MANILA OBSERVATORY

ECW

High-Definition Clean Energy, Climate, and Weather Forecasts for the Philippines

Annual Project Report • July 2024 to June 2025

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EXECUTIVE SUMMARY

We are pleased to report what we have accomplished in the fourth year (July 2024 to June 2025) of the High Definition Clean Energy, Climate and Weather Forecasts for the Philippines (or ECW) project. The ECW project was conceived as a way to carry over the broad predictions of global climate change to our local Philippine context. This "downscaling" effort spans three primary areas of work, namely, the **observation network**; **climate and weather prediction**; and **communications and outreach**.

Regarding the **observation network**, we continue to collaborate with partners to maintain and sustain our automated weather stations throughout the country. Given that most of these stations are over a decade old, a rehabilitation and replacement program is now underway to ensure the accuracy and timeliness of observational data, which is crucial for predicting the future of Philippine climate in this century.

We have commenced retrofitting the Lufft and Davis stations with standalone solar power systems, enabling them to operate off-grid or in areas with limited electricity access. The retrofit allows the stations to remain operational for over a year in the field. To maintain data accuracy, we have also embarked on a calibration program employing internationally accepted standards and equipment.

On **climate and weather prediction**, we now have the latest regional climate results for the Philippines and Southeast Asia. We have successfully downscaled the most recent global climate models, specifically, the sixth version of the Climate Model Intercomparison Project, or CMIP6. Preliminary results indicate how global warming at 1.5 or 2 degrees Celsius will manifest in various regions of the country. Some of these areas may even surpass the global average. Such a scenario is no longer farfetched as the planet is projected to enter the 1.5 degree territory by mid-century.

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Zooming in on Philippine climate, we have developed an objective method to identify the distinct climate zones in the country. As these climate zones are key to Philippine agriculture and the economy, any appreciable movement in these boundaries due to planetary warming will have important consequences.

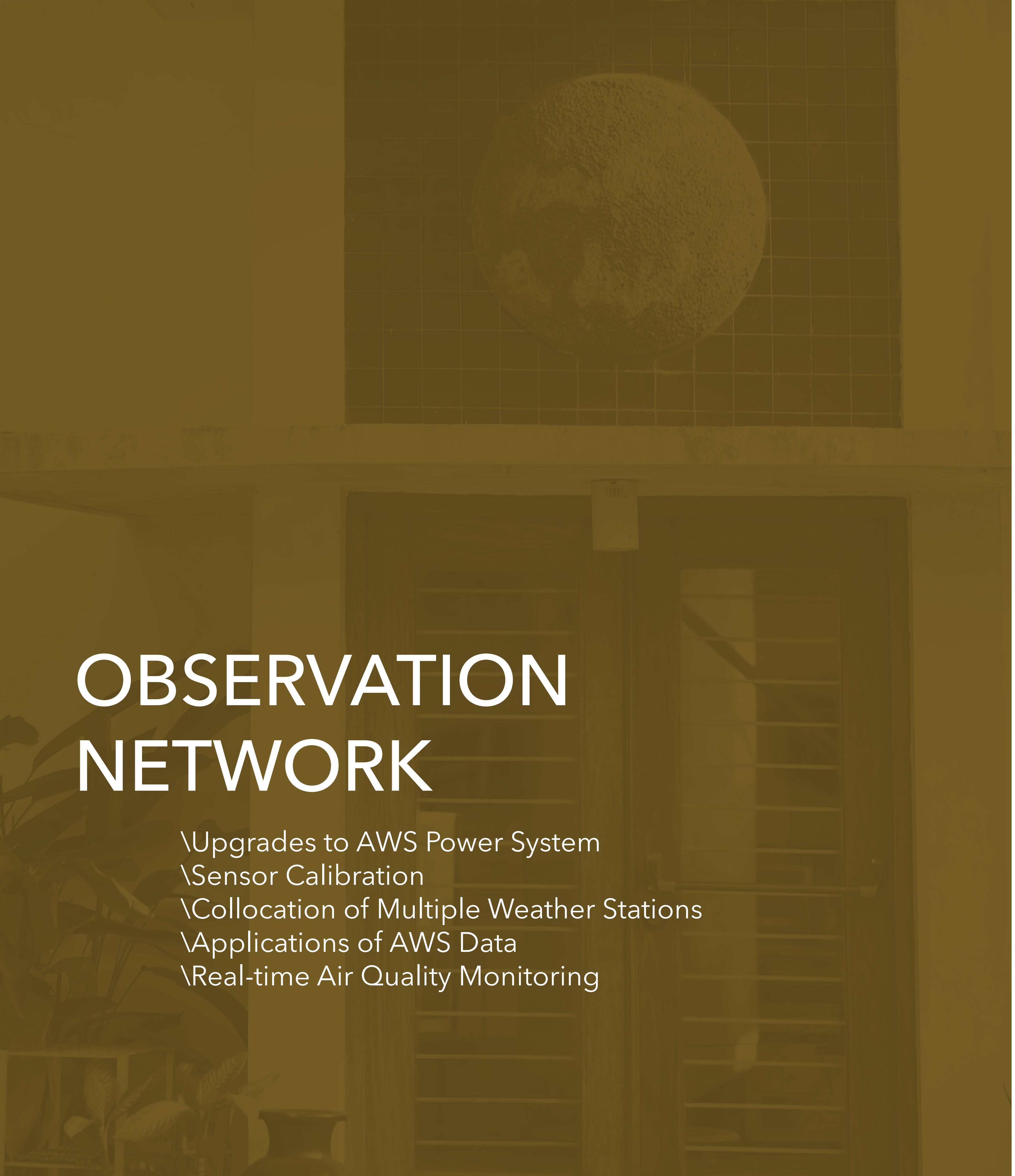
On **communications and outreach**, we continue to connect to those outside our scientific discipline to help us translate the technical jargon of climate change into accessible language that resonates with the public. Our Extreme Weather Bulletins undergo continuous refinement based on stakeholder feedback.

In displaying data from our weather stations, we are experimenting with user-friendly "cards" that incorporate actionable phrases in Filipino or the vernacular. These cards will be displayed in public spaces in the near future.

We are happy to report that we have forged a formal agreement with PAGASA to work together, especially in research, training, and data sharing. In working with local governments, noteworthy is our work on anticipatory action in BARMM. We continue to liaise with LGUs, especially through their local disaster risk reduction and management offices. Many have expressed appreciation for the technical and training assistance we provide.

This year, we conducted training sessions for student interns from various universities, including Mariano Marcos State, Visayas State, Rizal Technical, and Ateneo de Manila. Many interns possessed prior backgrounds in computer science, data, electronics engineering, and meteorology. We are happy to note the hands-on learning they gained while working with us in the field and laboratory. We consider it a privilege to have been part of their scientific learning and formation. From this internship experience, we hope to train more young Filipinos, if only to strengthen the scientific base of the country.

We are also pleased to announce that the fourth year of the ECW project has produced a rich harvest of publications in international, peer-reviewed journals. These and numerous other initiatives have contributed to elevating the country's position within the global scientific and climate community.



OBSERVATION NETWORK

\Upgrades to AWS Power System
\Sensor Calibration
\Collocation of Multiple Weather Stations
\Applications of AWS Data
\Real-time Air Quality Monitoring

The Automated Weather Station (AWS) network is still composed of units made by Lufft (Germany) and Davis (USA). As these are now about a decade old, much of the effort in the fourth year of the project has been on preventive maintenance and repair. A rehabilitation and sensor replacement program is now underway to keep the instruments working in top condition. Figure 1 shows the sites where the AWSs are located.

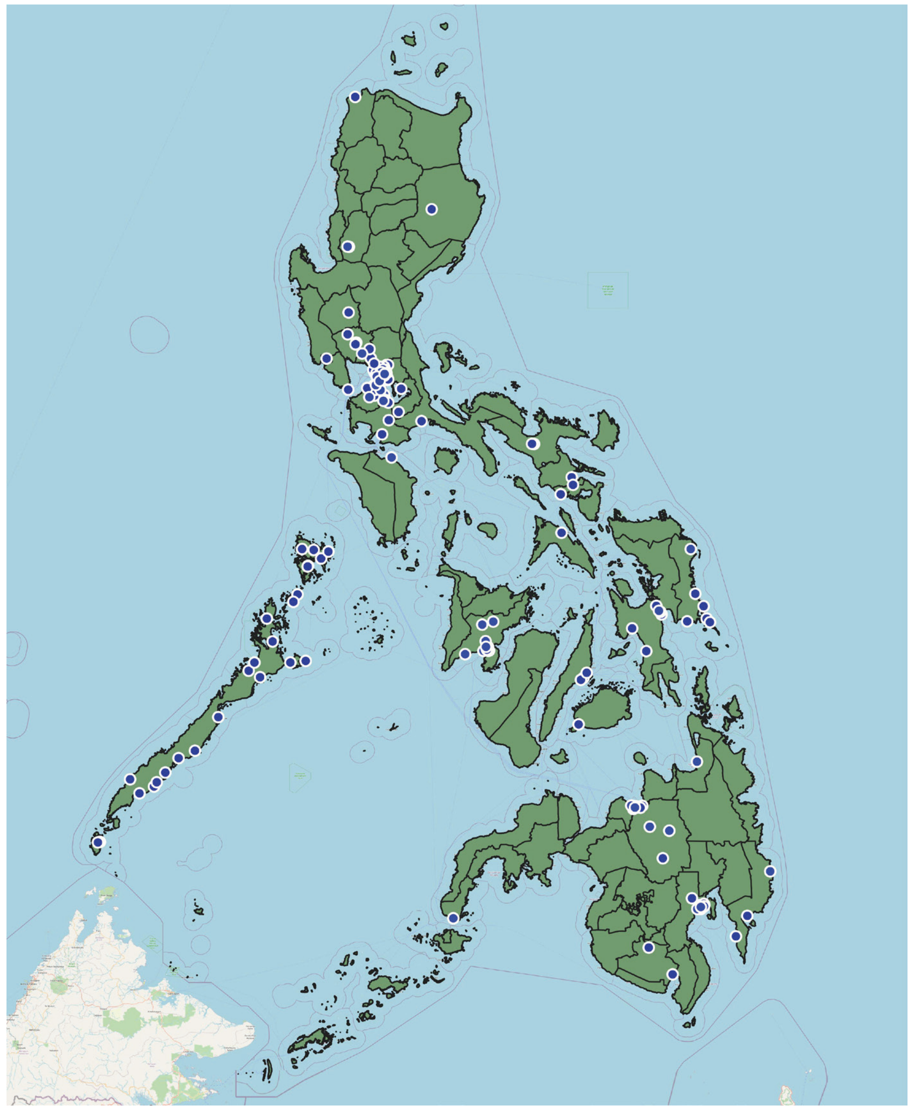


Figure 1. The current AWS network has a total of 181 stations: 92 Davis and 89 Lufft. Some stations remain offline due to particular challenges in gaining access to certain areas.

Upgrades to AWS Power System

One of our primary concerns has been to enhance the reliability of our AWSs. In the past year, efforts focused on ensuring that the AWSs have a consistent and reliable power source. Uninterrupted power is essential for continuous data collection and transmission. In many areas, especially remote or disaster-prone areas, power outages during extreme weather events such as typhoons hamper data collection and connection, which is precisely when real-time weather data is most crucial. Having an efficient power system not only reduces maintenance requirements but also enhances the overall stability and independence of our AWS network, the network's reach and reliability, and the shift toward renewable energy.

Figure 2. Lufft AWS at the Manila Observatory with the upgraded renewable power system.

Power Supply Upgrade of Lufft AWS

Lufft weather stations are commonly powered by solar energy so that stations can be deployed in remote areas with limited access to the power grid. However, stations can go offline if solar energy is not enough to charge the storage batteries, particularly during extended periods of adverse weather.

Through testing and development efforts, we now know how the battery depletes earlier than its specified lifespan. This problem led to frequent battery replacements in the past. To ensure that the AWS has consistent power, we have implemented a system that prevents the battery from being fully discharged, along with a secondary battery that activates when the primary battery is low. These improvements now result in more reliable and lasting station performance, with some now capable of operating for over a year without need for battery replacement. This power upgrade is a significant advancement in optimizing the efficiency and sustainability of our operations, benefiting both our stakeholders and the communities we serve.

Figure 3. Standalone Davis Automated Weather Station.

