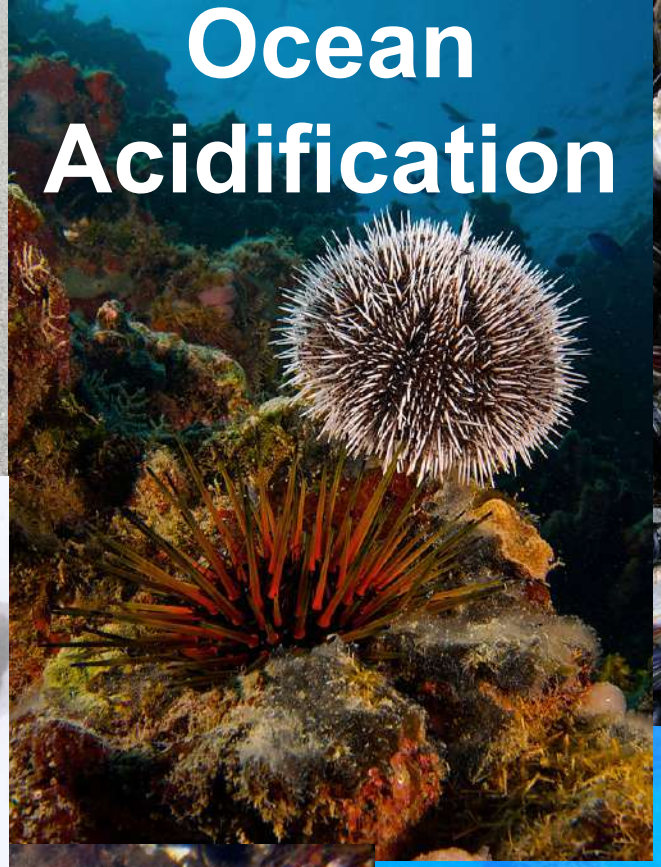
Ocean Acidification

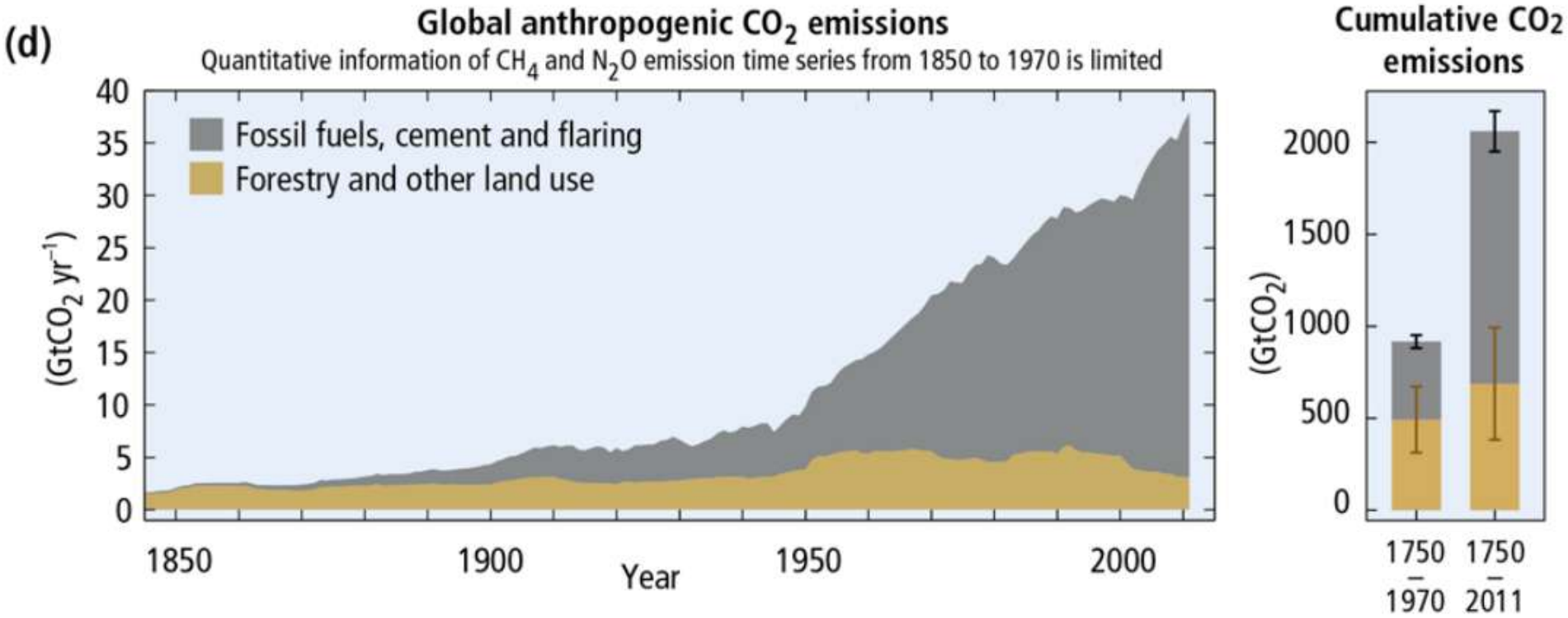


Learning Objectives

By the end of this unit, you will be able to:

- describe carbon dioxide dissolution and solubility in the context of the ocean carbon system
- explain how the ocean carbon system buffers the ocean against rapid changes in seawater pH, and …
- interpret real seawater pH and pCO_2 data

