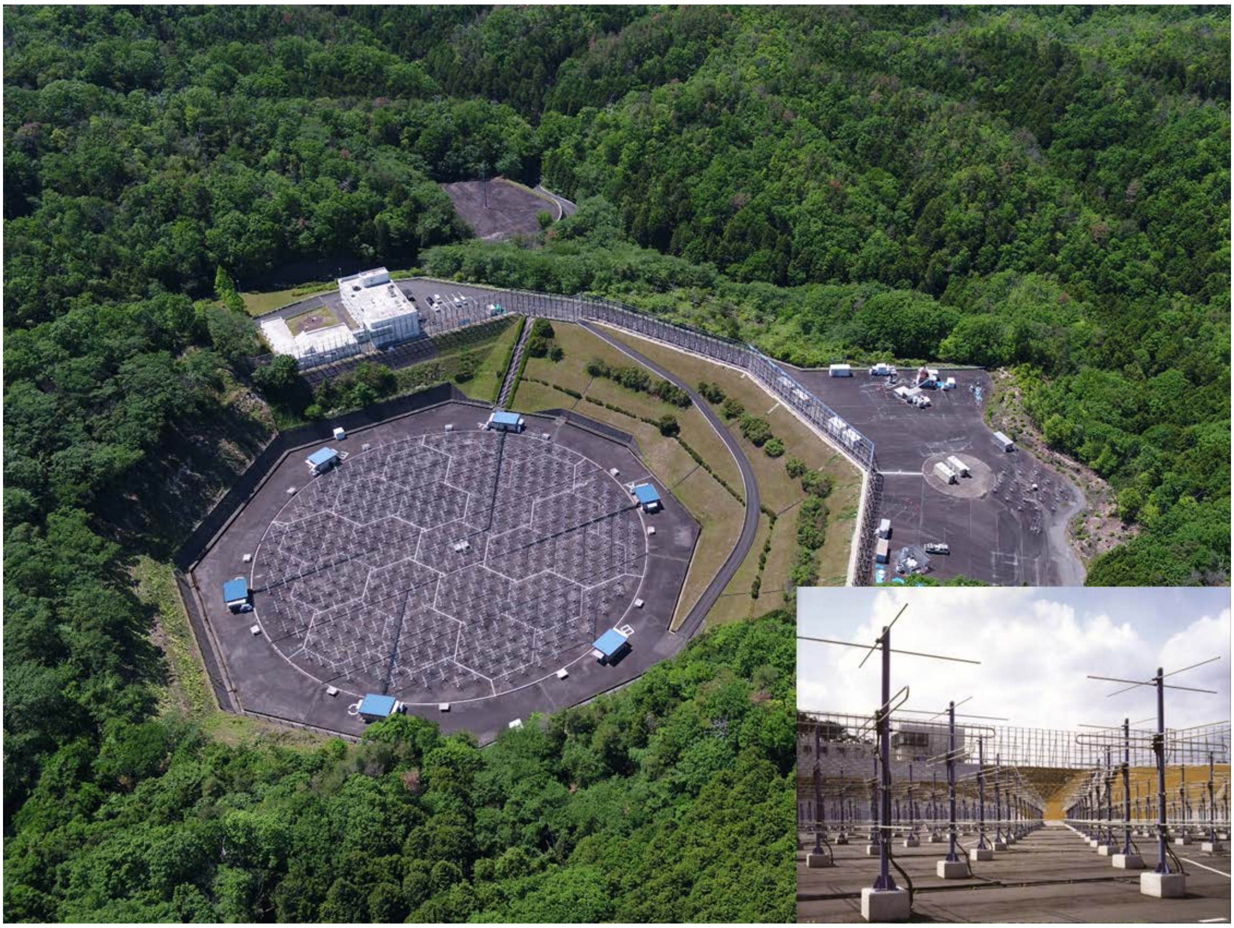
International Symposium on the 40th Anniversary of the MU Radar

November 18-21, 2024

Online & onsite hybrid meeting / Uji Campus, Kyoto University, Kyoto, Japan

URL: http://www.rish.kyoto-u.ac.jp/mu_40th_sympo/



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TRADITION MEETS INNOVATION

SGEPSS
Society of Geomagnetism and Earth, Planetary and Space Sciences

Preface

The MU (Middle and Upper atmosphere) radar operated by the Research Institute for Sustainable Humanosphere (RISH), Kyoto University was built in 1984 at Shigaraki in Koka-city, Japan. It is one of the most powerful and versatile VHF radars with an active phased array system consisting of 475 Yagi antennas. It has a monostatic circular antenna array with a diameter of 103 m, which can be divided into 25 independent sub-arrays. The MU radar now forms the core of the Shigaraki MU Observatory. Several other remote sensing instruments have also been developed, including a Rayleigh-Raman lidar, a 1.3-GHz wind profiler radar, and a lower thermosphere profiler radar. Collaborative experiments with the MU radar have been carried out to validate new instruments and to verify the new scientific knowledge provided by these instruments. Since 1984, RISH has conducted many collaborative research programs using the MU radar and associated facilities.

This international symposium is an important part of the 40th anniversary of the MU radar. It aims to review scientific achievements from the MU Observatory and to discuss the ongoing research activities and future plans using the MST/IS radars around the world. The symposium also covers theoretical and modeling studies of the atmosphere from the boundary layer to the ionosphere, and radio applications for atmospheric measurements such as meteorological radar, GNSS meteorology, and GNSS radio occultation.

We are delighted to announce that many attendees will join the International Symposium on the 40th Anniversary of the MU Radar, which will run from November 18 to 21, 2024. In particular, many graduate students and young researchers make oral and poster presentations.

Mamoru Yamamoto
Chair of the International Symposium on the 40th Anniversary of the MU Radar
Director of Research Institute for Sustainable Humanosphere, Kyoto University

Schedule (November 18-21)

18(Mon)	19(Tue)	20(Wed)	21(Thu)
	onsite registration 9:00-9:30		
onsite registration 9:30-10:30	opening 9:30-10:00	session 5 9:15-10:45	session 8 9:15-10:30
40th anniversary ceremony 10:30-11:30	session 1 10:00-11:15	break	break
lunch 90 min	group photo	session 6 11:15-12:30	session 9 11:15-12:30
bus tour to the MU radar 13:00-18:00 Uji campus ↓ MU radar ↓ Pottery shop ↓ Kyoto station	lunch 90 min	lunch 75 min	lunch 75 min
	session 2 13:00-14:30	session 7 & short poster presentation 13:45-15:30	session 10 13:45-15:15
	break	break	break
	session 3 15:00-16:30	POSTER session 15:45-17:15	session 11 15:45-16:45
	break		closing remarks
	session 4 17:00-18:45	banquet 17:30-19:00	

JST=GMT+9

International Symposium on the 40th Anniversary of the MU Radar

November 18 (Mon)

01:30UTC(10:30JST)- **Ceremony for the 40th Anniversary of the MU Radar**

Chair: Hiroyuki Hashiguchi

Opening Address

Mamoru Yamamoto
Director, Research Institute for Sustainable Humanosphere, Kyoto University

Address

Norihiro Tokitoh
Vice-President, Kyoto University

Congratulatory Address

Kazuo Shiokawa
President, Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)
President, Society of Geomagnetism and Earth, Planetary and Space Sciences (SGEPSS)

Katsuhiro Nakagawa
Director General, Radio Research Institute, National Institute of Information and Communications Technology (NICT)

Masaki Tsutsumi
Vice Director-General, National Institute of Polar Research (NIPR)

Presentation of the Letters of Appreciation

Naoto Masuda
Corporate Executive Senior General Manager, Electronics and Communication Systems Center, Mitsubishi Electric Corporation

Hiroki Iwanaga
Mayor, Koka City, Shiga Prefecture

Closing Address

Hirotsugu Kojima
Vice Director, Research Institute for Sustainable Humanosphere, Kyoto University

04:00UTC(13:00JST)- **Bus tour to the MU radar**

November 19 (Tue)

00:30UTC(9:30JST)- **Opening Ceremony**

Chair: Tatsuhiro Yokoyama

Opening address and introduction of the MU radar activities

Mamoru Yamamoto

Director of Research Institute for Sustainable Humanosphere (RISH), Kyoto University

Session 1

Chair: Tatsuhiro Yokoyama

O-01 [Onsite]

3-D structures of intense ionospheric disturbances studied by GNSS tomography

Susumu Saito, Taisei Nozaki, and Mamoru Yamamoto

O-02 [Onsite]

Northwestward Extension of Total Electron Content Enhancement and Irregularities Over Japan During a Magnetic Storm on May 2024

Yuichi Otsuka, Kazuo Shiokawa, Atsuki Shibori, Mamoru Yamamoto, Tatsuhiro Yokoyama, Koji Nishimura, Michi Nishioka, and Septi Perwitasari

O-03 [Onsite]

Coordinated observation of sporadic-E layers with sounding rockets and ground-based observations: SEEK, SEEK-2, and RIDE campaigns

Akinori Saito, Takumi Abe, Ayako Matsuoka, Keigo Ishisaka, Yoshifumi Saito, Masato Tagawa, Atsushi Kumamoto, Kumiko Yokota, Hirotsugu Kojima, Satoshi Kurita, Tatsuhiro Yokoyama, Naofumi Murata, Susumu Saito, Toru Takahashi, Michi Nishioka, Satoshi Andoh, Keisuke Hosokawa , Hiroyuki Nakata, Huixin Liu, Masaru Kogure, Takanori Nishiyama, Mitsumu K Ejiri, and Takatoshi Sakazaki

O-04 [Withdraw]

Statistical Study of Equatorial Spread-F Occurrence Observed Over Kototabang, Indonesia, During Decreased Solar Activity of 2005-2008

Ednofri

O-05 [Withdraw]

Assessment of Near-equatorial Ionospheric Responses to Solar and Meteorological Drivers Using VLF Propagation Technique

Ozuem V. Edward, Victor U. J. Nwankwo, and Timothy O. Akinsola

O-06 [Online]

Global Vertical Total Electron Content (VTEC) variation during an intense geomagnetic storm on June 22, 2015

Bhupendra Malvi, and P. K. Purohit

Lunch (~90 min)

04:00UTC(13:00JST)- **Session 2**

Chair: Akinori Saito

O-07 [Onsite]

Development of ionospheric vertical plasma drift model using radar observations in the Indian and Indonesian longitudes

P. PavanChaitanya, A. K. Patra, Y. Otsuka, T. Yokoyama, and M. Yamamoto

O-08 [Onsite]

Lunar tidal wave effects on equatorial ionospheric vertical ExB drift during sudden stratospheric warming

P. PavanChaitanya, A. K. Patra, Y. Otsuka, T. Yokoyama, and M. Yamamoto

O-09 [Online]

Semidiurnal Tidal Influence on the Occurrence of Post-midnight F Region FAI Radar Echoes

S. Sridharan, and S. Meenakshi

O-10 [Onsite]

Lifetime and Zonal Migration of Equatorial Plasma Bubbles based on GNSS Total Electron Content Observation in Indonesia

Prayitno Abadi, Yuichi Otsuka, Ihsan Naufal Muafiry, and Teguh Nugraha Putra

O-11 [Online]

Development of SEALION Equatorial Plasma Bubble Alert and Data Portal

Septi Perwitasari, Michi Nishioka, and Kukkai Kornyanat

O-12 [Online]

Geospace disturbance study enabled by coordinated observations of ground-based networks

Shun-Rong Zhang, and Liwen Ren

Coffee break (~30 min)

06:00UTC(15:00JST)- **Session 3**

Chair: Yuichi Otsuka

O-13 [Online, Video]

Exploring an Extension of Space Situational Awareness in Southeast Asian Region Utilizing EAR Observation Data

Afrizal Bahar, Varuliantor Dear, Asnawi Husin, Agri Faturahman, Jiyo, and Rezy Pradipta

O-14 [Onsite]

Modelling the 3-D structure and dynamics of sporadic E layers

Lihui Qiu, and Huixin Liu*

O-15 [Online, Video]

Multidiagnostic Observation of Ionospheric Irregularities over Indonesia Following the 15 January 2022 Tonga Volcano Eruption

Agri Faturahman, Asnawi Husin, Varuliantor Dear, Sefria Anggarani, Annis Siradj Mardiani, Adi Purwono, Jiyo Harjosuwito, and Rezy Pradipta

O-16 [Onsite]
The spatial features of E region irregularities revealed by all-sky radar
Wenjie Sun, Guozhu Li, and Jianfei Liu

O-17 [Onsite]
The Sanya Incoherent Scatter Radar System
Xinan Yue, Baiqi Ning, and Feng Ding

O-18 [Online, Video]
J-ARGUS: Expanding the observation capabilities to study the equatorial ionosphere
Danny Scipion, Fabiano Rodrigues, Marco Milla, David Hysell, Jorge Chau, and Kenneth Obenberger

Coffee break (~30 min)

08:00UTC(17:00JST)- **Session 4**
Chair: Susumu Saito
O-19 [Online, Video]
Development of 445 MHz wind profiling radar at NARL for meteorological applications
P Yasodha, T Narayana Rao, and A K Patra

O-20 [Onsite]
The Tibetan Plateau (Yangbajing) MST radar system
Yufang Tian, Xin Wang, and Daren Lyu

O-21 [Onsite]
The LARID: capabilities, advantages and limitations for observing low latitude ionosphere
Guozhu Li, Lianhuan Hu, Wenjie Sun, Baiqi Ning, et al.

O-22 [Onsite]
DDMA-MIMO observation with the MU radar
Tomoya Matsuda, Koji Nishimura, and Hiroyuki Hashiguchi

O-23 [Onsite]
Development of MIMO radar using 1.3-GHz atmospheric radar
Hiroyuki Hashiguchi, Yuna Ishii, Koji Nishimura, and Mamoru Yamamoto

O-24 [Online, Video]
Advanced Indian MST Radar with Multi-channel capabilities
M. Durga Rao, P. Kamaraj, K. M. V. Prasad, K. Jayaraj, J. Raghavendra, R. Ashrit, T.N. Rao, and A.K.Patra

O-46 [Onsite]
Ionospheric topside diffusive flux and the formation of summer nighttime ionospheric electron density enhancement over Millstone Hill
Yihui Cai, Xinan Yue, Wenbin Wang, Shun-Rong Zhang, Huixin Liu, and Jiuhou Lei

November 20 (Wed)

00:15UTC(09:15JST)- **Session 5**

Chair: Huixin Liu

O-25 [Online]

Meteor radar of Kazan Federal University and prospects for the development of a local area meteor network

D.V. Korotyshkin, O.N. Sherstyukov, and F.S. Valiullin

O-26 [Online]

Method of determination of meteor velocity by diffraction and comparison of meteor shower velocities based on observations in Kazan with other optical and radar data

D.V. Korotyshkin

O-27 [Withdraw]

Fine Structure of Vertically Propagation of Kelvin Wave "near" Tropopause during Wet and Dry Season Observed by the Equatorial Atmosphere Radar

Eddy Hermawan, Widya Ningrum, Albertus Sulaiman, and Sonni Setiawan

O-28 [Onsite]

Recent observations of atmospheric instabilities from the Indian network of ST/MST radars : Results inferred from NetRAD-ASMA campaign

Siddarth Shankar Das, N. Poddar, M. V. Ratnam, V. Venugopal, A. K. Ghosh, A. Paul, M. Naja, S. Abhilash, S. Bhattacharjee, M. Durga Rao, P. Nandakumar, V. Rakesh, S. K. Das, S. V. Sunikumar, D. S. Raj, N. Das, G. Pandithurai, and K. Raghunath

O-29 [Online]

Characteristics of vertical air motion over central Himalayan region using 206.5 MHz Stratosphere-Troposphere Radar

Nabarun Poddar, Siddarth Shankar Das, Manish Naja, and Samaresh Bhattacharjee

O-30 [Onsite]

Characteristics of the aspect sensitivity and the long-term variation of vertical wind velocity observed with Equatorial Atmosphere Radar

Noersomadi, Tiin Sinatra, Hubert Luce, Toshitaka Tsuda, and Hiroyuki Hashiguchi

Coffee break (~30 min)

02:15UTC(11:15JST)- **Session 6**

Chair: Noersomadi

O-31 [Online]

Investigation of The Turbulence Echo Power Observed by Equatorial Atmosphere Radar (EAR) with The Refractive Index Gradient and the Atmospheric Stability from Hourly Radiosondes with 10 m Vertical Sampling

Tiin Sinatra, Noersomadi, Asif Awaludin, Halimurrahman, Nani Cholianawati, Anis Purwaningsih, Toshitaka Tsuda, Hiroyuki Hashiguchi, and Hubert Luce

O-32 [Online]

Vertical motion of two types of heavy convective rainfall with different depths observed by the MU radar, a vertical pointing X-band radar, and the GPM

Shoichi Shige, Nozomu Toda, Kazumasa Aonashi, Yusuke Goto, Taro Shinoda, Nobuhiro Takahashi, and Hiroyuki Hashiguchi

O-33 [Withdraw]

Bright band observations with an Micro Rain Radar and the MU radar

Toyoshi Shimomai, Yutaro Saiki, and Hiroyuki Hashiguchi

O-34 [Onsite]

Applications of multi-receiver and multi-frequency radar imaging to atmospheric study

Zhen-Xiong You, Hiroyuki Hashiguchi, Mamoru Yamamoto, Yen-Hsyang Chu, Ching-Lun Su, and Chien-Ya Wang

O-35 [Onsite]

Observation of vertical wind profiles in clear air using a C-band solid-state radar

Hiroshi Yamauchi, Takashi Unuma, Akihito Umehara, and Ahoro Adachi

Lunch (~75 min)

04:45UTC(13:45JST)- **Session 7**

Chair: Koji Nishimura

O-36 [Onsite]

Characteristics of Mesoscale Wind Fields in Typhoons observed by the MU Radar

Yoshiaki Shibagaki, Hiroyuki Hashiguchi, Hubert Luce, Masayuki Yamamoto, and Manabu D. Yamanaka

O-37 [Online]

MJO affected Land Sea Breeze Circulation in West Coast of Sumatra

Albert Sulaiman, Wendi Herjupa, Anis Purwaningsih, Eddy Hermawan, Manabu D. Yamanaka, Noersomadi, and H. Hashiguchi

O-38 [Online]

Impact of Southerly Surge on Rainfall Pattern Over Java, Bali, West Nusa Tenggara and East Nusa Tenggara during Asian Winter Monsoon and Its Relationship to MJO Condition

Trismidianto, Didi Satiadi, Wendi Harjupa, Ibnu Fathrio, Risyanto*, Elfira Saufina, Robi Muharsyah, Danang Eko Nuryanto, Fadli Nauval, Dita Fatria Andarini, Anis Purwaningsih, Teguh Harjana, Alfan Sukmana Praja, Adi Witono, Ina Juaeni, and Bambang Suhandi

O-39 [Onsite]

Study of Orography-MJO Interaction and Its Impact on Rainfall Variability in West Sumatra

Didi Satiadi, Anis Purwaningsih*, Wendi Harjupa, Elfira Saufina, Ibnu Fathrio, Trismidianto, Fahmi Rahmatia, Ridho Pratama, Hiroyuki Hashiguchi, and Toyoshi Shimomai

O-40 [Onsite]
AI based WRF-DA modelling of the August 2018 Kerala flood
Kavya Johny, M.G. Manoj, and Ashish Shaji

06:00UTC(15:00JST)- **Short Poster Presentation – Elevator Speech**
Chair: Koji Nishimura
P-01～P-10 (3 minutes each)

Coffee break (~15 min)

Poster Session

06:45UTC(15:45JST)-08:15UTC(17:15JST) Hybrid Space

Banquet

08:30UTC(17:30JST)-10:00UTC(19:00JST) Hybrid Space

November 21 (Thu)

00:15UTC(09:15JST)- **Session 8**

Chair: Ramesh Karanam

O-41 [Onsite]

In-Depth Analysis of Atmospheric Dynamics Leading to Landslide in Kototabang on December 19, 2019: Integrating Satellite and Ground Observations

Fahmi Rahmatia, Anis Purwaningsih, Elfira Saufina, Didi Satiadi, Wendi Harjupa, Ridho Pratama

O-42 [Onsite]

Examination of Atmospheric Dynamics During the Extreme Rainfall Event in West Sumatera on March 7-8, 2024: Roles of MJO, WWB, and Kelvin Waves

Elfira Saufina, Trismidianto, Didi Satiadi, Wendi Harjupa, Risyanto, Anis Purwaningsih, Alfan Sukmana Praja, Ina Juaeni, Adi Witono, Ibnu Fathrio, and Fahmi Rahmatia

O-43 [Onsite]

The Mesoscale Convective Complex Triggered Extreme Rainfall and Devastating Floods in Bangka Belitung on February 8–10, 2016, linked to the Cold Surge, Borneo Vortex, MJO, and Equatorial Waves

Ibnu fathrio, Trismidianto, Didi Satiadi, Risyanto*, Alfan Sukmana Praja, and Anis Purwaningsih

O-44 [Online]

Diurnal and Seasonal Variations of Mesoscale Convective Systems Precipitation and Their Influence on Rainfall Patterns in the Indonesian Maritime Continent

Mukhamad Adib Azka, Nurjanna Joko Trilaksono, and Trismidianto

O-45 [Withdraw]

Estimation of convective Mass-flux from simultaneous measurements of 206.5 MHz wind profiler and X-band radar reflectivity measurements in the Himalayan foothills

Subrata Kumar Das, Adtiya Jaiswal, Abhishek Jha, and Manish Naja

O-46 [Move to Session 4]

Coffee break (~30 min)

02:15UTC(11:15JST)- **Session 9**

Chair: Zhen-Xiong You

O-47 [Onsite]

Unraveling the Complexity of Rain Microphysics in Equatorial Sumatra through GPM Satellite and Equatorial Atmospheric Radar Observations

Ravidho Ramadhan, Marzuki, Helmi Yusnaini, Hiroyuki Hashiguchi, and Mutya Vonnisa

O-48 [Onsite]
Estimation of Vertical Air Motion within Precipitating Clouds Using the Equatorial Atmosphere Radar in Combination with a Boundary Layer Radar

Nozomu Toda, Shoichi Shige, Christopher R Williams, Noriyuki Nishi, and Hiroyuki Hashiguchi

O-49 [Onsite]
Estimation of Raindrop Size Distribution Using Vertical Pointing Observations of Ground-Based X-Band Radar and MU Radar

Yusuke GOTO, Taro SHINODA, Haruya MINDA, Moeto KYUSHIMA, Nozomu TODA, Shoichi SHIGE, and Hiroyuki HASHIGUCHI

O-50 [Onsite]
The capability of the middle atmosphere dynamics and structure observation over the Tibetan Plateau based on the MST radar, lidar and cloud radar systems

Daren Lyu et al.

O-51 [Online, Video]
High and equatorial mesospheric dynamical response to the minor stratospheric warming of 2014/15: Comparison with major SSW events 2005/06 and 2008/09

Lynn Salome Daniel and G.J. Bhagavathiammal

Lunch (~75 min)

04:45UTC(13:45JST)- **Session 10**

Chair: Masashi Kohma

O-52 [Withdraw]
Meteor Radar Investigation of Middle and Upper Atmosphere Dynamics from Tropical to Polar Regions during Sudden Stratospheric warming: A Review

S. Eswaraiah, M.Venkat Ratnam, Kondapalli Niranjan Kumar, Chalachew Kindie Mengist, Gasti Venkata Chalapathi, Yong-Ha Kim, and S. Vijaya Bhaskara Rao

O-53 [Onsite]
Interhemispheric Coupling in the Middle Atmosphere Revealed by High-resolution Observations and Modelling (ICSOM) -Gravity-wave Permitting GCM Study for the Whole Middle Atmosphere-

Kaoru Sato, Haruka Okui, Shingo Watanabe, Dai Koshin, Masashi Kohma, et al.

