Dear Referee #2,

We really appreciate your precious time spent on carefully reviewing our paper titled "*Retrieval of the precipitable water vapor from shipborne multi-GNSS measurements in tropical cyclone-prone regions of the Northwest Pacific during the summer season in 2021*". We revised our manuscript by considering your comments and reviews as much as possible. In this way, we believe, the quality of our manuscript improved significantly.

In the following pages, **your comments are shown in black** while our replies are colored in blue, and *corrections and new explanations are shown in italic and red*.

Sincerely yours,

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D.-H. Sohn, B.-K. Choi, J. Hong, Y. Park, H. Jang, B.-I. Lee, and J.-K. Chung

[Responses to Referee #2 - comments] ---------------

[Comment 0] This paper by Sohn et al. describes an experiment conducted in the summer of 2021, which aimed at monitoring atmospheric water vapor in the northwestern Pacific Ocean using a shipborne GNSS antenna. After discussing the importance of such measurements and outlining the methodology used to retrieve water vapor data, the authors evaluate the technique using satellite radiometric measurements. The paper concludes with an analysis of a notable cyclonic event.

Numerous recent studies (cited in this paper) focus on retrieving and validating integrated water vapor content measurements from shipborne antennas. The novelty of this work may lie in its use of two operational meteorological satellite radiometers, as well as its detailed description of a cyclonic event based on GNSS measurements.

The paper is well written, with a clear structure. While some of the presented work may not be entirely original, I believe that several points deserve publication (as mentioned previously).

However, I have a few concerns:

- The methodology used to retrieve GNSS PWV is not rigorous enough, and several critical steps are either overlooked or not detailed enough (e.g., specific models for GNSS analysis, parameters for ZWD to PWV conversion).

- Some statements are not always adequately justified or supported by results.

These points will be addressed in more detail in the "Specific comments" section.

Thus, I recommend a major revision of this manuscript.

Response: We really appreciate your precious time spent carefully reviewing our manuscript and your comments.

[Comment 1] (Abstract) You should mention the discussion about tracking the cyclonic event.

Response: We thank you for your comment. In fact, we only focused on the PWV variation in tropical cyclone-prone regions of the Northwest Pacific and did not directly track tropical cyclones. However, we confirmed a strong correlation between the changes in PWV and precipitation, following the development of a tropical cyclone in the Northwest Pacific. The relevant sentence has been added in the abstract, as shown in the box below.

(L.30) ~ ~ with previous findings. *In particular, following the development of a tropical cyclone in the Northwest Pacific, we found a strong correlation between the GNSS PWV variation and precipitation.* We suggest that the PWV ~ ~

[Comment 2] (Line 34) QZSS is not a global satellite positioning system; it's a regional one
(https://qzss.go.jp/en/overview/services/sv02_why.html)

Response: We have removed the terms 'QZSS'. The revised sentence is as follows:

(L.34) ~ ~ System (GLONASS), Galileo, *and* BeiDou, ~~*and QZSS,*~~ is an effective tool ~ ~

[Comment 3] (Lines 39-40) The transition between this sentence and the next paragraph needs improvement.

Response: Thank you for your comment. For an improvement of the transition between paragraphs, we have revised the sentences as follows:

(L.40) ~ ~ 500 GNSS ground stations (IGS, 2025). *The vast majority of IGS stations and nationally operated GNSS stations are located on land. The land covers roughly 30 percent of the Earth's surface.* ~~*However,*~~ *Therefore,* there are limitations to monitoring ~~*global*~~ *the overall variation in* PWV ~~*variation on Earth*~~ using ~~*ground-based continuous operating reference*~~ *only* GNSS stations *on land*.
In contrast, the ocean covers over 70 percent of Earth's surface. ~ ~

[Comment 4] (Line 64) please improve the transition.