Human activities & atmospheric CO_2



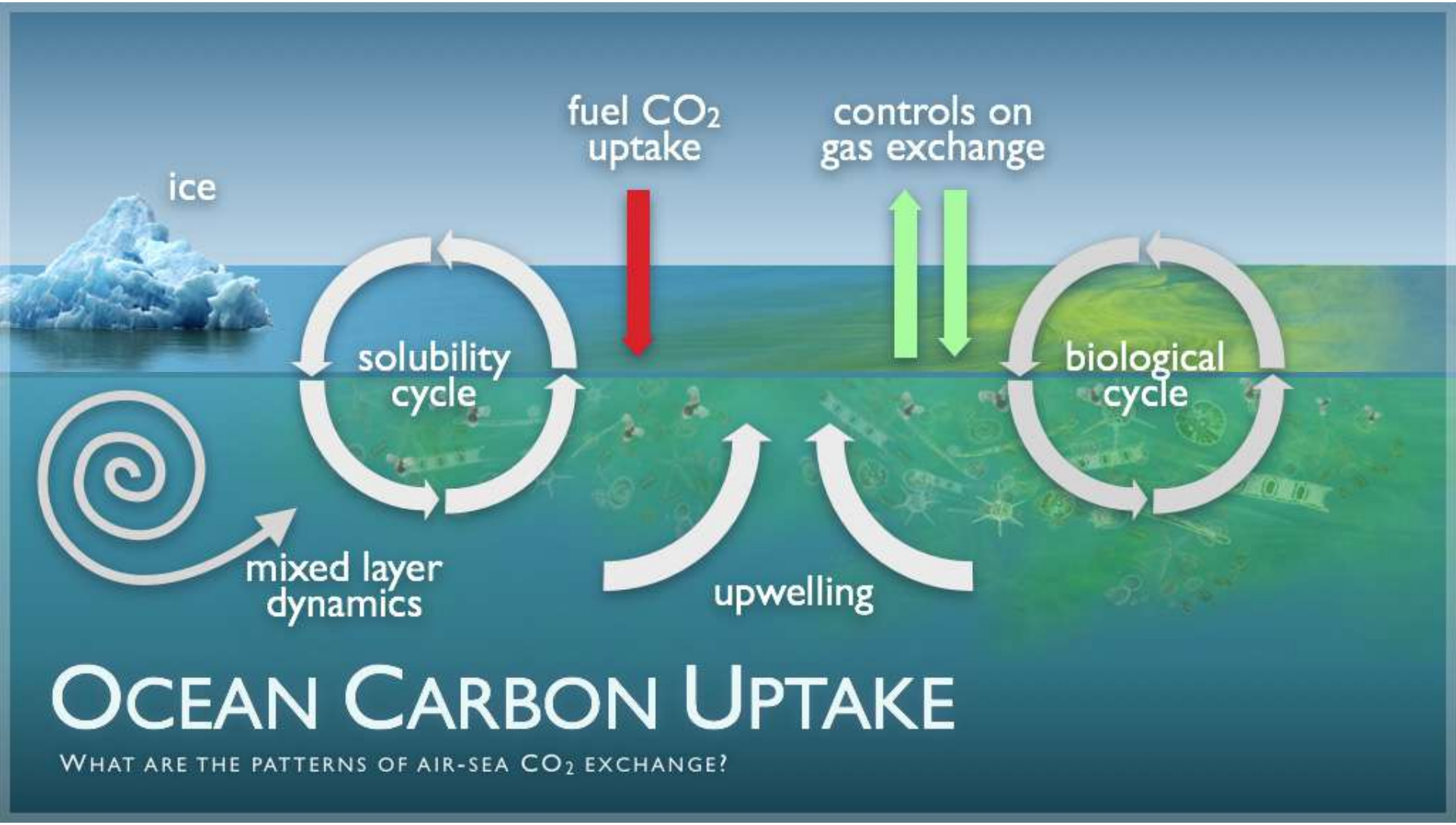
5th Assessment Report of the Intergovernmental Panel on Climate Change (2014)

Instructor Carbon Footprint

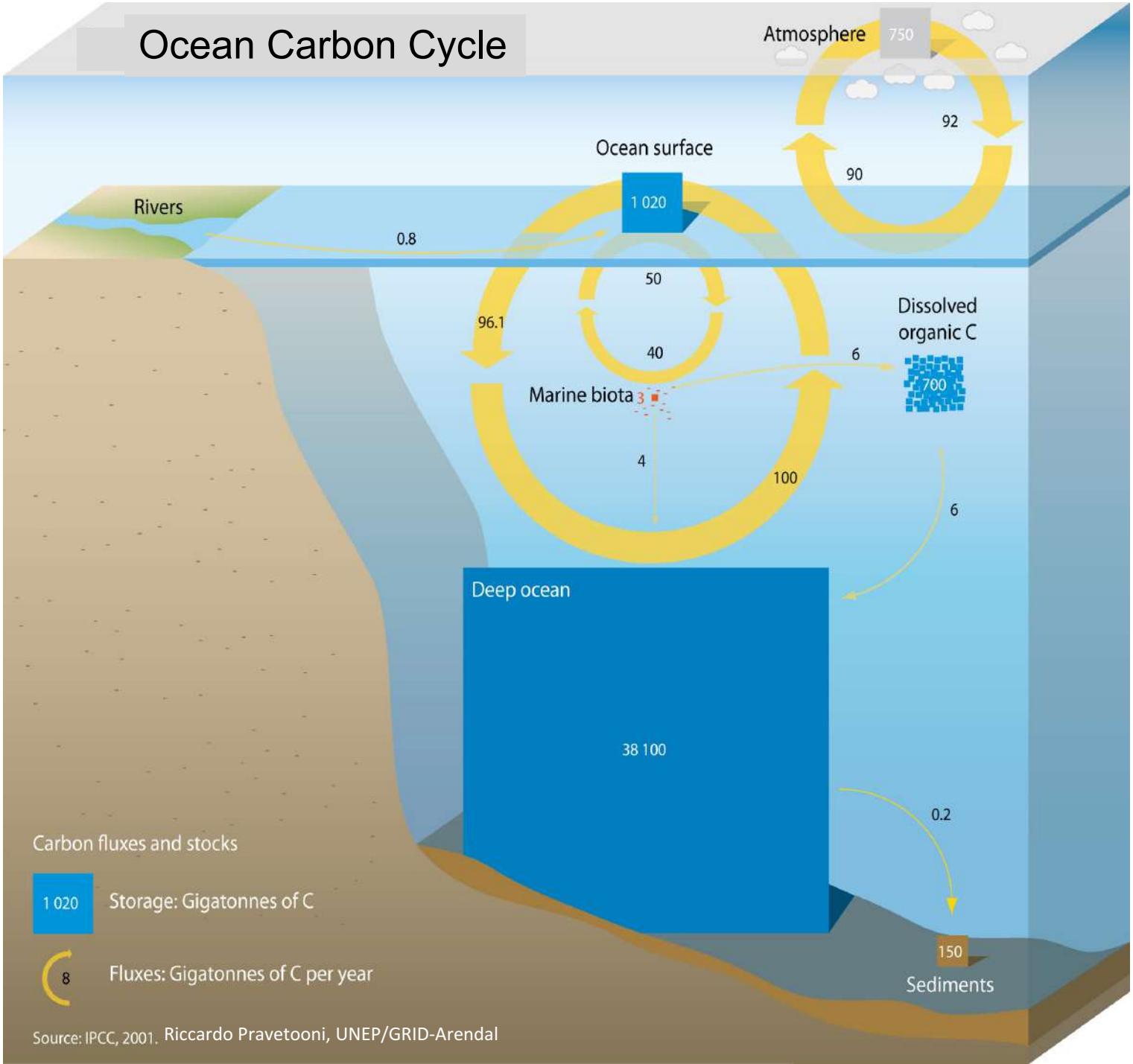
- 22 tons CO_2 eq per year emitted
- 5.5 tons of CO_2 eq per year absorbed by ocean

