Revisiting the carbon cycle

1/3 Modern observations guide the model

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In 2025, the peer-reviewed scientific journal Science of Climate Change published a 50-page study entitled "Revisiting the carbon cycle." This work thoroughly challenges the carbon cycle models proposed by the IPCC. We will detail the new model presented in this publication in three parts:

1. Modern observations guide the model;
2. Introduction to the MPO model;
3. Additions, illustrations, responses to objections.

Since the 1990s, under the influence of the UN/IPCC, one hypothesis has become the consensus: the increase in atmospheric CO_2 is **solely due** to human activities. Conversely, this first part of the article puts forward arguments suggesting that this increase is **mainly linked** to temperatures in tropical regions.

A consensus is proclaimed by the president of the Academy of Agricultural Sciences in 1948

1. Atmospheric CO_2 and its annual growth

1.1 Selecting the most reliable overall observations

Modern measurements of atmospheric CO_2 levels = [CO_2] began in 1958 at Mauna Loa (MLO) and in 1957 at South Pole (SPO). Since then, the level of CO_2 in the atmosphere has been increasing: from [CO_2] = 315 ppm (669 Gt-C) in 1959 to 425 ppm (903 Gt-C) in 2025 (1 ppm = 0.0001% → 2.12 Gt-C → 7.78 Gt-CO_2) .

It has also been observed that [CO_2] is higher at MLO than at SPO: it is therefore preferable to use an **overall average** rather than measurements from the MLO observatory alone. Around 1975, NOAA had four reference observatories and was able to calculate a global average. Furthermore, at the end of the 1970s, **global** "temperature" data measured via satellites became available, as well as measurements for $\delta^{13}C$.

For these reasons, the 1980-2025 interval is used in order to obtain the most reliable global measurements possible.

1.2 Global annual growth between 1980 and 2025

The overall annual growth rate (ppm/year) is calculated from X(t) = average of [CO_2] observations at four observatories. The annual growth for month **n** is obtained by the difference between X(t) for month (n+6) and X(t) for month (n-6), which also corresponds to calculating dX(t)/dt with dt = 12 months = 1 year (12 months to eliminate seasonality).

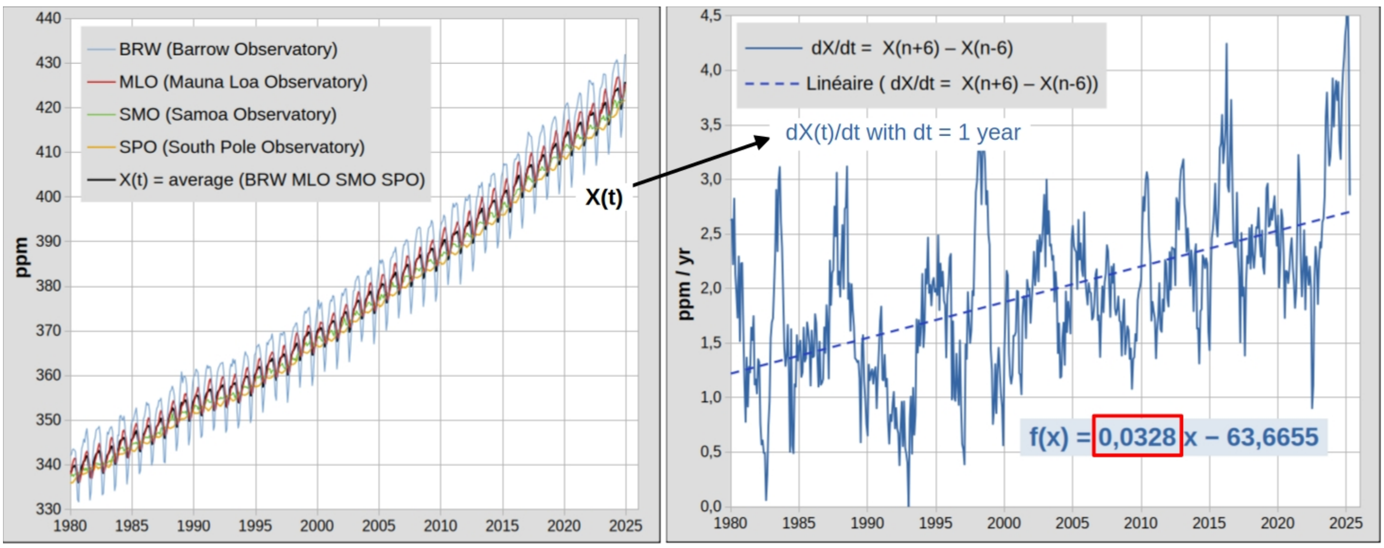


Figure 1: Global CO_2 level = X(t) = average of the four reference observatories here (left).
dX(t)/dt (annual growth for month n) is calculated as the difference between the average [CO_2] for month n+6 and month n-6 (right).

It should be noted that the **global** annual growth dX(t)/dt based on the average of 4 observatories tends to increase at a rate of **0.0328** ppm/year². It is this time series of 544 months between 1980 and 2025 (Fig. 1, right) that will be successively compared to anthropogenic emissions and then to various temperature anomalies.

2. Anthropogenic flux (CO_2 emissions caused by humans)

Anthropogenic emissions come from fossil fuel and cement manufacturing. The IPCC adds a secondary term, **LUC** = **L**and **U**se **C**hange. According to Carbonmonitor, there is a slight seasonal modulation in anthropogenic flux.

