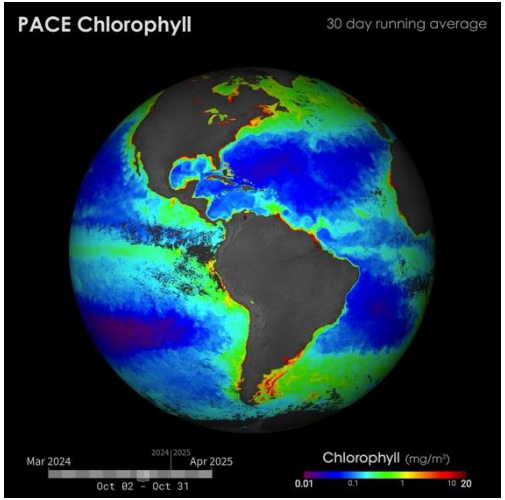
Using long-term Satellite Ocean Color Records for detecting Persistent Ocean Color trends

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21 January 2026

About me

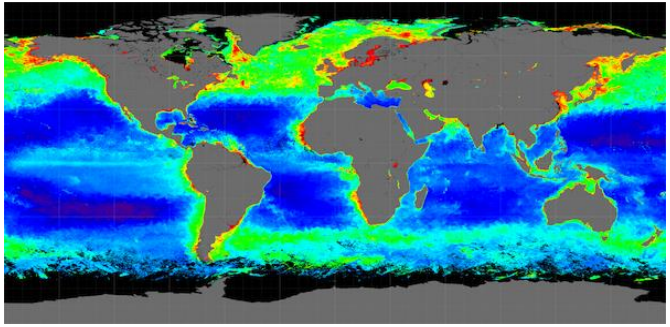




- I am Myung-Sook (Jina) Park, a Principal Research Scientist at the Korea Institute of Ocean Science & Technology (KIOST),
  working at the Korea Ocean Satellite Center.
- My work focuses on radiometric calibration, GOCI-II chlorophyll-a algorithm development, and long-term ocean color applications for climate research.
- I received my Ph.D. from Seoul National University and was a Visiting Research Scientist at NASA Goddard Space Flight Center (2022–2023).
- I am currently involved in a Korea–U.S. Joint Partnership Agreement (JPA) project with several NOAA scientists.

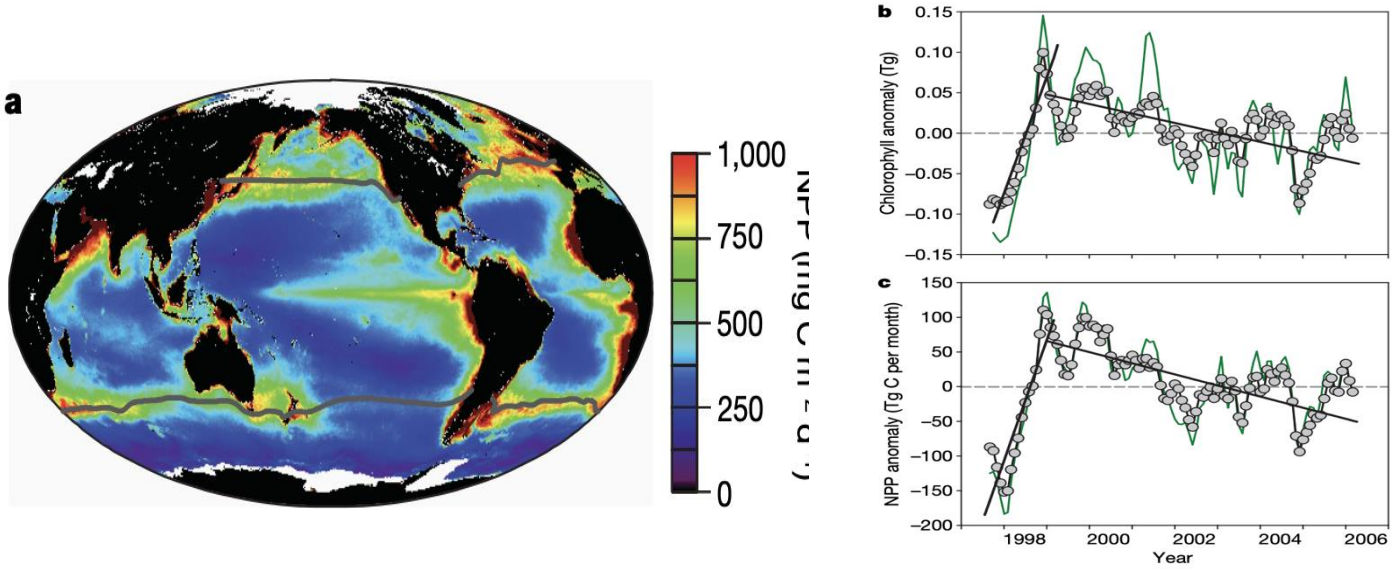
Importance of long-term ocean color data

