Going to Extremes in the "New Arctic"

CESM Tutorial
2019

Laura Landrum, Marika Holland

National Center for Atmospheric Research (NCAR), Boulder, CO

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Going to Extremes in the New Arctic

When does the Arctic become the "New Arctic" (or is it already)?

How is this Arctic climate "New"?

Changes in the extremes

extreme changes

3 examples:

Sea ice, surface temperatures, rain vs snow

This presentation: focused on description and definitions (processes will be part of the next step)

Going to Extremes in the New Arctic

Artic
Already a region of “extremes”
Observations – comparatively sparse
“Satellite era” 1979-present
Reanalysis products
Models

We do not have an observational “baseline” for Arctic climate

Model used for results presented here:

CESM1

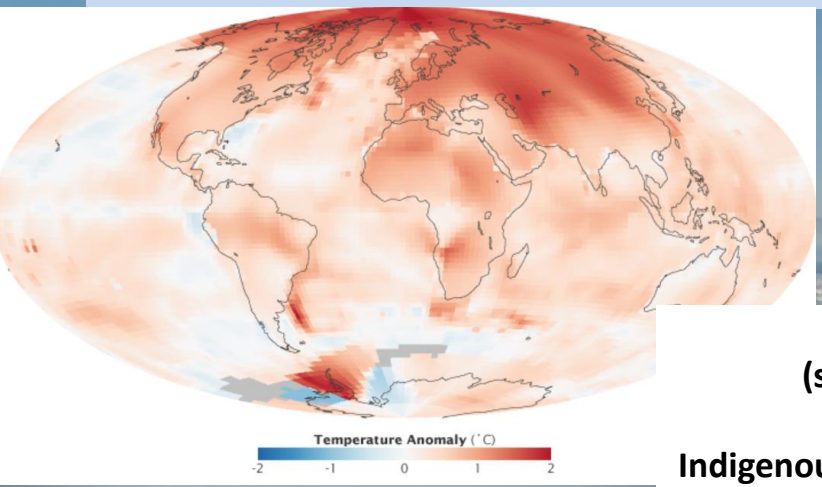
“**PI**” 1850 control run (1800 yrs)

“**LE**” Large Ensemble (40 simulations)

20th and 21st (RCP8.5)

Comparisons to observations when available

Going to Extremes in the New Arctic: Sea Ice



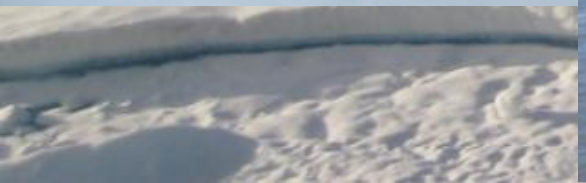
Marine access (shipping, resource access)

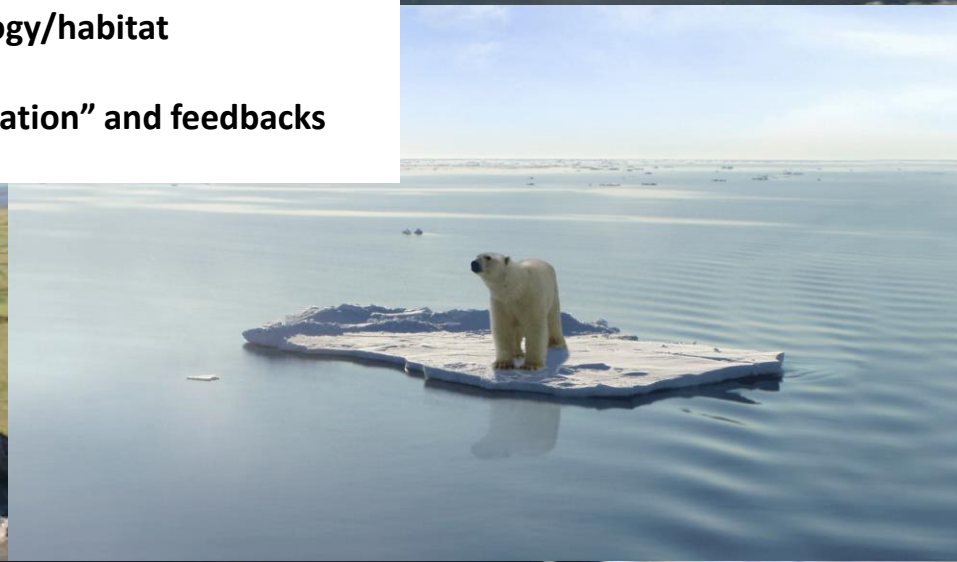
Indigenous communities – subsistence and culture

Coastal erosion

Ecology/habitat

”Arctic amplification” and feedbacks



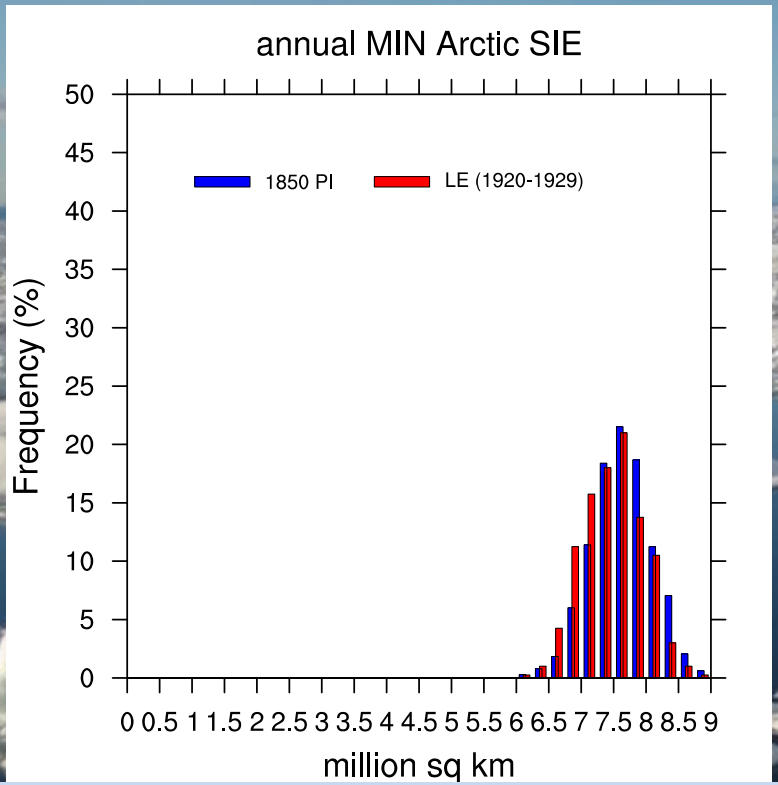


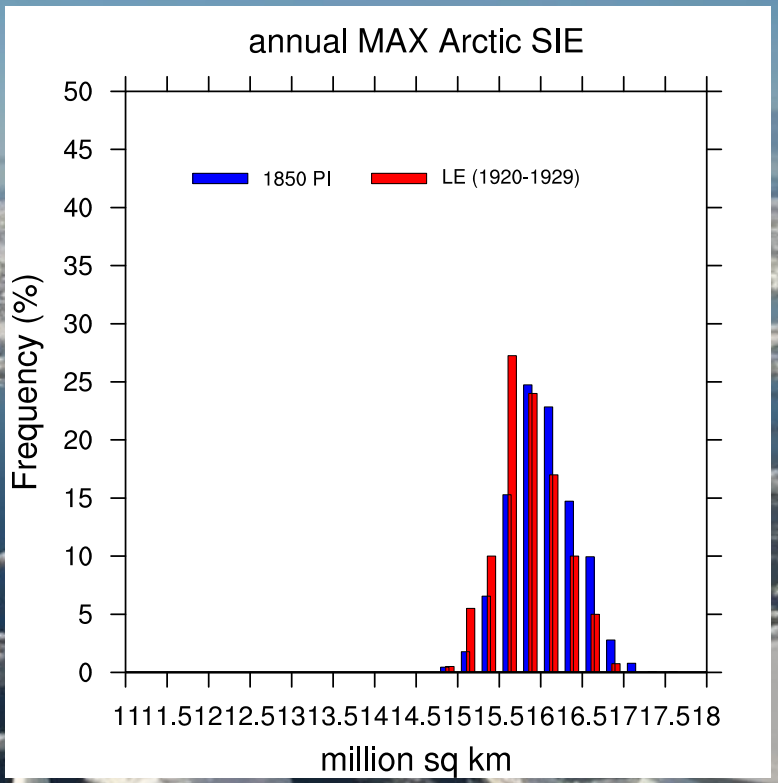
Going to extremes in the New Arctic: Sea Ice Extent

When do extreme Arctic sea ice extents become "extreme"?

Annual minimum and annual maximum Sea Ice Extent (SIE)

Arctic SIE: LE 1920-1929

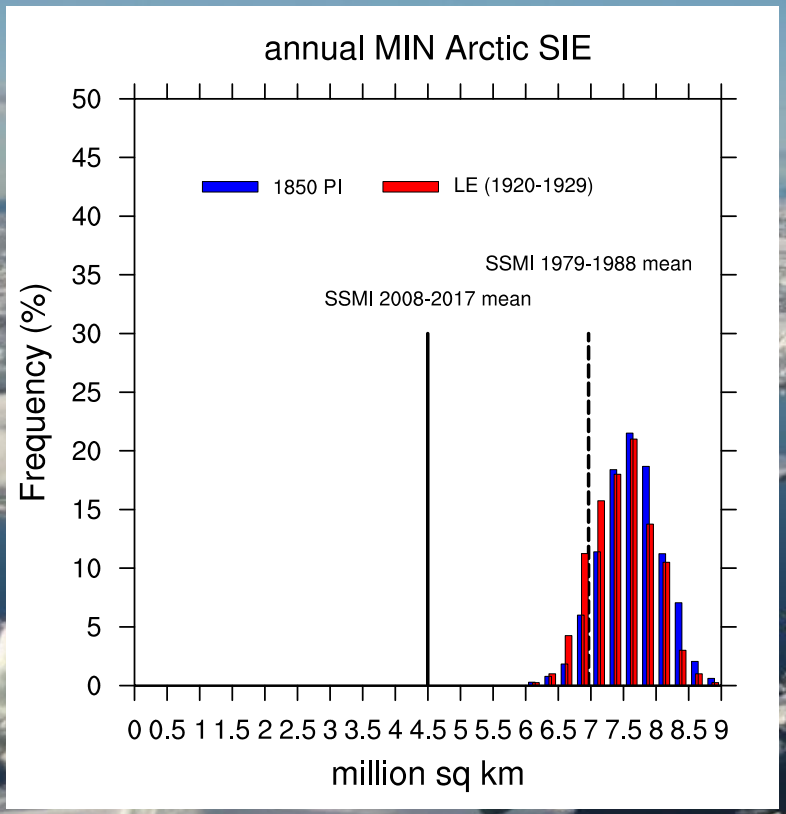


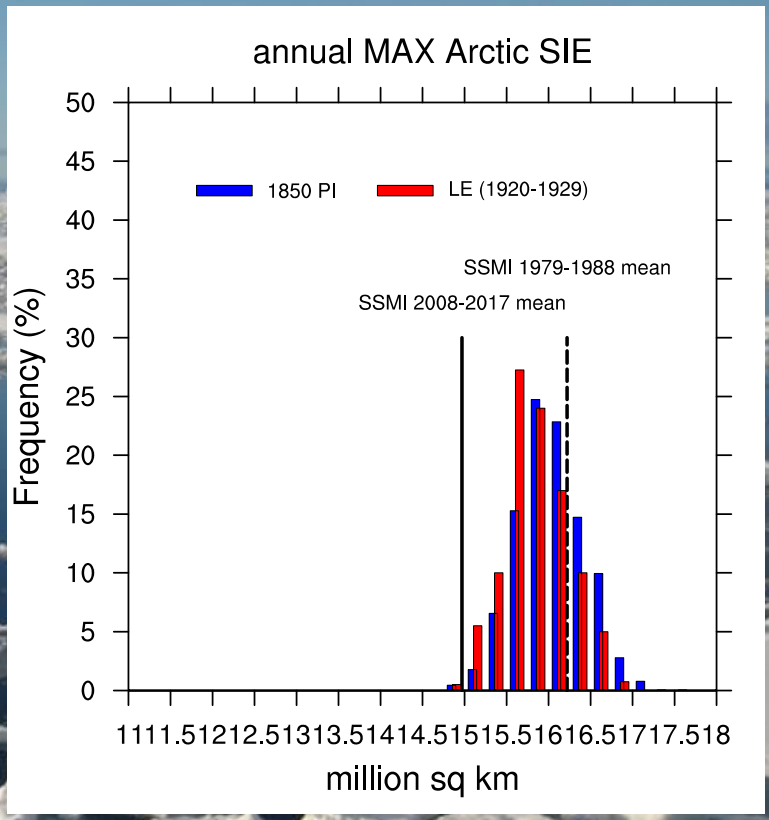


Histograms of annual daily extreme (annual MIN and MAX) Arctic Sea Ice Extent (SIE)
1850 control run
Large Ensemble (LE) 20th-21st Century (RCP8.5)
by decade

