2016-4-8, APEC 기후센터

변화하는 고위도 기후특성과 동아시아 한파발생

전남대학교 지구환경과학부 해양학과

정지훈

Contributors: 김백민(극지연구소), 박태원(전남대), 최자현(전남대)

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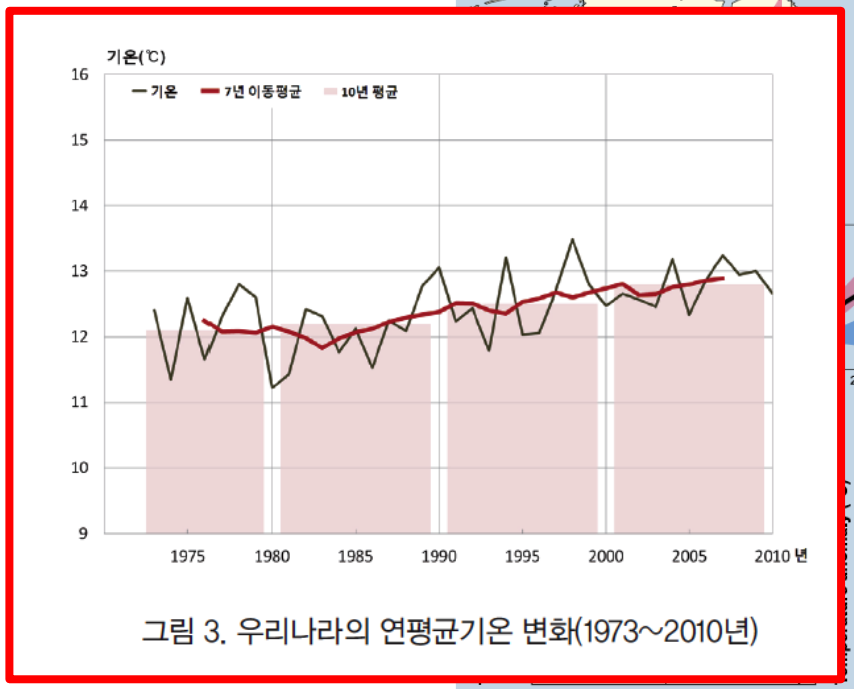
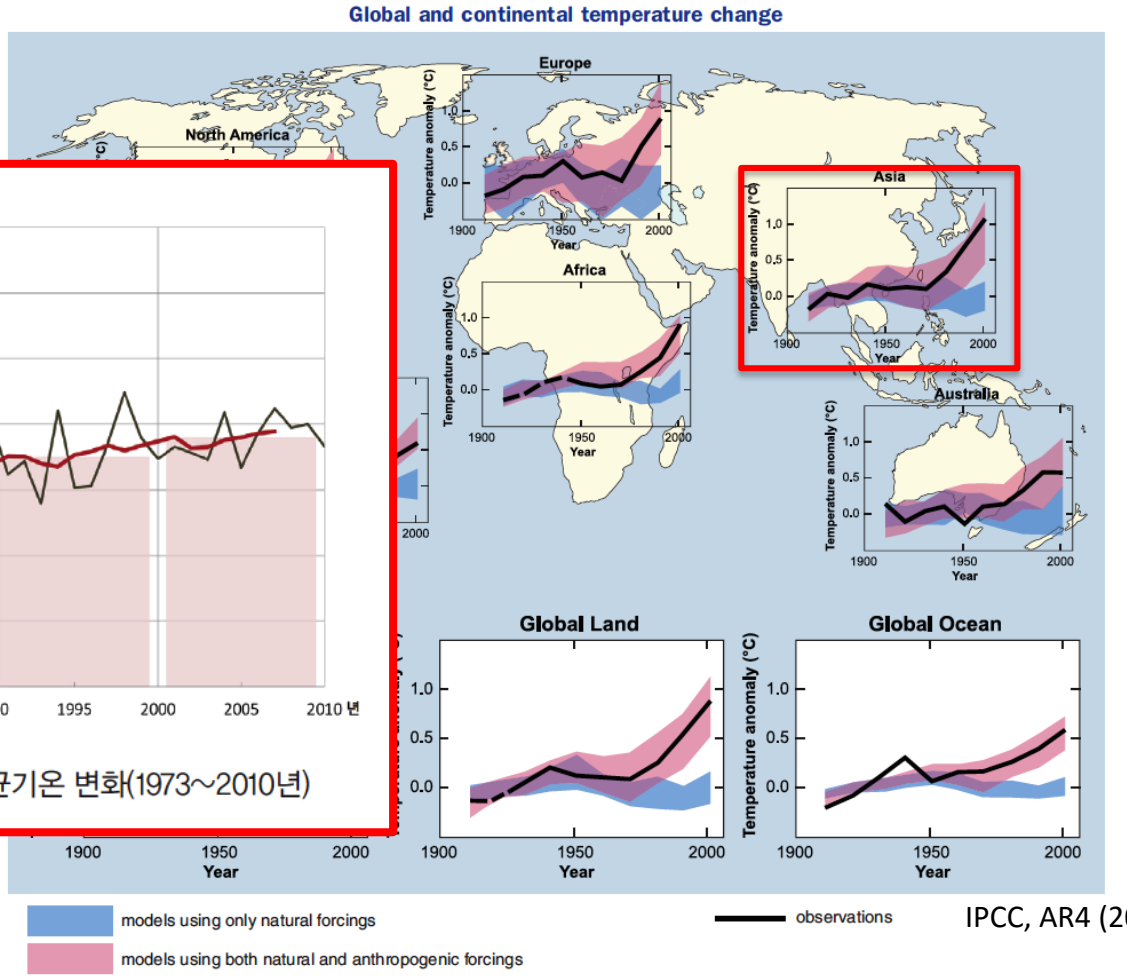


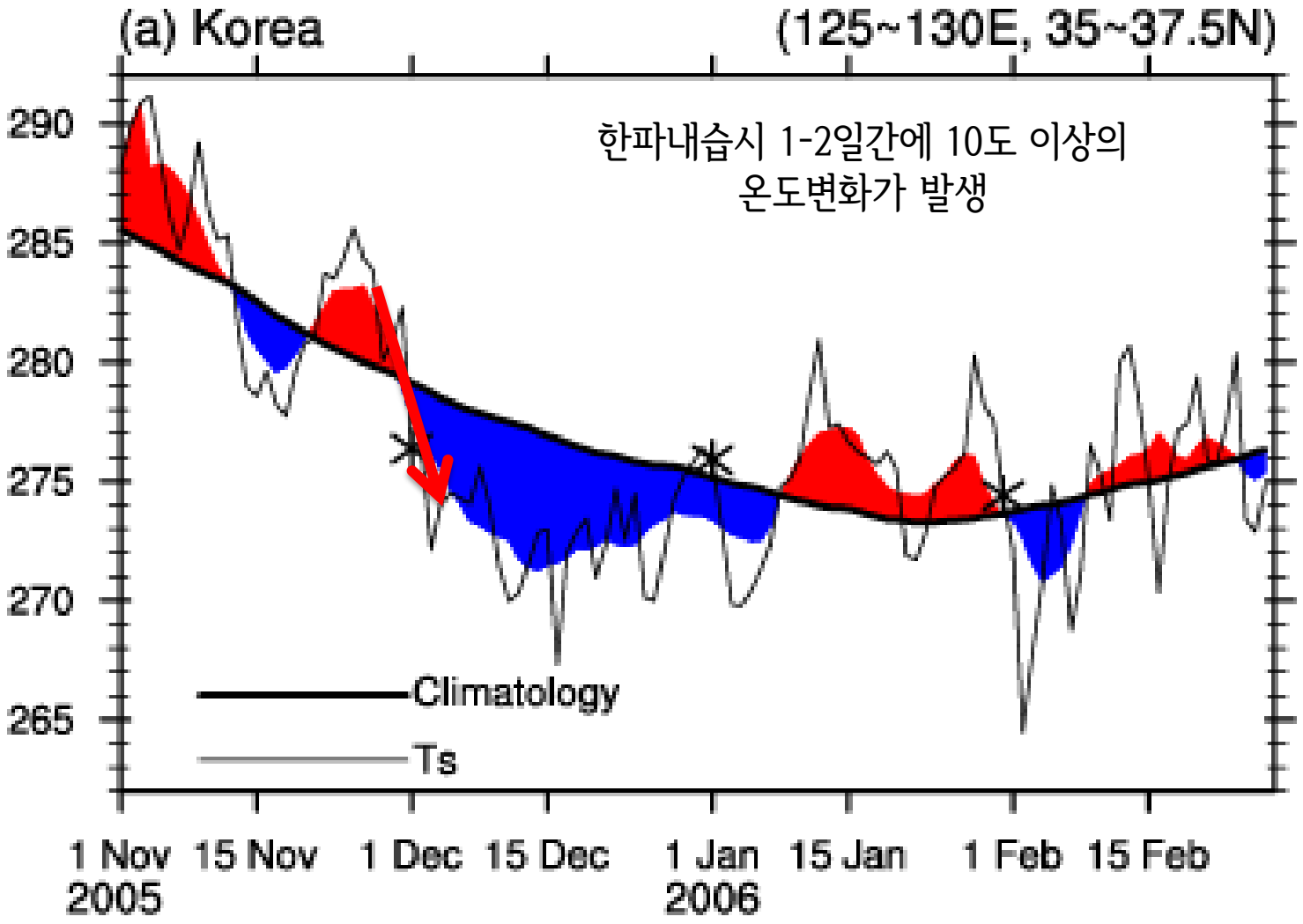
그림 3. 우리나라의 연평균기온 변화(1973~2010년)

기상연구소 기후변화백서 (2011)



IPCC, AR4 (2007)

과거 30여년간 약 1도 상승


(a) Korea
(125~130E, 35~37.5N)
290
285
280
275
270
265
한파내습시 1-2일간에 10도 이상의
온도변화가 발생
Climatology
Ts
1 Nov
2005
15 Nov
1 Dec
15 Dec
1 Jan
2006
15 Jan
1 Feb
15 Feb

Googling “한파”

#1

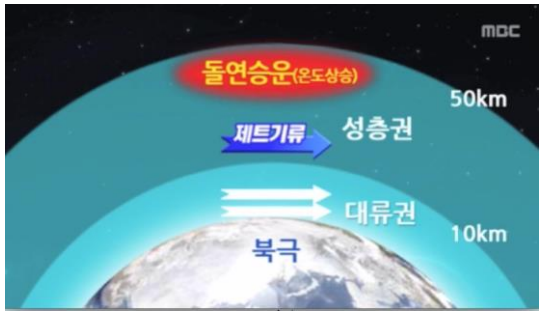
#5

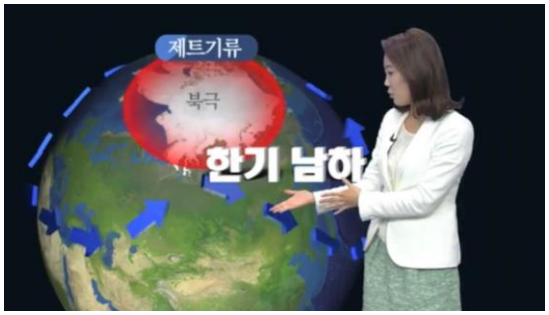
#4

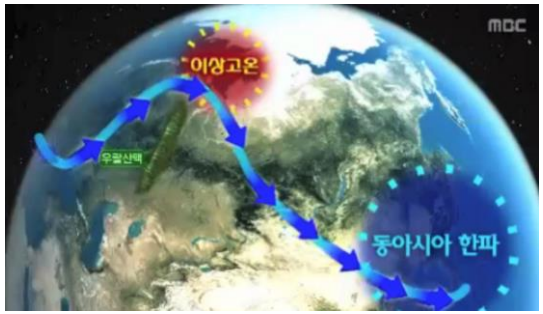
#3

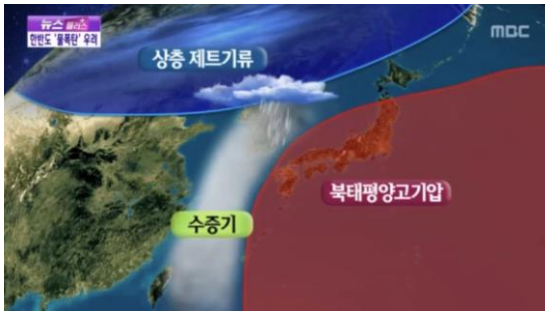
#2

초등학생도 이야기하는 “북극한파”

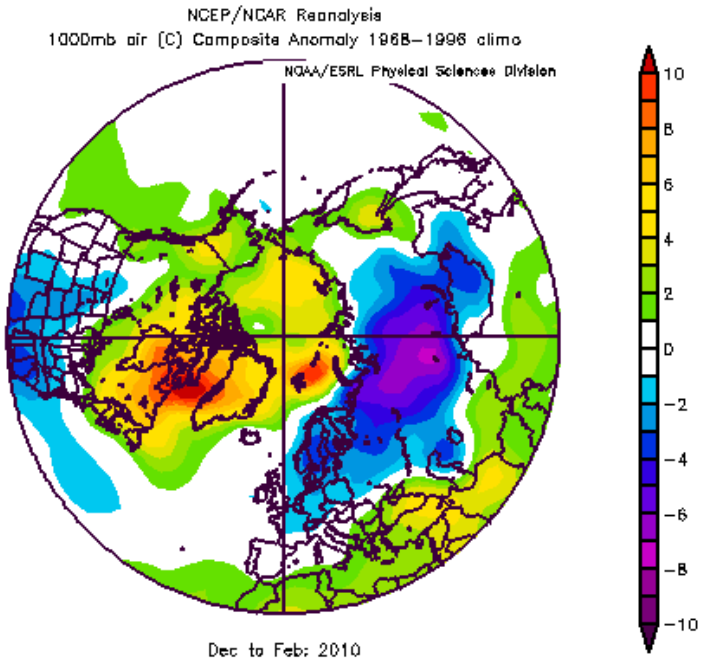


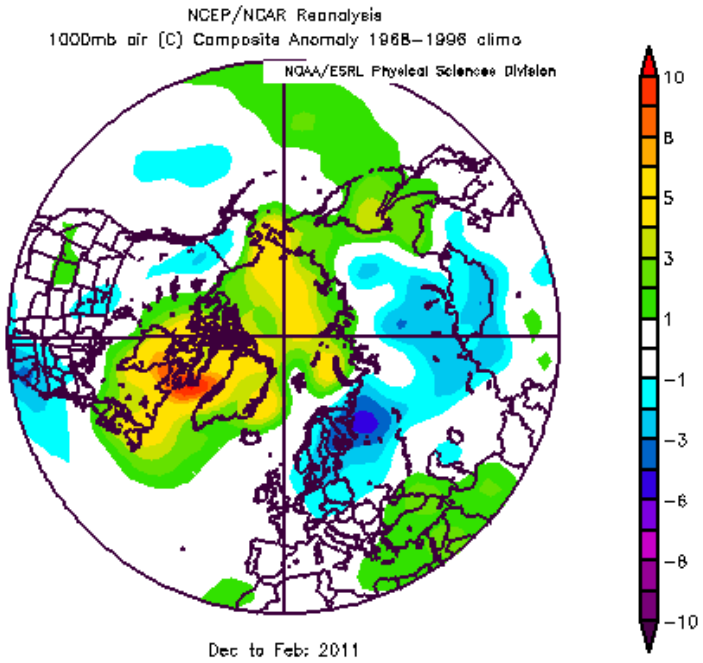


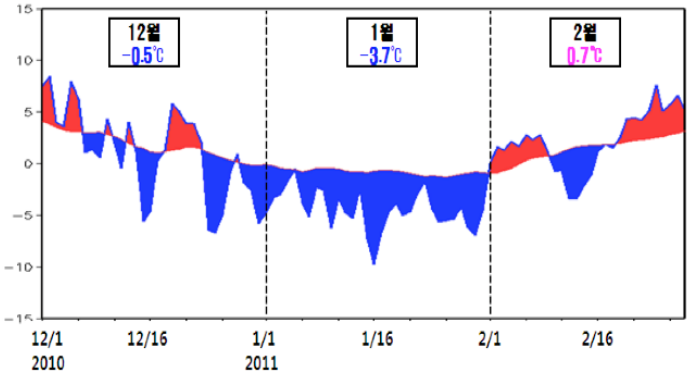




최근 연이어 발생하는 추위:2010 & 2011 겨울







2010년 12월 - 2011년 2월:
남한 평균기온

유럽-북미도 마찬가지…

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L06801, doi:10.1029/2012GL051000, 2012

Evidence linking Arctic amplification to extreme weather in mid-latitudes

Jennifer A. Francis[1] and Stephen J. Vavrus[2]

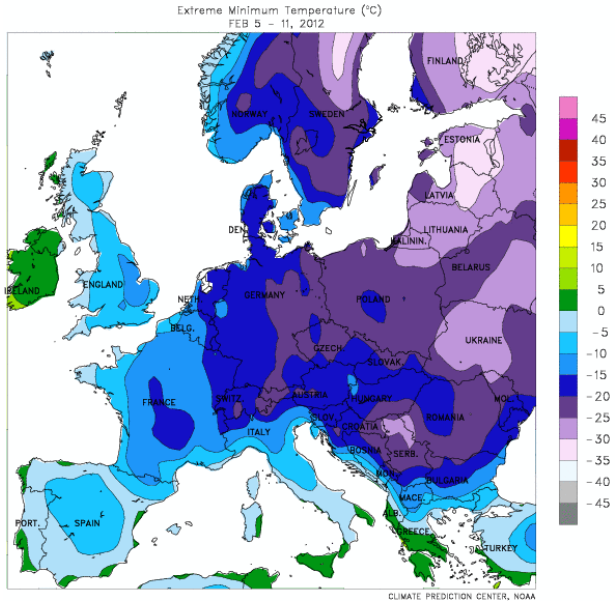
nature climate change

LETTERS

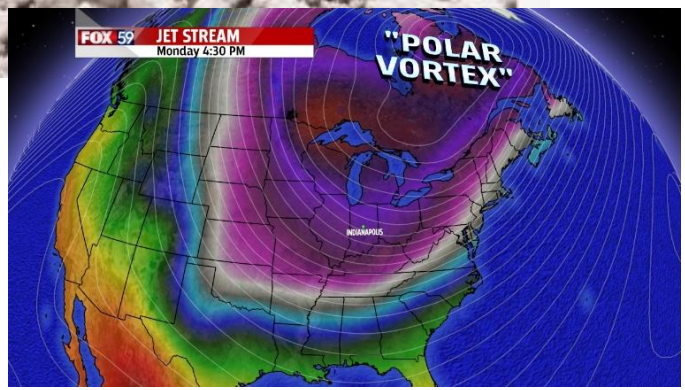
PUBLISHED ONLINE: 22 JUNE 2014 | DOI: 10.1038/NCLIMATE2271