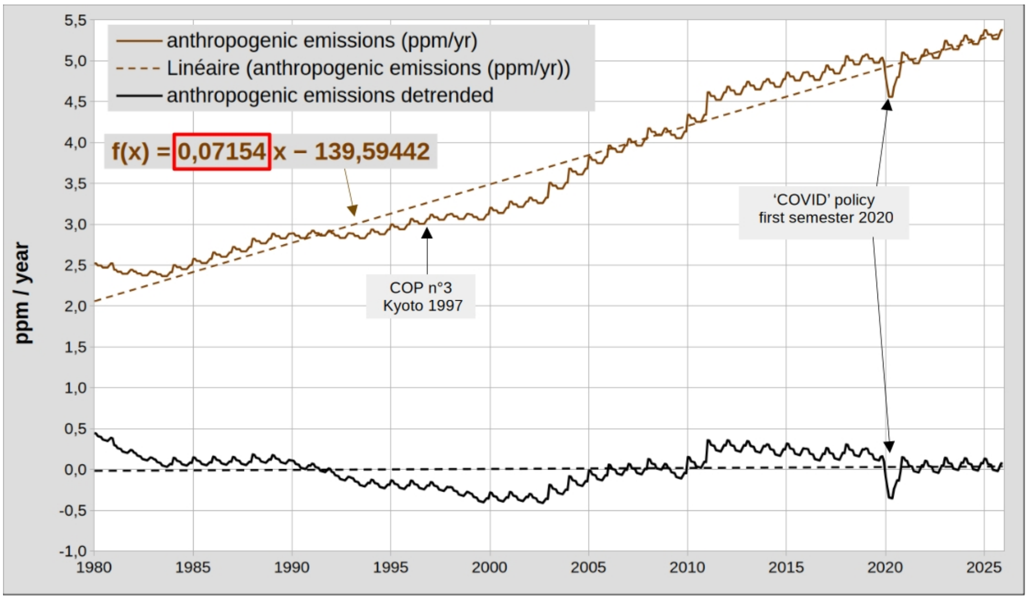


*Figure 2: Anthropogenic flux (ppm/year) according to CDIAC + BP statistical review + Carbonmonitor. Obtained by subtracting the linear trend (slope = **0.07154** ppm/year²), the detrended anthropogenic flux also corresponds to deviations from the trend (maximum transient in the first half of 2020).*

Political action seems to have a modest and unexpected influence on anthropogenic flux. After 1997 (post-Kyoto), attempts to limit emissions result in faster growth in practice (Chinese coal in the 2000s). In the first half of 2020, the effects of Covid policies were a (short-lived) decline in emissions and a (less short-lived) increase in debt in Europe.

3. Comparison of annual growth with anthropogenic flux

The annual growth of atmospheric CO_2 is expressed in ppm/year, so it can be **directly** compared with anthropogenic flux if expressed in ppm/year (1 ppm/year → 2.12 Gt-C/year → 7.78 Gt-CO2/year).
Between 1980 and 2025, the anthropogenic flux is approximately twice as large as the annual growth. To satisfy the IPCC's thesis that anthropogenic flux is the **sole** cause of annual growth, an adjustment must be made: multiply the anthropogenic flux by the ratio of the slopes of the long-term trends. For 1980-2025, this ratio is equal to 0.0328/0.0715 = 46%.
The IPCC refers to this ratio as the "**A**irborne **F**raction" = AF (for 1960-2020, AF = 44%) and gives the following justification: approximately half of anthropogenic emissions remain in the atmosphere (**but this does not apply to natural emissions!**).

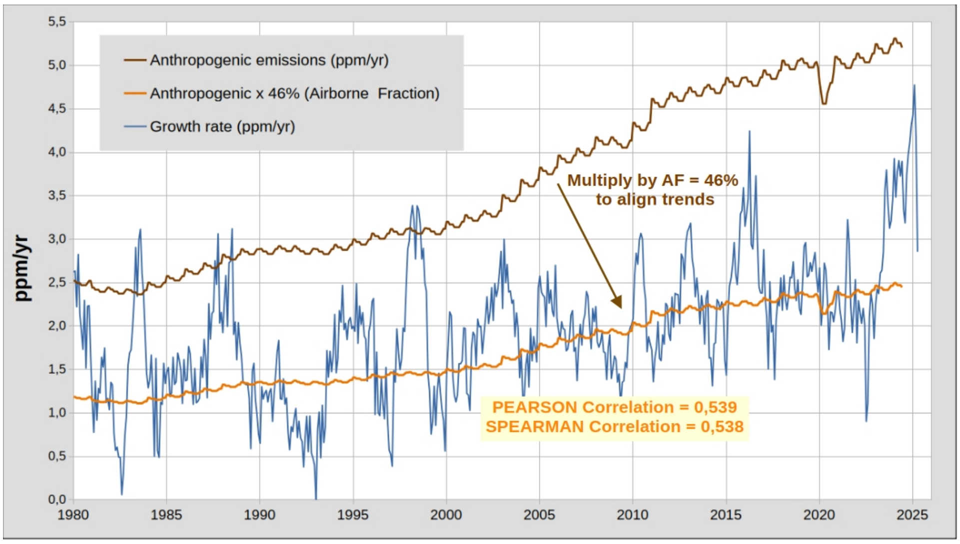


Figure 3a: Comparison between the overall annual growth in atmospheric CO_2 (blue curve) and anthropogenic flux (brown curve). Artificial adjustment (orange curve) by multiplying by the ratio of the two slopes (Figs. 1 and 2) 0.0328/0.0715 = 46%.

- In practice, multiplying the anthropogenic flux by 46% simply amounts to **artificially aligning** the two trends.
  We will quantify the resulting correlation using the PEARSON correlation or SPEARMAN correlation (0 → no correlation, 1 → perfect correlation). This gives us an **apparent** correlation PEARSON or SPEARMAN = 0.54, which is mainly the result of the artificial adjustment of the trends.

- Strictly speaking, the correlation must be evaluated by isolating the short-term covariances (residuals = transients = deviations from the trends of the two series). We must therefore subtract the linear trend **before** comparison → 'detrended series'.

