AOMSUC-11 Summary Report

The eleventh Asia-Oceania Meteorological Satellite Users' Conference (AOMSUC-11) was held virtually in Beijing, China, from 28-29 October to 1–5 November 2021 in conjunction with the 2021 FengYun Satellite User Conference (FYSUC). AOMSUC-11 which was hosted and sponsored by the China Meteorological Administration (CMA), was co-sponsored by the Japan Meteorological Administration (JMA), the Korean Meteorological Agency (KMA), the Australian Bureau of Meteorology (AuBOM), Roshydromet and Roscosmos of the Russian Federation (Roshydromet), the India Meteorological Department (IMD), the India Space Research Organization (ISRO), the Indonesian Agency for Meteorological, Climatological and Geophysics (BMKG), as well as the World Meteorological Organization (WMO) and the Group on Earth Observations (GEO).

AOMSUC-11 began with an extensive two-day virtual training event focused on satellite data and products. It brought together participants from WMO Regions II and V, as well as other WMO regions, taking advantage of the virtual nature of the event. The next four days were the plenary session of AOMSUC-11 and 2021 FYSUC consisting of both oral and poster presentations, virtually attended by over 400 people from 50 countries. The last day of the AOMSUC-11 was a small and focused coordination meeting that was attended by representatives mainly from WMO Regions II and V and the WMO Space Program that deals with satellite utilization and cooperation across Asia/Oceana.

On 1st November, the 11th Asia-Oceania Meteorological Satellites Users' Conference and 2021 FengYun Meteorological Satellites User Conference were held online. More than 400 participants including meteorological data providers, user representatives, and experts from 50 countries and regions, as well as WMO and GEO, the National Oceanic and Atmospheric Administration/National Environmental Satellite Data and Information Service (NOAA/NESDIS), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), European Centre for Medium Range Weather Forecasts (ECMWF) attended this event. Mr. ZHUANG Guotai, Administrator of CMA， Prof. Petteri Taalas, Secretary- General of WMO, and Dr. James Purdom, an Expert from the AOMSUC International Conference Steering Committee delivered remarks at the opening ceremony.

Mr. ZHUANG Guotai noted that the United Nations Framework Convention on Climate Change (UNFCCC) COP26 (Conferences of the Parties) was held in Glasgow, Britain. The international community has paid great attention to climate change and the increased extreme events against the backdrop of global warming. The Chinese government attaches great importance to meteorological disaster prevention and mitigation and climate change response as evidenced by its strong support to the development of meteorology, including satellite meteorology. In 2021, CMA launched two satellites, namely FY-4B and FY-3E. CMA will strengthen the role of FengYun satellites as a platform and bridge for international cooperation, and further honor the commitments on the international application of FengYun satellites made by Chinese leaders in an effort to develop FengYun satellites into an open, collaborative and win-win platform.

Dr. Petteri Taalas congratulated on the opening of this event. He stated that AOMSUC bears vital significance to users of this region to elevate the application capacity in fields like weather and climate, disaster preparedness, and response to climate change. He hoped that via mechanisms like AOMSUC and WMO Unified Data Policy, the application benefits of FengYun meteorological satellites data will be further developed to contribute to sustainable development across the globe.

Dr. James Purdom expressed that satellite data played a huge role in NWP and the launch of FY-3E satellite further filled in the key vacancy of global space-based observing systems, and provided vital data for global NWP. He hoped that via this event, experts would benefit and carry out in-depth discussions over the latest technologies in terms of the application of satellite data in NWP.

The plenary session of AOMSUC-11 consisted of six oral sessions. Posters were divided into 3 small groups on the 3nd November, which allowed for viewing and Q&A by everyone in time. The six oral presentation sessions each was co-chaired by an ICSC member and an expert from CMA, covering the following topical areas: (1) Current and Future Meteorological Satellite Programs, (2) Data and Product, (3) NWP, Forecasting and Nowcasting, (4) Land, Ocean and Atmospheric Products, (5) Space weather and (6) Climate.

The 2021 FengYun Meteorological Satellites User Conference took place on 2nd November. Participants conducted in-depth discussions over topics like elevating international exchanges and cooperation, optimizing the international application of FengYun satellites, the Emergency Support Mechanism in Disaster Prevention and Mitigation (FYESM), to jointly ramp up capacities for meteorological disaster preparedness and response to climate change in Asia Pacific and even the entire world.

This conference was the first-ever AOMSUC to be presented in a virtual format which presented challenges that the AOMSUC community had yet to encounter in Conference format, but every participant has given full support and assistance to attend this meeting and aall co-sponsors expressed their strong support for AOMSUC. This conference is the eminent scientific and technical event in the Asia-Pacific for those working in satellite remote sensing with applications in meteorology, climatology, oceanography and related fields. Both oral and poster presentations were of the highest quality. The keynotes for each conference session were well chosen and were presented by leaders in their field. It was evident throughout the conference that the new generation of geostationary and polar-orbiting satellites have already had a major impact in Asian/ Oceania region : the satellite operators are meeting their commitments as we inaugurate this new era in the Space-Based Component of the WMO Integrated Global Observing System (WIGOS). The participants welcomed the efforts being undertaken to introduce and utilize an unprecedented stream of new data.It was agreed that this early coordination in the generation of new products and services and the preparation for their utilization by the worldwide user community must be energetically sustained. At the end of AOMSUC-11, Dr. Kotaro Bessho from Japan Meteorological Agency, warmly welcomed everyone to the AOMSUC-12 which is going to be held in Tokyo, Japan.

Abstracts and presentations at AOMSUC-11 may be downloaded from the conference website: http://www.nsmc.org.cn/conference/fy-suf/2021/en/agenda.html. Training courses and materials are also available on the website. Session co-chairs provided summaries of their sessions, while CMA provided the summary of the training event and 2021FYSUC, both as shown below.

Training Event

The training events were conducted virtually through Microsoft Teams from 28 to 29 October 2021. There were 114 participants from 49 countries and regions registered and the average concurrent trainees were around 90. The training events were divided into two parts. One was for satellite operators including CMA, JMA and KMA, to introduce their satellite data service and products. The other one was for satellite products application, focusing on tropical cyclone, weather analysis and environment monitoring. In addition, three keynote presentations and an Australia and China Joint Regional Focus Group meeting were also arranged.

The Opening remarks were presented by the AOMSUC-11 Chair Dr. James Purdom, Deputy Director of International Cooperation Department, CMA, Mr. XU Xianghua, Deputy Director-General of National Satellite Meteorological Centre, CMA, Dr. ZHANG Peng, and Deputy Director-General of CMA Training Centre, Dr. WANG Zhiqiang. The chair for the first day training was XIAN Di from CMA.

Representatives from AOMSUC International Conference Steering Committee, WMO Space Systems and Utilization Division and VLab Community, Dr. Purdom, Zoya Andreeva and WEN Bo pre-recorded videos and played them on the training events. The opening ceremony was followed by the keynote presentation by Dr. Purdom, whose topic was *Environmental Satellites: An Observational Gateway to the Future*. He recalled the development of meteorological satellites and gave an overall explanation on satellite orbits, four resolutions and satellite data interpretation. He addressed the opportunities and challenges, and concluded that leadership, vision and focus on understanding and utilization were of most significance in today's meteorological satellite development. The presentations on *The WMO Space Programme Activities and Current Status of the New WMO Data Policy* and *VLab Activities and Satellite Training*, focusing on WMO policy on meteorological satellite and satellite training activities conducted by VLab Community, were pre-recorded by Ms. Andreeva and Dr. Bo respectively

Later on the first day, representatives from CMA, JMA and KMA broadcasted lectures on their satellite data services and applications. XIAN Di from CMA introduced FENGYUN Satellite Data Services, their Applications, and New Features of FY-4B FY-3E. FY-4B and FY-3E were newly launched this year. Mr. Taro HANDA from JMA played several pre-recorded videos introducing data services and RGB imagery of Himawari-8. He used flowchart method to show a step-by-step instruction, which was positively recognized by trainees and other instructors. Tae Kyu JANG, Ok Hee KIM and Jundong PARK from KMA gave a live presentation on GK2A data services and its application in risk weather analysis and tropical cyclone analysis. After all the presentations, the session chair gave a conclusion of all the lectures and instructors.

On the second day of training events, there were six live presentations on satellite products application plus Australia and China Joint Regional Focus Group meeting. In order to make the virtual training more relevant and interactive, organizers facilitated instructors to learn training needs from participants and instructors were also encouraged to use cloud-based learner response system like Socrative in class. Finally we collected 69 completed questionnaires before AOMSUC-11, and three of the instructors used Socrative to interact with trainees in class as facilitated by Bodo Zeschke from BOM. In the satellite application session, there were three instructors from CMA, one from BOM, one from BMKG and one from USA. They provided different perspectives in using satellite data addressing different phenomenon. RFG meeting was followed by this session and GAO Hao from CMA and Bodo Zeschke from BOM chaired this session together. In addition to 30-min presentation by each, we attempted to arrange an interactive session in order to encourage trainees to exchange and share their comments. Mr. Zeschke chaired this part and successfully inspired participants to make comments on what they have learned and what they would like to know more. This interactive session made up for the deficiency of online training to some extent. The chairs for the second day were ZHONG Qi from CMA and Bodo Zeschke from BOM.

