WCRP/SPARC SATIO-TCS joint workshop on Stratosphere-Troposphere Dynamical Coupling in the Tropics

Shigeo Yoden[1], Peter H. Haynes[2], Peter Hitchcock[3], Matthew H. Hitchman[4], Tieh-Yong Koh[5], Takatoshi Sakazaki[1], Sourabh Bal[6], and Achmad Fahrudin Rais[7]

[1] Kyoto Univ., Japan, (**yoden.shigeo.53r@st.kyoto-u.ac.jp**); [2] Univ. of Cambridge, UK; [3] Cornell Univ., USA; [4] Univ. of Wisconsin-Madison, USA; [5] Singapore Univ. of Social Sciences, Singapore; [6] Swami Vivekananda Inst. of Science & Technology, India; [7] Indonesian Agency for Meteorology, Climatology and Geophysics, Indonesia.

Date: 21-25 February 2020

Number Of Participants: **57**

Organising Commitee:

Shigeo Yoden (Kyoto Univ.), Peter H. Haynes (Univ. of Cambridge), Peter Hitchcock (Cornell Univ.), Matthew H. Hitchman (Univ. of Wisconsin-Madison), Tieh-Yong Koh (Singapore Univ. of Social Sciences), Takatoshi Sakazaki (Kyoto Univ.)

Host Institution:

Seminar House of Graduate School of Science, and Raku-Yu Kaikan, Kyoto University, Kyoto, Japan

Sponsors:

Background:

SATIO-TCS (Stratospheric and Tropospheric Influences On Tropical Convective Systems) is a SPARC activity focussed on enhancing our understanding of the coupling between stratospheric processes and tropospheric convective systems, particularly in the tropics.

Workshop Webage:

www-mete.kugi.kyoto-u.ac.jp/Kyoto2020/

Activitiy webpage:

www.sparc-climate.org/activities/satio-tcs/

A five-day joint workshop on the stratosphere-troposphere dynamical coupling in the tropics was held in February 2020 at Seminar House of Graduate School of Science, and Raku-Yu Kaikan, Kyoto University, Kyoto, Japan. There were 57 participants, including 21 from abroad, even though over 10 people had registered but could not come to Kyoto due to the influence of the COVID-19 pandemic. (If the meeting had been in March, we would have not been able to hold it because of the rapid worsening of the situation.)

The workshop was organised as part of SATIO-TCS, which is an international research activity under WCRP/SPARC focussing on stratosphere-troposphere coupling both upward and downward in the tropics associated with moist convection and its organized systems (see Figure 3). There is an increase in reports of observational evidence that stratospheric variations, such as sudden stratospheric warming (SSW) events, the equatorial quasi-biennial oscillation (QBO), the 11-year solar cycle (SC), and the anthropogenic cooling trend (CT) in the lower stratosphere, influence tropospheric variations in the tropics by modulating moist convection and its large-scale organization into meso-to-planetary-scale systems, in addition to diurnal and annual responses of the atmosphere to the periodic solar forcings. Such multi-scale interactions cover a wide range of space- and time-scales, including phenomena ranging from convective plumes, mesoscale moist convective systems, their diurnal variations, tropical convective clusters, tropical cyclones (TCs), intraseasonal variability (*e.g.*, the Madden-Julian Oscillation; MJO), monsoon as the seasonal variations, interannual variations like El Niño Southern Oscillation (ENSO) and decadal variations, to long-term change due to anthropogenic and natural forcing (*e.g.*, major volcanic eruptions). Some global general circulation models (GCMs) and regional cloud-resolving models show similar features as these observations, but such modelling studies are still in a rather preliminary state. Tropical stratosphere-troposphere coupling may play a significant role in long-term climate change and might also be exploited in sub-seasonal and seasonal weather prediction.

