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How large is nitrate turbulent diffusion into the euphotic zone?

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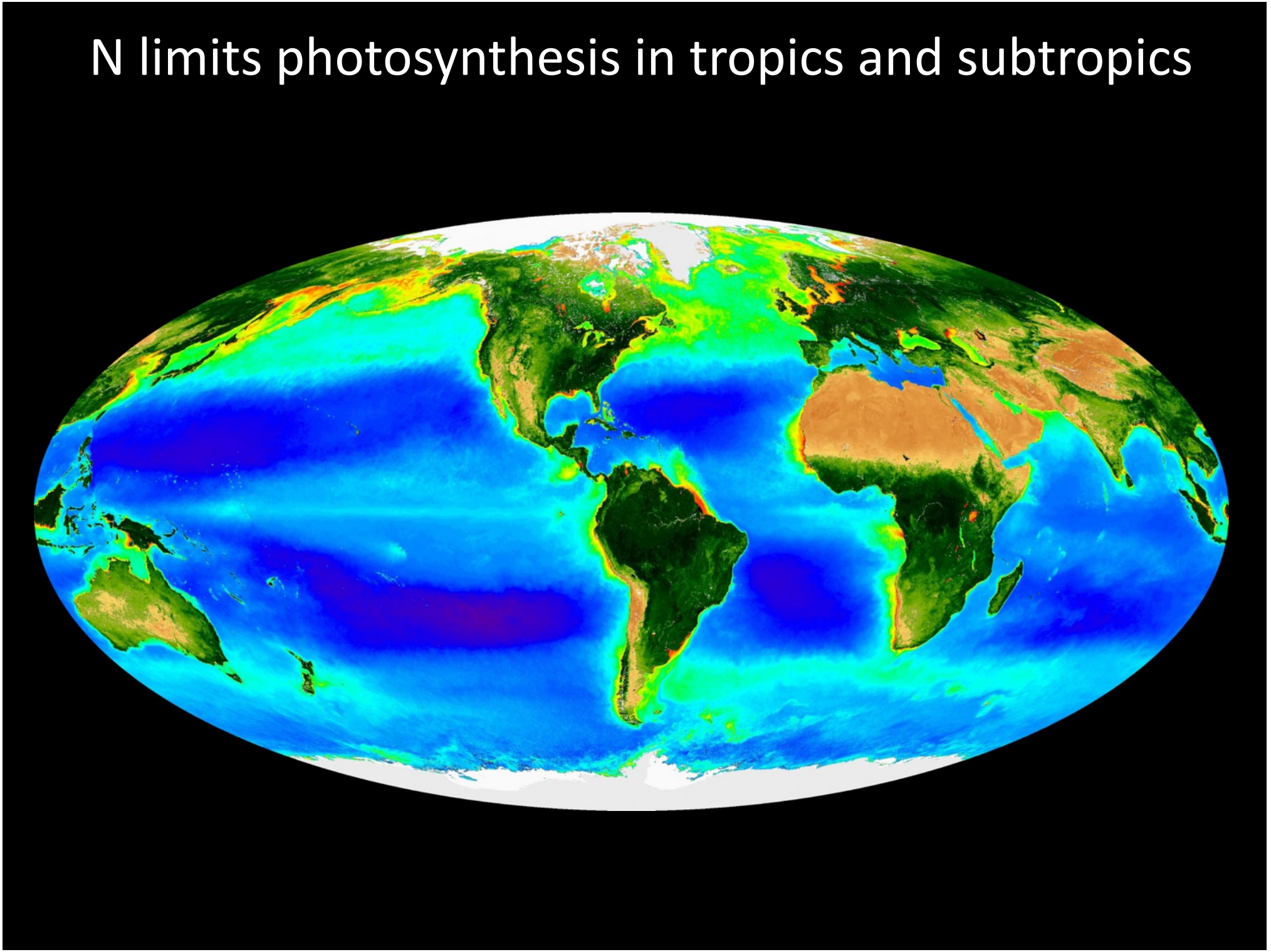
Why do we care about this number?

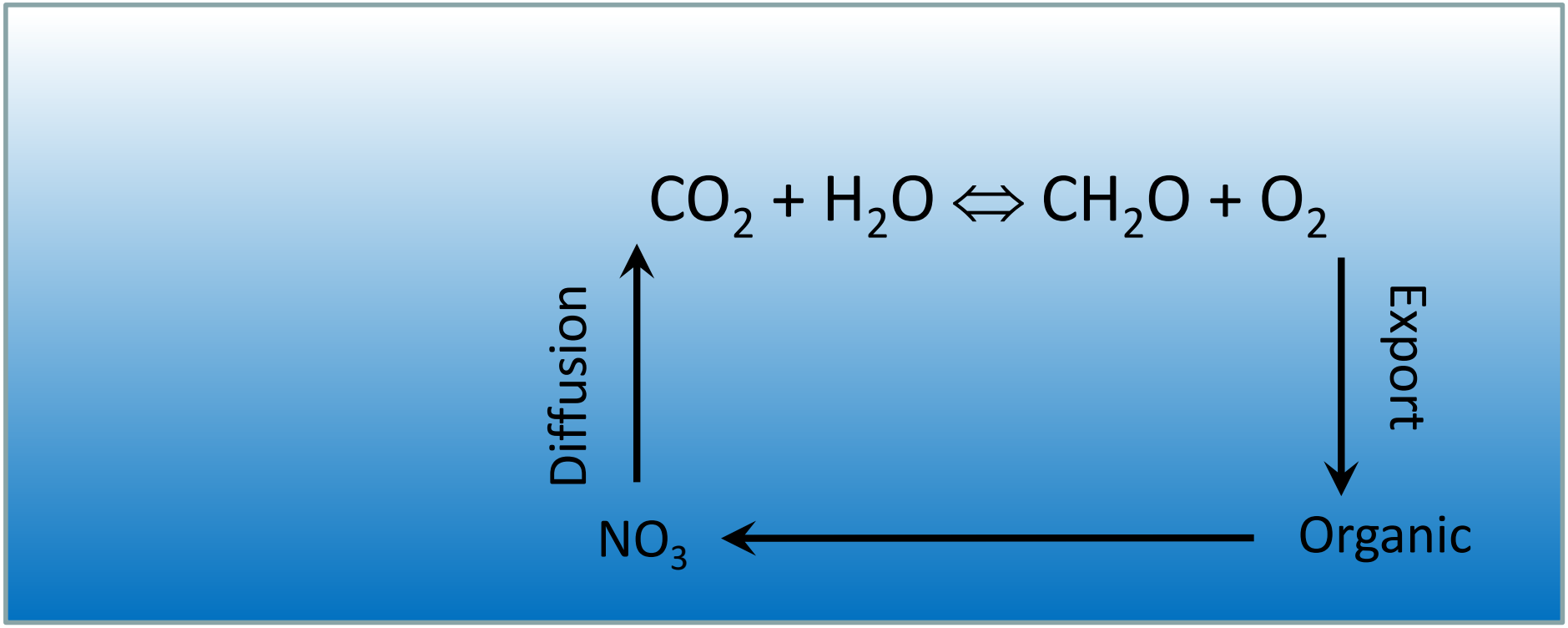
Relevance of N in the biosphere

"…the lack of a substantial geological reservoir of N makes it an ideal candidate for the search for life on Mars: Follow the nitrogen." (Capone et al, 2006, Science)

