

Air-sea interactions : air-sea gas exchanges

ATM2106

Composition of the Atmosphere near the surface

PERMANENT GASES			VARIABLE GASES			
Gas	Symbol	Percent (by Volume) Dry Air	Gas (and Particles)	Symbol	Percent (by Volume)	Parts per Million (ppm)*
Nitrogen	N ₂	78.08	Water vapor	H ₂ O	0 to 4	
Oxygen	O ₂	20.95	Carbon dioxide	CO ₂	0.038	385*
Argon	Ar	0.93	Methane	CH ₄	0.00017	1.7
Neon	Ne	0.0018	Nitrous oxide	N ₂ O	0.00003	0.3
Helium	He	0.0005	Ozone	O ₃	0.000004	0.04†
Hydrogen	H ₂	0.00006	Particles (dust, soot, etc.)		0.000001	0.01–0.15
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000002	0.0002

*For CO₂, 385 parts per million means that out of every million air molecules, 385 are CO₂ molecules.
†Stratospheric values at altitudes between 11 km and 50 km are about 5 to 12 ppm.

N : removed by biological processes on land and in the ocean.

: added to the atmosphere through the decaying of plant and animal matter.

O : removed through the organic matter decays and the combination with other substances.

: added during photosynthesis.

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- Higher percentage of H₂O close to the surface in warm, steamy tropical locations.
- The H₂O percentage approaches to zero in the polar regions.
- Water vapor is associated with latent heat, an important source of energy.
- Water vapor is a potent greenhouse gas.

Composition of the Atmosphere near the surface

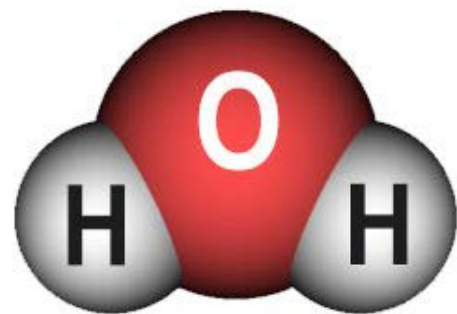
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- Carbon dioxide occupies only 0.038% of the atmosphere.
- Its source is the decay of vegetation, volcanic eruptions and burning fossil fuels.
- The removal of CO₂ is done through photosynthesis by plants on land and in the ocean.
- It is also directly dissolved by the surface water.

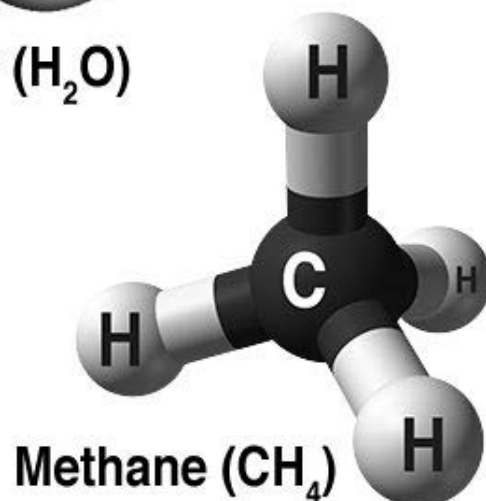
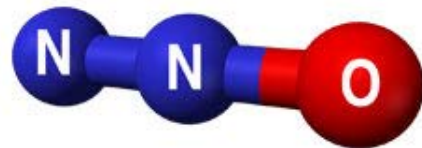
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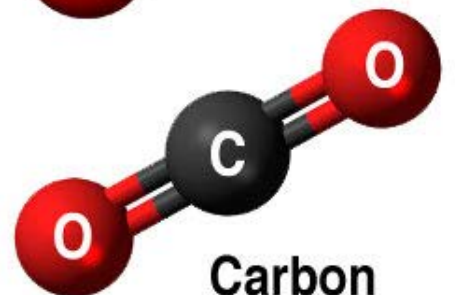


Water vapor (H₂O)

Nitrous oxide (N₂O)



Methane (CH₄)

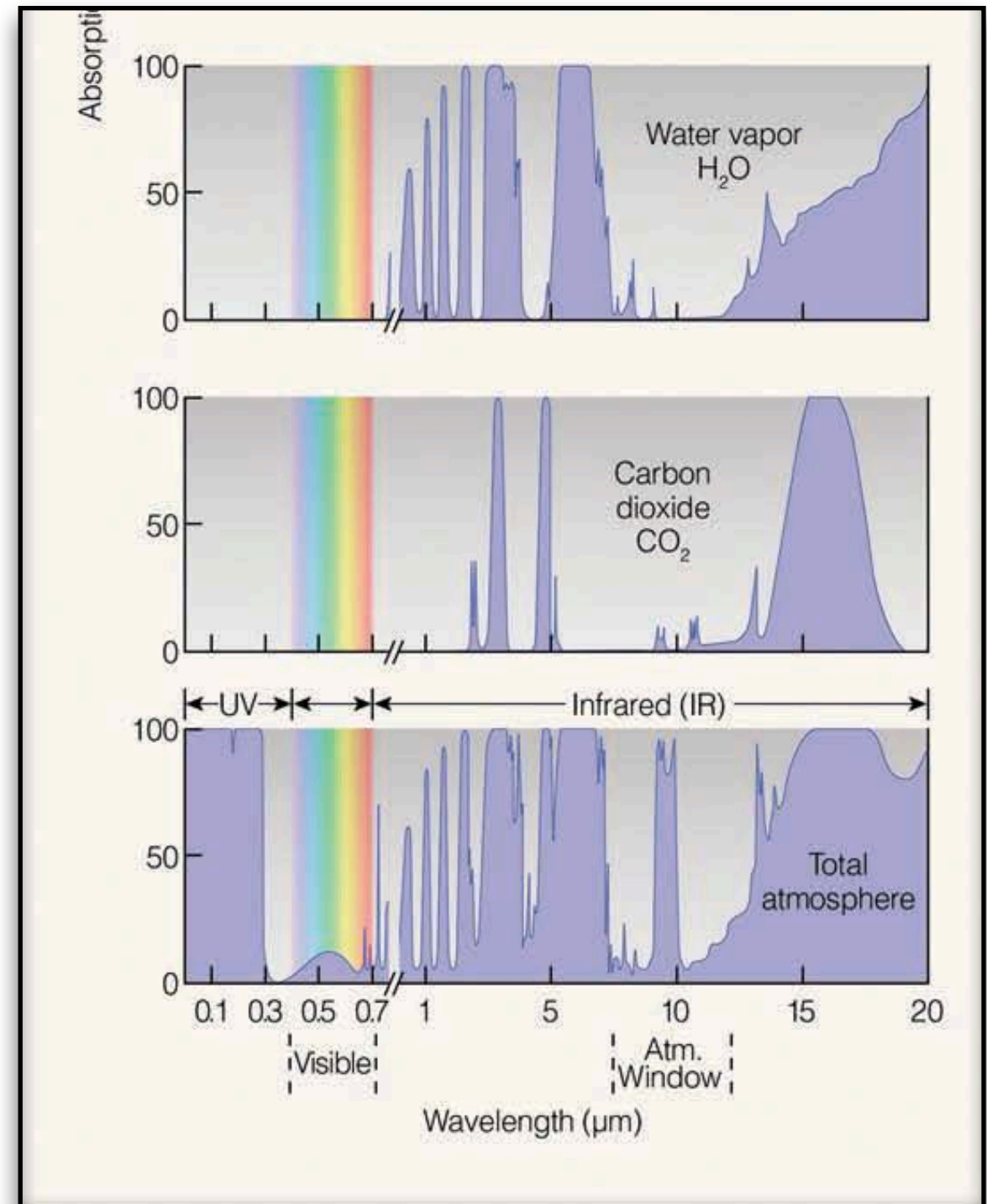
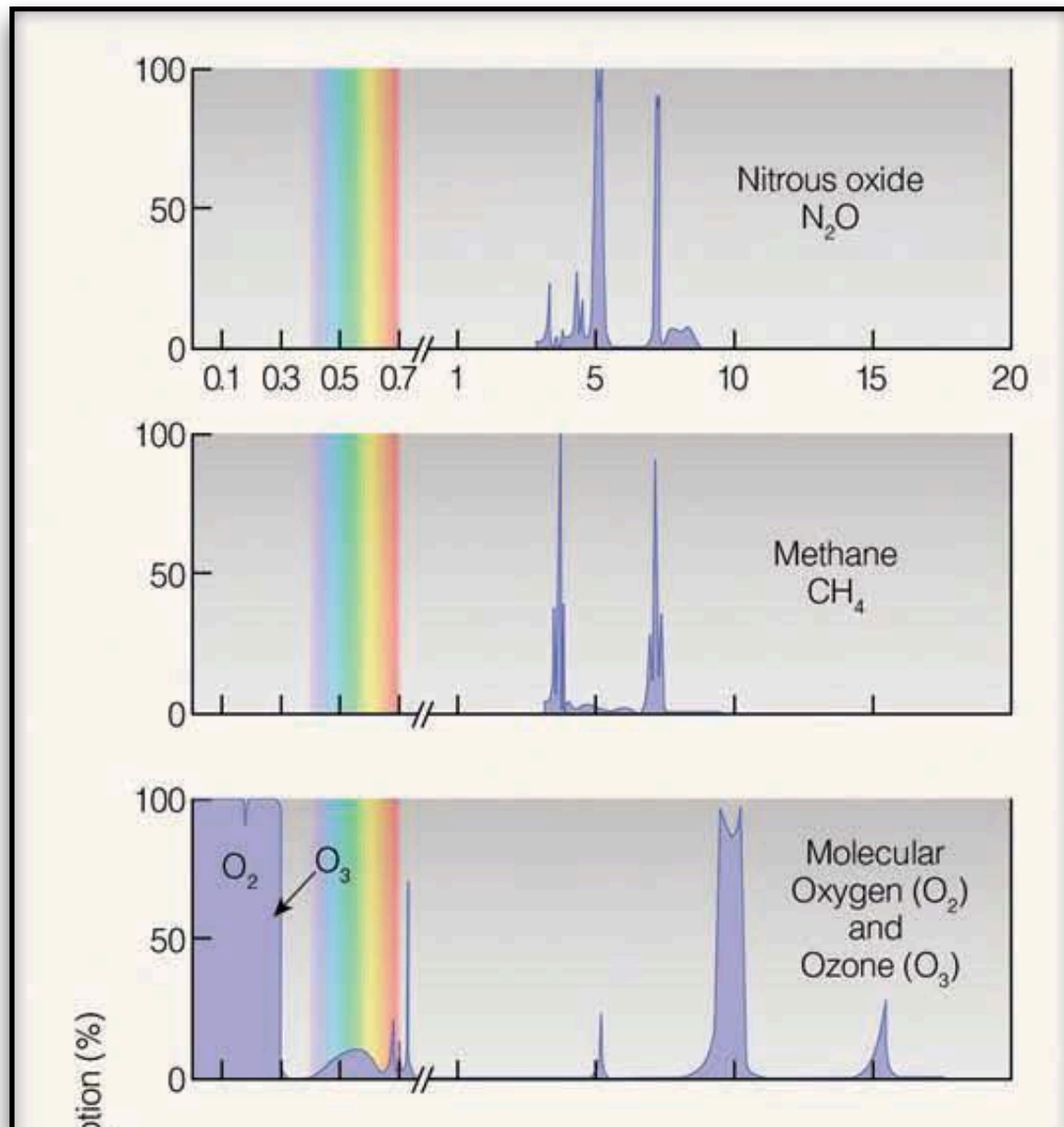


