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Introduction to the special issue on Taiwan-Philippine VOTE-Meteorology: Typhoon Study and Related Natural Hazard

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ABSTRACT

The Taiwan-Philippine VOTE (Volcano, Ocean, Typhoon, and Earthquake)-Meteorology project, funded jointly by MOST (Ministry of Science and Technology) of Taiwan and DOST (Department of Science and Technology) of the Philippines, focuses primarily on improving the forecast capability of typhoons in different time scales. It is a bilateral collaboration between Taiwan and the Philippines governments. Data from satellites, coastal weather radars, and numerical forecasting models such as Weather Research and Forecasting Model (WRF) and the Cloud-Resolving Storm Simulator (CReSS) are used to study the typhoon track and intensity and the associated precipitation over Taiwan and the Philippine areas. On the other hand, long-term behavior of typhoons, e.g., the seasonal and intra-seasonal variability of typhoons, in the region near Taiwan and the Philippines is also studied. The papers collected in this special issue are mostly based on the research work during this VOTE-Meteorology project, and their major results are summarized in this introduction.

1. INTRODUCTION

Taiwan and the Philippines have a long history of collaboration on meteorology science and technology. In recent years, the collaboration has been strengthened to a greater depth possibly due to the threats caused by the climate change. Both countries have experienced stronger and more frequent natural disasters, such as typhoons and heavy rain that caused tremendous property damages and human casualty. As a result, the two countries are ranked the regions of highest risk of being exposed to natural hazard threat. Since 2009, the National Science Council (renamed to Ministry of Science and Technology, MOST, in 2014) of Taiwan and the Department of Science and Technology (DOST) of the Philippines have jointly promoted meteorological science cooperation for typhoon and heavy rain research on several missions. The missions included rebuilding the upper-air sounding station at Manila area, providing materials and funding necessary for establishing 15 automatic surface weather stations around Luzon Island for typhoon monitoring purpose, jointly constructing Doppler weather radar at Basco (which is an island at the Bashi Channel), helping train personnel of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) to increase their radar and numerical modeling capability, and jointly establishing the Asia-Pacific Economic Cooperation (APEC) Research Center for Typhoon and Society under the APEC organization to provide knowledge and technology information for disaster reduction especially for natural hazards.

In 2016, three three-yearly collaborative research projects between the MOST of Taiwan and the DOST of the Philippines on the research topics related to Volcano, Ocean, Typhoon, and Earthquake (MOST-DOST VOTE) were proposed. One of the projects named "Improvement of forecast capability on weather, marine meteorology and short-range climate" is in the field of meteorology. Its main objectives are, through research collaboration of the university scientists and operation agencies between both countries, to more efficiently exchange the science and technology of observations and forecasts, to greatly improve the forecast capability, and to significantly reduce the damages and casualty associated with severe weathers, typhoons and

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heavy rain, ocean waves, and short-range climate. After three years of successful research work, many researchers in Taiwan and the Philippines who got involved in the project produced excellent research results. This special issue in TAO titled "Taiwan-Philippine VOTE-Meteorology: Typhoon Study and Related Natural Hazard" is thus proposed and devoted to collect eight research papers that are related to the project.

2. PROJECT OVERVIEW AND RESULTS

In the beginning phase of this VOTE collaboration program, three subprojects are proposed. They are: (1) Typhoon formation, structure, and intensity change in western North Pacific and wave observation and modeling; (2) Heavy rain monitoring and forecasting in the mountainous area and early warning landslides; and (3) Observations and dynamical downscaling of seasonal and sub-seasonal forecast.

2.1 Typhoon

With on average more than 20 typhoons (tropical cyclones, TC) affecting the Philippines and Taiwan each year, typhoons produce the most damage loss in both Taiwan and the Philippines among all weather systems (Fig. 1). The major objectives of this subproject are to advance the understanding of the typhoon movement and intensity change and to improve the capability of the weather service of the Central Weather Bureau (CWB), Taiwan and the PAGASA, Philippines in typhoon monitoring and forecast over the western North Pacific. Five subjects are identified for the study: (1) Enhancement of typhoon monitoring by using radar and satellite observations; (2) Improvement of data assimilation and numerical prediction system; (3) Development of forecast guidance and verification; (4) Improvement of storm surge and wave forecasts; and (5) Improvement of threat potential forecast and climate service.