Response: We thank you for your comment. For an improvement of the transition between paragraphs, we have revised the paragraph describing the tropical cyclone as follows:

(L.64) ~ ~ ~~*A typhoon is a typical meteorological phenomenon accompanied by heavy rain. The water vapor evaporated from warm ocean water plays an important role in the formation and development of a typhoon. A typhoon is an extremely intense tropical 65 cyclone that occurs over tropical or subtropical waters in the Northwest Pacific Ocean. The national meteorological agency continuously monitors meteorological elements, such as temperature, pressure, humidity, water vapor content, etc., in the formation regions and tracks of tropical cyclones. The Korean peninsula is mainly affected by typhoons in summer and early autumn.*~~ *Water vapor is one of the important factors driving weather patterns. In particular, the water vapor evaporated from warm ocean water plays an important role in the formation and development of a tropical cyclone in the Northwest Pacific.* The Korea Meteorological Administration (KMA) reported that about 87% of typhoons ~ ~

[Comment 5] (Lines 78-86) You should highlight the contributions and advancements of this article compared to your last study (Sohn et al., 2020).

Response: We thank you for your comment. As the reviewer suggested, we have further described the differences from the previous study as follows:

(L.78) ~ ~Sohn et al. (2020) reported on the retrieval of PWV from shipborne GNSS observations in the Northwest Pacific region from August to September 2018. *They calculated PWV using GPS-only data from low-cost equipment* and compared it with other datasets *(radiosonde and atmospheric infrared sounder on NASA's Aqua satellite). Later, another GNSS equipment with high-precision and multi-constellation capabilities was additionally installed on a vessel.* This study focuses on whether a comparable and stable data quality of the shipborne GNSS PWV can be obtained over different time periods with different other PWV datasets *using the additional GNSS equipment* based on previous research. ~ ~

[Comment 6] (Line 125 / Equation 2) I don't think this is the model you're actually using: the equation models delay correction for a zenith angle z, including a curvature correction (ΔR), but it's not meant for zenith delay correction alone. Please update the formula (e.g., with the one proposed by Davis, 1985). Also, lines 124-125 are ambiguous: Saastamoinen (1973) does not propose a model for horizontal gradients. Please clarify this.

Response: We appreciate your comment. As the referee suggested and another referee commented, we have rephrased as many sentences as possible in Section 2.2 on data processing. Equations (1) and (2) are also removed. The revised sentences are shown in the box below.

(L.103) ~ ~ This study employs the GNSS kinematic precise point positioning (PPP) method using dual-frequency measurements from a shipborne multi-GNSS receiver. PPP is a positioning method that provides a high level of position accuracy using a single GNSS receiver only. This method can be used to estimate the precise positioning and the amount of water vapor in the atmosphere. To perform kinematic PPP using multi-constellation GNSS, we use a multi-GNSS analysis software (MGAS) developed by the Korea Astronomy and Space Science Institute (Choi et al., 2017, 2018). *MGAS is capable of supporting multiple data processing strategies, such as static, kinematic, and dynamic options. Data from a continuously moving ship processed using kinematic PPP mode.*

The German research centre for geosciences (GFZ) rapid products are employed to estimate precise ship positioning and tropospheric zenith total delay (ZTD). These products include precise orbits and clock corrections for GPS, GLONASS, Galileo, BeiDou, and QZSS satellites. Tropospheric delay is still a significant error source in GNSS precise positioning. In the PPP processing, the tropospheric ZTD is estimated as an unknown parameter. For ZTD calculation, the Saastamoinen model (Saastamoinen, 1973) with global pressure and temperature 2 (GPT2) (Lagler et al., 2013) is employed as a prior value. In addition, the global mapping function (GMF) (Boehm et al., 2006) is used for tropospheric mapping.

The methods and models used in the PPP processing are summarized in Table 1. For kinematic PPP, we used dual-frequency observations from GPS (L1/L2), GLONASS (L1/L2), Galileo (E1/E5a), and BeiDou (B1/B2). The observation sampling interval is

[Comment 7] (Table 1) Processing: What is the temporal resolution of the tropospheric parameters you estimate? Are they estimated independently for each epoch, or do you introduce temporal correlation?