- Marine phytoplankton are tiny plants but widely spread throughout Earth's global oceans (70%), which is the most critical creature in climate change by absorbing CO_2 in the atmosphere.
- Under global warming, quantifying changes in phytoplankton biomass over a longer time scale is essential to examine the response of marine ecosystems, and climate feedback processes.
- Long-term ocean color data is the only way to examine the inter-annual variation in continuous ways in spatial and temporal domains.





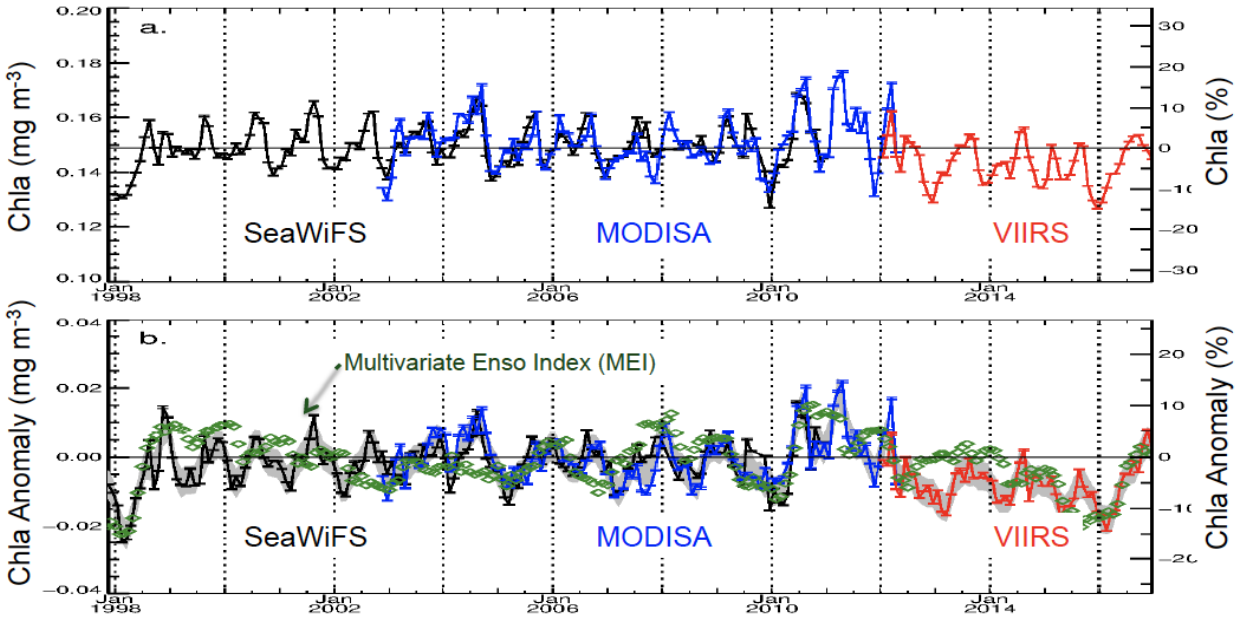
SeaWiFS observed multi-year variation of Chl-a and NPP



