Arctic Levers:

Unraveling a Hot Mess of Natural Shifts, Forced Warming, and Feedbacks

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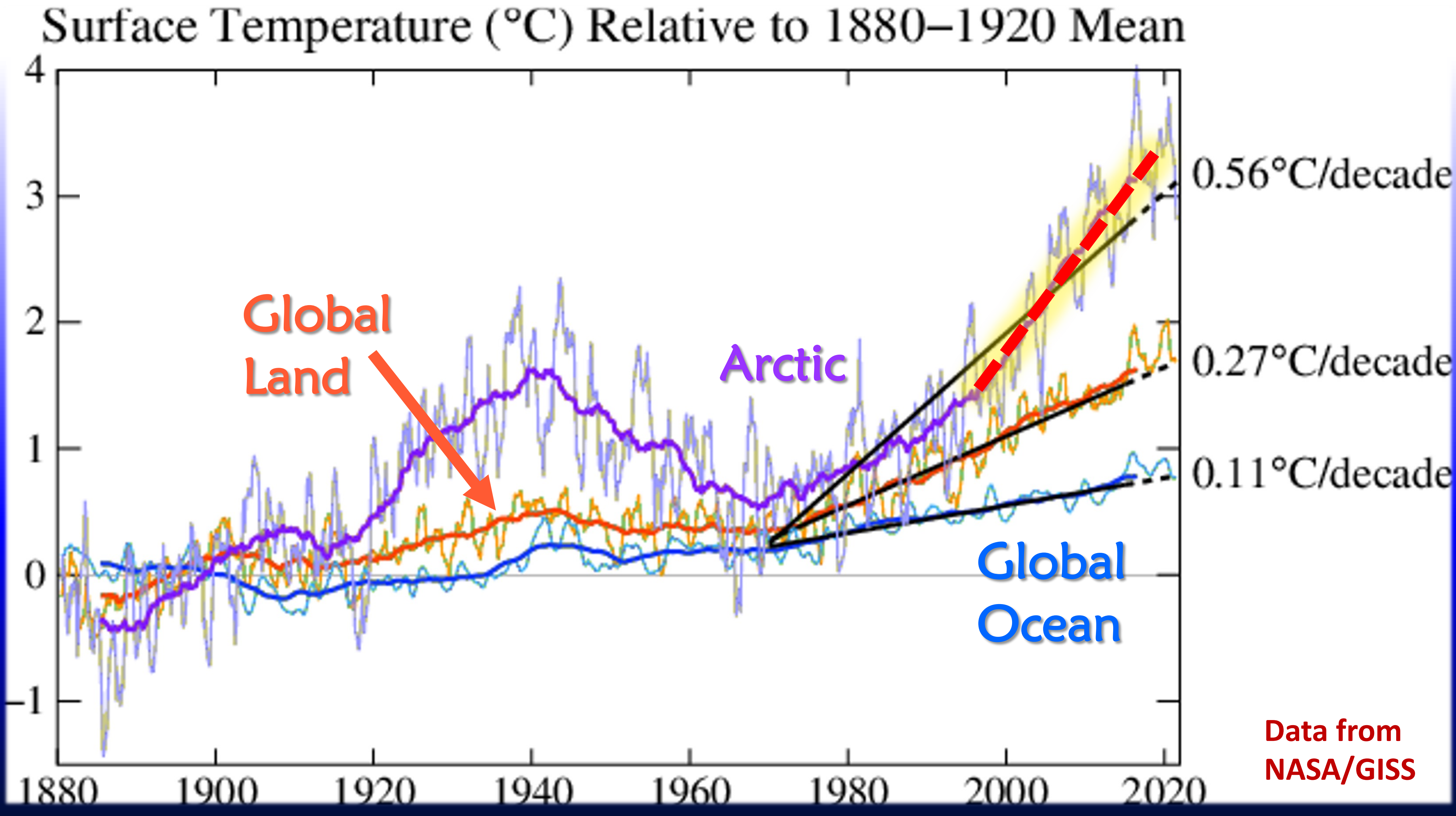
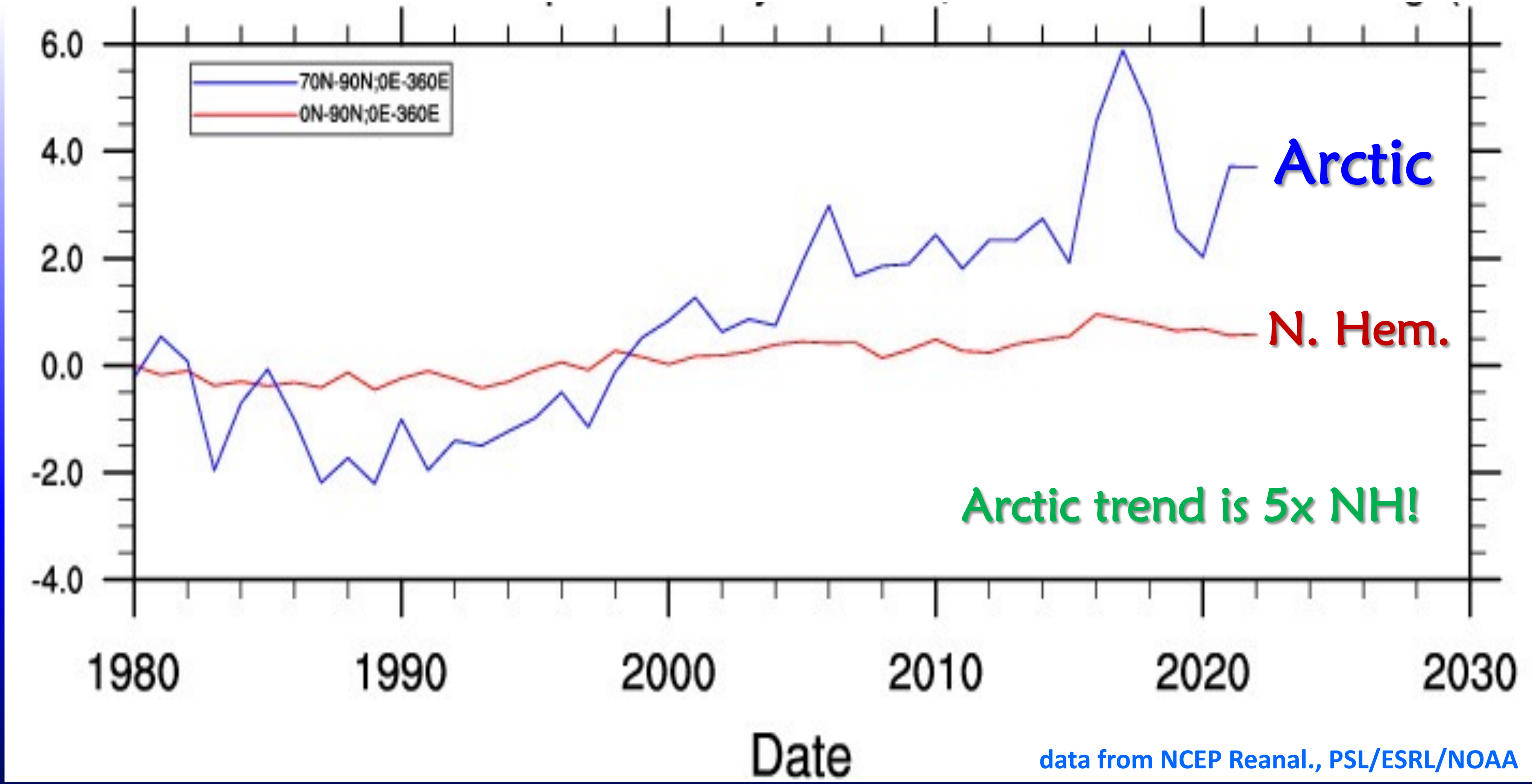
Global Warming Is Not Created Equal



