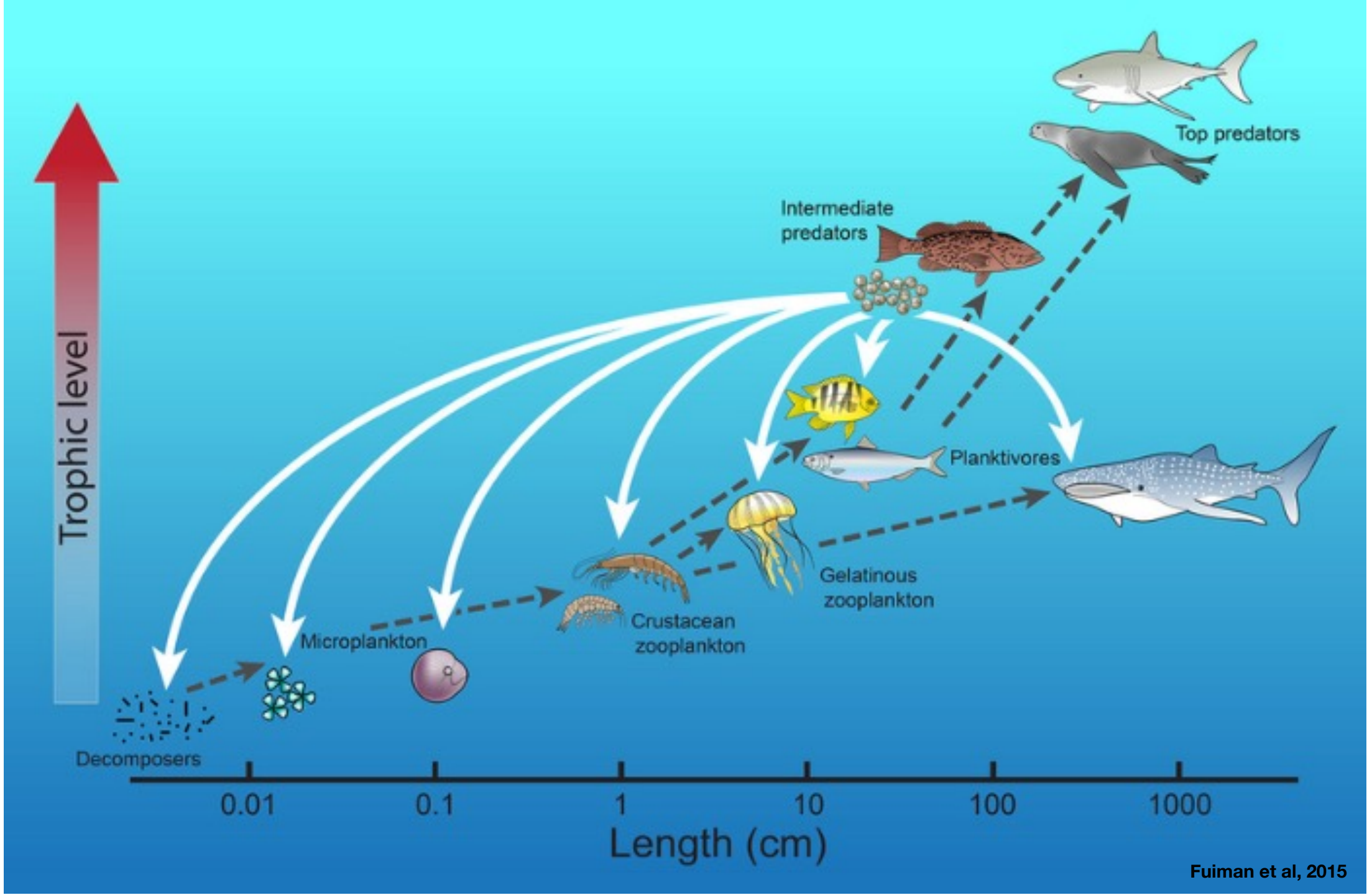
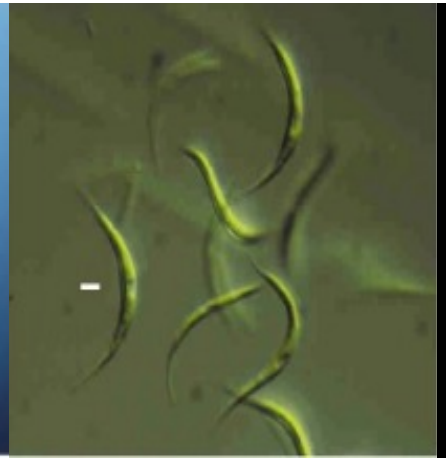
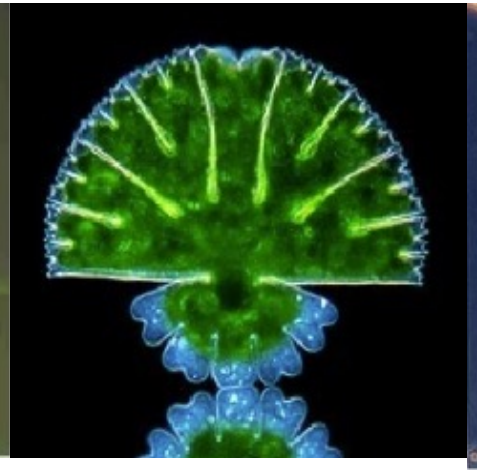
Fluid dynamics:
Life engine in the Ocean

