TM5

ongoing work

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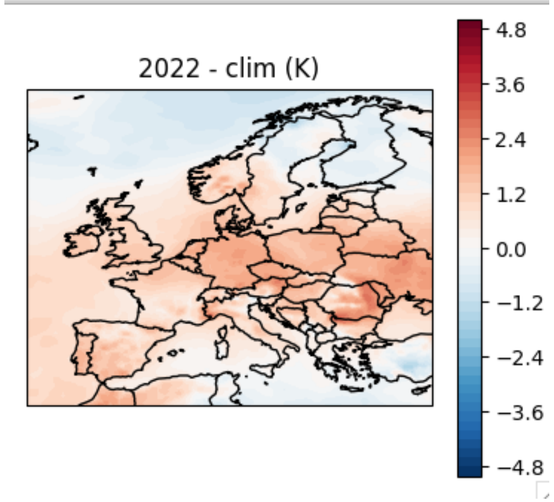
CT Europe near real-time CO_2 fluxes



- CT Europe flux inversions now 1-year behind the current (2020 is done)
- Carbon cycle anomalies are happening now, and attract interest
- Observations and models to simulate the biosphere and ocean are available quickly, but…
  - … bottom-up fossil fuel emission inventories are often updated at YYYY-2
  - … and contain relatively little spatiotemporal variability
- In Super et al (2020) we showed the use of “Activity data” and “Weather Proxies” to fill in many details in the fossil fuel emission field
- Auke van der Woude extended this to include EUROSTAT, and ENTSO-E statistics with a lag-time of MM-2 (i.e., March 2022 available now)
- And together with Remco de kok they automated the creation of 0.1x0.2 degree carbon cycle fluxes over Europe within the CTDAS pipeline

CT Europe near real-time CO_2 fluxes

- Not the only NRT product, but uniquely targeting Europe, and providing all fluxes needed for CO_2 modeling (i.e, not just fossil fuel emissions)

	IFS	CT-NRT	Carbon Monitor	CTE-HR (this)
Lag	After calendar year	1+ year	2 months	2 months
Resolution	80 km	1x1 °	National	0.1°x 0.2°
Temporal resolution	Hourly	3-hourly	Daily	Hourly
Fossil fuel	EDGAR Annual mean trends	CDIAC + extrapolation	Dynamic emission model	Dynamic emission model
Biogenic	CTESSEL + BFAS	Statistical fit	-	SiB4 + downscaling
Ocean	Takahashi (2009) clim.	Own clim	-	Dynamic downscaled clim.
Fire	GFAS	GFAS	-	GFAS
Data provided	Molc fractions **	Both	national fluxes	Fluxes
Reference	Agustí-Panareda et al. (2014)	NOAA GML website Andy Jacobson's work	Liu et al. (2020)	-