Standalone Solar-Powered Davis AWS

The Davis Vantage Pro 2 Plus requires constant power to log data and connect to the internet. The system thus relies on an external router. We have developed a prototype that integrates solar energy as the primary power source of the AWS to keep it operating fully standalone, especially in remote or electricity-challenged areas. The AWS is powered by two lead acid batteries that provide backup during low-sunlight and nighttime conditions. The power system is optimized for efficient battery use, thus extending battery life without compromising performance. This makes the station not only portable and off-grid capable but also environmentally friendly, contributing to a sustainable monitoring network.

Sensor Calibration

The Automated Weather Station has sensors that measure meteorological variables such as temperature, humidity, wind speed and direction, rainfall, and atmospheric pressure. These are essential for weather forecasting, climate monitoring, agriculture and disaster risk management. Understandably, the performance of these sensors degrades over time due to constant exposure to weather, dust, sun, electronic interference, and aging of components.

The accuracy and reliability of data is not possible without a routine calibration schedule. Calibration involves comparing sensor output with a reference standard under controlled conditions. This ensures that data measurements remain within acceptable tolerance limits and meet international standards. A key component here is the calibration chamber in which variables such as temperature, humidity, and pressure are carefully regulated. Such a chamber enables systematic calibration and a reliable assessment of the performance of different sensors (Figure 4). By simulating real-world environmental conditions in a controlled setting, our calibration system now gives us greater confidence in the accuracy of our AWS data in the field.

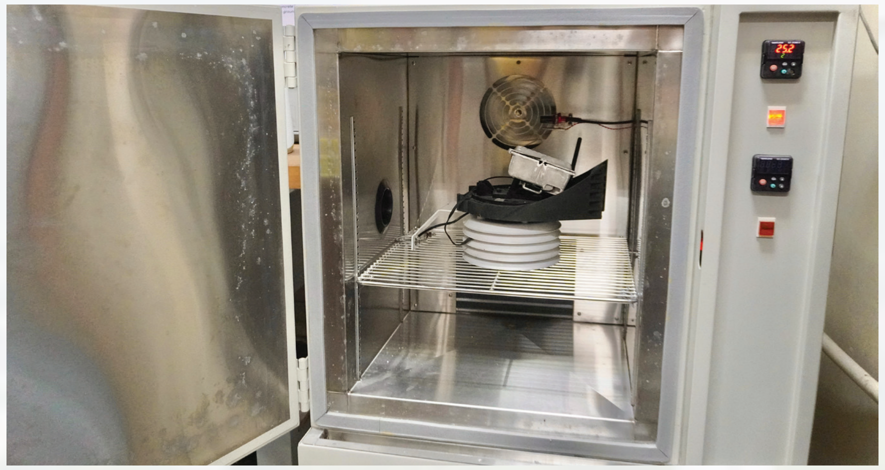


Figure 4. Davis AWS being calibrated in the MO's Temperature/Relative Humidity chamber.

Collocation of Multiple Weather Stations

The current AWSs have been in use for about a decade now and many of these are nearing the replacement cycle of 10 years. Five weather station units are thus being field tested now at the Manila Observatory to assess their performance. The tests will enable us to choose which AWS to eventually deploy to upgrade and replace the aging units in the field.

The five weather station units being tested are made by Lufft, Davis, Tempest, Logia, and Misol. The main goal of this study is to determine which weather station is cost-effective and reliable enough to meet the basic needs of accurate weather monitoring. One AWS is actually developed by a local company while the rest are sourced from abroad. Key weather parameters such as temperature, rainfall, UV and solar radiation, barometric pressure, humidity, and wind speed/direction are being monitored.

Figure 5. Different AWS brands (left to right): Lufft, Logia, Tempest, and Misol

Figure 6. Davis Automated Weather Station

All five weather stations are installed on the rooftop of the Manila Observatory (see Figures 5 and 6). Their temperature and relative humidity readings are also being compared with the Observatory's standard calibration system to determine their accuracy. Data is collected at 5-minute intervals, except for the Lufft station, which logs data every ten minutes

Measurements from each station vary in accuracy, resolution, and method of environmental sensing. Initial experiments show that rainfall accuracy ranges from ±2 to ±10 percent. Most use a tipping bucket mechanism, while another uses a haptic (or touch-sensitive) sensor to measure rain. For temperature, the accuracy is found to range from ±0.2 °C to ±1 °C. Temperature sampling frequency ranges from 10 second to 1 minute intervals, at a resolution of 0.1°C. See Figure 7.

This collocation experiment will cover other meteorological variables and will eventually help us decide which AWS units and sensors to deploy as replacement for the present set of AWS units in the field.

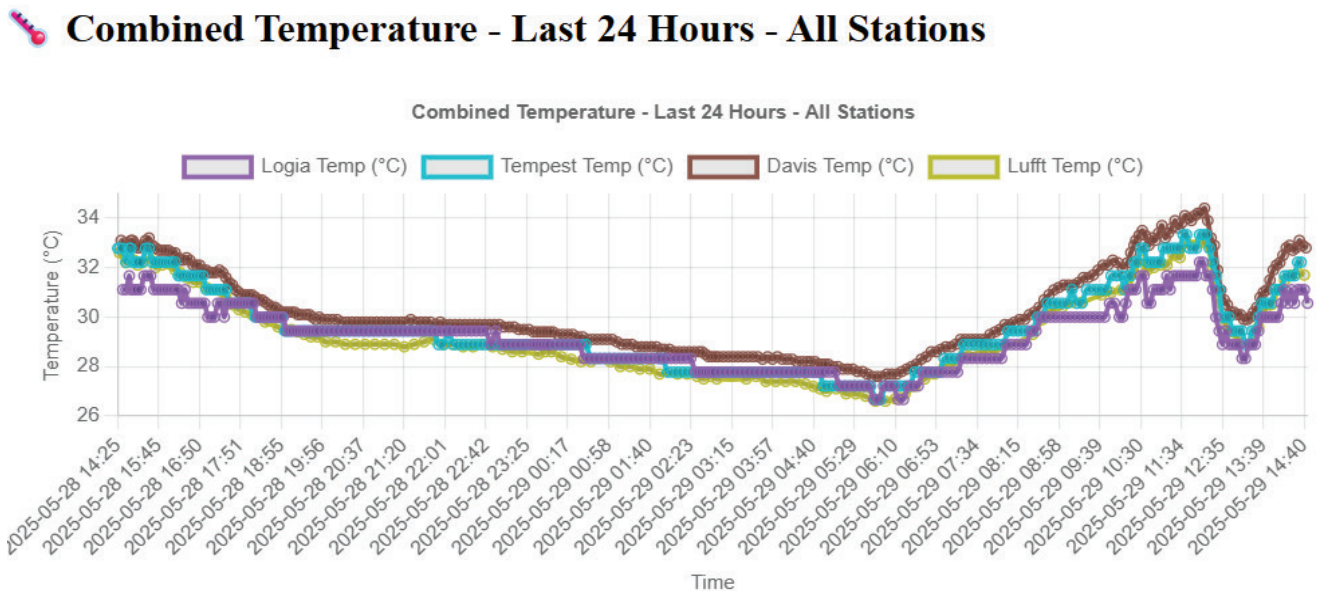


Figure 7. Sample temperature values measured by Davis, Lufft, Logia, and Tempest sensors.

Applications of AWS Data

AWS data use from 2014 to 2024 (Figure 8) indicates that the most common use of data is for weather and climate research. AWS data has been beneficial to research areas such as health, water and hydrology, urbanization research, renewable energy, disaster risk management, and scientific instrumentation. This underscores the significance of AWS data in scientific environmental work and decision-making.

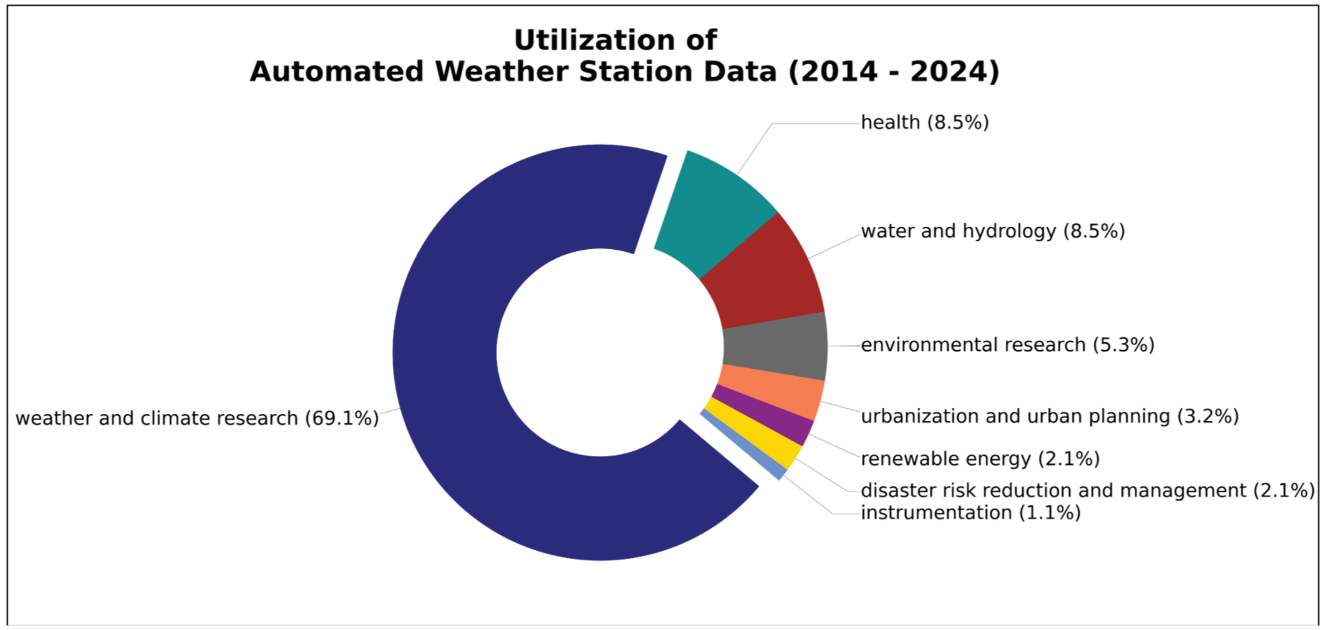


Figure 8. AWS data use from 2014 to 2024.

Real-time Air Quality Monitoring

Aside from measuring weather and climate, we now also monitor air pollution, particularly fine particulate matter or $PM_{2.5}$. This suspension of solid and liquid particles in the air, also known as aerosols, has significant impacts on human health, ecosystems, visibility, and climate. The extent of their impact continues to be an active area of research globally.

In this project, we work closely with the Air Quality Dynamics (AQD) Laboratory of the Manila Observatory (MO) to study the relationship between aerosols and local climate. A sunphotometer, which is part of NASA's AERONET (AErosol RObotic NETwork) program, is installed at the Manila Observatory to continuously measure aerosols. It is collocated with a Clarity sensor which measures $PM_{2.5}$ concentrations 24/7 in real time. The AQD Lab also measures $PM_{2.5}$ concentrations in Nangka, Marikina using another instrument called the AS-LUNG-O.

Real-time $PM_{2.5}$ measurements are important in spotting pollution episodes. For example, there was a gradual increase in daily average $PM_{2.5}$ concentrations (represented by the black triangles Figure 9 below) in MO starting on 14 August 2024. The average $PM_{2.5}$ level that day was 23 µg/m^3, classified as moderate according to the US Environmental Protection Agency (US EPA) Air Quality Index (AQI). A moderate level means air quality is generally acceptable. $PM_{2.5}$ continued to increase however, peaking on 19 and 21 August (53 and 51 µg/m^3, respectively), and crossing into the unhealthy for sensitive groups category. A gradual decrease was then observed from 22 to 25 August, going back to moderate AQI but higher still than 13 August levels. The same pattern of $PM_{2.5}$ levels was seen at the Nangka, Marikina monitoring station.

