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Satellite tools to explore the relationship between dust and primary producers' biomass

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Glacial-interglacial atmospheric pCO_2 change: The iron hypothesis (Martin, 1990)

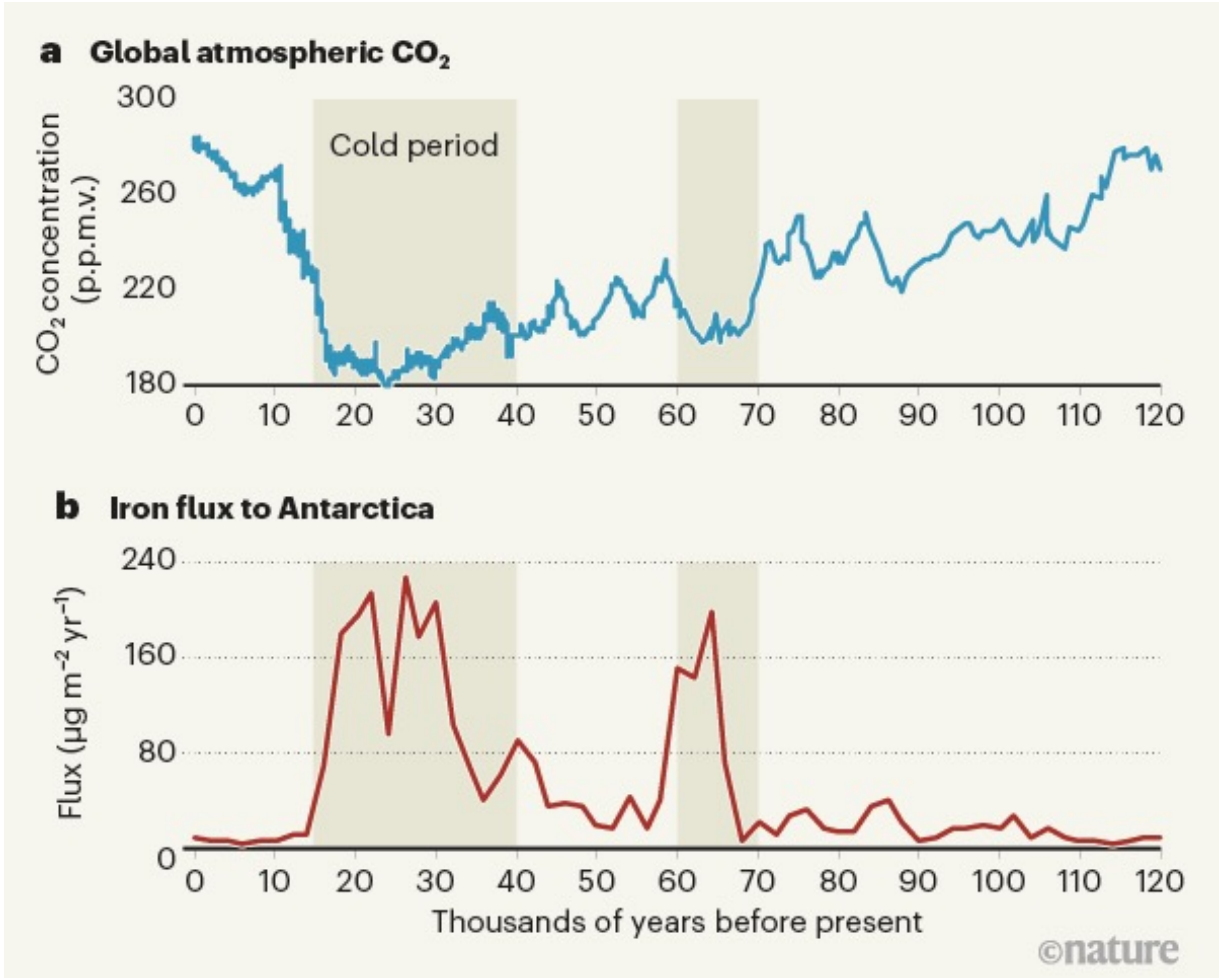
1) Net primary productivity (NPP) in some surface oceans is limited by iron (Fe),

