PICES-2021

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Application of the NEAT for global eutrophication assessment

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NPEC

- **Background**
- Methods 1
- Methods 2
- Results 1
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- Conclusion

- Human activities and their negative impacts on coastal waters are increasingly threatening the integrity of coastal ecosystems. Eutrophication, a process in which the addition of nutrients (largely nitrogen and phosphorus) to water bodies stimulates excessive algal growth with negative impacts, is a threat to the integrity of many coastal ecosystems.

- The NEAT (the NOWPAP Eutrophication Assessment Tool) is a **tool for a preliminary eutrophication screening** developed by CEARAC (the Special Monitoring and Coastal Environmental Assessment Centre) of the NOWPAP (Northwest Pacific Region Action Plan) hosted by the Northwest Pacific Region Environmental Cooperation Center (NPEC).

Main Author

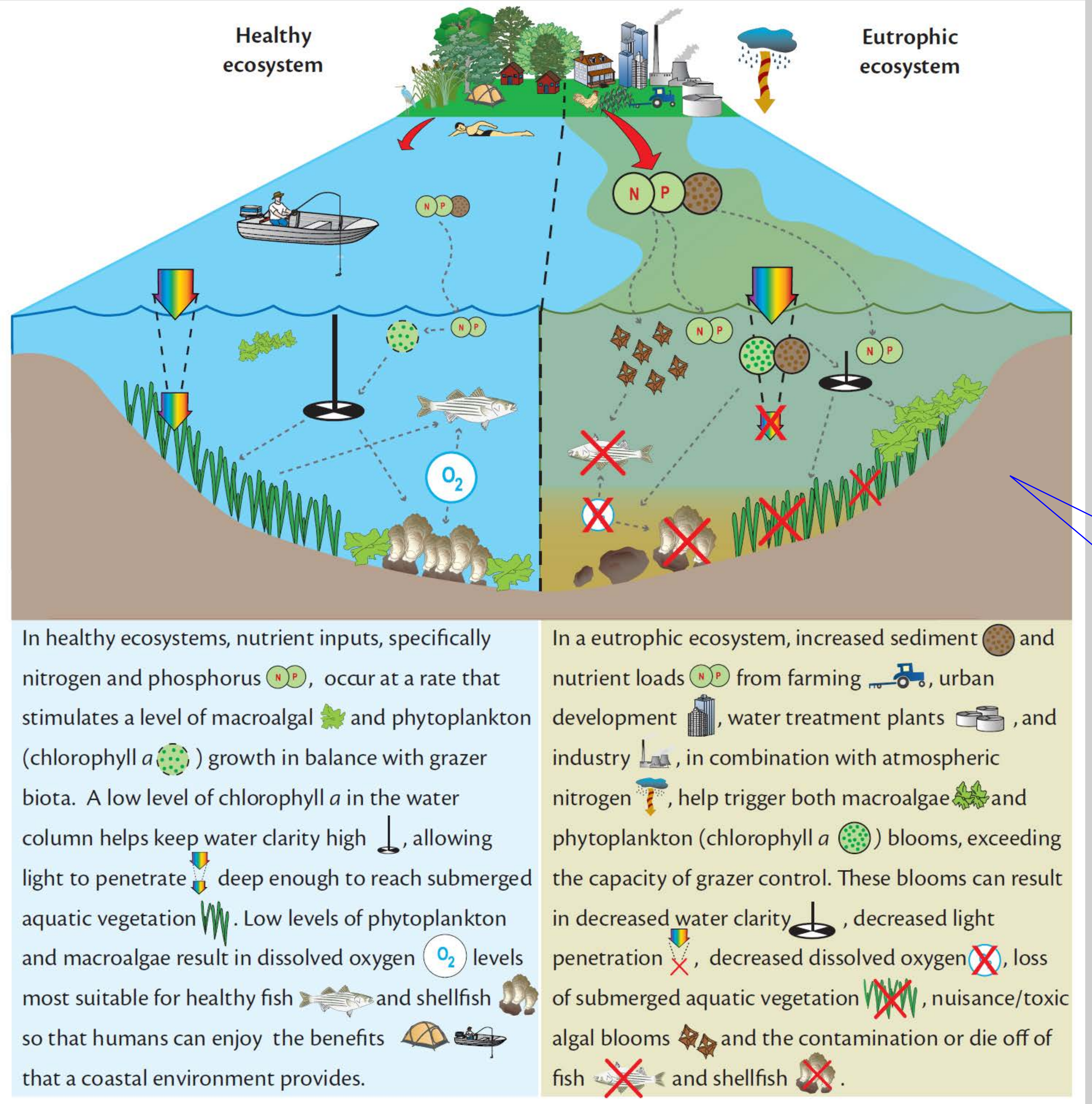
- The **NEAT detect symptoms of coastal eutrophication using satellite-derived chlorophyll-a (CHL) concentration**. It applies a long-term consistent data record of CHL to identify temporal trends in CHL and associated them with eutrophication potential waters.

- Here we introduce the **NEAT**, its strengths and limitations and the recent advances in its development. We also discuss the potential contribution of the **NEAT** as one of inexpensive global indices of coastal eutrophication potential.

- In the NEAT assessment use the term **eutrophic potential** to define waters associated with high concentrations of CHL, whereas the **eutrophication potential** term is associated with waters with CHL increasing trends.

- The **NEAT** introduces the prospect for a consistent global assessment of eutrophication trends with major implications for monitoring Sustainable Development Goals (SDGs) more specifically SDG 14: Life Below Water—conserve and sustainably use the oceans, seas and marine resources—indicator 14.1.1a "Index of coastal eutrophication".

Healthy vs. Eutrophic Ecosystem



Conceptual diagram comparing a healthy system with no or low eutrophic condition to an unhealthy system exhibiting eutrophic symptoms (Bricker et al. 2007)

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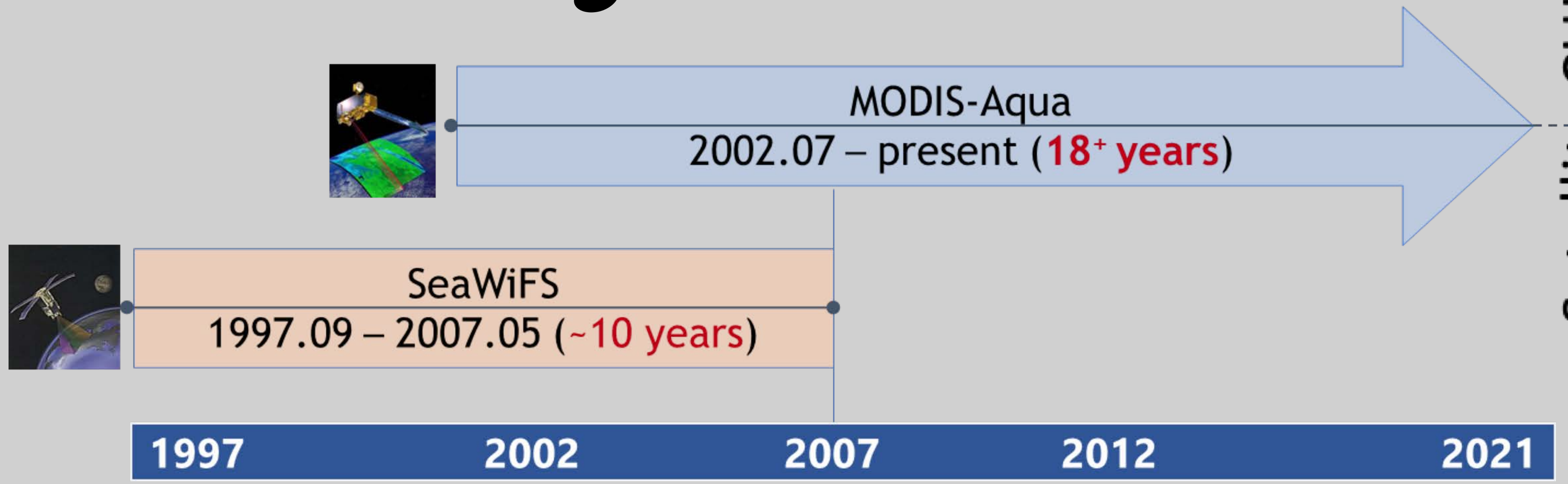
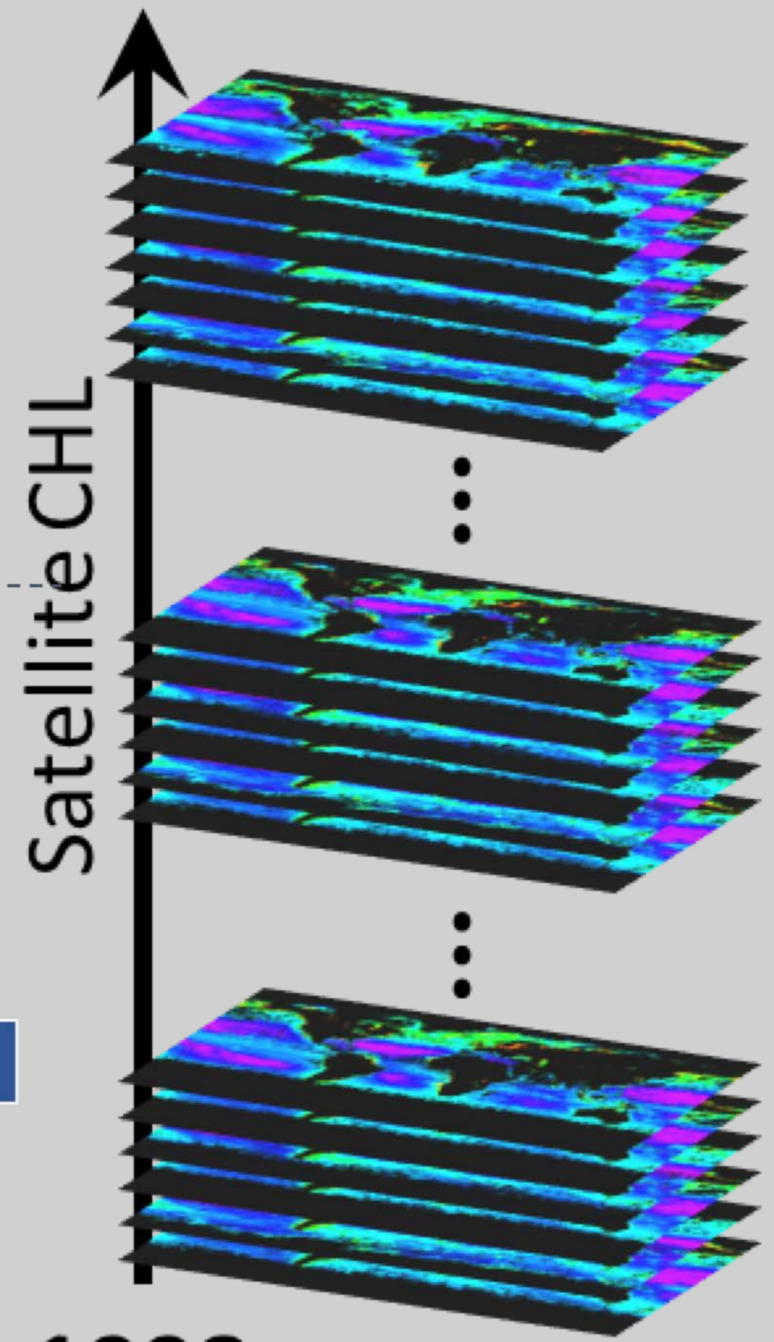
Global assessment based on combined SeaWiFS and MODIS-Aqua derived CHL with 4 km spatial resolution