Amplified mid-latitude planetary waves favour particular regional weather extremes

James A. Screen[1]* and Ian Simmonds[2]

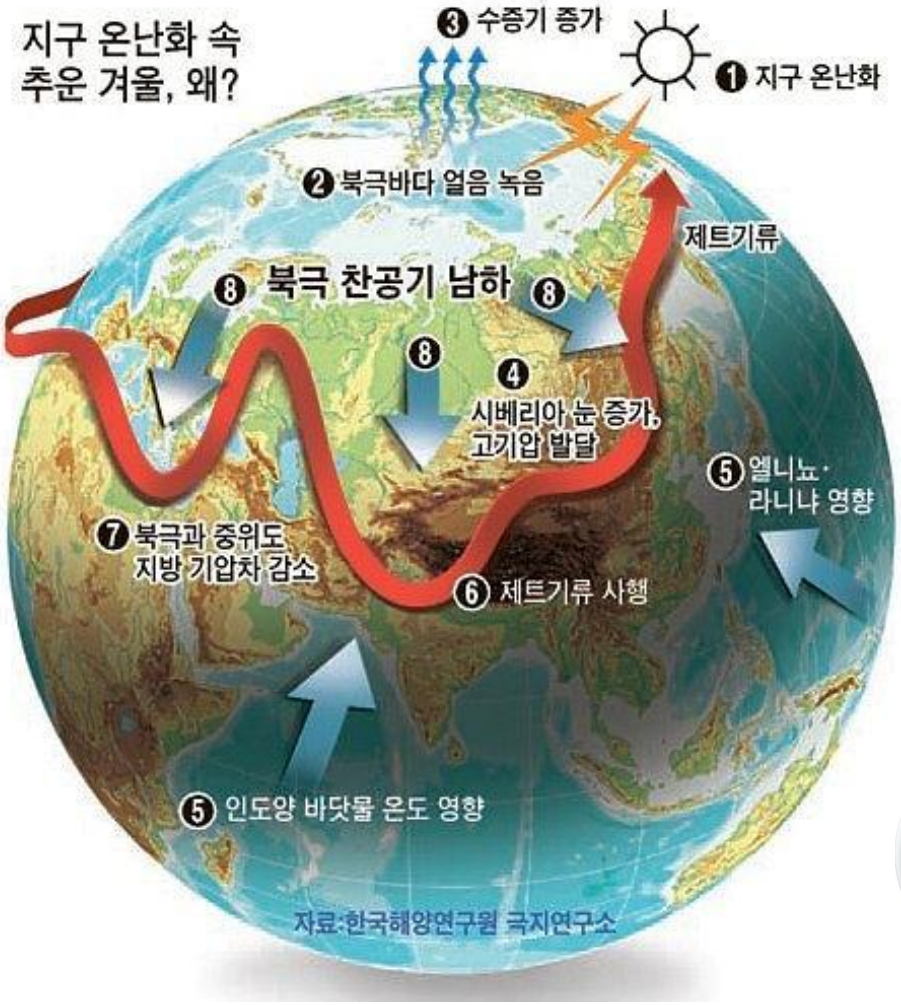


European
cold wave Feb. 2012



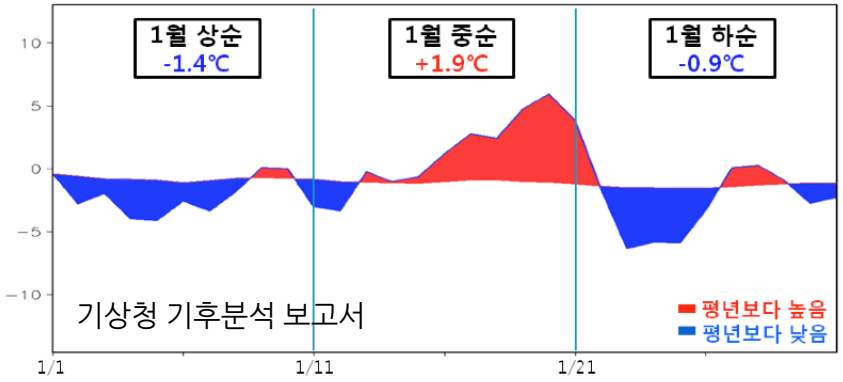
US cold wave 2014/5

제시되고있는 설명들


지구 온난화 속
추운 겨울, 왜?
❸ 수증기 증가
❶ 지구 온난화
❷ 북극바다 얼음 녹음
제트기류
❽ 북극 찬공기 남하
❽
❽
❹
시베리아 눈 증가,
고기압 발달
❺ 엘니뇨·
라니냐 영향
❼ 북극과 중위도
지방 기압차 감소
❻ 제트기류 사행
❺ 인도양 바닷물 온도 영향
자료:한국해양연구원 극지연구소

겨울철 기후특성의 변화

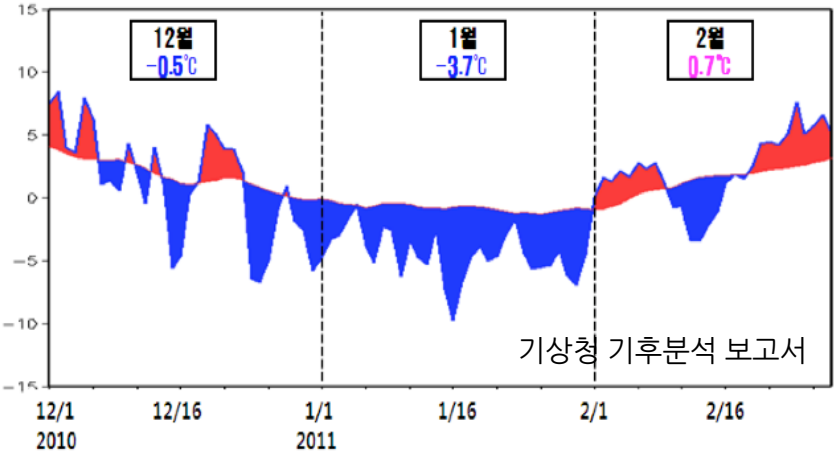
2012년 1월



[그림 4] 1월 전국 평균기온의 일변화(1.1~1.31, ℃)

보름이상의 주기를 가지는 계절내 진동

2010년 12월 – 2011년 2월



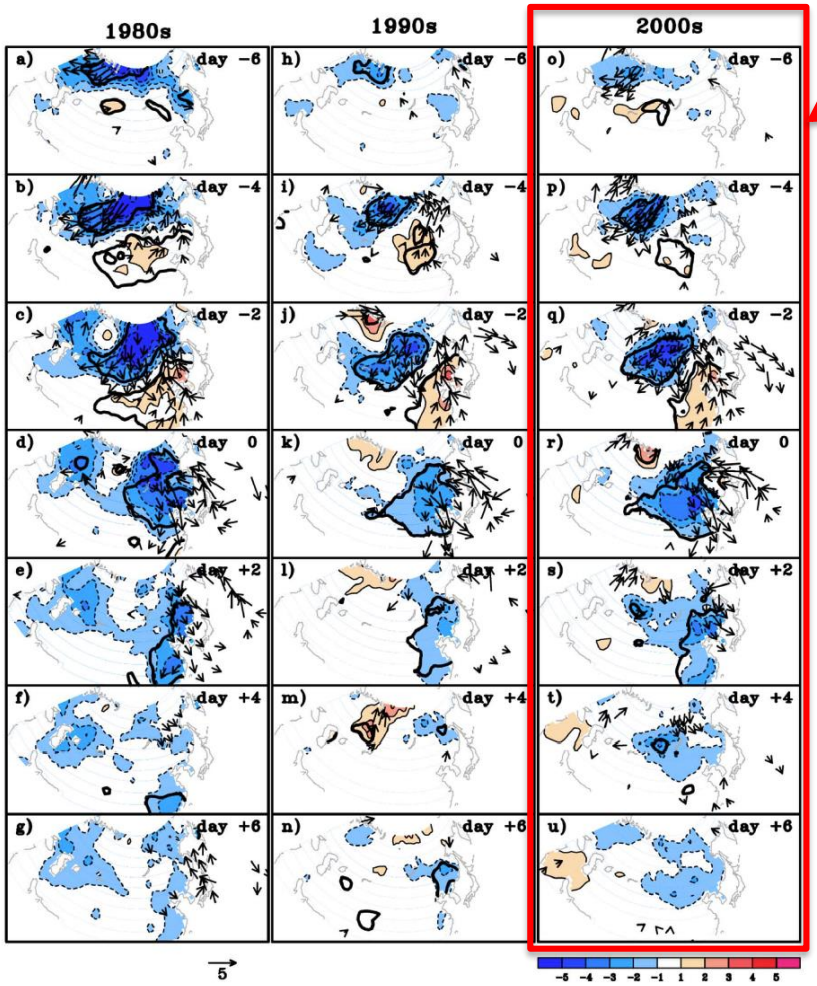
한달이상 지속되는 한파발생

최근 수년간 3한 4온의 특성이 약해지고 장주기 변동성 증가
강하고, 오래 지속되는 한파발생의 증가

➢ 기후 특성의 변화, 외적 요인에 의한 변동성 증가?

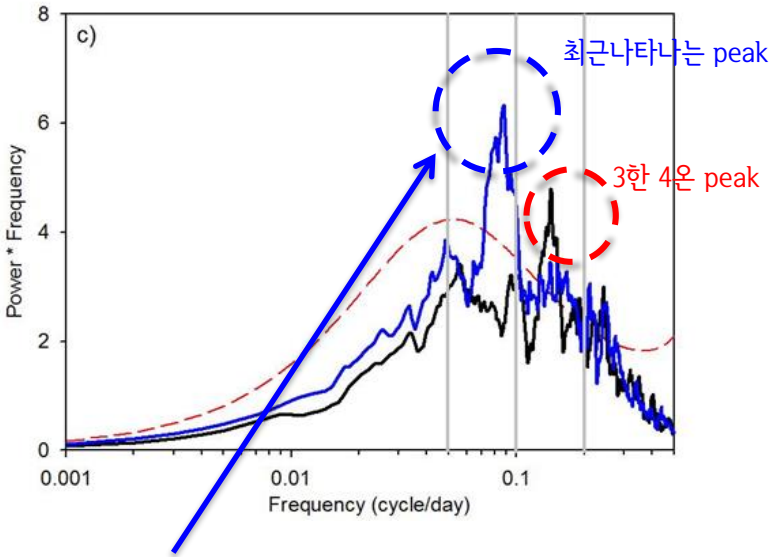
중장기 변동성의 증가

1980, 1990, 2000년대 한파발생시 기온변동



2000년대 들어 강력한 한파 발생이 늘고있으며, 한번 발생시 그 지속시간이 길어졌음

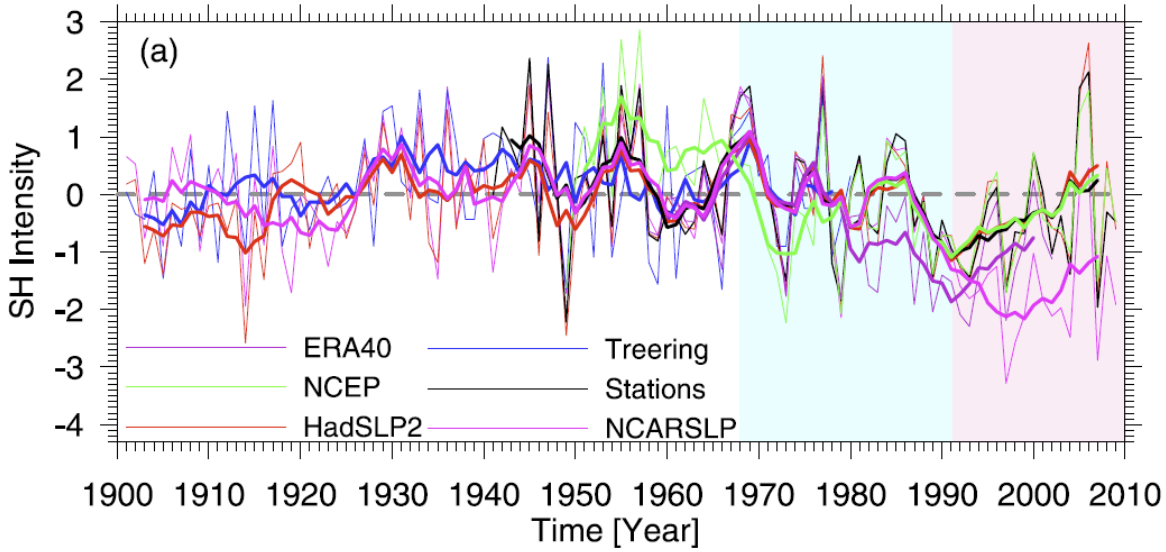
한반도 겨울철 기온의 power spectrum

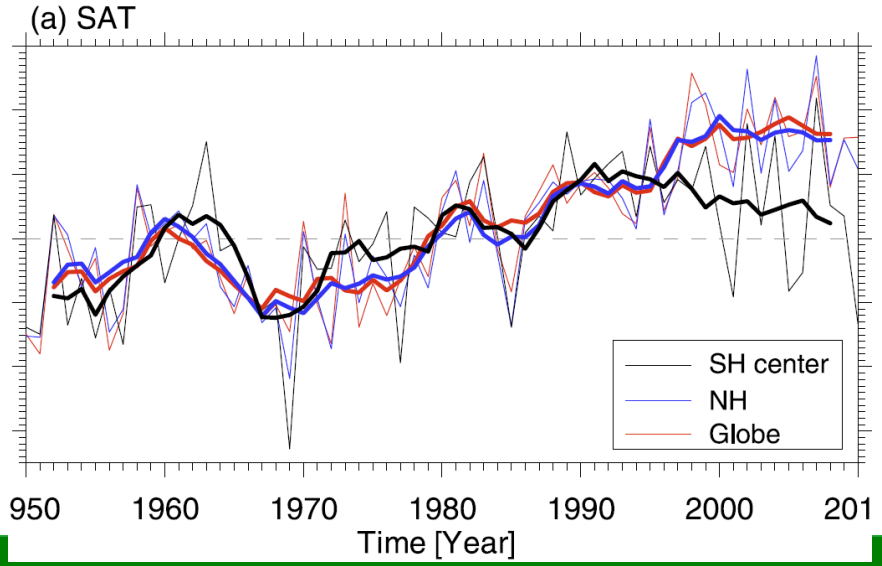


과거에 비해 기온의 중장기 (10일 이상) 변동성분이 크게 증가하였음

Woo, Jeong, et al. (2012, JGR)

시베리아 고기압 강도의 장기변화





동아시아 지역 기후 변동성의 장기 변화

동아시아 지역에서의 기온 극값 변화 경향

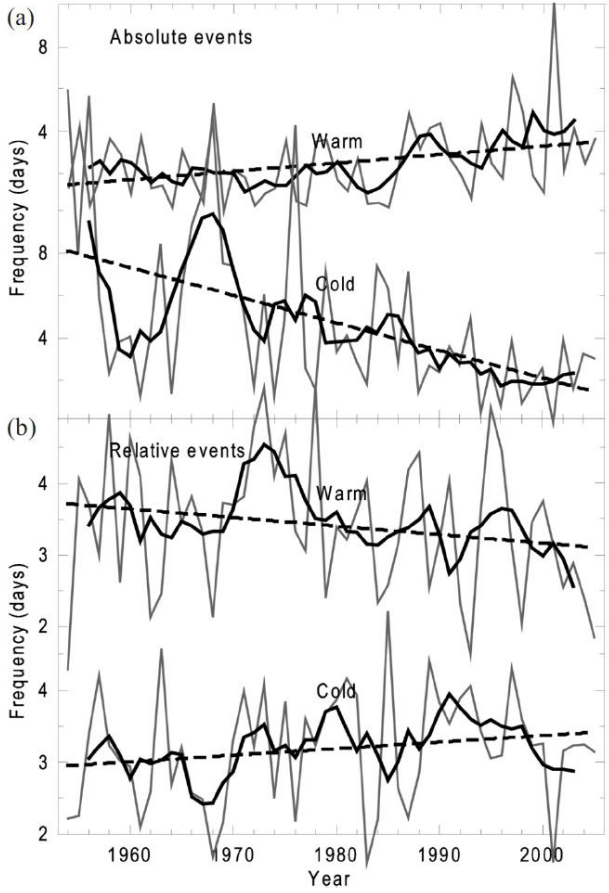
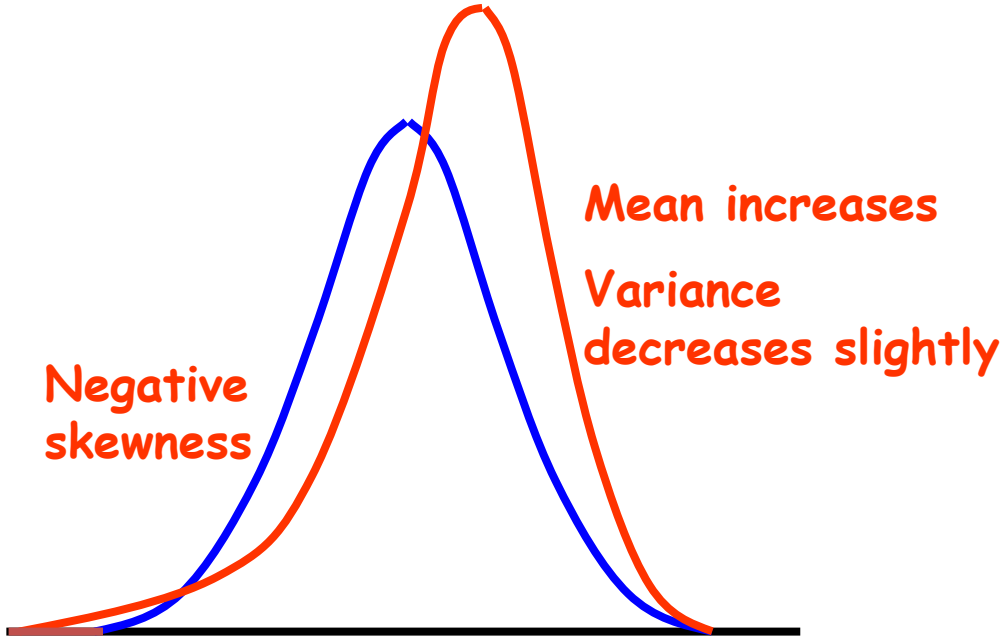


Fig. 1. Frequency of (a) absolute and (b) relatively cold and warm events in East Asia during winter monsoon. Thick solid and dotted lines are the 5-year running mean and linear trends of the time-series.

