Decadal Changes in the Arctic Sea Ice Cover and Surface Temperature with especial focus on Yamal, Alaska and the Canadian Peninsula

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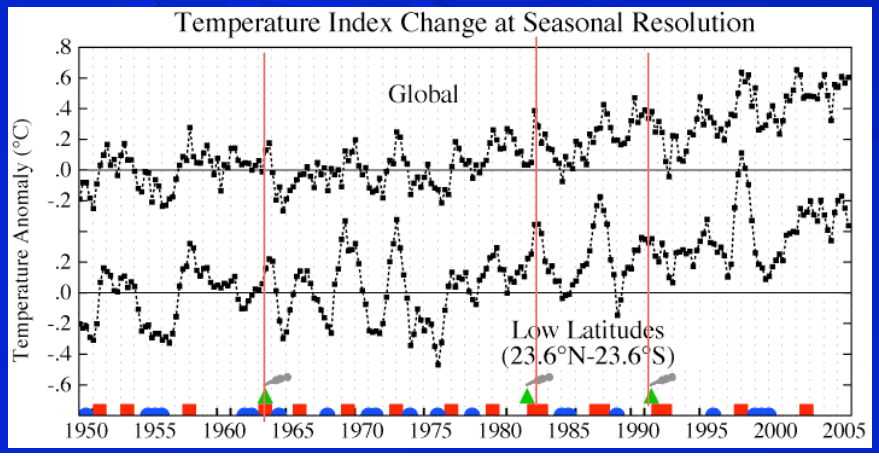
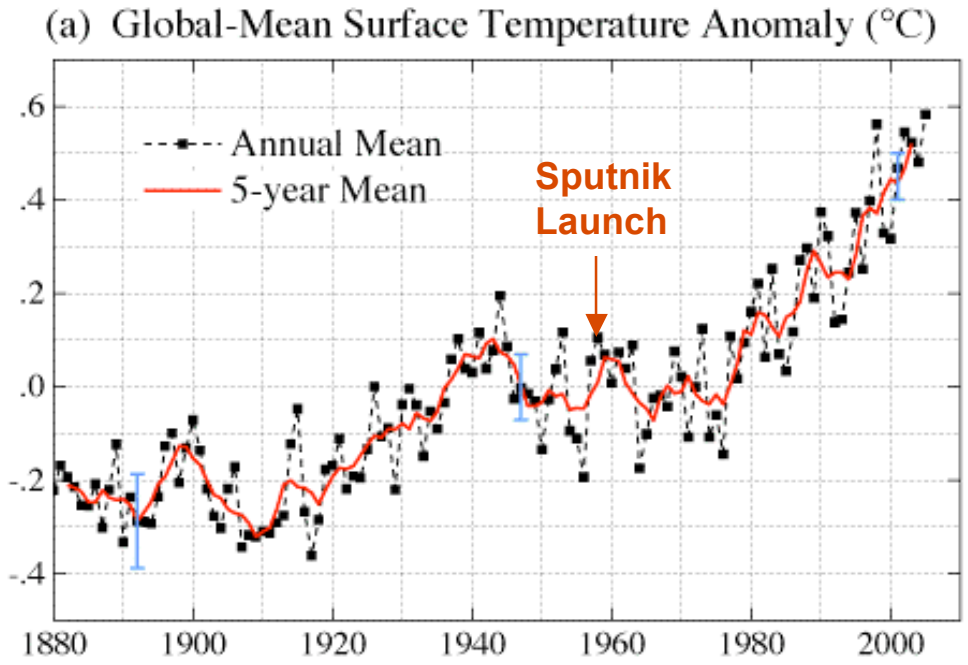
Relevant Information

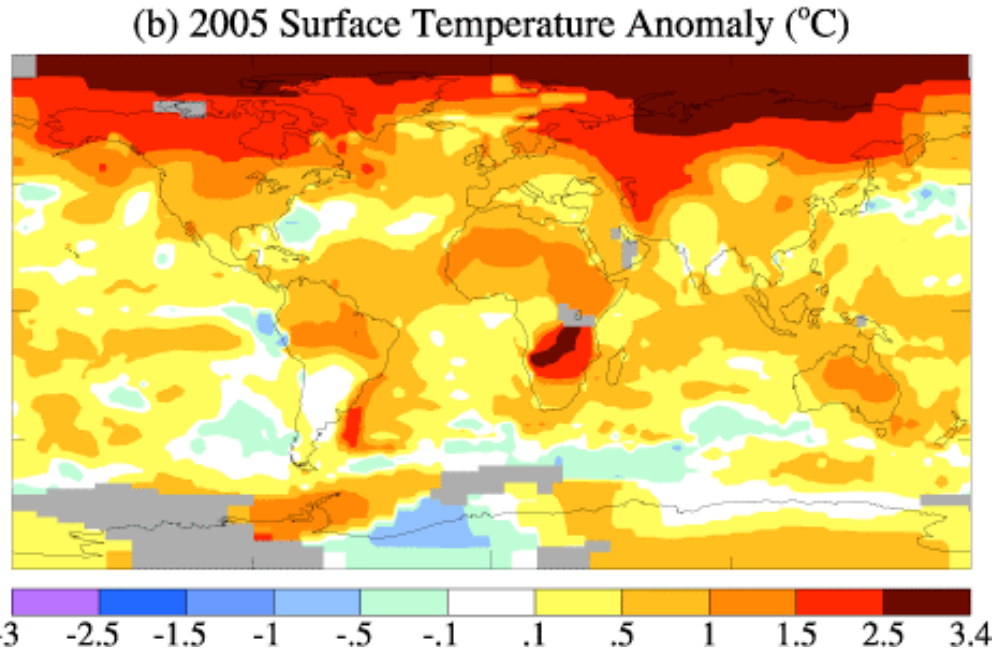
- Arctic sea ice in the central basin is thinning according to submarine studies. Rate of decline in thickness is about -3.6 to -4.3 cm/year. The ice cover in the 1990s is about 1.3 m thinner than in the 1958-1976 period.
- Some modeling studies indicate that the perennial ice cover will disappear as early as 2025 while others predict as late as 2080.
- AO and NAO are no longer correlated with the ice cover. Some scientists think that the phase has changed. New concepts like ARM are emerging
- Arctic temperature is rising, glaciers are melting, snow cover is decreasing, Greenland ice sheet is declining and permafrost is melting.

Surface temperature trends from meteorological stations around the world

- Rapid rise from 1910 to 1942
- Moderate cooling from 1942 to 1975
- Rapid rise from 1975 to the present (satellite era)
- Global cooling during volcanic erruptions

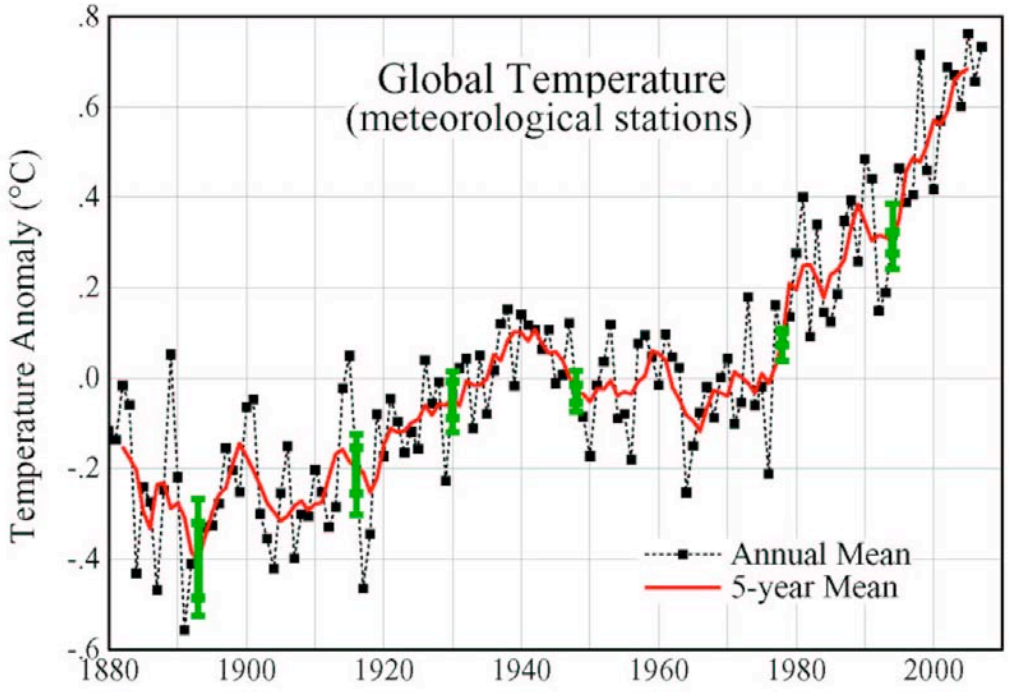


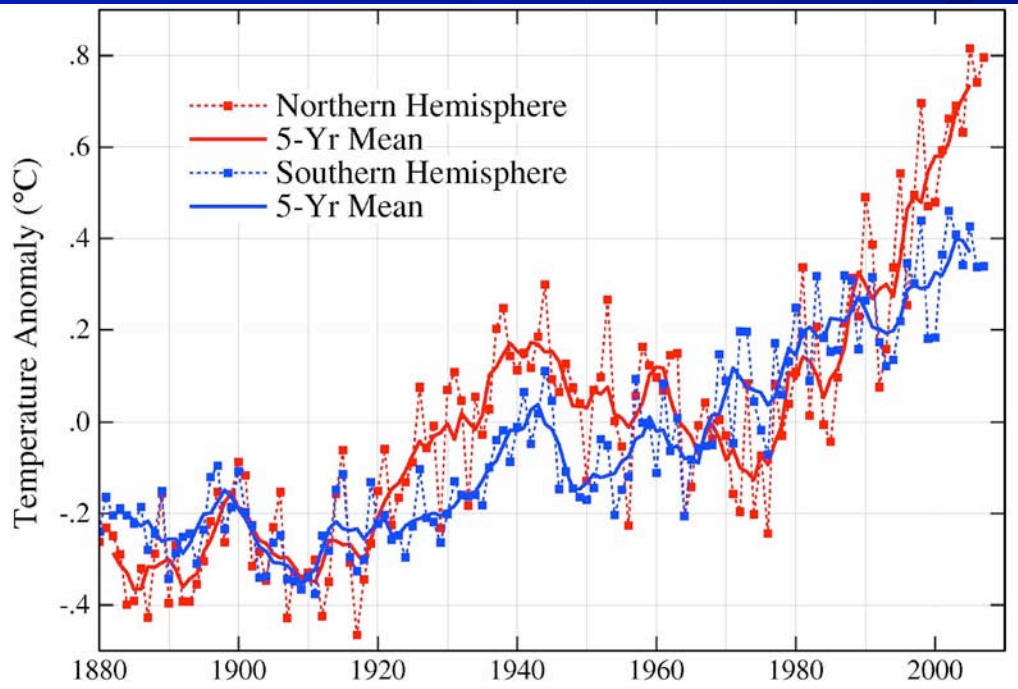




2007 is the second warmest year observed from meteorological stations

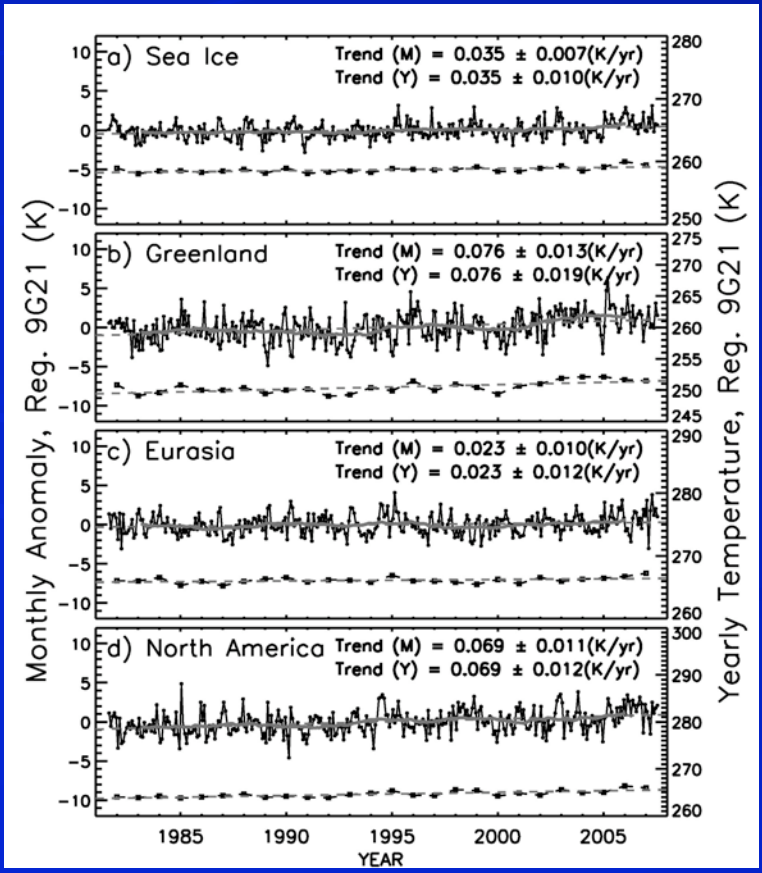
Ttrends in the Northern Hemisphere was considerably higher than that of the Southern Hemisphere.

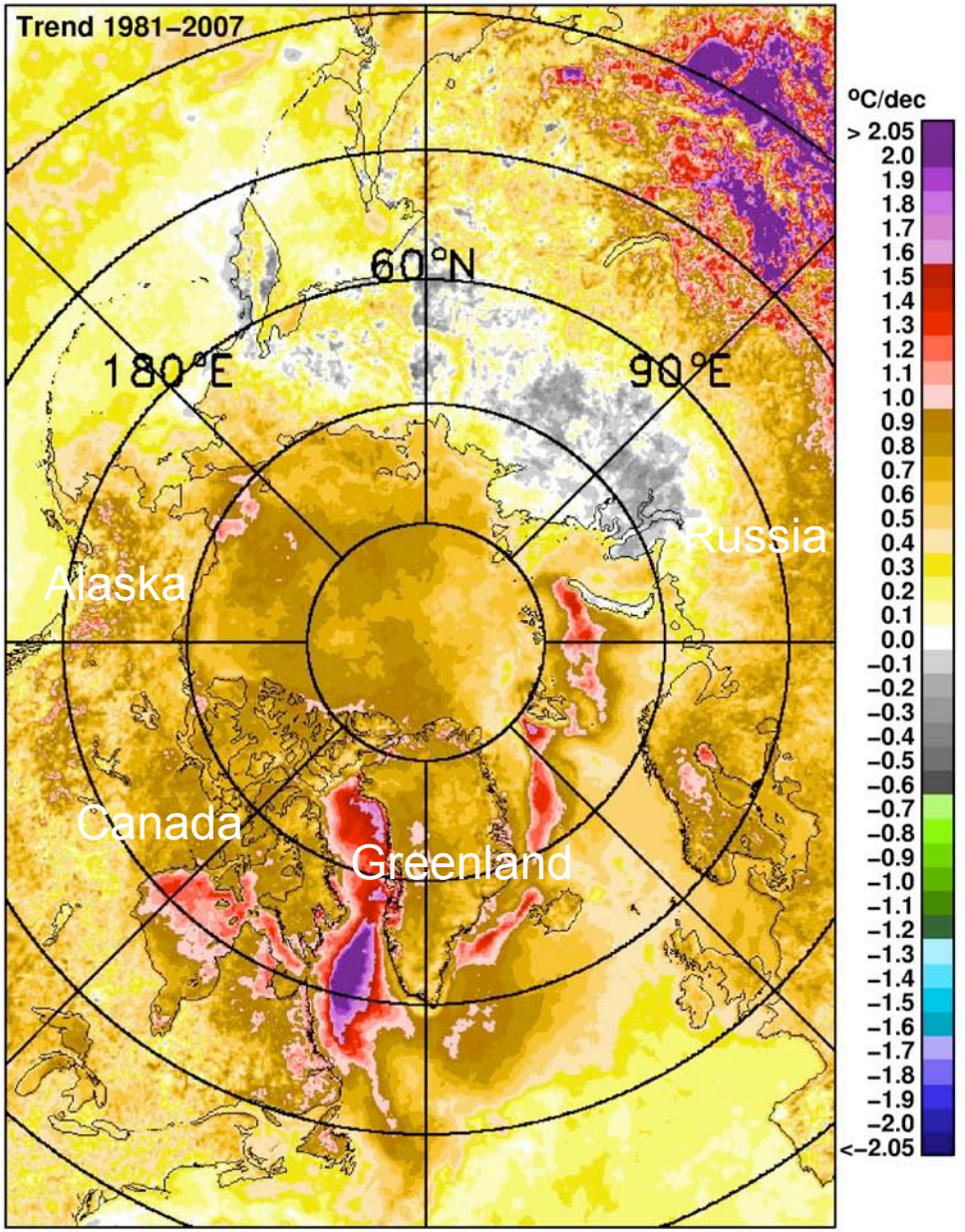




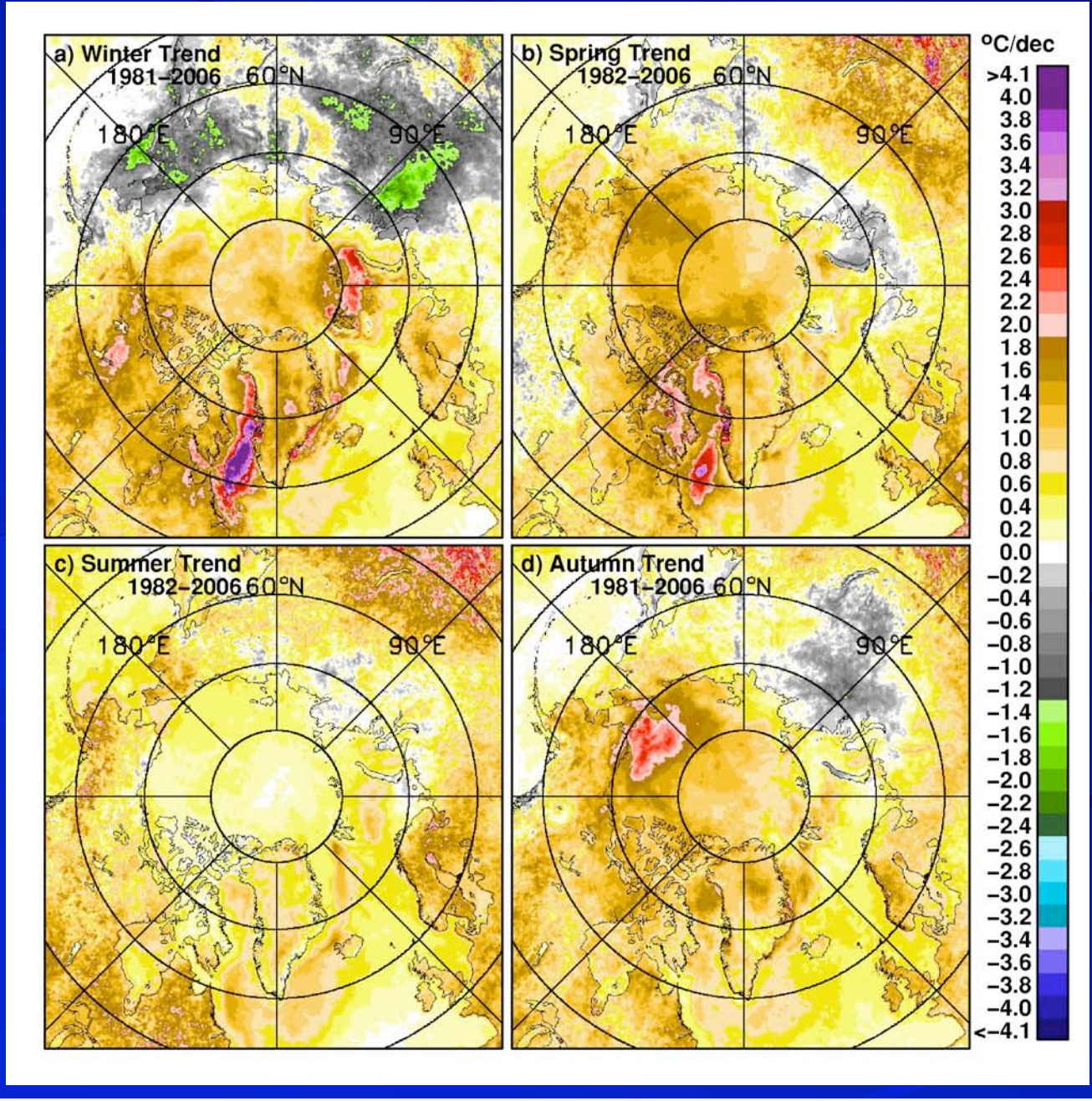
Trends in the Arctic Surface Temperature (1981 to 2007)