Marina Lévy
LOCEAN-IPSL

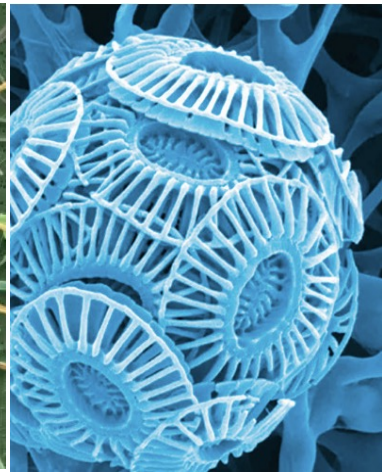
30 juin 2025

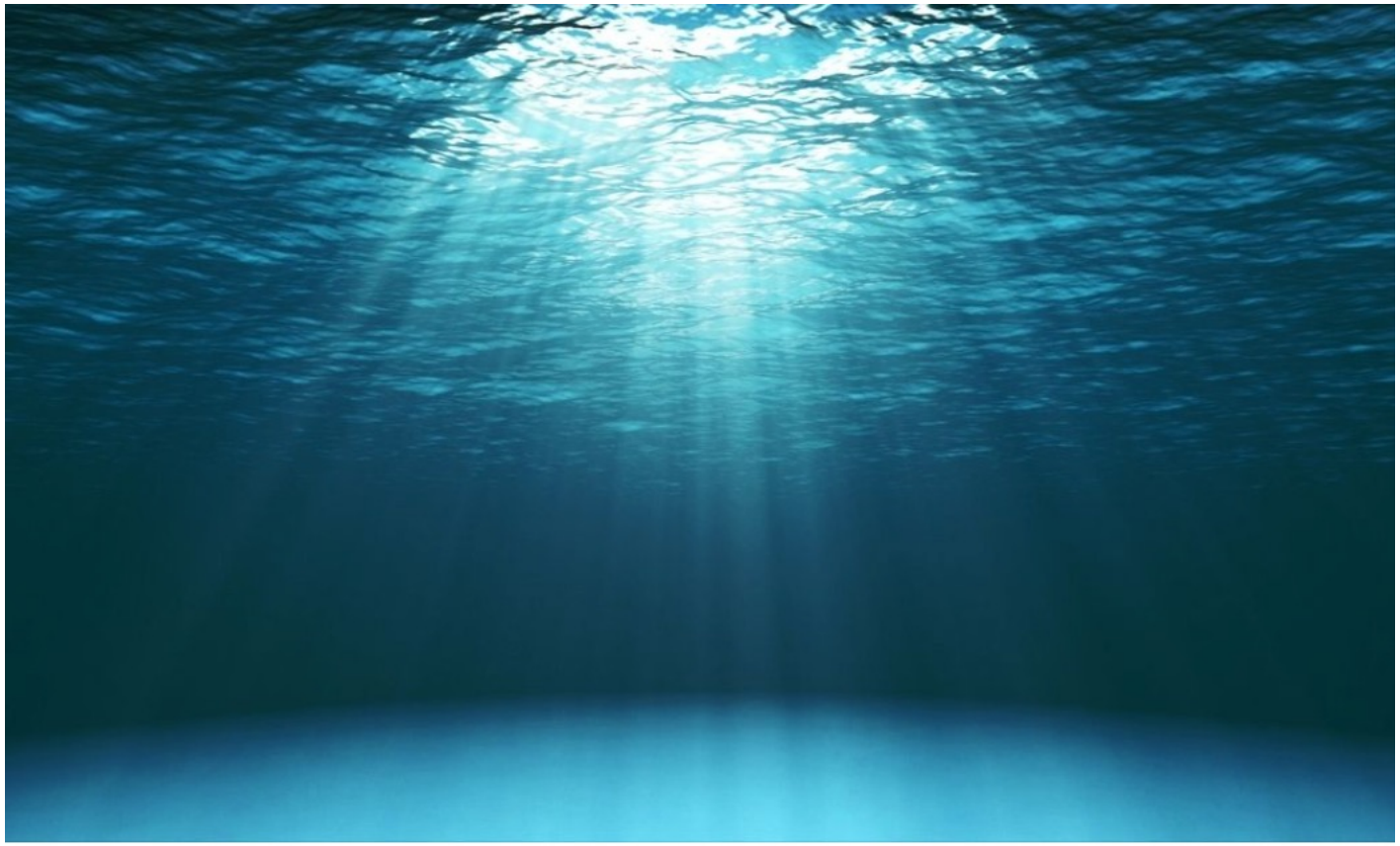


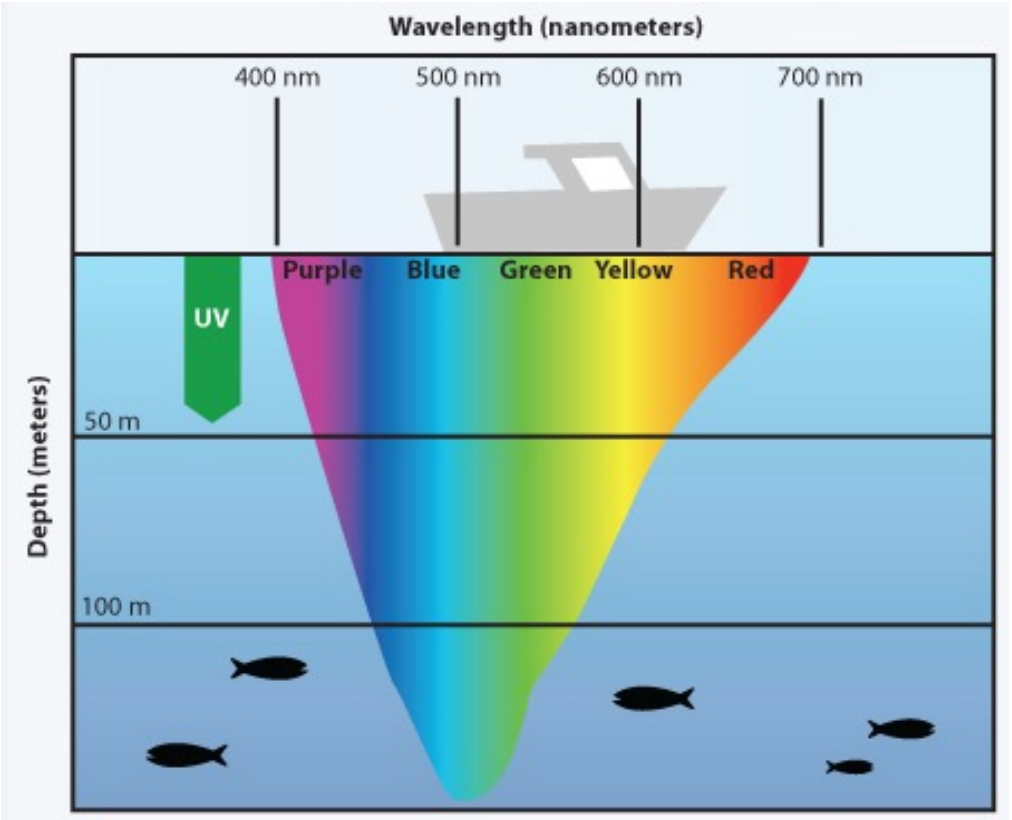
Fuiman et al, 2015

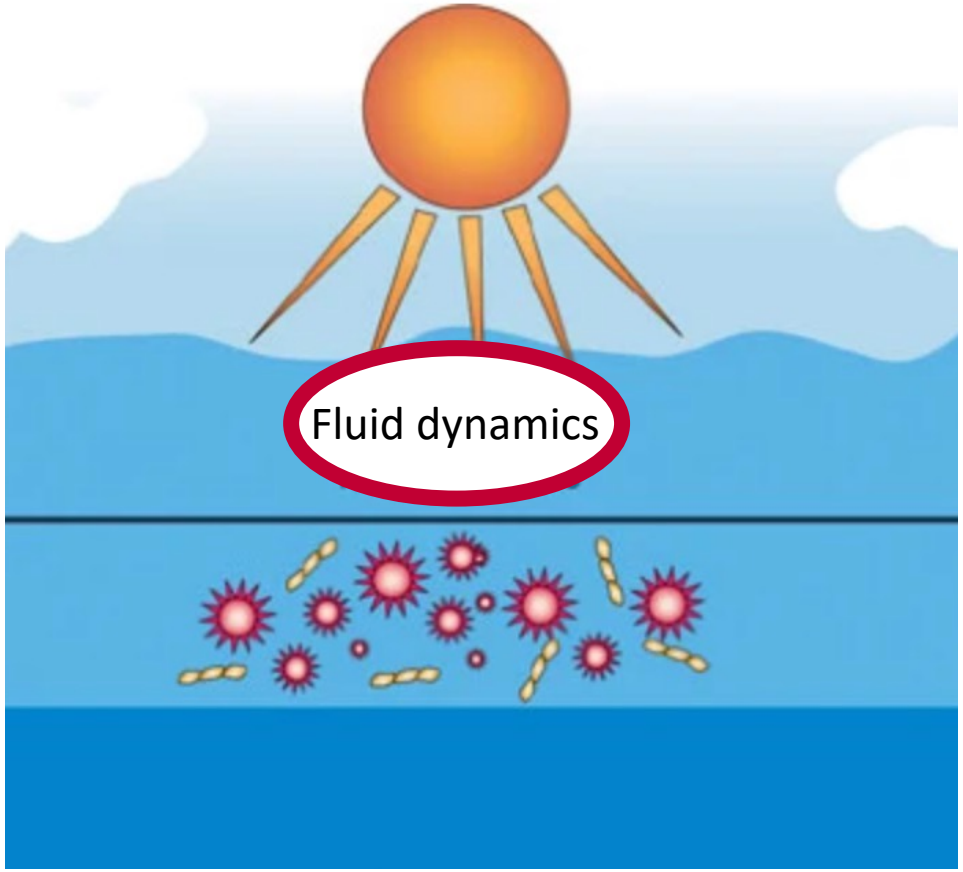
© Jan Rines

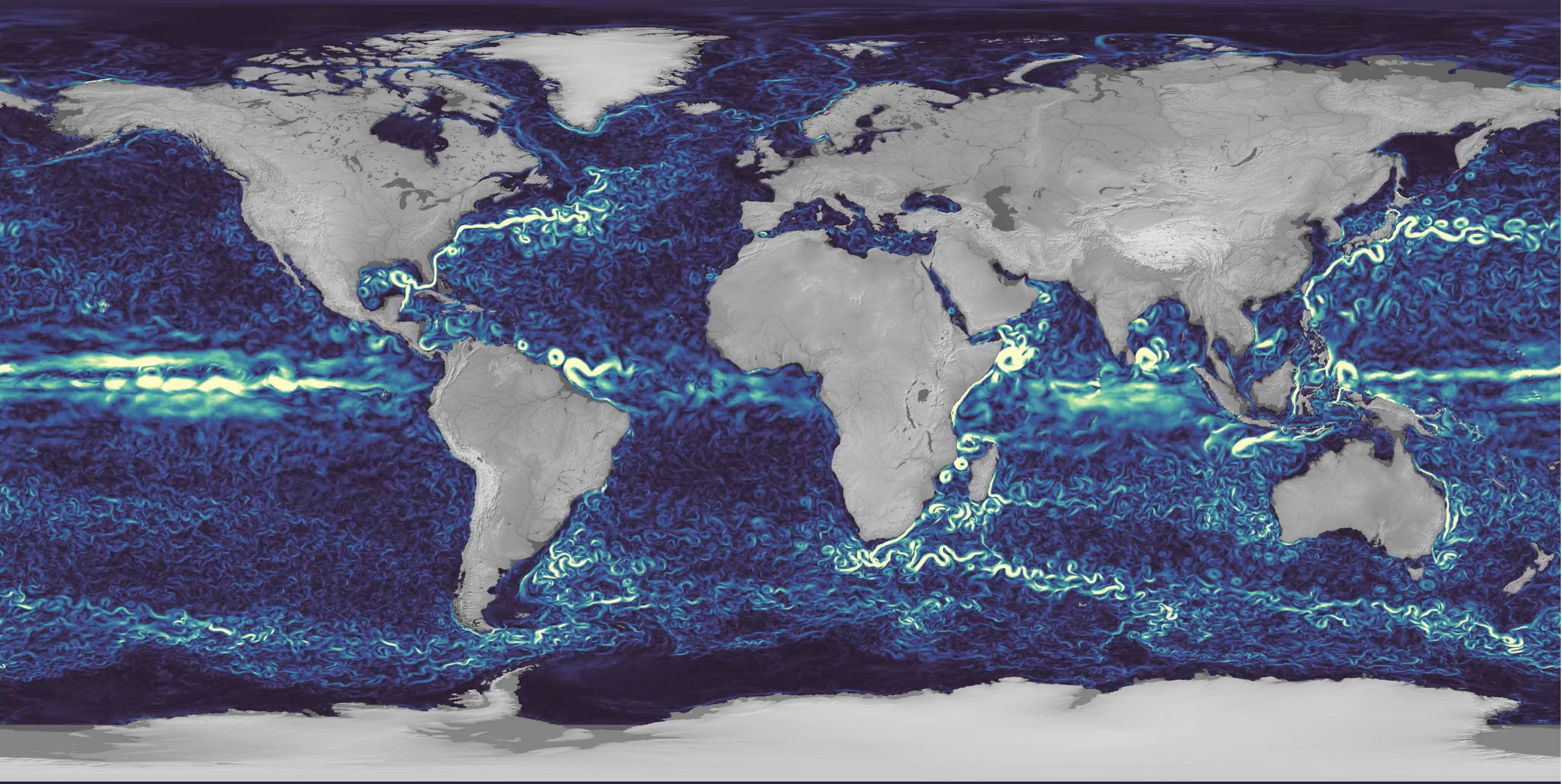




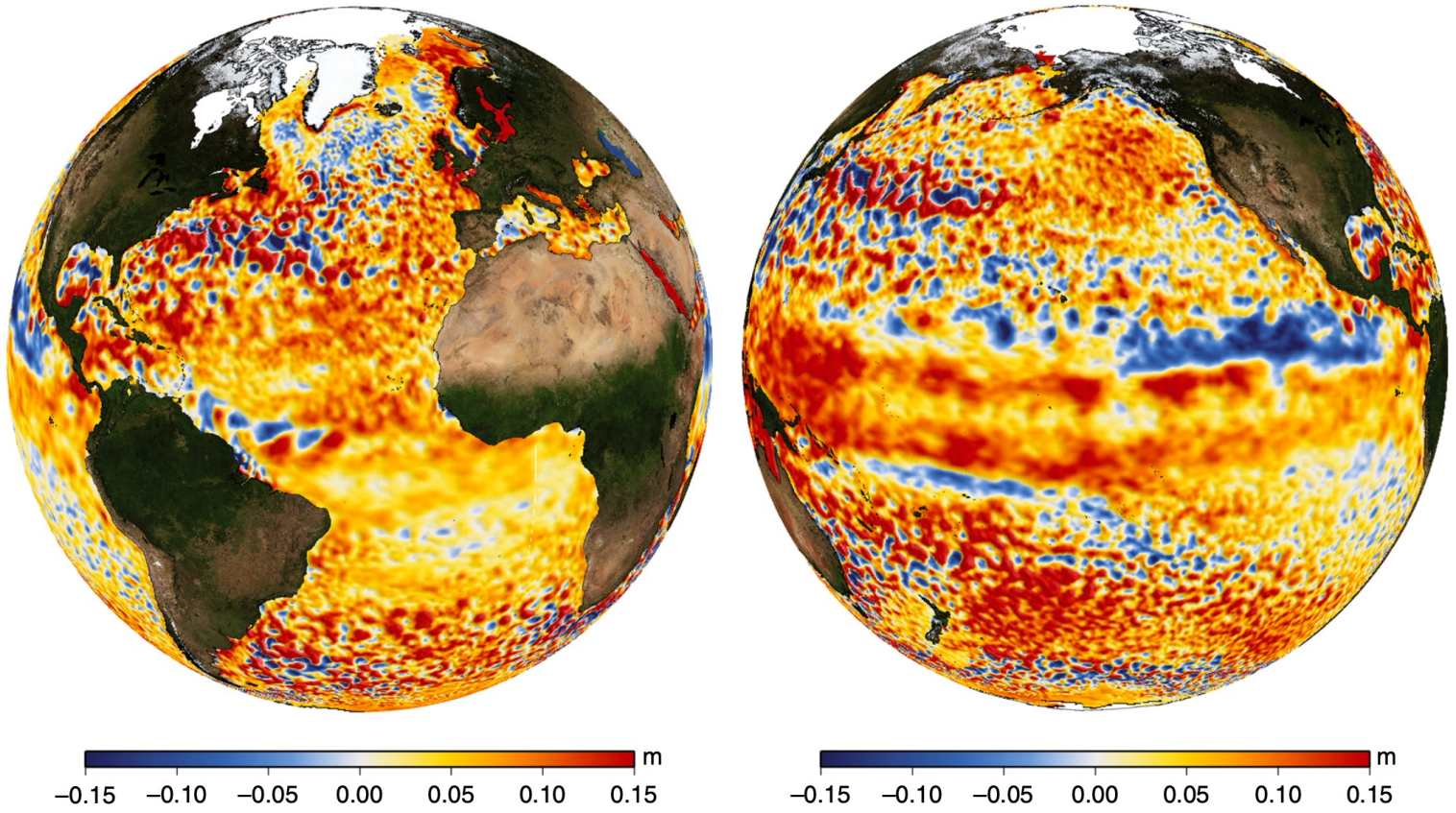

Wavelength (nanometers)
400 nm
500 nm
600 nm
700 nm
Purple
Blue
Green
Yellow
Red
UV
Depth (meters)
50 m
100 m

z



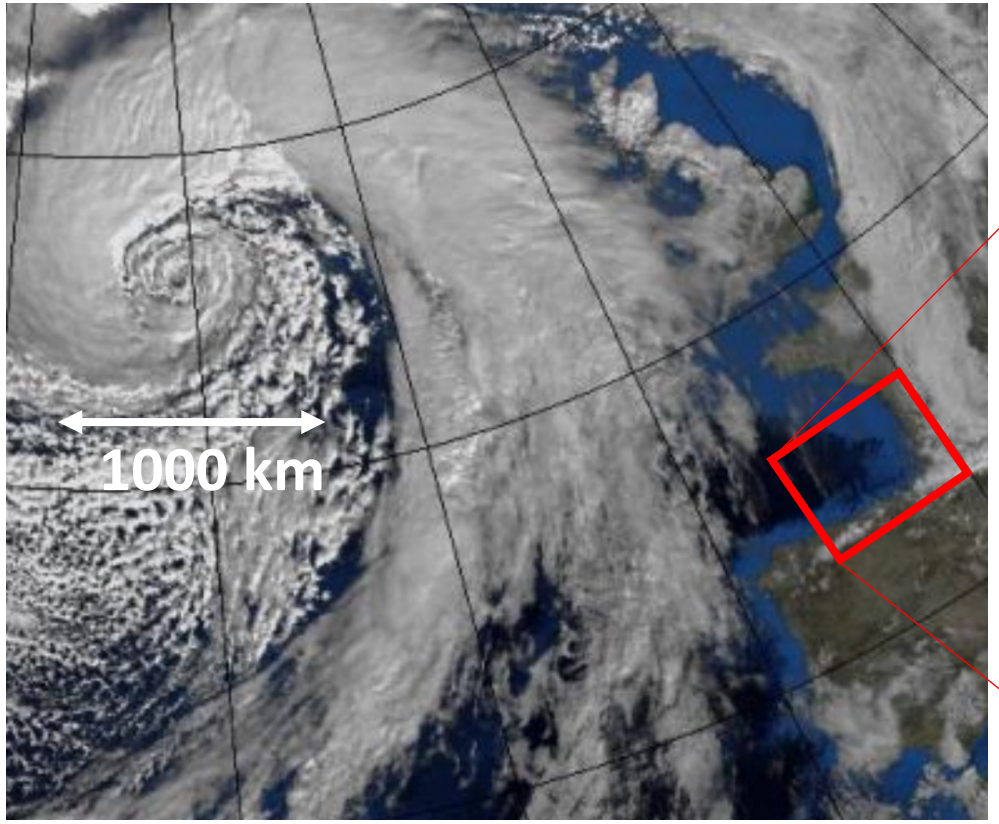


Ocean mesoscale eddies

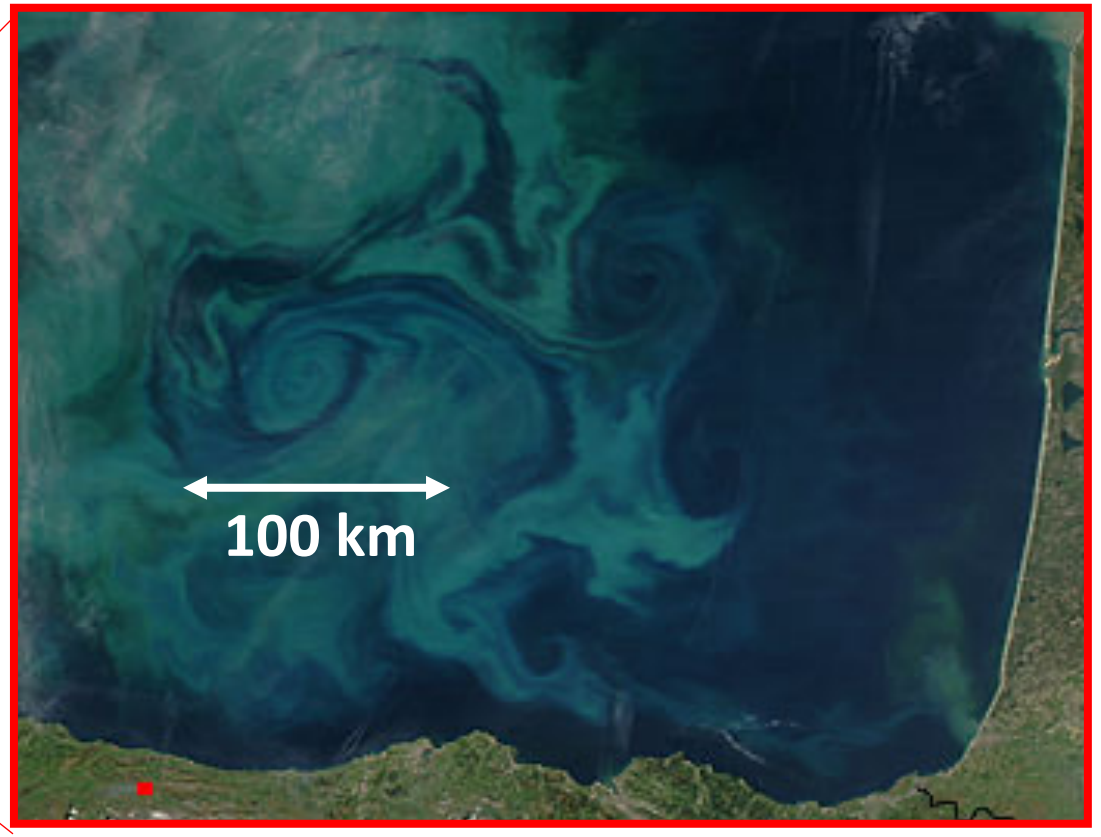


Sea-level Anomaly

Ocean mesoscale eddies

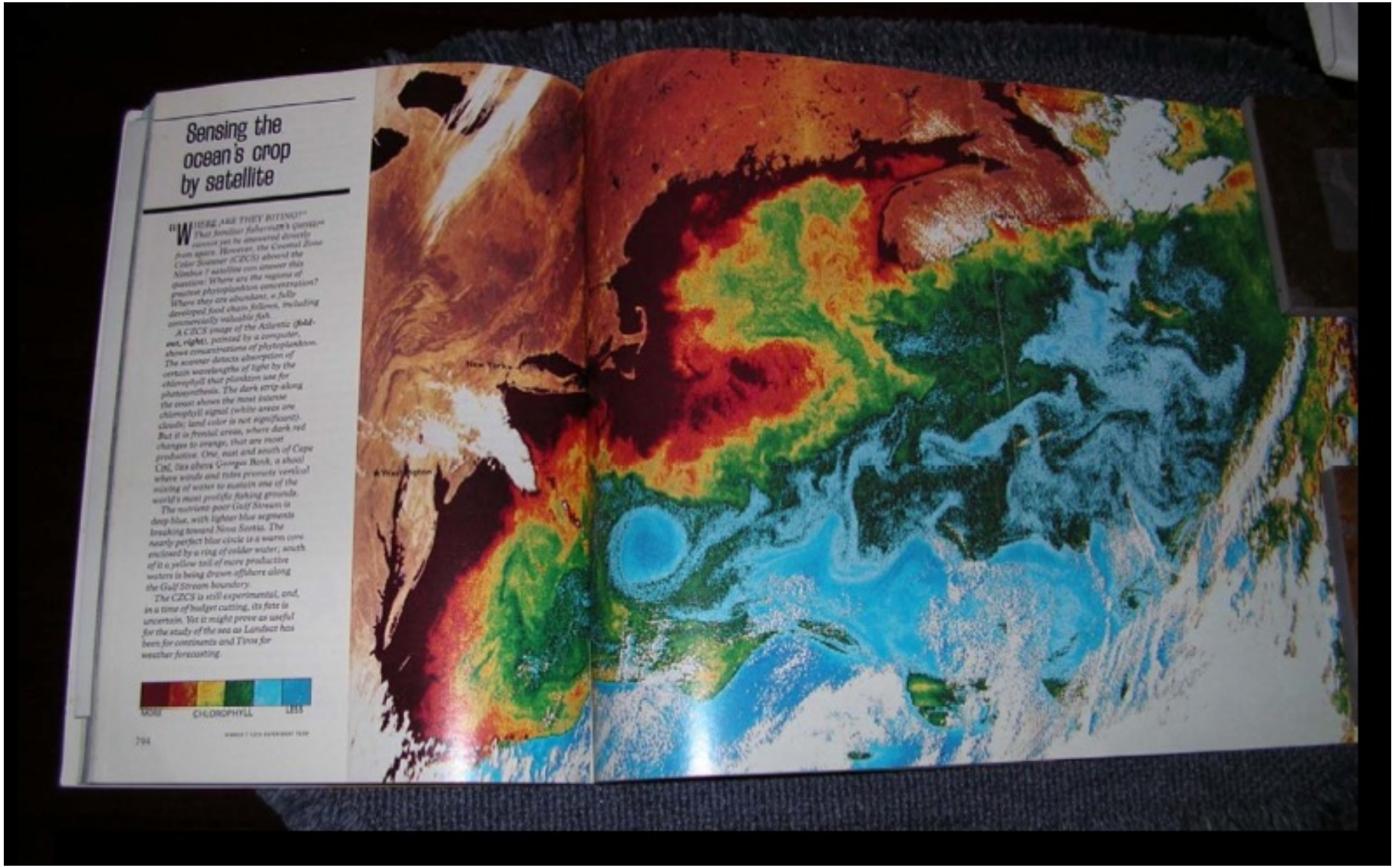


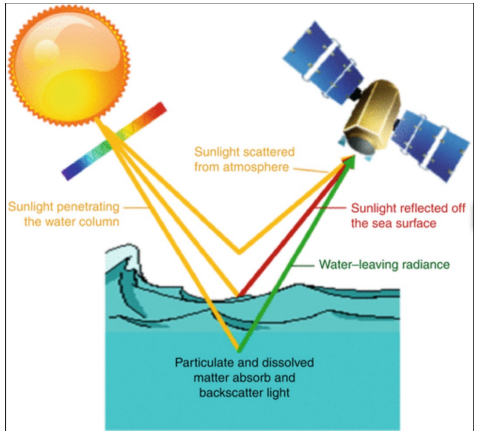
Atmospheric weather system - Clouds



Stirring of phytoplankton by ocean mesoscale eddies

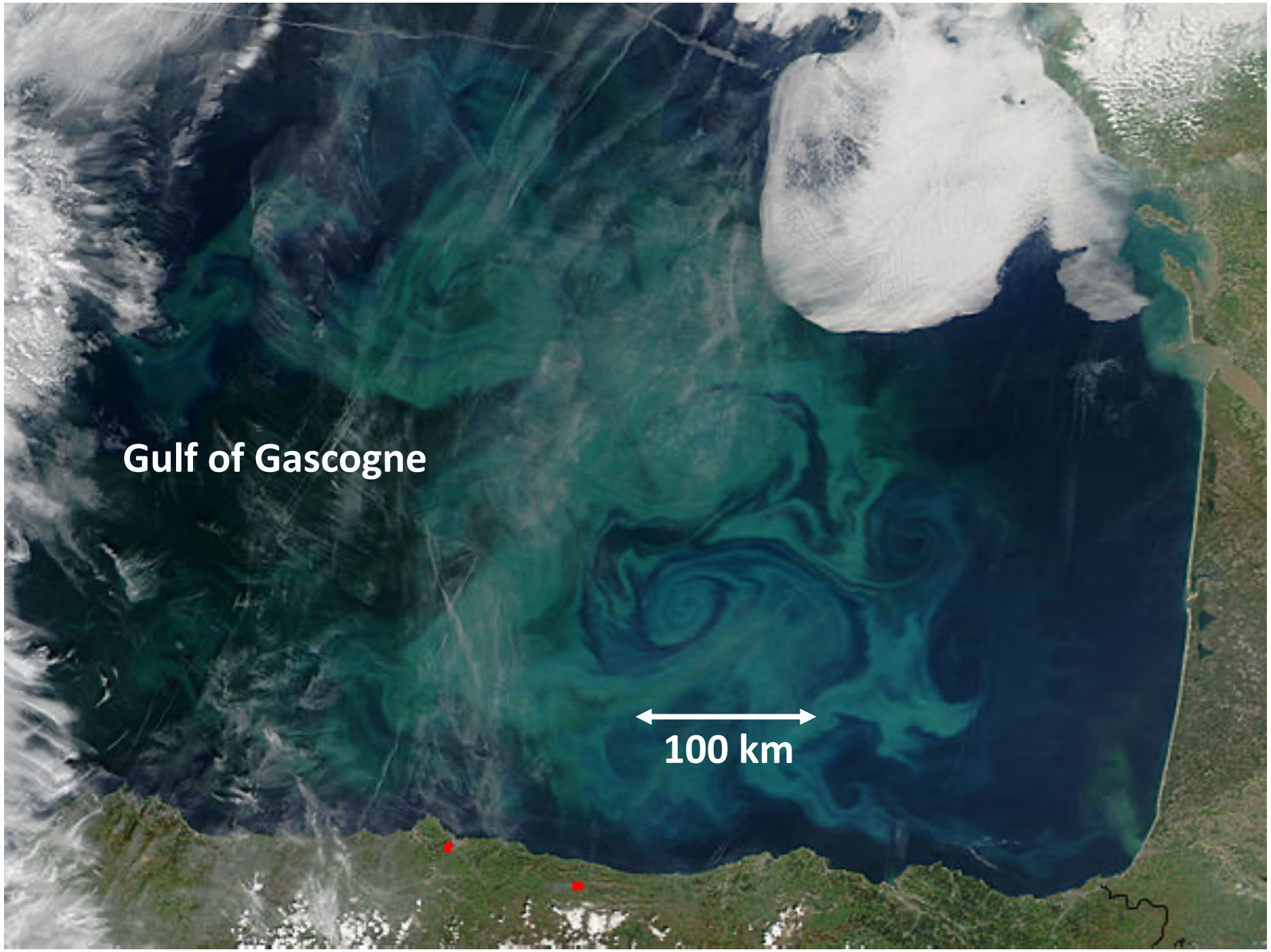
Phytoplankton are invisible to the eye but visible from satellites