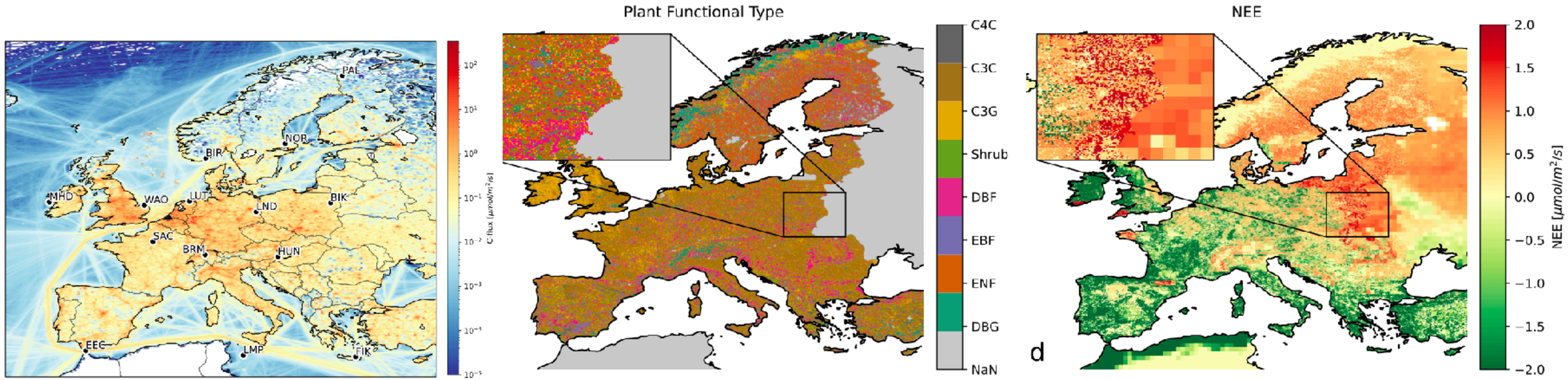
CT Europe near real-time CO_2 fluxes

- EUROSTAT data informs monthly industrial, on-road, shipping, and aviation emissions
- ENTSO-E data informs on monthly power plant emissions
- Temperature data (ERA5) informs on daily household emissions
- Wind and SST data (ERA5) informs on daily ocean emissions
- Other meteo data (ERA5) informs SIB4 to calculate GPP, TER, and NEE

(GNFR) Sector	Spatial downscaling	Activity data		
		Hourly	Daily	Monthly
(A) Public power	Power plant databases	Country-specific ENTSO-E generation data		
(B) Industry	Point source database	van der Gon et al. (2011)		Industry indicators (EU*)
(C) Other stationary combustion	Population density	CRT	Dynamic	Dynamic
(F) On-road emissions	Road network; Population density	CRT	CRT	Fuel demand (EU*)
(G) Shipping	Shipping tracks	None	None	Bunker fuel demand (EU*)
(H) Aviation	Airport locations	None	None	Kerosine demand (EU*)

CT Europe near real-time CO_2 fluxes

- This is now a publicly, and monthly updated product on the ICOS Carbon Portal



Near real-time CO_2 fluxes from CarbonTracker Europe for high resolution atmospheric modeling