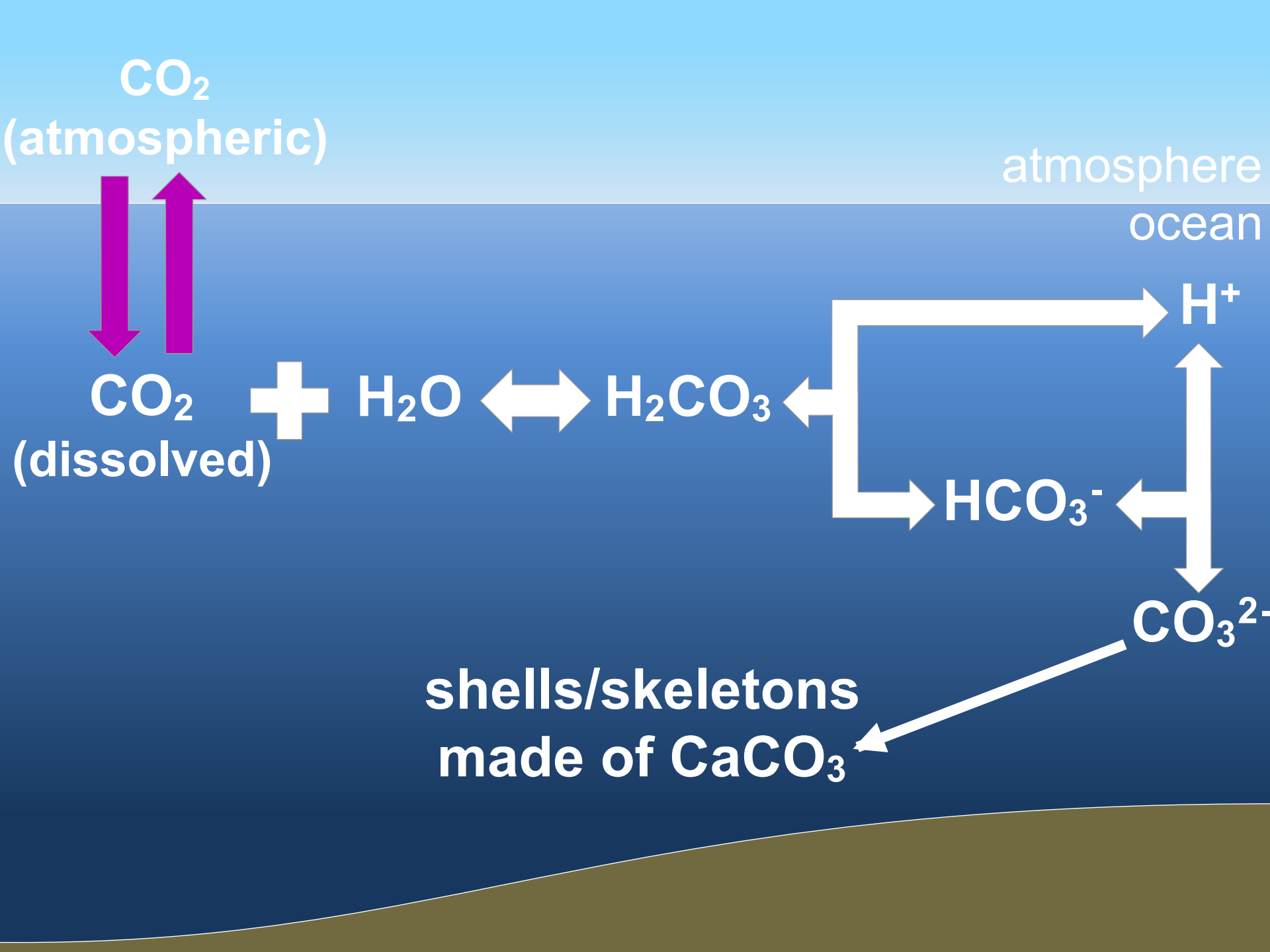
What happens to CO_2 in the ocean?

