Estimating CO2 emissions from fossil fuel combustion using an atmospheric sampling network of multiple tracers

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Aims of this study

- Central questions: Can additional measurements of $^{14}CO_2$, CO or APO complement an imaging spaceborne sensor to distinguish anthropogenic vs natural sources?
- Optimization of the spatiotemporal sampling of $^{14}CO_2$, CO or APO
  - Network design
  - Development of a consistent emission inventory at high spatial and temporal resolution
  - Development of high-resolution regional modeling frameworks
- Improve annual national inventories to a few %
  - Scales
    - Country
    - Country sub-regions (states, statistical regions)
    - Cities and emission hotspots
- Quantify emission trends over a few years

Representation of fluxes

- Linear flux model

$$\mathbf{f} = \sum_{i=1}^{N_{comp}} \mathbf{f}_{fix,i} + \mathbf{F}_i \mathbf{p}_i$$

F$_i$: uncertainty structure

p$_i$: adjustable parameter

f$_{fix}$: *a priori* flux

- Derived component

$$\mathbf{f}_j = \mathbf{f}_{fix,j} + \mathbf{f}_{sh,j} \mathbf{F}_i \mathbf{p}_i$$

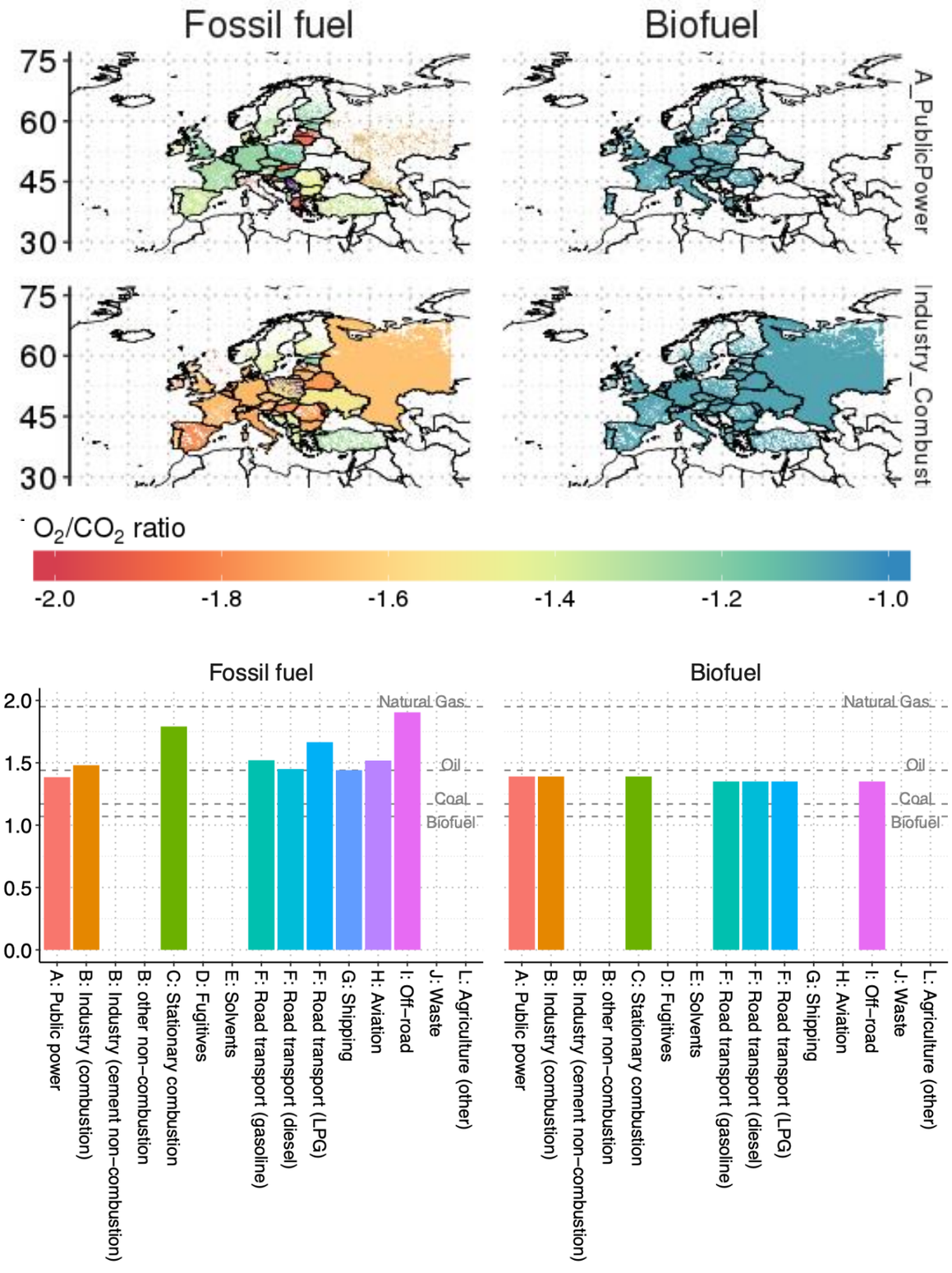
f$_{sh,j}$: $^{14}CO_2/CO_2$, CO/CO_2 or O_2/CO_2 ratios