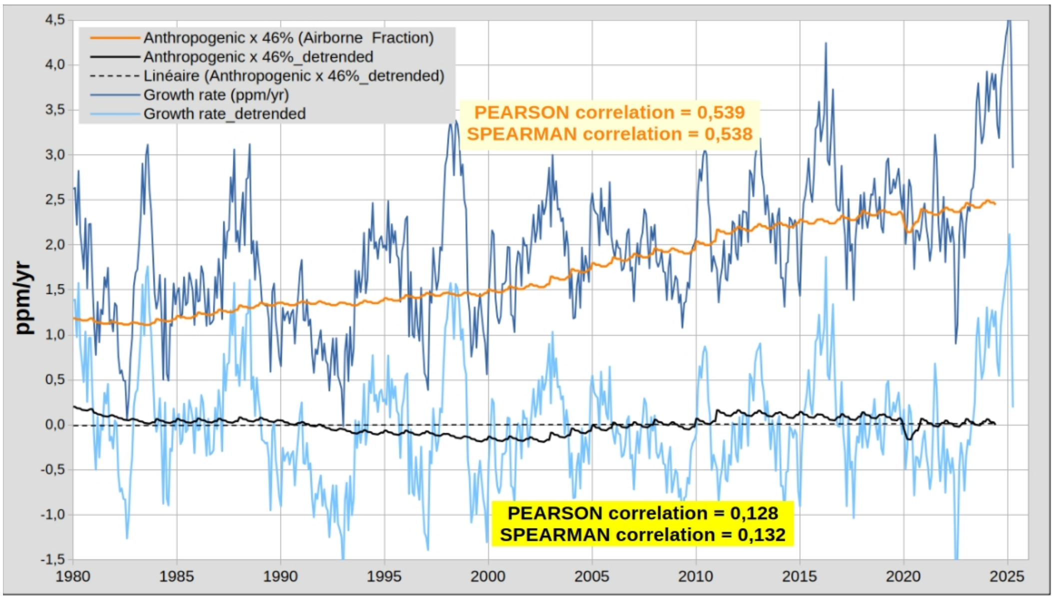


Figure 3b: Comparison between anthropogenic flux multiplied by AF = 46% (orange curve) and annual growth (post-adjustment correlation = 0.539 Pearson or 0.538 Spearman). Comparison between the same detrended series → correlation = 0.128 Pearson or 0.132 Spearman.

The poor correlation ≈ 0.13 between the two detrended series indicates that the IPCC's thesis should be questioned. On this subject, interested readers may consult article SCE_01/2025 (note that the observations and periods used are not identical in the two articles).

4. Comparison of annual growth with UAH_LT

The poor correlation (≈ 0.13 Pearson or Spearman) encourages us to look for **other correlations** with the growth of CO_2 in the atmosphere. Scientists have long noticed the visual similarity between annual growth and temperature. We will therefore compare the **global** temperature anomaly in the lower atmosphere = UAH_LT with the annual growth of atmospheric CO_2 = dX(t)/ dt. **However, these two quantities are not of the same nature**: we must therefore link them using an expression of the type **dX(t) /dt ≈ a (UAH_LT + b)**. Here we use a conversion coefficient **a** (referred to as sensitivity) to convert from °C to ppm/year. Furthermore, the effect of this sensitivity a is similar to that of the IPCC's Airborne Fraction: adjustment of trends. The offset **b** has no significance: we can have **b** = 0 by changing the reference for the UAH_LT anomaly.

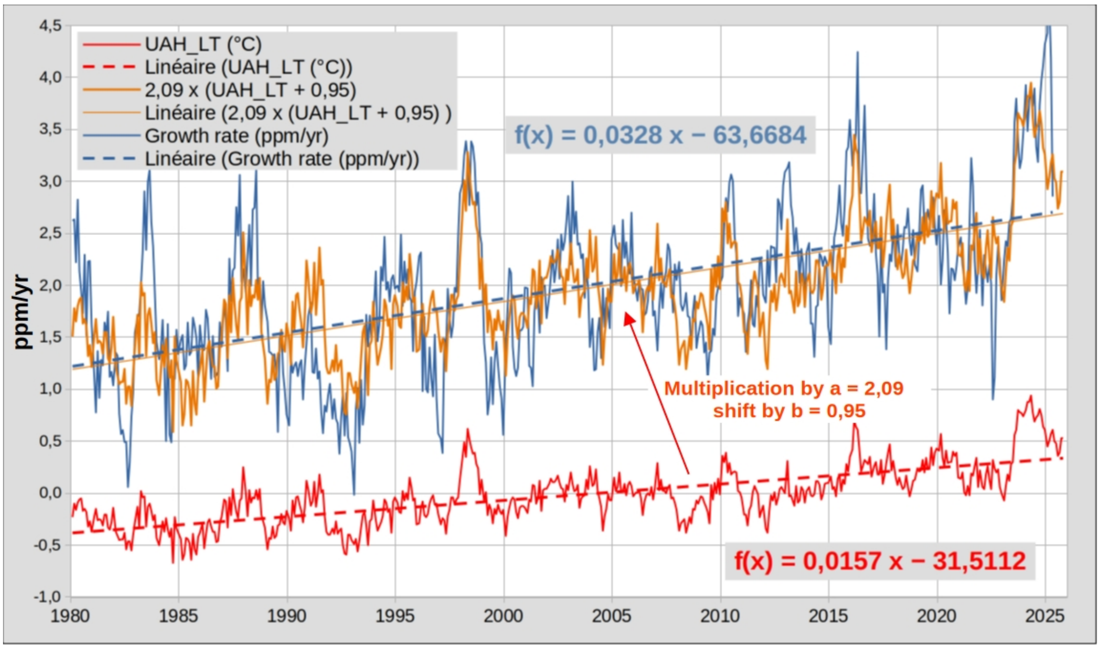


*Figure 4a: Comparison between the two series: overall annual growth in atmospheric CO_2 (four observatories) and UAH LT anomaly. Adjustment (orange curve) via the ratio of the two trends = sensitivity **a** = 0.0328 / 0.0157 = **2.09**.*

The correlation seems visually quite good, but its quantification requires the use of detrended series: that is, the linear trends must be subtracted before quantifying the correlation.

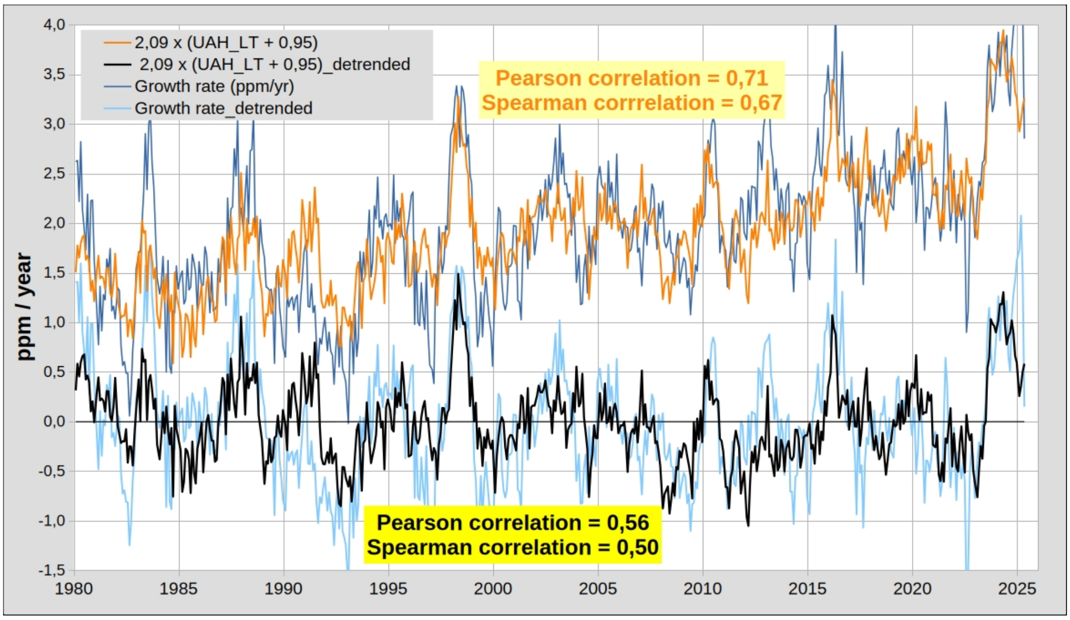


*Figure 4b: Comparison using sensitivity a (orange curve, post-adjustment correlation = 0.71 or 0,67). Comparison between detrended series → correlation = **0.56 or 0.50.***