LE (1920-1929) and 1850 control run are nearly the same for both Arctic MIN and MAX SIE

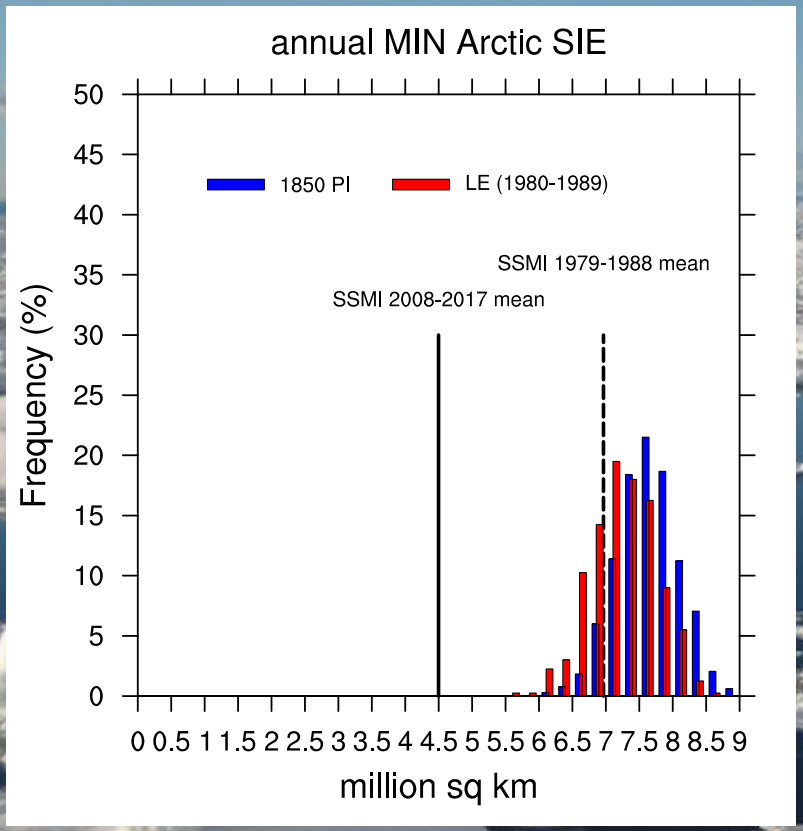
Arctic SIE: LE **1920-1929**

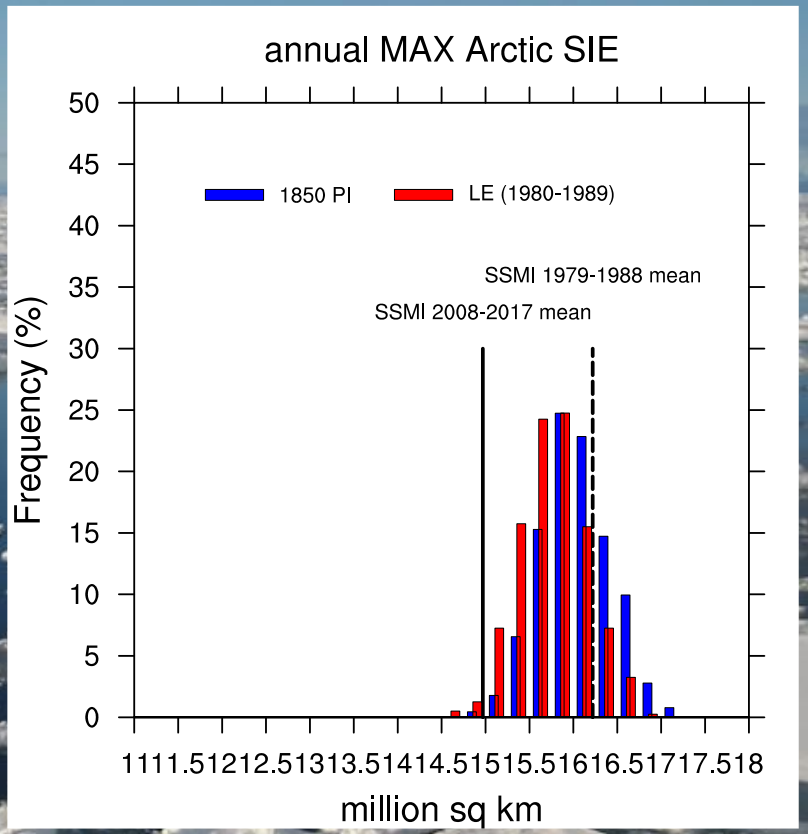




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

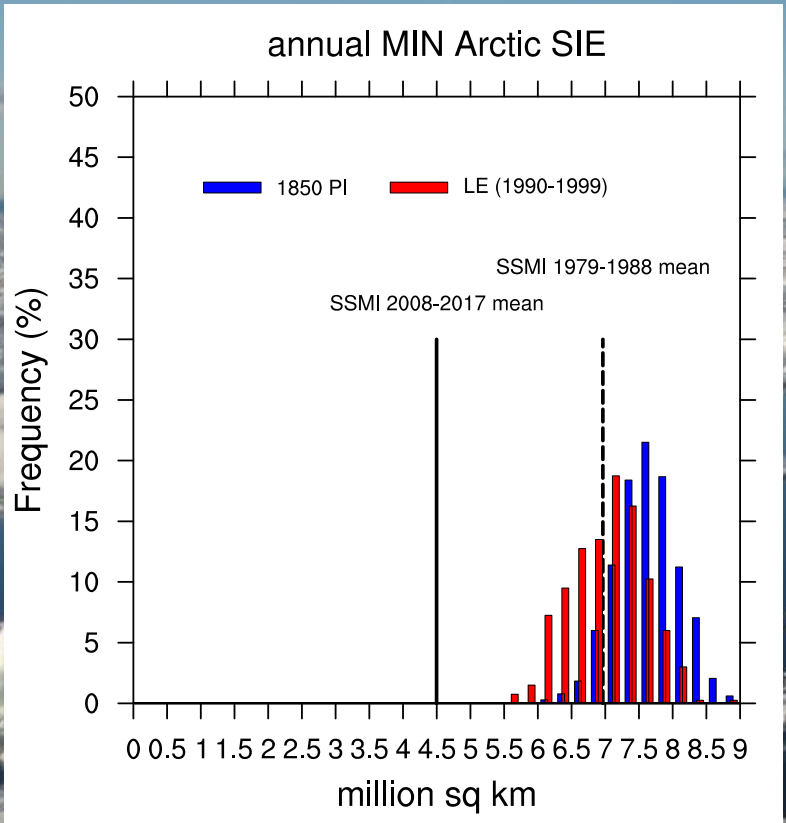
Arctic SIE: LE **1980-1989**

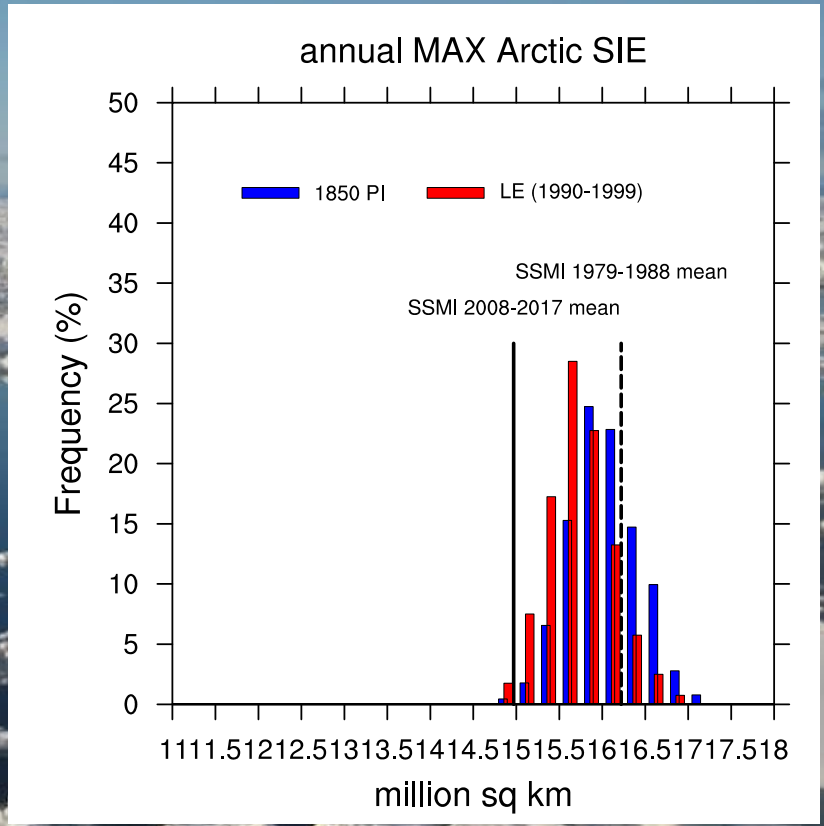




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

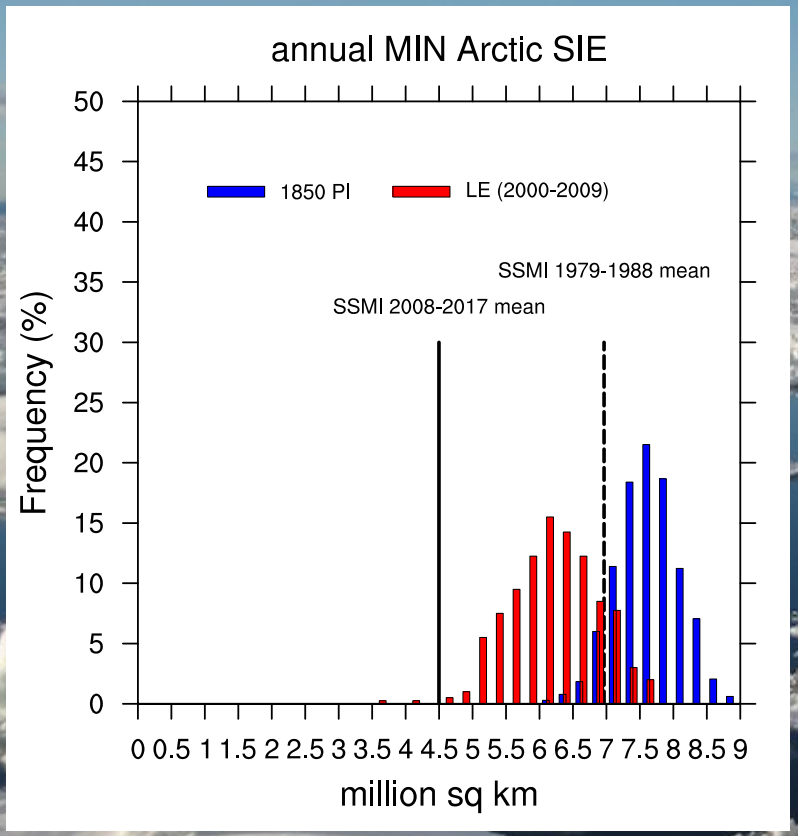
Arctic SIE: LE **1990-1999**

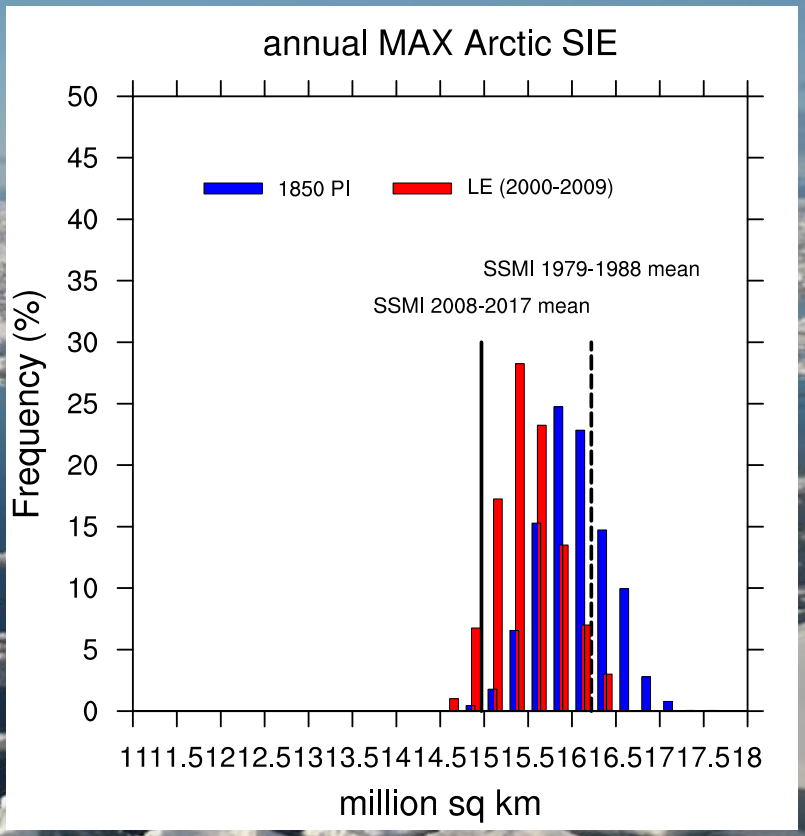