In the closing ceremony, Bodo Zeschke was invited to give a summary of the whole training event. Then Mr. Kenneth Holmlund, Head of WMO Space Systems and Utilization Division, Mr. MAO Dongyan, Deputy Director-General of National Satellite Meteorological Centre, CMA, Ms. NA Xiaodan from International Cooperation Department of CMA, and Ms. WANG Meihua, Deputy Director-General of CMA Training Centre, addressed at the AOMSUC-11 Training Events. On behalf of CMA Training Centre, Ms. WANG thanked all organizers, presenters and trainees for their efforts, and looked forward to the following AOMSUC-11 Conference and 2021 Fengyun Satellite User Conference.

Session summaries

Invited Conference Presentations

The 11th AOMSUC started with the keynote presentation addressed by Dr. Niels Bormann (ECMWF) on the **Satellite Data Assimilation for NWP**. He gave an overview of the latest developments in the use of satellite data at ECMWF. Over the years, the contribution of the FY-3 satellite series in the ECMWF system has grown, and with the FY-4 series CMA now operates the first hyperspectral infrared sounder in geostationary orbit, providing unprecedented temporal sounding coverage over the East Asian region. The importance of good temporal coverage has also been highlighted with the present constellation of MW sounding instruments, with implications for the future evolution of the global observing system. There is another key development that FY-3E was launched into the early morning orbit, forming an integral part of the CGMS baseline, alongside the JPSS and EPS programs. In addition, efforts are under-way to exploit hyperspectral infrared observation from Russian polar-orbiting satellites, giving further complementary orbital coverage. The Aeolus Doppler Wind Lidar provides, for the first time, wind-profile information from space, with very positive results. Recent increases in the number of available radio occultation observations have substantially enhanced the impact of this observing system, underlining the importance of combining observations with different strengths.

Dr. Niels Bormann emphasized that continued developments for enhanced exploitation of the observations is as important as new observations. One area involves opportunities arising through coupled Earth System approaches, allowing, for instance, a fuller exploitation of the surface information contained in observations previously only affecting the atmospheric assimilation. ECMWF is hence extending the very successful all-sky assimilation strategy to an "all-sky/all-surface" paradigm, with particular benefits expected for highly surface-sensitive observations such as JMA's AMSR2 passive MW imager.

Session 1: Current and Future Meteorological Satellite Programs

Chaired by: Dr. Allen HUANG (ICSC), Dr. WANG Jingsong (NSMC, CMA)

The session opened with a keynote presentation by Dr. ZHANG Wenjian, Assistant Secretary General of WMO, on **the value of Earth observing satellites in meeting WMO's mission**. In the presentation, the status of meteorological satellite is reviewed. The update of Space-based Component of WIGOS could be found at https://www.wmo-sat.info/oscar/spacecapabilities. Satellite observations are key to the success of global NWP that underpins most of WMO application areas, in particular for extreme weather events and climate monitoring.

He talked about the recent highlights in Data Policy. International Data Exchange has always been a major purpose of WMO. The WMO extraordinary Congress approved in October 2021 a new Unified Policy for the International Exchange of Earth System Data to replace the old policies for Resolutions 40 (weather), 25(hydrology) and 60 (climate). It will take a holistic view across all Earth system domains including weather, ocean, cryosphere and others, and it will also integrates processes for reviewing and updating requirements and implementation guidelines as systems evolve, with an emphasis on Earth system monitoring and prediction

Dr. ZHANG Wenjian also mentioned some considerations for the future, including the vision for the societal & economic requirements, international commitments and prioritization of the service requirements.

Dr. WANG Jingsong, from the National Satellite Meteorological Center, China Meteorological Administration (CMA), updated the conference on **status of FengYun Satellite Program and Its Future Development**. Until now, CMA has launched 19 FengYun meteorological satellites, with 8 of them in orbital operation. For the FengYun polar-orbiting meteorological satellites, the FY-3E works together with the FY-3C and FY-3D, constituting the constellation in three orbital planes. For the FengYun geostationary meteorological satellites, The FY-2 series together and FY-4 series offer an option for rapid regional and mesoscale observation modes. The FengYun satellites are becoming an important component of the space-based global observing system organized by the World Meteorological Organization (WMO). The observation data can be accessible freely under the open data policy. At present, the payloads of the satellites have several spectral bands, including visible (VIS), near-infrared (NIR), infrared (IR), microwave (MW) and so on. Five domestic ground stations (Beijing station, Guangzhou station, Urumqi station, Kiamusze station, and Kashgar station) and two overseas ground stations (Kiruna station and Troll station) form the global data acquisition network. Up to now, the archived data for various satellites in National Satellite Meteorological Center (NSMC) have reached 22 PB.

In 2021, China launched 2 FengYun satellites. Compared with previous satellites, the temporal resolution of the FY-4B has increased from 30 minutes to 1 minute. FY-3E, the world's first early-morning-orbit meteorological satellite, will fill the vacancy of the global early-morning-orbit satellite observation. In the future, China will build an observation network of the FengYun polar-orbiting meteorological satellites before 2025. The FY-5 series and FY-6 series will be launched before 2035.

The FengYun satellites generate large amounts of data for weather forecasting, disaster warning, and environmental and climate monitoring. The datasets from the FengYun satellites are provided to hundreds of countries. Meanwhile, CMA holds consultation meetings and training programs at regular intervals. In the future, China will continue to provide reliable and sustained products, and plan to improve the quality of observation through international meetings and academic journals.

Mr. Kotaro BESSHO-san from the Japan Meteorological Agency (JMA), Tokyo, Japan talked about **Status of Himawari-8/9 and their follow-on satellite program**. The JMA has been operating the Himawari-8 geostationary meteorological satellite since 7 July 2015 (Bessho et al. 2016). The Agency also began the operation of Himawari-9 serving as a back-up for Himawari-8 on 10 March 2017, and will keep this combination until the planned switchover in or around 2022. In case of a critical Himawari-8 malfunction, Himawari-9 will begin back-up observation. Himawari-8/9 are placed in geostationary orbit at around 140.7°E and provide observation and data collection services for the East Asia and Western Pacific regions. The pair of new-generation satellites will support JMA's stable provision of continuous satellite observation data for the Asia-Oceania region until 2029. Operational information regarding Himawari-8/9 is provided on JMA's Meteorological Satellite Center (MSC) website.

In January 2018, JMA launched an international service "HimawariRequest", in collaboration with the Australian Bureau of Meteorology. The service allows NMHSs users in Himawari-8/9 coverage area to request Target Area observation covering a 1,000 km x 1,000 km area every 2.5 minutes. As of 5 October 2021, there are 22 registered NMHSs, and have received 122 international requests since the commencement of the service. The requests are about tropical cyclones in South Pacific, bush fires in Australia, volcano in Indonesia and so on.

JMA has started the usage and distribution of new Himawari product of estimated sunshine durations, which is one of the parameters of Weather analysis maps. The product is based on Japan area observation of Himawari-8 every 2.5 minutes with a resolution of 1 x 1 km, and is updated every one hour. It is expected to use this product in various fields, especially in domestic agriculture.

JMA will pursue a seamless geostationary Earth orbit satellite system, keeping in mind the CGMS baseline and the Vision for WIGOS in 2040, including in particular the deployment of hyperspectral infrared sounder (HSS) across the full Geo-ring. HSS onboard the follow-on satellites is considered as one of potential payloads for its capacity to help improve JMA's services in relation to extreme weather monitoring, nowcasting and numerical weather prediction (NWP). To assess its impact on NWP, JMA has been performing Observing System Simulation Experiment (OSSE) since FY2018 (Okamoto et al. 2020).

Mr. BESSHO presented the status of JMA's consideration of the specification of follow-on satellites and their sensors. Himawari series satellites have been used widely not only in East Asia and Western Pacific regions but also in the whole world, and are recognized as an indispensable infrastructure. Positive suggestions, comments and requests for new satellites and candidate sensors from attendees are highly appreciated.

Dr. Jinho Shin, National Meteorological Satellite Center/Korea Meteorological Administration

(KMA) presented information on the **KMA's Current and Future satellites**. KMA has operated the Geo-KOMPSAT-2A (hereafter GK2A) since July of 2019 and utilized its various meteorological products for high impact weather analysis and warning, NWP data assimilation, climate monitoring research and so on. The GK2A data and images are available through various ways such as NMSC webpage, Open API, real-time FTP service and satellite broadcast.

KMA has also started the rapid scan request service from the last January for the domestic users as well as international users over the Asian Pacific regions (RA II and V) to support early warning of the high impact weather events. The global users can request the two-minute rapid scan observation via the NMSC webpage
http://datasvc.nmsc.kma.go.kr/datasvc/html/special/specialReqMain.do

Dr. Jinho Shin reported that to succeed the GK2A mission, KMA is planning the GK2A follow-on target to be launched in the last quarter of 2028 and it will have an upgraded imager and space weather instruments. And based-on the CGMS baseline for the future GEO satellite observation, KMA is considering the two-track strategy which includes another new GEO satellite with hyperspectral sounder, which means KMA will start to operate the VIS/IR Imager and GEO Hyperspectral sounder. KMA will have GEO Imager/Sounder observation capacity to strengthen the abilities of weather prediction and climate monitoring.

