Impact of desert and volcanic aerosol deposition on phytoplankton in the South Indian Ocean and Southern Ocean

Carla Geisen[1*], Céline Ridame[1], Emilie Journet[2], Benoit Caron[3], Dominique Marie[4] and Damien Cardinal[1]

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EGU2020 – main results

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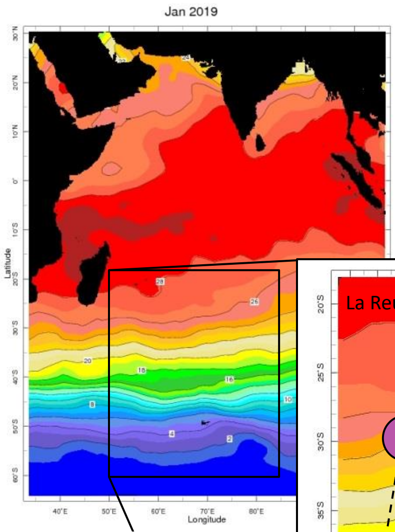
Study area

South Indian Ocean
and Southern Ocean

January - February 2019
End of the spring bloom

	Primary Production (mgC.m^{-3}.d^{-1})	NOx (µmol.L^{-1})	DIP (µmol.L^{-1})	dSi (µmol.L^{-1})	dFe (nmol.L^{-1})
Low Nutrient Low Chlorophyll	2.78	< 0.08	0.03 ± 0.00	1.79 ± 0.05	0.68
High Nitrate - Low Silicate - Low Chl	26.70	7.76 ± 1.38	0.66 ± 0.01	0.99 ± 0.00	0.39
Naturally fertilized Kerguelen plateau	54.42	20.6 ± 0.77	1.02 ± 0.08	1.36 ± 0.03	0.36 ± 0.13
High Nutrient Low Chlorophyll	7.24	22.49 ± 4.77	1.44 ± 0.05	16.67 ± 0.15	0.27 ± 0.02

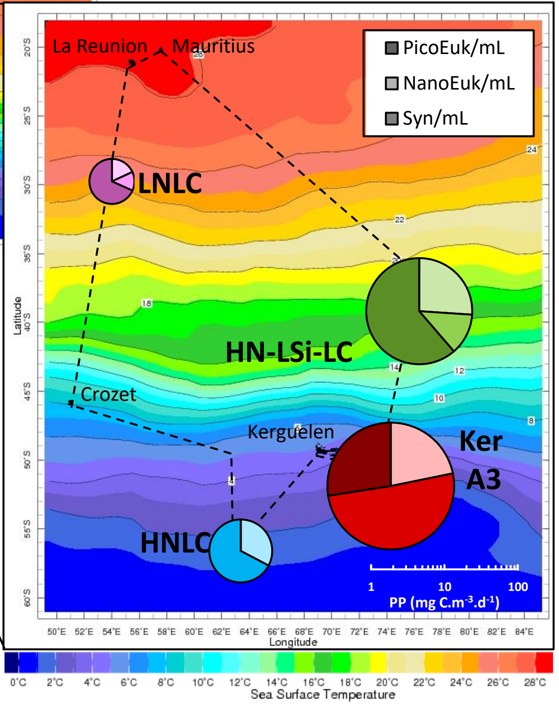


OISO29 cruise route and the **location of the 4 study sites** on **January 2019 Sea Surface Temperature.** Map adapted from Reynolds and Smith OISST version 2 sea surface temperature dataset, NOAA, IRI.

