Proceedings
of the Philippine Meteorological Society

Volume 2, March 2019 ISSN 2599-5537

Abstracts of Papers Presented in the

2019 PMS Annual Convention

Theme: "Leveling up Meteorological Service to Meet Societal Needs"

ISSN 2599-5537

Published by the Philippine Meteorological Society, Inc.
PAGASA Science Garden Complex
Agham Road, Diliman, Quezon City
Tel. No.: (+63 2) 929-4570

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Layout and Design: Ms. Ma. Teresa M. Pajarillo and
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New observation strategies for typhoon intensity over the Western North Pacific

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Recent activities on typhoon intensity observation/estimation using aircraft reconnaissance and ground-based Doppler radars in the western North Pacific are introduced. Since aircraft reconnaissance by the US military was ceased in 1987, new techniques of intensity estimation using microwave radiometer and a geostationary satellite are used in this basin without enough verification. The major obstacle of aircraft reconnaissance is the difficulty of having a specially-designed propeller aircraft that withstands strong turbulence. Since wind speed in a typhoon is stronger in the lower troposphere, it takes a great deal of labor and expense to measure the center position and the central pressure of a typhoon through low-altitude flight with slow speed. On the other hand, since the winds become weaker in the upper troposphere, it is possible to fly into the typhoon center if the risks of heavy icing and severe turbulence in a convective burst can be avoided by using an airborne weather radar. During T-PARCII (Tropical Cyclone-Pacific Asian Research Campaign for Improvement of Intensity Estimations / Forecasts), we succeeded in observing the central pressure of two intense typhoons, Lan (2017) and Trami (2018), by using a commercial jet aircraft (Gulfstream-II) with a newly-developed GPS dropsonde system. These flight missions were made in the upper troposphere (43,000ft, approximately 13.7 km) and were marked by very weak turbulence during eyewall penetration. These flights demonstrated a possibility of typhoon intensity observation using a civil aircraft. In the Pacific coast of Japan and Philippines, Doppler radars became available in this decade. The combination of aircraft reconnaissance off the coast with the ground-based velocity track display (GBVTD) analysis near the coast will provide accurate information on typhoon intensity.

Keywords: typhoon, aircraft reconnaissance, dropsonde

Development of a Storm Surge Forecasting and Warning System for the Philippines

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Philippines, located at the western rim of the Pacific Ocean, is a path to many turbulent typhoons and its archipelagic nature made it susceptible to storm surges. The storm surge which manifested on the 8th of November 2013, on the landfall of Typhoon Haiyan, distraught large areas of Leyte and Samar. Several days before Haiyan made landfall in the Philippines, PAGASA have forecast Haiyan's track and intensity well in advance and also forecast the occurrence of storm surge. PAGASA disseminated tropical cyclone bulletins and warnings and declared the highest alert level in the provinces along the path or track of typhoon Haiyan. Despite these efforts, typhoon Haiyan claimed the lives of 6,300 people many of which are due to storm surge, declared 1,062 missing, 28,688 were injured and total damage and economic losses estimated at $2 billion. The negative impacts of typhoon Haiyan could have been minimized if the people at risk and the people responsible to mitigate the risk have an understanding of the impact of the storm surge hazard. An operational storm surge forecasting and warning system was developed in this study which aimed to accurately forecast storm surge height and provide an impact based storm surge alerts, watch and warning information which is in accordance with standard processes of the multi-hazard early warning system as applied in the Philippines. The operational forecasting and warning system was initially used for the 2018 Typhoon Mangkhut (Ompong). To simulate the storm surge height, the Japan Meteorological Agency (JMA) storm surge model, historical storm surge occurrences in the Philippines and predicted tide for 2018 published by NAMRIA were used. Storm Surge Warning System entails the issuance of the Storm Surge Watch, 48 – hours before landfall and Storm Surge Warnings, 24 – hours before landfall. Field surveys and measurements were conducted to compare the simulations of storm surge heights and validate the effectivity of the impact based storm surge warnings.