O-54 [Withdraw]
Variability of low-latitude middle atmosphere during a major sudden stratospheric warming in the southern hemisphere

Amitava Guharay, and Paulo Prado Batista

O-55 [Onsite]
Spectral analysis of atmospheric waves in the upper troposphere-lower stratosphere (UTLS) observed with radiosondes at the Equatorial Atmosphere Radar (EAR) observatory

Anis Purwaningsih, Noersomadi, Toshitaka Tsuda, Nani Cholianawati, Halimurrahman, Tiin Sinatra, Asif Awaludin, and Hubert Luce

O-56 [Online]
Study of Low-Latitude Planetary Wave Dynamics during 2019 Minor Sudden Stratospheric Warming
G. Mitra, A. Guharay, P. P. Batista, and R. A. Buriti

O-57 [Withdraw]
Latitudinal Variation of Solar Diurnal, Semi-diurnal, and Terdiurnal Tides using a network of meteor radars and SD WACCM simulation
Pramitha Maniyatt, and Vikash Rishi Dharan K

Coffee break (~30 min)

06:45UTC(15:45JST)- **Session 11**
Chair: Hubert Luce
O-58 [Online]
Unlocking the Secrets of the Tropical Middle Atmosphere: 30 Years of Indian MST Radar Discoveries and Beyond
M. Venkat Ratnam

O-59 [Onsite]
Revisiting seasonal variations of atmospheric parameters in the lower atmosphere (2-20 km) from MU radar data (1987-2022)
Hubert LUCE, Toshitaka TSUDA, Hiroyuki HASHIGUCHI, and Noriyuki NISHI

O-60 [Onsite]
Cloud Base Height Characteristics based on Ceilometer Measurements in Mountainous areas of Sumatra
Helmi Yusnaini, Marzuki, Hiroyuki Hashiguchi, and Ravidho Ramadhan

O-61 [Onsite]
Meteor radar observations of long-term variabilities in arctic mesosphere and lower thermosphere winds over Esrange (67.9°N, 21.1°E)
K. Ramesh, Nicholas J. Mitchell, Neil P. Hindley, and Tracy Moffat-Griffin

07:45UTC(16:45JST)- **Closing Remarks**

Closing Address
Mamoru Yamamoto
Chair of the International Symposium on the 40th Anniversary of the MU Radar
Director of Research Institute for Sustainable Humanosphere (RISH), Kyoto University

Poster Session (November 20 (Thu) 06:45-08:15UTC(15:45-17:15JST))

P-01 [Online]
Preliminary results on CEJ occurrence in quiet space weather conditions during tropical cyclones "BIJILI" and "AILA"
M Gajalakshmi, and G J Bhagavathiammal

P-02 [Online]
Recent progresses of the MSTID studies from the perspective of satellite observations
Charles Lin, P. K. Rajesh, Min Yang Chou, and Pin Hsuan Cheng

P-03 [Onsite]
Ionospheric Signatures detected by GNSS-TEC and SAR Azimuth Offset during Latest Geomagnetic Storm in 2024: Indonesian Region
Ihsan Naufal Muafiry, Masato Furuya, and Prayitno Abadi

P-04 [Onsite]
The Monitoring of Localize Ionospheric Scintillation and RF Interference by GNSS Network
Tung-Yuan Hsiao

P-05 [Online]
Estimating MLT Winds from Non-Specular Meteor Trails: A Machine Learning Approach with RetinaNet
Armando Castro, and Danny Scipion

P-06 [Online]
African and American Equatorial Ionization Anomaly (EIA) Responses to 2013 SSW Event
O.R. Idolor, A.O. Akala, O. S. Bolaji, and E.O. Oyeyemi

P-07 [Onsite]
On the Atmospheric Solitary Waves Propagation over Bengkalis Island
Ahmad Ripai, Albertus Sulaiman, Husin Alatas, and Noersomadi*

P-08 [Online]
Quantifying the impact of extratropical planetary wave forcing on the QBO disruption in 2015/16 and 2019/20
G. J. BHAGAVATHIAMMAL

P-09 [Onsite]
Observation of Mixed Rossby-Gravity (MRG) Waves as Initiation of MJO Propagation using GNSS-RO Data
Herdiana Sri Wahyuningsih, Nurjanna Joko Trilaksono, and Noersomadi*

P-10 [Onsite]
Numerical simulation of orographic gravity waves observed over Syowa Station
Masashi Kohma, Kaoru Sato, David C. Fritts, and Thomas S. Lund

Organizing Committee

Mamoru Yamamoto (Chair)
Research Institute for Sustainable Humanosphere (RISH), Kyoto University
Hiroyuki Hashiguchi
Research Institute for Sustainable Humanosphere (RISH), Kyoto University
Hubert Luce
Research Institute for Sustainable Humanosphere (RISH), Kyoto University
Tatsuhiro Yokoyama
Research Institute for Sustainable Humanosphere (RISH), Kyoto University
Koji Nishimura
Research Institute for Sustainable Humanosphere (RISH), Kyoto University
Masanori Yabuki
Research Institute for Sustainable Humanosphere (RISH), Kyoto University
Akinori Saito
Graduate School of Science, Kyoto University
Masaki Tsutsumi
National Institute of Polar Research
Yuichi Otsuka
Institute for Space-Earth Environmental Research (ISEE), Nagoya University
Yasukuni Shibata
Graduate School of System Design, Tokyo Metropolitan University
Susumu Saito
Electronic Navigation Research Institute (ENRI)
Michi Nishioka
National Institute of Information and Communications Technology (NICT)

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The Kyoto University Foundation

Kyoto Prefecture and Kyoto Convention & Visitors Bureau

RISH Symposium Program of Research Institute for Sustainable Humanosphere (RISH), Kyoto University

The Meteorological Society of Japan

Society of Geomagnetism, Planetary and Space Sciences (SGEPSS)

Abstracts
Oral Session

3-D structures of intense ionospheric disturbances studied by GNSS tomography

Susumu Saito[(1)], Taisei Nozaki [(2)], and Mamoru Yamamoto[(3)]

(1) Electronic Navigation Research Institute, National Institute of Maritime, Port and Aviation Technology, Tokyo, Japan (susaito@mpat.go.jp)

(2) Course of Communications and Computer Engineering, Kyoto University, Kyoto, Japan

(2) Research Institute of Sustainable Humanosphere, Kyoto University, Kyoto, Japan

To understand mechanisms of ionospheric disturbances, it is important to know the 3-D structures of ionospheric density distribution. We have developed a near-realtime 3-D ionospheric tomography system based on the GNSS network observation over Japan (https://www.enri.go.jp/cnspub/tomo3/). Incoherent scatter observations by the MU radar are used to verify the results of the 3-D ionospheric tomography and to improve the tomography. Sssessanga et al. (2021) has incorporated ionosonde observations into the 3-D tomography to improve the tomography performance, especially accurate reproduction of ionospheric height. We further improved the 3-D tomography to have better results.

In the recent a few years, intense ionospheric disturbances frequently occur in the mid-latitude region associated with enhancement in the solar activity. In the mid-latitude region, there are two types of large amplitude ionospheric disturbances, one is the equatorial plasma bubbles (EPBs) and the other is that associated with intense geomagnetic storms which is called storm enhanced density (SED) or storm-induced plasma stream (SIPS). The latter sometimes accompany sharp ionospheric depletions in it. However, the mechanism of them are not well understood yet.

We investigated the 3-D structures of ionospheric disturbances occurred in 2023 and found that ionospheric irregularities are embedded only in regions of enhanced ionospheric density and the region are elevated in height. This suggests that the irregularities and the enhanced density are caused by eastward polarization electric field which is induced by westward neutral wind.

O-2

Northwestward Extension of Total Electron Content Enhancement and Irregularities Over Japan During a Magnetic Storm on May 2024

Yuichi Otsuka(1), Kazuo Shiokawa(1), Atsuki Shibori(1), Mamoru Yamamoto(2), Tatsuhiro Yokoyama(2), Koji Nishimura(2), Michi Nishioka(3), and Septi Perwitasari(3)

(1) ISEE, Nagoya U., Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

(2) RISH, Kyoto U., Gokasho, Uji, Kyoto 611-0011, Japan

(3) NICT, 4-2-1 Nukui-Kitamachi, Koganei, Tokyo 184-8795, Japan

A super geomagnetic storm with a SYM-H minimum value of -512 nT occurred in May, 2024. In this study, we analyse global Total Electron Content (TEC) obtained from Global Navigation Satellite System (GNSS) receivers, thermospheric neutral wind from a Fabry-Perot interferometer (FPI) in Darwin, Australia, and plasma drift velocity observed by the MU radar in Shigaraki, Japan. The GNSS-TEC map shows that TEC enhancement with an amplitude of approximately 20 TECU appeared around (40°N, 150°E) at approximately 12 UT (21 JST) on May 11, 2024 and extended northwestward. This feature is similar to Storm-Enhanced Density (SED). After 13 UT (22 JST), ionospheric irregularities, indicated by the Rate Of TEC change Index (ROTI), were observed at the poleward edge of the TEC enhancement. The ROTI enhanced region also extended northwestward. Simultaneously, ROTI enhancement also appeared over Australia in the southern hemisphere, suggesting a geomagnetic conjugate structure of the ROTI enhancement. Zonal winds observed by the FPI in Darwin were approximately 80 m/s westward on average from 13 to 20 UT on May 11. The zonal plasma drift velocity observed by the MU radar in Japan was approximately 70 m/s westward at 13 UT (22 JST). We found that TEC depletions are embedded within the TEC enhancement and coincide with ROTI enhancement, indicating the presence of plasma bubbles. These results suggest that the westward extension of the TEC enhancement and the plasma density irregularities could be caused by westward ExB plasma drift driven by westward disturbance winds. From the temporal variation of the ROTI enhancement on the global map, we find that the ROTI enhancement is initiated around the magnetic equator at a longitude of 180°E around 8 UT (local post-sunset) and moves westward, extending poleward. These results suggest that plasma bubbles generated at the magnetic equator during local post-sunset extend to higher latitudes and that both the plasma bubbles and the surrounding dense plasma move westward due to E×B plasma drift caused by the westward disturbance winds.

O-3

Coordinated observation of sporadic-E layers with sounding rockets and ground-based observations: SEEK, SEEK-2, and RIDE campaigns

Akinori Saito(1), Takumi Abe(2), Ayako Matsuoka(1), Keigo Ishisaka(3), Yoshifumi Saito(2), Masato Tagawa(4), Atsushi Kumamoto(5), Kumiko Yokota(4), Hirotsugu Kojima(6), Satoshi Kurita(6), Tatsuhiro Yokoyama Naofumi Murata(7), Susumu Saito(8), Toru Takahashi(8), Michi Nishioka(9), Satoshi Andoh(9), Keisuke Hosokawa(10) , Hiroyuki Nakata(11), Huixin Liu(12), Masaru Kogure(12), Takanori Nishiyama(13), Mitsumu K Ejiri(13), Takatoshi Sakazaki(1)

(1) Graduate School of Science, Kyoto University (2) Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (3) Faculty of Engineering, Toyama Prefectural University (4) Graduate School of Engineering, Kobe University (5) Graduate School of Science, Tohoku University (6) Research Institute for Sustainable Humanosphere, Kyoto University (7) Japan Aerospace Exploration Agency (8) Electronic Navigation Research Institute (9) National Institute of Information and Communications Technology (10) Graduate School of Informatics and Engineering, University of Electro-Communications (11) Graduate School of Engineering, Chiba University (12) Graduate School of Science, Kyushu University (13) National Institute of Polar Research

The discovery of quasi-periodic (QP) echoes inside sporadic E (Es) layers by the MU radar shed light on the complexity of the ionospheric processes at midlatitudes. Intense Doppler velocity, distinct periodicity, and apparent descending motion in a wide altitudinal range intrigued many scientists and several physical processes had been discussed intensively. Profs. Shoichiro Fukao and Mamoru Yamamoto conducted a series of sounding rocket experiments, SEEK (Sporadic-E Experiment over Kyushu) in 1996 and 2002, that were coordinated with ground-based observation with radars and beacon receivers to elucidate the relationship between the Es layers and QP echoes. It directly observed physical parameters inside of QP echoes that cannot be measured with remote measurement including the MU radar. SEEK campaigns revealed that the Es layers are generated and developed through various coupling processes, such as coupling between the E- and F-regions, couplings between the northern and southern hemispheres, and coupling between the neutral and ionized atmospheres. The dynamic behavior of Es is still unrevealed and far from its forecast and prediction. After the SEEK campaigns, networked observations of GNSS receivers on the ground and satellites have progressed, and the two-dimensional structures of Es have been clarified. Furthermore, numerical simulations have also progressed to reproduce the dynamics of Es layers. Based on these recent progresses, another coordinated observation of Es layers with a sounding rocket and ground-based observation is in preparation to be carried out in the summer of 2025. The Rocket Investigation of Daytime E-region (RIDE) campaign is a direct observation of the neutral and ionized atmospheres, electric field, and magnetic field that generate the Es layer at an altitude of 90-130 km. This will be achieved by the S-310-46 rocket from Uchinoura in the summer of 2025. The project has three principal objectives: (1) To elucidate and predict phenomena in which the interaction between the neutral and ionized atmospheres is important by combining in-situ observations from rocket experiments with numerical models and ground-based observations, (2) to complete the in-situ measurement package of the neutral and ionized atmospheres and electromagnetic fields, and (3) to develop human resources for future missions. The S-310 rocket is equipped with seven instruments, each designed to measure a specific physical quantity as follows: Neutral mass spectrometer (neutral atmosphere composition), neutral atmosphere density and wind instrument (neutral atmosphere density and velocity), ion drift velocity instrument (ion composition, temperature, and velocity), impedance probe (plasma density), Langmuir probe (electron temperature and plasma density), electric field instrument (the electric field), and magnetic field instrument (the magnetic field). The numerical simulations provide insight into the relationship between the formation of the Es layer and wind/electric field, as well as the relationship between wind and altitude for horizontal migration of the Es layer. In addition to the direct measurements obtained by rockets, ground-based observations will be conducted using an ionosonde receiver network and a GNSS receiver network. Wide-area multi-point observations of aviation VHF radio waves and ship VHF radio waves anomalously reflected by the Es layer will be conducted to elucidate the impact of the Es layer on social systems that utilize radio waves.

Statistical Study of Equatorial Spread-F Occurrence Observed Over Kototabang, Indonesia, During Decreased Solar Activity of 2005-2008

Ednofri

Agam Space and Atmospheric Observation Laboratory, BRIN, Indonesia

We report a statistical study of the occurrence of equatorial spread-F (ESF) over Kototabang, Indonesia (0.2° S, 100.3° E, -10.4° magnetic latitude) during 2005-2008. ESF occurrences were categorized into three types, i.e., range spread-F (RSF), mixed spread-F (MSF), and frequency spread-F (FSF). The statistical results show that the dominant ESF irregularities during and after midnight are MSF and FSF, while RSF dominates before midnight for all seasons. The types of ESF mostly occur in the solstices, except for the maximum RSF occurrence in the equinox. Furthermore, the occurrence of ESF events shows that the dependence of solar activity on ESF varies with the seasons. RSF follows the pattern of solar activity, whereas the reversed pattern applies to MSF and FSF. Comparing the concurrent observations of equatorial plasma bubble (EPB) and RSF measurement, our study confirms the evidence that RSF events over Kototabang are related to EPB.

Assessment of Near-equatorial Ionospheric Responses to Solar and Meteorological Drivers Using VLF Propagation Technique

Ozuem V. Edward[(1)], Victor U. J. Nwankwo[(2)], and Timothy O. Akinsola[(3)]
(1) Centre for Space Research (CESPAR), Anchor University, Lagos, Nigeria
(2) Centre for Space Research (CESPAR), Anchor University, Lagos, Nigeria
(3) Centre for Space Research (CESPAR), Anchor University, Lagos, Nigeria

In electromagnetic wave (EMW) propagation, the ionosphere plays a crucial role and is highly dynamic and sensitive to various perturbations from both solar and terrestrial sources. These perturbations, which could come in various forms, can significantly impact radio communications across various frequency ranges, thereby causing issues such as signal absorption, fading, and delay. Proper monitoring and understanding of these effects could provide insights into appropriate strategies to mitigate potential threats to technological systems in the face of ionospheric variability. Our ground-based receivers at the Anchor University Centre for Space Research (CESPAR), located in the near-equatorial region of West Africa, record solar-terrestrial data for observations of ionospheric irregularities. In this study, we investigate the impact of these drivers on the near-equatorial ionosphere by combining analysis of the propagation characteristics of very low frequency (VLF) radio waves (received at CESPAR) with proxies of solar (and geomagnetic) and meteorological drivers. We present results that reflect the prompt impact of sudden ionospheric disturbances (SID) and delayed geomagnetic perturbations in the lower ionosphere, as well as irregularities that appear to be connected to meteorological dynamics. This multi-parametric integrated approach enhances our understanding of ionospheric perturbations, contributing to better space weather models and communication system reliability.

Global Vertical Total Electron Content (VTEC) variation during an intense geomagnetic storm on June 22, 2015

Bhupendra Malvi [(1)], P. K. Purohit [(1)]

[1]Department of Applied Sciences, National Institute of Technical Teachers' Training and Research (NITTTR), Bhopal - 462002, M.P., India

In solar physics, one of the most important scientific goals is to figure out how the sun, the space weather that causes storms, and the effects on Earth are all connected. The disturbance in the earth's magnetic field was caused by changes in the ionosphere during intense geomagnetic storms. Geomagnetic storms are extreme space weather events with significant effects on the ionosphere. The ionosphere reacts dramatically and unexpectedly to variable magnetospheric energy inputs resulting from solar disturbances in geospace. The influence of space weather events on the ionosphere must be understood in order to estimate the environmental impact on the functioning of terrestrial and space-based systems. In this paper, we studied one of the most intense geomagnetic storms on June 23, 2015 and Dst (storm time ring current index) reaching -204 nT was recorded for the 24th solar cycle, which caused very significant and long-term changes in the ionosphere. We analyze the detailed summary of the nature of the behavior of the ionospheric Total Electron Content (TEC) in both hemispheres (Northern and Southern) over different geographic latitudinal and longitudinal stations using data from receivers over 45 stations (26 from the Northern Hemisphere and 19 from the Southern Hemisphere) identified from the IGS network all across the globe.

Development of ionospheric vertical plasma drift model using radar observations in the Indian and Indonesian longitudes

P. PavanChaitanya[1*], A. K. Patra[1], Y. Otsuka[2], T. Yokoyama[3], and M. Yamamoto[3]

(1) National Atmospheric Research laboratory, Gadanki, India
(2) Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan
(3) Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan
*Corresponding Author: pavanpeddapati@gmail.com; pavan@narl.gov.in

In this work, we present daytime vertical plasma drift models for the Indian and Indonesian sectors. We use vertical plasma drifts estimated using the Doppler measurements of daytime 150 km radar echoes observed by the 53 MHz MST radar, Gadanki, India and 47 MHz Equatorial Atmosphere Radar (EAR), Kototabang, Indonesia. In this work, we have used radar observations from 2006 to 2020. Notably, the estimated vertical plasma drifts at the two locations agree exceedingly well with those measured by the CINDI onboard C/NOFS. The models have been developed using feed forward artificial neural network. The model produces vertical plasma drift as a function of local time and day-of-the-year, providing local time, day-to-day, and seasonal variations in vertical plasma drift with maximum error of ~2.7 m s^{-1}. The model successfully reproduces the local time and day-to-day variations in vertical plasma drifts, which are unique aspects of these models. Importantly, we show that while the plasma drifts at the two locations in general agree with each other, on many days they differ remarkably despite that these locations are longitudinally separated by only 20°. The local time variations in the vertical plasma drift provide unique opportunity to study electrodynamics and ionospheric weather, which cannot be done using satellite-based models. Also we find that the model drifts differ remarkably from those of Scherliess-Fejer (1999) model, which is so commonly used by the ionospheric community. The results and usefulness of the models are presented and discussed.

Lunar tidal wave effects on equatorial ionospheric vertical ExB drift during sudden stratospheric warming

P. PavanChaitanya[1*], A. K. Patra[1], Y. Otsuka[2], T. Yokoyama[3], and M. Yamamoto[3]

(1) National Atmospheric Research Laboratory, Gadanki, India
(2) Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan
(3) Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan
*Corresponding Author: pavanpeddapati@gmail.com; pavan@narl.gov.in

In this paper, we study variations in equatorial ionospheric vertical **E**x**B** drift during sudden stratospheric warming (SSW) events over Indonesian region. For this study, we have used observations of vertical **E**x**B** drift estimated from Doppler shifts of the 150-km echoes observed by the 47 MHz Equatorial Atmospheric Radar (EAR), Kototabang, Indonesia from 2017 to 2019. We have analyzed four SSW events that occurred in the period: February 2017, February 2018, January 2019, and September 2019. Results show that the vertical **E**x**B** drifts were highly upward/southward in the morning hours and near zero or downward/northward in the afternoon hours, showing clear semidiurnal variation during the SSW events. The observations also show day-to-day variations, which are found to be governed by planetary-scale variability with periodicity of ~15 days and ~6 days. What is most remarkable is the onset of semidiurnal variations occurring during SSW events were close to the new and full moons, which indicates that the lunar tidal wave effects were highly enhanced during SSW events. These results are first of their kind from Indonesian sector and illustrate the type of variability that SSW can induce in the vertical **E**x**B** drift. These results are presented and discussed in the light of current understanding of SSW related coupling processes.

Semidiurnal Tidal Influence on the Occurrence of Post-midnight F Region FAI Radar Echoes

S. Sridharan [1], and S. Meenakshi [1]

(1) National Atmospheric Research Laboratory, Gadanki, Pakala Mandal, Tirupati District, Andhra Pradesh

The Equatorial Atmosphere Radar observations at Kototabang (0.2°S, 100.3°E) are used to study the possible semidiurnal tidal influence on the occurrence of post-midnight echoes from the field-aligned irregularities (FAIs) due to spread F. It is found that the post-midnight FAI echoes show high percentage of occurrence (PO) during June–July and low PO in December–January of low solar activity years. As solar activity approaches minimum, the PO increase is extended to May, August, and September. The temperature data obtained from the SABER (Sounding of Atmosphere by Broadband Emission Radiometry) instrument on board TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics) satellite are subjected to the space-time Fourier analysis. The results reveal that at the low-latitude upper mesospheric heights, though the migrating diurnal tide propagating westward with zonal wavenumber (k) 1 (DW1) dominates the migrating semidiurnal tide propagating westward with $k = 2$ (SW2) particularly during the equinox months, the SW2 tidal amplitudes are larger than DW1 during June–July. The post-midnight FAI echoes appear to be more frequent during the sudden stratospheric warming of the Solar Minimum Years 2018–2019 and 2008–2009 but not in the Solar Maximum Year 2013. The dominance of SW2 over DW1 is also noted during these years. This indicates that the SW2 plays a major role in the occurrence of post-midnight spread F. It is suggested that the dominant semidiurnal variation of zonal electric field can become eastward and lift the F layer to higher heights during midnight hours, which can favour the growth of the Rayleigh-Taylor instability to cause delayed spread F around midnight.

Lifetime and Zonal Migration of Equatorial Plasma Bubbles based on GNSS Total Electron Content Observation in Indonesia

Prayitno Abadi(1), Yuichi Otsuka(2), Ihsan Naufal Muafiry(1), and Teguh Nugraha Putra(1)

(1) Research Center for Climate and Atmosphere, BRIN, Bandung, Indonesia

(2) Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Nagoya, Japan

The two-dimensional (2D) Rate of Total Electron Content (TEC) Change Index (ROTI) maps, derived from the Indonesia Continuously Operating Reference Systems (Ina-CORS), have been utilized to investigate the lifetime and zonal migration of Equatorial Plasma Bubbles (EPBs). These ROTI maps cover an extensive longitudinal range from 95°E to 145°E and a latitudinal span from 5°N to 15°S, allowing for comprehensive tracking of EPB migration from their onset locations to their points of disappearance. The maps can be obtained through Zenodo (https://doi.org/10.5281/zenodo.13293416), an open repository. The maps collected from August 2023 to June 2024 observe 997 EPBs, with all EPBs displaying eastward migration from their onset longitude. Our survey reveals that the zonal migration of EPBs ranges from 0.7° to 33.5° in longitude, with a peak occurrence at 15°, while their lifetimes range from 1 to 12 hours, peaking around 5 hours. Notably, when the zonal migration exceeds 25°, some EPBs can survive until sunrise or even beyond. Further investigation indicates that stronger EPBs, characterized by more poleward extension, can survive longer; they migrate farther and have extended lifetimes. Specifically, EPBs with a latitudinal extension of at least 13° can survive more than 25° of zonal migration while drifting eastward, with lifetimes ranging from 6 to 12 hours. In contrast, EPBs with a latitudinal structure below 13° typically have shorter zonal migrations of less than 25°. These findings suggest that the strength of EPBs plays a crucial role in determining their longevity and migration behavior, highlighting the importance of considering the strength of EPB in monitoring EPB impacts on Global Navigation Satellite Systems (GNSS) application in the regional sector.

Development of SEALION Equatorial Plasma Bubble Alert and Data Portal

Septi Perwitasari[1], Michi Nishioka[1], and Kukkai Kornyanat[1,2]

(1) NICT, Tokyo, Japan

(2) University of Scranton, Pennsylvania, USA

The equatorial plasma bubble (EPB) is one of the most important features in space weather because of its significant effect on communication and navigation. Therefore, real-time information on the EPB occurrence will be useful in detecting the degradation of radio propagation conditions. SEALION is an ionospheric observation network in Southeast Asia that has been on operation since 2003. SEALION various ionospheric observation (ionosonde, VHF radar, GNSS-receivers) are installed across the Southeast Asia; Chiang Mai (18.76°N, 98.93°E), Chumphon (10.72°N, 99.37°E), Phuket (7.90°N, 98.39°E), Bac Liu (9.30°N, 105.71°E), Cebu (10.35°N, 123.91°E) and Kototabang (0.20°S, 100.32°E). The real-time alert is currently based on the auto-detection of spread-F from SEALION FMCW ionosonde. The validation has been carried out with the manual scaling data and found to have >80% match. Statistical studies of the seasonal and local time variation have also been carried out and compared to previous studies, which have a good agreement. To accommodate data sharing among the ionospheric community, especially in Southeast Asia, we have also developed a data portal to access and download SEALION and ASEAN-IVO data. This portal provides ready-to-use ASCII data as well as data plots. The is planned to provide auto scaled ionogram parameters (h’Es, h’F, foEs, and foF2), GTEX, ROTI, and S4 data. This system is planned to be open in the 2025 fiscal year. We will discuss the auto-detection development, validation, and future improvement during the presentation.

O-12

Geospace disturbance study enabled by coordinated observations of ground-based networks

Shun-Rong Zhang (MIT Haystack Observatory)
Liwen Ren (International Meridian Circle Program Office)

The modern understanding of geospace disturbances adopts a systems science approach, emphasizing the coupling processes between the magnetosphere, ionosphere, and thermosphere. True global and continuous observations are highly desirable to resolve spatial and temporal ambiguities in observational domains during significant storm events. However, such comprehensive observations are not yet readily available, and multi-technique and multi-point observations, along with organized and coordinated efforts, are essential to maximize scientific return. An effective and feasible observational configuration could be established in the meridional direction as a function of latitude, particularly the Meridian Circle over the Asian-Australian and American sectors, connected via both poles. This is a rare region where existing facilities are denser and more closely spaced. For example, Chinese Meridian Project enables extensive coverage with clutters of new facilities; observations in Japan and South Asian provide complimentary views in the broad mid- and low latitude regions. By integrating these monitoring abilities along the Meridian Circle, global space research communities have initiated and are implementing the International Meridian Circle Program (IMCP). Over the last decade, geospace storm campaigns have been conducted using IMCP and other ground-based assets, including the global incoherent scatter radar (ISR) network. In this presentation, we provide a summary of IMCP science cases and highlight storm-time ionosphere-thermosphere coupling processes, as demonstrated by ISR and other instrument observations during selected storm campaigns.