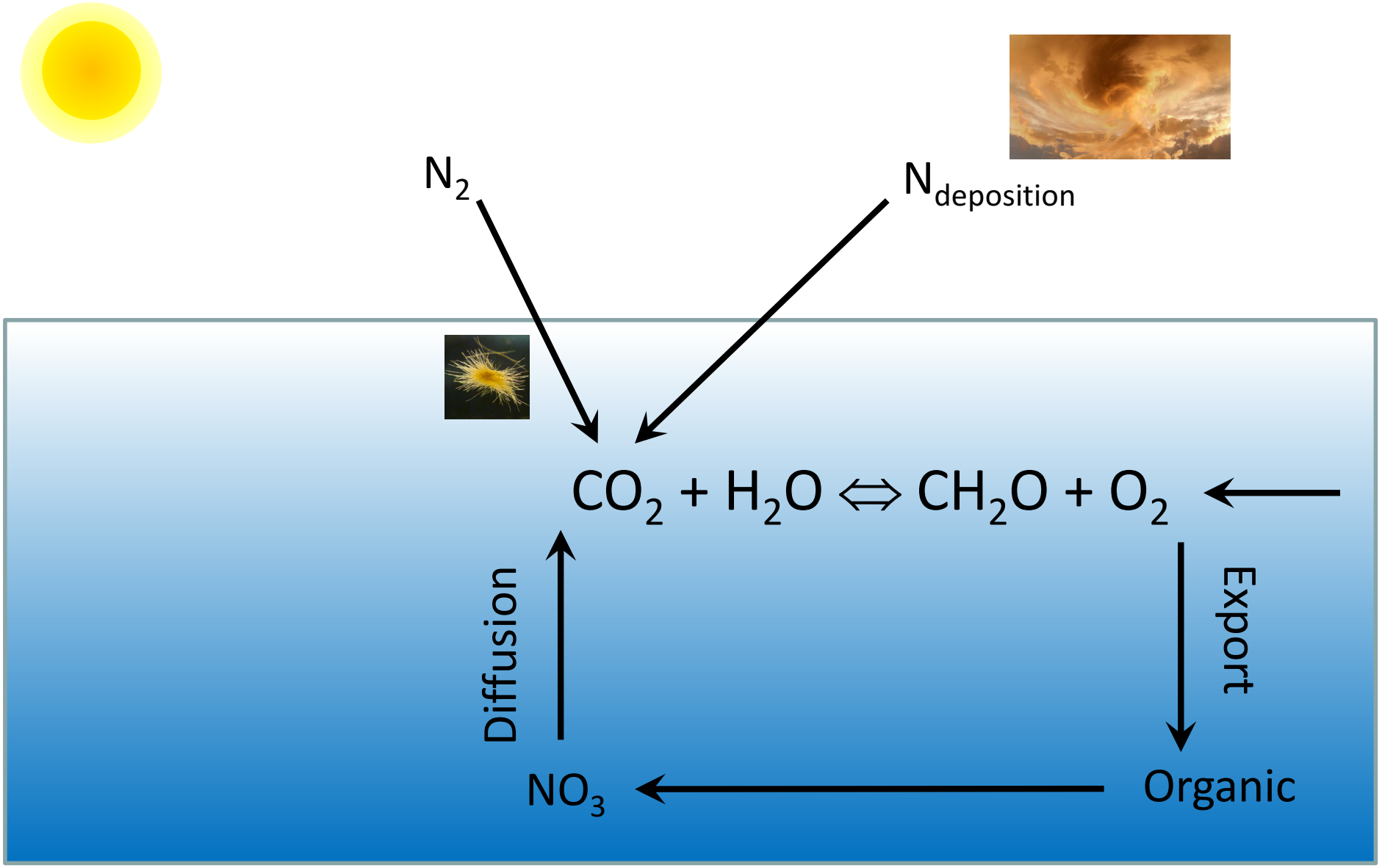
N limits photosynthesis in tropics and subtropics



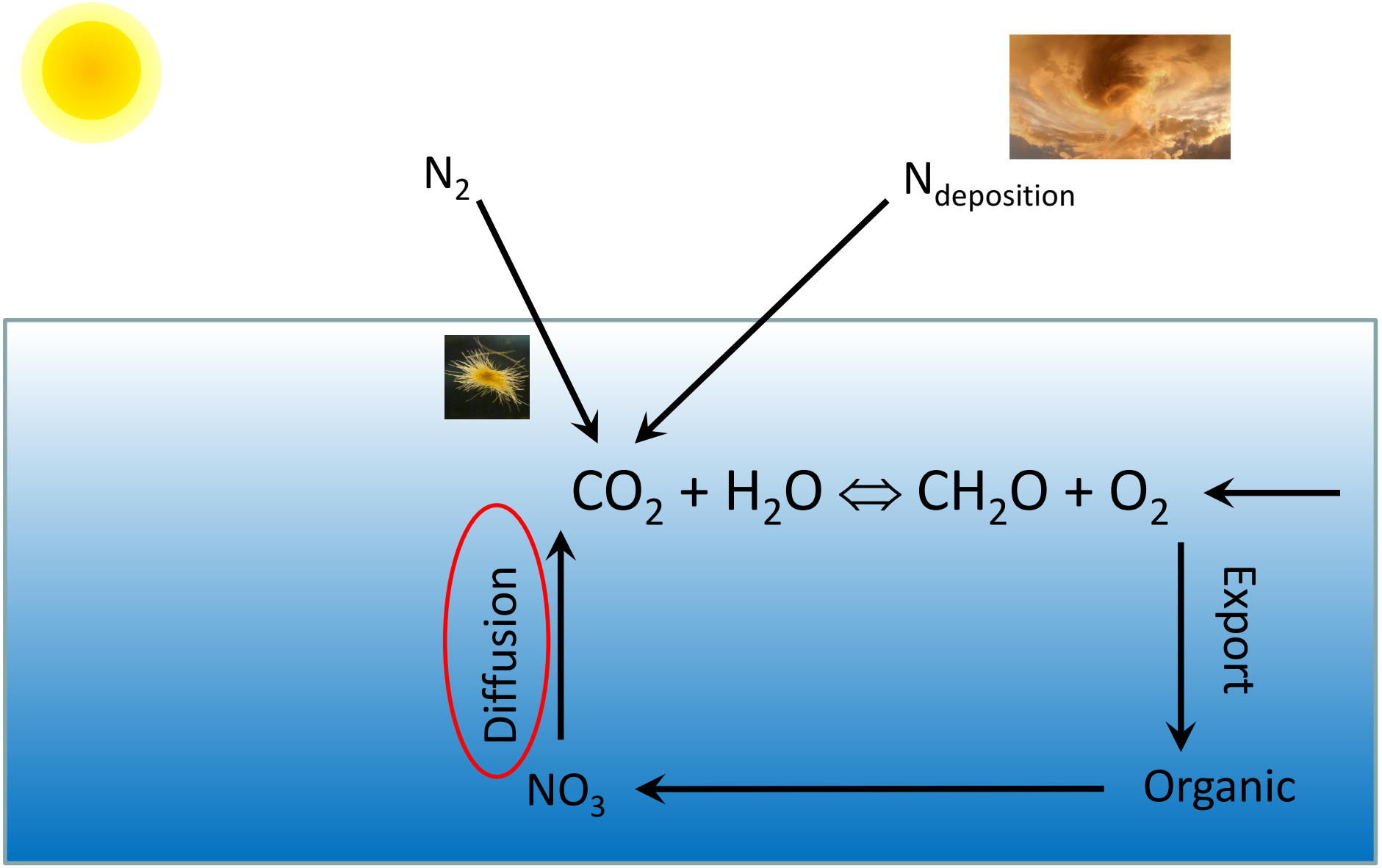
New N and the biological carbon pump: 1D traditional view



