MEDUSA

Model of Ecosystem Dynamics, nutrient Utilisation, Sequestration and Acidification

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Oxford
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NERC
SCIENCE OF THE ENVIRONMENT

UKESM1 and iMARNET

- Development of UKESM1 required the selection of its marine BGC component
- iMARNET project evaluated six UK marine BGC models to select the "best" model
- Models were simulated identically for the present-day and evaluated for nutrient cycles, air-sea CO2 fluxes and primary production
- Evaluation also considered compute cost
- MEDUSA was selected as "best fit" for UKESM1

Kwiatkowski et al., *Biogeosciences*, 2014

Philosophy of MEDUSA

- MEDUSA idea : realism/simplicity balance
- Focus on the carbon cycle, export production and surface-to-deep ocean connectivity
- Intermediate complexity approach
- Basic NPZD structure still (broadly) valid, so increment upwards from this :
  - ➔ MEDUSA's double-NPZD structure

Double NPZD - ingredients

N
nutrients

- Nitrogen: largely a legacy choice (cf. Fasham)
- Silicon: see diatoms
- Iron: now well-established that significant regions in iron stress

P
Phytop.

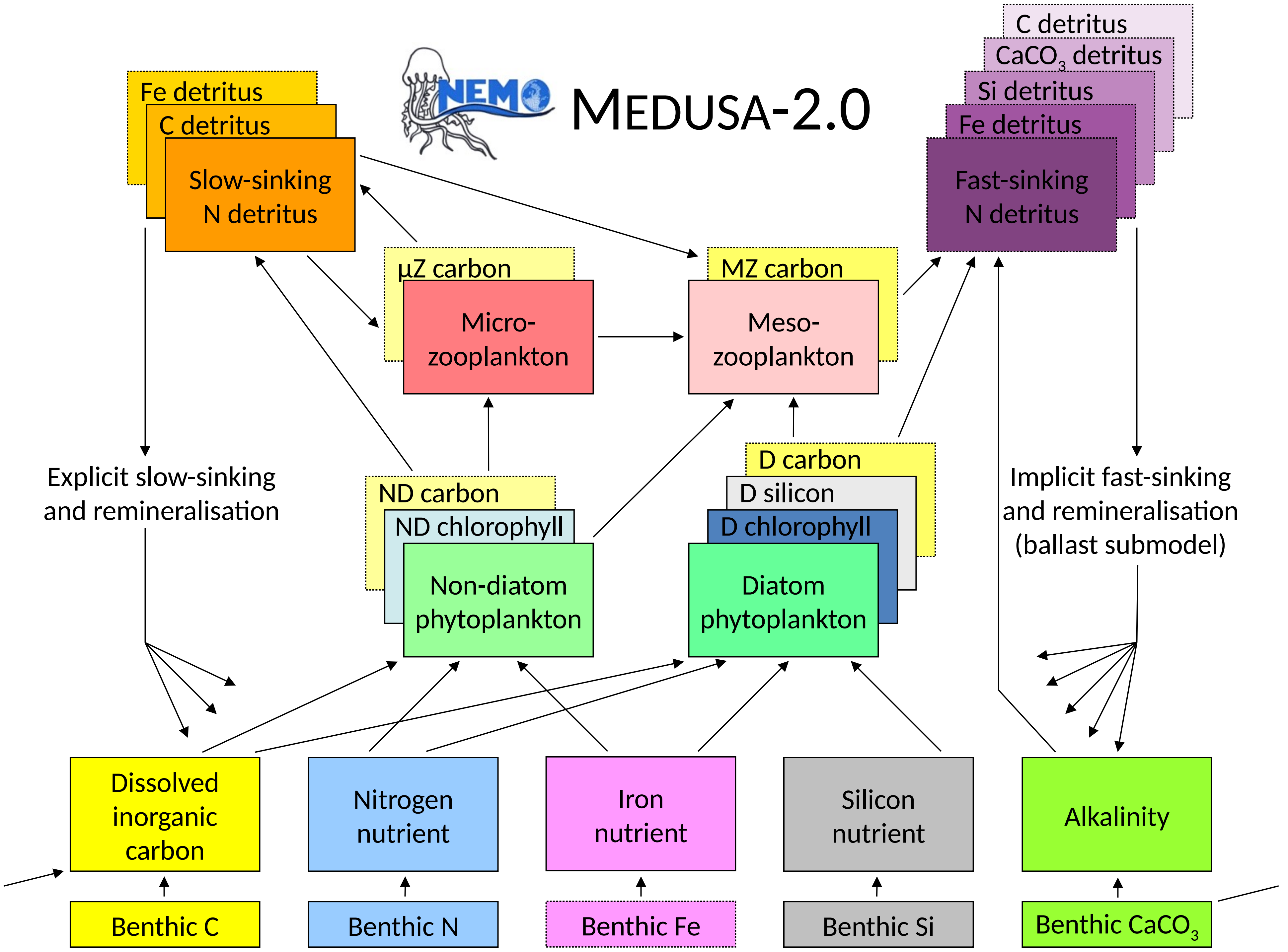
- Diatoms: major players in ecosystems; controls on abundance relatively well-understood (large, fast-growing); no (major) mysteries
- Non-diatoms: small phytoplankton are key players in ecosystems, especially oligotrophic ones; modelled as fast-growing generic phytoplankton

Z
Zoop.

- Zooplankton: micro- and meso- added to complement (= eat) corresponding phytoplankton

D
Detritus

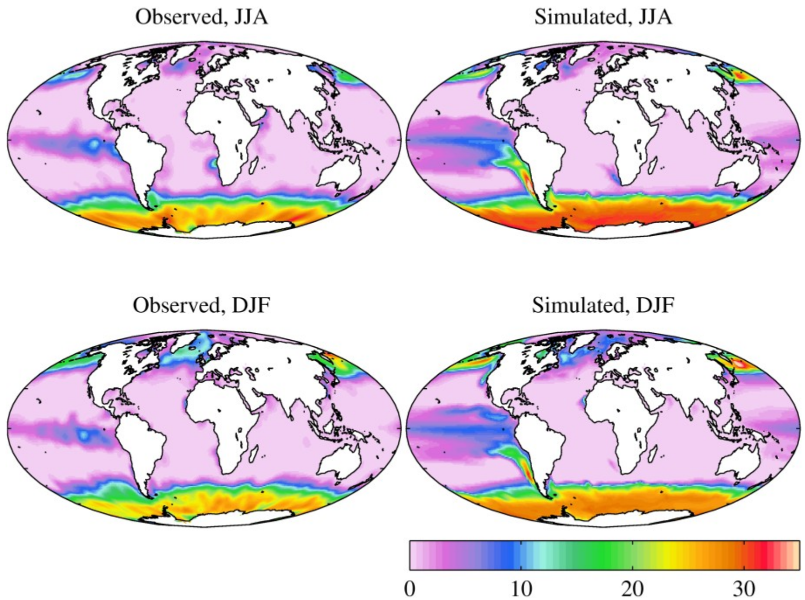
- Explicitly modelled pools of slow-sinking organic detritus; implicitly modelled pools of fast-sinking organic + inorganic detritus