- The initial rise of monthly Chl-a anomaly: 1997 to 1999 El Nino to La Nina transition
- Global Chl-a concentration drop since 1999
- MEI cannot distinguish between natural and anthropogenic changes in climate forcing

Behrenfeld, M., O'Malley, R., Siegel, D. *et al.* Climate-driven trends in contemporary ocean productivity. *Nature* **444**, 752–755 (2006). https://doi.org/10.1038/nature05317

Multi-mission satellite ocean color data record (NASA&NOAA)



<NASA SeaWiFS-MODISA-VIIRS 일관성 조사>
(Franz et al. 2017)

Climate Signals in Ocean Color Emerge Within 20 Years

Cael et al., Nature (2023)

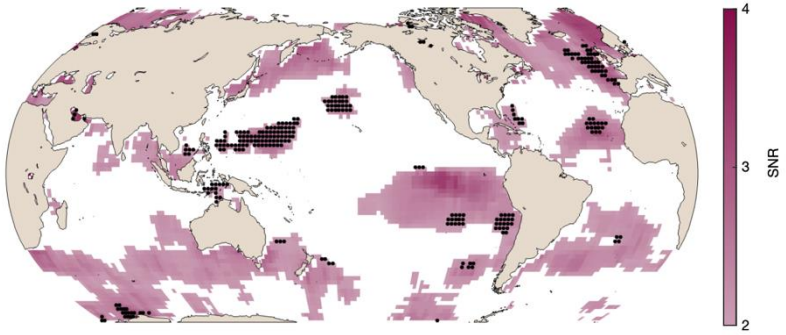


Fig. 1 | Map of locations where the ocean-colour trend SNR is higher than 2 for a 20-year annual time series. The intensity of the purple colour indicates the SNR. Black stippling indicates regions with significant trends in Chl as well (10% of the ocean). MODIS-Aqua data from July 2002 to June 2022.

- **Rrs detects climate-driven ocean color trends earlier a nd more extensively than** chlorophyll-a **(~40% of the o cean).**
- **Models confirm the observed Rrs trends are climate-d riven, not short-term variability.**

The Washington Post
Democracy Dies in Darkness

MORNING MIX

Climate change is changing the ocean's color — and fast, scientists say

By María Luisa Paúl

July 21, 2023 at 7:41 a.m. EDT



A Landsat 8 view of Brazil's Ilhabela archipelago and the surrounding suspended sediment, chlorophyll and colored dissolved organic matter patterns was collected on June 7, 2019. (NASA/Goddard Space Flight Center)

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Beachgoers around the world would probably give different descriptions of the ocean. Those gazing at the Caribbean Sea might describe clear or turquoise water, while those along Argentina's coastline, where major rivers empty into the Atlantic Ocean, could report a light brown, sediment-rich view.

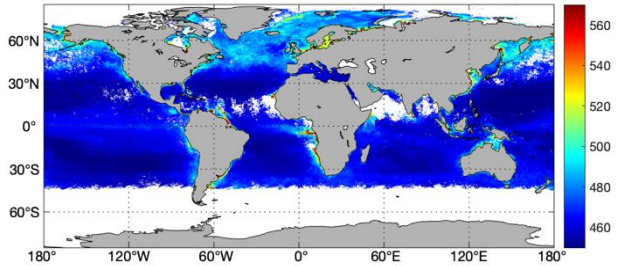
Questions

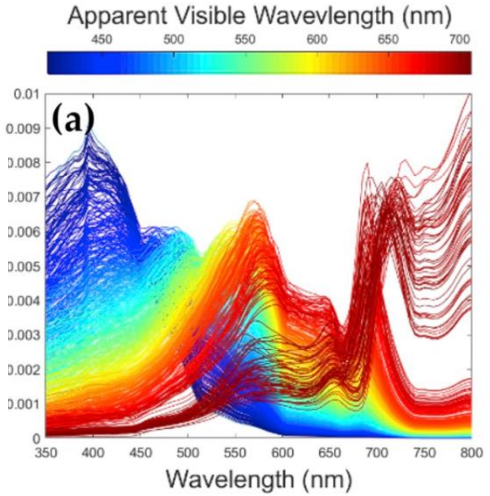
Q. How can we effectively diagnose climate change impacts on ocean ecosystems using long-term ocean color data?