Keywords: storm surge, forecasting, warning system and impact based

Extended-Range Tropical Cyclone Forecasting in the Philippines

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This study investigates the potential predictability of tropical cyclone (TC) occurrence in the Philippine Area of Responsibility (PAR) using the NCEP 16-day Global Ensemble Forecast System (GEFS). The TC detection and tracking algorithm operationally being used by the Central Weather Bureau was utilized to detect and track TC-like vortices (TCLV) from the 6-hourly NCEP-GEFS model runs covering the period from 1 January to 31 December in 2015 and 2017. A 2×2 contingency table was used to summarize the event forecast relative to the observed occurrence of TC over the PAR. A forecast hit is declared if there is at least 30% overlap between the polygons created from the drawn circles with 500 km radius centered at the identified forecast TCLV center and the observed TC track (here, we used the best tracks archived by the Regional Specialized Meteorological Center-Tokyo in combination with the TC tracks data of the Philippine Atmospheric, Geophysical and Astronomical Services Administration to include weaker storms). The hindcast period of evaluation indicates a hit-rate of 0.62 and 0.30 in 2015, while 0.32 and 0.30 in 2017 for the 1- and 2-week TC forecasts, respectively in the PAR. Possible indicators for forecast hit are further investigated, which revealed that the TC characteristics primarily govern predictability. It is also shown that both the El Niño–Southern Oscillation and the Madden–Julian Oscillation (MJO) influence TC predictability over the PAR. Specifically, we found that the stronger the TC and the farther to the eastern boundary of the PAR it was developed, which typically occurs during El Niño (the case of 2015), the higher chance it could be forecasted both for the 1- and 2-week lead times. It is further revealed that TC forecasts performed well during an active phase of the MJO.

Keywords: extended-range tropical cyclone forecasts, ENSO, MJO, the Philippines

Diurnal variability of atmosphere and ocean in Northwest Luzon, Philippines

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Variability in rainfall in the Philippines is very high, with cycles ranging from decadal (ENSO, PDO), seasonal (monsoons), intraseasonal, to diurnal. The diurnal cycle contributes significantly to the total precipitation in the Asian Monsoon region but the process is not so well understood in the Philippines. The project Regional Scales of Variability in Precipitation (RSVP) was thus conceptualized to characterize the diurnal variability of precipitation throughout the Philippines over time and to relate amplitude of the diurnal signal to ocean conditions, with the land-sea breeze being an important process contributing to the diurnal signal. Data from various sources such as satellite, automated weather stations, shipboard observations, and model outputs were analyzed mostly through Fast Fourier Transform and correlation analysis. Results show that in certain areas of the Philippines, the range of rainfall over a day may exceed range of rainfall over a season. These areas include the larger islands but especially the NW Luzon area during the southwest monsoon, with rainfall that peaks over land in the late afternoon and over the ocean at night. Diurnal signal may be attributed to the land-sea breeze circulation that includes a strong breeze from the sea from 0800 to 1400H and a strong breeze from land starting 2200 to 0200H. Shipboard observations of surface winds, salinity, temperature, and current profiles also showed local land-sea breeze was found to be a very important forcing at the coast and affected the strength and extent of the Northwest Luzon Coastal Current. Simulations using Weather Research and Forecasting (WRF) model were able to capture the patterns in diurnal variability. Though model results showed overestimation in mean precipitation across the domain, model experiments showed that the variability of sea surface temperature (SST) significantly contributes to the diurnal variability of rainfall.

Keywords: Diurnal, rainfall, ocean, land-sea breeze, WRF, northwest Luzon

Increasing "enhanced habagat" days in Western Luzon from 1960: A manifestation of global warming?

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"Enhancement of Habagat" is a phrase that most Filipino's came to understand in the current decade. Continuous heavy rainfall in places along Western Luzon, particularly NCR in August of 2012 and 2013, caused/causes significant damage to properties and even loss of lives during the peak of southwest monsoon season. These phenomenon disrupts the country's agriculture, as well ask economic sector. Using daily-averaged precipitation and JMA Tropical Cyclone (TC) best-track data from 1958 to 2017, this study aims to elucidate the mechanism of the phenomenon commonly referred to as the "enhancement of Habagat". Evaporative heating on top of TCs to the east or northeast of Luzon produce westward-propagating tropical Rossby waves, which in turn induce stronger westerlies in the southern Indochina region. The induced westerlies bring in more moisture from the Indian Ocean to the Northwestern Pacific region which feed the TC with more water vapor. This positive feedback between a TC and westerly moisture flow sustains the continuous rainfall along western Luzon when moisture-laden air masses interact with local topography. Moreover, a significant increasing trend was found for the upper 85th percentile "habagat" rain days. Habagat days increased from 20.7 days/year in the 1960's to 26.9 days/year in the current decade (2010-2017). The increased number of days is likely due to the increase in TC frequency to the east of Taiwan, which was shown to be modulated by the warming waters of the Maritime continent.

