A photograph of a vast Arctic sea with numerous white ice floes of various sizes scattered across the dark water. The sky is overcast and grey. The text is overlaid on this background.

Radical Spatial Shift of Atmospheric Circulation Pattern: The Driving Forcing for Recent Rapid Changes in Arctic Climate System

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In Collaborations With

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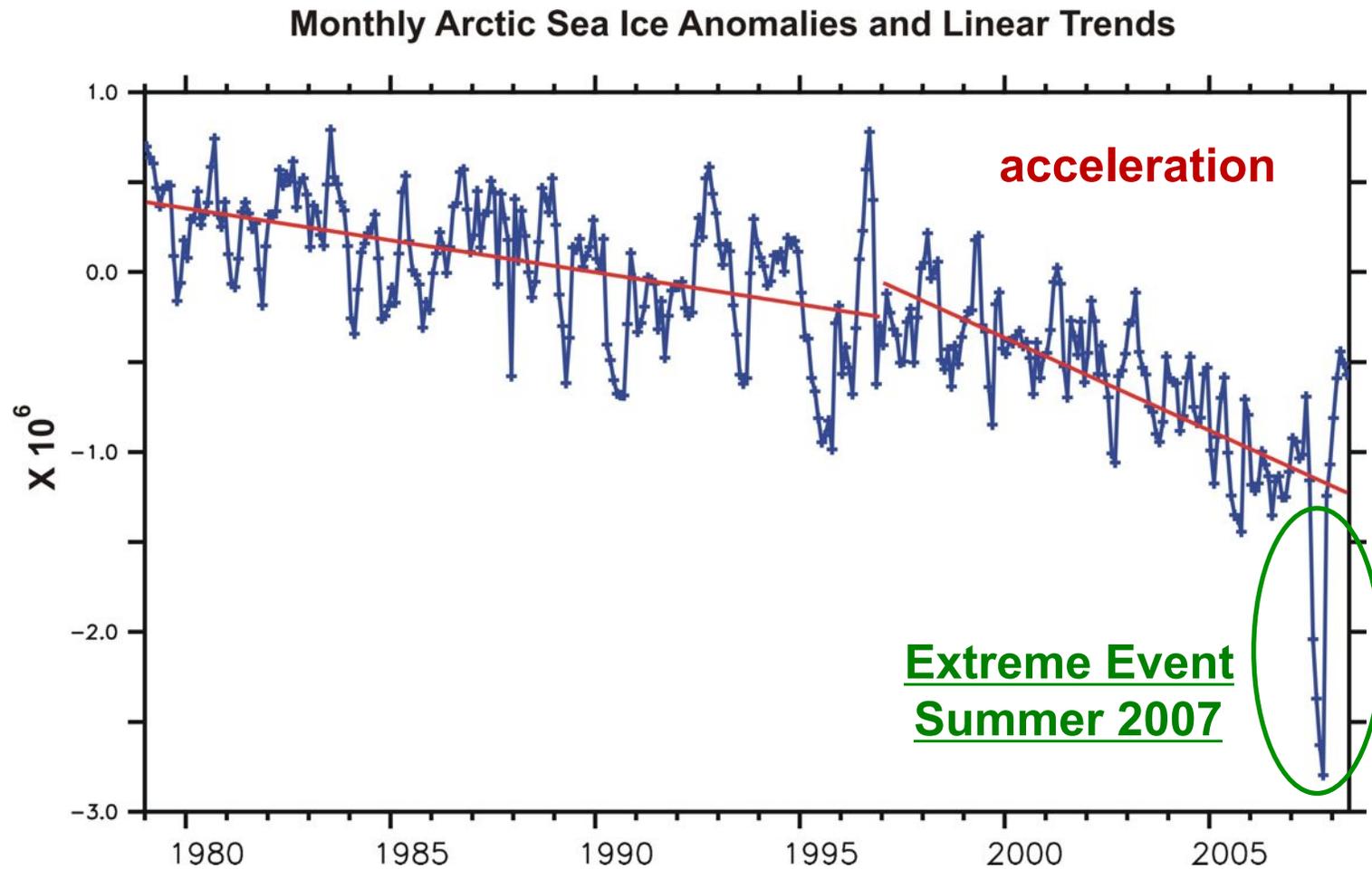
¹Bjerknes Centre for Climate Research, Norway