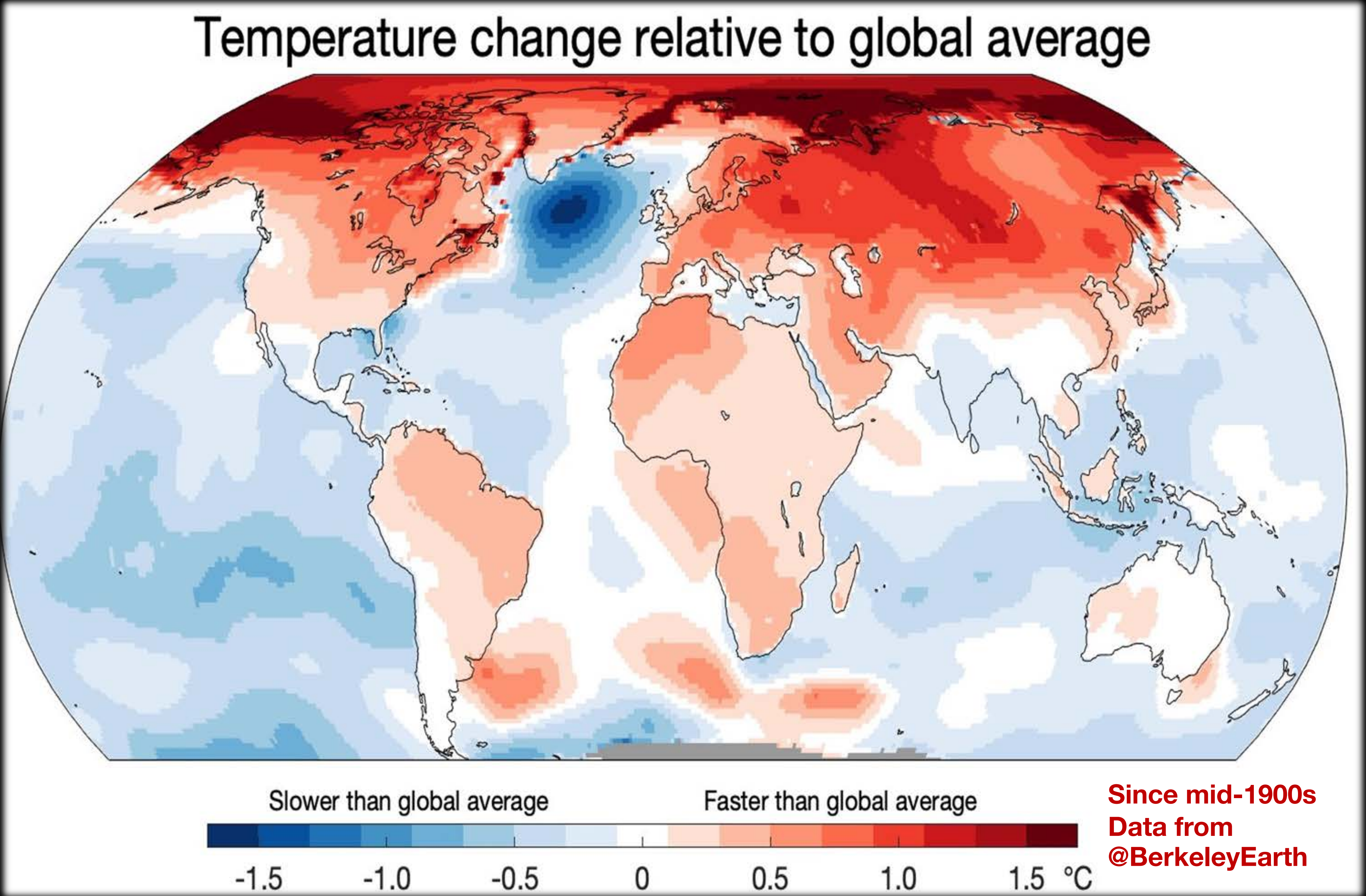
Data from NASA/GISS

Cold-Season (Oct.-Feb.) SST Anomalies



data from NCEP Reanal., PSL/ESRL/NOAA

Warming in Arctic
>> land areas
>> oceans



Since mid-1900s
Data from
@BerkeleyEarth

Plot by Ed Hawkins

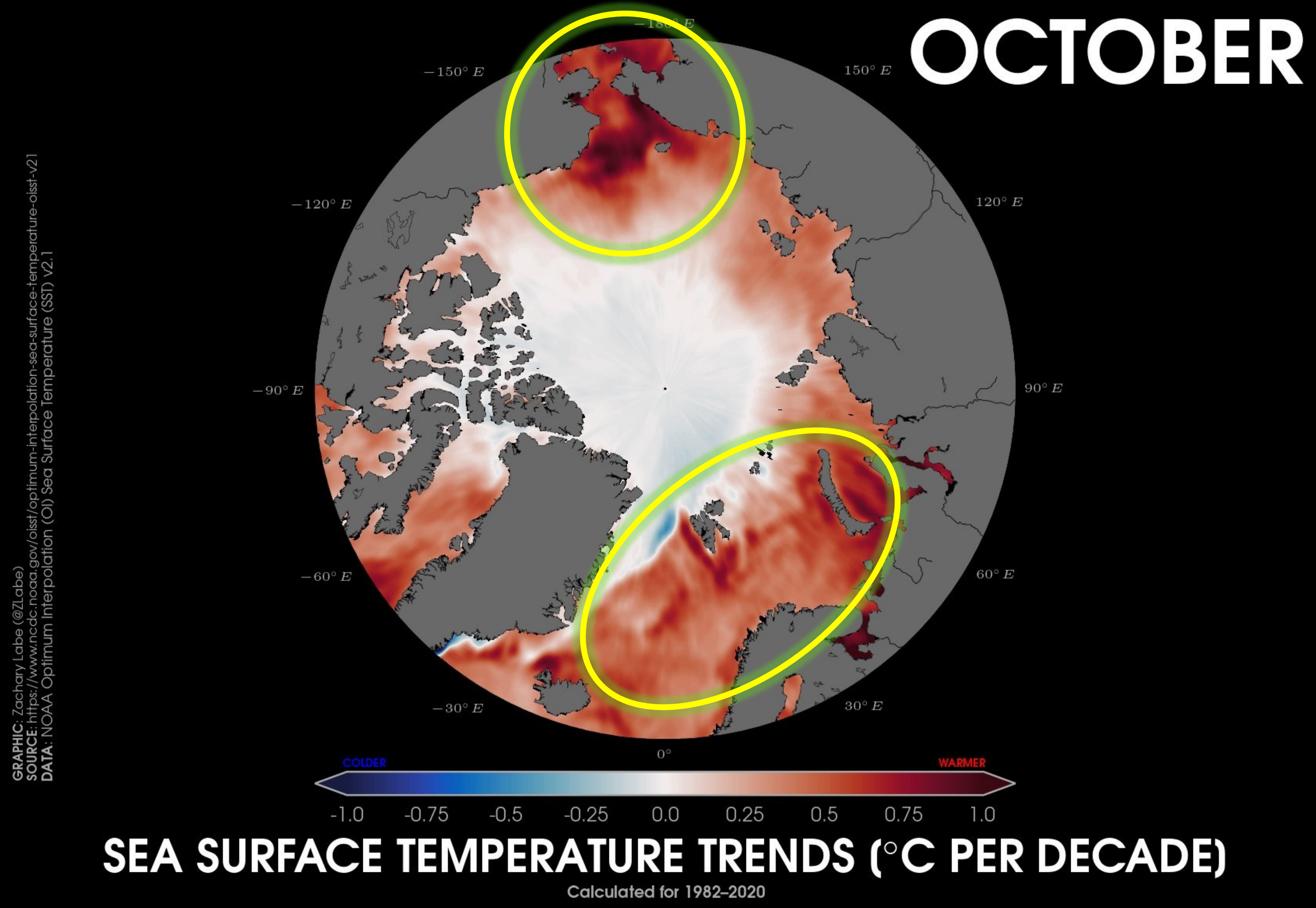
Strong gradient → strong wind

Weak gradient → weak wind

Surface temperature trends

October 1982-2020

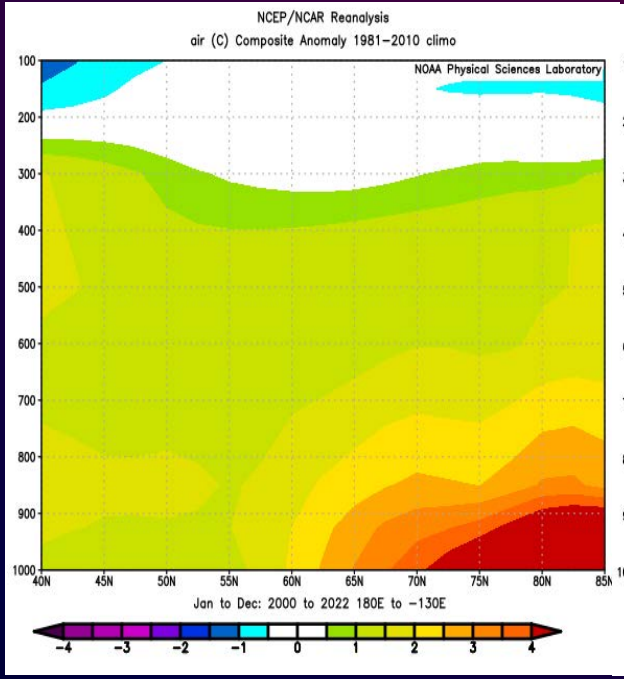
HOTSPOTS



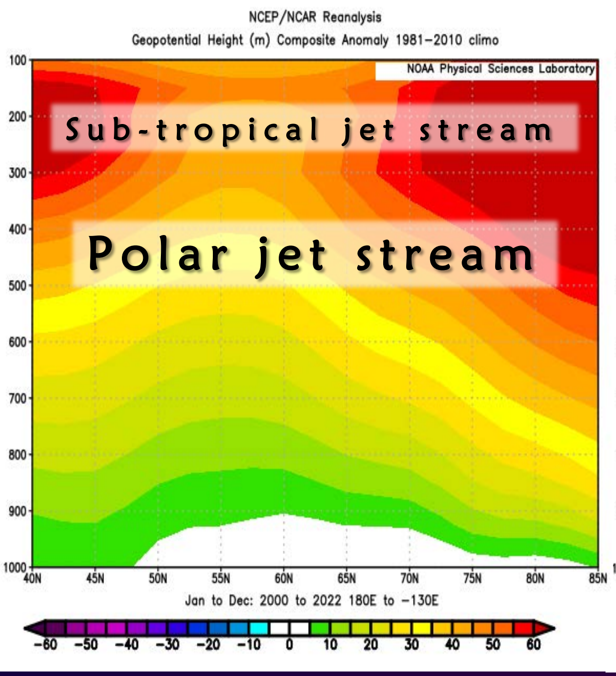
by Zack Labe @ZLabe

Arctic Amplification: N. Pacific

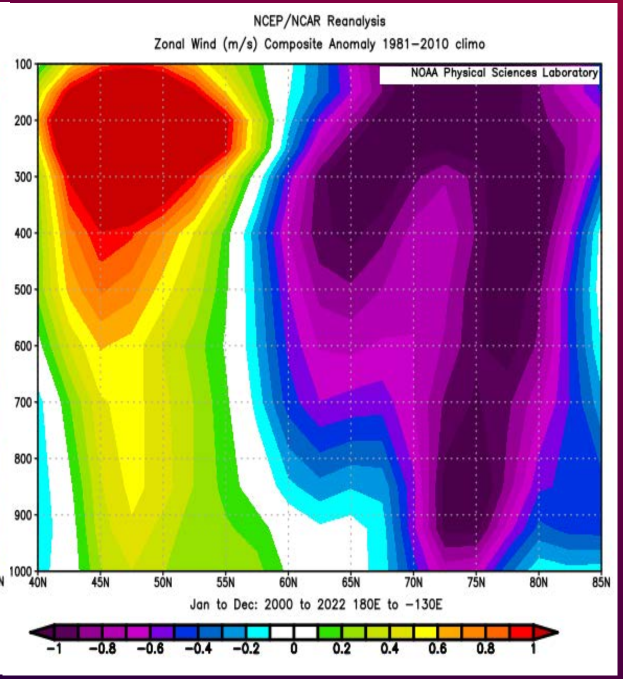
Temperature anomalies
2000 to 2022 (annual)



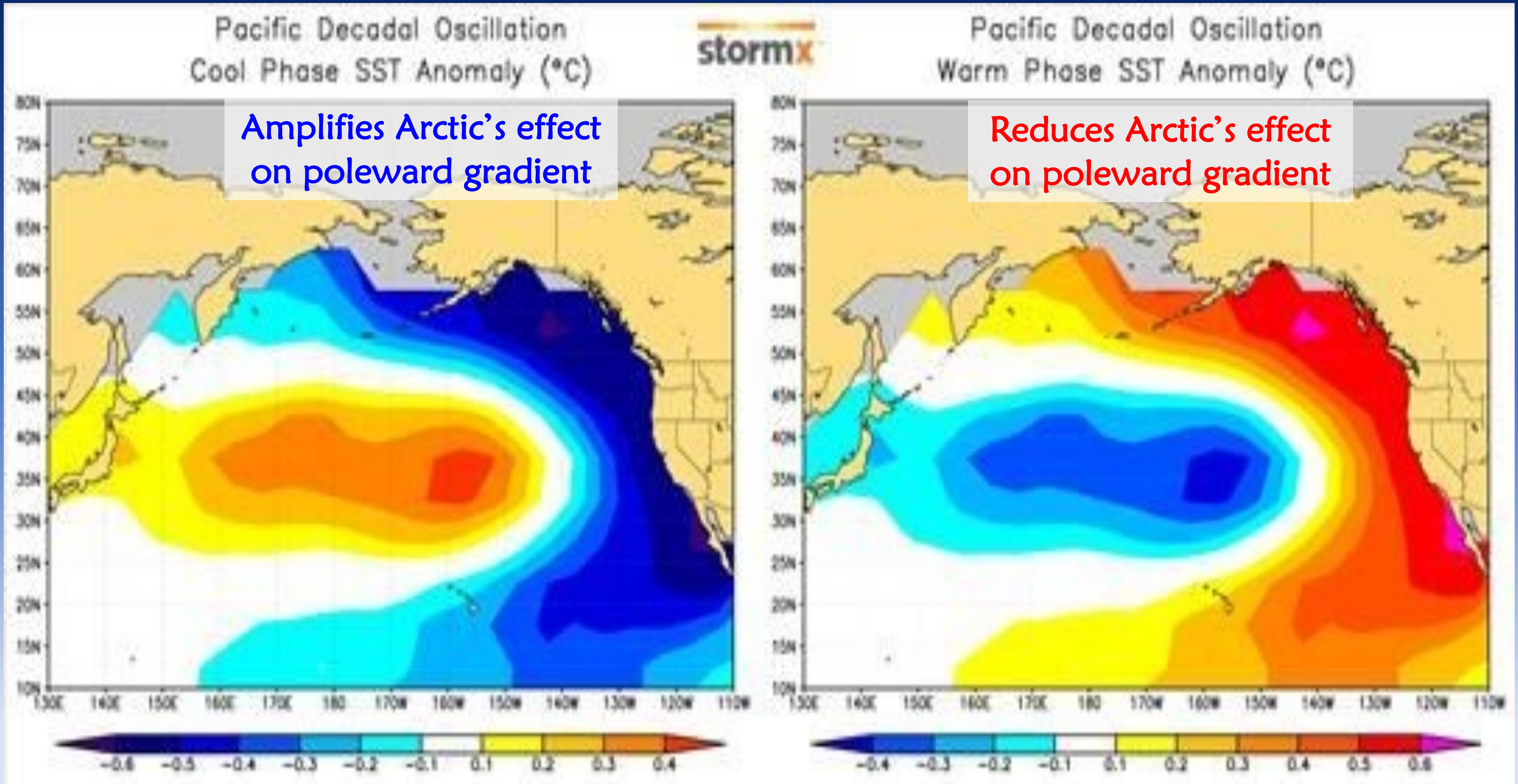
Height anomalies
2000 to 2022



Zonal wind anomalies
2000 to 2022



Pacific Decadal Oscillation (PDO)



