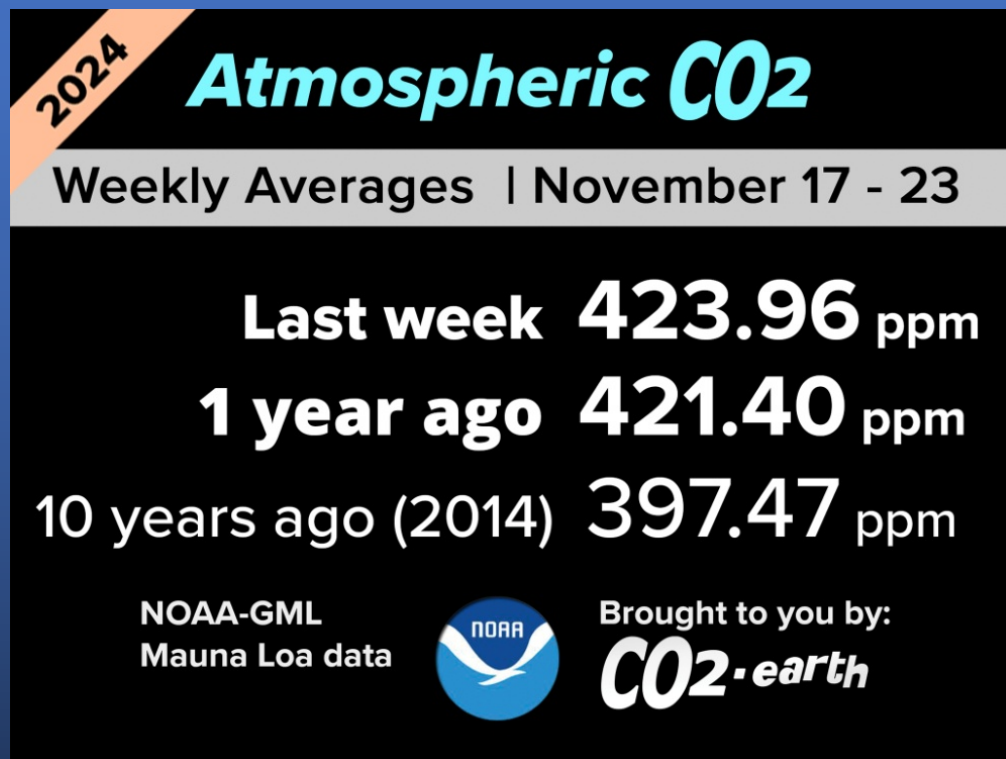


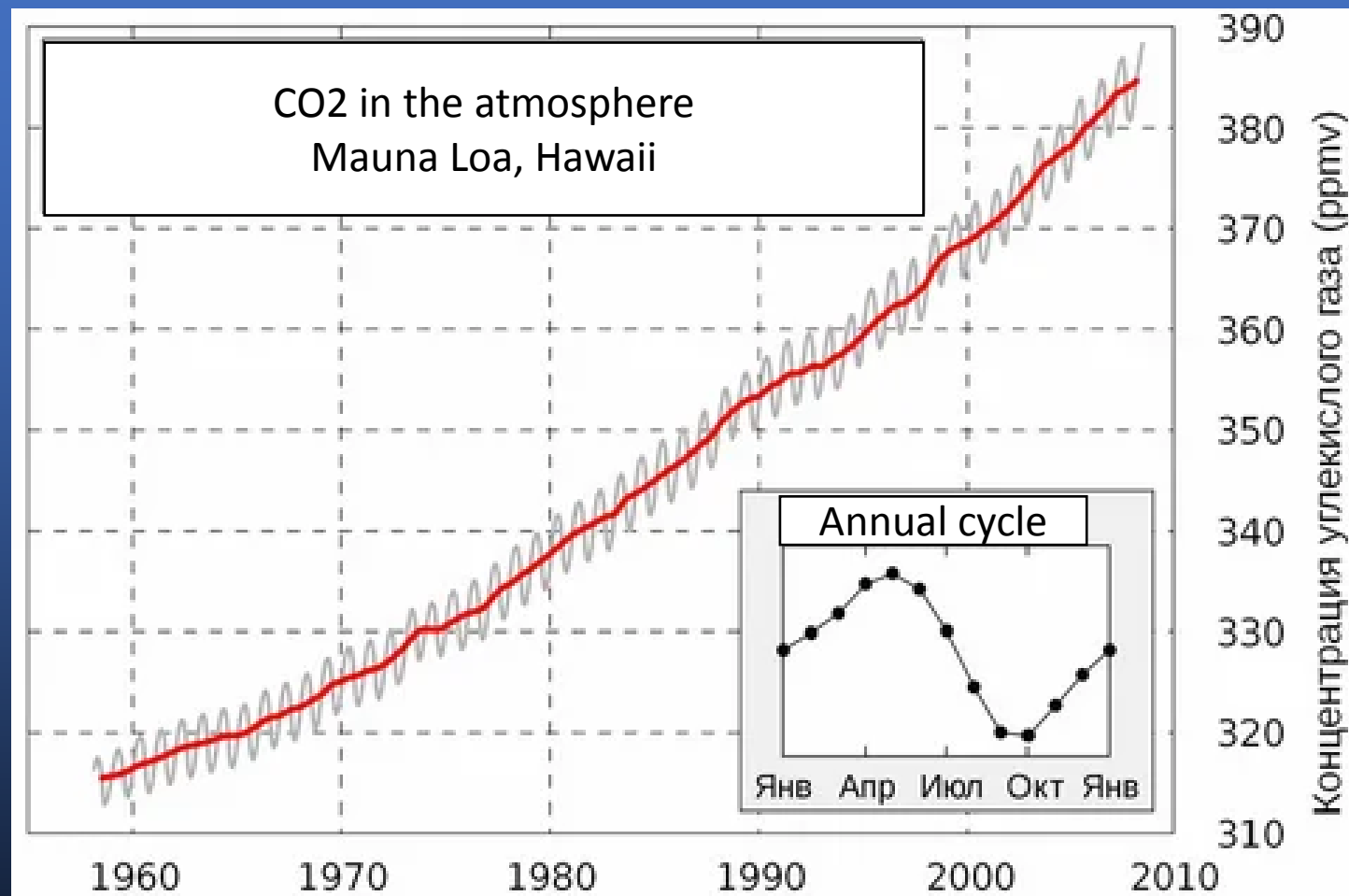
CO₂ fluxes at the surface of the Black Sea

Konovalov S.K., Orekhova N.A., Medvedev E.V.
FSBSI FRC «Marine Hydrophysical Institute RAS»

