Bio Bloom Forecast

A proposal to be submitted to the
NASA Ocean Biology and Biogeochemistry program
which may entail future CESM ESPWG involvement

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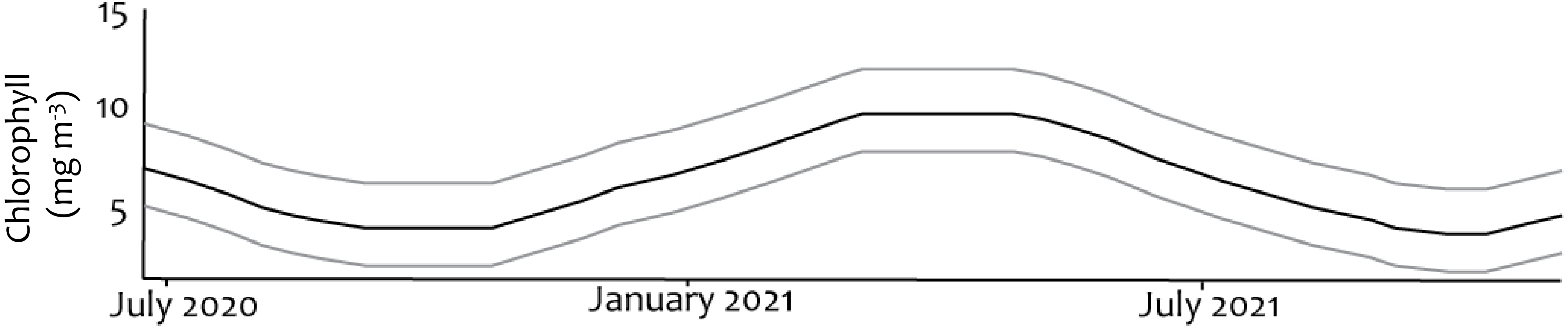
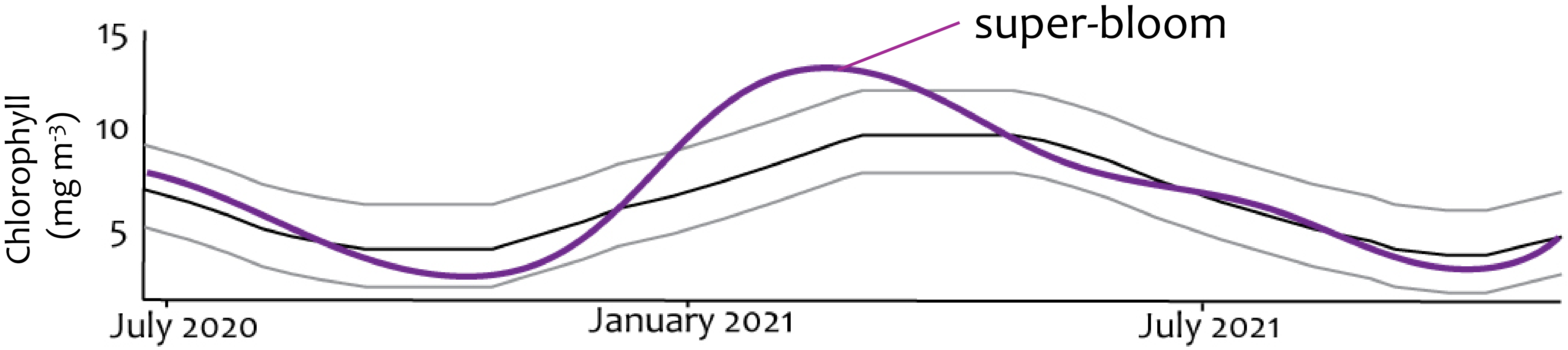
National Center for Atmospheric Research

