Response to reply to comment

Response to 'Reply to Comment on: "Rainfall, fog and throughfall dynamics in a subtropical ridge top cloud forest, National Park of Garajonay (La Gomera, Canary Islands, Spain) by G. García-Santos and L.A. Bruijnzeel"'

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Abstract:

We respond to the reply by García-Santos and Bruijnzeel (2013) (referred to henceforth as GB2013) to our previous comment (Ritter and Regalado, 2013; hereafter RR2013) of García-Santos and Bruijnzeel (2011) (denoted as GB2011). We provide additional arguments that support that our earlier comments were pertinent and point towards the misinterpretation of fog water estimates, erroneous rainfall estimates, and large data dispersion as the main reasons invalidating most of their results.

KEY WORDS Canary Islands; corrected rainfall; fayal-brezal; fog; laurisilva; throughfall.

We respond to the different issues pointed out in the reply comments of GB2013 and provide further arguments about some of the errors detected in GB2011:

NOVELTY OF THE STUDY

First of all, we do not agree with the authors when stating that their own work (García Santos et al. 2004) and ours (Ritter et al., 2005, 2008; 2009a; 2009b; Katata et al., 2009; Ritter and Regalado, 2010), both carried out at the same site, using the same data and reporting the same hydrological variables than GB2011 "were not pertinent to the work under consideration" or "were not relevant in the context of GB2011". Secondly García-Santos (2007) PhD thesis was not available for us when the Ritter et al. (2008) manuscript was submitted (October 2007), and obviously not when it was prepared. This is the main reason why we did not cite it. Certainly we find it highly relevant, as we further discuss below. Nevertheless, García-Santos (2007) is not a peer reviewed publication and as such its results may be taken with a pinch of salt, as it has been put in evidence in our comment of GB2011, the latter being basically a reproduction of Chapter IV from García-Santos (2007). The authors also obviate that as early as in Ritter et al. (2005) the commented corrections on fog water collection to account for wind impacting not perpendicularly on the QFC were already considered.

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RAIN GAUGES RESOLUTION AND RAINFALL WIND CORRECTIONS

In their reply to our comment the authors state that "each of the gauges … was calibrated individually by Miss García-Santos, and the effective capacity of the tipping bucket was found to be 5 ml". First of all it is not normal practice that commercial rain gauges are "calibrated" (more accurately would be to say "checked") to verify the manufacturers specifications. We thus put into doubt, nor we recall, this was actually done by Miss García-Santos while she was a PhD student at ICIA. We have though verified the resolution of the used rain gauges owned by ICIA, and originally specified by the manufacturers as 0.2 mm, and certify this was certainly 0.2 mm/tip, i.e. a orifice area of 200 cm^2 and 4 ml tipping bucket volume was measured in our lab. We also compared our rainfall measurements with those of the Garajonay National Park climatic records for the period 1999-2010 (Parque Nacional de Garajonay, Memoria Anual, 2010). For the year 2004 the Garajonay National Park reported a rainfall value of 845.8 mm at a nearby station in Laguna Grande (table 3 in Parque Nacional de Garajonay, Memoria Anual, 2010). For the period January 2004 to December 2004 our rainfall data renders 818.0 mm, i.e. yielding a difference of only

27.8 mm with respect to the Park's data. However using a 0.25 mm resolution instead of 0.20 mm, this would give 1022 mm for the same period, i.e. a 203.2 rainfall surplus, suggesting once more that the raingauge resolution used by GB2011 is incorrect. Thus our original comments in RR2013 about errors in water input estimates in GB2011 remain relevant.

