문서번호 APCC-출장-19-0798(2019-10-22)

결재	선임연구원	과장	부서장	원장
	10/21 여새림	10/22 이우섭	10/22 유진호	10/22 권원태
협조				

TRAVEL REPORT FORM
출장보고서

I. **Travel Overview** 출장개요

1. Traveler(s) 출장자

Department 소속	Position 직위(직급)	Name 성명	Note 비고
기후사업본부	선임연구원	여새림	

2. Travel Period 출장기간

10/14~10/18

3. Occasion and destination 행사 및 출장지

일시	출발지	도착지	업무 수행 내용	비고
10/14	부산	슈투트가르트	이동	
10/15~16	슈투트가르트		워크숍 참석 및 발표	워크숍 발표 10/15
10/17~18	슈투트가르트	부산	이동	

II. **Major Activities** 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

— 한-독 환경워크숍은 주요 환경 이슈에 대하여 한국과 독일 전문가가 모여 토의하는 자리로 재독한국과학기술자 협회가 주관하고 한국과학기술총연합회와 독일 슈투트가르트시가 후원하는 국제 워크숍임

— 2017년 (제1회, 독일 본)과 2018년 (제 2회, 독일 슈투트가르트)에는 미세먼지를 비롯한 대기오염에 관한 주제로 워크숍이 성공적으로 개최되었고, 올해는 도시 폭염에 관한 분석 및 이를 저감하기 위한 도시계획 적용방안 마련이라는 주제로 제3회 한독 환경워크숍이 개최됨

— 이에 한국 측 폭염 관련 전문가로 초청발표를 수행함 (한국측 연사로는 제주대학교 박수국교수, 울산과기대 이명인교수, 건설기술연구원 정승현박사가 초청 발표를 수행함)

— 주요 발표 내용 요약

- Freibrug 대학 Helmut Mayer 교수: heat wave가 인간 생활에 미치는 영향을 측정하는 지수는 현재까지 PET, PT 등 많이 개발되었지만, 대부분 air temperature의 statistical 특성을 바탕으로 개발된 지수로서, 인간이 지각하는 heat wave를 표현하는데 한계가 있음. 따라서 sensible heat flux, wind, evaporation 등의 보다 다양한 기상 변수 활용하여 flow chart를 통한 지수를 개발함

- 제주대학교 박수국 교수: 한국의 아파트 지구 (마곡 지구, 고덕-강일 지구)에서 urban planing에 대한 8가지 시나리오(vegetation, multi-layer tree, cool-roof, cool-pavement, rainwater garden, roof-top등)에 따른 heat wave 반응을 살펴봄. 시뮬레이션 결과, 태양 고도를 고려한 tree planting과 multi-layer planing, rainwater garden, roof-top garden이 heat wave의 영향을 줄일 수 있는 도시계획으로 제안됨

- Leibniz 대학 Gunter Gross 교수: 중규모, 지역(regional) 규모, local 규모 simiulation을 위한 model이 제시됨, 각각 ICON, FITNAH, ASMUS, 모델을 사용중임. 최근에는 regional과 local 규모를 아우를 수 있는 PALM-4U 모델 프로젝트가 수행중임. 이를 통해 urban hot spot를 identify 함으로써 적절한 대책을 마련할 수 있음

- APCC 여새림: heat wave에 대한 적절한 urban planing을 위해서는 신뢰도 높은 기후예측 정보 생산이 필수적임. APCC에서 수행중인 기후예측 업무와 특히 올해 폭염 예측을 위한 모니터링 업무를 소개함. 우리나라 폭염의 특징을 대규모 순환장의 특징에 따라서 두가지 타입으로 나누고, 각각의 예측인자를 발굴하는 연구를 소개하고 이를 실제 폭염 기후예측에 어떻게 활용이 가능한지 토의하였음. 특히 동-서 방향 파동형태의 우리나라 폭염은 유럽 지역의 blocking과 관련된 현상으로 이에 대한 심층연구가 필요함이 제시되었으며, 올해에는 이러한 연구 결과가 모니터링 분야에만 적용되었다면, 이를 더욱 발전시켜 모델 결과와 융합하여 예측 업무에 활용도를 높일 필요가 있음이 제시됨

- Technical university Berlin, Dieter Scherer 교수: heat stress hazard를 정량화 하는 방식에 대해 제시함. daily mean air temperature를 이용한 degree-day approach가 heat stress hazard를 측정하는데 유용한 방식으로 제시됨

- 울산과기대 이명인 교수: 우리나라 폭염 사례에 대하여 EOF 분석을 적용하여 스칸디나비아 패턴과 Circumglobal teleconnection 패턴으로 분류함. 특히, 스칸디나비아 패턴은 최근에 강도와 빈도가 강화된 특징이 있음, 이는 중부 유럽지역의 건조 시그널과 관련된 현상임. 기후 모델을 이용하여 heat wave의 attribution

을 살펴봄. 예를 들면 2016년 우리나라 폭염의 경우 drying condition, warm SST, arctic sea ice melting이 영향을 미쳤음을 기후 모델 실험을 통해 확인함. 또한 machine learning을 기반으로한 서울지역 폭염 예측 성능 향상에 대하여 소개함

- German weather service, Dr. Meinolf Kosmann: 도시 기후 모델인 MUKLIMO_3를 이용하여 2031-2060년 근 미래의 stuttgart시의 heat wave를 모의하고 이것이 인간 활동에 미치는 영향을 확인함.

- University of Stuttgart, Jurgen Baumuller 교수: 기후 변화 적응 및 Climate in the German planning law 등 기후 변화 적응 정책관련 독일의 사례를 제시함

※발표 프로그램 및 발표 자료 첨부

※워크숍 현장 사진

2. Relevance to APEC Climate Center's Activities 결론 및 소감

— 폭염과 관련하여 기후적인 분석 및 이슈사항 뿐만 아니라 실제 우리 생활에 직접적으로 필요한 도시계획 및 관련 도시 법안 마련 그리고 도시규모의 모델링을 통한 근미래 폭염 전망 등 다양한 분야에 대한 한국과 독일의 최신 연구 동향을 파악할 수 있었음

— 최근 빈번하게 발생하고 국민 생활에 큰 영향을 미치는 폭염에 대하여 APCC, 기상청, 과학원 등 기후 관련 기관에서 활발하게 폭염 메커니즘 및 예측 방향에 대하여 연구가 수행되고 있고, 이러한 연구 결과들을 바탕으로 가까운 미래에는 기후예측 정보에 폭염 정보를 포함시키고자 하는 노력이 수행되고 있는데, 이렇게

생산된 기후 예측 정보를 실제 도시 계획이나 관련 법안 마련에 적극적으로 활용될 수 있는 방안에 대해서도 고민이 필요함

— APCC와 기상청을 중심으로 수행된 연구 결과를 바탕으로 폭염 정보를 포함한 기후 예측 정보를 생산함에 있어서 기본적으로는 국민의 일상생활에 필수적인 정보로 활용될 뿐만 아니라 더 나아가 도시 계획, 인체 열 스트레스 분석 관련 보건 분야 등 다양한 수요자를 고려하여 보다 다양한 방식으로 활용 방안을 모색할 필요가 있음

— 현재 제공되고 있는 폭염 영향예보에 기후예측 정보를 적극 활용하여 콘텐츠를 다각화 하는 등의 활용방안이 기대됨. 예를 들면, 본 워크숍에서 제시된 human perception index등을 활용하여 폭염 예측 정보를 다양화 하는 등의 활용도 향상을 기대함

— 특히 폭염에 취약한 도시 기후에 대한 이해를 높이고, 도시 열섬 관련 모델링 및 선진국에서 현재 수행중인 도시 기후관련 법안 마련 연구 등 최근 연구 동향을 파악하는 등의 지속적인 관심이 필요함

3. Suggestions and Remarks 건의사항

III. References (Presented and Collected Materials) 주요 수집자료

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

3rd Korea-Germany Environmental Workshop

Challenge for urban planning: Heat stress in urban quarters

Organizer
VeKNI (Korean Scientists and Engineers Association in Germany)

Support
City of Stuttgart, **KOFST** (Korean Federation of Science and Technology Societies)

Coordinator
Dr. Hyunjung Lee
(VeKNI; City of Stuttgart, Office for Environmental Protection, Department of Urban Climatology)
hyunjung.lee@vekni.org; Hyunjung.Lee@stuttgart.de

15-16 October 2019

Conference hotel (Tagungshotel) "campus.guest" of the University of Stuttgart
Universitätsstraße 34, 70569 Stuttgart-Vaihingen, Germany

Verein Koreanischer Naturwissenschaftler und Ingenieure in Deutschland

OVERVIEW

Approaches to analyze human heat stress in urban quarters

Urban planning in many cities worldwide is currently challenged to react to four different developments:

1. increasing severe heat due to regional climate change
2. increase of urban population
3. demographic change, i.e. increase in the proportion of the risk group "elderly people“
4. provision of affordable housing

Based on statistical analyses of long-term measured data and results of regional climate simulations, increasing heat refers not only to the long-term evolution of the near-surface air temperature, but also to embedded heat waves that will be more frequent and intense as well as longer lasting in the future. As the design of many cities - such as in Central Europe - and their population are not really adapted to severe heat, enhanced negative impacts on well-being, efficiency and health of the urban population are to be expected, especially on consecutive days with severe heat stress. Elderly people are particularly vulnerable because their thermo-physiological capacity for the adaptation to heat is decreasing with age.