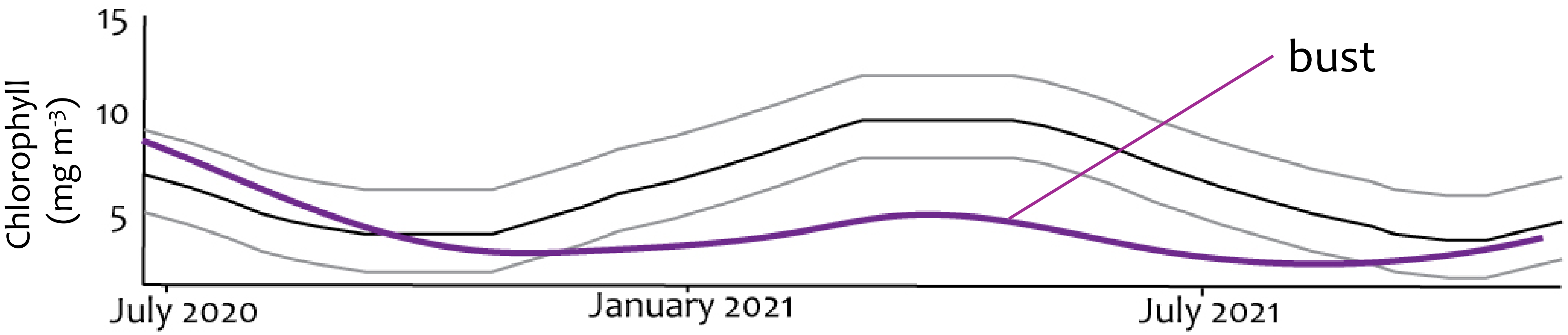
Phytoplankton bloom extremes



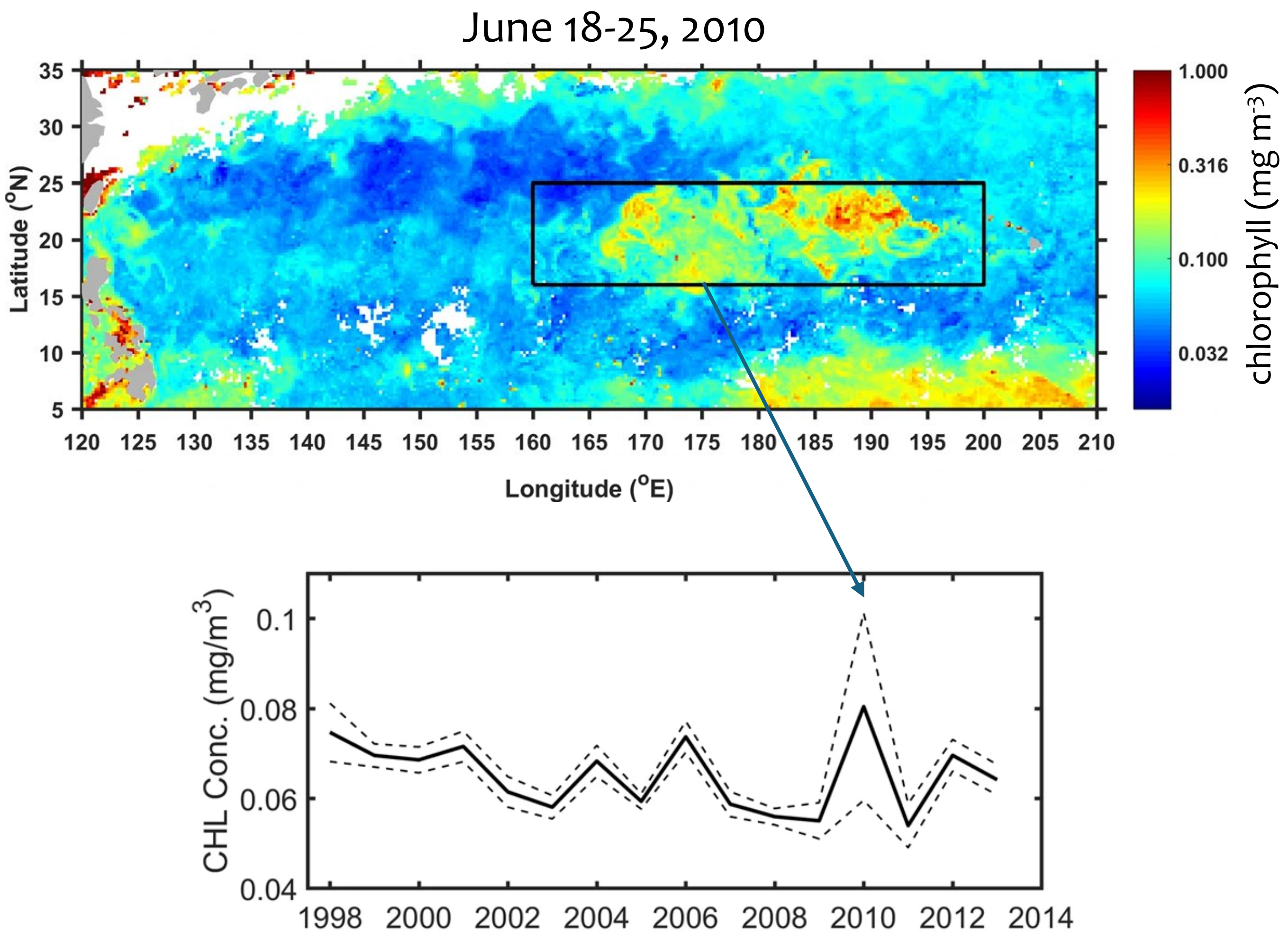
Phytoplankton bloom extremes



Phytoplankton bloom extremes



North Pacific subtropical gyre super-bloom



Chow et al. (2019)

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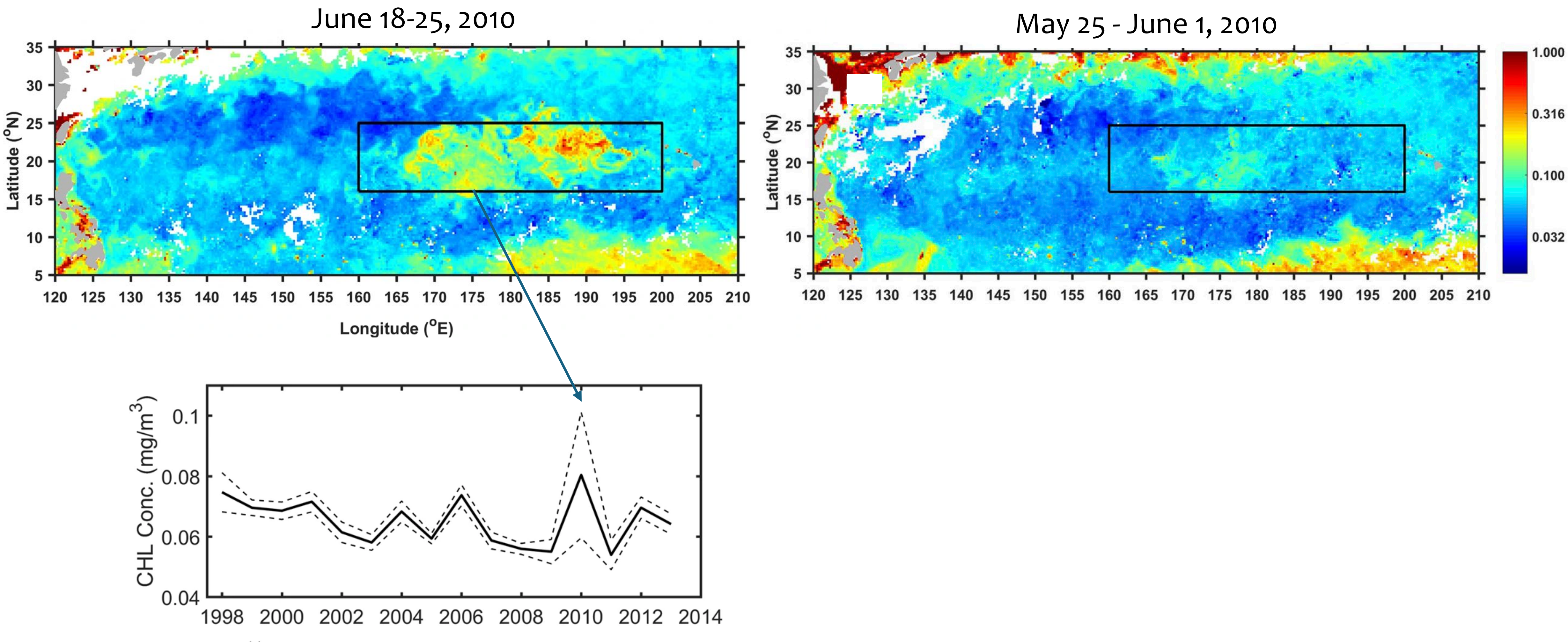
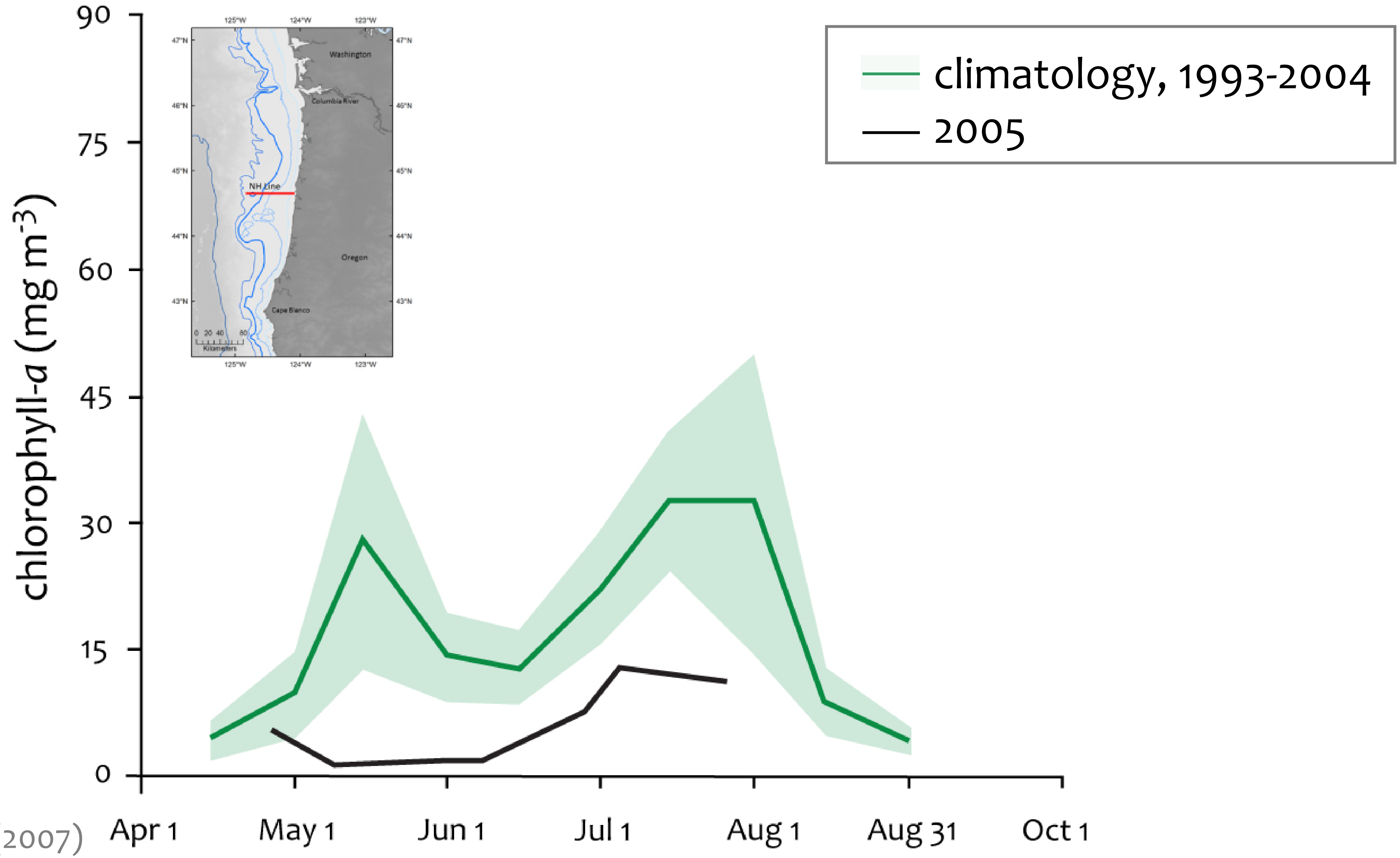