Exploring an extension of Space Situational Awareness in Southeast Asian Region Utilizing EAR Observation data

Afrizal Bahar[1], Varuliantor Dear[1], Asnawi Husin[1], Agri Faturahman[1], Jiyo[1], and Rezy Pradipta[2]

[1] Space Research Center, National Research and Innovation Agency, Indonesia
[2]Institute for Scientific Research, Boston College, USA

Abstract The concept of Space Situational Awareness (SSA) refers to the ability to detect and track threats, enabling appropriate mitigation measures aimed at protecting space assets. In this paper, we explored a possible extension of this concept by considering not only asset protection but also connectivity to satellites in orbit by users under various circumstances. Turbulence in ionospheric layer at low latitude can degrade connectivity to satellites (GNSS and SATCOM). Field Aligned Irregularities (FAI) from such turbulence are often detected by Equatorial Atmosphere Radar (EAR) when the radar beam is pointed perpendicular to magnetic field lines. EAR has been operational in Kototabang (0.20 S, 100.32 E; 10.36 S dip latitude), with beam steering capability up to 30 degree from zenith direction. At ionospheric altitude, EAR's direct horizontal coverage is around ~200 km. However, considering the physical properties of Equatorial Plasma Bubbles (EPB), we can extend the effective "viewing area". The north-south elongation of EPB implies an additional ~4000 km coverage from EAR meridionally. Eastward drift of EPB implies a further ~2000 km extension of coverage zonally. In this scheme, EAR effectively "guesses" the location of FAI when they are not directly in the field of view. In our study, we reconstructed the EPB geometry in three dimensions (3-D) based on EAR FAI data and the above assumptions. The reconstructed 3-D EPB geometry may be useful to many types of users such as those in maritime, aviation or aerospace sector operating in the Southeast Asian region -- therefore extending the concept of SSA more widely.

Keyword: Space Situational Awareness (SSA), Equatorial Plasma Bubble, Scintillation, GNSS

Modelling the 3-D structure and dynamics of sporadic E layers

Lihui Qiu[(1)], Huixin Liu [(1)]

(1) Kyushu University, Japan

Sporadic E (Es) layers are thin layers of concentrated metallic ions in the mesosphere and lower thermosphere (MLT) region. Their occurrence can cause the uneven distribution of plasma density and affects the performance of the Global Navigation Satellite System and high/very high frequency (HF/VHF) radio communications. Currently, the three-dimensional (3-D) Es layer structure and evolution process have not yet been fully understood. In this study, we investigated the structural and dynamic characteristics of the large-scale Es layers over East Asia by using a 3-D Es layer numerical model driven by neutral winds from the Whole Atmosphere Community Climate Model with thermosphere and ionosphere eXtension model (WACCM-X). The simulation results show that the Es layer is a tilted structure rather than a narrow flat blanket. In addition, the Es layers mainly occur in the 3-D spatial position of the convergent vertical wind shear. The apparent horizontal velocity (~300-400 m/s) of Es structure is mostly westward and northward, which is different from the ion drift velocity (~100 m/s). This indicates that Es structure can develop rapidly over a large area simultaneously rather than drifting from one location to the next. This study systematically analyzed the physics of the 3-D Es structure, which can be helpful for understanding the Es horizontal structure and dynamics recorded by different instruments, such as satellites and global navigation satellite system (GNSS) receiver networks.

Multidiagnostic Observation of Ionospheric Irregularities over Indonesia Following the 15 January 2022 Tonga Volcano Eruption

Agri Faturahman[1], Asnawi Husin[1], Varuliantor Dear[1,2], Sefria Anggarani[1], Annis Siradj Mardiani[1], Adi Purwono[1], Jiyo Harjosuwito[1], and Rezy Pradipta[3]

(1) Research Center for Space, Research Organization for Aeronautics and Space (ORPA), National Research and Innovation Agency (BRIN), Bandung, Indonesia

(2) School of Electrical Engineering and Informatics, Institut Teknologi Bandung (ITB), Jl. Ganesha 10, Bandung 40132, Indonesia

(3) Institute for Scientific Research, Boston College, Chestnut Hill, Massachusetts, USA

We present an analysis of multidiagnostic ionospheric measurements conducted in Indonesia after the Tonga volcanic eruption on 15 January 2022. This study utilized observational data obtained from the Indonesian CORS GNSS network, ionosondes, and GISTM receivers, together with Himawari-8 satellite imagery. We found some unseasonal equatorial plasma bubbles (EPBs) developed in the longitude sector of the Indonesian region, with earlier than usual onset times. These EPBs' zonal drift velocities show a directional split, with some drifting eastward at 138.0 ± 6.9 m/s and others drifting westward at 39.6 ± 2.0 m/s. Simultaneously, traveling ionospheric disturbances (TIDs) generated by the Tonga eruption propagated across Indonesia at 434.6 ± 21.7 m/s. Total electron content (TEC) data showed how equatorial plasma bubbles (EPBs) and traveling ionospheric disturbances (TIDs) interact with each other over the region. In addition, increasing the rate-of-TEC index (ROTI) and the S4 scintillation index also shows that the ionosphere has plasma density irregularities. We also found that EPB and TID in the ionosphereic F layer caused spread-F echoes or the F-region traces to disappear from the ionogram. In the ionogram, we also detected sporadic E-layer intensification, which lasted for several hours. Furthermore, as mentioned from several references, the Lamb waves were generated during the eruption, and we found they arrived in eastern Indonesia, more than 5,000 km from Tonga, about 4 hours after the eruption, moving at a speed of ~310 m/s. The Lamb waves moved across Indonesia with a duration of 4 hours 40 minutes, coinciding with the sunset period.

The spatial features of E region irregularities revealed by all-sky radar

Wenjie Sun[1], Guozhu Li[1], and Jianfei Liu[1]

(1) Institute of Geology and Geophysics, Chinese Academy of Sciences

All-sky radar measurements provide a unique capability to resolve the spatial structure of E region irregularities over a large zonal region. With the all-sky radar interferometry observations at Ledong (18.4°N, 109.0°E) in Hainan, China, the spatial structure and zonal drift of low latitude E region irregularities over a large region are investigated. It is revealed that the E region irregularities, including both the continuous and quasi-periodic (QP) types shown in radar range-time-intensity maps, occurred most frequently in summer. The continuous type was observed being generated locally without obvious zonal drift. The QP type generally covered ~40-500 km zonally, and consisted of up to 9 (peaking at 3-4) irregularity patches separated by ~20-130 km (peaking at ~60 km). The spatially separated irregularity patches predominantly drifted westward at the speed ~50-200 m/s. Gravity waves were surmised to be a major source for causing the spatially separated structures of low latitude QP type E region irregularities. Further, a case of wavelike structure of E region irregularities elongating more than 200 km zonally, and a case of double layer E region irregularities showing synchronized QP/wavelike features were observed, providing concrete evidence for the gravity wave modulating mechanism for their generation.

O-17

The Sanya Incoherent Scatter Radar System

Xinan Yue(1), Baiqi Ning(1), and Feng Ding(1)

(1) Institute of Geology and Geophysics, Chinese Academy of Sciences#19 BeiTuCheng West Road, ChaoYang District, Beijing 100029, P.R.China

The Sanya Incoherent Scatter Radar (SYISR) was led by the Institute of Geology and Geophysics, Chinese Academy of Science. It was proposed with the main objective of low latitude ionospheric monitoring and investigation and has been successfully developed over the past decade. The system consists of the Sanya (18.3°N, 109.6°E) trans-receiving main station and Danzhou (19.5°N, 109.1°E) and Wenchang (19.6°N, 110.8°E) receiving only stations. Three stations form a quasi-equilateral triangle at Hainan Island and use Global Navigation Satellite System satellite common view technique to achieve the time synchronization. In this presentation we will describe the development process of SYISR and highlight some interesting results up to date.

J-ARGUS: Expanding the observation capabilities to study the equatorial ionosphere

Danny Scipion[(1)], Fabiano Rodrigues[(2)], Marco Milla[(3)], David Hysell[(4)], Jorge Chau[(5)], and Kenneth Obenberger[(6)]

(1) Radio Observatorio de Jicamarca, Instituto Geofísico del Perú, Perú

(2) University of Texas at Dallas, USA

(3) Pontificia Universidad Católica del Perú, Perú

(4) University of Cornell, USA

(5) Leibniz-Institute of Atmospheric Physics, Germany

(6) Air Force Research Laboratory, USA

The Instituto Geofisico del Peru (IGP) through the Radio Observatorio de Jicamarca (ROJ) is dedicated to study the equatorial ionosphere. The IGP-ROJ has been key to remote sensing research of the troposphere, stratosphere, mesosphere, and thermosphere for more than 60 years. Due to its location close to the magnetic equator, the investigations conducted at IGP-ROJ are relevant for the space weather at low latitudes.

This work presents the development of two spaced receiving stations, which in combination with the high power-large aperture 50 MHz radar of IGP-ROJ constitutes the J-ARGUS multi-static system, which will provide wavenumber diversity to radar experiments and allow for better estimates of vector Doppler velocities and also enhance the research areas at the ionospheric equator. The first receiving station will be located at the IGP's Huancayo Observatory, about 170 km east of IGP-ROJ, and the second station will be located at Santa Maria campus of Pontificia Universidad Católica del Perú about 50 km south of IGP-ROJ. Each station will operate over a wide band (~10-80 MHz) and will allow for perpendicular-to-B and oblique radar observations.

Development of 445 MHz wind profiling radar at NARL for meteorological applications

P Yasodha, T Narayana Rao and A K Patra
National Atmospheric Research Laboratory, Gadanki – 517112
pyasoda@narl.gov.in

National Atmospheric Research Laboratory (NARL) has designed and developed a cost-effective state-of-the-art 445 MHz wind profiling radar, to probe the atmosphere upto ~8-12 km, for meteorological applications. This radar is the first of its kind in India, to use spaced antenna technique for continuous wind profiling. The flexible modular design of the antenna array facilitates different base line lengths, allowing improved estimates of wind products. 445 MHz is chosen as the frequency of operation as it can be realized at a lower cost and requires only a small area in contrast to the massive 50/200 MHz class radars. In addition, the performance of 445 MHz radar is much superior to L band (1 GHz) radars in terms of height coverage during clear air. Further, the wind estimates with 445 MHz radar are more accurate during precipitation/convection, while the 1 GHz radars provide erroneous estimates. The developed 445 MHz radar provides horizontal winds continuously from a height as low as 112 m to ~8-12 km (depending on the atmospheric conditions), in which majority of the meteorological processes occur. Besides continuous wind profiling, the radar measurements can also be used for studying the atmospheric boundary layer, turbulence and precipitation. The spaced antenna technique is chosen as it works with only vertical beam and hence does not require complex beam steering network, making the system configuration simple and cost-effective. As with one vertical beam, one wind profile can be obtained, this radar provides high-temporal resolution measurements required to study transient phenomena like wind Gusts.

The radar antenna array, comprising 252 microstrip patch elements, is designed with a modularity feature and is arranged in 7 subgroups, forming a quasi-circular array. Three of the outer subgroups forming an equilateral triangle and the center subgroup are chosen for wind profiling application in spaced antenna mode. Each subgroup is energized with a 2 kW Transmit Receive (TR) module. All four groups radiate with a peak power of 8 kW during the transmit mode with a 3-dB beam width of 5.3^{o}. During the receive mode, the atmospheric backscatter signal collected by each subgroup is processed independently in a multi-channel receiver unit. Full-correlation analysis (FCA) is applied to the four receive channels data to derive the horizontal wind (zonal and meridional) components. The derived winds agree well with those obtained by radiosonde and a collocated 1.28 GHz wind profiling radar. Photograph of the wind profiling radar is shown in figure below

Figure: 445 MHz Wind profiling radar

O-20

The Tibetan Plateau (Yangbajing) MST radar system

Yufang Tian(1), Xin Wang(1), and Daren Lyu(1)

(1) Key Laboratory of Middle Atmosphere and Global Environment Observation (LAGEO), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

The new powerful Tibetan Plateau (Yangbajing) MST radar (30.1°N, 90.5°E; 4300 m MSL) obtained atmospheric echoes for the first time on October 18, 2023. It is a fully digital multipolar phased array MST radar with a more flexible detection ability. The Tibetan Plateau (Yangbajing) MST radar operates at 50 MHz. It has a circular array with a diameter of 153 m consisting of 931 3-element crossed Yagi antennas and 800 transmit and receive (T/R) modules. The peak power is 1.92 MW. The power of each T/R module is adjustable with a maximum power of 2400W. This new MST radar makes use of the fully digital two-dimensional phased array technology, multi-polarization observation technology (arbitrary switching of linear polarization, left-handed circular polarization, and right-handed circular polarization transceiver polarization modes), digital multi-beam technology (maximum support for 20 beam simultaneous detection), radar automatic calibration technology, and radar health management technology. The preliminary verification results of the detection capability and data quality of the Tibetan Plateau (Yangbajing) MST radar show that it will play an essential and indispensable role in studying the dynamics of the whole atmosphere over the Tibetan Plateau and in revealing the vertical coupling process between the lower atmosphere, the middle and upper atmosphere, and the ionosphere.

The LARID: capabilities, advantages and limitations for observing low latitude ionosphere

Guozhu Li(1) (2) (3), Lianhuan Hu(1) (2), Wenjie Sun(1) (2), Baiqi Ning(2), et al.

(1) Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences (IGGCAS), Beijing, China.

(2) Beijing National Observatory of Space Environment, IGGCAS, Beijing, China.

(3) College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing, China.

(gzlee@mail.iggcas.ac.cn)

A Low lAtitude long Range Ionospheric raDar (LARID) has been recently developed at Dongfang (19.2°N, 108.8°E, dip Lat, 13.9°), China, for monitoring low latitude ionospheric variabilities over a large longitude region. In this talk, we will present the system design of LARID and its preliminary observations. To validate the long-range measurements by LARID, observations by ground-based GNSS TEC receivers, ionosondes and VHF radars are also included. The results demonstrate that the LARID can detect various ionospheric variations at low latitudes, including (a) equatorial plasma bubble irregularities over a large longitude span of ~180°, from Africa to Pacific, (b) near-range E region irregularities drifting more than 1000 km, (c) background ionospheric parameters retrieved from ground scatters, (d) travelling ionospheric disturbances, and (e) sporadic E structures reflecting HF radio waves at low elevation angles. It is expected that the LARID will provide an important tool for investigating different types of low latitude ionospheric variabilities over a broad longitude zone, and will contribute significantly to the regional ionospheric weather forecasting.

(a)

(b)

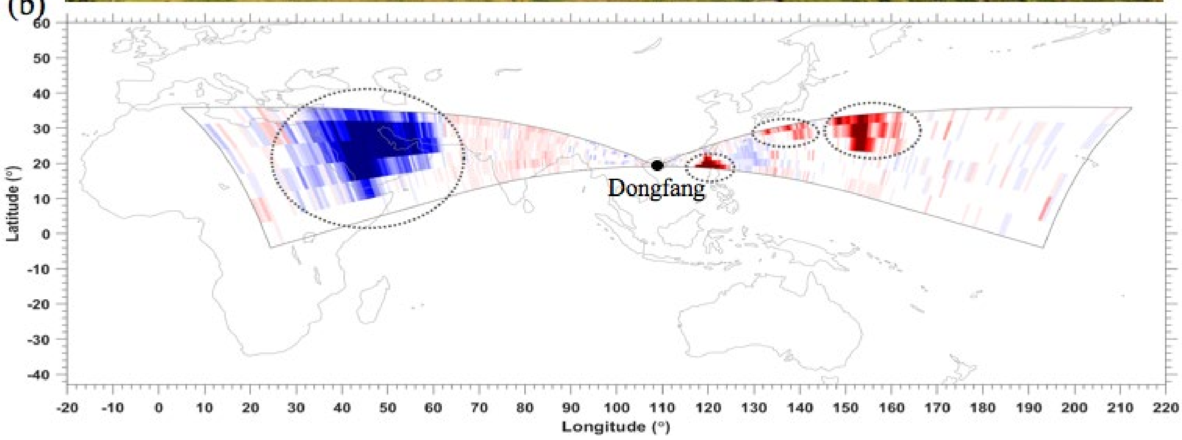

Figure 1. (a) The view of LARID at Dongfang, China, (b) the Doppler velocity of equatorial plasma bubble irregularities observed by the LARID on 5 November, 2023.

DDMA-MIMO observation with the MU radar

Tomoya Matsuda(1), Koji Nishimura(2), and Hiroyuki Hashiguchi(2)

(1) Mitsubishi Electric Corporation, Tsukaguchi-Honmachi, Amagasaki, Hyogo 661-8661, Japan

(2) Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Kyoto 611-0011, Japan

1. Introduction

MIMO (Multiple-Input Multiple-Output) technology, widely used in communications, has also been applied in phased array radar systems [1]. By employing MIMO technology, it is possible increase the degrees of freedom in transmit signals, enabling enhanced system performance and versatility. The MU radar, capable of operating as a MIMO radar, facilitates demonstration experiments through observations. In a MIMO radar system, multiple orthogonal signals are transmitted simultaneously and received by multiple receivers. To generate orthogonal signals, the Doppler Division Multiple Access (DDMA) method, which segregates transmit signals in the Doppler domain, was selected.

2. Experimental Observation with DDMA-MIMO/Capon Combination

The Beamformer and Capon methods are established techniques for estimating the direction of arrival in phased array radar systems [2]. Notably, the Capon method enables enhanced or even super-resolution by calculating optimal weight vectors for each antenna element. Given the compatibility between MIMO radar signal processing and direction of arrival estimation, a synergistic effect can be anticipated from combining MIMO's virtual aperture expansion with the Capon method's super-resolution capabilities. To validate this effect, observations toward the moon were conducted using the MU radar.

3. Results of the Observation Experiment

Figure 1 illustrates the distribution of the moon reflection echoes calculated using the Beamformer method. The results indicate improved angular resolution due to the virtual aperture expansion provided by MIMO (left) compared to the normal mode (right). Figure 2 shows the distribution using the Capon method, further demonstrating enhanced angular resolution attributable to the Capon method, with additional improvement observed through synergy with MIMO. The Beamformer method is recognized for its alignment with antenna pattern theory; hence, a comparison with theoretical values was conducted to verify accuracy. The main beam exhibited good agreement with theoretical predictions.

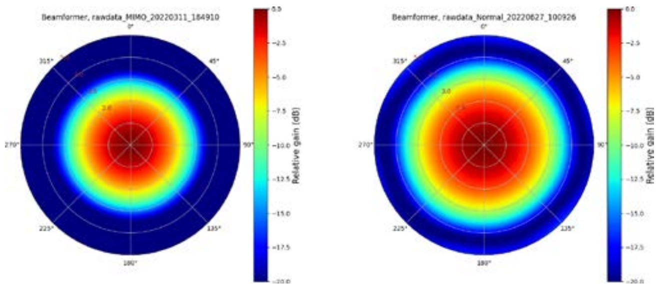

Figure 1. Distribution of the moon reflection echoes using the beamformer. (Left: DDMA-MIMO Observation, right: Normal Observation)

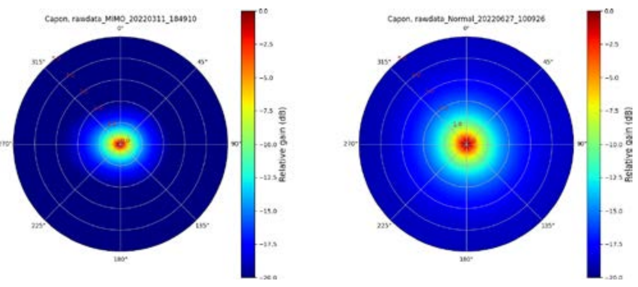

Figure 2. Distribution of the moon reflection echoes using the Capon method. (Left: DDMA-MIMO Observation, right: Normal Observation)

[1] M. S. Davis, “Principles of modern radar: Advanced techniques,” in Princ. Mod. Radar Adv. Tech., Melvin William L. and Scheer James A., Ed. Scitech publishing, 2013, ch. 4, pp. 119–145.
[2] N. Kikuma, Adaptive Antenna Technology (in Japanese), Ohmsha, 2003.

O-23

Development of MIMO radar using 1.3-GHz atmospheric radar

Hiroyuki Hashiguchi(1), Yuna Ishii(1), Koji Nishimura(1), and Mamoru Yamamoto(1)

(1) Research Institute for Sustainable Humanosphere (RISH), Kyoto University

The phased-array radar technology has been primarily utilized for atmospheric radars, and it has also been employed as meteorological radars for research purposes. Various phased-array applications that perform Digital Beam Forming (DBF) with multiple receivers have been developed. DBF provides multiple receive beams in a single scan, which dramatically reduces the scan time. However, conventional phased array radars cannot distinguish transmit signals at the receivers. Therefore, they are categorized as Single-Input Multiple-Output (SIMO) radars.

As a further development of the phased-array technology, the Multiple-Input Multiple-Output (MIMO) technique, which was originally developed for communication systems, has been applied to radars, making a new contribution for radar signal processing [Li and Stoica, IEEE, 2008]. The orthogonality of the transmit signals is the most definitive difference between SIMO and MIMO radars. The transmit waves can be separated by adopting orthogonal waveforms for each transmitter. A MIMO approach for atmospheric radars was applied for atmospheric and ionospheric synthesis radar imaging observation, attempting to use Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and polarization diversity [Urco et al., IEEE, 2018, Urco et al., AMT, 2019].

We applied the Doppler Division Multiple Access (DDMA) method, which utilizes a slow-time direction (Doppler frequency domain) to obtain the orthogonal transmit waveforms, to the VHF-band MU radar [Matsuda and Hashiguchi, IEEE, 2023]. In this research, we verified DDMA-MIMO scheme using the 1.3 GHz atmospheric radar LQ-7 (Figure 1). Unlike the MU radar, LQ-7 has only one receiving channel, so we constructed a system that enables signal separation with multi-channel receivers by using Software Defined Radio (SDR) and devising local frequencies. For LQ-7 observations, so-called Spano codes are usually used as the pulse compression code, but this causes an overlap of the frequency bands used by the Spano codes and the DDMA-MIMO. This problem was solved by using complementary codes. We conducted MIMO observation experiments using constructed system and compared the calculated theoretical beam pattern with the observation results. The results are in good agreement with the theoretical values, and it can be said that LQ-7 works as a MIMO radar and virtual aperture is expanded. In addition, by adaptive beamforming process such as the Capon method, the MIMO radar exhibits good performance with high angular resolution and high clutter suppression due to the increase in the number of channels used for beam steering. The observation results show that high angular resolution is achieved by using the Capon method compared with the non-adaptive Fourier method.

Figure 1. LQ-7 wind profiler at the Shigaraki MU Observatory

Advanced Indian MST Radar with Multi-channel capabilities

M. Durga Rao, P. Kamaraj, K. M. V. Prasad, K. Jayaraj,
J. Raghavendra, R Ashrit, T.N.Rao and A.K.Patra

The Advanced Indian MST Radar (AIR) in active phased array configuration with 360º azimuth beam agility, modularity, multi-channel capability and built-in scalability has been realised at NARL, Gadanki, India (13.45°N, 79.18°E). Several latest technologies have been implanted in the radar development, such as placing state-of-the-art 1-kW high-power solid state Transmit-Receive modules (TRM) near antenna elements in the outdoor environment to minimize feeder losses, complex distributed control signal system to each TRM through optical fiber, flexible antenna array configuration to support upto a maximum of 64 channels with multi-channel direct digital receiver system for Spaced Antenna (SA) and Interferometry/ Imaging applications. The system has been validated for its scientific usage in a variety of experimental modes, like Doppler beam swinging (DBS) and Velocity-Azimuth-Display (VAD) modes in the troposphere and the results are found to be very encouraging. The multi-receiver capability has been tested with different array apertures and base lengths for interferometry and spaced antenna experiments. The improved detectability and high-resolution capabilities with built-in flexibilities caters the present and future scientific requirements of the atmospheric research community. The Moon echoes were successfully detected and two-way radiation pattern was characterized. Also, to explore the sensitivity of AIR for the space debris, several experiments were carried out and successfully detected the Indian LEO satellites upto 1m x 1m size and further it is deuced that it is possible to detect a minimum LEO object size of 0.05 m^2. Further echoes from the Moon bound objects, during the Chandrayaan-3 orbital period in Aug 2023.

In this paper, we present the AIR system configuration with multi-channel facility, validation of products, new capabilities and few scientific results obtained using the AIR system.

Meteor radar of Kazan Federal University and prospects for the development of a local area meteor network

Korotyshkin D.V[(1)] , Sherstyukov O.N. [(1)] , Valiullin F.S.[(1)]

(1) Kazan Federal University, 18, Kremlyovskaya Street, Kazan 420008, Russian Federation, e-mail: dmitry.korotyshkin@kpfu.ru

Radar observations of meteors in Kazan, Russia, began in 1955 at the Problematic Radio Astronomy Laboratory (PRAL) of Kazan University, initiated by K.V. Kostylev. Regular meteor observations commenced in 1979, and by 1986, the meteor radar was upgraded with a phase interferometer featuring a 9.5 wavelength baseline, designed for precise angle and altitude determination, alongside a pulsed transmitter with a power of 100 kW. In 2015, a SKiYMET meteor radar model, produced in Australia and Canada, was installed at PRAL, utilizing measuring baselines of 45x45 meters.

In 2020, the meteor radar underwent significant hardware and software upgrades: the measuring baselines expanded to 220x160 meters, and the number of receiving channels increased from 5 to 12 (see Fig. 1). These enhancements led to a doubling of recorded meteors (up to 60,000 per day) and a fourfold improvement in the angular resolution of meteor reflections, achieving a resolution no worse than 0.3 degrees.

