ADDENDUM

Estimates of natural flows in the MPO model

JC Maurin 2026

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 (± 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**.

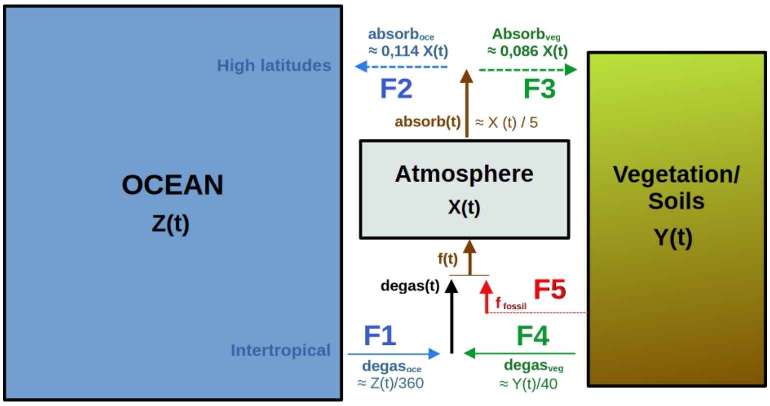


Figure 1: Ratings of the five flows and stocks in the three compartments (Figure 15 in Revisiting the carbon cycle)
***Stocks X,Y,Z**: 1 ppm = 0,0001% → 7,8 Gt-CO_2 = 7,8 x 10^{12} kg of CO_2 → 2,12 Gt-C = 2,12 x 10^{12} kg of carbon*
***Flows F1, F2, F3, F4, F5** : 1ppm/year → 2,12 Gt-C/year ; 1 Gt-C/year → 3,67 Gt-CO_2/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_2 concentration.
- be virtually compatible with the 6 WG1 reports of the IPCC → F3 ≈ 0.078 X(t)

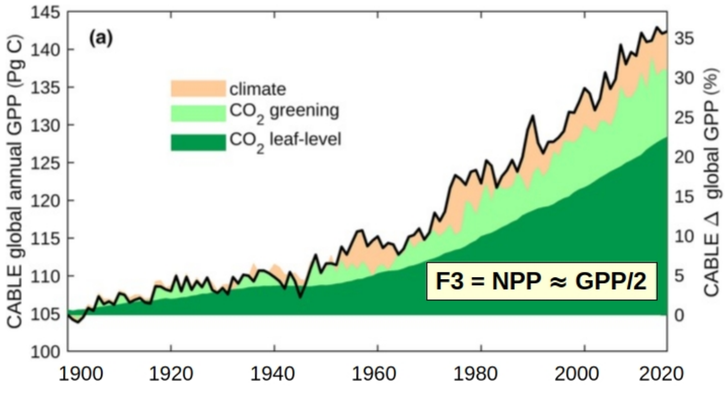


*Figure 2: GPP ≈ 2 * NPP according to Figure 2 in Haverd et al, 2019 https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/gcb.14950*

For **effective multi-year** carbon sequestration by vegetation, i.e., F3, **N**et **P**rimary **P**roduction → NPP ≈ GPP/2 must be used, where GPP = **G**ross **P**rimary **P**roduction (see here).

		Flow in Gt-C / yr					X(t) → [CO_2]	Residence time (year) = X(t) / (flow 2 + flowx 3)	
Dates	Assessment Report	Flow 2	F2/X(t)	*Flow 3 if **GPP***	Flow 3 if **NPP**	F3/X(t)	in Gt-C	*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 ≈ 0.112 X(t) and F3 ≈ 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_2 concentration.
- virtually compatible with the figure 3.1a AR3 WG1 report of the IPCC → F2 ≈ 90 Gt-C/year ±25% around 2000 .
- compatible with the previous choice of F3 = 0.086 X(t).

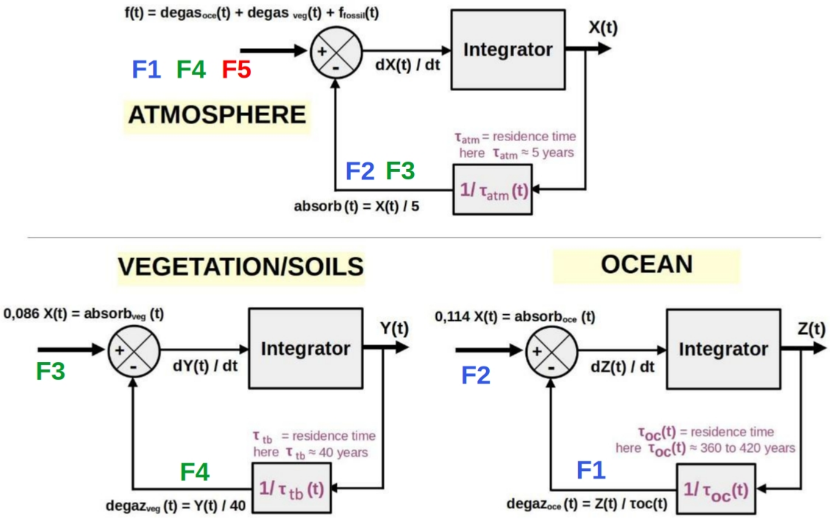


Figure 4: The three compartments have a common simple model but different residence times → τ = Stock / outgoing flow (based on Figure 14 in Revisiting the carbon cycle)

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_2 (ratio and $\delta^{13}C$) from 1980 to 2025.