Components in the state vector

	CO_2	CO	$^{14}CO_2$	APO
Anthropogenic	TNO Fossil Fuel Emissions			
	TNO Biofuel emissions			
	TNO cement production emissions ($CaCO_3$ + heat -> CaO + CO_2)			
			LSCE Nuclear power plants	
Biogenic	VPRM GPP		VPRM-ORCHIDEE MICT	VPRM GPP
	VPRM Reco		VPRM-ORCHIDEE MICT	VPRM Reco
		MEGAN vegetation		
		Liu (2018) Soil fluxes		
	GFAS open biomass burning			
Oceans	PlankTOM5.3	NEMO PISCES	PlankTOM5.3	PlankTOM5.3
Photochemistry	LMDZ	LMDZ	LMDZ (Wang 2016)	CO and CH4 fields WP22
Initial/boundary conditions	WP2 fields	WP2 fields (D2.2)	LMDZ Wang 2016	Jena Carboscope

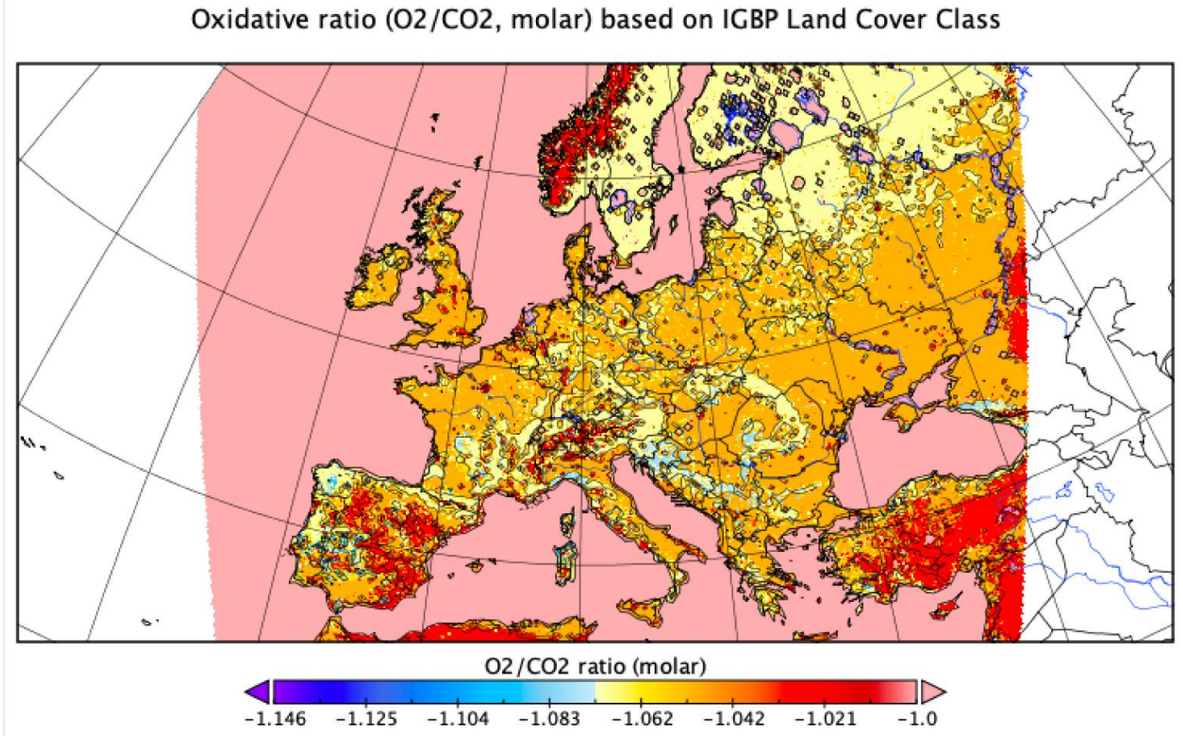
Anthropogenic emissions

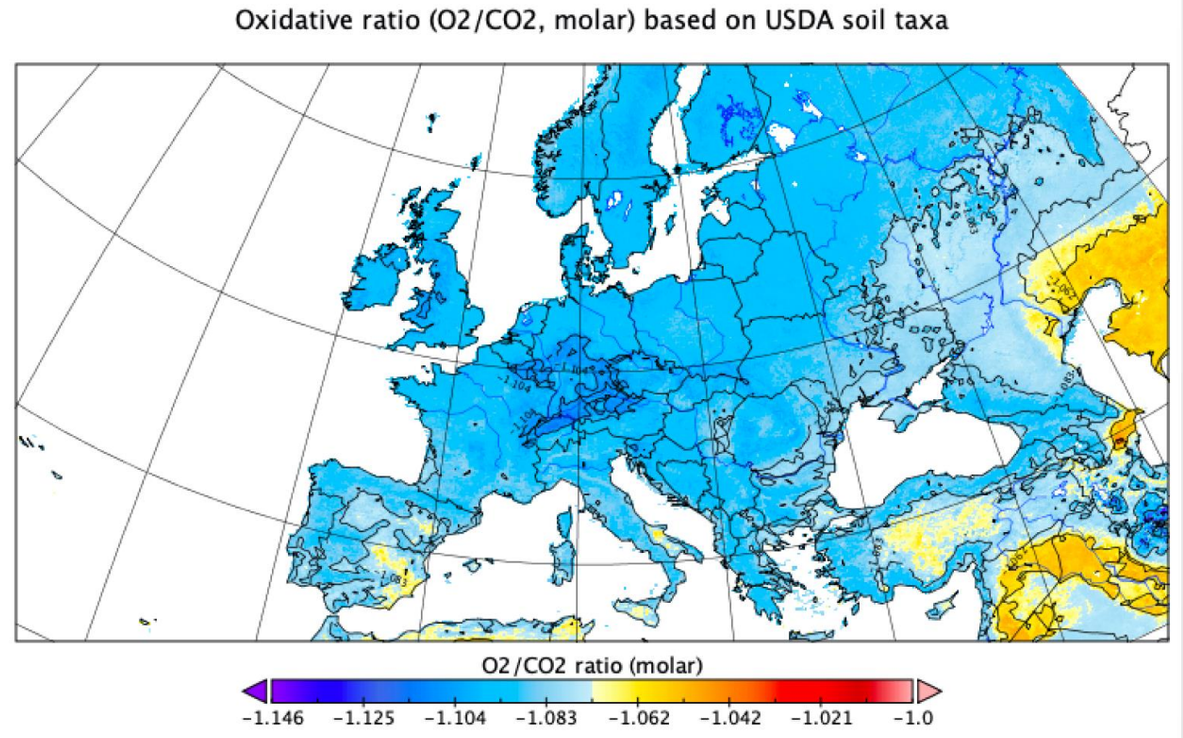
- TNO inventory
  - Derived directly from CO2 emission inventory activity data
  - O_2/CO_2 ratio derived
    - COFFEE (Steinbach 2011)
    - H:C fuel ratio
      - UNFCC fraction of gaseous, liquid, solid, biomass or other (waste)
  - Assumptions:
    - S and N have negligible impact
    - Fuels burn completely (no CO, CH_4)
    - Energy production proportional to O_2 consumption
- Includes non-combustion emissions
  - Cement production reaction
  - Lime production and iron and steel furnaces
  - Agricultural processes



