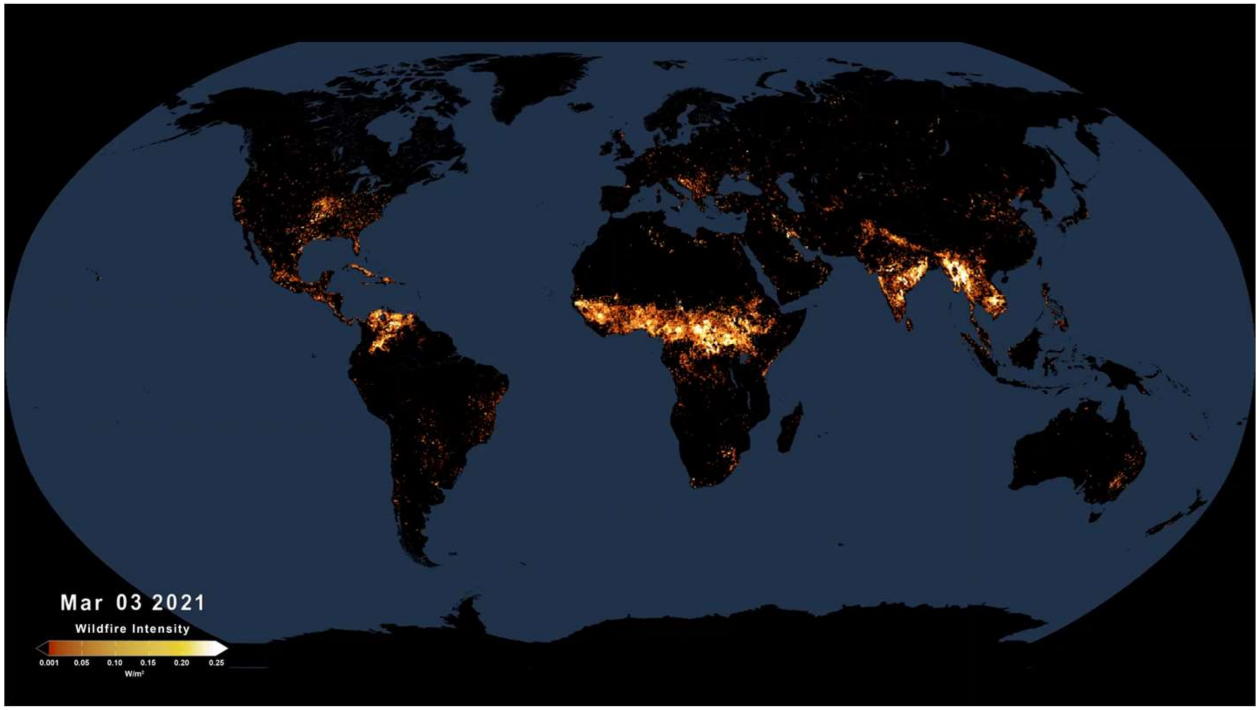
PYROPLANKTON Wildfires and ocean biogeochemistry

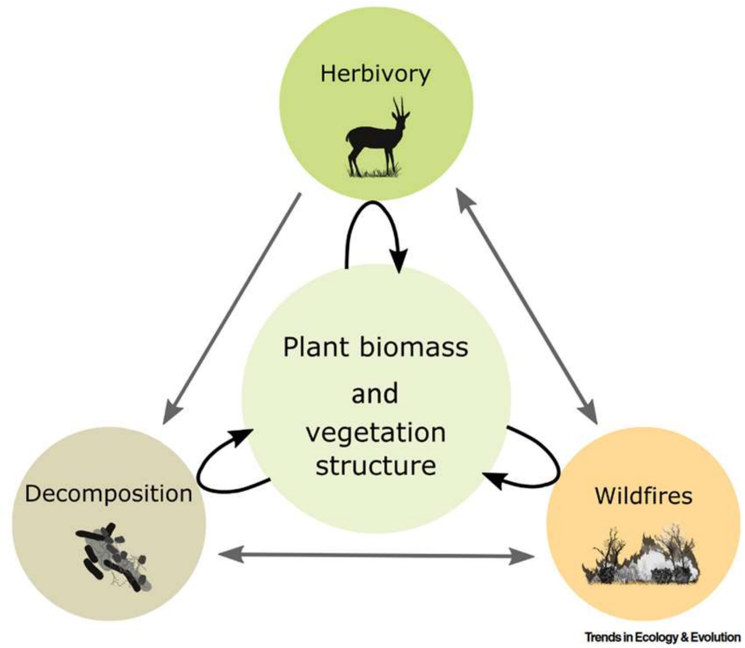
Joan Llort

ES Seminar

07-11-2023

Wildfires are part of land ecosystems dynamics



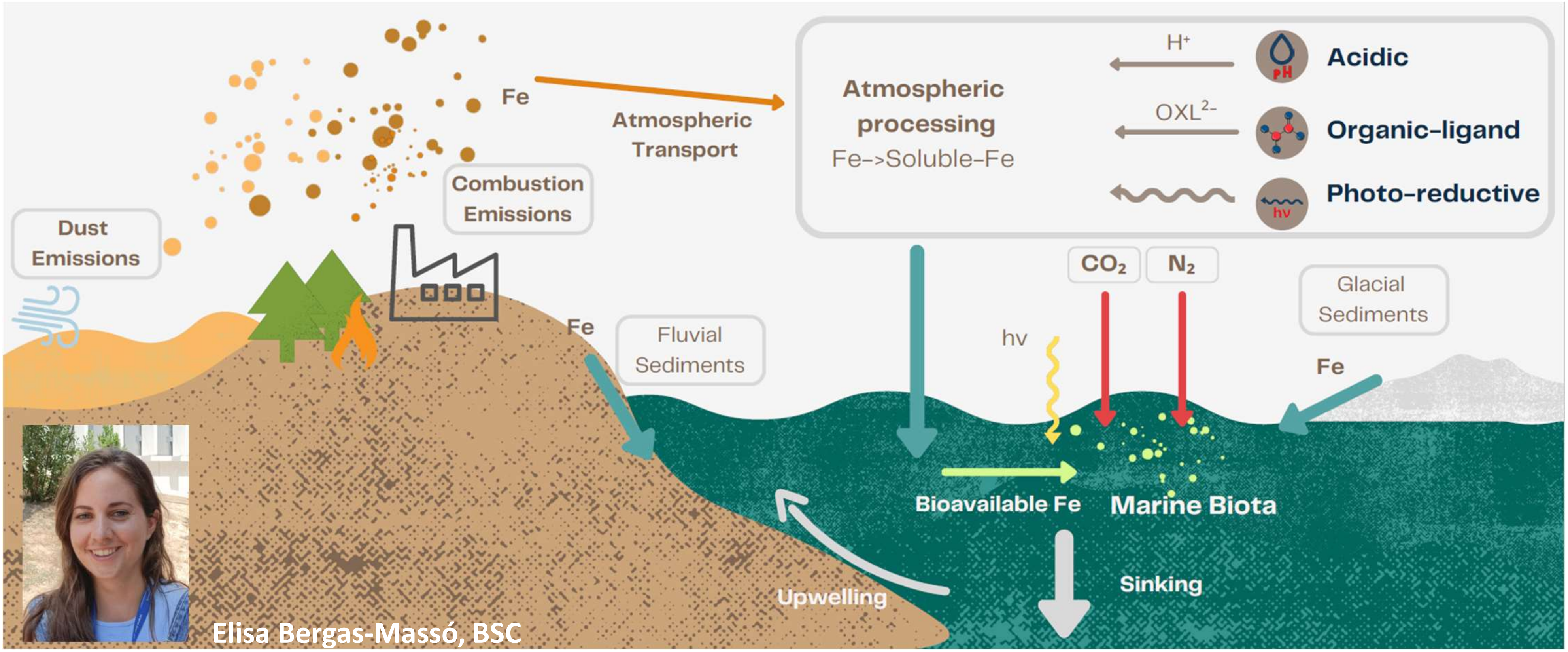


Wildfires, bacterial activity and grazing are the three remineralisation pathways on land

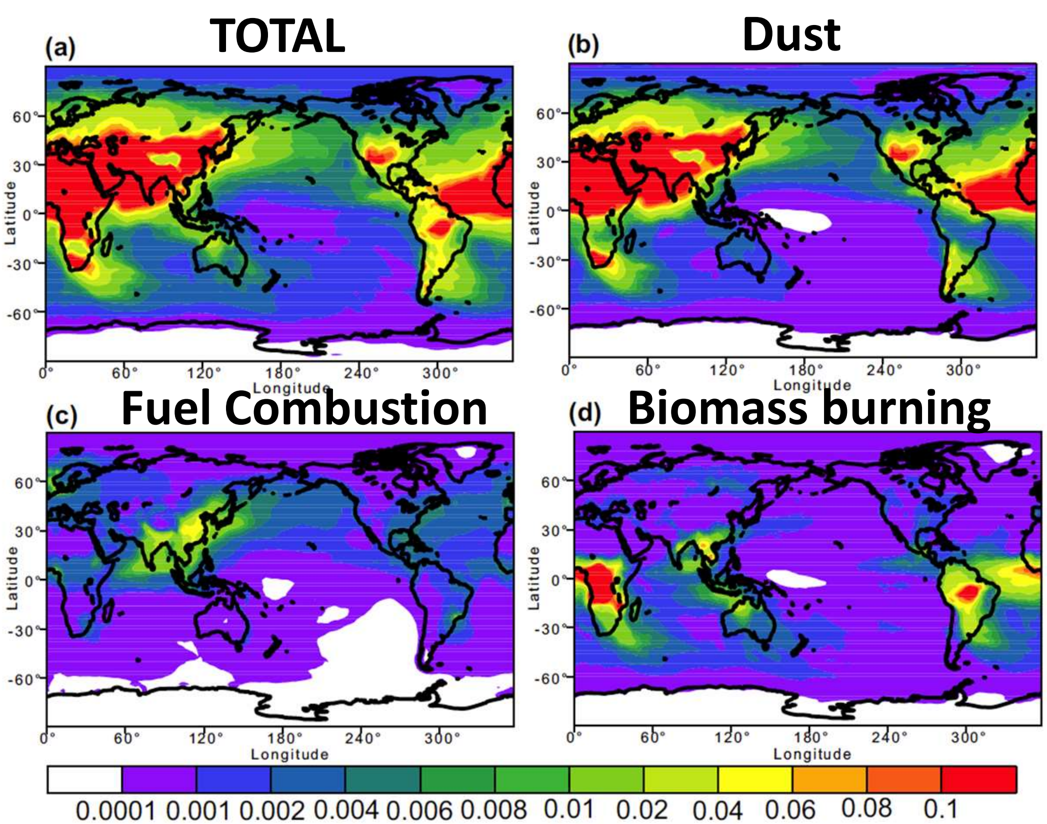
Pausas and Bond, 2020
On the Three Major Recycling Pathways in Terrestrial Ecosystems
Cell Press Reviews

Improved atmospheric chemistry in EC-Earth3

Myriokefalitakis et al. 2022, Bergas-Massó et al. 2023



Pyrogenic Fe and phytoplankton



Modelled deposition DFe flux (ng Fe m−2 s−1)

REVIEW ARTICLE OPEN

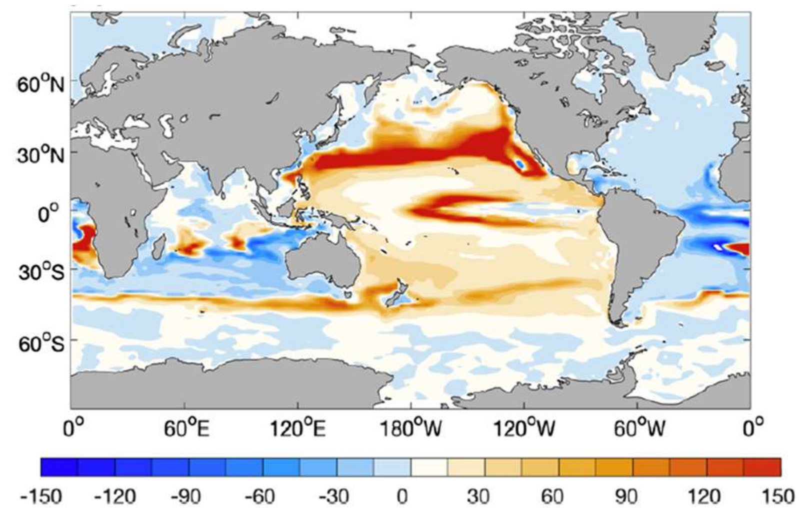
Check for updates

Ocean fertilization by pyrogenic aerosol iron

Akinori Ito[1], Ying Ye[2], Clarissa Baldo[3] and Zongbo Shi[3]

