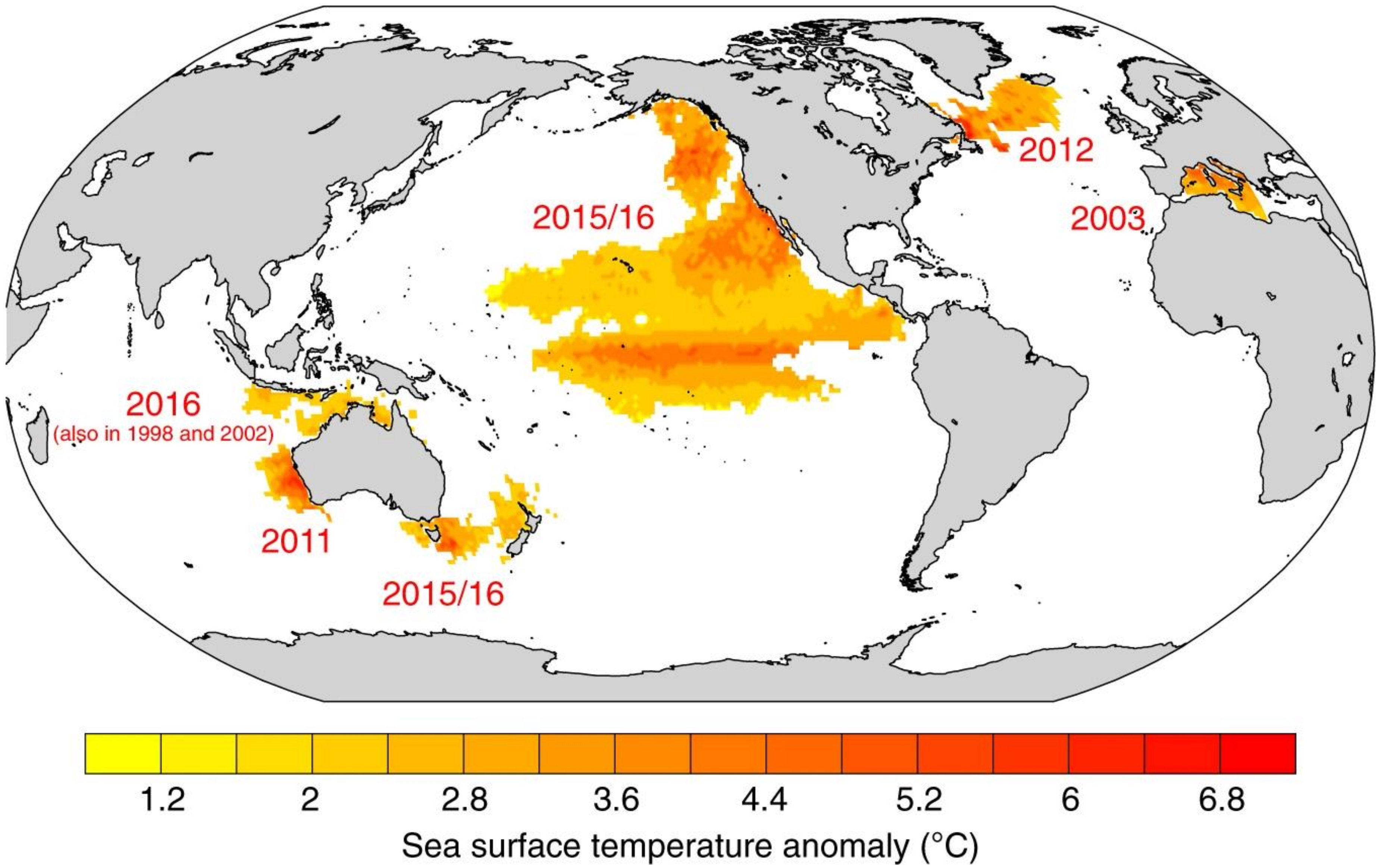
# Weakened carbon export and respiration during the extreme 2016 El Niño heatwave

Lionel A. Arteaga[1,2], Cecile Rousseaux[1], Ivona Cetinic[1,3], Seth Bushinsky[4]
[1]NASA GSFC, [2]UMBC, [3]MSU, [4]University of Hawaii

Ocean Carbon From Space (2025)

# Motivation: Marine heatwaves and ecosystems

## Global MHWs




*Frölicher and Laufkötter (2018)*

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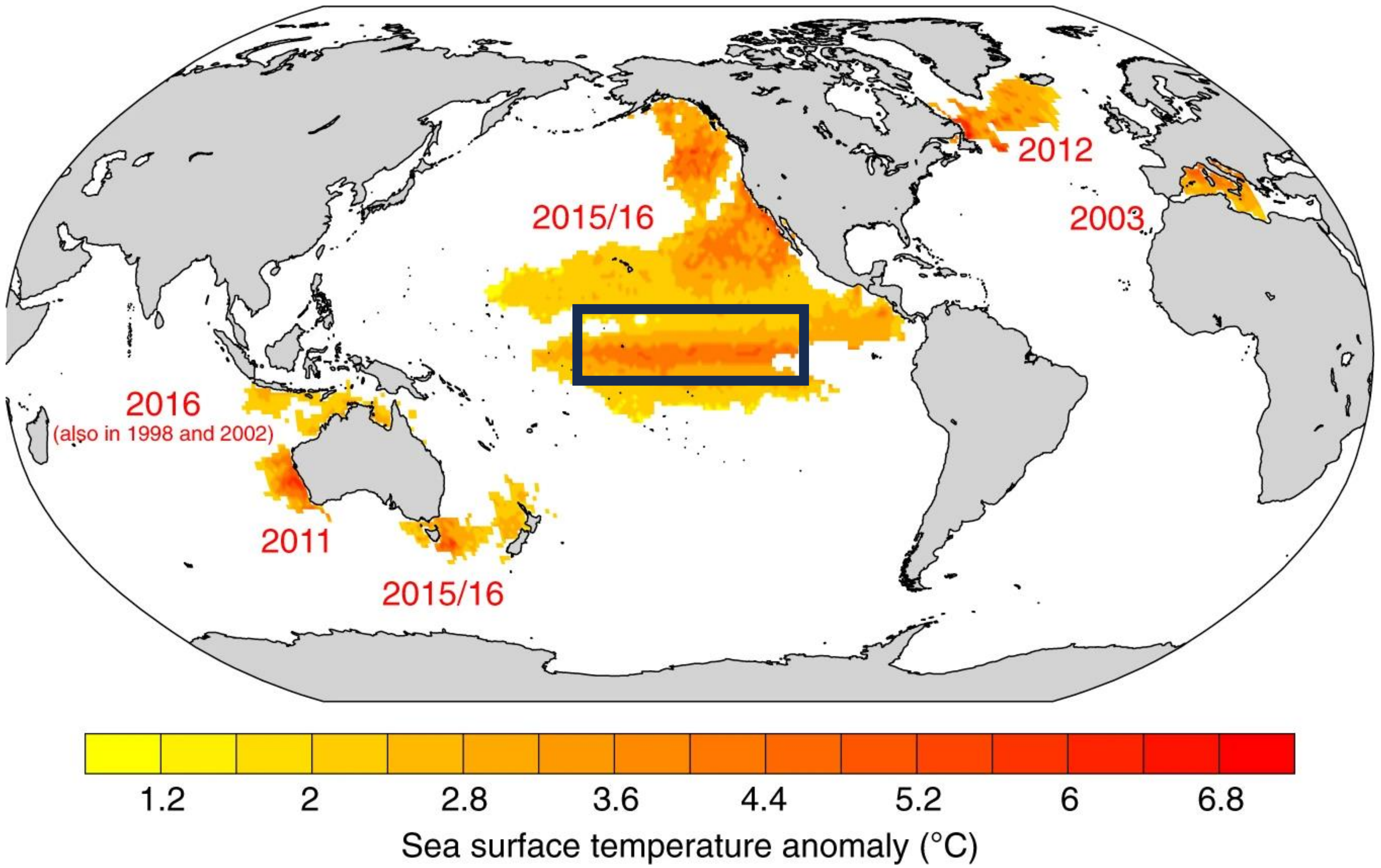
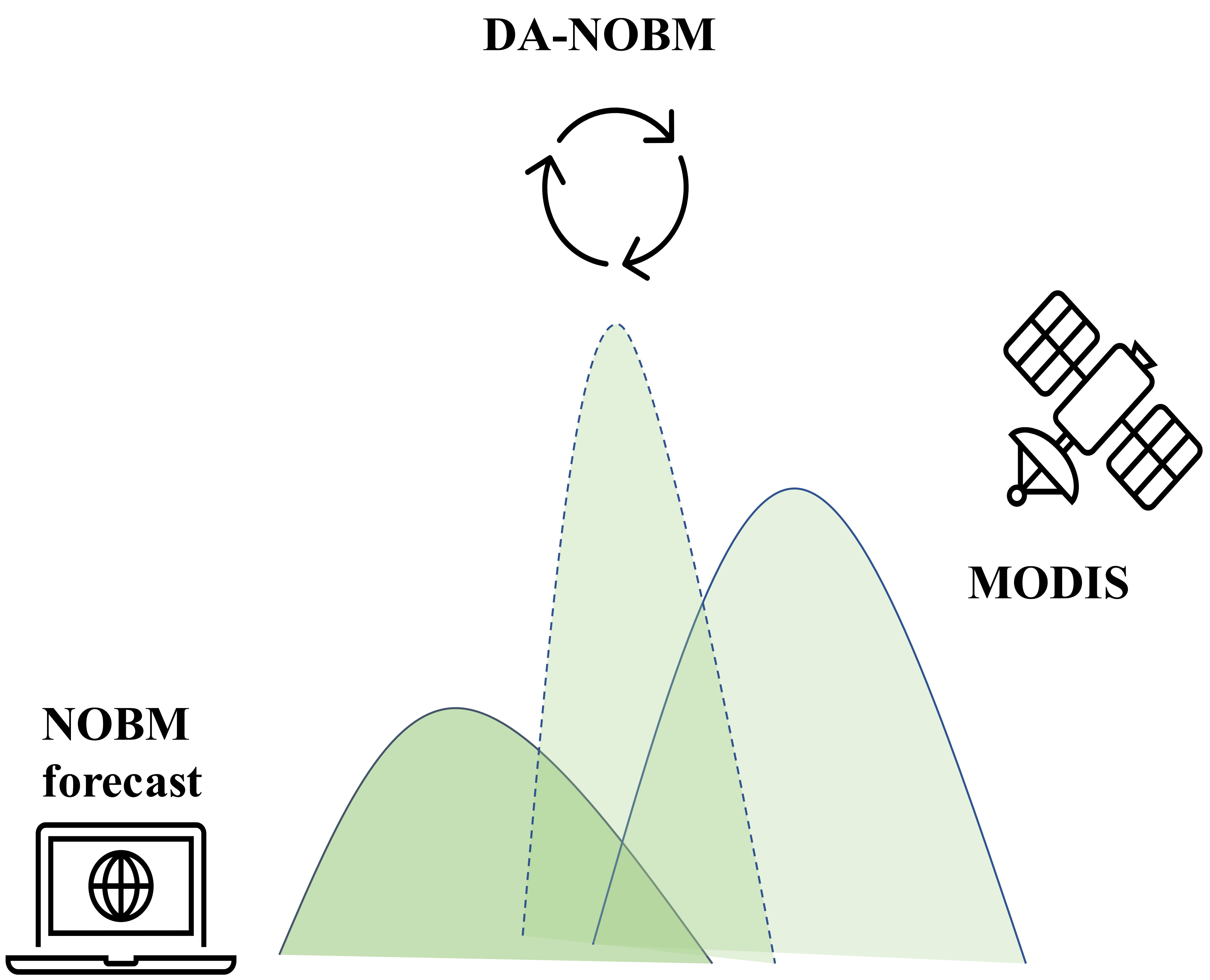
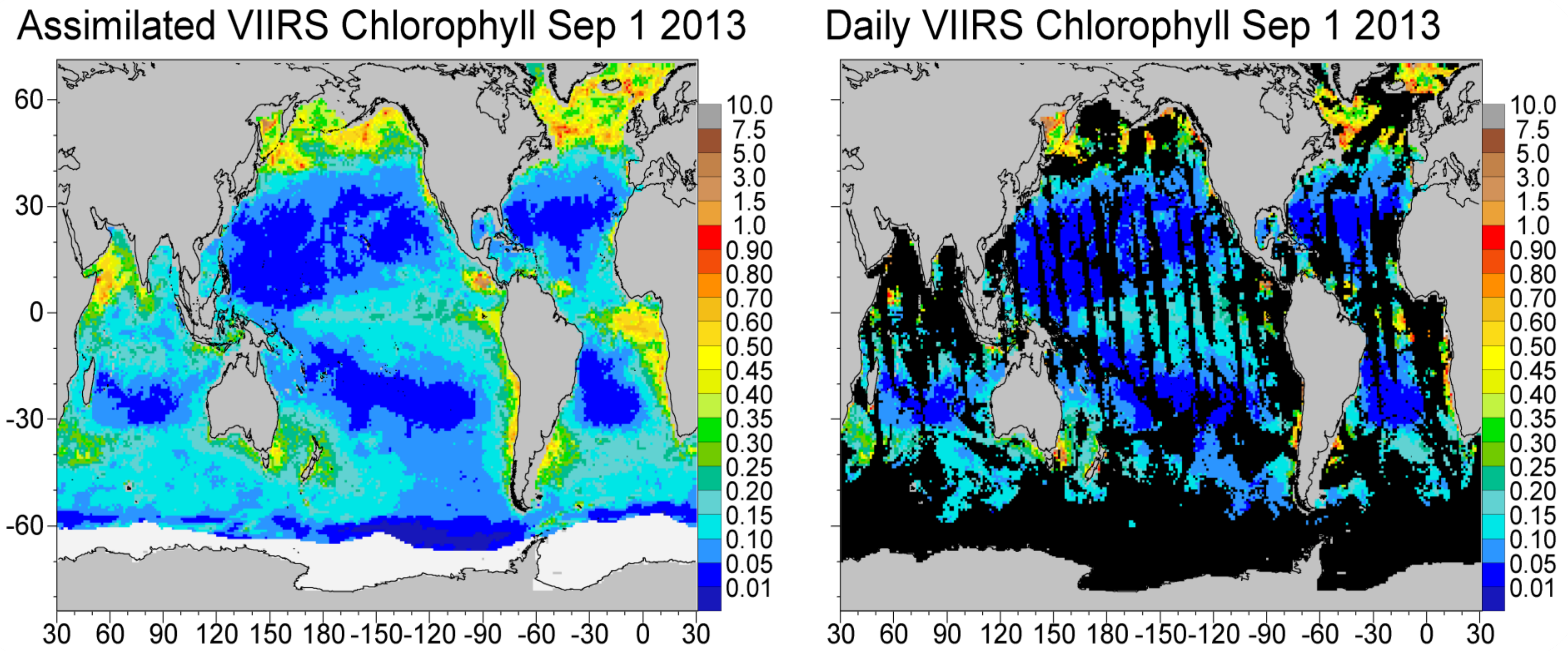