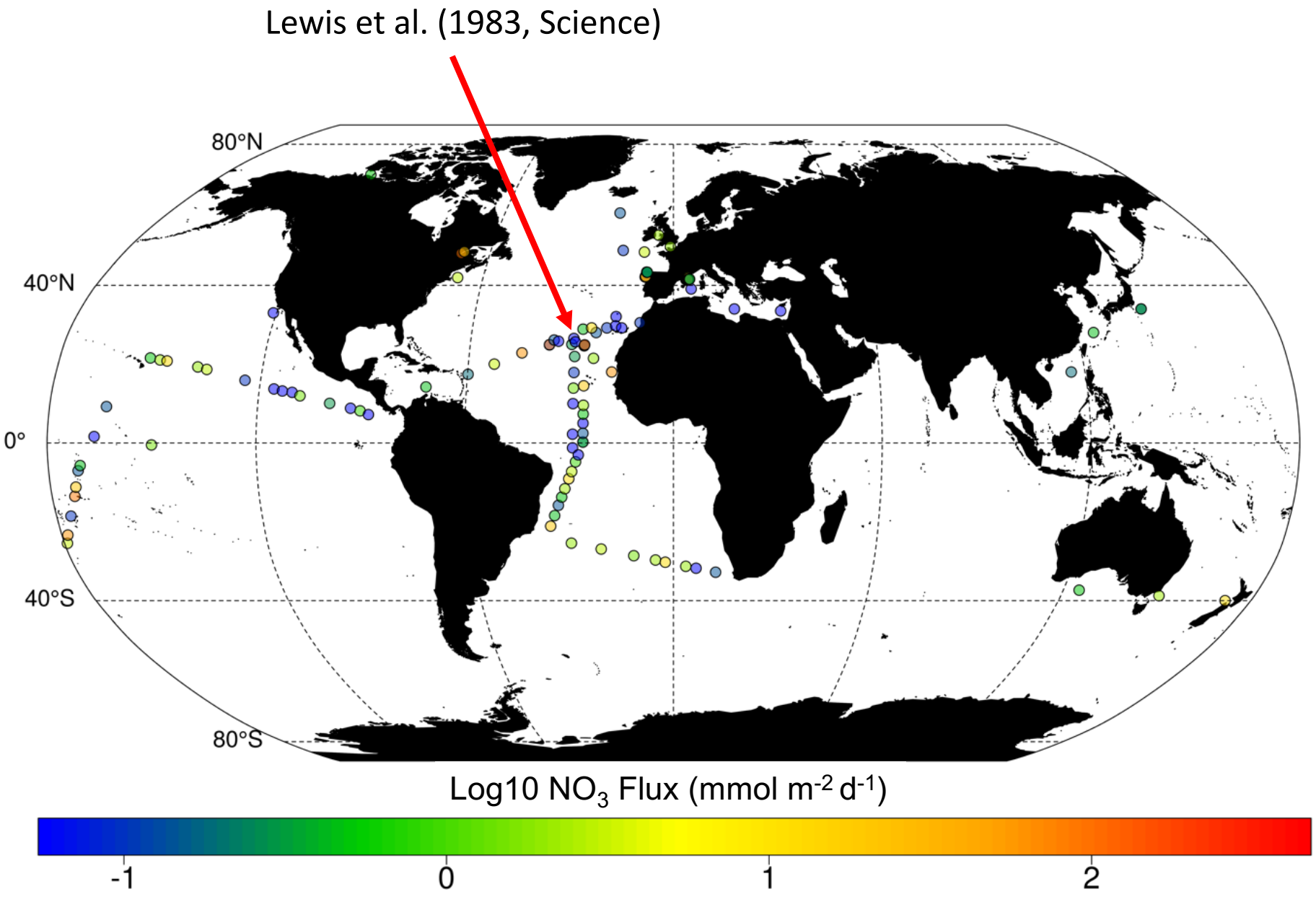
New N and the biological carbon pump: 3D current view



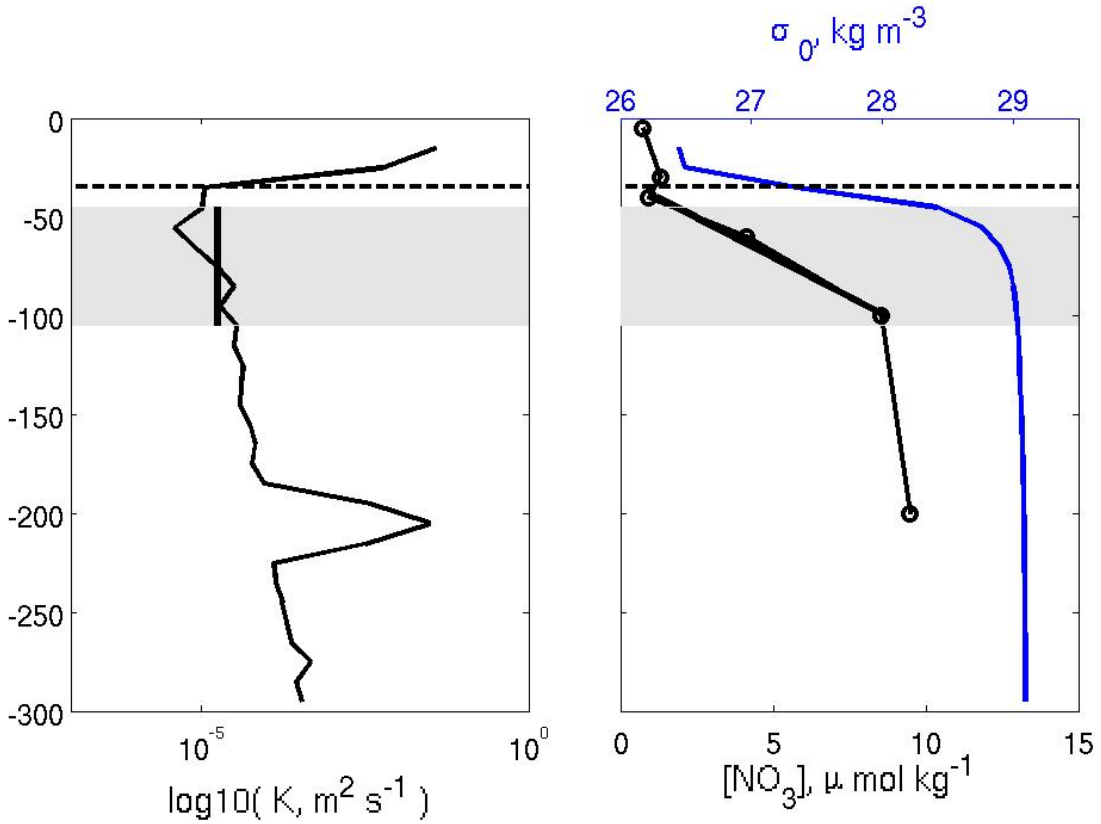
New N and the biological carbon pump: 3D current view



Estimates of NO_3 diffusion derived from observations



Calculation of NO_3 diffusion across the nutricline



$$Flux_{nut} = \langle K_z \rangle \frac{d\,[nut]}{dz}$$

Microstructure turbulence profiler by Miquel Alcaraz (CSIC-Barcelona)

Vertical diffusivity (Kz):

$$Kz = 0.2\frac{\varepsilon}{N^2}$$ Osborn (1980)

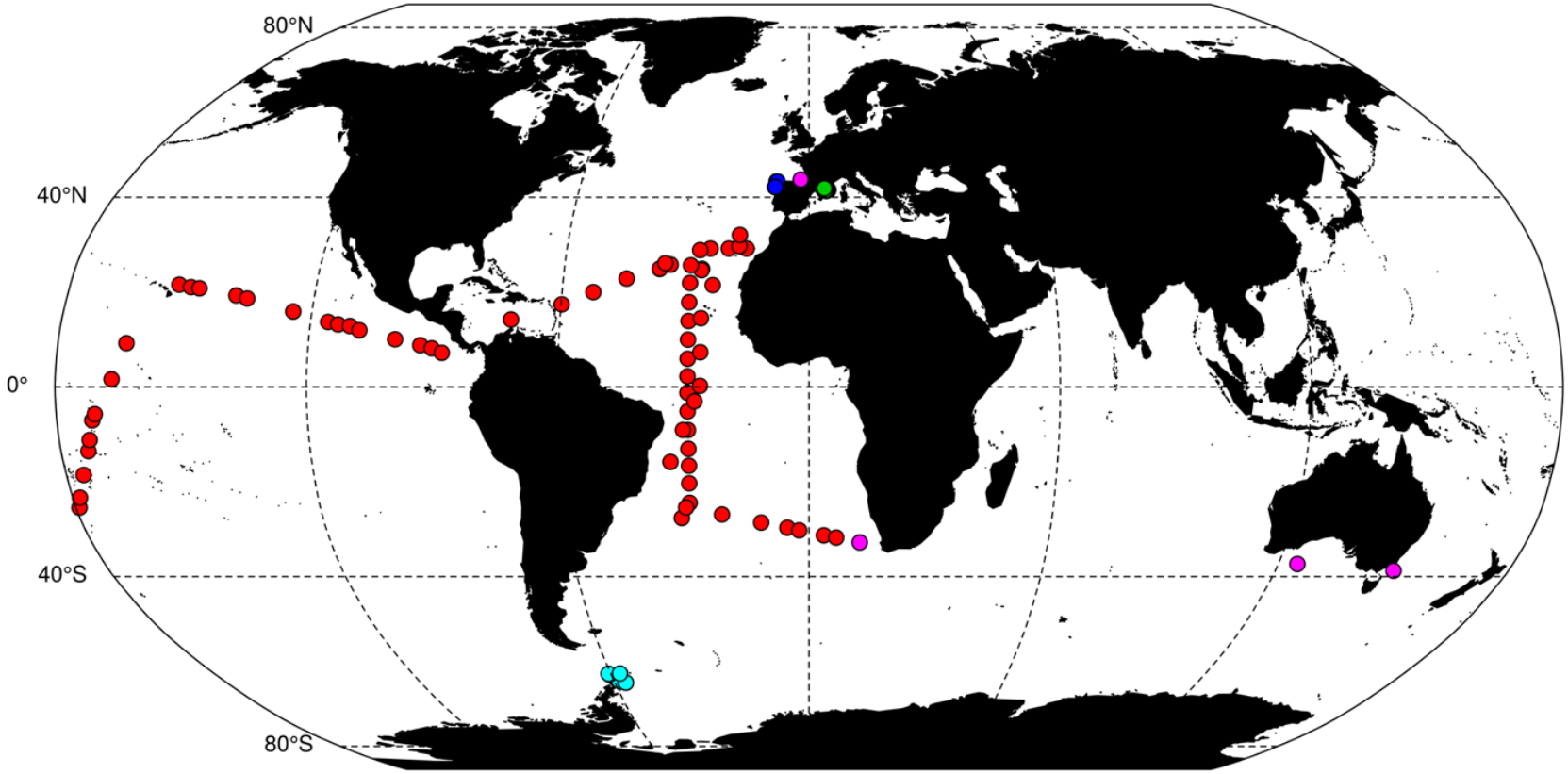
ε Dissipation rate of turbulent kinetic energy