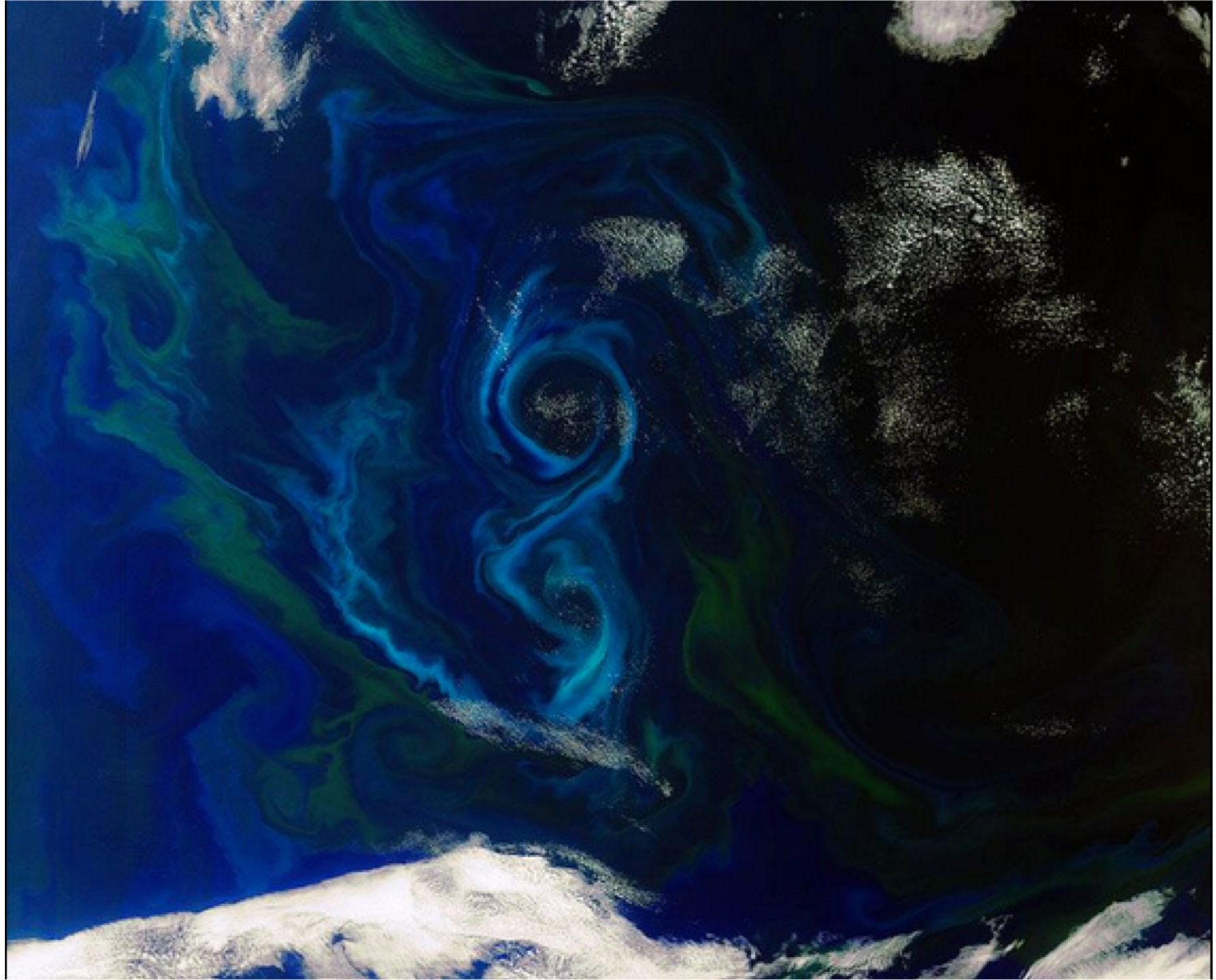


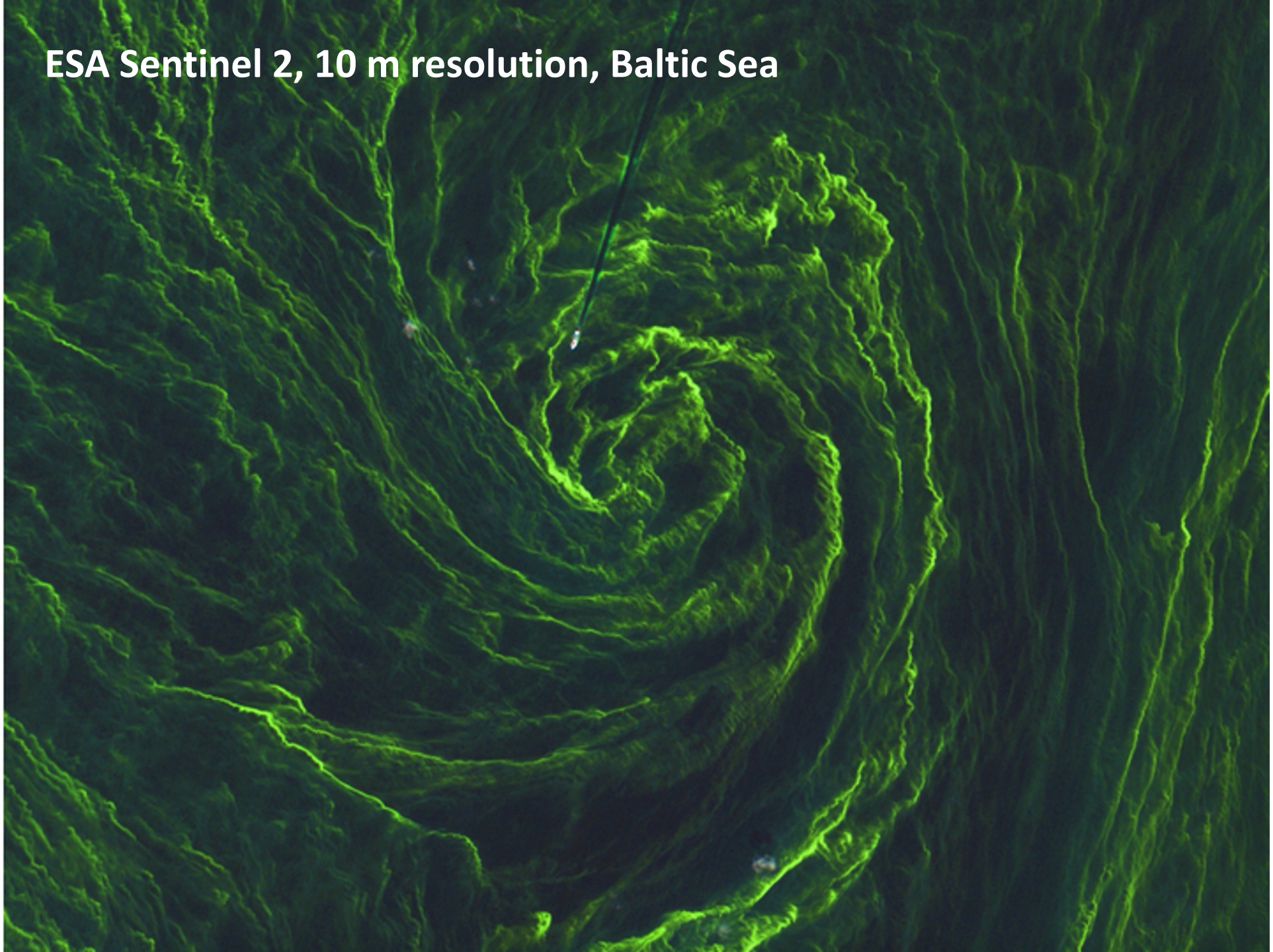
NATIONAL GEOGRAPHIC

December 1981 issue

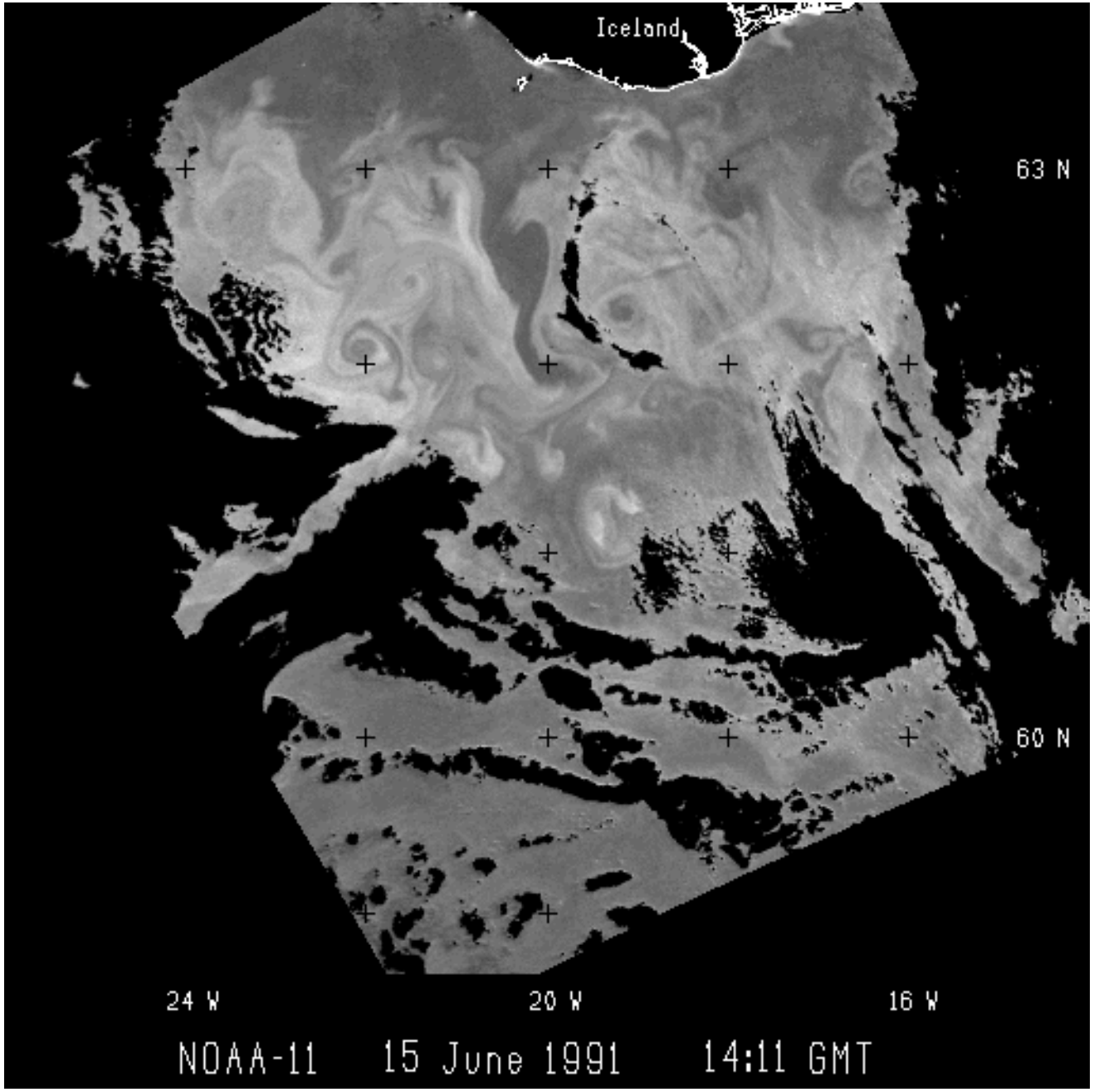

Gulf of Gascogne
100 km

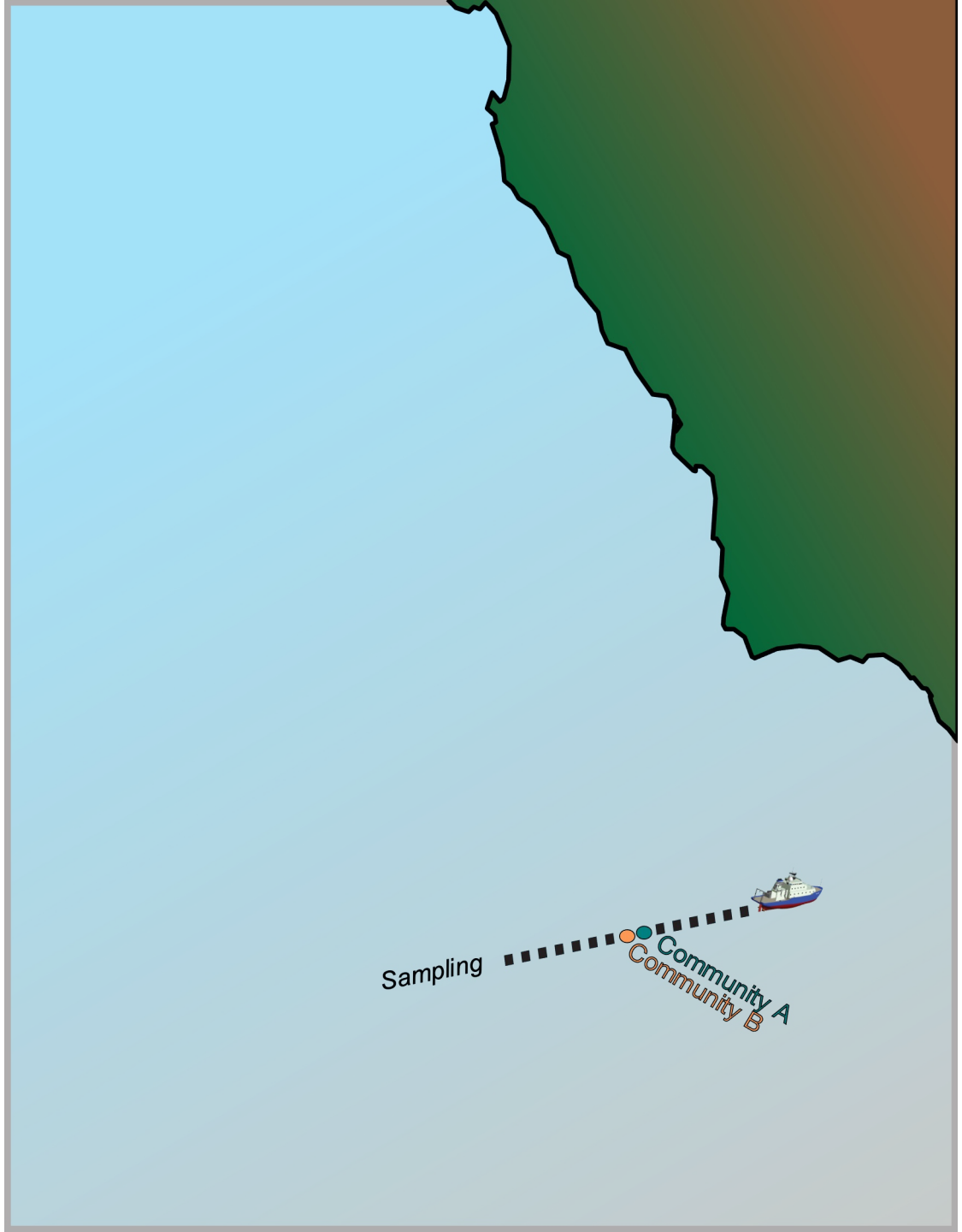

Gulf of Finland



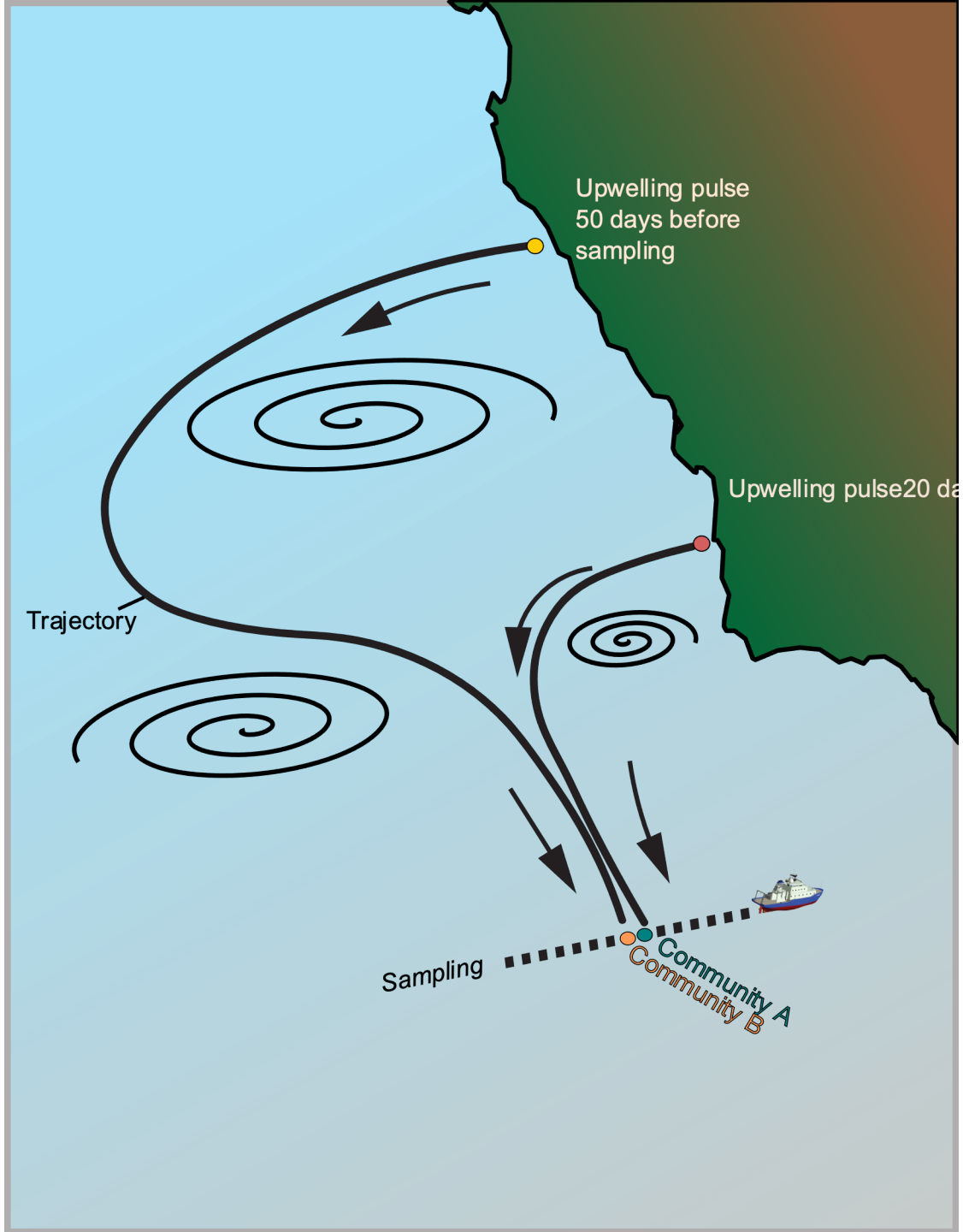

ESA Sentinel 2, 10 m resolution, Baltic Sea

Evolution over 8 days

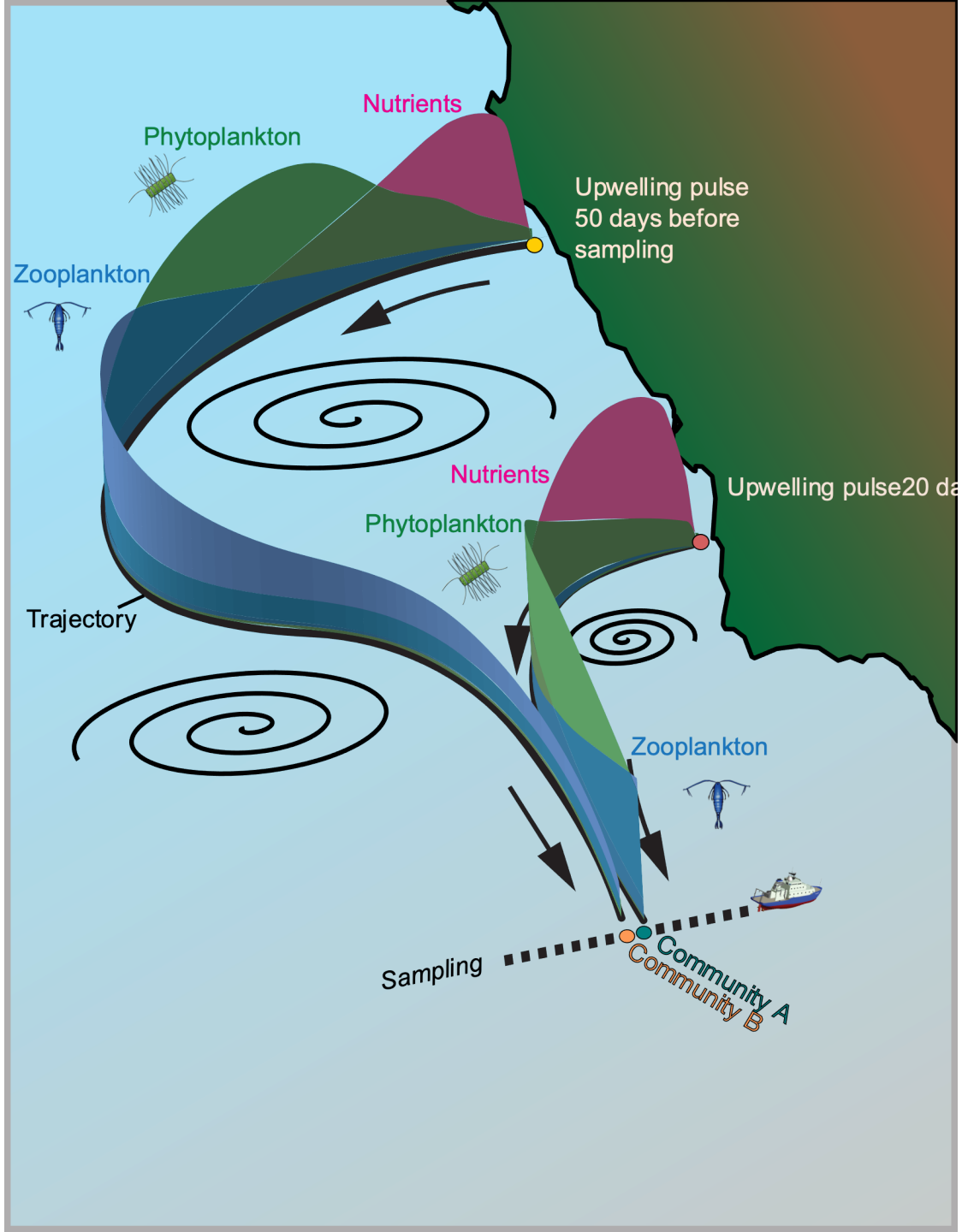




Gangrade and Mangolte, 2024

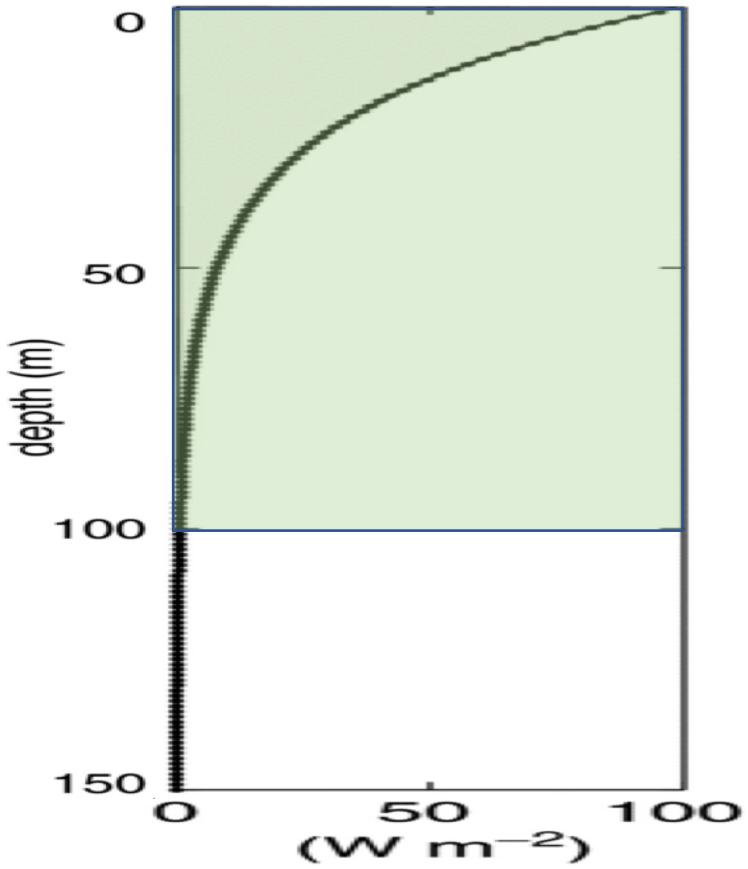


Gangrade and Mangolte, 2024

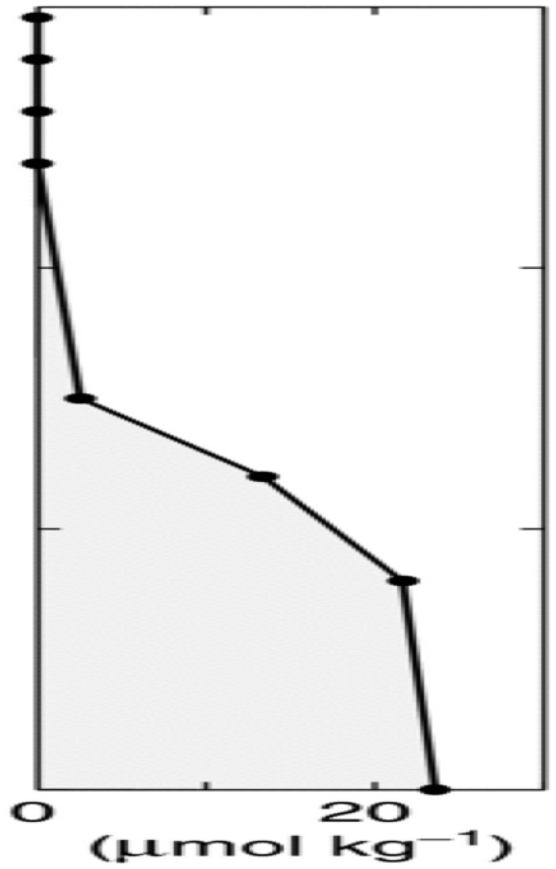


Gangrade and Mangolte, 2024

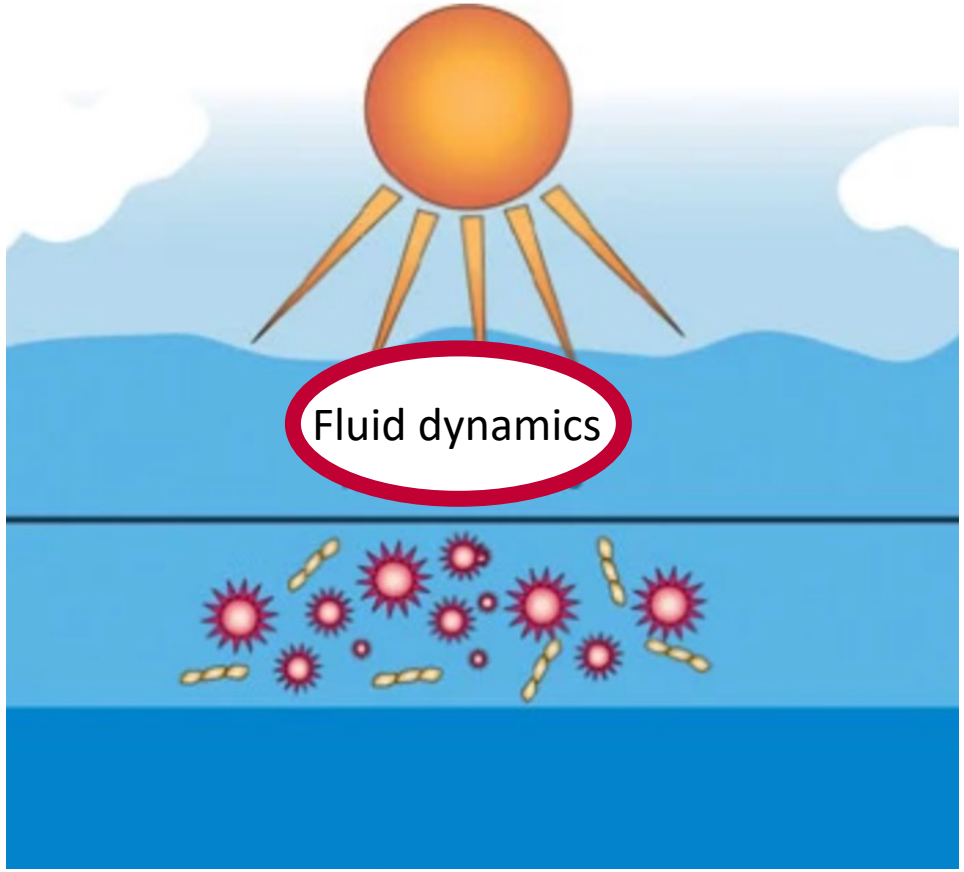
Light

