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

Meeting Report for the Third Workshop (S2S-SEA III)

Singapore, 22 – 26 July 2019

ASEAN Specialised Meteorological Centre (ASMC)

# Acknowledgements

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# Contents

# Executive Summary

The S2S-SEA III workshop, which was held from 22-26 July 2019, marked the start of the second phase of the Capability-building Programme in Subseasonal-To-Seasonal Prediction for Southeast Asia (S2S-SEA). The programme was initiated in 2017 by the Meteorological Service Singapore (MSS), host of the ASEAN Specialised Meteorological Centre (ASMC; asmc.asean.org). S2S-SEA was conducted in collaboration with the WMO's S2S Prediction Project (s2sprediction.net). It is a multi-year series of workshops comprising two phases. The first two workshops in the first phase (S2S-SEA I and II, 2017-18) focused on assessing model skill for Southeast Asia (Rahmat, et al., 2018), while the ongoing second phase of workshops (S2S-SEA III and IV, 2019-2020) explore product development for risk- and impact-based predictions on the S2S timescale with the overarching aim of disaster risk reduction. This aim is to be achieved by engaging end-users in different applications.

*Participants of the S2S-SEA III workshop: NMHS representatives, end-user from disaster management agencies and trainers from IRI, ECMWF, RIMES and ESCAP.*

## Workshop objectives

The third workshop aimed to bring together ASEAN National Meteorological and Hydrological Services (NMHSs) and National Disaster Management Authorities (NDMAs) to promote the development and uptake of subseasonal products in Southeast Asia (list of participants in Annex A). To achieve this objective, the workshop was split into two parts. The first three days involved only the NMHSs, focusing on assessing skill and exploring probabilistic products. Following the first three days, the NMHSs in their

small groups were required to produce a one-page showcase, which was used to explain to the end-users the potential and limitations of S2S products. The NDMA participants then joined in the last two days to discuss the case studies and potentially useful subseasonal products.

## NMHS Sessions: Days 1 - 3

The first three days involved recapping concepts in previous workshops, introducing participants to probabilistic ensemble forecasts, and preparing for case studies. During the workshop, participants made use of the IRI data library: both an online analyses tool and a data repository for many atmospheric products. IRI also introduced the use of PyCPT (Python interface to Climate Predictability Tool) for assessing the skill and forecasts for weekly rainfall anomalies and percentiles with and without Model Output Statistics (MOS) calibration. For the case studies, most groups focused on the first two weeks of lead time, for which the ECMWF model successfully captured the rainfall anomalies for the case studies, as well as was generally more skilful.

During the first three days, the facilitators emphasised that it is crucial for product development to be backed by robust scientific research. Through analysing model skill (verification) and understanding the relevant regional climate drivers on the S2S timescale (attribution of skill), NMHSs will be able to advise end-users better on the potential and limitations of prediction products.

## Bringing together NMHSs and End-Users: Days 4 and 5

After a brief introduction to the NDMA participants, the NMHSs had their work cut out for them to explain the various products they perceive to be useful for the end-users. Following presentations on disaster risk reduction and vulnerability profiles of regions in Southeast Asia, the groups then brainstormed about ways in which subseasonal forecasts could benefit the NDMA users. *A key finding from this activity was that end-users consider 1-2 weeks' lead time sufficient (varies depending on application) to prepare for any extreme weather conditions, thus broadly matching the skill of the model's variables analysed during the first three days of the workshop*.

Two 'serious games' were also held, where participants worked in teams simulating roles as water resource managers. Participants noted that a seemingly simple decision-making activity could get complicated when multiple forecasts information and different lead times are available. However, they acknowledged that the expertise of NMHSs

helped in the decision-making process and that they were able to appreciate the benefits of additional information provided by probabilistic forecast over only deterministic forecast. A post-workshop output which is a primer document on S2S, led by ESCAP and with contributions from ASMC and RIMES, was published (ESCAP, ASMC, and RIMES, 2019). The report is meant to educate on and promote the use of S2S prediction output for disaster risk reduction in Southeast Asia.

## Future plans

Going forward, the SEA-S2S Pilot project was introduced on the last day of the workshop. The Pilot Project was scheduled to begin in November 2019. This project, along with the outcomes from this third S2S-SEA workshop, will form the basis of the final S2S-SEA workshop to be conducted by 2021.

# 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 the ASEAN Specialised Meteorological Centre (ASMC; asmc.asean.org), and in collaboration with the WMO's S2S Prediction Project (s2sprediction.net) and other partners at different stages. The Programme is 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 ongoing second phase of workshops (S2S-SEA III and IV, 2019-2020) explore developing products for risk- and impact-based assessments 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.

## S2S Prediction Project Model Database

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 is accessible from (1) ECMWF database (apps.ecmwf.int/datasets/data/s2s-reforecasts), (2) the IRI Data Library (iridl.ldeo.columbia.edu/SOURCES/.ECMWF/.S2S), and (3) from a site hosted by CMA (s2s.cma.cn). The MEPS provides an extensive set of reforecasts (hindcasts) dataset from several modelling centres. At the moment, the forecast products lag by three weeks and cannot yet be used operationally.

However, access to the reforecasts dataset will allow ASEAN's National Meteorological and Hydrological Services (NMHSs) to preview and assess as a region the S2S dataset's potential benefits and limitations ahead of the real-time products' being made operational. To prepare for the operational products being eventually released either provisionally through the real-time pilot project (2019-2020), or operationally through the WMO Lead Centre platform (Robertson, 2018), S2S-SEA aims to:

- Familiarise the participants with the MEPS database.
- Improve regional understanding of the mechanisms of subseasonal-to-seasonal predictability (for e.g. the Madden-Julian Oscillation).

- 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.

Hence, S2S-SEA activities aim to build capacity and enhance collaboration among the NMHSs in the region to tackle the predictability of the weather and climate on this timescale. This report summarises the proceedings at the Third Workshop (S2S-SEA III). A summary of activities during the First and Second Workshop (S2S-SEA I & II) is available in the S2S News Letter 10 (Rahmat, et al., 2018).

# Day 1: 22nd Jul 2019, Monday

## Introductions

**Highlights**

- Introduction to S2S Prediction Project
- Review of past workshops
- Introduction to IRI Data Library, CPT, and PyCPT
- Setting up and introduction to Jupyter Notebook

The workshop started with a welcome address from Prof Erland Källén, who highlighted the importance of thinking about the end-users when developing prediction products. He also emphasised the research that needs to be done before issuing these products. The welcome address was followed by a round-table introduction by all of the 5-day participants, who came from various backgrounds: forecasters for short-term weather forecasts, staff who were working already on subseasonal predictions, and also weather and hydrological modellers.

