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OESCHGER CENTRE CLIMATE CHANGE RESEARCH

APO VARIATIONS IN CENTRAL EUROPE OBTAINED AT THE JUNGFRAUJOCH RESEARCH STATION, SWITZERLAND IN COMPARISON TO A COMBINED RECORD OF SCRIPPS LA JOLLA AND ALERT VALUES

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Physics Institute

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Thanks to Ralph Keeling and his team to share the data

Methods: Measurement and sampling site

Location of the sample site

Sphinx at Jungfraujoch

- Located in central Europe at 7º 59’ E, 46º 33’ N
- 3580 m a.s.l.
- Mostly remote

Methods: Flask measurements

CO_2 and O_2 measurements on IRMS (Delta^{plus}XP):
$\delta CO_2/N_2$ (44/28), $\delta O_2/N_2$ (32/28)

Each flask is measured two times five cycles consisting of eight SA/ST pairs

$$\delta O_2/N_2 = \left(\frac{R_{sample}}{R_{standard}} - 1\right) \cdot 10^6$$ [per meg]

$\delta^{13}C$ of CO_2 measurements on GC/IRMS (Delta^{plus}XP):

Each flask is measured three times

CO_2 cryogenically enriched

N_2O and CO_2 are separated by GC

$$\delta^{13}C = \left(\frac{R_{sample}}{R_{standard}} - 1\right) \cdot 10^3$$ [‰ VPDB] $$^{13}R = \frac{^{13}C}{^{12}C}$$

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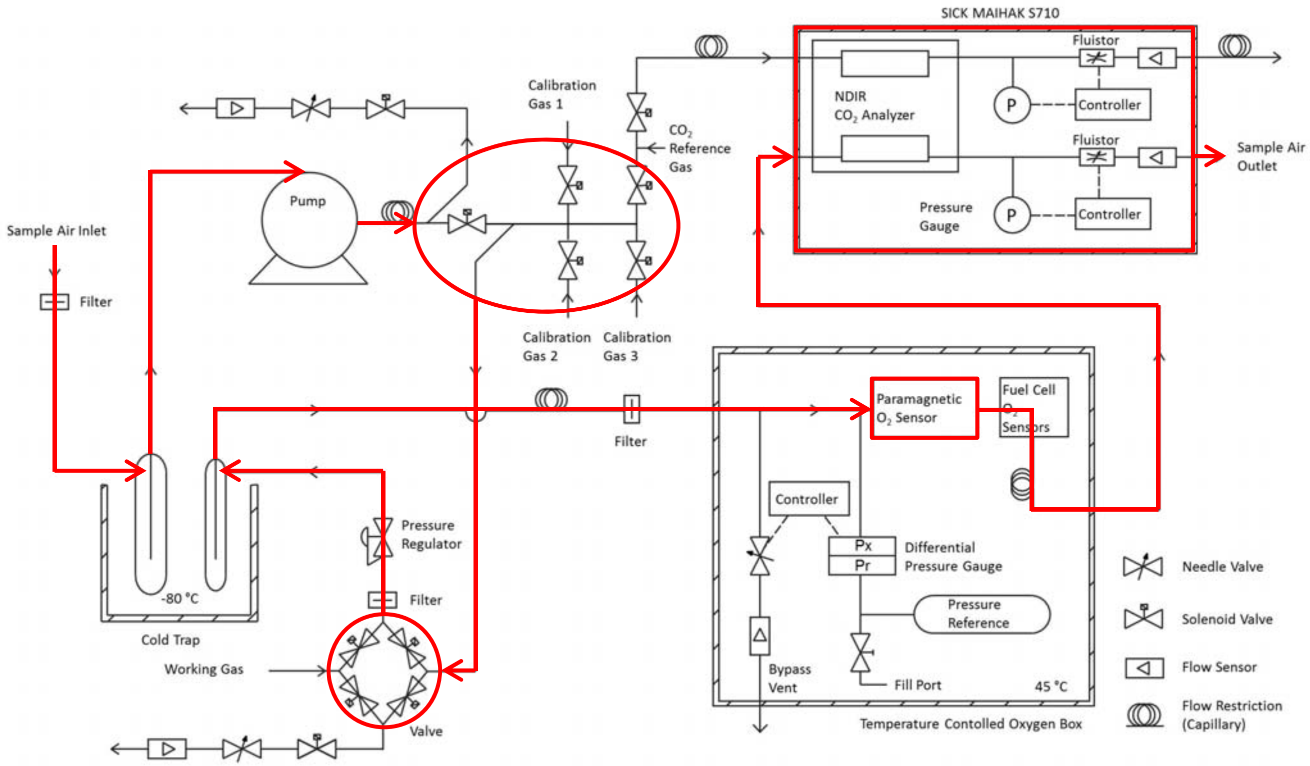
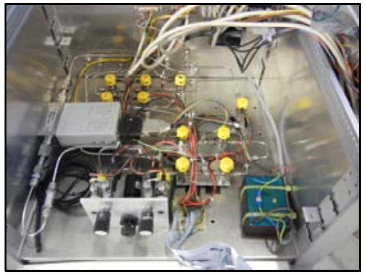
ICOS INTEGRATED CARBON OBSERVATION SYSTEM

Methods: In-situ CO_2 and O_2 measurement system





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Flask and in-situ measurements at JFJ

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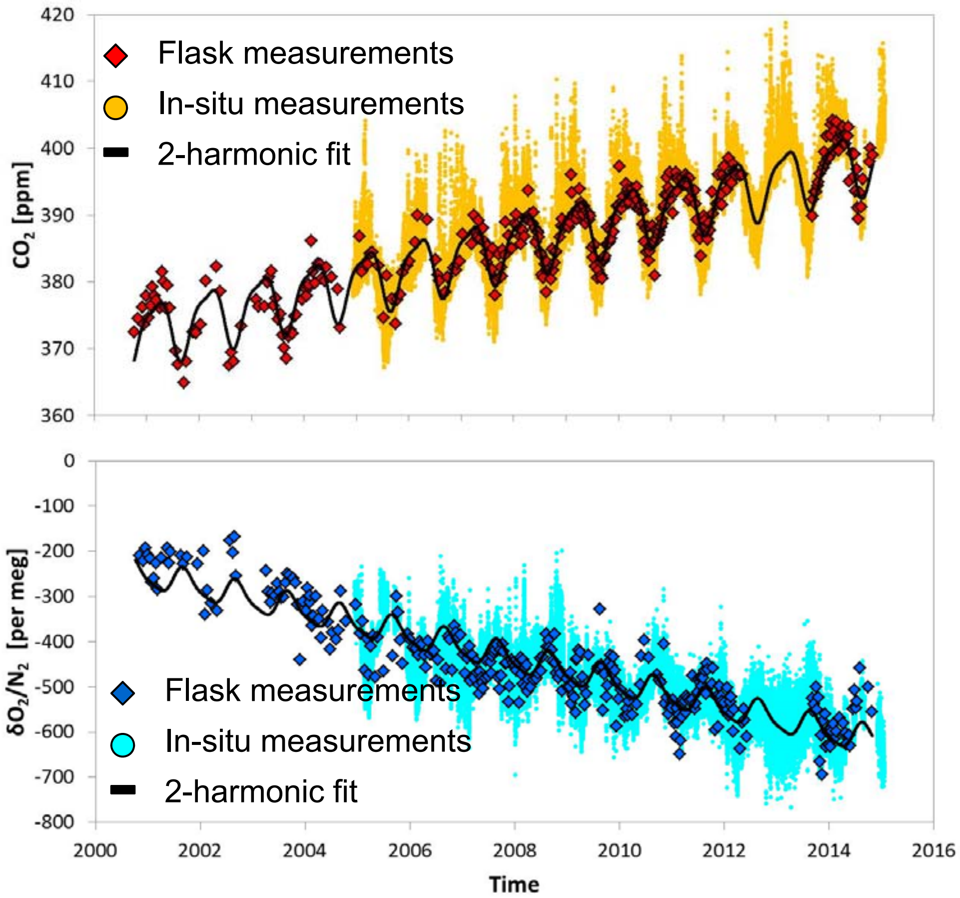
Flask and in-situ measurement slopes



CO_2 record:

Slope in-situ: 2.07 ± 0.06 ppm yr^{-1}

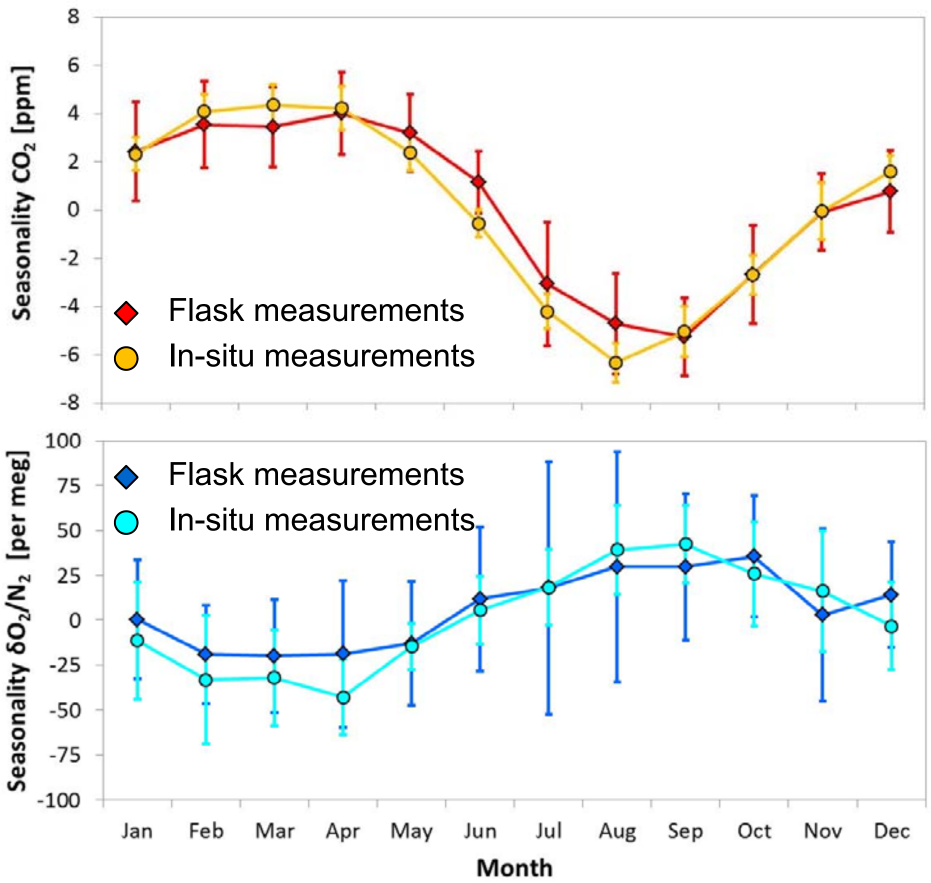
Slope flasks: 1.91 ± 0.15 ppm yr^{-1}
(1.90 ± 0.24 ppm yr^{-1})