²Arctic Region Supercomputing Center, University of Alaska Fairbanks, USA

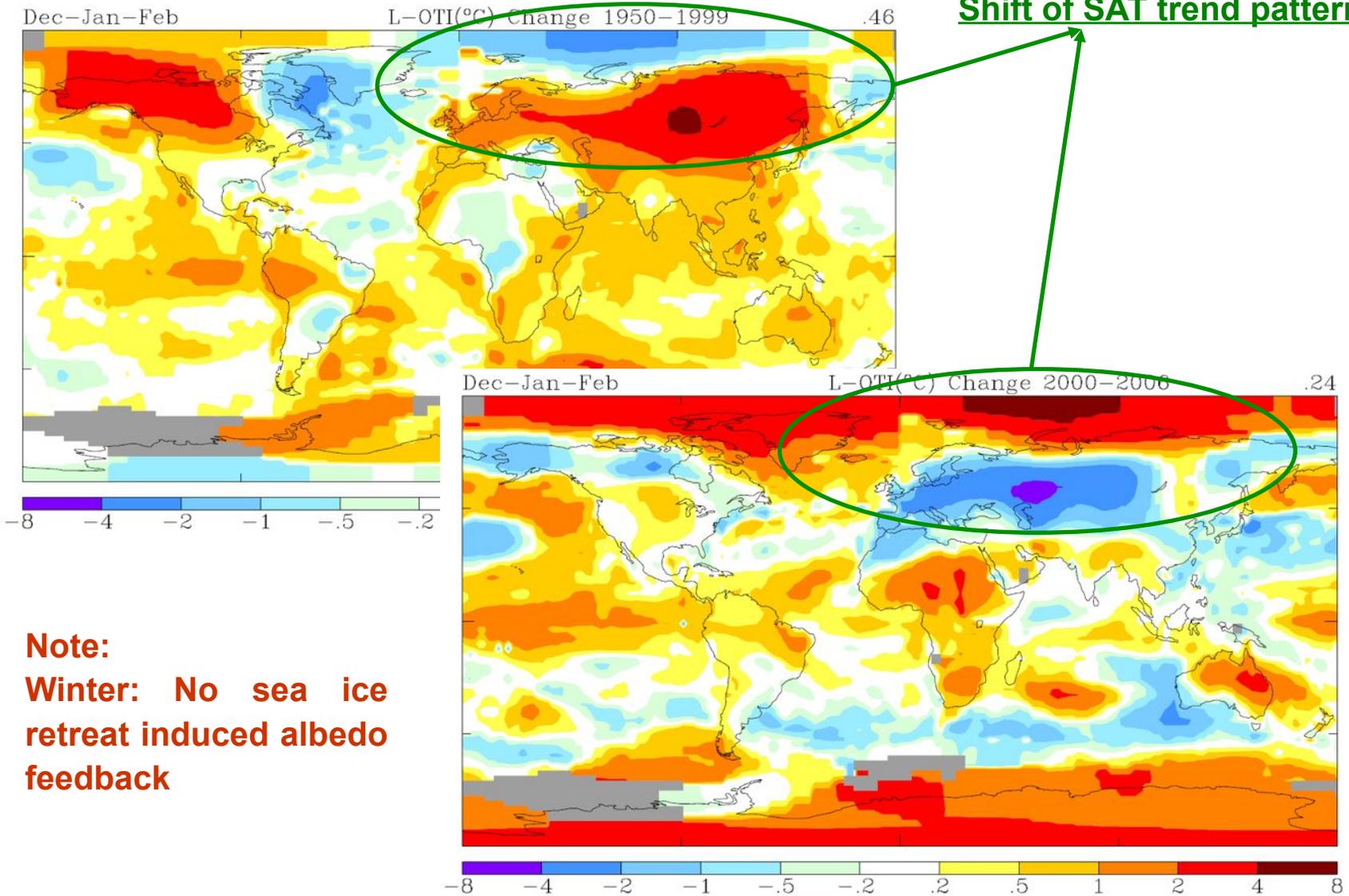
³Alfred Wegener Institute for Polar and Marine Research, Germany

⁴NASA Goddard Space Flight Center, USA

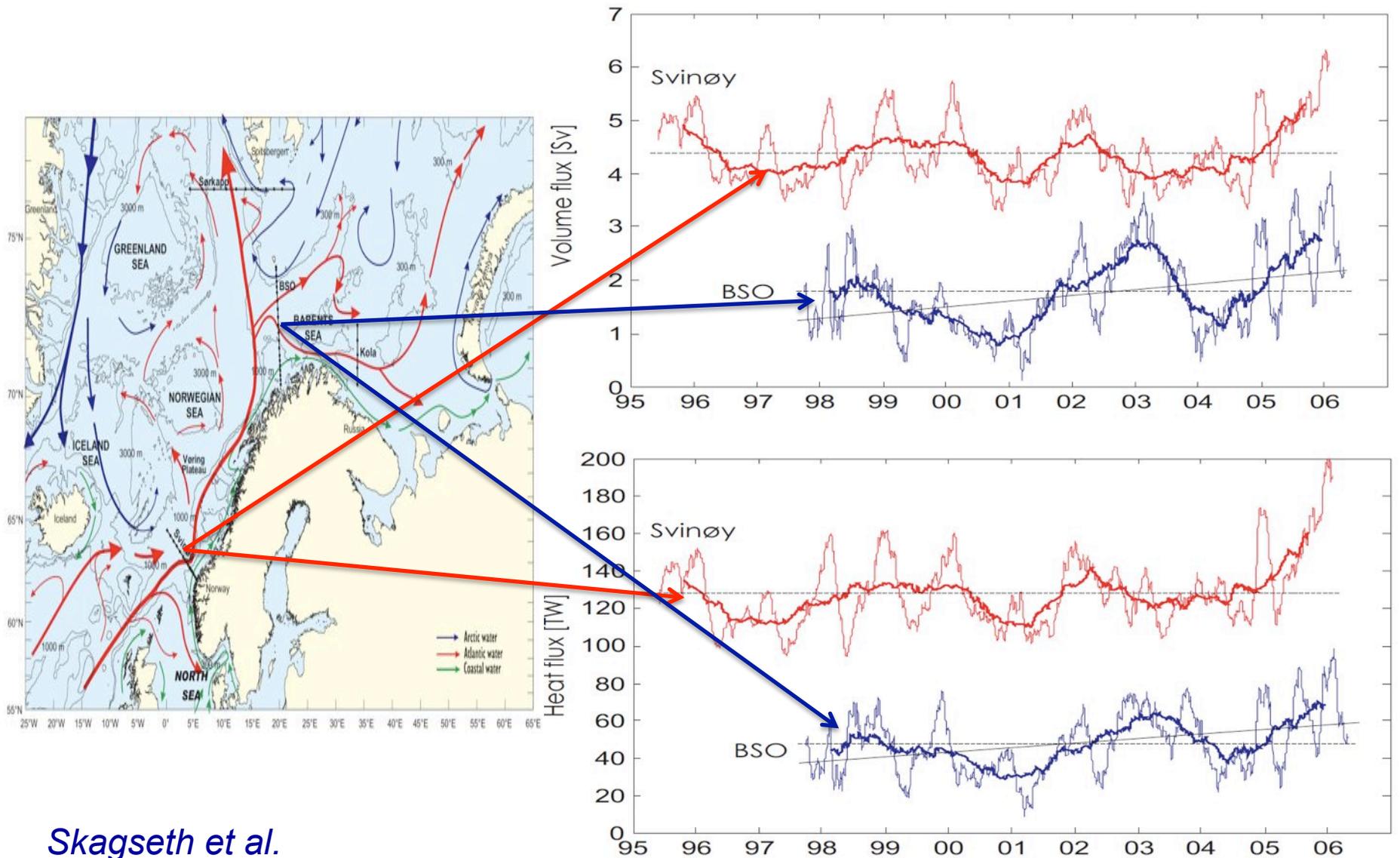
- Rapid Changes: Accelerated Reduction of Sea Ice Coverage



