CLUES TO SEA ICE CHANGE FROM SATELLITE-DERIVED ATMOSPHERIC PARAMETERS

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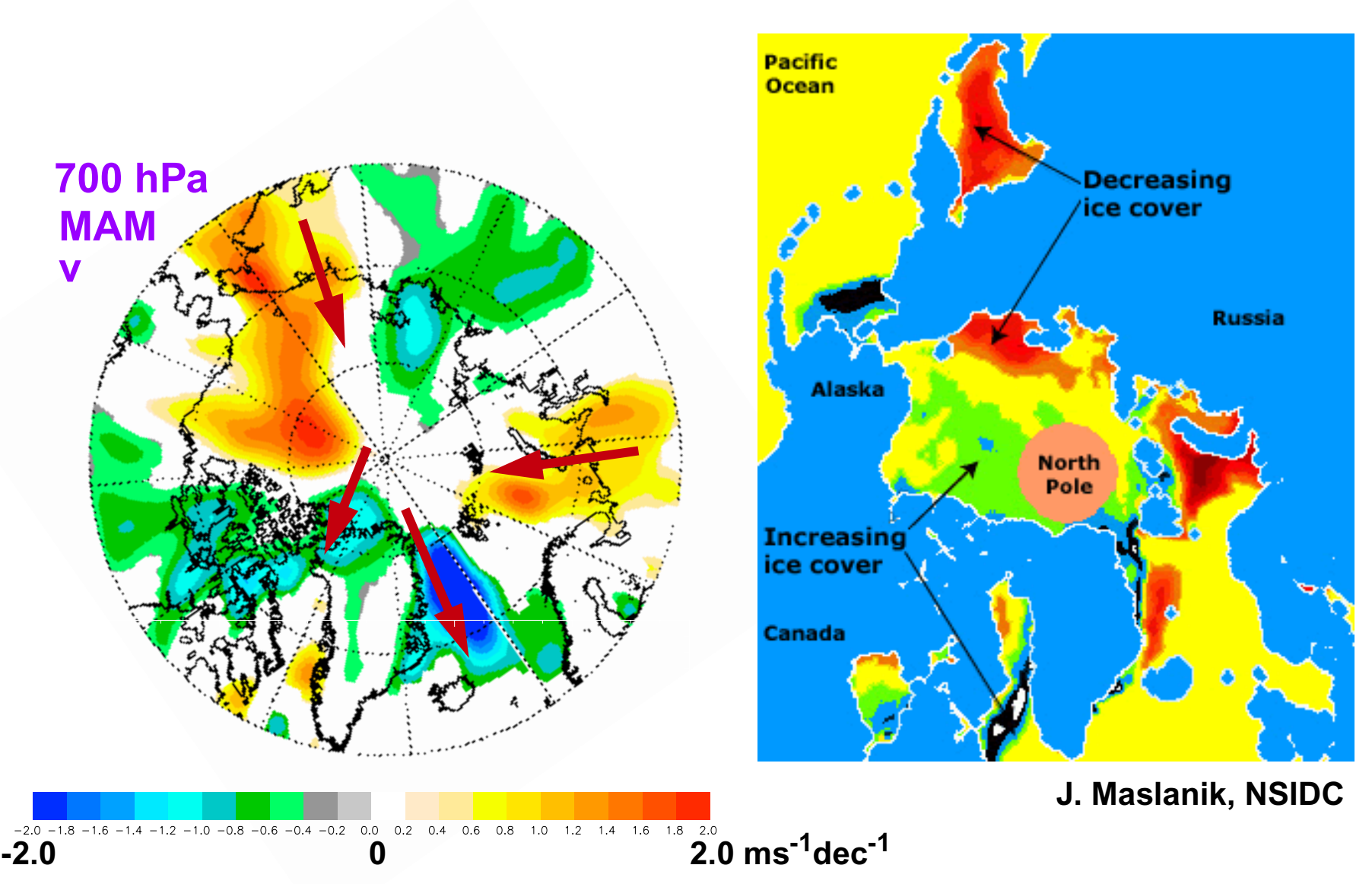
OVERVIEW

The observed dramatic changes in Arctic sea ice extent, thickness, and melt duration during recent decades are believed to be caused by changing patterns of dynamic and thermal forcing. The relative importance of these effects likely varies spatially and temporally. Using atmospheric parameters derived from satellite sounding instruments, we are attempting to identify which factors (such as changes in 10-meter winds, surface longwave fluxes, advective heating) are most closely related to sea ice change in several representative regions. Time series of sea ice extent in the peripheral seas (Fig. 1) will be analyzed in combination with atmospheric forcing parameters.