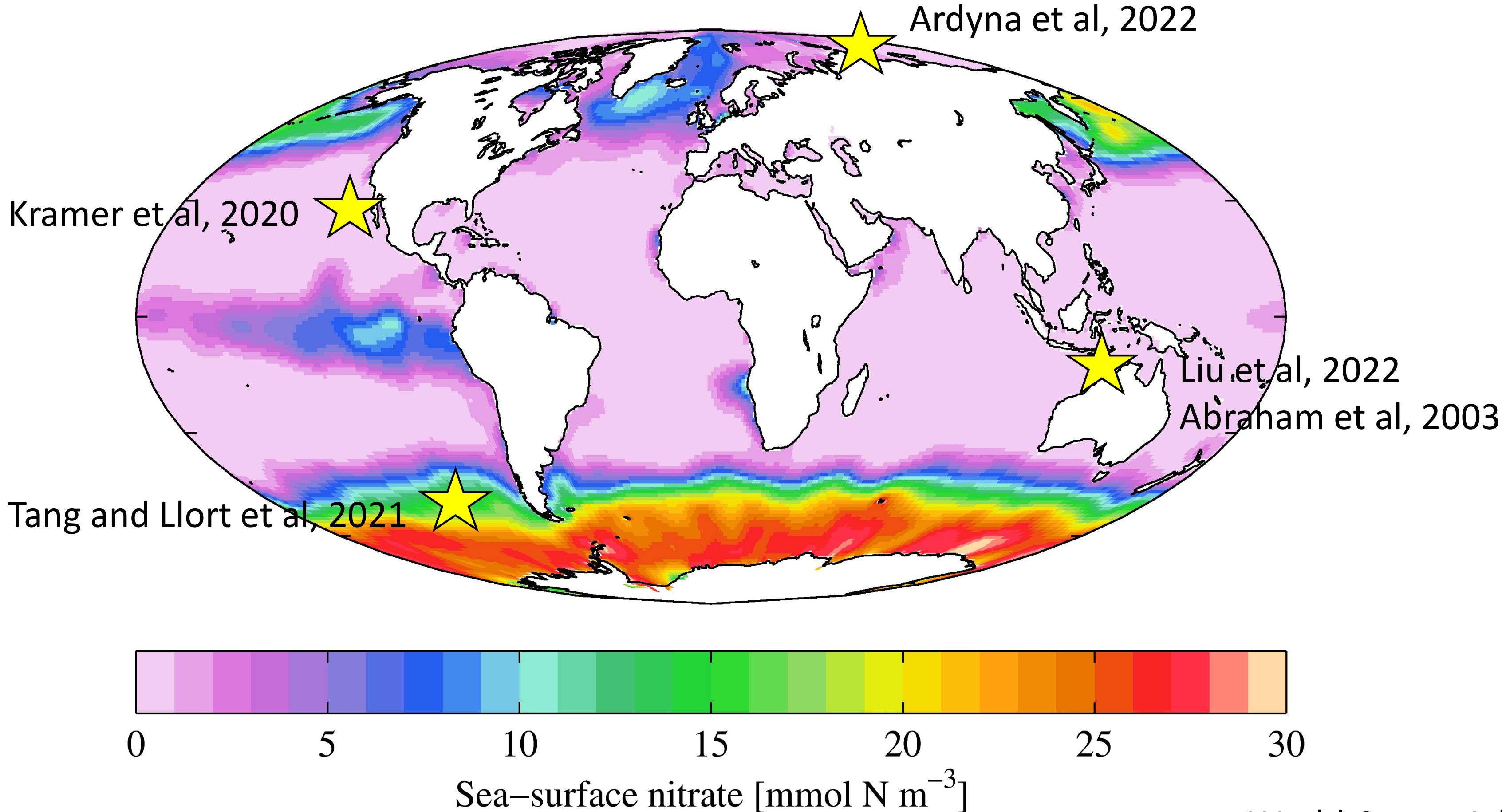
Aerosols supply bioaccessible iron to marine biota which could affect climate through biogeochemical feedbacks. This paper review progresses in research on pyrogenic aerosol iron. Observations and laboratory experiments indicate that the iron solubility of pyrogenic aerosol can be considerably higher than lithogenic aerosol. Aerosol models highlight a significant contribution of pyrogenic aerosols (~20%) to the atmospheric supply of dissolved iron into the ocean. Some ocean models suggest a higher efficiency of pyrogenic iron in enhancing marine productivity than lithogenic sources. It is, however, challenging to quantitatively estimate its impact on the marine biogeochemical cycles under the changing air quality and climate.

npj Climate and Atmospheric Science (2021)4:30; https://doi.org/10.1038/s41612-021-00185-8



Simulated change in NPP_{nano} (mgC m−2 day−1) induced by Pyrogenic DFe

Capturing the impact of pyrogenic aerosols



World Ocean Atlas, 2009

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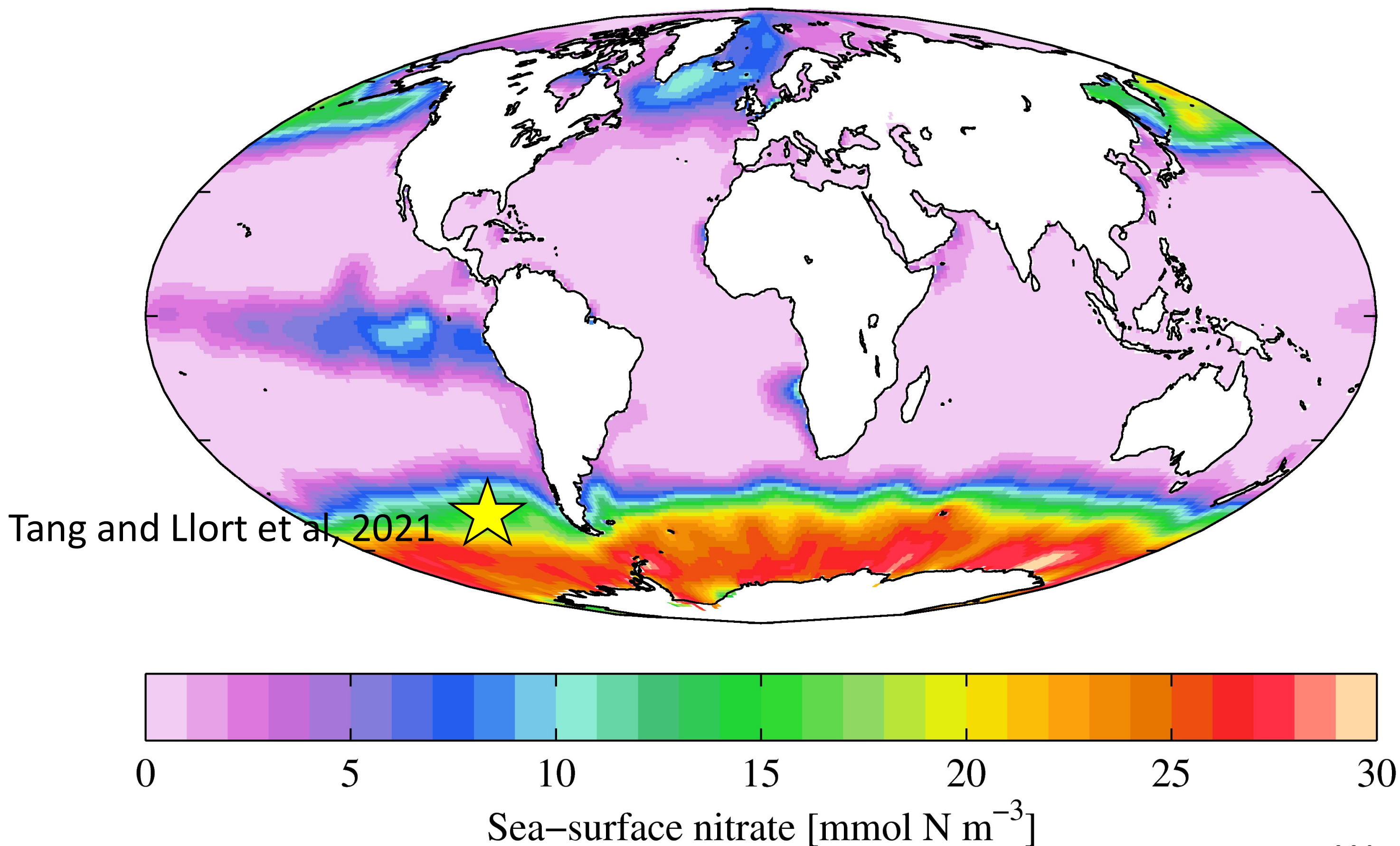
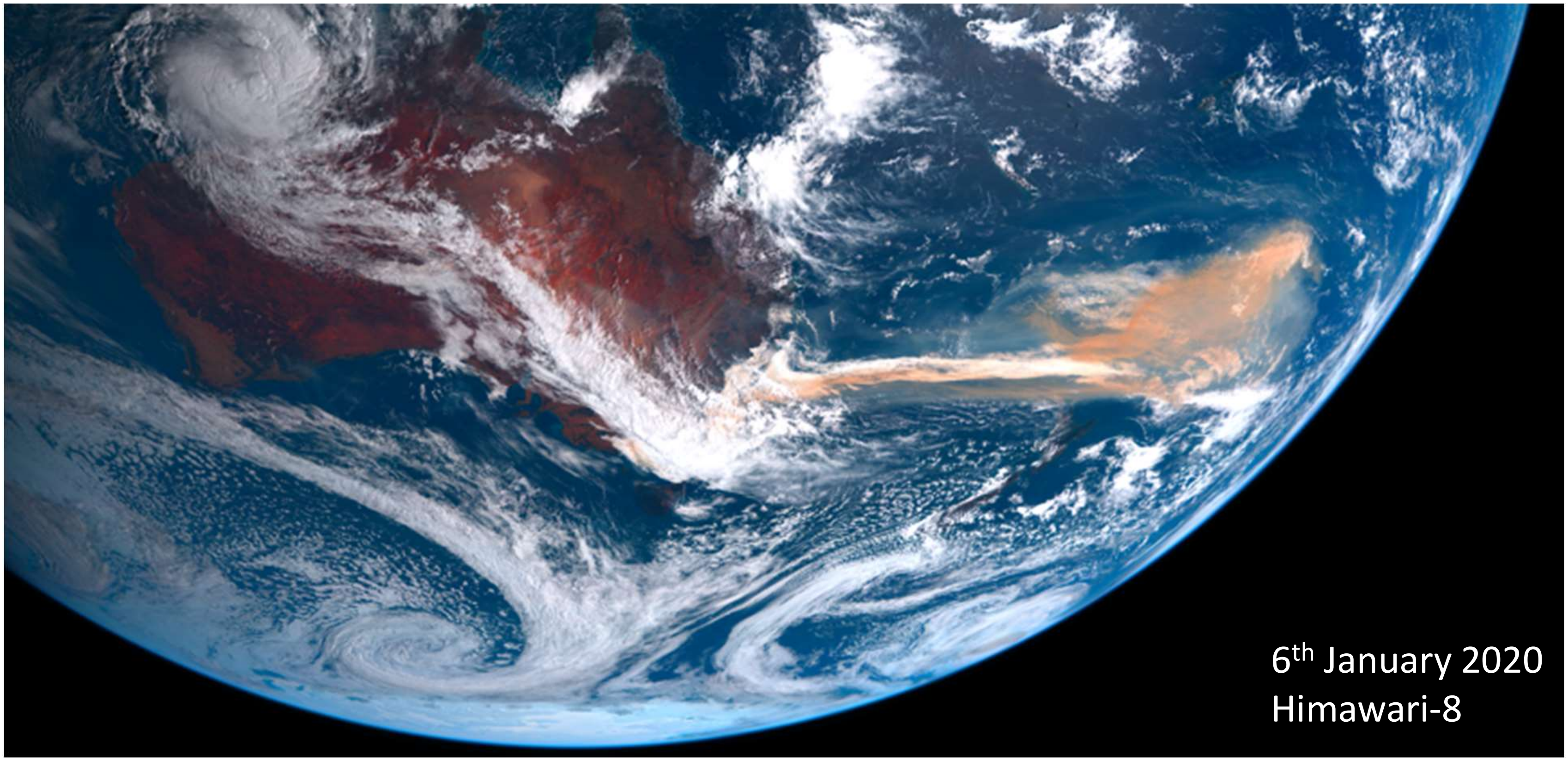


World Ocean Atlas, 2009

Australian 2019/20 wildfires



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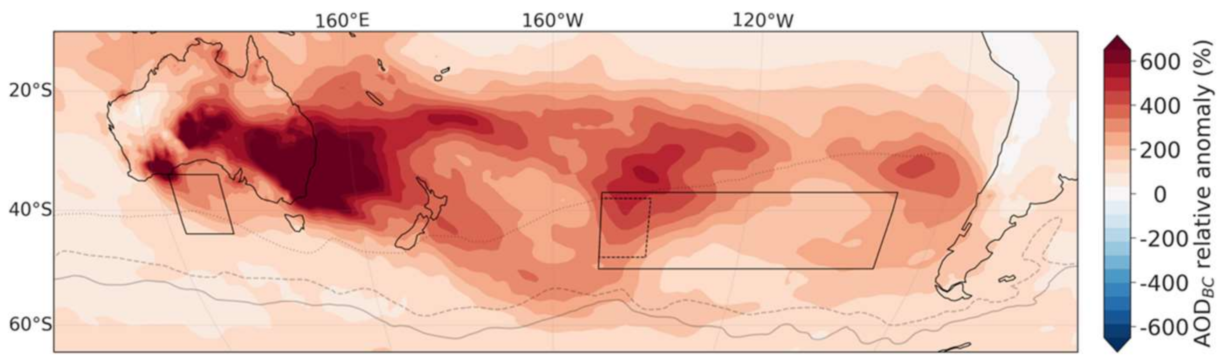
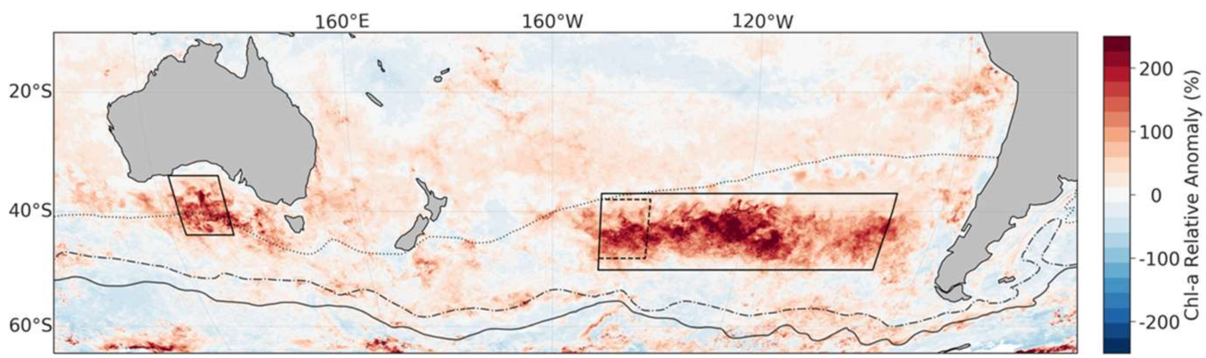
AOD and Phytoplankton anomalies in 2019/20