Prof. Alexander Uspensky from ROSHYDROMET, Moscow, provided a report on **Current state and prospects of Russian space-based meteorological observing systems**. In accordance with Russian Federal Space Program 2016-2025, Roscosmos (VNIIEM Corporation, Lavochkin Association) and Roshydromet (SRC Planeta) jointly develop the satellite meteorological observing systems of Meteor-3M, Electro-L, Arctica-M types. Three meteorological (of the same type) satellites on sun-synchronous orbits should compose the Meteor-3M system (manufactured by VNIIEM Corporation). The system Electro-L (manufactured by Lavochkin Association) should comprise of 3 similar geostationary meteorological satellites placed at 14.5° W, 76° E, and 166° E orbital positions. Currently, this orbital constellation consists of 13 Earth observation satellites. Oncoming Arctica-M constellation is to be comprised of 2 HEO spacecrafts on "Molnya"-type high elliptical orbits (HEO). The design and payload of these and Electro-L series satellites are generally similar. The flight tests of the Arctica-M spacecraft № 1 (launched on February 28, 2021) were completed, and the results of them are discussed.

Prof. Alexander Uspensky also talked about update of Roshydromet ground segment. The ground segment also includes the network of DCP (more than 650) stations. The segment provides the acquisition, processing and distribution of satellite data and products from 11 Russian and 22 foreign Earth observation satellites for use in operational meteorology, NWP, hydrology, agrometeorology, climate studies and environmental monitoring. One of the segment purposes is to support the data collection system from Roshydromet network of ground observation sites via geostationary and HEO satellites.

Mr. Mark Paese, Deputy Assistant Administrator of National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), provided an overview of **NOAA: Current and Future Satellite Systems**. In his address he pointed out forecasting weather, understanding climate trends and changing ecosystems, and monitoring environmental hazards requires high-quality, timely, and global observations from Earth observing satellites. To meet these challenges NOAA is evolving their business model to stay current with the expanding complexity of Earth observing contributors including our partners among the meteorological satellite agencies of Asia. NOAA continues to forge partnerships around the globe to share the Earth observation on a full and open basis and to ensure users to have the information they need to address pressing policy concerns.

NOAA operates 15 environmental satellites. Over the past five years, NOAA's advanced geostationary and polar-orbiting satellites, the GOESR, GOES-S, and NOAA-20 (JPSS series) have become operational. NOAA plans to launch two additional GOES series and three additional JPSS series satellites between 2022 and 2031, including GOES-T which is planned for launch on February 14, 2022. These missions, along with other NOAA collaborations (COSMIC, JASON, DSCOVR, etc.) are key contributions to the WMO space-based component of the Global

Observing System (GOS).

In addition, NOAA is evolving its approach towards common ground systems, satellite architecture, data stewardship, data distribution and user preparedness to ensure a more mission-effective, integrated, adaptable organization that anticipates and responds efficiently to changing technology (e.g. CubeSats, Cloud), emerging partnerships and evolving observation requirements. This evolution requires a new approach to satellite observing system architecture as well as to product development and prioritization processes. In particular, they are examining how to maximize their resources and effectiveness through partnerships for observations and blended products (e.g. LEO/GEO Flood Forecasting).

Dr. Paul Counet, Head of Strategy, Communication and International Relations, EUMETSAT, provide an insight into **EUMETSAT updated strategy, programmes and plans**. In July this year, EUMETSAT improved its EUMETSAT Destination 2030 Strategy, from resource mobilization, development and risk management to delivery, innovation and preparation for the future. Now, EUMETSAT is operating 11 satellites including sentinel-3 A&3B, Jason-3, Sentinel-6, Meteosat-9/10/11, Meteosat-8, and Metop-A/B/C. For the next 5 years, EUMETSAT will launch 5 new satellites, which is a major contribution to the Vision for WIGOS 2040 and to international partnerships. MTG system includes 3 satellites, 2 imagers and one sounder, and EPS-SG system has 2 satellites.

Dr. Kenneth Holmlund, from Satellite Systems and Utilization Division, WMO, presented the **Status of the WMO Integrated Global Observing System**. In his report, he gave an update of the status of WIGOS and related issues like the new WMO Data Policy, maintaining the requirements for satellite data and the challenges for data exchange and provision, in particular for Least Developed Countries (LDCs) and Small Island Developing States (SIDs). International Data Exchange has always been at the core of the WMO activities. Before this year WMO had 3 different data policies for Weather, climate and hydrology, the data related activities cemented in the WMO Conventions. A new Unified Policy for the International Exchange of Earth System Data replaces the old policies. It takes a holistic view across all Earth system domains including weather, ocean, cryosphere and others, and it will also integrates processes of reviewing and updating requirements and implementation guidelines as systems evolve, with an emphasis on Earth system monitoring and prediction.

The Vision for WIGOS in 2040, adopted by the WMO Congress in 2019, presents a likely scenario of how user requirements for observational data may evolve over the next 20 years. It provides high-level targets to guide the evolution of the WIGOS in the coming decades. It anticipates a fully developed and implemented WIGOS framework supports all activities of WMO and its Members within the general areas of weather, climate and water. A key-contribution towards WIGOS 2040 is provided by the satellite agencies through the CGMS (Coordination Group for Meteorological Satellites) Baseline， and additional observations are required e.g. as coordinated by the Committee on Earth Observing Satellites (CEOS) or as provided by the private sector.

Session 2: Data and Products

Chaired by: Dr. WENG Fuzhong (ICSC & CMA)

This session started from a keynote speak and consisted of 8 presentations. The reports cover the latest Asian/Oceania, NOAA and EUMETSAT satellite data services including the facilitation of data access and utilization, dissemination and distribution, as well as product applications and status of V-lab training event.

The keynote speaker, Ms. Agnes Lane, the Team Leader of Data Requirements and Planning, Australian Bureau of Meteorology (AuBoM) presented “**Utilization of satellite data at the Bureau: current applications and future opportunities”**. AuBoM has been a big user of Earth observations from space for several decades. The Bureau is currently assimilating the data from over 30 satellites into numerical weather prediction model and visualization systems every day and provides the information on weather forecasts and warnings across Australia and other regions to support the national commitments for safety and security. In her presentation, she presented satellite activities in the AuBoM including new services being developed to address user needs, opportunities offered by new generation satellites, the Bureau's responses to the growth and momentum in the Australian space sector, and the opportunities for strengthening international partnerships.

Dr. ZHANG Xingying, Deputy director of National Satellite Meteorological Center (NSMC), CMA, reported "**FengYun Satellite data and products**". CMA has archived the domestic and foreign satellite data on Atmosphere, Land, and Ocean since 1988 with a total data volume of 23PB from 49 satellites and including 172 parameters. In accordance with CGMS and CEOS, FengYun Geophysical products cover 7 types (cloud/radiation, atmospheric parameter, sea surface, land surface, cryosphere, atmospheric composition, space weather) of 78 parameters, meeting the main demand of WMO Integrated Global Observing System (WIGOS)， and the application requirements of weather monitoring, agricultural-meteorological monitoring and atmospheric environment monitoring. The newly launched satellites FY-3E and FY-4B will enrich the baseline products in various types. The combination of FY-3C, FY-3D and FY-3E will provide global data coverage for numerical weather prediction (NWP) at 4-hour intervals, effectively improving the accuracy and time efficiency of global NWP, which is of great significance to perfect the global earth observing system. And the products of FY-4A and FY-4B will be integrated to offer seamless and a wide range of continuous observation images for users. He also mentioned the FengYun series meteorological satellite product quality verification system which is an important part of FengYun series meteorological satellite ground system. Based on the construction of FengYun satellite ground system project, FY- 3 product quality validation platform and FY-4 product quality control platform have been completed. The full-automatic business validation function of FengYun series business products is preliminarily realized.

Mr. Bodo Zeschke from Bureau of Meteorology, Australia, talked about the **Satellite Meteorology Training in WMO RAV during 2020/2021: The Australian VLab Centre of Excellence experience**. Mr. Bodo introduced the satellite meteorology training conducted by the Australian VLab Centre of Excellence since the start of 2020 with multiple attendees, various topics covered and a constellation of presenters. The training focuses on the monthly Regional Focus Group meetings as well as collaboration with other Centers of Excellence within the context of the WMO Global Campus. Relevant topics include dissemination of the latest developments in effectively utilizing Himawari-8 and polar orbiting satellite data and associated resources within WMO RA V and neighbor regions and the co-hosting of Regional Focus Group meetings with experts from Australia, China, Indonesia, South Korea and the United States of America.