Four papers were written by researchers working in this subproject, including Chen et al. (2021), Gile et al. (2021), Jiang et al. (2021), and Yeh et al. (2021). Yeh et al. (2021) examined the applicability of the TWRF model (based on the Weather Research and Forecasting model, specifically for the typhoon prediction) of the CWB, Taiwan in the rainfall prediction of Typhoon Koppu (2015) which brought intensive small horizontal-scale rainfall at Baguio, Philippines. It also aims to improve the understanding of the mountainous terrain effect on the rainfall and structural changes of Typhoon Koppu. Modeling results show that heavy rainfall was caused by the outer rain band of the typhoon, which gradually reorganized over the western coastal area when Koppu weakened after landing. The formation and intensification, the weakening and southward shifting, and then the northward approaching and passing of the rain band resulted in the extreme rainfall at Baguio.

Jiang et al. (2021) investigated the feasibility of using a blending scheme to combine global coarse-resolution analysis with a high-resolution limited-area model. By regularly introducing large-scale information, the accumulated forecast error was corrected in a high-resolution model due to continuous data assimilation cycles. The impact of incorporating the blending scheme into three-dimensional variational (3DVAR) and local ensemble transform Kalman filter (LETKF) data assimilation systems are evaluated using a frontal rainband case. Results reveal that incorporating the blending scheme successfully mitigates accumulated forecast error and improves model quantitative precipitation forecast (QPF) skill for both systems. Also, blending large-scale water vapor to correct moisture field plays a key role in this case. Furthermore, the blending scheme imposes a larger impact in 3DVAR than that in LETKF.

Chen et al. (2021) studied the impact of assimilating dual-Doppler radar retrieval winds from eight sets of dual-Doppler radars using four-dimensional data assimilation (FDDA) on the prediction of Typhoon Nesat (2017) that passed over Taiwan. The wind field retrieved from dual-Doppler radars has a vertical extent from 1 to 10 km and the horizontal resolution is 1 km. The radar retrieval winds are assimilated using FDDA for two update cycles in addition to the existing hybrid 3DEnVar for all other observations in TWRF. For Typhoon Nesat, the wind structure and rainfall forecasts are improved with the assimilation of radar-retrieval winds. The overall improvements demonstrated by this case study suggest potentially high impacts for improving the prediction of typhoon-related rainfall with assimilation of dual-Doppler radar data.

Gile et al. (2021) evaluated TC intensity forecast from the Weighted Analog Intensity Prediction (WAIP) and determined its applicability as baseline intensity forecast guidance of the PAGASA. The method generates a rank-weighted average of intensity evolutions of 10 historical analogs from the 1945 - 2014 Joint Typhoon Warning Center (JTWC) best tracks that closely resemble the PAGASA official forecast track and initial intensity at the time the forecast is generated. WAIP proved to be more skillful in providing intensity forecast at 12 to 96 h and less skillful at 120 h relative to persistence.

2.2 Heavy Rain

The major objective of this subproject is to improve the capability on heavy rainfall monitoring and forecast over the mountainous areas using various surface observations, remote sensing instruments, and numerical models. It is composed of three major tasks: (1) Rainfall estimation in the mountain region using operational radar systems; (2) Quantitative rainfall prediction in the mountainous areas using high resolution mesoscale models and ensemble system; and (3) Heavy precipitation systems monitoring using

