P-010

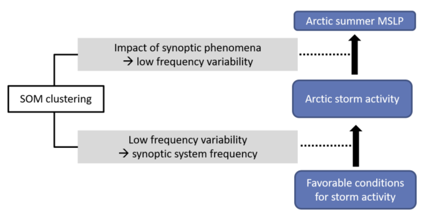
The role of synoptic cyclones for the formation of Arctic summer circulation patterns as clustered by Self-Organizing Maps

Min-Hee Lee, Joo-Hong Kim*

Unit of Arctic Sea-Ice Prediction, Korea Polar Research Institute

1. Introduction

- Low-frequency atmospheric circulation modes in the Arctic have attracted much attention owing to their role as controlling factors in the spatiotemporal sea-ice variability. Among the different seasons, the summer circulation pattern has received research focus because of its temporal proximity to the September sea-ice minimum.
- The summer season is known to be the most synoptically active in the Arctic Ocean with the large variability of baroclinic frontal zone along the land-ocean boundary. As a result, summer in the Arctic Ocean is stormier than the winter, which manifests as local cyclogenesis, as well as migratory mid-latitude cyclones.
- Therefore, Arctic cyclones and their role in controlling sea-ice have been critical topics in understanding the Arctic summer.
- From a scale interaction perspective, the Arctic is a singular region, where the zonal scales from synoptic to planetary merge, due to the reduced length of latitudinal circles. So, if a strong synoptic system persists or frequently passes near the pole, it can directly contribute to a low-frequency circulation pattern



- In this study, we want to show
  1) the impact of storm as the synoptic event which make up the seasonal averaged circulation in Arctic
  2) the possible low-frequency teleconnection that can be a favorable condition for the storm activity.

- For identifying the summer Arctic circulation pattern, we adopted the self-organizing map clustering (SOM) method which can sufficiently distinguish the representative patterns with the physical meaning from the large climate data set.

2. Data & Method

a. Data

- Daily MSLP, skin T, U, V, T, q, RV from ERA-Interim reanalysis
- NOAA Extended Reconstructed SST (ERSST) version 4
- NOAA NCDC Snow cover extent
- Period : boreal summer (JJA) for 1979-2017
- Domain : 60°N- 90°N

b. Method

- SOM clustering method
  - one of clustering method which is originated from the neural networks
    - i) classify the data into a specified number of pattern
    - ii) relocate the resultant patterns according to the similarity between the patterns
  - more accurate and linearly independent than the patterns from other clustering & empirical orthogonal function (EOF) method
- Cyclone tracking and gridding method
  - Detection
    - i) A local $RV850_{max}$ (> 2.0×10^{-5} s^{-1}) in each 11×11 grid window.
    - ii) The closest local $MSLP_{min}$ within a 400 km radius of the local $RV850_{max}$.
    - iii) MSLP which increases by at least 15 Pa in all directions within a 500 km distance from the local $MSLP_{min}$
    - iv)The equatorward limit of detection : 30°N for Northern Hemisphere extratropical storms.
  - Tracking
    - i) For a given storm, a circular tracking boundary with a 750 km radius is set at each 6-hourly time step, and the location of the storm at that time step is set as the center of the circle. Then, the storm centers at the next time step are examined within the boundary.
    - ii) If one storm center is found within the boundary, it is determined as the next storm position. In case of multiple storm centers, priority is given to the closest storm center located in the front half of the circle, towards the direction of the storm's movement. If there is no such storm center at the front half of the circle, the closest one is selected as the next position. If no storm appears within the boundary, the tracking of that given storm stops.
    - iii) Finally, only storms with lifetimes equal to or greater than 1days are considered.
  - Gridding

    Cyclone tracks is transformed into grid-cell counts. Due to singularity near the pole, we constructed equidistant grid-cells that were 500 km x 500 km and centered on the pole, rather than the conventional latitude-longitude grid cells.

