ECR Symposium and WCRP/SPARC workshop

"WCRP Grand Challenges and Regional Climate Change"

OCTOBER 19-20, 2017

KOREA POLAR RESEARCH INSTITUTE, INCHEON, SOUTH KOREA

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WCRP/SPARC Local Workshop

October 19-20, 2017

Korea Polar Research Institute, Incheon, Korea

Thursday, October 19

Welcome and Session 1 (Chair: Baekmin Kim)

8:30 Registration

9:00 Opening and Logistics

9:05 Welcoming Remark (President of KOPRI)

9:10 **In-Sik Kang**: Stratospheric Influence on Predictability Enhancement in Late Winter (Keynote speech)

9:40 **Alexey Karpechko**: Predictability of Sudden Stratospheric Warmings in the ECMWF extended range forecast system

9:55 **Harry Hendon**: Impacts and predictability of Antarctic stratosphere-troposphere coupling during Austral Spring-Summer

10:10 **Yuna Lim**: The influence of QBO on MJO prediction skill in the subseasonal-to-seasonal (S2S) Models

10:25 PHOTO & COFFEE BREAK

Session 2 (Chair: Kaoru Sato)

10:55 **Shigeo Yoden**: An emerging SPARC activity, SATIO-TCS: Stratospheric And Tropospheric Influences On Tropical Convective Systems (Invited)

11:15 **Andrew Charlton-Perez**: Stratosphere-Troposphere coupling: A Regime View

11:30 **Kanghyun Song**: The ENSO-SSW relationship

11:45 **Patrick Martineau**: Lower-stratospheric control of the frequency of sudden stratospheric warming events

12:00 **Judith Perlwitz**: What determines the strength of the QBO-Stratospheric Polar Vortex Connection?

12:15 LUNCH

Session 3 (Chair: Gufran Beig)

13:30 **Hye-Yeong Chun:** Small-Scale Convective Gravity Waves: Contributions to the Large-Scale Circulations in the Middle Atmosphere (invited)

13:50 **Min-Jee Kang:** Momentum flux of convective gravity waves derived from an off-line gravity wave parameterization: Spatiotemporal variations at source level

14:05 **Byeong-Gwon Song:** Gravity Wave Activities in the Upper Mesosphere at King Sejong Station, Antarctica (62.22°S, 58.78°W) and Their Correlation with the Jet Stream in the Lower Atmosphere

14:20 **Yueyue Yu:** A stochastic Model with a Low-Frequency Amplification Feedback for the Stratospheric Northern Annular Mode

14:35 **Anu Xavier**: Extreme Rainfall Events Modulation by Monsoon Low Level Jet

14:50 COFFEE BREAK

Session 4 (Chair: Mijeong Park)

15:20 **Yan Xia:** On the climate impacts of upper tropospheric and lower stratospheric ozone

15:35 **Gufran Beig:** Trends in temperature of the middle atmosphere and its linkage to stratosphere ozone recovery

15:50 **Larry Thomason:** SAGE III on the International Space Station

16:05 **Ha-Rim Kim:** Changes in robust atmospheric circulation and its impact on poleward moisture transport into the Arctic during winter,

Poster Session (16:30-18:30)

Welcome Dinner: 19:00-

Friday, October 20

Session 5 (Chair: Seok-Woo Son)

9:00 **Jinro Ukita:** A Stratospheric Pathway for the Arctic-Midlatitude Climate Linkage (invited)

9:20 **Su-Jong Jeong:** Accelerating rates of Arctic carbon cycling revealed by long-term atmospheric CO_2 measurements (invited)

9:40 **Seungmok Paik:** Attributing causes of 2015 record minimum sea-ice extent in the Sea of Okhotsk

9:55 **Mee-Hyun Cho:** Flaring Black Carbon Impacts on Arctic Climate

10:10 COFFEE BREAK

Session 6 (Chair: Joowan Kim)

10:45 **Wen Chen**: Role of stratosphere-troposphere interaction on the winter cold extremes in East Asia (invited)

11:05 **Hye-Jin Kim:** Eurasian winter temperature change and its association with Arctic sea ice loss

11:20 **Jiankai Zhang:** Persistent Shift of the Arctic Polar Vortex towards the Eurasian Continent in Recent Decades and its climatic impact

11:35 **Chang-Eui Park:** Emergence of aridification can be reduced by limiting the global warming to 1.5℃

11:50 **Laura Pan:** Atmospheric Composition and the Asian Monsoon: Recent Progresses and Collaboration Opportunities

12:05 LUNCH

Session 7 (Chair: Changhyun Yoo)

13:30 **Jinwon Kim:** Effects of atmospheric river landfalls on the precipitation characteristics in the Western US (invited)

13:50 **Joowan Kim**: Thermal characteristics of the tropical tropopause layer in CMIP5 models

14:05 **Mijeong Park:** Fate of pollution emitted during the 2015 Indonesian Fire Season

14:20 **Fahim Khokhar:** An assessent of SLCP trends over Pakistan

14:35 **Joo-Hong Kim:** Thermal evolution of late summer melt ponds

14:50 ADJOURN

Poster Session

1. **Hemanth Kumar -** Cross tropopause flux observed at sub-daily scales over south India monsoon regions
2. **Shipra Jain -** Occurrence of persistently low tropopause temperature and ozone over the Asian monsoon region as observed from Aura satellite
3. **Vazhathottathil Madhu -** Solar activity and associated changes in column ozone based on chemistry climate model simulation
4. **Dibas Shrestha** – Variability of Tropopause over South Asian Monsoon Region
5. **Jin-Haeng Lee** - Differences in the tropical convective activities during different phases of quasi biennial oscillation (QBO)
6. **Myung-Il Jung** - Possible impact of tropospheric ozone and methane on the recent Arctic warming
7. **Lei Song** - The Relationship between the Variation of High Latitude Stratospheric Planetary Wavenumber

1and the Cold Anomalies over Eastern China

8. **Feiyang Wang** - Effect of Madden-Julian Oscillation Occurrence Frequency on the Interannual Variability of Northern Hemisphere Stratospheric Wave Activity in Winter

9. **Ji-Hee Yoo** - Characteristics of inertia-gravity waves revealed in rawinsondes at Jang Bogo Station, Antarctica (74°374'S, 164°13.7'E)

10. **Chao Wang** - A definition of the dynamical tropopause based on the Gaussian curvature of isentropic potential vorticity

11. **Hyesun Choi** - Reexamination on the type classification of Stratospheric Sudden Warming

12. **Hataek Kwon** - A numerical simulation of strong wind event at King Sejong Station, Antarctica.

13. **Ja-Young Hong -** The characteristics and impacts of extreme Atlantic windstorms on Arctic warming

14. **Sang-Yoon Jun -** Dynamical core in atmospheric model does matter in the simulation of Arctic climate

15. **Seok-Woo Son** – Does coupled ocean enhance ozone-hole-induced Southern Hemisphere circulation changes?

16. **Xuan Chen** - Shifting urban heat island clock in Megacity: a case study of Hong Kong

17. **Jinlong Huang** – The Precondition for Arctic Stratospheric Polar Vortex displacement Events

18. **Manuela Keguep -** Contribution to the aerial carbon sequestration assessment in the mangroves of Djirnda and Joal- Fadiouth (regions of Thiès and Fatick, Senegal- West Africa)

19. **Mohan Kumar Das -** Numerical Simulation and Dynamical Downscaling of South Asian Monsoon precipitation

20. **Lev Labzovskii -** The contribution of large urban areas to local CO2 anomalies retrieved from OCO-2 and GOSAT spaceborne observations

21. **Sujung Lee -** Analysis of the characteristics of Korean precipitation variability in a changing climate

22. **Jin-Sil Hong -** Understanding the mechanisms leading to pure Extreme heat and Tropical night in Korea.

23. **Ho Thi Ngoc Huyen -** Long-term change of the tropical cyclone tracks and potential impacts over the southern region of Vietnam

24. **Lufeng Huang** - The impact of urbanization in Beijing area to local ecosystem

25. **Suqin Duan** - On the utility (or futility) of using stable water isotopes to study convection

26. **Lan Dai -** Linking meteorological drivers of spring-summer drought regimes to agricultural drought risk in China

27. **Jung Choi -** Regional climate response to aerosol versus greenhouse gas forcing

28. **Iman Rousta -** Assessment of SST variabilities in association with Climate Change

29. **Seunghwon Hyun -** Understanding a role of internal variability on the increase of global mean surface temperature in a warming scenario.

30. **Yan Chen -** Impacts of urban air conditioning on urban heat island over the northern hemisphere in summer

31. **Jaeyoung Hwang** - A Climatology of Northern Hemisphere Blocking in CESM Large Ensemble simulations

32. **Stefanie Kremser** – Developing observational data sets for assessing and validating climate models

33. **Shiyan Zhang** – Change in trend of Hadley circulation after 2000

SESSION 1

Stratospheric Influence on Predictability Enhancement in Late Winter

In-Sik Kang

Seoul National University, Seoul, Korea

Abstract: Prediction skill usually degrades as lead time increases, since prediction is to some degree an initial value problem. However, retrospective forecasts with initial conditions from early November show that prediction skill for the whole troposphere and lower stratosphere increases with lead time after the first month, and relatively high predication skill appears in February (lead time of 3 month) over the tropics and the Pacific-North American (PNA) region compared to those of the lead times of 1 month (December) and 2 months (January). This is not due to a later winter growth of SST signals as the SST prediction skill is monotonically decreased as the lead time increases. The high predictability in the tropics is also not only for ENSO years but also for non ENSO years, indicating that the quasi-biennial oscillation (QBO) may also contribute to the prediction signal. The dynamics associated with the skill increase is not fully understood, but we demonstrate that the relatively high prediction skill in February is due to the influence of stratospheric memory on the troposphere effective during late winter.

Predictability of Sudden Stratospheric Warmings in the ECMWF extended range forecast system

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We analyze the skill of the Arctic stratospheric retrospective ensemble forecasts (hindcasts) of the ECMWF extended-range forecasts system with a focus on the predictability of the major sudden stratospheric warmings (SSWs) during the period 1993-2016. 13 SSWs took place during this period. We find that forecasts initialized 10-15 days before the SSWs show worse skill than forecasts initialized during normal conditions because they strongly underestimate the magnitude of the circulation anomalies. At the same time the anomaly patterns are predicted with a skill comparable to that during normal conditions. Using spread of ensemble members to estimate SSW probability we show that some SSWs can be predicted with >0.9 probability at lead times of 12-13 days if a difference of 3 days between actual and forecasted SSW is allowed. Focusing on SSWs with significant impacts on the tropospheric circulation we find that, on average, predicted SSW probability slowly increases from nearly zero at one month lag to 0.3 at day 13 and then rapidly increases to nearly 1 at day 7. The period between days 8-12 is when most of the events analyzed here are predicted with a probability 0.5-0.9 which considerably exceeds the observed SSW occurrence frequency. Therefore we suggest that this period can be considered an SSW predictability limit in this system. We also find indications that some SSWs may be predictable at longer lead times, however this result is uncertain, and such long predictability would likely be possible only for few events, if at all.