22-Year Trends in Lower Tropospheric Winds versus Sea Ice Change



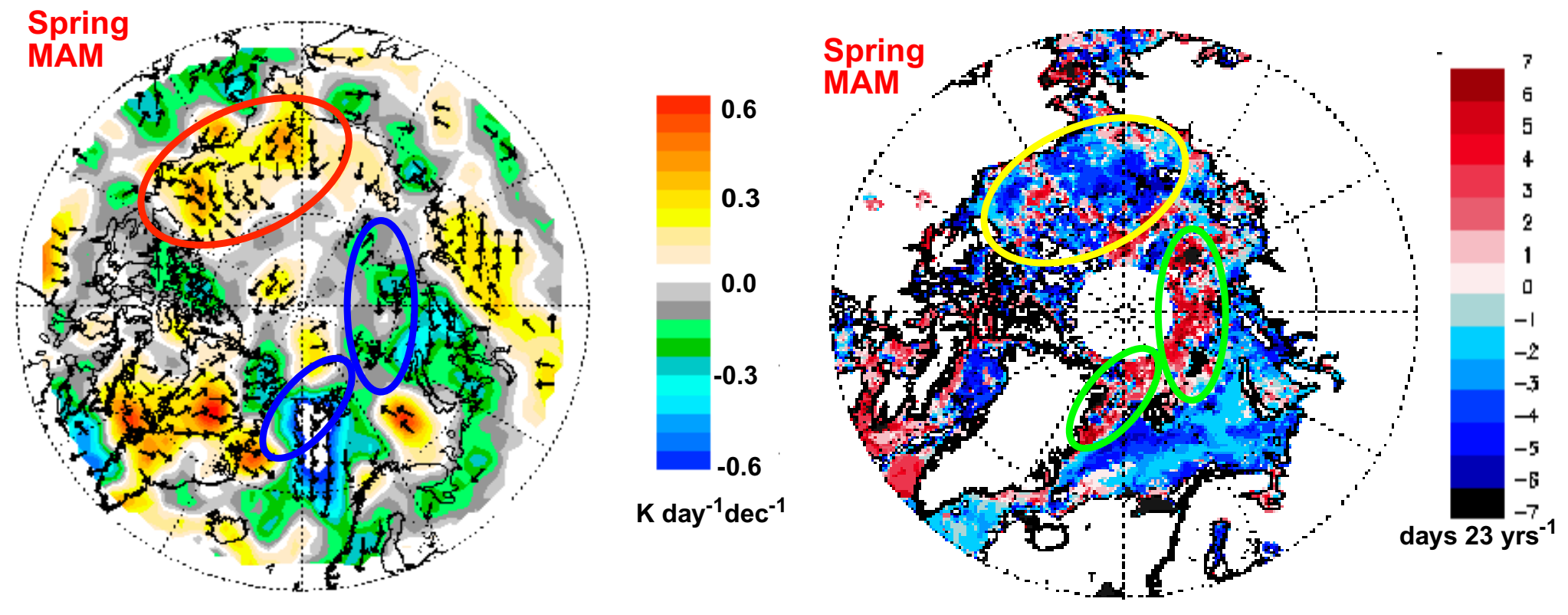
J. Maslanik, NSIDC

Figure 2: Trend in satellite-derived (TOVS) meridional winds in the 1000-to-700 mb layer during spring (1980 to 2001) versus observed changes in sea ice extent (1978 to ~1998).

