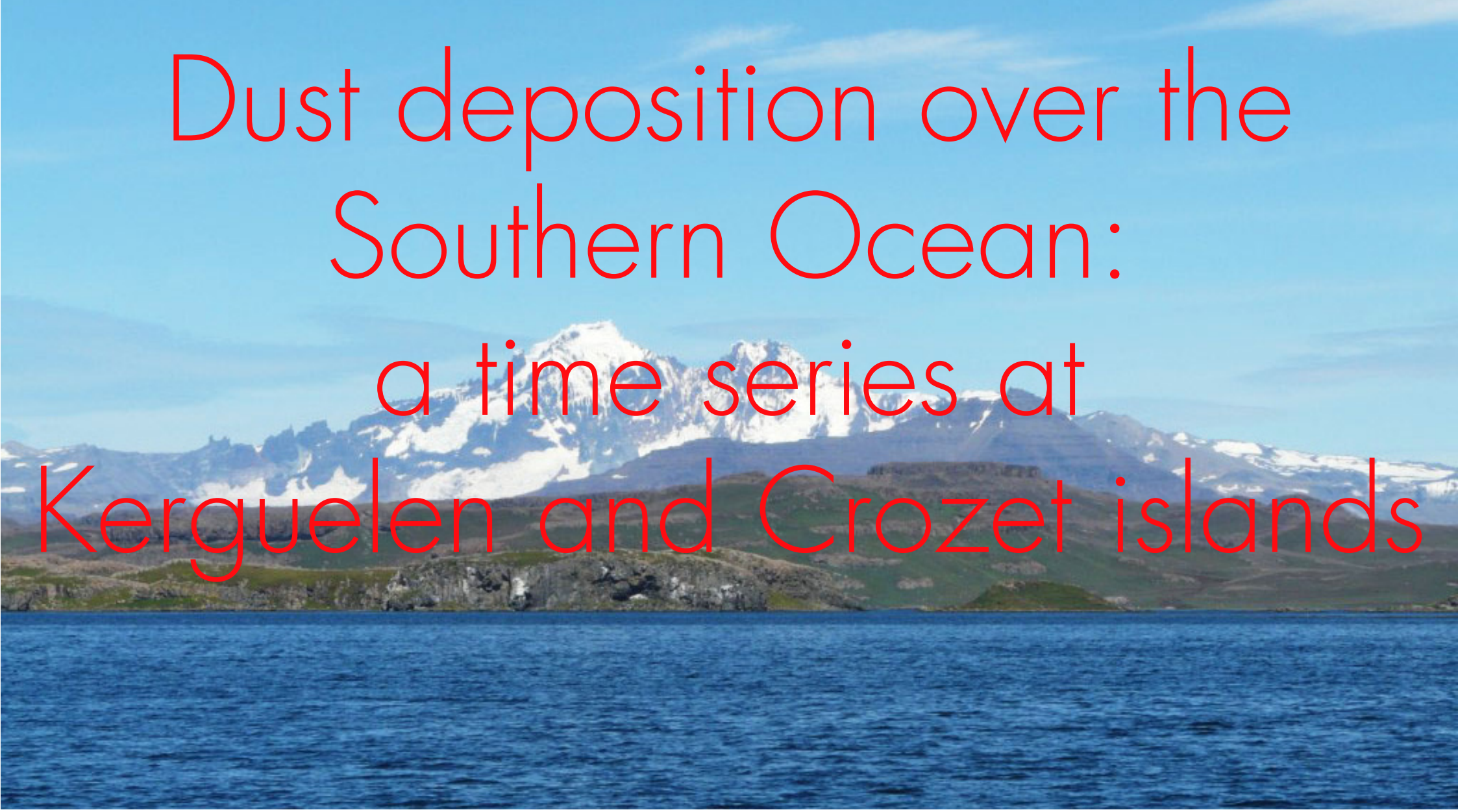
Dust deposition over the Southern Ocean: a time series at Kerguelen and Crozet islands



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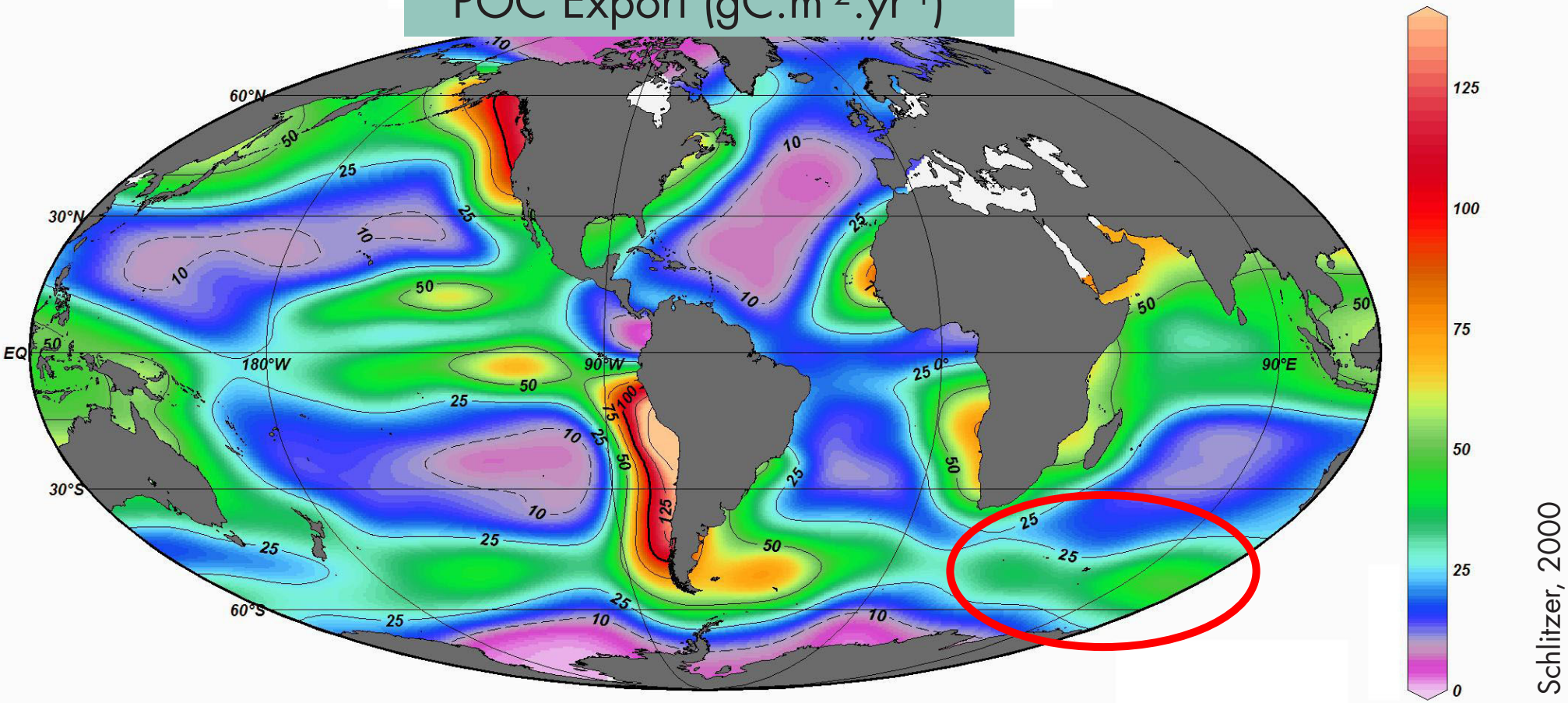
IPEV INSTITUT POLAIRE FRANÇAIS Paul Emile Victor

