APO Workshop 2023-08-23

The suitability of atmospheric oxygen measurements to constrain Western European fossil-fuel CO_2 emissions and their trends

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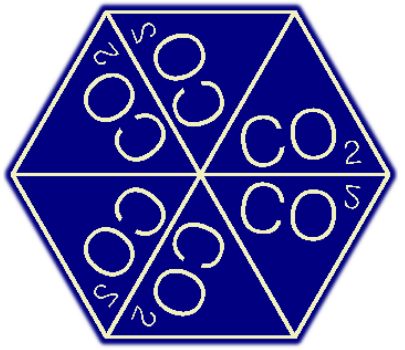
Saqr Munassar[BGC], Penelope A. Pickers[UEA],
Michael Rothe[BGC], Yasunori Tohjima[NIES],
Sönke Zaehle[BGC]



Many thanks to:
Data contributors, DKRZ computing center

Motivation: The global carbon cycle

CO_2

CO_2 CO_2 CO_2

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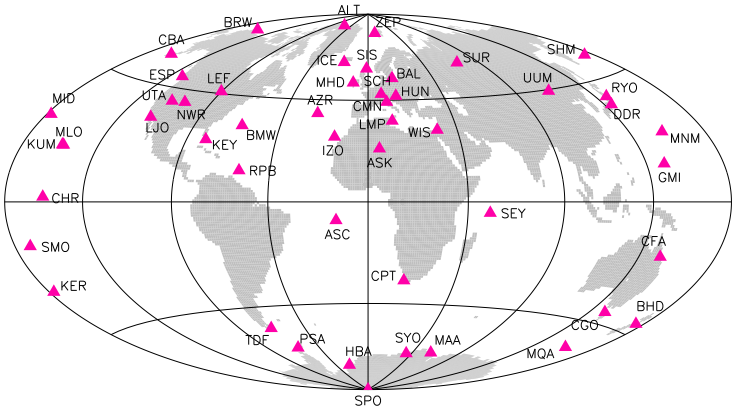
CO_2



CO_2

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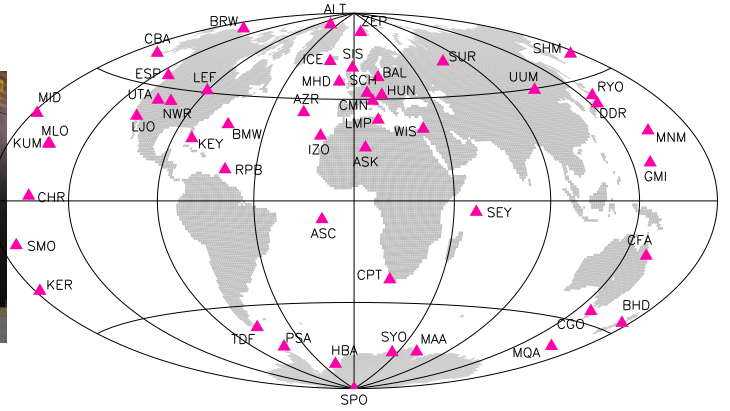
CO_2 inversion

CO_2



CO_2

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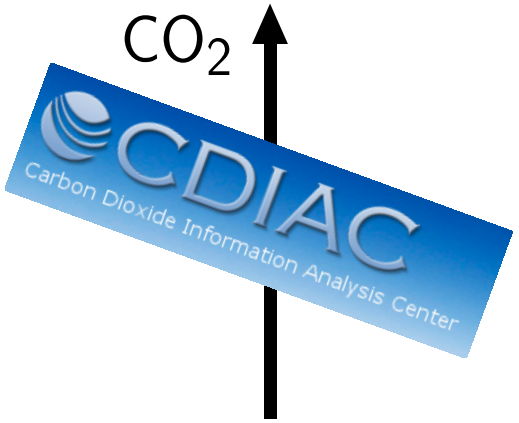
CO_2

CO_2

Fossil-fuel CO_2 emissions



Detailed “bottom-up” inventories exist, but

– completeness?

– political manipulation?

$\Rightarrow$ Need for independent validation

The global “oxygen cycle”

CO_2 ↑ ↓ O_2

$$= \alpha_F \cdot CO_2$$

$\alpha_F \approx -1.0$ (coal)

$\alpha_F \approx -1.4$ (fuel mix)

$\alpha_F \approx -2.0$ (gas)

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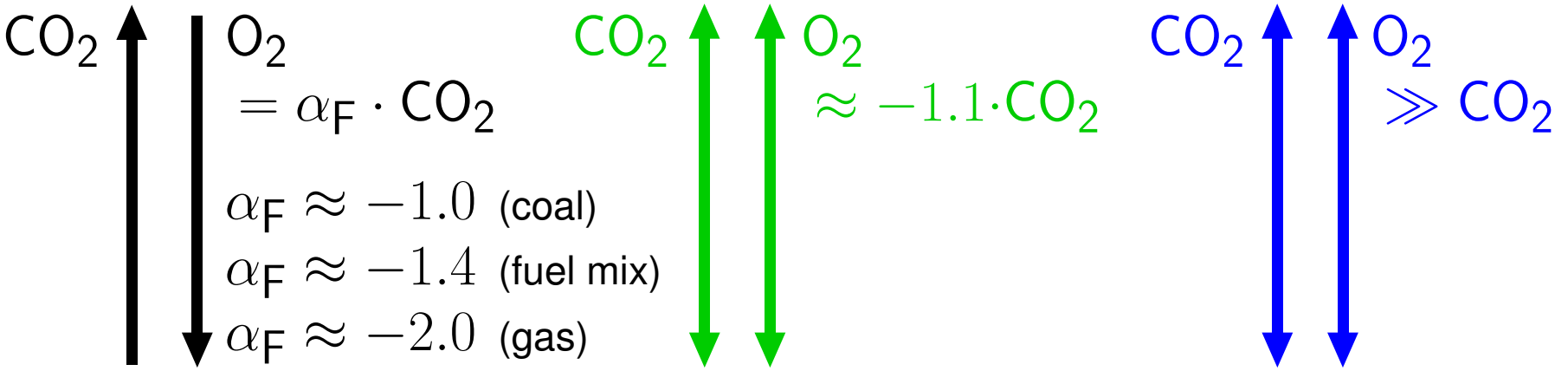

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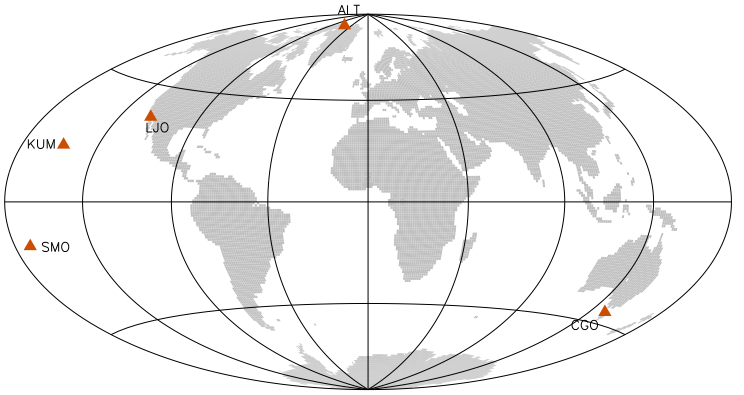
CO_2 O_2



