On the use of ERA5 Reanalysis data for Precipitable Water Vapor Estimation using Philippine GNSS CORS stations

CHRISTIAN DAVID C. AQUINO
Dr. ERNEST P. MACALALAD

epmacalalad@mapua.edu.ph

Space and Atmospheric Research Group
Department of Physics – Mapúa University

April 22, 2024
Precipitable Water Vapor (PWV)

- Considered as **water vapor that can condense to rain or snow**
- Good **rainfall indicator**
- Precursor to Climatological Studies

\[
PWV = \frac{1}{\rho_w} \int_{z_s}^{z_t} \rho q \, dz
\]

where:

- \( \rho_w \) = density of liquid water
- \( \rho \) = density of air
- \( q \) = specific humidity
- \( z_s \) = surface height
- \( z_t \) = tropospheric height
How to retrieve PWV?

- Radiosonde
- GNSS Estimations
- Microwave Radiometry
- Near Infrared Radiometry
- Radio Occultation
- LIDAR
How to retrieve PWV?

- Radiosonde
- GNSS Estimations
- Microwave Radiometry
- Near Infrared Radiometry
- Radio Occultation
- LIDAR
GNSS-PWV Estimation

https://d3i71xaburhd42.cloudfront.net/18121d3d2d8a952763d9b3a3dc769913898a0c1d/12-Figure1.1-1.png
GNSS-PWV Estimation

- Zenith Total Delay
- Station Geoid Height
- Station Latitude
- Surface Pressure
- Surface Temperature

Zenith Hard Delay (Saastamoinen, 1972)

- Zenith Wet Delay
- Weighted Mean Temperature (Bevis, 1992)

\( \pi \) (Askne & Nordius, 1987)

Precipitable Water Vapor
GNSS-PWV Estimation

Station Dependent Constants

- Zenith Total Delay
- Station Geoid Height
- Station Latitude
- Surface Pressure
- Surface Temperature

Zenith Hard Delay (Saastamoinen, 1972)

- Weighted Mean Temperature (Bevis, 1992)

π (Askne & Nordius, 1987)

Precipitable Water Vapor
GNSS-PWV Estimation

Station Dependent Constants
Observables

Zenith Total Delay
Station Geoid Height
Station Latitude
Surface Pressure
Surface Temperature

Zenith Hard Delay (Saastamoinen, 1972)
Weighted Mean Temperature (Bevis, 1992)

Zenith Wet Delay

π (Askne & Nordius, 1987)

Precipitable Water Vapor
GNSS-PWV Limitations
DEPARTMENT OF PHYSICS

ERA5 Reanalysis

- https://www.ecmwf.int/en/about/media-centre/focus/2020/fact-sheet-earth-system-data-assimilation

- https://www.ecmwf.int/en/about/media-centre/focus/2021/fact-sheet-earth-system-modelling.ecmwf
ERA5 Reanalysis

- Physics-based model
- High spatial resolution (0.25° x 0.25°)
- High temporal resolution (1-hourly)
- All-weather solution

https://climate.copernicus.eu/sites/default/files/inline-images/era5_t2m_201601.png
Objectives

Main Objective:

To determine the potential of using ERA5 Reanalysis data alongside GNSS data to compute for PWV in different locations in the Philippines.

Specifically:

• Determine the accuracy of GNSS-PWV and compare it against RS-PWV;
• Determine the accuracy of GNSS-ERA5-PWV and compare it against RS-PWV;
• Apply corrections to GNSS-ERA5-PWV and compare it against RS-PWV.
Methodology

- Synoptic Observations
- ERA5 Reanalysis
Data Availability

![Venn diagram showing data availability]

- Radiosonde
- GNSS-ZTD
- Stations
- ERA5
- Surface Meteorology
Sources

Coverage:
2015 to 2017
12-Hourly PWV

Sources:
Radiosonde – University of Wyoming
GNSS ZTD – Philippine Active Geodetic Network (PAGeNet)
Surface Meteorology – Ogimet
ERA5 Model – ECWMF
Results - Legaspi

Albay 2015 - 2017

- RS-PWV
  - Frequency

- GNSS-PWV
  - Frequency
  - $R = 0.9843$

- GNSS-ERA5-PWV
  - Frequency
  - $R = 0.9847$

- $y = 0.93x - 7.70$

- $y = 0.93x - 3.20$

- $y = 0.99x + 4.48$

$R = 0.9997$
Results - Legaspi

Albay Surface Pressure

Albay Pressure Difference
Results - Mactan

Cebu 2015 - 2017

RS-PWV

GNSS-PWV

GNSS-ERA5-PWV

\[ R = 0.9805 \]

\[ R = 0.9806 \]

\[ R = 0.9998 \]

\[ y = 0.92x - 1.39 \]

\[ y = 0.92x + 0.69 \]

\[ y = 1.00x + 2.10 \]
Results - Mactan

Cebu Surface Pressure

Cebu Pressure Difference
Results - Davao

Davao 2015 - 2017

(a) RS-PWV
(b) GNSS-PWV
(c) GNSS-ERA5-PWV

\[ y = 0.86x + 6.26 \]

\[ y = 0.86x + 6.26 \]

\[ y = 1.00x + 1.87 \]
Results - Davao

Davao Surface Pressure

Davao Pressure Difference
Future Work

• Error Analysis
  • Bias
  • Correction

• Application
  • GNSS Stations without Synoptic Data
References