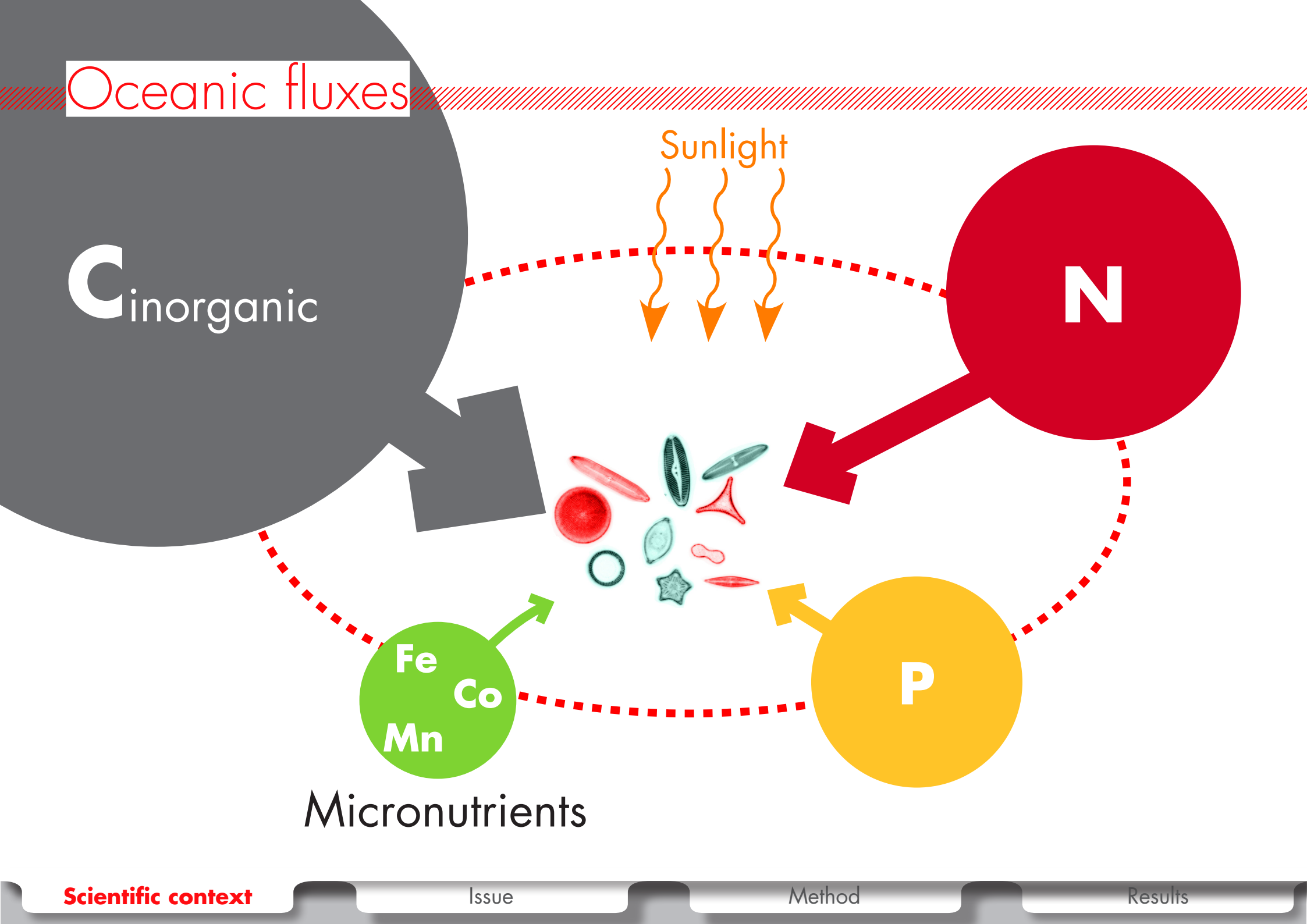

Scientific context

Carbon export in the open ocean

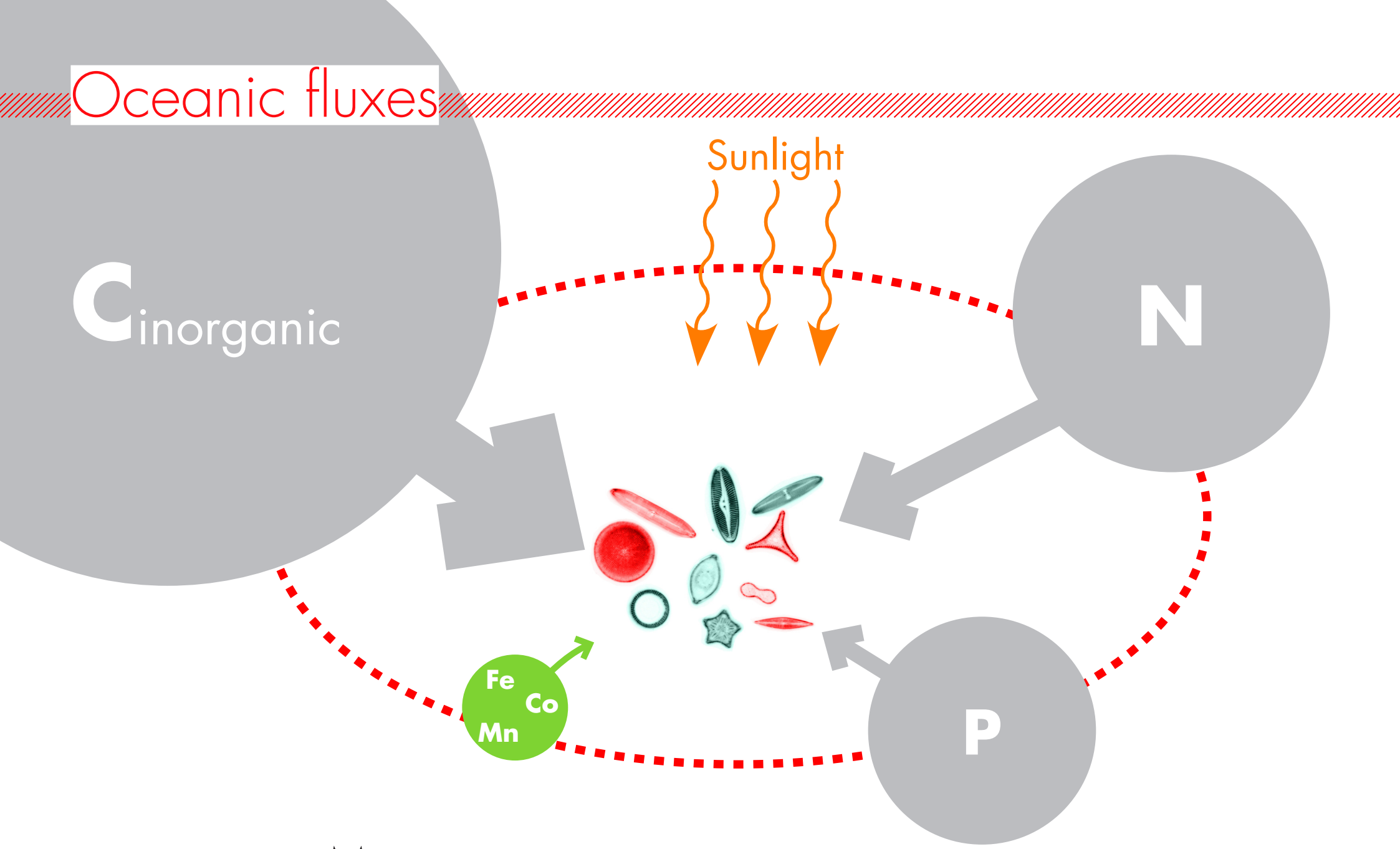


The open ocean is an important sink of carbon
Strong contribution of high southern latitudes