Response: We thank you for your comment. In this work, the GNSS data is acquired at 30-second intervals, and the tropospheric delays are estimated every 5 minutes. As the reviewer suggested, we have revised the relevant sentences as shown in the box below.

(L.121) ~ ~ *The observation sampling interval is set to 30 s. Furthermore, the precise position and tropospheric ZTD values are estimated every 5 minutes.* ~ ~

(L.175) ~ ~ The *time series of* shipborne GNSS PWV ~~time series~~ *estimated at 5-minute intervals* is shown in Fig. 4, as well as the frequency of PWV bins. ~ ~

(L.130) **Table 1.** Models and methods for multi-GNSS kinematic PPP processing

Item	Models and Methods
~~GNSS~~ *Signals*	GPS (L1, L2), GLONASS (L1, L2), Galileo (E1, E5a), BeiDou (B1, B2)
Sampling rate	30 sec
Elevation cutoff	10°
Satellite orbit and clock	~~IGS final products~~ *GFZ rapid products*
Earth rotation parameters	~~IGS final products~~ *GFZ rapid products*
~~Solid Earth tide~~	
~~Ocean tide~~	~~IERS conventions 2010~~
~~Pole tide~~	
Satellite PCO/PCV	~~IGS14.atx~~ *igs14_2188.atx*
Receiver PCO/PCV	~~IGS14.atx~~ *igs14_2188.atx*
Receiver clock	Estimated by the Gauss-Markov model
Phase wind-up	Wu et al. (1993) *& nominal yaw-steering mode*
Ionospheric delay	Eliminated by the ionosphere-free linear combination
Tropospheric delay	Estimated with zenith wet delay, tropospheric gradient component
Tropospheric mapping function	~~Global mapping function~~ *GMF*
Meteorological information	~~GPT2 model~~ *GPT2*
Ambiguity	Float solutions

[Comment 8] (Table 1) It seems to me that not all AERAT1675 antennas are modeled in the igs14.atx database. Which model do you consider? Is it an elevation-only calibration model (more suitable for an antenna that is not permanently oriented toward the north).

Response: We used an 'Aeroantenna Technology Inc. AT1675-7MW antenna'. This antenna is the same model as a 'Magellan MAG111406 antenna'. We are basically using antenna calibration information based on igs14.atx. If there is no antenna model in igs14.atx, a value of zero is applied for all directions. However, we applied antenna calibration values extracted from ngs14.atx. The antenna calibration information from ngs14.atx is below (from https://geodesy.noaa.gov/ANTCAL/LoadFile?file=MAG111406_NONE.atx). In addition, following another referee's suggestion, we have provided the week number for the used igs14.atx file (Please see the response to comment 7).

```
                                             START OF ANTENNA
MAG111406      NONE                          TYPE / SERIAL NO
FIELD            NGS            3   28-OCT-08 METH / BY / # / DATE
    0.0                                       DAZI
    0.0  80.0  5.0                            ZEN1 / ZEN2 / DZEN
    2                                         # OF FREQUENCIES
NGSRA_2400                                    SINEX CODE
CONVERTED FROM RELATIVE NGS ANTENNA CALIBRATIONS  COMMENT
  G01                                         START OF FREQUENCY
   -0.24     0.87    60.14                    NORTH / EAST / UP
  NOAZI   0.00  -0.13  -0.11  -0.04  -0.14  -0.23  -0.38  -0.61  -0.80  -1.04  -1.28  -1.62  -1.96  -2.38  -2.81  -3.04  -2.97
  G01                                         END OF FREQUENCY
  G02                                         START OF FREQUENCY
   -1.59     0.34    60.85                    NORTH / EAST / UP
  NOAZI   0.00  -0.23  -0.31  -0.28  -0.29  -0.38  -0.60  -0.87  -1.32  -1.72  -1.96  -2.16  -2.13  -1.93  -1.63  -1.03   0.02
  G02                                         END OF FREQUENCY
                                             END OF ANTENNA
```

(L.95) ~ ~ receiver connected to an Aeroantenna Technology Inc. AT1675-*7MW* antenna *(same model as: Magellan Professional MAG111406 antenna)*. ~ ~

(L.130) **Table 2.** Models and methods for multi-GNSS kinematic PPP processing

Item	Models and Methods
Satellite PCO/PCV	~~IGS14.atx~~ igs14_2188.atx
Receiver PCO/PCV	~~IGS14.atx~~ igs14_2188.atx

[Comment 9] (Table 1) You use GPT2 / GMF: is the ship displacement taken into account when applying these models?