Biosphere

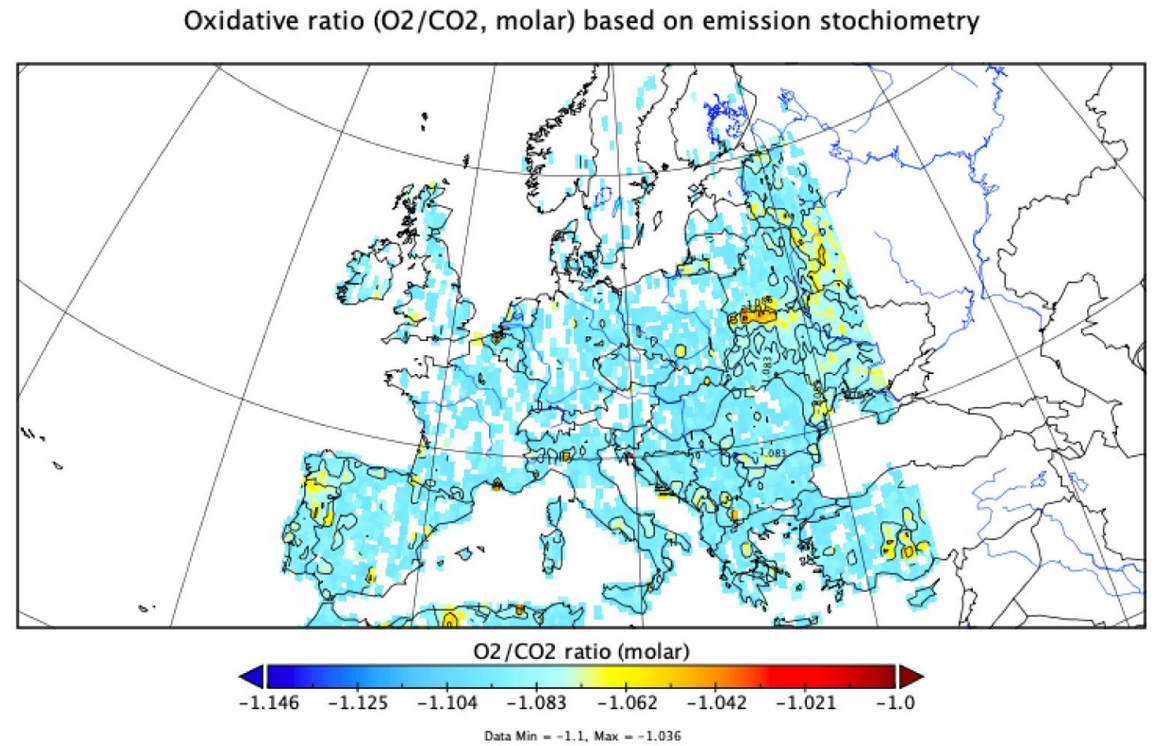
- Biosphere fluxes from VPRM
- Fraction of $R_{Heterotroph}$ from ORCHIDEE
- Normally assumed a -1.1 ratio
- O_2/CO_2 ratio according to Clay and Worral (2015)
  - For NPP and $R_{Autotroph}$ by vegetation type (IGBP land cover types)
  - For $R_{Heterotroph}$ by soil type (USDA global soil database)





