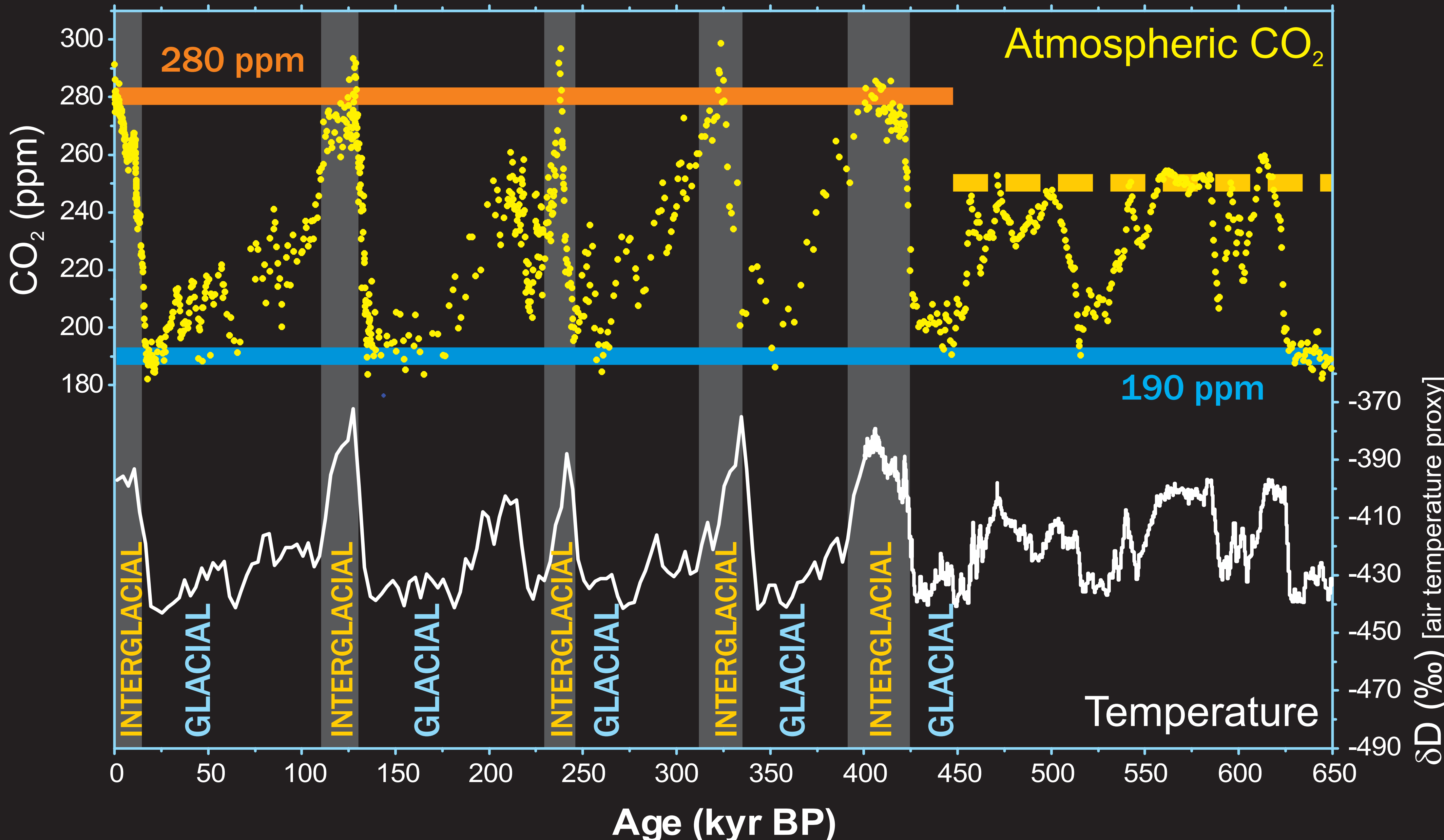
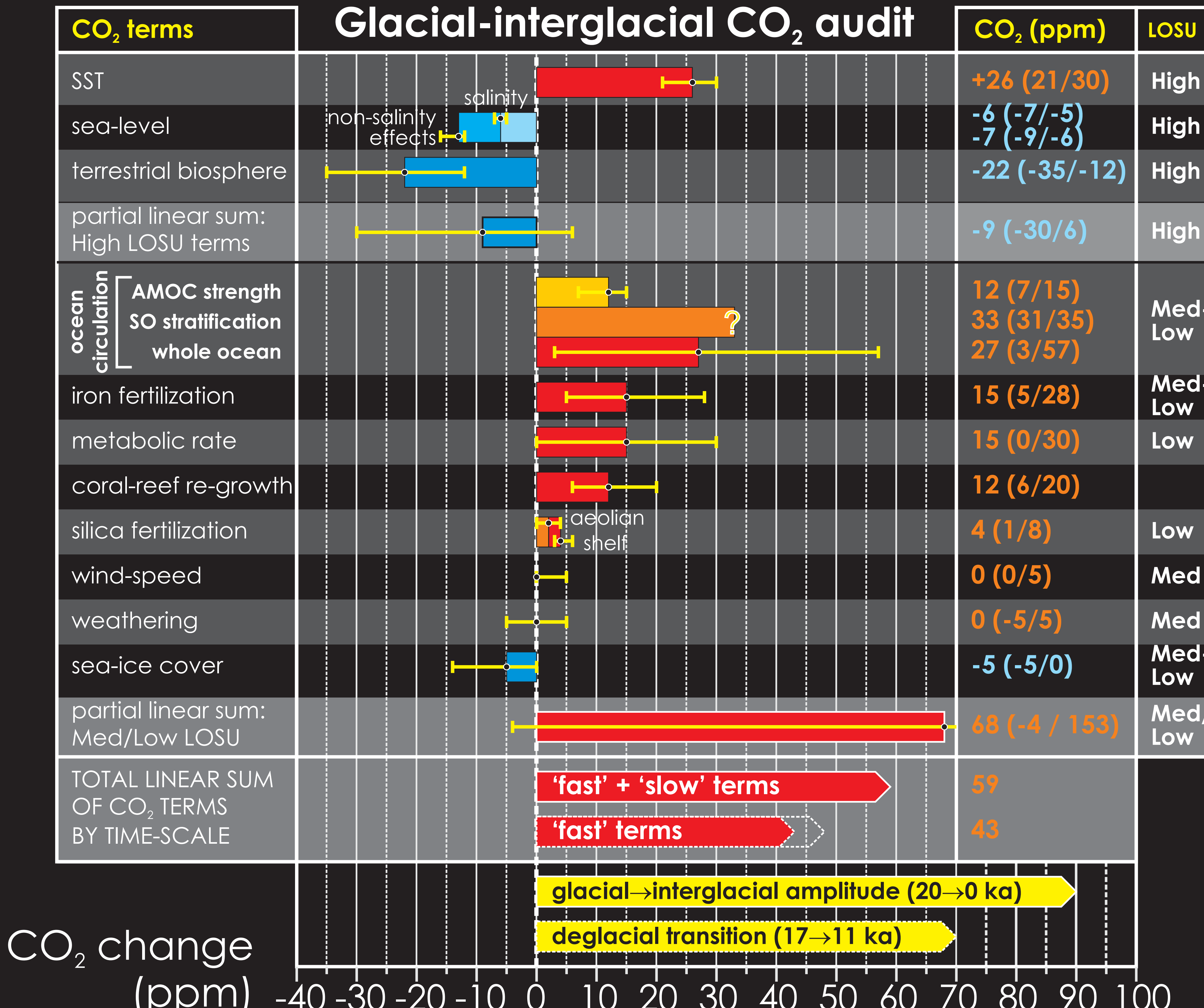
Classic CO_2 (and climate) problems in 'shallow time':
Why was glacial CO_2 'low'?

