Introduction to the Biosphere-Atmosphere system

Lecture Autumn 2025

Part VII

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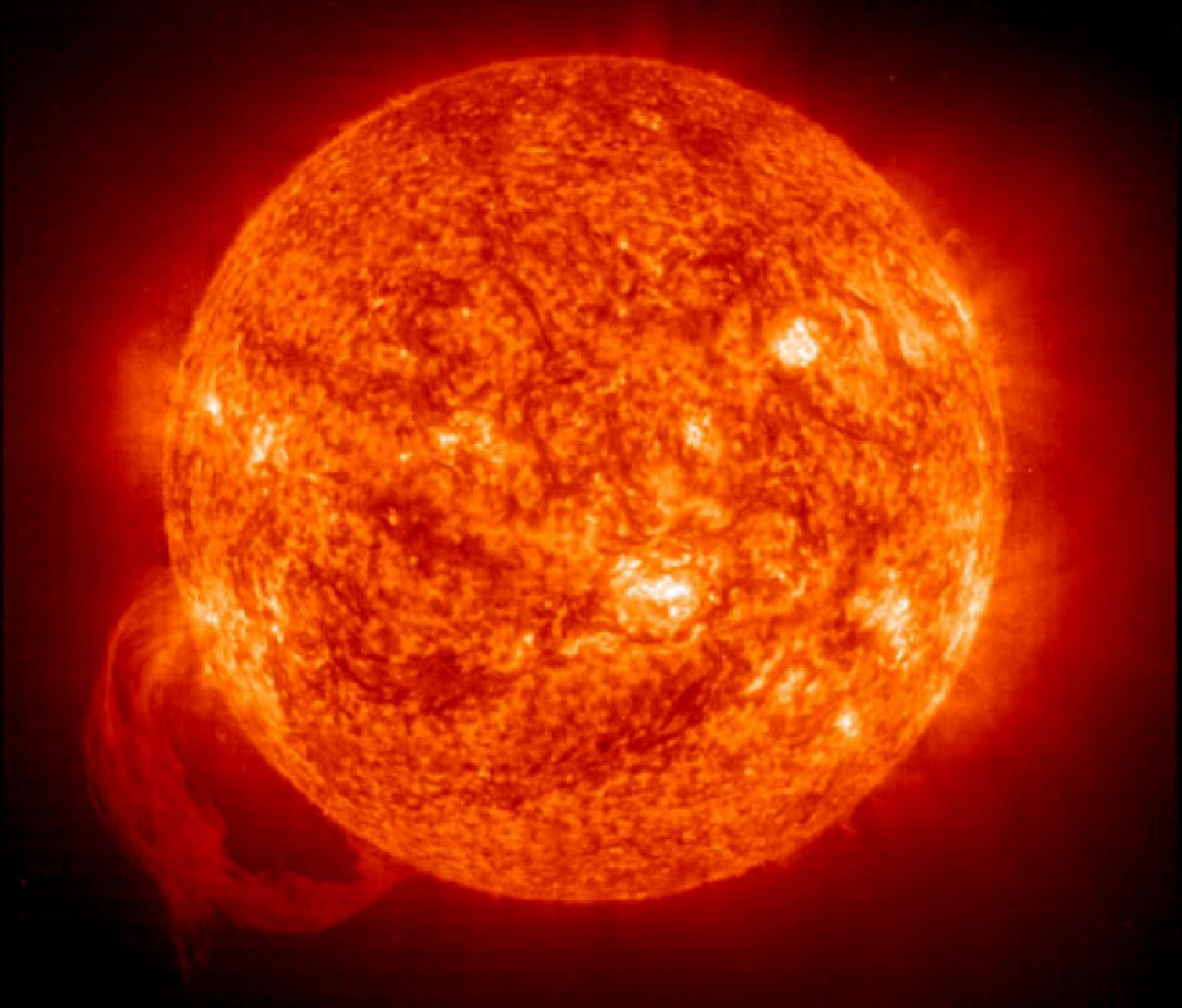
Solar radiation



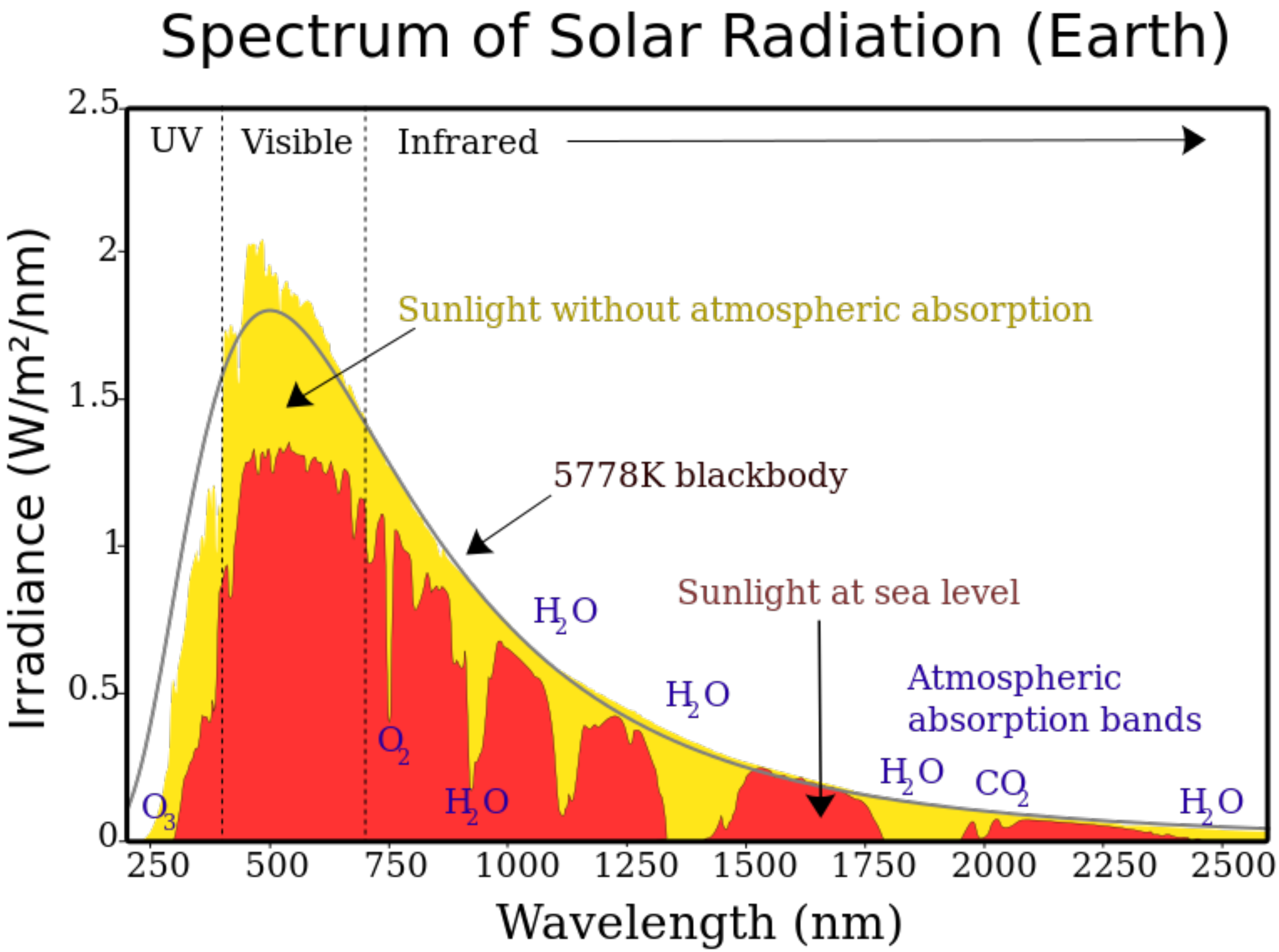
What is the solar radiation?

Solar radiation is the electromagnetic energy emitted by the sun.

Solar energy can be expressed as “solar irradiance” which is the power per unit area (Wm^{-2})

Annual average solar radiation arriving on top of the atmosphere is 1361 Wm^{-2}.

What are we looking for



Atmospheric absorption

By passing the atmosphere, the solar radiation is attenuated.

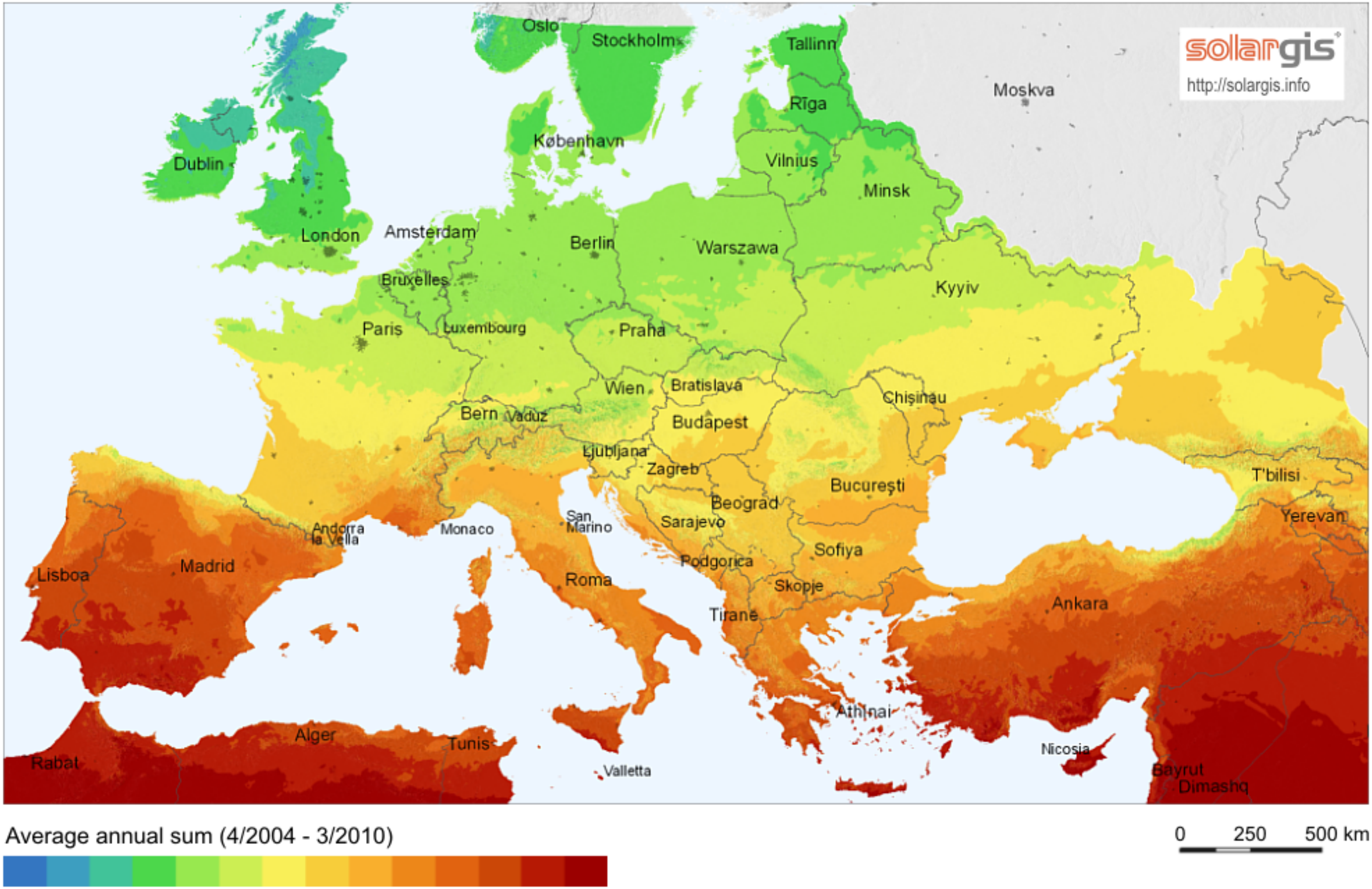
Attenuation happens by absorption and scattering.

Scattered light still contributes to the energy budget.

The maximum solar irradiance reaching to the ground at sea level is approx. 1000 Wm^{-2}.

Global horizontal irradiation

Europe



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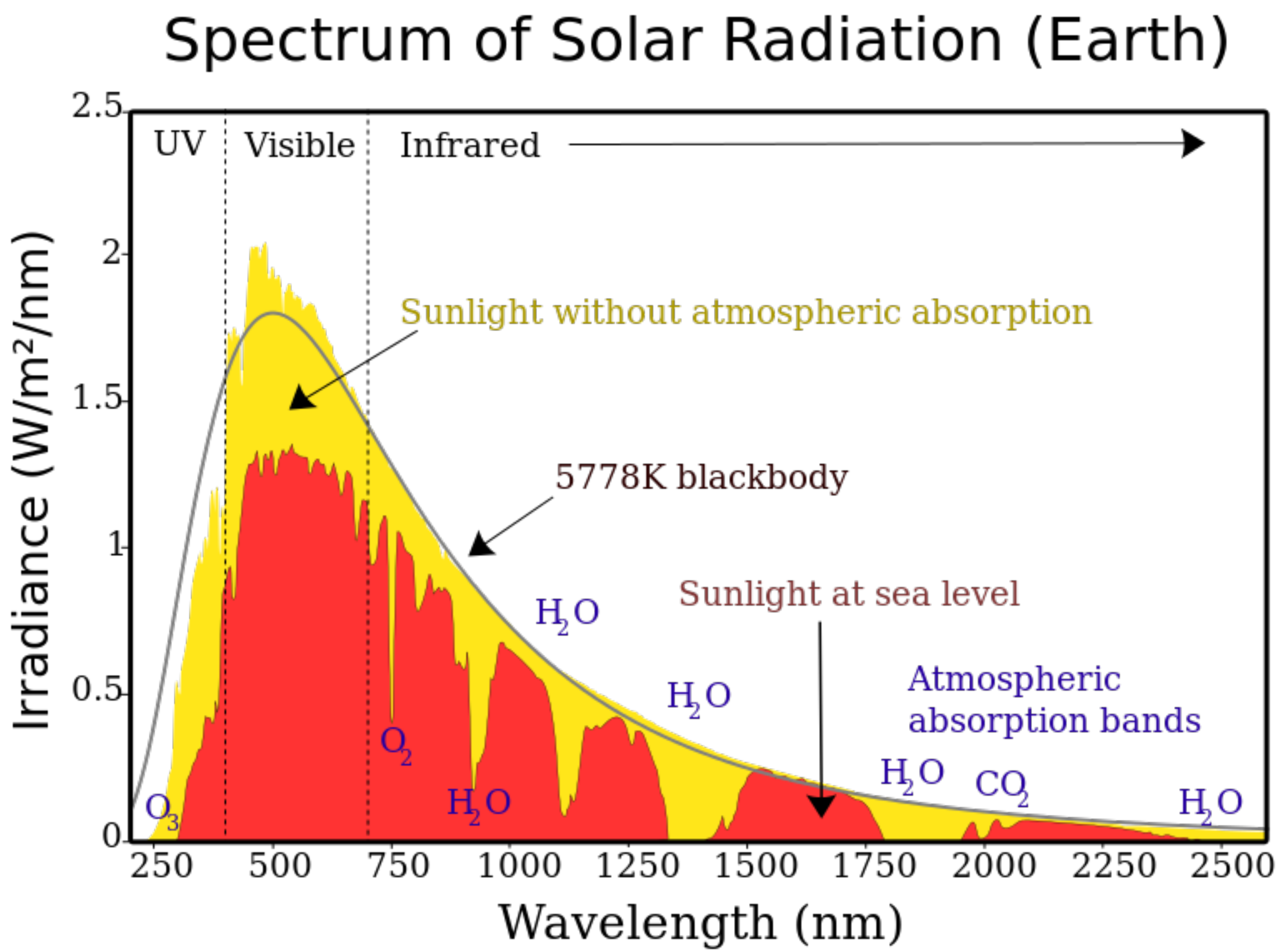
What is sunlight?

