Changing seasonality of the Baltic Sea

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Main idea

Trends in environmental variables are not always easy to detect as the time series are often (1) poorly sampled (e.g. too few samples per year in spite of strong annual variability), (2) short in length, (3) have high measurement error (especially in case of satellite measurements).

At the same time, trends in **seasonal timing** (**phenology**) of many variables have more distinct patterns and trends compared to the time series of the variables themselves. Example: Surface Incoming Shortwave (SIS) radiation. Very regular, no obvious trends visible. Trends detected in timing!

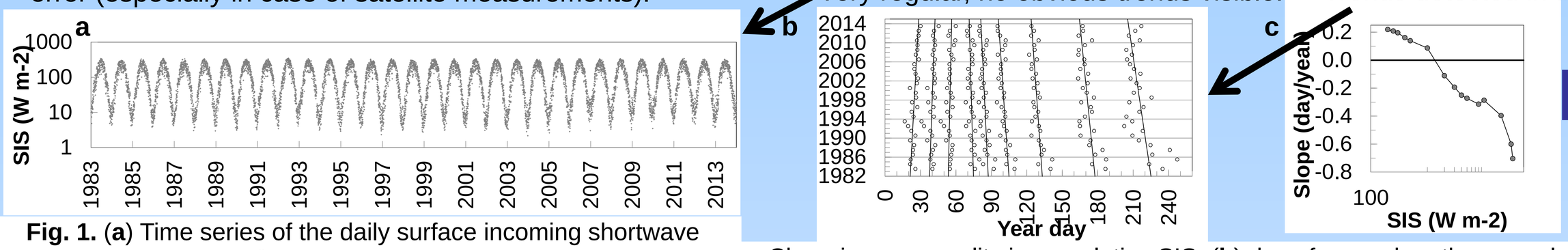

Fig. 1. (**a**) Time series of the daily surface incoming shortwave irradiance (SIS, W m^{-2}) derived from geostationary Meteosat sensors, averaged over the Baltic Sea.

Changing seasonality in cumulative SIS. (**b**) day of year when the annual sum of daily mean SIS reaches the following thresholds: 200, 500, 1000, 2000, 3000, 5000, 10000, 20000 and 30000 W m^{-2}. (**b**) Slopes of the linear regressions in panel (b).

SIS

SST

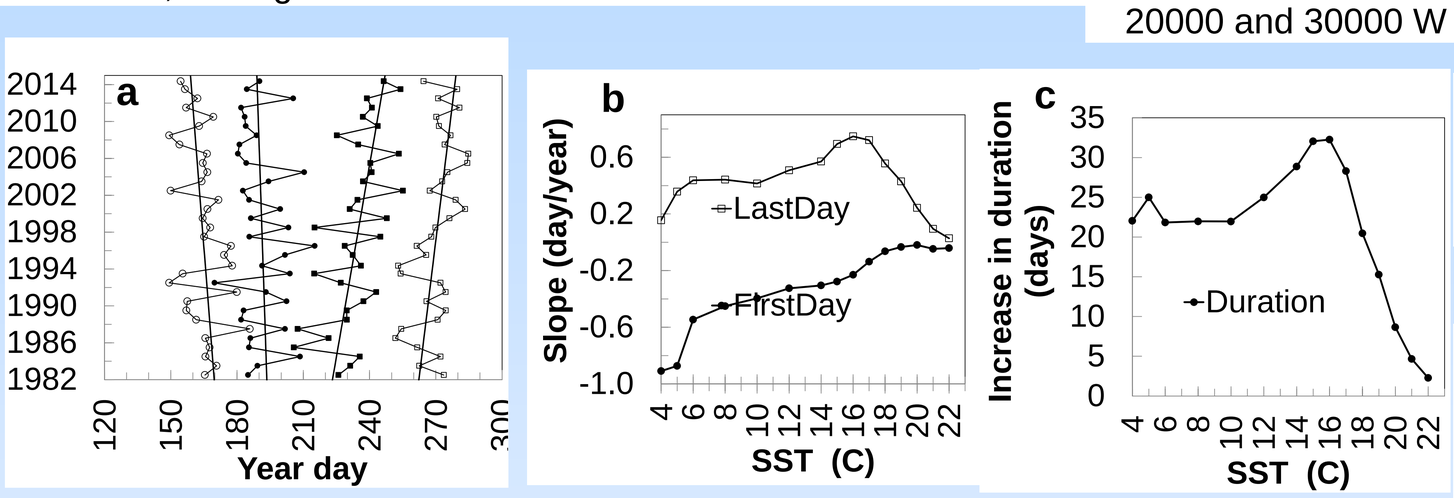

Fig. 2. (**a**) Phenology of SST in the Baltic Sea. First day when 12 ˚C is reached (open circles), first day when 17 ˚C is reached (filled circles), last day when 17 ˚C is reached (filled squares), last day when 12 ˚C is reached (open squares).

(**b**) Rate of change (day/year) in the day of year when a SST level is first reached (filled circles) and when it is last reached (open squares).
(**c**) Increase in the duration of a period with SST above a certain level from 1982 to 2014.