Clues to Observed Changes in Sea Ice Melt

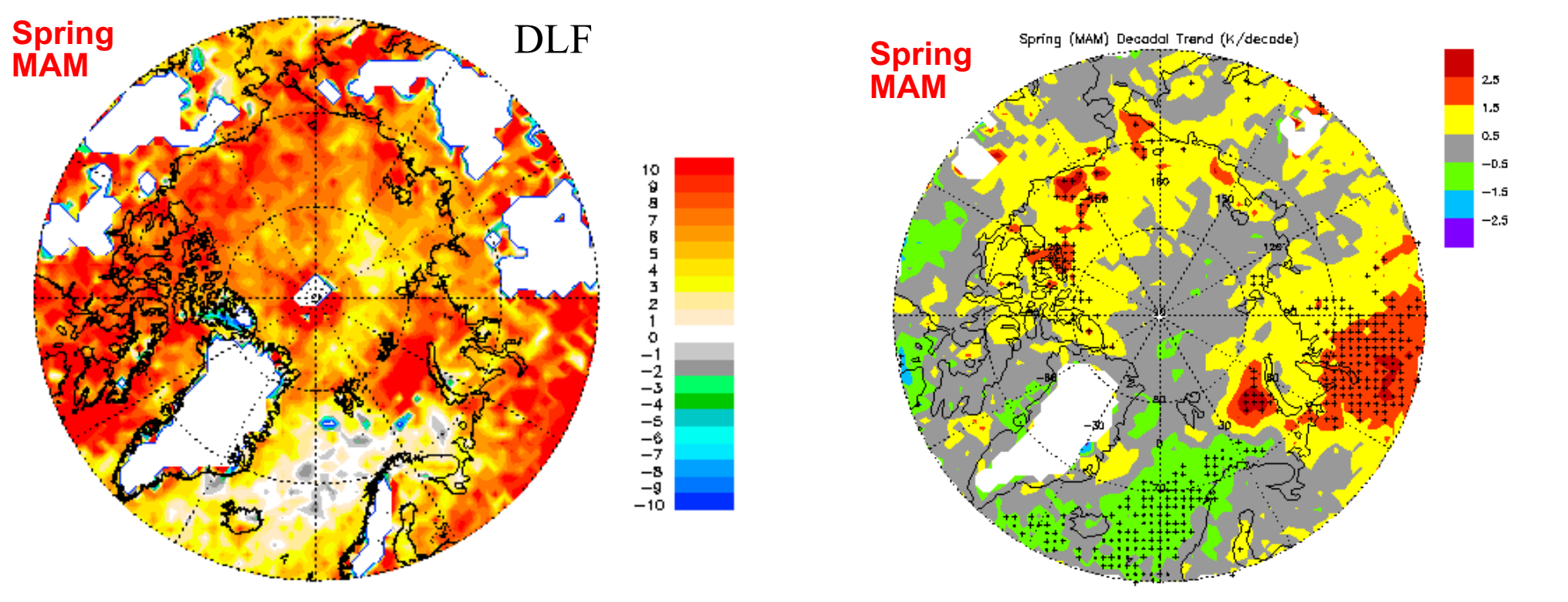
22-year Trends in Related Parameters

Sensible Heating 1000-700 mb (K/day/dec) **Melt Onset Date (day/dec)**

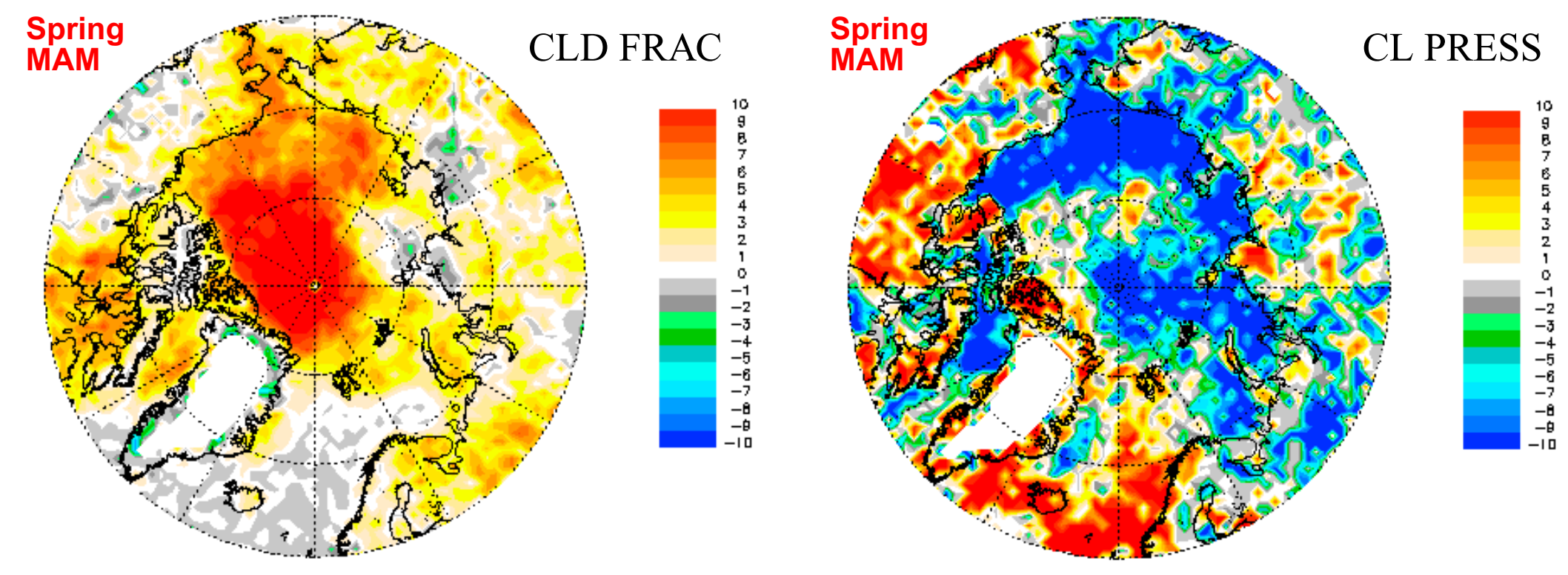


after Belchansky *et al*, J. Clim, 2004

Downwelling Longwave Flux (W/m²/dec) **Surface Skin Temperature (K/dec)**



Cloud Fraction (5/dec) **Cloud-top Pressure (mb/dec)**



Total Column Water Vapor (%/dec)

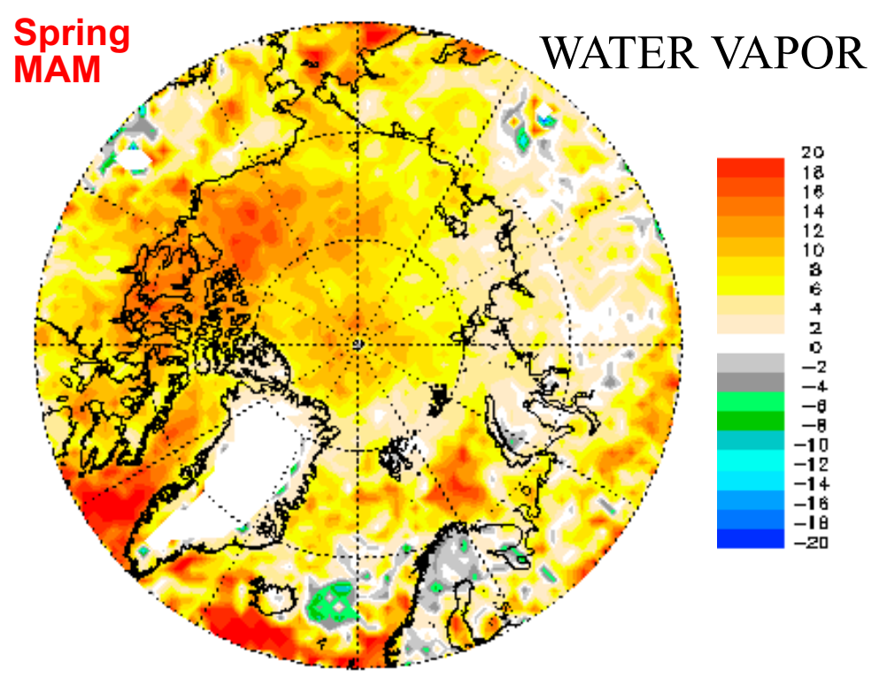


Figure 3: We compare 22-year changes (1980 to 2001) during spring in a variety of satellite-derived parameters to observed changes in the date of melt onset. All variables except melt onset are calculated from radiances measured by the TIROS Operational Vertical Sounder (TOVS). Retrievals from this instrument have been improved for Arctic conditions (Francis, 1994; Francis and Schweiger, 2000: Scott et al, 1999). Melt patterns are derived from passive microwave by Belchansky et al, 2004.