2) Here, dust is an important input of Fe, promoting CO_2 (atm) drawdown,

3) The export of organic matter to the deep ocean constitutes a millennial-scale CO_2 (atm) sink,

4) 20-25% of the rise in pCO_2 (atm) during the last deglaciation (~19-12 kyr BP) is thought to be due to dust-Fe fertilization,

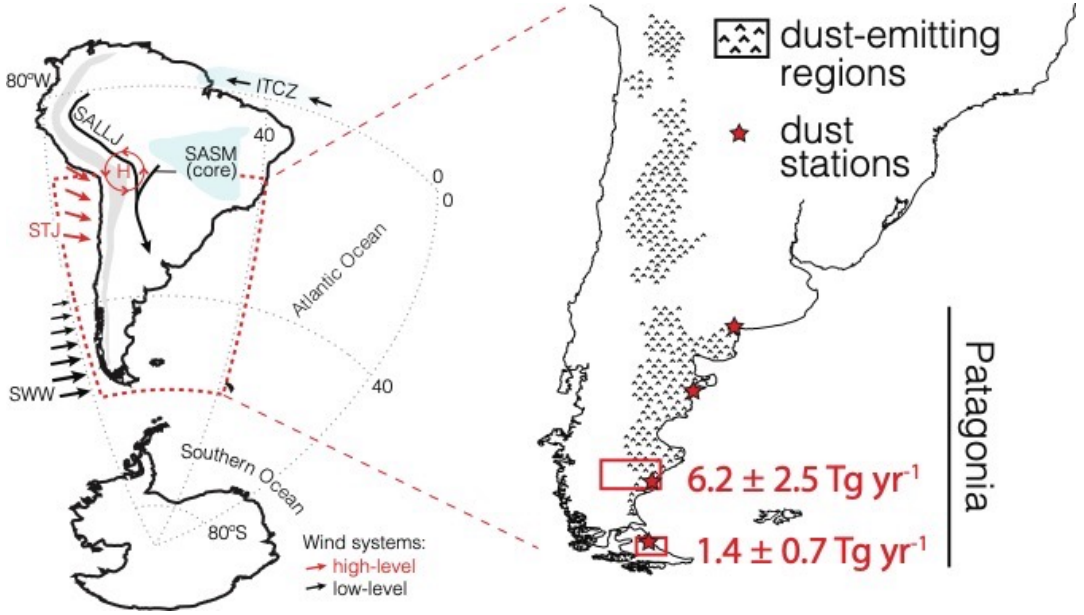
5) The identification of rises in NPP associated with present-day dust deposition would partially confirm the Fe hypothesis.



Stoll (2020), Nature

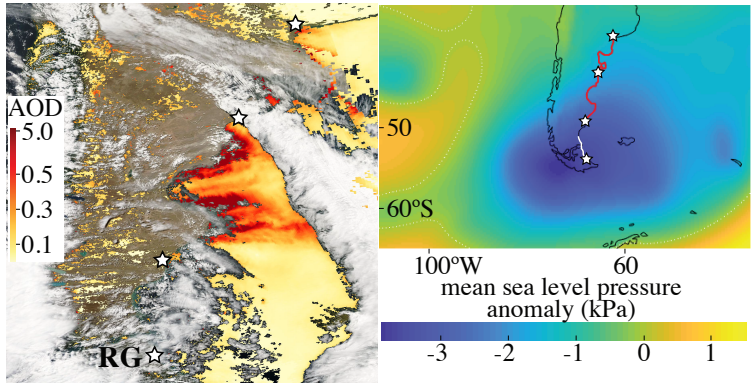
High-latitude dust emissions in southern South America