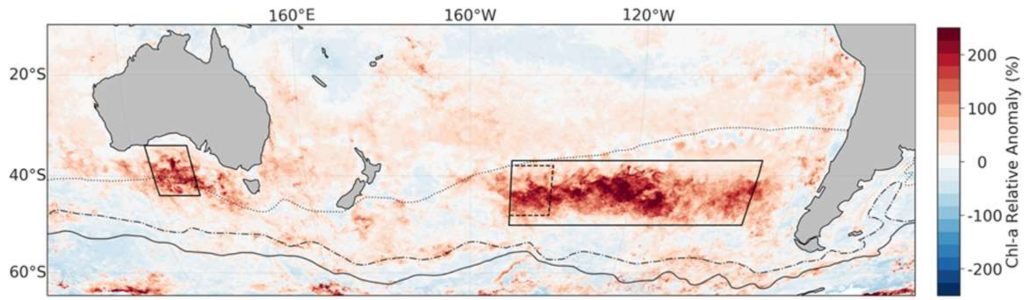
Black-Carbon AOD relative anomaly derived from atmospheric reanalysis (CAMS)

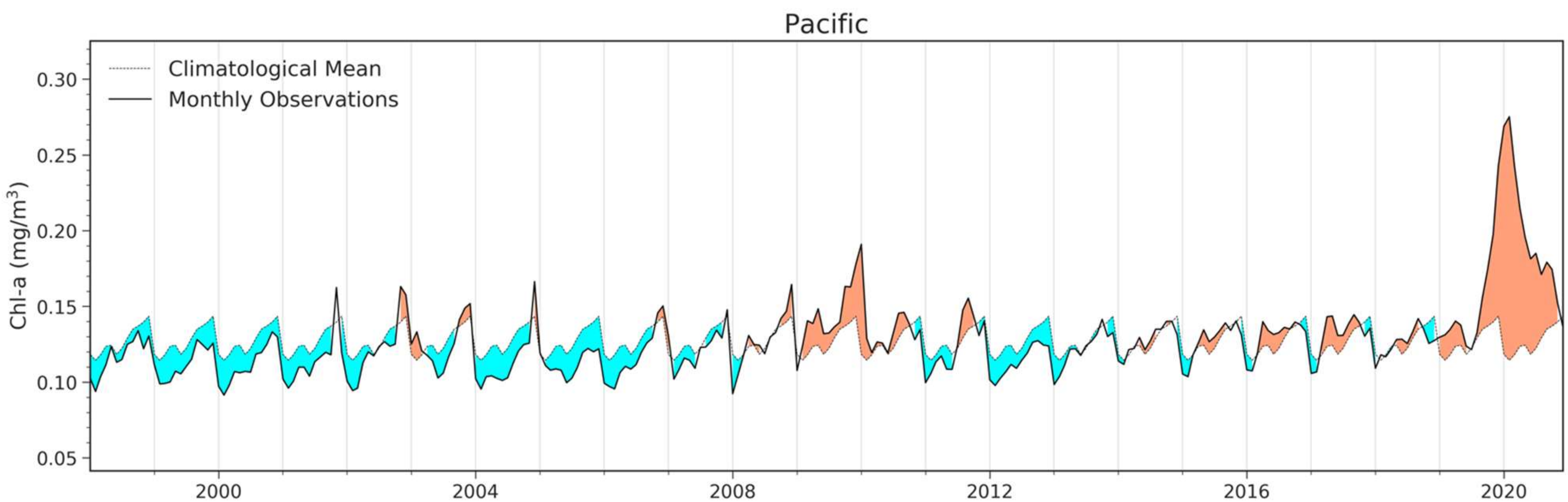


Tang and Llort et al., 2021, Nature

Surface Chl concentration observed from satellite. Relative anomaly computed over a 22-years long records (ESA's OC-CCI)

Unprecedented Chl concentration



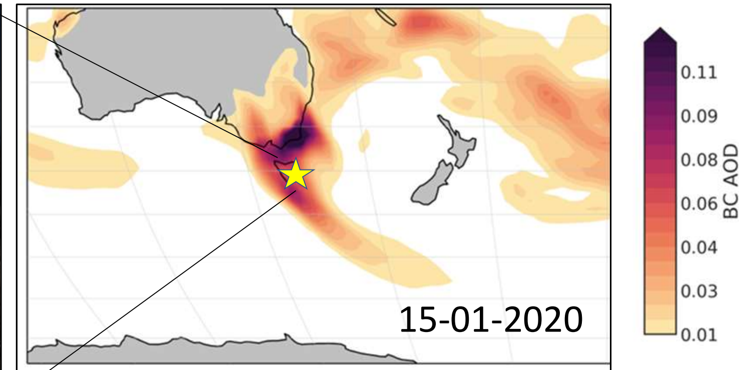


Chl-a anomaly lasted more than 12 months!!

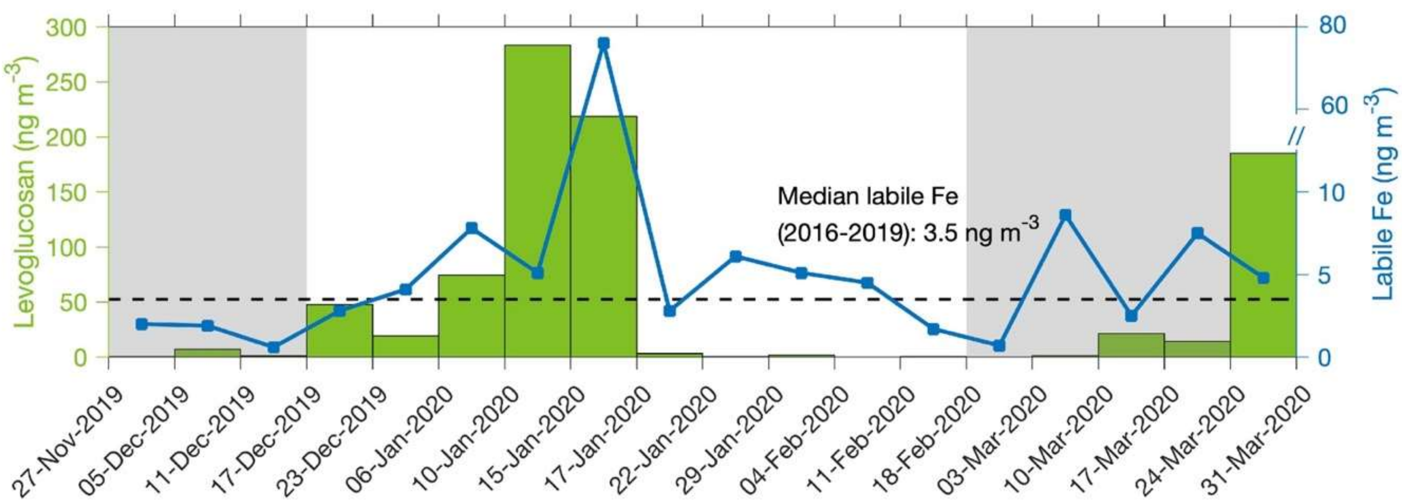
Iron and levoglucosan content in aerosols

High TFe and LFe in aerosols sampled when
a smoke plume from wildfires crossed the station.

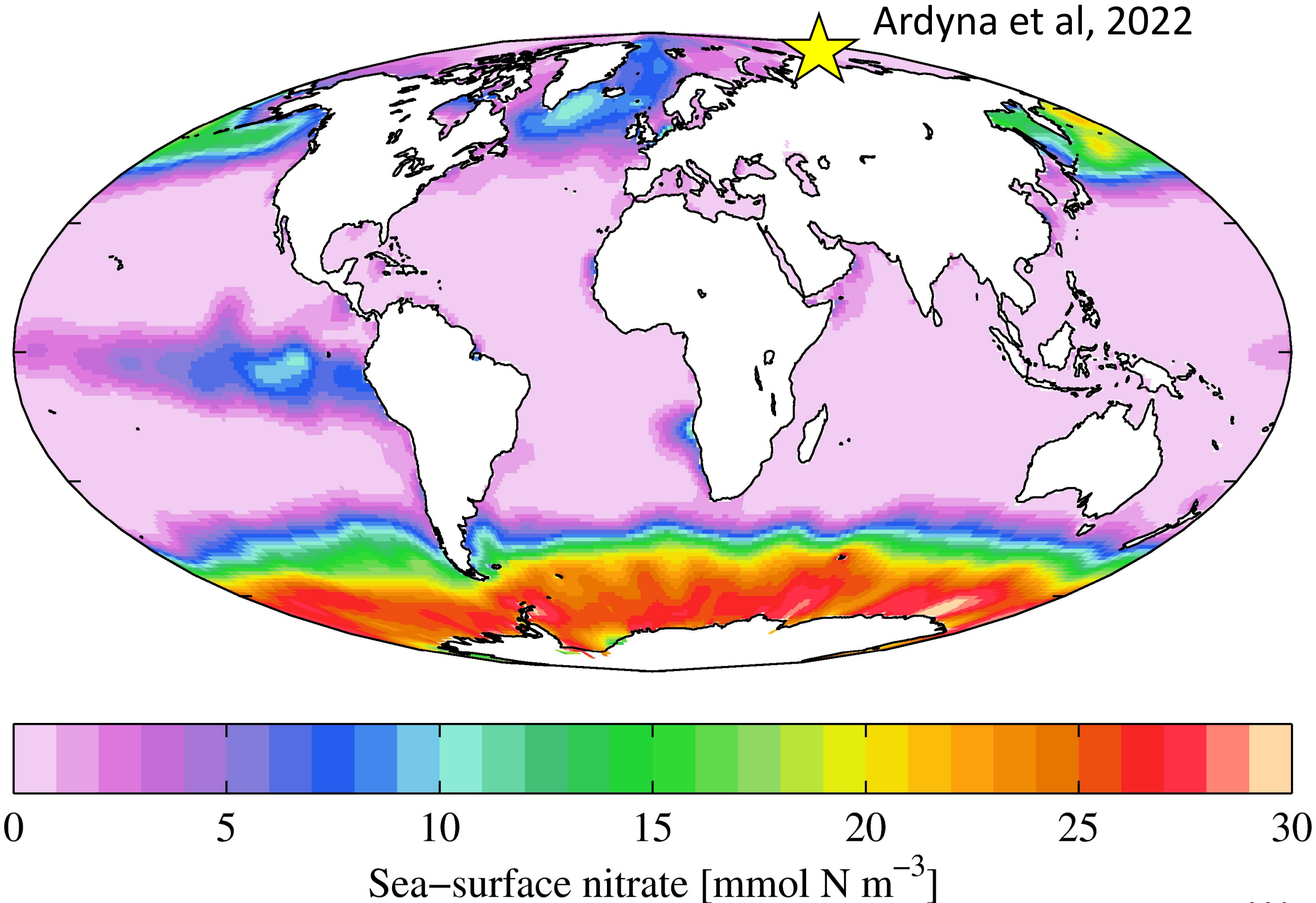
High concentrations of Levoglucosan too
(tracer for biomass burning origin)



M. Perron, A. Bowie (IMAS-UTAS)



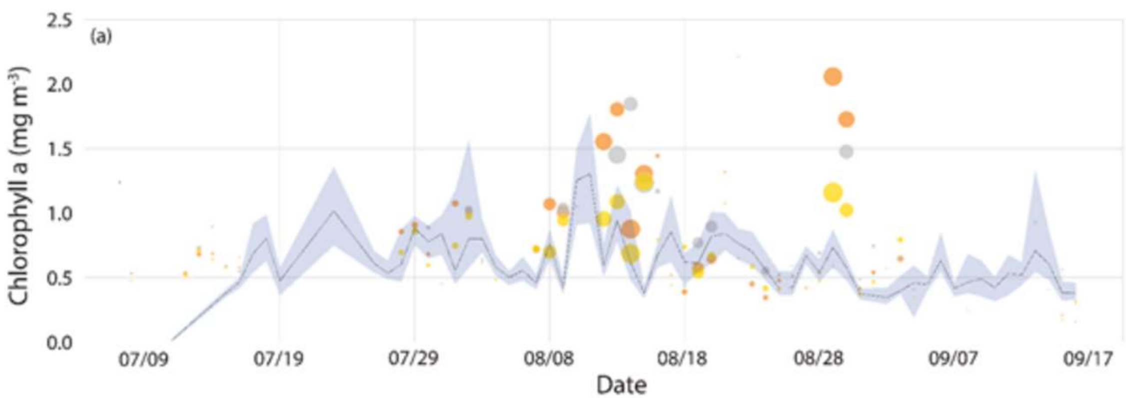
Capturing the impact of pyrogenic aerosols