Importance of investigation



<https://www.co2.earth/carbon-in-the-ocean>

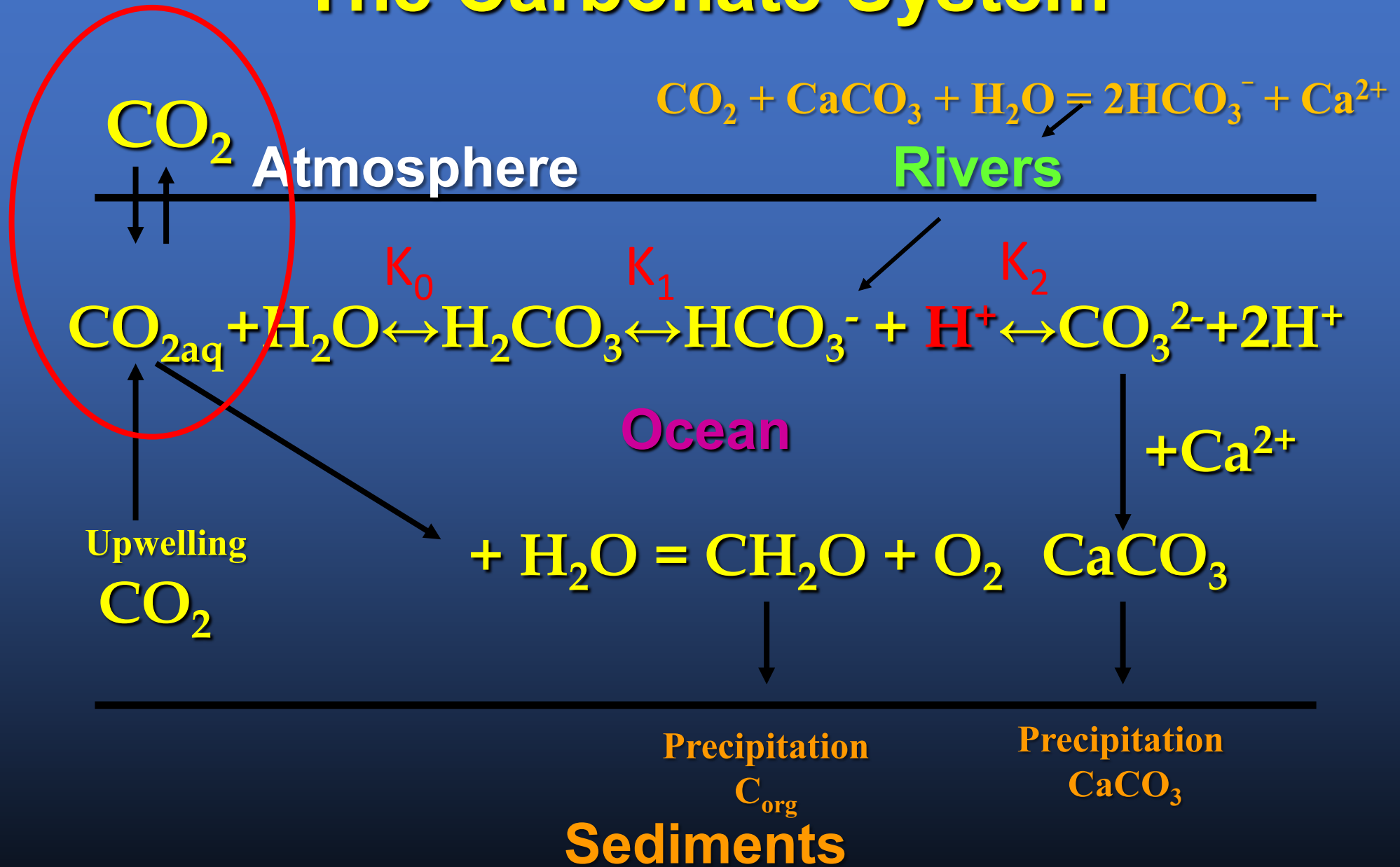


CO₂ has increased in the atmosphere by 51% (287 ppm) since 1750
The World Ocean absorbs 25% of anthropogenically generated CO₂

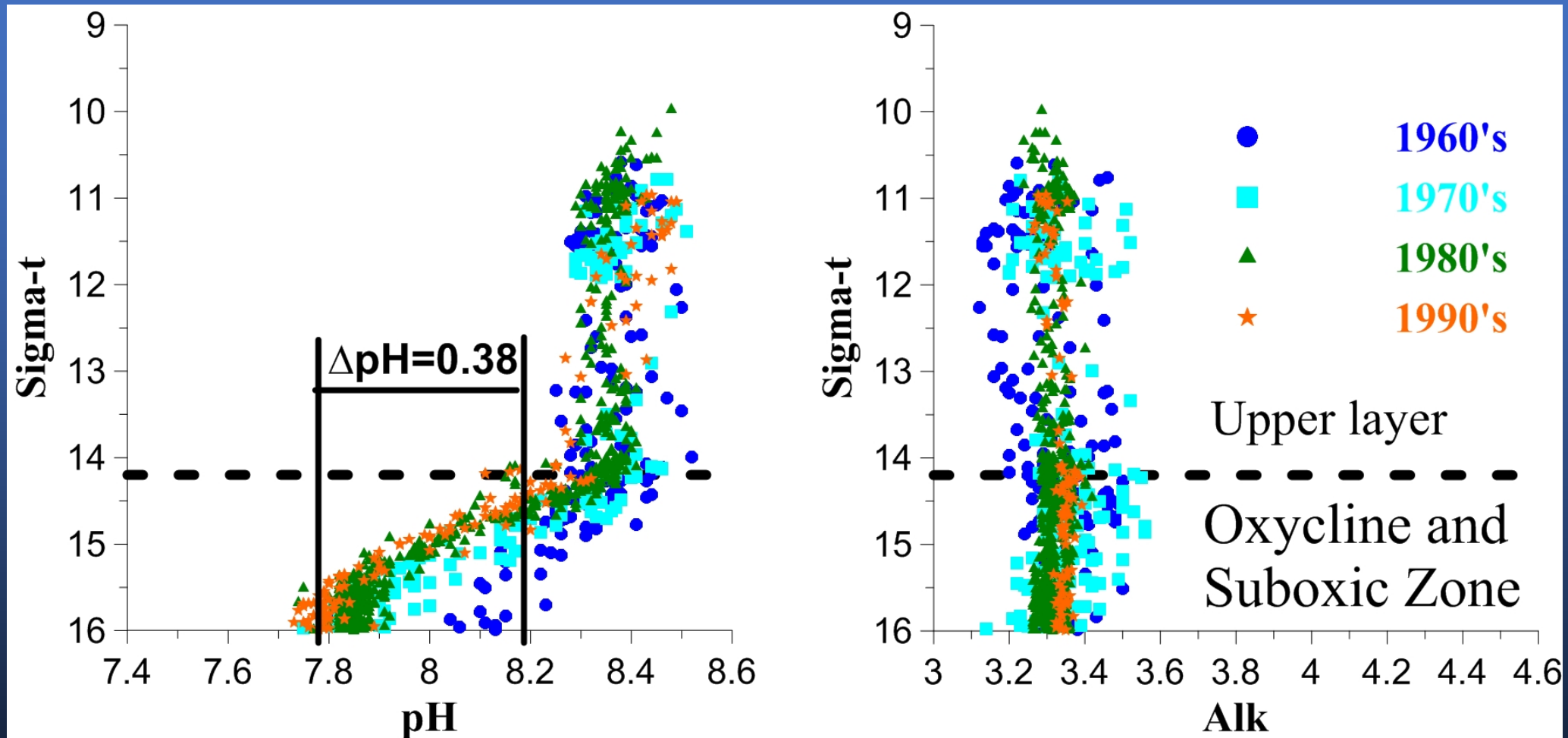
Major topics

- Consequences of CO₂ increase in the Black Sea waters
- What rules the CO₂ flux at the sea surface
- Intra-annual variations of pCO₂ and ΔpCO₂
- Intra-annual variations in FCO₂
- Average annual flux of CO₂ at the Black Sea surface