This report will detail the technical specifications of the updated meteor complex, including the accuracy parameters of the phase angle measurement system derived from both modeling and actual measurements. It will also highlight the primary astronomical and meteorological capabilities of the all-weather meteor radar at KFU, alongside results from 24-hour radio meteor observations conducted between 2015 and 2024.

A critical issue with classical backscatter meteor radars is that the use of Doppler frequency shifts averages zonal and meridional wind speeds over a region with a radius of 150-200 km, employing the least squares method. However, studying phenomena such as internal gravity waves necessitates high spatial resolution due to the short wavelengths involved. Components of wind speed in specific areas cannot be accurately estimated because the least-squares matrix equations are poorly conditioned. To address this challenge, the proposal involves implementing distributed meteor radio echo reception sites. The report will discuss the prospects for expanding the antenna field, increasing the number of receiving antennas, and developing additional spaced reception sites, and thus promoting radio meteorology in Kazan.

The research conducted by Korotyshkin D.V. and Valiullin F.S. was funded by a grant from the Ministry of Education and Science of the Russian Federation FZSM2023–0015, allocated to Kazan Federal University to fulfill a state task in the field of scientific activity.

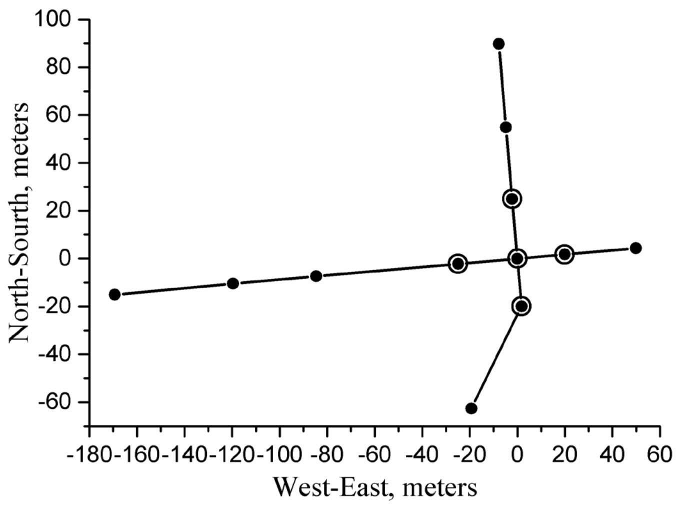

Figure 1. The layout of the meteor radar antennas at Kazan University. The circled points indicate the initial placement of 45x45m.

Method of determination of meteor velocity by diffraction and comparison of meteor shower velocities based on observations in Kazan with other optical and radar data

Korotyshkin D.V[(1)]

(1) Kazan Federal University, 18, Kremlyovskaya Street, Kazan 420008, Russian Federation, e-mail: dmitry.korotyshkin@kpfu.ru

The study of meteor influx is an important task of meteor astronomy. One of the main goals is to determine the radiants of meteor showers and identify them with their parent bodies (comets, asteroids). For radiant meteors satisfying the condition of specularity of radio reflections, the Jone's statistical method can be applied. For effective use of this method it is desirable to know the velocity of the meteor particle, which allows to limit the selection when constructing the radiant distribution, as meteor showers of the same stream have similar velocities. In addition, knowledge of the velocity of the meteor shower is necessary to determine the orbital elements of the meteor shower.

There are several methods to determine the velocity of a meteor particle. Each of them is based on one of the physical principles - either the velocity is determined by movement (head echo) or by analyzing the diffraction pattern. The main limitation in determining velocities is the requirement for a relatively high signal-to-noise ratio. As a result, the obtained data is significantly limited because the number of meteors depends on the amplitude in a power-law relationship. This negatively affects the accuracy of the Jone's method, especially for weak and irregular meteor showers, whose zenith hour rate (ZHR) is relatively small.

This paper presents a new approach to determining the velocities of meteoric particles, which allows us to calculate the velocities for 60-70% of the total number of registrations with an accuracy of 1-10% at a signal-to-noise ratio starting from -5 dB. The proposed method is fully automatic. Approaches to improve the signal-to-noise ratio and criteria for rejecting unsuitable meteor radio echoes will also be presented.

In addition, the study will compare the results of using this technique for radio meteor shower observations on the Kazan Federal University (Kazan, Russia) meteor radar with optical and other radar observations. The results of the study will include interday analysis of the distribution of meteor particle velocities, as well as intraday radiant meteor shower radiant variations using filtering based on meteor particle velocities obtained using the developed method.

The work was funded by a grant from the Ministry of Education and Science of the Russian Federation FZSM2023–0015, allocated to Kazan Federal University to fulfill a state task in the field of scientific activity.

Fine Structure of the Vertically Propagation of Kelvin Wave "near" Tropopause during Wet and Dry Season Observed by the Equatorial Atmosphere Radar

Eddy Hermawan(1), Widya Ningrum(1), Albertus Sulaiman(1), Sonni Setiawan(2)

(1) National Research & Innovation Agency (BRIN) of the Republic of Indonesia

(2) IPB University of the Republic of Indonesia

E-mail: eddy.hermawan@brin.go.id and eddy_lapan@yahoo.com

ABSTRACT

As a unique region at the equator flanked by two large continents (Asia and Australia) and two large oceans (Indian and Pacific) with diverse land distribution, Indonesia experiences hydrometeorological disasters almost all year round. This disaster is closely related to the presence of extreme rainfall, especially during the La-Nina era. Not only by *Madden Julian Oscillation* (MJO), the previous studies found that extreme rainfall is generally closely related to the presence of atmospheric waves, one of which is the role of Kelvin waves. Unfortunately, most studies on Kelvin waves have not discussed the vertical structure of Kelvin waves. Most of them investigated the Kelvin waves near surface, using in-situ observation or taken from the re-analysis data (generally taken from ERA-5 data). On the other hand, generally they are not using data that already designed with good time and spatial high resolution. By this reason, at this present study we are very interest to investigate of the fine structure of Kelvin waves, especially during rainy and dry season using the Equatorial Atmosphere Radar (*EAR*) at Kototabang, Bukittinggi, West Sumatera, Indonesia that already designed with good time and spatial height resolution. Studies on propagation and vertically structure of Kelvin wave were still limited on OLR data, GPS, RO, NCEP / NCAR reanalysis and radiosonde. EAR data were expected to explain not only an about propagation, also the vertical structure of Kelvin wave better than other technique. To analyze the Kelvin wave propagation above Kototabang, spectral analysis method were used with both the FFT (*Fast Fourier Transform*) and the Wavelet technique. Statistical analysis was also done with cross-correlation technique (*Cross Correlation Function*) and cross Spectral (*Cross Spectrum*) to investigate the relevance between Kelvin wave and the KTTL (Kototabang Tropical Tropopause Layer). Based on EAR data analysis for period of 1 December 2007 – 31 December 2008, Kelvin wave was detected above Kototabang with eastward zonal propagation and downwards vertically. Spectral analysis during this period showed that the Kelvin wave appeared periodic every 18 days at 17.41 km altitude near the Tropopause layer (~17 km). Power spectrum analysis indicate that the Kelvin wave energy was stronger during wet season than during dry season. During wet months, the Kelvin wave is dominant at 16.97 km in altitude and appear periodic every 15 days. While in dry months, it is more dominant at 16.52 km in altitude and appeared every 18 days. Statistical analysis results during wet and dry season indicate a correlation between zonal wind dynamics with the fluctuation of Tropopause height, spontaneously and in spontaneously. Cross-spectrum analysis showed that zonal wind dynamics activity affected the height fluctuation of the Tropopause where the Kelvin wave tend to rise the KTTL height during wet season, while in dry season it will lower the KTTL height.

Keywords: Kelvin waves, Propagation, EAR, KTTL, Spectral analysis.

Recent observations of atmospheric instabilities from the Indian network of ST/MST radars : Results inferred from NetRAD-ASMA campaign

Siddarth Shankar Das(1),*, N. Poddar(1,2), M. V. Ratnam(3), V. Venugopal(1,2), A. K. Ghosh(4), A. Paul(5), M. Naja(6), S. Abhilash(7), S. Bhattacharjee(6), M. Durga Rao(3), P. Nandakumar(5), V. Rakesh(7), S. K. Das(8), S. V. Sunikumar(1), D. S. Raj(4), N. Das(4), G. Pandithurai(8), K. Raghunath(3)

(1) Space Physics Laboratory, Vikram Sarabhai Space Centre, ISRO, Thiruvananthapuram, India
(2) Department of Physics, University of Kerala, Thiruvananthapuram, India
(3) National Atmospheric Research Laboratory, DoS, Gadanki, India
(4) Satish Dhawan Space Centre, ISRO, Sriharikota, India
(5) Institute of Radio Physics and Electronics, University of Calcutta, Kolkata, India
(6) Aryabhatta Research Institute of Observational Sciences, Nainital, India
(7) Advanced Centre for Atmospheric Radar Research, CUSAT, Kochi, India
(8) Indian Institute of Tropical Meteorology, MoES, Pune, India

*e-mail : siddarth_das@vssc.gov.in & dassiddhu@yahoo.com

Asian Summer Monsoon Anticyclone (ASMA) develops as a response to diabatic heating associated with convection, encompasses a westerly in mid-latitudes and easterly in the tropics. The occurrence of a Tropical Easterly Jet (TEJ) in the NH summer and Sub-Tropical Jet (STJ) in the NH winter are the prominent features associated with the ASMA region and has a strong influence on the onset and withdrawal of Indian summer monsoon. Air mass transport within ASMA is one of the major sources of air pollution for the upper troposphere and lower stratosphere (UTLS) region. High amount of water vapour and low amount of ozone are found over ASMA. TEJ and STJ play a key role in the horizontal distribution of tropical upper tropospheric humidity and mid-latitude ozone over the Indian region. The vertical structure of the tropopause layer and its variability at various time scales play an important role in the exchange of minor constituents, especially water vapour and ozone between the stratosphere and troposphere. This exchange process will remove water vapour from the air as it enters the stratosphere and in the reverse direction, intrusion of stratospheric ozone into the troposphere. It has an impact on the global weather-climate system. India has a network of Stratosphere-Troposphere (ST) / Mesosphere-Stratosphere-Troposphere (MST) radars located at Gadanki (13.5ºN, 79.2ºE, 53 MHz), Cochin (10.04ºN, 76.3ºE, 205 MHz), Nainital (29.35ºN; 79.45ºE, 206.5 MHz), Guwahati (26.2ºN, 91.75ºE; 212 MHz) and Haringhata (22.94ºN; 88.51ºE, 53 MHz), which are located in and around the ASMA region. In this context, an experimental campaign entitled 'NetRAD-ASMA (Network of ST/MST radars and balloon borne measurement Campaigns of the Asian Summer Monsoon Anticyclone)' Phase-I (winter campaign) was conducted during 12-16 February 2024 by operating the network of four ST/MST radars (Haringhata, Gadanki, Nainital and Kochi) along with regular radiosonde (6-12 hrs) measurements from Balasore, Nainital, Gadanki, Silkheda, Pune, Kochi and Trivandrum. In addition, ozonesondes were also launched in an interval of 6 hrs during intense observation period from Balasore and to get background information, ozonesondes were also launched from Gadanki, Trivandrum and Nainital. Micro-pulse, Rayleigh and Mie Lidars were also operated from Gadanki. Initial results shows the enhancement of ozone concentration (Balasore) by about 60 nbar in the lower stratosphere, which persist for about 12-18 hrs. Trajectory analysis shows that the balloon drifted drastically with the upper tropospheric westerlies and thus the stratospheric ozone was measured over the head Bay of Bengal which is about 160 km from the Balasore launching station. Vertical air motion as observed from ST-Radars from the four locations show the presence of strong updrafts and downdrafts. Initial analysis shows that the enhancement of lower stratospheric ozone can be explained in terms of the balance between the photolysis of molecular oxygen and photo-dissociation of ozone as well as adiabatic process in compression and expansion of air mass. The detailed results will be presented and discussed in the upcoming conference.

Characteristics of vertical air motion over central Himalayan region using 206.5 MHz Stratosphere-Troposphere Radar

Nabarun Poddar[1][2], Siddarth Shankar Das[1], Manish Naja[3], Samaresh Bhattacharjee[3]

(1) Space Physics Laboratory, Vikram Sarabhai Space Centre, ISRO, Thiruvananthapuram

(2) Department of Physics, University of Kerala, Thiruvananthapuram

(3) Aryabhatta Research Institute of Observational Sciences, DST, Nainital

Vertical motion (*w*) of air is an important dynamical variable as it facilitates the study of different atmospheric processes across different scales. This w has embedded the signatures of the prevailing atmospheric dynamics starting from local mesoscale processes right up to planetary scale circulations, all of which can be quantified with appropriate precision and period of observation of *w*. The upward and downward motion of air parcels are set in place to attain radiative-convective equilibrium in the troposphere. This indirectly controls the weather phenomena over a region in the lower troposphere. And has direct control over the dynamical, radiative, and chemical interactions between the well-mixed troposphere and the stably stratified stratosphere in the upper troposphere and lower stratosphere (UTLS) region through the transition inversion layer- the tropopause, whose vertical structure and temporal variability manifests the vertical exchange of mass and momentum between the lowest two layers of the atmosphere. These processes, termed as "Stratosphere-Troposphere Exchange" (STE) by the atmospheric science community, play a vital role in determining the climatological features of a region. To quantify all these processes precision in measured *w* becomes very important, but like any region of interest, having accurate measure of vertical motion of air is very difficult owing to its relatively small magnitude compared to the horizontal components of wind. In this aspect, a state-of-the-art, indigenously developed stratosphere–troposphere (ST) radar operating at 206.5 MHz, which is a pulse-Doppler radar at Nainital (29.35°N; 79.45°E) – the region of interest in the central Himalayas, gives direct measurements *w* which has been used to study the long-term characteristics of vertical air motion and its role in the dynamical processes. Multiple years of *w* measured from the radar vertical Doppler have been characterized. Further *w* is averaged for periods of observation in a day for all days in a season. Monthly mean of hourly data shows the presence of downdrafts in the lower troposphere, whereas in the upper troposphere it is the mixture of both updrafts and downdrafts. Weaker downdrafts are observed during the monsoon season. This gives us an insight into the long-term characteristics of *w* over the region with seasonal variations associated with the various local climatological features. Hints of two-step transfer of air parcel from lower levels to the UTLS region is also observed. Details of results shall be presented at the upcoming symposium.

Characteristics of the aspect sensitivity and the long-term variation of vertical wind velocity observed with Equatorial Atmosphere Radar

Noersomadi[(1)], Tiin Sinatra[(1)], Hubert Luce[(2)], Toshitaka Tsuda[(2)] and Hiroyuki Hashiguchi[(2)]

(1) Research Center for Atmosphere and Climate, National Research and Innovation Agency (BRIN), Bandung, Indonesia

(2) Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan

This work is concerned with the statistical analysis of the long-term observations of the Equatorial Atmosphere Radar (EAR, Indonesia (0.20°S, 100.32°E)) observation from June 2001 to December 2019, with particular focus of the aspect sensitivity of the echo power and the vertical wind component. We define the aspect sensitivity (AS) as the ratio of the echo power in the vertical beam to the mean echo power among the four oblique beam directions tilted by 10°. By considering the high humidity at 3-5 km of lower troposphere, a relatively dry level at 8-10 km in the upper troposphere and the sharp change at the16-18 km of tropopause, we examine the relation between AS and the horizontal wind components. In the lower troposphere, a linear regression shows a positive slope of 0.41, indicating that the large eastward winds correspond to high AS values. On the other hand, high AS values correlate with large westward winds in the upper troposphere and tropopause regions with a negative slope of –0.49. We also discussed the long-term vertical velocities W measured directly from the vertical beam and the combination of symmetrical oblique beams.

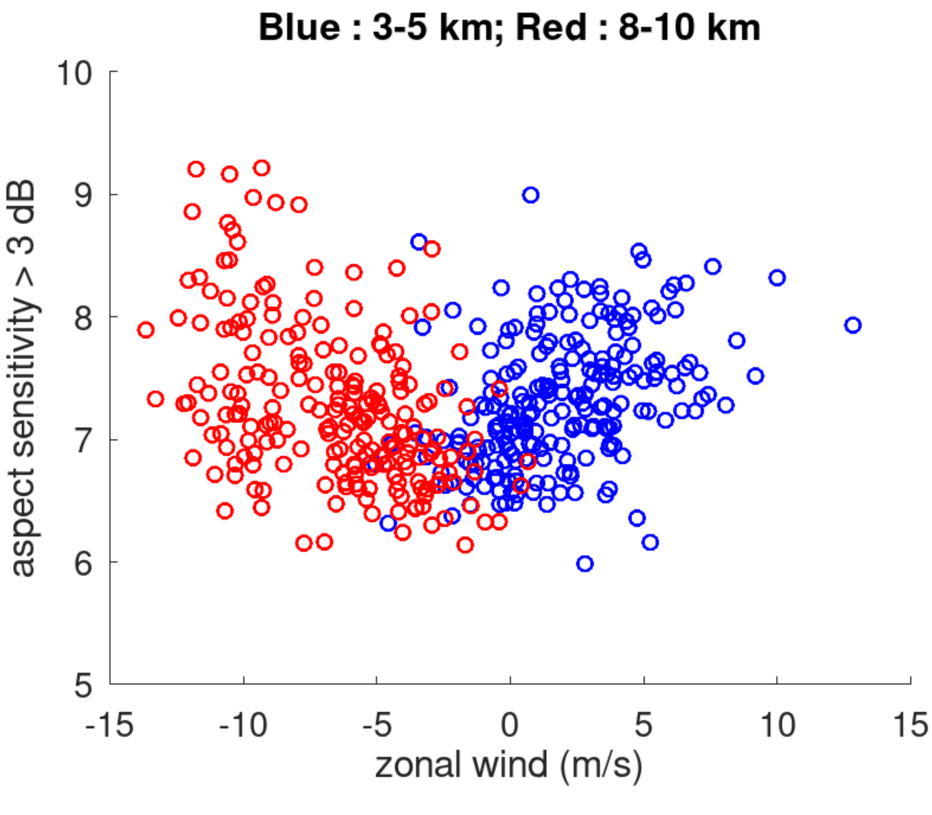

Figure 1. Scatter diagram of monthly aspect sensitivity and zonal wind.

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Investigation of The Turbulence Echo Power Observed by Equatorial Atmosphere Radar (EAR) with The Refractive Index Gradient and the Atmospheric Stability from Hourly Radiosondes with 10 m Vertical Sampling

Tiin Sinatra (1), Noersomadi(1), Asif Awaludin(1), Halimurrahman(1), Nani Cholianawati(1), Anis Purwaningsih(1), Toshitaka Tsuda(2), Hiroyuki Hashiguchi(2), Hubert Luce(2)

(1) Research Center for Climate and Atmosphere, National Research and Innovation Agency (BRIN), Bandung, Indonesia

(2) Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Japan

This work examines the time-height variations of turbulence echo power observed with the equatorial atmosphere radar (EAR) situated at 100.32°E, 0.204°S, Kototabang, Sumatra, Indonesia on December 15, 2005. This study focuses on the relationship between radar reflectivity (η) and the background refractive index gradient ($dn/dz = M$), as well as the behaviour of atmospheric turbulence. The atmospheric stability (occurrence of turbulence) is represented by the Richardson number (***Ri***). The vertical echo power (S_o) is sampled at 150-meter intervals using the EAR. Intensive radiosonde soundings were conducted at the EAR site, with launches occurring hourly, which provides a unique data set for examining time-height variations of atmospheric parameters. Temperature (***T***), relative humidity, pressure, and horizontal wind velocity (***U***) were measured at two-second intervals, with the balloon ascending at a rate of approximately 5-6 m/s. As the original radiosonde data points were not uniform, we applied interpolation to create a profile with a uniform interval of 10 m. Initially, we compared the time and height structure between S_o and M^2/N^2. The cross-correlation analysis at 3-5.5 km altitude resulted in a peak value of 0.64, while at 6-9 km altitude, the peak value was 0.61. Subsequently, we analysed R_i at 10-meter intervals from ***T*** and ***U***. We, then, calculated the percentage occurrence of R_i***-KHI*** ($0 < R_i < 0.25$) and R_i***-CI*** ($R_i < 0$) out of 20 determinations in each 200-meter layer. The continuity in the R_i distribution is clearly evident. At altitudes between 6 and 9 km, several systematic layers of intense radar echoes emerged with the downward phase progression. R_i***-CI*** exhibited a corresponding downward structure at the same altitude. S_o exhibited a clear downward progression at altitudes of 6-9 km, and R_i***-CI*** showed a similar structure at the same altitude. However, no coincidence was identified with R_i***-KHI***. We conducted a further investigation into the time-height structure of S_o and ***R***.

Keywords: hourly radiosonde, EAR, M^2/N^2, R_i***-KHI***, R_i***-CI***

Vertical motion of two types of heavy convective rainfall with different depths observed by the MU radar, a vertical pointing X-band radar, and the GPM

Shoichi Shige(1), Nozomu Toda(1), Kazumasa Aonashi(1), Yusuke Goto(2), Taro Shinoda(2), Nobuhiro Takahashi(2), and Hiroyuki Hashiguchi(3)

(1) Graduate School of Science, Kyoto University, Kyoto, Japan

(2) Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Nagoya, Japan

(3) Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Uji, Japan

Vertical air motion within precipitating clouds is an important physical quantity for convective motion validation of next-generation satellite precipitation missions such as the Japan Exploration Agency (JAXA) Precipitation Measurement Mission (PMM) with the Ku Doppler radar. Atmospheric Doppler radars (also called wind profilers) transmitting in the 50-MHz band directly measure vertical motion due to atmospheric turbulence in all weather conditions. There are only a few 50-MHz atmospheric Doppler radars in the world because they require a large antenna aperture with a diameter of about 100 m. A prime example is the Middle and Upper atmosphere radar (MU). We have started to observe precipitation using the MU radar and a vertical pointing X-band Doppler radar, and succeeded in capturing heavy convective rainfall during the rainy season in 2023 when the Global Precipitation Measurement (GPM) core satellite passed over the MU radar. At the moment of the GPM passage, the MU radar captured an upward motion of heavy convective rainfall with an echo top height of about 10 km or less, and shortly thereafter, an upward motion of heavy convective rainfall with an echo top that reached near the tropopause (about 14 km altitude). It has been speculated from the Tropical Rainfall Measurement Mission (TRMM) and GPM observation that the former relatively shallow convective rainfall was dominated by a “warm rain” process below the melting layer. In fact, the radiometer on board the GPM also showed that the former had weaker ice scattering in the high frequency channels than the latter. Contrary to the speculation above, however, the MU radar captured a shallow but strong upward motion just above the melting layer. On the other hand, in the latter deep convective rainfall, the upward motion captured by the MU radar was deeper but weaker in strength. Thus, the vertical motion observation by the MU radar improves our understanding of convective precipitation processes that cannot be obtained by current satellite precipitation observations alone, and are useful for convective motion validation of next-generation satellite precipitation missions.

Bright Band Observations with a Micro Rain Radar and the MU Radar

Toyoshi Shimomai(1), Yutaro Saiki(1), and Hiroyuki Hashiguchi(2)

(1) Graduate school of natural science and technology, Shimane University,
1060 Nishikawatsu, Matsue, Shimane, 690-0876, JAPAN

(2) RISH, Kyoto University, Gokasho, Uji, Kyoto, 611-0011, JAPAN

A Micro Rain Radar (MRR) was operated at the MU observatory during 2011 - 2016. MRR is a vertically pointing FM-CW Doppler radar operated at 24 GHz. A bright band is observed as the enhanced radar echo area associating with melting hydrometeors. The MU radar can measure the background vertical wind. The characteristics of bright band obtained from MRR observations are compared with the background vertical wind velocity observed with the MU radar.