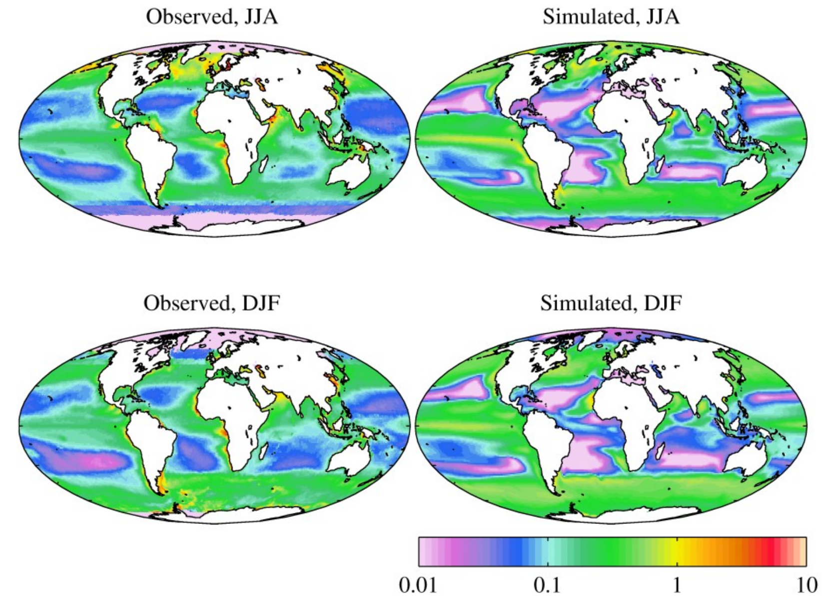
Yool *et al.*, 2013

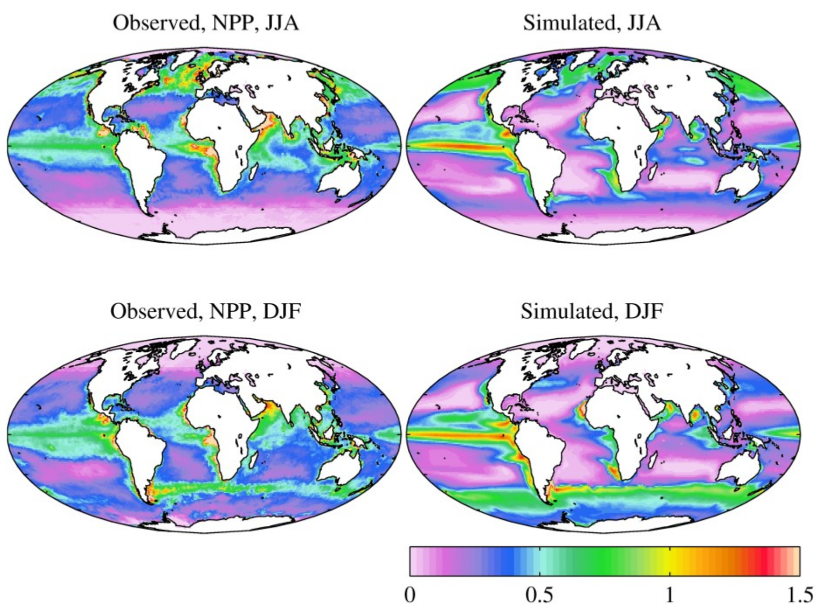
MEDUSA-2
present-day validation

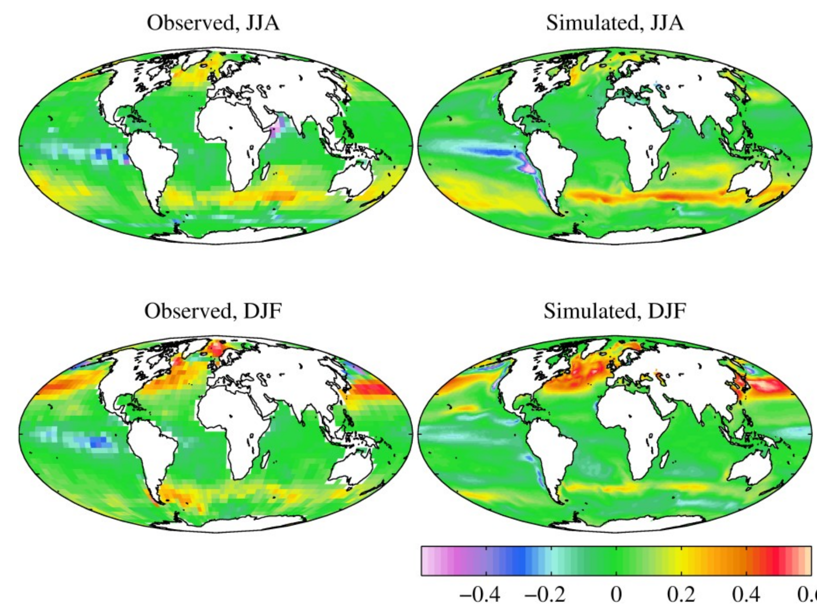
DIN



Chlorophyll







Primary production

Air-sea CO_2 flux

MEDUSA – UKESM1

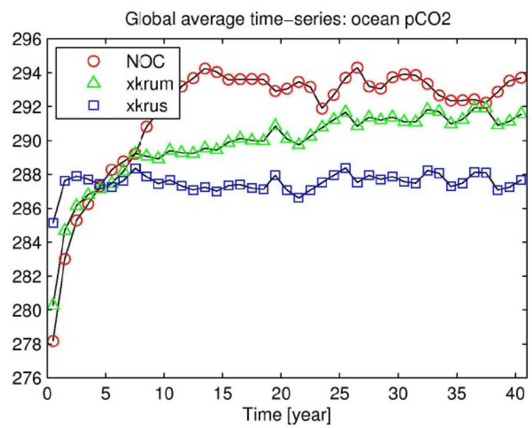
-- developments --

New carbonate Chemistry

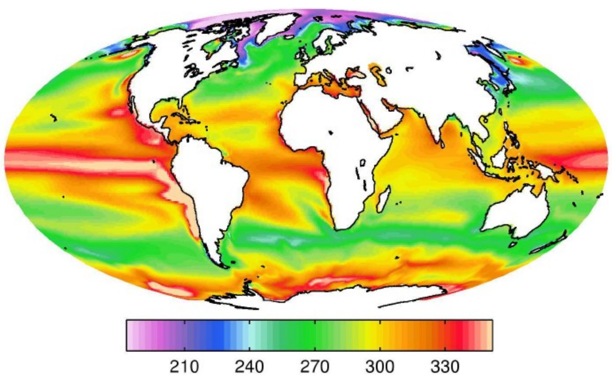
Carbonate chemistry

- MOCSY (Orr et al., 2015) added to MEDUSA
- Uses up-to-date parameterisations
- Gas transfer schemes updated, harmonised
- Main differences are faster equilibriation (gas transfer) and shallower CCD (MOCSY)
- Air-sea exchange could be optimised (CFCs?)