The Carbonate System

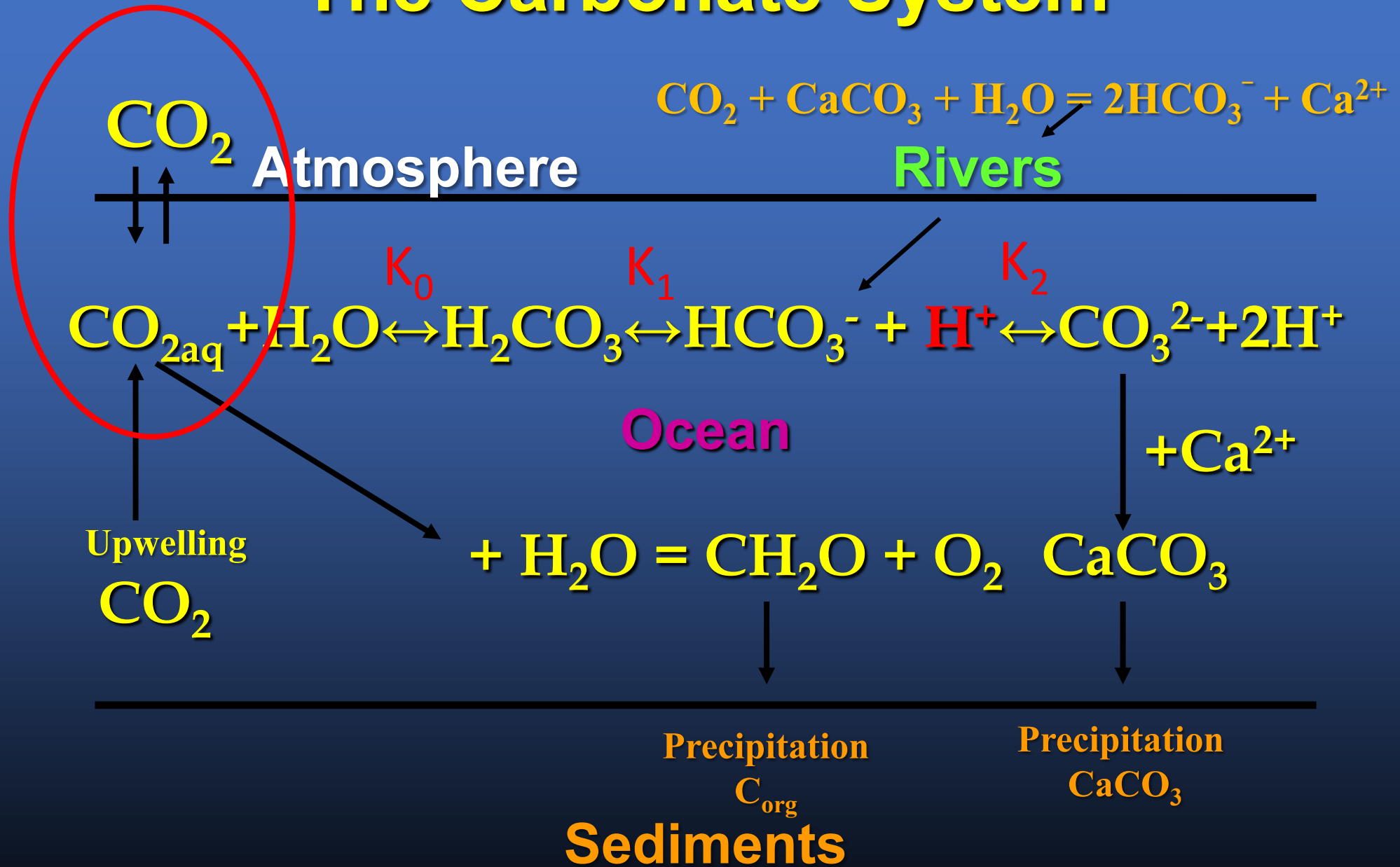


Decadal changes in the carbonate system



Concentration of H^+ has increased by 2.5
Alk has revealed minor changes.

The Carbonate System



CO₂ flux at the sea surface (Wannikhof, 2014)

$$F_{\text{CO}_2} = k \cdot K_0 \cdot \Delta p\text{CO}_2,$$

F_{CO_2} – поток углекислого газа на границе с атмосферой, моль·м⁻²·сут⁻¹;

K_0 – растворимость CO₂, моль·м⁻³·атм⁻¹;

$\Delta p\text{CO}_2$ – градиент между $p\text{CO}_2$ водой и атмосферой, атм;

k – скорость газопереноса, м·сут.⁻¹, параметризованная как функция скорости ветра:

$$k = 0.251 \cdot U^2 \cdot (Sc/660)^{-0.5}$$

U – скорость ветра, м·с⁻¹;

Sc – число Шмидта;

0,251 – эмпирически выведенный параметр, см·ч⁻¹ ·(м·с⁻¹)⁻² соответственно

Governors of the CO₂ flux

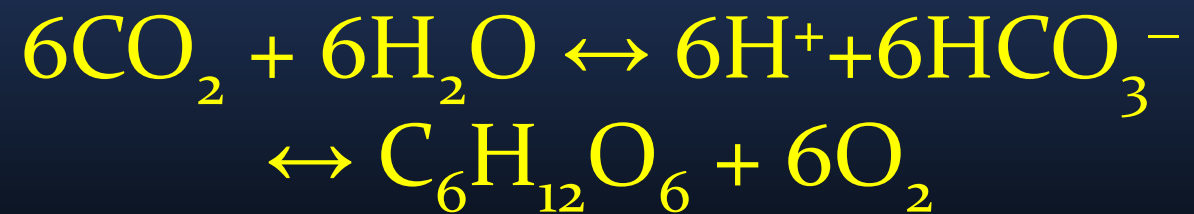
Temperature,
salinity,
wind !!!!

Gradient of pCO₂ at the sea
surface

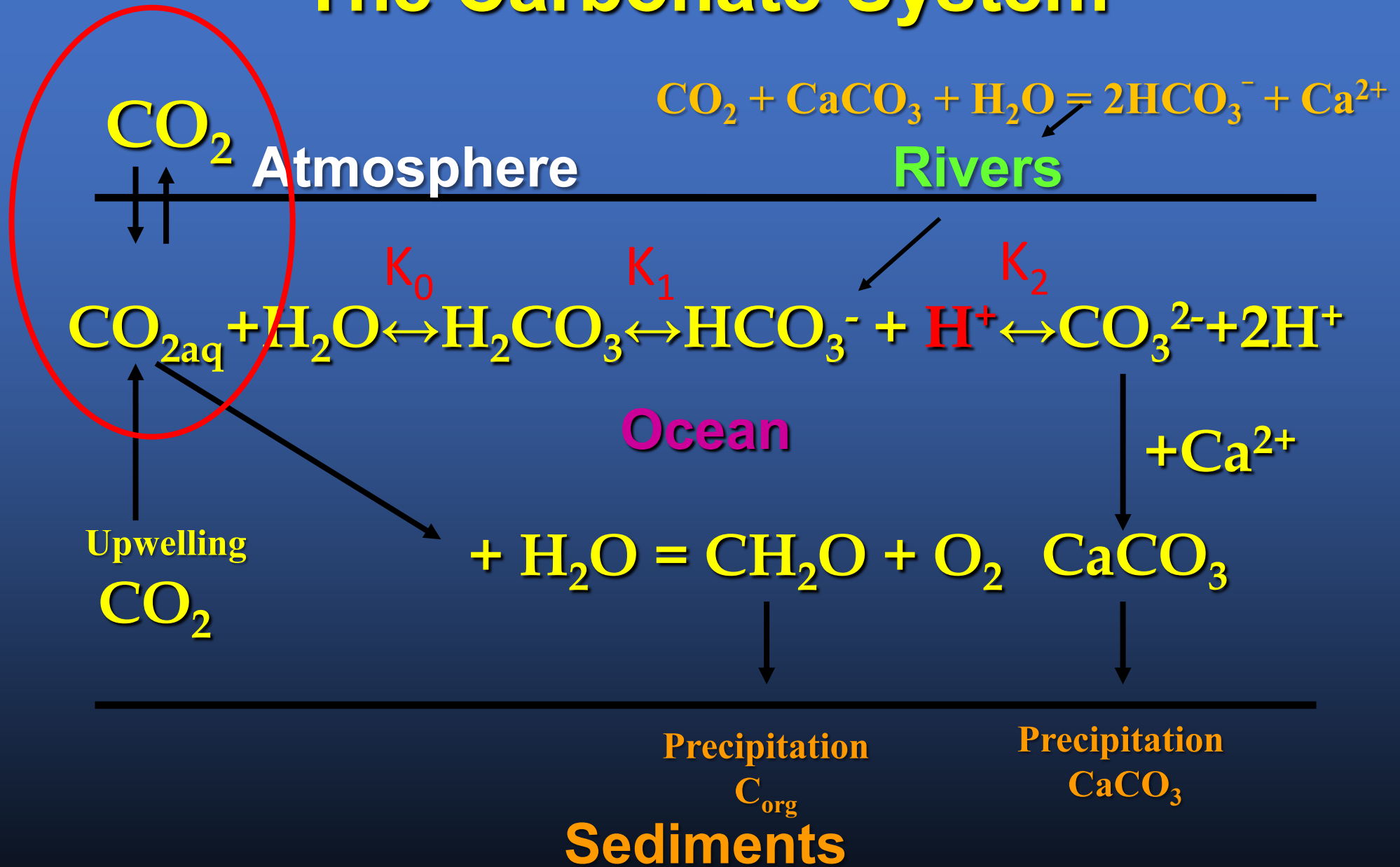
$$F_{\text{CO}_2} \propto U^2 \cdot \Delta p\text{CO}_2$$