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

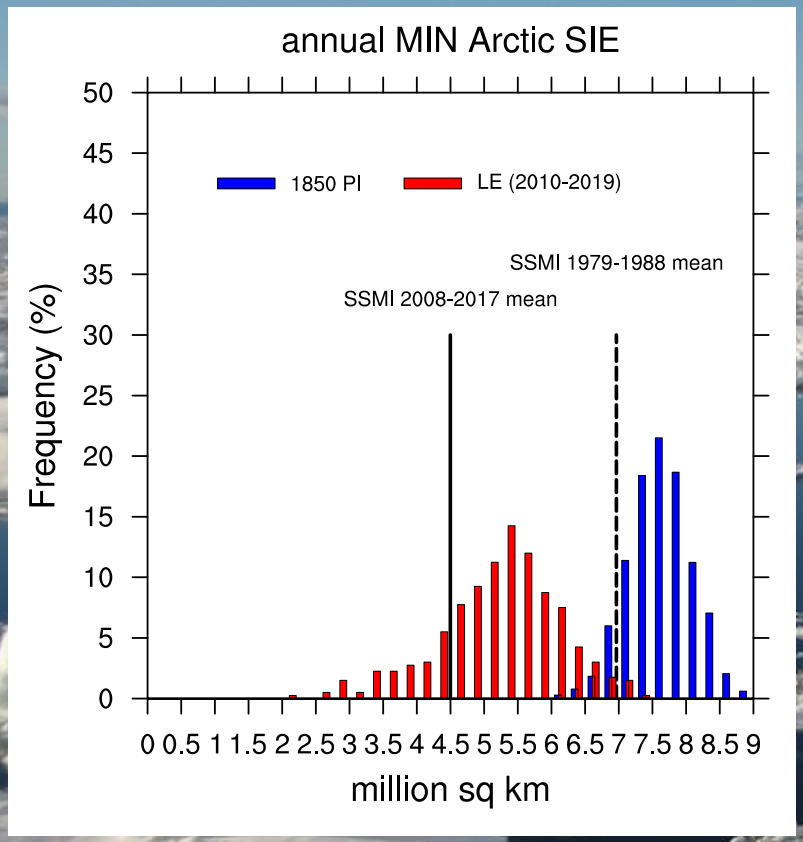
Arctic SIE: LE **2000-2009**

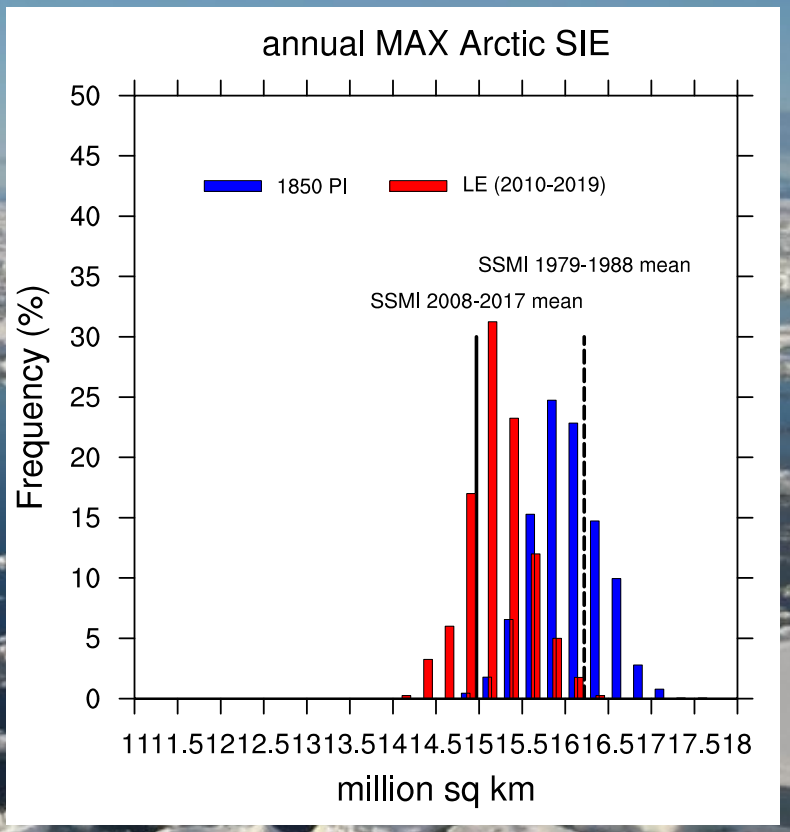




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

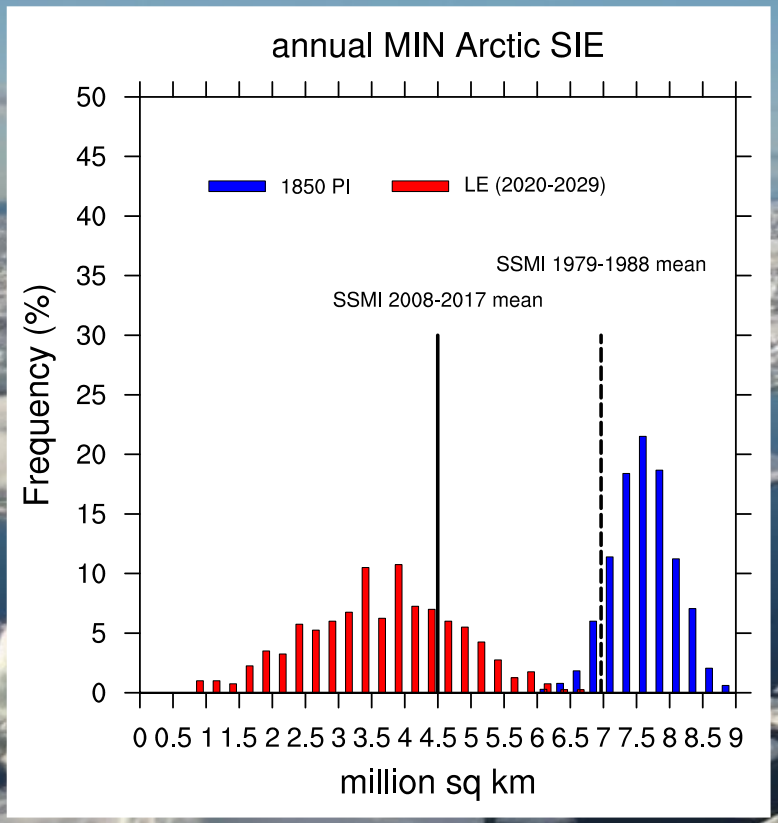
Arctic SIE: LE **2010-2019**

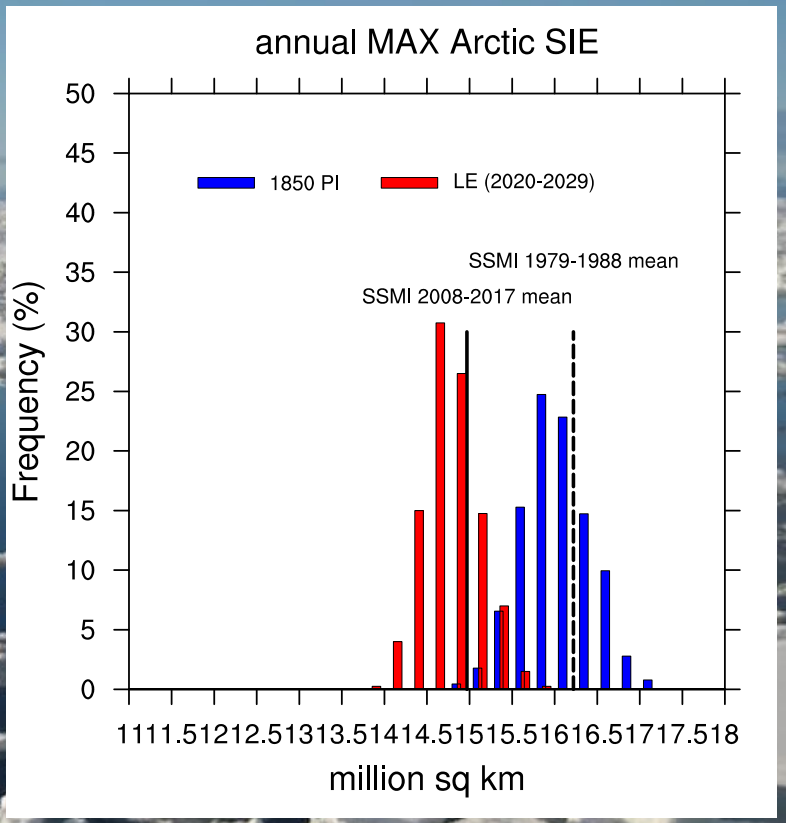




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

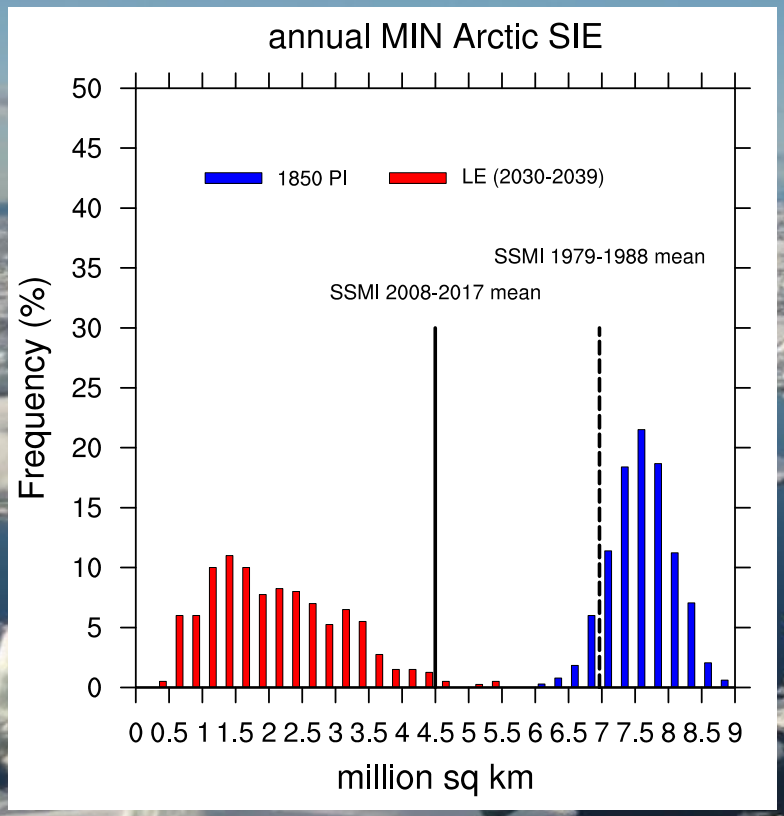
Arctic SIE: LE **2020-2029**

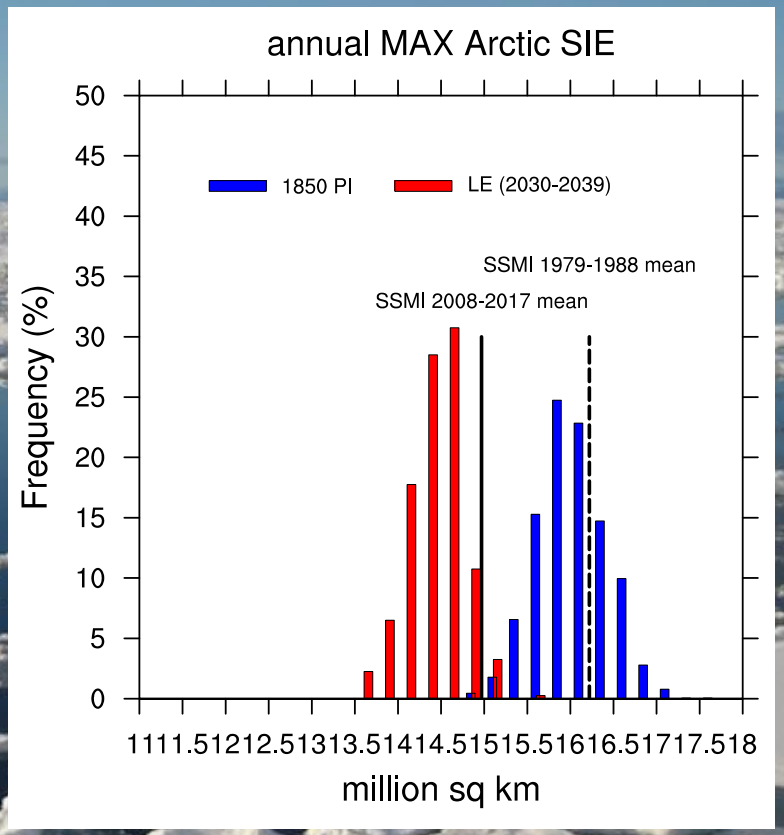




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