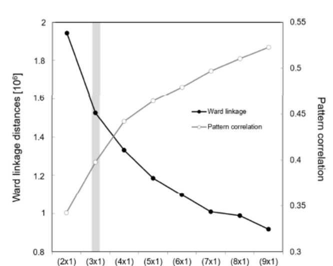
3. Results

a. Determination of optimal SOM number

- The optimal number should be

  i) large enough to accurately capture the daily pattern
  → large pattern correlation between daily fields & SOM pattern

  ii) sufficiently small that the clusters are distinctive from each other
  → large distances among each SOM patterns



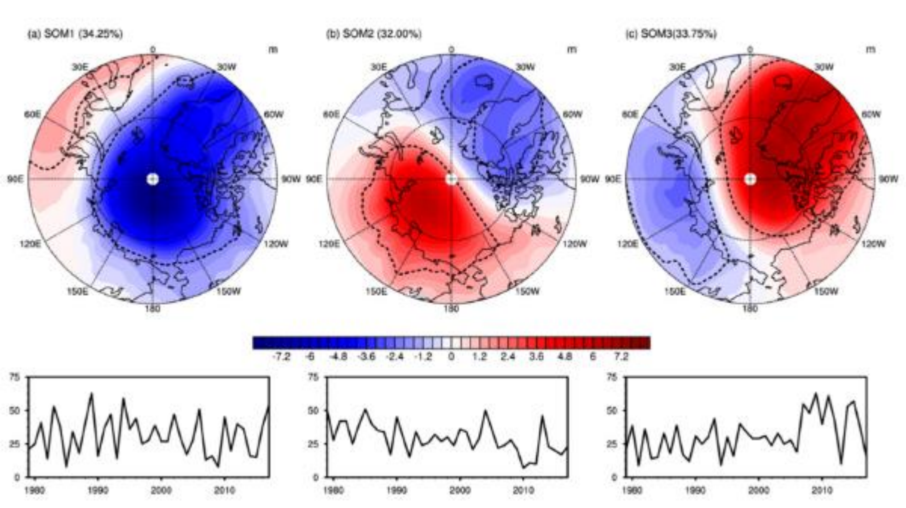
$$d(r,s) = \sqrt{\frac{2n_r n_s}{(n_r+n_s)}}\|\bar{x}_r - \bar{x}_s\|_2$$

where n_r and n_s are the number of elements in clusters r and s, respectively, and $\bar{x}_r$ and $\bar{x}_s$ are the centroid patterns of clusters r and s, respectively.

- As the number of SOMs exceeds 3, it can be seen that the increasing tendency of pattern correlation and the decreasing tendency of the distance are both slowed down.
- We therefore set an appropriate number of SOM pattern for the MSLP variation over Arctic to a (3x1) (that is, 3 row by 1 column).

b. SOM patterns for the summer MSLP in the Arctic

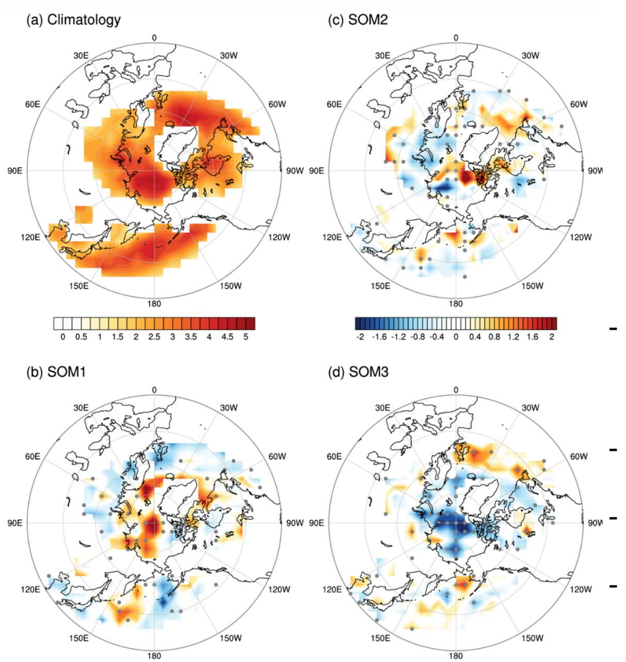
- MSLP SOM pattern & their annual frequency of occurrence (days/JJA)