Dr. Ashim Kumar Mitra, India Meteorological Department (IMD), India introduced **Operationalization of Multi Mission Meteorological Data Reception and Processing System at India Meteorological Department (IMD): Data access and products**. IMD has established the Multi-Mission Meteorological Data Receiving and Processing System (MMDRPS) for INSAT-3D, INSAT-3DR and INSAT-3DS satellites. MMRDPS system comprise the following major components: three Earth stations, Data Acquisition system, Data Processing System, Data storage & data supply system and Satellite Imagery Display System. Each Earth station is receiving the data in redundant mode from each payload (Imager, Sounder and DRT) and raw data archival storage facility. MMDRPS has a very high-end processing system which cuts down the processing time from 15 minutes to 7 minutes and updates calibration coefficient in operational chain using Cal/ Val site & GISCS data. The system is capable of processing the RAPID scan data of INSAT-3DR Imager payload conducted during Extreme weather events. The Product Monitoring and Management Software (PMMS) has an interface with the Database management system and Process Scheduling Server (PSS), which runs on all configured Data processing systems. The PMMS is capable of displaying the current processing status as well as the status of products already processed on configured data processing system. MMDRPS has a storage capacity of the order of 2.0/2.0PB (Main/ Mirror) & 324TB SSD which facilitates online sharing of processed data from all Indian meteorological satellites to the registered users as per IMD data policy. All available past satellite datasets starting from 1983 are being kept in online mode in due course. The MMRDPS system is being used to receive & process the INSAT-3D and INSAT-3DR satellites data since 1st October 2019. The system is generating around 98 GB raw data and 125 GB processed data on daily basis. The MMDRPS has dedicated Web-based Data supply System (DSS) in main &redundant mode to meet web-based data supply anduser requirements in near real time as well as offline mode (both local and remote global) based on data dissemination policy of IMD. The MMRDPS system is hosting two website and online data visualization facility (RAPID) in redundancy mode.

Mr. Takuya Sakashita, Japan Meteorological Agency, Japan presented the **Data dissemination and distribution of Himawari-8/9 and their recent updates**. JMA provides data and products from Himawari satellites for National Meteorological and Hydrological Services in several ways such as HimawariCloud using land line, HimawariCast using commercial communication satellite, and HimawariJDDS which provides satellite products such as high-resolution cloud information. HpFP (High-performance and Flexible Protocol) in addition to the current HTTP(S) is investigated to be implemented into HimawariCloud. In addition, for research, development and education purposes, JMA distributes archived data through their cooperative institutes. For private sectors, data are distributed via the Japan Meteorological Business Support Center. In 2021, JMA updated its online satellite imagery to enhance scrolling and zooming capacity. He also mentioned that JMA is now planning to switch over from Himawari-8 to -9 in the third to fourth quarters in Japanese Fiscal Year 2022.

Mr. Taekyu Jang from National Meteorological Satellite Center, Korea Meteorological Administration (KMA) introduced **KMA's satellite data service**. The Geo-KOMPSAT-2A (GK2A) data is available through the internet and satellite broadcast. For the internet service, there are various ways such as NMSC website, Open API and real-time FTP service. Users can easily access the various image products at the NMSC website. The Open API service is the key-based system. Using the registered key, users can download the GK2A data for a certain period of time. The DCPC (Data Collection or Productions Center) NMSC web portal also provides data service for the GK2A and COMS. He also introduced the rapid scan request service that is available through the NMSC website. The service area is the Asian Pacific regions (RA II and RA V). It aims to support the early warning of the severe weather events such as typhoon and thunderstorm.

Dr. Mitch Goldberg, NOAA/NESDIS, presented **NOAA: Products and Services**. NESDIS provides the environmental products, information and services to promote and protect the Nation's security, environment, economy, and quality of life. Products to be sustained are codified in the NESDIS-Level Requirements, grouped into general thematic categories of foundational data, geophysical products and analytical reports. To meet the required mission, NESDIS routinely provide these products to stakeholders and users in a timely manner. The minimum levels of support (product name, product description, geographic coverage, refresh and latency) to be provided are specified in the NESDIS Product Baseline. Data access is provided through the NESDIS Product Distribution and Access (PDA), NESDIS/NCEI Archive, Direct Broadcast and GEONETCAST.

In addition to the NESDIS Product Baseline and data access, Dr. Goldberg also reported the NESDIS has established an Enterprise Proving Ground (EPG) program to maximize the impact of satellite products and services to NOAA's broader Mission Service and stakeholders, and to support the earth system prediction; environmental stewardship; climate monitoring; and social justice. The EPG mission is to demonstrate the impact of NESDIS product and services to NOAA's missions like climate, weather-ready nation, healthy oceans, resilient coastal communities and emerging missions focusing on authoritative outcomes for driving research and meeting operational user needs. Key elements of the EPG include 1) Assessing value and impact of NESDIS products to NOAA mission, understanding user readiness and identifying opportunities to address shortfalls and emerging needs, 2) Enhancing NOAA services through collaborative development of new research and applications by using NESDIS /partner data and products, 3) Demonstrating new/improved product and services in the user environment along with training, and 4) Collaborating with NOAA testbeds to support the demonstration and transition of operational and experimental products, and translating ground risk reduction (PGRR) advances into user applications.

NESDIS will develop, acquire, and leverage a diverse suite of satellites and in-situ observing system platforms to create products and reports for their stakeholder/user community. This includes developing, launching and operating NOAA's flagship weather satellites, leveraging non-satellite NOAA measurements and observations, utilizing partner' observing system data from national and international governmental agencies as well as acquiring commercial data.

Mr. Joachim Saalmueller, EUMETSAT, talked about **EUMETSAT Data Services Evolution and Product News**. During the last few years, EUMETSAT has undertaken a notable shift in how it can offer data to its user community. The new data services include EUMETView, EUMETSAT Data store, Data tailor for customized data, EUMETCast Terrestrial, and European Weather Cloud, to meet the increased demand for huge data and products. EUMETView is an online Map service that provides visualization of products through a customizable web user interface and enhanced set of open Geospatial Consortium (OGC) standard APIs. EUMETView makes it possible to create and save maps by using the user interface, or integrate with user's personal service, via the API. The UMETSAT Data store provides users with a download and linked data tailoring service for online data. Tailored data allows users to subset and aggregate data products in space and time, filter layers, generate quick-views, re-project, and reformat into common GIS format (netCDF, GEO TIFF, etc.). It also offers a uniform way to transform both historical and near real-time satellite data provided by EUMETSAT. In addition, EUMETSAT also operates 3rd-party near real-time (NRT) data based on the collaboration with several Asian partner agencies in CEOS/CGMS. Mr. Saalmueller also provided a brief overview of recent product evolutions, such as HSAF soil moisture, ocean color and aerosol products.

Session 3: NWP, Forecasting and Nowcasting

Chaired by: Dr. James Purdum (ICSC), Dr. FANG Xiang (CMA)

This session consisted of ten oral presentations. The first one, a keynote, covered the development and evolution of deep convection and severe storms. Seven presentations demonstrated the application of satellite data in NWP, and two introduced the latest algorithms.

The session opened with a keynote presentation by Dr. Purdom titled "Convection and Severe Storms". In his presentation, he introduced the development and evolution of deep convection and severe storms, and pointed out geostationary satellite is the only observing tool capable of monitoring weather across those scales (and those scales interactions). Nowcasting convection and evolution requires frequent imaging and soundings that can only be provided by geostationary satellites. He also mentioned that radars are very useful in determining storm intensity, but often leaves their cause unknown. The animation of GOES imagery was shown in his presentation, which clearly monitored the development and evolution of deep convection. Subsequently, Dr. Purdom described the formation of deep convection based on four aspects, including stability, vertical motion and cumulus formation, mesoscale moisture distribution and vorticity. Meanwhile, he suggested a conceptual model that emphasized convective scale interaction. Last, he identified many ways forward.

Mr. Yoshiaki Sato from Japan Meteorological Agency summarized the satellite data utilization in NWP. The World Meteorological Centers (WMC) such as JMA operate several numerical weather prediction (NWP) models as a backbone of their services. The data are utilized for the weather forecasting, weather warning and advisory, typhoon forecast, seasonal climate outlook, and so on. Preparing initial conditions for these NWP models is a very important step for the NWP forecasts, since the errors at the initial time grow with the forecast time exponentially. To minimize the errors, it is important to utilize as various types of observation data over the NWP domain as possible in their data assimilation systems. Since there are regions where it is difficult to observe the atmosphere directly such as ocean, desert, high mountains and polar regions, the utilization of the satellite remote sensing data is critical. For example, JMA utilizes various satellite data, such as the data from infrared and microwave sounders and imagers, atmospheric motion vectors, ocean surface wind vectors from scatterometers, GNSS radio occultation, and space-borne precipitation radar in its NWP data assimilation systems. For the future sensors, some NWP centers are assessing the impact with collaborating the satellite operators for realizing WMO vision titled "Vision for the WMO Integrated Global Observing System (WIGOS) in 2040".