Trends in Ts >66.5°N = 0.64°C/dec
Trends over Sea ice = 0.35°C/dec
Trends over Greenland = 0.76°C/dec
Trends over Eurasia = 0.23°C/dec
Trends over North Am = 0.69°C/dec
>60°N for both Eurasia and North Am

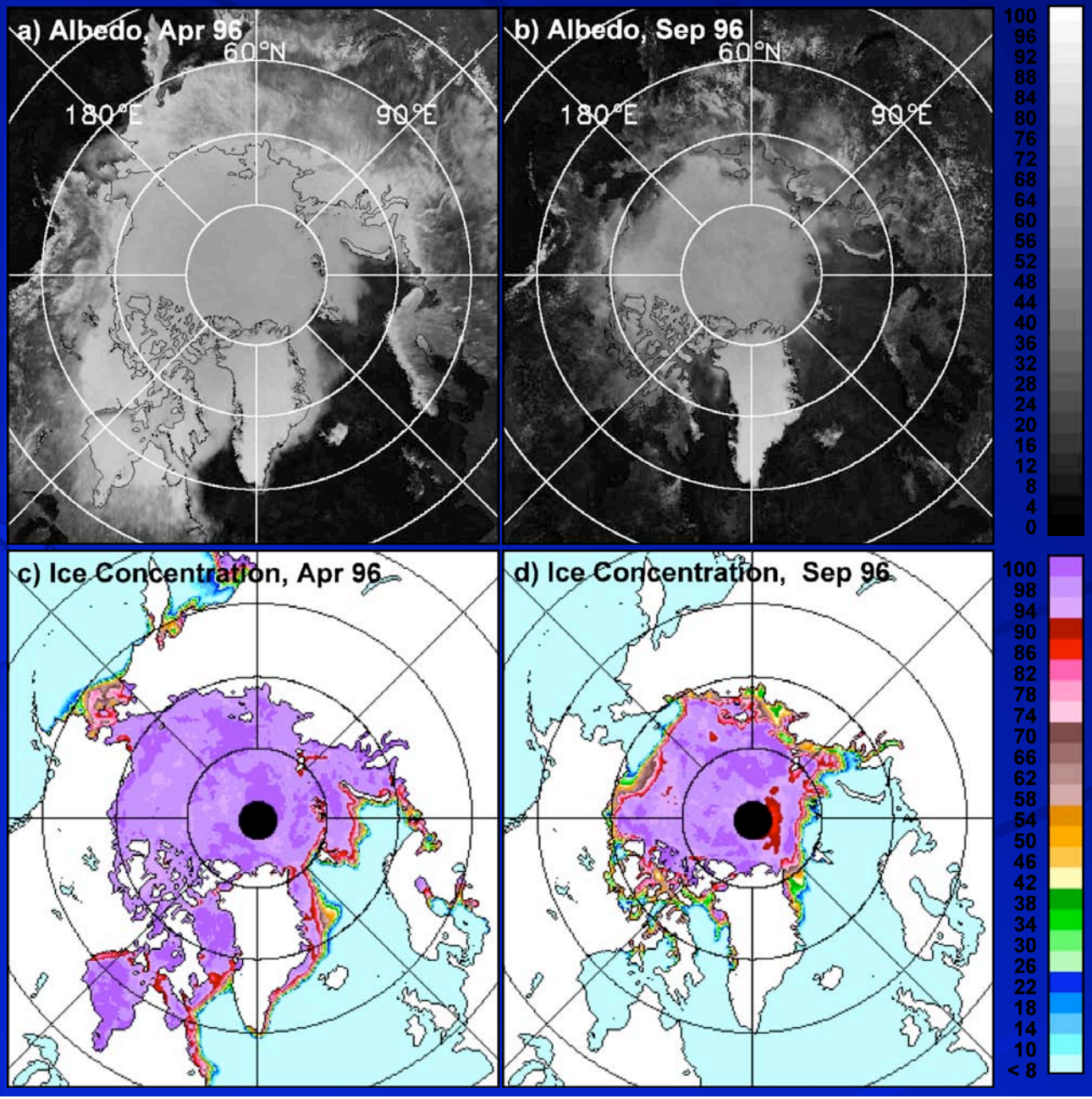




Seasonal Trends in the NH Surface Temperature

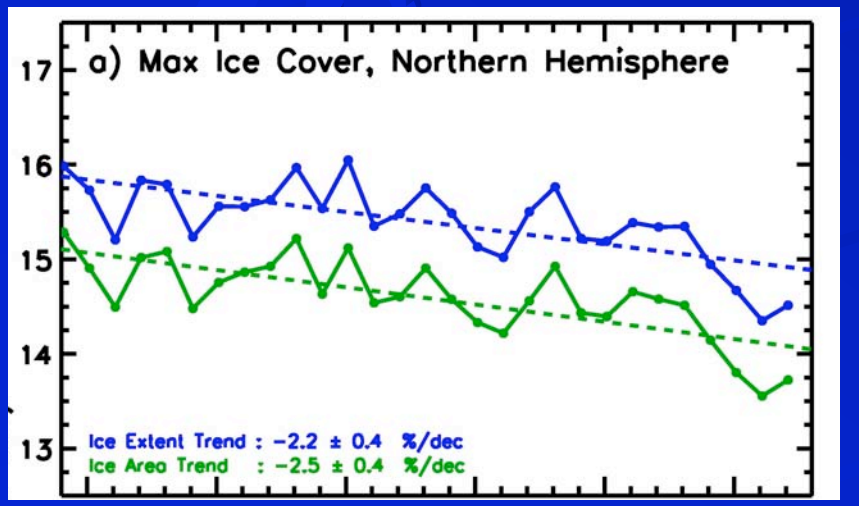


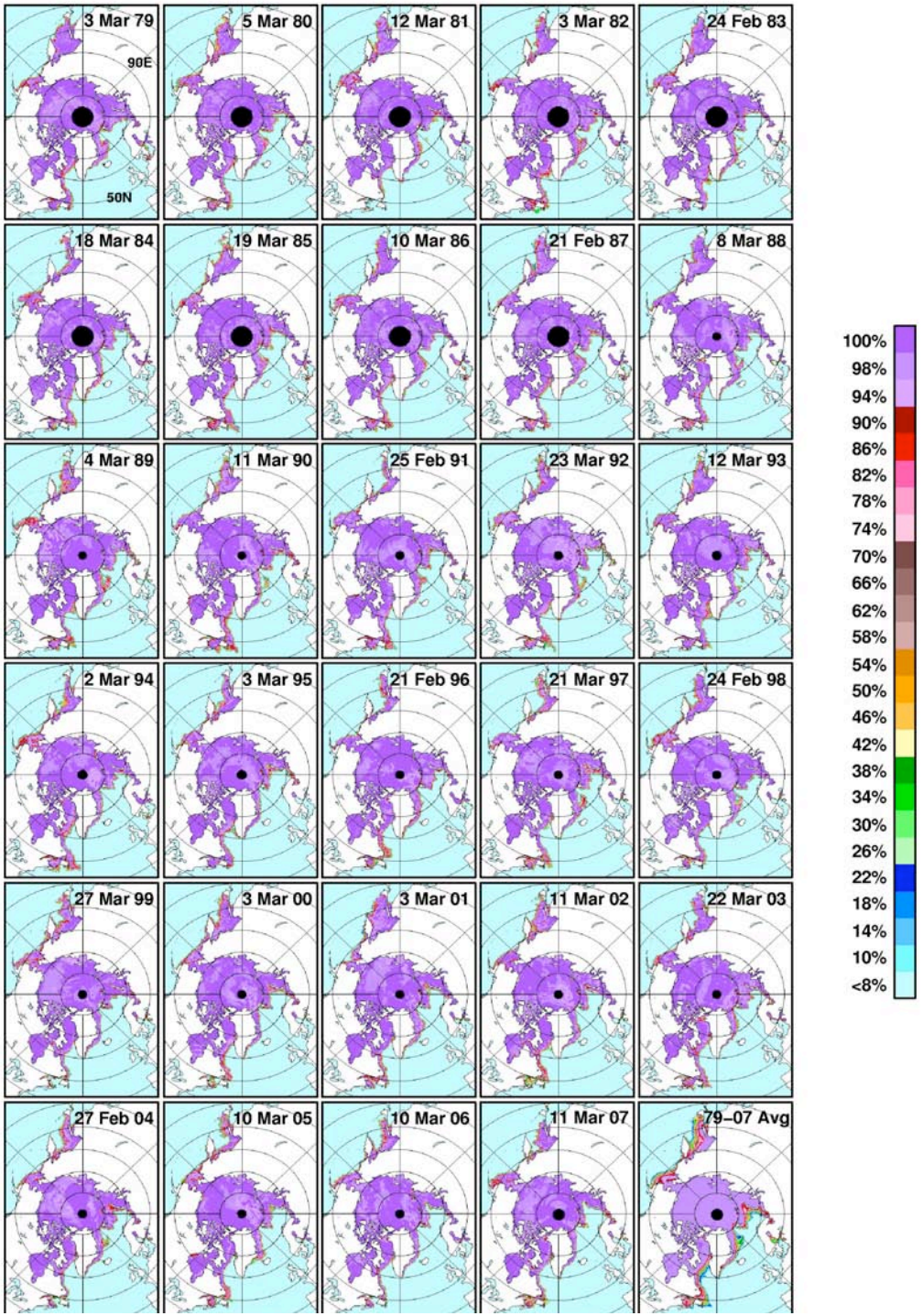
Arctic Albedo and Ice Concentration



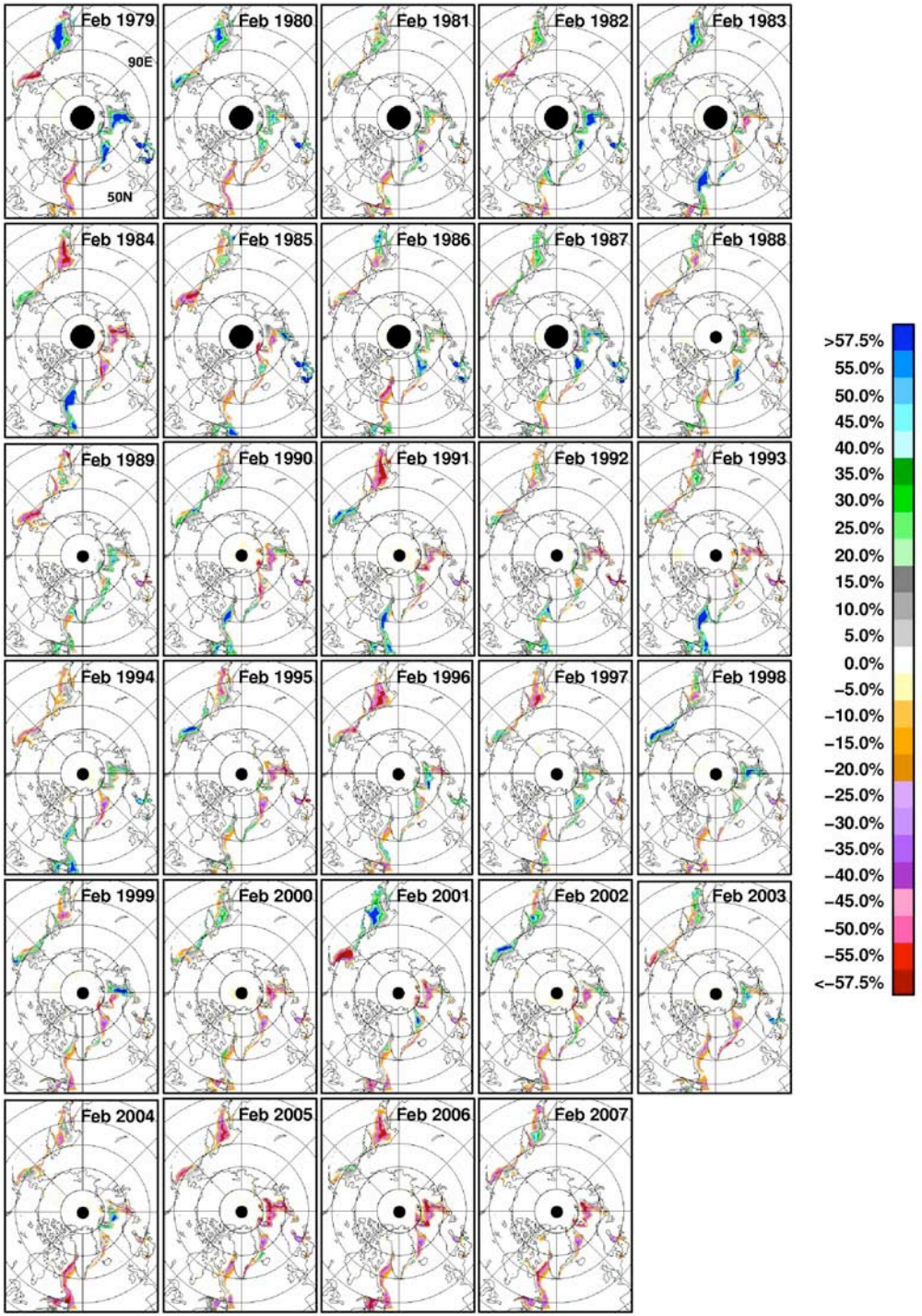
Yearly Arctic Ice Cover during Maximum Extents 1979-2007