N Brünt Väissälä frequency

Our goal

To determine the best proxy for nitrate turbulent diffusion into the euphotic zone

Database of microstructure turbulence (2006-2015)

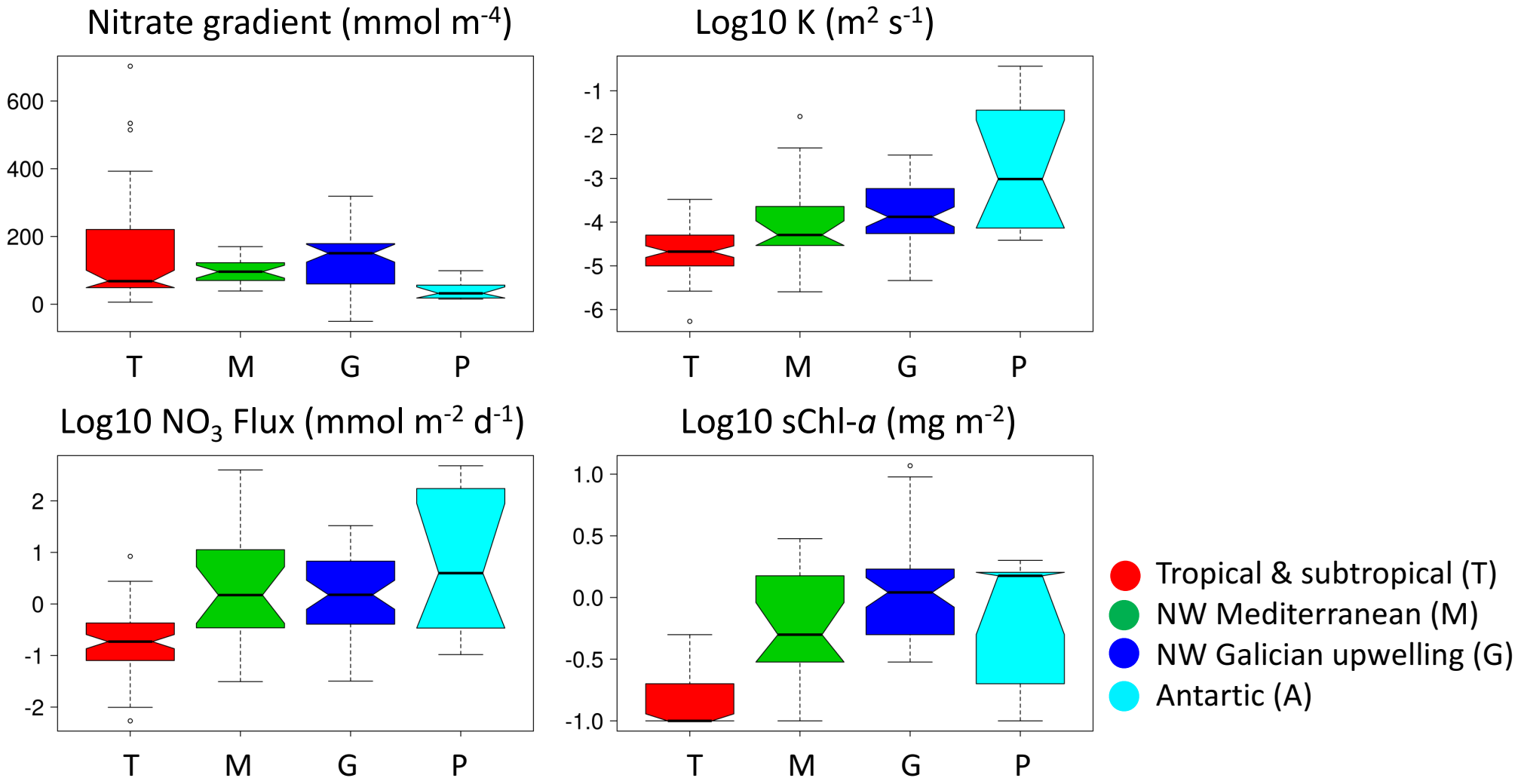


17 cruises; 155 stations:

- 155 Microturbulence (MST profiler, 0-300 m)
- Nitrate concentration (0-200 m)
  - 149 Observations
    - 6 WOA09 database
    - 3 Nitrate-density relationship

- Tropical & subtropical (71)
- NW Mediterranean (19)
- NW Galician upwelling (51)
- Antartic (10)
- Others (4)

Variability in NO_3 gradient, K, NO_3 flux and sChla



Multivariable fractional polynomial method (MFP)

- Stratification: **SST**, SSS, MLD*, maxN^2, dmaxN^2, avrN^2
- Nitrate: sNO_3 , nitraD, **grNO_3**
- Chlorophyll-a: DCM, maxChla, **sChla**

0.1 (0.125) Kg m^{-3} for ocean (coastal) regions

Multivariable fractional polynomial method (MFP)

	R^2-adj	AIC
Tropical and subtropical		
$FNO_3 = f(\mathbf{grNO_3}, SSS, sNO_3, avrN_2)$	0.75	143
$FNO_3 = f(\mathbf{grNO_3, SST})$	0.41	189
NW Mediterranean		
$FNO_3 = f(avrN_2)$	0.68	72
$FNO_3 = f(\mathbf{SST, sChla})$	0.64	77
NW Galician upwelling		
$FNO_3 = f(\mathbf{grNO_3}, maxChla)$	0.64	77
$FNO_3 = f(\mathbf{grNO_3})$	0.51	110
Antartic		
$FNO_3 = f(\mathbf{SST})$	0.75	38
Global		
$FNO_3 = f(\mathbf{SST, grNO3, sChla}, DCM)$	0.55	545
$FNO_3 = f(\mathbf{SST, grNO3, sChla})$	0.52	553

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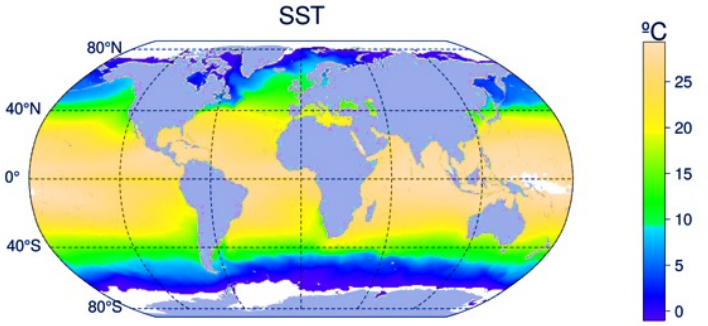
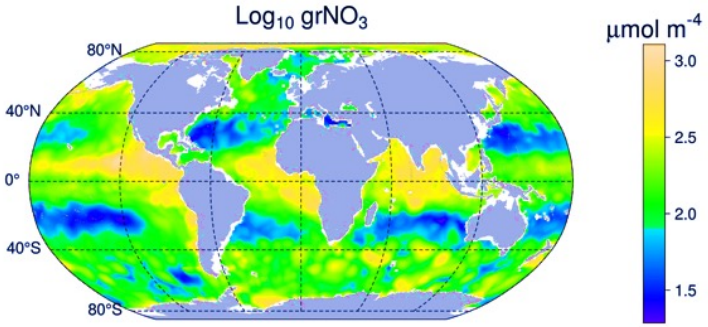
Prediction of NO_3 turbulent diffusion