- SOM1: Positive AO-like pattern, negative MSLP centered at Arctic Ocean & Greenland large interannual variation, slightly low variability and frequency in 2000s
- SOM2: Dipole mode between positive Kara/Laptev Sea and negative Greenland/Iceland slightly small interannual variation in 1990s, decreasing trend
- SOM3: Dipole mode between positive in Arctic Ocean near Greenland vs. negative Eurasian, Negative AO-like pattern, recent shift of frequency after 2007

c. Cyclone activities associated with the SOMs

- Composite of cyclones frequency



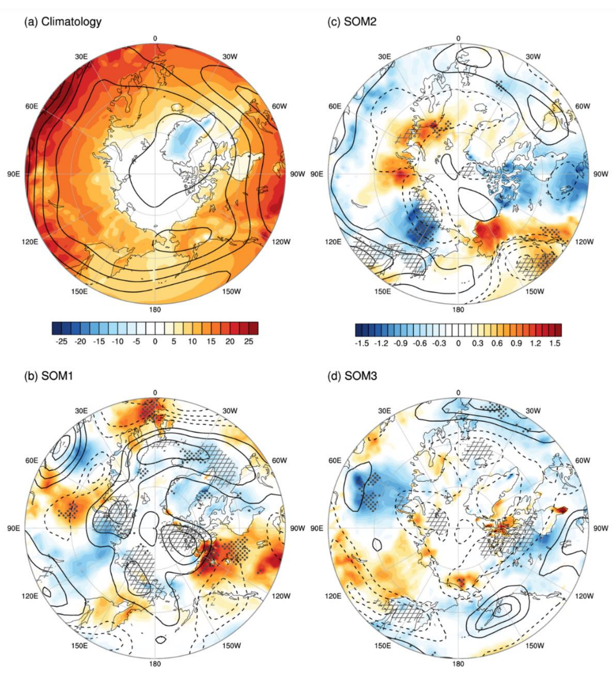
- Correlation (MSLP, storm activity)

SOM	Activity Cire	Freq.	Dur.	CentP	ACE
1	Positive	-0.23	-0.33	0.6	-0.39
	Negative	-0.6	-0.72	0.87	-0.55
2	Positive	-0.48	-0.58	0.75	-0.42
	Negative	-0.39	-0.42	0.54	-0.48
3	Positive	-0.65	-0.69	0.82	-0.49
	NEgative	-0.15	-0.23	0.47	-0.25

- Most area-averaged MSLPs over core area for each SOM pattern are significantly related to the cyclone activity
- SOM1: increase in Arctic Ocean, more storms from Greenland Sea
- SOM2: increase (decrease) in Canada (along Eurasian coastal line)
- SOM3: decrease (increase) in Arctic Ocean (Norwegian Sea, Bering Sea, Eurasian continent)

d. Large-scale fields relevant to the cyclone activity forming each SOM

- Composite difference of U200 (contour) and Skin T (shading)