BGC CO₂



The Carbonate System

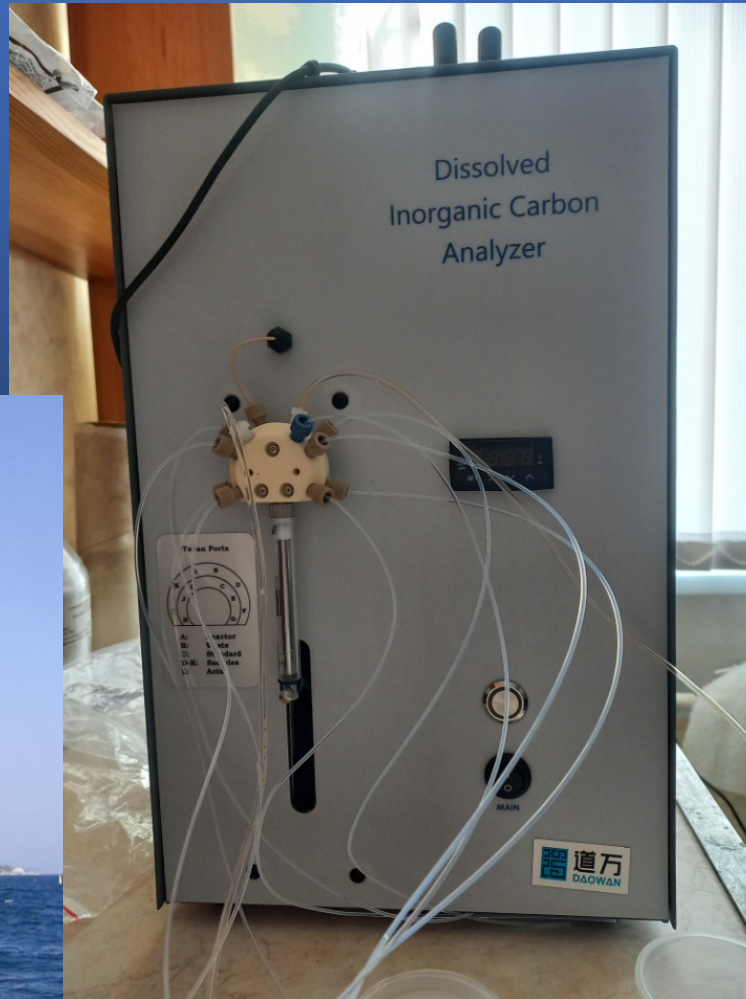
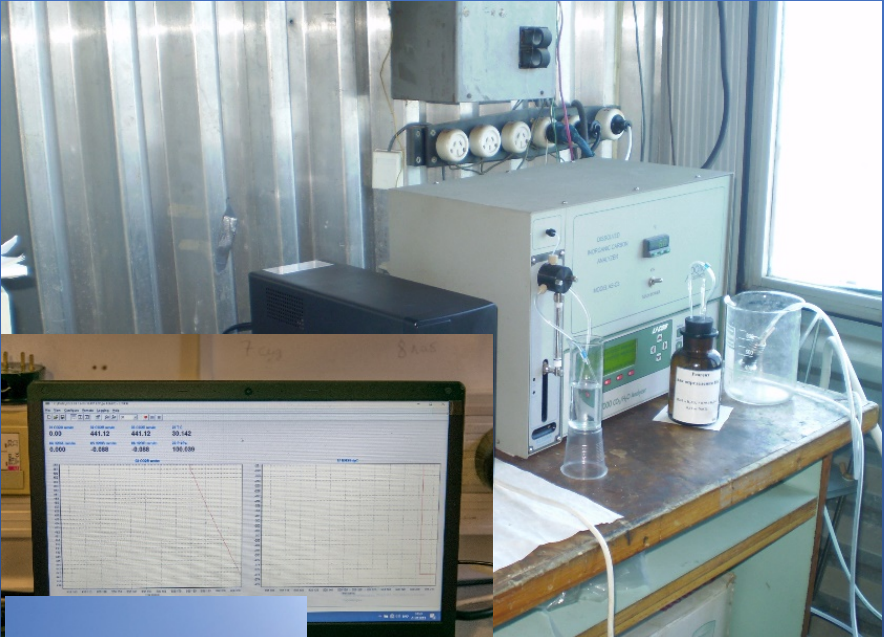


Direct measurements of CO₂

Infrared LI-7000 analyzer for determination of CO₂ in water, equipped with an equilibrator between the sea sample and the analyzer circuit



Monitoring of CO₂ in the sea water and atmosphere



Контроль качества
данных +
систематическая
калибровка прибора по
поверочной смеси;
ошибка в пределах 1%;
Диапазон определения 0
– 3000 мд

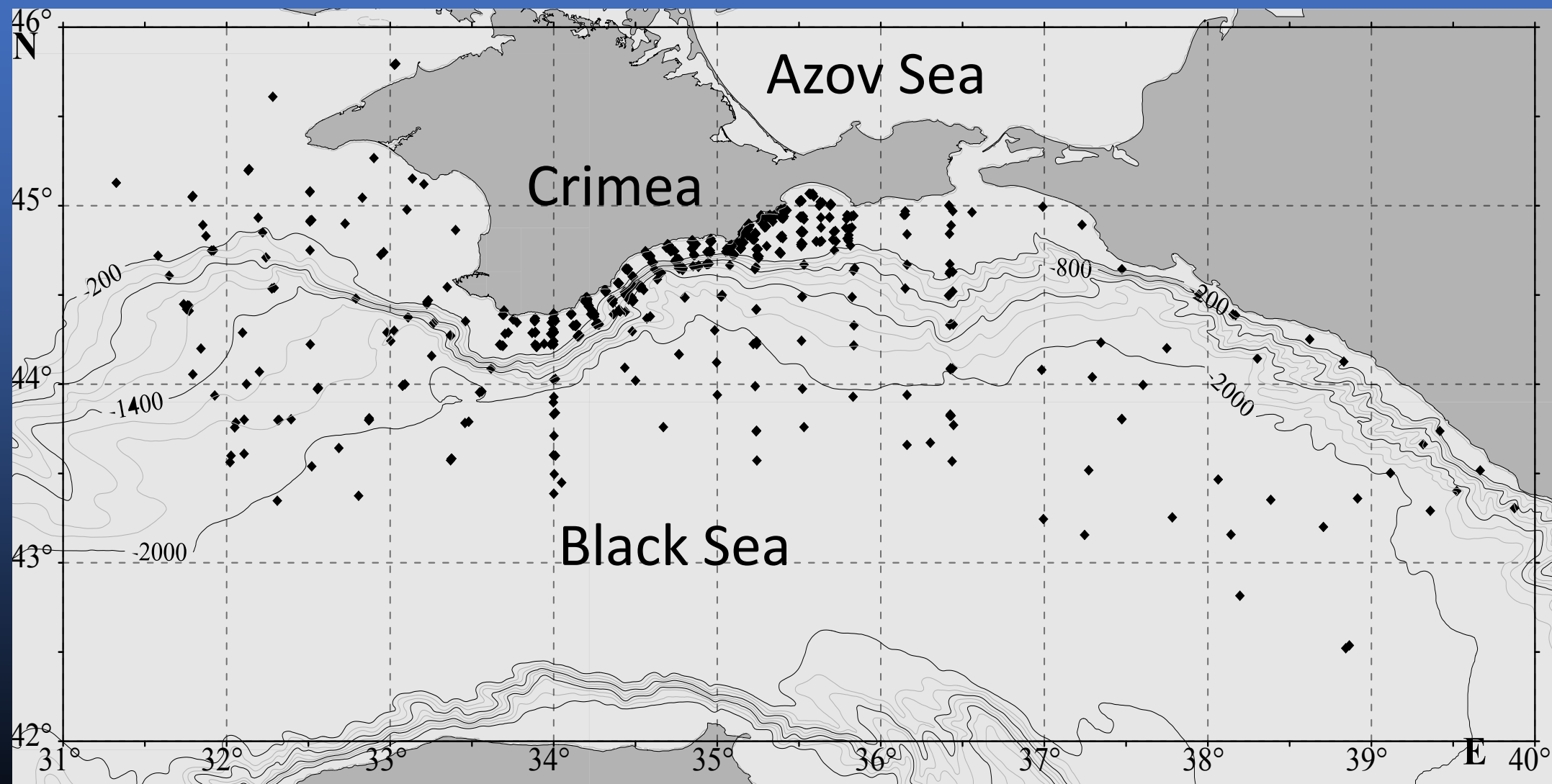


CO₂ studies at R/V «Professor Vodyanitsky»