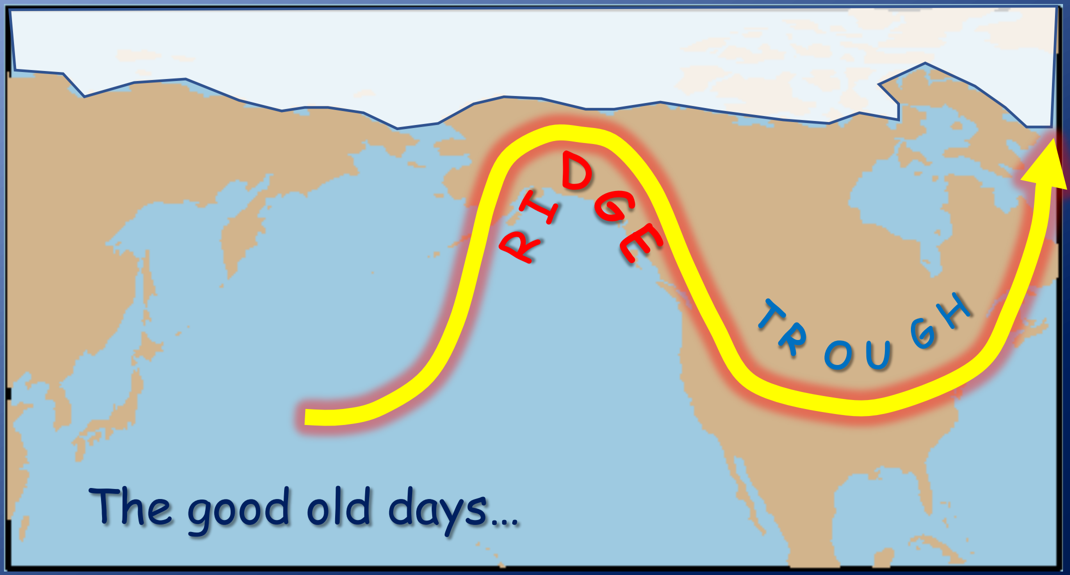
Negative PDO => stronger Arctic amplification (Screen & Francis 2016)

Positive PDO => stronger west-coast ridge (Sung et al 2016, Lee et al 2015)

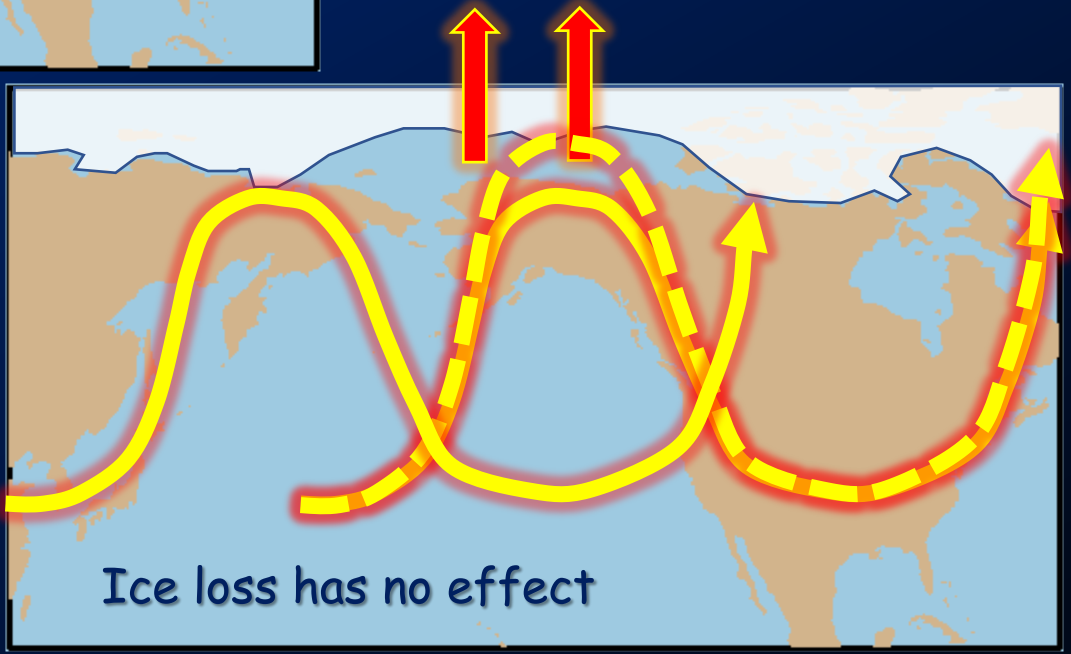
The

"It Takes Two to Tango"

Hypothesis*



Extra heating intensifies ridge, making it more persistent.

