Biogeosciences Discussions

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Comment on bg-2022-84

Anonymous Referee #3

Referee comment on "Continuous ground monitoring of vegetation optical depth and water content with GPS signals" by Vincent Humphrey and Christian Frankenberg, Biogeosciences Discuss., https://doi.org/10.5194/bg-2022-84-RC3, 2022

The authors present an experimental technique using GNSS that can be used to provide continuous VOD estimates. The paper is well-written and the level of detail provided is generally appropriate. Given that the paper is likely to be read by a wide audience, many of whom are not familiar with GNSS, I would recommend including some additional details (see below). The technique and methodology presented have the potential to be hugely valuable for the microwave remote sensing community, particularly those concerned with observing soil and vegetation. The authors provided valuable recommendations on the deployment of similar set-ups, and outline several potential applications. This paper is highly innovative, timely and can be expected to have a significant impact in the field of hydrology and remote sensing. To my knowledge, the theory and methodology are sound. I recommend that it is accepted for publication in this special issue if the following comments can be addressed.

Major comments:

- In lines 554-556, and the discussion in lines 569-589, AGB and CWC are used to refer to the total aboveground portion of the vegetation, including leaves, branches, trunks etc.. However, as discussed in lines 523-531, observations and modeling studies have shown that L-band transmissivity is primarily sensitive to leaves. This suggests that the GNSS VOD produced here is primarily sensitive to leaves and that the dynamics observed in GNSS VOD are primarily due to variations in leaves with the sensitivity to branches and trunks depending on leaf moisture content. The same is also true for other L-band VOD products. Nonetheless, I think this should be mentioned in lines 565-576 as it provides some explanation for the difference among the estimates based on the models of Vitucci and Brandt. It also serves as a caution to users on the

interpretation of AGB derived from VOD.. It is also relevant for the discussion of CWC because (1) the CWC is calculated using the estimated AGB and (2) the definition of "canopy", in the sense of which constituents are observed, varies depending on leaf moisture content - the dynamics in this CWC are expected to be primarily due to leaf water dynamics.

- Define what is meant by canopy in the paper. Is it used to mean the aboveground portion of the vegetation? The portion above the sensor? Or the upper layer of the forest? It is important to be clear here because the paper is likely to be read from both the remote sensing community as well as the forest ecology community. This is also relevant in the context of the discussion above regarding canopy water content.

- Lines 107-110: I would not use "proxy" here. GNSS-VOD should not be considered a direct proxy for biomass or leaf water status. The current formulation suggest that the relationship between GNSS-VOD and biomass and leaf water status is more direct than it is. It is fine to say that GNSS-VOD could be useful to interpolate and gap-fill sparse and labour-intensive measurements of biomass and leaf water status but there many assumptions and models needed between the two.

- Section 3.1: For readers not familiar with GNSS, it would be helpful here to provide some description of how the data shown in Figure 3 are obtained in terms of satellite overpasses, viewing geometry etc.. A short description of GNSS constellations would be helpful. It would also be helpful to explain how Figure 3 should be read in terms of azimuth and incidence/elevation angle. Please label azimuth and incidence angle on the plots and/or mention in the caption to improve readability for new users.

- Section 3.1: Provide details on how data from different GNSS constellations are merged. In particular, mention if there are any systematic differences and how they are

handled during merging.

- Line 294 – 302: I'm not convinced by this argument. If non-random multipath interferences are not excluded, will they not introduce or contribute to spurious values of VOD rather than random noise? If so, there is a danger that these are incorrectly interpreted as VOD variations? Please demonstrate that this is not the case.

- Section 3.3: I found the nomenclature in this section, particularly the use of the terms anomaly and static, confusing and potentially misleading. In practice, the issue is that a robust estimate of the temporal variation can only be obtained at the expense of spatial aggregation, i.e. a loss of spatial resolution. The methodology to obtain the time series itself is fine, but I would recommend re-thinking the nomenclature.

- Lines 495 to 507: Why is it necessary to optimize v_veg with a daily time step? In a forest, in particular, this quantity is likely to vary over much longer time scales. This could obviate the need for some of the low-pass filtering in later steps.

- The conclusion should include some discussion of the trade-off between temporal and spatial resolution. Lines 460-466 could be moved to the conclusion as part of this discussion. It is relevant in terms of the processing, but also in terms of sensor installation. I think it is important to emphasize that the capacity to obtain finer angular resolution comes at the expense of temporal resolution. There are applications where one might be more critical than the other, and many applications where the trade-off is non-trivial.

Minor comments:

I would recommend having it proof-read by a native speaker to remove small errors.

Line 11: time-consuming destructive samples

Line 18: at a forested site

Line 24: Sensitivity to rainfall and dew deposition events ….

Line 33: remove “direct”. The information is not direct. It needs to be inferred from retrieval products.

Line 39: re-phrase. The use of arguably and currently is awkward.

Line 166: How many leaf samples? Provide details of the protocol used to ensure that the leaves collected were representative.

Line 228: Define vegetation density for readers not familiar with microwave remote sensing.

Figure 2: In the caption, replace “Canopy transmissivity” with GNSS VOD.

Line 247: This should be Eq.9 ?

Line 279: It would be useful to indicate which data are excluded on Figure 3(d), in terms of time of day so that the reader can put the discussion in this section in the context of the data they see in Figure 3.

Line 419: The study of Vermunt describes a diurnal cycle in backscattern (not VOD) due to dew and interception. It belongs in the first paragraph of this section.

Line 454: v_veg is called the volume density here and the vegetation density elsewhere. Define it once, clearly, in Line 228 and use a single term throughout.

Line 506: What metrics are used to evaluate agreement?

Line 515: What is the cost function used here?

Line 531 – 533: Remove "Thus," from this sentence. The assumption does not follow from the previous two sentences. Though it is a necessary assumption. You should write "It is assumed that the dielectric … ".

Line 538: the retrieved gravimetric …

Line 715: time of the Sentinel-2 overpass

Line 739: We suggest placing …