SPARC Local Workshop on “WCRP Grand Challenges and Regional Climate Change”

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1. Overview

SPARC (Stratosphere–Troposphere Processes and their Role in Climate) is one of the core projects of the World Climate Research Program (WCRP), coordinating international efforts to address relevant issues in climate and climate prediction via better understanding of the stratosphere–troposphere system. SPARC is a broad umbrella body that supports many scientific activities solving environmental issues, such as atmospheric dynamics and predictability, chemistry and climate, and long-term records for understanding climate. Much of the scientific activity of SPARC is directly linked to the WCRP’s “grand challenges”, particularly the issues of “Clouds, Circulation and Climate Sensitivity”, “Weather and Climate Extremes”, “Near-term Climate Prediction”, “Carbon Feedbacks in the Climate System”, and “Melting Ice and Global Consequences”.

A SPARC local workshop was held at the Korea Polar Research Institute, 18–20 October 2017, in Incheon, South Korea, focusing on “WCRP Grand Challenges and Regional Climate Change” to promote international collaboration on these issues. This SPARC-sponsored workshop aimed at not only international collaborations with Asian scientists, but also capacity development for SPARC-related activities in Asia. Active discussions among 79 scientists and students from 10 different countries (Fig. 1) filled the workshop and sessions of various SPARC and SPARC-related research topics on stratosphere–troposphere coupling, atmospheric composition, Arctic climate, and climate change and variability. We briefly describe them below.

2. Stratosphere–troposphere coupling

2.1 Predictability

The importance of stratosphere–troposphere coupling for

sub-seasonal-to-seasonal prediction has been widely recognized. The workshop opened with an examination of predictability issues, presented by In-Sik KANG, who investigated the role of the stratosphere in the boreal-winter seasonal prediction. He proposed that the stratospheric “memory” could be a potential source of predictability in the tropics and the Pacific–North American regions and that seasonal forecasting could be significantly improved during boreal winter by adding information on sea surface temperature and the stratosphere. Harry HENDON discussed the impact of stratosphere–troposphere coupling and seasonal prediction by focusing on the Southern Hemisphere. He reviewed the coupling processes and showed how the prediction skill of an Australian seasonal prediction model could be improved. Moreover, Yuna LIM presented the effect of the quasi-biennial oscillation (QBO) on the wintertime Madden–Julian oscillation (MJO), including its predictability. She showed that the enhanced MJO prediction during the easterly phases of the QBO, highlighting that the QBO could be a predictability source of the MJO. However, the mechanism of the QBO–MJO relationship remains an open question. Relating the issues, Shigeo YODEN introduced an emerging SPARC activity that aims to improve knowledge on the stratosphere and troposphere influences on tropical convective systems (referred to by the acronym SATIO-TCS). He discussed the stratospheric influences on multi-scale processes in tropical convection.

2.2 Dynamical processes

Dynamical processes of stratosphere–troposphere coupling, especially over the extra-tropical region, were presented and discussed. Mainly, the participants discussed the strength of the coupling and detailed mechanisms in various atmospheric conditions. Andrew CHARLTON-PEREZ presented a regime behavior of the stratosphere–troposphere coupling in the North Atlantic. He showed that the negative phase of the North Atlantic Oscillation appeared more persistently during periods of weak stratospheric winds. Patrick

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Fig. 1. The participants of the SPARC local workshop gathered in the presentation room in KOPRI (photographed by Hye-Rim JUN).

MARTINEAU used a series of idealized model simulations to show that stratospheric variability, including sudden stratospheric warming (SSW), was sensitive to the temperature structure in the lower stratosphere. Kanghyun SONG presented on the impact of the El Niño–Southern Oscillation on SSW and analyzed seven different SSW definitions that had previously been proposed in the literature. Many of these SSW definitions exhibited an increase in the frequency of occurrence during El Niño, whereas consistent change was lacking across the definitions during La Niña. Additionally, Judith PERLWITZ discussed the relationship between the QBO and polar vortex (Holton–Tan effect) using historical simulations of a 10-member ensemble. The ensemble mean presented a reasonable Holton–Tan effect, but significant variations were found across the members, mainly during the easterly phase of the QBO. This uncertainty turned out to be related to different frequencies of occurrence of SSW in each member.