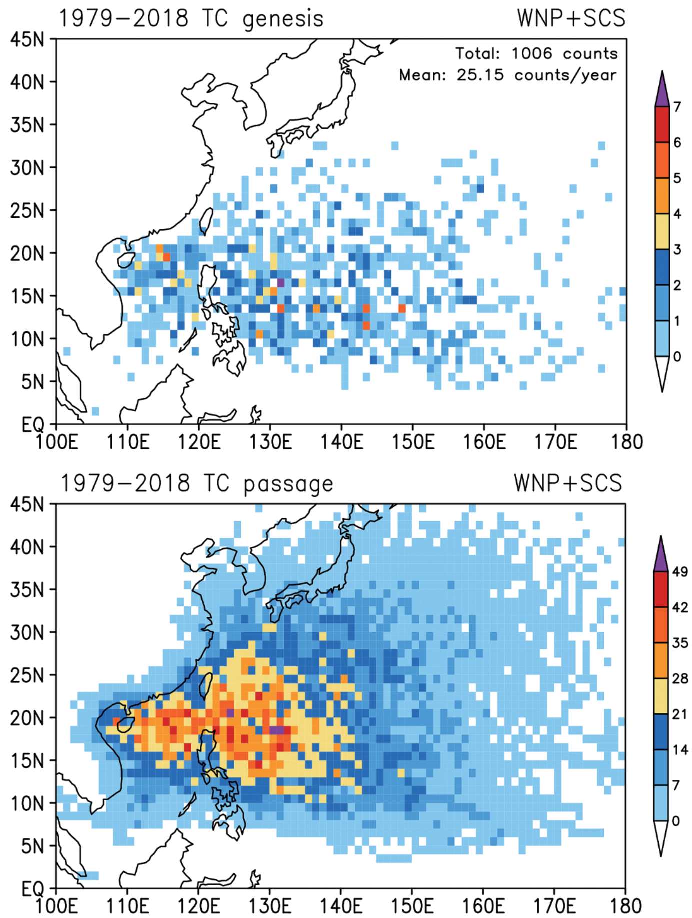

Fig. 1. The spatial distribution of (top panel) the genesis location of western North Pacific tropical cyclones and (bottom panel) tropical cyclone total passage during the 40 years of 1979 - 2018. The passage is calculated as the total number of the six hourly tropical cyclone data reported in the JMA best track dataset. The distribution is presented in the 1- by 1-degree longitude-latitude grid (adapted from Lu et al. 2021).

satellite data. The study area is selected at Mount Makiling in Los Banos, Laguna, at the southern Luzon. The advantage of selecting this location for study is that mountain rangers in the Makiling monitoring office can help in monitoring for landslide occurrences. A rain drop size distribution (DSD) measurement is conducted in the area with deployment of disdrometers. Numerical modeling with high resolution is performed in the same area to test the capability of QPF using NCEP global forecast model output as initial condition. Satellite data, especially from GPM (global precipitation mission) is planned to be used to monitor the severe precipitating systems from ocean.

Being a part of this subproject, Macuroy et al. (2021) analyzed the DSD measured by an optical Parsivel disdrometer in Southern Luzon, Philippines and utilized it to generate dual-pol relations for the nearby Tagaytay radar. The resulting quantitative precipitation estimates (QPEs) calculated from the generated R(Z) relations were compared to rain gauge stations near the disdrometer and were evaluated for the Tropical Storm Yagi Monsoon event of 2200 UTC 10 August to 0400 UTC 11 August 2018. Results show that the area's DSD demonstrates relatively larger average raindrop diameters than some of its Asian counterparts, albeit a smaller number in the total number of raindrops when compared with the same areas. In terms of QPE evaluation, results showed a consistent pattern observed wherein the R(Z) relations using finer time steps.

The second paper of this subproject is a radar-related study by Lin et al. (2021). They applied a fuzzy logic algorithm upon the radar reflectivity data to provide a probability guidance for segregating interference-contaminated echoes from precipitating echoes. Specifically, adequate features to highlight interference characteristics are required for the algorithm to be effective based on prior experiences. The approach is to derive membership functions, with their relatively objective weights determined based on the superior result of sensitivity test from interference cases. The above process results in a value that quantifies the possibility of each bin being affected by interference. Several cases were examined for demonstrating the ability of the fuzzy logic approach in removing interference echoes from radar reflectivity map. Moreover, the presented method can be feasibly implemented in real-time multi-radar operations as a quality control (QC) aid.

2.3 Seasonal Forecasts

Asian summer monsoon evolves with most of the variability in Indo-China (April), followed by Bay of Bengal and South China Sea in May. During the final months of the boreal summer monsoon, a lot of variability is in Arabian Sea, Northern China, South China Sea (SCS), Philippine Sea (PHS), and northwestern Pacific (WNP) in August-September. The summer monsoon in SCS is thus closely linked to the tropical WNP monsoon (Murakami and Matsumoto 1994; Wang 1994). The convection in SCS and WNP monsoon exhibits pronounced quasi-biweekly and 30 - 60 days variability (Kemball-Cook and Wang 2001; Lu et al. 2020; Sui et al. 2020) that further modulate TCs (Chen et al. 2020; Lai et al. 2020; Wu et al. 2020). In this subproject, three tasks are carried out: (1) Creating a virtual data center to assist the scientific meteorological data collection and exchange between Taiwan and Philippine research partners; (2) Analysis and modeling the convection coupled processes important for the multiscale tropical disturbance; and (3) Analysis of predictability and forecast skill of a multi-model ensemble (MME) forecast project.