*Frölicher and Laufkötter (2018)*

# Tools: NASA Ocean Biogeochemical Model




Level-4 products: Fill gaps in satellite retrievals and provide data that cannot be derived from current sensors

# Foundational work

# Foundational work: ENSO and chlorophyll

communications
biology

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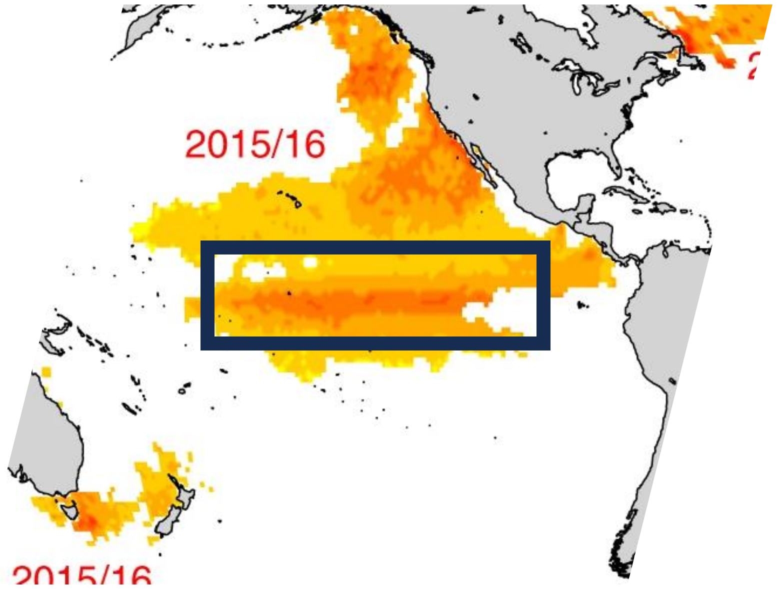
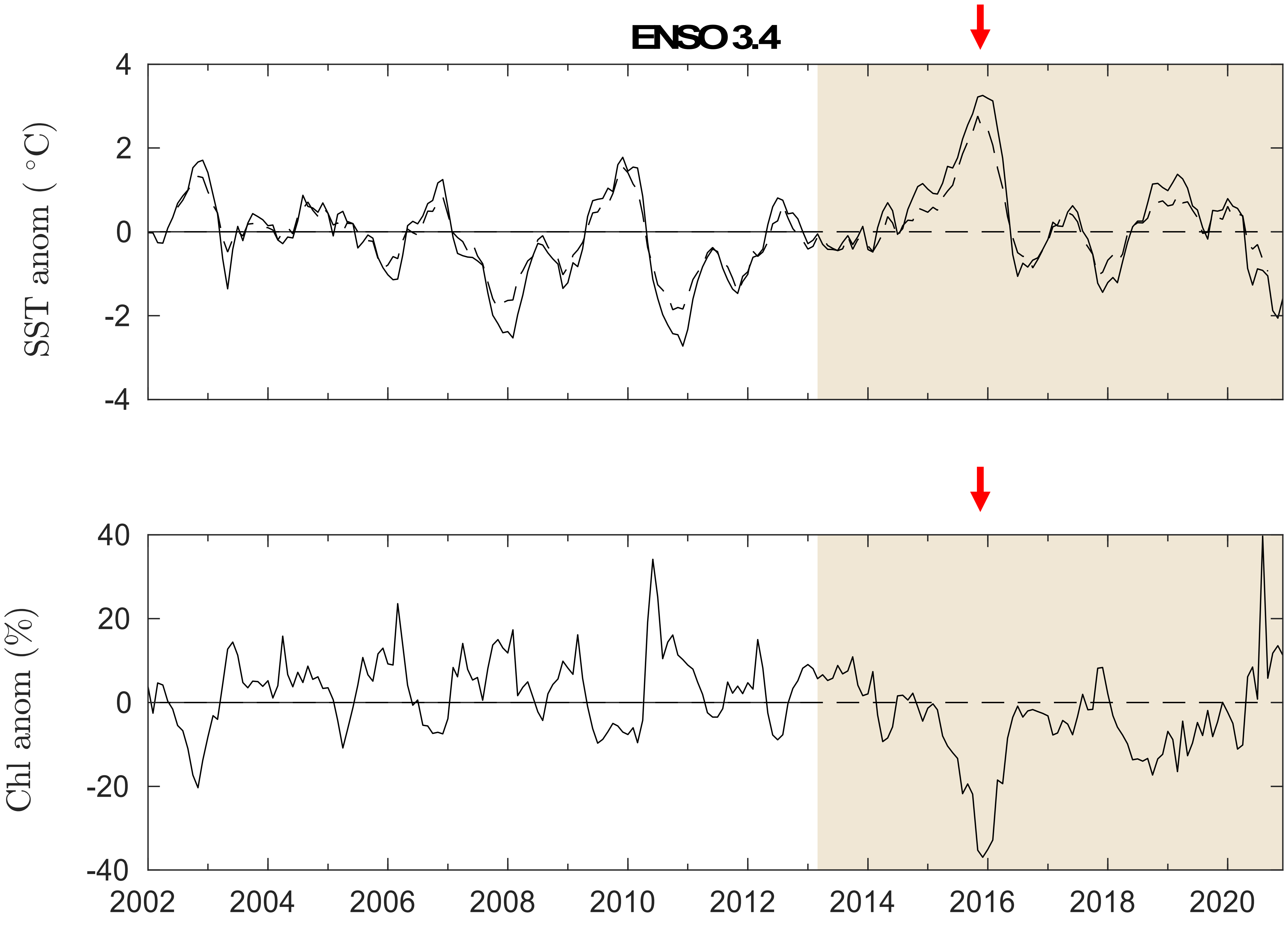
https://doi.org/10.1038/s42003-023-04645-0 OPEN

Impact of Pacific Ocean heatwaves on phytoplankton community composition

Lionel A. Arteaga [1,2] & Cecile S. Rousseaux [3]

**ENSO 3.4**

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# Foundational work: ENSO and phytoplankton ecology

communications
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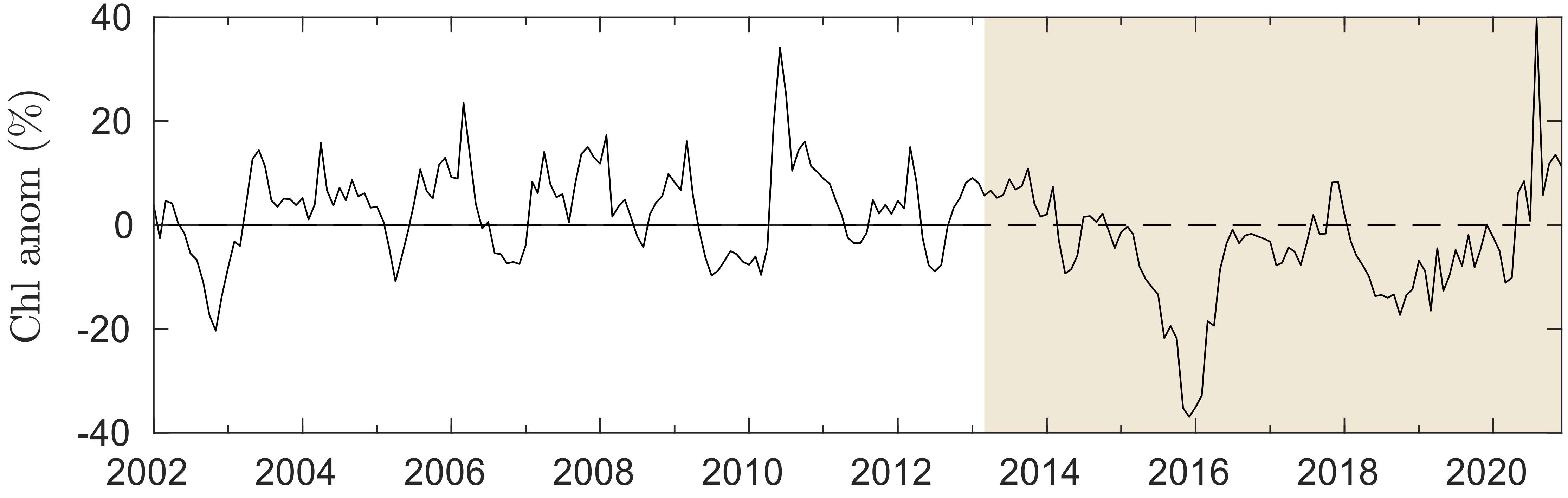


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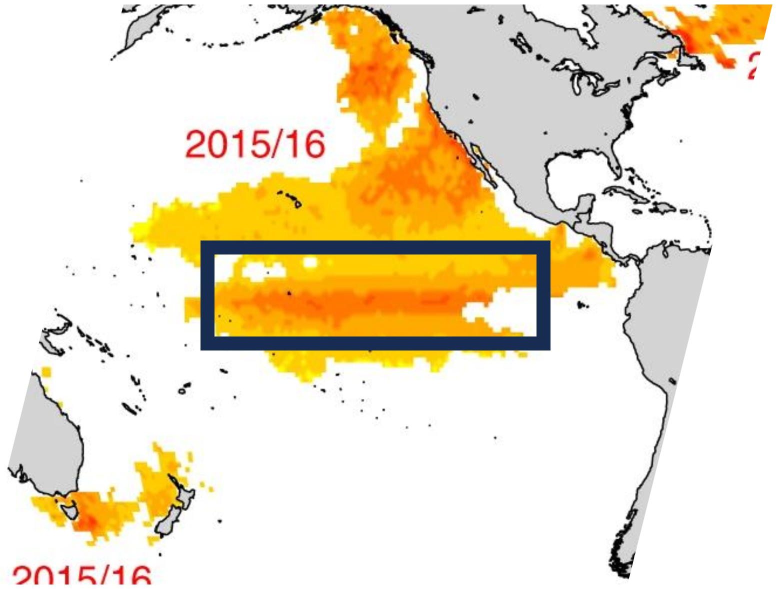
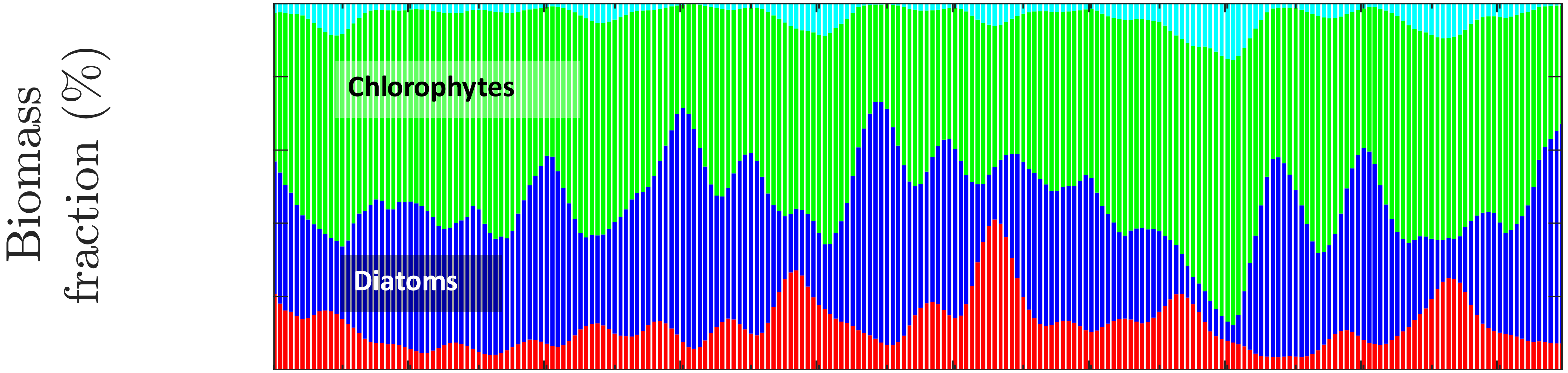



