



## **Ratio of PAR to broadband solar radiation based on the long-term measurements in Moscow**

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The results of long-term observations of photosynthetically active solar radiation (1980-2010) in Moscow are discussed. The detailed analysis of the ratio of PAR to integral radiation ( $q_f$ ) is presented. The simple empirical model for the  $q_f$  evaluation from the standard meteorological measurements was obtained. It consists of three blocks. The first one describes the  $q_f$  dependence on the solar elevation, atmosphere turbidity, surface albedo under cloudless sky conditions. The complicated  $q_f$  relationship on solar elevation was obtained. The increase of atmosphere aerosol concentration leads to the small increase of  $q_f$ . In winter (surface albedo more 40%)  $q_f$  is more than in summer (surface albedo less 25%) on 3-7%. Furthermore the influence of smoky haze on the  $q_f$  variations in summer 2002 and 2010 is discussed in detail. The decrease of the portion of PAR in the total solar radiation due to high concentration of the smoke aerosol in the atmosphere as a result of biomass burning is very significant – up to 30-50%. The second block of the model describes the effects of the overcast sky on  $q_f$ . The influence of various cloud types (upper-air and middle-level clouds, stratocumulus and stratified clouds, rain-producing clouds) on the portion of PAR to total solar radiation is analyzed. The investigation of  $q_f$  dependence on the cloud optical thickness is shown the increase of the  $q_f$  value with the increase of the cloud layer. The solar flux under the most optical dense clouds (Ns and Cb) is characterized by the most significant contribution of PAR – up to 70-80%. The third part of the model is deals with the ratio PAR to total solar radiation in the sums of different time scale (day, month, pentad, decade, vegetation period, and year). It is shown that  $q_f$  has daily and seasonal course changing throughout the year for 2-4%. The statistical characteristics of daily  $q_f$  values were determined taking into account the daily average cloud amount (clear days, intermediate, overcast) and season (cold period with surface albedo more 40% and warm period with surface albedo less 25%). The variation coefficient of  $q_f$  in the daily sums varies from 5% till 8% under clear sky conditions and increasing up to 7-17% under average cloud amount. On the average  $q_f$  with snow cover is more than in its absence for 3-5%. The analysis of the long-term annual course of PAR ratio in the sums of total solar radiation during the vegetation period shows the increase of PAR sums during the last twenty years. Using this simple model the PAR values for some central regions of European part of Russia during the day, month and vegetation period were calculated. Besides that the PAR sums for various periods of vegetation season for the most spreaded trees and bushes (the appearance of the first leaves, the beginning of the blossom, and the beginning of fruiting) were determined.