Dome C and Vostok ice core data; *Siegenthaler et al.* [2005] (*Science* **310**)



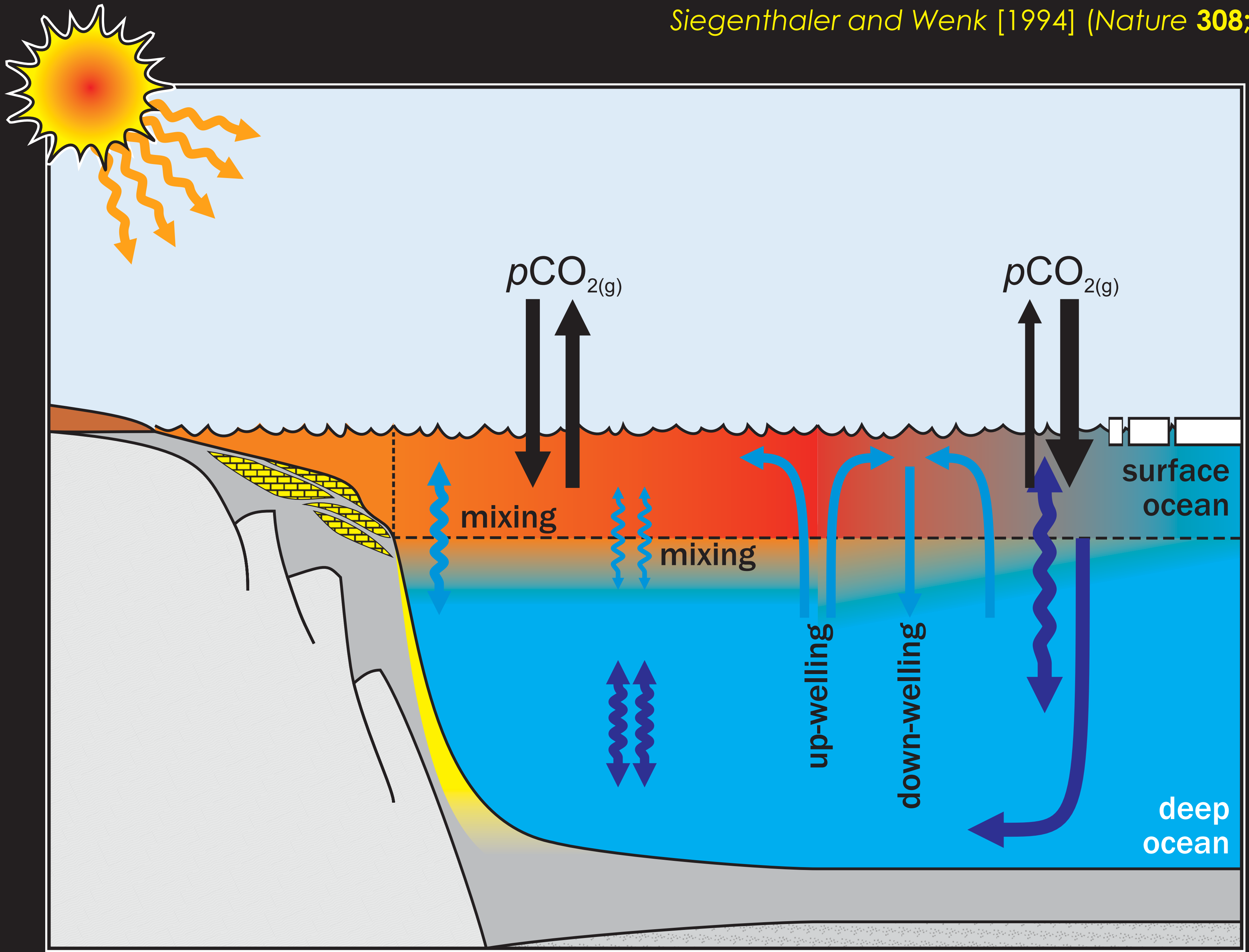


Glacial-interglacial CO_2 audit
CO_2 terms
CO_2 (ppm)
LOSU
SST
+26 (21/30)
High
sea-level
salinity
non-salinity effects
-6 (-7/-5)
-7 (-9/-6)
High
terrestrial biosphere
-22 (-35/-12)
High
partial linear sum: High LOSU terms
-9 (-30/6)
High
ocean circulation
AMOC strength
SO stratification
whole ocean
12 (7/15)
33 (31/35)
27 (3/57)
Med-Low
iron fertilization
15 (5/28)
Med-Low
metabolic rate
15 (0/30)
Low
coral-reef re-growth
12 (6/20)
silica fertilization
aeolian
shelf
4 (1/8)
Low
wind-speed
0 (0/5)
Med
weathering
0 (-5/5)
Med
sea-ice cover
-5 (-5/0)
Med-Low
partial linear sum: Med/Low LOSU
68 (-4 / 153)
Med/Low
TOTAL LINEAR SUM OF CO_2 TERMS BY TIME-SCALE
'fast' + 'slow' terms
59
'fast' terms
43
glacial→interglacial amplitude (20→0 ka)
deglacial transition (17→11 ka)
CO_2 change (ppm)
-40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100

SST

Lower LGM ocean surface temperatures enhance the solubility of CO_2, increasing the sequestration of CO_2 in the ocean interior.