O_2 record

Slope in-situ: -23.6 ± 0.6 per meg yr^{-1}

Slope flasks: -26.7 ± 1.8 per meg yr^{-1}
(-20.3 ± 2.1 per meg yr^{-1})

Flask and in-situ seasonality



CO_2 record:

Seasonality in-situ: 10.68 ± 1.17 ppm yr^{-1}

Seasonality flasks: 9.27 ± 2.35 ppm yr^{-1}
(8.27 ± 1.85 ppm yr^{-1})

O_2 record

Seasonality In-situ: 85.2 ± 30.4 per meg yr^{-1}

Seasonality flasks: 55.4 ± 46.2 per meg yr^{-1}
(62.9 ± 47.7 per meg yr^{-1})

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Carbon partitioning: The flask and in-situ measurements

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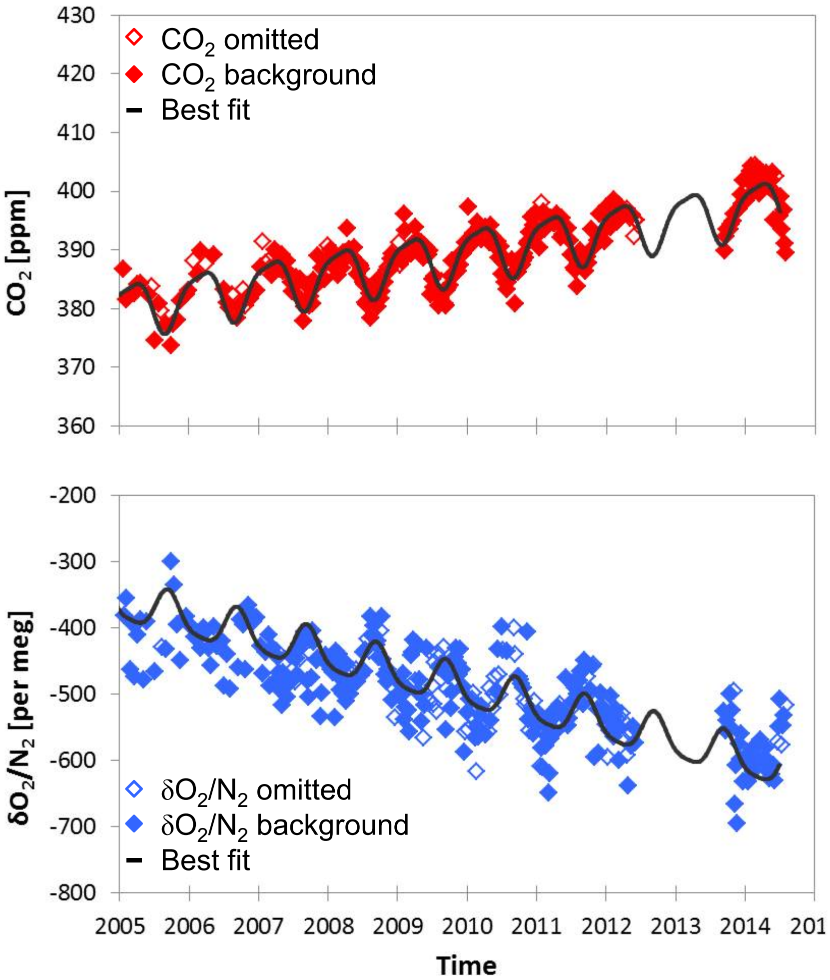
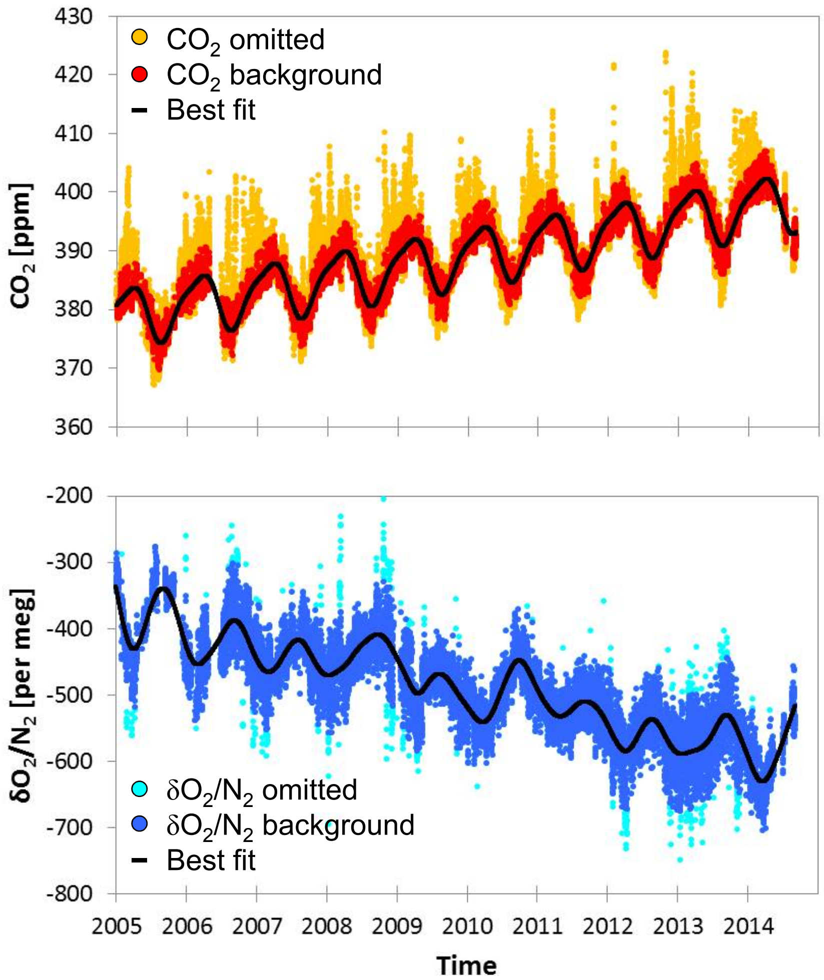
Flask measurements



In-situ measurements



Carbon partitioning based on flask measurements

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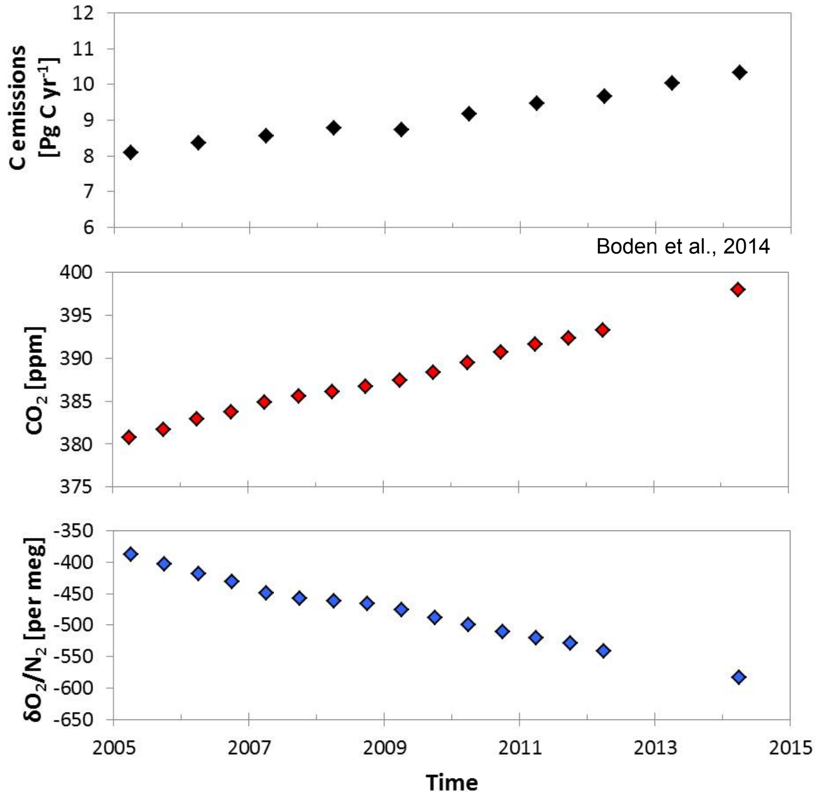
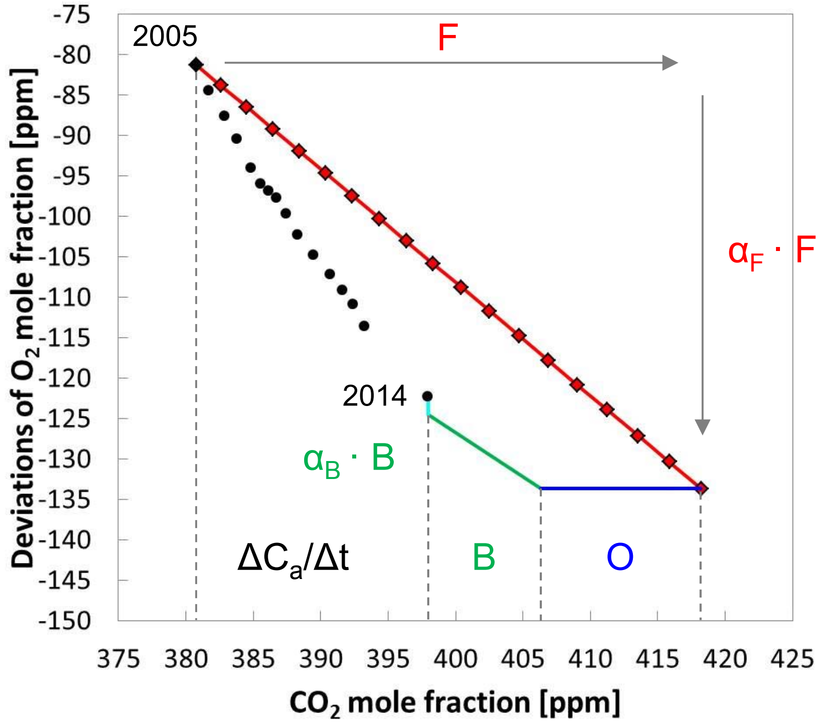




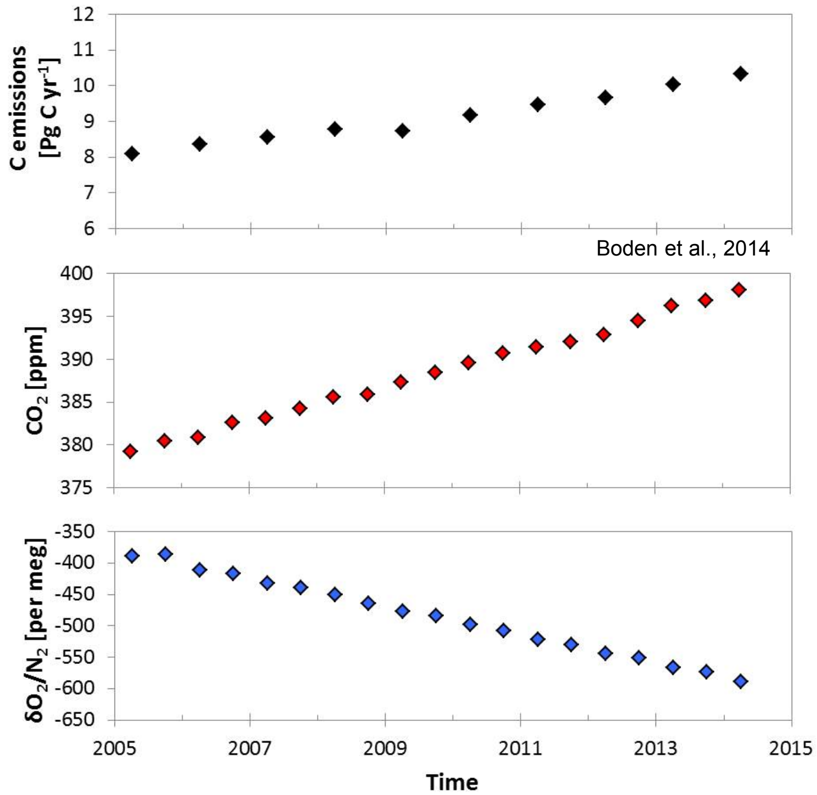
F = 9.11 Pg C yr^{-1} (100 %)

