Secchi Depth, Euphotic Depth, Turbidity and Surface Irradiance
Lake Constance data documentation

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Lake name: Lake Constance

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Sampling site

Lake Constance (LC) is a temperate, large (476 km^2), deep (mean depth = 101 m, max. depth 252 m), and warm-monomictic lake north of the European Alps of glacial origin. It has weak pelagic-benthic coupling, and little allochthonous input into the pelagic zone (Bäuerle and Gaedke 1998). The focal measuring site is in the north-western fjord-like arm of the lake (mean depth ca. 100 m, max. depth 146 m), which may experience intensive internal seiching (Gaedke and Schimmele 1990, 1991). The hydrodynamics have been studied intensively during the study period considered here (1979-1998) (e.g. Bäuerle *et al.* 1998 and lit. cited therein, Ollinger & Bäuerle 1998) but also thereafter (cf. publications by Frank Peeters, Univ. of Constance, and scientists of the *Institut für Seenforschung Langenargen*). For the relationship between weather conditions and ecological aspects of Lake Constance, see Gaedke *et al.* (1998).

Secchi depth

The Secchi depth z_s was measured using a Secchi disk approximately weekly during the growing season (Apr - Nov) and bi-weekly during the winter months from 1979 - 1999 (Tilzer 1988, Tilzer and Beese 1988).

Underwater photosynthetically active radiation (PAR) measurements and the euphotic depth

The euphotic depth z_{eu} reflects the *depth* where photosynthetic available radiation (PAR) is *1*% of its *surface* value. This depth is determined by surface irradiance, surface reflection and turbidity, i.e. the attenuation coefficient of the water which characterizes how easily light penetrates the water column. Penetration of underwater photosynthetically active radiation (PAR) was measured using a QSP-200 underwater radiometer equipped with a spherical receptor (Biospherical Instruments, San Diego). Underwater irradiance gradients were determined within 1h around solar noon by lowering the underwater radiometer and correcting the underwater measurements for variations of surface irradiance using a reference sensor (QSR-240) on the ship's deck. Surface reflection and backscattering losses were assumed to comprise 10% of incident irradiance (Tilzer and Beese 1988).

In Lake Constance, 80% of the variability in water transparency can be explained by chlorophyll concentration changes (Tilzer, 1983; Tilzer and Beese, 1988; Tilzer 1991).

Secchi depth is closely but not linearly correlated with both euphotic depth and chlorophyll concentration. The relation between z_{eu} [m] and z_s [m] is described by the equation: $z_{eu}=4.71*z_s^{0.57}$ with a coefficient of determination $r^2 = 0.85$ (Tilzer and Beese (1988)). This relation can be used to reconstruct Z_{eu} on missing dates.

Above-surface PAR measurements

Above-surface PAR measurements were taken with a pyranometer near the shore of the lake (Tilzer and Beese (1988)). A star pyranometer measured the incoming global solar radiation of wave length 300-3.000nm on Lake Constance limnological institute's roof or on deck of the research vessel. The area under the measurement curve during the incubation period (4 hours around noon) was determined planimetrically, the result was the temporal integral of global solar radiation. The calculation from global irradiance (energy values) to the part of PAR which really enters water (quanten) was done by Tilzer (1983) and Häse (1996). PAR was derived from global radiation with a constant factor of 0.46 (Talling 1957). To convert the units from energy to quanta, a factor of 2.11 mmol/kJ was applied, based on the assumption that the average energy content of PAR is 218 kJ per Mol (corresponding to the green visible light at 550 nm). For further details, see Tilzer (1983 and literature therein).

Note that independent data on daily global radiation and direct surface radiation are available from the weather station in Constance (DWD[1], Deutscher Wetter Dienst, German Weather Service, check out their rules for using these data, especially for commercial use!). These data are not part of this data package and have to be ordered directly from the DWD.

Datasets

We provide four datasets:

1. Dataset 1 (n = 865) contains the approximately weekly (Apr-Nov) to bi-weekly (Dec-Mar) measurements of the Secchi depth [m] from 1979-1999.
2. Dataset 2 (n = 420) comprises the approximately weekly (Apr-Nov) to bi-weekly (Dec-Mar) measurements of the euphotic depth [m] between 1986-1997;
3. Dataset 3 comprises the approximately weekly (Apr-Nov) to bi-weekly (Dec-Mar) underwater measurements (n = 11577) of PAR [mmol quanta h^{-1}] at different depths [m] providing the basis to calculate the euphotic depth (Dataset 2). Six values for the dates:

- 08.07.86
- 01.06.87
- 09.06.87
- 22.01.91
- 17.12.91
- 10.06.92

have been interpolated due to measurement errors on these dates.

4. Dataset 4 (n = 5839) contains daily PAR measurements [mol/m^2/d] at the shore of the lake in the vicinity of the main sampling station (Tilzer and Beese 1998).

[1] July 2018: https://www.dwd.de/EN/ourservices/solarenergy/solarenergie.html

Dataset 1:

Filename: "Dataset_1_Secchi_Depth"
This dataset provides the Secchi depth for the years 1979-1999.

Column headers

A. Date

B. Secchi depth [m]

Dataset 2:

Filename: "Dataset_2_Lake_Constance_Euphotic_zone"
This dataset provides the depth of the euphotic zone [m] from 1986-1997.

Column headers

A. Date

B. Depth of the euphotic zone [m]

Dataset 3:

Filename: "Dataset_3_Lake_Constance_Irradiance_Depth_Resolved"
This dataset provides the depth-resolved irradiance determined within 1h around solar noon providing the data for calculating the euphotic depth in Dataset 2 from 1986-1997. E_o and a depth of 0m refer to just below the water surface. The variable k_o is the attenuation coefficient. E_z/E_o is the percentage of light that penetrates into a certain depth z. z_{eu} is the euphotic depth obtaining 1% of the surface radiation.

Column headers

A. Date

B. Depth [m]

C. E_z/E_o (%)

D. E_z (mmol quanta / h)

E. Z_{eu} (m)

F. mean k_o (m-1)

Dataset 4:

Filename: "Dataset_4_Lake_Constance_PhotosyntheticallyActiveRadiation_AboveSurface"
This dataset provides the daily, above-surface measurements of PAR from 1979-1994.

Column headers

G. Date

H. PAR [mol/(m^2*d)]

References

General references on Lake Constance

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Specific references for this data package

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