Dear Dr. Green,
Please find below our response to the reviewer comments. The comments of the reviewer are provided in Black. Our response is highlighted in Blue.

In addition, please note that we have moved Figures A1 and A2 from the Appendix to Supplementary Materials so that we have one single additional file containing all ancillary tables and figures including those requested by the reviewers.

General Comment:

The submitted manuscript presents the analysis of ASCAT time series data (backscatter, slope & curvature) over the greater Amazon region with regards to water dynamics and two drought events. Additional meteorological (e.g. precipitation from GPCP) and water dynamics (from EWT – GRACE) information are incorporated into the analyses for comparison. The following comments & suggestions are the remaining issues that have not been fully addressed in the last review round; Non-appearing comments from last review are considered as solved by the reviewer:

Major Comments:

1. The study analyses are based on very small changes in backscatter (sometimes well below 0.1 dB in variation). This puts a massive demand on radiometric stability (and NESZ) of the ASCAT sensor. Please elaborate on this topic and include justifying statements. How far are these small backscatter variations showing significant and stable correlations to variations in environmental properties in the Amazonian vegetation? Is there a lower limit in sensitivity? The reviewer thinks it would be reasonable to define a lower limit.

Answer authors:
Wilson et al. (2010) mention that ASCAT was expected to have an accuracy of +/-0.3dB at 95% confidence level. A subsequent validation study by Anderson et al. (2011) showed a calibration accuracy of 0.15 - 0.25 dB. Therefore, changes on the order of 0.1dB are unquestionably close to the limits of the sensor. It is important to note, however, that the radiometric accuracy is expected to be better (i.e. less noisy) over stable, homogeneous targets (e.g. evergreen rainforest). Furthermore, the results presented here have been averaged in space or time, or both, which also reduces the noise. Consequently, it is reasonable to assume that the spatial and temporal patterns observed can be attributed to geophysical variability rather than observation error. This point has been summarized in Lines 145-147.

Answer reviewer:
This point is still considered critical by the reviewer. The changes in the text are well received. However, the sentence in lines 145-146 "…reduce noise, the backscatter data is averaged in space (over the ecoregions of interest) and/or time (to monthly or decadal intervals)." is still a qualitative statement. Please quantify the averaging in space and time. More precise, please provide a table showing the number of equivalent looks that are used for averaging. It is required to understand how many samples were used to stabilize the backscattered signal.

Author response:
Tables S1 and S2 have been added in Supplementary Materials. The following has been included in the description of the ASCAT data: "To reduce noise, the backscatter data is averaged in space (over the ecoregions of interest) and/or time (to monthly or dekadal intervals). The number of grid points averaged is provided in Tables S1 and S2. Data are available every 1-2 days (Wagner et al. 2013)."

6. Concerning vegetation penetration one major point is when the C-band EM waves start to interact with anything but not vegetation, like soil under vegetation: How far are soil influences on the backscatter signal playing a role, especially for lower vegetated or dry areas (e.g. Cerado)? Please evaluate and discuss potential non-vegetation influences on the signal, like soil scattering. Is there a criterion or threshold-based approach to find and exclude regions and/or times when non-vegetation effects, like from soil, have a too distinct/significant influence?

Answer authors:
Microwave interactions with vegetated surfaces are complex due to the variety, in terms of size and dielectric properties, of the vegetation constituents and the influence this has on the propagation of microwaves through the vegetation, interactions within the vegetation and interactions between the soil and vegetation. We always consider the total backscatter as a combination of contributions from a soil-vegetation continuum. The rationale behind using the slope, for example, is that an increase in slope is indicative of a transition in behaviour between predominantly surface scattering (from the soil) to predominantly volume or multiple scattering (from the vegetation) and vice versa. This tells us if the normalized backscatter variations are due to soil only, vegetation only, or some combination of both. Naturally, for areas or periods when slope is low, there may be a contribution of soil scattering to the total backscatter signal. This is also reflected in the correspondence between EWT and backscatter, since EWT is an aggregated signal including soil and vegetation water among other elements. Thus, we agree that in terms of backscatter dynamics there might be added-value in further analyzing this, however the main aim of this research was to investigate the backscatter incidence angle relationship. Working with the slope values allows us to observe the physical process of fresh biomass change (either due to phenology or water status) through its effect on the backscatter incidence angle relationship. As this is, in itself, an indicator of which type of scattering contributes to the signal, and these are continuous processes, we do not see the added-value of introducing criteria or thresholds to categorize behaviour rather than use the information directly.

Answer reviewer:
As far as the reviewer understands from the answer of the authors, "...when the slope is low, there may be a contribution of soil scattering to the total backscattering signal…". Another statement says: "The rationale behind using the slope, for example, is that an increase in slope is indicative of a transition in behaviour between predominantly surface scattering (from the soil) to predominantly volume or multiple scattering (from the vegetation) and vice versa.". These two statements motivate that for regions with non-closed-canopy conditions and significant soil contribution, the water sensitivity of the slope

and curvature may be due to soil moisture dynamics rather than vegetation water ones. The reviewer agrees that this misfit in water dynamic sensitivity might be weakened, as the different water storage compartments (soil, vegetation) are linked by the soil-plant-atmosphere system. In the end, the reviewer would ask for including a paragraph in the discussion section to address this challenge of soil scattering contributions in the backscattered signal and how to deal with it.

Author response:
The following sentences have been included in the Conclusion section: "For regions with non-closed-canopy conditions and significant soil contribution, the water sensitivity of the slope and curvature may be influenced, or even dominated by soil moisture dynamics (Greimeister-Pfeil et al. (2022)). Furthermore, the various storage compartments (soil, vegetation) are linked by the soil-plant-atmosphere system."

