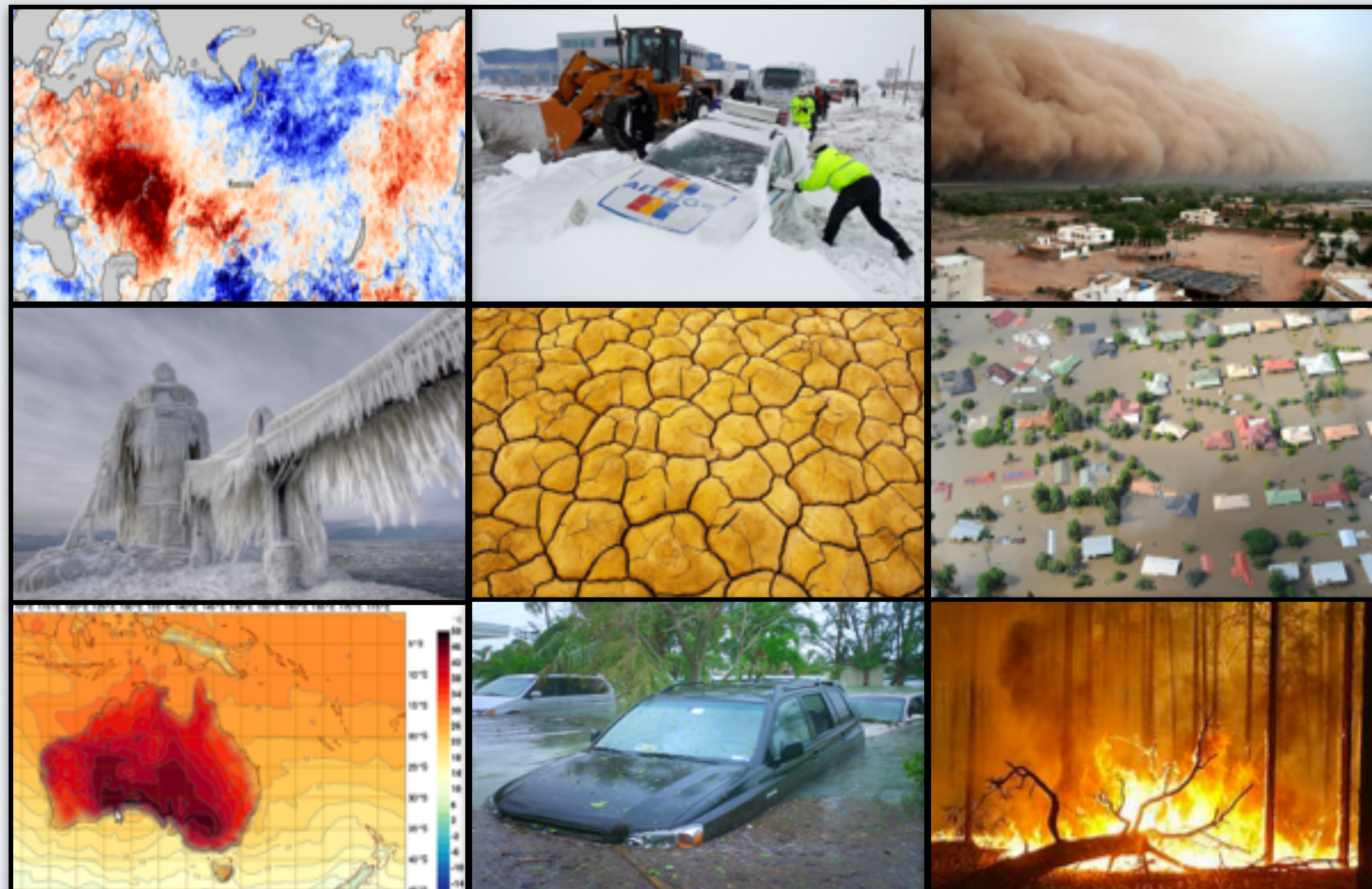
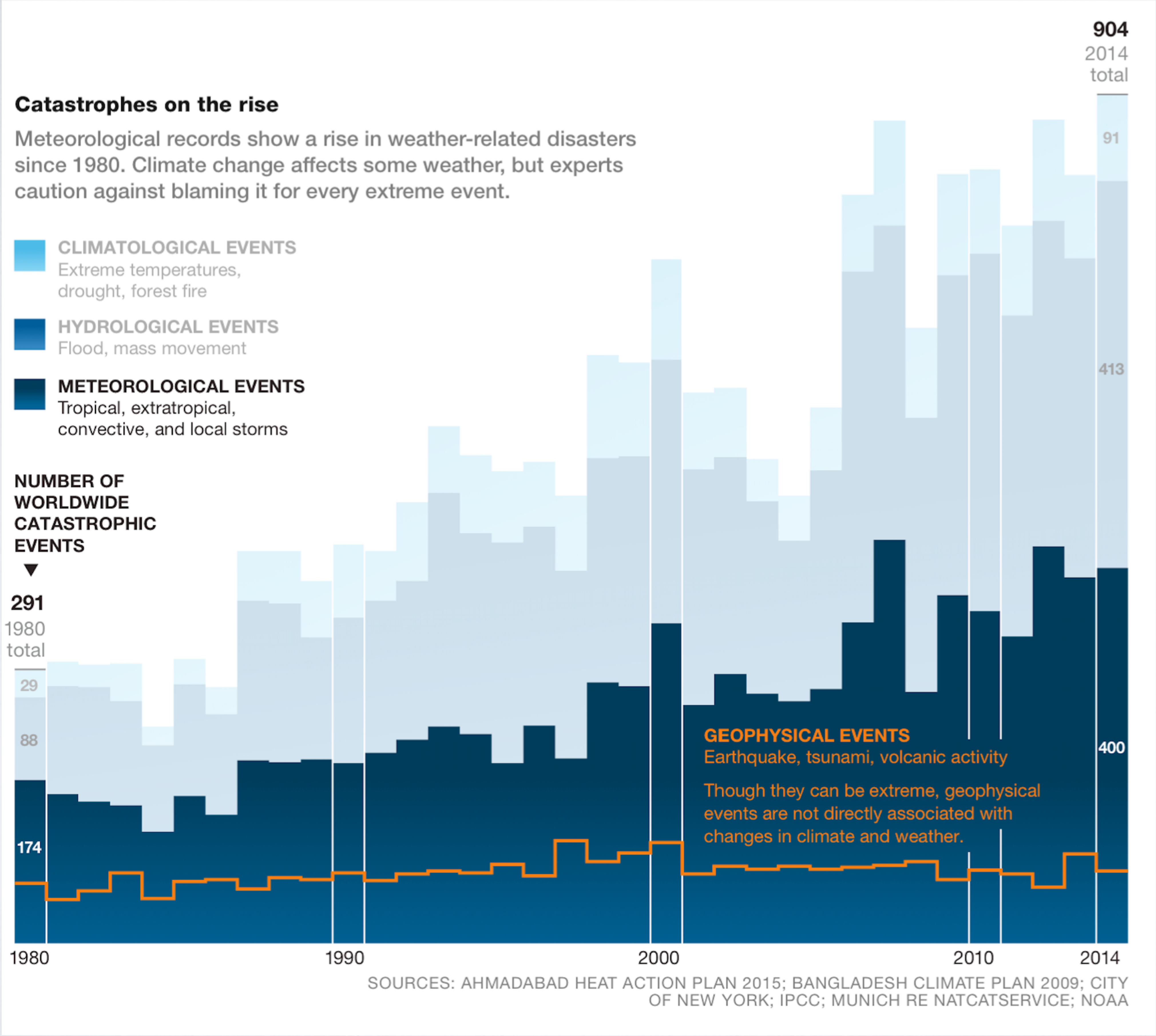
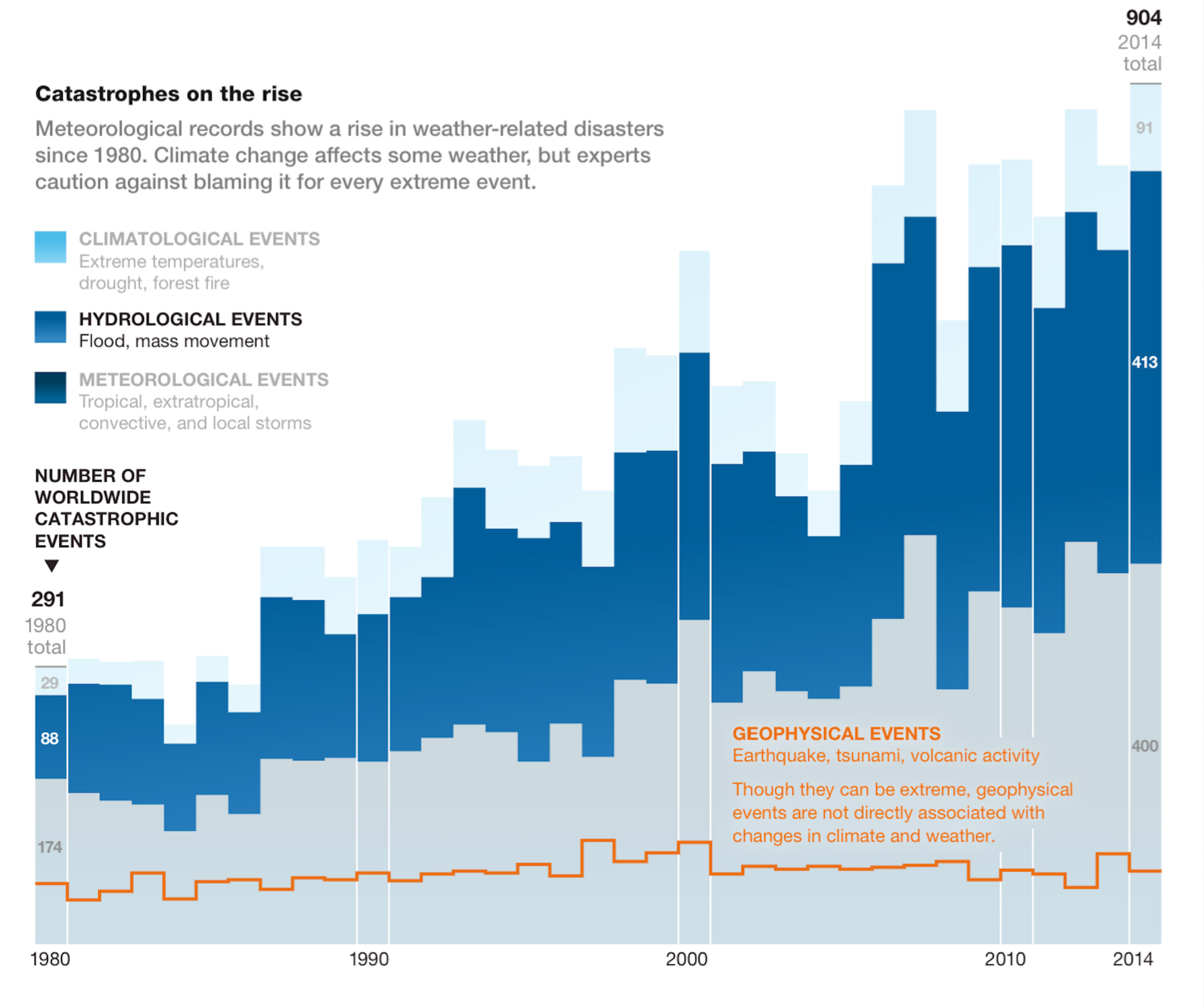
Cold Waves in a Warming World and Their Sub-seasonal Prediction



Baek-Min Kim, Korea Polar Research Institute


904
2014 total
Catastrophes on the rise
Meteorological records show a rise in weather-related disasters since 1980. Climate change affects some weather, but experts caution against blaming it for every extreme event.
CLIMATOLOGICAL EVENTS
Extreme temperatures, drought, forest fire
HYDROLOGICAL EVENTS
Flood, mass movement
METEOROLOGICAL EVENTS
Tropical, extratropical, convective, and local storms
NUMBER OF WORLDWIDE CATASTROPHIC EVENTS
291
1980 total
29
88
174
91
413
400
GEOPHYSICAL EVENTS
Earthquake, tsunami, volcanic activity
Though they can be extreme, geophysical events are not directly associated with changes in climate and weather.
1980
1990
2000
2010
2014
SOURCES: AHMADABAD HEAT ACTION PLAN 2015; BANGLADESH CLIMATE PLAN 2009; CITY OF NEW YORK; IPCC; MUNICH RE NATCATSERVICE; NOAA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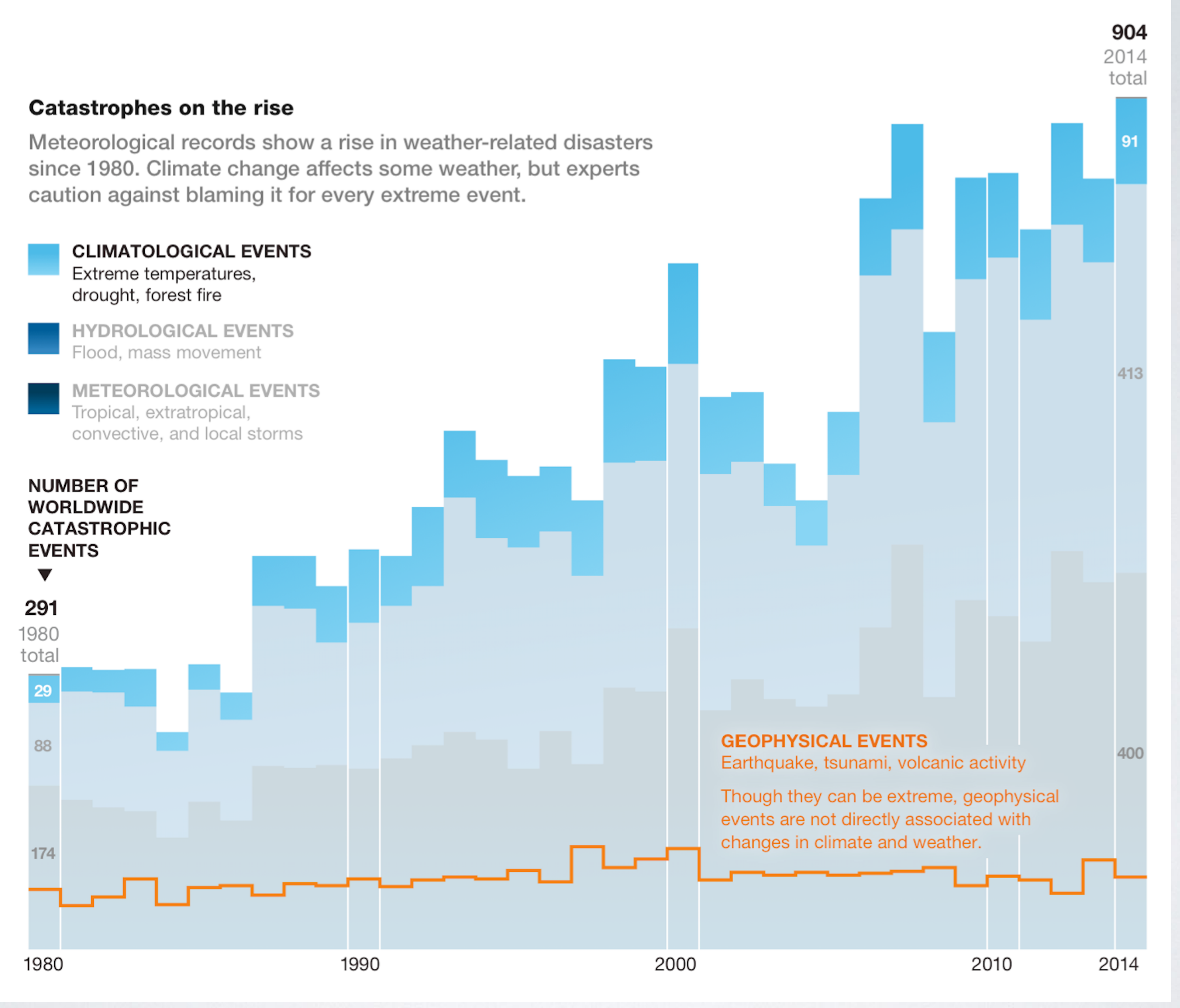

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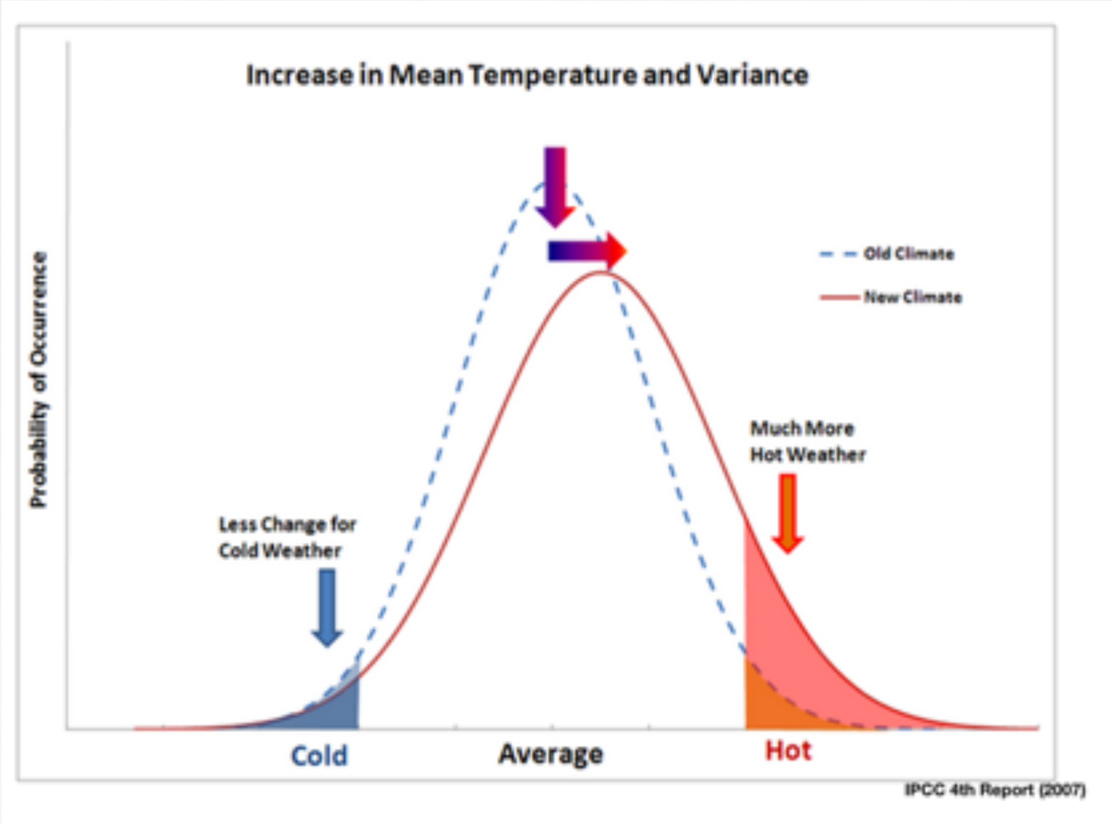
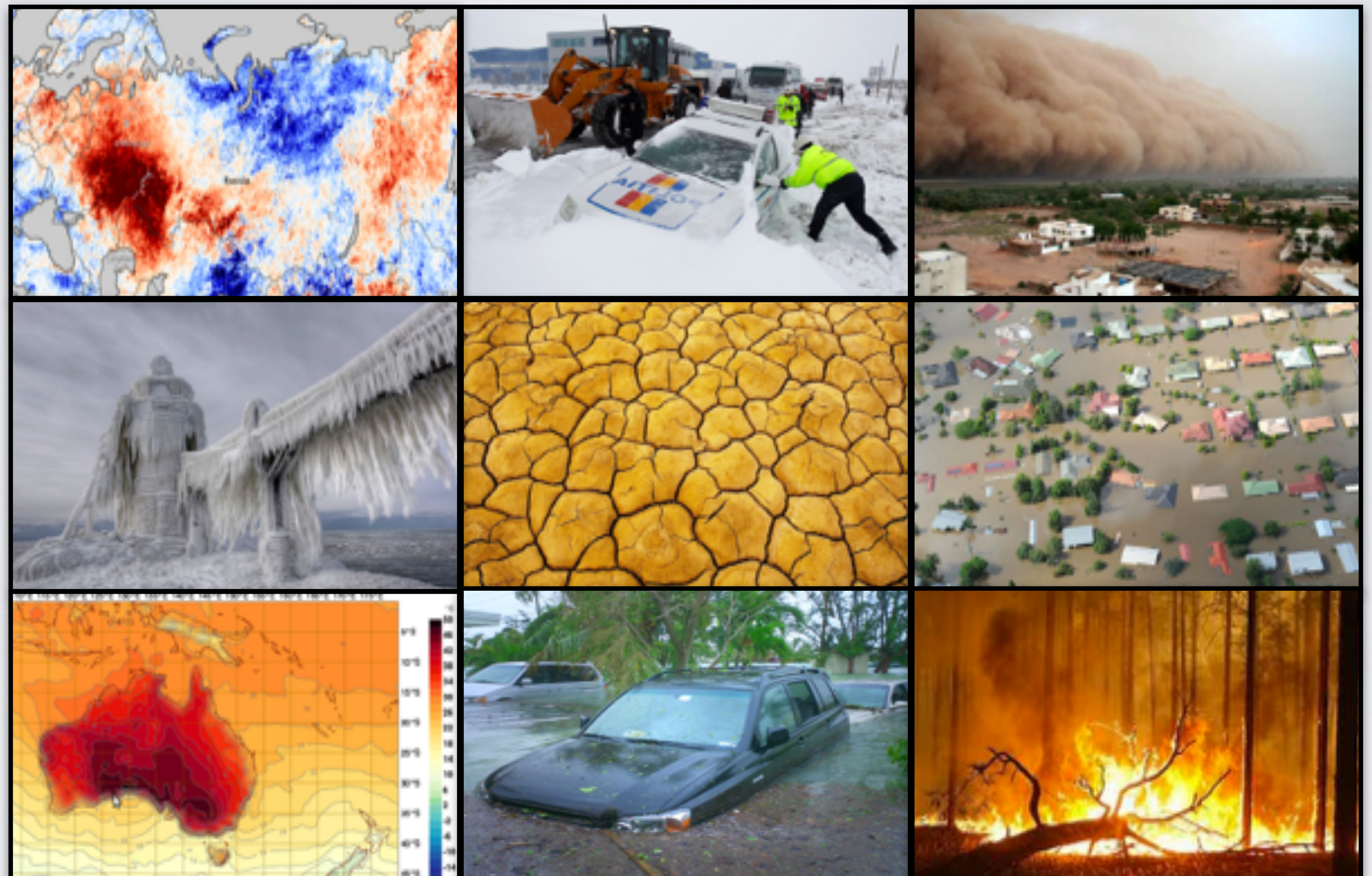
Global Warming & Extreme Weather: A general view

- Broadening of PDF
  - Increase in variability
- Shift of mean
  - Toward warmer climate
  - Increase in humidity
  - Increase in (heavy) rain



Partly explain…



December, 2009

- “Biggest cold surge in historical record”-MBC
- “Extremely negative Arctic Oscillation played as a culprit”-KBS
- “Warm Arctic air pushed cold air southward” -Joongang News

February, 2012

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Early 2012 European cold wave

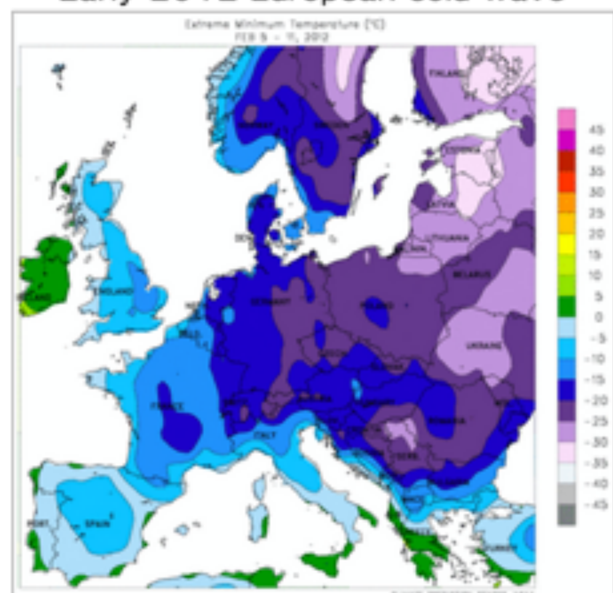
From Wikipedia, the free encyclopedia

あ→A This article may be expanded with text translated from the corresponding article in the German Wikipedia. *(February 2012)*
Click [show] on the right to read important instructions before translating. [show]

The Early 2012 European cold wave was a deadly cold wave that started on January 27, 2012 and brought snow and freezing temperatures to much of the European continent. There were 824+ deaths reported.[1] Particularly low temperatures hit several Eastern and Northern European countries, reaching as low as −39.2 ° C (−38.6 ° F) in Finland. The heaviest snow was recorded in the Balkan region.

Contents [hide]

Early 2012 European cold wave



Extreme minimum temperature 4 to 11 February 2012, computer generated contours, based on preliminary data.