Response: We thank you for your comment. We apply the GMF and GPT2 model to derive PWV using GNSS data received from the antenna. Since the ship's position is computed every epoch, the ship's displacement is also taken into account.

[Comment 10] (Equations (3) and (4)) please specify how the parameters Ps and Tm, which are essential for an accurate retrieval of PWV, are determined.

Response: Thank you for your comment. Following the referee's suggestion, we have added sentences related to the determination of pressure and temperature. You can see the revised sentences in the box below.
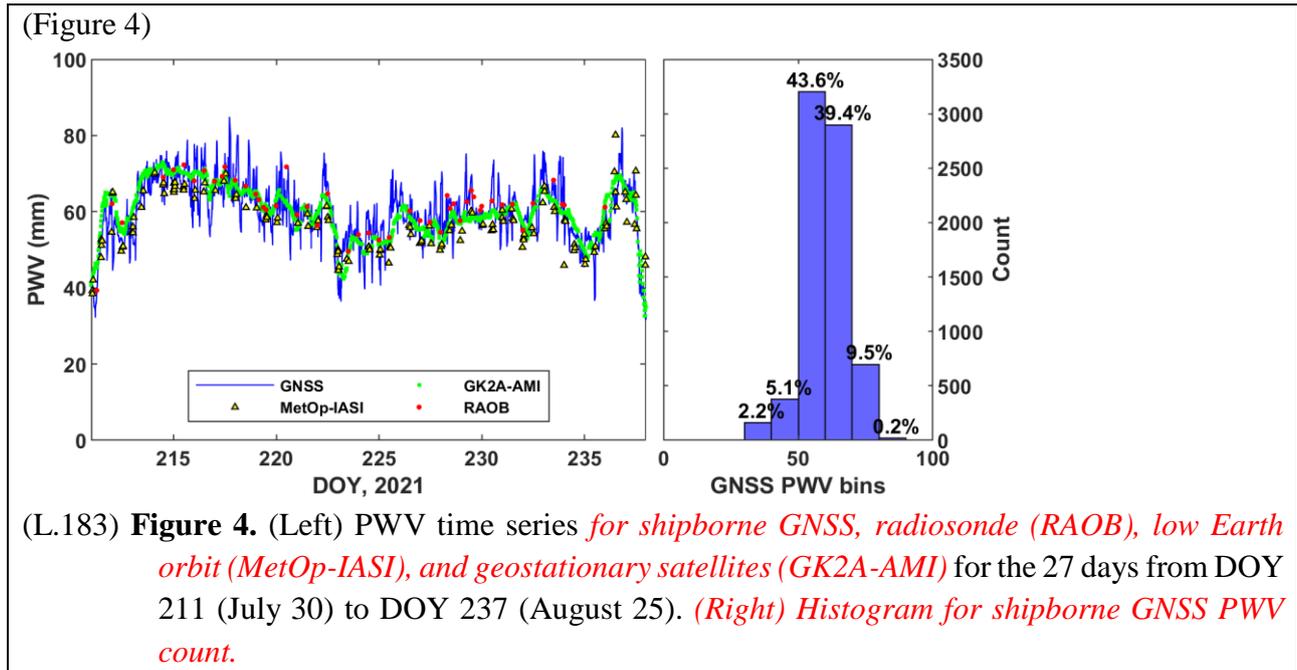
(L.140) ~ ~ kilometres (Elgered et al., 1991). *Surface pressure P_s is estimated by interpolating climatological grid coefficients of the GPT model according to the vessel's location and applying harmonic functions to account for seasonal variability.* ZWD is ~ ~

(L.144) ~ ~ and T_m refers to the mean weighted temperature of the atmosphere (Davis et al., 1985; Bevis et al., 1994). *The T_m is estimated using a linear relationship, $T_m = 70.2 +$*

> *0.72 T_s, with surface temperature T_s (Bevis et al., 1994). The T_s is obtained from the GPT model at the vessel's specified position. ~ ~*

[Comment 11] (Figure 4) are you sure about the label "Frequency"? Should it not rather be "Count"?