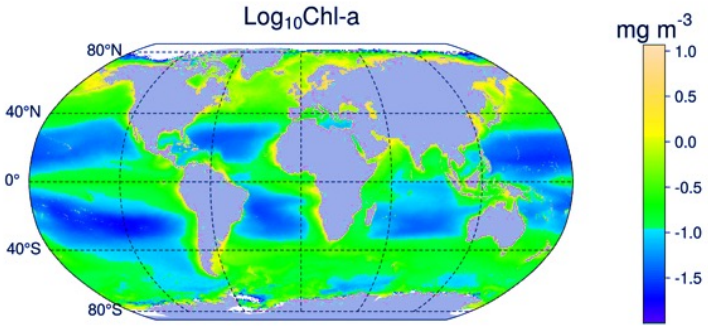
$$FNO_3 = a + b(((\boldsymbol{SST}+c)/d)^{-1})e(((\boldsymbol{SST}+c)/d)^2) + f*\log(\boldsymbol{grNO_3}/100) + 0.2(sChla+g)$$



SST from WOA13

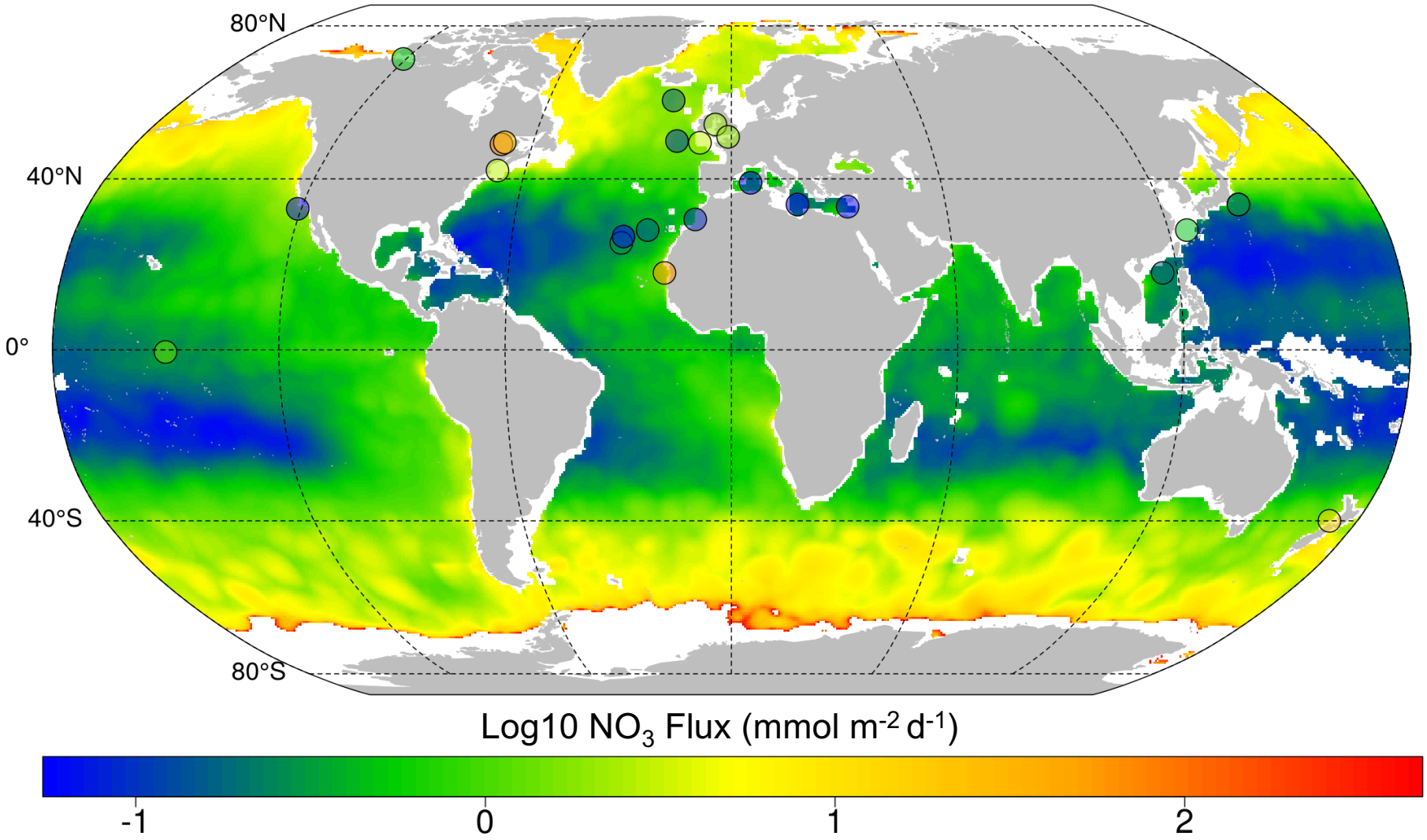


$grNO_3$ from WOA13



sChla from Globecolour (1998-2017)

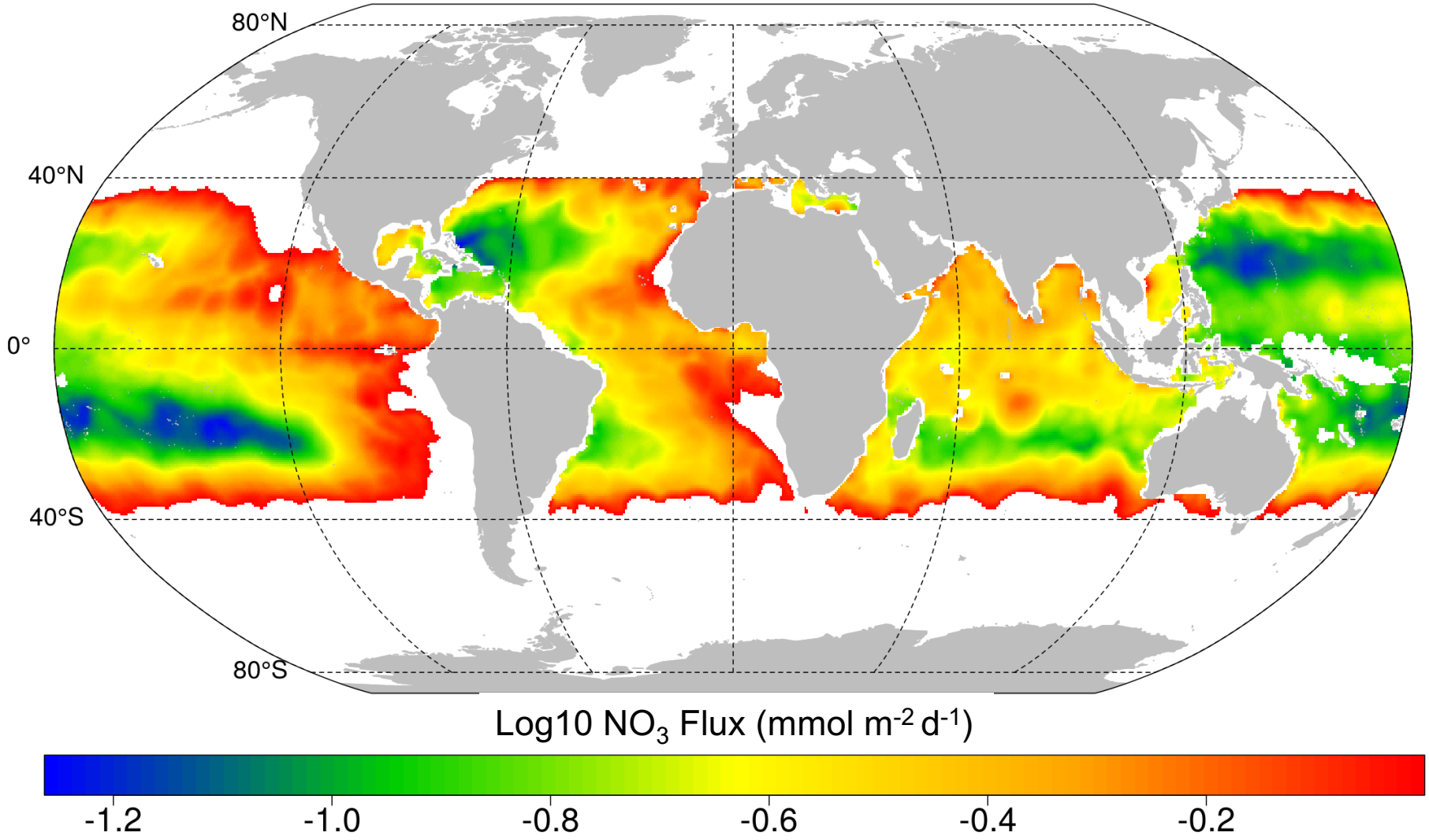
Prediction of NO_3 turbulent diffusion + observations



