DUE Coastcolour

Technical Note

Estimation of the potential primary productivity in coastal zones using MERIS data in Coastcolour

Version 1

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Revision History

Version	Date	Change	Author
1	21.06.2011	Initial version	R. Doerffer

Contents

1 SCOPE OF THIS DOCUMENT

This document describes the scientific background and implementation of the algorithm for Potential Primary Production.

2 INTRODUCTION

Primary production by green plants is one of the key processes, which determine nearly all life on earth as well as the biochemical transformation of matter on land and in the aquatic environment.

Primary production depends on the biomass of green plants as well on the environmental conditions, such as the availability of light and nutrients. Thus, its geographical distribution and seasonal development is extremely variable. Remote Sensing is a major tool to determine the distribution of biomass and further derive also primary production by various methods.

While this techniques has been established already for land surfaces and the open ocean (Platt & Sathyendranath, 1991), the estimation of the productivity of coastal zones from remote sensing data is technically more difficult for various reasons. Although coastal zones comprise only 7 % of the global ocean water surfaces, its primary production is rather high and is estimated to surmount 20% of the global primary production.

Due to the importance of PP and consequently due to the request of Coastcolour users, the development and test of prototype algorithms has become part of this project.

The algorithm, which is described here, has been developed for shallow coastal waters with high turbidity, where light is a strong limiting factor. It is based on previous work by Platt and Sathyendranath, which has been described in various publications.

Core of the procedure is the relationship between available light and the fixation of carbon by photosynthesis per unit of biomass (mostly expressed in units of chlorophyll concentration).

This relationship is described by the PI- curve, which stands for production per unit of biomass and I for the available light, expressed in units of mol photons. The PI relationship is described by 2 parameters. Alpha is the slope of the initial increase of PP with light, and Pmax is the maximum PP.

In particular Pmax is temperture dependent.