✓ We suggest a new approach to analyzing the marine ecosystem changes in the multi-decadal ocean color data (OC-TraC)

Apparent Visible wavelength

$$AVW = \frac{\sum_{i=\lambda_1}^{\lambda_n} R_{rs}(\lambda_i)}{\sum_{i=\lambda_1}^{\lambda_n} \frac{R_{rs}(\lambda_i)}{\lambda_i}} = \left(\frac{\sum_{i=\lambda_1}^{\lambda_n} \lambda_i^{-1} R_{rs}(\lambda_i}{\sum_{i=\lambda_1}^{\lambda_n} R_{rs}(\lambda_i)} \right.$$





- An optical water classification index, a one-dimensional geophysical metric that is inherently correlated to R_{rs} spectral shape.
- A weighted harmonic mean of $R_{rs}(\lambda)$ wavelengths, constrained by the relative intensity of reflectance.

Vandermeulen, R. A., Mannino, A., Craig, S.E., Werdell, P.J., 2020: "150 shades of green: Using the full spectrum of remote sensing reflectance to elucidate color shifts in the ocean, " Remote Sensing of Environment, 247, 111900, doi: 10.1016/j.rse.2020.111900

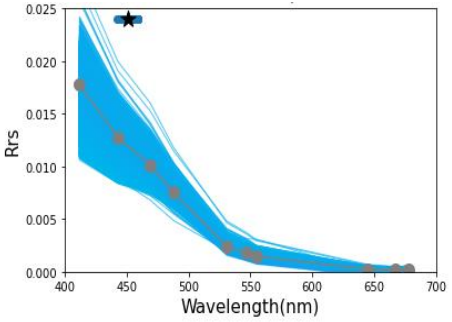
Research Objectives

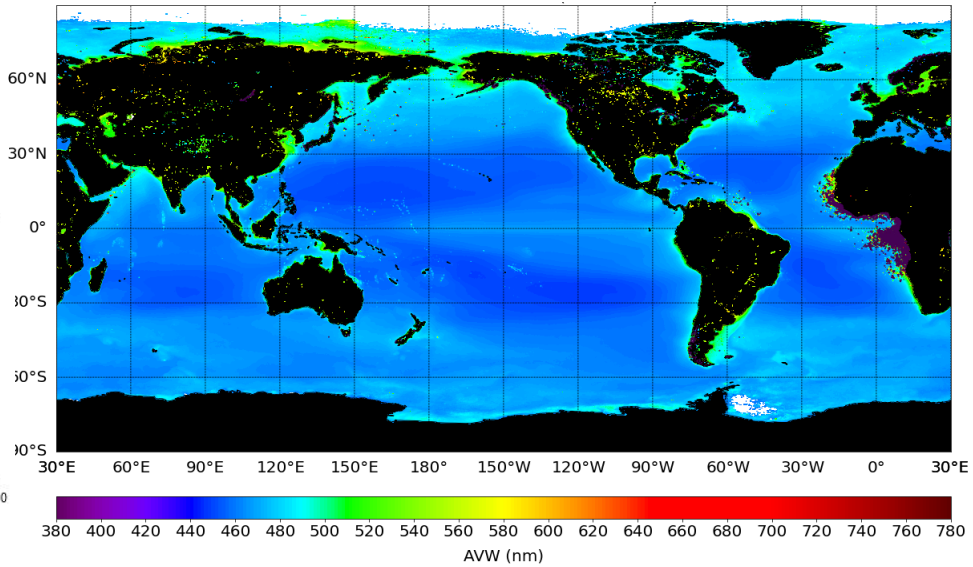
- Primary Objective
  - To detect and quantify climate-driven changes in global ocean bio-optical properties using the AVW index derived from long-term satellite Rrs observations.