Choi et al. 2009 (TAO)



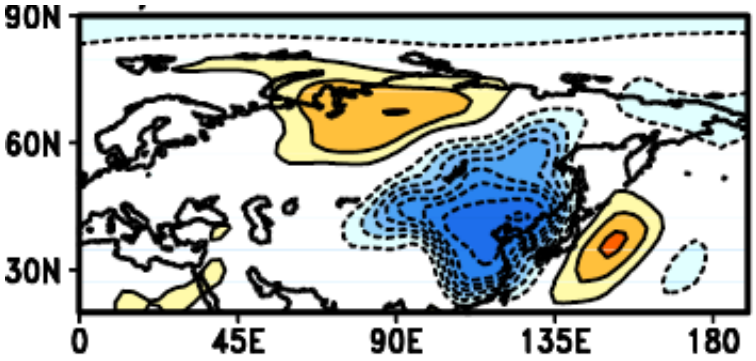
평균 기온증가를 감안한
한파발생 횟수 변화

변동성의 증가로 인한 극기상의 증가가 나타남

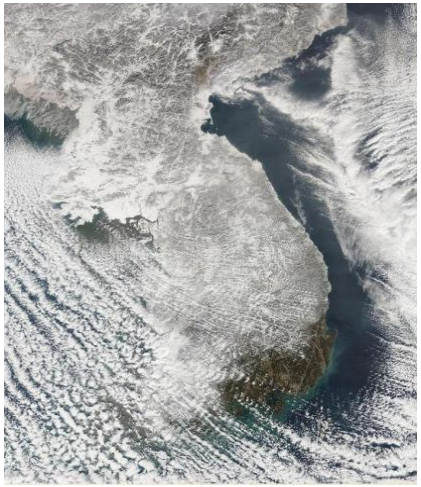
What is Cold Surge more physically?

Cold surge …

- Sudden temperature drop within a day or two
- Strong cold wind
- Long-lasting cold weather
- Heavy snowfall
- Freezing surface



Satellite image by Terra of NASA on Jan.7, 2010

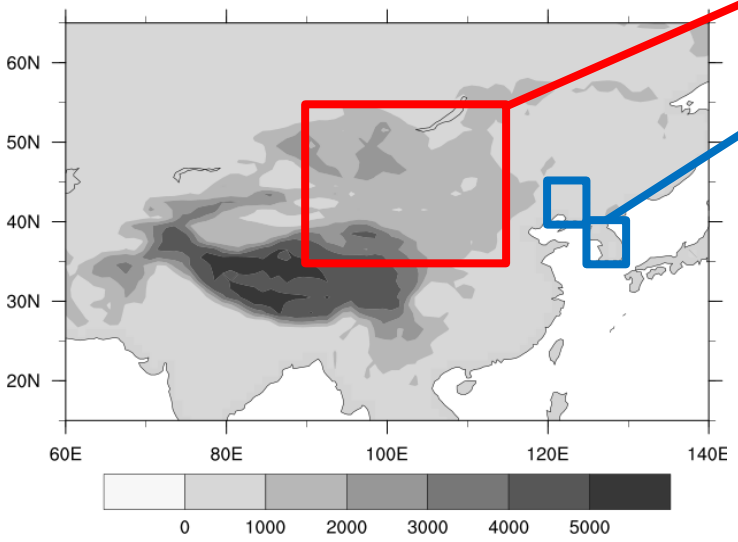


☒ Definition of cold surges

- The typical scenario of cold surge occurrence
  - The Siberian high reaches certain intensity,
  - Eastward moving upper level short-wave trough aloft over Lake Baikal deepens as it propagates toward quasi-stationary East Asian coastal trough
  - Surface anticyclone moves southward together with very cold air accumulated over eastern Siberia - a cold surge occurrence

- Criteria for cold surge occurrence
  - Surface anticyclone (expansion of Siberian High)
  - Temperature drop
  - Northerly Wind

Cold Surge Definition



1. Siberian high center ≥ 1035 hPa

2. Temperature drop ≥ 1.5*STD

(winter temperature anomaly)

3. Temperature anomaly ≤ 0

Duration

Temperature anomaly > -0.5*STD

Intensity

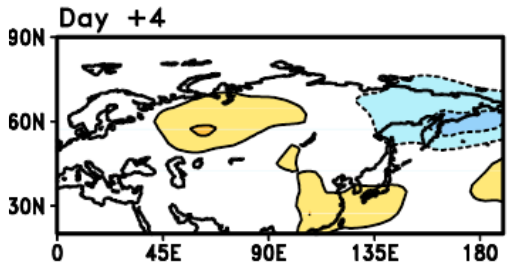
sum of temperature anomaly during cold surge

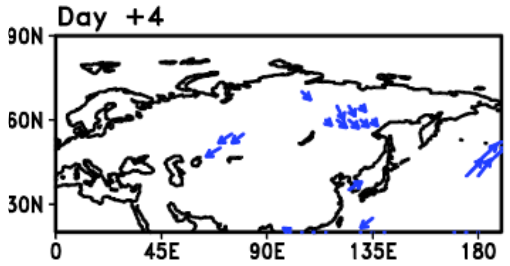
Similar in Zhang et al. 1997, Jeong and Ho 2005, Park et al. 2008

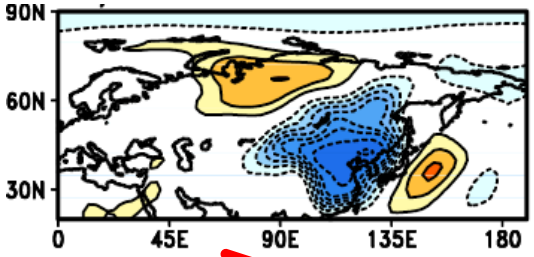
Cold Surge Occurrence Mechanism

기상청 Korea Meteorological Administration

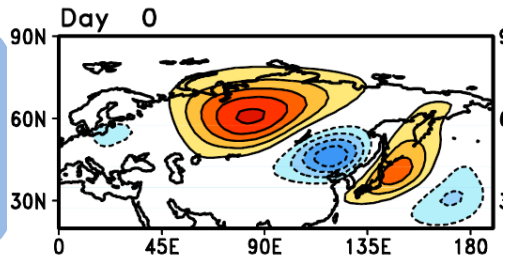
Expansion of the Siberian High → **Strong northerly wind** → **Bringing cold air**



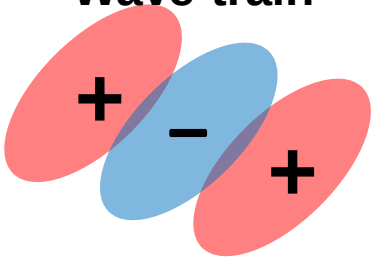




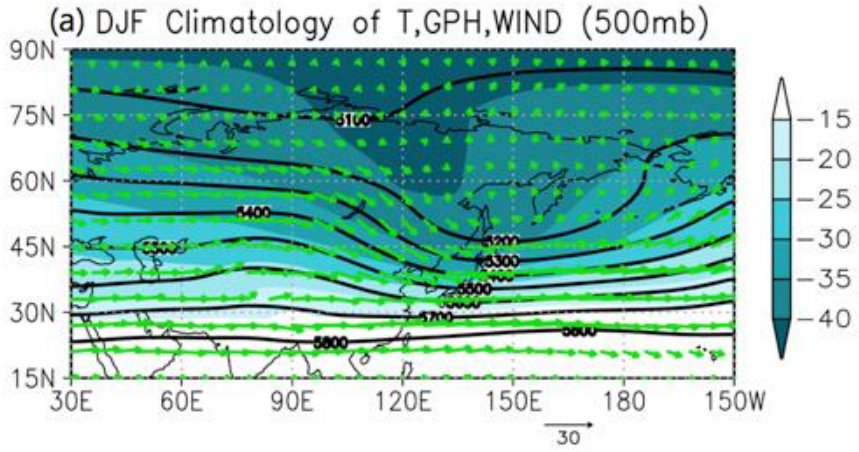
Upper-tropospheric wave-train

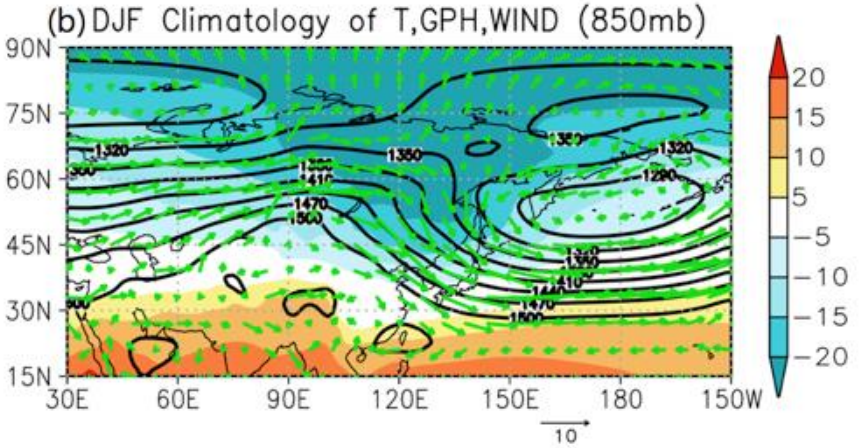


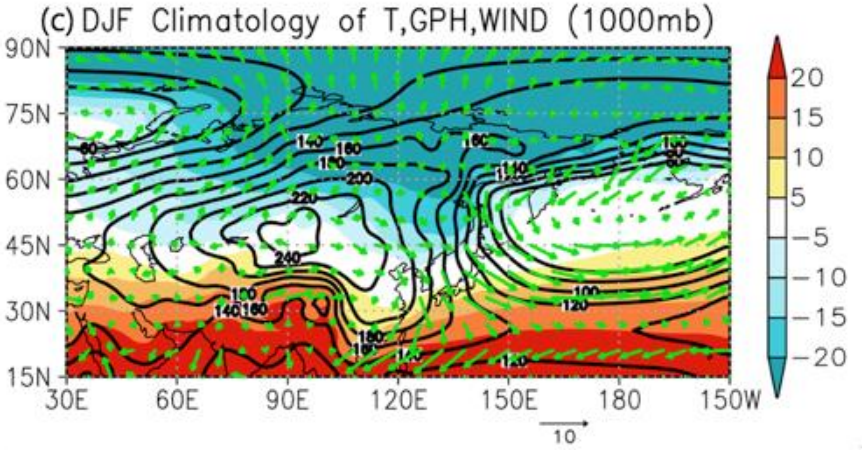
Wave-train



전남대학교 CHONNAM NATIONAL UNIVERSITY

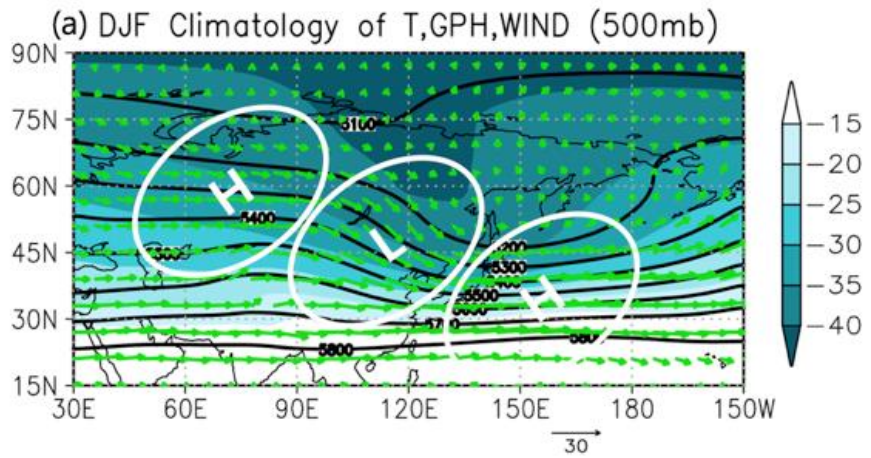

(a) DJF Climatology of T,GPH,WIND (500mb)
90N
75N
60N
45N
30N
15N
30E
60E
90E
120E
150E
180
150W
30
−15
−20
−25
−30
−35
−40

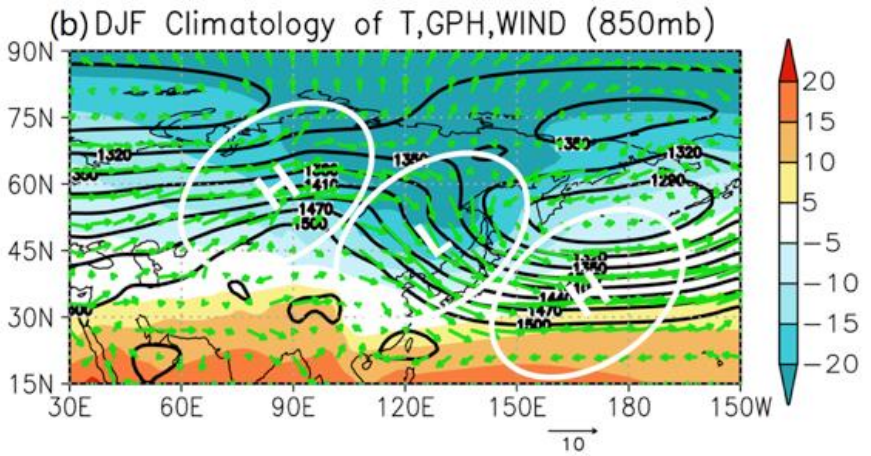

(b) DJF Climatology of T,GPH,WIND (850mb)
90N
75N
60N
45N
30N
15N
30E
60E
90E
120E
150E
180
150W
10
20
15
10
5
−5
−10
−15
−20

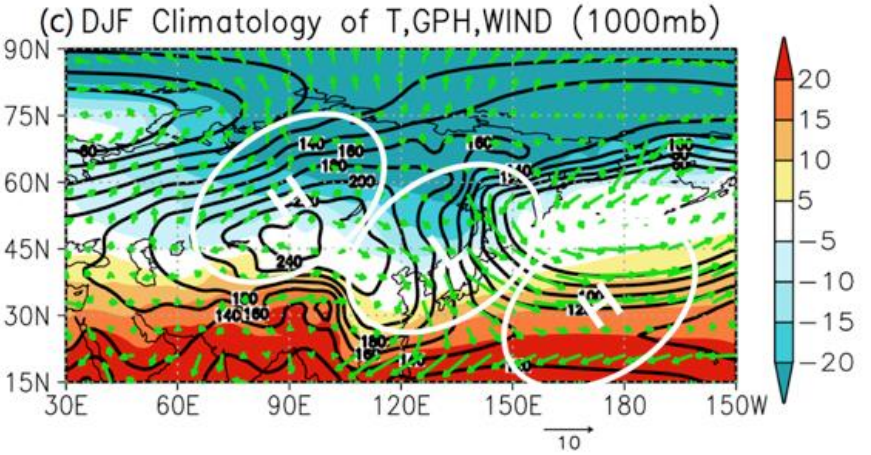

(c) DJF Climatology of T,GPH,WIND (1000mb)
90N
75N
60N
45N
30N
15N
30E
60E
90E
120E
150E
180
150W
10
20
15
10
5
−5
−10
−15
−20

Wave Train Type

"Classical"







On the Role of Successive Downstream Development in East Asian Polar Air Outbreaks[1]

CHANG HI JOUNG

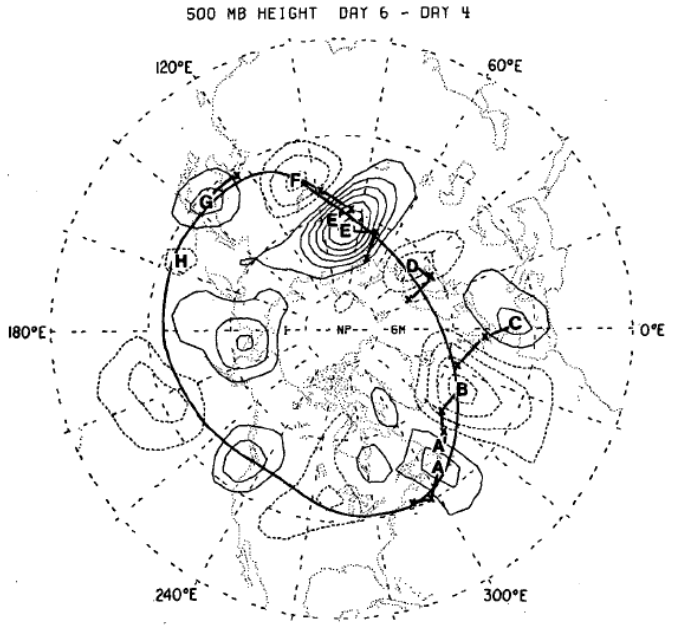
Department of Meteorology, College of Natural Sciences, Seoul National University, Shinrim-Dong, Kwanak-Ku, Seoul, Korea

MATTHEW H. HITCHMAN

Department of Atmospheric Sciences, University of Washington, Seattle 98195

(Manuscript received 25 November 1981, in final form 7 June 1982)

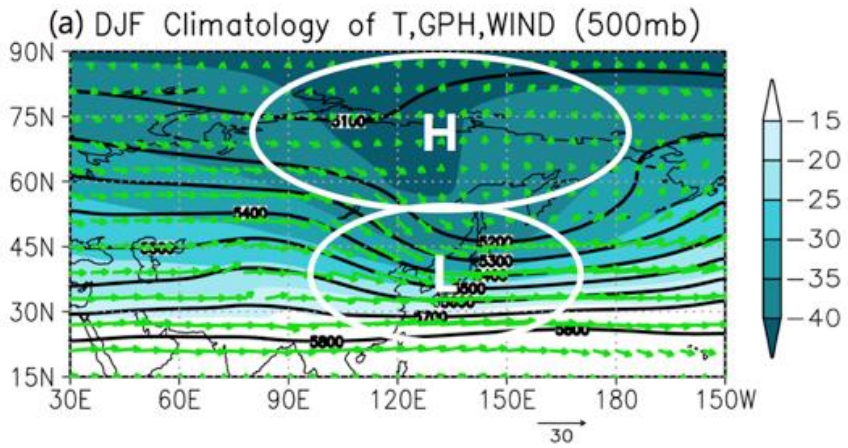
Surface pressure gradient over Korea exceeding 2.5 mb(100km)-1
Drop in daily mean SAT at South Korean stations of more than 5oC in a day

