

# ADDENDUM

## Estimates of natural flows in the MPO model

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### Summary

- The quantification of the four natural flows is based primarily on measurements of  $[CO_2]$ ,  $\delta^{13}C$ , and SSTi. These observations were made in both hemispheres between 1980 and 2025. The  $[CO_2]$  measurements, collected at the [four NOAA baseline observatories](#), are used to determine the average mass of carbon in the atmosphere =  $X(t)$ .
- The estimates of the four natural flows proposed by the MPO model remain broadly similar ( $\pm 25\%$  except for F1) to those proposed by the IPCC in the Arx WG1 reports (see Fig. 3).

The **MPO** model (**M**ixed **P**roportional **O**cean) complies with the three compartments and four natural flows used in IPCC reports. This simplification is implemented here over a limited period, covering the years **1980 to 2025**.

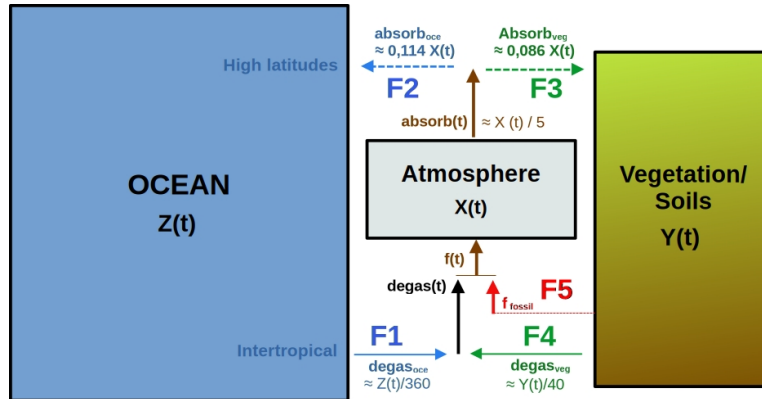


Figure 1: Ratings of the five flows and stocks in the three compartments (Figure 15 in [Revisiting the carbon cycle](#))  
**Stocks X,Y,Z:** 1 ppm = 0,0001% → 7,8 Gt-CO<sub>2</sub> = 7,8 x 10<sup>12</sup> kg of CO<sub>2</sub> → 2,12 Gt-C = 2,12 x 10<sup>12</sup> kg of carbon  
**Flows F1, F2, F3, F4, F5:** 1ppm/year → 2,12 Gt-C/year ; 1 Gt-C/year → 3,67 Gt-CO<sub>2</sub>/year → 0,47 ppm/year

## 1. Flows leaving the atmosphere F2 and F3

### 1.1 Dimensioning of F3

Flow 3 is calibrated so as to:

- correspond to NPP estimates according to [Haverd et al 2009](#).
- be proportional to atmospheric CO<sub>2</sub> concentration.
- be virtually compatible with the 6 WG1 reports of the IPCC →  $F3 \approx 0.078 X(t)$

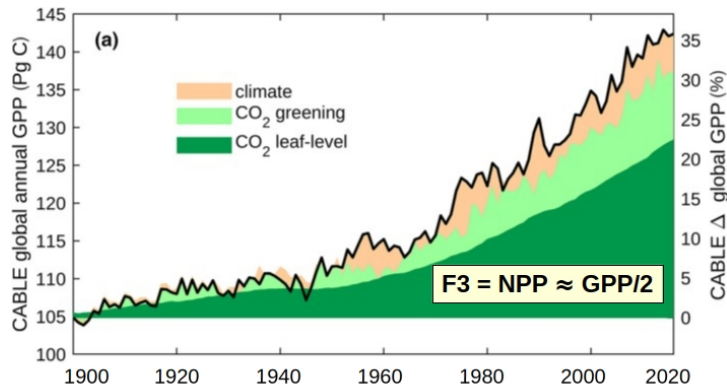


Figure 2:  $GPP \approx 2 * NPP$  according to Figure 2 in [Haverd et al, 2019](#) <https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/gcb.14950>

For **effective multi-year** carbon sequestration by vegetation, i.e., F3, **Net Primary Production** →  $NPP \approx GPP/2$  must be used, where **GPP = Gross Primary Production** ([see here](#)).