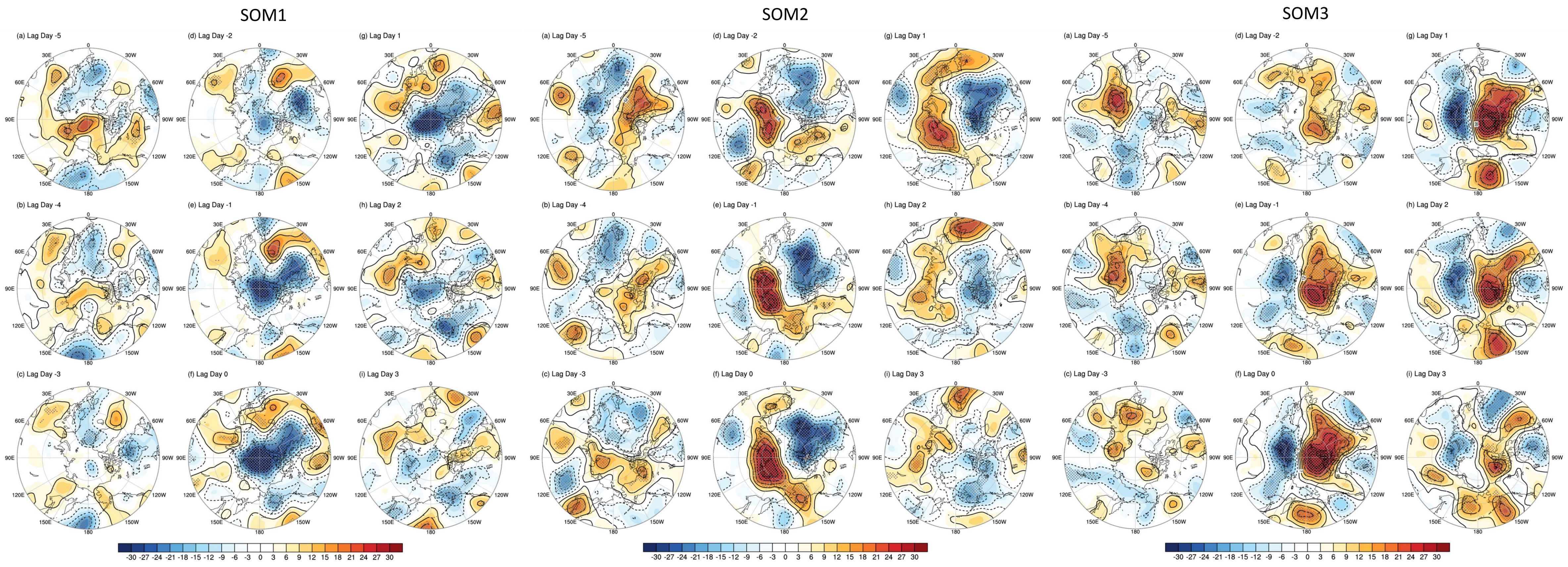


- SOM1: warm coastal line & cold Arctic Ocean → increase in U200 & EGR over Arctic Ocean
- SOM2: relatively warm in Pacific sector and cold in Atlantic sector → increase (decrease) in U200 & EGR over Atlantic (Pacific) sector
- SOM3: warm Arctic ocean & cold Eurasian continent → decrease in U200 & EGR over Arctic Ocean

- Area averaged EGR over core area for each SOM show the consistently related to the cyclone activity for the region (figure not shown).

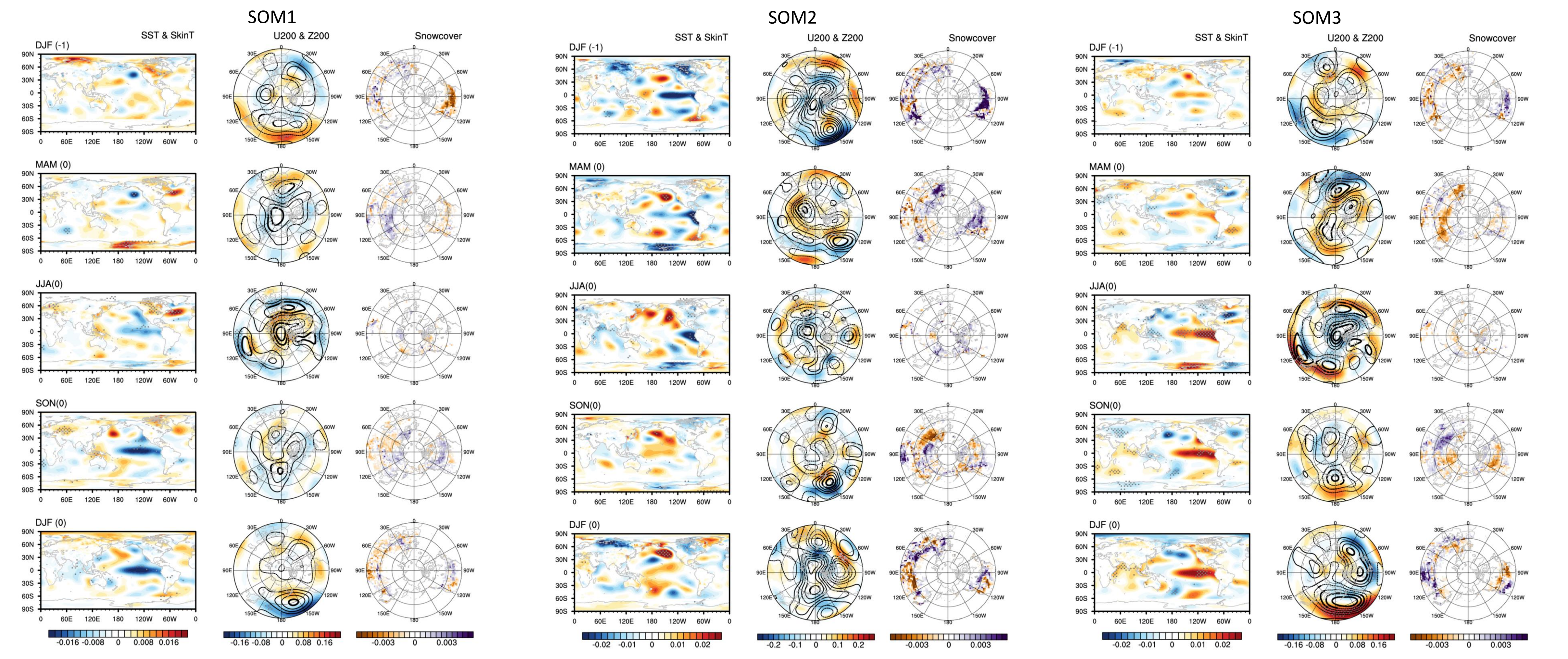
e. Synoptic evolution associated with the SOMs