The Kyoto workshop not only covered stratosphere-troposphere dynamical coupling in the tropics, but also teleconnections to the extratropics, and was jointly organized with:

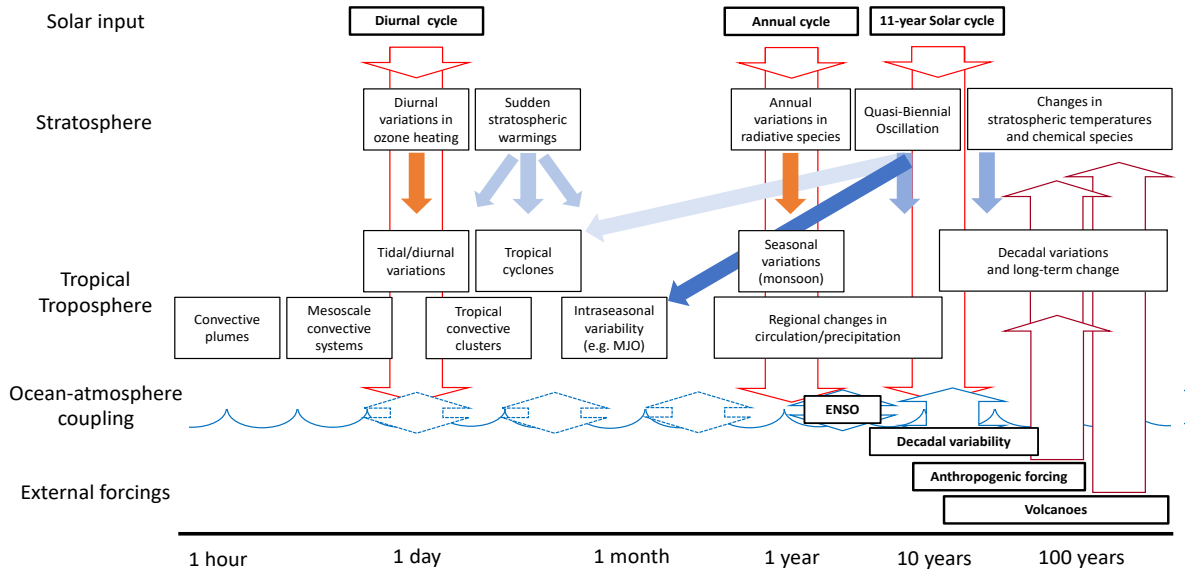

Figure 3: *Stratospheric and tropical tropospheric processes on different timescales and possible couplings between them indicated by red (periodic response to solar forcings) and blue (responses on other timescales) arrows. Darker blue indicates coupling that has been clearly identified from either observations or models, lighter shades indicate coupling for which some evidence exists but which are still subject to uncertainty. (Haynes et al., 2020)*

Years of the Maritime Continent (YMC), Project for solar-terrestrial environment prediction (PSTEP), JSPS KAKENHI "Stratosphere-troposphere dynamical coupling in the tropics", JSPS-DG-RSTHE of Indonesia Bilateral Joint Research Project "Scientific research on extreme weather in changing climate in the Maritime Continent and its societal application". Two-day core sessions were planned for the latest results of observations and data analyses, numerical experiments, and theoretical studies on the stratosphere-troposphere dynamical coupling in the tropics, with further sessions included on some specific subjects related to the influences of solar activity variations on weather and climate, and the implications for extreme weather and climate in the Maritime Continent under the scope of stratosphere-troposphere dynamical coupling.

A detailed account of the talks and posters presented at the workshop is set out below. There have been several interesting developments since the introductory workshop on this topic held in Kyoto in October 2015 (Geller *et al.*, 2017), including further model studies of QBO-MJO connections, of possible effects of SSWs on the tropical troposphere and of the effect of tropopause temperature structure on the intensity of tropical cyclones.