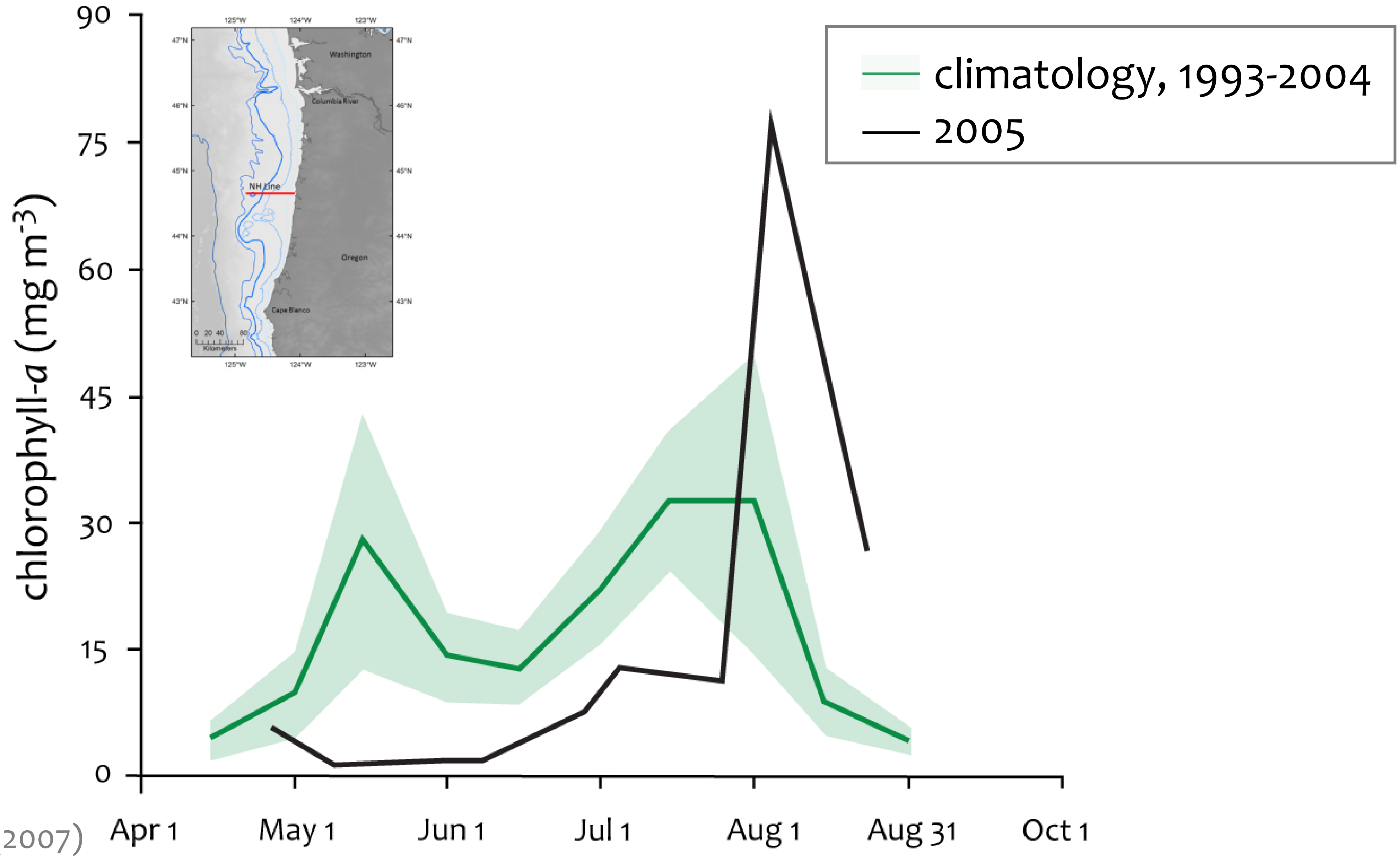
Chow et al. (2019)

