Statistical model for seasonal prediction of wintertime temperature over South Korea

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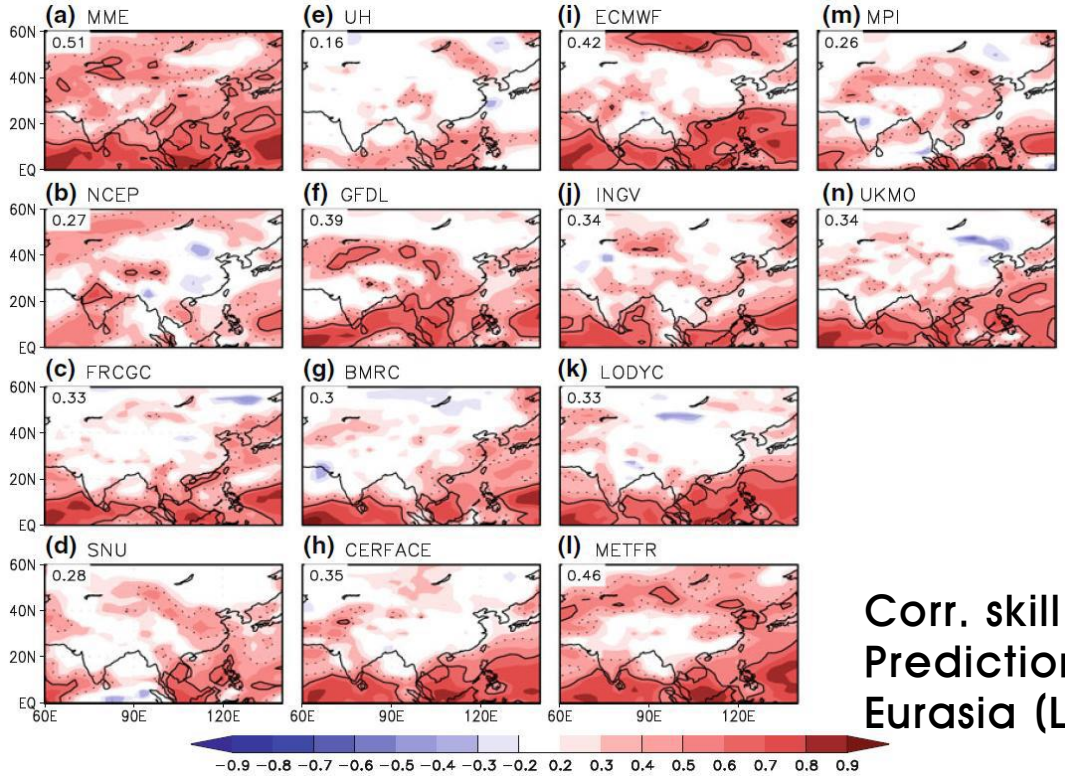
기상청

Motivation

* Skill of Dynamical model for wintertime temperature



Corr. skill for 1 month–lead DJF Prediction of SAT over mid–latitude Eurasia (Lee et al. 2013)

- Unreliable predictability for wintertime SAT of the dynamic models over Eurasia
- Support to operational seasonal prediction of SAT over the Korean Peninsula(KP)
- Finding predictor and development of statistical prediction model

Data and Method

* Analysis period and Data

(Considered the temporal coverage of observational SAT data over the KP)

- NCEP/NCAR R1 circulation (U, GPH, omega) and temperature
- NCEP/NCAR R1 Sea ice concentration (Validated with HadISIC)
- ERSST v4
- NOAA Snow cover (Validated with IMS 24kim data set)
- CMAP precipitation (Validated with GPCP)
- Observational SAT data at 45 surface station over the KP

- **Training periods : 1973–2015 (Boreal winter, Dec. to Feb.)**
- **Available dataset until 2nd week in November**
  (Due to utilize for operational prediction)

* Predictors discovery :

- **Lag correlation** between target month and climate factors
- **Understanding Physical and Dynamical linkage**
  between the predictor and SAT in the KP

* Statistical model :

- Multiple Linear Regression model based on the predictors
- **Individual month of winter season for operational seasonal prediction**

Summary of Predictors

* Predictors for individual month of winter season

By lag corr. and composite analysis….

Sea ice concentration

ENSO

Arctic Oscillation(AO)

Month	Predictors		
December	SIC over Laptev in Sep.(SIC_{lapt})	SST tendency in tropical eastern Pacific (Oct.-Sep.) ENSO	Snow advanced index over Eurasia in Oct.(SAI)
January	SIC over Kara in Oct.(SIC_{kara})	Zonal gradient SST tendenry in tropical Pacific (East – West) ($ENSO_{like}$)	Z500 over Tamyr Peninsula in Oct. ($Z500_{Tamyr}$)
February	SIC over Barents in Oct. ($SIC_{barents}$)	SST tendenry over north sea of Australia (Oct. – Sep.) SST_{naus}	SST ano. Over Gulf stream in Oct. (SST_{Gulf})

Convection in western Pacific

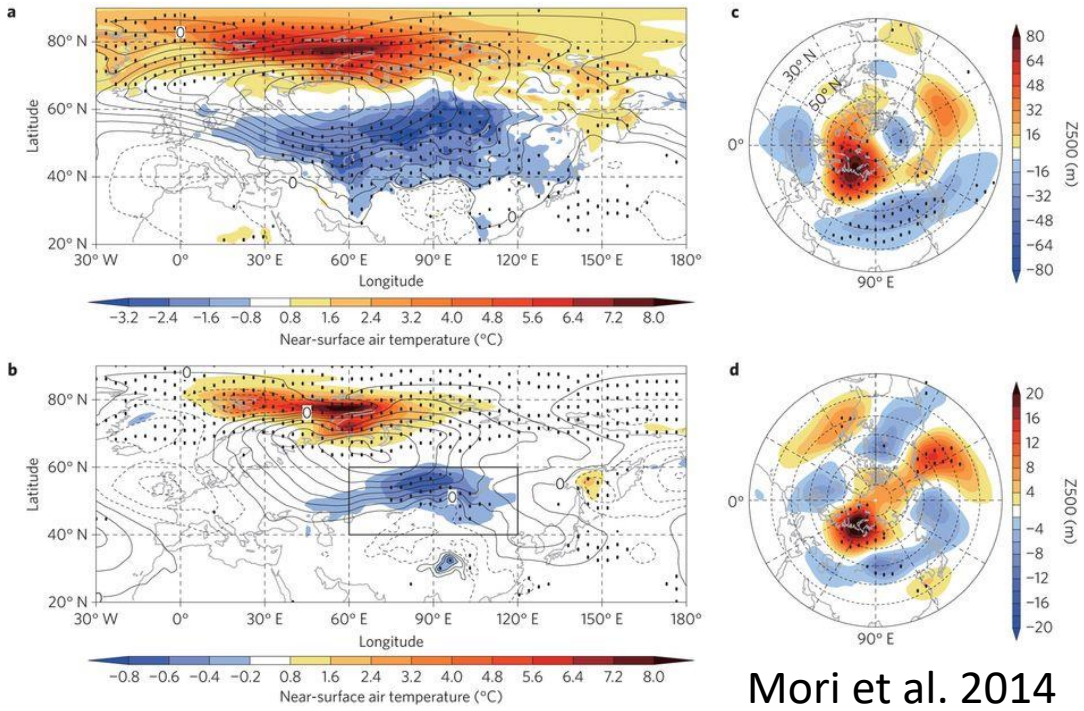
Wave propagation from Atlantic

Among all of predictors, SIC and ENSO mainly contribute to predictability !!

Relationship between SIC and SAT in East Asia

* Tropospheric pathway

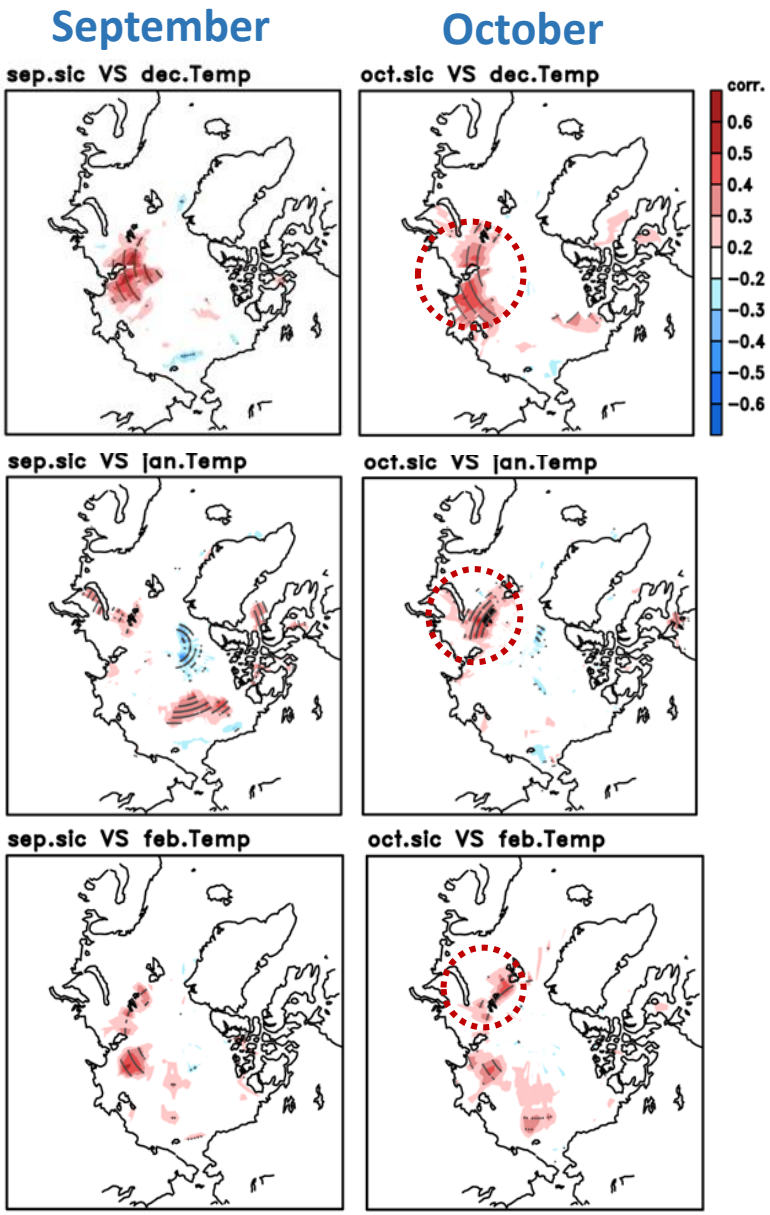
SAT and Z300 related SIC loss over Barents-Kara sea