• Rapid Changes: Further Amplified Air Temperature Increase



• **Rapid Changes: Further Enhanced Atlantic Warm Water Intrusion**



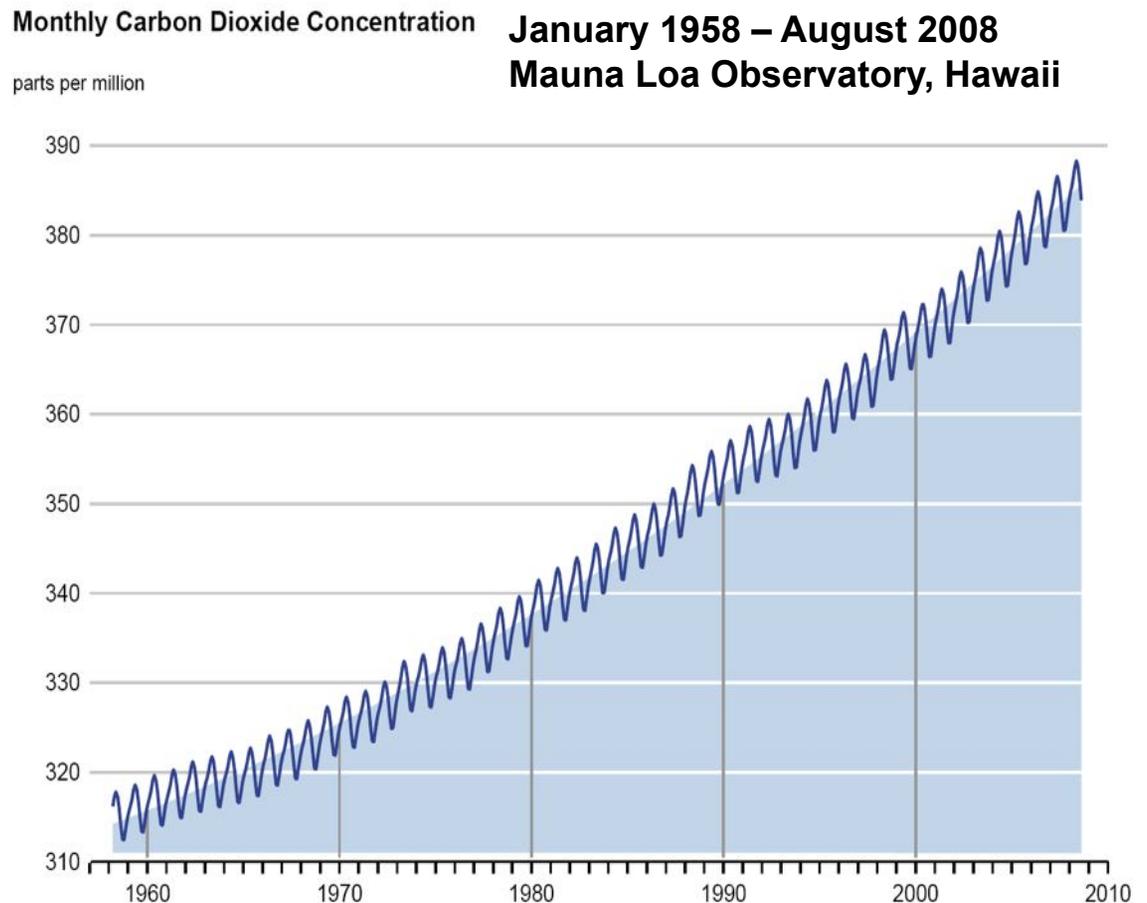
Skagseth et al.

• Question: What has driven the acceleration?

- the greenhouse gas increase ITSELF cannot explain the acceleration of sea ice reduction and the extreme event of sea ice cover loss in summer 2007
- the greenhouse gas increase ITSELF cannot explain the surface air warming pattern change, and provide dynamic forcing for ocean and sea ice motion

No obvious change in the increase of CO₂ since mid-1990s

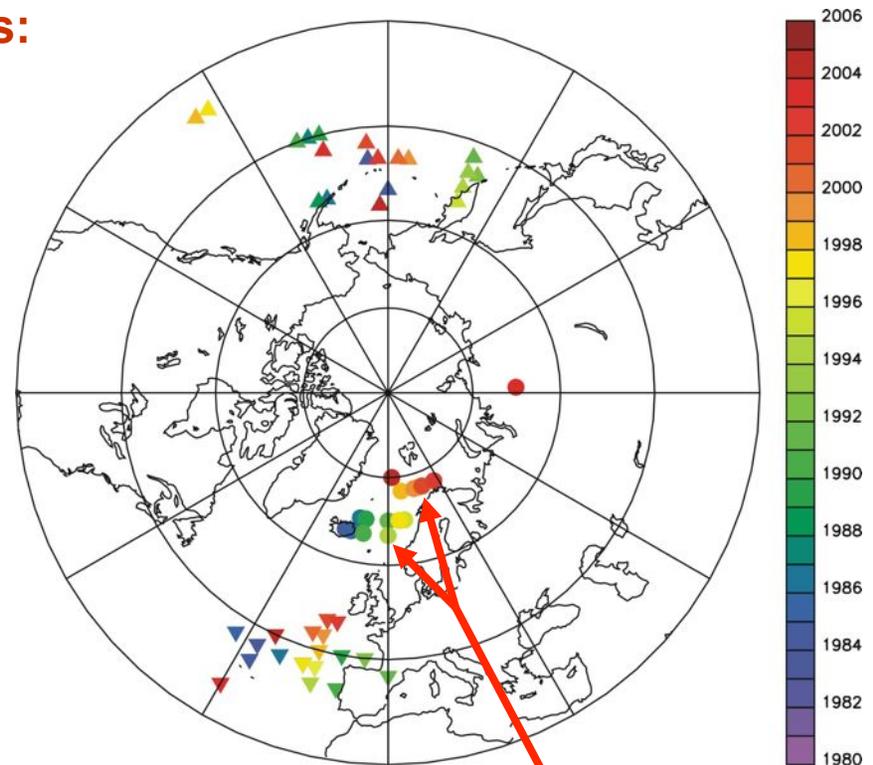
Keeling et al. 2005



- Atmospheric circulation shift and Arctic Rapid change Pattern (ARP)