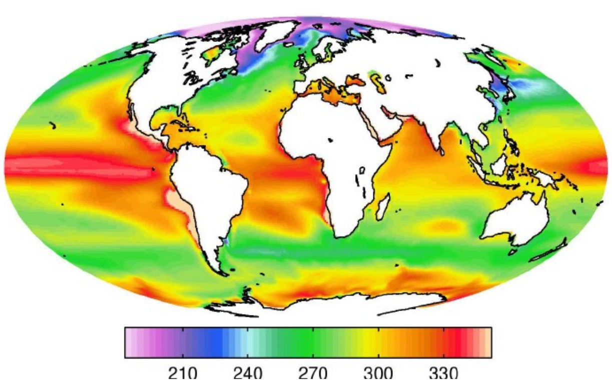
Example With Ocean pCO_2



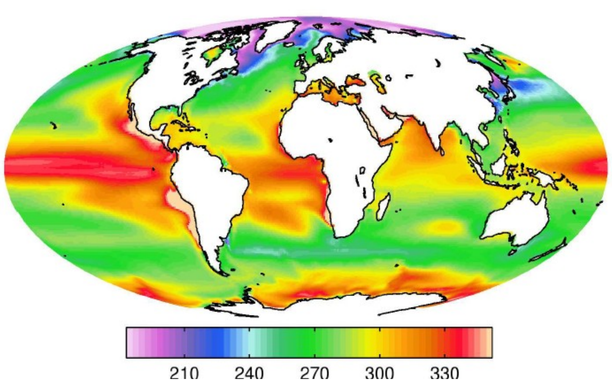
Old chemistry; old dynamic



Old chemistry; new dynamic



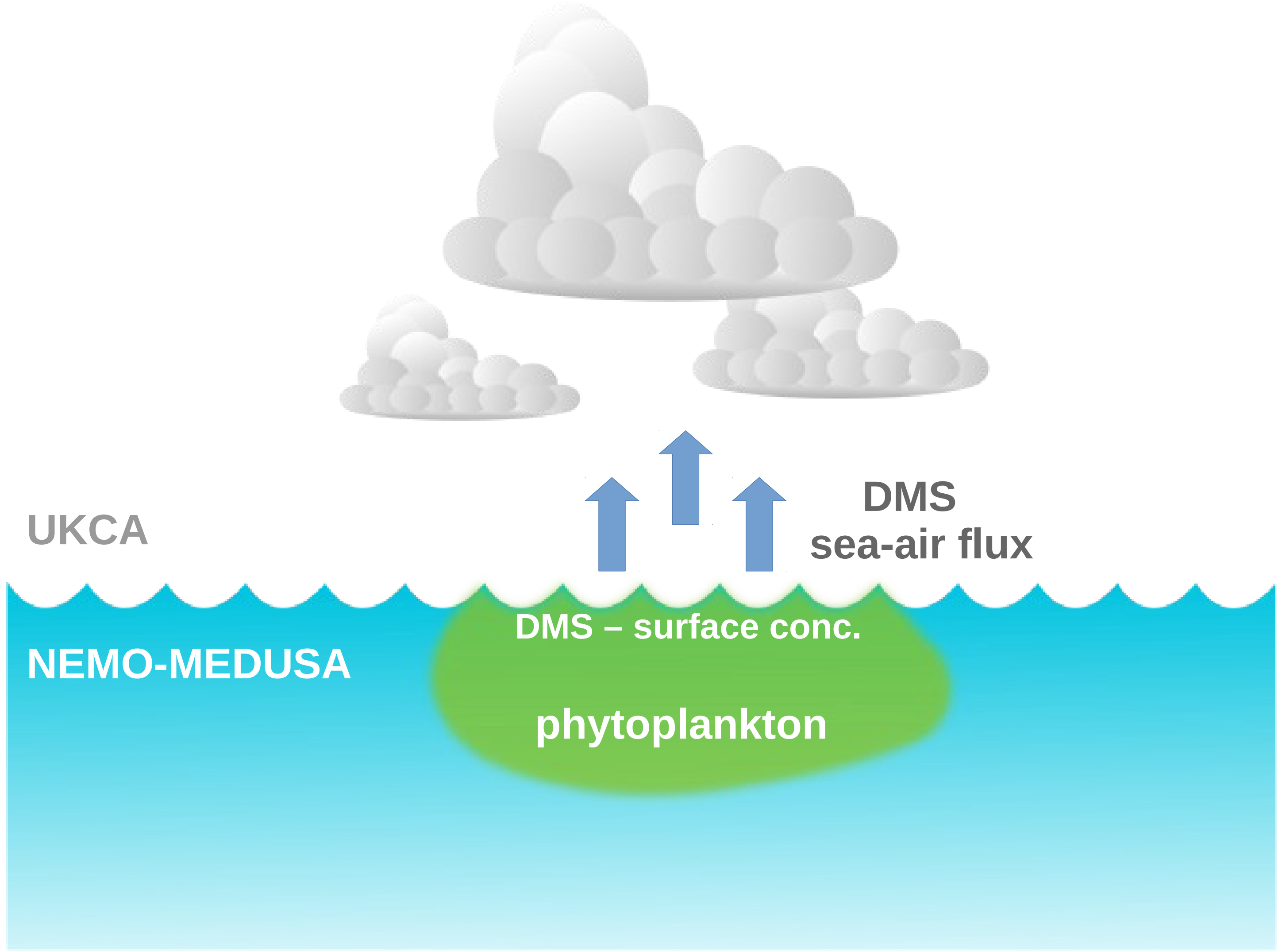
MOCSY; new dynamic



DMS surface concentration

DMS (dimethylsulfide) needed by the atm. Chem. component

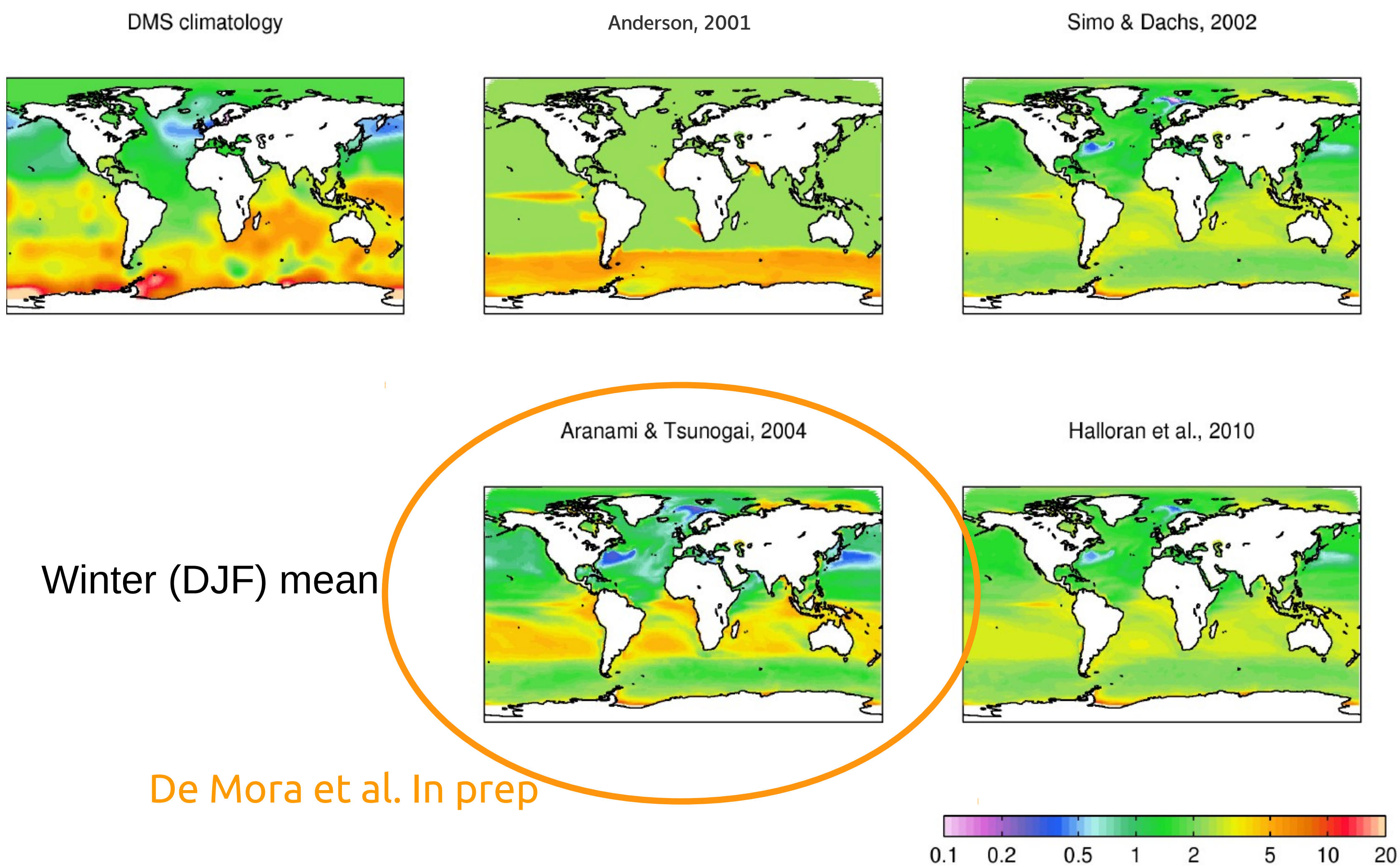
- DMS acts in cloud formation process.
- Can affect cloud coverage within climate change.



DMS surface concentration

DMS <u>diagnostic</u> has been added in MEDUSA.

- Tried 4 different DMS formulations.



De Mora et al. In prep

MEDUSA – UKESM1

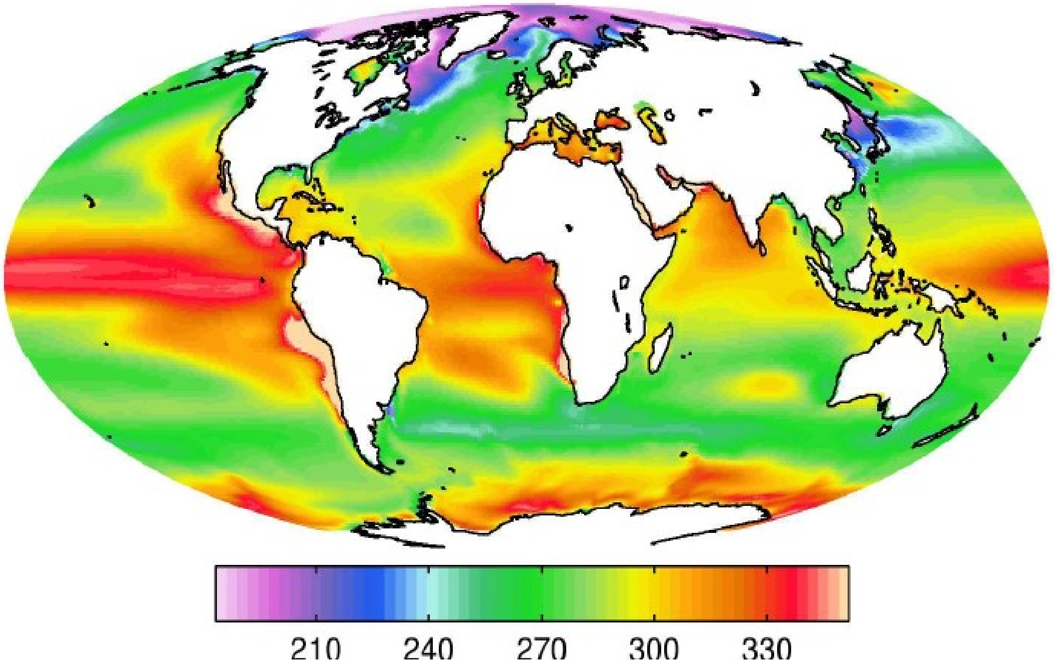
-- Coupling with other component --

2D – CO2 fluxes

Atmosphere component now provides 2D surface [CO_2] field

(previously – only a global mean surface [CO_2] value.)

- More realistic air-sea fluxes
- Changes in local CO_2 in and out-gassing.



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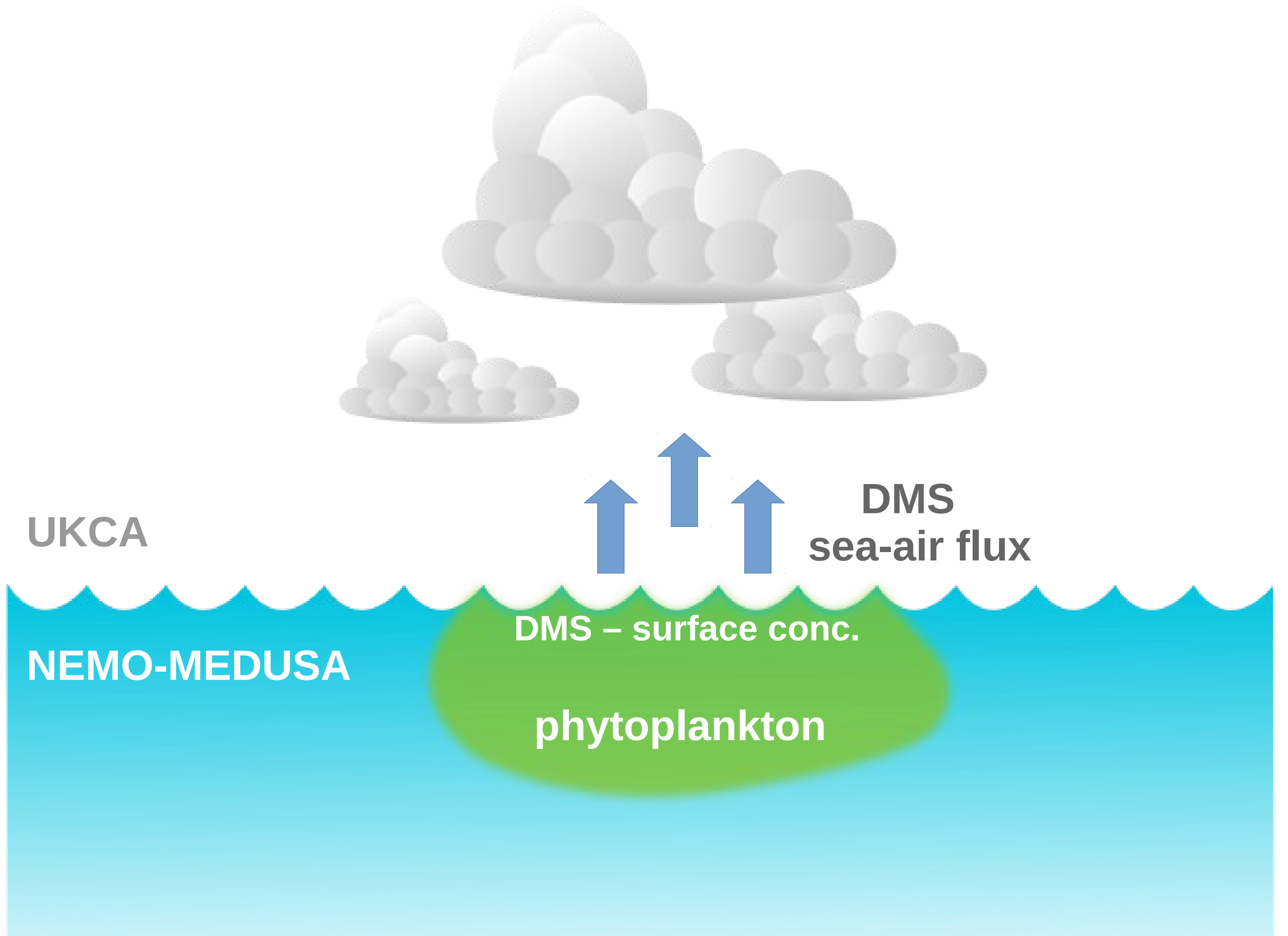
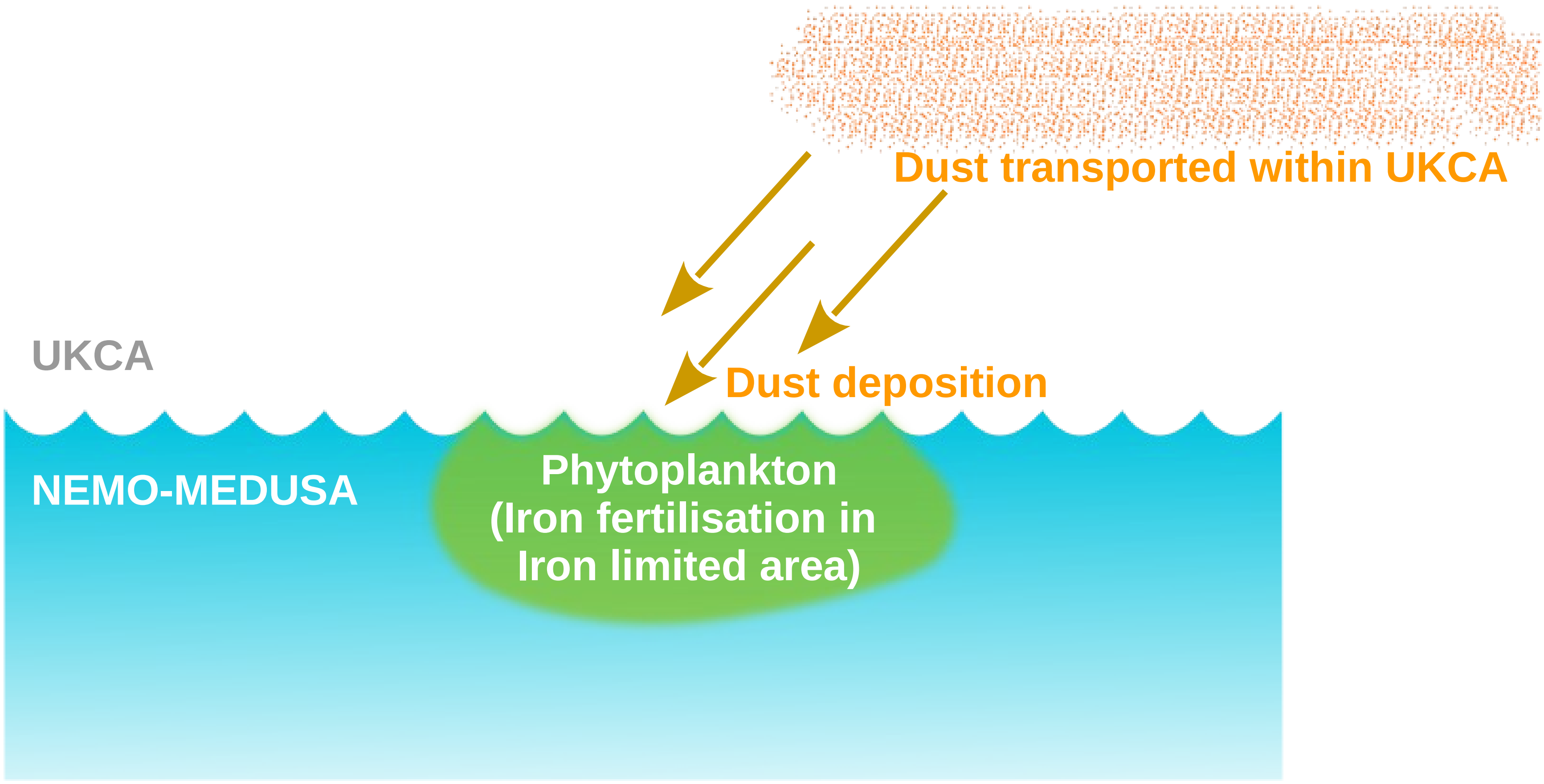


