Validating CI2 and DU2 Monsoon Indices for the Philippines using Rainfall and Wind Data

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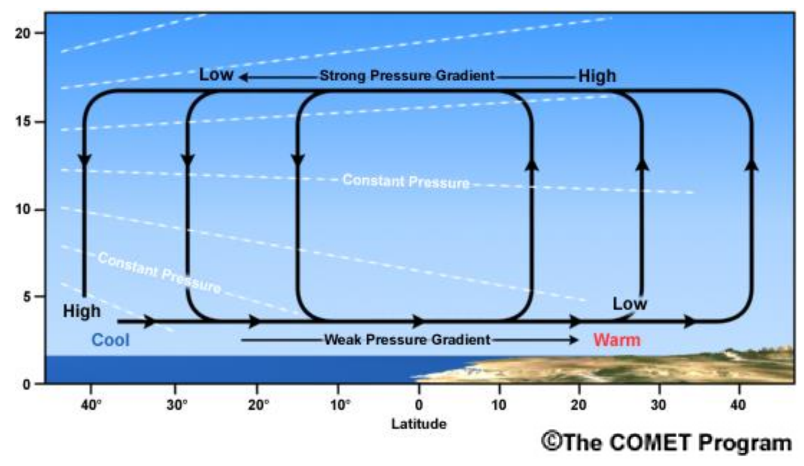
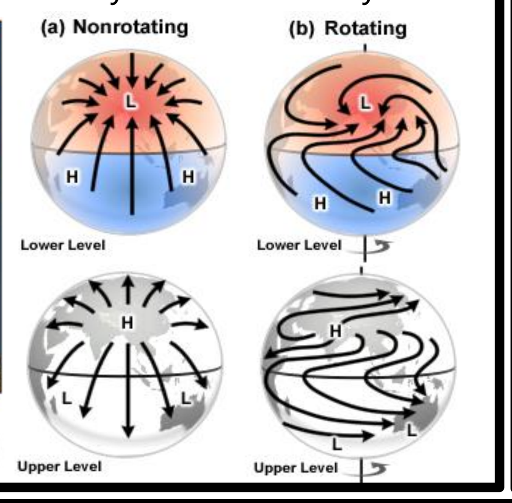
Abstract: There are two kinds of monsoon that occur in the Philippines – southwest monsoon during June to September and northeast monsoon during November to February. In these months, intense rainfall and strong prevailing winds are experienced by most provinces in the archipelago. This study aimed to measure the strength of the southwest and northeast monsoon episodes in a 31-year period (January 1983 to December 2013) with the use of existing monsoon indices. Specifically, the study intended to validate the CI2 (convection) and DU2 (differential zonal wind) monsoon indices for the Philippines using rainfall and wind station data for the 31-year period. Monthly mean outgoing longwave radiation (OLR) data averaged over the vicinity of the Philippines (10°-20°N, 115°-140°E) from NOAA and monthly mean differential zonal winds at 850-hPa pressure level averaged over 5°-15°N, 90°-130°E and 22.5°-32.5°N, 110°-140°E from NCEP were used in the study to infer the strength of the monsoon. Rainfall and wind indices derived from station data were used to validate these datasets. The relationship between the monsoon indices and the standardized rainfall and wind anomaly indices were used to identify the strong monsoon episodes in the 31-yr period and their impact to specific regions in the Philippines. Moreover, a monsoon index for the Philippines is constructed based on the CI2 and DU2 monsoon indices and rainfall and wind cluster maps. Furthermore, a risk index corresponding to the result of the effect of the monsoon was developed with the aid of risk maps, which can be contributed to disaster risk management and reduction.