Formed	January 27, 2012
Dissipated	February 17, 2012
Lowest temperature	−39.2 ° C (−38.6 ° F) (February 2, Kuusamo, Finland)
Damage	$660 million (2012 USD)[1]
Fatalities	1,040+[1]
Areas affected	Europe and North Africa

Countries affected [edit]

Effects [edit]

Eastern, Northern and Western Europe [edit]

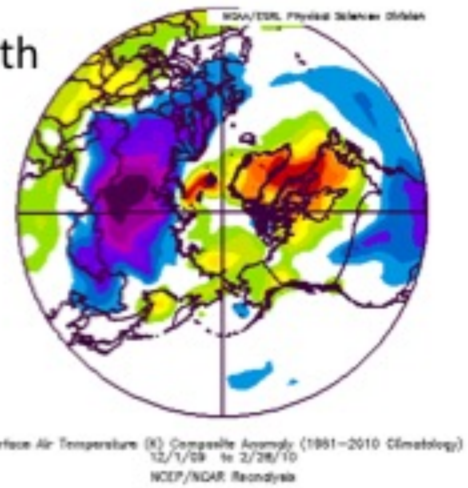
The northern half of Europe was affected primarily by greater cold and – except for a

January, 2014

Multiple patterns

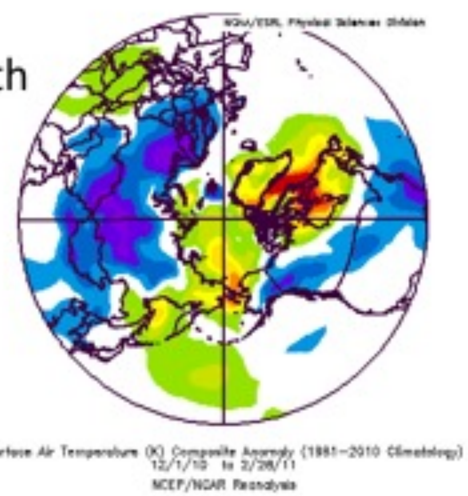
2009/10 DJF

Both



2010/11 DJF

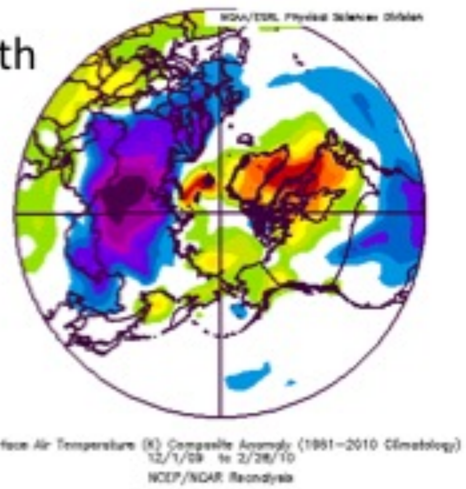
Both



Multiple patterns

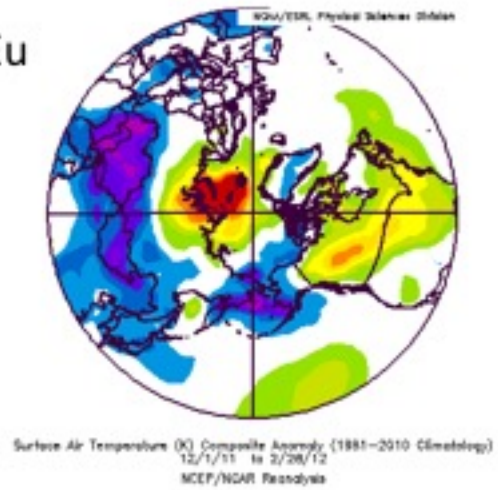
2009/10 DJF

Both



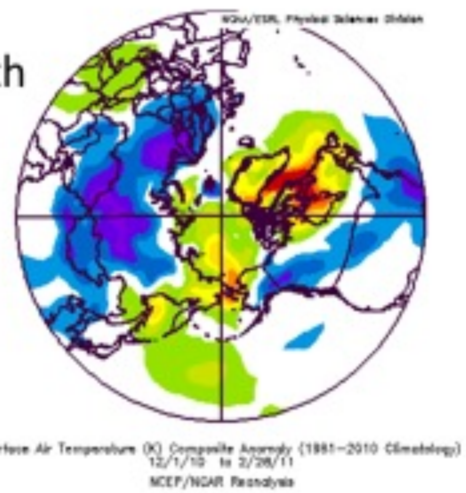
2011/12 DJF

Eu



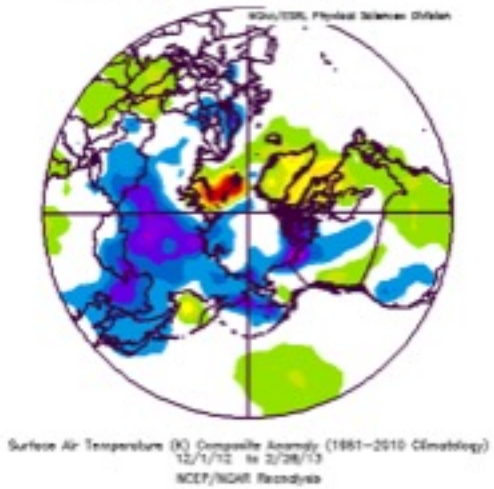
2010/11 DJF

Both

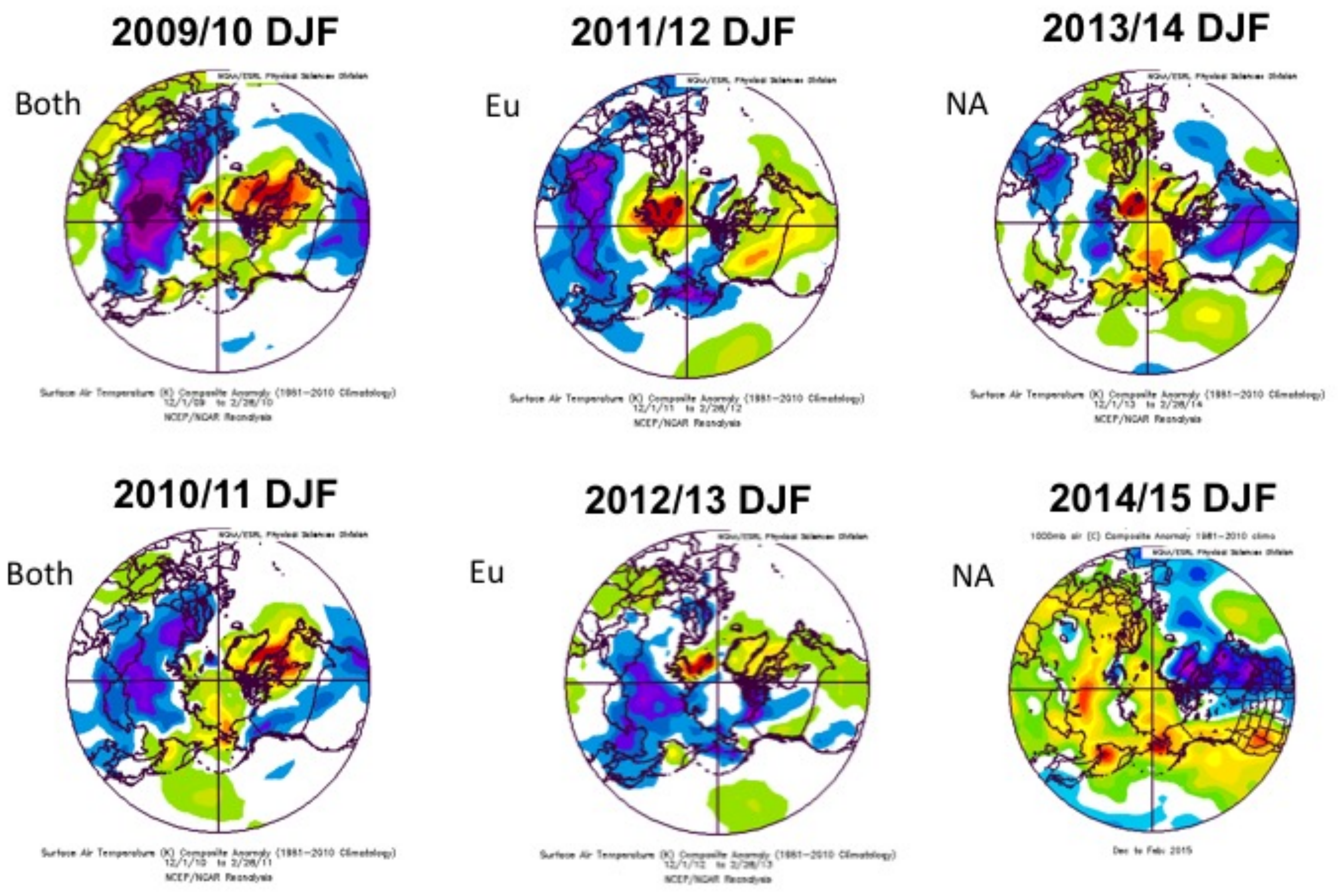


2012/13 DJF

Eu



Multiple patterns



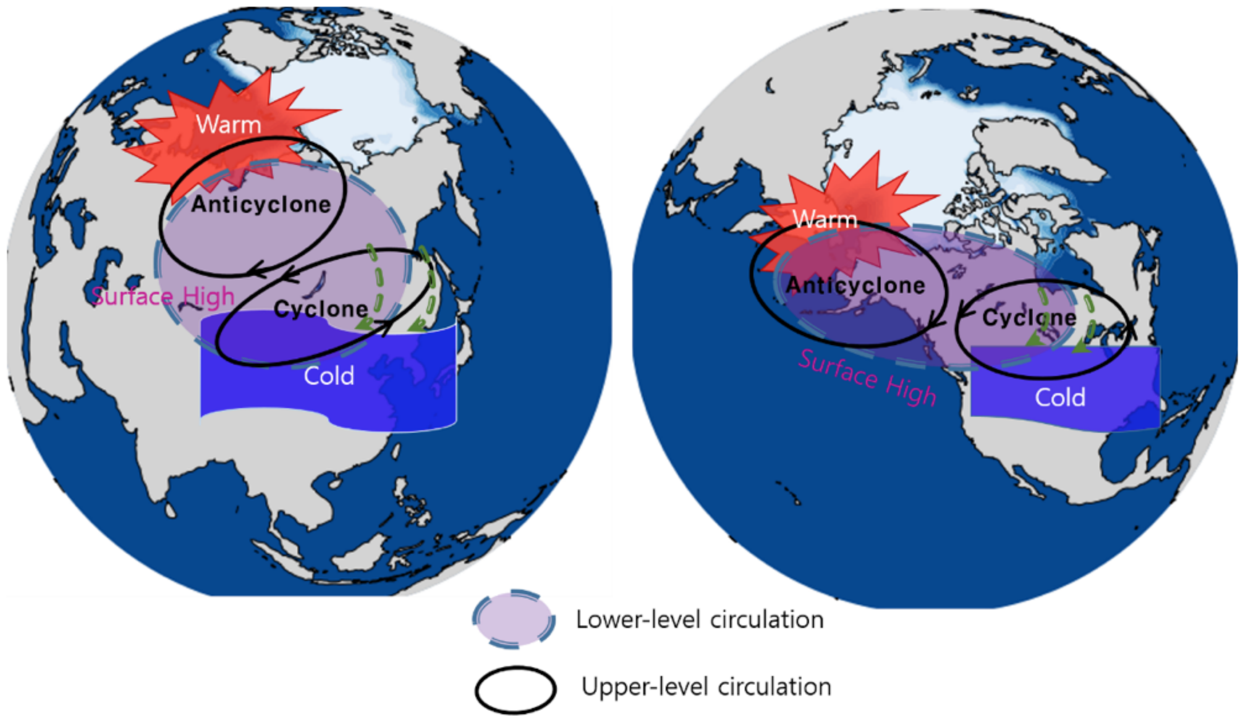
nature geoscience

LETTERS

PUBLISHED ONLINE: 31 AUGUST 2015 | DOI: 10.1038/NGEO2517

Two distinct influences of Arctic warming on cold winters over North America and East Asia

Jong-Seong Kug[1], Jee-Hoon Jeong[2*], Yeon-Soo Jang[1], Baek-Min Kim[3], Chris K. Folland[4,5], Seung-Ki Min[1] and Seok-Woo Son[6]



WHY INCREASING COLD WAVES IN A WARMING WORLD?

- A growing number of studies have found pronounced changes in atmospheric circulation due to Arctic sea-ice loss, including changes in the tropospheric jet stream that may lead to cold extremes over Eurasia and North America.

  -See Vihma (Survey of Geophysics, 2014) for comprehensive reviews…

- "It's an interesting idea, but alternative observational analyses and simulations with climate models have not confirmed the hypothesis, and we do not view the theoretical arguments underlying it as compelling"

  -Global Warming & Winter Weather by Wallace, Held, Thompson, Trenberth, and Walsh (Science, 2014)

WHY INCREASING COLD WAVES IN A WARMING WORLD?

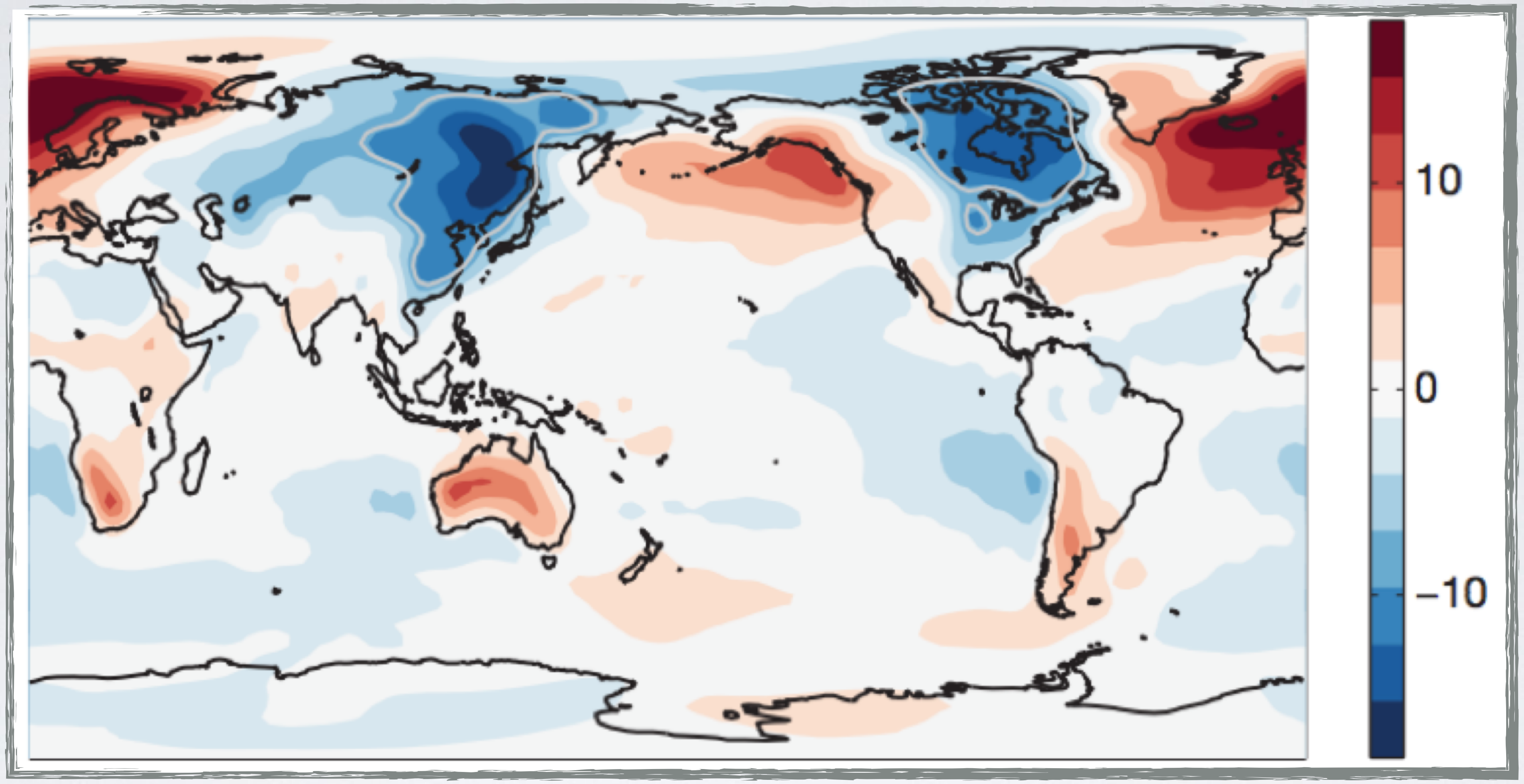
But, note that:
Global warming-extreme link just relies on the thermodynamic arguments
Extremes heavily rely on the regional circulation patterns and, therefore, atmospheric dynamics that generate the circulation!

WHY INCREASING COLD WAVES IN A WARMING WORLD?

But, note that:
Global warming-extreme link just relies on the thermodynamic arguments
Extremes heavily rely on the regional circulation patterns and, therefore, atmospheric dynamics that generate the circulation!

Then what is the source of the regional circulation pattern?

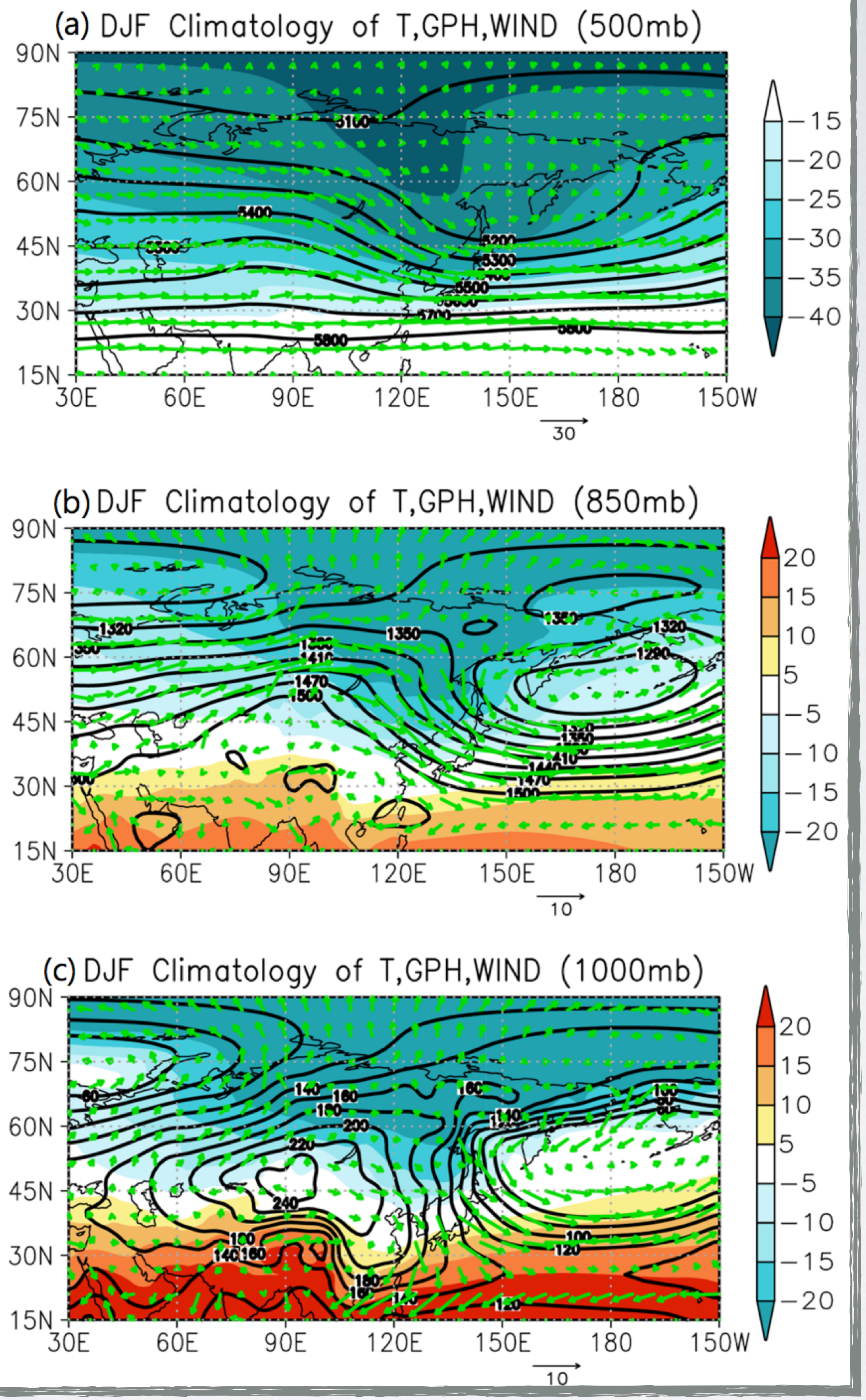
Topic 1: Basic understanding of East Asian cold waves in a dynamic perspective



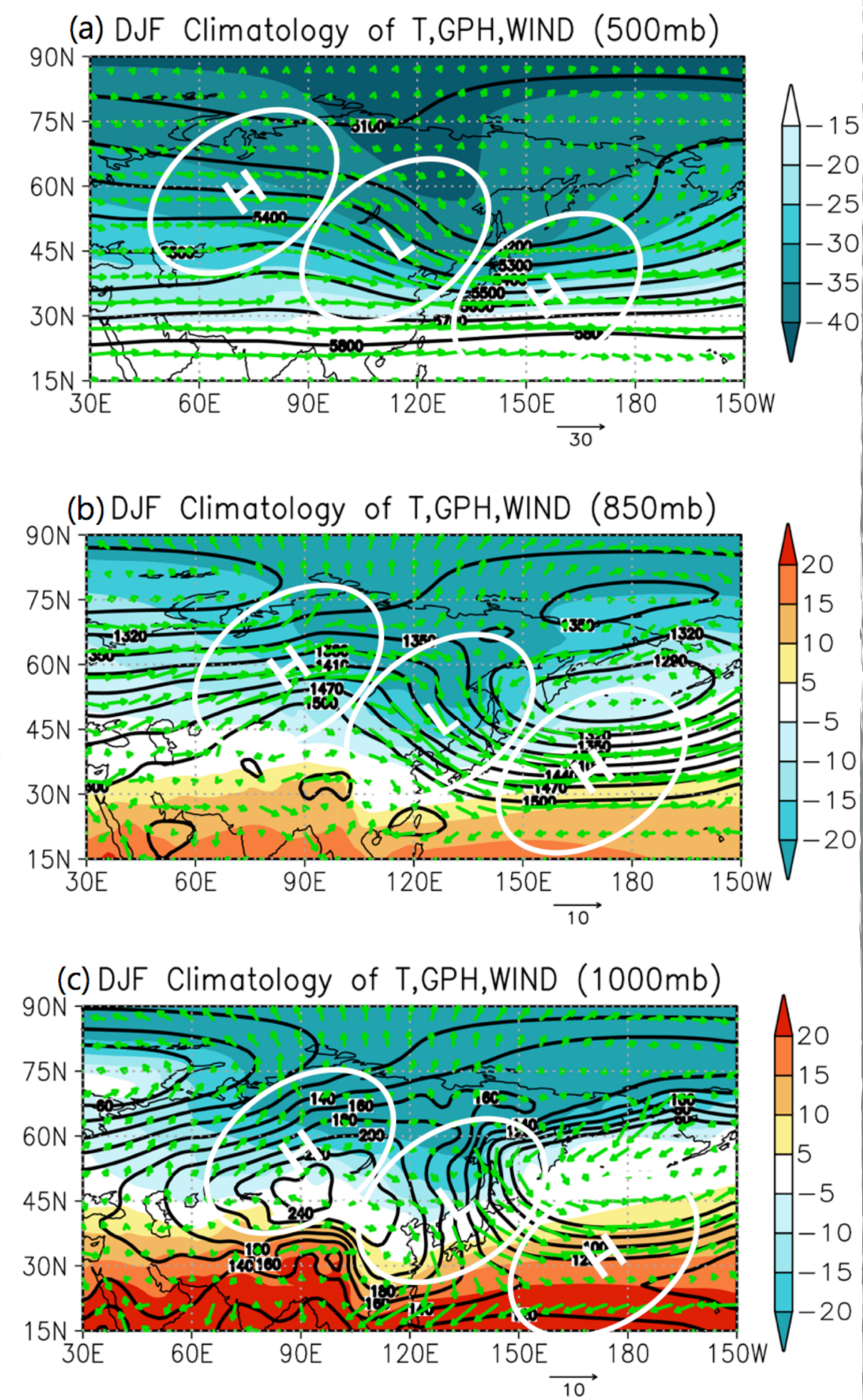
Observed Northern hemisphere winter (December-February) months surface temperature deviation (K) from zonal mean (-8K conotour shown in grey, pointing to the similarity between the width of the cold regions in America and Asia)

From Figure 1 of Kaspi and Schneider (2011).