Impacts and Predictability of Antarctic Stratosphere-Troposphere Coupling During Austral Spring-Summer

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Stratosphere-troposphere (S-T) coupling in the Southern Hemisphere (SH) is an important dynamical process that provides predictability of the Southern Annular Mode (SAM). Time domain EOF analysis (in the calendar month-height domain) is applied to Antarctic polar cap geopotential heights for April through March, 1979-2016 from the surface to 0.1hPa. The leading EOF pattern, which accounts for 60% of the vertical-temporal variance of polar cap heights, is characterised by a maximum loading in the stratosphere in early spring through summer with downward propagation of height anomalies to the surface from October through January. Its expansion coefficient (one value per year) is highly correlated with the tropospheric SAM from October to January (r= 0.7 in October). The physical interpretation of the mode is that it depicts strengthening and weakening episodes of the stratospheric polar vortex that typically occur in early spring and extend down to the surface through early summer. Analysis of predictions from the BoM POAMA and ACCESS-S1 seasonal predictions systems suggest skilful prediction of the S-T coupled mode is possible from austral winter, implying that the likelihood of having either a positive or negative tropospheric SAM in the following spring to early summer seasons can be foreseen with some confidence. Interestingly, skilful prediction of this S-T coupled mode for September to January is possible with POAMA (which has a minimally resolved stratosphere) from June initial conditions but only from August initial conditions with ACCESS-S1 (which has a fully resolved stratosphere). Predictability of this mode does not appear to derive from prediction and covariation with ENSO, as the correlation of the S-T mode with the Nino indices is not significant.

The influence of QBO on MJO prediction skill in the subseasonal-to-seasonal (S2S) Models

Yuna Lim[1)], Seok-Woo Son[1)], Andrew G. Marshall[2)], Harry H. Hendon[2)], Kyong-Hwan Seo[3)]

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The recent studies have shown that Madden-Julian Oscillation (MJO) is significantly modulated by the stratospheric Quasi-Biennial Oscillation (QBO). In general, boreal-winter MJO convections over the Indian Ocean and Maritime Continents become stronger during the easterly phase of QBO (EQBO) than the westerly phase (WQBO). In this study, such finding is applied to the latest operational models, which participated in the WCRP/WWRP Subseasonal-to-Seasonal (S2S) prediction project, to examine the stratospheric influence on the MJO prediction skill. On average, S2S models exhibit the MJO prediction skills of 2-5 weeks with a pronounced inter-model spread. All models further show a higher MJO prediction skill during EQBO than WQBO winters, consistent with more organized and stronger MJO. Based on a bivariate anomaly correlation coefficient of 0.5, the improvement of MJO prediction skill during EQBO winters is up to 10 days compared with WQBO winters. Such an improvement is highly associated with the reduced MJO amplitude and phase errors, with the latter being more important with increasing forecast lead times. This result clearly indicates that MJO prediction skill is sensitive the stratospheric mean state, highlighting the importance of stratospheric data assimilation in the operational S2S prediction.

SESSION 2

An emerging SPARC activity, SATIO-TCS:
Stratospheric And Tropospheric Influences On Tropical Convective Systems

Shigeo Yoden[1], Marvin A. Geller[2], Peter H. Haynes[3]

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In the last decade or two, stratosphere-troposphere two-way dynamical coupling has attracted much interest, such as the annular mode variability in both hemispheres and two-way coupling during extreme events such as stratospheric sudden warming (SSW). The standard paradigms for interpreting and explaining stratosphere-troposphere coupling have been based on balanced dynamics; the non-local aspects of potential vorticity (PV) inversion, planetary wave propagation, wave-mean flow interaction in both troposphere and stratosphere.

Our new SPARC activity, SATIO-TCS (Stratospheric And Tropospheric Influences On Tropical Convective Systems) has its focus on stratosphere-troposphere coupling in the tropics, where no comparable interpretive paradigm exists. Observational data analyses and global and cloud-resolving numerical-model studies all point to an important stratospheric influence on tropical convection and convective systems, and the multi-scale dynamics of these systems is likely to play a vital role in determining the tropical response to changes in the stratosphere.

There is observational evidence that stratospheric variations, such as SSW events, the equatorial quasi-biennial oscillation (QBO), and anthropogenic cooling trend (ACT) in the lower stratosphere, do influence tropospheric variability in the form of moist convection or its large-scale organization into meso-to-planetary-scale systems, which include cloud clusters, tropical cyclones, the Madden-Julian Oscillation (MJO), and likely monsoon systems. Some global general circulation models and regional cloud resolving models show similar behaviors and characteristics to these observations on the stratospheric and tropospheric influences on tropical convective systems, but such modeling studies are in a rather preliminary state.

SATIO-TCS seeks to promote the science on stratosphere-troposphere coupling (upward and downward) in the tropics, focusing on its influences on moist convection and organized convective systems, as there is a need for more coordinated studies with a wide variety of research activities, including observations, data analyses, and numerical model studies. A summary of the kick-off workshop of SATIO-TCS, which will be held on 9th to 14th in October 2017 in Kyoto, will be reported in this workshop.

Stratosphere-Troposphere coupling: A Regime View

Andrew Charlton-Perez[1)], Laura Ferranti[2)], Robert Lee[1)]

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Stratosphere-troposphere coupling is now recognized as a critical component of sub-seasonal predictability in the wintertime extra-tropics. However, making use of and understanding this coupling is hampered by our lack of understanding of what determines the strength and persistence of this coupling. Indeed, if one focusses on individual Sudden Stratospheric Warming events, there can be a wide range of responses to seemingly similar anomalies in the lower stratosphere. In this study, we propose a new minimal Markov model of stratosphere-troposphere coupling to help quantify the tropospheric response to stratospheric anomalies in the North Atlantic. Our model is based on the four canonical North Atlantic weather regimes, their regime transitions and how these transitions depend on lower stratospheric winds. By fitting the model to observed ERA-Interim data, we show that during periods of weak stratospheric winds, transitions to the NAO- regime and the persistence of this regime is increasingly probable and that the reverse is true for strong winds. These changes to regime occupancy, transition and persistence come at the expense of a reduced frequency of both NAO+ and Atlantic Ridge regime states. The minimal model can be used to compare coupling in model simulations with observations and to construct toy experiments that shed light on our observed picture of the response of the troposphere to SSW events.

ENSO-SSW relationship

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Stratospheric sudden warming (SSW) events exhibit pronounced interannual variability. Based on WMO definition, it has been suggested that SSW events occur more preferably during El Niño-Southern Oscillation (ENSO) winters (both El Niño and La Niña winters) than during ENSO-neutral winters. This relationship is re-evaluated here by considering seven different definitions of SSW. For all definitions, SSW events are detected more frequently during El Niño winters than during ENSO-neutral winters, in agreement with a strengthened planetary-scale wave activity. However, such systematic relationship is not found during La Niña winters. While three SSW definitions, including WMO definition, show a higher SSW frequency during La Niña winters than during ENSO-neutral winters, other definitions show no difference or even lower SSW frequency. This result, largely insensitive to the choice of reanalysis datasets and ENSO index, indicates that the reported ENSO-SSW relationship is highly dependent on the details of the SSW definition. This result is discussed in terms of background wind, latitudinal range of wind reversal, and characteristics of planetary-scale waves during El Niño- and La Niña-winter SSW events. Implication of this finding to SSW-related downward coupling and surface climate variability is also discussed. It is particularly emphasized that La Niña-winter SSW events have more organized downward coupling than El Niño-winter SSW events.

Lower-stratospheric control of the frequency of sudden stratospheric warming events

Patrick Martineau[1)], Gang Chen[2)], Seok-Woo Son[3)], Joowan Kim[4)]

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The sensitivity of stratospheric polar vortex variability to the basic-state stratospheric temperature profile is investigated by performing a parameter sweep experiment with a dry dynamic core GCM where the equilibrium temperature profile in the polar lower and upper stratosphere is systematically varied. It is found that stratospheric variability is more sensitive to the temperature distribution in the lower stratosphere than in the upper stratosphere. In particular, a cold lower stratosphere favors a strong time-mean polar vortex with a large daily variability, promoting frequent sudden stratospheric warming events in the model runs forced with both wavenumber-1 and wavenumber-2 topographies. Although a warm polar upper stratosphere favors a relatively weak polar vortex, it does not have a large impact on variability. This result suggests that the lower stratosphere acts as a valve for the upward propagation of planetary-scale waves, therefore controlling stratospheric variability and the frequency of sudden stratospheric warming events.

What determines the strength of the QBO-Stratospheric Polar Vortex Connection?

Judith Perlwitz[1)], Lantao Sun[1)], John Albers[1)], Yaga Richter[2)], Julio Bacmeister[2)]

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The strength of the relationship between quasi-biennial oscillation (QBO) and the Northern Hemisphere (NH) stratospheric polar vortex, or Holton-Tan (H-T) relationship, on multi-decadal time scale is investigated using 10-member AMIP historical simulations for the period 1957-2015. The experiments were conducted with a newly-developed higher-top Community Atmosphere Model Version 5 (CAM5) that is capable of internally generating the QBO. Overall, the model ensemble-mean consistently shows strengthening (weakening) of the polar vortex with westerly (easterly) phase of the QBO as in reanalysis. However, substantial variations across individual ensembles with respect to the strength of the H-T relationship and subsequent tropospheric impacts on 58-year time scale are found that is associated with a variation in the frequency of occurrence of major stratospheric sudden warming in the QBO east phase. It is shown that this sensitivity is consistent with the QBO's modulation of the zero-wind line in the lower stratosphere affecting planetary wave propagation.

SESSION 3

**Small-Scale Convective Gravity Waves:
Contributions to the Large-Scale Circulations in the Middle Atmosphere**

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Convective gravity waves (CGWs) have wide phase-speed spectrum and thus can contribute significantly to the large-scale circulations in the middle atmosphere without seasonal restriction, when they are dissipated through the wave breaking, critical-level filtering, and radiative damping processes. In particular, CGWs with horizontal wavelengths of less than 100 km and vertical wavelengths longer than 10 km carry the momentum flux up to the upper mesosphere and transport significant amount of gravity-wave drag (GWD) there when they dissipated. These scales of CGWs are neither fully observed from satellites nor simulated from, even, recent high-resolution global circulation models (GCMs) with horizontal resolution of ~0.25o x 0.25o, which need to be parameterized in GCMs. In the present study, contributions of these small-scale CGWs to the large-scale circulations in the middle atmosphere in various scales, such as annual cycle in the mesosphere, Brewer-Dopson circulation in the stratosphere, and quasi-biennial circulation (QBO) in the tropical stratosphere will be discussed, through some GCM results that included a state-of-art convective GWD parameterization and an off-line calculation of a convective GWD scheme using global analysis data. Spatiotemporal characteristics of convective sources and cloud-top momentum flux in the troposphere will be shown, and the propagation of CGWs in the middle atmosphere and resultant drag will be discussed. Some issues in CGW parameterization for GCMs and analysis of CGWs by satellite data will be discussed.