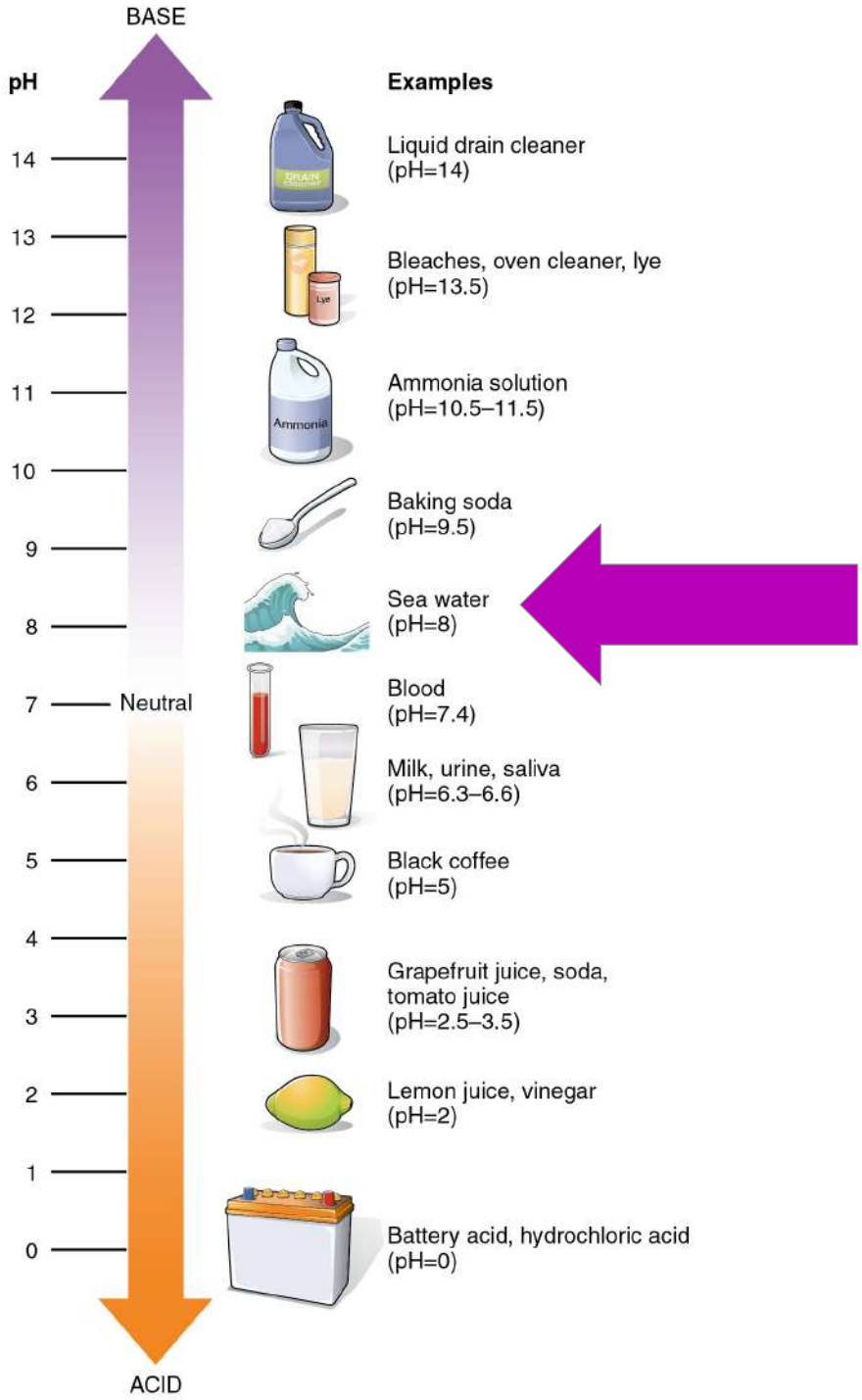
Ocean Absorption of CO_2

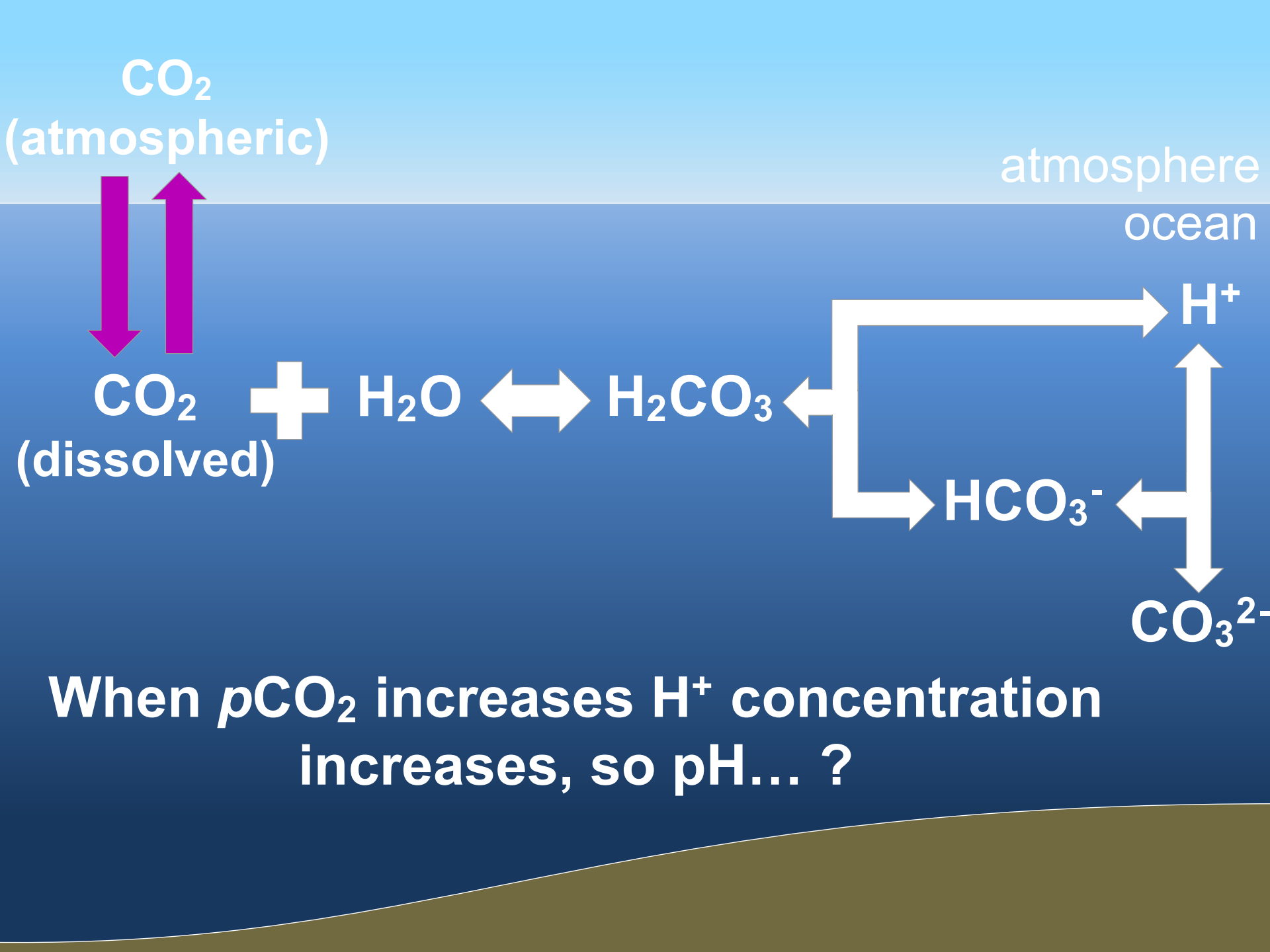


PMEL Carbon Program NOAA

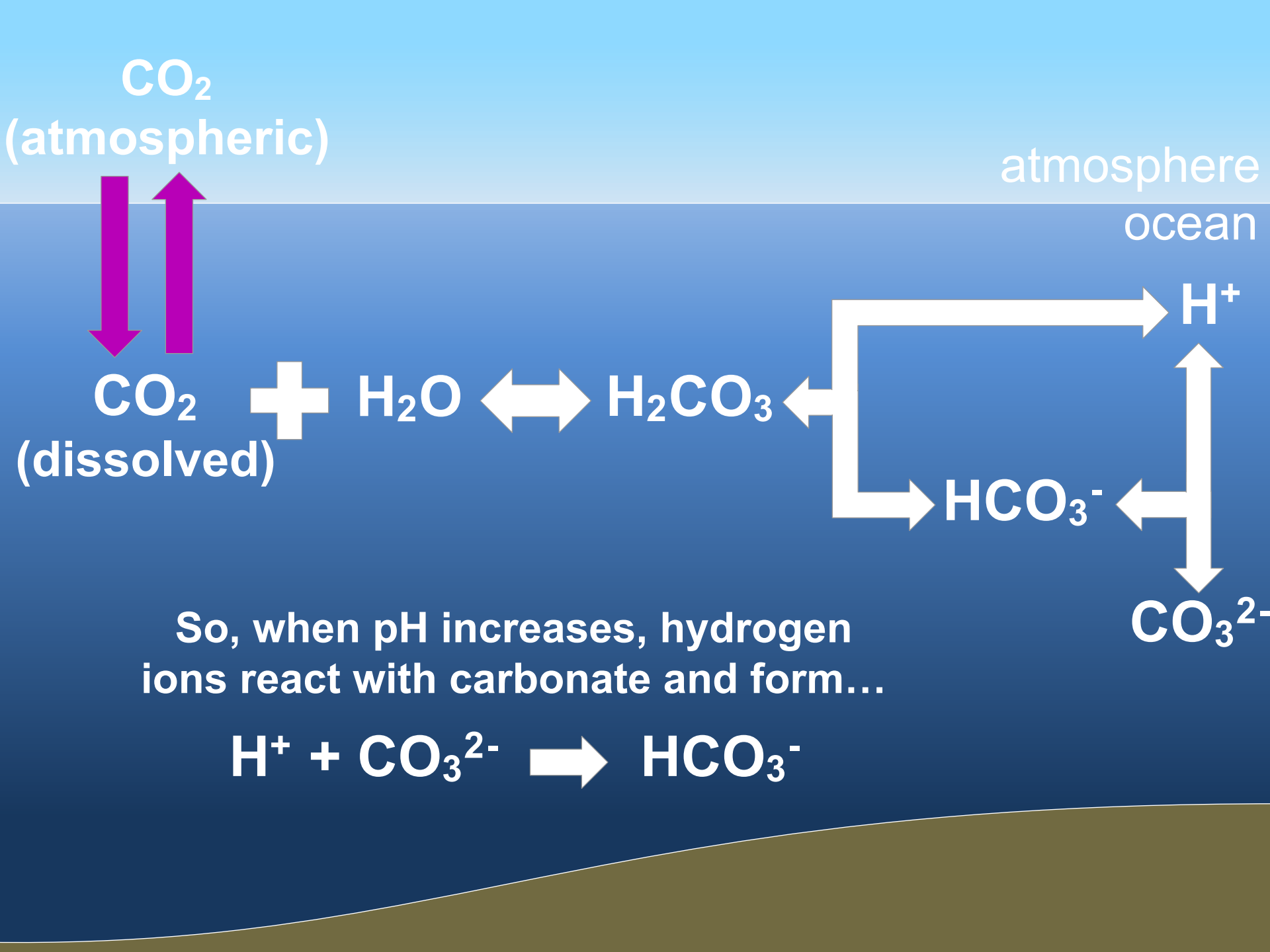

Ocean Carbon Cycle
Atmosphere
750
92
90
Ocean surface
1 020
Rivers
0.8
50
96.1
40
Marine biota 3
6
Dissolved organic C
700
4
100
6
Deep ocean
38 100
0.2
150
Sediments
Carbon fluxes and stocks
1 020
Storage: Gigatonnes of C
8
Fluxes: Gigatonnes of C per year
Source: IPCC, 2001.
Riccardo Pravetooni, UNEP/GRID-Arendal


CO_2
(atmospheric)
atmosphere
ocean
CO_2
(dissolved)
H_2O
H_2CO_3
H^+
HCO_3^-
CO_3^{2-}
shells/skeletons
made of $CaCO_3$


BASE
pH
Examples
14
13
12
11
10
9
8
7
Neutral
6
5
4
3
2
1
0
ACID
Liquid drain cleaner
(pH=14)
Bleaches, oven cleaner, lye
(pH=13.5)
Ammonia solution
(pH=10.5–11.5)
Baking soda
(pH=9.5)
Sea water
(pH=8)
Blood
(pH=7.4)
Milk, urine, saliva
(pH=6.3–6.6)
Black coffee
(pH=5)
Grapefruit juice, soda,
tomato juice
(pH=2.5–3.5)
Lemon juice, vinegar
(pH=2)
Battery acid, hydrochloric acid
(pH=0)