"An improved physical understanding of the influence of both soil and vegetation on slope and curvature is essential. Future research should also include forward electro-magnetic modelling of multi-angular backscatter (i.e slope and curvature) to improve our understanding of how they relate to vegetation water and biomass variations as well as soil moisture."

6. There is a spatio-temporal scale gap as well as a sensing volume gap (C-band EM wave penetration vs. 3D gravity field dynamics) between GRACE EWT and ASCAT observations. Hence, the reviewer has doubts that (lines 181-183)"…in each ecoregion, there is clear agreement between the seasonality of EWT and backscatter. This indicates that backscatter is influenced by moisture availability in terms of total terrestrial water storage, which includes groundwater storage." This is a strong statement and "a clear agreement" is not really statistically quantified. Please add some statistical or more quantitative analysis for justification of this agreement. Moreover, please explain and/or discuss the scale gap and sensing volume gap of the two remote sensing observations.

Answer authors:
There is an obvious scale and sensing volume mismatch between the two datasets. This is why we do not consider it sound to provide a statistical or quantitative comparison between the two. It would be dominated by artefacts of the difference in spatial and temporal scale between the two products. We have included the following text in Section 2.3 by way of explanation. Lines 156-158: "Precipitation, radiation and humidity are hypothesized to be the main atmospheric forcing for vegetation activity in the Amazon (\citep{nemani_climate-driven_2003}). Therefore, these three forcings are compared to slope and curvature. As they are on similar temporal and spatial scale quantitative comparisons are performed." Lines 163-165: " EWT includes variations in all terrestrial water storage terms including groundwater, soil moisture, vegetation, and surface water. Therefore, EWT is only qualitatively compared to backscatter, which is affected by soil moisture and vegetation. "

Answer reviewer:
Many thanks for all explanations and adaptions concerning sensing volume mismatch. Please also include the spatio-temporal scale gap/mismatch of GRACE-based EWT with

ASCAT-based backscatter & derivatives as a statement close to the statement in lines 163-165.

Author response:
Lines 165-170 have been revised and now read:
"Note that EWT includes variations in all terrestrial water storage terms including groundwater and surface water, in addition to the variables of interest in this paper, namely soil moisture and vegetation. Furthermore, EWT is based on monthly data with a spatial resolution of hundreds of kilometers. Statistical comparisons between the EWT and ASCAT would be strongly influenced by the sensitivity of EWT to ground- and surface water and by artefacts of the difference in spatial and temporal scale between the two products. Therefore, EWT is only qualitatively compared to backscatter, which is affected by soil moisture and vegetation."

Minor Comments:

6. Figure 14:
Figure 14(a) is indicative of the seasonal variations observed across the evergreen forest ecoregions. Note that the diurnal differences are very small (< 0.06 dB). These seem to be really small differences.
How about signal stability in terms of radiometric resolution? i.e. How noise-prone are these subtle differences? Please add an explanatory paragraph and some discussion about this point.

Answer authors:
Refer to our response to major comment 2. The variability in backscatter from evergreen forest ecoregions is extremely limited. In fact, the Amazon rainforest has long been used as a calibration target for spaceborne radar systems (Birrer et al. (1982); Kennet and Li (1989); Frison and Mougin (1996); Hawkins et al. (2000)). This has been included in lines 192 to 195 of the revised manuscript in the discussion of Figure 4.

Answer reviewer:
Please explain also in the text paragraphs referring to Figure 14 and also Figure 15 that these very small fluctuations in backscatter may only be scientifically evaluable in rainforest regions, where the spatio-temporal backscatter dynamics (radiometric variations) are the most stable in the world.

Author response:
The following statement has been added at the end of the discussion of Figure 15: "Note that the very small fluctuations in backscatter observed in Figures 14 and 15 may only be scientifically evaluated in rainforest regions, where the spatio-temporal backscatter dynamics (radiometric variations) are among the most stable in the world."

13. Lines 366-368:
"… by vegetation structure and water content, and interactions between the soil and vegetation is essential to improve our ability to interpret and optimally use VOD derived

from ASCAT." Is there forward modelling on VOD from ASCAT? Maybe even a sensitivity study? Please add references or a statement of future work at this point in the manuscript.

Answer authors:
We added the following sentence (Lines 414-415) to make it clearer that the study presented here was conducted as part of the continued development of ASCAT VOD products: "Therefore, this research contributes directly to the continued development of the ASCAT VOD products".

Answer reviewer:
Thank you for adding the sentence. However, it would be very interesting to understand if there are publications or even internal sensitivity studies on modelling or even estimating VOD from ASCAT. If these references exist, please add them to the paragraph.
Moreover, it would be of great interest (of the reviewer) if there exists motivation of the authors for a forward electro-magnetic modelling study of multi-angular backscatter derivatives (meaning slope and curvature) and how they are linked/influenced by vegetation dynamics (water & biomass). Or is this already existing somewhere? It could lead to a direct retrieval of variables of the vegetation dynamics (e.g. VWC or wet biomass or dry biomass) from slope and curvature.

Author response:
Refer to comment above regarding disentangling soil and vegetation effects and the recommendation to perform forward electro-magnetic modeling to improve understanding. In addition, the paragraph has been edited as follows:"
Slope and curvature may be influenced by the number and distribution of the scatterers, and their dielectric properties, all of which influence the optical depth i.e. the attenuation of the signal by the vegetation.Our improved understanding of the slope and curvature and how they are affected by vegetation structure and water content, and interactions between the soil and vegetation is essential to improve our ability to interpret and optimally use VOD derived from ASCAT. Therefore, this research contributes directly to the continued development of the ASCAT VOD products. For example, it provides further insights in the VOD calculated from ASCAT by Vreugdenhil et al. (2016), where the main temporal dynamics stem from the slope and curvature."