- Long-term consistent CHL time series (1998-2018, **20+ years**)

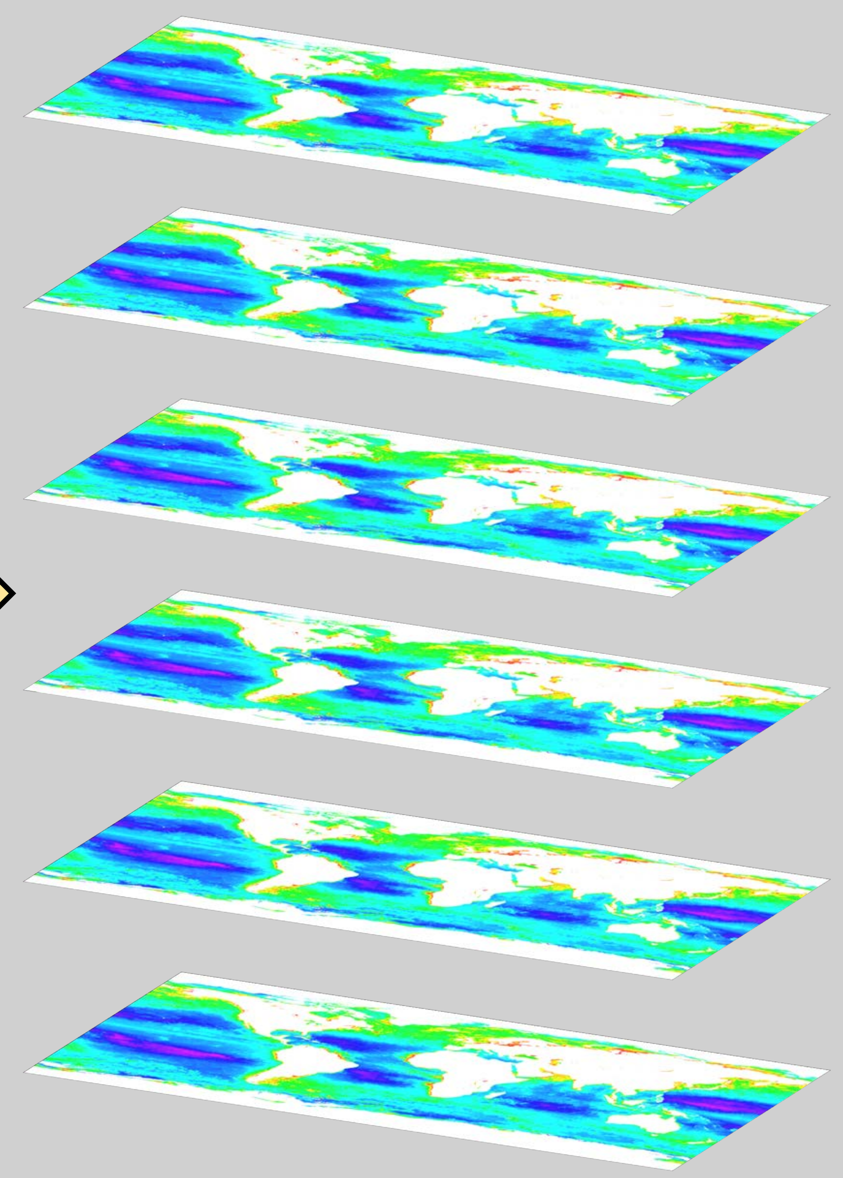
CHL time series (Monthly) → **Annual CHL max** → **CHL trend**



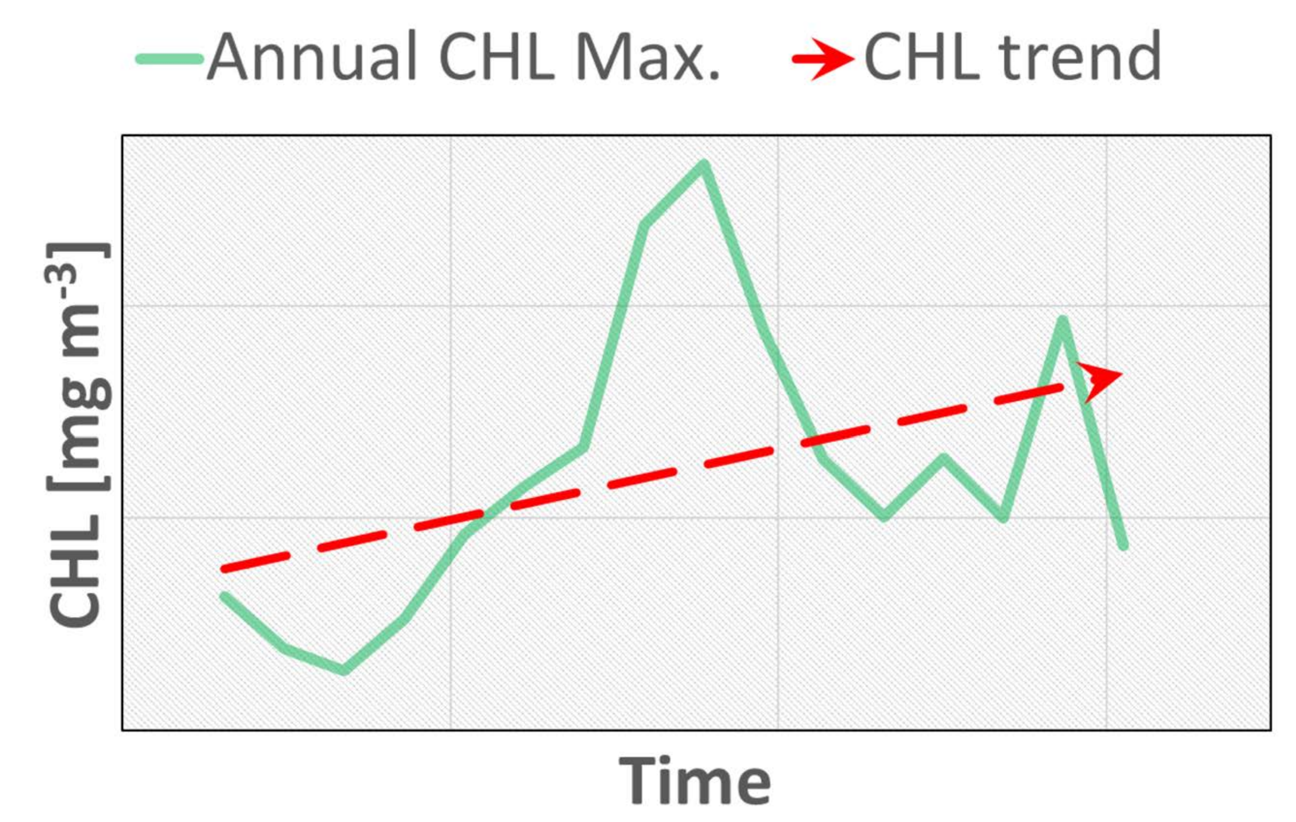
SeaWiFS and MODIS-Aqua derived CHL combined to generate a single, long-term consistent CHL



