

Review of the manuscript *How extreme river discharge events shape coastal biogeochemical dynamics: the 2024 northern Adriatic case*, by Di Biagio et al, submitted to **State of the Planet** (SP-2025-09).

Manuscript overview

The manuscript details a study into the drivers of the observed 2024 eutrophication issues in the Northern Adriatic Sea. To this end the authors use 9 different sources of information, which are handily listed, and of which 3 are observational or semi-observational (satellite product) sources and 6 are modelling products. They use these sources to visualise the differences between the 2024 season and the long-term mean of 1990-2022 for Po river discharge, sea water temperature, marine phosphate levels and marine net primary production (all from model sources). Selecting periods of high river discharge the authors then proceed to quantify the elevated levels and suggest main driver mechanisms for the observed high Chl-a levels in the different periods.

Review overview

The manuscript is well written but the presented analysis is not very deep or detailed. The proposed driving mechanisms for the observed high Chl-a levels are mainly speculative and a real quantification is not presented. A very similar analysis was done with purely observational data by Vona et al (2025), as is referenced in the manuscript, but it is unclear what the use of the model products is contributing. Indeed, Vona et al (2025) showed positive correlations between Po river discharge on one hand and marine Chl-a and TSM concentrations from satellite data. Yet in this manuscript only a few drivers are used, despite the fact that the selected model products are quite extensive. Therefore I suggest that the authors 1. Include more drivers in their analysis (at the very least a proxy for the underwater light climate, possibly also NOx concentrations, zooplankton biomass and strength of stratification) and 2. Present a better quantification of the anomalous events. The promised quantification currently consist of Tables 2 and 3 and textual indications of visible differences. As it is now it is unclear to me what the current manuscript adds to the understanding we get from the work by Vilibić et al (2025) and Vona et al (2025).

Apart from this I would like to see more discussion on the reference period used. For the long-term mean the authors use the period 1999-2022, likely due to availability of modelled products on CMEMS. But marine temperature trends around Europe tend to show an increase in annual mean temperature starting around 1980 (e.g. Raicich & Colucci, 2019 and examples on <https://ocean.ices.dk/core/iroc>). Here the reference period is completely within the current warming period, which makes me suspect that any current year will show anomalies with respect to the long-term mean in term of temperature (2024 was the warmest year on record in all marine T time series I have seen), and exhibit associated anomalies in Chl-a (faster regeneration of nutrients at the very least). During the whole reference period the discharges of the Po river have been declining (Marini & Grilli, 2023) as is pointed out by the authors. Only considering anomalies from 1 year with a high discharge level with an unstable reference period has its limitations. This should at least be discussed in the manuscript.

More detailed comments are provided below.

Recommendation

Major revision

Detailed Comments

1. Table 1: I really like this overview of data sources, it works well with the text.
2. Line 44: has the decrease in P inputs led to the NAS system being P limited in the coastal zone?
3. Line 54-57: a reference to figures 1 and A1 could be added here, as could a quick mention of the 2024 annual mean discharge and the annual mean discharge over the reference period. This would allow readers to compare the 2024 annual value with those reported by Vona et al (2025, their figure 4A) and better quantify just how out of the ordinary the year was.
4. Line 83-84: this is definitely worth adding as eutrophication is only a problem when undesirable consequences occur. Most definitions of eutrophication include the negative effects, as does the cited MFSD, and so stating that there are high chlorophyll levels is not enough. So I would put this earlier in the text and not add it as an afterthought.
5. Line 84-87: I would rephrase this as now the point of this sentence is unclear. Any in any case, the authors do not try to establish a direct connection between Po discharge and mucilage events. Even the connection to elevated Chl-a levels is not direct but simply by inference.
6. Line 110: Not quite clear to me, do products 1 and 2 include satellite derived Chl-a data assimilation? It would be good to add this information to Table 1, which products used Chl-a assimilation and which EFAS river data, as you look for similarities in response to these drivers and model results, and interdependencies should be clear.
7. Line 145: please explain exactly what the climatology is. As far as I understand it, it is the 1999-2022 mean of the same product, correct?
8. Section 2.1: Why I there no mention of the quite large differences in y-axis scale in Figure 3? Or the fact that the model is not able to reproduce the peaks present in the satellite data? Because the model is used to investigate Chl-a levels compared to the drivers, but does not seem to capture the extreme highs which could indicate eutrophication occurring.
9. Line 178: do you mean Figure 4a? Because Figure 1a shows observational data.
10. Line 184-185: "promoted the huge increase", it certainly would have facilitated the Chl-a increase, but how can you be so sure? You only examine 3 drivers and then present increases in those as the de facto evidence that this is what caused the Chl-a increase. I would word this more carefully.
11. Line 186-187: "drove", I think you mean is associated with? This is pure speculation after all, and neglects other drivers such as availability of other nutrients, light availability, carbon availability and grazing. And it should be "*both in model and satellite data*"
12. Line 187: please show the active radiation in the appendix or provide a reference. And as the Chl-a levels in Figure 3c show an autumn peak that is higher than the one in May the autumn Chl-a levels do not look all that low to me.
13. Line 238-241: please rephrase as grammatically incorrect. And I don't see why you use the word "despite". Vona et al reported positive correlation between observation time series, thus providing a good indication of eutrophication drivers. The current study does not contradict that work as far as I can see, neither does it expand much upon it. Vona et al do report a strong correlation between total suspended sediment concentrations and Chl-a levels in the NAS (both from satellite data), a driver that is not considered here at all (high rainfall events can lead to strong soil erosion, causing high levels of TSM in river discharge).
14. Line 268: intense positive anomalies of what?
15. Line 274-279: please rephrase as grammatically incorrect and overly long. And as said before I would like to see an earlier discussion of any undesirable disturbance caused by the high Chl-a levels.

16. Line 295: I don't feel that you have presented any real evidence for this claim, even though I would expect the operational model to do better as it has a higher spatial resolution. Figure 2c shows exactly that, as the satellite signal is different to both model products.
17. Appendix: I miss a discussion on Figure 1A, which shows that the EFAS product underestimates Po river flow, especially during peak discharges. As these peak discharges are the focus of the study a quantification of this error in EFAS forcing should be included.

References

- Marini, M., & Grilli, F. (2023). The role of nitrogen and phosphorus in eutrophication of the northern Adriatic Sea: history and future scenarios. *Applied Sciences*, 13(16), 9267.
- Raichich, F., & Colucci, R. R. (2019). A near-surface sea temperature time series from Trieste, northern Adriatic Sea (1899–2015). *Earth System Science Data*, 11(2), 761-768.
- Vilibić, I., Terzić, E., Vrdoljak, I., Novković, I. D., Vodopivec, M., Ciglencčki, I., ... & Hamer, B. (2025). Extraordinary mucilage event in the northern Adriatic in 2024—a glimpse into the future climate?. *Estuarine, coastal and shelf science*, 317, 109222.
- Vona, I., Colella, S., Sammartino, M., Brando, V. E., & Falcini, F. (2025). Positive correlation between the Po River discharge and ocean colour trends of Chl and TSM in the Adriatic Sea. *Frontiers in Remote Sensing*, 6, 1574347.