Momentum flux of convective gravity waves derived from an off-line gravity wave parameterization: Spatiotemporal variations at source level

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Global distribution of gravity wave (GW) momentum flux is important information to determine the wave characteristics for GW modeling in general circulation model (GCM) and to understand the relationship between GWs and other atmospheric phenomena. However, the small-scale GWs with horizontal wavelengths of few tens of kilometers are neither detected from global observation, such as satellite data, nor fully represented by high-resolution GCMs with horizontal grid spacing of ~0.25°. In this study, spatiotemporal variations in momentum flux spectra of convective gravity waves (CGWs) at the source level (cloud top), including nonlinear forcing effects, are examined using an off-line version of physically-based CGW parameterization (Kang et al. 2017) and global reanalysis data. We used 1-hourly NCEP Climate Forecast System Reanalysis (CFSR) forecast data for a period of 32 years (1979-2010), with a horizontal resolution of 1° x 1°. The cloud-top momentum flux (CTMF) of CGWs is not solely proportional to the convective heating rate but is affected by the wave-filtering and resonance factor (WFRF), background stability and temperature underlying the convection. Consequently, the primary peak of CTMF is in the winter hemisphere midlatitude in association with storm-track region where secondary peak of convective heating exists, whereas the secondary peak of CTMF appears in the summer hemisphere tropics and intertropical convergence zone (ITCZ), where primary peak of convective heating exists. The magnitude of CTMF fluctuates largely with 1 year and 1 day periods, commonly in major CTMF regions. At low latitudes and Pacific storm-track region, a 6-month period is also significant, and the decadal cycle appears in the Southern Andes. The equatorial eastern Pacific region exhibits substantial inter-annual to decadal scale of variabilities. Interestingly, the correlation between convective heating and the CTMF is relatively lower in the equatorial region than in other regions. The CTMF in the 10°N to 10°S during the period of February to May 2010, when the PreConcordiasi campaign held, approximately follows a lognormal distribution but with a slight underestimation in the tail of the probability density function.

Gravity Wave Activities in the Upper Mesosphere at King Sejong Station, Antarctica (62.22°S, 58.78°W) and Their Correlation with the Jet Stream in the Lower Atmosphere.

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King Sejong Station (KSS; 62.22°S, 58.78°W) is in a hot spot of strong gravity wave (GW) activity along the Antarctic Peninsula. Horizontal winds in the upper mesosphere (80–100 km altitude range) have been observed using a very high frequency (VHF) meteor radar at KSS since March 2007. Wind variance calculated from the deviation in the horizontal wind after subtraction of the mean and tidal components is used as a proxy of GW activity in the upper mesosphere for 8 years from 2007 to 2014. The GW activities are strong at two periods, in April–May and August–September, which are different from seasonal variations with semi-annual cycle that have been reported from other stations in Antarctica. The autumn formation and spring breakdown of the Antarctic vortex can enhance GW activities in the lower atmosphere (the troposphere and stratosphere) near KSS. We investigated the jet stream in the lower atmosphere as a potential source of GWs observed in the mesosphere through correlation analysis. GW activities in the lower atmosphere were determined based on the gravity wave momentum flux (GWMF) estimated from the high-resolution (0.25° x 0.25°) European Centre for Medium-Range Weather Forecasts (ECMWF) analysis. The residual of the nonlinear balance equation (RNBE) is used as a diagnostic of the jet/front GWs, and it is calculated in the lower atmosphere using the ERA-Interim reanalysis data. The GWMF and RNBE have similar temporal variabilities in the lower atmosphere, particularly in winter. The RNBE in the upper stratosphere (30–2 hPa altitude range) is correlated well with observed GW activities above 88 km, particularly in April and September. Therefore, it can be inferred that the jet stream in the upper stratosphere around KSS during spring and autumn is the possible source of GWs observed in the upper mesosphere.

A Stochastic Model with a Low-Frequency Amplification Feedback for the Stratospheric Northern Annular Mode

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We consider three indices to measure the polar stratospheric mass and stratospheric meridional mass circulation variability: anomalies of (i) total mass in the polar stratospheric cap (60–90°N, above the isentropic surface 400 K, PSM), (ii) total adiabatic mass transport across 60°N into the polar stratosphere cap (AMT), (iii) and total diabatic mass transport across 400 K from the polar stratosphere into the troposphere below (DMT). It is confirmed that the negative stratospheric Northern Annular Mode (NAM) and PSM indices have a nearly indistinguishable temporal evolution and a similar red-noise-like spectrum with a de-correlation timescale of 4 weeks. This enables us to examine the low-frequency nature of the NAM in the framework of mass circulation, namely.

The DMT index tends to be positively correlated with the PSM with a red-noise-like spectrum, representing slow radiative cooling processes giving rise to a de-correlation timescale of 3−4 weeks. The AMT is nearly perfectly correlated with the day-to-day tendency of PSM, reflecting a robust quasi 90-degree out-of-phase relation between the AMT and PSM at all frequency bands. Variations of vertically westward tilting of planetary waves contribute mainly to the high-frequency portion of AMT. It is the wave amplitude's slow vacillation that plays the leading role in the quasi 90-degree out-of-phase relation between the AMT and PSM. Based on this, we put forward a linear stochastic model with a low-frequency amplification feedback from low-frequency amplitude vacillations of planetary waves to explain the amplified low-frequency response of PSM/NAM to a stochastic forcing from the westward tilting variability.

Extreme Rainfall Events Modulation by Monsoon Low Level Jet

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Extreme rainfall events have been observed to have increasing trend in recent decades. Indian summer monsoon rainfall accounts for more than 60% of annual rainfall. Low level jet is responsible for moisture incursion into India during the summer monsoon season (June-September). We studied the role of monsoon low level jet in modulating the heavy rainfall events over the south-western coast of India using the ECMWF re-analysis data and India Meteorological Department (IMD) rainfall data from 1979 to 2007. The evolution of monsoon low level jet (MLLJ) characteristics prior to the heavy rainfall events were studied. Steady rise in MLLJ core speed, depth, zonal water vapour flux, horizontal wind shear and cyclonic vorticity were seen towards the day of heavy rainfall and declining thereafter. The large scale advection of moisture brought about by strengthening of the monsoon low level jet is shown to be a pre-requisite for heavy rainfall over the Indian subcontinent. A significant result of this study is that continuous monitoring of progression of monsoon low level jet improves the predictability of heavy rainfall days.

SESSION 4

On the climate impacts of upper tropospheric and lower stratospheric ozone

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The global warming simulations of the general circulation models (GCMs) are generally performed with different ozone prescriptions. We find that the differences in ozone distribution, especially in the upper tropospheric and lower stratospheric (UTLS) region, account for important model discrepancies shown in the ozone-only historical experiment of the Coupled Model Intercomparison Project Phase 5 (CMIP5). These discrepancies include global high cloud fraction, stratospheric temperature, and stratospheric water vapor. Through a set of experiments conducted by an atmospheric GCM with contrasting UTLS ozone prescriptions, we verify that UTLS ozone not only directly radiatively heats the UTLS region and cools the upper parts of the stratosphere, but also strongly influences the high clouds due to its impact on relative humidity and static stability in the UTLS region and the stratospheric water vapor due to its impact on the tropical tropopause temperature. These consequences strongly affect the global mean effective radiative forcing of ozone, as noted in previous studies. Our findings suggest that special attention should be paid to the UTLS ozone when evaluating the climate effects of ozone depletion in the 20th century and recovery in the 21st century. UTLS ozone difference may also be important for understanding the inter-model discrepancy in the climate projections of the CMIP6 GCMs in which either prescribed or interactive ozone is used.

TRENDS IN TEMPERATURE OF THE MIDDLE ATMOSPHERE AND ITS LINKAGES TO STRATOSPHERIC OZONE RECOVERY

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During the past two decade, significant advancement has been made to understand the long term trends caused due to anthropogenic activities and that of natural variability in the whole atmosphere from ground to thermosphere. A global picture of the temperature response to Greenhouse gas increase and solar activity in the middle atmospheric regoin will be addressed in this talk with respect to geography, period of analysis and seasons. The discrepancy in the solar signal of temperature obtained by experimental data and the model results over the equatorial regions is still unresolved. The question of break in trend as a result of ozone recovery is briefly touched upon. The interpretation of the various reported results which were showing no tend in mesopause region earlier but started showing a negartive trend in recent time is a challenge. Hence, now the major challenge is in the interpretation of the various reported results which are diverse and even indicates latitudinal variability.

SAGE III on the International Space Station

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The Stratospheric Aerosol and Gas Experiment (SAGE III) began its mission aboard the international space station in February 2017. Currently, it is in its check out period and data will be publically released no later than the end of this year. In this presentation, we will discuss features of the mission including the quality of profiles of stratospheric ozone, water vapor, and aerosol extinction at nine wavelengths. We will also discuss the mission process, science goals and opportunities for collaboration with the SAGE III mission.

Changes in robust atmospheric circulation and its impact on poleward moisture transport into the Arctic during winter.

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During the past decades, the surface warming has been most rapid in the winter Arctic. Using the monthly ERA-Interim reanalysis data (1979-2017), we show that change of poleward moisture transport across 70°N into the Arctic during winter (December – February), followed by the downward infrared radiation (IR). This downward IR can be attributed to an enhanced poleward moisture flux and heat flux into the Arctic by an atmospheric circulation, which increases the total column water, clouds, and surface temperature. Particularly, the enhanced poleward moisture transport is mostly due to changes in the robust of climate variability for recent decades. This robust mode called the Barents Oscillation (BO). It was originally founded as the second leading Empirical Orthogonal Function (EOF) of monthly winter sea level pressure (SLP) anomalies (December – March) in regionally confined Atlantic Ocean or seen as the third EOF of SLP anomalies over the Northern Hemisphere (a primary center of action located over the Barents Seas of North Atlantic sectors). It has been strongly correlated with an anomaly of turbulent heat fluxes over the Barents-Kara Seas (BKS), explained by the remote atmospheric responses with triggering stationary Rossby waves. This quasi-stationary anticyclonic circulation relevant to the BO mode affects the Arctic winter warming especially over the BKS by the warm advection. By analyzing the regression pattern of SLP anomalies, we found that the increased poleward moisture flux for the recent decades is related to the enhanced variability of the BO mode and their relationship with enhanced BO mode affect the over the entire Arctic in recent decades. These recent changes linked to enhanced poleward moisture transport and Arctic cloud formation, which led to considerable downward IR, and consequently enhanced cloud-moisture-temperature relationship in the Arctic winter warming.

SESSION 5

A Stratospheric Pathway for the Arctic--- Midlatitude Climate Linkage

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A major challenge is to understand how Arctic sea ice changes affect the atmospheric flow patterns and climate of the Northern Hemisphere. Increased heat fluxes from the newly open ocean in late autumn and increased cyclogenesis in the heated regions impact on structure of planetary waves. A warmer Arctic changes the meridional temperature gradient and the baroclinic-barotropic interactions between the synoptic storm tracks and the atmospheric large-scale waves. The vertical propagation of planetary waves influences the stability of the stratospheric vortex and can trigger negative phases of the Arctic Oscillation.

Here we discuss the climate response to Arctic sea ice reduction based on the results of a set of atmospheric general circulation model experiments and reanalysis data for the recent period. Arctic sea-ice loss results in increased poleward eddy heat fluxes, thereby enhancing upward propagation of planetary-scale waves into the stratosphere in early winter. This leads to more frequent breakdowns of the polar stratospheric vortex during late winter, which feeds back to the troposphere.

The model experiment and ERA-Interim reanalysis data agree well with respect to temporal and spatial characteristics associated with vertical planetary wave propagation. The results thus provide strong evidence that the Arctic sea-ice loss, especially from the Barents-Kara Seas, significantlymodulates atmospheric circulation in winter and drives stratosphere–troposphere coupling processes by enhancing poleward eddy heat fluxes.

In the talk we raise two new questions regarding this stratospheric pathway of the Arctic-Midlatitude climate linkage: why is it that the Barents-Kara Seas so important? Why are simulation results so diverse? The first question addresses the details of planetary wave structure, which lead to an interesting question of wave-mean flow interaction. For the second question, among many factors we focus on a sea-ice data issue, highlighting difficulties in integrated SST and SIC data from satellite observations for high-latitudes.