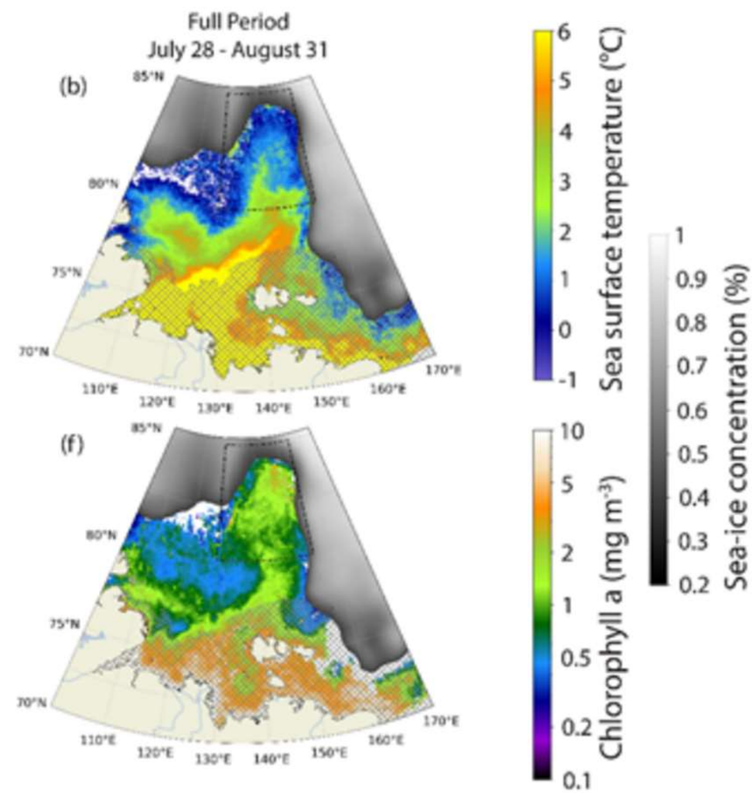


World Ocean Atlas, 2009

Capturing the impact of pyrogenic aerosols II

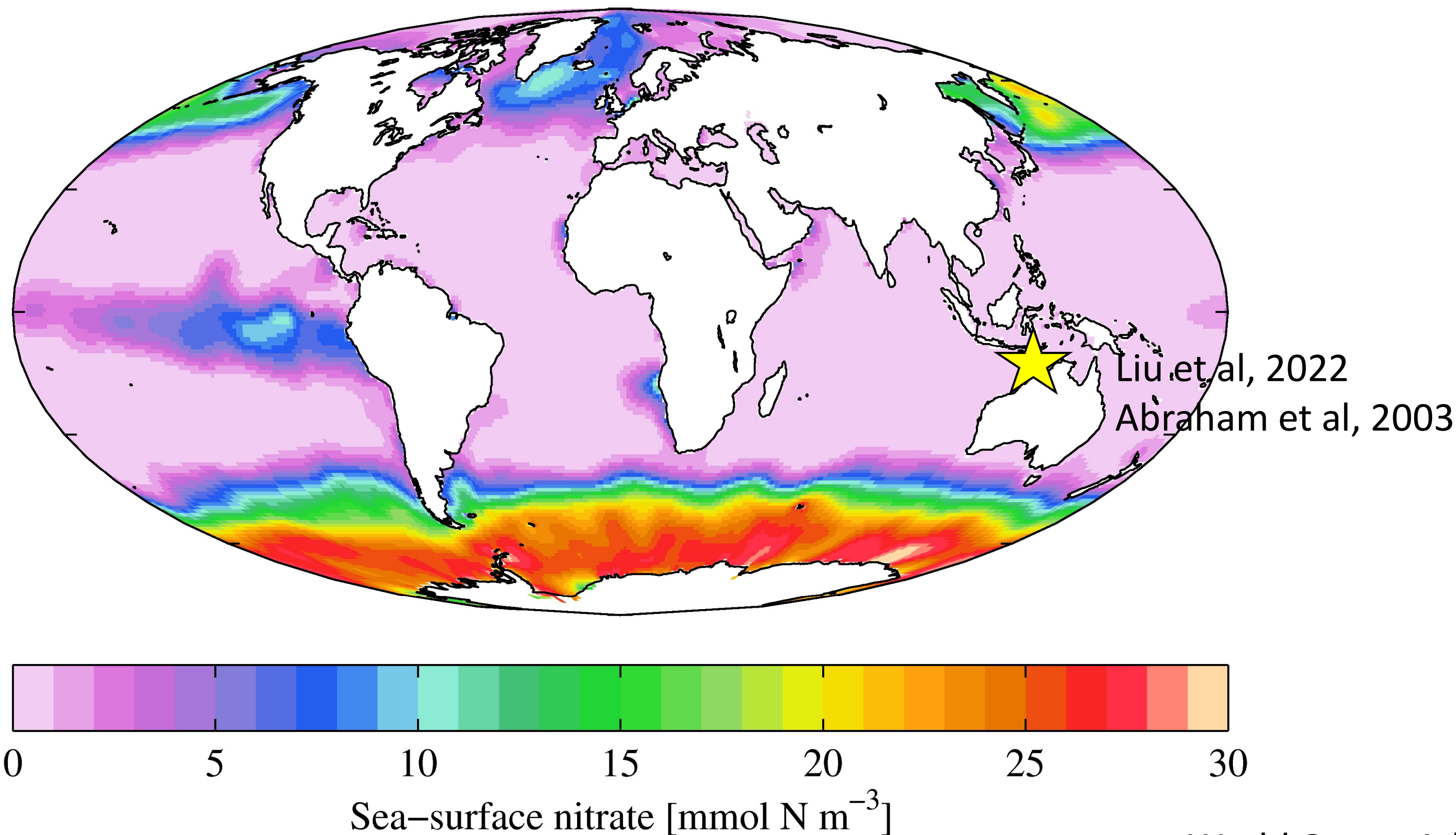
High phytoplankton blooms in the Arctic Ocean are associated with the deposition of N from boreal wildfires





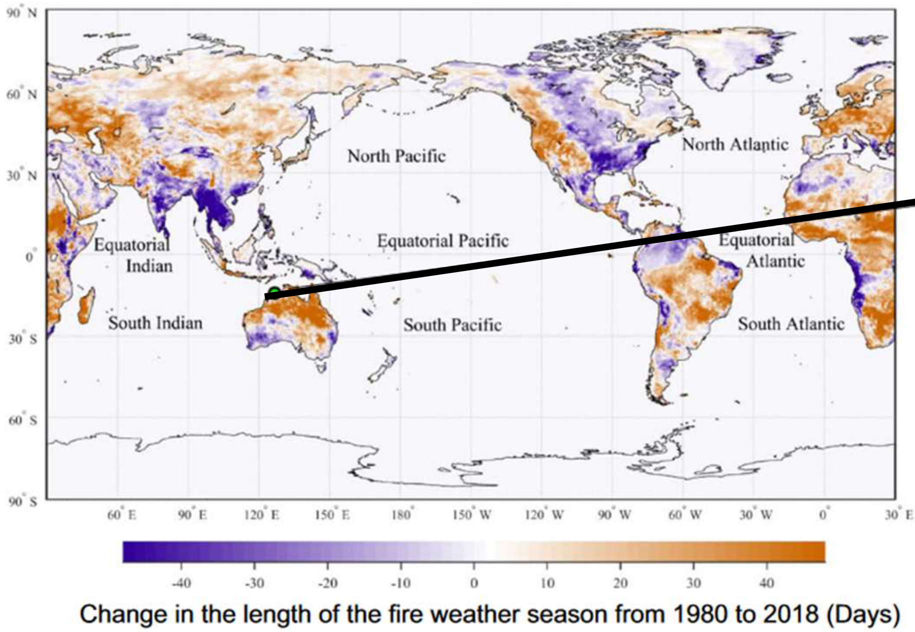
Ardyna et al, 2022, *in press*,
Nature Comms. Earth and Environment

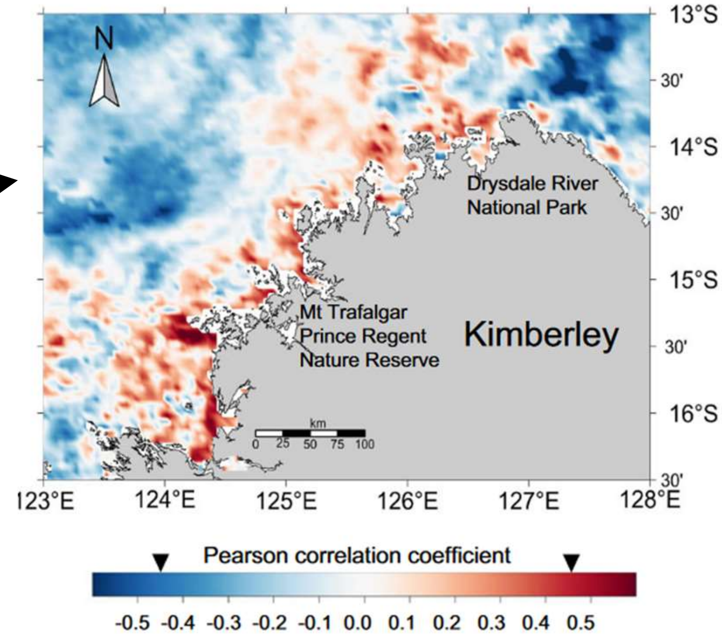
Capturing the impact of pyrogenic aerosols



World Ocean Atlas, 2009

Capturing the impact of pyrogenic aerosols III

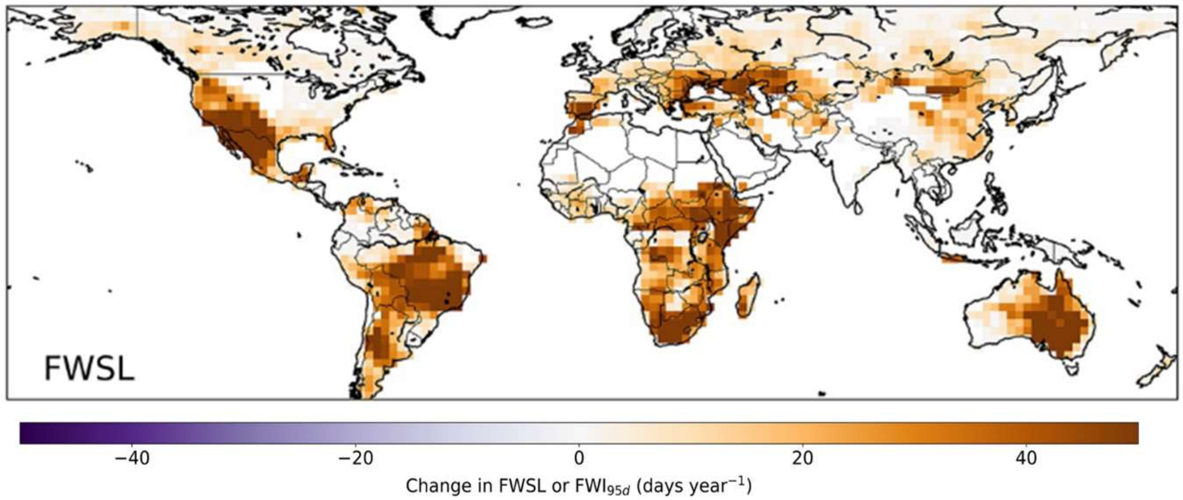


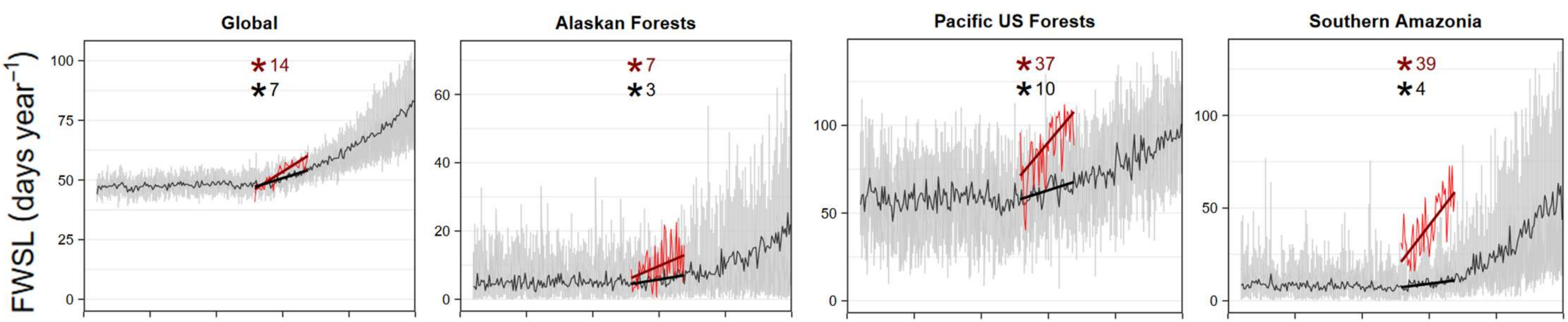


- Decadal variability in Chl is associated with fire activity in tropical oceans.
- During the positive phase of the IOD, fire is the main driver (more important than rainfall and cyclones).

Liu et al, 2022, Nature Comms.