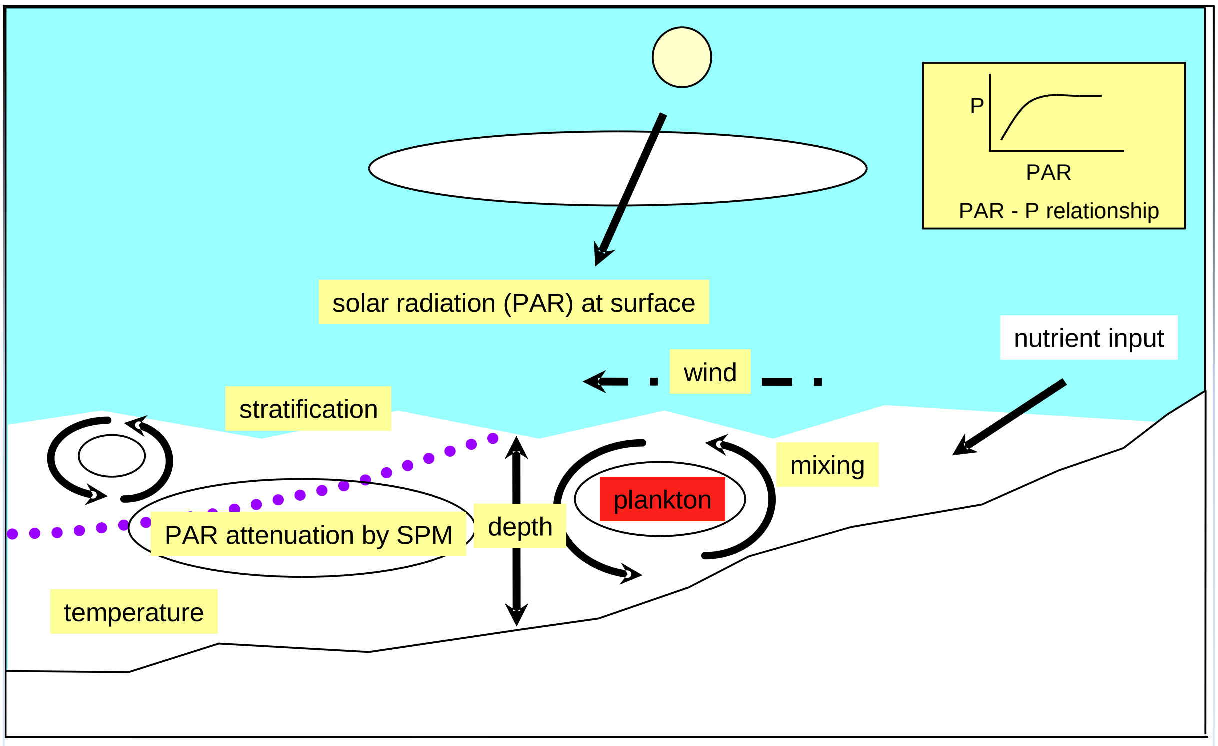


Figure 1: Processes, which determine primary production in shallow coastal waters.

Since photosynthesis depends on the wavelength of light, the knowledge of the spectral composition of light and the absorption spectrum of the plant are key parameters, which have to be determined.

The PI relationship is variable, it depends on the type of plants and its health conditions and it cannot be determined directly by remote sensing techniques. Thus, for this part of the algorithm in situ or lab observations are necessary. Since PI data are not available for nearly all Coastcolour sites, we can only determine the potential primary production using a fixed PI curve and assume a cloudless day for the period with longest sun shine (around June 21 in the northern and December 21 in the southern hemisphere). This then enables us to compare different sites even in the lack of in situ data of the PI parameters. Then the production depends on the phytoplankton biomass, the depth of water or depth of the upper mixed layer and its transparency.