Dates	Assessment Report	Flow in Gt-C / yr					X(t) → [CO <sub>2</sub> ] in Gt-C	Residence time (year) = X(t) / (flow 2 + flow 3)	
		Flow 2	F2/X(t)	Flow 3 if GPP	Flow 3 if NPP	F3/X(t)		if flow 3 = GPP	if flow 3 = NPP
1990	AR1 fig 1.1	92	12,3 %	102	51	6,8 %	750	3,87	5,24
1995	AR2 fig 2.1	92	12,3 %	GPP ?	61,8	8,2 %	750	GPP ?	4,88
2001	AR3 fig 3.1a	90	11,9 %	120	60	7,9 %	730? 755	3,60	5,03
2007	AR4 fig 7.3	92,2	12,1 %	122,6	61,3	8,0 %	762	3,55	4,96
2013	AR5 fig 6.01	80	9,7 %	123	61,5	7,4 %	829	4,08	5,86
2021	AR6 fig 5.12	79,5	9,1 %	142	71	8,2 %	870	3,93	5,78
Average (F2+F3) / X(t) = 19 % = 1 / 5,3 11,2 % + 7,8 % = 19 %		11,2 % = Average		Average = 7,8 %		average residence time (year)	3,8	5,3	

Figure 3: According to the six WG1 reports of the IPCC, on average  $F2 \approx 0.112 X(t)$  and  $F3 \approx 0.078 X(t)$

We finally adopt  $F3 = 0.086 X(t)$ , which is consistent with [Haverd 2009](#) and close to  $0.078 X(t)$ , the average of the six WG1 reports of the IPCC.

## 1.2 Dimensioning of F2

Flow 3 is calibrated so as to be :

- proportional to atmospheric CO<sub>2</sub> concentration.
- virtually compatible with the [figure 3.1a](#) AR3 WG1 report of the IPCC →  $F2 \approx 90 \text{ Gt-C/year} \pm 25\%$  around 2000 .
- compatible with the previous choice of  $F3 = 0.086 X(t)$ .

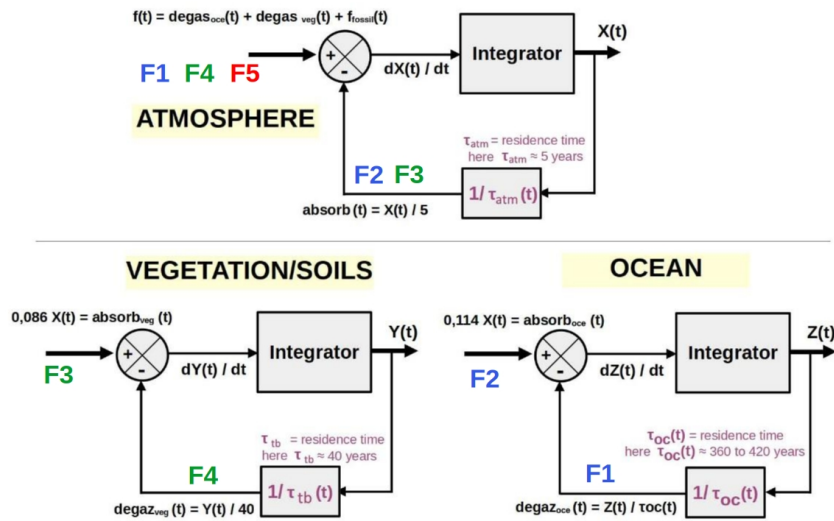


Figure 4: The three compartments have a common simple model but different residence times →  $\tau = \text{Stock} / \text{outgoing flow}$  (based on Figure 14 in [Revisiting the carbon cycle](#))

The MPO model adopts a residence time in the atmosphere of 5 years.

We therefore have  $(F2 + F3) = X(t)/5 = F2 + 0.086 X(t)$ . We finally adopt  $F2 = 0.114 X(t)$ .

## 2. Flows entering the atmosphere F1 and F4

We follow the simple models shown in Figure 4: flows will be calculated using an expression based on stocks  $Y(t)$  and  $Z(t)$  and the residence time of the compartment. The calculations will use observations of atmospheric CO<sub>2</sub> (ratio and  $\delta^{13}\text{C}$ ) from 1980 to 2025.