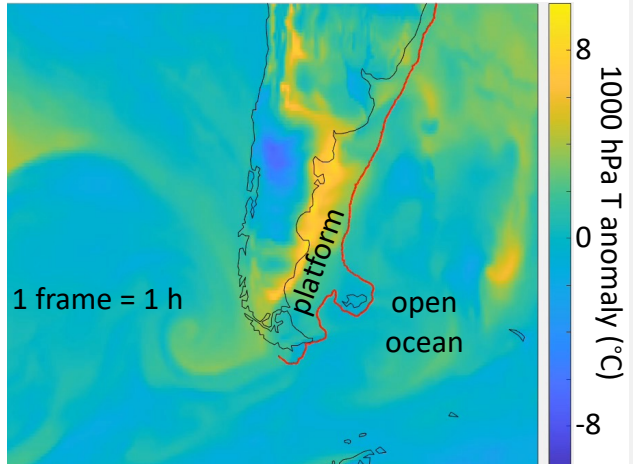
1) Patagonia is in southern South America



2) Cyclonic cold fronts trigger synoptic dust storms

Example: 9 February 2010





3) Main present-day dust source to Southern Oceans and Antarctica (e.g., Neff & Bertler, 2015)

4) During the last deglaciation, the Atlantic sector of the southern oceans (>34°S) is estimated to have contributed 41% of dust-induced global CO_2 drawdown through iron fertilization (Lambert et al., 2021)

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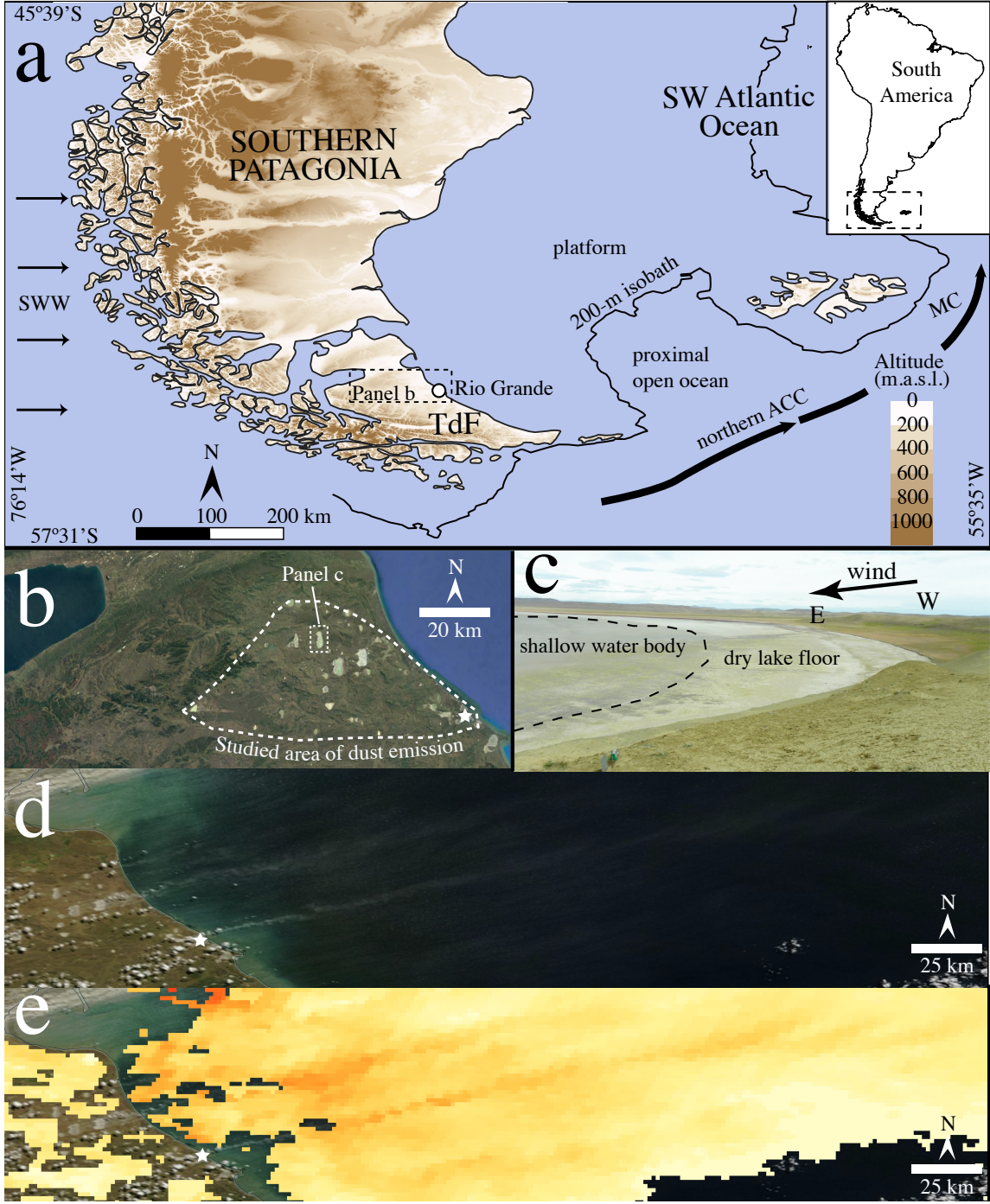
Southernmost emissions of dust in Patagonia