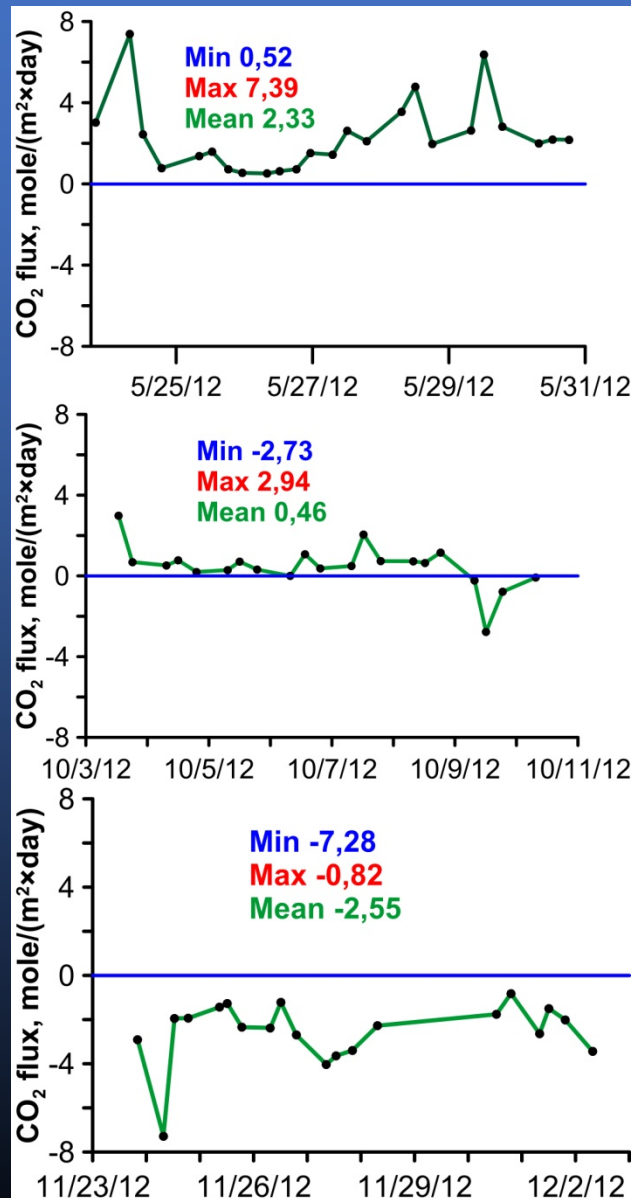


ультразвуковой измеритель
метеорологических
величин «АМК-04» - измерение
потоков импульса и тепла

Area of studies



CO₂ flux at the sea surface

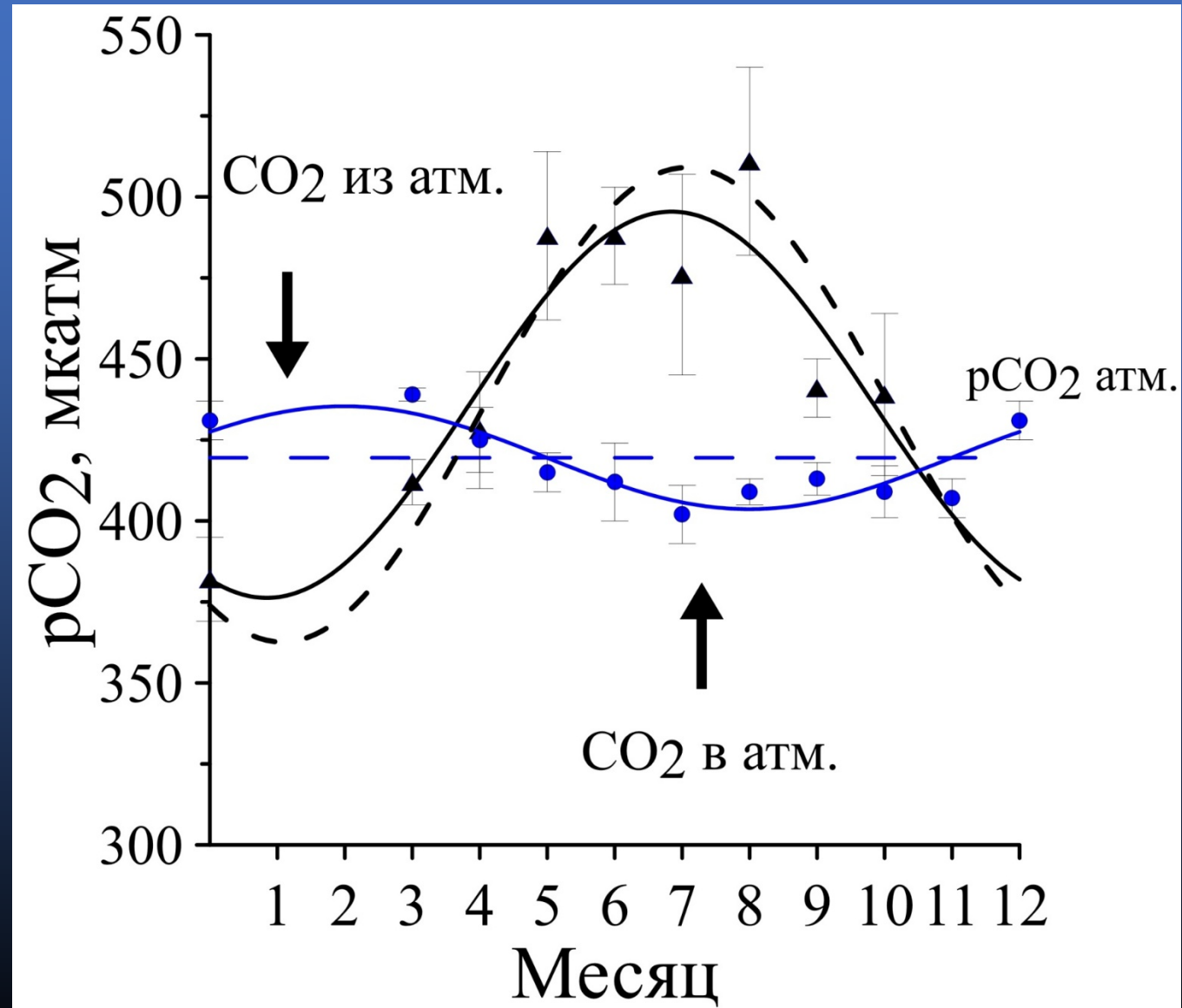


Spring - Summer. Despite active consumption of CO₂ due to photosynthesis, CO₂ is released to the atmosphere.