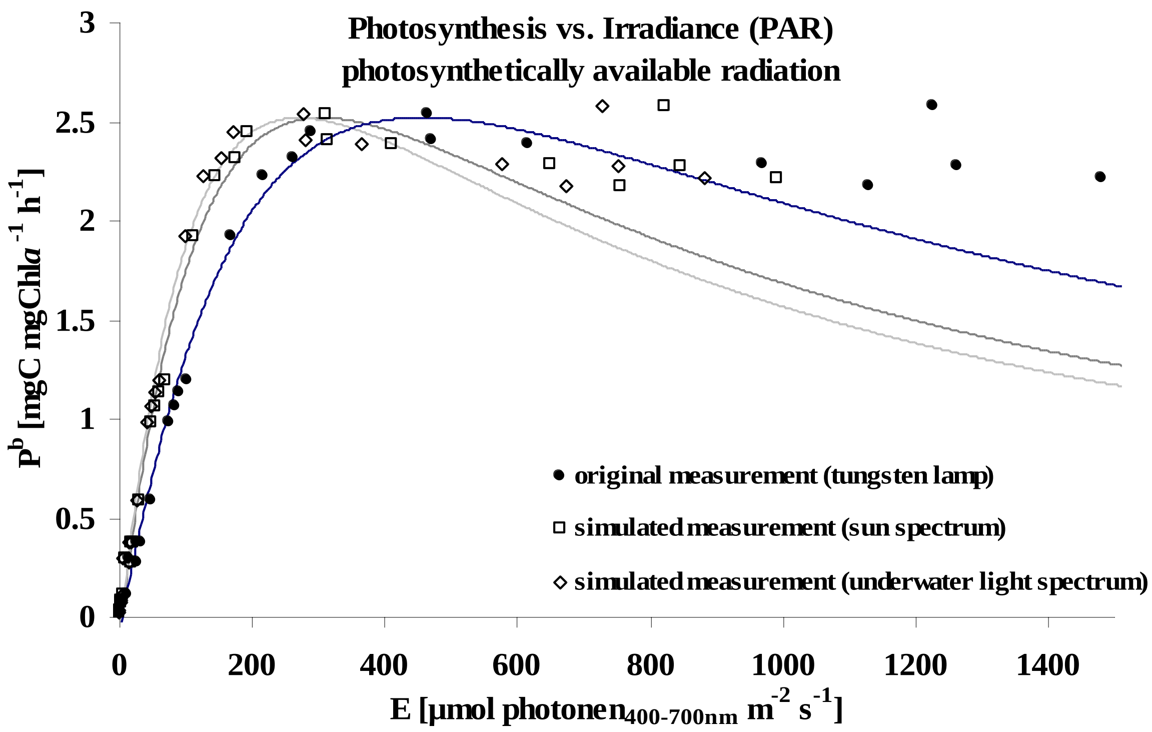


Figure 2: PI Curves measured in the North Sea (R. Röttgers, HZG).

To determine the net productivity it is necessary furthermore to know or measure the respiration by the plants, i.e. the consumption of their own production. This rate is also temperature dependent. Also here, we will use the same temperature dependent rate for all sites, because these data are also not available in Coastcolour. Using the PI and respiration rates together with the vertical light profile one can compute the critical depth, which is the maximum depth of the water column in which the plankton cell must remain statistically per 24 hours in order to balance primary production and respiration. If the depth of water or of the upper mixed layer, in which a plankton cell will remain, is deeper than the critical depth, the plankton population will not grow. This is the case during winter, when the water column is well mixed, sun is low and the days are short.

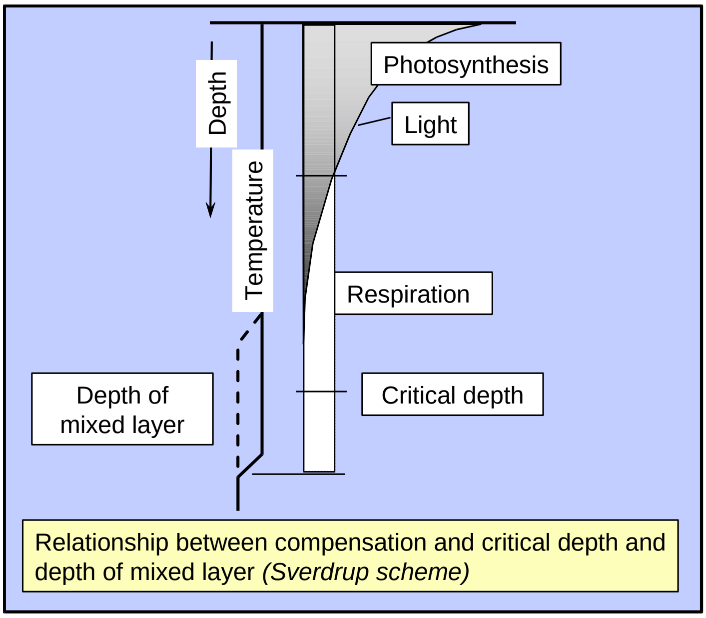


Figure 3: Scheme of the Critical Depth

3 OUTLINE OF THE ALGORITHM

We use the following variables for computing primary production:

(1) chlorophyll concentration (from MERIS)

(2) absorption spectrum of phytoplankton (from measurements, available from the bio-optical model)

(3) spectral downwelling irradiance at water surface for 24 for hours with 30 minutes interval, can be computed for a clear sky from date and latitude

(3) attenuation spectrum of pure water and of all water constituents (from measurements used in bio-optical model)

(4) concentration of water constituents (from MERIS data)