Accelerating rates of Arctic carbon cycling revealed by long-term atmospheric CO2 measurements

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The contemporary Arctic carbon balance is uncertain and the potential for a permafrost carbon feedback of anywhere from 50 – 200 PgC (1) compromises accurate 21st Century global climate system projections. The 42-year record of atmospheric CO2 measurements at Barrow, Alaska (71.29 N, 156.79 W) reveals significant trends in regional land-surface CO2 anomalies (ΔCO2), indicating long-term changes in seasonal carbon uptake and respiration. Using a carbon balance model constrained by ΔCO2, we find a 13.4 % decrease in mean carbon residence time (50% confidence range = 9.2 – 17.6%) in North Slope tundra ecosystems during the past four decades. Retrieved temperature dependencies of respiration and carbon uptake suggest cold season Arctic carbon release will likely continue to exceed growing season carbon uptake under continued warming trends

Attributing causes of 2015 record minimum sea-ice extent in the Sea of Okhotsk

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Arctic sea ice extent (SIE) is an important indicator of global warming and understanding contributions of regional SIE changes to the Arctic SIE is critical to quantifying human and natural influences on the Arctic climate change. In 2015 February-March (late winter), the SIE over the Sea of Okhotsk (Okhotsk SIE) hit the lowest record, significantly contributing to the record minimum Arctic SIE in 2015. Understanding the past changes in sea-ice cover in the Sea of Okhotsk also provides important implications for atmospheric and oceanic conditions, ecosystems, as well as transportation corridor over the North Pacific. In this study, we examined causes of the record minimum late winter SIE in the Sea of Okhotsk using a fraction of attributable risk (FAR) approach. Using this method, we quantified the role of anthropogenic influences by comparing the probability of occurrence of extreme Okhotsk SIE events using the Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model simulations performed with and without anthropogenic forcing. It was found that because of anthropogenic influence, the probability of extreme low Okhotsk SIEs that exceed the 2015 event has increased by more than four times. In addition, it was suggested that a strong negative phase of the North Pacific Oscillation (NPO) during midwinter (January–February) 2015 also contributed to the 2015 extreme SIE event. An analysis based on multiple linear regression was conducted to quantify relative contributions of the external forcing (anthropogenic plus natural) and the NPO (internal variability) to the observed SIE changes. About 56.0% and 24.7% of the 2015 SIE anomaly was estimated to be attributable to the external forcing and the strong negative NPO influence, respectively. The attribution results indicate that anthropogenic influence largely responsible for the unprecedented 2015 reduction in the Okhotsk SIE. Further, projections from the CMIP5 models indicate that a sea ice–free condition may occur in the Sea of Okhotsk by the late twenty-first century in some models.

Flaring Black Carbon Impacts on Arctic Climate

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A large reduction of high-latitude gas petroleum activity since the dissolution of the Soviet Union has been increasing again in the recent 2000s. The accompanying gas flaring produces black carbon, a typical warming aerosol. However, to date, precise emission data in association with the high-latitude gas flaring activity, which are potentially an important source of black carbon at high latitudes are currently missing in many places and even geographically misplaced. In this study, we examined the impacts of black carbon emission from the gas flaring on the Arctic climate in 2000s. We prescribed realistic black carbon emission by the gas flaring over high-latitude in the model simulation and found that Arctic surface air temperature increase is highly sensitive to the prescribed black carbon source. By analyzing the simulation results in detail, we found that the increase in net incoming radiation by the black carbon plays a major role.

SESSION 6

Role of stratosphere-troposphere interaction on the winter cold extremes in East Asia

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In this talk, the downward influence form the stratosphere on the winter climate in East Asia is firstly presented with both a case study and composite analysis. The results indicate that the downward propagation of stratospheric anomalies has evident influences on the tropospheric circulation with particularly significant signals over East Asia. Downward and non-downward propagating events for anomalous stratospheric polar vortex are further compared. The result reveals that the time-scale of downward propagating events are longer than that of non-downward propagating events. And in weak stratospheric polar vortex cases the strength of anomaly for downward propagating event is about two times that of non-downward propagating event. The circulation, wave evolution and the changes in low-level are discussed, too.

Eurasian winter temperature change and its association with Arctic sea ice loss

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Surface air temperature in the northern mid-latitudes has shown a significant cooling trend in recent winters especially from late 1990s to early 2010s in spite of increasing greenhouse gas concentrations. Such an unexpected cooling, which was particularly strong across the Eurasia, has been partly attributed to the Arctic sea ice loss. Here, by performing canonical component analysis, the statistical relationship between the Arctic sea ice and Eurasian winter surface air temperature, often referred to as the warm Arctic-cold Eurasia pattern, is re-evaluated. A significant timelagged co-variability is observed between the Arctic sea ice concentrations over the Barents-Kara seas and the Eurasian winter surface air temperature, the former leading the latter up to one season. More importantly, the timing of an abrupt sea ice loss in autumn, which occurred around 1998, is consistent with the beginning of Eurasian winter cooling. These results suggest that both short-term variability and long-term trend of Eurasian winter surface air temperature are likely influenced by regional sea ice changes over the Barents-Kara seas.

Persistent Shift of the Arctic Polar Vortex towards the Eurasian Continent in Recent Decades and its climatic impact.

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The wintertime Arctic stratospheric polar vortex has weakened over the past three decades and consequently cold surface air from high latitudes is now more likely to move into the middle latitudes. However, it is not known if the location of the polar vortex has also experienced a persistent change in response to Arctic climate change and whether any changes in the vortex position has implications for the climate system. Here, through the analysis of various datasets and model simulations, we show that the Arctic polar vortex shifted persistently towards the Eurasian continent and away from North America in February over the past three decades. This shift is found to be closely related to the enhanced zonal wavenumber 1 waves in response to Arctic sea-ice loss, particularly over the Barents-Kara seas (BKS). Increased snow cover over the Eurasian continent may also have contributed to the shift. Our analysis reveals that the vortex shift induces cooling over some parts of the Eurasian continent and North America which partly offsets the tropospheric climate warming there in the past three decades. The results further indicate that the shift of the polar vortex towards Eurasia is closely related to a 'Eurasia-North America dipole' (ENAD) mode that is identified in the total column ozone (TCO) over the Northern Hemisphere, showing negative and positive TCO anomaly centres over Eurasia and North America, respectively. The positive trend of the ENAD mode explains an enhanced TCO decline over the Eurasian continent in the past three decades. In the future, the potential vortex shift in response to persistent sea-ice loss, and its associated climatic impact deserve attention to better constrain future climate changes.

Emergence of aridification can be reduced by limiting the global warming to 1.5℃

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Atmospheric Composition and the Asian Monsoon: Recent Progresses and Collaboration Opportunities

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The Asian monsoon system impacts the lives of billions of people through the variability of precipitation and winds. Along with this major weather phenomenon is a significant chemical transport pattern that couples surface emissions of the region to the global chemical environment and the climate system. The chemical impacts and climate coupling through monsoon convective transport are new research topics that have emerged in the last decade. Since 2015, Atmospheric Composition and the Asian Monsoon (ACAM) has been a SPARC/IGAC jointly sponsored activity. In this presentation, I will highlight the research collaborations centered on the interactions and couplings between the regional emissions and the monsoon dynamics, including impacts on regional air quality and on climate relevant stratospheric composition changes. Outstanding scientific questions, field campaigns in planning, and potential collaboration opportunities will be discussed.

SESSION 7

Effects of atmospheric river landfalls on the precipitation characteristics in the Western US

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Landfalling atmospheric rivers (ARs) play a crucial role in the winter hydroclimate of the US Pacific coast region as they are frequently related to heavy precipitation and flash flooding events. Thus, understanding of the effects of AR landfalls on the precipitation characteristics in the WUS region and evaluating the capability of climate models to accurately simulate AR landfalls and their key hydrologic effects is an important practical concern for WUS, from flood forecasting to future water resources projections.

This study aims to understand the effects of AR landfalls on the characteristics of regional precipitation in WUS, especially the seasonal means and the PDFs as well as their variations according to regions and landfall locations. Towards this goal, this study analyzes the seasonal and daily precipitation characteristics for the 10 winters (November – March) from November 1999 to March 2010 using the 4km-resolution daily PRISM data. The AR-landfall chronology is obtained based on the vertically-integrated water vapor flux calculated from the MERRA2 reanalysis according to the methodology Guan and Waliser (2015). The regional variations of the winter precipitation characteristics are calculated in terms of the three Bukovsky regions in WUS, a widely used geographical climate subdivisions in WUS.

The AR-related fraction of winter PR and associated daily PR PDFs in individual Bukovsky regions vary strongly for landfall locations; AR landfalls in the northern WUS coast (NC) affect mostly the Pacific Northwest (PNW) region while those in the southern WUS coast (SC) affect both the Pacific Southwest (PSW) and the Great Basin (GB) regions. The effects of AR landfalls on the daily precipitation PDF also varies strongly according to the landfall locations and regions. The NC (SC) landfalls increase the frequency of heavy PR in PNW (PSW and GB) but reduce it in PSW (PNW). The inland GB region is affected by both NC and SC landfalls, but the effects of SC landfalls are larger than the NC landfalls.

Thermal characteristics of the tropical tropopause layer in CMIP5 models

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The climatology, seasonality, and intraseasonal to interannual variability of the tropical tropopause layer (TTL) temperature field are examined using the state-of-the-art climate models that participated in the Coupled Model Intercomparison Project Phase 5 (CMIP5). Both historical simulations and future projections based on the Representative Concentration Pathway (RCP) 8.5 scenario are used to evaluate model performance and to identify potential changes in the TTL temperature. It is found that historical simulations successfully reproduce the spatio-temporal structure of the TTL temperature in comparison to reanalysis data. The interannual variability associated with El Niño-Southern Oscillation and intraseasonal variability associated with equatorial waves are also reasonably well captured. However, the models show non-negligible biases in several aspects: 1) most models have a warm bias around the cold-point tropopause; 2) large inter-model differences occur in the amplitude of the seasonal cycle in upper-tropospheric and lower-stratospheric temperature; 3) many models overestimate lower stratospheric warming in response to volcanic aerosols; 4) temperature variability associated with the quasi-biennial oscillation and Madden-Julian oscillation is absent in most models; 5) equatorial waves in the TTL exhibit a wide range of variations among the models with unrealistically persistent Kelvin waves in several models. In the RCP 8.5 scenario, the models predict robust warming at 100 hPa and cooling at 70 hPa. A weakened seasonal cycle in the TTL temperature is also predicted in most models at both the 100- and 70-hPa levels. These findings may have important implications for cross-tropopause water vapor transport and related global climate change and variability.

Fate of pollution emitted during the 2015 Indonesian Fire Season

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The El Niño-driven fire season in Indonesia, 2015, is recorded to have the most severe fire emissions since NASA's Earth Observation System (EOS) satellites started making observations of tropospheric pollutants from space. Carbon monoxide (CO), one of the major pollutants emitted during the fire season, has direct impacts on chemistry in the troposphere as a precursor to ozone O3 and carbon dioxide (CO2) and through interactions with the hydroxyl radical (OH) that increase the lifetime of methane (CH4). The relatively long chemical lifetime of CO (weeks to months) enables long-range transport as well as vertical transport into the upper troposphere and lower stratosphere (UTLS) region. In this study, measurements of CO from the Terra/MOPITT (Measurement of Pollution in the Troposphere) and Aura/MLS (Microwave Limb Sounder) are used to characterize the global impact of high CO emitted during the 2015 Indonesian fire season. The MOPITT and MLS instruments together provide a powerful tool for exploring global distributions of CO with overlap in the UTLS region. Simulations of CO from the Community Atmosphere Model with Chemistry (CAM-chem) are used to better understand transport pathways of CO from the surface into the lower stratosphere. We find that high concentrations of CO from the September-October 2015 Indonesian fires persisted in the UTLS throughout 2016, much longer than previous years with significant fire emissions.

