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Capability-building Programme in Subseasonal-to-Seasonal Prediction for Southeast Asia (S2S-SEA)

Meeting Report Fourth Workshop (S2S-SEA IV)

August 2023, Singapore and online

ASEAN Specialised Meteorological Centre

ACKNOWLEDGEMENTS

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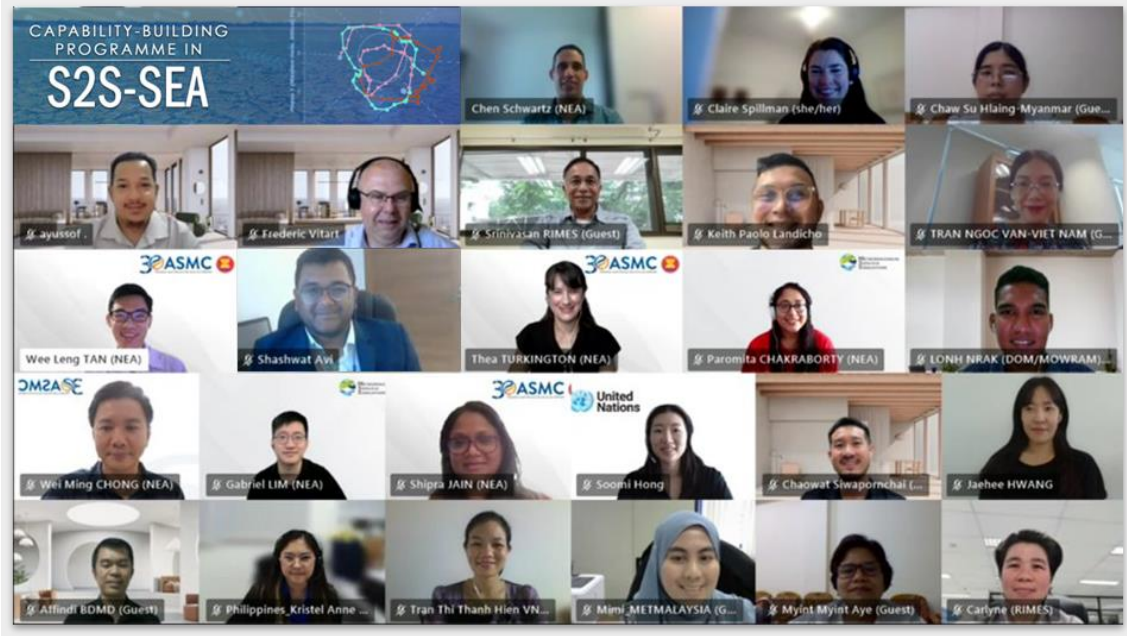
EXECUTIVE SUMMARY

The S2S-SEA IV workshop in August 2023, led by the ASMC and the Centre for Climate Research Singapore, marked the end of a four-part workshop series on Subseasonal-to-Seasonal (S2S) prediction in Southeast Asia. The workshop series aimed to build capacity and enhance collaboration among the National Meteorological and Hydrological Services (NMHSs) in the ASEAN region regarding S2S prediction. The fourth S2S-SEA Workshop included two virtual sessions (15 and 30 August) and an in-person segment between 22 and 24 August 2023, conducted in Singapore. Fifteen NMHS representatives from nine ASEAN Member States attended the in-person training, along with six trainers. Encompassing the in-person training, the two virtual sessions allowed more users to participate in the workshop, as well as more time for reflection in between the sessions. An additional 26 users and three trainers attended the virtual sessions, leading to a total number of 50 participants in SEA-SEA IV over the in-person and virtual sessions.

Key takeaways shared by the participants during the workshop included information on latest updates on sources of S2S predictability (including questions that are still unanswered), a better awareness of S2S products, and the procedure to give a S2S briefing to users (something NMHSs are not always trained in). The workshop also discussed the future of S2S predictions and plans for collaboration in the ASEAN region. Common challenges faced by NMHSs raised in the workshop include the need for improved communication, data access, and automation. Plans were made for fortnightly discussions between ASEAN NMHSs to review climate drivers and S2S outlooks.

Since the first workshop in 2017, many of the NMHSs in Southeast Asia have moved from research to delivering operational S2S products. While there is still more to do around delivering actionable products, discussions during the S2S-SEA IV highlighted that sharing experiences and expertise in the region is useful for the continued development of S2S predictions in Southeast Asia.



Group photo during the first virtual session of S2S-SEA Workshop (15 August 2023).

Group photo during the S2S-SEA Workshop, Singapore (in-person, 22-24 August 2023).

INTRODUCTION

The Capability-building Programme in Subseasonal-To-Seasonal Prediction for Southeast Asia (S2S-SEA) was initiated in 2017 by the Meteorological Service Singapore (MSS), host of ASMC (asmc.asean.org), and in collaboration with the WMO's S2S Prediction Project and other partners at different stages. The Programme was a multi-year series of workshops split into two phases. In the first phase, the workshops (S2S-SEA I and II, 2017-18) focused on assessing model skill for Southeast Asia, while the second phase of workshops (S2S-SEA III and IV, 2019, 2023) explored product development for risk- and impact-based predictions on the S2S timescale through engagement with end-users in different applications. Given the relatively good skill of subseasonal forecasts for the region (e.g. Li & Robertson, 2015), there is potential to maximise the benefits of S2S predictions for Southeast Asia.

From the WMO's S2S Prediction Project, an S2S Multi-model Ensemble Prediction System (MEPS) database was set up to host the model outputs from the WMO's Global Producing Centres (GPCs). The MEPS comprises ensembles of subseasonal forecasts up to 60 days. The database was accessible from (1) ECMWF database, (2) the IRI Data Library, and (3) from a site hosted by CMA. The MEPS provides an extensive set of reforecasts (hindcasts) datasets from several modelling centres. Throughout S2S-SEA, the forecast products lagged by three weeks and so could not be used operationally.

Objectives of S2S-SEA

Through the S2S Prediction Project, the products on the MEPS had a delay of three weeks and could not be used operationally. Nevertheless, access to these forecast and reforecast datasets allowed operational centres to preview and assess their potential benefits and limitations ahead of real-time products being made operational. In preparing for the eventual release of operational products through the WMO LC-SSFMME, S2S-SEA aims to:

- Familiarise the participants with the MEPS database;
- Improve regional understanding on the mechanisms of subseasonal-to-seasonal predictability;
- Equip the participants with the knowledge to investigate the skill and usefulness of the subseasonal forecasts in applications;

- Provide training to participants in generating products tailored for risk- and impact-based predictions on the S2S timescale.