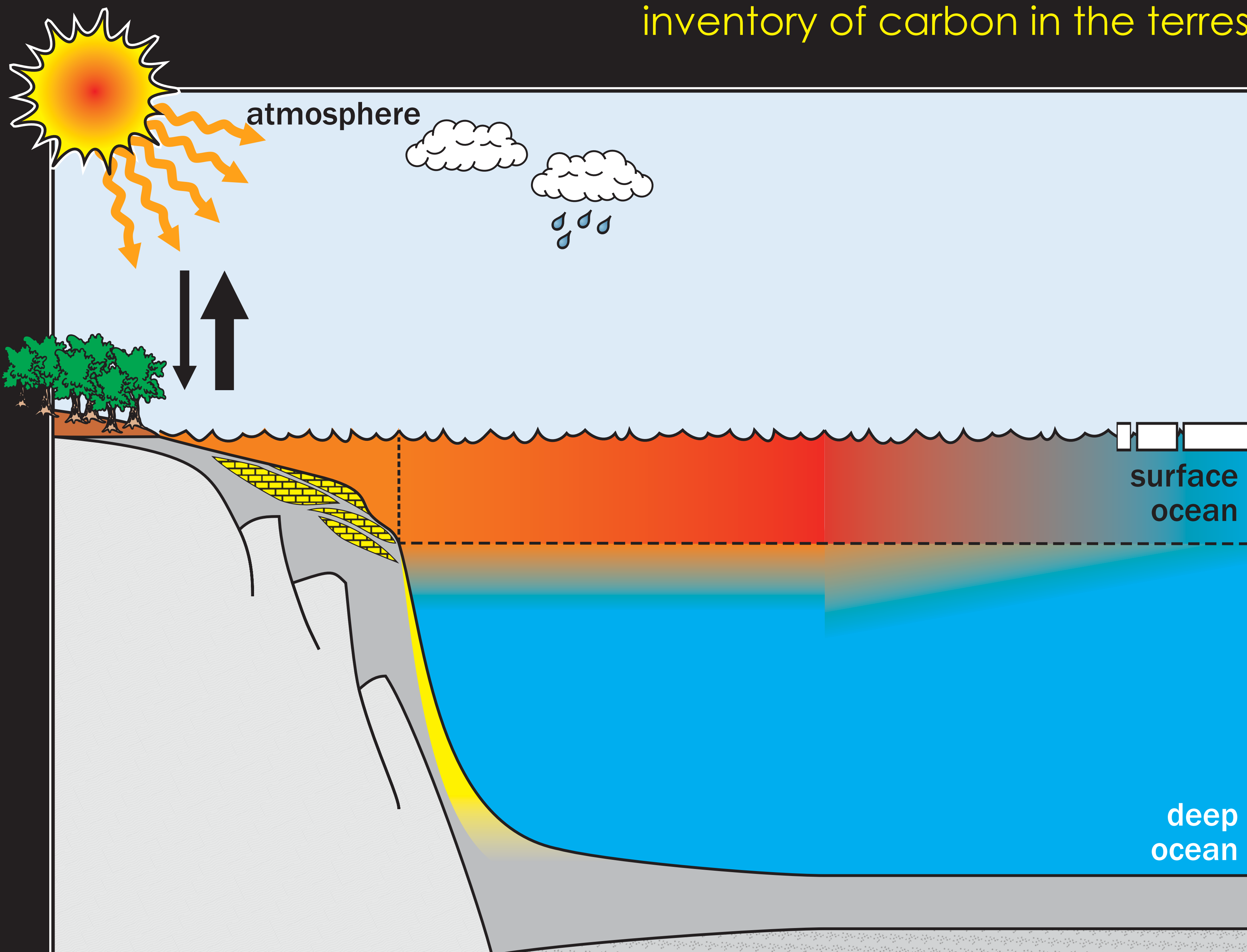
Siegenthaler and Wenk [1994] (*Nature* **308**; *Keir* [1993] (*JGR* **98**)



> Change the ocean temperature in the **C-Model** and explore how sensitive atmospheric $p\mathrm{CO}_2$ is to an e.g. ~4°C glacial cooling (relative to the Holocene).

Terrestrial carbon

A colder, drier glacial climate, and lower pCO_2 and hence reduced CO_2 'fertilization' of productivity, is likely to have resulted in a reduced inventory of carbon in the terrestrial biosphere.



> Fossil fuel CO_2 emission experiments have been envisaged as the main application of the model but this can be made use of.