Dr. Peiming Dong from Chinese Academy of Meteorological Sciences described the preparation for assimilation of the combined microwave sounding observations aboard on the early morning satellite FY-3E in GRAPES. The early morning satellite (FY-3E) was launched successfully on 5th July, 2021. Together with the morning-orbit and the afternoon-orbit satellites, China is now operating satellites in three-orbits observing the global earth atmosphere. For microwave sounding, the most important satellite sensor to the NWP, the four channels at 23.8 and 31.4 GHz and the frequencies near 53.596 GHz are newly added. In his presentation, Dr. Peiming Dong introduced the preliminary results of assimilating FY-3E microwave sounding observation in GRAPES. The two microwave data streams from temperature sounder (MWTS) and microwave humidity sounder (MWHS) are integrated into a combined microwave sounding data sets (CMWS) with a total of 32 channels and are then used in one data stream of data assimilation. The satellite observation operator in GRAPES is transferred to the Advanced Radiative Transfer Modeling System (ARMS), a new generation of rapid radiative transfer model developed in China. The accuracies of the ARMS forward tangle and adjoint models implemented for CMWS are verified. The bias characteristics are analyzed and bias correction is prepared. The physical retrieval scheme of cloud liquid water (CLW) and total precipitation water (TPW) is also designed and will be utilized in the cloud detection.

Dr. Hancheol Lim, National Meteorological Satellite Center, Korea Meteorological Administration, presented information on the updated status of the algorithms for GK2A products in 2021. NMSC has started the public service of the variety GK2A products since July of 2019, and they tried to update the GK2A products algorithms to solve the technical issues and false detection getting from case studies or an operating of the product algorithms. This presentation reported the main updates of the GK2A product algorithms in 2021, focusing on the performances of the newly updated algorithms. Main updates are as follows. First of all, the false detections of the fog in dawn and dusk times were decreased, and they improved the discontinuity of Asian Dust band over boundaries area between land and ocean. In addition, there were some improvements such as cloud detection, atmospheric motion vector and radiation algorithms. He introduced the application of new algorithms in fog, aerosol, convective initiation, radiation and night time AI visible images, and conducted the comparison before/after the improvement. Last, Dr. Hancheol suggested the application of AI technique in GK2A satellite images.

Ms. Olga Nechepurenko, National Research Tomsk State University, provided a probabilistic model for detection which is used to determine a zone of possible thunderstorm development using satellite imagery and remote sensing data. According to the computation, the zones are identified in which atmospheric parameters correspond to conditions favorable for the formation of phenomena to various degrees. Machine learning and neural networks have been used for performing calculations based on data from the Suomi-NPP, MetOp and NOAA polar-orbiting weather satellites. The model input data are vertical temperature and specific moisture content profiles restored in the MIRS software package by NOAA/NESDIS Satellite Applications and Research Center (STAR). Microwave measurements from AMSU/MHS instruments are utilized as input data for processing in the MIRS. The MIRS employs a physically based 1DVAR assimilation system to solve atmospheric and underlying surface parameters. The accuracy requirements of retrieved parameters are comparable to those suggested by the World Meteorological Organization (WMO). The vertical profiles of dewpoint temperature, relative humidity, dewpoint depression, values of stability indices (Vertical Totals, Cross Totals, Total Totals, and K-index), and the height of the convective cloud base are also added to the model input. The probability of thunderstorm presence is computed for each pixel in the satellite image. The approach is computer-assisted and based on the Python programming language. Following completion of the computations, each pixel is allocated to a value of the probability of thunderstorm development at a specific point. The probability of actual thunderstorm presence is 78% for the Russian West Siberian Territorial Administration for Hydrometeorology and Environmental Monitoring (50-70 N and 50-100 E), when the validity of actual thunderstorm development is 80%. With increasing values of probability, the validity of hazardous events increases. In 15% of cases, false positive thunderstorm detection occurs with a probability level larger than 80%.

Mr. Shiro Omori from Japan Meteorological Agency provided an overview of satellite-based nowcasting products. For forecasters who need to watch current and near future weather condition nowcasting products are highly helpful because the skills of current numerical weather prediction (NWP) models, even if they are designed for short range weather forecast, is limited in the forecasting range of zero to six hours in comparison with that of nowcasting products. Many nowcasting products have been developed from ground-based (mainly weather radar) observations or satellite-based observations. The value of satellite-based nowcasting products is particularly apparent in regions where ground-based observations are limited or non-existent, especially in the developing countries and islands countries. Besides that, new-generation meteorological satellites, which started their operation recently, have more observation bands and enable more frequent observation, and forecasters who utilize satellite imageries don't have expertise for utilization of satellite data necessarily. Therefore, it has become more important to develop simple and easy-to-understand nowcasting products. Whereas many satellite operators provide various satellite products, WMO established, for user convenience, consistent and harmonized mechanism to ensure continuous and sustained provision of consistent, well-characterized satellite products for nowcasting and severe weather risk reduction, called SCOPE-Nowcasting.

Mr. Kadek Sumaja, Indonesia Agency for Meteorology Climatology and Geophysics, provided a mitigation strategy for heavy rain and strong wind on aviation caused by tropical cyclones. Weather conditions in several areas in Indonesia are influenced by tropical cyclones even though geographically Indonesian archipelago has very little chance for tropical cyclones formation. Since tropical cyclones are counted as one of the most devastating natural disasters, serious attention is needed to mitigate its impact that can reach up to thousands of kilometres from the centre of the storm. This motivated them to figure out the relationship between the location and category of tropical cyclones to heavy rain and strong winds at I Gusti Ngurah Rai Airport as well as how to develop a mitigation plan to support aviation services. This research collected data of tropical cyclone events from 2011 to 2020, and combined it with heavy rain and strong winds data at I Gusti Ngurah Airport in the same period. Furthermore, those data were plotted on a map to display the location and category of tropical cyclones during heavy rain and strong wind events in this Airport. Moreover, the ECMWF reanalysis data associated with weather satellite data were utilized to do further analysis. The result shows that heavy rain which coincided with tropical cyclone activity mostly occurred in January, but the highest likelihood of occurrence was in November and March. Regarding the strong wind that occurs simultaneously with tropical cyclone activity, January is the month with the most occurrence followed by February, March and December. For locations and categories, some heavy rain events at I Gusti Ngurah Rai Airport are potentially influenced by tropical cyclones in the early stages of growth located in the waters south of Bali with significant amount of convective cloud coverage. Furthermore, strong winds are dominantly influenced by tropical cyclones at mature stages located in waters between Indonesia and Australia. This shows that the size of the tropical cyclone category does not directly determine wind speed in the surrounding area, but the distance of a certain area from the centre of a tropical cyclone tends to have more influence on the maximum wind speed. Lastly, the mitigation strategy to mitigate the impact of heavy rain and strong winds due to tropical cyclone activity is by optimizing flight meteorological information services, during November and March (NDJFM), especially when a low-pressure area or Tropical cyclone in the growth phase were formed in the Southern Ocean of Bali and the Mature Phase in the Northwest of Australia (between Bali and Australia).

Dr. Michiko Otsuka from Japan Meteorological Agency described Data Validation and Mesoscale Assimilation of Himawari-8 Optimal Cloud Analysis Products. Himawari-8 optimal cloud analysis (OCA), which employs all 16 channels of the Advanced Himawari Imager, provides cloud properties such as cloud phase, top pressure, optical thickness, effective radius, and water path. By using OCA, the water vapor distribution can be inferred with high spatiotemporal resolution and with a wide coverage, including over the ocean, which can be useful for improving initial states for prediction of the torrential rainfalls that occur frequently in Japan. OCA products were first evaluated by comparing them with different kinds of datasets (surface, sonde, and ceilometer observations) and with model outputs, to determine their data characteristics. Overall, OCA data were consistent with observations of water clouds with moderate optical thicknesses at low to middle levels. Next, pseudorelative humidity data were derived from the OCA products, and utilized in assimilation experiments of a few heavy rainfall cases, with the Japan Meteorological

Agency's nonhydrostatic model-based Variational Data Assimilation System. Assimilation of OCA pseudorelative humidities caused significant differences in the initial conditions of water vapor fields compared to the control, especially where OCA clouds were detected, and their influence lasted relatively long in terms of forecast hours. Impacts of assimilation on other variables, such as wind speed, were also seen. When the OCA data successfully represented low-level inflows from over the ocean, they positively impacted precipitation forecasts at extended forecast times.

Ms. Mae Liu, Chinese Academy of Meteorological Sciences, reported the analysis of the observation errors of FY-3C MWRI radiance data for all-sky assimilation in regional NWP. All-sky observations of space-based microwave imager contain information of strong meteorological sensitivity related to cloud and precipitation. But the observation error in all-sky data assimilation is apparently non-Gaussian behavior which cannot meet the basic assumption that the observation error is Gaussian in the data assimilation. A symmetric cloud dependent all-sky observation error model developed by European Centre for Medium-Range Weather Forecasts (ECMWF) was used for FY-3C Microwave Radiation Imager (FY-3C MWRI) in this article, observations during super typhoon Maria and Lekima were selected, and the all-sky observation error was analyzed after quality control and normalization. The results show: (1) The first-guess (FG) departures and 'symmetric cloud' both agree in map. The standard deviation of FG departures binned as a function of 'symmetric cloud' shows larger observation error in cloudy situations than in clear sky. (2) The all-sky FG departures normalized by the symmetric error model become far more Gaussian than in clear sky. (3) All-sky approach brings 43.9~54.63% more data than clear sky, with the biggest increases in the area of the outer spiral cloud band and cloud wall of typhoon. This result preliminarily demonstrates the assimilation potential of FY-3C MWRI all-sky observation data, and the utilization of observation data of the current domestically made FengYun series microwave imagers is expected to improve the numerical weather prediction.