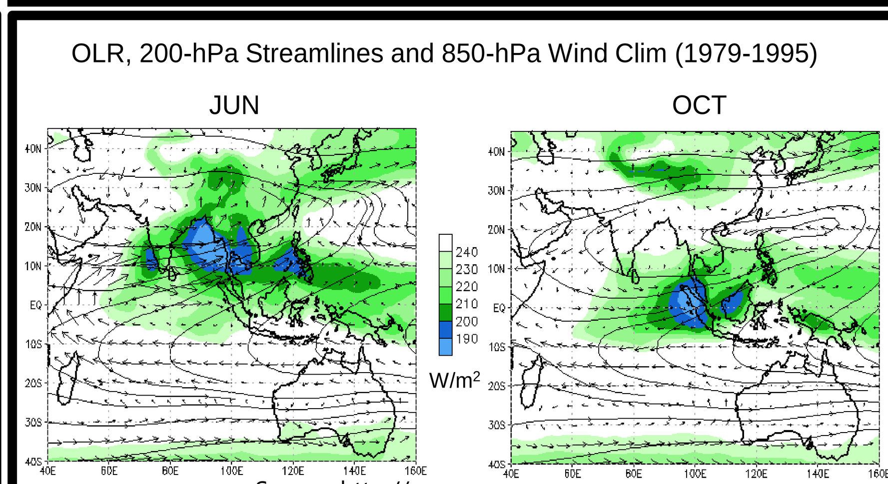
1 | What Causes Monsoon?

Global-scale monsoon is a moist sea breeze modified by the Coriolis effect. It is the response to the positive net radiation in the summer hemisphere as the surface responds to the seasonal oscillation of solar heating. The evolution of the regional monsoons depends on the distribution of land and ocean, SST gradients, and net ocean heat transport. Differences in the heat capacity of the land and ocean result in large temperature gradients between the land and ocean surfaces. Horizontal temperature gradients lead to upper level pressure gradients, horizontal pressure gradients and transverse circulation. The circulation is not directly from ocean to land because the Earth's rotation causes Coriolis deflection and affects where the winds and ocean currents form and how intense they become. Finally, the moist processes within clouds affect the vertical velocity and the radiative effects of the clouds in turn affect the differential heating between cloudy and non-cloudy areas.