In order to reduce the negative heat impacts on the urban population as well as increase the resilience of adaptation measures related to heat. suitable urban design strategies were proposed by urban planning in the past. Besides high albedo materials, evaporation from porous surfaces, cooling possibilities by water, and natural ventilation, they mainly address the promotion of urban green infrastructure. However, their practical effectiveness for the urban population has not yet been satisfactorily clarified.

Given this background, the 3rd Korea-Germany Environmental Workshop represents an excellent platform to share the knowledge, experiences and still existing action deficits in this issue that has a rising significance in both countries.

PROGRAM | Tuesday, 15 October 2019

12:00 - 13:00	Registration
13:00 - 13:30	Opening and welcome remarks - **Dr. Wonsun Park** (VeKNI President; GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany) - **Dr. Hans-Wolf Zirkwitz** (City of Stuttgart, Head of the Office for Environmental Protection, Germany) - **Dr. Hyunjung Lee** (VeKNI; City of Stuttgart, Office for Environmental Protection, Department of Urban Climatology)

Session 1
Approaches to analyze human heat stress in urban quarters

Chair **Dr. Hyunjung Lee** (VeKNI; City of Stuttgart, Office for Environmental Protection, Department of Urban Climatology)

13:30 - 14:00	Quantifying heat stress in urban quarters under a human-biometeorological perspective - **Prof. Dr. Helmut Mayer** (Albert-Ludwigs-University of Freiburg, Chair of Environmental Meteorology, Germany)
14:00 - 14:30	Analysis of human thermal environments in the apartment complex by computer simulation - **Prof. Dr. Sookuk Park** (Jeju National University, College of Applied Life Science, Republic of Korea)
14:30 - 15:00	Summer heat simulated by numerical models: cascade from meso-scale to micro-scale models - **Prof. Dr. Günter Groß** (Leibniz University Hannover, Institute of Meteorology and Climatology, Germany)
15:00 - 15:30	Practical uses of climate analysis in monitoring Korean heat waves - **Dr. Sae-Rim Yeo** (APEC (Asian-Pacific Economic Cooperation) Climate Center, Busan, Republic of Korea)
15:30 - 16:00	Coffee break

Continuation of session 1

Chair **Prof. Dr. Wilhelm Kuttler** (University of Duisburg-Essen, Campus Essen, Applied Climatology, Germany)

16:00 - 16:30	Investigations on urban heat stress hazards and their changes over time - **Prof. Dr. Dieter Scherer, Dr. Ute Fehrenbach** et al. (Technical University of Berlin, Institute of Ecology, Chair of Climatology, Germany)
16:30 - 17:00	Heatwave prediction from global to urban scale based on numerical and statistical methods - **Prof. Dr. Myong-In Lee** (Ulsan National Institute of Science & Technology, Republic of Korea)
17:00 - 17:30	Numerical simulations on human thermal comfort in summer in the city of Stuttgart as basis for the adaptation to regional climate change - **Dr. Meinolf Koßmann** (German Weather Service, Department of Climate and Environ-mental Consulting, Offenbach, Germany)
17:30 - 18:00	Urban climate function maps: a tool for identifying and mitigating "hot spots for humans" in urban quarters - **Prof. Dr. Lutz Katzschner** (University of Kassel, Environmental Meteorology, Germany)
19:00 -	**Dinner together** (Conference hotel "campus.guest" of the University of Stuttgart)

Session 2
Recommendations for urban planning to reduce local human heat stress

Chair **Dr. Wonsun Park** (VeKNI President; GEOMAR Helmholtz Centre for Ocean Re-search Kiel, Germany)

8:30 - 9:00	Heat stress in urban areas - consequences for human health and countermeasures - **Prof. Dr. Wilhelm Kuttler** (University of Duisburg-Essen, Campus Essen, Applied Climatology, Germany)
9:00 - 9:30	Heatwave in urban areas of South Korea and their countermeasures - by the case of the Metropolitan region Daegu - **Dr.-Ing. Yongseok Kwon** (Daegu Gyeongbuk Development Institute, Daegu, Republic of Korea)
9:30 - 10:00	German Planning Law - ready for climate change and heat stress? - **Prof. Dr. Jürgen Baumüller** (University of Stuttgart, Institute of Landscape Planning and Ecology, Germany)
10:00 - 10:30	Coffee break

Continuation of session 2

Chair **Prof. Dr. Helmut Mayer** (Albert-Ludwigs-University of Freiburg, Chair of Environmental Meteorology, Germany)

10:30 - 11:00	Potential of green infrastructure to reduce human heat stress in urban quarters - **Prof. Dr. Stephan Pauleit**, Technical University of Munich, Chair for Strategic Land-scape Planning and Management, Germany)
11:00 - 11:30	Mitigation of heat stress for pedestrians in urban street canyons due to trees dependent on site conditions and tree characteristics - **Dr. Hyunjung Lee** (VeKNI; City of Stuttgart, Office for Environmental Protection, De-partment of Urban Climatology, Germany)
11:30 - 12:00	An introduction on urban planning measures for dealing with urban heat wave - **Dr. Seunghyun Jung** (Korea Institute of Civil Engineering and Building Technology, Goyang, Republic of Korea)
12:00 - 12:30	Closing discussion - (Chair) **Dr. Hyunjung Lee** (VeKNI; City of Stuttgart, Office for Environmental Protection, Department of Urban Climatology, Germany)
13:00 -	**Lunch together** (Conference hotel "campus.guest" of the University of Stuttgart)

VENUE

**Walking from the S-Bahn station "Universität" in Stuttgart
to the Conference hotel (Tagungshotel) "campus.guest" of the University of Stuttgart
(walking distance: about 2 minutes)**

Attention
The Conference hotel (Tagungshotel) "campus.guest" has a bistro and a restaurant
(no other restaurant near the hotel).
The bistro is daily open from 15:00 to 24:00 CET (food from 17:30 to 21:30 CET).
The restaurant is daily open from 12:00 to 14:00 CET.

국외출장 세부일정(2019.10.14.~18.)