Fire Weather Season increasing globally





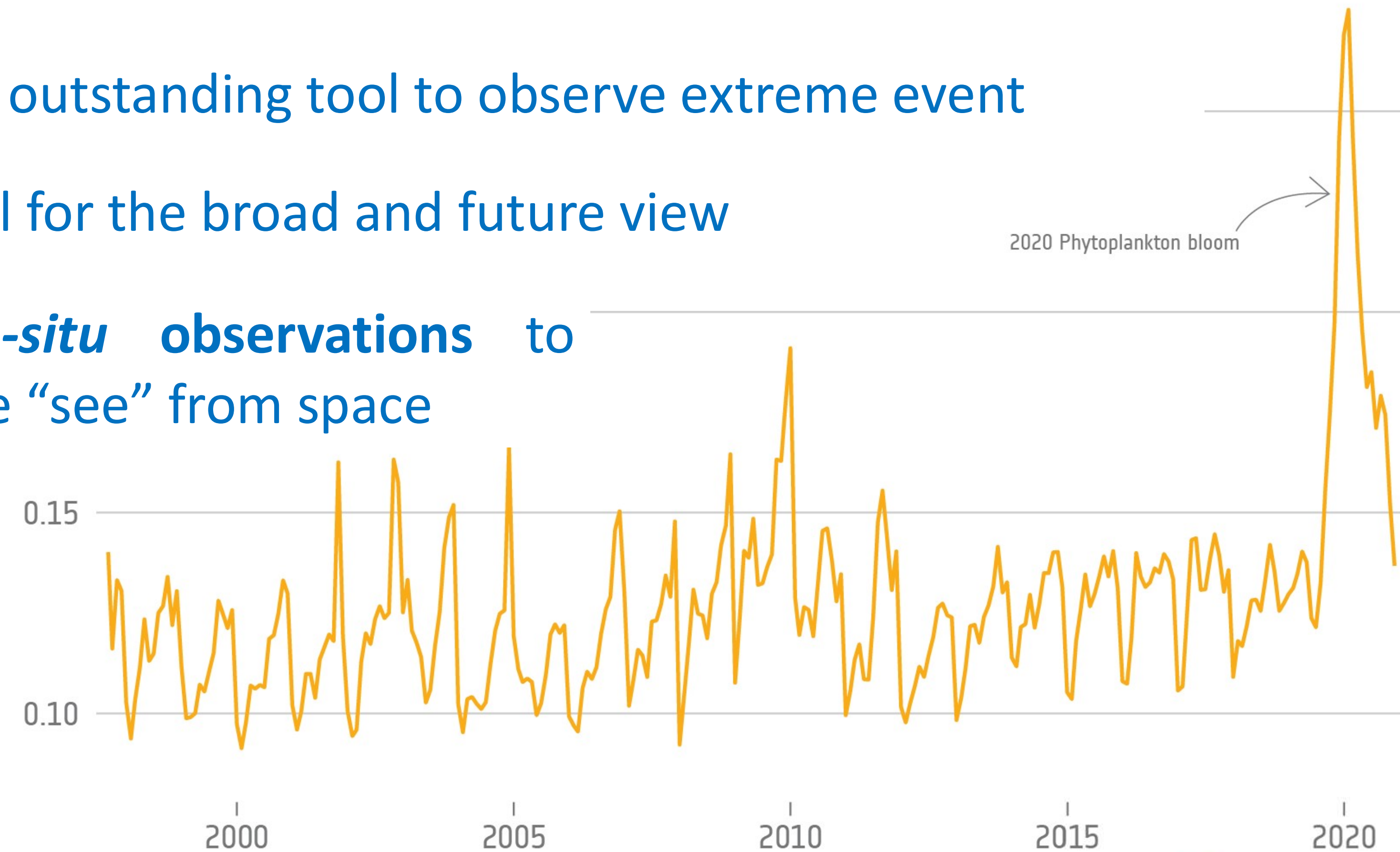
Jones et al, 2022, Review of Geophysics

Preparing the unprecedented

Satellite data are an outstanding tool to observe extreme event

Models are essential for the broad and future view

Yet, we need ***in-situ* observations** to understand what we “see” from space



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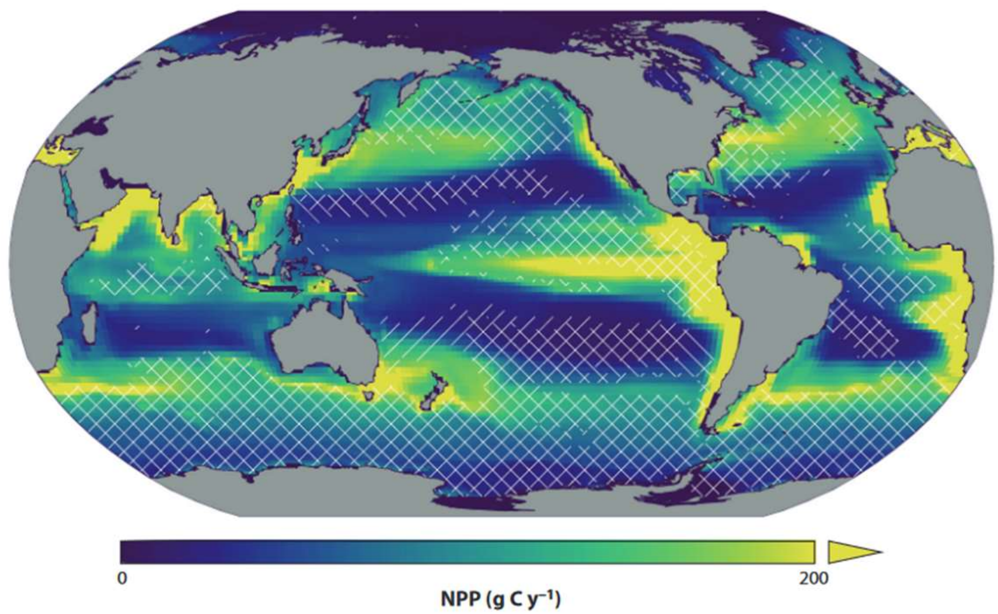
How will increasing fire activity impact future marine primary production?

First modelling efforts (including ONLY iron) suggest that most of the global ocean can be impacted by increasing pyrogenic aerosols.



Hamilton et al, 2022,
Annual Rev Marine Sciences

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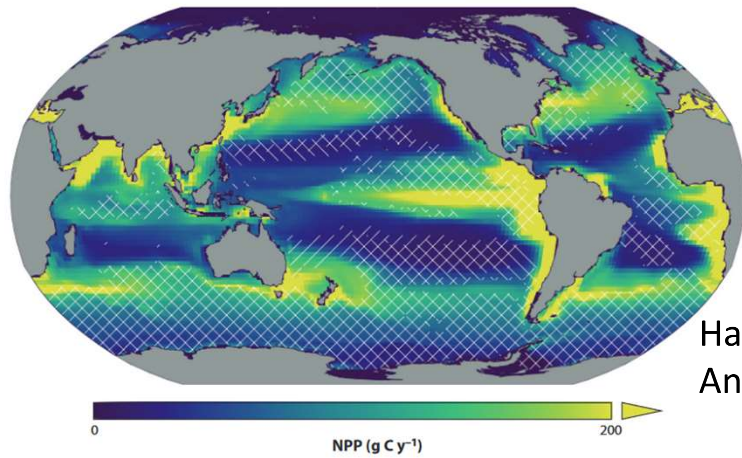

Hamilton et al, 2022, Annual Rev Marine Sc.

Major knowledge gaps:

- Nutrients other than Fe
- Potential toxicity
- Interaction with organic matter
- Dust – ash mix at emission

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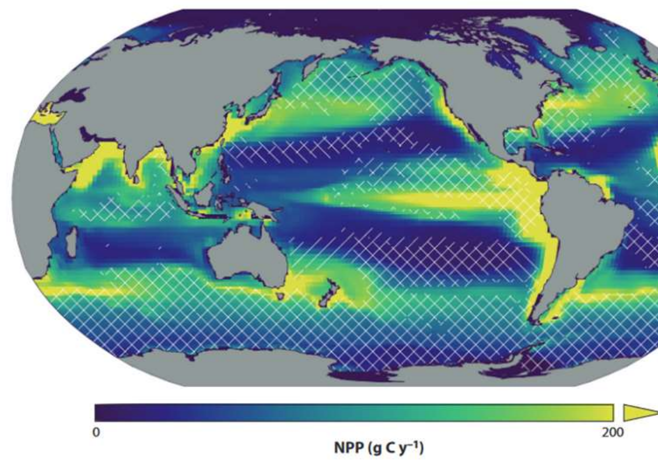

Hamilton et al, 2022, Annual Rev Marine Sc.

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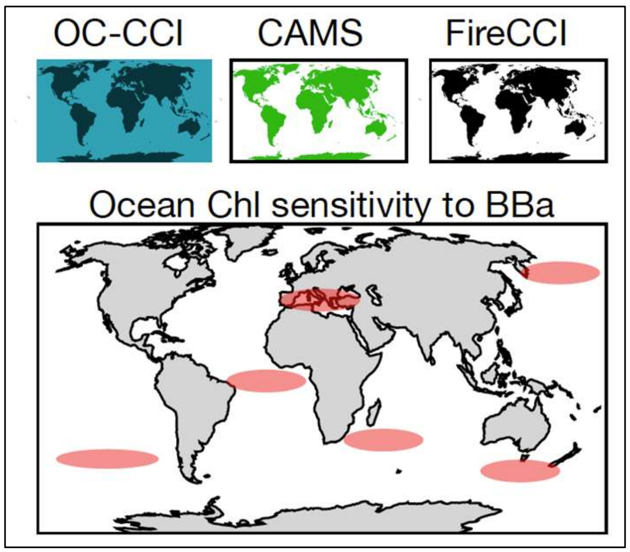
→ PYROPLANKTON

Funded by ESA and the BSC

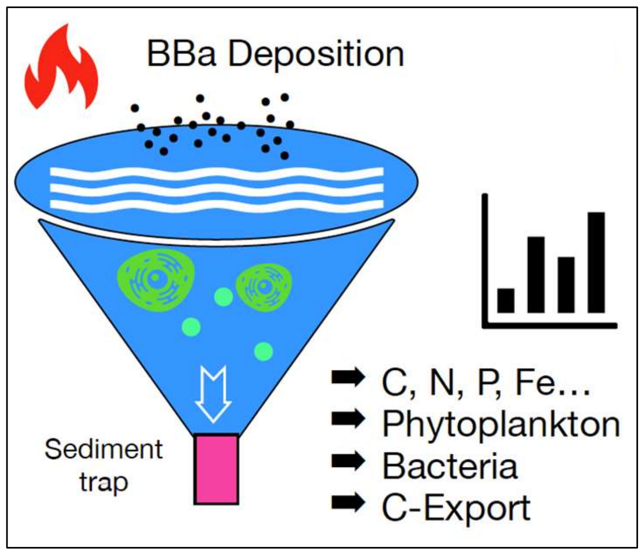
PYROPLANKTON strategy

In PYROPLANKTON will build mechanistical understanding of the BBa impact on marine primary production by means of satellite and groundbreaking mesocosm experiments.

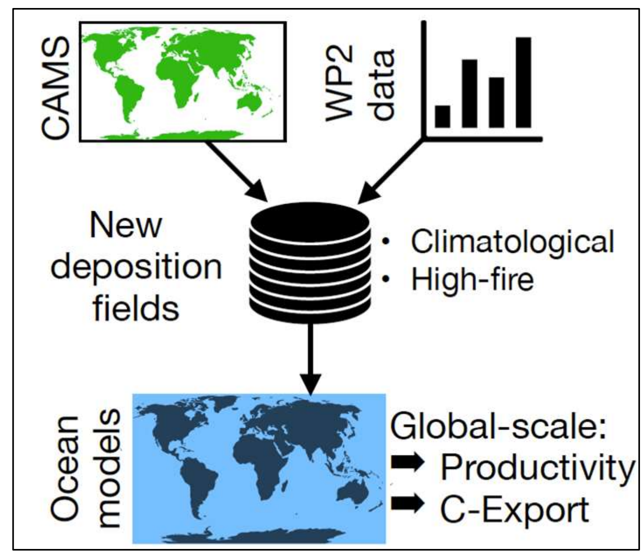
Remote observations



Mesocosm experiments



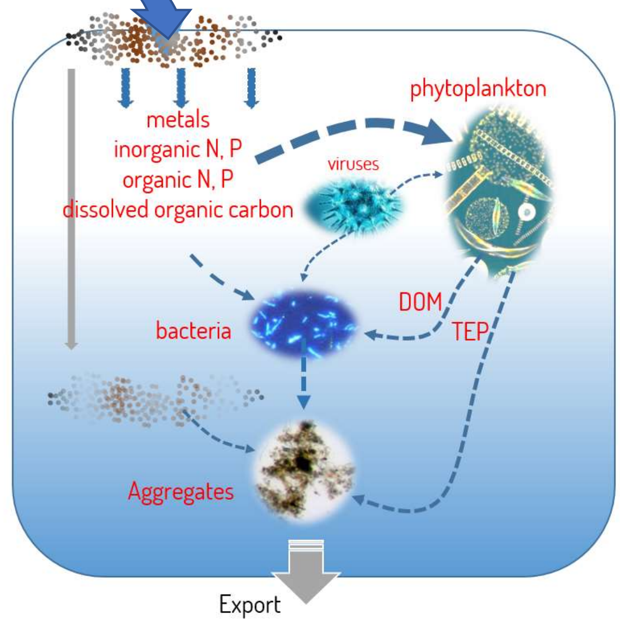
Ocean BGC models



PYROPLANKTON experiment

Simulating ash deposition events

Cristina Santin
IMIB-CSIC (Spain), Swansea Un. (UK)



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Wildfire ash in 'climate reactors'

- 9 Tanks of 300 L (surface seawater) in a 'clean room' container: 'trace metal clean.'
- Filtered (no plankton) or natural assemblage
- LEDs of different wavelengths to "reproduce" the sunlight spectrum
- Monitoring of PAR, pH and Temp
- Weak turbulence to mimic natural conditions
- End with a conical shape and a sediment trap
- Rain simulator at the top to deposit aerosols

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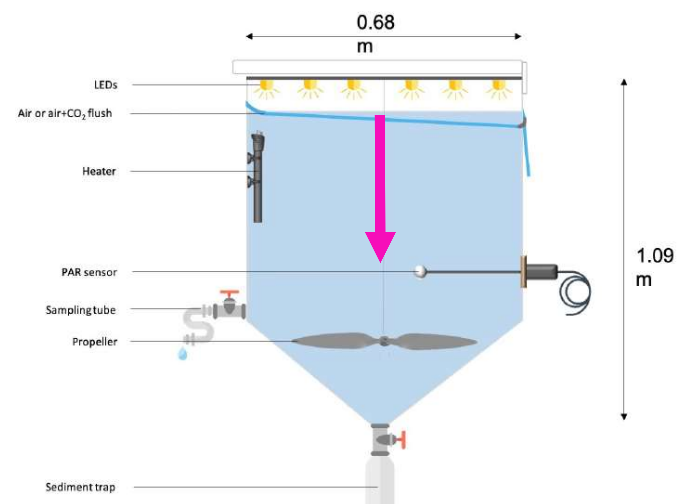

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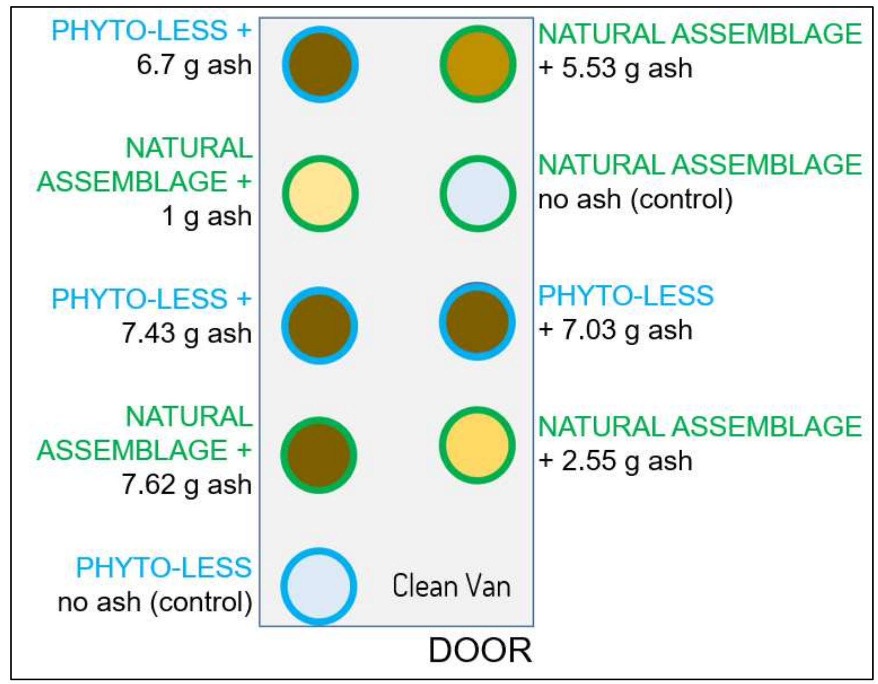
Methodology