2 | Monsoon in the Philippines

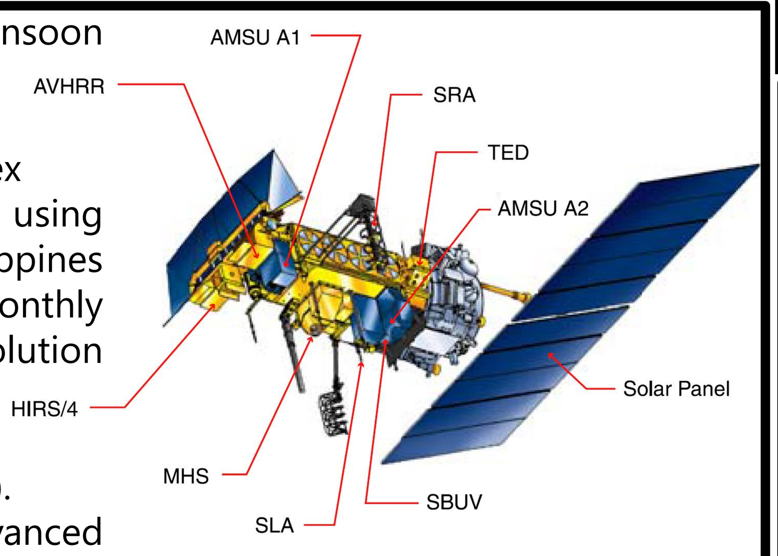


Source: http://www.cpc.ncep.noaa.gov

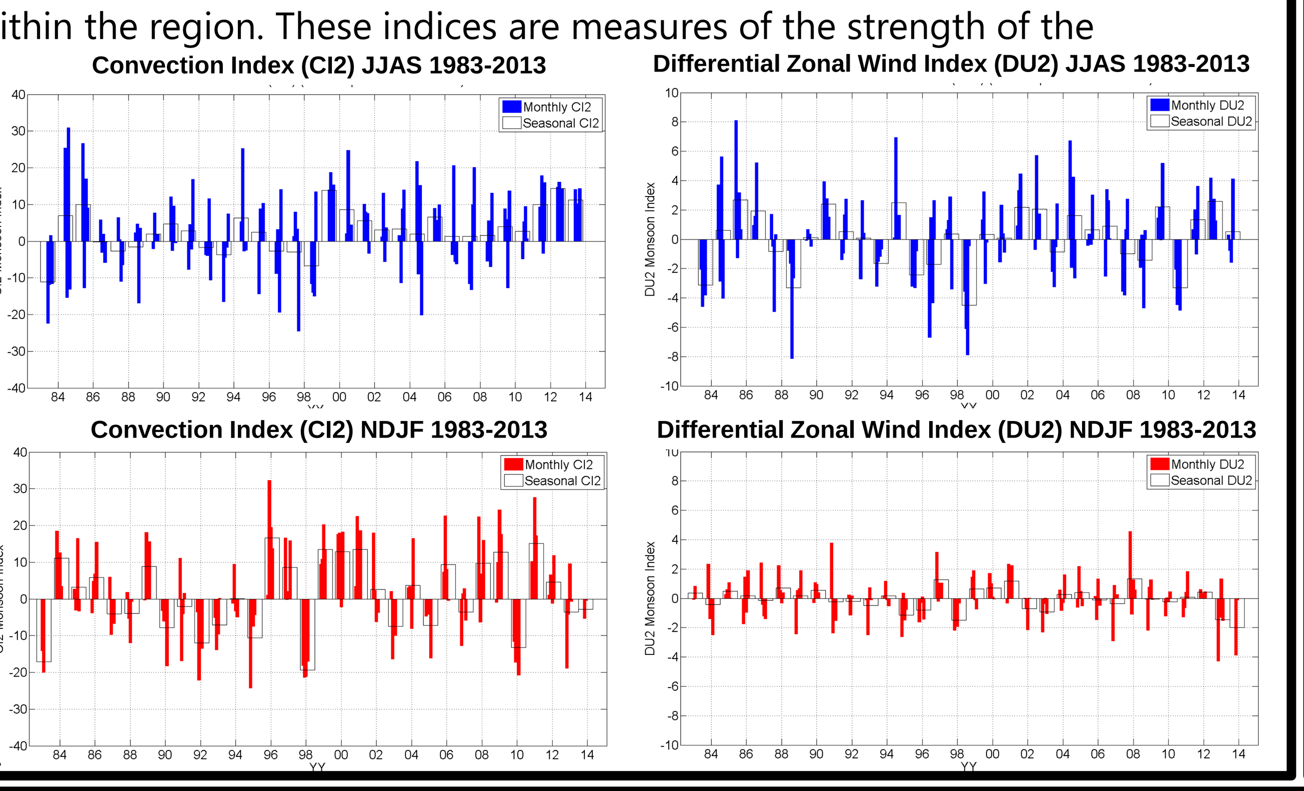
The Asian monsoon is regionally varied. The earliest onset of the Asian summer monsoon is over the southern Bay of Bengal in late April, over the Indo-Chinese peninsula and south India in early May, and then it progresses north and northwestward into the continent reaching Japan by late June to July. Given this regional evolution, the Asian summer monsoon can be divided into 3 separate but interactive monsoon sub-systems: the south Asian monsoon, the east Asian summer monsoon and the Western North Pacific summer monsoon. *Hagupit ng Habagat* were the terms coined by the media for the most recent extreme episodes of the southwest monsoon which hit the Philippines in 2012 and 2013. These strong monsoon episodes have brought hydrometeorological hazards to most parts of the northwestern sections of the country. Floods, landslides and strong winds were observed when torrential rains lasted for several days with varying intensities year to year.

3 | Monsoon Indices

Wang and Fan (1999) in their study of the monsoon indices for the South Asian monsoon suggested two monsoon indices for the South East Asian monsoon region: a convection index **CI2** and a circulation index **DU2**. CI2 is a measure of the convective activity using outgoing longwave radiation (OLR) over the Philippines and its vicinity. The gridded OLR data set is the monthly mean values from 1983 to 2013 with a spatial resolution of 2.5° latitude x 2.5° longitude global grid. The monthly mean OLR values were averaged over the vicinity of the Philippines (10°-20°N, 115°-140°E). The data set source were soundings from the Advanced Very High Resolution Radiometer (AVHRR) of NOAA's (National Oceanic and Atmospheric Administration) Polar Orbiting Environmental Satellite (POES). This satellite payload monitors the reflected energy in the visible and infrared portions of the electromagnetic spectrum. Presently, the daily OLR values are being measured by NOAA-19.