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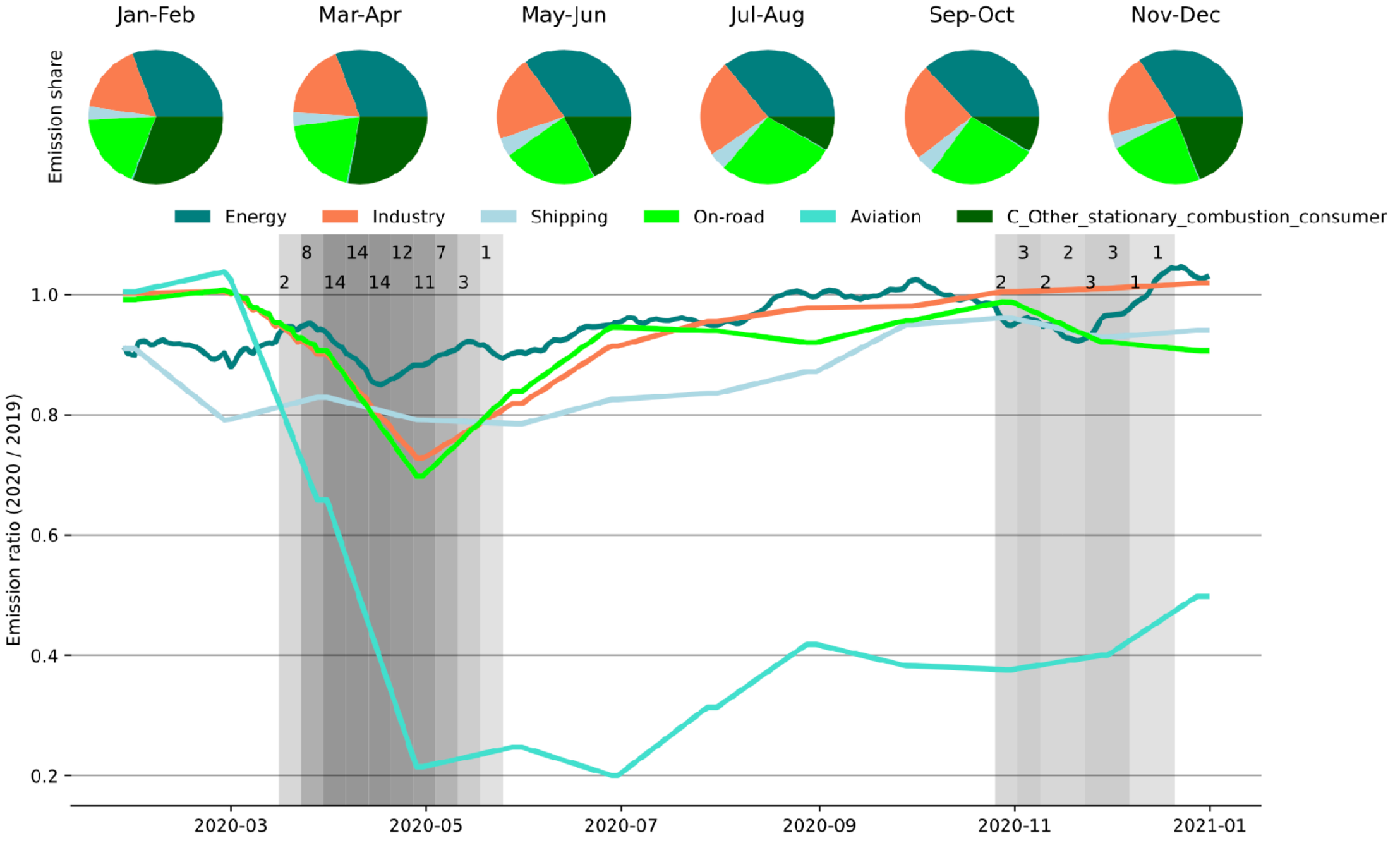
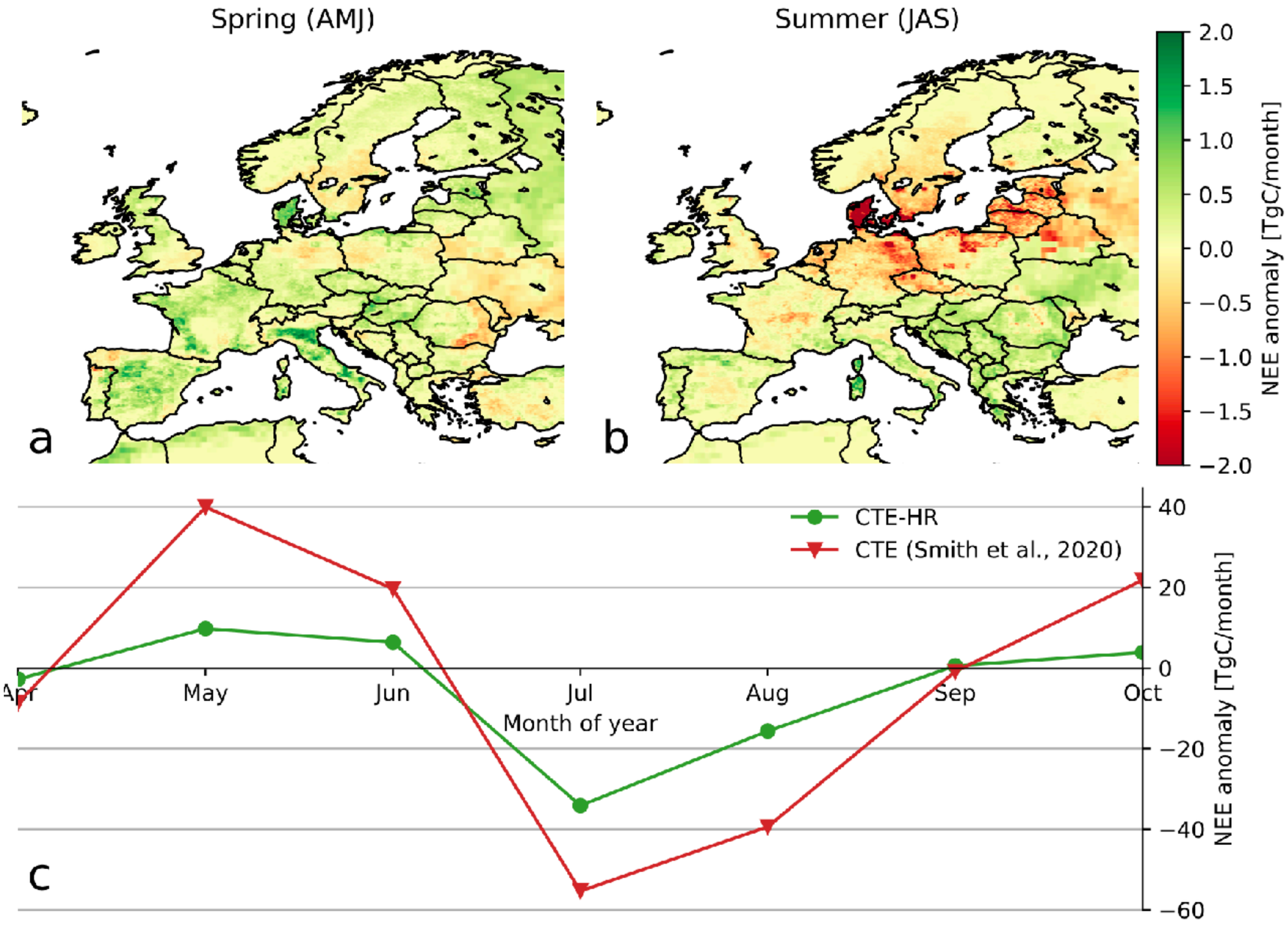