Carbon dioxide (CO₂)

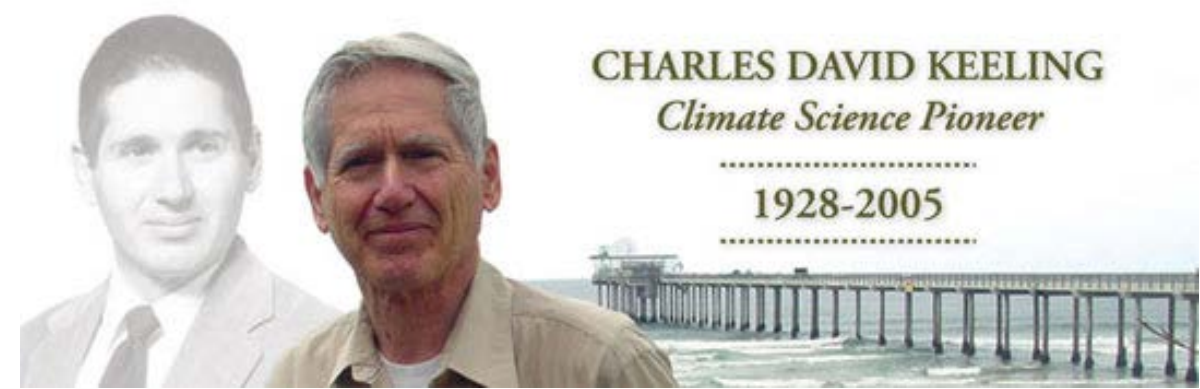
- Greenhouse gases strongly absorb a portion of the earth's outgoing radiant energy.

Image from <https://climate.nasa.gov/causes/>

Absorption of radiation by gases



Measuring CO₂

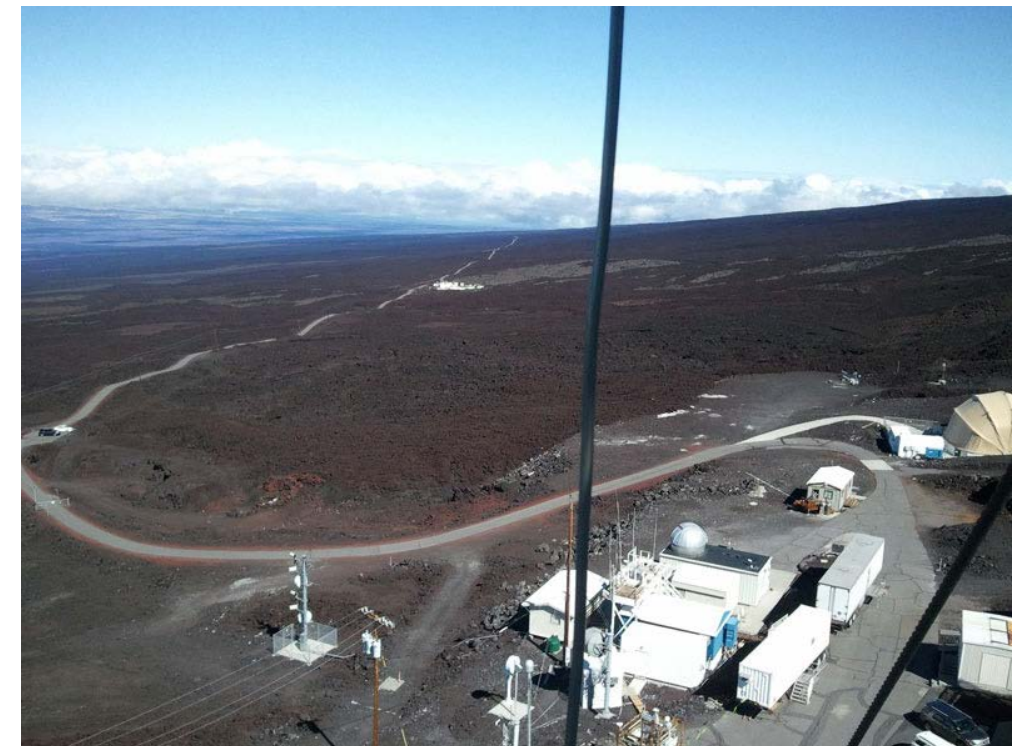


CHARLES DAVID KEELING

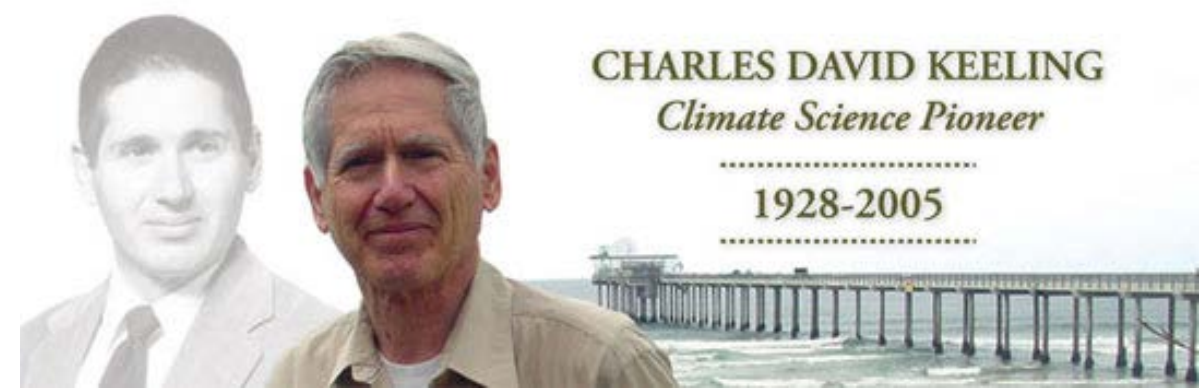
Climate Science Pioneer

1928-2005

- Keeling curve
 - In 1953, Charles Keeling came up with the way to precisely measure CO₂ in the air.
 - Started to measure CO₂ and find diurnal cycle of CO₂.
 - In March 1958, he set up his instrument at Mauna Loa, Hawaii where there was no vegetation.
 - video



Measuring CO₂

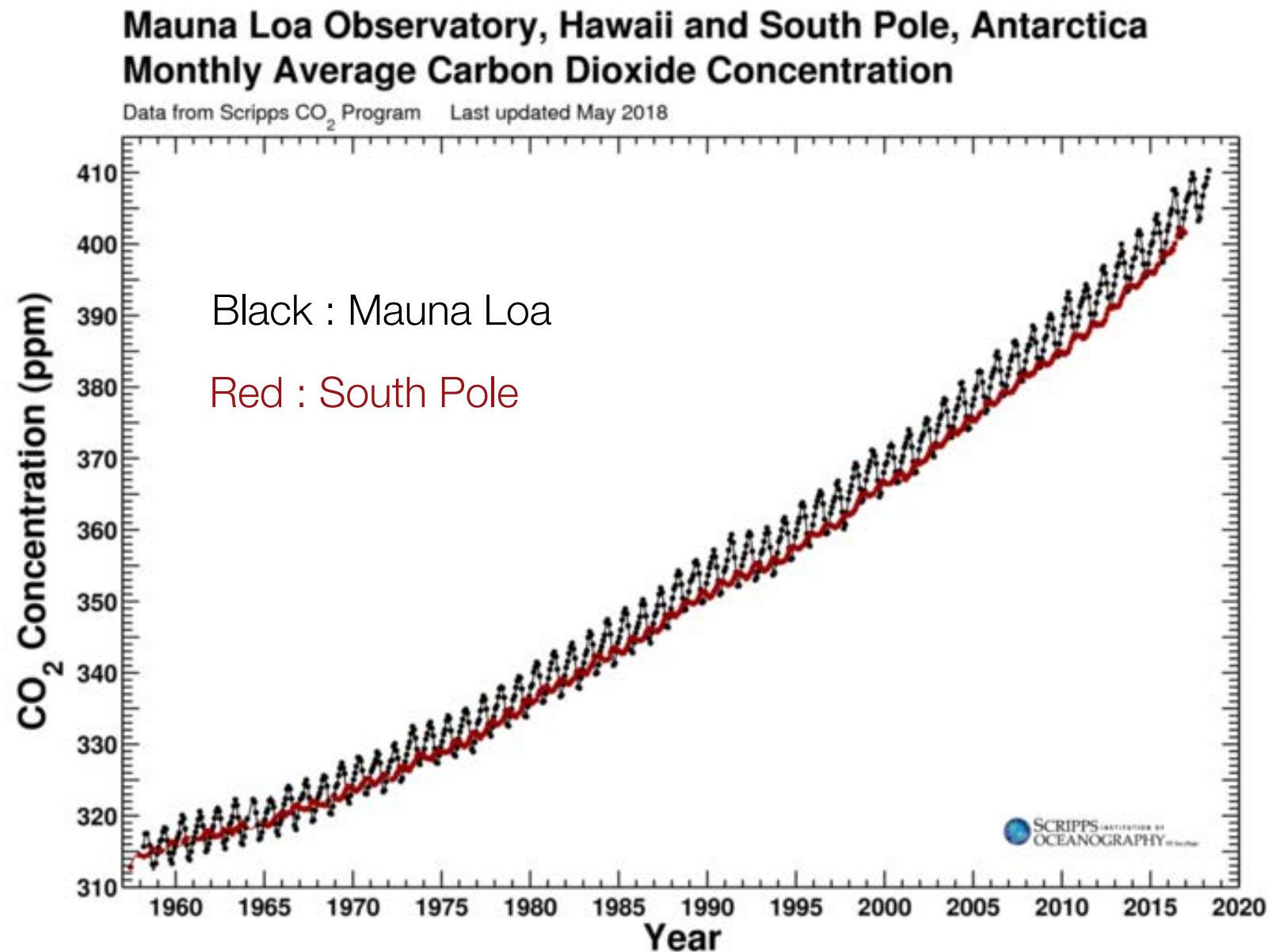


CHARLES DAVID KEELING

Climate Science Pioneer

1928-2005

- Keeling curve
- Seasonal cycle of CO₂ concentration
- Long-term trend
- Video #1
- Video #2