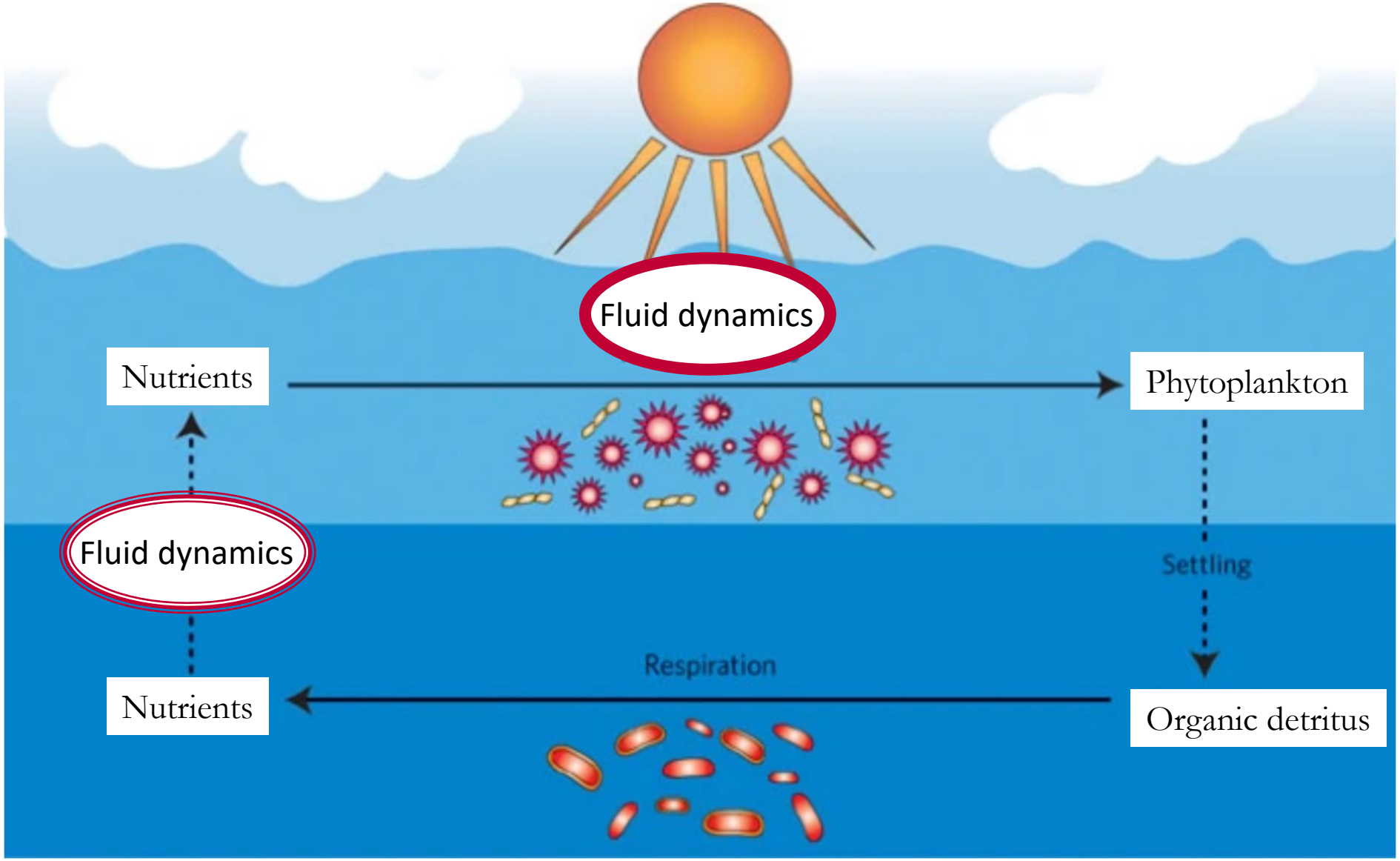


Nitrate



z



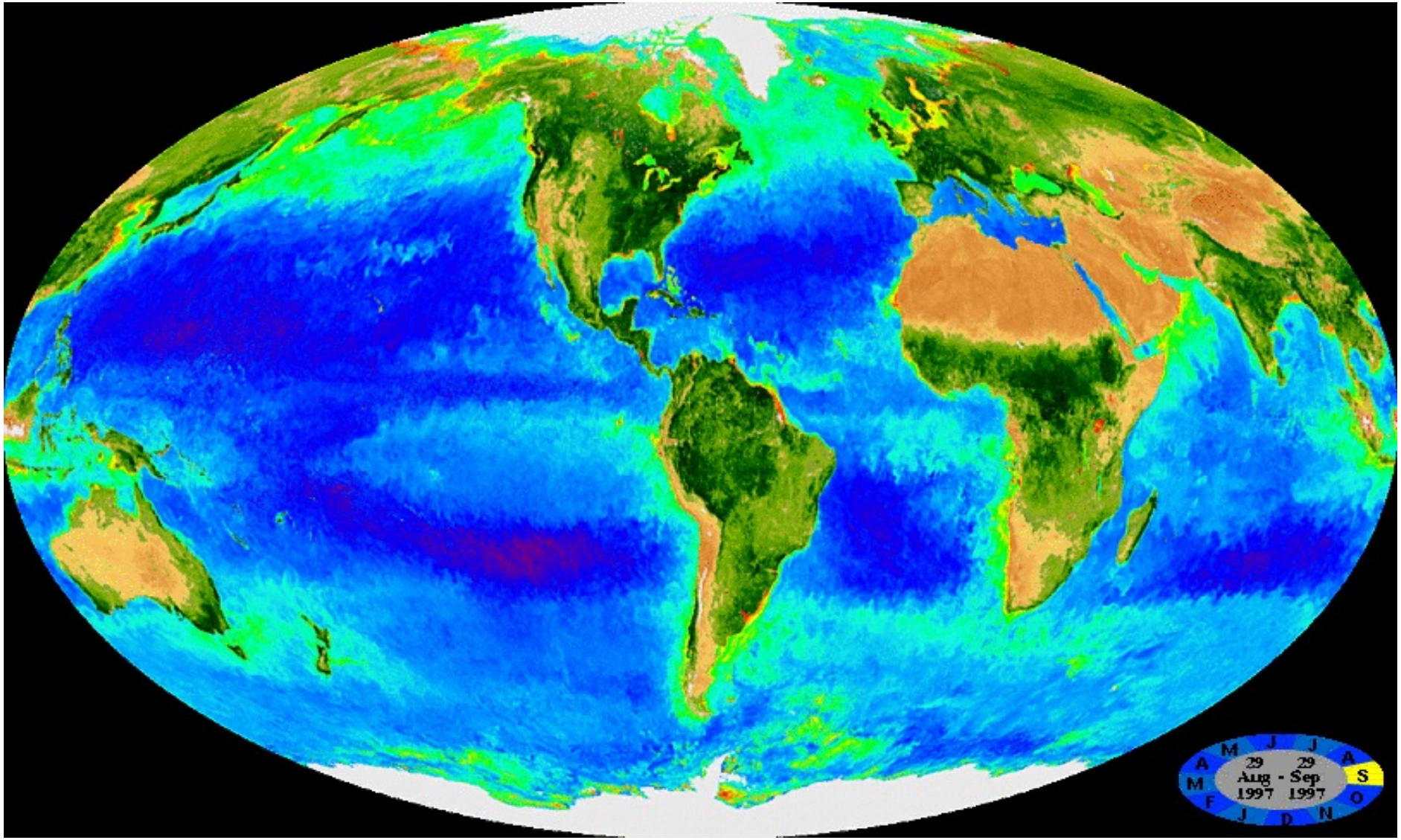


Adapted from Najjar, 2009

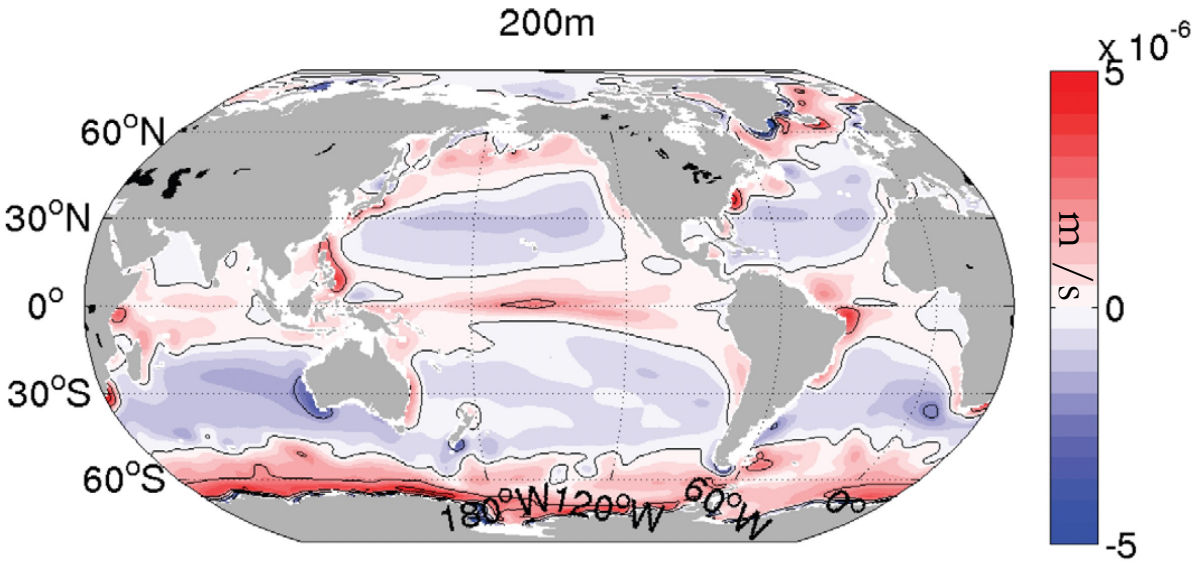
Basin-scale patterns of phytoplankton

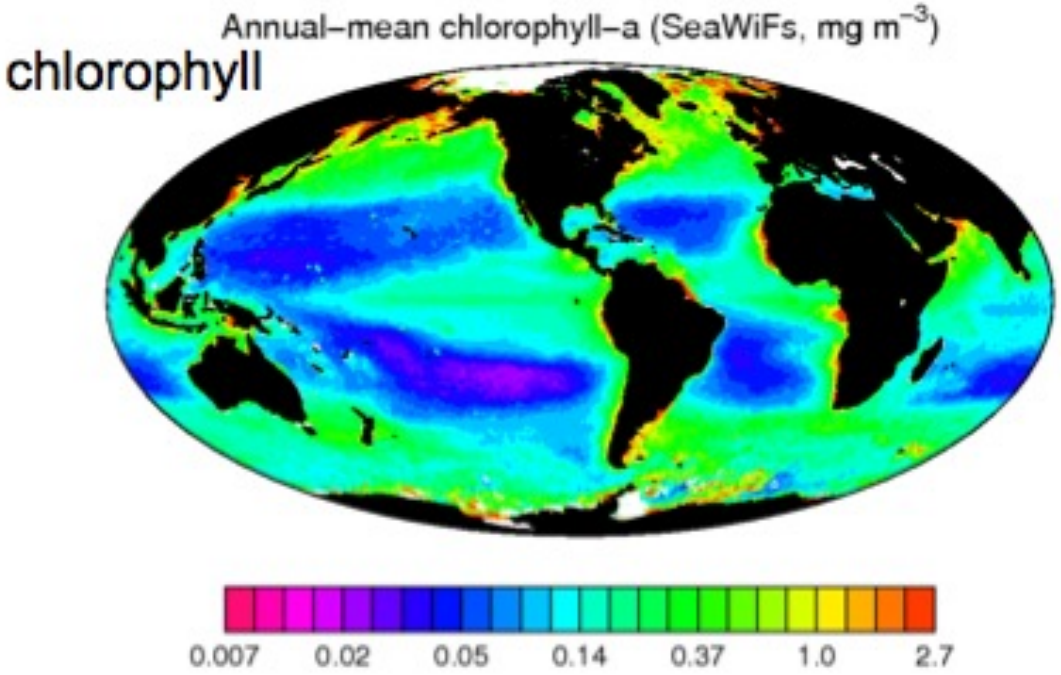
Ocean forests

Ocean deserts



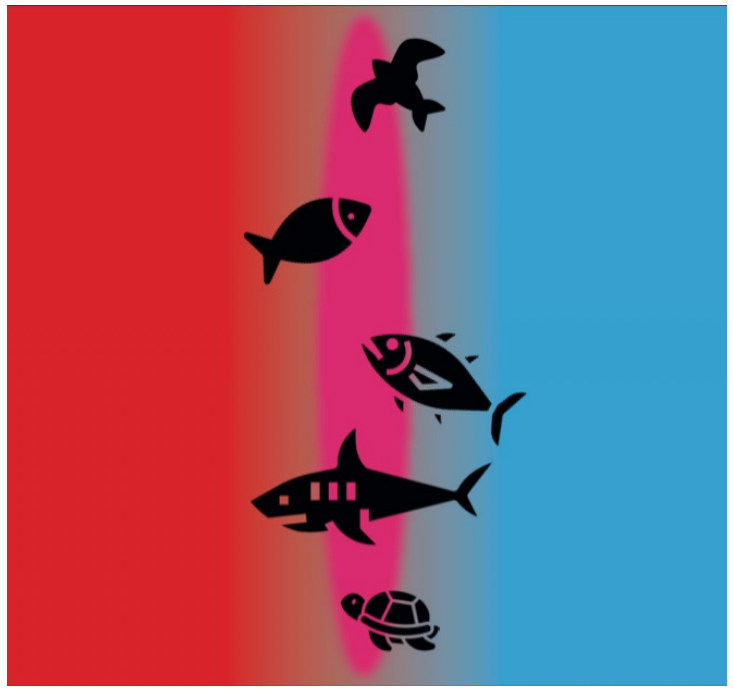
Wind-driven vertical currents

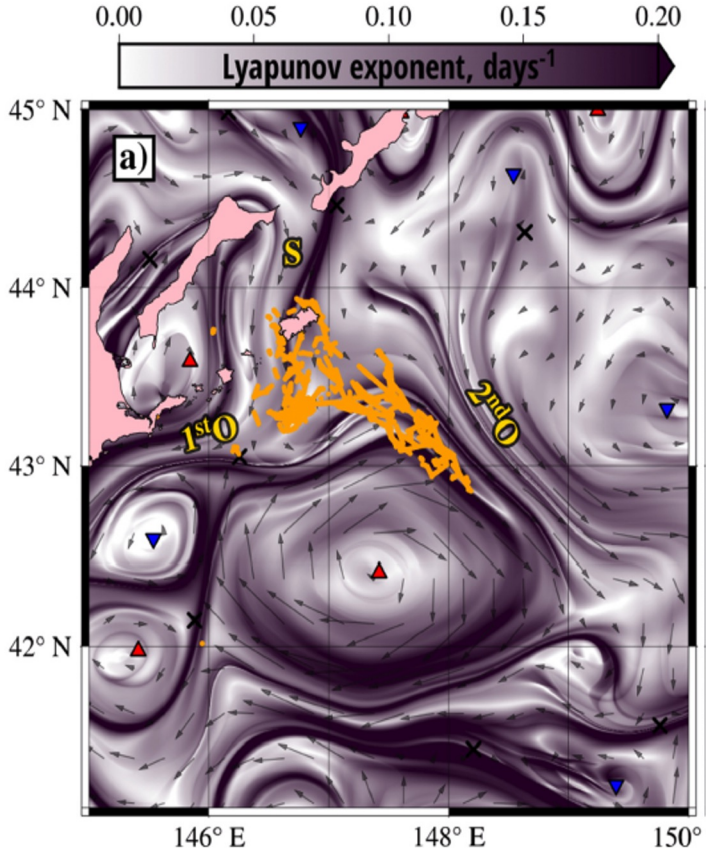




Liang et al., 2017

Fishermen discovered fronts are hotspots



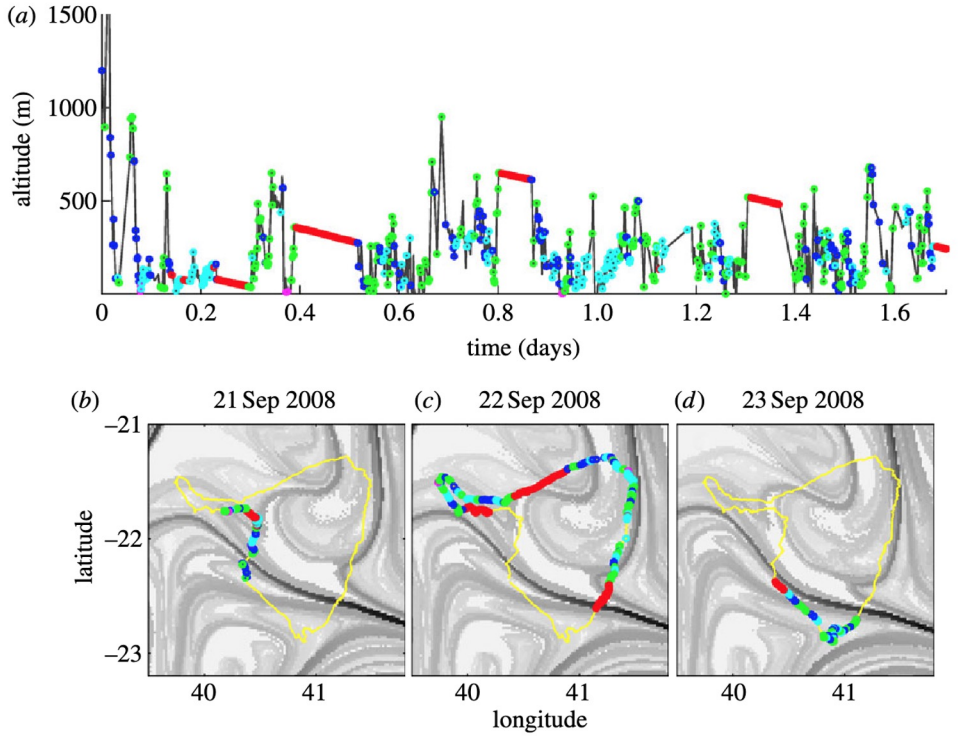


Prants, 2024

Seabirds hunt fronts too

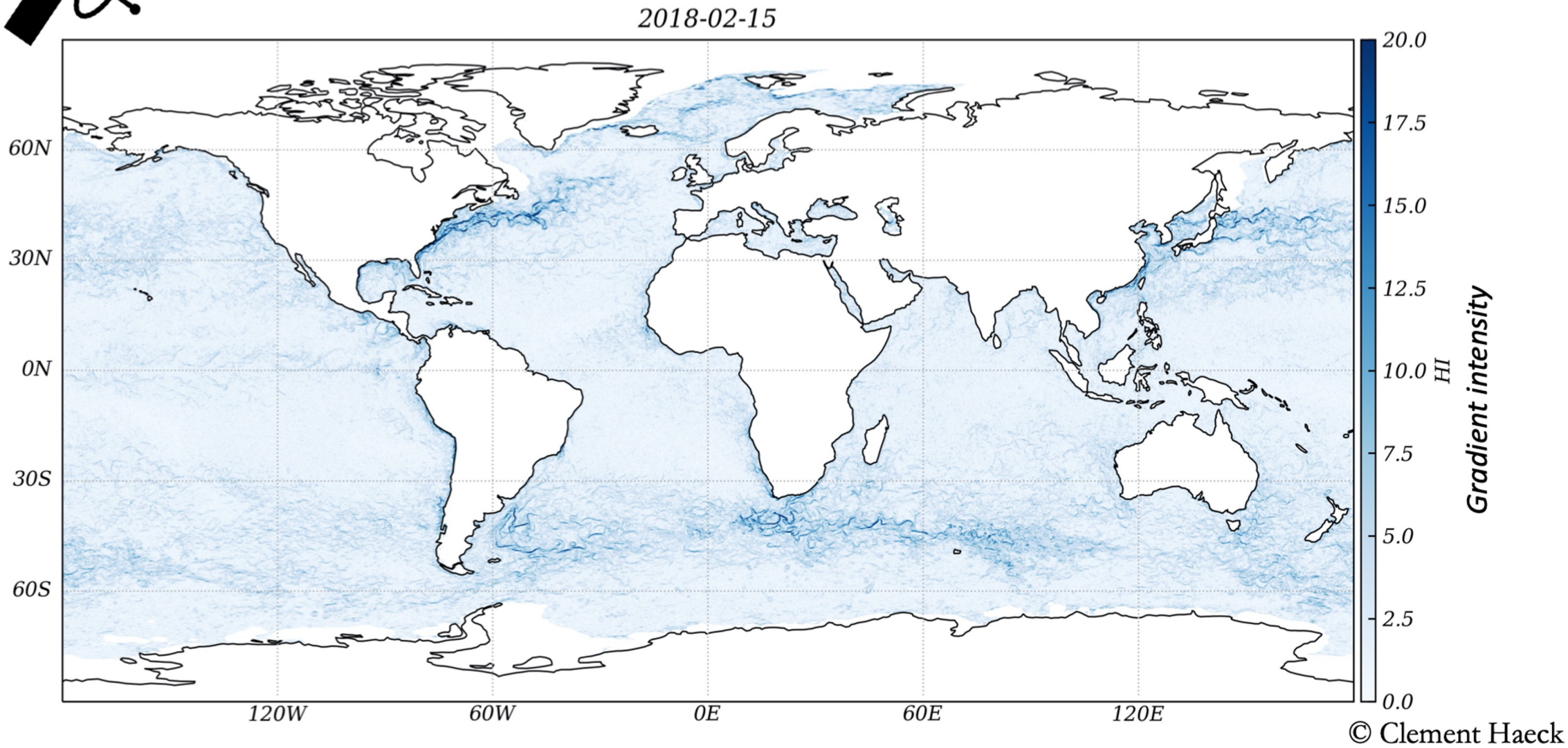
Fregate birds foraging behavior in the Mozambique Channel