Dust (iron) deposition

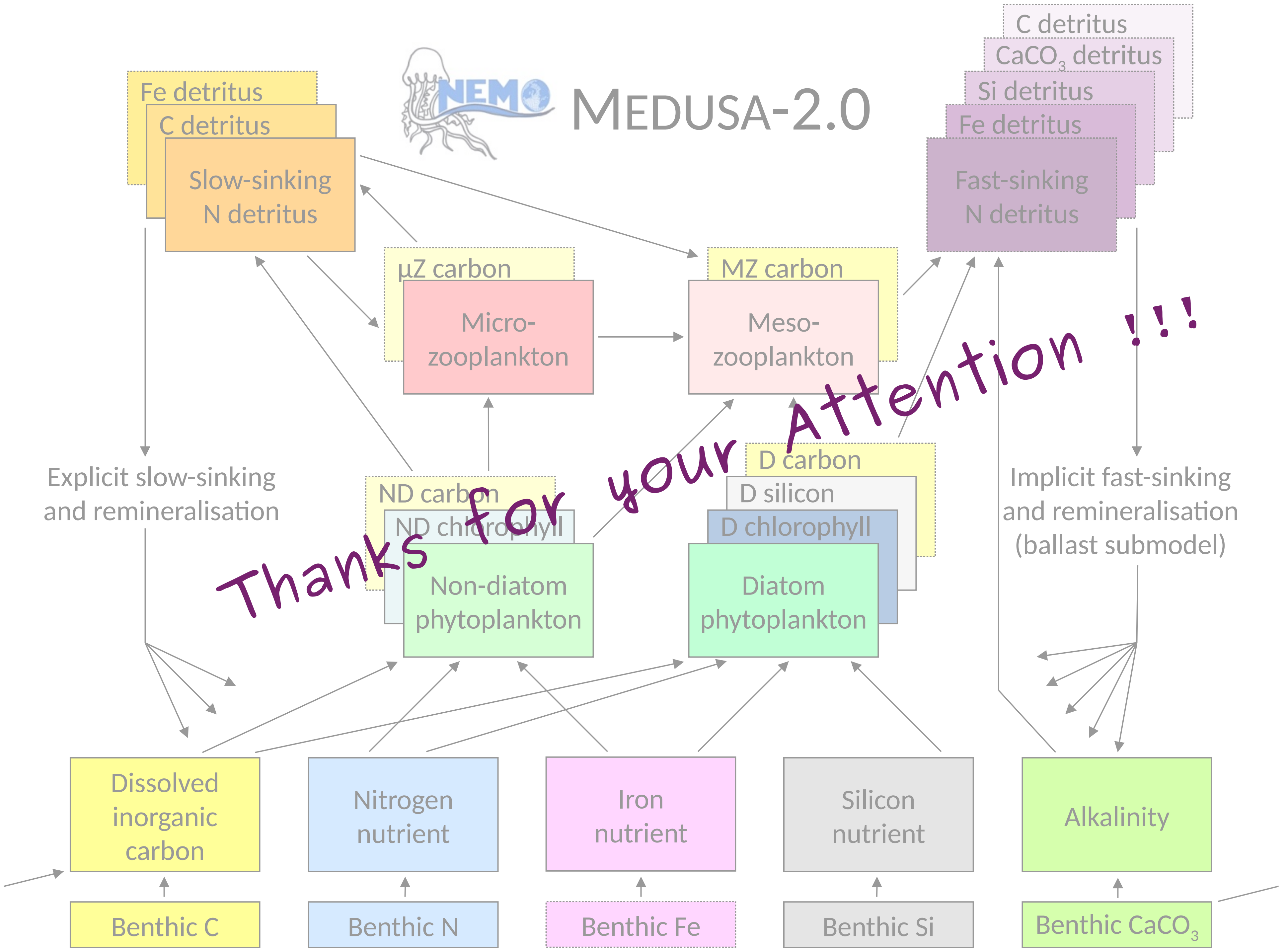
Dust deposition is important for the iron it provides (or not) in iron limited area.

- Dust dep. extremely important.
  Controls Primary prod. in large areas through iron limitation.
- UKCA-MEDUSA coupling – models biogeoch. changes and feedbacks related to dust deposition changes.



Plus -

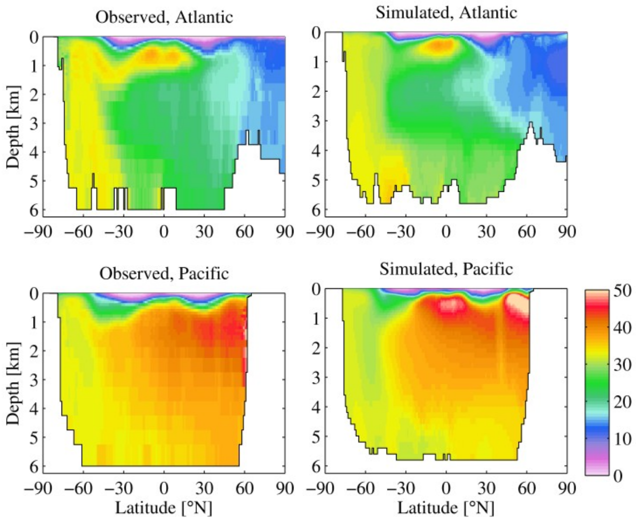
- Lots of “invisible” development for MEDUSA to best fit the new NEMO version (3.6)
- Also added an “ideal” tracer to evaluate the water mass ventilation



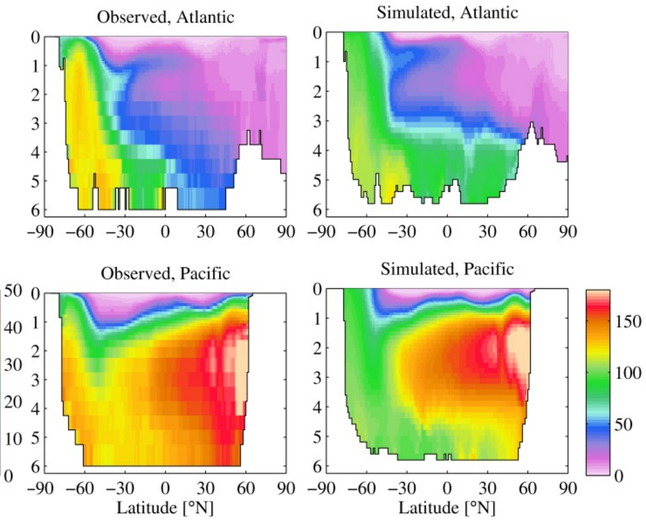
Thanks for your Attention !!!