Keywords: rainfall, tropical cyclone, monsoon, habagat

Tropical cyclone-enhanced Southwest monsoon over Western Philippines

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The Philippines experiences prevailing Southwest monsoon (local term: “Habagat”) that brings moist, warm air from equatorial, low-latitudinal water to the western portion of the Philippines during June-September. The recent Habagat event in the Philippines was enhanced and influenced by the occurrence of five (5) tropical cyclones (TC) namely, Tropical Storm Henry (Son-Tinh), Severe Tropical Storm Inday (Ampil), Tropical Depression Josie (13W), Tropical Storm Karding (Yagi), and Severe Tropical Storm (Bebinca). Enhanced Habagat brought torrential, continuous rain resulted in flooding and landslide over western Philippines. An increase in rainfall of about 20%-173.6% than normal in selected station was observed. The heavy rainfall event had caused massive socio-economic impact.

This study investigates the intensification of Habagat by analyzing a 68-year rainfall climatology and 1307 TCs existed in the Philippine Area of Responsibility (PAR) for 1951-2018. The dynamical normalized seasonality (DNS) is used as the Habagat index and is calculated using the zonal wind of the National Centers for Environmental Prediction (NCEP) Reanalysis 1. The DNS index and the increased rainfall associated with Habagat are significantly correlated (r=0.74). The study showed that the enhancement of Habagat is due to the existence of nearby TC located along far north, northeast to east of the Philippines and occurrence in the South China Sea. Hence, varying location of TC had induced the transport of high moisture content and caused heavy rainfall over western Philippines. To further assess TC-enhanced Habagat, spatial Fast Fourier Transform (FFT) is employed. Spatial FFT decomposes total wind flow to monsoonal flow and cyclonic flow. Anomalous westerly flow is strengthened by the TC.

Keywords: southwest monsoon, tropical cyclone, DNS, FFT

Cloud Seeding Operations in the Philippines: A Science-Based Approach

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Over the years, cloud seeding operations (CSO) have been found helpful intervention to address rainfall deficiencies during drought season and enhance freshwater resources in water reservoirs for multi-purpose activities such as power generation, irrigation, industrial and domestic consumption, among others. In other countries such as Thailand, India, Indonesia and China, a science-based technique of CSO has been employed through meteorological analyses and application of state-of-the-science tools. This study aims to undertake a science-based CSO in the country through analyses of meteorological conditions and application of available meteorological technologies such as Doppler radar, upper air soundings, satellite and numerical weather prediction models, among other. These tools are employed to determine suitability of the atmosphere for CSO and identify and monitor the development and movement of potentially seedable clouds through a developed “Decision Support System” or operational framework to identify the day either “Go”, “No-Go” or “Standby” day. Further, several sizes of the seeding agent, sodium chloride, (200μ, 150μ, 80μ, 50μ, 30μ) have been tested in multiple cloud seeding experiments such as in Batangas, Zamboanga, Bohol, Pantabangan and Angat watershed to determine its efficacy. As a result, although more experiments need to be undertaken to generalize the findings, preliminary result shows that the greater buoyancy of the much finer sizes of the seeding agents have been found to attract more moisture aloft which favors better growth of the clouds eventually producing artificial rains. Doppler radar is used to validate the growth and rainfall activities induced by CSO. Furthermore, establishment of thresholds for various weather parameters in different regions will help a lot towards effective science-based cloud seeding operation in the country.