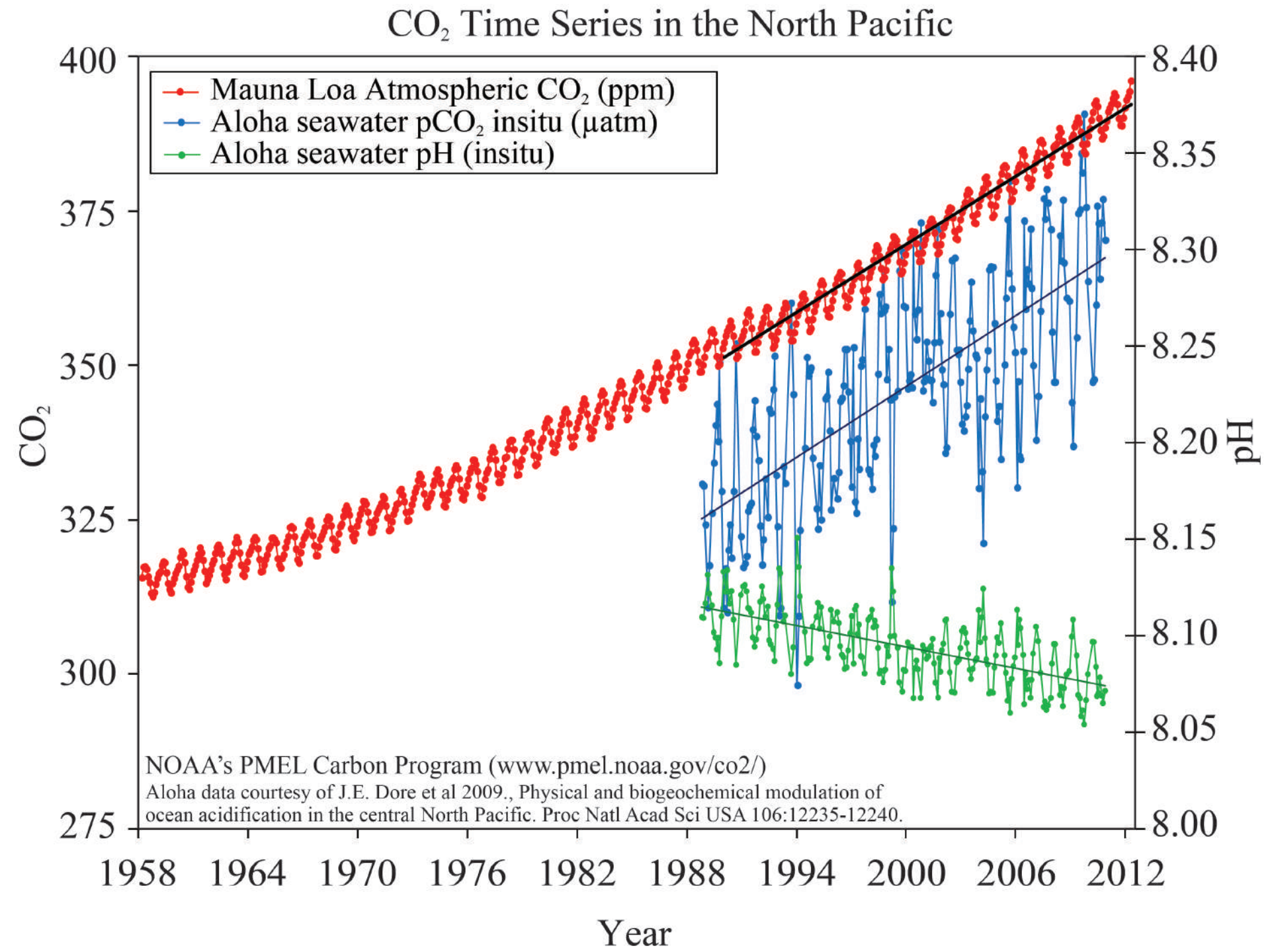


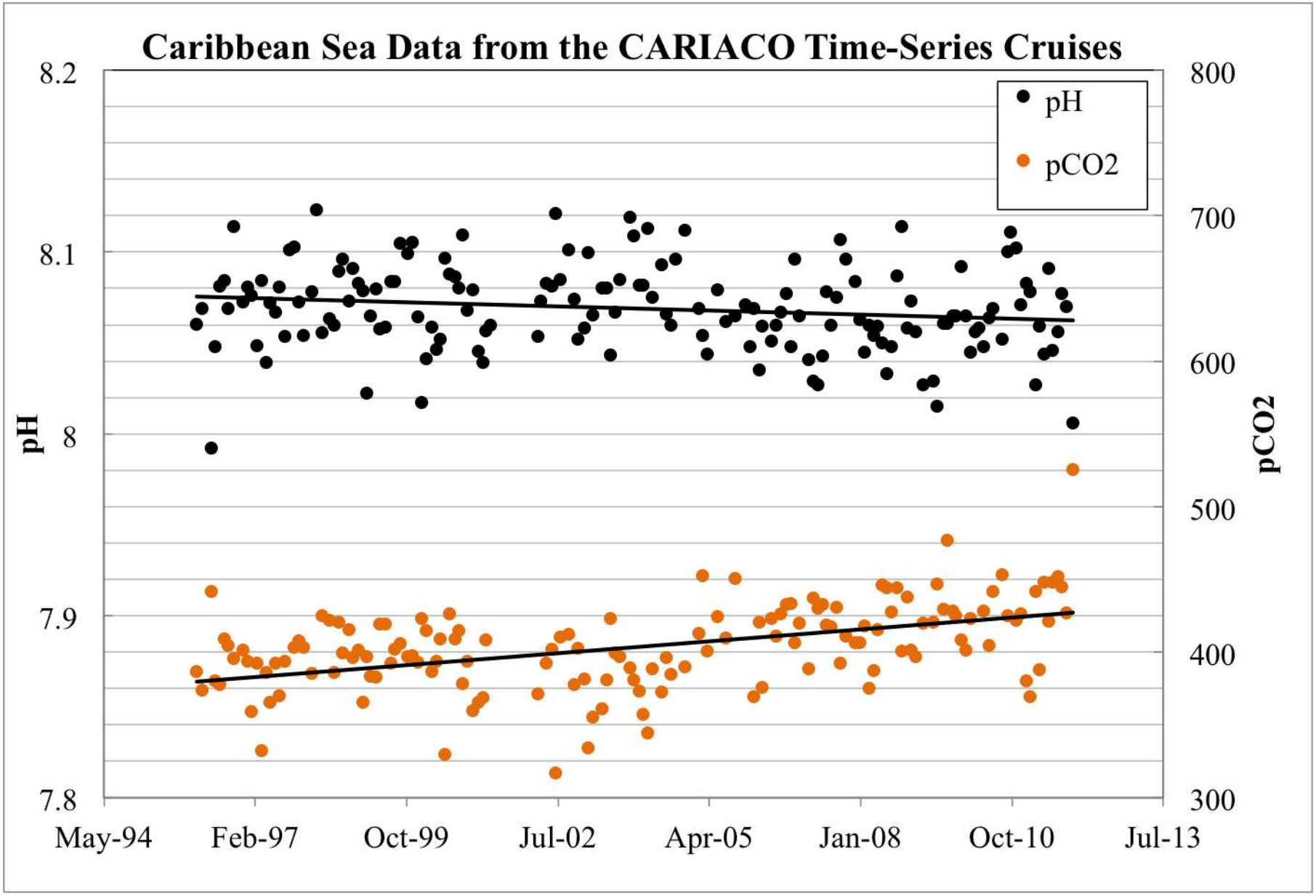
When pCO_2 increases H^+ concentration increases, so pH… ?

