A new ground reference model for estimating boreal forest fPAR

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1. Introduction

The fraction of absorbed PAR (fPAR) is a key parameter used in carbon balance studies, and is listed as one of the Essential Climate Variables (ECV). Temporal courses of fPAR for boreal forests are difficult to measure, because of the complex 3D structures, and spatial and temporal heterogeneity of the incident radiation conditions. Thus, they are most often estimated based on models which quantify the dependency of absorbed radiation on canopy structure and optical properties of foliage. In this study, we adapted a physically-based canopy radiation model into a fPAR model, and compared modeled and measured fPAR in structurally different boreal forest stands.

The model is based on the spectral invariants theory, and uses leaf area index (LAI), canopy gap fractions and spectra of foliage and understory as input data. The model differs from previously developed more detailed fPAR models in that the complex 3D-structure of coniferous forests is described using an aggregated canopy parameter – photon recollision probability p. The strength of the model is that all model inputs (p, i_D) are measurable or available through other simple models.

2. Materials & methods

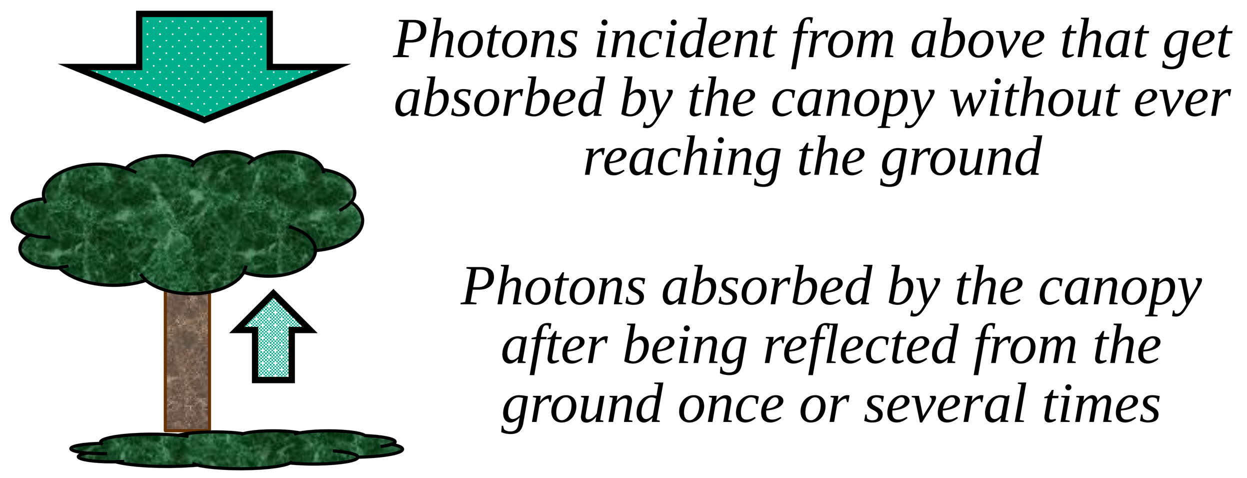

Fig. 1. Schematic representation of the fPAR model.

The fPAR calculation is based on the canopy radiation budget model (Fig.1) developed by Stenberg et al. (2013); Canopy spectral absorptance (Ac(λ)):

$$A_C(\lambda) = i_0\alpha_C(\lambda) + \frac{[t_0+i_0(1-Q)\omega_C(\lambda)]\rho_G(\lambda)i_D\alpha_C(\lambda)}{1-Q\omega_C(\lambda)i_D\rho_G(\lambda)}$$

where

t_0 = zero order transmittance ($i_0 + t_0 = 1$)
Q = fraction of backward scattering
i_D = diffuse interceptance
ρ_G = ground reflectance
i_0 = interceptance, which is composed of two leaf albedo (ω_L) dependent components, α_c and ω_c:

$$\alpha_C = \frac{1-\omega_L}{1-p\omega_L} \qquad \omega_C = \frac{\omega_L - p\omega_L}{1-p\omega_L}$$

Ground reference measurements were performed using the TRAC and LAI-2000 instrument. (For more details see Majasalmi et al. 2014).

ID	desciption	ba	n	dbh	h	cl	CC	LAI
YP	young pine	13	5220	10.2	8.8	4.5	0.6	1.6
YS	young spruce	16	2355	9.2	7.9	5.9	0.7	2.6
MS1	mature spruce	22	446	21.5	20.0	8.3	0.5	2.3

Table 1. Stand description. *Abbreviations: ba = basal area (m^2/ha), n = number of trees per hectare, dbh = diameter at breast height (cm), h = tree height (m), cl = crown length (m), CC = canopy cover (%), LAI = leaf area index.*

Polynomial functions were fitted to the measured canopy gap fractions to create a hemispherical gap fraction distribution for each stand. These hemispherical gap fraction distributions were used together with sky irradiance models (Kittler and Darula, 2006) to simulate incoming radiation fields for clear and overcast sky conditions.