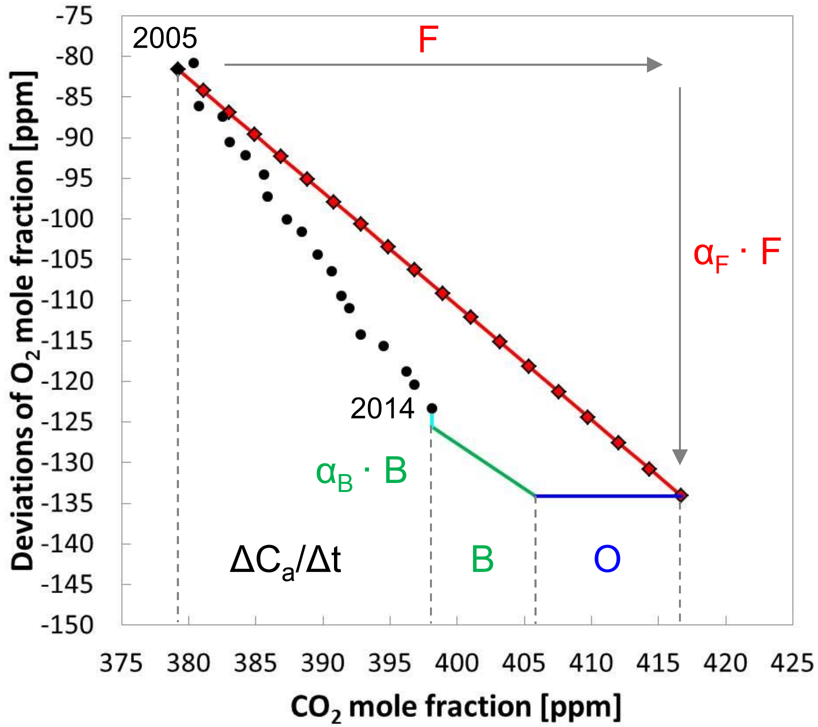
B = -2.04 Pg C yr^{-1} (22.4 %)

$\Delta C_a/\Delta t$ = 4.18 Pg C yr^{-1} (45.9 %)

O = -2.89 Pg C yr^{-1} (31.7 %)

Carbon partitioning based on in-situ measurements





$F = 9.11$ Pg C yr^{-1} (100 %)

$\Delta C_a/\Delta t = 4.59$ Pg C yr^{-1} (50.4 %)

$B = -1.89$ Pg C yr^{-1} (20.7 %)

$O = -2.64$ Pg C yr^{-1} (28.9 %)

Carbon partitioning based on Scripps data

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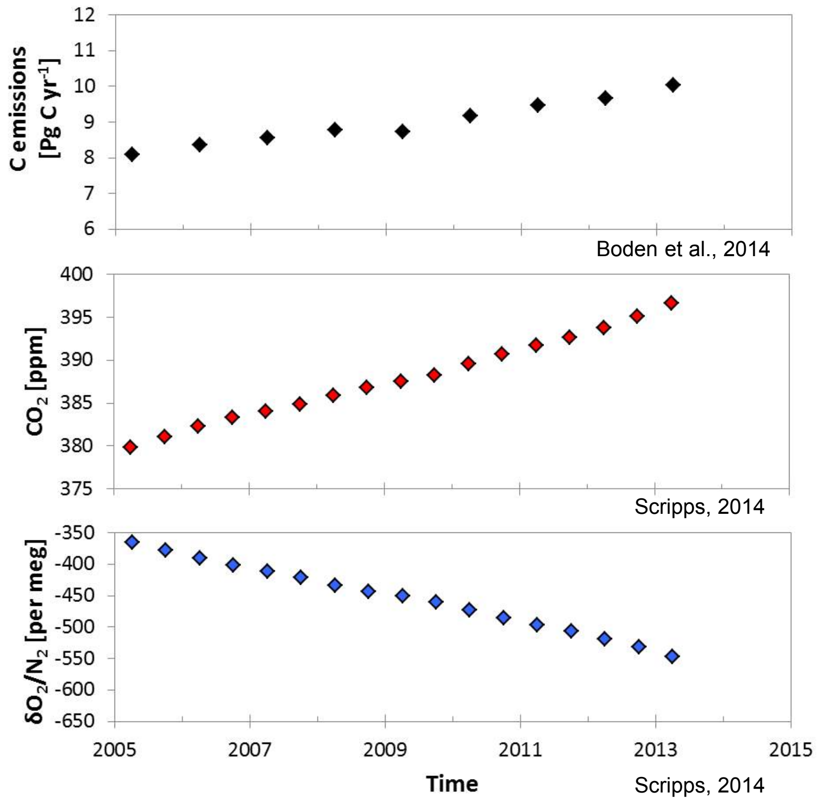
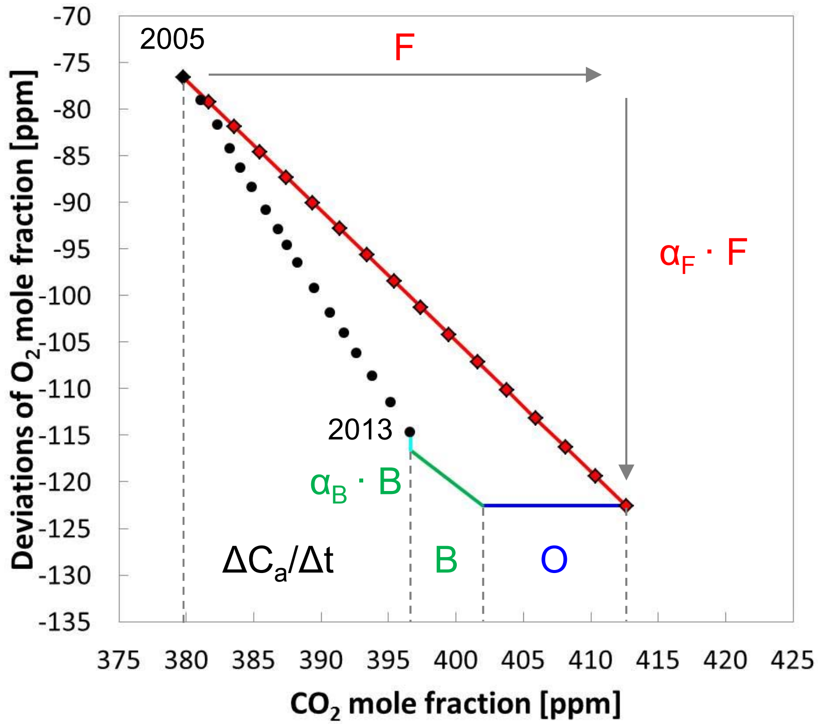
Scripps data (La Jolla and Alert)





$F = 8.98$ Pg C yr^{-1} (100 %)

$\Delta C_a/\Delta t = 4.59$ Pg C yr^{-1} (51.2 %)

$B = -1.48$ Pg C yr^{-1} (16.5 %)

$O = -2.91$ Pg C yr^{-1} (32.4 %)

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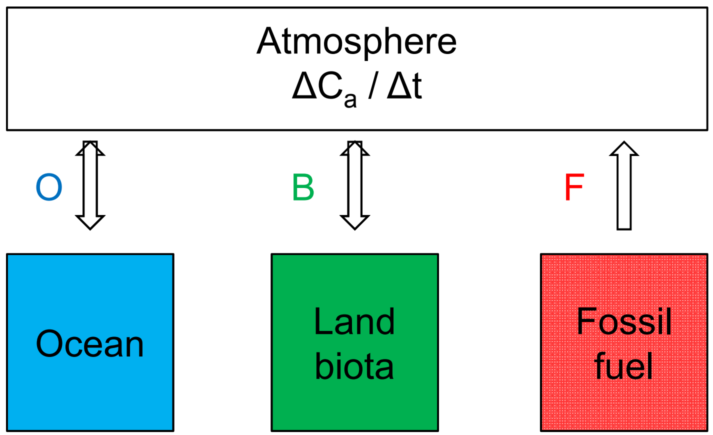
Carbon partitioning



Dataset	Period	F[1]	O		B		$\Delta C_a/\Delta t$	
		Pg C yr^{-1}	Pg C yr^{-1}	%	Pg C yr^{-1}	%	Pg C yr^{-1}	%
JFJ Flask	2005-2014	9.11±0.5	-2.89±0.8	31.7	-2.04±0.8	22.4	4.18±0.1	45.9
JFJ in-situ	2005-2014	9.11±0.5	-2.64±0.8	28.9	-1.89±0.8	20.7	4.59±0.1	50.4
Scripps[2]	2005-2013	8.98±0.4	-2.91±0.9	32.4	-1.48±0.9	16.5	4.59±0.1	51.2

[1] Boden et al., 2014
[2] Scripps Institute of Oceanography, 2014

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Carbon partitioning based on JFJ in-situ measurements

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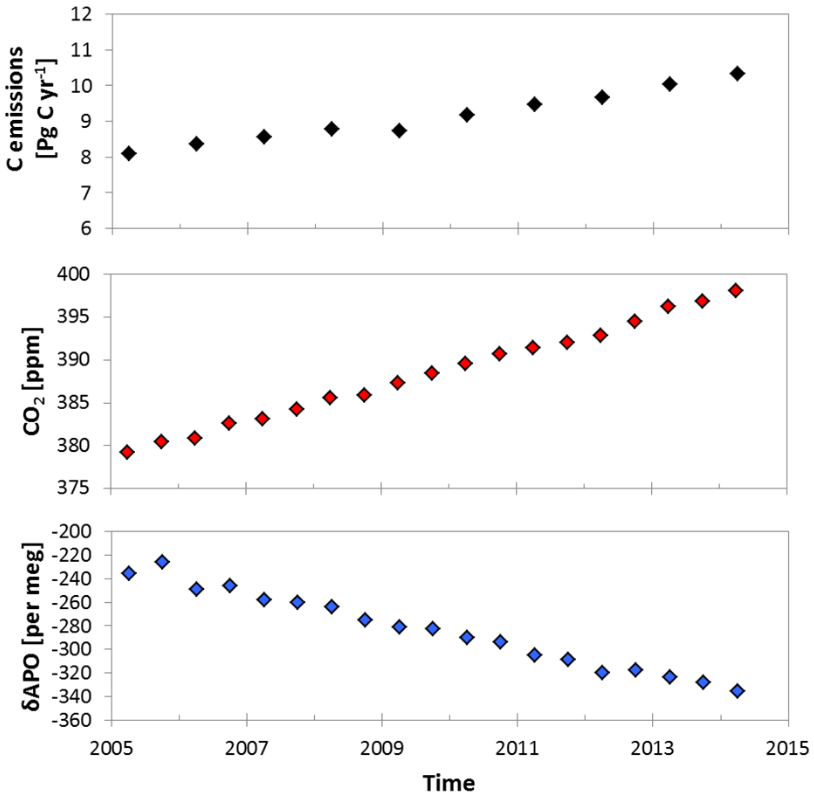