(c) Deflation pan showing a windward dry lake floor and a leeward shallow water body

(d) True color Terra/MODIS image of a dust event on 21 February 2014, where two dust plumes are identified

(e) These plumes are clearly defined by higher-than-background Aerosol Optical Depth (AOD, Terra/MODIS)



Cosentino et al. (2020), JGR: Biogeosciences

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Obtaining dust deposition fields for individual events

(A) Combine two datasets to constrain dust emission:

1. Surface visibility data (in situ). Parameter: dust-related visibility reduction (1-hr resolution).

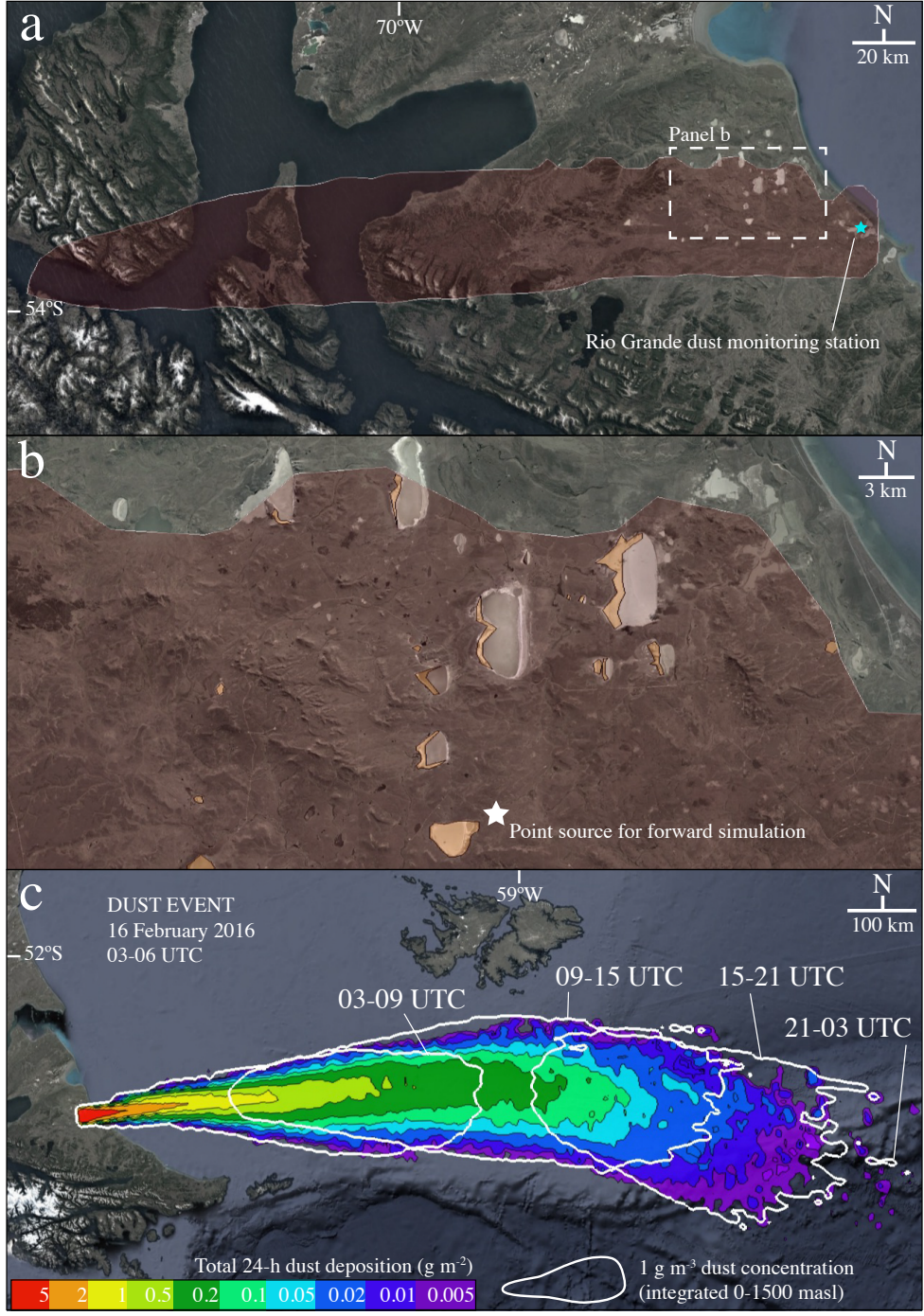
2. Dust sampling: passive collectors. Continuous dust mass collection (10 years, ~1-month resolution).