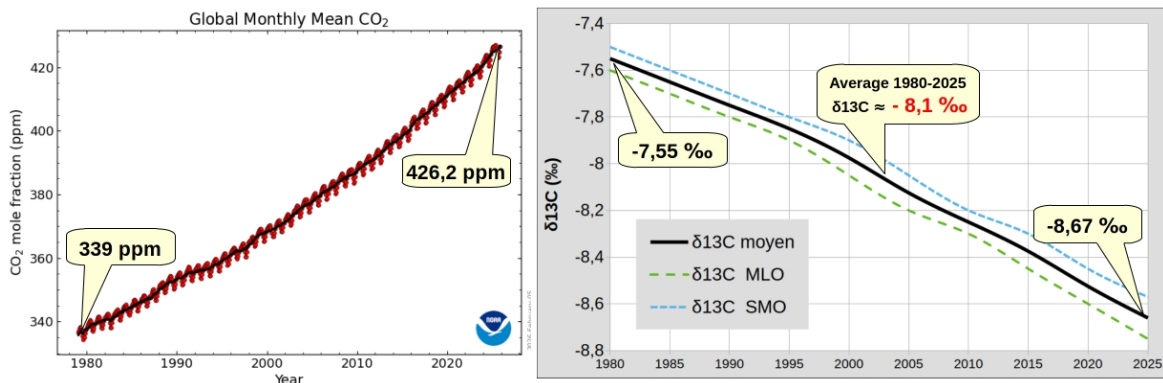


Figure 5 : **Global** atmospheric CO<sub>2</sub> levels according to [NOAA](#) (1 ppm → 2,12 Gt-C);  $\delta^{13}\text{C}$  in the atmosphere according to [Scripps CO<sub>2</sub>](#)

Between 1980\* and 2025, the CO<sub>2</sub> level in the atmosphere will increase:  $426.2 - 339 = +87.2$  ppm, representing a net contribution of +185 Gt-C. This net contribution must be such that  $\delta^{13}\text{C} = -13.0\text{‰}$ , because between 1980 and 2025 we have:

$$\text{ppm} : (339 * -7,55) + (87,2 * -13,0) = (426,2 * -8,67)$$

$$\text{Gt-C} : (719 * -7,55) + (185 * -13,0) = (904 * -8,67)$$

\* 1980 because we need to have measurements of  $\delta^{13}\text{C}$  and CO<sub>2</sub> levels in both hemispheres.

[Koutsoyiannis 2024a](#), reports similar values in Fig. 10 for net contributions:  $-12.9\text{‰} > \delta^{13}\text{C} > -13.3\text{‰}$

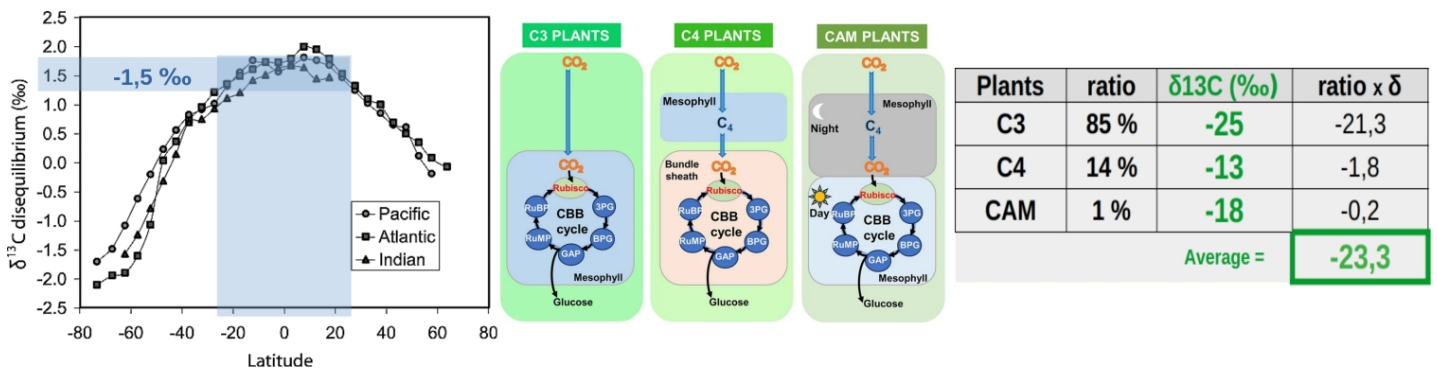


Figure 6: For  $\delta^{13}\text{C}$ , the net intertropical ocean contribution is  $< 1.5\text{‰}$  to the atmosphere (fig 8 Quay et al., 2003)  $\rightarrow -8,1 - 1,5 \approx -9,6\text{‰}$   
 For net vegetation/soil input,  $\delta^{13}\text{C}$  depends on the type of vegetation  $\rightarrow$  on average,  $\delta^{13}\text{C} \approx -23.3\text{‰}$

## 2.1 Estimating net contributions to the atmosphere for oceans and vegetation/soils

• Between 1980 and 2025, anthropogenic emissions will contribute 360\* Gt-C to the atmosphere, but growth will only be 185 Gt-C. According to the IPCC model, the Ocean and Vegetation/Soil compartments would absorb about half of the 360 Gt-C of anthropogenic carbon, thereby offsetting the 185 Gt-C increase observed in the atmosphere.