Mori et al. 2014

Low SIC over Kara and Barents → increasing SAT → Favorable condition for development of anticyclonic circulation ano. → Frequent blocking over Ural Mt. and eastern Europe → Wave propagation, cyclonic circulation ano. over East Asia → Cold condition

Lag relationship btw. SIC and SAT in KP



Lag correlation map
btw. SIC in autumn and SAT in KP during winter

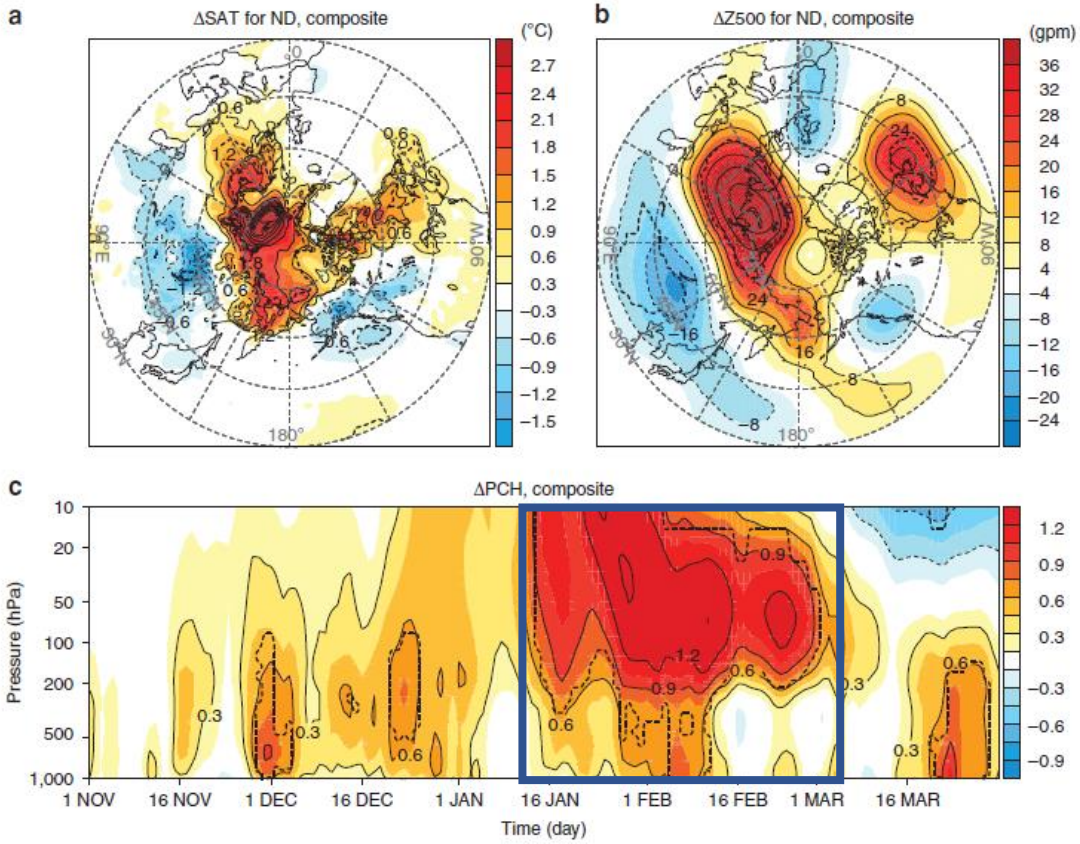
- High correlation
  over Laptev, Kara and Barents Sea
- Regional difference
  according to individual month

! Whether this predictor is
physically related to SAT in KP or not?

Relationship between SIC and SAT in East Asia

* Stratospheric pathway

SAT and Z300 related SIC loss in early winter (Kim et al. 2014)



SIC loss related circulation pattern (Anti-cyclonic(cyclonic) ano. over Ural Mt.(East Asia)) through tropospheric pathway

→ Favorable condition for upward propagation toward stratosphere → Wave breaking → Weakening of stratospheric polar vortex → Tropospheric coupling → Negative AO like type circulation → Cold condition over East Asia

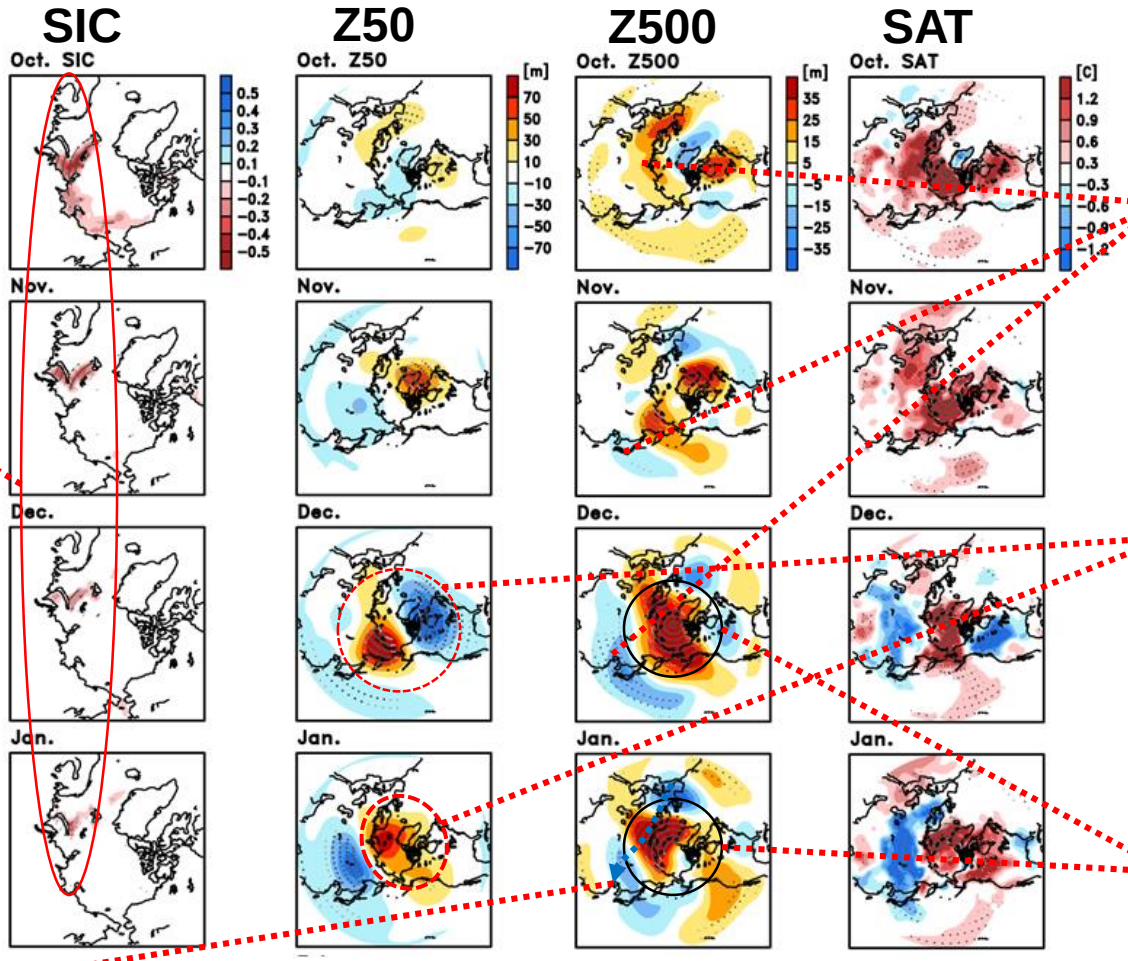
→ Delayed relationship btw autumn SIC and winter AO

The relation reveals well in lag correlation for finding predictor in our model !

SIC Predictor and its related circulation and SAT

*Predictor for SAT in January : SIC over Kara sea region

In case of low SIC over Kara sea in October…..



Tropospheric path

Continuously low SIC until winter season

Anti-cyclonic anomaly like blocking over Ural Mt. → Deepening of East Asian trough → Cold condition in EA and KP

Stratospheric path

Good condition for vertical propagation of stationary wave

Weakening of stratospheric westerly

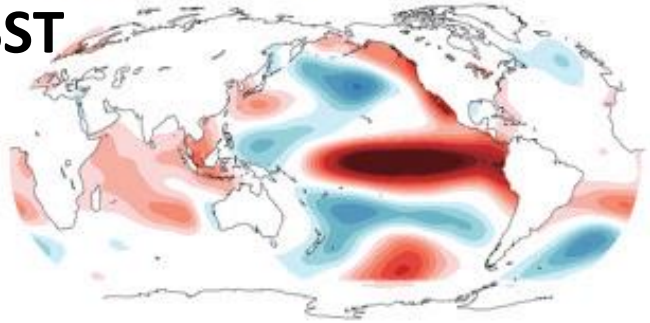
AO-like type tropospheric circulation → Cold condition in EA and KP

SIC predictor is physically related to SAT over KP in Jan.

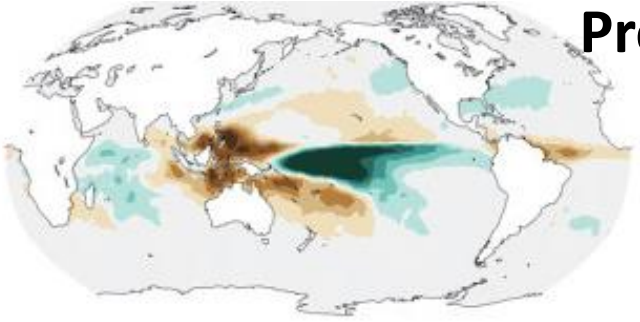
Impact of ENSO on East Asia in winter

In El-Nino developing winter season ….

SST

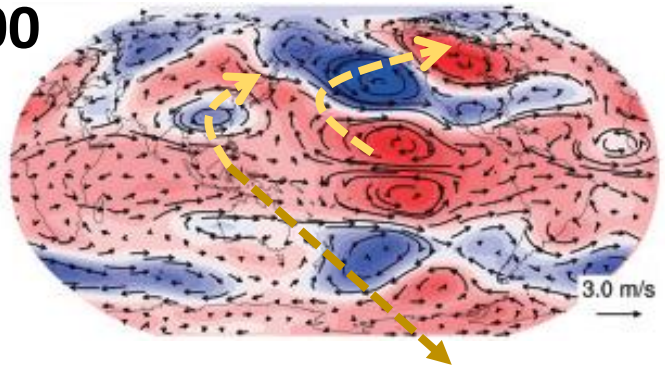


Prec.