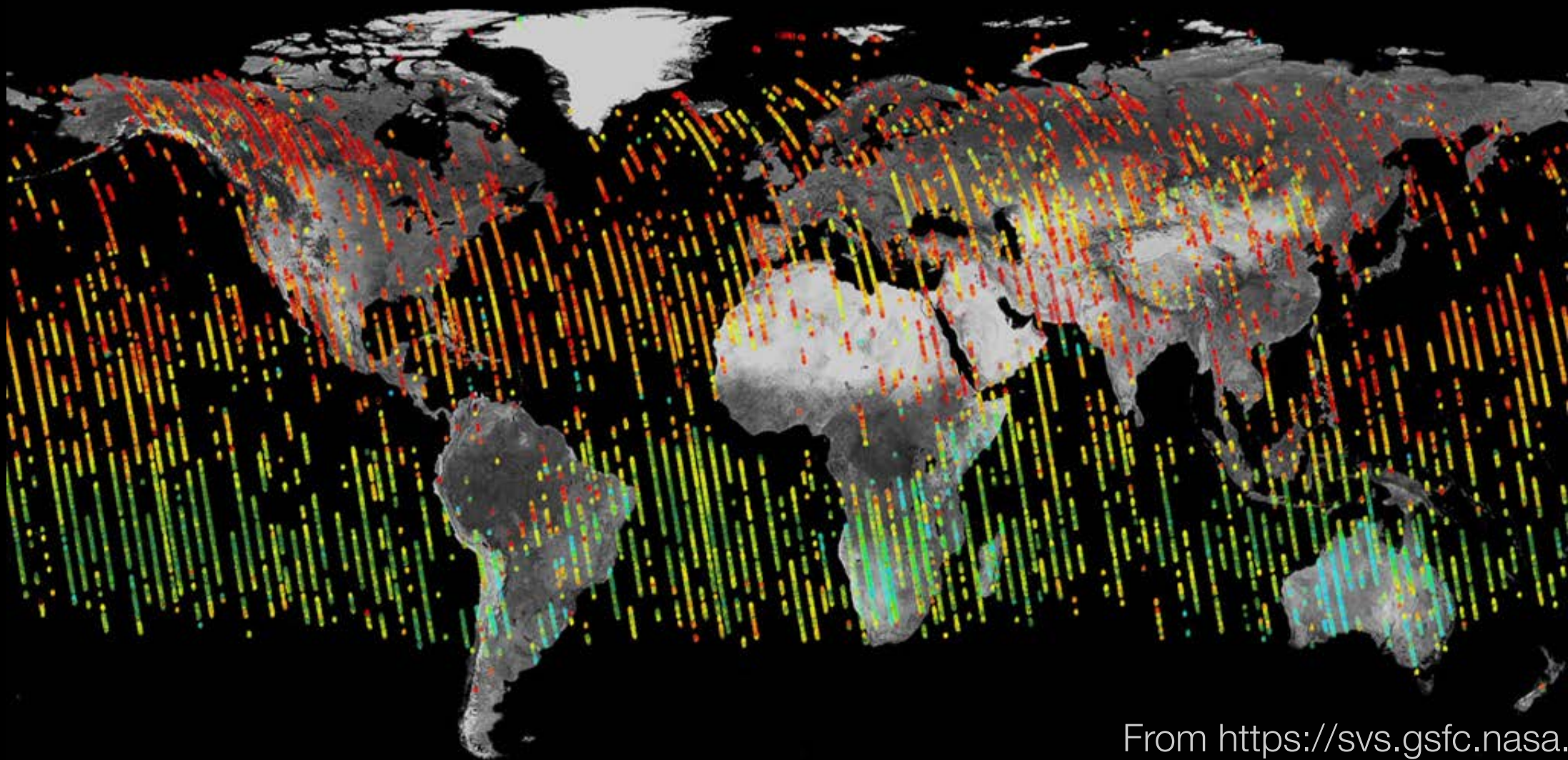
From http://scrippsco2.ucsd.edu/graphics_gallery/mauna_loa_and_south_pole/mauna_loa_and_south_pole

Measuring CO₂



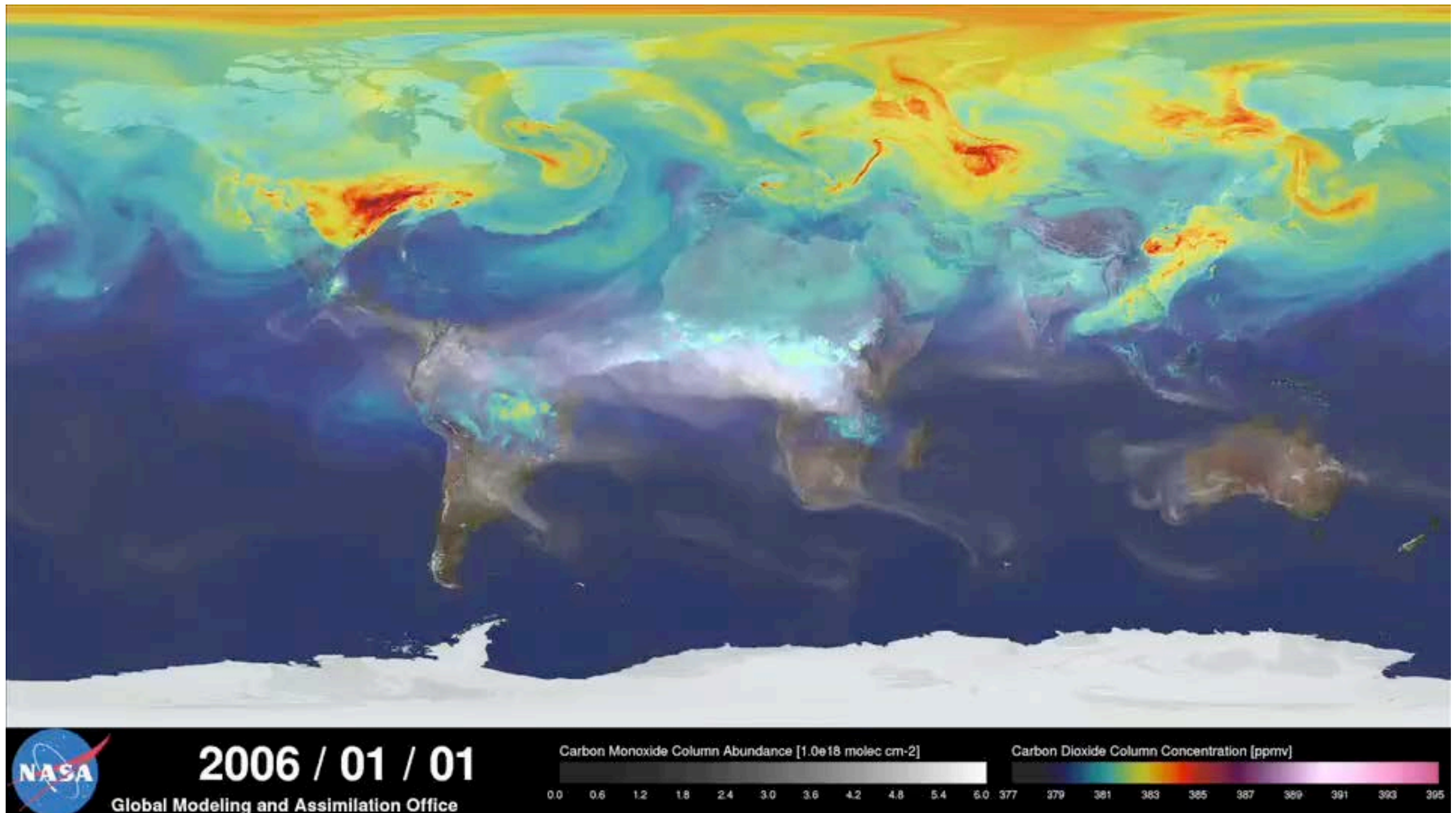
- Since 1996, the satellite started to measure CO₂ from the space.

The OCO-2 satellite circles Earth every 99 minutes, and collects carbon dioxide measurements over a narrow ground track each orbit.