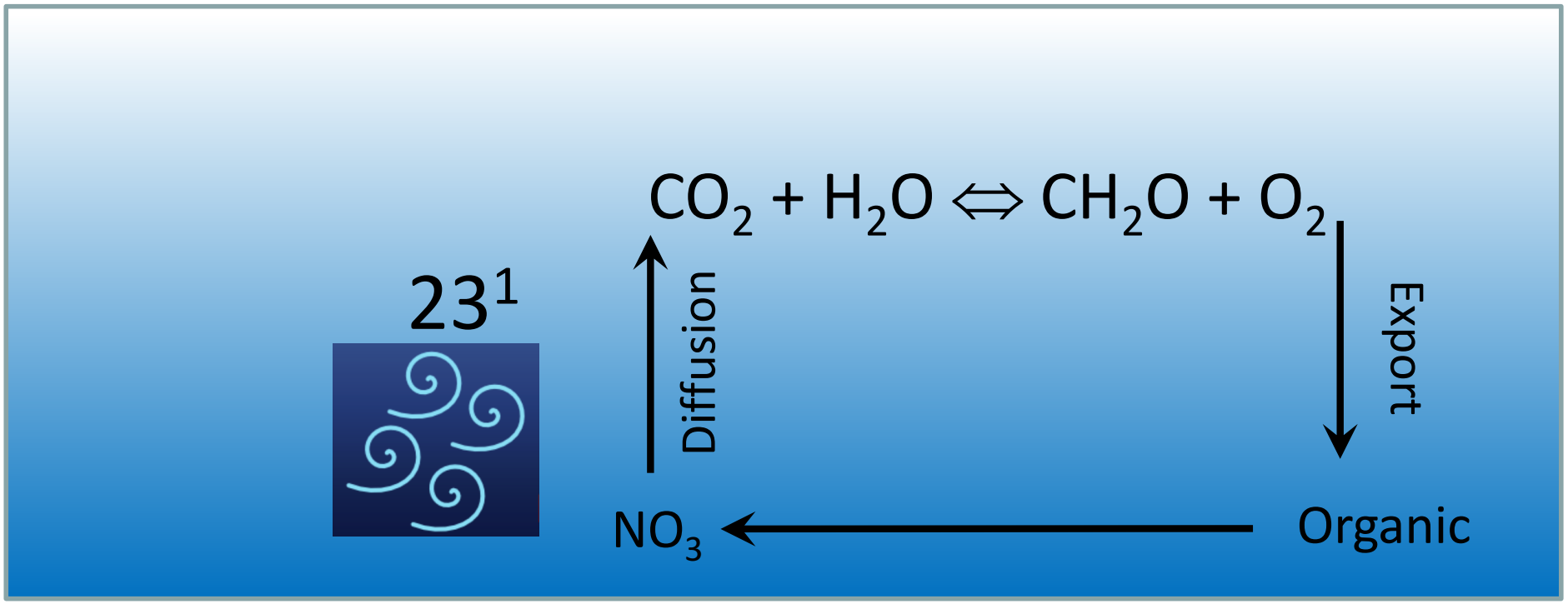
Prediction of NO_3 diffusion for 40ºN – 40ºS

NO_3 Flux < 1 mmol m^{-2} d^{-1}

sChla < 1 mg m^{-3}

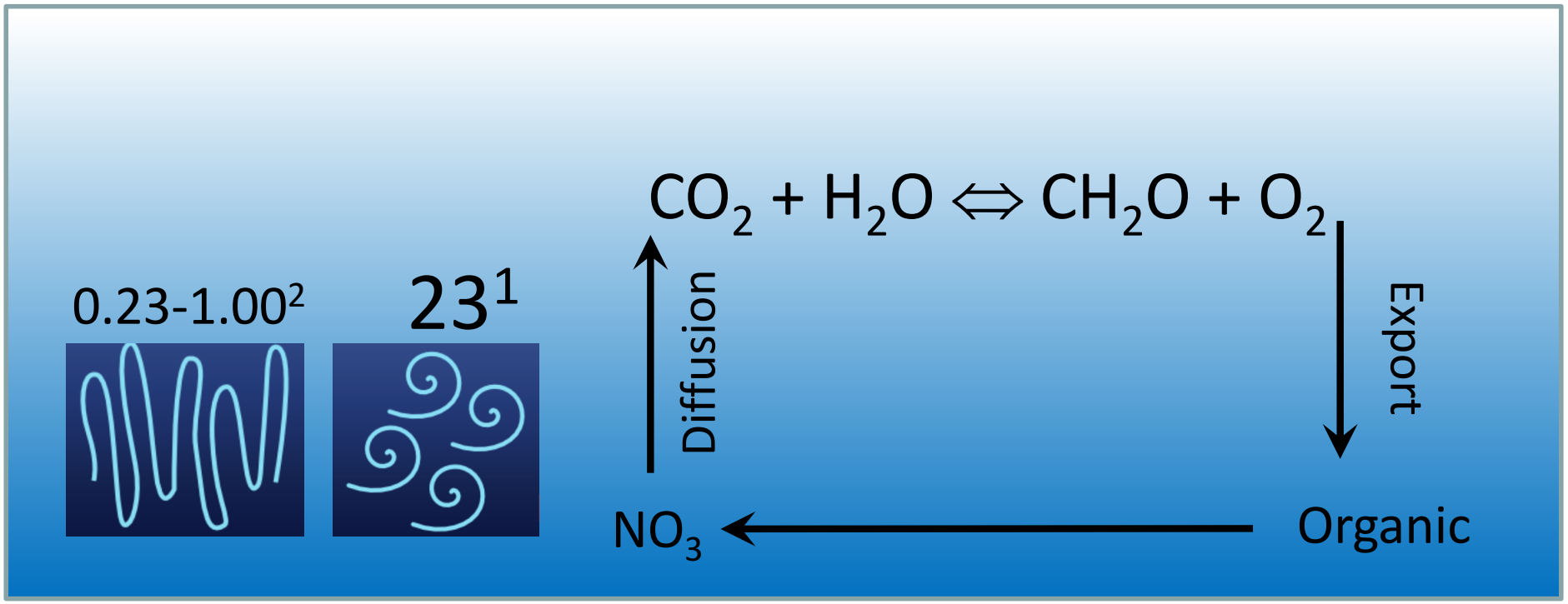


Nitrogen budget for 40ºN – 40ºS (TmolN yr^{-1})



[1]This study

Nitrogen budget for 40ºN – 40ºS (TmolN yr^{-1})