Sunlight is the portion of the solar radiation that consist of ultra violet (UV), visible, and infra red (IR) radiation.

It's the same as we already had! The solar radiation.

But, we experience sunlight as the combination of bright light and radiant heat.

Once more…



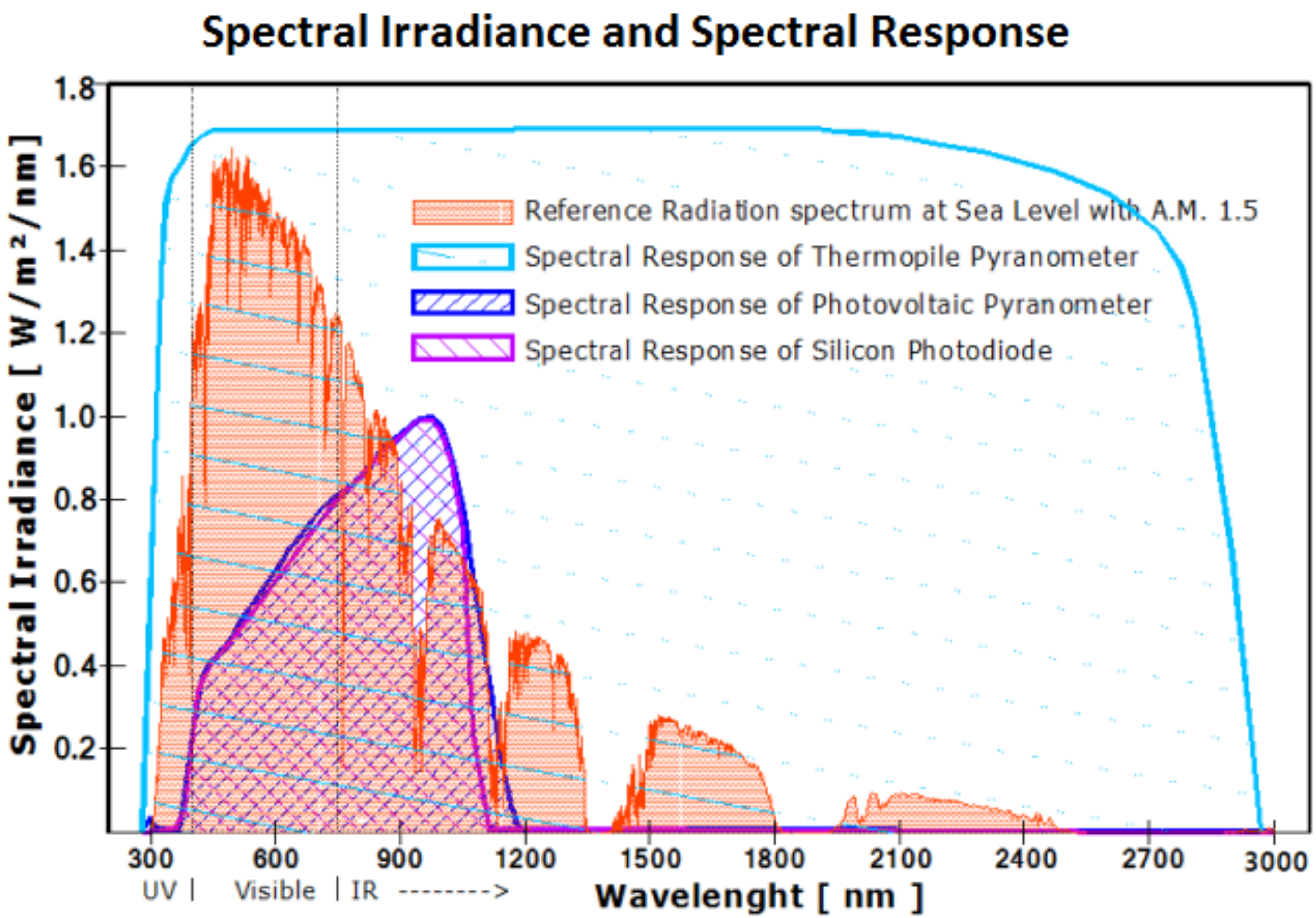
Spectrum of Solar Radiation (Earth)
UV
Visible
Infrared
Sunlight without atmospheric absorption
5778K blackbody
Sunlight at sea level
Atmospheric absorption bands
O_3
O_2
H_2O
H_2O
H_2O
H_2O
CO_2
H_2O
Irradiance ($W/m^2/nm$)
Wavelength (nm)
0
0.5
1
1.5
2
2.5
250
500
750
1000
1250
1500
1750
2000
2250
2500

How do we measure sunlight?

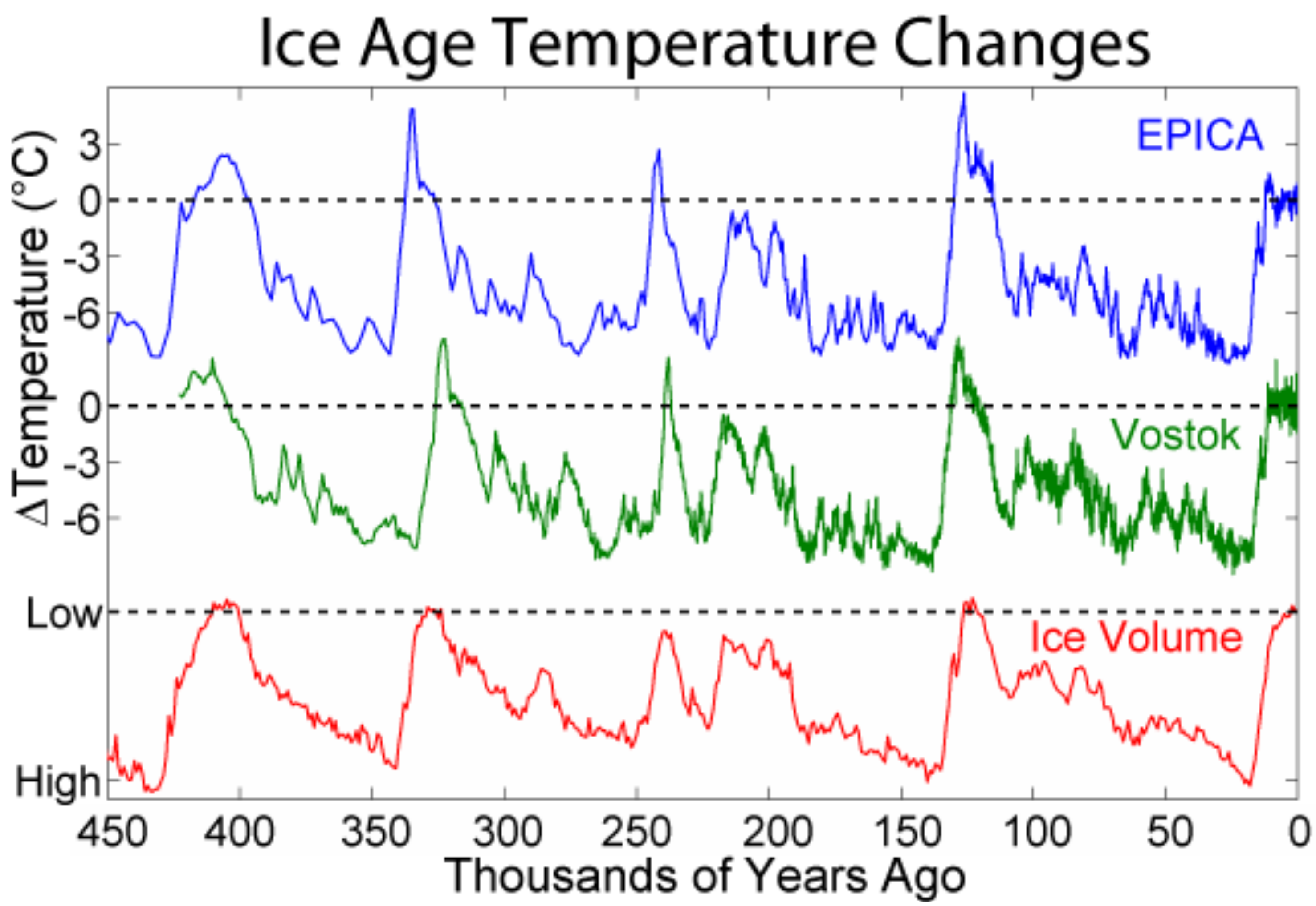
We use instruments called pyranometers. The need to comply to scientific ISO and the World Meteorological Organisation (WMO) standards.

Thermopile pyranometers measure the photon flux density over a large range of 300-2800 nm wavelength.

Performance of different measurement systems



How does the solar system determines dynamic in the Earth system?



Positive feedbacks: Increase in albedo, lower temperature lead to more snow/ice cover and that reflects sunlight which lowers temperature. Reduction of forests further increases albedo.

Negative feedbacks: Ice sheets lead to erosion and less land is available for ice sheets to grow on which reduces albedo. Cold dry air because less evaporation occurs and ice sheet growth stops.

Next glacial period will not occur due to high CO2 concentrations!

Ice age on hold

Determining the natural length of the current interglacial

P. C. Tzedakis[1]*, J. E. T. Channell[2], D. A. Hodell[3], H. F. Kleiven[4,5] and L. C. Skinner[3]

No glacial inception is projected to occur at the current atmospheric CO_2 concentrations of 390 ppmv (ref. 1). Indeed, model experiments suggest that in the current orbital configuration—which is characterized by a weak minimum in summer insolation—glacial inception would require CO_2 concentrations below preindustrial levels of 280 ppmv (refs 2–4). However, the precise CO_2 threshold[4–6] as well as the timing of the hypothetical next glaciation[7] remain unclear. Past interglacials can be used to draw analogies with the present, provided their duration is known. Here we propose that the minimum age of a glacial inception is constrained by the onset of bipolar-seesaw climate variability, which requires ice-sheets large enough to produce iceberg discharges that disrupt the ocean circulation. We identify the bipolar seesaw in ice-core and North Atlantic marine records by the appearance of a distinct phasing of interhemispheric climate and hydrographic changes and ice-rafted debris. The glacial inception during Marine Isotope sub-Stage 19c, a close analogue for the present interglacial, occurred near the summer insolation minimum, suggesting that the interglacial was not prolonged by subdued radiative forcing[7]. Assuming that ice growth mainly responds to insolation and CO_2 forcing, this analogy suggests that the end of the current interglacial would occur within the next 1500 years, if atmospheric CO_2 concentrations did not exceed 240 ± 5 ppmv.

The notion that the Holocene (or Marine Isotope Stage 1, MIS1), already 11.6 thousand years (kyr) old, may be drawing to a close has been based on the observation that the duration of recent interglacials was approximately half a precession cycle (~11 kyr; ref. 8). However, uncertainty over an imminent hypothetical glaciation arises from the current subdued amplitude of insolation variations as a result of low orbital eccentricity (Fig. 1). It has thus been proposed that at times of weak eccentricity–precession forcing, obliquity is the dominant astronomical parameter driving ice-volume changes, leading to extended interglacial duration of approximately half an obliquity cycle (~21 kyr; ref. 9). In this view, the next glacial inception would occur near the obliquity minimum ~10 kyr from now[7].