Stratosphere-troposphere dynamical coupling in the tropics

The workshop was opened by **Peter Haynes**, who provided a review of stratosphere-troposphere coupling in the tropics, including current observational and modelling evidence for coupling from the stratosphere to the tropical troposphere, the current understanding of potentially relevant mechanisms for communication and for feedbacks with the troposphere, and the possible implications of the coupling for weather and climate prediction (Haynes *et al.*, 2020). The impact of an SSW through dynamically induced tropical stratospheric cooling that further triggers deep convective activity in the troposphere was shown by **Kunihiko Kodera**. **Nawo Eguchi** used NICAM (Nonhydrostatic ICosahedral Atmospheric Model) to study enhanced deep convection and TCs over the southwestern Indian Ocean and the southwestern Pacific Ocean during the SSW event in January 2010. Further, results of the examination of the impact of the stratospheric circulation changes related to SSW on the tropical troposphere was presented by **Kohei Yoshida**, who used 5,000-year ensemble simulations with a 60 km horizontal resolution global atmospheric model MRI-AGCM3.2.

A comparison of the representation of the semi-annual oscillation (SAO) in the equatorial stratosphere and lower mesosphere among six major global atmospheric reanalysis datasets was shown by **Yoshio Kawatani**. The climatology of residual mean meridional circulation – a main component of the Brewer–Dobson circulation – and the potential contribution of gravity waves (GWs) for the annual mean state and each season in the whole stratosphere based on the transformed-Eulerian mean zonal momentum equation were examined by **Kaoru Sato** using four modern reanalysis datasets.

Masato Shiotani explained his proposal about Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES-2) satellite observation to obtain global information with unprecedented accuracy on the whole atmosphere including upper mesosphere and lower thermosphere.

On the second day, **Matt Hitchman** gave a historical review on the downward influence of the QBO on the tropical and subtropical troposphere based on observational studies (Hitchman *et al.*, 2020). **Chidong Zhang** tested the hypothesis that the static stability near the tropopause can be modulated by the temperature perturbations of the QBO through diagnosing precipitation changes between QBO easterly and westerly phases as a function of the cloud-top height. A set of GCM experiments in which the model's stratospheric winds are nudged to observations in order to ensure a better representation of the QBO in the tropopause region were described by **Zane Martin**. **Hyemi Kim** (presented by I. Simpson) assessed the representation of this connection in 29 models participating in the Coupled Model Intercomparison Project 6 (CMIP6) in capturing the observed QBO-MJO connection. The role of tropical stratospheric zonal winds on QBO influences on the Arctic-midlatitude linkage and sea-ice were studied by **Jinro Ukita** using reanalysis data.

Isla Simpson used 20-member ensemble simulations of CESM-WACCM with greenhouse-gas driven warming, under a high emissions scenario, to understand dynamical response to tropical lower stratospheric heating in the context of stratospheric sulfate geoengineering. Anticyclonic Rossby wave gyres that form near the tropopause due to equatorially-symmetric Matsuno-Gill heating provide a mechanism to influence tropical and subtropical atmospheric chemistry, as shown by **Catherine Wilka**. **Suhas Ettammal** showed the relationship between the strength of convectively coupled mixed-Rossby-gravity waves and troposphere-stratosphere coupling based on ERA-Interim data.

A three-dimensional minimal model that produces a self-sustained oscillation reminiscent of the QBO in a radiative–moist convective quasi-equilibrium state was presented by **Shigeo Yoden**, who showed the influence of QBO-like oscillations on the aggregation of moist convective systems. **Tieh-Yong Koh** reported the universal scaling characteristics of rain cluster distribution which favours a hypothesis coined as self-organized criticality (SOC) of organized rain clusters over tropical oceans, while **Takatoshi Sakazaki** identified the theoretically expected high-frequency global normal modes in the atmosphere with the use of newly-available ERA5 hourly global reanalyses dataset.