Failure to bloom: California Current



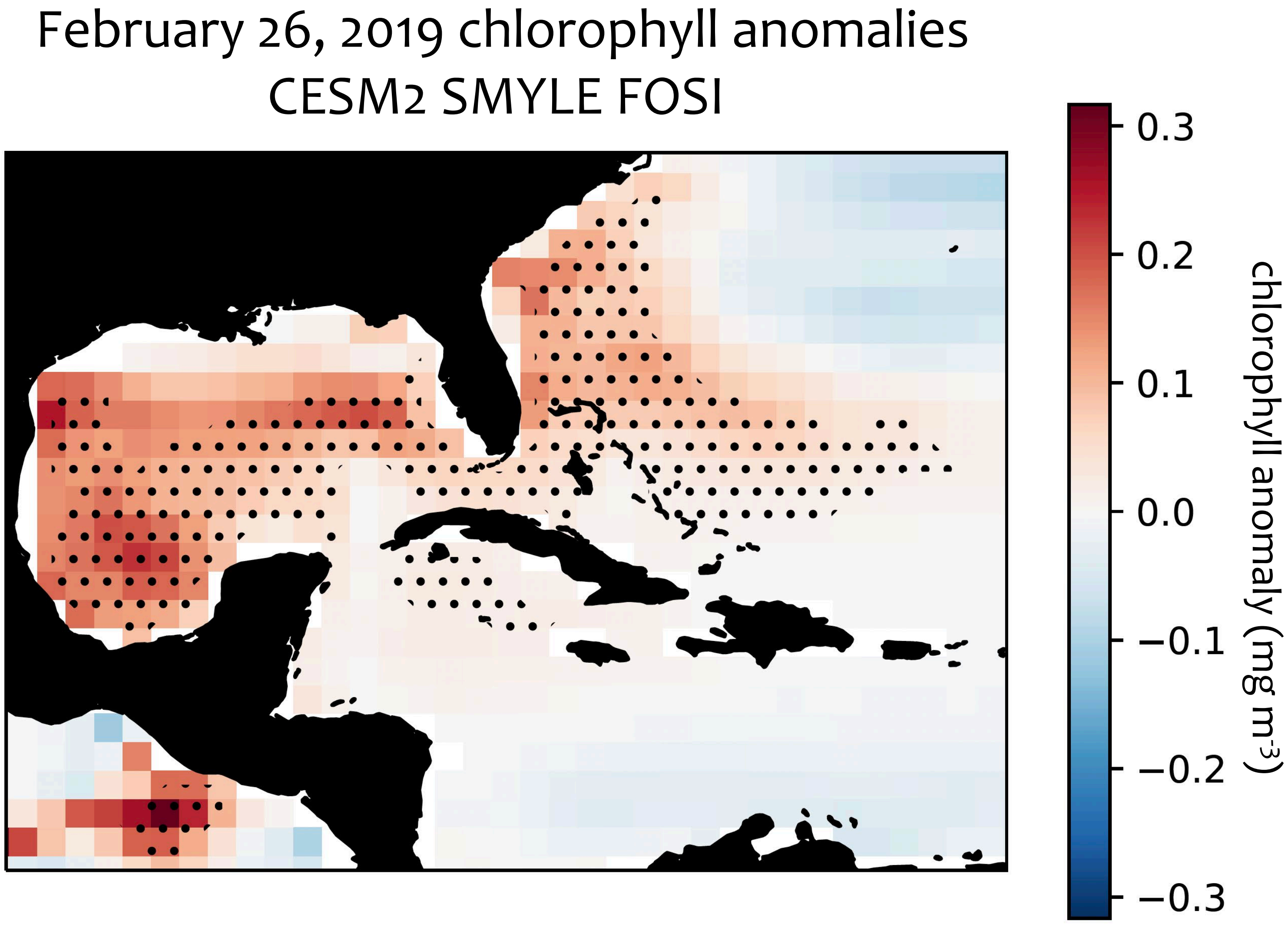
adapted from Barth et al. (2007)

~~Failure to bloom~~ Super bloom!



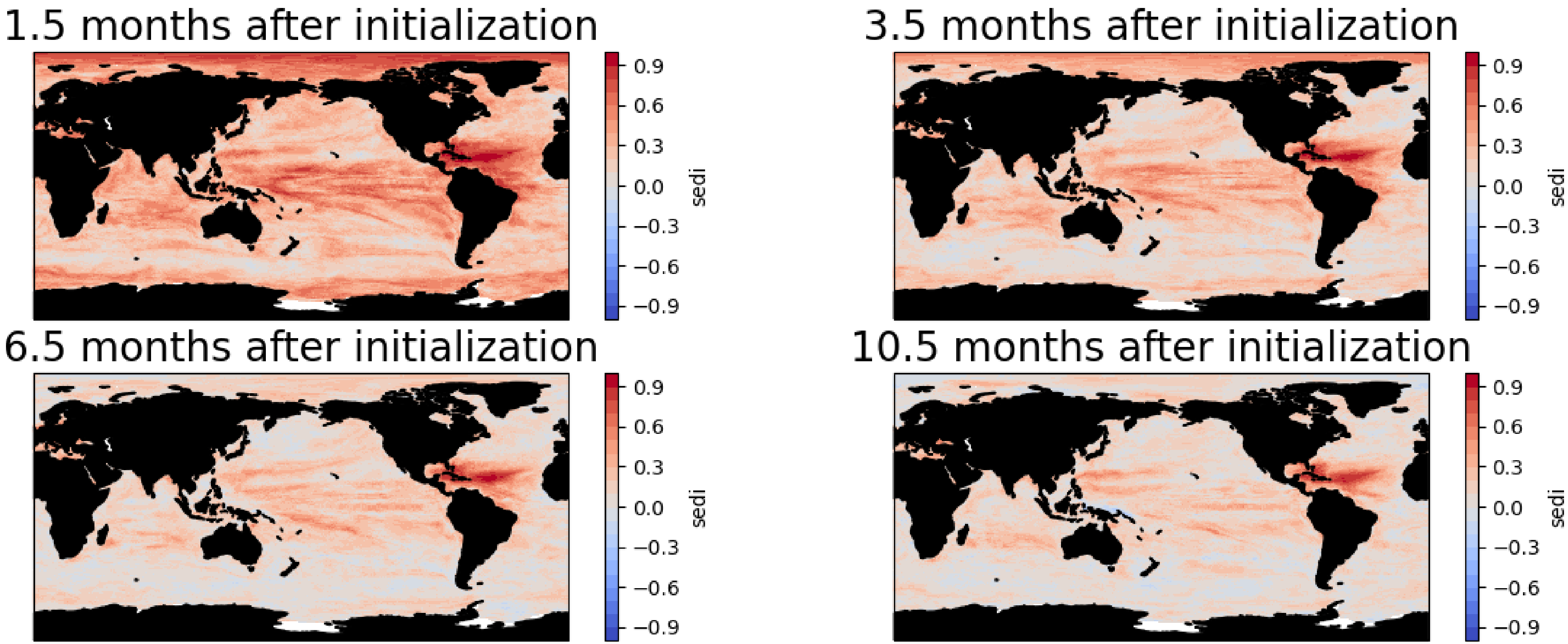
adapted from Barth et al. (2007)