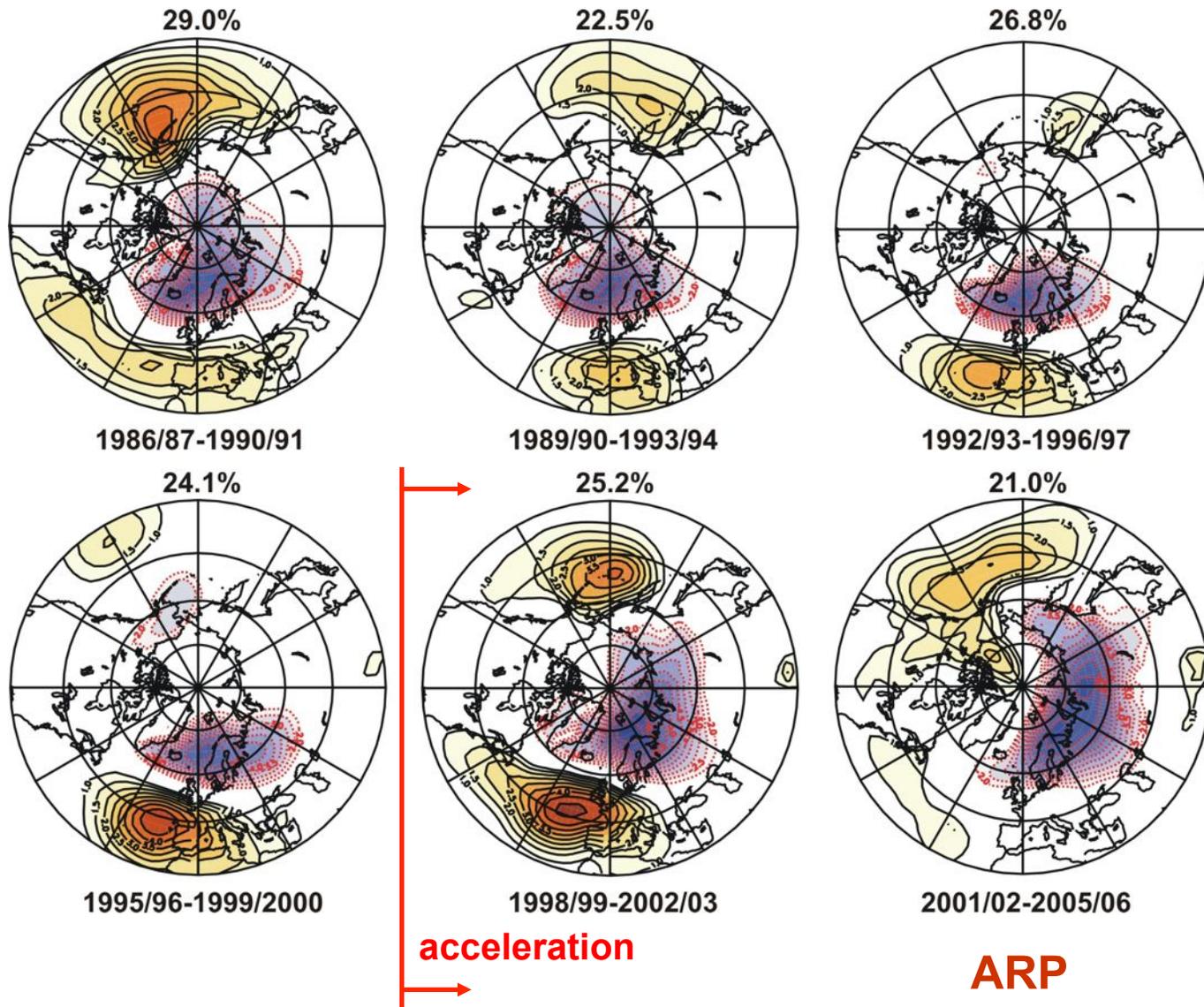
Running EOF/PC (Rn-EOF/PC) analysis:

- 30-winter-month running window
- EOF/PC analysis seeks spatially- and temporally-coordinated pattern that explains maximum variance and identifies centers of action