Response: We appreciate your comment. As shown in the figure below, we have replaced the term 'Frequency' with 'Count' in Figure 4.

(Figure 4)

(L.183) **Figure 4.** (Left) PWV time series *for shipborne GNSS, radiosonde (RAOB), low Earth orbit (MetOp-IASI), and geostationary satellites (GK2A-AMI)* for the 27 days from DOY 211 (July 30) to DOY 237 (August 25). *(Right) Histogram for shipborne GNSS PWV count.*

[Comment 12] (Line 199) in fact, for a significant contribution to PWV, water vapor is no longer present above roughly 10–15 km altitude.

Response: We thank you for your comment. As you noted, water vapor is largely confined to the lowest 10–15 km of the atmosphere. The Vaisala Radiosonde RS41-SG has a maximum operating altitude of 40 km in the sheet. And the collected radiosonde data were also obtained up to 30 km. This study calculated PWV based on recorded radiosonde data. Following the reviewer's suggestion, we have added a sentence as follows:

> (L.199) ~ ~ drift more than 300 km from its release point. *Although more than 99% of atmospheric water vapor is concentrated below approximately 10–15 km, PWV was calculated by integrating radiosonde measurements acquired during ascent to the maximum observation height. ~~So~~ However*, some of the received ~ ~

[Comment 13] (Section 4.1) maybe you could mention some studies comparing GNSS and RS41 retrieval? Were the comparison realized during the whole cruise or only the "experiment" area?

Response: Following the referee's comment, we have added sentences about the comparison between GNSS PWV and radiosonde measurements. As shown in the box below, Männel et al. (2021) used the RS41 radiosonde to compare with GNSS-based PWV in the Arctic region. And the radiosonde observations were made during the whole cruise in this work. You can see this in Figure 4. The relevant sentence has been added to the manuscript as follows:

(L.189) ~ ~ ISABU had conducted 2-5 radiosonde observations per day over the ocean. *These observations were made during the whole cruise (Fig. 4).* PWV ~ ~

(L.211) ~ ~ and reasonably accurate measurements when compared to RAOB. *Männel et al. (2021) reported a relatively smaller RMS of 1.47 kg m^{-2} in a comparison between the GNSS-based PWV and RS41 radiosonde observations, but conducted their experiments in the generally dry Arctic region.* The correlation ~ ~

[Comment 14] (Sections 4.1 / 4.2) would a synthetic figure presenting the PWV time series from the different techniques not be of interest? Possibly as a conclusion to Section 5? I leave this to your judgment. Section 4.2: satellite PWV is given with respect to the sea surface, whereas your antenna must be located between 10 and 20 m above the sea level; should the GNSS PWV therefore not be vertically corrected and referred back to the sea surface? An order of magnitude is that the PWV vertical variation is roughly dPWV = −4e-4 PWV dh: for dh = 20 m and PWV = 60 mm, this gives about 0.5 mm. Could you please clarify this point?

Response: We thank you for your suggestion. Following the referee's suggestion, we plot a synthetic figure presenting the PWV time series from the different observation systems. You can see this in Fig. 4.

We fully agree with your comment about the correction for the height difference. As you pointed out, the height difference between the GNSS antenna installed on the vessel and the sea surface is approximately 20 m, which would correspond to a PWV correction of about 0.5 mm. However, it was not explicitly considered in this work, because the magnitude is small relative to the overall uncertainty. For more precise comparisons in future work, we will apply a vertical correction for the antenna height. We have added a brief statement of this point to the revised manuscript.