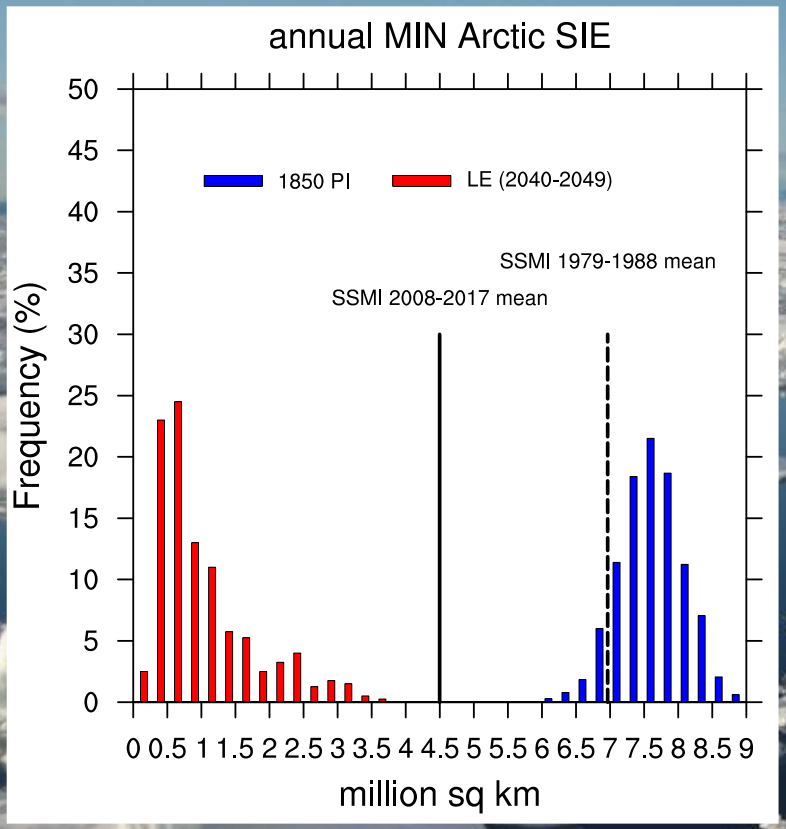
Arctic SIE: LE **2030-2039**

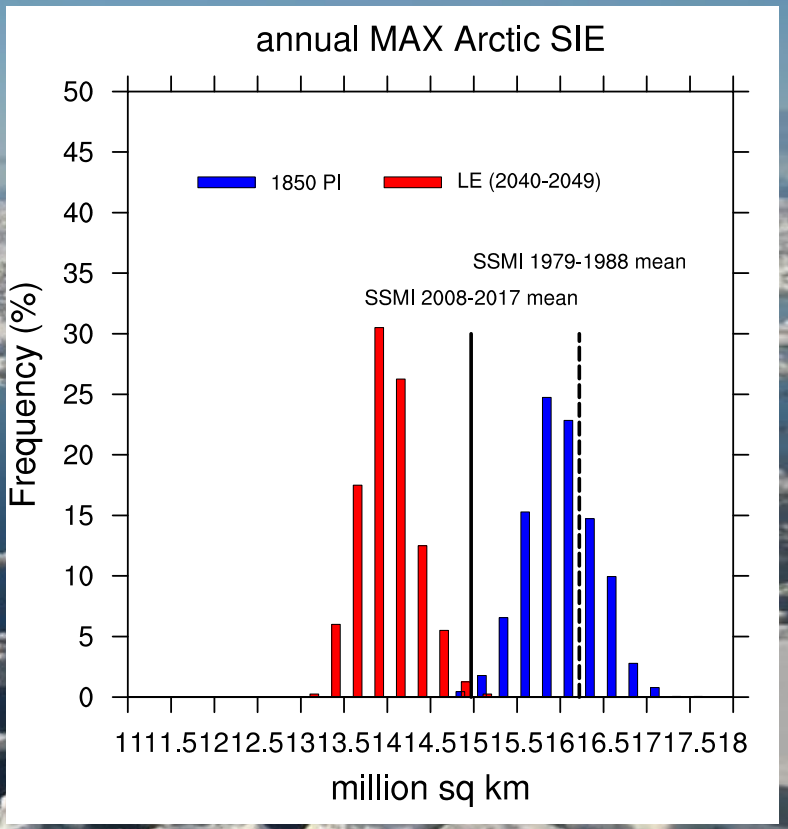




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

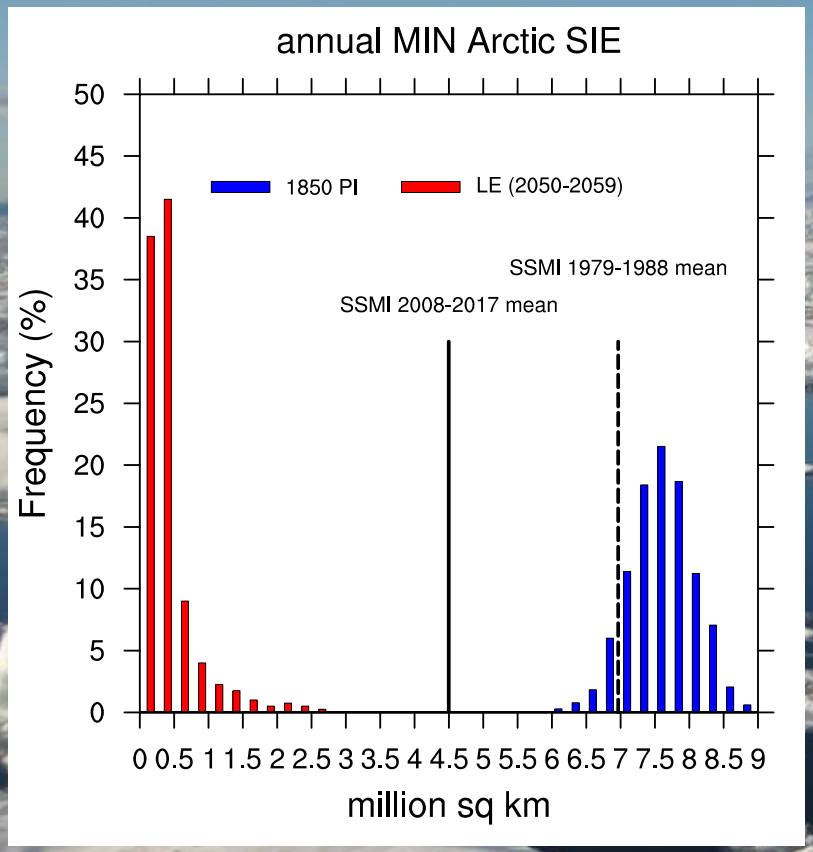
Arctic SIE: LE **2040-2049**

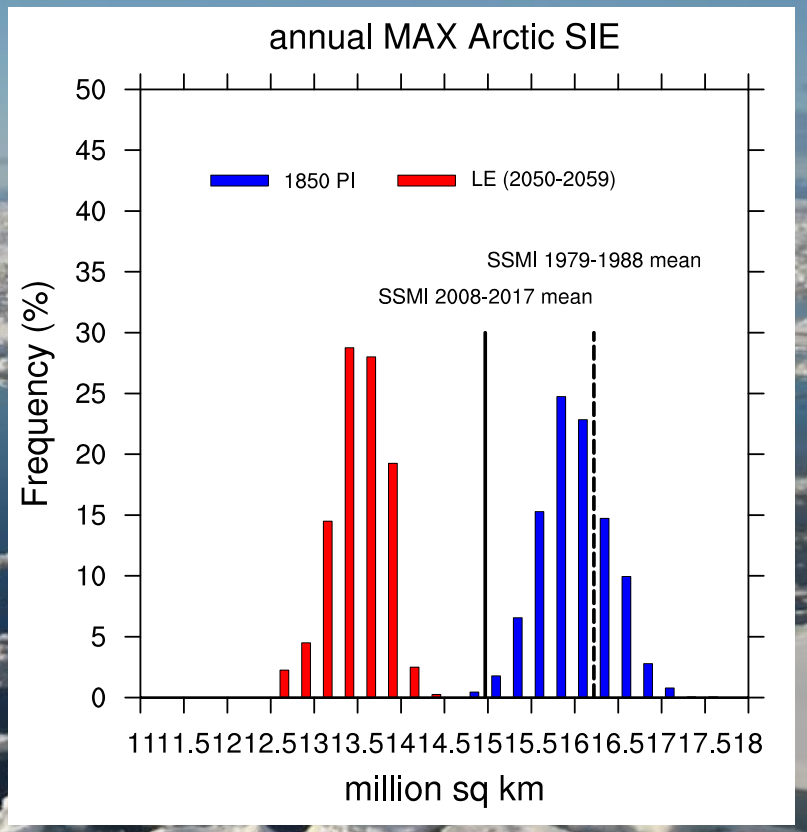




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

Arctic SIE: LE **2050-2059**





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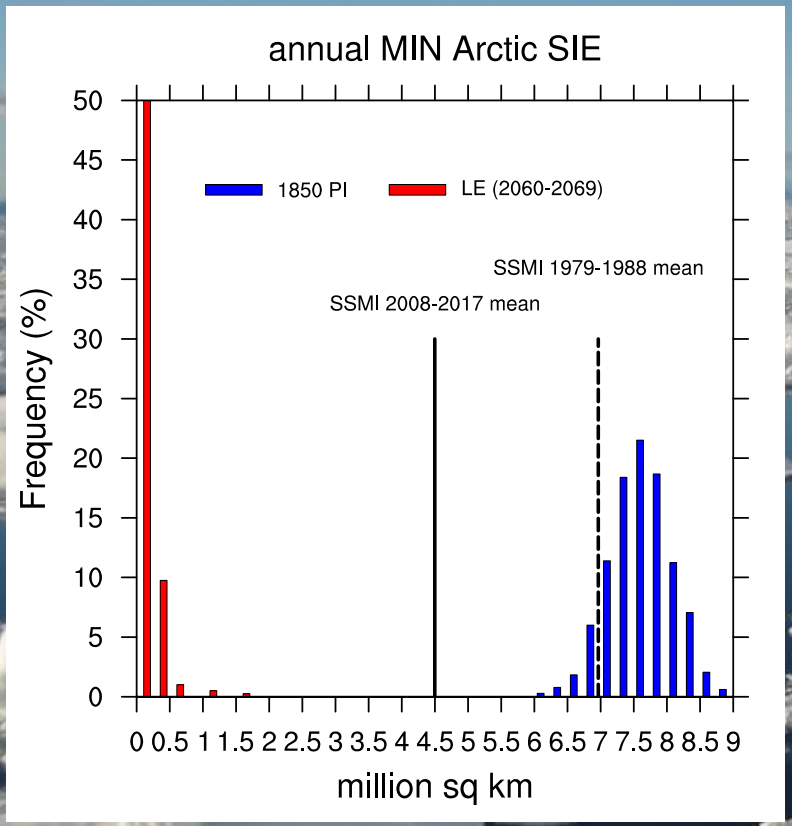
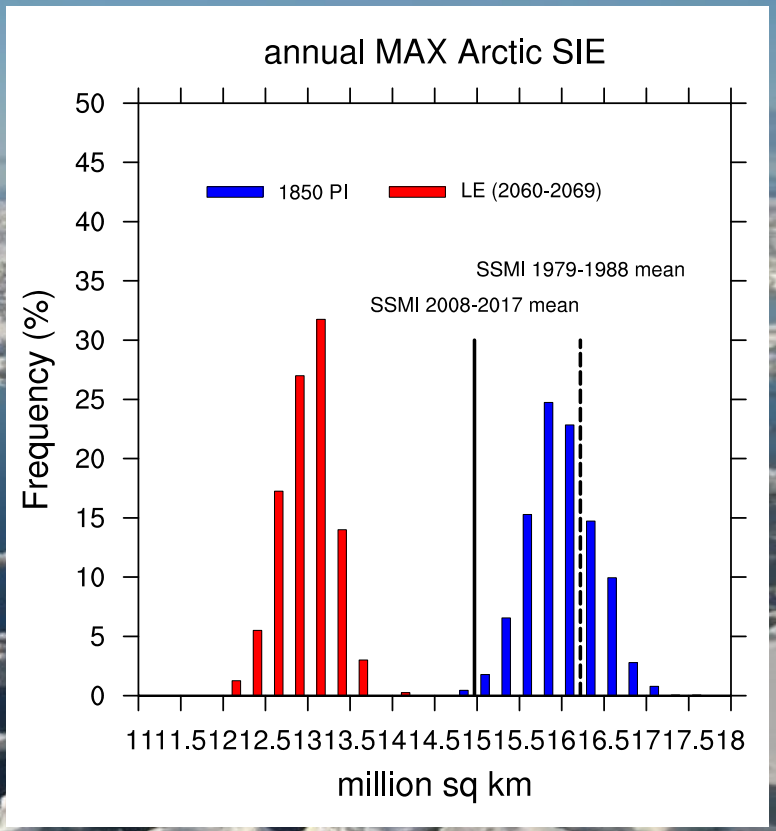
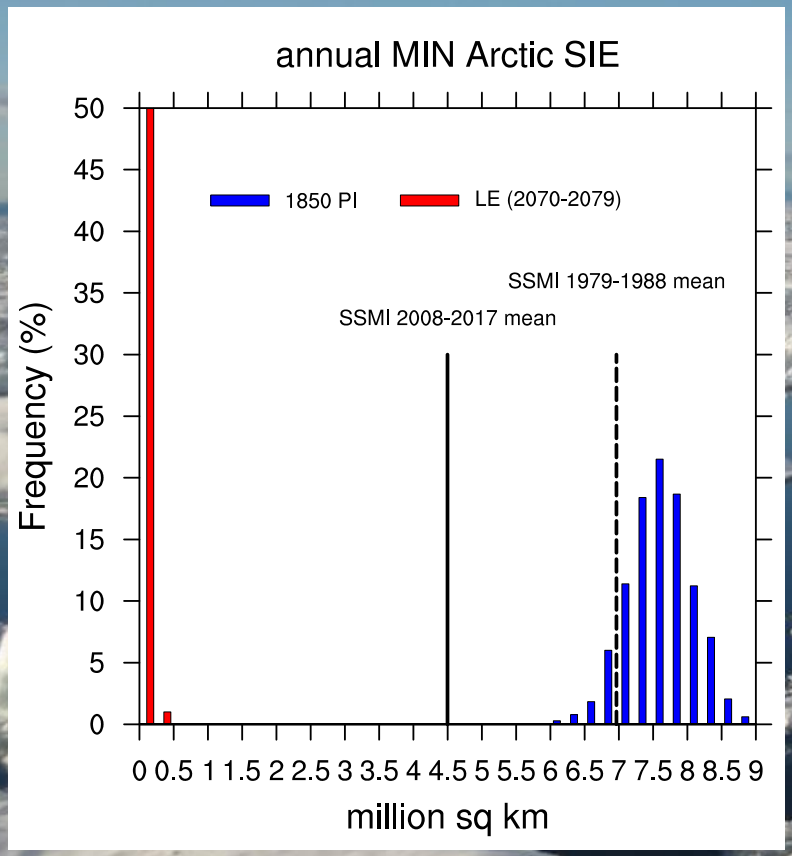
Arctic SIE: LE **2060-2069**