The overall aim of the S2S-SEA programme was to build capacity and enhance collaboration among the NMHSs in the region. Its objectives are also in line with broader WMO initiatives such as the recent "Early Warnings for All" initiative, co-led by WMO and the UN Office for Disaster Risk Reduction (UNDRR). The initiative seeks to ensure that everyone is protected from hazardous weather or climate events through early warning systems by the end of 2027.

As the operational, near real-time forecast information from the S2S database was estimated to be available at the end of 2023, the schedule of this programme was timely.

Fourth S2S-SEA Workshop (S2S-SEA IV)

The Fourth S2S-SEA Workshop (S2S-SEA IV) was held in August 2023, over two virtual sessions and an in-person workshop on 22 - 24 August 2023, conducted in Singapore. The key elements of S2S-SEA IV are as follows:

1. End-user Interactions: S2S-SEA Phase 2 focuses on increasing NMHSs-end user interactions to help with product development. As discussed in previous workshops, for S2S predictions to be useful, not only should they be skilful (covered in Phase 1), but also understandable to users and able to be applied.

2. Virtual sessions: The first virtual session aimed to provide participants with a refresher on key concepts, as well as focus on understanding user needs to form the foundation for the physical workshop. The final virtual session after the in-person segment, allowed participants to connect and discuss products with the end users and future collaboration.

3. Models and Tools: Unlike the previous workshops which focused on the use of tools, S2S-SEA IV instead focused on the application of readily available S2S products (see S/N 4 below), although a recap of available tools was also provided.

4. Application of S2S products: The second set of activities focused on the application of S2S products. This included considering impact-based forecasting, how to work with users to identify actions that can be taken, and tailoring products for these actions.

5. Fundamentals for S2S Prediction: S2S-SEA IV also included detailed lectures on the fundamentals of S2S prediction, such as appropriate skill scores to use and their interpretations, probabilistic products, and identifying and using windows of opportunity.

6. Next steps: As this is the final workshop in the series, discussions were held to gather feedback on next steps for collaboration in the region on improving S2S prediction and related services.

VIRTUAL SESSION: 15 AUGUST 2023

The first virtual session provided a foundation to the workshop and was chaired by Dr Govindarajalu Srinivasan (RIMES).

Highlights

- Introduction to key concepts of S2S Prediction
- Review of S2S-SEA and past workshops
- Examples of use of seasonal and S2S predictions

Introduction

The workshop started with a welcome address from Eugene Chong (Head, ASMC Services Branch). Mr Chong welcomed all the participants, trainers, and organizers, and wished them well for the upcoming hybrid workshop. He also highlighted the developments that have been made in S2S prediction and the potential usefulness of such products, as well as the ASMC Capability Programme extension to 2027.

Introduction on S2S Prediction

Frederic Vitart (ECMWF) presented the first talk on Introduction to Subseasonal-to-Seasonal Prediction. He gave an introduction on prediction skill, MJO phases and their impacts on the rainfall, usefulness of the prediction of MJO, reliability diagram, end-to-end forecasting system, list of models S2S database, and the S2S Prediction Project. He also provided details on how to access the S2S data.

There were a number of questions around predictability, such as the improvement with more ensemble members for the ECMWF model, as well as around tropical cyclones and when drivers are present. Dr Vitart replied that predictability does vary – both in terms of geographical location (increase in ensemble members more important for extra-tropics), and timing (presence of MJO may bring increased skill). There was also a question on the format and visuals compared to seasonal forecasts (which some users are more familiar with), with the response that in many ways S2S forecasts are similar, but for shorter averaging periods (weekly instead of 3-monthly).

S2S-SEA and past workshops

Thea Turkington (ASMC) provided a review of past S2S-SEA workshops. The idea of S2S-SEA was to act as a bridge between the global S2S Prediction Project and Southeast Asia community (particularly ASEAN NMHSs). The program was originally designed for 2017-2020 but extended to 2023, due to travel restrictions as well as to allow for outcomes to be included from the S2S SEA Pilot Project (2020-2022). The previous 1st, 2nd, and 3rd workshops had lectures on key S2S topics, complemented with practical training on Python coding, and testing out different products (both deterministic and probabilistic). Dr Turkington also presented some examples from the workshops, e.g., tailored products, rainfall terciles at different lead times, flooding cases in Thailand and user engagement through preparation of a 1-page summary outlook, serious games, and brainstorming sessions.

Figure 1 Participants of Virtual Session A, 15 August.

Definitions

As part of the foundations for the workshop, Dr Turkington led a session on definitions of commonly used terms to be used during the workshop. This highlighted the difference between climate information and climate service (the latter being climate information that is used to assist decision making), and intermediary user (someone who uses climate information to produce a climate service) and end user (uses climate services in decision making). Discussion

after highlighted that there may be some small differences in the definition depending on the institution, however, all agreed for this workshop on the general definitions.

Examples of use

There were three presentations from intermediary/end users on the application of the S2S database and S2S products. Tshencho Dorji (RIMES) presented on RIMES' experience and presented several case studies. He presented on the Bhutan Climate Services Toolkit - a suite of guidance and tools for climate information. RIMES worked with WMO, NMHS Bhutan, and KMA to customize the toolkit for Bhutan. The initiative included designing and customizing a toolkit with subseasonal forecasting as one of the main components, along with training of the staff. Three sectors were identified, and the web platform was customized for these three sectors (agriculture, flood, and public health). The speaker also shared best practices, such as phased implementation and development of a scalable design, and the benefits of leveraging academic institutions.