Oceanic fluxes



Oceanic fluxes

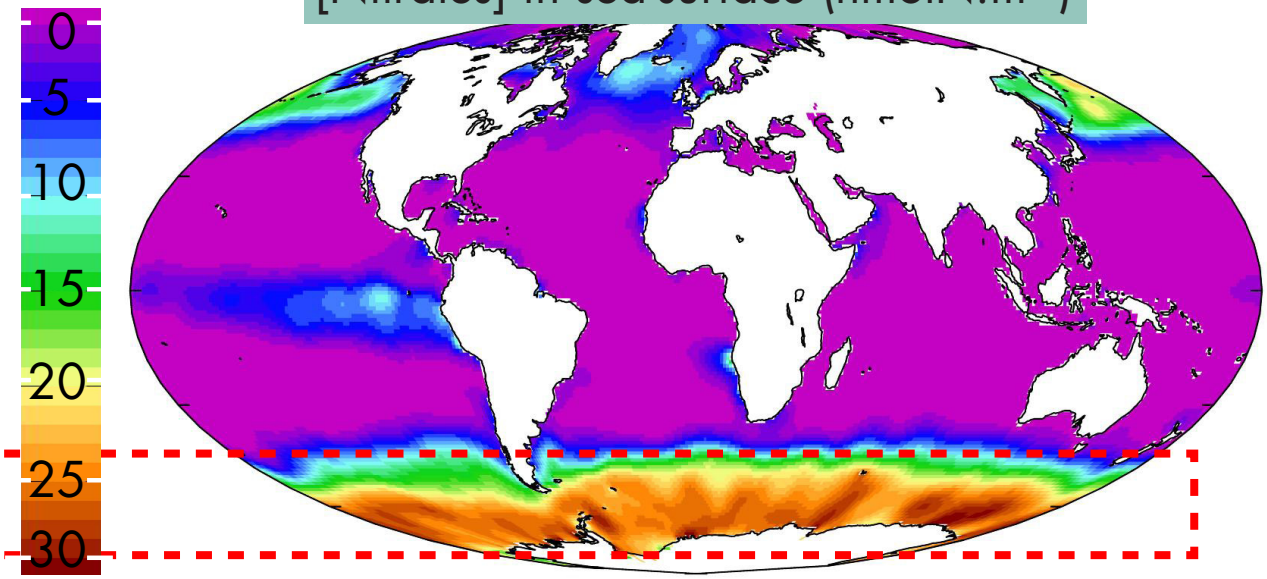


Micronutrients

Southern Ocean: HNLC area

Limited by micronutrients supplies

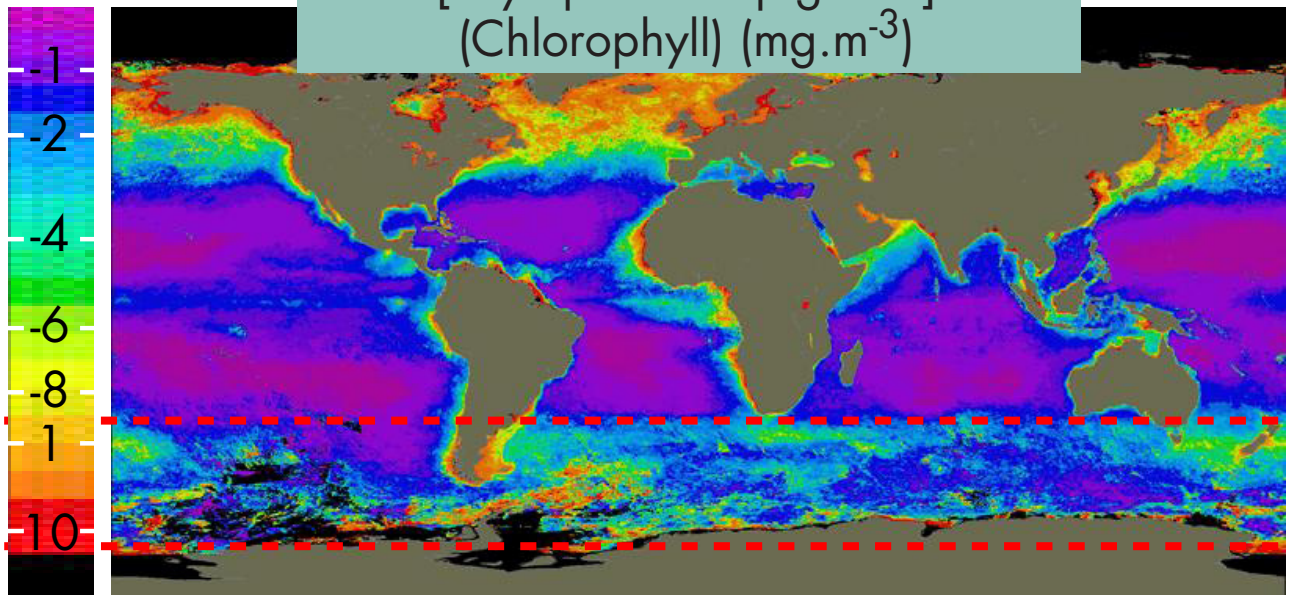
[Nitrates] in sea-surface (nmolN.m^{-3})



NOAA World Ocean Atlas

Lot of macronutrients

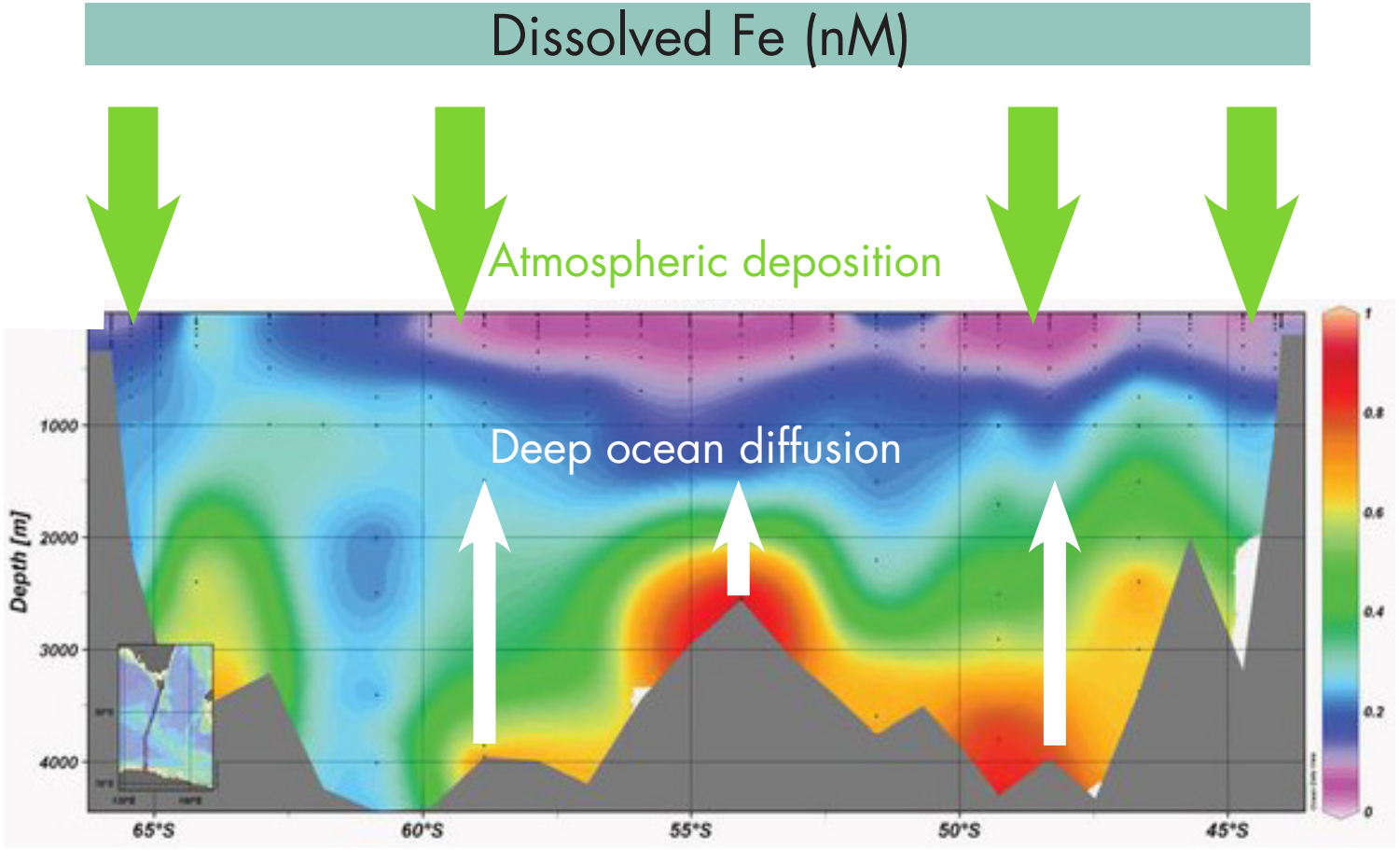
[Phytoplankton pigment] (Chlorophyll) (mg.m^{-3})