- Specific Objectives
  - To characterize the spatial patterns and temporal evolution of ocean-color trends over the global ocean.
  - To distinguish climate-driven signals from short-term natural variability by comparing satellite observations with model simulations.

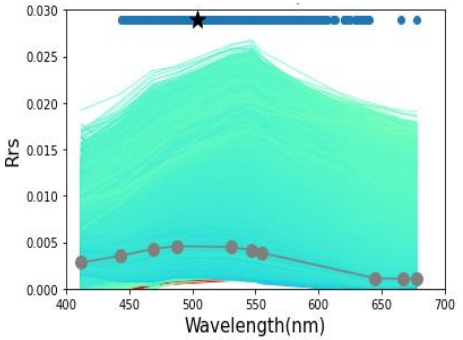
Global distribution of ocean color

Rrs spectrum Case I water (North Pacific)



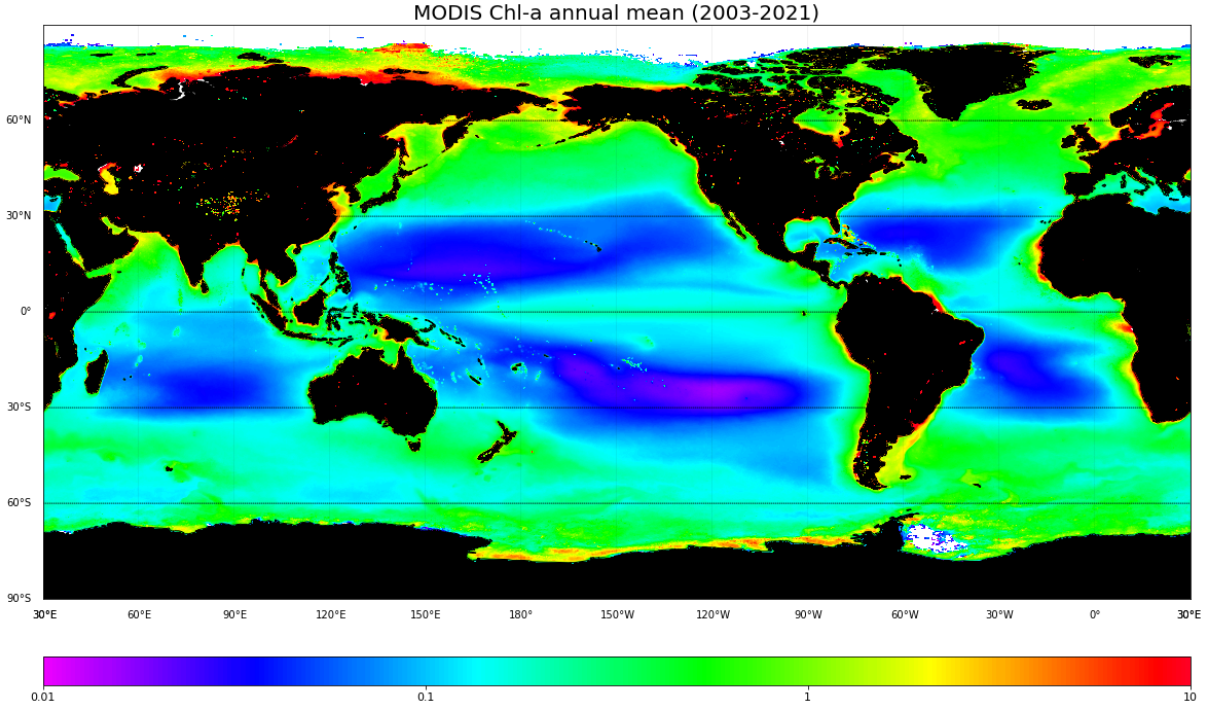


Rrs spectrum Case II water (Yellow Sea)