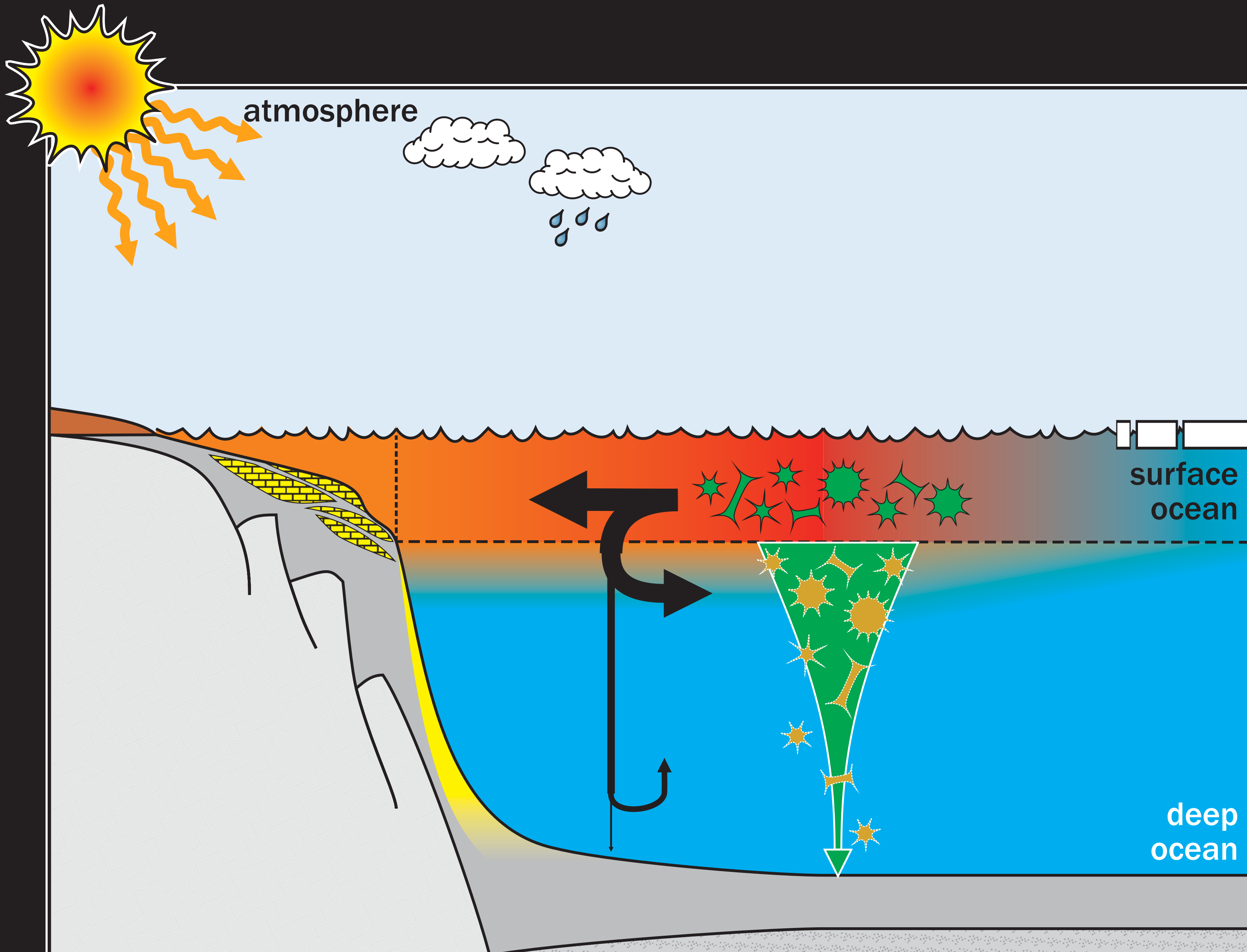
> Add Fossil Fuels
> Fossil Fuels *On*
> *Sinewave*
(avoids complications and additional emissions associate with SRES emissions scenarios)
> Enter a total amount

> Hint: estimates of CO_2 addition to the ocean/atmosphere at last glacial range from ca. 300-700 PgC.

Q. What constraints might there be on the amount of terrestrial carbon transferred to the ocean+atmosphere?

Q. How much added CO_2 stays in the atmosphere compared with in the ocean? (Is this independent of the amount of CO_2 released?)

Marine biology and the 'biological pump'



> Other ways of changing ocean productivity (and the biological pump) that are plausible and testable?

> Model parameters
> Biological
> Lower the ‘half saturation’ value.
Be careful not to increase the algal maximum growth rate too high ... you can crash the model ...