*Updates on the S2S Prediction Project*

Dr Frédéric Vitart from the European Centre for Medium-range Weather Forecasts (ECMWF) then gave an introduction on S2S and the S2S Prediction Project. S2S forecasts are a mix of initial-value problem for the atmosphere (for example, forecasting the Madden Julian Oscillation, MJO) and boundary-value problem (for example soil moisture, snow cover, sea ice, and sea-surface temperatures). However, there are some atmosphere-only (by persisting the boundary values) models that have reasonable skill, indicating that at the S2S timescale, the primary issue is initial-value, followed by boundary values for additional skill.

Since the inception of the S2S Prediction Project, the S2S community and data have grown. As of the start of this workshop, more than 100 TB of data is available from the database, the number of users of the database has increased, and more than 70 articles using the S2S database have been published. Dr Vitart also provided an overview of the S2S Prediction Project Phase 2 (2019-2023) including the various science questions to be tackled (e.g. how might anomalies in land surface states contribute to extremes?) and the increasing focus in providing service to users of the products (e.g. the Real-time Pilot for S2S Applications research & demonstrations).

*Overview of the S2S-SEA Capability Building Programme*

Focusing next on the regional level, Mr Raizan Rahmat provided an overview of the S2S-SEA Capability Building Programme and reviewed the outcomes from the first two workshops of the series. The first workshop assessed model skill for weekly rainfall and temperature anomalies, while the second workshop assessed various indices, such as the number of wet or dry days in a week. Recapping the examples from the earlier workshops, he demonstrated the potential skill of S2S forecasts, which provided motivation for the Third Workshop. Mr Rahmat also covered essential concepts for the rest of the workshop, including deterministic forecasts ("spot" forecasts of actual rainfall amount) and probabilistic forecasts (which capture the uncertainty). The concept of lead times, or how far ahead the forecast is produced from the event, within the modelling system and workshop convention was also introduced.


*Mr Raizan Rahmat introducing the role of the S2S-SEA Capability Building Programme in bridging the S2S Prediction Project to Southeast Asia's NMHSs.*

## Getting practical

*Linux, Virtual Machines, and Jupyter Notebook*

The rest of Day 1 focused on the practical matters of installing the required software on the participants' laptops and familiarising them with the technical concepts covered during the workshop. Each participant installed a virtual machine on their laptops, which allowed all the necessary tools to be pre-installed. This approach is useful when the tool that is being used depends on specific packages/dependencies. Otherwise, these dependencies can lead to installation challenges with participants using different operating systems.

*During the afternoon Mr Ryan Kang and Ms Regine Ho led the group in exploring the basics of Linux (the OS of the virtual machine) and Python.*

In between these activities, Dr Vitart elaborated on the S2S models and the S2S Database, with a focus on the ECMWF model

used during the workshop. He also highlighted sources for up-to-date information on S2S models (necessary as many of the S2S models are regularly updated) as well as S2S products, such as the MJO RMM index, available through the ECMWF research page and the S2S Museum respectively.

*Hands on experience using IRI Data Library for plotting.*

*Introducing IRI Data Library*

Dr Ángel Muñoz from the International Research Institute for Climate and Society (IRI) introduced the IRI Data Library: a web browser interface that allows users a central access point for many environmental datasets, as well as users to perform various mathematical operations for analysis, and a 'Map Room' to visualise the output and data. Participants tested out locating data, analysing this data and created short animations of climate plots.

*Introducing PyCPT*

The final activity of the day was the introduction of PyCPT by Dr Muñoz. PyCPT is a Python interface for the Climate Predictability Tool (CPT). The CPT is designed to produce statistical forecasts using model output, including training the model, validation and verification at the seasonal timescale. As statistical techniques in CPT require significant amounts of training data, PyCPT helps by downloading sufficient S2S data for training, formatting the data for input into CPT, as well as visualising the output. Going forward, Dr Muñoz noted that IRI wanted to build a community for the development of PyCPT. Before ending the day, the participants had the opportunity to make their first trial runs of PyCPT.

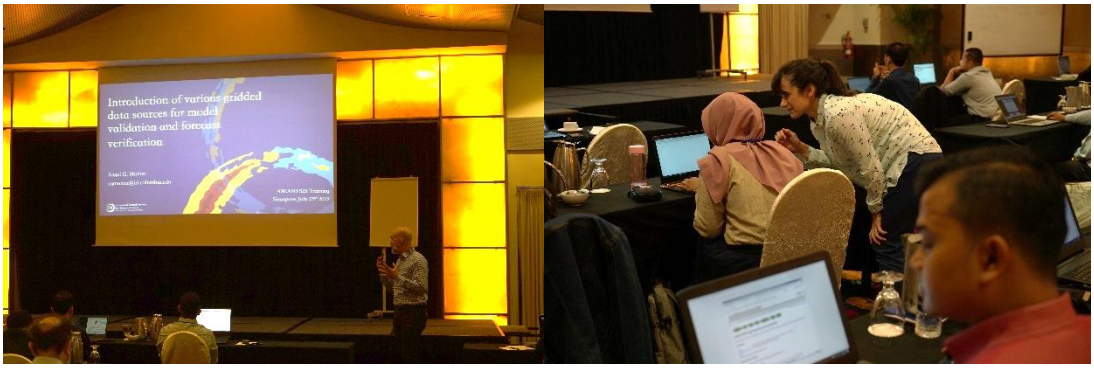
# Day 2: 23rd Jul 2019, Tuesday

## Gridded products and introduction to forecast verification

**Highlights**

- Data sources for model verification
- Ensemble predictions systems
- Assessing probabilistic forecast performance
- PyCPT detailed walkthrough

Dr Ángel Muñoz from IRI introduced to participants forecast verification techniques and gridded products used for verification. He emphasised that the verification has to be done before the forecast is being used as one needs to be aware of its performance and limitations. There are various methods to verify the model forecast, and the specific application of the forecasts is used to determine the appropriate verification method.




*(Left) Dr Muñoz giving an introductory lecture on forecast verification. (Right) Dr Turkington assisting the participants in the practical session on IRI Data Library.*

*Types of verification scores*

Dr Muñoz referred to the WMO's Guideline on Verification of Operational Seasonal Climate Forecasts (2018) by Dr Simon Mason for the list of attributes and metrics for verification. As there are multiple ways to assess model forecast, Dr Muñoz covered several different methods, which are Pearson's, Spearman's and Kendall's correlations, Two-Alternative Forced Choice (2AFC), Generalized Relative Operating Characteristic (GROC), and Relative Operating Characteristic (ROC). He showed an example of the association between model and observation, which demonstrates strong Pearson correlation. Pearson's and Spearman's correlation were compared, with the former requiring linear relationships between variables, while the latter does not require that

assumption. Both methods are sensitive to outlier data. Dr Muñoz also mentioned that both GROC and ROC fall under 2AFC, and they measure discrimination.

