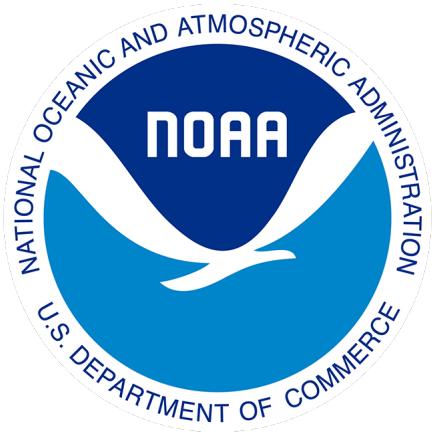
# Arctic Climate and Weather Extremes: Detection, Attribution, and Future Projection

Xiangdong Zhang, Timo Vihma, Annette Rinke, and Kent Moore

Special Thanks to Emily Jack-Scott and AGCI Colleagues

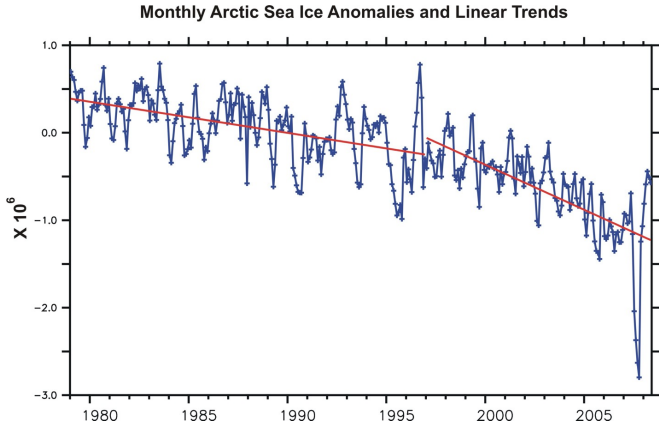
- Background: Initiated in late 2018, but delayed by the COVID-19 Pandemic
- Funding Support:



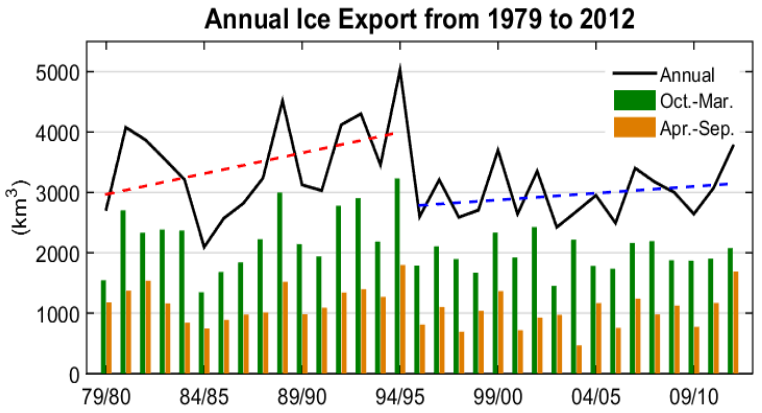



# Motivations

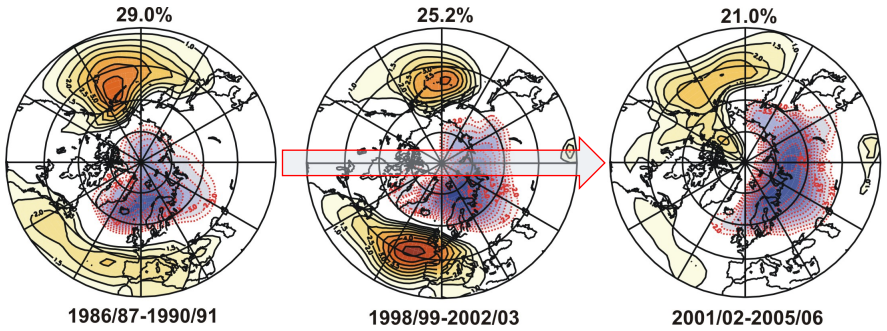
- **Climate Extremes - Tipping Point and Climate State Shift (?)**