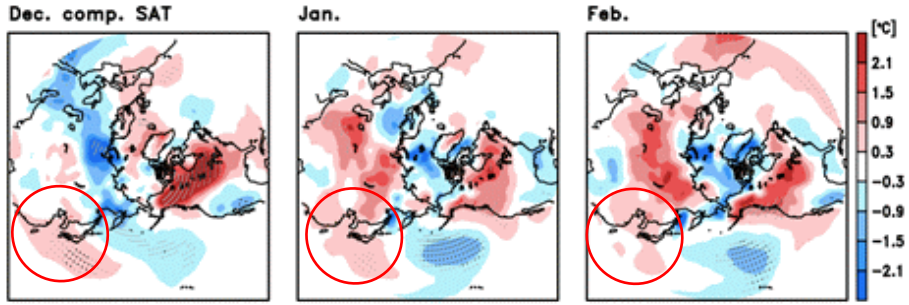


Cold(warm) SST ano. and suppressed(enhanced) convection in Western(Eastern) Pacific

Z300



SAT



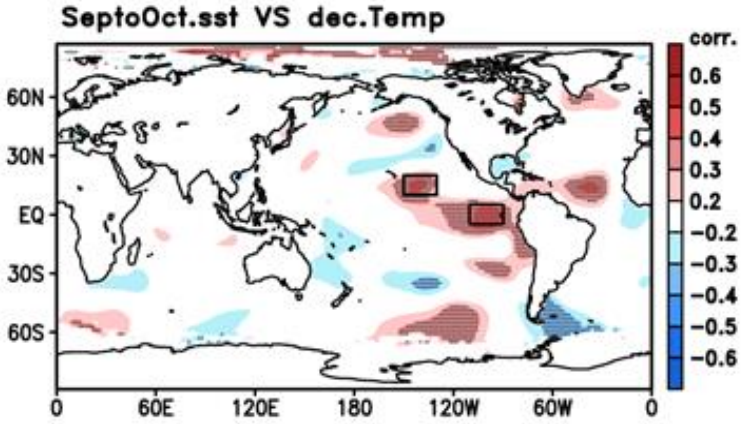
El-Nino-related circulation → Impact on whole NH circulation including East Asia

In KP, Anti-cyclonic ano. and warm condition in case of El-Nino

! Whether this mechanism is still working
in relationship btw. our predictor and SAT in KP or not ?

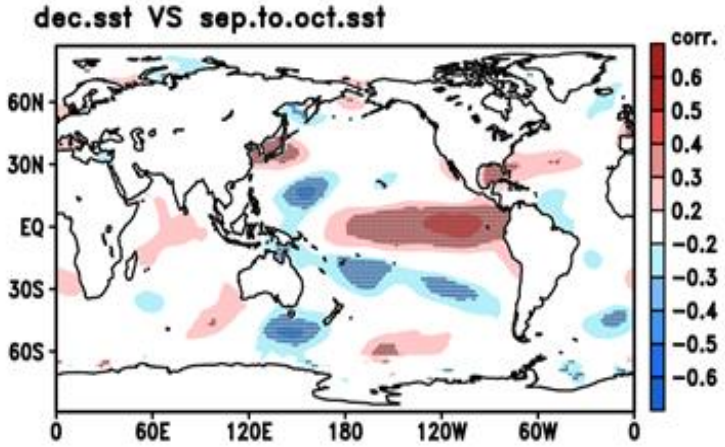
ENSO Predictor and its related circulation and SAT

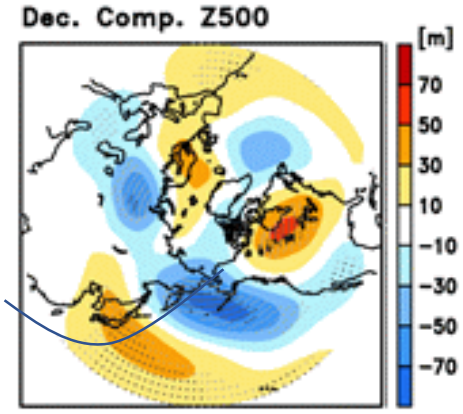
* Predictor for SAT in Dec. : SST tendency (Oct –Sep) in eastern Pacific



Positive correlation to SAT in KP : 0.58

* Lag relationship between predictor and SST/Z500 in Dec.





➔ ENSO predictor is also physically related to SAT in KP

Statistical models

Based on 3 predictors in individual month,

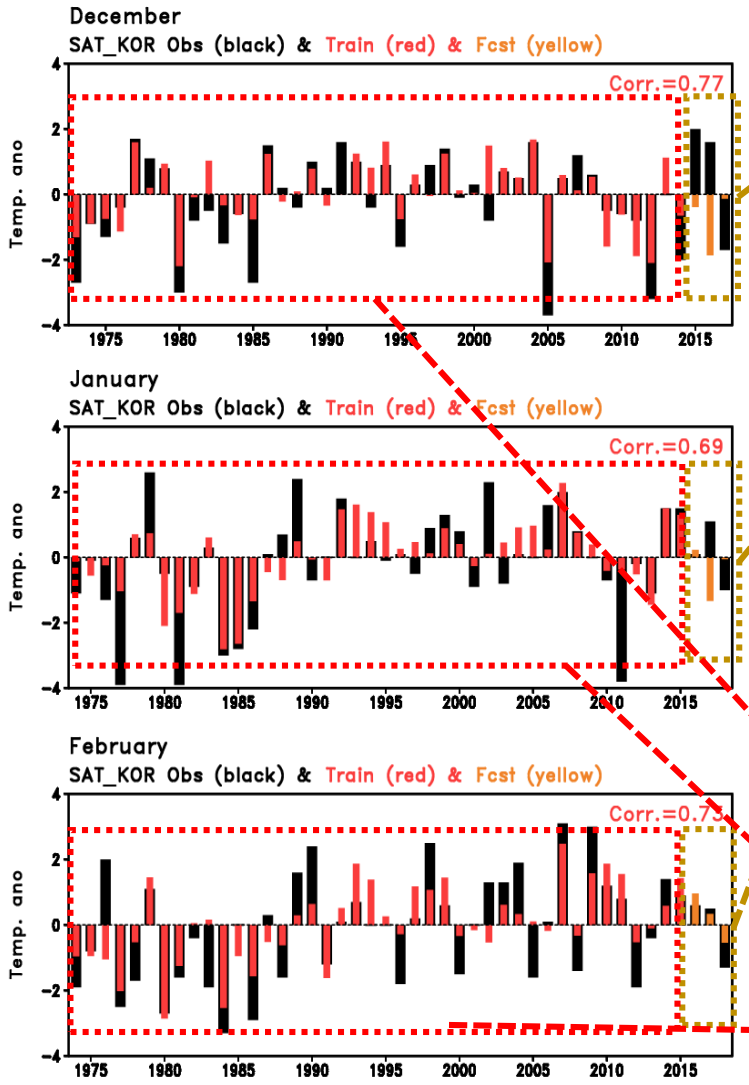
No significant correlation among the predictors (not shown)

Target Month	Statistical prediction model
December	$0.81*SIC_{lapt} + 0.73*ENSO - 0.19*SAI$
January	$0.41*SIC_{kara} + 0.61*ENSO_{like} - 0.48*Z500_{Tamyr} + 0.42*LTrend$
February	$0.41*SIC_{barents} - 0.54*SST_{naus} - 0.52*SST_{Gulf} + 0.62*LTrend$

- No significant linear-trend of SAT in Dec.
- In contrast, remarkable trend in Jan. and Feb.

→ linearly considering trend

Performance of statistical model



Operational Prediction, 2015/16~17/18

* **Dec. : Bad**

Despite of less SIC in 2015, blocking in central Europe → Due to its wave response, KP is dominated by anti-cyclonic ano.

In 2016, impact of big Elnino is less considered in our model.

* **Jan. : Relatively better than Dec.**

* **Feb. : Good**

Model skill in training period

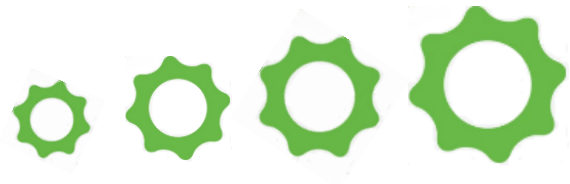
Target month	Train prd skill	Cross val. skill
December	0.77	0.70
January	0.69	0.60
February	0.73	0.69

2018/19?

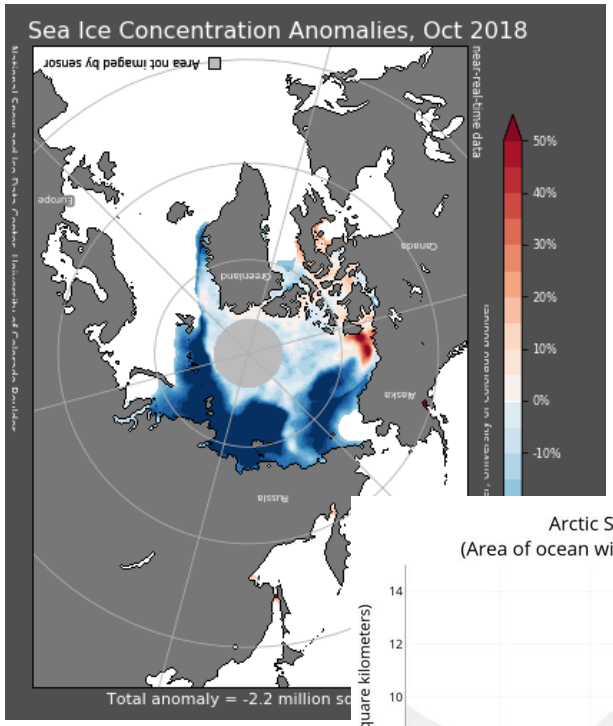
How about our model prediction in upcoming winter ?

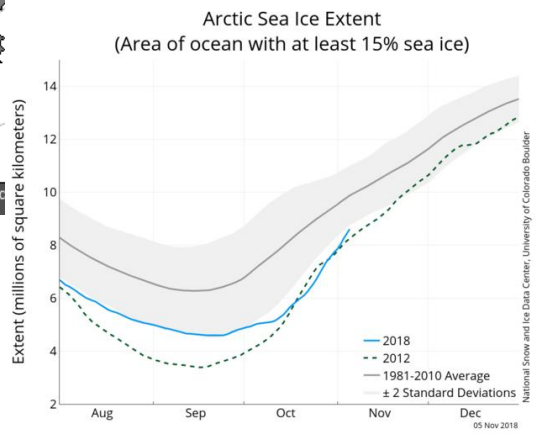
- December : Below normal (-1.6)
- January : near normal or weak above normal (+0.8)
- February : near normal (+0.4)

Thank you !