Extent trend: -2.2%/decade
Areas trend: -2.5%/decade



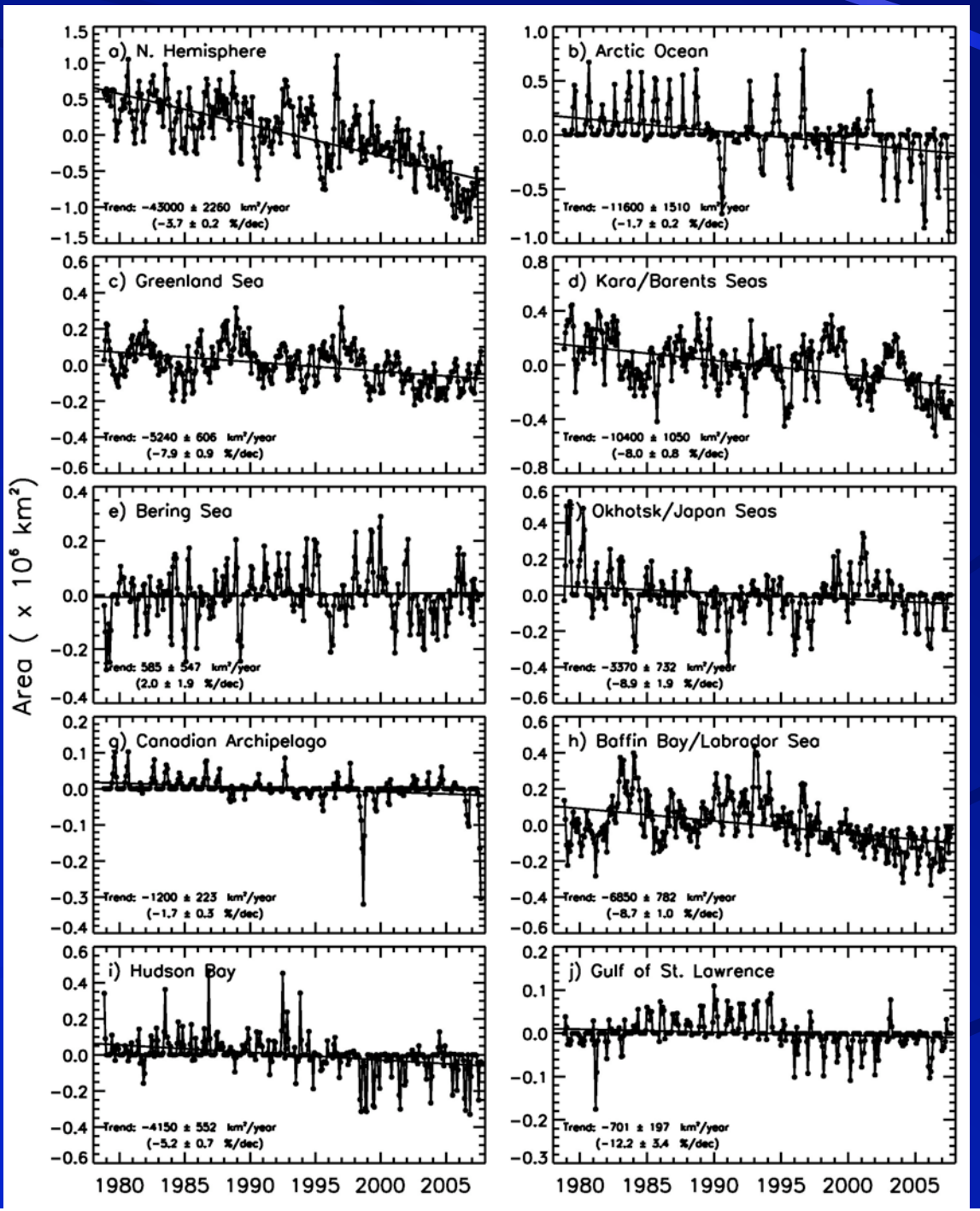


Winter Anomalies show consistent declines during the last four years



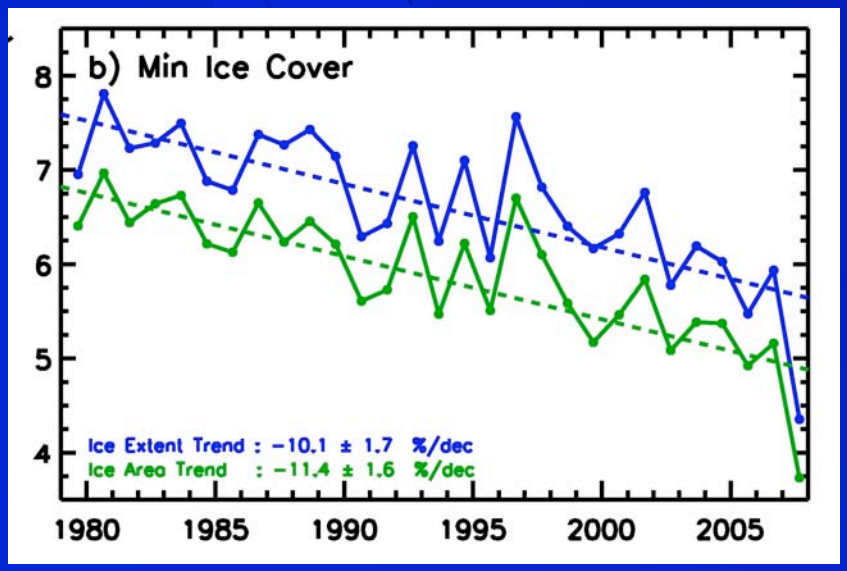
Pan-Arctic and Regional Trends

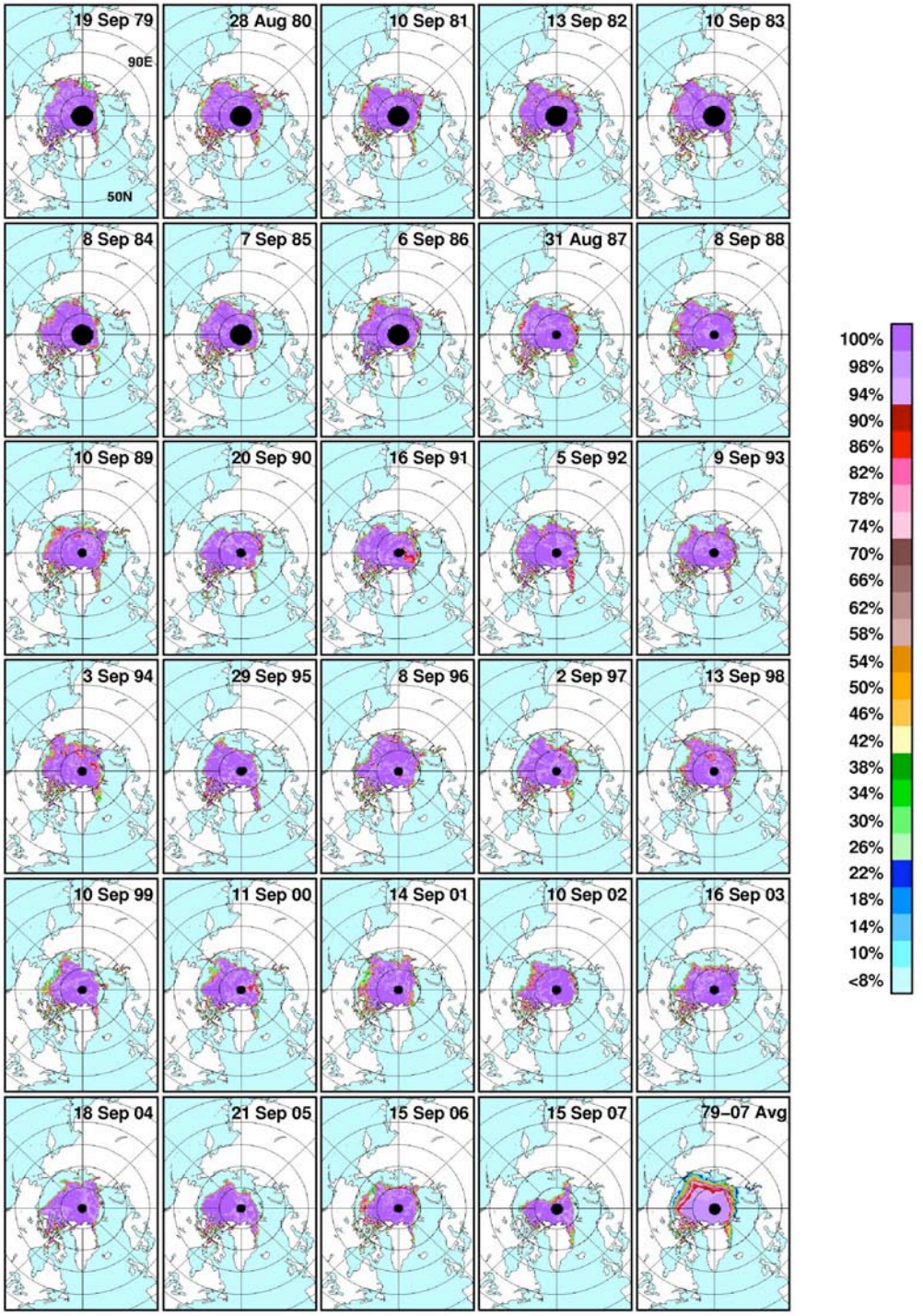
NH = -3.7%/dec
AO = -1.7 %/dec
GS = -7.9%/dec
KBS = -8%/dec
BS = 2.0%/dec
OS = -8.9%/dec
CA = -1.7%/dec
BB = -8.7%/dec
HB = -5.2%/dec
GSL = -12.2%/dec



Yearly Arctic Ice Cover during Minimum Extents 1979-2003

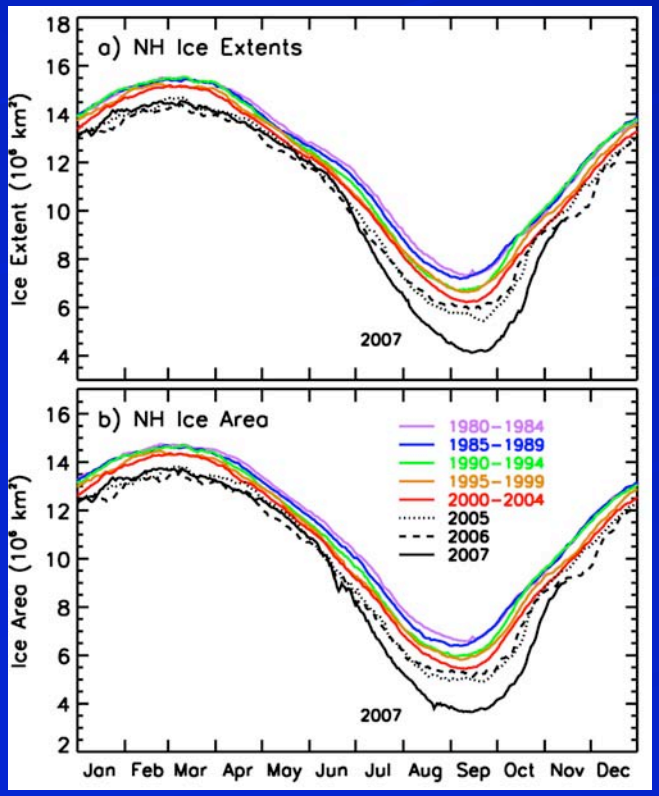
Extent trend: -10.1%/decade
Area trend: -11.4%/decade

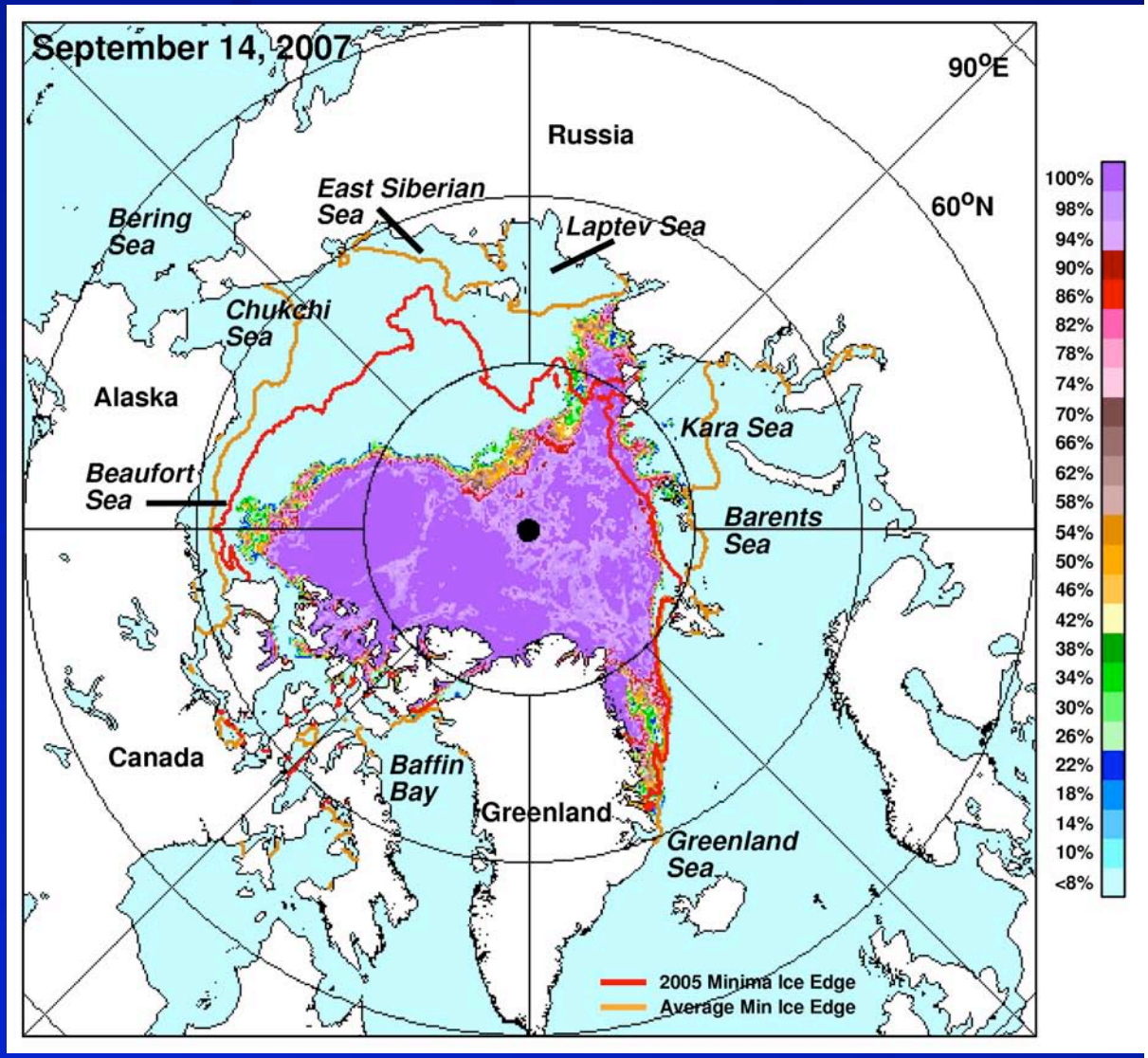




The Big Sea Ice Anomaly in 2007

2007 ice minimum area was 27% less than 2005 and 38% less than climatological average.



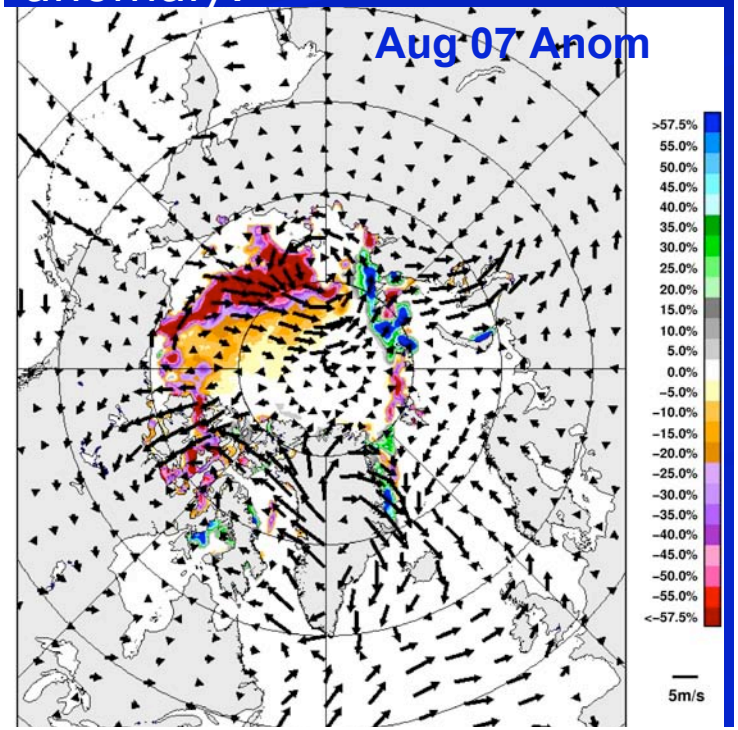


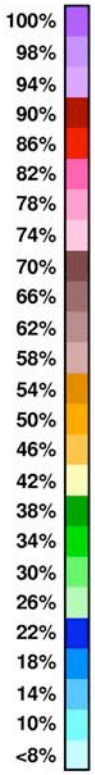
Ref: Comiso, J.C., C. Parkinson, R. Gersten and L. Stock, Accelerated decline in the Arctic sea ice cover, *Geophysical Research Letter* (in press).

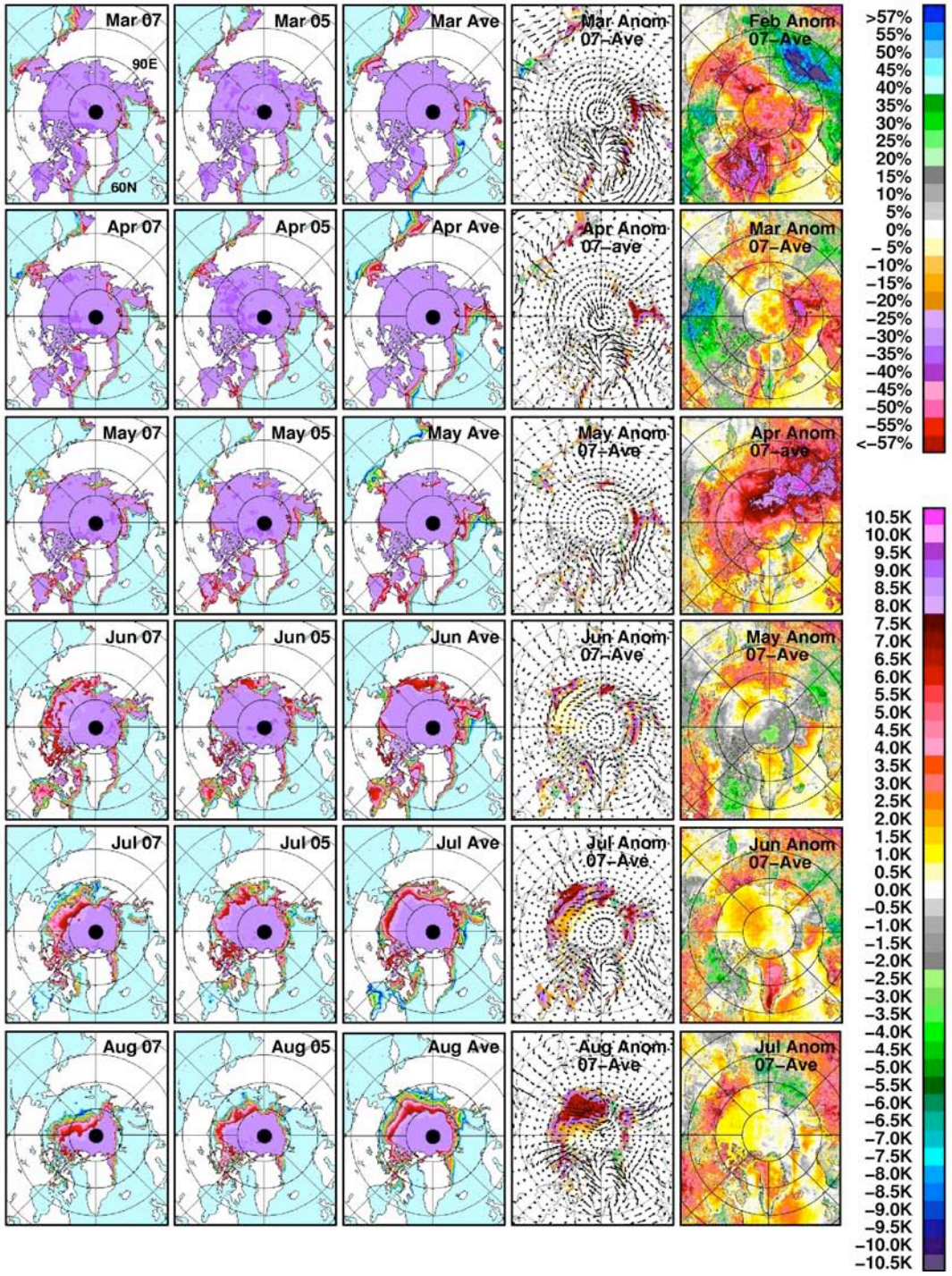
Arctic Perennial Ice – 1979 to 2007

Temporal Variations in the ice cover, wind and surface temperature (March to May 2007)

Data indicates significant temperature and wind effects. In August, there was a cyclone in the region that may have facilitated anomaly.



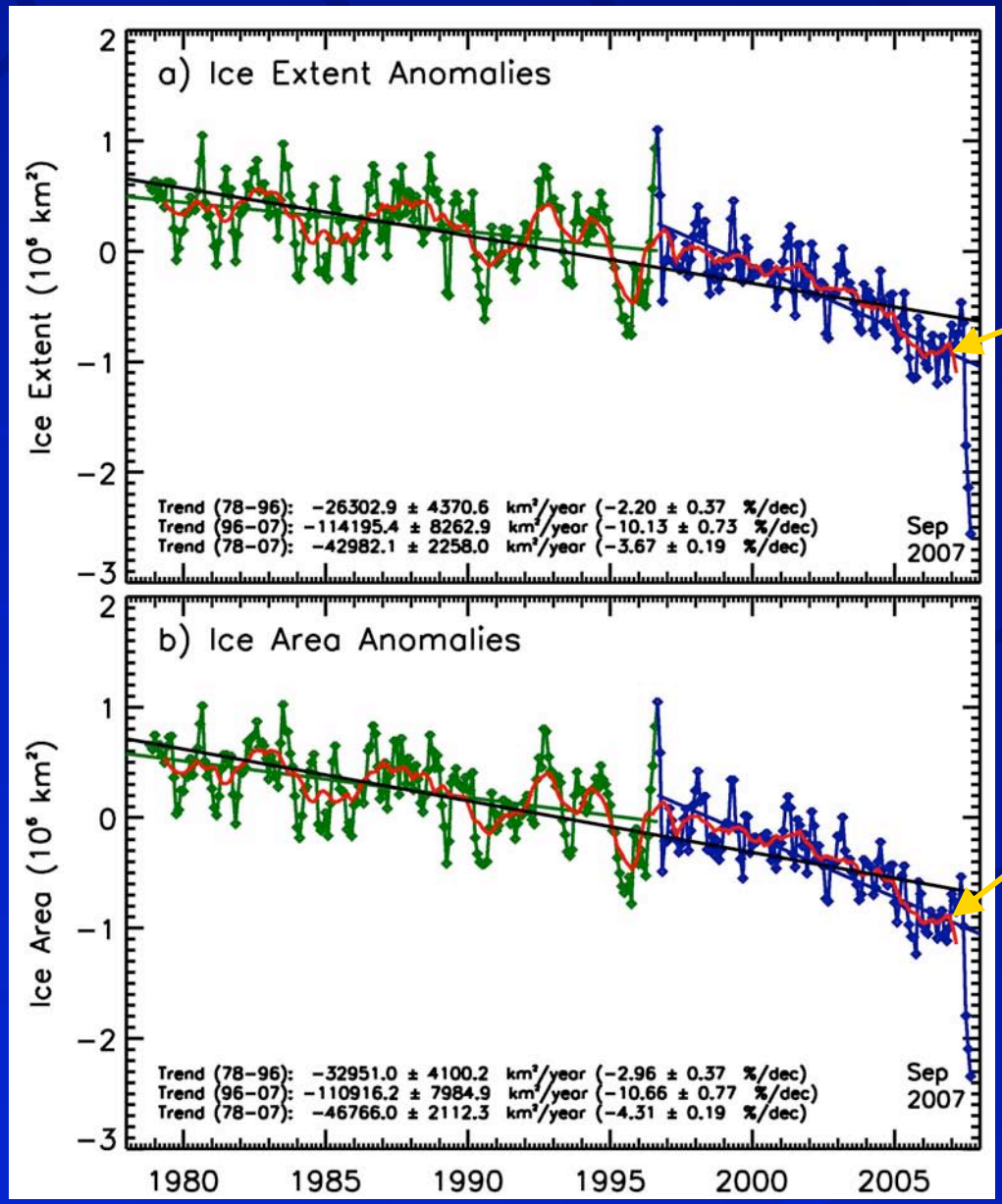




Total Ice Cover/Monthly Anomalies

From 1978 to 1996, the trend in the ice extent was -2.2% per decade. Since 1996, the trend has changed to -10.1% per decade suggesting a large acceleration in the decline.

Acceleration in the decline makes it difficult for ice to recover because of ice albedo feedback.