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CO_2 O_2 $\gg CO_2$

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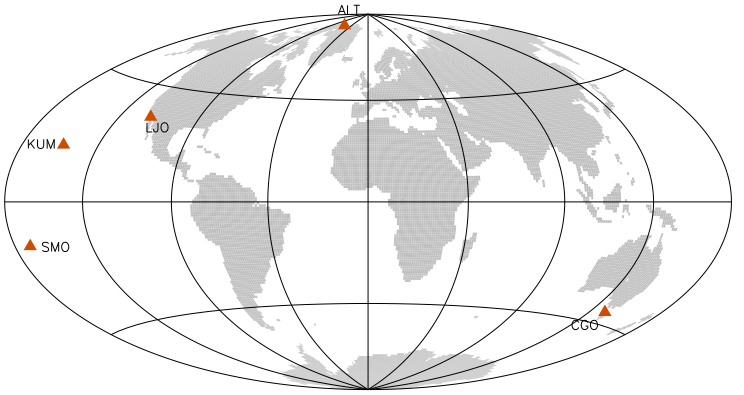
$$\mathrm{APO} = \mathrm{O_2} + 1.1 \cdot \mathrm{CO_2}$$

[Stephens et al., 1998]

APO



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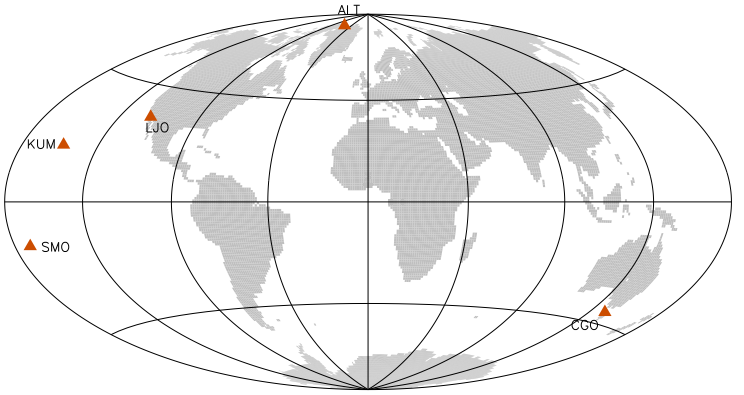

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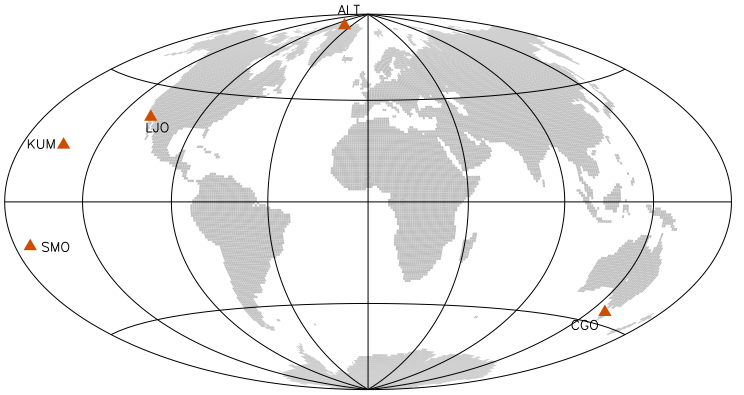

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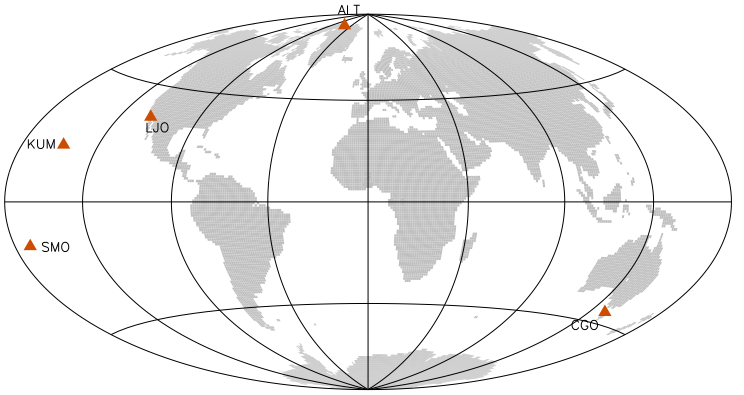

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APO inversion

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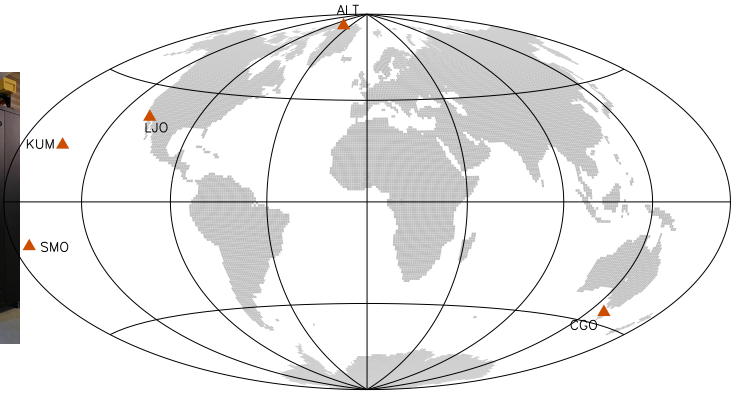

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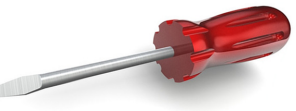
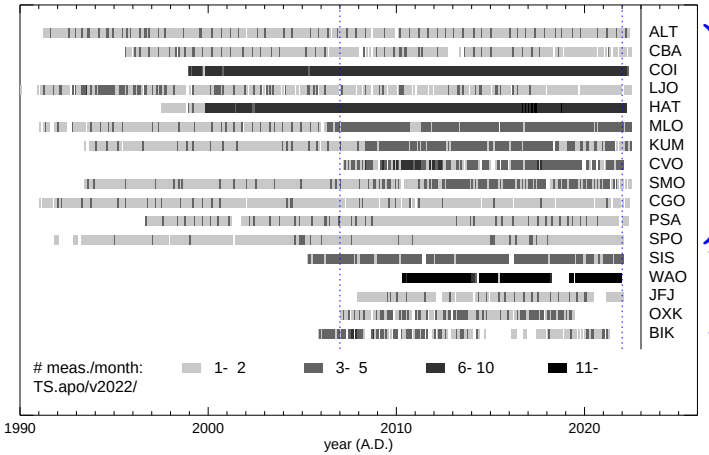


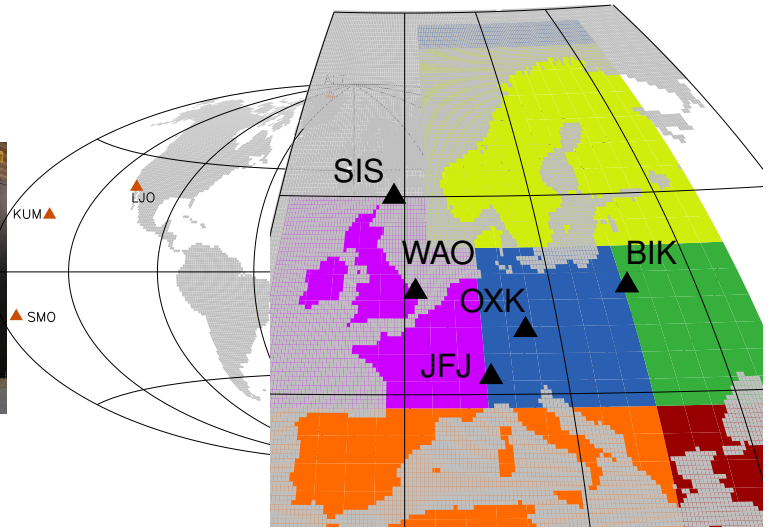
APO inversion – extended



Set A: Global background

Set B: European

APO



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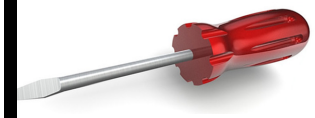