(B) Use HYSPLIT 4 to model particle trajectories.

1. Backward dispersion of a dust event with point-source emission from the monitoring station (Figure a).

2. Mapping dust sources within the backward dispersion contour (Figure b).

3. Forward dispersion simulation (Figure c).



Cosentino et al. (2020), JGR: Biogeosciences

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Using AOD to track dust deposition?

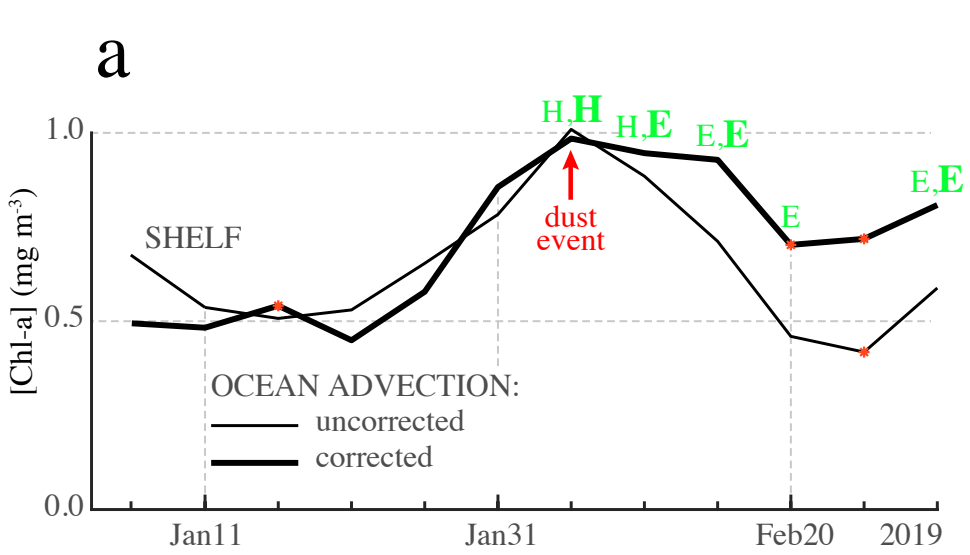
We used particle dispersion modelling to obtain dust deposition fields for each event, and used those fields as search zones where we built [Chl-a] time series.