Keywords: cloud seeding operations, state-of-the-art technologies, cloud seeding agents, rainfall deficiencies

Polarimetric Analyses of Selected Tornadic and Nontornadic Thunderstorms in the Philippines

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The advent of polarimetric radars has offered powerful techniques to study the microphysics and dynamics of severe convective storms. This study aims to determine the statistical significant differences in similar polarimetric variables across tornado stages (before, during and after) and between tornadic and nontornadic thunderstorms using non-parametric tests. These variables include horizontal reflectivity factor (Zhh:dBz), differential reflectivity (Zdr:dB), the magnitude of the copolar cross correlation coefficient (ρhv) and specific differential phase (Kdp:o/km).Initial interpretations on the microphysical features of small samples of tornadic and nontornadic thunderstorms in the Philippines using polarimetric observation are presented and distinctive characteristics of tornadic thunderstorms in the Philippines with some known features of tornadic supercells in Great Plains (USA) are compared. As a result, some paired stages showed evidences of similarity on the distributions indicated by p-value greater than 0.05 such as "before and after" for Zhh, "during and after" for Zdr, and "before and during" for ρhv with the exception of Kdp. Furthermore, all similar variables between tornadic and nontornadic thunderstorms revealed significant statistical differences.

Cases for tornado and nontornado events were studied to analyze microphysical properties across tornado stages and nontornadic thunderstorm. High Zhh values were mostly collocated with high Zdr and Kdp, indicative of a hail-rain mixture and heavy rainfall. Presence of hook or bow echo manifested formation of tornado in USA and in the Philippines although several distinctive features were observed. Due to limited cases, the results should not be over-generalized but can serve as a preliminary study to foster future related investigations. Furthermore, the results provide a basis for operational meteorologists to identify severe weather threats such as presence of hail and heavy rains through various polarimetric features found in this study. Additional studies taking into account other polarimetric variables with more cases are highly recommended in the future.

Keywords: polarimetric radar, tornadic thunderstorms, polarimetric variables

Towards Impact-based Forecasting and Warning in the Philippines

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The World Meteorological Organization has continually emphasized the importance of providing impact-based forecast and warning services to increase the relevance and value of the National Meteorological and Hydrological Services' forecasts and warnings. With the Philippines being exposed to a range of hazards such as landslides, flooding, drought and tropical cyclones, PAGASA is developing ways to improve its services by introducing impact-based forecasting and warning. Impact-based forecasting emphasizes what a hazard will do rather than what the hazard will be. Through funding from DOST-PCIEERD, PAGASA is currently working with UK Met Office on a project entitled "Weather and Climate Science for Service Partnership for South East Asia: Building a Safer Community to Weather and Climate Variability through Science and Innovation" which includes conduct of pilot studies in designing and developing an impact-focused framework, identifying functional needs for impact-based forecasting and developing personnel capacity on impact-based forecasting. The aim is to establish forecast and warning services that allow the consequences of severe weather events to be understood by users and drive relevant entities to initiate appropriate mitigating actions. It is recognized that strengthening relations between warning-provider and disaster management agencies is an important step in the successful implementation of the project. Workshops for technical personnel and relevant stakeholders to ensure a consistent understanding of an impact-based warning system is also a critical part of the project.

Keywords: impact-based forecast, severe weather, impact-based warning, disaster management

Characterization of Frost Events in Benguet, Philippines

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Frost events are rare in a tropical country like the Philippines, yet, this weather event affects the region of Benguet. Until now, it is difficult to study the characteristics of frost in detail due to the scarcity of observational data, compounded by the complex terrain in this isolated region. This study aimed to characterize frost formation in Benguet with the use of land surface temperature (LST) observations from MODIS satellite, numerical simulation of surface temperature using available ground weather station, Weather Research Forecasting (WRF) model, synoptic weather maps, as well as digital elevation model (DEM). Comparing the result of the WRF simulation and MODIS satellite observations to the ground weather observations, it was found that WRF performs well to both daytime and nighttime as compared to the remote sensing data. In spite of the subtle difference, both yielded temperature values consistent with anecdotal reports of 10 °C by local farmers and agriculturists established as threshold for frost occurrence. The prevailing synoptic weather system and the corresponding mesoscale patterns were found to have a vital contribution to frost events. The synoptic wind pattern from the NCEP FNL reanalysis showed that frost events coincide with weak northeasterly wind flow during boreal winter. Weak monsoon flow is due to several synoptic scale flow patterns like intrusion of strong easterlies, difluence of wind due to tropical cyclones at the east of the country, or mid-latitude high pressure systems positions. Weak wind speed and above freezing temperature during frost occurrences led to the conclusion that frost events in Benguet are primarily radiative frost.