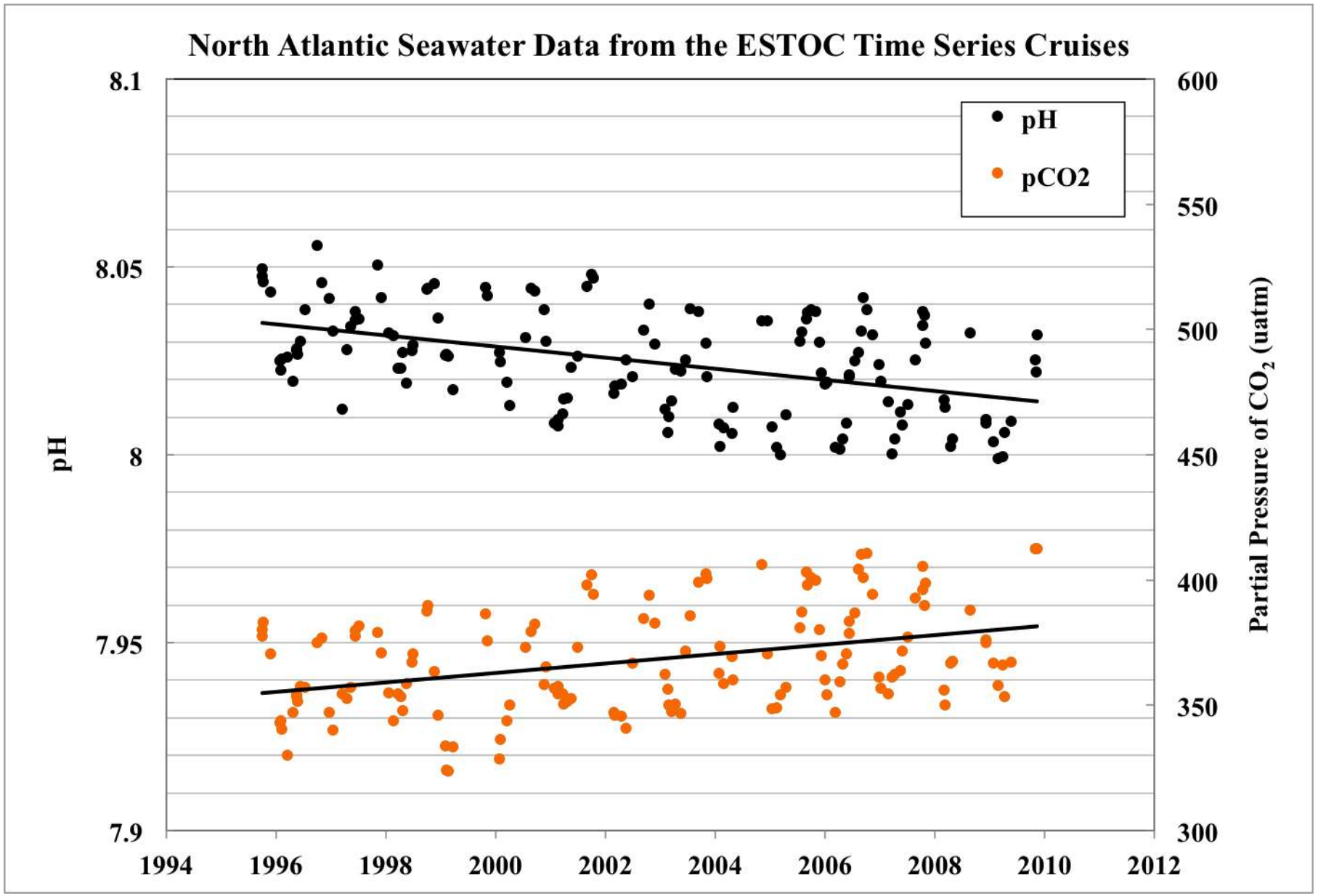

CO_2
(atmospheric)
atmosphere
ocean
CO_2
(dissolved)
H_2O
H_2CO_3
H^+
HCO_3^-
CO_3^{2-}
So, when pH increases, hydrogen ions react with carbonate and form…
$H^+ + CO_3^{2-} \rightarrow HCO_3^-$

Solubility Chart Exercise

True or False: Since the ocean carbon cycle can buffer against changes in pH, we should not see any change in seawater pH as a result of anthropogenic input of CO_2.