- 4 tanks filled with 0.2 µm filtered seawater = no phytoplankton

  → Nutrients dissolution kinetic

- 5 tanks filled with unfiltered water = Natural assemblage

  → Impact on biota



Collecting ash

- Wildfire in forest of *Pinus halepensis*
(high severity, no rain before the sampling)

- Probably important soil component (Si, Al, Fe)

- We used the <20 um fraction (~20% total sample)

C. Santin

M. Santiso

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C. Santin

M. Santiso

"Ash samples were collected from the Santa Barbara and Carpinteria (California) areas during the Thomas Fire **by brushing ash deposited on car windshields** (…)". Ladd et al, 2023

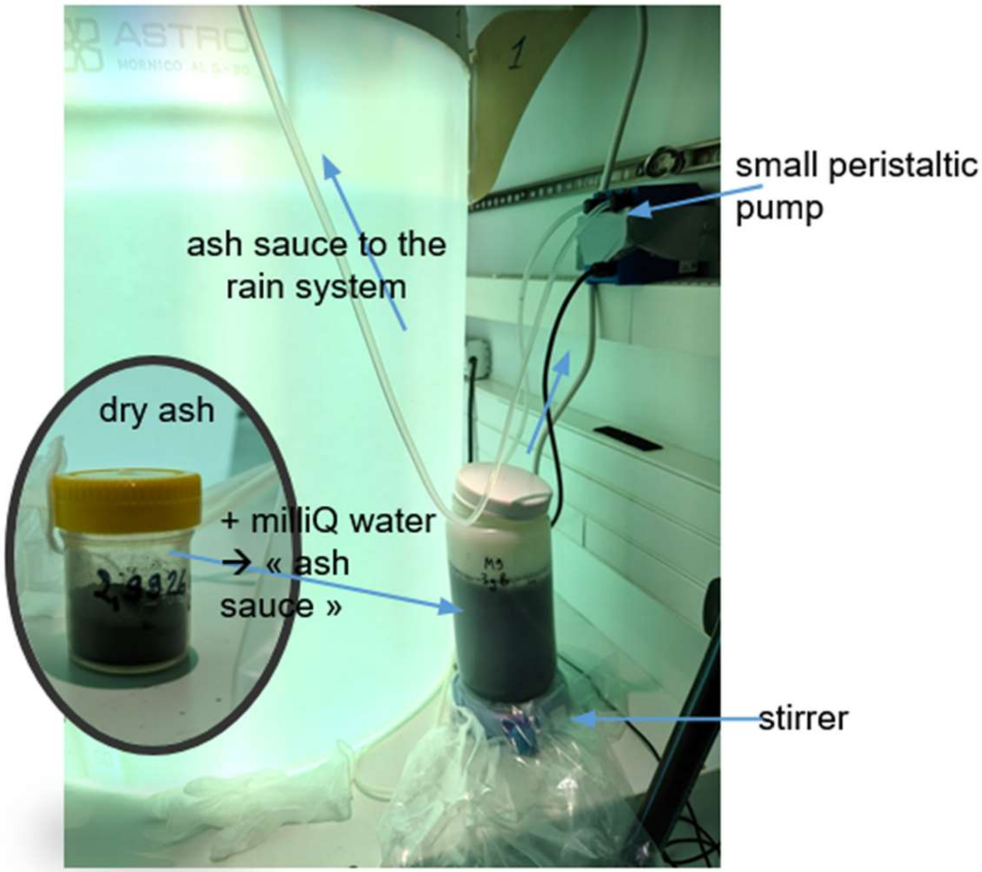
Seawater in oligotrophic conditions

On going nutrient limitation in July in Mediterranean Sea:

- N, P
- not DFe

Oligotrophic system (Chla at the start of the experiment = 0.3 µg.l-1

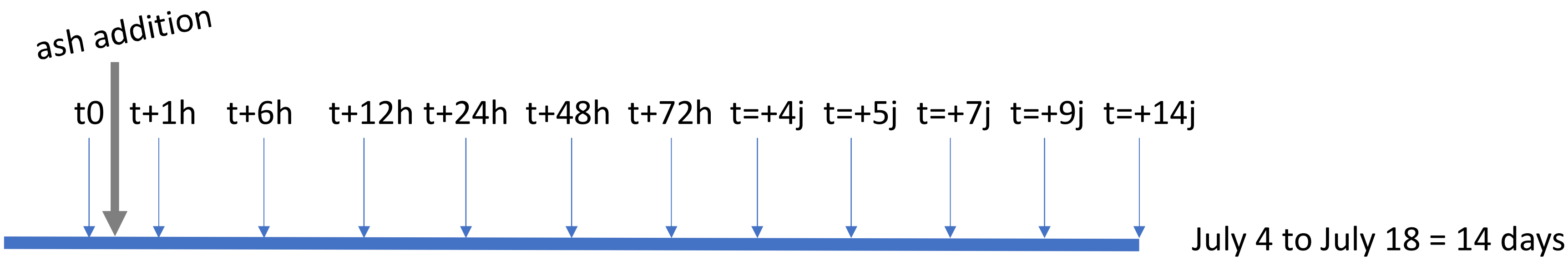
Ash Addition



Compared to dust

		P	N	Fe	total carbon	Organic carbon
this study (Cristina Results), “our” ashes	Part conc wt.%	0.22 %	0.64 %	2.8 %	14.6 +/- 0.1 %	11.1 +/-0.2 %
saharan dust	end member (Guieu et al. 2002)	0.082 +/- 0.011 %		4.45 +/- 0.49 %		
	DUNE dust (Guieu et al. 2014)	0.044 +/- 0.009 %	0.11 +/- 0.01 %	2.28 +/- 0.19 %	6.75%	

Methodology



- Nutrients
- Cytometry
- Pigments
- Particulate and Dissolved Matter
- Polymers
- Primary Production
- Bacteria Production
- …

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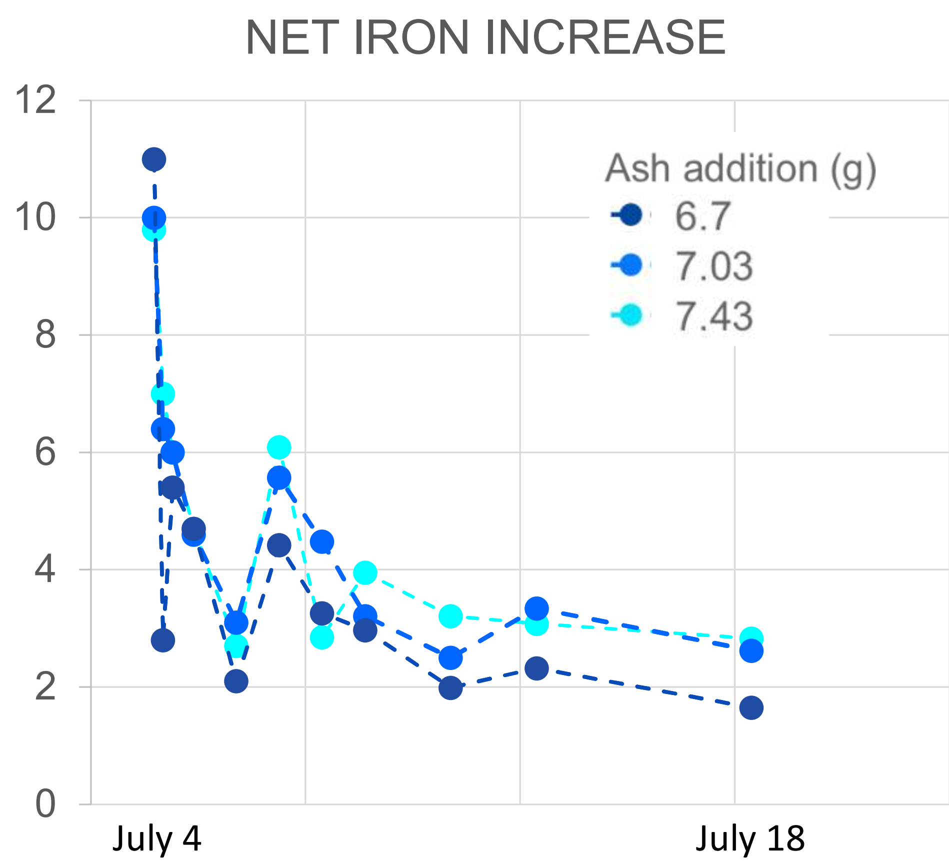
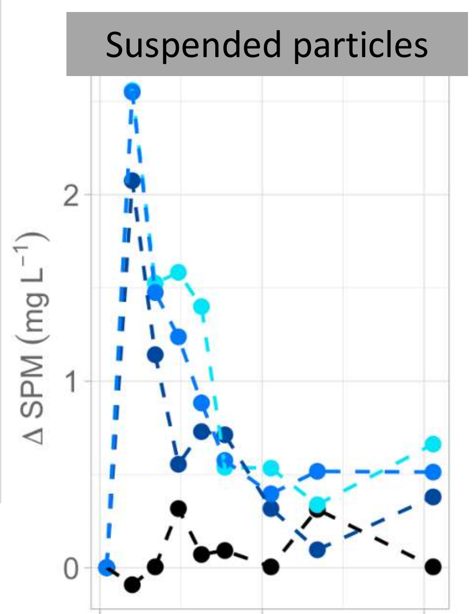
Results: Iron

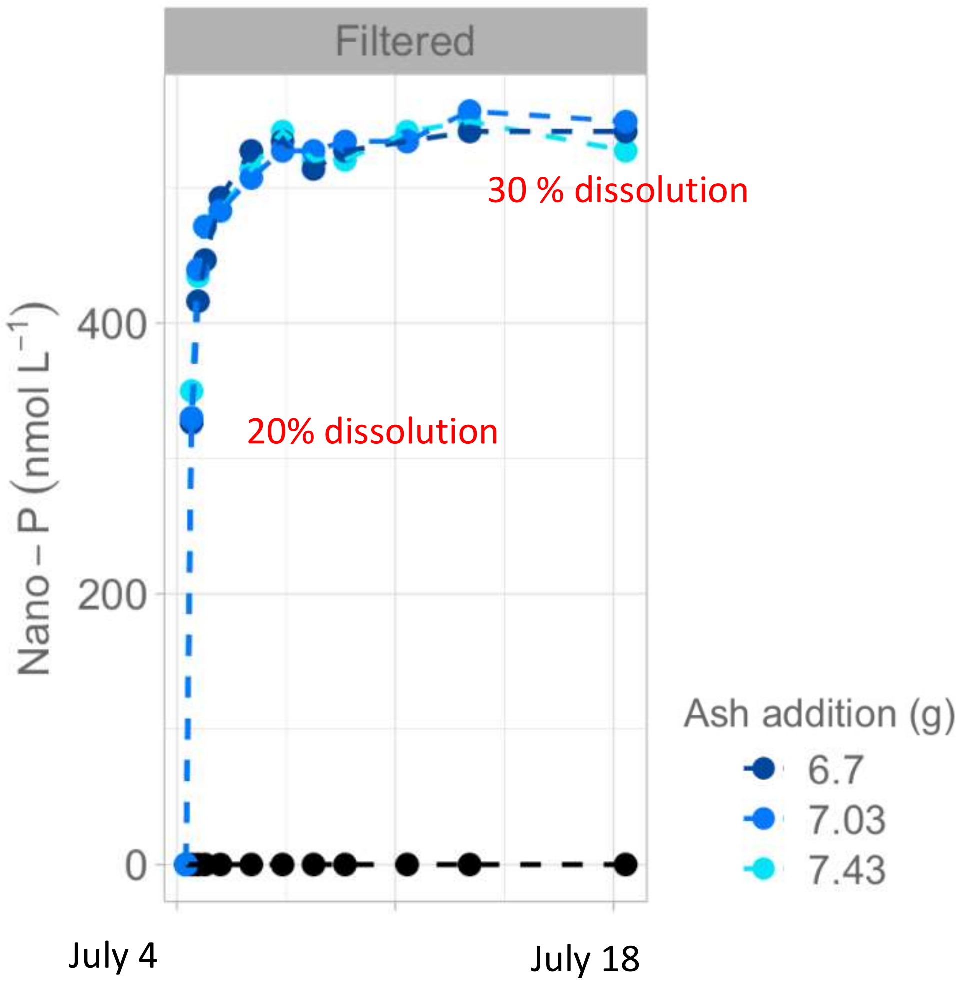


- Excellent reproducibility of the triplicates ➔ Reliable of results!
- Swift release of iron from the particles upon deposition: 4 times increase in the in situ concentration (+10 to 12 nM increase of DFe in surface seawater)