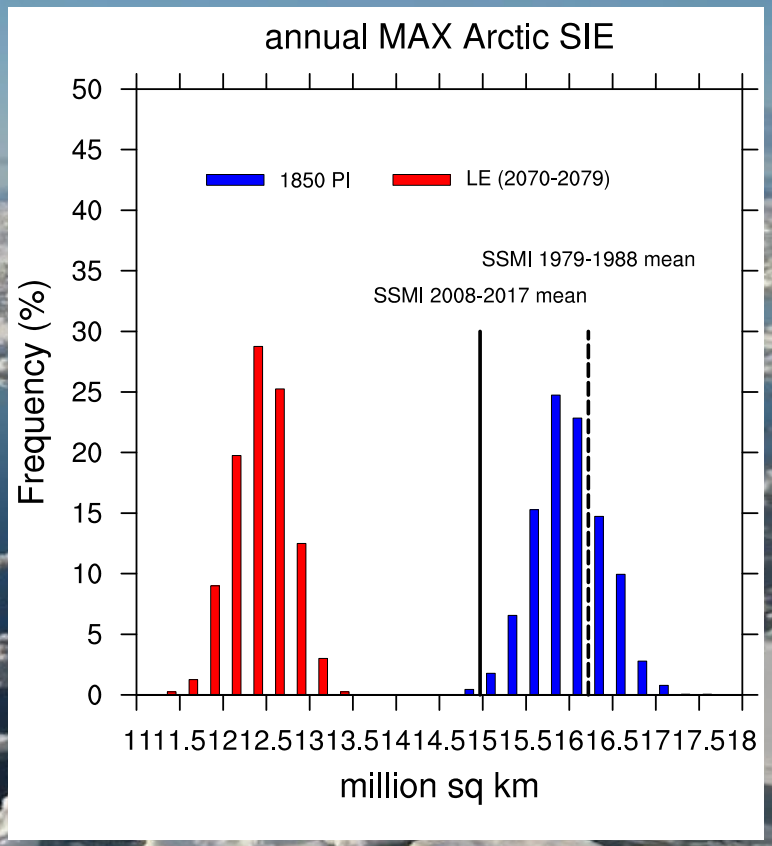




Satellite observations (SSMI) shown for first (dashed; 1979-1989) and last decadal (solid; 2008-2017) means for comparison

Arctic SIE: LE **2070-2079**





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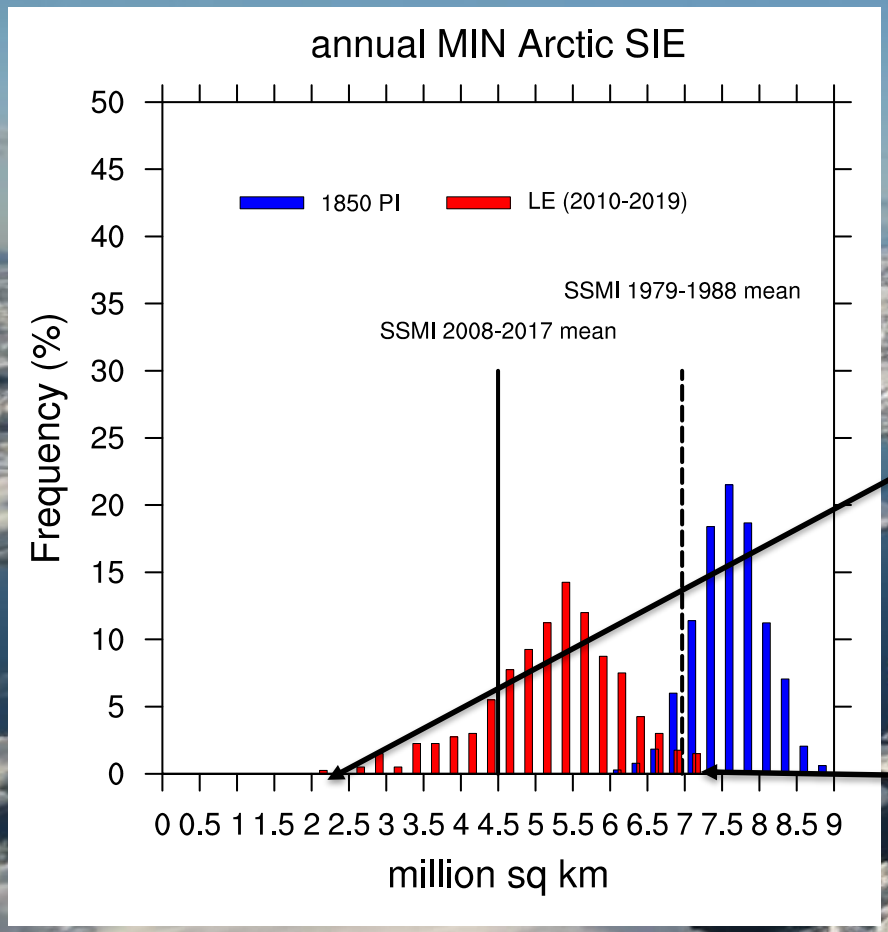
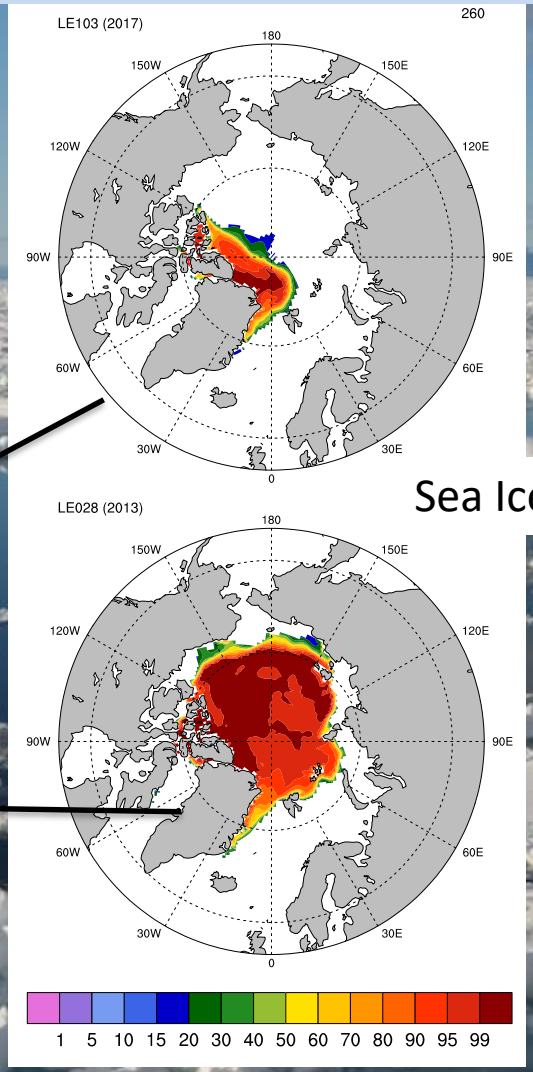
Arctic SIE: LE **2010-2019**





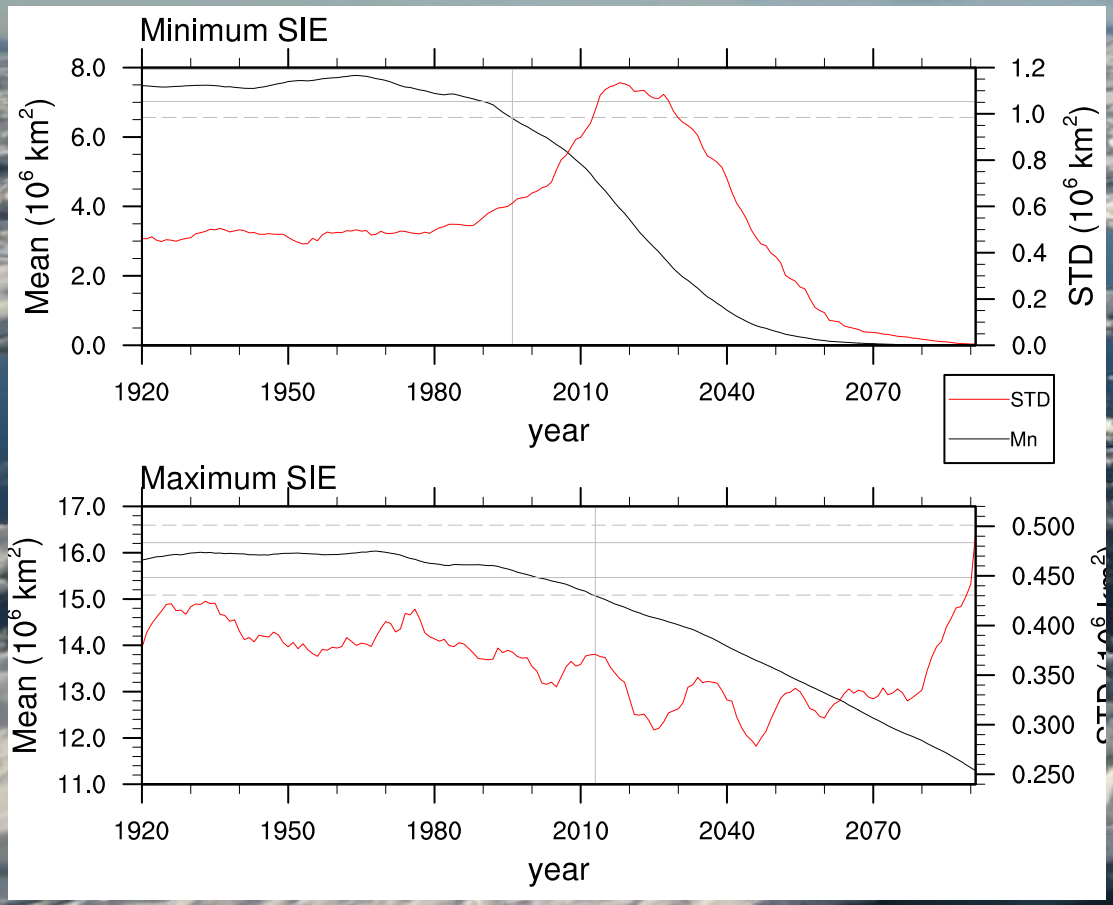
Sea Ice Concentration

Extreme changes in an extreme and further range of extremes!