Ked490

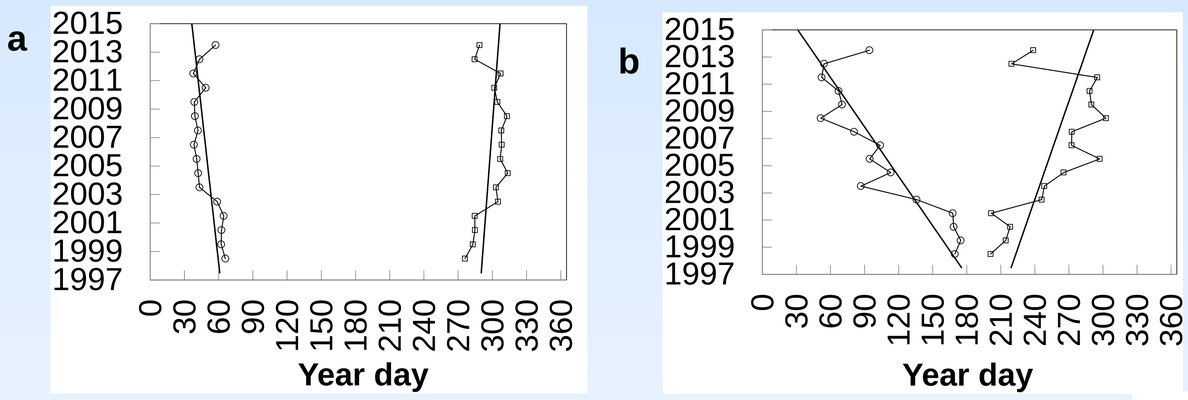

Fig. 3. Phenology of diffuse light attenuation coefficient Ked490 = 0.1 m^{-1} (**a**) and Ked490 = 0.4 m^{-1} (**b**) in central Baltic Sea. The first day of the year (circles) and the last day of the year (squares) with the respective value of Ked490 (spatial average).

Chla

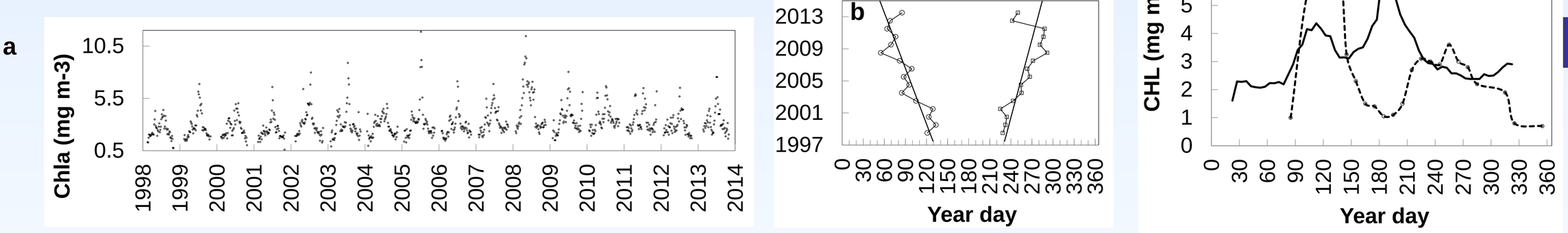

Fig. 4. (**a**) Time series of the 5-day mean CHL (mg m^{-3}) in the central Baltic derived from the ESA-CCI processing of SeaWiFS, MERIS and Aqua-MODIS satellite data (Lavender et al., 2015).

(**b**) Phenology of the “high chlorophyll season” (CHL >= 3 mg m^{-3}) in the Baltic Sea: day when CHL = 3.0 mg m^{-3} is reached for the first time and day when it is reached for the last time during the season.

(**c**) Mean annual cycle of CHL in central Baltic for 1997-2013 (solid line) compared with CHL measured *in situ* in 1985-1989 (circles, dashed line, from Kahru et al. 1991).

Cyanobacteria accumulations

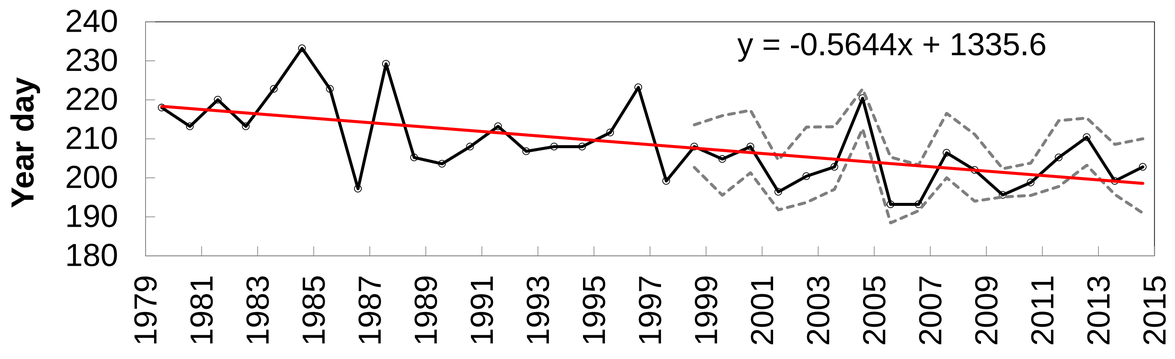

Fig. 5. Temporal change in the timing of cyanobacteria accumulations for the Baltic Sea. The circles connected with a solid line show the “center of timing” (Kahru and Elmgren 2014)

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