Modeling climate extremes in the new Arctic and the possible impacts on vessel traffic

AGCI Arctic Climate and Weather Extremes – May 20, 2022

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Laura Landrum, Marika Holland, and many others

Image from NASA

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Science Questions

1) What is an extreme in the “new Arctic” climatologically speaking?

2) What are some human impacts of this “extreme” new state?

Photo: Greenland Adventure Tours
The Arctic as we know it is changing rapidly

1) What is an extreme in the “new Arctic” climatologically speaking?

Photo: Greenland Adventure Tours

Photo: Steffen Olsen, Danish Met Institute, June 2019
What does it mean to be “extreme” in a changing climate?

Shifting Baseline Syndrome

2019

1950

1800

Image: Cameron Shepherd

NCAR
UCAR
May 20, 2022
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Arctic temperatures are increasing fastest over the globe.
Arctic temperatures are increasing fastest over the globe.

Both the mean and the spread can change.

Figure: Climate.gov
Data: ARC 2020
Coupled Earth System Model Large Ensembles are crucial for understanding statistics of climate change.

Preindustrial Control Simulation
- 100’s – 1000’s of years
- Constant forcing
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Historical + Future radiative forcing
- 1850-2100
- Changing observed or projected forcing

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Introduce Perturbation
- Same Model
- Same forcing
- 1e-14 K in initial atmospheric temperature
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Large Ensembles provide sufficient samples help constrain what is normal or extreme in a changing climate.

CESM1-LE: 40 members

Global Mean Surface Temperature Anomaly (K)

From Kay et al. 2015
What is “normal” minimum sea ice in the future?

From Landrum and Holland 2020
What is “normal” minimum sea ice in the future?

![Minimum sea ice Extent](image)

From Landrum and Holland 2020
What is “normal” minimum sea ice in the future?

Minimum sea ice Extent

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What is “normal” minimum sea ice in the future?

Minimum sea ice Extent

1850
2000’s

SSMI 1979-1988 mean
SSMI 2008-2017 mean

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Minimum sea ice Extent

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2010’s

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Minimum sea ice Extent

From Landrum and Holland 2020
What do “extreme” ice extent look like with wider distribution?

Minimum sea ice Extent

1850
2010’s

From Landrum and Holland 2020

Sea Ice Concentrations during (2010-2019) min SIE extremes

SSMI 1979-1988 mean
SSMI 2008-2017 mean

From Landrum and Holland 2020
So when do “extremes” become “normal”? 

**Time of Emergence (ToE):**
The year when the ensemble mean exceeds the reference decadal mean (1920’s) by 2 standard deviations

From Landrum and Holland 2020
Time of Emergence for minimum sea ice extent: In the past - climate change has already happened!

Large Ensemble | ToE for Minimum Extent
---|---
CanESM2 | 1996
CESM1-LE | 1995
GFDL-CM3 | 1995
GFDL-ESM2M | 1995
MPI-ESM | 1992

From Landrum and Holland 2020
Time of Emergence for maximum sea ice extent is a bit more uncertain.

<table>
<thead>
<tr>
<th>Large Ensemble</th>
<th>ToE for Minimum Extent</th>
<th>ToE for Maximum Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>CanESM2</td>
<td>1996</td>
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<td>MPI-ESM</td>
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<td>1997</td>
</tr>
</tbody>
</table>

From Landrum and Holland 2020
Time of Emergence for temperatures is spatially heterogeneous.

In the 2010’s!!

From Landrum and Holland 2020
Time of Emergence for temperatures is spatially heterogeneous.

In the 2040’s!!

From Landrum and Holland 2020
How might people experience the “new” normal?

1) What is an extreme in the “new Arctic” climatologically speaking?

2) What are some human impacts of this “extreme” new state?

Photo: Greenland Adventure Tours

Photo: Steffen Olsen, Danish Met Institute, June 2019
Model can provide statistics about outlier events

From DuVivier et al. 2020

17% of floes melt before 365 days

0% of floes melt before 365 days

From DuVivier et al. 2020
Changing ice and wind conditions are likely to impact fall whale hunting success.