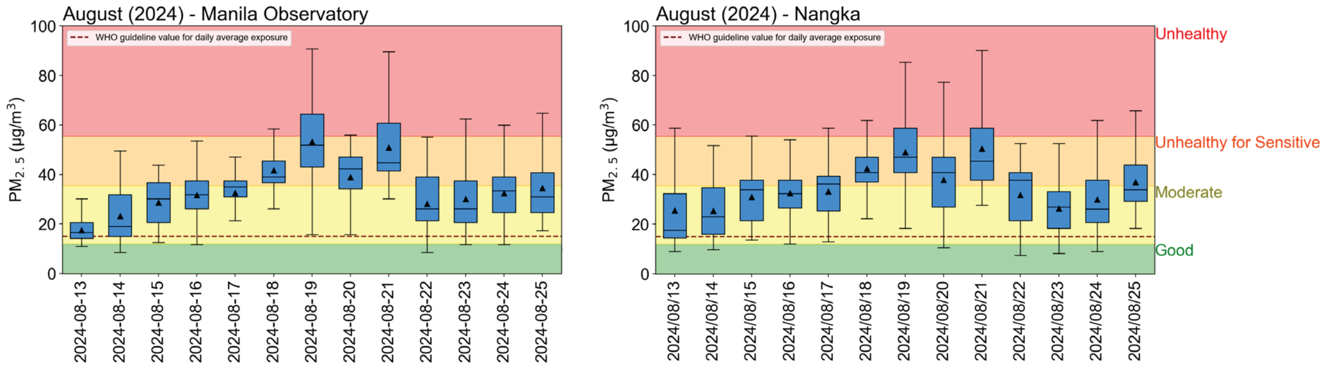
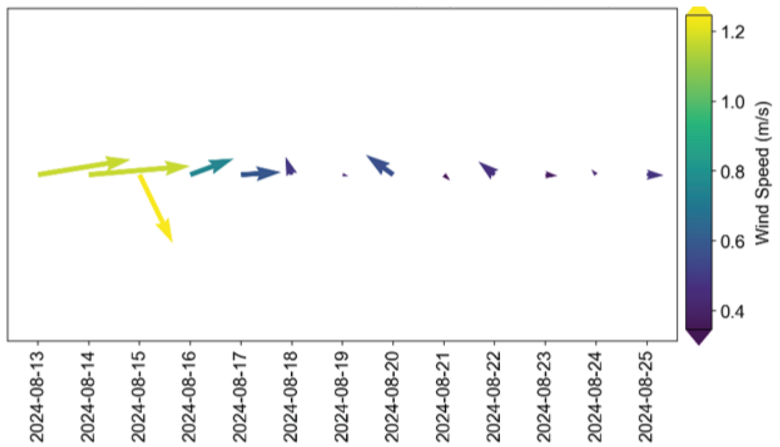


Figure 9. $PM_{2.5}$ levels at MO and Nangka, Marikina stations from 13 - 25 August 2024. Background colors represent Air Quality Index (AQI) categories used by the US EPA.



Analysis of wind measurements show that beginning 16 August 2024, the wind slowed significantly, as shown in Figure 10. The stagnant conditions most probably contributed to the observed increase in $PM_{2.5}$ levels.

Figure 10. Quiver plot of wind speed and direction measured at MO from 13 - 25 August 2024. The arrow's shaft points in the direction the wind is blowing from.

Another pollution episode was observed on 28 April 2025, as shown by the significant increase in $PM_{2.5}$ levels in both MO (28 µg/m^3) and Nangka, Marikina (31 µg/m^3) monitoring sites (Figure 11). This was most probably due to the landfill fires in Rodriguez, Rizal that started in the afternoon of 27 April 2025. Wind measurements in MO, shown in Figure 12, indicate the predominantly easterly wind which may have helped the transport of landfill fire emissions to places downwind of Rodriguez, Rizal.

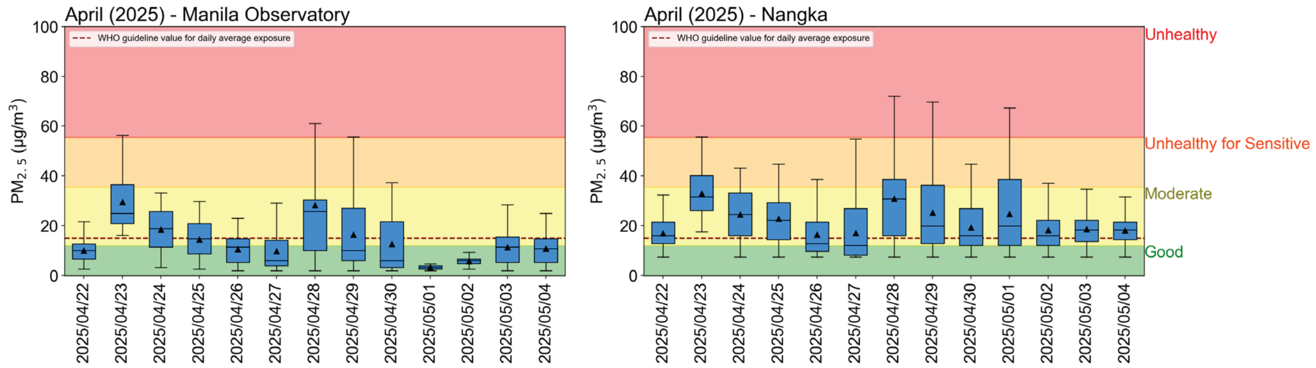


Figure 11. PM2.5 levels at MO and Nangka, Marikina stations from 22 April to 4 May 2025.

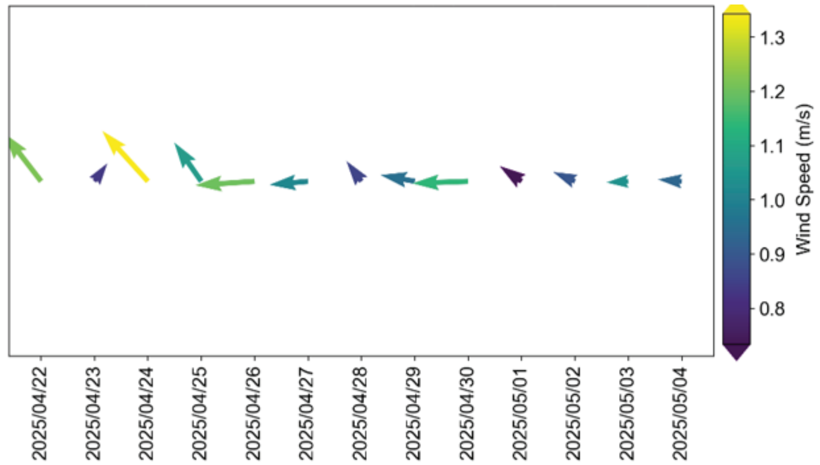


Figure 12. Wind speed and direction measured at MO from April 22-May 4, 2025. The arrow's shaft points in the direction the wind is blowing from.

CLIMATE AND WEATHER PREDICTION

\Regional Climate Models for Southeast Asia
\Climatic Impact-drivers in Megacities
\A New Way of Classifying Philippine Climate
\Heat Index Forecasting

Regional Climate Models for Southeast Asia

An updated regional climate model dataset for Southeast Asia at 25-km resolution is currently undergoing validation. To provide context, global climate models are usually at 100-500 km resolution. Upon completion, this dataset will be made publicly available for use by communities, especially those in the climate impact and adaptation sectors. This dataset is a product of dynamically downscaling the most recent global climate models (specifically, the sixth version of the Climate Model Intercomparison Project, or CMIP6) through a collaborative resource-sharing initiative of the regional climate modeling network, CORDEX SEA (or Coordinated Downscaling Experiment Southeast Asia). Here at MO, analysis of projected temperature and rainfall extremes, as well as tropical cyclone characteristics, is now being done, with a primary concern on future changes at global warming levels of 1.5 and 2.0 degrees.

Figure 13 shows how our regional climate model simulations are able to capture finer-scale changes that are understandably not seen in global circulation models. These maps are a projection of what may happen when the world warms up to 2 degrees relative to pre-industrial temperatures.

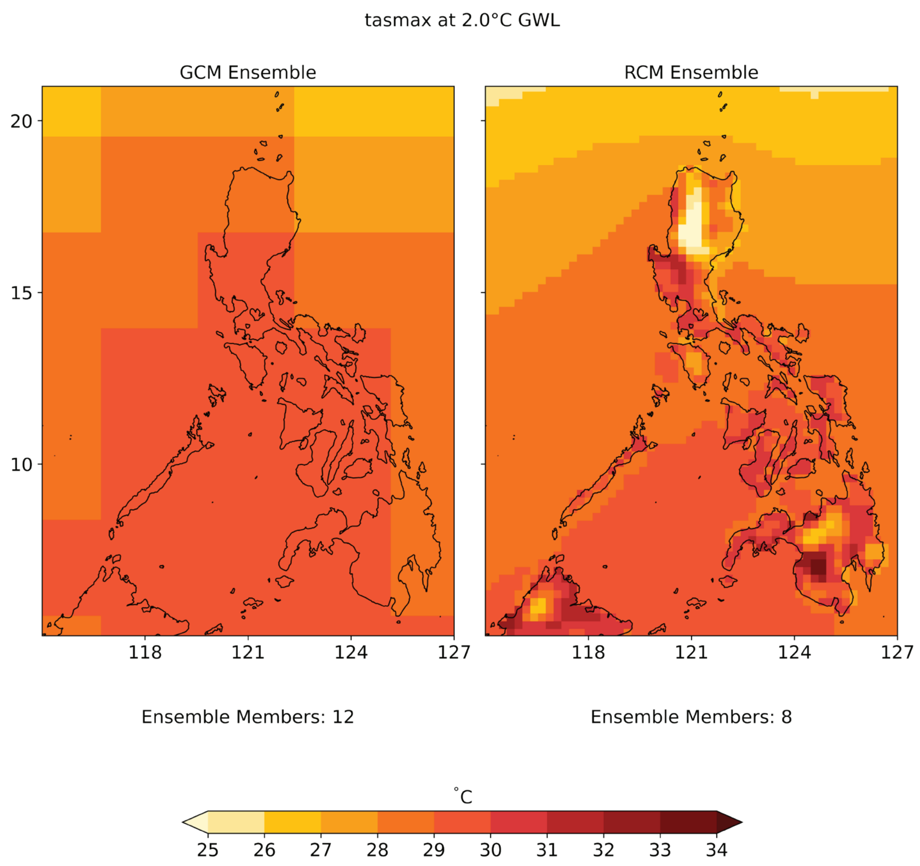


Figure 13. Maximum temperature simulated by coarsely resolved General Circulation Models (GCMs) vs finely resolved Regional Climate Models (RCMs) at Global Warming Level 2.0 degrees.

Climatic Impact-Drivers in Megacities

The Manila Observatory also leads the latest project of the CORDEX-SEA network, called CARE for SEA megacities project. This project aims to generate policy-relevant information on future climatic impact-drivers for Southeast Asian megacities. New downscaling approaches are implemented to generate very high-resolution climate information and to investigate climate change impacts on extreme temperature and rainfall in Metro Manila.

A land surface physics-based downscaling model called HRLDAS (High-Resolution Land Data Assimilation System) can provide sub-kilometer temperature information for less computational resources compared to conventional dynamical downscaling methods. As shown in Figure 14, we have used HRLDAS to show how temperatures in Metro Manila have increased from 2001 to 2020.

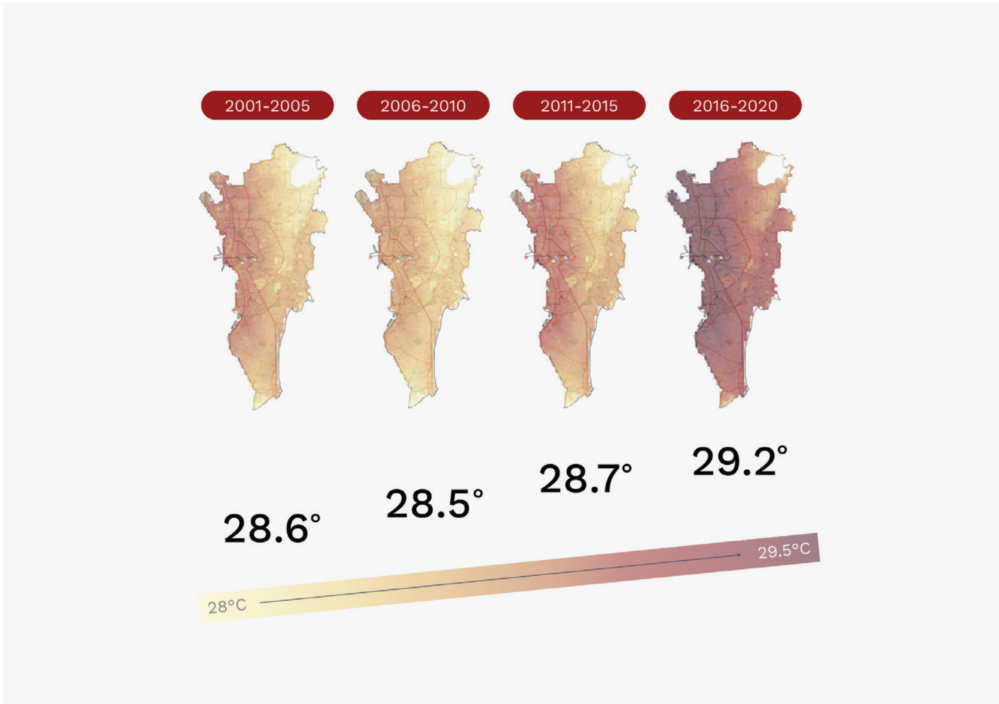


Figure 14. Five-year mean temperatures in Metro Manila from HRLDAS simulation with ERA5 boundary data.