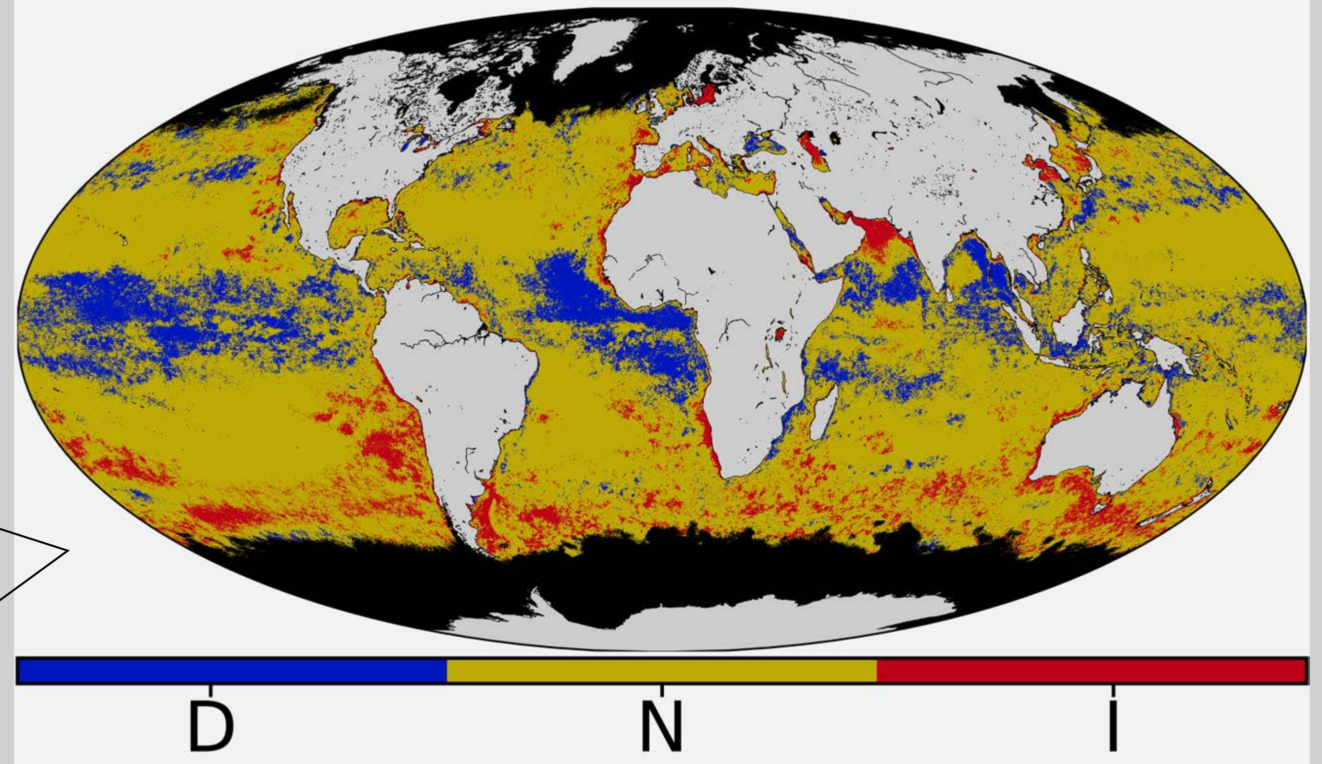
Trend Estimation



Pixelwise trend detection



Trend in Annual CHL Max



D: Decreasing, N: No Trend, I: Increasing

Trends in annual CHL max based on Sen's slope method (Sen, 1968) at 90% significance level. Polar regions with a few observations (< 70% of the study period) were masked.

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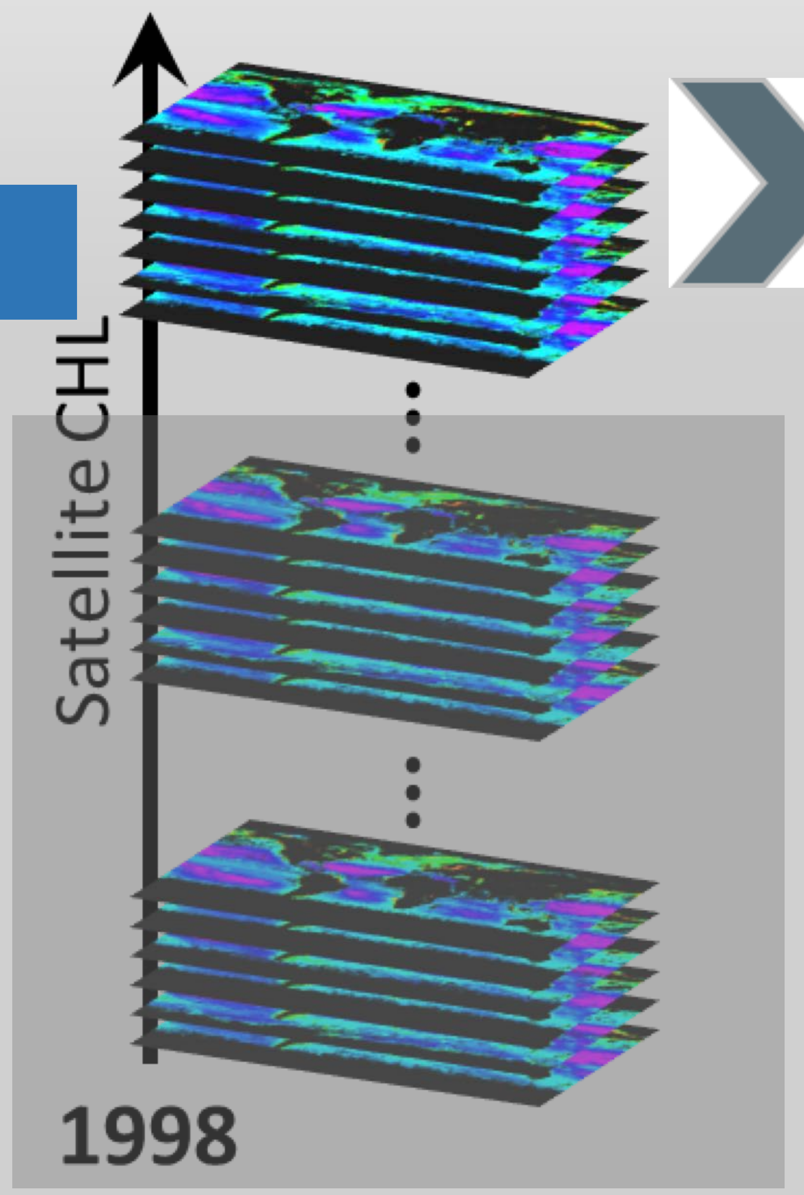
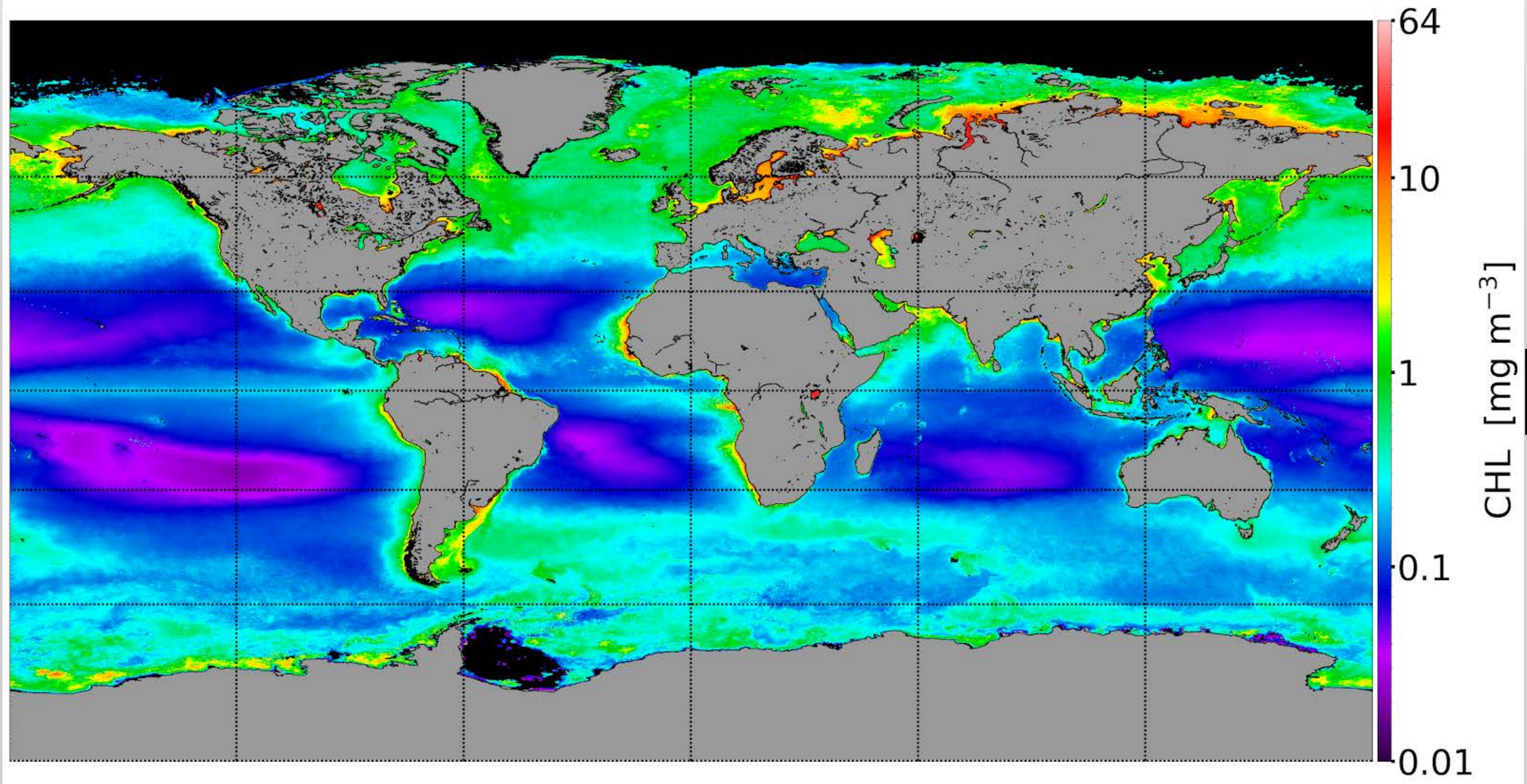
CHL time series (Monthly) → 3-year Mean CHL → CHL threshold