3D-GPS tracking + satellites

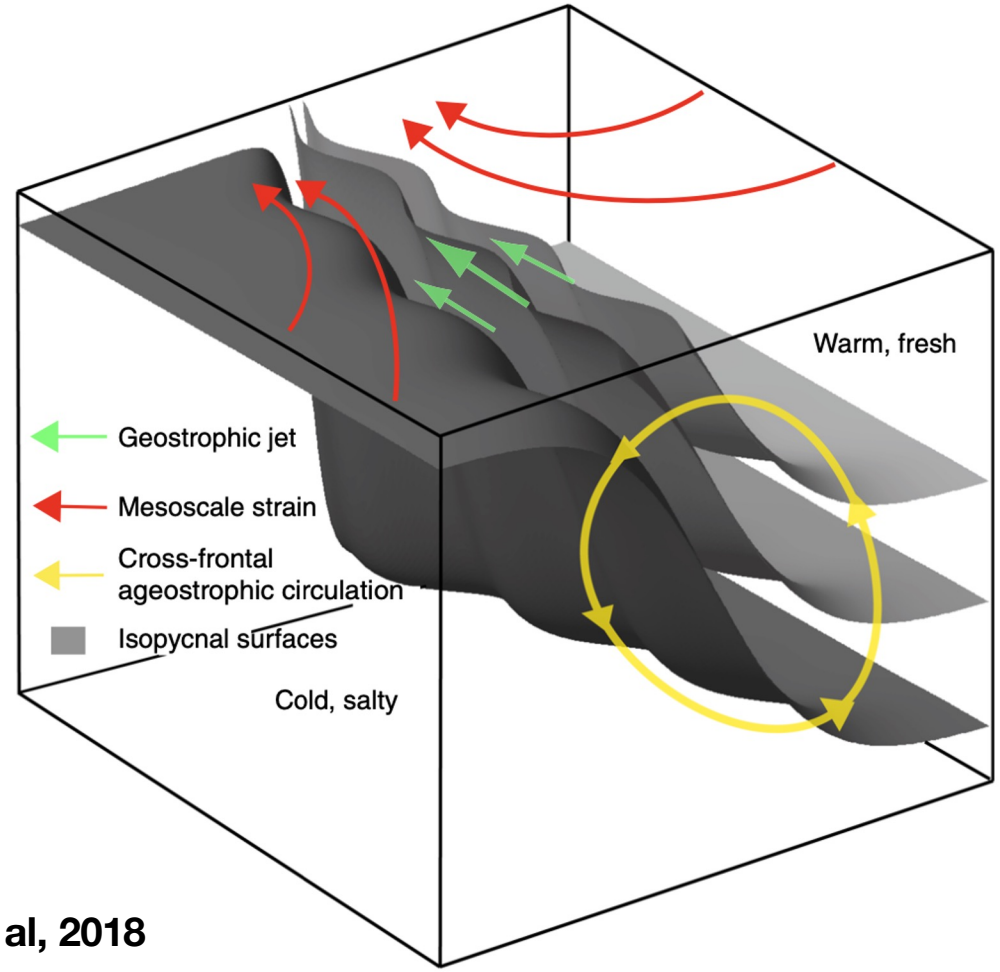


De Monte, 2012

Sea-surface temperature fronts



© Clement Haeck



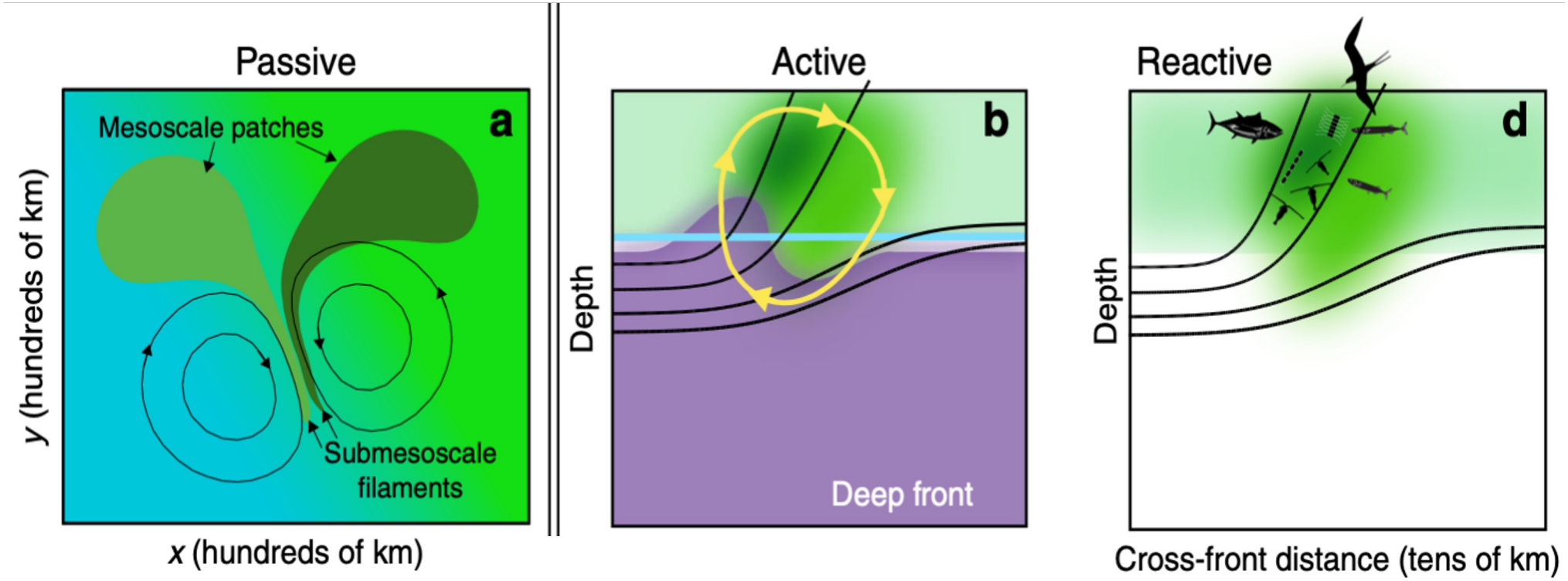
Levy et al, 2018

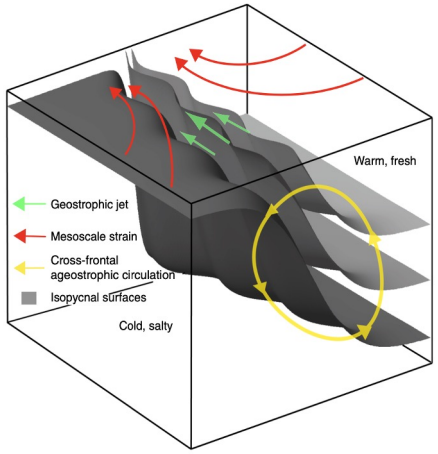
REVIEW ARTICLE

DOI: 10.1038/s41467-018-07059-3 OPEN

The role of submesoscale currents in structuring marine ecosystems

Marina Lévy[1], Peter J.S. Franks[2] & K. Shafer Smith[3,4]





REVIEW ARTICLE

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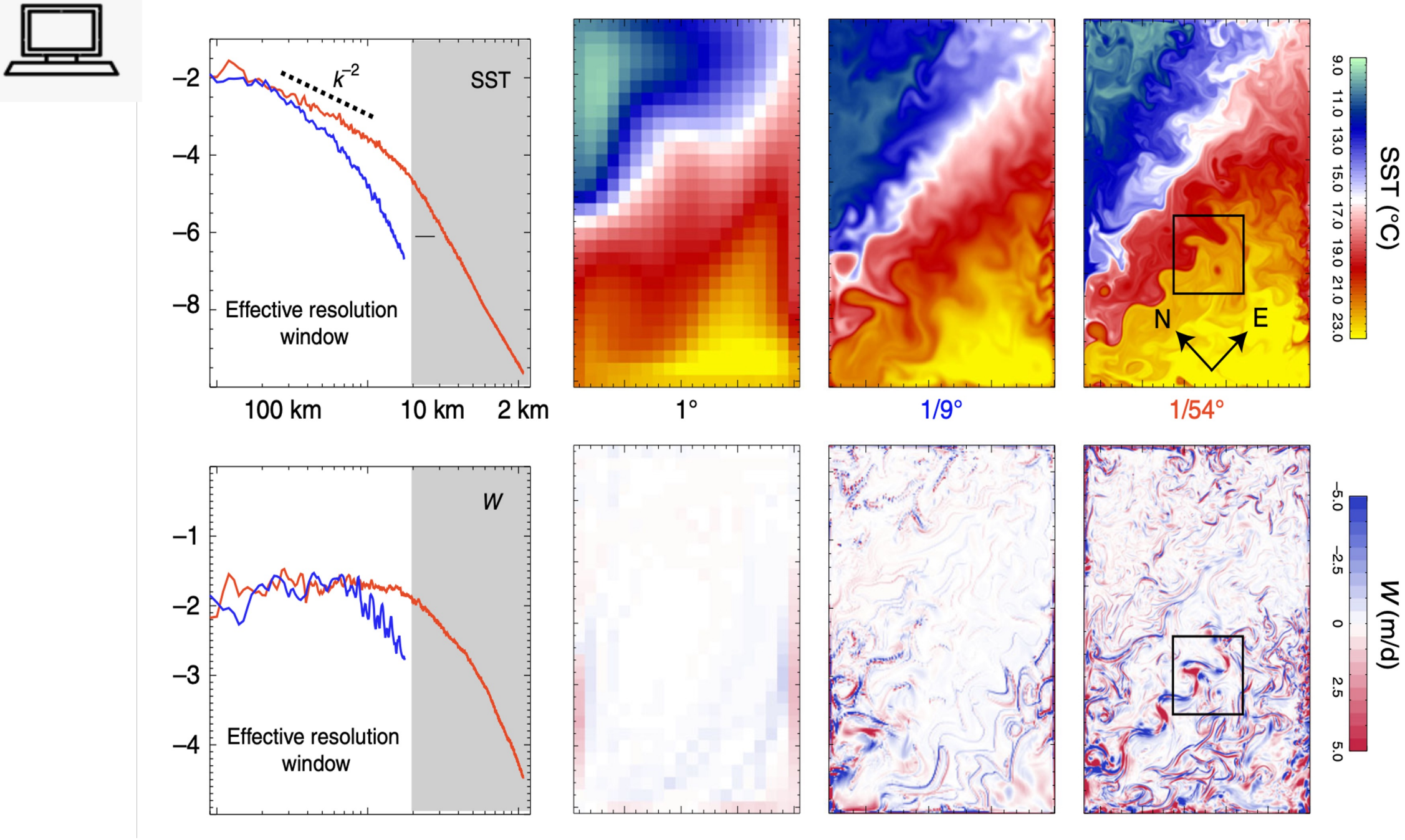
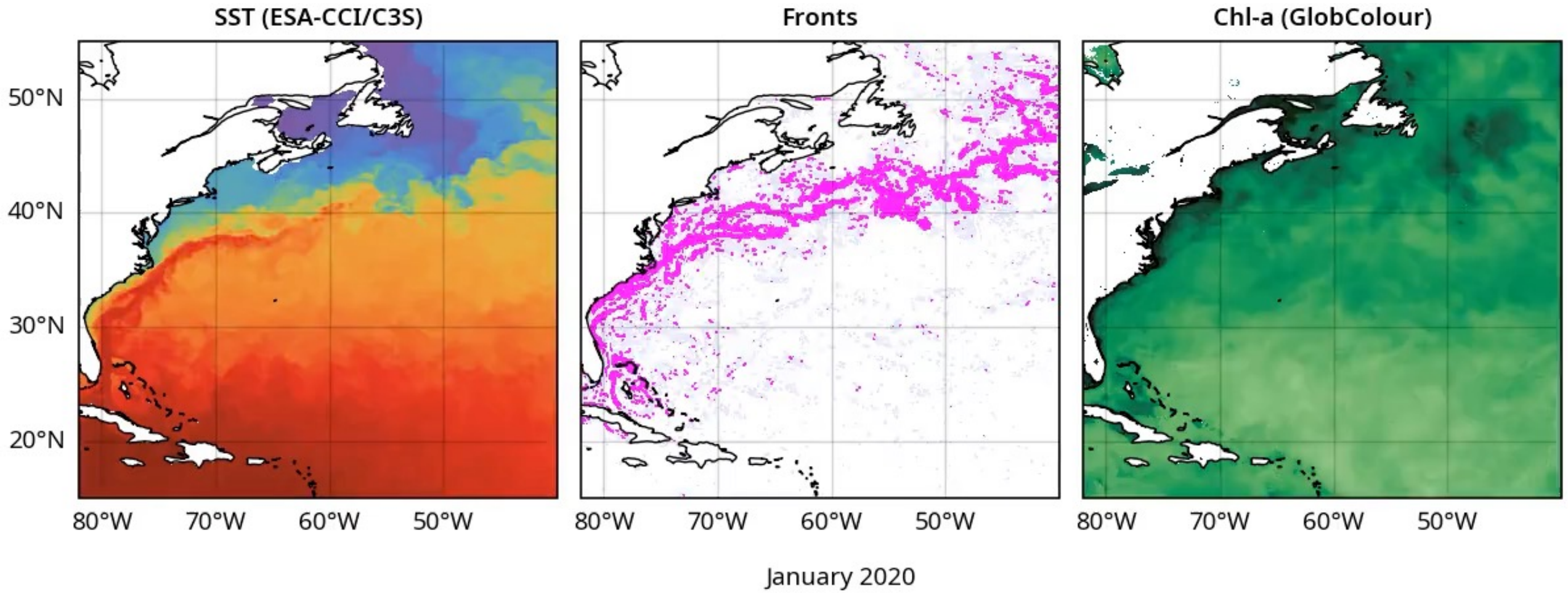
The role of submesoscale currents in structuring marine ecosystems