MODIS data was used to map the risk of frost over the study area. The risk is associated with the physiographic factors that contribute to the mesoscale extreme events in the mountainous area of Benguet. Results showed that the elevation and morning potential insolation (MPI) are among the physiographic variables that influence the frost risk. Moreover, a Frost Event Indicator for Benguet was developed by applying multinomial logistic regression on WRF-simulated weather parameters.

Keywords: radiative frost, radiative cooling, land surface temperature, topography

Suitability Assessment of Temporary Crops based on Agrometeorological Forecasts using Logistic Regression

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Climate variability can be observed in the Philippines for the observance of the following phenomena: fluctuations in rainfall, humidity and temperature. There has been fluxes in the agrometeorological factors in return that resulted to problems were encountered by agriculture sector. In this study, time series forecasting technique of Autoregressive Moving Average (ARIMA) was used to forecast agrometeorological variables; maximum temperature, minimum temperature, sunshine duration, relative humidity and amount of rainfall in the province of Laguna. And based from these monthly forecasts, suitability of temporary crops was assessed using Logistic Regression. This paper intended to determine the accuracy of the developed tool in assessing the suitability of crops based on the forecasted variables, and in forecasting the agrometeorological variables; and the reliability of the developed tool in assessing the suitability of crops based on the forecasted variables. 10 yearlong data were utilized to build and to evaluate the models. Verification of the models has been done for 2015-2017-time period. As result, the system garnered an overall forecast accuracy of 91.64% in forecasting agrometeorological variables using ARIMA and 82.41% overall classification accuracy of Logistic Regression model in assessing the suitability of crops. The system obtained a value of 1 in Cronbach's alpha which perceives that the system possesses excellent reliability and consistent results in the time of testing. The study concludes that the system, using ARIMA and Logistic Regression, was able to serve its purpose: to forecast agrometeorological variables and to assess the suitable crops with accurate and reliable results based on the analysis and simulation of data.

Keywords: convection phase, episodic climate event, spatial/temporal rainfall pattern, rainfall forecasting, maritime continent

Interdecadal Shifts in the Winter Monsoon Rainfall of the Philippines

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This study investigates the interdecadal shifts in the winter monsoon (November to March) rainfall of the Philippines from 1961 to 2008. Monthly analysis of the winter monsoon rainfall shows that the shifts are most remarkable during December. This month corresponds to the second peak planting of rice and other agricultural products in the Philippines. Therefore, an understanding of the different mechanisms leading to these interdecadal shifts in rainfall are crucial for agricultural planning and management of water resources.

Two interdecadal shifts are identified in the December rainfall time series around 1976/1977 and 1992/1993. To facilitate the examination of the possible mechanisms leading to these shifts, the analysis period is divided into three epochs: 1961–1976 (E1), 1977–1992 (E2), and 1993–2008 (E3). The mean and interannual variability of rainfall during E2 are suppressed compared with the two adjoining epochs. The shift around 1976/1977 is related to the phase shift of the Pacific Decadal Oscillation (PDO) from a negative phase to a positive phase and features an El Niño-like sea surface temperature (SST) change over the Pacific basin, while that around 1992/1993 is related to a La Niña-like SST change. Further analysis of the largescale circulation features shows that the decrease in the mean rainfall during E2 can be attributed to the weakening of the low-level easterly winds, decrease in moisture transport, and decrease in tropical cyclone activity. In addition, the suppressed interannual variability of rainfall during E2 can be partly attributed to the El Niño-like SST change and the weakening of the East Asian winter monsoon.

Keywords: Philippines; winter monsoon; interdecadal shifts; Pacific Decadal Oscillation (PDO)

Society Profile

The **Philippine Meteorological Society, Inc.** (PMS) is a non-stock, non-profit governmental organization dedicated to the advancement of the atmospheric sciences and related disciplines in the Philippines.

Objectives of the Society

- Formulates, implements and coordinates projects to strengthen education, research and development in the atmospheric and related sciences;
- Establishes linkages with universities/colleges, operational forecast centers/offices, meteorological societies, non-government organizations and the private sector;
- Conducts research and extension services in various sectors impacted by climate change;
- Conducts training, seminars, workshops, symposia, etc. on atmospheric science and related disciplines;
- Publishes and distributes results of research and other scientific information on atmospheric and other related fields;
- Promotes meteorology, hydrology, climatology, agrometeorology, and astronomy as a profession; and
- Administers gifts, grants and donations of cash, property and services that will redound to the benefit of the society.