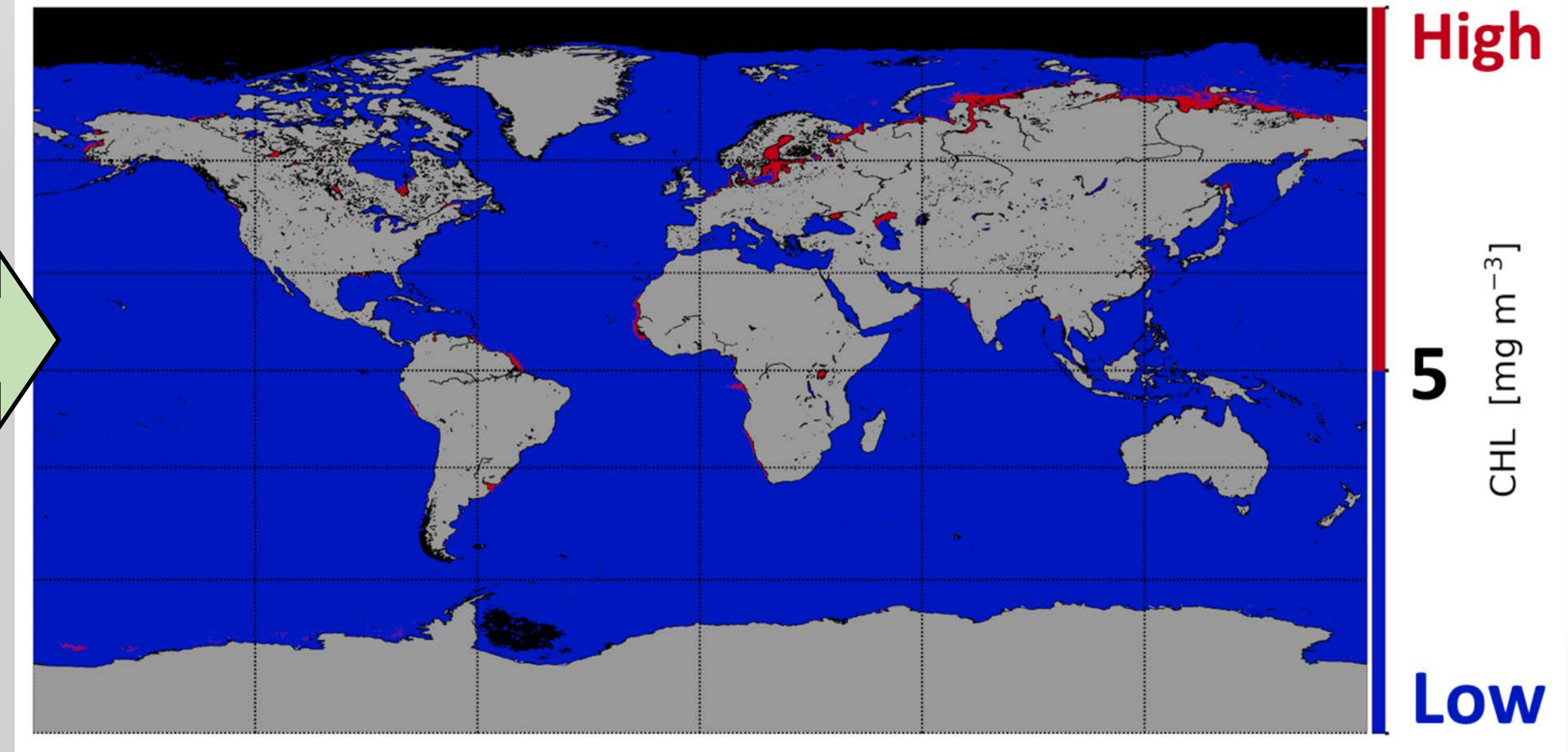
CHL Threshold (Estimate of CHL level)





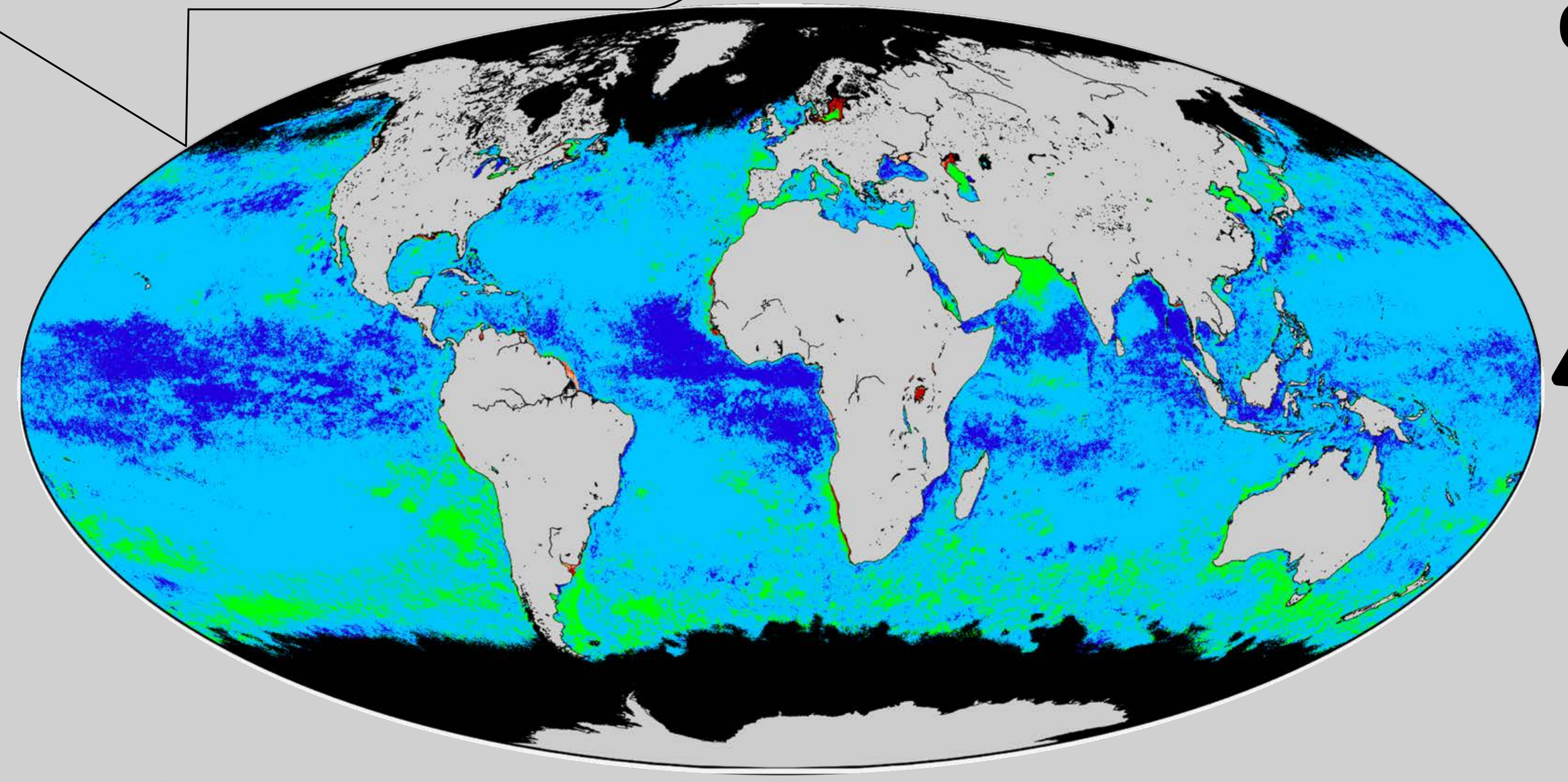
Composite of most recent 3-year of the analysis period