With respect to the rainfall corrections applied to include the effect of both wind velocity and terrain slope, GB2013 incorrectly state that "the wind corrections used by Ritter et al. (2008) follow the approach of Sevruk (2005) which was developed originally for the correction of monthly precipitation data in the Swiss Alps. However, the Discussers applied the Sevruk corrections to hourly data in the Canaries". The Sevruk (2005) reference was cited in Ritter et al. (2008) solely to justify the need for such corrections: "When windy conditions prevail, actual rainfall incident to the forest may be underestimated if this is assumed to be equal to the rain gauge measurements (Sevruk 2005) (page 924 in Ritter et al. (2008)"; "Corrections of rain gauge measurements for wind induced losses and the effect of inclined rainfall falling on a sloping surface under windy conditions are advisable (Sevruk 2005)... (page 927 in Ritter et al. (2008)". The corrections applied by Ritter et al. (2008) were thus not those of Sevruk (2005) but the ones described in their equations (4)-(6), after Førland et al. (1996) (see also eqs. (2), (5)-(6) in Holwerda et al. (2006)). Corrections to account for inclined rainfall falling on a sloping terrain were conducted after Sharon (1980), as indicated in the text. Thus GB2013 misinterpreted the procedure followed by Ritter et al. (2008). By contrast, the wind corrections used by GB2013, followed the method proposed by Yang et al. (1998) for Alaska measurements. Accordingly the corrected rainfall reported by GB2011 for the second yearly measurement period was P_a*=1693 mm. This large rainfall value seems unexpected for a semirarid climatic region as the Canary Islands. For instance the mean yearly rainfall value for the Laguna Grande area during the period 1999-2010 was 672.6 mm (range 361.8 mm-933.9 mm), and the absolute maximum reported in the Garajonay National Park was 1117 mm. Furthermore this value of 1693 mm is even above the annual historical maximum of 1552 mm registered in the occidental Canaries since 1946 at 1378 m a.s.l. in Vilaflor (Tenerife), or the 1431 mm registered in Aguamansa (Tenerife) at 1074 m a.s.l. during an atypical heavily rainy period in the early 50's (source: Agencia Estatal de Meteorología, Centro Meteorológico Territorial en Canarias Occidental).

NUMBER OF THROUGHFALL GAUGES

The above discussion about errors in the resolution of the raingauges, although substantial and relevant, is simply distracting the attention from the main point of our criticisms, and this is the insufficient number of throughfall gauges (just two) the authors used to arrive to most of their results. The acknowledgement by GB2011 (in their Methods section), and the reiteration in GB2013, that the number of throughfall gauges employed was insufficient does not solve the large uncertainty inherent in their results, but this simply represents their own reconnaissance of the limitations of the work published. To this respect GB2013 indicate that "the high variability of the throughfall measurements, [which] affects the reliability of the estimate but not necessarily the mean value itself". Contrary to their statement, it is pretty obvious that the computed mean is an estimate of the "true" TF mean value and, as such, it would be certainly affected by the number of throughfall gauges used. This has been shown for instance in a numerical study carried out with TF data collected at the same site (cf. Fig. 5 in Ritter and Regalado, 2010). This is why our original comments about the invalidity of most of the water input estimates provided by GB2011, based on these two point measurements below the canopy, remained unaffected by the author's reply to our comments.

RAINFALL-ONLY AND MIXED PRECIPITATION CONDITIONS

Lets make it simple and clear here: with the use of an unsheltered fog collector and a raingauge above the canopy it is not possible to confidentially detect those events when rainfall was the only water input to the forest. The QFC, because is unsheltered, will collect rainfall, as the raingauge will, during rainy and mixed precipitation events, the amount of rainfall collected by these two equipments being affected rather unpredictably by their particular design and the prevailing wind conditions. We reproduce in Fig. 1 the Fig. 4 from Ritter et al. (2008) to illustrate this issue. For low wind speeds (0-1 m s^{-1}) a linear relationship may be suggested, although this departs from the 1:1 line (Fig. 1a), due to the non-ideal design of the QFC trough as a rainfall collecting device. As wind speed augments (Figs. 1b-f), data scattering increases further departing from the bisection line, and indicating that the QFC mesh collects wind-driven rainfall that remains undetected by the raingauge. Thus the criterion "a day with rainfall-only was considered to occur when the amount collected by the fog collector was negligible (either no fog water was present or it was less than 10% of the total amount of rainfall registered by the rain gauge, i.e. $F_c < 0.1P_a$*)" used by GB2011 remains inappropriate, despite the insistence of GB2013. This is because it does not account for the wind speed dependence shown in Fig. 1, but more importantly, because the fog catcher used was unsheltered, and the uncertain rainfall amounts it collects during rainy events make impracticable any attempts to distinguish this from the presumed fog water dripping from the mesh. Furthermore, there is a fundamental error implicit in the expression:

$$F_c < 0.1P_a^* \qquad (1)$$

in terms of unit consistency, i.e. F_c has units of L m^{-2} of vertical effective screen while P_a^* has units of mm. Thus the above inequality (1) is also erroneous for this reason, and therefore inapplicable. The error stems from the fact that GB2011 refer F_c in terms of depth equivalents, i.e. mm (see below for a thorough discussion). Also notice that, although not acknowledged, the criterion used by GB2011 was in fact not (1) but

$$F_c - P_a^* < 0.1P_a^* \qquad (2)$$

otherwise (1) would not make sense under rainy conditions, and this would imply again a unit mix-up, i.e. the water collected by QFC, expressed as L m^{-2} of vertical effective screen, would have been subtracted from the rainfall P_a^* (in mm).