To simulate extreme rainfall, we are now exploring a strategy called PGW (or Pseudo-Global Warming). Large-scale changes are first derived from the downscaled CORDEX-SEA data and then superimposed on the boundary data to represent current conditions. This experiment design allows us to investigate the effect of a warmer climate on certain extreme events, such as extreme rain brought about by typhoons. Compared to traditional dynamic downscaling, the computational requirements of this strategy are lower.

A New Way of Classifying Philippine Climate

Philippine climate may not have the usual four seasons of the midlatitudes, but it is also not simply wet and dry. Its complexity arises from how the country straddles the subtropical and tropical regions, our topography, the archipelagic combination of mountains and coasts and sea, the effect of the large-scale monsoons and other inter-annual, intra-seasonal systems that interact with each other.

The first global climate classification was introduced by Koppen (1884, 1918) and his successors in the late 19th and early 20th century using rainfall, temperature, and certain thresholds in an attempt to show the impact of climate on vegetation. This has been updated recently using higher resolution data of rainfall and temperature (Beck et al., 2023). However, this classification cannot fully represent the complex features of Philippine climate, which include the monsoons and other multi-scale systems and interactions.

Jose Coronas SJ, in the 1920s, developed the first climate zones of the Philippines based on MO's analysis of monthly mean rainfall. This was later modified by Kintanar (1984; henceforth, MCCC or Modified Coronas Climate Classification) and has been the de facto climate classification scheme of the country ever since. The MCCC categorizes Philippine climate into four types. Two are located generally along the western and eastern coastal regions where monsoon impacts are more pronounced, while the other two are intermediate types located between the two previously mentioned areas. Recent studies (e.g., Basconcillo et al. 2023) however suggest that other variables, such as temperature, should be considered for a better representation of the regional climate in the Philippines.

A century after the work of Fr. Coronas, we began a new study to classify Philippine climate by applying Self-Organizing Maps (SOMs) to gridded rainfall and temperature data (Olaguera et al. 2025). Our results show five climate classes as shown in Figure 15. This method can be used to see connections between Philippine climate and society (e.g. culture and economy). Additionally, it can also provide a baseline from which to diagnose how a warmer planet will shift these climate zones and affect specific Philippine regions in the future.

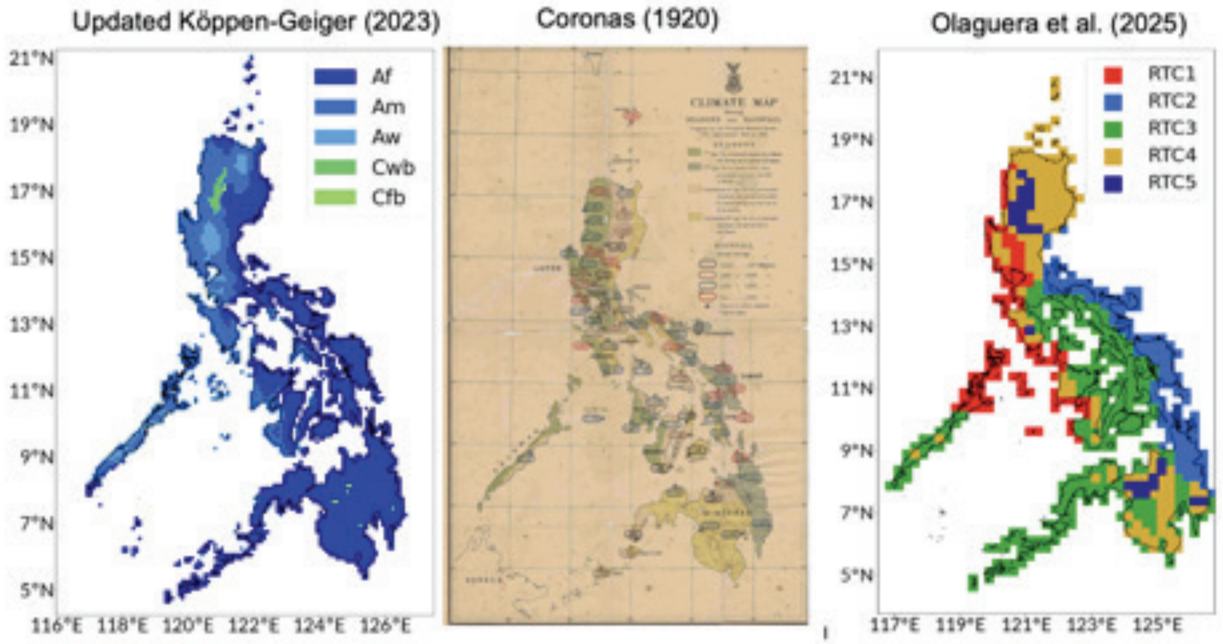


Figure 15. Climate zones in the Philippines according to the updated Köppen-Geiger (Beck et al., 2023), Coronas (1920), and Olaguera et al. (2025).

Heat Index Forecasting

The Weather Research and Forecasting (WRF) model that we use in the experimental forecasts of this project has been observed to underestimate our forecasts of the Heat Index (HI). We think this discrepancy primarily stems from the underestimation of relative humidity (RH), an important variable in determining HI. We have thus begun investigating how moisture is transported within the atmosphere, especially within the so-called planetary boundary layer (or PBL, i.e. from the ground to about 1 km above the surface) during heatwave events.

In technical terms, we examined how sensitive RH is to the so-called shape exponent of the momentum diffusivity coefficient (p), that is in the Asymmetric Convective Model v2 PBL scheme. This scheme governs moisture diffusion within the PBL. A higher (lower) value of p signifies weak (strong) vertical mixing of moisture within the PBL.

As a case study, forecasts were initialized at 8am Local Standard Time (LST) on selected days in Davao City. These were subsequently validated with observed sounding profiles and data from the AWS. Results indicate that the vertical profiles of water vapor or moisture (Q) and RH are sensitive to the value of the p parameter (Figure 16). This means that the distribution of RH is highly influenced by how the model diffuses moisture within the PBL.

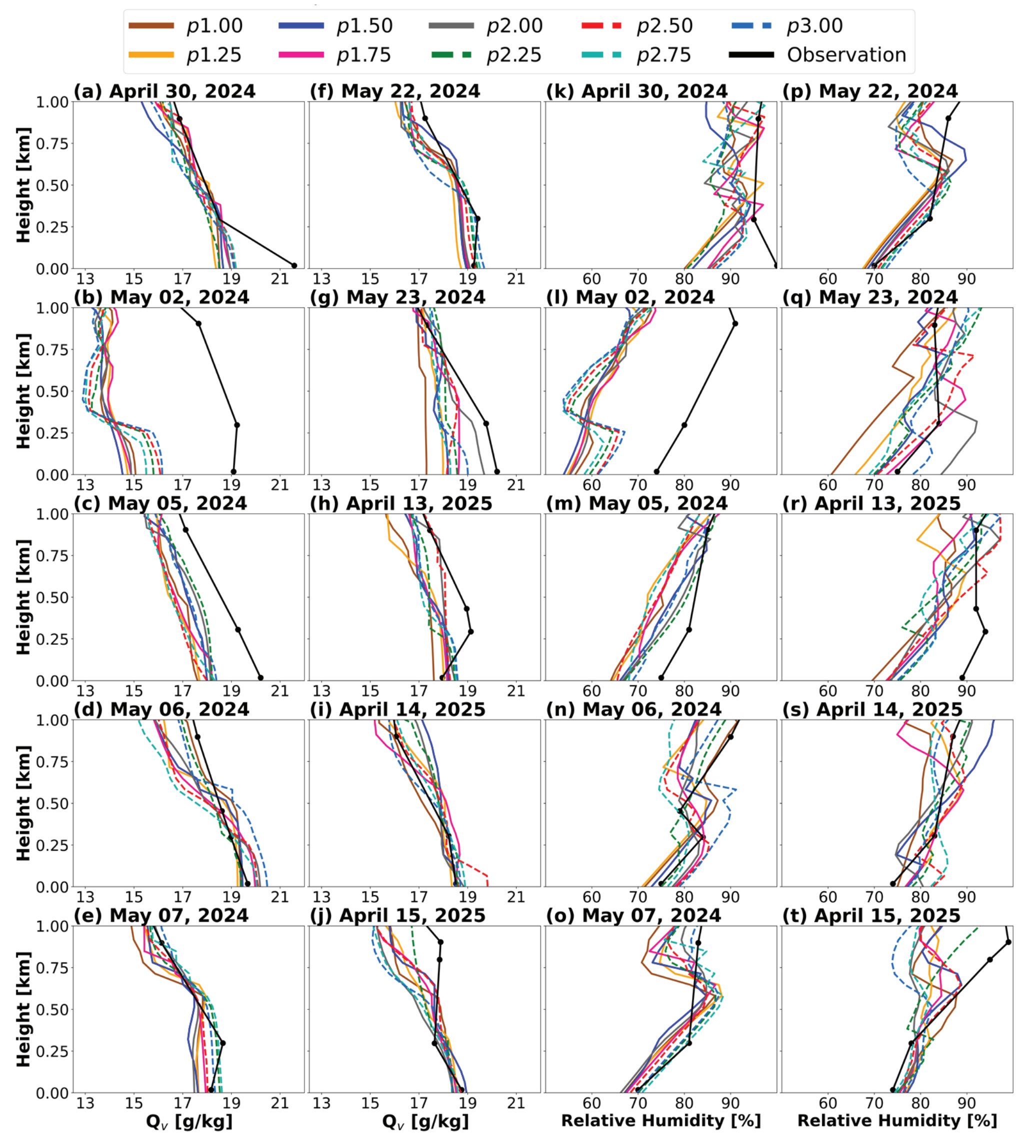


Figure 16. Vertical profiles of simulated and observed (black line; sounding at 8am LST) water vapor (Q; g/kg) and Relative Humidity (%) for selected days, extracted at the location of the sounding data (Davao City; 125.65°E, 7.11°N).

Heat index levels are usually based on thresholds set by the National Weather Service of the National Oceanic and Atmospheric Administration (NWS-NOAA, 2023). For the Extreme Caution category (33°C to 41°C), all WRF simulations with varying p values showed a good probability of detection (POD) (Figures 17 and 18). Among these, the simulation with p = 3.00 demonstrated the best performance.

However, despite the relatively high POD, all simulations exhibited a success ratio of less than 60%. The microphysics, which controls cloud and rain formation, and the land surface, which controls soil moisture, are also critical in simulating surface temperature and RH. The work therefore on forecasting heat index is far from done and will entail more experiments to reduce the bias in temperature and RH prediction.