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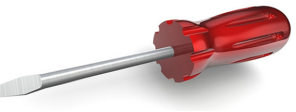

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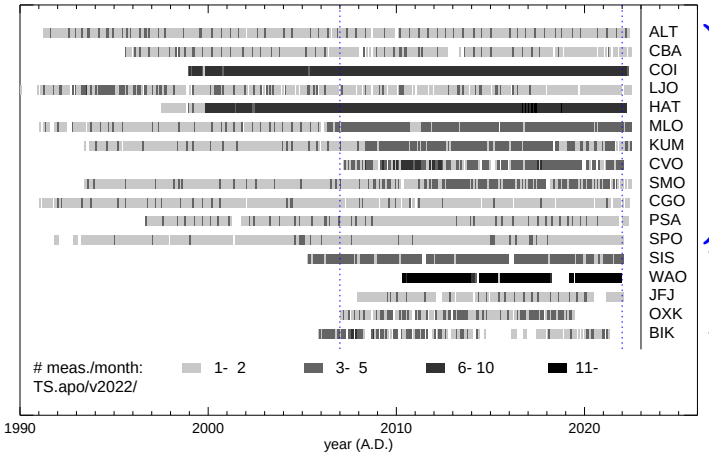

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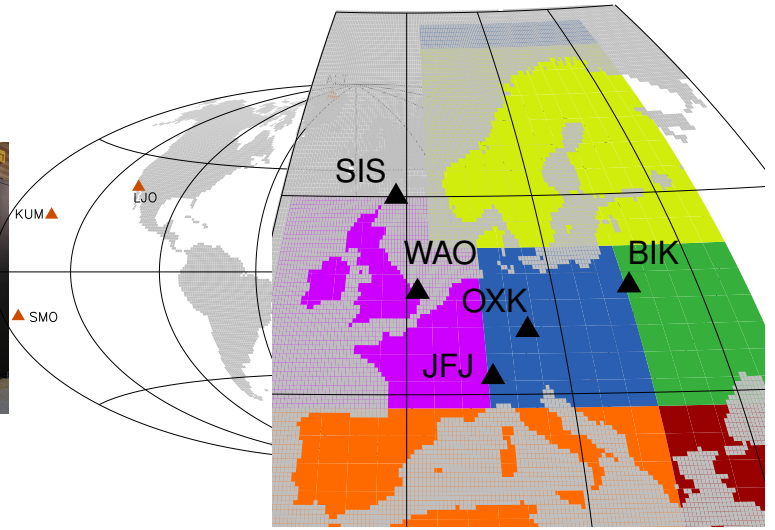

$$\text{APO} = (\alpha_F + 1.1) \cdot CO_2$$

$$= \beta \cdot$$

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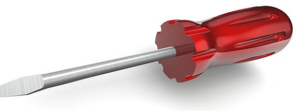
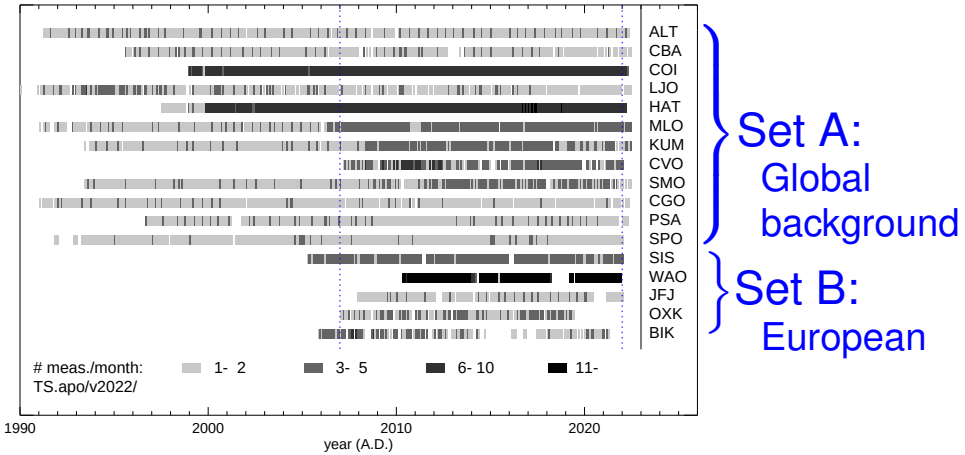
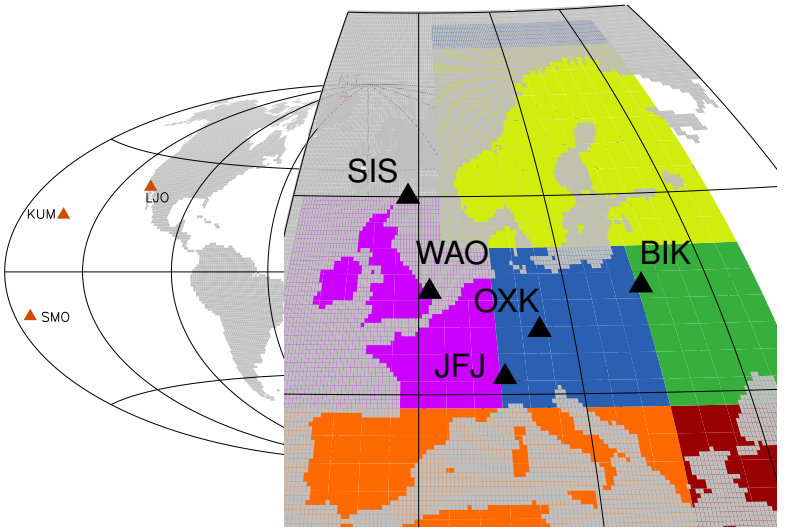
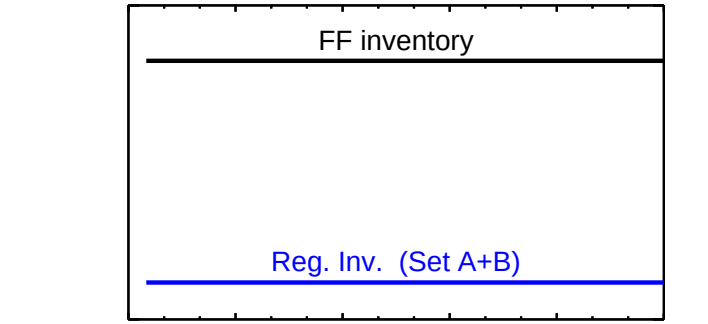
$$\text{APO} \approx O_2$$