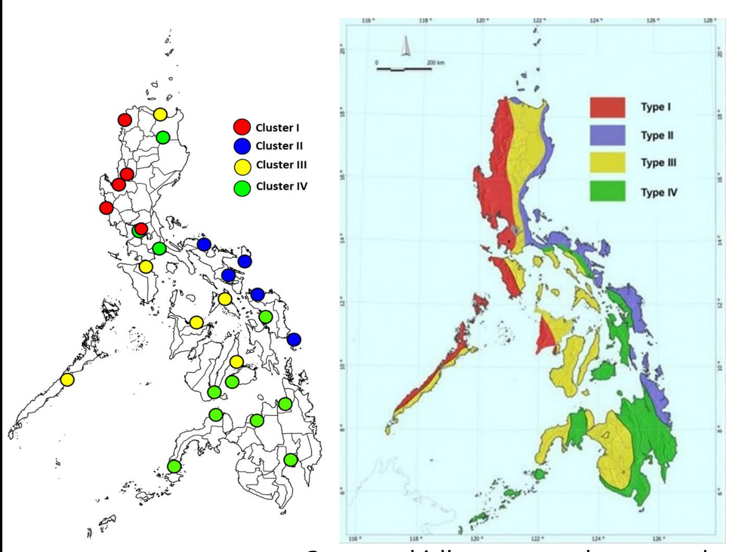


DU2 is the differential zonal wind anomalies at the 850-hPa level over two domains (SW and NE domains). The choice of the domains of the indices are based on the area of maximum convective activity within the region. These indices are measures of the strength of the monsoon for both the southwest monsoon (JJAS) and the northeast monsoon (NDJF) seasons. Variability in the strength of the monsoon (SWM and NEM) over the 31-yr period is evident and can be attributed to climate oscillations such as the El Nino Southern Oscillation.



4 | Validating Existing Monsoon Indices for the Philippines Using Rainfall and Wind Data

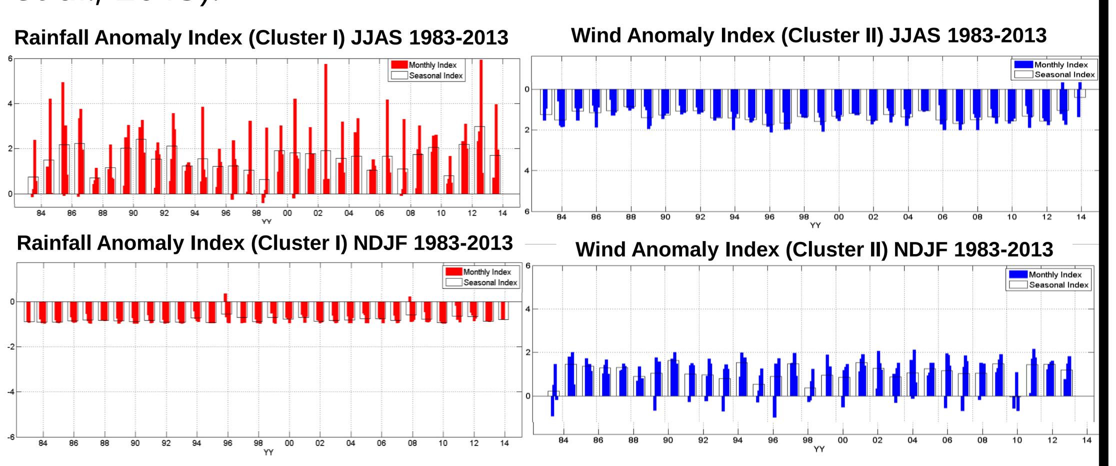
Monthly mean rainfall and wind data were gathered from 27 PAGASA meteorological stations. Hierarchical cluster analysis was conducted to aid in the validation of the standardized rainfall and wind anomaly indices with the existing monsoon indices.