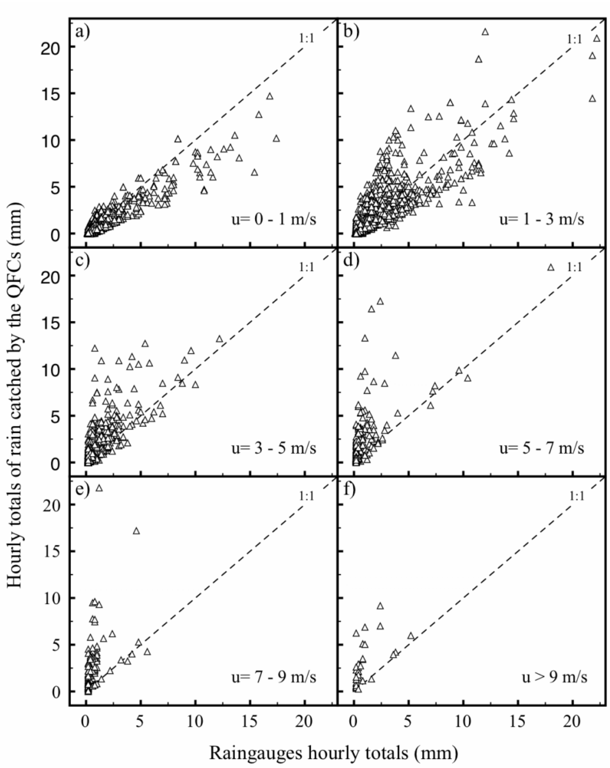

Figure 1. Effect of wind speed (u) in the amounts of rainfall collected by a QFC, referred to the area of the gutter and not to the vertical mesh area, compared to those measured with a rain gauge (see Ritter et al. (2008) for further details).

Equivalent arguments would be applicable to those events referred as with "mixed precipitation" i.e. those registering fog and rain. The authors in GB2011 could have used in this case the throughfall measurements below the canopy in order to detect whether there was an excess of throughfall water over the incident rainfall measured above the stand, but due to the inherent large variability of throughfall and the reduced number of throughfall gauges employed (two) such a subtraction procedure would be prone to large errors and therefore would make unattainable the distinction of mixed precipitation events. Thus our original comments about the distinction of rainfall-only and mixed precipitation events by GB2011 and discussed in RR2013 would remain unaltered.

ARTIFICIALLY COLLECTED FOG WATER: UNITS AND MISCONCEPTIONS

The issue of fog water collection units is not a matter of using mm instead of L m^{-2} of collecting screen, as GB2013 discuss, but of the misinterpretation the authors make of the artificially collected fog water. First of all, L m^{-2} (vertical screen) is more rigorous and less prone to misconceptions than mm, and that is why the use of the former is widely extended and recommended for reporting fog collection estimates. By contrast, the use of mm units instead of L m^{-2} for rainfall quantification helps to visualize this as the depth of a water layer over e.g. the soil surface, but such a visualization looses its meaning when dealing with the volume of fog water collected on a vertical screen. However, as previously stated, the error in GB2011 arises not because the authors use a particular unit notation, i.e. mm instead of L m^{-2} of collecting screen, but because millimeters of artificially collected fog water were erroneously interpreted. Bruijnzeel et al. (2005) and Marzol-Jaén et al. (2011) were cited by GB2013 to justify the choice of mm units for their reported QFC values. However, in their review Bruijnzeel et al. (2005) mostly deal with fog deposition inputs, and not with fog water artificially collected, and as such the mm notation would make sense in the former case. By contrast Marzol-Jaén et al. (2011) basically reported their QFC water yields as L m^{-2}, although certainly the same unit error, as discussed below, is reproduced there about the stand fog collection efficiency. Also Marzol-Jaén et al. (2011) erroneously compared their annual QFC fog water yields with those of fog water dripping below the canopy reported by Prada et al. (2009), as a consequence of expressing both quantities in mm units in this particular instance. Needless to say that García-Santos is coauthoring both publications, i.e. GB2011 and Marzol-Jaén et al. (2011), and this might thus explain this matter. Therefore the citation of these two references, i.e. Bruijnzeel et al. (2005) and Marzol-Jaén et al. (2011), by GB2013 does not provide any additional support to their fog yield unit notation choice but aggravates its consequences.