*Arteaga and Rousseaux (2023)*

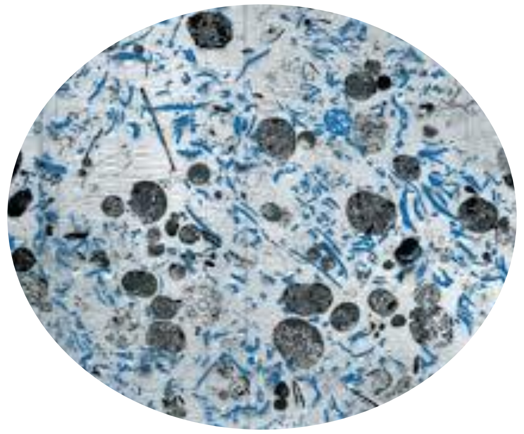
These results suggest a strong decline in carbon export in 2016.

Can we prove it?

# Current tools: NOBM and ML products

## NASA Ocean Biogeochemical Model

- Assimilation of satellite ocean color
- Arteaga and Rousseaux (2023)



## SOCA-BBP

- ML-based on BGC-Argo and remote sensing
- Sauzede et al. (2016,2024)


## GOBAI-$O_2$ (Aparent Oxygen Utilization-AOU)

- ML-based on BGC-Argo and ship observations
- Sharp et al. (2023)

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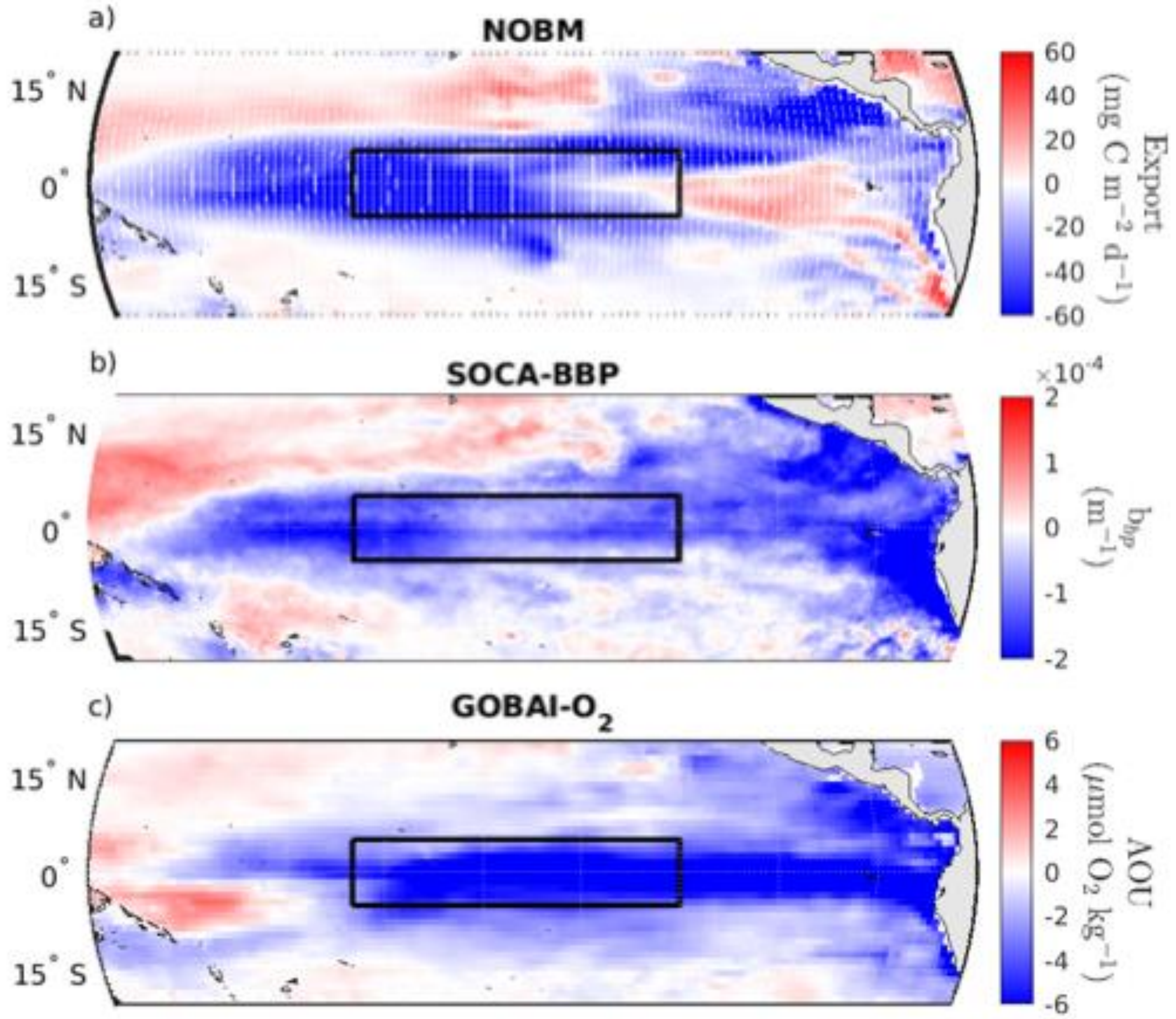
# Upper ocean patterns in export-related variables




**Anomalies during the 2016 El Niño**

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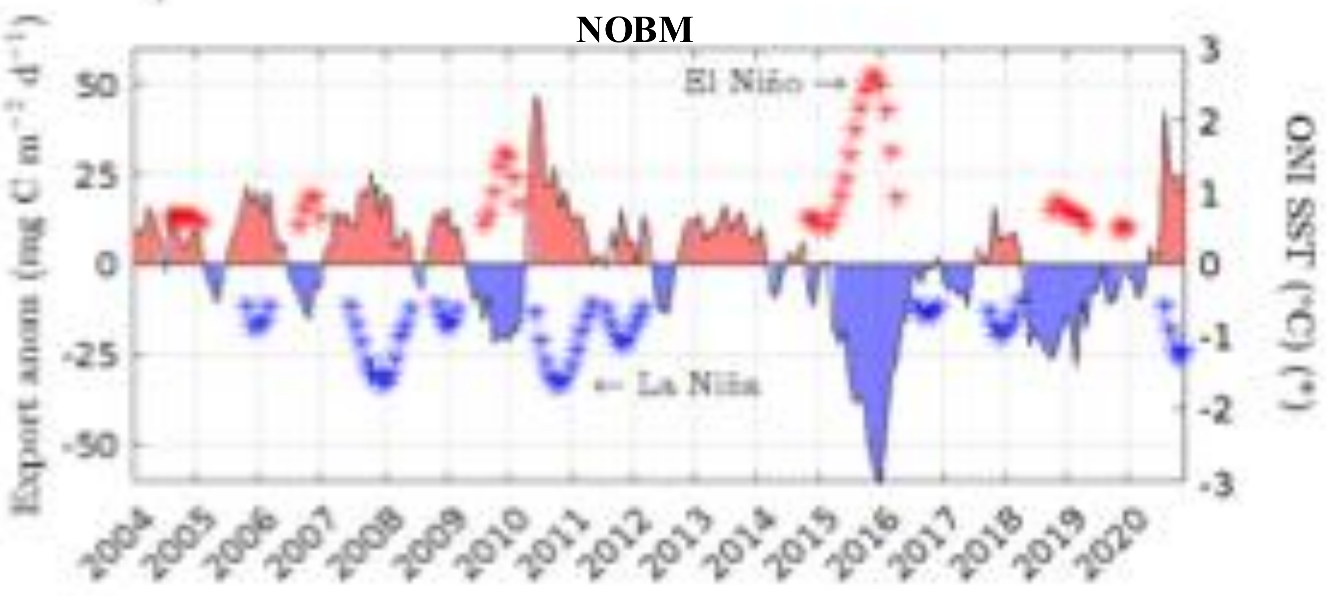
# Anomalies in export, $b_{bp}$, and AOU

Total MLD POC flux anomalies (——)




ENSO (SST) anomalies (*)

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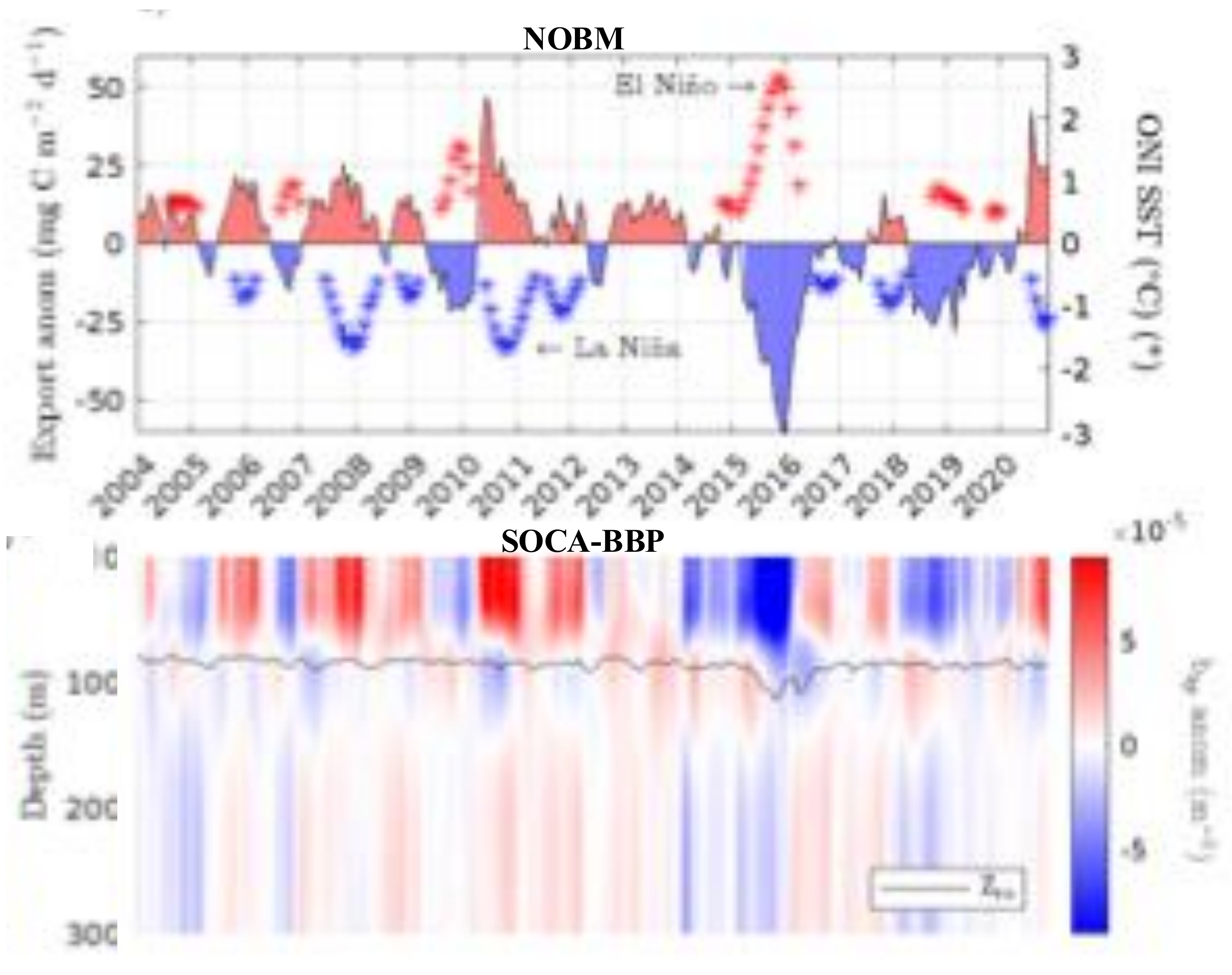
# Anomalies in export, $b_{bp}$, and AOU