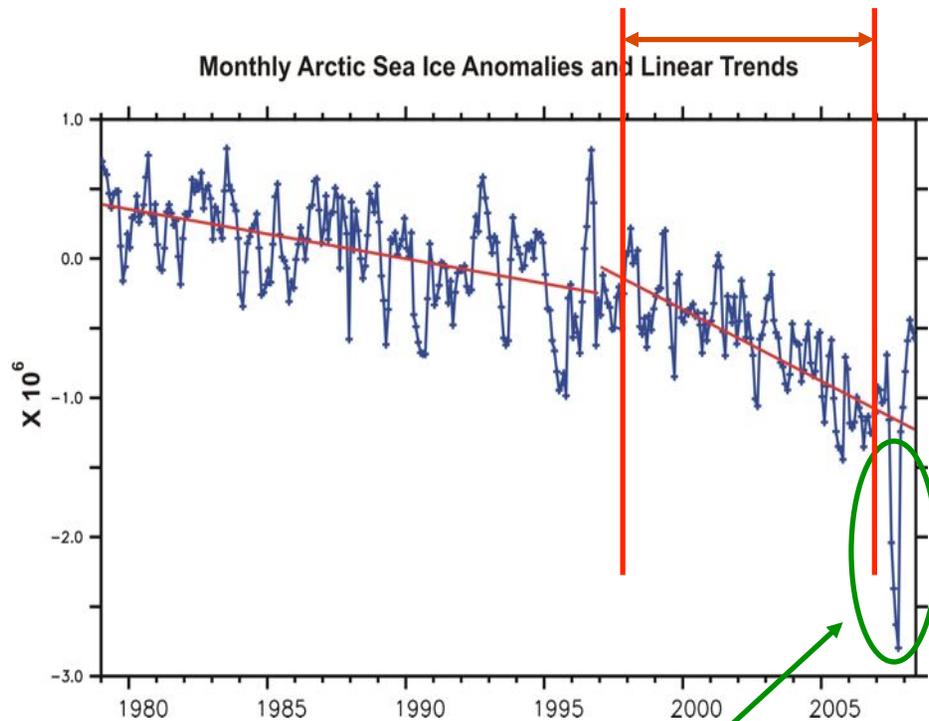


In mid-1990s

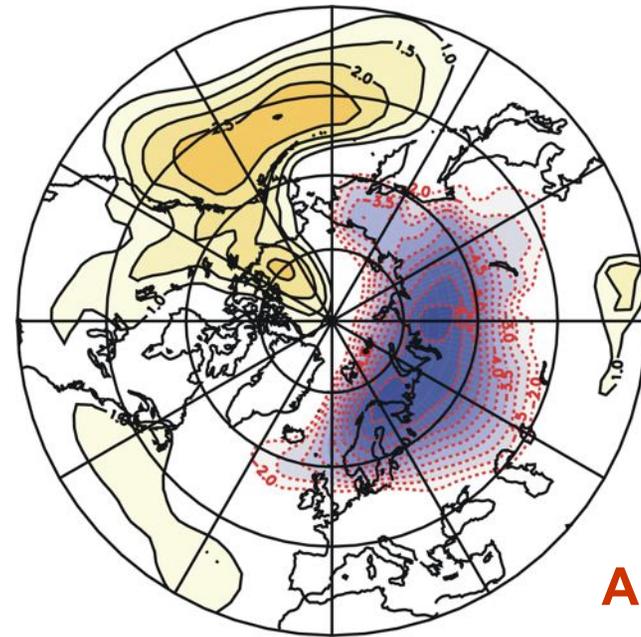
• Atmospheric circulation shift and Arctic Rapid change Pattern (ARP)



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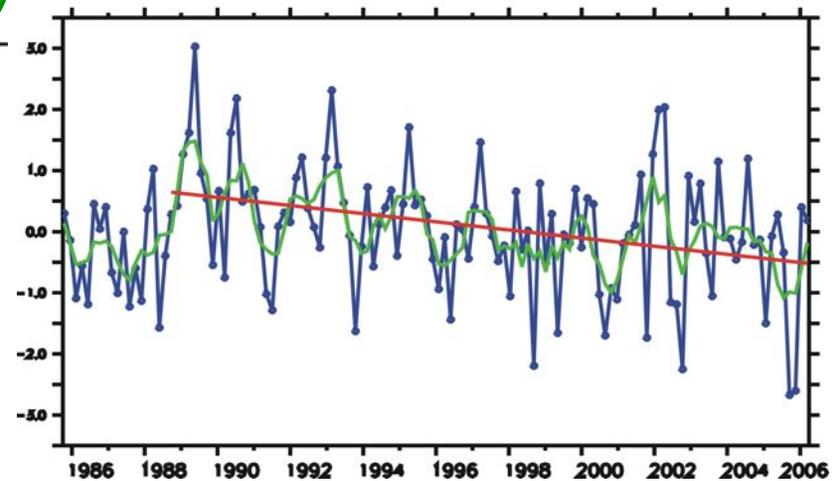