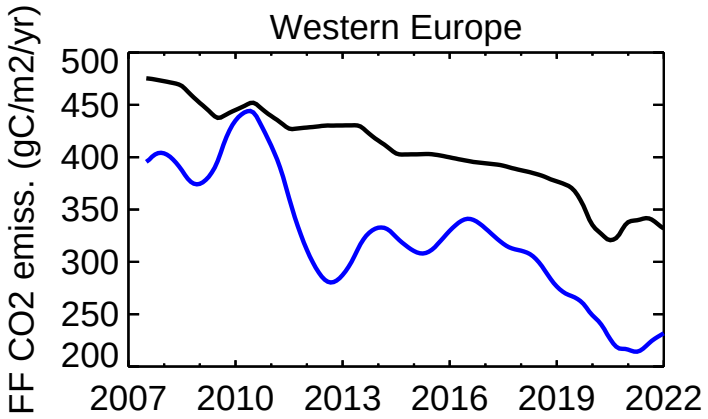


Emission estimates









- similar trend as FF inventory,
  but large variations exceeding the expected uncertainty

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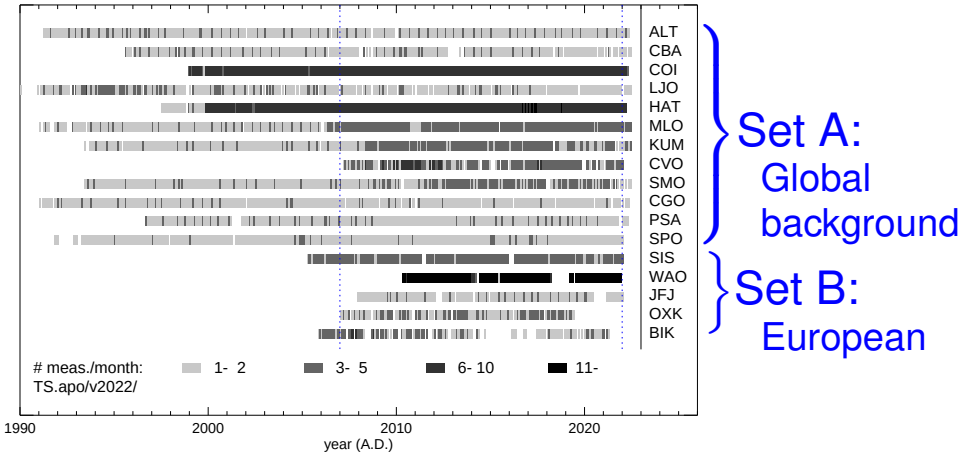
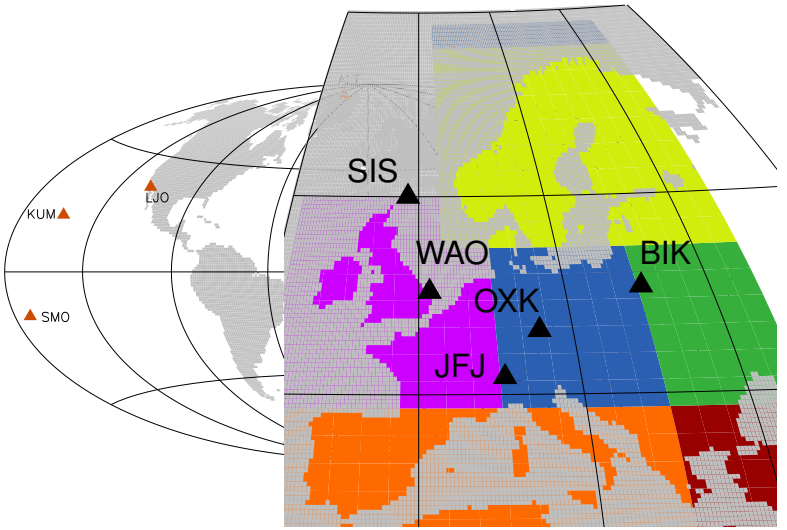
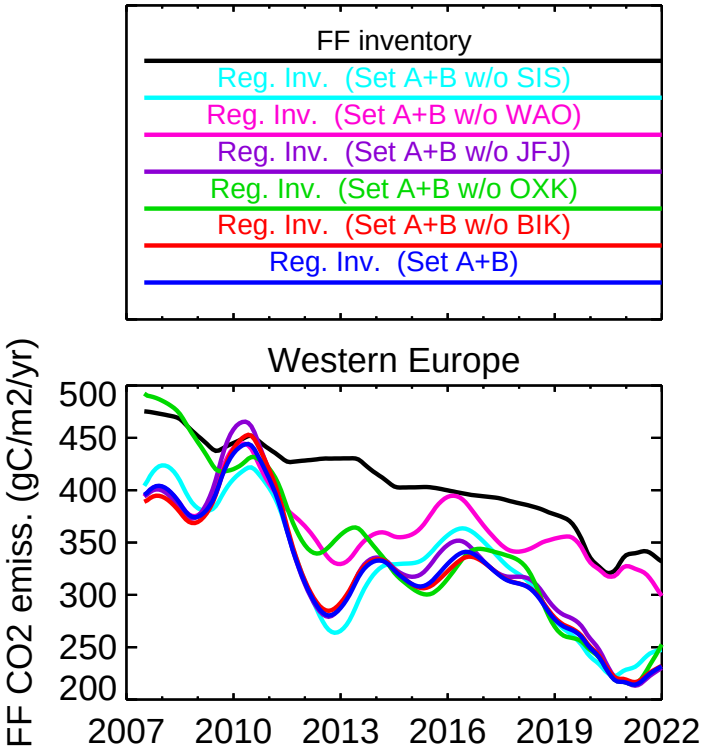
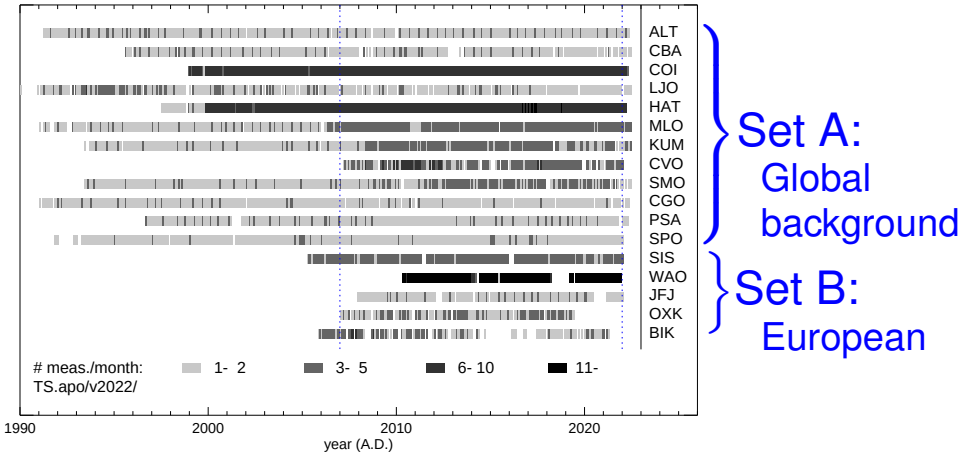