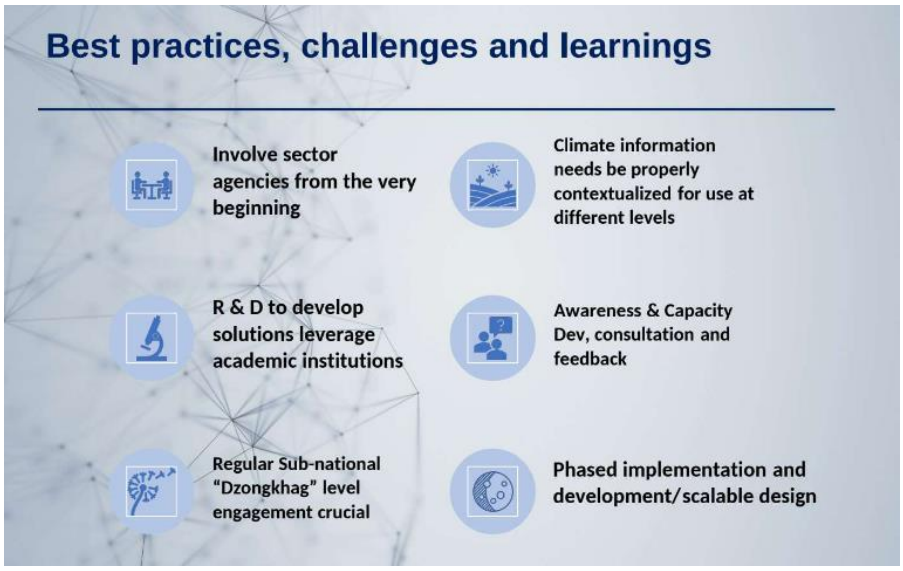


Figure 2 Sharing of lessons learn from by Tschencho Dorji (RIMES).

Shashvat Avi (UN ESCAP) presented and demonstrated the automated seasonal impact-based forecasting tool developed by UN ESCAP. Mr Avi introduced the concept of impact-based forecasting and the tool for exposure analysis for different regions and admin boundaries. He added that the tool can identify data type automatically and perform multilevel exposure analysis (national, provisional, regional), data classification (divides the hazard into different classes), although there are currently limits to the format of data the tool uses. He also summarized challenges in impact-based forecasting, notably: data availability, quality, and out-of-date data. Their team is currently working on the improvement of the tool, to be used on their risk and resilience portal.

Keith Paolo Landicho (the AHA Centre) presented on the collaboration between the AHA Centre and ASMC, with a particular focus on the S2S SEA Pilot Project. He discussed forecast outlook guidance developed in the pilot project including active weather/climate phenomena (IOD, MJO, ENSO), regional assessment of extremes, plots (quartile, tercile, percentile), research as well as DMA workflow integration, and plans to integrate some of the subseasonal information into their online Disaster Management and Response System.

End of session

The final segment of the day was led by Chen Schwartz, where the ASEAN NMHSs representatives were asked to provide information on how subseasonal forecasts are being produced and used in the region. Six of the nine ASEAN NNMHSs already provide subseasonal outlooks (Table 1), with the other three countries surveyed providing seasonal outlooks and considering developing subseasonal outlooks.

Table 1 Summary of responses on current subseasonal outlooks. Green shading indicates that this is available in the country. A full summary is included in the Annex.

		Lao PDR	Myanmar	Philippines	Singapore	Thailand	Viet Nam
What is the timestep for the subseasonal outlook?		Weekly	10 days	Weekly	Weekly	Weekly, 15 days	10 days
What is the maximum lead time of the subseasonal outlook?		1 month	1 month	2 weeks	4 weeks	4 weeks	1 month
What variables are provided?	**Temperature**						
	Precipitation						
	TC activity						
	Other						
Which sectors use subseasonal products?	**Agriculture**						
	Health (environmental)						
	Water						
	Other						

DAY 1 SINGAPORE: 22 AUGUST 2023

The first day of the in-person workshop in Singapore. This day was chaired by Dr Shipra Jain (ASMC)

Highlights

- Recap of key concepts
- Walkthrough of available products
- Review of sources of predictability

Opening

Dr Aurel Moise, Deputy Director of Department of Climate Research, Centre for Climate Research Singapore, gave opening remarks, welcoming the participants as we return to physical workshops and training after 3 years of physical restrictions, and look forward to more collaboration and physical meetings in the future. This is followed by the opening remarks by Dr Andrew Robertson, Senior Research Scientist from IRI Columbia, introducing the WWRP/WCRP S2S Prediction Project where the second half of the project focused on the application of science to inform decisions. Dr Robertson added that with Southeast Asia being a region of higher skill and potential, the S2S-SEA workshop series can fulfill this potential to build up the regional capabilities in making predictions and applications with the information.

Figure 3 Introduction to the S2S Prediction Project by Dr Robertson

Dr Thea Turkington (ASMC) provided an overview of the S2S-SEA Workshop series, first with a recap of the first virtual session on 15 Aug 2023 and on the increasing trend of the S2S products availability since the first S2S-SEA workshop in 2017. Dr Turkington highlighted the focus of the fourth workshop, with product development, communication/interactions with the users, as well as discussions on future of S2S in SEA.

Recap of key concepts

This is followed by two lectures, first on probabilistic and deterministic outlook by Dr Turkington and on past workshops achievement and the assessment of S2S model skill by Dr Robertson.

Dr Turkington provided some examples of deterministic and probabilistic forecast through interactive activity, explaining the types of forecasts (e.g., anomaly, categorial, tercile, threshold). The purpose and use of the hindcast as the reference state and distribution in the model was introduced. The pros and cons of deterministic and probabilistic forecasts were discussed, with deterministic forecast being less useful for subseasonal timescale but easier for users' interpretation, while probabilistic forecast retaining the information of likelihood and can provide information on the extremes.

Dr Robertson provided a recap of previous workshops, from the introduction of data base for various S2S models and focusing on ECMWF for products and case studies for comparison between leadtime in the first workshop, to the preparation of various statistics and index (e.g. number of dry days) in the second workshop, and eventually to developing actual forecast products using PyCPT by IRI Columbia in the third workshop. Dr Robertson demonstrated the skill score for the region using PyCPT2, showing the skill for the region and signal in the forecast and went through some of the different types of skill score for deterministic and probabilistic forecast and its possible usage. Correlation, RMSE, RPSS were introduced, which could be shown as a skill score map or average over a region of concern. The concept of the use of hindcast for the comparison with the observations over the hindcast period was introduced, or one can also make evaluation of an event of concern through the forecast or hindcast.