Mr. Wei Han from China Meteorological Administration provided a method for improving high impact weather forecasts using FY-4A GIIRS. Targeted observations for Typhoon Maria using the Geostationary Interferometric Infrared Sounder (GIIRS) at a temporal resolution of 15 min provide unprecedented information on impact studies of high-temporal-resolution from geostationary hyperspectral IR sounders. This study investigates the impacts of different temporal resolutions for GIIRS assimilation on Maria analyses and forecasts. Results reveal that assimilating higher resolution data captures more detailed temporal and spatial structures and stronger warm anomalies. Additionally, the track forecast for Maria from assimilating higher temporal resolution GIIRS radiances is better than those from assimilating radiances with lower temporal resolution, and both are better than the control experiment. The accuracy of the different temporal resolutions GIIRS experiments (from 3 h to 15 min) is improved (from 18% to 43%), and the intensity forecast errors are also reduced (from 12% to 18%). Meanwhile, high-temporal GIIRS assimilation also improves the coastal precipitation forecasts during typhoon landfall.

Session 4: Land, Ocean and Atmospheric Products

Chaired by: Prof. Jun Li (CMA)

Session 4 consists of a keynote and 10 oral presentations, among which 7 are from China, 2 are from the United States, 1 is from South Korea, and 1 is from New Zealand. The topics cover the products of the Community Satellite Processing Package (CSPP), FengYun-3, FengYun-4, GK2A, FORMOSAT-7/COSMIC-2, as well as research on product redevelopment, archiving and distribution.

Dr. Allen Huang from University of Wisconsin-Madison introduced the Community Satellite Processing Package (CSPP). CSPP includes many software packages, image generation tools, and visualization capabilities, which can empower the users to generate weather and environmental products from international weather satellite systems' measurements in real-time or near real-time (NRT). The CSPP products have been widely used in weather, disaster, flood, air quality, and environmental domains.

Prof. Fuzhong Weng from Chinese Academy of Meteorological Sciences described their study by using two K/Ka band channels at 23.8 and 31.4 GHz of FY-3E satellite for retrieving atmospheric cloud liquid water and total precipitable water. With the four additional channels added to the previous MWTS-II, the combined MWTS-III and MWHS-II microwave sounding capability is greatly enhanced. The global cloud liquid water product derived from two channels shows a reasonable distribution, and the scan-angle dependence of the MWTS-III cloud liquid water can be significantly reduced after an asymmetric bias correction.

Mr. Byung-il Lee and his colleagues from KMA developed the AMI (Advanced Meteorological Imager) based Atmospheric Profile (AAP) algorithm for retrieving atmospheric temperature and humidity profiles using GK2A/AMI data. The retrieval for the clear sky is performed at every 10 minutes with 6 km horizontal resolution although the AMI resolution is 2 km. The validation with radiosonde shows temperature RMSE of about 0.9 K (between surface and 400 hPa) and relative humidity of about 12% (between surface and 300 hPa).

Prof. Chao Liu from Nanjing University of Information Science and Technology introduced their study on cloud property retrievals for the FY-4A spectral radiometer. In their study, a systematic cloud mask, phase, optical and microphysical property products are developed, and the algorithms can detect cloud and clear pixels with successful rates over 90%. Besides the traditional water and ice phases, super-cooled water and overlapping clouds can also be detected. In addition, the cloud optical thickness (COT) and cloud particle effective radius (CER) retrievals are also quite accurate compared with the MODIS C6 operational product.

Dr. Melanie Abecassis from University of Maryland described the OceanWatch program. CoastWatch provides a range of services from data distribution to capacity-building and to tool development and direct collaboration on projects and applications. The OceanWatch, which is central Pacific regional node of CoastWatch, facilitates access to available satellite oceanographic datasets by users in the Pacific Islands region and beyond. Moreover, CoastWatch organizes satellite training classes and provides lectures, self-paced tutorials, R and Jupyter notebooks of example scripts.

Dr. Feixiong Huang from National Space Science Center, Chinese Academy of Sciences introduced the wind speed retrieval algorithm and preliminary validation results from the GNOS-II onboard the FY-3E satellite. The GNOS-II payload onboard FY-3E is the upgraded GNSS remote sensor of GNOS-I onboard FY-3C and FY-3D. It has both the GNSS radio occultation and GNSS reflectometry that can monitor atmosphere, ionosphere and the Earth surface. GNOS-II GNSS-R can now retrieve ocean surface winds and sea ice coverage.

Dr. Yizhe Zhan and his colleagues from MetService New Zealand built a cloud-based satellite system. The increasing usage of satellite data requires staging and processing various products promptly. The bandwidth and I/O speed of the conventional data center have become a bottleneck. By migrating all the legacy satellite systems to the Amazon Web Services (AWS) cloud, now they are able to monitor, stage, process, and deliver the satellite products to both internal and external users efficiently at a relatively low cost.

Dr. Yingwa Chan from Hong Kong Observatory introduced the typical applications of FORMOSAT-7/COSMIC-2 (FS7/CS2) radio occultation (RO) data. By obtaining the FS7/CS2 RO data, the changes of the vertical stability of the atmosphere and the variations of moisture at different pressure levels can be evaluated. Based on the RO soundings, the plume height of the Fukutoku-Okanoba volcano and the occurrence of stratospheric intrusion along the eastern coast of China were effectively monitored.

Dr. Dongjie Cao from National Satellite Meteorological Center, China Meteorological Administration analyzed the characteristics of lightning activity observed by FY-4A Lightning Mapping Imager (LMI). The LMI carried by FY-4A is the first satellite-borne lightning imager developed by China and one of the first geostationary satellite-borne lightning imagers launched in the world. The analysis results show that the LMI can effectively detect lightning over China and its surrounding areas to track and provide early warnings of strong convective weather.

Dr. Chunqiang Wu from National Satellite Meteorological Center, China Meteorological Administration described a method for monitoring the instrument performance of FengYun satellite. The radiative transfer models (RTMs) together with the numerical weather prediction

(NWP) fields are used to simulate the reference radiances. Through monitoring the difference of observed and simulated brightness temperatures of satellite instruments against instrument parameters, the quality and stability of the data can be evaluated from different perspectives such as geographic location, observation geometry, time and spectral ranges.

Session 5: Space weather

Chaired by: Dr. ZHANG Xiaoxin (CMA)

There are 11 presentations in this session, 6 from China, 1 from the United States, 2 from South Korea, 1 from Japan, and 1 from Canada, covering the daily operational application and the research status of space weather.

This session opened with a keynote presentation by Prof. ZONG Qiugang titled "Solar Wind -Magnetosphere -Ionosphere Coupling - A Spatial Observatory on Chinese FY-3E & 4B meteorological Satellites". In his presentation, he introduced the BD-IES system which developed by Peking University. Energetic particles injections associated with magnetic sub-storm and storm are ones of the most dynamic processes in Earth's magnetosphere and have global consequences and broad implications for space weather. They can be monitored by using energetic electron detectors on both geosynchronous and sun-synchronous satellites. There are two BD-IES instruments to be installed in the Chinese Sun-synchronous (FY-3E) and geosynchronous (FY-4B) satellites, launched on 4 July, 2021 (FY-3E) and June 3, 2021 (FY-4B) respectively. Using a pin-hole technique, the BD-IES instrument measures 50–600 keV incident electrons in eight energy channels from 18 directions covering a range of 180° in polar angle. The sun-synchronous satellite- FY-3E, for the first time, provides the energetic electron measurements in dawn-dusk sector to the best of our knowledge. Data collection by the BD-IES instrument have recently passed 5 months mark, which marks a successful milestone for the mission.

Dr. Mamoru Ishii from National Institute of Information and Communications Technology introduced the national and international activities of Space Weather Research and Operation, and pointed out that the needs of space weather information in human activities have been increasing in the world. Space weather impact on social activity occurs rarely, but once happens, the damage will be global and severe. One of the insurance companies estimated that if the most significant space weather event in human history, Carrington event on September 1859, occurs now, the economic loss will be equivalent to the 2011 Tohoku earthquake in each of North America and Europe. US government takes this fact seriously and assigns space weather as one of the threat in "US strategic National Risk Assessment". Some other entities, e.g., UK, South Korea and Lloyds insurance company has prepared their own report of social impact of space weather. Some international organizations are also interested in space weather impact. ICAO has been discussing to use space weather information in civil aviation operation.