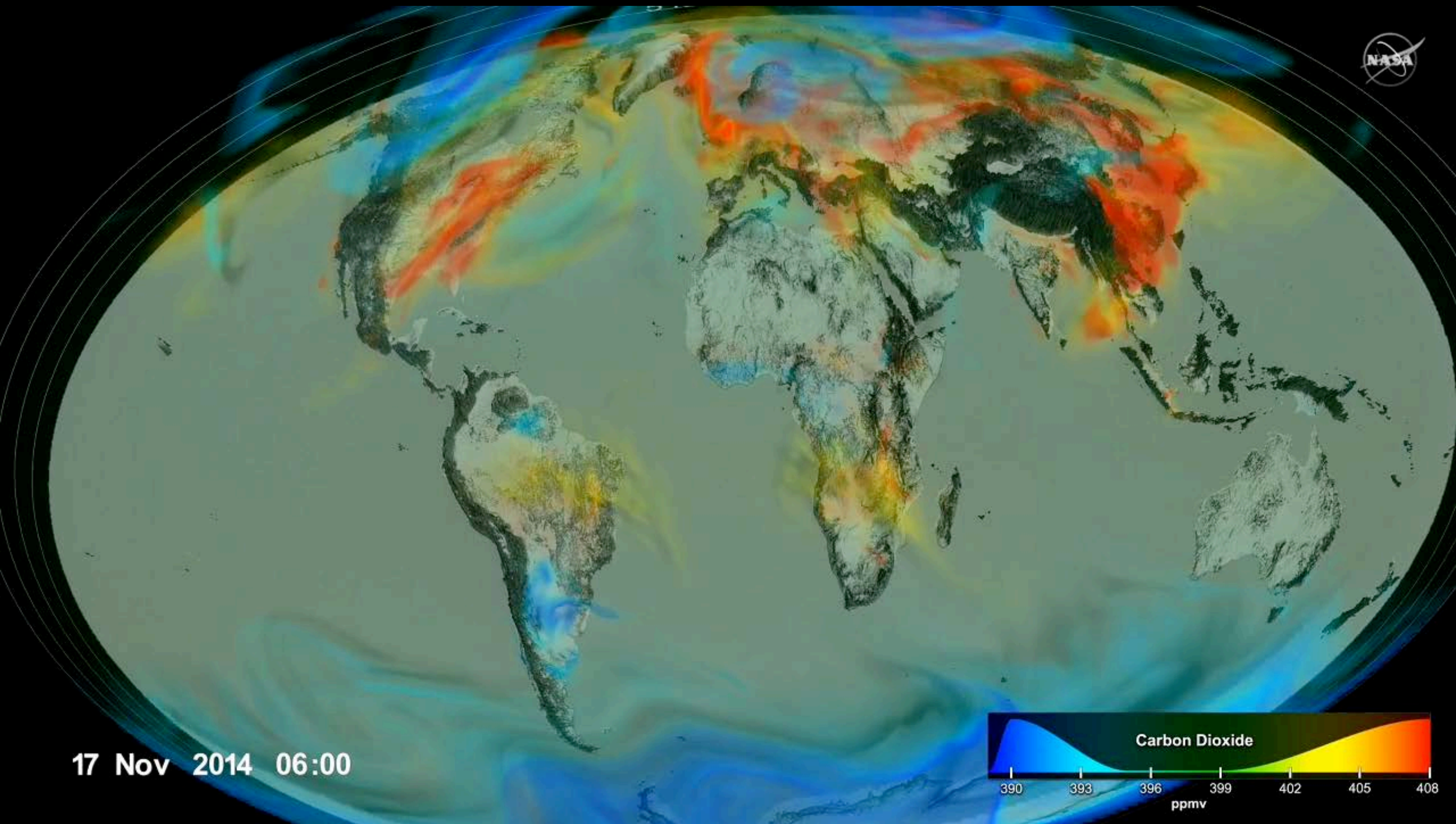


Modeling of CO₂

a NASA supercomputer model called GEOS-5



Using observations from NASA's Orbiting Carbon Observatory (OCO-2) satellite, scientists developed a model of the behavior of carbon in the atmosphere from September 1, 2014 to August 31, 2015.



The Current CO₂ level (2018)

June 01: 411.68 ppm

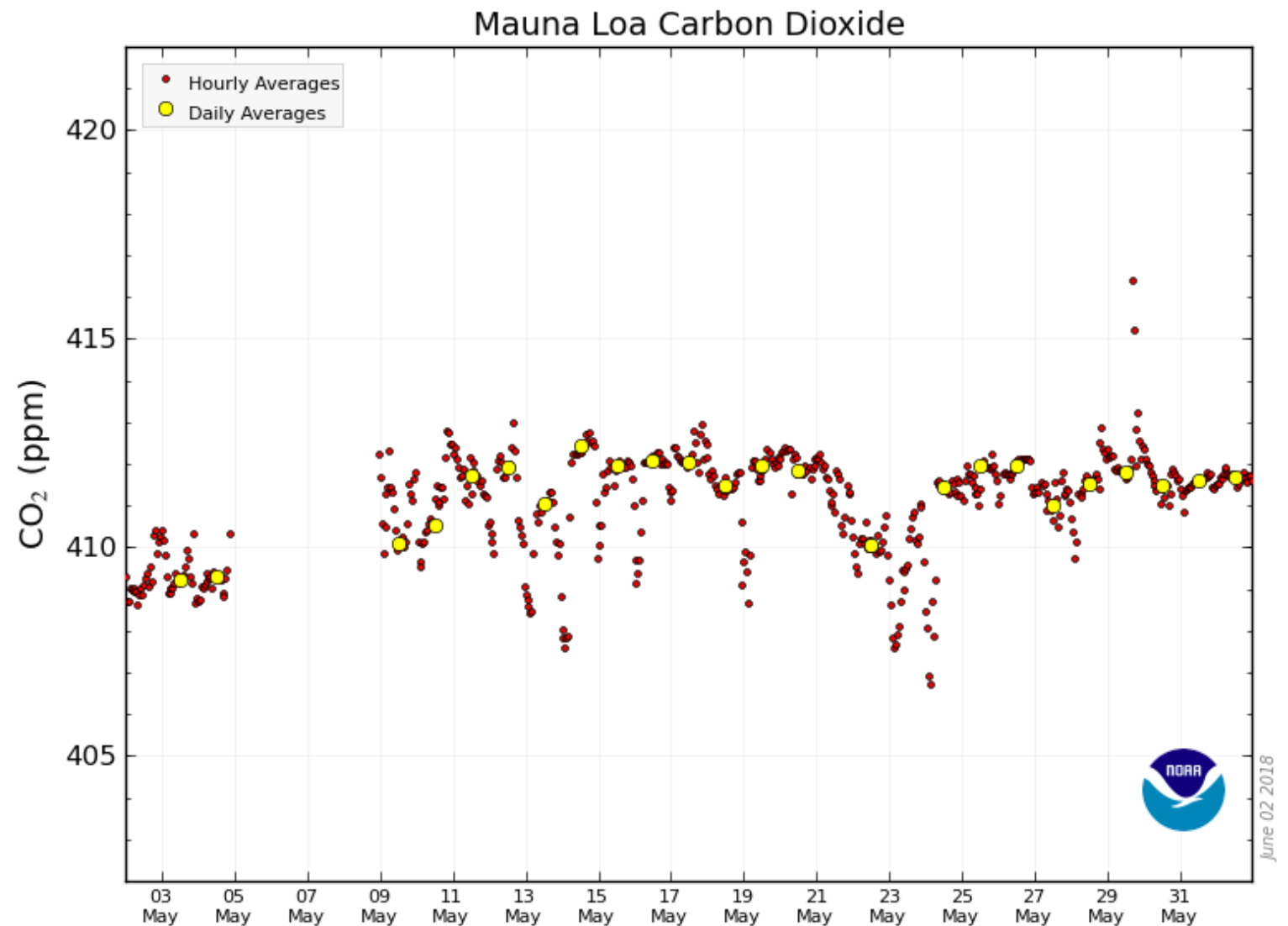
May 31: 411.61 ppm

May 30: 411.47 ppm

May 29: 411.80 ppm

May 28: 411.54 ppm

Last Updated: June 2, 2018



The Current CO₂ level (2019)

