APPENDIX A

Validation data

Observational data on the forest properties and top-of-the-canopy albedo for two pine stands, two beech stands and one oak stand in Europe were taken from the IMECC database (accessed online at 30. April 2013: http://fluxnet.ornl.gov/site_list/Network/32), data of the fifth site were provided by the Tartu Observatory (Kuusk et al., 2009, 2013).The Estonian forest (EE-Jär, 58.31° N, 27.30° E) consists of a pine stand (*Pinus sylvestris* L.). The stand height was about 15 metres, the age was 125 years (in 2013), and the stand density was 1122 trees per hectare. The second pine stand (*Pinus sylvestris* L.) under study was planted in 1906 in the Netherlands (NL-Loo, 52.17° N, 5.74° E). The forest density was about 404 trees per hectare, trees were 15.6 m tall.

The first of two beech forests (*Fagus sylvatica* L.) was located in Germany (DE-Hai, 51.08° N, 10.45° E) and has been totally unmanaged since 1997. Before being classified as a reserve the forest was occasionally logged for timber over a period of about 30 years. As a consequence the forest moved towards a late successional forest with trees aged between 1 and 250 years with the tallest trees reaching 33 m in height. The tree density was about 334 trees per hectare; *Fraxinus excelsior* and A*cer pseudplatanus* are co-dominant. The second beech stand was located in France (FR-Hes, 48.67° N, 7.07° E). It was a rather young forest (48 years in 2013) and, with 2616 trees per hectare, densely populated. The dominant tree cover was 21 m tall with a high canopy closure. The oak stand is situated in France (FR-Fon, 48.48° N, 2.78° E) and consists mainly of *Quercus petraea* L. In 2006 the stand density was 1134 trees per hectare, of which 234 were *Quercus petraea* and 900 were *Carpinus betulus*. The average canopy height of *Quercus petraea* was about 27 m whereas the *Carpinus betulus* were about 10 to 20 metres tall, stand age was about 150 years.

For all validation sites, stand-level albedo was observed from in situ incoming and outgoing shortwave radiometric measurements and recorded in the IMECC database with the exception EE-Jär. From this database years were only selected when outgoing and incoming shortwave radiation was recorded. Albedo was calculated as the ratio of downward and upward radiation as observed with two-way pyranometers. The overall expected instrumental accuracy is in the range 4 – 7% in clear sky and 1 – 4% in overcast conditions (Cescatti et al., 2012). The radiation measurements cover the wavelengths from 0.21 to 2.80 μm.

The albedo at EE-Jär is measured as top-of-canopy bidirectional reflectance factor (BRF) with a UAV spectrometer (Kuusk, 2011). The measured BRF was carried out at different dates in July and August in 2012 and transformed with the help of the 6S atmosphere radiation transfer model (Vermote et al., 1997) and the FRT forest reflectance model (Kuusk and Nilson, 2000) into visible and near-infrared albedo for the solar zenith angle 39.8 degree which corresponds to the maximum solar zenith angle at midday at Järvselja site at summer solstice.

Only EE-Jär and DE-Hai provided measured crown sizes (Table 3). For the remaining sites, species-specific allometric relationships were used to estimate the height of the crown base, the crown radius and length derived from three different data sets (Condés and Sterba, 2005; Pretzsch et al., 2002; Zeidel, 1991). For sites where the coordinates of the individual trees were absent, we assumed a uniform tree distribution. Only the simulation for EE-Jär was run exclusively with observed parameters (see Table 3) and compared with simulated albedo. For all other sites, the observed albedo was, finally, compared to the calculated albedo. However, variation in the amount and timing of cloudiness causes considerable day-to-day variation which can be smoothed out when integrated over several weeks (Hollinger et al., 2010). Therefore, integrated daily values for the whole month June were calculated to

compare to the simulated values.

Every simulation was performed for 1 hectare (10,000 m²) of forest. This one hectare was divided in 25 squares (20 m x 20 m) and the albedo was simulated for each square separately. The variation between the squares was considered to be a measure of the sensitivity of albedo to the footprint for a given canopy structure. The scan line of the UAV spectrometer is about 2.5 – 3.0 m (Kuusk, 2011). The footprint of surface albedo measured by the pyranometers depends on their height above the canopy (ranging from 5 to 10 m). However, for the experimental sites under study, typically 80% of the signal originates from within 300 – 1200 m^2 (i.e. 10 – 20 m) around the tower (Cescatti et al., 2012). To capture all possible spatial scales of observed albedo values, each site is presented as the mean albedo of June (2001-2010) by MODIS (Pinty et al., 2011a; Schaaf et al., 2002) at ~ 1 km resolution. The range of MODIS observations are derived from 9 pixels surrounding the tower.