An assessment of SLCP trends over Pakistan

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The increase in global temperatures since the mid-20th century is attributed to the observed increase in anthropogenic greenhouse gas (GHG) concentrations. Water and agriculture sectors are likely to be most sensitive to climate change-induced impacts in Asia. Agricultural productivity in Asia is likely to suffer severe losses because of high temperature, severe drought, flood conditions, deforestation and soil degradation. Although, Pakistan is not contributing much to GHG emissions (ranked 135) as compared to other industrialized nations, however, it is listed on number 12 among the nations that are most vulnerable to the global warming. The impacts of climate change/global warming can be copped by having better understating of the mechanisms, identifying the sector of most vulnerability, and controlling the emissions of GHG and short-lived climate pollutants (SLCPs)contributing directly and/or indirectly to climate change. SLCPs are substances with a relatively short atmospheric lifetime of order of few days to few decades and have warming effect on near term climate. The main SLCPs are BC, CH4, tropospheric O3, and many HFCs. A reduction in SLCP emissions can lower 0.5° C by 2050 with significant co-benefits for human health and agricultural productivity through reduced local air pollution in addition to the short-term mitigation of climate problems.

Methane is one of the most significant drivers of climate change, as well as the main precursor of tropospheric ozone, a powerful greenhouse gas and air pollutant. Ozone has been estimated to cause around 150,000 deaths annually worldwide and affects the health of many more.

This study propose to monitor the CH4 concentrations over Pakistan during the last decade. Efforts are made to track the spatial and temporal changes in CH4 concentrations over Pakistan. Analyses exhibit a temporal increase of about 2.7% during the selected time period. Rice cultivated regions of Punjab and Sindh consistently showed high CH4 concentrations. Satellite observations exhibited a constant seasonal variability in CH4 concentrations over Pakistan, being highest in summer and lowest in winter except for the year 2010. An anomalous shift in seasonal cycle of Methane is observed as a repercussion of the devastating floods of 2010, which resulted in a loss of about 0.5 Million Hectares of

Rice cropland. Furthermore, preliminary results of tropospheric ozone retrieved from satellite observations will also be discussed

Thermal evolution of late summer melt ponds

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The thermal evolution of melt ponds on sea ice was investigated through a combination of autonomous in situ observations in the East Siberian Sea and a two-dimensional model including high-resolution fluid simulations. Shortwave radiation and high-resolution temperature profiles were measured simultaneously for two ponds on the same ice floe, with similar depth and insolation but differing salinity. The pond salinity caused significant differences in the observed temperature profiles. Complementary fluid dynamical simulations show that thermal convection occurs in freshwater ponds, but conductive heat transfer may dominate in salt stratified ponds. Such differences in sensible heat transfer through ponds, which controls flux perturbations, are of potential climatological significance for the sea ice energy budget. This highlights the importance of better constraining and understanding the internal heat transfer dynamics and the salinity of melt ponds.

POST SESSION

Cross tropopause flux observed at sub-daily scales over south India monsoon regions

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The effect of deep convection in modulating the thermal structure and dynamics of the tropical tropopause at sub daily scales is investigated using data from radiosondes launched over two sites in the Indian Monsoon region (Gadanki (13.5°N, 79.2°E) and Trivandrum (8.5°N, 76.9°E)) during a special campaign called Tropical Tropopause Dynamics (TTD) conducted between December 2010 and March 2014. The data from these soundings are classified into 6 convective categories based on the past and present cloudiness over the launching region after the radiosonde has reached tropopause altitude. The background anomalies of temperature, relative humidity and horizontal wind speed for the six different convective categories are obtained for both the stations using the radiosondes over both the stations. Similar background anomalies (T, RH and Wind speed) are also obtained for the six convective categories during different seasons. Cooling and moistening anomalies are found during the active convection (category 4). The horizontal wind speed showed a strong anomaly indicating the presence of synoptic scale features. Vertical wind obtained simultaneously from the MST radar operated in zenith mode over Gadanki clearly showed strong updraft during the active convection indicating the strength of convection in the transport of chemical species from troposphere to stratosphere. The ozone profiles obtained using ozonesondes launched over Gadanki during the same period are also segregated according to the above the convective categories. During the active convection, high and low ozone values are found in the upper troposphere and the lower troposphere, respectively. The cross tropopause ozone mass flux at the tropopause and convective outflow level estimated from the ozonesonde, MST radar and ERA-Interim showed positive values indicating the transport of ozone from the lower altitudes to upper troposphere through deep convection. Similarly, the total mass flux crossing the cold point tropopause over Gadanki showed upward flux during the active convection.

Occurrence of persistently low tropopause temperature and ozone over the Asian monsoon region as observed from Aura satellite

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This paper reports the observation of persistently low tropopause temperatures (100 hPa temperatures, T100) and ozone throughout the year as compared to the corresponding zonal mean values over the Bay of Bengal (BOB), which is a part of the Asian monsoon region. The long term data from Earth Observing Satellite (EOS) Aura aboard Microwave Limb Sounder (MLS) and Tropospheric Emission Spectrometer (TES) have been used to study the causative processes contributing to the low tropopause temperatures. The long term mean T100 (from 2006-2010) is noted to be ~2.2 K lower than the zonal mean values over the BOB. Despite the occurrence of most intense convective activity over the northern tropics, the water vapour near the tropopause is observed to be relatively low over the BOB. The multiple linear regression analysis has been carried out to study the contribution of convection, ozone and Brewer Dobson Circulation (BDC) in giving rise to persistently low T100 over this region. The results show that the low ozone mixing ratios contributes ~1.2 K to the persistently low T100. The convective activity also contributes to the persistently low T100, but its contribution is mainly during the NH summer monsoon period and also relatively less (~0.35 K) as compared to the ozone.

Solar activity and associated changes in column ozone based on chemistry climate model simulation

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Solar Activity have much direct impact at the earth atmosphere and the climate systems. Solar cycle variability is greatest at ultraviolet wavelengths, which are largely absorbed by the stratospheric ozone layer. The direct effects of solar variability are therefore felt predominantly in the total column ozone. Recent modelling studies and observational evidence indicate that total ozone would be expected to vary approximately in phase with solar cycle. In the paper, we examine the long-term effect of solar cycle variability on total column ozone changes using the chemistry climate model simulation and the long period reanalysis data sets.

To understand the impact of solar cycle variability on the atmospheric column ozone, we used the solar radio flux at 10.7 cm (2800 MHz), which is an excellent indicator of solar activity (F10.7 index), total column ozone from the chemistry coupled climate model (CHASER-MIROC-ESM) simulation (1980 - 2010) and the other long-term reanalyse products. It is confirmed from the analysis that the total column ozone concentration changes in phase with the solar cycle and the maximum concentration during the positive phase of solar cycle. There is a strong positive correlation between total column ozone with F10.7 cm radio flux (indicator of solar activity) over the tropics and the correlation value diminishes towards higher latitudes. We performed the EOF analysis of total column ozone to understand the spatial correlation of column ozone variability with the solar cycle. The spatial pattern of EOFs also confirmed the impact of solar activity on the column ozone variability over the tropics.

Variability of Tropopause over South Asian Monsoon Region

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The seasonal variability of tropopause is studied using AIRS/Aqua L3 Monthly Standard Physical Retrieval (AIRS+AMSU) V006 (AIRX3STM) datasets from September 2002 to 2016 around two major monsoon hit locations, Central Himalayan Region (CHR, 77E-91E and 25N-30N) and Bay of Bengal Region (BoB, 80E-98E and 9N-24N), in the South Asian monsoon region. The relation between tropopause height (TH), tropopause temperature (TT) and tropopause pressure (TP) are examined. The preliminary finding shows the notable differences in tropopause characteristics between the regions. There is strong seasonal variability in TH ranging from a minimum of ~15.5 km in winter (December - February) to a maximum of ~17.7 km in mature summer season (June - August) over CHR. In contract, very week seasonal variation of TH (< 0.4 km; 16.8 km in winter and 16.5 km in summer season) is observed over the BoB region. Despite the fact that BoB region is at lower latitude, TH is higher over CHR by ~0.5 km in summer. Over CHR the TT is warmer in winter (-70.7 oC) and cooler during summer season (-78.1 oC). On the other hand, TT is slightly warmer (-79.7 oC) in summer compared to winter (-81.4 oC). Similar pattern with strong seasonal variability of TP (minimum of 95 hpa during summer and maximum of 119 hpa during winter season) is observed over CHR. In conclusion, analysis of equivalent potential temperature calculated by using JRA-55 reanalysis data at two pressure level (200 hpa and surface) indicates strong convection during summer near Himalayan Foothills and is responsible for the reverse seasonal pattern of tropopause characteristics between the regions.

Differences in the tropical convective activities during different phases of quasi biennial oscillation (QBO)

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Recent observational studies have suggested that the quasi-biennial oscillation (QBO), defined as a phenomenon describes the wind reversal in the tropical stratosphere with periods of about 20 to 35 months, affects the tropical troposphere by modulating deep convection. According to Plumb and Bell (1982), anomalous meridional circulation during the QBO easterly phase (QBOE) intensifies convective activities in the tropics and weakens convection in the subtropics, and the opposite is true for the QBO westerly phase (QBOW). In this study, we investigate differences in the tropical convective activities during different QBO phases, using five metrics representing convection: (i) deep convective heating rate (DCH), (ii) cloud top pressure (CTP), (iii) convective available potential energy (CAPE), (iv) precipitation, (v) outgoing longwave radiation (OLR). DCH and CTP are obtained from the NCEP Climate Forecast System Reanalysis (CFSR), and CAPE is calculated using the temperature and mixing ratio data of CFSR. We used satellite-observed OLR data from the National Oceanic and Atmospheric Administration (NOAA) and precipitation data from Global Precipitation Climatology Project (GPCP) version 2.2. The QBOE and QBOW are selected when the zonal wind anomaly from the monthly climatology at 30 hPa is less than -0.5 standard deviation and greater than 0.5 standard deviation, respectively. The composite analysis of the five metrics is performed during different QBO phases, after removing a seasonal cycle. The convective activities are intensified (weakened) in the maritime continents and weakened (intensified) in the equatorial eastern and central Pacific region during QBOE (QBOW) in all metrics. Because the regions of strong and weak convective activities exist in a same latitude band (10°N-10°S) with a comparable magnitude, longitudinally averaged values do not present significant differences between the two QBO phases. Given that the convective activity is strongly influenced by El Niño Southern Oscillation (ENSO), we performed the same composite analysis after excluding the ENSO effect. During the QBOE, the convective activities are intensified in the maritime continents and weakened in the central and eastern Pacific, which appears as a dipole pattern. During the QBOW, this dipole pattern is shifted to the east: the convective activities are intensified in the western Pacific and weakened in the eastern Pacific. As in the original composite results including the ENSO effect, longitudinally averaged convective activities are not significantly different from each QBO phase.