Walkthrough of available products

A walkthrough on the online S2S products was done, with Dr Claire Spillman (AuBoM) and Mr Tan Wee Leng (ASMC) introducing the products by ACCESS-S2 and ECMWF Extended Range respectively. Dr Spillman covered the timescale of the ACCESS-S2 from the subseasonal-to-seasonal period and walked through some products for specific regions of Australia, where participants could draw and reference for communication with the users. Dr Spillman also showed ACCESS-S2 global S2S products, with regional maps for both deterministic and probabilistic forecasts, and with accompanying skill map. Mr Tan walked through the ECMWF's EC Charts, demonstrating how to select variables, compare different model runs, and compare different variables (e.g. tropical depression, tropical storm, and hurricane). He also highlighted the meteogram product, with ECMWF now using 101 members for their forecast. The verification products available on the EC Charts was shown as well.

After lunch, the group continued the showcase of available products, with Dr Robertson walking through the IRI subseasonal products. These products are based on a combination of three North American subseasonal models, with additional calibration. Via the IRI MapRoom, intermediary users can view weekly and biweekly products, including flexibility in choosing the threshold of exceedance. Through interaction with the map, users can also view the probability distribution function and probability of exceedance curves. The information can be downloaded in a variety of file formats. Dr Robertson also pointed out that when looking at past outlooks, the observations also are available for comparison. There was some discussion on the interpretation of probabilities, as well as the small differences between the S2S model data in the S2S Database and in the IRI library.

Sources of predictability

Mr Chen Schwartz (ASMC) brought the room back to understanding behind the model skill through a lecture on sources of predictability at the subseasonal timescale. He started with an overview of the Madden-Julian Oscillation, one of the key sources of variability at the subseasonal timescale. He gave an overview of skill of MJO amplitude and phase, as well as the relationship between MJO and extreme precipitation. He then introduced the Quasi-Biennial oscillation (QBO) and how it affects the predictability of MJO (particularly in boreal winter). The BSISO was also introduced – a mode of variability that has some similarities with MJO, but a larger northward (and occurs mainly around boreal summer). Moving away from the tropics, Mr Schwartz introduced the North Atlantic Oscillation and Sudden Stratospheric Warming (SSWs). For sources of predictability covered both the observed teleconnections, but also how these teleconnections are represented in the models.

Figure 4 Mr Schwartz discussing the Madden Julian Oscillation

Briefing template

With many sources of information and points to consider, the rest of the afternoon was spent covering briefings and briefing templates. Briefing templets help intermediary users prepare climate information to share with other intermediary users or end-users. Dr Spillman gave a lecture on how to put together a template. Key was to answer the 5 ‘w’ questions: ‘who’ are you talking to, ‘what’ do they care about, ‘where’ do they care about, ‘when’ do they care, ‘why’ do they care? There is also the question about ‘how’ it is going to be delivered. It is important to put the information in context, as well as combine with other information.

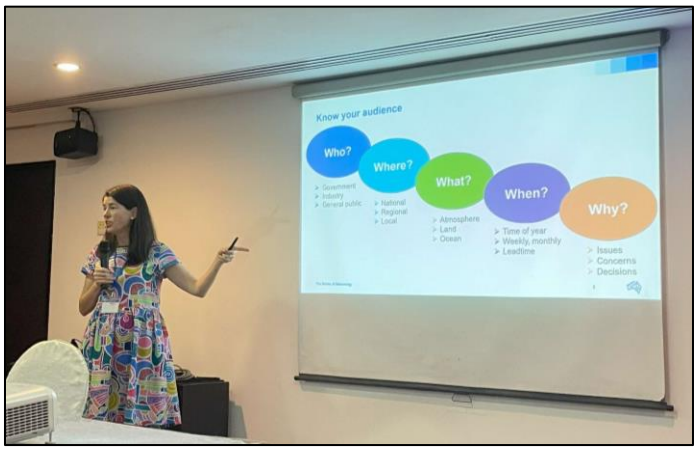


Figure 5 Dr Spillman presenting the 5 'w's to know your audience.

Mr Schwartz then gave an overview of how the ASMC fortnightly outlook is prepared (the information used to prepare a briefing to colleagues). This includes an overview of the last outlook, and what happened (including disasters reported by the AHA Centre), followed by a review of the relevant drivers and their outlook, and finishing with the rainfall and outlook from various sources (including skill assessment). This provided an example for participants to use the next day.

Key takeaways from Day 1 included latest updates on sources of predictability (including still unanswered questions), a better awareness of products, as well as how to give an S2S briefing (something NMHSs not always trained in).

DAY 2 SINGAPORE: 23 AUGUST 2023

Day 2 focused on communication with group work and discussions. This day was chaired by Dr Thea Turkington.

Highlights

- Ready-set-go framework
- Communication
- Windows of Opportunity
- Sharing by NMHSs

Are you 'Ready-Set-Go'?

Dr Andrew Robertson gave an overview of the IRI framework on climate services as well as the Ready-Set-Go framework. The framework includes four steps, a) generate – may involve running models, b) translating – may involve downscaling, calibration, c) transfer – communication of tailoring forecast information, e.g., forecasting monsoon onset date at local level, designing the product that can be easily used, and d) usage – understanding what works and what doesn't. The Ready-Set-Go considers the combination of seasonal (Ready), subseasonal (Set), and weather (Go) information, with the philosophy to be prepared and have a more proactive approach than reactive approach. He stressed that seasonal and subseasonal provide more time to act but information becomes less specific for longer lead time, and optimal way going forward is to use these together. He ended the lecture with examples of heatwaves and forecast based financing in Peru. He also mentioned that looking at multiple products could be useful.

Figure 6 Warm up on communication: participants try to communicate key points of an outlook through a version of the game 'broken telephone', led by Dr Jain.

Preparing briefings

The participants then put what they learnt into action by starting to prepare briefing templates. Participants worked in groups to prepare a briefing template, where ASMC staff and trainers oversaw their progress and helped them with the questions.

Communication

Following the lunch break, Dr Claire Spillman discussed communicating with users. First, she spoke about the importance of getting to know the users and their decision-making process. This knowledge about the decision-making process helps both the producers and users of climate information. The time scale at which decisions are made by users in the context of S2S timescales is important – as well as determining (and sharing) the financial benefits of using S2S.

Dr Spillman then elaborated on the information needed to produce a user-specific forecast tailored to the user's decision-making process. Points to consider in user-specific forecasts include optimal lead time, relevant variables, spatial scales, the level of accuracy and skill of the forecast and the way the forecast is used. The importance of getting from users' information on specific events was also stressed: this includes information on specific event that happened, and whether the user would do something differently (depending on the forecast), as well as what can they do in a year with a negative-impact forecast.