3. Results

3.1 Model validation

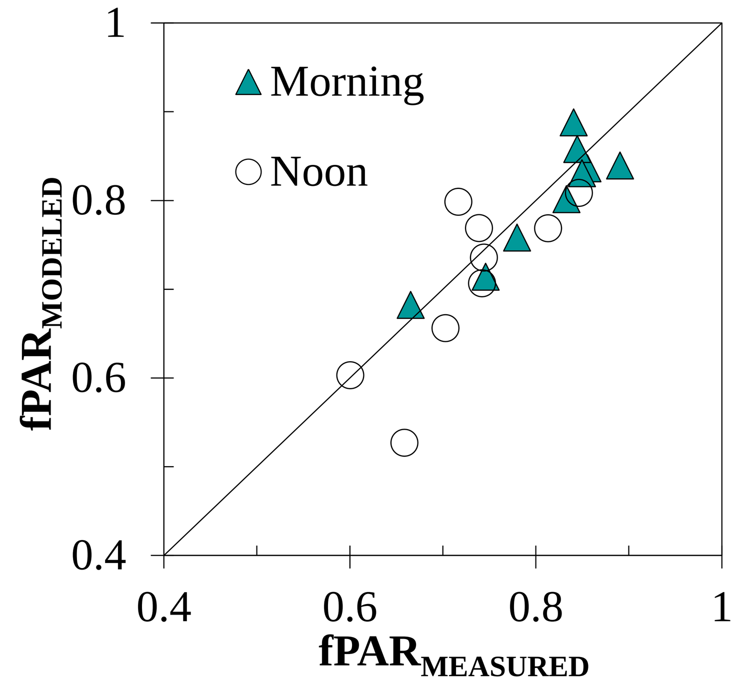

Fig. 2. Comparison of measured and modeled fPAR.

The RMSE for morning fPAR was 0.03 (r =0.9) and 0.06 (r =0.78) for noon fPAR). The relationship was stronger in the morning than at noon due to more stable (clearer) sky conditions.

3.2 Modeled courses of fPAR

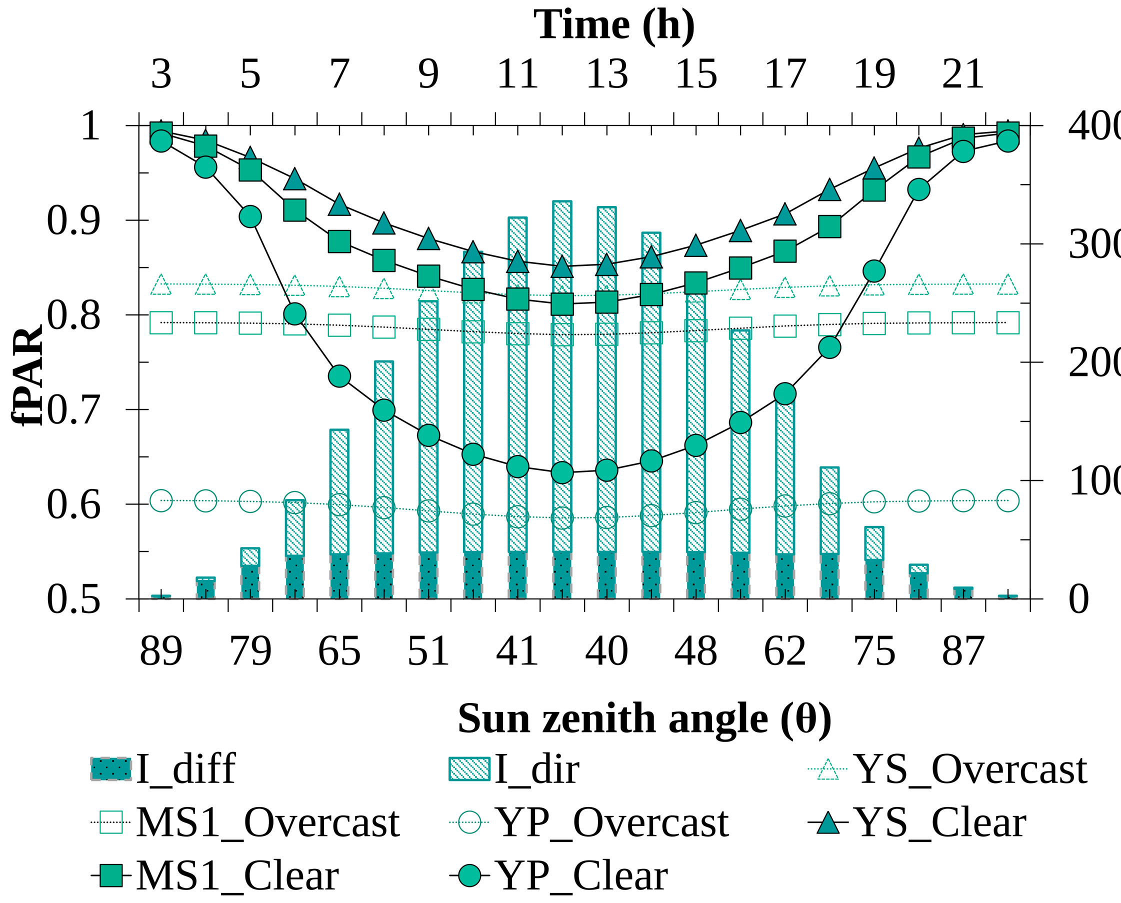

Fig. 3. The modeled diurnal courses of fPAR in three coniferous stands.