날짜	일정
10월14일(월)	부산-독일/슈투트가르트 이동
10월15일(화)	워크샵 등록 Session 1 Approaches to analyze human heat stress in urban quarters 참석 - 모델 시뮬레이션을 통한 heat stress 측정, 중규모 및 미규모에서 heat stress 시뮬레이션 등 모델링을 통한 도시 열파에 대한 이해 - 도시 열파에 대한 numerical, statistical 분석 방법, 도시 열파에 대한 mitigation 및 adaptation 방안 - 우리나라 폭염 특성 분석 및 현업 활용 부분에 대한 발표 (15:00~15:30) - 한-독 과학자들과 도시 열파 관련 토의
10월16일(수)	Session 2 Recommendations for urban planning to reduce human heat stress 참석 - 도시 열섬 효과에 때한 측정 방법 및 human health에 미치는 영향 분석 결과 - 도시 열섬에 대응하기 위한 도시 계획 수립에 관한 내용 - 한-독 과학자들과 토의
10월17일(목) ~10월18일(금)	독일/슈투트가르트-부산 이동

3rd Korea-Germany Environmental Workshop
Challenge for urban planning:
Heat stress in urban quarters

Practical uses of climate analysis in monitoring Korean heat waves

Sae-Rim Yeo
APEC(Asia-Pacific Economic Cooperation) Climate Center
Busan, Korea

APCC
APEC CLIMATE CENTER

Contents

APEC Climate Center

Mission

The mission of APCC is to enhance the socio-economic well-being of member economies by utilizing up-to-date scientific knowledge and applying innovative climate prediction techniques

Functions

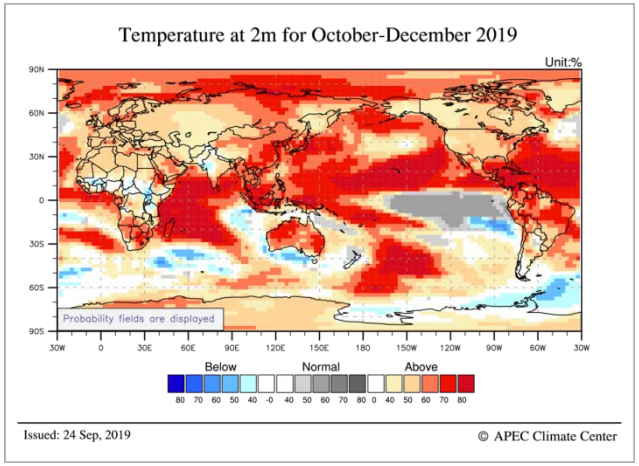
Climate Prediction: Developing a **value-added reliable real-time climate prediction system**, through a state of the art **multi model climate prediction system** utilizing model predictions from member economies

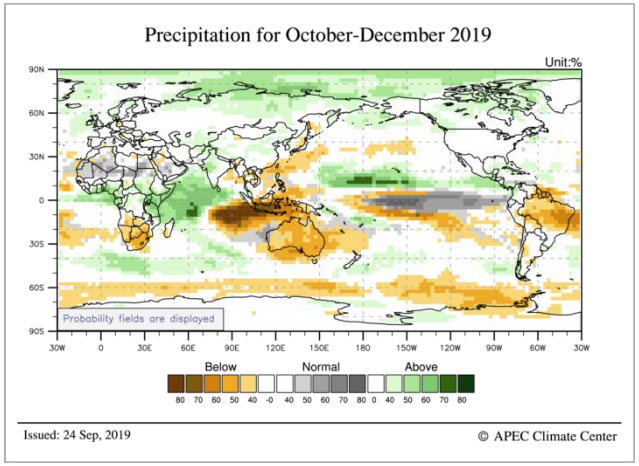
Center for climate data : Acting as a **center for climate data** and related information with open access to member economies

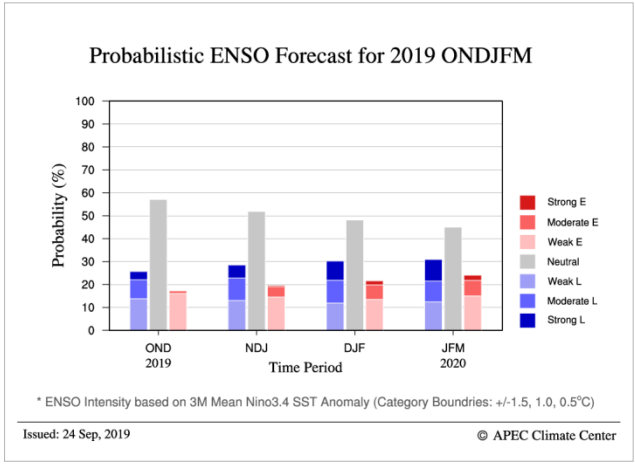
Capacity Building: **Helping build the capacity of member economies** in producing and using reliable climate prediction information

Climate prediction in APCC

- The APEC Climate Center collects forecast information from **17 leading climate forecasting centers** and institutes in 11 countries. These forecasts are combined using the **multi-model ensemble (MME)** scheme and the high quality climate forecast information is disseminated to APEC member economies and Pacific Islands through APCC's website
- Continuous **verification** of climate prediction against actual observed data **to enhance reliability** of APCC MME climate services



