected sites in Russia (Fig. 5.16), although temperature has been generally increasing continuously in colder permafrost located close to the Arctic coasts (Romanovsky et al. 2012a), the temperatures of warmer permafrost in the continental interior have been relatively stable or even decreasing slightly. Permafrost temperature has increased by 1°C–2°C in northern Russia during the last 30 to 35 years, but this trend was interrupted by colder conditions in summer 2009 and winters 2009/10 and 2010/2011 at many locations in the Russian Arctic, especially in the western sector (Fig. 5.16). However, the warming trend resumed in 2012.

In 2012, new record high temperatures at 20-m depth were measured at most permafrost observatories on the North Slope of Alaska, i.e., north of the Brooks Range (Fig. 5.17a), where measurements began in the late 1970s. The exceptions were the coastal sites, West Dock, and Deadhorse (Fig. 5.17b), where temperatures in 2012 were the same as the record-high temperatures observed in 2011 (Fig. 5.17b). Changes in permafrost temperatures at 20-m depth are typically lagging by one year compared to the changes in surface temperatures. The data suggest that a coastal warming trend has propagated southward towards the northern foothills of the Brooks Range, where a noticeable warming in the upper 20 m of permafrost has become evident since 2008 (Romanovsky et al. 2012b). Record high temperatures were also observed in 2012 in the Brooks Range (Chandalar Shelf) and in its southern foothills (Coldfoot). However, permafrost temperatures in Interior Alaska (e.g., Healy, Birch Lake, College Peat, and Old Man; Fig. 5.17c) were still decreasing in 2012. These distinct patterns of permafrost warming on the North Slope and a slight cooling in the Alaska Interior in 2010–11 are in good agreement with air temperature patterns observed in the Arctic and the sub-Arctic over the last five years