Type I: Wave-driven Cold Surge (East-Asia, North-America)



(a) DJF Climatology of T,GPH,WIND (500mb)
90N
75N
60N
45N
30N
15N
30E
60E
90E
120E
150E
180
150W
30
-15
-20
-25
-30
-35
-40
(b) DJF Climatology of T,GPH,WIND (850mb)
10
20
15
10
5
-5
-10
-15
-20
(c) DJF Climatology of T,GPH,WIND (1000mb)
10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75N
60N
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30N
15N
30E
60E
90E
120E
150E
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150W
30
H
L
H
-15
-20
-25
-30
-35
-40
(b) DJF Climatology of T,GPH,WIND (850mb)
10
20
15
10
5
-5
-10
-15
-20
(c) DJF Climatology of T,GPH,WIND (1000mb)
10

Type II:Convectively-driven Cold Surge (South East-Asia)

Northeasterly Cold Surges and Near-Equatorial Disturbances over the Winter MONEX Area During December 1974. Part II: Planetary-Scale Aspects

C.-P. CHANG AND K. M. W. LAU

Department of Meteorology, Naval Postgraduate School, Monterey, CA 93940

(Manuscript received 11 June 1979, in final form 7 December 1979)

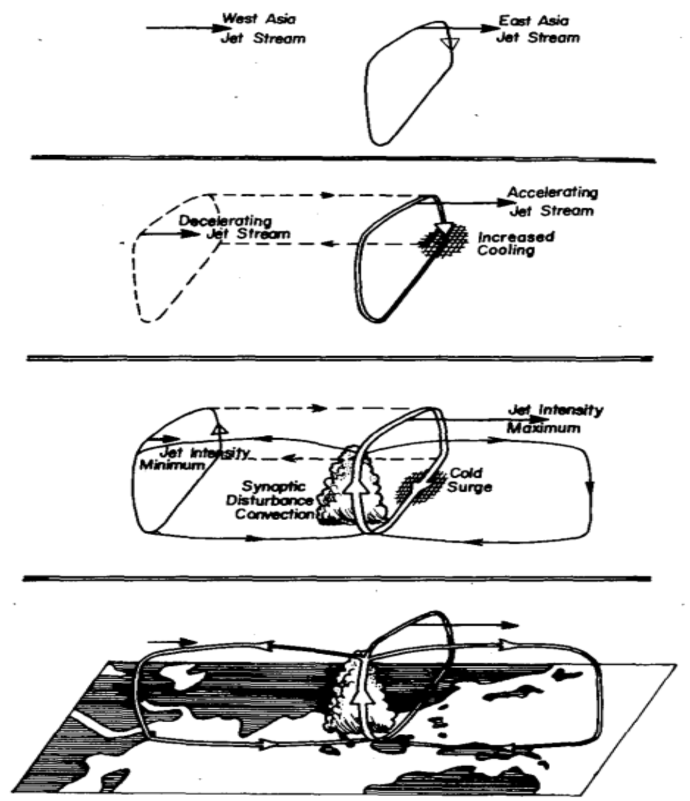
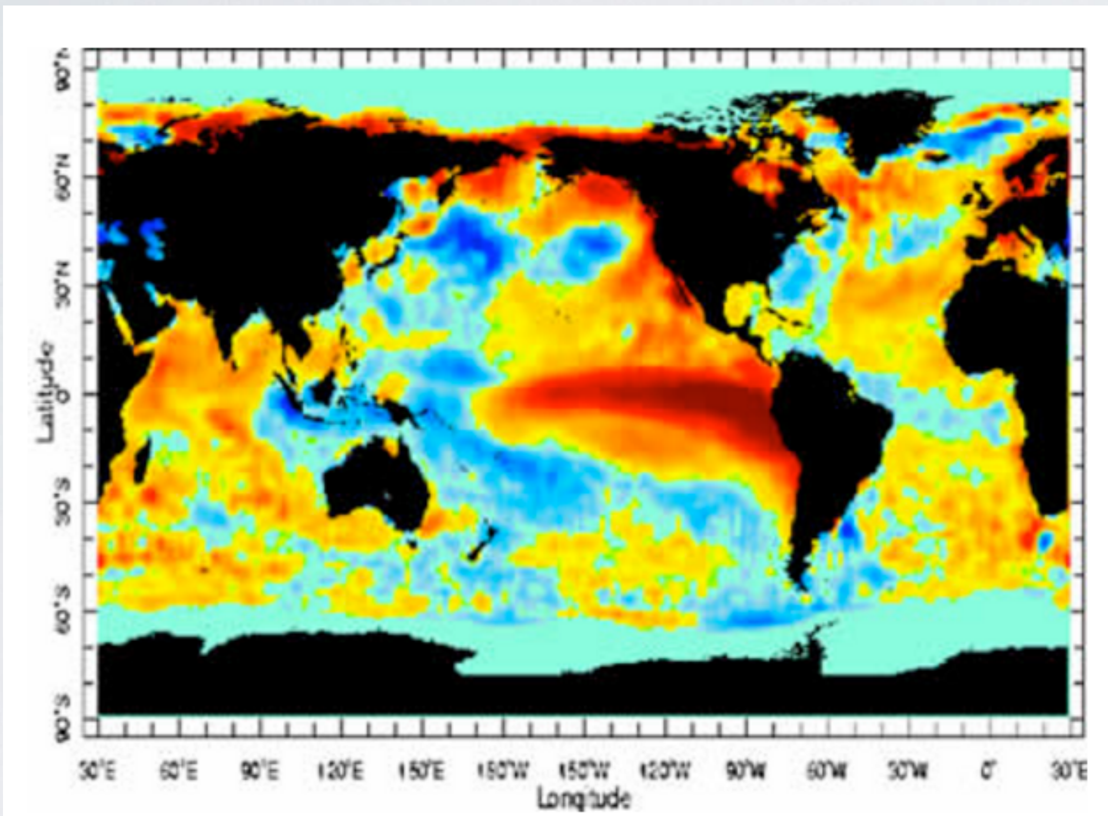
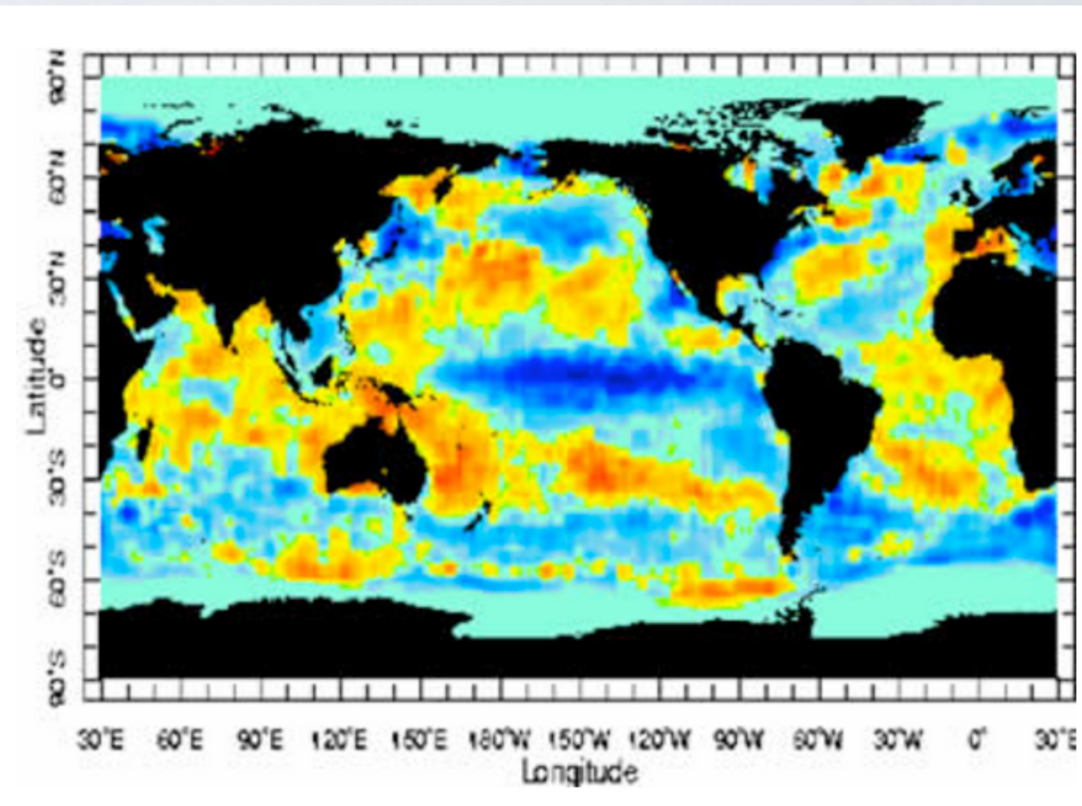


FIG. 14. Schematic diagram showing the sequence of events before and after the cold surge in the South China Sea. See text for details.

Key players are:

1) ENSO
2) MJO





97/98 El Nino

98/99 La Nina

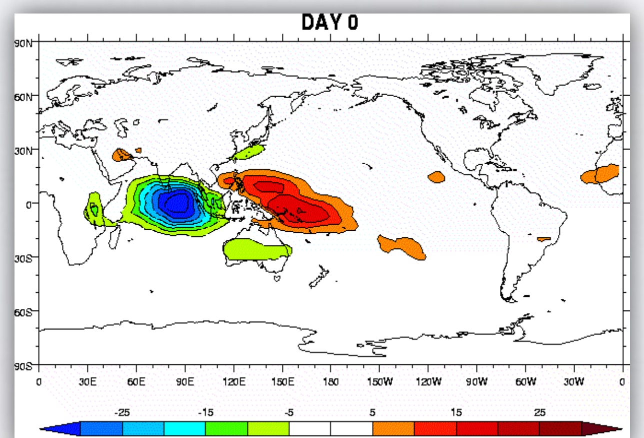
MJO-JET RELATION

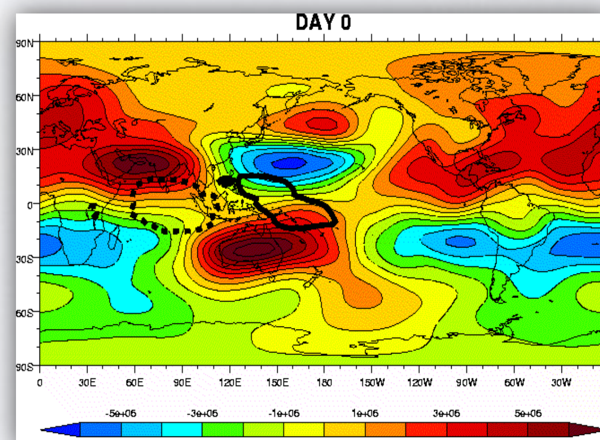
Q. J. R. Meteorol. Soc. (2006), **132**, pp. 485–503 doi: 10.1256/qj.04.87

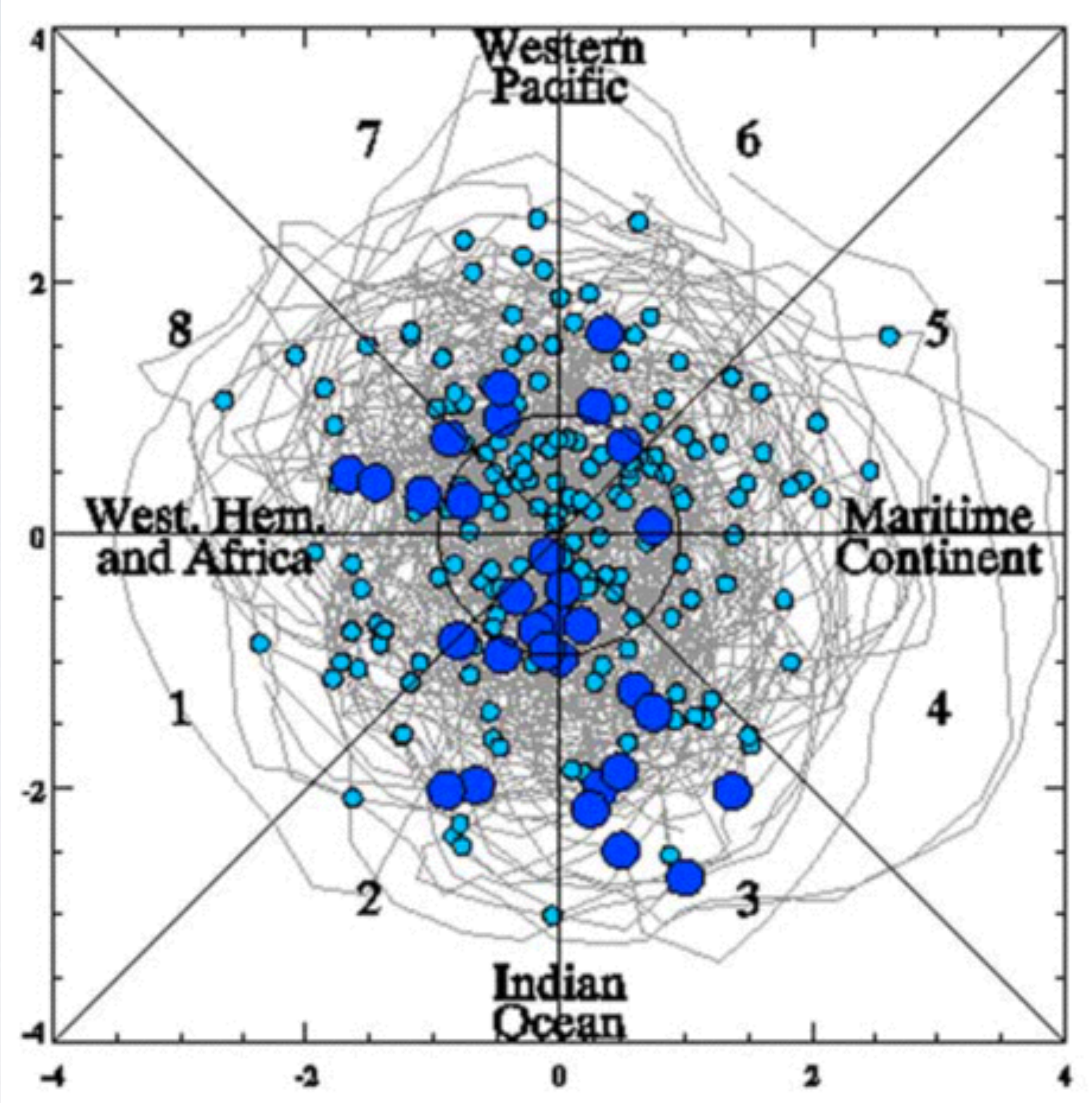
A new look at the midlatitude–MJO teleconnection in the northern hemisphere winter

By BAEK-MIN KIM[1]*, GYU-HO LIM[1] and KWANG-YUL KIM[2]
[1]*Seoul National University, Seoul, Korea*
[2]*Florida State University, Florida, USA*

(Received 3 June 2004; revised 22 July 2005)







Western Pacific
West. Hem. and Africa
Maritime Continent
Indian Ocean
1
2
3
4
5
6
7
8
4
2
0
-2
-4

MJO-JET RELATION

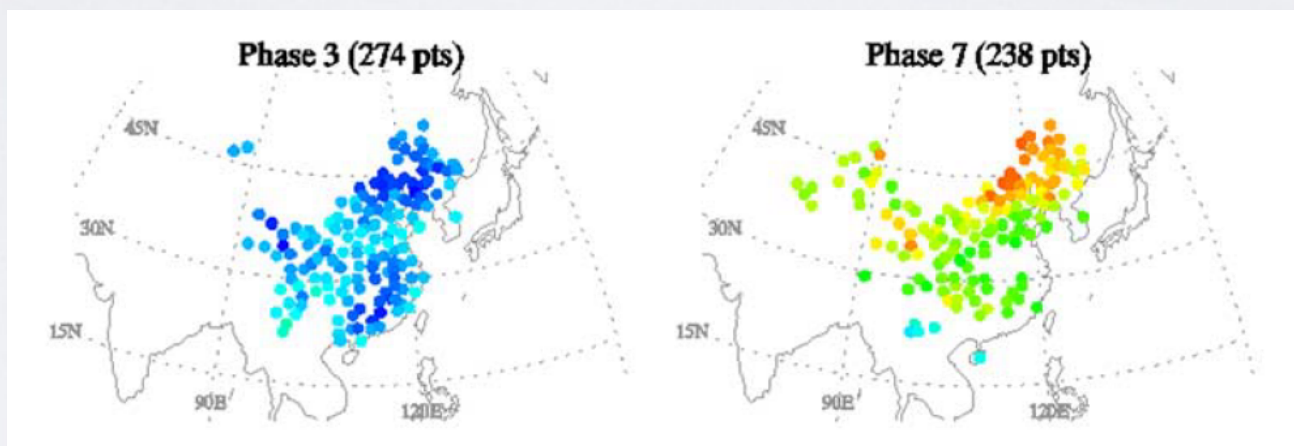
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 110, D11104, doi:10.1029/2004JD005408, 2005

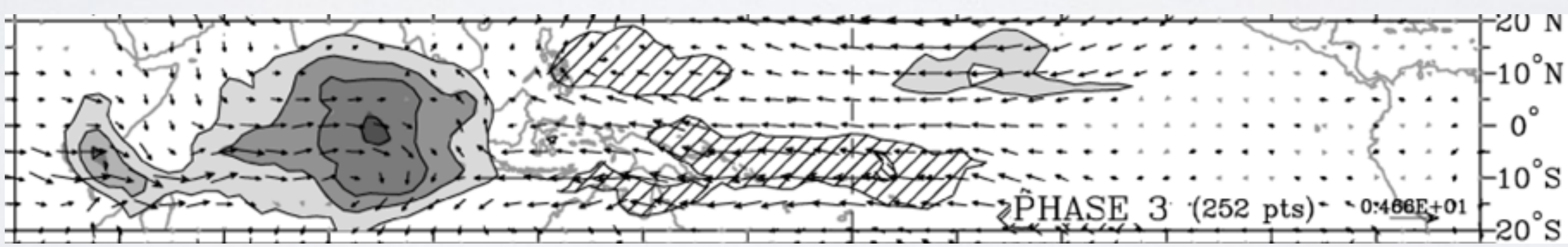
Influence of the Madden-Julian Oscillation on wintertime surface air temperature and cold surges in east Asia

Jee-Hoon Jeong, Chang-Hoi Ho, and Baek-Min Kim
School of Earth and Environmental Sciences, Seoul National University, Seoul, Korea

Won-Tae Kwon
Korea Meteorological Administration, Seoul, Korea

Received 31 August 2004; revised 11 November 2004; accepted 1 March 2005; published 4 June 2005.





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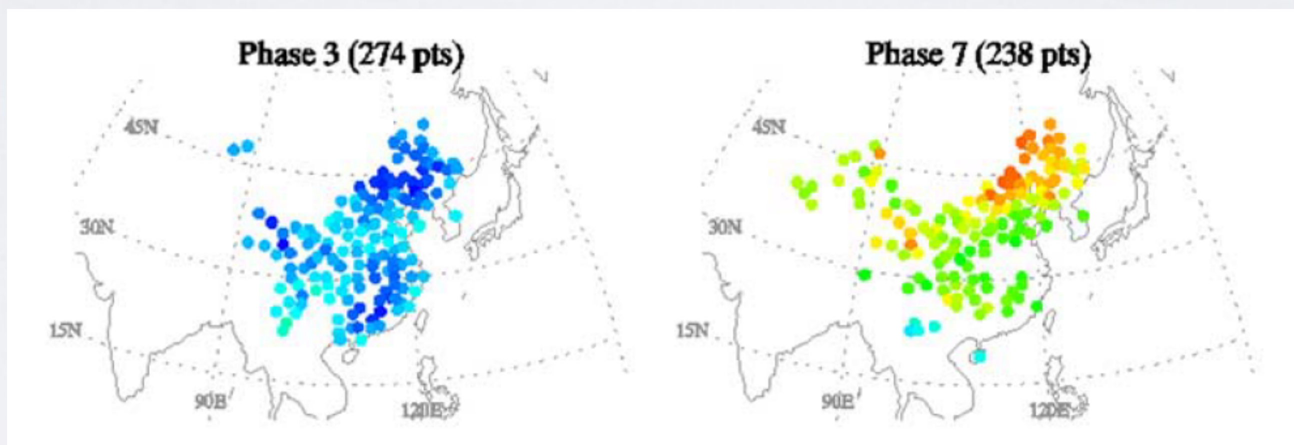
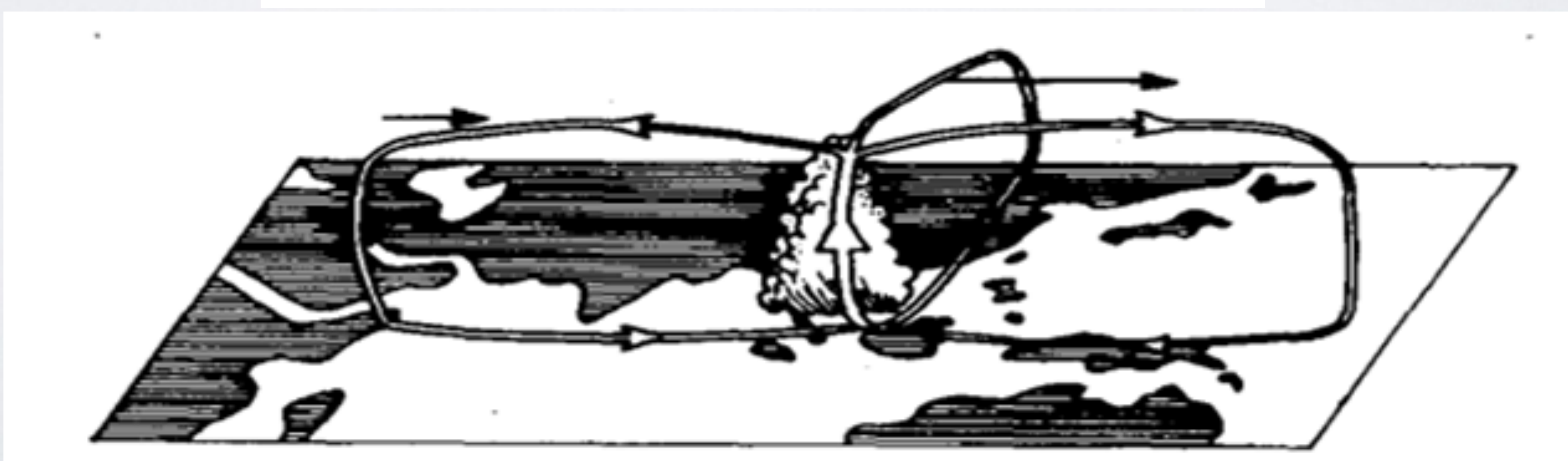


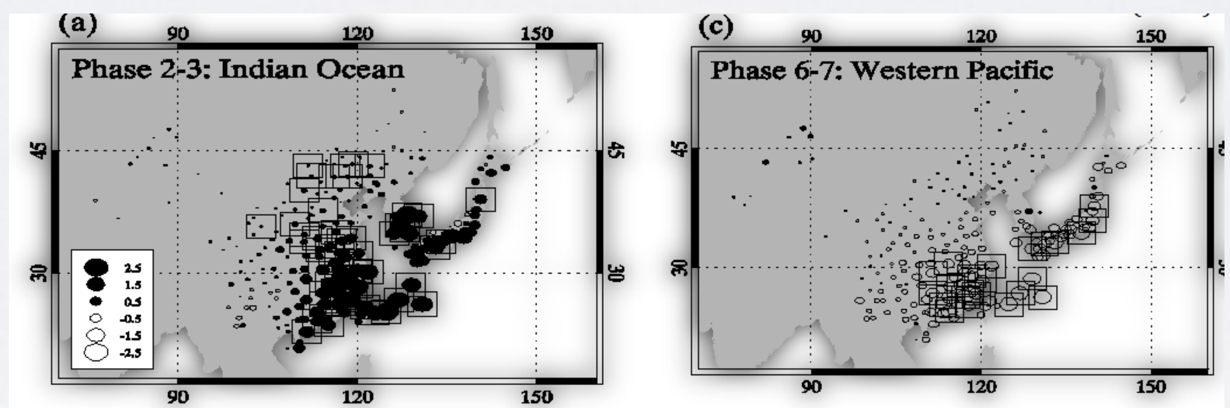


Systematic Variation in Wintertime Precipitation in East Asia by MJO-Induced Extratropical Vertical Motion

JEE-HOON JEONG, BAEK-MIN KIM, CHANG-HOI HO, AND YEON-HEE NOH

School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea

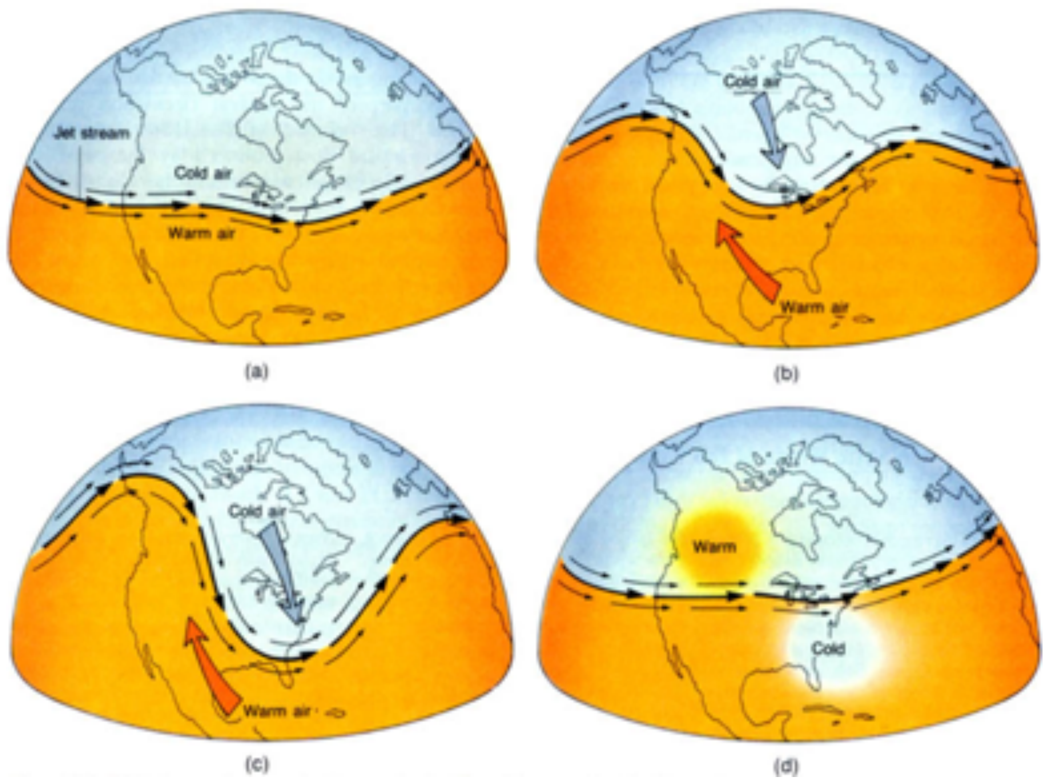
(Manuscript received 4 December 2006, in final form 20 June 2007)