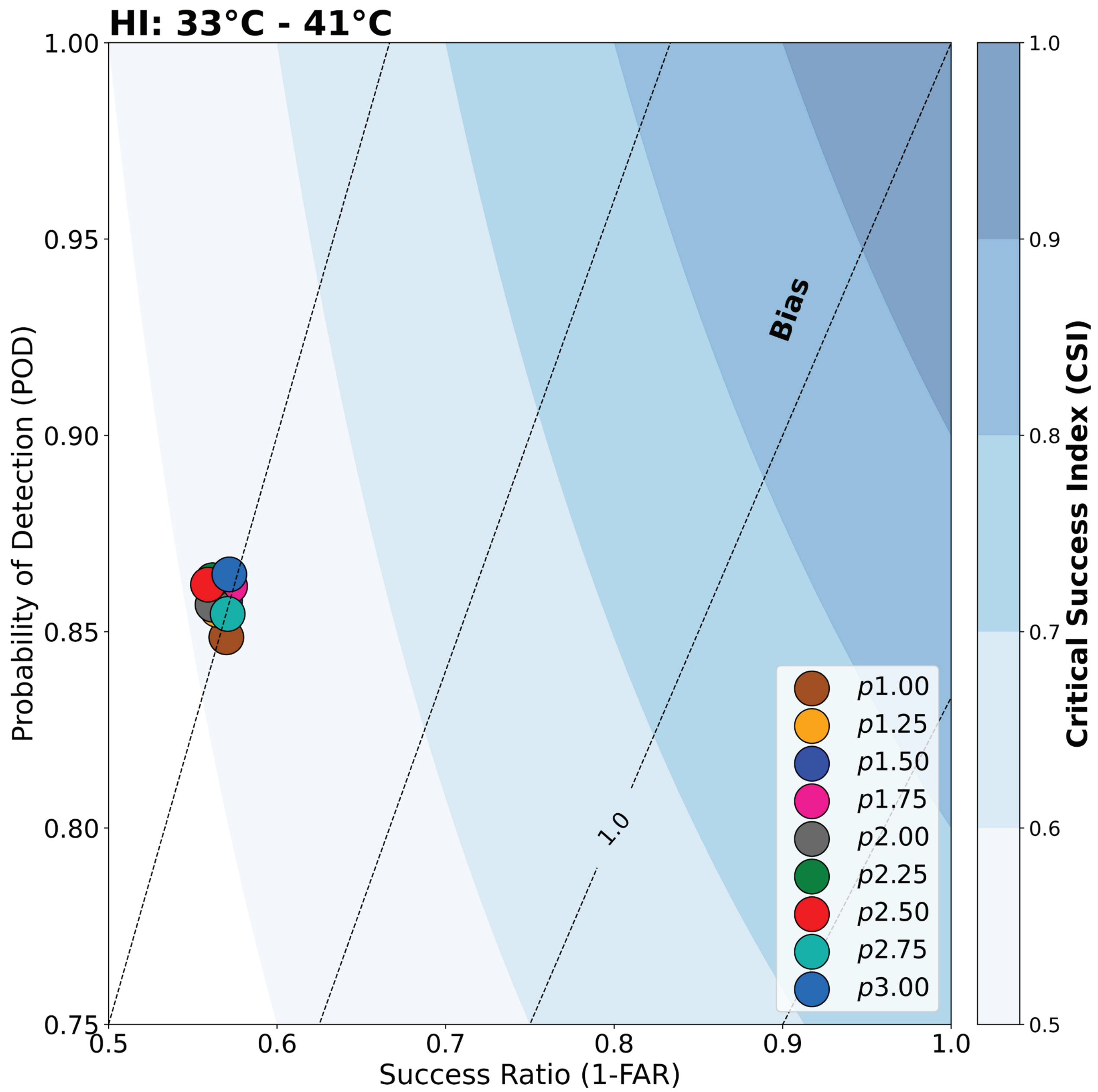


Figure 17. Performance diagram of different WRF simulations with varying p values for the Extreme Caution HI category (33°C - 41°C). The observed data from AWS stations in Davao City were used.

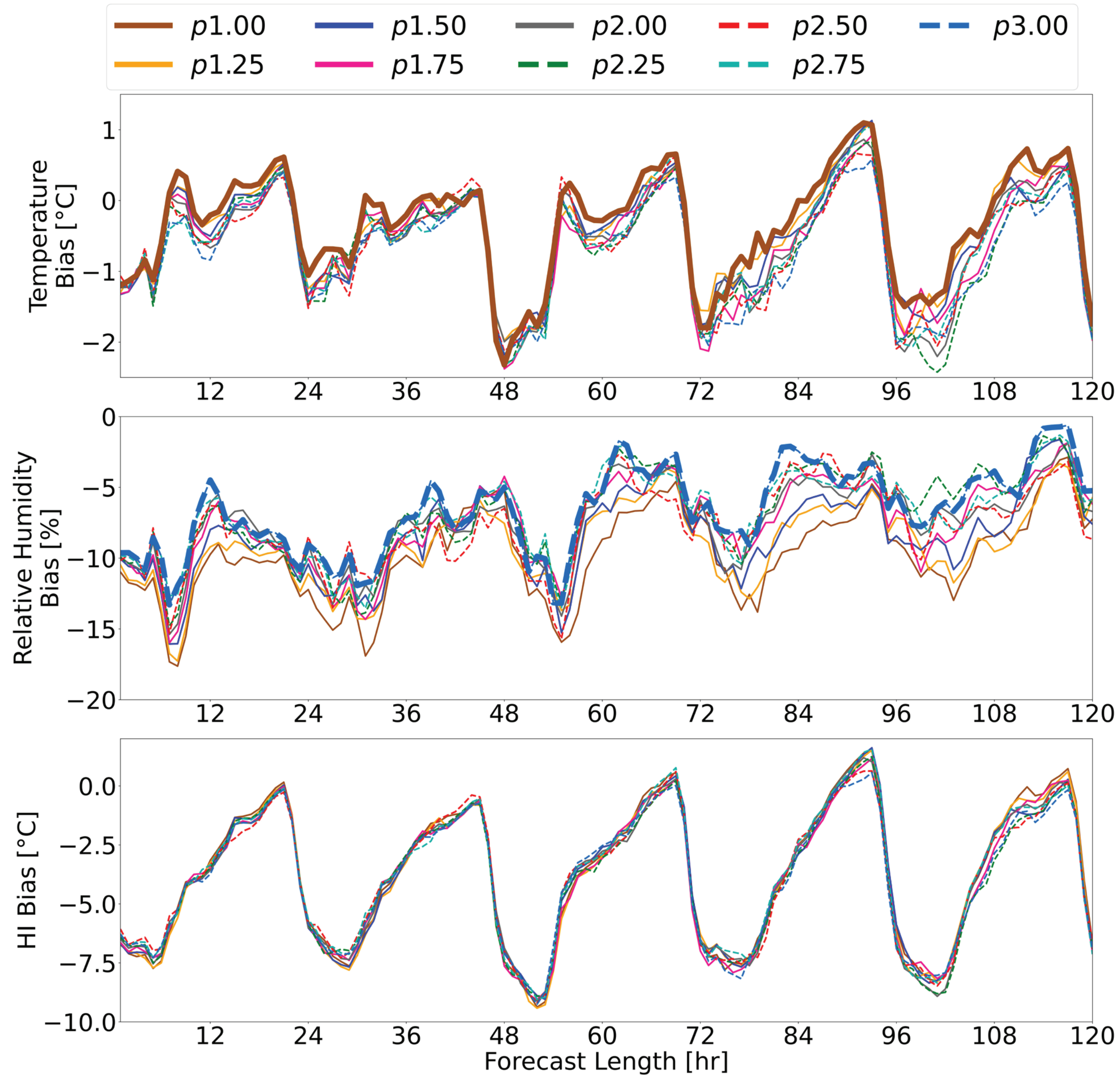
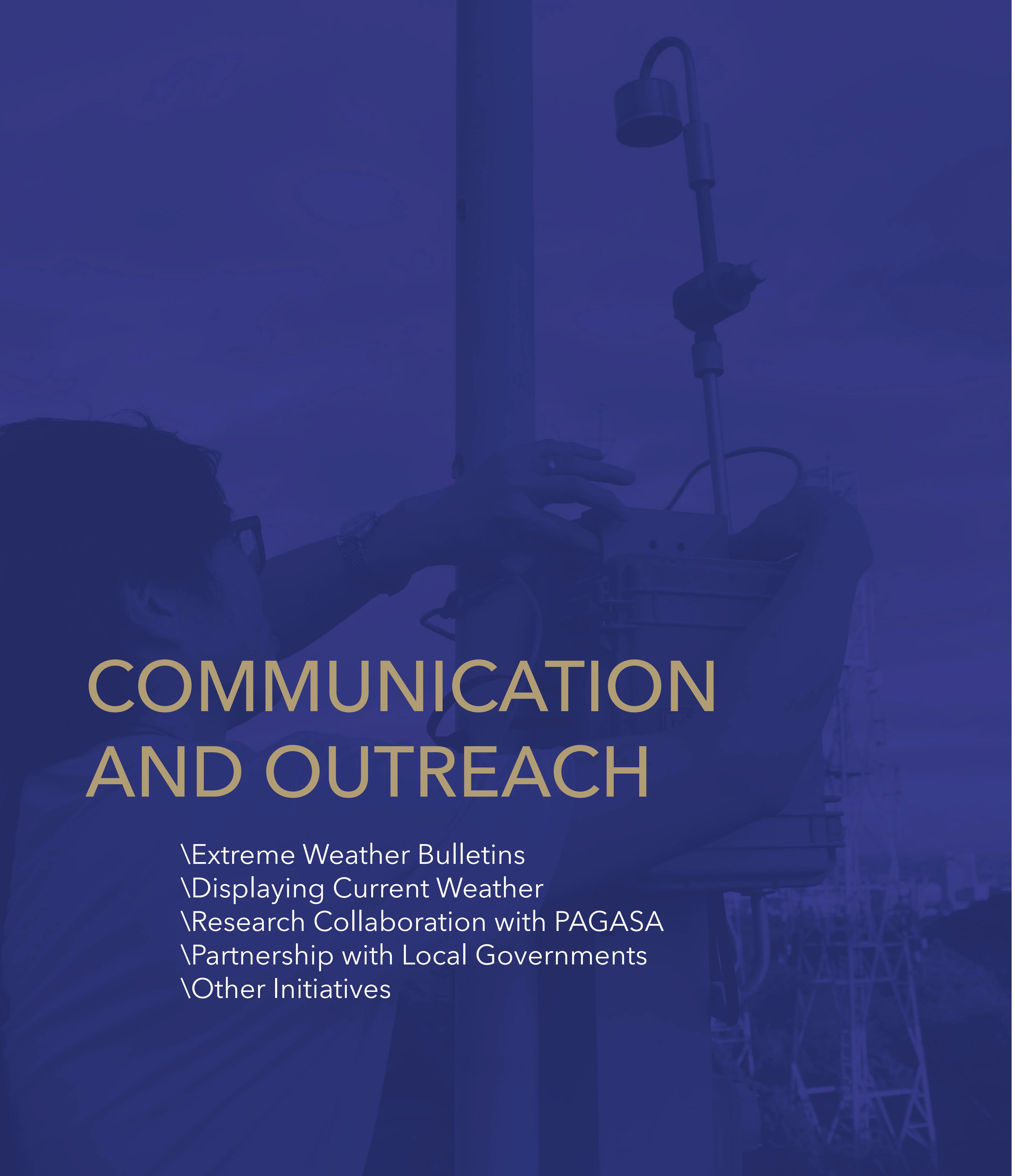


Figure 18. Time series of forecast bias of the different values of the p parameter. The bias is relative to the observed data from the Davao AWS station.