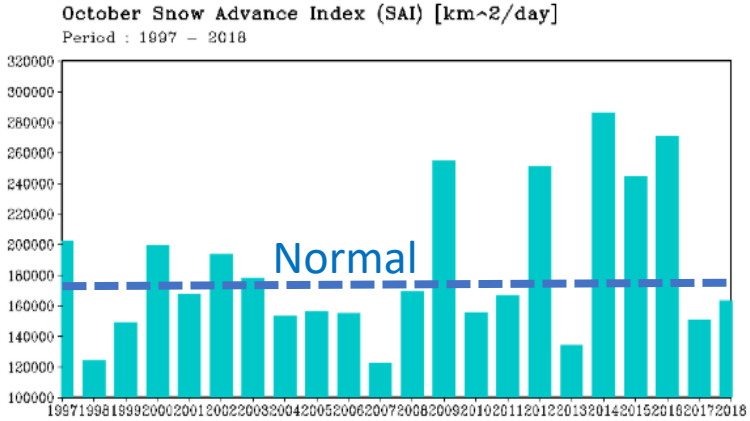
2018/19 ?





Much small SIC
over Barents-Kara-Laptev in Oct.
→ Negative SAT in KP

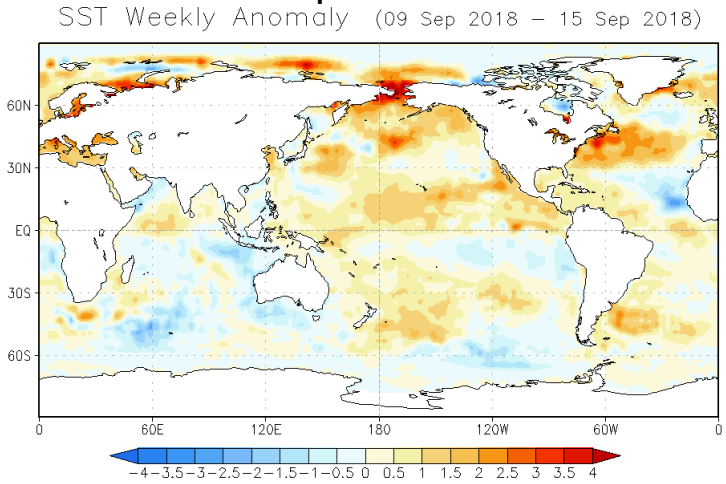
Snow Advanced Index

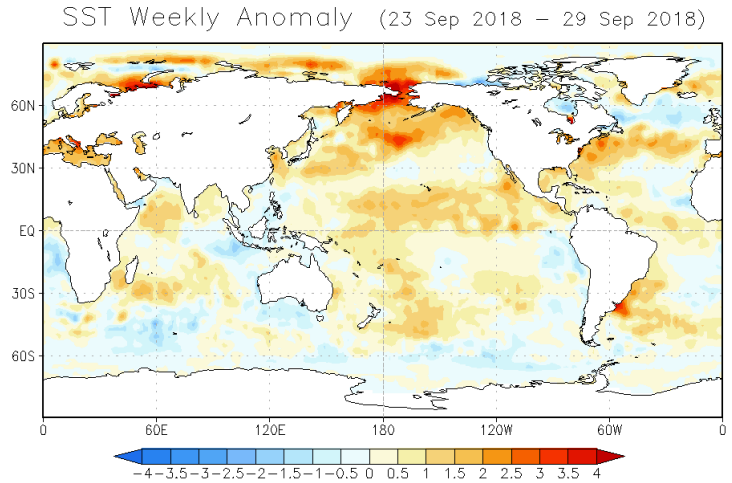


Normal or below normal
→ negative SAT in Dec.

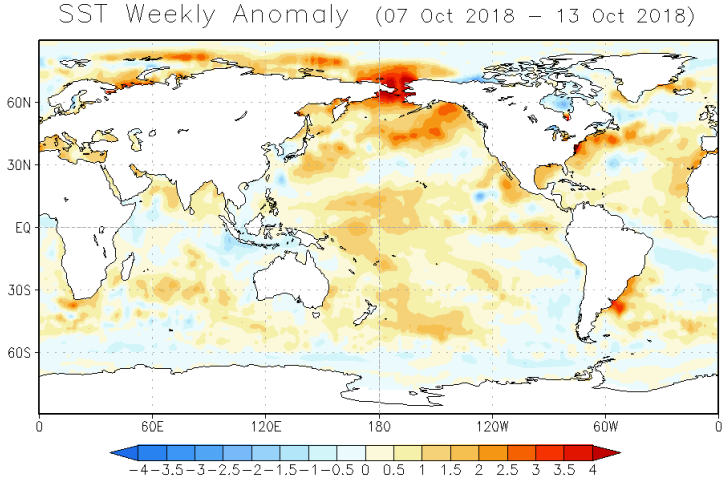
2018/19 ?

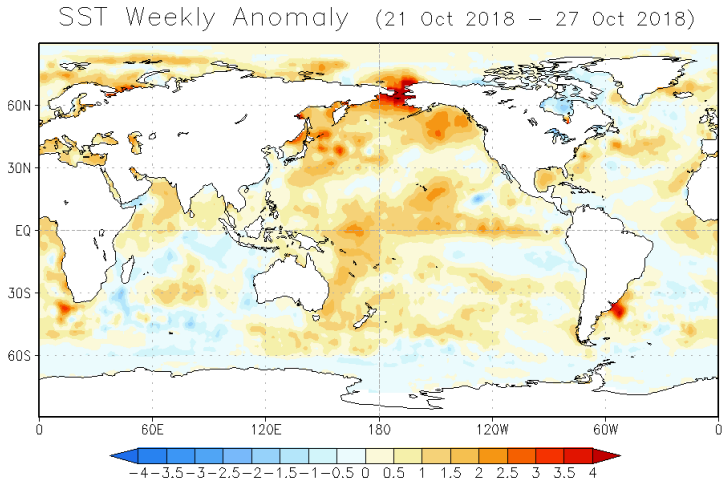
September





October

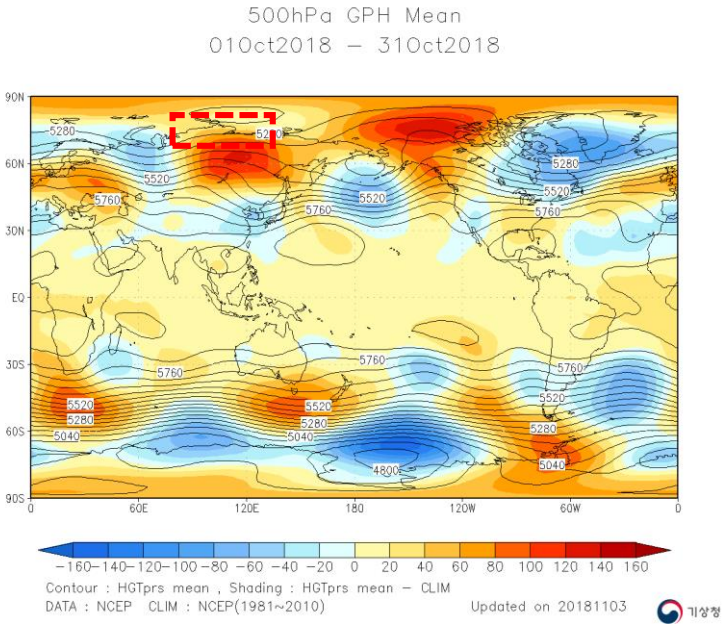




Weak El-Nino → positive SAT in Dec. and Jan.

Positive SST anomaly in Gulf stream → contribution negative SAT in Feb.

2018/19 ?



Z500 over Tamyr in Oct. → negative correlation to AO

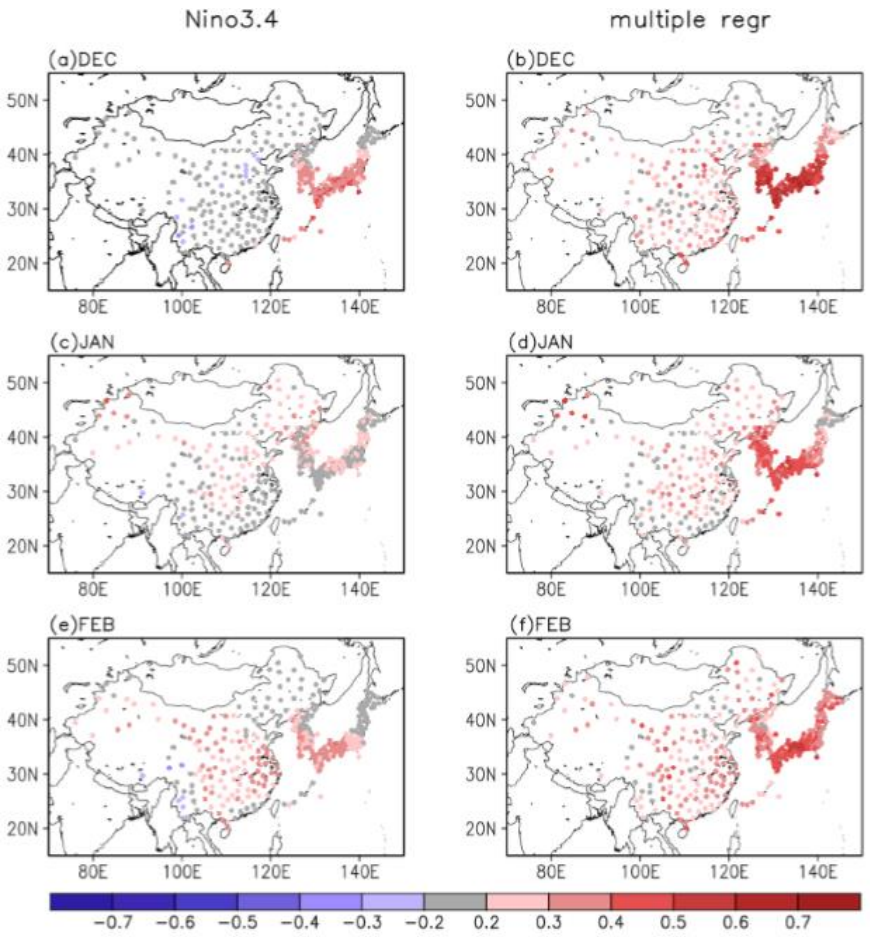
Positive ano. → contribution to negative SAT in Feb.