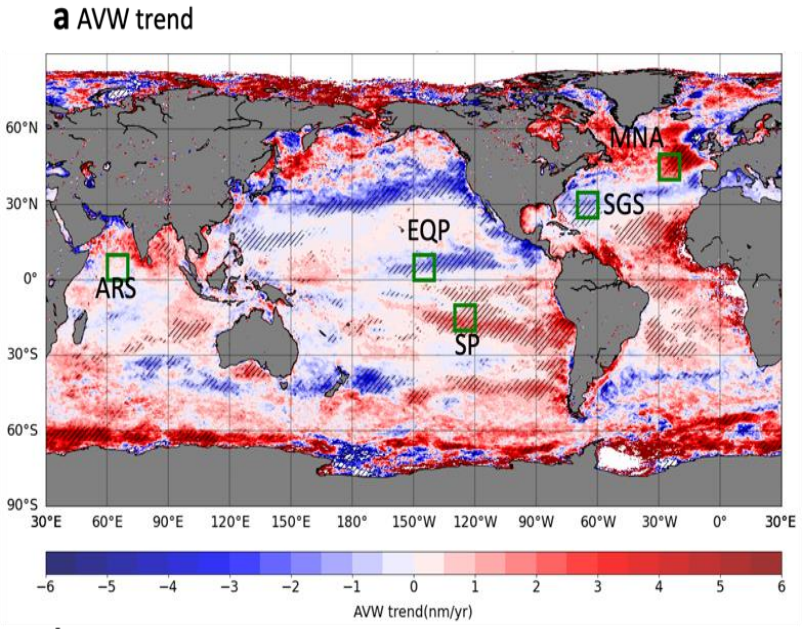
The clearest, blue-color waters occur in the center of five subtropical gyre circulations (NPSG, SPSG, IOSG, NASG, SASTG).

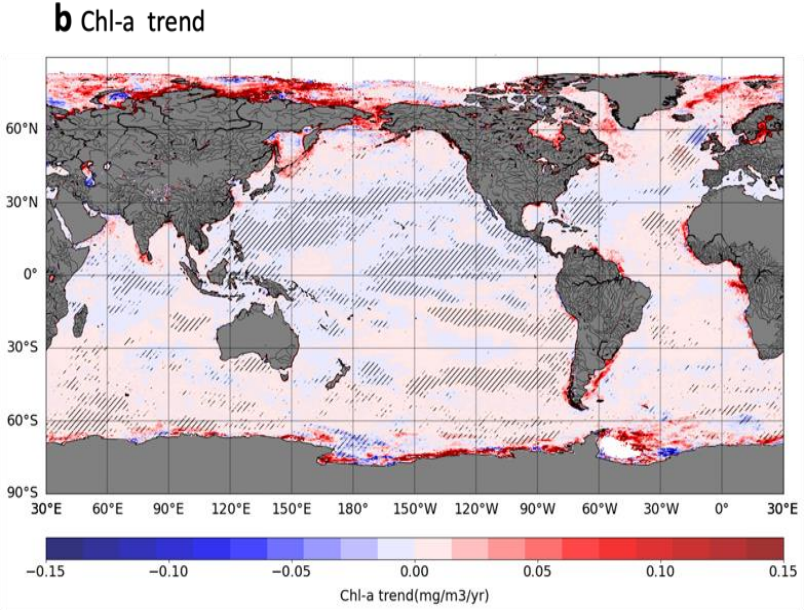
Distribution of Chl-a



The bluest ocean color is found where phytoplankton biomasses are minimized where nutrient supplies are extremely limited.