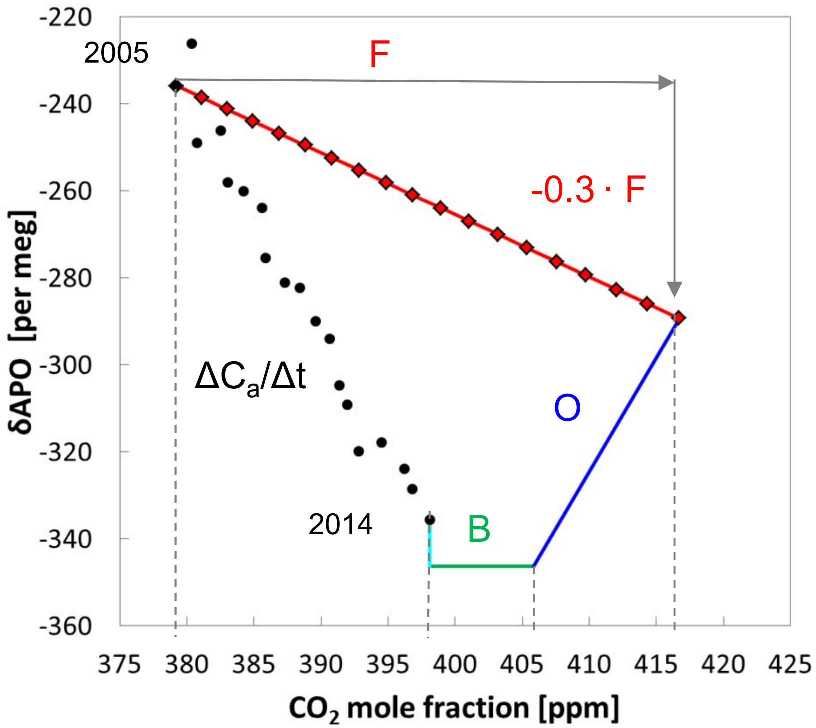

F = 9.11 Pg C yr^{-1} (100 %)

B = -1.89 Pg C yr^{-1} (20.7 %)

$\Delta C_a/\Delta t$ = 4.59 Pg C yr^{-1} (50.4 %)

O = -2.64 Pg C yr^{-1} (28.9 %)

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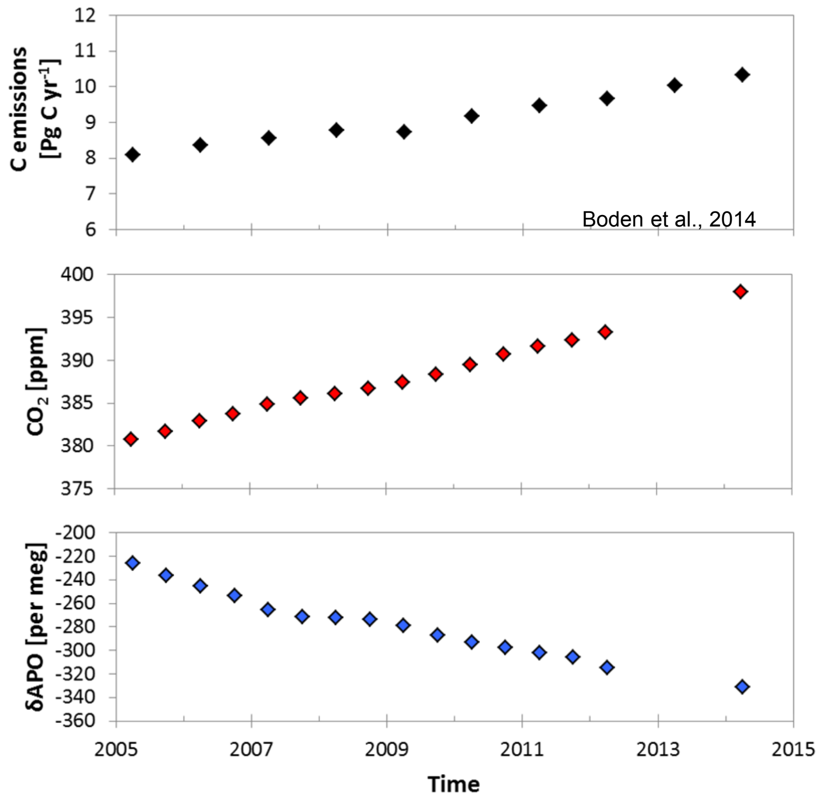
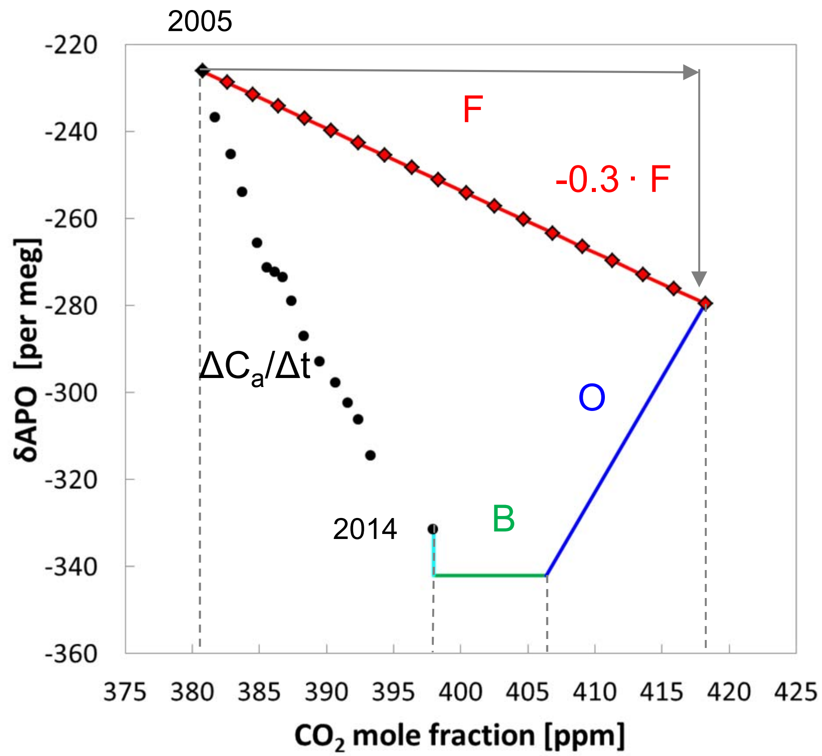
Carbon partitioning based on JFJ flask measurements





F = 9.11 Pg C yr^{-1} (100 %)

B = -2.04 Pg C yr^{-1} (22.4 %)

$\Delta C_a/\Delta t$ = 4.18 Pg C yr^{-1} (45.9 %)

O = -2.89 Pg C yr^{-1} (31.7 %)

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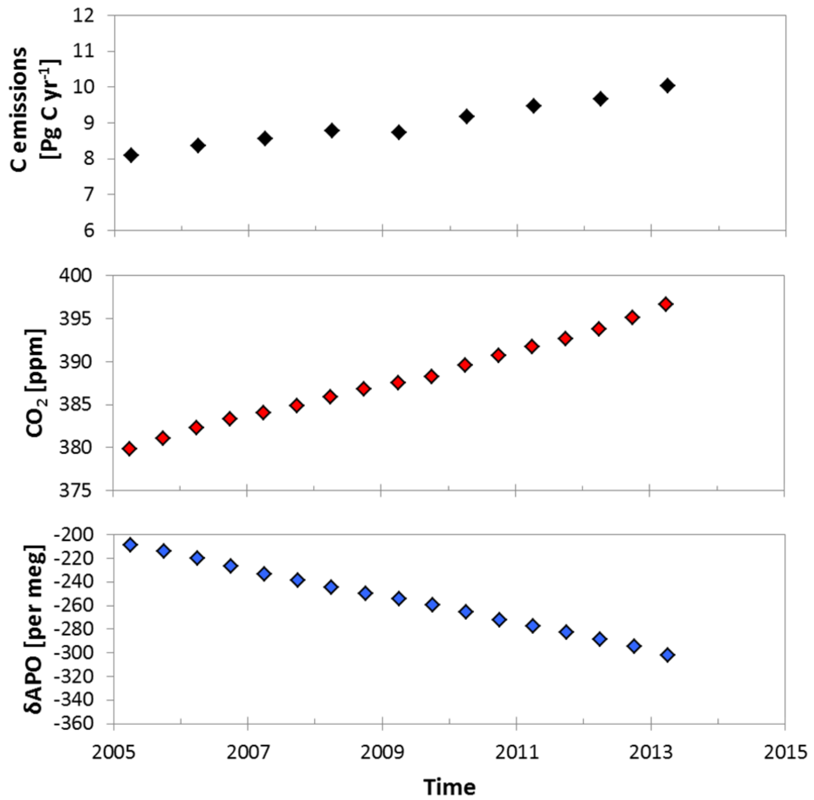
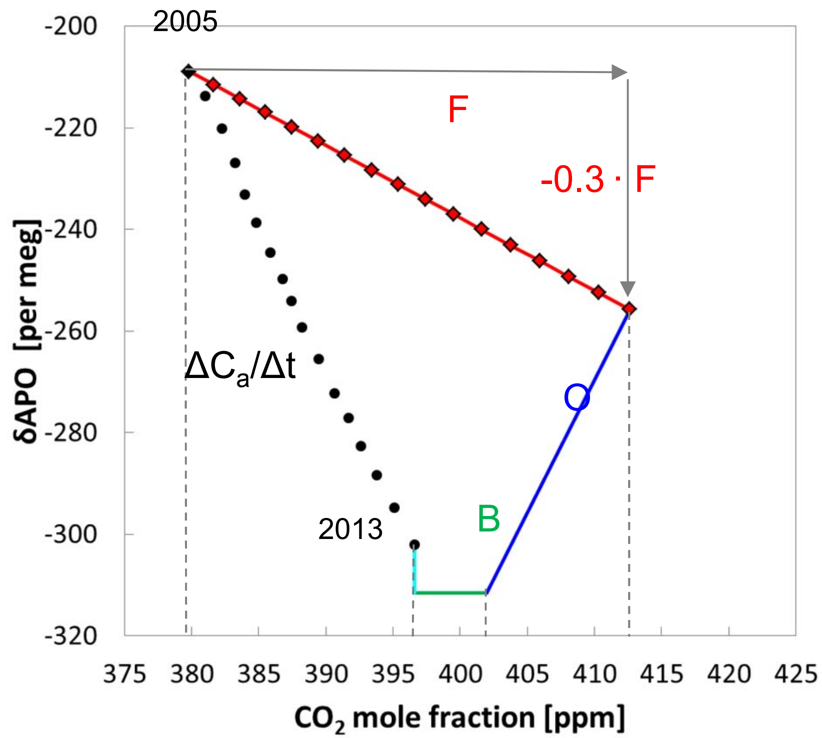
Carbon partitioning based on Scripps measurements