While dust emission is well-constrained based on visibility and mass flux data, we do not have in situ data over the ocean to validate modelled dust deposition.

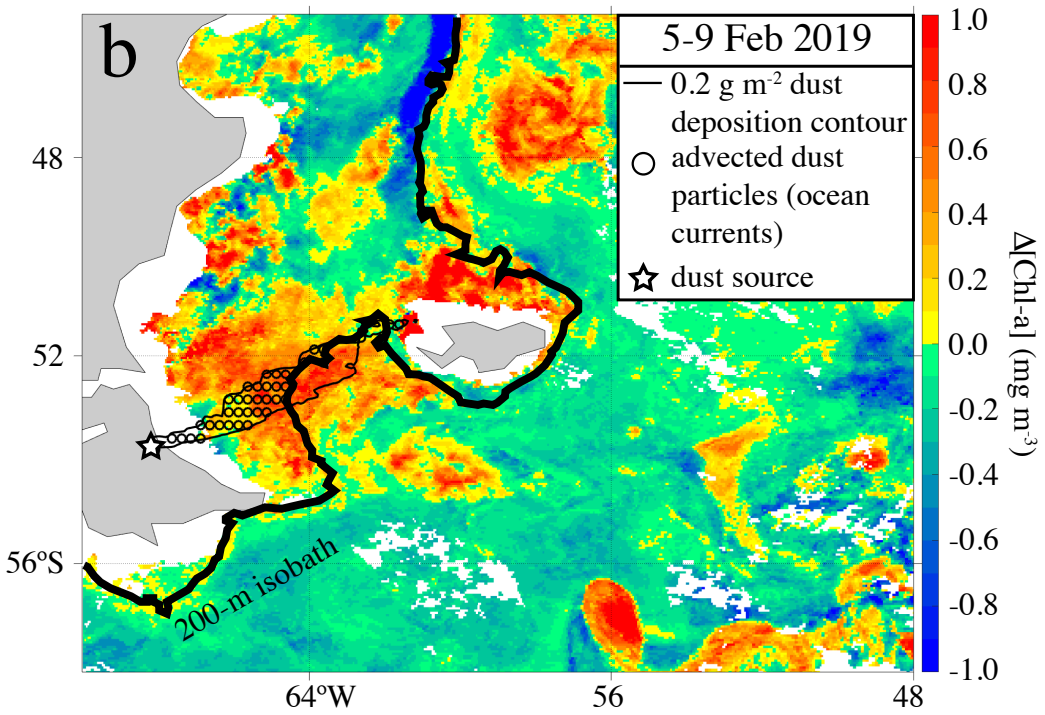
Can we use AOD to determine dust deposition fields for individual events?
Only if we can adecuately resolve dust AOD vertically to isolate near-surface concentrations.

- The Copernicus Data Store provides a dataset of multi-sensor satellite observations of dust aerosol layer height.
- However, only an average altitude of aerosol loading is available (i.e., height level at which the largest aerosol extintion is observed).
- Can near-surface dust AOD be reliably estimated based on available AOD observations?

Satellite chlorophyll-a concentration ([Chl-a]) vs. dust in southernmost Patagonia: Data



Cosentino et al. (2020), JGR: Biogeosciences



Satellite data sets used in this study:

(1) Surface [Chl-a], as a proxy of primary producers' biomass

(2) Surface ocean height, to calculate geostrophic ocean currents

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Satellite [Chl-a]