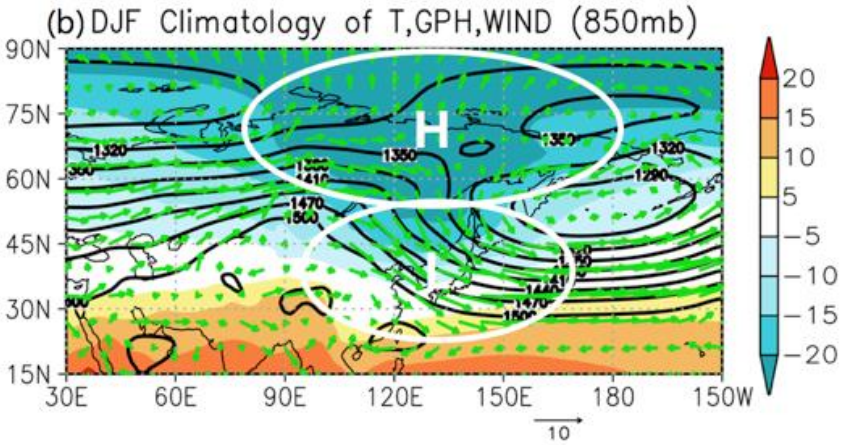


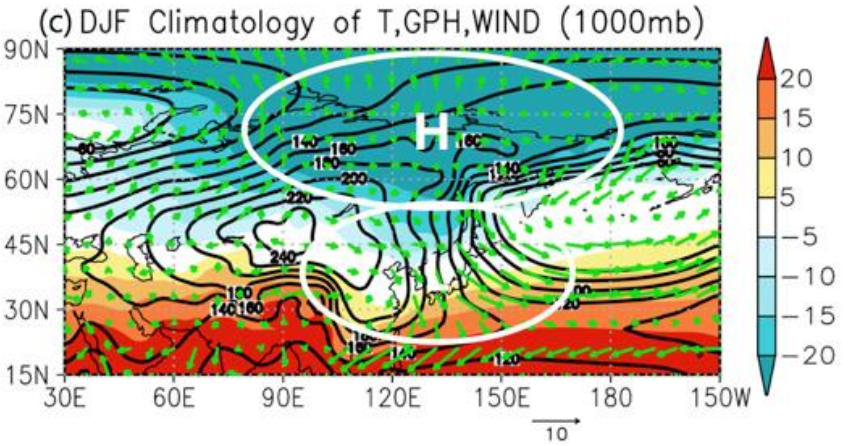
Two-day difference maps of 500 hPa GPH

Blocking Type

쎈놈



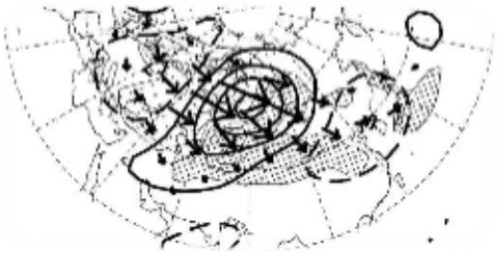




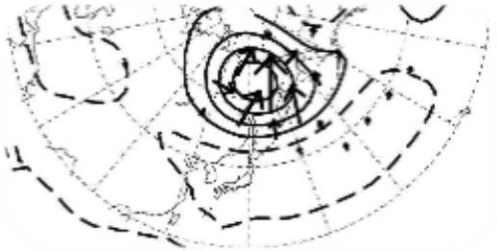
Distinct Type from Wave-Train

Intra-seasonal Amplification of Siberian High

Atlantic origin

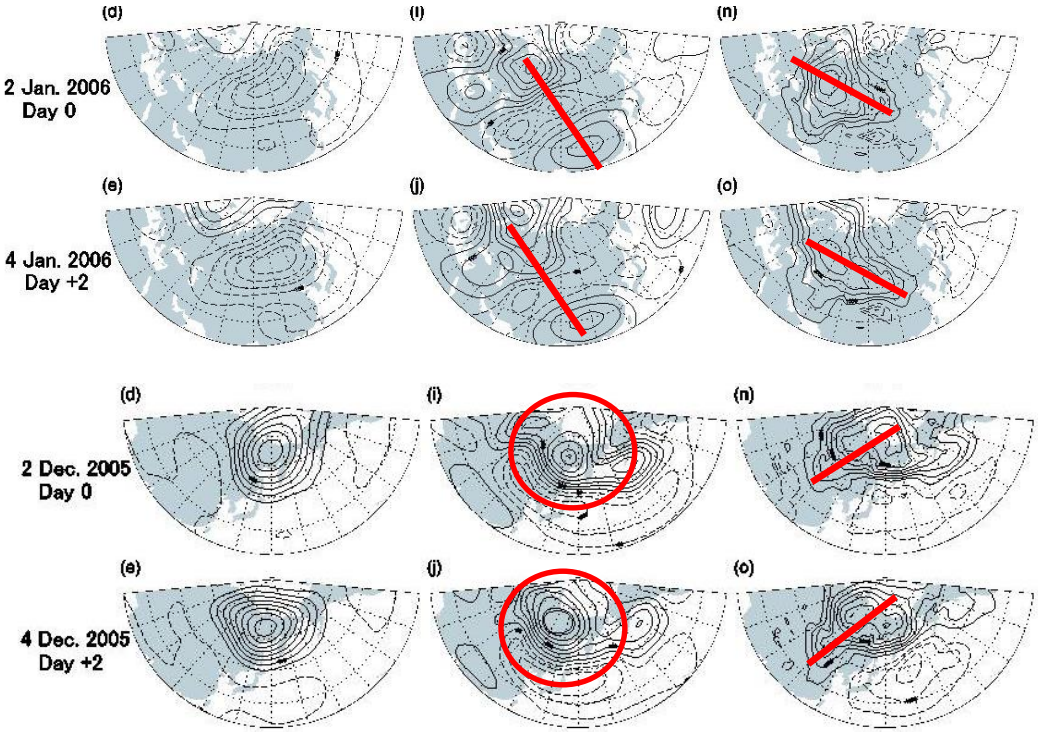


Pacific origin



[Takaya and Nakamura, 2005b]

2005/06 Case Study

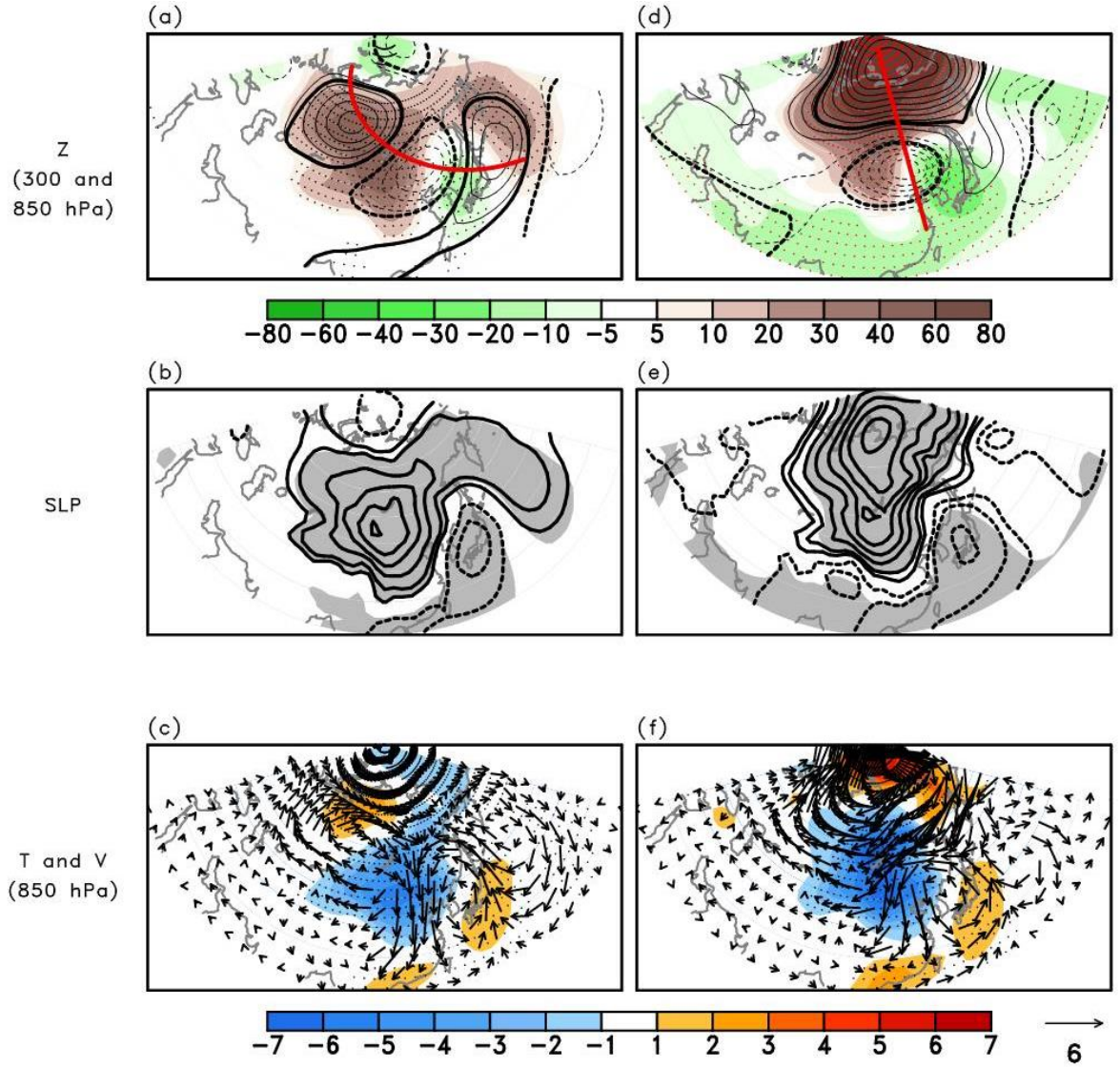


[Park et al., 2008]

Clustering Results

Atmospheric Circulation

	# of cold surges
Wave-Train	273 (82.2)
Blocking	59 (17.8)
Total	**332 (100)**



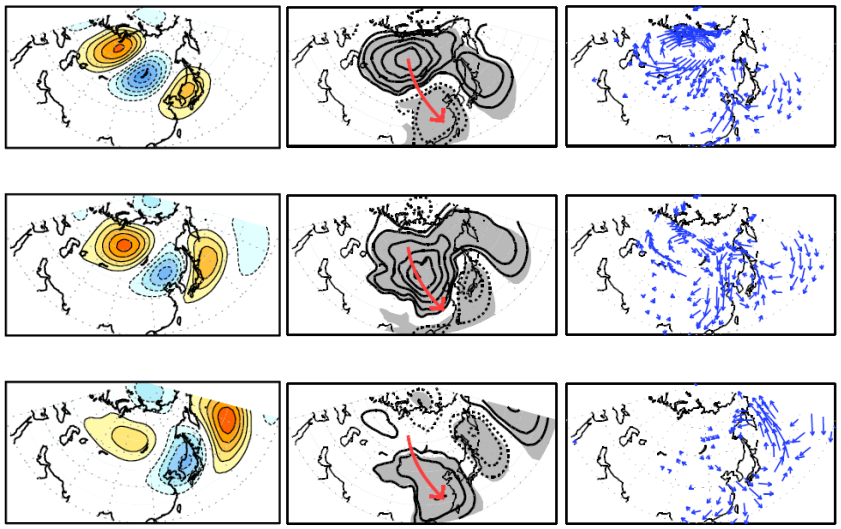
Clustering Results

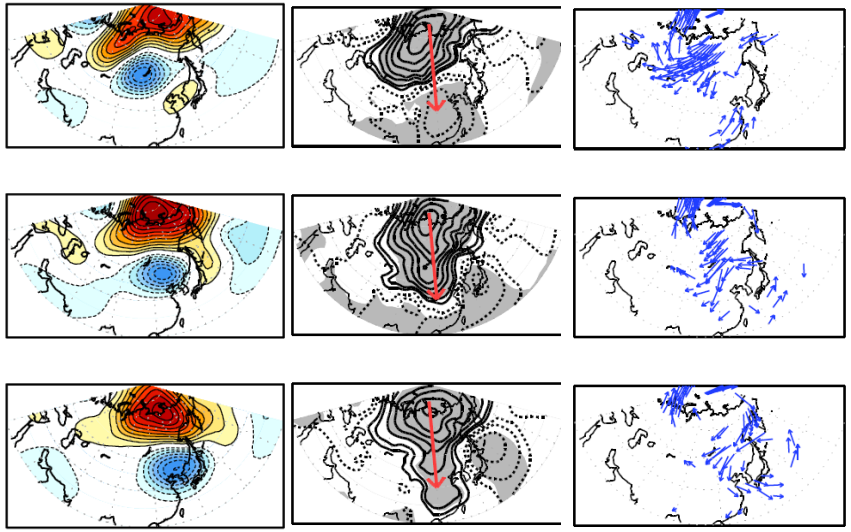
Wave-Train VS Blocking

Day −2

Day 0

Day +2



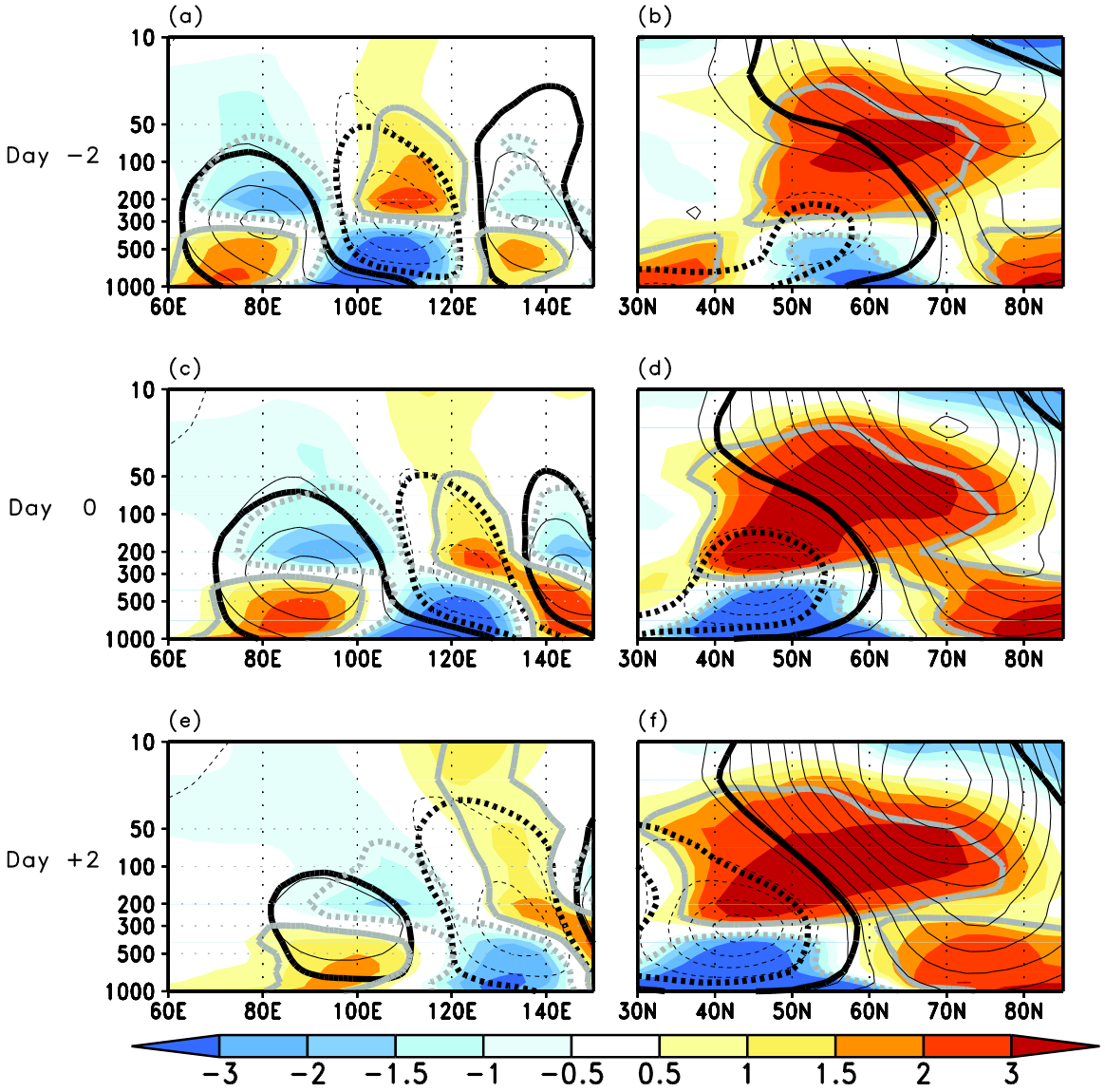


- Wave-train
- Southeastward expansion of the Siberian High

- Blocking
- Southward expansion of the Siberian High
- **Stronger and longer** cold surge
- **More predictable** cold surge