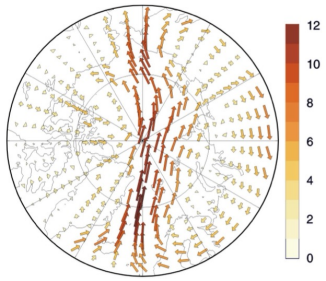



Zhang et al., 2010

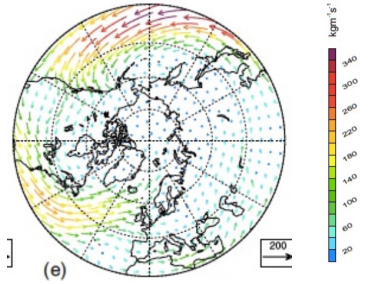



Wei et al., 2019

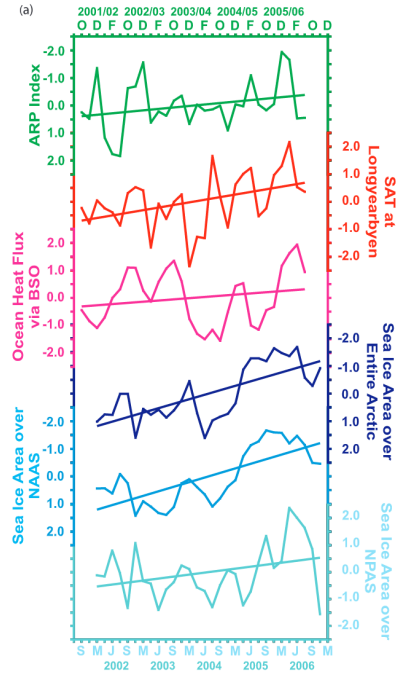



ATM Heat Transport




ATM Moisture Transport




GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L22701, doi:10.1029/2008GL035607, 2008

**Recent radical shifts of atmospheric circulations and rapid changes in Arctic climate system**

Xiangdong Zhang,[1] Asgeir Sorteberg,[2] Jing Zhang,[3] Rüdiger Gerdes,[4] and Josefino C. Comiso[5]

particular, the exceptional northeastward invasion of the poleward center of action into the Barents Sea and the final formation of ARP have been detected for the first time which augments evidences of recently-observed drastic changes in Arctic climate system, perhaps implying a new era of global-warming-forced climate change and shedding light on recent arguments about a tipping point of Arctic climate system change toward a qualitatively different new state.