High ≥ 5 mg m^{-3} (mostly coastal regions); Low < 5 mg m^{-3}



Blue: CHL < 5 mg m^{-3} (open ocean mostly)
Red: CHL ≥ 5 mg m^{-3} (coastal waters mostly)

Polar regions with fewer observations are masked.



	D	N	I
H	HD	HN	HI
L	LD	LN	LI

NEAT-based Eutrophication Assessment → CHL Trend, CHL Level

H: High, L: Low

Terauchi et al. (2014, 2018)

Eutrophic potential waters: HD, HN and HI
Eutrophication potential waters: HI and LI

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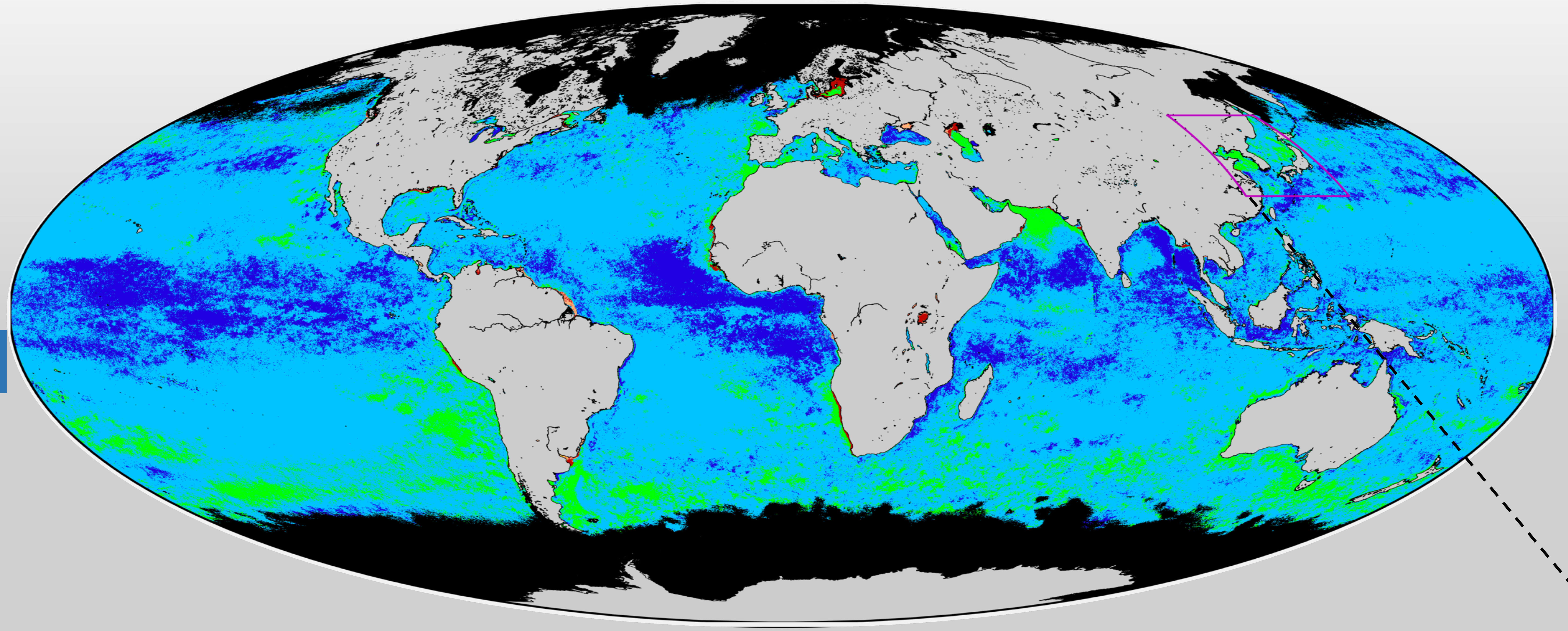
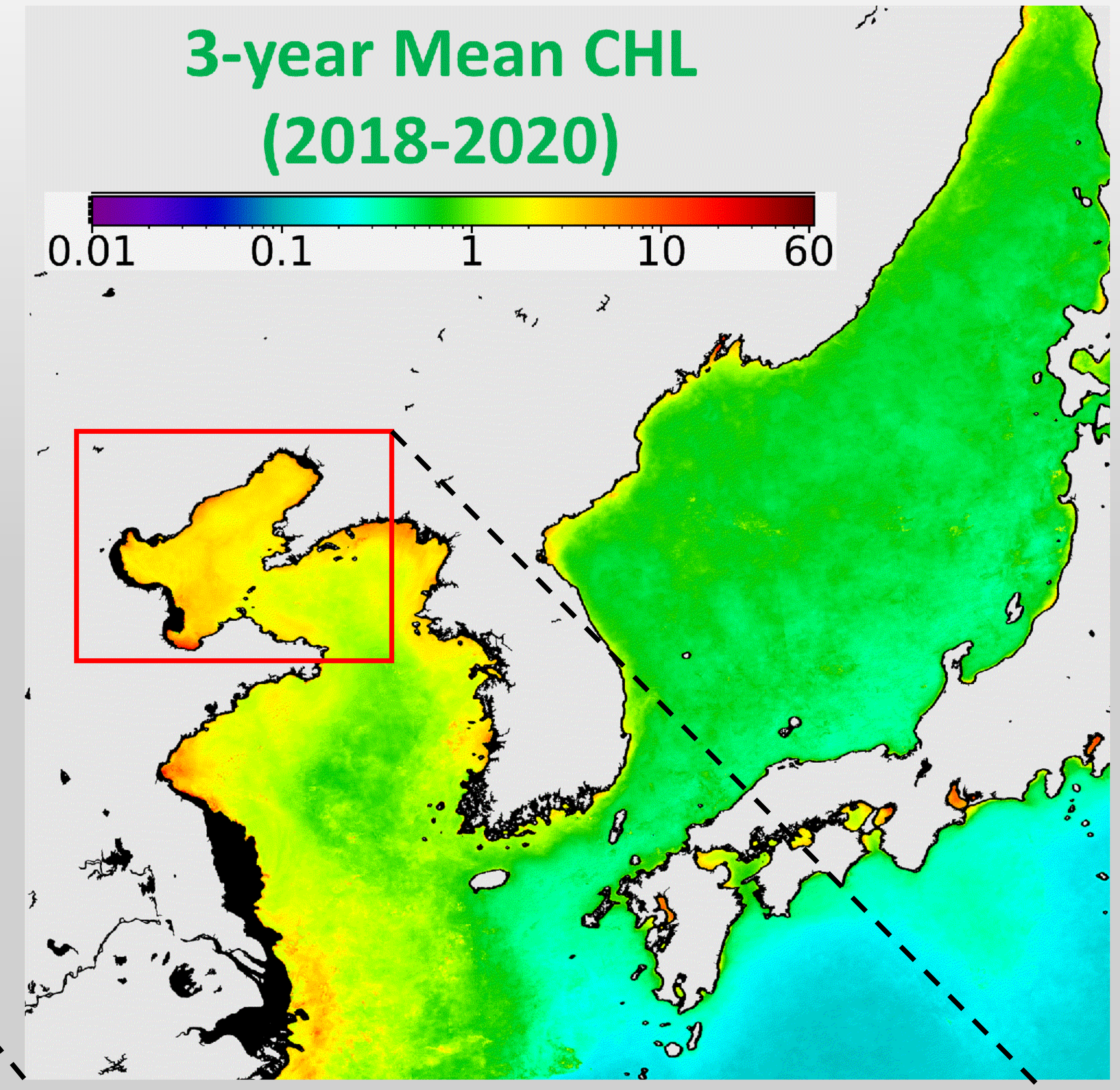
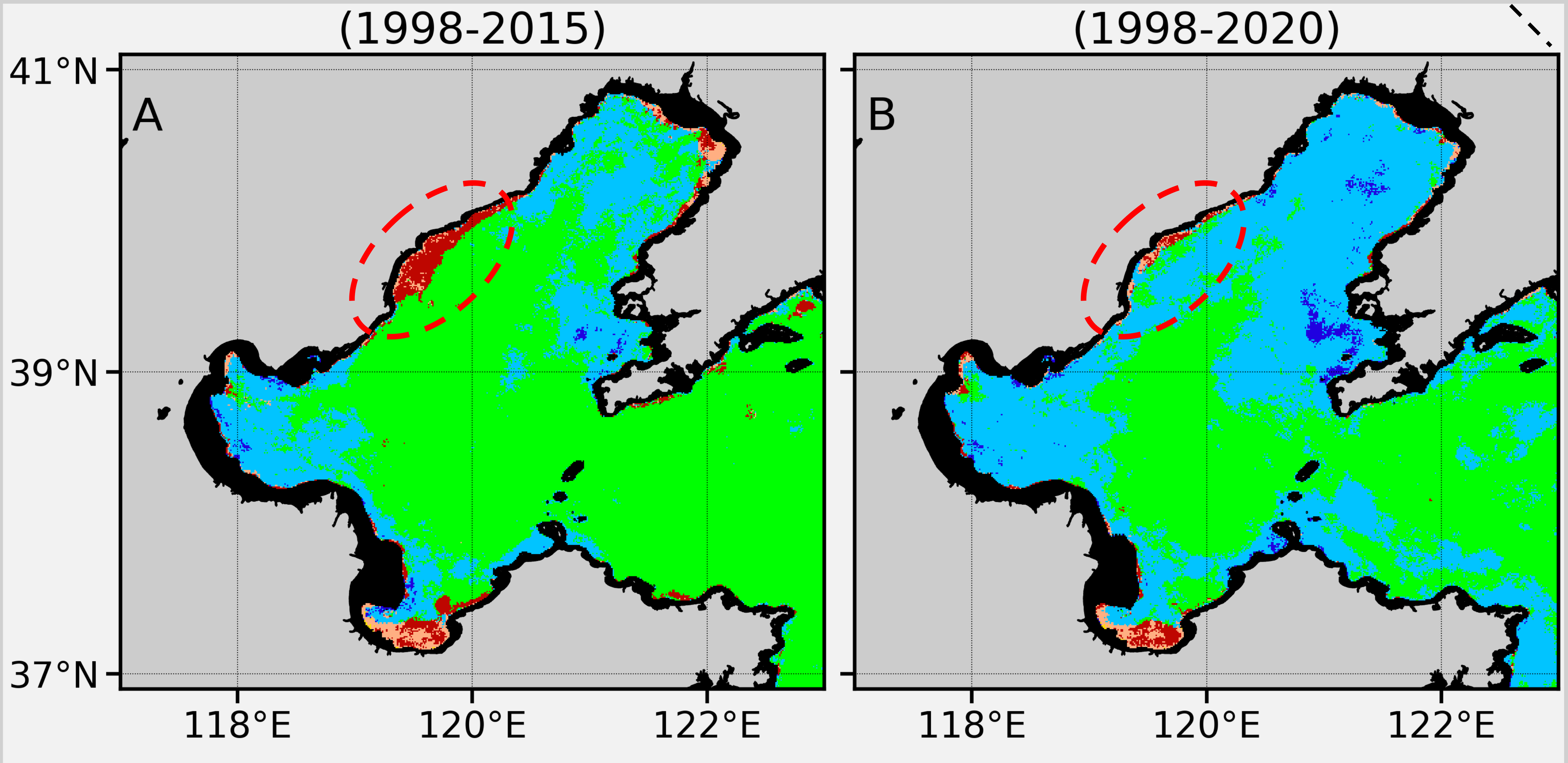
NEAT-based eutrophication assessment: NOWPAP region





