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Interactive comment on "CloudRoots: Integration of advanced instrumental techniques and process modelling of sub-hourly and sub-kilometre land-atmosphere interactions" *by* Jordi Vila-Guerau de Arellano et al.

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Response to reviewer RC2 Understanding sub grid variability of mass and energy fluxes, especially over heterogeneous landscapes or those subjected to full sun and shade under days with fair weather clouds remains a challenge to our field. This is an interesting effort to bring together observations and models to better understand these processes. I've always been curious about how sunlight can drive fluxes which in turn drive pbl growth and humidification of the boundary layer, which then affect humidity and the production of fair weather clouds. Hence a mix of positive and negative

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Discussion paper

feedbacks acting in concert.

1.- Answer: We thank Prof. Dennis Baldocchi for his evaluation. In particular his review shows the broad overview that helps to connects this CloudRoots paper with previous reserach. His suggestions to clarify some assumptions in treating the scintillometer data and the photosynthesis-conductance model are treated in this response that includes the modifications introduced in the revised manuscript.

This paper describes the detailed CloudRoots experiment. It joins a class of papers, like many of the key papers in the past that described FIFE, HAPEX, BOREAS, the Boardman ARM Field Experiment and various Kansas studies that provide the background for large investigator integrated field experiments. This newer generation of studies has some advantages over the past studies with the emergence of SIF as a proxy for photosynthesis. Plus there are better sensors for boundary layer height and more flux stations.

2.- Answer: We have included references to these previous campaigns to better connect our work to similar previous campaigns

Abstract/Introduction Overall it has the connections between leaf and soil, to canopy, to landscape, to region to boundary layer set of measurements and models to provide a rich database for discovery, model validation and model parameterization.

Methods

The team is using state of art eddy covariance measurements methods that are well vetted, though ICOS. Spatial integration is with scintillometers and inference of fluxes with remote sensing like SIF. The CLASS model is one of the best and is based on LES origins and can be used to drive a simpler one dimensional model. The scale of this work is over 10 km, which is reasonable. The study was in Germany and conducted as 3 intensive field experiments over the summer growing season. Land is flat and the landscape is well documented and assessed. Interesting to see mini lysimeters, soil

CO2 chambers and leaf physiological capacity measured, eg leaf gas exchange and sap flow, too. Well planned and executed.

My one complaint is use of MOST to interpret scintillometer measurements. They are often advocated to measure spatial averages, but the edges of the sampling will see advection, so there can be problems inverting fluxes with 2D measurements into a 1D framework. Eddy covariance works around this by establishing an internal boundary layer with large fetch.

3.- Answer: Unfortunately, until a better framework is developed to link statistical parameters (in this case Cx2) to fluxes, we need to continue assuming Monin-Obukhov Similarity Theory (MOST). We agree that MOST should be used with care in conditions that violate the assumptions underlying MOST. An example of this is transition zones at field edges where measurements of Cx2 are not only determined by the turbulent flux of the underlying surface but also from air advected from the neighboring field. During the CloudRoots experiment, we have checked that advection was not affecting our measurements for two reasons. First of all, the scintillometer transmitter and receiver are far enough from the edges of the field given the height of the sensor (1.95m), the wind speed and direction during the IOPs (see figure below), and the stability conditions. All of these make that footprints are small enough to fit within the field. A quick calculation for typical footprint length (90% footprint contribution) for the 3 IOPs yields: IOP1 (85m), IOP2 (30m) and IOP3 (75m). Second, the scintillometer has a path weighting function that is maximum in the middle of the path and near-zero at the transmitter and receiver positions. Therefore the main measurement of the signal occurs in the center of the field as figure 1 shows (see below). The figure also shows the main wind direction and speed during the three IOPs. The scintillometer application used in this paper (a laser scintillometer) should not be confused with the more common long-path scintillometers that are known for their capability to capture area-averaged fluxes at the landscape scale. Laser scintillometers can only be operated over short paths (<150m) and have the advantage that fluxes can be estimated at short time intervals, as is demonstrated in this paper. Another aspect of MOST is the ambiguity of the MOST functions. The choice of MOST functions mainly influences the size of the fluxes. As our focus is on the dynamical behavior of fluxes at short timescales in response to rapid changes in radiative forcing, the correct representation of the size of the fluxes is of secondary importance to us. In relation to the main manuscript, and at section 2.3.6, we have clarified the assumption of MOST and provide information on the footprints.

One thing I do like about scintillometer, and something this team has done, is look at instant fluxes with sun and shade and calculate changes in surface conductance. That approach to me has proven powerful and interesting. Van Kesteren, B., Hartogensis, O. K., Van Dinther, D., Moene, A. F., De Bruin, H. A. R., & Holtslag, A. A. M. (2013). Measuring H2O and CO2 fluxes at field scales with scintillometry: Part II–Validation and application of 1-min flux estimates. Agricultural and forest meteorology, 178, 88-105. All this information is then integrated through measurements of boundary layer devel- opment. Not sure of other such comprehensive field studies, that compete, even FIF, BOREAS or HAPEX.