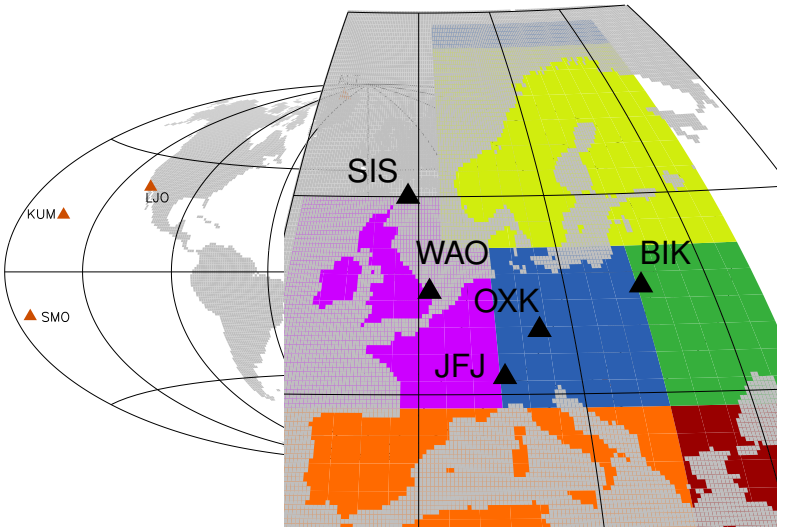




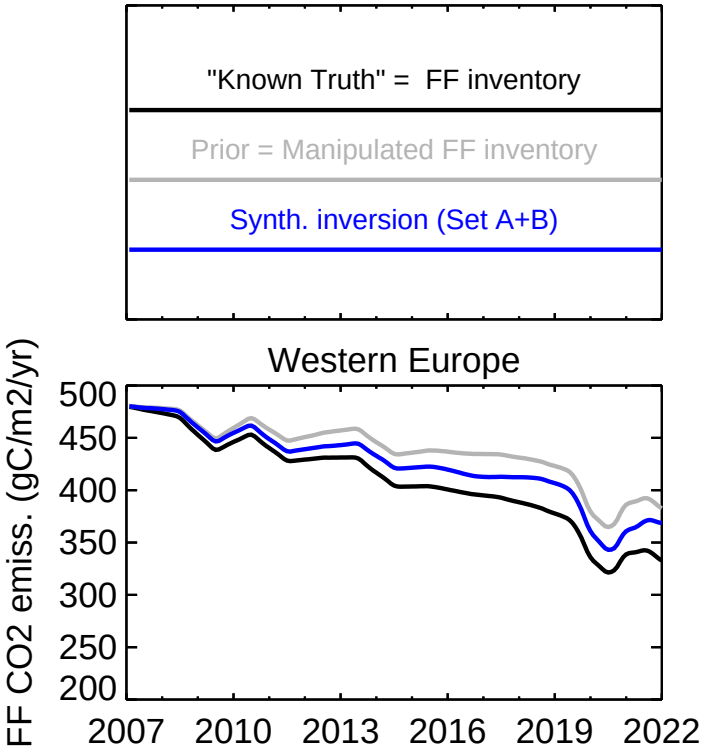
- similar trend as FF inventory,
  but large variations exceeding the expected uncertainty
- year-to-year variations inconsistent across stations

Potential of station sets

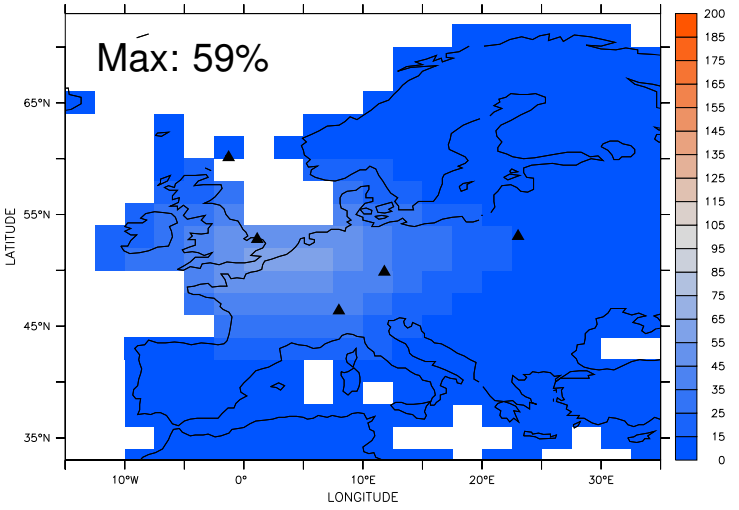




– Std. set-up: Recovering about half of trend

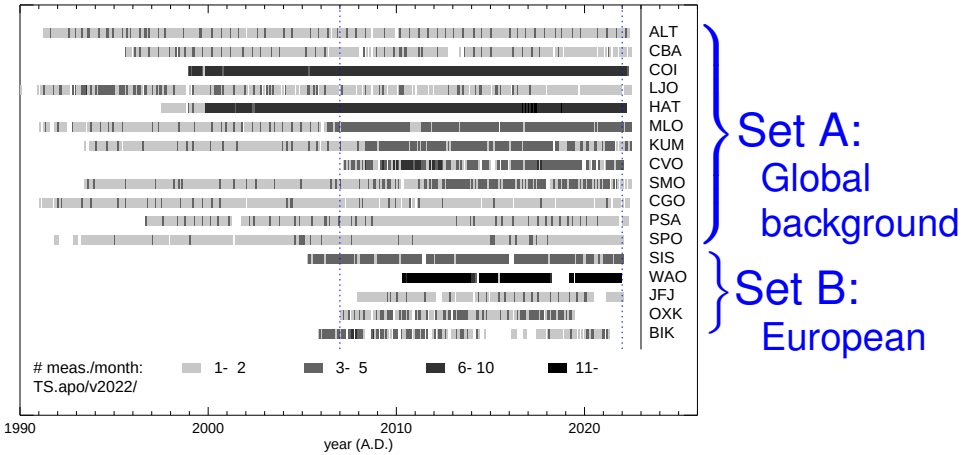


Set A+B



(POSTERIOR−PRIOR)/(TRUTH−PRIOR) * 100.