Summer 2007

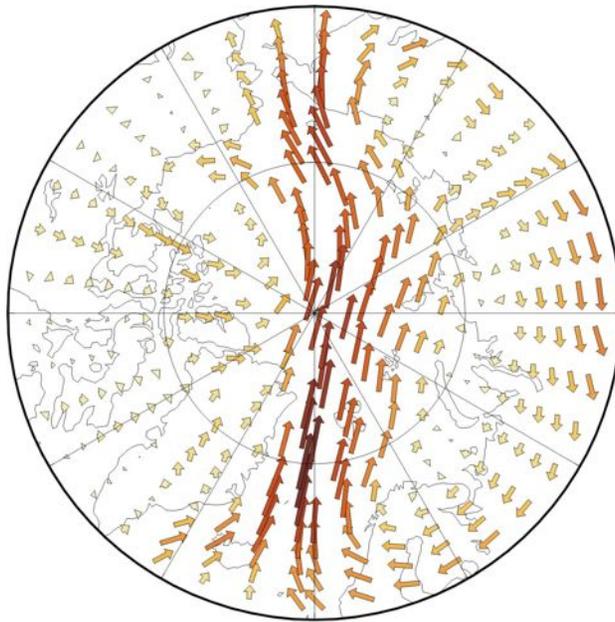


ARP

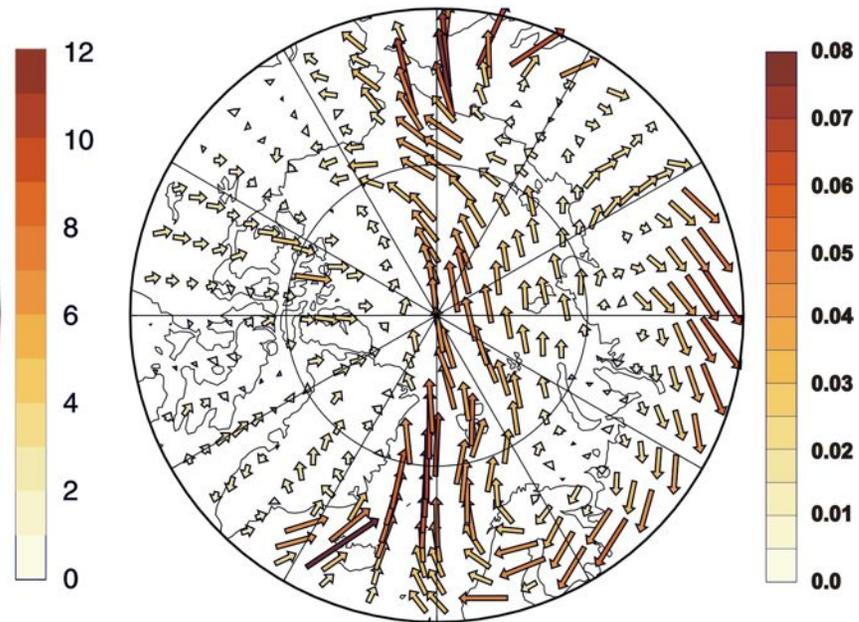
Projected Winter Monthly ARP Index



- ARP provided a shortcut of air and ocean heat transport into Arctic

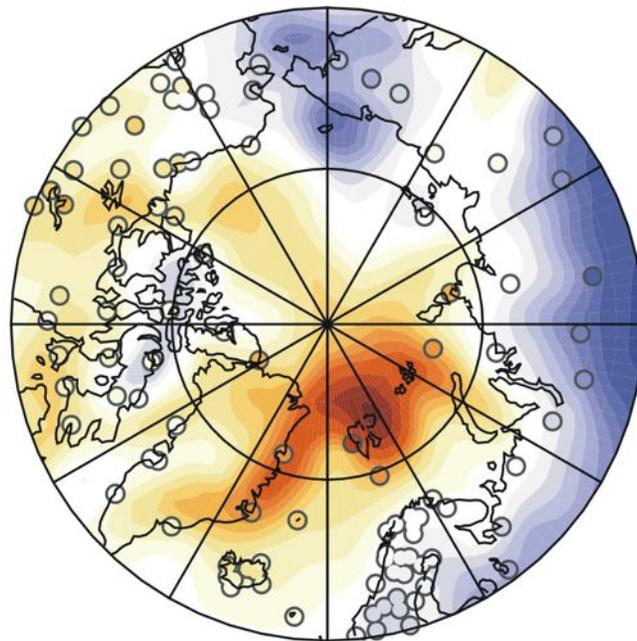


Heat transport regressed
onto winter ARP index
(surface - 850 hpa)

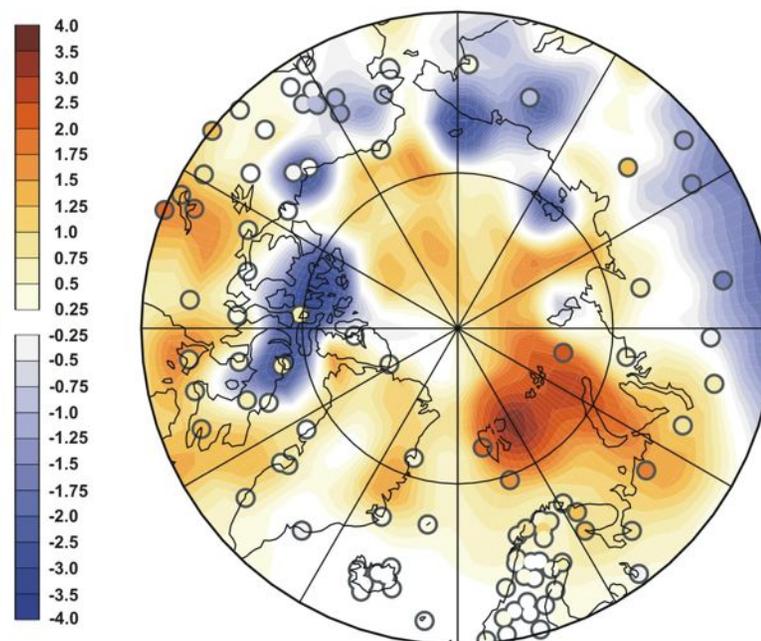


Surface wind stress regressed
onto winter ARP index

- ARP caused Arctic Ocean warming and Eurasian land mass cooling

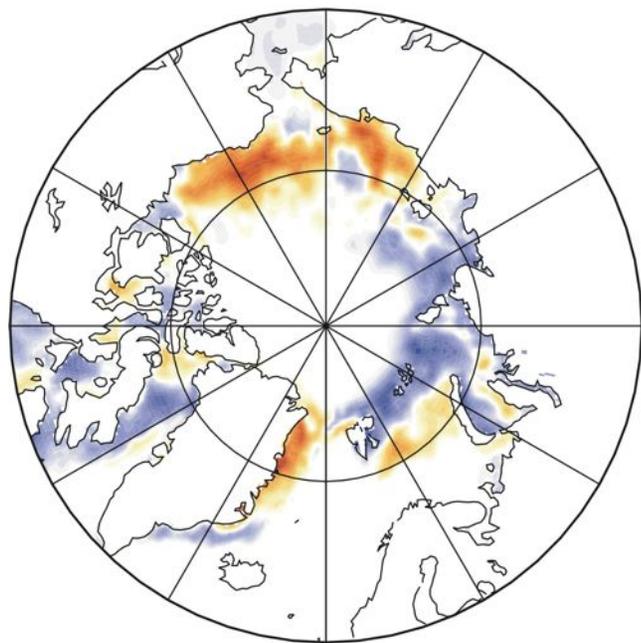


**Winter Surface Air Temperature
Regressed onto ARP Index**

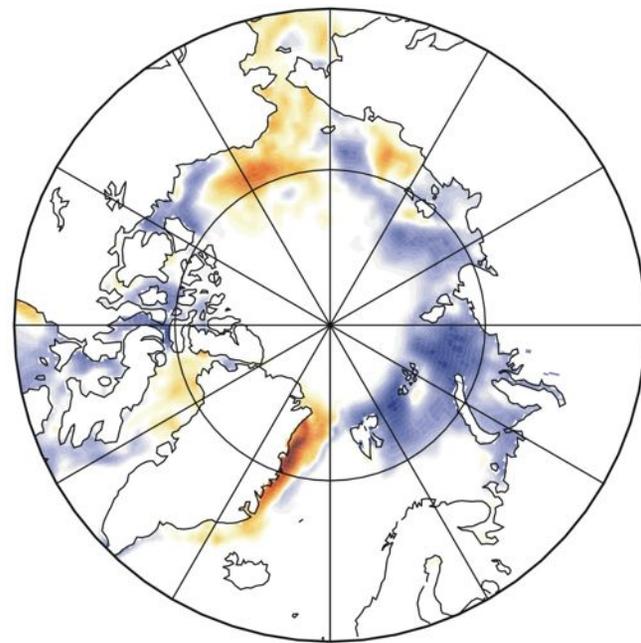
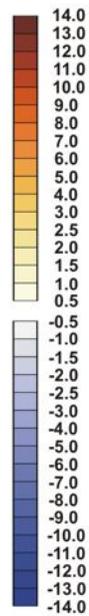


**Winter Seasonal Surface Air
Temperature Linear Trend**

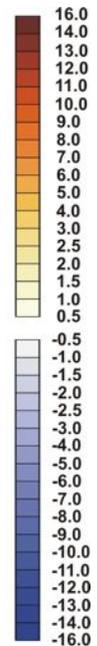
- ARP reduced the North Atlantic Arctic sea ice coverage