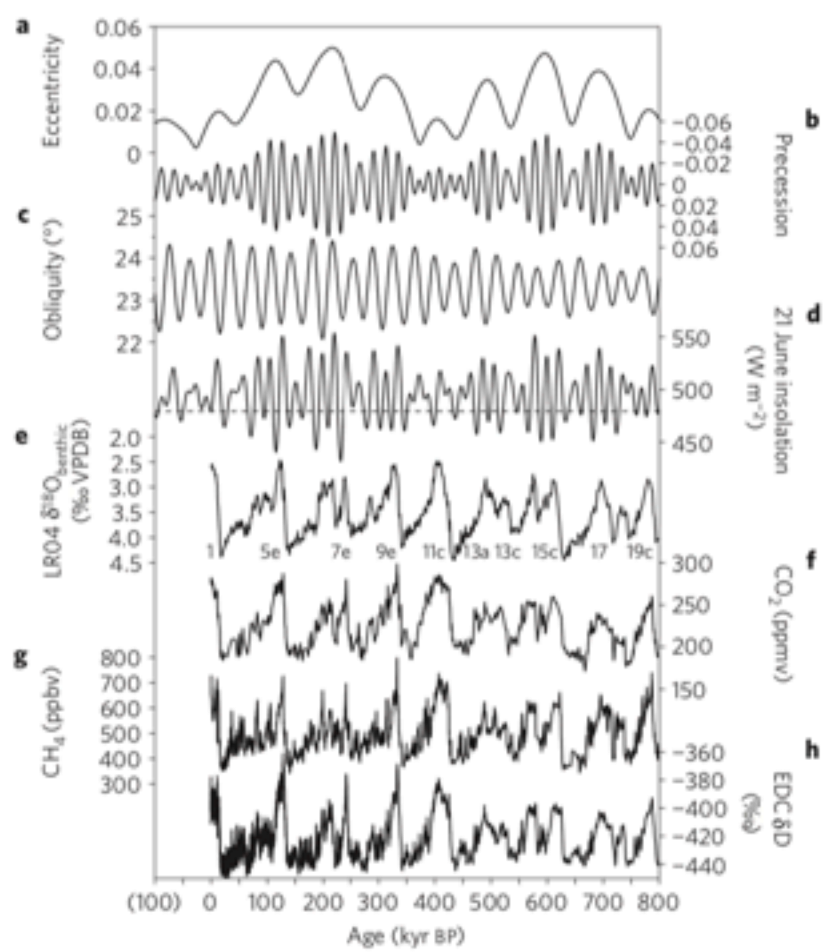
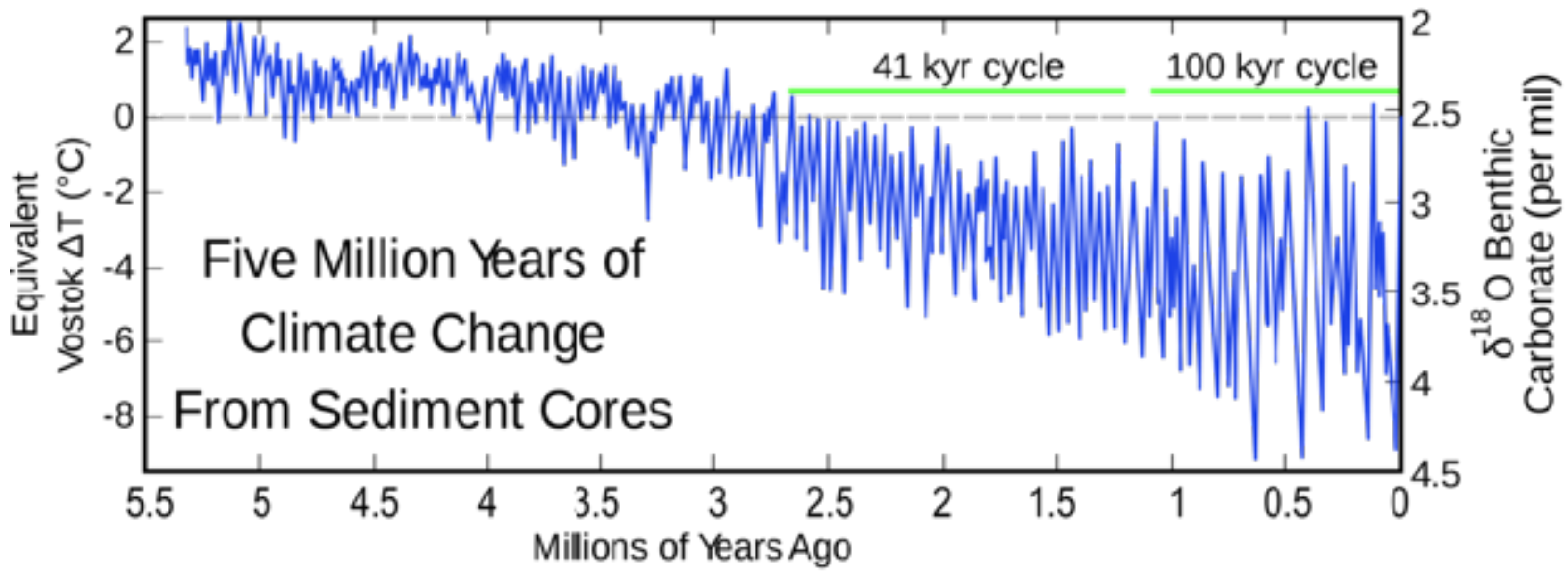
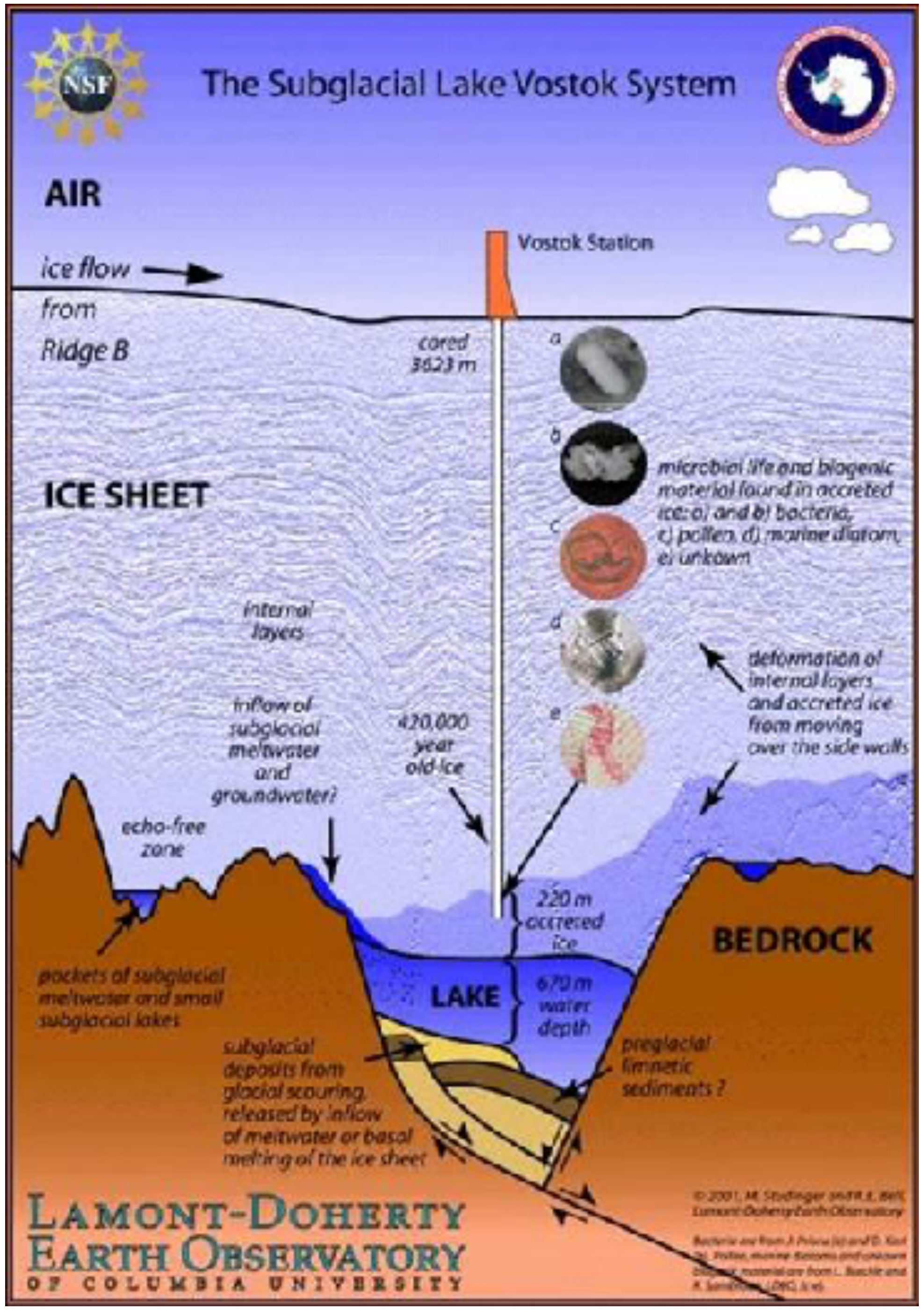


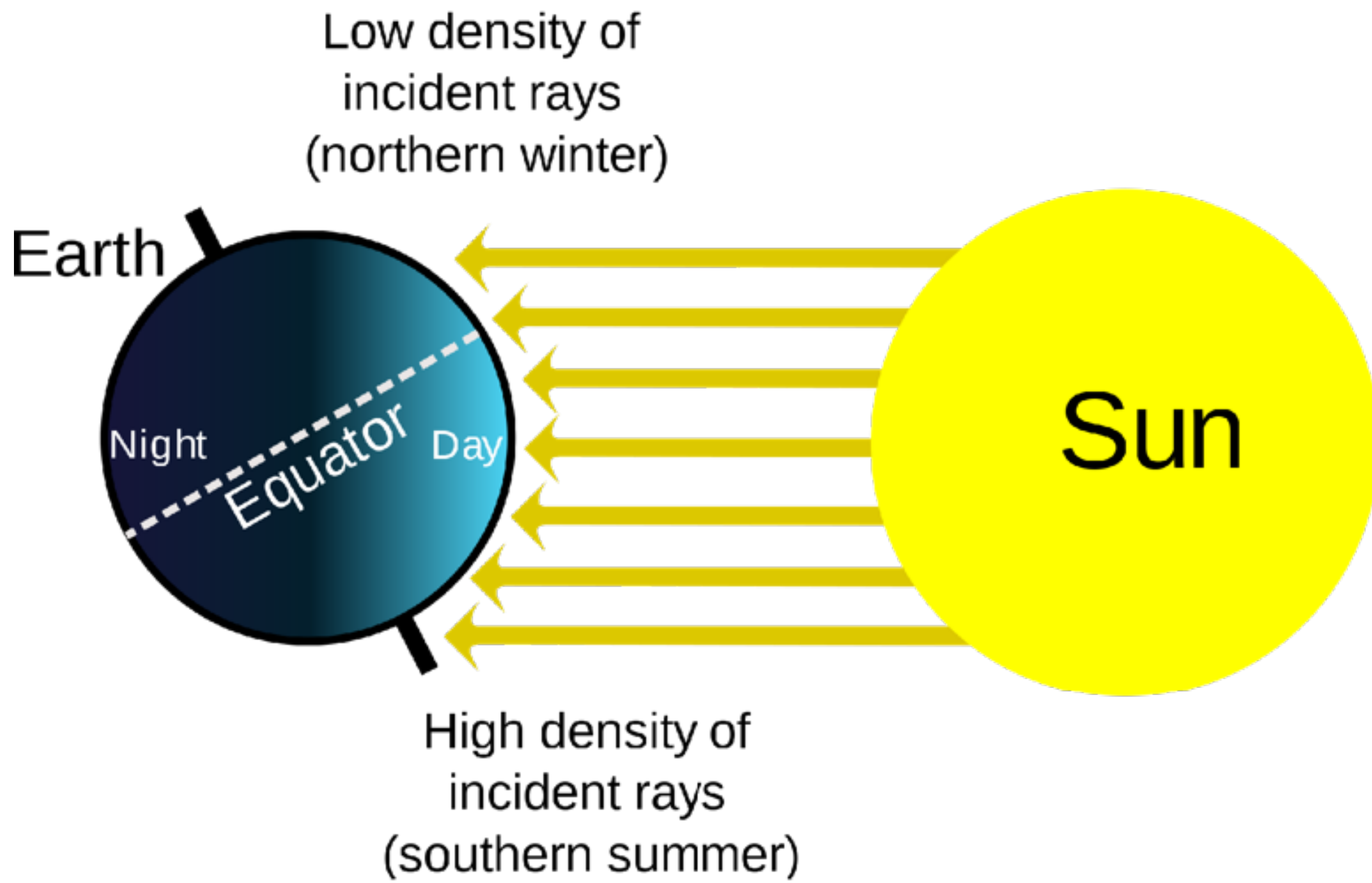
Figure 1 | Astronomical parameters 100 kyr after present—800 kyr BP and palaeoclimatic records 0–800 kyr BP. a, Eccentricity[29]; **b**, precession index, plotted on an inverse vertical axis[29]; **c**, obliquity[29]; **d**, 21 June insolation 65° N (ref. 29); **e**, $\delta^{18}O_{benthic}$ record from the LR04 stack[28]; **f**, atmospheric CO_2 concentration in Antarctic ice cores[12]; **g**, atmospheric CH_4 concentration in the Antarctic EDC ice core[13]; **h**, δD composition of ice in the EDC ice core[18]. Marine Isotopic Stages and sub-Stages corresponding to interglacials are indicated. Ages in parentheses denote years after present. The dashed line indicates the current 21 June insolation level at 65° N.