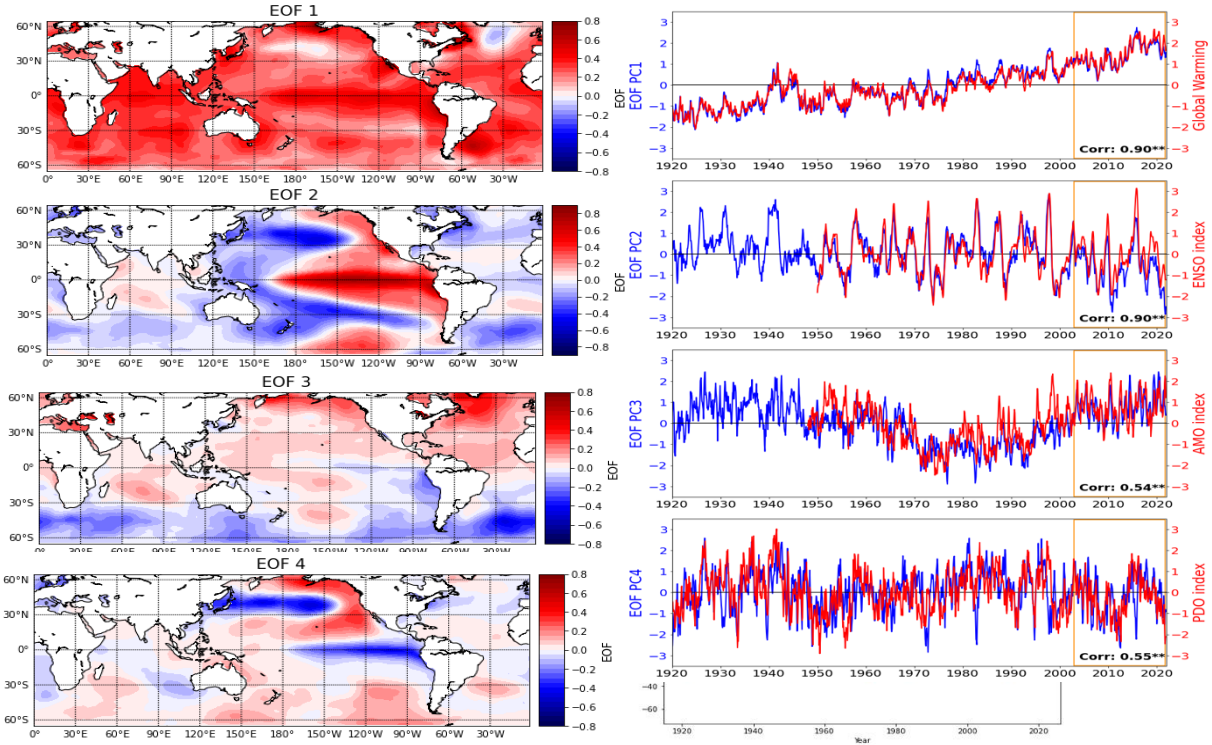
Typical Trends





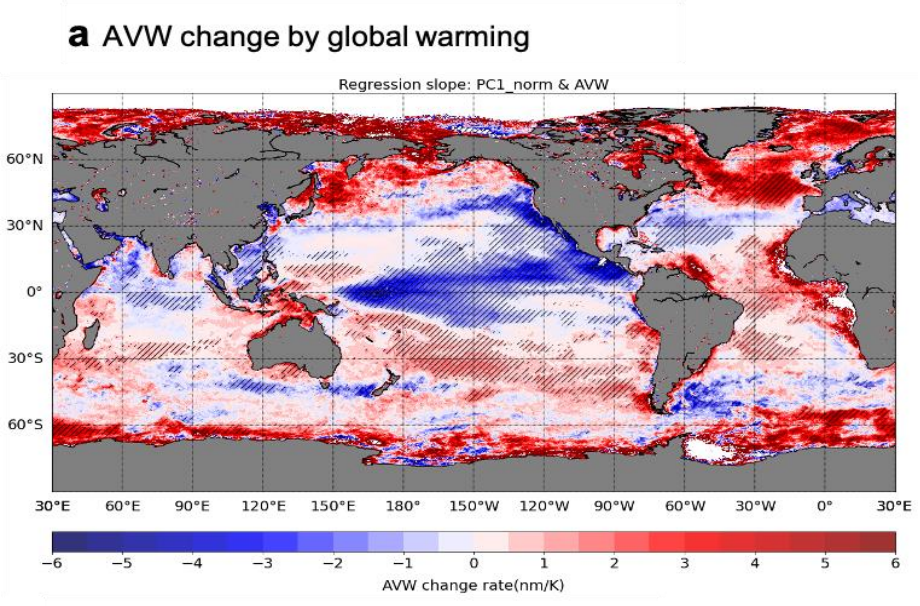
- Negative AVW trends correspond to ocean blueing, while positive trends indicate greening.
- Regions without significant trends are largely influenced by strong natural variability rather than a lack of climate impact.