NASA/GSFC

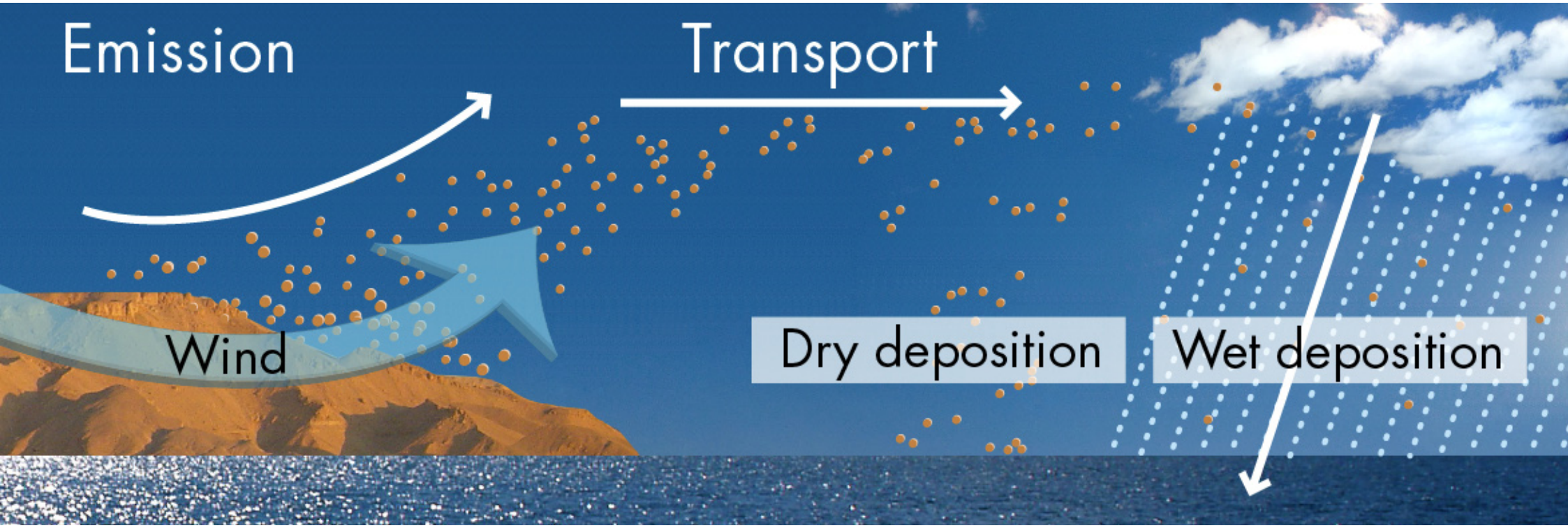
Limited phytoplankton

Micronutrients supply



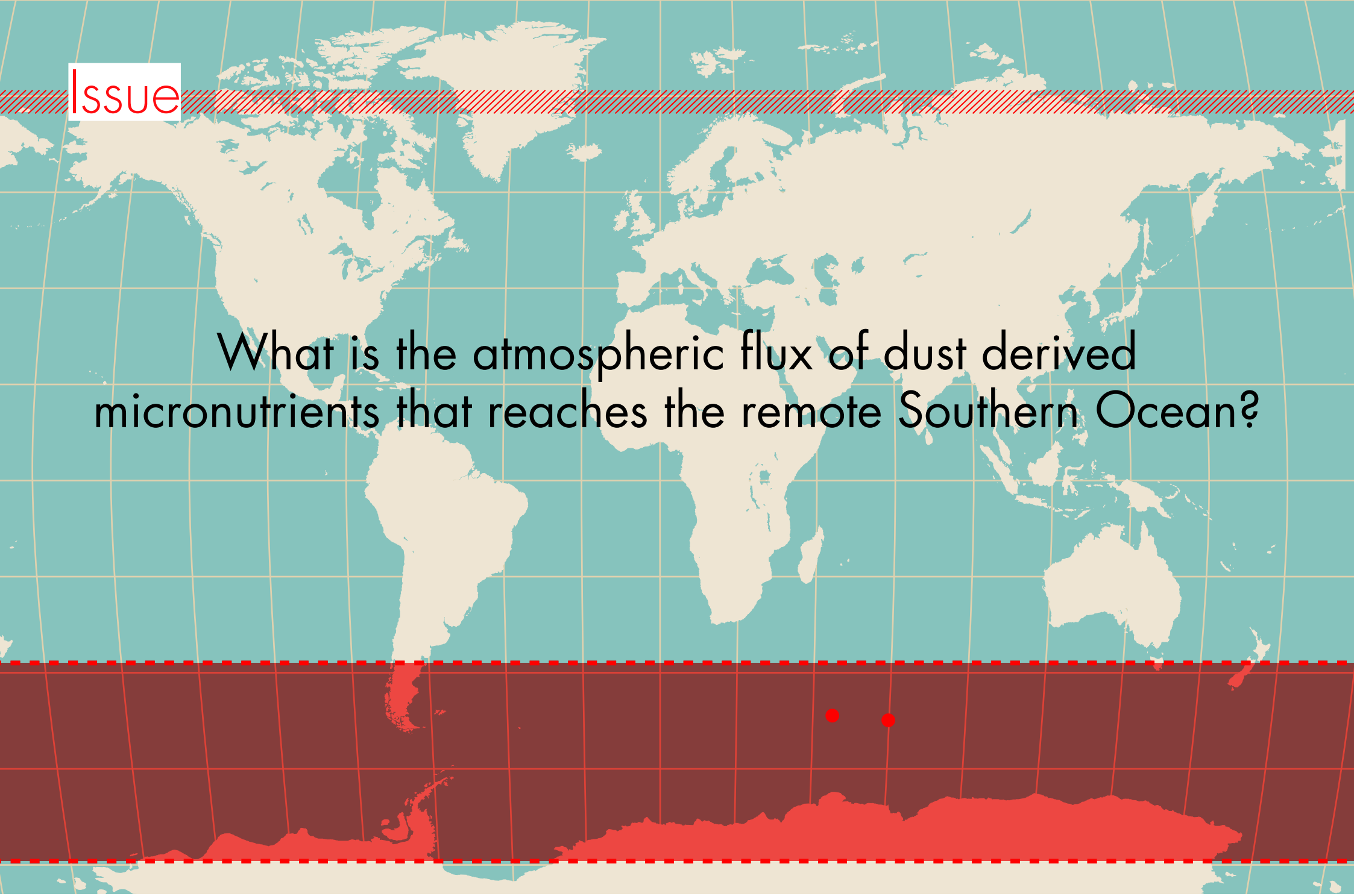
Dust deposition:
major source of micronutrients

Dust cycle




Issue

Issue

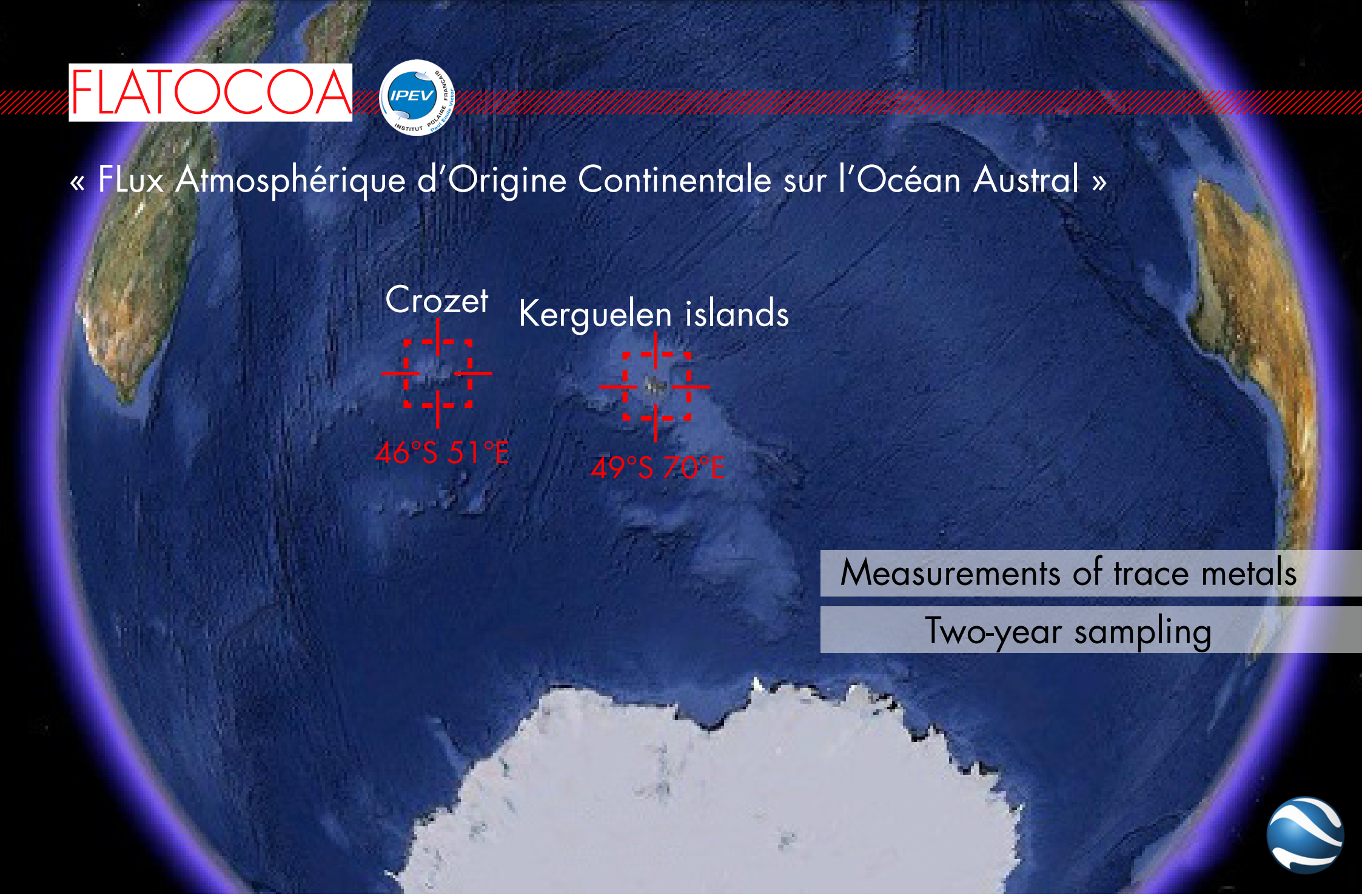


What is the atmospheric flux of dust derived micronutrients that reaches the remote Southern Ocean?