COMMUNICATION AND OUTREACH

\Extreme Weather Bulletins
\Displaying Current Weather
\Research Collaboration with PAGASA
\Partnership with Local Governments
\Other Initiatives

Extreme Weather Bulletins

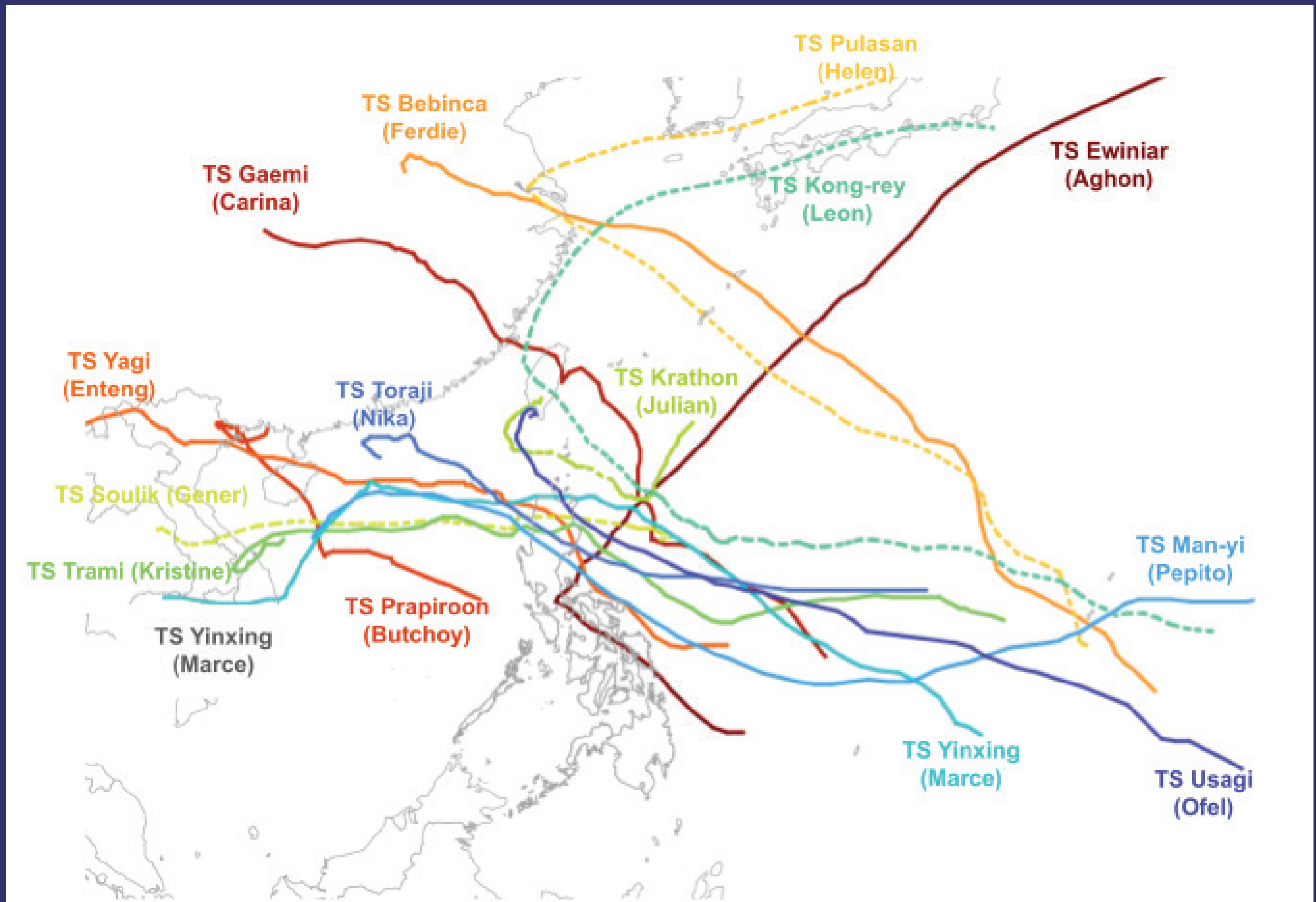


Figure 19. Tracks of tropical cyclones which impacted the Philippines in 2024.

Several Extreme Weather Bulletins (EWBs) with forecasts of extreme rainfall and wind were released from June 2024 to May 2025. These include the extreme rainfall event on 14 to 19 January 2025 that affected eastern Mindanao, causing flooding and landslides in Region 11 and CARAGA. This extreme rainfall event was brought about by the shear line (previously referred to as "tail-end of cold front") and not by a tropical cyclone.

Other EWBs covered Tropical Storm (TS) Gaemi (Carina) which did not make landfall but brought extreme rainfall over western Luzon, particularly in Metro Manila in July 2024. TS Gaemi (Carina) was preceded by TS Prapiroon (Butchoy), which cut across the Visayas region before exiting west of Mindoro. Together, these two events affected a large portion of the country, affecting more than 6 million people.

In early September, TS Yagi (Enteng) made landfall over Aurora and enhanced the southwest monsoon, affecting around 3 million in Luzon. TS Bebinca (Ferdie), which did not make landfall, was followed closely by TS Soulik (Gener), TS Pulasan (Helen) and TD 17W (Igme), affecting more than 1.5 million people across the country.

Table 1. List of extreme events which affected the Philippines in 2024 and the number of related EWBs released for each event.

Bulletin Dates	Extreme Event	Number of Bulletins	Impact Areas*	Number Of Affected persons*
Jan 30-31, 2024	Trough of LPA (Shearline)	2	Region 11, CARAGA	975,306
May 24-25, 2024	TY Ewiniar (Aghon)	2	Region 3, CALABARZON, MIMAROPA, Region 5,7,8,NCR	152,266
	STS Prapiroon (Butchoy)	0	(with Butchoy) Regions 1,2,3,CAL-ABARZON,MIMAROPA,Region 5,6,7,8,9,10,11,12,CARAGA,BARMM, CAR, NCR	6,498,918
Jul 21-24, 2024	STY Gaemi (Carina)	5		
Jul 26, 2024	95W	1	Warning of extreme rainfall over western Luzon due to SWM and previous Gaemi (Carina)	
Sep 2-3, 2024	TS Yagi (Enteng)	2	(with SWM) Regions 1,2,3, CALABAR-ZON, Regions 5,6,7,8, CAR, NCR	3,032,995
Sep 11, 2024	TD Bebinca (Ferdie)	1	(With Gener, Helen, Igme) Regions 2,3,MIMAROPA,Region 5,6,7,9,10,11,12,CARAGA,BARMM, CAR	1,629,519
	TS Soulik (Gener)	0		
	TS Pulasan (Helen)	0		
	TD 17W (Igme)	0		
	TS Krathon (Julian)	0	Regions 1,2, CAR	
Oct 22-25, 2024	TS Trami (Kristine)	4	(with Leon) Regions 1,2,3,CAL-ABARZON,MIMAROPA,Region 5,6,7,8,9,10,11,12,CARAGA,BARMM, CAR, NCR	9,652,607
	Leon	0		
Nov 6, 2024	TY Yinxing (Marce)	1	Region 1,2, CAR	387,514
Nov 15-17, 2024	STY Man-Yi (Pepito)	3	Luzon (Pepito combined with Nika and Ofel) Region 1,2,3,CALABARZON,MIMA-ROPA,Region 5,6,CAR	4,316,052
Nov 11, 2024	TY Toraji (Nika)	2		
Nov 12-14, 2024	STY Usagi (Ofel)	3		

*Impact areas and total number of persons affected as reported by the NDRRMC

By mid-October, TS Trami (Kristine), intensified into a severe tropical storm and made landfall in Divilacan, Isabela at 12:30am PHT on October 24. Prior to landfall, it stalled and dumped a substantial amount of rain over the Bicol region (south of the storm track), which caused widespread flooding and damage.

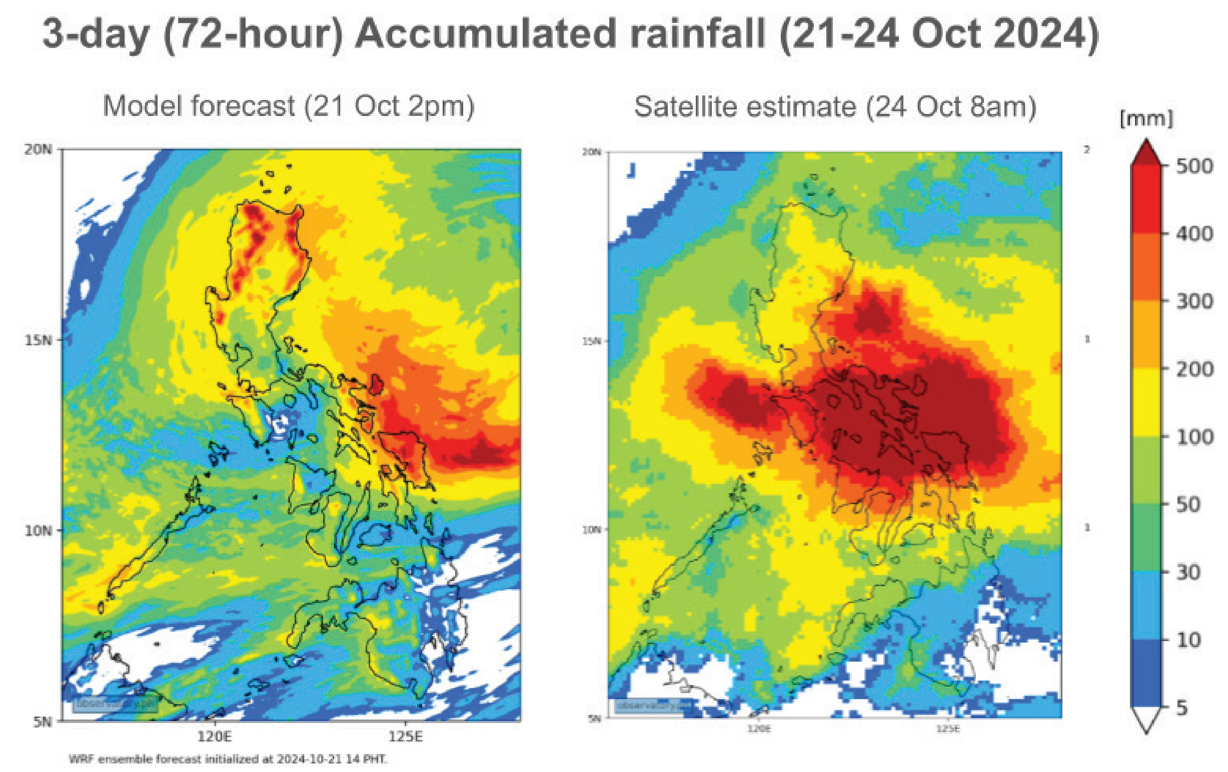


Figure 20. Forecasted and observed (satellite) 3-day accumulated rainfall brought by TS Trami (Kristine) which made landfall in Divilacan, Isabela but inundated the Bicol region and surrounding areas.

Forecasted accumulated rainfall exceeded monthly rainfall totals. Satellite estimates showed accumulated rainfall that was more than double the climatological monthly rainfall total covering a much larger area.

Figure 20 shows the 3-day accumulated rainfall from 21 to 24 October 2024 as (a) forecasted by the model on 21 Oct 2024; and (b) estimated by satellite (GSMaP) on 24 Oct 2024. While the forecast indicated rainfall exceedances (i.e. climatological monthly rainfall totals at nearby stations of Legazpi: 333mm; Catbalogan: 305.7mm; Catarman: 338.4mm), the actual rainfall over a large portion of the Bicol, southern Luzon, northern Visayas regions exceeded 500mm.

One of the impact areas, the Bicol River Basin (BRB) which serves as a catchment area for most of the Bicol Region, is a densely populated, highly vulnerable area. The excessive amount of rain from TS Trami (Kristine), which was then followed by TS Kong-rey (Leon) within a short period of time in an already saturated flood plain, caused catastrophic flooding that was swift to rise and slow to subside, thus inundating the urban centers of Naga and Iriga cities, and large portions of agricultural and residential land. It affected more than 9.5 million people and caused more than 10.5 billion pesos worth of damage to infrastructure in Regions 1, 2, 3, CALABARZON, MIMAROPA, Regions 5, 7, 10, 11, 12, CARAGA and CAR.

From 2 to 16 November 2024 a series of four typhoons devastated northern Luzon: Typhoon Yinxing (Marce, Category 5), Typhoon Man-yi (Pepito, Category 5), Typhoon Toraji (Nika, Category 1), Typhoon Usagi (Ofel, Category 4), affecting almost 5 million people and causing an estimated PhP3B worth of damage to infrastructure in Regions 1, 2, 3, 5 and CAR.

This succession of four simultaneous tropical cyclones over the Western Pacific has not been reported since records began in 1951. Figure 21 below shows, from left to right: Typhoons Yinxing (Marce), Toraji (Nika), Usagi (Ofel), and Man-yi (Pepito) on 11 November 2024.