The diagrams represent the 0.2-20µm **phytoplankton composition.** Size (log scale) indicates the importance of **primary production** in the area

Composition of the 0.2-20µm phytoplankton community

Microphytoplankton cells (20-200µm) are not included in the dataset



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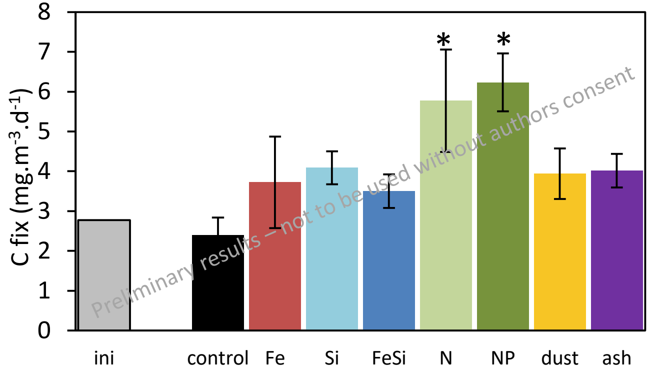
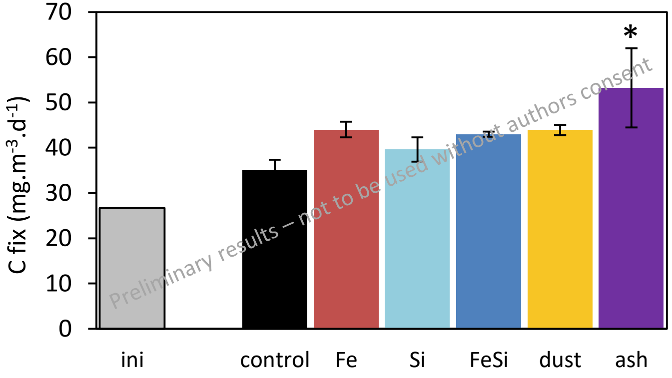
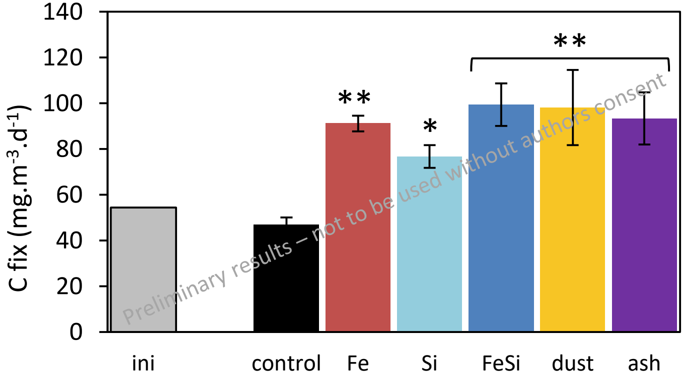
Low Nutrient - Low Chlorophyll (LNLC)



High Nitrate - Low Silicate - Low Chl (HN-LSi-LC)



Naturally fertilized Kerguelen plateau (Ker A3)



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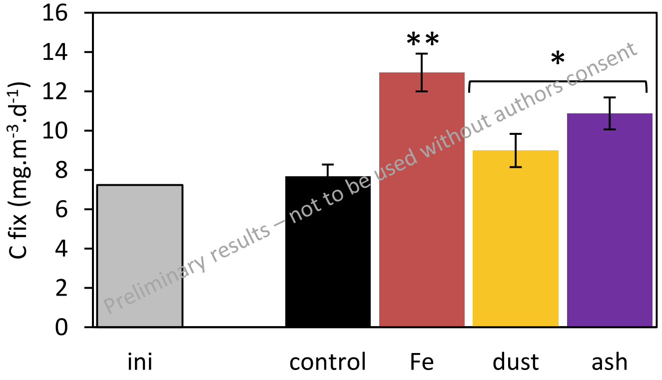

ANOVA followed by a Tukey HSD test (p-val <0.05)

- In most tested biogeochemical areas, a representative dry deposition of desert dust and volcanic ash triggered an **increase of primary production** ($mg.m^{-3}.d^{-1}$)
- The deposition of natural aerosols can represent an important source of new nutrients to remote areas of the ocean.