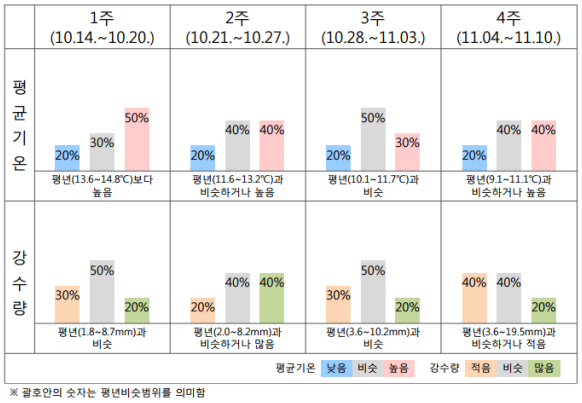




Operational long range forecast in Korea

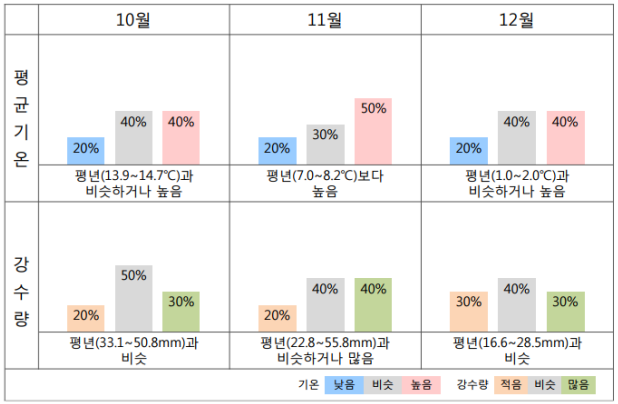
Korea Meteorological Administration

1-month outlook



※ 괄호안의 숫자는 평년비슷범위를 의미함

3-month outlook



※ 괄호안의 숫자는 평년비슷범위를 의미함

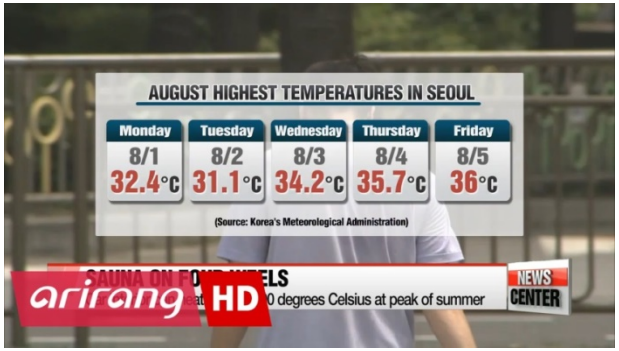
GloSea5

Operational long range forecast

APCC MME
WMO MME

Analysis on Korean climate

2018 Summer Korean Heat Wave

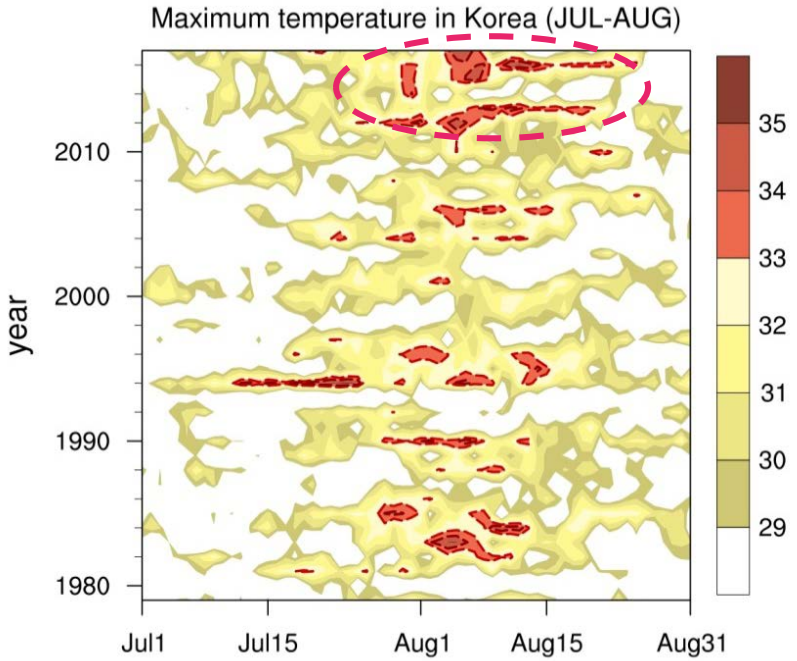


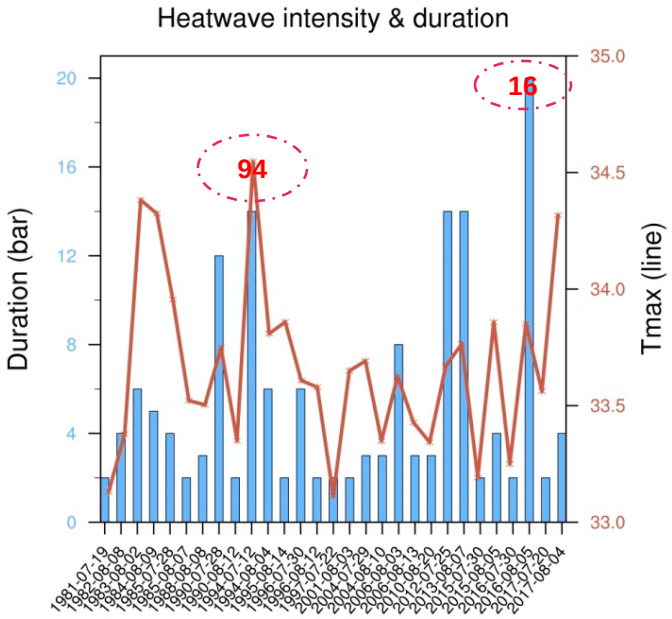
- Frequent occurrence of extreme heat waves in Korea in recent years
- Atmospheric heat wave brings serious consequences for society, economy, ecosystem and human health
- Operational long range forecast should contain heat wave information
- It is important to understand physical processes of heat waves in Korea and improve their predictability

General characteristics of heat waves in Korea

Data

- Daily mean maximum temperature from 61 weather station in Korea 1979-2017 (KMA)
- Large scale atmospheric variables: NCEP Reanalysis 2
- NOAA OISST v2, OLR

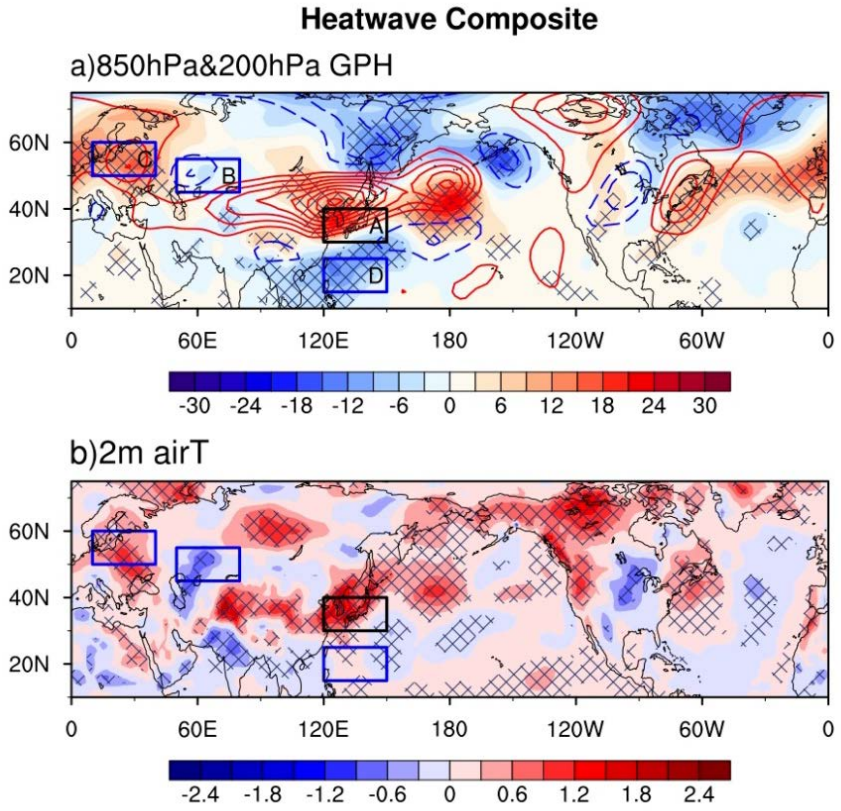




- Definition of Korean heat wave (KMA)
  - A period of at least 2 consecutive days in which the daily Tmax exceeds 33°C
  - Heat wave events are designated by red shadings
  - Occurrence of heat wave significantly increased after about 2010

- Duration and intensity of heat wave event (29 cases)
  - Intensity is measured by averaged Tmax
  - Long-lasting heat wave – 2016, 1994 (20days)
  - Maximum intensity – 1994 (1994 heat wave was outstanding case)
  - Strong heat wave not always tend to last longer and vice versa (corr.: 0.43)

General characteristics of heat waves in Korea

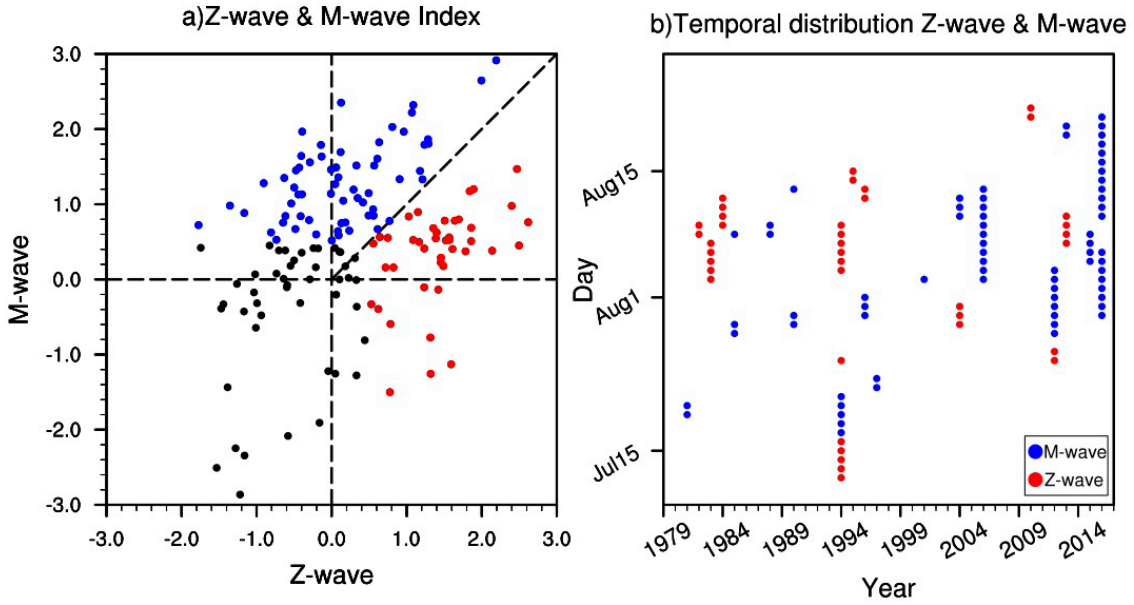


❖ Large-scale atmospheric circulation pattern in relation to Korean heat wave

- Composite of 850- and 200-hPa GPH, T2m anomalies for heat wave days
- Fundamental component for sustaining heat wave is high pressure system and well defined high pressure anomaly can be found over Korea with barotropic structure
- Positive anomaly over Korea is flanked by negative anomaly to south and north showing a meridional wave-like structure from subtropical WNP to East Asia → northward propagating teleconnection originated from heat source in the subtropical WNP
- Zonal wave like structure consists of high pressure centers over Europe and East Asia and low pressure over Middle East → Korean heat wave may also be related to the mid-latitude wave like structure

❖ Simple circulation indices are designed to capture the dynamical features of Korean heat waves (850GPH)
– Z-wave index: Korea-Japan(30-40N,120-150E) – Middle East(45-55N, 50-80E) + Europe(50-60N, 10-40E)
– M-wave index: Korea-Japan(30-40N,120-150E) – subtropical WNP(15-25N, 120-150E)