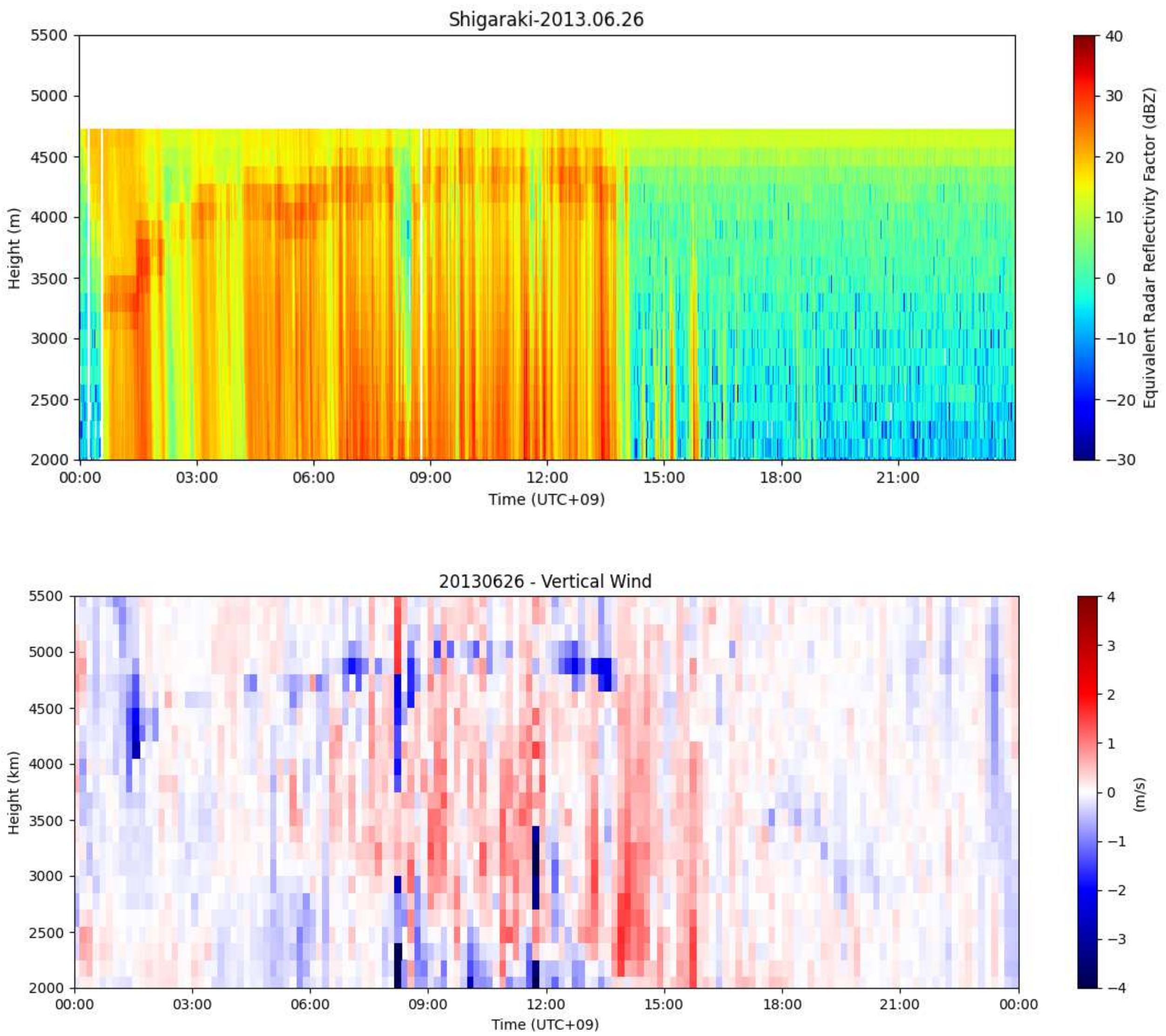

Figure 1. (a) Ze observed with a MRR (b) Vertical wind observed with the MU radar.

Applications of multi-receiver and multi-frequency radar imaging to atmospheric study

Zhen-Xiong You(1), Hiroyuki Hashiguchi(2), Mamoru Yamamoto(2), Yen-Hsyang Chu(3), Ching-Lun Su(3), Chien-Ya Wang(4)

(1) Center for General Education, China Medical University, Taiwan

(2) Research Institute for Sustainable Humanosphere, Kyoto University, Japan

(3) Department of Space Science and Engineering, National Central University, Taiwan

(4) Department of Optoelectric Physics, Chinese Culture University, Taiwan

High-resolution observations of the atmosphere using multi-receiver and multi-frequency imaging techniques of VHF radar are presented. The MU and Chung-li radars, both pulsed and phased-arrayed VHF radars, were employed to collect the data. Adaptive retrieval algorithms such as Capon and NC-Capon methods are applied to these multi-channel received radar echoes. As a result, multiple layers, multiple echo centers, angular power distribution, and so on, in the radar volume could be resolved to a certain extent. Plenty of investigations into atmospheric structures and dynamics can be made based on high-resolution imaging results, for example, clear-air turbulences, small-scale wavy layer structures, field-aligned plasma irregularities, meteors, aspect sensitivity in neutral and ionospheric irregularities. Some of these observational achievements will be shown.

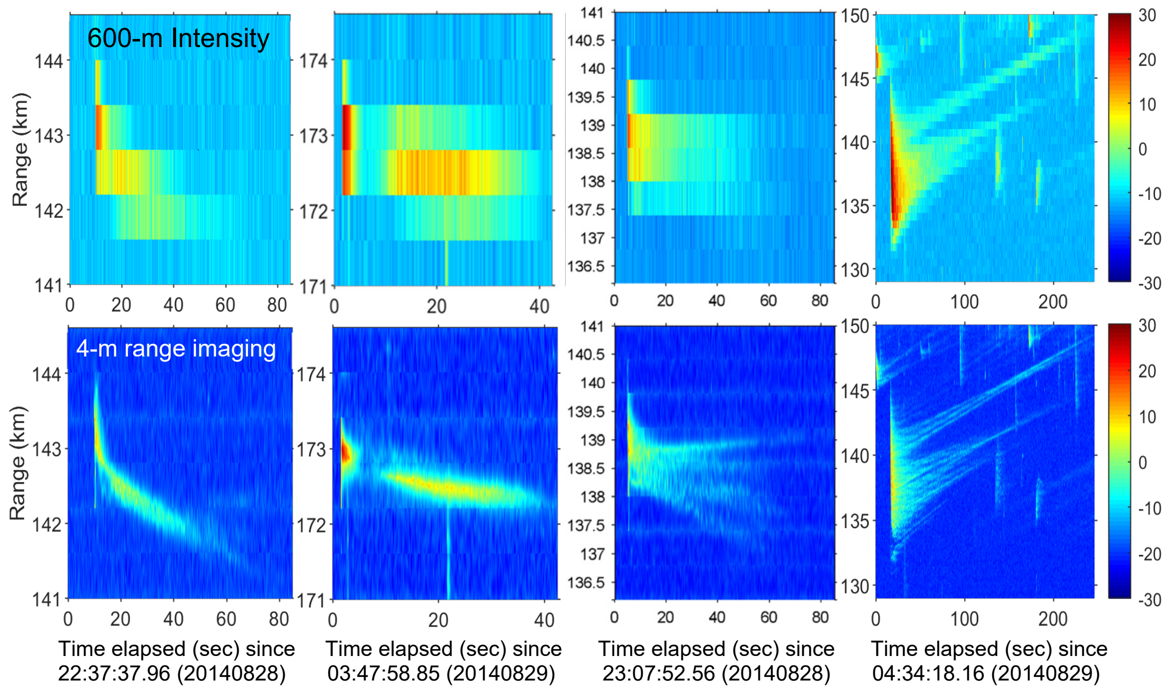

Figure 1. Four cases of meteors and long-duration trail echoes observed by Shigaraki MU radar. Upper panels: initial range resolution 600 m. Lower panels: multi-frequency range imaging with 4-m step.

Observation of vertical wind profiles in clear air using a C-band solid-state radar

Hiroshi Yamauchi(1), Takashi Unuma(1), Akihito Umehara(1), and Ahoro Adachi(2)

(1) Meteorological Research Institute, Nagamine 1-1, Tsukuba, Ibaraki, Japan

(2) Meteorological College, Asahimachi 7-4-81, Kashiwa, Chiba, Japan

Preliminary results of clear-air vertical wind profile observations using a C-band solid-state radar are reported. Information on the winds at the lower troposphere in non-precipitation areas is important for estimating convergence and amount of water vapor supplied to precipitation areas. For this reason, it is desirable to be able to obtain wind profiles in the clear air not only through a wind profiler network but also through a weather radar network. Weather radars in Japan are currently being upgraded from single-polarization radars equipped with electron tube transmitters to dual-polarization radars equipped with solid-state transmitters. Clear air atmospheric echoes are weak and easily obscured by strong nearby ground clutters. Hence, observing Doppler velocity of the clear air echo requires both high sensitivity and high efficeincy of ground clutter removal. Compared to electron tube type radar, solid-state radar has a low peak transmitting power (1/100) and therefore lower sensitivity. However, since the latter can transmit pulses about 10 times more frequently than the former, it is expected that by increasing the number of FFT points, it will be possible to more efficiently remove ground clutter and improve sensitivity.

To evaluate the capability of solid-state weather radars for clear air observations, we compared the vertical wind profiles obtained using high-PRF clear-air mode observations of the Meteorological Research Institute (MRI) C-band Advanced Solid-state Polarimetric radar (MACS-POL) with those obtained using a 1.3 GHz wind profiler (WPR) also at MRI. Figure 1 shows (a) the vertical wind profile calculated using the VAD method from clear air mode PPI observation results with a PRF of 10,000 Hz and elevation angle of 45° at MACS-POl, and (b) the vertical wind profile calculated using WPR. In (a), the wind profiles were generally similar to those in (b), although the height at which temporally and spatially consistent wind vectors were obtained decreased over time from about 3.5 km to about 1.5 km.

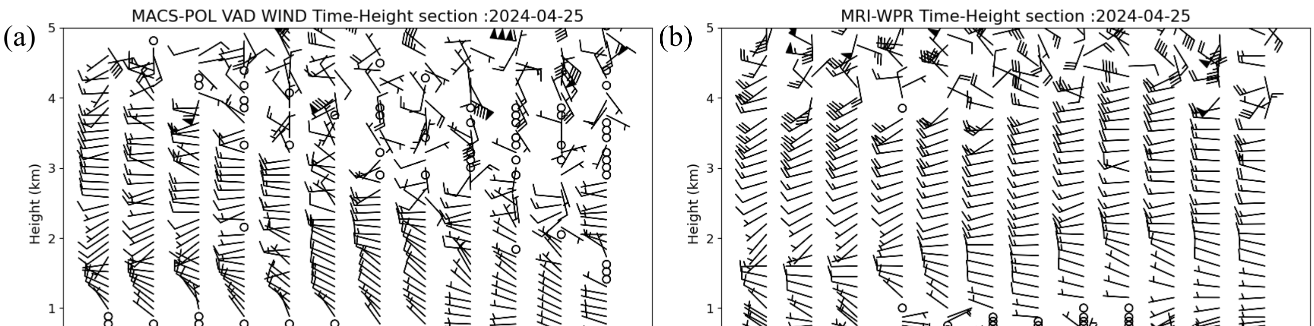

Figure 1. Time series of vertical wind profiles obtained by (a) MACS-POL clear air mode and (b) WPR from 1200 JST to 1730 JST on 25 April 2024.

Characteristics of Mesoscale Wind Fields in Typhoons observed by the MU Radar

Yoshiaki Shibagaki[(1)], Hiroyuki Hashiguchi[(2)], Hubert Luce[(2)],

Masayuki Yamamoto[(3)] and Manabu D. Yamanaka[(4)]

(1) Osaka Electro-Communication University, Osaka, Japan

(2) Research Institute for Sustainable Humanosphere, Kyoto University, Kyoto, Japan

(3) National Institute of Information and Communications Technology, Tokyo, Japan

(4) Research Institute for Humanity and Nature, Kyoto, Japan

Between 1984 and 2023, the centers of 35 typhoons in mature and decaying stages, traversed within 100 km of the MU radar site. Among them, five severe typhoons with central pressures below 960 hPa, were observed by the MU radar. These typhoons are T9019, T9426, T0918, T1821, and T1824. The center of T9426 passed quite close to the radar. The centers of T9019 and T1824 moved 35-40 km southeast of the radar, while the center of T1821 passed about 70 km to the northwest. For all typhoons, tangential and radial wind components are calculated from zonal and meridional winds, subtracted from the moving speed of typhoons. We demonstrate the mesoscale wind structures of each typhoon as follows.

In the case of T9426, the meso- α -scale wind filed is characterized by cyclonic rotation with a maximum at low levels, outflow regions tilted outward with height, and updrafts influenced by convection and topography. Meso- β and meso- γ -scale eyewall and rainbands embedded in the typhoon are associated with the tilted outflow and low-level strong cyclonic wind. In the vicinity of the typhoon center, the tangential wind exhibited a vertical spiral structure for the center, which is considered to be the result from deformation of the center of the decaying typhoon.

The meso- α -scale wind behavior of other typhoons is partially similar to that of T9426, with the intensification of cyclonic wind and more evident radius-height circulation. Particularly, the vertical structure of T0918 indicates meso- β -scale significant updraft regions (exceeding 2.0 m/s), with intensification of low-level cyclonic wind and vertical shear of radial wind.

The accumulation of such observational case studies is crucial for advancing our understanding of the kinematic structures and multi-scale aspects of typhoons.

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MJO affected Land Sea Breeze Circulation in West Coast of Sumatra

Albert Sulaiman[(1)], Wendi Herjupa[(1)], Anis Purwaningsih[(1)], Eddy Hermawan[(1)], Manabu D. Yamanaka[(2)], Noersomadi[(1)], H. Hashiguchi[(3)].

[(1)]Research Center for Climate and Atmosphere- Badan Riset dan Inovasi Nasional (BRIN), Bandung, Indonesia.

[(2)]Kobe University, Japan.

[(3)]Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Japan.

This The IMC diurnal cycle is more important, and it appears as modulation (strengthening) of the amplitude of intra seasonal, seasonal to annual, and inter annual climate variability. In the paper, we investigates the dynamics of sea-breeze circulation over west coast at Sumatera in the presents of Madden Julian Oscillation (MJO). We compare the diurnal variation of wind speed derived from EAR in the normal and active MJO condition respectively. To better understand the mechanism quantitatively, we have developed an analytical model of land-sea breeze circulation based on the 2D non-rotating, compressible Boussinesq equations. In this model, the MJO effect is represented by the background zonal wind. The results indicate that sea breeze circulation strengthens during the strong MJO phases 4 and 5. In-depth explanations of the dynamics of the land-sea breeze and its connection to rainfall are provided.

Impact of Southerly Surge on Rainfall Pattern Over Java, Bali, West Nusa Tenggara and East Nusa Tenggara during Asian Winter Monsoon and Its Relationship to MJO Condition

Trismidianto (1) *, Didi Satiadi (1), Wendi Harjupa (1,2,3), Ibnu Fathrio (1), Risyanto (1), Elfira Saufina (1), Robi Muharsyah (4), Danang Eko Nuryanto (5), Fadli Nauval (1,6), Dita Fatria Andarini (1,7), Anis Purwaningsih (1), Teguh Harjana (1), Alfan Sukmana Praja (1), Adi Witono (1), Ina Juaeni (1), Bambang Suhandi (1)

[1]Center for Climate and Atmospheric Research, National Research, and Innovation Agency, Bandung 40173, Indonesia.
[2]Department of Computer Engineering, School of Electrical Engineering, Telkom University, Bandung, Indonesia
[3]Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan
[4]Center for Climate Change Information, Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), Jakarta, Indonesia.
[5]Research and Development Center, Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), Jakarta, Indonesia.
[6]Department of Atmospheric Science, Texas A&M University
[7]School of Geography, Earth, and Atmospheric Sciences, The University of Melbourne

* Correspondence: trismidianto@brin.go.id

. **Abstract**

The impact of the SS and its interaction with the MJO on rainfall patterns in Java, Bali, West Nusa Tenggara, and East Nusa Tenggara has been studied during the NDJFM months, namely January 2001 to March 2019. The primary source of rainfall observation data used in this study is 2,140 weather-monitoring stations operated by BMKG. Furthermore, the utilization of GSMaP data is warranted given that observational data is restricted to daily land-based data complemented by the OLR, MJO, and ERA5 ECMWF datasets. Whereas active MJO conditions are identified by CPC indices, active SS events are determined by the average daily meridional wind in Western Australia, which is greater than 9.5 m/s. During the study period, 61 SS events were found; the majority, 17, happened during the active MJO and 44 during the inactive MJO. A decrease in SST anomalies, a strengthening and modification of wind patterns, and an overall increase in rainfall in the southern part of the IMC as the SS moves northward are all signs of the impact of the SS event. The research results found that the response to rainfall from Java to East Nusa Tenggara was different. Rainfall increases more in the western study area when the active MJO and more in the eastern study area when the inactive MJO is due to SS. SS reduces rainfall in the Jakarta region, regardless of the activity or inactivity of the MJO. Additionally, even in places where the island still experiences an increase in extreme rainfall, SS tends to significantly reduce the likelihood of experiencing extreme rainfall on Java Island. When SS and MJO coincide, the likelihood of heavy rains is generally not much higher than when SS occurs alone. The findings also indicate that, while playing a significant role, SS is more dominant than MJO in terms of supporting increased water vapor transport in the southern IMC region. Additional findings suggest that local land-sea wind circulation may interact with large-scale synoptic circulations like the monsoon, SS, and MJO to produce spatiotemporal variability in rainfall on Java Island. Whether or not there is MJO, the main increase in rainfall happens in the afternoon and decreases in the morning when SS occurs. Overall, convective instability analysis reveals that SS increases precipitation, most likely through raising VIMFC and lowering CIN.

Keywords: Southerly Surge, MJO, Rainfall, Java, Bali, East Nusa Tenggara

Study of Orography-MJO Interaction and Its Impact on Rainfall Variability in West Sumatra

Didi Satiadi[1], Anis Purwaningsih[1], Wendi Harjupa[1,2,3], Elfira Saufina[1], Ibnu Fathrio[1], Trismidianto[1,], Fahmi Rahmatia[1], Ridho Pratama[1], Hiroyuki Hashiguchi[4], Toyoshi Shimomai[5]

(1) Research Center for Climate and Atmosphere, National Research and Innovation Agency (BRIN), Bandung, Indonesia
(2) Department of Computer Engineering, School of Electrical Engineering, Telkom University, Bandung, Indonesia
(3) Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan
(4) Research Institute for Sustainable Humanosphere, Kyoto University, Kyoto, Japan
(5) Department of Electronic and Control Systems Engineering, Shimane University, Shimane, Japan

This study explores the influence of the interaction between orography and the Madden-Julian Oscillation (MJO) on rainfall variability in the mountainous region of West Sumatra, Indonesia. We utilized diagnostic variables derived from observational data over Kototabang and reanalysis data from ERA5. The reanalysis dataset includes precipitation, zonal winds (U), vertical winds (W), Vertically Integrated Moisture Convergence (VIMC), Froude Number (FR), Lifting Condensation Level (LCL), Level of Free Convection (LFC), Level of Non-Buoyancy (LNB), Convective Available Potential Energy (CAPE), and Convective Inhibition (CINH). Additionally, observational data from the Equatorial Atmosphere Radar (EAR), X-Band Radar (XBR), Optical Rain Gauge (ORG), Microwave Radiometer (RDM), and Radiosonde at Kototabang Station were employed to verify the ERA5 data. We investigated the impact of MJO phases over the study area using MJO indices from the Australian Bureau of Meteorology (BOM). Hourly data spanning 21 years (2001–2022) from five selected locations across the mountains, varying in elevation (coast (L1), windward slope (L2), mountain top (L3 and L4), and leeward slope (L5)), were analyzed. Composite diurnal variations of diagnostic variables over these locations during MJO phase-3 (MJO-3), MJO phase-4 (MJO-4), and the mean were plotted, and results were examined to understand the influence of topography and MJO on rainfall variability across elevations and MJO conditions. Our findings reveal that topography significantly influences rainfall distribution, with higher rainfall observed on windward slopes and peaks, particularly along the coast and mountain tops. The rainfall pattern mirrors that of VIMC, suggesting moisture convergence as a key regulator of rainfall variability over the terrain. Furthermore, MJO exerts a notable impact on rainfall intensity across the mountains, with MJO-3 significantly increasing rainfall at all locations, whereas MJO-4 has a limited effect. This MJO-induced rainfall variation correlates strongly with VIMC patterns, which, in turn, are influenced by zonal wind dynamics. During MJO-3, reduced zonal wind speeds, caused by opposing MJO low-level convergence flows, enhance moisture convergence, while MJO-4 increases zonal wind speeds due to supporting low-level convergence flows. Overall, our study underscores the importance of VIMC patterns shaped by wind dynamics in regulating rainfall variability across terrain under different MJO conditions, emphasizing the role of orography in shaping local rainfall patterns, while MJO's large-scale circulation mainly influences rainfall intensities across elevations, contingent upon its phase.

Keywords: Orography, Topography, MJO, Rainfall, West Sumatra

AI based WRF-DA modelling of the August 2018 Kerala flood

Kavya Johny[(1)], M.G. Manoj[(1)], and Ashish Shaji[(1)]

(1) Advanced Centre for Atmospheric Radar Research,

Cochin University of Science and Technology

Kerala, a coastal state in southern India, is experiencing unprecedented extreme weather events in recent years due to climate change and anthropogenic interventions. Frequent extreme events have resulted in significant loss of life and infrastructure. The objective of the present paper is to evaluate the performance of integrating artificial intelligence with ensembles of a numerical model (weather research and forecasting -WRF) in simulating such extreme events, particularly focusing on the August 2018 Kerala flood. A monsoon depression in the head Bay of Bengal caused an extended period of extremely heavy rainfall that occurred during 14th – 16th August 2018. This study aims to evaluate the skill of WRF model in predicting such extreme rainfall events with sufficient lead time. The study identifies the ideal set of parameterizations schemes to best replicate the atmospheric dynamics during the event through a series of simulations. Model predictability can be significantly improved by assimilating Doppler weather radar (DWR) observations, and this study investigates the efficiency of assimilating DWR data in WRF (WRF-DA) in terms of spatial location, intensity and lead-time. This is achieved from multiple forecast outputs generated by varying the initial conditions. An artificial neural network (ANN) model is trained with these outputs to provide the best possible forecast performance in terms of intensity and spatiotemporal distribution. The overarching goal is to demonstrate how the integration of artificial intelligence with physical models could enhance real-time forecasting performance. This improvement could be a breakthrough for early warning systems and disaster preparedness.

In-Depth Analysis of Atmospheric Dynamics Leading to Landslide in Kototabang on December 19, 2019: Integrating Satellite and Ground Observations

Fahmi Rahmatia(1), Anis Purwaningsih(2), Elfira Saufina(2), Didi Satiadi(2), Wendi Harjupa(2, 3), Ridho Pratama(1)

(1) Agam Observation Station, Directorate for Laboratory Management, Research Facilities, and Science and Technology Park, National Research and Innovation Agency, Agam, Indonesia

(2) Research Center for Climate and Atmosphere, National Research and Innovation Agency, Bandung, Indonesia

(3) Disaster Prevention Research Institute, Kyoto University, Japan

This study examines the atmospheric dynamics leading to the hydrometeorological disaster (landslide) at Kototabang, Indonesia, on 19 December 2019, employing multi-instruments including satellite and ground observations. Atmospheric conditions were analyzed using wind data from Equatorial Atmospheric Radar (EAR), and precipitation data from Optical Rain Gauge (ORG) and Disdrometer-Parsivel installed at the Agam Observation Station – Kototabang. Spatial precipitation data from the Global Satellite Measurement of Precipitation (GSMaP) were also used as supplementary data in precipitation analysis. Moreover, cloud developments were also identified using Ceilometer and Himawari-8 satellite data. We also used the European Centre for Medium-Range Weather Forecasts (ECMWF) Atmospheric Reanalyses (ERA-5) dataset, including Convective Available Potential Energy (CAPE), K-Index, specific humidity, and wind velocity. Furthermore, moisture over the Kototabang site was tracked back from 72-h before 16 local time (LT) (19 December 2019) using the Lagrangian Model from The Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT), developed by the National Oceanic and Atmospheric Administration (NOAA). The Results indicate that daily rainfall measured by the ORG increased persistently several days before the event and reached more than 30 mm/day (moderate rainfall intensity) on 19 December 2019. Himawari-8 data showed convective cloud development starting on 18 December 2019, at 18 LT, peaking at 23 LT, with low clouds present until early December 19, producing light to moderate rain. Convective clouds redeveloped rapidly at 16 LT, leading to moderate to heavy rain. CAPE and K-index values peaked in the morning and evening, indicating increased convective cloud development in the afternoon. According to the lagrangian moisture tracking, terrestrial moisture was mainly transported from the north direction toward the Kototabang site, ranging from 12-30 g/kg. Consistent with the main trajectory, the disturbance of meridional wind is correlated to the positive phase of the Equatorial Rosby wave. Moreover, based on EAR data ranging from 3 to 10 km, there was a vertical shifting of wind direction resulting in high vertical wind shear supporting convective cloud formation detected in the morning to afternoon on 19 December 2019. Furthermore, the oceanic moisture sources (from the Indian Ocean and the coastal area of West Sumatra) also contribute to the moistening but with lower specific humidity. The low variability waves were found to be responsible for disturbing zonal wind propagation shown by EAR data and zonal-wind filtering. This research suggests the detailed atmospheric dynamics leading to landslides important for understanding hydrometeorological disaster mechanisms over study area. Moreover, we highlight that moderate rainfall intensity over this study location leads to landslides, indicating a high vulnerability of this location toward rainfall conditions. Therefore, the findings are essential for early warning systems development. Furthermore, we suggested that study on land condition over this region can be beneficial to enrich the understanding of landslide mechanisms over this area.