Three coniferous stands were selected to demonstrate the effect of forest structure on diurnal and seasonal fPAR. The largest differences in diurnal fPAR occurred around solar noon, and the differences diminished as the solar zenith angle increased (Fig. 3).

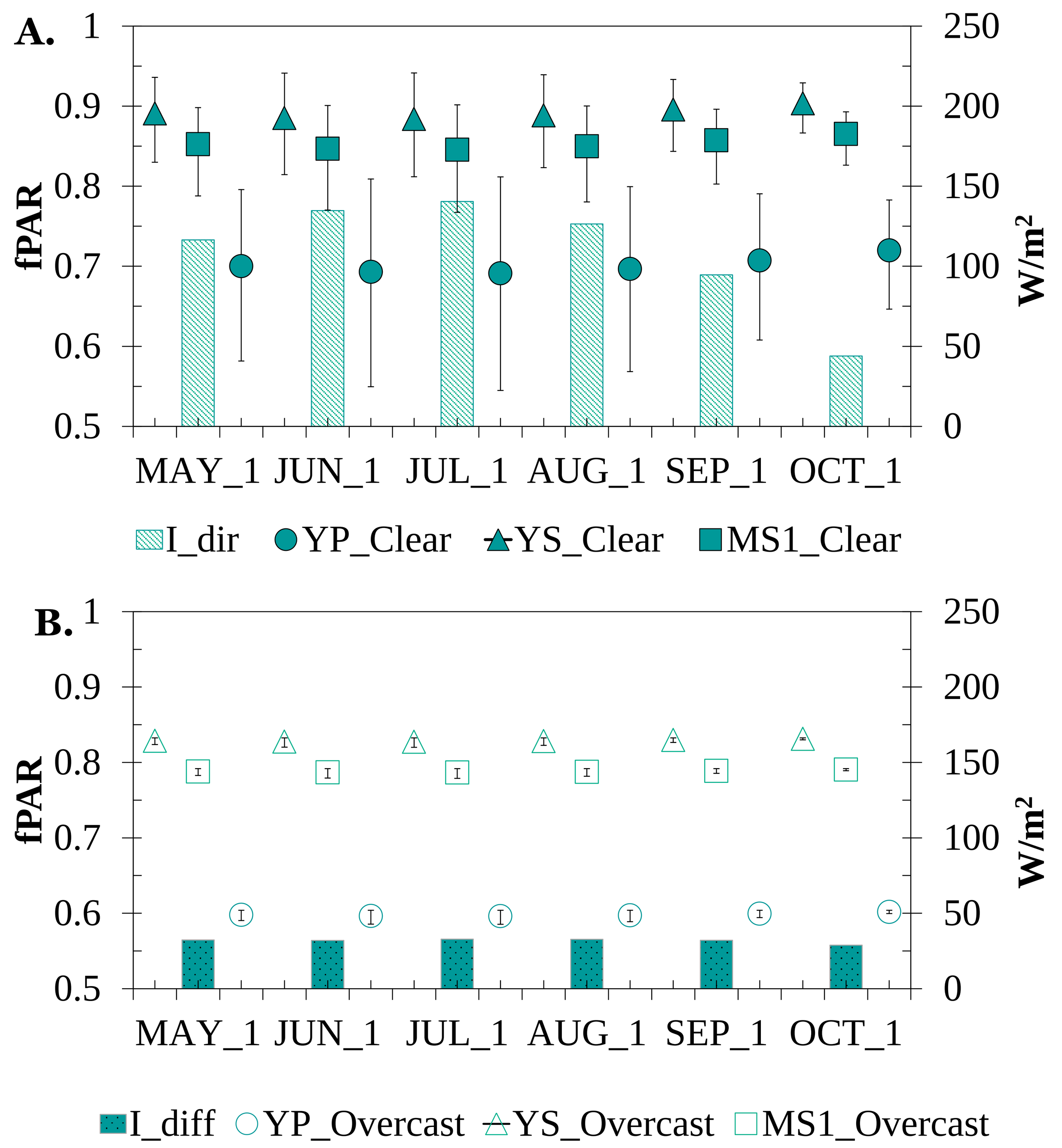

Fig. 4. Seasonal courses of fPAR in three coniferous stands assuming A. clear and B. overcast sky conditions.

In the two dense spruce stands (YS, MS1) the daily average fPAR showed little variation throughout the season whereas in the sparser pine stand (YP) more dispersion was observed (Fig. 4).

4.Conclusions

- Good agreement was found between modeled and measured fPAR.
- Our ground reference fPAR model can be used to quantify the effect of forest structure on both diurnal and seasonal fPAR.

References

Kittler, R., Darula. S. 2006.The method of aperture meridians: a simple calculation tool for applying the ISO/CIE Standard General Sky. Lighting Res. Technol. 38,2, 109-122.

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