Trends in the convergence of sensible heat in the lower troposphere during spring (top left) show intriguing patterns of change that appear to be related to observed changes in melt onset (upper right). Sensible heating is calculated from TOVS 3-D wind fields and temperature profiles. Changes in TOVS-derived surface downwelling longwave flux (middle left) and surface skin temperature (middle right) are consistent with the melt changes, particularly in the Beaufort Sea area. Longwave changes appear to be related to increasing spring cloud fraction (lower left), which are associated with interesting changes in cloud top height (lower right). Generally higher cloud-tops, perhaps linked to stronger storm systems, dominate the peripheral seas in spring. Increased water vapor throughout the Arctic (bottom) supports this speculation. Further work will investigate changes in cloud thickness, cloud base height, and cloud water/ice content.

We are grateful to NSF, NASA, and NOAA for providing funding for this work.

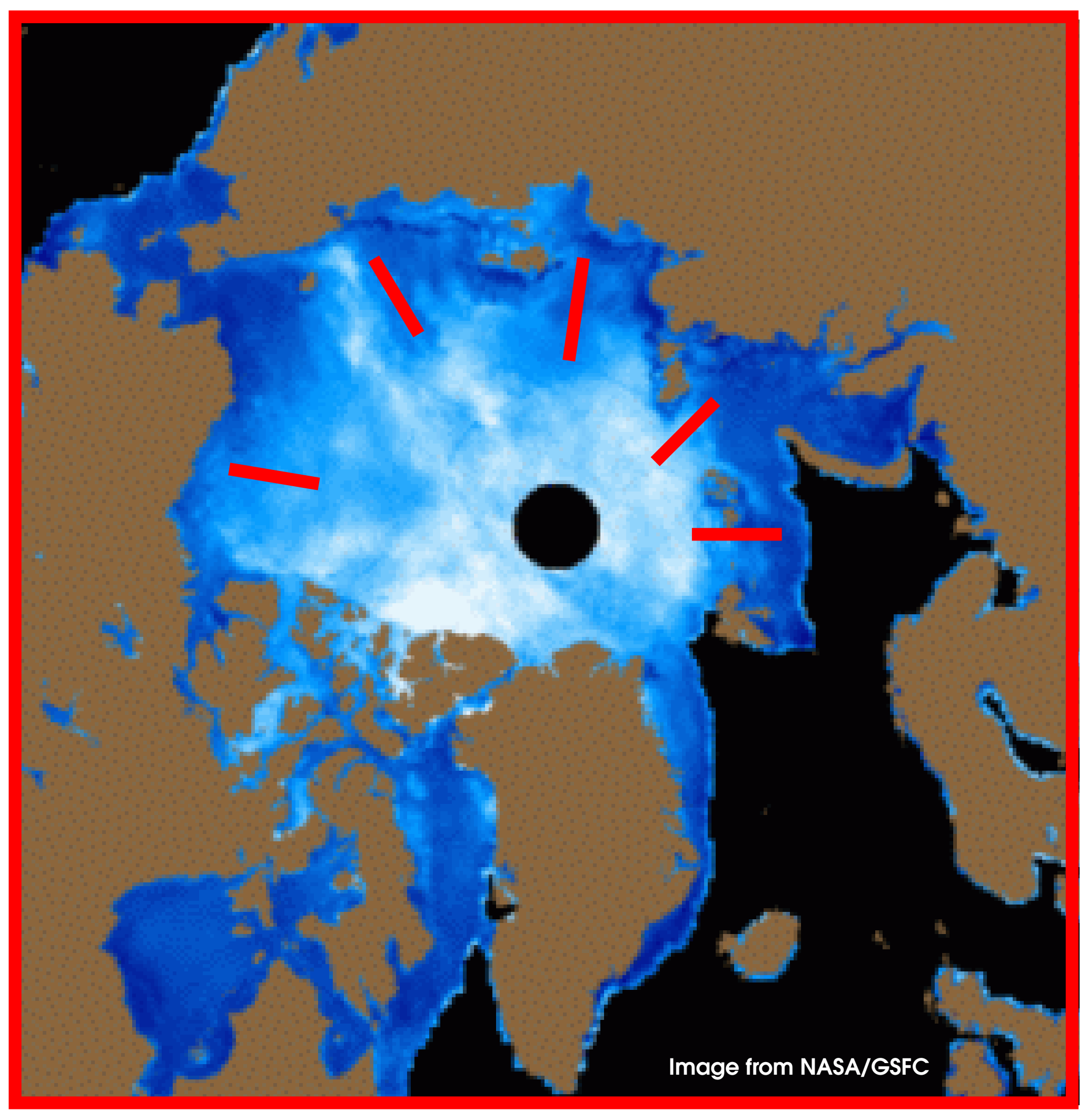


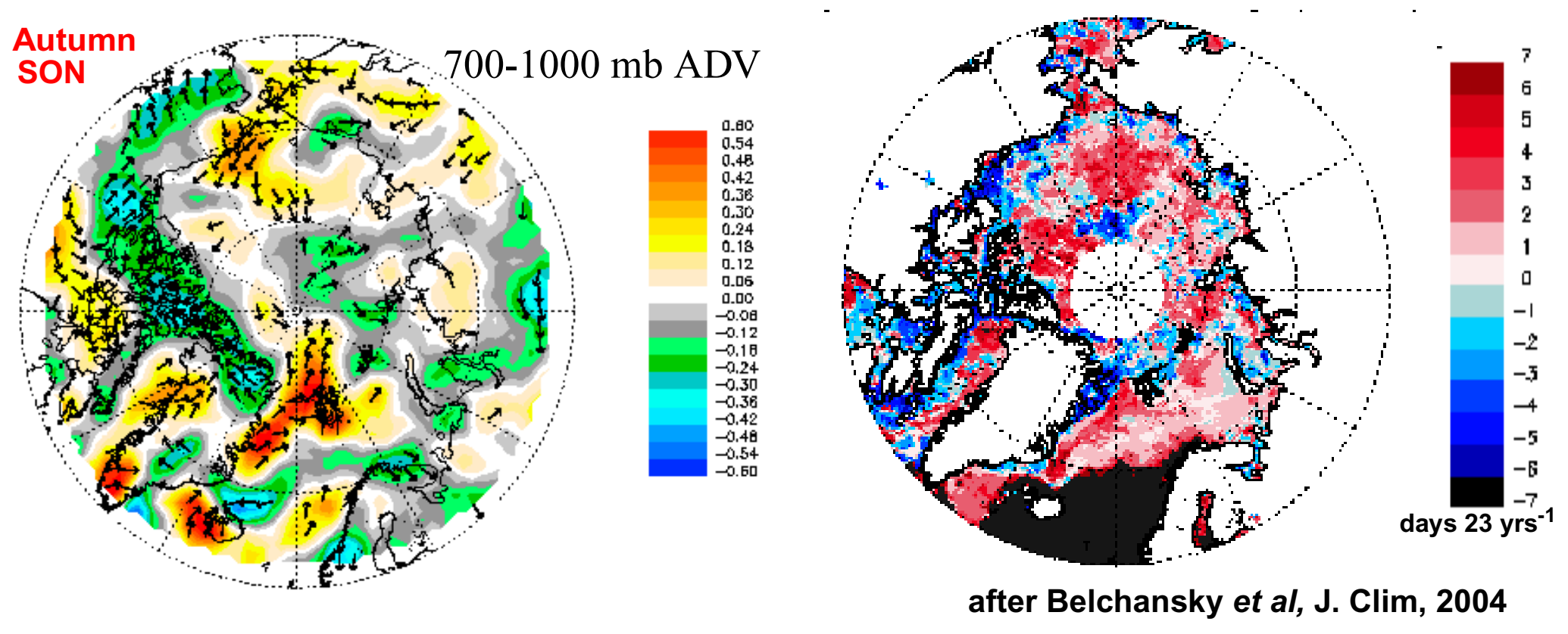
Image from NASA/GSFC

Figure 1: Illustration of method to derive time series of sea ice extent in 5 representative regions of the Arctic Ocean. Distance is measured southward from an arbitrary point to the location where ice concentration first decreases below 50%. This technique will be used to quantitatively identify relationships between sea ice variability and forcing parameters. Ice concentration from NASA Bootstrap algorithm obtained from NSIDC.