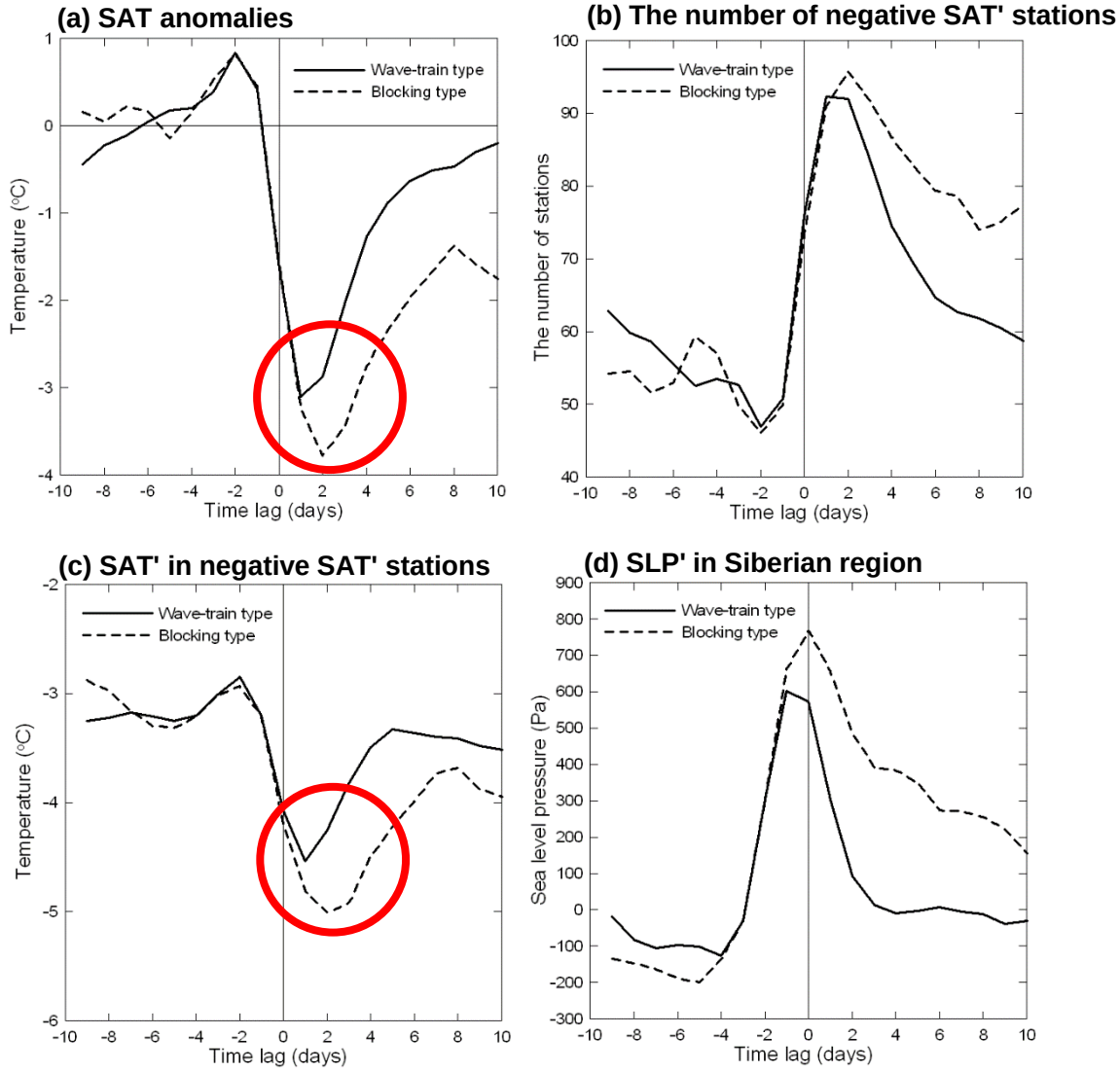
Clustering Results

Vertical Structure



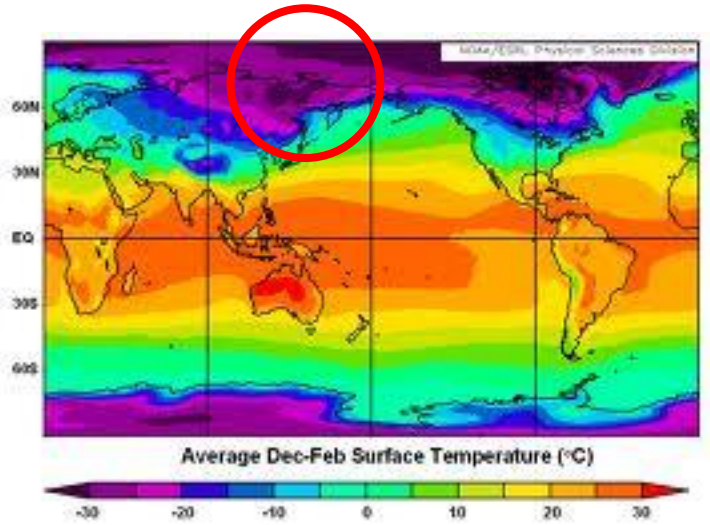
Clustering Results

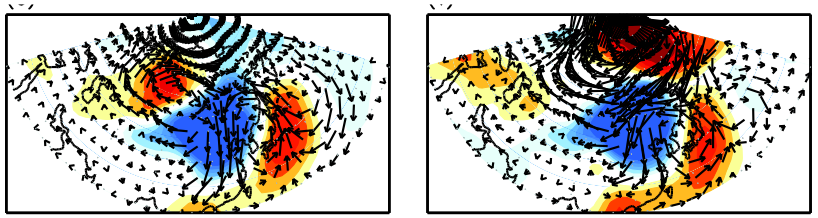
Daily-lagged Composites



Clustering Results

Oymyakon, Russia





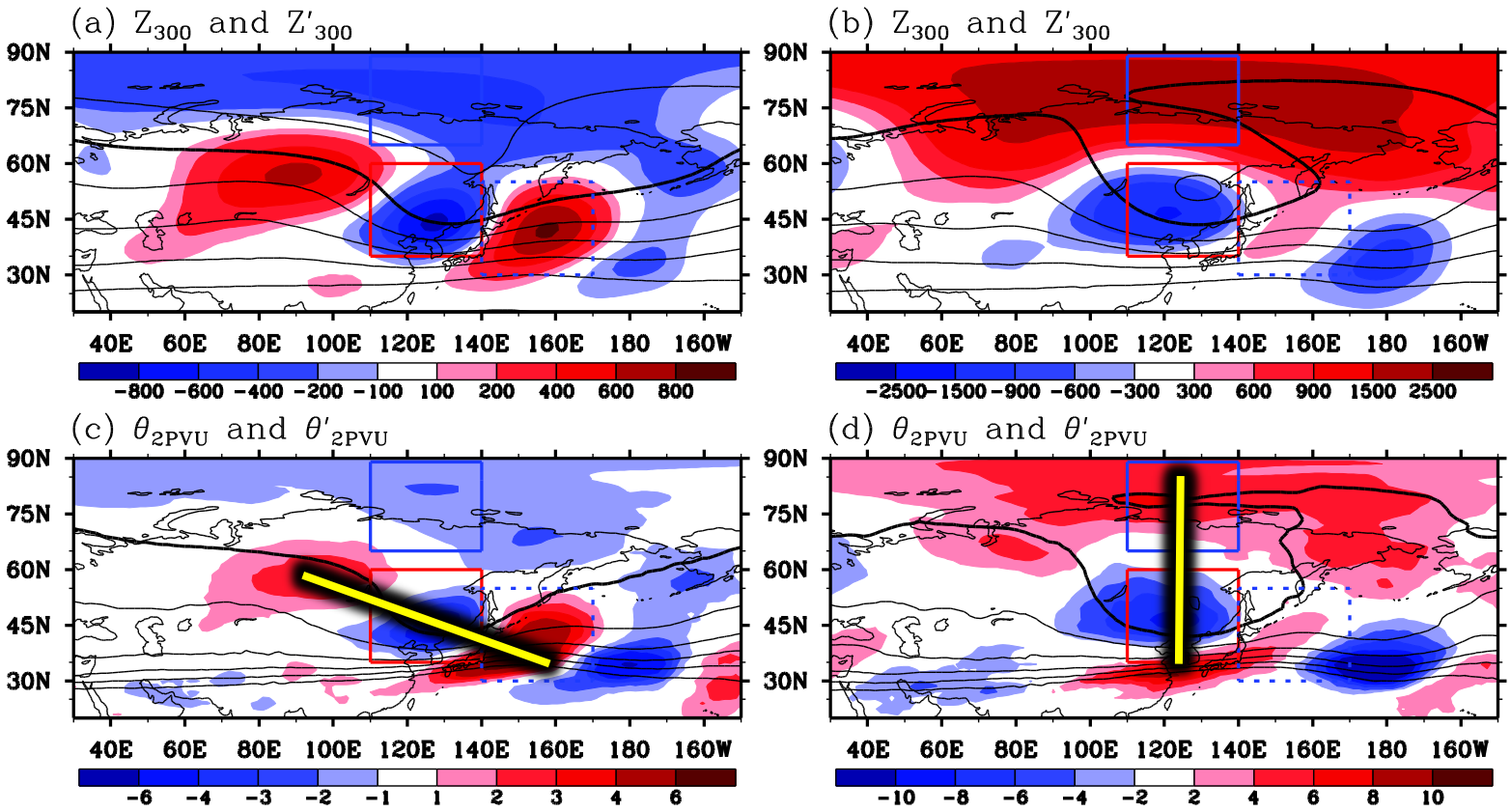
Climatological Temperature for Oymyakon (1981-2010)													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	−16.6 (2.1)	−12.5 (9.5)	2.0 (35.6)	11.7 (53.1)	26.2 (79.2)	31.1 (88)	34.6 (94.3)	32.9 (91.2)	23.7 (74.7)	11.0 (51.8)	−2.1 (28.2)	−6.5 (20.3)	34.6 (94.3)
Average high °C (°F)	−42.5 (−44.5)	−35.4 (−31.7)	−20.8 (−5.4)	−3.7 (25.3)	9.1 (48.4)	20.0 (68)	22.7 (72.9)	18.2 (64.8)	8.9 (48)	−9.2 (15.4)	−30.7 (−23.3)	−42 (−44)	−8.8 (16.2)
Daily mean °C (°F)	−46.4 (−51.5)	−42 (−44)	−31.2 (−24.2)	−13.6 (7.5)	2.7 (36.9)	12.6 (54.7)	14.9 (58.8)	10.3 (50.5)	2.3 (36.1)	−14.8 (5.4)	−35.2 (−31.4)	−45.5 (−49.9)	−15.5 (4.1)
Average low °C (°F)	−50 (−58)	−47.3 (−53.1)	−40 (−40)	−23.9 (−11)	−4.7 (23.5)	4.0 (39.2)	6.2 (43.2)	2.6 (36.7)	−3.7 (25.3)	−20.4 (−4.7)	−39.3 (−38.7)	−48.8 (−55.8)	−22.1 (−7.8)
Record low °C (°F)	−65.4 (−85.7)	−67.7 (−89.9)	−60.6 (−77.1)	−46.4 (−51.5)	−28.9 (−20)	−9.7 (14.5)	−9.3 (15.3)	−17.1 (1.2)	−25.3 (−13.5)	−47.6 (−53.7)	−58.5 (−73.3)	−62.8 (−81)	−67.7 (−89.9)

Dynamical Index for Cold Surge Type

Classification of Cold Surges based on Clustering Method

Wave-train (284)

Blocking (68)



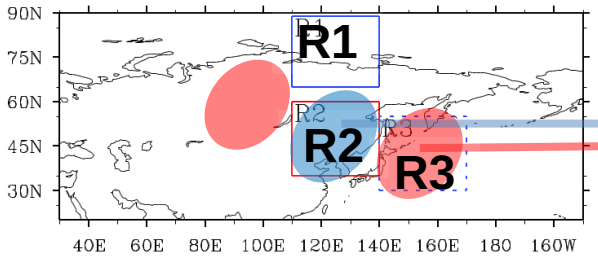
Contour : climatology
Shading : anomaly

Dynamical Index for Cold Surge Type

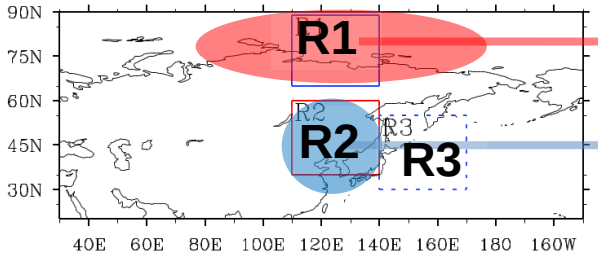
Wave-Train Index (WI) and Blocking Index (BI)

Potential temperature on 2 PVU

Wave-train type



Blocking type



Wave-train Index (WI)

WI = Potential temperature anomaly difference

R3 minus **R2**

Wave-train pattern at tropopause

Blocking Index (BI)

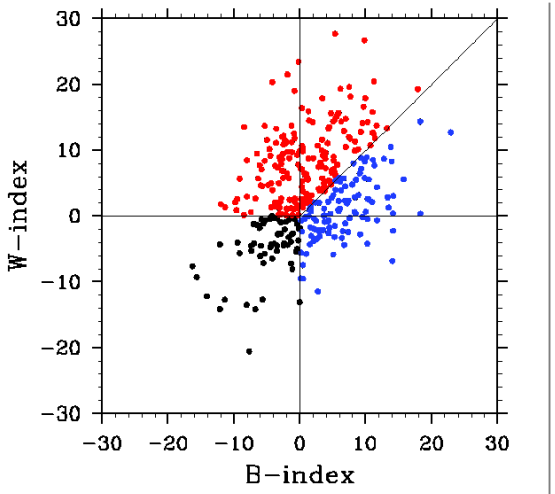
BI = Potential temperature anomaly difference

R1 minus **R2**

Dipole structure at tropopause

Classification using Dynamical Index

Atmospheric Circulation



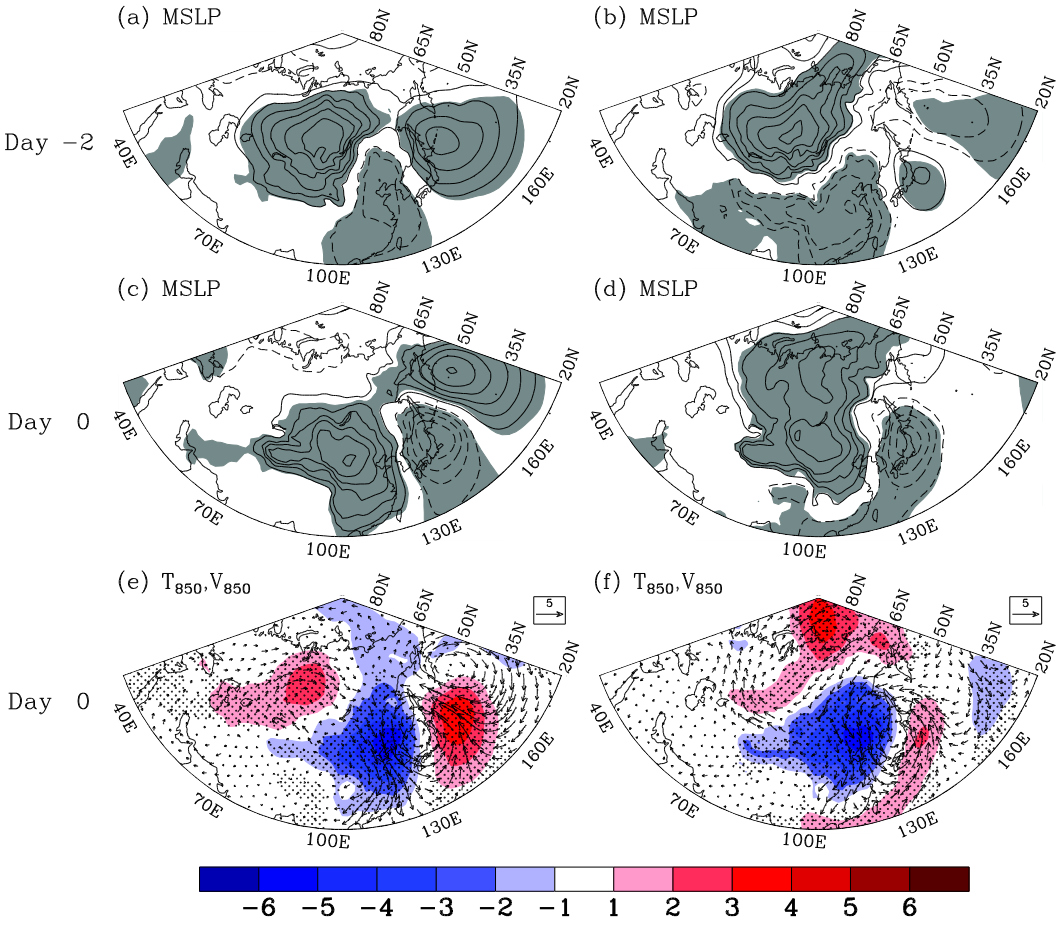
Wave-train type (188)

Blocking type (104)

Unclassified (60)