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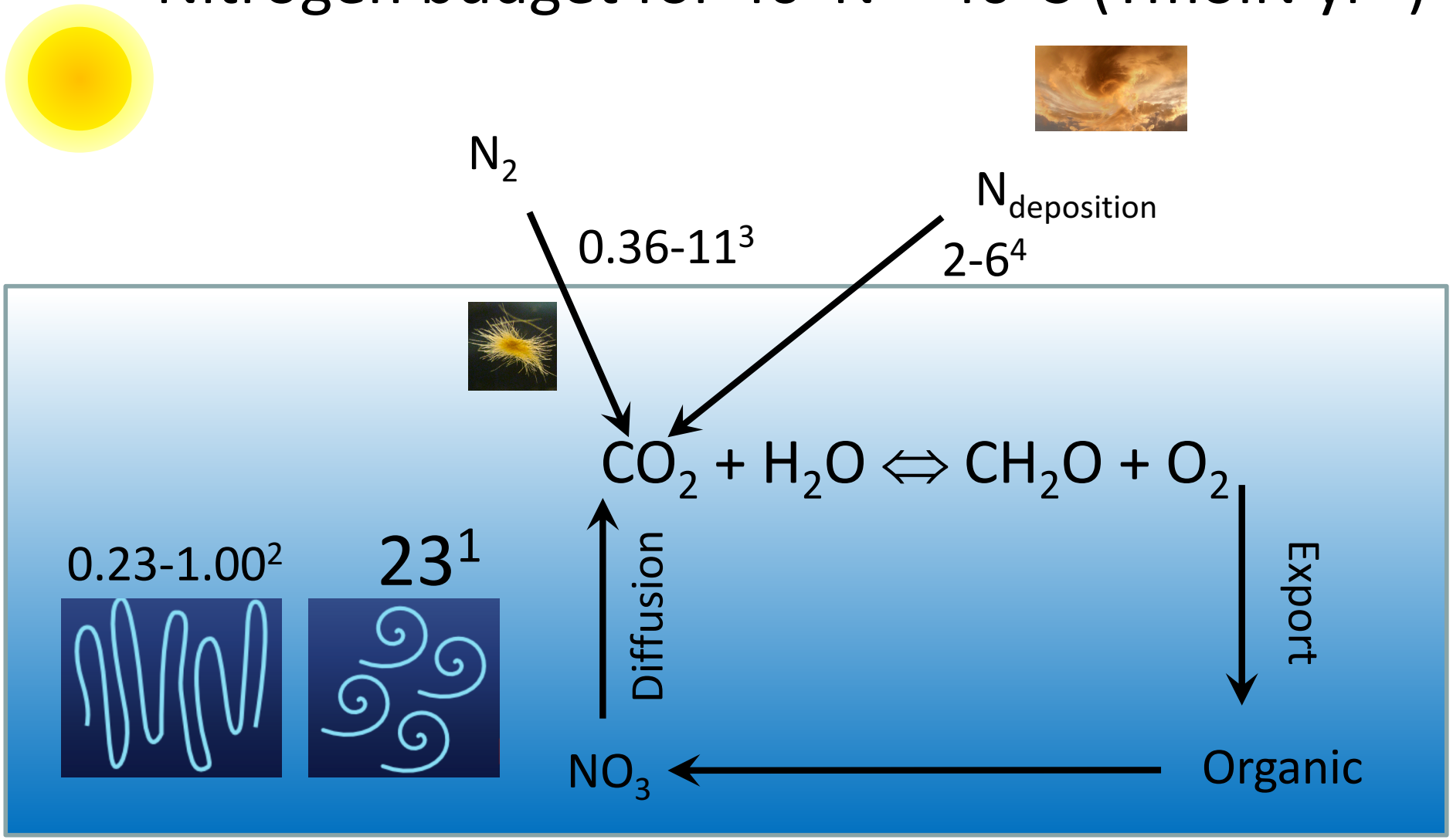
[2]Fernández-Castro et al. (2015)

Nitrogen budget for 40ºN – 40ºS (TmolN yr^{-1})



[1]This study
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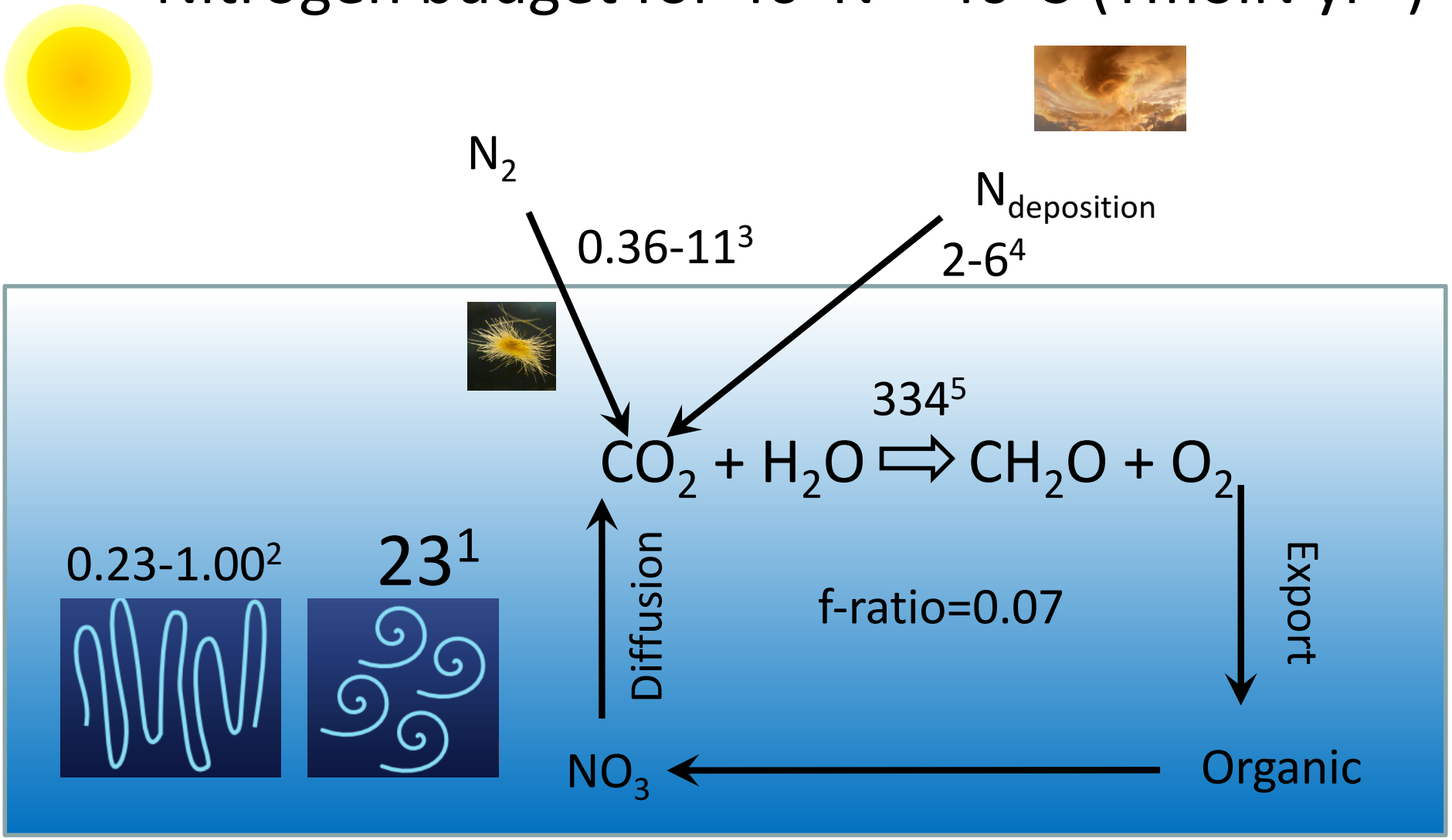

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[3]Carpenter & Capone (2008)
[4]Okin *et al.* (2011)

[5]NPP(Uitz et al, 2008)
23% DOC production (Teira et al, 2001)
20% ratio phyto respiration to GP (Geider, 1992)
Variable stoichiometry (Galbraitha & Martiny, 2015)

Conclusions

1. A global model including *SST, gradNO*, and *sChla* explains 52% of the variability
2. Nitrate turbulent diffusion supplies ca. 23 TmolN yr^{-1} between 40ºN – 40ºS (f-ratio=0.07)

Thanks to…

Ministerio de Economía y Competitividad

- Grant CTM2012-30680 to B. Mouriño-Carballido
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Xunta de Galicia