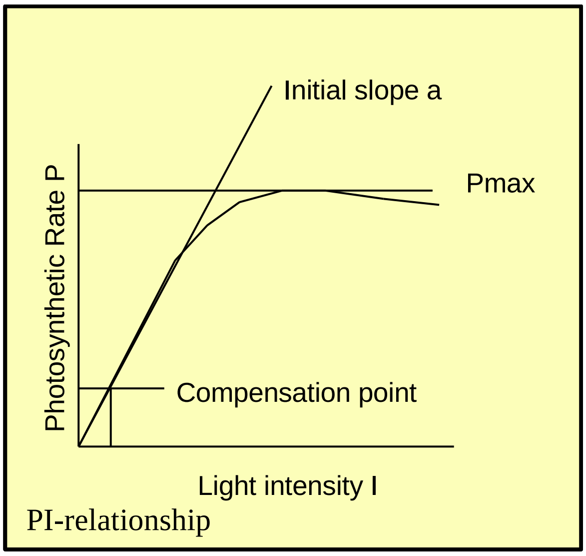
(5) depth of water or the upper mixed layer (bathymetric chart and climatology, or temperature maps)

(6) water temperature (AATSR data)

(7) geographical coordinates (latitude)

(8) fixed PI curve (temperature dependent)

(9) fixed respiration rate (temperature dependent)



$$P(z) = \frac{B(z)\cdot\alpha\cdot I(z,\lambda)}{\sqrt{1+(\alpha\cdot I(\lambda,z)/P_{max})^2}}$$

Photosynthesis Equation

Different versions of PP model

All spectral

- PAR available radiation
- PUR (usable radiation
- PSII absorption by photosystem II

Figure 4: PI Curve with PP parameters alpha and Pmax and the basic equation for computing PP.

The algorithm comprise the following steps:

- compute the distribution of phytoplankton chlorophyll from MERIS data
- compute the distribution of all water constituents, which determine kd, the spectral downwelling irradiance coefficient, or derive directly kd from MERIS data
- map the distribution map to a grid for which the bathymetry is available and / or the depth of upper mixed layer from climatological data or model results
- assume a constant vertical profile for chlorophyll and kd or provide a profile from measured or climatological data, which is linked to the surface concentrations

Loop:

- for itime= 0 to 24 hours, step 0.5 hour
- compute surface spectral irradiance from sky model for clear sky
- for ilayer = 0 to maxdepth, step 0.5 m
- compute Ed for mid of ilayer using kd
- compute for mid of ilayer mol photons from spectral Ed
- compute gross PP for ilayer and time step using PI curve, the biomass of the layer and mol photons in this layer and temperature
- compute loss of carbon from phytoplankton biomass for ilayer using phytoplankton biomass and the respiration rate per time step, needs temperature
- compute net PP = gross PP - respiration per layer and time step

Integrate net PP of all layers and time steps: Result is the net primary production per 24 hours and square meter wate column in unit gC m-2 day-1

The scheme has been coded in C. It requires as input variables consistent maps of chlorophyll concentration, kd(lambda), water depth and day of the year, latitude and water temperature.