Biomass burning

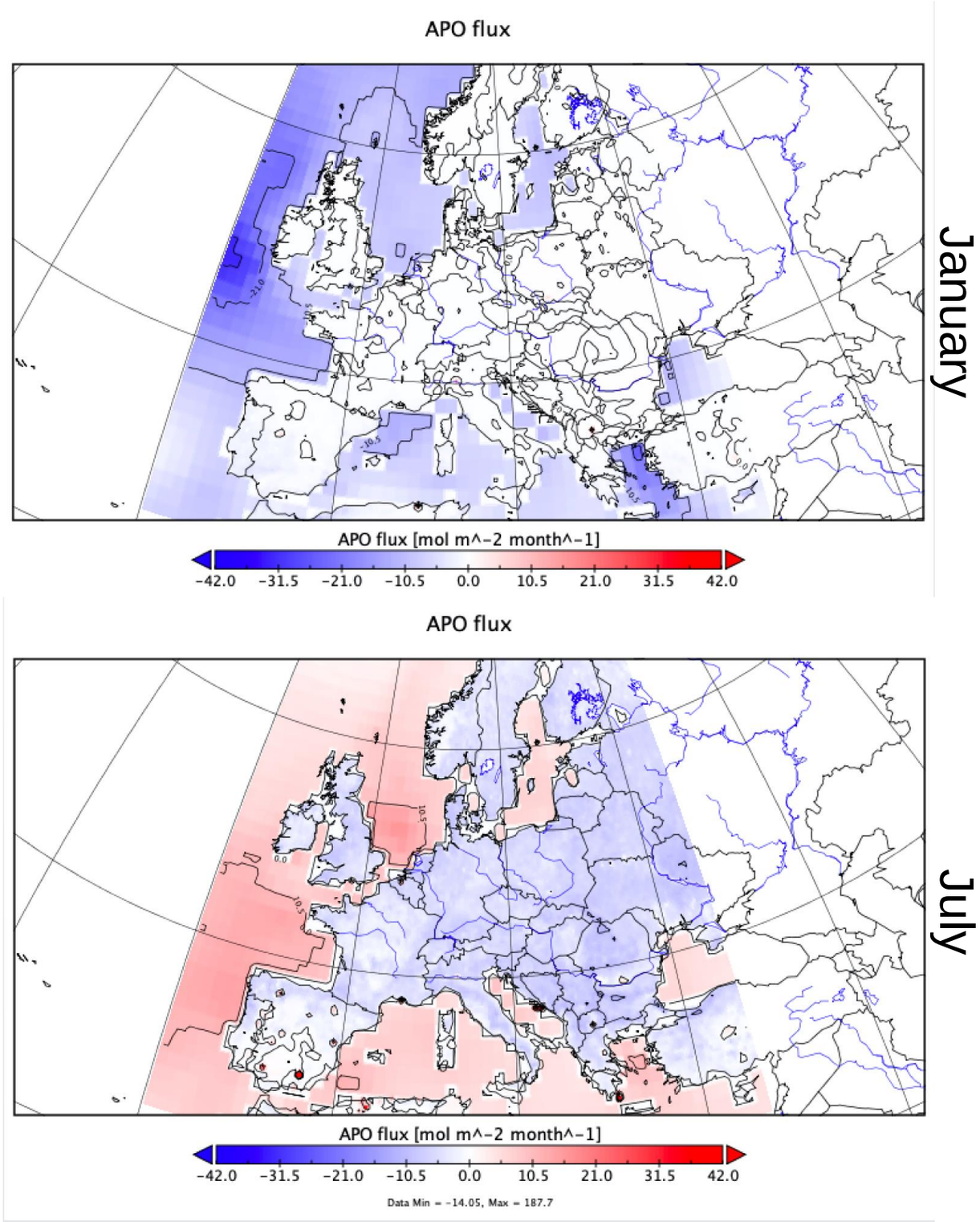
- Biomass burning emissions for CO_2, CO and NO_x obtained from CAMS GFASv1.2
- O_2/CO_2 from stoichiometry with CO_2, CO and NOx emissions
- Caveat: CAMS GFASv1.2 uses old Andrea and Merlet 2001 EFs



Ocean

- Gridded CO_2, O_2, and heat fluxes were obtained from NEMO-PlankTOM5 model (Buitenhuis et al., 2010)
- N_2 fluxes obtained from NEMO-PlankTOM5 heat fluxes and the Keeling et al. (1993) formula.

$$f_{APO} = f_{O_2} + 1.1 f_{CO_2} - \frac{X_0^{O_2}}{X_0^{N_2}} f_{N_2}$$



Preliminary results