A younger, thinner Arctic ice cover: Increased potential for rapid, extensive sea-ice loss

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[1] Satellite-derived estimates of sea-ice age and thickness are combined to produce a proxy ice thickness record for 1982 to the present. These data show that in addition to the well-documented loss of perennial ice cover as a whole, the amount of oldest and thickest ice within the remaining multiyear ice pack has declined significantly. The oldest ice types have essentially disappeared, and 58% of the multiyear ice now consists of relatively young 2- and 3-year-old ice compared to 35% in the mid-1980s. Ice coverage in summer 2007 reached a record minimum, with ice extent declining by 42% compared to conditions in the 1980s. The much-reduced extent of the oldest and thickest ice, in combination with other factors such as ice transport that assist the ice-albedo feedback by exposing more open water, help explain this large and abrupt ice loss. **Citation:** Maslanik, J. A., C. Fowler, J. Stroeve, S. Drobot, J. Zwally, D. Yi, and W. Emery (2007), A younger, thinner Arctic ice cover: Increased potential for rapid, extensive sea-ice loss, *Geophys. Res. Lett.*, *34*, L24501, doi:10.1029/2007GL032043.

1. Introduction

[2] Over the past two decades, reductions in the amount of Arctic sea ice that survives summer melt have resulted in more newly formed ice (first-year ice) and less of the relatively thick, old ice that makes up the perennial ice cover [e.g., *Johannessen et al.*, 1999; *Comiso*, 2002; *Belchansky et al.*, 2004; *Nghiem et al.*, 2006; *Kwok*, 2007]. While these studies effectively describe the extent of multiyear ice (MYI; defined here as ice that has survived at least one melt season), little is known about changes within the MYI cover itself. Such changes are significant since MYI that has survived several melt seasons is assumed to be thicker than younger MYI, so any change in the age distribution of ice within the perennial pack should also result in a net loss of ice volume.

2. Changes in Sea-Ice Age

[3] Using satellite data and drifting buoys, it is possible to observe the formation, movement, and disappearance of sea ice. This history can then be used to estimate ice age, as shown by *Fowler et al.* [2004] and *Rigor and Wallace* [2004]. In the *Fowler et al.* [2004] approach, ice movement is calculated using a cross-correlation technique applied to sequential, daily satellite images acquired by the Scanning Multichannel Microwave Radiometer (SMMR), the Special Sensor Microwave/Imager (SSM/I), and the series of Advanced Very High Resolution Radiometer (AVHRR) sensors. Motion vectors are then blended via optimal interpolation with International Arctic Buoy Program drifting-buoy vectors [*Fowler*, 2003]. Using the resulting gridded vector fields for 1979 through summer 2007, ice age can then be estimated by treating each grid cell that contains ice as an independent Lagrangian particle and advecting the particles at weekly time steps. Ice that survives summer melt is considered to have aged for one year, or an additional year in the case of MYI. *Fowler et al.* [2004] and *Rigor and Wallace* [2004] provide further details.

[4] Maps of ice age for March in individual years (Figure 1) show the continued transformation to a younger ice pack described by *Johannessen et al.* [1999], but also illustrate shifts in age distribution within the remaining perennial pack. The area where at least half of the ice fraction in March consists of ice that is at least 5 years old has decreased by 56%, from 5.83×10^6 km^2 in 1985 to a minimum of 2.56×10^6 km^2 in 2007. Most of the perennial pack now consists of ice that is 2 or 3 years old (58% in March 2006 vs. a minimum of 35% in March 1987). The fraction of 5+ year old ice within the MYI decreased from 31% in 1988 to 10% in 2007. Older ice types have essentially disappeared, decreasing from 21% of the ice cover in 1988 to 5% in 2007 for ice 7+ years old. The greatest change in age distribution occurred within the central Arctic Basin. In this area (region 1, Figure 1), 57% of the ice pack was 5 or more years old in 1987, with 25% of this ice at least 9 years old. By 2007 however, the coverage of ice 5+ years old decreased to 7%, and no very old ice (9 + years old) has survived. From 2004 onward, and in particular in 2006 and 2007, the remaining oldest ice has been confined to a small portion of the Arctic (regions 6–8); essentially a relict of the perennial ice cover of 20 years ago.

3. Relationship Between Ice Age and Thickness Within the Perennial Sea Ice Cover

[5] The significance of this transition to a younger MYI pack in terms of overall change in ice volume depends on the assumption that older MYI is thicker than younger MYI. If this assumption is valid, it should be possible to use age as a proxy for thickness, just as thickness has been used to infer age in sonar data [e.g., *Tucker et al.*, 2001; *Yu et al.*, 2004]. For MYI as a whole, the fact that first-year ice (FYI) is thinner than MYI is well documented. Thus, areal coverage of MYI, retrieved from microwave data [e.g., *Belchansky et al.*, 2004; *Nghiem et al.*, 2006; *Kwok*,