Keywords: atmospheric dynamics, landslide, satellite and ground observation, rainfall, Kototabang

Examination of Atmospheric Dynamics During the Extreme Rainfall Event in West Sumatera on March 7-8, 2024: Roles of MJO, WWB, and Kelvin Waves

Elfira Saufina(1), Trismidianto(1), Didi Satiadi(1), Wendi Harjupa(2,3), Risyanto(1), Anis Purwaningsih(1), Alfan Sukmana Praja(1), Ina Juaeni(1), Adi Witono(1), Ibnu Fathrio(1), Fahmi Rahmatia(1)

(1) Research Center for Climate and Atmosphere, National Research and Innovation Agency, Bandung, Indonesia

(2) Disaster Prevention Research Institute, Kyoto University, Japan

(3) Agam Observation Station, Directorate for Laboratory Management, Research Facilities, and Science and Technology Park, National Research and Innovation Agency, Agam, Indonesia

The West Sumatra region experienced extreme rainfall intensity reaching 300-394 mm/day, from 7-8 March 2024, resulting in floods and landslides in at least 12 regencies. This rainfall intensity significantly exceeds the threshold for the extreme rainfall category (100 mm/day). This study examined the atmospheric dynamics responsible to the extreme rainfall case. We investigated large-scale atmospheric variabilities, analyzed cloud clusters using Himawari-8 and rainfall intensity using the Global Satellite Mapping of Precipitation (GSMaP) satellite, and supported them with ground observation from ceilometer and disdrometer data at the Kototabang site. We conducted a detailed analysis of atmospheric parameters from ERA5 re-analysis datasets including wind velocity, Integrated Vapor Transport (IVT), Convective Available Potential Energy (CAPE), and Convective Inhibition Energy (CINH). Moreover, the Lagrangian Model from The Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT) developed by the National Oceanic and Atmospheric Administration (NOAA) was utilized for moisture transport trajectory throughout extreme rainfall. The results indicate that the extreme rainfall event was generated by a Mesoscale Convective System (MCS) that developed over the region, as evidenced by cloud evolution observed through the Himawari-8 satellite. Further analysis using ERA5 data reveals that the MCS was triggered by widespread moisture convergence in the area, which supported convection and cloud formation. Zonal wind analysis shows that this moisture convergence was primarily caused by a Westerly Wind Burst (WWB) from the Indian Ocean interacting with the West Sumatra region's local topography and atmospheric circulations. The presence of the WWB was associated with active Madden-Julian Oscillation (MJO) conditions in Phase 4, where its convective center was situated east of Sumatra Island. The strong MJO conditions (amplitude > 2) created a significant pressure gradient, resulting in a strong westerly wind west of the MJO convective center. This WWB transported substantial moisture (more than 400 kg/m/s) from the Indian Ocean to the West Sumatra region, as shown by IVT analysis and the HYSPLIT model. This moisture supply fueled intense convection over the area, indicated by higher CAPE and K-Index values, and lower CINH values, leading to significant cloud formation and rainfall (more than 20 mm/hour according to GSMaP measurements). Additionally, our findings indicate that before the extreme rainfall event, the MJO was active in the Indian Ocean (Phase 3), coinciding with an atmospheric Kelvin wave. The interaction between the MJO and the Kelvin wave likely enhanced low-level convergence and convection over the ocean, preconditioning the area with elevated moisture levels. This moisture was subsequently transported by the WWB to the West Sumatra region. In conclusion, our analyses suggest that the interplay among the MJO, WWB, and Kelvin wave played a significant role in the extreme rainfall event. These findings improve our understanding of the atmospheric dynamics leading to extreme rainfall in West Sumatra and are crucial for developing early warning systems in the region.

Keywords: Extreme rainfall, West Sumatera, Kelvin waves, MJO, WWB

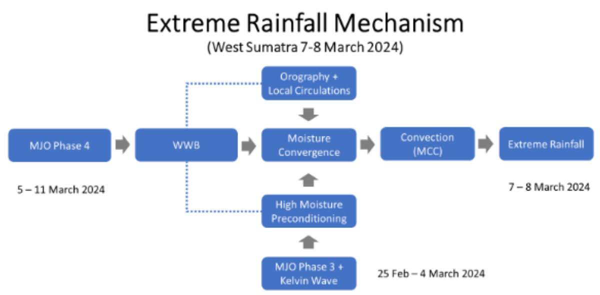


Figure 1. Diagram of graphical abstract

The Mesoscale Convective Complex Triggered Extreme Rainfall and Devastating Floods in Bangka Belitung on February 8–10, 2016, linked to the Cold Surge, Borneo Vortex, MJO, and Equatorial Waves

Ibnu fathrio(1), Trismidianto(1), Didi Satiadi(1), Risyanto(1), Alfan Sukmana Praja(1), Anis Purwaningsih(1)

(1) Research Center for Climate and Atmosphere (PRIMA), National Research and Innovation Agency (BRIN), Bandung 40135, Indonesia

This study investigates the Mesoscale Convective Complex (MCC) event over the Bangka Belitung Islands on 8-9 February 2016, which resulted in extreme rainfall and severe flooding. Using infra-red brightness temperature data from the Himawari-8 satellite, rainfall data from GsMAP and rain-gauges observation, various atmospheric indices, and ERA5 reanalysis datasets, we examined the mechanisms underlying MCC formation. Findings indicate that the Cold Surge (CS) event preceding the MCC played a crucial role in moisture supply, with further enhancement from wind convergence between the CS and a cyclonic circulation over the Indian Ocean. The CS flow was blocked by vortices in the Indian Ocean, the Karimata Straits, and the Java Sea, leading to additional moisture accumulation. The active Madden-Julian Oscillation (MJO) in phase 4, with its convective center over the South China Sea, and the wet phase of Equatorial Rossby (ER) waves, further intensified moisture convergence. These combined effects of the CS, MJO, and ER waves contributed to MCC formation and extreme rainfall. Results on moisture tracking indicate that the South China Sea contributes to nearly 80% moisture over the boundary layers and 54% over the free troposphere layers of Bangka Belitung during the rainfall peak at 8 March 2016. The high moisture from South China Sea was due to the roles of the strengthening of CS from 5 to 8 March 2016. The study suggests that large-scale moisture convergence, dominated by the interactions of MJO, ER waves, and blocked CS, triggered the MCC, while the removal of these blockages led to its dissipation. These insights significantly enhance our understanding of MCC formation in this region, highlighting the importance of cyclonic circulations, wind convergence, and atmospheric phenomena. The findings have important implications for designing early warning systems for floods related to extreme rainfall, improving the accuracy and reliability of flood forecasts, and enhancing disaster preparedness to mitigate impacts on vulnerable communities.

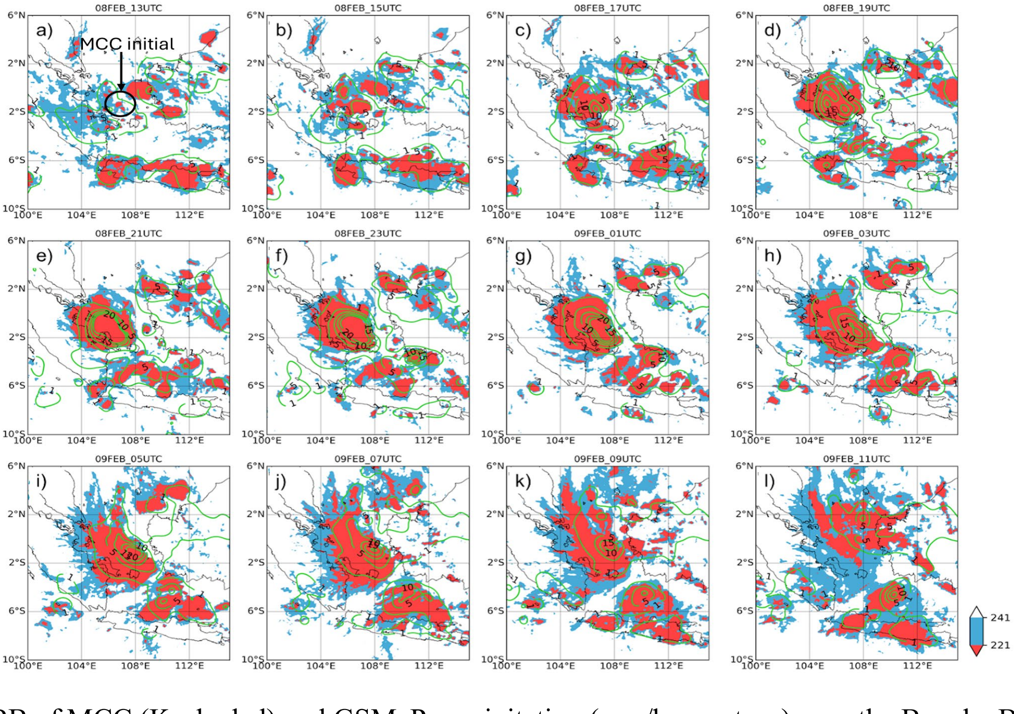


Figure 1. TBB of MCC (K, shaded) and GSMaP precipitation (mm/hr, contour) over the Bangka Belitung area on February 8, 2016 at 13 UTC until February 9, 2016 at 11 UTC. Red color shading indicates interior cold clouds with TBB ≤ 221 K, and blue color shading indicates cloud shields with TBB ≤ 241 K.

Diurnal and Seasonal Variations of Mesoscale Convective Systems Precipitation and Their Influence on Rainfall Patterns in the Indonesian Maritime Continent

Mukhamad Adib Azka[1], Nurjanna Joko Trilaksono[2], and Trismidianto[3]

(1) Meteorological, Climatological, and Geophysical Agency, Jakarta, Indonesia

(2) Faculty of Earth Science and Technology, Bandung Institute of Technology, Bandung, Indonesia

(3) National Research and Innovation Agency, Bandung, Indonesia

Mesoscale Convective Systems (MCSs) are organized of convective and stratiform clouds that combine into complex storm systems and produce mesoscale circulation. MCS plays an important role in the hydrological cycle and global circulation through the distribution of water and energy in the atmosphere. Apart from that, MCS often produces extreme weather such as thunderstorms, strong winds, turbulence, heavy rain, and even floods. The Indonesian Maritime Continent (IMC) is a region that is very favourable for MCS development. An important variable from MCS that has positive and negative impacts is precipitation. MCS and non-MCS precipitation have different characteristics due to differences in the size and duration of the clouds produced. One of the impacts of differences in precipitation in the BMI area is seasonal rainfall patterns. It is not yet known with certainty the impact of differences in MCSs and non-MCSs precipitation on rainfall patterns. This study aims to determine the diurnal and seasonal variations in MCS and non-MCS precipitation and determine their impact on rainfall patterns at BMI. MCS identification and tracking uses the flexible object tracker (FLEXTRKR) algorithm. Diurnally, MCS precipitation predominantly occurs from 00.00 to 06.00 local time (WIB), whereas non-MCS precipitation predominantly occurs from 12.00 to 18.00 local time (WIB). MCS precipitation is 2 times higher than non-MCS precipitation, even more so in the December to February (DJF) season. The South Indian Ocean region of Sumatra and the Western Pacific Ocean are affected by MCS precipitation in all seasons. The contribution of MCS precipitation reaches 80% in almost all BMI areas, with the largest contribution from the meso-β circular convective system (MβCCS) type at around 50%. Meanwhile, the most dominant intensity of heavy rain is produced by the mesoscale convective complex (MCC) type. Non-MCS precipitation predominantly occurs in the Nusa Tenggara, Sulawesi, Maluku Islands and parts of Papua. MCS precipitation has a very dominant contribution in influencing rainfall patterns in monsoonal and equatorial regions. Meanwhile, non-MCS precipitation has a dominant contribution in areas with local rainfall patterns.

Key words: mesoscale convective system (MCS), FLEXTRKR algorithm, diurnal and seasonal precipitation, rainfall patterns.

Estimation of convective Mass-flux from simultaneous measurements of 206.5 MHz wind profiler and X-band radar reflectivity measurements in the Himalayan foothills

Subrata Kumar Das(1), Adtiya Jaiswal(1), Abhishek Jha(2) and Manish Naja(3)

(1) Indian Institute of tropical Meteorology, Ministry of Earth Sciences, Pune, India

(2) Society for Applied Microwave Electronics Engineering & Research

(SAMEER), Mumbai, India

(3) Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, India

Correspondence: subrata@tropmet.res.in

Cumulus convection significantly alters the large-scale atmosphere by redistributing mass, momentum, and energy through dry and moist dynamic processes. Current weather prediction models, with their native spatial resolution, cannot explicitly represent cumulus convection. Instead, they parameterize its effects using the mass-flux scheme, which models convection as an ensemble of updrafts and downdrafts within a grid box. This is achieved by treating convective cells as one-dimensional entraining plumes. Mass flux is then calculated as the product of the fractional area covered by convection and the vertical velocity within convective cells.

In this work, we aim to measure updraft/downdraft velocities and convection morphology (convective area fraction) using the 206.5 MHz ST Radar installed at Nainital (29.4°N, 79.5°E;1793m AMSL), India, in the Himalayan foothills and ground-based X-band radar. These measurements will be used to estimate convective mass flux in a radar domain comparable to a numerical weather prediction (NWP) grid box. The observational estimates of mass flux for the region will create a novel database of representative mass flux profiles for different types of convection (shallow, congestus, deep, and overshooting). This database can improve the accuracy of sub-grid scale convection representation in numerical models. Details will be presented in the conference.

Ionospheric topside diffusive flux and the formation of summer nighttime ionospheric electron density enhancement over Millstone Hill

Yihui Cai (1), Xinan Yue (1), Wenbin Wang (2), Shun-Rong Zhang (3), Huixin Liu (4), and Jiuhou Lei (5)

(1) Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China

(2) High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA

(3) Haystack Observatory, Massachusetts Institute of Technology, Westford, MA, USA

(4) Department of Earth and Planetary Science, Kyushu University, Fukuoka, Japan

(5) CAS Key Laboratory of Geospace Environment, University of Science and Technology of China, Hefei, China

The topside ionospheric O+ diffusive flux has rarely been studied, but it is not only important for analyzing the relative contributions of various physical processes (such as ambipolar diffusion, neutral winds, and electric fields) and chemical processes to the ionospheric structure. It is also significant to study the dynamics and mass coupling between the ionosphere and the plasmasphere, for example, it is an upper boundary condition necessary for the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIEGCM). We performed a statistical analysis of the O+ diffusive flux in the topside ionosphere using Millstone Hill (42.6°N, 288.5°E) ISR data from 1970 to 2018. We obtained its characteristics as a function of solar activity, geomagnetic activity, altitude, local time, and season. Furthermore, the new specification of the topside O+ diffusive flux was used to drive the TIEGCM, which provides new insight into the competing roles of topside diffusive flux, neutral winds, and electric fields in forming the mid-latitude summer nighttime ionospheric electron density enhancement (MSNA). Simulations indicate that while magnetic meridional winds, which turn equatorward before sunset, are essential to sustain the daytime ionization near dusk, the topside diffusive flux is critically important for the formation and timing of the summer evening density peak. This new finding from the Millstone Hill observations may lead to an ultimate understanding of the more generic MSNA features in both the Northern and Southern Hemispheres

Unraveling the Complexity of Rain Microphysics in Equatorial Sumatra through GPM Satellite and Equatorial Atmospheric Radar Observations

Ravidho Ramadhan[1,2], Marzuki Marzuki[1], Helmi Yusnaini[1], Hiroyuki Hashiguchi[2], and Mutya Vonnisa[1]

(1) Department of Physics, Universitas Andalas, Padang 25163, Indonesia.

(2) Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan.

Abstract

Sumatra, with its complex topography extending nearly perpendicular to the equator in the western Indian Ocean, plays a crucial role in the global atmospheric circulation system. To understand atmospheric dynamics in the equatorial region of Indonesia, the ground-based Equatorial Atmospheric Radar (EAR) has been operating in Kototabang (100.32° E, 0.20° S) for over two decades. However, vertical observations from EAR often fail to provide a comprehensive view of the microphysics in the lower equatorial atmosphere, which is highly variable locally. The advent of the Global Precipitation Measurement (GPM) satellite, equipped with the Dual-Frequency Precipitation Radar (DPR), offers potential to complement EAR data and reveal the complexities of precipitation microphysics in equatorial Sumatra. Analysis of GPM DPR data from 2014 to 2021 reveals vertical structural contrasts in precipitation across Sumatra, segmented into five regions: Ocean, Coast I (west coast), Land I (west of the Barisan Mountains), Land II (east of the Barisan Mountains), and Coast II (east coast) (Figure (1)). Key findings include differences in precipitation type distribution, rain top height (RTH), heavy ice particle presence, and drop size distribution (DSD) (Figure (2-4)). Stratiform and deep convective rains were most frequent in Coast I, followed by Ocean, Land I, Land II, and Coast II. Conversely, shallow convective rain was more common over the Ocean, with decreasing frequency towards Coast I, Land I, Land II, and Coast II. The percentage of large raindrops (mass-weighted mean diameter (Dm) > 2 mm) was about 2% over the Ocean, increasing to 4-6% in Land II and Coast II, consistent with higher percentages of heavy ice particles and elevated RTH in these areas. Additionally, GPM DPR data highlight discrepancies between vertical profiles and surface precipitation data, underscoring the complexities of land-sea precipitation migration mechanisms. However, DSD parameters from GPM DPR exhibit inconsistencies compared to surface observations, particularly for deep convective rain. Thus, enhanced DSD observations in the equatorial Indonesian region are essential, with simultaneous monitoring from EAR to achieve a more comprehensive understanding.

Keywords: Sumatra, equatorial precipitation, DSD, GPM DPR, EAR.

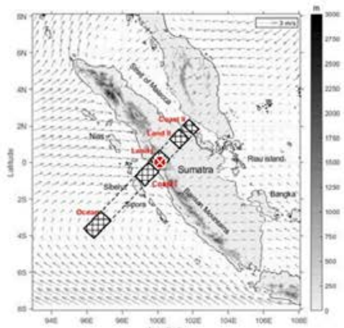


Figure 1. Topography and near surface wind in Sumatra. The dashed box and the black solid box are the study area. Red circle with white cross is EAR location.

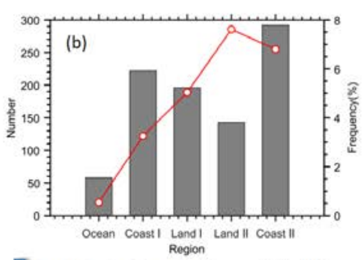


Figure 2. Number (histogram) and frequency (red line) of heavy ice precipitation for each region for deep convective rains.

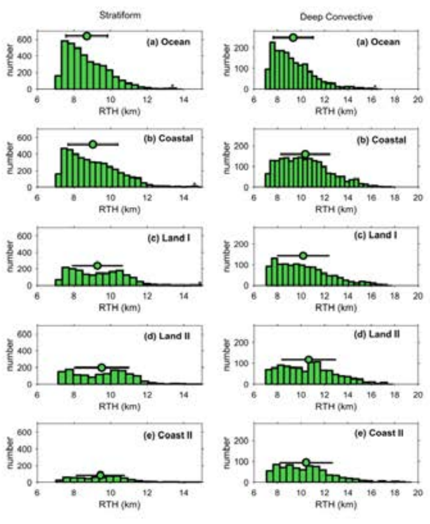


Figure 3. Histogram of rain top height (RTH) for stratiform (a-e) and deep convective rains (f-j) for several selected location in the study area. The error bars on the histogram show the mean and standard deviation values.

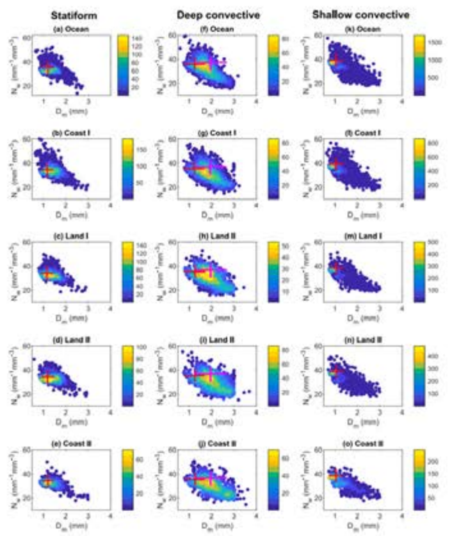


Figure 4. Scatter plot of Nw versus Dm at altitude of 0.75 km for stratiform (a-e), deep (f-j) and shallow convective rains (k-o) from GPM Ku-band data for several selected location in the study area. Colorbars indicate the number of profiles. Crosses on the figures in the second and third columns indicate data intervals for <10 mm/h rainfall (red) and > 10 mm/h rainfall (magenta) clusters based on Marzuki et al. (2013b).

Estimation of Vertical Air Motion within Precipitating Clouds Using the Equatorial Atmosphere Radar in Combination with a Boundary Layer Radar

Nozomu Toda(1), Shoichi Shige(2), Christopher R Williams(3), Noriyuki Nishi(4), and Hiroyuki Hashiguchi(5)

(1) Kyoto University, Graduate School of Science, toda.nozomu.84n@st.kyoto-u.ac.jp

(2) Kyoto University, Graduate School of Science, shige@kugi.kyoto-u.ac.jp

(3) University of Colorado Boulder, christopher.williams@colorado.edu

(4) Faculty of Science, Fukuoka University, nornishi@fukuoka-u.ac.jp

(5) Kyoto University, Research Institute for Sustainable Humanosphere, hasiguti@rish.kyoto-u.ac.jp

The 47-MHz Equatorial Atmosphere Radar (EAR) in Indonesia provides nearly continuous observations of vertical radial motion with one-minute time-resolution. Developing a method to estimate vertical air motion from long-term EAR radial motion estimates could benefit the validation of the next-generation satellite missions such as the JAXA PMM with the Ku Doppler radar.

During precipitation, the EAR simultaneously observes Bragg scattering (caused by atmospheric turbulence that moves with the vertical air motion) and Rayleigh scattering (caused by hydrometeors falling faster than the vertical air motion). Therefore, when estimating the vertical air motion, it is necessary to remove the Rayleigh scattering signal to prevent downward biases.

Previous studies have estimated vertical air motions using EAR observations. However, the vertical air motion was estimated manually by visually inspecting the spectral diagram and identifying the Bragg and Rayleigh scattering peaks. Such a method is not suitable for long-term analysis. This study describes a method for automatically estimating vertical air motion using the EAR in combination with a 1.3-GHz boundary layer radar (BLR), which is more sensitive to hydrometeors than atmospheric turbulence so that the BLR spectral diagram is dominated by Rayleigh scattering.

In this study, we refined two methods described in Williams (2012) and Williams et al. (2018). The former method (hereafter referred to as W12) uses two profilers with different frequencies (i.e., 50- and 920-MHz). A weighting function created by the higher frequency profiler spectrum filters the lower frequency profiler spectrum to suppress the Rayleigh scattering signal. The latter method (W18) detects "peaks" and "valleys" based on threshold values. Both methods have instances when their estimations fail. Often, "error cases" in one method are accurately estimated by the other method. Therefore, we made a new algorithm combining W12 and W18 to provide a more accurate estimation. The vertical velocity estimates from the new algorithm were in good agreement with the manual estimates from previous EAR studies and were more accurate than those using W12. This indicates that our method may be effective for long-term analysis.

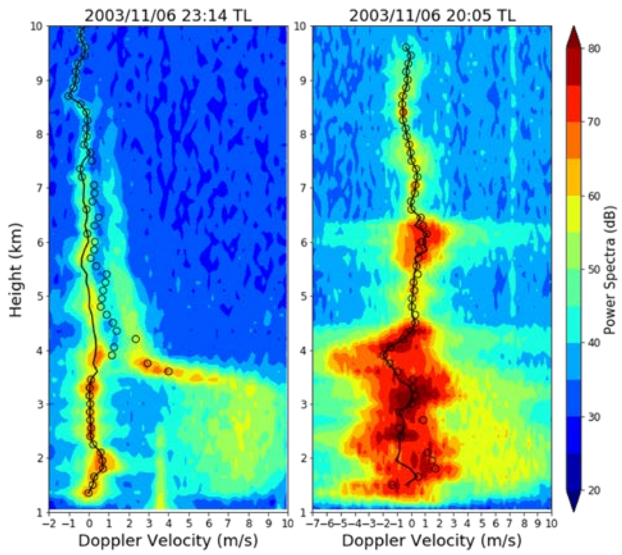


Figure 1.

Spectra of the EAR in stratiform (left) and convective (right) precipitation. The mean Doppler velocity retrieved from the single-frequency method (circles) and this study (solid line) are shown. Positive value indicates downward.

Estimation of Raindrop Size Distribution Using Vertical Pointing Observations of Ground-Based X-Band Radar and MU Radar

Yusuke GOTO(1), Taro SHINODA(1), Haruya MINDA(1), Moeto KYUSHIMA(1),

Nozomu TODA(2), Shoichi SHIGE(2), and Hiroyuki HASHIGUCHI(3)

(1) Institute for Space-Earth Environmental Research, Nagoya University, Furo-cho, Chikusa, Nagoya, Japan

(2) Graduate School of Science, Kyoto University, Kitashirakawaoiwake-cho, Sakyo, Kyoto, Japan

(3) Research Institute for Sustainable Humanosphere, Kyoto University, Gokasho, Uji, Japan

Most of the research on raindrop size distribution (DSD) is based on ground-based in-situ observations. DSD is derived from cloud microphysical processes. Raindrops fall to the ground after undergoing various processes aloft such as condensational and collision-coalescence growths, collision-breakup, and evaporation. Therefore, investigating the variations of DSD aloft is important for understanding the cloud microphysical processes. The purpose of this study is to estimate the altitude variations of DSD using vertical pointing observation data from ground-based X-band radar and MU radar, and to discuss the cloud microphysical processes that cause the altitude variations of DSD.

The ground-based X-band radar owned by Nagoya University (NuX) has been conducting 8 vertical pointing observations every 5 minutes since January 18, 2023 at the Shigaraki MU observatory (34.85°N, 136.11°E). Using the radar reflectivity factor (Z_e) [mm^6/m^3], vertical Doppler velocity (V_d) [m/s], and Doppler velocity width (σ_d) [m/s] observed by NuX, the DSD (assuming gamma distribution $N(D)=N_0D^{\mu}e^{-\Lambda D}$) was estimated at each grid point (150 m vertical interval) in combination with the scatter simulations using T-matrix method. Note that D is raindrop diameter, and N_0, Λ, and μ are intercept, slope, and shape parameters, respectively. From the estimated DSD, the median of the raindrop diameter (D_0) was estimated for each altitude using the following equation, $D_0=(\mu+3.67)/\Lambda$. Since V_d is the sum of the falling velocity of precipitation particles weighted by the radar reflectivity factor (V_{tz}) and the vertical air motion (V_a, $V_d=V_{tz}+V_a$), V_a observed by the MU radar was subtracted from V_d to remove the effect of V_a. To limit the analysis to the rainfall region, grid points below 1500 m from the 0°C altitude were only used. Note that ERA5 was used to detect the 0°C altitude. For the estimation of the dominant cloud microphysical processes, the vertical variations of dBZ_e ($=10\log_{10}Z_e$) and differential reflectivity (Z_{DR}) in XRAIN (TANOKUCHI radar, 34.83°N, 135.69°E) were also used. The analysis was limited to the periods of rainfall from 9:40 JST (0:40 UTC) to 16:59 JST (7:59 UTC) on June 2, 2023, during which the mean $|V_a|$ in the analysis region was less than 1 m/s and the Doppler velocity width due to vertical air motion (σ_{air}) was less than 1.2 m/s to reduce the error.