Yool *et al.*, 2013

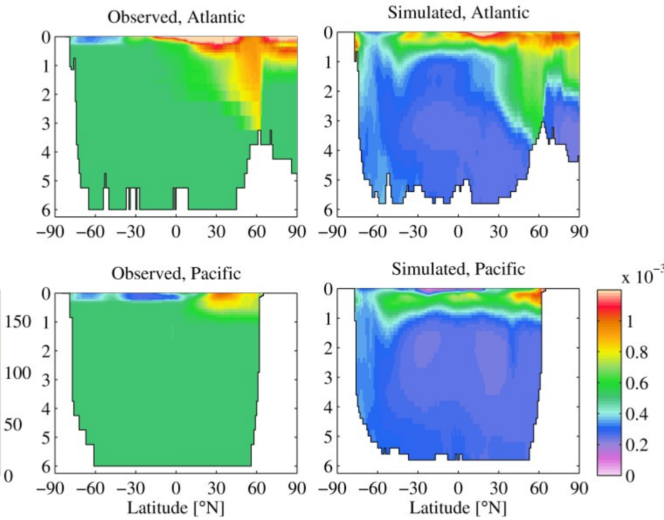
DIN



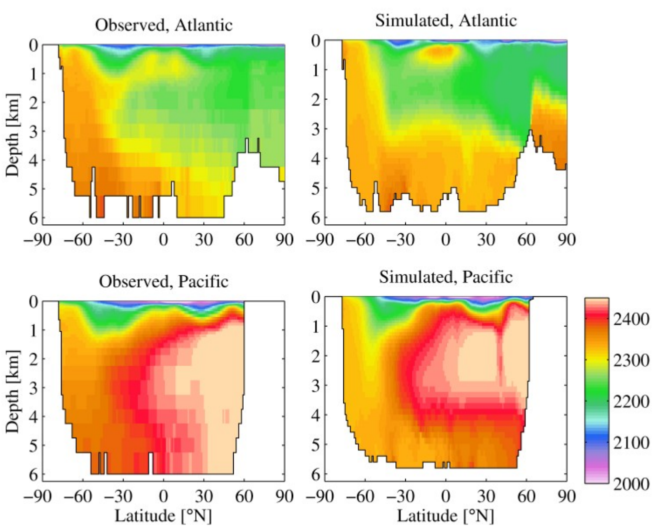
Silicic acid



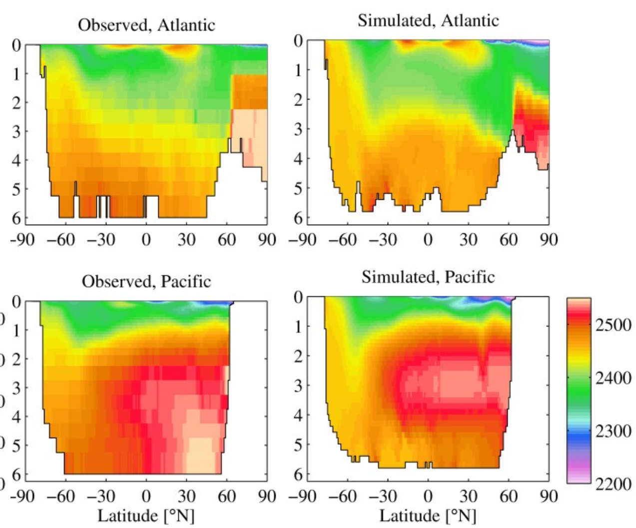
Iron



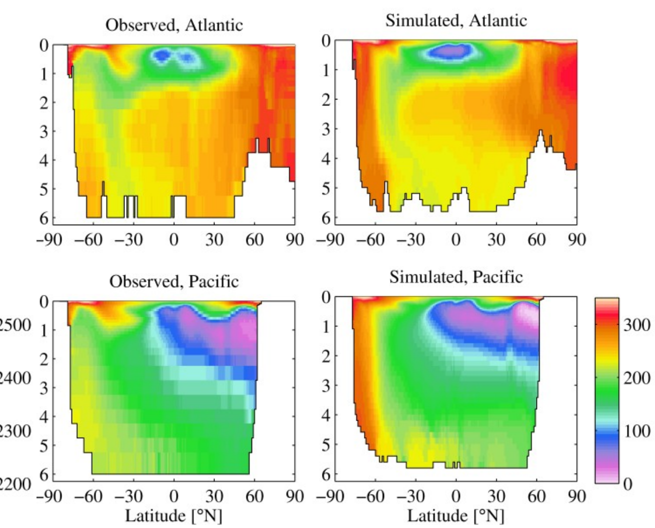
DIC



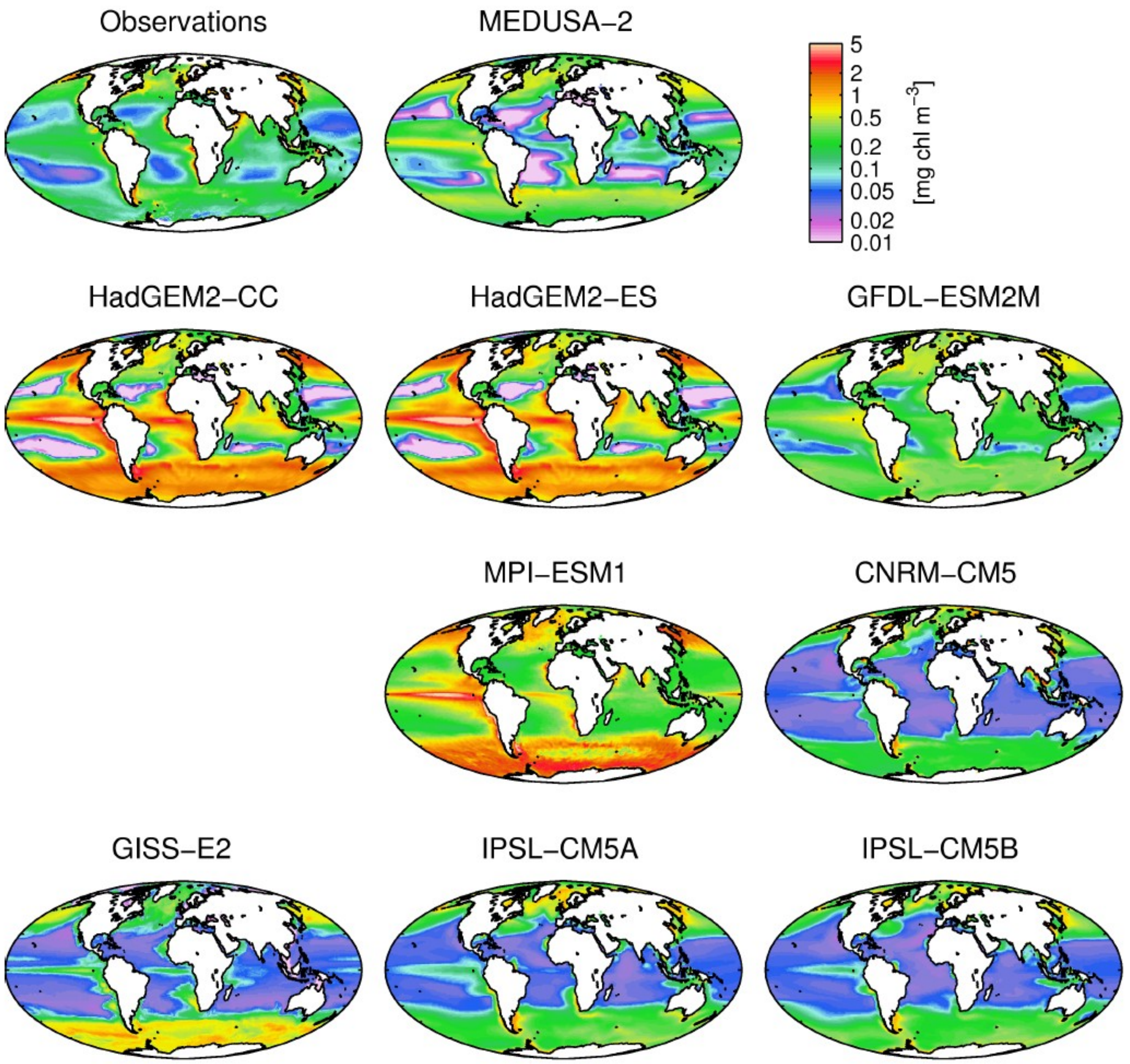
Alkalinity

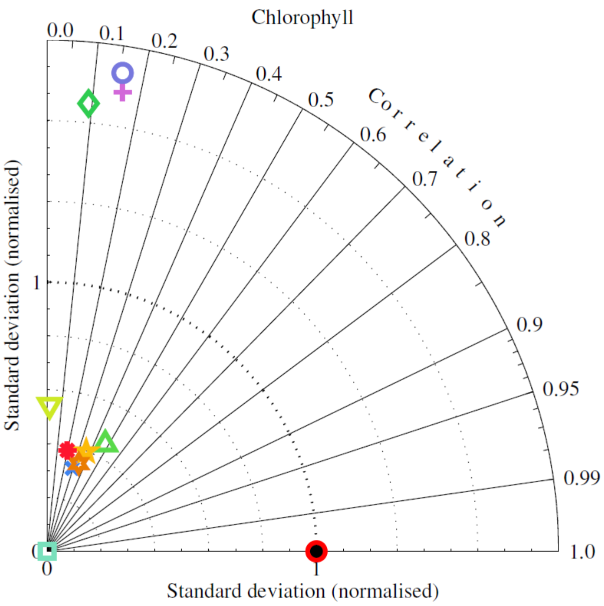


Oxygen

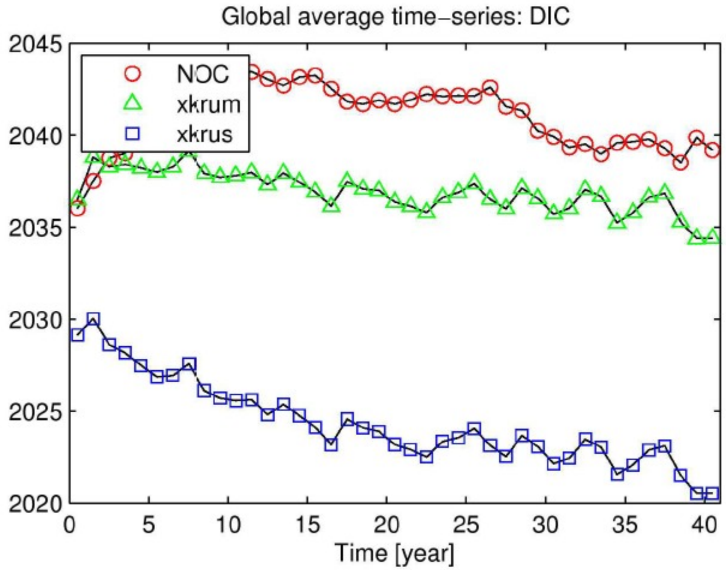


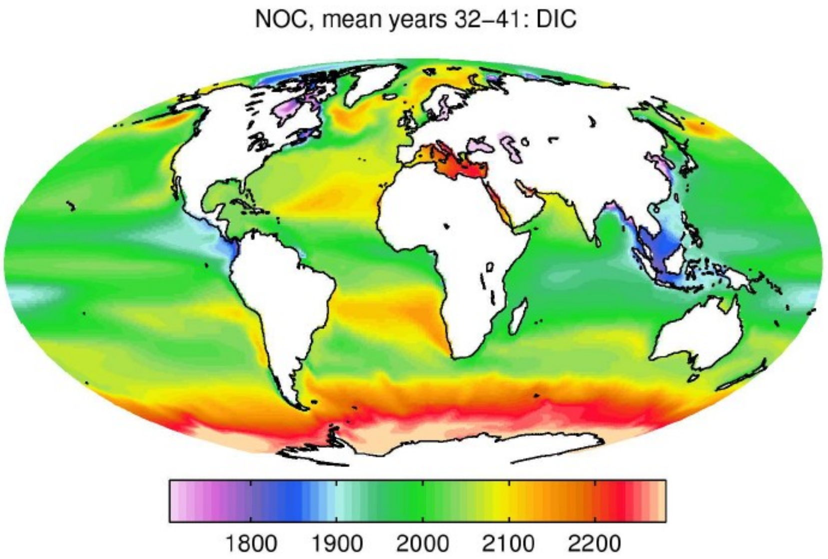
Meanwhile, in CMIP5 ...