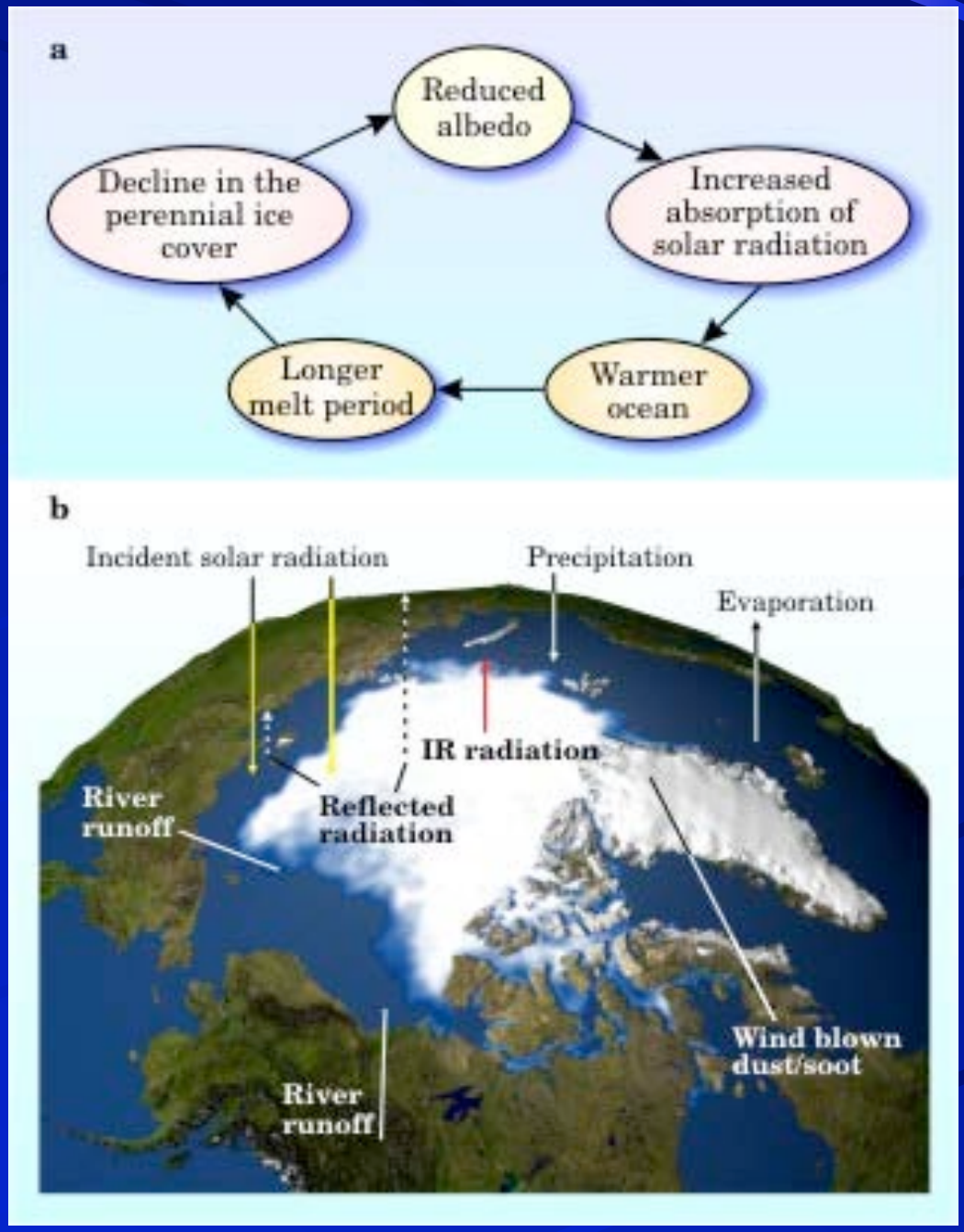


-10.1%/dec

-10.7%/dec

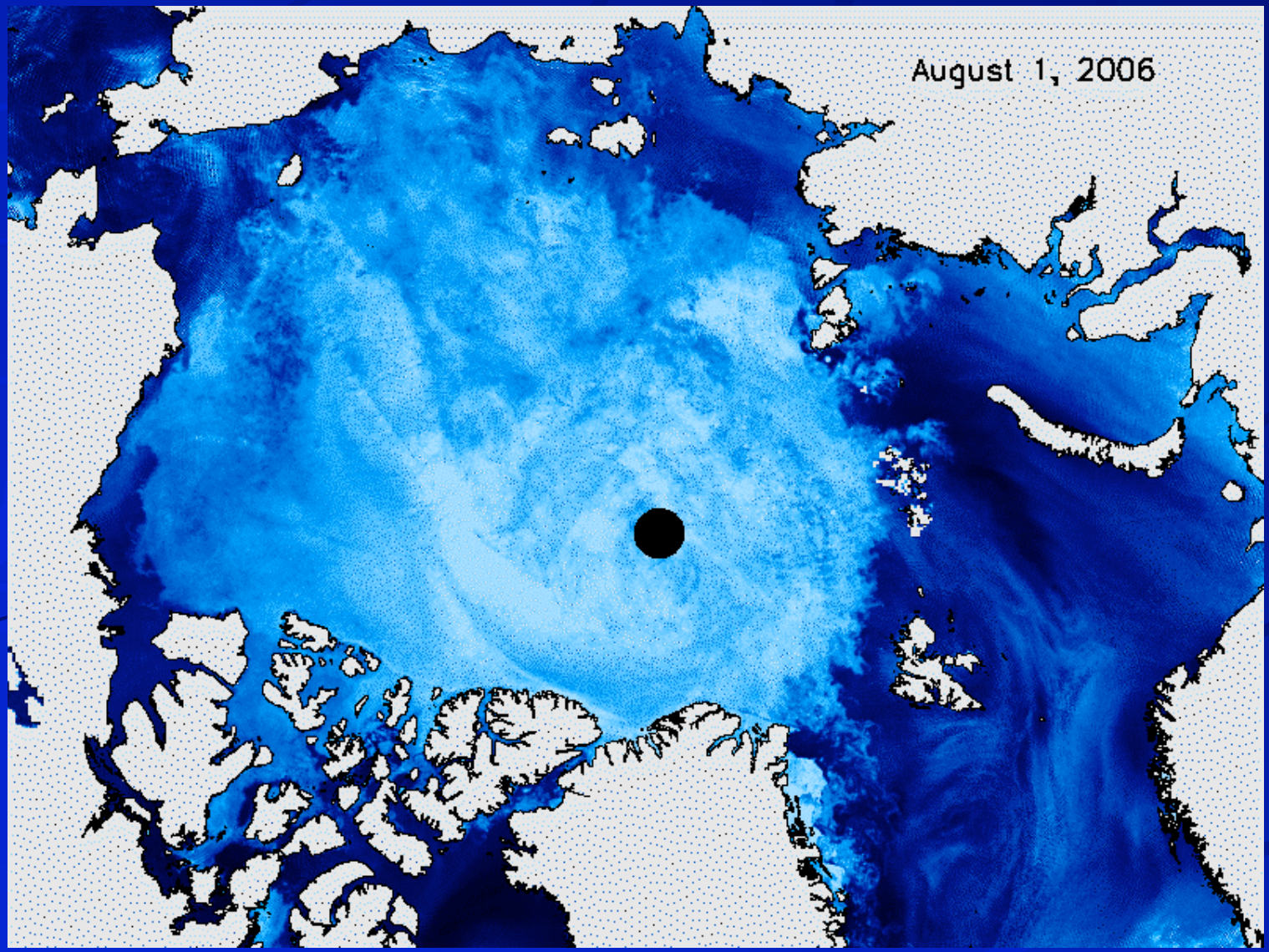
Polar Amplification-Feedbacks

- **Ice-Albedo Feedback –relevant to retreating perennial ice cover and also over land**
- **Cloud feedback – positive or negative, depending on the height of clouds**
- **Other feedbacks are mainly positive**

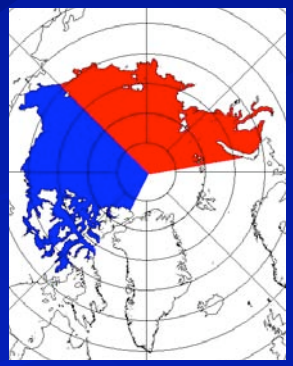


Conditioning: The first summer polynya in 2006 – an evidence of a warm ocean

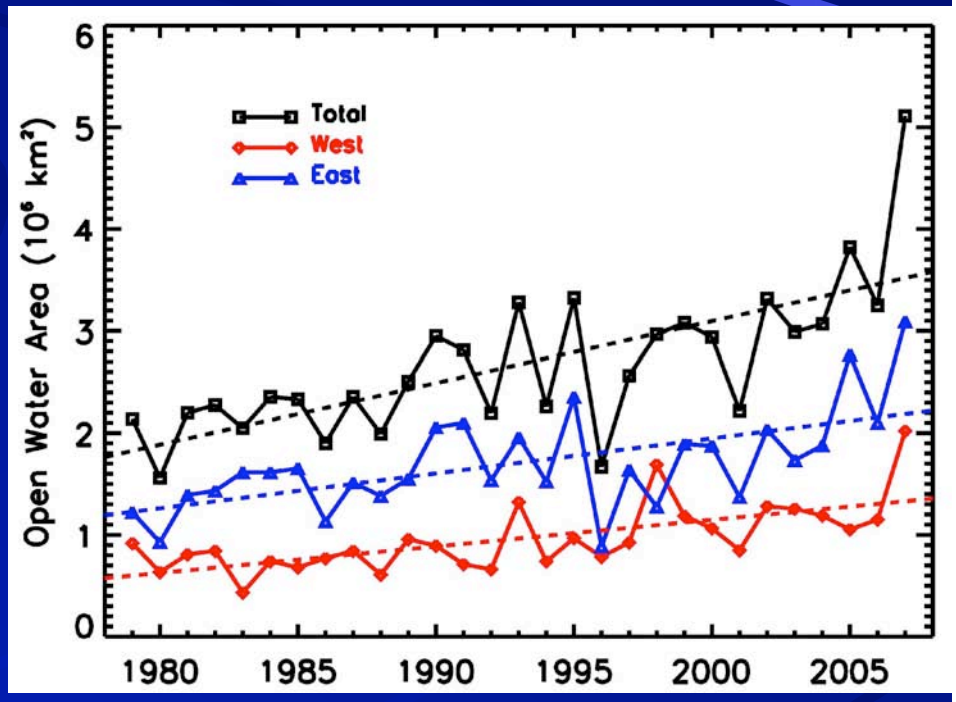
Multiyear ice to the south kept the ice cover from being a record low.

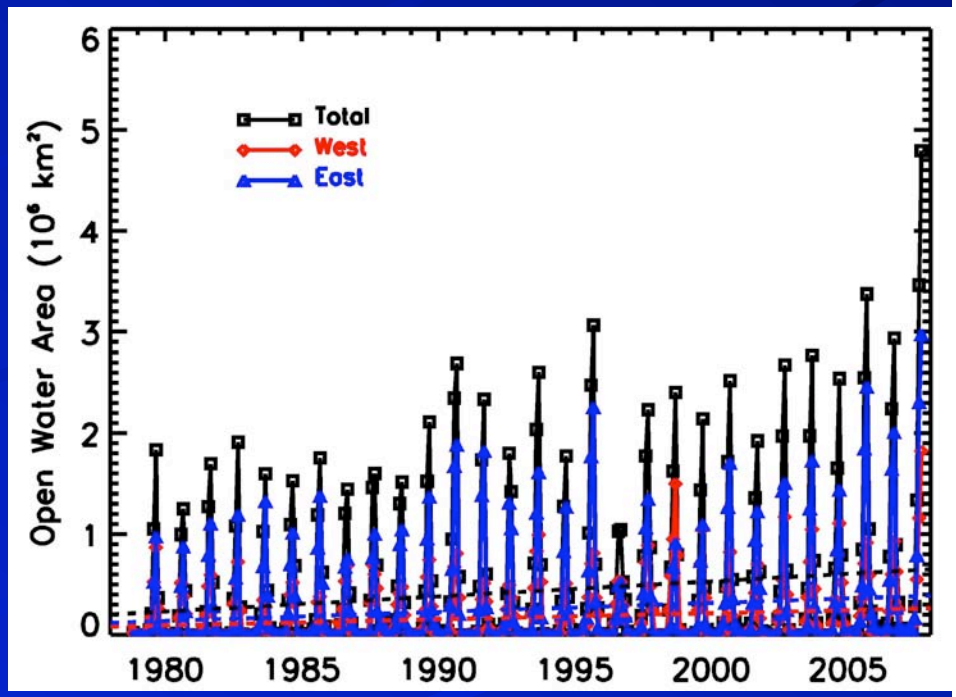


Ice-albedo feedback Effect



More open water area means more solar heating of the Arctic ocean mixed layer. Trends in water area are 20, 27 and 23% for east (red), west (blue) and total (blue+red), respectively. This translates to trends in solar flux which surely accelerates the retreat of the ice cover.

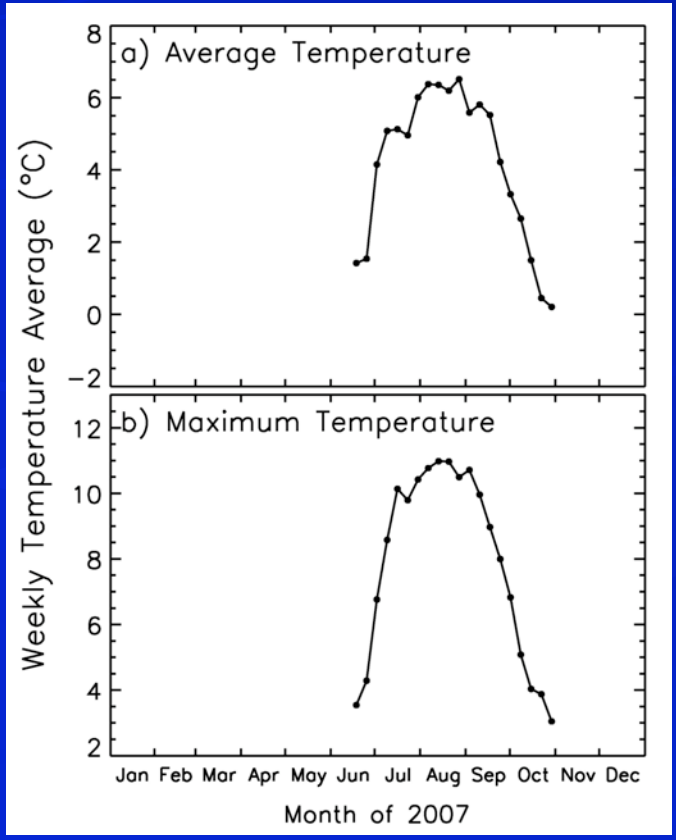


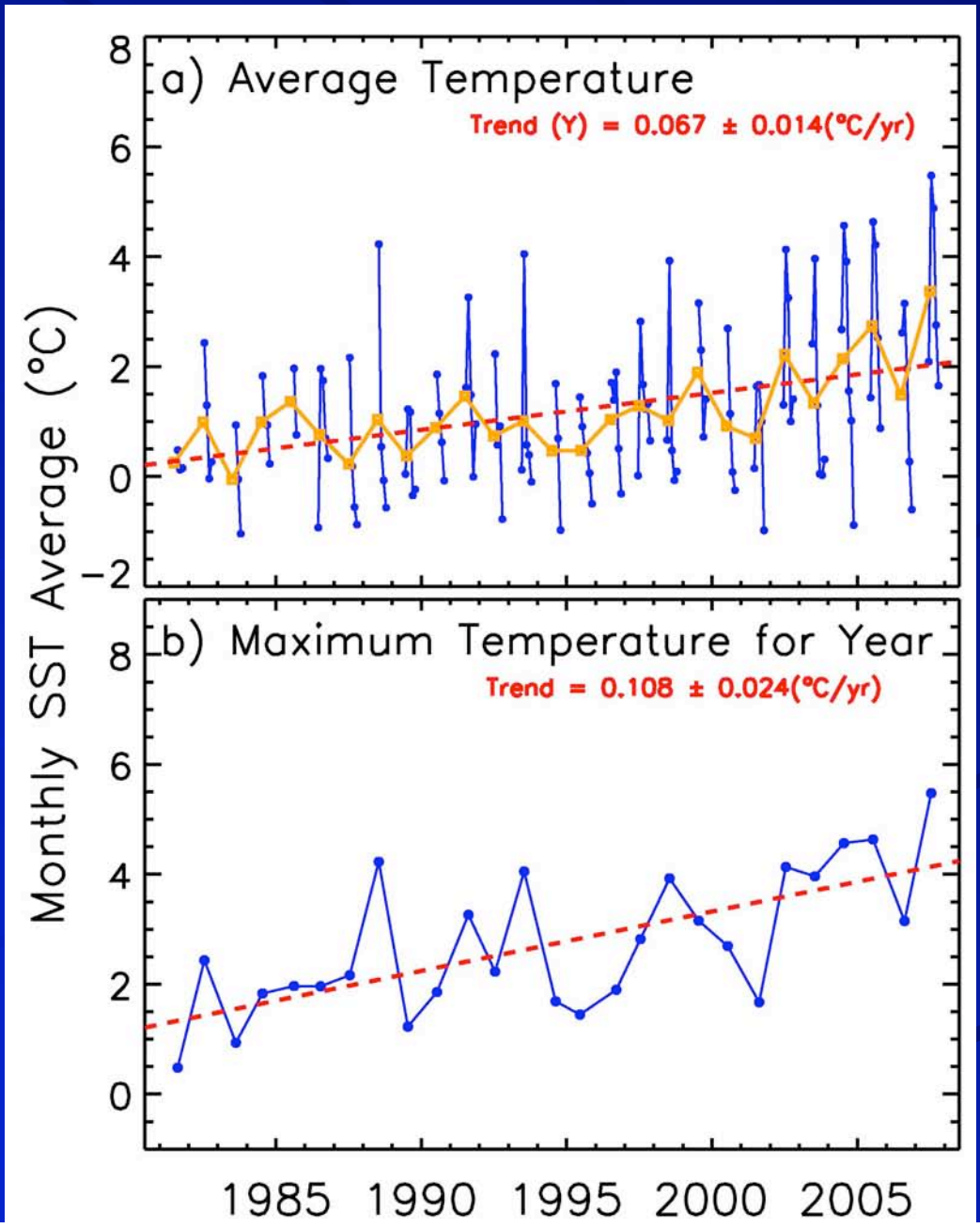


SST interannual variability and trends in the Western Region

Trends in Ave SST = 0.7°C/dec
Trends in Max SST = 1.1°C/dec

High warming rate in early July 2007 (= 0.4°C per day)