CESM2 generates bloom extremes



Bloom extremes are potentially predictable

CESM2-SMYLE super-bloom predictability



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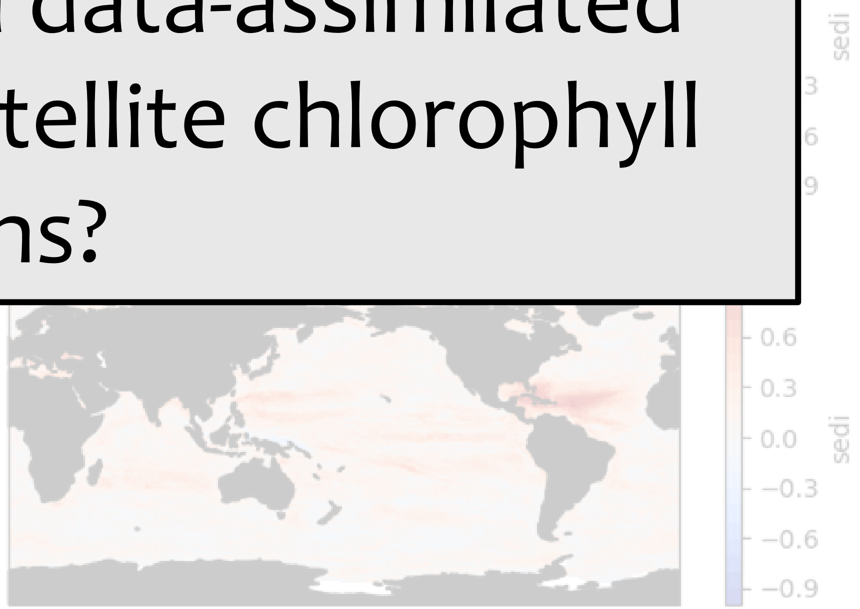
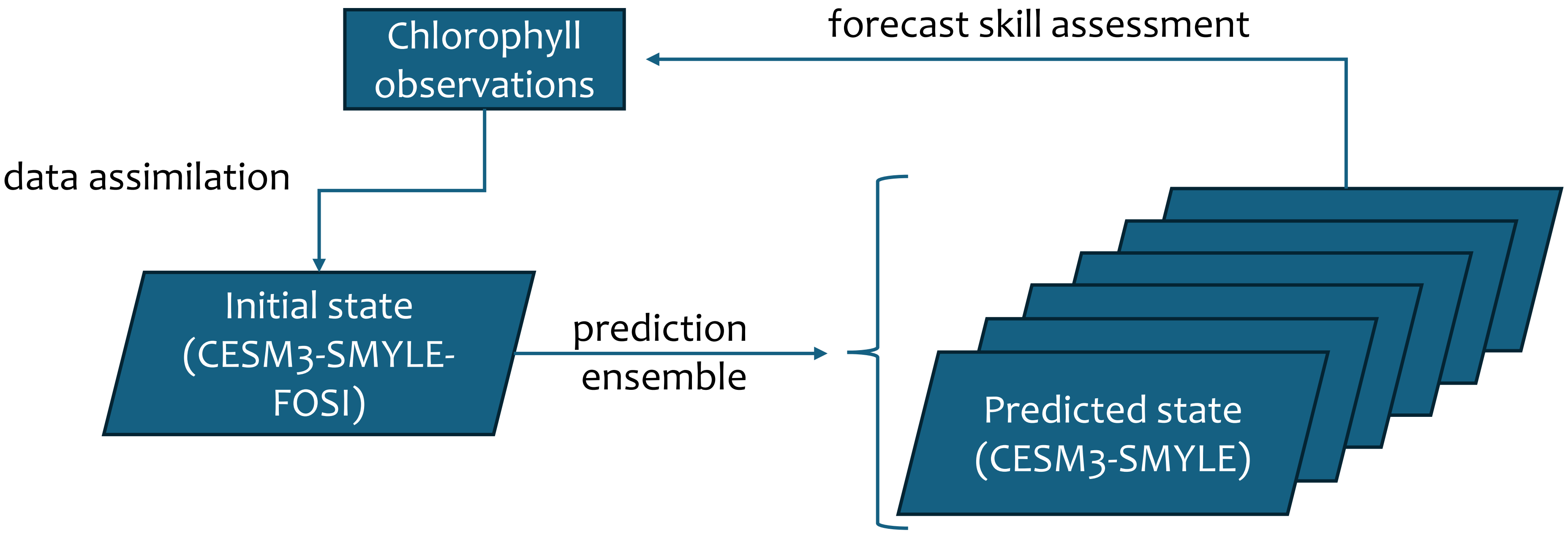


Can we improve our bloom extreme forecasts by initializing them with a data-assimilated state that incorporates satellite chlorophyll observations?