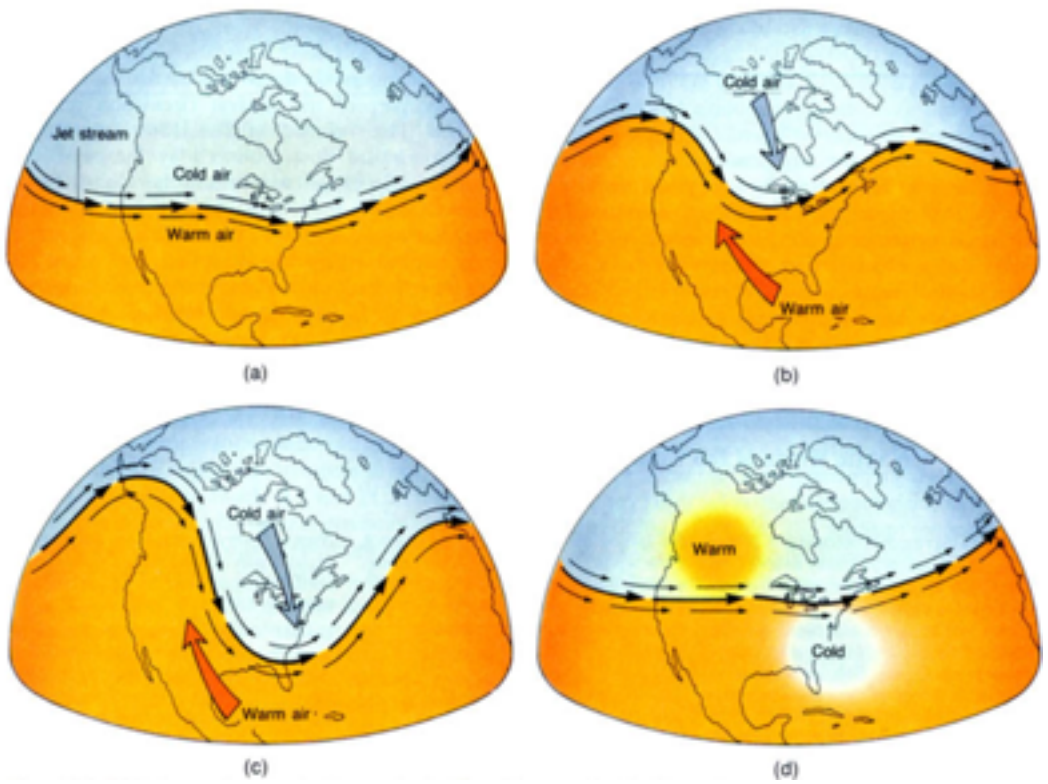
from Jeong *et al.* (2008)

Topic II: Arctic factors for Eurasian cold waves in a dynamic perspective

Polar Vortex



Polar Vortex



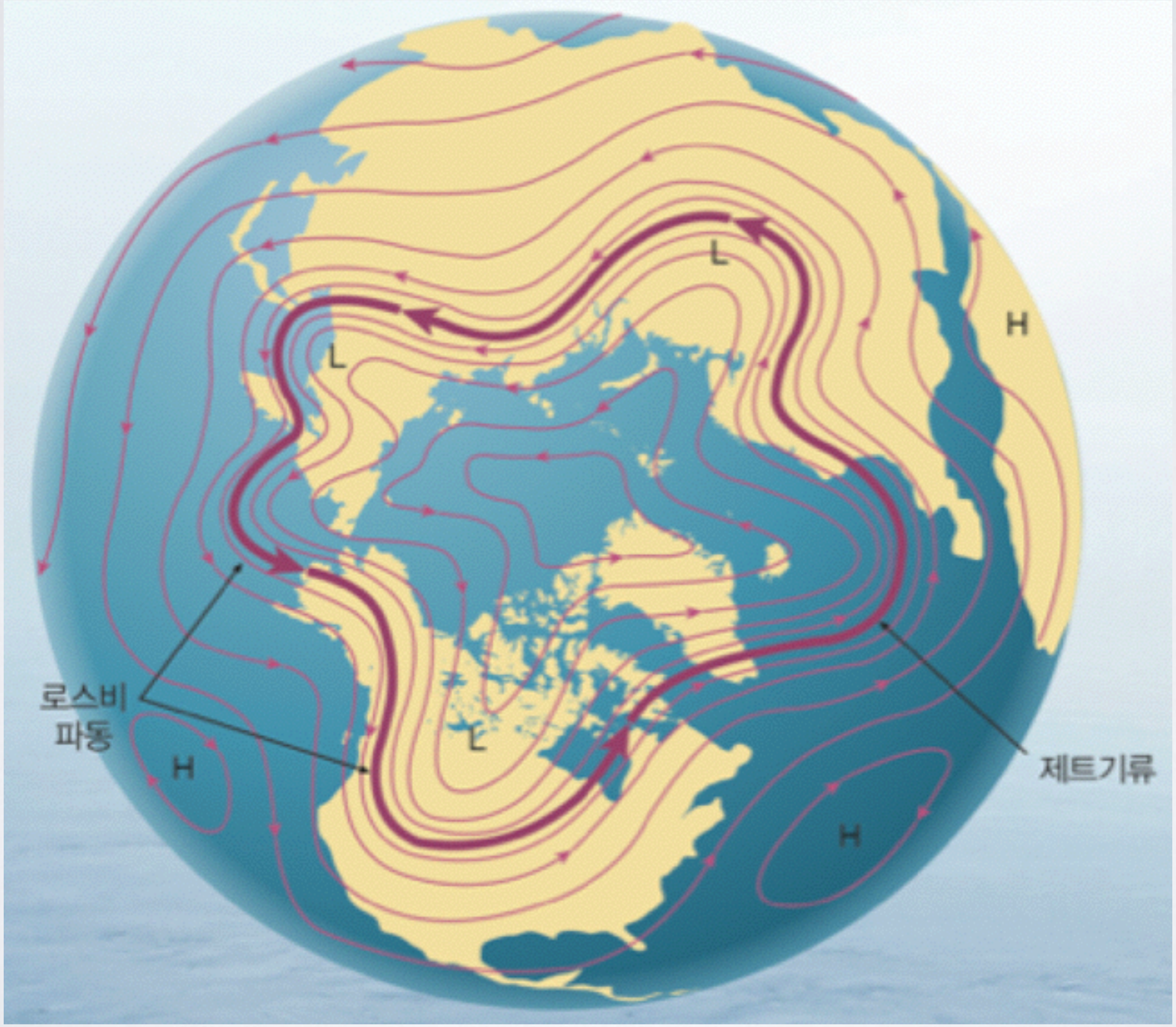
Cold (surface) Arctic & Dense air
-> upper-level strong cyclone

Existence of polar front & jet
<- a consequence from
thermal wind balance

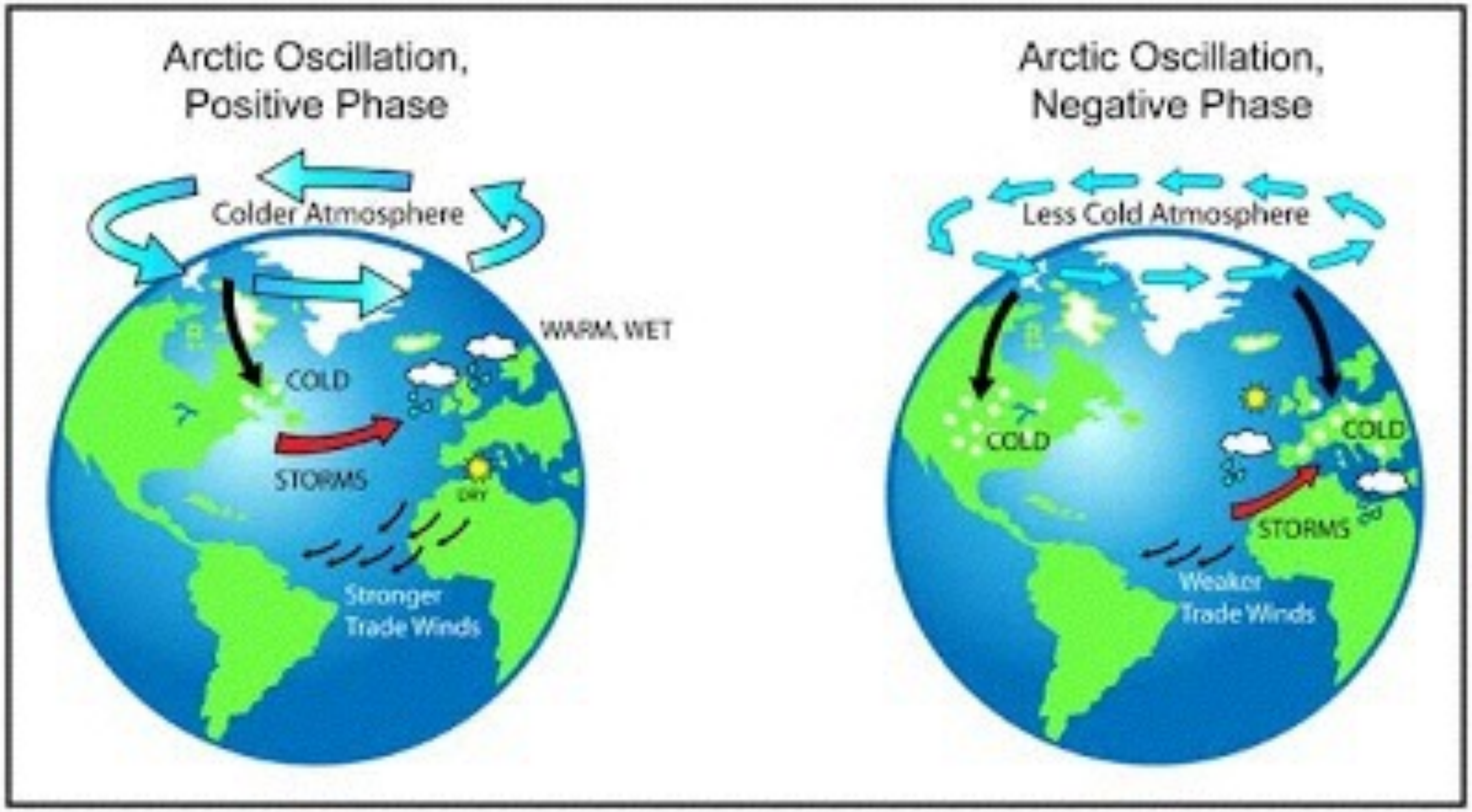
Rossby waves are generated
due to the baroclinic instability
<- Natural variability

God-Fathers of Dynamic meteorology

POLAR VORTEX

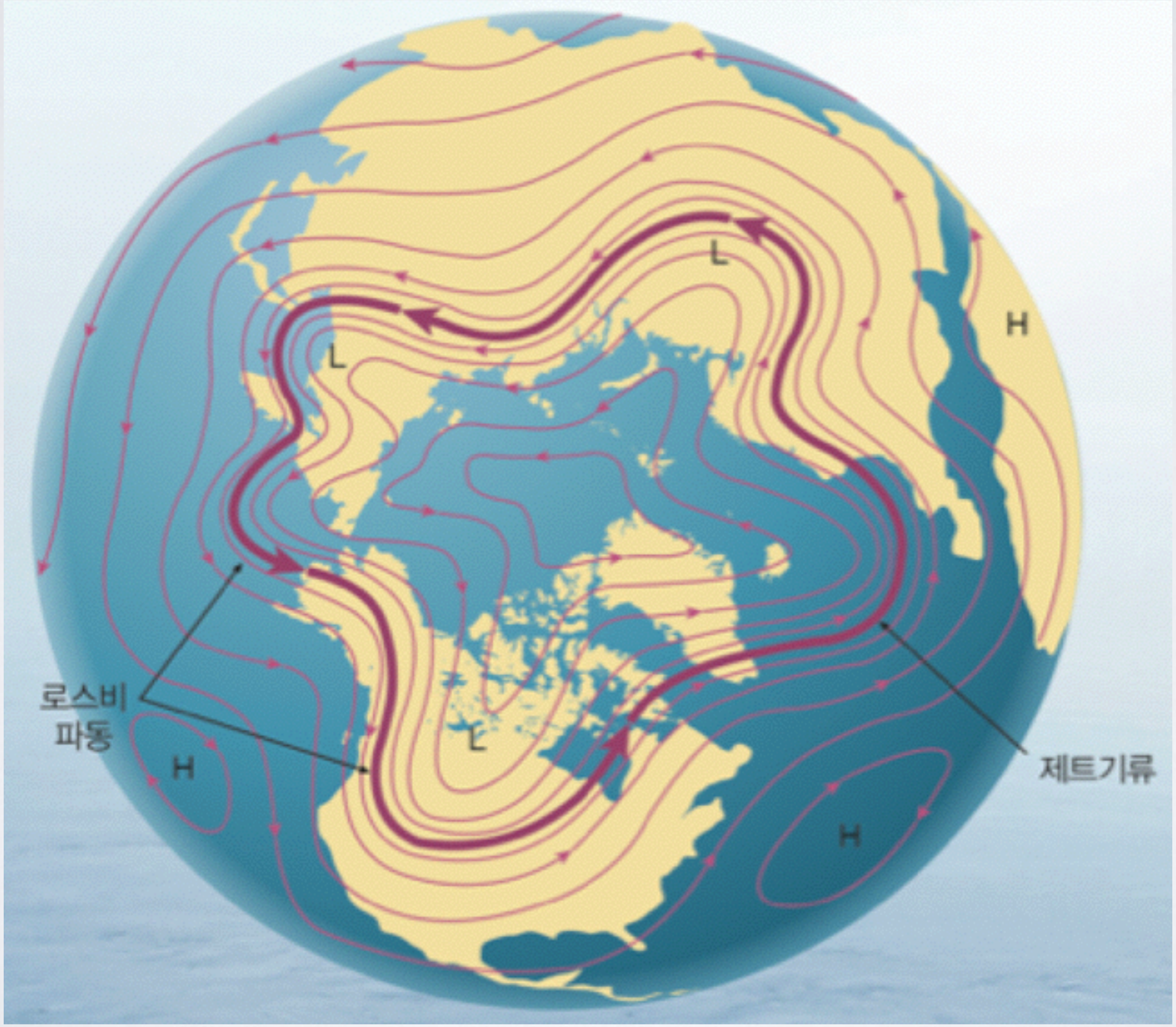


Arctic Oscillation



So, AO is simply a repetition of periodical strengthening and weakening of polar vortex

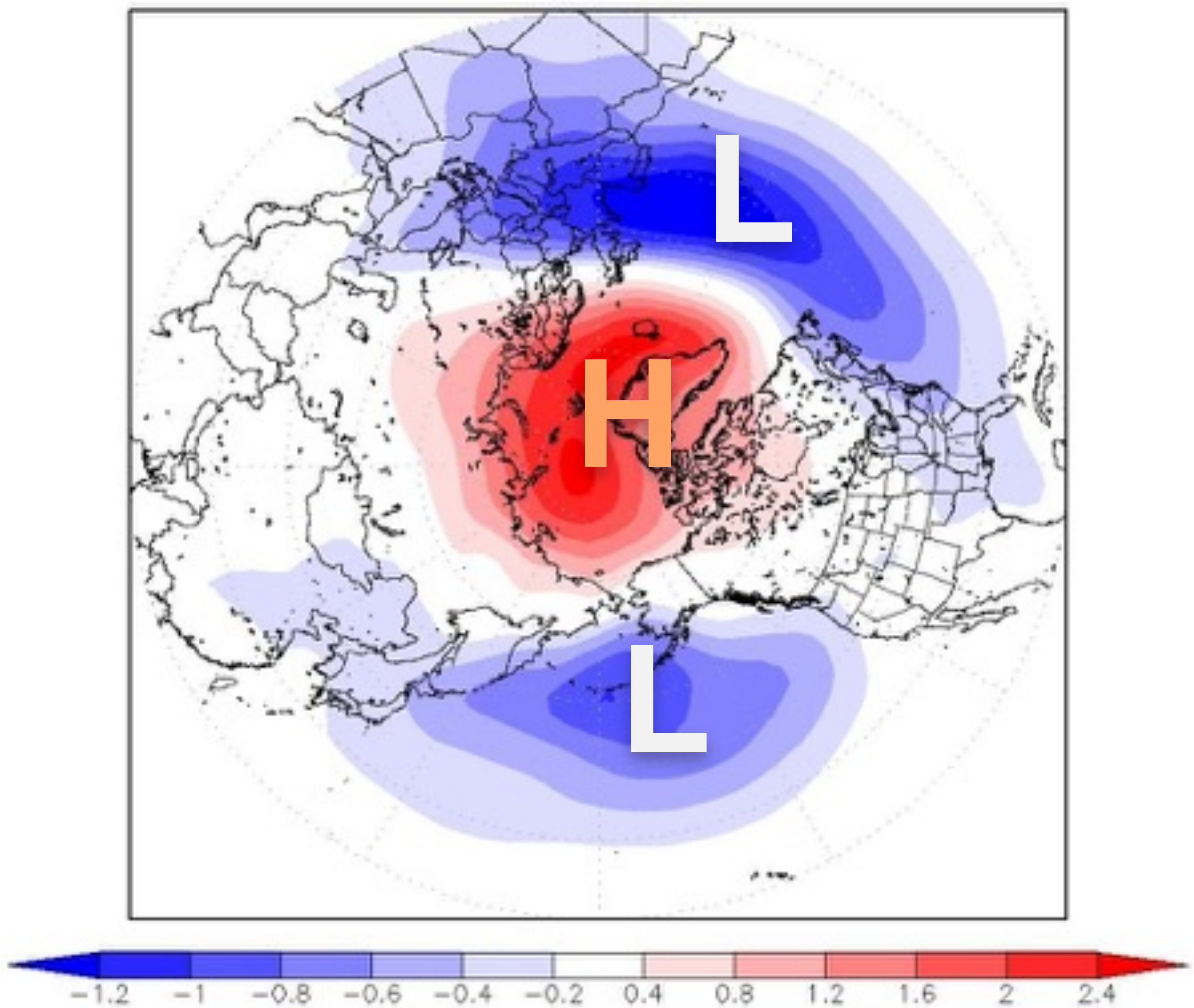
POLAR VORTEX

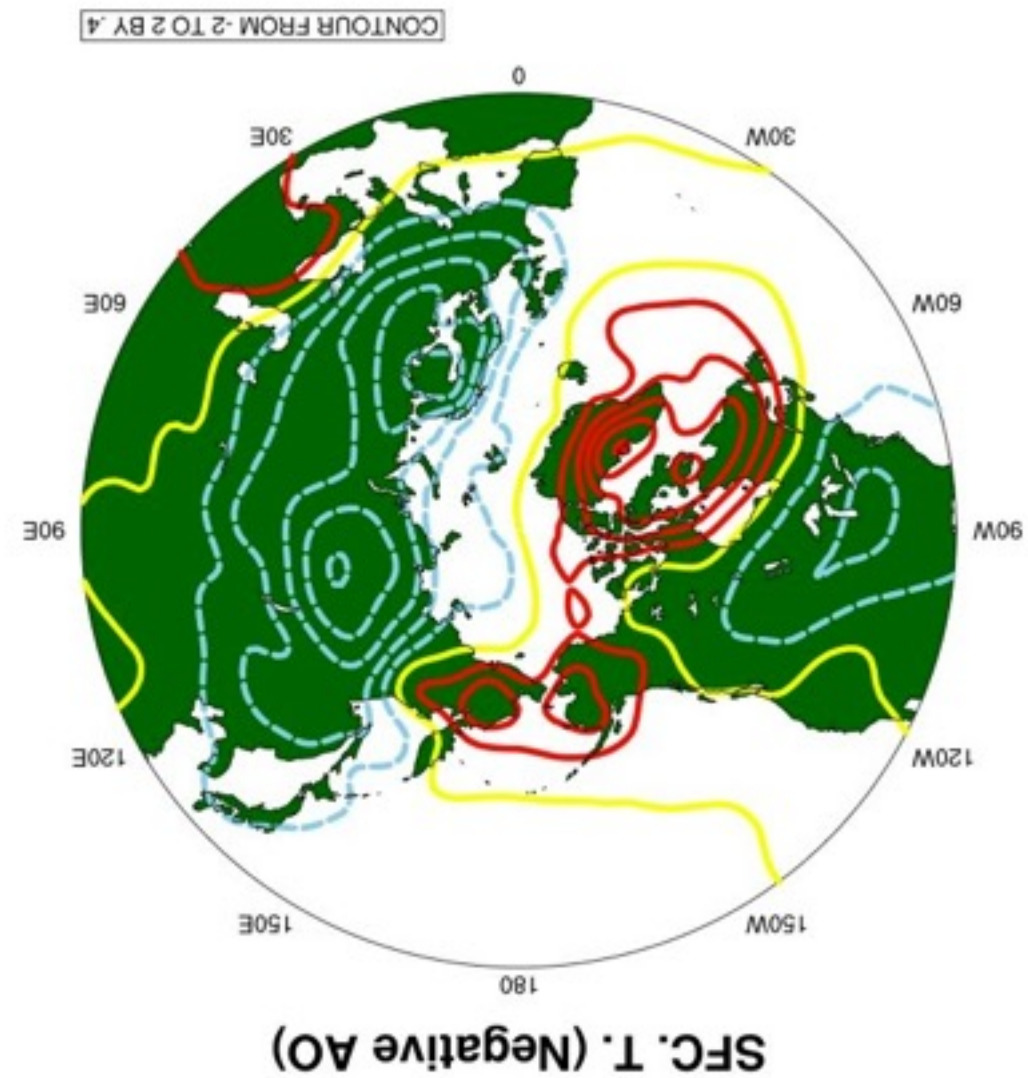


KOPRI 극지연구소

Arctic Oscillation (Pattern)

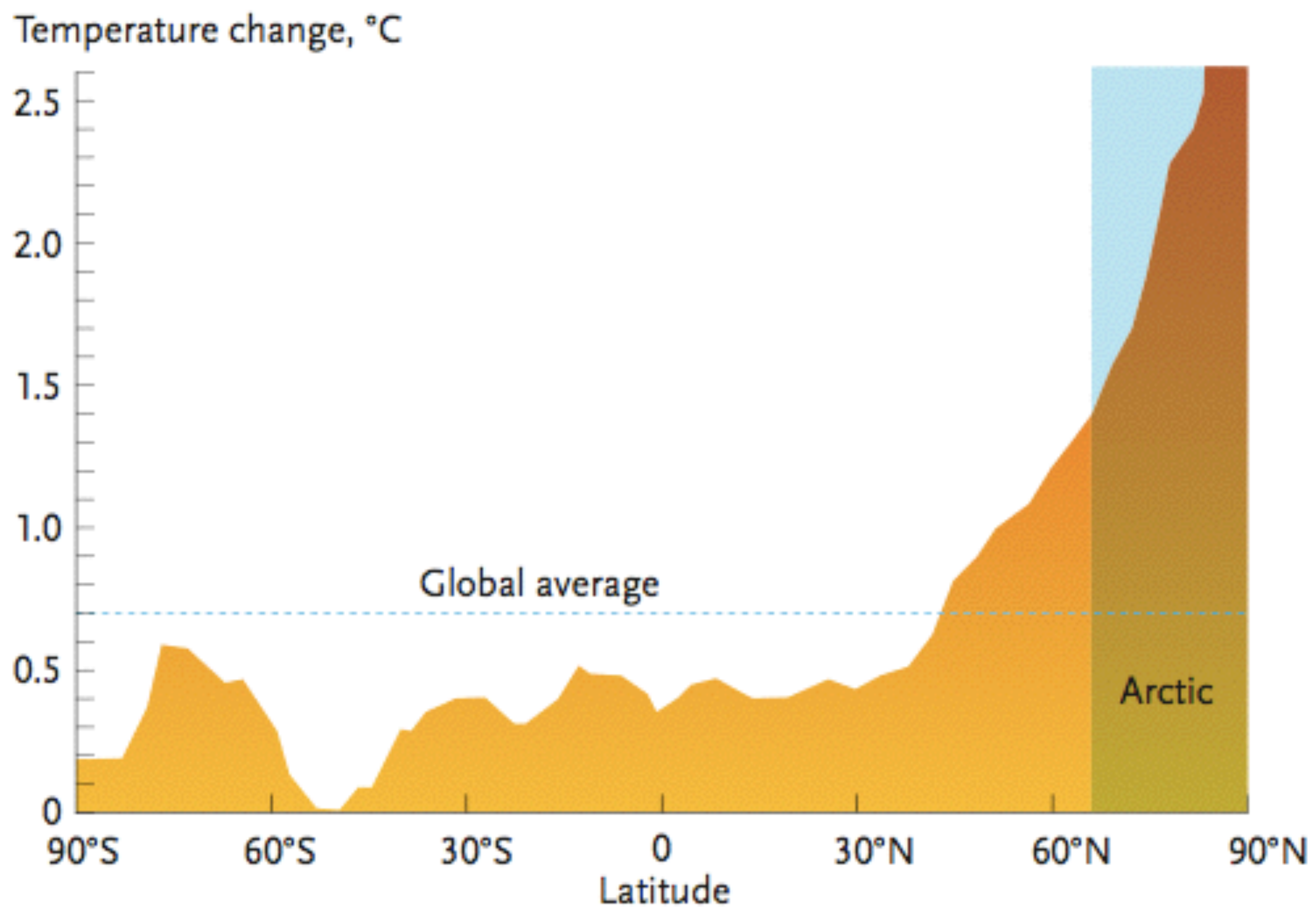
Typical Negative AO Pattern





Korea Polar Research Institute,KORDI

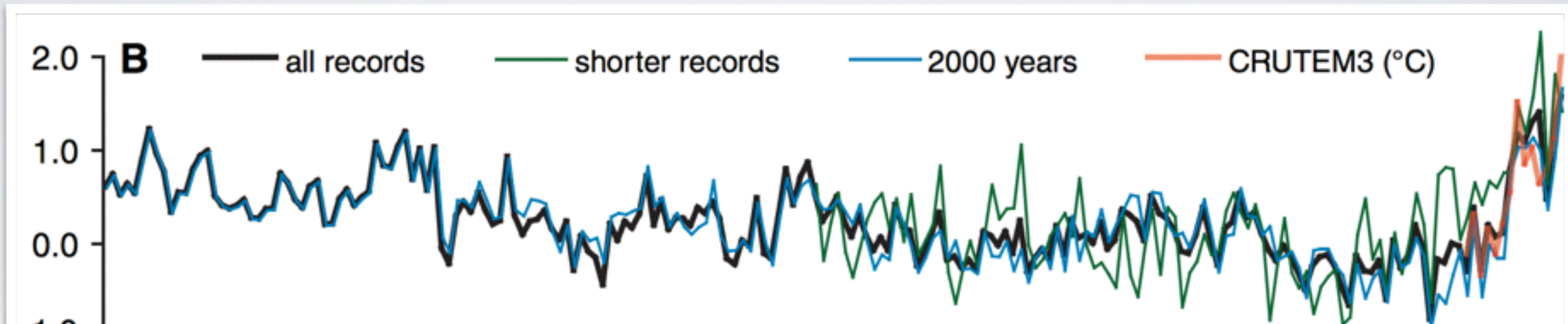
GLOBAL MEAN VS. ARCTIC TEMP.