Marina Lévy[1], Peter J.S. Franks[2] & K. Shafer Smith[3,4]

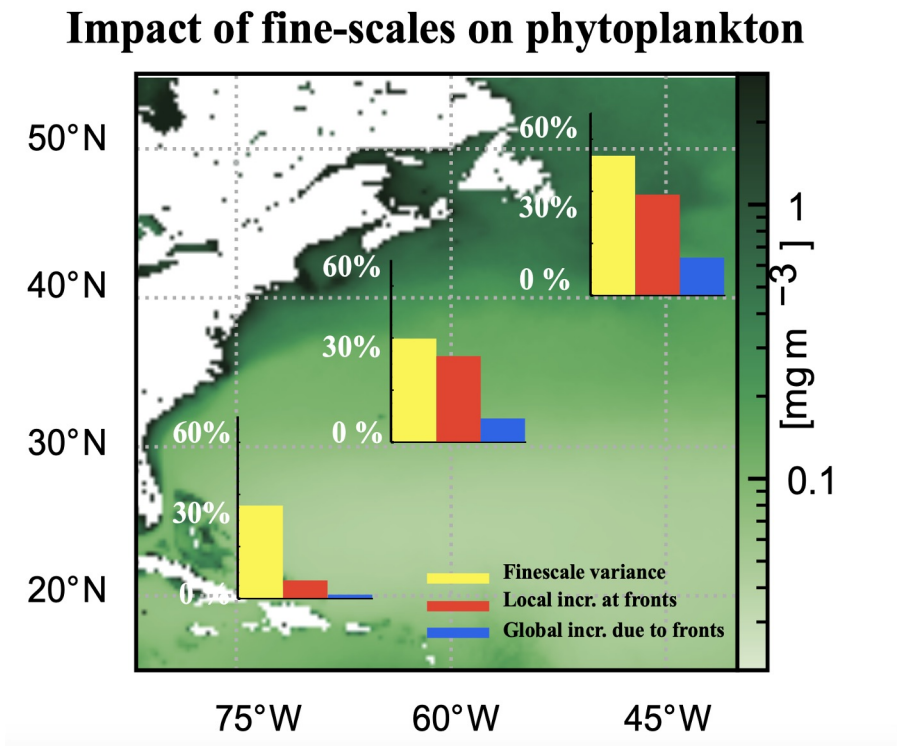

SST
k^{-2}
−2
−4
−6
−8
Effective resolution window
100 km
10 km
2 km
1°
1/9°
1/54°
N
E
9.0 11.0 13.0 15.0 17.0 19.0 21.0 23.0
SST (°C)
W
−1
−2
−3
−4
Effective resolution window
−5.0 −2.5 0 2.5 5.0
W (m/d)

Bridging scales: from one front to multiple fronts



Haeck et al., 2023

Bridging knowledges : from fronts to community structure

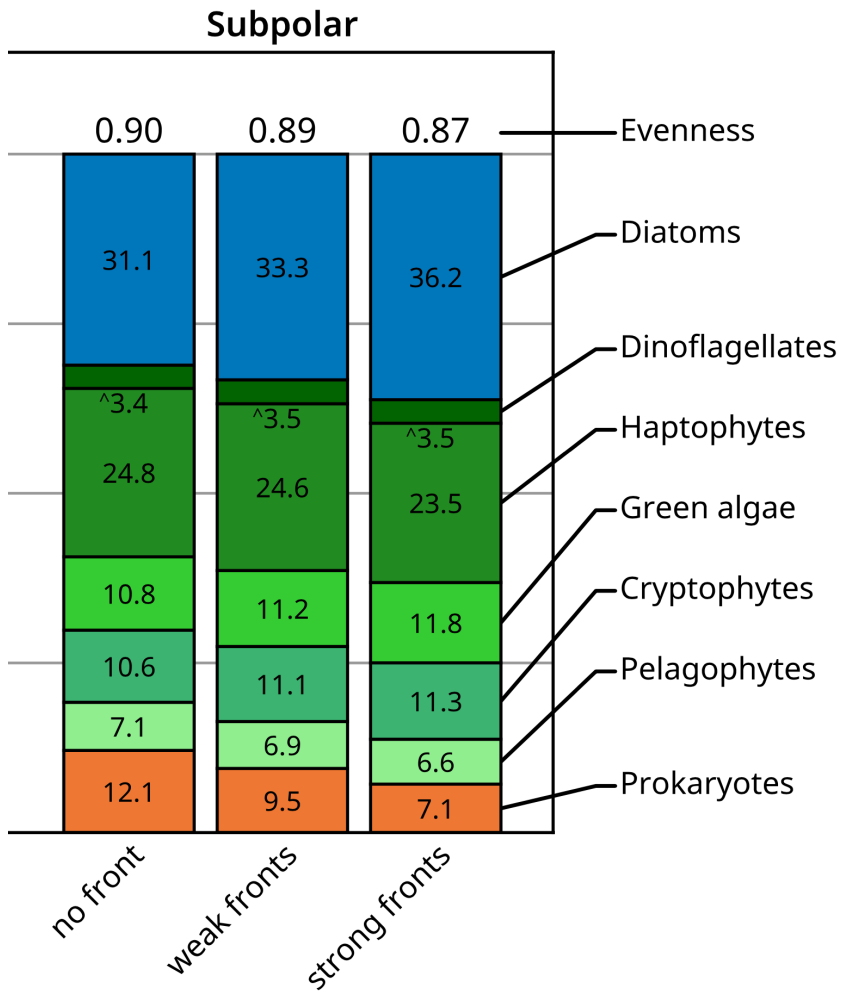


Lévy et al, 2024

Annual Review of Marine Science

The Impact of Fine-Scale Currents on Biogeochemical Cycles in a Changing Ocean

Marina Lévy,[1] Damien Couespel,[2] Clément Haëck,[1] M.G. Keerthi,[1] Inès Mangolte,[1] and Channing J. Prend[3,4]



Lévy et al, 2025

$$\langle\overline{\partial_t C}\rangle = -\langle\nabla\cdot(\overline{C}\,\overline{\mathbf{v}})\rangle - \langle\nabla\cdot(\overline{C'\mathbf{v}'})\rangle + \langle\partial_z(\overline{k_z}\partial_z\overline{C})\rangle + \langle\partial_z\overline{(k_z'\partial_z C')}\rangle + \langle\overline{B_C}\rangle + \langle\overline{B_C'}\rangle$$

Mean advection

Eddy advection

Mean Vertical mixing

Eddy Vertical mixing

Mean biogeochemical reactions

Eddy biogeochemical reactions

< . > : Average over bio-provinces and over periods > 1 year

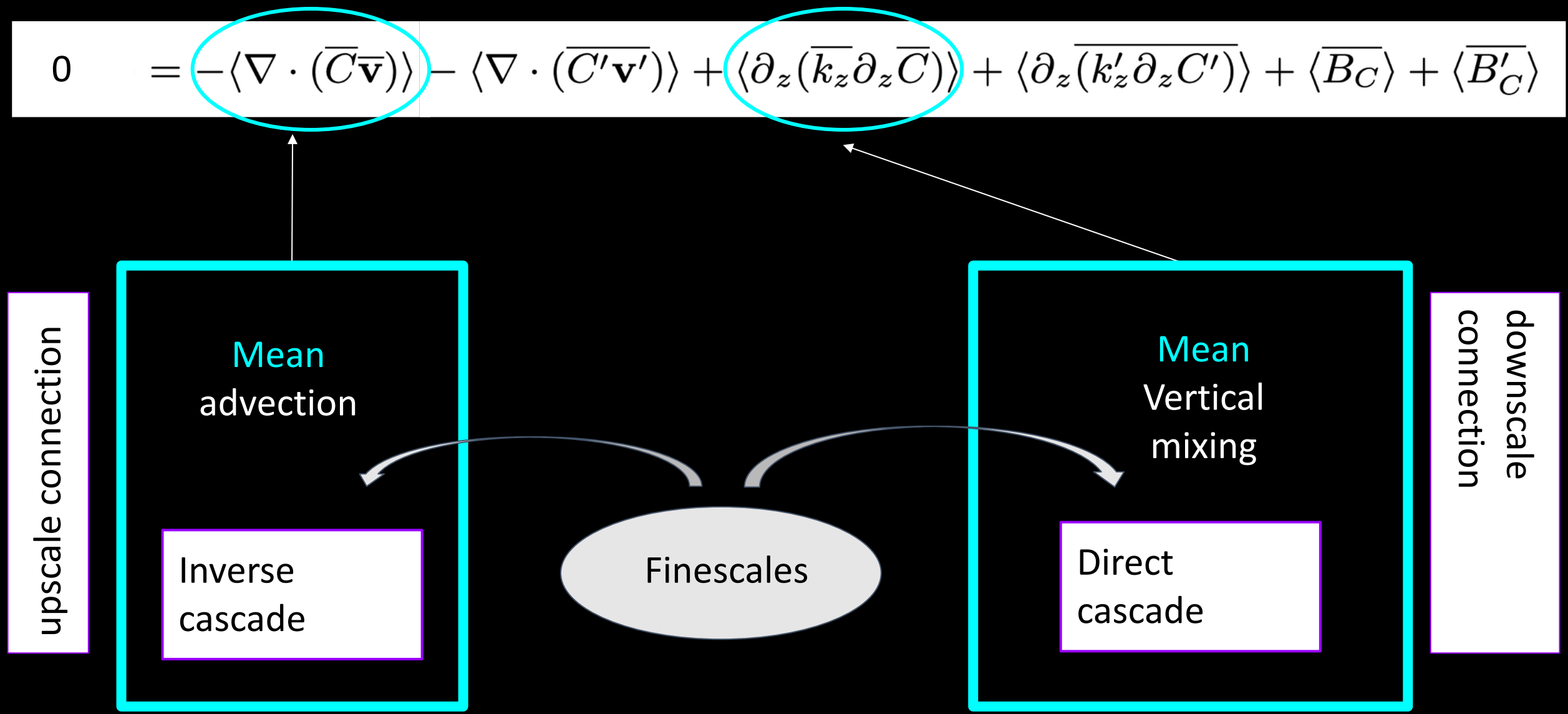
$\langle\overline{\partial_t C}\rangle =$

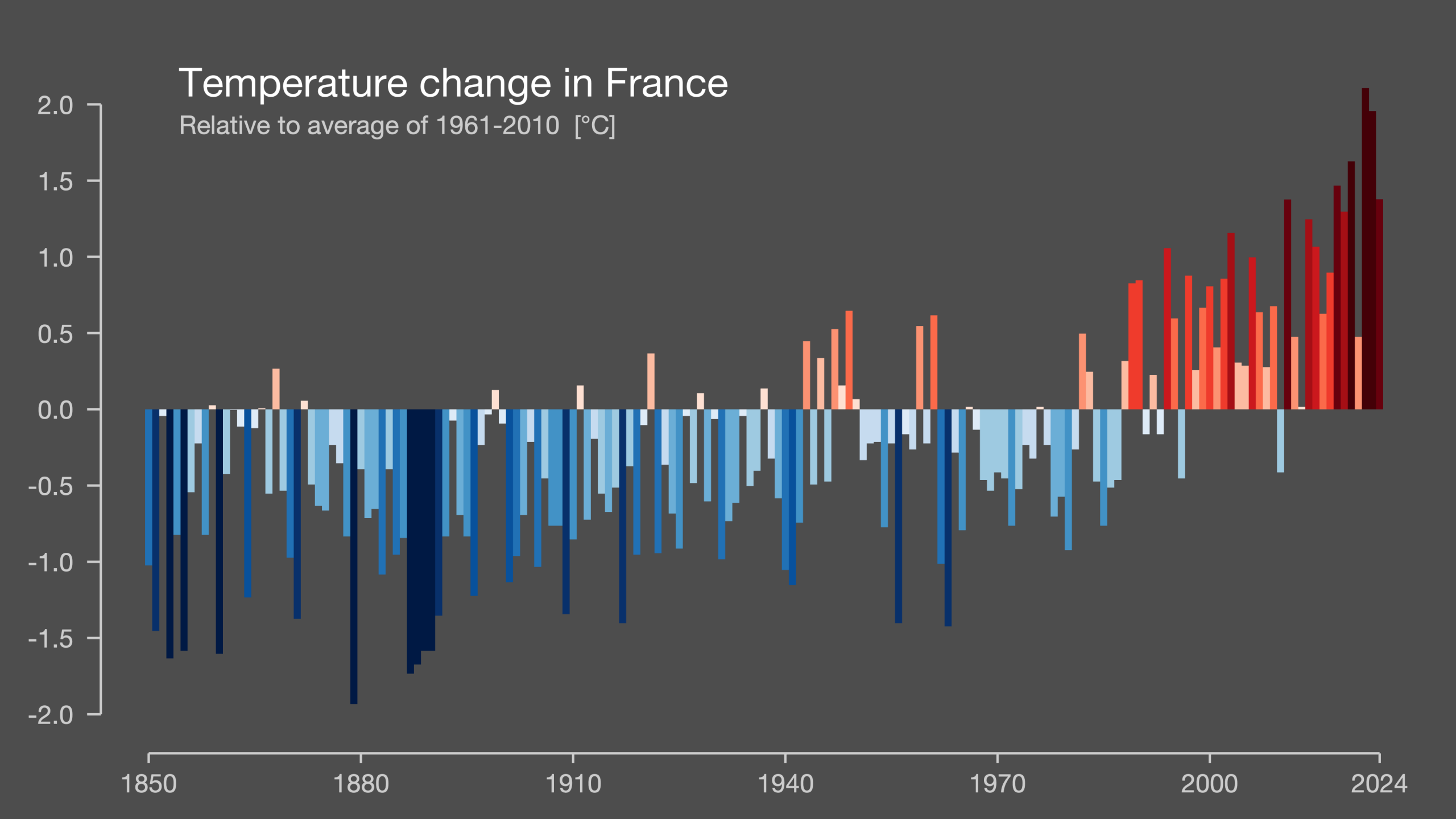
0 : Mean state

> and < : Natural variability

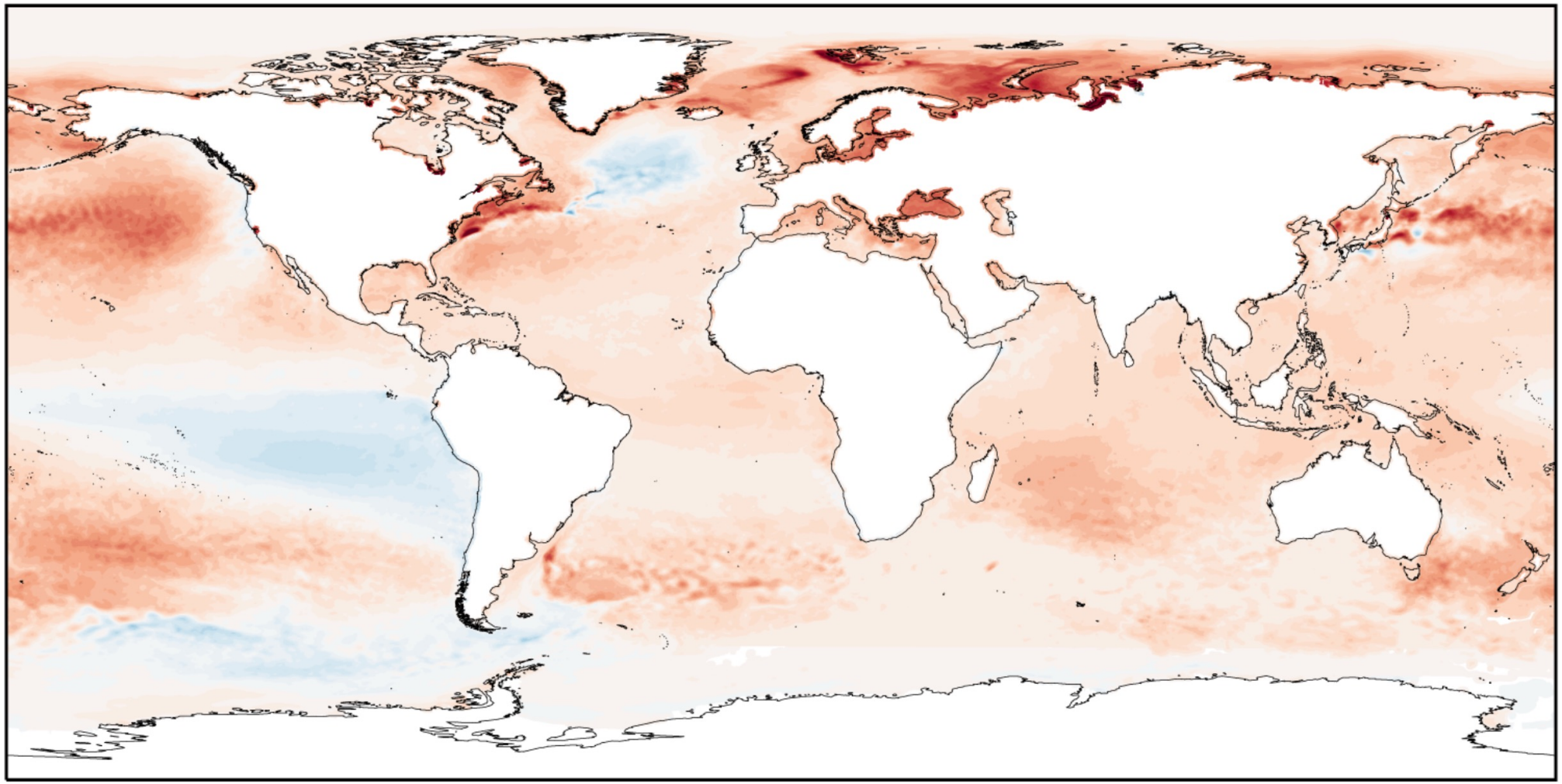
long term trend: Climate change

$$0 = -\langle \nabla \cdot (\overline{C}\,\overline{\mathbf{v}}) \rangle - \langle \nabla \cdot (\overline{C'\mathbf{v}'}) \rangle + \langle \partial_z (\overline{k_z} \partial_z \overline{C}) \rangle + \langle \partial_z (\overline{k_z' \partial_z C'}) \rangle + \langle \overline{B_C} \rangle + \langle \overline{B_C'} \rangle$$