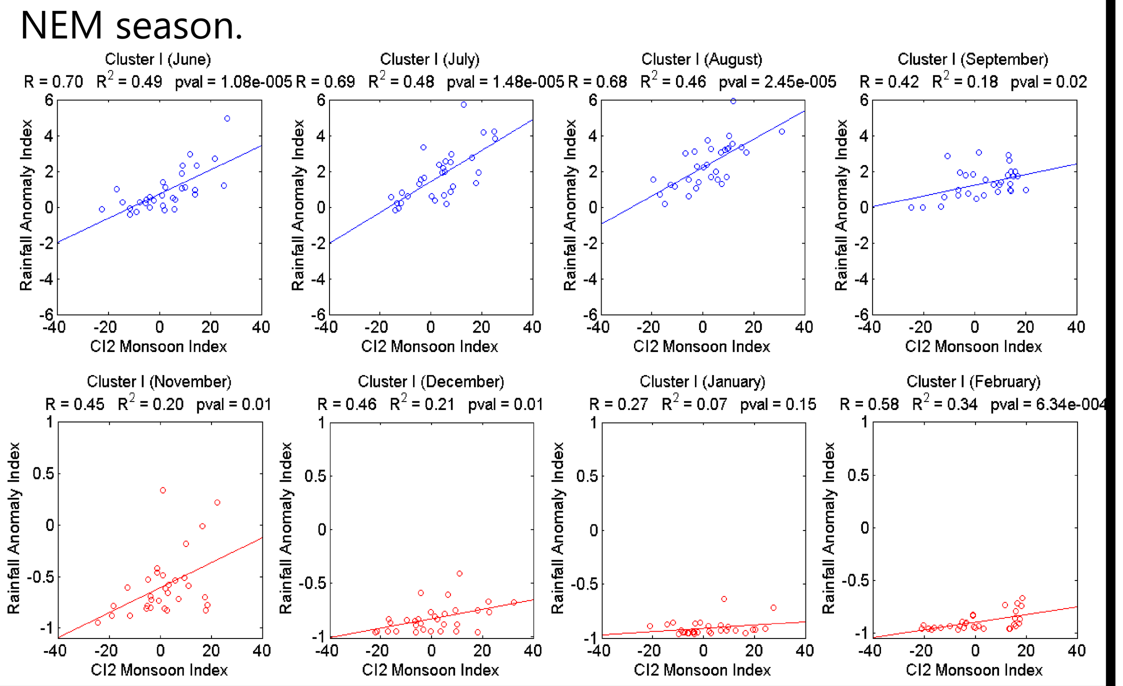
Source: kidlat.pagasa.dost.gov.ph

Although cluster analysis yielded stations that are displaced from one type to another, the cluster map fairly resembles the current climate types of the Philippines, which is based on modal of the yearly type of rainfall distribution.

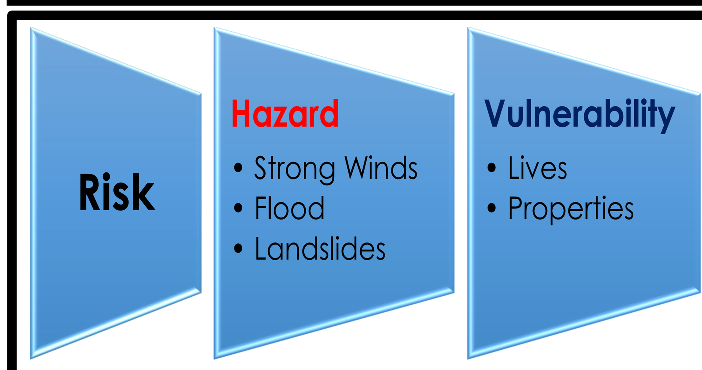
Rainfall (RAI) and wind (WAI) anomaly indices were computed based on standardized anomaly equation (adopted from Cruz *et al.*, 2013).



Correlations were significant at 95% confidence level between CI2 and RAI in cluster I during the SWM season and for all clusters during the NEM season in general. DU2 and WAI correlations were significant at 95% confidence level for all clusters for the SWM season and clusters III and IV for the NEM season.



5 | Risk Maps for Hazards brought about by Strong Monsoon Episodes (Strong Winds, Floods, Landslides)

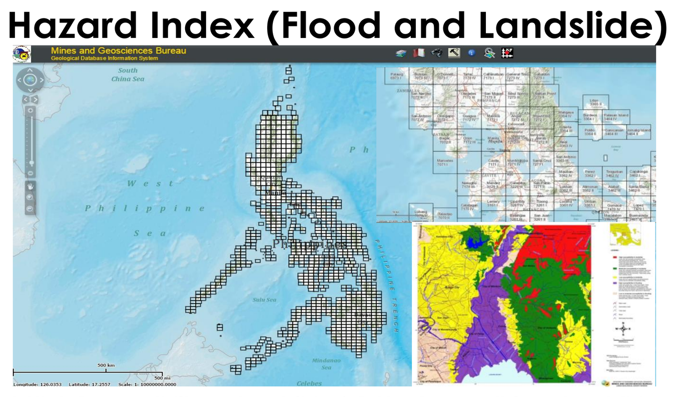


Risk maps were constructed based on the risk equation as defined by UNISDR:

$$R = H \times V$$

where **H** was computed from hazard factors, i.e., computed monsoon indices and hazard index based on hazard susceptibility maps of the MGB, and **V** is the vulnerability factor derived from populations and house counts. Total risk, R_T, is the sum of risk to lives (R_L) and risk to property (R_P) for in each hazard.