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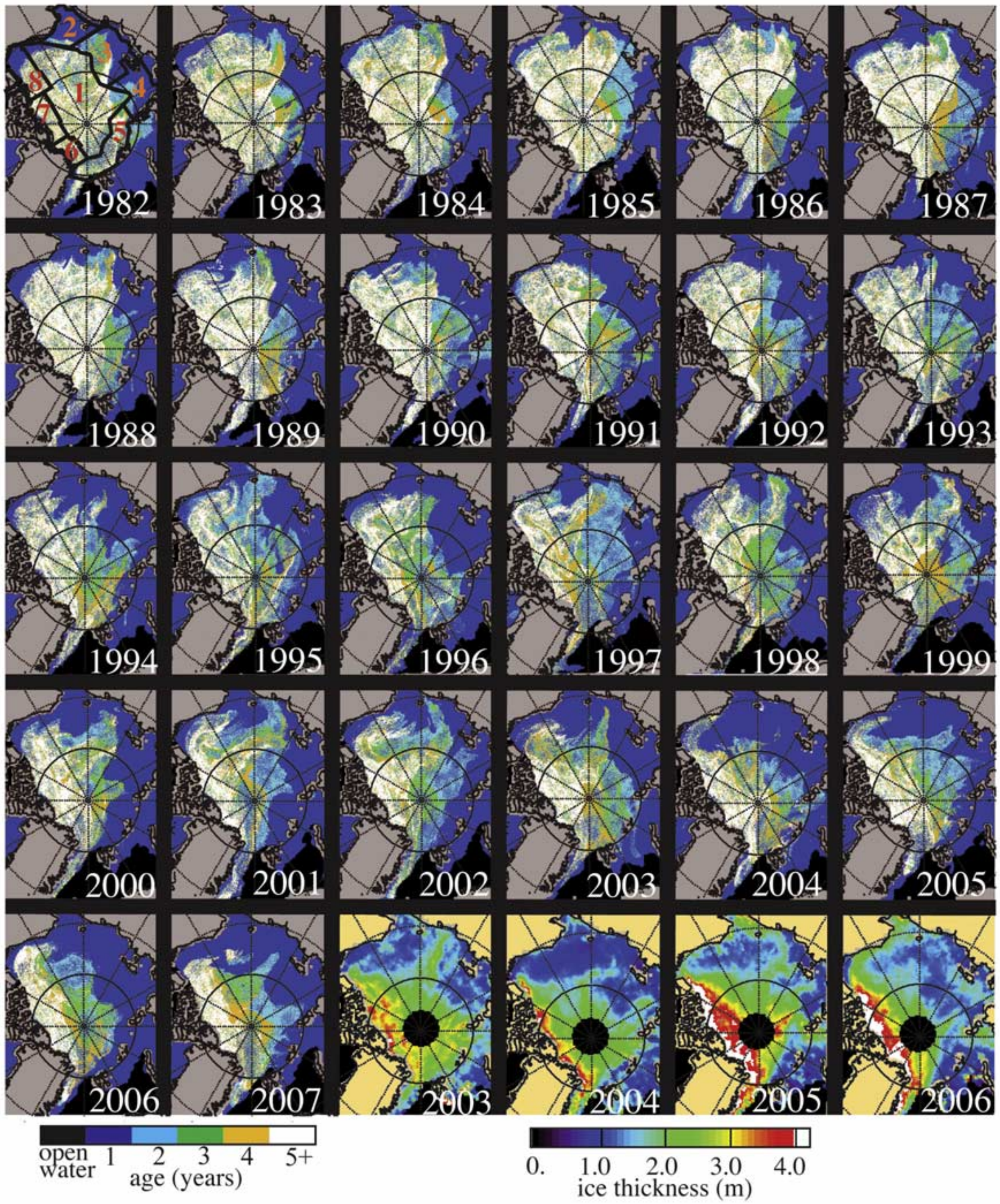

Figure 1. Sea ice age for each year from March 1982 through March 2007 (panels with gray land mask). Eight regions used for analysis are indicated in the first panel. ICESat-derived ice thickness for spring 2003, spring 2004, spring 2005, and spring 2006 are shown in the last four panels with yellow land masks. An animation of the weekly age data is available at http://ccar.colorado.edu/~jimm/age_movie1.mov.

6. Conclusions

[16] Analysis of satellite-derived sea-ice age data and a new proxy record of ice thickness for 1982–2007 shows that in addition to less multiyear ice overall in the Arctic, the mean age and thickness of ice within the remaining multiyear ice pack have decreased due to loss of the oldest ice types, and the remaining older and thicker ice is now confined to a much smaller portion of the Arctic Ocean than in earlier years. Given this, the ice cover is likely to be increasingly susceptible to large, rapid reductions in ice extent and fractional coverage. Such extreme variability is particularly evident during the current summer when more ice was lost than during any previous summer on record, with ice extent and ice area reaching new lows that are well below the previous minima. The replacement of older, thicker ice by younger, thinner ice over much of the Arctic Ocean, combined with cumulative effects of warming, unusual atmospheric circulation patterns, and resulting intensification of the ice-albedo feedback, contributed to this large and abrupt loss of ice. Taken together, these changes suggest that the Arctic Ocean is approaching a point where a return to pre-1990s ice conditions becomes increasingly difficult and where large, abrupt changes in summer ice cover as in 2007 may become the norm.