For more detailed information about the biological response of different phytoplankton groups, please refer to the longer version of this presentation

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EGU2020 – extended version

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Natural aerosols

	Desert dust	Volcanic ash
Ocean deposition ($Tg.year^{-1}$)	450 (global), 10,3 (Austral) [1]	128-221 (Pacific) [2]
Dissolution in sea water (1 hour)	Fe: 20-200 $nmol.g^{-1}$ [3] Si: 1.1-12.17 $\mu mol.g^{-1}$ [4] N: 0.2-7.0 $\mu mol.g^{-1}$ P: 0.65-5.0 $\mu mol.g^{-1}$ [5, 6]	Fe: 10-340 $nmol.g^{-1}$ [3] Si: 0.03-2.06 $\mu mol.g^{-1}$ [3, 4] N: 35-855 $nmol.g^{-1}$ [3] P: 0.01-0.97 $\mu mol.g^{-1}$ [3]

Representative deposition events :

→ An average Saharan **dust event** corresponds to 10 $g.m^{-2}$ to the surface waters of the Mediterranean Sea [7]. Assuming a mixed layer of 30m, this corresponds to a particle charge of 0.3 $mg.L^{-1}$. In our study, we chose a high but still realistic particle charge of **2 $mg.L^{-1}$**.

→ Deposition range of **volcanic ash** are highly variable. Millimeter thick ash layers deposited to the sea surface are common range for the open ocean cited by the literature [8], inducing an ash load of over 250 $g.m^{-2}$, resulting in a particle charge of over 50$mg.L^{-1}$.
In our experiment in the remote area of the Southern Ocean, **25$mg.L^{-1}$** were chosen.

Objective of the study : quantify the response of natural phytoplankton communities to a realistic dry deposition event of desert dust and volcanic ash through primary production and cell abundance

[1] Jickells *et al.*, 2005
[2] Olgun et al., 2010
[3] Olgun *et al.*, 2013
[4] Geisen *et al.*, 2019
[5] Louis *et al.*, 2015
[6] Ridame *et al.*, 2002
[7] Guieu *et al.*, 2010
[8] Duggen *et al.*, 2010

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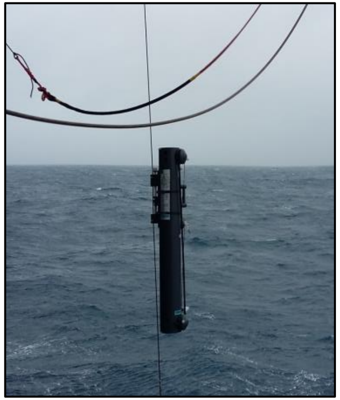
Experimental setup



- **trace metal clean conditions**
  Go-Flo sample bottles, Kevlar wire, laminar flow hoods, acid washed material

- **sub-surface water sampling** at 10 meter depth to ensure
  - the presence of **phytoplankton** (euphotic zone)
  - **no metal contamination** by the ship crossing

- **Experimental protocol**
  - Addition of representative particle charges
    - **Desert dust** : 2mg.L^{-1} **Patagonia**, Argentina
    - **Volcanic ash** : 25mg.L^{-1} **Eyjafjallajökull**, Iceland
    - Control without experimental addition
    - Mono and multiple nutrient addition
      2nmol.L^{-1} **dFe**, 2µmol.L^{-1} **dSi**, 2µmol.L^{-1} **DIN**, 0.2µmol.L^{-1} **DIP**

- **Incubation for 48h**
  with a 10m **luminosity** filter
  Continuous surface water flow for constant local **temperature conditions**

- Cell abundances were analyzed by **Flow cytometry** and primary production using the **^{13}C-labeling technique (IRMS)**

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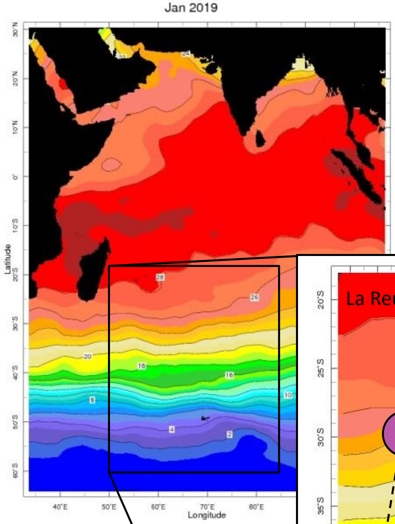