Vostok ice cores since 1970'ties used to assess Paleoclimate

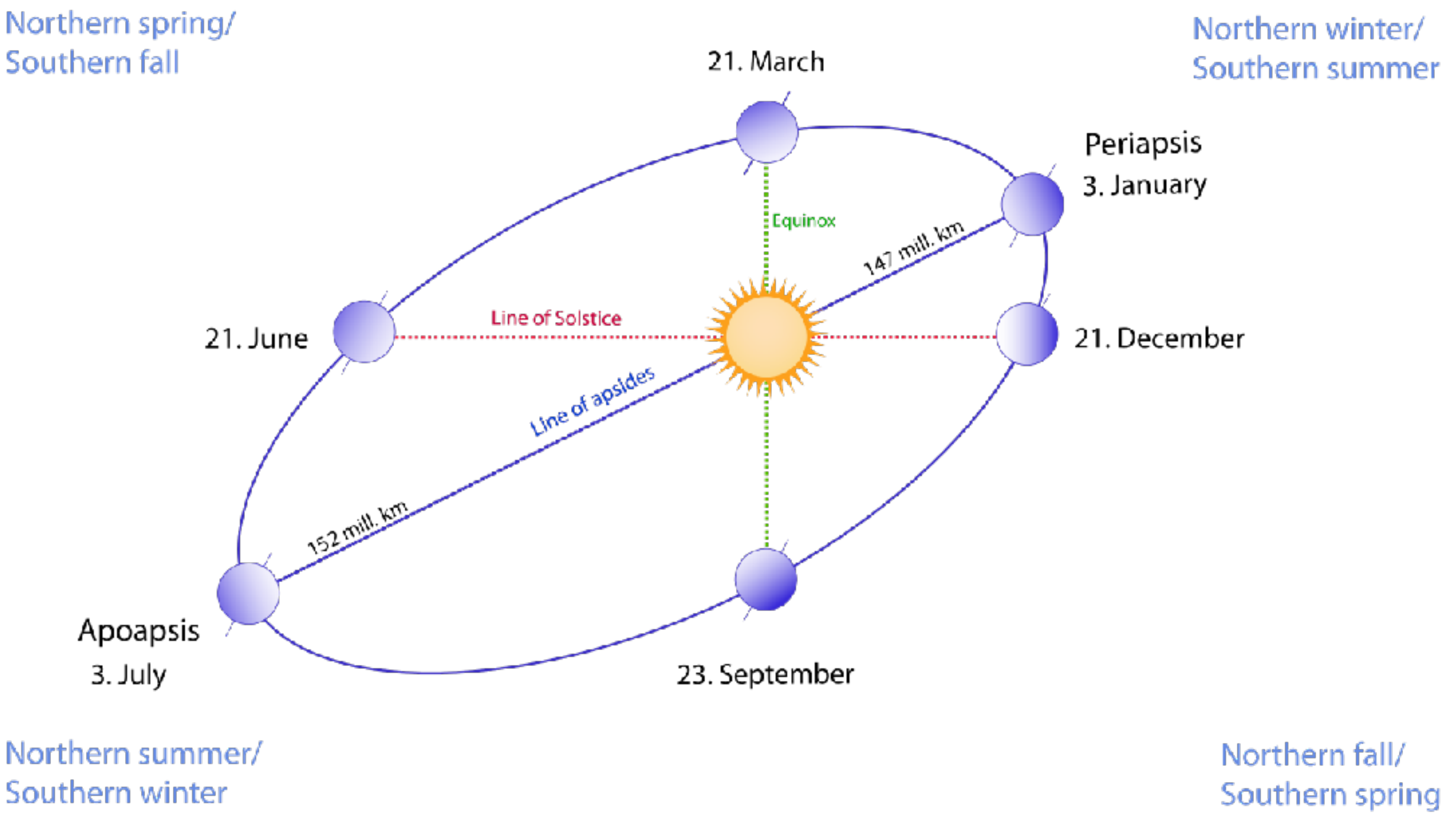




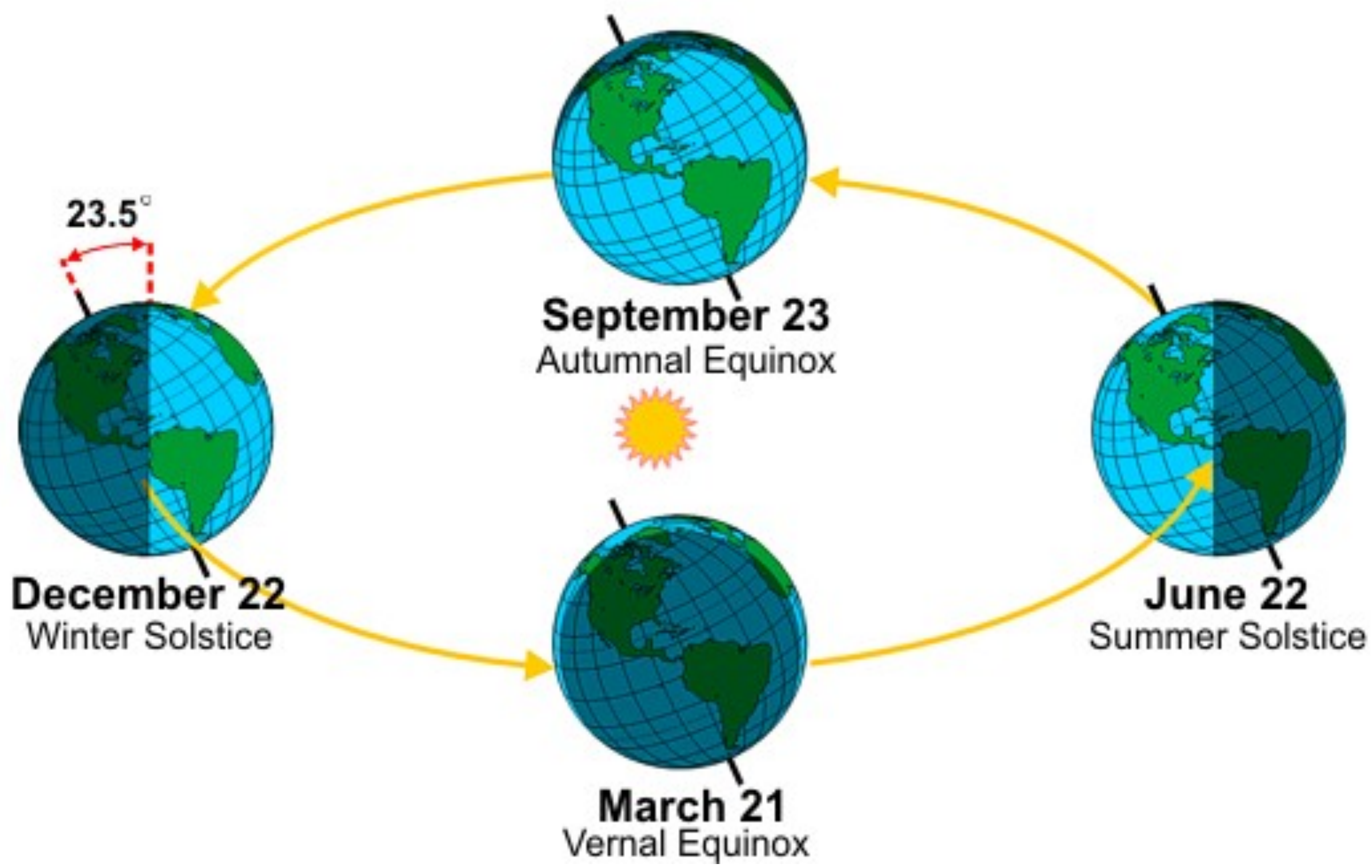
Daily and seasonal rhythms



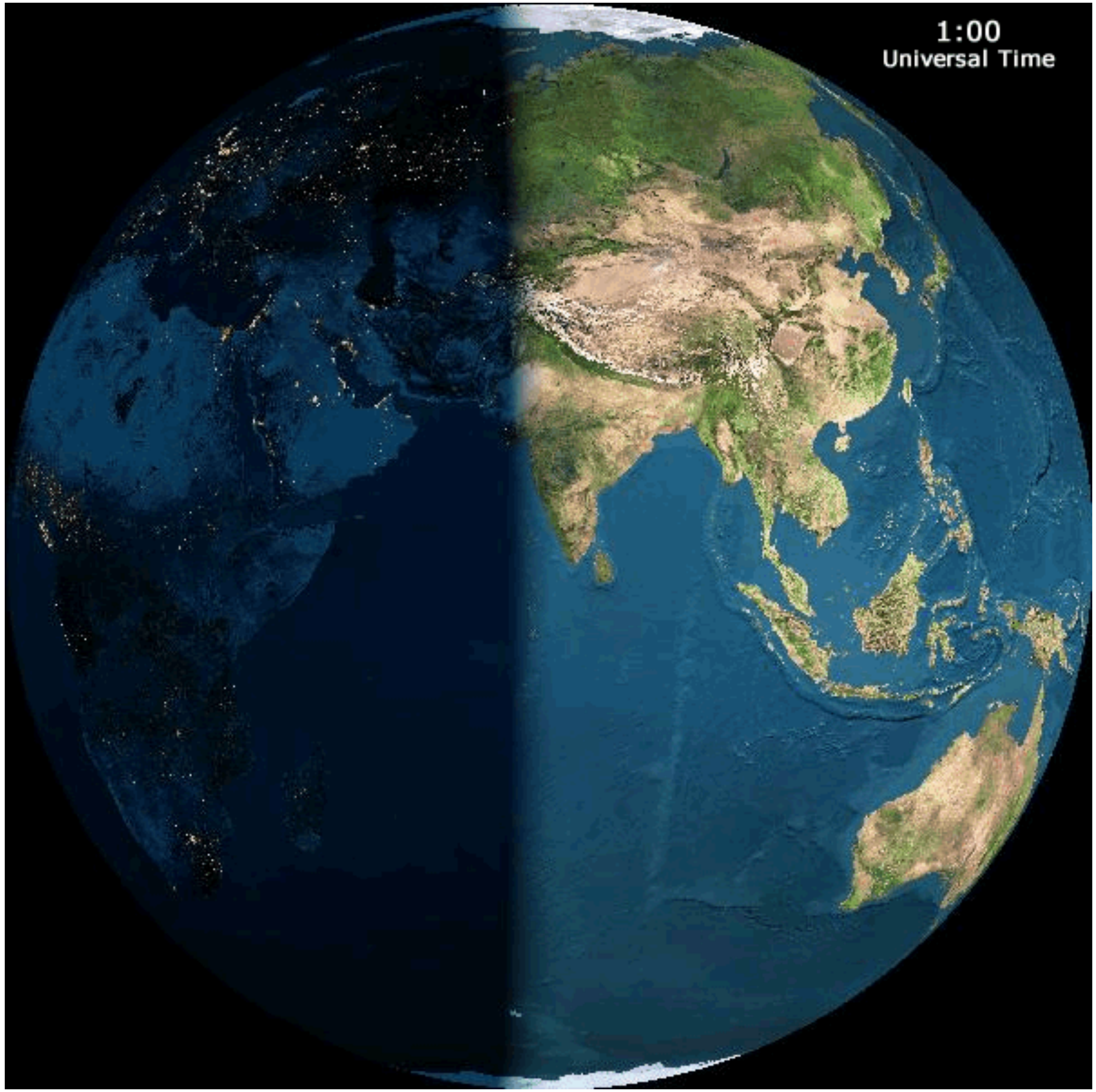
Yearly change of solar radiation



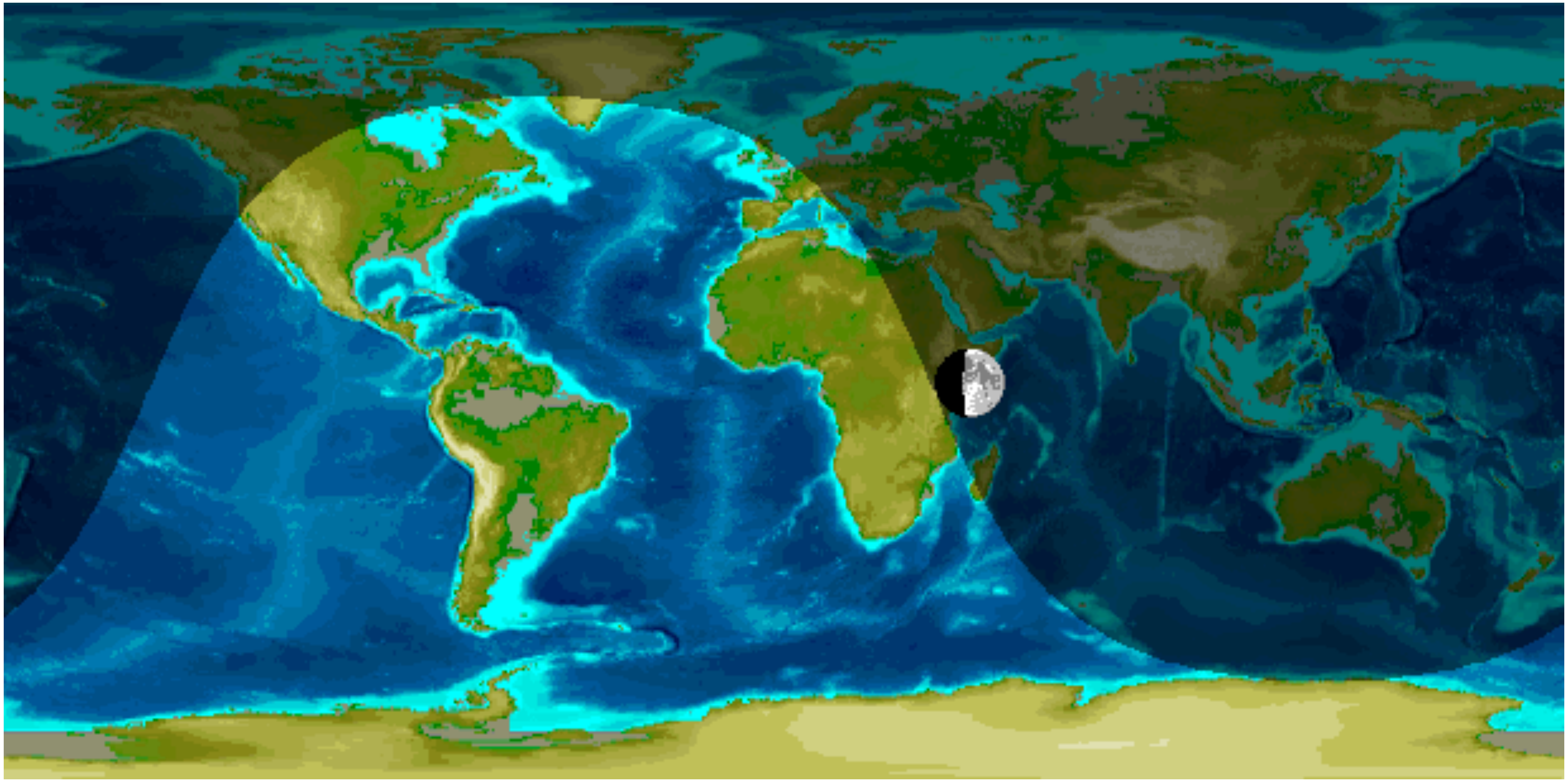
A major cause of changing day length is the rotational angle