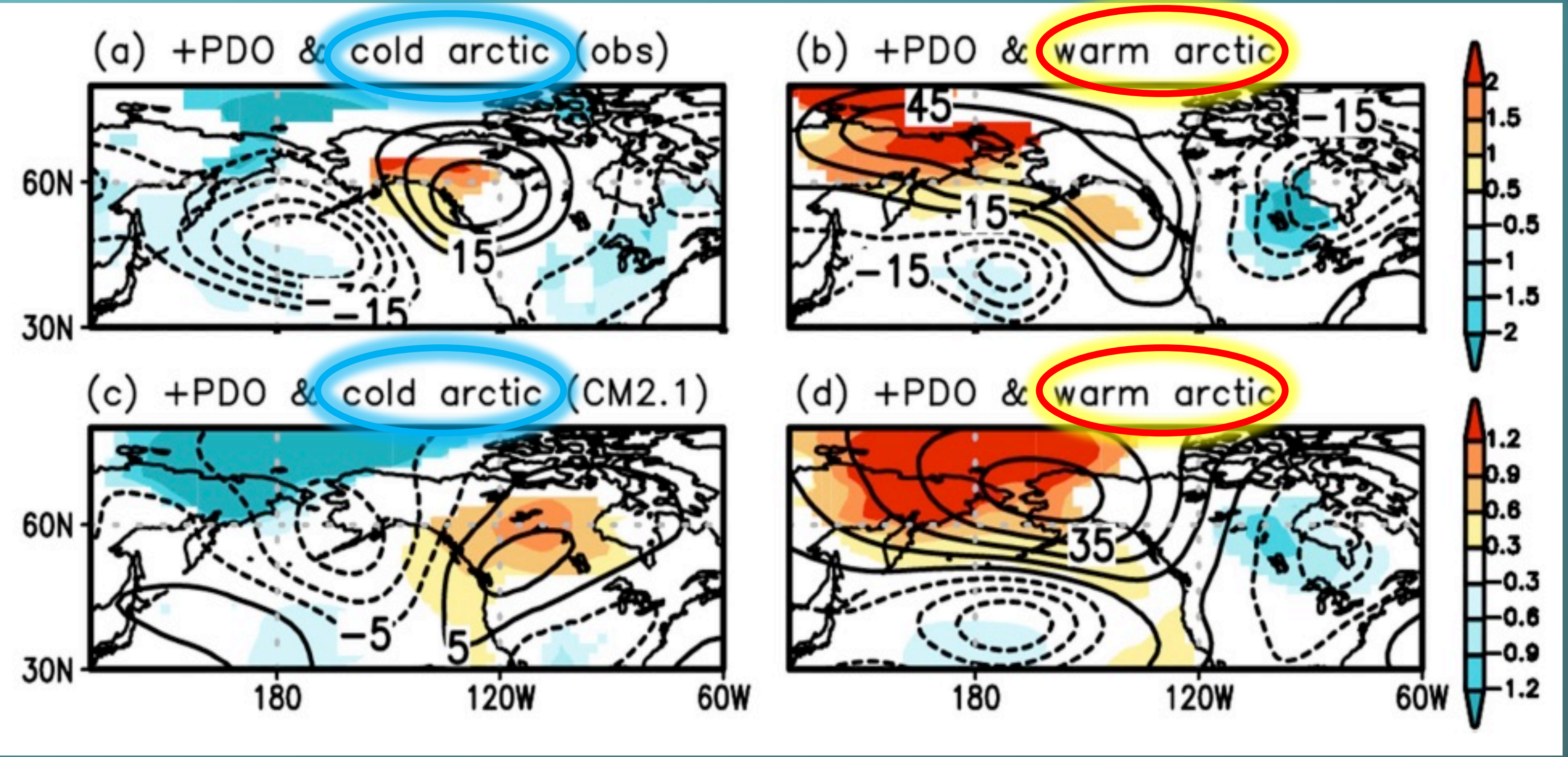


*Francis et al, 2017

TTT in Pacific/N. America: +PDO

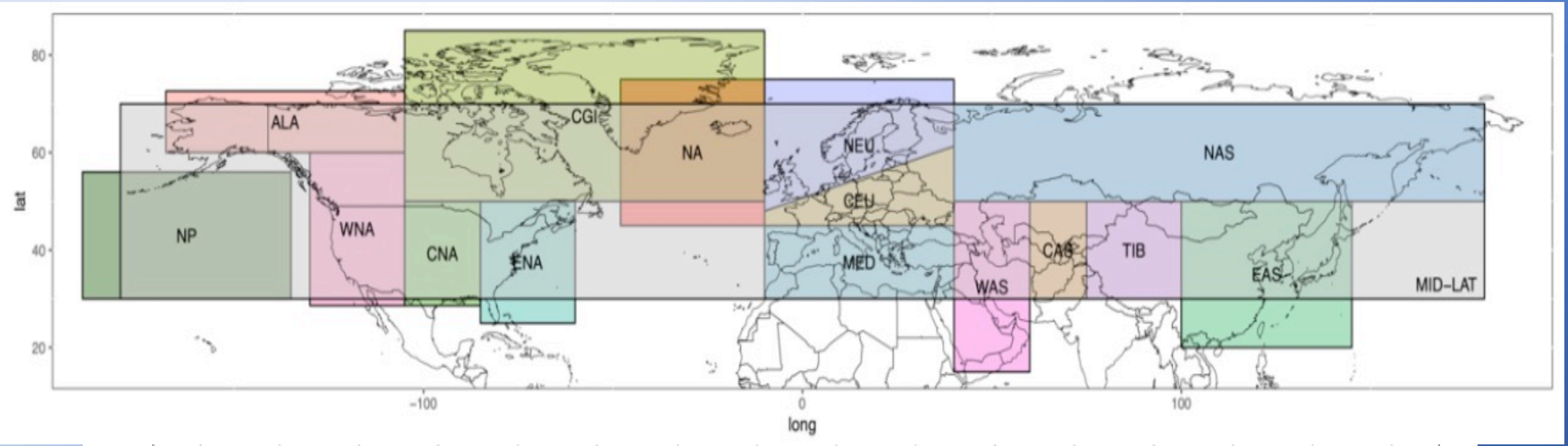
Obs

Model

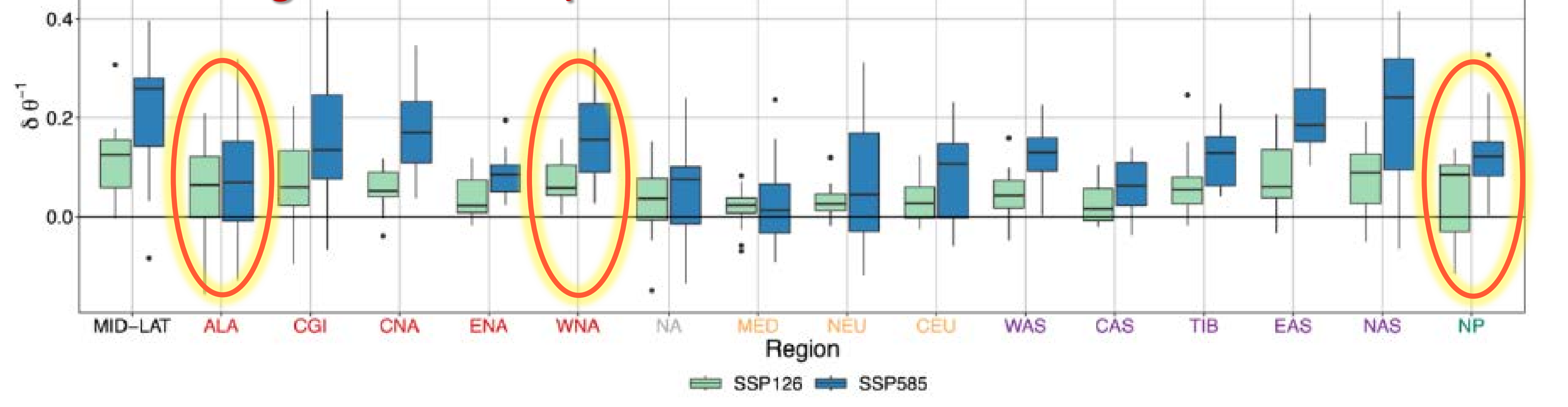


Obs and model simulations show stronger Pacific ridging when PDO+ *and* warm Arctic in Pacific sector

Sung et al, ERL 2016



Change in summer persistence from 1981-2000 to 2018-2100

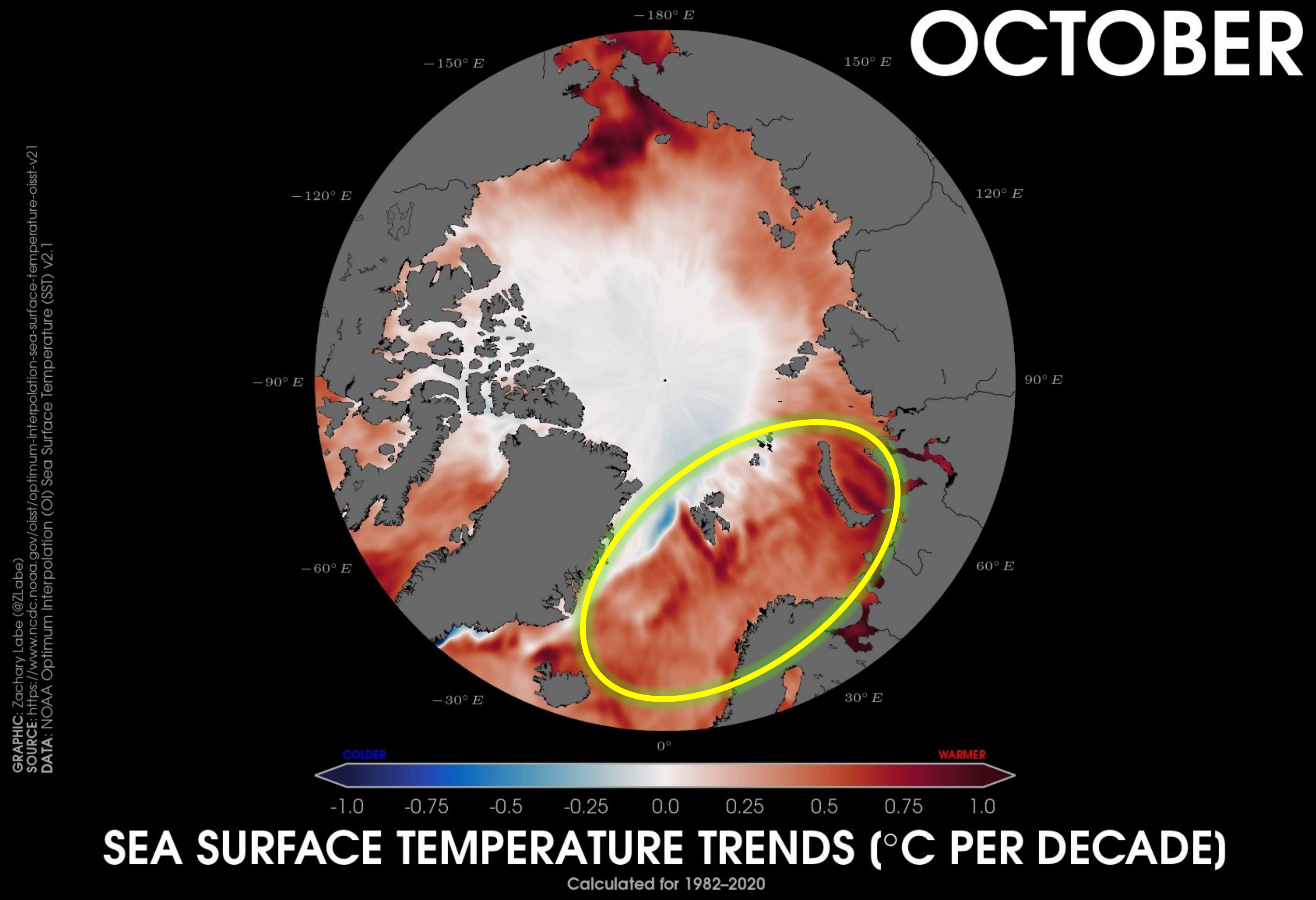


from Coumou and De Luca (2020)

Surface temperature trends

October 1982-2020

HOTSPOTS



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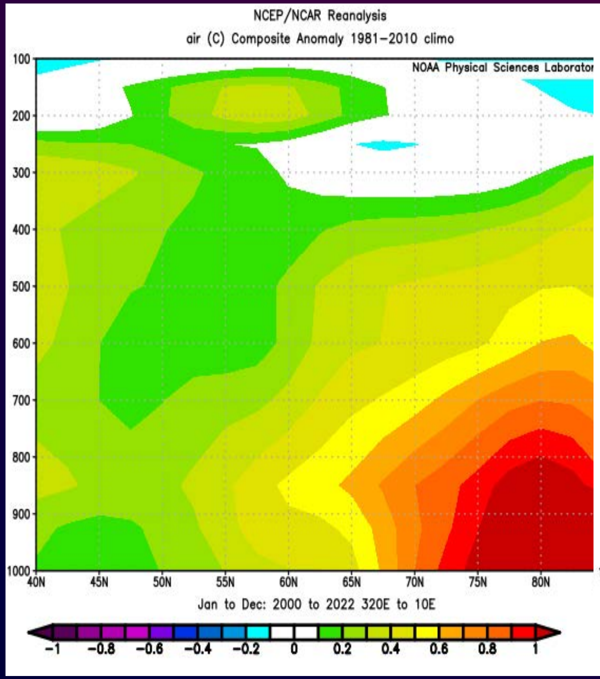
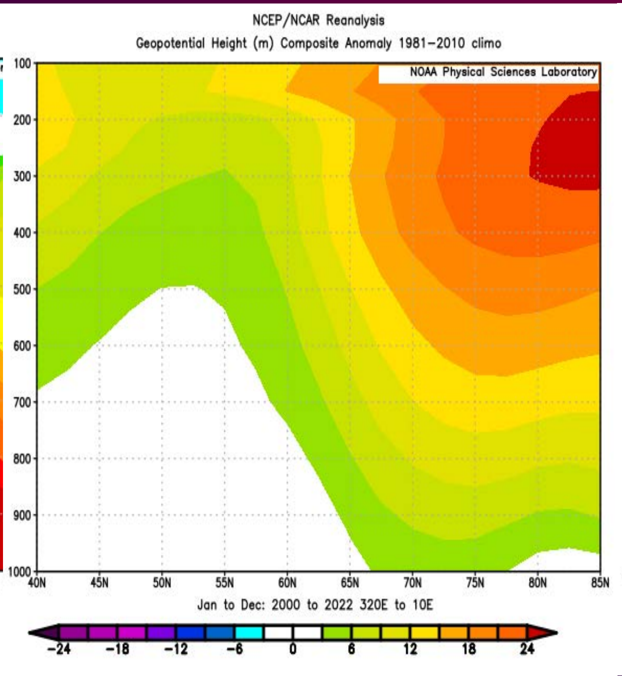
Arctic Amplification: N. Atlantic

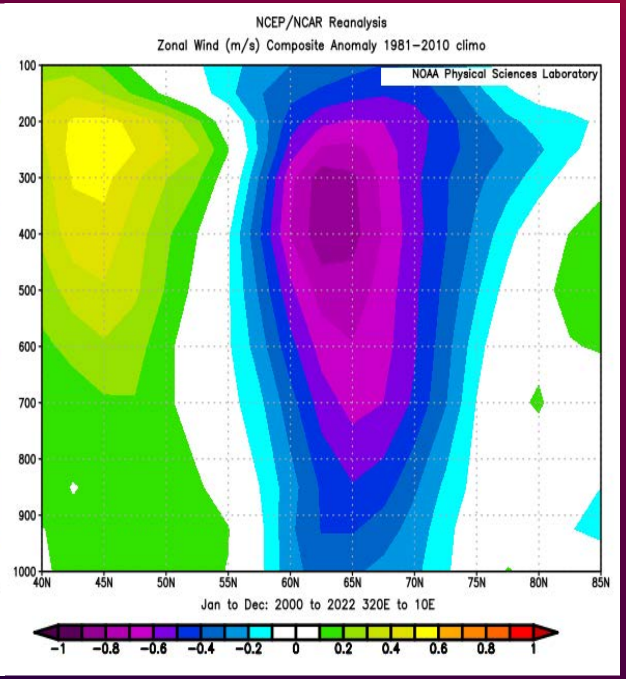
Temperature anomalies
2000 to 2022 (annual)