*More on IRI Data Library*

Following the introduction to the IRI Data Library's (IRIDL) basic features on Day 1, Dr Muñoz further shared on ways to download gridded observation products. Through the practical sessions, the participants were taught to use IRIDL for data selection, visualisation, downloading, as well as filtering and interpolation of the data for display, using CHIRPS v2.0 as an example observation dataset. He also showed how the Expert Mode (Ingrid) tool on IRIDL could be used to generate climatology, time series, and spatial plots of averages. To modify and match the resolutions between the model forecasts and observations, participants were taught interpolation techniques through the Expert Mode. The appropriate interpolation technique is necessary when comparing model forecasts with observations. For example, it has to be done at the coarser resolution of the two to avoid introducing artificial features that may arise when data is processed to match the higher resolution dataset.

*More on PyCPT*

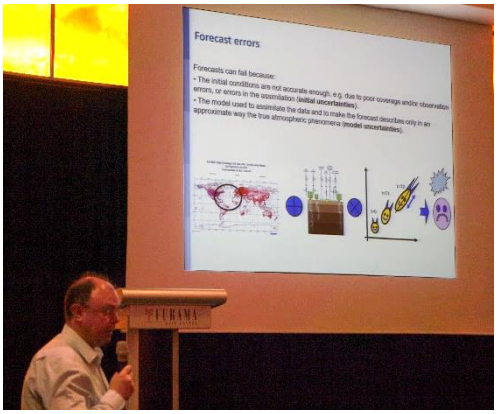

*PyCPT script and sample outputs. Participants were shown how to run the scripts and check their outputs.*

Dr Muñoz also went through the PyCPT scripts with the participants, describing the verification parts of the code in detail. To improve the verification's statistical significance in the example used for the workshop (ECMWF forecast and CHIRPS), PyCPT increases the number of verification samples by including data in the proximity (before and after) of the period of interest.

## Probabilistic predictions

*Ensemble predictions*

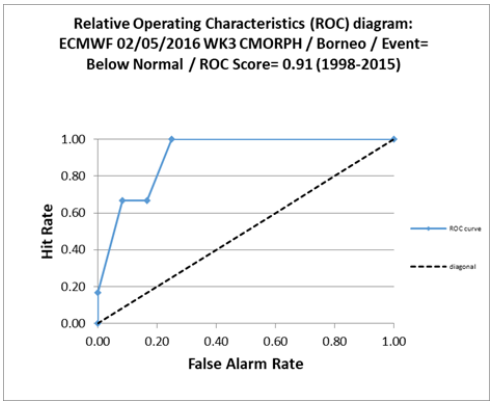
Dr Frédéric Vitart from ECMWF gave an introductory lecture on ensemble predictions. He mentioned that while ensemble prediction is more complicated than a simple value from the deterministic forecast, forecast errors can proliferate in a chaotic system and an ensemble prediction can help to capture uncertainty in the forecast.




*Dr Vitart explaining ensemble forecast. He explained the possible forecast errors in the ensemble system.*

Dr Vitart then touched on how an ensemble is produced and the need for a multi-model approach to capture differences between models (such as differences in model physics and data used). The various strategies to generate the different ensembles have their advantages and disadvantages and it is not clear yet which approach is more optimal for S2S, and more research on this is needed.

*Probabilistic forecast verification*




*A screenshot showing model skill at a lead time of three weeks based on the ROC score from an introductory lecture probabilistic forecast verification by Dr Turkington.*

Dr Thea Turkington from the Centre for Climate Research Singapore introduced the concept of probabilistic forecast verification to ensure a good foundation for subsequent activities. Dr Turkington compared and contrasted the two different types of forecasts, deterministic and probabilistic. She also covered basics such as probabilistic distribution function, cumulative distribution function, probabilities of exceedance, tercile forecasts, and probabilistic threshold forecast. The attributes of a 'good' probabilistic forecast were covered, such as *discrimination*, *sharpness*, *resolution*, *reliability* and *skill*, but of course, the *usefulness* of the forecast is also essential.

To test participants' understanding of the concepts of probabilistic forecast and verification, Dr Turkington led a practical session using Microsoft Excel adapted from a

similar exercise conducted by Dr Richard Graham from the UK Met Office. The participants were provided ensemble hindcast S2S data to assess the skill of tercile predictions and use this to evaluate the confidence to attach to the predictions. Participants compared model performance over lead times of one week and three weeks using ROC scores for different terciles.

## Guest Presentation: MJO-ENSO/IOD interactions

Dr Koh Tieh Yong from the Singapore University of Social Science (SUSS) and who is a member of the Madden-Julian Oscillation (MJO) Task Force presented on the MJO-El Niño Southern Oscillation/ Indian Ocean Dipole (ENSO/IOD) interactions in Southeast Asia region and provided the modelling perspectives regarding these interactions. Dr Koh mentioned that while observations can be coherently assimilated into and consequently improve simulations in dynamical models, we have yet to develop a regional model well adapted to the tropical weather and climate, especially on convection which is vital for MJO simulations.

*Dr Koh on MJO-ENSO/IOD interactions.*

Results that Dr Koh shared included his team exploration of a model that was adjusted to be sensitive to convection. The model's modifications sufficiently improved common model biases for Southeast Asia/the Maritime Continent, but the model still lacked in many areas. Other study results shared in the presentation included the effect of ENSO and IOD on the MJO RMM amplitude, which depends both on the time of year and the phases of both ENSO and IOD. Overall Dr Koh highlighted the importance of convection in models for Southeast Asia, as well as understanding the interplay between subseasonal and seasonal drivers.

# Day 3: 24th Jul 2019, Wednesday

**Highlights**

- Advanced techniques in PyCPT (MOS)
- Forecast products in PyCPT
- Forecast skill and confidence in relation to climate drivers
- Practical sessions in PyCPT
- Preparation for case studies

## Model Output Statistics

Dr Ángel Muñoz started the third day by describing the calibration techniques in PyCPT called Model Output Statistics (MOS). He emphasised that due to uncertainties in (1) initial/boundary conditions, (2) unknown or unresolved physical processes, and (3) the chaotic nature of the climate system, models will always contain errors. If these errors are systematic, these can be corrected using MOS. Otherwise, the errors are managed by capturing the uncertainty using probabilistic predictions. MOS correction is a technique commonly used for removing mean, amplitude and conditional biases in seasonal forecasts, but in *subseasonal* forecasts the method has not been as elaborately tested. Therefore, testing the technique for the subseasonal timescale was a key outcome of this workshop.