\*  $\sim 1260 \text{ Gt-CO}_2$ , or  $\sim 343 \text{ Gt-C}$  according to [World Energy Outlook](#), but the IPCC adds approximately 5% LUC  $\rightarrow 343 * 1.05 \approx 360 \text{ Gt-C}$ .

• Let z be the net contribution from the ocean and y the net contribution from vegetation/soils. According to the IPCC model, we would therefore have  $z \approx y \approx -(360-185)/2 = -87.5 \text{ Gt-C}$  (both compartments are carbon sinks). The table below shows that observations contradict this IPCC model.

Balance sheet 1980-2025	Anthropogenic	Ocean	Vegetation /soils	Net contribution
Atmosphere in (Gt-C)	360			
Atmosphere out (Gt-C)				
<b>Net (Gt-C)</b>	<b>360</b>	<b>-87,5</b>	<b>-87,5</b>	<b>185 Gt-C</b>
$\delta^{13}\text{C}$ (‰)	<b>-29</b>	<b>-9,6</b>	<b>-23,3</b>	<b>-40,9 ‰</b>
Net x $\delta^{13}\text{C}$	-10440	837	2040	<b>-7563</b>
<b>Min (‰)</b>	<b>-31</b>	<b>-6,0</b>	<b>-20,0</b>	<b>-48,0 ‰</b>
Net x $\delta^{13}\text{C}$	-11160	525	1750	-8885
<b>Max (‰)</b>	<b>-27</b>	<b>-12,0</b>	<b>-28,0</b>	<b>-33,6 ‰</b>
Net x $\delta^{13}\text{C}$	-9720	1050	2450	-6220

Figure 7a: The IPCC model does not allow for a net input of 185 Gt-C with  $\delta^{13}\text{C} = -13\text{‰}$   
 $360 + -87.5 + -87.5 = 185$ ; but  $-10440 + 837 + 2040 = -7563$  and  $-7563 / 185 = -40.9\text{‰}$

In the lower part, for a wide range of values  $\delta^{13}\text{C}$ , it is shown that  $\delta^{13}\text{C}$  net contribution **remains far** from  $-13\text{‰}$  ( $-48\text{‰}$  to  $-33.6\text{‰}$ ).  
 See also pages 22-24 in [The Cause Of Earth's Climate Change Is The Sun](#).

• According to the MPO model, which contradicts the IPCC model, the ocean is a net source with respect to the atmosphere, i.e., z is positive  $\rightarrow F1 > F2$ .

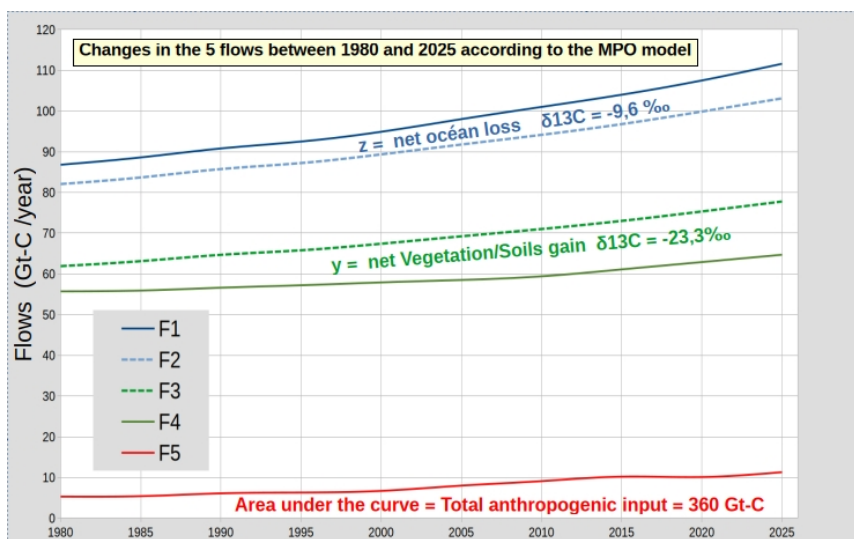


Figure 7b: According to MPO, the ocean is a net source for the atmosphere ( $F1 > F2$ ), while vegetation/soil is a sink ( $F3 > F4$ ). However, the sum (ocean + vegetation/soil) is **overall a sink** ( $y > z$ ) with respect to the atmosphere.