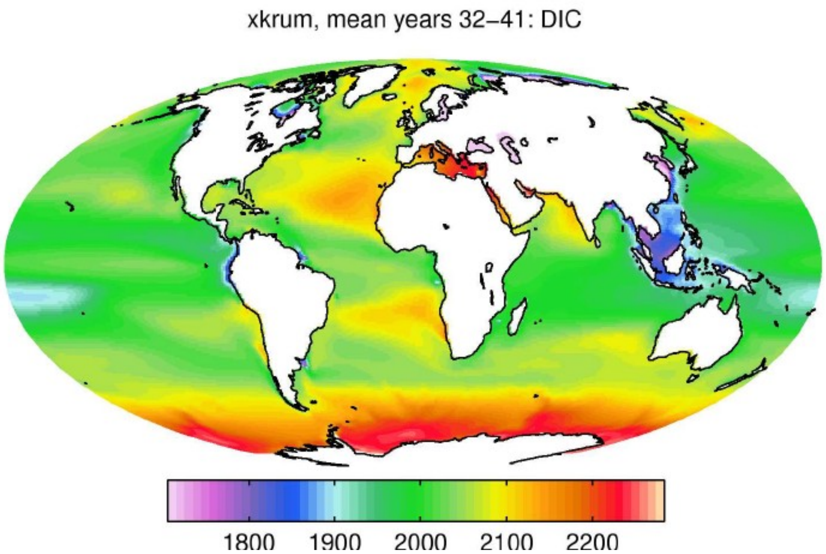


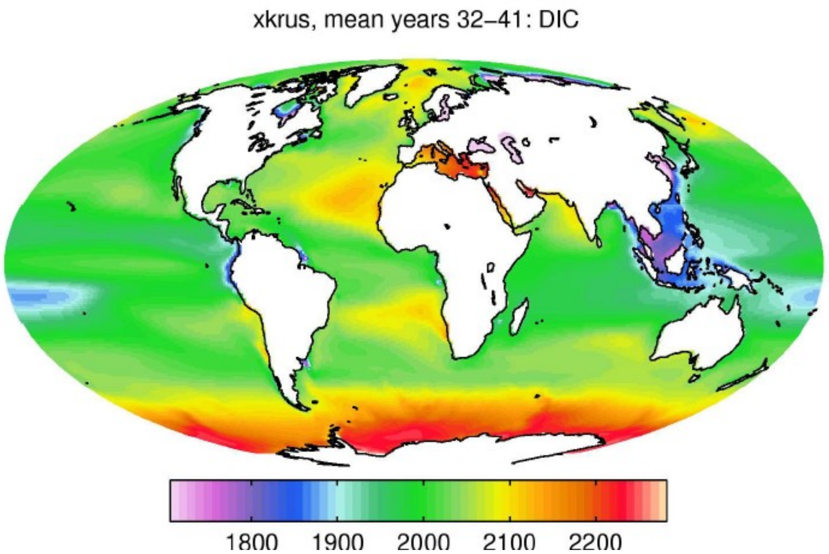


DIC

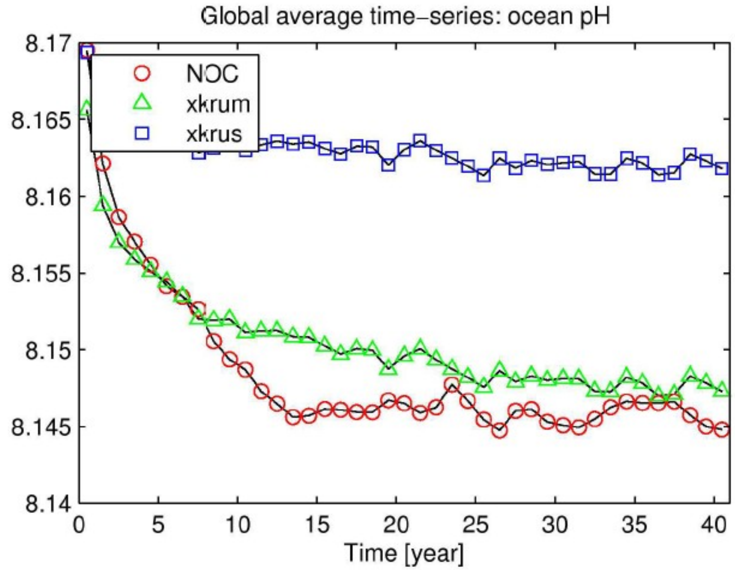

Global average time−series: DIC
NOC
xkrum
xkrus
2045
2040
2035
2030
2025
2020
0
5
10
15
20
25
30
35
40
Time [year]

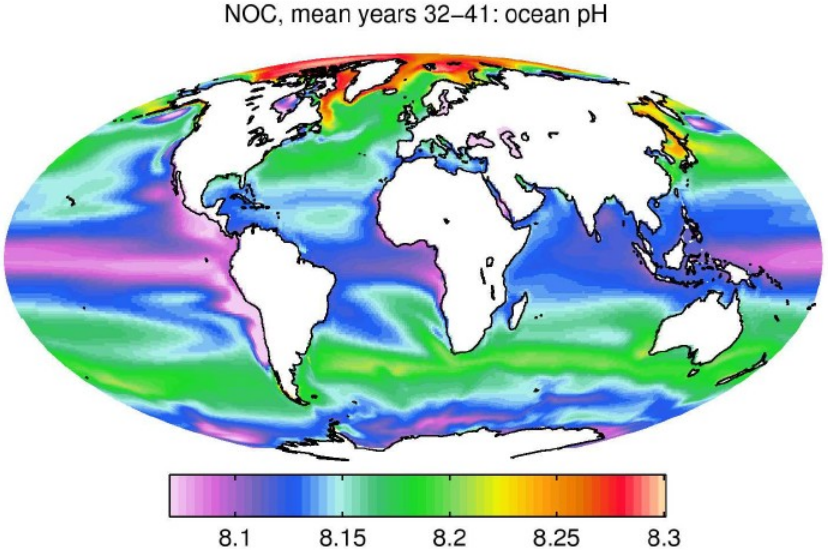

NOC, mean years 32−41: DIC
1800
1900
2000
2100
2200

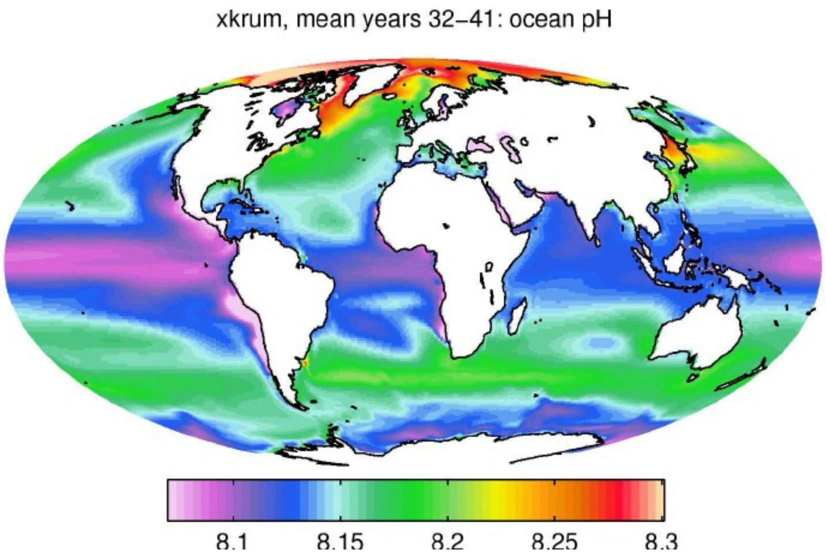

xkrum, mean years 32−41: DIC
1800
1900
2000
2100
2200

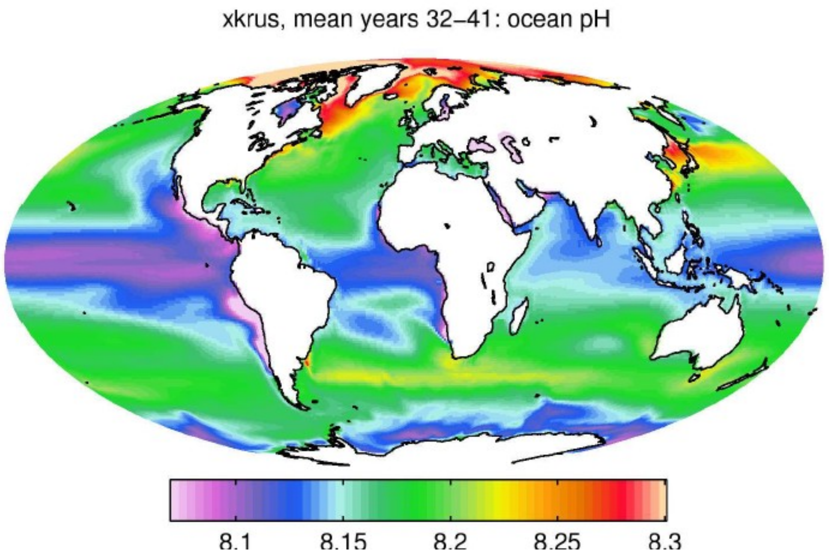

xkrus, mean years 32−41: DIC
1800
1900
2000
2100
2200

pH

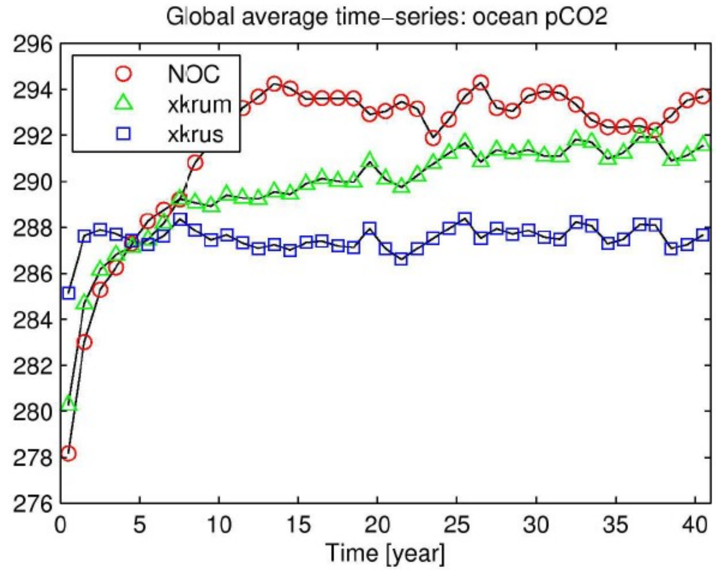

Global average time−series: ocean pH
NOC
xkrum
xkrus
8.17
8.165
8.16
8.155
8.15
8.145
8.14
0
5
10
15
20
25
30
35
40
Time [year]