Method

FLATOCOA

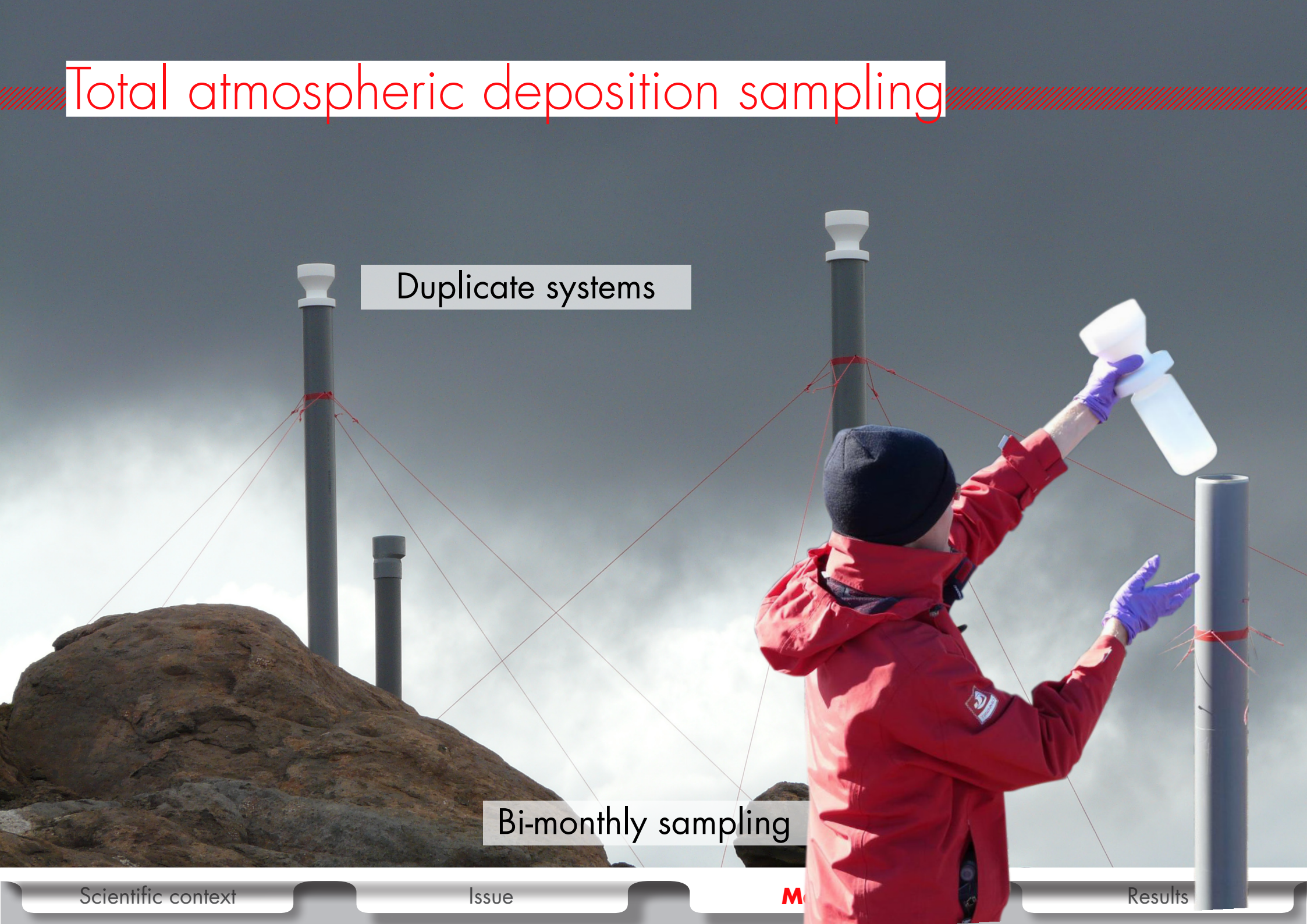
« FLux Atmosphérique d'Origine Continentale sur l'Océan Austral »



Measurements of trace metals

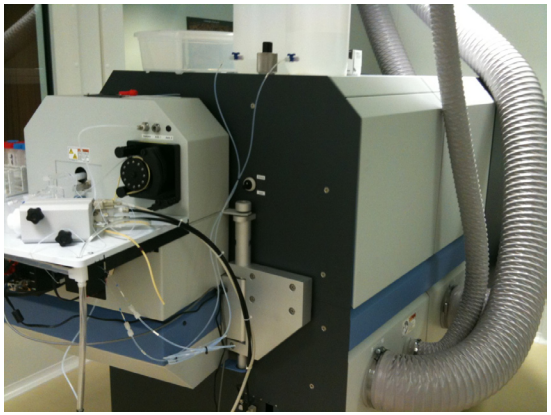
Two-year sampling

Total atmospheric deposition sampling



Analytical techniques

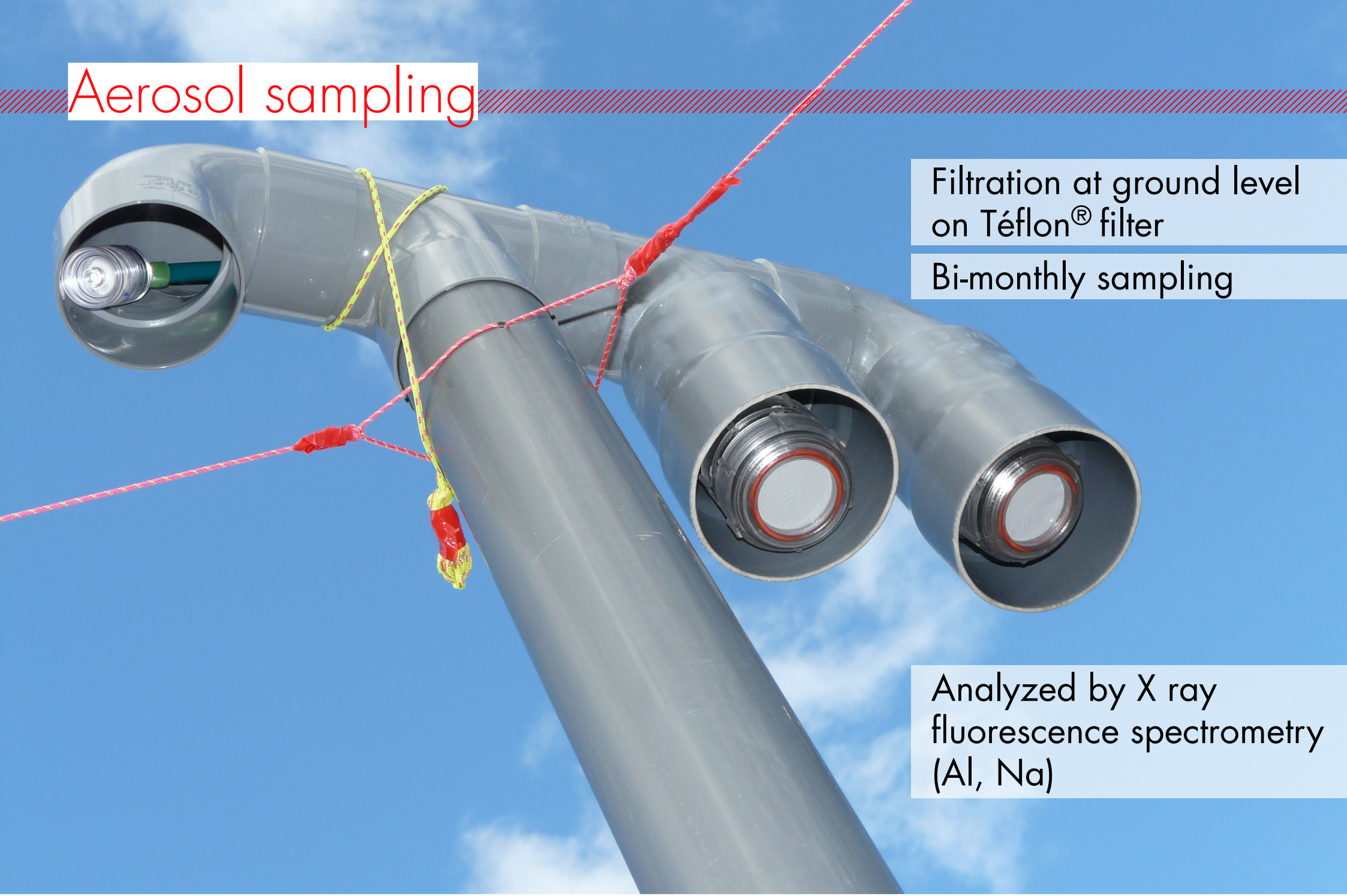
ICP-AES and HR-ICP-MS



hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	ununnium 111 Uuu [272]	unubium 112 Uub [277]		ununquadium 114 Uuq [289]				