In the following session, a series of studies on gravity waves was presented and discussed. Hye-Yeong CHUN summarized characteristics of convective gravity waves and their roles in driving the large-scale circulation in the mesosphere, the Brewer–Dobson Circulation, and the QBO. She also discussed issues on satellite-based analysis and parameterization. Min-Jee KANG further demonstrated spatiotemporal structures of the convective gravity waves in reanalysis data and off-line gravity wave parameterizations. Byeong-Gwon SONG presented observed characteristics of gravity waves. He discussed activities of gravity waves in the upper mesosphere, observed at King Sejong Station in Antarctica.

3. Atmospheric composition

3.1 Ozone

The importance of ozone in the upper troposphere and lower stratosphere (UTLS) was highlighted in the atmospheric composition session. Joowan KIM presented a warm bias in the tropical UTLS, found in many of the histori-

cal simulations that participated in phase 5 of the Coupled Model Intercomparison Project (CMIP5). By comparing the ozone forcing data of CMIP5 with observation, he suggested that the warm bias could originate from the ozone bias near the tropical tropopause. Yan XIA also discussed that UTLS ozone could cause a global-scale radiative impact by changing the distribution of high clouds and stratospheric water vapor. Switching the topic to new measurements, Larry THOMASON introduced the essential features of the third Stratospheric Aerosol and Gas Experiment (SAGE III) instruments onboard the International Space Station in February 2017. He discussed scientific opportunities from the newly available datasets (ozone, stratospheric water vapor, and aerosol extinction). Gufran BEIG, who comprehensively examined issues on the long-term temperature trend of the middle atmosphere, described the impact of ozone recovery in the stratosphere.

3.2 Chemical transport

Chemical transport processes were demonstrated and discussed, with a focus on tropospheric and troposphere-to-stratosphere transport. Laura PAN addressed coupling processes between the Asian monsoon and regional transport processes. She also introduced new SPARC activity on atmospheric composition and the Asian monsoon (referred to by the acronym ACAM), emphasizing the importance of research collaborations to improve our understanding on the impacts of the Asian monsoon on regional air quality and climate-relevant stratospheric composition changes. Mijeong PARK explored the effect of recorded fires in Indonesia on the stratosphere. She demonstrated the transport of carbon monoxide emitted from these fire events into the lower stratosphere. Evident chemical transport to the stratosphere was found not only in satellite measurements but also in chemistry–climate model simulations. Fahim KHOKHAR discussed the long-term change and variability of short-lived climate pollutants and their impacts on health and agriculture in Pakistan. He also reported an increasing trend in methane in the same regions.

4. Arctic climate

4.1 Arctic processes

Studies on Arctic processes and their global impacts also received attention at the workshop. Su-Jong JEONG presented his recent research on the Arctic carbon cycle, based on long-term CO₂ observations at Barrow, Alaska. He suggested that the Arctic carbon cycle has accelerated in the North Slope tundra area of Alaska, and that carbon released in the cold seasons could continue to exceed the carbon uptake during the growing season under warming conditions. The influence of atmospheric circulation on Arctic sea ice was discussed by Ha-Rim KIM, who explored the role of poleward moisture transport in increased downward infrared radiation and surface air temperature over the Arctic and its linkage with the Barents oscillation. Seungmok PAIK discussed possible causes of the recent record-breaking sea-ice loss in 2015. He mainly focused on sea-ice loss in the Sea of Okhotsk and attributed it to anthropogenic forcings and the negative phase of the North Pacific Oscillation. Mee-Hyun CHO emphasized the importance of measuring anthropogenic black carbon emitted from gas petroleum activity in the high latitudes by proving that it could accelerate Arctic warming through an increase in net incoming radiation.

Internal processes of the Arctic climate system were also discussed. Joo-Hong KIM examined the thermal evolution of melt ponds on sea ice and the role of salinity in the thermal process using in-situ observations in the East Siberian Sea. He showed that salinity significantly modulated the heat transport process in melt ponds, highlighting the importance of internal heat transfer dynamics and the salinity data of melt ponds in the Arctic.