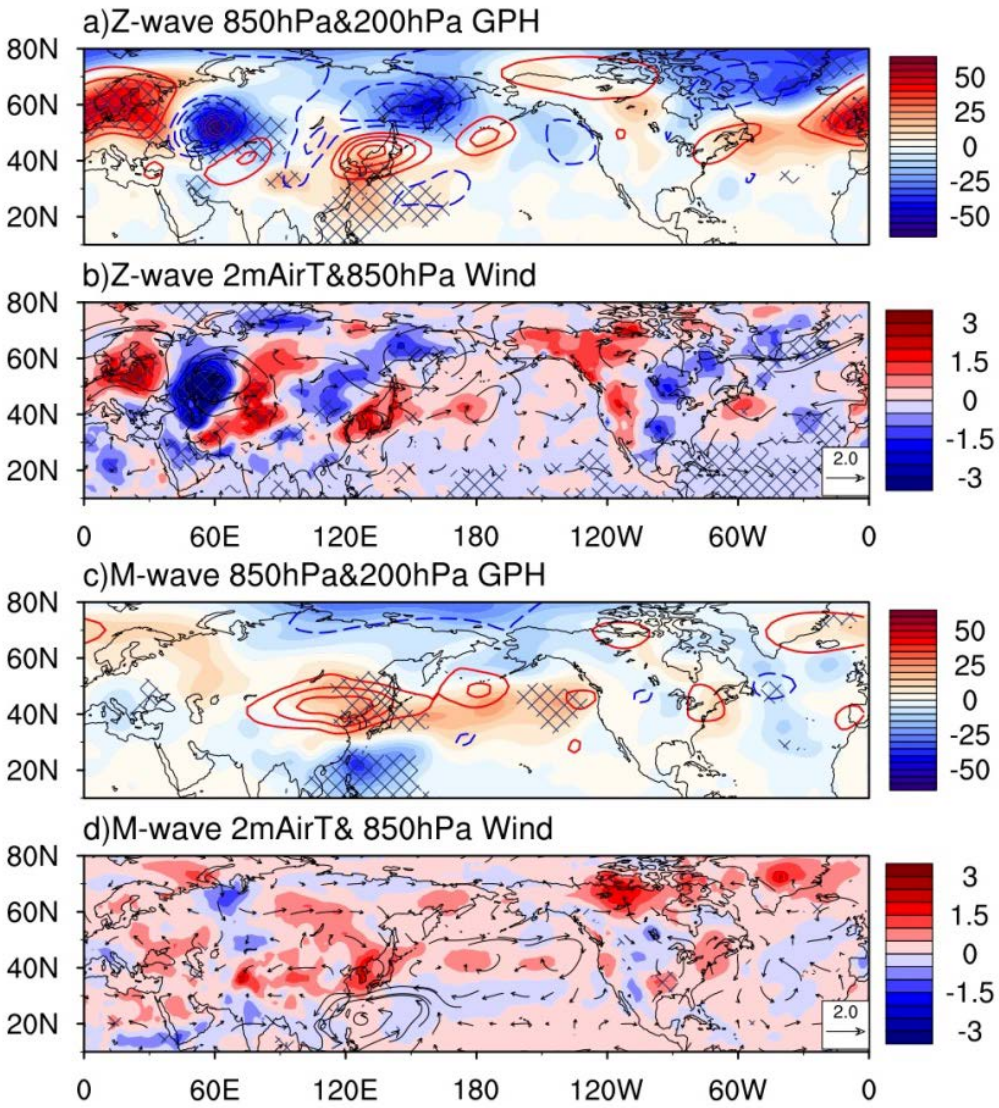
Classification of Z-wave and M-wave



❖ Scatter plot of normalized Z-wave and M-wave indices

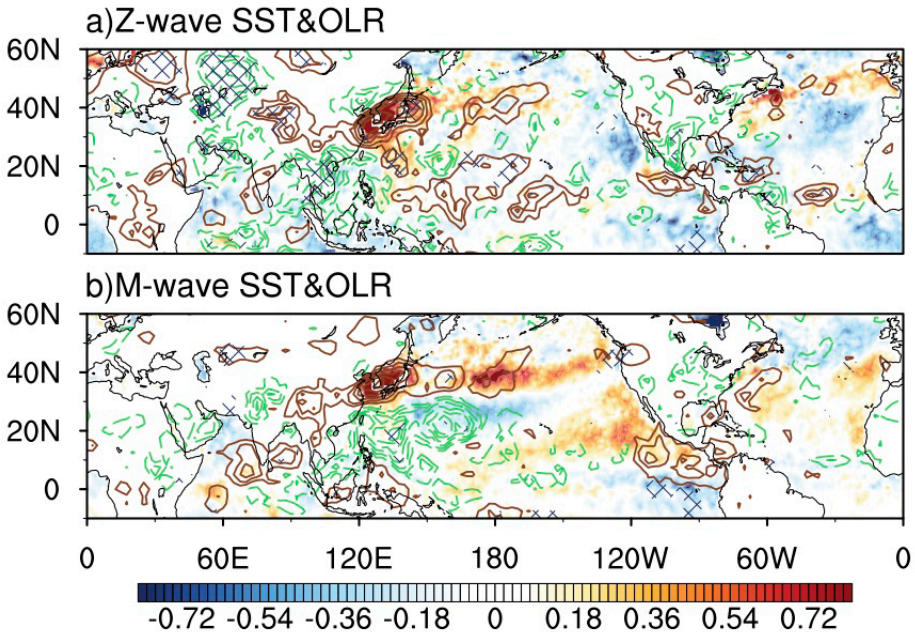
- Most heat wave cases are plotted where either Z-wave or M-wave index is greater than zero → Korean heat waves are generally related to the large scale atmospheric circulations represented by two indices
- Z-wave (M-wave) type heat wave is defined by Z-wave (M-wave) index being greater than 0.5 standard deviation and being greater than M-wave (Z-wave) index
- The temporal distribution of Z-wave and M-wave → M-wave heat wave tends to occur more frequently in recent years (2013, 2015, and 2016)

Large scale circulation for two types of heat wave



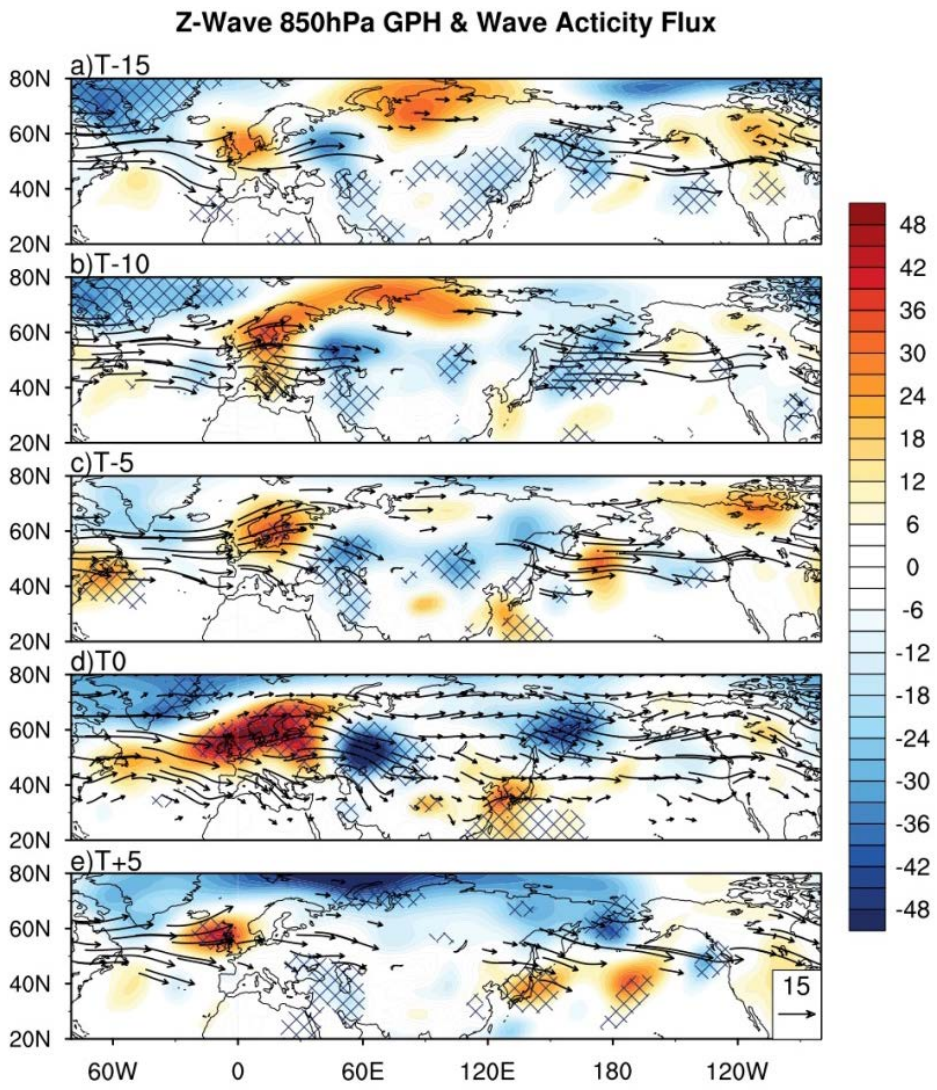
- ❖ Large-scale atmospheric circulation for two types of heat wave
- Composite of 850- and 200-hPa GPH, T2m and 850hPa wind anomalies for Z-wave and M-wave
- Z-wave: Zonal wave train across Eurasian continent / Positive NAO like structure / The circulation centers of wave train barotropic structure, except for tilted baroclinic structure over central Asia/ Warm air T over Europe and Korea coincide with high pressure anomaly centers
- M-wave: Positive and Negative GPH anomaly over Korea and subtropical WNP/ baroclinic structure over WNP→ related to heat related convective activities