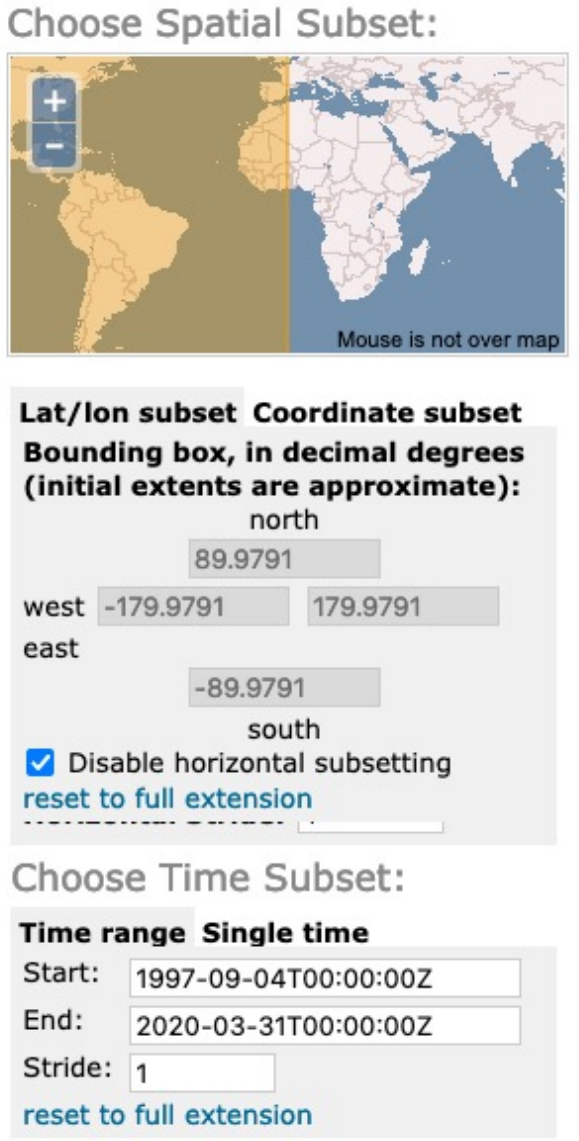
unidata
THREDDS data server NetCDF Subset Service

Ocean Colour (OC) - Climate Change Initiative (CCI) v4.2 (Sathyendranath et al., 2019):

- 4-km spatial resolution,
- merges MERIS, Aqua-MODIS, SeaWiFS and VIIRS (helps with reducing missing data due to clouds!).

To further reduce missing data due to clouds, we used 5-day composite values.

Satellites can quantify the contribution of phytoplankton functional types to total [Chl-a] (e.g., Brewin et al., 2021): useful to link dust chemistry, ocean chemistry and nutrient requirements. Such data products are not yet available on the OC-CCI portal (I believe).



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Ocean currents to correct for post-depositional dust particle movement

Velocities were calculated from gridded maps of satellite-derived sea surface height by the Copernicus Marine and Environment Monitoring Service (CMEMS) with 1-day and 0.25° resolutions.

Altimeter-derived currents account only for the geostrophic component of the currents. The CMEMS portal also includes a total surface current product that combines satellite height data with modelled Ekman currents at the surface. This may improve the representation of surface dust particle advection.