Total MLD POC flux anomalies (——)

Backscattering ($b_{bp}$) anomalies

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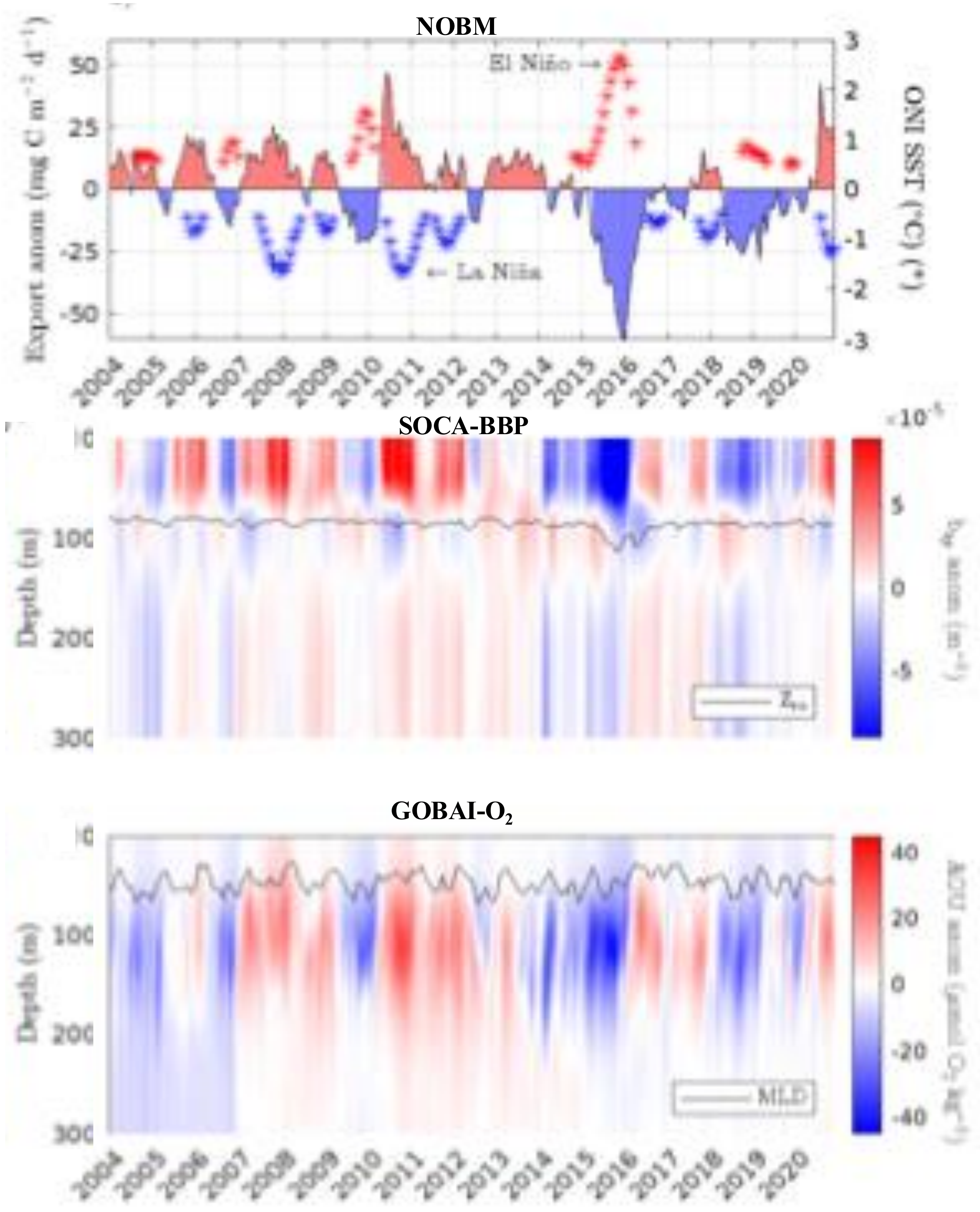


Backscattering ($b_{bp}$) anomalies

Respiration (AOU) anomalies

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# Anomalies in export, $b_{bp}$, and AOU

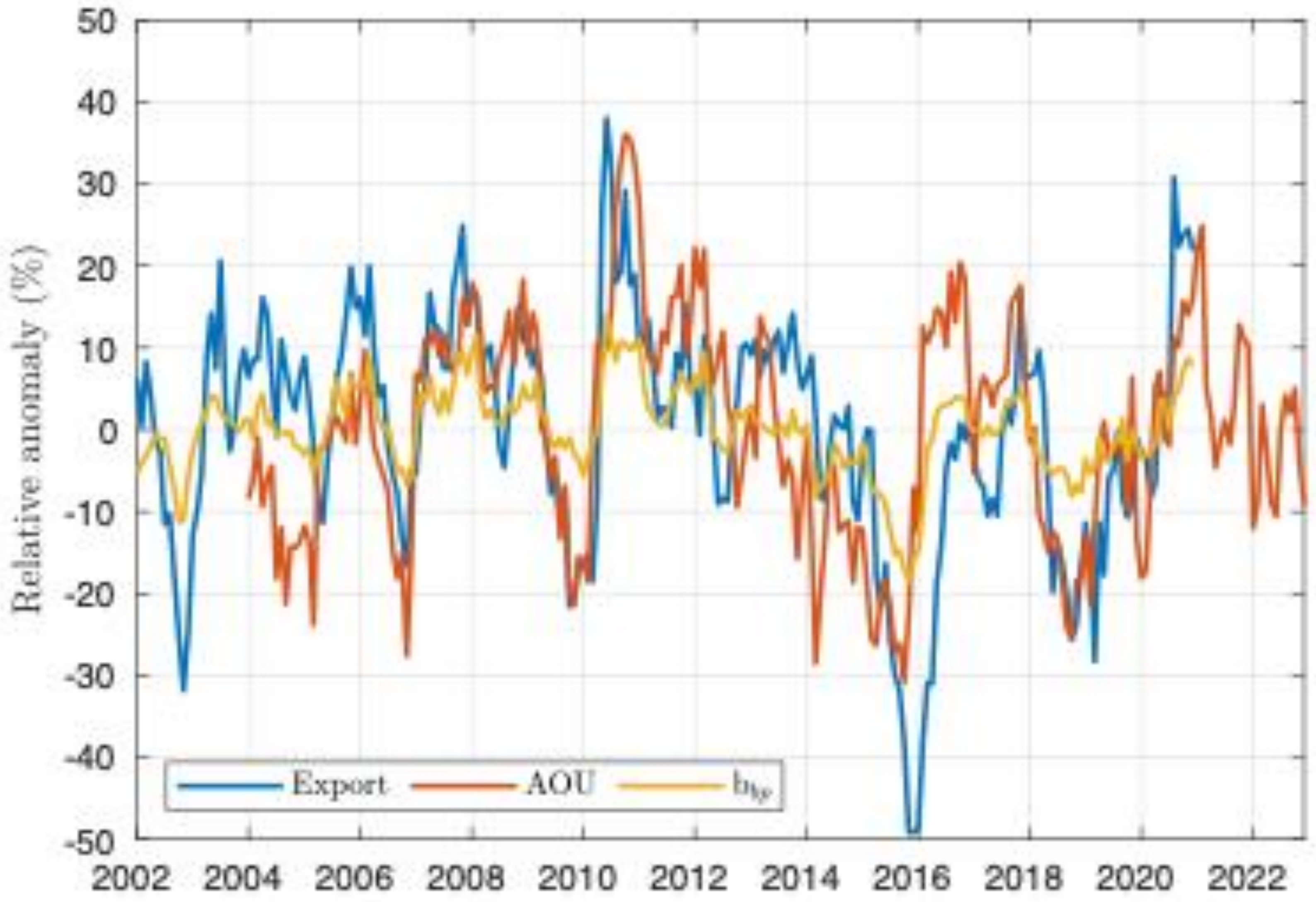


Figure 3: **Similarity in the interannual change of export, particles, and respiration in the central equatorial Pacific.** Relative monthly anomalies (%) in modeled mixed layer export, particle backscatter ($b_{bp}$) (averaged for the top 50 m), and Apparent Oxygen Utilization (AOU) (averaged between 100 – 200 m). Model export output and Argo-based $b_{bp}$ were obtained for 2002–2020. Argo-based dissolved oxygen is available from 2004 to 2022. Similarly as in Figure 2, variables are computed at a monthly temporal resolution and averaged for the ENSO 3.4 region.

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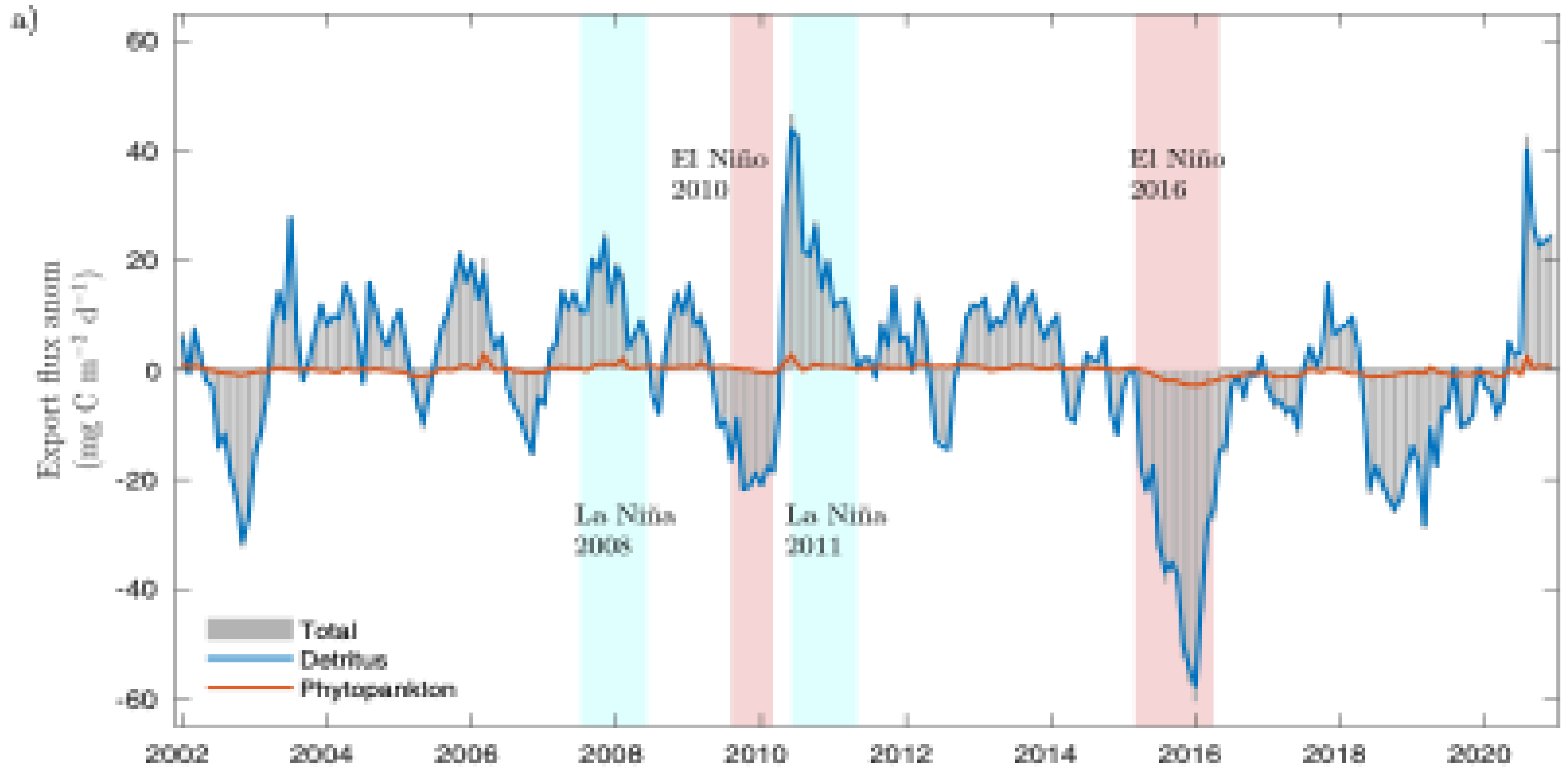
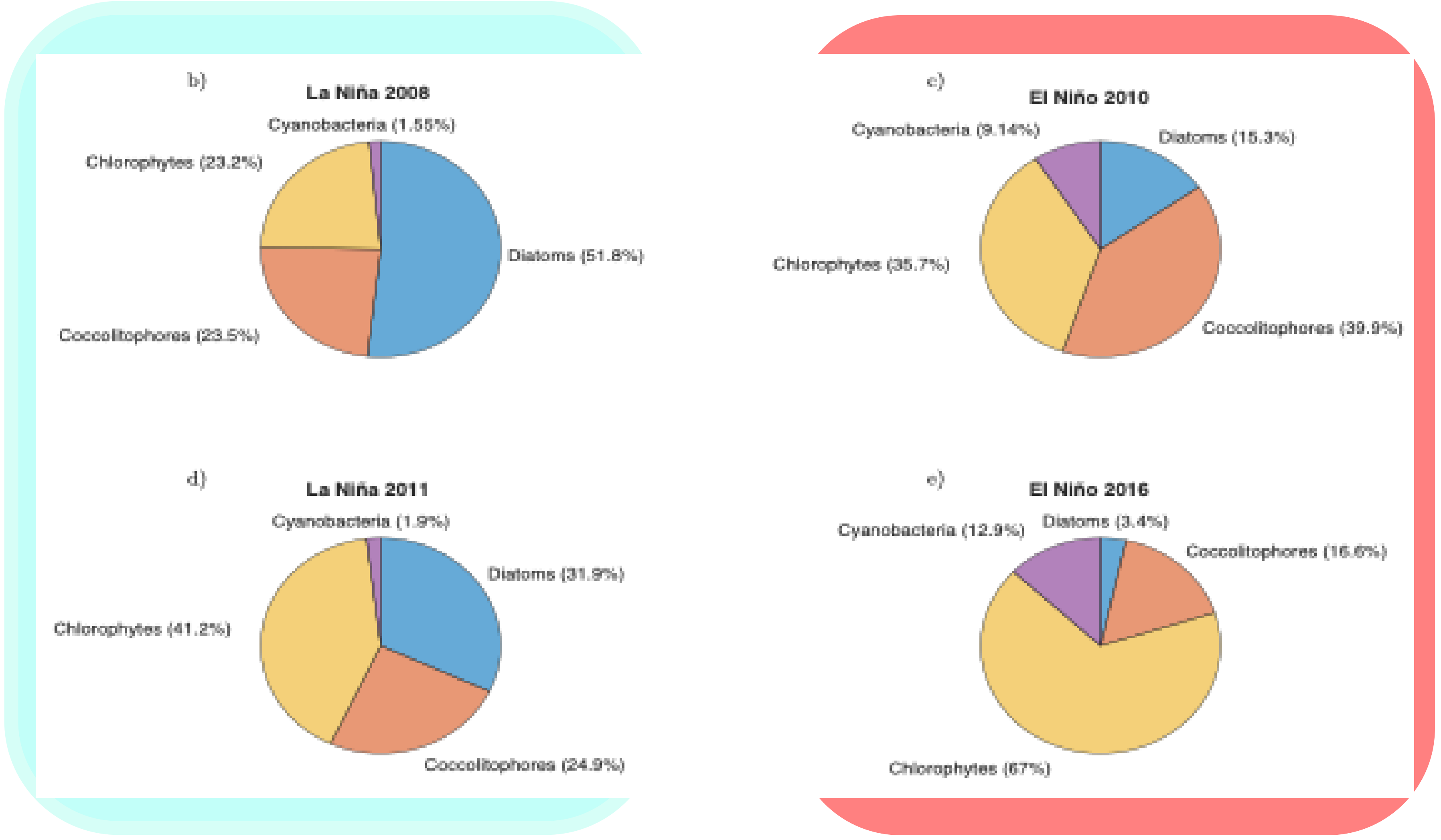
# Plankton composition impact on export