In order to comply with the observations in Fig. 5 (which imply a total net input of 185 Gt-C with  $\delta^{13}\text{C} = -13.0\text{‰}$ ), we must simultaneously have (Gt-C) :

$$360 + z + y = 185$$

$$(360 * -29) + (z * -9,6) + (y * -23,3) = (185 * -13,0)$$

Solving the system of two equations gives:  $z = 288 \text{ Gt-C}$  and  $y = -463 \text{ Gt-C}$ . We have  $(y+z) = -463 + 288 = -175$ . The net contribution of the ocean = z is positive, but nature is overall a sink because  $(y + z)$  is negative. These two net contributions y and z between 1980 and 2025 allow us to place a constraint on each of the flows F1 F4.

## 2.2 Dimensioning of F1

F1 will be almost compatible with [figure 3.1a](#) of the AR3 WG1 report, which proposes  $F1 \approx 90 \text{ Gt-C/year} \pm 25\%$  around 2000.

**Constraint 1:** The ocean must provide a net input of 288 Gt-C over 45 years ( $F1 > F2$ ).

Rough estimate in Gt-C/year:  $288 / 45 = 6.4 \rightarrow$  with  $F1 \approx F2 + 6.4$ , we comply with a net input of 288 Gt-C over 45 years.

Note that F2 is estimated by  $F2(t) = 0.114 X(t)$ .

Rather than using a rough estimate, we ultimately adopt  $F1 = Z(t) / \tau_{oc}$  with a variable residence time (for 1980-2025,  $\tau_{oc} \approx 340$  to 440 years). The residence time allows us to comply with constraint 1 but also to have  $\tau_{oc}$  as a function of SSTi (intertropical sea surface temperature). To do this, we use the partial pressure of  $\text{CO}_2$  in the ocean ( $p\text{CO}_2$  is proportional to  $\text{SSTi}^{12.5}$ ).

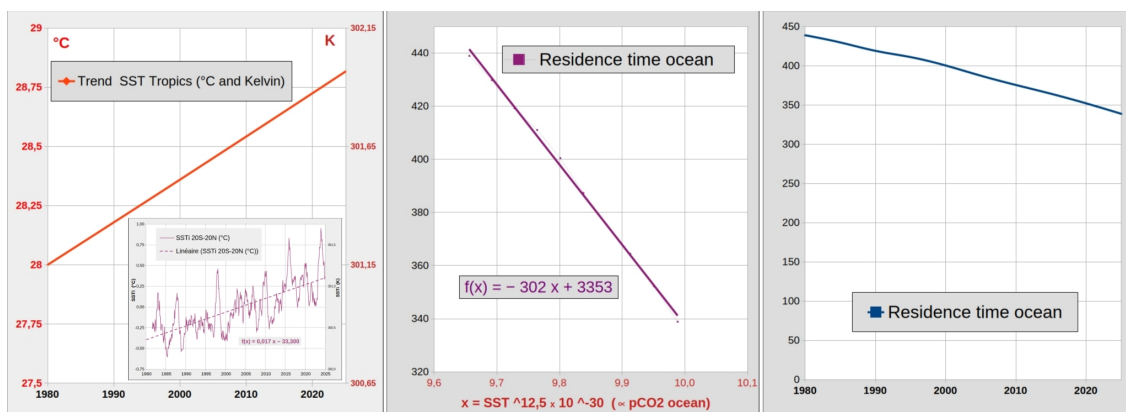


Figure 8: Determination of ocean residence time based on SST Tropics

## 2.3 Dimensioning of F4

**Constraint 2:** Vegetation/Soil must provide a net input of -463 Gt-C over 45 years ( $F3 > F4$ ).

Rough estimate in Gt-C/year:  $-463 / 45 = -10.3 \rightarrow$  with  $F4 \approx F3 - 10.3$ , the net contribution of -463 Gt-C over 45 years is respected. Note that F3 is estimated by  $F3(t) = 0.086 X(t)$  in accordance with [Haverd et al 2009](#).

Rather than the rough estimate, we ultimately adopt  $F4 = Y(t) / \tau_{veg}$  with  $\tau_{veg} \approx 40$  years, which allows us to meet constraint 2.

## The Revisiting the Carbon Cycle Model

[Part 1](#) of the article explains the reasons behind the model (study of correlations and  $\delta^{13}\text{C}$ ).

[Part 2](#) of the article presents the model used in Figures 14 and 15 of § 6 of *de 'Revisiting the carbon cycle'*.

[Part 3](#) provides illustrations to help readers better understand the model and addresses the most common objections.

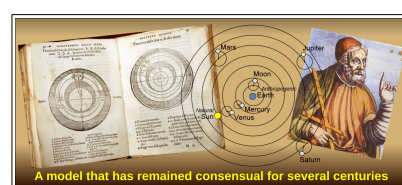
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