- In the NOWPAP region, a finer resolution data (1 km) that combines SeaWiFS, MERIS and MODIS-Aqua derived CHL is used. This dataset covers the period from 1998 to 2020. West of 127 E, the CHL estimates are based on the YOC algorithm (Siswanto et al. 2011; Terauchi et al. 2018).
- Figure A (1998-2015) and B (1998-2020) show a comparative eutrophication assessment in the Bohai Sea in two different periods.
- Dashed ellipses highlight the decrease in eutrophication potential waters (LI and HI).
- The decrease in these patches can be linked to control measures implemented in China to reduce nutrient emissions from terrestrial sources (Wang et at. 2018; Zheng et al. 2018) in addition to other oceanographic and climatic factors (Zhai et al. 2021).



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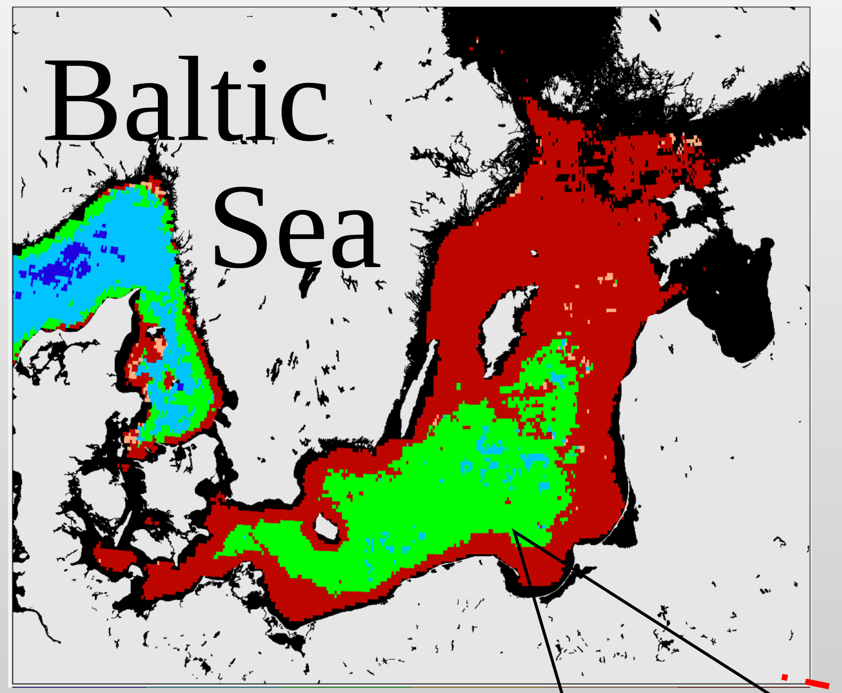
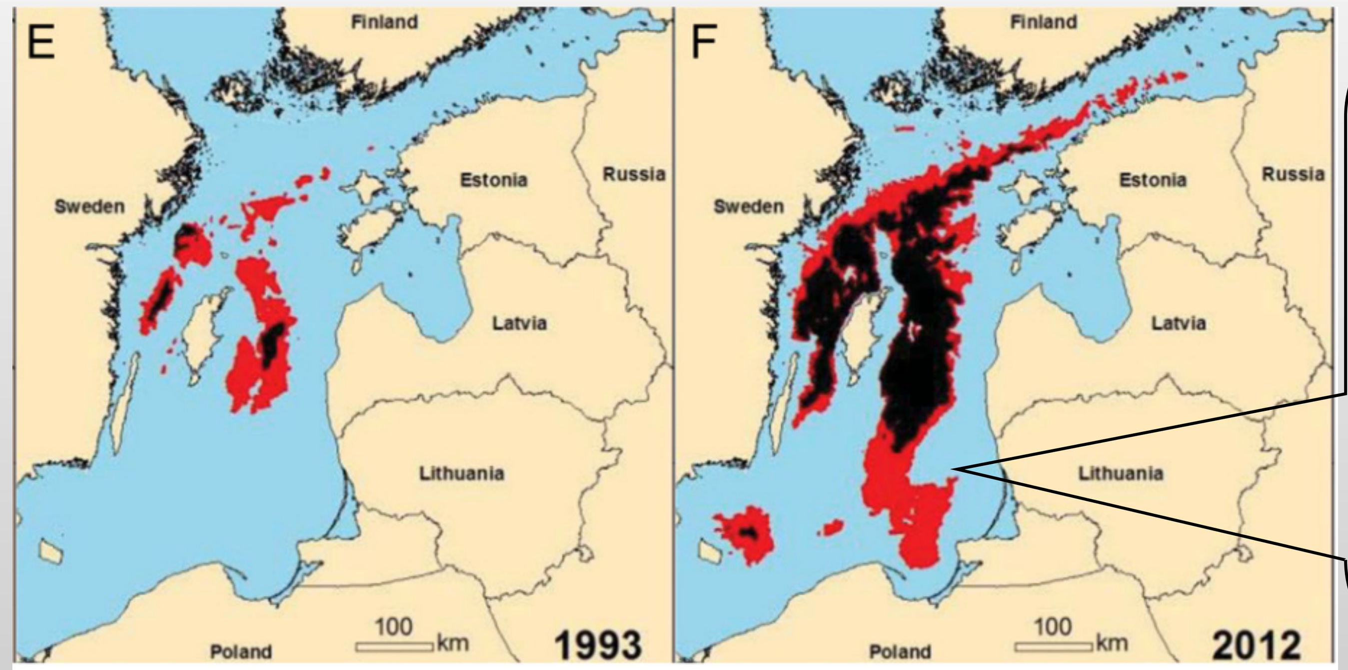
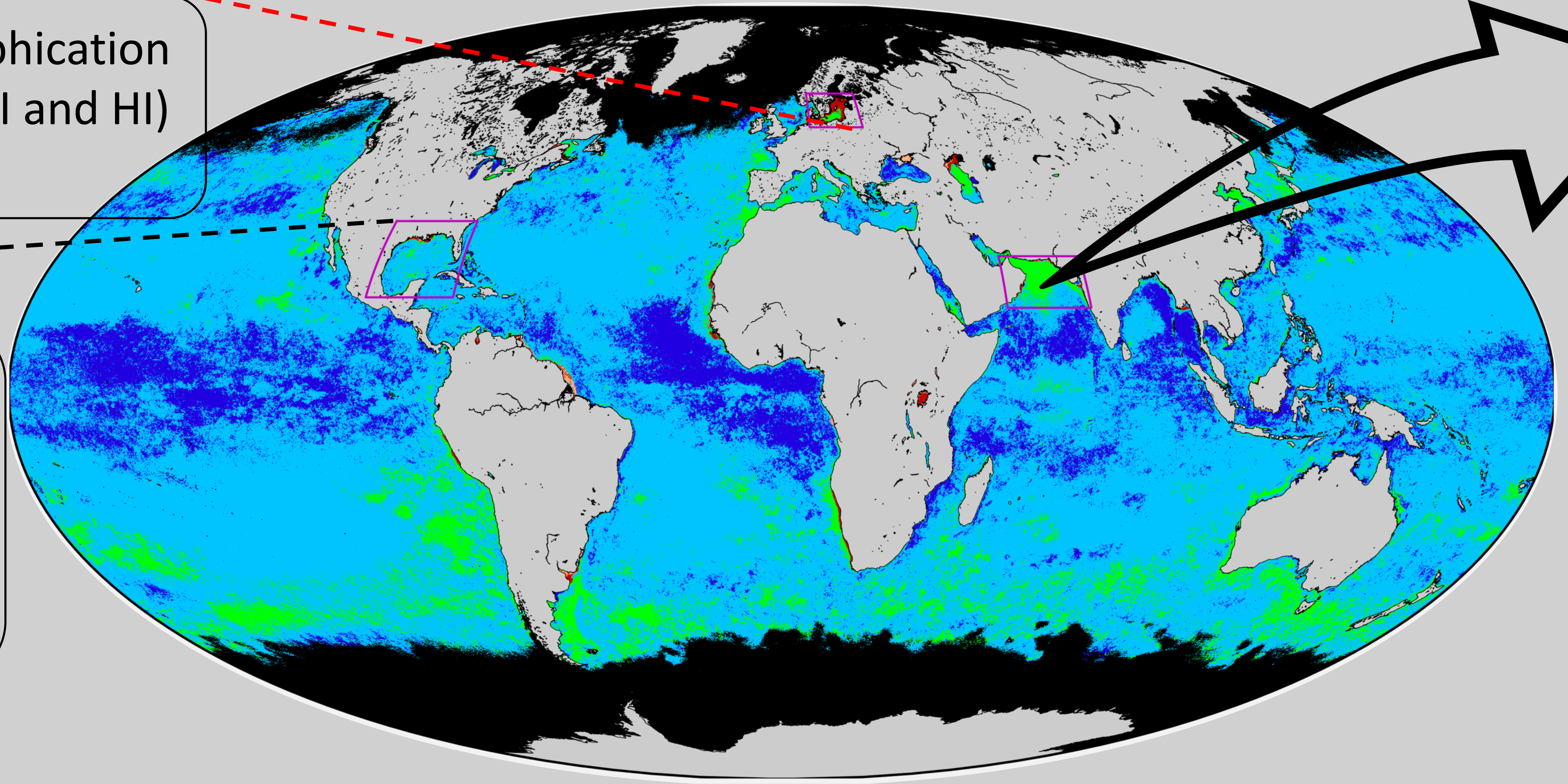
NEAT-based eutrophication assessment: examples from known eutrophication areas