Two papers were written by researchers involved in this subproject including Lu et al. (2021) and Villafuerte II et al. (2021). Lu et al. (2021) documented the climatology and variability of Taiwan and Philippine (TWPH) TC activity with specific attention to the difference in the TCs formed over the western North Pacific (WNP) and over the South China Sea (SCS). Different from over the broad Northwest Pacific Basin (0° - 60°N, 100°E - 180°) where the WNP-born TC frequency dropped sharply in late-1990s and the SCS-born TC frequency slightly increased in mid-1990s, over TWPH three distinct epochs are identified. A weak-variability epoch occurred during 1979 - 1996, a persistent low-ACE epoch during 1997 - 2002, and a more variable epoch during 2003 - 2018. The second epoch is most noteworthy. The unusually weak TC activity during this period in particular over the Philippines was associated with anomalously strong anticyclone over the SCS and the Philippine Sea during the East Asian summer monsoon season. The anomalous anticyclone strengthened the low-level confluent flow and convection over the SCS.

Villafuerte II et al. (2021) investigated the potential predictability of TC activity over the Philippine Area of Responsibility (PAR) on weekly timescales using the NCEP 16-day Global Ensemble Forecast System (NCEP-GEFS). An algorithm developed by Tsai et al. (2011) was utilized to detect and track TC-like vortices (TCLV) from the 6-hourly NCEP-GEFS model runs covering a two-year period from 1 January to 31 December in 2015 and 2017. The hindcast period covering the evaluation of NCEP-GEFS indicates a hit-rate of 0.49 and 0.19 for the 1- and 2-week TC forecasts, respectively in the PAR. It is also revealed that the stronger the TC and the farther it developed to the eastern boundary of the PAR, which typically occur during El Niño, the higher chance it could be forecasted one week ahead of time.

3. FUTURE STUDIES

After the first phase of the VOTE-meteorology collaboration program, typhoon research on improving the forecast capability of track, intensity, and rainfall has greatly benefited to both Taiwan and the Philippines. Radar data at Basco and Aparri provided by PAGASA have extended the lead time of skillful forecast by 12 hours earlier than the forecast without the observations by the two radars. PAGASA personnel have got much more familiar with radar data for their monitoring and forecast. Similar situation has also been applied to numerical modeling effort. Moreover, the program has encouraged researchers in both parties to summarize their studies in the 8 papers published in this special issue of TAO.

As a result of this successful experience, the collaboration will be continued and strengthened due to mutual benefit for both parties. A second phase of this project from 2019 to 2022 has been funded and is ongoing. In the second phase, with the same spirit as the phase one, the major goal of the project is, through capacity building of human resources, data exchange, and science and technology collaboration, to improve the forecast capability on severe and extreme weather events and ocean hazards in Taiwan and the Philippines.

REFERENCES

Chen, D.-S., L.-F. Hsiao, J.-H. Xie, M. S. Peng, C.-T. Fong, P.-L. Chang, W.-T. Fang, J.-S. Hong, and T.-C. Yeh, 2021: Impacts of assimilating dual-Doppler radar-retrieval winds on the TWRF predictions of Typhoon Nesat (2017). *Terr. Atmos. Ocean. Sci.*, **32**, 649-667, doi: 10.3319/TAO.2021.10.01.03. [Link]

Chen, J.-M., P.-H. Lin, C.-H. Wu, and C.-H. Sui, 2020: Track variability of South China Sea-formed tropical cyclones modulated by seasonal and intraseasonal circulations. *Terr. Atmos. Ocean. Sci.*, **31**, 239-259, doi: 10.3319/TAO.2019.11.07.02. [Link]

Gile, R. P., J. C. S. Sugui, J. S. Galang, E. O. Cayanan, H.-C. Tsai, Y.-L. Lin, A.-M. Chia, P.-Y. Lin, K.-C. Lu, and B. J.-D. Jou, 2021: Application of Weighted Analog Intensity Prediction (WAIP) guidance on Philippine tropical cyclone events. *Terr. Atmos. Ocean. Sci.*, **32**, 669-691, doi: 10.3319/TAO.2021.03.03.01. [Link]

Jiang, S.-Y., J.-S. Hong, and B. J.-D. Jou, 2021: Blend global analyses into the cyclic convective-scale data assimilation system to improve short-term QPF.