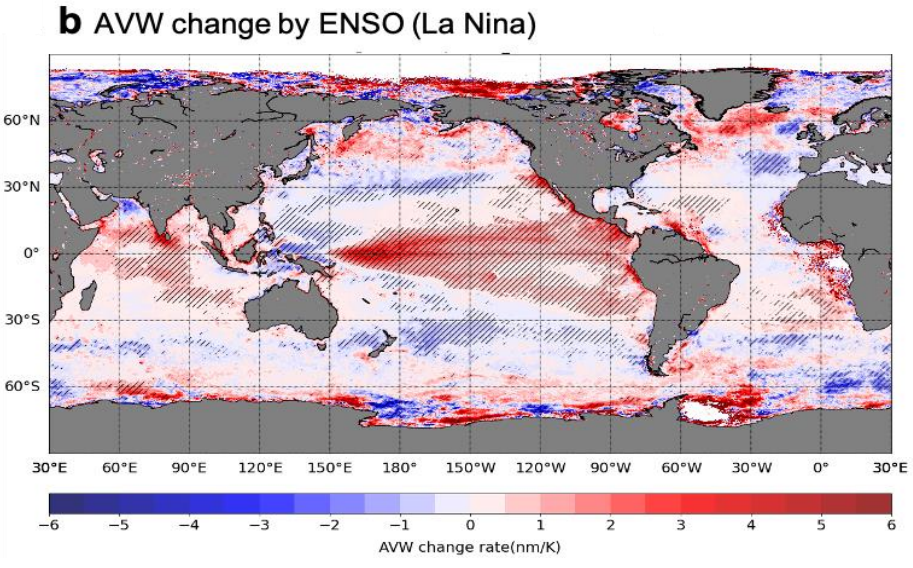
OC-TraC: Four major ocean physical modes



The key difference is that global warming produces a **persistent trend**, whereas ENSO represents **natural oscillations around zero**.

Anthropogenic Climate impacts masked by natural variability





Conclusion

- **“ Satellite observations reveal climate-driven optical shifts in ocean color beyond natural variability”**

- We use Ocean Physical Modes together with a satellite ocean color spectrum index to untangle ocean color change due to anthropogenic warming from natural variability.
- The analysis can detect the El Niño-Southern Oscillation signal in ocean color that has in fact masked the climate change trend.
- We suggest climate change enhances color contrast across the global ocean, as the water gets bluer in the tropical and mid-latitudes and greener in the high latitudes.
- This approach reveals a **persistent ocean color shift footprint**—toward bluer conditions in the tropics and greener at high latitudes—although the Atlantic Ocean exhibits greater regional variability.
- The contrasting color shifts suggest ocean desertification in the Pacific and Atlantic subtropical oceans, and more productive high-latitude oceans, with likely impacts on ecosystems and fisheries.

How Blue Is Our Planet Changing?

- The iconic “Blue Marble” image, captured in 1972 by the Apollo 1 7 mission.



Ocean color satellite data has become a quantitative indicator of climate change

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Thank you!

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Satellite Ocean Color * Climate Applications
Open to collaboration

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