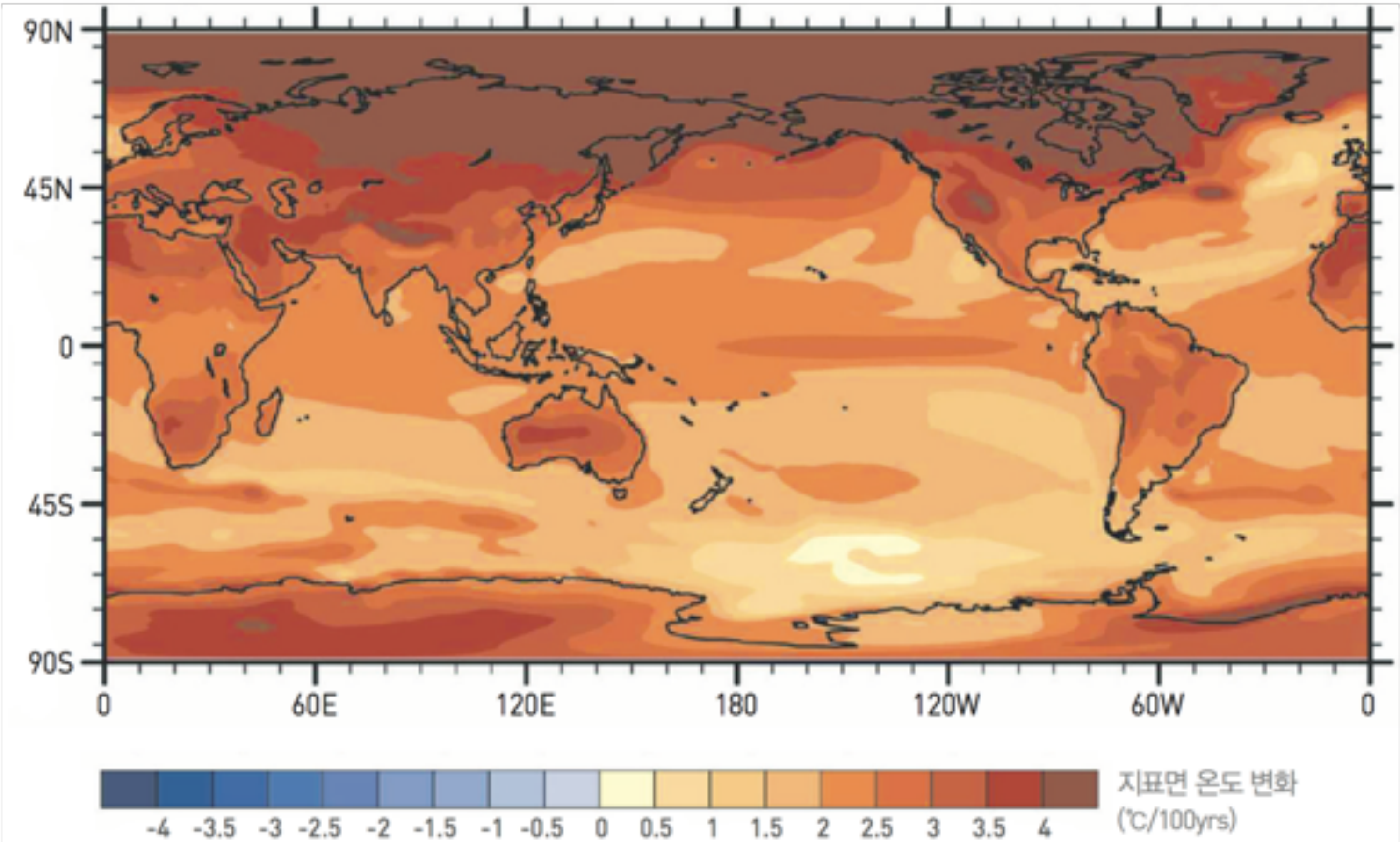
The average increase in surface temperature since the 1951–1980 reference period is greatest in the Arctic.

SWIPA Ann. Report (2009)

ARCTIC TEMPERATURE RECONSTRUCTED FROM 2000 YRS AGO…



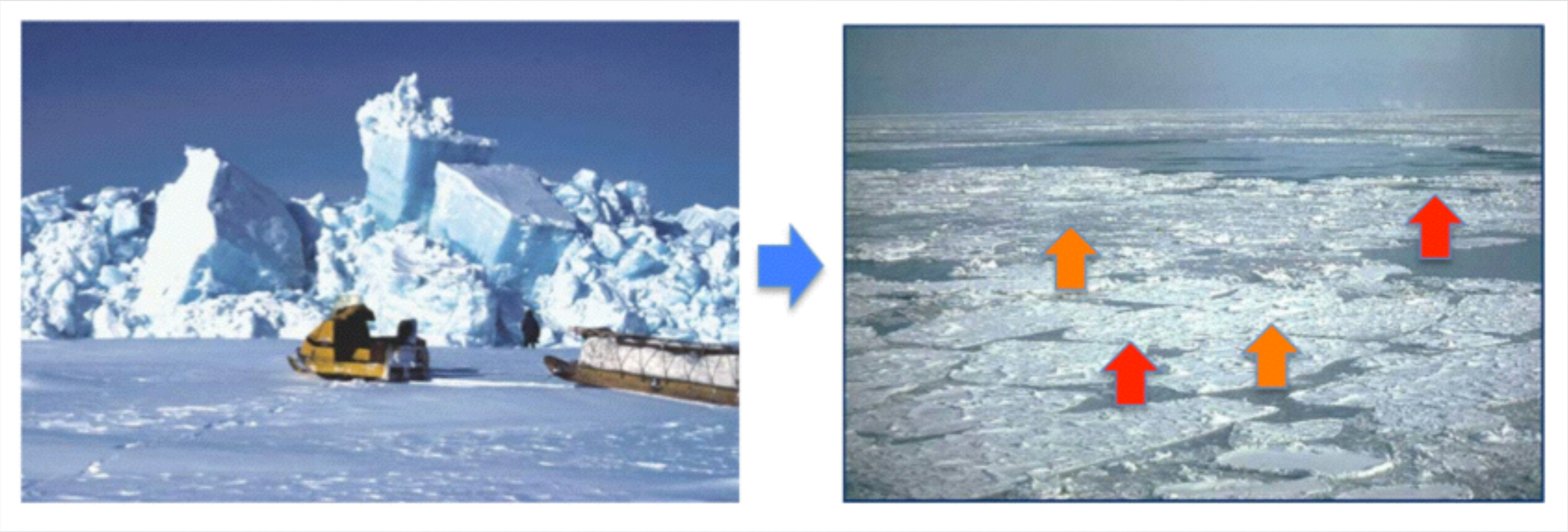
Kauffmann et al. 2009, Science



Surface temperature difference between future (2080-2100)-present (1980-2000) simulated by NCAR CCSM3

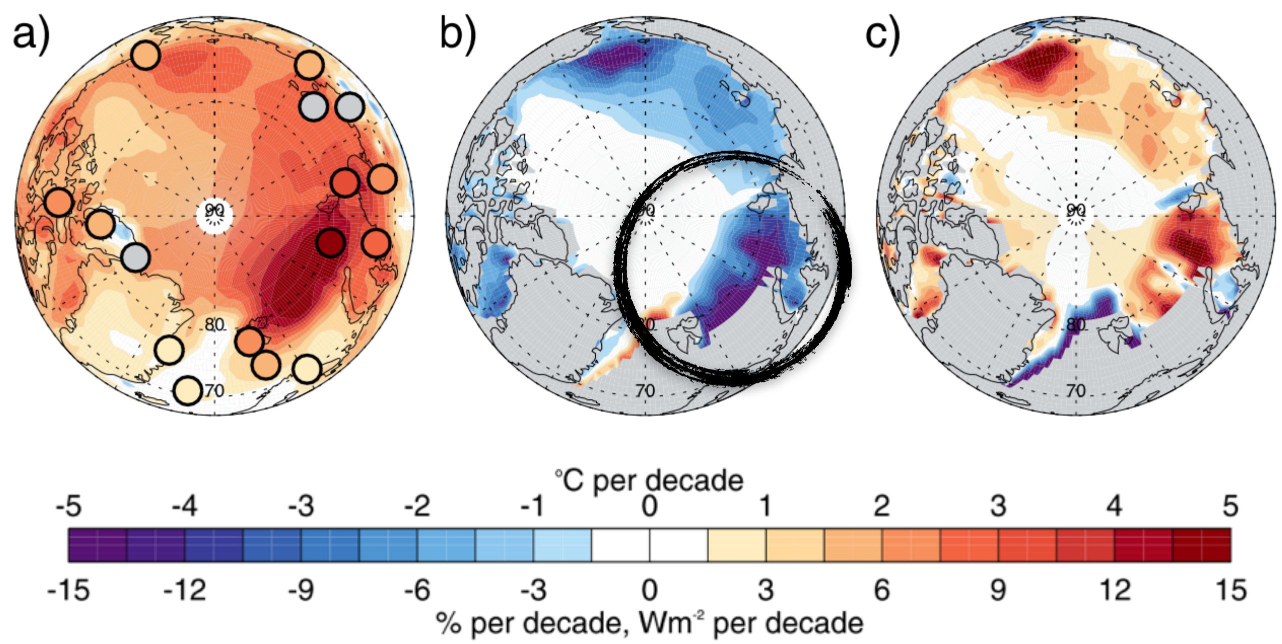
Meehl (2006)

FUTURE WARMING EXPECTED FROM MODELS



LESS SIC IN EARLY WINTER

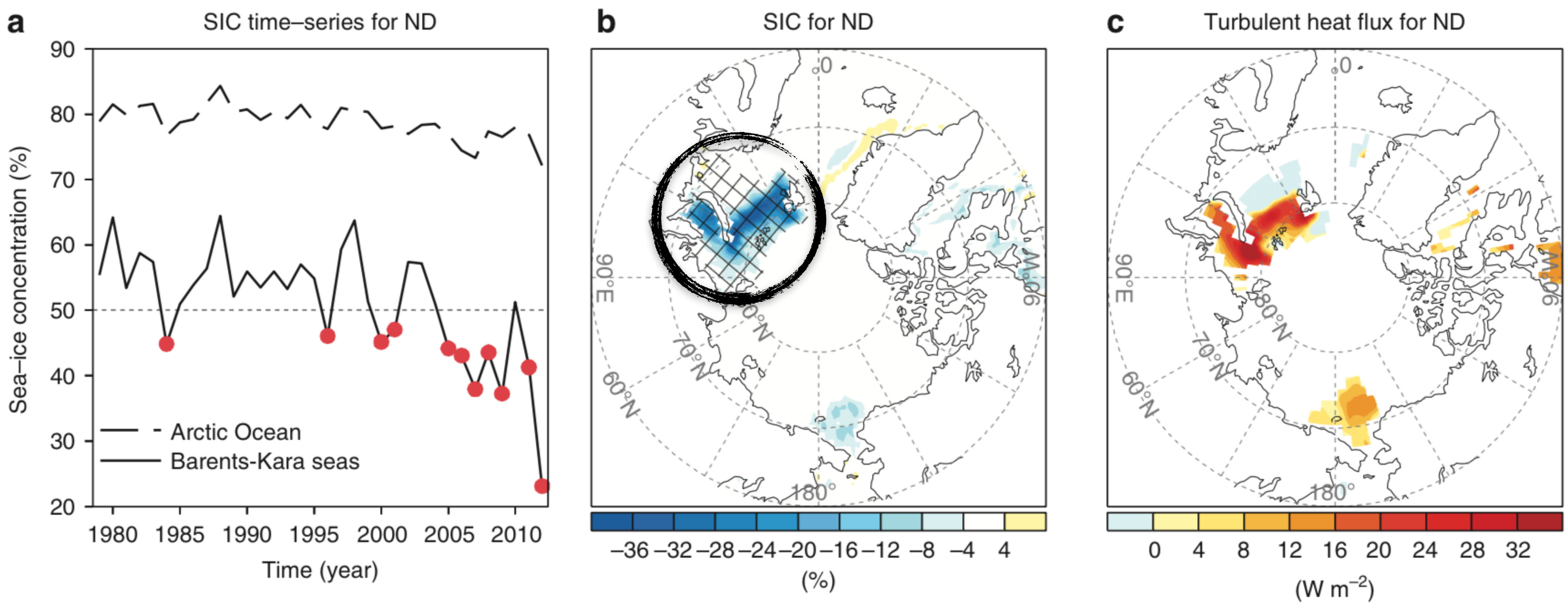
Linear Trend (89-09) of a) src T., b) SIC, c) Turbulent hflx for ONDJ



Screen & Simmonds (GRL, 2010)

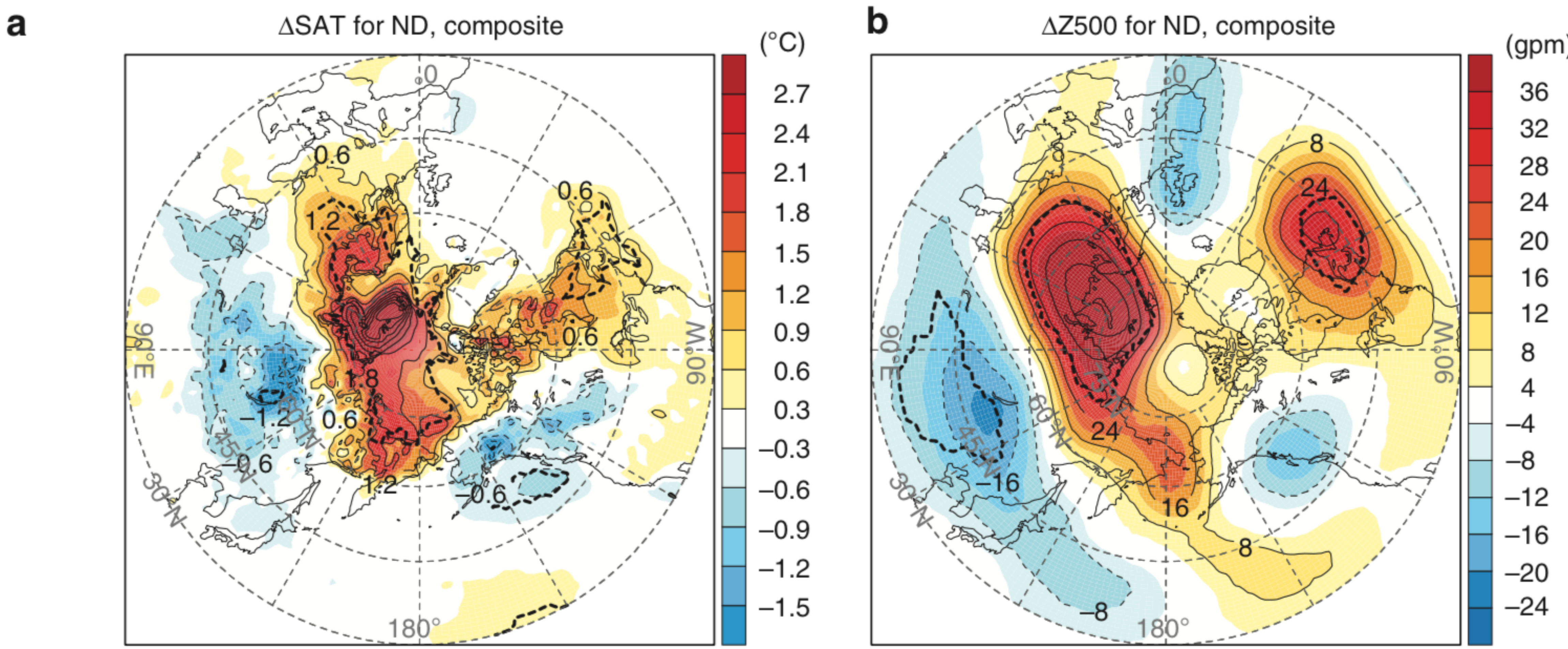
"The sea ice anomalies in the Barents–Kara Seas play a key role in establishing new atmosphere–sea ice coupled relationships in the warming Arctic"
-Yang & Yuan (JC, 2014)

SIC VARIABILITY OVER B/K SEAS IN EARLY WINTER



Kim et al. (Nature Communications, 2014)

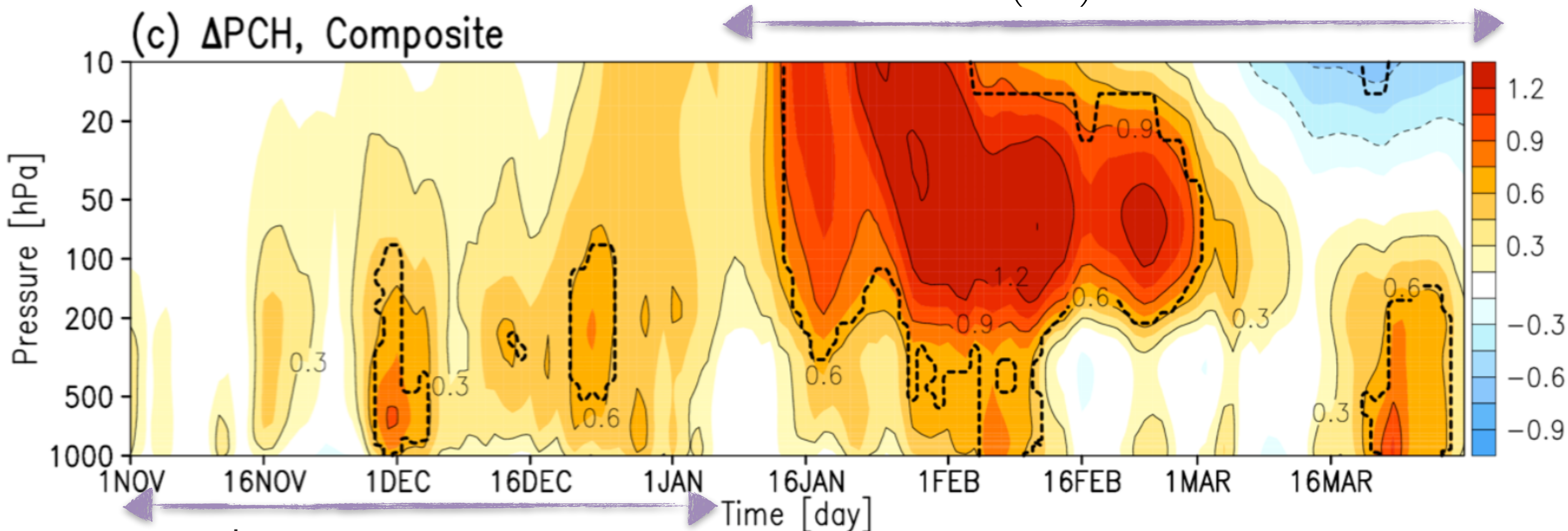
TROPOSPHERIC RESPONSE (EARLY WINTER COMPOSITE)

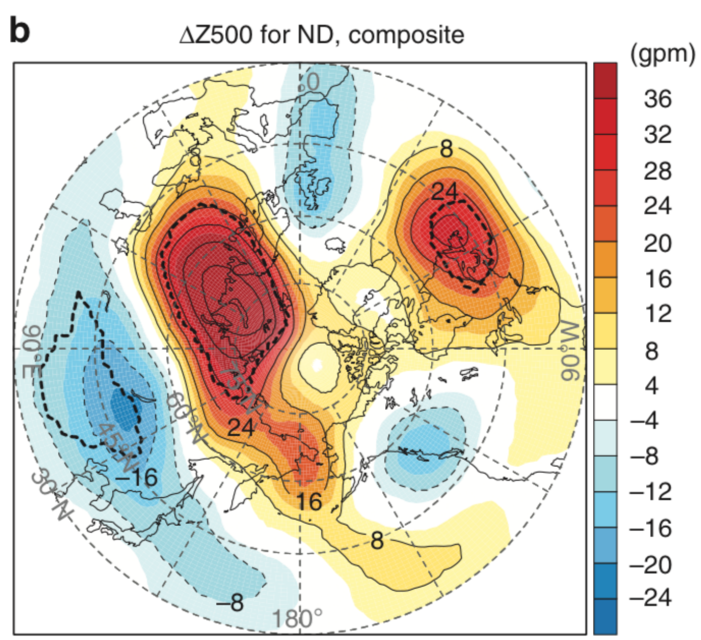


Kim et al. (Nature Communications, 2014)

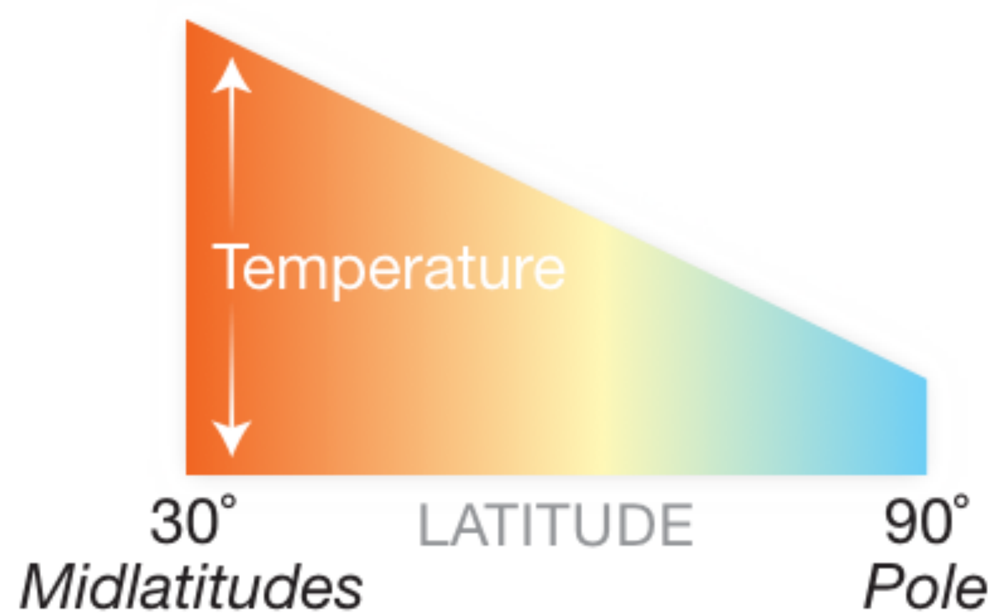
- Warm Arctic Cold Continents (Overland and Wang 2010)
- Warm Arctic Cold Eurasia (Mori et al. 2014)

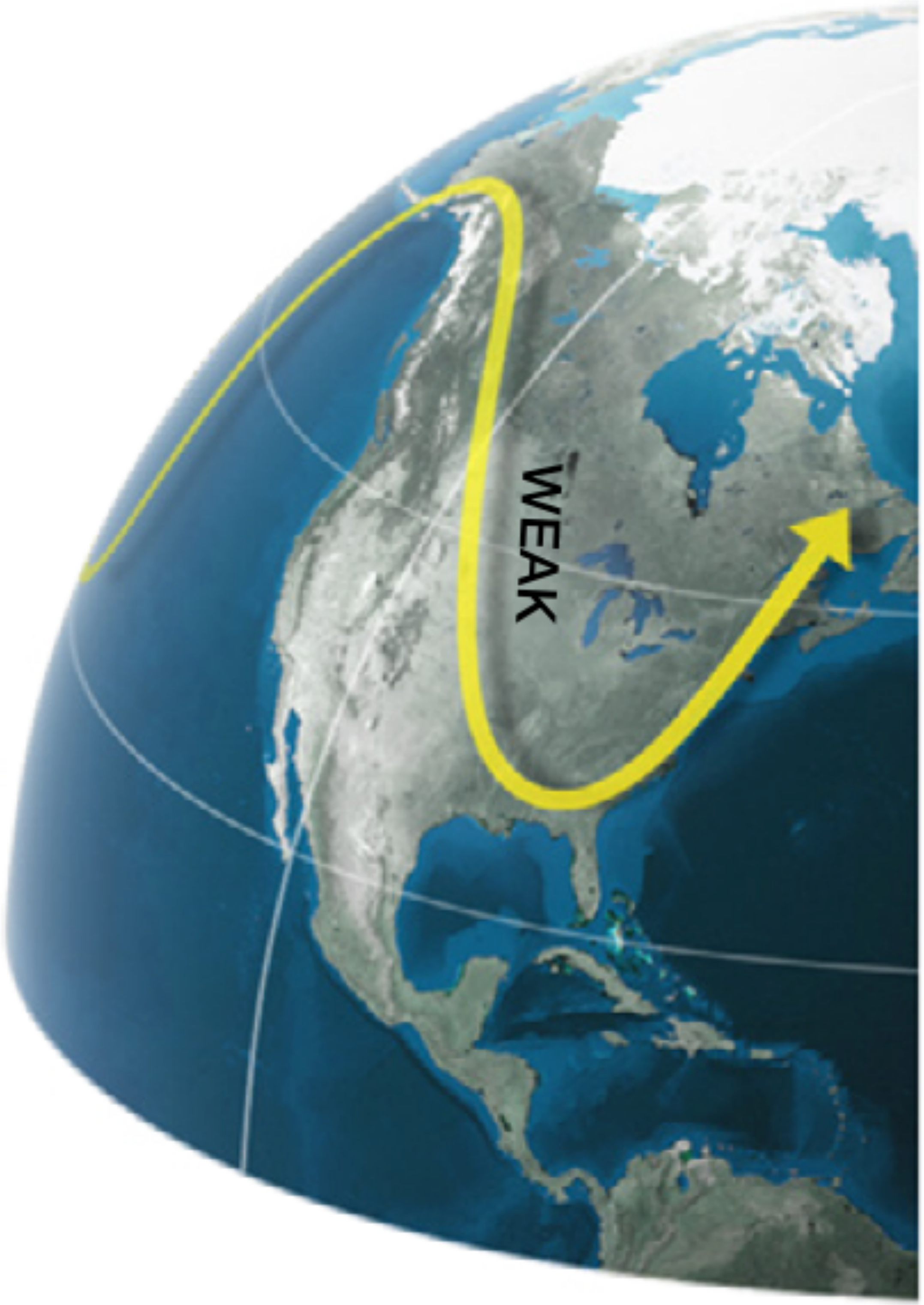
NAM (AO) dominates





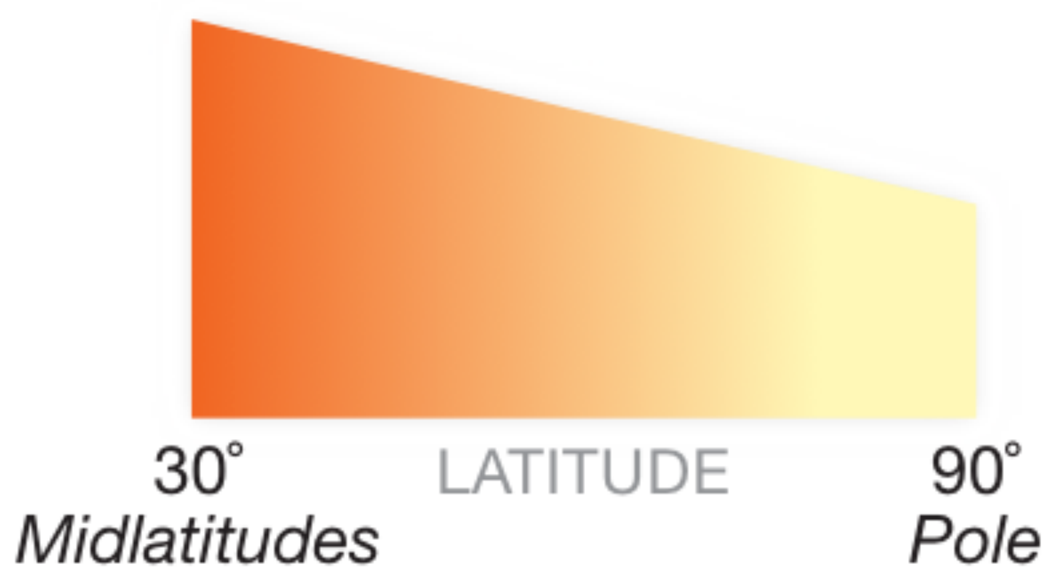
STRAIGHTER JET STREAM
The jet stream gets most of its energy from the temperature contrast between the air masses it separates. A strong jet is a straighter jet that keeps cold air bottled up in the Arctic.