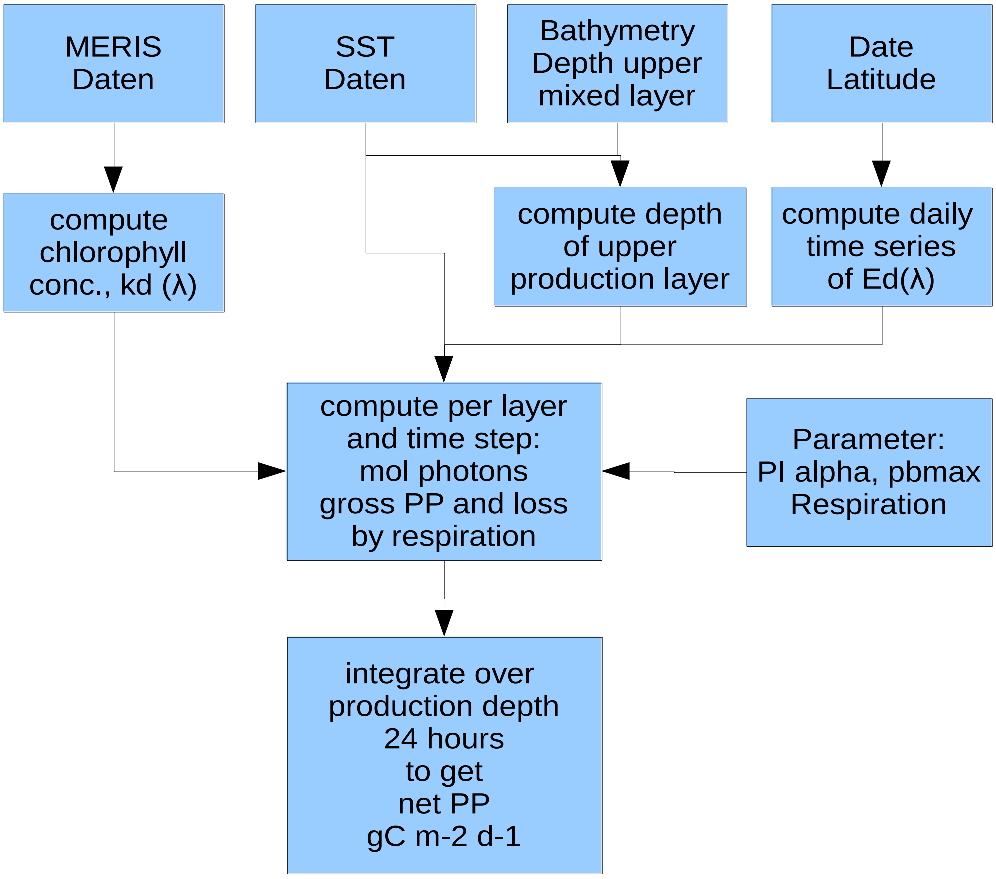


Figure 5: Scheme for the computation of potential primary productivity

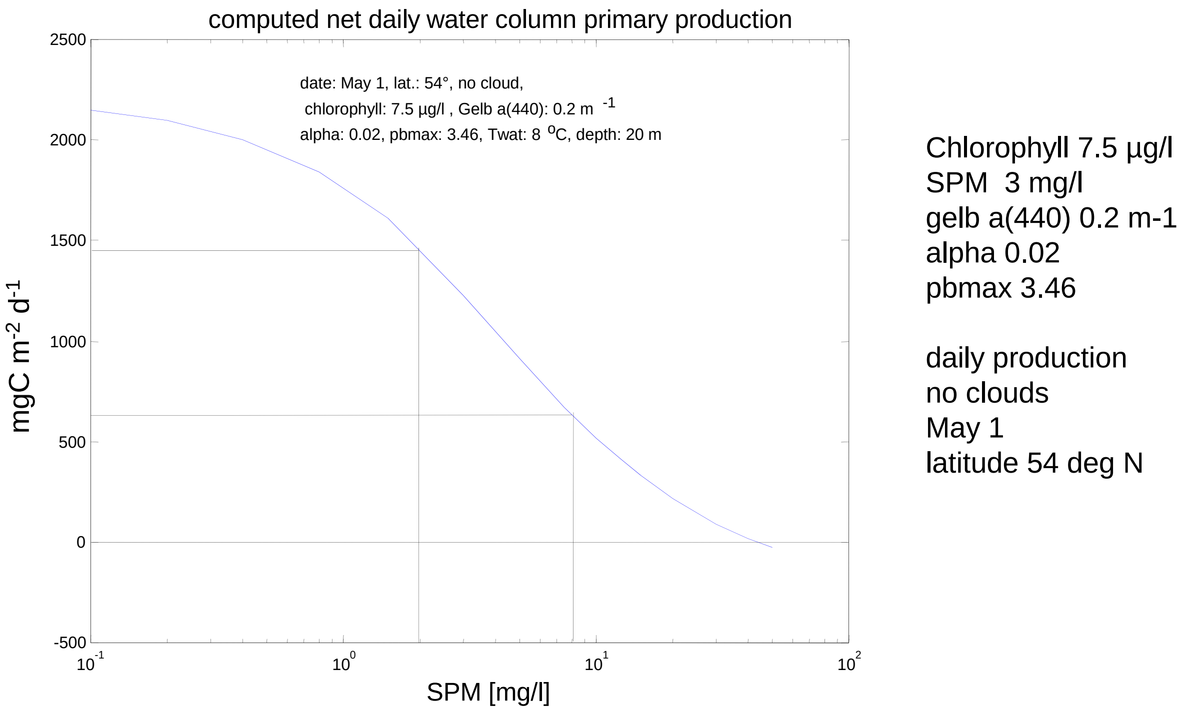


Figure 6: Primary productivity as a function of suspended matter, which is an important factor for light attenuation in coastal zones.

Example

The procedure has been tested for the German Bight, for which PI data are available.

Fig. 7 shows a PP map derived from a MERIS image (Aug. 3, 2004) which shows an intense plankton bloom in the plume of the Elbe river estuary.