Terr. Atmos. Ocean. Sci., **32**, 633-647, doi: 10.3319/TAO.2021.09.13.01. [Link]

Kemball-Cook, S. and B. Wang, 2001: Equatorial waves and air–sea interaction in the boreal summer intraseasonal oscillation. *J. Clim.*, **14**, 2923-2942, doi: 10.1175/1520-0442(2001)014<2923:EWAASI>2.0.CO;2. [Link]

Lai, Q., J. Gao, W. Zhang, and X. Guan, 2020: Influences of the equatorial waves on multiple tropical cyclone genesis over the western North Pacific. *Terr. Atmos. Ocean. Sci.*, **31**, 227-238, doi: 10.3319/TAO.2020.03.20.01. [Link]

Lin, P.-F., L. K. M. Lagrimas, J.-B. Wang, P.-L. Chang, W.-T. Fang, J. G. C. Almario, B. J.-D. Jou, and E. O. Cayanan, 2021: Removing interference echoes in Philippine radars using a fuzzy logic approach. *Terr. Atmos. Ocean. Sci.*, **32**, 755-776, doi: 10.3319/TAO.2021.12.20.01. [Link]

Lu, M.-M., C.-H. Sui, J.-R. Sun, and P.-H. Lin, 2020: Influences of subseasonal to interannual oscillations on the SCS summer monsoon onset in 2018. *Terr. Atmos. Ocean. Sci.*, **31**, 197-209, doi: 10.3319/TAO.2020.02.25.01. [Link]

Lu, M.-M., C.-H. Sui, C.-H. Wu, A. L. S. Solis, and M.-D. Cheng, 2021: Tropical cyclone climatology and variability in Taiwan and Philippine Region during 1979 - 2018. *Terr. Atmos. Ocean. Sci.*, **32**, 725-740, doi: 10.3319/TAO.2020.11.30.01. [Link]

Macuroy, J. T., W.-Y. Chang, D. V. Faustino-Eslava, P. A. J. Sanchez, C. L. Tiburan Jr., and B. J.-D. Jou, 2021: Evaluations on radar QPE using raindrop size distribution in Southern Luzon, Philippines. *Terr. Atmos. Ocean. Sci.*, **32**, 693-724, doi: 10.3319/TAO.2021.02.22.01. [Link]

Murakami, T. and J. Matsumoto, 1994: Summer monsoon over the Asian continent and western north Pacific. *J. Meteorol. Soc. Jpn.*, **72**, 719-745, doi: 10.2151/jmsj1965.72.5_719. [Link]

Sui, C.-H., P.-H. Lin, W.-T. Chen, S. Jan, C.-Y. Liu, Y. J. Yang, C.-H. Liu, J.-M. Chen, M.-J. Yang, J.-S. Hong, L.-H. Hsu, and L.-S. Tseng, 2020: The South China Sea Two Islands Monsoon Experiment for studying convection and subseasonal to seasonal variability. *Terr. Atmos. Ocean. Sci.*, **31**, 103-129, doi: 10.3319/TAO.2019.11.29.02. [Link]

Tsai, H.-C., K.-C. Lu, R. L. Elsberry, M.-M. Lu, and C.-H. Sui, 2011: Tropical cyclone–like vortices detection in the NCEP 16-day ensemble system over the western North Pacific in 2008: Application and forecast evaluation. *Weather Forecast.*, **26**, 77-93, doi: 10.1175/2010waf2222415.1. [Link]

Villafuerte II, M. Q., T.-T. Lo, H.-C. Tsai, and E. O. Cayanan, 2021: Assessing the potential predictability of tropical cyclone activity in the Philippines on weekly timescales. *Terr. Atmos. Ocean. Sci.*, **32**, 741-754, doi: 10.3319/TAO.2021.08.23.03. [Link]

Wang, B., 1994: Climatic regimes of tropical convection and rainfall. *J. Clim.*, **7**, 1109-1118, doi: 10.1175/1520-0442(1994)007<1109:CROTCA>2.0.CO;2. [Link]

Wu, L., H. Zhang, J.-M. Chen, and T. Feng, 2020: Characteristics of tropical cyclone activity over the South China Sea: Local and nonlocal tropical cyclones. *Terr. Atmos. Ocean. Sci.*, **31**, 261-271, doi: 10.3319/TAO.2019.07.01.02. [Link]

Yeh, T.-C., E. O. Cayanan, L.-F. Hsiao, D.-S. Chen, and Y.-T. Tsai, 2021: A study of the rainfall and structural changes of Typhoon Koppu (2015) over northern Philippines. *Terr. Atmos. Ocean. Sci.*, **32**, 619-632, doi: 10.3319/TAO.2021.07.12.02. [Link]