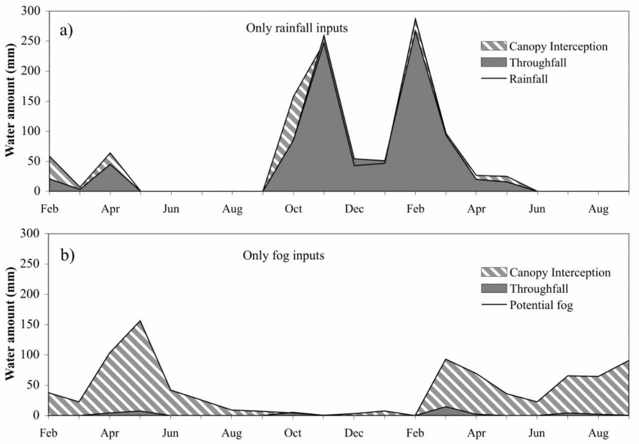

Figure 2. Reproduction of García-Santos (2007) Fig. IV.12: a) “Seasonal distribution of monthly water inputs, throughfall and derived potential interception totals on days with rainfall-only at the Laguna Grande ridge top site between February 2003 and September 2004.” b) “Idem for potential fog inputs (corrected fog collected above the canopy) and throughfall on days with fog-only.

In order to illustrate the issue of the inappropriateness of fog units and the confusion of the artificially collected fog water with the fog water input to the forest, we reproduce in Fig. 2 the Fig. IV.12 from García-Santos (2007), where the commented paper derives from (cf. Fig. 5 in GB2011). It may be noticed that, according to the author, during fog only conditions, throughfall (in mm) and collected fog water (with units L m^{-2} of collecting screen, but that the author denotes as mm) were subtracted in order to derive the canopy interception (stripped area), such that she concludes that e.g. of the order of 150 mm of water may be held by the vegetation at some stage (May 2003) during the measurement period considered. Furthermore, when GB2011, based on this same figure (Fig. 5 in GB2011), concludes that “only 5.9% of F_c passed the canopy as TF on average, confirming that the fog screen was much more efficient at trapping fog than the forest canopy, …” is falling into this same error of comparing variables with different units, i.e. F_c (L m^{-2} of vertical effective screen) with TF (mm). In other words the reported 5.9% “efficiency” factor was computed from the mean of the ratios of monthly TF and F_c values appearing in Fig. 5 (bottom panel) in GB2011, i.e.

$$\frac{TF}{F_c}\frac{(mm)}{(L\,m^{-2}\ \text{vertical screen})}\times 100 \qquad (3)$$

The authors in fact considered this result of such relevance that it was worth stressing it in the abstract section – see also Marzol-Jaén et al. (2011). To be able to arrive to such an “efficiency” result they would have had to compare instead L m^{-2} of QFC collecting screen with, for instance, L m^{-2} of vertical intercepting foliar area, and not with liters over soil ground area (mm) of TF as they did. We hope these examples help to illustrate that the authors misinterpreted the fog water collected by the artificial catcher as that intercepted by the vegetation and dripping onto the soil ground, and that using the appropriate units (L m^{-2} effective mesh and mm, respectively) would have helped to avoid many errors.

WIND SPEED CORRECTIONS IN FOG WATER COLLECTION

GB2013 did not clarify in their reply, as they did not do in GB2011, how they presumably “corrected” their fog records to take into account for what the authors refer to as wind speed (u) effects or the collectors’ efficiency (C_{eff}). Thus we are inclined to conclude that our initial guess, that the equation (4) in RR2013

$$C_{eff} = -0.002u^2 - 0.022u + 0.6 \qquad (4)$$

was used, is correct. This was derived by Frumau et al. (2011) under conditions of occult precipitation (fog + wind-driven rainfall) and, when applied to fog-only conditions, its interpretation would be physically implausible as already discussed in RR2013. In GB2013 the authors state that “do not believe the assumptions to be as erroneous as claimed” by us, but do not provide arguments to clarify how an equation that, when applied to fog-only conditions results counterintuitive and physically unrealistic, was actually applied. Formula (4) is simply indicating that, during wind-driven precipitation, the rainfall amount collected by the trough of an unsheltered wire harp collector would decrease with increasing wind speed, being, as expected, maximal (C_{eff} = 0.6) when u is negligible. Thus, its application to solely fog-only events, as indicated in GB2011, would be flawed.

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have to be approved beforehand by the RTA20001-097 project PI.

CONCLUSIONS

We have provided additional arguments to those already discussed in RR2013 that indicate fundamental errors detected in GB2011. Summarizing these are i) rainfall estimates: assumed erroneous raingauge resolutions and corrections that render increased rainfall outputs; ii) fog water precipitation: physically implausible corrections, misinterpretation and misuse of fog water units; iii) throughfall: insufficient number of gauges (two) incapable of characterizing water dripping below the canopy. We therefore consider that such errors are neither largely inconsequential nor would be easily sorted by addressing them in an erratum, as suggested in GB2013.

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