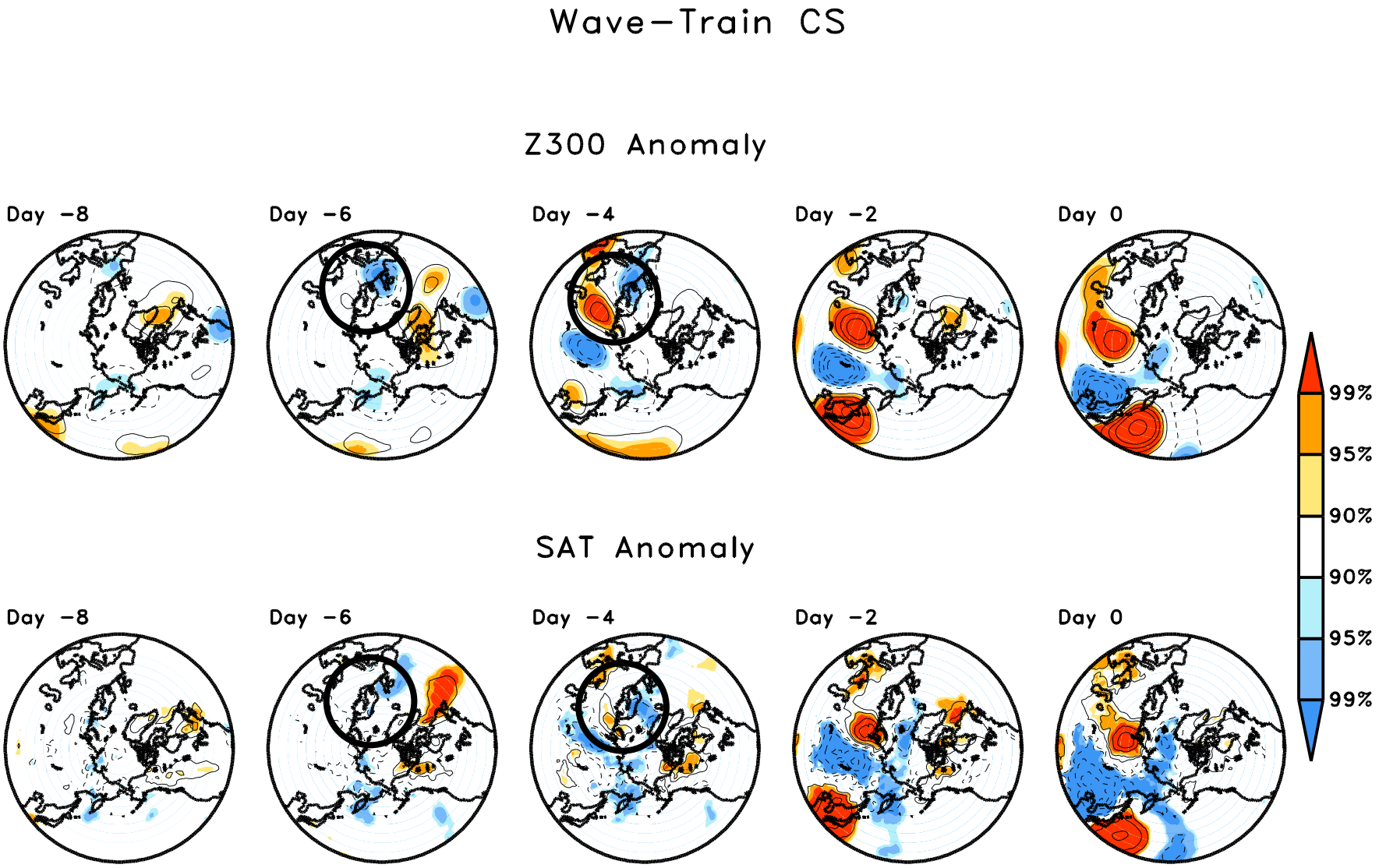
Wave-train type

Blocking type



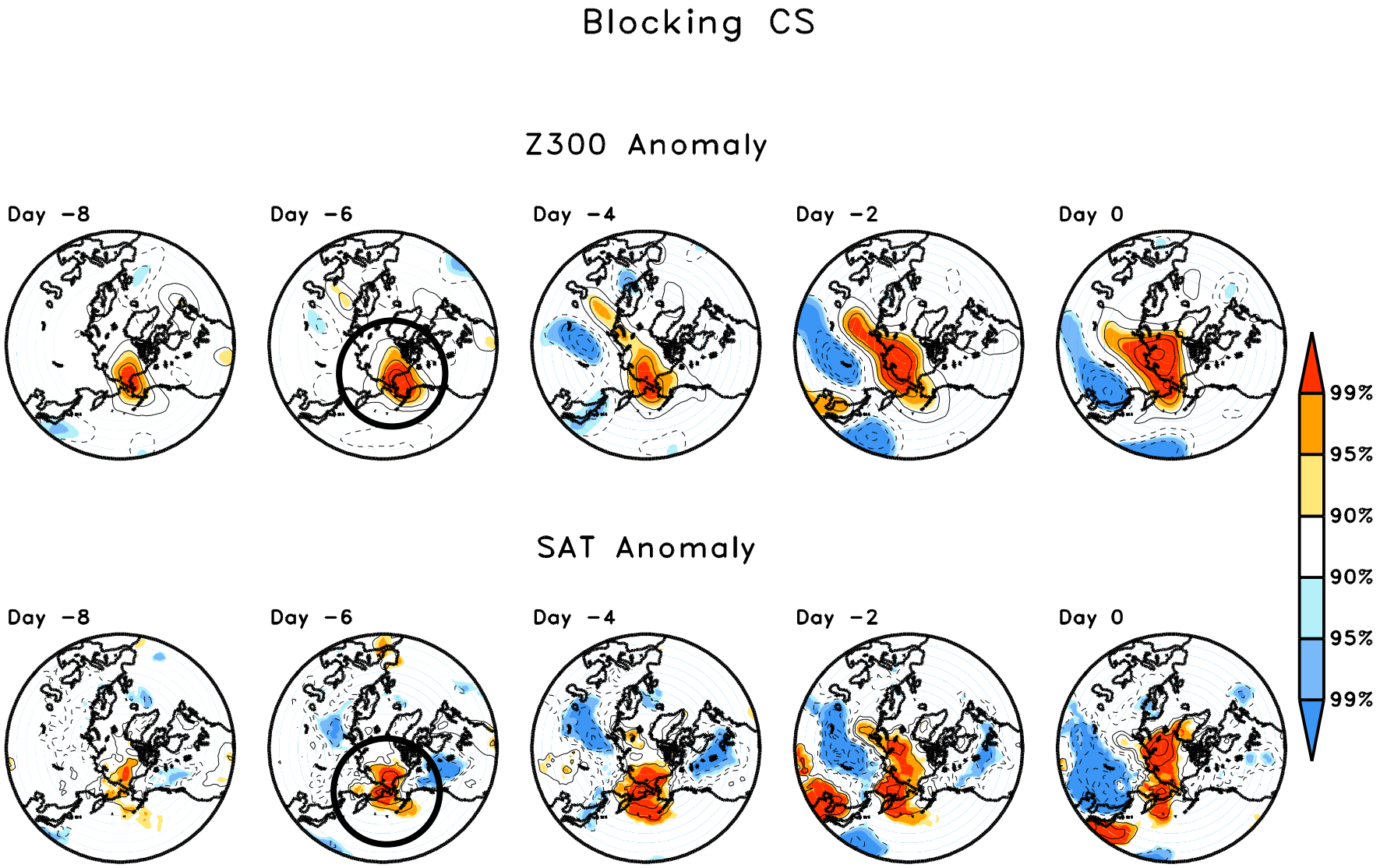
Origin of wave-train cold surges

Features before Cold Surge Occurrence



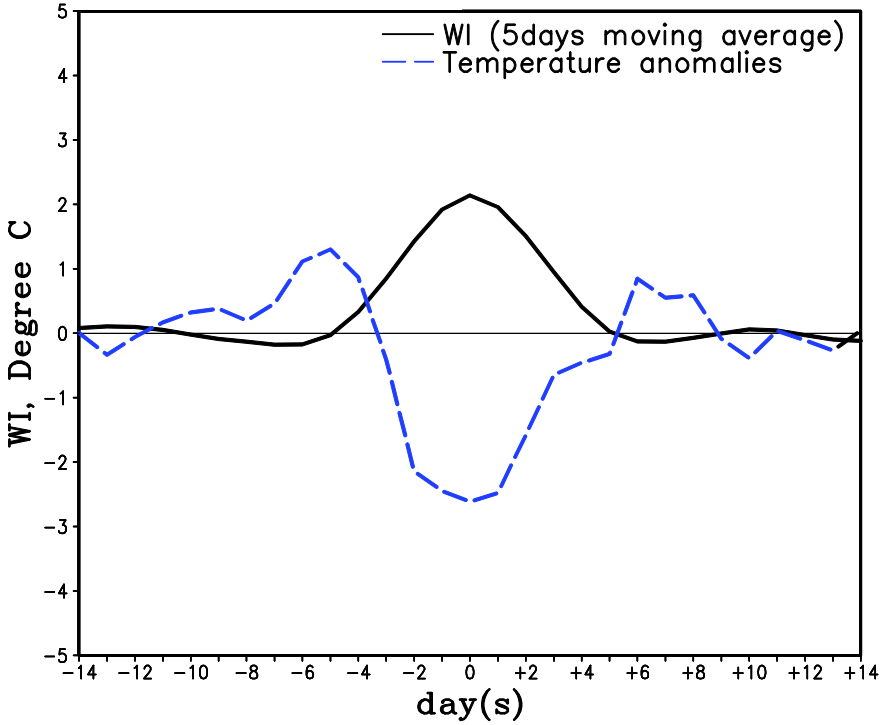
Origin of blocking-type cold surges

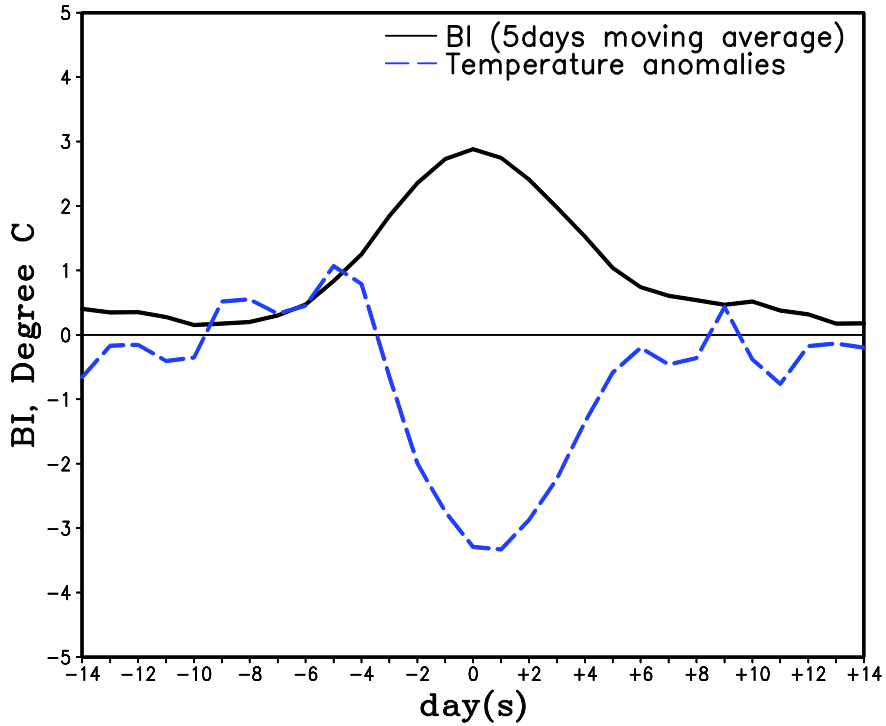
Features before Cold Surge Occurrence



Applications of Dynamical Index

WI and BI in NCEP CFSv2 reforecast data

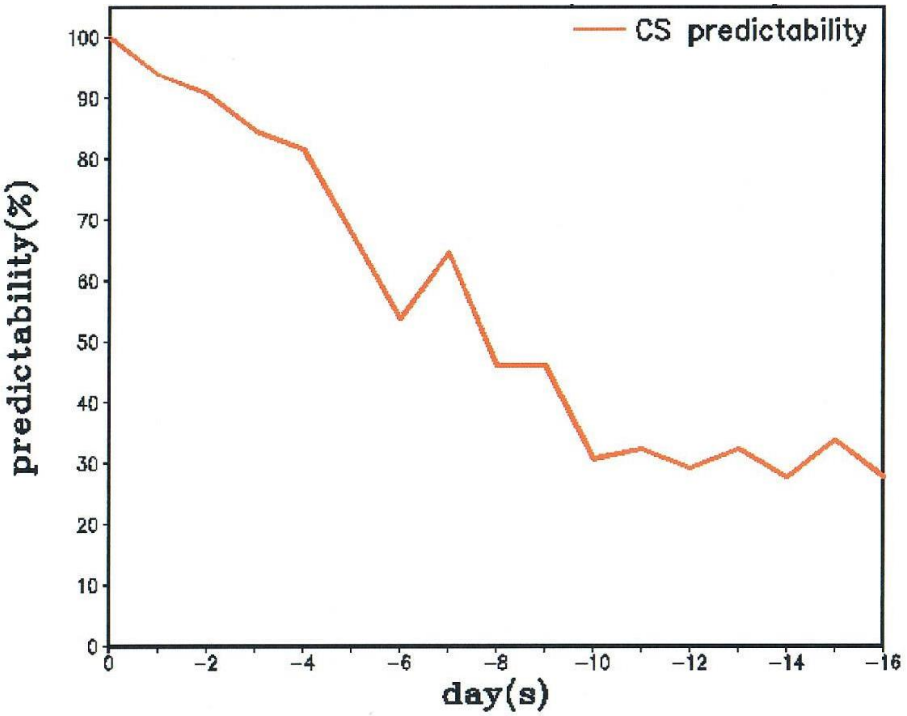




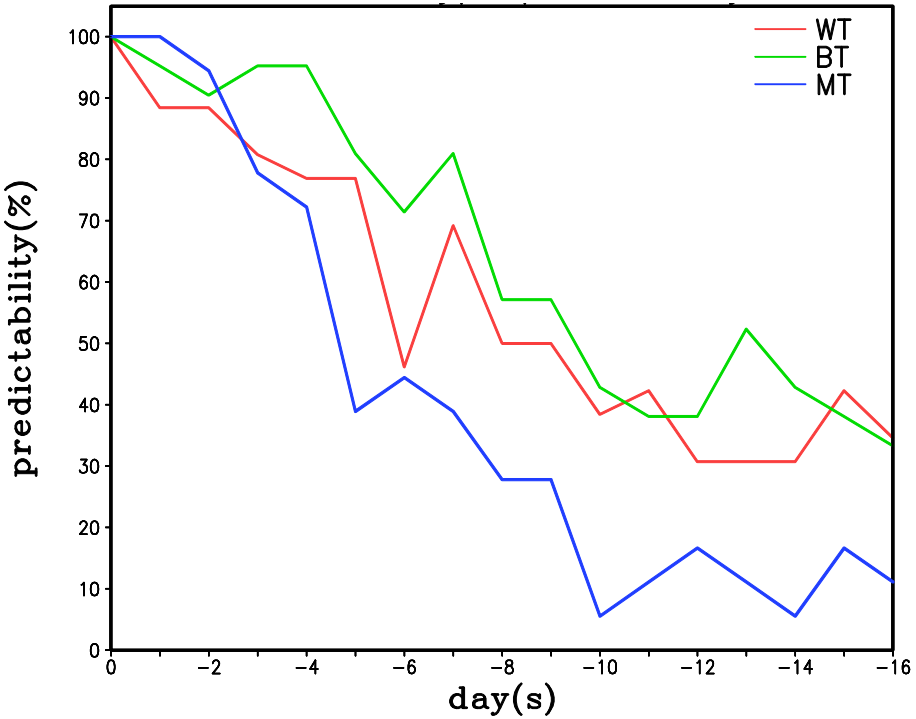
How predictable?

Cold Surge Predictability in NCEP CFSv2 reforecast data

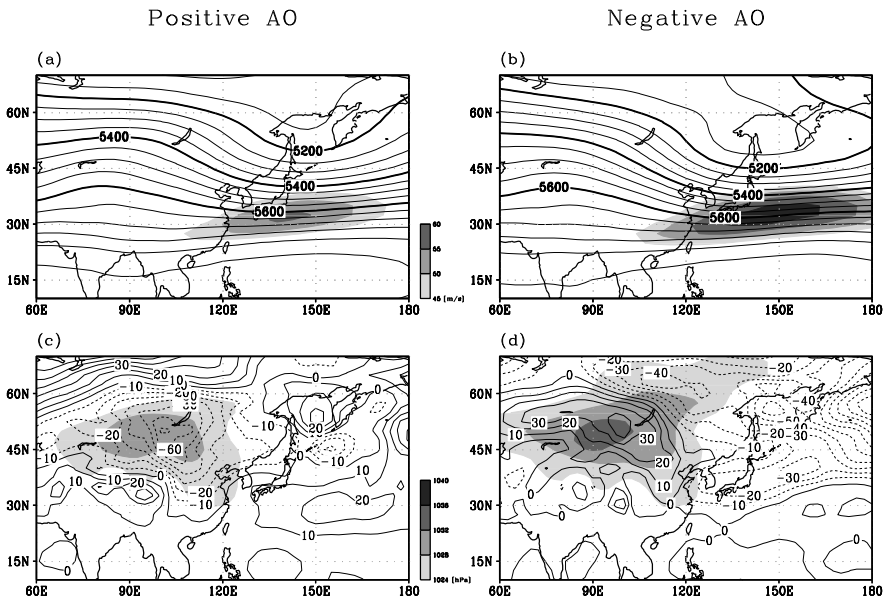
NCEP CFSv2 Cold Surges Predictability

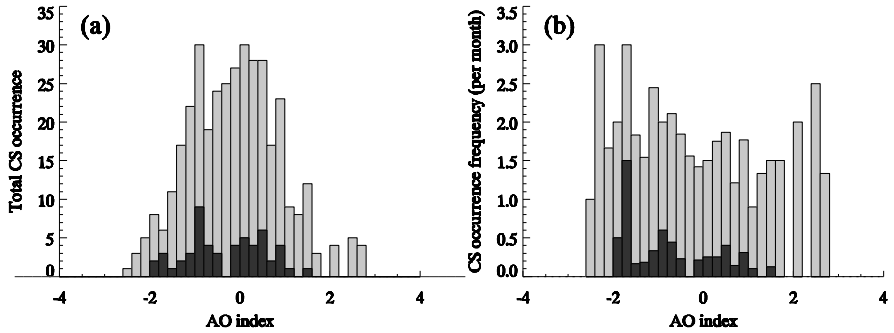


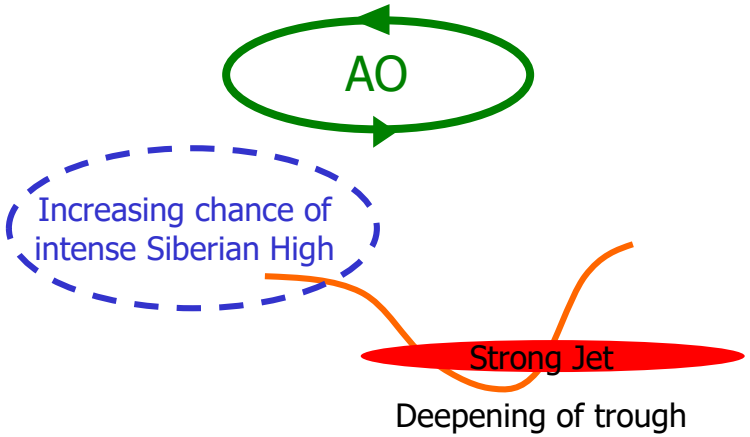
NCEP CFSv2 Cold Surges Type Predictability



한파발생에 영향을 주는 외부 인자들

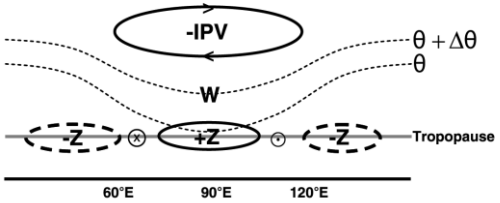




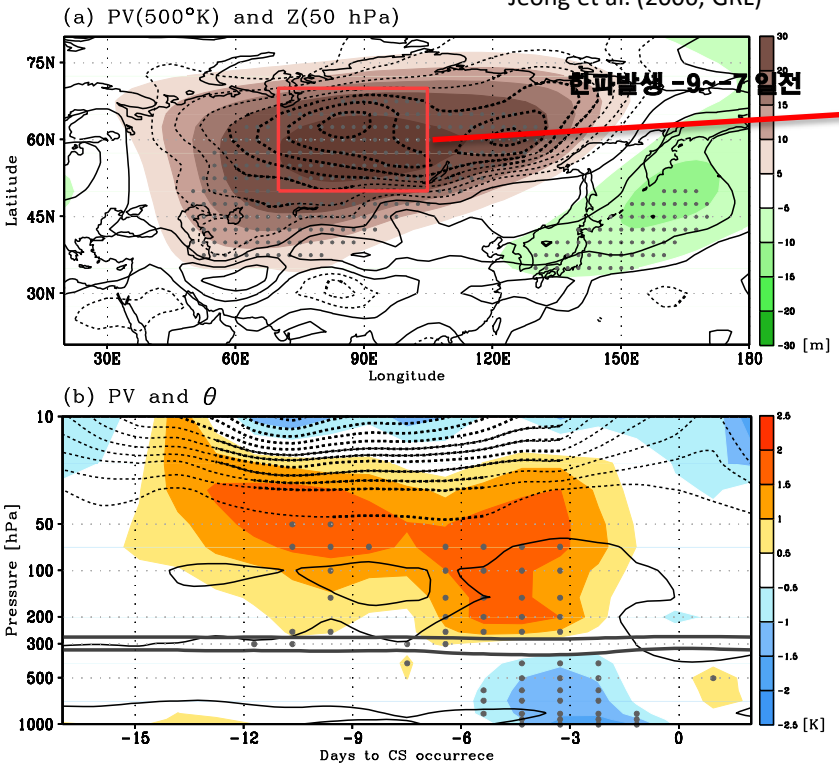


Favorable condition for cold surge occurrence

성층권의 영향

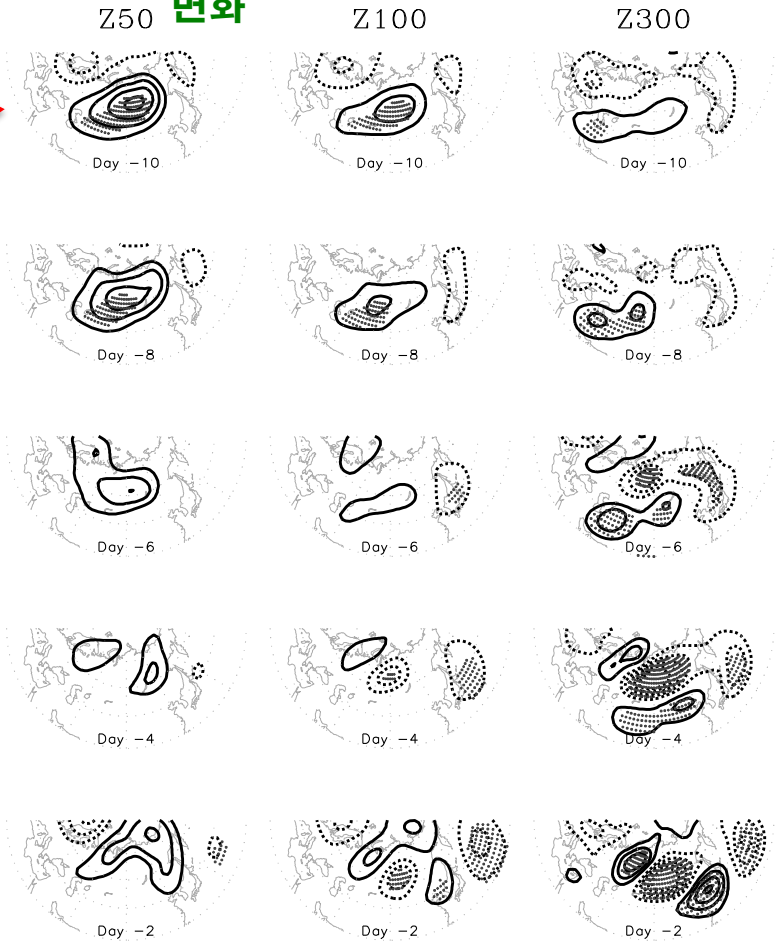


Jeong et al. (2006, GRL)