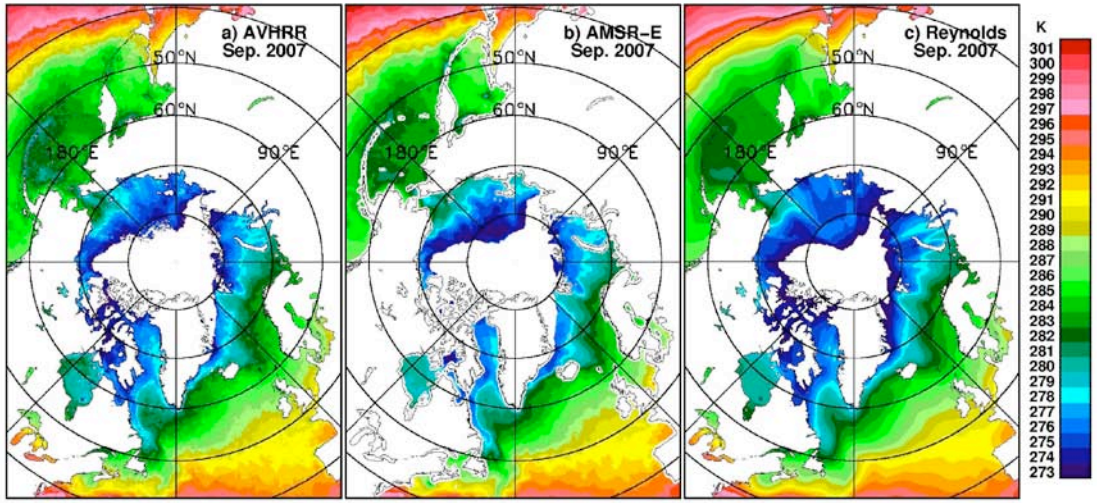


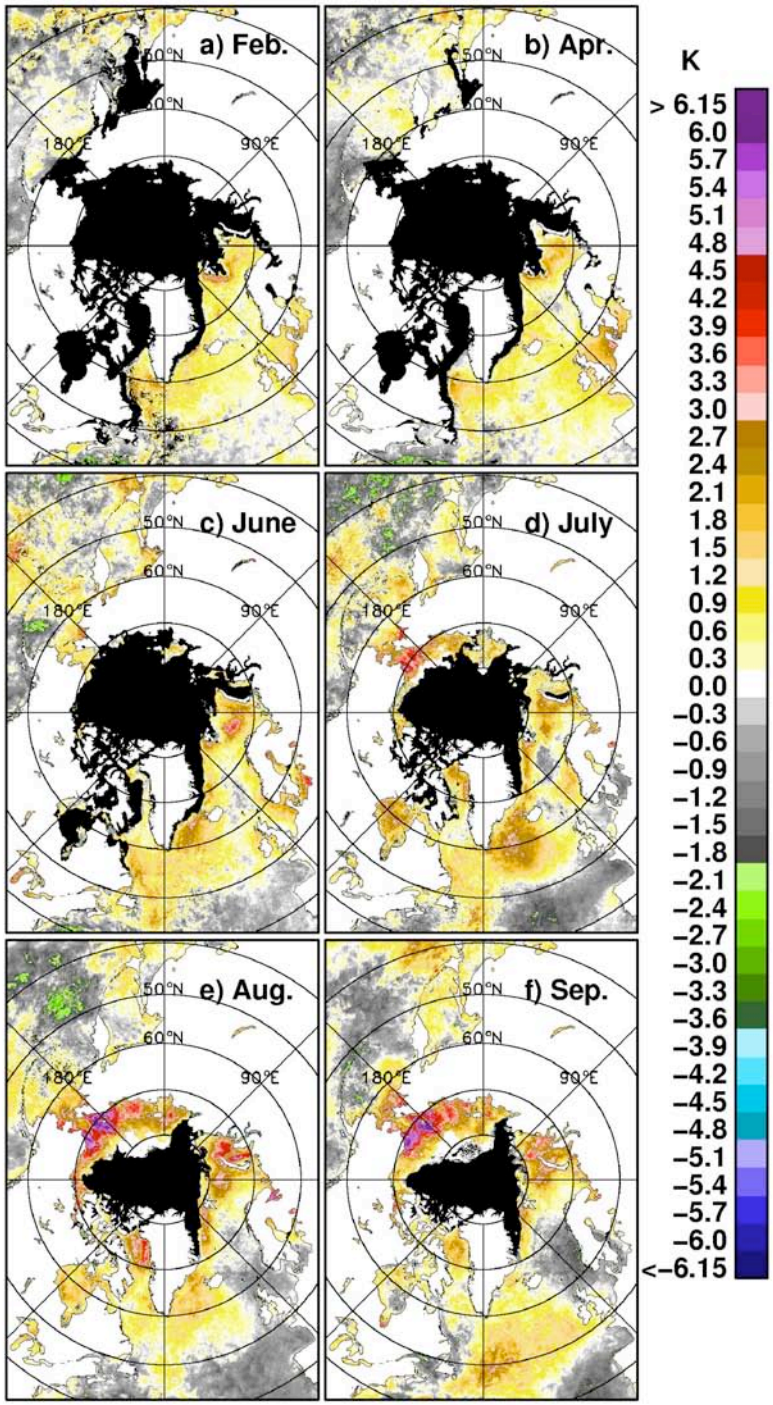


Enhanced water temperatures in 2007

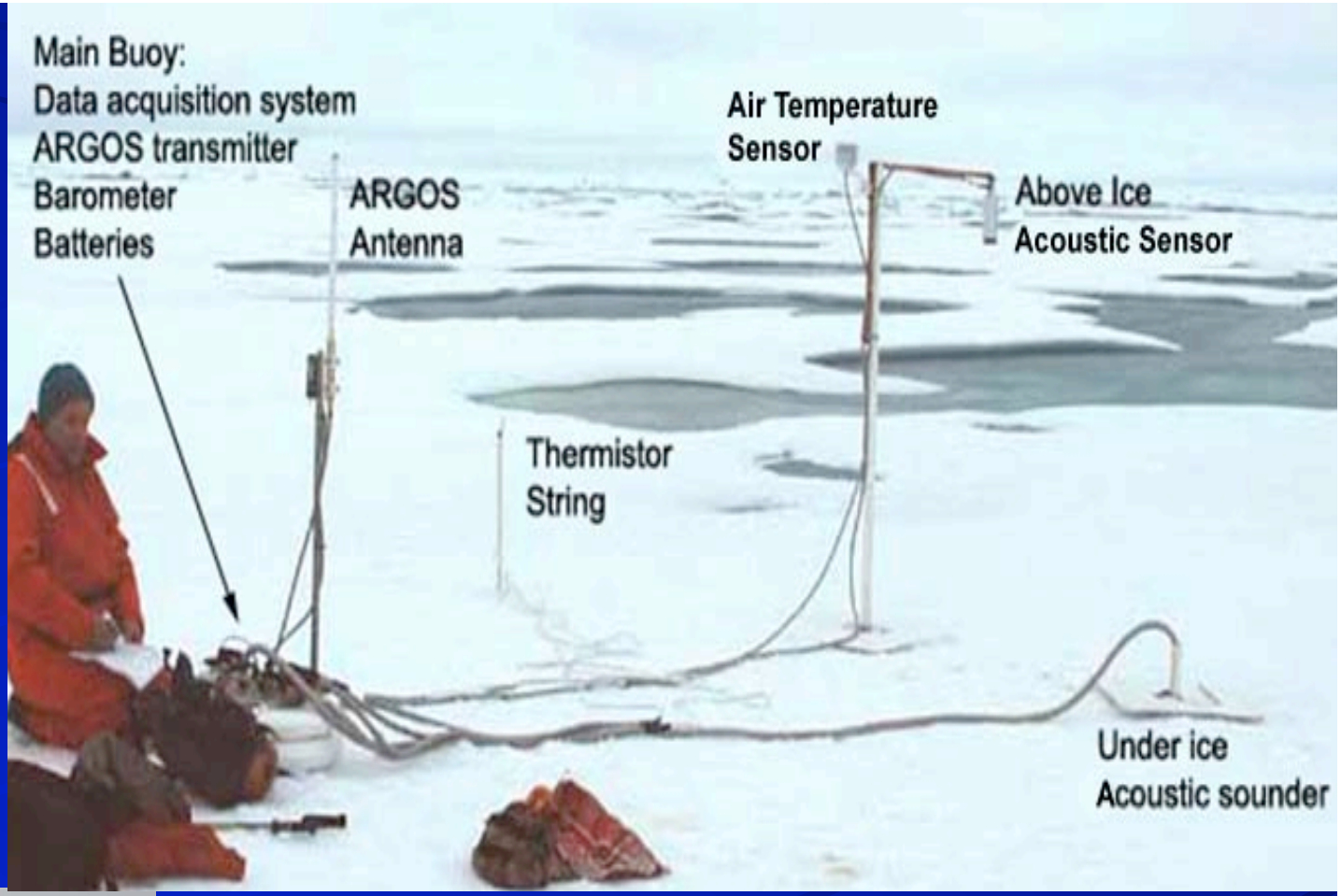
Anomaly maps based on AVHRR data from 1981 to 2007 show significant warming of Arctic SSTs in 2007

Infrared and microwave SSTs are consistent and could provide the means to assess how the mixed layer in the Arctic Ocean is changing.



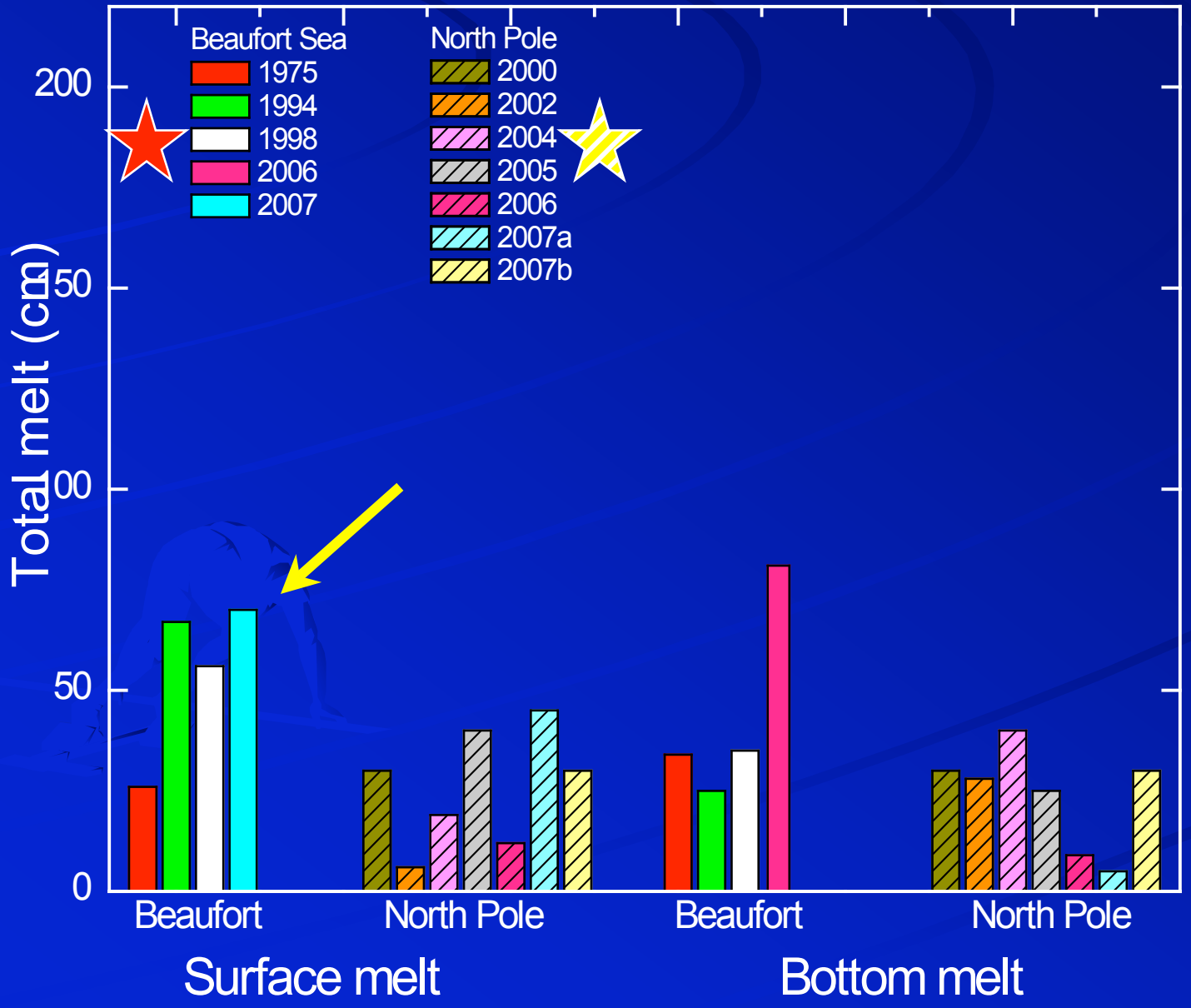


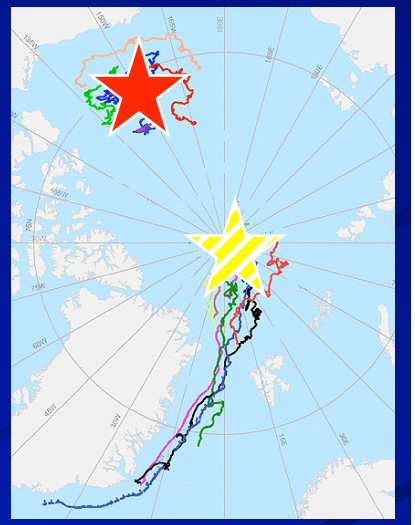
IPY 2007 measure ments



Don Perovich and the CRREL Group at the Beaufort Sea in 2007

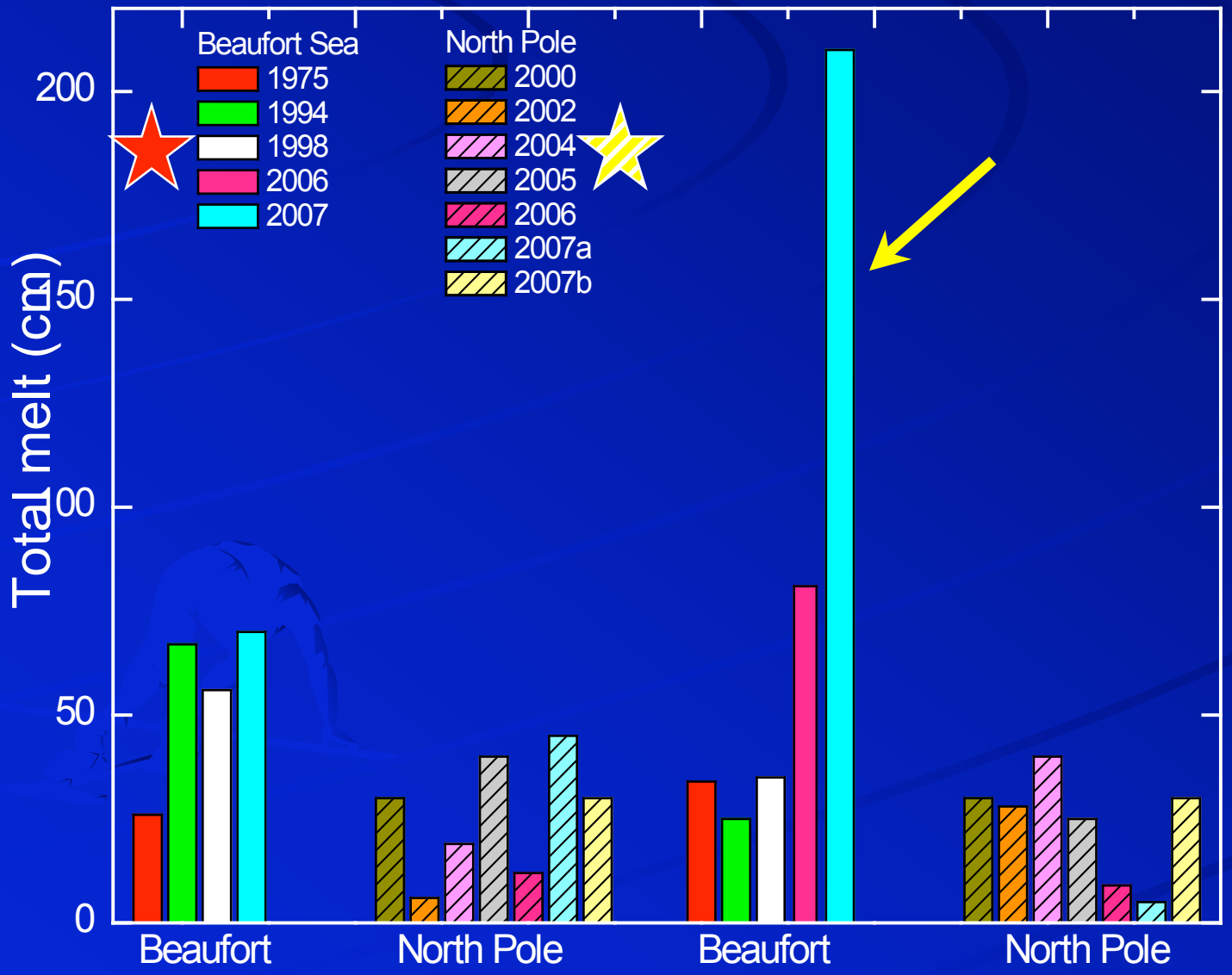
Summer ice melt

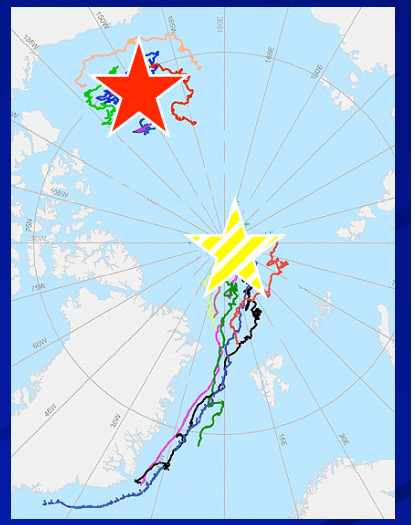




2007 Beaufort – typical surface melt

Summer ice melt





2007 Beaufort – huge increase in bottom melt

Estimate of solar heating

$$F_{ocn} = F_r (1 - \alpha) (1 - C)$$

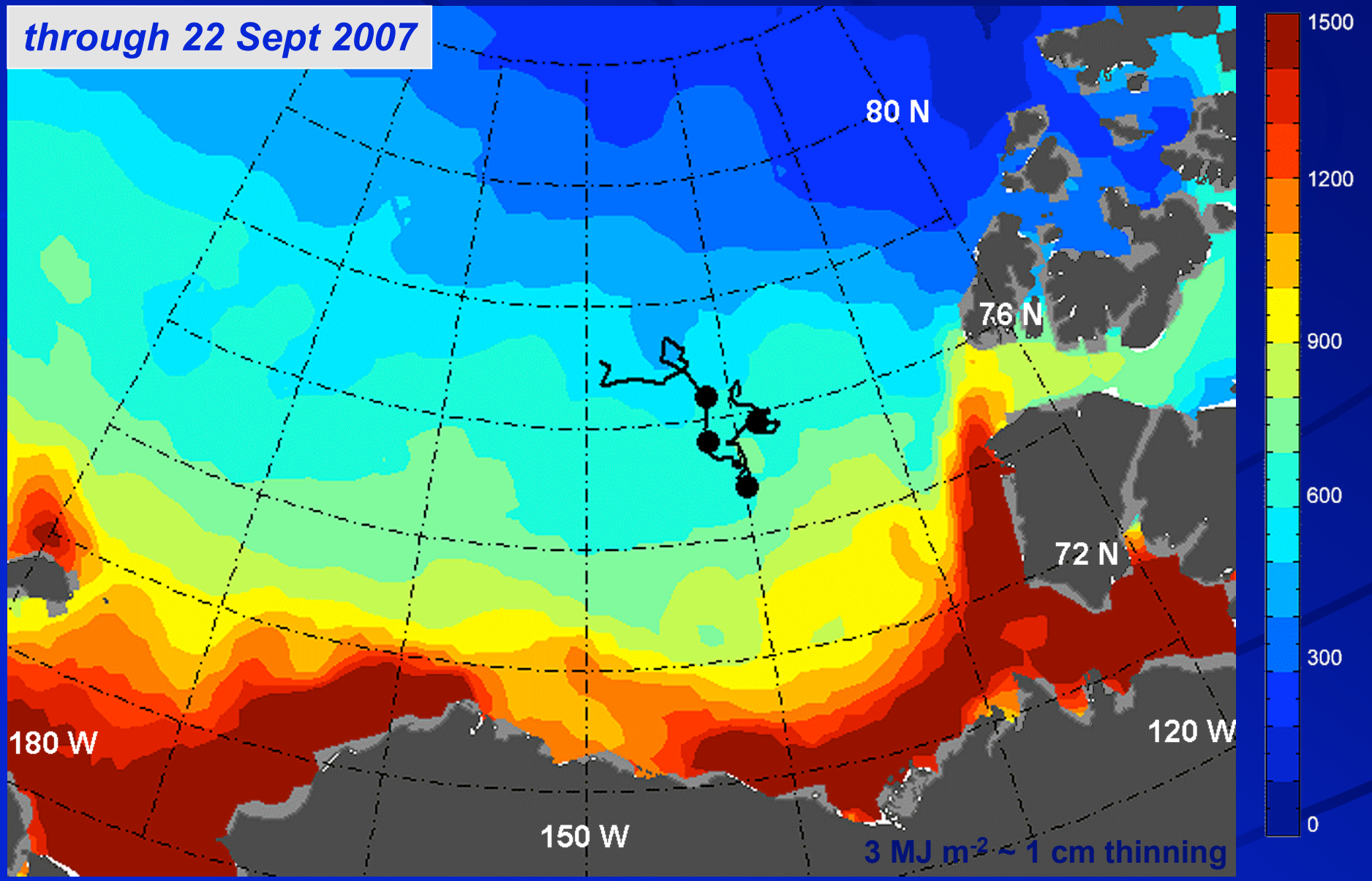
Input:
- 25 x 25 km EASE grid
- Incident (F_r) from EMFCW
- Ice concentration (C) - SSMI
- Water albedo (α) = 0.07

Output:
Solar input to the ocean (F_{ocn})