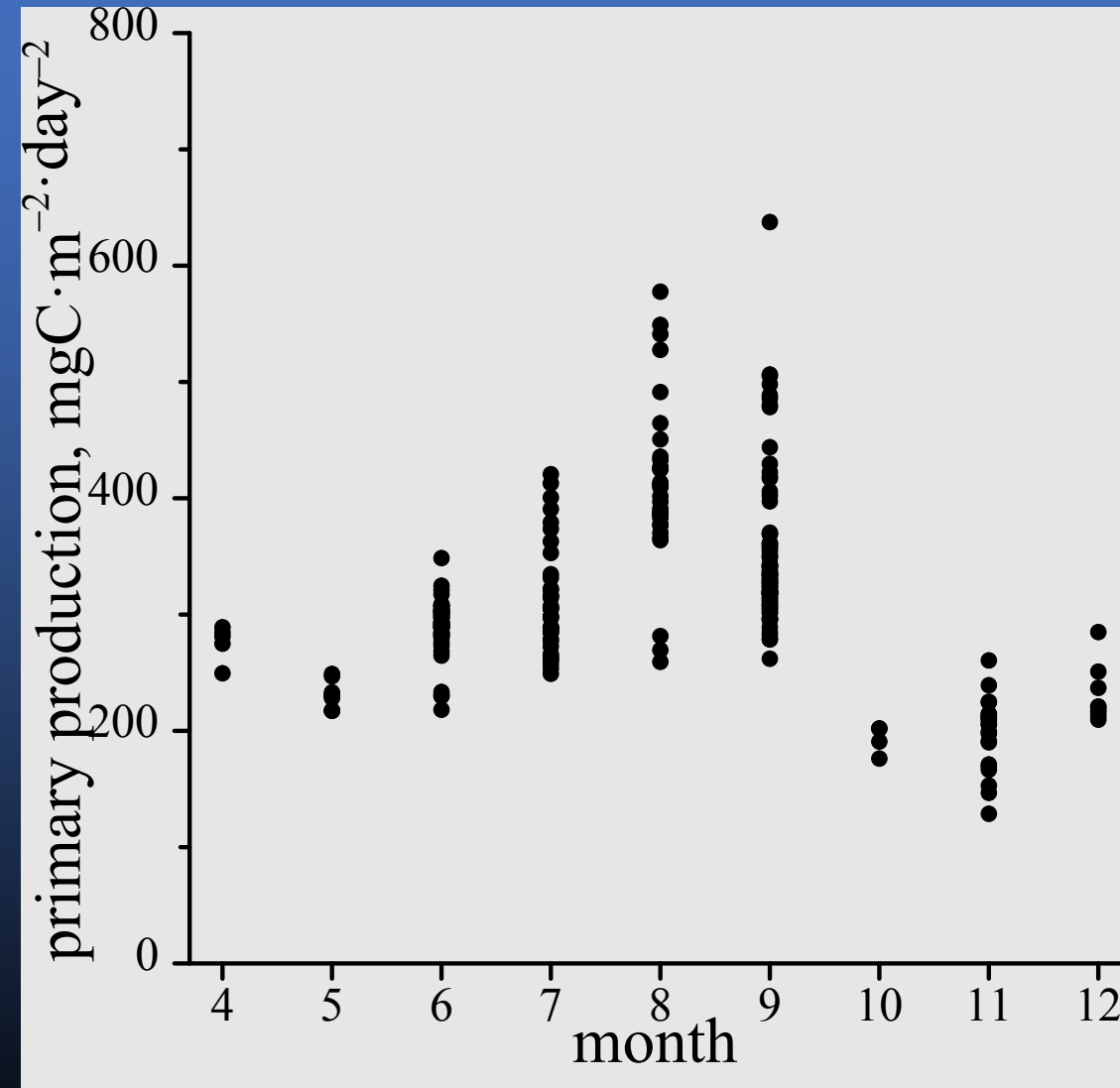
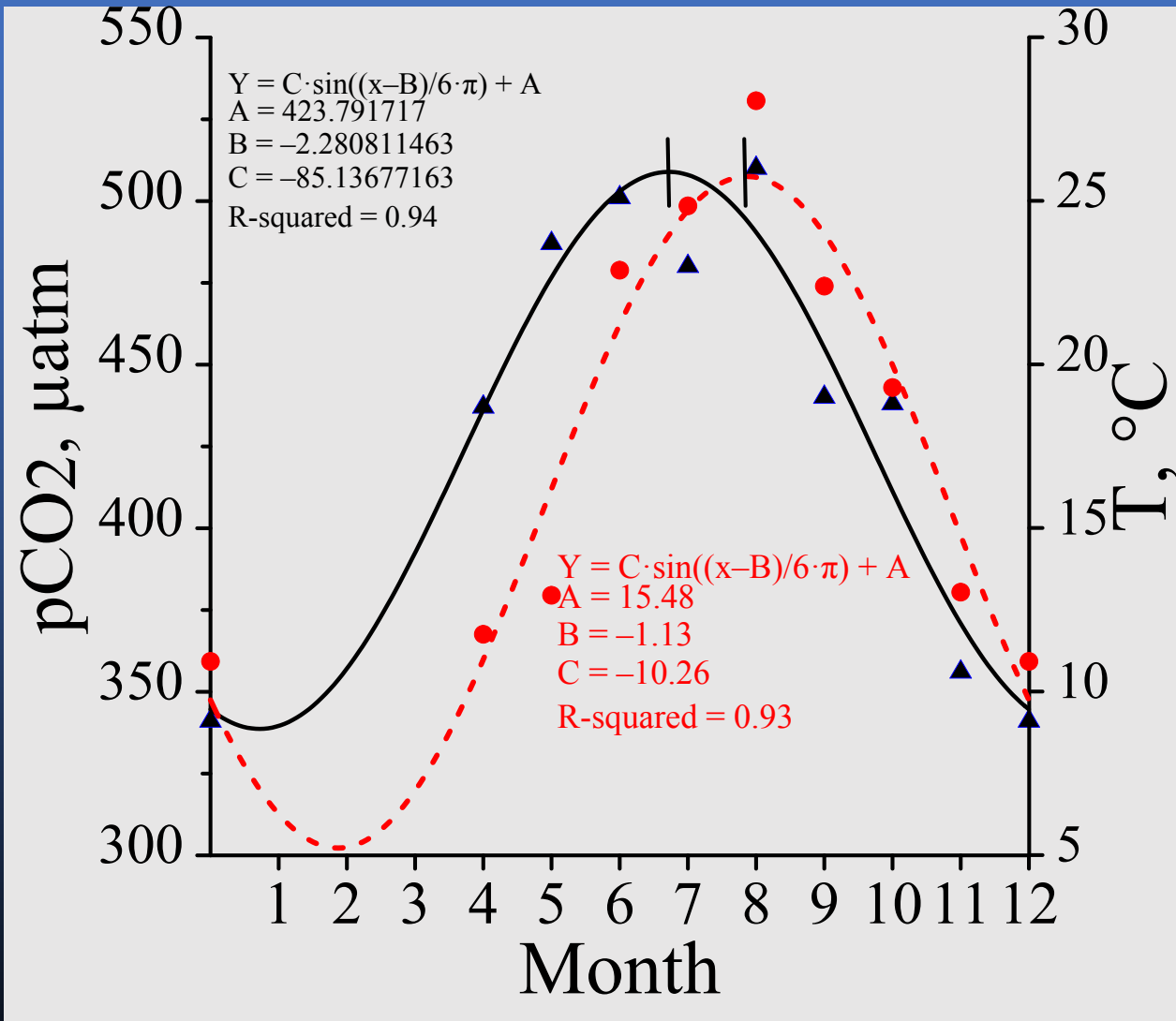
Fall. The sea and atmosphere are in an equilibrium and there is NO flux of CO₂ at the sea surface.

Winter. CO₂ is actively consumed by sea from the atmosphere.