Arctic SIE: Extreme change in Extreme events

Year of emergence

year at which 10-yr mean lies outside early 20th Century 10-yr mean by more than ±2 STD



Year of emergence

1996 (minimum SIE)

2013 (maximum SIE)

Going to Extremes in the New Arctic: Surface Air Temperatures

Influences:

atmospheric circulation

Ecology

phenology, seasonal mis-match (pollinators, grazers, breeding seasons…)

Permafrost

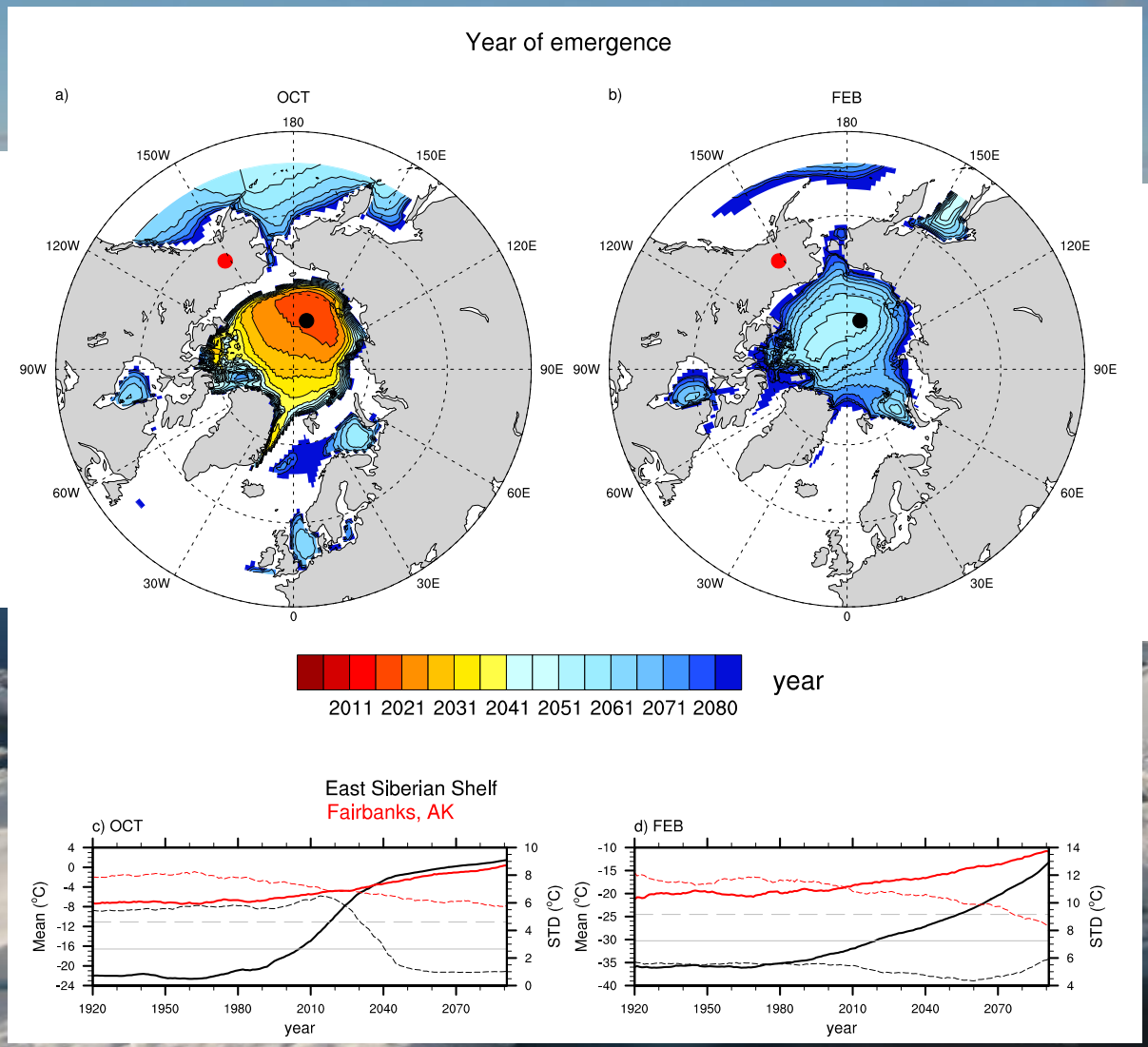
Going to extremes in the New Arctic: surface air temperature

When do Arctic temperatures become “extreme”?

Going to Extremes in the New Arctic: Surface Air Temperatures

October emergence:

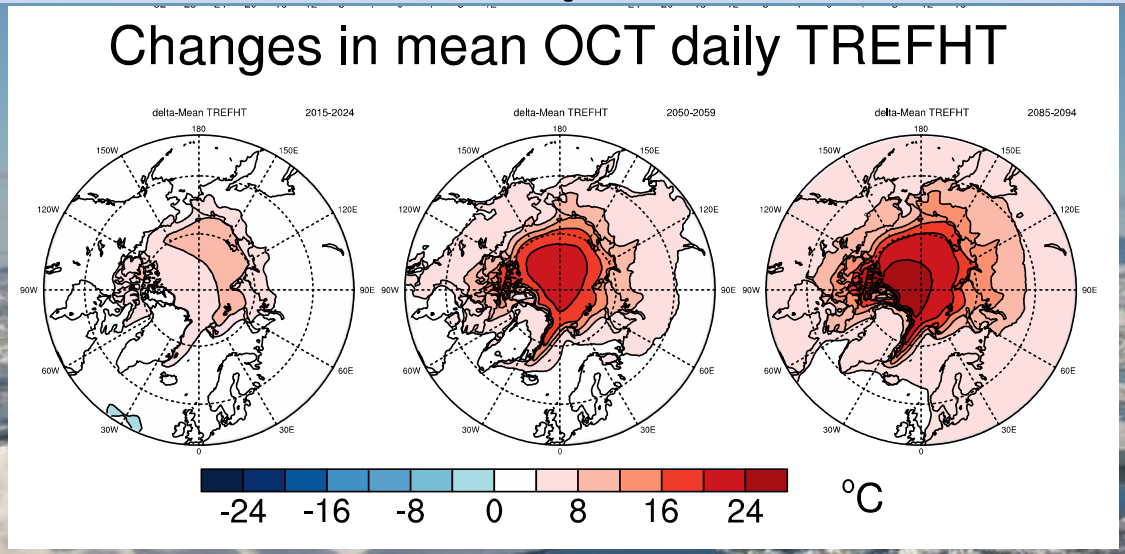
- influenced by declining summer sea ice concentration
- Timing varies by region
- Land regions not emergent (by this definition) primarily due to high STD



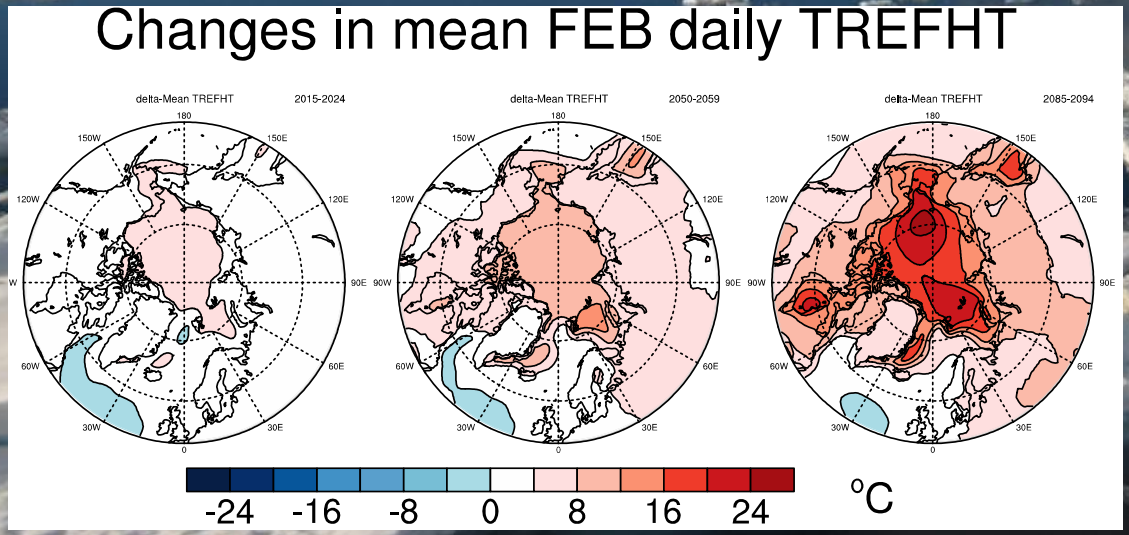
February emergence:

- influenced by winter sea ice thinning
- Central Arctic ocean emerges earliest
- Winter temps emerge later than fall temps

Going to Extremes in the New Arctic: Surface Air Temperature changes



(2015-2024) (2050-2059) (2085-2094)



Greatest warming over ocean

Fall temperatures increase first

By end of 21st C Arctic ocean warming similar in fall, winter

Going to Extremes in the New Arctic: Precipitation

The Washington Post
Democracy Dies in Darkness

Morning Mix

Starvation killed 80,000 reindeer after unusual Arctic rains cut off the animals' food supply

By Ben Guarino November 16, 2016 Email the author

Reindeer in the Russian peninsula of Yamal. (The Siberian Times)

rain vs snow seasons

river runoff

Snow cover
(insolation, water storage)
Ecology/habitat

Permafrost

infrastructure

Hansen et al., 2014: Warmer and wetter winters: characteristics and implications of an extreme weather event in the High Arctic, Environ. Res. Let.,**9**,11.

Going to extremes in the New Arctic: precipitation phase change

When does the Arctic rain season become “extreme”?

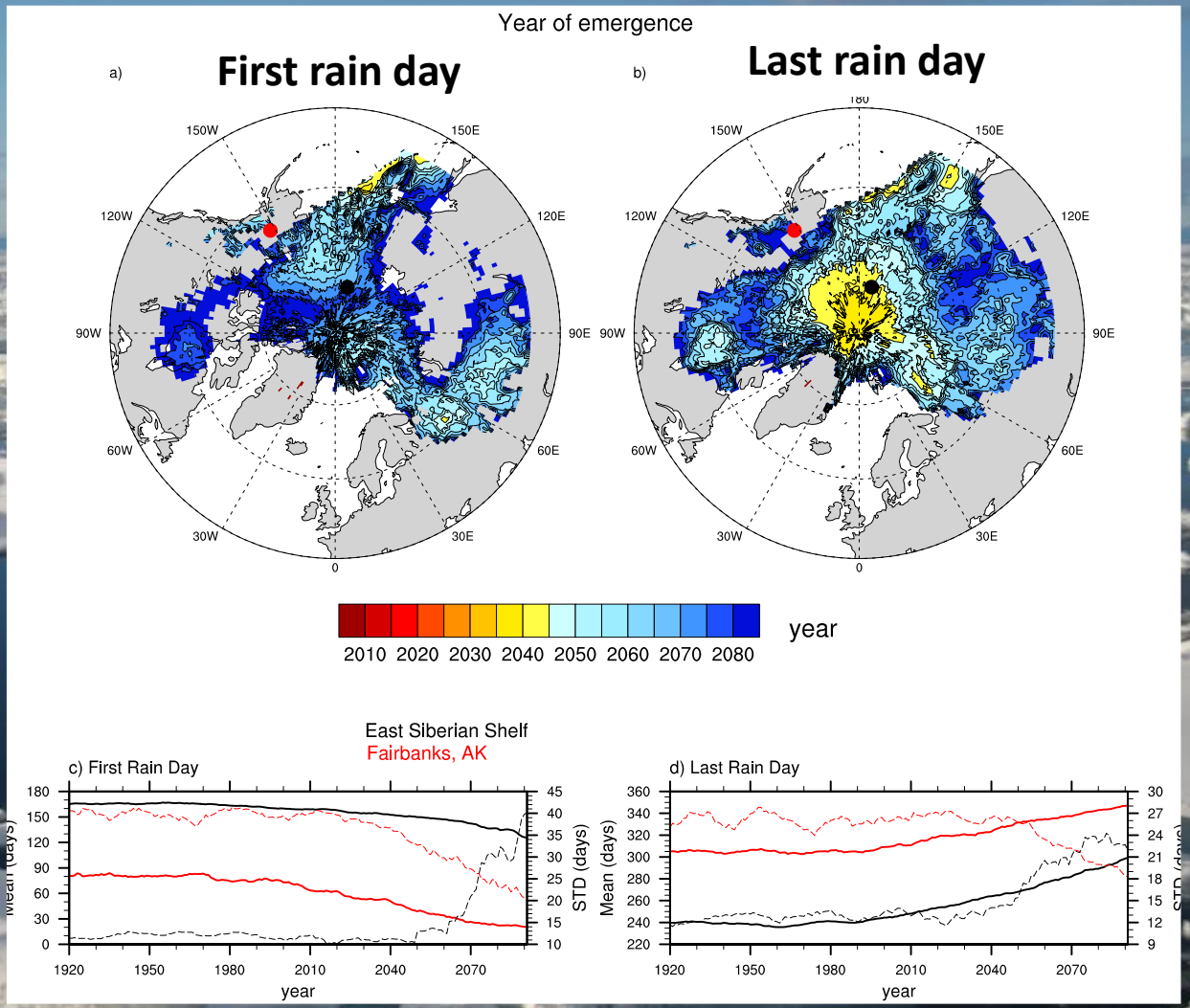
Going to Extremes in the New Arctic: ”rainy season” emergence

rainy day:

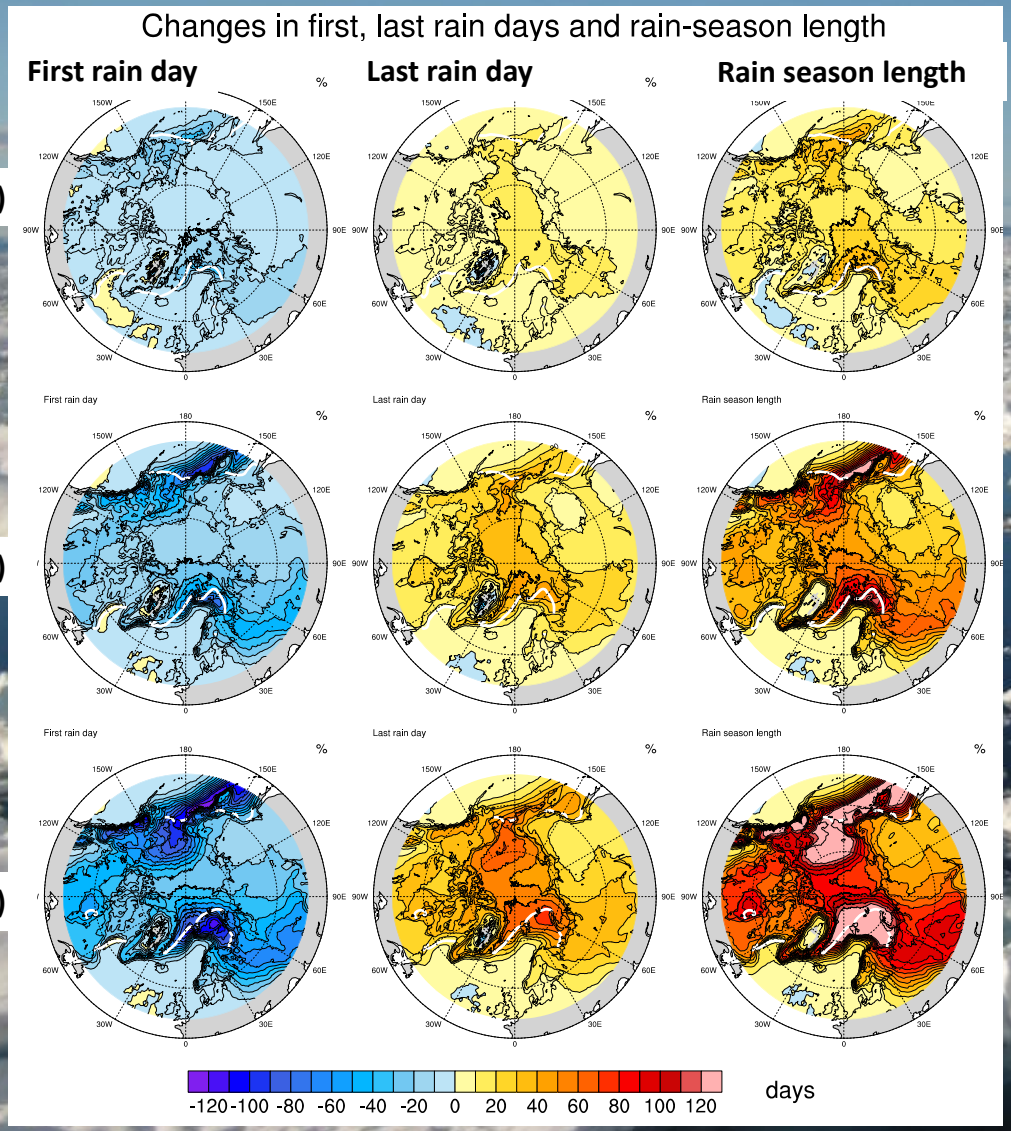
1) precip >= 0.2 mm/day

2) >= 60% liquid (rain) rather than solid (snow)

- Land (e.g. Fairbanks) high STD, compared to open ocean (related to TEMP)
- Last day of rain emerges earlier than first day of rain (OCT daily temps emerge earlier than FEB)



Going to Extremes in the New Arctic: Rain Season changes



21stC changes:

Largest changes over ocean

last rain day ↑ earlier in 21st C than than first rain day ↓

Changes are **enormous**: season ~60/90-120 days longer by mid/late 21stC!

Going to Extremes in the New Arctic

When will the Arctic become the "New Arctic" (or is it already)?

CESM1 LE suggests:

Arctic Sea ice extent
1996 MIN SIE
2013 MAX SIE

Surface Air Temperatures
October: Arctic ocean
2015-2029
February: Arctic ocean
2045-2070

Rainy season
2040-2070

How extreme are simulated changes?

Arctic Sea ice extent
3-4 months of 0 ice
($1x10^6$ km^2 less than "ice free definition!)

Surface Air Temperatures
October and February:
Arctic ocean 20°-24°C
Arctic lands 8°-12°C
warmer

Rainy season
Rainy season length
↑ 60-120+ days over most of Arctic by end of century

Going to Extremes in the New Arctic

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1996 MIN SIE
2013 MAX SIE

Surface Air Temperatures
October: Arctic ocean
2015-2029

Rainy season
2040-2070

"New Arctic"
Cryosphere → Hydrosphere

Arctic Sea ice extent
3-4 months of 0 ice
($1x10^6$ km^2 less than "ice free definition!)

Surface Air Temperatures
October and February:
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Rainy season
Rainy season length
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Going to Extremes in the New Arctic

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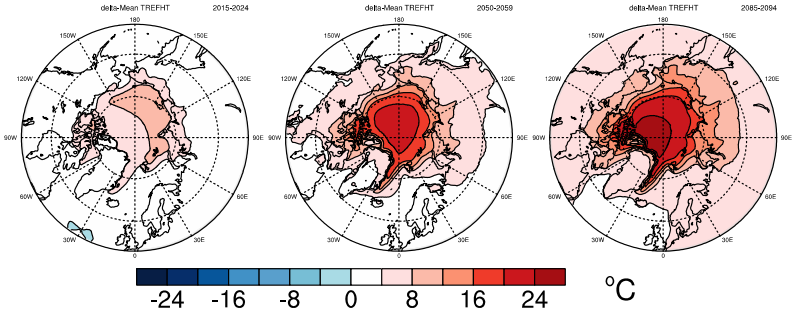
Extra slides

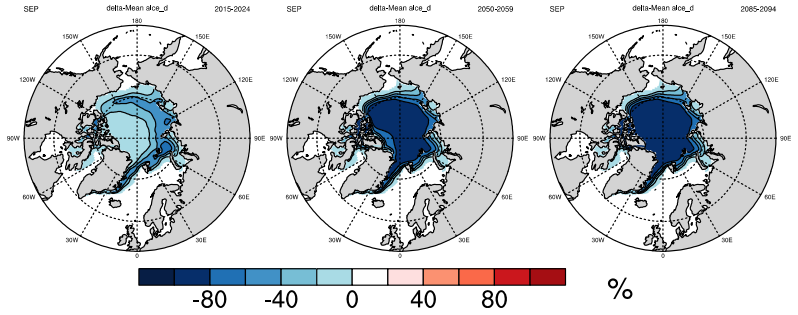
Going to Extremes in the New Arctic: Surface Air Temperature changes

(2015-2024) (2050-2059) (2085-2094)

Changes in mean OCT daily TREFHT

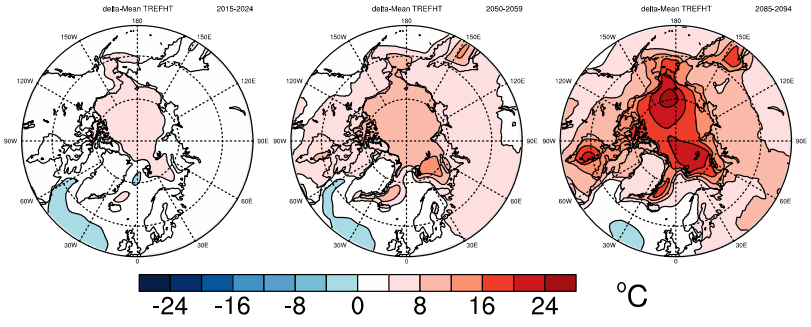


Changes in mean SEP aice_d

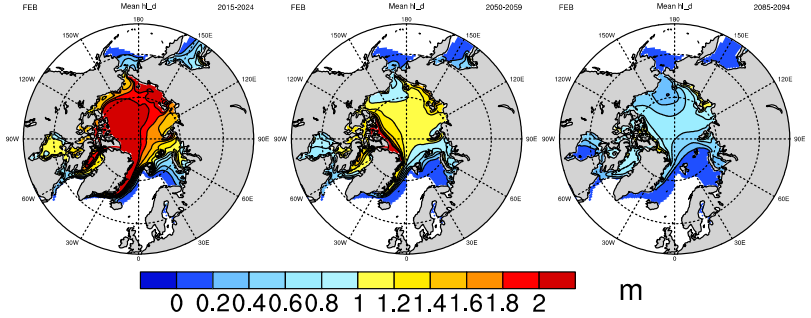


(2015-2024) (2050-2059) (2085-2094)