Neglect ice for now

Incident solar, ice concentration, and albedo -> heat input

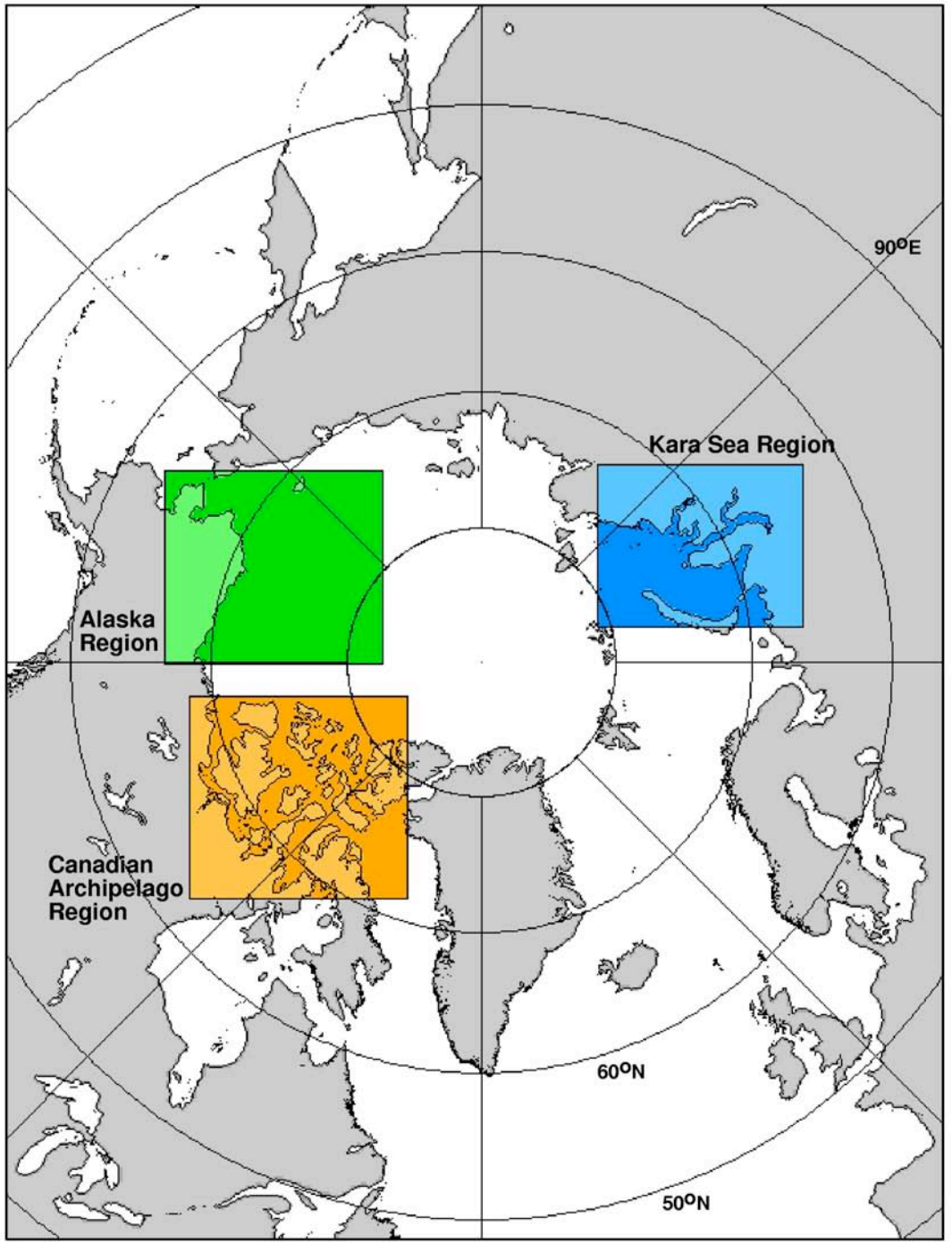
Total solar heat input to ocean



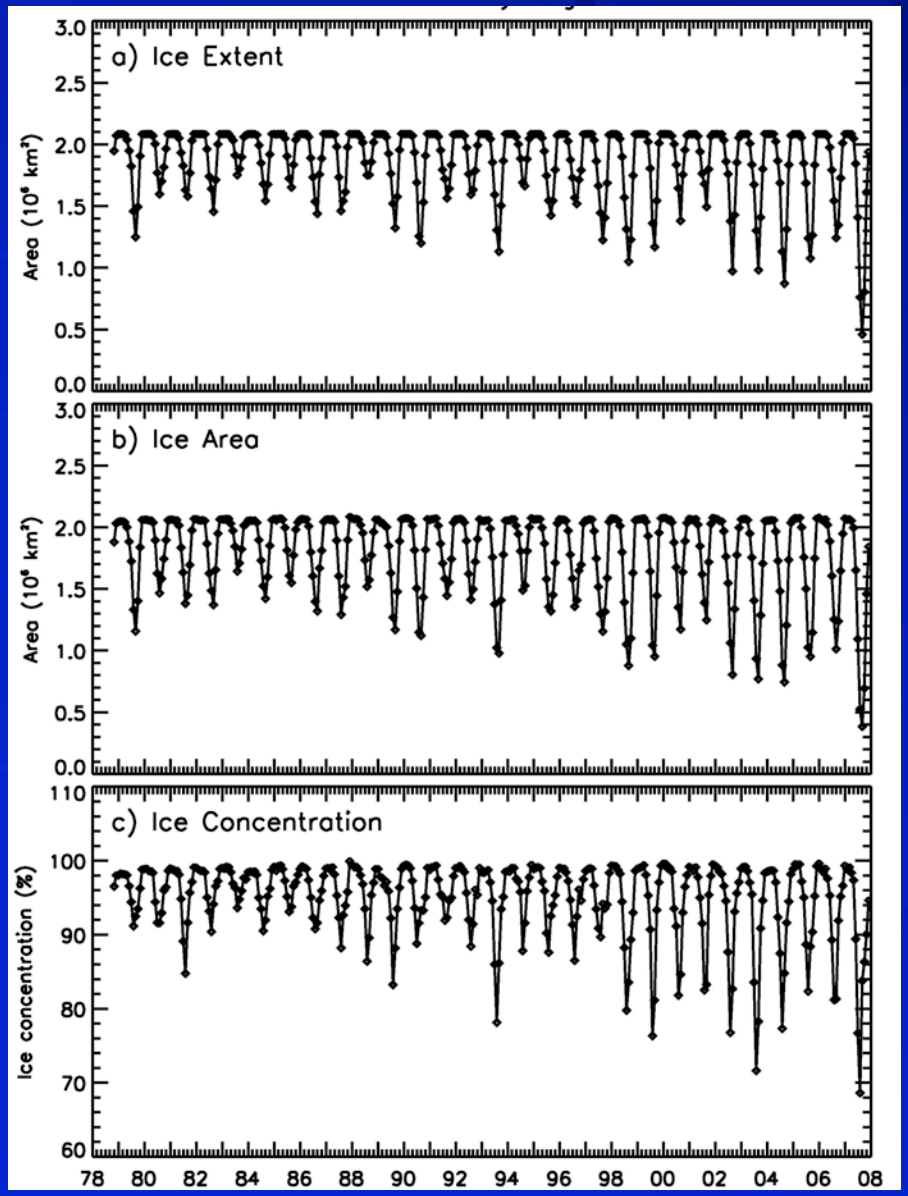
Heat input near buoy from 600 to 800 MJ m^{-2}

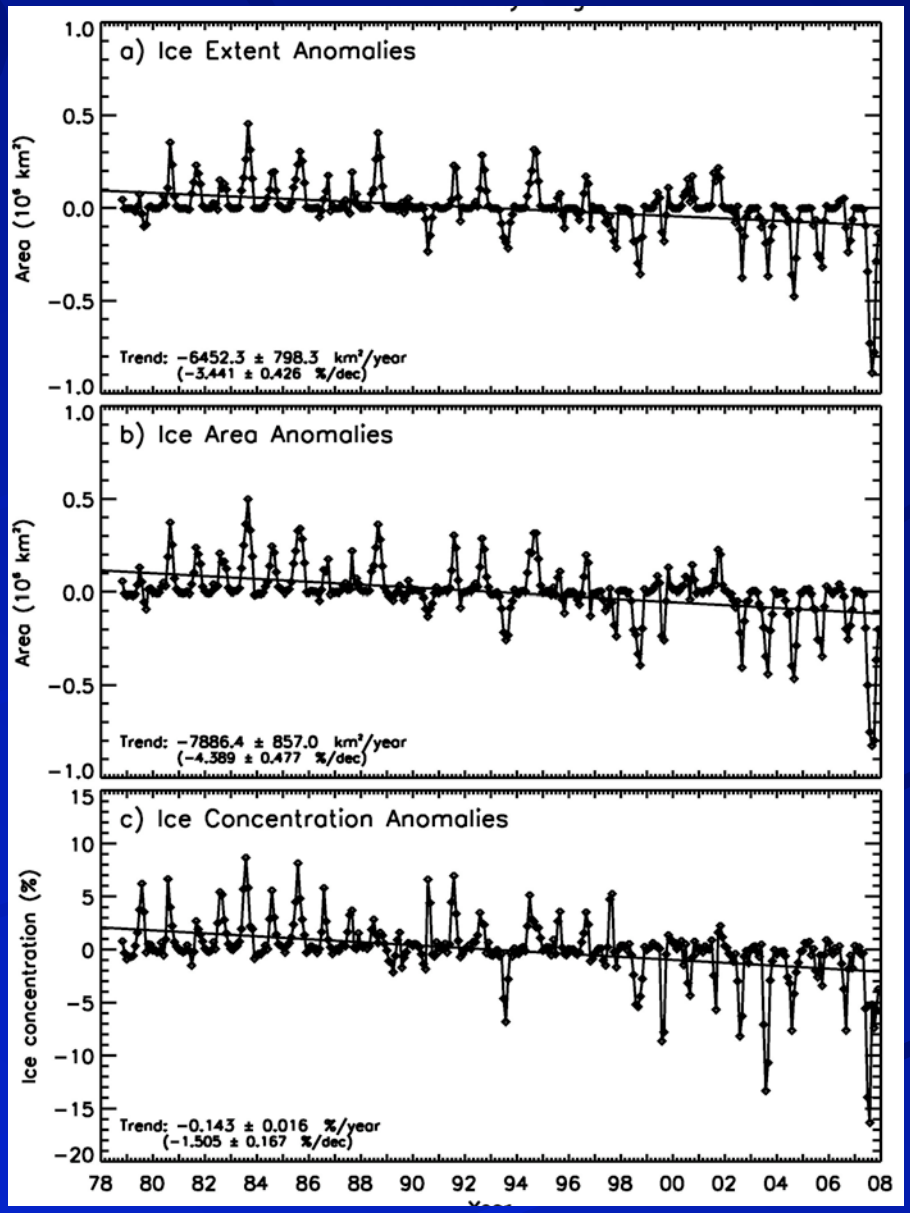
Some Study Areas:

1. Kara Sea
2. Chukchi Sea
3. Canadian Archipelago



Chukchi Sea ice extent, area and IC





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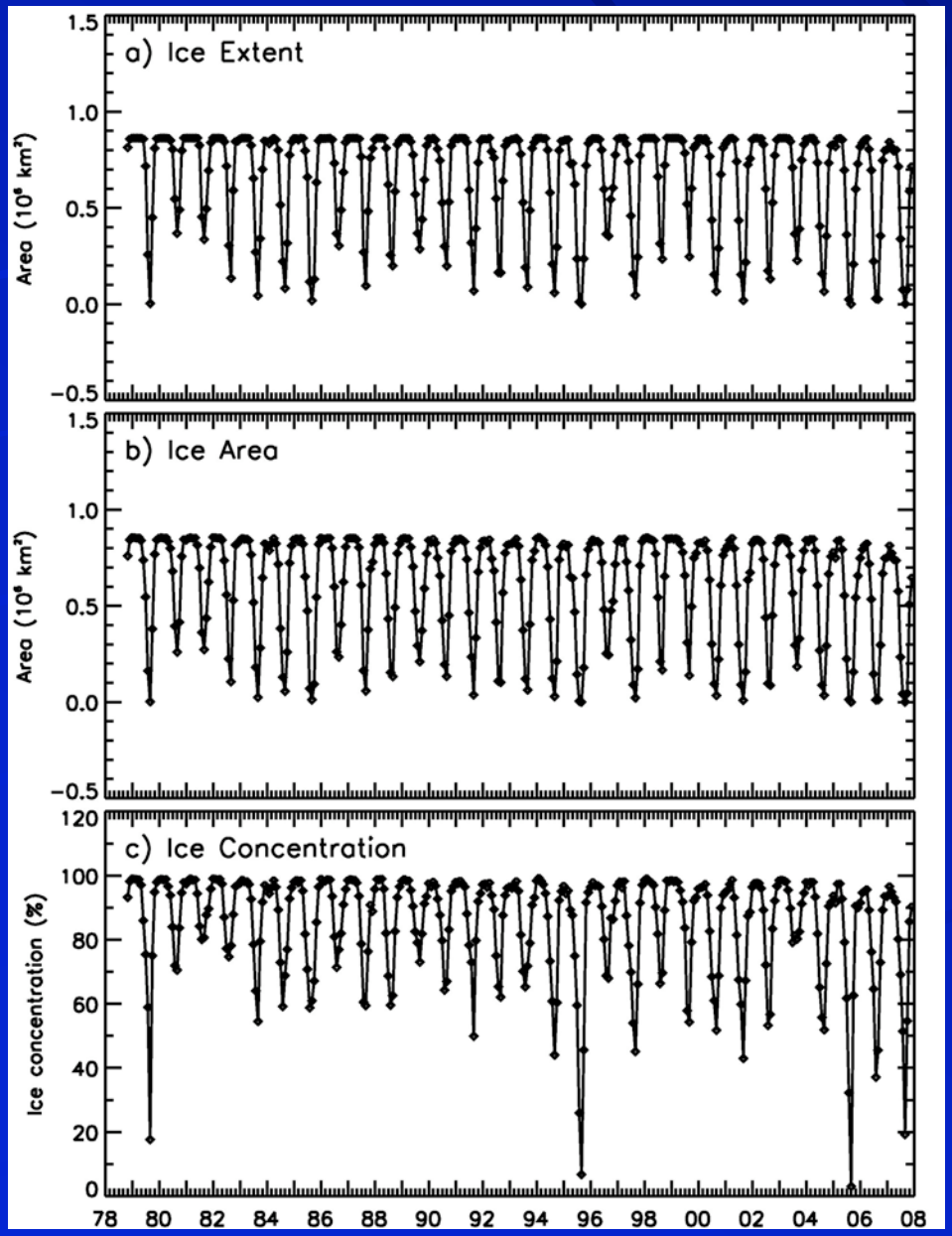
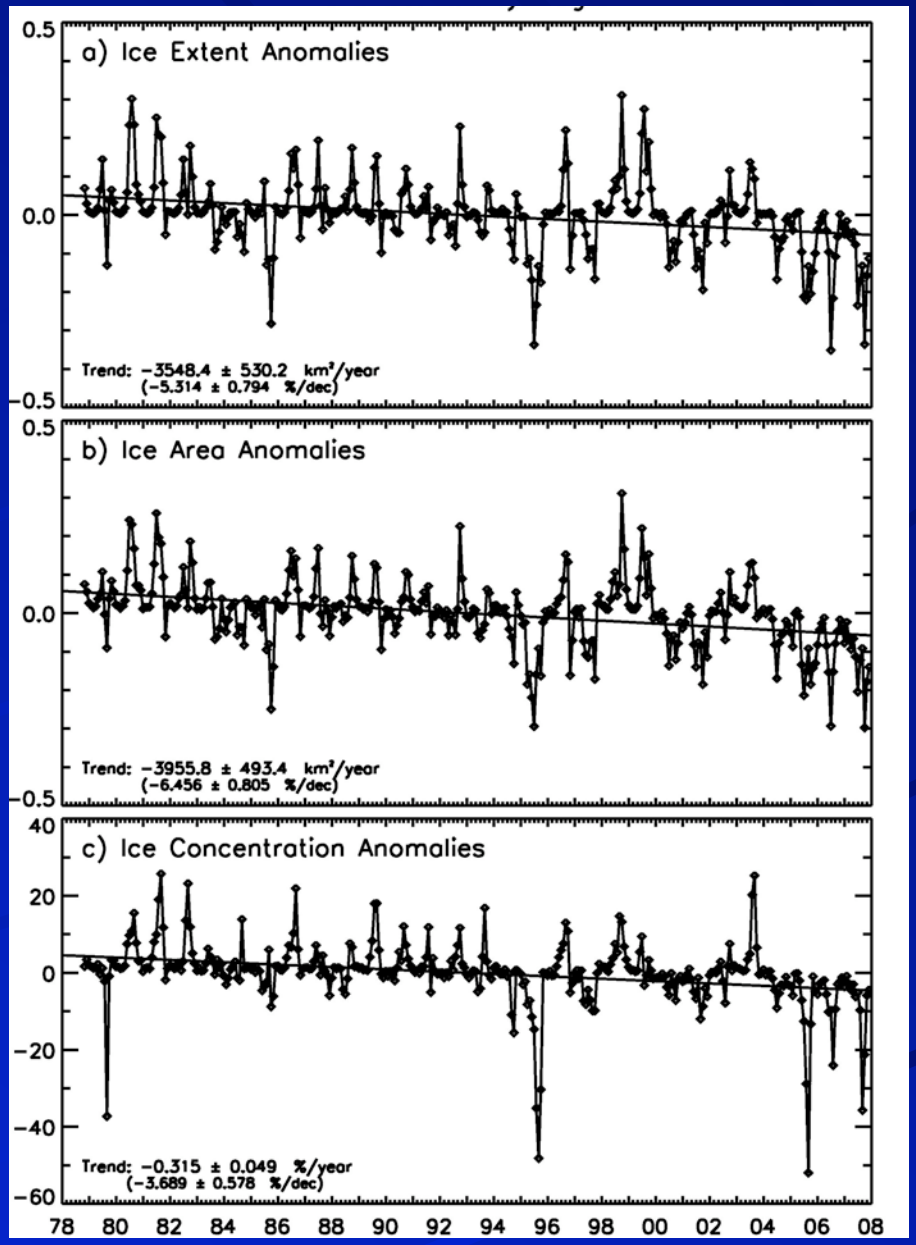
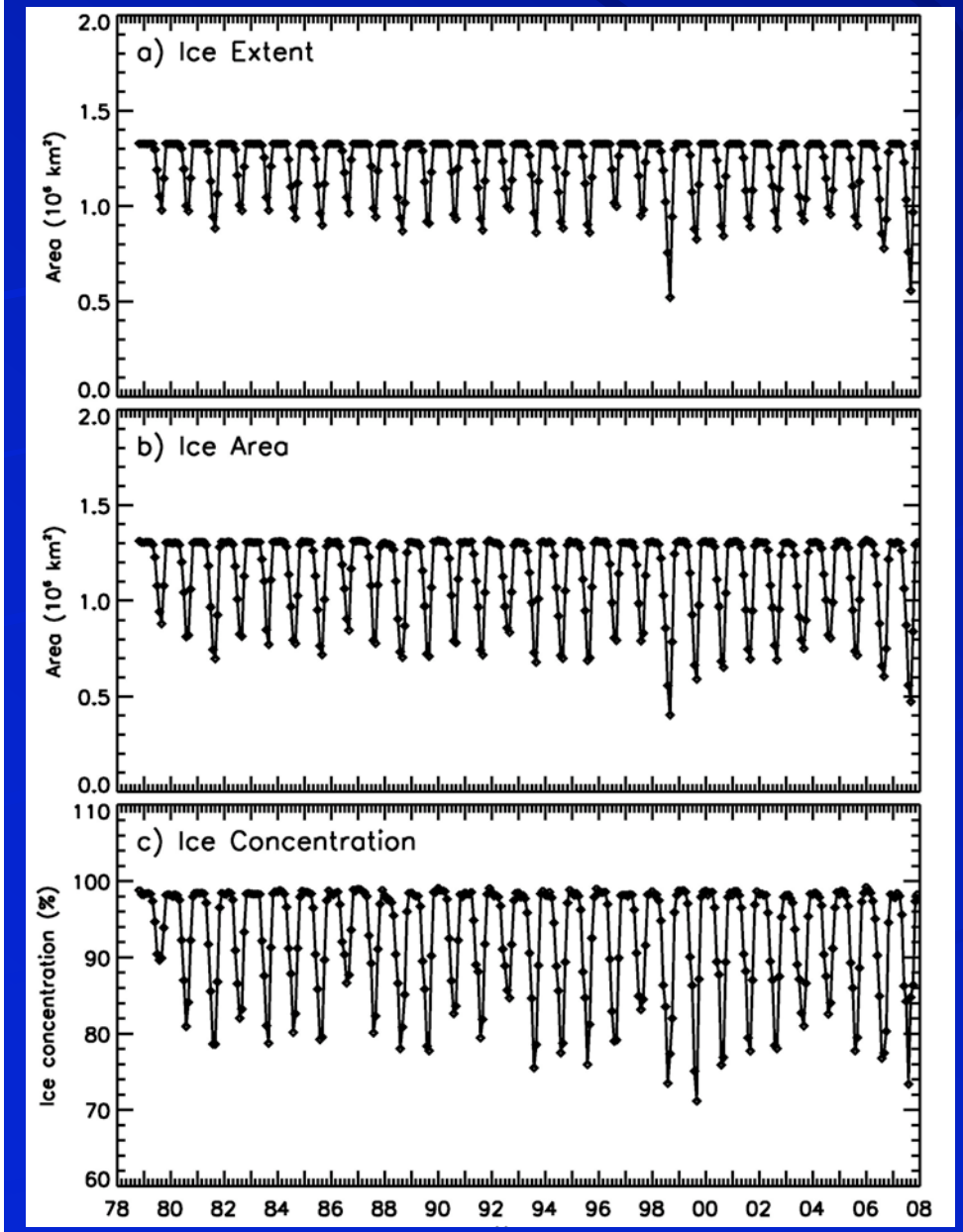
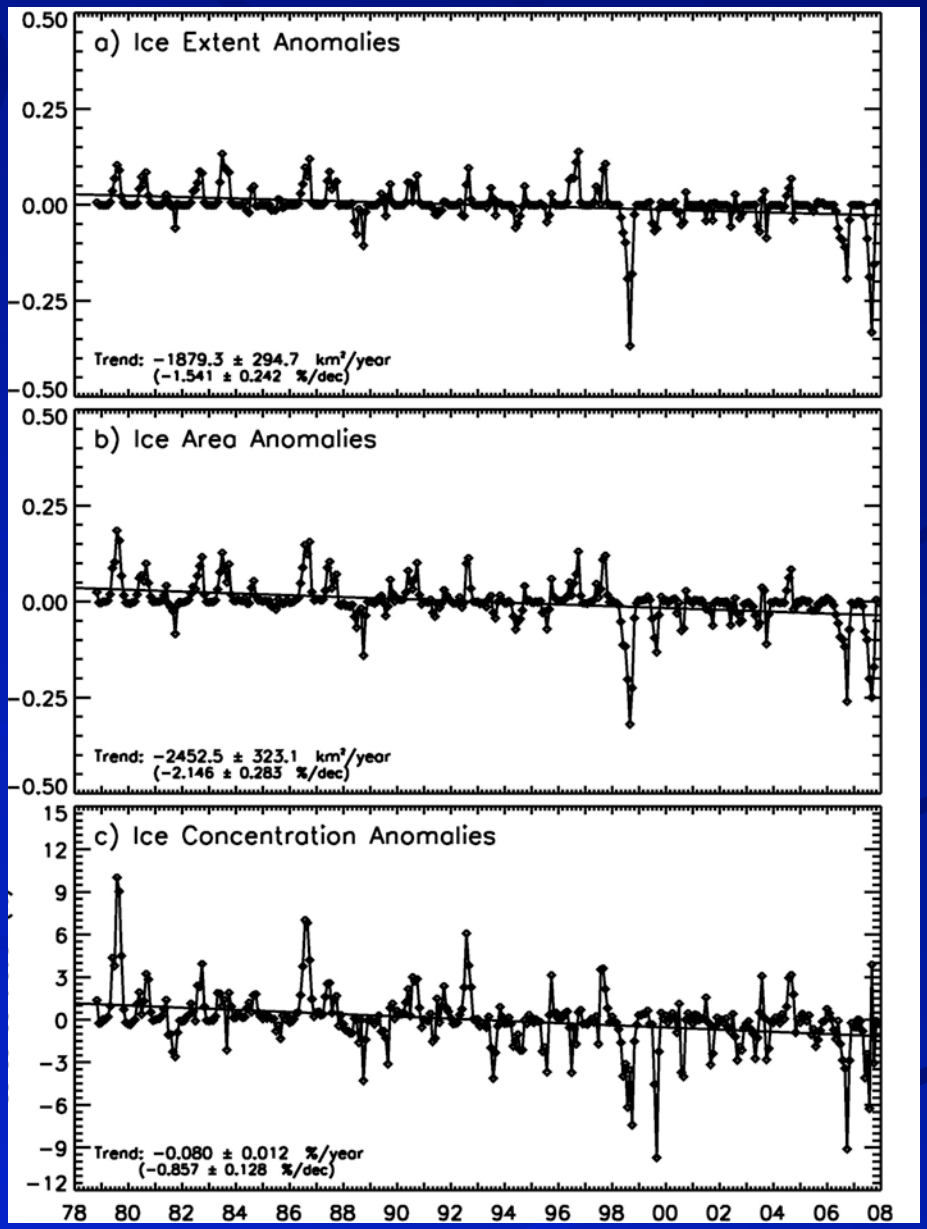