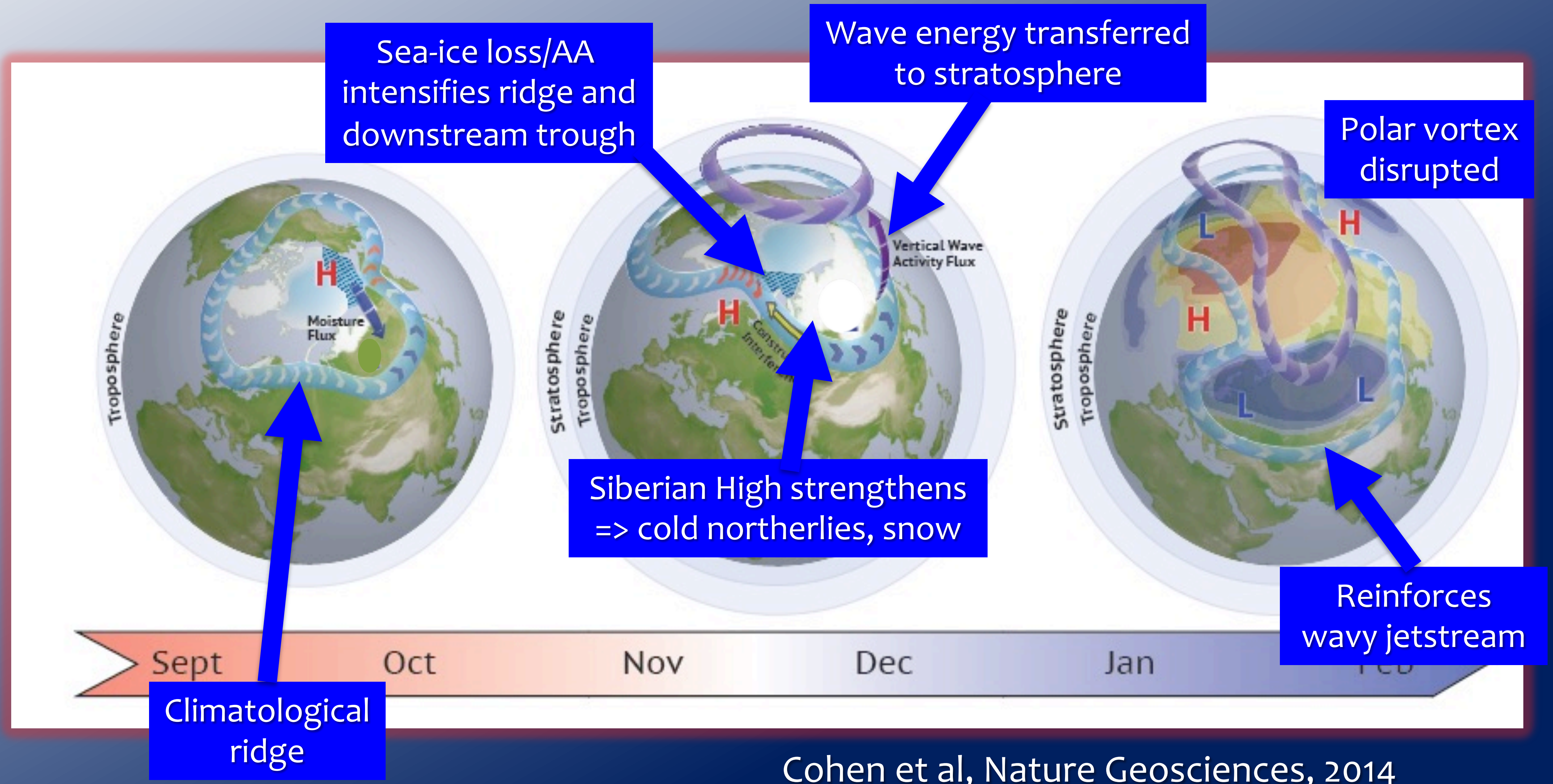
Height anomalies
2000 to 2022



Zonal wind anomalies
2000 to 2022



Evidence of "Two to Tango" in Eurasia

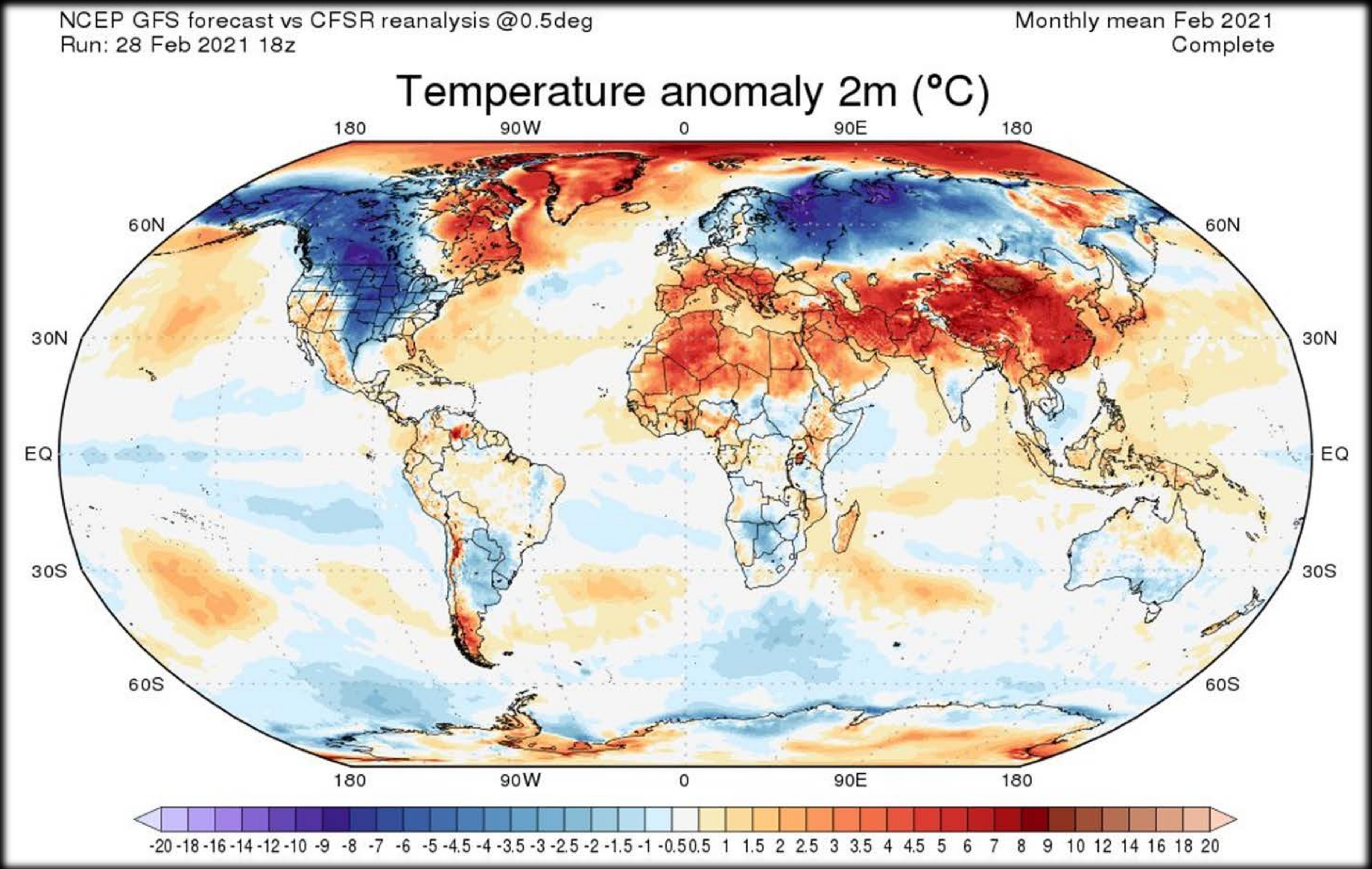


Cohen et al, Nature Geosciences, 2014

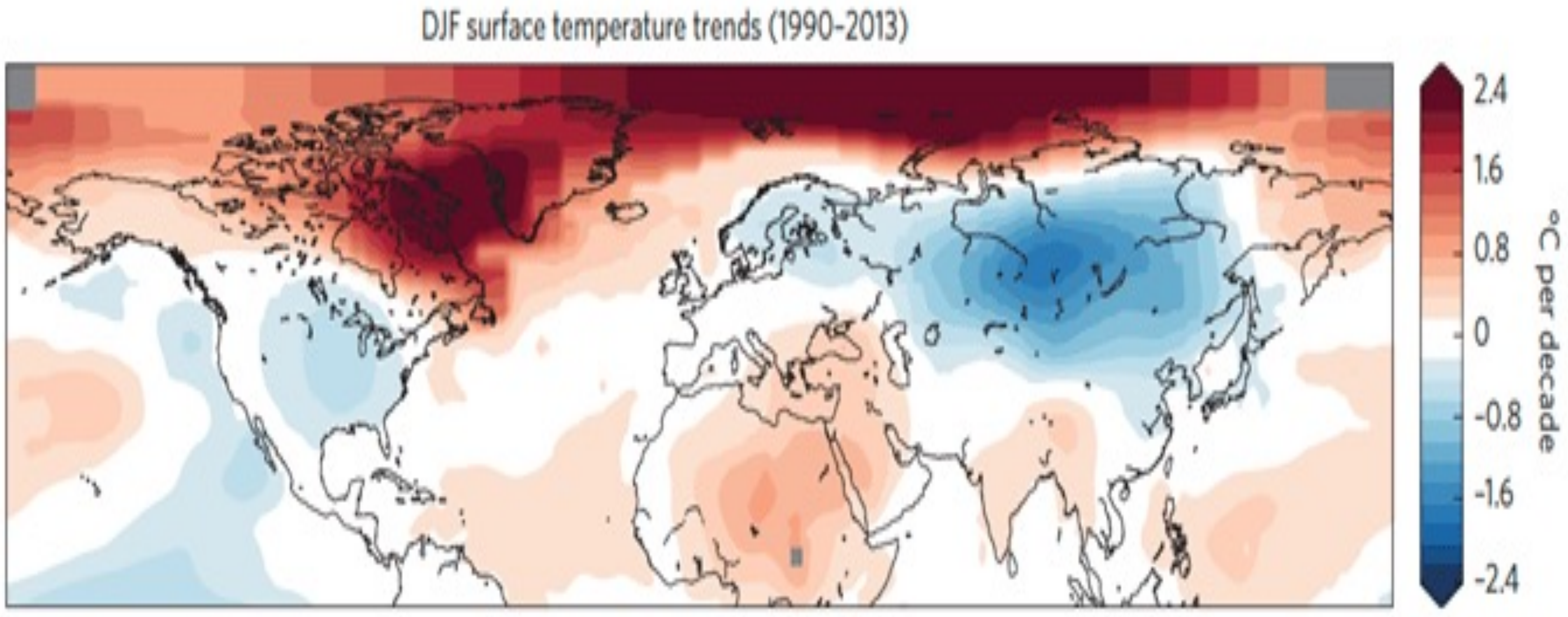
also Jaiser et al 2012, 2013; Kim et al 2014; Furtado et al 2015; Wu and Smith 2016; Zhang et al 2016; Kretschmer et al 2016; Nakamura et al 2016; Zou et al 2017; McKusker et al 2017; Zhang et al 2018; Ye et al 2018; Hoshi et al 2019

Texas Freeze Feb. 2021

Temperature differences from average

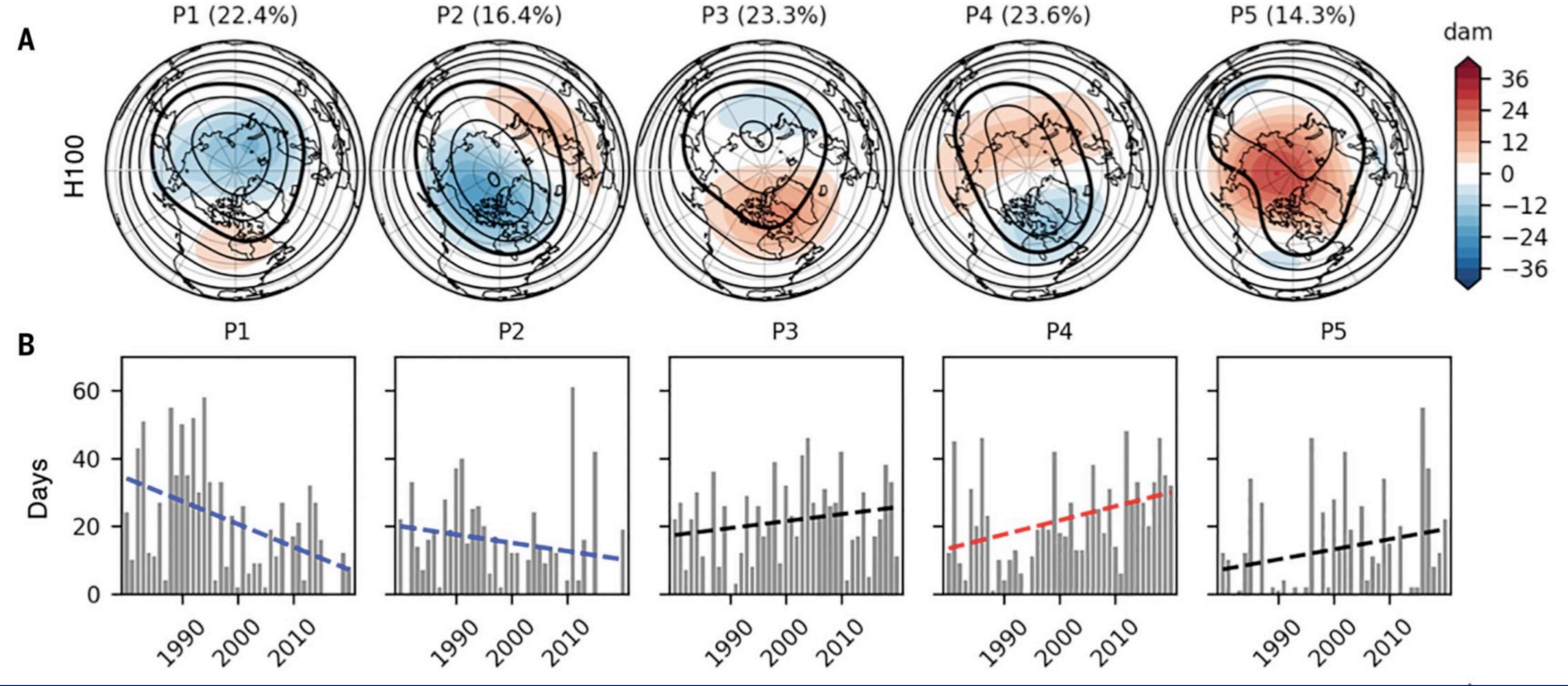


Near-surface air temperature trends – DJF (1990-2013)