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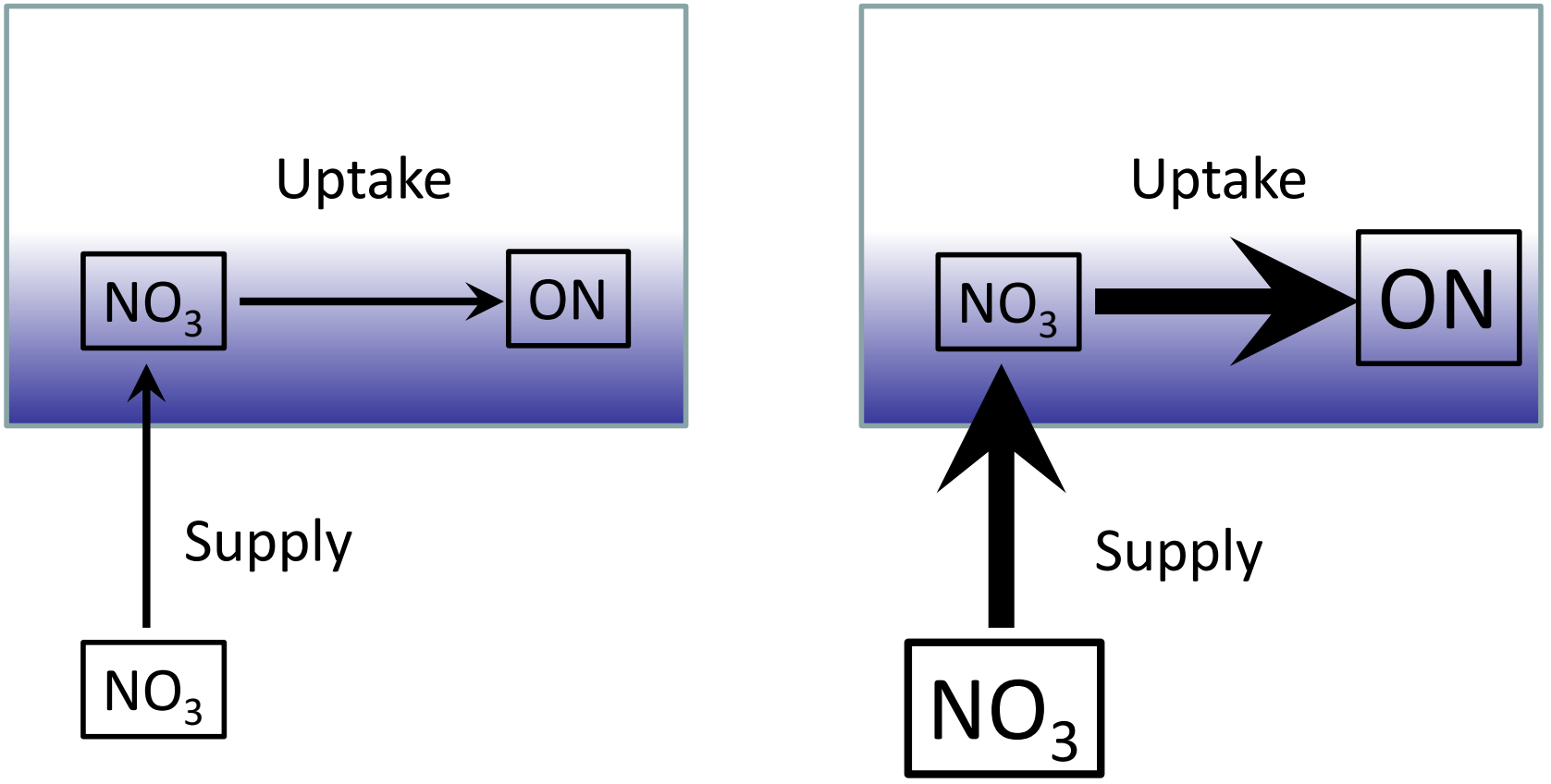
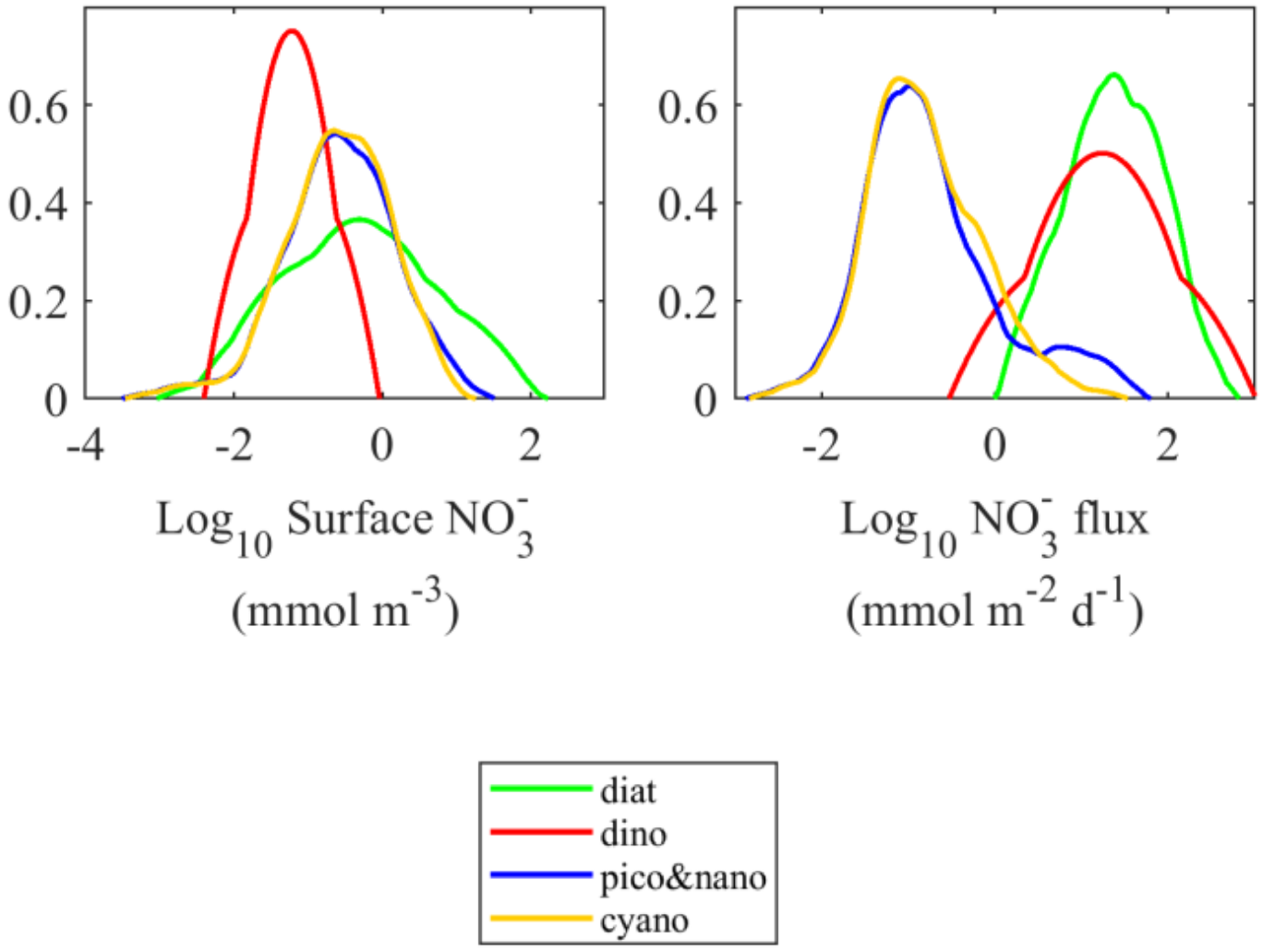
- 09MMA027604PR to M. Ruiz

Steady-state: concentration ≠ supply

$$\frac{dNO_3}{dt} = Supply - Uptake = 0$$



Role of nitrate in the distribution of phytoplankton groups



(Villamaña et al., in prep)

Database of microstructure turbulence (2006-2015)

Domain	Region	Cruise	N	Date	
T	Northeast subtropical Atlantic	CARPOS	8	20 Oct-21 Nov 2006	
T	North and South tropical and	TRYNITROP	18	14 Apr-2 May 2008	3
T	Atlantic, and Pacific	Malaspina	47	19 Dec 2010-10 Jul 2011	
M	Northwest Mediterranean	FAMOSO1	6	14-22 Mar 2009	
M	Northwest Mediterranean	FAMOSO2	10	30 Apr-13 May 2009	
M	Northwest Mediterranean	FAMOSO3	3	7-14 Sep 2009	4
M	Northwest Mediterranean	PERFIL2	1	27 Jun-1Jul 2009	
G	Ría de Coruña (NW Spain)	HERCULES1	4	6 Jul 2010	
G	Ría de Coruña (NW Spain)	HERCULES2	4	28 Sep 2011	
G	Ría de Coruña (NW Spain)	HERCULES3	16	17-20 Jul 2012	
G	Ría de Vigo (NW Spain)	DISTRAL	10	14 Feb 2012-24 Jan 2013	
G	Ría de Pontevedra and Vigo (NW)	ASIMUTH	12	18-21 Jun 2013	8
G	Ría de Vigo (NW Spain)	STRAMIX	1	5-6 Aug 2013	
G	Ría de Vigo (NW Spain)	CHAOS	2	20-28 Aug 2013	
G	Ría de Coruña (NW Spain)	NICANOR	13	18 Mar 2014-19 Nov	
A	South Shetland Islands	COUPLING	10	8-21 Jan 2010	1
O	Bay of Biscay	PERFIL1	1	18-26 Jul 2008	1

N=17