

## Cover Letter

### Response of the authors to the reviewer's comments

---

Manuscript: Transmissivity of solar radiation within a *Picea sitchensis* stand under various sky conditions

Sigrid Dengel (corresponding author)

---

The authors would like to thank the referees for their valuable remarks, constructive comments, and careful corrections which helped to increase the overall quality of the manuscript.

All changes are marked in **bold red** throughout the revised manuscript.

Anonymous Referee #1

#### General comments

The manuscript by Dengel et al. describes measurements of the vertical and horizontal distribution of solar radiation in a Sitka spruce plantation in Scotland under three different sky conditions in summer. Besides the PPFD also the spectral distribution of incoming and transmitted radiation is investigated. Data sets including spectral properties in forest stands are quite rare and thus valuable to get a better understanding of the light climate in forests. The manuscript addresses this information gap in a technically well written manner, but several major issues especially on the methodological side need to be clarified before publication in Biogeosciences.

The main issue is that, as the authors state correctly, solar radiation distribution is very heterogeneous both vertically and horizontally. Solar angle and biomass distribution play an important role as well as seasonal properties of leaves. To address this large spatiotemporal variability a high spatial and temporal resolution is crucial as well as a high sample size. Regarding the presented data it is not clear if measurements were only performed on one day for each sky condition. If so, the general statements of the paper are not appropriate since they only describe a snapshot at this time. A much larger dataset would be needed to describe the high variability and to derive k-values etc.

Reviewer # 1 detailed comments	Response	Author's reasoning , comments
Introduction:  - Some information on why Sitka spruce is an important species and worth investigating would be helpful.	Dealt with	We have now added a few sentences on why Sitka spruce is important. It is the most frequently planted commercial tree species in the UK and Ireland and very valued for its fast growth and high timber quality.
- 3828-8ff: The research questions stated here are not really what the paper is about. The paper shows a data set of measurements and does not address questions b) and c) in detail.	Dealt with	Thank you very much for pointing this out. We have now modified the objectives b and c and have improved the wording making the research questions much clearer.
Materials and Methods:  - General: more information on the methodology needed: how many days, what	Dealt with	More information has now been provided, including number of days, solar angle and clearness index.

days, what was the solar angle, what clearness index, what aerosol optical density (if available).		
- For description of the light climate, especially in coniferous stands, a spherical approach would better describe the plant relevant radiation, but mostly cosine-corrected sensors such as in this study are used. This is especially relevant in higher latitudes such as Scotland with quite low solar angles throughout the year where this effect can play a large role. Some discussion about that issue would be informative.	Dealt with	We agree. Spherical sensors have never caught on in forest or crop science, perhaps because results would not be comparable with other papers. This point is now mentioned in the discussion. End of section 4.2.
- 3829-8: The instrument has 512 channels with resolution of 3 nm. That should cover a spectrum of 1536 nm, but only 700 nm (350 – 1050 nm) are measured. Please clarify the discrepancy.	Dealt with	We have now explained that the sensor doesn't work well at high wavelengths as the values become too noisy and also not relevant to the current study.
- 3829-10: Solar noon: what sun angle? What days?	Dealt with	We have now also included this information.
- 3829-11: Tower and forest floor scans were carried out back-to-back: In 3829-6 it is stated that above and below canopy measurements are done simultaneously, here it seems they were performed one after another.	Dealt with	The tower is used for the vertical scans and a transect along the forest floor is used for the horizontal evaluation which have been carried out back to back.
- 3829-16: was the influence of the tower and the tower gap somehow tested and quantified?	Dealt with	All measurements were carried out along the southern side of the tower where they are not influenced by the tower structure (shading) or by the artificial gap created during the tower setup. This information has now also been explained in the main text.
- 3829-19ff: A quantification of the definitions needs to be done, e.g., by fractional cloud cover and clearness index.	Dealt with	No cloud cover in eights estimations were carried out. We estimated the clearness index which is now also included in the main text.
- 3829-23: The normalization is a good and reasonable way for comparison of the different sky conditions. But also absolute values might be of large importance as also stated later in the discussion with the saturation of light. There might be more in the data than can be seen in the normalized values.	Dealt with	We agree. Therefore we have included more figures where irradiance is used as energy, using its corresponding units of mW/m <sup>2</sup> /nm.

- 3829-25ff: Was there an influence of the tower and the gap on the LAI measurements?	Dealt with	This should not be the case as we have measured away from the tower and on the opposite direction from the artificial gaps. This way the measurements were carried out along the same vertical path as the spectral measurements. Images were "halved" and mirrored in order to estimate the vertical distribution of LAI in the canopy. A sentence has now been included in the main text explaining this procedure a bit in more detail.
- 3830-22: Why was the band 430-470nm chosen as blue? This seems a bit of an arbitrary value.	Dealt with	We chose these wavelengths as they are those within "blue" light that evoke stomatal opening (see several citations within text). We have rephrased the original sentence to avoid any further confusion.
- 3831-14ff: Did the authors compare the measurements by the two different systems? Was there a high agreement? The caption contains the word "spectral", but it seems that the TRAC is not measuring spectrally but only the GER1500?	Dealt with	No, we did not compare the PAR measurements as the GER1500 is measuring as a one point measurement while the TRAC is measuring continuously at 32Hz. In order to give reliable comparison values one would need to carry out measurements with the GER1500 instrument at a higher resolution than 2.5m. We have now deleted the sentence that is misleading in this section and also modified the subtitle to include PPFD only.
- 3831-15f: Rather belongs into chapter 2.2.1	Dealt with	We have removed the information on spectral flux density below the canopy from this section so that it remains as a stand-alone section on below canopy PPFD.
- 3832-1: Here it is stated that measurements were done routinely throughout the year. Is this data shown somewhere? When was it measured? Which data is used for which results in this manuscript? This needs to be clarified.	Dealt with	Those measurements will be reported elsewhere. We have removed the sentence informing the reader about the regular measurement and modified the sentence to include only those measurements carried out as part of this study.
Results: - 3832-19: The shift is not from the visible (380-780 nm) to the far-red/infrared region, but at 700nm which still is in the visible region.	Dealt with	This sentence has now been modified to clarify this issue.
- 3832-23: The mean canopy height is 18.5m, but effects start only at 11m. This can happen when only a profile in one location is taken. Thus it cannot be generalized, because if the profile is taken right next to the stem of the trees, it would look completely different. Thus	Dealt with	At 11 m above canopy we encountered a sunfleck, while the canopy is closing at around 14-15 m above ground. This effect is well visible in all figures related to the vertical measurements.