The correlation between these two series (0.71 or 0.67) is higher than between anthropogenic emissions and annual growth (0.54, Fig. 3b). This is even more true for the two detrended series: the UAH_LT temperature anomaly correlates better (**0.56 or 0.50**) with annual growth than anthropogenic emissions do (≈ **0.13**).
The following paragraphs attempt to locate the origin of this correlation between temperature and annual growth.

5. Comparison of annual growth with UAH_LT_Tropics

5.1 UAH_LT anomaly versus UAH_LT_Tropics anomaly

The intertropical zone (≈ 40% of the Earth's surface and ≈ 50% of the energy from the Sun) is the area where the temperature is highest. In this zone, temperature should therefore have a strong influence on **natural** carbon exchanges between the three compartments: Ocean, Vegetation/Soil, and atmosphere (Fig. 5d). For temperature, we use the UAH_LT_Tropics anomaly (Tropics → 20S -20N).

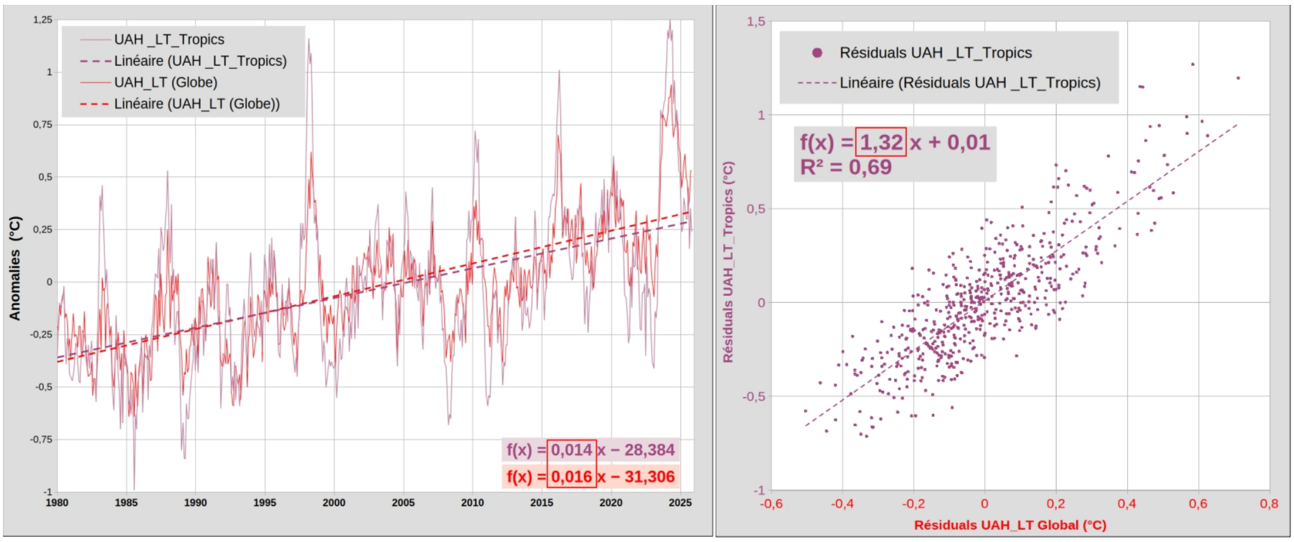


*Figure 5a: Two UAH temperature anomalies for the lower troposphere: global in red and intertropical in purple. Right: anomalies as a function of date; the global anomaly (0.016 °C/year) is increasing slightly faster than the intertropical anomaly (0.014 °C/year). Left: Residuals for the intertropical region (deviations from the trend) as a function of residuals for the global region: deviations in the intertropical region are ≈ **1.32** times greater than deviations for the global region.*

• The heat capacity of the ocean is much greater than that of the atmosphere: the ocean therefore warms less quickly than the atmosphere. For the globe as a whole, the ocean (free of ice) represents 67% of the surface area, but for the intertropical zone, the ocean represents 75% of the surface area and therefore has a greater influence. This results in a lower slope (0.01415) for UAH_LT_Tropics than for UAH_LT (0.01562).

• It should also be noted that transients or deviations from the trend are greater (x 1.32) for the intertropical zone: these transients are often linked to ENSO events (El Niño and La Niña) originating in the **intertropical** Pacific Ocean.

5.2 Comparison of UAH_LT_Tropics anomaly and annual growth

• For annual growth rate in the intertropical zone, we use the average from the two observatories, MLO and SMO. The MLO SMO annual growth trend (0.0329) remains virtually unchanged from that for four observatories (0.0328). Is the correlation in the intertropical zone better than that for the globe as a whole (Fig. 4b)?