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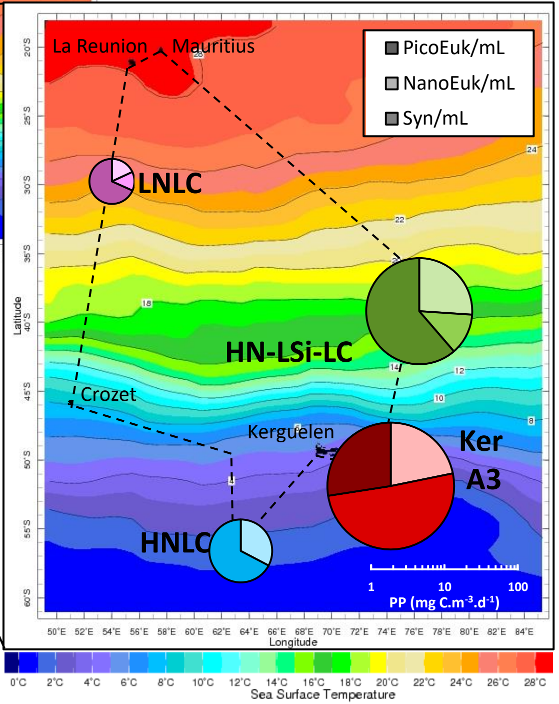
Composition of the 0.2-20µm phytoplankton community

Microphytoplankton cells (20-200µm) are not included in the dataset



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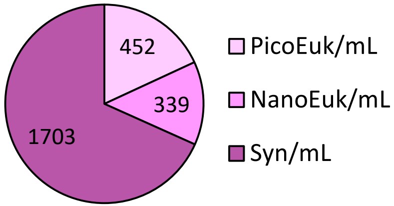
Low Nutrient - Low Chlorophyll (LNLC)

29°58'S / 54°06'E
SST : 24.63°C

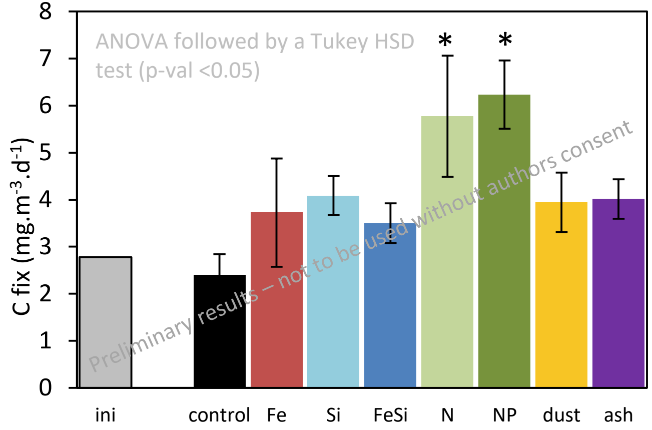
Initial conditions

NOx : < 0.08 µmol.L^{-1}
DIP : 0.03 ± 0.00 µmol.L^{-1}
dSi : 1.79 ± 0.05 µmol.L^{-1}
dFe : 0.68 nmol.L^{-1}