The usefulness of a forecast depends on the timing of the decision being made, as well as the level skill needed to see benefit of using the forecast. Ideas and examples were also presented on how producers might overcome the challenged of communicating the idea of skill to users. The importance of industry engagement was also explained, including some ideas for an effective engagement.

Outlook products should not be produced in isolation – in-depth engagement with users improves products significantly and should pro-actively seek feedback.

During the Q&A session with Dr Spillman, she shared that to avoid asking too many questions (in questionnaires to users), interviewers can start by talking to the users, conduct many

interviews with different users from a certain sector, and listen to the users (put them in the center). She emphasized the point that it is not about the amount of question we ask but about the information given by the users.

There was then a short activity where the NMHSs were broken into groups and got to a chance to interview 'representatives' from different sectors. From ASMC, Dr Thea Turkington, Dr Shipra Jain and Mr Tan Wee Leng acted as users from the agriculture, tourism, and defense sectors, respectively, each assigned to a group. Each group then had to up with sector-specific questions to ask the user over a 20-minute period. All three groups had engaging conversations, although some challenges were identified. This included explaining how subseasonal information can supplement seasonal outlooks, discussing potential products without examples on hand (concepts become abstract), how/why users should trust the forecasts, as well as some users are less forthright in sharing of relevant information on their needs.

Windows of opportunity

Following the activity, Dr Robertson spoke about 'windows of opportunity'. He first showed week 3-4 probabilistic skill around the globe for each season for precipitation and temperature. An example for a global probabilistic forecast was presented with a comparison to what was observed. The large-scale drivers during the example forecast were shown with an ongoing La Niña event as well as an active phase of the MJO. Accurate rainfall prediction came from a combination between the impact of those 2 large scale drivers. Dr Robertson shared an example of using 'windows of opportunity' from Bihar, India, where typically S2S forecasts are given only for the first two weeks. However, when large-scale drivers are present, the forecasts can be extended up to week 4. Windows of opportunity in Southeast Asia is something that could be explored more in the future.

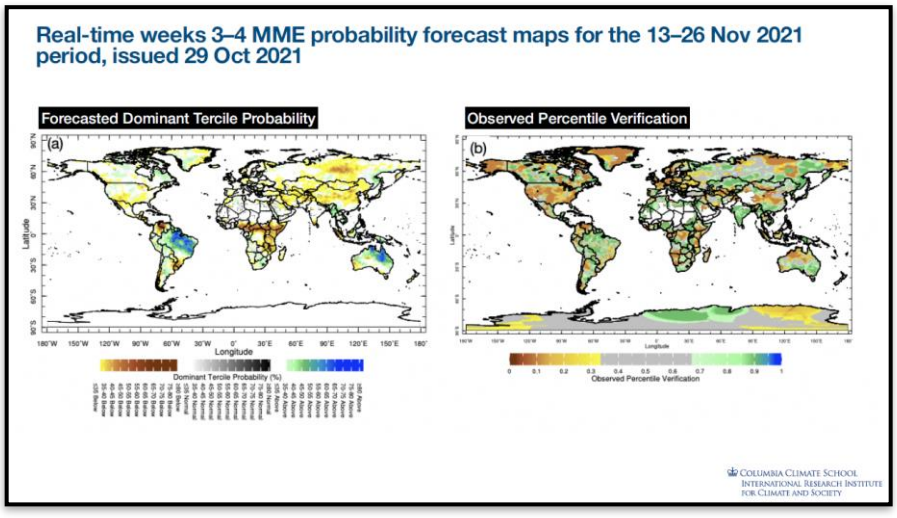


Figure 7 Example S2S forecast when La Nina and MJO were present, increasing skill in rainfall prediction for parts of the globe, including parts of Southeast Asia.

Sharing by NMHSs

Throughout the day, NMHSs shared the current state and

future of S2S services in their country. During the morning sharing session, Dr Paromita Chakraborty (MSS) gave a brief overview of the products being produced/used by the Meteorological Service Singapore. Ms Valerie Villasica (PAGASA) presented S2S products which included TC threat potential based on 6 hr forecast of the GFS, multiple rainfall products (e.g., GFS based models, rainfall anomalies, rainfall exceedance probabilities) based on NCEP – CFSv2 based CPT, wind and temperature products, and tropical monitoring of MJO (only for forecasters not for the public). Future plans included web-based S2S forecasting system, verification of current S2S products, extension of the S2S products to cover Week 3- 4, impact-based forecasting. Ms Tran Ngoc Van (VNMHA) showed the S2S products they use for operations, and it included EC charts, GEFS rainfall prediction. They also issue 3 bulletins for hydroelectricity, water source, coal and mineral sector.

During the afternoon session, Thailand, Myanmar, Lao PDR and Cambodia presented on the S2S products provided by their NMHS. Mr Chaowat Siwapornchai (TMD) presented first on their current products and the methods used to produce them. Data is downloaded from IRI and postprocessed with basic statistical methods, with guidance from other GPCs and Climate drivers are also considered. Future plans for S2S activities include upgrading 4-week forecast with SubX and ECMWF data (including potential further calibration and verification). Mr Sengsouly Somchanhmavong and Ms Sengcan Sillattana (DMH Lao PDR) shared next their forecasting products across all timescales from nowcasting, weather, subseasonal, seasonal. The seasonal forecast is given in the form of bulletin. Ms Chaw Su Hlaing and Dr Myint Myint Aye (DMH Myanmar) presented the S2S activities in the country, with the 10-day forecasts are given using WRF. Future plans include improving the accuracy of medium and long-range forecasts and to apply S2S operationally (potentially using PyCPT), with analysis of weather events in Myanmar using the S2S database. Finally, Mr So Im Monichoth and Mr Lonh Nrak (MOWRAM) presented about their current products: weather and seasonal forecasts, including the satellite products used and the process of producing them. Information was also provided on the platforms by which the forecasts are disseminated.

Key takeaways from Day 2 included more knowledge on how to communicate with users, including learning about user needs, and ways that outlook bulletins can be improved.

DAY 3 SINGAPORE: 24 AUGUST 2023

The focus of the day was looking forward to next steps in development of S2S services in Southeast Asia. This day was chaired by Mr Chen Schwartz.