F = 8.98 Pg C yr^{-1} (100 %)

B = -1.48 Pg C yr^{-1} (16.5 %)

$\Delta C_a/\Delta t$ = 4.59 Pg C yr^{-1} (51.2 %)

O = -2.91 Pg C yr^{-1} (32.4 %)

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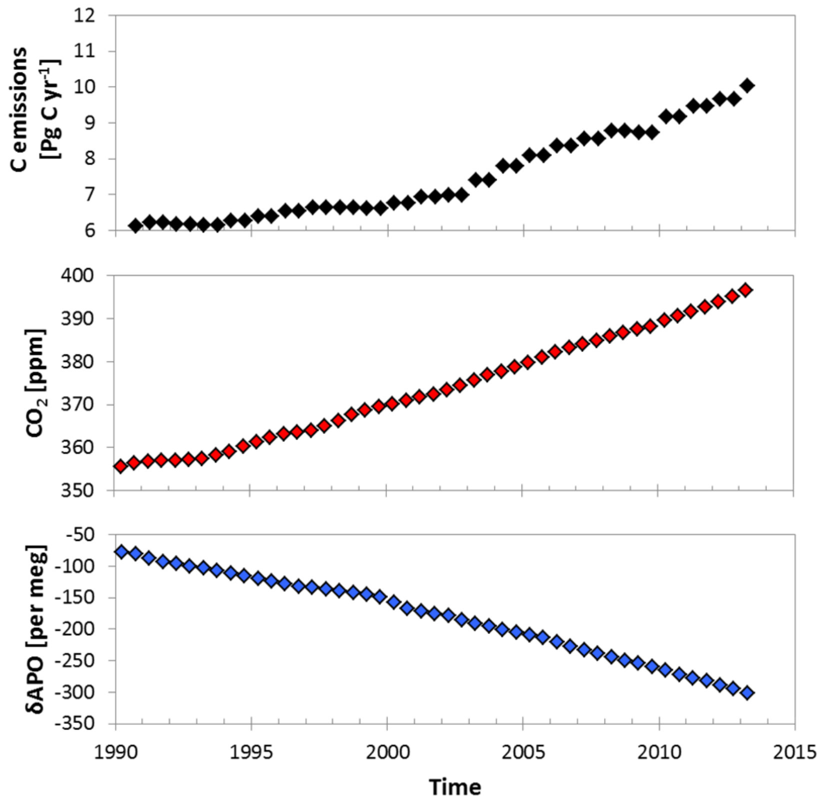

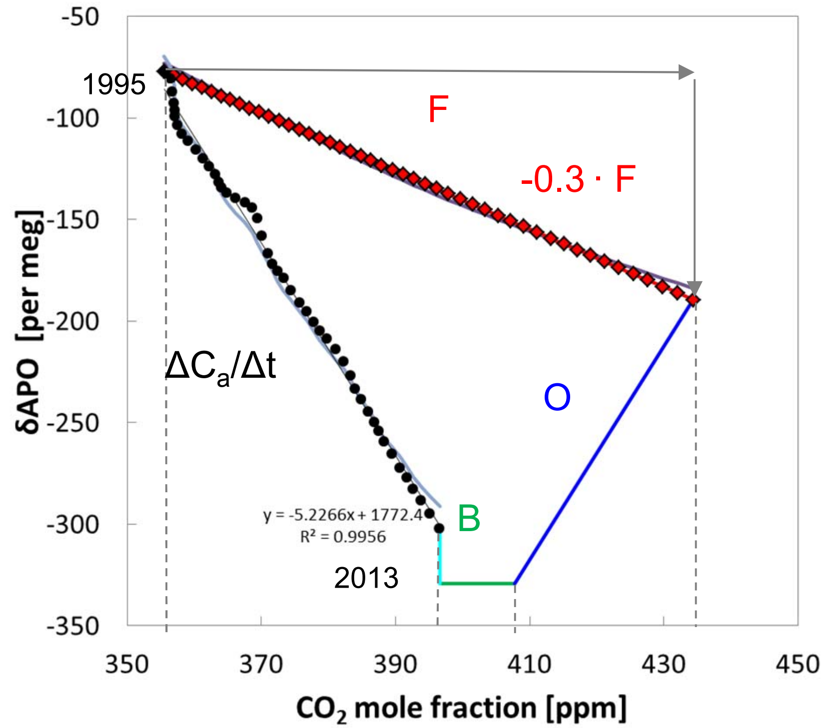

$F = 7.5$ Pg C yr^{-1} (100 %)

$B = -1.06$ Pg C yr^{-1} (14.2 %)

$\Delta C_a/\Delta t = 3.91$Pg C yr^{-1} (52.1 %)

$O = -2.53$ Pg C yr^{-1} (33.7 %)

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Residual interpretation

$$O_{2,meas.} = -1.4 \cdot F + 1.1 \cdot B + Z + S_{O2}$$

$$O_{2,meas.\ Trend}$$

$$O_{2,exp.} = -1.4 \cdot F$$

$$O_{2,exp.\ Trend}$$

$$\Delta O_{2,meas.} = O_{2,meas.} - O_{2,meas.\ Trend}$$

$$\Delta O_{2,exp.} = O_{2,exp.} - O_{2,exp.\ Trend}$$

Double difference: → cancelling the fossil fuel influence!

$$\Delta(\Delta O_2) = O_{2,meas.} - O_{2,meas.\ Trend} - (O_{2,exp.} - O_{2,exp.\ Trend})$$

$$= O_{2,meas.} - O_{2,exp.} - (O_{2,meas.\ Trend} - O_{2,exp.\ Trend})$$

Residual interpretation

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$CO_{2,meas.} = F - O - B + S_{CO2}$

$CO_{2,meas.\ Trend}$

$CO_{2,exp.} = F$

$CO_{2,exp.\ Trend}$

$\Delta CO_{2,meas.} = CO_{2,meas.} - CO_{2,meas.\ Trend}$

$\Delta CO_{2,exp.} = CO_{2,exp.} - CO_{2,exp.\ Trend}$

Double difference: → cancelling the fossil fuel influence!

$$\Delta(\Delta CO_2) = CO_{2,meas.} - CO_{2,meas.\ Trend} - (CO_{2,exp.} - CO_{2,exp.\ Trend})$$
$$= CO_{2,meas.} - CO_{2,exp.} - (CO_{2,meas.\ Trend} - CO_{2,exp.\ Trend})$$

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Residual interpretation, ratio of the double differences

$$\frac{\Delta(\Delta O_2)}{\Delta(\Delta CO_2)} = \frac{1.1 \cdot \Delta B + \Delta Z + \Delta S_{O2}}{-\Delta O - \Delta B + \Delta S_{CO2}}$$

One can distinguish four different cases:

- ΔZ is dominating → ratio gets towards: infinity $^-$
- ΔB is dominating → ratio gets towards: – 1.1
- ΔO is dominating → ratio gets towards: 0^-
- ΔS is dominating → ratio gets towards: > 0

What does the data tell us?

Residual interpretation, ratio of the double differences

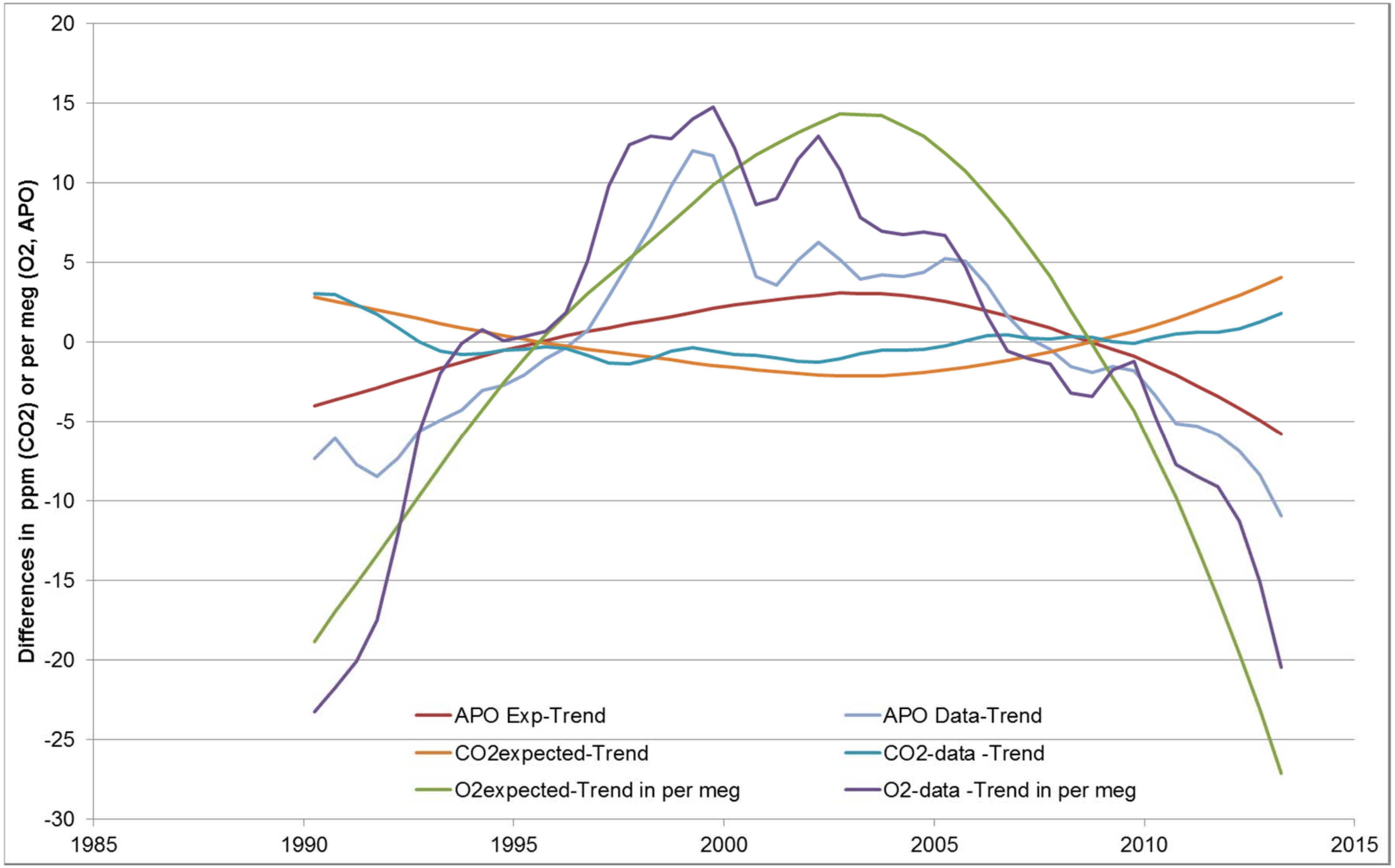
$$\frac{\Delta(\Delta\text{APO})}{\Delta(\Delta\text{CO}_2)} = \frac{\Delta Z - 1.1 \cdot \Delta O + \Delta S_{O2} + 1.1 \cdot \Delta S_{CO2}}{-\Delta O - \Delta B + \Delta S_{CO2}}$$

One can distinguish four different cases:

- ΔZ is dominating → ratio gets towards: infinity $^-$
- ΔB is dominating → ratio gets towards: 0^-
- ΔO is dominating → ratio gets towards: 1.1^+
- ΔS is dominating → ratio gets towards: > 1.1

What does the data tell us?