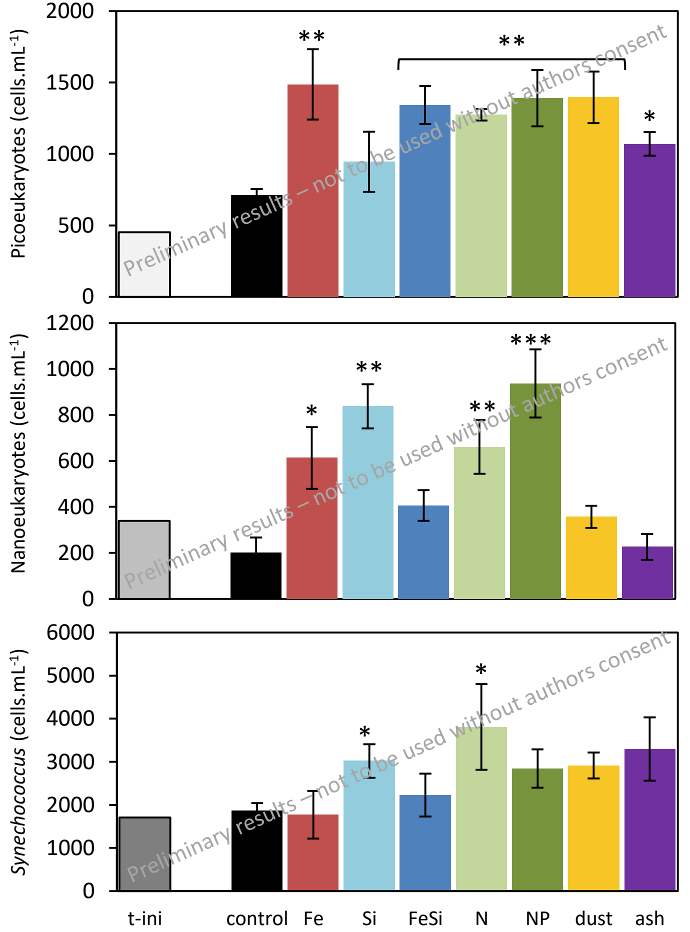


The 0.2-20µm phytoplankton community is dominated by ***Synechococcus*** cyanobacteria

Biological response



- Primary production (PP) was triggered by **nitrogen** addition. Dust or ash had no significant effect.
- All tested phytoplankton types responded to **N addition**, but also to **ash** (picoeukaryotes), **Fe** (pico/nanoeukaryotes), **Si** (Nano/Synechococcus).



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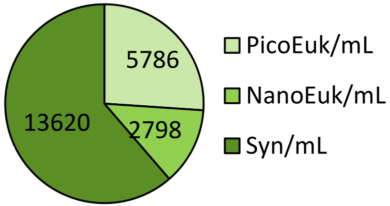
High Nitrate - Low Silicate - Low Chl (HN-LSi-LC)

42°29'S / 74°54'E
SST : 12.18°C

Initial conditions

NOx : 7.76 ± 1.38 µmol.L^{-1}
DIP : 0.66 ± 0.01 µmol.L^{-1}
dSi : 0.99 ± 0.00 µmol.L^{-1}
dFe : 0.39 nmol.L^{-1}