4.- Answer: We agree with his comment that these one-minute fluxes are an original part of this CloudRoots reserach

Results Information on plant physiological performance is pertinent as it provides parameter information for subroutines in CLASS. I'd like to know more about Vcmax, Jmax and the Ball Berry or Medlyn/Leuning type stomatal conductance parameters used by the model.

5.- Answer: We have included in the supplementary information a new Table S1 including the equivalence of the A-gs parameters to the values of Vcmax, Jmax and TPU at 298 K. The Table is located at the end of the response. . Regarding the formulation of the leaf and canopy conductances, we have provided an explanation in section 2.1 and the key references: Jacobs and De Bruin (1997), Ronda et al. (2001) and

Pedruzo-Bagazgoitia et al. (2017). The paper plays a new role to look at cloud induced fertilization of evaporation. Most studies focus on enhancement of co2 flux. So this is new and novel. Interesting to see At constant Q*, the median of LvE is always higher under clear skies than for cloudy skies. Diffuse fraction plays a minor role and the decrease on LvE under cloudy conditions is mainly due to the reduction in the incoming shortwave radiation. There remains some debate and discussion on the term evaporation over evapotranspiration. I favor the former after hearing John Monteith advocate for it. The paper drives towards a connection with large scale integrated SIF to landscape average evaporation. Since water and carbon fluxes are tightly coupled, I am open minded to this spatial scaling assessment. At boundary-layer integrated scale, they find that modelled sensible heat flux correlates better with the area weighted average flux than the local flux estimates. I find this interesting as we are dealing with a similar problem. How to best average fluxes from a network of flux towers as a lower boundary condition for a pbl model? Or do we get integration of fluxes at 30 m scale with ECOSTRESS?

5.- Answer: In calculating the sensible heat flux as the area-weighted flux we were limited by the eddy-covariance spatial measurements. Therefore this aggregated sensible heat flux is only based on two values taken above two different land conditions as shown in Figure 1. We appreciated very much the suggestion of the 30 meter data of ECOSTRESS, and we plan to use it in future CloudRoots studies that aim to investigate the impact of surface heterogeneity on the boundary-layer and cloud-dynamics. In this paper, we have also included an estimation of the heterogeneity of evapotranspiration inferred from the SIF data (see Figure 14). As shown in Figure 18c, the aggregated of this estimation is slightly higher than the more local measurements of evapotranspiration.

This leads me to a suggestion. The PI should also look at ECOSTRESS data for their domain and compare the integrated evaporative fluxes with what they are producing. These data are publicly available and could be a nice alternative constraint. Fisher, J.

B., et al. (2020), ECOSTRESS: NASA's Next Generation Mission to Measure Evapotranspiration From the International Space Station, Water Resources Research, 56(4), e2019WR026058, doi:10.1029/2019wr026058.

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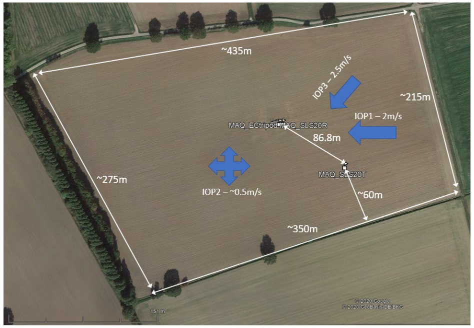

Figure 1: Scintillometer transmitter and receiver locations in relation to the dimensions of the CloudRoots field. The blue arrows indicate the wind-direction on the 3 IOPs with the wind-speed at z=2m.

5.- *Answer*: We have included in the supplementary information a new Table S1 including the equivalence of the A-gs parameters to the values of Vcmax, Jmax and TPU at 298 K. The Table is:

Table S1: Equivalent temperature-normalized maximum carboxylation, electron transport and triose phosphate utilization rates (V_{cmax25}, J_{max25} TPU_{25}, respectively) commonly used in the Farquhar-Berry-von Caemmerer (FBvC) model of leaf photosynthesis (Farquhar *et al.*, 1980). Fits between the FBvC and A-g_s models were obtained using the plantecophys package (Duursma, 2015) based on A-g_s model output with parameter values noted in Table 3, a constant temperature of 25°C and PAR of 1500 μmol m^{-2} s^{-1}.

Parameter setting (table 3)	V_{cmax25} (μmol m^{-2} s^{-1})	J_{max25} (μmol m^{-2} s^{-1})	TPU (μmol m^{-2} s^{-1})	RMSE
Default	81.11	240.95	-	7.53
IOP1	98.37	196.43	12.97	5.96
IOP2	93.69	121.09	7.58	2.16
IOP3	15.43	15.77	0.82	2.56

Fig. 1.