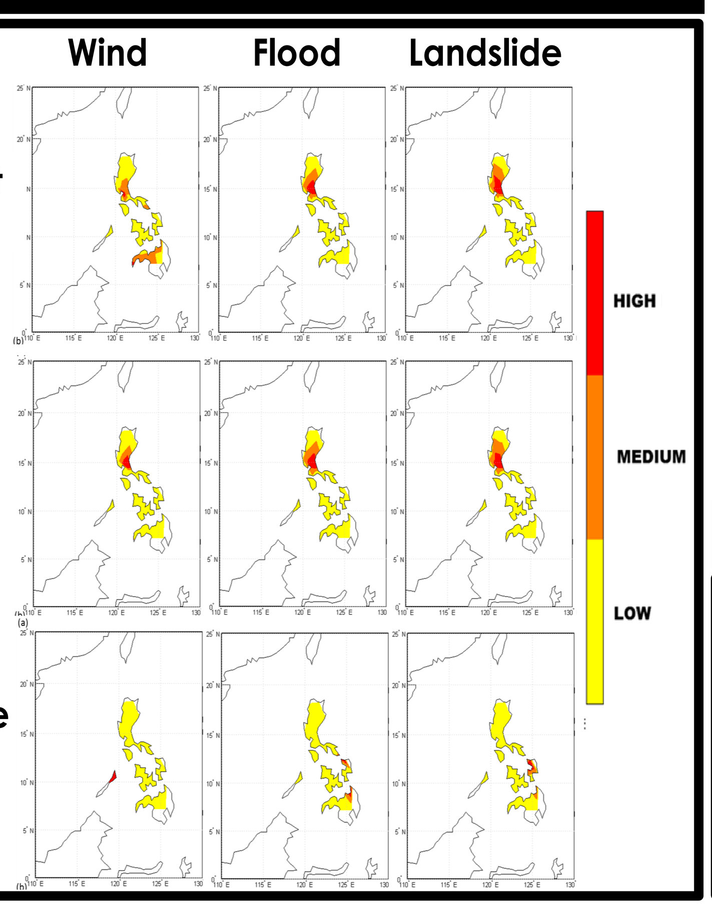
Hazard Index (Flood and Landslide)



4-High Susceptibility to Landslide | 1-Not Susceptible to Landslide

3-High Susceptibility to Flooding | 1-Not Susceptible to Flooding

Source: Geological Database Information System



6 | Conclusions

A monsoon index for the Philippines was constructed based on the monsoon indices, standardized rainfall and wind anomaly indices, and rainfall and wind clusters with the following properties:

Monsoon Index	Index Sign	Properties of Monsoon	Monsoon Index	Index Sign	Properties of Monsoon
CI2	+	Strong	RAI	+	Rain above normal
	–	Weak		–	Rain below normal
DU2	+	SW > NE	WAI	+	Wind above normal
	–	SW < NE		–	Wind below normal

The monsoon indices developed for the Philippines can be used in risk assessment with hazards due to strong winds and intense rainfall. Risk maps were able to point out incidents that happened and monitored by the NDRRMC in specific areas during and after the hydrometeorological hazards brought about by strong episodes of the monsoon.

Selected References and Acknowledgments

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Interpolated OLR data and CDC Derived NCEP Reanalysis Products Pressure Level Data (u-wind) were provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/.

The authors would like to thank the Department of Science and Technology-Science Education Institute (DOST-SEI), Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), CARbON and Bagtasa Laboratory and to all those who have contributed to this poster presentation.

Estrebillo, Loren Joy D.
Validating CI2 and DU2 Monsoon Indices for the Philippines using Rainfall and Wind Data.
Presented at the Sixth Asia/Oceania Meteorological Satellite Users' Conference.
Tokyo, Japan. November 10-12, 2015