## Forecasting in relation to drivers

Dr Andrew Robertson gave a lecture on the predictability behind the S2S timescale which is linked to the climate drivers, for example, MJO, ENSO and other slowly-varying surface boundary conditions such as sea-surface temperatures, soil moisture, and snow and ice. He noted that the skill of subseasonal predictions tends to cover larger areas of the globe compared to seasonal timescale, but the skill maximum in subseasonal predictions tends to be lower in these areas. Thus the prediction skill in both timescales can complement in line with the "Seamless Predictability" concept. For Southeast Asia, for example, he quoted a study by Li & Robertson, 2015 which demonstrated the influence of both ENSO and MJO on rainfall predictability in the region. Focusing on a case study over Borneo in June - July 2002, he showed how the forecasts from ECMWF model for both positive and negative rainfall anomalies, as observed in CMAP observations, performed well in the presence of MJO propagating through the Maritime Continent.

## Practical sessions and case studies

Participants spent the rest of Day 3 delving deeper into PyCPT's features and running PyCPT in full, which includes configuring and generating specific products of interest. They have flexibility in choosing between deterministic (anomalies) or probabilistic forecasts (terciles, above/below thresholds), and calibrated (MOS) or non-calibrated forecasts (no MOS). Participants explored a variety of skill score maps which helps them to interpret forecasts confidence. To prepare for the end-user sessions on Day 4 and Day 5, the NMHS participants also discussed which products among those available in PyCPT that they considered to be useful for the case studies.

*Mr Raizan Rahmat discussing with the participants investigating the Viet Nam 2018 case study.*

One of their tasks for the case studies was to explain simply the potential and limitations of the products of their choice. Another task is to understand the needs of the end-users better and consider other possible products not already available. In short, they were to come up with ways in which subseasonal forecasts could be practically used, using the case studies as examples. To this end, they produced 1-page case study 'brochures' to share with end-users and prepared a 15-min presentation for Day 5 incorporating inputs from end-users. The five case studies covered significant drought and heavy rainfall conditions in different parts of Southeast Asia in 2016-2018.

## PyCPT wish list

Dr Muñoz also led a discussion on improving the PyCPT. It was time to get feedback from the participants, having being exposed to the tool for a few days, on how PyCPT could be further improved in terms of the products, features and interface. Some participants suggested simple look-and-feel improvements such as changes in the labels and sizes on the maps, visual feedback to alert users of errors or completed runs, and the ability to save plots. Other changes required more effort, for example, in adding start dates for model data being downloaded and processed, allowing OPeNDAP access CPT datasets, running and processing multiple models and ensemble members. It was also suggested to have more detailed documentation for PyCPT. Dr Muñoz informed that IRI would be incorporating these changes through partners' contributions.

# Day 4: 25th Jul 2019, Thursday

## S2S introduction to end-users

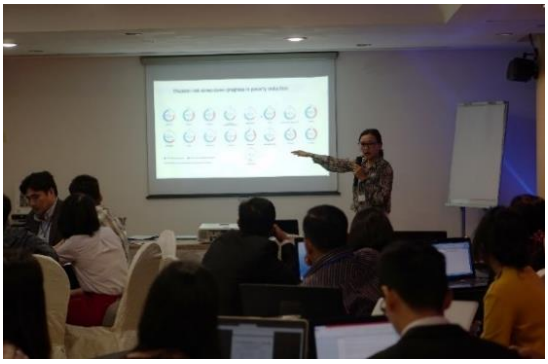
The last two days of S2S-SEA III were dedicated to end-users to discuss how S2S prediction could potentially be useful for different applications. Dr Robertson started Day 4 by giving an introductory talk on S2S. The S2S Prediction Project aims to bring together weather and climate communities, including researchers, forecasters, and end-users, toward more "seamless" prediction across scales. For the second 5-year phase of the project from 2019 to 2023, it will focus on various research questions, including a new S2S Research-to-Operations (R2O) focus to develop forecast and verification products. An S2S "real-time pilot" project would start in November 2019 to demonstrate real-time use of S2S predictions across a spectrum of applications & Global Framework for Climate Services (GFCS) sectors.

### Highlights

- Introduction to S2S to end-users
- Application of S2S in disaster-risk reduction
- Case studies and vulnerability profiles
- MJO Task Force activities
- "Serious Games": decision-making simulation activities

*Dr Robertson giving an introductory talk on S2S predictions to end-users from different sectors.*

## Disaster risk reduction



*Ms Rafisura (UN ESCAP) sharing with participants the potential use of S2S predictions in disaster-risk reduction.*

Ms Kareff Rafisura from the ESCAP gave an introduction on how weather and climate predictions could be useful for disaster risk reduction. She shared that products from S2S predictions can potentially be used as one of the tools to reverse the trend of the poverty trap in this region when applied to various sectors. But for S2S predictions to be useful, we have to bring in end-users early to co-design forecasts products. Ms Rafisura also highlighted some challenges such where end-users tend to look

at more localised scales than models can possibly inform, and there is institution inertia among agencies in some countries to act on available prediction information. Agencies also need to formulate decision-trees to respond to prediction information and manage disaster risk, and decision-linked processes need to be specific for each sector.

Ms Rafisura also shared four strategies to promote S2S products for disaster risk reduction and encourage uptake. These are user-needs assessment, product co-development, pilot testing, and co-integration into decision-making. Participants were then instructed to use this framework to guide their within-group discussions on the case studies.


*Recommended strategies, for promoting S2S products for disaster risk reduction under S2S-SEA, which are being incorporated into the fourth and fifth workshop.*

## Vulnerability profiles of case study locations

Ms Laura Hendy covered impacts on the region by the five case studies that the NMHSs participants had prepared materials for on Day 3. These events were high impact events that affected various sectors in each country.

Using the Sub-National Human Development Index's (SHDI) database, Ms Hendy identified the exposure and vulnerability of the populations for each of the regions. SHDI is a proxy index that measures the reverse of vulnerability, i.e. high SHDI means less vulnerable. However, it should be noted that an extreme event could severely impact a region with high SHDI. Thus, information on vulnerability is combined with the likelihood of events to generate risk maps for various categories of extreme events. Subsequently, the costs of action have to be weighed against the costs of inactions for each town or city.