Considering both condition of predictors and the linear trend of SAT…..

- December : Below normal
- January : normal or weak above normal
- February : Below normal

For December, Statistical Model & Predictor

ENSO related tropical convection is important
which play role on forcing to midlatitude teleconnection

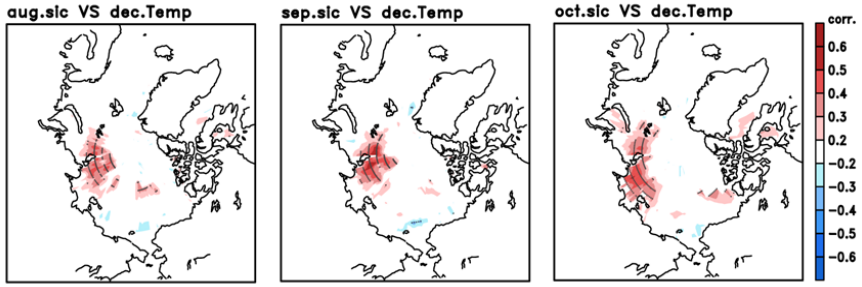


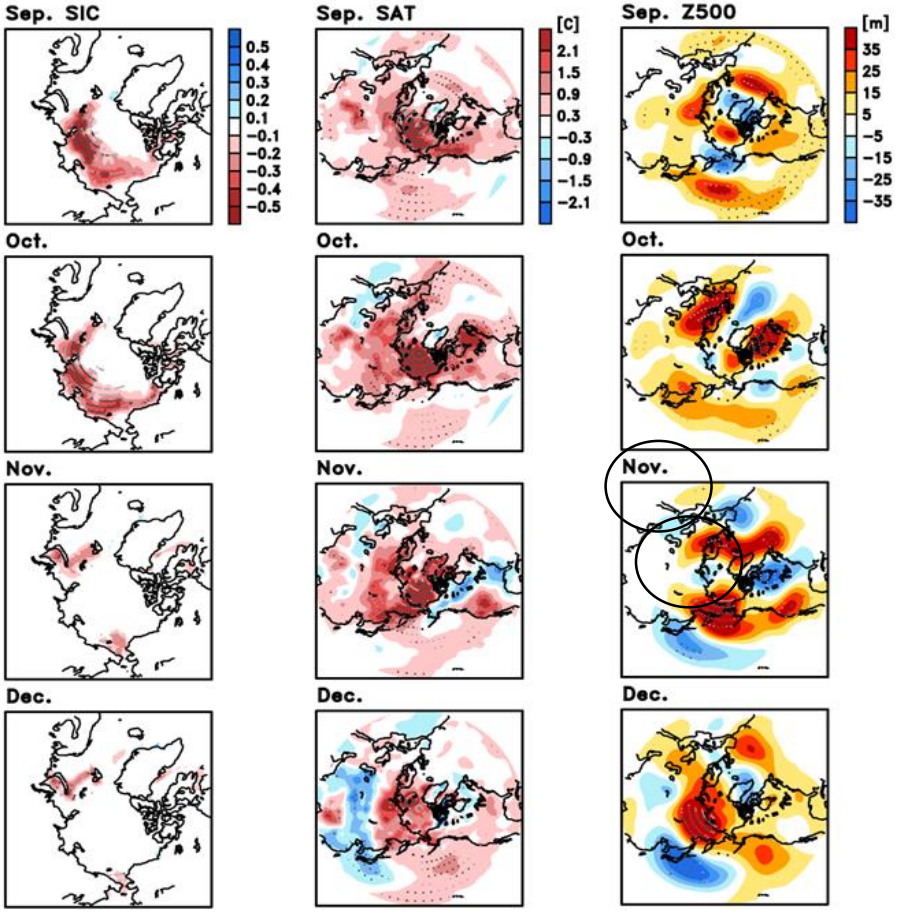
Multiple regression based on both precipitations related ENSO over Western North Pacific and Central Pacific

➔ more explanation of SAT variability over KP in winter season than by Nino3.4 index

R&D result from Prof. Kug

* Predictors, Lag correlation(detrended) with SAT in Dec.





Predictor :
SIC over Kara-Laptev Sea in September

- 9월 카라-랍테프 해 많이 녹으면 10월 랍테프 해 해빙 많이 녹는 경향, 11월 카라-바렌츠 및 척치해 해빙 여전히 적음

- 9월 ~11월 해빙이 많아 녹은 지역에서 강한 기온 상승이 관측, 고기압성 순환 발달

- 12월에 북동시베리아 지역 **강한 양의 지위고도 편차**, 그 남쪽에 **음의 지위고도 편차 발달**
- **우리나라에서는 북풍 강화 및 한기 남하**

10월 유라시아 눈덮임속도가 우리나라에 미치는 영향

○ 10월 유라시아 대륙 눈덮임면적

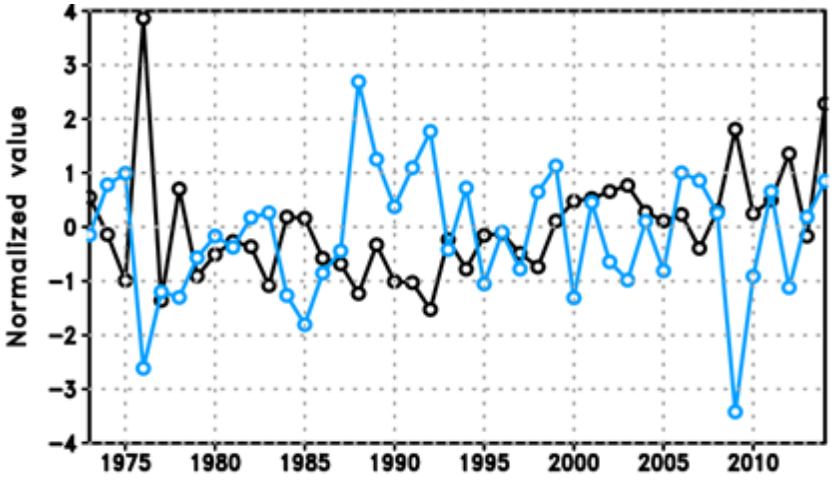
- 유라시아 대륙이 얼마나 눈으로 덮여 있는지는 **대륙고기압의 발달과 밀접한 관련**이 있음 (Snow-Albedo Feedback)
- 최근 연구(Cohen et al., 2011)에 의하면, 유라시아 지역에 눈이 덮인 유무보다 10월에 눈이 얼마나 빨리 덮이느냐(**눈덮임속도**)가 **겨울철 평균 북극진동과 연관이 큰 것으로 분석**됨

※ **눈덮임속도 지수의 정의**
0-180E, 25N-65N(유라시아 대륙) 영역에서 평균된 10월 마지막 주 눈덮임에서 10월 첫째 주 눈덮임을 뺀 값으로 정의함

<10월 눈덮임속도 지수와 기온의 상관성>

	Dec	Jan	Feb
우리나라 기온	**-0.31***	**-0.32***	-0.10

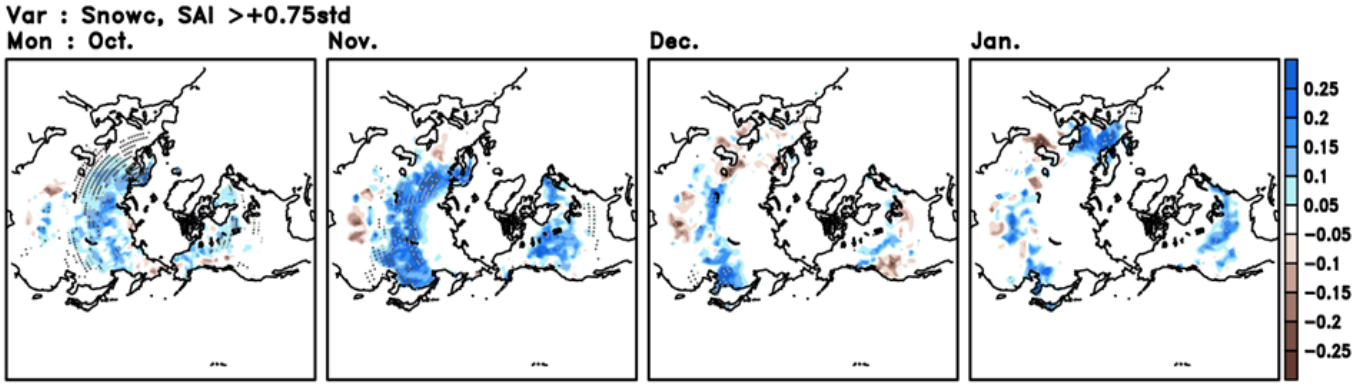
< 10월 눈덮임속도 지수와 북극진동 지수>



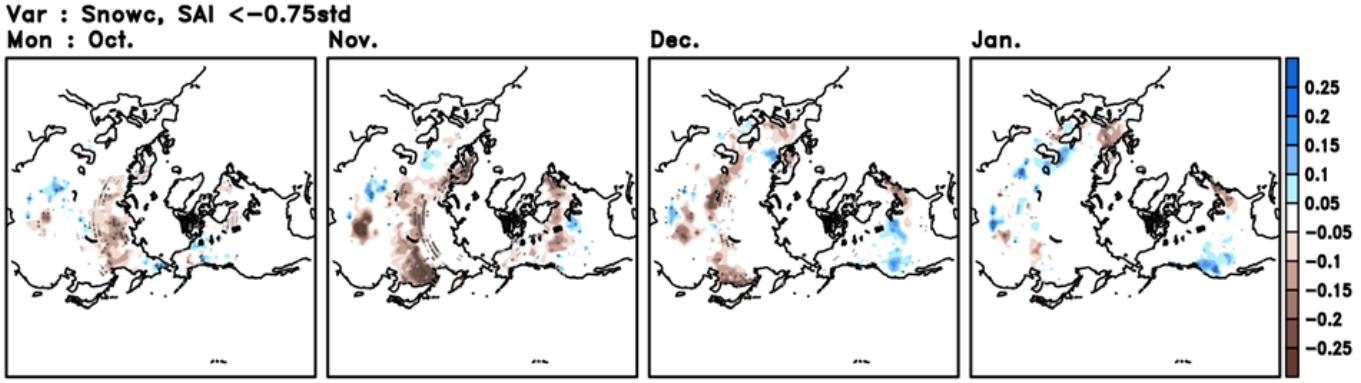
※ 상관계수: 1973 ~ 2014년 기간 -0.53,
1997 ~ 2010년 기간 -0.70