June 03: 414.34 ppm

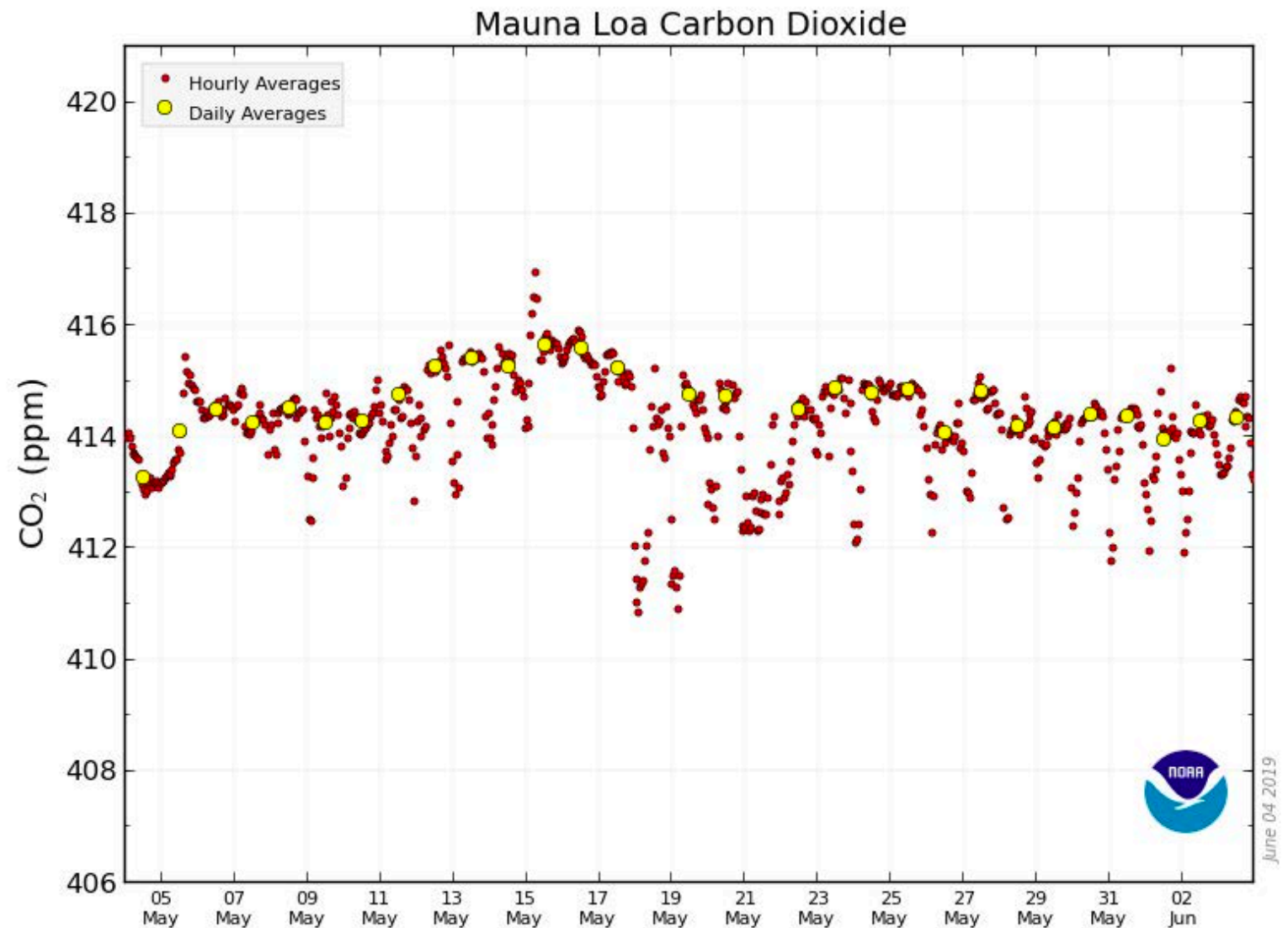
June 02: 414.28 ppm

June 01: 413.96 ppm

May 31: 414.36 ppm

May 30: 414.40 ppm

Last Updated: June 4, 2019



The global carbon cycle

Unit : Gigaton

The Global Carbon Cycle

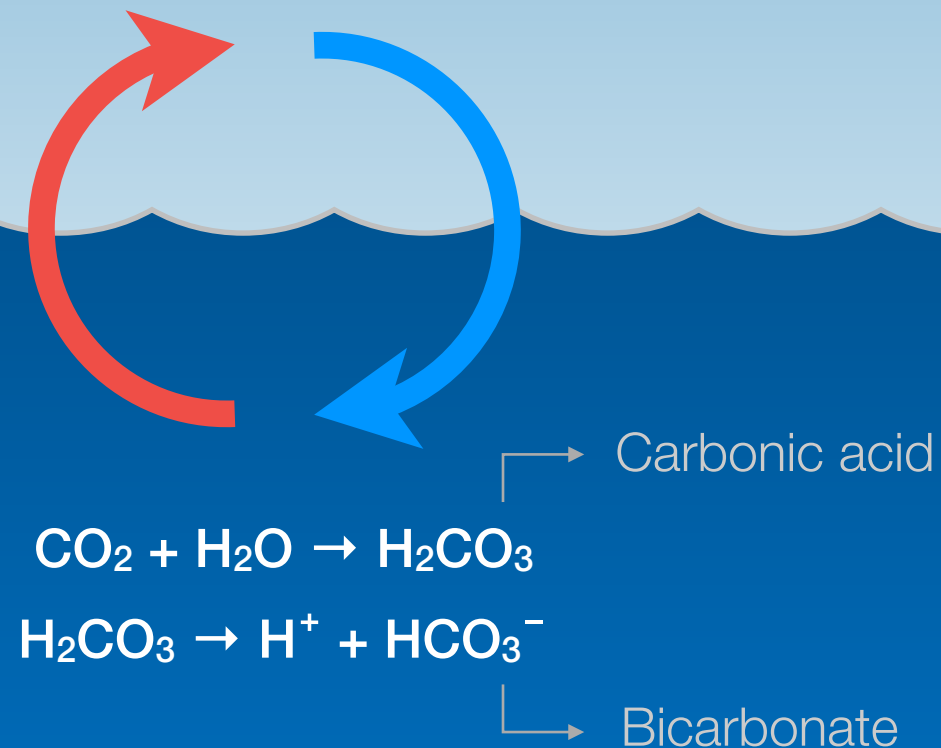
© Sinauer Associates, Inc.

Air-sea CO₂ exchange

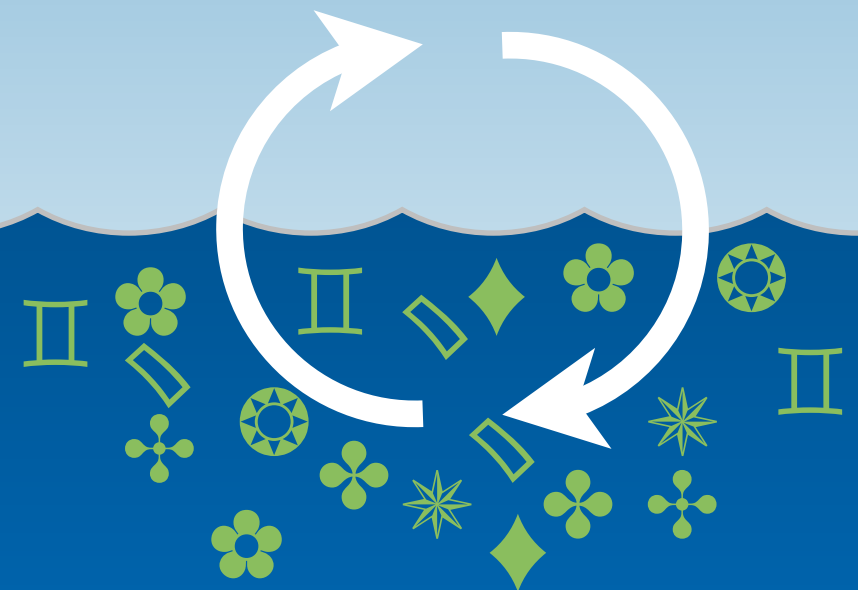
$$\text{CO}_2 \text{ flux} = K_w (p\text{CO}_{2,\text{ocean}} - p\text{CO}_{2,\text{atmosphere}})$$