Summer Sea Ice Concentration Regressed onto ARP Index

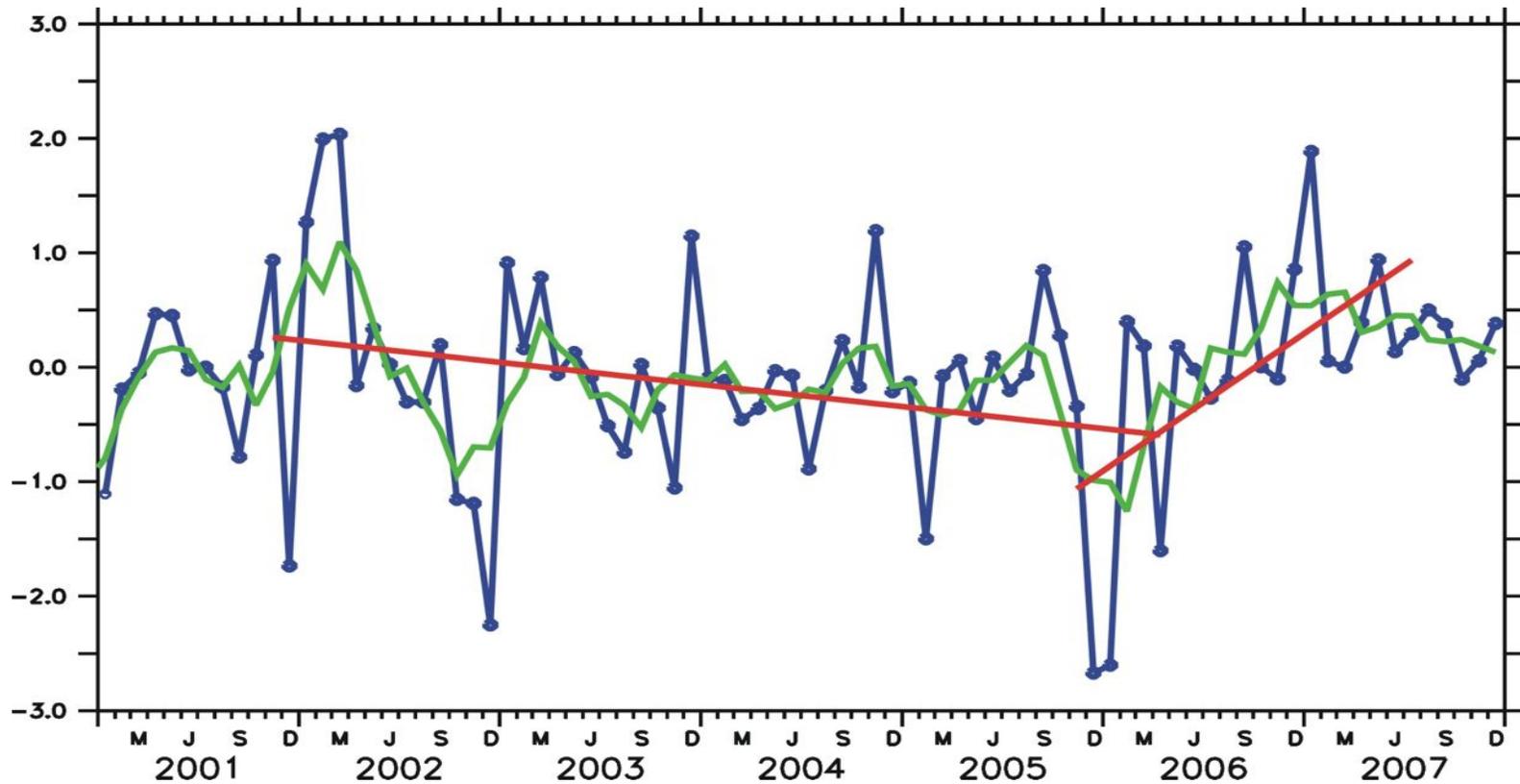


Summer Seasonal Sea ice Concentration Linear Trend



- Swift phase change of ARP resulted in the extreme event of sea ice cover loss in summer 2007

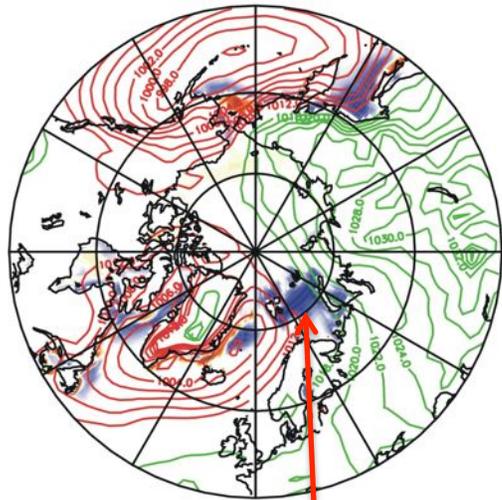
ARP Index (All Months Included)



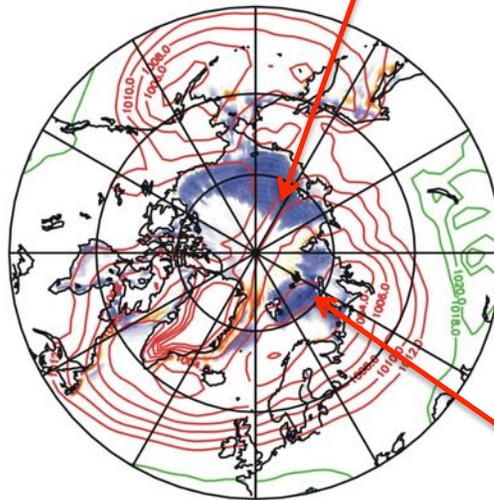
• Swift phase change of ARP resulted in the extreme event of sea ice cover loss in summer 2007

- ✓ The ARP phase change reversed wind pattern and reduced sea ice cover
- ✓ The ARP phase change enhanced Pacific warm air and warm water inflow
- ✓ The enlarged open water enhance albedo feedback