> Or:

> Set Initial Conditions
> Phosphorous
> *Surface*, *Middle*, and/or *Deep* Phosphorous

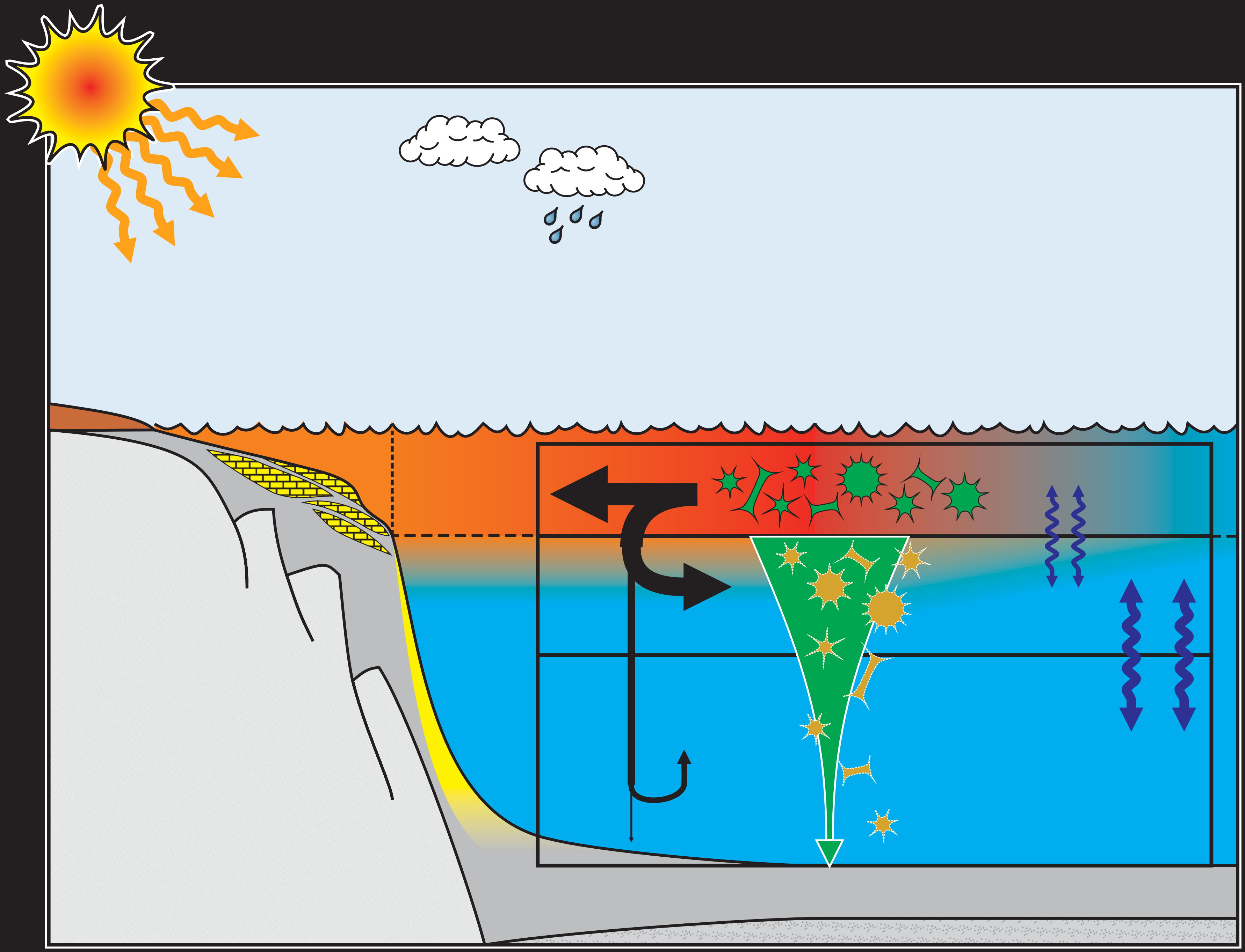
Q. What sort of paleoceanographic constraints can be brought to bear on the model?

Q. Other further ways of changing the biological pump (efficiency)?

> Model Parameters
> Organic Carbon
> *Fraction Remineralized*

> Q. What sort of paleoceanographic constraints can be brought to bear on the model?
(And/or ice-core constraints?)

Ocean circulation



> AMOC, AABW/CPDW production changes ... ?

> What about testing deep stratification? (i.e. the idea that e.g. a deep highly saline layer sat at the bottom of the ocean).

> Model Parameters
> Physical
> *mixing* (intermediate to deep)