Possible impact of tropospheric ozone and methane on the recent Arctic warming

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Both tropospheric ozone (TO3) and methane (CH4) concentrations have kept increasing during the last few decades as in carbon dioxide (CO2) concentrations. The previous studies mostly using low-resolution models suggested the TO3- and CH4-induced radiative forcings can affect not only the regional climate but also the Arctic climate. Such conjecture is re-visited in this study by conducting a series of AGCM experiments. Specifically, the direct impacts of increasing TO3 and CH4 concentrations, in the absence of atmosphere-ocean coupling, are quantified with the time slice experiments varying TO3, CH4, or CO2 concentrations. The increasing TO3 and CH4 concentrations show distinct surface climate impacts only in the boreal winter in the Northern Hemisphere high latitudes. In the Arctic, the TO3- and CH4-related warming is even comparable to the CO2-induced one. Such warming, that is partly caused by enhanced downward long-wave radiation, suggests that the seasonality of Arctic warming in the recent decades might be partly influenced by seasonally-dependent TO3 and CH4 effects.

The Relationship between the Variation of High Latitude Stratospheric Planetary Wavenumber 1and the Cold Anomalies over Eastern China

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The variations of high latitude stratospheric planetary wavenumber 1 is discussed by performing EOF analysis onto the geopotential height field along 65N at 50-hPa. The two leading modes correspond to the variations of the strength and phase of the wavenumber 1. By lead-lag regression analysis , we found the EOF2 mode is closely associated with the cold anomalies over East Asia during its clockwise movement. We divide the life cycle of EOF2 into 8 phases and exert composite analysis upon 54 events with whole life cycle evolution. The geopotential height anomalies at 50-hPa move clockwise from phase1 to phase8. The surface cold anomalies over Eastern China emerge in phase3 and peak in phase5. The cold anomalies are caused by the southward extension of the Siberian high accompany by strong surface northerly winds. The strengthening of the Siberian high and strong surface northerly winds are associated with the deepening and southwestward expansion of the East Asian trough. The Rossby wave trains propagate along polar front and subtropical waveguides leading to the strengthening of the Siberian high and the East Asian trough. The upstream Rossby wave train wave source is associated with the downward propagation of stratospheric signal when the EOF2 pattern moves clockwise in phase2-3. This downward signal also contributes to the westward propagation of anticyclonic anomalies over Eastern Eurasia, which leads to the building of tropospheric Rossby wave train along polar front waveguide. The deepening of the East Asian trough in this study is not impacted by the downward propagation of lower-stratospheric signal over East Asia directly, however, the upstream tropospheric Rossby wave trains are the main factor to the strengthening of the East Asian trough.

Effect of Madden-Julian Oscillation Occurrence Frequency on the Interannual Variability of Northern Hemisphere Stratospheric Wave Activity in Winter

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This study uses reanalysis datasets and numerical experiments to investigate the influence of the occurrence frequency of the individual phases of the Madden-Julian Oscillation (MJO) on the interannual variability of stratospheric wave activity in the Northern Hemisphere mid and high latitudes during the winter (November-December-January-February: NDJF). Our analysis reveals that the occurrence frequency of MJO phase 4 in winter is significantly positively correlated with the interannual variability of the Eliassen-Palm (E-P) flux divergence anomalies in the Northern Hemisphere extratropical stratosphere; i.e., the higher (lower) occurrence frequency of MJO phase 4 corresponds to weaker (stronger) upward wave fluxes and increased (decreased) E-P flux divergence anomalies in the middle and upper stratosphere at mid to high latitudes, which implies depressed (enhanced) wave activity accompanied by a stronger (weaker) polar vortex in that region. The convection anomalies over the Maritime Continent related to MJO phase 4 excite a Rossby wave train that propagates poleward to Northern Hemisphere mid and high latitudes, and is anti-phase with wavenumber 1 at mid and high latitudes. As the spatial distribution of the convection anomalies during MJO phase 7 has an almost opposite, but weaker, pattern compared with that during MJO phase 4, the occurrence frequency of MJO phase 7 has an opposite and weaker effect on the Northern Hemisphere stratosphere compared with MJO phase 4. However, the other MJO phases (1, 2, 3, 5, 6, and 8) cannot significantly influence the Northern Hemisphere stratosphere over interannual timescales because the wave responses in these phases are not in phase or out of phase with the background stationary wave.

Characteristics of inertia-gravity waves revealed in rawinsondes at Jang Bogo Station, Antarctica (74˚374'S, 164˚13.7'E)

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Wind and temperature structure and characteristics of inertia-gravity waves (IGWs) are investigated revealed in high-vertical resolution rawinsonde data collected at Jang Bogo Station (JBS), Antarctica (74˚374'S, 164˚13.7'E) for 2 years (2015–2016). Observed wind and temperature data are compared with those from four global reanalysis data (CFSR, MERRA, ERA-Interim, and NCEP/NCAR) at JBS. The reanalysis data correspond well with the observation, although wind bias at 850 hPa is considerable, especially in the NCEP/NCAR. The gravity wave (GW) analyses are conducted for two atmospheric layers covering the troposphere (Z = 2–7 km) and the lower stratosphere (Z = 15–22 km) considering tropopause height at JBS. The GW activity, estimated from the average total GW energy per unit mass, is stronger in the stratosphere (5.32 J kg-1) than in the troposphere (3.57 J kg-1). The characteristics of inertia-gravity waves (IGW) are investigated using stokes parameter method based on quasi-monochromatic wave theory. The average intrinsic frequency, vertical and horizontal wavelengths of IGWs in the troposphere (stratosphere) are 3.43 f (1.81 f) (where f is the Coriolis parameter), 1.21 km (1.3 km), and 62.94 km (196.72 km), respectively. Intrinsic horizontal group velocities are centered near zero with the magnitude of less than 10 m s-1 in both layers. Considering ground-based group velocity, it is found that the observed IGWs in the stratosphere propagate east and southward with relatively larger magnitude in wintertime than summertime due to the strong background wind associated with the stratospheric polar vortex. The vertical propagation direction of IGWs has strong seasonal variation in the stratosphere while it is less evident in the troposphere. Downward propagating waves appear only from May to October with the reduction of upward propagating waves. For upward (downward) propagating waves, zonal momentum flux is negative (positive), implying IGWs to propagate westward (eastward) relative to the background wind. Most of the downward propagating waves have positive meridional momentum flux, while upward propagating waves have both positive and negative values of meridional momentum flux. In the troposphere, momentum fluxes do not have preference of direction.

A definition of the dynamical tropopause based on the Gaussian curvature of isentropic potential vorticity

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The dynamical tropopause has traditionally been defined as an isopleth of isentropic potential vorticity (IPV). This approach, which is based on the existence of a large gradient in IPV between low values in the tropical upper troposphere and large values in the extratropical lowermost stratosphere, has several advantages. However, defining the tropopause as a single IPV isopleth at all longitudes and times carries limitations that can affect the identification and quantification of transport across the dynamical tropopause, and may introduce biases in descriptions of the seasonal and climatological variations of the tropopause boundary. Recent work has attempted to address these limitations by introducing the equivalent latitude transformation. This adaptation provides a more objective and flexible definition of the tropopause that allows for variations in time, but involves a more complicated set of calculations and additional data requirements and does not allow for variations in longitude. Here we describe a different approach based on ideas from the field of differential geometry. Specifically, we propose that transport boundaries along an IPV surface, such as the tropopause, may be defined as contours of zero Gaussian curvature. Simplification of the resulting expression yields a formula for identifying the tropopause contour on an isentropic surface that depends only on latitude and IPV, without the need for transformations or spatial derivatives. This definition compares well with previously-proposed definitions, while also allowing for spatiotemporal variations in the value of IPV that corresponds to the tropopause. We summarize daily and regional variations in the tropopause according to this and other definitions for the year 2015.

Reexamination on the type classification of Stratospheric Sudden Warming

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During stratospheric sudden warmings (SSW), stratospheric polar vortex is characterized by displaced off the pole toward low-latitude (displacement-type) or split into two vortexes (split-type) by undergoing the distortion and the division due to wave-mean interaction. We find that even though SSW events are identified as split-type, the evolutions can be distinctively different depending on the dominant wave disturbance prior to SSW in the middle stratosphere. Thereby, we classify the split-type SSW into displacement-split type (DS type) and split- split type (SS type). The frequencies of the both split types in the reanalysis data are almost similar and show distinct dynamic features during prewarming phase. In the SS type, the characteristics of the known split type are more clearly seen. The DS type is rather similar to the displacement-type characteristics prior to the SSW. In the WACCM simulation with climatological surface boundary conditions, however, the number of split-type SSW is much less than the observed as previous studies reported and we found that this largely due to the inability of WACCM to simulate SS type. Most of the split-type SSW are simulated as DS type, and the incidence rate of SS type to DS type is very low to 0.21 level.

A numerical simulation of strong wind event at King Sejong Station, Antarctica.

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Despite the recent significant climatic changes observed over West Antarctica, adequate validation of regional simulations of extreme weather events is rare for this region. To address this gap, simulation results from a recent version of the Polar Weather Research and Forecasting model (Polar WRF) covering Antarctic Peninsula at a high horizontal resolution of 3 km are validated against near-surface meteorological observations. We selected a case of high wind speed event on 7 January 2013 recorded at Automatic Meteorological Observation Station (AMOS) in King Sejong station, Antarctica. It is revealed by in situ observations, numerical weather prediction, and reanalysis fields that the synoptic and mesoscale environment of the strong wind event was due to the passage of a strong mesoscale polar low of center pressure 950hPa. Verifying model results from 3 km grid resolution simulation against AMOS observation showed that high skill in simulating wind speed and surface pressure, respectively. Our evaluation suggests that the Polar WRF can be used as a useful dynamic downscaling tool for the simulation of Antarctic weather systems.

The characteristics and impacts of extreme Atlantic windstorms on Arctic warming

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Over the past decades, the Arctic temperature has been increased at almost twice the global mean which is referred to as the Arctic amplification. The Arctic warming is most pronounced during fall and winter. Windstorms often occur during boreal winter seasons, and are of concern as they are associated with anomalous warming events. These windstorms lead to an enhanced poleward energy transport by moisture intrusion from mid-latitude to the Arctic. Since most extreme windstorms occur over the North Atlantic sector, we classify the North Atlantic windstorms according to the storm intensities (minimum central pressures) during winter for the last 36 years (December-January-February 1981-2016), and explore their relationship with Arctic, particularly the Atlantic side of the Arctic Ocean, temperature and atmospheric circulation changes.

Dynamical core in atmospheric model does matter in the simulation of Arctic climate

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With climate model simulations using finite volume (FV) and spectral element (SE) dynamical cores, we examine the differences between the two simulations focusing on the simulated Arctic climate and northern hemispheric circulations. In full-physics simulations under the carefully controlled very similar physical parameterization schemes, and same surface boundary conditions representing current climate, the SE core simulates winter SAT of about 2 K higher in the Arctic than FV core. The SE core simulates an enhanced northward eddy heat transport in mid-latitude, an increasing in sinking motion at troposphere over Arctic, and, in turn, lower tropospheric warming over the Arctic region compared to the FV core. The circulation change causing the temperature change can be described by differences in eddy moment and heat fluxes. Downward longwave radiation by moist and cloudy low troposphere also contributes to enhancement in near surface warming over Arctic. Comparing with the reanalysis datasets, the FV core simulates much colder Arctic than three reanalyses mean, and this tendency of simulating colder Arctic of the FV core also appears across climate models participate in historical AMIP simulation of CMIP5. In reduced sea ice experiments, only the SE core simulates robust response of cooling down over North America. The results show that special attention for selecting dynamic core of climate model is needed when the target is Arctic climate and associated teleconnection phenomena.