Potential of station sets



Set A:
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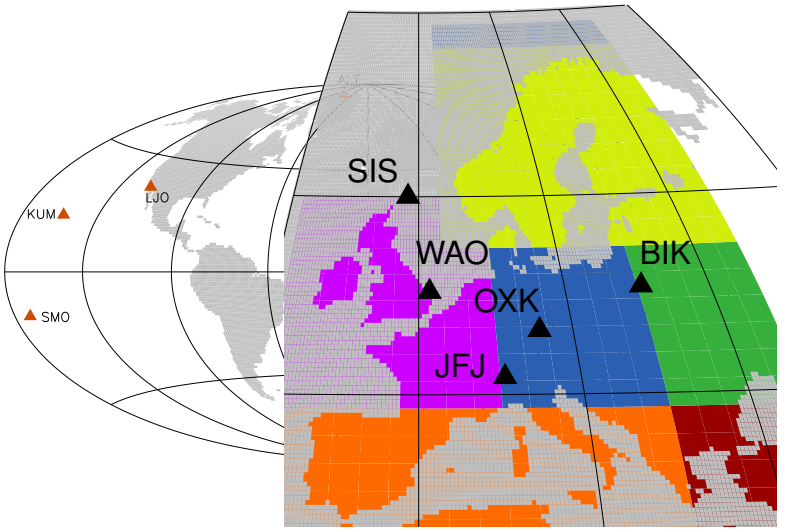
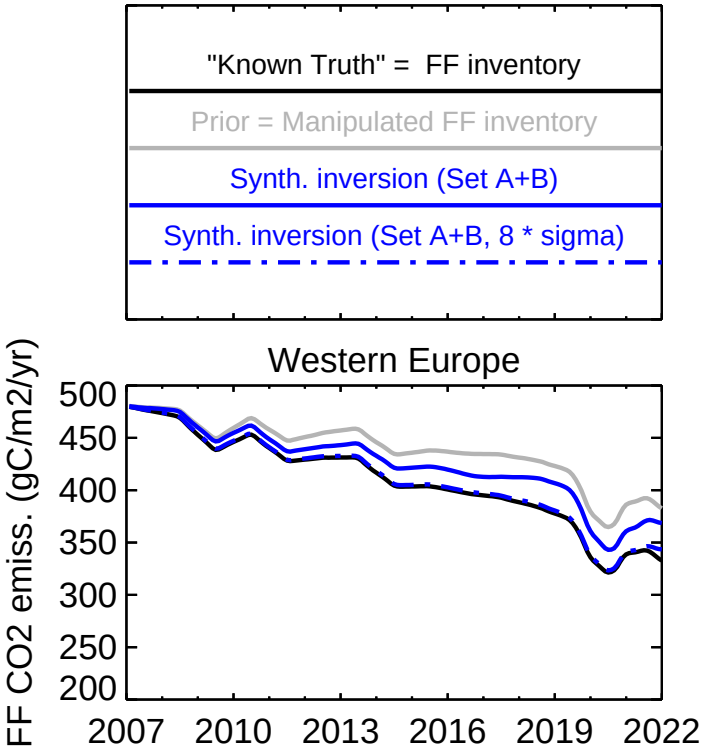
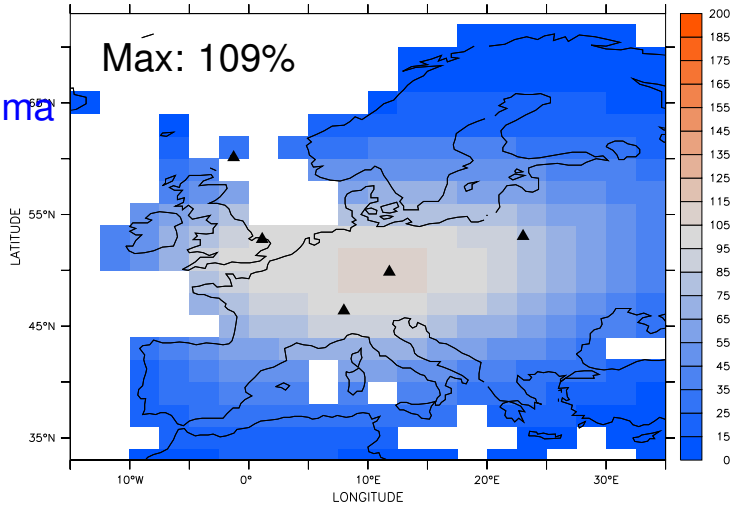




– Std. set-up: Recovering about half of trend
– More freedom: Trend recovery almost complete

Set A+B,
8-fold sigma



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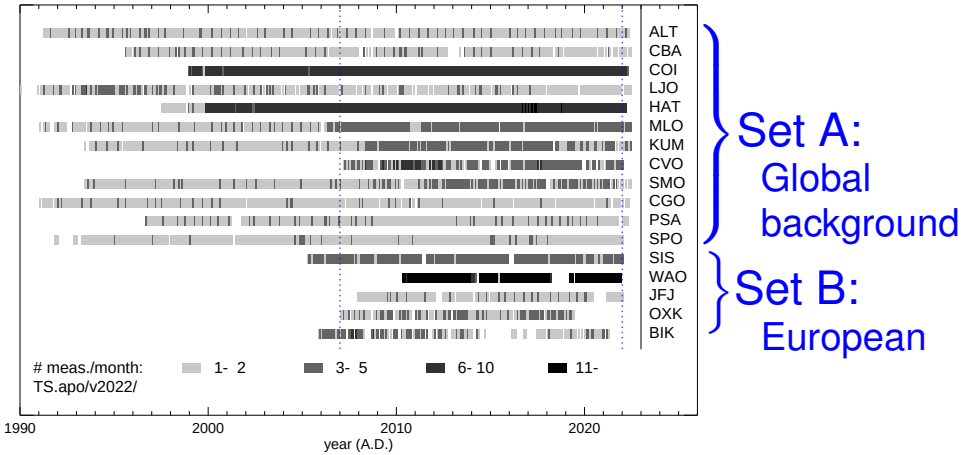
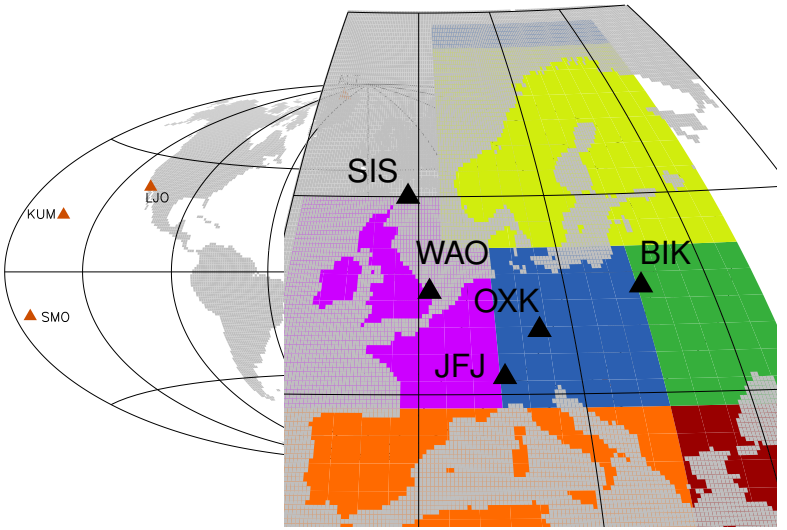
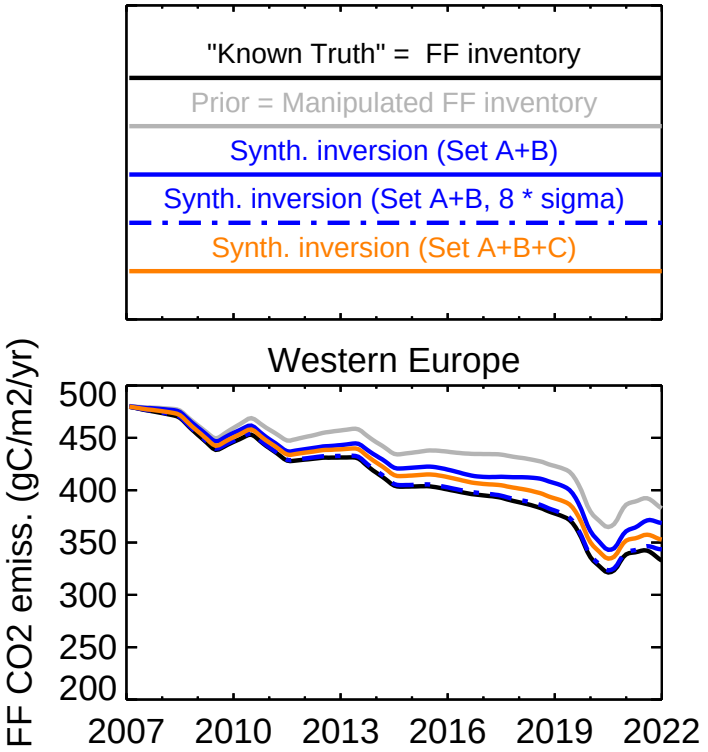
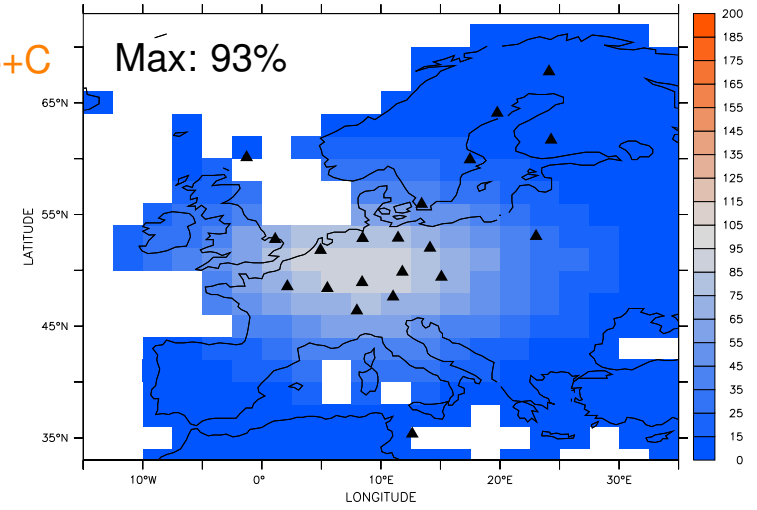