$f(\text{wind speed, ...})$ \swarrow \searrow $f(T, S, \text{carbon, ...})$

Solubility pump

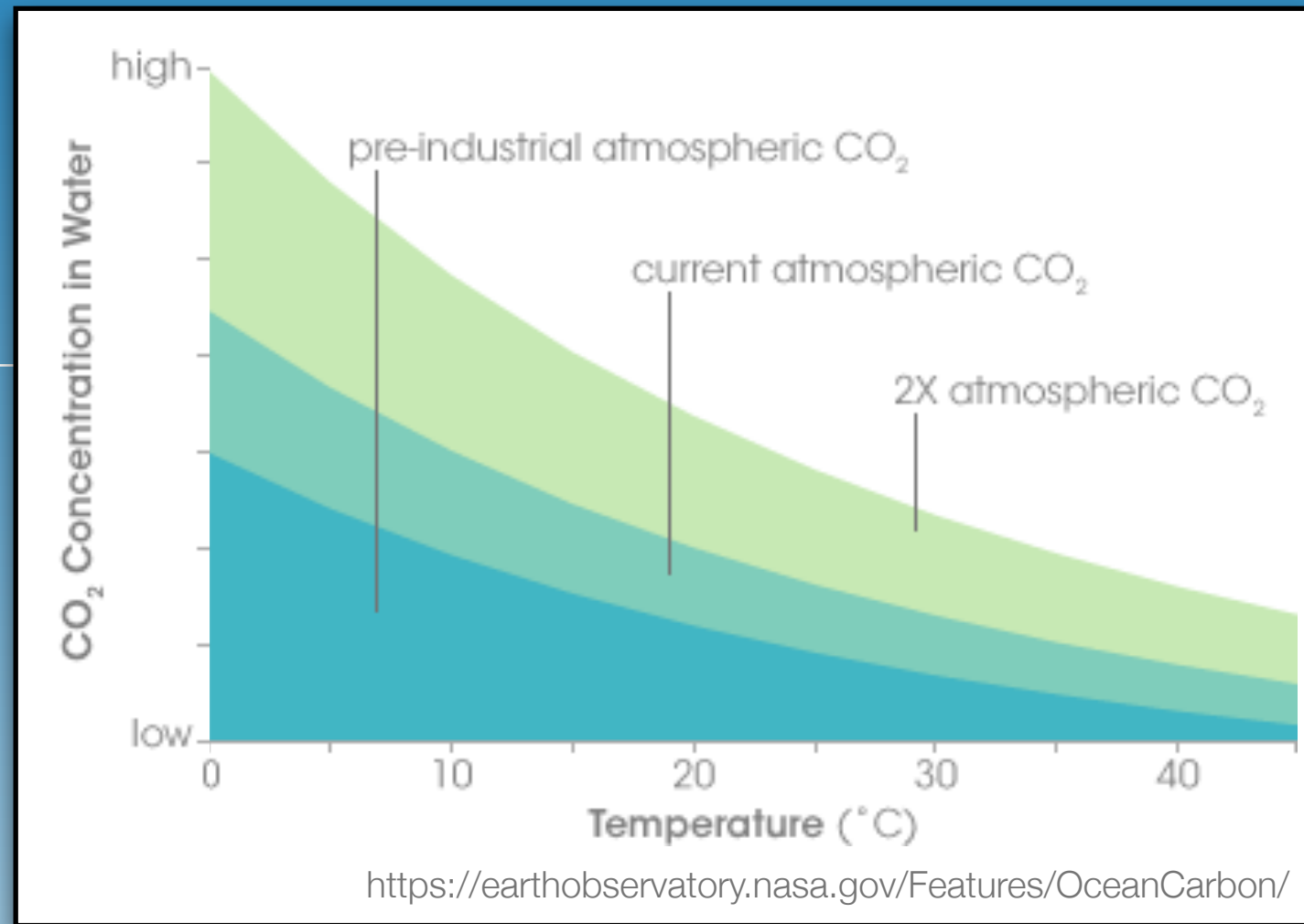


Biological pump

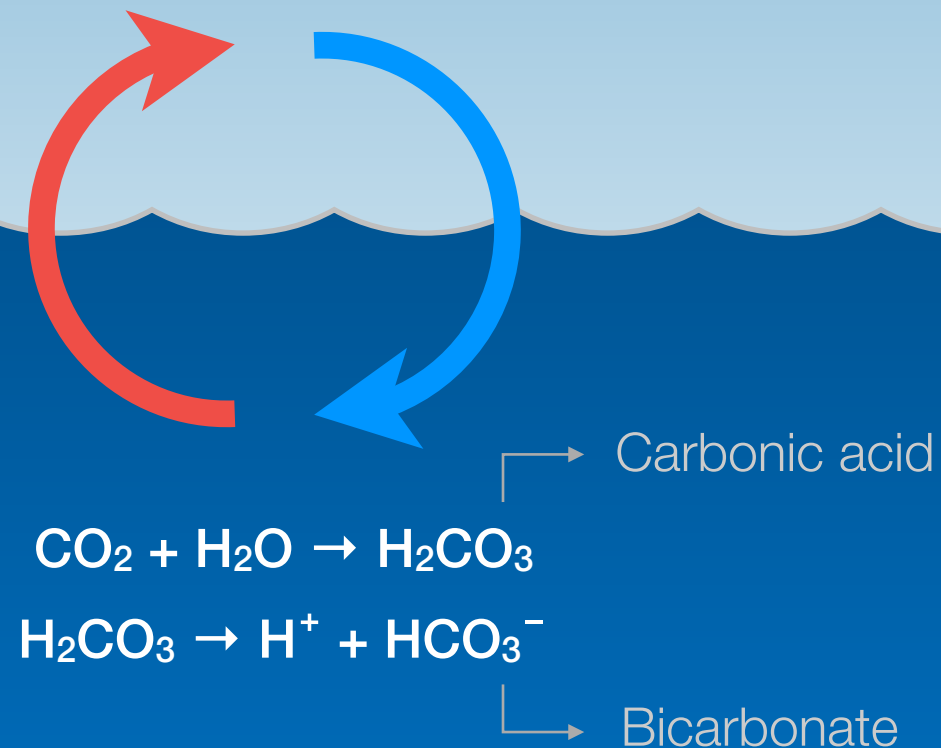


Air-sea CO₂ exchange

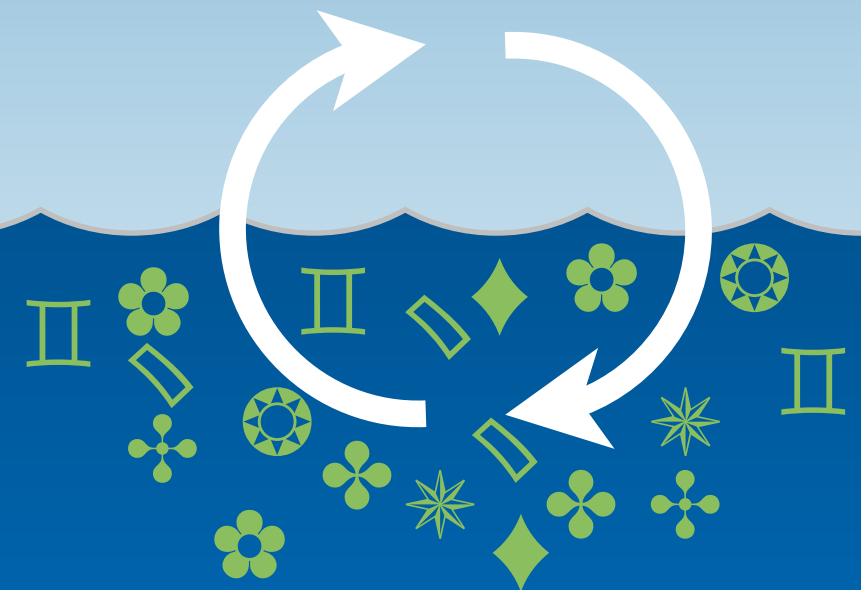
Video



Solubility pump

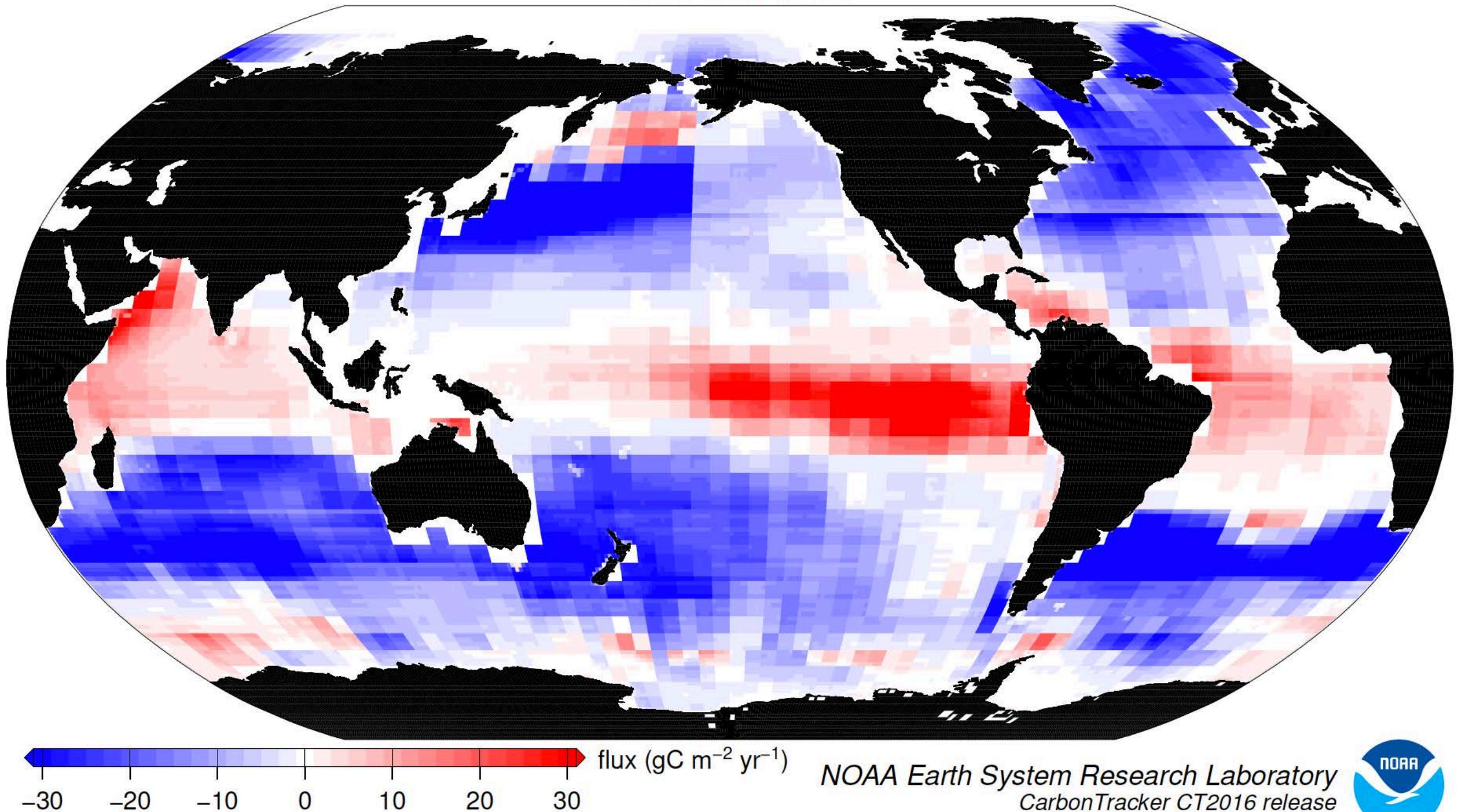


Biological pump

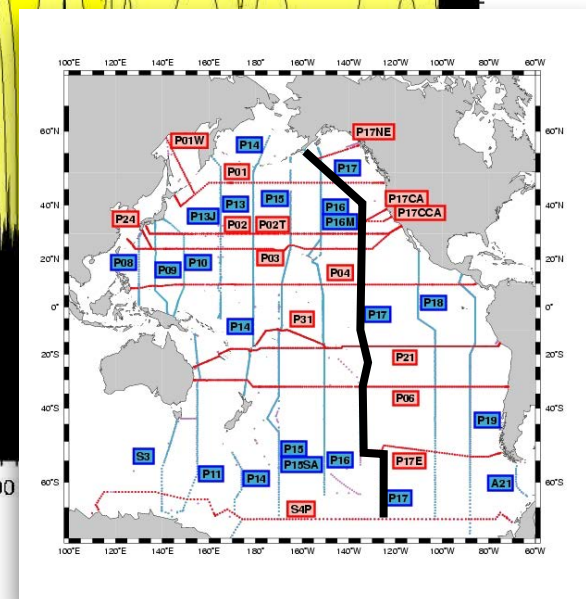
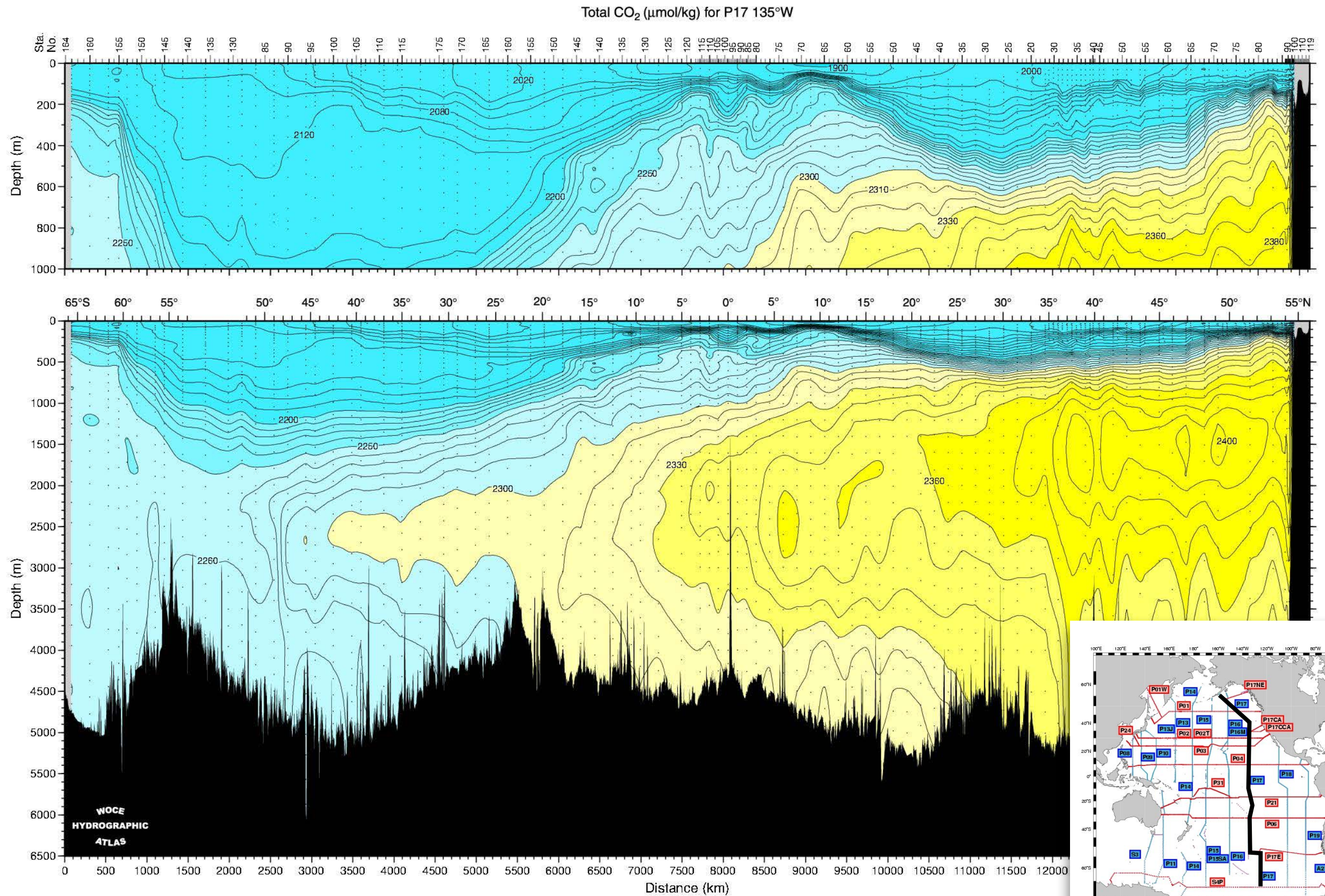