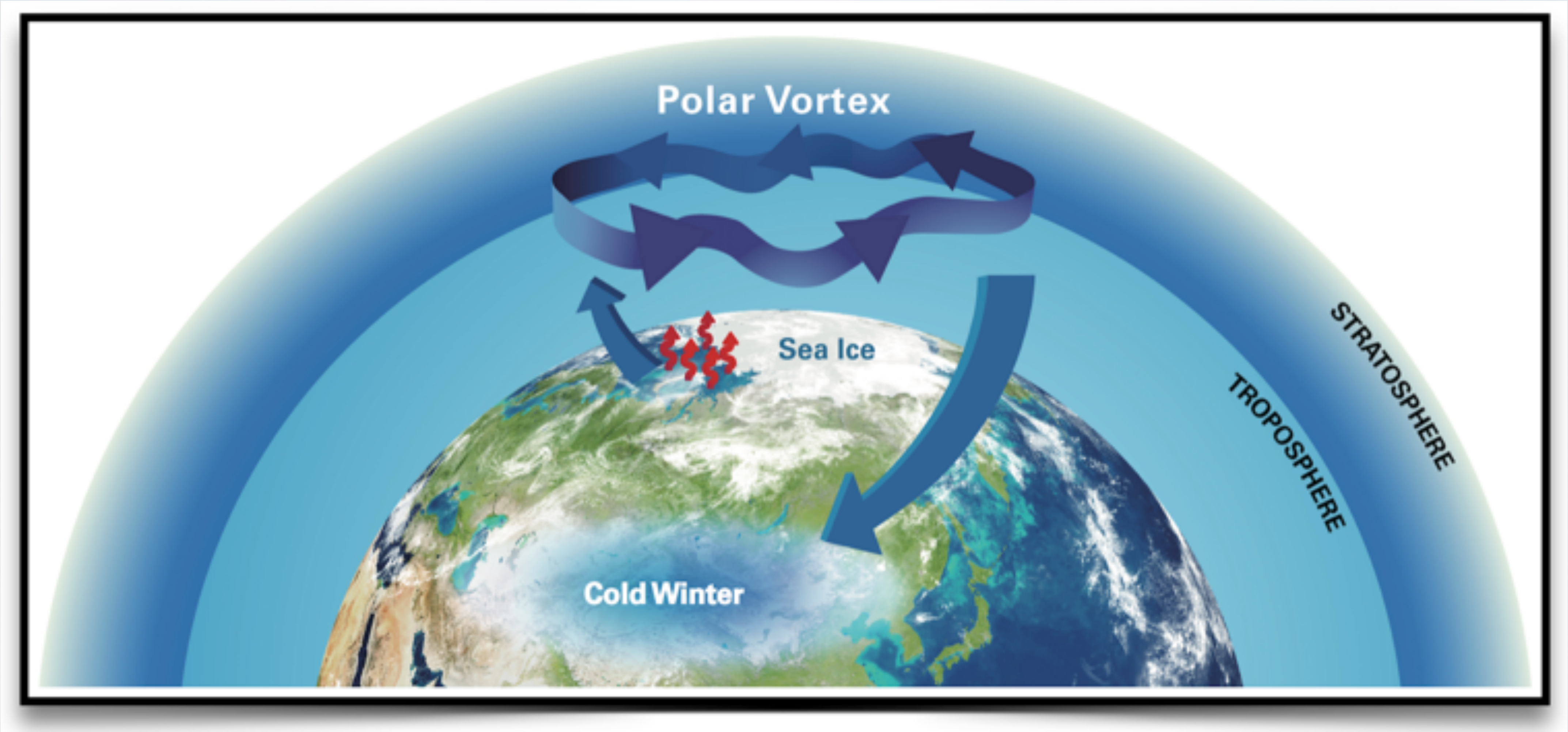


WAVIER JET STREAM

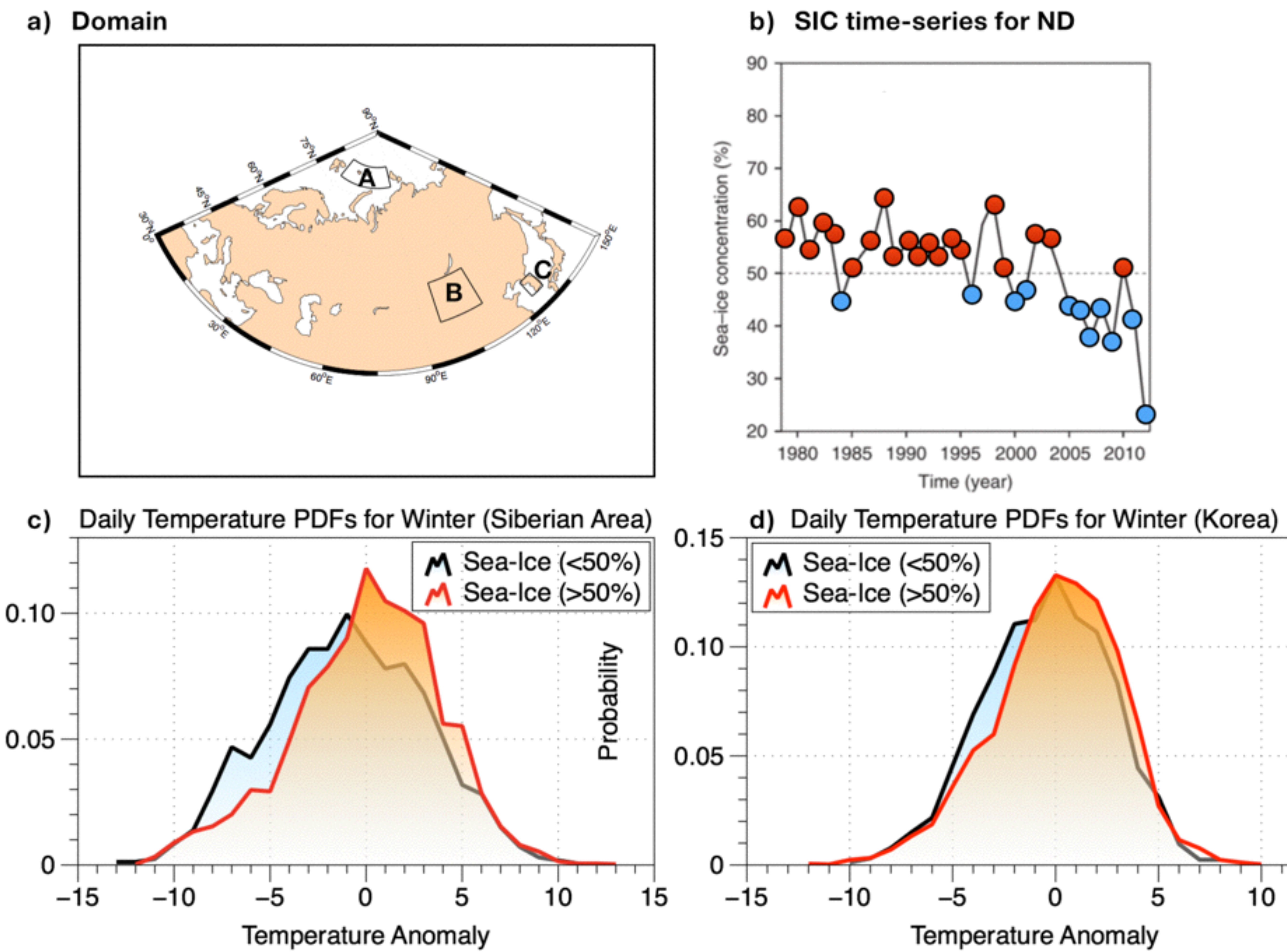
As the Arctic warms faster than the midlatitudes, the temperature contrast decreases. That weakens the jet, letting Arctic air flow south—over eastern North America, for instance.



Cold Extreme by Warming Arctic



Kim et al. 2014, Nature Comms.

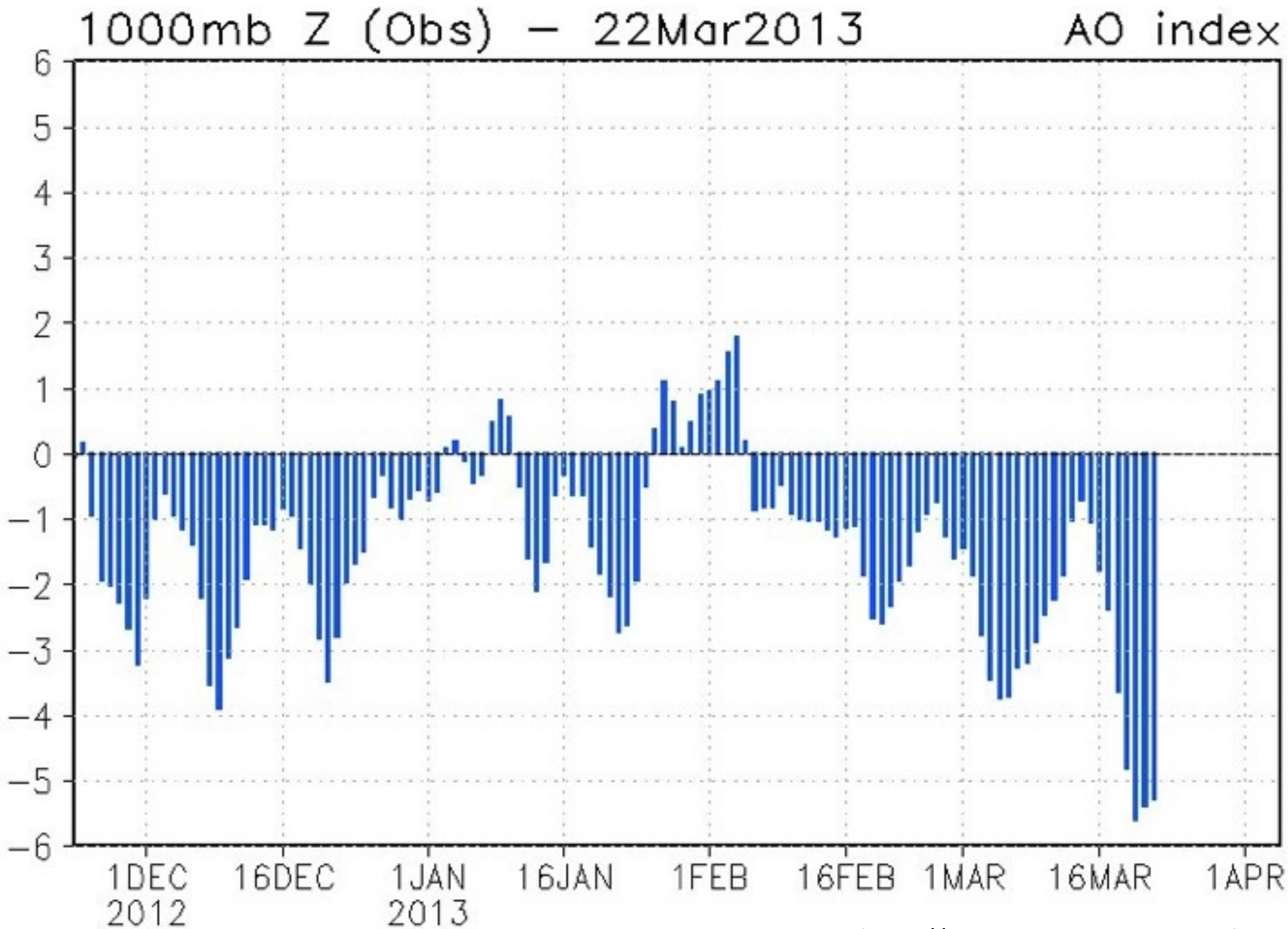


a) Domain
A
B
C
30°N
45°N
60°N
75°N
90°N
0°E
30°E
60°E
90°E
120°E
150°E
b) SIC time-series for ND
Sea-ice concentration (%)
90
80
70
60
50
40
30
20
1980
1985
1990
1995
2000
2005
2010
Time (year)
c) Daily Temperature PDFs for Winter (Siberian Area)
Sea-Ice (<50%)
Sea-Ice (>50%)
0.10
0.05
0
−15
−10
−5
0
5
10
15
Temperature Anomaly
Probability
d) Daily Temperature PDFs for Winter (Korea)
Sea-Ice (<50%)
Sea-Ice (>50%)
0.15
0.10
0.05
0
−15
−10
−5
0
5
10
Temperature Anomaly

Time-scale of Arctic Oscillation

Korea Polar Research
Institute,KORDI

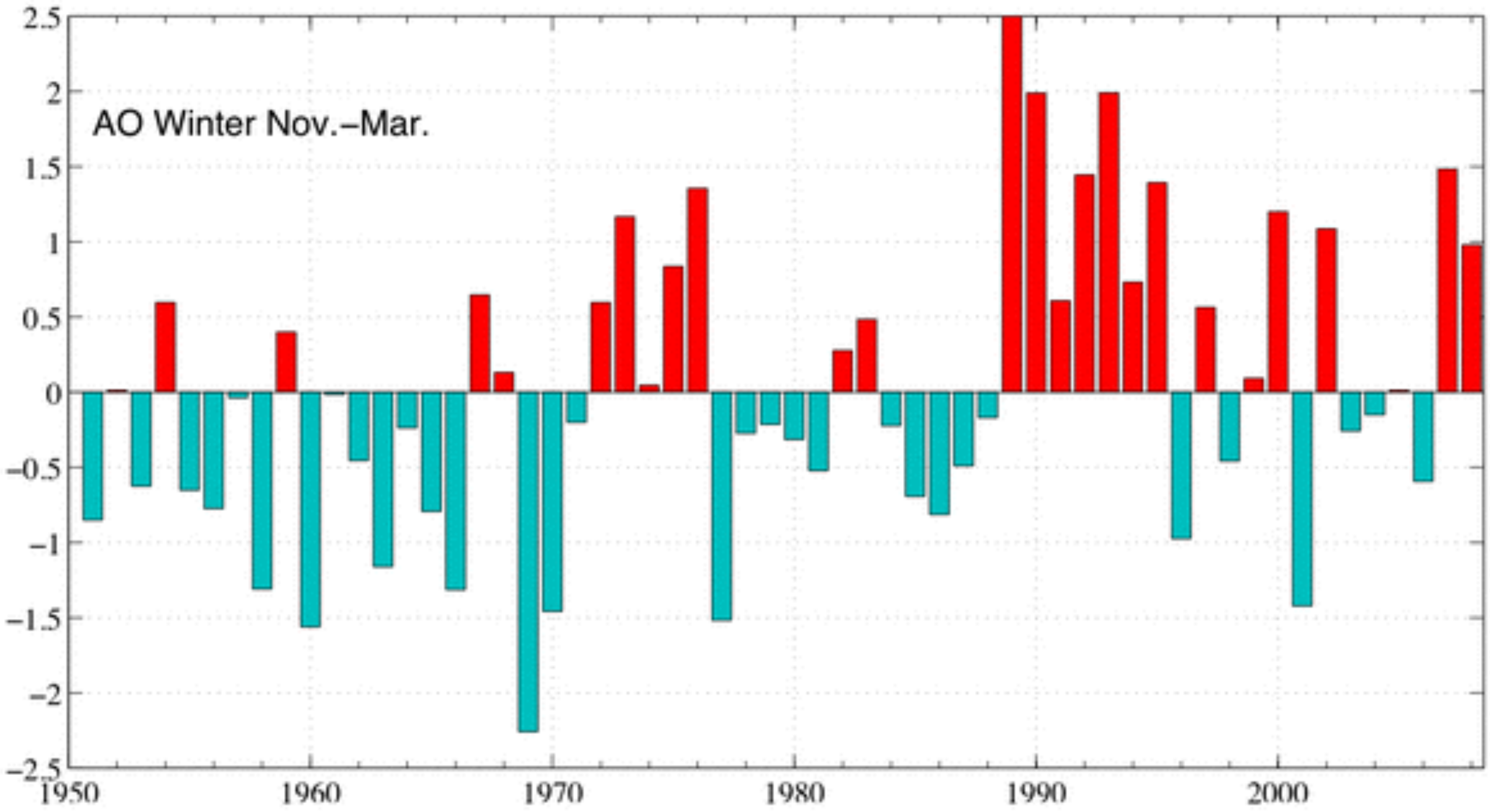
(Sub-)weekly & sub-seasonal time-scale



From CPC (http://www.cpc.ncep.noaa.gov)

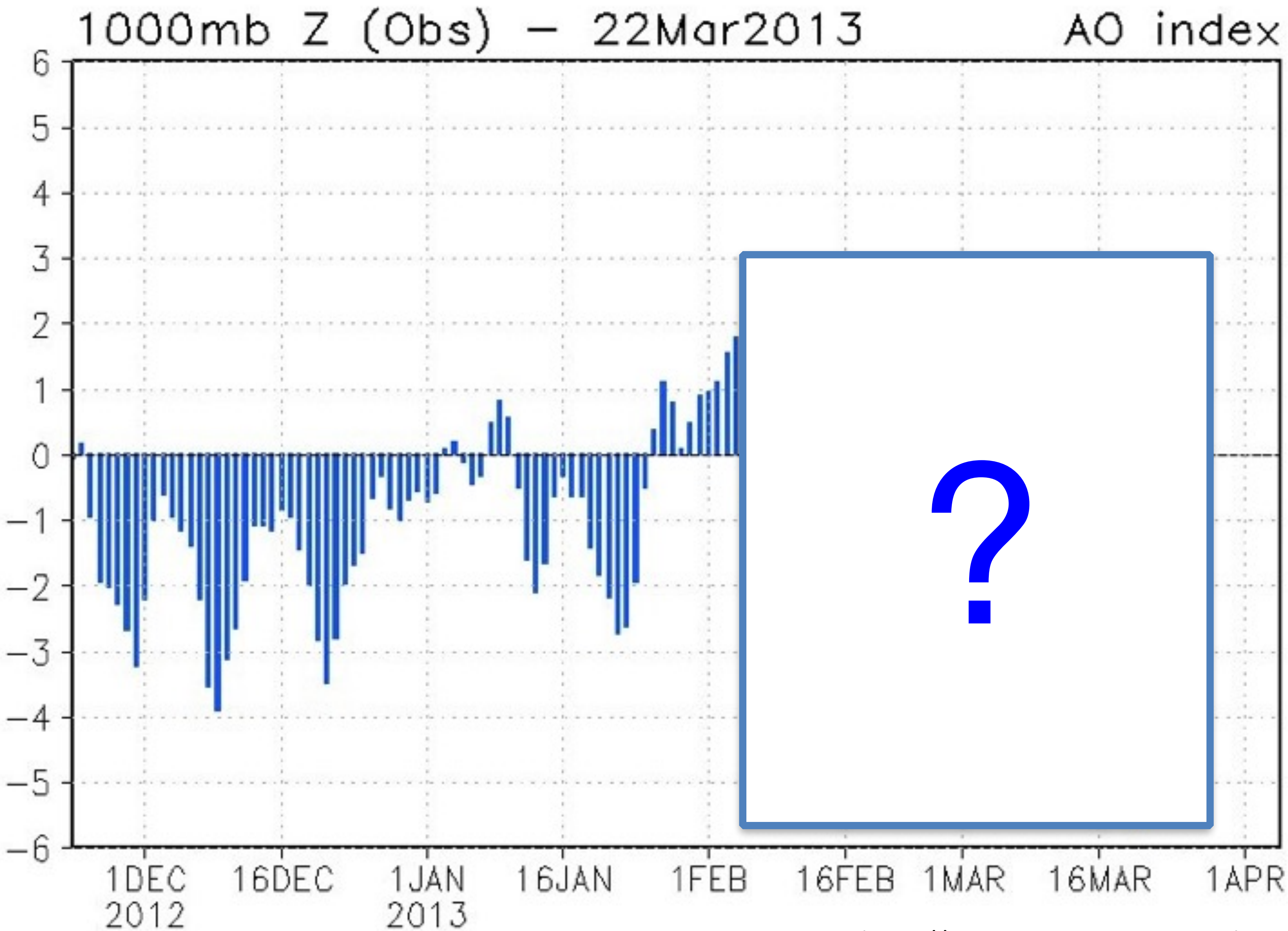
Korea Polar Research Institute,KORDI

Inter-annual time-scale



Korea Polar Research Institute,KORDI

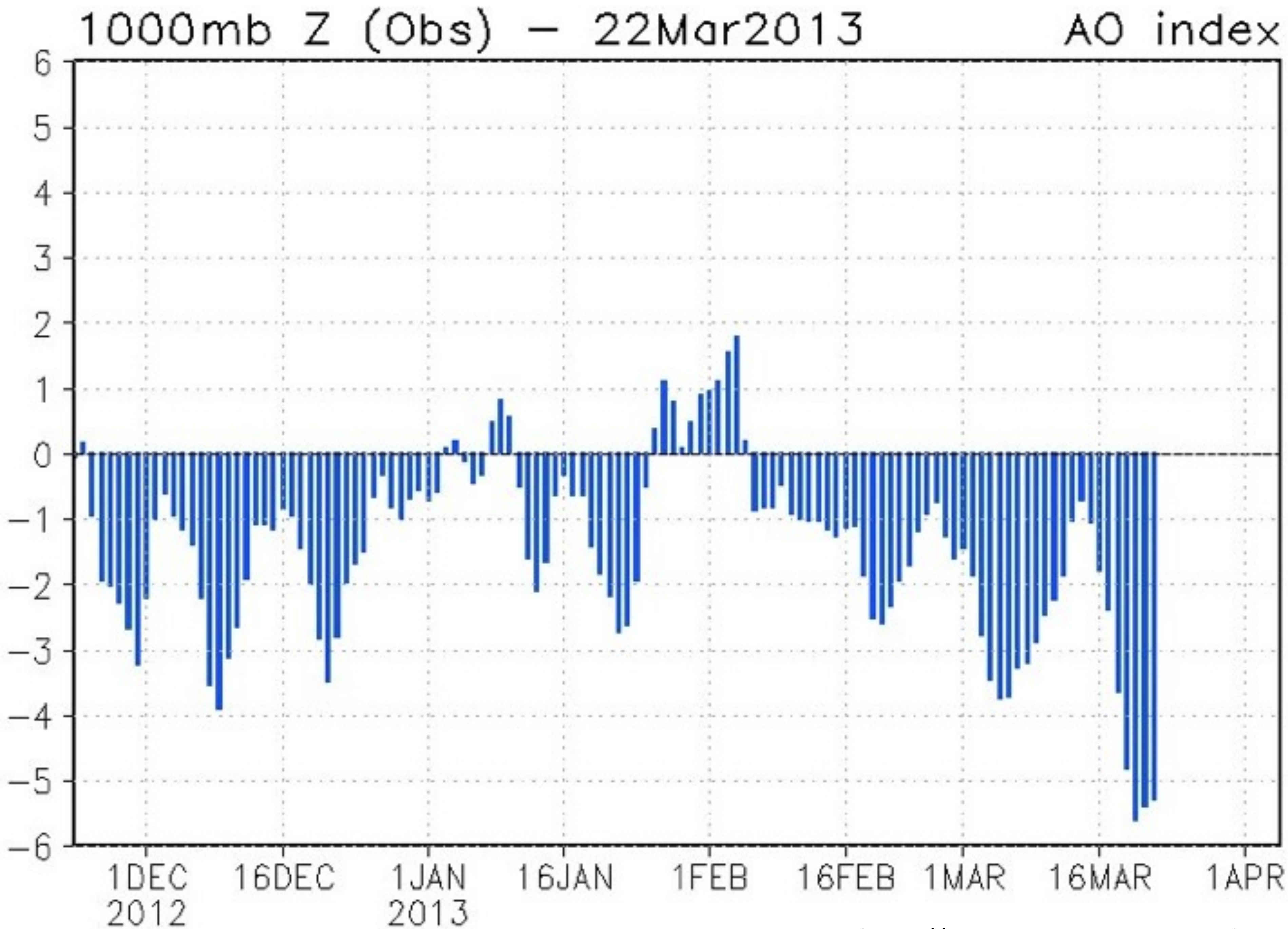
Can we predict Arctic Oscillation in advance?