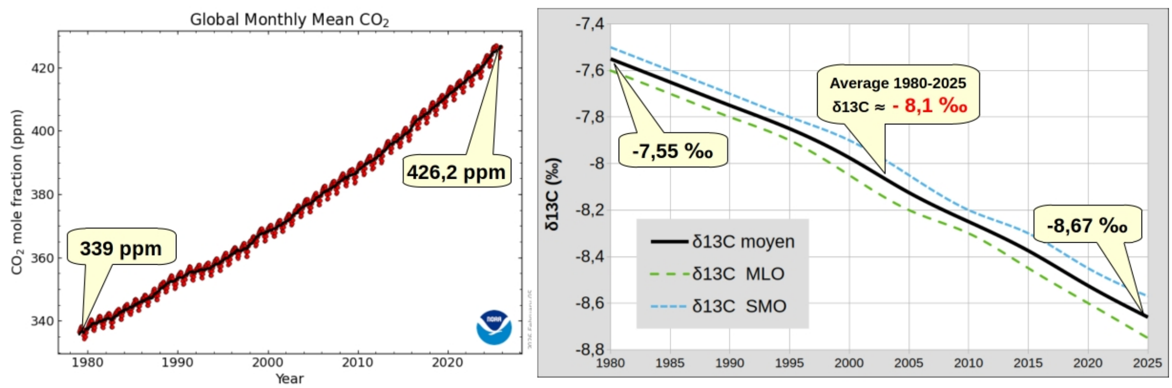


*Figure 5 : **Global** atmospheric CO_2 levels according to NOAA (1 ppm → 2,12 Gt-C); $\delta^{13}C$ in the atmosphere according to Scripps CO_2*

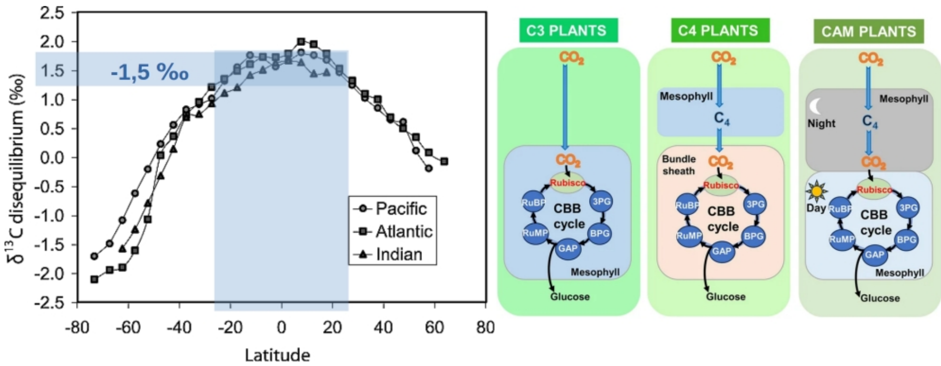
Between 1980* and 2025, the CO_2 level in the atmosphere will increase: 426.2 - 339 = +87.2 ppm, representing a net contribution of +185 Gt-C. This net contribution must be such that $\delta^{13}C$ = -13.0‰, because between 1980 and 2025 we have:

ppm : **(339 * -7,55) + (87,2 * -13,0) = (426,2 * -8,67)**

Gt-C : **(719 * -7,55) + (185 * -13,0) = (904 * -8,67)**

* *1980 because we need to have measurements of $\delta^{13}C$ and CO_2 levels in both hemispheres.*

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



Plants	ratio	δ13C (‰)	ratio x δ
C3	85 %	-25	-21,3
C4	14 %	-13	-1,8
CAM	1 %	-18	-0,2
		Average =	-23,3

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

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.

** ~1260 Gt-CO_2, or ~343 Gt-C according to World Energy Outlook, but the IPCC adds approximately 5% LUC → 343 * 1.05 ≈ 360 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 ≈ y ≈ - (360-185)/2 = - 87.5 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)				
Net (Gt-C)	**360**	**-87,5**	**-87,5**	**185** Gt-C
δ13C (‰)	**-29**	**-9,6**	**-23,3**	**-40,9** ‰
Net x δ13C	-10440	837	2040	**-7563**
Min (‰)	*-31*	*-6,0*	*-20,0*	**-48,0** ‰
Net x δ13C	*-11160*	*525*	*1750*	-8885
Max (‰)	*-27*	*-12,0*	*-28,0*	**-33,6** ‰
Net x δ13C	*-9720*	*1050*	*2450*	-6220

Figure 7a: The IPCC model does not allow for a net input of 185 Gt-C with $\delta^{13}C$ = -13‰
360 + -87.5 +-87.5 = 185; but -10440 + 837 + 2040 = -7563 and -7563 / 185 = -40.9‰
*In the lower part, for a wide range of values $\delta^{13}C$, it is shown that $\delta^{13}C$ net contribution **remains far** from -13‰ (-48‰ to -33.6‰).*
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 → F1 > F2.