- rapid drop (big particles)
- high concentrations after a strong decrease

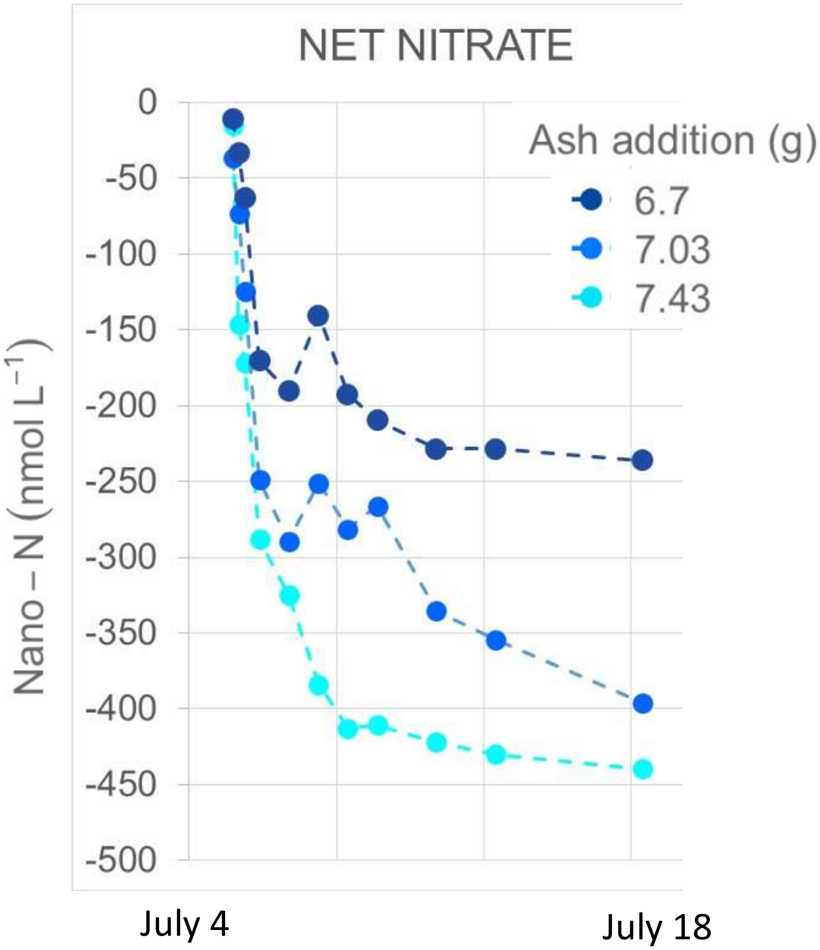
Results: Phosphates



- Very good reproducibility of the triplicates minicosms ~7 g ash
- Reached a plateau after several days: small particles still in suspension
- Net and strong increase of 0.53 µmol.l-1 of PO4

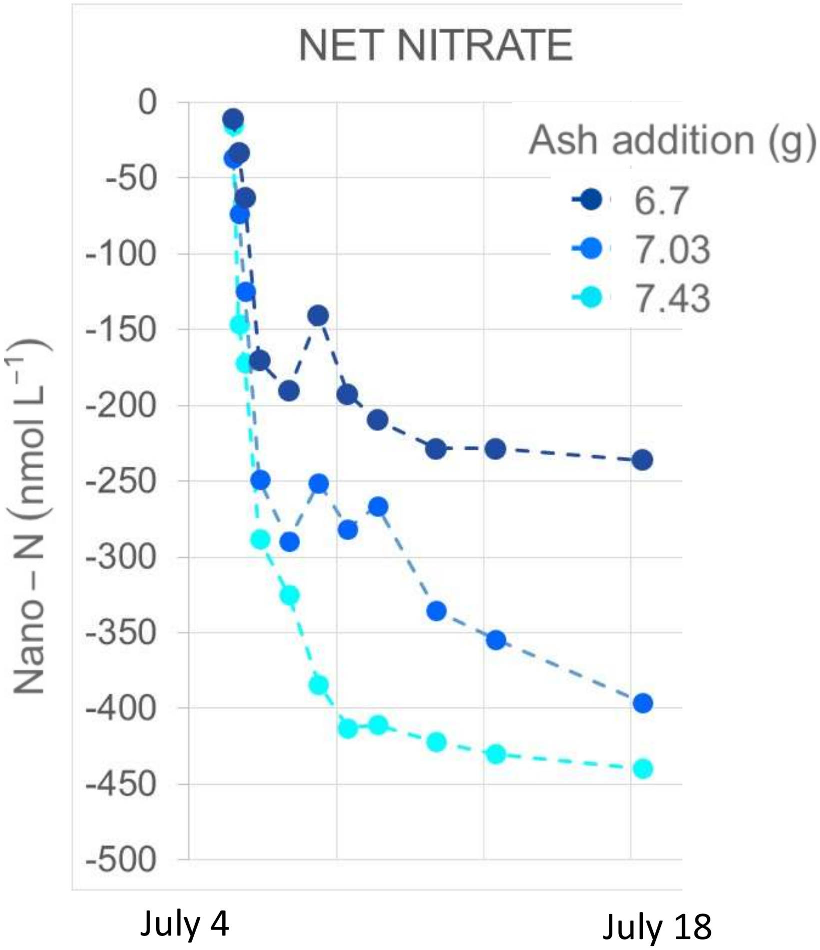
(in situ PO4 at that time ~ DL = 7 nM)

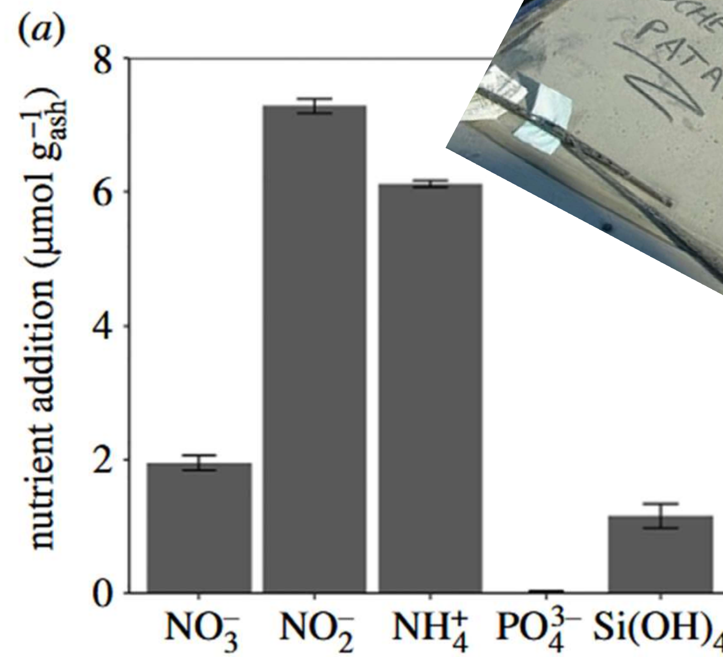
Results: Nitrate

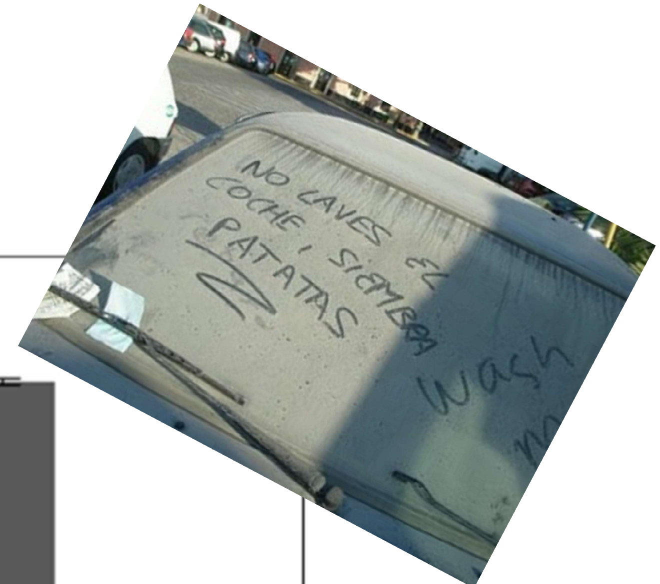


- No NO3 release
- A strong decrease that is dependent on the amount of ash :
  - Adsorption onto the particles?
  - Consumption?

Results: Nitrate



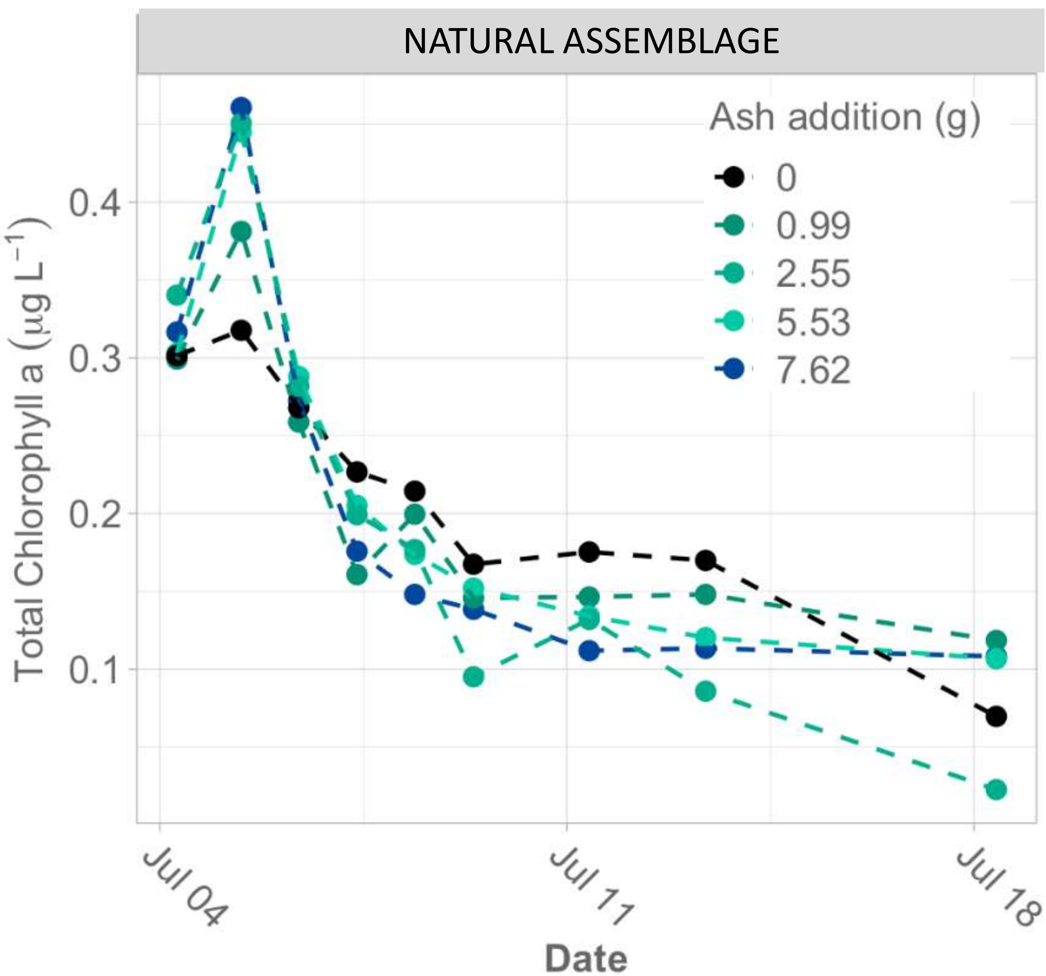




Ladd et al, 2023

- Strong release of NOx in California fires

Results: Impact on phytoplankton

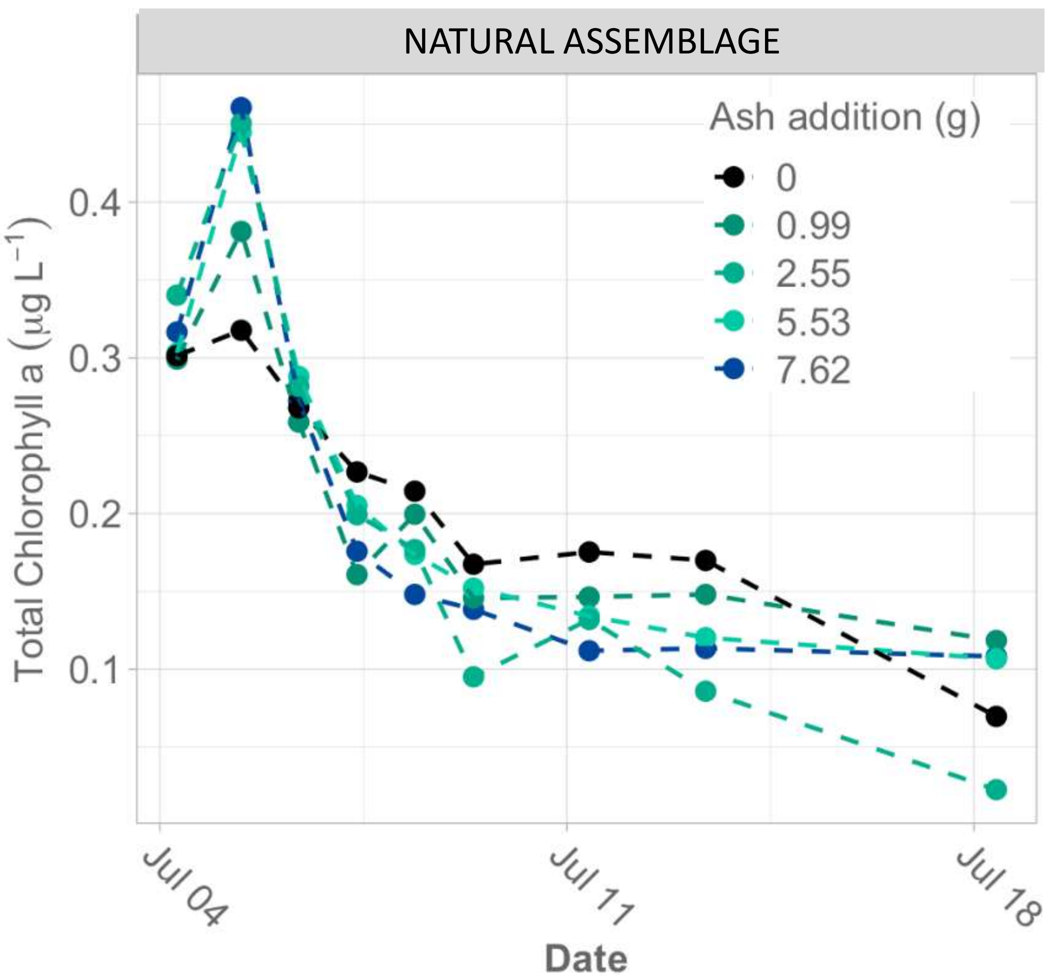


- Fast (+24h) and strong (x ~2) response
- Nice gradient from low to high ash flux
- Decrease after 2 days and

Chla treatments < Chla control

- N limitation?
- Toxic effects?