10월 유라시아 눈덮임 속도가 우리나라에 미치는 영향

<10월 눈덮임이 빠를 때 10월, 11월, 12월, 1월 눈덮임 면적 편차의 분포>



<10월 눈덮임이 느릴 때 10월, 11월, 12월, 1월 눈덮임 면적 편차의 분포>

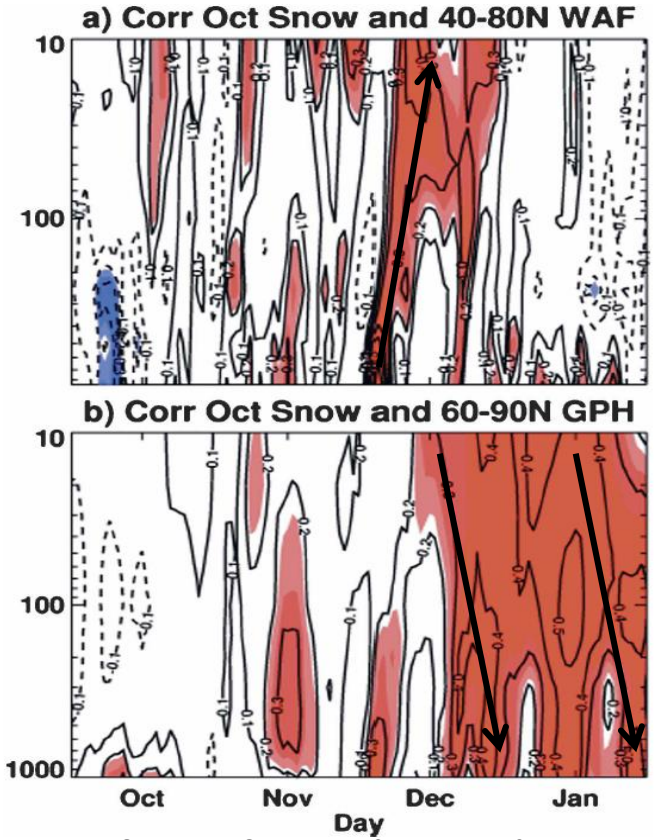


➔ 10월 유라시아 대륙 눈이 빨리(늦게) 덥히면 11월과 겨울철에도 눈이 많은(적은) 경향

10월 유라시아 눈덮임과 북극진동

유라시아 눈덮임과 겨울철 음의 북극진동 발생의 연관성

(Cohen et. al. 2007 …)



10월 유라시아 지역 넓고 빠른 눈덮임
(그와 연관된 순환장)

↓

대류권 stationary wave 연직전파

↓

성층권 극소용돌이 약화
극지역 기온상승 및 양의 지위고도 편차

대류권 영향

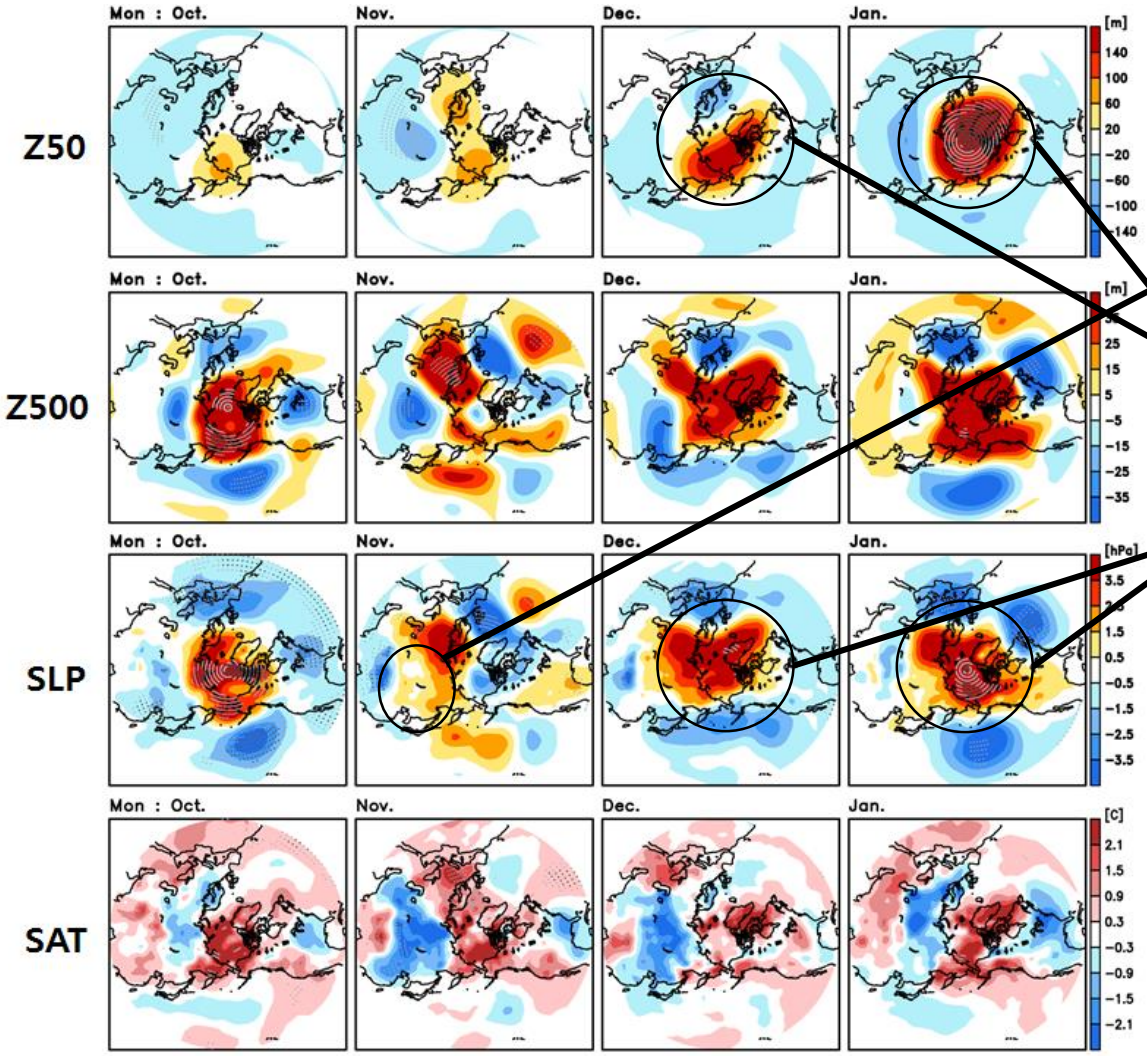
↓

음의 북극진동 유도

10월 눈덮임과 40° N~80° N에서 평균된 정상파 파동활동 속 (Wave Activity Flux, WAF) (위) 및 북극지역 (60° N~90° N) 평균된 지위고도 편차 (아래) 사이의 상관관계, Cohen et al. 2007

10월 유라시아 눈덮임 속도가 우리나라에 미치는 영향

<10월 눈덮임 속도가 빠를 때 순환장 및 기온>



* 10월 눈덮임이 빠를 때,

– 초겨울 대륙고기압 발달 (Snow–Albedo Feeback)

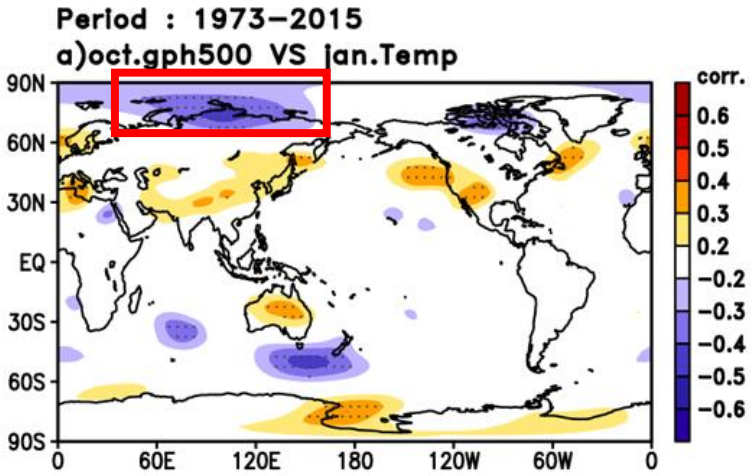
– 성층권 극소용돌이 강화

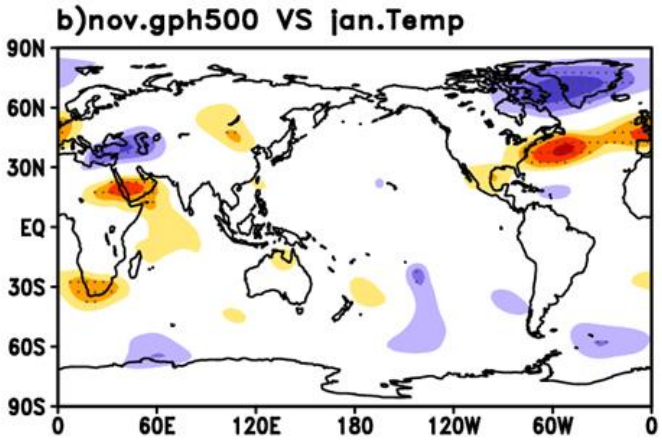
– 12월과 1월 음의 북극진동과 유사한 순환장 패턴

– 유라시아 음의 기온 편차 경향

10월 타미르반도 순환장이 우리나라에 미치는 영향

*우리나라 1월 기온과 상층 순환장 사이의 지연상관성



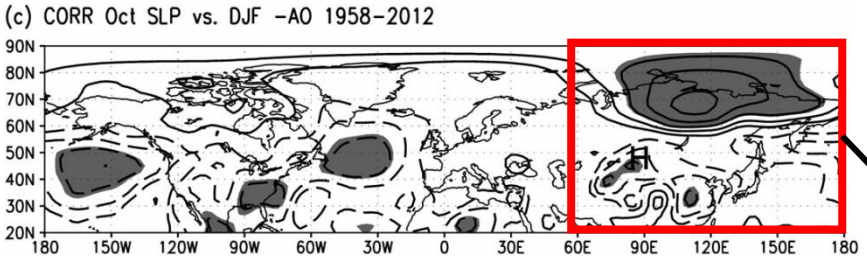


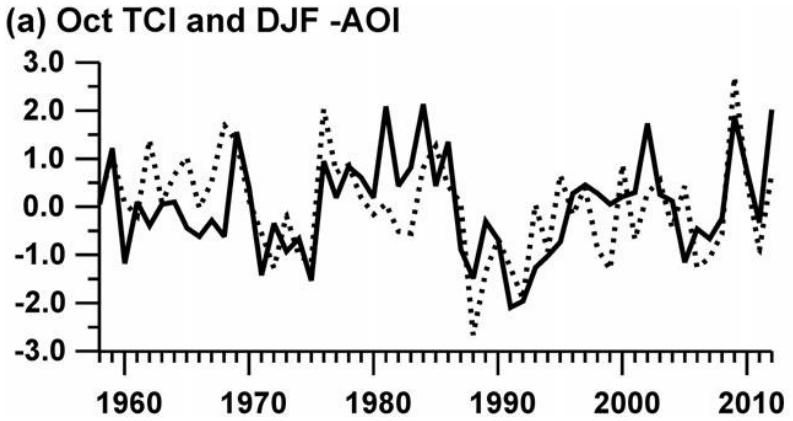
- 예측인자
  : 타미르반도 부근 상층(500hPa) 지위고도 편차
  (80° ~120° E, 70° ~80° N)

