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Sensitivity of phytoplankton dynamics to river discharge and flushing events, an idealised model study

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River discharge is not only a key forcing agent for estuarine hydrodynamics, but also for biological processes, such as formation of phytoplankton blooms. Observations have shown that blooms preferably form during low river flow, and with this knowledge, attempts have been done to prevent bloom formation by manipulating release of water from dams.
To gain insight into the basic processes that underlie the observed features described above, experiments have been performed with an idealised vertical 2D biogeochemical model, which accounts for advection by subtidal flow and horizontal dispersion. The domain is a channel with an exponentially increasing width towards the sea. Experiments have been carried out for different river discharge conditions, and also the response of the model to a sudden fresh water discharge has been investigated. Parameters were chosen such that they are representative for the Taw Estuary (SW England), for which specific data were available.
The model results reveal that during a constant low river discharge, even if the model starts with uniformly low biomass in the domain, a bloom forms on a timescale of days due to continuous nutrient-rich river runoff, and will stabilise if conditions do not change. The maximum biomass occurs midway in the channel, which is consistent with observations in Taw Estuary. The mechanism for this is that a large amount of phytoplankton, which abundantly forms in the narrow upstream part of the channel, is advected downstream by the locally strong flow. In case of high discharge (three times as the low discharge), the biomass accumulation is suppressed by strong advection and finally turns out to be a few orders of magnitude lower than that in the low flow scenario. In the scenario of a high river runoff following a long-lasting low discharge (i.e. a flushing event), the total biomass in the estuary is significantly reduced, the along-channel biomass maximum is shifted downstream, and the existing bloom dampens or even vanishes, as is often observed in field. This behaviour is caused by intensified river flow, which flushes phytoplankton out of the estuary.