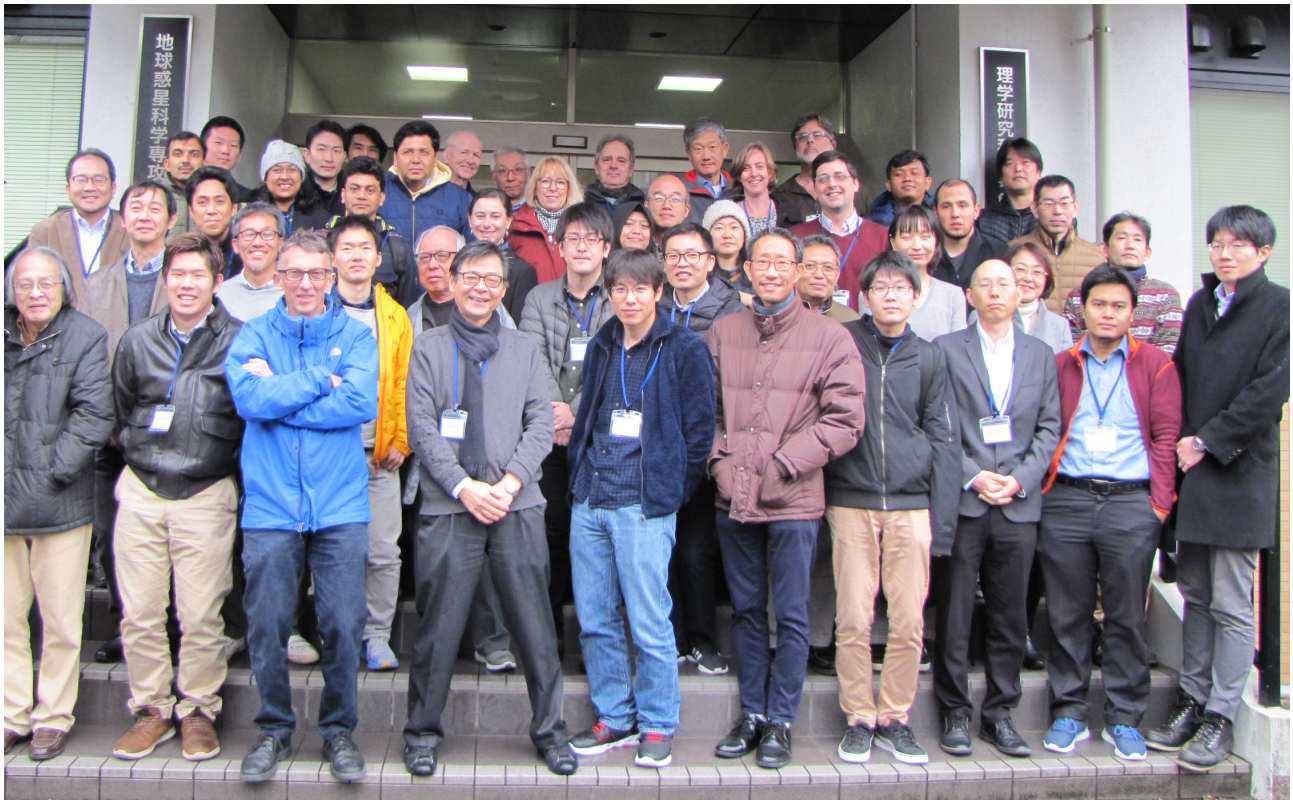

Figure 4: *Workshop participants at the Department of Geophysics, Kyoto University.*