**THE ARCTIC** shifts to a new normal

Martin O. Jeffries, James E. Overland, and Donald K. Perovich

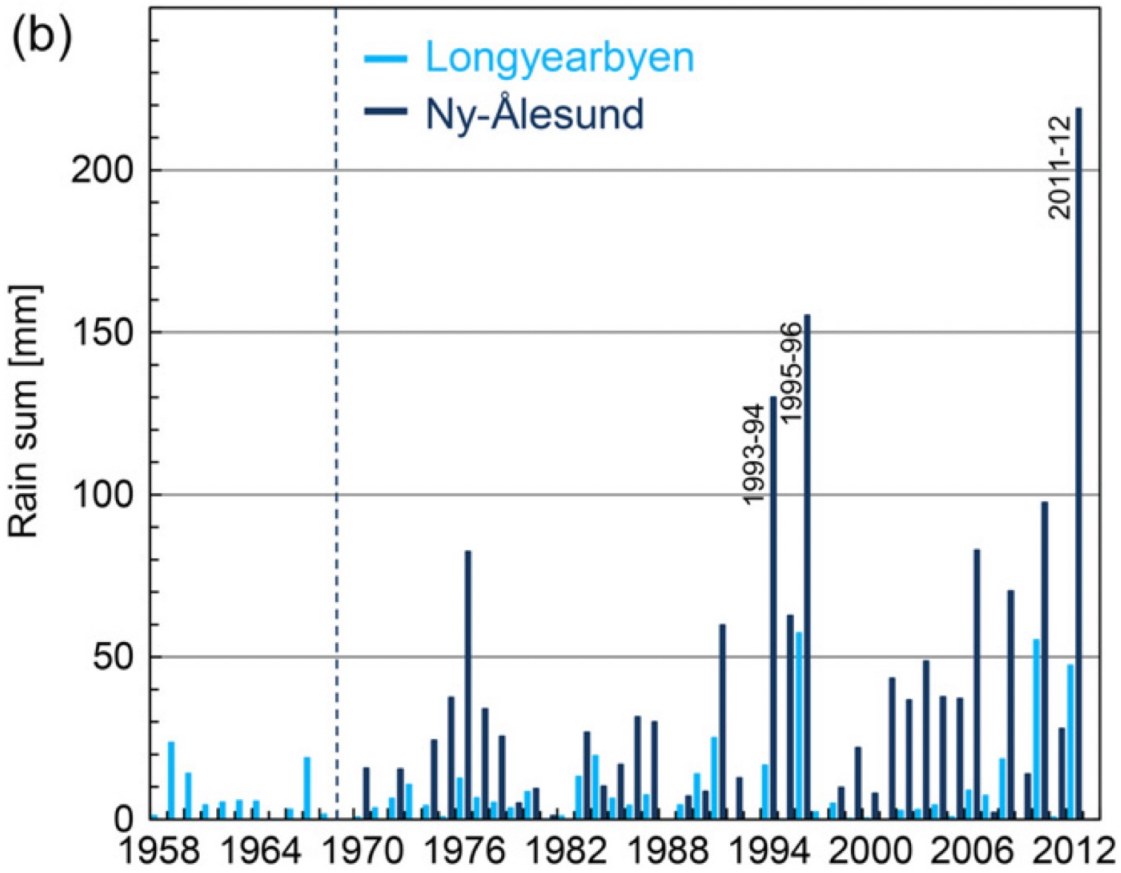
Thinning sea ice, thawing permafrost, and greening tundra are among numerous pervasive trends in today's Arctic.

October 2013 Physics Today

Zhang et al., 2008, 2013

# Motivations

- **Climate Extremes - Tipping Point and Climate State Shift (?)**




Hansen et al., 2021

***A regime shift in the Southeast Greenland marine ecosystem***


Heide-Jørgensen, M.P.[1)], P. Chambault[1,2)], T. Jansen[1,3)], C.V.B. Gjelstrup[3)], A. Rosing-Asvid[4)], A. Macrander[5)], G. Víkingsson[5)], X. Zhang[6)], C. S. Andresen[7)], B.R. MacKenzie[3)],