- 우리나라 1월 기온과의 상관성 : -0.42

10월 타미르반도 순환장이 우리나라에 미치는 영향

10월 타미르반도 순환장과 겨울철 **평균** 북극진동 (Kryjov 2015, IJC)



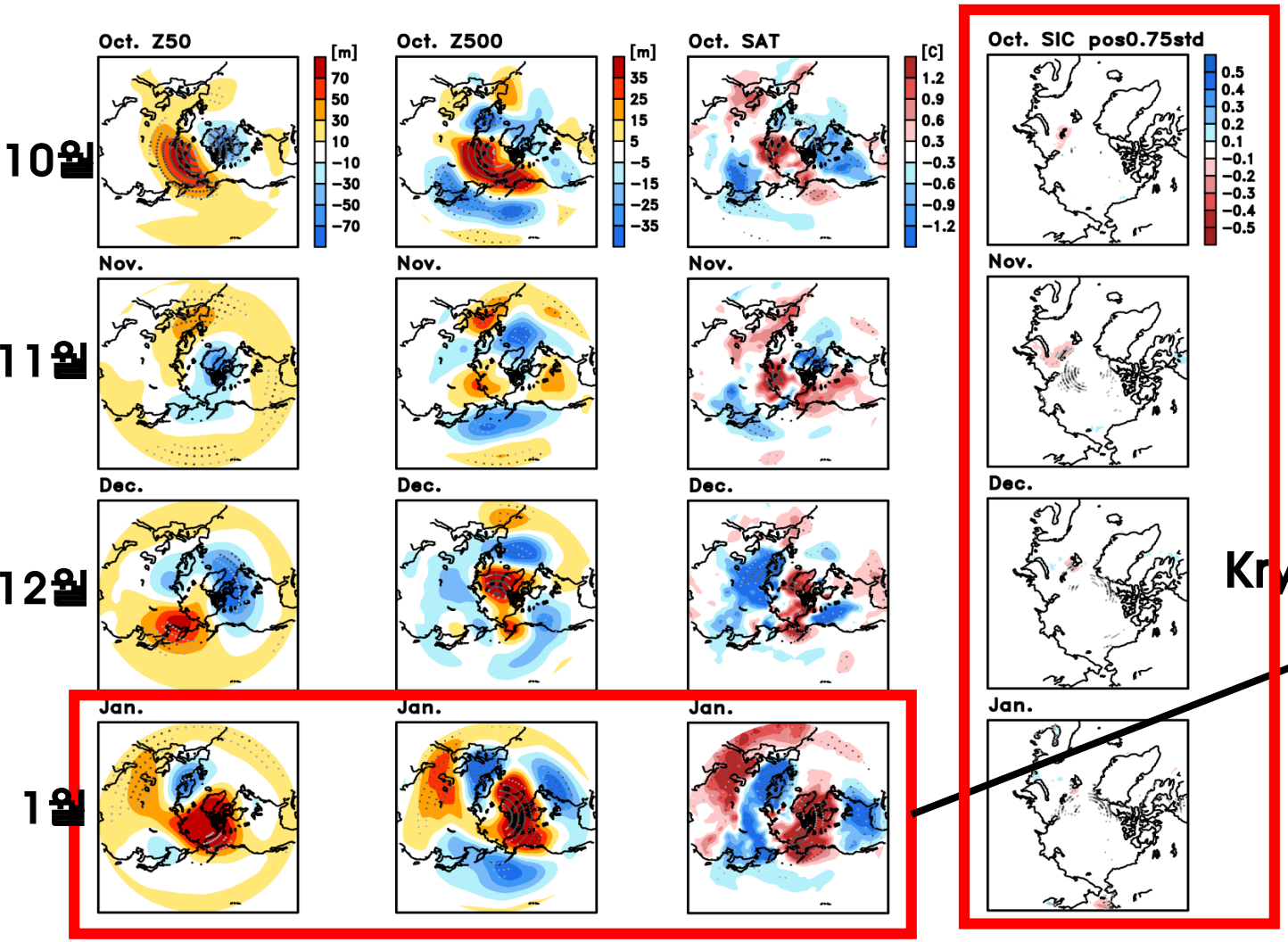


Stationary wave 연직전파 강화
(Cohen et al. 2007; Garfinkel et al. 2010)
→ 성층권 극소용돌이 약화
→ 대류권 음의 AO 변동
→ 우리나라 겨울철 낮은 기온 가능성

– 10월 카라 해 해빙과 역학이 매우 비슷
→ 두 예측인자가 같은 것을 현상을 보여주는 건 아닌가?
→ Overfitting?

10월 타미르반도 순환장이 우리나라에 미치는 영향

<10월 타미르반도 고기압성 순환이 강할 때>

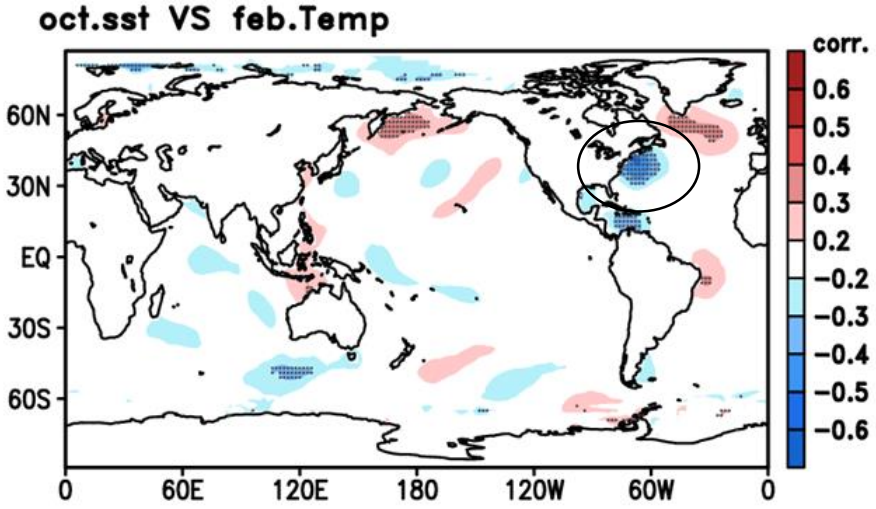


해빙과의 상관성은 약한 것 같음

Kryjov 2015 의 역학

10월 Gulf Stream 지역 해수면온도의 영향

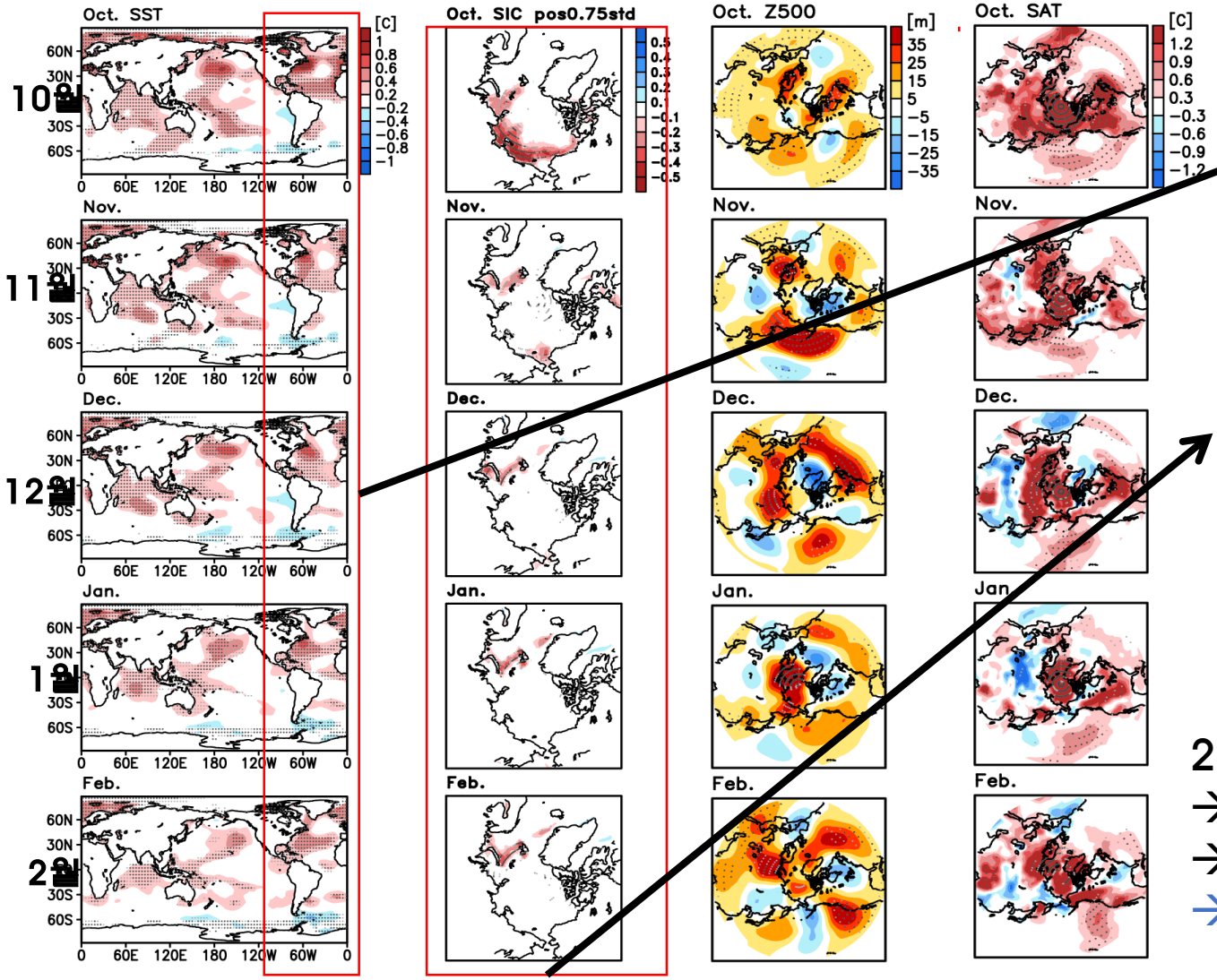
*우리나라 2월 기온과 10월 해수면온도 사이의 지연상관성



- 예측인자
  : 걸프 스트림 부근 해수면온도 편차
  (285° ~305° E, 35° ~50° N)