From CPC (http://www.cpc.ncep.noaa.gov)

Korea Polar Research Institute,KORDI

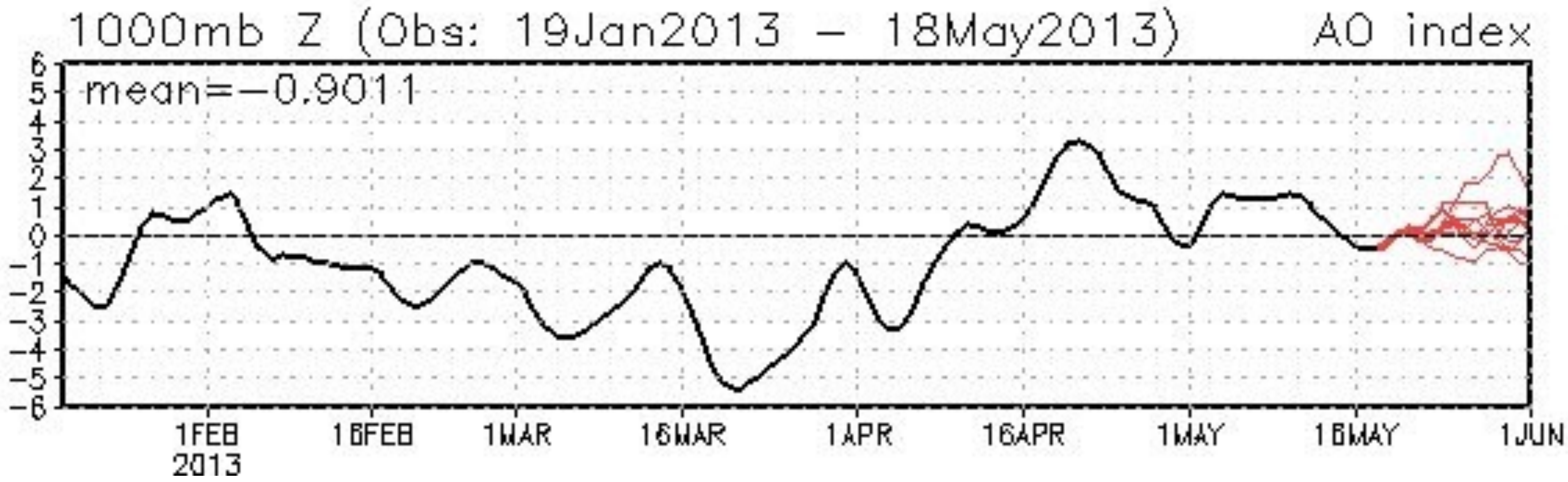
Can we predict Arctic Oscillation in advance?



From CPC (http://www.cpc.ncep.noaa.gov)

Korea Polar Research Institute,KORDI

Not yet…



From CPC (http://www.cpc.ncep.noaa.gov)

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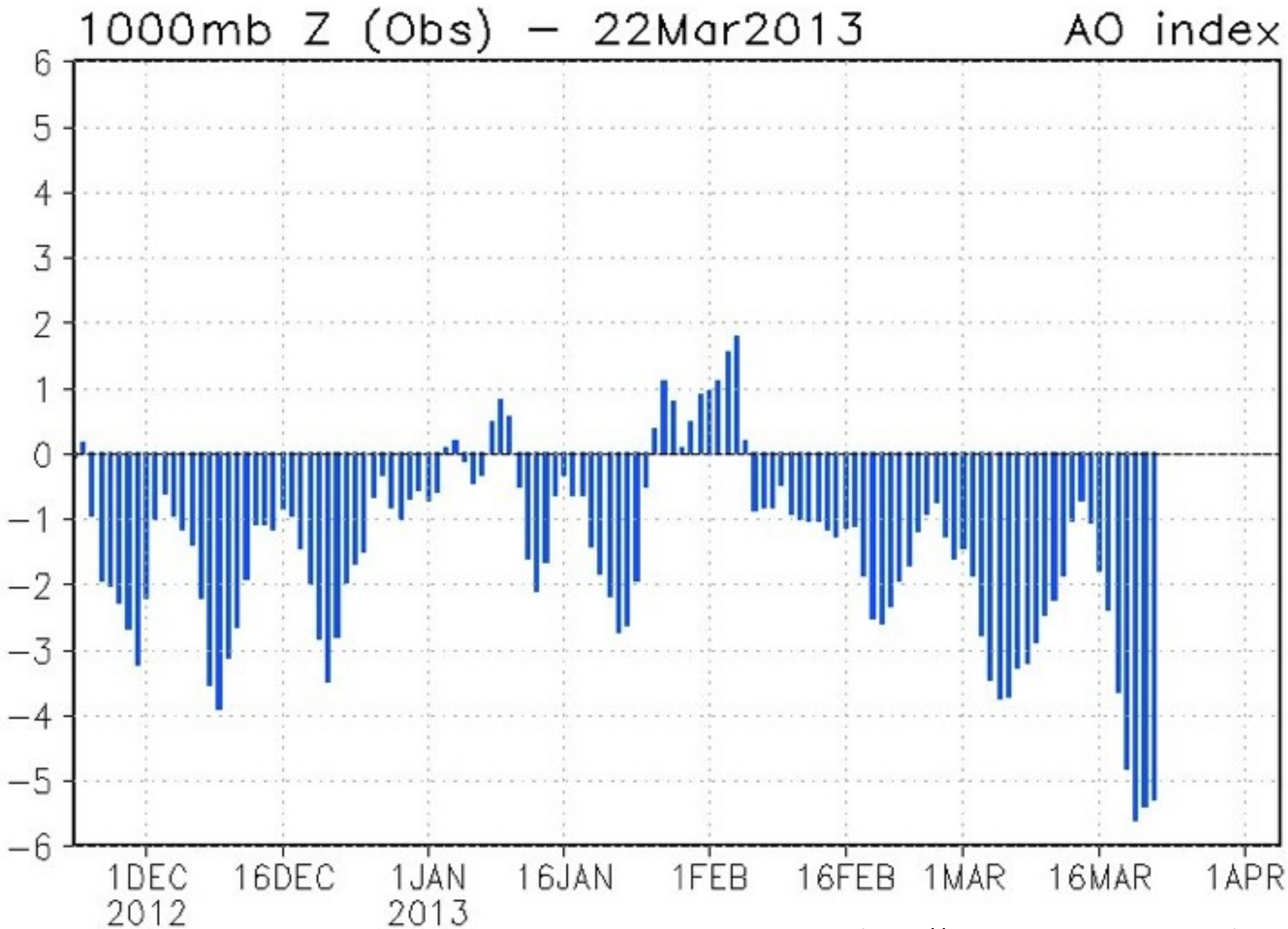
A hint from vertical structure of Arctic Oscillation



From CPC (http://www.cpc.ncep.noaa.gov)

Korea Polar Research Institute,KORDI

Stratospheric Harbingers of Anomalous Weather Regimes

Mark P. Baldwin* and Timothy J. Dunkerton

Observations show that large variations in the strength of the stratospheric circulation, appearing first above ~50 kilometers, descend to the lowermost stratosphere and are followed by anomalous tropospheric weather regimes. During the 60 days after the onset of these events, average surface pressure maps resemble closely the Arctic Oscillation pattern. These stratospheric events also precede shifts in the probability distributions of extreme values of the Arctic and North Atlantic Oscillations, the location of storm tracks, and the local likelihood of mid-latitude storms. Our observations suggest that these stratospheric harbingers may be used as a predictor of tropospheric weather regimes.

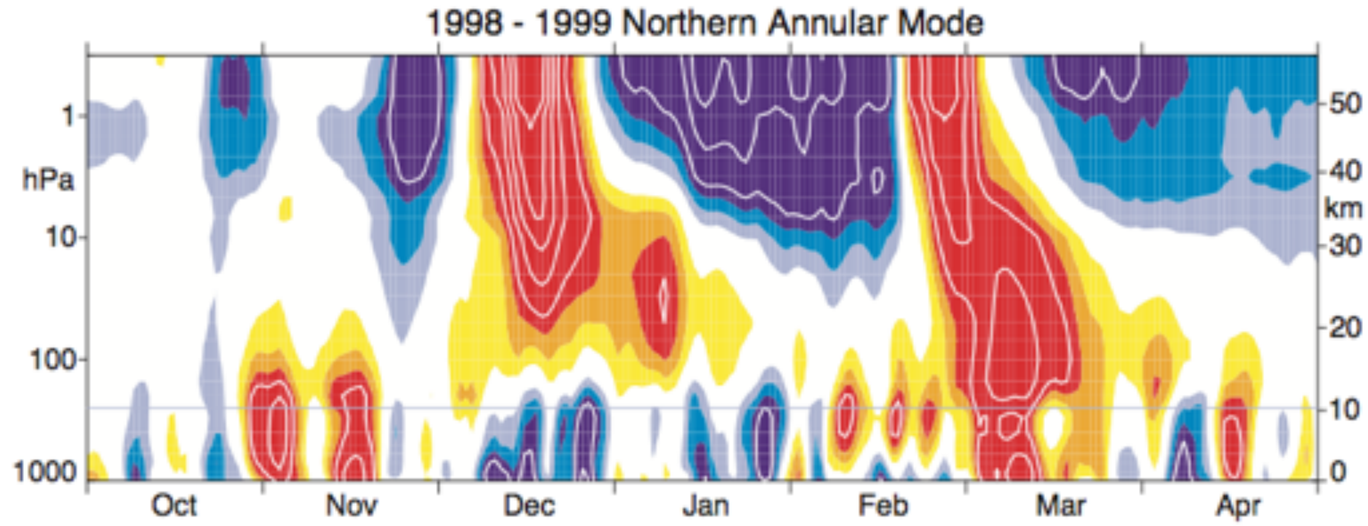


Fig. 1. Time-height development of the northern annular mode during the winter of 1998–1999. The indices have daily resolution and are nondimensional. Blue corresponds to positive values (strong polar vortex), and red corresponds to negative values (weak polar vortex). The contour interval is 0.5, with values between −0.5 and 0.5 unshaded. The thin horizontal line indicates the approximate boundary between the troposphere and the stratosphere.

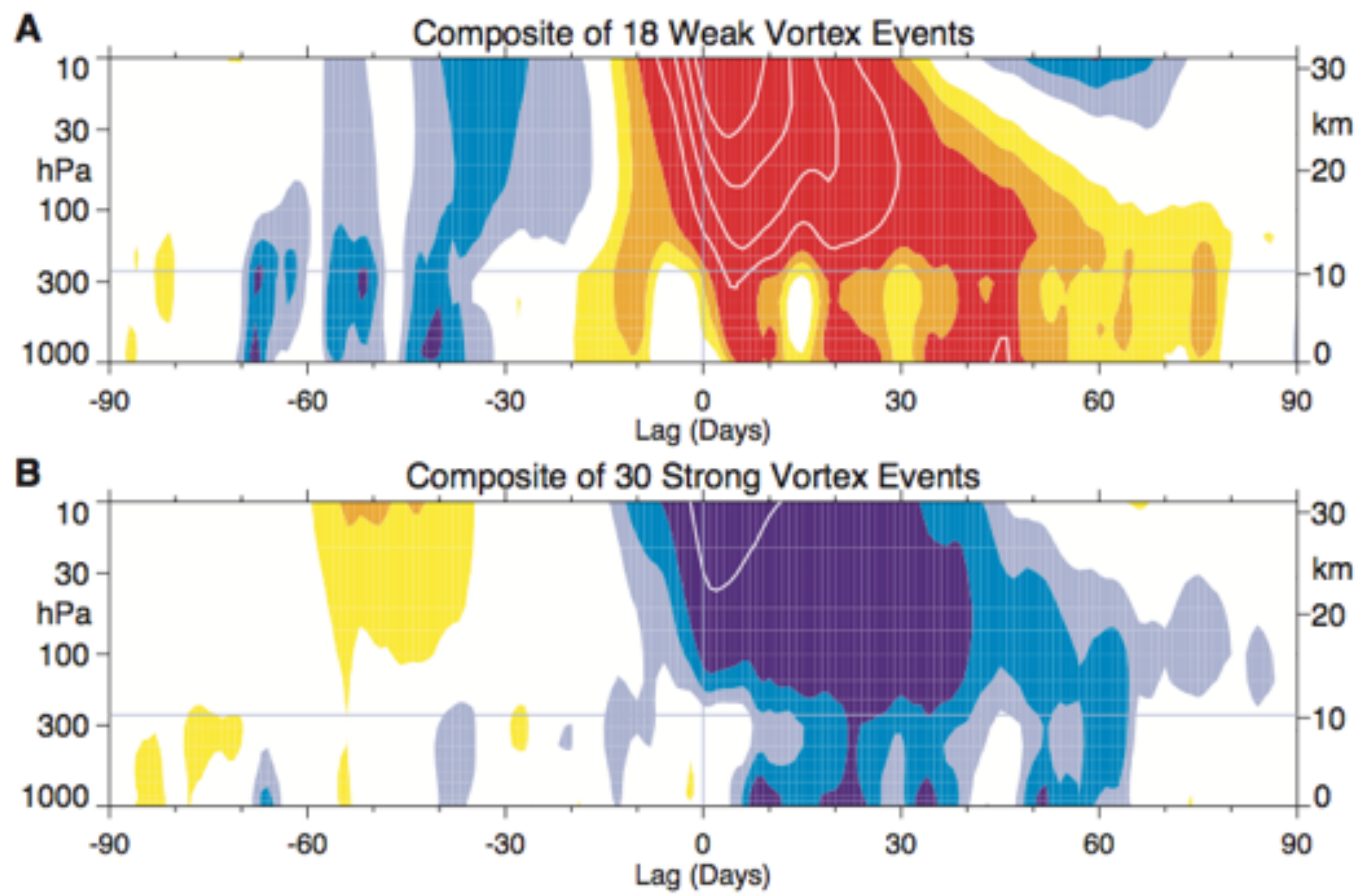
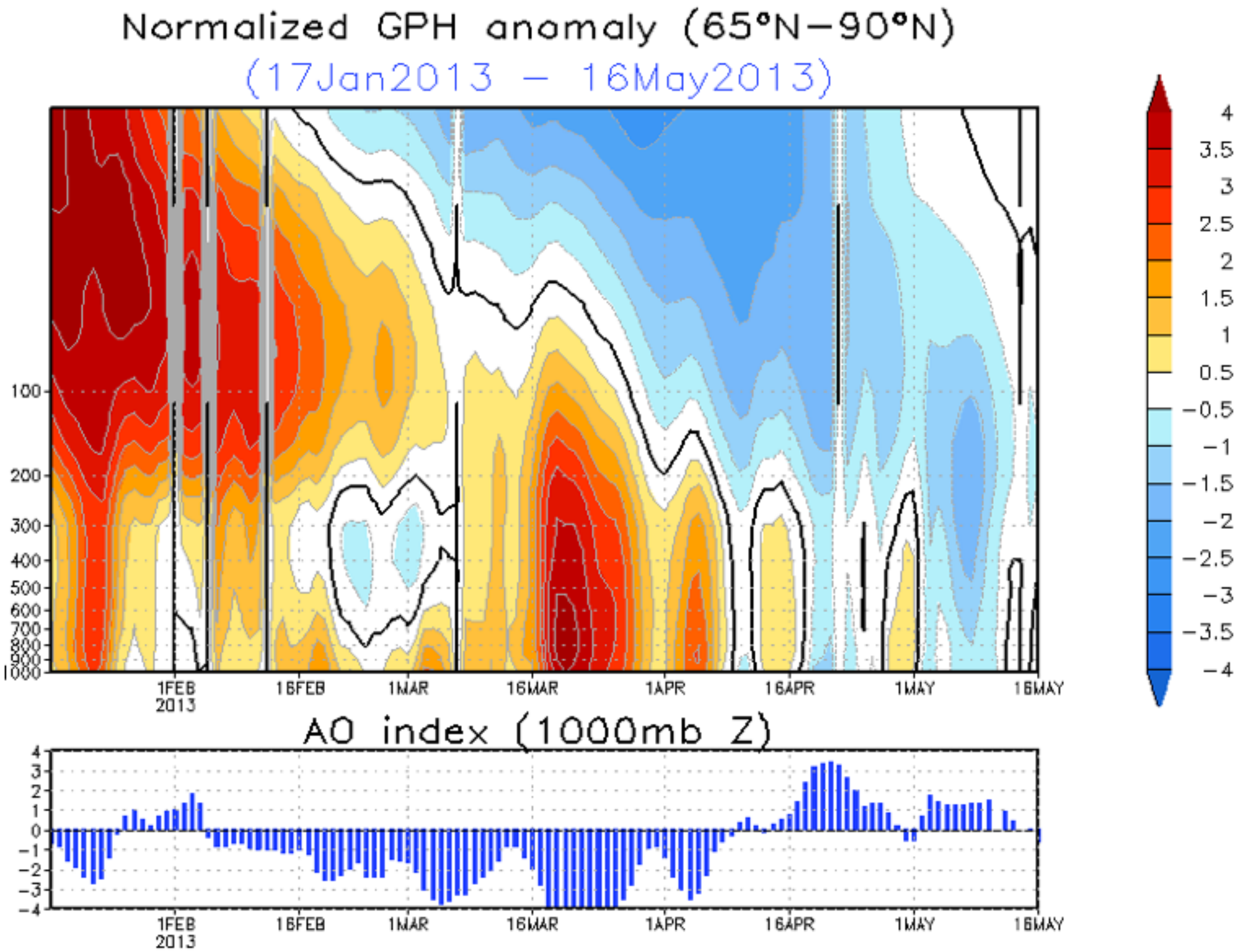
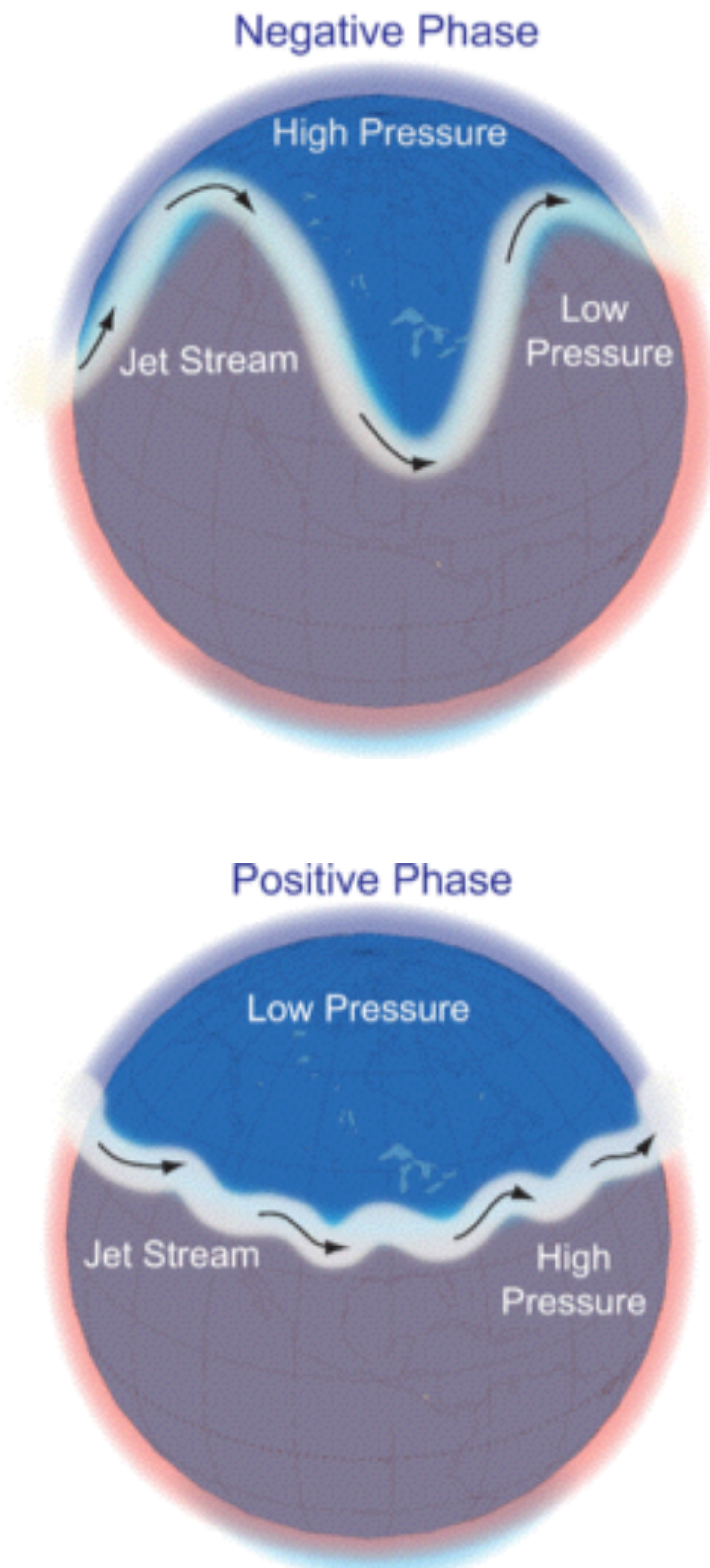


Fig. 2. Composites of time-height development of the northern annular mode for (**A**) 18 weak vortex events and (**B**) 30 strong vortex events. The events are determined by the dates on which the 10-hPa annular mode values cross –3.0 and +1.5, respectively. The indices are nondimensional; the contour interval for the color shading is 0.25, and 0.5 for the white contours. Values between −0.25 and 0.25 are unshaded. The thin horizontal lines indicate the approximate boundary between the troposphere and the stratosphere.

