What you need to know about the carbon cycle, atmosphere –ocean CO_2 interactions and climate change

I The carbon cycle reactions (part of the biological pump)

Important reactions

Photosynthesis: $CO_{2(aq)} + H_2O \rightarrow CH_2O + O_2$ (this is the BIO PUMPing "formation" reaction!!!)

Respiration $CH_2O + O_2 \rightarrow CO_{2(aq)} + H_2O$ (The BIO PUMP sequesters CO_2 when organic matter sinks and is respired)

The above reations move carbon back and forth between the organic reservoir and the inorganic reservoir.

II The carbonate system

When the carbon is in it's inorganic phase (CO_2) then we must consider the carbonate family and it's reactions:

1 $CO_{2(aq)} + H_2O \leftrightarrow H_2CO_{3(aq)}$ (carbonic acid)
2 $H_2CO_{3(aq)} \leftrightarrow H^+_{(aq)} + HCO_3^-{}_{(aq)}$ (bicarbonate ion)
3 $HCO_3^-{}_{(aq)} \leftrightarrow H^+_{(aq)} + CO_3^{-2}{}_{(aq)}$ (carbonate ion)
4 $Ca^{++}_{(aq)} + CO_3^{-2}{}_{(aq)} \leftrightarrow CaCO_3$ (calcium carbonate mineral)

Reactions 1-3 describe the dissolved system reaction 4 is the formation of the solid, $CaCO_3$ "limestone"

A) For the **dissolved phases:**
This is a buffered reaction and bi-carbonate is favored at ocean pH. Thus the sum reaction **of the dissolved species** moves towards **bicarbonate at all times.** So the important summary equation for the dissolved **ΣCO_2 is :**

$CO_{2(aq)} \leftrightarrow 2HCO_3^-{}_{(aq)} \leftrightarrow CO_3^{-2}{}_{(aq)}$
Also written as
$CO_{2(aq)} + CO_3^{-2}{}_{(aq)} \leftrightarrow 2HCO_3^-{}_{(aq)}$
This signifies if carbon dioxide is added CO_3^{-2} is consumed in the transformation to HCO_3^-. The consequence is that calcium carbonate dissolves or is harder to precipitate.

And the governing equilibrium constant is:

$$K^1 = \frac{[CO_{2(aq)}][CO_3^{-2}]}{[HCO_3^-]^2}$$

What does this mean? It means that more CO_2 added to the water does NOT stay as CO_2 it dissociates to and on short(ish) timescales the reaction has 3 consequences –
lots of carbon is dissolved in the ocean as bicarbonate (the ocean sequesters CO_2)
the pH of the ocean decreases (ocean acidification)
carbonate ion is disfavored – there is proportionally less CO_3^{-2} because of this:
the formation of $CaCO_3$ is also disfavored.

B) The **solid phase**: (the carbonate pump, and sediment connection)
The above equation #4 is the condensed of what is 2 steps within the organism

a. **$2HCO_3^-{}_{(aq)} \rightarrow 2CO_3^{-2}{}_{(aq)} + 2H^+ \rightarrow$** (bicarbonate is taken up and converted to carbonate)
b. $Ca^{++}_{(aq)} + 2\,CO_3^{-2}{}_{(aq)} + 2H^+ \leftrightarrow CaCO_3 + CO_2 + H_2O$ (calcium carbonate mineral)
c. Ω is the saturation state and is governed by:

$$\Omega = \frac{[Ca^{++}][CO_3^{-2}]}{K'_{sp}}$$