Day-night example



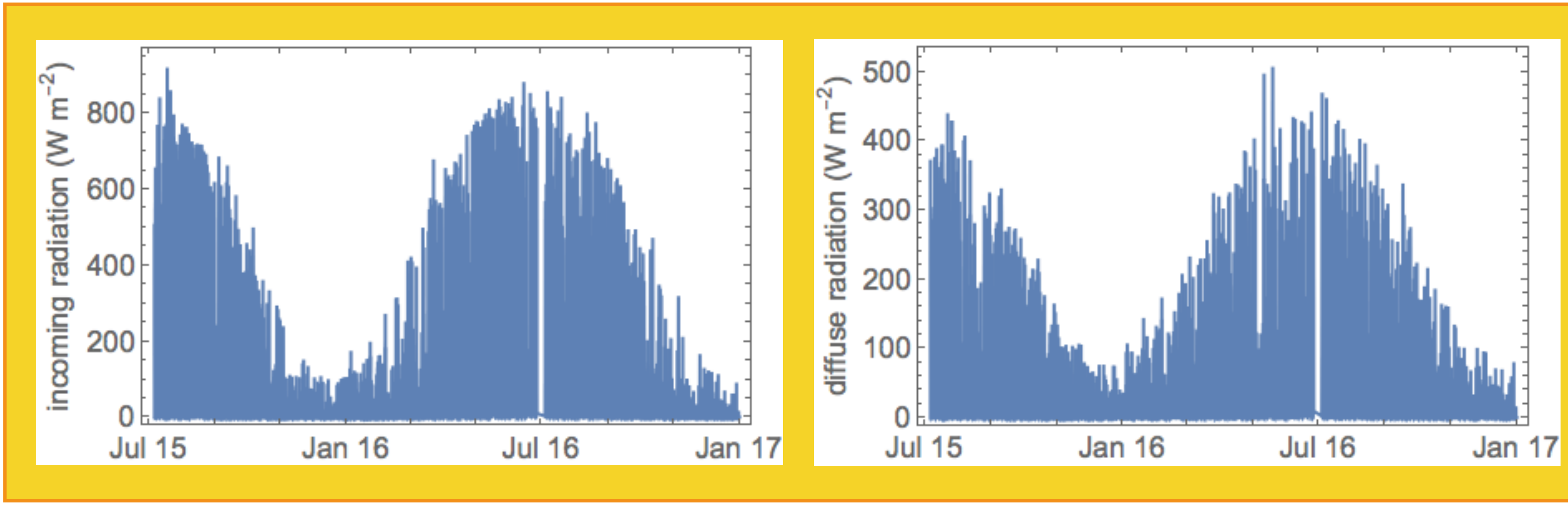
Day-night overview

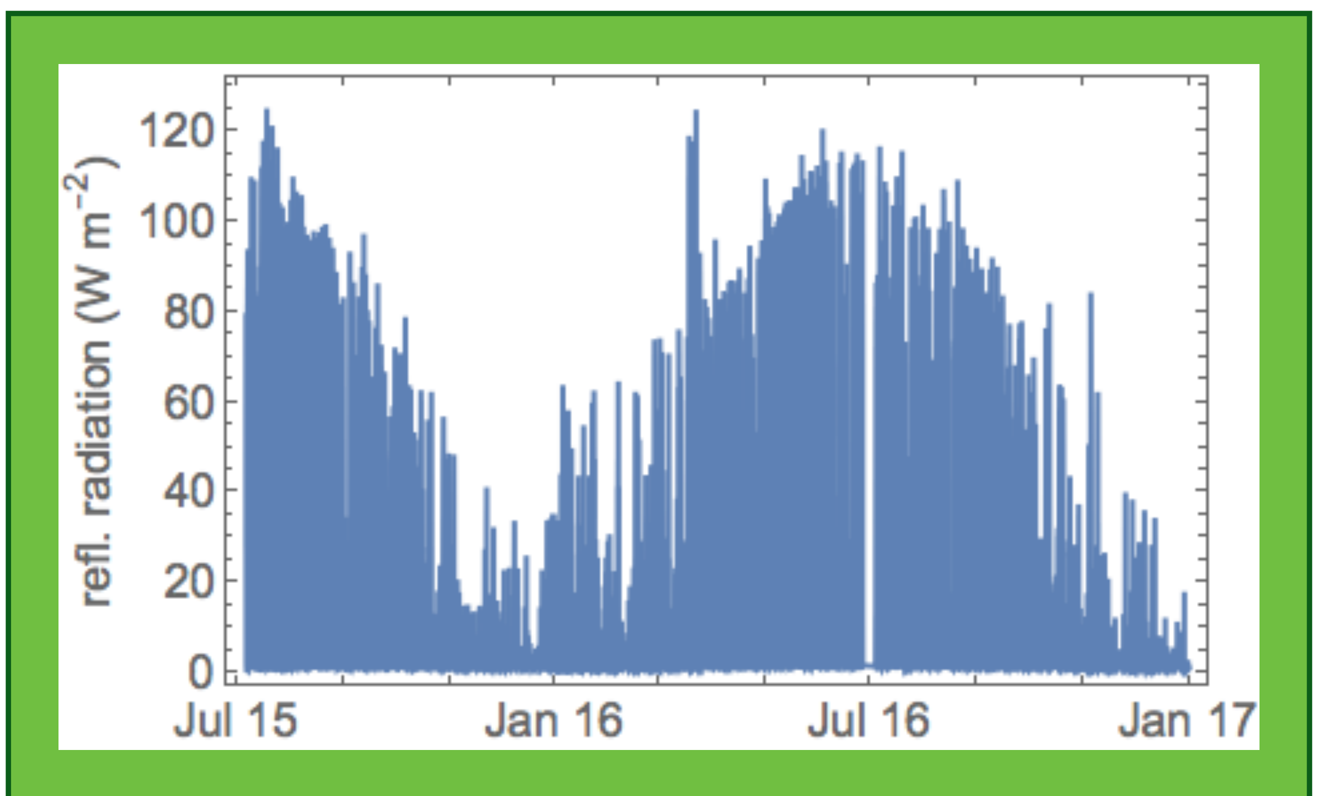


Implications of seasonal behaviour of ecosystems

Radiation measurements at SMEAR Estonia since summer 2015

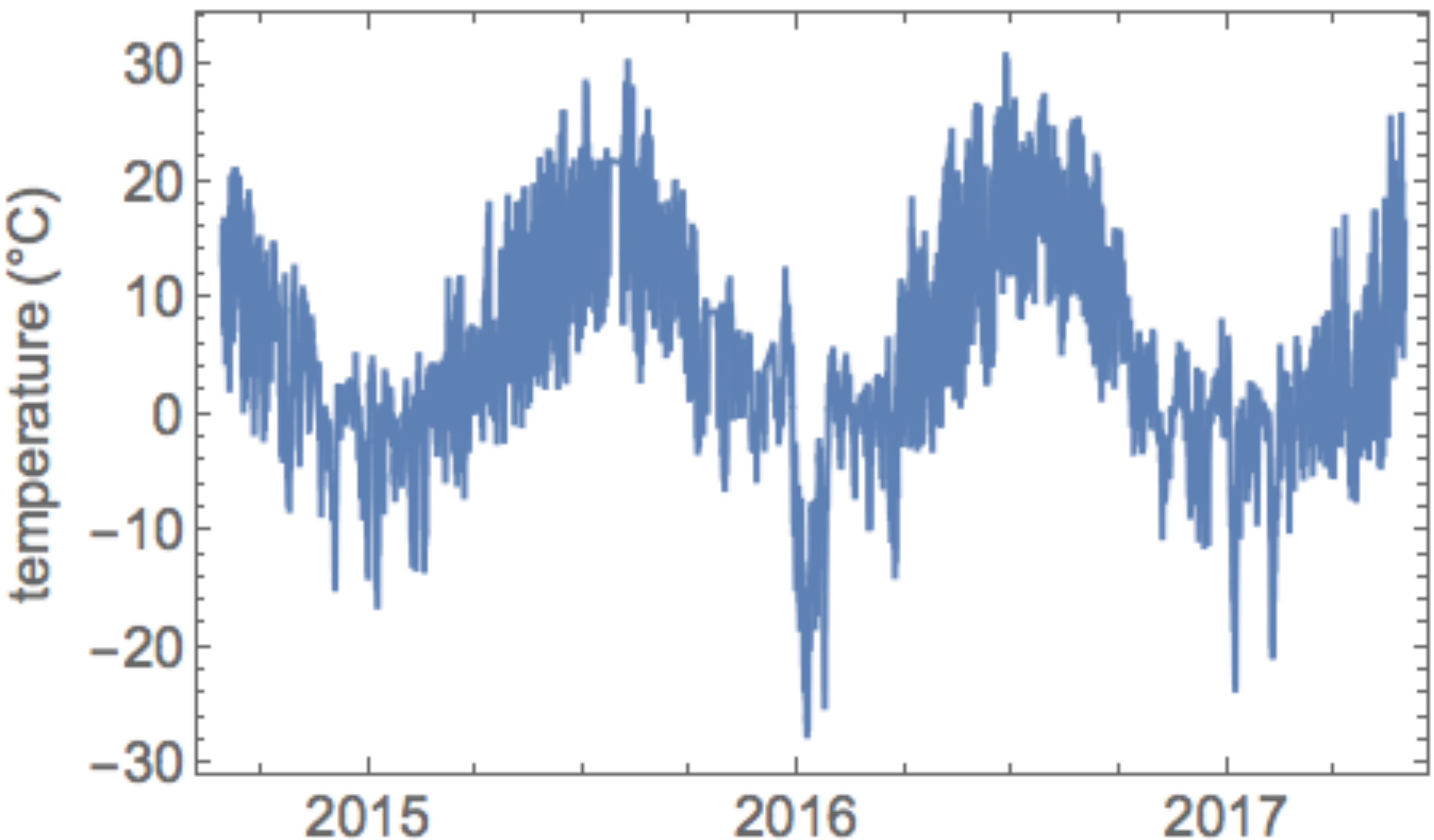
incoming radiation



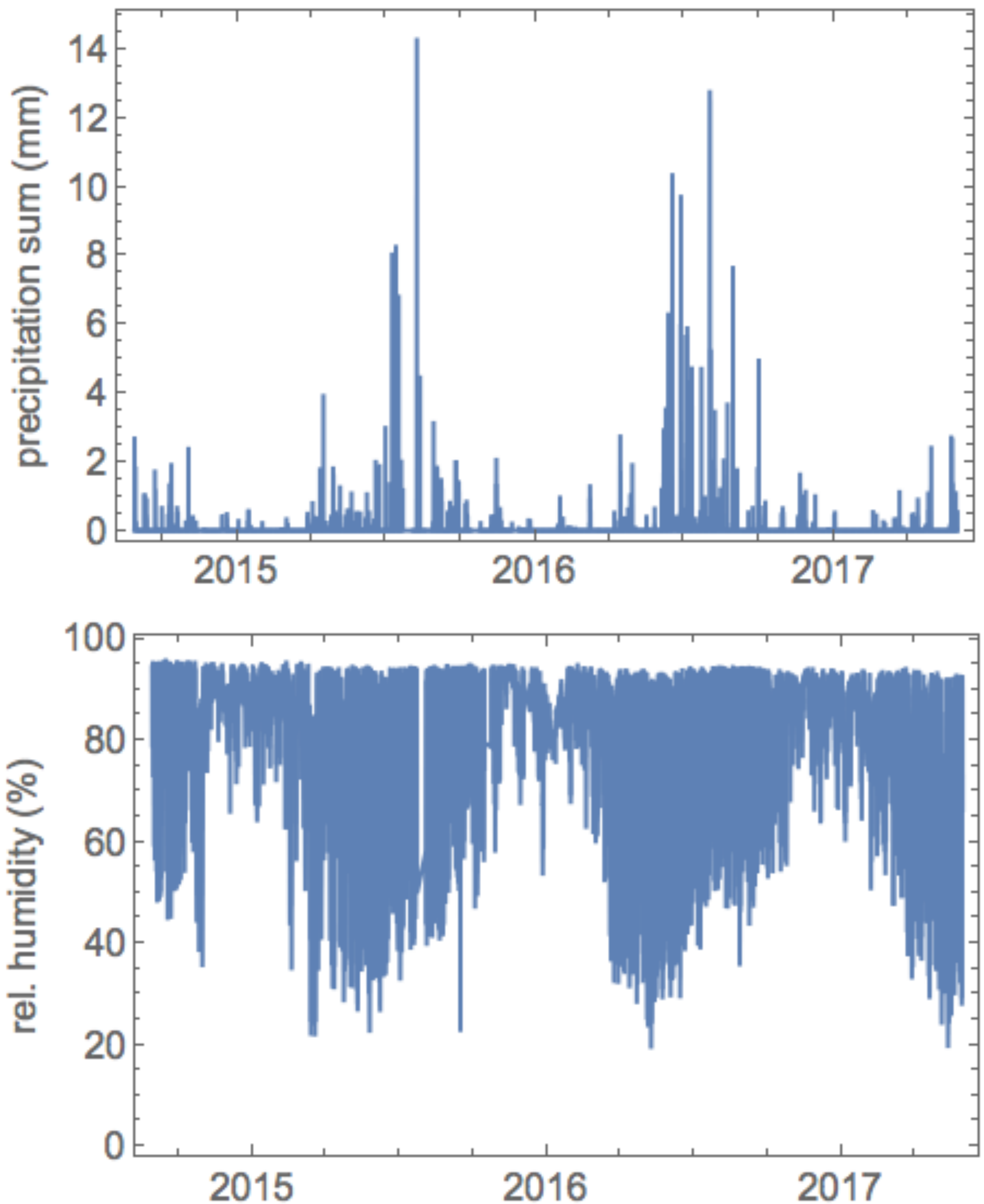


reflected radiation

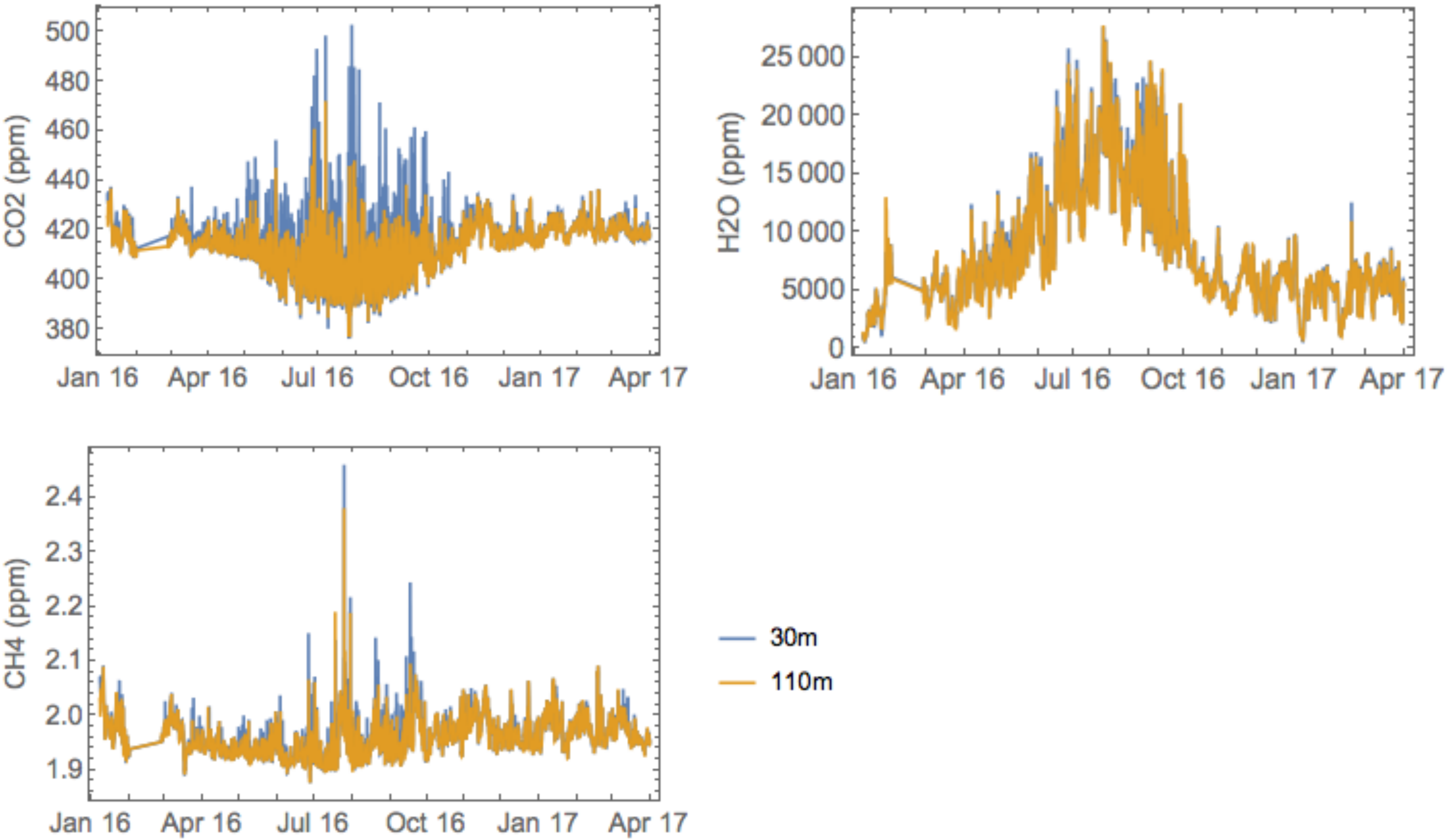
Temperature follows the seasonal and daily sunlight cycle