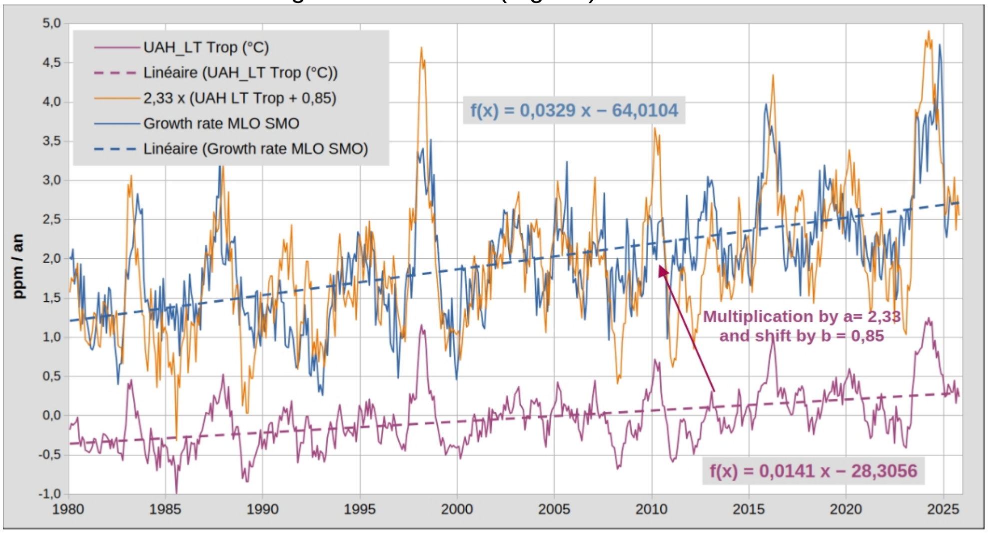


*Figure 5b: Annual growth in atmospheric CO_2 (MLO SMO average) and UAH_LT_Tropics anomaly (purple curve). Adjustment of UAH_LT_Tropics (orange curve) via the ratio of the two trends = sensitivity **a** = 0.0329 / 0.0141 = **2.33**.*

According to ice core records, there is an ≈ 800-year lag between the [CO_2] proxy and the temperature proxy (variations in the temperature proxy precede variations in the [CO_2] proxy).
According to Humlum et al 2013, there is a systematic delay of ≈ 10 months between d[CO_2] /dt = annual growth and temperature. However, the best modern observations (Fig. 5b) indicate instead a near-simultaneity (to ± 5 months) between the **intertropical** annual growth peaks (MLO SMO) and **intertropical** temperature via satellites.
As before, the correlation must be calculated from the detrended series.

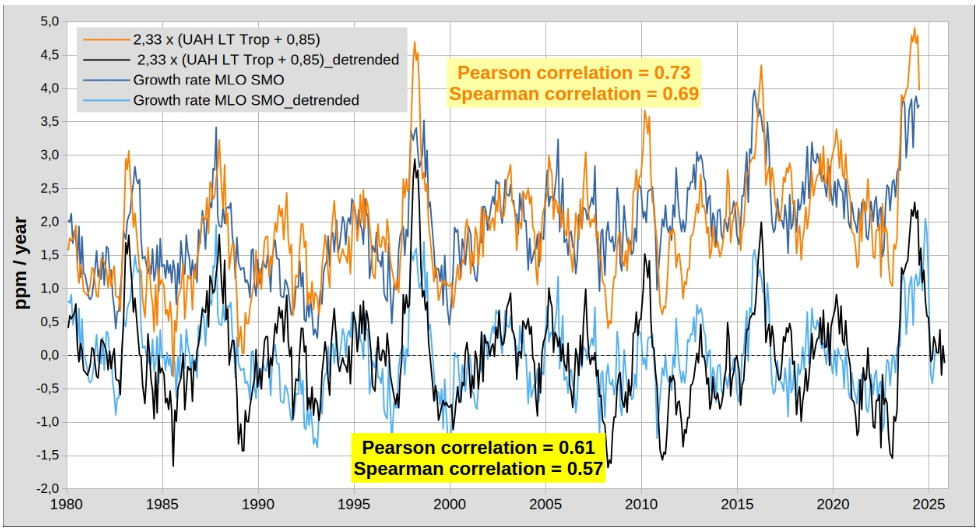
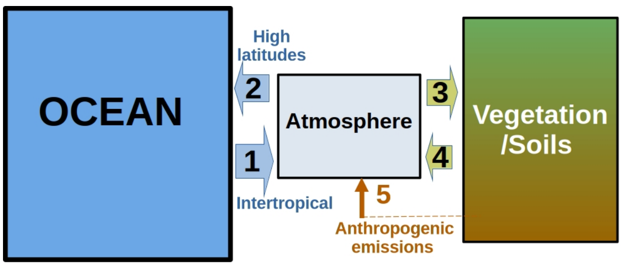


*Figure 5c: Comparison after adjustment (orange curve) via sensitivity **a** = 2.33 (post-adjustment correlation = 0.73 or 0.69). Comparison between detrended series → correlation = **0.61 or 0.57.***

The correlation is better with UAH_TL_**Tropics**_detrended (0.61 or 0.57) than with UAHLT_detrended (0.56 or 0.50 fig. 4b).
What are the reasons that would allow the temperature in the **intertropical zone** to be correlated with annual growth?
Intertropical temperature does not influence anthropogenic emissions, but it can influence **natural** carbon exchanges between the atmosphere and the ocean or vegetation/soil compartments (flows 1, 2, 3, 4, Fig. 5d). Flow 1 (corresponding to carbon degassing by the intertropical ocean) is highly dependent on temperature.



Annual Growth rate	Slope (ppm/yr²)	Comparison	Slope	Adjustment	Pearson correlation detrended	Spearman correlation detrended
BRW MLO SMO SPO	0.0328	anthropogenic emissions	0.0715	AF = 46%	0.13	0.13
BRW MLO SMO SPO	0.0328	UAH_LT	0.0157	a = 2.09	0.56	0.50
MLO SMO	0.0329	UAH_LT_Trop	0.0141	a = 2.33	0.61	0.57

*Figure 5d: on the left, simplified diagram of carbon exchanges with four natural flows + anthropogenic flow. On the right, the table shows that annual growth and temperature are most closely correlated (**0.61 or 0.57**) in the intertropical zone.*

6. Trends (long term) versus transitory (short term)

• The figure below, using standard tools for comparing time series (544 residuals in XY), provides another argument for choosing a thesis favoring UAH LT Tropics rather than the IPCC thesis.