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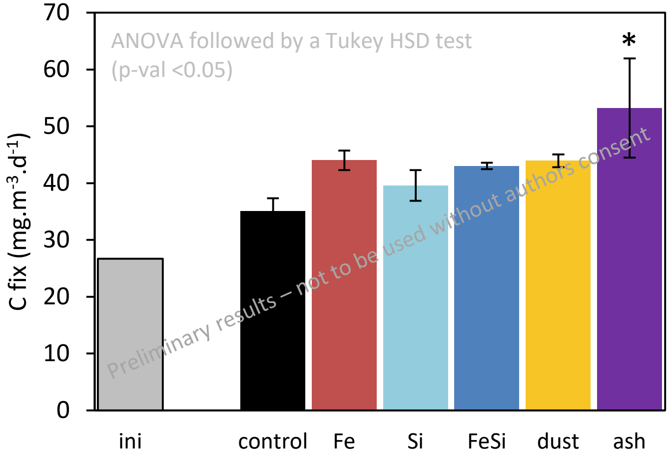
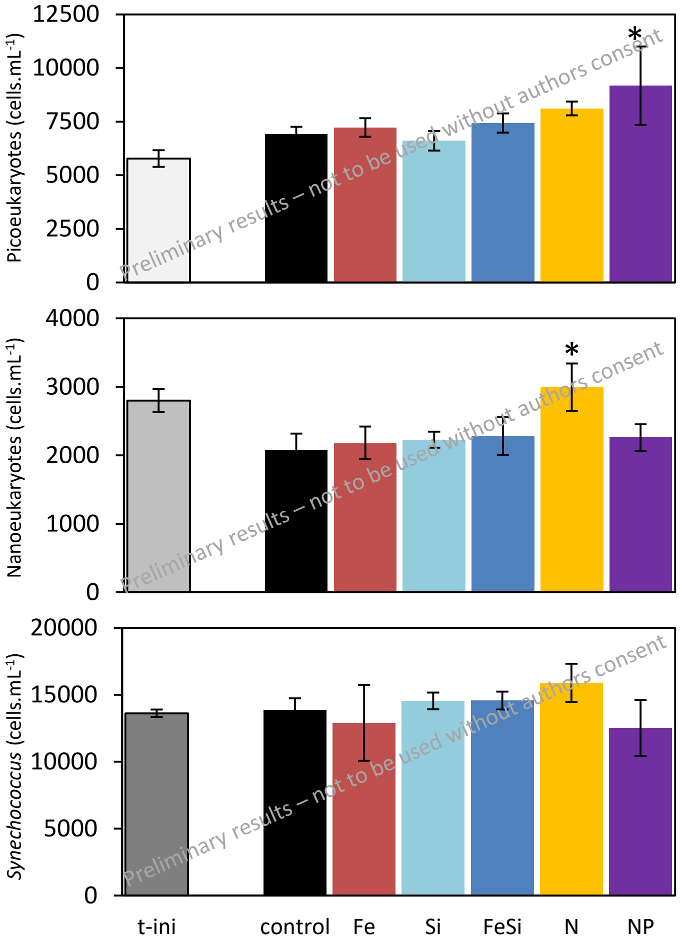
Biological response



- PP was triggered by ash addition.
- Ash stimulated picoeukaryote growth, whereas dust stimulated nanoeukaryote development. No significant effect on *Synechococcus* was recorded.



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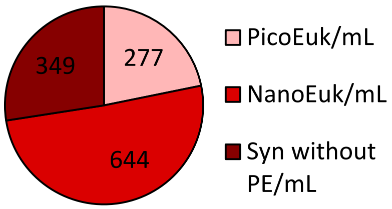
Naturally fertilized Kerguelen plateau (Ker A3)

50°38’S / 72°02’E
SST : 4.35°C

Initial conditions

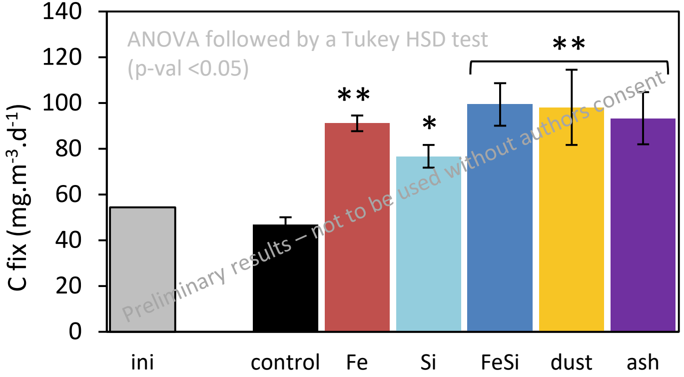
NOx : 20.6 ± 0.77 µmol.L^{-1}
DIP : 1.02 ± 0.08 µmol.L^{-1}
dSi : 1.36 ± 0.03 µmol.L^{-1}
dFe : 0.36 ± 0.13 nmol.L^{-1}
End of spring bloom