Poster session I

Poster presentations showed the variable influence of stratospheric vortex splits on the equatorial troposphere (**Sourabh Bal**), the signature of strong meridional coupling between polar and tropical regions due to SSW events during 2007-2017 (**Surendra Dhaka**, presented by V. Kumar), and modelling studies of the response of tropical lower stratospheric circulation and convective systems to the 2019 SSW event in the Antarctic Stratosphere (**Shunsuke Noguchi**). Further, topics included the downward propagation of planetary wave packets to the troposphere during the Northern Hemisphere (NH) Winter (**Yuya Matsuyama**), the climatology of traveling and stationary planetary waves in the NH winter middle atmosphere (**Koki Iwao**), the evaluation of the QBO's impact on the NH winter stratospheric polar vortex in CMIP5/6 models (**Jian Rao**), and descriptions of the 3D structure and formation of UTLS jetlets associated with potential vorticity dipoles in TCs (**Matt Hitchman**), and of the the response of the tropical troposphere to SSWs in simulations previously used to study the extratropical response (**Peter Haynes**). Other presentations focussed on the remote influences of the QBO on the troposphere with a composite difference analysis (**Vinay Kumar**), the possible mechanisms of QBO and ENSO influence on the MJO-induced Rossby wave train (**Lon Hood**), and the downward extension of QBO-related zonal wind anomalies to the troposphere (**Masakazu Taguchi**). Furthermore, insights were given on the evaluation of the QBO effects on ENSO teleconnections and the Walker circulation (**Jorge Garcia-Franco**), as well as results from MIROC Models with and without non-orographic GW parameterization to examine the ENSO modulation of the QBO (**Yoshio Kawatani**) and the influences of the SC and the QBO on the NH winter polar vortex (**Yusuke Aimono**).

Influences of solar activity variations on weather and climate

Lon Hood presented evidence that the 27-day solar oscillation has an influence of UV spectral irradiance variations on both tropical tropospheric temperature and the occurrence rate of MJO events in boreal winter. He also reported the influence of SC on MJO occurrence rate. **Yuhji Kuroda** explained that solar related North Atlantic Oscillation (NAO) signal tends to peak in February of solar maximum year, but it also tends to show long-term drift with lags of few years. A study on the relationship between oxygen isotope variations in an ice-core from Dome-Fuji as a temperature proxy with solar activity and oceanic variations, with 10-year and 20-year periodicitieswas presented by **Yuko Motizuki**. The 10-year periodicity correlate significantly well with the SC when the solar activity is strong.

Yousuke Yamashita reported the outcome of numerical experiments which simulate the negative anomalies of total ozone in Arctic spring in the QBO-West phase of solar minimum years, largely due to the transport effect. Results from using a chemistry-climate model under the potential of Grand Solar Minimum (GSM) scenarios to counter the climate change by projected anthropogenic greenhouse gas emissions through the 21st century were presented by **Ulrike Langematz**. Under the influence of a GSM, they found a less pronounced warming in the eastern part of the Pacific Ocean and enhanced longitudinal temperature and pressure gradients, accompanied by stronger easterlies and an overall stronger Walker Circulation. **Yvan Orsolini** reviewed on the solar impacts on climate through energetic particle precipitation (EPP) in the mesosphere and lower thermosphere. He emphasized a role of EPP in explaining the lagged response of the NAO to the SC. **Tobias Spiegl** presented about modelling the transport and deposition of 10Be produced by the strongest solar particle event during the Holocene. The result agrees well with the proxy reconstructions, and the timing of the event in NH spring is most robust in their model simulations.

Extreme weather and climate in the Maritime Continent

Kunio Yoneyama reviewed the typical features from ocean surface to the stratosphere observed during YMC intensive observation periods. He also added that the measuring campaign for 2020 will focus on the relationship between meso-scale sea surface temperature (SST) distribution and atmospheric convection, and also high accurate water vapor measurement in the upper troposphere. Results from numerical experiments on the intensity and structure of TCs modulated by SST, were given by **Tetsuya Takemi,** highlighting the role of temperature lapse rate around the tropopause. **Tri W. Hadi** reported on the synoptic component of Borneo Vortex in the Maritime Continent using space-time frequency analysis of outgoing long wave radiation to investigate the role of equatorial waves.