## POC carbon flux across main ecosystem compartments



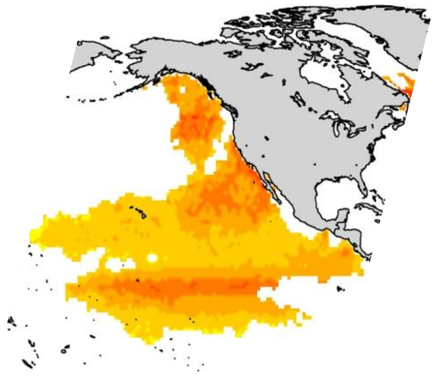

## Community composition in El Niño vs La Niña years



# Conclusions, Gaps, & Priorities

# Conclusions

## Weakened carbon export and respiration during the extreme 2016 El Niño heatwave



✓ Multiple lines of evidence point to a significant decline in equatorial Pacific carbon export during the 2016 El Niño

- How much further weakening can we expect as ENSO/MHWs intensify?
- Are there important implications for the global carbon cycle?
- How about other marine regions under heat stress?
- Do we believe these results?

# Conclusions

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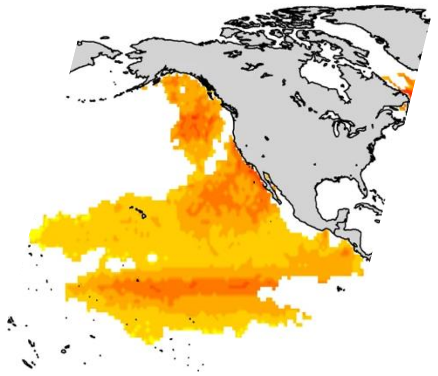

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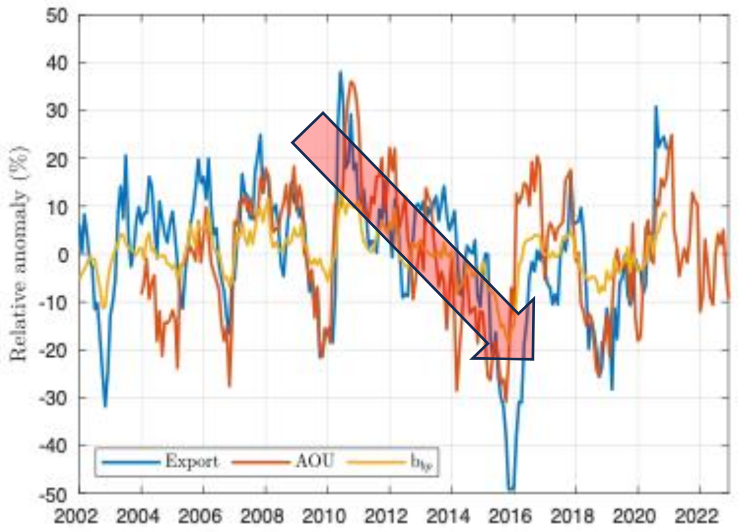
Carbon export and
Machine Learning results

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# Conclusions

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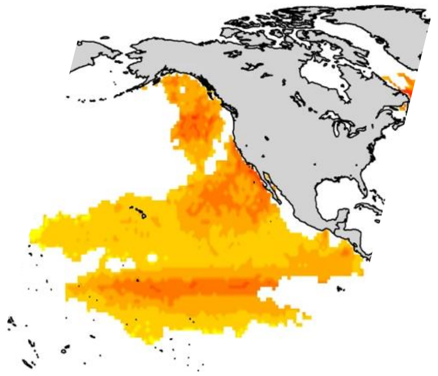

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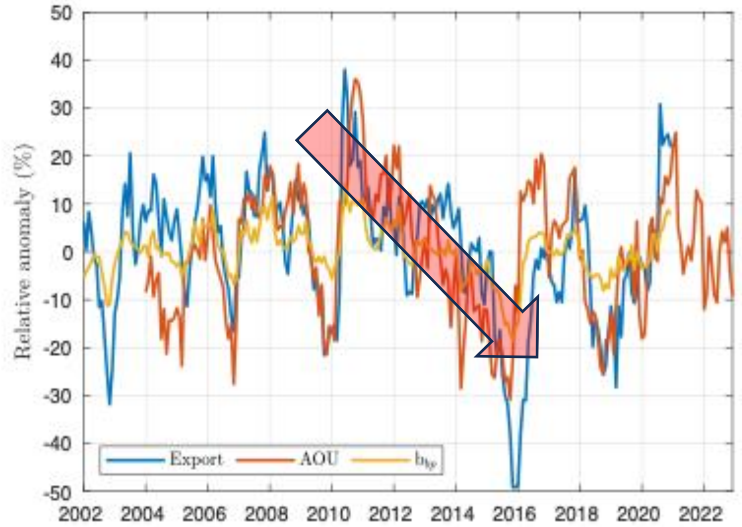
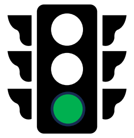
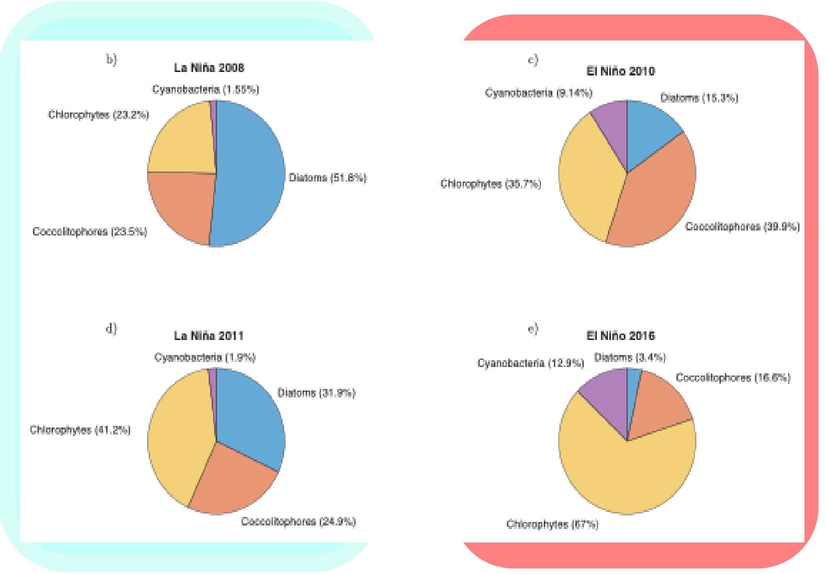


Ecological changes

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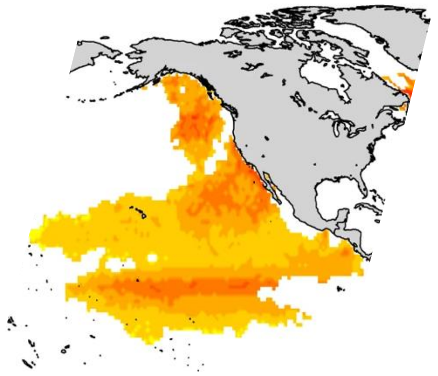

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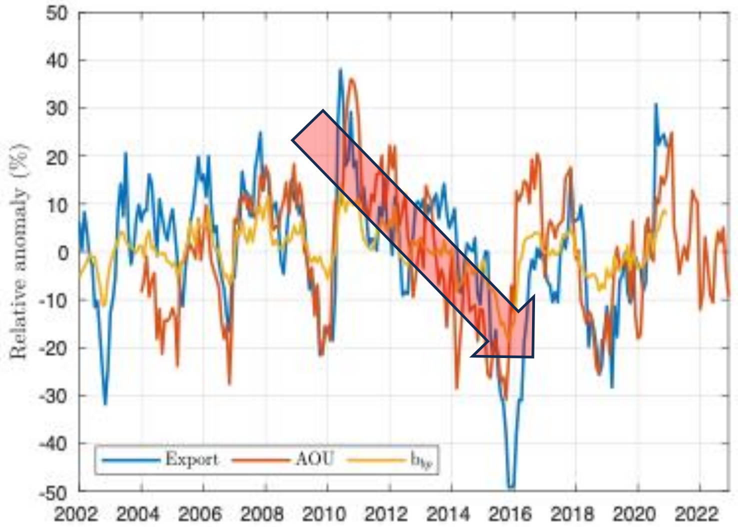