Large scale circulation for two types of heat wave



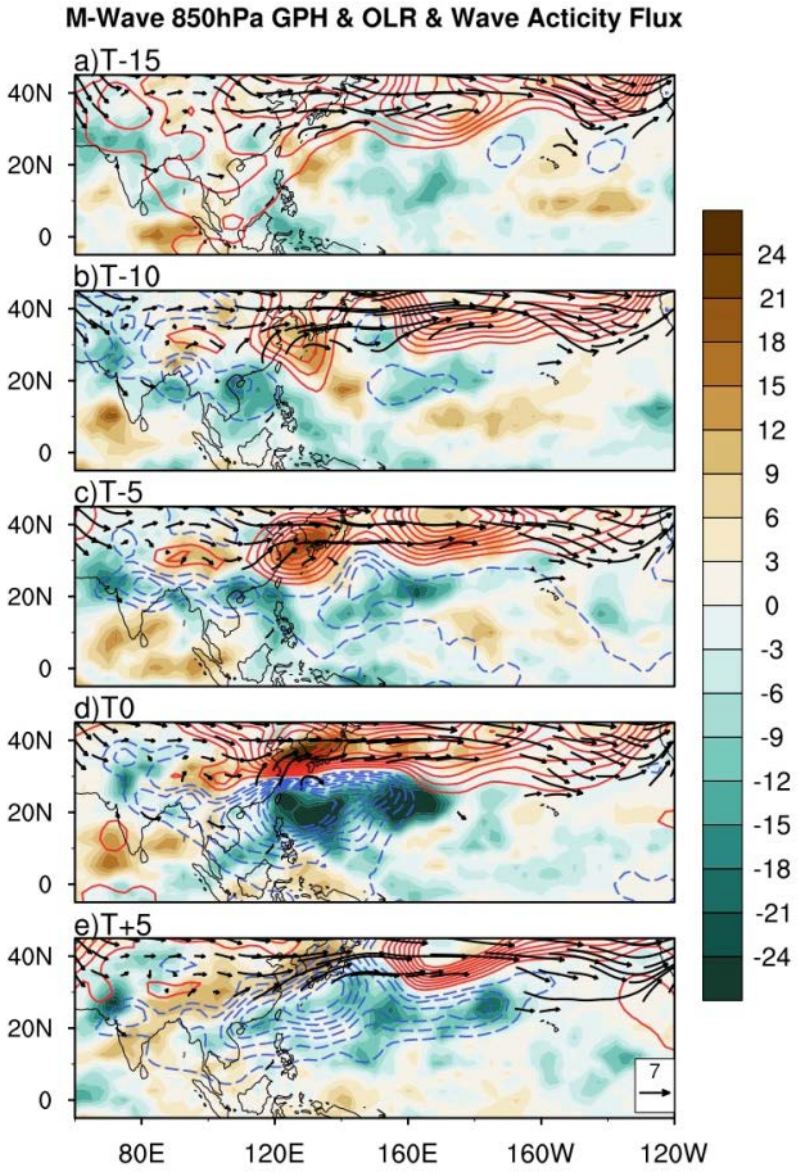
- ❖ Large-scale atmospheric circulation for two types of heat wave
- Composite of SST and OLR anomalies
- Z-wave & M-wave: Suppressed convection is evident over Korea, which facilitates increased solar radiation via reduced cloud cover / Negative SST anomalies are commonly found over tropical eastern Pacific (Previous studies showed that summer air temperature in East Asia becomes generally warmer than normal in La Nina years)
- Z-wave: Tripole SST pattern over North Atlantic → consistent with positive NAO-like atmospheric structure / enhanced convection is found over Bay of Bengal, south Asia, Pakistan → Similar feature with Circumglobal teleconnection (CGT)
- M-wave: well organized enhanced convection over subtropical WNP and suppressed convection over Korea → Similar feature with Pacific-Japan (PJ) pattern

Temporal evolution of two types of Korean heat wave



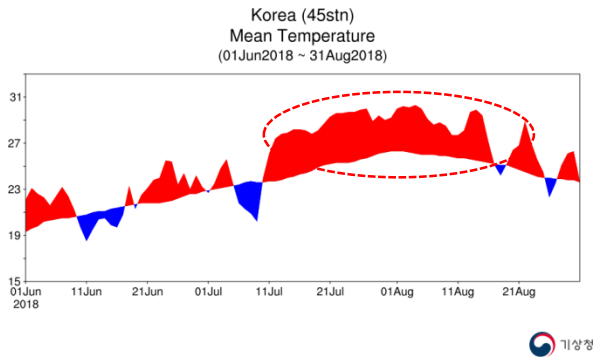
- Temporal evolution of Z-wave
  - For understanding developing mechanism and improving prediction skill
  - Composite of 850GPH and wave activity flux anomalies from 15 days before and 5 days after the heat wave event
  - T-15: low pressure anomaly over North Atlantic → part of wave train
  - T-10: wave structure gets stronger and more significant
  - T-5: positive and negative anomaly over Europe and Russia moves eastward and high pressure anomaly appears over south of Korea
  - T0: propagation of wave activity flux is evident across Eurasian continent to East Asia
  - T+5: wave structure soon collapses
  - Z-wave is closely tied to wave train started over North Atlantic Ocean and Europe about 15 days before the onset of heat wave
  - Atmospheric variability over North Atlantic Ocean should be considered in monitoring Z-wave heat wave
  - Previous studies also highlighted the role of North Atlantic Ocean in affecting East Asia climate by triggering Rossby wave that propagated eastward

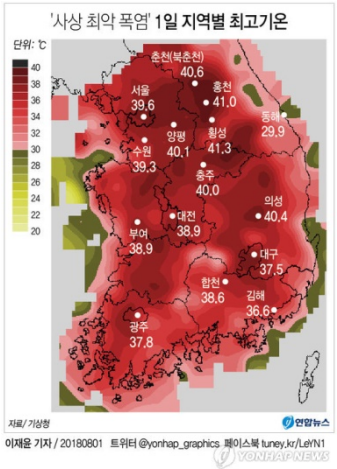
Temporal evolution of two types of Korean heat wave



- ❖ Temporal evolution of M-wave
- Composite of 850GPH ,OLR, and wave activity flux anomalies from 15 days before and 5 days after the heat wave event
- T-15: enhanced convection appears over tropical western Pacific
- T-10: OLR structure becomes strong and moves northward, showing enhanced convection over subtropical WNP and suppressed convection over Korea
- T-5: low-pressure anomaly appears over subtropical WNP and high pressure anomaly dominates over Korea/ meridional propagation of wave activity flux from WNP to Korea can be found
- T0: Strong and well organized enhanced convection over subtropical WNP
- M-wave is related to anomalous convective heating over subtropical WNP, which leads atmospheric Rossby wave that propagates poleward and forms M-wave pattern
- In terms of precursory signals, the convective activity over subtropical WNP and their propagation should be considered for monitoring M-wave

Application of Korean heat wave analysis to operational climate prediction





Extreme and unprecedented heat wave in 2018!

