Sea Surface Temperatures: High latitude SSTs and their interaction with the Arctic sea ice cover

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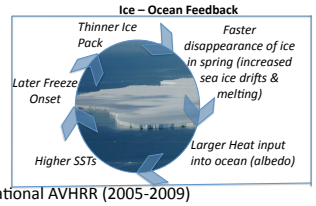
Background

- The Arctic sea ice pack is decreasing in extent (4% /decade), and thickness (declining 1.75 meters since 1980), and is shifting from predominantly multi-year (MY) to first-year (FY) ice.
- Warming of Arctic Ocean is most pronounced since 2000. (2007 having 5°C anomalies in SSTs in Chukchi/Beaufort & Laptev/East Siberian Seas).
- From 1979-2005, the Arctic Ocean and surrounding seas have seen an increase in solar heat input of up to 4%/year.
- Melt season length (crucial for the maintenance of the ice pack) is increasing for the entire Arctic by 6.4 days/decade (some areas increasing 10 days/decade).

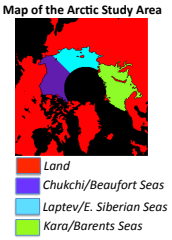
Hypothesis

- This Ice-Ocean positive feedback exists & can be shown with satellite data
- As the sea ice pack changes we expect this feedback loop become more prominent:



Data Used

- **Ice thickness** from: ICE Sat (2003-2008)
- **SSTs** from: Pathfinder AVHRR (1982-2005) & Operational AVHRR (2005-2009)
- **Ice Concentrations** from: SMMR (1982-1986), SSM/I (1987-2002) & AMSR-E (2003-2009)
- **Melt & Freeze Onset Maps** (1982-2009) from: SMMR, SSM/I & AMSR-E brightness temperatures



Correlations

What is the relationship between summer (JJAS) SSTs and freeze onset?

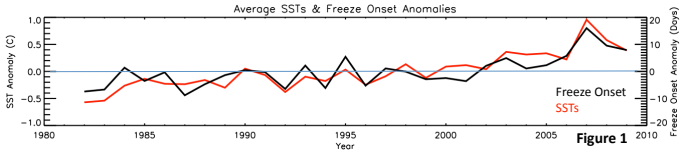


Figure 1

Fig. 1 SSTs force freeze onset (R^2=0.74). This is a linear relationship with the forcing growing stronger since the early 2000's (R^2=0.83).

What is the impact of the freeze onset on the ice thickness or maximum sea ice extent the following year?

Fig. 2 The later the freeze onset in the fall, the thinner the ice pack in the following spring (R^2=-0.79).

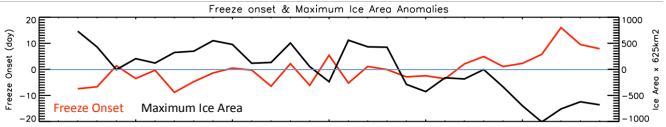


Figure 2

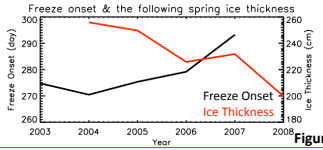


Figure 3

Fig. 3 An earlier freeze onset date doesn't always mean a larger ice pack (R^2=-0.44), but since 2001 later freeze onset & smaller ice areas dominate.

What is the effect of the timing of the melt onset on summer SSTs?

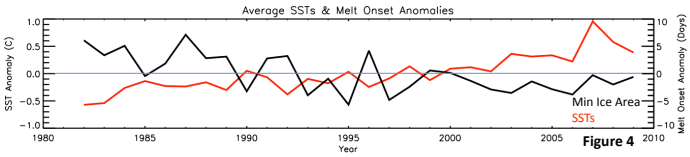


Figure 4

Fig. 4 There is **not a linear relationship (R^2=0.32).** When the melt onset is positive the mean SST is negative & v.v. But when there are more days of an ice-free ocean the SSTs are higher (R^2=0.65). Timing of melt onset does not play a large role in affecting the mean SSTs, but rather how quickly the ocean becomes ice-free.

What is the effect of the ice area and summer SSTs?

Fig. 5 The smaller the ice area the higher the SSTs (R^2=-0.81). No relationship between ice thickness and mean SSTs.