Clues to Observed Changes in Melt Season Duration

22-year Trends in Related Parameters

Sensible Heating 1000-700 mb **Melt Duration**



after Belchansky *et al*, J. Clim, 2004

Downwelling Longwave Flux (W/m²/dec) **Surface Skin Temperature (K/dec)**

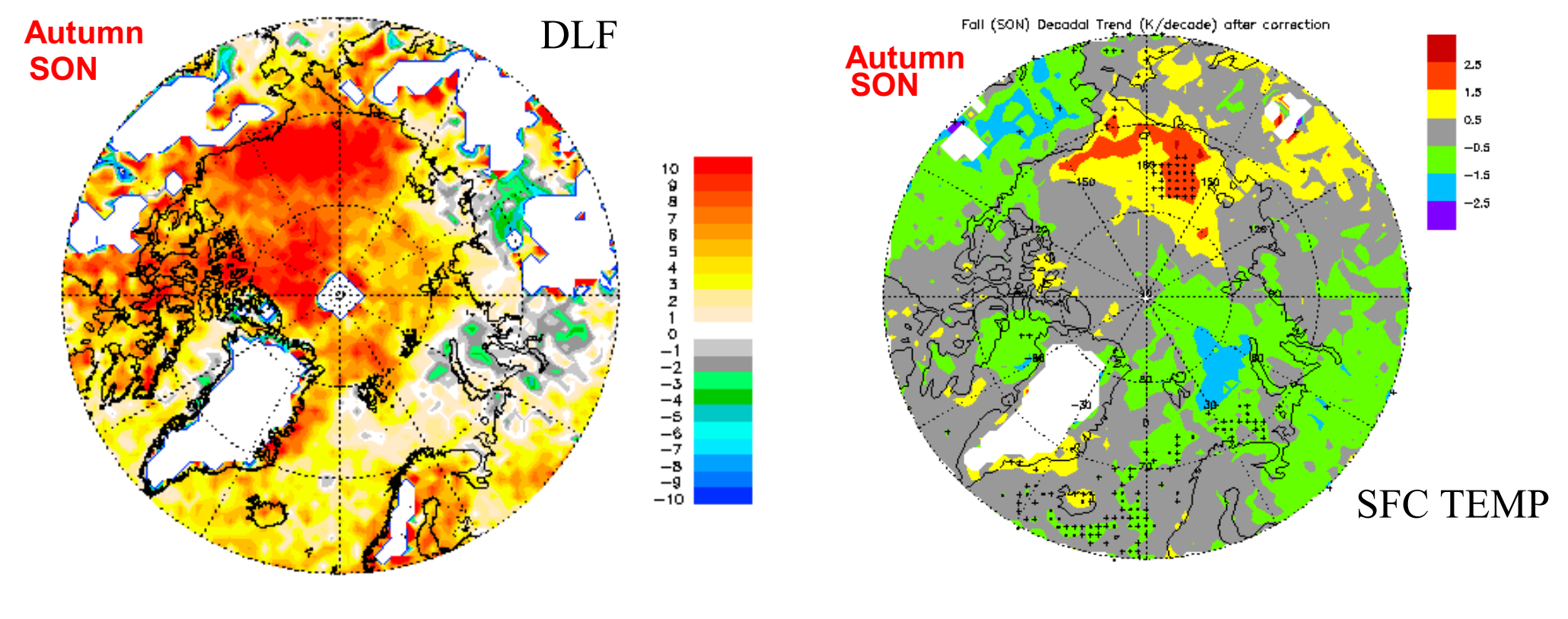
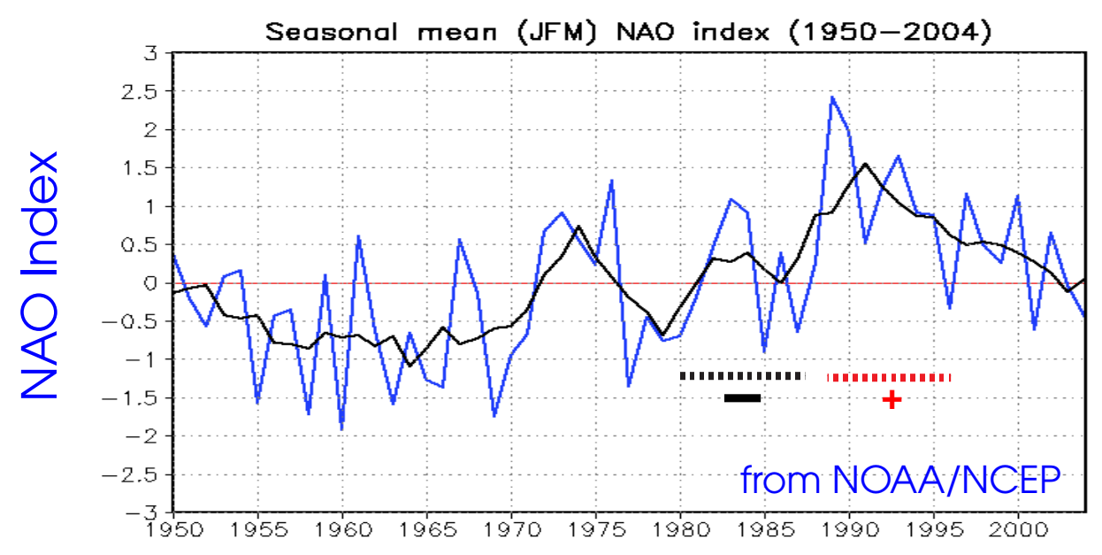
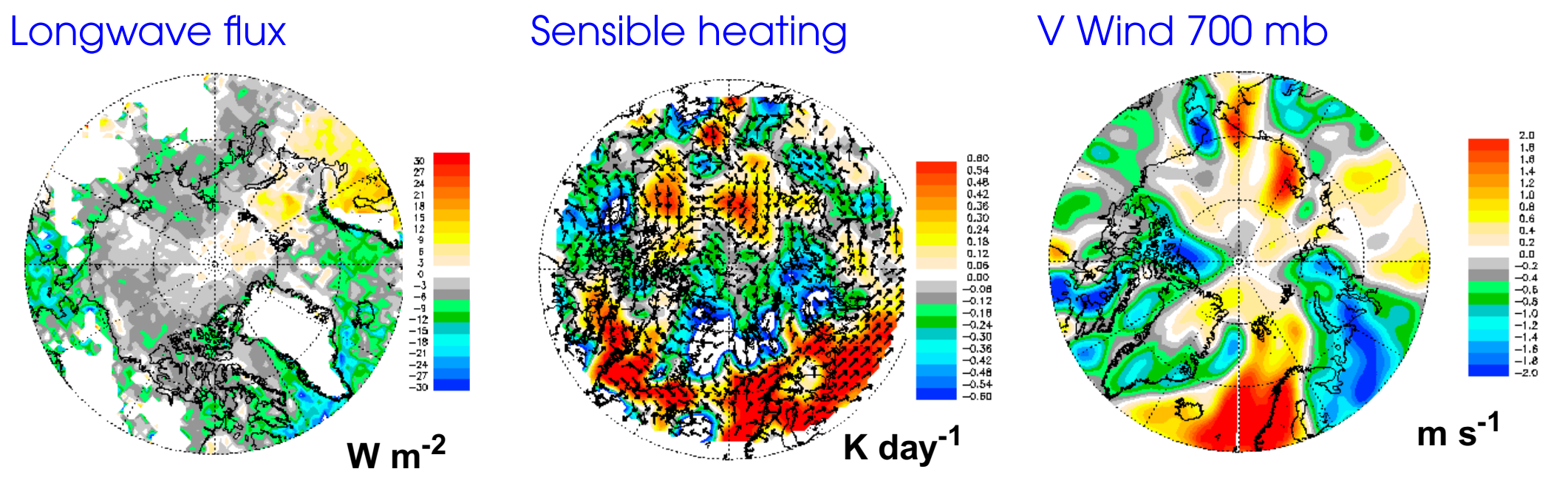


Figure 4: Autumn trends in sensible heat convergence (upper left), longwave flux (lower left), and surface temperature (lower right) are compared with changes in melt season duration (upper right). Areas of longer melt duration appear related to increased heat transport in the Chukchi Sea area, as well as increased longwave flux and surface temperatures.

Connections with the NAO



Winter (DJF) +NAO – (-NAO)



Spring (MAM) +NAO – (-NAO)