*Ms Hendy shared on the vulnerability profiles of different regions for five case studies that would be co-analysed by the NMHS and end-users.*

## MJO Task Force: An introduction

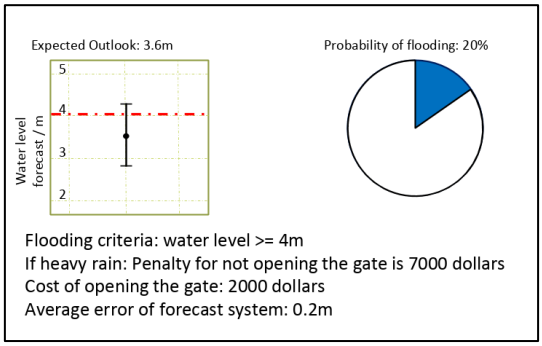
An expert from the MJO scientific community, Assoc Prof Koh Tieh Yong (Singapore University of Social Sciences), was invited to share with participants the upstream

scientific activities related to S2S Predictions, particularly the MJO research activities of the WMO's Working Group on Numerical Experimentation (WGNE) MJO Task Force (MJO-TF). He shared the goal of the MJO-TF is to facilitate improvements in the representation of the MJO in weather and climate models. The other aim is to increase the predictive skill of the MJO and related weather and climate phenomena. Assoc Prof Koh also broadly highlighted the plans for future activities in the MJO-TF which may be of interest to S2S-SEA. These include ongoing analyses of how well key physical processes are represented in simulations of MJO propagating through Maritime Continent, and the enhanced observations and modelling efforts from the Year of Maritime Continent (YMC; https://www.pmel.noaa.gov/ymc/).

## Serious Games

Two "serious games", adapted from the Hydrologic Ensemble Prediction Experiment (HEPEX), were conducted during the workshop to simulate decision-making with forecast products. The first activity tested the concepts and applications of deterministic forecast vs probabilistic forecast, while the second activity simulated decision-making using forecasts with various lead times.

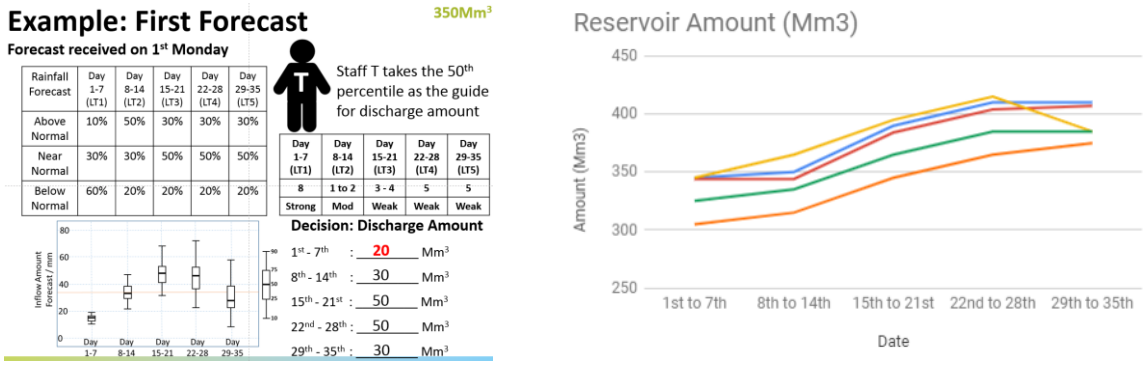
For the first activity, the participants were provided with forecasts and had to decide whether to open a flood gate (anticipating heavy rainfall) to divert water away from the city or not, a decision that cost less than the city flooding. In the first round, participants used both deterministic and probabilistic forecasts, while in the second they only used deterministic forecast. Comparing the two rounds, the participants shared that the additional spread provided by probabilistic forecast was valuable information crucial to their decision-making. Consequently, the participants were able to appreciate the benefits of additional information provided by probabilistic forecast over just deterministic forecast alone.




*Example of single-day outlook information provided in the first activity to help participants simulate making decisions.*

The second activity used weekly (subseasonal) forecast products for the upcoming five weeks. The participants had to decide on the amount of water to be discharged from a reservoir to ensure enough water after the rainy season while not overflowing the dam. The forecast products included rainfall tercile forecasts, MJO forecast, and boxplots of

consequent water inflow to the reservoir. Even with additional information, three groups (out of five) were unable to keep the water level in the safe region and overflowed the dam by the fourth round. Participants noted that multiple forecasts information at different lead times could complicate a seemingly simple decision-making activity. However, they acknowledged that the expertise of NMHSs helped in the decision-making process. Overall, the decision-making games received positive feedback from the participants with some of the NMHSs interested in conducting similar activities in their training workshops.




*(Left) Forecast provided for the second activity was rainfall terciles, MJO, and inflow amount. The participants had to plan the discharge amounts with the information provided. (Right) The reservoir amounts for each group after each forecast periods.*

## Case study discussions

The NMHS and end-user participants were split into five groups on Day 4 to analyse five different extreme weather events (case studies) in recent years. The objectives were to study if such S2S predictions were able to predict such events, as well as what type of derived forecast products were more skilful and, at the same time, useful for the different sectors. Based on the group discussions and information from the preceding four days, each group produced a short presentation to highlight their results.

# Day 5: 26th Jul 2019, Friday

## Case studies presentations

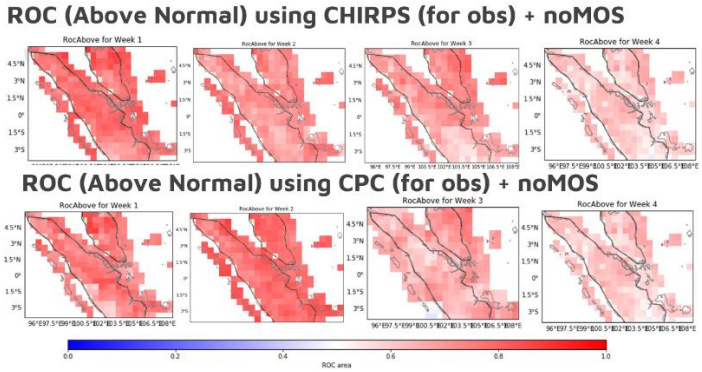
Day 5 started with presentations on each of the five case studies. These case studies were selected because of their severity and significant impacts on the affected communities.

### Highlights

- Case studies presentations
- Breakout Session: S2S predictions in various sectors
- Real-time pilot project

### February 2016: flash floods in Malaysia and Indonesia

The year 2016 experienced a strong El Niño, which usually leads to drier conditions in February over large parts of Maritime Continent. It was, however, unusually wet during this period. The heavy rain events were due to the combined effects of a Northeast Monsoon Surge and the MJO in Phase 4, which typically brings wetter weather over the Maritime Continent.