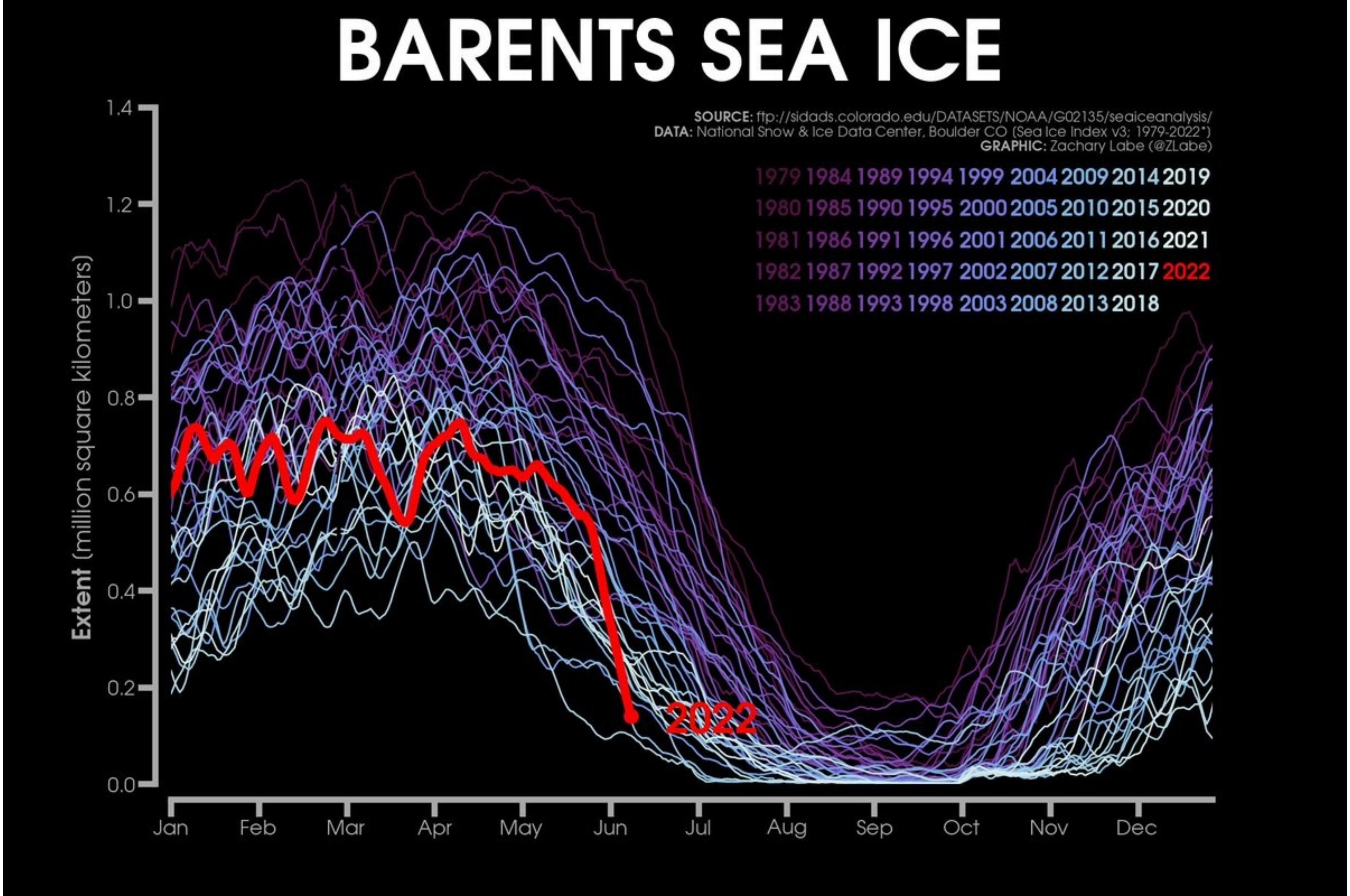


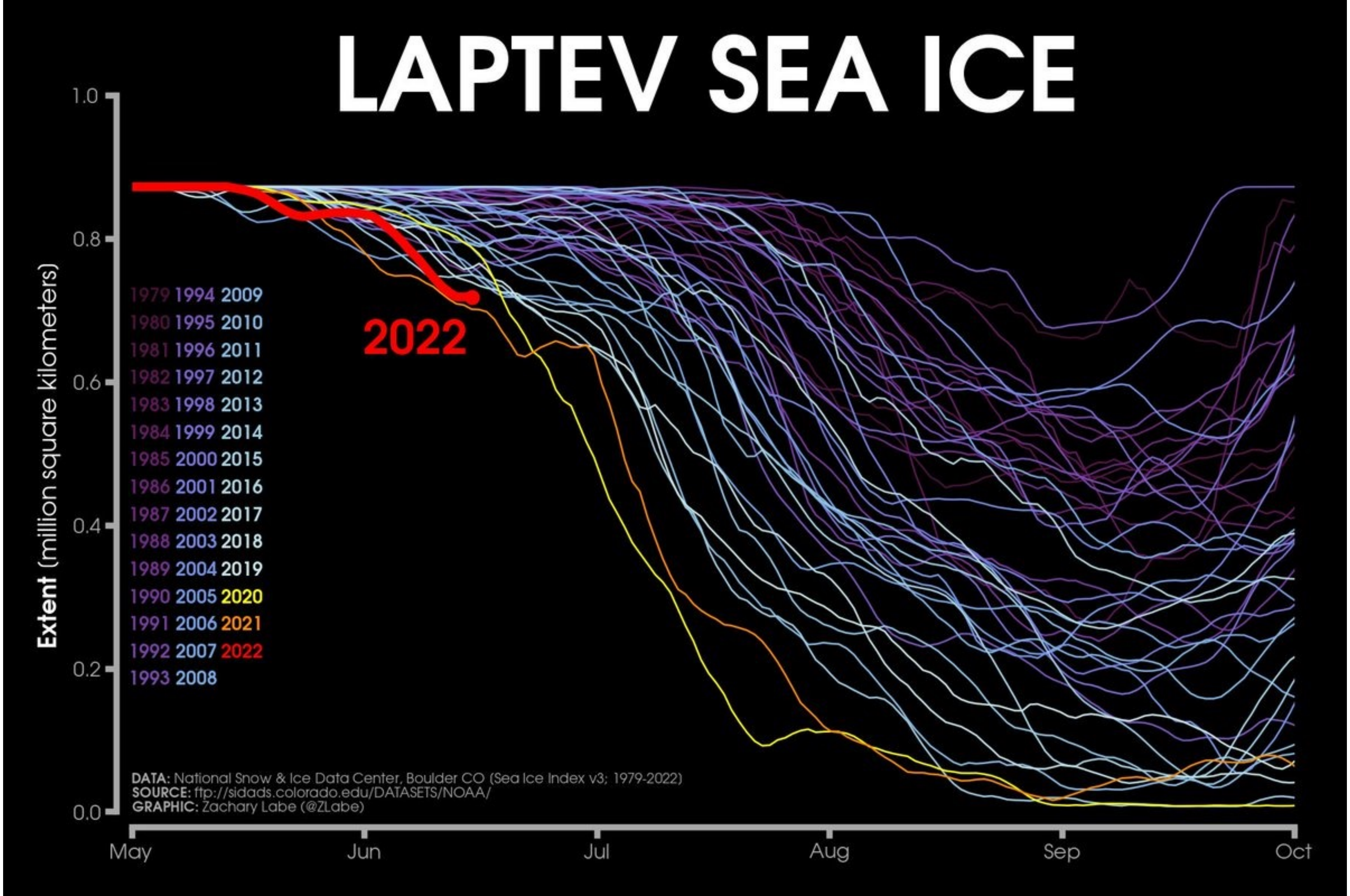
from Cohen et al. (2014)

Changing Patterns of the Stratospheric Polar Vortex



from Cohen et al. *Science* (2021)