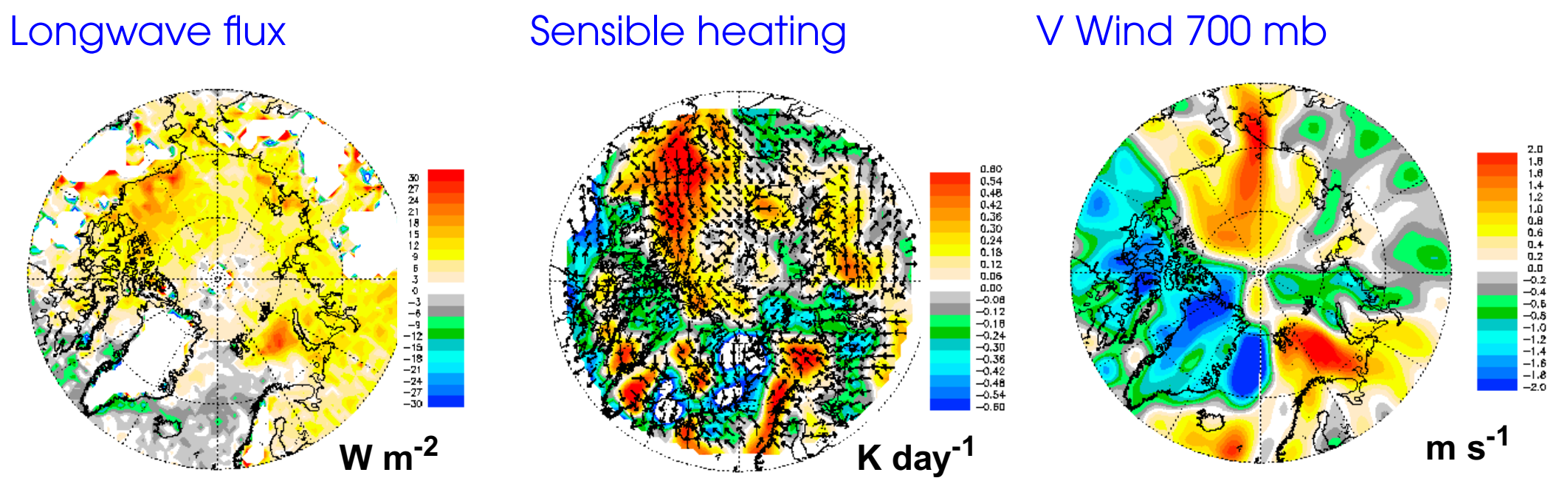
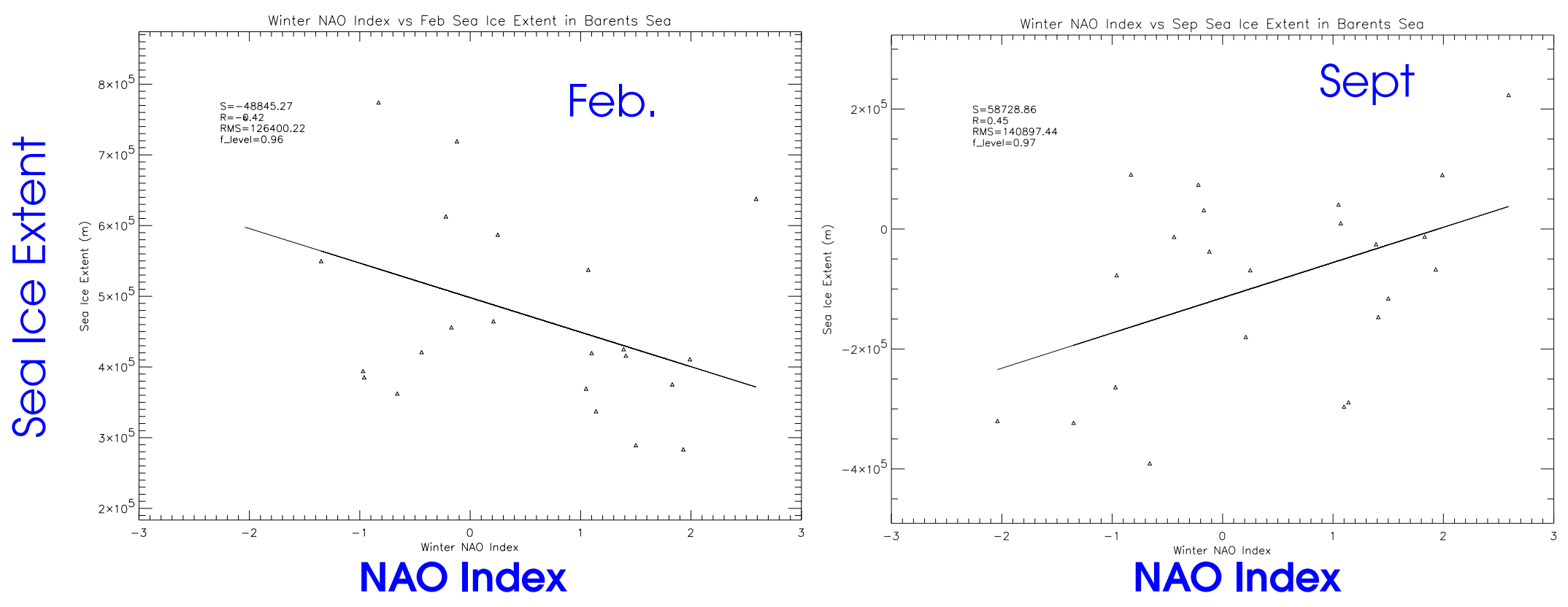


Figure 5: In winter (top) the primary NAO-driven forcing appears to be predominantly dynamic in the Atlantic sector, while in spring thermodynamics (longwave flux and advection) appear to contribute substantially.