– Std. set-up: Recovering about half of trend
– More freedom: Trend recovery almost complete
– More stations (ICOS): Improved trend recovery

Set A+B+C



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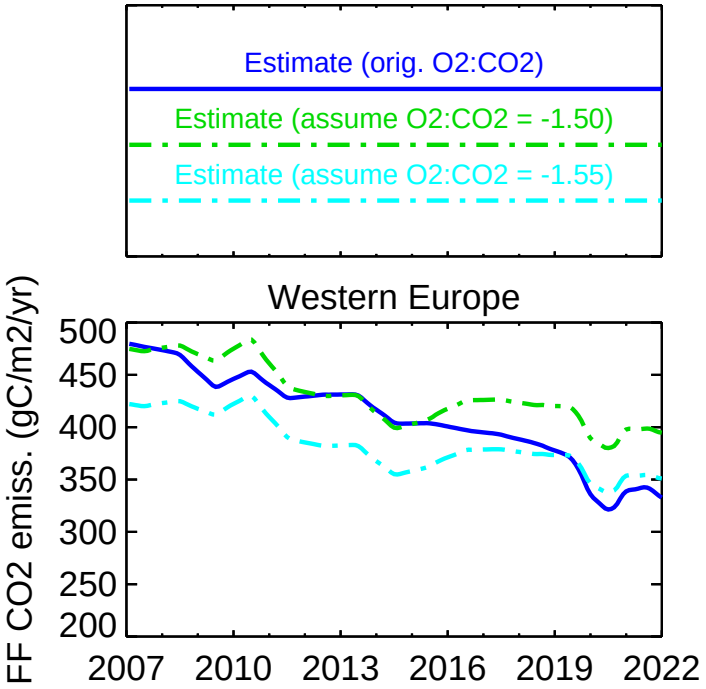
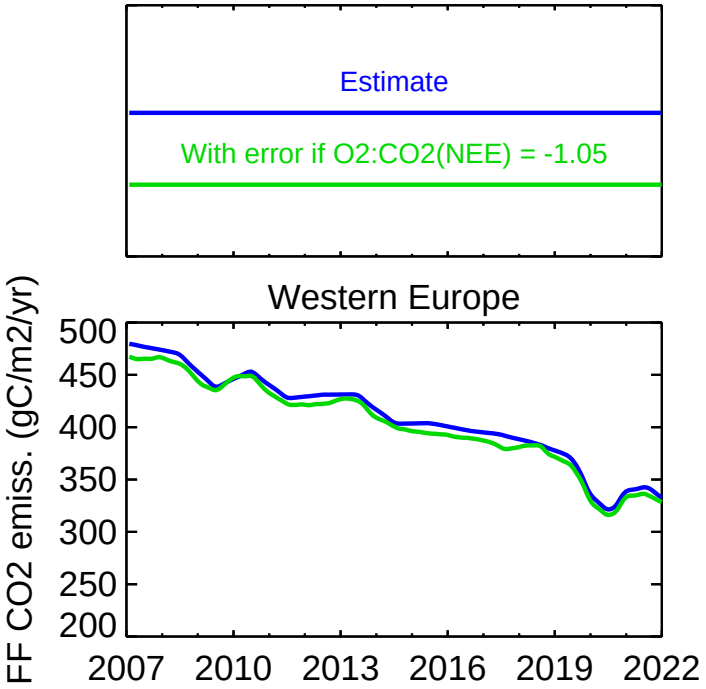
Error influence: FF stoichiometry



- APO inversion constrains the FF-related APO flux
  $\rightarrow$ CO_2 emissions depend on assumed O_2:CO_2
- Here we use O_2:CO_2 of FF inventory
- Test: Varying O_2:CO_2 between –1.50 and –1.55 changes CO_2 emissions estimate by about half the decadal reduction
  $\rightarrow$ Need to know O_2:CO_2 to better than 0.05

Error influence: NEE stoichiometry



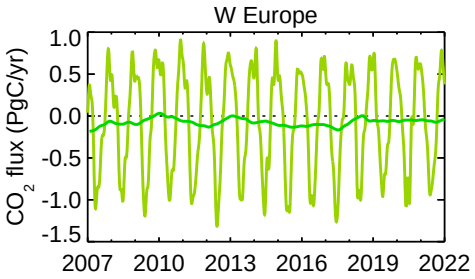
What if true O_2:CO_2 of terrestrial biosphere was –1.05 (rather than –1.1 as in APO def.)?