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Aerosol sampling



Filtration at ground level on Téflon® filter

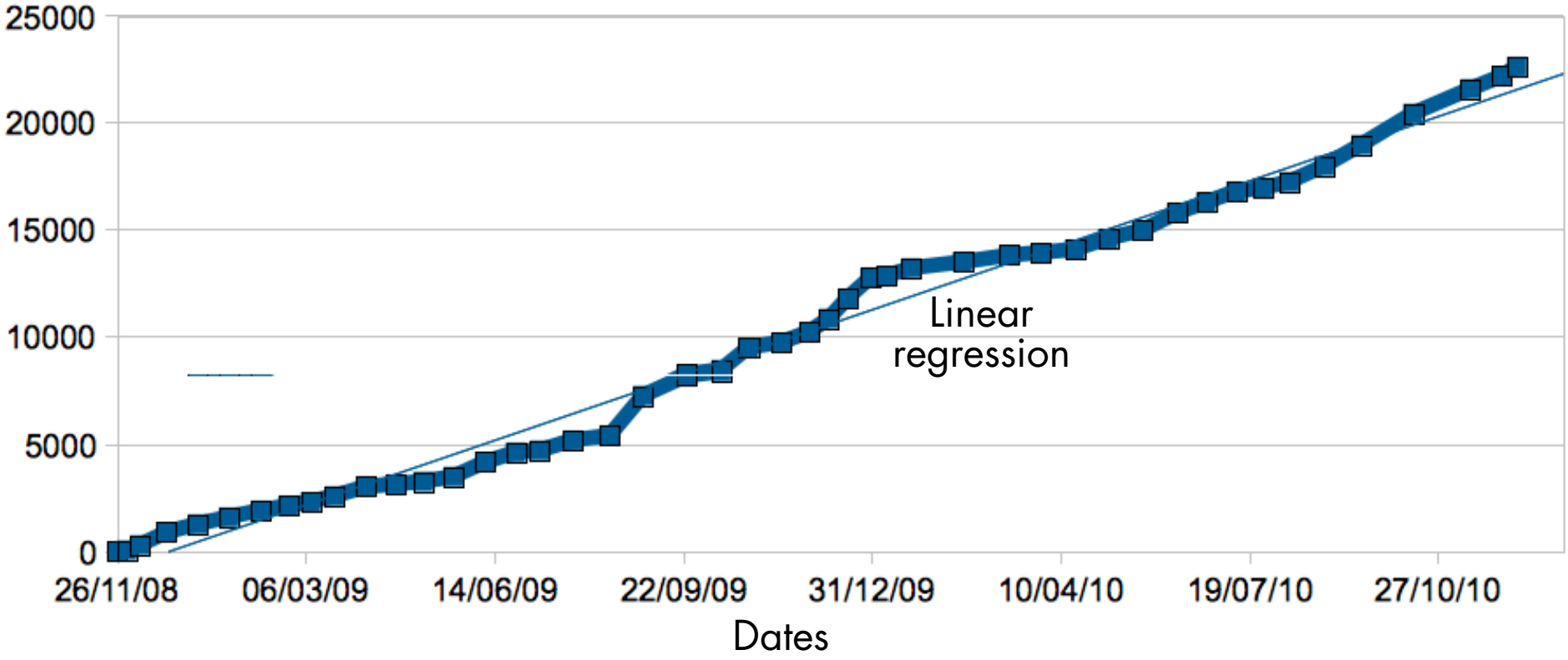
Bi-monthly sampling

Analyzed by X ray fluorescence spectrometry (Al, Na)


Results

Iron total deposition flux

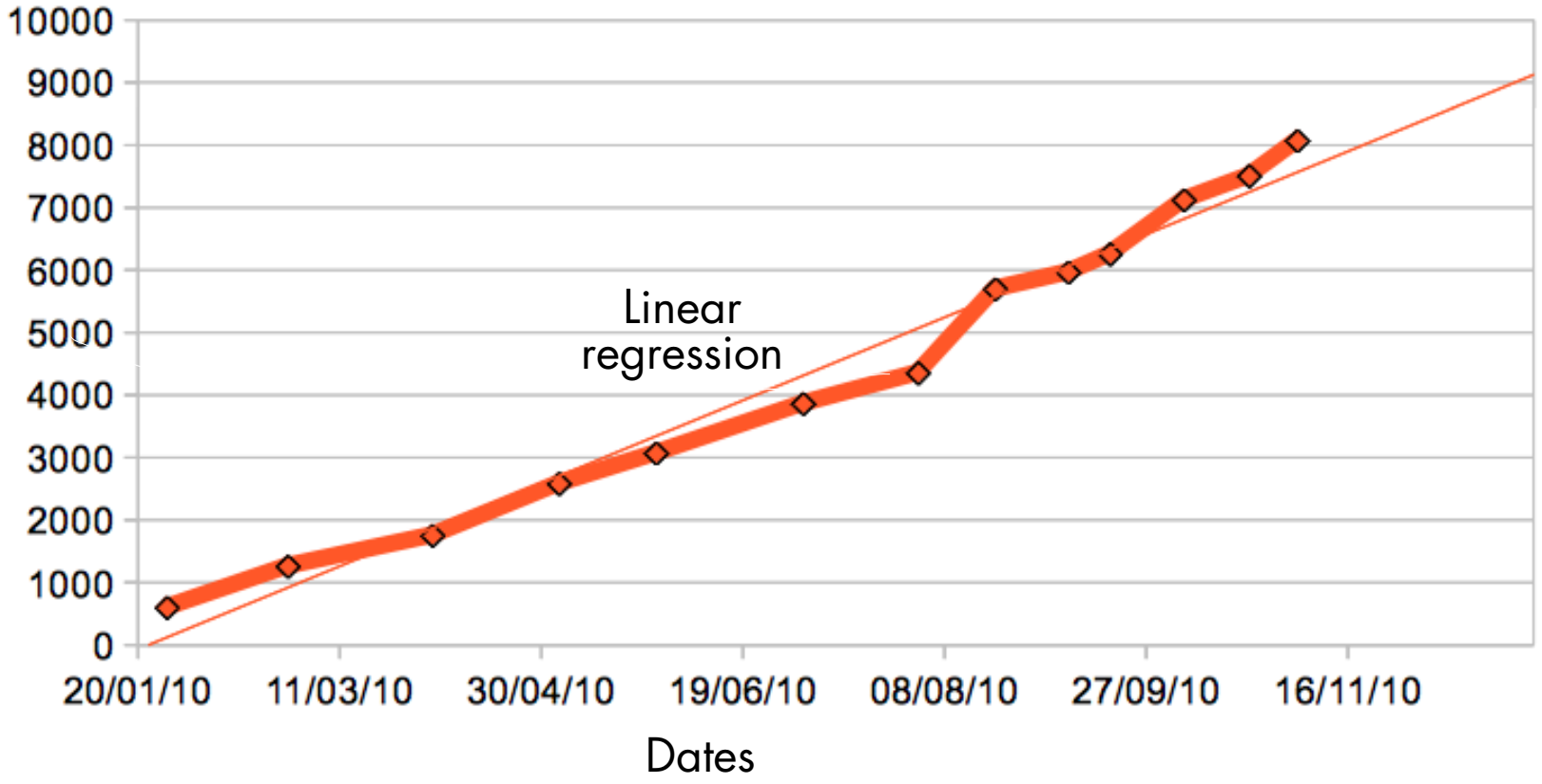
Accumulated iron flux at Kerguelen for 2009-2010 ($nmol.m^{-2}$)



Averaged iron flux at Kerguelen over 2009-2010:
540 $nmol.m^{-2}.d^{-1}$

Iron total deposition flux

Accumulated iron fluxes at Crozet for 2010 (nmol.m^{-2})

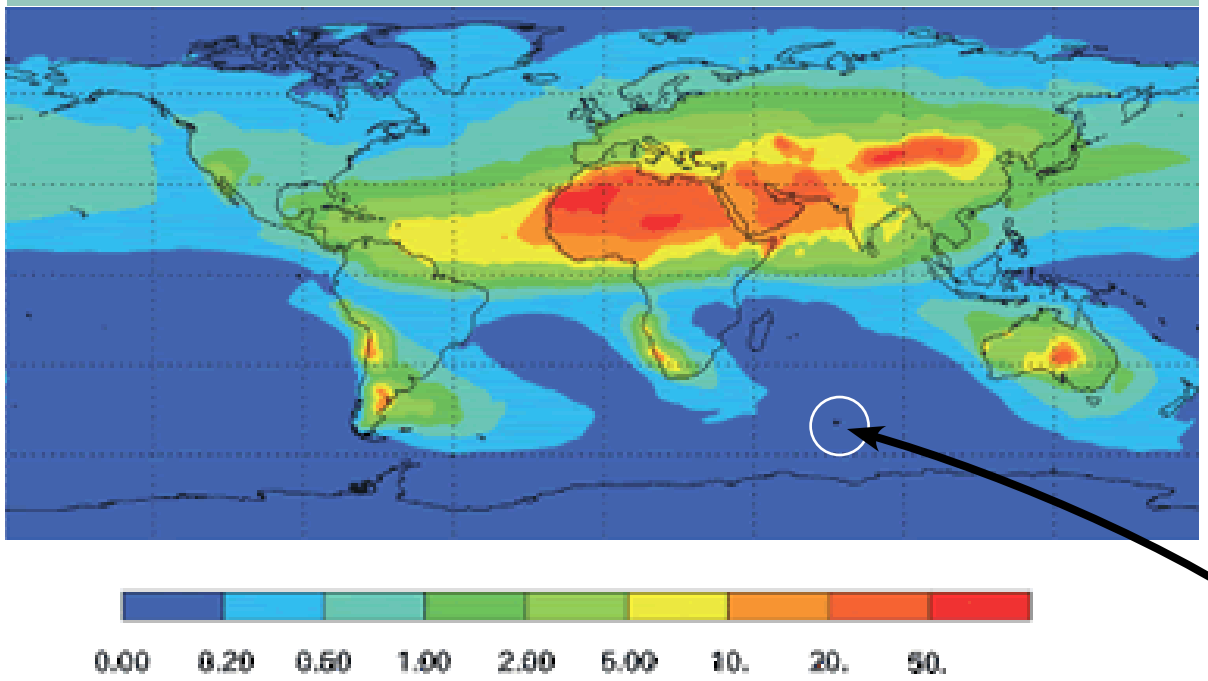


Averaged iron flux at Crozet:
480 nmol.m^{-2}.d^{-1} (Ker: 540 nmol.m^{-2}.d^{-1})