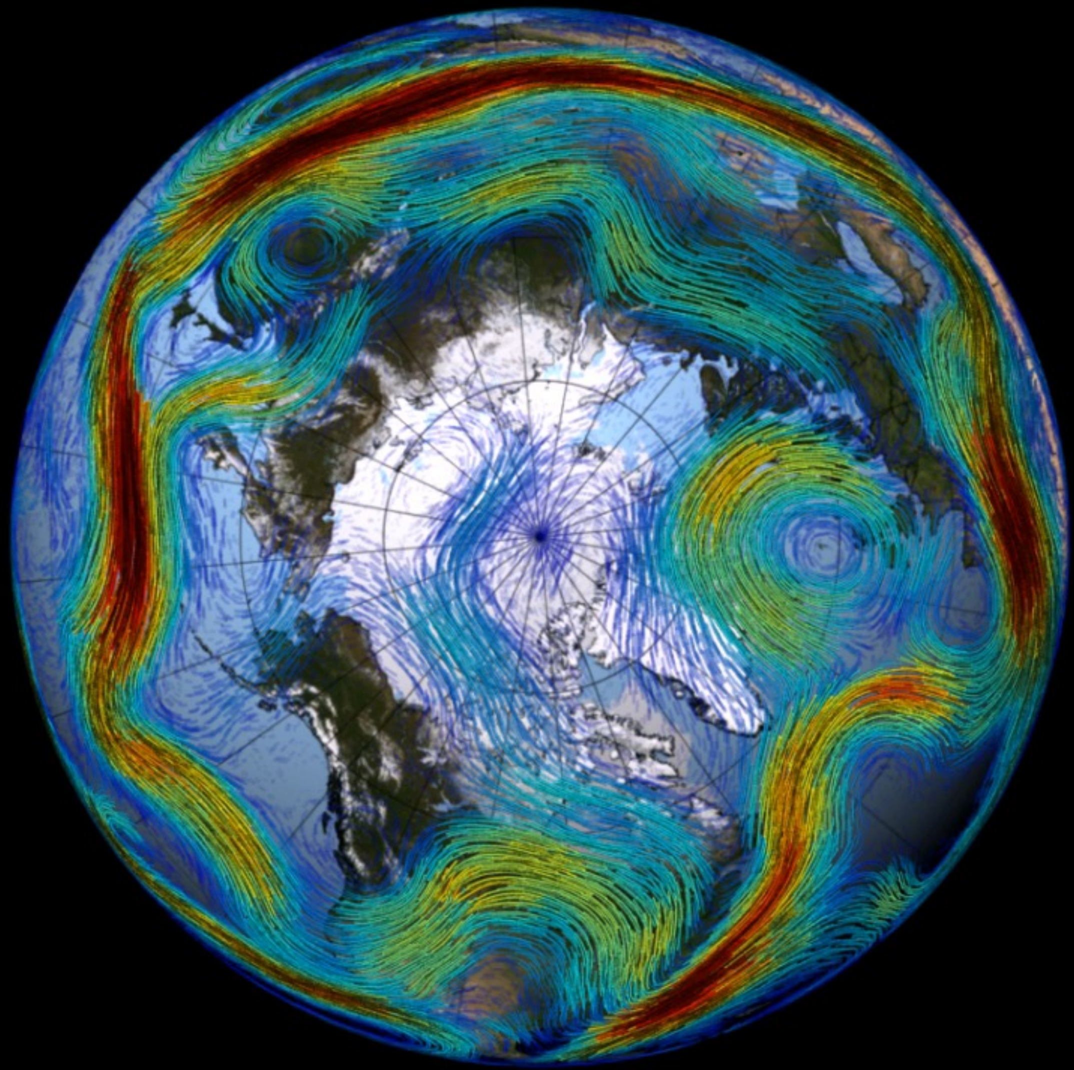

BARENTS SEA ICE
SOURCE: ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/seaiceanalysis/
DATA: National Snow & Ice Data Center, Boulder CO (Sea Ice Index v3; 1979-2022*)
GRAPHIC: Zachary Labe (@ZLabe)
1979 1984 1989 1994 1999 2004 2009 2014 2019
1980 1985 1990 1995 2000 2005 2010 2015 2020
1981 1986 1991 1996 2001 2006 2011 2016 2021
1982 1987 1992 1997 2002 2007 2012 2017 2022
1983 1988 1993 1998 2003 2008 2013 2018
Extent (million square kilometers)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2022



LAPTEV SEA ICE
Extent (million square kilometers)
1.0
0.8
0.6
0.4
0.2
0.0
May
Jun
Jul
Aug
Sep
Oct
2022
1979 1994 2009
1980 1995 2010
1981 1996 2011
1982 1997 2012
1983 1998 2013
1984 1999 2014
1985 2000 2015
1986 2001 2016
1987 2002 2017
1988 2003 2018
1989 2004 2019
1990 2005 2020
1991 2006 2021
1992 2007 2022
1993 2008
DATA: National Snow & Ice Data Center, Boulder CO (Sea Ice Index v3; 1979-2022)
SOURCE: ftp://sidads.colorado.edu/DATASETS/NOAA/
GRAPHIC: Zachary Labe (@ZLabe)

Parting points:

- Temperature gradients make winds. Mess with those gradients and winds will change, weather will change.
- Regional Arctic amplification can enhance or reduce influences of SST fluctuations (natural or forced), and vice versa (“Levers”)
- Ocean-ice-jetstream feedbacks accelerate sea-ice loss via poleward heat fluxes
- Latest research suggests rapid Arctic warming will contribute to:
  - Increased frequency of polar vortex disruptions
  - Increased persistence of weather regimes
  - Increased heat, drought, and fires in western U.S.
- Ocean influence on Barents/Kara region may be waning ala Cold Blob



by NASA's Science Visualization Studio

Thank-you!

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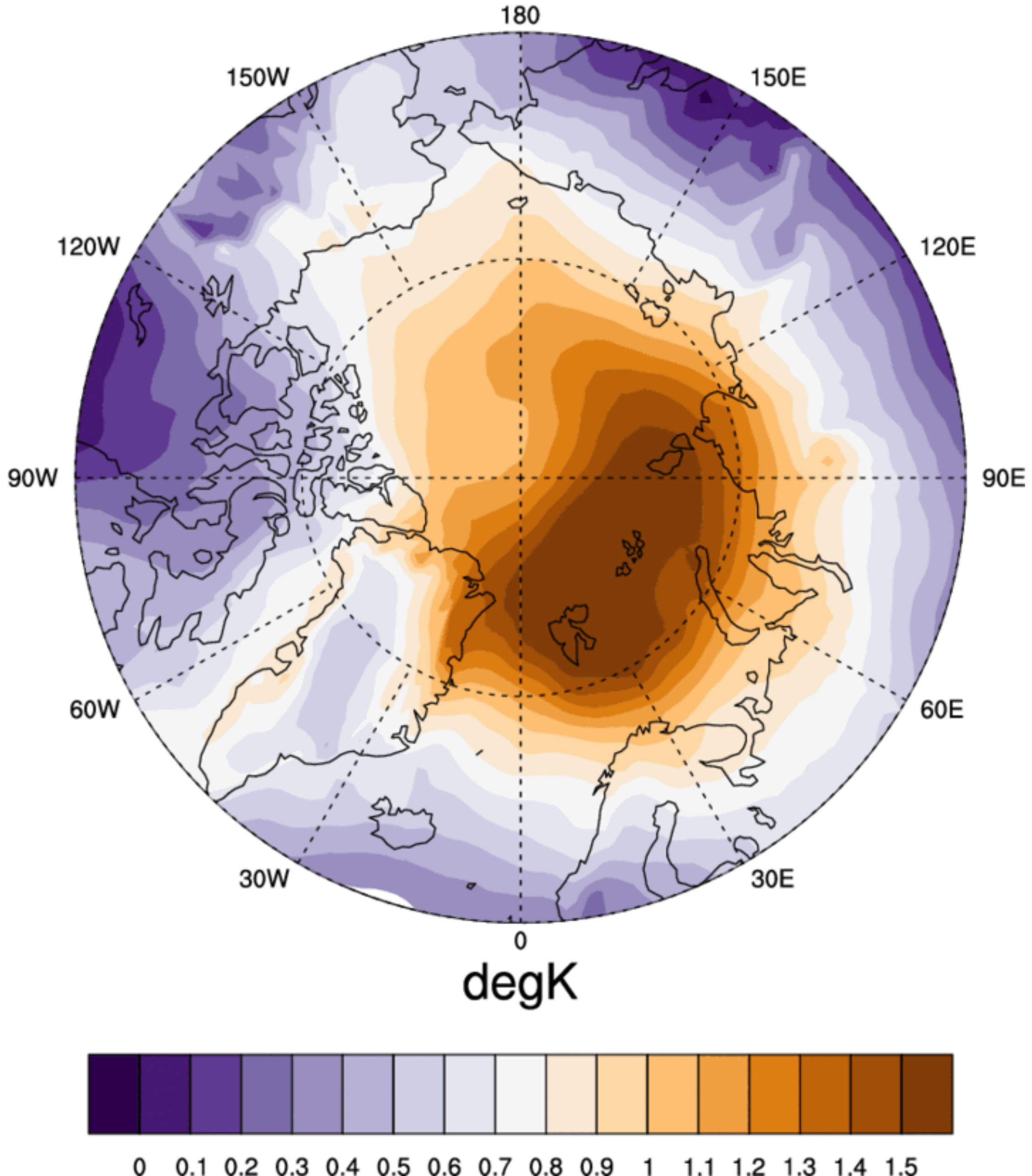
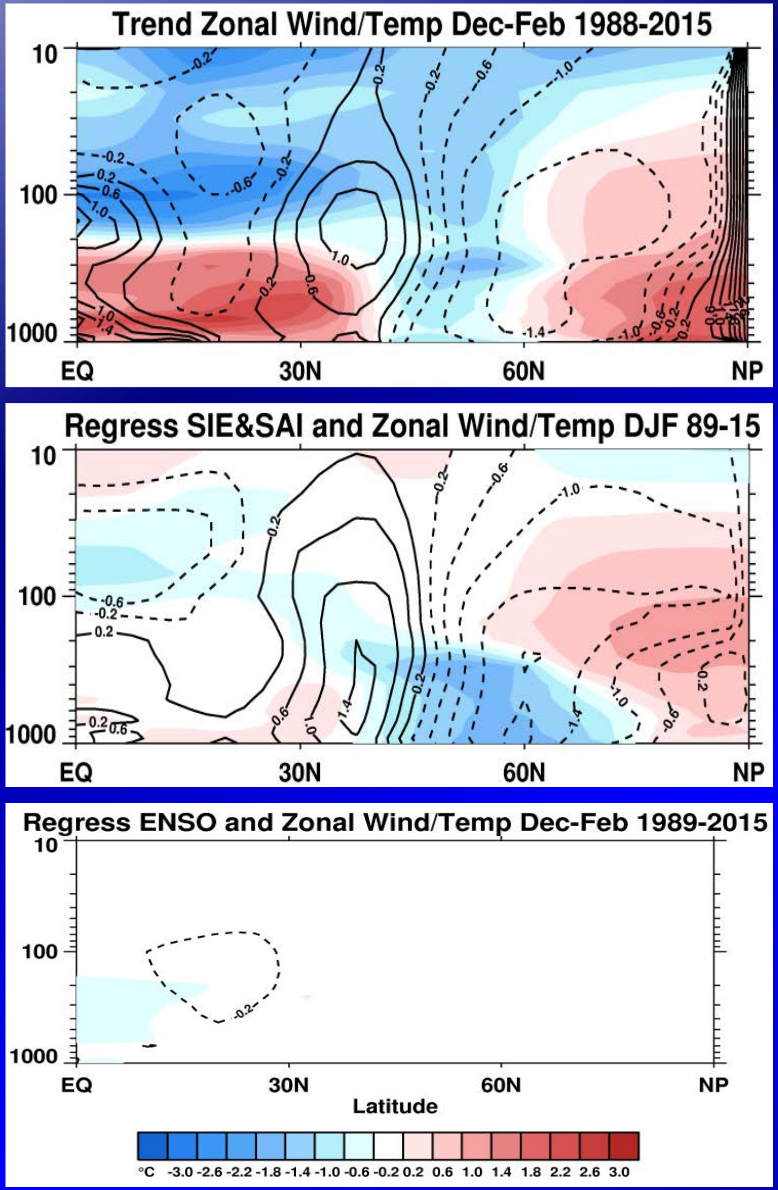
Extras

ERA5
Oct to Feb 2000-2021

850mb Air Temperature Anomaly 1981-2010 Climatology



Arctic versus ENSO impacts on winter (DJF) zonal-mean zonal winds and temperatures.