Our plan



forecast skill assessment
Chlorophyll observations
data assimilation
Initial state (CESM3-SMYLE-FOSI)
prediction ensemble
Predicted state (CESM3-SMYLE)

Our plan requires significant computational resources and builds on anticipated CESM3-SMYLE efforts

To create a chlorophyll-assimilated, initialized CESM3-SMYLE over 1997-2024:

Data assimilation

N_{yrs} x N_{ens} x hours

25 x 40 x 4,000

= 4 million core hours

CESM3-SMYLE

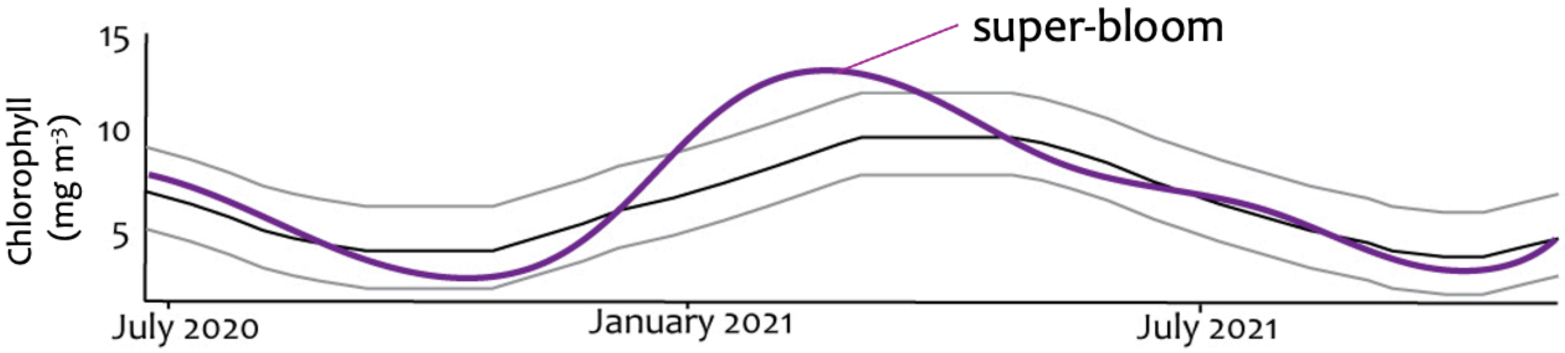
N_{yrs} x N_{ens} x N_{init} x hours

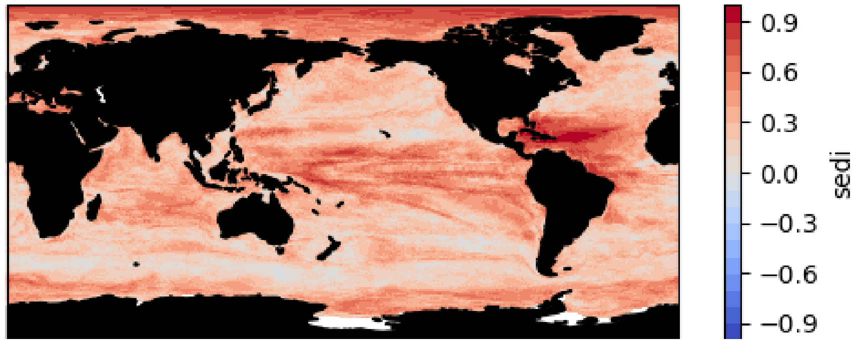
25 x 10 x 1 (May?) x 40,000

= 10 million core hours

Summary

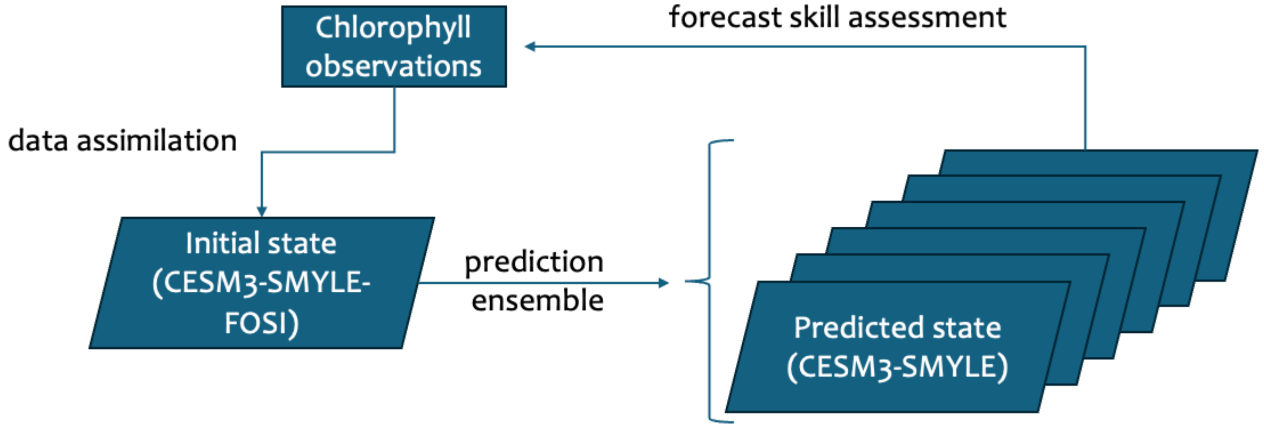
Phytoplankton bloom extremes can have significant impacts on ocean ecosystem health.





CESM2-SMYLE indicates that the bloom extremes are potentially predictable in advance, and forecast skill may be improved by chlorophyll assimilation.

We are developing a plan to assimilate chlorophyll into the CESM3-SMYLE forecast system



The End!

Backup slides

Benefits of assimilating chlorophyll

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Journal of Marine Systems 69 (2008) 205 – 225

JOURNAL OF MARINE SYSTEMS

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Assimilation of SeaWiFS ocean chlorophyll data into a three-dimensional global ocean model

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Received 25 May 2005; received in revised form 7 December 2005; accepted 27 February 2006
Available online 1 March 2007

Abstract

Sea-viewing Wide Field-of-view Sensor (SeaWiFS) chlorophyll data were assimilated with an established three-dimensional global ocean model. The assimilation improved estimates of chlorophyll relative to a free-run (no assimilation) model. Compared to SeaWiFS, annual bias of the assimilation model was 5.5%, with an uncertainty of 10.1%. The free-run model had a bias of 21.0% and an uncertainty of 65.3%. In situ data were compared to the assimilation model over a 6-year time period from 1998 through 2003, indicating a bias of 0.1%, and an uncertainty of 33.4% for daily coincident, co-located data. SeaWiFS bias was slightly higher at −1.3% and nearly identical uncertainty at 32.7%. The free-run bias and uncertainty at −1.4% and 61.8%, respectively, indicated how much the assimilation improved model results. Annual primary production estimates for the 1998–2003 period produced a nearly 50% improvement by the assimilation model over the free-run model as compared to a widely used algorithm using SeaWiFS chlorophyll data. These results suggest the potential of assimilation of satellite ocean chlorophyll data for improving model results.