Iron fluxes in literature

From atmospheric dust transport model

Simulated average dust deposition flux ($g.m^{-2}.yr^{-1}$)



Estimated Fe flux (3,5% Taylor & Mc Lennan, 1985):

$< 360\ nmol.m^{-2}.d^{-1}$

(Jickells et al., 2005)

Iron fluxes in literature

Indirect measures

Calculation from:

- measured surface aerosol concentrations at sea level,
- dry deposition velocity,
- scavenging ratio for rain deposition (Luo et al, 2003; et Tegen et al, 2002)

$$F_{total} = F_{dry} + F_{wet}$$

$$F_{dry} = C_{air} \cdot V_{deposition}$$

$$F_{wet} = C_{air} \cdot SR \cdot rainfall$$

15-45 $nmol.m^{-2}.d^{-1}$
(Wagener et al., 2008)

First conclusion

< 360 nmolFe.m^{-2}.d^{-1} $\sim$ 540 nmolFe.m^{-2}.d^{-1}

Slight underestimation of the model

15-45 nmolFe.m^{-2}.d^{-1} $<$ 540 nmolFe.m^{-2}.d^{-1}

Indirect measures inadequate

Iron dry deposition

$$F_{dry\ deposition} = C_{air} \cdot V_{deposition}$$

Dry deposition velocity over the Southern Ocean :

V_d = 1-3 $cm.s^{-1}$ (Ezat and Dulac, 1995; Wagener et al, 2008)

	FLATOCOA	**Wagener et al, 2008**
Air iron concentration ($ng.m^{-3}$) mediane ± SD	1,86 ± 1,75	1,00 ± 0,49
Iron dry deposition ($nmol.m^{-2}.d^{-1}$)	20 - 60	31 ± 11

Second conclusion

	FLATOCOA	Wagener et al, 2008
Air iron concentration ($ng.m^{-3}$) mediane ± SD	1,86 ± 1,75	1,00 ± 0,49
Iron dry deposition ($nmol.m^{-2}.d^{-1}$)	**< 10%**	**> 50 %**

of total deposition

Discrepancy on total deposition comes from wet deposition

Iron wet deposition

$$F_{wet\ deposition} = C_{air} \cdot SR \cdot rainfall$$

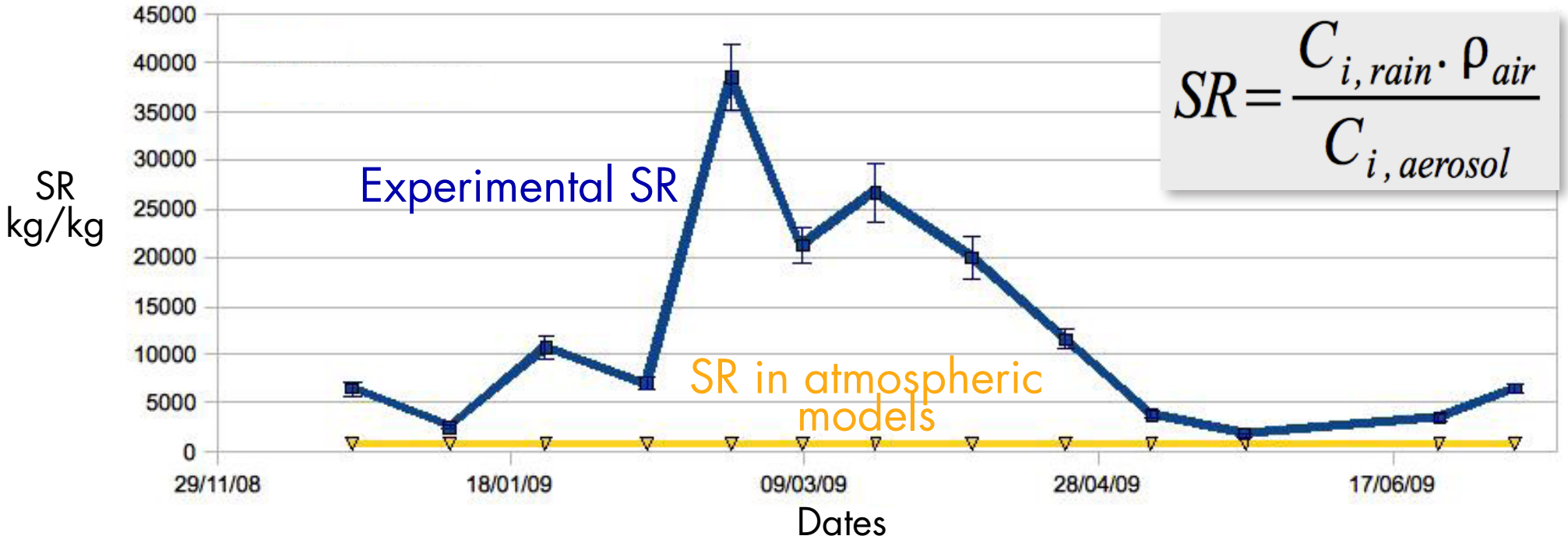
	FLATOCOA	Wagener et al, 2008
Air iron concentration ($ng.m^{-3}$) mediane ± SD	1,86 ± 1,75	1,00 ± 0,49
Rainfall ($mm.d^{-1}$)	2 – 3	3,1 ± 0,3