a higher sample number is needed if general conclusions want to be drawn.		
- 3833-6: The statement that much less of PAR is entering the canopy under clear sky compared to overcast and cloudy only holds for normalized values. But in absolute terms it might still be larger as can be seen in Fig. 3.	Dealt with	PAR is larger within the canopy in clear conditions only in regions surrounding sunflecks or along the forest floor. We have included a further figure in Fig. 3 showing from 5 m above the ground downwards to show this effect.
- 3833-11: approximately 1600 $\mu\text{mol}/\text{m}^2/\text{s}$ ; why is the real value not given? If only one measurement is considered, the information that can be gained from these plots is very limited.	Dealt with	We reported approximate values as all measurements were carried out within 2 hours. This means small changes in exact PAR can occur. Furthermore all instruments measuring PAR at that location showed similar values around 1600 $\mu\text{mol}/\text{m}^2/\text{s}$ . The probability that measurements can be taken again in exact location (time and space) under exact the same solar radiation intensity is rather small. Therefore we limited the data used in the current study to show a snapshot showing 3 distinctive sky conditions and a difference in PAR of approx. 600 $\mu\text{mol}/\text{m}^2/\text{s}$ .
- 3833-22ff and Fig. 4: The relationships and k-values cannot be derived from one measurement only, many measurements at different solar angles are needed for that.	Dealt with	We do agree. We are not generalising this, we just show what an effect these three conditions are having on estimating an attenuation coefficient. We have extended some of the sentences to make this clearer.
Discussion: - 3835-11: I would rather suggest that the laterally incoming diffuse radiation that makes up a much higher fraction under overcast conditions is responsible for the blue enhancement.	Dealt with	We have added a further sentence stating that the directional properties of direct versus diffuse radiation may also have a role in explaining this difference in blue light distribution.
- 3835-19: No generalization can be made, if data are only from one day.	Dealt with	The sentences has been corrected. By "this" we meant Smith's results. "this" has been replaced to read correctly "'if Smith's results..." Generalisation cannot be made from one measurement only, we do agree.
- 3835-22 – 3836-6: This information is not really new.		We do not claim it to be.
- 3836-7 – 3836-22: This paragraph would fit better in the introduction part. In the discussion only the relevant aspects regarding the direct results of the authors should be included.	Dealt with	This paragraph has now been moved to the introduction section and modified accordingly.

- 3836-22: Not possible from one day of data.		This was found for both cloudy and overcast days, in Norway spruce and also described in Smith's review.
- 3837-8: Derivation of k-values from one measurement profile not possible. - 3837-25ff: Exactly that is why a high number of samples with high spatiotemporal resolution are needed.	Dealt with	We have not tried to standardise the light extinction coefficient, we have illustrated how one is estimating the value and what a difference a change in sky condition it makes.
- 3839-1ff: The entire chapter seems to have nothing to do with the results presented. Were CO2 exchange or photosynthesis rates measured on the sampling days?	Dealt with	Yes, CO2 exchange measurements were carried out but due to power, corrections applied to the data, quality control and low turbulence gaps up to half a day do exist on those days. We decided to avoid showing incomplete data and have therefore included data from the only other Sitka spruce forest (250km away - same species, same age, plantation and very similar CO2 exchange and less gaps in the data). By including these measurements we represent the bigger picture of how forests react to changes in sky conditions. The instruments used here (GER-1500, TRAC, laptops and photo camera) were running off their internal batteries.
- In the discussion a lot of general conclusions are stated that cannot be drawn from the underlying data set.		We have not generalised our results but have stated in several places that if other published results are general we may conclude that ours are as well.
- The research questions from the introduction are not well answered in the discussion.	Dealt with	We have reformulated our research questions and hope to have dealt with them in the appropriate manner and extend.
Figures: - Fig. 5: Why is this a typical spectrum? Only one day measured!	Dealt with	There are many scans carried out under clear conditions that all have the same spectral distribution. This can also be found in several publications. The intensity at nm scale does vary but the general spectral distribution remains the same.
- Fig. 7: In the current format not relevant for paper.		We believe it does improve the overall quality of the manuscript as it does the deliver a "big picture" visualisation showing how CO2 exchange of Sitka spruce is influenced by a change in sky conditions on eight consecutive days, including overcast, cloudy and 4 consecutive clear days.
Technical corrections - 3826-7: "a" leaf area index - 3837-12: Smith (1983) also "stated"	Dealt with	Both have been corrected.