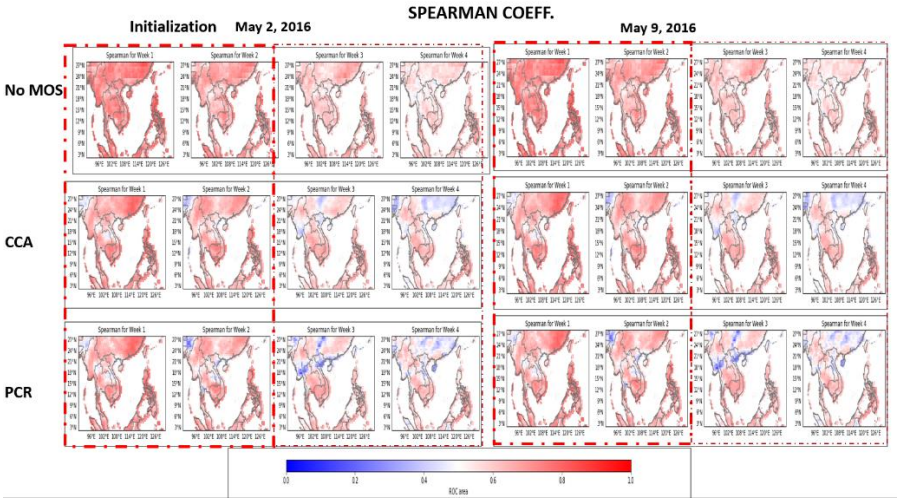

*Participants' slide showing high ROC Skill Score (Above-Normal Tercile category) for lead times of one or two weeks ahead for the area of interest.*

For the flooding event which occurred in the week of 4-10 February 2016, there was a lead time up to two weeks where "No MOS" predictions indicated higher probabilities of above-normal rainfall occurring. As for the skill score, higher ROC scores for lead times of one and two weeks ahead were observed. MOS techniques of PCR and CCA were able to improve the probabilities of above-normal rainfall up to a lead time of two weeks.

For this case, the end-users found deterministic forecasts to be more useful. They also requested for higher spatial resolution forecasts but would be content with a minimum lead time of one week. In terms of tailored probabilistic forecast products, they preferred absolute thresholds over percentile thresholds for rainfall amount exceedance because absolute thresholds were simpler to interpret.

## May 2016: drought over the Philippines and Myanmar

The model's forecast of anomalies from ECMWF for the drought event in May 2016 (model initialisation dates May 2 and May 9, 2016) shows good skill in forecasting the event with a correlation score of 0.7 for "No MOS" configuration in PyCPT. The skill decreased when CCA and PCR were applied but still showed relatively good skill when forecasting one or two weeks ahead. For three or four weeks ahead, the skill diminishes but still significant in most of the areas in the Philippines and Myanmar.



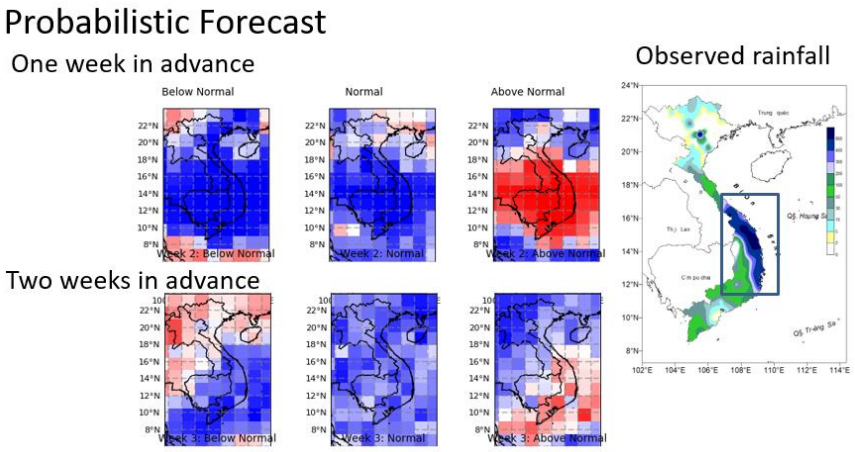

*Participants' slide showing high Spearman coefficient for Week 1 and Week 2 for predictions with "No MOS" compared to predictions with CCA or PCR applied.*

End-users generally commented that forecasts should be simple to understand, and be 'as accurate as possible'. They also noted that for some end-users, for example, military users, qualitative assessments and text messages of forecast information are preferred as such users do not understand forecast maps and therefore are unable to interpret the maps themselves.

## 12-18 December 2016: Heavy rainfall over Vietnam

Using tercile probabilities of above-normal precipitation ("No MOS"), the heavy rainfall conditions over Vietnam was detected up to a lead time of two weeks. However, the prediction signal in two weeks' lead time was much weaker than one week's lead time. A forecast produced using PCR, however, degraded the result. The NMHS participants in the group postulated that it could be due to the choice of predictor domain that could have the wrong large-scale physical factors. The group also suggested for a synoptic map-room to be made available with mean sea level pressure and wind fields, for example, combined with S2S predictions. Such a setup would be instrumental in providing better

understanding of large-scale background factors and consequently better forecasts during the Northeast Monsoon season during which this event took place.

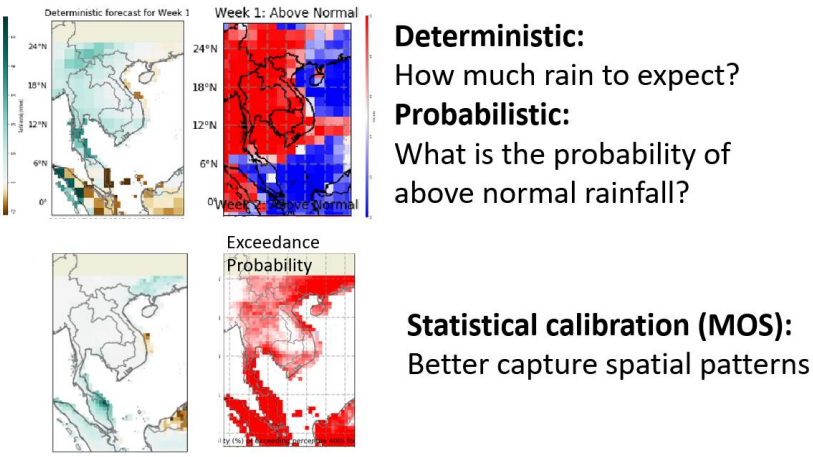



*(Left) Heavy rain could be detected with a lead time of up to two weeks (forecast in Week 3) using "No MOS" configuration. (Right) Observed rainfall total amount for the period 12-18 December 2016.*

From the end-user perspectives, they noted that frequent forecast updates would be useful following the first detection of heavy rainfall signal (two weeks in advance). They also requested for NMHSs to provide historical information of similar rainfall events which also led to flooding. This accompanying information would be useful to make comparisons with impending events, i.e. if they would lead to similar consequences and which would help decision-makers direct resources to more flood-prone areas.