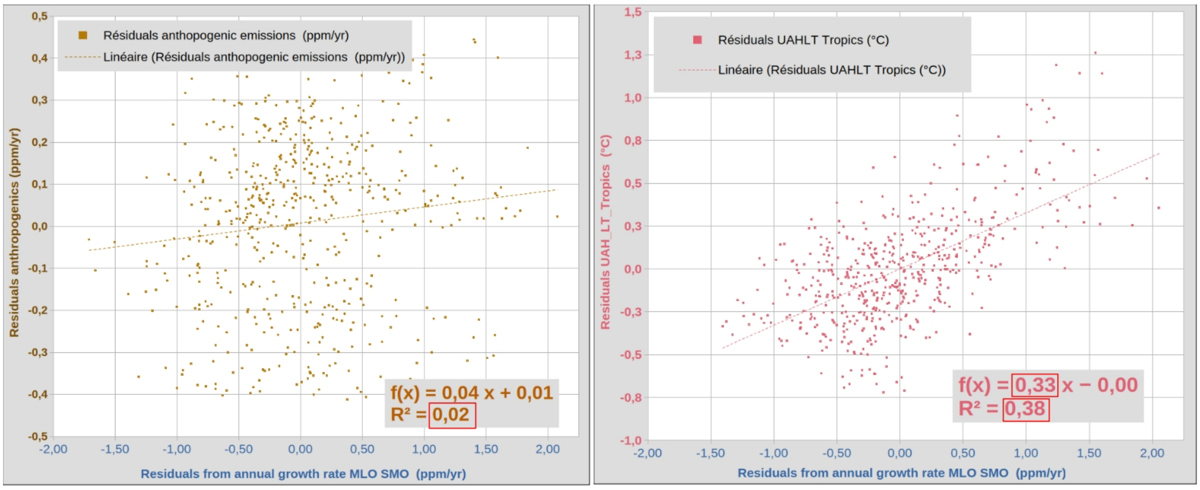


*Figure 6a: on the left, the IPCC's thesis is contradicted by the absence of a relationship between residuals/transients (**R^2 = 0.02**). On the right, the relative alignment of the residuals (**R^2 = 0.38**) suggests a relationship between the residuals of the two series.*

6.1 Annual growth: long term and transients

• For annual growth, the IPCC authors (AR6 § 5.21) separate the long-term trend (which would be the result of anthropogenic flux **alone**) from short-term transients (fluxes 3 and 4 would be influenced by ENSO).

• It should be noted that the ratio linking the residuals or transients (**0.33** → Fig. 6a on the right) is close to that linking the trends (**0.43** = 0.0141/0.0329 → Fig. 5b). Physicists who are not IPCC authors see this as an indication that the **same** physical phenomena govern both the trend **and** the transients. To go further, we must take into account the random noise that affects all observations. For the same level of random noise, large deviations (transients) from the trend are less affected than small deviations. If we retain only the residuals corresponding to the largest deviations from the trends, then we improve the signal-to-noise ratio.
In order to retain ≈ 50% of the initial 544 residuals, only deviations (residuals) > 0.15 ppm/year or > 0.15 °C are retained.

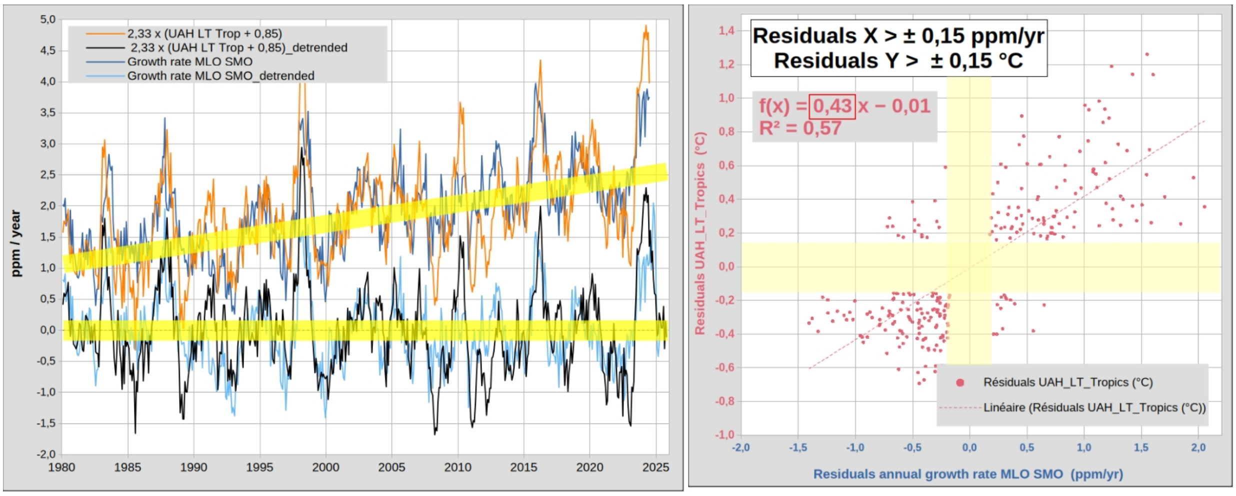


Figure 6b: on the left, same as fig. 5c, but the yellow bands show the deviations/residuals to be eliminated in order to retain ≈ 50% of the deviations/residuals. On the right, same as fig. 6a on the right, but retaining only ≈ 50% of the residuals (the largest deviations).

• By retaining the largest deviations/transients/residuals (≈ 50% of transients), we note that the ratio (**0.43**) linking the largest deviations (transitory or residual) is now **the same** as that linking long-term trends (**0.43**). This result is obtained using a standard signal processing procedure and the **best** observations available for the **intertropical** zone.
This important result is explained below.

• - A **long-term** increase of 0.43°C for UAH_LT_Tropics coincides with a **long-term** increase of 1 ppm/year for annual growth.
- A **transient** increase of 0.43°C (deviations > 0.15°C for UAH_LT_Tropics) also coincides with a **transient** increase of 1 ppm/year for annual growth.

• In the intertropical zone, the ratio (Δ temperature)/(Δ annual growth) = **0.43** °C/ppm/year is identical for the long term **and** for the largest transients. The following two paragraphs show that this similarity between the long term and transients is not found for UAH_LT or for anthropogenic flux.

6.2 Global (UAH_LT) or intertropical (UAH_LT_Tropics)?

The figure below shows that the UAH_LT temperature anomaly does not exhibit this similarity between long-term and transient trends. The trend ratio is 0.01572 / 0.0328 = 0.48 (Fig. 4a), but when comparing 100% of the residuals, the ratio = 0.18, and for the largest residuals (50%), the ratio = 0.23.