Air-sea CO₂ exchange

1°x1° ocean fluxes
2001–2015 mean

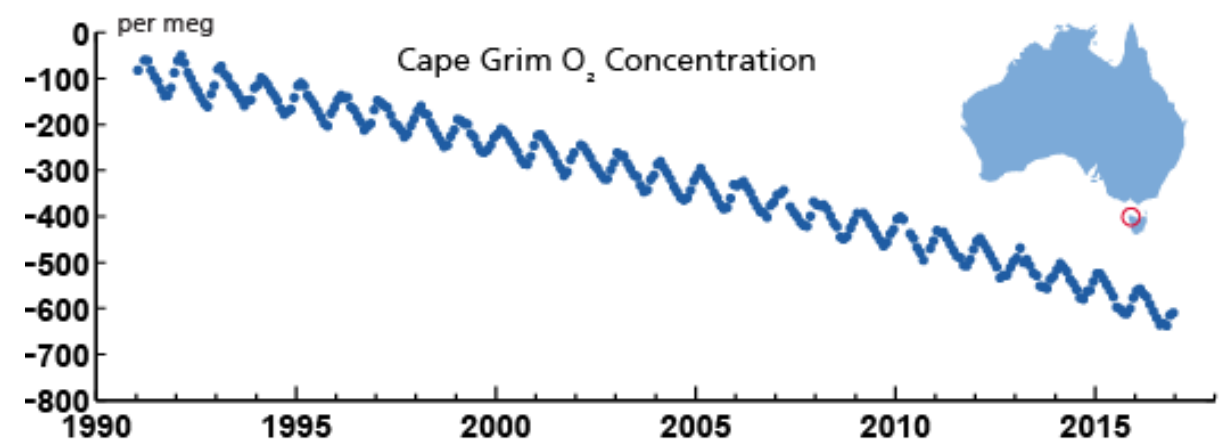
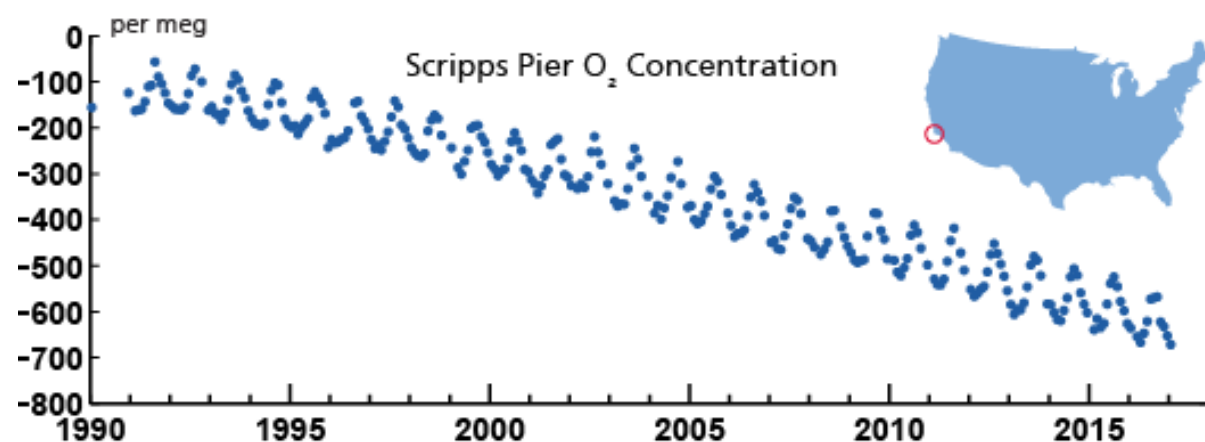


CO₂ in the ocean

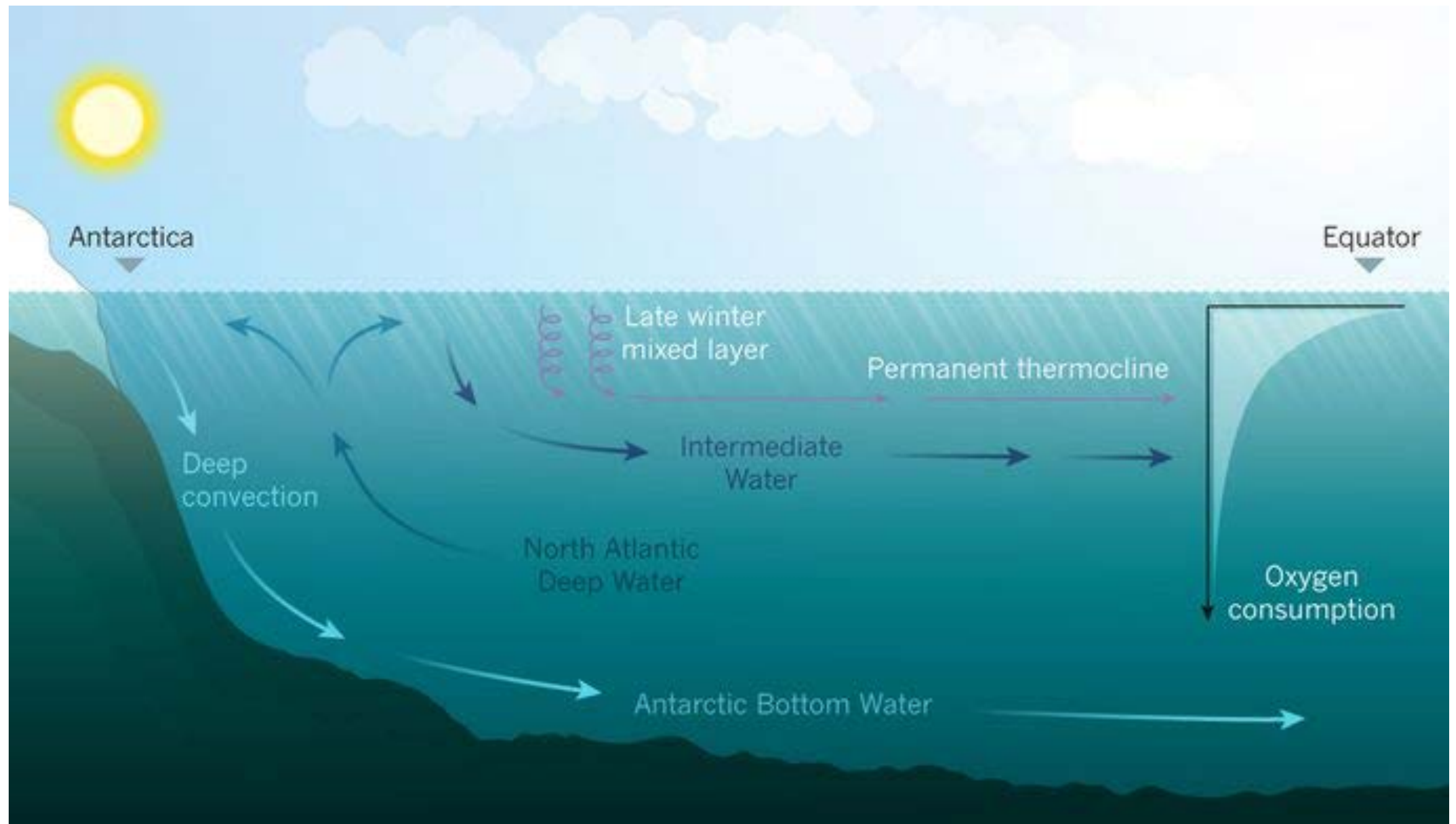


Oxygen

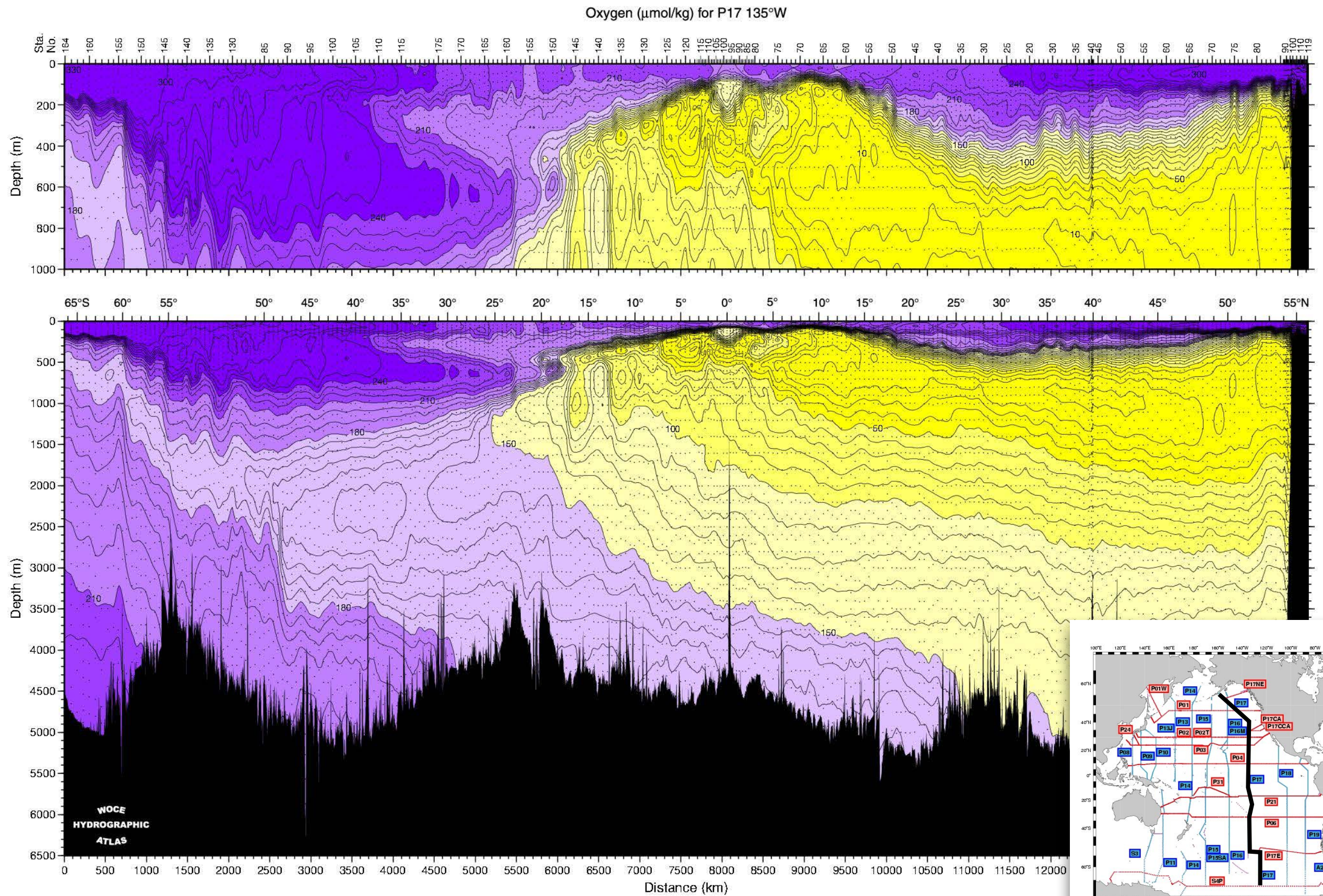
- O_2 is a major component of the atmosphere, comprising roughly 21% by volume.
- Oxygen levels are decreasing globally due to fossil fuel burning, although the changes are too small to have an impact on human health.
- On average, we lose 19 O_2 molecules out of every 1 million O_2 molecules each year.