(L.246) ~ ~ geostationary satellite data showed an RMSE of approximately 2–5 mm (Wong et al., 2015; Du et al., 2024). *Although the PWV correction due to the height difference between the GNSS antenna and sea level was not considered,* the present results are reasonably consistent with previous studies. ~ ~

[Comment 15] (Line 235) the link is no more valid

Response: We thank you for your comment. As noticed in the link (https://datasvc.nmsc.kma.go.kr/datasvc/html/main/main.do?lang=en), the satellite data service previously available on the KMA NMSC website was terminated on December

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(L.235) ~ ~ the web-based service
(https://datasvc.nmsc.kma.go.kr/datasvc/html/main/main.do?lang=en
https://data.kma.go.kr/resources/html/en/aowdp.html). Since the GK2A-235 AMI ~ ~
(L.377) ~ ~ NMSC data provision service
(https://datasvc.nmsc.kma.go.kr/datasvc/html/main/main.do?lang=en
https://data.kma.go.kr/resources/html/en/aowdp.html). The ~ ~

[Comment 16] (Figure 6) The are 1225 data pairs. I believe that ZTDs are estimated every hour (from fig 4): that's a lot of matching points for a 27-day cruise, isn't it? (or I missed something about the matching procedure).

Response: We thank you for your comment. According to the GK2A fact sheets, the GK2A-AMI scans the Earth's hemisphere full disk every 10 minutes. But we compared GNSS PWV and GK2A-AMI data at 30-minute intervals. In calculation, 1,296 (27x24x2) values could be compared, but some data were not collected for unknown reasons. In this regard, we revised the sentence as shown in the box below.

(L.235) ~ ~ provided by the web-based service. *~~Since the GK2A-235 AMI produces a full-disk~~* *~~image every 10 minutes, it was compared with GNSS PWV at 10-minute intervals.~~ The* *GK2A-AMI captures the Earth's hemisphere every 10 minutes, but comparisons with* *GNSS PWV were performed at 30-minute intervals.* As shown in Fig. 6a, ~ ~
(L.243) ~ ~ A total of 1,225 pairs are analysed*, as some data were not collected*. The mean ~ ~

[Comment 17] (Section 4.2) have you evaluated the spatial variability of the satellite PWV over the 0.5×0.5 degree areas? It would be interesting to confront this variability with the observed discrepancies: is this variability stable from one area or period to another? Is a larger variability associated with larger discrepancies?

Response: We appreciate your comment. We believe that evaluating the spatial variability of the satellite PWV over a 0.5 x 0.5 degree area is a valuable research topic. In this study, we assumed that spatial variability within 100 kilometers was stable, based on the study of Wu et al. (2022). Following your suggestion, we will conduct future work to determine if the variability is stable from one satellite observation to another.

(L.238) ~ ~ Wu et al. (2022) reported that a 100 km distance threshold could be taken as a reference threshold to validate shipborne GNSS PWV using satellite products. At this time, the number of satellite observation values within the target area was a minimum of 267, a maximum of 401, and an average of 350. ~ ~

[Comment 18] (Figure 8) at the very end of the leg, there is also a very strong decrease in PWV, following a very high precipitation rate. Is this also related to a meteorological event, or is it linked to the northward movement of the ship only?

Response: We thank you for your comment. At the beginning of the time series in Fig. 8, PWV increases as the vessel moves from mid-latitude to low-latitude. And the relationship between precipitation and PWV can also be confirmed through Fig. 8 and previous studies. Therefore, we believe the sharp decrease in PWV in the final part of the cruise is the result of a combined effect of precipitation and the movement from low-latitude to mid-latitudes. In fact, it may be difficult to distinguish whether this strong decrease in PWV is related to a meteorological event or simply the northward movement of the vessel. We added a sentence to the manuscript about the decrease in PWV due to vessel movement from low to mid-latitude as follows:

(L.343) ~ ~ followed by a gradual decrease as the storm moves away. *In addition, the movement of the vessel from low to mid-latitudes also affects the decrease in PWV, as shown in the final part of the time series in the Fig. 8.* Although high-frequency ~ ~

[Comment 19] (Figure 9) could you add the position of the ship?