Not applicable : scavenging ratio

$$SR = \frac{C_{i,rain} \cdot \rho_{air}}{C_{i,aerosol}}$$

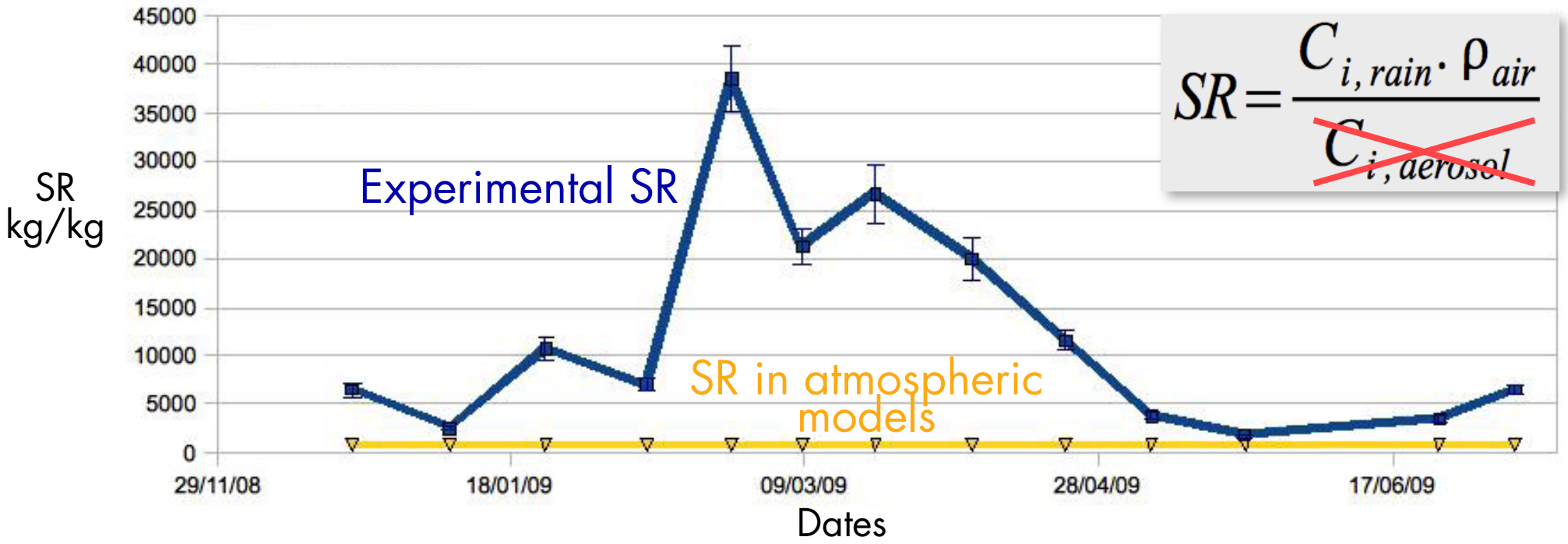
Scavenging ratio

Scavenging ratio of atmospheric dust



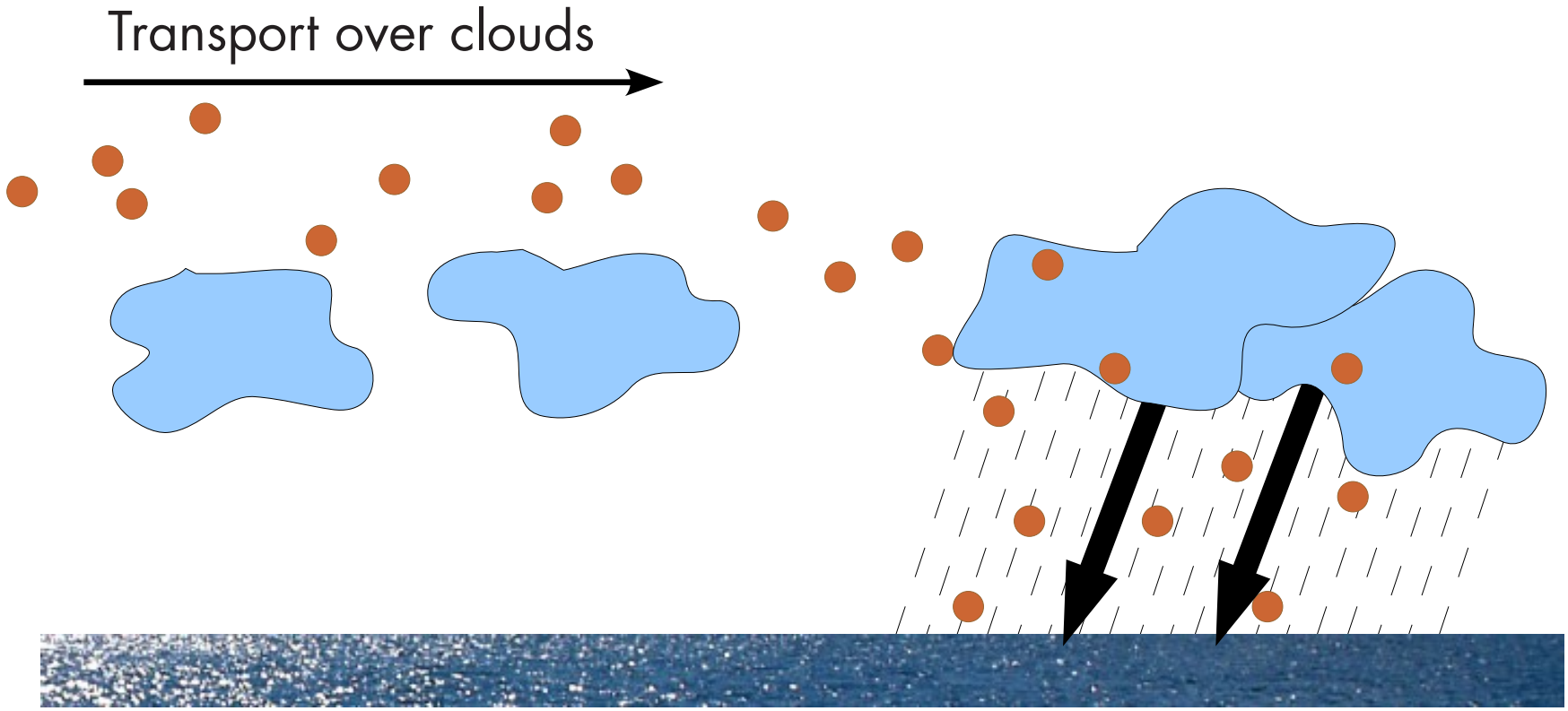
Scavenging ratio

Scavenging ratio of atmospheric dust



Strong dust gradient from ground to high altitude
Flux controlled by dust amounts at altitude
Deposition area

Probable dust transport and deposition behaviour



Scavenged by rain much faster than mixed in the boundary layer

Significantly effective mechanism

Conclusion

- First direct validated measurements of atmospheric deposition over the Southern Ocean:
  Kerguelen: **540 nmolFe.m^{-2}.d^{-1}**
  Crozet : **490 nmolFe.m^{-2}.d^{-1}**
  Low gradient of atmospheric flux between Kerguelen and Crozet islands: **possible extrapolation over a large area.**

- **Atmospheric models** seem **slightly underestimated** fluxes over the Southern Ocean.

- **Indirect measures** (scavenging ratio, aerosol concentration at groung level) **underestimate strongly** dust depostion: aerosols near the surface is not representative of the atmospheric column.

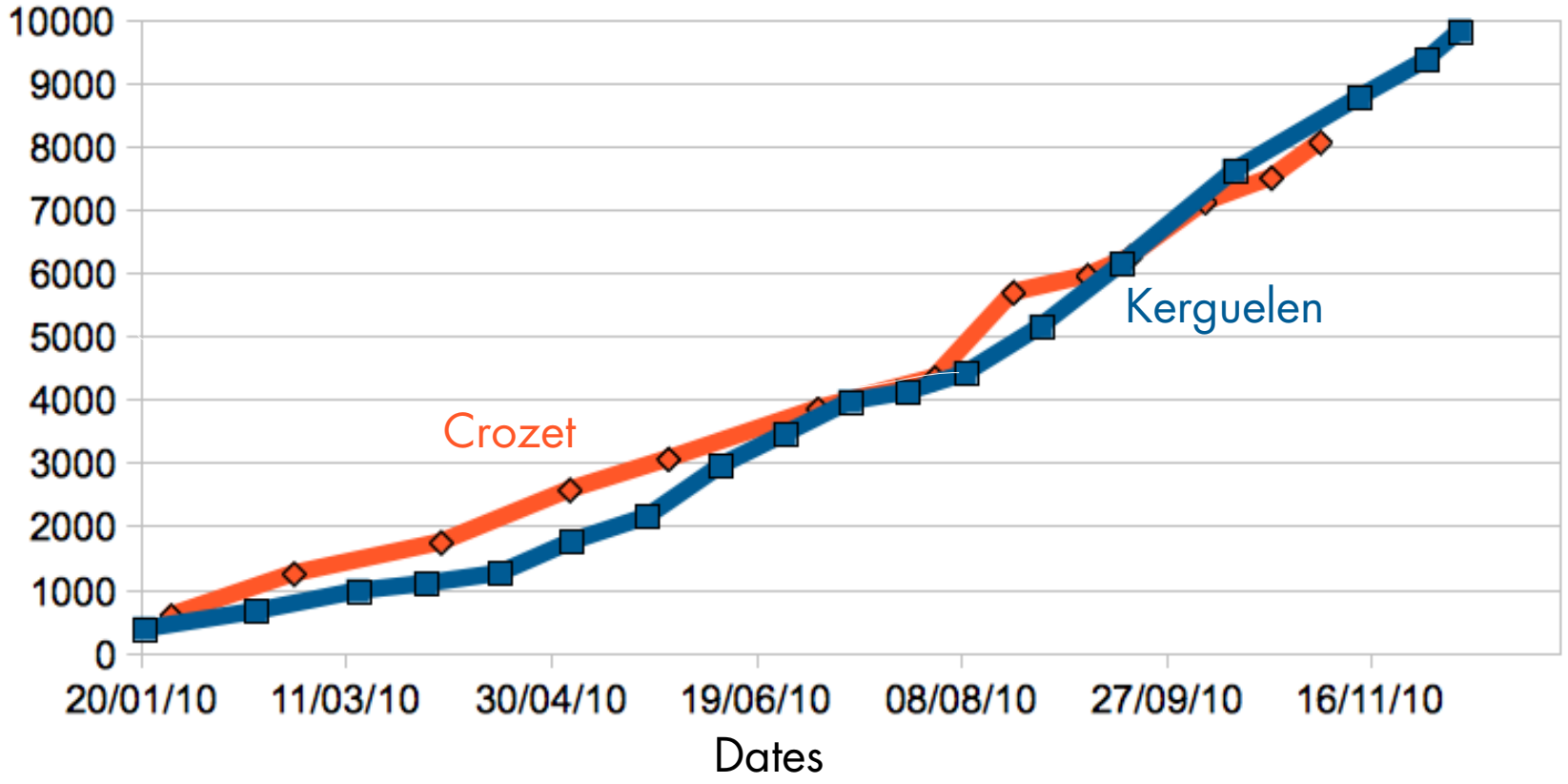
To complete the job...

- **Prospective:**
  Global dust transport and deposition validated data over the Southern Ocean including solubility of iron et al. .

- **Requiered:**
  - Solubility in Kerguelen rain water,
  - Uncertainty of measured deposition using duplicate sampling and variability on the both sites,
  - Source region investigation: Patagonia,
  - Very long transport using CO satellite data as continetal air masses tracker
  - Tuning a global dust model.

Iron total deposition flux

Accumulated iron fluxes at Kerguelen and Crozet for 2010 (nmol.m^{-2})



Averaged iron flux at Crozet:
480 nmol.m^{-2}.d^{-1}