극진동의 변동과 관련되어 발생한 성층권 섭동이 하층의 조절 (adjustment)을 유도 하여 한파 발생의 초기조건을 제공

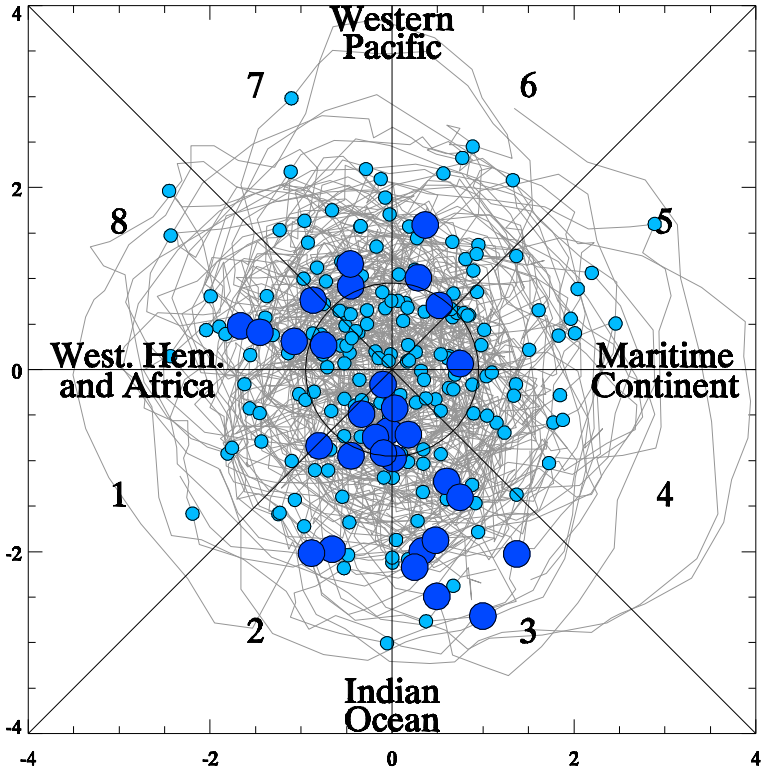
한파발생 전후의 지위고도 변화



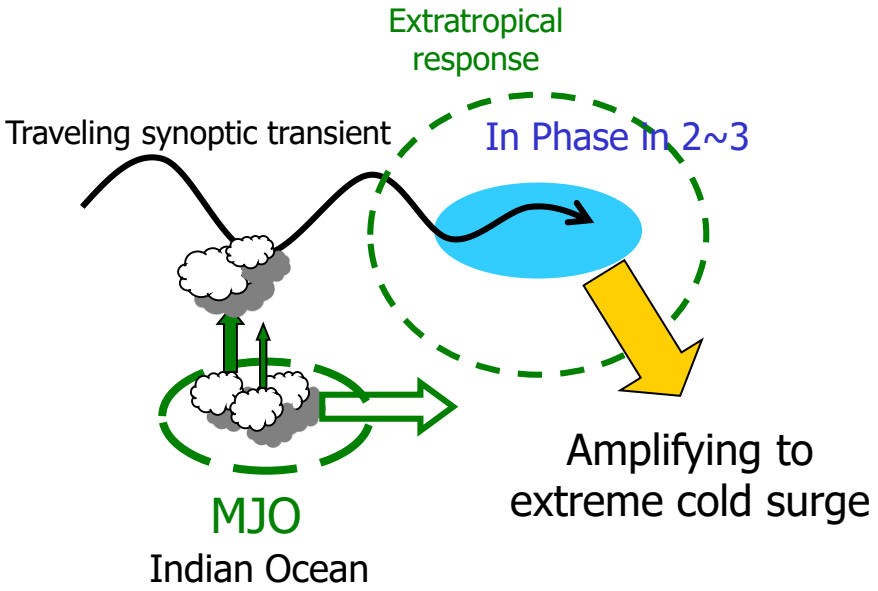
하부성층권

대류권상층

열대 계절내 진동 (MJO)



MJO center가 인도양에 있을때
강한 한파발생증가



북극해빙-북극온난화와 관련된 한파발생

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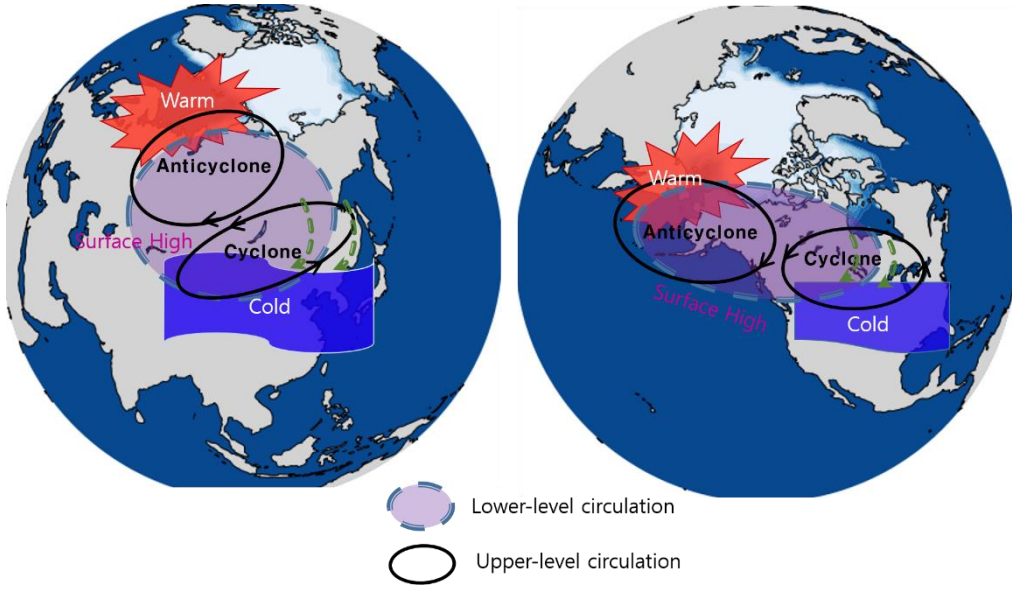
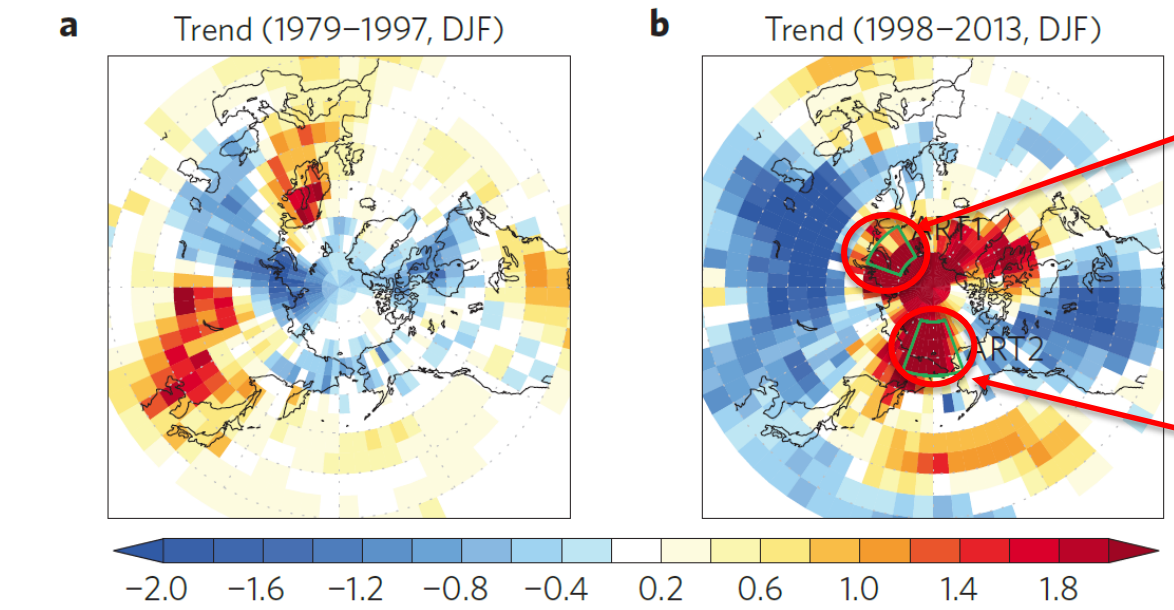
Two distinct influences of Arctic warming on cold winters over North America and East Asia

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]

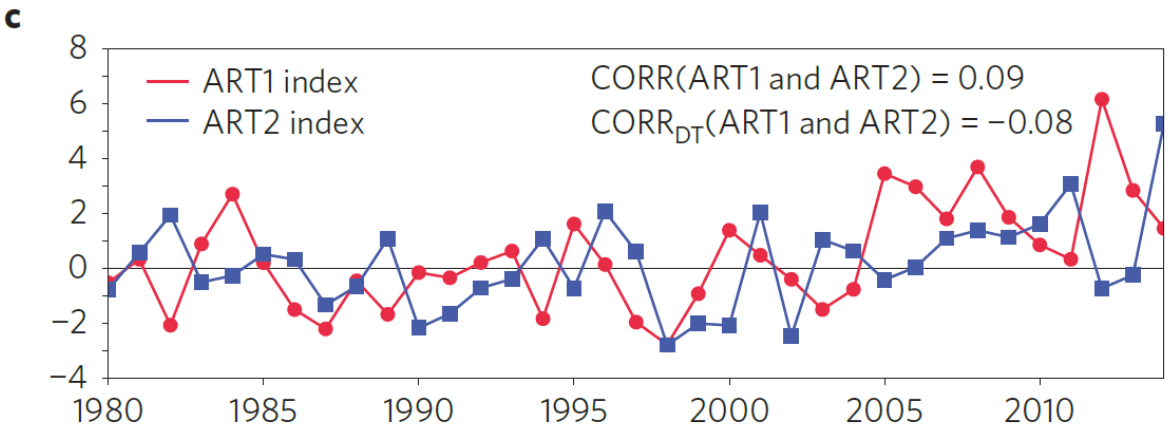


Identified two ‘hotspots’ in the Arctic



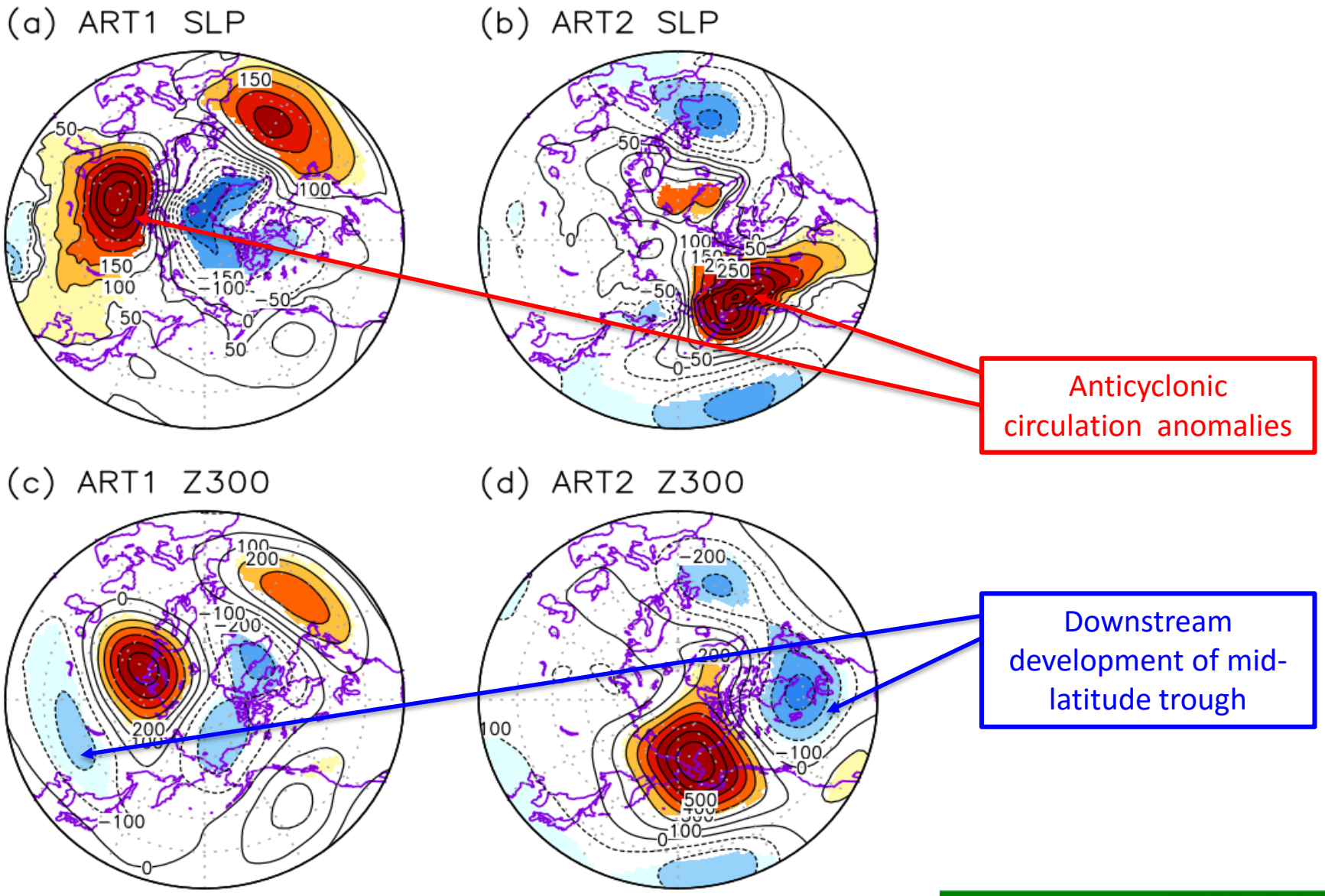
ART1: SAT anomalies over the Barents-Kara Sea

ART2: SAT anomalies over the east Siberian-Chukchi Sea

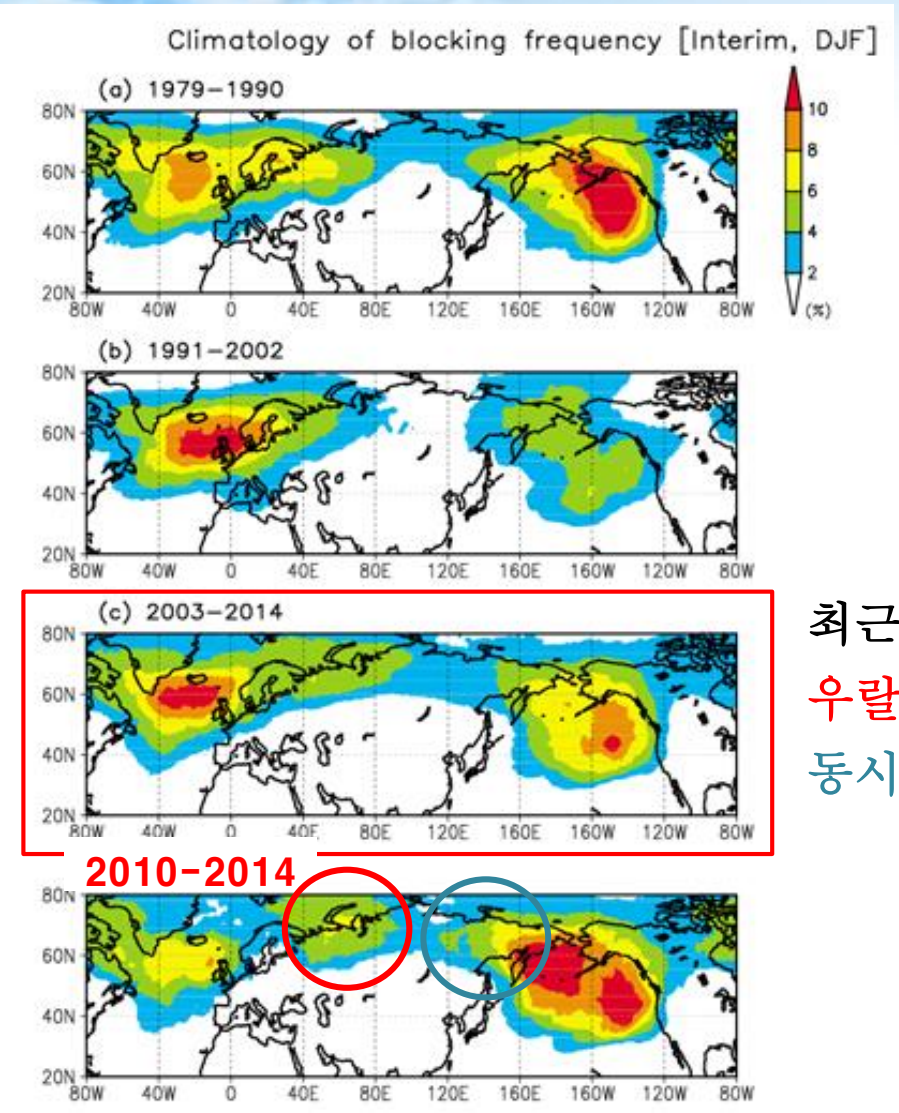


The two ART indices are almost independent with each other but both show positive trends