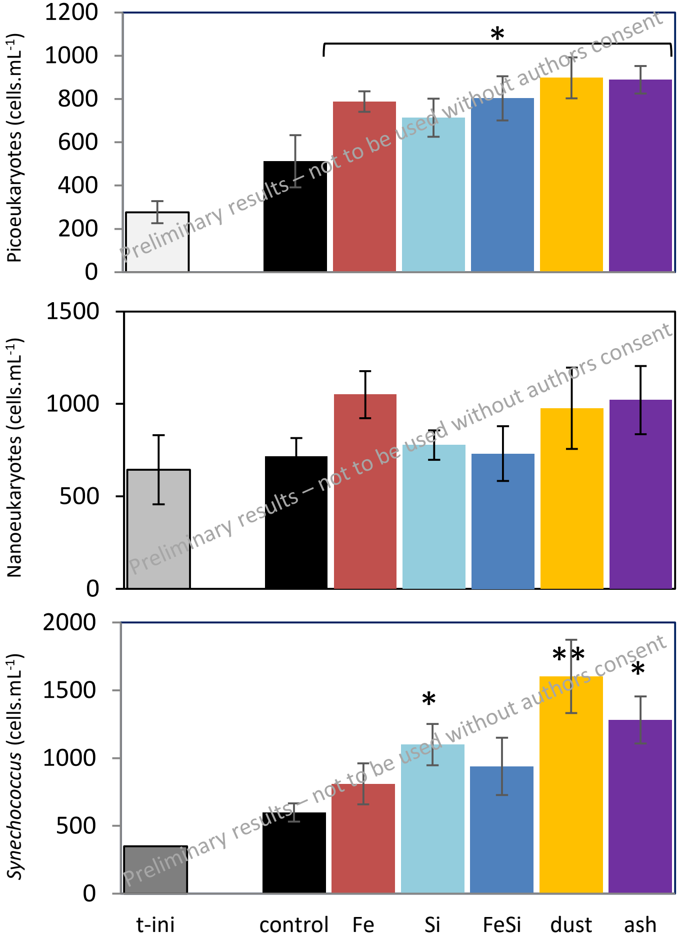
The 0.2-20µm phytoplankton community is dominated by **nanoeukaryotes**

Microphytoplankton cells are not included in this dataset, but it is known that diatoms represent 70-98% of the biomass at this station [(2)]

Biological response



- PP was triggered by aerosol and nutrient addition.
- Picoeuk growth was stimulated by all tested treatments, whereas no significant impact was visible for nanoeuk
- *Synechococcus* increased most after dust deposition. It is to be highlighted that the local population had no phyco-erythrin (PE) signature, which could be an acclimation to cold water [(1)]
- **Preliminary diatom data indicate response to Fe, which could explain the majority of the biological response [(2)]**



[(1)] Pittera *et al.*, 2014 [(2)] Sarthou *et al.*, 2008

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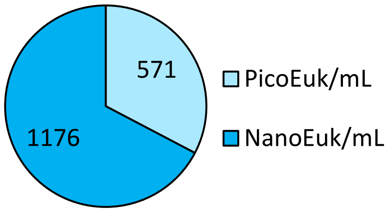
High Nutrient - Low Chlorophyll (HNLC)

56°30'S / 62°59'E
SST : 2.15°C

Initial conditions

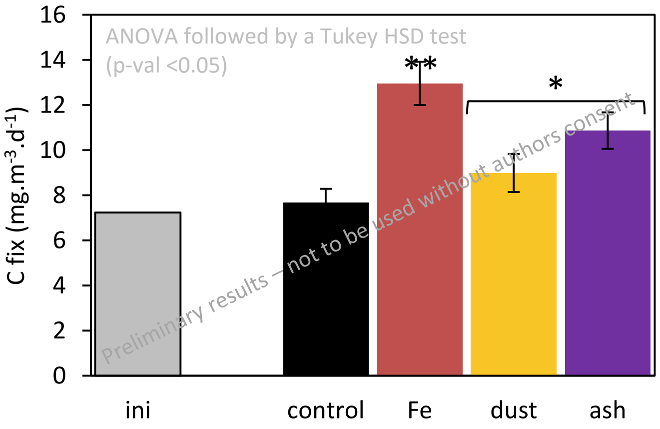
NOx : 22.49 ± 4.77 µmol.L^{-1}
DIP : 1.44 ± 0.05 µmol.L^{-1}
dSi : 16.67 ± 0.15 µmol.L^{-1}
dFe : 0.27 ± 0.02 nmol.L^{-1}