Dr. XU Jiyao from The Chinese Academy of Sciences introduced the Chinese Meridian Project (CMP, with the full name of Space Environment Ground Based Comprehensive Monitoring Network). CMP is a ground-based space environment monitoring facility. CMP consists of 31 ground-based observatories located roughly along 100°E, 120°E longitudes and 30°N, 40°N latitudes respectively, forming a two-cross network configuration. CMP will form a detection layout of one chain (from sun to geospace), three networks (upper atmosphere, ionosphere, and magnetosphere) and four focuses (polar regions, north area of China, south of China, and Tibetan plateau). The project was scheduled to be constructed in two major steps. The first phase has been put into operation since 2012. Construction of the second phase started in 2019 and will be completed in 2023.

Dr. WANG Wenbin from National Center for Atmospheric Research, USA introduced the responses of thermosphere and ionosphere to energy flux from the magnetosphere with an instance. In this work, they employ the recently developed Multiscale Atmosphere-Geospace Environment (MAGE) model to simulate the processes by which solar wind and IMF affect low and middle latitude thermosphere and ionosphere during a long-lasting period of geomagnetic activity induced by a stream interaction region (SIR) event that happened in September 2020. The model shows that the changes in ionospheric electron densities can be both instantaneous by penetration electric fields and delayed associated with disturbance dynamo and neutral wind circulation, which makes the low latitude ionospheric densities changes complicated with both TID signatures and rapid electric field-induced features, whereas those at middle latitudes show primarily TID signatures related to TADs. Model simulated neutral temperature, composition and TEC are compared with data from the GOLD mission and GPS TEC maps to obtain new insight into the physical processes in the global thermosphere ionosphere responses to high-latitude magnetospheric inputs.

Dr. Larisa Trichtchenko from Canadian Space Weather Forecast Centre introduced the space weather in WMO. Firstly, the space weather phenomenon as a near-earth space condition was introduced. Examples of technical infrastructure affected by space weather were then given, space weather observations and services were presented, and the presentation concluded with a schedule of WMO activities related to space weather and the current status of WMO.

Prof. CUN Jun from Sun Yat-sen University introduced the effects of space weather on planetary atmospheric escape. The space weather condition, in terms of both solar extreme ultraviolet (EUV) radiation and upstream solar wind (SW) dynamic pressure, may drive substantial neutral and plasma outflow on Solar System bodies including the Earth. Understanding this aspect of the terrestrial and planetary atmospheres is thus crucial not only for characterizing their current active states but also for deciphering their long-term evolutionary paths over the entire solar system history. While atmospheric escape on the Earth occurs in a rather simple manner, manifest as predominant Jeans escape of light neutrals, escape on other planets is far more complicated and diversified. In particular, chemistry-induced escape and sputter-induced escape in various forms are of paramount importance on Mars, Venus and Titan, the three most extensively studied planetary bodies with permanent atmospheres. In this talk, he briefly present how these two fundamental processes play a key role in accelerating ambient neutrals to high velocities and driving substantial escape. These two escape channels are sensitively controlled by the impinging solar EUV photons and solar wind charged particles, respectively, thus forming a sophisticated scenario by which atmospheric escape is modulated by the space weather condition.

Dr. Jiyoung Kim from Korea Meteorological Administration introduced the current status and future plan of satellite-based space weather observation of the Korea Meteorological Administration (KMA). The operational data service of the space weather data from the Korean geostationary meteorological satellite/ Korean space weather monitor (GK2A/KSEM) has started since 25 July 2019 after in-orbit test of 6 months. The data include energetic particle flux of electron and proton, magnetic field, and satellite internal charging. The preliminary result of data analysis during the weak solar event will be also presented with data inter-comparison with GOES-16 satellite. The future plan of the space weather observation by the GK5 satellite will be finally presented.

Prof. NI Binbin from Wuhan University introduced the Linkage between ring current proton precipitation and electromagnetic ion cyclotron waves. Based upon a robust conjunction between Van Allen Probe B and NOAA-19, they performed a detailed analysis to capture simultaneous enhancements of EMIC waves and ring current proton precipitation. By assuming that ring current proton precipitation is mainly caused by EMIC wave scattering, they established a physical model between the wave-driven proton diffusion and the ratio of precipitated-to-trapped proton flux, which is subsequently applied to infer the intensity of EMIC waves required to cause the observed proton precipitation. Their simulations indicate that the model results of EMIC wave intensity are consistent with the wave observations, within a factor of 1.5. Their study therefore strongly supports the dominant contribution of EMIC waves to ring current proton precipitation, and offers a valuable means to construct the global profile of EMIC wave intensity using low-altitude POES proton measurements, which generally have a broad L-shell coverage and high time resolution in favor of near-real-time conversion of the global EMIC wave distribution for space weather studies.

Prof. SHEN Chenglong from University of Science and Technology of China introduced the interaction between multiple CMEs during their propagation in interplanetary space. Such interaction between multiple CMEs can form complex structures as seen from the in situ measurements. These complex structures have been called complex ejecta, or multiple interplanetary CMEs (ICMEs). In addition, when the shock driven by the following CME propagates into the previous CME, they may form a special type of complex structure called shock-ICMEs structure. Previous results show that the interaction between shock and ICMEs would significantly enhance their effect on space weather. In recent years, by using multiple satellites observations from Venus Express, Wind and STEREO, they studied the evolution of shock-ICMEs interaction structures in detail. The main findings are: (1) Shocks became weaker during its propagation in previous ICME; (2) The geoeffectivness of previous ICMEs enhanced obviously by a factor of 1.8; (3) The shock can accelerate the particles inside the previous ICME and enhance the intensity of energetic particles in the ICME.

Dr. Kichang Yoon from National Radio Research Agency, MSIT introduced the overview of Korean Space Weather Center's role and space weather operation, and national preparations for the next 25th solar maximum. And finally, he explained KSWC's R&D activities focusing on recent accomplishments and future plan.

Dr. DONG Liang from Yunnan Observatories introduced the ability of FengYun Satellite payload to warn solar radio bursts. He first introduced the physical background of this pre-warning method. And then, he compared the variation time of solar radio flux with that of soft X-ray flux on GOSE and FengYun satellite in the event of solar radio burst interfering navigation communication on September 6, 2017. The data are from GOSE satellite soft X-ray monitoring channel (1.0-8.0A) and FY-2 (2G) soft X-ray monitoring channel (1.8-12.9KeV). And then, he introduced their foundings: the soft X-ray flow of the two satellites had an advance time (more than 4 minutes) compared with the jamming time of navigation signals. Furthermore, he pointed out that the data from FengYun satellite payloads can be quickly accessed which lays a foundation for the rapid transmission of the warning information through BeiDou short message transmission function.

Session 6: Climate

Chaired by: Dr. Kotaro Bessho (JMA), Dr. Peng Zhang (CMA)

This session consisted of 11 presentations, 10 oral and one poster. Prof. Tadahiro Hayasaka gave a keynote presentation on Space-based Climate Monitoring and Application Studies in Japan. In Japan, the data of microwave imager, visible-infrared imager, and precipitation radar are merged to create a precipitation dataset GSMaP, which is provided to researchers and society. Satellite observations of clouds, aerosols, water vapor, and SST that are closely related to precipitation were introduced, focusing on precipitation phenomena that lead to floods such as torrential rains and typhoons that are characteristic of Asia. Climate monitoring and research by using satellite data, and its utilization in society were introduced. The presentation also introduced the Japanese satellites GCOM-W, GCOM-C, GPM, ALOS-2, GOSAT-1 & 2 and Himawari-8, 9 that are currently in operation and their follow-on missions, as well as EarthCARE, a joint mission with Europe in the near future, and the ACCP project that is being jointly promoted with the United States. International cooperation on the Earth observation satellites is expected to become increasingly important not only in the development and operation of satellites, but also in the utilization of data in Asia and other regions of the world.

Prof. Yuriy Kuleshov reported on WMO Space-based Weather and Climate Extremes Monitoring (SWCEM) for East Asia and Western Pacific. The demonstration project focused on monitoring drought and heavy precipitation and it was implemented in geographical domain which covers the South-East Asia region and the Western Pacific Ocean area from 40°N to 45°S; 50°E to 120°W. SWCEM space-based observations of precipitation have been incorporated into other WMO activities to strengthen the capacity of Members, especially in Small Island Developing States and Least Developed Countries, in climate change adaptation and disaster risk reduction. Satellite precipitation estimates and derived products are a significant contribution to strengthening Multi-Hazard Early Warning Systems.

Ms. Ling Sun reported on “Progress of FengYun series dataset for climate”. NSMC has pushed forward the FengYun data reprocessing with improved data quality. FengYun FCDR is processed with the historical data, including 7 instrument series on 13 satellites, with 20 years data for optical imager and more than 10 years for microwave. The recalibrated dataset is released for application test. Based on the FengYun FCDR, FengYun CDR is also promoted. At present, parameters of more than 10 years for OLR, AMV, SST, snow and sea ice are done.

Mr. Kotaro Bessho reported on “Toward the upgrade of Geo-Ring observation”. In the presentation, the current status and future plan to establish and upgrade the “Geo-Ring” observation using four types of sensors were shown. Satellite users in Asia and Oceania were informed of the utilization methods of these new generation observation capabilities from geostationary orbit in various fields such as nowcasting, forecasting and products generation.