## 2-8 January 2017: Floods in southern Thailand

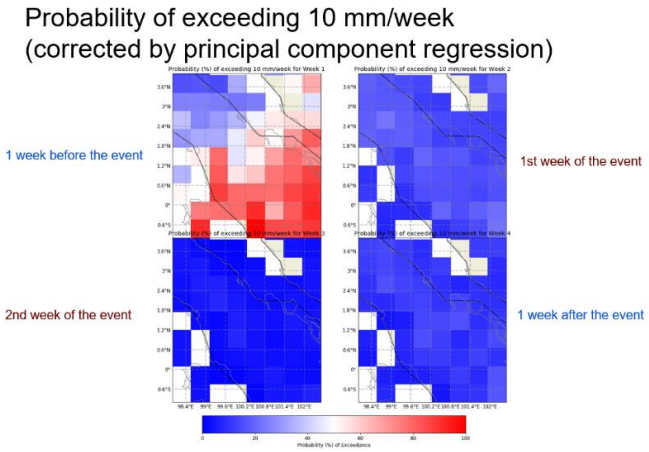
For this case study, MOS was better at capturing spatial patterns of the flooding in southern Thailand. The skill of the model was observed up to a lead time of two weeks. End-users had expressed that they would need up to two or three weeks of lead time. Thus the model in this instance was able to provide useful information for decision-makers to plan for the extreme event.



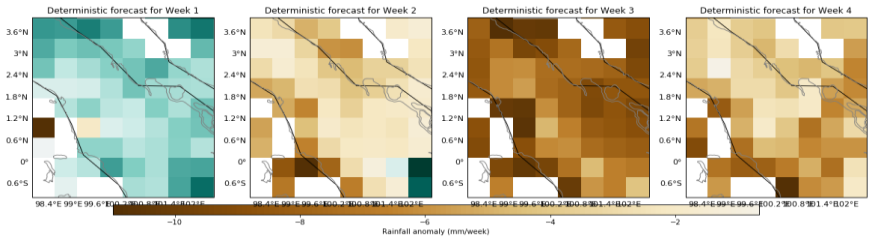

*Participants' slide showing MOS-applied prediction (bottom row) was better than no MOS configuration (top row) in capturing the spatial pattern of the flooding in southern Thailand for both the deterministic (left column) and probabilistic (right column) predictions.*

## 6-19 August 2018: Drought related haze in Indonesia and Malaysia

For this case study, the participants used the products: the probability of rainfall exceeding 10 mm/week and weekly rainfall anomalies. The PyCPT's MOS configuration of PCR provided a better estimation of more severe drought conditions. A lead time of up to three weeks could be observed using this approach.




*A lead time of three weeks to detect the drought conditions using PyCPT's MOS configuration.*




*Rainfall anomaly forecasted one week before the haze event. Week 2 and week 3 correspond to the period of the haze event (at a lead time of 2 and 3 weeks, respectively).*

End-users required the risk for haze-conducive conditions to be predicted two weeks in advance so that more effective pre-emptive measures could be taken, for example, to distribute face masks to the most vulnerable communities. They also suggested for such forecasts capabilities to be institutionalised through inter-agency cooperation to allow for faster response time to impending disasters. These entities would be provided with, for example, risk maps accompanied by S2S predictions.

## Breakout Session: S2S predictions in various sectors

A breakout session was organised for participants to come together to discuss emergencies caused by weather and climate and how S2S products can potentially be applied. Participants were split into four groups: water resources, agriculture, public health management (focusing on heatwave, air quality, and climate-related diseases), and disaster risk reduction (flooding and landslides). Each group was allocated thirty minutes to brainstorm and five minutes to present their ideas.

Participants were given discussion questions asking: (1) what specific S2S products would be useful to the relevant applications, including minimum spatial resolution required (e.g. provincial or national level), (2) the minimum length of lead-time desired, (3) rainfall or temperature thresholds that the application would be sensitive to, and (4) platforms (modes of delivery) and level of information that might be useful for different types of end-users.

### Water resources

Participants focused on hydrological droughts arising from shortfalls in groundwater, reservoirs and lakes. Problems on water availability (and conservation) were also discussed regarding the sufficiency for the whole population, specific population or city area, for consumption, irrigation and ecology purposes. Local-scale resolution information for monitoring water levels of river basins would be useful to detect impending droughts. Also, drought-related indices such as the Standard Precipitation Evaporation Index (SPEI) and soil moisture would be helpful to monitor drought cases. For prediction purposes, tercile probabilities for above-, below- and near-normal rainfall categories were mentioned as potential useful S2S products, as well as the outlook on the number of dry days, with lead times between two weeks to less than three months.

During the Q&A session, the difficulty in translating S2S products was brought up. It was suggested that more efforts were needed to explain the basis of the products at the

national level. An example of such activities is climate or monsoon forums held at local levels that include training for the community to read maps and interpret weather forecasts from the available weather and climate information portals. It was also shared that among variables linked to drought, temperature was also closely monitored apart from rainfall.

### Agriculture management

The key challenges identified in agriculture management were the need for strategic planning and timing for ploughing (or tillage), sowing, transplanting of seedlings, harvesting and post-harvesting, irrigation and treatments of crops. Deterministic forecasts (with uncertainty bars to show the forecast spread) and tercile probabilities (with thresholds of below- and above-normal) were the S2S products mentioned that could be useful for agricultural applications. A lead time of two to three weeks was also suggested to be enough for forecasting rainfall amount and temperature. The timeliness of forecasts is necessary for both dry spells and wet conditions. It was also shared that different spatial resolutions could be useful for various applications, in the sense that institutes and agencies could benefit differently from the provincial, national and transnational (regional) levels of information provided.

During the Q&A session, the example of the Australia 2018 heatwave, fire and drought (which occurred mainly in the central, eastern and south-eastern regions of Australia) was highlighted. In anticipation of such events, changes in local practices of agriculture in Australia were necessary, such as farmers having to adjust timings for treatment of crops to minimise losses due to fire and drought. Experienced farming practices and seasonal predictions of the climate would help alleviate the problem of crop losses, with farmers being mindful of the variability and changes in the climate from time to time. In applying S2S products, the use of lead-times shorter than that of seasonal prediction can be useful to prepare farmers for harvesting. For example, if rainfall is forecasted to be consecutive for 15 to 20 days, it could help with initial harvesting for specific crops.

### Public health management (heatwave, air quality, and diseases)

Extreme temperatures (or dry weathers) in the region could lead to forest fires, leading to haze and deterioration of air quality, affecting public health. Participants discussed that predictions with a lead time of three months would benefit the government

and community to prepare for risks of extreme temperatures and low rainfall. While indices such as the Pollutant Standards Index (PSI) have been useful in providing health advisories for the public, participants also discussed the feasibility of "age-dependent" thresholds for the tolerance of air pollution.