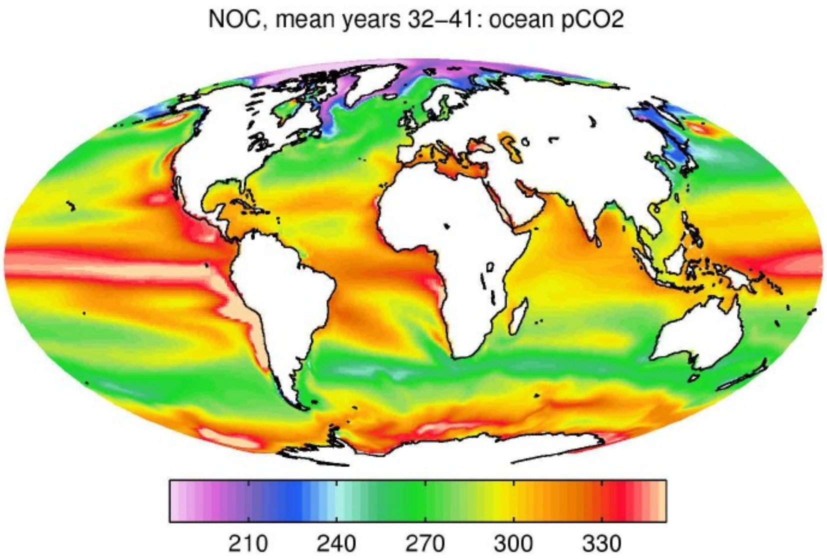

NOC, mean years 32−41: ocean pH
8.1
8.15
8.2
8.25
8.3

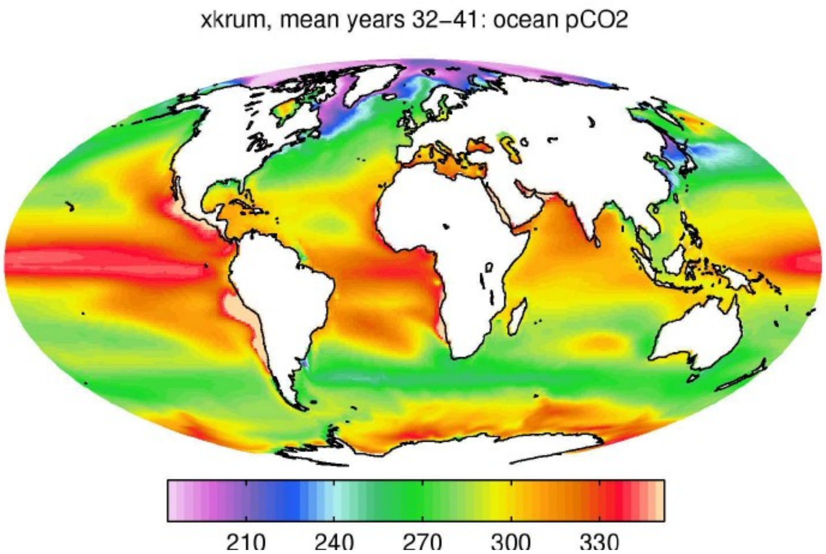

xkrum, mean years 32−41: ocean pH
8.1
8.15
8.2
8.25
8.3

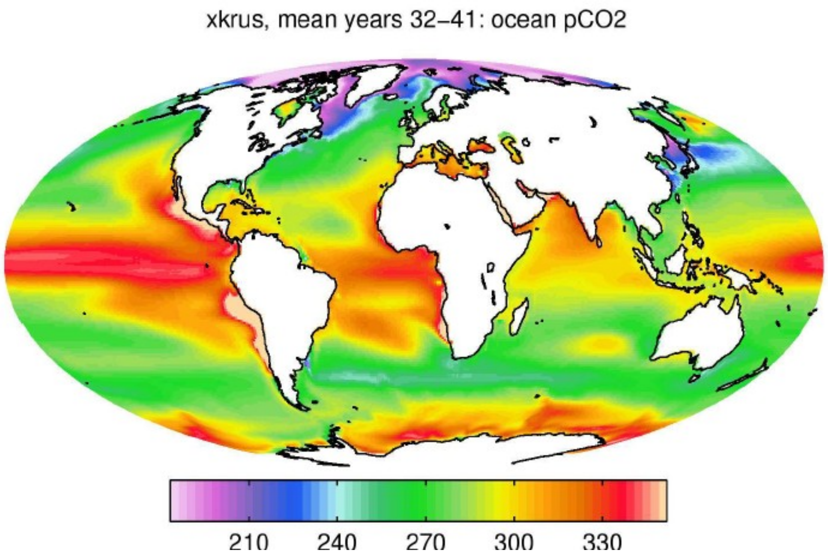

xkrus, mean years 32−41: ocean pH
8.1
8.15
8.2
8.25
8.3

pCO_2

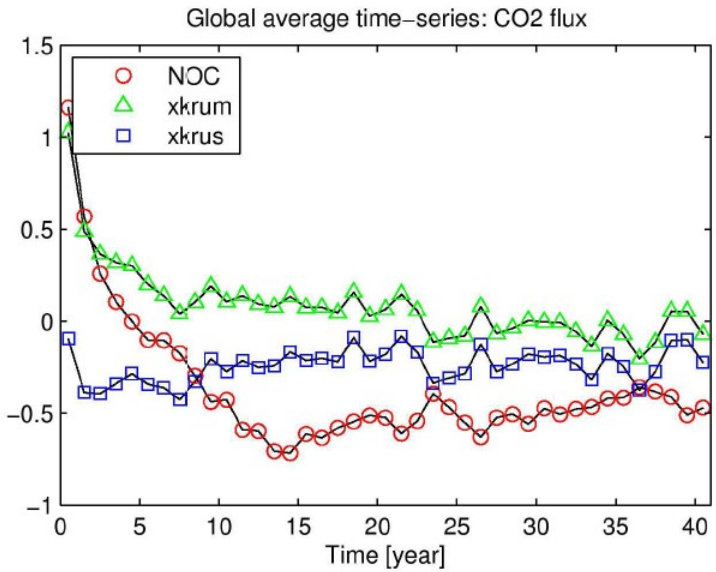

Global average time−series: ocean pCO2
NOC
xkrum
xkrus
296
294
292
290
288
286
284
282
280
278
276
0
5
10
15
20
25
30
35
40
Time [year]