4.2 Interaction with midlatitudes

The Arctic–midlatitude connection, focusing on winter-time climate, was discussed. Jinro UKITA reviewed the Arctic–midlatitude climate linkage using a set of general circulation model experiments and reanalysis data. He analyzed atmospheric responses to Arctic sea-ice loss and showed that the sea-ice loss in early winter resulted in increased poleward eddy heat fluxes and upward propagation of planetary-scale waves. This process induces the frequent breakdown of the stratospheric polar vortex and feeds back to the midlatitude troposphere in late winter. He added discussion on data uncertainty issues in Arctic research. Jiankai ZHANG presented the effect of sea-ice-induced planetary-scale waves on stratospheric circulation. He explained that recent sea-ice loss likely pushed the stratospheric polar vortex toward the Eurasian continent. Additionally, Hye-Jin KIM examined the relationship between sea-ice loss in the Barents–Kara seas and surface air temperature in Eurasia using statistical methods. She showed a significant covariability between the sea-ice loss and cold air temperature over Eurasia (which we know as the “warm Arctic–cold continent” pattern). Her results were consistent with the above two presentations.

5. Regional climate change and variability

Lastly, various subjects on climate change and variability were discussed. For the stratospheric effect on extratropical climate, Wen CHEN reviewed the processes of stratosphere–troposphere interaction during boreal winter and their impacts on cold extremes in East Asia. He suggested that the time scale of downward propagating stratospheric events was longer than that of non-downward events, emphasizing the importance of the stratospheric impact for understanding regional climate variability. Moreover, Yueyue YU examined the stratospheric northern annular mode in the context of mass circulation and proposed a stochastic model that explained low-frequency amplification feedback in the high-latitude region.

Switching topics to hydrology, Jinwon KIM presented the global features of atmospheric rivers and their impacts on wintertime precipitation over the western United States. Anu XAVIER introduced the roles of the Indian summer monsoon on regional circulation and heavy rainfall over India. She highlighted the role of the monsoon low-level jet in modulating extreme rainfall events in this region. Chang-Eui PARK discussed the issue of emerging aridification in a warming climate. He argued that limiting global warming to $\sim 1.5^{\circ}\text{C}$ above the pre-industrial level could notably reduce the emergence of aridification.

6. Summary

Through this two-and-a-half-day workshop, the participants discussed and shared important scientific issues and findings in SPARC and WCRP grand challenge activities. Some of the key issues can be summarized as follows:

(1) In terms of stratosphere–troposphere coupling, participants actively discussed the dynamical behavior of the coupled stratosphere–troposphere system and its applications for seasonal and sub-seasonal predictions. In the tropics, the QBO–MJO relationship earned attention, while its physical mechanisms remain to be clarified.

(2) Regarding atmospheric composition, participants highlighted the potential roles played by UTLS ozone in stratospheric water vapor and the global radiation budget. International collaboration was encouraged to better understand the transport processes in the Asian monsoon.

(3) Arctic processes were an important topic of discussions at the workshop. A series of presentations reported robust midlatitude influences from Arctic sea-ice loss, and participants shared issues and ideas in Arctic research. In particular, the interactions between sea ice, planetary waves and stratospheric circulation remain to be better understood.

The workshop presentations and discussions provided an updated picture of SPARC and WCRP research. They also contributed to identifying and sharing critical scientific issues in SPARC research with relevance to Asian countries. A half-day symposium for early career researchers (ECR symposium), organized as a half-day pre-workshop session in the afternoon of 18 October prior to the SPARC local workshop,

provided ECRs with the chance to learn from a series of invited lectures from distinguished SPARC scientists and to share their research. In 2018, the SPARC General Assembly will be held during 1–5 October 2018 in Kyoto, Japan.

This workshop was organized by Seok-Woo SON (Seoul National University, Korea), Gufran BEIG (Indian Institute of Tropical Meteorology, India), Kaoru SATO (University of Tokyo, Japan), and Tianjun ZHOU (The State Key Laboratory of Numerical Modelling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, China). Local organizers were Baek-Min KIM (Korea Polar Research Institute, Korea), Yu-Kyung

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