Highlights

- Briefing by participants
- Future direction in S2S (global and Southeast Asia)
- Future collaboration in S2S for Southeast Asia

Briefings by participants

After some time to finalise their briefing templates, participants shared what they had done, with different countries presenting different approaches.

The first sharing was by Ms Valerie Villasica (PAGASA), providing an overview and background on the climate in the Philippines before elaborating on the outlook, noting through the template the parts that are optional accordingly to the audience's background in the topic. Ms Villasica also shared that the use of memes was very useful for their end-users to better relate to the situation, but preparation in advance is needed. Dr Paromita Chakraborty and Mr Gabriel Lim (MSS) presented an approach on the use of interactive digital technology (e.g. chat function, interactive plots), although it was highlighted these are not to replace but to complement the briefings. Mr Mohd Noor'arifin Haji Yussof and Mr Mohammad Affindi Haji Sabli (BDMD) presented a simple bulletin outlook template, with various modular components to insert the relevant information. They highlighted the importance of communications, and the ways people can reach out to BDMD, while keeping to the limited space in a bulletin or presentation.

Figure 8 Presentation of briefing templates developed during the workshop by Mr Nrak, Mr Siwapornchai, and Ms Sarmani.

Mr Chaowat Siwapornchai (TMD) briefing template covered the targeted audience needs, highlighting the potential users and the impact and decision that may arise from their outlook.

TMD's briefing outlooks also combine and compare different sources of information while keeping it simple for the audience's understanding. Mr So Im Monichoth and Mr Lonh Nrak (MOWRM) demonstrated their briefing format that can be easily converted between physical bulletin and slides mode, showing the usefulness of creating briefing templates. Ms Tran Ngoc Van and Ms Tran Thi Thanh Hien (VNMHA) had to give a verbal presentation using their briefing template as the projector stopped working. They are still able to communicate the content despite the technical difficulties through using the briefing template, sharing on the outlook at a wider region before focusing on a local scale for area of concern. Finally, Mr Sengsouly Somchanhmavong and Ms Sengcan Silattana (DMH, Lao PDR) gave a short briefing of the bulletin template with input of the best practice from the examples.

During the briefing sharing, the use of products was also mentioned, including specifically the products for heat waves. There was the discussion around using probabilities products being less preferred by the users with a perceived higher difficulty in understanding and application of the outlook, thus emphasizing the importance on training and education for the users. Another challenge faced would be when outlooks from different climate centers disagree with each other. While it is convenient to show models agreement, explanation is even more essential when they do not with the responses to be based in science. This is followed by the discussion on how to handle the situation of different responses in the media on ENSO.

Future direction in S2S (Global)

Dr Andrew Robertson gave a presentation on future directions in S2S, focusing primarily on the 'generate and translate' part of developing climate services. The ECMWF 2021 artificial intelligence (A.I.) challenge to improve S2S predictions was mentioned, participants having to beat the ECMWF Extended Range Model to qualify and the group with the most improved skill being the winner. In total, there were less than 20 entries despite being an online challenge. Methods used range from straight empirical to postprocessing (including Machine Learning (ML) and model output statistics) and more complex methods. The algorithms by the participants are publicly available (in GitHub), with some level of technical skills needed to use and implement. Overall, small skill improvement over the models were achieved in the challenge. All the winners used machine learning to post process S2S models in the challenge. Some additional improvement in the use of ML and AI is seen in the S2S Summit held a year and a half after the challenge. A possible challenge is that subseasonal models are lacking the huge catalogue of past cases for ML, although there may be ways to expand this.

Dr Robertson continued on his presentation with a sharing on the PyCPT module by IRI. He shared on the many positive feedback and there are strong reasons to continue improving it further with many people using it. An overview of PyCPT as a tool to implement the NextGen approach was given, including assessment of the past model performance and automatically generating and verify the tailored products. Developed in 2023 for easier usage in multiple operating system, the next version of the module, PyCPT 2.5, focused particularly for seasonal. Work on subseasonal has started but may not be finalized until later in the year. Dr Robertson ended the presentation by running through some steps of PyCPT.

Future Direction in S2S (Southeast Asia)

SEA Regional Climate Centre Network

Mr Wee Leng Tan (MSS) led a presentation and discussion on the Southeast Asia Regional Climate Centre Network (SEA RCC). This is a collaboration between BMKG (Climate Data Note lead), PAGASA (Climate Monitoring Node lead), and MSS (Long-range Forecasting Node Lead). After a quick overview of the website, including highlighting the tropical cyclone outlook by PAGASA (currently the only subseasonal product), Mr Tan gave an overview of the future plans for adding subseasonal information to the website. Using Mentimeter, feedback was sought from the participants about what S2S products they would like to see on the S2S website. On the variables useful for their work, rainfall and temperature are top of the list with all participants choosing these two, followed by wind (64%) and then MJO (21%) and MSLP (14%). For the products type, tercile probabilities map is chosen as the most useful product, with all participants choosing it, with the anomaly map chosen by most of the participants (84%). 62% of the responses chose climatology map as being useful for their work, with quintile and decile probabilities map being less useful for their work (38% and 15% respectively). For the skill score, anomaly correlation had the highest selection (86%), with ROC score, mean square skill score and RPSS chosen by less than half of the participants (43%, 35%, 35%). The results show that the rainfall and temperature being the most important variable, and the NMHSs participants are still more comfortable with the conventional products and skill score they are familiar with. For the file format for download, the participants prefer image plots, followed by data files (e.g. netCDF, grib, binary files) and then GIS-format (e.g. shp, xml, GeoTIFF). Hence, the current set of products on the SEA-RCC LRF can fulfil the needs of the NMHSs, with some additions needed to fulfil their needs fully (e.g. wind forecast, climatology map).

ASMC Fortnightly

A quick recap on the ASMC fortnightly outlook and its format was provided by Dr Thea Turkington, and followed by a sharing on the future of ASMC fortnightly where the finalized images will be automated to allow for weekly updates and the text explanation to retain its fortnightly update frequency. Dr Turkington shared the idea of the involvement of the ASEAN NMHSs in the fortnightly discussions, covering the review of the past two weeks, the current state of climate drivers, and discuss outlook for drivers at subseasonal timescales at each session. NMHSs are welcomed to share on notable events, provide feedback and possibly lead parts of the discussion. The first three trials are to be held on 29 Sep, 13 Oct and 27 Oct 2023, with a review of the trials at the start of November. Dr Turkington sought the interest from the participants with quite a high level of interests from the NMHSs. Dr Claire Spillman also suggested the recording of the discussion for participants who are interested in the discussion but unable to participate.