Response: As the referee suggested, we added the sentence about the vessel's location and marked the position of the ship in the Fig. 9.

(L.310) ~ ~ Philippine Sea, trapping a significant amount of water vapor in the atmosphere. *At this time, the vessel was located at 22.45°N and 126.69°E (Fig. 9).* ~ ~
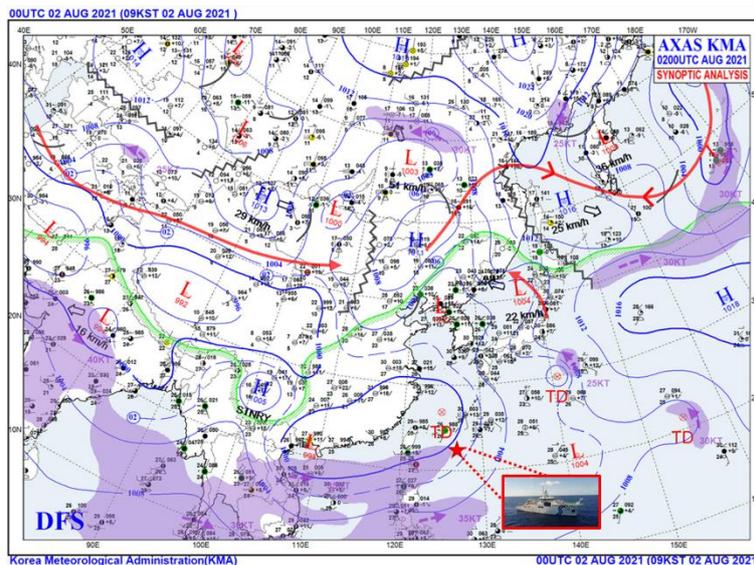
(L.316) ~ ~ **Figure 9.** Surface synoptic analysis weather map for Northeast Asia at 00:00 UTC on *DOY 214* (August 2, 2021) *from the Korea Meteorological Administration (KMA)*. A tropical depression area is forming in the western Philippine Sea. *The red star (★) marks the vessel location at the time.* ~ ~

[Comment 20] (Figures 10-11) could you add the corresponding day-of-year in the caption? Is it possible to locate the depressions mentioned / the typhoon on the maps?

Response: We thank you for your suggestion. Following the referee's comment, we added DOY (day of year) to the caption of the Fig. 10 & 11 to help the reader's understanding.

Figure 10 was used to show the precipitation, and no tropical depression was formed around the ship at this time. In the case of Fig. 11, this is a figure to explain the relationship between PWV and typhoon, so we have clarified the typhoon OMAIS's location.

(L.330) ~ ~ **Figure 10.** Weather forecast chart for mean sea level pressure (MSLP) and accumulated precipitation from the Korea Meteorological Administration (KMA) at 12:00 UTC on *DOY 222* (August 10, 2021). The red star (★) marks the vessel location at the time. ~ ~