- Composite of daily evolution in the synoptic scale H500 anomalies from -5 to 3 days for the best matching events of each SOM.
  - Although all 3588 days had to be classified into one of the SOM patterns, the similarity between the daily anomaly field and the SOM pattern varied from day to day. Therefore, if there are consecutive days with one SOM pattern, the best matching day need to be determined as lag 0 days. We selected the days with the smallest RMSE between daily anomaly and the SOM pattern.
  - Consistent with the composite of storm frequency for each SOM, the low pressure system developed at the high baroclinicity zone and moved to the region of negative core in each SOM pattern.



f. Possible global teleconnections as the favorable conditions for the baroclinicity

- Composite against high pass (< 10 yr) filtered SOM frequency

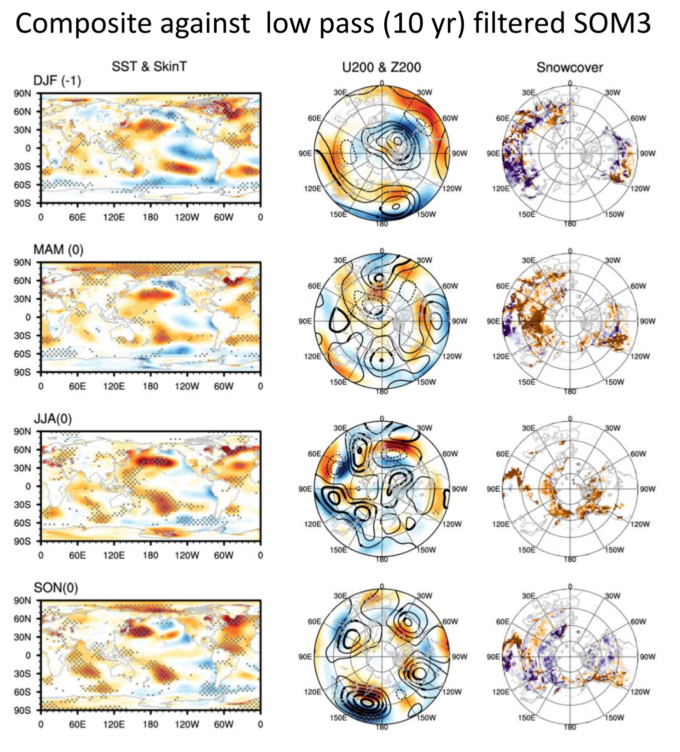


SOM1:
- Developing phase of La-Nina
- Positive snow extent anomaly over cold Eurasian continent from spring to summer
- Positive AO-like pattern with reduced Aleutian Low in the following winter
- Negative snow anomaly over warm Eurasian continent in the following fall and winter

SOM2:
- Decaying phase of La-Nina
- Positive snow extent anomaly over high latitude except northeast Russia from the preceding spring
- Negative NAO-like pattern in the following winter

SOM3:
- Developing phase of El-Nino
- Negative (positive) anomaly in snow over warm Eurasian continent (America) from winter to summer
- Positive (negative) snow anomaly in Eurasian (America) in following fall & winter
- Positive NAO-like pattern with strong Aleutian Low in following winter