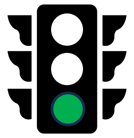

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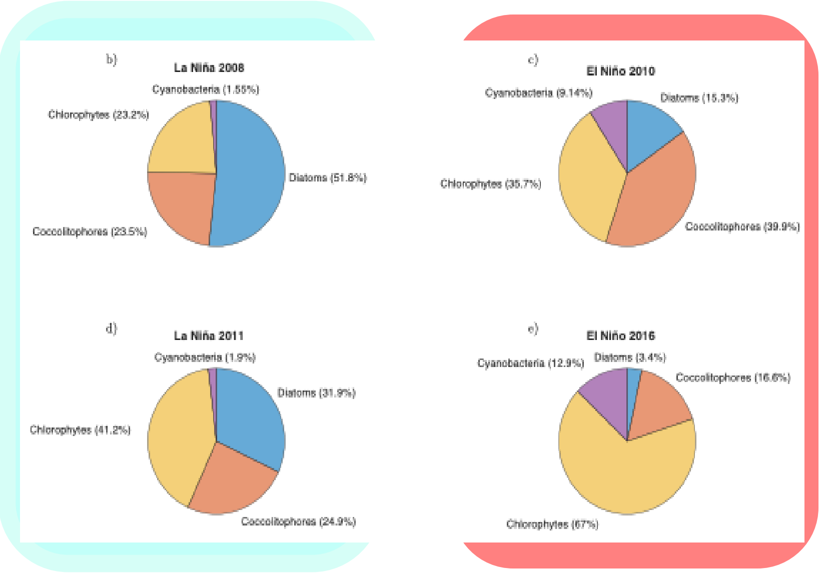
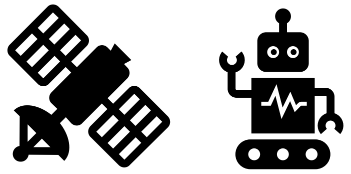



## Gaps & next steps



**Phytoplankton ecology products**

1 – 5 years → 1 0 years

# Weakened carbon export and respiration during the extreme 2016 El Niño heatwave

Arteaga et al (in review) – lionel.arteagaquintero@nasa.gov

Ocean Biology & Biogeochemistry

GMAO
Global Modeling & Assimilation Office

UMBC

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# ML-products validation

## SOCA-BBP

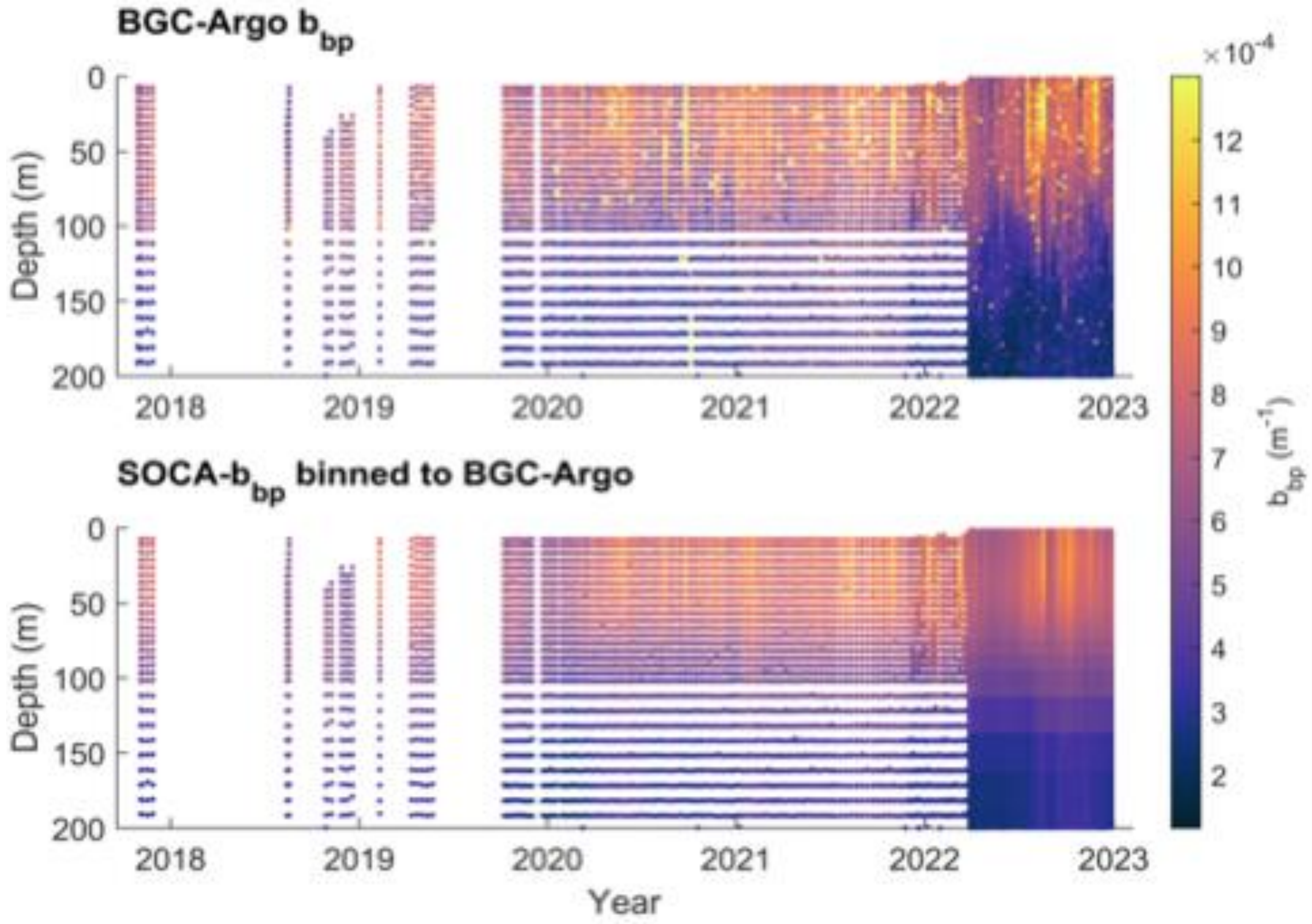



Figure S7: Vertical patterns and interannual changes in depth-resolved $b_{bp}(700)$ within the ENSO 3.4 region from (top) BGC-Argo floats and (bottom) the SOCA-BBP product binned to the resolution of matching float profiles.

## GOBAI-$O_2$

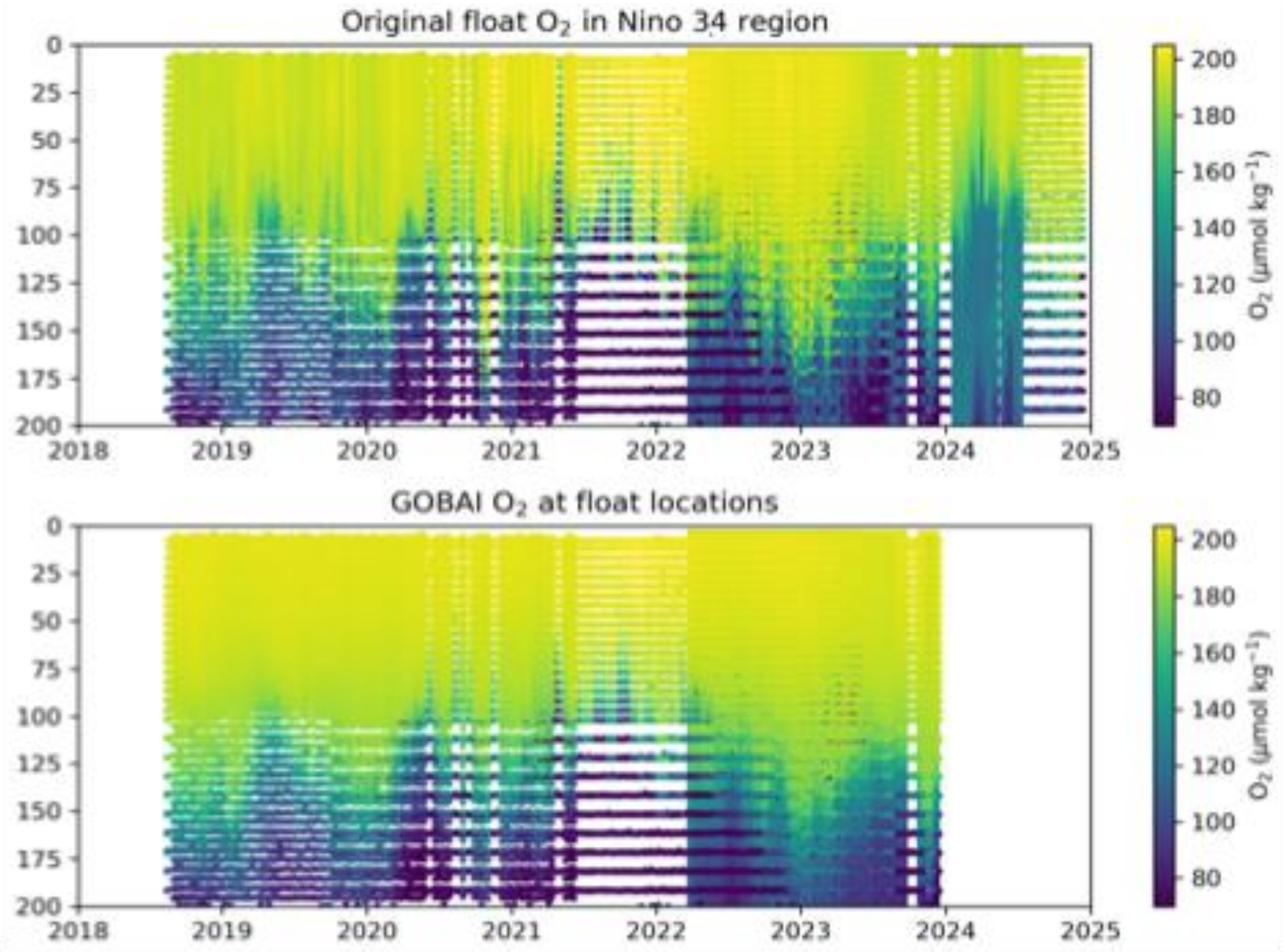
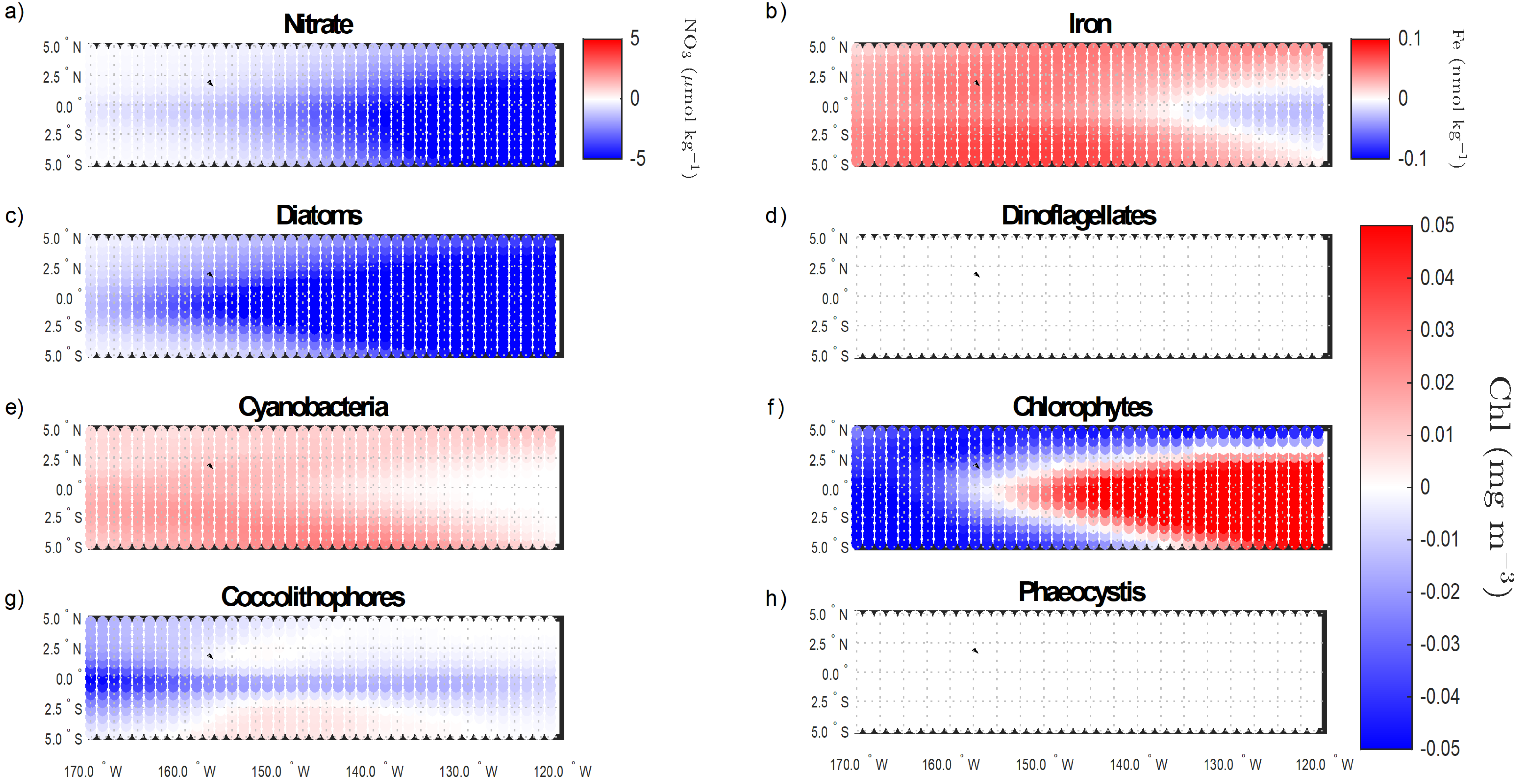



Figure S10: Vertical patterns and interannual changes in depth-resolved dissolved oxygen in the central equatorial Pacific (box coordinates) from (top) BGC-Argo floats and (bottom) the GOBAI-O2 product binned to the resolution of matching float profiles.