Future collaboration in S2S for Southeast Asia

The workshop was concluded with the discussion on the future of S2S for the SEA region. Dr Shipra Jain (ASMC) provided a quick introduction on the S2S Prediction Project in WWRP, and the future of WWRP with future projects. The S2S timescale will be covered by SAGE (S2S for Applications for aGriculture and Environment), which will focus on research to operations. There will be equitable representation of social and physical scientists, as well as regional and gender balance. The three themes of SAGE are science, science-to-service, and policymaking, covering water resources, agriculture, energy, and health.

Figure 9 Sharing of key discussion points on future collaboration in S2S for Southeast Asia

This was followed by breakout group discussions on the next step of S2S in SEA, focusing on products in used and needed, challenges faced and the potential for collaborations. A range of products are used by the NMHSs for ENSO, IOD, MJO, TC, SST, and various rainfall and temperature products, with requests of products on heat stress, heat/cold wave, and monsoon index and its forecast for onset and termination. The availability of real-time S2S products and data was also mentioned for their processing to their local needs. For collaborations, the participants looked forward to the ASMC attachment programs and are interested in working together on regional reports, monsoon index and outlook, as well as outlook on drought/flood and heat stress. Training on PyCPT2.5 and coding on Python, as well as on GIS and visualization were also suggested for future regional workshops. The NMHSs faced similar challenges, with communications and interpretation of probabilistic forecasts and impact-based forecast for the users, data access and budget constraints, and the need for automation to meet operational needs while managing the current work commitment.

Key takeaways from Day 3 included future direction of S2S both globally and regionally, with inputs from the NMHSs. Collaboration within the region is strongly supported, with the NMHSs sharing many key issues and challenges.

VIRTUAL SESSION B: 30 AUGUST 2023

With a week for reflection, the NMHS participants and trainers joined together again online along with an additional 26 representatives from the user sector to discuss co-development of S2S products. This day was chaired by Soomi Hong (UN ESCAP).

Highlights

- Discussions between users and producers
- Testing of briefing templates
- Discussion on co-development

Putting into practice the lessons learnt

After welcome remarks and an overview of S2S prediction and the in-person workshop, the first of the two breakout sessions was introduced. The NMHS representatives were split into five groups with various user representatives (see Annex for the list of participants). The NMHS representatives then got to test out their briefing templates that they developed during the in-person workshop and receive feedback from the users.

During the five breakout groups, various NMHS representatives presented outlooks for their country for the next two weeks (at the weekly timescale), followed by a general discussion. Some users had difficulties following the presentations (as they were previously unfamiliar with S2S products), but simple maps and messages made it easier to follow. Users were also interested in how the outlook related to hazards, and questions along these lines how different sectors have different needs, for example how heavy rainfall is defined may be different for the agriculture sector compared to the disaster sector. Visualization was also discussed in a number of groups – including one suggestion for a more consistent colour scheme to help users.

Co-development of S2S products

The final activity of the workshop focused on co-development of products. Raihanul Haque Khan (RIMES) first introduced co-development. Participants then split into four breakout groups, each tasked with coming up with a potential use case, and then to comment on each of the four pillars for climate services development: generate (generate climate information and knowledge), translate (translate into relevant information for users), transfer (how to provide the translated information), and use (put the translated climate information into use).

Group A: This group focused on agriculture and livestock sector, and the use of S2S products for food system resilience. Variables of interest included temperature (maximum and minimum), precipitation, humidity, wind speed and monsoon onset and withdrawal. Translating

into heat stress indices and advisories (which include specific action points) were thought to be useful, along with transfer of the advisories based on location. Distribution of the information also through collaboration with local cooperatives.

Group B: This group also focused on agriculture, with a specific focus on irrigation management to improve water use efficiency and crop health. Similar to group A, variables included precipitation and temperature, along with real-time monitoring of soil-moisture data, and translate this to soil moisture forecast and crop water needs. This information should be combined with crop calendars to help produce potential yield forecasts based on decision trees, transfers using mobile apps, SMS alerts or local agriculture extension services.

Group C: This group focused on heat waves and El Niño. Temperature and relative humidity were seen as the key variables, along with linking with drought and incorporating urban heat island effect (for cities). The information could then be incorporated into action plans for heat waves (including things to do and things not to do).

Group D: This group focused on agriculture and extreme (heavy) rainfall. The goal was to translate subseasonal rainfall information (including skill) to agriculture-related information taking into account the sensitivity of crops to extreme rainfall. Methods to transfer the information included through community leaders and applications that are accessible to farmers.

Overall, there was good discussion between the NMHS participants and the users. Both sides provided valuable information to the discussions: on what could potentially be predicted (NMHSs) or what information was needed and decisions that could be made (users). However, most groups found that more investigation or study is needed to better define the four climate service pillars, therefore much more discussion. But with this final virtual session (along with the earlier training), it is hoped that both the NMHS representatives and the users that attended have the confidence and knowledge to continue discussing and working on co-development of S2S products.