Intra-annual variations in $p\text{CO}_2$ in the sea and atmosphere



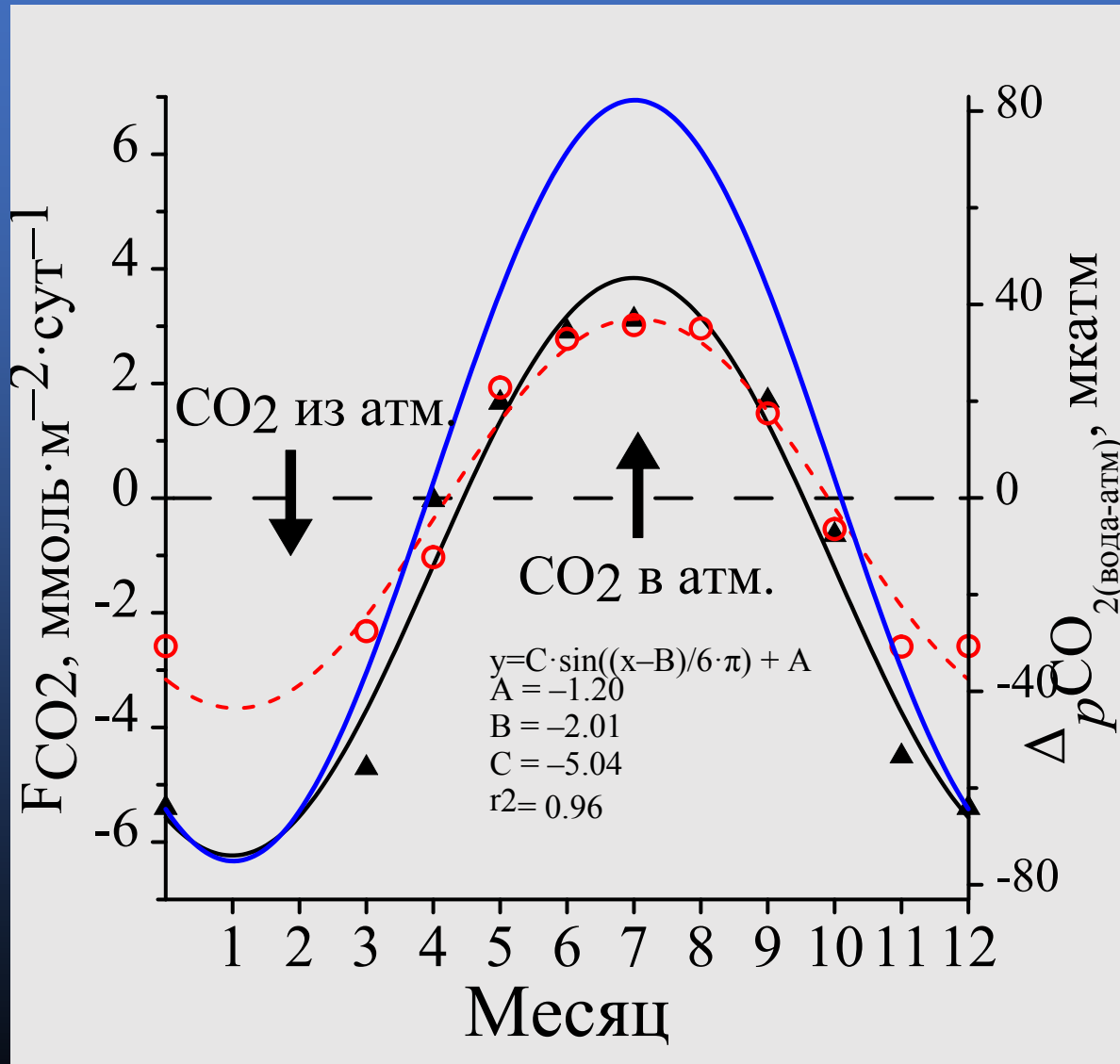
The influence of temperature and bioproductivity



On CO₂ dynamics

- Dynamics of CO₂ in surface waters and direction of CO₂ flux at the sea surface depends primarily on the temperature, which governs the solubility of CO₂ in water and coefficients of dissociation of carbonic acid.
- Processes of photosynthesis are far less important for dynamics of CO₂ in the surface waters, BUT they are important for biological transport of CO₂ from surface to deeper layers of water.
- Warming will result in decreasing consumption of CO₂ from the atmosphere, but it will result in further acidification and oxygen deficit in deeper waters.

CO₂ fluxes at the Black Sea surface



Intra-annual variations in Δp_{CO_2} (blue solid line) and F_{CO_2} at the sea surface, calculated with data on-sea observations in 2015–2024 (red dotted line), and with on-sea observations on Δp_{CO_2} and average climate data on the wind and temperature (black solid line).

The flux of CO₂ from the atmosphere to the sea

The flux of CO₂, calculated for average climate values of the wind and temperature, is equal to $-1,20 \text{ ммоль} \cdot \text{м}^{-2} \cdot \text{сут}^{-1}$.

The flux of CO₂ from the atmosphere to the Black Sea is equal to **7,83 Мт CO₂ per year**, when integrated for the entire area of the sea. Yet, this values should be actually higher because strong winter winds are not correctly accounted.

The CO₂ flux at the sea surface

- Gradient of $p\text{CO}_2$ governs the direction and influences the value of the CO₂ flux, BUT the wind is more important for intra-annual variations and for the annual values of the CO₂ flux.
- The fact that the flux of CO₂ from the atmosphere to the sea in the cold period of the year is higher by its value than the flux of CO₂ from the sea to the atmosphere in the warm period is due to the wind, rather than any other reasons.

What's next?

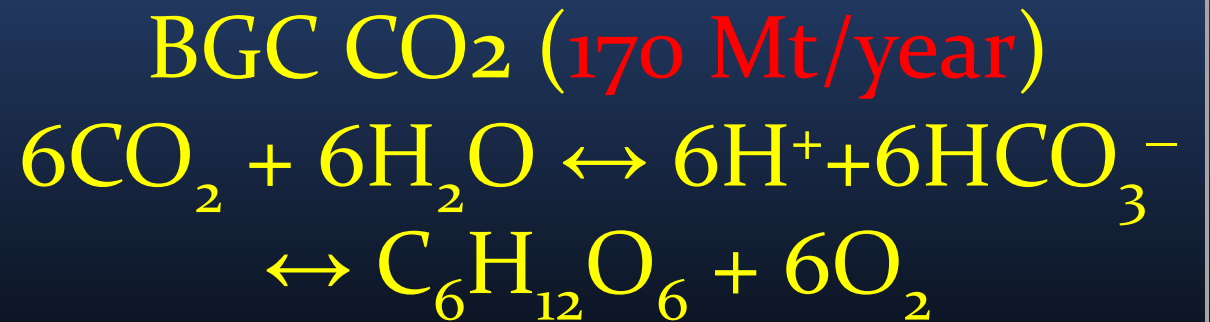
Temperature,
salinity,
wind !!!!