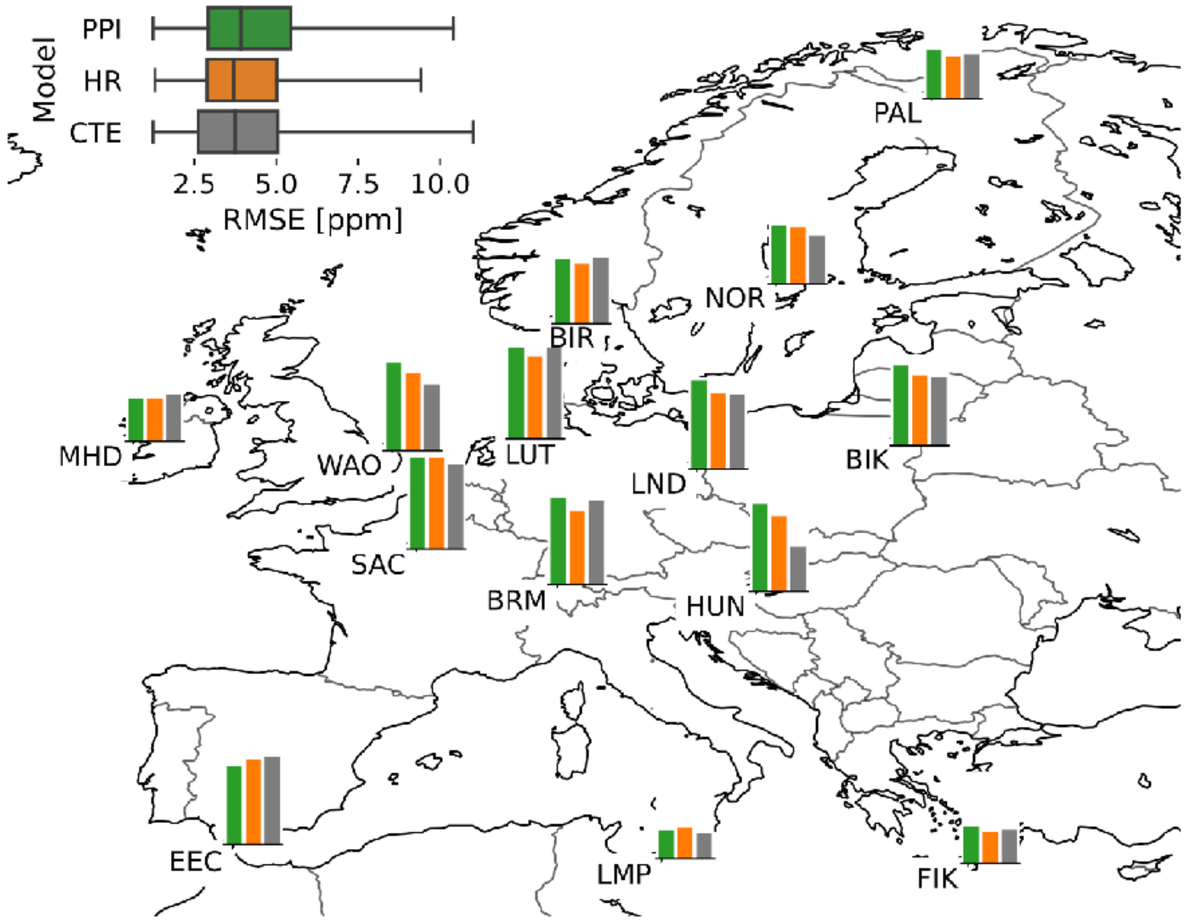