# ENSO 3.4: Ecological re-arrangement (early 2016)



# Foundational work: ENSO and phytoplankton ecology

communications
biology

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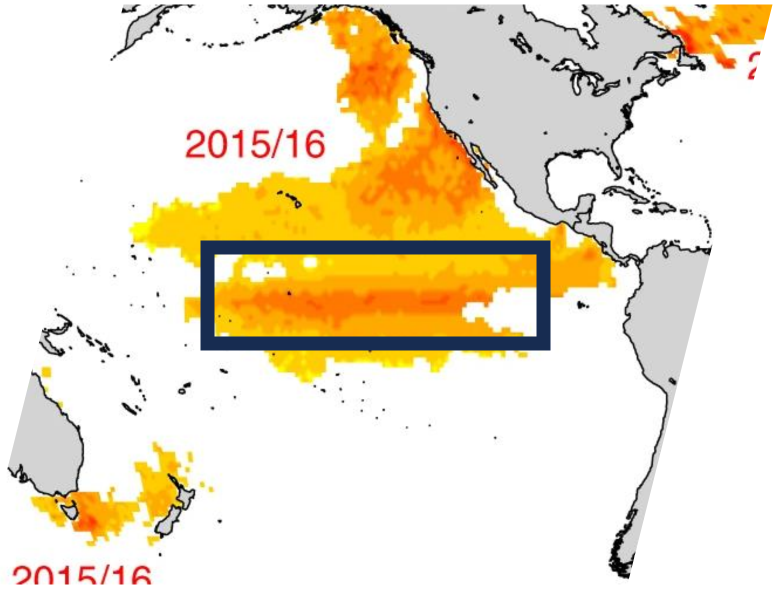


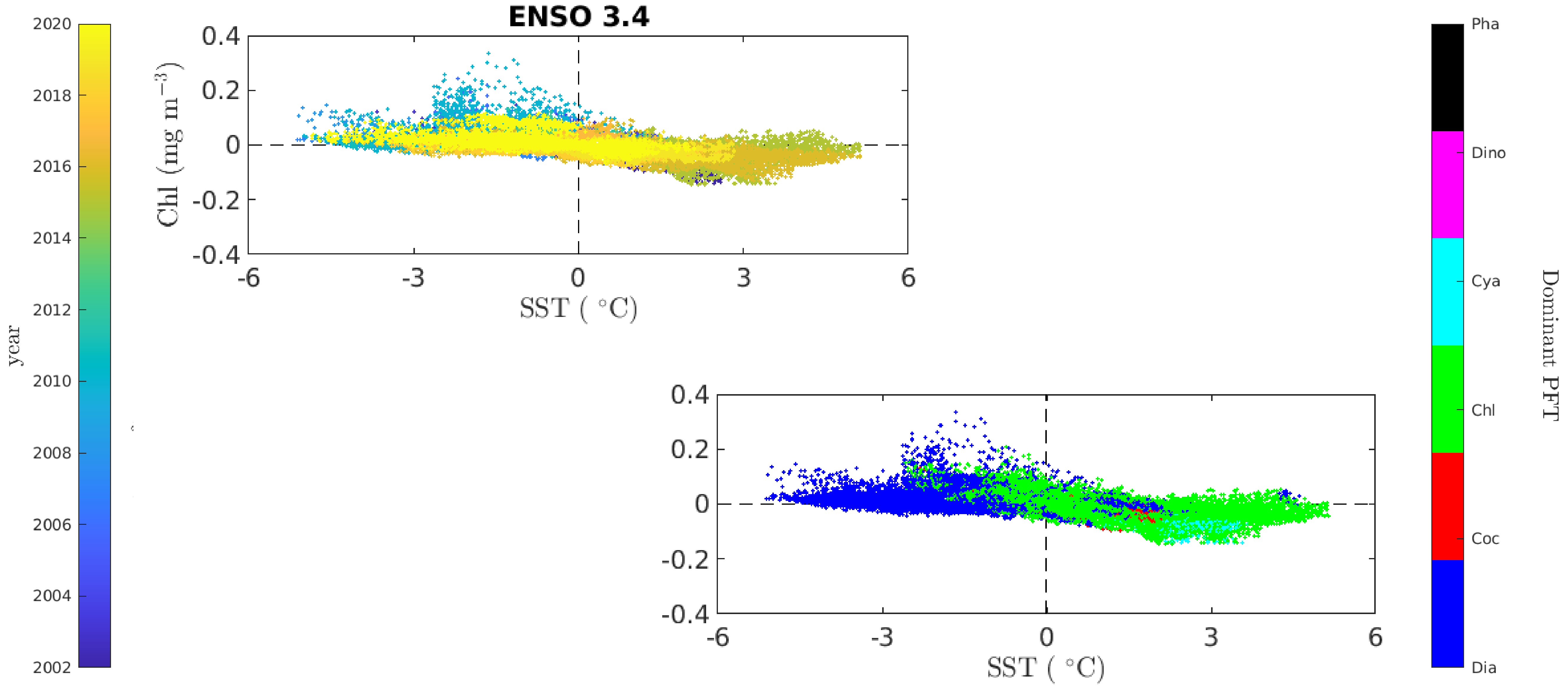


*Arteaga and Rousseaux (2023)*

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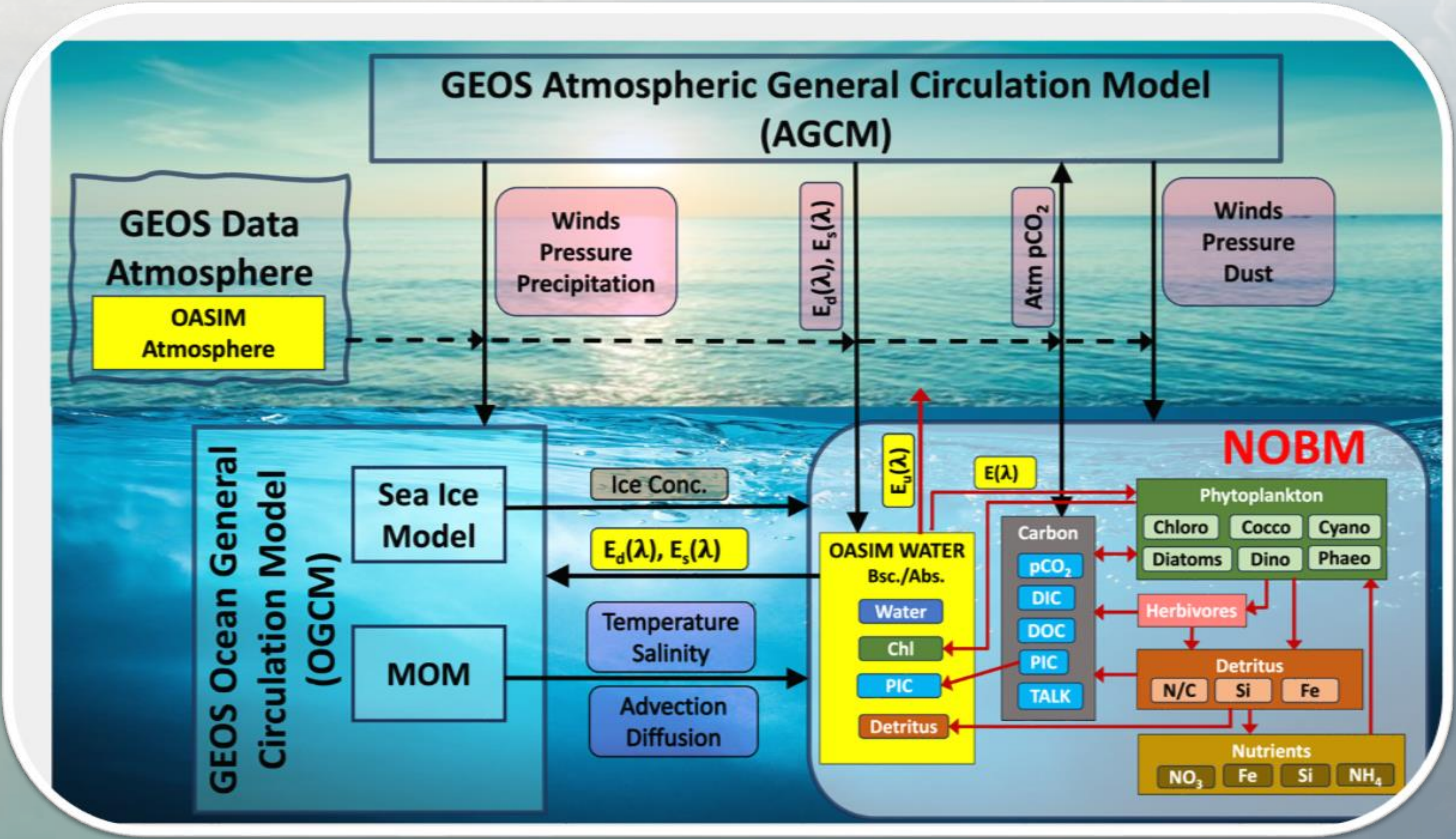
# NASA Ocean Biogeochemical Model (NOBM)

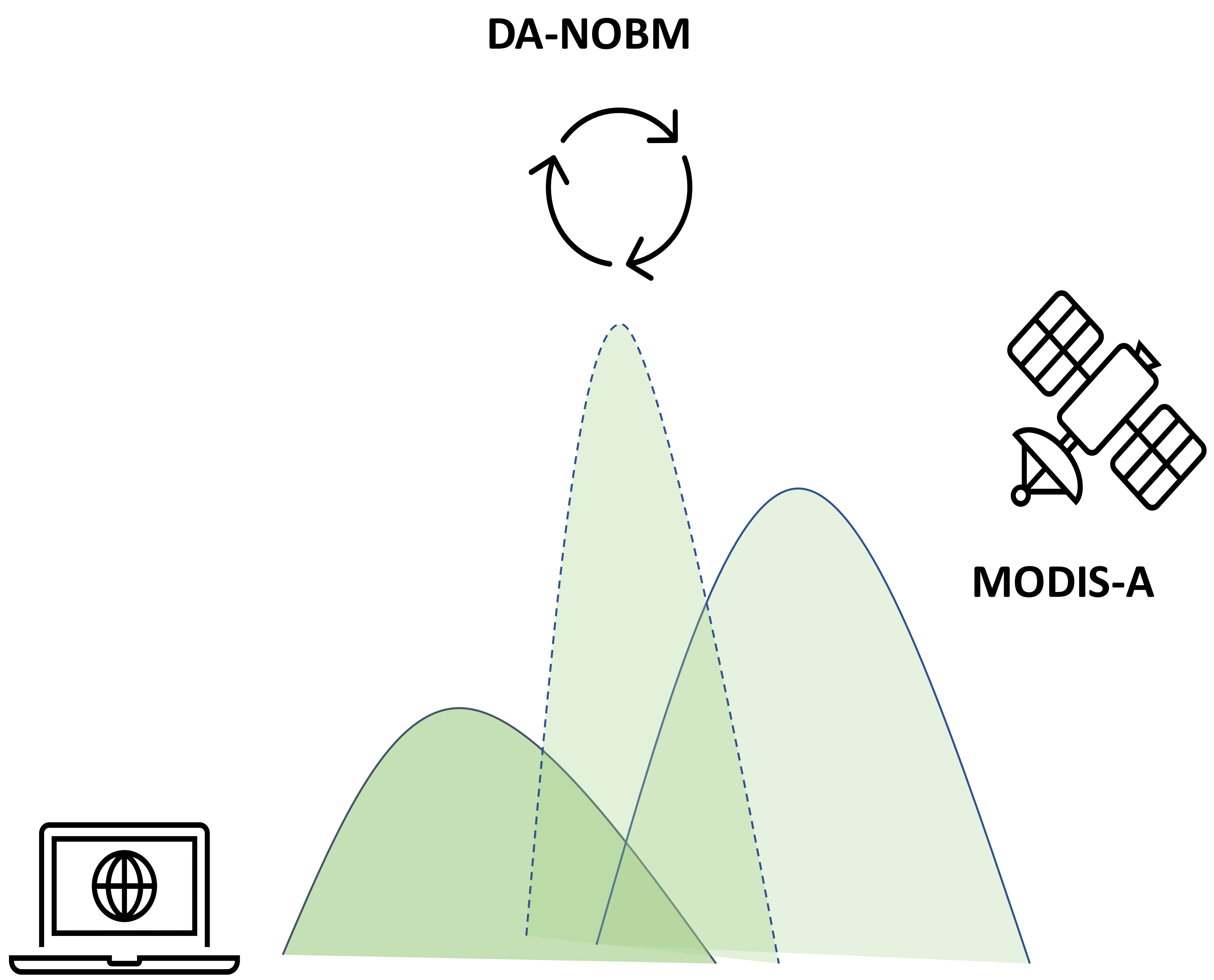
A medium complexity BGC-model for assimilation of satellite ocean color