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2) Department of Ecology and Evolutionary Biology, The University of California, Santa Cruz, CA, United States
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5) Marine and Freshwater Research Institute, Fornubúðum 5, 220 Hafnarfjörður, 101 Reykjavík, Ísland
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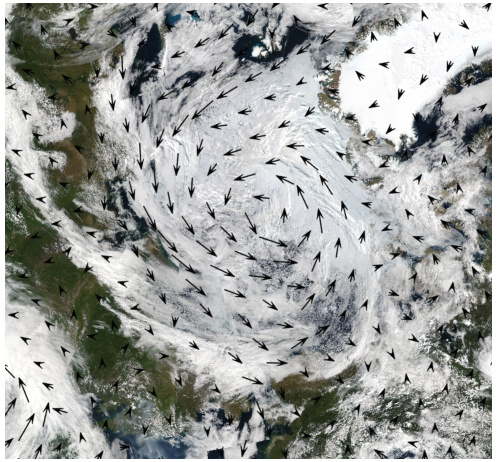
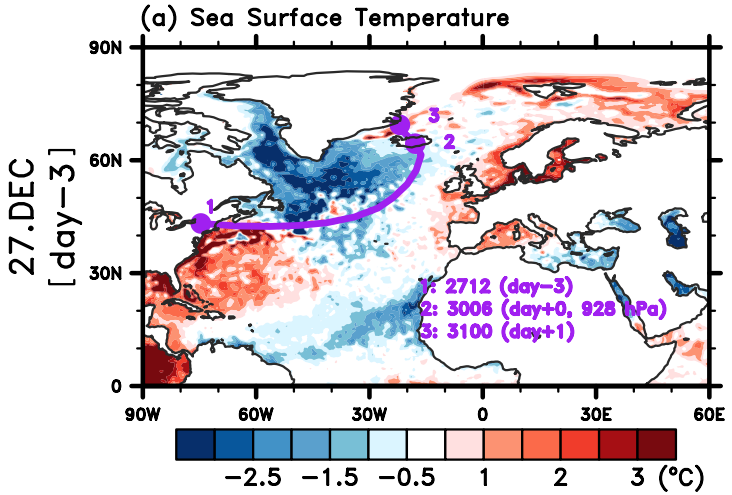
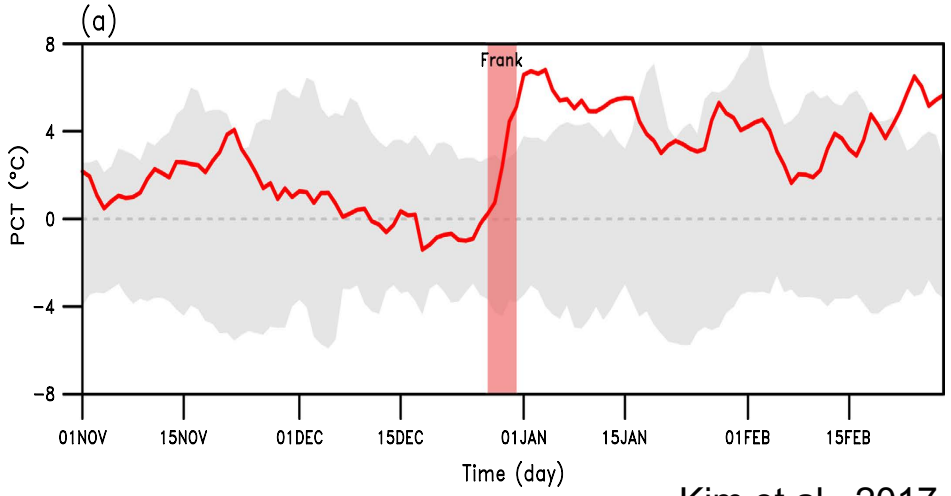
# Motivations