Extremely high temperature persists over one month

Temperature in Seoul reached about 40°C

More than 3400 people have been treated for heat related illnesses, such as heat stroke

KMA is planning to proactively act for extreme heat wave event

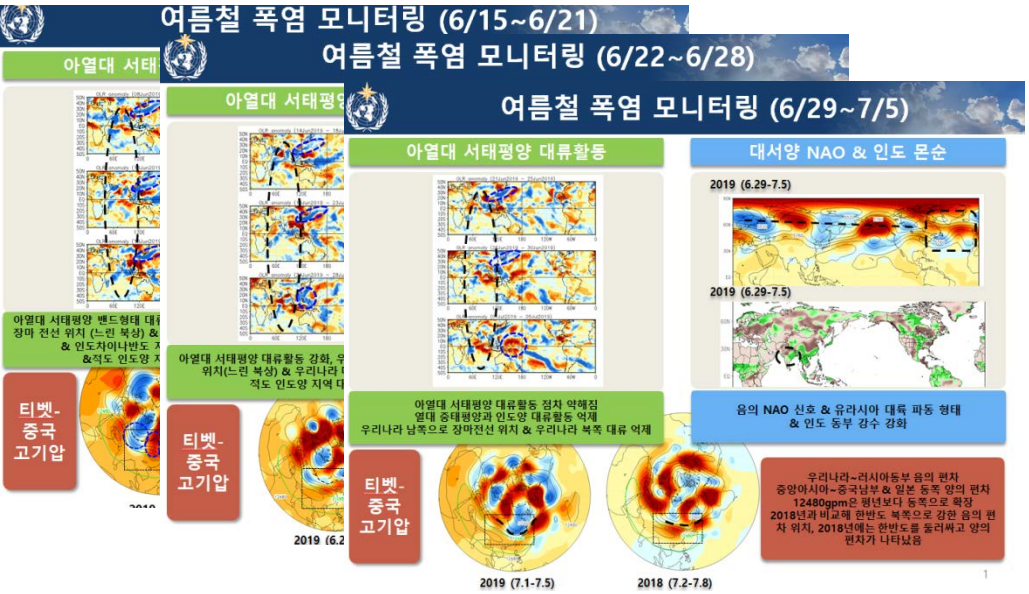
→ Weekly climate monitoring for proactive action for heat wave events in 2019 summer

→ APCC co-work with KMA by providing weekly monitoring information of heat wave

Monitoring components for two type of heat wave in Korea

- ❖ Z-wave: North Atlantic Oscillation, Enhanced convection over South Asia & North India
- ❖ M-wave: Enhanced convection over western north Pacific

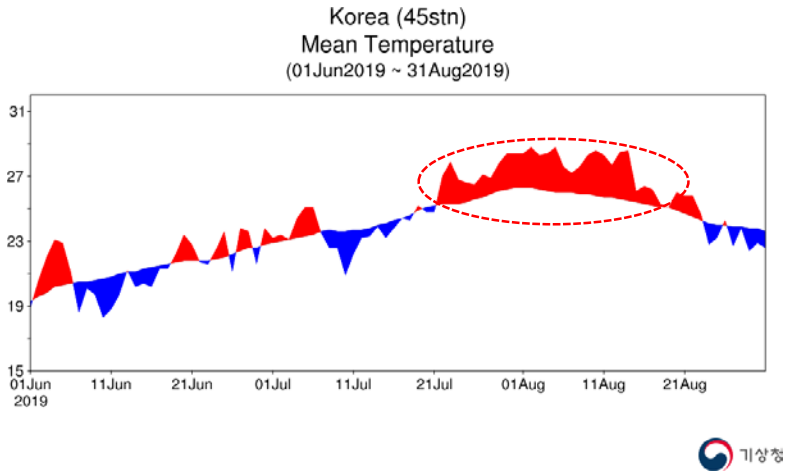
Application of Korean heat wave analysis to operational climate prediction



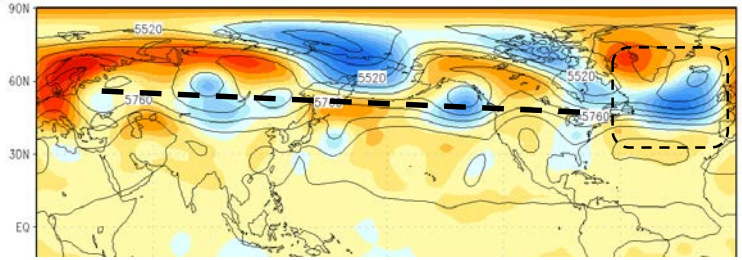
Examples of weekly heat wave monitoring : OLR, 500hPa and 200hPa GPH, Global precipitation

2019 summer heat wave – not so strong as 2018 heat wave
Heat wave occurred in early August in 2019
Before the heat wave occurrence

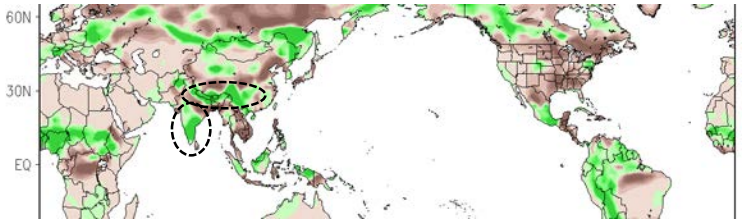
The wave structure appears over Eurasian continent in accordance with enhanced precipitation over northern India → Zonal wave type heat wave mechanism seems to work



2019 (7.20-7.26)



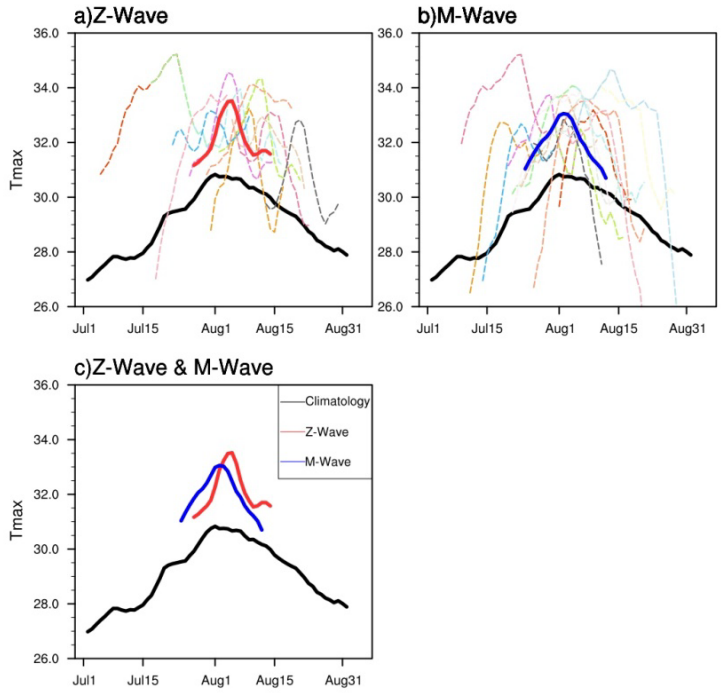
2019 (7.20-7.26)