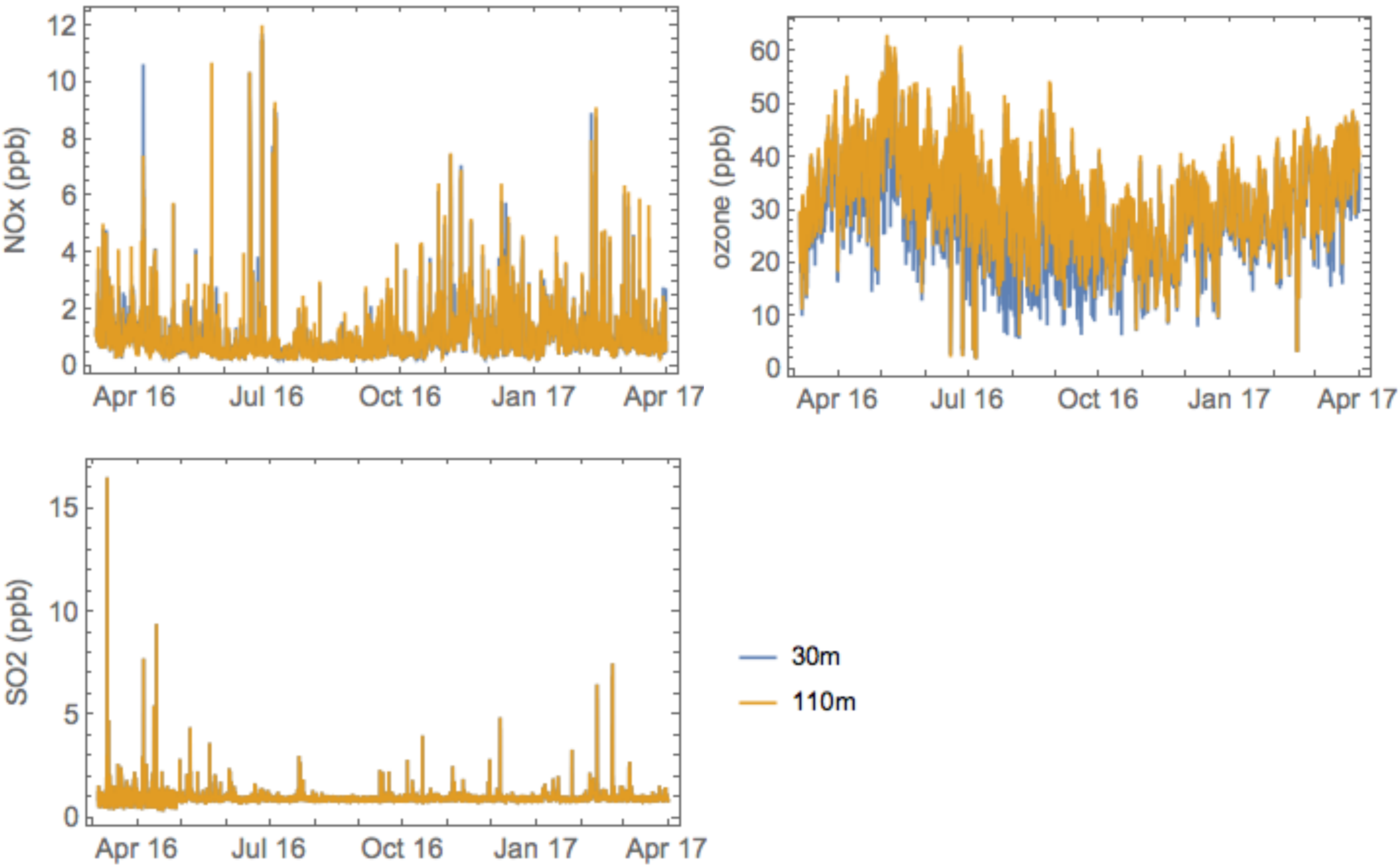
Water vapour and rel. humidity follow the temperature and by that the solar cycle



Action of seasonal cycle driven processes change the state of the atmosphere



Ozone is driven by solar cycle, NOx and SO2 are driven by human activities



Theory of the seasonal behaviour

Atmos. Chem. Phys., 17, 15045–15053, 2017
https://doi.org/10.5194/acp-17-15045-2017

Atmospheric Chemistry and Physics
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EGU

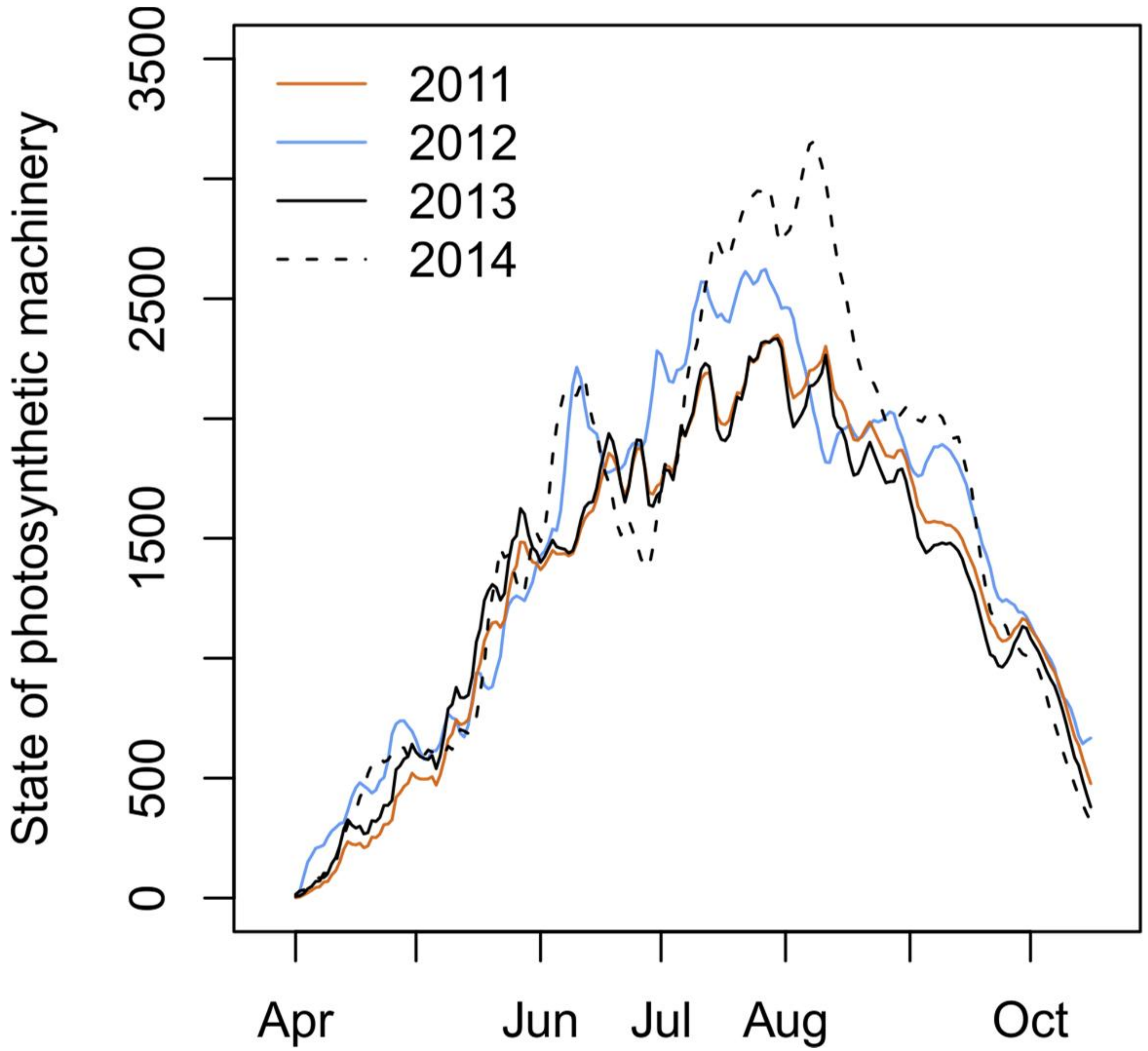
Annual cycle of Scots pine photosynthesis

Pertti Hari[1], Veli-Matti Kerminen[2], Liisa Kulmala[1], Markku Kulmala[2], Steffen Noe[3], Tuukka Petäjä[2], Anni Vanhatalo[1], and Jaana Bäck[1]

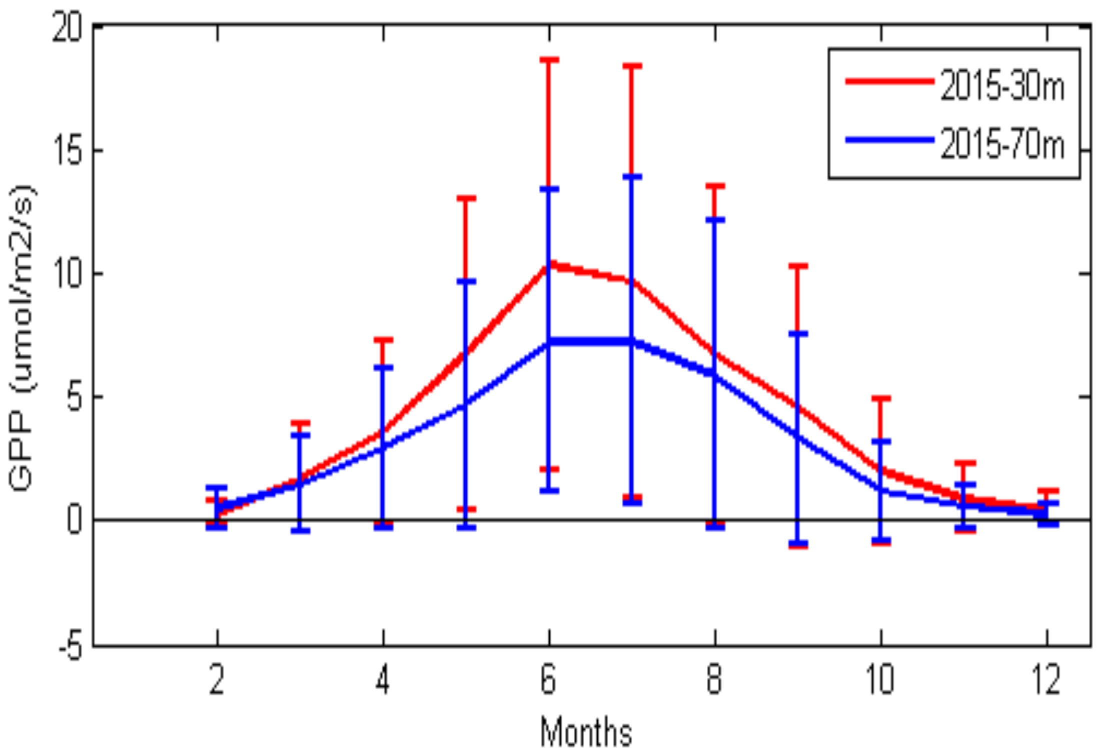
$$\frac{\mathrm{d}S}{\mathrm{d}t} = \mathrm{Max}\left\{0, a_1\left(T + T_f\right)\right\} - a_2 S - a_3 \mathrm{Max}\left(T_f - T\right) I. \quad (5)$$

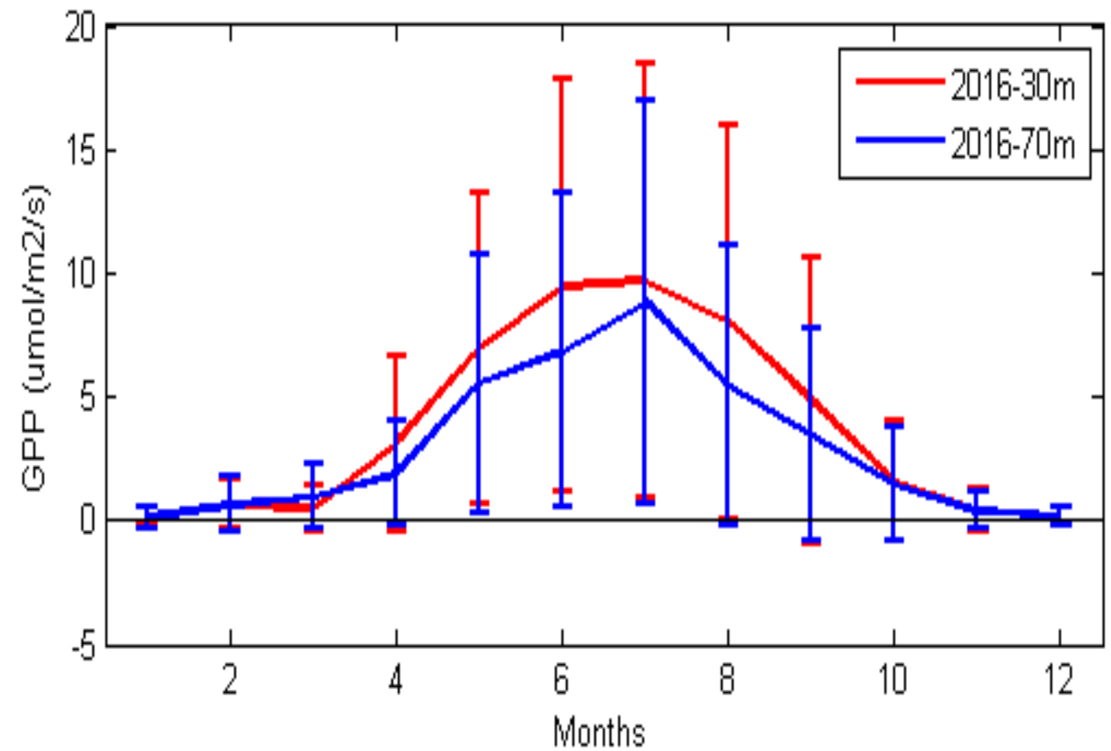
Equation (5) defines the state of the photosynthetic machinery at any moment t when temperature and solar radiation records are available.