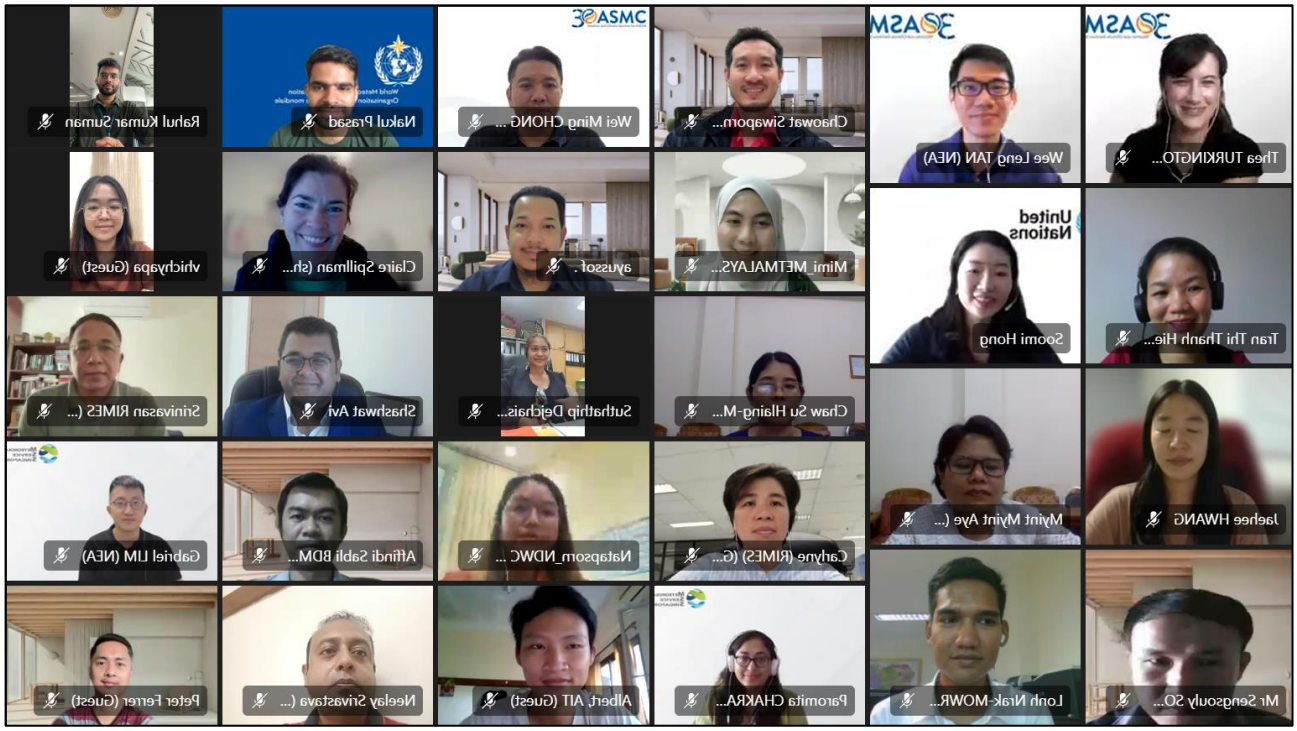


Figure 10 Participants during Virtual Session B of the S2S SEA-IV workshop.

CONCLUSION

The four-part workshop series on the Subseasonal-to-Seasonal (S2S) prediction in Southeast Asia that started in 2017 was concluded with the S2S-SEA IV workshop in August 2023. The S2S-SEA IV workshop consist of both physical in-person and virtual sessions to involve more participants, with the in-person segment focused on the application of S2S products.

The workshop aimed to provide the participants a better understanding of S2S prediction and developed briefing S2S outlook templates for their respective countries. Challenges faced by NMHSs and the need for improved communication, data access, and automation were also highlighted in the in-person segment workshop, with the future of S2S predictions and plans for collaboration in the ASEAN region on S2S also discussed, For the virtual sessions, a session on the background of S2S in SEA and another on user engagement with the regional users were held. In total, over 50 participants were engaged in the S2S-SEA IV workshop. The S2S SEA workshop series demonstrated the importance of sharing experiences and expertise for the development of S2S predictions in Southeast Asia.

ANNEX

Full list of questionnaire results from Virtual session homework (held on 15 August 2023).

Table 2 Results from ASEAN NMHSs that provide subseasonal outlooks.

	Lao PDR	Myanmar	Philippines	Singapore	Thailand	Viet Nam
Timestep of the outlook?	Weekly	10 days	Weekly	Weekly	Weekly, 15 days	10 days
What is the maximum lead time?	1 month	1 month	2 weeks	4 weeks	4 weeks	1 month
Which variables are included?	Temperature, precipitation, tropical storm	Temperature, precipitation, fog, rainy days, Bay Condition including cyclone information	Temperature, precipitation, wind (850, 700, 200hPa), TC Genesis Potential	Temperature, precipitation, winds (925hPa, 850hPa)	Temperature, precipitation	Temperature, precipitation
What climate information is the outlook based on?	ECMWF, ENSO, APCC. SCOPIC. FOCUS. RSMC JMA, KMA	Analogue method, statistical, ENSO, MJO, IOD, Products from Global Climate Center	Dynamical - GEFS, NCEP, ECMWF information on climate drivers like ENSO and MJO	Dynamical - ECMWF, IRI products, ACCESS, information on climate drivers like ENSO, MJO	Composite using the statistical method with dynamic output (IRI, SubX model) and climate phenomena (MJO, IOD, ENSO, Monsoon) as a guideline	Dynamical - ECMWF, IRI products, ACCESS, APCC, TCC, information on climate drivers like ENSO, MJO
As a user of subseasonal information, who are your producers?	ECMWF, JMA, KMA	IMD, NCMRWF/BCWC, WMO, ECMWF, IRI, JMA	ECMWF, BOM, CPC, NCEP-NOAA for MJO	ECMWF, BoM, IRI, APCC	IRI NOAA BOM APCC BCC ECMWF	ECMWF, TCC, NCEP, BoM, IRI, APCC
Which sectors are users?	Agriculture, environmental health, water	Agriculture, disaster risk reduction, health, irrigation, water	Agriculture, public, water	Environmental health, water	Agriculture, environmental health, tourism, water	Energy, environmental health, mining, water
Do you produce tailored outlooks for select users?	Yes	No	Yes	Yes	Yes	Yes

Table 3 As above, but for NMHSs not currently providing subseasonal outlooks

	Brunei	Cambodia	Malaysia
a) Does your NMHS produce seasonal outlooks?	Yes	Yes	Yes
b) Is your NMHS currently considering or developing subseasonal products/outlooks?	Yes	Yes	Yes

List of Participants

Facilitators and resource persons

Name	Organisation
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Claire Spillman	Australian Bureau of Meteorology
Frederic Vitart	European Centre for Medium-Range Weather Forecasts
Govindarajalu Srinivasan	Regional Integrated Multi-Hazard Early Warning System
Soomi Hong	United Nations Economic and Social Commission for Asia and The Pacific
Thea Turkington	ASEAN Specialised Meteorological Centre
Chen Schwartz	ASEAN Specialised Meteorological Centre
Shipra Jain	ASEAN Specialised Meteorological Centre
Wee Leng Tan	ASEAN Specialised Meteorological Centre

National Meteorological and Hydrological Services participants

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Other participants (virtual sessions)

Name	Organisation
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Nina Karla Alparce Jaim	Regional Integrated Multi-Hazard Early Warning System
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Prangya Gupta	United Nations Economic and Social Commission for Asia and The Pacific
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