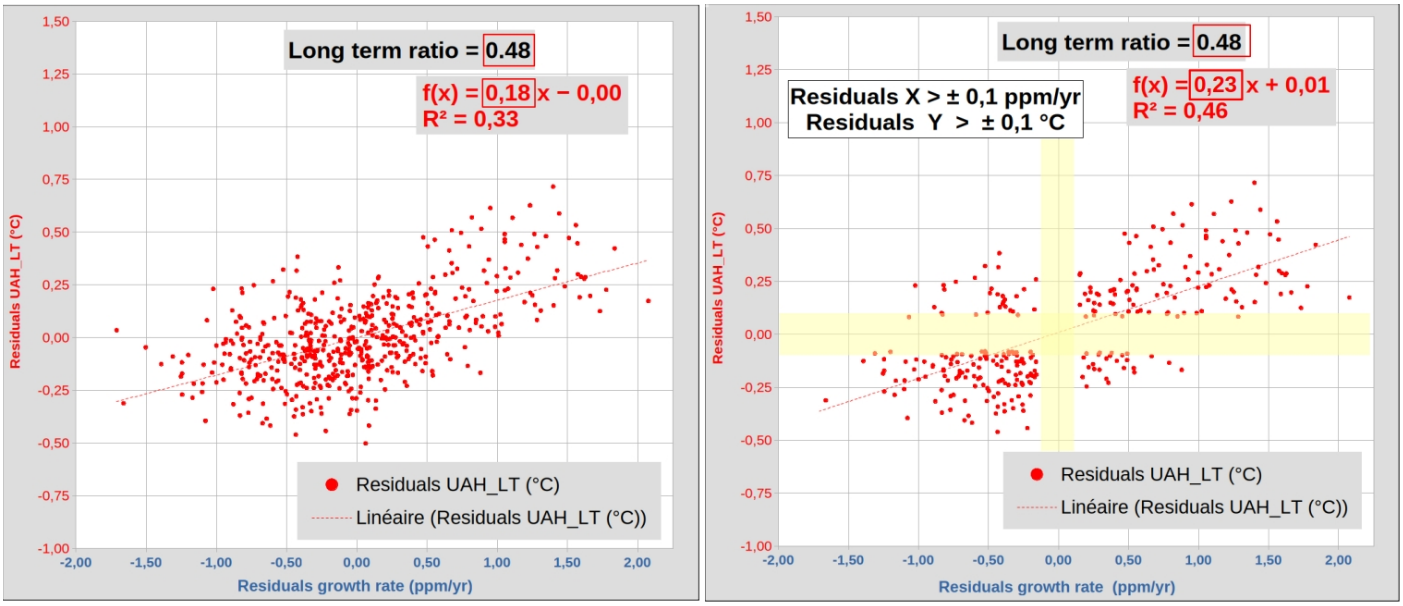


Figure 6c: left, comparison for 100% of residuals; right, comparison for 50% of residuals: their ratio = 0.23, which remains far from the long-term trend ratio = 0.48.

6.3 The IPCC thesis is not compatible with observations

• For annual growth, the IPCC authors (AR6 § 5.21) therefore separate short-term transients (which would be driven by ENSO via flows 3 and 4) from the long-term trend, which would be the result of anthropogenic flow alone (the IPCC multiplies by the trend ratio = 46% designated by Airborne Fraction, see Fig. 3a).

• We recall the result obtained by comparing, after adjustment, anthropogenic flux and atmospheric CO_2 growth: Pearson correlation 0.54 versus 0.73 for UAH_LT_Tropics. For the same detrended series, we have 0.13 versus 0.61 or 0.57 for UAH_LT Tropics. We repeat the procedure illustrated in Fig. 6c, but apply it to the anthropogenic flux: do we find the long-term trend ratio (0.07154/0.0328 = 2.18) by calculating the ratio of residuals (deviations or transients)?

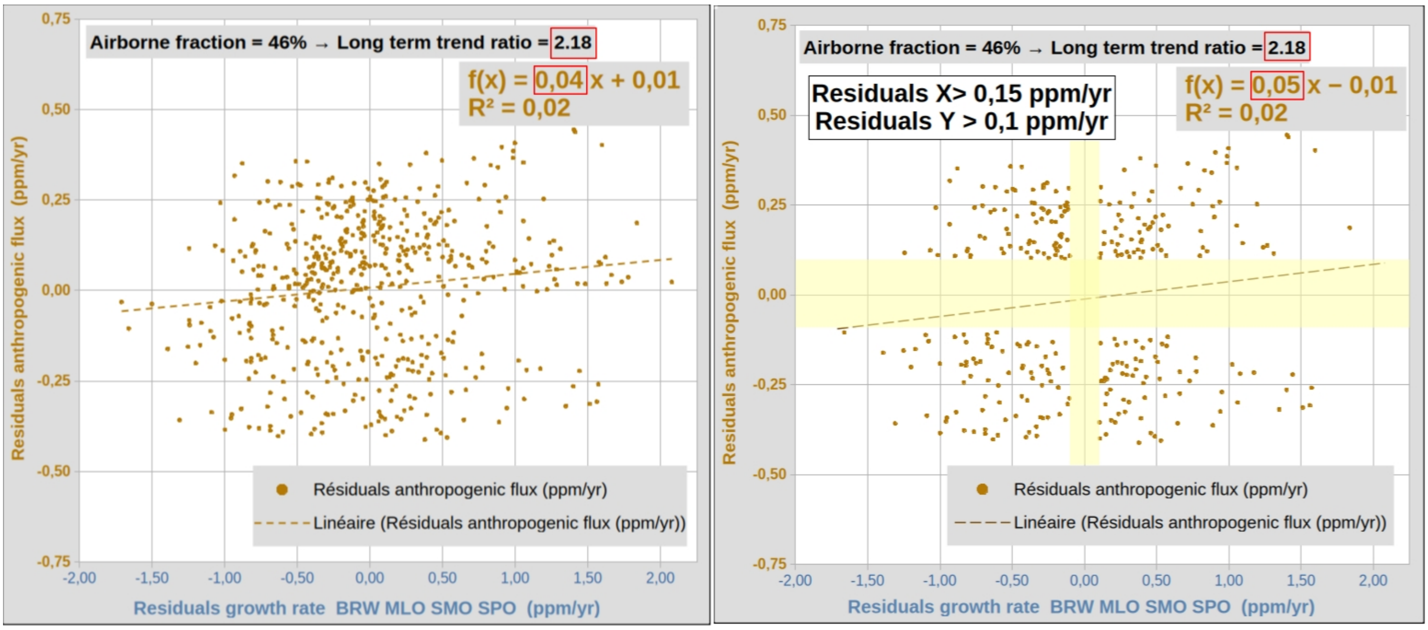


Figure 6d: Two graphs showing anthropogenic flow residuals as a function of annual growth residuals.
On the left, 100% of residuals are used; on the right, only 50% of residuals (the largest ones) are retained.