Does coupled ocean enhance ozone-hole-induced Southern Hemisphere circulation changes?

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The ozone-hole-induced Southern Hemisphere (SH) circulation changes, such as poleward shift of westerly jet and Hadley cell widening, have been typically explored with either coupled general circulation models (CGCMs) prescribing stratospheric ozone or chemistry-climate models (CCMs) prescribing surface boundary conditions. Only few studies have utilized ocean-coupled CCMs with a relatively coarse resolution. To better quantify the role of interactive chemistry and coupled ocean in the ozone-hole-induced SH circulation changes, the present study examines a set of CGCM and CCM simulations archived for the Coupled Model Intercomparison Project phase 5 (CMIP5) and CCM initiative (CCMI). Although inter-model spread of Antarctic ozone depletion is substantially large especially in the austral spring, both CGCMs with relatively simple ozone chemistry and CCMs with fully interactive comprehensive chemistry reasonably well reproduce long-term trends of Antarctic ozone and the associated polar-stratospheric temperature changes.

Most models reproduce a poleward shift of SH jet and Hadley-cell widening in the austral summer in the late 20th century as identified in reanalysis datasets. These changes are quasi-linearly related with Antarctic ozone changes, confirming the critical role of Antarctic ozone depletion in the austral-summer zonal-mean circulation changes. The CGCMs with simple but still interactive ozone show slightly stronger circulation changes than those with prescribed ozone. However, the long-term circulation changes in CCMs are largely insensitive to the coupled ocean. While a few models show the enhanced circulation changes when ocean is coupled, others show essentially no changes or even weakened circulation changes. This result suggests that the ozone-hole-related stratosphere-troposphere coupling in the late 20th century may be only weakly sensitive to the coupled ocean.

Shifting urban heat island clock in Megacity: a case study of Hong Kong

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With increasing level of urbanization in the near-future, exact assessment of the impact of urbanization on urban heat island (UHI) is a critical process to adapt regional climate and environmental change. However, our understandings of UHI mainly relied on the intensity or magnitude of UHI. The present study first evaluates the impact of urbanization on UHI duration changes by comparing three stations with different rate of urbanization such as highly-developed and developing urban area over Hong Kong from 1990 to 2015. Results show the climatology of UHI intensity in highly-developed is much higher than that of developing area, but the climatology of the UHI duration is similar with each other. Over the past 25 years, however, the UHI duration has been increased only in the developing urban area from 13.59 to 17.47 hours. Both earlier UHI starting and later UHI ending time concurrently contributes to the lengthening of UHI duration. The difference of UHI duration change between two areas are supported by the population and nightlight changes from space. Positive changes in nightlight, which suggests enhancing economic infrastructure at there, only placed in the developing urban area. Our results suggest changes in UHI duration should be included in the assessment of regional climate change as well as urban planning in the Megacity.

The Precondition for Arctic Stratospheric Polar Vortex Displacement Events

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The preconditions for Arctic stratospheric polar vortex displacement events towards Eurasia (EUR events), North America (NA events) and the Atlantic (ATL events) are investigated through composite analysis of the European Centre for Medium-Range Weather Forecasts Interim reanalysis (ERA-Interim) data for 1979-2015. The EUR events are preceded by increased blocking frequency over northern Europe and decreased blocking frequency over the Bering Strait. The anomalous blocking patterns lead to an anomalous zonal wave-1 that has a negative center over Eurasia in the stratosphere and is conducive to displacement of the polar vortex towards Eurasia. Increased blocking frequency over the Bering Strait and decreased blocking frequency over northern Europe exist prior to the NA events. The anomalous blocking patterns lead to anomalous zonal wave-1 and wave-2 that have negative centers over North America in the stratosphere and create favorable conditions for polar vortex displacement towards North America. The stratospheric polar vortex shift towards North America is more elongated than that of the other two types of events. The ATL events are preceded by increased blocking frequency over the eastern North Atlantic and decreased blocking frequency over the Bering Strait. The anomalous blocking patterns lead to anomalous zonal wave-1 and wave-2 that have negative centers over the Atlantic in the stratosphere and create favorable conditions for polar vortex displacement towards the Atlantic. A significant difference in the zonal wave-2 heat flux entering the lower stratosphere exists prior to polar vortex displacement events with small and large vortex deformation. Finally, displacement of the polar vortex towards these three selected regions is observed after defining three types of tropospheric blocking events that have a similar spatial pattern of blocking frequency anomalies as the patterns prior to the three types of polar vortex displacement events.

Contribution to the aerial carbon sequestration assessment in the mangroves of Djirnda and Joal- Fadiouth (regions of Thiès and Fatick, Senegal- West Africa)

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This study contributes to evaluate carbon sequestration potential at Djirnda and Joal. Mangroves decline due to anthropogenic and climatic factors. It was hypothesized that Avicennia africana, Djirnda sites sequest more carbon than Rhizophora spp and Joal; Chave (2005) is more stable than Komiyama (2008) in the biomass estimation in mangroves. We measured dendrometrics' parameters and estimated above ground carbon stock based on regression model. Rhizophora spp and Avicennia africana at Djirnda and Joal (81.74%; 91.19%; 8.81%; 18.72%). Avicennia Africana has C sequestration rate at Joal and Djirnda (18.386, 14.88 TCO2/ha). Sites and species Interaction has no impact on carbon sequestration but both influence on carbon sequestration (P < 0.005; 0.000; 0.026). Avicennia africana has a great carbon sequestration potential than Rhizophora spp ((296.71; 98.804 Kg CO2). Djirnda's mangrove sequesters more CO2 than Joal mangrove (141.151 and 114.032 Kg CO2). Statistics tests reveal the stability of Chave et al (2005) regression model with lower differences between his standard deviation and confidences intervals (12.06; 8.34; 6.76) than Komiyama et al (2008) regression model. Beyond efforts related to reforestation project, mangrove ecosystem management must take into account the quantification of the carbon sequestered from the global carbon stock.

Numerical Simulation and Dynamical Downscaling of South Asian Monsoon precipitation

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Study of monsoon (JJA) rainfall over south Asian region, being agriculture dependent region, has paramount importance. Present study, although preliminary on dynamic long range prediction of summer monsoon (JJA) rainfall over the south Asian region could be a first step towards such valuable research by WRF-ARW model. Numerical simulation of the seasonal monsoon rainfall during June-July-August (JJA) is carried out using WRF-ARW model over the south Asian region. The NCEP/ FNL analysis data is utilized as initial and lateral boundary conditions (LBCs) at six hours intervals. The model is run for the study domain of the south Asian region and 12 separated boxes are selected representing different geographical characteristics over the eight countries (Afghanistan, Bangladesh,

Pakistan, India, Nepal, Bhutan, Sri Lanka and Maldives) for studying the monsoon precipitation. Observed rainfall of TRMM, GPCP, and CMAP are used for verifications of the simulated rainfall. Results show that in general the large scale seasonal distributions of rainfall observed by different sources are simulated fairly well by the model. However, a closer look at the time series of the simulated rainfall over smaller regions represented by different boxes over the south Asian region indicate that the model values are generally underestimated over Afghanistan, Pakistan and northwestern parts of India and overestimated in the central parts of India, Western Ghat mountains, Nepal, Bhutan, Bangladesh, Sri Lanka and Maldives. This type of research will not only help the grass-root farm worker in the field, but also to the planners for timely coping with unwanted weather generated problems. In addition, the study/research has also been carried out to understand broad characteristics of rainfall over the south Asian region.

The contribution of large urban areas to local CO2 anomalies retrieved from OCO-2 and GOSAT spaceborne observations

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Urban areas are currently responsible for nearly 70% of global CO2 emissions worldwide. Using spaceborne observations, we investigate the contribution of different urban areas to the modification in local CO2 signal. Anomalies in CO2 signal are quantified in the numerically predefined urban areas all over the world based on the CO2 measurements from OCO-2 (Orbiting Carbon Observatory) and GOSAT (Greenhouse Observing SATellite). Numerical determination of urban areas' boundaries had been performed using threshold method applied for DMSP-OLS (Defensive Meteorological Satellite Program, Operative Linescan System) night-lights observations. High agreement between CO2 anomalies in considered urban areas retrieved from two different systems is evidenced. Our results demonstrate that high CO2 anomalies are found over Northern Hemispheric urban areas (East Asia, USA, India and Pakistan), while in Southern Hemisphere urban anomalies are outweighed by strong seasonal CO2 sinks. Moreover, we identify weak positive relationship between CO2 anomalies from OCO-2 and side factors such as urban heat island temperature and population count.

Analysis of thecharacteristics of Korean precipitation variability in a changing climate.

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We study the characteristics of Korean summertime (June-July-August, JJA) precipitation variability for 1973-2016 using the daily precipitation dataset obtained from the Korea Meteorological Administration (KMA). We analyze the trend of total precipitation amount as well as its frequency at each month. We also analyze the frequency trend of daily precipitation amountlower and higher than 10%, respectively, to investigate the intensityof extreme precipitation events. In June, the total precipitation amount and its frequency decreased for the entire analyzed period. While the frequency of the precipitation lower than 10% isincreased in June, ithigher than 10% is decreased. This indicates that the decrease of total rainfall in June is mainly caused by a decrease of extreme rainfall event. The total precipitation amount, its frequency and the precipitation frequency higher than 10% precipitation is increased in Korean during July, whereas the frequency of the precipitation lower than 10% decreased. The total precipitation amount in August isincreased except for some regions of northern part of Korea, and the frequency of total precipitation increased especially in southern part of Korea. The frequency of the precipitation lower and higher than 10% decreased in the northern part and increasing at southern part of Korea, which is in contrast to the southern part of Korea. We also used the hourly precipitation dataset to examine the changes in the frequency of consecutive precipitation hours in climatological Changma-period. It is found that the frequency of rainfall event with a short time period is gradually increasing, in contrast, the frequency of rainfall event with a long time period is decreased after the mid-1990s.

Understanding the mechanisms leading to pure Extreme heat and Tropical night in Korea.

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In this study, it is found that the atmospheric fields leading to pure extreme heat (hereafter, pure-EH) and pure tropical night (hereafter, pure-TN) in Korea are different. We compare with anomalous atmospheric fields in pure-EH and pure-TN, respectively. When the pure-EH occurs, the sky condition is clear with a dry and barotropic structure of anomalous high geopotential height over Korean peninsula. Whereas, when the pure-TN occurs, the sky condition is cloudy with a humid and baroclinic structure of anomalous high or weak geopotential height. It is also found that the pure-EH is mainly induced by incoming shortwave radiation, which is in contrast in the pure-TN. We suggest that there are different mechanisms leading to pure-EH and pure-TN in Korea.

Long-term change of the tropical cyclone tracks and potential impacts over the southern region of Vietnam

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Vietnam is considered as one of the countries most affected by climate change. Over the past several years, tropical cyclones (TCs) generated from the South China Sea have increased and more landfall over Vietnam causing socio-economic damage and negative impacts on environment. There are many previous studies on TC activity and its impacts in the central part of Vietnam, while the southern region has been received little attention despite high vulnerability of this area. This is due to several factors: population density is very high along the coastal region and the public awareness on disaster impacts is quite low. Furthermore, the main seasonal rice crop is the same time with winter monsoon period and TC season over this region.

In this study, the historical data of TCs with their tracks and intensity for last 50 years including the International Best Track Archive for Climate Stewardship (IBTracks) and one from the Joint Typhoon Warning Center (JTWC) is analyzed to find the seasonal and interannual variations of TCs affecting the southern part of Vietnam. This information will be used as the base for any mitigation and adaptation.