Number of **Unsafe** hunting days for **small boats**

Figure from ‘Ana Stringer and Ralf Bennartz, Vanderbilt University

* Ongoing work
Changing Ice and wind conditions

Longer ice-free season

From Barnhardt et al. 2016

Increasing Wind Speed Trend: 2006-2100

Figure from Vavrus and Alkama 2021
Changing atmospheric and sea ice conditions affect shipping risk

September shipping route availability

Figures from Ralf Bennartz

* Ongoing work
Changing atmospheric and sea ice conditions affect shipping risk

September shipping route availability

Modeled frequency of Beaufort Level 9 (strong gale) along shipping route

Figures from Ralf Bennartz

* Ongoing work
Conclusions

1) What is an extreme in the “new Arctic” climatologically speaking?
- Coupled large ensembles are essential for determining changing extremes.
- Time of emergence to a new, “extreme” climate has already happened in many instances.
- Changing variance and regional time of emergence impacts our ability to plan.

2) What are some human impacts of this “extreme” new climate state?
- Open ocean routes increase
- Unclear if ocean transport is more accessible depending on boat size, wave height, and other risk factors.
What we experience and perceive as extreme is shifting dramatically.

Comic: XKCD
Thank you!

Questions?
Please email me!!
duvivier@ucar.edu

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Definition of extremes change in time
Human experience vs. statistics. 2deg doesn’t matter to a human…How we as humans notice extremes.
Ice extremes vs become normal (PDFS) extremes
Changing climate is more than just changing mean. Also changes variability and distribution. Or combo of both!
When is it going to be ice free? Can’t answer this (Alex’s work).
Question: when do extremes now become “normal”?  
Climate change is in the past, not the future!
Approach could be more relevant for policy makers. New port? What might we encounter and how fast will this be obsolete?
Changing baselines or frog in a pot
Include:
   — Navigation: Brown work, Vandy work, Steve Vavrus
   — MOSAIC: melting out possibility
   — Wildlife: polar bear habitat/penguins
Clara seminar: think about change in mean state but also variability. Widening of extremes and extremes are more extreme (Re-watch seminar)
Ice free season length (Barnhardt)
Coupled Earth System Models provide means for statistical analysis.
Coupled Earth System Model Large Ensembles are crucial for understanding statistics of climate change.

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Sea ice extent variance increases during the transition to "seasonal" Arctic.

From Holland et al. 2019
"Time of Emergence" (ToE)

The year when the decadal mean of an ensemble exceeds the reference decade by 2 standard deviations (based on reference decade variability)

Reference decade 1950-1959

(year refers to the first year of the decadal mean – e.g. “1980” refers to 1980-1989 decadal mean)

Landrum & Holland, Nature Climate Change, 2020
The choices we make determine whether and when the Arctic ocean might be sea ice free.

Satellite observations
Historical
High emissions
Low emissions

Jahn et al., 2016

Jahn 2018
How do distributions change in future decades?

**Minimum sea ice Extent**

1850
2060’s

SSMI 1979-1988 mean
SSMI 2008-2017 mean

From Landrum and Holland 2020
How do distributions change in future decades?

Minimum sea ice Extent

From Landrum and Holland 2020
Time of Emergence for October surface temperatures: Cape Morris Jesup

From Landrum and Holland 2020

No ToE!
Tails of wind distribution are also likely to increase.

Figure from ‘Ana Stringer and Ralf Bennartz, Vanderbilt University
More open ocean and stronger winds will impact waves.

Seawall planned for Utqiagvik will help protect the Arctic Alaska city

Helicopters rescue Norway cruise ship passengers amid storm

Photo from: National Snow and Ice Data Center

Photo from: ABC News
Combination of decreasing ice and increasing wind lead to large waves at Drew Point.

Figure from Ian Franda and Steve Vavrus, University of Wisconsin

* Ongoing work
Map of today’s talk
The landscape of “normal” is shifting.
What does it mean to be “extreme” in a changing climate?

Comic: XKCD