- Composite against low pass (10 yr) filtered SOM3



4. Summary and Discussion

- Several studies have shown that the activity of synoptic cyclones is more prevalent during summer in the Arctic Ocean, and it has been suggested that they potentially contribute to seasonal mean Arctic climate.
- Our results add to literature on the quantitative contribution of synoptic cyclone activity to the amplitude of seasonal mean anomalies in individual activity cores of the three dominant Arctic summer circulation patterns as clustered by the SOM method.
- We have also confirmed that the spatiotemporal distribution of synoptic cyclones in the Arctic domain is a major controlling factor for the Arctic summer circulation patterns.
- The summer cyclone activities in the central Arctic Ocean are enhanced only for the circulation pattern (e.g., SOM1) that occurs at the land-Arctic Ocean boundary area with enhanced baroclinicity and is co-located with the climatological major cyclone pathways.
- The composite daily evolutions demonstrated the generalized formation processes and elucidated the timescales of the three SOM patterns of atmospheric circulation in the Arctic well. Furthermore, considering the short e-folding timescales of SOMs, the summer-mean Arctic circulation patterns reflect the accumulation of short timescale events.
- Considering that the summer baroclinic instability is also influenced by the preceding spring snow cover and SST evolution, it can be predictable on seasonal time scale in the same year.
- In association with low frequency variability of SOM3 occurrence frequency, a La-Nina like pattern with warm northwestern Pacific and cold eastern Pacific SST anomalies occurred thorough whole year. This may have a linkage with recent large climate change such as the global/Arctic warming.

KOMES Fall Meeting :: 30 Oct – 1 NOV 2019

KOPRI

극지역 여름철 평균 순환장 형성에 대한 종관규모 저기압 활동의 영향

이민희[1], 김주홍[1]

[1]극지연구소 북극해빙예측사업단

극지역 (≥ 60°N) 여름철 (6-8월) 평균 순환장 형성에 대한 중고위도-종관규모 저기압의 기여를 파악하기 위하여, 자기조직화지도 방법을 이용해 극지역 여름철 일별 해면기압장을 세 가지 패턴으로 분류하였다. 첫 번째 패턴 (SOM1)은 Arctic Circle에 뚜렷한 저압성 아노말리가 지배적인 패턴이고, 나머지 두 패턴은 Arctic Ocean을 덮는 고압성 아노말리를 가지는 쌍극모드라는 공통점이 있지만, SOM2는 Arctic Ocean을 포함한 유라시아 반도쪽이 고압성 아노말리, 대서양 쪽이 저압성 아노말리를, SOM3는 Arctic Ocean을 포함한 그린란드, 대서양 지역에 고압성 아노말리, 유라시아 대륙쪽이 저압성 아노말리를 보이는 차이를 가지고 있다. 매 여름마다 각 패턴으로 분류된 날들의 빈도를 세어 그 변동성을 살펴보면, SOM1은 큰 경년변동을, SOM2는 약한 감소 경향을, SOM3는 2007년 이후 큰 증가를 보여주고 있다. 저기압 트랙 자료를 이용하여 각 SOM 패턴과 관련된 종관규모 저기압의 형태를 살펴보면, 극지역 여름철의 순환장이 저기압의 활동과 밀접한 관련이 있음을 알 수 있다. SOM1은 극지역 저기압의 활동성 강화와 관련된 패턴으로, 육지 지역과 극지 해양 사이의 남북 온도 경도 강화로 인한 대기 불안정성이 해당 지역에 증가한 것을 볼 수 있었다. 나머지 패턴에서도 저압성 (고압성) 아노말리 코어를 중심으로 저기압의 활동이 활발해지는 것을 확인하였다. 또한 SOM 패턴의 각 코어를 중심으로 한 저기압의 활동성과 해당 지역의 평균 순환장 사이의 관계 또한 통계적으로 유의미한 관계를 보였다. 각 SOM으로 분류된 이벤트들이 유지되는 시간규모는 3-5일 정도임을 감안하여, 각 SOM 패턴으로 분류된 날 들 중에서 대표패턴과 유사도가 높은 날들을 모아 Lag 0 일로 정의하고, 이 날을 기준으로 5일 전부터 3일 후까지의 종관패턴을 분석해 보았다. 각 패턴마다 저기압 아노말리가 점차 이동하여 0일에 코어에 자리잡는 모습을 확인할 수 있었다. 이처럼 짧은 규모의 기상 패턴의 반복은 나아가 경년 혹은 장주기 변동의 일부도 설명할 수 있는데, 이 연구에서의 저기압의 활동은 극지역 여름철 순환장을 형성하는 데에 있어 중심적인 역할을 하는 것으로 분석된다.