Temperature change in France
Relative to average of 1961-2010 [°C]
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
1850
1880
1910
1940
1970
2000
2024

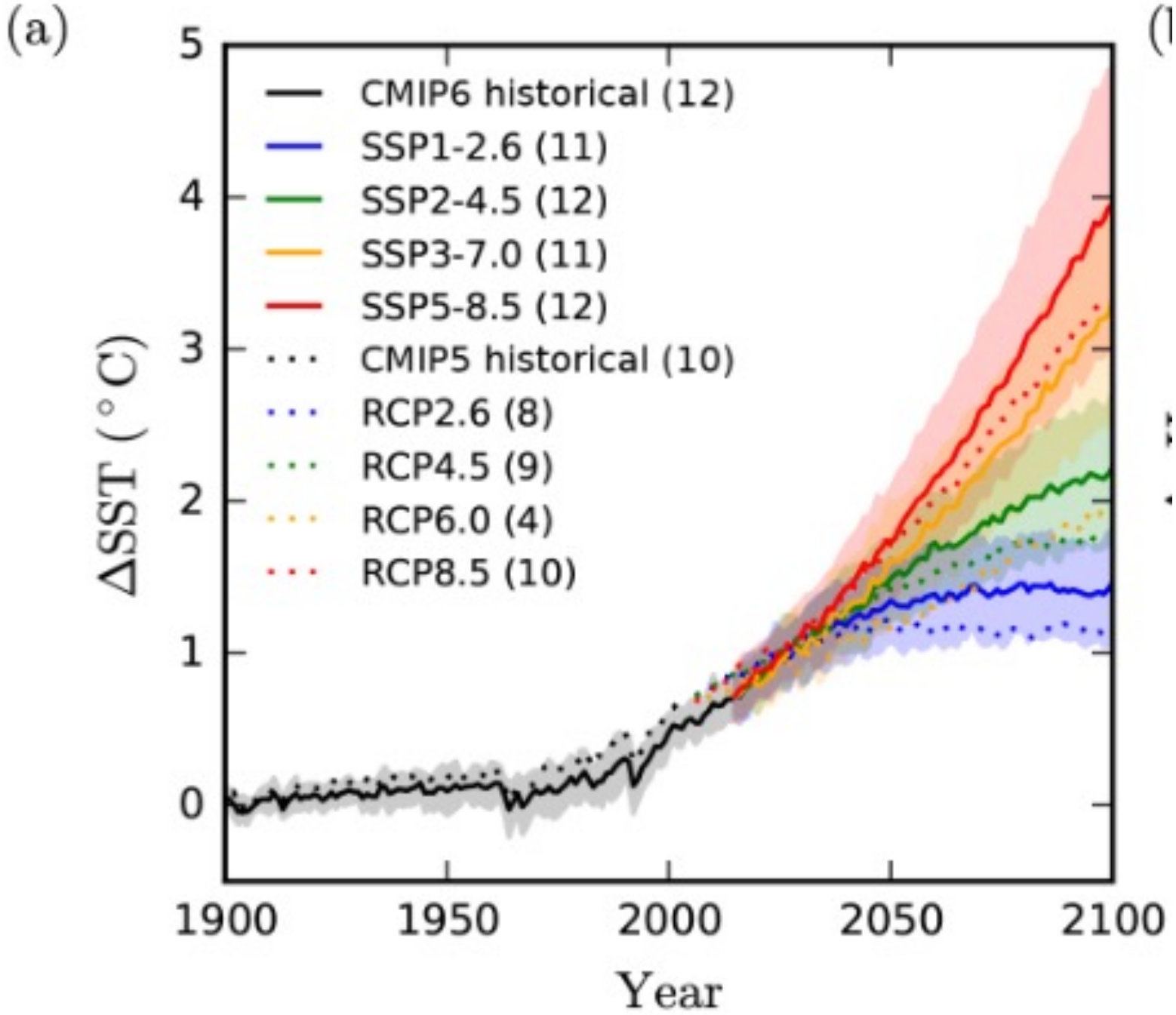
Sea surface temperature trend

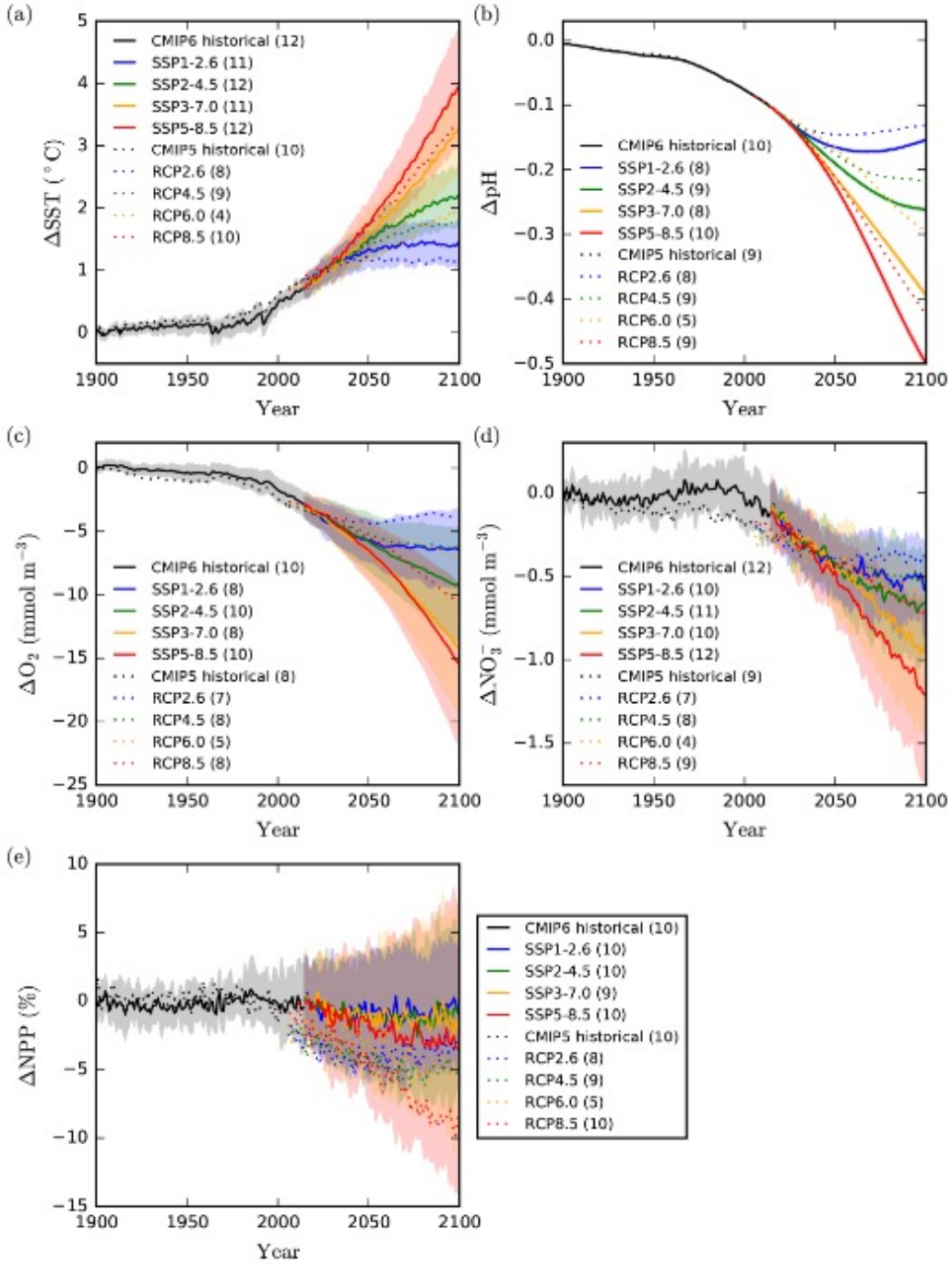


-1.0 -0.8 -0.6 -0.4 -0.2 -0.0 0.2 0.4 0.6 0.8 1.0

Trend (degC/decade)

Copernicus 2024


(a)
CMIP6 historical (12)
SSP1-2.6 (11)
SSP2-4.5 (12)
SSP3-7.0 (11)
SSP5-8.5 (12)
CMIP5 historical (10)
RCP2.6 (8)
RCP4.5 (9)
RCP6.0 (4)
RCP8.5 (10)
ΔSST (°C)
0
1
2
3
4
5
1900
1950
2000
2050
2100
Year

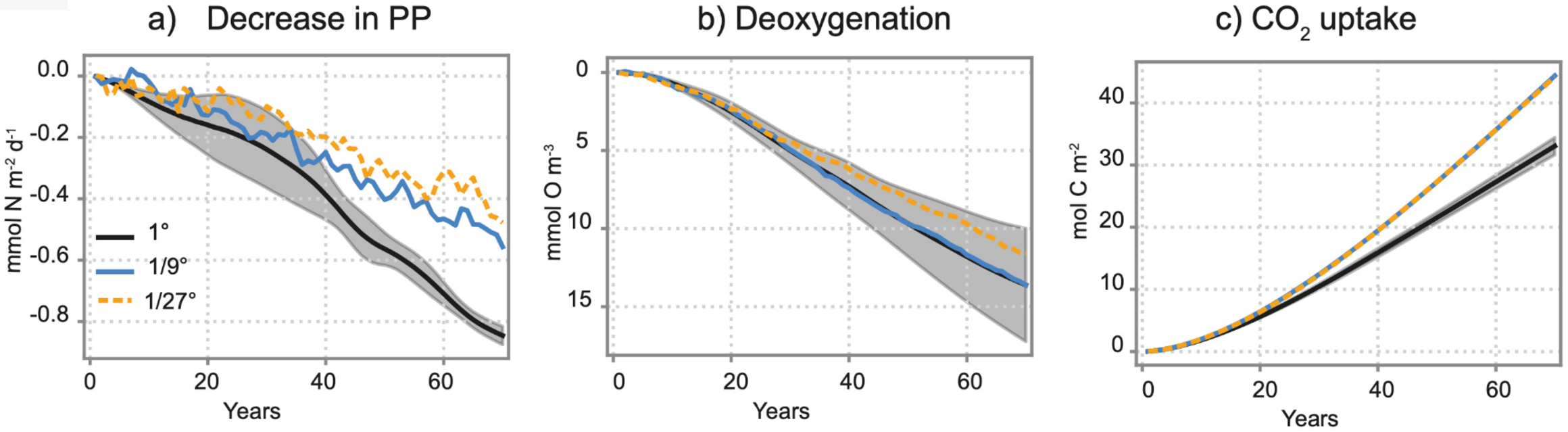


Biogeosciences, 17, 3439–3470, 2020
https://doi.org/10.5194/bg-17-3439-2020

Biogeosciences
Open Access
EGU

Twenty-first century ocean warming, acidification, deoxygenation, and upper-ocean nutrient and primary production decline from CMIP6 model projections

Lester Kwiatkowski[1], Olivier Torres[2], Laurent Bopp[2], Olivier Aumont[1], Matthew Chamberlain[3], James R. Christian[5], John P. Dunne[6], Marion Gehlen[7], Tatiana Ilyina[8], Jasmin G. John[6], Andrew Lenton[3,4], Hongmei Li[8], Nicole S. Lovenduski[9], James C. Orr[7], Julien Palmieri[10], Yeray Santana-Falcón[11], Jörg Schwinger[12], Roland Séférian[11], Charles A. Stock[6], Alessandro Tagliabue[13], Yohei Takano[8,14], Jerry Tjiputra[12], Katsuya Toyama[15], Hiroyuki Tsujino[15], Michio Watanabe[16], Akitomo Yamamoto[16], Andrew Yool[10], and Tilo Ziehn[3]



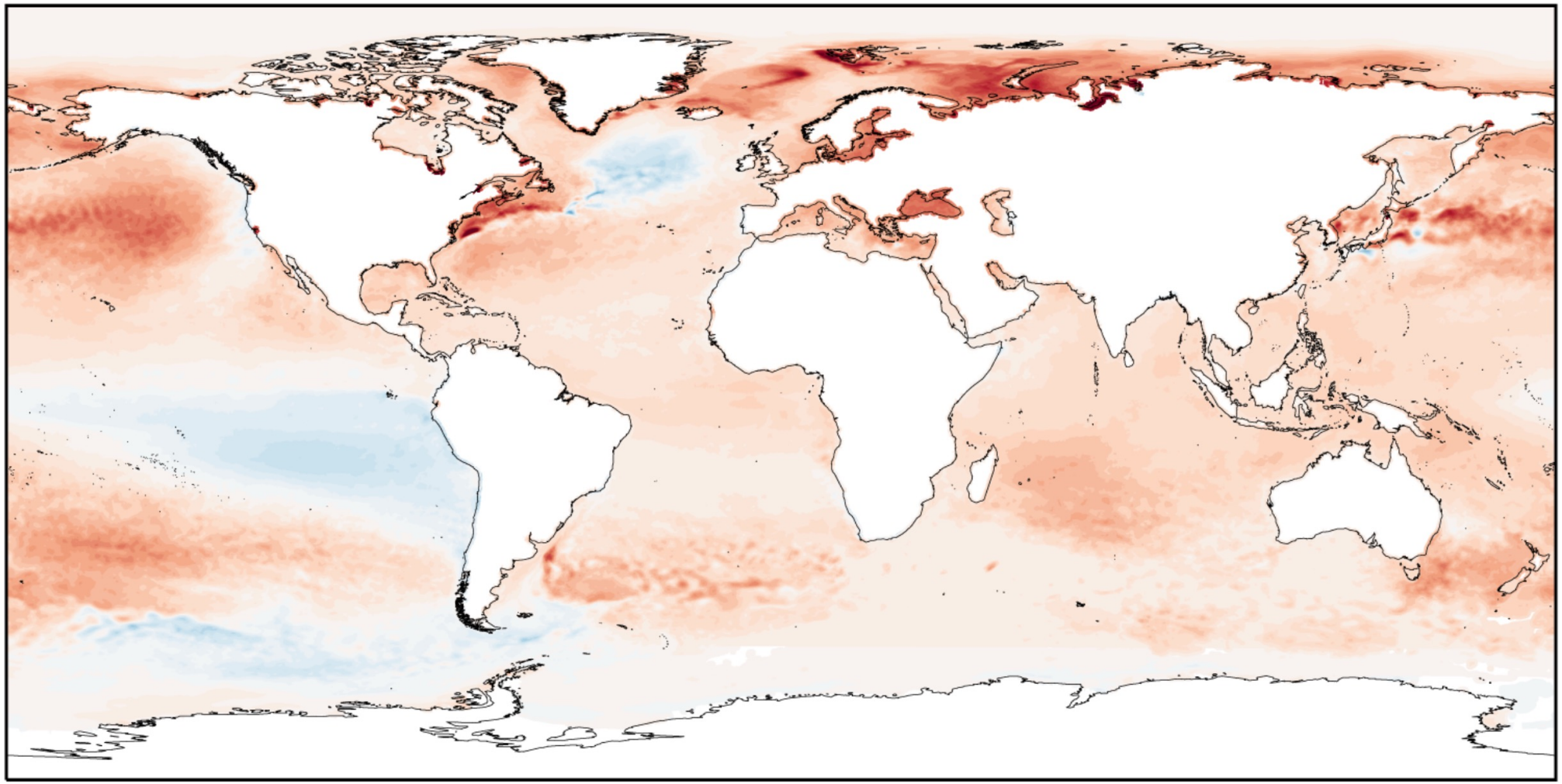
Damping of climate change impacts and of climate change with finescales

due to upscale feedback, no change in eddy fluxes

Oceanic primary production decline halved in eddy-resolving simulations of global warming

Damien Couespel[1], Marina Lévy[1], and Laurent Bopp[2]

Sea surface temperature trend



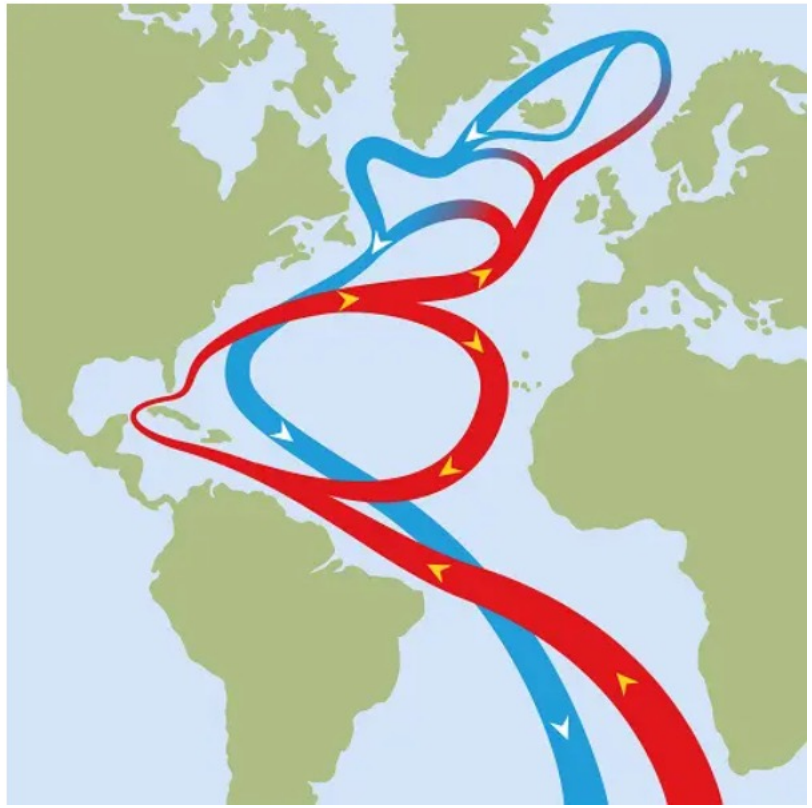
-1.0 -0.8 -0.6 -0.4 -0.2 -0.0 0.2 0.4 0.6 0.8 1.0