(L.348) ~ ~ **Figure 11.** Weather forecast chart from Korea Meteorological Administration (KMA) at 12:00 UTC on *DOY 234* (August 22, 2021). An ~ ~
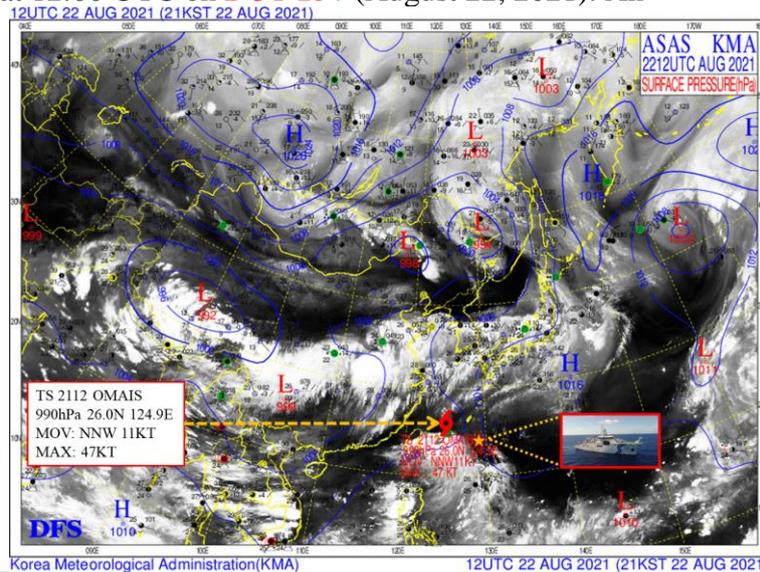
[Comment 21] (Line 336) please replace "cyan" with "magenta".

Response: We appreciate your comment on the mistake. We have replaced the word 'cyan' with 'magenta'. The corrected term is shown in the box below.

(L.336) ~ ~ As shown in the ~~cyan~~ *magenta* rectangular B of Fig. 8, ~ ~

[Comment 22] (Line 344) I am not sure this is noise; it may rather be spatio-temporal variability.

Response: We agree with you. To prevent confusion among readers, we have removed the sentence.

(L.343) ~ ~ followed by a gradual decrease as the storm moves away. ~~Although high frequency noise is present, the time series can be characterized by a three-phase structure: an initial sharp increase, a mid-period of relative stability, and a final stage marked by increasing instability.~~ ~ ~

[Comment 23] (Line 355) please use "showed" instead of "demonstrated".

Response: Thank you for your comment. We have changed the word 'demonstrated' to 'showed'.

(L.355) ~ ~ over oceanic regions. We ~~demonstrated~~ *showed* that reliable results ~ ~

[Comment 24] (Line 357) here you state that you have demonstrated the reliability of GNSS measurements during the typhoon. You have shown a correlation between precipitation peaks and a decrease in PWV, and highlighted a good agreement over the whole period between GNSS, RS, and satellite measurements, but not specifically during the typhoon activity period. Could you nuance this statement? Or alternatively, could you complement it with time series of the differences, to be compared in parallel with the meteorological conditions?

Response: Thank you for your insightful comment. In the Discussion section, we intended to show that the decrease in GNSS PWV is closely related to precipitation, which also includes rainfall associated with tropical cyclone activity. As you suggested, however, we did not perform a dedicated comparison specifically for the tropical cyclone activity period. To avoid potential confusion for readers, we have revised the sentence accordingly as follows:

(L.357) ~ ~ at different times and comparing them with another dataset. *Furthermore, we showed that decreases in GNSS-derived PWV are closely associated with precipitation, which also includes rainfall related to tropical cyclone activity.* ~ ~

[Comment 25] (Conclusion) Ultimately, would the purpose of PWV retrieved from shipborne GNSS antennas not be to calibrate and/or validate satellite water vapor measurements?

Response: Thank you for your comment. Your point is certainly well taken. However, this study focuses on PWV derived from shipborne GNSS observations because observational systems capable of monitoring atmospheric water vapor over the Earth's ocean surface are currently limited. The primary objective was to evaluate the feasibility and applicability of ship-based PWV measurements. To this end, the derived PWV values were validated through comparisons with radiosonde observations and data from low-Earth-orbit and geostationary satellites. Following your suggestion, we have added the relevant sentences as shown in the box below.

(L.372) ~ ~ Consequently, such data are anticipated to play a growing role in weather forecasting and climate research, particularly in oceanic regions where other observations remain sparse. *In addition, PWV retrieved from shipborne GNSS observations can be used to calibrate or validate satellite water vapor measurements.*

We hope the revised manuscript will better meet the requirements of your journal for publication. I really appreciate your comments, which improved the quality of our manuscript tremendously.

Sincerely yours,

Dong-Hyo Sohn, Ph.D.

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