Polar Cap Index = (-1)*AO index



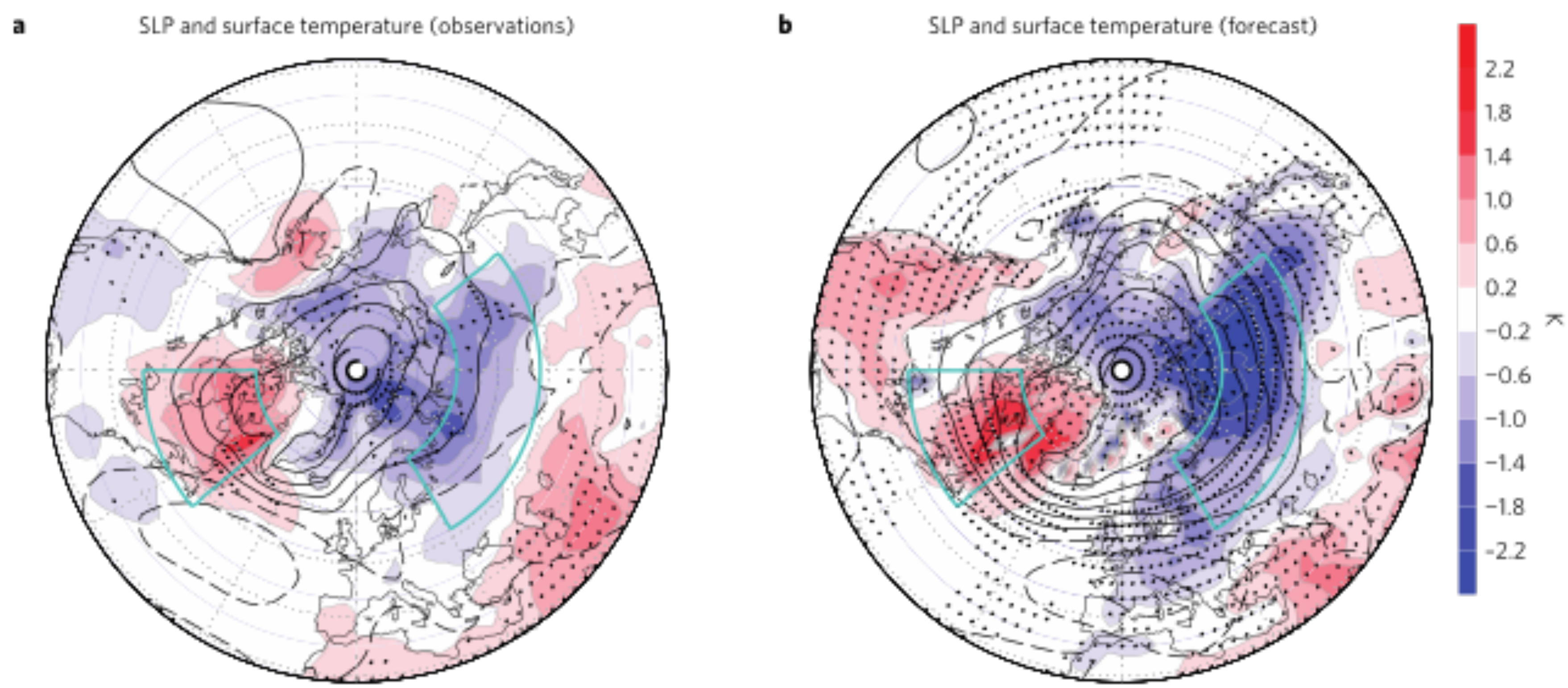
From CPC (http://www.cpc.ncep.noaa.gov)



LETTERS
PUBLISHED ONLINE: 13 JANUARY 2013 | DOI: 10.1038/NGEO1698
nature geoscience

Enhanced seasonal forecast skill following stratospheric sudden warmings

M. Sigmond[1]*, J. F. Scinocca[2], V. V. Kharin[2] and T. G. Shepherd[1,3]



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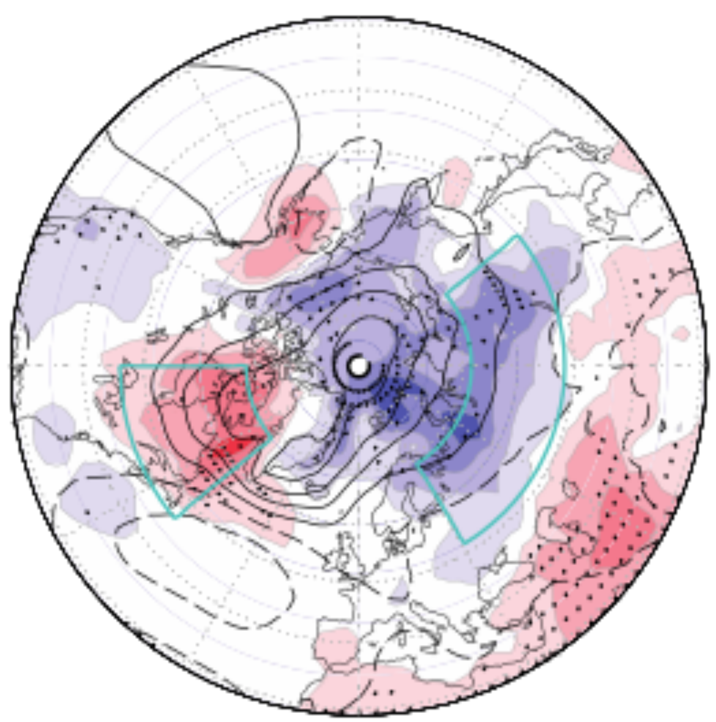
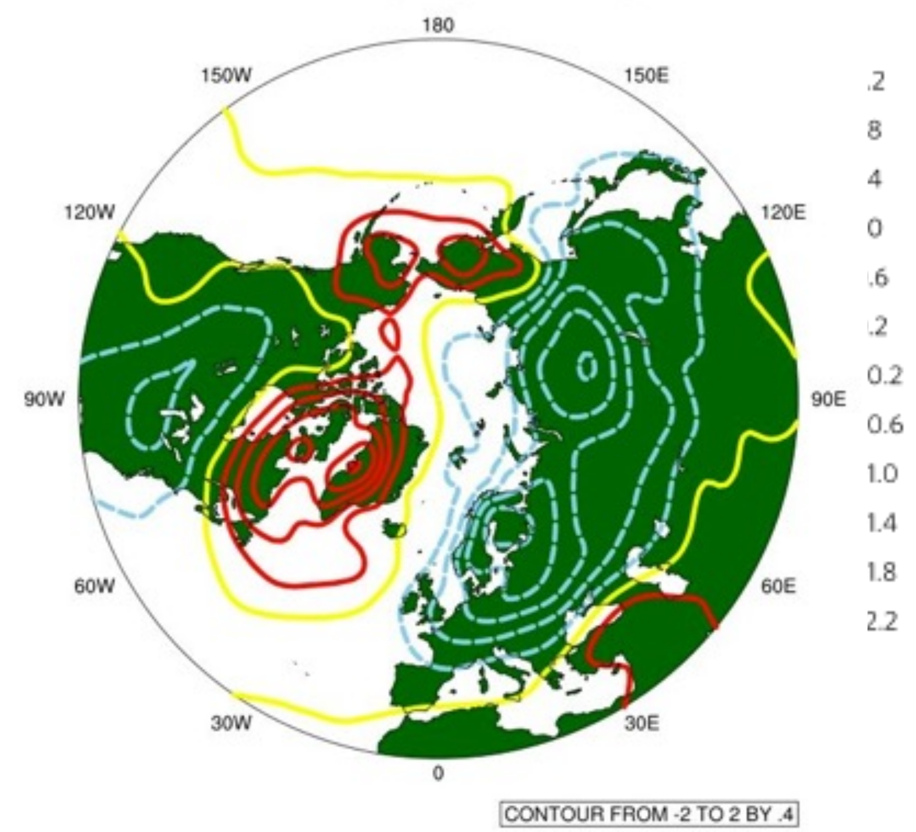
Enhanced seasonal forecast skill following stratospheric sudden warmings

M. Sigmond[1]*, J. F. Scinocca[2], V. V. Kharin[2] and T. G. Shepherd[1,3]

a SLP and surface temperature (observations)

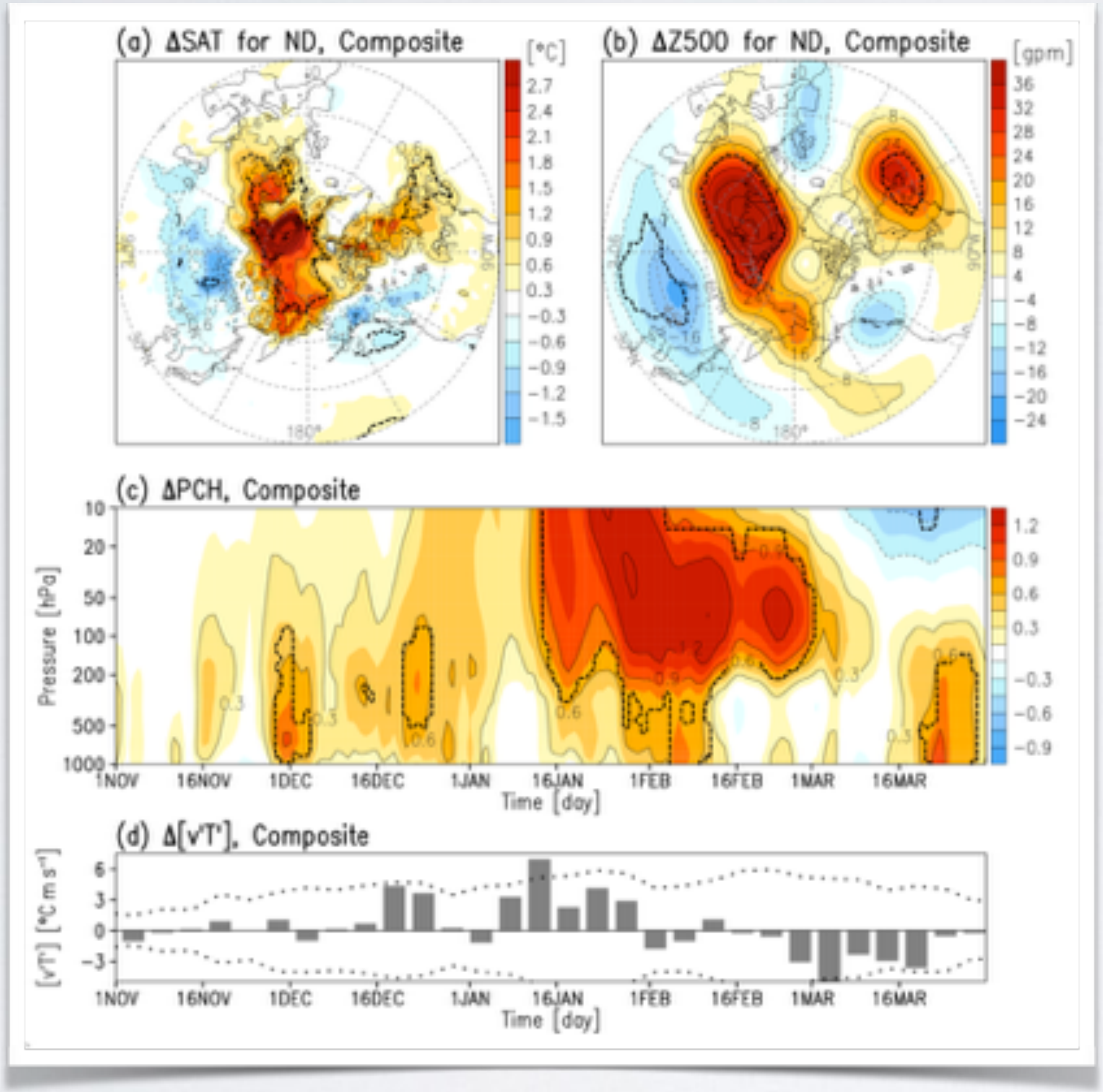


SFC. T. (Negative AO)

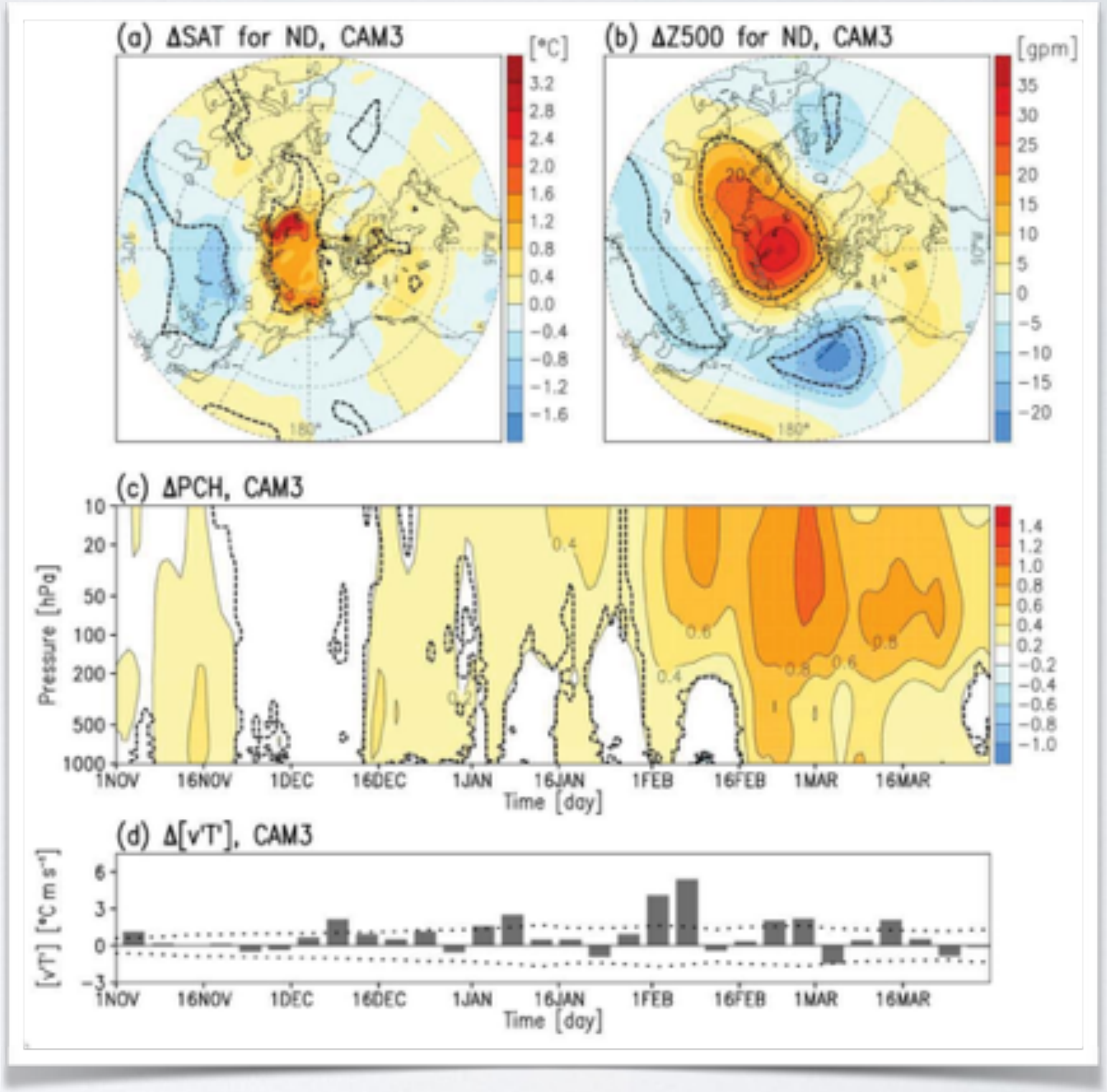


Cold Extremes in a Warming World, Why?

Weakening of Stratospheric Polar Vortex by Arctic Sea-Ice Loss



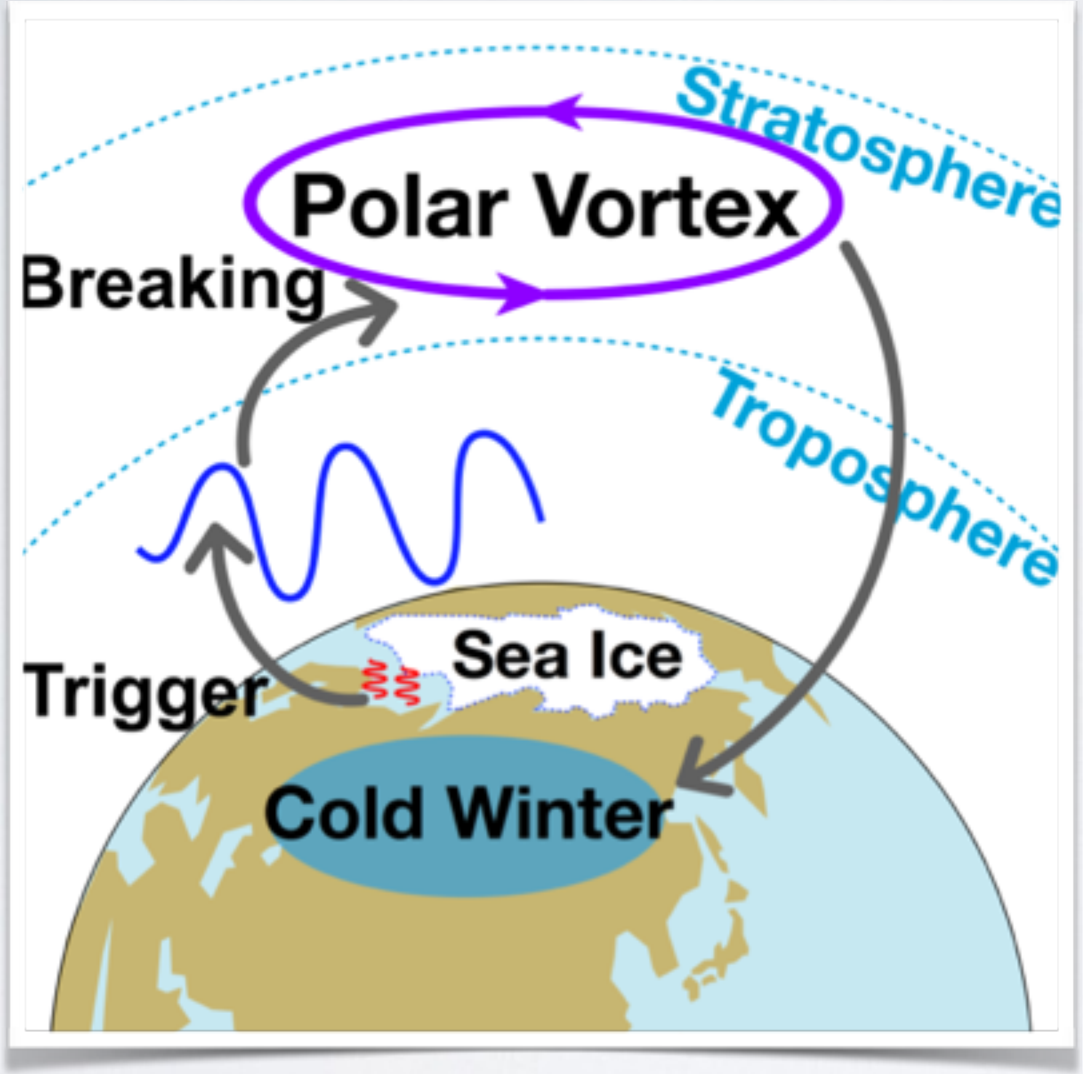
Reanlysis



Model

Kim et al. 2014, Nature Comms.

Cold Extremes in a Warming World, Why?



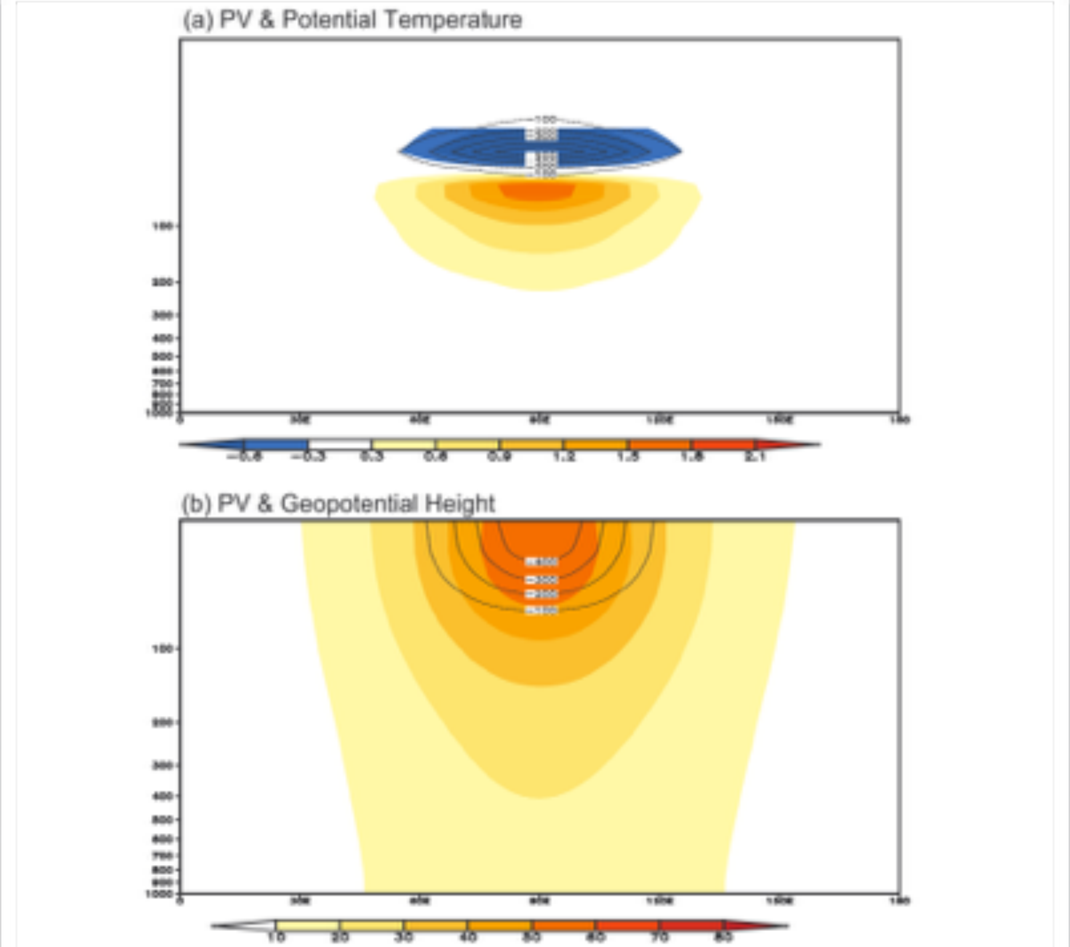
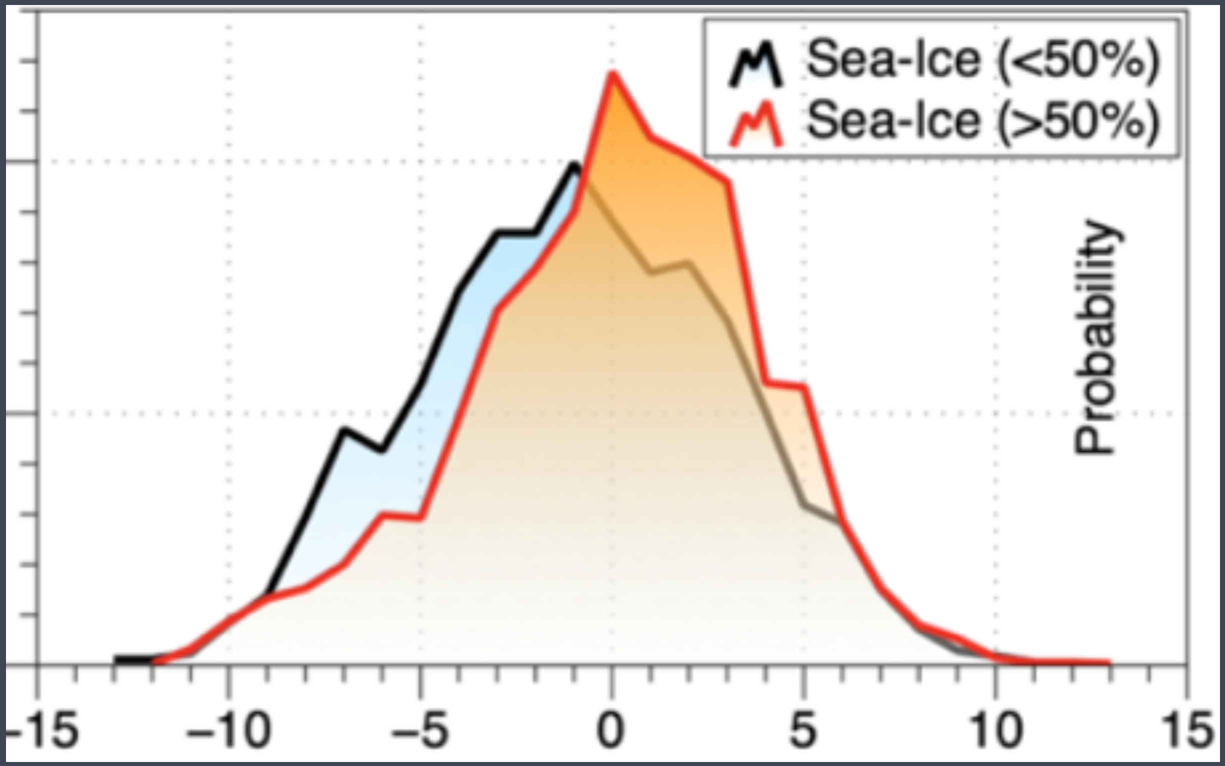


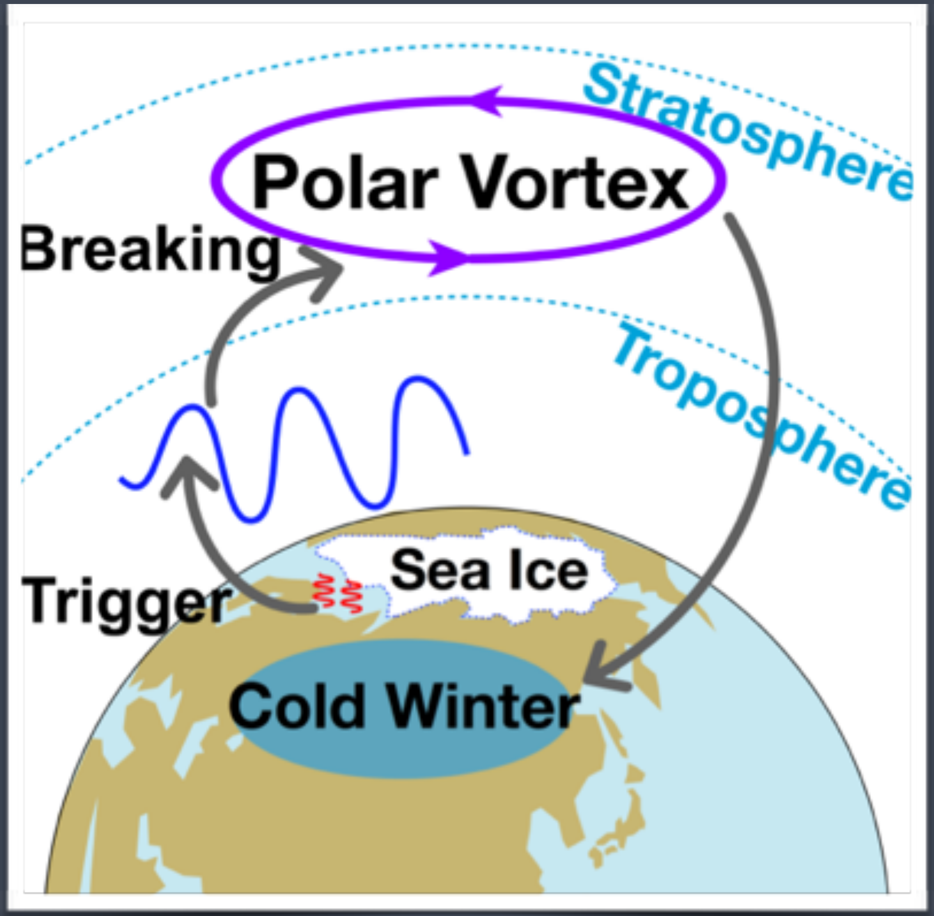
Fig. 3. The balanced (a) potential temperature (K) and (b) geopotential height (m) anomaly (shaded) of prescribed PV anomaly (contours). Contour interval is 0.01 PVU.

Kim et al. (2009)

Cold Extremes in a Warming World, Why?



Atmospheric Dynamics partly answers.



THANK YOU A LOT
FOR YOUR ATTENTION!

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