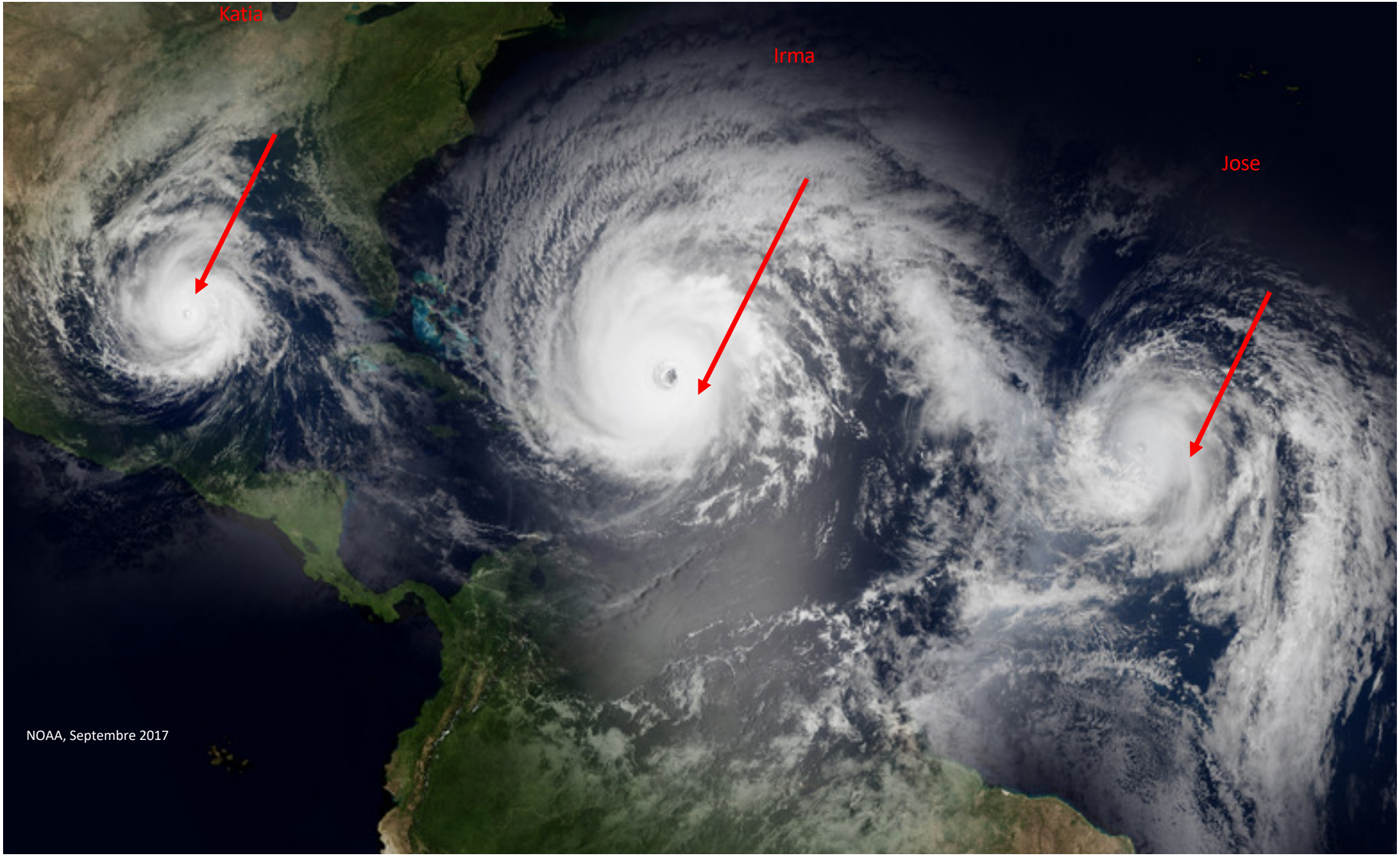
Trend (degC/decade)

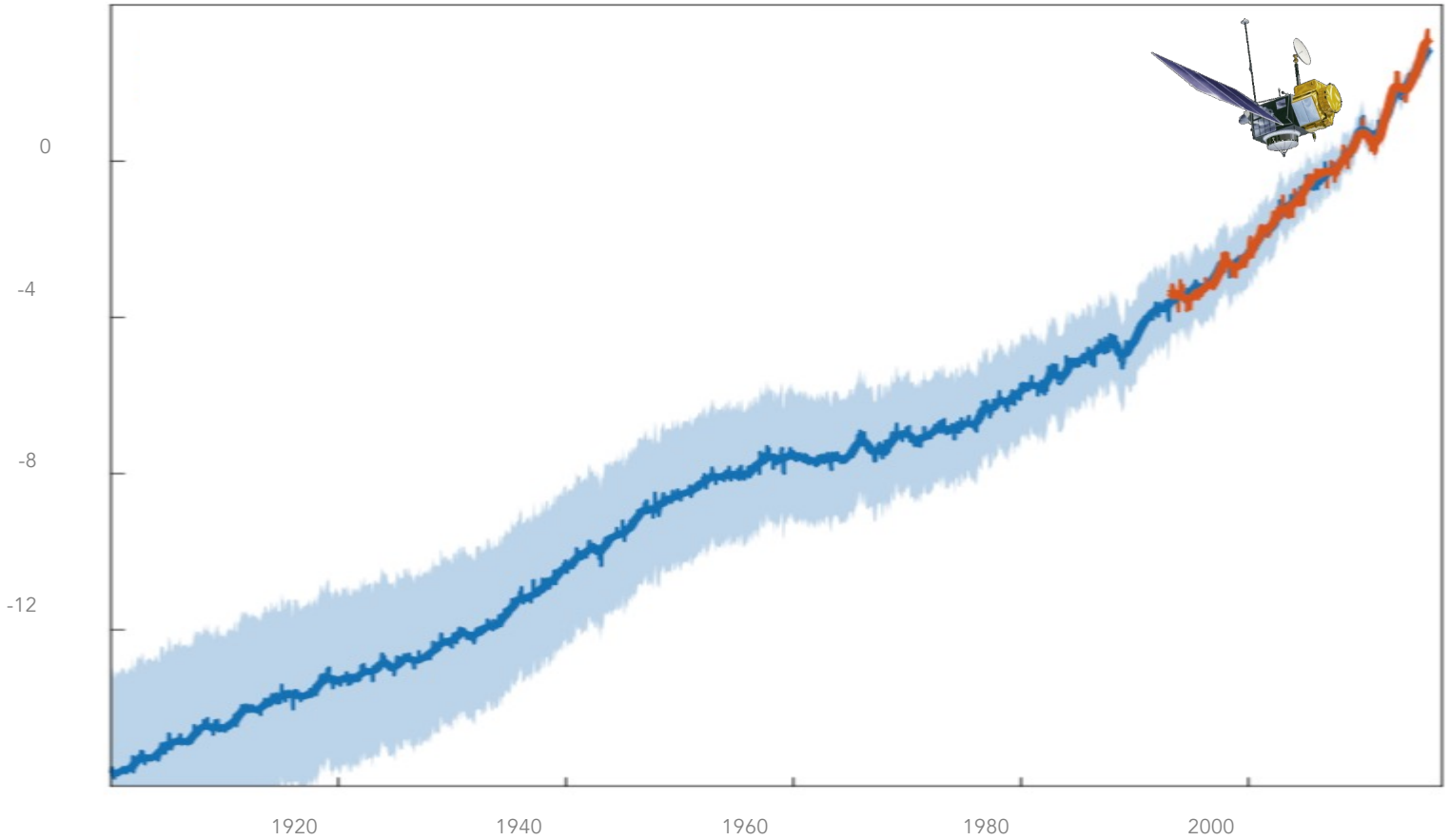
Copernicus 2024


FROM THE DIRECTOR OF INDEPENDENCE DAY
THE DAY AFTER TOMORROW
WHERE WILL YOU BE?


SCIENCES ET AVENIR
Déchets nucléaires
La solution Myrrha
p.24
LA FIN DU GULF STREAM
L'hiver polaire en Europe
p.38
44 scientifiques sonnent l'alerte



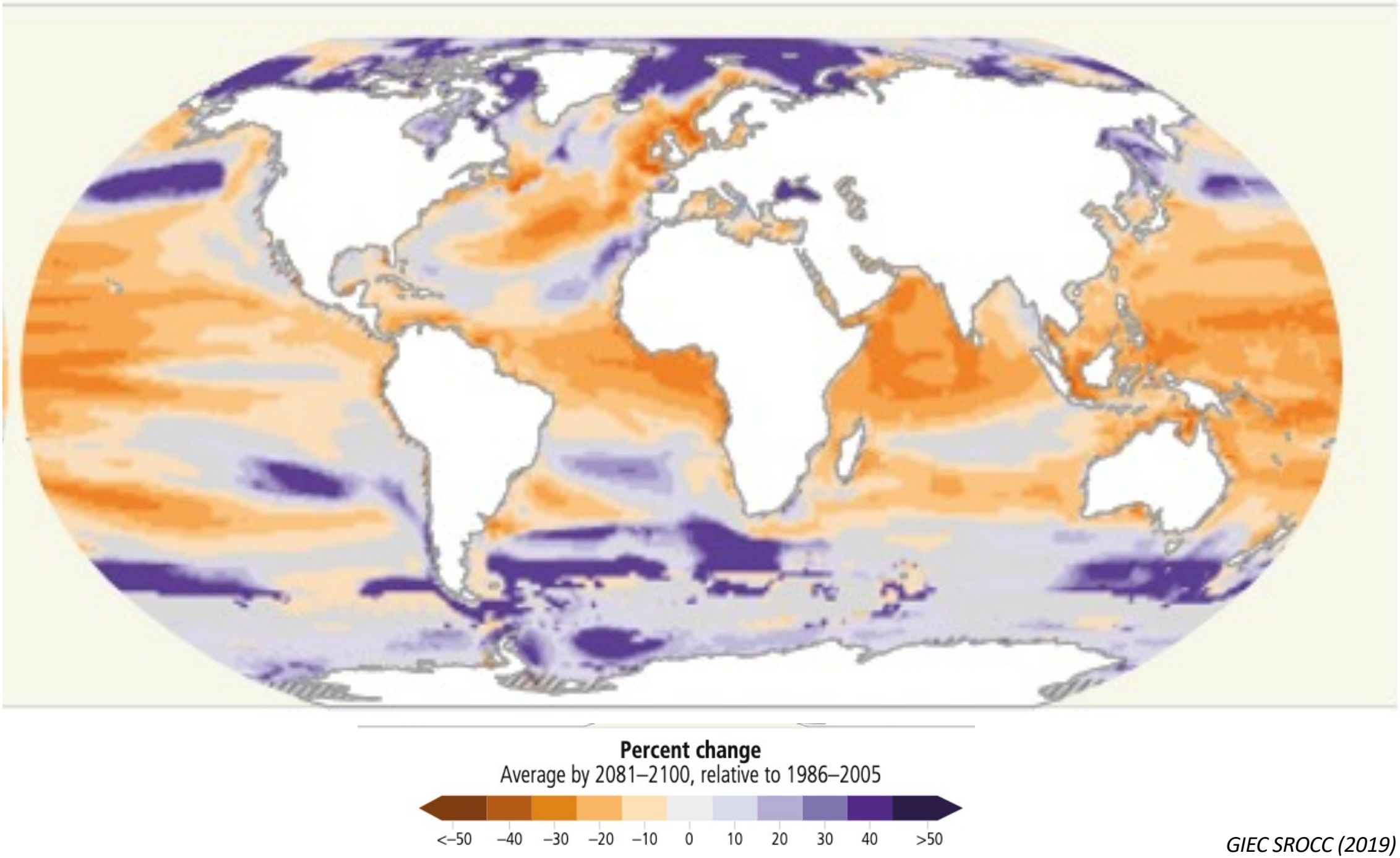

Katia
Irma
Jose
NOAA, Septembre 2017



23 cm

Bleached coral reefs in Moorea, French Polynesia. ***Alexis Rosenfeld / Getty Images***

Les centaines de milliers de poissons retrouvés échoués sur la plage de Quintana au Texas. - Quintana Beach Country Park



GIEC SROCC (2019)


Photo: Alexis Rosenfeld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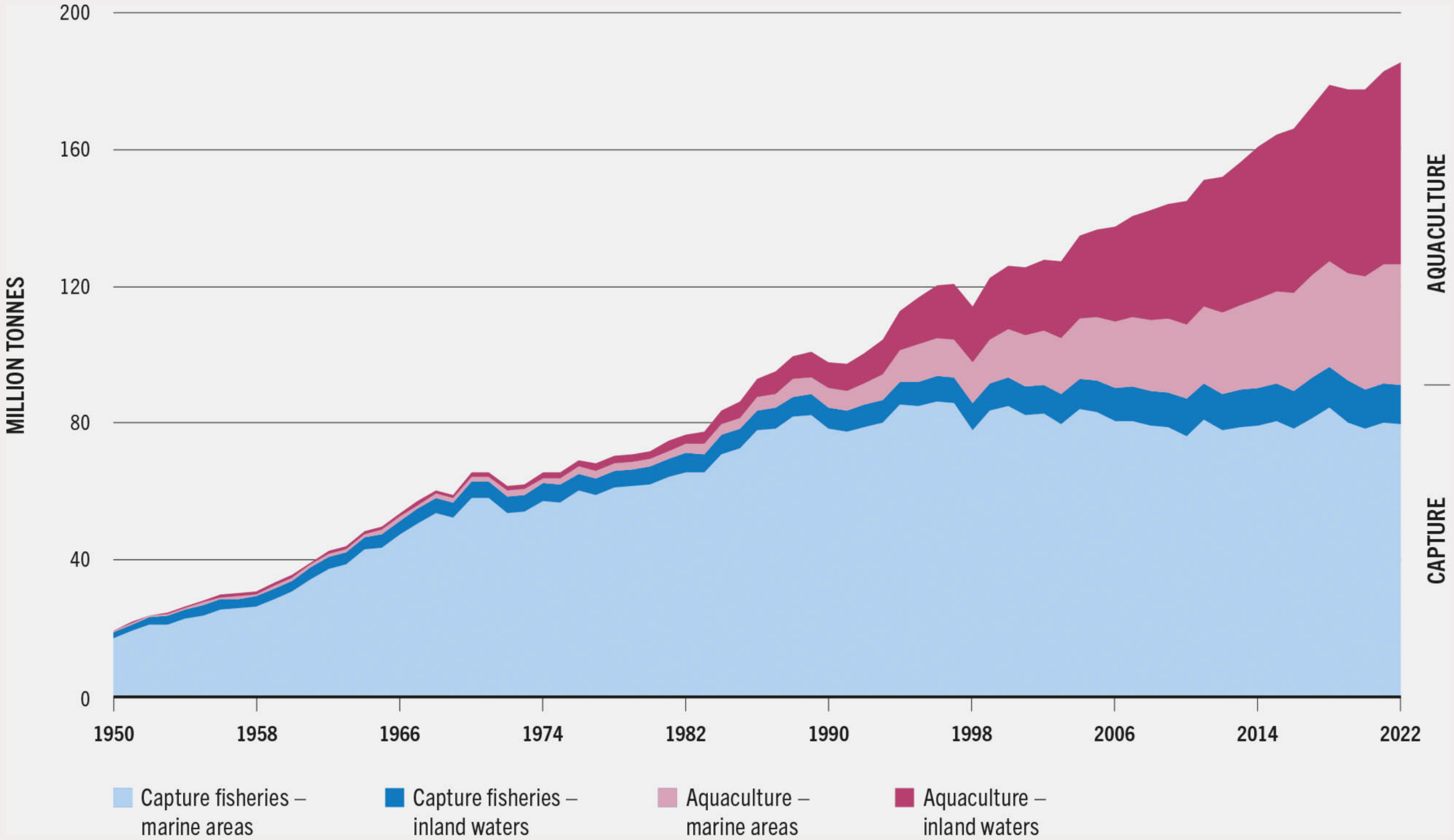

NOTES: Aquatic animals excluding aquatic mammals, crocodiles, alligators, caimans, aquatic products (corals, pearls, shells and sponges) and algae. Data expressed in live weight equivalent.

SOURCE: FAO. 2024. FishStat: Global production by production source 1950–2022. [Accessed on 29 March 2024]. In: FishStatJ. Available at: www.fao.org/fishery/en/statistics/software/fishstatj. Licence: CC-BY-4.0.


Photo: Alexis Rosenfeld


Photo: Alexis Rosenfeld


UN OCEAN
CONFERENCE
NICE 2025
FRANCE


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS


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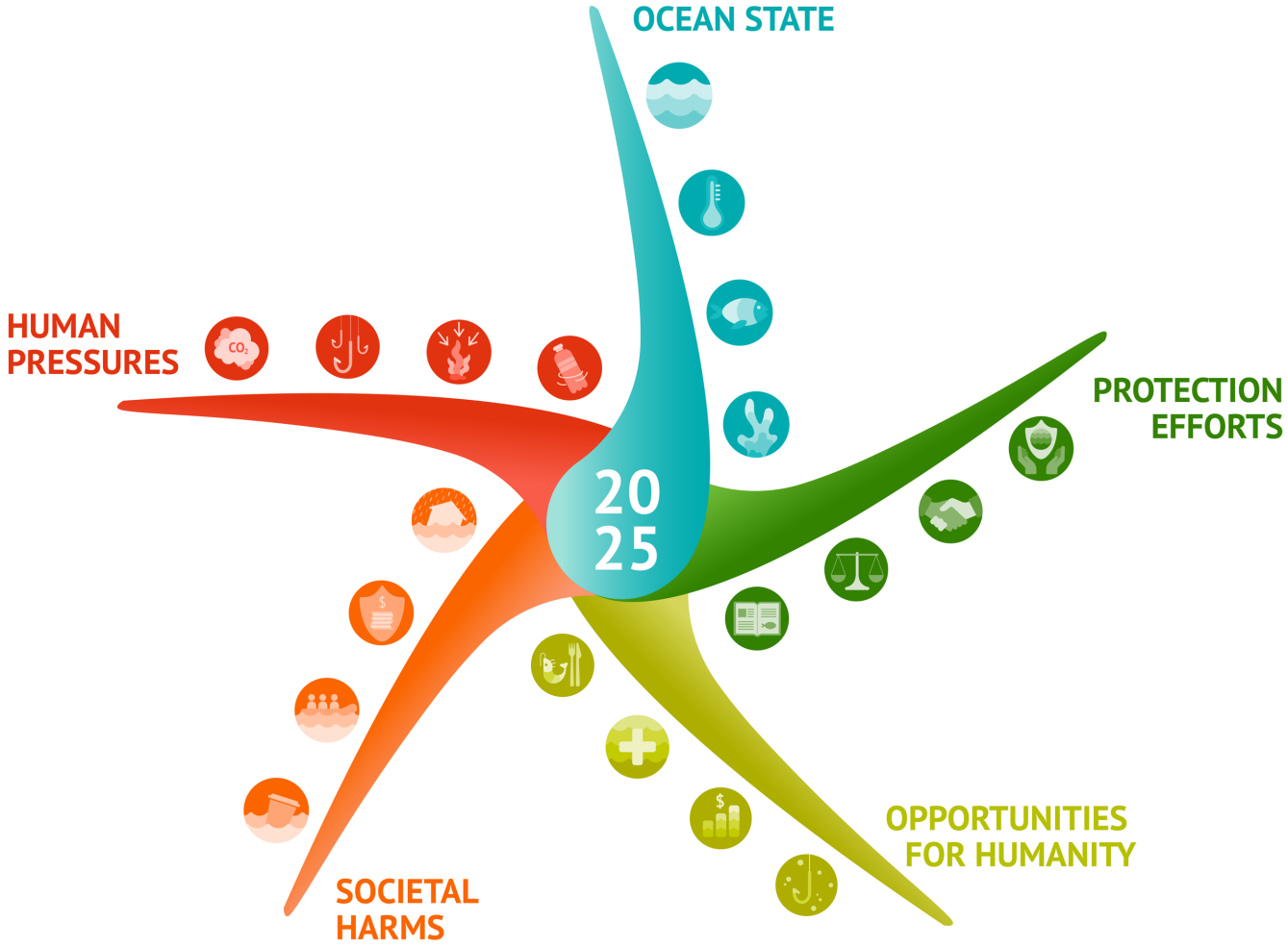

The **sea is rising**— its level has **increased by 23 cm** since 1901

Global **losses from tropical storms and floods hit US$ 102 billion**

We have **set policies to protect 8.34% of the ocean**

1,677 marine species are currently at **risk of extinction**

Marine animal food production reached a **record of 115 million tonnes**

37.7% of fish stocks are overexploited

Starfishbarometer.org

Epilogue