For both the median Λ and μ at each altitude of the estimated gamma distribution, the values generally increased with decreasing altitude. This means that the width of the DSD narrows with decreasing altitude, which is similar to the case of a previous study that examined the altitude variations of the DSD during the summer monsoon in southeastern India. In this study, the number of particularly small raindrops decreased with decreasing altitude, resulting in a narrower raindrop particle size distribution and D_0 increased with decreasing altitude. The cloud microphysical processes causing altitude variations in the DSD were estimated from XRAIN and showed that collision-coalescence and evaporation were the main factors. While previous studies in India described the evaporation as the main factor contributing to the altitude variations of Λ and μ, the present study suggests that a variety of microphysical processes may be contributing. To examine in more detail, we used the relative humidity from ERA5 to distinguish between dry and wet cases: periods in which there were altitudes within the analysis region with relative humidity below 80% were classified as dry cases, while those without such altitudes were classified as wet cases. The analysis suggested that in dry cases, D_0 increased with decreasing altitude mainly due to evaporation, whereas in wet cases, the increase in D_0 was primarily due to collision-coalescence. Thus, even though the trend of altitude variations in D_0 is the same, the predominant cloud microphysical processes are different depending on the relative humidity.

A statistical analysis will be conducted since data for two years during the rainy season has been collected.

The capability of the middle atmosphere dynamics and structure observation over the Tibetan Plateau based on the MST radar, lidar and cloud radar systems

Daren Lyu[1] et al.

(1) Key Laboratory of Middle Atmosphere and Global Environment Observation (LAGEO), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

The in-depth understanding of the middle atmosphere dynamics and structure has become increasingly important, especially in the Tibetan Plateau, a global climate-sensitive area referred to as the Third Pole. A new powerful MST radar, lidars and Ka&W-band Dual millimetres wavelength Cloud Radar system was established to obtain the atmospheric wind field profiles, temperature, density of the whole neutral atmosphere and also include the cloud microphysical and microphysical observations. Strong convective processes, cirrus, over the Tibetan Plateau region can be revealed by using the Ka&W dual-wavelength cloud radar and Infrared Radiation Thermometer. The lidar system is capable of conducting observations both day and night. The lidar system's altitude coverage for the temperature observation is 15-105 km at night, 30-50 km, and 80-110 km during the daytime. As for the wind field, the lidar system can well fill the gap of the MST radar in the altitude range of 20-60 km at night and 20-40 km during the day. The combination of the powerful and co-located observation apparatus will play an essential role in resolving the two transition regions in the atmosphere with high resolution: the upper troposphere-lower stratosphere (UT-LS) and the mesosphere-lower thermosphere (MLT) regions. This comprehensive system can monitor upward transport and convection, characterize the whole atmosphere over the Tibetan Plateau, and reveal the dynamics and structure of the middle and upper atmosphere.

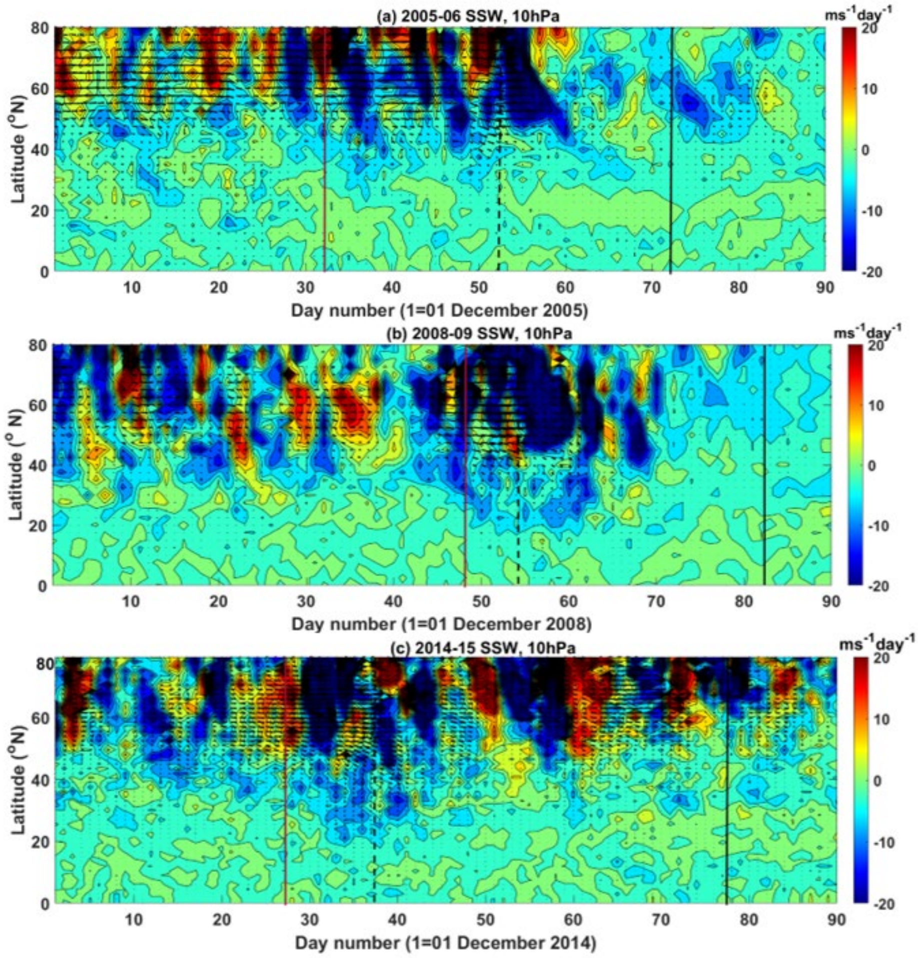
High and equatorial mesospheric dynamical response to the minor stratospheric warming of 2014/15: Comparison with major SSW events 2005/06 and 2008/09

Lynn Salome Daniel[1] and G.J. Bhagavathiammal[1,2*]

1 Department of Medical Physics, Anna University, Sir C V Raman Science Block, Sardar Patel Road, Chennai- 600025, Tamil Nadu, India

2 Centre for Climate Change and Disaster Management, Anna University, Sardar Patel Road, Chennai- 600025, Tamil Nadu, India

We present the high and equatorial mesospheric dynamical response to the minor stratospheric warming that occurred in 2014/15 and compared it with the major stratospheric warming events of 2005/06 and 2008/09. Meteor radar observations over Esrange (67.88°N, 21.07° E), Mohe (52.97°N, 122.53°E) and Kototabang (0.20°S, 100.32°E) have been extensively utilized in addition to ERA 5 Reanalysis datasets. Possessing the unique feature of a vortex displacement and split, the minor warming of 2014/15 was observed on 27 December 2014 followed by four subsequent temperature peaks. During the 2014/15 minor SSW, the tropical stratospheric temperature decreased, causing upwelling similar to the major SSW events 2005/06 and 2008/09. The equatorial mesospheric zonal wind in 2014/15 displayed maximum westward wind with a delay of ~19 days after the vortex disruption similar to the major SSW events. Whereas, over Esrange and Mohe, the westward wind maxima occurred about the vortex disruption during all the warming events. During the minor SSW 2014/15, the ~16-day planetary wave is observed to be relatively stronger in the equatorial mesosphere than the high latitude mesosphere. The Eliassen Palm flux diagnostics revealed the intrusion of planetary wave energy from high latitudes to the tropical band, suggesting meridional and equatorward propagation of planetary waves.



Meteor Radar Investigation of Middle and Upper Atmosphere Dynamics from Tropical to Polar Regions during Sudden Stratospheric warming: A Review

S. Eswaraiah 1*,M.Venkat Ratnam2 , Kondapalli Niranjan Kumar3, Chalachew Kindie Mengist4, Gasti Venkata Chalapathi 5, Yong-Ha Kim6, and S. Vijaya Bhaskara Rao7

1Mohan Babu University, Tirupati, India

2National Atmospheric Research Laboratory, Tirupati, India

3National Centre for Medium Range Weather Forecasting, Noida, India

4Department of Atmospheric Sciences, Pusan National University, Busan , Korea

5Department of Physics, Government Degree College, Anantapur, India;

6Department of Astronomy and Space Science, Chungnam National University, Daejeon, Korea

7Department of Physics, Sri Venkateswara University, Tirupati, India

Correspondence: eswar.mst@gmail.com

Abstract

The investigation of atmospheric dynamics during Sudden Stratospheric Warmings (SSWs) is crucial for understanding the complex interactions within the Middle and Upper Atmosphere. This review synthesizes meteor radar data of mesospheric and lower thermosphere (MLT) winds collected from Tropical to Polar regions during the SSWs that occurred in the Northern Hemisphere (NH) in 2017 and 2018 and in the Southern Hemisphere (SH) in 2010 and 2019.

In this study, we analyze the meteor radar data from an array of global stations, spanning latitudes from equatorial to polar regions. The data reveal distinct variations in wind patterns, wave activities, and turbulence before, during, and after the SSWs. Notably, the NH SSWs of 2017 and 2018 exhibited pronounced alterations in mesospheric wind fields, with significant deceleration of the zonal winds and enhanced meridional circulation, indicating strong coupling between the stratosphere and MLT. These changes were more marked in higher latitudes, reflecting the hemispheric asymmetry in the SSW impacts.

In the SH, the 2010 and 2019 SSWs presented unique features due to the difference in the geographical and climatological conditions compared to the NH. The SH SSWs led to remarkable changes in the mesospheric temperature and wind structures, highlighting the critical role of the Antarctic vortex and its influence on atmospheric wave dynamics. The analysis of the SH SSWs also emphasized the importance of interhemispheric comparisons to understand the global atmospheric responses to SSW events.

In conclusion, the meteor radar investigations during the 2017, 2018 NH SSWs and the 2010, 2019 SH SSWs highlight the intricate interactions between different atmospheric layers and the significant impact of SSWs on global atmospheric circulation. The continued deployment and enhancement of meteor radar networks are imperative for improving predictive models and understanding the broader implications of these dynamic atmospheric phenomena.

Interhemispheric Coupling in the Middle Atmosphere Revealed by High-resolution Observations and Modelling (ICSOM)
-Gravity-wave Permitting GCM Study for the Whole Middle Atmosphere-

Kaoru Sato[(1)], Haruka Okui[(1,2)], Shingo Watanabe [(3)], Dai Koshin[(1,4)], Masashi Kohma[(1)], et al.

(1) Department of Earth and Planetary Science, the University of Tokyo, Tokyo 113-0033, Japan

(2) University of Bath, UK.

(3) Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan,

(4) National Center for Atmospheric Research, U.S.A.

In contrast to the stratosphere, the mesosphere and lower thermosphere (MLT) remains a region of great unknowns due to its remoteness and the crucial role of momentum transport by gravity waves, which have small spatio-temporal scales. Recent satellite observations and model studies have unveiled the presence of several interesting phenomena that span the entire middle atmosphere. Among these are the interhemispheric coupling (IHC), characterized by a positive correlation between temperatures in the winter polar stratosphere and the summer polar upper mesosphere with a time lag of several days, and a sudden stratopause elevation up to a height of about 80 km following sudden stratospheric warming. To elucidate the dynamical mechanism behind these middle atmosphere variabilities, an international joint project “Interhemispheric Coupling Study by Observations and Modelling (ICSOM)” has been undertaken. This project comprises three components: a series of observation campaigns using a global radar network capable of observing mesospheric gravity waves, the development of a data assimilation system to produce global reanalysis data for the entire middle atmosphere over 20 years (JAWARA), and the reproduction of the phenomena observed by the radar network using a gravity-wave permitting high-resolution general circulation model. Our studies by combining these three ICSOM components reveal that the IHC occurs by sequential processes: 1. Formation of cold anomaly in the equatorial stratosphere extending deep into the summer hemisphere associated with sudden stratospheric warming, 2. Enhanced generation of quasi-two day waves and secondary GWs by modified mean zonal winds, causing enhanced negative forcing in summer middle latitudes, 3. Modulation of primary GWs by the resultant mean zonal wind modification. The new resources produced by the ICSOM project provide a powerful tool for quantitative dynamical studies of various topics within the MLT region and the coupling between the MLT region and other atmospheric regions, by treating seamlessly the hierarchical structure including gravity waves.

Variability of low-latitude middle atmosphere during a major sudden stratospheric warming in the southern hemisphere

Amitava Guharay(1) and Paulo Prado Batista(2)

(1) Space & Atmospheric Sciences Division, Physical Research Laboratory, Ahmedabad, GJ, India
(2) Heliophysics, Planetary Sciences and Aeronomy Division, National Institute for Space Research, São José dos Campos, SP, Brazil

Behaviour of extratropical southern latitudes during a major sudden stratospheric warming is investigated using meteor radar winds and reanalysis data. In response to the warming at polar latitudes, a simultaneous cooling in the tropical and extratropical stratosphere is observed. An evident feature of latitudinal propagation of a planetary wave with zonal wavenumber 1 and 2 from high to low latitudes is found associated to the warming. There is a signature of split of the polar vortex into two parts of different sizes and progress towards low latitude. Noticeable air mass mixing between low and high latitude atmospheres is believed to be driven by planetary wave breaking. The meridional wind exhibits oscillations of period 2-4 days during the warming period in the stratosphere. No wave feature is evident in the mesosphere during the warming period, although a 12-14-day periodicity is observed following the warming event, resembling with the results of other simultaneous studies from the Antarctic locations.

Spectral analysis of atmospheric waves in the upper troposphere-lower stratosphere (UTLS) observed with radiosondes at the Equatorial Atmosphere Radar (EAR) observatory

Anis Purwaningsih(1), Noersomadi[1], Toshitaka Tsuda[2], Nani Cholianawati[1], Halimurrahman[1], Tiin Sinatra[1], Asif Awaludin[1], Hubert Luce

(1) Research Center for Climate and Atmosphere, National Research and Innovation Agency (BRIN), Indonesia

(2) Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Japan

*Email: anis.purwaningsih@brin.go.id

We analyzed frequency and vertical wave number spectra of temperature (T), zonal (u), and meridional (v) wind velocity obtained with radiosondes during the CPEA campaign from 24 November 2005 to 22 December 2005 at the Equatorial Atmosphere Radar (EAR) observatory (0.204 S, 100.319 E). T, u, and v fluctuations were recognized in the upper troposphere and lower stratosphere (UTLS), which were further decomposed into various atmospheric waves. We applied spectral analysis in time (frequency) and space (wavenumber) domains using Fast Furrier Transformation. Moreover, the periodogram analysis using sinusoidal curve fitting was used to determine the dominant wave periods. The result from frequency spectra in area-preserving form shows that the diurnal tides appeared in the frequency spectra of T and u above 22 km with a vertical wavelength of about 5 km, but there was no clear spectral peak for v. The diurnal tide seemed to show hemispheric symmetry relative to the equator because the diurnal signal only appeared in u, but there was no clear spectral peak for v. Moreover, results also indicate the appearance of short-period oscillations in T, u, and v represented the superposition of atmospheric gravity waves, showing the highest energy at a wavelength with wave periods of 2-7 days. The strongest period is 5 days from the periodogram results of T, u, and v data. Furthermore, the Equatorial Kelvin waves with periods of 10-14.5 days oscillation were identified in T and u, but they did not appear in v. Based on the periodogram analysis, the 13.1-day oscillation of T and u data dominates the stratosphere area, representing the oscillation of dominant Kelvin waves over the high range. The results suggest that within a 29-day campaign, the behavior of atmospheric waves can be decomposed and analyzed using FFT and Periodogram, and the result is important to understand the energy and momentum flux exchange triggered by the identified waves, especially in the study area.

keywords: FFT, periodogram, diurnal tides, Mixed-Rossby Gravity waves, Kelvin waves

Study of Low-Latitude Planetary Wave Dynamics during 2019 Minor Sudden Stratospheric Warming

G. Mitra [1,2], A. Guharay[1], P. P. Batista[3] and R. A. Buriti[4]

(1) Space and Atmospheric Sciences Division, Physical Research Laboratory, Ahmedabad, GJ, India

(2) Department of Physics, Indian Institute of Technology, Gandhinagar, GJ, India

(3) Heliophysics, Planetary Sciences and Aeronomy Division, National Institute for Space Research, INPE, São José dos Campos, SP, Brazil

(4) Department of Physics, Federal University of Campina Grande, Campina Grande, PB, Brazil

The present study examines dynamic variability of the planetary waves (PWs) in the equatorial and extratropical middle atmosphere during the September 2019 minor sudden stratospheric warming (SSW) in the Southern Hemisphere, using meteor radar wind data from São João do Cariri (7.4°S, 36.5°W) and Cachoeira Paulista (22.7°S, 45°W) in combination with the reanalysis data. Both traveling and stationary waves exhibit notable activity during the SSW, with zonal wavenumber 1 PWs playing a crucial role in preconditioning the event. The wind spectra revealed a dominant quasi-16-day wave (Q16DW) before the SSW, followed by a significant burst of quasi-6-day wave (Q6DW) following the event. Warming associated barotropic/baroclinic instability in the low and mid-latitude middle atmosphere seems to drive the excitation of the Q6DW. Additionally, the potential vorticity map revealed significant latitudinal mixing of air masses between the tropics and high latitudes, resulting in instability. The Eliassen-Palm flux analysis further highlighted the propagation of Q6DW and Q16DW from mid to low latitudes, underscoring the significant influence of the rare 2019 Antarctic SSW on the planetary wave dynamics.

Latitudinal Variation of Solar Diurnal, Semi-diurnal, and Terdiurnal Tides using a network of meteor radars and SD WACCM simulation

Pramitha Maniyatt[1] , Vikash Rishi Dharan K[1]

[1]Indian Institute of Science Education Research Thiruvananthapuram

Atmospheric solar tides are global-scaled oscillations with periodic harmonics of the solar day (24-, 12-, 8-hours, etc.). These tides are driven by the diurnal variations in heating caused by the absorption of solar UV radiation by atmospheric water vapour and ozone. Our present study deals with the latitudinal variation of solar diurnal, semi-diurnal, and terdiurnal tides in the Mesosphere Lower Thermosphere (MLT) region, utilising data from a comprehensive network of five meteor radars strategically located across the Globe. The study, conducted using the Skiymet meteor radars operated by the University of Bath, spans diverse latitudinal zones, including tropical, mid-latitude, and polar regions, with meteor radar installations at Ascension, Bear Lake Observatory (BLO), King Edward Point (KEP), Esrange, and Rothera. The method involves calculating zonal, meridional and vertical wind vectors by meticulously analysing meteor position data files. These data are parsed into clusters based on height and time bins, enabling the determination of wind components. These estimated wind vectors are used to extract the tidal parameters by applying a non-linear least squares fitting method to zonal and meridional wind data, thereby computing the amplitudes and phases of diurnal, semi-diurnal and ter-diurnal solar tides. Thus, the obtained solar tidal amplitudes are used to evaluate the SD WACCM simulated tidal amplitudes at these five locations. It is observed that in the tropical region, there is a clear equinoctial enhancement in meridional semi-diurnal tide amplitudes of about 17 ms-1. However, for the mid-latitude and polar regions, the enhancement occurs during August-September and winter solstices peaking at about 35 ms-1. Overall, SD WACCM can mimic tidal variations at various latitudes but tends to constantly underestimate tidal amplitudes derived from meteor radar data. Consequently, the accuracy of SD WACCM simulations improves following bias correction. This study holds significance in unravelling the latitudinal variation in solar tides. Also, it serves as a basis for evaluating WACCM simulations of zonal and meridional winds and tides over tropical, mid-latitude, and polar latitude regions.

Unlocking the Secrets of the Tropical Middle Atmosphere: 30 Years of Indian MST Radar Discoveries and Beyond

M. Venkat Ratnam

National Atmospheric Research Laboratory, Department of Space, Government of India, Gadanki-517112, India,

vratnam@narl.gov.in ; vratnam@gmail.com

The genesis of the Indian Mesosphere-Stratosphere-Troposphere (MST) radar came from the Indian Middle Atmospheric Programme (IMAP) to study middle atmospheric dynamics and its underlying processes. Numerous focused campaigns of national and international importance were conducted. Using the unique data collected over the past 30 years, along with complementary measurements, several stimulating results have been reported, covering a wide range of topics. An overview highlighting the unique results obtained using long-term observations of the Indian MST radar and complementary techniques, covering the complete middle atmosphere, is presented. Extensive studies have been made in characterizing turbulence, winds, and waves. It has been possible to characterize different active wave modes that affect the overall dynamics and energetics of the middle atmosphere. A good understanding has been gained on convection, waves, and the associated energetics. Unique results include the quantification of the momentum carried by high-frequency waves generated in the troposphere up to the mesosphere, the demarcation of the complete tropical tropopause layer using MST radar observations alone, indications of the strengthening of the tropical easterly jet in the recent decade, unusual behavior of the Hadley circulation during drought and El Niño years, the revelation of the mechanisms for the occurrence of mesospheric echoes at tropical latitudes, quantification of turbulence, evidence for the role of anthropogenic changes on the dynamics of the mesosphere, and the generation of an empirical model by combining multi instrument data sets. These data sets have also been used to validate numerous ground-based and space-borne measurements, including several re-analysis products over a tropical latitude. Vertical wind in the UTLS region is consistently found to be upward, suggesting that deep convection is not necessary for transporting water vapor from the troposphere to the lower stratosphere. Thus, the middle atmospheric program has significantly contributed to the understanding of not only the middle atmosphere but also meteorological applications, including lower and upper atmospheric processes. Unresolved issues and ways to tackle them in future experiments are highlighted.

O-59

Revisiting seasonal variations of atmospheric parameters in the lower atmosphere (2-20 km) from MU radar data (1987-2022)

Hubert LUCE(1), Toshitaka TSUDA(1), Hiroyuki HASHIGUCHI(1), Noriyuki NISHI(2)

(1) RISH, Kyoto University, Japan

(2) Faculty of Science, Fukuoka University, Japan

Long-term MST radar data can be used to describe seasonal dynamics and annual trends of atmospheric parameters for a better understanding of atmospheric processes such as gravity waves and turbulence. To mark the 40th anniversary of the MU radar, the GRATMAC dataset covering a period of 35 years (1987-2022) in the lower atmosphere (2-20 km) is currently being used to re-analyze the seasonal variation of (1) turbulence parameters (such as turbulent kinetic energy and dissipation rates), (2) the spectral properties (slope and variance) of wind speed and wind components, momentum fluxes and body forces in the frequency range of gravity waves, and the possible relationship(s) between (1) and (2). An overview of some of the results will be presented, after stressing the importance of managing radar data gaps correctly and other possible instrumental biases related to the VHF backscattering mechanisms.

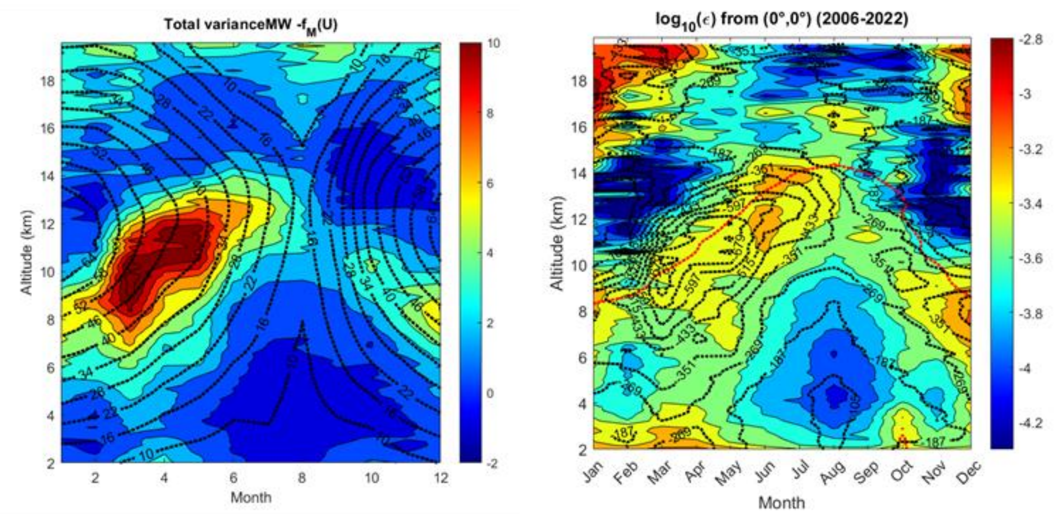


Figure: (Left) Contour plot of an "anomaly of" the variance $\langle V'^2 \rangle$ of the meridional wind component computed from 1-day time series and averaged over (1987-2022) and the corresponding contour plot of wind speed (dashed black lines). (Right) Contour plot of an estimate of TKE dissipation rate ε (in log scale) and contour plot of the variance anomaly shown in the left panel (dashed black lines).

Cloud Base Height Characteristics based on Ceilometer Measurements in Mountainous areas of Sumatra

Helmi Yusnaini(1), Marzuki Marzuki(1), Hiroyuki Hashiguchi(2) and Ravidho Ramadhan(1)

(1) Department of Physics, Universitas Andalas, Padang 25163, Indonesia

(2) Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Gokasho, UJI, Kyoto 611-001, Japan

The presence of clouds and vertical structures has a great influence on radiation balance, atmospheric circulation, hydrological cycle, and climate. Studying cloud characteristics over a long period of time can help us improve our understanding of the uncertainties in weather forecasting and climate prediction. Cloud base height (CBH) characteristics have been studied from observations of the Ceilometer CT25K installed at Kototabang (0.202°S, 100.317°E), an area 864.5 m above sea level and 40 km from the coastline in the western part of Sumatra island. CBH data with high resolution (measurements every 15 s) were analyzed for 18 years of observations (April 2002-December 2021 with two years of missing data). During the study period, the average frequency of occurrence of single, two, and three-layer clouds was 41.1%, 6.0%, and 0.4%, respectively, out of 76.5% of the total data during the observation period. Low clouds (<2 km) have a frequency of 71.4%, while medium clouds (2km - 6km) 25.4%, and high clouds (>6 km) 3.1%. The average CBH was found to be lower as the number of cloud layers increased. The occurrence of low clouds near the surface (<0.5 km) was found to be maximum before the peak rainfall occurred in October (15.2%) and minimum in February (5.8%). A single layer cloud event from ceilometer observations on January 18, 2009 at 1:00 am with an altitude of 2.90 km was also observed near Kototabang (0.2038°S, 100.3936°E) from CALIPSO satellite observations with a lower altitude (1.7293 km). CBH observations from CALIPSO for a long year are needed to observe the characteristics of cloud in Kototabang.

