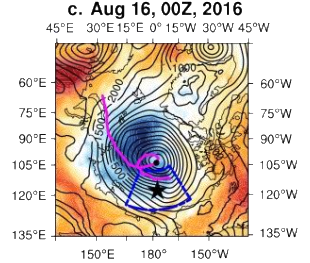
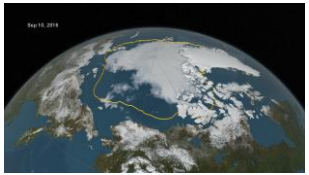
Bridging Scale Gaps Between Cyclones and Climate Change

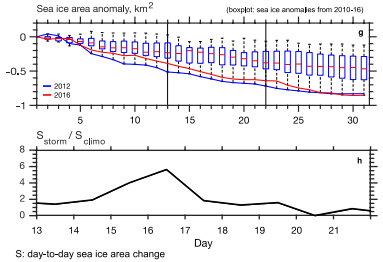
Xiangdong Zhang, NCSU | Arctic Cyclones and AMOC/AMO

Motivation: Conventionally climate studies focus on monthly/seasonal/annual mean state. However, drastic changes and extremes events observed each day are primarily driven by synoptic and mesoscale systems.

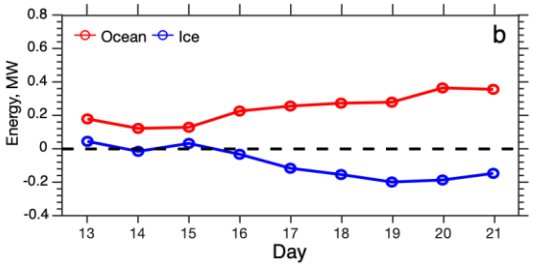
What we have learned: The 2016 summer super strong cyclone (captured for the first time in field observations) enhanced air-sea-ice interactions and accelerated summer sea ice loss, contributing to the third record low of pan-Arctic sea ice extent since 1979.



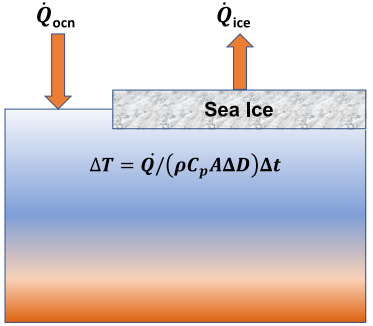




Sea ice area decreasing rate considerably increased when cyclone intensified.

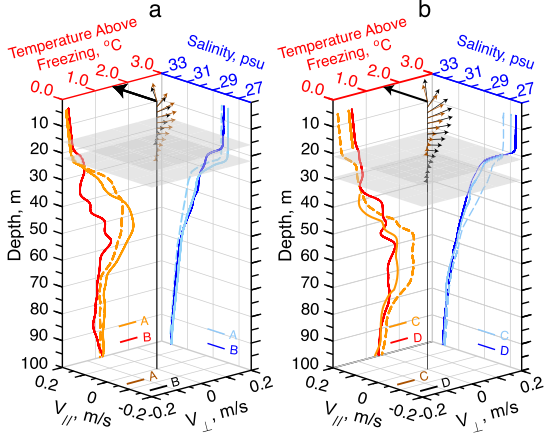


The open water area gains heat energy, but sea ice surface losses heat energy.



ΔT	16 August 2016 (6-19h)	19 August 2016 (2-11h)
$\dot{Q}_{ocn}$ Based	0.0076°C	0.0063°C
CTD Observed	0.05°C (0.08°C)	0.12°C (0.46°C)

The open water gain of heat energy is not enough to increase ocean temperature to the observed ones.



- Cyclone-induced Ekman upwelling transports heat energy from the deeper Pacific-origin warm water to the upper mixing layer.
- Cyclone-driven strong wands enhances ocean mixing in the upper mixed layer.
- Ocean-to-sea ice heat flux is enahnced to increase sea ice basal melt.

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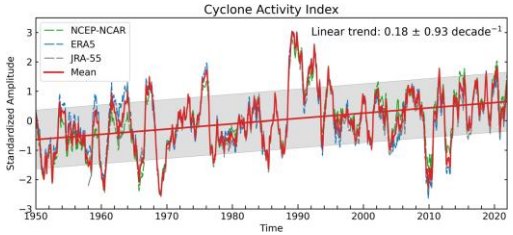
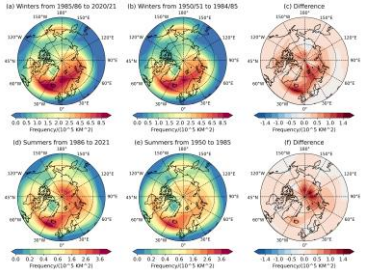
Why significant for climate studies: Intense cyclones are not single, random events. Their frequent occurrence have lingering, cumulative, and upscale effects to accelerate long-term climate change.

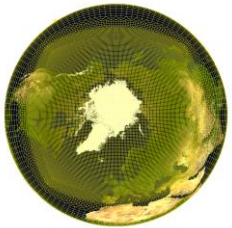


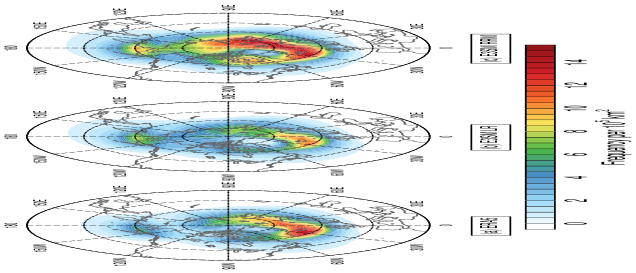
Arctic cyclone activity has intensified



The frequency of occurrence of strong cyclones propagating into or generated within the Arctic has significantly increased.

Challenges: (1) Lack of systematic, high-resolution atmosphere, sea ice, and ocean observations; (2) large biases and discrepancies in high-resolution Earth system models.





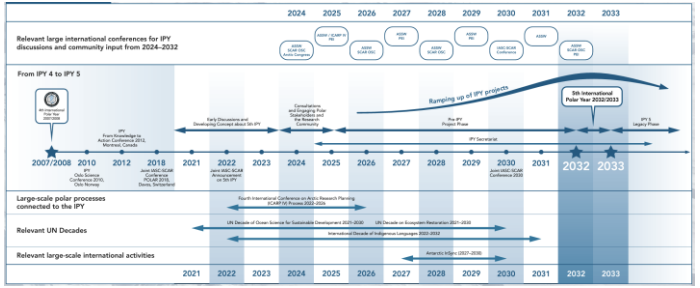
The E3SM-Arctic RRM improved the simulation of strong cyclone frequency over the Atlantic Arctic. However, it overestimates the frequency in the central Arctic.

The way forward and opportunities: Strengthen multi-scale, high-resolution (in both space and time) observational and modeling studies.

(1) Coordinate high-resolution field observations from the stratosphere to the deep ocean covering longer time and larger areas;

(2) Integrate observations and model improvement to better represent high-resolution processes, especially the missing physics.

(3) Exploit national and international collaborations, such as the 5th IPY.



Refs: Peng and Zhang, et al., 2021; Zhang et al., 2023