$\rightarrow$ non-zero $APO^{NEE} = 0.05 \cdot NEE$

$\rightarrow$ Small interannual error

Error influence: NEE stoichiometry

NEE IAV $\ll$ NEE seasonality



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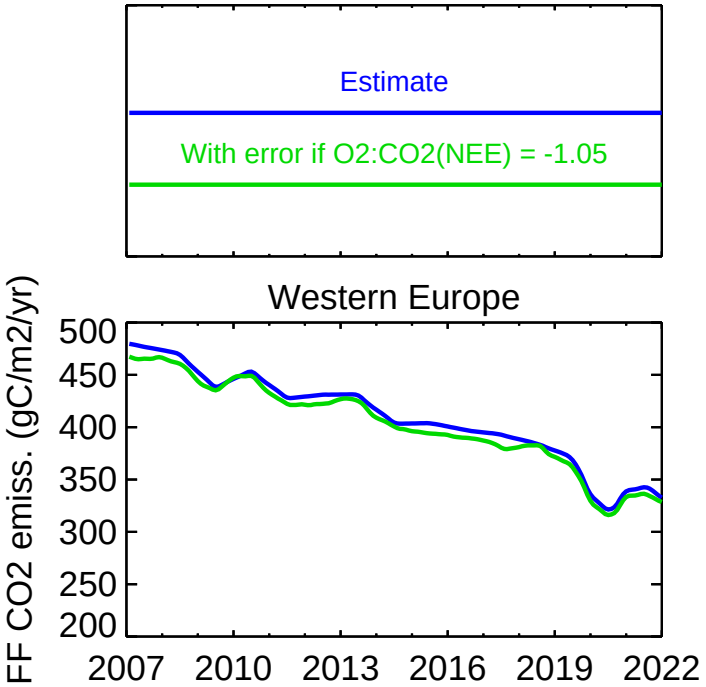
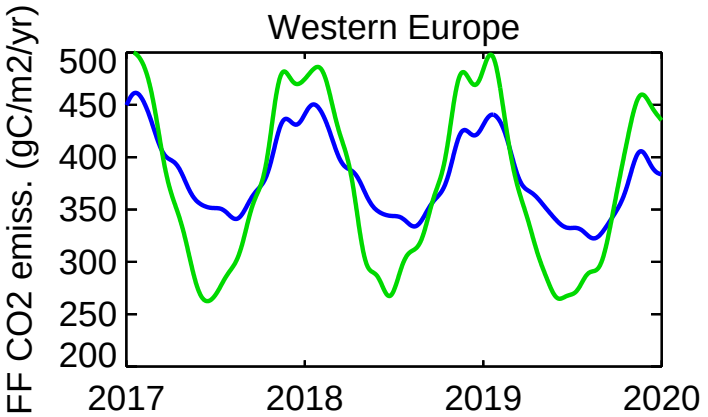
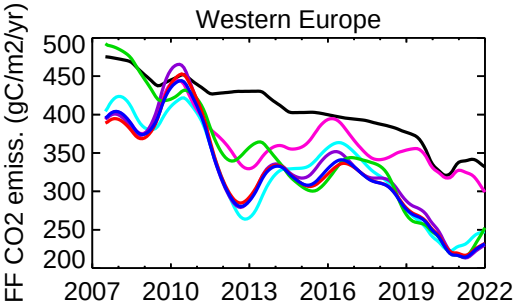
(but large seasonal error)





Summary

- First estimates of fossil-fuel CO_2 emissions based on few APO observations on continents (Europe) still show unrealistically large year-to-year variations



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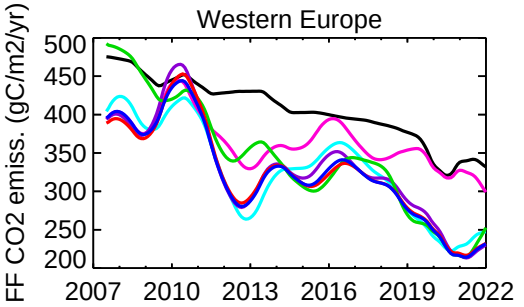

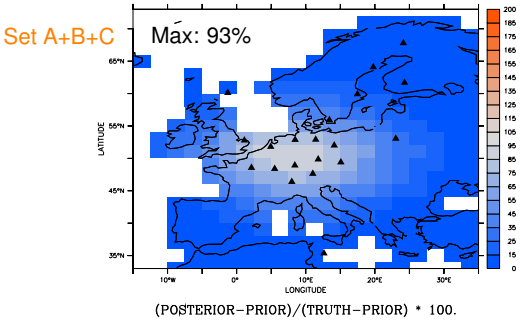

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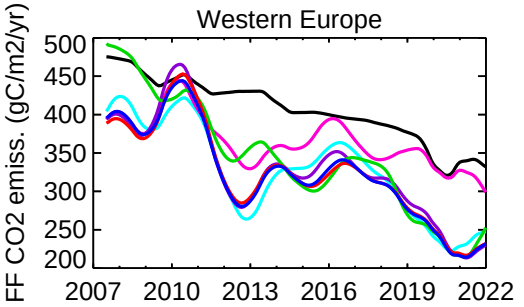

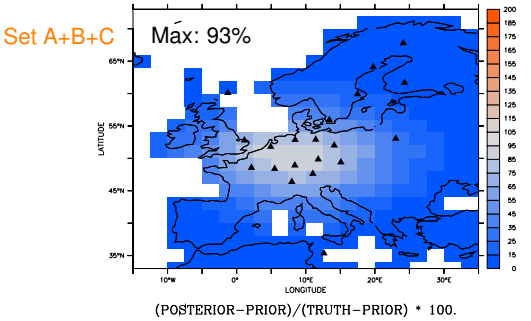

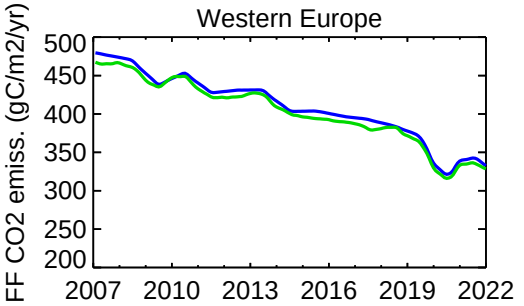

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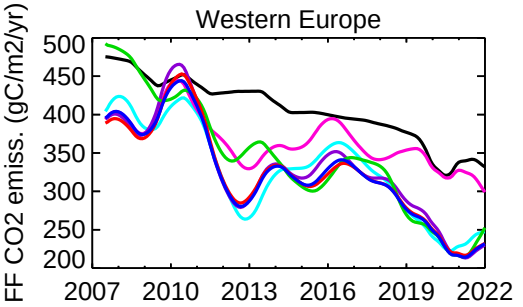

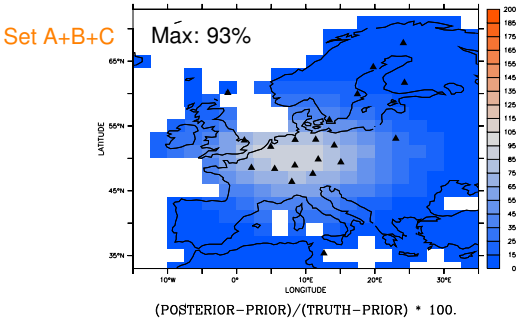

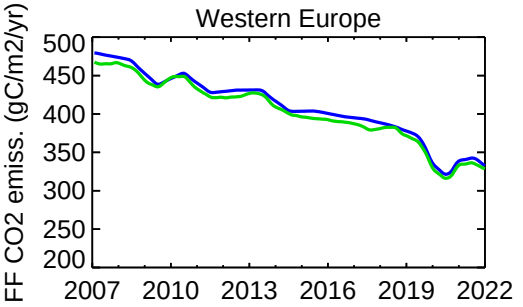

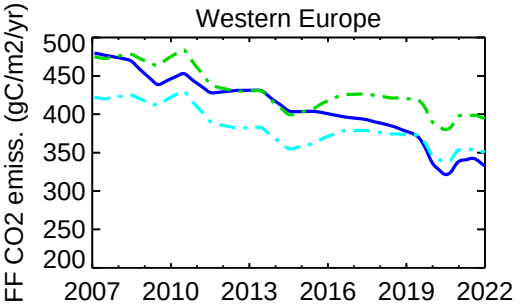

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Continued continental APO measurements seem valuable investment in FF verification capabilities