Summary

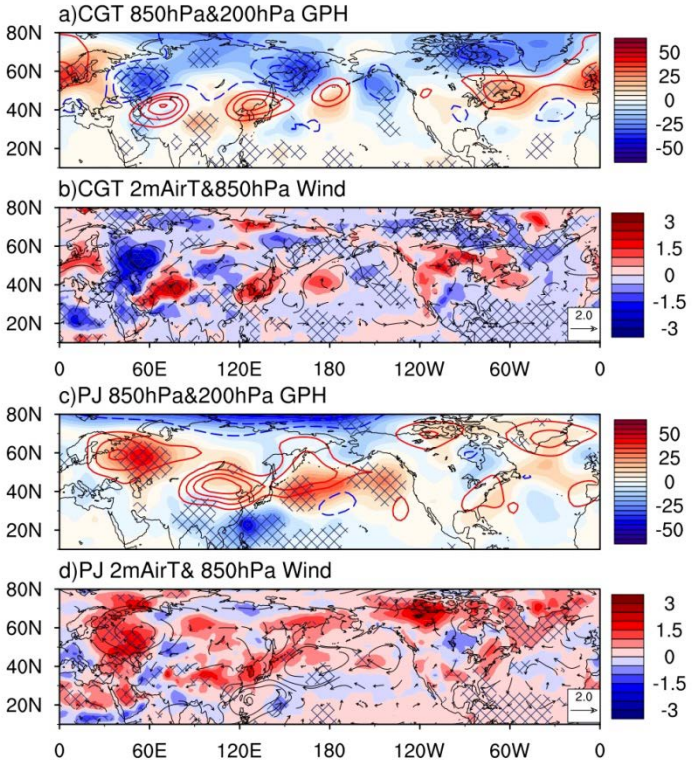
- In recent years, extreme heat wave events frequently occur in Korea
- The physical characteristics of Korean heat wave is investigated and the results are applied to operational seasonal forecast
- Most of Korean heat waves for the period of 1979-2017 are classified into two types based on atmospheric circulation features as Z-wave and M-wave
- Z-wave type is characterized by a pronounced zonal wave train across the Eurasian continent
  The dynamical properties and circulation anomalies of Z-wave are similar to those of CGT pattern
- M-wave type is characterized by meridional dipole atmospheric structure over subtropical WNP and East Asia
  It seems that northward propagation of Rossby waves induced by anomalous convective heating over the subtropical WNP lead to the development of M-wave as in PJ pattern
- Wave propagation across the Eurasian continent to East Asia started from North Atlantic Ocean about 15 days before the occurrence of Z-wave
- The development of M-wave is accompanied by northward propagation of meridional dipole structure of convective activity from tropical western Pacific to East Asia

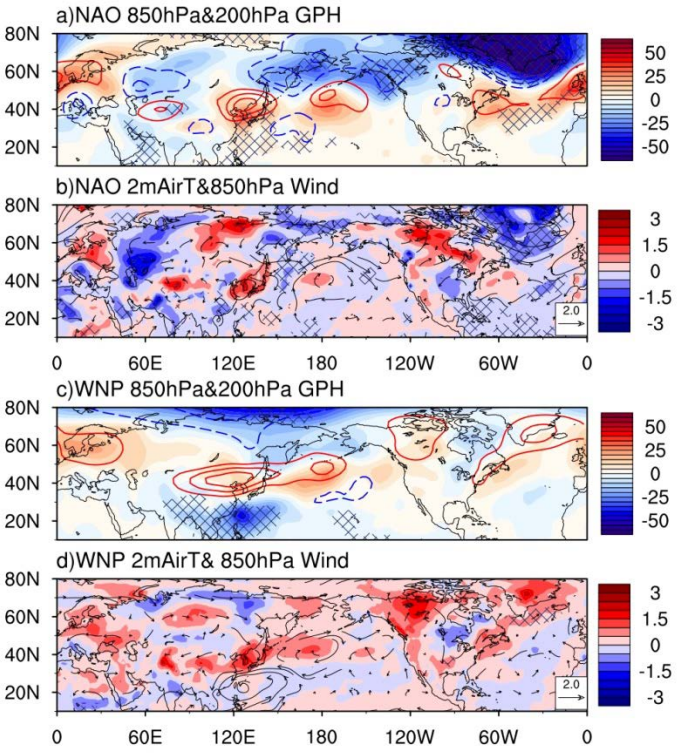
Thank You

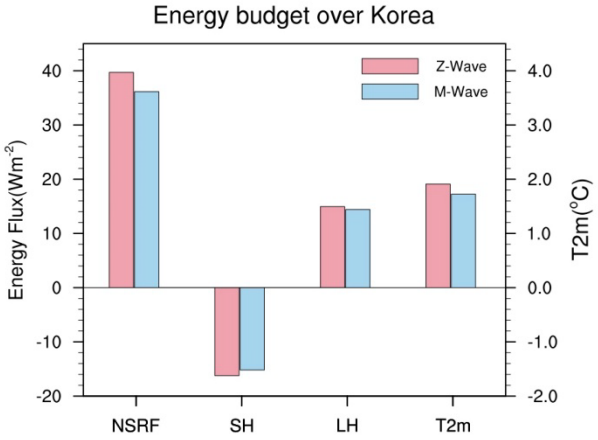


Temporal evolution of Korean Temperature during day-10 to day +10

- Z-wave generally occur during late-July to early-August, while occurrence of M-wave shows large inter-event spread from mid-July to mid-August
- Z-wave generally sustains above the climatology after the peak of heat wave, while M-wave steeply decrease below the climatology within 10 days
- Z-wave has stronger intensity than M-wave after the peak phase of heat wave
- M-wave exhibits larger amplitude before the peak phase of heat wave
- Z-wave type shows steeper temporal evolution than M-wave type

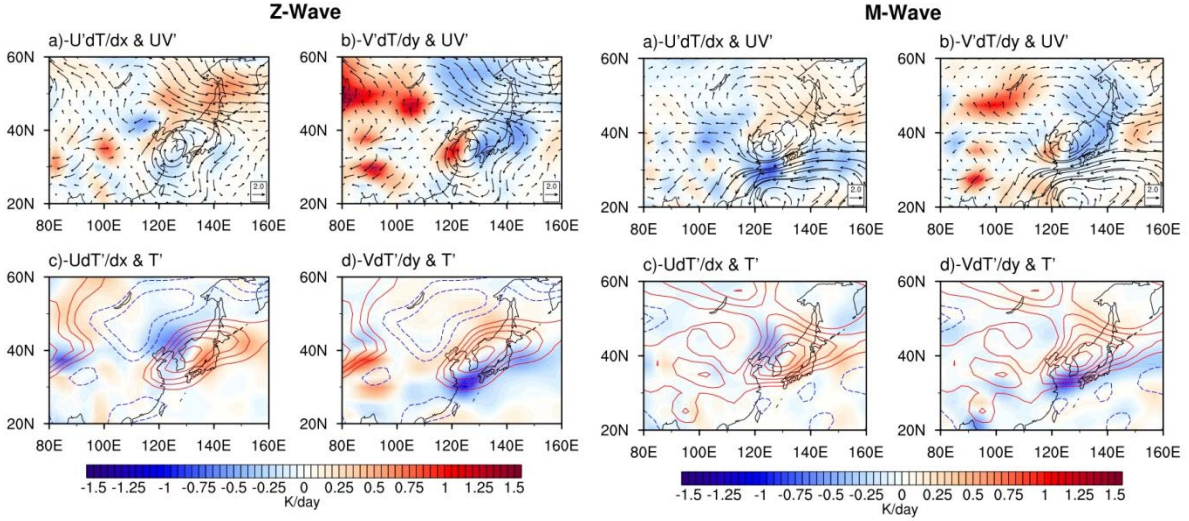

a)CGT 850hPa&200hPa GPH
80N
60N
40N
20N
50
25
0
-25
-50
b)CGT 2mAirT&850hPa Wind
3
1.5
0
-1.5
-3
2.0
0
60E
120E
180
120W
60W
0
c)PJ 850hPa&200hPa GPH
d)PJ 2mAirT& 850hPa Wind


a)NAO 850hPa&200hPa GPH
80N
60N
40N
20N
50
25
0
-25
-50
b)NAO 2mAirT&850hPa Wind
3
1.5
0
-1.5
-3
2.0
0
60E
120E
180
120W
60W
0
c)WNP 850hPa&200hPa GPH
d)WNP 2mAirT& 850hPa Wind



Net surface heat flux (Positive fluxes are defined to be directed downward)

- ❖ high pressure → clear sky → downward net radiation flux
- ❖ dry condition → suppressed evapotranspiration → reduced latent cooling
- ❖ excessive net surface radiation flux and reduced latent cooling lead to atmospheric heating



Thermal advection: $-u'\,\partial\bar{T}/\partial x\,, -v'\,\partial\bar{T}/\partial y\,, -\bar{u}\;\partial T'/\partial x,\;\; -\bar{v}\;\partial T'/\partial y$

- ❖ mean temperature advection by anomalous southerly wind ($-v'\,\partial\bar{T}/\partial y$) largely affects warming over west Korea for both Z-wave and M-wave

- ❖ Warming over Korea during heat wave event is mainly driven by the net surface radiation flux and latent heat flux