Step 1: Differences from trend of Scripps data



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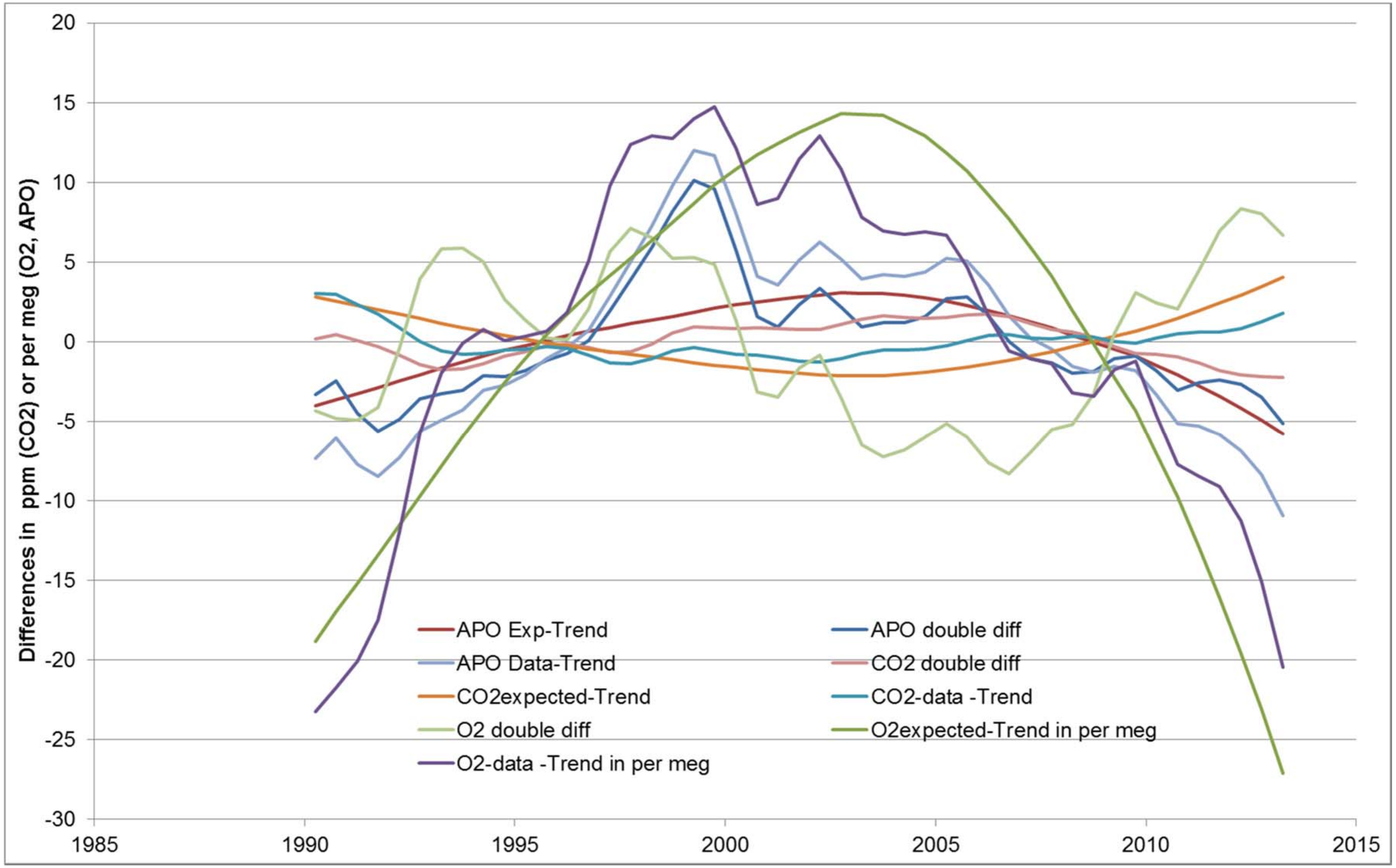
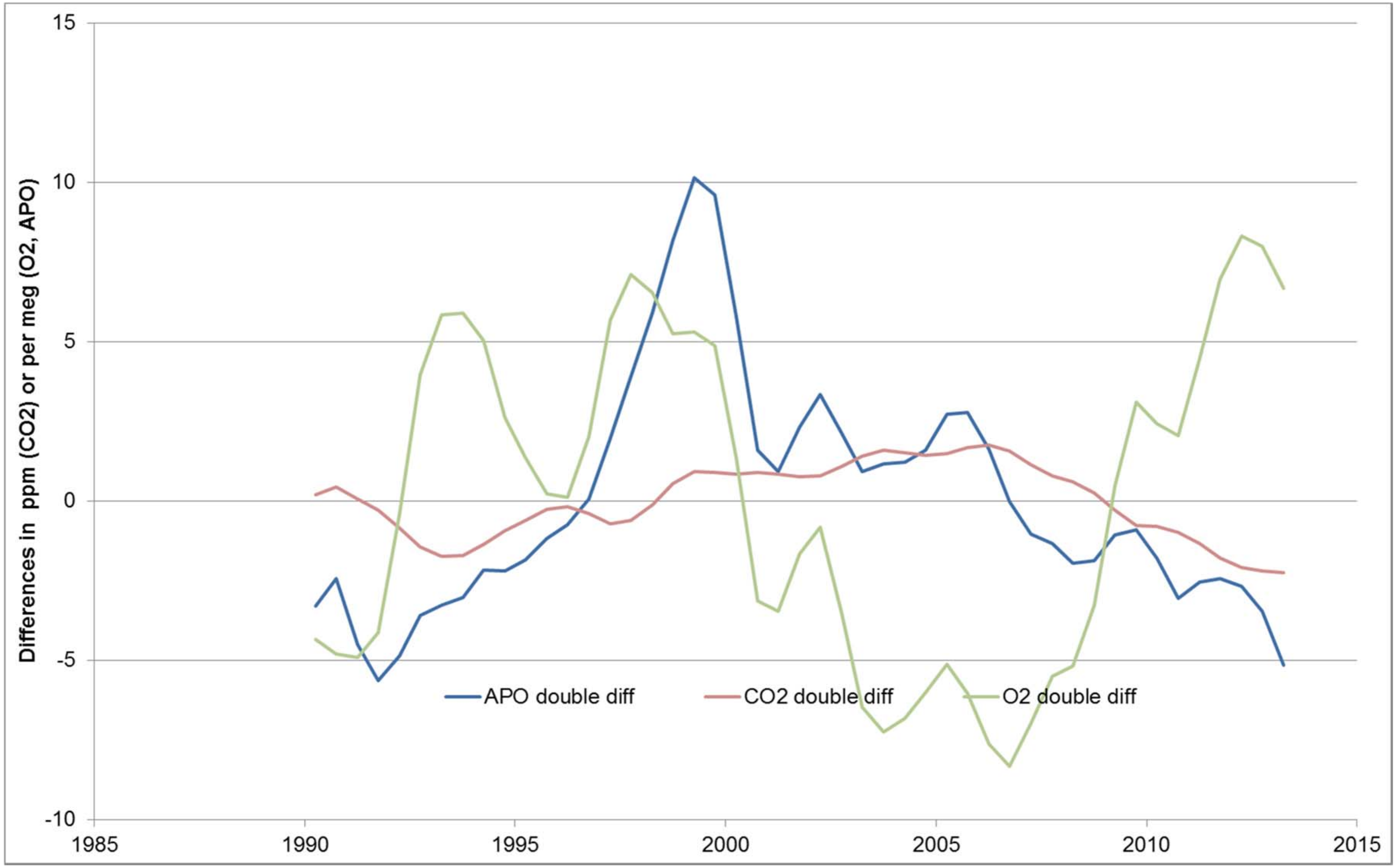
Step 2: Adding double differences from Scripps data



Step 2: Double differences only from Scripps data



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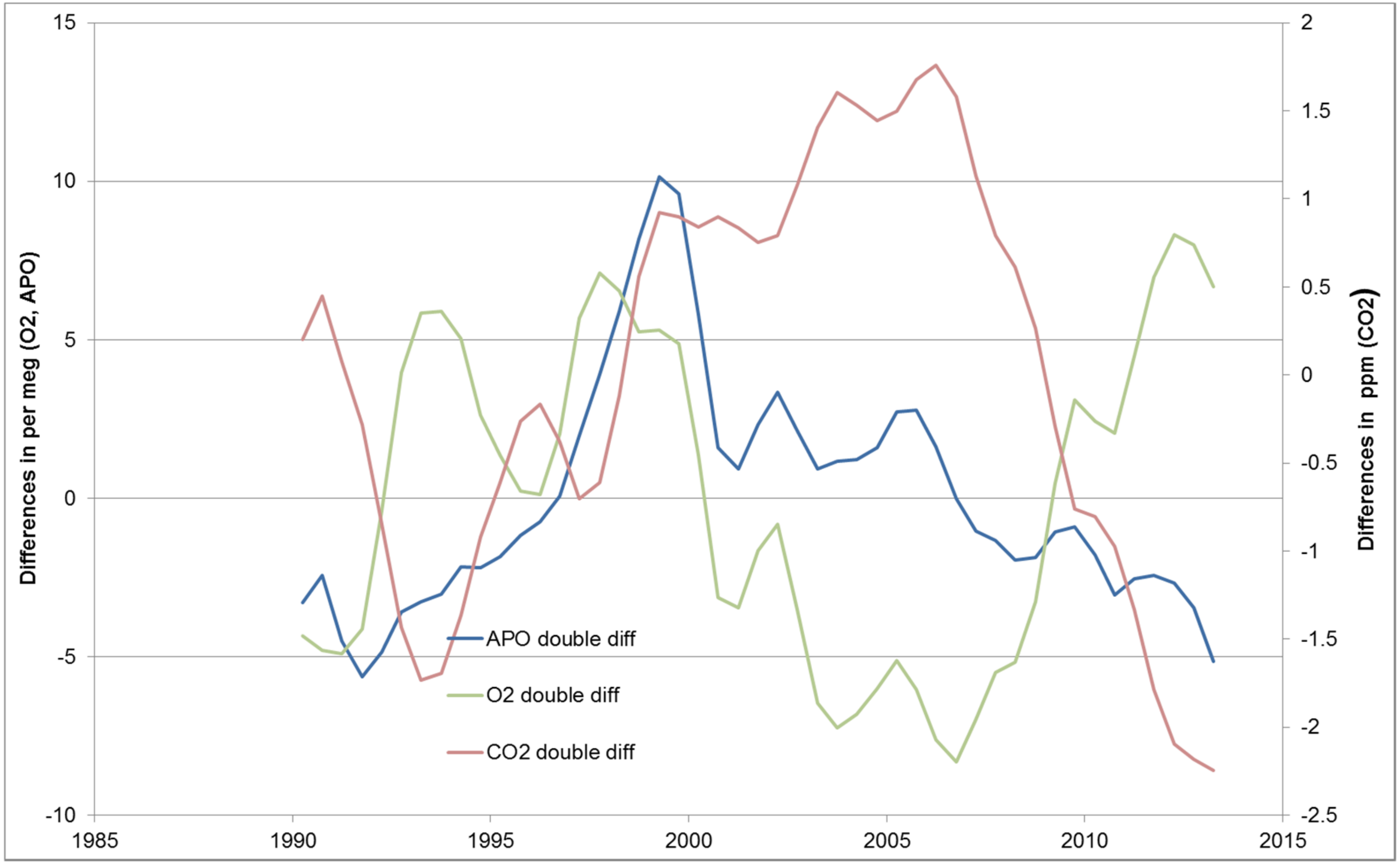
Step 2: Double differences only from Scripps data