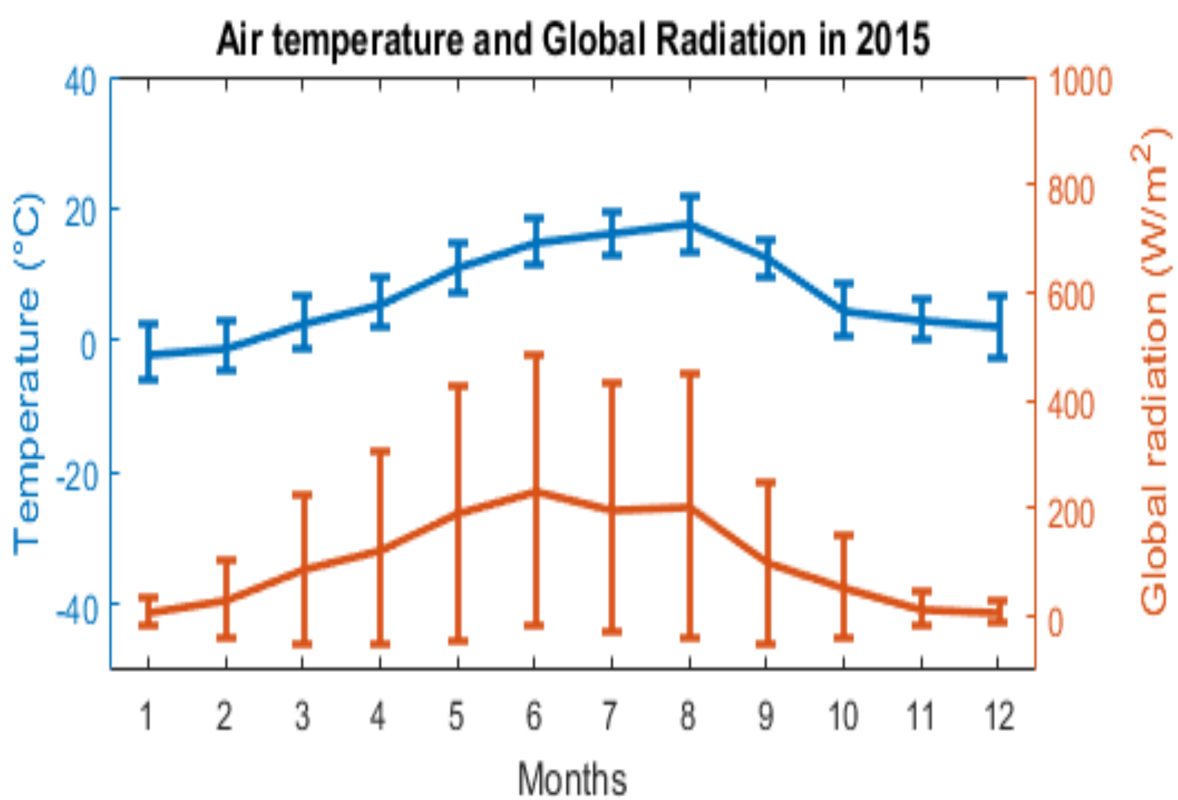
Seasonal behaviour of photosynthesis process

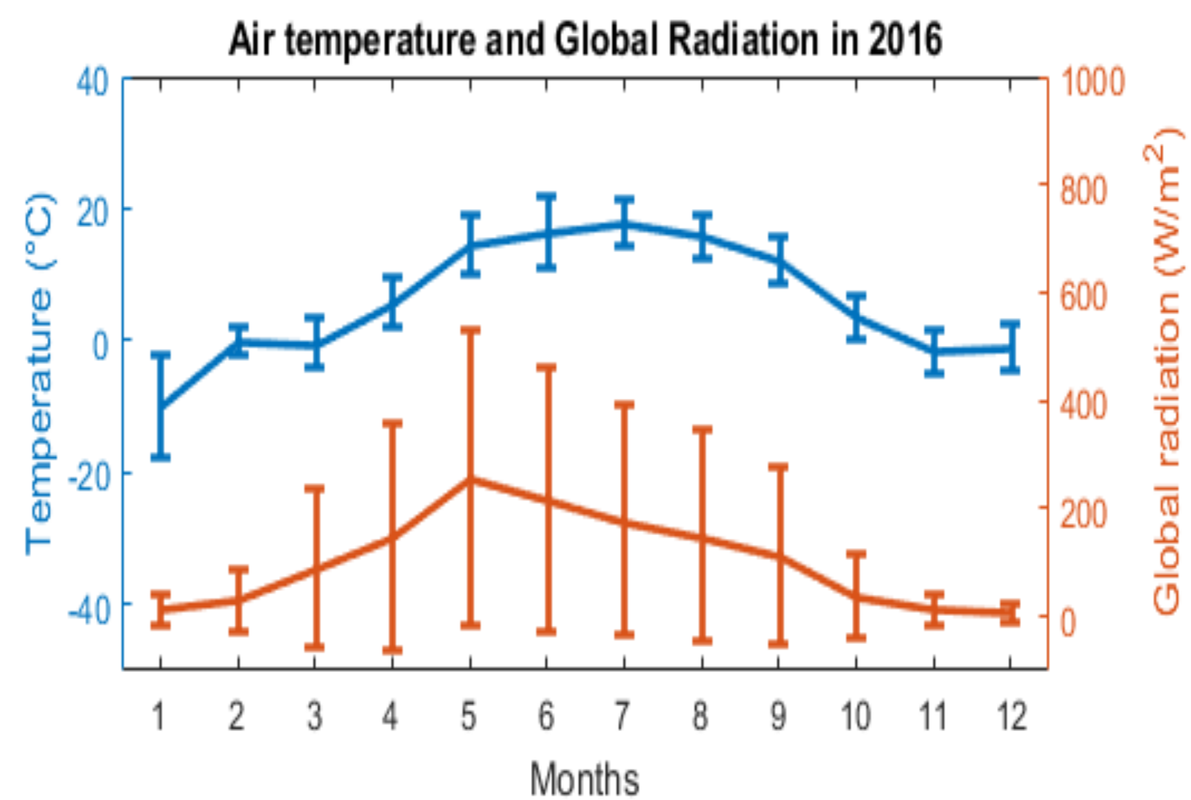


Primary production dynamics measured at SMEAR Estonia



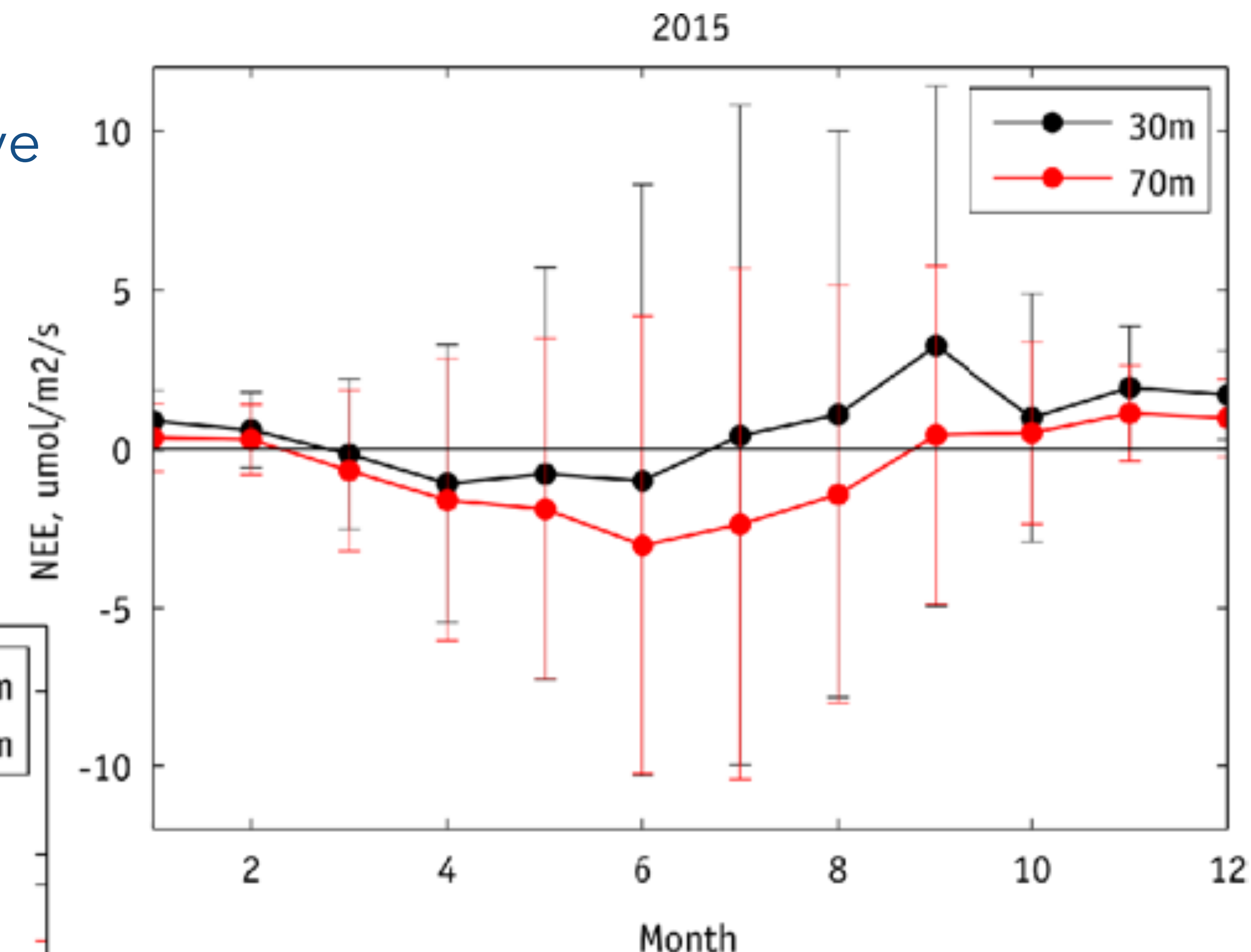


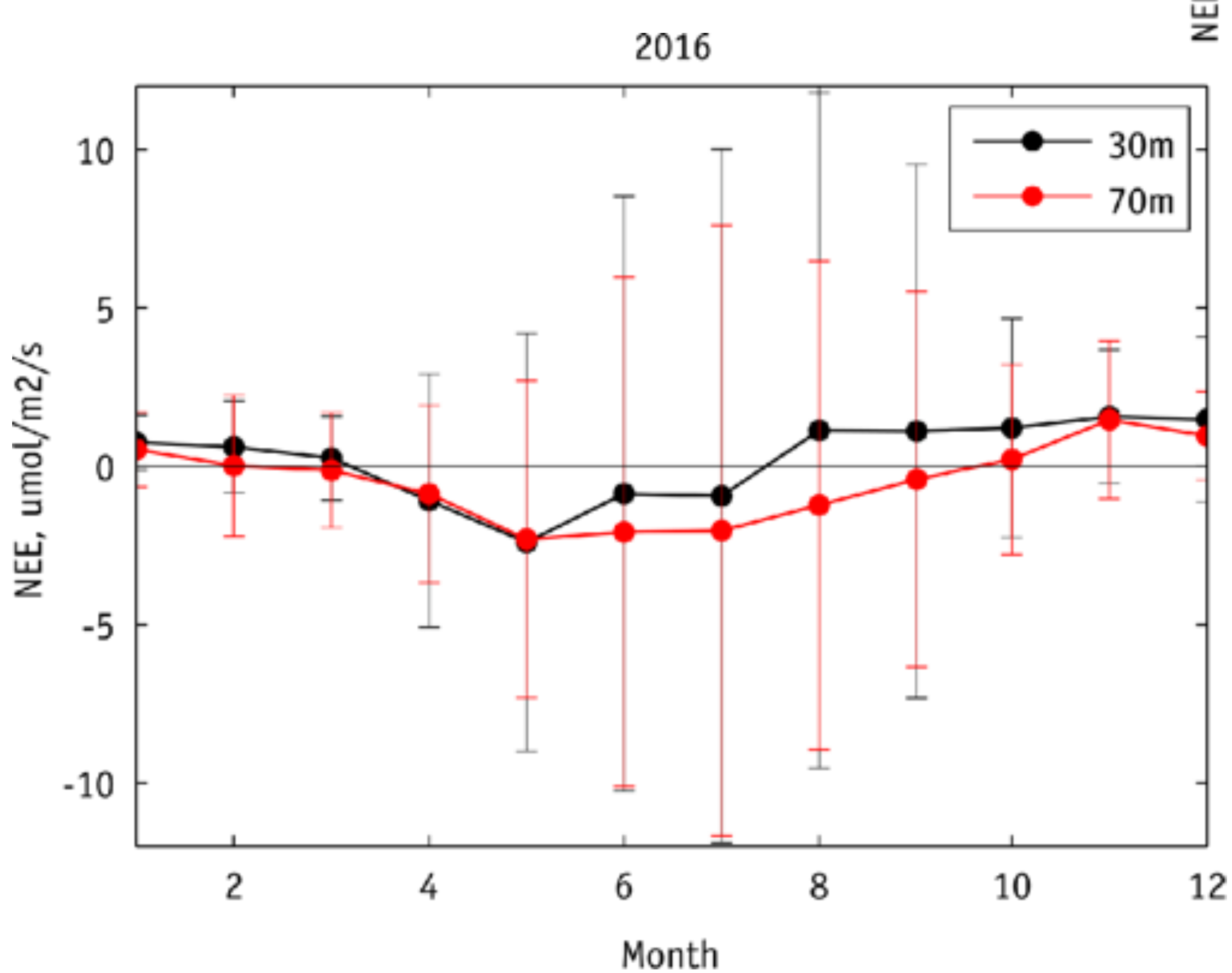




Seasonal cycle determines times when forests are sinks or sources for CO_2

30m flux measurements are more sensitive to spatial stand heterogeneity (clear cut areas, different age structure, species composition).