Dynamical process: SLP and Z300 associated with ARTs



Preliminary results Ⅰ – 블로킹 최근 변동성



최근 10년 경향 -

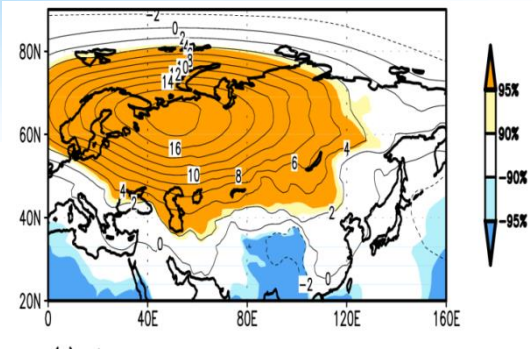
우랄/바렌츠 지역 블로킹 빈도수 증가

동시베리아 지역 블로킹 빈도수 증가

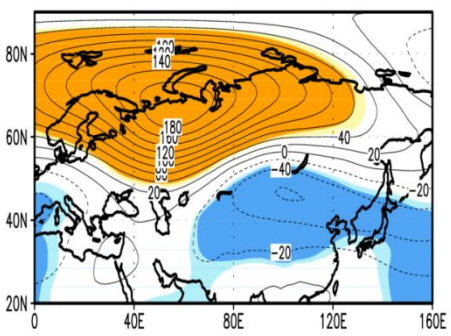
우랄 블로킹-한파 관련성

✓ 우랄 블로킹 발생시 composite (1979-2014, DJF)

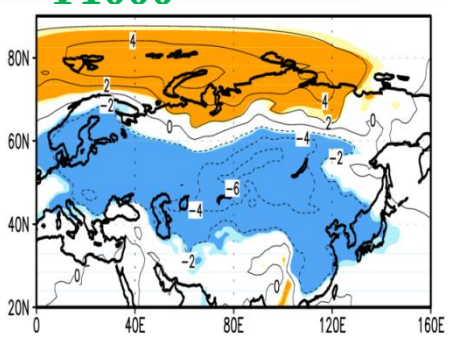
SLP



Z500

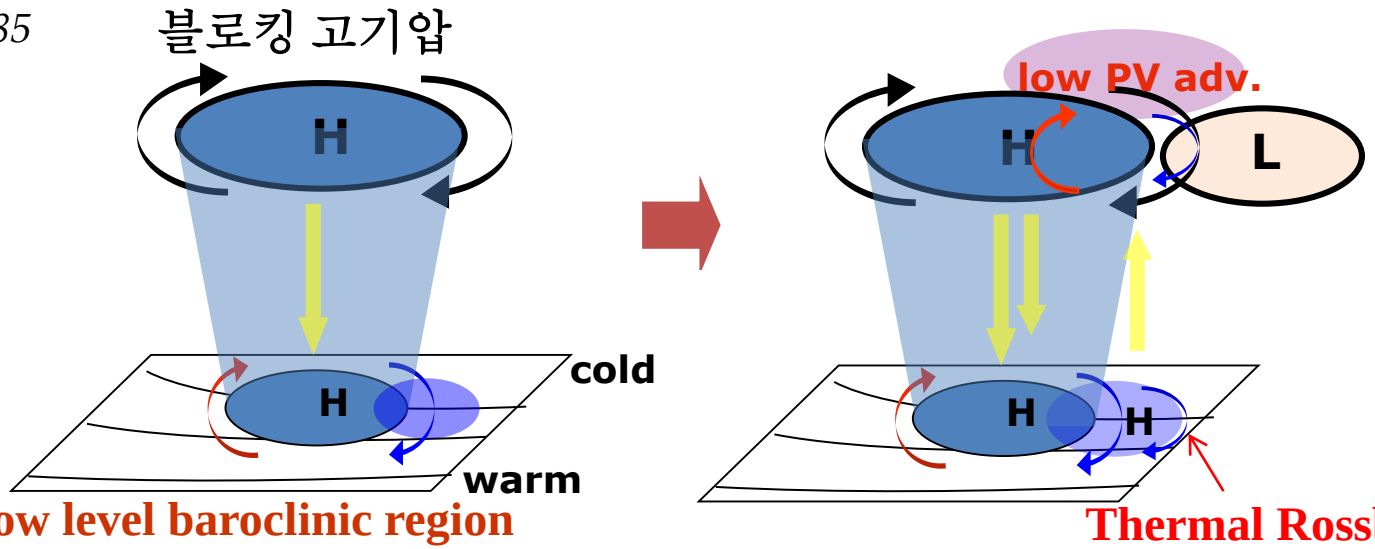


T1000



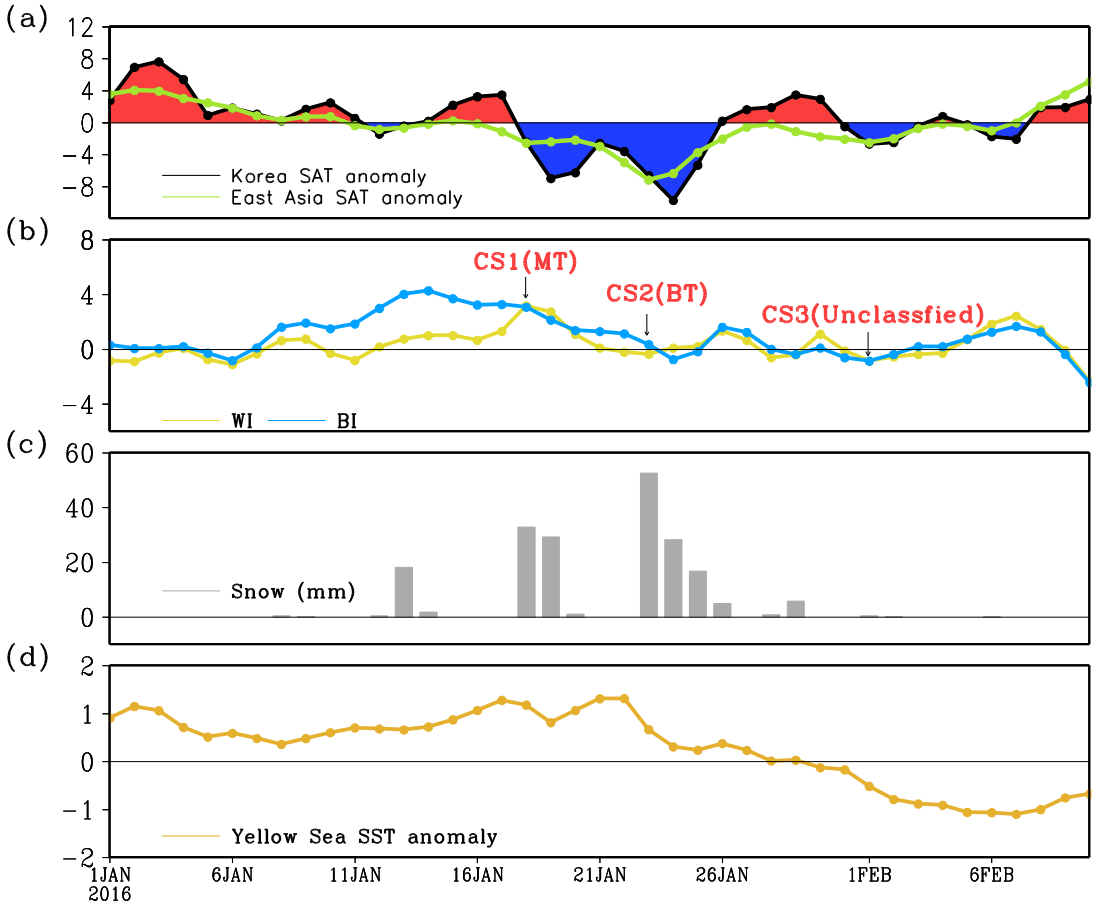
블로킹과 시베리아 고기압 상-하층간 상호작용으로 한파 발달

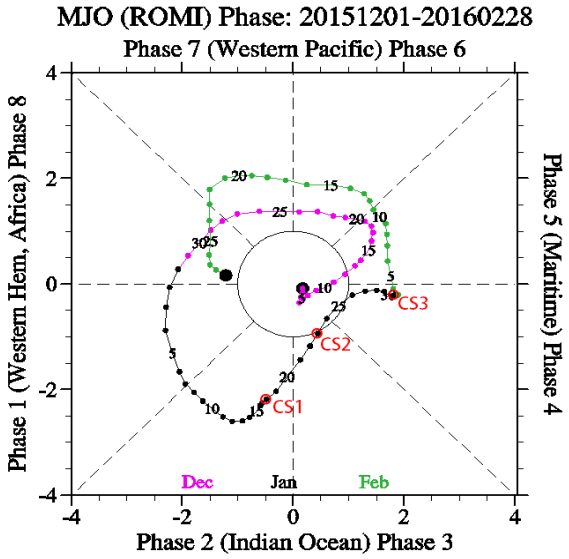
Hoskins et al., 1985

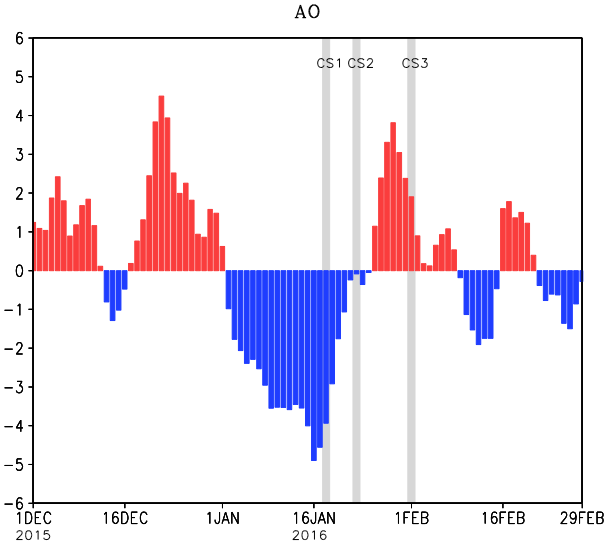


2015/16 겨울 한파 case

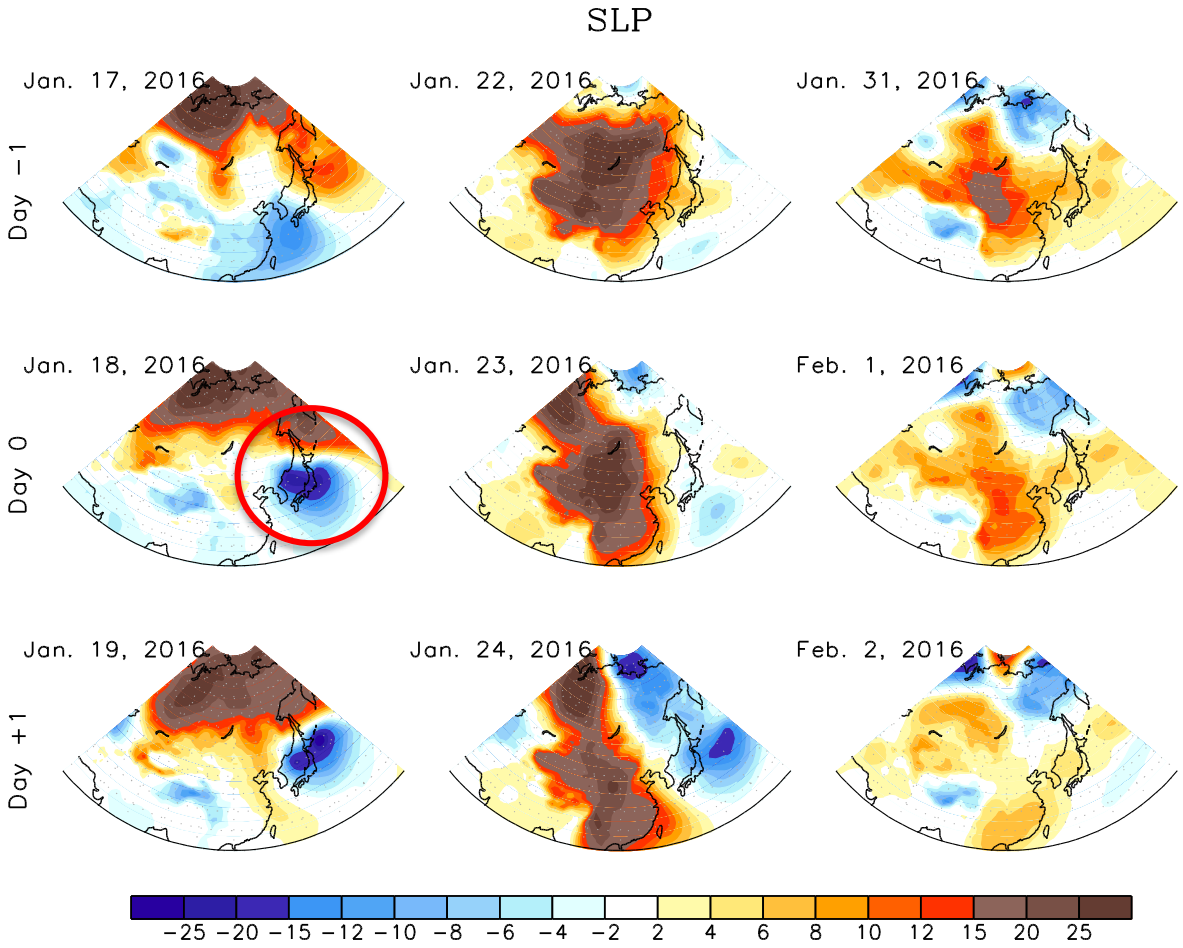
2015/16 겨울 한파 case







Blocking type + travelling cyclone



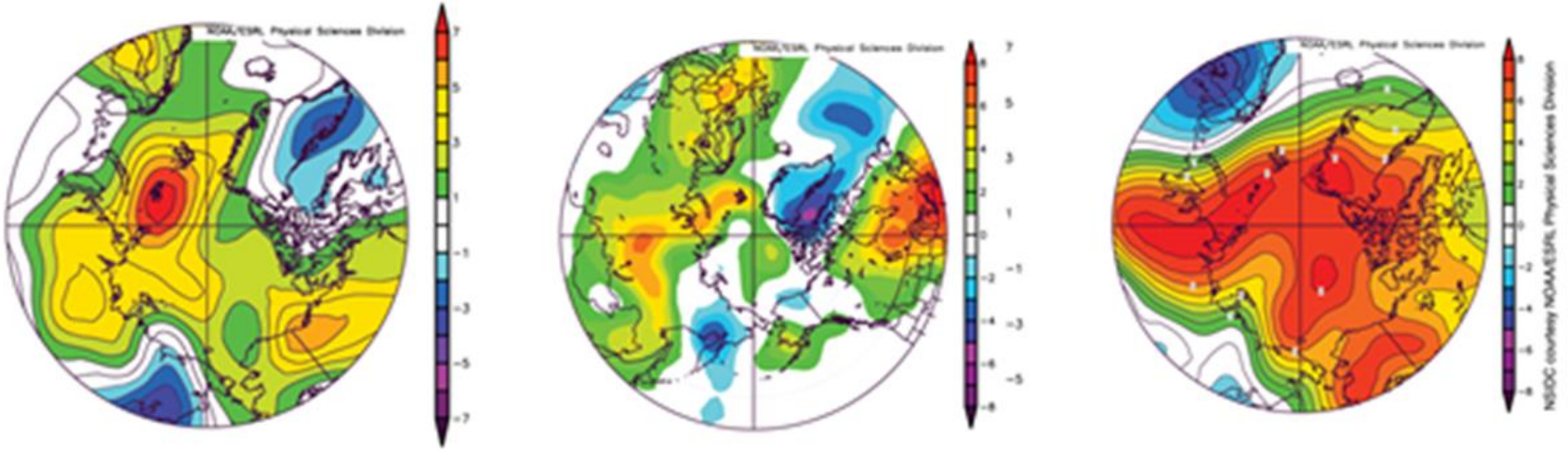
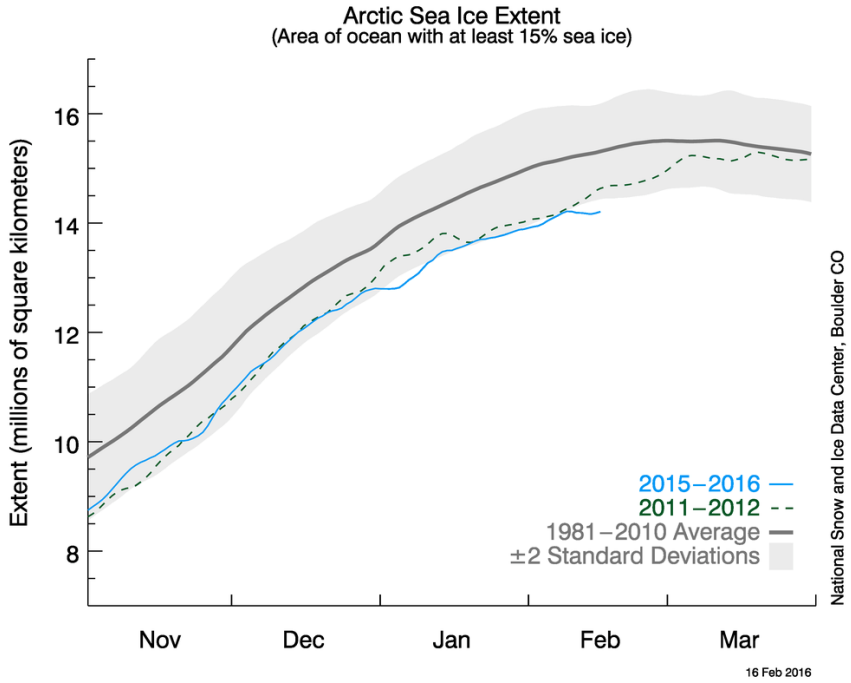


그림 2. 평년(1981~2010) 대비 기온편차 : 2015년 11월(왼쪽), 2015년 12월(중앙), 2016년 1월(오른쪽)
(자료 출처: NOAA ESRL (http://www.esrl.noaa.gov/))



Record-breaking low sea-ice

감사합니다.

Clustering Results

Duration

5 days after cold surge occurrence

Wave-train

Blocking