JGR Oceans

RESEARCH ARTICLE
10.1029/2018JC014329

Assimilation of Global Total Chlorophyll OC-CCI Data and Its Impact on Individual Phytoplankton Fields

H. K. Pradhan[1], C. Völker[1], S. N. Losa[1,2], A. Bracher[1,3], and L. Nerger[1]

[1]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, [2]Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia, [3]Institute of Environmental Physics, University of Bremen, Bremen, Germany

Key Points:
- Multivariate assimilation of satellite chlorophyll data improves simulation of phytoplankton functional groups and influences them differently
- Small phytoplankton is weakly deteriorated in the Southern Ocean, while diatoms are improved globally
- Regional variability of assimilation leads to stronger improvement at midlatitudes and equator than at high latitudes

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Pradhan, H. K., Völker, C., Losa, S. N., Bracher, A., & Nerger, L. (2019). Assimilation of global total chlorophyll OC-CCI data and its impact on individual phytoplankton fields. *Journal of Geophysical Research: Oceans, 124*, 470–490. https://doi.org/10.1029/2018JC014329

Received 2 JUL 2018
Accepted 19 DEC 2018

Abstract The coupled ocean circulation-ecosystem model MITgcm-REcoM2 is used to simulate biogeochemical variables in a global configuration. The ecosystem model REcoM2 simulates two phytoplankton groups, diatoms and small phytoplankton, using a quota formulation with variable carbon, nitrogen, and chlorophyll contents of the cells. To improve the simulation of the phytoplankton variables, chlorophyll-a data from the European Space Agency Ocean-Color Climate Change Initiative (OC-CCI) for 2008 and 2009 are assimilated with an ensemble Kalman filter. Utilizing the multivariate cross covariances estimated by the model ensemble, the assimilation constrains all model variables describing the two phytoplankton groups. Evaluating the assimilation results against the satellite data product SynSenPFT shows an improvement of total chlorophyll and more importantly of individual phytoplankton groups. The assimilation improves both phytoplankton groups in the tropical and midlatitude regions, whereas the assimilation has a mixed response in the high-latitude regions. Diatoms are most improved in the major ocean basins, whereas small phytoplankton show small deteriorations in the Southern Ocean. The improvement of diatoms is larger when the multivariate assimilation is computed using the ensemble-estimated cross covariances between total chlorophyll and the phytoplankton groups than when the groups are updated so that their ratio to total chlorophyll is preserved. The comparison with in situ observations shows that the correlation of the simulated chlorophyll of both phytoplankton groups with these data is increased whereas the bias and error are decreased. Overall, the multivariate assimilation of total chlorophyll modifies the two phytoplankton groups separately, even though the sum of their individual chlorophyll concentrations represents the total chlorophyll.

"Annual primary production estimates produced a nearly 50% improvement by the assimilation model over the free-run model."

"[Assimilation produces] an improvement in total chlorophyll and … individual phytoplankton groups."

Benefits of assimilating chlorophyll

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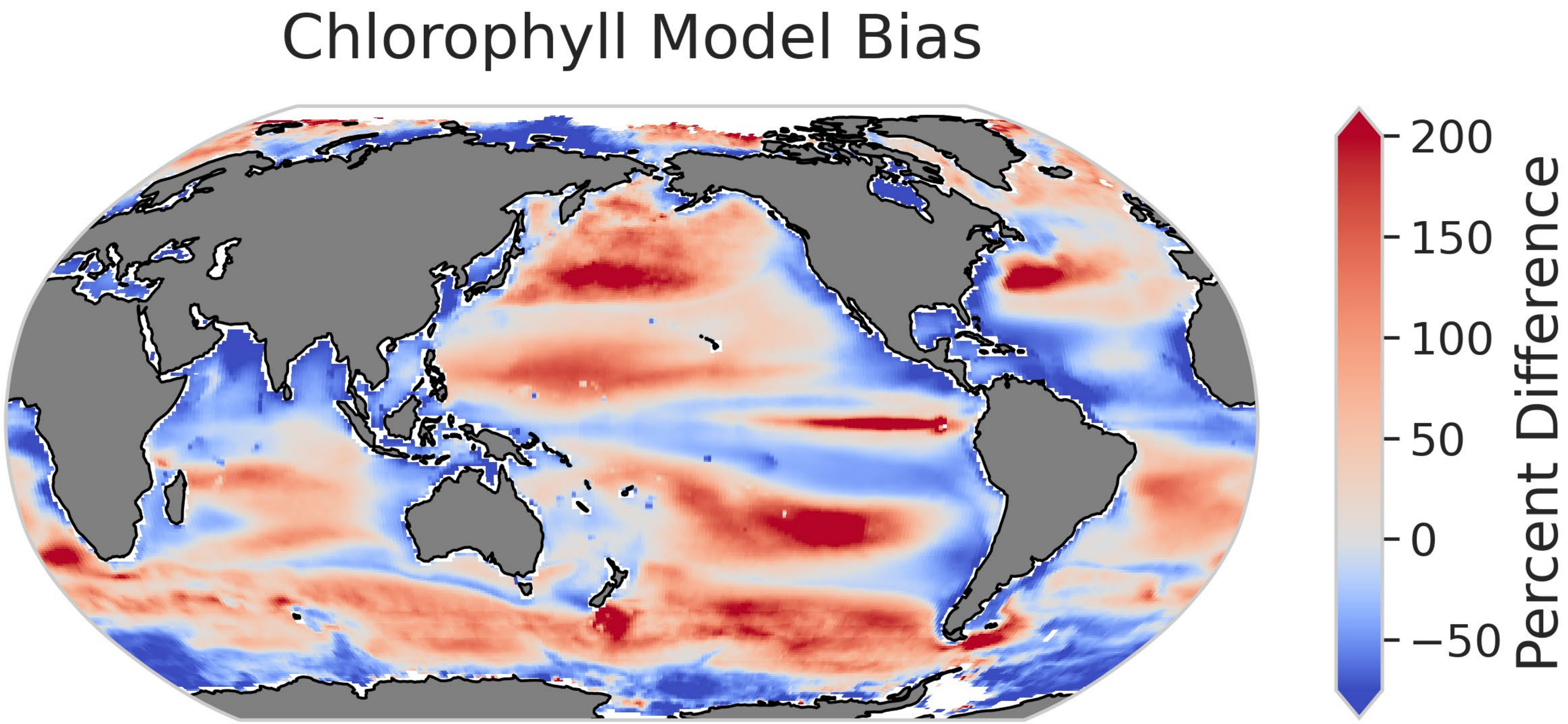
Do the benefits of assimilating chlorophyll translate into forecast skill?

"Annual primary production estimates produced a nearly 50% improvement by the assimilation model over the free-run model."

"[Assimilation produces] an improvement in total chlorophyll and … individual phytoplankton groups."