Society's mission

- To develop and disseminate knowledge of meteorology and related hydrologic sciences (hereinafter referred to as "Meteorology")
- To promote and advance the professional application of Meteorology
- To encourage collaboration amongst Members of the Society, individuals, bodies both corporate and non-corporate who may share the Society's interest in Meteorology
- To promote among the public an understanding of weather and an appreciation of the value of Meteorology and its applications

Society's Structure

The Society's affairs are run by an elected Board of Trustees, within the constraints of the By-laws of the Society. The Society is served by Executive officers composed of a President, a Vice-President, Secretaries, a Treasurer, an Auditor and a Business Manager duly appointed by the Board of Trustees. In addition, the Board of Trustees appointed members to serve certain committees such as the Membership and Awards Committee.

Services Offered by the Society

- Consultancy (weather, climate, hydrology, air pollution and water quality assessment)
- Client-customized weather forecasts and extended outlooks
- Wind and wave forecast
- Capacity building in the mitigation of impacts of extreme weather and climate
- Conducts lectures, seminars and conference on current environmental issues

Past Activities of the Society

In order to meet its responsibilities and challenges, the PMS has sponsored a number of symposia both local and international.

- 2018 PMS Annual Convention – March 15, 2018
  Theme: "Recent Advances in Philippine Weather, Climate, and Hydrologic Information
- 12th National Meteorological Hydrological Convention – March 2, 2017
  Theme: "Shaping the Future of Philippine Meteorology and Local Governance"
- 11th National Meteorological Hydrological Convention – February 17-18, 2016
  Theme: "The Role of Meteorology in Disaster Prevention and Mitigation"
- 10th National Meteorological Hydrological Convention – November 19-20, 2014
  Theme: "Extreme Weather and Climate: Impacts and Preparedness"
- 9th National Meteorological Hydrological Convention – February 20-21, 2014
  Theme: "State-of-the-Art Technologies in response to Extreme Weather Climate Events"
- 8th National Meteorological Hydrological Convention – February 21-22, 2013
  Theme: "Today's Meteorologists: Scaling up Effective Early Warning Services (EWS)".
- 7th National Meteorological Hydrological Convention – November 17-18, 2011
  Theme: **"**Dots, Isobars and Meteograms: Understanding the Science of Meteorology**"**
- 6th National Meteorological Hydrological Convention - November 18-19, 2010
  Theme: "Adaptation Strategies: Building Blocks for a Climate Change Resilient Phil."
- 5th National Meteorological Hydrological Convention – November 19-20, 2009
  Theme: "Understanding the Climate Change Issues: A Key to a better planning and investment." Makati Convention Hall
- 4th National Meteorological Hydrological Convention – November 27-28, 2008
  Theme: "Connection and Fusion: Coping with Winds of Change."
- Co-Organized the Symposium titled "Rediscovering Philippine Setting: Meteorology and Mineralization and Tectonics" – October 2-4, 2008
- 3rd National Meteorological Hydrological Convention – March 26-27, 2008
  Theme: "Climate Change: Local, Regional and Global Initiatives"
- 2nd National Meteorological Hydrological Convention – November 27-28, 2006
  Theme: "Weather Climate and Water Implication to Sustainable Development."
- 1st National Meteorological Hydrological Convention – December 12-13, 2005
  Theme: "Towards Understanding Weather, Climate and Consequences to Hydrology for Socio-Economic Development".
- PMS-ADPC National Workshop (May 15, 2003)
- Symposia on Tropical Cyclones in the South China Sea and Western North Pacific Ocean
- Extreme Climate Events (ECE)
- National Symposium on the Application of Weather and Climate information

Aside from the sponsored local and international symposia, PMS also conducted other activities in 2018 as follows:

- "3rd PAG-ASA para sa mga Bata: A Blood Letting Activity" in partnership with Weather Bureau Multipurpose Cooperative (WBMPC) – June 19, 2018
- Information, Education and Communication (IEC) Campaign for PAGASA employees entitled "IEC on PAGASA Products and Services for New PAGASA Personnel" – June 22, 2018

Published by the Philippine Meteorological Society, Inc.
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