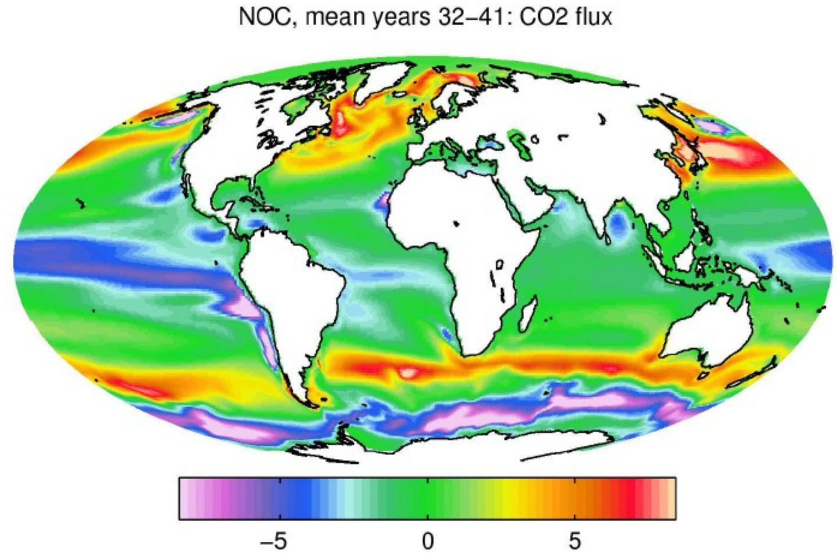

NOC, mean years 32−41: ocean pCO2
210
240
270
300
330

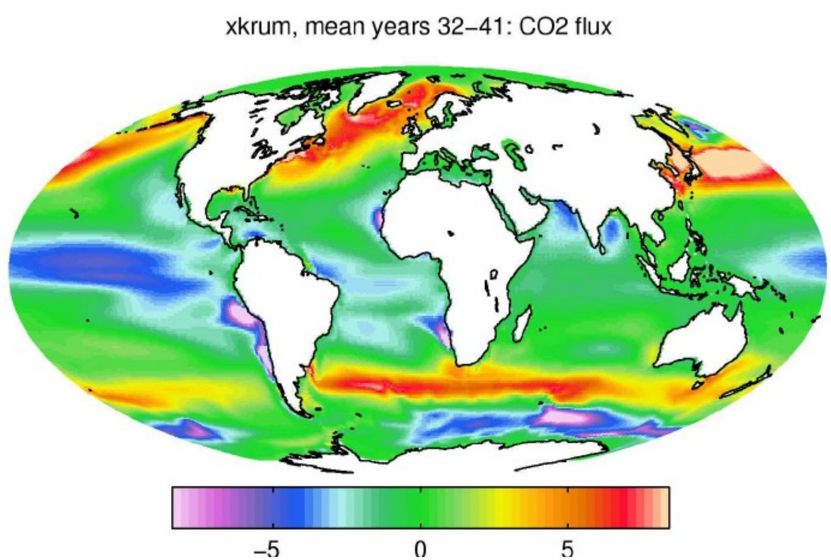

xkrum, mean years 32−41: ocean pCO2
210
240
270
300
330

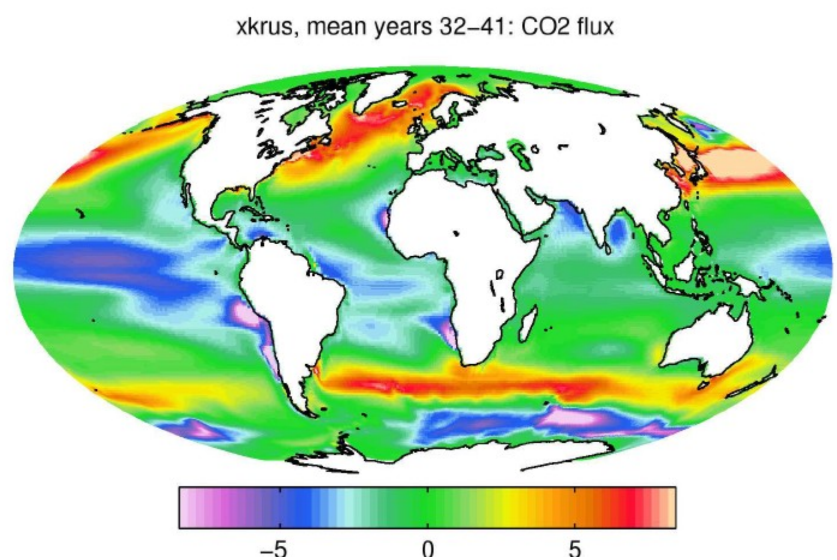

xkrus, mean years 32−41: ocean pCO2
210
240
270
300
330

Air-sea flux

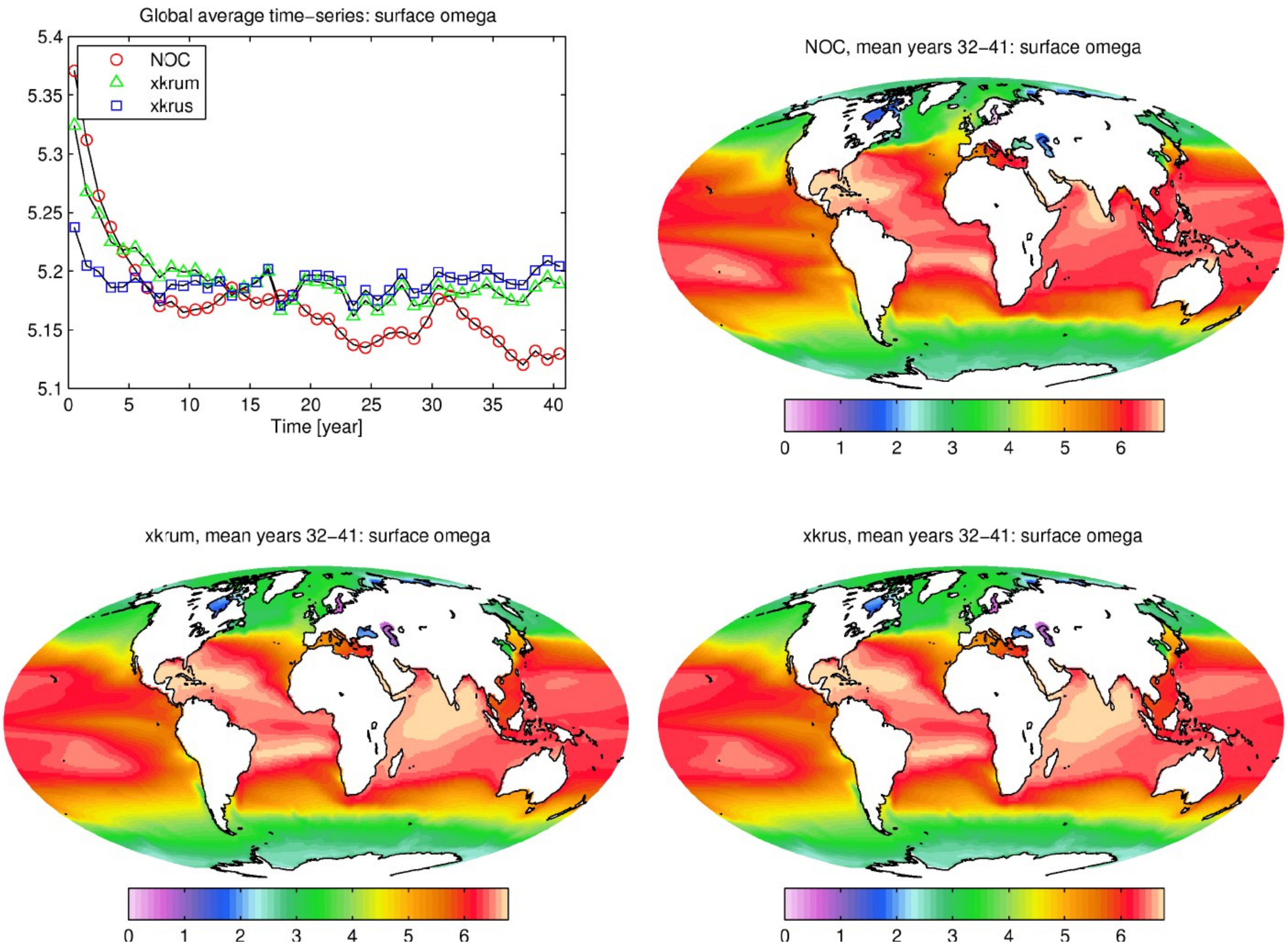

Global average time−series: CO2 flux
NOC
xkrum
xkrus
1.5
1
0.5
0
−0.5
−1
0
5
10
15
20
25
30
35
40
Time [year]


NOC, mean years 32−41: CO2 flux
−5
0
5

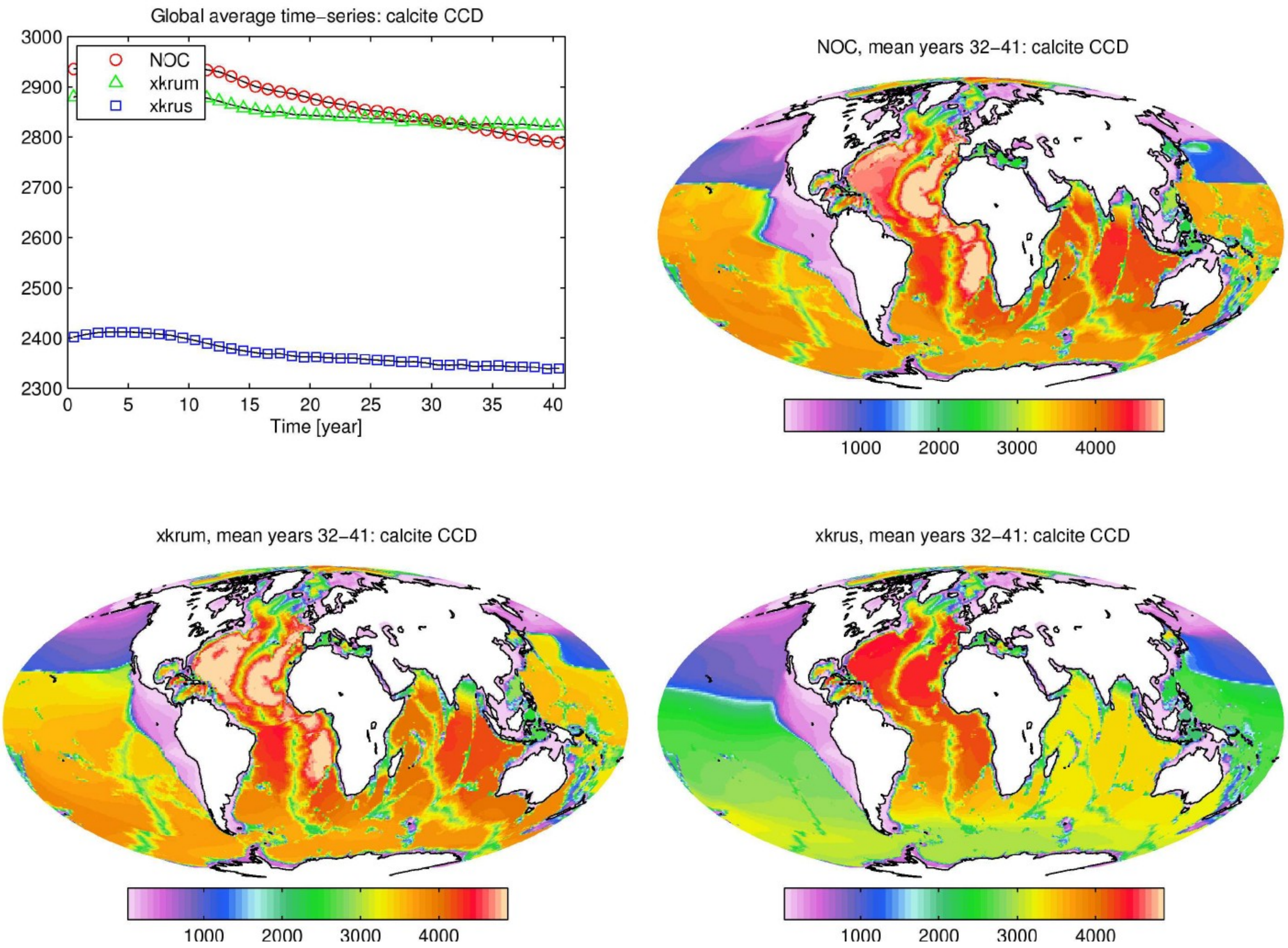

xkrum, mean years 32−41: CO2 flux
−5
0
5


xkrus, mean years 32−41: CO2 flux
−5
0
5

Surface omega



Calcite compensation depth



Carbonate chemistry

- MOCSY (Orr et al., GMD, 2015) carbonate chemistry scheme added to MEDUSA
- Uses up-to-date parameterisations
- Previous scheme (Blackford et al., 2007) remains compile-time default (i.e. if key_mocsy is absent)
- Wanninkhof (2014) Schmidt number and gas transfer velocity schemes added (new default)
- Implementation of MOCSY also harmonises gas transfer velocity across MEDUSA (an old bug)