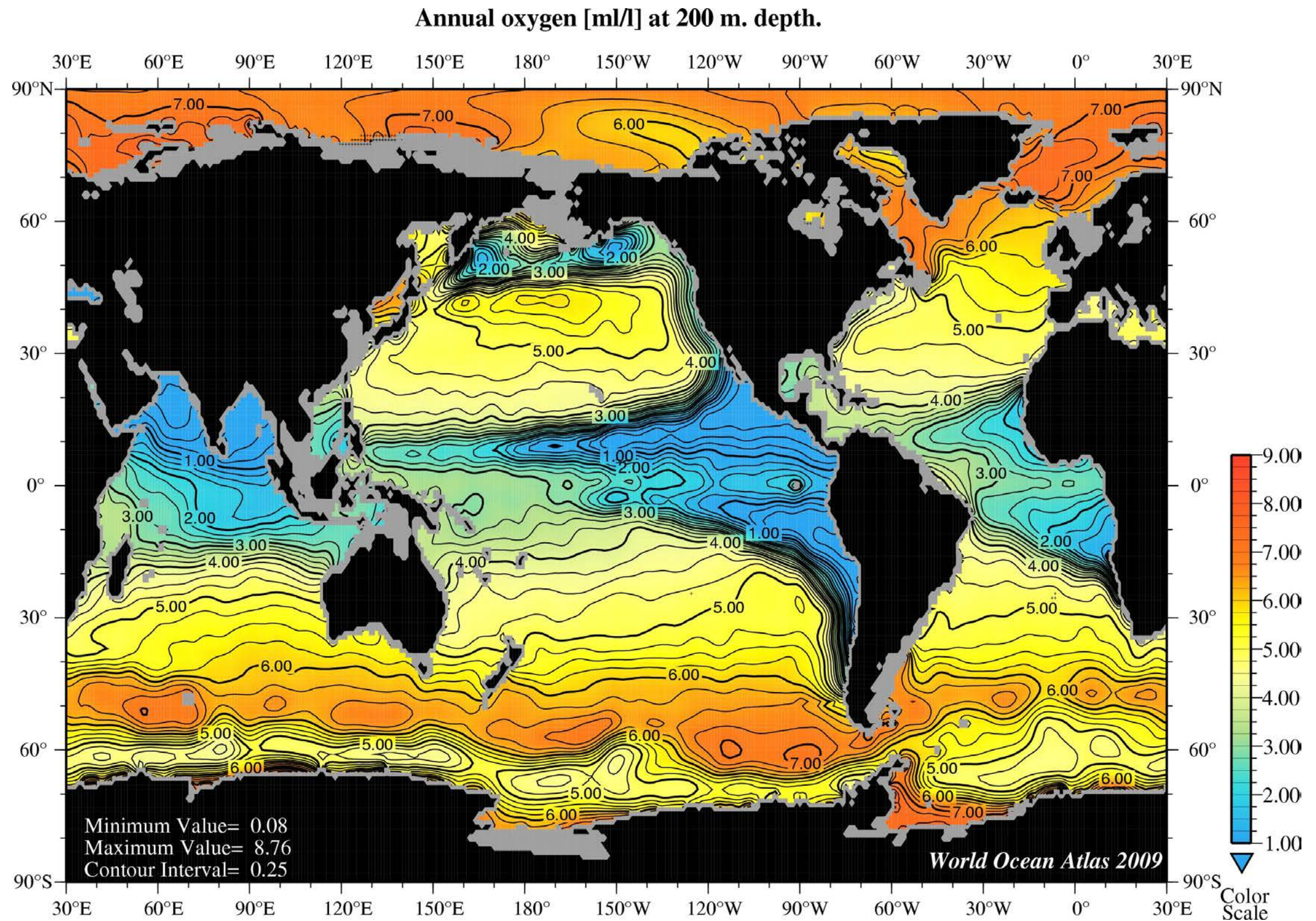
Oxygen cycle in the water



O₂ in the ocean



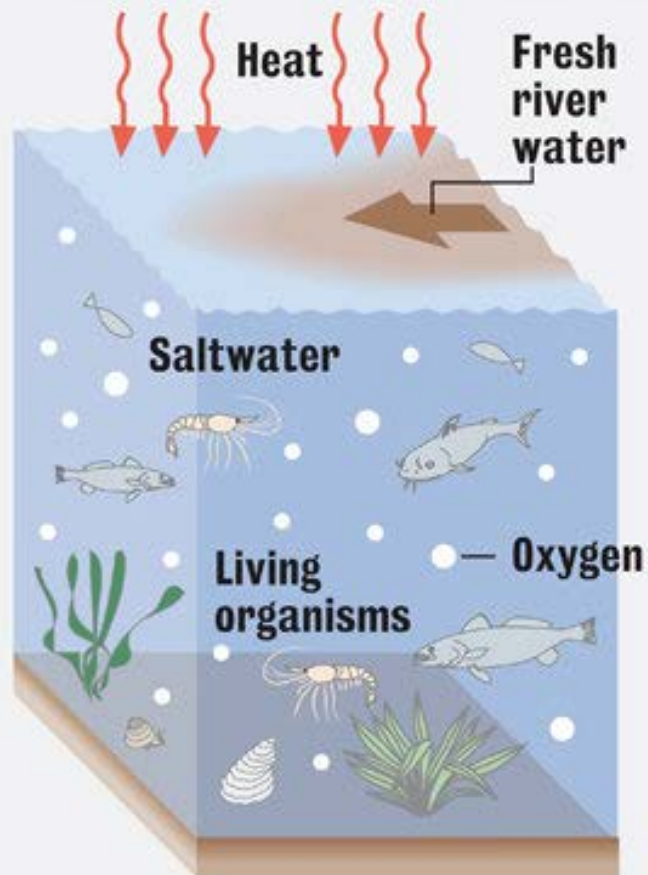
Oxygen at 200 m



Dead zone

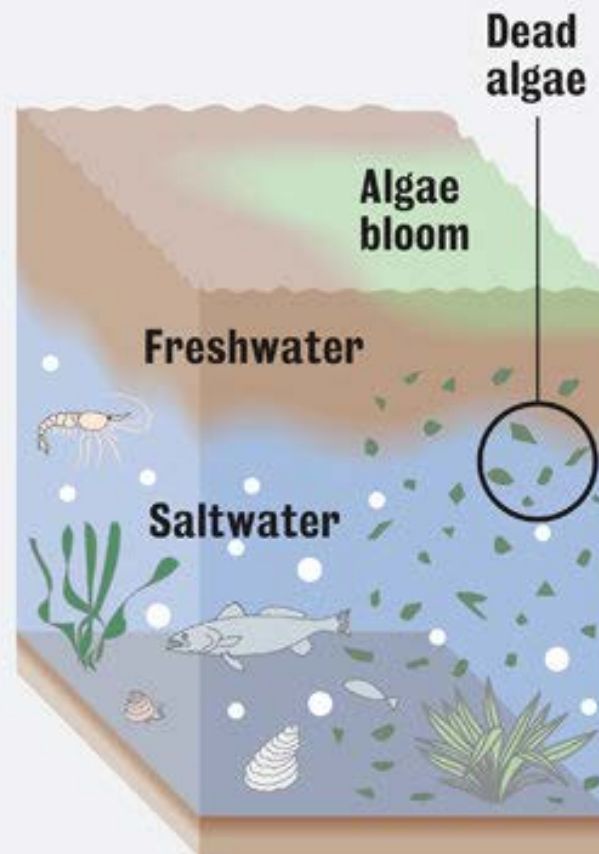


HOW THE DEAD ZONE FORMS

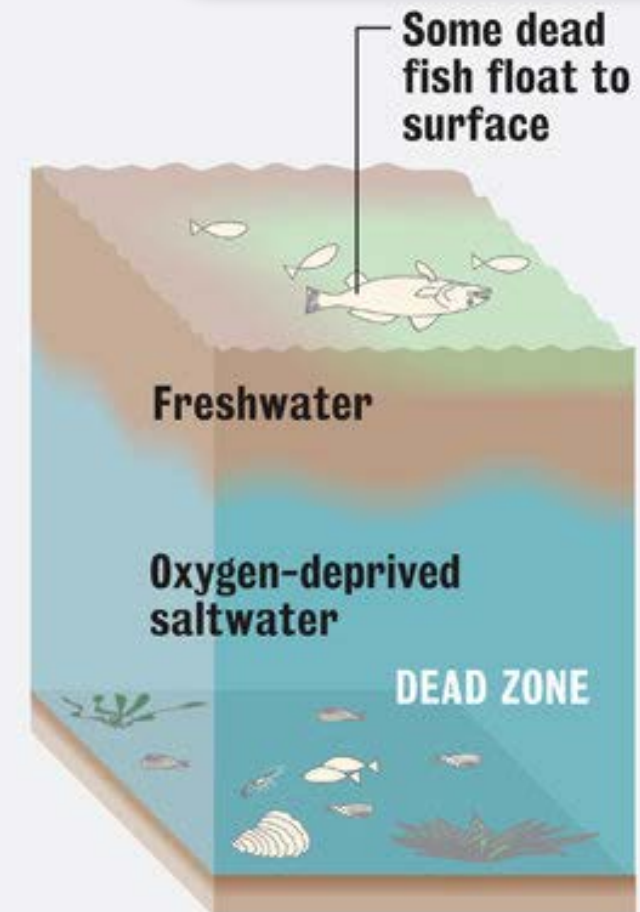


1 During the spring, sun-heated freshwater runoff from the Mississippi River creates a barrier layer in the Gulf, cutting off the saltier water below from contact with oxygen in the air.

Source: Staff research



2 Nitrogen and phosphorus from fertilizer and sewage in the freshwater layer ignite huge algae blooms. When the algae die, they sink into the saltier water below and decompose, using up oxygen in the deeper water.



3 Starved of oxygen and cut off from resupply, the deeper water becomes a dead zone. Fish avoid the area or die in massive numbers. Tiny organisms that form the vital base of the Gulf food chain also die. Winter brings respite, but spring runoffs start the cycle anew.

STAFF GRAPHIC BY DAN SWENSON

Declining oxygen level in the water

The global map indicating coastal sites with hypoxic condition