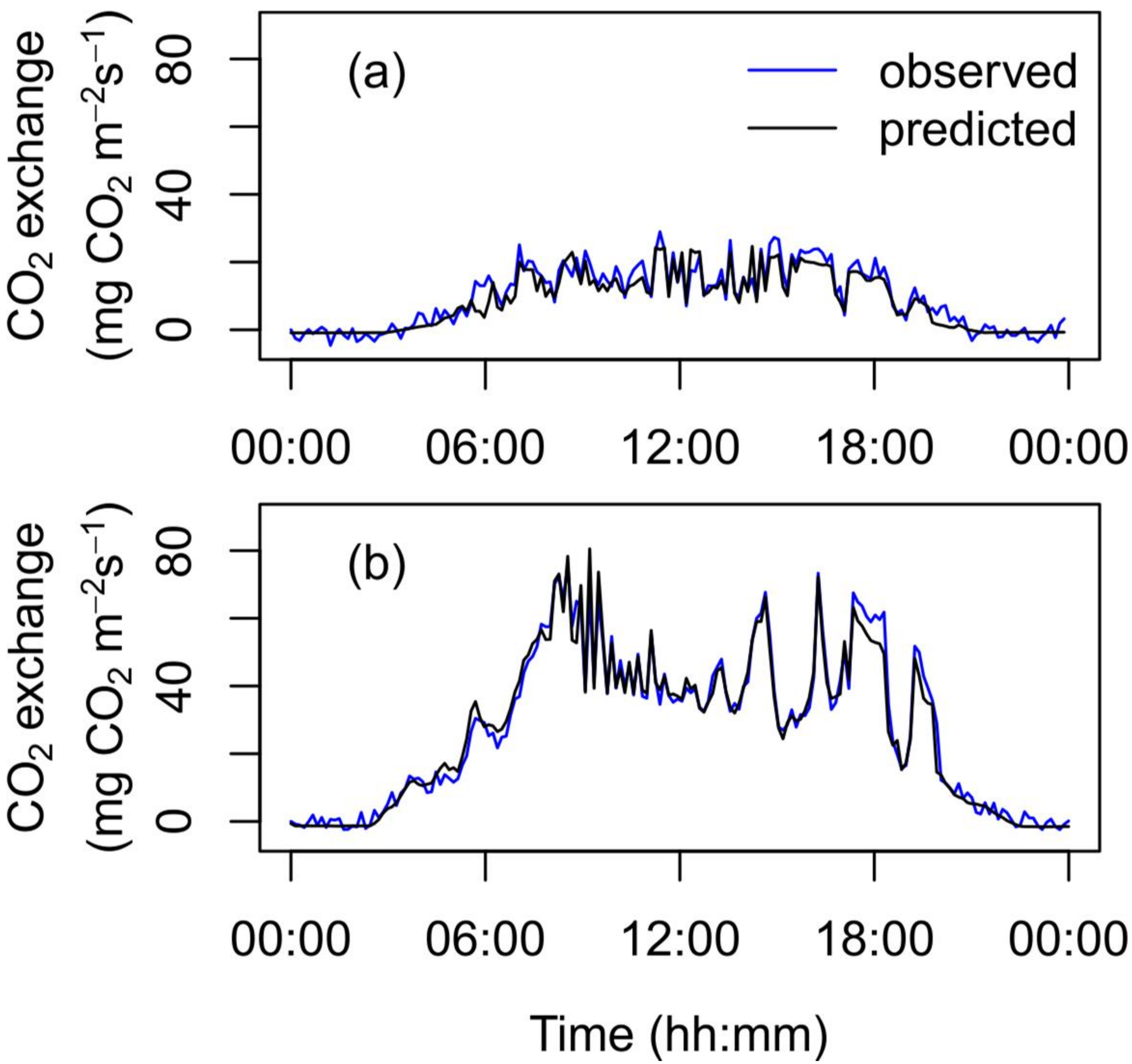




NEE = GPP - RE

Day-night overview

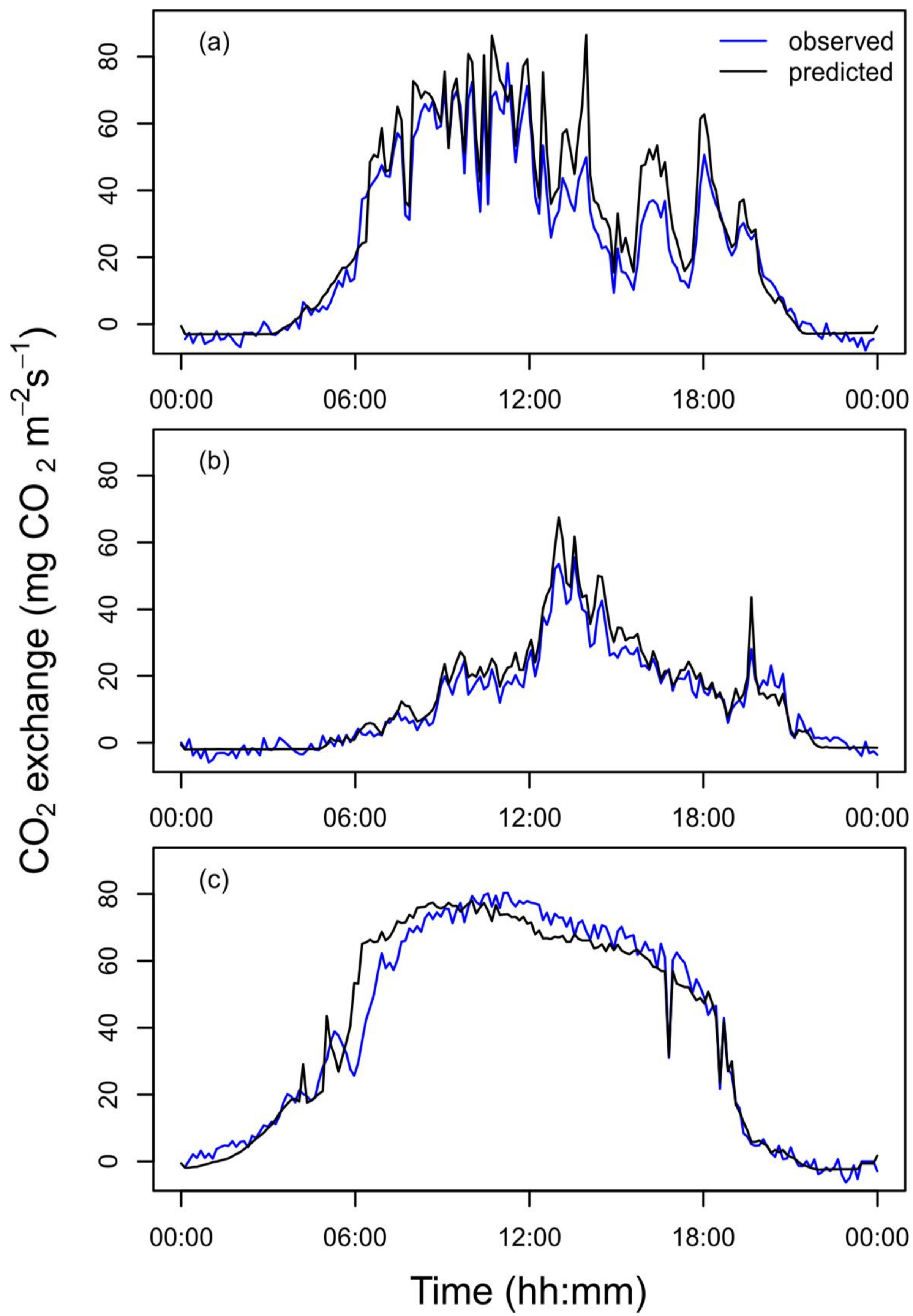
Daily courses of ecosystem processes are directed by the sunlight



Measured and predicted CO_2 exchange during two days.

A. early in the spring (May 8) and B in midsummer (July 18) as function of time

Changes in radiation by cloud cover modulate the daily incoming radiation



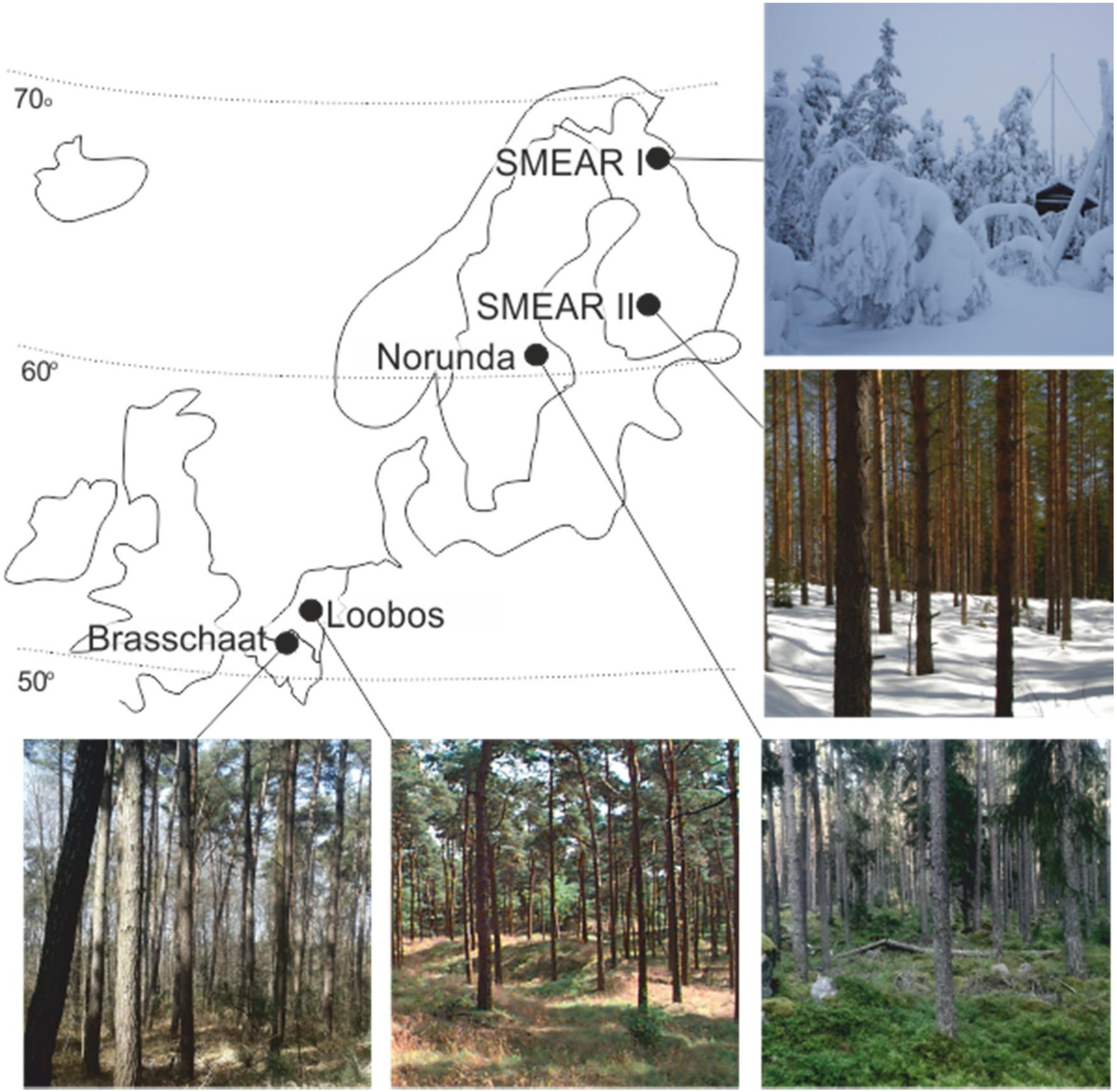
Measured and predicted leaf CO2 exchange

(a) during a day of intermittent cloudiness (August 5),

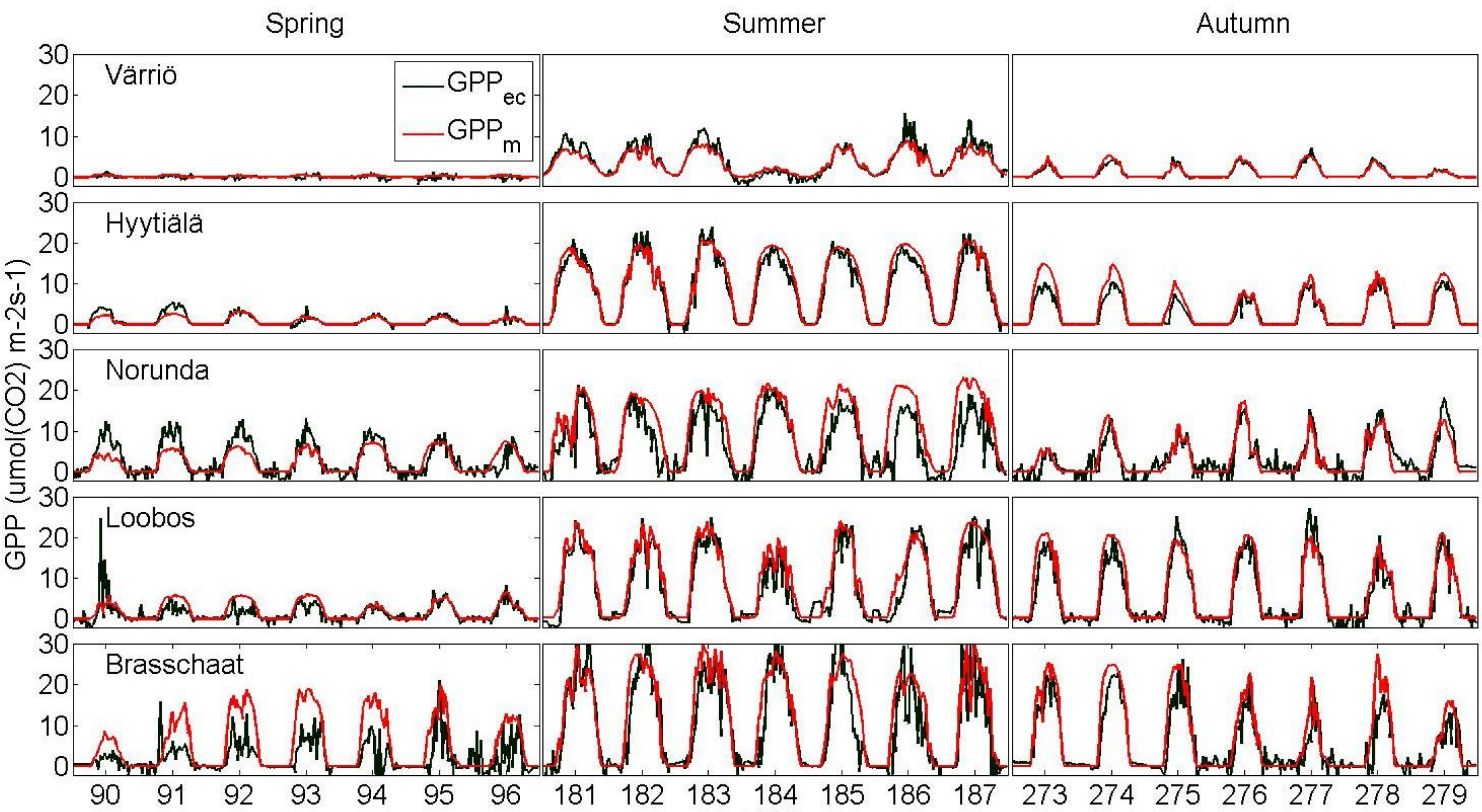
(b) during a cloudy day (July 22), and

(c) during a sunny day when the stomata close partially (July 7) in Finnish Lapland, 68N.

Different solar angles due to geological location



Interplay of daily and seasonal cycle on GPP at different ecosystems



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