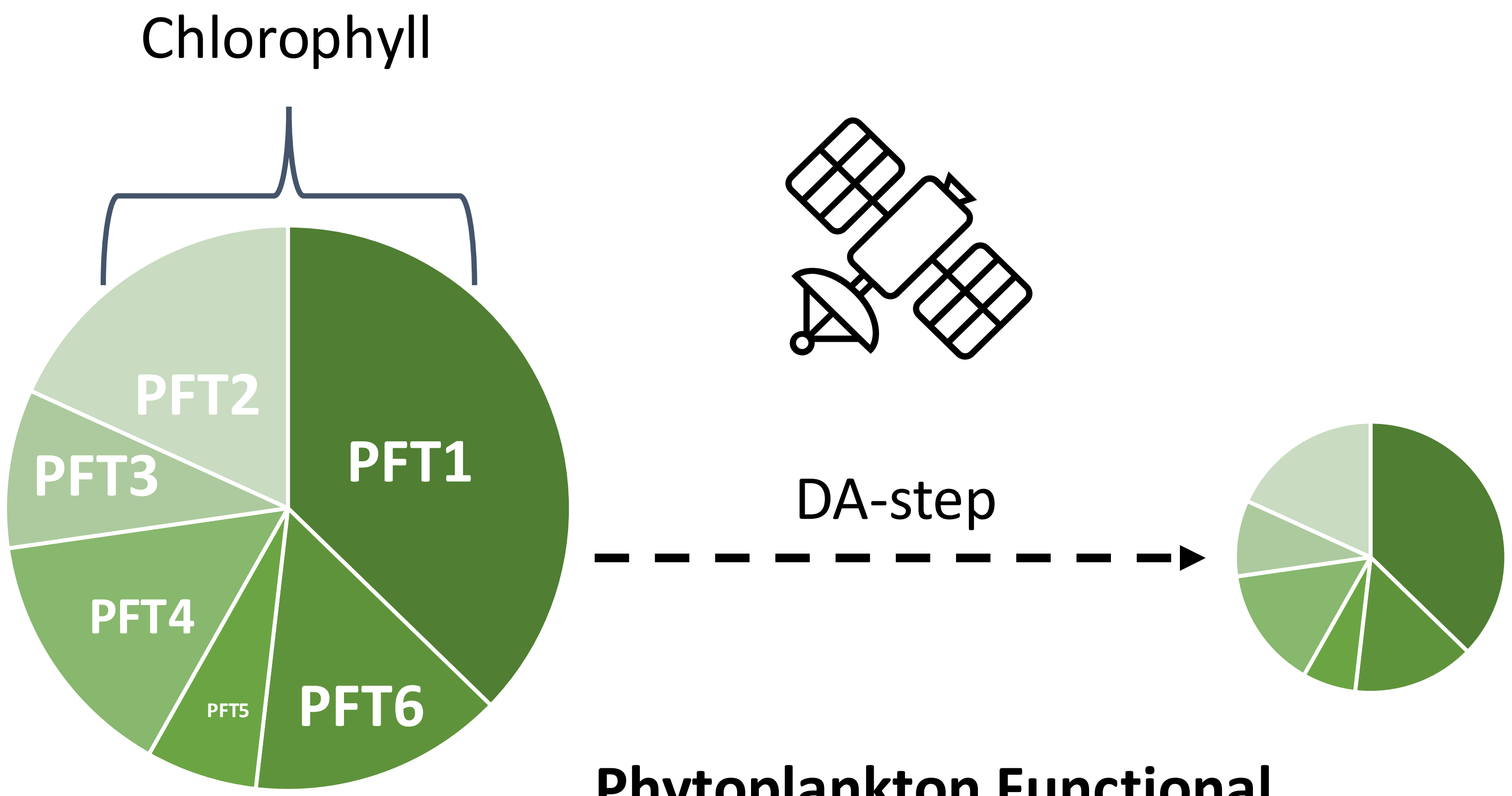

## Model features

- Assimilation: Chlorophyll, absorption of CDOM, and PIC (MODIS-Aqua).
- Domain: Global, waters < 200 m.
- Time: 2002-2020
- Forcing: Reanalysis products (winds, humidity, shortwave, longwave radiation, etc.) and satellite data (aerosols and clouds).
- Resolution: 2/3 x1.25 degrees (Poseidon).

# Backup: NASA Ocean Biogeochemical Model (NOBM)




Sequential DA of Chl, PIC, and aCDOM




**Phytoplankton Functional Types (PFTs)**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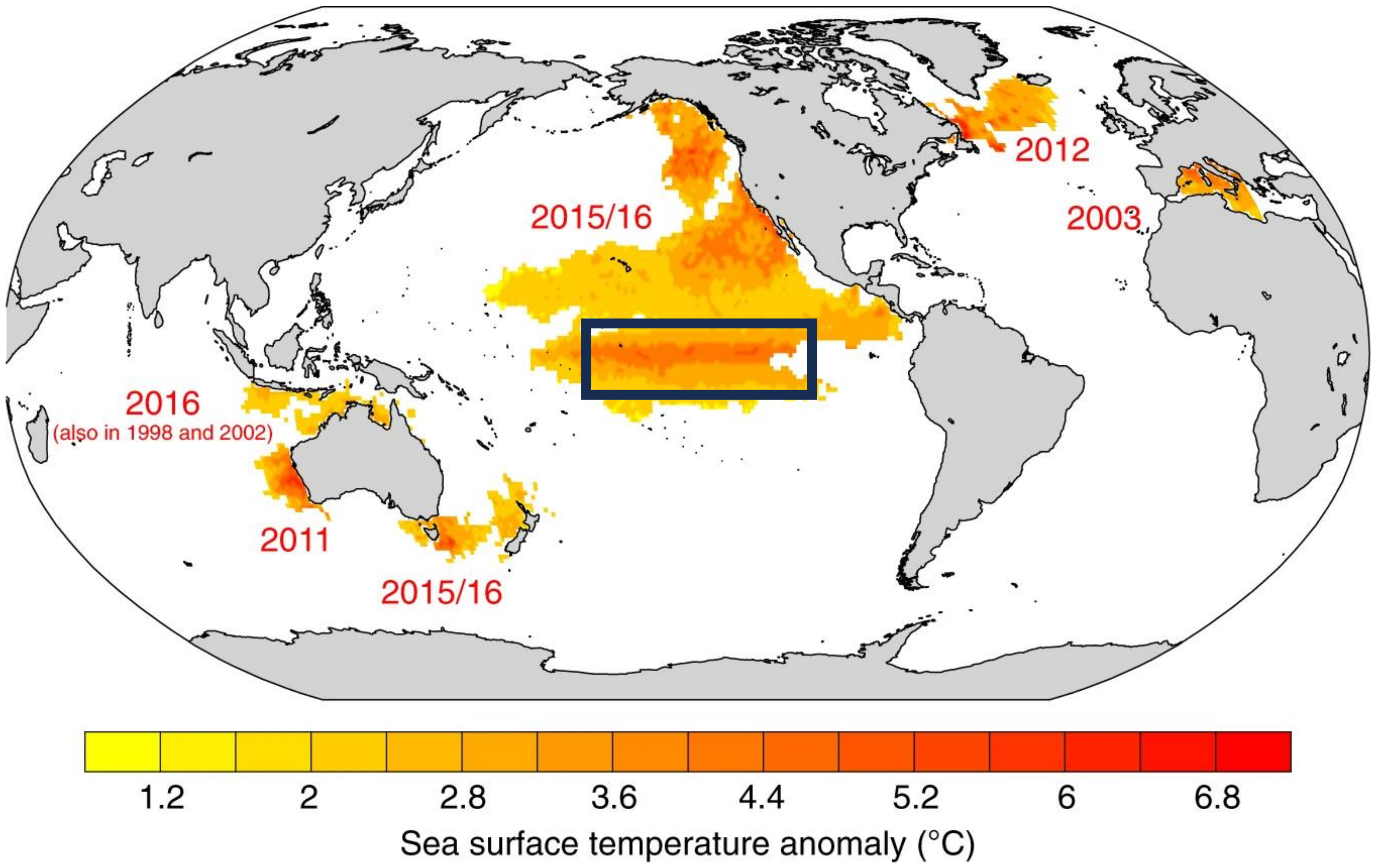
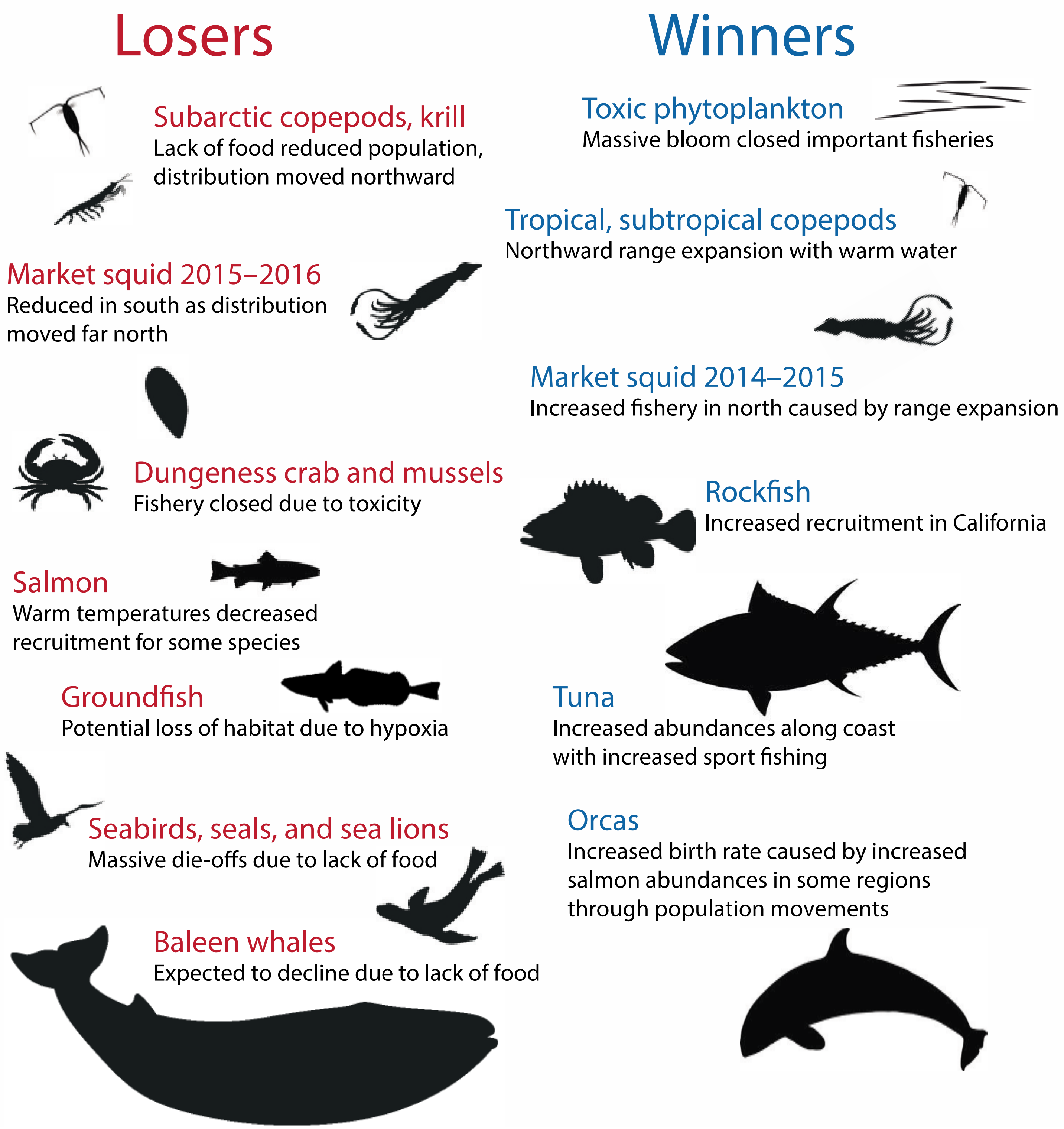



*Frölicher and Laufkötter (2018)*

## Ecosystem impacts

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# Backup: Validation