Results: Impact on phytoplankton



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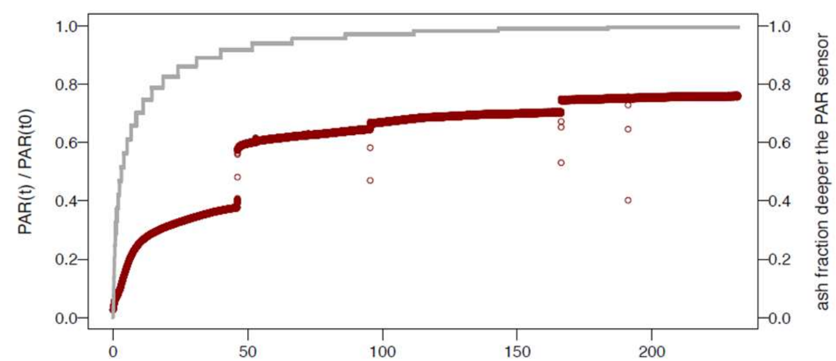

➔ Light attenuation by ~20% (100 uE) driven by ~125 mg of ash (equivalent to a deposition flux of 0.3 g/m2)

PYROPLANKTON modelling

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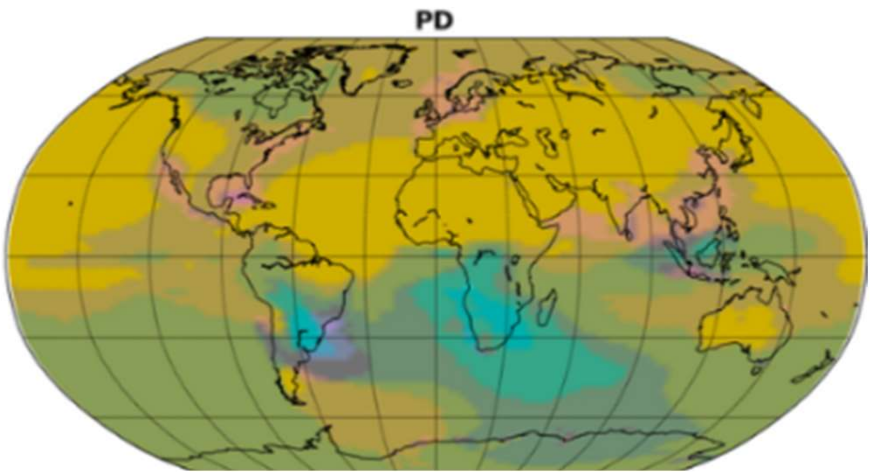
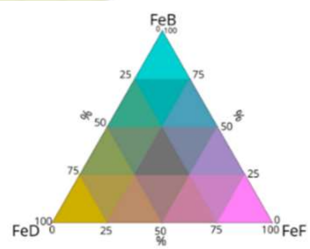
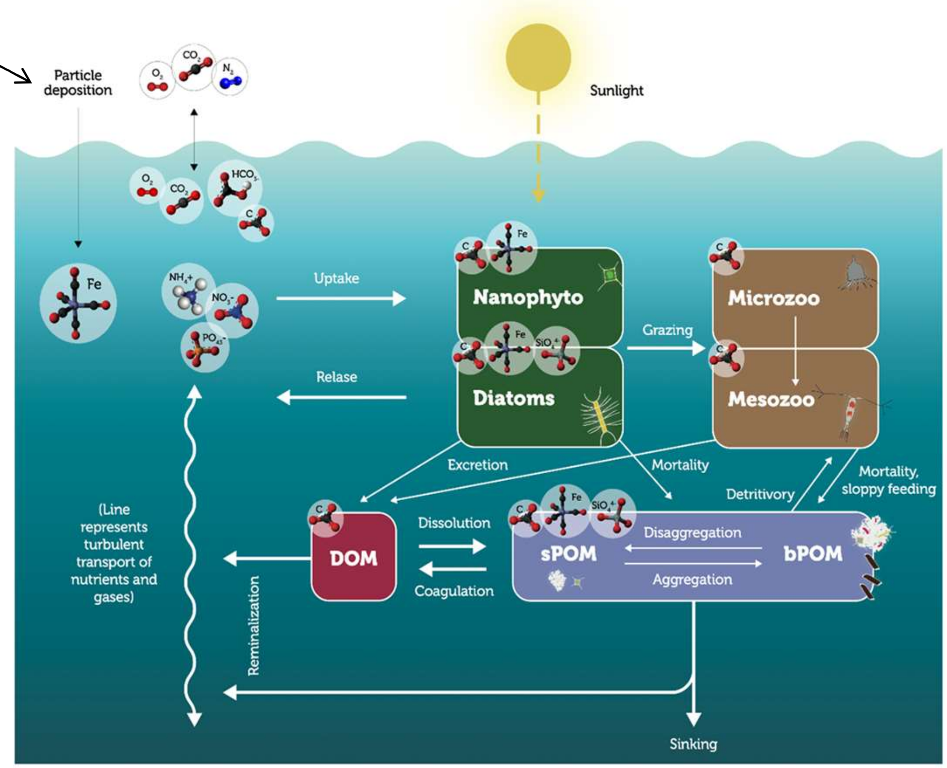
Impact on the marine iron & primary production

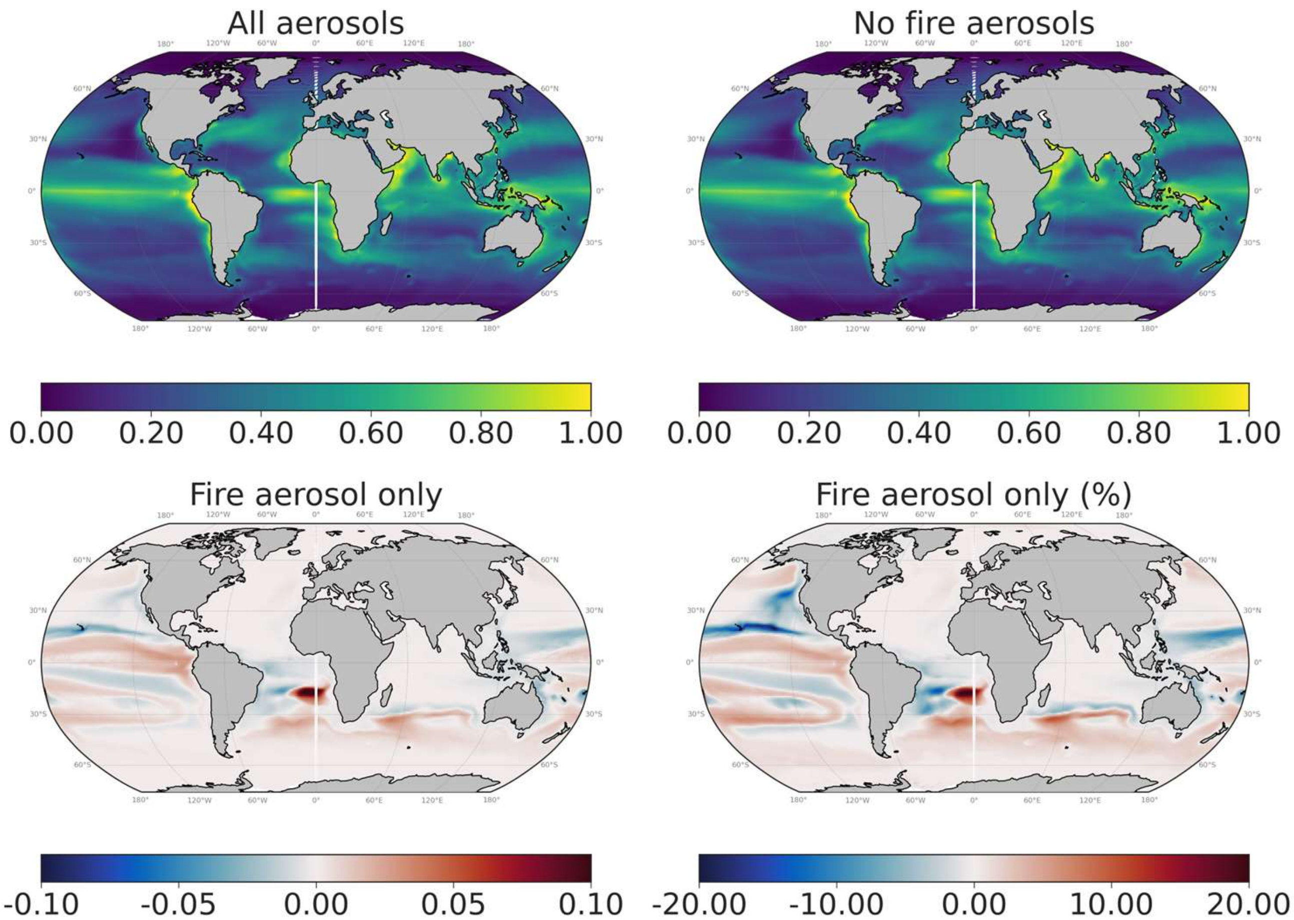


Bergas-Massó et al, 2023





Impact of new deposition fields



- Signficant impact on the SH
- Negative anomalies (?!)
- Impact of submonthly deposition events?

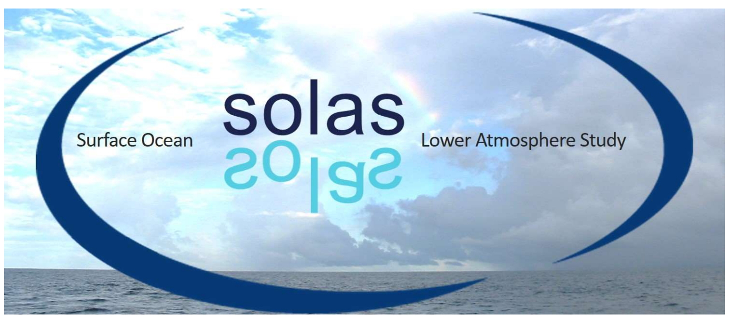
Fire science Learning AcRoss the Earth system

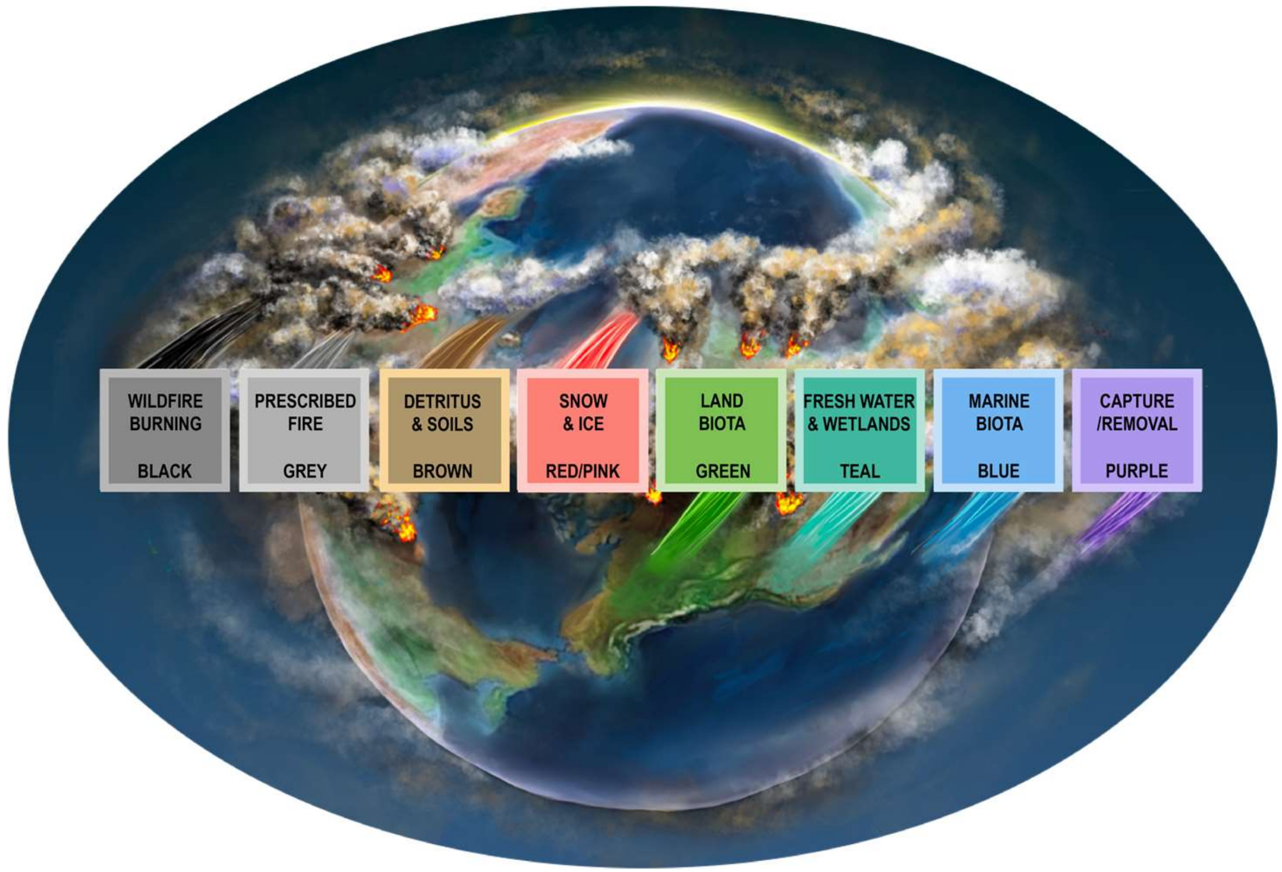
FLARE

WORKSHOP

18th-21st September 2023

Future Eart – ESA Joint Call





Miriam H Morrill - Pyrosketchology.com