During the Q&A session, various thresholds for warm temperatures was discussed, for notifications of risks of extreme temperatures. In some countries, 40°C was the threshold over which schools would be closed. Participants also mentioned the use of the Heat Index provided by the World Meteorological Organization (WMO) to indicate the risk of extreme temperatures and humidity levels. For S2S predictions of such events, participants acknowledged the potential usefulness of S2S predictions but wondered if they would end up with more false alarms than correct forecasts.

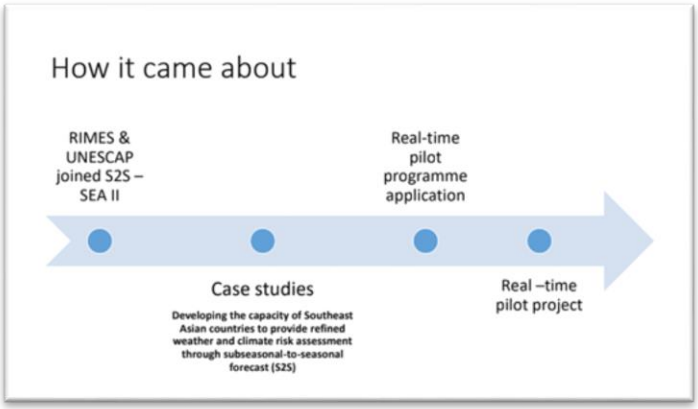
### Disaster risk reduction (on flooding and landslides)

Participants discussed that municipal and communal (~1 to 2 km) resolutions information are necessary for forecasting floods and landslides respectively. Information required is the total amount of rainfall in flood- or landslide-prone areas, as well as the duration and intensity of the rain. Other key inputs necessary for predicting the risk of flooding or landslides are topography, slope, soil type, irrigation activities, water levels in reservoirs or dams, and vegetation cover of the prone areas. Given the complexity of landslides occurrences, and they could occur during rainy or non-rainy seasons, participants questioned if S2S predictions could be effective. For flooding, the challenges come more from downstream issues, for example, properly working drainage system that can ensure smooth water flow out of the city.

In summary, participants highlighted that while S2S predictions can help inform decisions to minimise the impact of exigencies, other downstream factors in the different sectors can make the problems difficult to solve. Nevertheless, these problems present opportunities to strengthen the links between the information providers (NMHSs) and consumers (end-users).

## Real-time pilot project

As part of the second phase of the S2S Prediction Project, a real-time pilot initiative has been developed with the WWRP's Societal and Economic Research Applications (SERA) group. The main goals include demonstrating the value of S2S forecasts in various applications, promote the interdisciplinary research for the development of S2S applications, as well as to reach more potential users of S2S forecasts. One of the 16 accepted application projects was submitted by ASMC, in collaboration with UNESCAP, and RIMES for the development of S2S forecasts for disaster risk management in selected Southeast Asia countries. With the presence of NMHS representatives, end-users, and the co-chairs of the S2S Prediction Project, the last day of the Workshop provided an excellent opportunity for feedback from the participants regarding the workplan for the S2S-SEA real-time pilot project.




*Origins of the ASMC, UNESCAP, RIMES application for S2S Real-time Pilot Project*

A draft workflow was presented to the participants to elicit feedback. The preliminary plan for the pilot project was for ASMC to provide plots to NMHSs who would then translate these for the NDMA participants (the end-users). To close the communication loop, end-users will give regular feedback on how the information was used, suggest what modifications are needed for the plots or assessments, and highlight any weather- and climate-related disasters encountered. When discussing the feasibility of this workflow, most participants thought the weekly cycles of information provided would be too frequent to process, preferring instead every fortnight.

With regards to potential end-users to engage with, many of the countries identified the national disaster risk management agencies (or national equivalent) in their country. Some less commonly identified potential users were agriculture groups, water resources, and public health. When asked about products of interests, most groups identified broad categories (rainfall, temperature, wind, and SST). However, for participants who gave specific examples, these varied widely between scales (weekly, 10-day, monthly), as well as variables (rainfall anomalies, number of dry days, probability of heavy rainfall). The discussions showed that while there is potential to use S2S information in Southeast Asia,

narrowing down to the products relevant to particular end-users requires further in-depth investigation.

Mr Randy Adrian from the ASEAN Secretariat closed this session by highlighting the importance of such pilot projects to understand how to apply subseasonal forecast information. He mentioned that there was potential for some regional support for such projects and that regional agencies like ASMC and AHA Centre, NMHSs, and end-users should work together to utilise the subseasonal forecast information and therefore better prepare the region to mitigate against climate- and weather-related disasters.

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# Annex A – List of Participants

## Facilitators and resource persons

| Name | Organisation |
|---|---|
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| **Dr. Angel Munoz** | International Research Institute for Climate and Society (IRI) |
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| **Dr. Thea Turkington** | Meteorological Service Singapore |
| **Mr. Ryan Kang** | Meteorological Service Singapore |
| **Mr. Tan Wee Leng** | Meteorological Service Singapore |
| **Dr. Govindarajalu Srinivasan** | Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) |
| **Assoc. Prof. Koh Tieh Yong** | Singapore University of Social Sciences |
| **Ms. Kareff May Rafisura** | United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) |
| **Ms. Laura Hendy** | United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) |

## End-user participants

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| **Mr. Than Naing Soe** | Department of Disaster Management, Myanmar |
| **Mr. Kritanai Torsri** | Hydro-Informatics Institute, Thailand |
| **Ms. Siti Nooraznie Binti Abdul Rahim** | Ministry of Energy, Science, Technology, Environment and Climate Change |
| **Mr. Saysompheng Phonesavanh** | Ministry of Labour and Social Welfare, Lao PDR |
| **Mr. Jeff Lim Chee Wei** | Singapore Food Agency |
| **Mr. Pham Doan Khanh** | Viet Nam Disaster Management Authority |
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| **Mr. Rafizam Bin Ramli** | Malaysian Meteorological Department |
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| **Ms. Efthymia Pavlidou** | Meteorological Service Singapore |
| **Ms. Huan Jiayan** | Meteorological Service Singapore |
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| **Ms. Suci Pratiwi** | Meteorology, Climatology, and Geophysical Agency, Indonesia |
| **Mr. Junie Ruiz** | Philippine Atmospheric, Geophysical and Astronomical Services Administration |
| **Ms. Cherry Jane Cada** | Philippine Atmospheric, Geophysical and Astronomical Services Administration |
| **Mr. Krirerk Phungsara** | Thai Meteorological Department |
| **Ms. Nichanun TRACHOW** | Thai Meteorological Department |
| **Mr. Francis Colledge** | UK Met Office |
| **Mr. Ta Huu Chinh** | Vietnam National Centre for Hydro-Meteorological Forecasting |
| **Ms. Ho Thi Ha** | Vietnam National Centre for Hydro-Meteorological Forecasting |