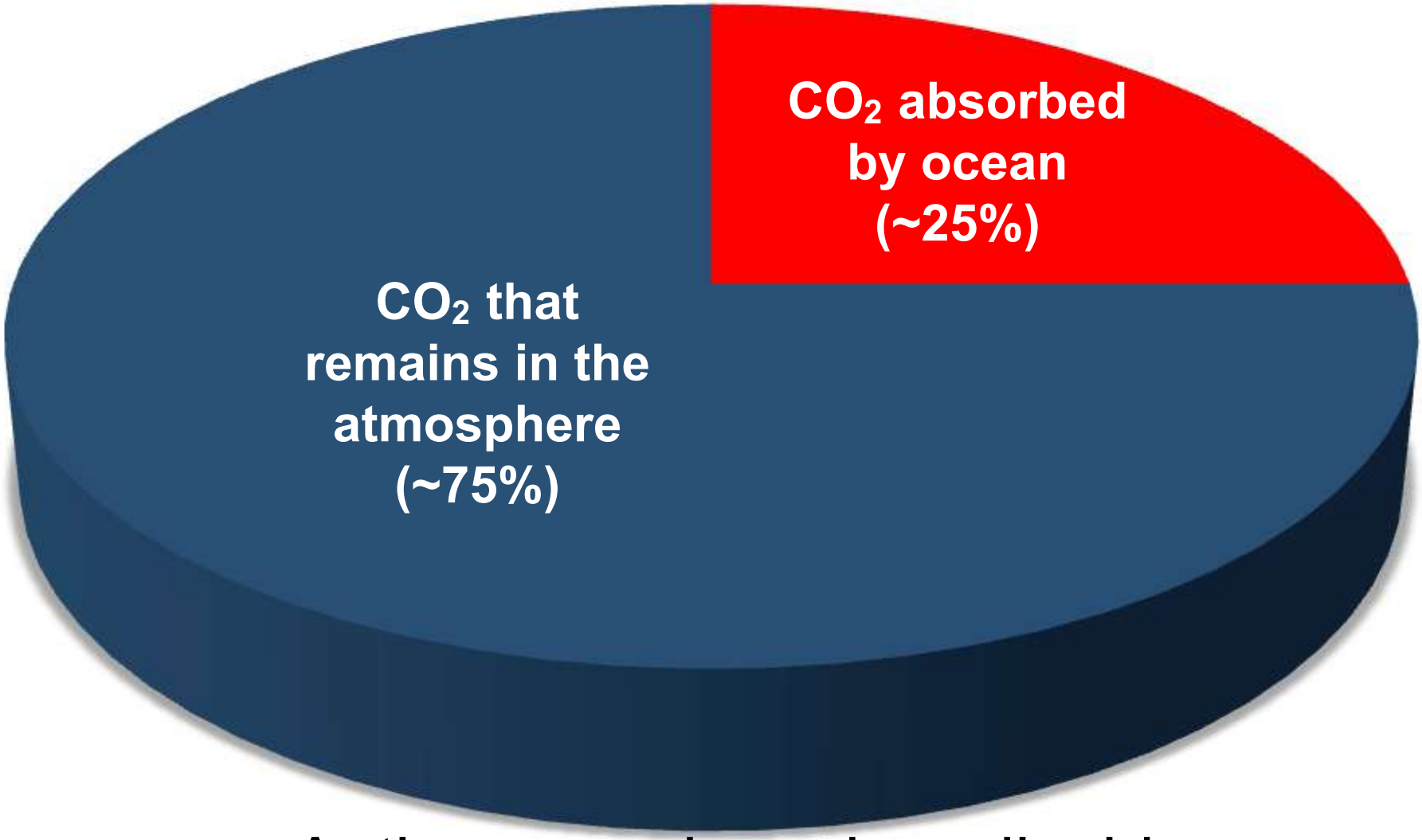

CO2 Time Series in the North Pacific
Mauna Loa Atmospheric CO2 (ppm)
Aloha seawater pCO2 insitu (µatm)
Aloha seawater pH (insitu)
400
375
350
325
300
275
CO2
8.40
8.35
8.30
8.25
8.20
8.15
8.10
8.05
8.00
pH
1958
1964
1970
1976
1982
1988
1994
2000
2006
2012
Year
NOAA's PMEL Carbon Program (www.pmel.noaa.gov/co2/)
Aloha data courtesy of J.E. Dore et al 2009., Physical and biogeochemical modulation of
ocean acidification in the central North Pacific. Proc Natl Acad Sci USA 106:12235-12240.


Caribbean Sea Data from the CARIACO Time-Series Cruises
pH
pCO2
8.2
8.1
8
7.9
7.8
800
700
600
500
400
300
May-94
Feb-97
Oct-99
Jul-02
Apr-05
Jan-08
Oct-10
Jul-13


North Atlantic Seawater Data from the ESTOC Time Series Cruises
pH
pCO2
pH
Partial Pressure of CO2 (uatm)
8.1
8.05
8
7.95
7.9
600
550
500
450
400
350
300
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

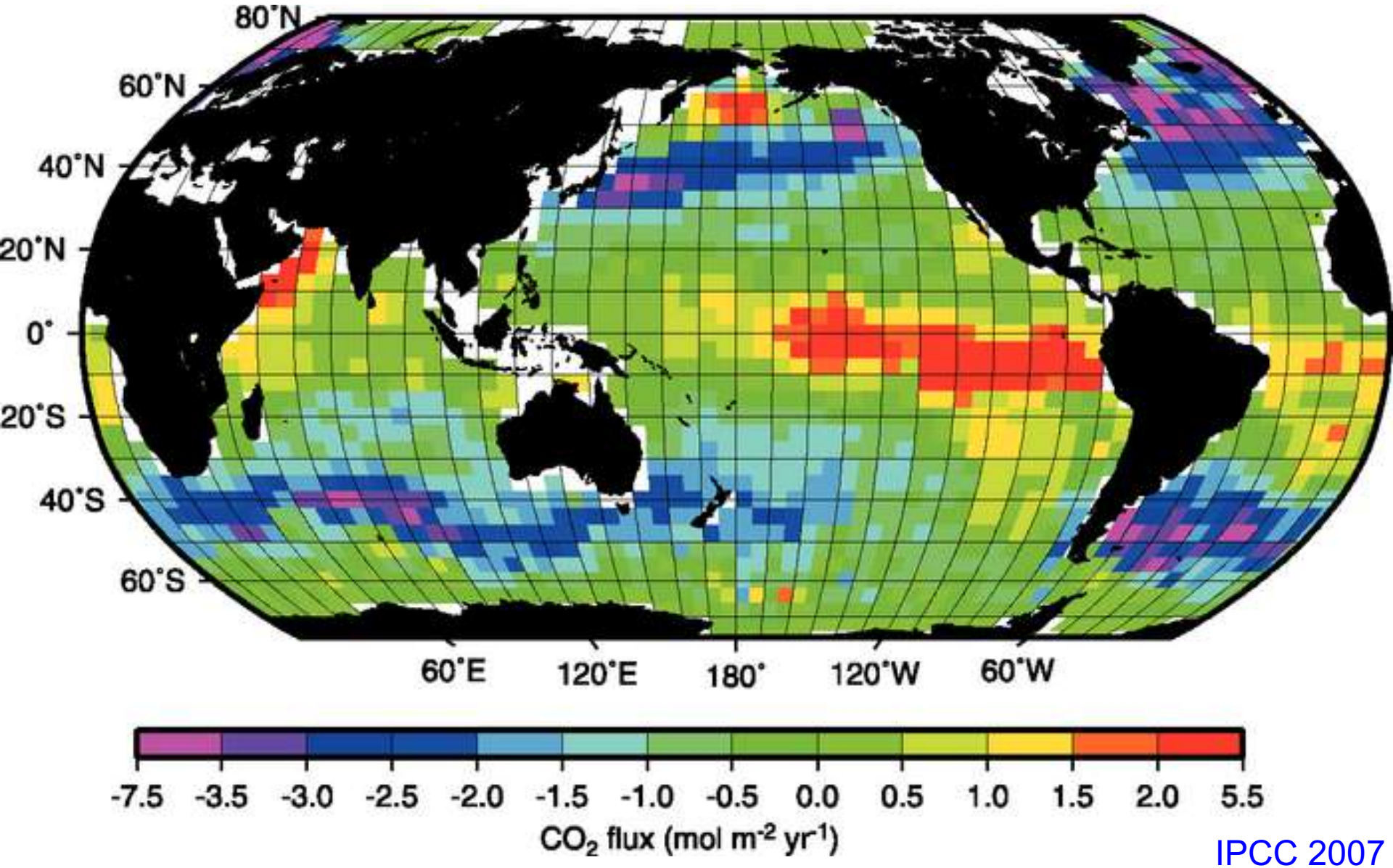
Extra slides

Oceans absorb atmospheric CO_2



Anthropogenic carbon dioxide

Regions absorbing/releasing CO_2



IPCC 2007