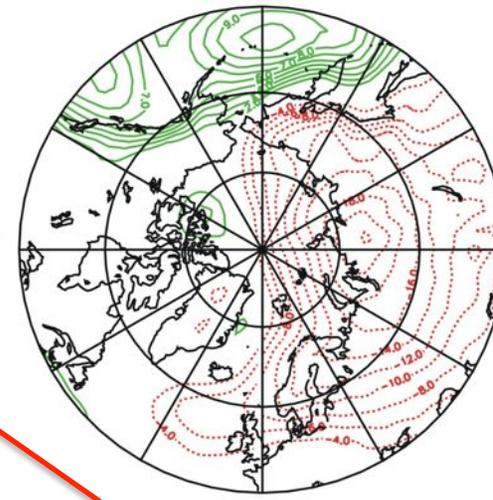
Composite Analyses of SIC and SLP Based on ARP Index



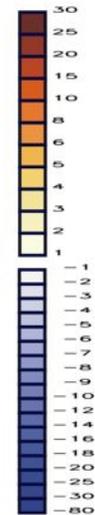
Negative ARP (mainly in winter) Before 2006



Positive ARP (mainly in summer) After 2006



Differences in SLP



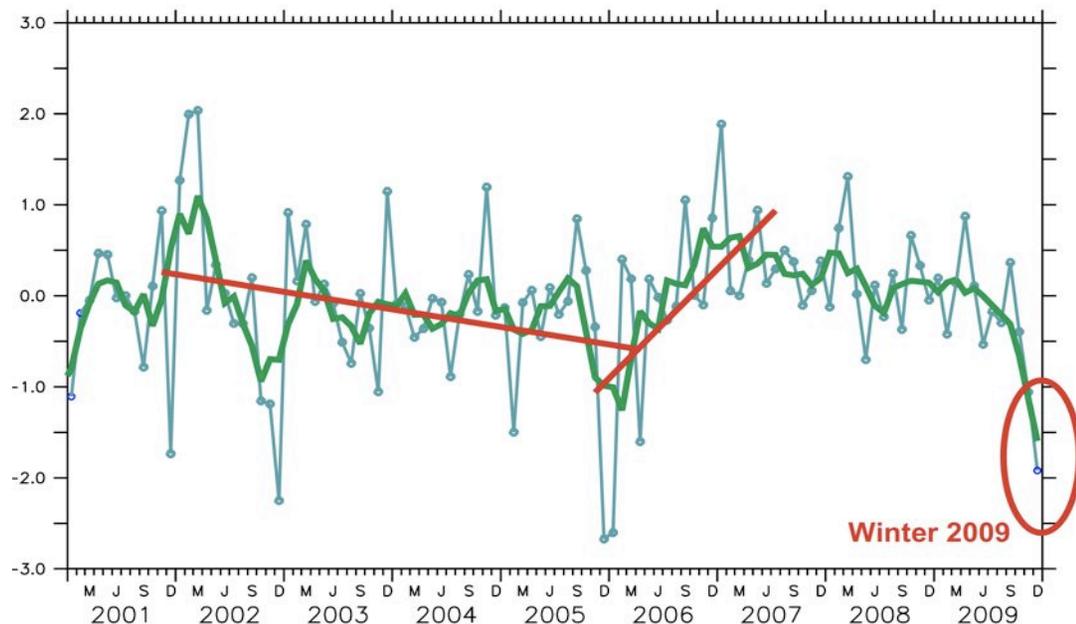
The ARP associated atmospheric and oceanic heat transport reduced sea ice and enlarged open water

✓ The previously warmed ocean retains the decreased sea ice
✓ The enlarged open water enhance albedo feedback

Summary

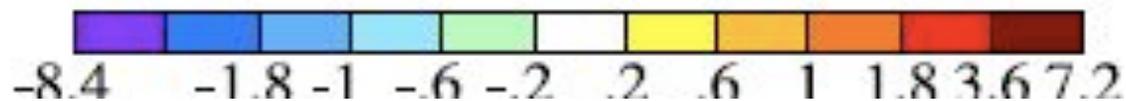
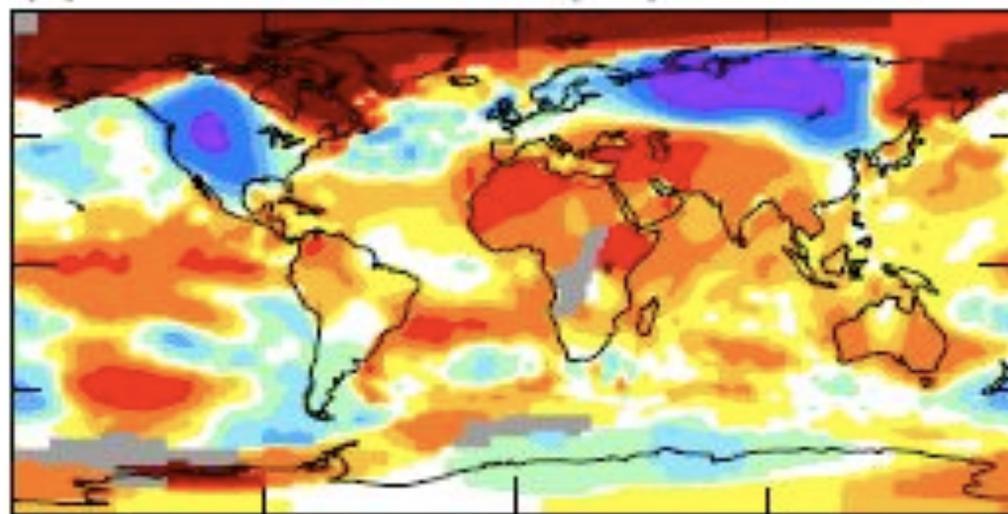
- **Atmospheric circulation pattern has shifted drastically in the latest decade, which speeded up global-warming-forced changes and caused a rapid change event.**
- **ARP enhanced Arctic-global interactions:**
 1. **It built a shortcut for warm air inflow to the central Arctic, increased warm water intrusion, and increased sea ice deformation.**
 2. **It redistributed polar cold air to Eurasia, causing cold weather events there.**
- **Detection of ARP may provide skillful information for predicting future occurrences of extreme or rapid climate change event in Arctic.**

ARP Index and SAT Anomalies in December 2009



(a) December 2009 (#4)

.59



Hansen et al. 2010