The impact of urbanization in Beijing area to local ecosystem

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Urbanization makes distinct contributions to regional climate change and urban ecosystem alteration. With the accelerative urbanization occurred in China embodied with population growth and urban area expansion over the past few decades, studying the impact of urbanization on local ecosystem makes great sense to predict the future ecosystem alteration and stabilization. This study described the impact of urbanization on spring and autumn phenology in Beijing and Chengde, two cities near with each other in north China during 1986-1996. Three types of phenophase, first leaf date (FLD), first flowering date (FFD) and first coloring data(FCD) of five plant species (e.g., Robinia pseudoacacia, Amygdalus daviana, Syringa oblate, Sophora japonica, and Ulmus pumila) were analyzed in this study. The results shows that there are obvious gap between the phenology date in these two different cities because of latitude difference. However, the spring phenology date in Beijing has very distinct tendency to advance during this decade, comparing with those in Chengde which was not developed so much as Beijing. Besides, the autumn phenology date didn't show obvious difference in 10-year tendency. Our results suggest that, high level of urbanization has stronger impact on spring phenology than autumn phenology.

On the utility (or futility) of using stable water isotopes to study convection

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Atmospheric water-vapor isotopes have been proposed as a potentially powerful constraint on convection, which plays a critical role in Earth's present and future climate. It is shown here, however, that the mean tropical profile of HDO in the free troposphere does not usefully constrain the mean convective entrainment rate or precipitation efficiency. This is demonstrated using a single-column analytical model of atmospheric water isotopes. The model has three parameters: the entrainment rate, the precipitation efficiency, and the distance that evaporating condensates fall. At a given relative humidity, the possible range of HDO is comparable to both the measurement uncertainty in the mean tropical profile and the structural error of a single-column model. Therefore, the mean tropical HDO profile is unlikely to add information about convective processes that cannot already be learned from relative humidity alone.

Linking meteorological drivers of spring-summer drought regimes to agricultural drought risk in China

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China has experienced frequent severe droughts in recent decades, with the frequency and severity of these droughts projected to increase further under climate change. An understanding of the physical processes that contribute to extreme droughts is essential for seasonal forecasting, but the dominant physical mechanisms responsible for droughts in most parts of China are still unclear. Moreover, despite numerous studies on droughts in China, there are few clear connections between meteorological and climatological drivers of drought and the associated agricultural consequences. The objectives of this study are (1) to identify robust spring-summer drought regimes over China, (2) to investigate physical mechanisms associated with the development of each regime, and (3) to better clarify connections between meteorological drought regimes and agricultural drought risk. First, we identify six recurrent precipitation regimes over China by applying an area-weighted k-means clustering technique to spatial patterns of spring–summer Standardized Precipitation Index (SPI) in the ten-member ERA-20CM ensemble for 1900–2010. Second, we project these precipitation regimes onto agricultural drought risk and harvest area maps for the three main cereal crops (rice, maize, and wheat) in China. Three of the recurrent precipitation regimes are identified as corresponding to agricultural drought. Third, the physical mechanisms and meteorological context behind each drought regime are investigated. This work provides a new approach to diagnosing the physical mechanisms behind agricultural drought impacts. The results could help to improve seasonal drought prediction and water management practices in China.

Regional climate response to aerosol versus greenhouse gas forcing

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We compare the effects of greenhouse gases (GHGs) and anthropogenic aerosols (AERs) on the regional climate changes, in particular 31 regions covering all land and ocean areas in the world. The long-term trends of JJA (June-July-August) and DJF (December-January-February) surface air temperature (SAT) from 1951 to 2005 are evaluated for single forcing experiments of eight models that are archived for the Fifth Coupled Model Inter-comparison Project (CMIP5). Both the multi-model ensemble mean (MMM) and inter-model spread are evaluated. The MMM trends typically show the GHG-induced warming and AERinduced cooling in all regions with smaller inter-model and inter-region spreads in JJA than DJF. Generally, the regions with stronger GHG-induced warming trends show the stronger AER-induced cooling trends. Both warming and cooling trends are amplified particular in the Northern Hemisphere high-latitude regions (e.g., Arctic Ocean, Alaska, and Greenland) during DJF. Notable exceptions are Northern Europe and North Asia. In these regions, only a significant GHG-driven warmings are evident. Southeast Asia is one of the most insensitive regions in response to the anthropogenic forcing. The SAT trends over the oceans are generally weaker than those over the land, in particular the Southern Pacific and Southern Ocean show the smallest value of trends.

Assessment of SST variabilities in association with Climate Change

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Climate change and global warming have tremendous consequences for humans. Melting glaciers, rising oceans level, droughts, storms and prevalence of diseases are just some of the challenges that climate change will bring them. This study investigated the temperature changes of sea level in the 40 °W to 70 °E longitudes and latitudes 0 to 90 °N. For this purpose, the monthly average SST data for the statistical period 1948-2013 were obtained from NCEP/NCAR database. And then, by calculating the anomalies and using the Rodionov's regime shift detection method, changes in SST were identified and analyzed. The results of the Rodionov method, showed 4 regimes for SST in the studied area (1948-1963, 1964-1986, 1987-1996, and 1997-2013). Which based on absolute changes to positive numbers, they can divided into two larger periods (the colder period of 1948-1994 and the warmer period 1995-2013). So, the year of 1995 can be considered as the year to begin the continuous heating of SST. Also the results showed that the annual average of SST in the colder period (1994-1998) was -0.13 °C less than the average of the whole period (66 years), while in the warmer period (1995-2013), it was 0.31 °C above the average of whole period. Thus, the SST in the second period increased by 0.44 °C. Furthermore, The study of monthly temperature and temperature changes in SST in the study area showed that, during the statistical period of 66 years, the months of August and October had the most temperature changes, so that from 1948 to 1994, The temperature of these two months was -0.15 °C than the average of the whole period (66 years), while in second period (1995-2013) they respectively were changed to 0.38 and 0.37 °C above the mean of the whole period. So the August and October in the second period (warmer period) respectively experience an increase by 0.53 and 0.52 °C. And September and July, with a total change of 0.50 and 0.47 °C were in the next ranks of the most-affected months. February and March in the period 1948-1994 (colder period) were respectively -0.11 and -0.10 °C below the average of the whole period and 0.25 °C above the average of whole period in the period 1995-2013 (warmer period). Which in total these two months in the second period, respectively, had an increase by 0.36 and 0.35 °C, that they located in the first and second ranks of the month with the lowest temperature variation at SST of the study area. The months of January and April, with the total change of 0.37 and 0.38 °C, were in the next ranks of the months with the smallest changes in SST.

Understanding a role of internal variability on the increase of global mean surface temperature in a warming scenario.

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It is important to understand which factors are associated with an increasing rate of global mean surface temperature (GMST) in a warming climate. In this study, we analyze the Community Earth System Model Large Ensemble (CESM-LE) dataset under Representative Concentration Pathway (RCP) 8.5 (30-ensemble member) and 4.5 scenarios (15-ensemble member), respectively. Obviously, the linear trend of GMST is larger in the RCP8.5 than that in the RCP4.5 until the period when the ensemble mean GMST in both RCPs reaches to 2˚C. In addition, it is found that the trend of GMST simulated in the RCP8.5 is larger in the Northern Eurasia than that in the RCP4.5, however, it is larger in the RCP4.5 in the Arctic ocean than that in the RCP8.5. This indicates that there is a regional difference in a warming pattern in the RCP8.5 and RCP4.5 in the period when the GMST reaches to 2C. To examine the details, we further analyze how internal variability, which is defined as the major variability of GMST deviated from the ensemble mean surface temperature, is associated with such a difference.

Impacts of urban air conditioning on urban heat island over the northern hemisphere in summer

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In summer season, heat flux from air conditioning of building in one of major source of the urban heat island (UHI), which effects on local urban climate. In recent decades, the air conditioning heat flux is significantly increased due to both rapid urbanization and economic growth. As the global mean temperature increases, in addition, cooling demands over urban area are projected to increase continuously. However, the impacts of increasing air conditioning heat flux on UHI and local climate are remained unclear despite numerous impacts of urban climate changes on residing people in urban area. In this study, the potential impacts of air conditioning on UHI and local climate in warmer climate are investigated based on coupled atmosphere-land model with modified parameterizations of urban air conditioning. The air conditioning heat flux are signified over India due to both high urban fractions and efficiency of thermal conduction. As concentration of carbon dioxide is increased, increasing air conditioning heat flux increase the strength of UHI by more than 20%. Present study suggest that increasing demands of urban air conditioning should be considered for better projection of future climate.

A Climatology of Northern Hemisphere Blocking in CESM Large Ensemble simulations

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The Northern Hemisphere (NH) blocking and its future change are investigated using forty ensemble simulations of Community Earth System Model (CESM). The historical simulations qualitatively reproduce the spatial distribution of NH blocking frequency. However, ensemble spreads are substantially large with significantly underestimated Euro-Atlantic (EA) blockings but overestimated North Pacific (PA) blockings. These dipolar biases, which are largely associated with the model mean biases, are remarkably similar to those in climate model simulations archived for the Coupled Model Inter-comparison Project phase 5 (CMIP5). The future climate simulations, driven by Representative Concentration Pathway 8.5 (RCP 8.5) scenario, further reveal that overall blocking frequency may decrease in a warm climate. Such a decline is hinted for PA blocking in all duration categories, whereas decrease in EA blocking mainly appears in relatively short-lived events. A clear exception is the western Russia where blocking frequency is projected to increase in a warm climate, possibly due to the Arctic sea ice loss. This result, which is particularly robust in cold season, is consistent with previous studies on the CMIP5 models.

Developing observational data sets for assessing and validating climate models

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Different observations-based data sets have been created by the group at Bodeker Scientific to assess and validate the performance of New Zealand's Earth System Model (NZESM) with a particular focus on NZESM's ability to simulate the effects of southern middle and high latitude climate change on the climate of New Zealand. These data sets include:

- Daily global total column ozone maps at 1.25° longitude and 1° latitude resolution from 1 November 1978 to 31 December 2016. This database has also been provided to many international research groups and will be used in the forthcoming 2018 WMO/UNEP Ozone Assessment.
- Monthly mean zonal mean vertically resolved ozone fields in 5° latitude zones and on 70 pressure/altitude levels extending from 1979 to 2016.
- Daily, monthly and annual mean climatologies of cloud fields over southern middle and high latitudes derived from the ISCCP (International Satellite Cloud Climatology Project) data set.
- An easily accessible reference database of daily high vertical resolution temperature profiles from high southern latitude sites, each for at least 10 years, for use in boundary layer height analysis.
- An easily accessible database of aerosol measurements time series from southern middle and high latitude sites, each for at least 10 years.

This presentation will describe the construction of these data sets.

Change in trend of Hadley circulation after 2000 Author(s) and affiliation:

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The annual mean strength and width of the Hadley circulation (HC) are examined using various datasets including reanalysis datasets, CMIP5 and CCMI outputs. In several reanalysis datasets, there is a positive trend in the HC strength after 2000 and a negative trend in the HC width. However, opposite trends in HC strength and width are found in both multi-mean CMIP5 historical experiments and multi-mean CCMI ODS-fixed experiments. The trends in the HC strength and width are closely related to the tropical tropospheric meridional temperature gradient changes. The anti-correlation between the HC strength and width can be explained by the energy changes associated with Hadley cell.