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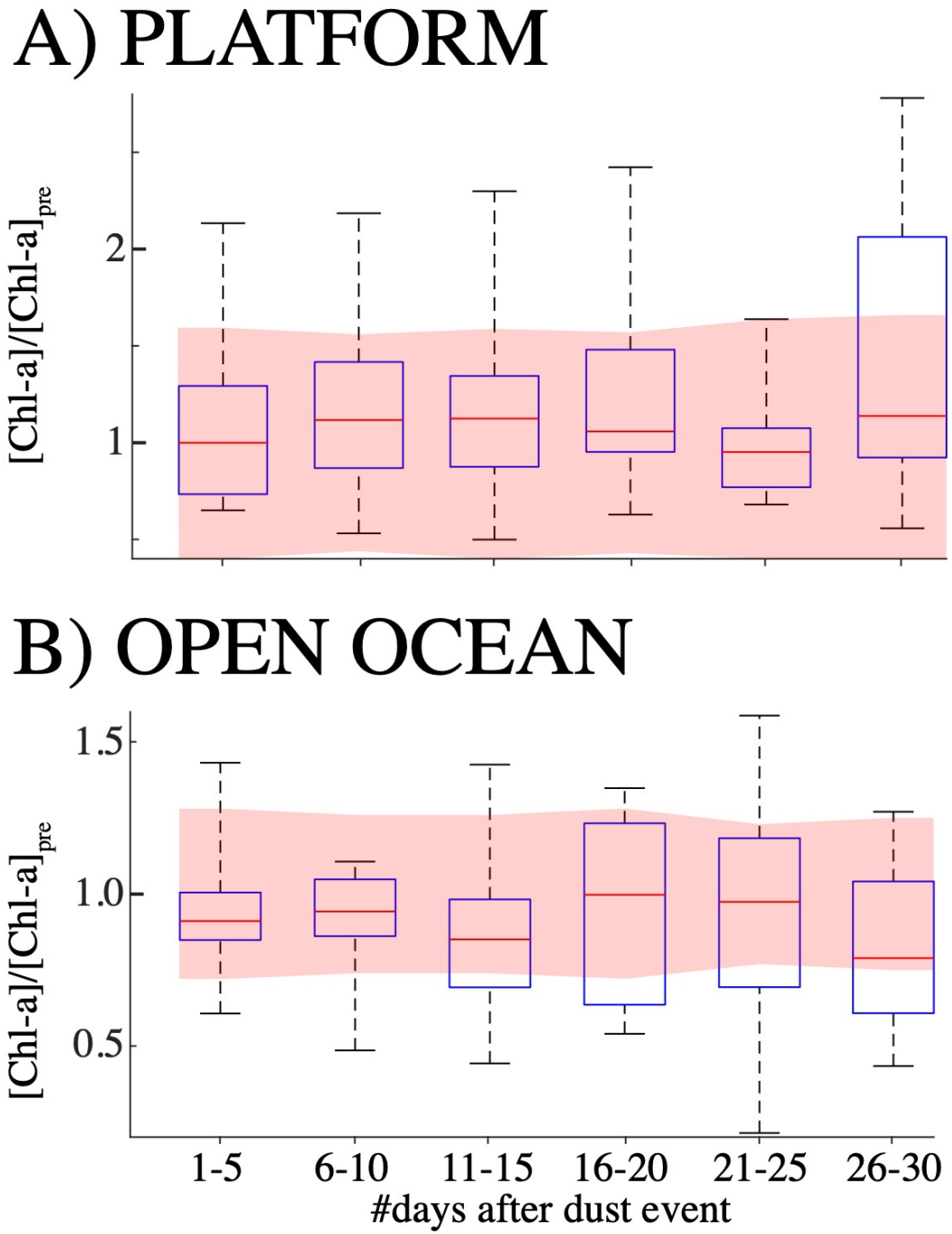
Satellite [Chl-a] vs. dust in southernmost Patagonia: Results

Between December 2008 and February 2019, 73 dust events, defined as a reduction in surface visibility due to dust, were identified at the Rio Grande city airport.

Dust dispersion for a subset of 32 events, taking place during peaks in dust mass accumulation, mostly during austral summer, were simulated.

Based on our methodology, no evidence is found for an influence of dust on chlorophyll-a concentrations.



Cosentino et al. (2020), JGR: Biogeosciences

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Main conclusion and way forward

Does satellite chlorophyll-a respond to southernmost Patagonian dust?

- An individual event-based analysis of [Chl-a] shows no evidence for an influence of Patagonian dust deposition on satellite [Chl-a].

Possible ways satellites may improve understanding of the dust-NPP connection in the future

- Vertically-resolved AOD to identify regions of probable dust deposition.
- Quantify contribution of different phytoplankton functional groups to total [Chl-a].
- Correction for clouds in AOD and [Chl-a] observations is key for high-latitude dust research.