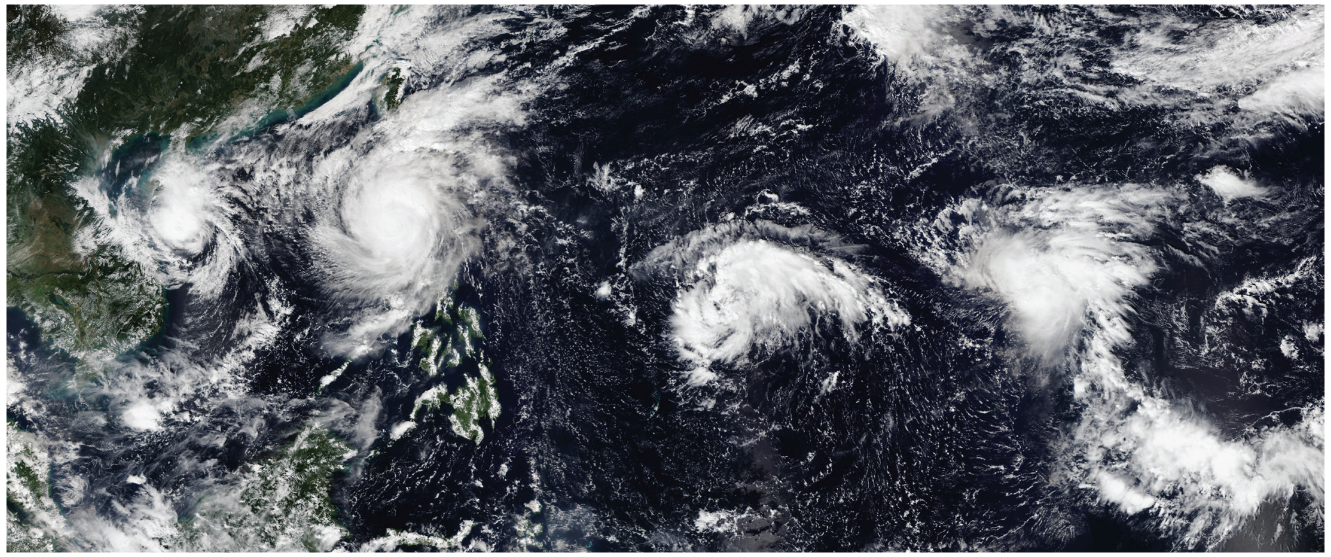


Figure 21. Composite image of Typhoons Yinxing (Marce), Toraji (Nika), Usagi (Ofel), and Man-yi (Pepito) on 11 November 2024. Image source: https://en.wikipedia.org/wiki/2024_Pacific_typhoon_season#/media/File:Yinxing,_Toraji,_Usagi,_and_Man-yi_2024-11-11_0000Z.jpg

Displaying Current Weather

We continue to develop locale-specific, user-friendly weather display cards to communicate timely weather information. For now, these are posted on our panahon.observatory.ph website. Designed to make vital weather data from our AWS network accessible to everyone, this system will eventually be deployed in public spaces or wherever there is need for critical updates.

Three main cards are cycled automatically in the weather dashboard. The first card shows the current temperature, location, date, and time; paired with an appropriate weather icon and a familiar or typical action tip in Filipino, e.g. "Maaraw at mainit! Magdala ng payong at uminom ng tubig". The second card displays the current rainfall status, again with the location, date, and time, along with a relevant image and a practical suggestion like "Umaambon, magbitbit ng payong, mahirap magkasakit..." The third card presents the current air quality while the fourth card shows a summarized three-day weather outlook for the area, using easy-to-read icons and brief daily highlights to help people plan ahead.

Clarity and brevity are central to the dashboard's design since it will be displayed on electronic boards along public roads or mall displays where viewers can only momentarily see the information. Each card is being designed to highlight key information through large icons, bold fonts, and straightforward advice. As the cards are locale-specific, the preference is to translate information to Filipino or the vernacular, using friendly, familiar words that render the information less technical and more understandable.

While the current version focuses on temperature, rainfall, and the five-day forecast, additional cards are also being designed to relay special alerts such as official typhoon warnings and drought alerts from PAGASA, and other supplementary information from our site-specific stations. These are all being developed to strengthen vital weather and climate communication, with data being pulled from a custom API, which aggregates real-time readings from our network of automated weather stations. Generated from our own numerical model runs, our five-day weather forecasts are largely experimental since these are continually being refined and validated with actual observations on the ground. As these are research-based and site-specific, the experimental forecasts are designed to complement the official forecast from PAGASA and other global providers of weather information.

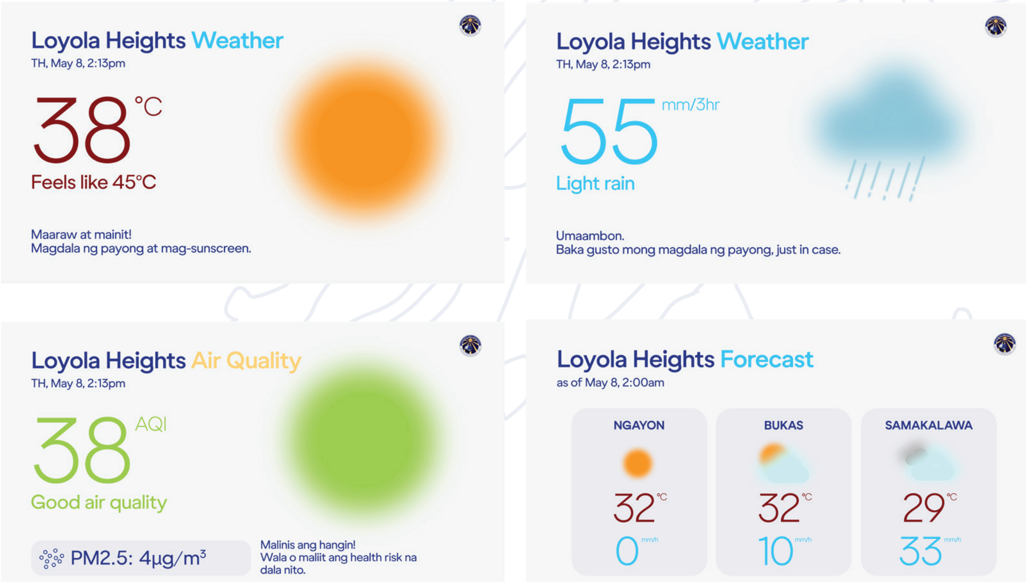


Figure 22. Initial drafts of weather cards for Loyola Heights, Quezon City. Icons will be changed to action-based icons.

Research Collaboration with PAGASA

We are happy to report that we have formalized research collaboration with PAGASA. This partnership promises to significantly strengthen our country's capacity in dealing with climate change.

Even before this formal agreement was inked in July 2024, both MO and PAGASA scientists were already doing research together and publishing in peer-reviewed journals. Key publications include analyses of extreme rainfall events, such as the 10 January 1999 extreme weather event over Hinatuan, Surigao del Sur, and the characterization of this climatologically and exceptionally wet place. Several studies also examined large-scale climate drivers, including the Madden–Julian Oscillation, tropical cyclones, the southwest monsoon, and their influence on rainfall patterns over Luzon and eastern Mindanao. In addition, PAGASA and MO developed an objective method to determine the withdrawal times of the southwest monsoon, thus potentially improving PAGASA's operational forecasts.

At present, research collaboration is on redefining Philippine climate zones through objective methods such as Self-Organizing Maps based on rainfall and temperature; identifying and locating shear lines that cause extreme rainfall during the northeast monsoon season; the spatiotemporal analysis of hail events; and a climatological investigation of enhanced southwest monsoon events.

We hope to engage PAGASA in other areas that are of mutual concern and beneficial to the Philippines and Southeast Asia. Together, we view these collaborative efforts between our institutions as vital to strengthening the country's scientific capacity and social resilience to climate and disaster risk.

Partnership with Local Governments

Anticipatory Action in BARMM

Through all that we have learned and worked on in this ECW project, the Manila Observatory was able to develop triggers for Anticipatory Action (AA) in the case of droughts, floods, and typhoons. As the name suggests, AA is about the timely deployment of resources ahead of a disaster. The application of these AA triggers was made possible through a consortium of partners in the Strengthening Resilience through Early Warning System, Enhanced Anticipatory Actions and Multi-risk Landscape Approach in Bangsamoro Autonomous Region in Muslim Mindanao (SUPREME BARMM) project.

Led by Oxfam Pilipinas (OPH) and funded by the European Civil Protection and Humanitarian Aid Operations (ECHO), this project involved partners in BARRM including the Bangsamoro Rapid Emergency Action on Disaster Incidence (READi) and the newly-formed Mindanao River Basin Management Council (MRBMC).

The AA triggers are designed to work as part of the Pre-Disaster Risk Assessment (PDRA) protocol that is followed by disaster risk managers before responding to any disaster. Actions designed to minimize loss, damage and suffering of potential victims are implemented prior to the occurrence of the extreme event. Forecast or prediction uncertainty is thus a concern that enters invariably into disaster risk assessment (e.g. will the anticipatory action still be beneficial to the community even if the worst case scenario does not occur?)

Two AA Alerts for drought were issued at the height of the 2023-2024 El Niño event. ENSO monitoring and community/household needs assessment surveys started in May 2023 when the El Niño warnings were raised by PAGASA. By January 2024, a Level 1 AA activation alert was issued for specific barangays within the Pikit Cluster of the BARMM Special Geographic Areas (SGAs), as well as in Datu Saudi Ampatuan and Datu Piang. Anticipatory actions included distribution of water, sanitation and hygiene (WASH) kits, drought-resistant vegetable seeds and farm tools, as well as information, education and communication (IEC) activities on El Niño and drought. In April 2024, the Level 1 Activation Alert was continued in the same barangays, with anticipatory actions involving rice distribution (25 kg per household) and cash assistance (P2,500 per household).

Figure 23. Community and household needs assessment surveys and monitoring were done by SUPREME BARMM partners at the start of El Nino. Results of these surveys were later used to determine the appropriate anticipatory and rapid response actions for the affected communities.

Figure 24. First activation of AA: 2,000 families were provided with water and sanitation (WASH) kits, drought-resistant vegetable seeds and farm tools, as well as information, education and communication tools on El Niño and drought.

Figure 25. The second round of AA involved directly providing communities with cash and rice subsidies as drought conditions continued.

The AA Triggers for drought, flood and tropical cyclones were presented to the BARMM READi PDRA team in September 2024 in Davao. A simple implementation of the AA risk matrix for select locations helped participants to integrate AA in their operations, using the different forecast products, together with their local knowledge and data on exposure and vulnerability. The participants also suggested further improvement of these tools, including the addition of local information, simplification of processes, and integration into GIS-enabled platforms. Consortium partners also shared current efforts to include AA and related tools in the policies and operations of the DRRMs.

Figure 26. The AA Triggers, Thresholds and Early Action Protocols (EAP) were turned over to the BARMM government by the SUPREME BARMM Consortium, led by Oxfam PH, during the ECHO Monitoring Visit in September 2024.

Other Local Governments

Important to the success of our AWS network is the engagement of LGUs through their Disaster Risk and Reduction Management Offices (DRRMOs). They are key partners in ensuring the sustainability of the AWS network. Data collected from these stations play a critical role in informing LGUs' operational decisions on disaster preparedness and response. In collaboration with various LGUs, we have been able to rehabilitate and integrate more AWSs into our network, thus expanding our coverage of real-time weather data.

In 2024, the Palawan Provincial DRRMO signed a MOA with MO to collaborate in managing their AWS and other weather forecasting-related projects in the province. Palawan currently hosts a total of 27 AWS units, six of which are rain gauge-only stations. Additionally, through a partnership with the Puerto Princesa City DRRMO, five new AWS units were added to the MO network. Two units previously operated by Weather Philippines Foundation Inc. (WPF) in Puerto Princesa were also successfully repaired.

Figure 27: MO's Paola Bañaga meeting with representatives from the Office of Civil Defense Region 10, DOST Region 10, Xavier University–Ateneo de Cagayan, and the Mindanao PRSD

MO expanded its operations in Northern Mindanao by formally partnering with Region 10 through a MOA. This collaboration includes the Office of Civil Defense Region 10, the Department of Science and Technology (DOST) Region 10, Xavier University–Ateneo de Cagayan, and the Mindanao Regional Services Division of PAGASA. In coordination with LGUs in Region 10, MO was tasked to assess and repair the AWSs that were previously managed by WFP. To date, Region 10 has benefited from the restoration of three AWS units in Misamis Occidental, one in Lanao del Norte, and six in Bukidnon.