Gradient of pCO₂ at the sea
surface

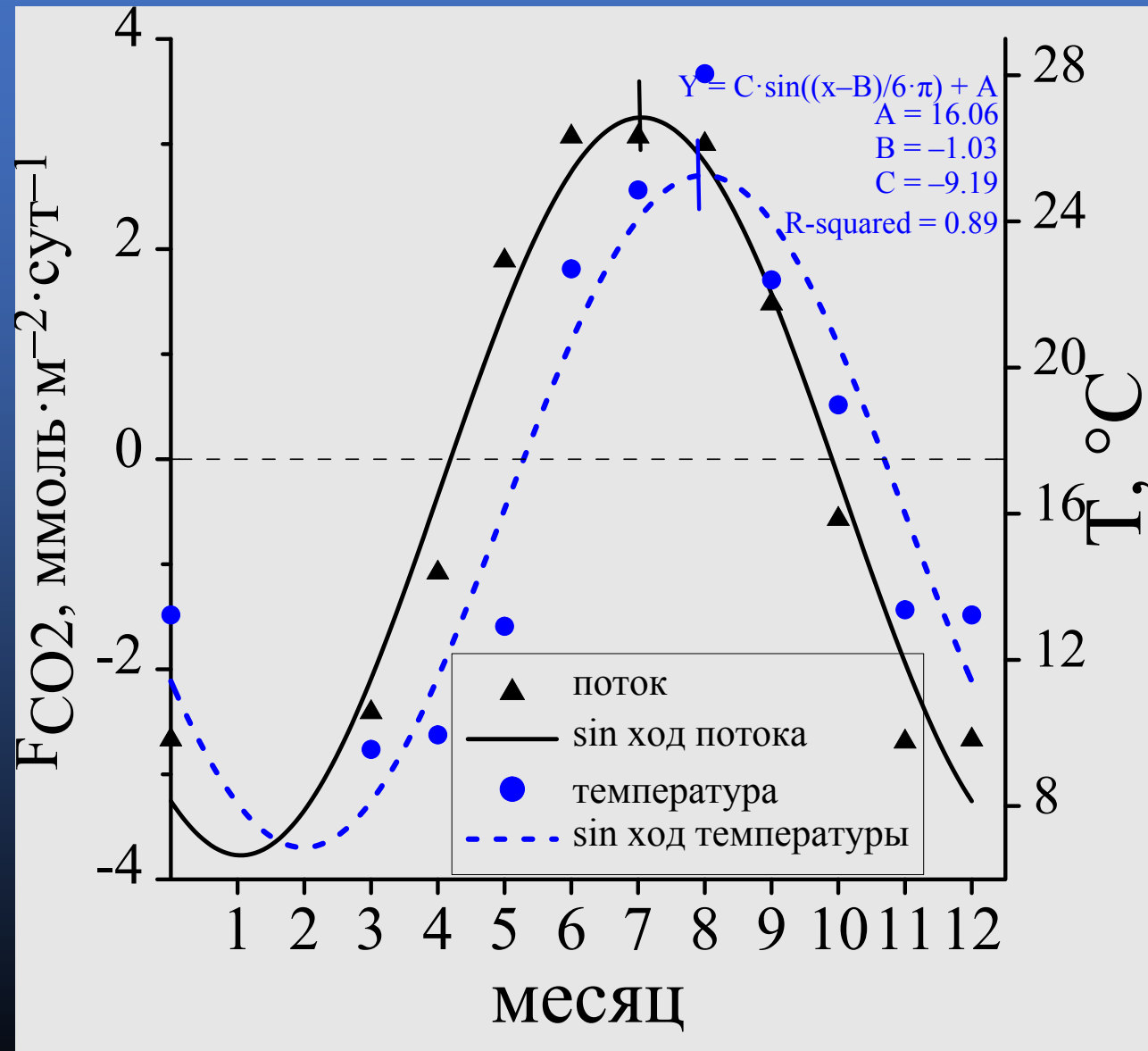


$$F_{\text{CO}_2} \propto U^2 \cdot \Delta p\text{CO}_2$$

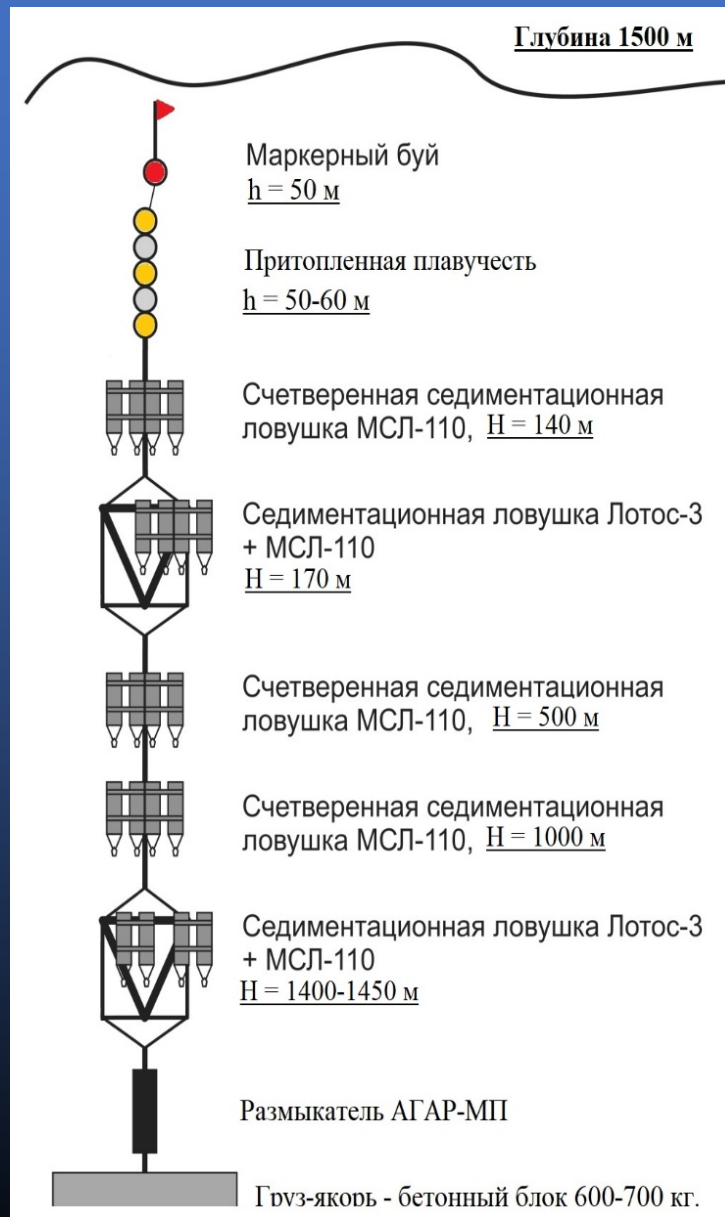
8 Mt/year



Temperature and the flux of CO₂

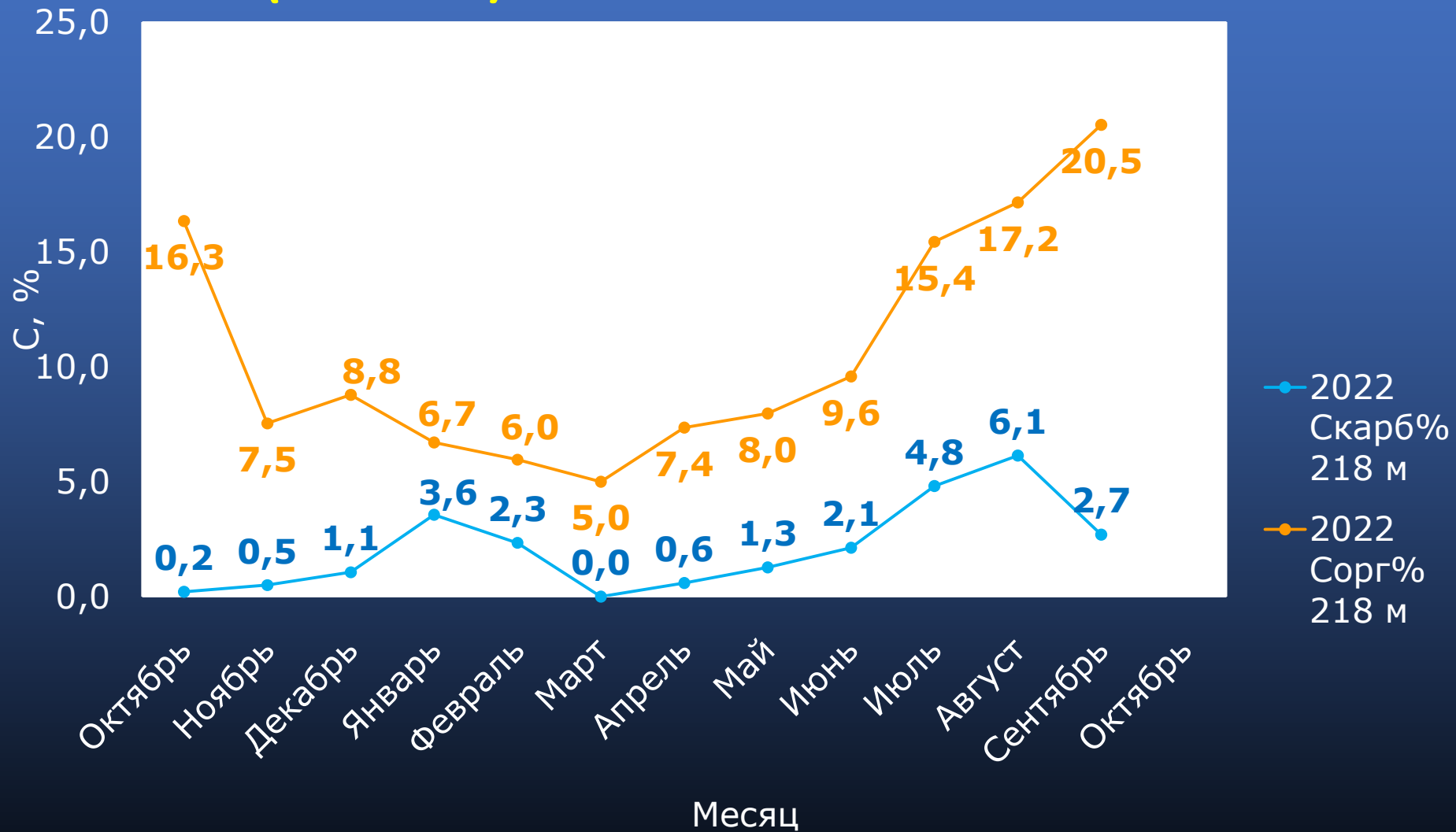


Sediment flux stations



Thanks for Your attention

Сезонный ход Сорг% и Скарб% в подповерхностном слое в 2022 (Лотос)



Внутригодовой ход потока CO₂ на поверхности моря

Открытая часть

Кацивели