- **Weather Extremes**

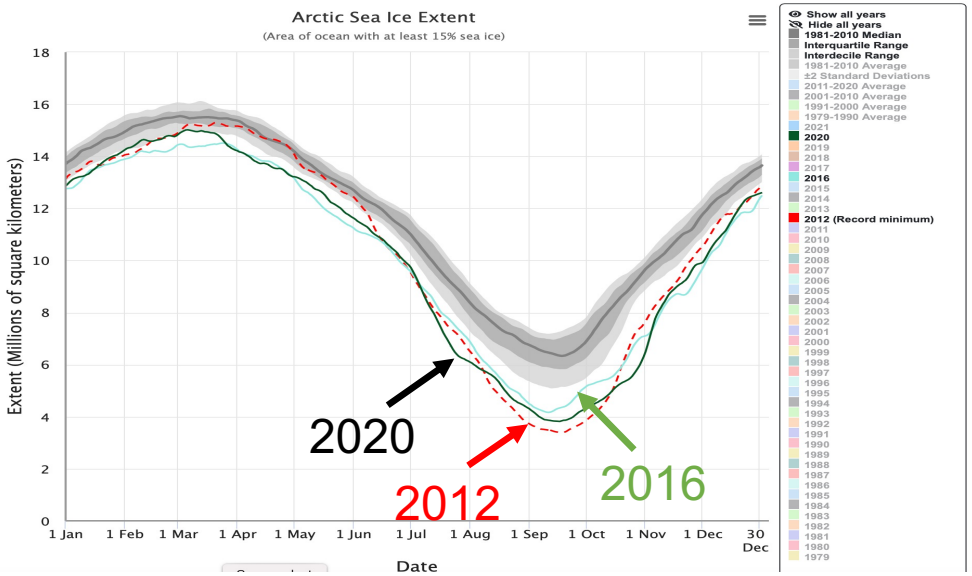


A cyclone in August 2016



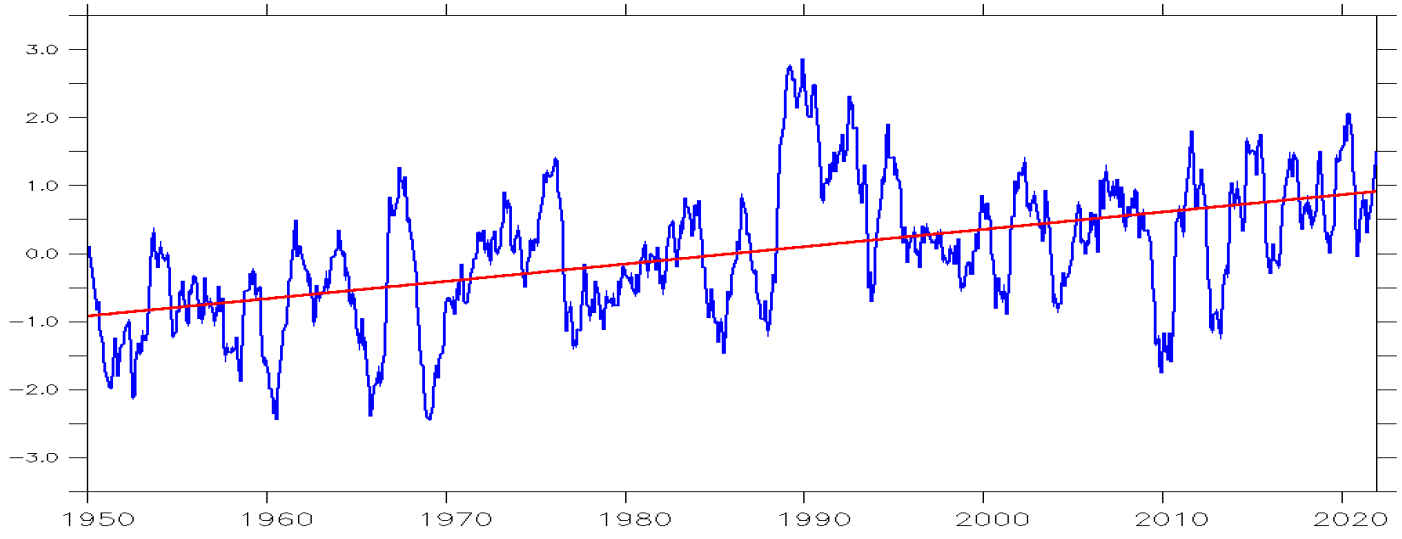




Kim et al., 2017




NSIDC

Arctic Cyclone Activity Index



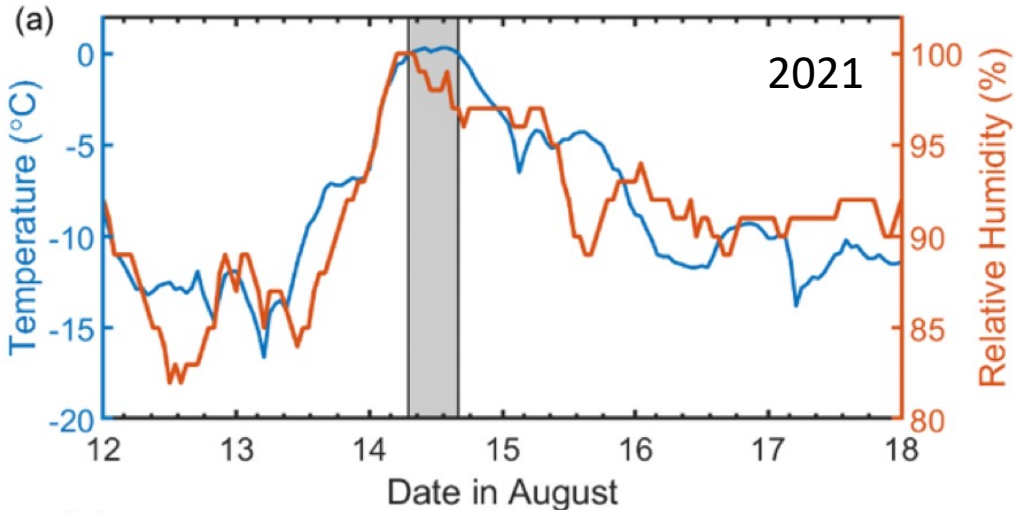

**Uncertainties in Analysis Metrics**

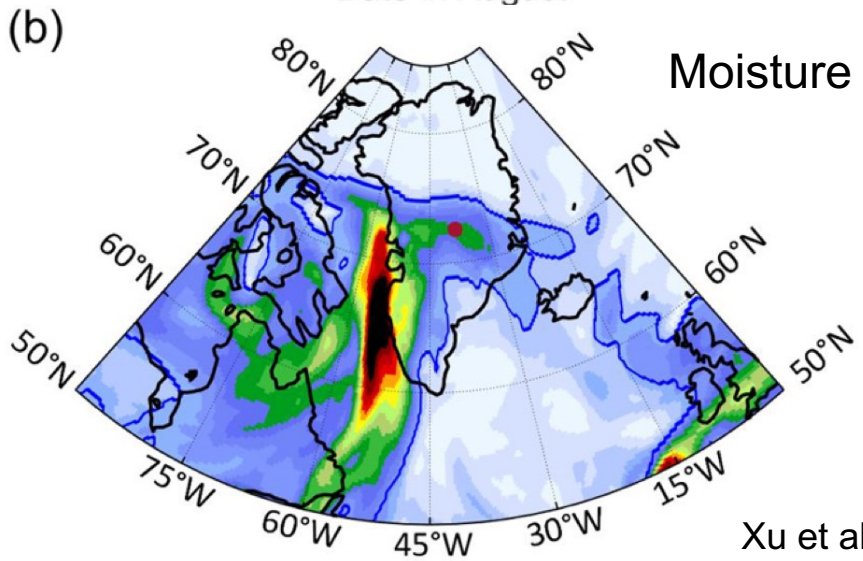
Zhang et al., 2004, 2022

# Motivations

- **Weather Extremes**

For the first time to observe rainfall at Summit

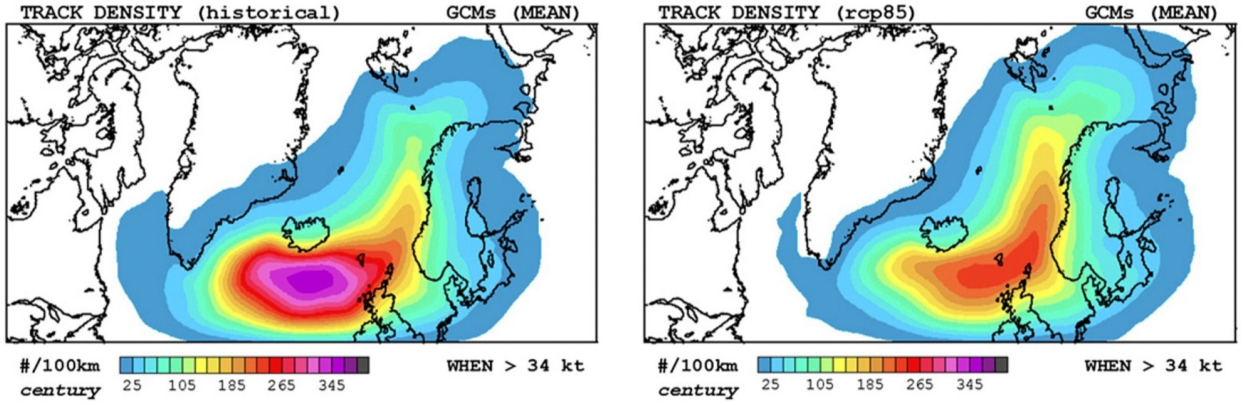


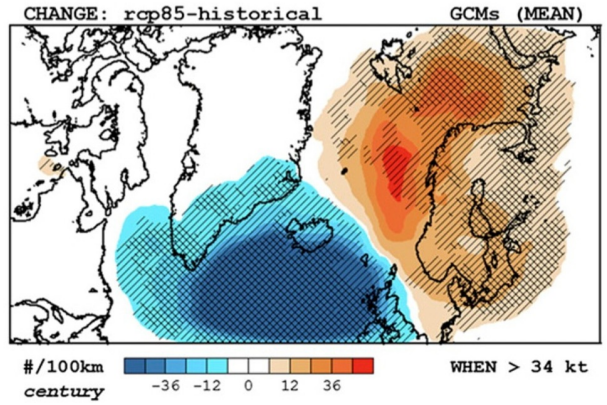




Moisture Transport

Xu et al., 2022

Changes in Polar Low Track Density
(CMIP5; Historical vs. RCP 8.5)




Morenno-Ibanez et al., 2021

# Objectives:

**The objective of the proposed workshop is to bring together interdisciplinary expertise from atmosphere, ocean, and sea ice communities to**

- **gain further insight into the processes of each climate system component and interactions across these components involved in the extreme events;**
- **synthesize results to improve understanding of feedback processes;**
- **identify key questions and knowledge gaps; and**