As a further test the procedure was compared with results of the ECOHAM phytoplankton model (Moll et al, 1998). For this comparison the chlorophyll concentration produced by ECOHAM were used together with measured irradiances and standard PI parameters. Using these parameters an annual series of PP for the German Bight was computed (Fig. 8, blue line). The annual course as well as the integrated PP of 172 gC m-2 y-1 show a good agreement with the ECOHAM results (186 gC m-2 y-1).

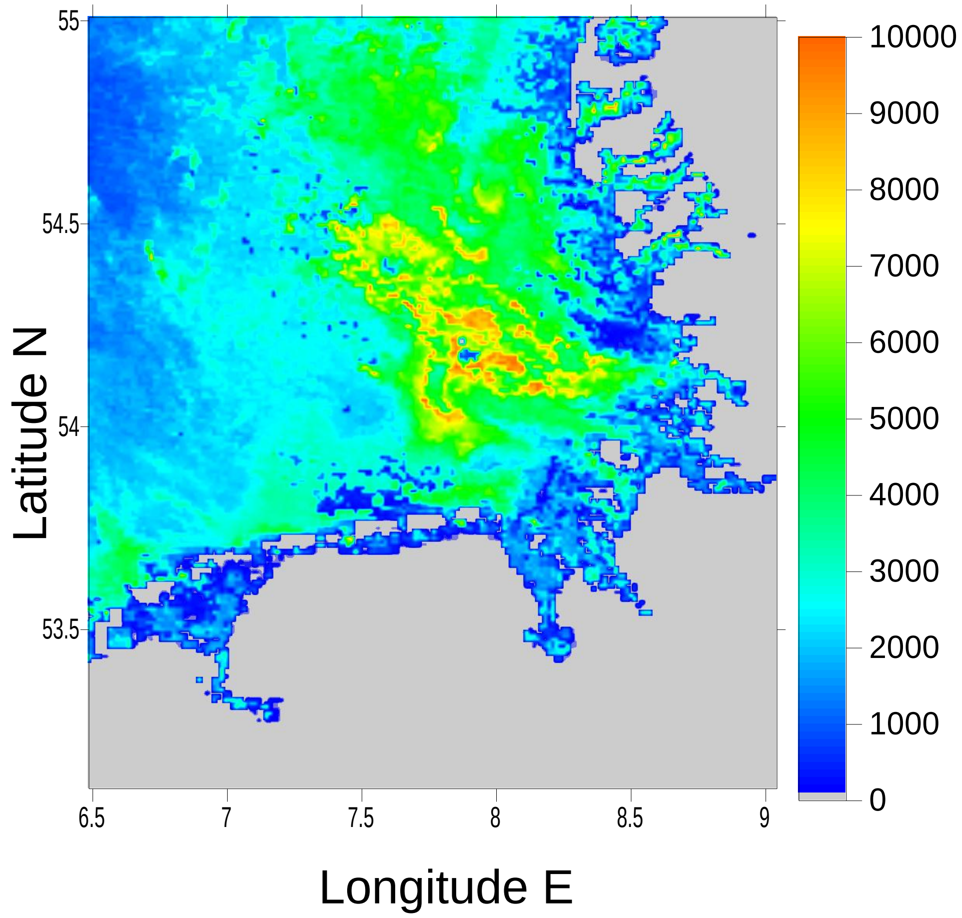


Figure 7: Net primary productivity (gC m-2 d-1) in the German Bight during a plankton bloom (yellow - brown patches) computed from MERIs data (Aug., 3, 2004)