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Step 3: Ratio of double differences for O_2 and CO_2

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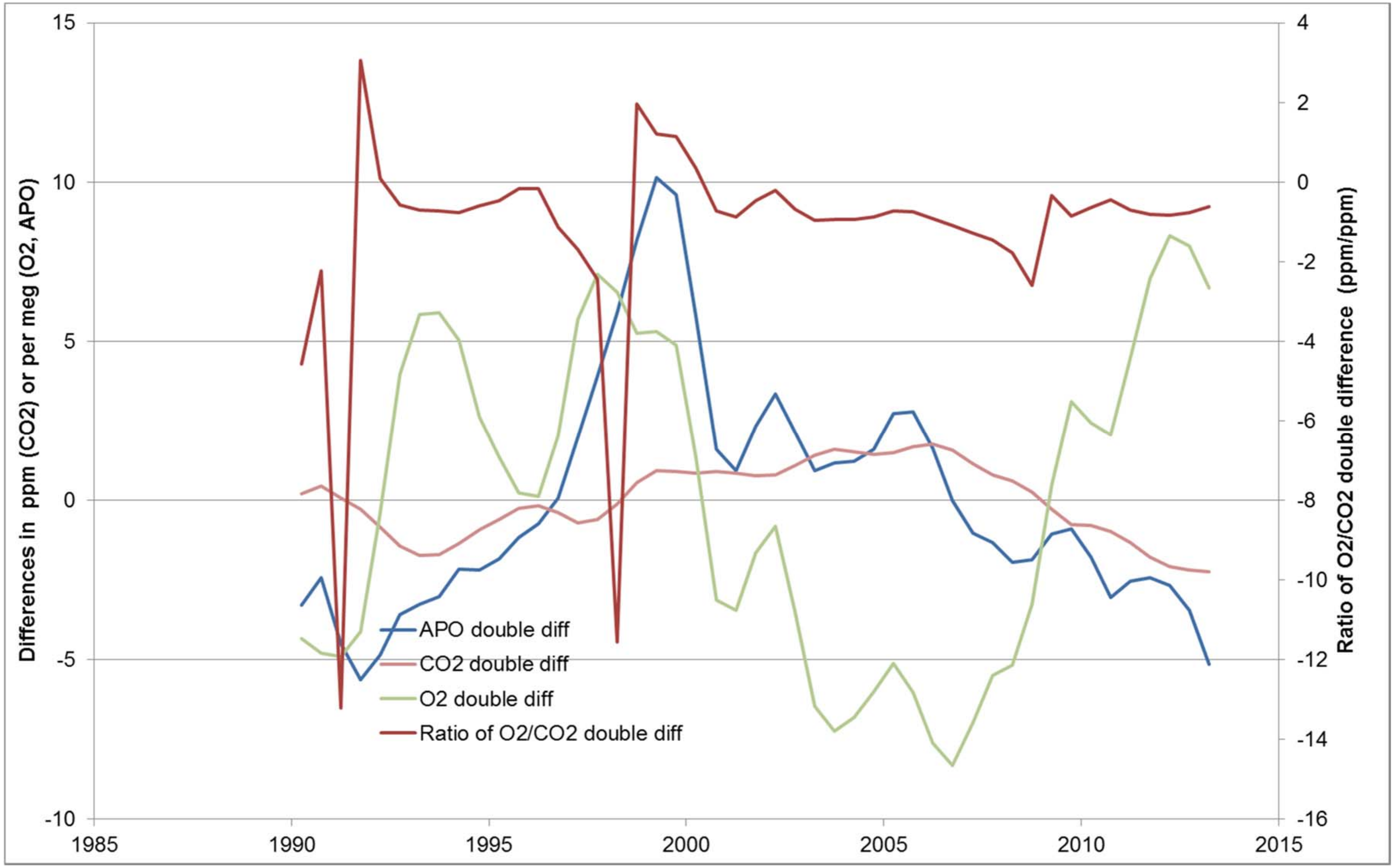

Step 3: Ratio of double differences for (O_2 , APO) and CO_2

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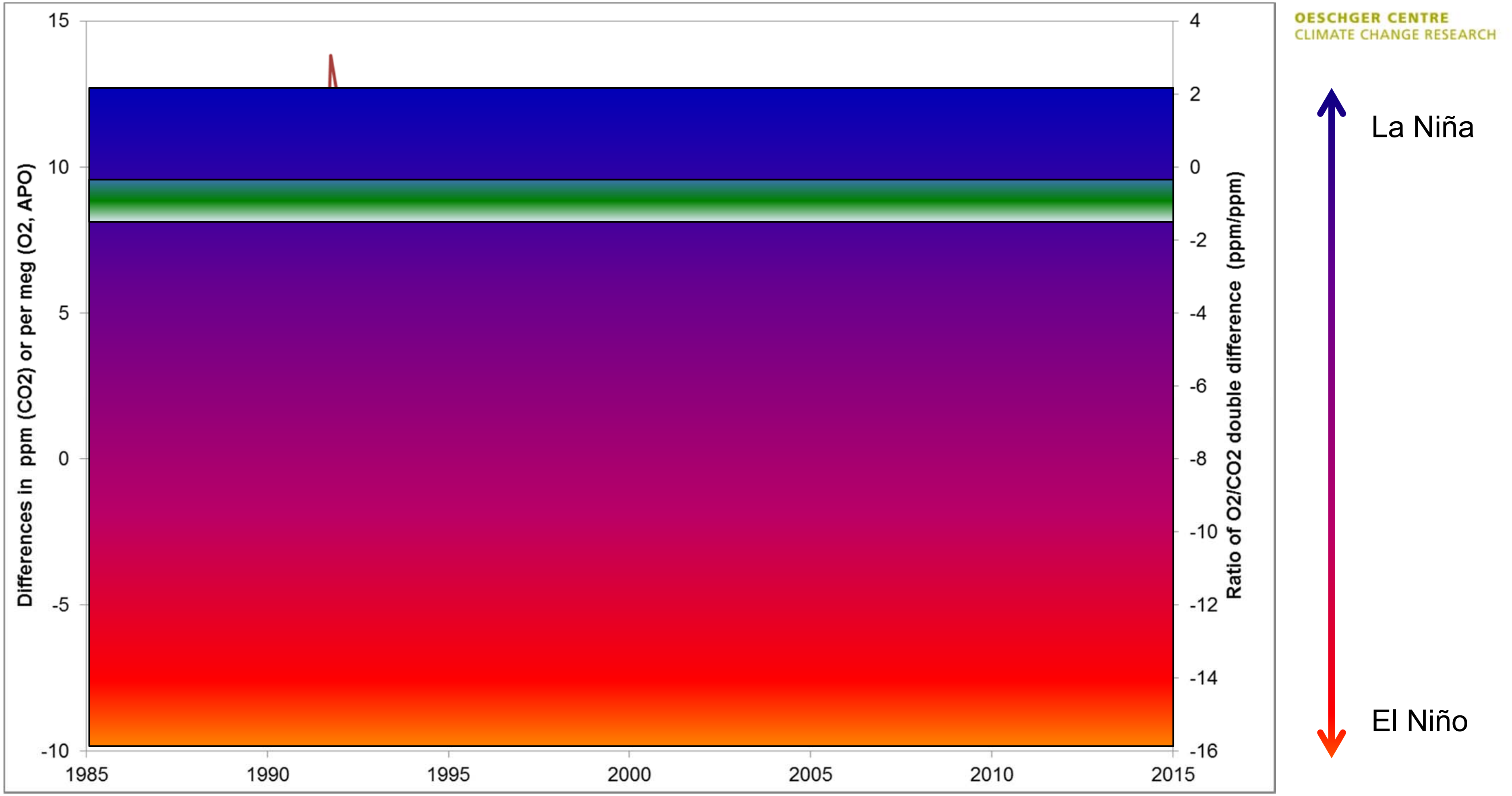