- **suggest a way forward to make progress on the topic.**

# Deliverable:

- **A workshop summary/recommendation to funding agencies;**
- **A review/synthesis paper (a discussion session on May 21)**
- **…**

# Overarching Scientific Questions to stimulate discussions:

- What are the physically based metrics that can consistently detect extreme events at different temporal and spatial scales?
- What are the large-scale atmosphere, ocean, and sea ice settings and underlying processes/mechanisms for conditioning occurrence of extremes?
- What are the regional or local scale atmospheric and oceanic drivers for occurrence of extremes?
- What are the feedback processes between large-scale and regional scale systems and across atmosphere, sea ice, and ocean to cause extreme events?
- How do the long-term changes (past + future) in the Arctic/global climate system impact the processes mentioned above?
- Where are the sources of predictability of extreme events at different temporal and spatial scales?

## Workshop sessions

1. Perspectives from the changing Arctic climate system

Extremes events are a part of the climate system.
Changes in extremes and mean variable often associated, metrics,
Broad perspectives needed. Here 8 talks.

2. Observed and modelled extreme climate and weather events in the Arctic

A lot of attention on the occurrence and strength of extremes.
Case studies and statistical analyses addressing many variables, regions, and seasons.
7 talks today - tomorrow

3. Large-scale feedbacks, processes and teleconnections

Extreme events forced by local and remote mechanisms -> complex feedbacks on various scales, including tropical teleconnections. 7 talks on Wednesday

4. Synoptic- and meso-scale systems, air-sea-ice interactions and driving mechanisms

Synoptic cyclones and Polar lows -> strong impacts on societies -> a lot of attention. Also strong impacts on the climate system. 8 talks on Thursday

5. Attribution, future projection and impacts

Reasons for changes in extremes? Attribution to AA? Extreme events in the future? Their impact e.g. on navigation?  Answers given in 5 talks on Friday.

Discussion and synthesis: Reviewing state of knowledge and identifying research gaps and future directions

Saturday: Optional writing session