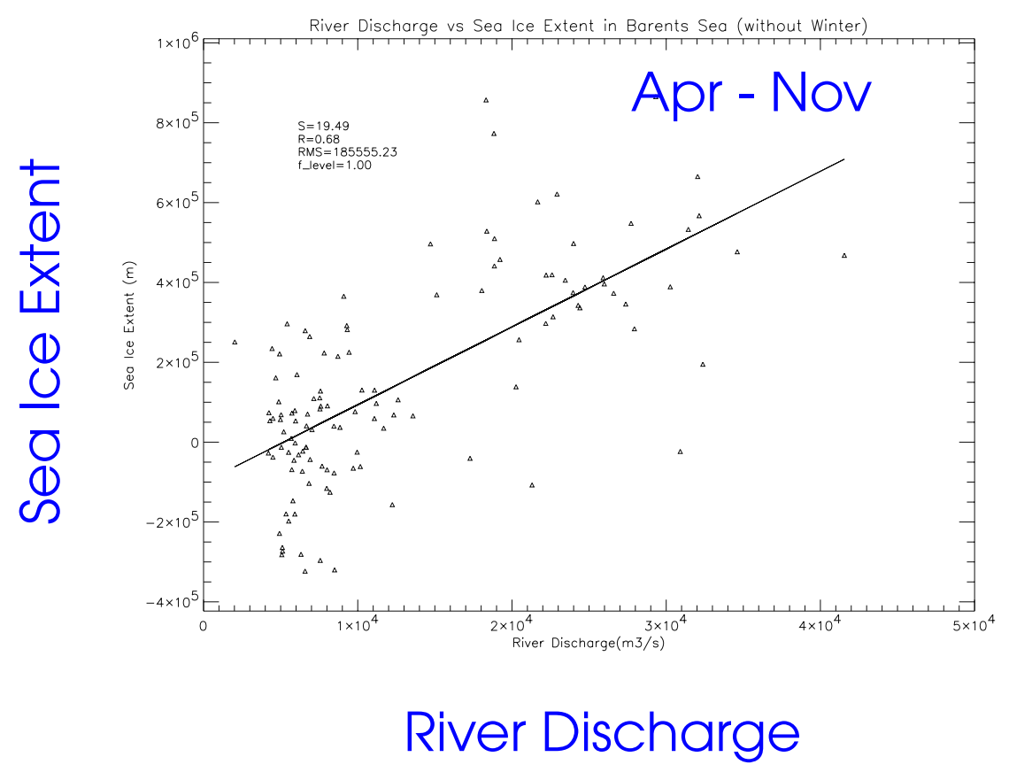
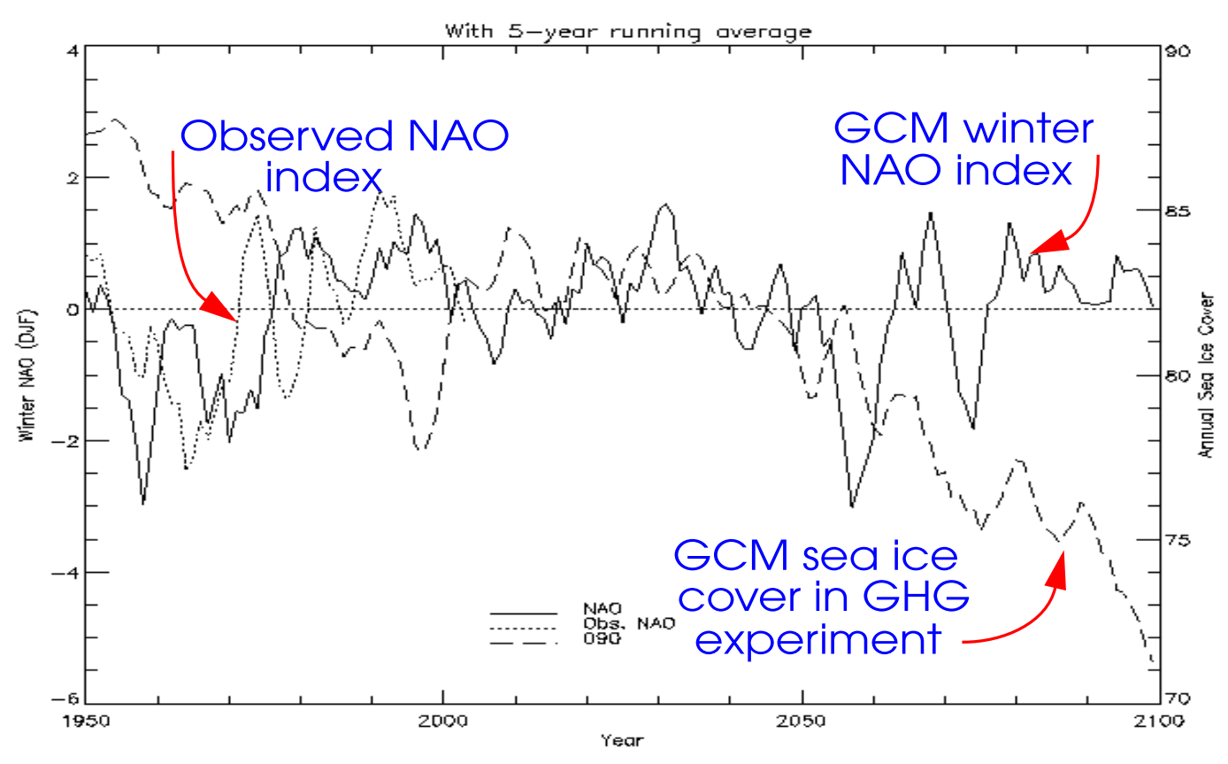


Figure 6: Top: Comparison of winter NAO index with sea ice extent in the Barents Sea during Feb. (left) and Sept. (right). In winter months there is less sea ice in the Barents Sea when the winter NAO index is positive, therefore dynamic effects (stronger offshore winds) dominate. In summer there is more sea ice in positive NAO conditions, thus it appears that decreased salinity may be linked with increased sea ice formation.

Bottom: Discharge from rivers emptying into the Barents Sea versus sea ice extent from April to Nov. Maximum river discharge occurs in spring when sea ice is most extensive (from Chan, 2004).

What Does the Future Hold?

Clearly there are close ties between the AO/NAO and sea ice. Recent tendencies for predominantly positive NAO indices have apparently led to increased net precipitation and runoff in the Eurasian Arctic, but interactions among the "players" are complex and their relative roles may change in the future. Models offer the only hope for planning for and adapting to future change. And the future, according to the GISS GCM, is not far away:



References

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