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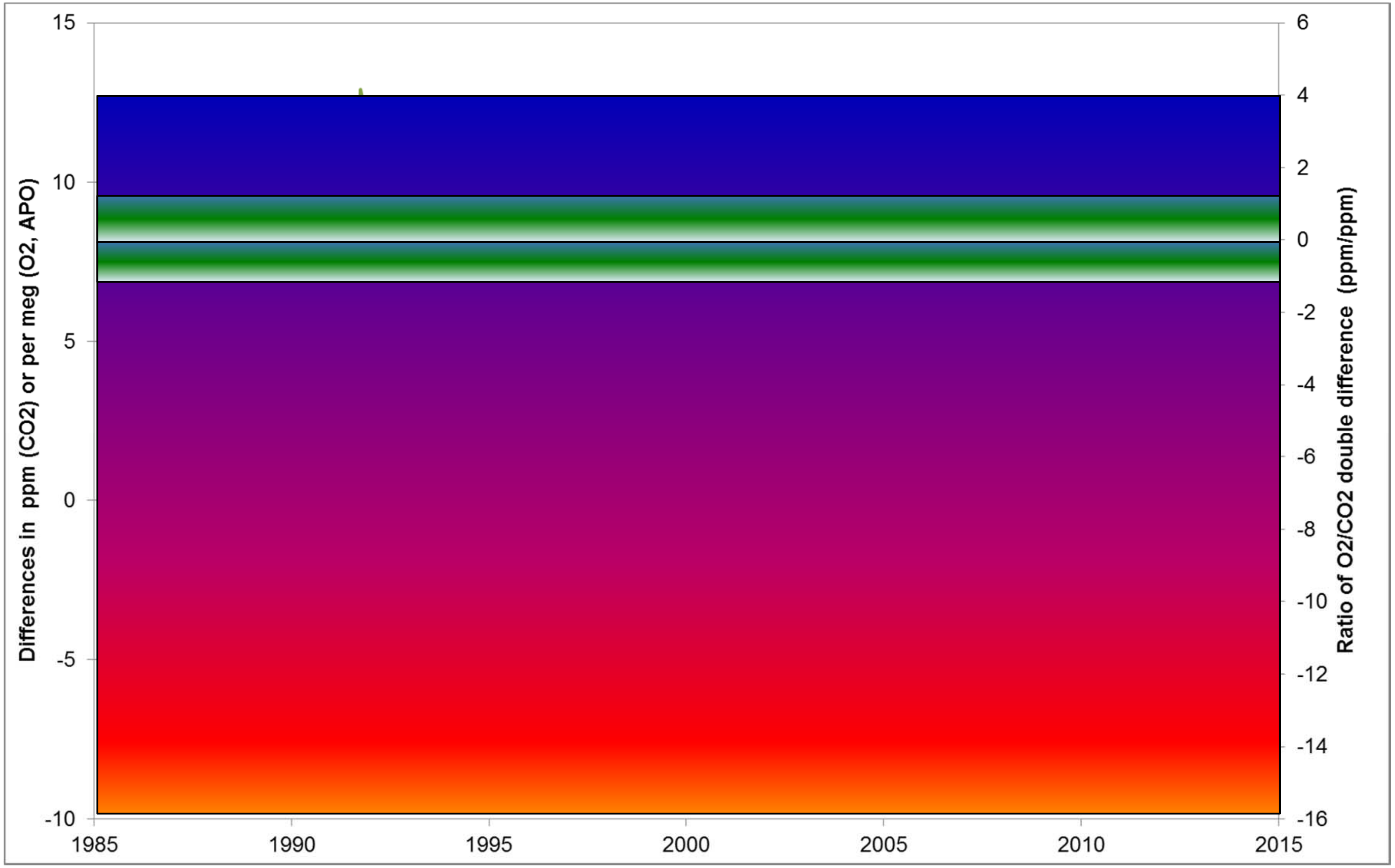
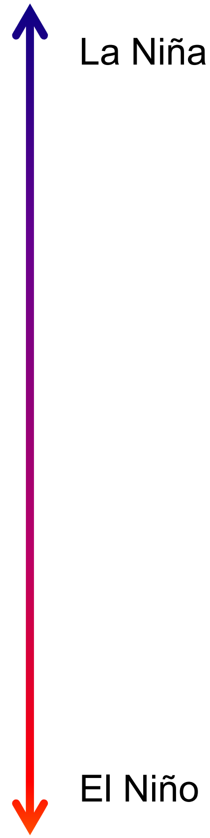
Step 3: Ratio of double differences for (O_2 , APO) and CO_2





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Step 3: dito for Scripps and Jungfraujoch

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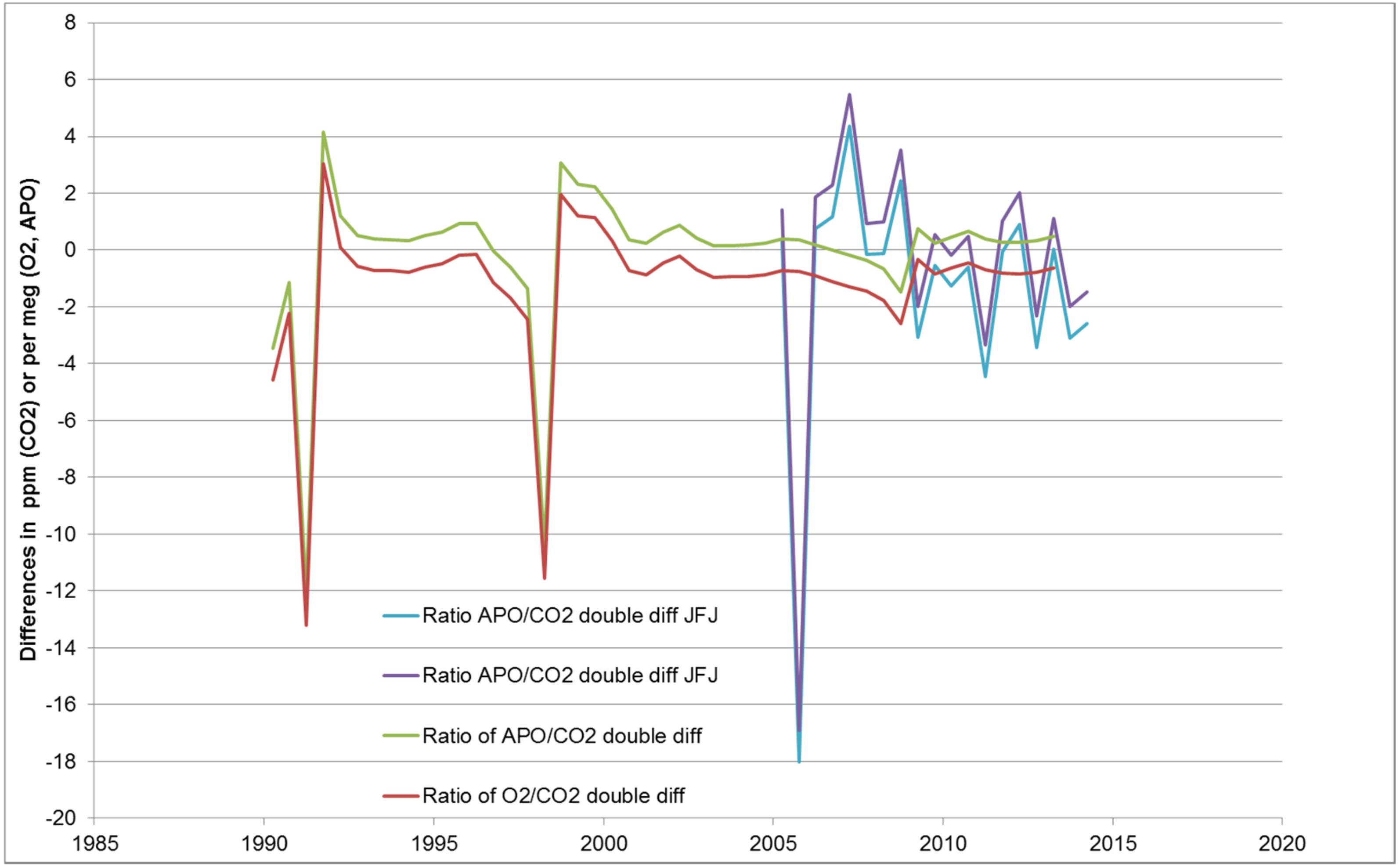
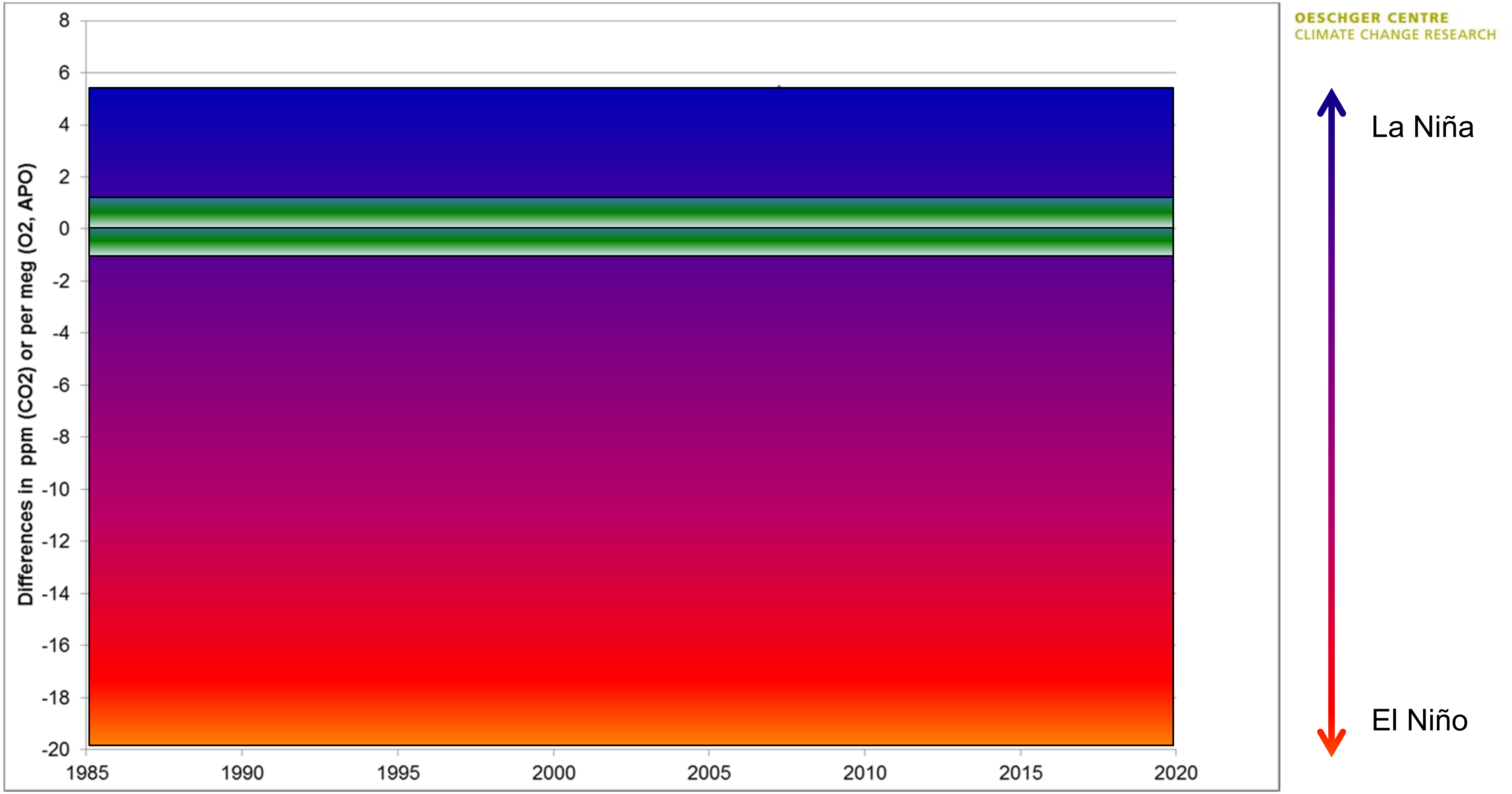


Step 3: dito for Scripps and Jungfraujoch



Conclusions

- The flask and in-situ measurements are in agreement for the trend analysis.
- The ocean takes up about 30 % of the emitted carbon, about 20 % are taken up by the terrestrial biosphere and about 50 % remain in the atmosphere
- There is a rather good agreement between the Jungfraujoch and Scripps data (La Jolla and Alert mean) regarding the partitioning. Jungfraujoch points to a stronger biosphere influence compared to Scripps data.
- Double differences of oxygen (or APO) and carbon changes might be a tool for process separation.

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Thank you for your attention!


10th International
Carbon Dioxide Conference
20 – 25 August 2017, Interlaken, Switzerland