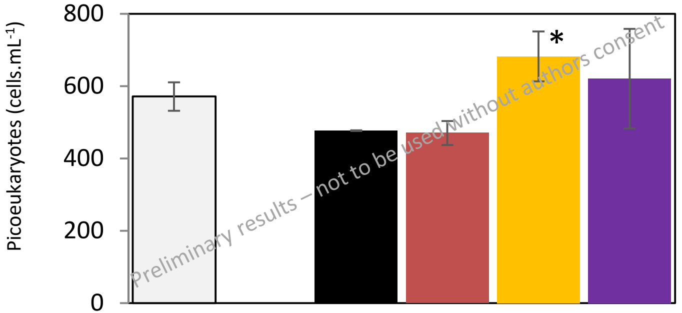
The 0.2-20µm phytoplankton community is dominated by **nanoeukaryotes**

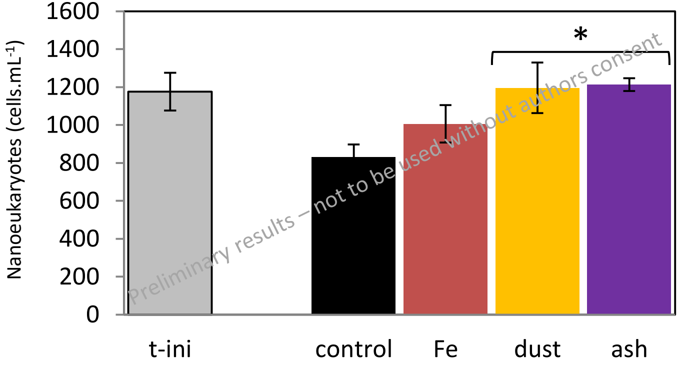
Microphytoplankton cells are not included in this dataset

Biological response



- PP was triggered by aerosol and iron addition.
- Picoeukaryote growth is stimulated by dust addition, whereas nanoeukaryotes increase growth at both dust and ash addition.
- **The increase of PP at the Fe enrichment are most probably to be explained by diatom response**
  (data not yet available)





Absence of *Synechococcus* cyanobacteria at a surface water temperature of 2.15°C

Discussion

- **The deposition of natural aerosols can represent an important source of new nutrients to remote areas of the ocean [1,2].**

- **In the Fe-(co)limited areas of the Southern Ocean, a representative dry deposition of desert dust and volcanic ash triggered an increase of primary production. In the N-limited LNLC area, aerosol deposition did not cause a significant biological response.**

- One aim of this study was to compare the response of different types of phytoplankton to an addition of desert dust and volcanic ash. To date, data concerning diatoms are not yet finalized, but preliminary results (not shown) indicate that **iron addition increased Si uptake** at the reference Kerguelen station A3, known to be diatom rich [3].

- The low dSi concentration of 1.36µmol.L^{-1} indicates the end of the Kerguelen plateau spring bloom. Earlier in the season, dSi concentrations reach 16µmol.L^{-1} [4]. **At this late point of the bloom season, a new nutrient input is most likely to stimulate biological activity [5].**

- Surprisingly, Si addition stimulated *Synechococcus* growth in 2 of the 4 stations (LNLC and Ker bloom A3).

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[1] Jickells *et al.*, 2005 [2] Mahohwald *et al.*, 2005 [3] Armand *et al.*, 2008 [4] Closset *et al.*, 2014 [5] Rogan et al., 2016

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Thank you for your attention

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