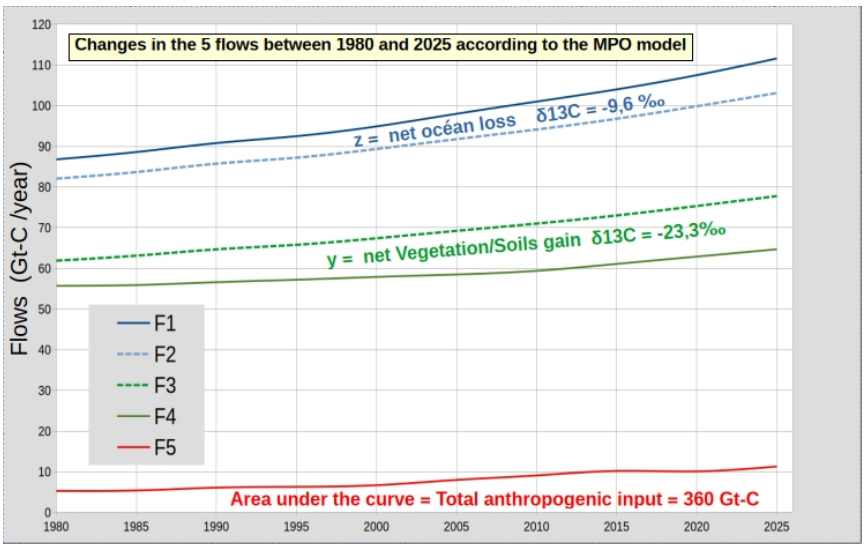


Figure 7b: According to MPO, the ocean is a net source for the atmosphere (F1 > F2), while vegetation/soil is a sink (F3 > F4).
*However, the sum (ocean + vegetation/soil) **is <u>overall</u> a sink** (y > z) with respect to the atmosphere.*

In order to comply with the observations in Fig. 5 (which imply a total net input of 185 Gt-C with $\delta^{13}C$ = -13.0 ‰), 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 Gt-C and y = -463 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 ≈ 90 Gt-C/year ±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 → with **F1 ≈ 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) / τ_{oc} with a **variable** residence time (for **<u>1980-2025</u>**, τ_{oc} ≈ 340 to 440 years). The residence time allows us to comply with constraint 1 but also to have τ_{oc} as a function of SSTi (intertropical sea surface temperature). To do this, we use the partial pressure of CO_2 in the ocean (pCO_2 is proportional to SSTi $^{12.5}$).

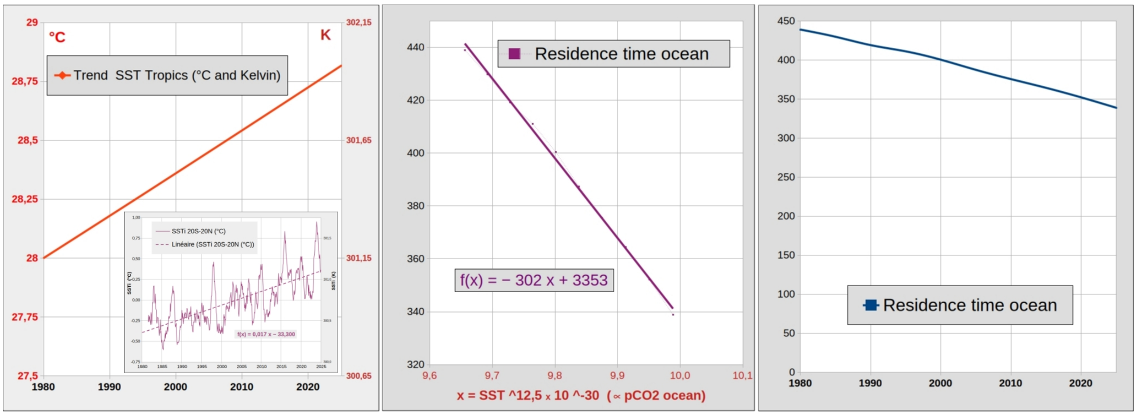


Figure 8: Determination of ocean residence time based on SST Tropics

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 → with **F4 ≈ 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) / τ_{Veg} with τ_{Veg} ≈ 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 $\delta^{13}C$).
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.

These three sections are also available for download as PDF files : 1/3, 2/3, 3/3.

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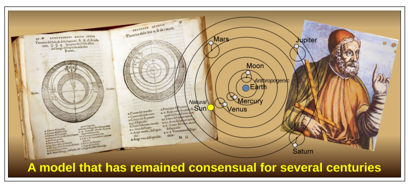

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