Dr. Moeka Yamaji gave a presentation on recent progress in Global Satellite Mapping of Precipitation (GSMaP) product. JAXA has developed and provided Global Satellite Mapping of Precipitation (GSMaP), which is hourly global precipitation dataset generated under the Global Precipitation Measurement (GPM) mission. GSMaP algorithms have been updated for several times, and the next major version-up to V05 is planned in November 2021. JAXA will re-process the historical data using the new algorithm for producing 21-year GSMaP climatology from 2000. GSMaP applications are expanding, not only in weather and climate monitoring but also in disaster management, agricultural monitoring, educations and so on.

Dr. Francisco Lang reported on “A Climatology of Open and Closed Mesoscale Cellular Convection over the Southern Ocean derived from Himawari-8 Observations”. The results of the climatology show that open MCC clouds are roughly uniformly distributed over the SO storm track across mid-latitudes, while closed MCC clouds are most predominant in the Southeast Indian Ocean with a second maximum along the storm track.

Mr. HANDA Taro gave a presentation on “Himawari-8 calibration and navigation performance and future plan”. To improve the quality of Himawari data, JMA has updated navigation and calibration processes at ground system even after the start of AHI operation. In addition, it became possible to store coefficients for correcting sensor sensitivity for visible and near-infrared (VNIR) bands in L1B data of Himawari Standard Data. The coefficients have been updated every year.

Dr. Hitoshi Hirose reported on “A histogram matching method for GSMaP improvement in geostationary meteorological satellite observing areas”. To improve the homogeneity of the GSMaP products, improvements were made in the major algorithm updated in 2021 for reducing the accuracy difference between PMW and GEO products. A histogram matching method corrects the rain rate distribution in GEO observing areas to match the rain rate distribution in PMW observing areas. The gap between GEO and PMW observing areas was reduced by this correction.

Mr. Jan Muhammad reported on “An Assessment of Climate Prediction and its Impact on Selected Urban Cities of South Asia Using Geo-Spatial Techniques”. Meteorological parameters selected are average temperatures, maximum and minimum temperatures, rainfall, and humidity. Meteorological events such as heavy rain with thunder, extreme snow fall, flooding with torrential rainfall, highly increase ratio of heat waves, drought condition, continuously hitting tropical cyclonic activities, earthquake, land sliding etc., which are the major source of changing the meteorological parameters like temperature, relative humidity, pressure and wind patterns.

Prof. Yangwon Lee gave a presentation on “Drought Monitoring for the Korean Peninsula Using GK2A/AMI”. A daily database for TCI, VCI, and VHI using GK2A/AMI products for monitoring agricultural drought in Korea was constructed. With an increased volume of GK2A/AMI data, more effective drought monitoring for the Korean peninsula can be expected.

Mr. Wu reported “Progress on FY-3/MWRI Fundamental Climate Data Record”. In China, an independent FCDR was produced recently after the re-processing archived historic FY-3 Microwave Radiation Imager (MWRI). This FCDR contains the brightness temperature data from three MWRIs mounted on FY-3B/3C/3D satellites from 2010 to 2020.

2021 FengYun Satellite International User Conference

Due to the constraints imposed by the COVID-19 pandemic not allowing a face-to-face meeting, the 2021 FengYun Satellite International User Conference (FYSUC) was shortened into one day, and held jointly with AOMSUC-11 virtually, on 2nd November 2021. The 2021 FYSUC was hosted and sponsored by China Meteorological Administration (CMA) and China National Space Agency (CNSA).

The 2021 FYSUC Chair Prof. YANG Jun, Director-General of the office of meteorological satellite project of CMA welcomed the participants to the FYSUC in his welcome remarks He summarized the 1st FYSUC that held in HaiKou, HaiNan province of China on November 15-17 2019, and wished a success for the conference. He stressed the three main goals of the 2021 FYSUC: 1) to build a platform for the FengYun satellite international users especially for users along Belt and Road region, 2) to exchange their ideas of satellite data access and sharing, 3) product development and application to better serve the national social and economic development.

The conference which consisted of 22 reports from 10 countries was chaired by Prof. YANG Jun (NSMC/CMA), Prof. WENG Fuzhong (CAMS/CMA), Prof. TANG Shihao (NSMC/CMA), and Prof. Jun LI (NSMC/CMA). Of the twenty-two presentations, the first keynote discussed the value of satellite observations for characterizing and predicting high impact weather events. Four reports introduced the FengYun Satellites programs, progress, services and updated plan. Four reports addressed the product retrieval and dataset establishment, and the other 13 reports focused on the utilization progress, shortcomings and future needs.

The conference opened with a keynote presentation on "The value of satellite observations for characterizing and predicting high impact weather events across temporal and spatial scales" by Dr. Dr. Paulo Ruti of EUMETSAT. He discussed the value of satellite observations in the characterization and prediction of high-impact weather events in the tropics and mid-latitudes. He pointed out the necessity of satellite observations into data assimilation, and highlighted the impact of satellite data on providing a strong constraint to the model dynamics. He then confirmed the role of satellite observations in tropical cyclone prediction and simulation observation requirements. Satellite data influence and optimize model results by coupling assimilation. Meanwhile, the different observational needs to improve the simulation and prediction of such important phenomena over the tropics.

Regarding the four reports of FengYun satellites programs, progress, services and update plan, two focused on the FengYun satellite programs, detailed latest progress and updated plan of the FY-3 and FY-4 satellite programs respectively. The in-orbit test of FY-3E and FY-4B that were launched in 2021, were highlighted, with an emphasis on the applications of FY-3E in El Nino-La Nina analysis, ocean surface wind retrieval, the polar sea ice monitoring, FY-4B in solar and space weather detection, NWP data assimilation, rainstorm, severe convective early warning. Two presentations reported an overview of the Belt and Road service of FengYun Satellite, and the CMACast service. They showed the current situations of data distribution service, international user service, as well as the cooperation and system upgrading plans.

Addressing product retrieval and dataset establishment, one presentation detailed a Global Scene-Dependent Atmospheric Retrieval Testbed (GSDART), which could retrieve the FY-3D microwave sounding instruments to obtain the three-dimensional thermal structure of the global atmosphere. The 3D structure of global atmospheric temperature, water vapor and surface pressure field retrieved by FY-3D, and the future plan to integrate FY-3E data on this platform were introduced. The second report presented a method to improve the retrieval of ocean precipitation based on the cross orbital scan radiometer. The method made possible to improve monitoring of high-impact weather systems and multi-satellite precipitation products. Another presentation introduced the FY-4A super-resolution open source dataset for improving the resolution of FengYun images. Tests of the super-resolution algorithm showed that it can significantly improve the spatial resolution of FY-4A satellite. Finally a presentation detailed convection deep learning prediction, which has better convection identification results than other models based on FY-4A satellite. The prediction time of this method is 4 hours, which can be applied in operational service in the future.

Utilizations and applications with FengYun and multiple satellites data were the focus of the next thirteen presentations, which covered weather monitoring and prediction, environmental disaster monitoring and assessment, numerical weather prediction, agricultural and aviation applications. Among them, four reports presented the application of FengYun and other satellites data in Seychelles, Namibia, Maldives and Hong Kong, China respectively. In Seychelles, satellite data are mainly for extreme weather events monitoring, FengYun satellite data could play important role in tropical cyclone monitoring. FengYun satellite data have a key role in monitoring of vegetation, dust, lake water, drought, and weather prediction in Namibia. The FY-2 and FY-4 series satellite have played a crucial role in public weather services in the Maldives, including weather forecasting and early warning services. In Hong Kong China, FengYun satellite products are applied in the strong convection, typhoon, lightning and monsoon monitoring, as well as environmental disaster monitoring. Two presentations focused on fire and volcanic eruption monitoring, while one detailed forest fire and burned area identification in India. The significant role of FY-4A with high temporal resolution in local fire monitoring was highlighted. Another report presented the capability of FengYun satellite data for global volcanic eruption monitoring, and inversion of volcanic ash height. Two reports introduced the application of FengYun satellite data for meteorological and hydrological disasters monitoring in Belt and Road countries, such as flood monitoring in Iran, and vegetation and drought events monitoring in Africa. Two presentations reported on high impact weather monitoring and aviation risk assessment. Finally three reports showed the applications of FengYun satellite data in crop classification, land cover classification and heat wave monitoring. High quality FengYun satellite data could be used to improve the accuracy of crop identification in Africa, and enhancing the capability of sugarcane growth, drought, and heatwave disaster monitoring and assessment in Belt and Road countries.

In the one-day FengYun satellite international user conference, the international users showed the fruitful applications of FengYun and multiple satellites data in their countries. In general, FengYun satellite data have been applied in many countries and have played an important role in weather monitoring, numerical weather prediction, environmental monitoring, disaster early warning and agricultural assessment. International users have increasing requirements for FengYun satellite data, especially for customized products according to their own weather and climate characteristics.