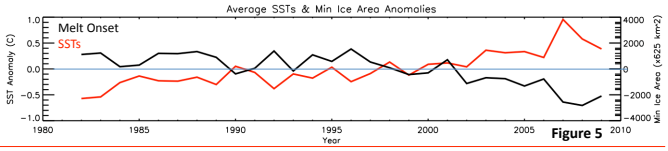


Figure 5

Results

Is the Arctic Ocean having a larger impact on the sustainability of the ice pack in recent years compared to the past?

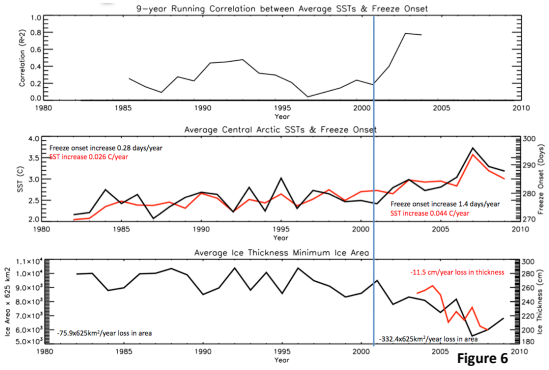


Figure 6

Yes. **Fig. 6** Beginning in 2001, the 9-yr running correlation between SSTs & freeze onset increased dramatically. Since 2001, the ice pack has lost 4x's the amount of area, the SSTs have increased at double the rate, and the freeze onset day is increasing at 5x's the rate compared to before 2001.

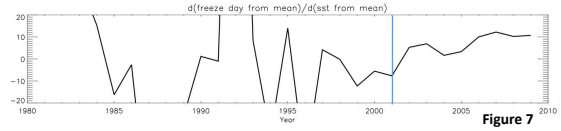


Figure 7

Fig. 7 Noise is seen before 2001 meaning that a change in SSTs does not imply a change in freeze onset, but since 2001 a positive linear trend is seen. Since 2001, for every 0.1°C increase in SSTs the freeze onset increases by 3 days.

Table corresponds to Figure 1.

	1982		2001		2002		2009	
	MY	FY	MY	FY	MY	FY	MY	FY
Ice Area x 625km²	5071	3632	5261	3209	3545	5324	2374	5914
Freeze Onset	248	287	251	299	253	293	257	298

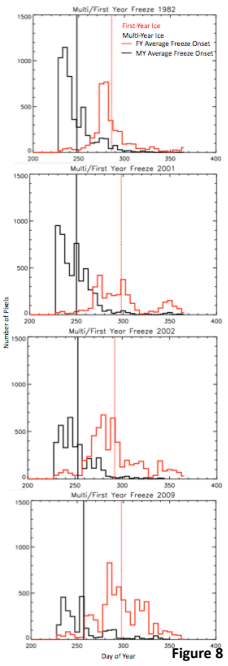


Figure 8

Fig. 8. 2002 is the first year on record when 60% of the ice is first-year ice. **The dominance of this thin weak ice is what causes the ice-ocean feedback process to intensify & take off.**

If currents trends continue, in 2 years average SSTs will increase by ~ 0.1°C, freeze onset will be delayed by 3 days and the resulting ice will become ~ 15 cm thinner.

Why is this feedback process intensifying?

Due to a ***thinner & first-year dominated ice pack,*** which has rapidly declined in thickness and increased in area since the early 2000s.

A thinner first-year ice pack is more venerable to movement & ridging via winds & requires less energy to completely melt in the spring exposing the ocean. The ocean, with its higher albedo, allows for larger heat absorption, which raise the SSTs. Larger SSTs increase side & bottom melting of the thin ice, increasing the ocean area & input of heat into the ocean.

Higher SSTs in the fall require larger heat loss & thus a longer time for the ocean to refreeze, delaying the freeze onset. A later freeze onset means that the ice has a shorter season to solidify & strengthen, so a weaker, thinner ice pack is present in the following spring.

This ice ocean feedback process has always existed, but between 2001 & 2002 the ice pack shifted from 60% MY ice to 60% FY ice. This shift caused the intensification of the ice-ocean relationship and the runaway effect seen here.