- **There is no similarity** between the long-term trend ratio (2.18) and the transient ratio (0.04), even when selecting the largest (0.05).
  There is no relationship (R^2 = 0.02) between annual growth transients and anthropogenic flux transients.
  Correlation does not always imply causation, but **the absence of correlation indicates an absence of causality.**

- The table below summarizes the analysis of correlations with annual atmospheric CO_2 growth. The analysis **does not use the concept of residence time**, but only the best observations (544 months between 1980 and 2025).

	dX/dt or annual growth		Temperature anomaly		Long-term	Residuals or deviations or transient				Pearson (Spearman) correlations	
						100% of résidues		50% of résidues			
	Annual growth	Slope (ppm/an²)	Température UAH	Slope (°C/yr)	long-term trend ratio	Ratio	R²	Ratio	R²	Post-adjustment correlation	Detrended Corrélation
Global	BRW MLO SMO SPO	0.03277	UAH_ LT	0.0157	**0.48** (2.09)	0.18	0.33	**0.23**	0.46	0.71 (0.67)	0.56 (0.50)
Inter tropical	MLO SMO	0.03294	UAH_LT_Trop	0.01415	**0.43** (2.33)	0.33	0.38	**0.43**	0.58	**0.73 (0.69)**	**0.61 (0.57)**
§3	BRW MLO SMO SPO	0.03277	Anthropogenic	0.07154 ppm/yr²	**2.18** (46%)	0.04	0.02	0.05	0.02	0.54 (0.54)	0.13 (0.13)

Figure 6e: Summary table of comparisons; the intertropical temperature UAH_LT_Trop shows the best ***detrended*** *correlation (0.61 or 0.57) and the Δ temperature/Δ annual growth ratios are* ***identical*** *for the long term (0.43) and large transients (0.43).*

The main cause of the increase in atmospheric CO_2 does not therefore appear to be anthropogenic emissions; rather, it seems to be linked to variations in temperature in the intertropical zone.
The following paragraph gives additional reasons why "Revisiting the carbon cycle" ultimately favors **intertropical ocean** surface temperature (SSTi) and flux 1 (Fig. 5d).

7. Intertropical ocean degassing is believed to be the main cause of the correlation

7.1 Orders of magnitude

- 75% of the Earth's surface between 23°26' S and 23°26' N is ocean → the temperature of the lower troposphere in the intertropical zone largely reflects the temperature of the **ocean** SSTi = intertropical **S**ea **S**urface **T**emperature. This is because the heat capacity of the ocean is higher than that of the atmosphere (depending on depth, the ratio is 10 to 1000 here fig.1).
- The carbon stock in the ocean is about 16 times greater than that in vegetation/soils.
- The partial pressure of CO_2 in water at the ocean surface varies **greatly** depending on its temperature (function of $SST^{12.5}$). The **same** increase in SST temperature will therefore have a greater effect on flux 1 (warm intertropical zone SST ≈ 25°C to 32°C) than on flux 2 (high latitudes, cold zone SST ≈ 5°C to 15°C). For the same increase of 0.5°C, the reader can verify that $30.5^{12.5} - 30^{12.5} > 10.5^{12.5} - 10^{12.5}$ (the correct calculation in Kelvin yields the same inequality).

7.2 The ^{13}C isotope and $\delta^{13}C$

• In addition to the above considerations, "Revisiting the carbon cycle" adds modern observations on the ^{13}C isotope in the atmosphere: the evolution of $\delta^{13}C$ cannot be attributed **solely to a net anthropogenic carbon input** (see §4 here).
An additional net contribution is required: does it come from the Ocean compartment or the Vegetation/Soil compartment?

• With regard to the vegetation/soil compartment, it is likely that plant decomposition (flow 3 in Fig. 5d) increases with temperature. However, plant decomposition is probably lower than carbon absorption by vegetation (flow 4 in Fig. 5d) because the overall greening of the planet suggests that flow 4 > flow 3 → no **net** input.

• The same increase in temperature has a greater effect on flux 1 (warm zone) than on flux 2 (cold zone) → flux 1 > flux 2 → possible **net** input. On the other hand, for flux 1 in the intertropical zone, $\delta^{13}C$ is 1.5‰ lower than that of the atmosphere. A **net** additional input of carbon from the **intertropical** ocean to the atmosphere would then balance the $\delta^{13}C$ budget ('Revisiting the carbon cycle' estimates flux 1 in order to close the balance for $\delta^{13}C$).

• 'Revisiting the carbon cycle' therefore compares annual growth (but observed at MLO) and the **intertropical ocean** temperature SSTi (but since 1959, therefore excluding satellite observations). In Figure 2, the small anthropogenic contribution is deducted from annual growth: the correlation is then excellent. In Figure 3 (similar to Figure 5b here), the anthropogenic contribution is also deducted. Section 7 and Figures 22, 23, and 24 detail the evolution of $\delta^{13}C$ from 1980 to 2020.

8. Conclusions

• The model used in “Revisiting the carbon cycle” is based on correlation analysis using the **most reliable modern measurements**. The weak correlation between anthropogenic flux adjusted via the ‘airborne fraction’ and annual growth calls into question the IPCC's thesis. On the other hand, the correlation observed between the detrended series suggests that the temperature of the intertropical zone significantly influences annual growth, mainly through natural carbon exchanges (Fig. 6e).

• Regarding natural carbon exchanges in the intertropical zone, other evidence (§7) indicates that the influence of the ocean predominates over that of vegetation and soils. However, the correlation obtained is not perfect: the ocean plays a major role, but other secondary factors also intervene.

• In the natural sciences, it is common practice to quantify correlations by selecting the best available observations and applying signal processing methods. Although the young science of climate is often considered “settled,” why not apply these proven methods to it?

• In the IPCC's AR6 WG1 report, the term “model” appears 14,192 times, compared to 3,106 occurrences for the term “observation” (82% vs. 18%). If the IPCC Bureau recognized that observations should guide models, it would select more observers among its editors. Unfortunately, such an aggiornamento would risk undermining the “scientific consensus” of modelers/editors.

Part 2 of the article presents the model used in Figures 14 and 15 of § 6 of “Revisiting the carbon cycle.”
Part 3 provides illustrations to help better understand the model and answers common objections.

References

Revisiting The Carbon Cycle https://doi.org/10.53234/scc202510/10

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