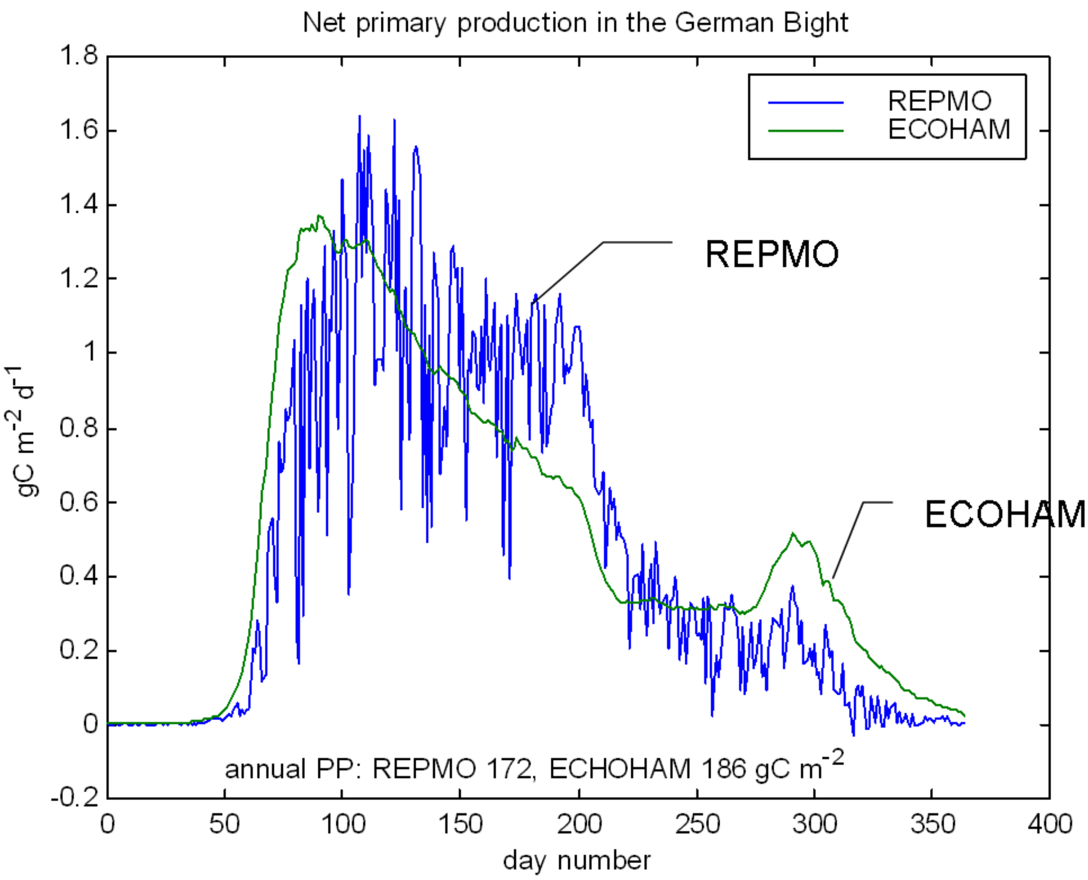


Figure 8: Comparison of annual net PP using the model for the PP computation with remote sensing data (REPMO) with the ECOHAM model, from which the chlorophyll concentration wee used. The scatter of the data comes from measured irradiance, while ECOHAM uses mean