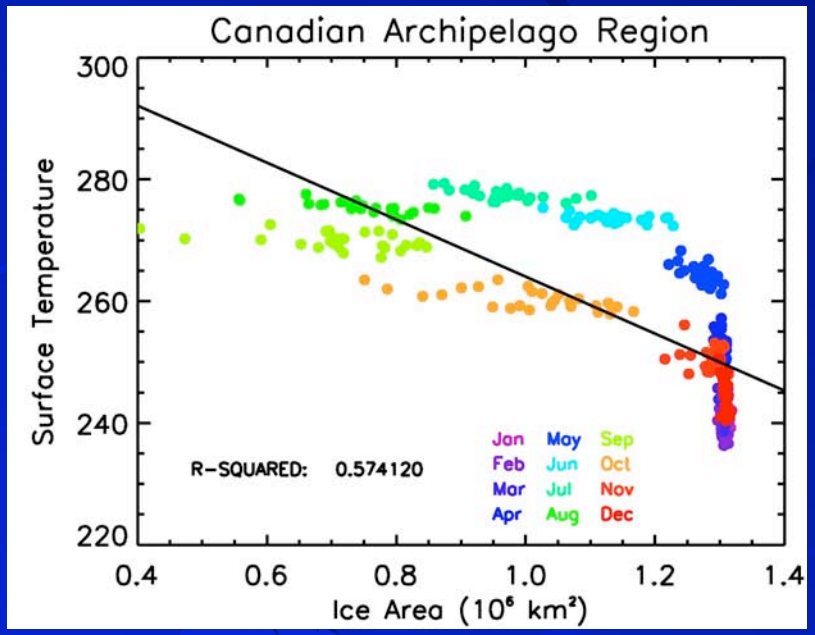


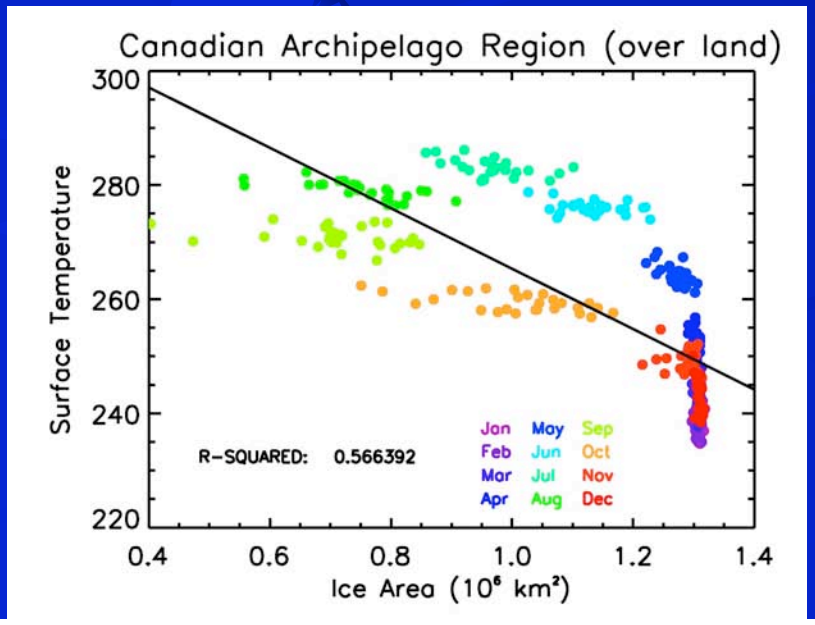
Canadian Archipelago ext, area & IC

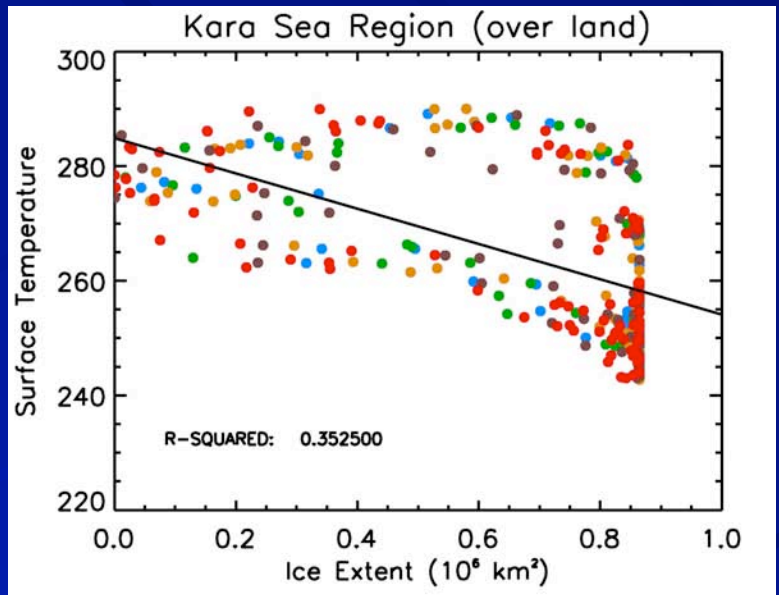


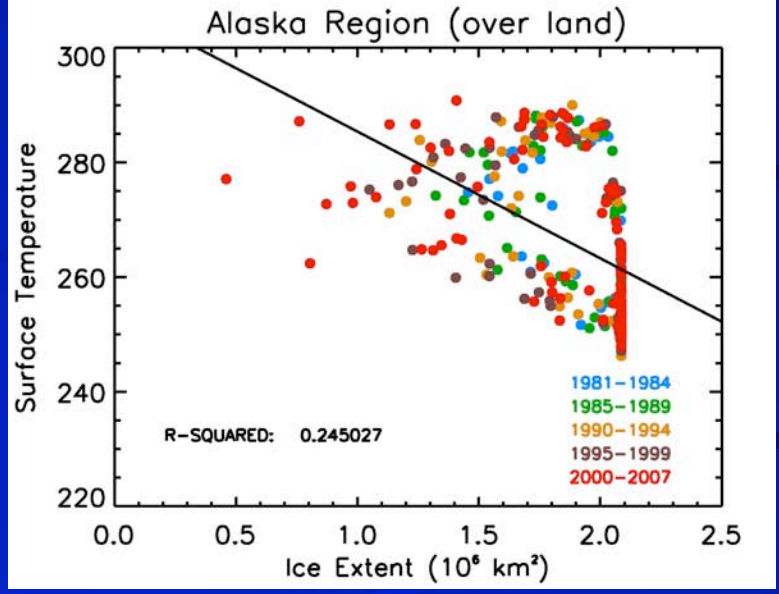


Correlation of ice extent to surface temperature

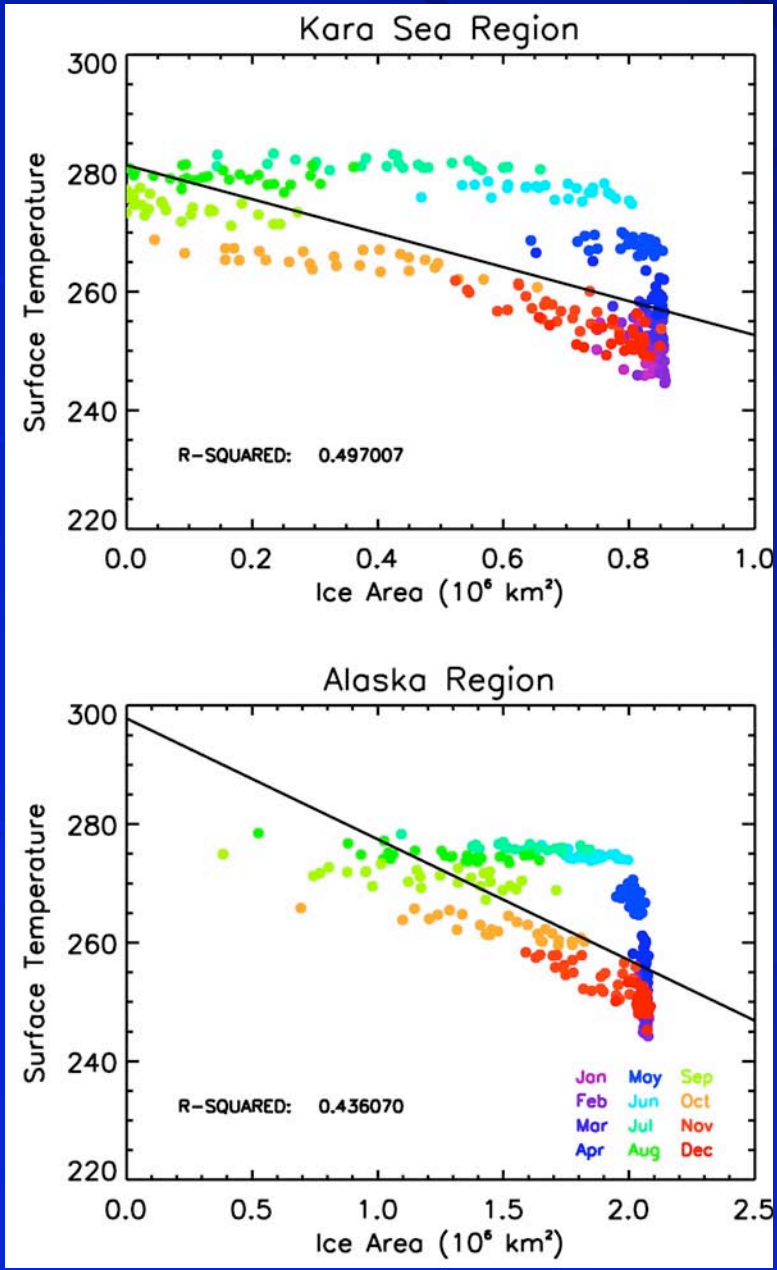


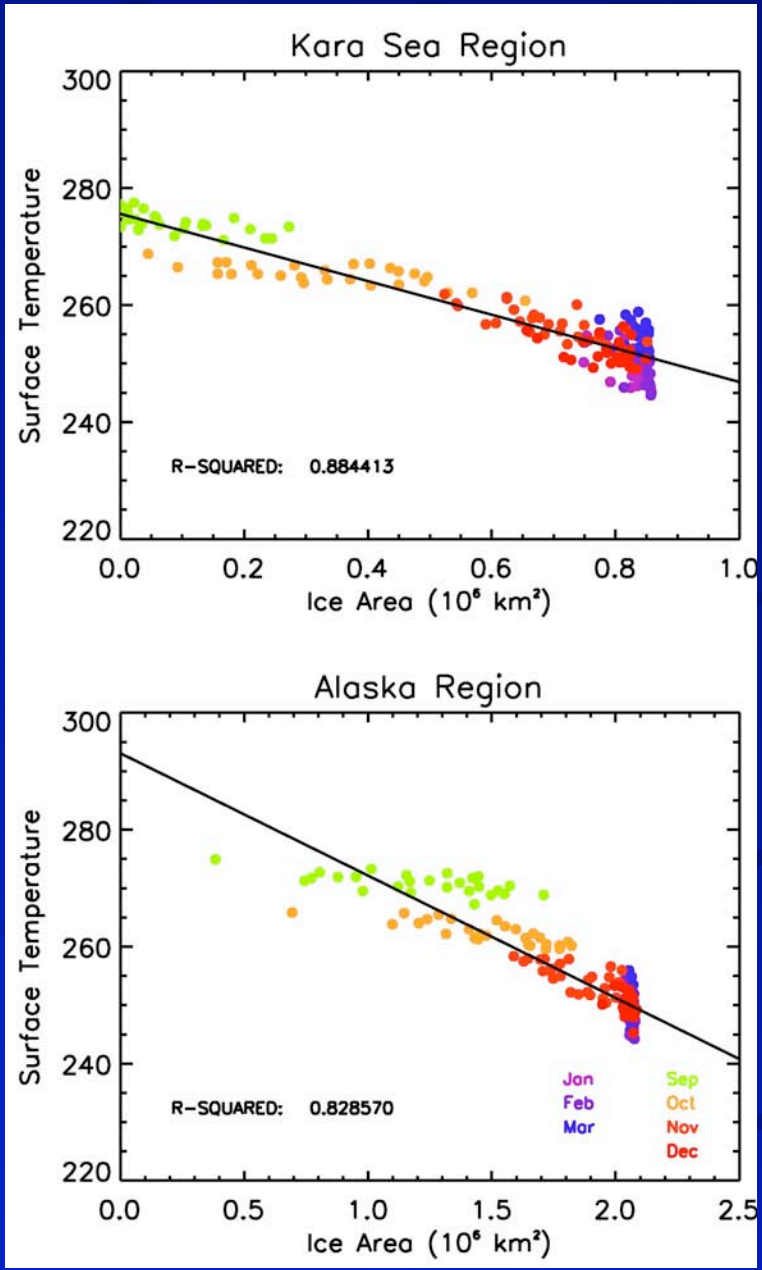




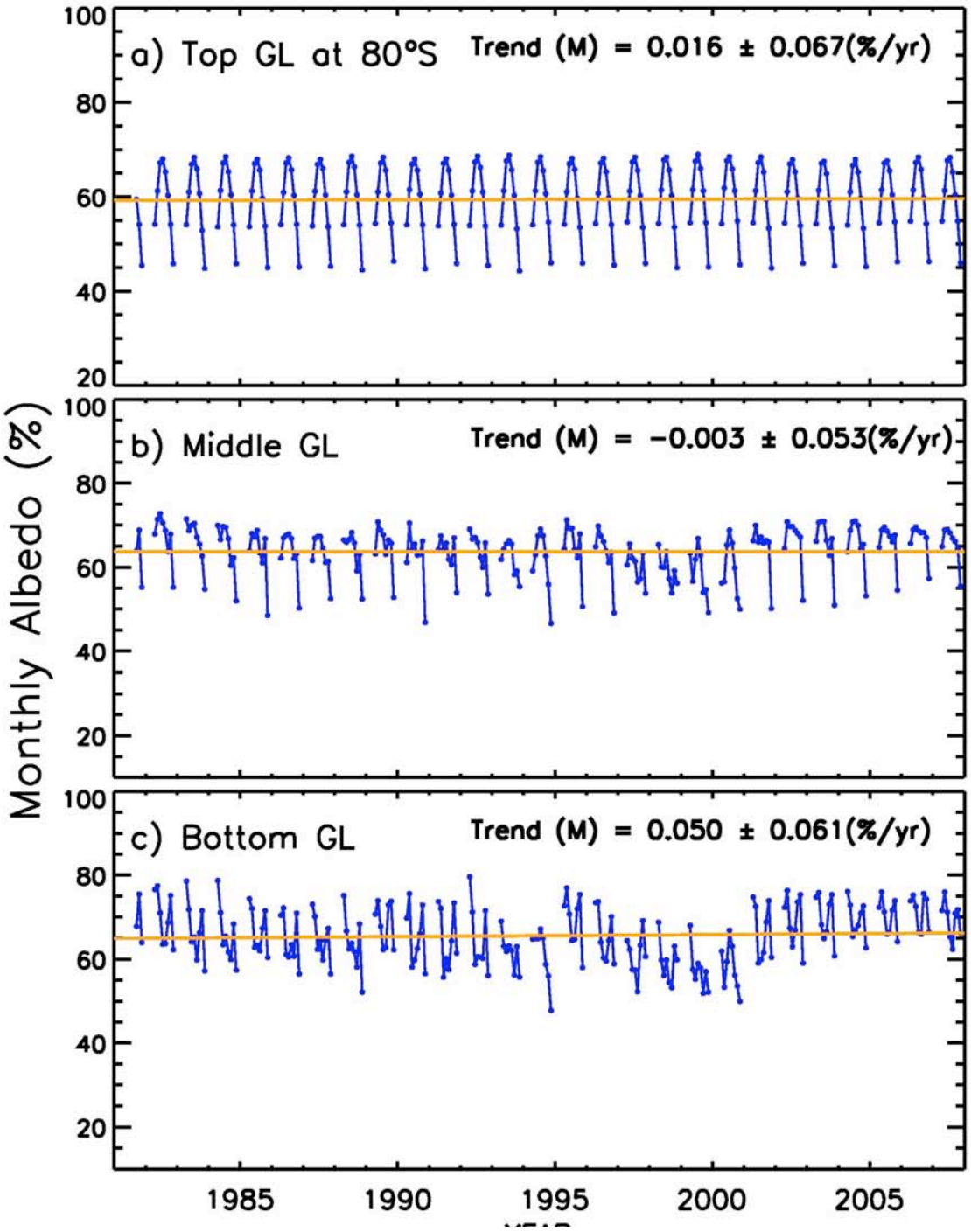


Kara and Chukchi Seas

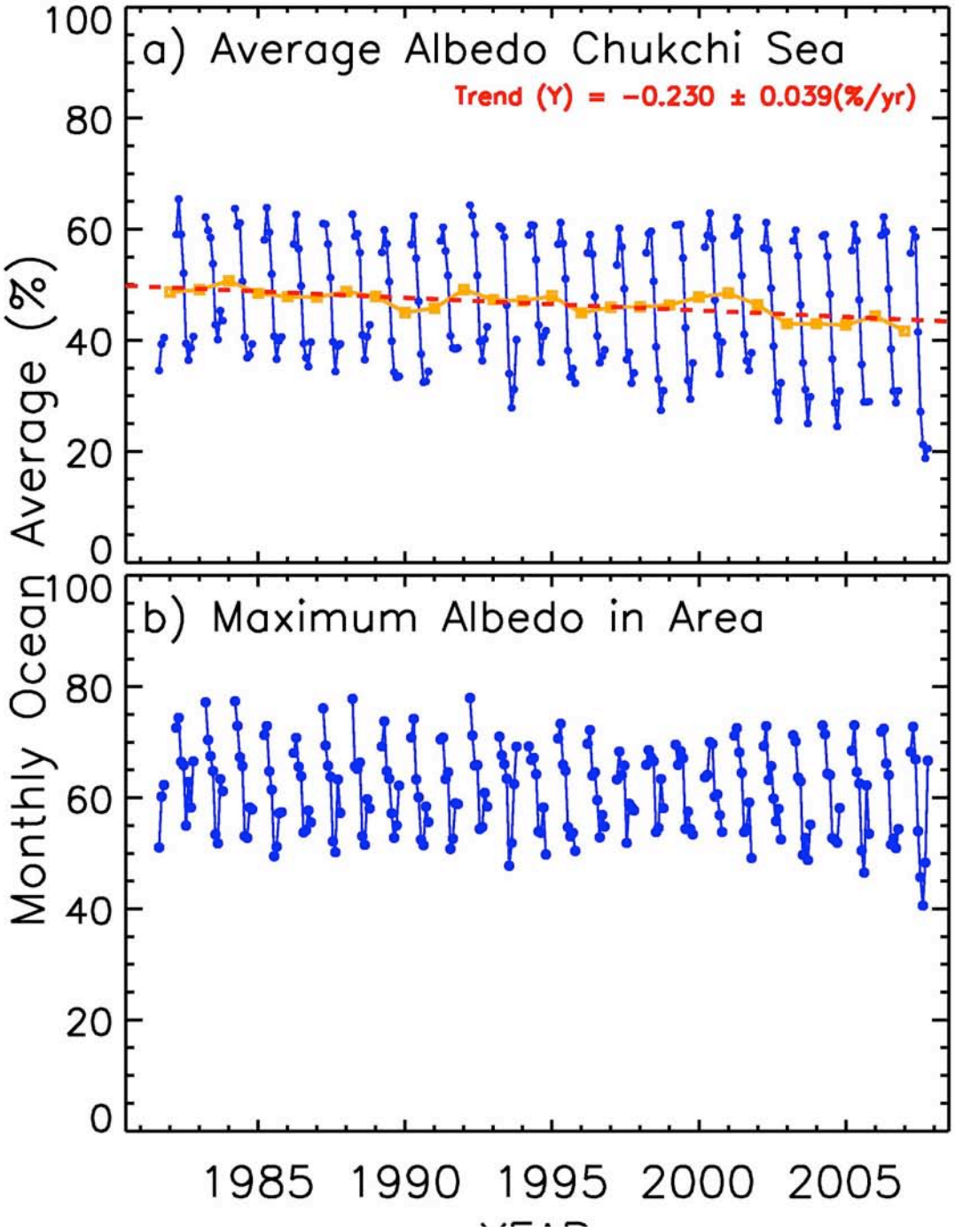




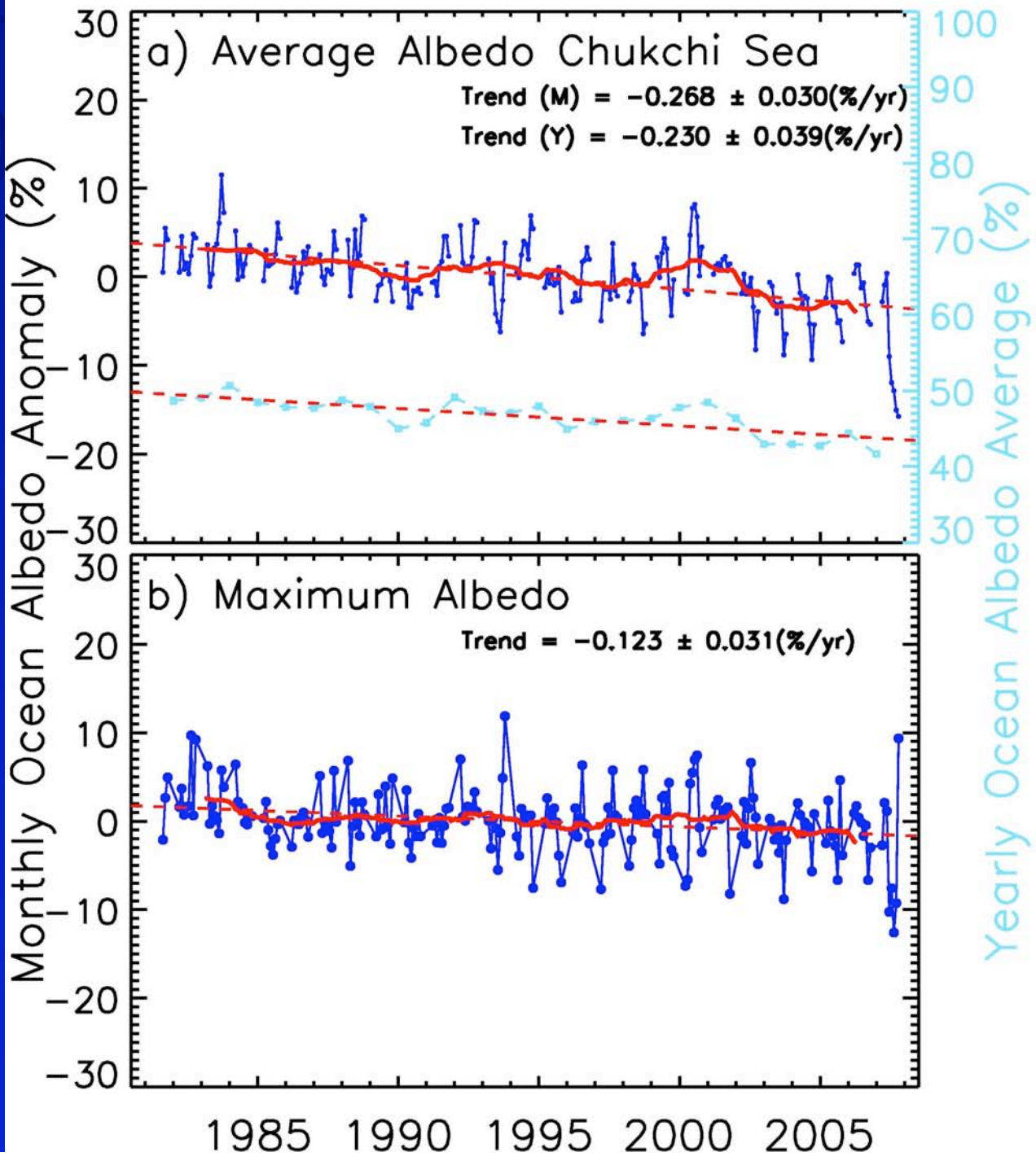
Greenland Albedo at 3 study areas



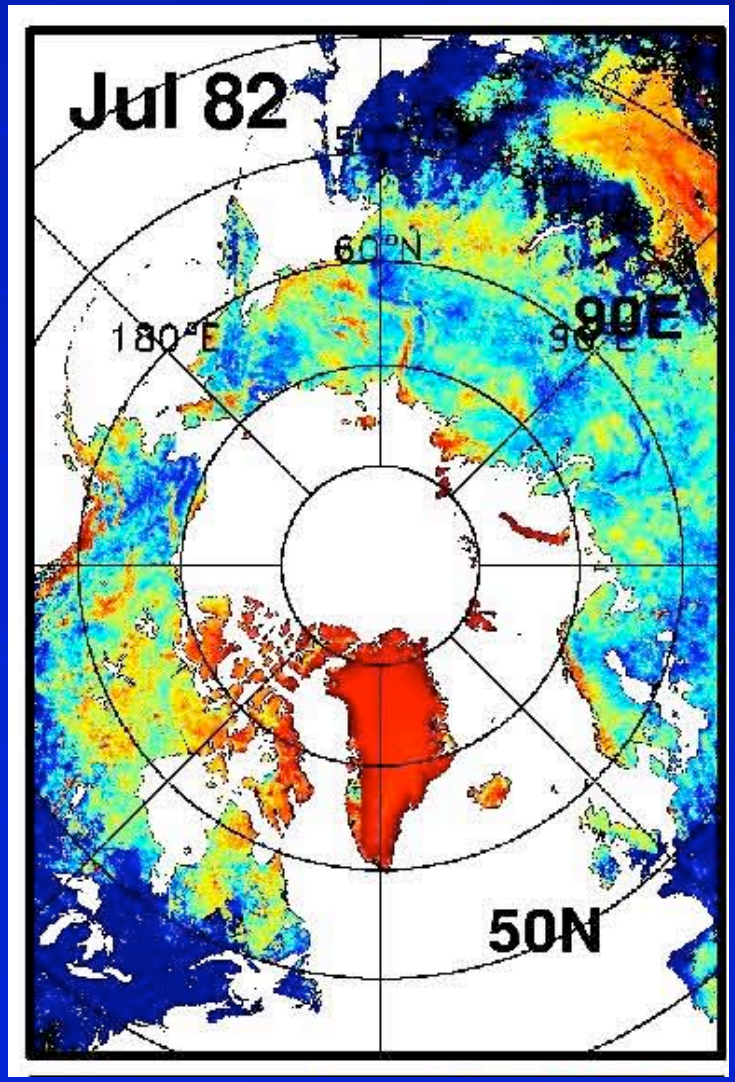
Chukchi Sea Monthly and Maximum Albedo and Decadal Trend

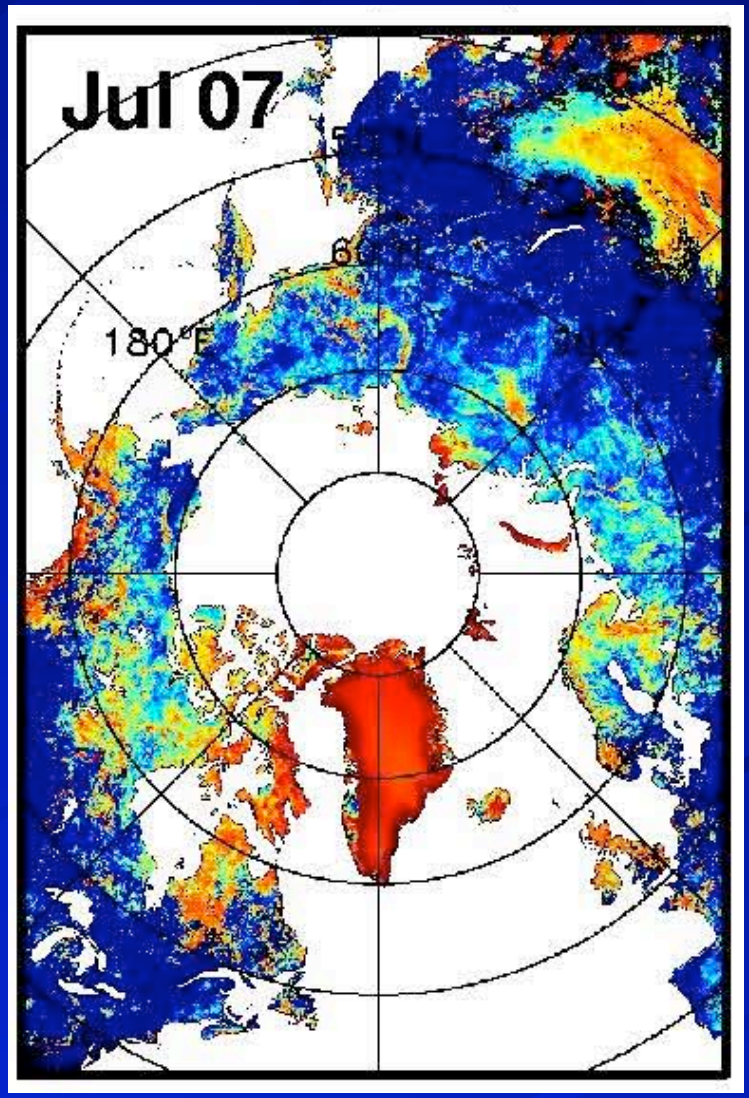


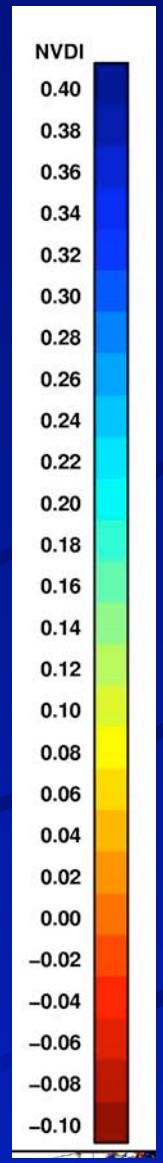
Average Monthly and Maximum Albedo in the Chukchi Sea region



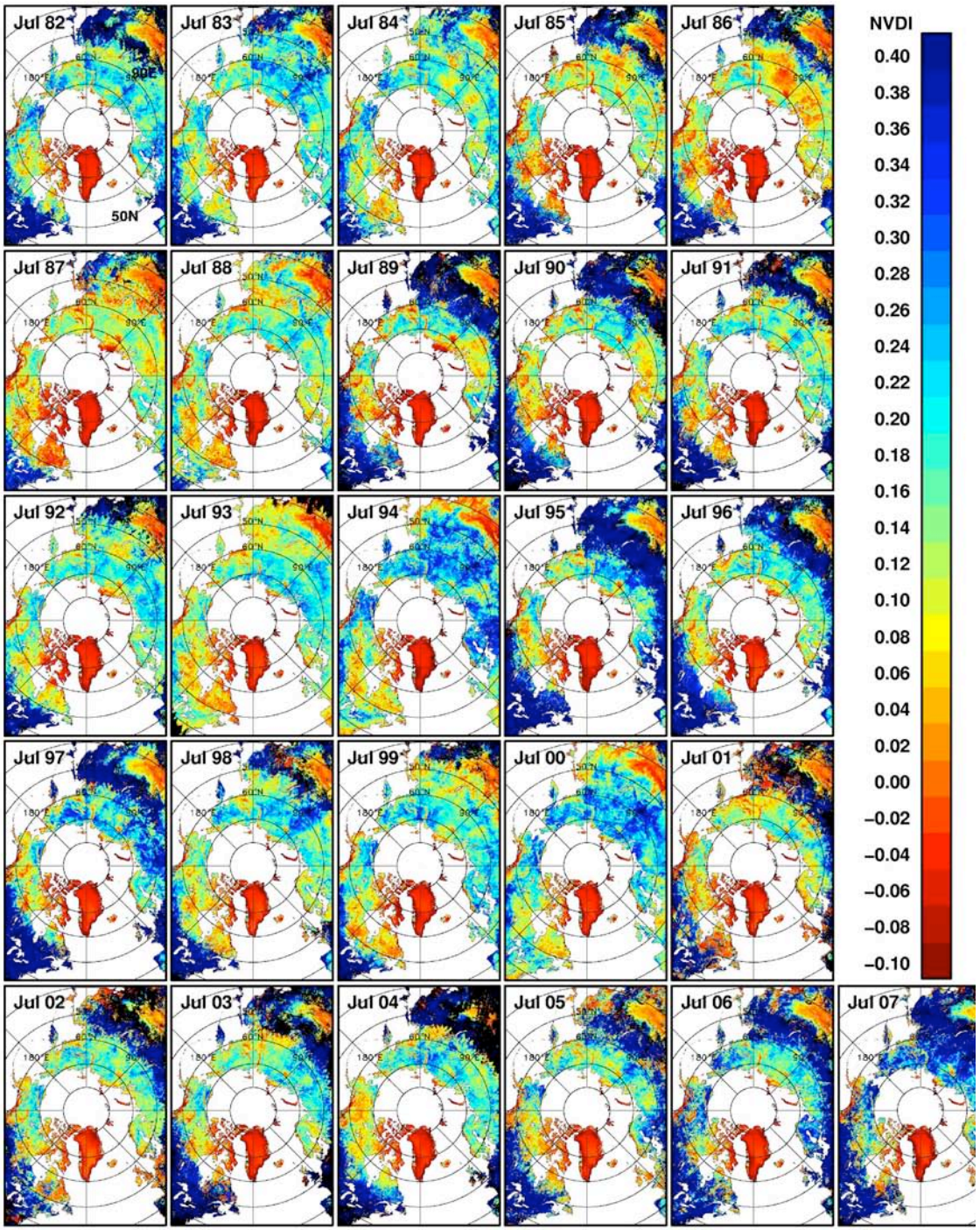
Very preliminary estimates for July 1982 & 2007







Very preliminary estimates of NDVI for July 1982 to 2007



Summary and Conclusions

- The perennial ice is now declining at 11.4 % per decade. The 2007 ice minimum area was 38% less than climatological average and 27% less than previous lowest area in 2005.
- Conditioning: Open water area in the Western Arctic is declining at 27%/decade. SST and SIT in the region has been increasing at 0.7°C per decade suggesting Ice-Albedo Feedback effects. In 2007, the bottom melt rate was unusually high.
- Modeling studies, ice drift analysis, and submarine observations show considerable thinning in the ice cover in part due to advection of thick multiyear ice to the Atlantic Ocean where they melt.
- For the perennial ice to recover, sustained cooling is required both in winter and summer. Current data do not support this. The tipping point for perennial ice is likely reached.
- Temperature over land is shown to be correlated to ice concentration in three study areas. The retreat of the ice cover must therefore affect land temperature which in turn affects NDVI. A hysteresis effect has to be taken into account.
- Preliminary data shows that the extent of relatively high NDVI in the pan Arctic region is increasing.

Lorenz: "Weather is what you get, Climate is what you expect"