Takeshi Enomoto reported the model predictability of two heavy rainfall events on July 2018 and October 2019 in Japan. The model output highlighted that the north-eastward migration of TC in the Sea of Japan is a key and the vortex intensity affects forecast tracks.

Manabu D. Yamanaka argued that tropical land-sea contrasts played an important role in regional and larger-scale strato-tropospheric water and momentum budgets. He described that the most dominant mode of cloud-rainfall generation is the diurnal cycle mainly around the tropical coastal regions. The extreme rainfall causing flood in Jakarta at the end of 2019 evidently coincides with the strong cross equatorial northerly surge, as shown by **Rezky Yunita**. **Nurjanna Joko Trilaksono** reported characteristics study of hailstorm over Greater Bandung Area, Indonesia during March-April 2017 obtained with an X-band radar observation.

Poster session II

The second poster session contained results from using the COSMIC data to detect the SC signal in the tropospheric temperature (**Surendra Dhaka;** presented by V. Kumar), a simulation of the ozone change of Halloween event in 2003 and Carrington event in 1859 using MIROC3.2 Chemistry-Climate Model (**Hideharu Akiyoshi**), and a verification of precipitation forecast by pattern recognition with a new metric, the Pattern Similarity Index (**Shigenori Otsuka**). Others presented examinations of the stratospheric influence on the aggregation of tropical moist convective systems with a regional cloud-system resolving model (**Takahiro Banno**), the characteristics of jumping cirrus at the top of deep convective clouds based on the ground observations by visible light cameras (**Takafumi Seguchi**), the analyses of the seasonal variation of the tropopause height using a diagnostic equation for the lapse-rate-tropopause heights (**Masashi Kohma**), and usage of the hourly CMORPH dataset to determine the diurnal pattern of extreme rainfall over Java and the surrounding waters (**Achmad Fahrudin Rais**). Further, an explanation how the eastern pacific El Niño brings warm and non-warm winters to the Far East by composite analyses with reanalysis datasets (**Masahiro Shiozaki**) was shown along with the investigation of projected future changes in extreme precipitation in a 60-km AGCM large ensemble and their dependence on return periods (**Ryo Mizuta**), the 21st century drought projection in the Indochina region based on the optimal ensemble subset of CMIP5 models (**Rattana Chhin**), and the proposal of a new framework to visualize impacts of a model change or multi-model results in a single diagram for climate sensitivity experiments (**Shipra Jain** presented by S. Yoden).

Acknowledgments

The workshop conveners (SY, PHH, PH, MHH, TYK, and TS) would like to thank the generous sponsors of the meeting: The SPARC project of the World Climate Research Programme (WCRP), the Grants-in-Aid for Scientific Research <KAKENHI>, 15H05816 and 17H01159, and Bilateral Joint Research Project with Indonesia DG-RSTHE, through the Japan Society for the Promotion of Science (JSPS) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. S. Bal and A.F. Rais thank WCRP/SPARC for their travel grant support. Thanks also to local technical support by the staff of the Integrated Earth Science Hub, Kyoto University (Y. Uemoto, A. Abe, and T. Takahata). We also thank invited speakers and all attendees whose participation made it a most successful workshop.

References

Geller, M., P. Haynes, S.-W. Son, and S. Yoden, 2017: Report on the international workshop on stratosphere-troposphere dynamical coupling in the tropics, 22-24 October 2015, Kyoto, Japan. *SPARC newsletter*, **48**, 17-21.

Haynes, P., P. Hitchcock, M. Hitchman, S. Yoden, H. Hendon, G. Kiladis, K. Kodera, and I. Simpson, 2020: Stratosphere-troposphere coupling in the tropics. *J. Meteor. Soc. Japan*, to be submitted.

Hitchman, M., S. Yoden, P. Haynes, S. Tegtmeier, and V. Kumar, 2020: An observational history of the direct influence of the stratospheric QBO on the tropical and subtropical UTLS. *J. Meteor. Soc. Japan*, submitted.