- 우리나라 1월 기온과의 상관성 : -0.46

10월 걸프스트림 지역 해수면온도의 영향



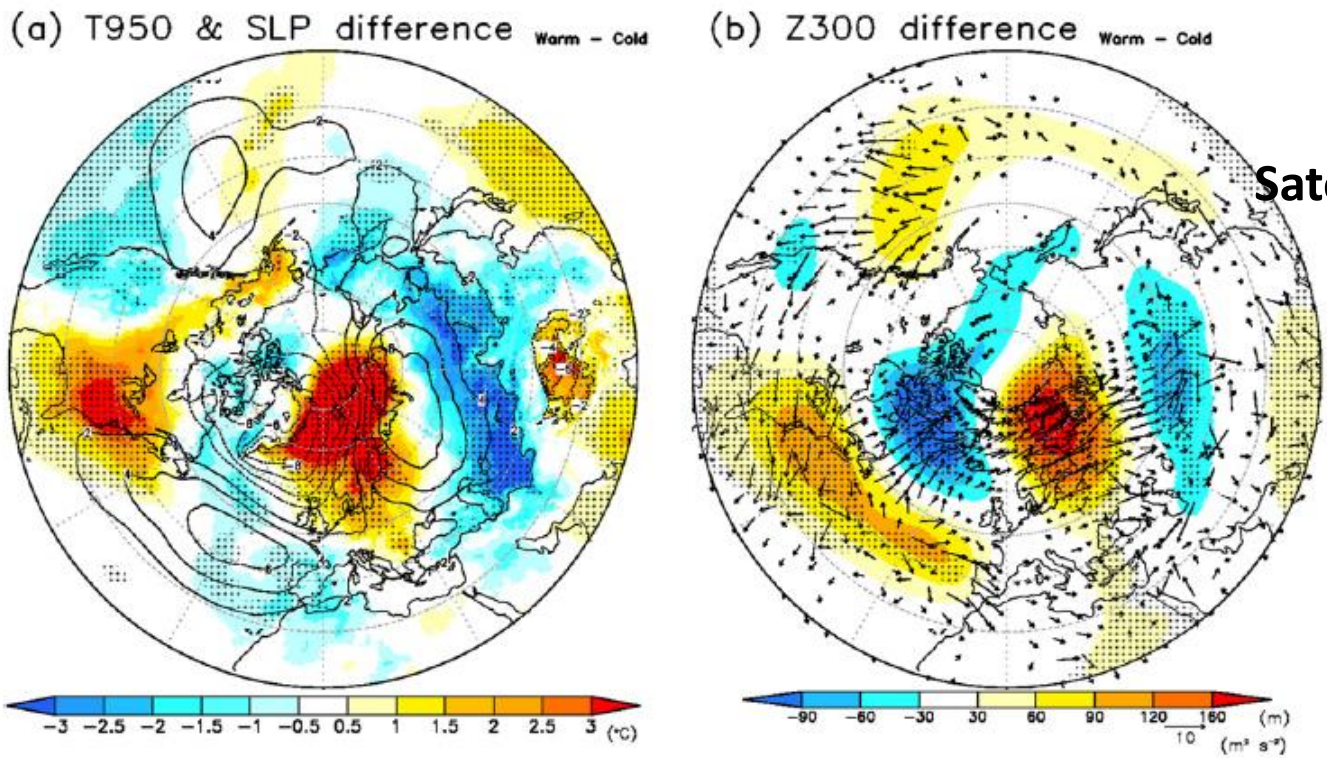
가을철 걸프스트림 지역 해수면온도가 높으면 지속적으로 높은 경향

해빙이 2월까지 매우 많이 녹는 경향 (해빙의 자체 메모리 보다 더 많이 녹게 만듦)

2월 우랄 고기압 편차 발달
→ 풍하측 저기압성 편차
→ 동아시아 기압골 강화
→ 우리나라 추운 경향

10월 Gulf stream 지역 해수면온도의 영향

앞서 10월 카렌츠 해와 같은 역할을 하는 것은 아닌지…
해빙의 자체 메모리 보다 더 많이 녹게 만드는 원인…



Sato et al 2014

12월 걸프스트림 지역 SST 높은 경우에서 낮은 사례의 합성도의 차
→ 대기 순환장 및 해양에 의한 열수송 → 12월과 1월 까지 해빙을 많이 녹게 할 수 있음
→ 대류권 내에서의 순환장 변화 유도 (우랄 고기압 편차→우리나라 저기압 편차)

- 예측인자 간 & 예측인자와 기온 사이의 상관성

예측인자&기온	10월 랍테프 해 해빙 (SIC_{Laptev})	가을철 동태평양 해수면온도 경향 (ENSO)	10월 눈덮임속도 (SAI)
12월 기온	**0.51**	**0.58**	**-0.31**
10월 랍테프 해 해빙		**0.12**	**-0.29**
가을철 동태평양 해수면온도 경향			**-0.08**

변수	10월 카라 해 해빙농도	적도 태평양 해수면온도 경향 (10월 – 9월)의 동서경도 (동태평양-서태평양)	10월 타미르반도 Z500
1월 우리나라 기온	**0.46****	**0.50****	**-0.42****
10월 카라 해 해빙농도		**0.22**	**-0.26**
적도 태평양 해수면온도 경향(10월 – 9월)의 동서경도 (동태평양-서태평양)	×		**-0.12**

변수	10월 바렌츠 해 해빙농도	호주 북쪽지역 해수면온도 경향 (10월 – 9월)	10월 걸프해류 해수면온도
2월 우리나라 기온	0.43**	-0.52**	-0.46**
10월 바렌츠 해 해빙농도		-0.26	-0.25
호주 북쪽지역 해수면온도 경향 (10월 – 9월)	×		-0.22
10월 걸프해류 해수면온도	×	×	

Relationship

SNOW over Eurasia
Gulf stream

눈과 SIC 연관성이 있지 않나?
-> 실제 그런 논문들이 있다. 하지만 그것이 SNOW 변동 전부를 설명하지 않는다.
실제 지역에 따라
Snow도 wave 연직전파의 한 원인이다.

October is the time to start to cover over Eurasian continet by snow
At this time, if the snow is covered quickly and much, it creates a big anomaly.
The snow cover speed index can reflects
how quickly the snow has been covered and how quickly it has been covered.

눈은 2가지 방법으로 동아시아 겨울에 영향을 미친다.
The first is the reflection of solar radiation.
The second is impact trough stratosphere
SAI in autumn shows high correlation to Arctic Oscillation in winter season
Snow related wave pattern is propagated well vertically toward stratosphere. And then
This wave can break the westerly wind accumulately in staratosphere

타미르 반도와 SIC 상관성
둘사이의 상관성은 about 0.4 정도 통계적으로 유의하다.
But

Sea ice 가 세 계절에서 모두 똑같은 역할?
월별 우리나라 기온과 연관된 sic 지역이 다름
뿐만 아니라 sic가 어느지역에서 녹느냐에 따라 그와 연관된 순환장 변화가 다름
따라서 다른

In terms of Influential time, tropospheric pathway such as Ural blocking and deepening of East Asian trough, directly influence the circulation. So, much sea ice loss in autumn tend to remain open sea in kara Barents, then KP can be cold in the early winter
Stratospheric pathway related to SIC tend to be working in the 늦겨울이 조금 더 working 하고 because stratospheric process need to take time to accumulate the wave breaking.

ENSO eveolution has its seasonality. That means circulation pattern related to ENSO is somewhat different among dec, jan and feb. this seasonality is mainly induced by combination of convection over western and central pacific. Our predictor related to ENSO can reflect well the convection western and eastern Pacific than just nino 3.4

ENSO도 세 계절 같은 영향아닌가?
I can not explain details of ENSO impact of cir. and temp in KP in presentation time limit.
ENSO impact on sat in KP is finally due to teleconnection by ENSO related convection in western and eastern Pacific.
If you consider jus nino3.4, we can not get the correlation in jan and feb. you can get little correlation to SAT in just December .(That means relationship have seasonality. Because competition)
Our predictors shows relationship with ENSO but I think our index seem to be reflected well convection variability in western pacific and eastern pacific then just nino3.4 index

In autumn season, Elnino or Lanina is developing season.
I think Tendency and zonal gradient shows well probability of development to Elnino or Lanina than the snap shot in specific month.
Because tendency and gradient show developing phase.
So, correlation to sat in KP is higher than based on just nino3 or nino3.4

Tendency가 큰데 음이면 라니냐인데 엘니뇨 효과가 들어가는거 아니냐
실제 그럴수 있다. 그래서 절대값에 대한 정보도 추가해 봤는데
큰 차이가 없더라.
In last year is big elnino year. In autumn season elnino is already develop enough.
So out predictor value is small because of tendency, but real elnino is big. So our model can not reflect impac of real elnino.
I have a plan that Enso predictor can consider both absolute value of SST and tendency

SIC loss in Laptev in autumn is little different to general SIC and its related circulation.
When SIC is less than in normal in autumn, high anomaly develops over norther Siberia, in contrast, cyclonic anomaly develops in EA including KP. Dipole pattern in East Asia n
This dipole pattern is similar to blocking type coldsurge suggested by park et al 2015.
Blocking type cold surge is stronger and longerlasting than wave train type from upstream. actually blocking occur frequently in that region.

We should research more why dipole pattern in winter season occur?

We investigated the circulation related to the model error .
We get clear wave like pattern over Eurasia
That means that Our model can not simulate the wave pattern propagating from Atrantic

Generally statistcal can not consider all of climate factor related to predictant.
Statistical prediction just give one of information of prediction.
We decided our outlook from many information well.

AO is natural variability that means many climate factor can influence the AO variability.
I think snow is one of factor influencing the AO.

Circulation over Tamyr is also one of factor.
Actually, Snow is not strongly correlated to SIC variability or tamy ciruculation.