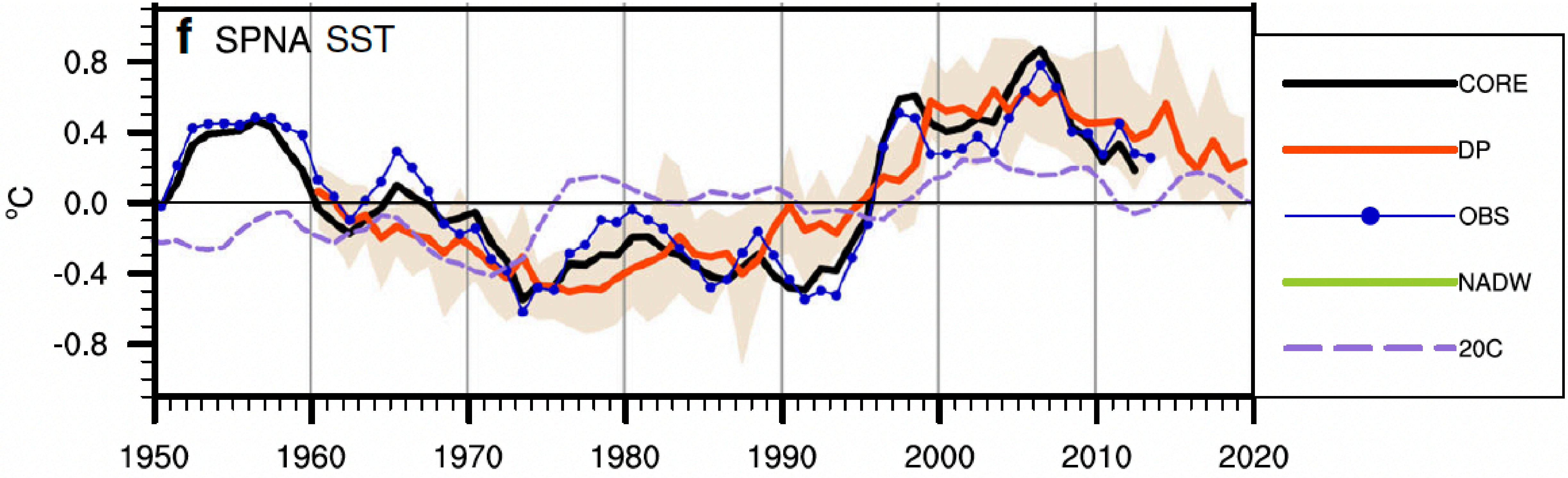
CESM2 has large chlorophyll biases



Clow et al. (in prep.)

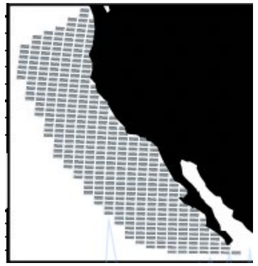
Physical oceanography: Initializing with a data-assimilated state improves forecast skill

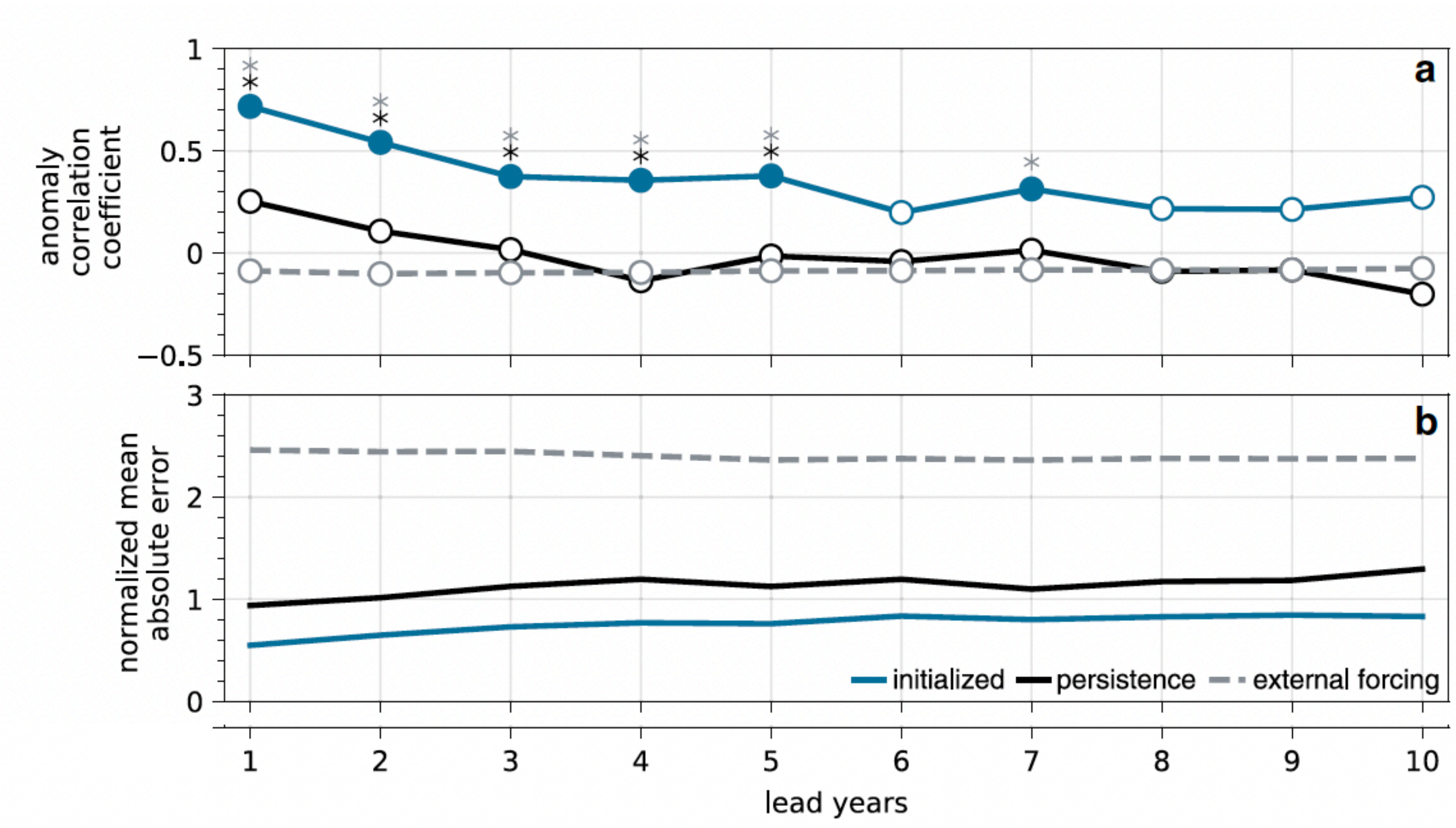
SST in the Subpolar North Atlantic



Yeager et al. (2017)

Biogeochemical oceanography: Initializing with FOSI improves predictability





Brady et al. (2020)