Key words: 극지역 여름철 순환장, 중-고위도 종관규모 저기압, 자기조직화지도, 저기압 탐지 및 트래킹

2019년 한국기상학회 정기총회 및 가을학술대회 일정표

10월 30일(수)					
08:30~09:20	1층 로비	등록			
09:20~09:40	300C	개회식			사회: 권영철 (KIAPS)
09:40~10:00	300C	[초청강연1] 황종성 연구위원 (한국정보화진흥원)			좌장: 민승기 (포항공대)
10:00~10:20		[초청강연2] 하경자 교수 (부산대)			
10:20~10:40		[초청강연3] 홍성유 단장 (KIAPS)			
10:40~10:50	300C	단체사진			
10:50~11:00	휴식				
학술발표					
발표장	300C	101-102	105-106	201	205-206
11:00~12:30	기후 1	[특별세션 3] 특이기상연구센터 성과 1	환경 및 응용기상 1	[특별세션 11] 기상산업 활성화	관측 및 예보 1
	진경 (극지연구소)	함유근 (전남대)	구자호 (연세대)	송근용 (기상산업기술원)	김기훈 (국립기상과학원)
12:30~13:50	300A-B	중식			
13:50~15:20	기후 2	[특별세션 3] 특이기상연구센터 성과 2	[특별세션 10] AR6 기후변화 시나리오	[특별세션 8] 관측 사각 영역 기상 자료	관측 및 예보 2
	김백민 (부경대)	차동현 (UNIST)	최준태 (국립기상과학원)	권병혁 (부경대)	정성화 (기상레이더센터)
15:20~15:40	휴식				
15:40~16:40	300C	평의원회		포스터 발표 1 (3층 로비)	
16:40~17:40	300C	정기총회			
18:00~20:00	300A-B	간친회			
10월 31일(목)					
발표장	202-204	101-102	105-106	201	205-206
09:00~10:30	기후 3	대기물리 1	[특별세션 7] 도시기상 빌딩숲 집중관측 1	[특별세션 4] KIM 개발 성과와 미래전략	[특별세션 6] 강원 영동 입체공동관측 1
	정지훈 (전남대)	엄준식 (부산대)	변재영 (국립기상과학원)	강현석 (수치모델링센터)	권태영 (강릉원주대)
10:30~10:50	휴식				
10:50~12:20	기후 4	대기물리 2	[특별세션 7] 도시기상 빌딩숲 집중관측 2	[특별세션 5] 관측시스템 수치예보 영향 1	[특별세션 6] 강원 영동 입체공동관측 2
	김선태 (APEC 기후센터)	임교선 (경북대)	박문수 (한국외국어대)	박세영 (수치모델링센터)	김병곤 (강릉원주대)
12:20~13:20	300A-B	중식			
13:20~14:50	포스터 발표 2 (3층 로비)				
14:50~16:20	기후 5	[특별세션 1] HPC 기상기후연구	환경 및 응용기상 2	[특별세션 5] 관측시스템 수치예보 영향 2	관측 및 예보 3
	현유경 (국립기상과학원)	조민수 (KISTI)	임윤진 (국립기상과학원)	이승우 (수치모델링센터)	박혜숙 (국가기상위성센터)
16:20~16:40	휴식				
16:40~18:10	기후 6	[특별세션 2] 폭염영향예보와 대응	환경 및 응용기상 3	대기역학 1	관측 및 예보 4
	구태영 (국립기상과학원)	김용준 (한국외국어대)	정수종 (서울대)	김주완 (공주대)	이시혜 (KIAPS)
11월 1일(금)					
발표장	202-204	101-102	105-106	201	205-206
09:00~10:30	[특별세션 9] (English) Climate & Earth System 1	대기물리 3	환경 및 응용기상 4	대기역학 2	관측 및 예보 5
	국종성 (포항공대)	이현호 (공주대)	이승재 (국가농림기상센터)	박상훈 (연세대)	이은희 (KIAPS)
10:30~10:50	휴식				
10:50~12:20	[특별세션 9] (English) Climate & Earth System 2	대기물리 4	환경 및 응용기상 5	대기역학 3	관측 및 예보 6
	이준이 (부산대)	박상서 (UNIST)	김주홍 (극지연구소)	김정훈 (서울대)	박세영 (수치모델링센터)
12:30~	202-204	폐회식 및 우수포스터 시상			사회: 민승기 (포항공대)