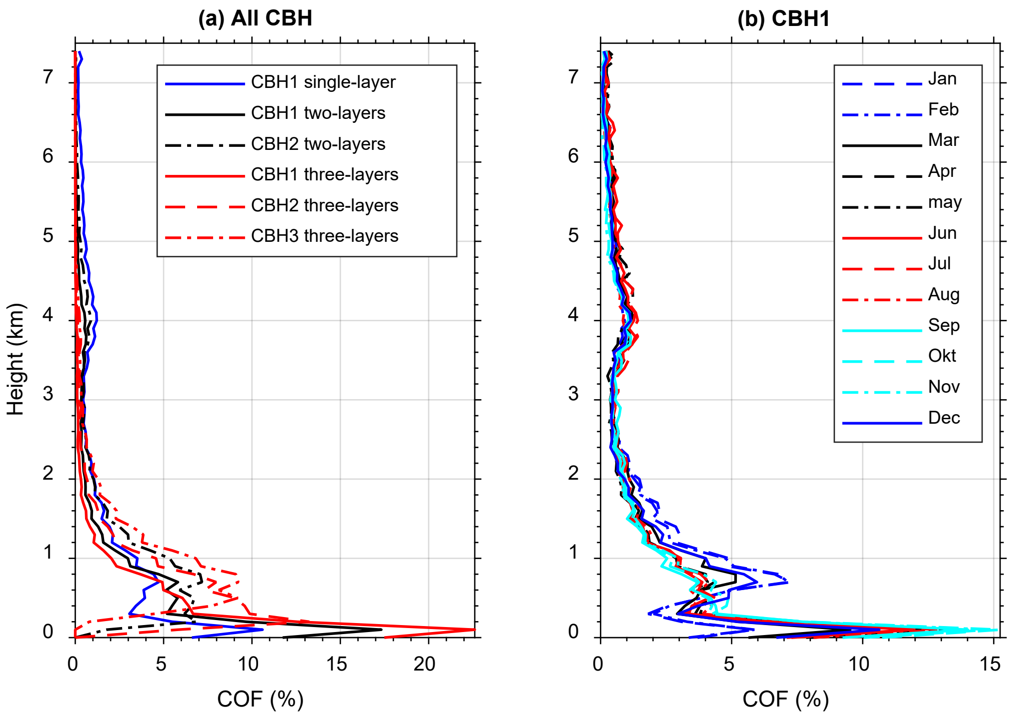


Figure 1. Cloud Occurrence Frequency (COF) in different heights during the observation period (a) to every type CBH, and (b) CBH1 in every month.

Meteor radar observations of long-term variabilities in arctic mesosphere and lower thermosphere winds over Esrange (67.9°N, 21.1°E)

K. Ramesh [(1), *], Nicholas J. Mitchell [(1, 2)], Neil P. Hindley [(3)], Tracy Moffat-Griffin [(1)]

(1) British Antarctic Survey (BAS), Cambridge, UK
(2) Centre for Atmospheric and Environment Research, University of Bath, Bath, UK
(3) Centre for Climate, Adaptation and Environment Research, University of Bath, Bath, UK

The VHF radar has been operational since August 1999 to detect the meteor echoes in the mesosphere and lower thermosphere (MLT; ~80-100 km) over Esrange (67.9°N, 21.1°E). In the present study, the performance of Esrange meteor radar has been carefully investigated to determine if there is any significant change over the duration of the data set (1999-2022), as it is an essential step in the studies of long-term variability. It is found that the average altitude of the meteor echoes in each month is consistent between ~88 and ~91 km throughout the observational period. The long-term variabilities in the monthly zonal (U) and meridional winds (V) in the arctic MLT are investigated using Esrange meteor radar observations during 1999–2022. The summer (June-August) mean zonal winds are characterized by westward flow up to ~88-90 km and eastward flow above this height. The summer mean meridional winds are equatorward with strong jet at ~85-90 km, and it weakens above this height. The U and V exhibit strong interannual variability that varies with altitude and month or season. Further, the responses of U and V anomalies (from 1999 to 2003) to solar cycle (SC), Quasi Biennial Oscillation at 10 and 30 hPa, El Niño-Southern Oscillation, North Atlantic Oscillation, ozone (O_3) and carbon dioxide (CO_2) are analysed using multiple linear regression. From the analysis, significant regions of correlations between MLT winds and above potential drivers vary with altitude and month. The long-term and interannual variabilities in the zonal and meridional winds can be attributed to the above potential drivers.

Abstracts
Poster Session

Preliminary results on CEJ occurrence in quiet space weather conditions during tropical cyclones "BIJILI" and "AILA"

M Gajalakshmi[1*], G J Bhagavathiammal[1,2]

1 Department of Medical Physics, Anna University, Sardar Patel Road, Guindy, Chennai-600025, India
2 Centre for Climate Change & Disaster Management (CCCDM), Department of Medical Physics, Anna University, Sardar Patel Road, Guindy, Chennai-600025, India

Abstract:

This work presents the occurrence of Counter Electro Jet (CEJ) in quiet space weather conditions through the case studies of tropical cyclones BIJILI and AILA. The Cyclonic Storm (CS) BIJILI happened from 14 April 2009 to 17 April 2009 and Severe Cyclonic Storm AILA was from 23 May 2009 to 26 May 2009 over the Bay of Bengal. In this study, we have used the horizontal components of Earth's magnetic field over the equatorial Tirunelveli (TIR, 8.7^{o}N, 77.7^{o} E) and off-equatorial station Alibag (ABG, 18.6^{o} N, 72.8^{o} E) in the Indian sector and obtained from the Indian Institute of Geomagnetism. The strength of Equatorial ElectroJet was calculated using $\Delta H_{EEJ}= \Delta H_{TIR}-\Delta H_{ABG.}$ The occurrence of CEJ was observed on the maximum intensified stage of cyclones (BJILI on 15 April 2009 & 16 April 2009, ALILA on 24 May 2009 to 26 May 2009), and the intensity of EEJ was suppressed by about ~30nT. In addition, at the time of CEJ, we observed the robust appearance of Gravity Wave (GW) with periods of 4-5 hours. The comprehensive results will be presented in detail.

Key Word: EEJ, CEJ, Tropical Cyclones, Gravity wave

Recent progresses of the MSTID studies from the perspective of satellite observations

Charles Lin(1), P. K. Rajesh(1), Min Yang Chou(2) and Pin Hsuan Cheng(3)

(1) Department of Earth Sciences, National Cheng Kung University, Taiwan

(2) Goddard Space Flight Center, NASA, Greenbelt, MD, USA

(3)Aerospace Engineering and Science, University of Colorado at Boulder, Boulder, CO, USA

MU radar plays an important role to unveil the connection of the Es layer and F-layer Perkins instabilities in formation of medium scale traveling ionospheric disturbance (MSTID) by showing that the spatial alignments of the observed echoes have the similar wavefront alignment to the F-layer MSTID. Comprehensive theoretical model simulations (Yokoyama et al., 2009) supports the analytical theory of the Es-Perkins instability coupling proposed by Tsunoda (2006). Recently, new satellite observations indicate that MSTID may have other complex aspects in addition to previous observations. For example, Rajesh et al. (2016) showed that the appearance seasons, longitudes and wavefront alignments of MSTIDs are not well explained by the Es-Perkins coupling theory. Cheng et al. (2021) showed that there are also northward propagation of MSTIDs from low to mid-latitudes that requires additional mechanisms to explain. Chou et al. (2017) showed that gravity wave driven by an typhoon could trigger low-latitude MSTIDs. All these new features prompt the need of further studies of MSTID with various formation mechanisms or developments. This presentation will highlight these new aspects from recent satellite observations to prompt further discussions.

P-3

Ionospheric Signatures detected by GNSS-TEC and SAR Azimuth Offset during Latest Geomagnetic Storm in 2024: Indonesian Region

Ihsan Naufal Muafiry[(1)], Masato Furuya[(2)], and Prayitno Abadi[(1)]

(1) Research Center for Climate and Atmosphere, Indonesian National Research and Innovation Agency (BRIN), Bandung 40135, Indonesia

(2) Natural History of Science Dept., Faculty of Sciences, Hokkaido University, N10 W8, Sapporo 060-0810, Japan

The latest 2024 geomagnetic storm from May 9-12 has reached the level of “Severe” on the NOAA geomagnetic storm scale. By using the nationwide GNSS network in Indonesia, we detected high GNSS-ROTI (Rate of TEC Index), indicating strong ionospheric disturbances. Based on the GNSS-TEC anomaly isolated by 120-minutes moving averages, TEC depletion beyond 5 TECU have been detected. Thus it is likely such disturbances were due to the generation of Equatorial Plasma Bubble on May 9th, 2024. To further analyze the ionospheric disturbance, we used L-band SAR images from ALOS-2/PALSAR-2 and performed azimuth offset tracking method. ROTI map and GNSS-TEC anomaly map derived from GNSS SIP (at 300 km altitude) show N-S feature of disturbances with almost covering whole country around 16:40 UT. We selected two consecutive frames of ascending SAR images available around the same time (16:39 UT, May 9th 2024) and location of the disturbance in the GNSS-ROTI. Because the SLC image on May 9th was apparently defocused, we generated forward- and backward-looking SLC (single look complex) images to examine the effect of ionosphere. Next, pixel offset tracking between these two SLC images were performed, which might be similar to (26) in Yamashita et. al. (2022); we processed only the single SLC image. It is notable that typical NE-SW azimuth streaking geometry has been observed beyond 20 pixels likely due to the ambient of geomagnetic field-line. The slight differences in direction of ionospheric feature from both GNSS-ROTI and SAR images are probably attributable to the satellite geometry toward the targeted area. In order to verify that these findings are due to storms, we compared pixel offset tracking results from images taken on non-storm days or during periods of quiet ionospheric activity. We used SAR images from January 18th and February 1st, 2024, when ionospheric activity was low according to GNSS-ROTI data. Both images exhibited high coherence and the pixels offset tracking results indicated the absence of NE-SW stripes, unlike those observed on May 9th, 2024. GNSS-TEC anomaly data also showed no TEC depletion for these quiet days. It appears highly likely that the azimuth streaking observed in low-latitude regions is predominantly caused by equatorial plasma bubbles generation. Given the strong SAR azimuth stripes on May 9th, such anomalies should be considered in surface deformation studies in equatorial regions using L-band SAR, as these anomalies occur almost daily especially during the equinox seasons.

Keywords: Geomagnetic Storm, GNSS-TEC, SAR images

The Monitoring of Localize Ionospheric Scintillation and RF Interference by GNSS Network

Tung-Yuan Hsiao[1*]

[1] Nuclear Science and Technology Development Center, National Tsing Hua University, Hsinchu, Taiwan

Contemporary navigation, communications, and electronic warfare systems heavily depend on the uninterrupted accessibility of Global Positioning Satellite Systems (GNSS) or comparable systems for the purposes of location determination, navigation, and time synchronization (PNT). Irrespective of the deliberate or inadvertent nature of the purpose, the act of Global Navigation Satellite System (GNSS) jamming, also known as jamming, has the potential to significantly impede or entirely interrupt applications that depend on Positioning, Navigation, and Timing (PNT). Therefore, the assurance of PNT functionality emerges as an essential imperative. Due to the inherently weak power of normal GNSS signals, the operational integrity of these systems and the effective completion of their tasks might be compromised by the interference caused by low-cost GNSS jammers. In the present study, the phenomenon of localized scintillation structure, characterized by the disruption of radio signals due to abnormalities, is duly acknowledged. The presence of irregularities within the ionosphere can have an impact on the propagation of radio waves passing through it. In this study, a low-cost GNSS network is established in the Taiwan region utilizing Septentrio GNSS mosaic X5 modules. The purpose of this network is to monitor the quality of the GNSS signal and determine whether any interference originates from ionospheric abnormalities or the local RF environment.

Estimating MLT Winds from Non-Specular Meteor Trails: A Machine Learning Approach with RetinaNet

Armando Castro[1] and Danny Scipion[1]

(1) Radio Observatorio de Jicamarca, Instituto Geofísico del Perú, Perú

The Instituto Geofisico del Peru (IGP) through the Radio Observatorio de Jicamarca (ROJ) has been able to detect non-specular meteors due to the high-power large-aperture (HPLA) radar located at (11.95° S, 76.87° W, 1° dip angle). There have been many studies to estimate the Mesospheric Lower Thermospheric (MLT) winds obtained from specular and non-specular meteors trails. The main difficulty to estimate the MLT winds from non-specular meteor trails is the presence of the Equatorial ElectroJet (EEJ) during most of the day and night. Usually, the better estimates are obtained during the night where their presence is weak.

In the present study, we present a novel technique which uses a machine learning approach with RetinaNet to discriminate between the non-specular meteor trails in the presence of EEJ, and by using interferometry between different receivers to estimate the zonal and meridional winds.

African and American Equatorial Ionization Anomaly (EIA) Responses to 2013 SSW Event

O.R. Idolor[1], A.O. Akala[1], O. S. Bolaji[2], E.O. Oyeyemi[1],

[1]University of Lagos, Lagos Nigeria

[2]Bowen University, Iwo, Nigeria

Abstract

This study investigates the responses of the African and American Equatorial Ionization Anomaly (EIA) regions to 2013 Sudden Stratospheric Warming (SSW) event. The Total Electron Content (TEC) data obtained from chains of Global Positioning System receivers within ±40° geomagnetic latitudes in the African and American sectors were used to construct the EIA structures for both longitudinal sectors. The responses of the EIA structures, constructed from the TEC, ΔTEC, and ionospheric irregularities data to the 2013 SSW event were investigated. During the SSW peak phase, EIA structures in both longitudinal sectors responded significantly, with the pole-ward flow of plasma from the equator to higher crests' locations (strengthening of the EIA). Furthermore, a clear asymmetry in plasma distribution in the northern and southern crests of the EIA was observed. Generally, for the entire data span, TEC enhancements and ionospheric irregularities occurrences during SSW were more in the American sector than the African sector. The geomagnetic activity of 17 January 2013 caused negative TEC response in the African sector and positive TEC response in the American sector. Moderate storm-induced TEC enhancements were generally lower than SSW-induced TEC enhancements. Furthermore, solar flux-induced TEC of 10 January 2013 was lesser than the SSW-induced TEC of 15–16 January 2013.

Keywords: Equatorial ionization anomaly, vertical drift, ionospheric irregularities, sudden stratospheric warming, geomagnetic storms

P-7

On the Atmospheric Solitary Waves Propagation over Bengkalis Island

Ahmad Ripai[(1)], Albertus Sulaiman[(2)], Husin Alatas[(1)] and Noersomadi[(2)]

(1) Department of Physics, IPB University, Bogor, Indonesia

(2) Research Center for Atmosphere and Climate, National Research and Innovation Agency (BRIN), Bandung, Indonesia

The dynamics of the atmospheric soliton over Bengkalis Island are investigated. We detected the signature of an atmospheric soliton propagating from land toward the coastal region on April 7, 2022, at 00.20 local time observed with X-band weather radar. We applied a single soliton solution using the KdV equation. The model of soliton pulse shows a maximum amplitude 625.47 m and an average internal velocity of 16.67 m/s. Solitons break up into convection cells when they reach the coastline.

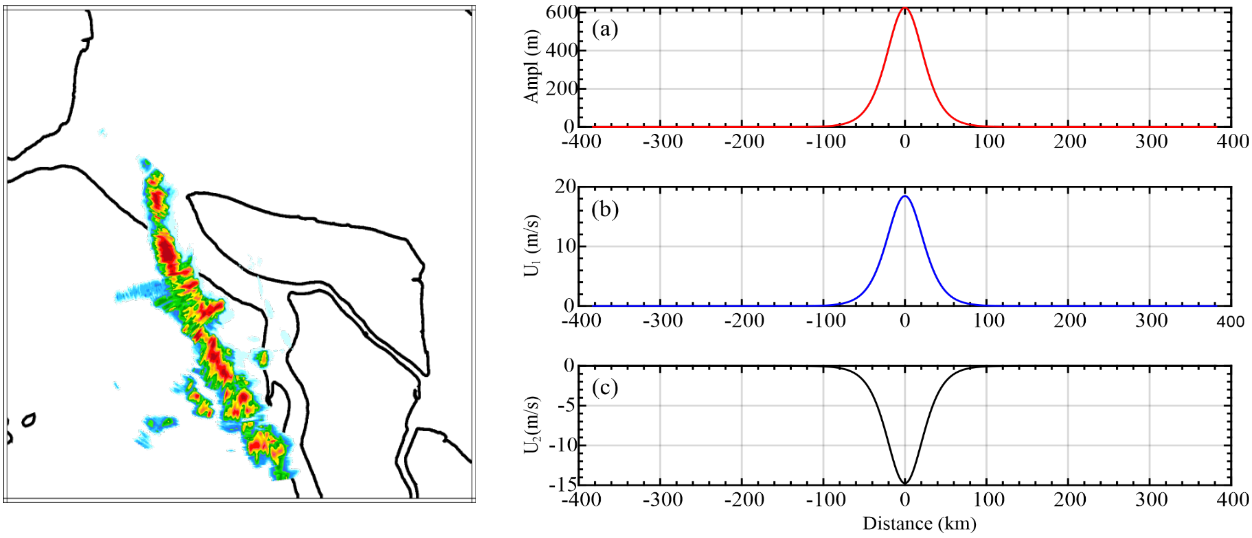


Figure 1. Signature of soliton characterized by a squall line of the convection cell around Bengkalis Island (left panel). Model of soliton pulse based on the single solution of the KdV equation (right panel).

Quantifying the impact of extratropical planetary wave forcing on the QBO disruption in 2015/16 and 2019/20

G. J. BHAGAVATHIAMMAL[1]

1 Department of Medical Physics, Anna University, College of Engineering Guindy, Sardar Patel Road, Chennai-600025, Tamil Nadu, India

Presenting Author Name: G J Bhagavathiammal
selvigjb@gmail.com / Mobile: +919942948562

ABSTRACT

Sudden stratospheric warming is an important robust dynamical event which occurs in the polar stratosphere. It is well believed that the mechanism for the occurrence of sudden warming is due to the interaction of upward propagating planetary waves generated from the lower atmosphere with the background flow. The present work describes the unusual effect of extra-tropical planetary wave forcing on the equatorial QBO by disturbing its regular descending wind flow in 2015/16 and 2019/20. The dynamical variables temperature, wind components and geopotential height are utilized from ECMWF ERA5 Reanalysis datasets. Eliassen Palm (E-P) flux 2-D and 3-Dimensional method, a traditional diagnostics tool is used to realistic visualization of this dynamical interaction. Horizontal and vertical component of E-P flux is used to characterize the intensity of upward propagating planetary waves from lower atmosphere. We found a prominent horizontal transfer of planetary wave energy from high to equatorial latitudes both in the case of 2015/16 and 2019/20. The reach of upward and equatorward propagating planetary waves to tropical regions significantly disturbs the equatorial QBO. The detailed analysis will be presented in detail.

Keywords: Planetary wave forcing, Quasi-biennial Oscillation (QBO), E-P Flux, SSW

Observation of Mixed Rossby-Gravity (MRG) Waves as Initiation of MJO Propagation using GNSS-RO Data

Herdiana Sri Wahyuningsih[1], Nurjanna Joko Trilaksono[1], and Noersomadi[2]

(1) Faculty of Earth Science and Technology, Bandung Institute of Technology (ITB), Bandung, Indonesia

(2) Research Center for Climate and Atmosphere, National Research and Innovation Agency (BRIN), Bandung, Indonesia

The Madden-Julian Oscillation (MJO) is characterized by convective propagation from Indian Ocean passing through Indonesian area to Pacific Ocean. This research investigates the role of Mixed-Rossby Gravity (MRG) waves that propagate westward from Pacific Ocean initiating the MJO. The role of MRG is analyzed using vertical temperature distribution with an atmosphere profile from COSMIC2-GNSSRO. We identified the waves with space-time spectral temperature anomaly at levels 14, 17, and 21 km as a representation of the upper troposphere, tropopause, and lower stratosphere. We focus on the case study of pre-, during, and -post of two MJO cases (K1 with no MRG and K2 with MRG). K1 showed a cold anomaly in the tropopause level in pre-, whereas K2 described a cold anomaly at the tropopause within pre- and during the period. The cold anomaly seen in pre-time is because of convective activity in Indian Ocean. Meanwhile, the cold anomaly at the tropopause during K2 showed an active MJO over Indonesia area. In the active MJO phase, there is a dipole pattern of warm temperature (cold) in the upper troposphere (tropopause). We found that MRG is triggering two dipole patterns in -the post-period when MJO occurred associated with MRG. This occurrence is due to the westward propagating of the cold anomaly by MRG that initiated the MJO.

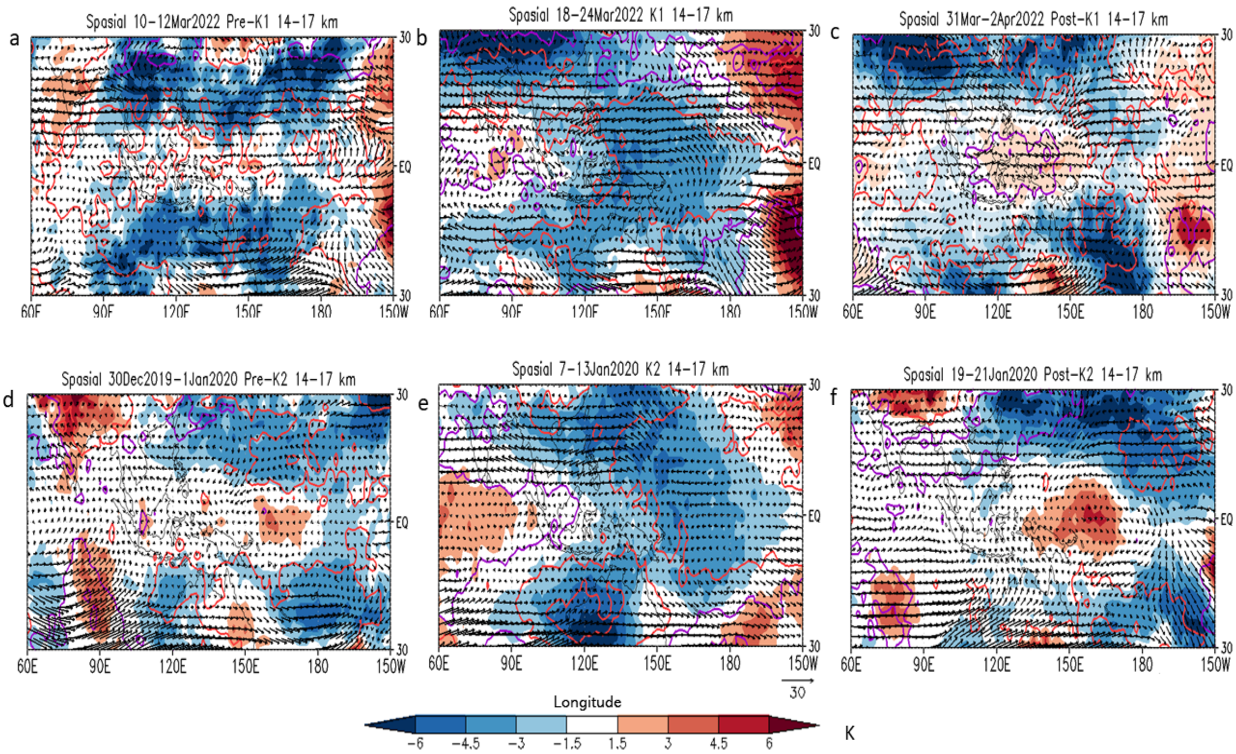


Figure 1. Spatial distribution of temperature anomaly at *pre* (a and d), *during* (b and e), and *post* (c and f) MJO active phase over Indonesia area.

Numerical simulation of orographic gravity waves observed over Syowa Station

Masashi Kohma(1), Kaoru Sato(1), David C. Fritts(2), and Thomas S. Lund (2)

(1) The University of Tokyo

(2) GATS Inc., CO, USA

A high-resolution model in conjunction with realistic background wind and temperature profiles has been used to simulate gravity waves (GWs) that were observed by an atmospheric radar at Syowa Station, Antarctica on 18 May 2021. The simulation successfully reproduces the observed features of the GWs, including the amplitude of vertical wind disturbances in the troposphere and vertical fluxes of northward momentum in the lower stratosphere. In the troposphere, ship-wave responses are seen along the coastal topography, while in the stratosphere, critical-level filtering due to the directional shear causes significant change of the wave pattern. The simulation shows the multi-layer structure of small-scale turbulent vorticity around the critical level, where turbulent energy dissipation rates estimated from the radar spectral widths were large, indicative of GW breaking. Another interesting feature of the simulation is a wave pattern with a horizontal wavelength of about 25 km, whose phase lines are aligned with the front of turbulent wake downwind of a hydraulic jump that occurs over steep terrain near the coastline. It is suggested that the GWs are likely radiated from the adiabatic lift of an airmass along an isentropic surface hump near the ground, which explains certain features of the observed GWs in the lower stratosphere.