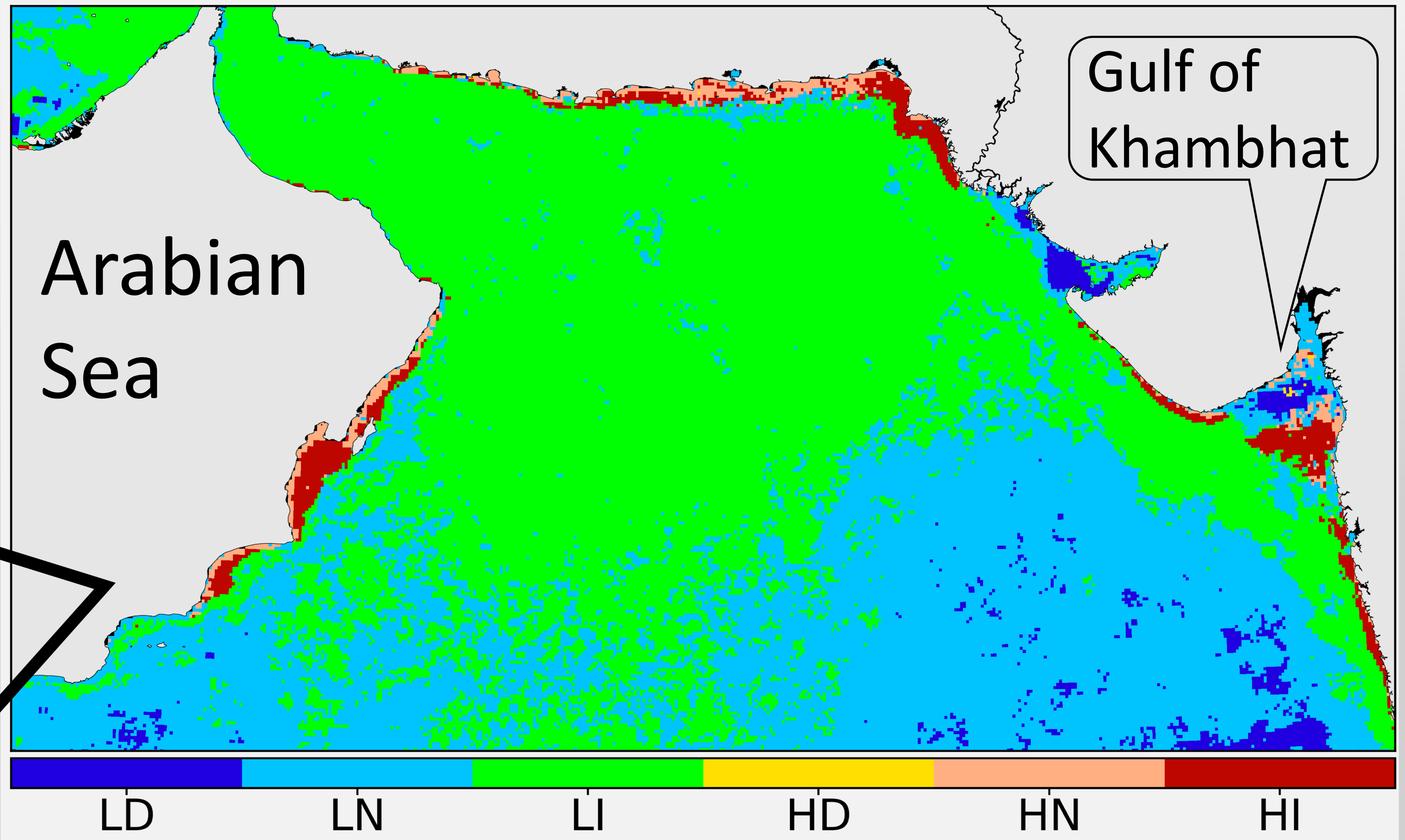


NEAT-based eutrophication potential waters (LI and HI) in the Baltic Sea

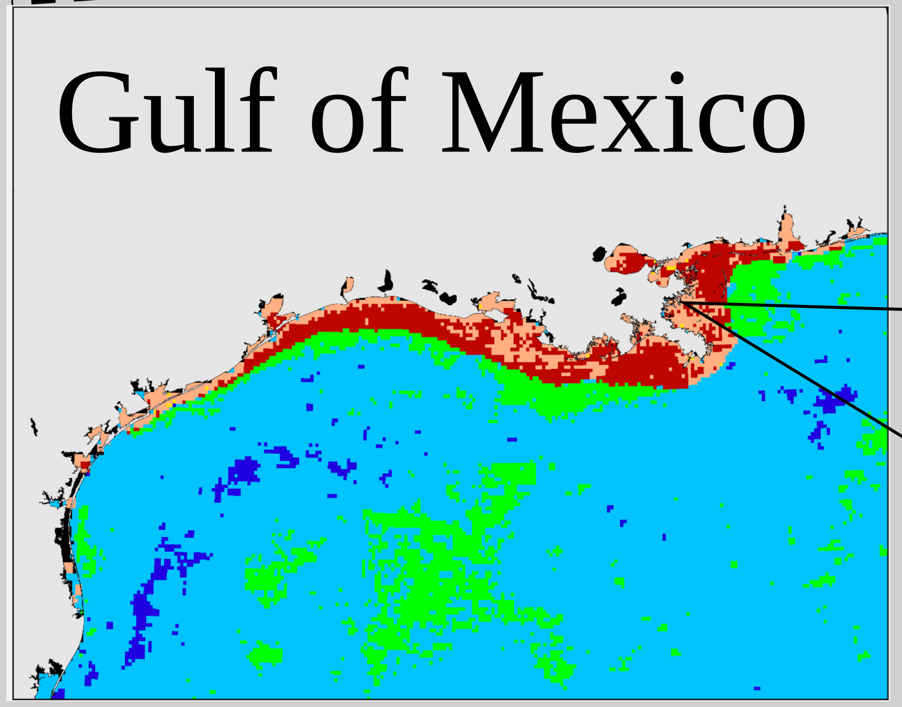


Spatial distributions of bottom hypoxia and anoxia over time. **Red**: bottom oxygen <2 mg L^{-1}, **Black**: bottom oxygen <0 mg L^{-1} for 1993 (E) and 2012 (F). (Carstensen et al. 2014)



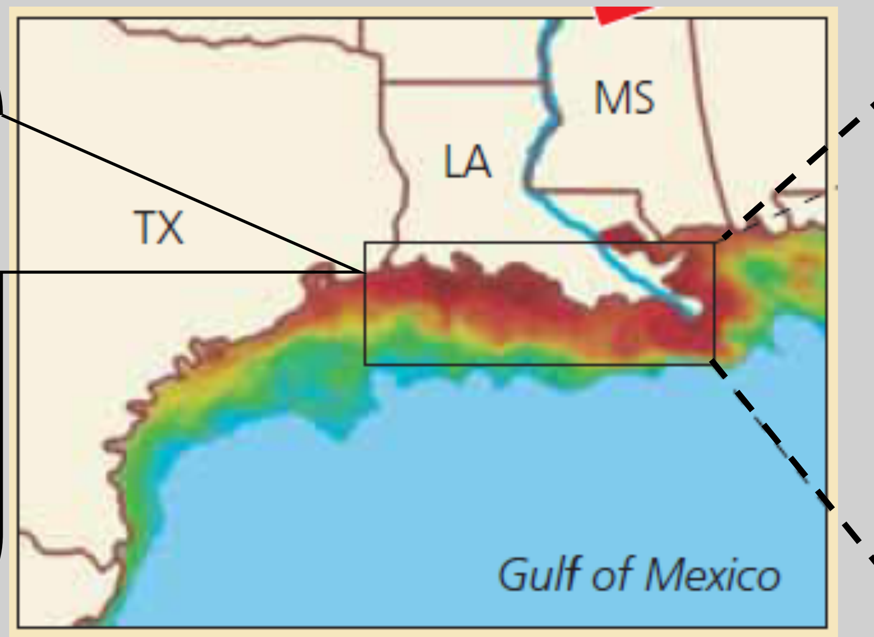


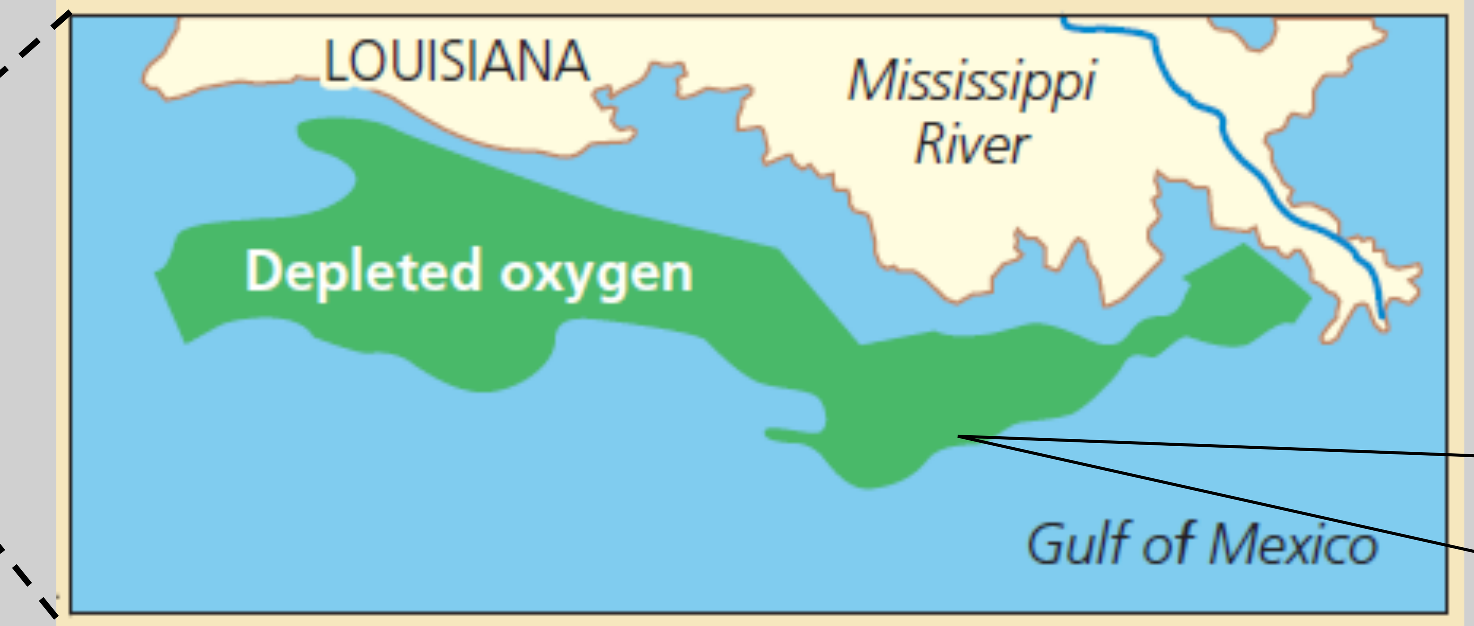
- Eutrophication potential waters (LI and HI) distributed along the coastal regions in the Arabian Sea.
- Also, most of the open ocean is characterised by increasing CHL concentrations.
- In the Gulf of Khambhat the growth and distribution of phytoplankton is highly influenced by freshwater inflow characterised by high anthropogenic nutrient load (George et al. 2012).



NEAT-based eutrophication potential waters (LI and HI) in the Gulf of Mexico

A satellite image during summer 2006 showing high concentrations of phytoplankton in reds and greens.
(Miller & Spoolman, 2014)





The world's third largest oxygen depleted zone (after the Baltic Sea and the northwestern Black Sea). Oxygen < 2 mg L^{-1}.
(Miller & Spoolman, 2014)

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- In this study we introduced a robust satellite-based eutrophication screening tool (NEAT) that synthesizes in a single map the information of CHL levels and trends to generates a map eutrophication potential.
- When applied to the Bohai Sea, in the NOWPAP region, the NEAT revealed a significant shrinkage of eutrophication potential waters (Li and HI) between two different periods.
- In other select areas, such as the Gulf of Mexico and the Baltic Sea the NEAT successfully identified the eutrophication potential areas associated with severe symptoms of eutrophication including the well-known "dead-zones".
- In the Arabian Sea, several eutrophication potential coastal waters were also identified. In some of these coastal areas (e.g., Gulf of Khambhat) reports indicate anthropogenic nutrient load pressures to the adjacent coastal waters.
- The NEAT is a preliminary eutrophication assessment tool solely based on satellite-derived CHL. It provides the initial screening of eutrophication for prioritized actions with potential to be used as a global index of eutrophication.
- Progress is being made for the development of a global assessment tool based on the NEAT. The Group on Earth Observations and the Google Earth Engine are supporting this development. Once the tool becomes ready, a rapid and inexpensive eutrophication assessment can be performed in any part of the global ocean.

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