Jan-Feb
Mar-Apr
May-Jun
Jul-Aug
Sep-Oct
Nov-Dec
Emission share
Energy
Industry
Shipping
On-road
Aviation
C_Other_stationary_combustion_consumer
8 14 12 7 1
2 14 14 11 3
3 2 3 1
2 2 3 1
Emission ratio (2020 / 2019)
1.0
0.8
0.6
0.4
0.2
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01


Spring (AMJ)
Summer (JAS)
a
b
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
NEE anomaly [TgC/month]
CTE-HR
CTE (Smith et al., 2020)
40
20
0
−20
−40
−60
Apr
May
Jun
Jul
Aug
Sep
Oct
Month of year
NEE anomaly [TgC/month]
c

CT Europe near real-time CO_2 fluxes

- Comparison of mole fractions against:
  - CT Europe optimized fluxes (GCB2021)
  - poor-person inversion (projection of Mauna Loa CO_2 growth rate on NEE)
  - all fluxes outside Europe the same
- Transport of all fluxes (coarsened to 1x1 degree!) with TM5-zoom
- Transport of CTE-HR fluxes with WRF-STILT
  - full 0.1x0.2 degree transport and flux resolution
  - or with fluxes coarsened to 1x1 degree
  - or with diurnal profiles flattened

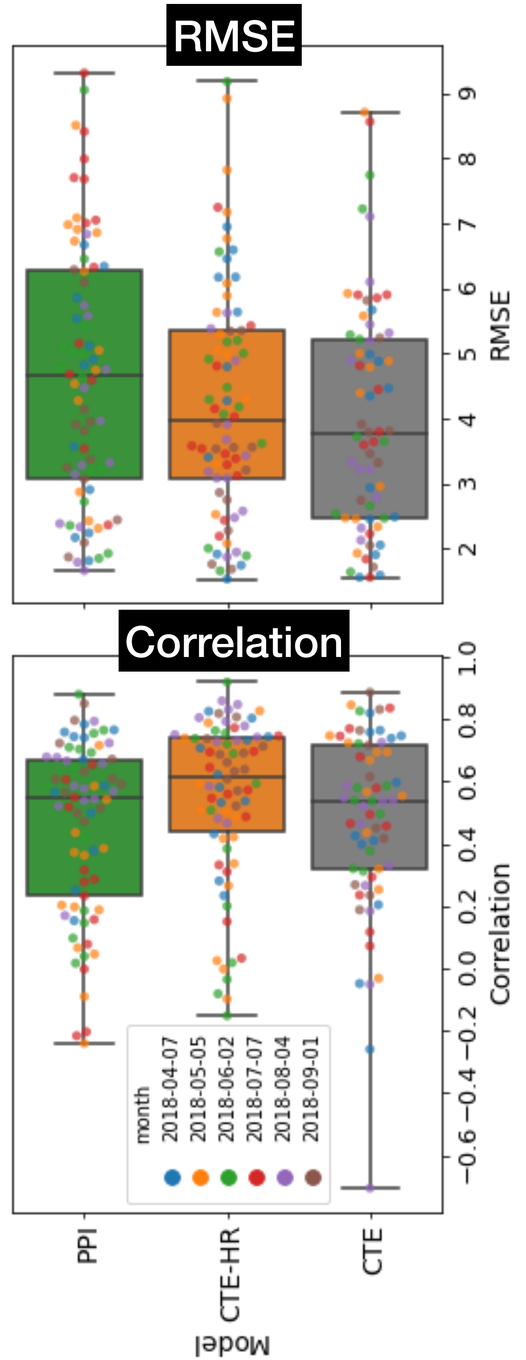
Root-mean square errors at 10 sites (max=6 ppm)
2018 daytime observations