Other Initiatives

Asia-Pacific Ministerial Conference on Disaster Risk Reduction

The Philippines, together with the United Nations Office for Disaster Risk Reduction (UNDRR), hosted the 2024 Asia-Pacific Ministerial Conference on Disaster Risk Reduction (APMCDRR) from 14 to 18 October 2024, at the Philippine International Convention Center. The gathering's aim was to monitor, assess, and improve joint action in accomplishing the Sendai Framework for Disaster Risk Reduction 2015-2030 in the Asia-Pacific region.

The Manila Observatory participated in this conference through an exhibit organized by Pilipinas Shell Foundation Inc. Our climate/weather research and community engagements were included in this exhibit, along with a display of an AWS unit.

Figure 28. Manila Observatory as exhibitor at the 2024 Asia-Pacific Ministerial Conference on Disaster Risk Reduction through Pilipinas Shell Foundation, Inc.

IoT Conference 2024

Dr. Sherdon Niño Uy, Head of the Data and Sensor Development Laboratory (DSD Lab) of MO, participated in the Internet of Things (IoT) Conference 2024,]held in October 2024, at the SMX Convention Center in Pasay City. He was one of the speakers in the "Panel Discussions: IoT for Agriculture and Disaster Management" session. With the theme "Connected Ecosystem in Building the IoT-Ready Philippines," the conference was organized to establish a unified environment for the promotion, sharing, and integration of technologies meant to benefit various sectors in the Philippines.

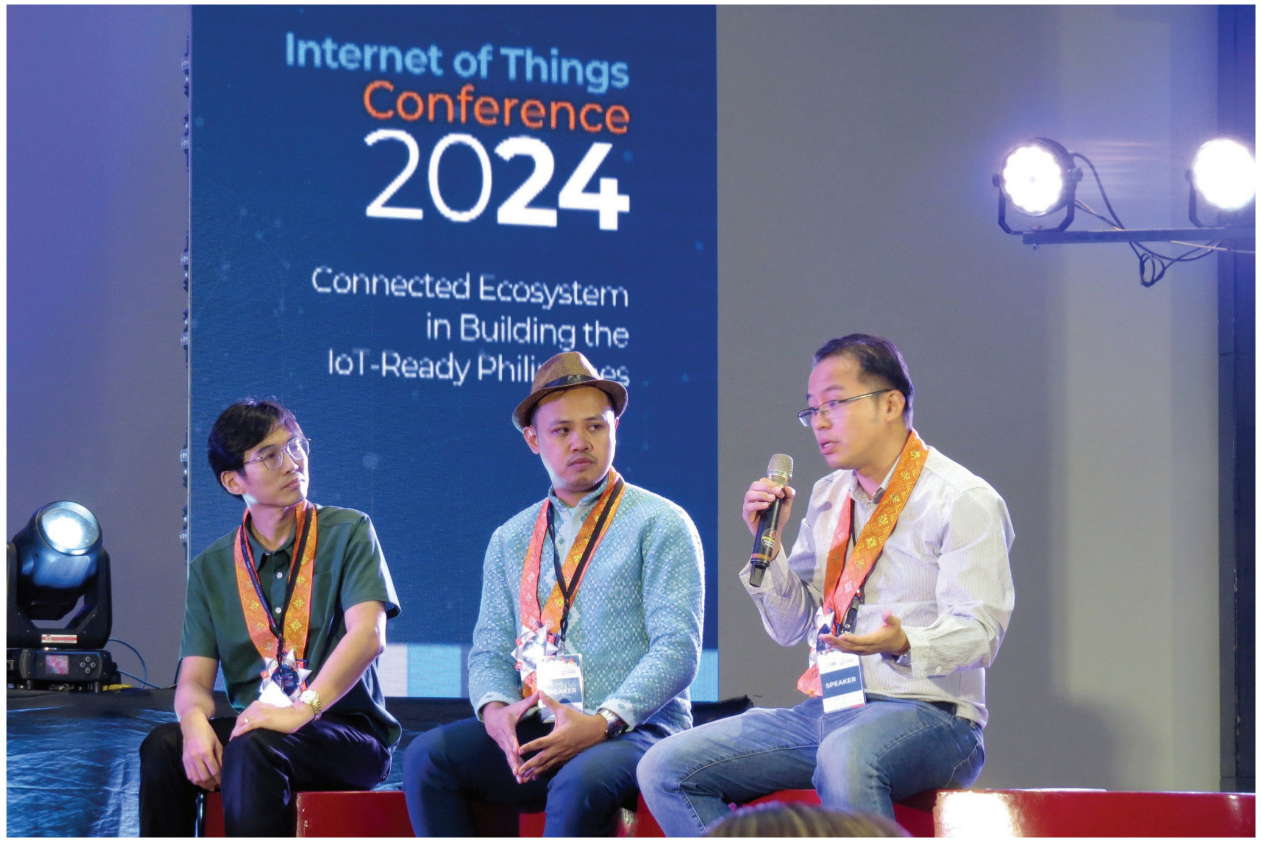


Figure 29. Dr. Sherdon Niño Uy at the panel discussion on IoT applications in agriculture and disaster management

League of Corporate Foundations

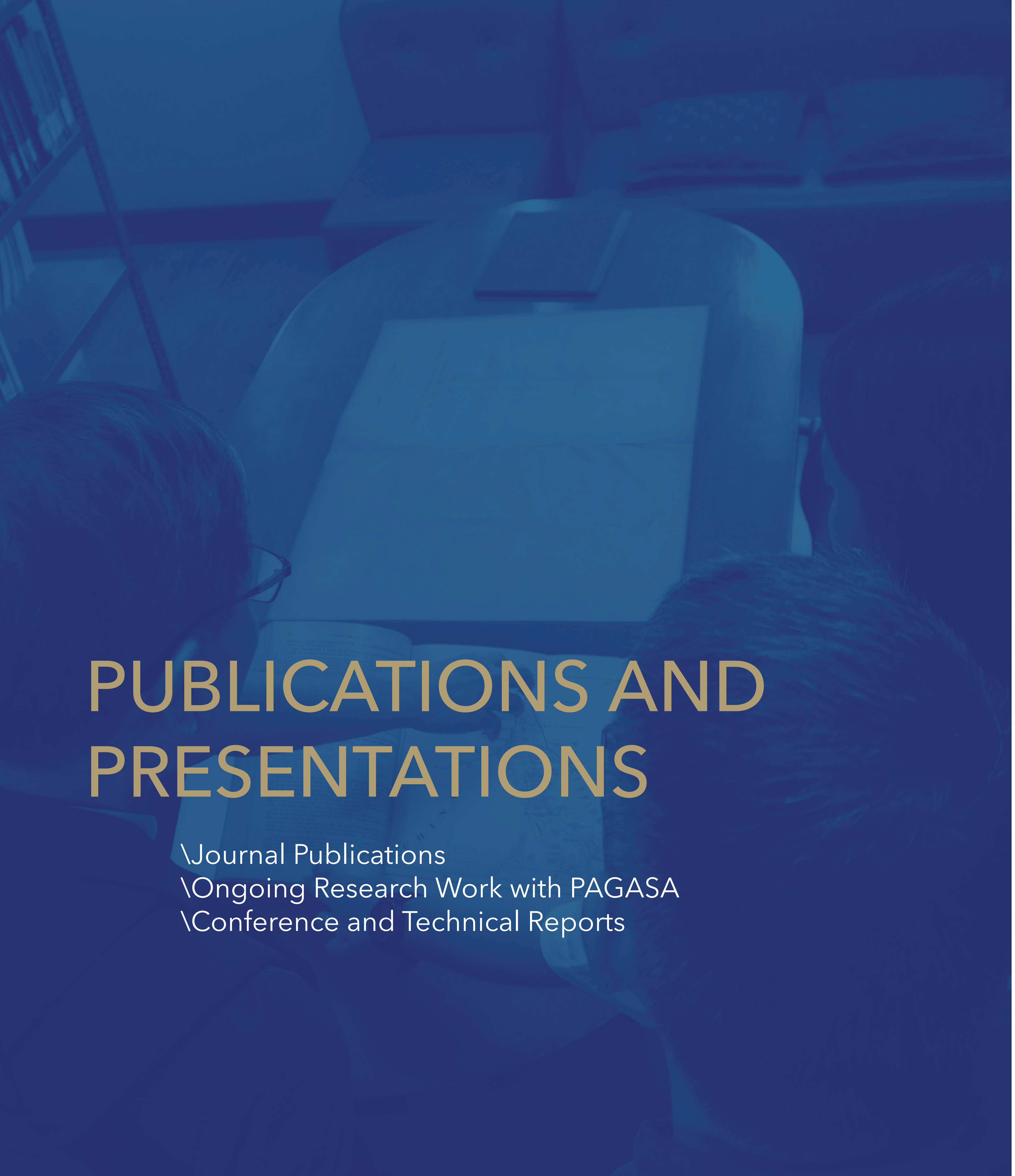
By virtue of Presidential Proclamation No. 299, s. 2000, the Philippines observes Corporate Social Responsibility (CSR) Week every first week of July. Organized by the League of Corporate Foundations (LCF), this year's CSR Expo took place on 3 to 4 July 2024 under the theme "Reimagining a New and Inclusive Future." The Expo centered on the utilization of technology and innovation for inclusive societal change and holistic national development.

Among the distinguished speakers in this Expo was Dr. Sherdon Niño Uy (DSD Lab head) who took part in the session on "Building Resilience: Utilizing Technology for an Inclusive Post-Pandemic Future with Enhanced Disaster Preparedness and Community Engagement". The session dwelled on the vital connection of technology, inclusivity, and community engagement to a resilient future.

Internships

Figure 30. MMSU and VSU student interns replacing the AWS rain gauge and performing preventive maintenance of AWS at the MO rooftop.

This year, we were joined by student interns from Mariano Marcos State University (MMSU) and Visayas State University (VSU), who assisted us in the field operation and maintenance of our AWS network. They worked on sensor calibration, equipment quality checks, and field deployment, thus gaining valuable hands-on experience with the MO technical team. In the second half of 2024, we also worked with interns from Rizal Technological University (RTU) and Ateneo de Manila University , many of whom had computer science and engineering backgrounds. They focused on data monitoring, electronics work, and the improvement of our instrumentation systems. In the field or at the lab, all of our interns were able to contribute meaningfully to our mission. We are proud to have been part of their scientific learning and formation.



PUBLICATIONS AND PRESENTATIONS

\Journal Publications
\Ongoing Research Work with PAGASA
\Conference and Technical Reports

Journal Publications

Bathan, A.A.L., Olaguera, L.M.P., Cruz, F.A.T., Villarin, J.R.T., Maquiling, J.T., Cambaliza, M.O.L., Manalo, J.A., Matsumoto, J. (To be published in late 2025). Influence of tropical cyclones, southwest monsoon on rainfall variability over the western coast of the Philippines. Atmos. Res. 326. https://doi.org/10.1016/j.atmosres.2025.108273

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Ongoing Research Work with PAGASA

Olaguera, L.M..P, Badua, E.K., Llorin, A.G.A., Cruz, F.A.T., Villarin, J.R.T., Manalo, J., Villafuerte, M.Q., Matsumoto, J. (2025). Rainfall and temperature-based Philippine climate zones using Self-Organizing Maps. Manuscript under review. SOLA.

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Olaguera, L.M.P., Bathan, A.A.L., Badua, E.K., Bañares, E., Petilla, C.E.R., Manalo, J.A., Cruz, F.A.T., Villarin, J.R.T. (2025) A comparative analysis of Enhanced Southwest Monsoons during 2012, 2013, and 2024 in the Philippines. Manuscript in preparation.

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Cruz, F., "Climate research to support climate action in the Philippines", Centre for Climate Research Singapore (CCRS) Seminar, Singapore, 3 September 2024

Cruz, F., Uy, S.N., Olaguera, L.M., Dado, J.M., Avila, F., Magnaye, A., Llorin, A.G., Henson, K., Loqueloque, D., Gozo, E., Teodoro, R., Villarin, J.R., "Supporting climate and disaster resilience in the Philippines through energy, climate and weather forecast research", Oral Presentation, 9th GEWEX Open Science Conference, Sapporo, Japan, 7-12 July 2024

Dado, J.M., Aragon, L.G.A., Cruz, F., Villarin, J.R., Simpas, J.B., Cambaliza, M.O., Bañares, E., Visaga, S.M., Apostol, G.L., "Spatiotemporal assessment of heat stress indices in Metro Manila, Philippines", Oral Presentation, 9th GEWEX Open Science Conference, Sapporo, Japan, 7-12 July 2024

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