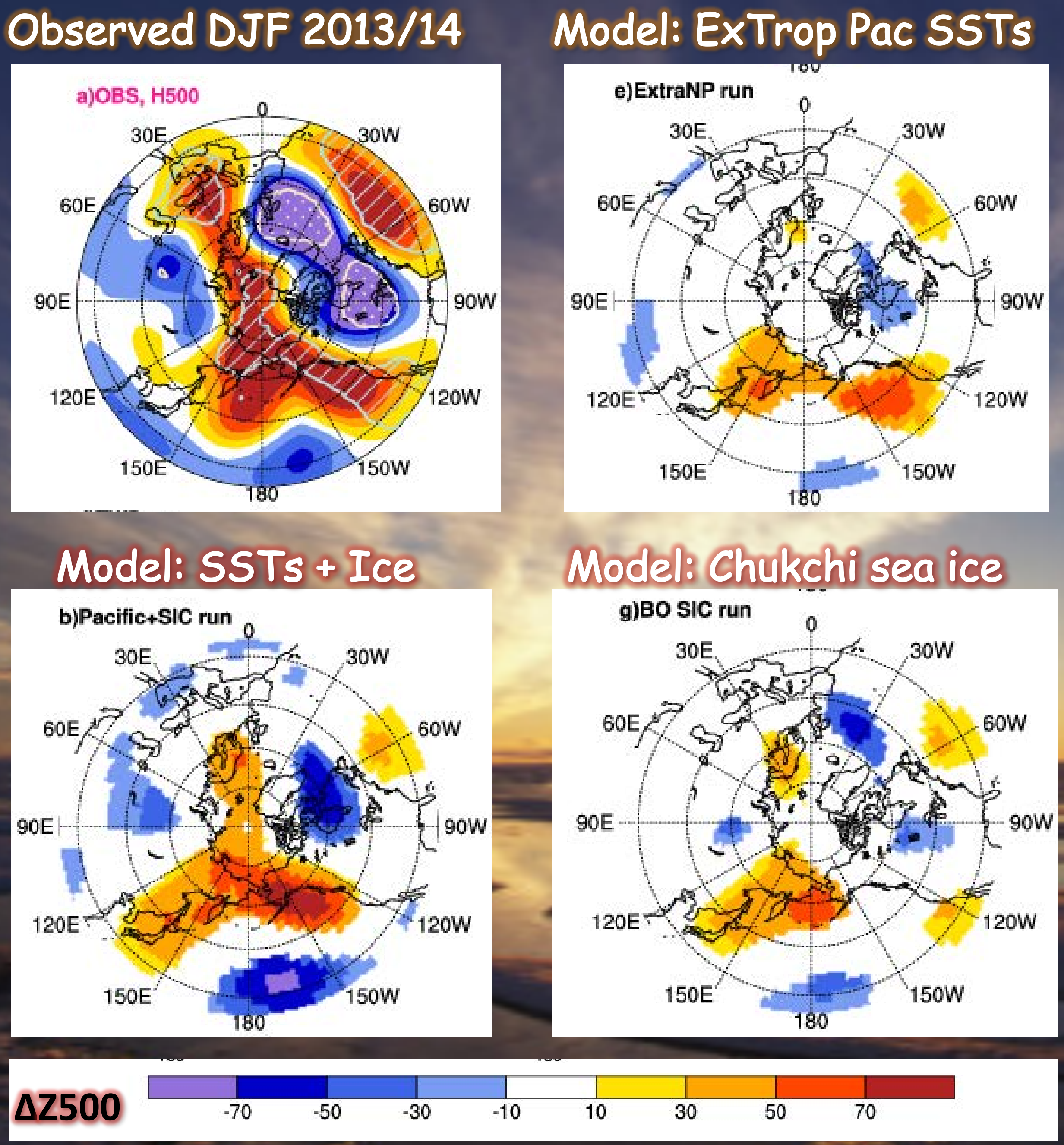


Observed trends in U (contours) and continental T (color)

Portion of trends explained by Barents/Kara ice loss in Nov. and Eurasian snow advance in Oct.
=> Cooling over mid-latitude continents and U contours similar to observed trends.

Portion of observed trends explained by ENSO.
=> None in mid-latitudes.

Cohen GRL 2016

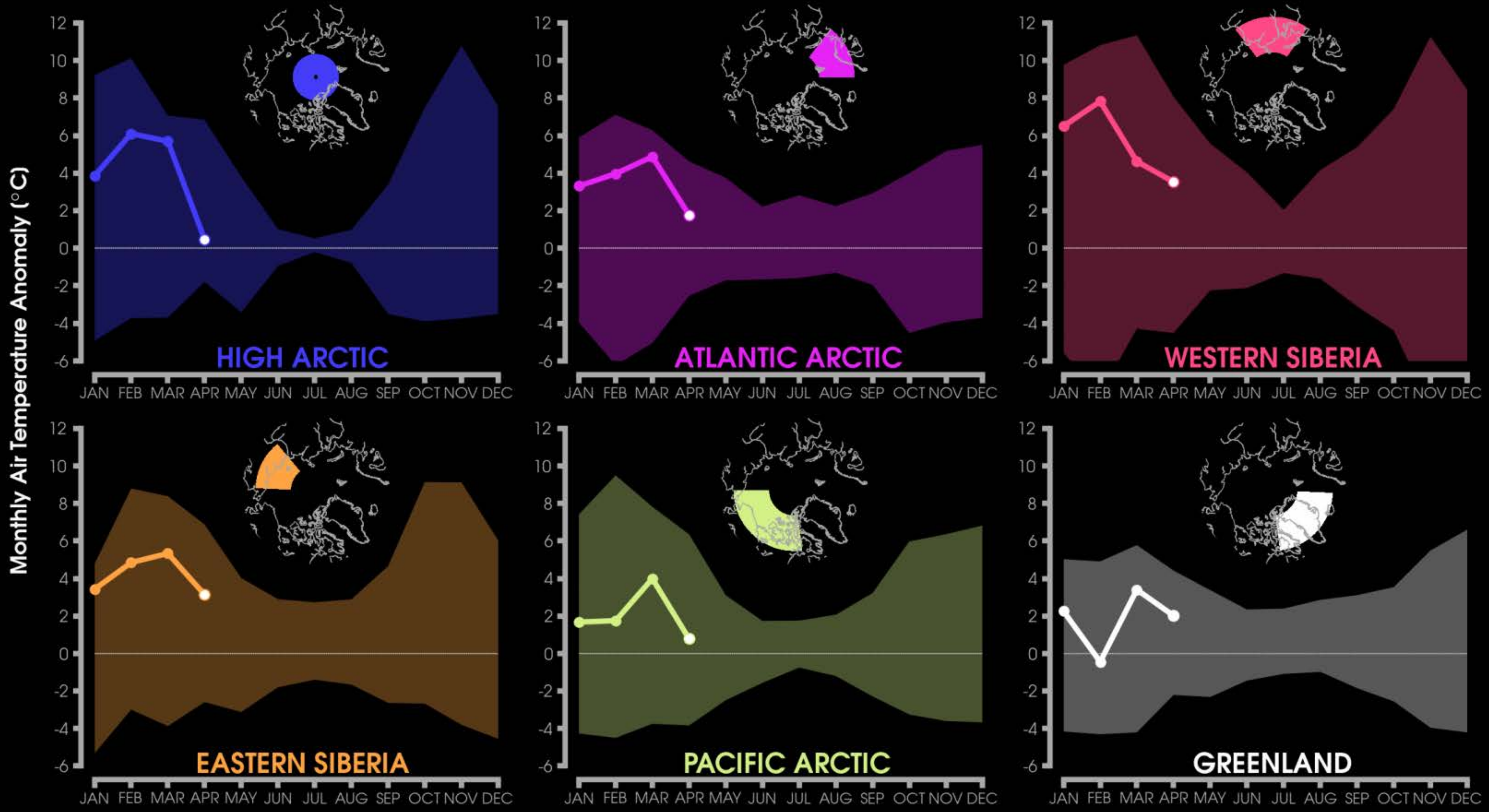


Pacific ridge initiated by SST anomalies (PDO+) is intensified by ice loss in Pacific sector of Arctic

=> Stronger ridge more persistent

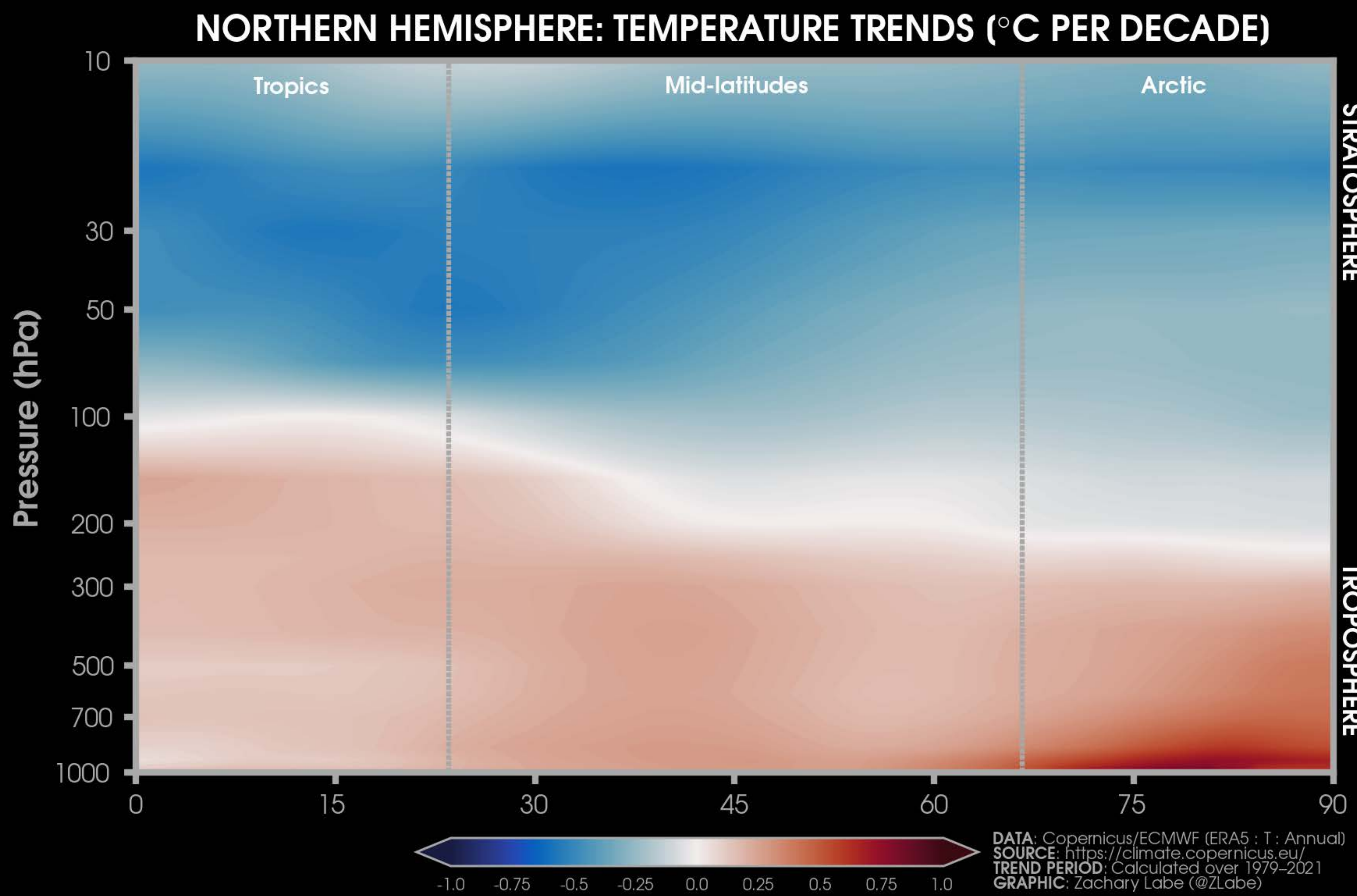
Lee et al, GRL 2015

REGIONAL TEMPERATURE ANOMALIES IN 2022



DATA: Copernicus Climate Change Service/ECMWF (*Preliminary* ERA5/ERA5T : 2-m T : Shading (records) from 1950-2021)
SOURCE: https://climate.copernicus.eu/
GRAPHIC: Zachary Labe (@ZLabe)

BASELINE: 1951-1980



NORTHERN HEMISPHERE: TEMPERATURE TRENDS (°C PER DECADE)
Tropics
Mid-latitudes
Arctic
STRATOSPHERE
TROPOSPHERE
Pressure (hPa)
10
30
50
100
200
300
500
700
1000
0
15
30
45
60
75
90
-1.0
-0.75
-0.5
-0.25
0.0
0.25
0.5
0.75
1.0
DATA: Copernicus/ECMWF (ERA5 : T : Annual)
SOURCE: https://climate.copernicus.eu/
TREND PERIOD: Calculated over 1979–2021
GRAPHIC: Zachary Labe (@ZLabe)