Changes in mean FEB daily TREFHT



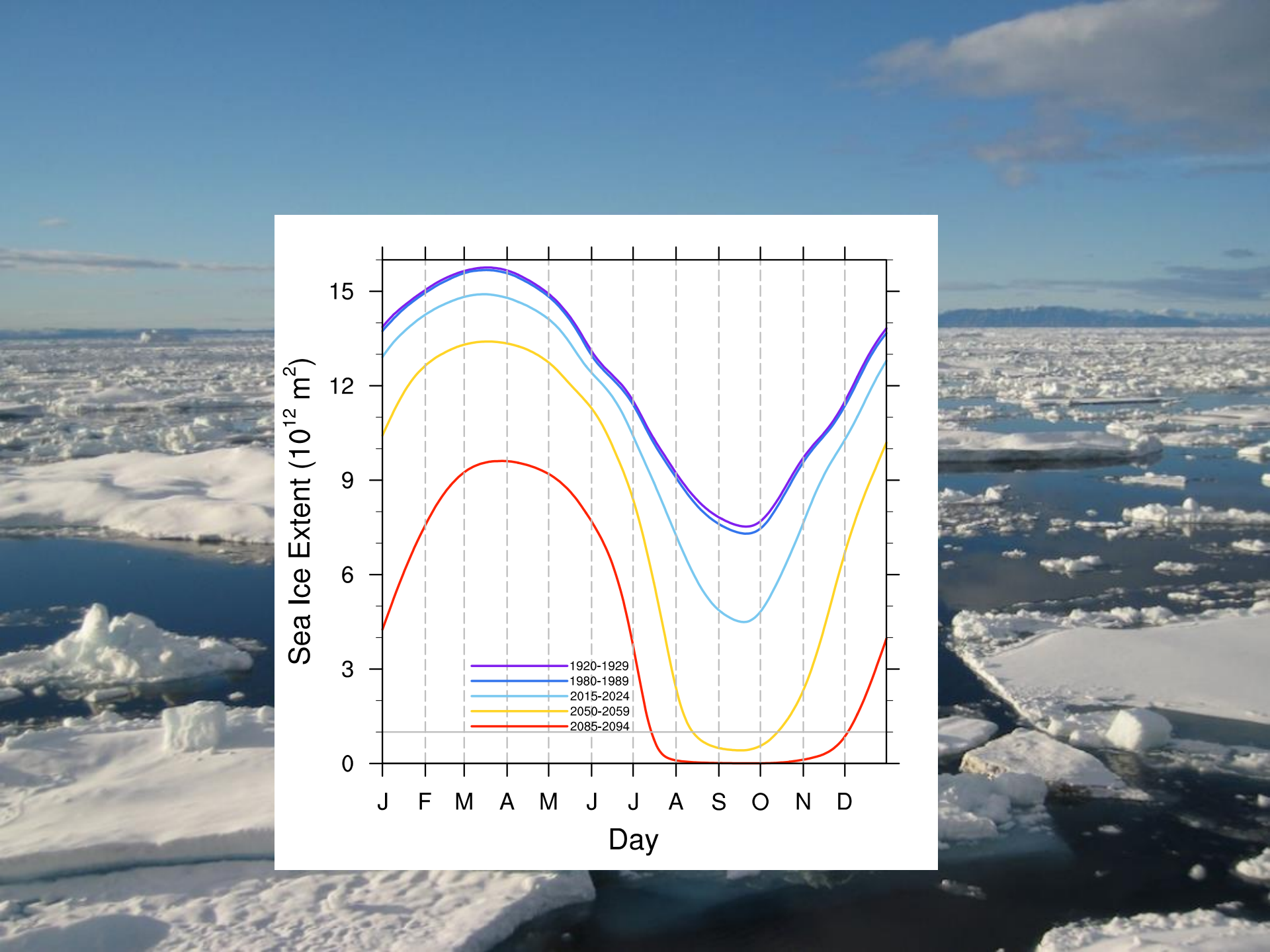
climatological mean FEB hi_d



Changes in October daily temperatures (2020-2029) over Arctic Ocean

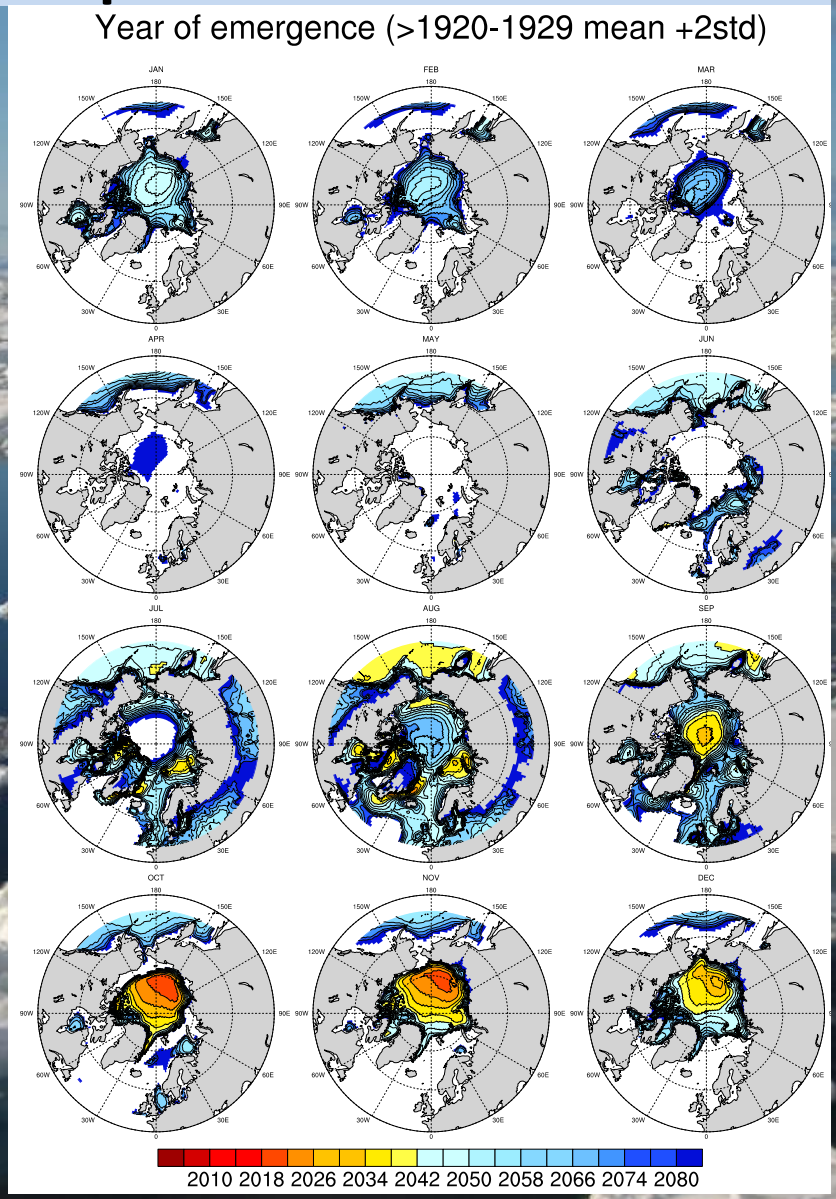
2-10 °C

Changes over Arctic land are substantial (2-6°C) yet not enough to emerge from variability


Sea Ice Extent (10^{12} m^2)
15
12
9
6
3
0
J F M A M J J A S O N D
Day
1920-1929
1980-1989
2015-2024
2050-2059
2085-2094

Going to Extremes in the New Arctic: Surface Air Temperatures

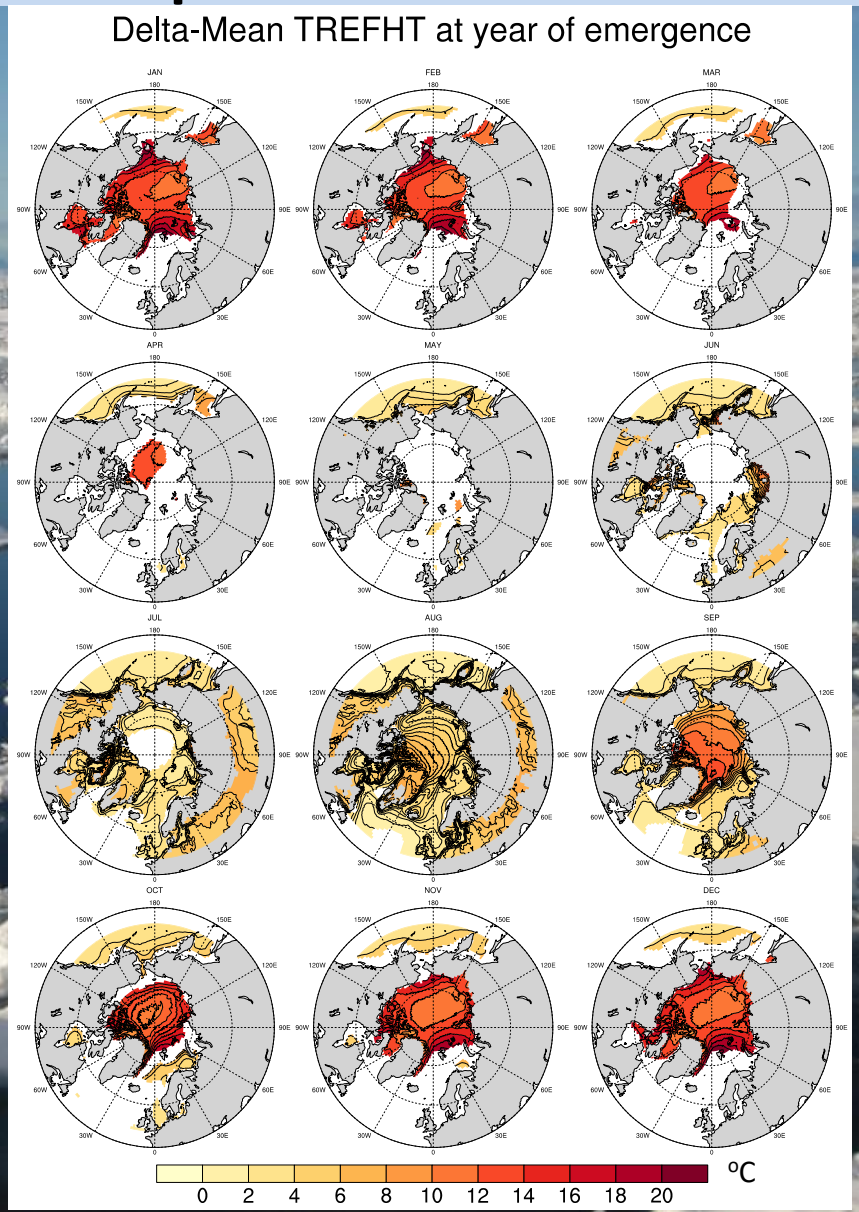
When does the 10-yr mean daily (by month) surface temperature exceed the early 20thC mean by more than 2 STD?



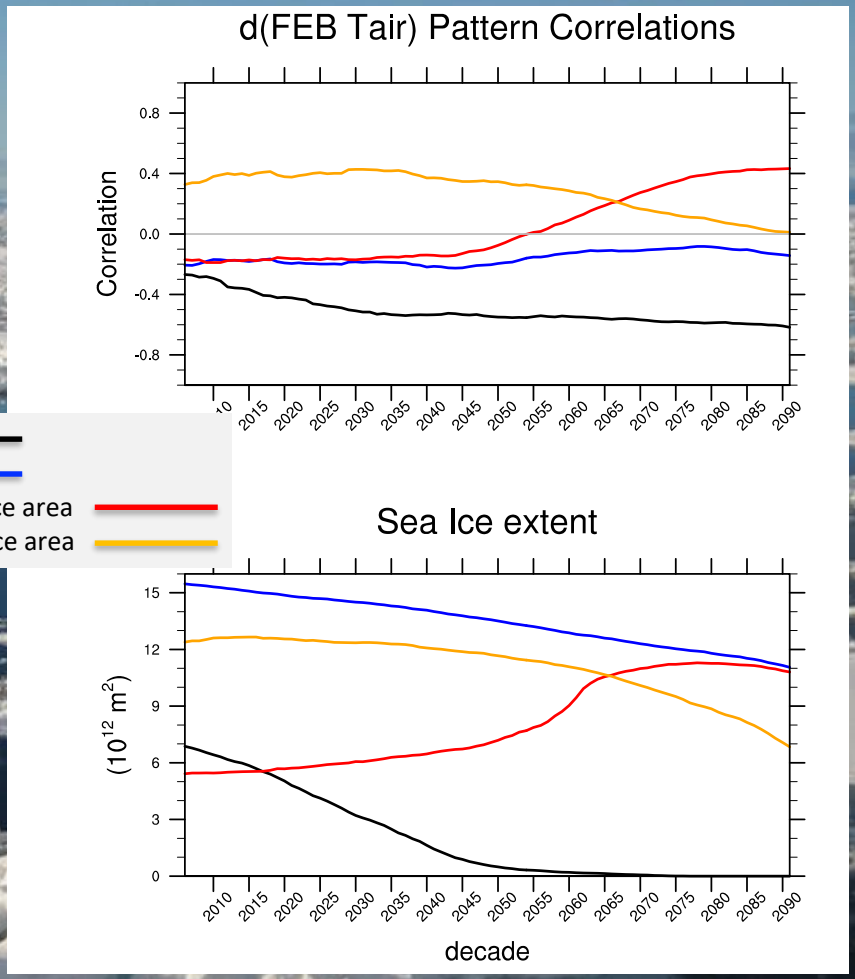
Going to Extremes in the New Arctic: Surface Air Temperatures

How much warmer is the temperature at year of emergence?

8-18+ ºC, Oct-Mar!



Going to Extremes in the New Arctic: Surface Air Temperatures and Sea Ice



°C

Going to Extremes in the New Arctic: Surface Air Temperatures and Sea Ice

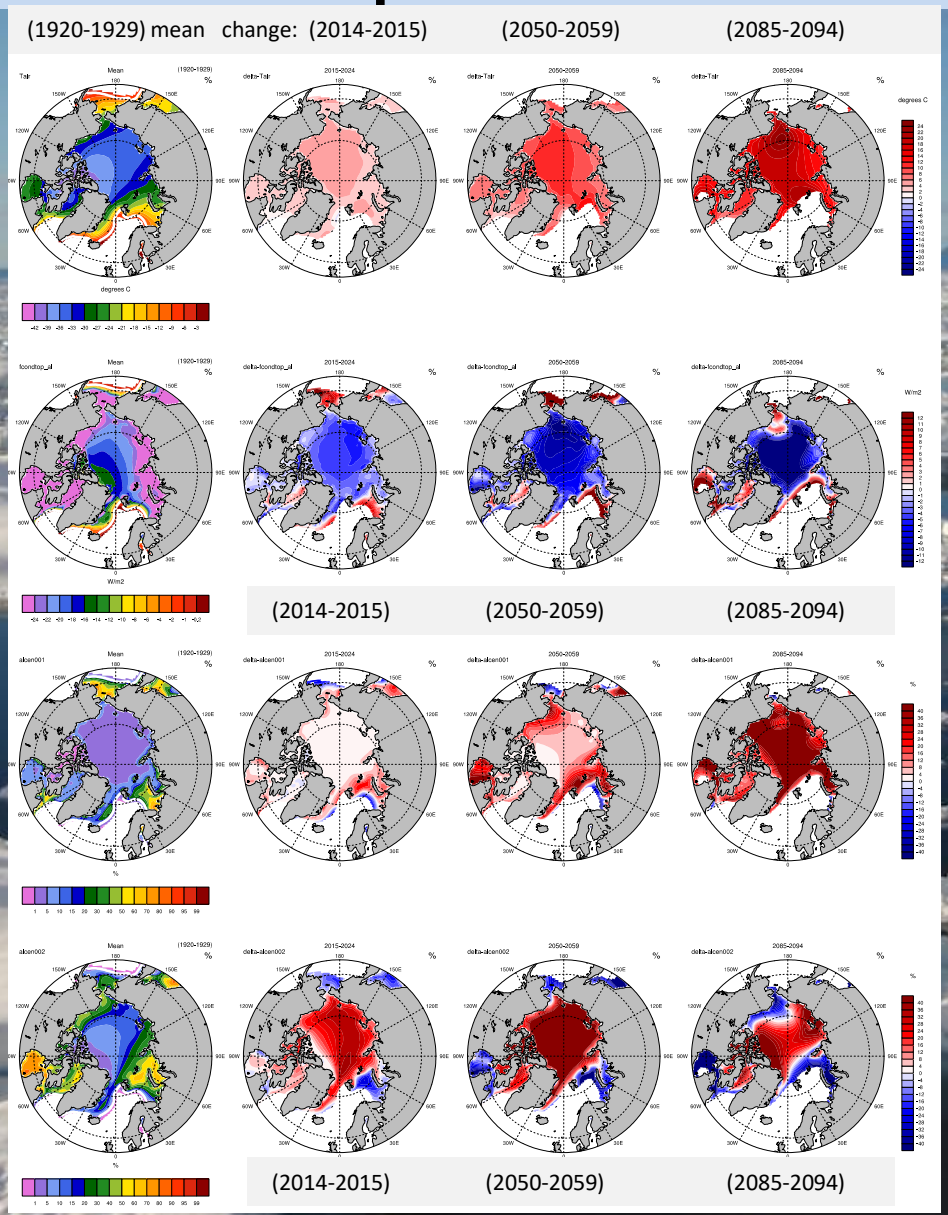
FEB

Air Temperature

Conductive Heat Flux
(ice-to-atm is neg)

Thinnest (<0.64 m)
sea ice concentration

Thin (0.64-1.39 m)
sea ice concentration



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