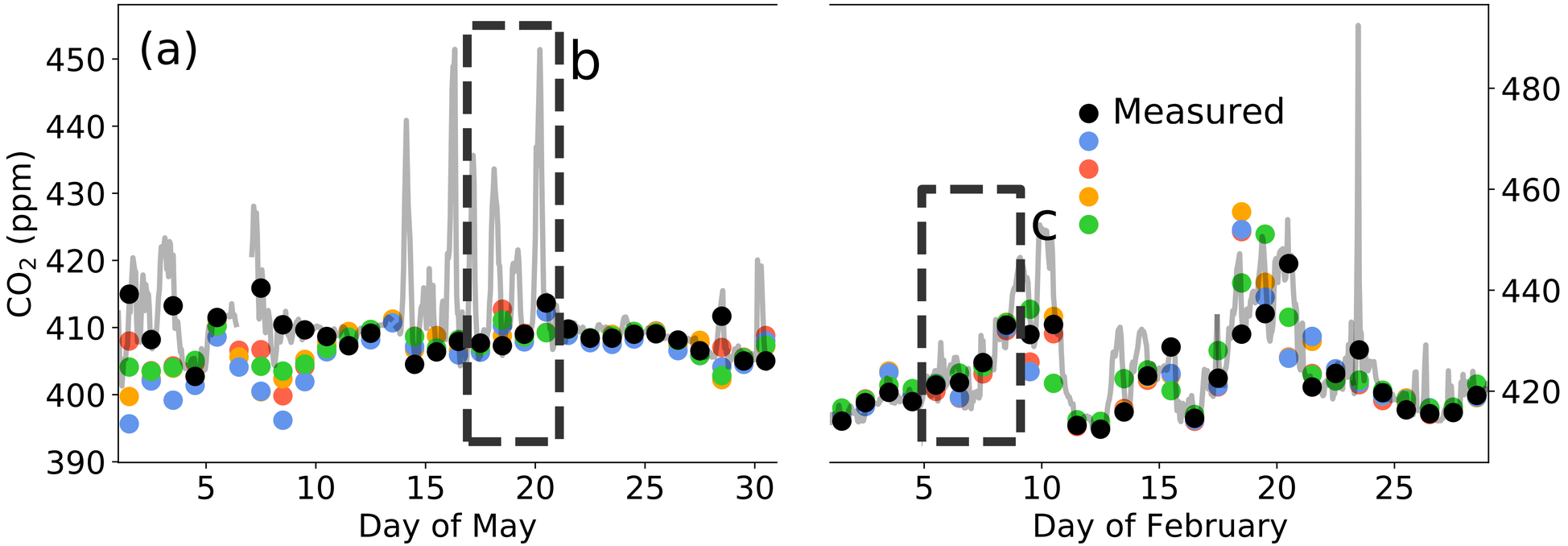
green = poor person's inversion

orange = CTE-HR

grey = CTE2021

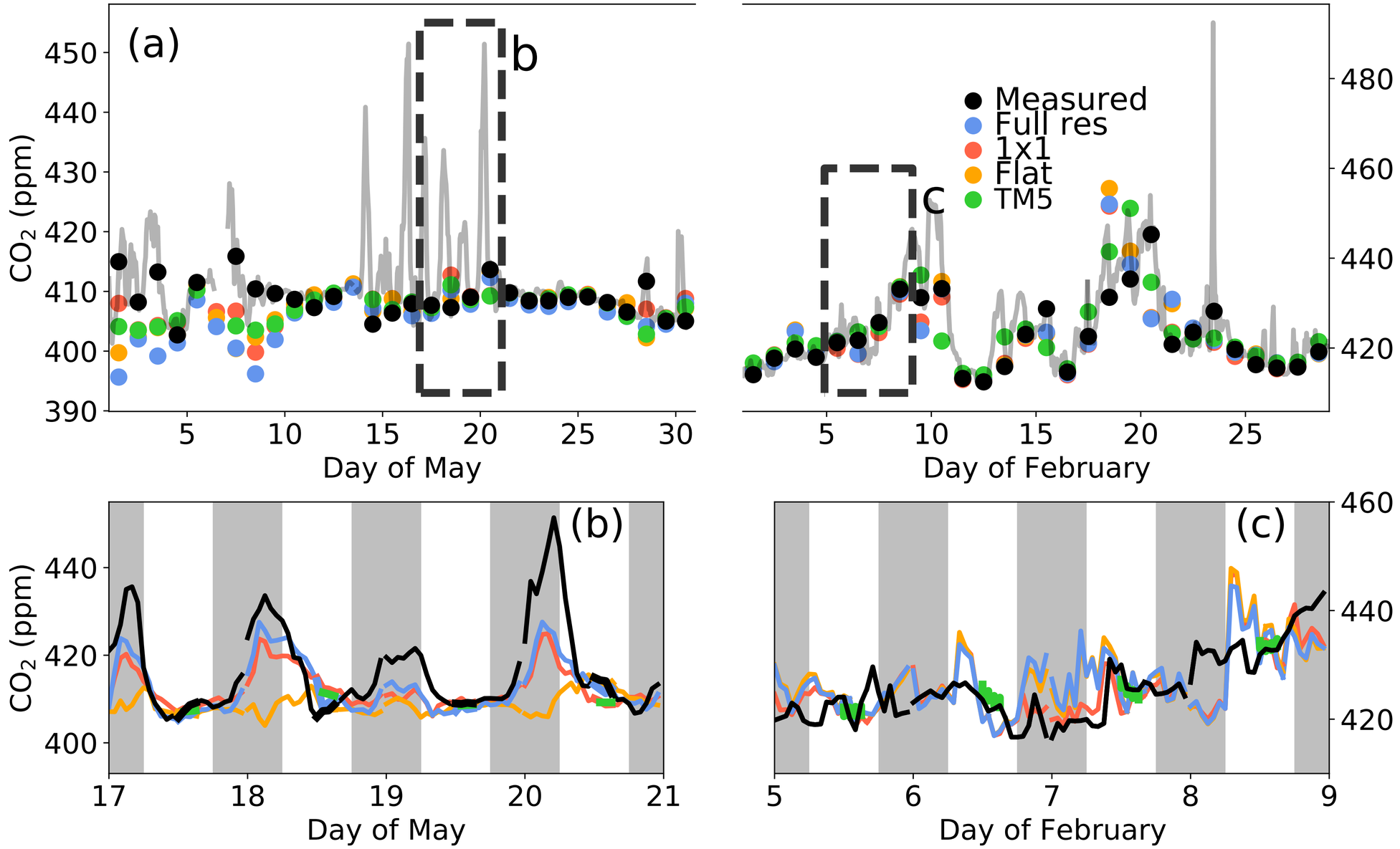


Lutjewad CO_2 mole fractions (data courtesy of RUG)

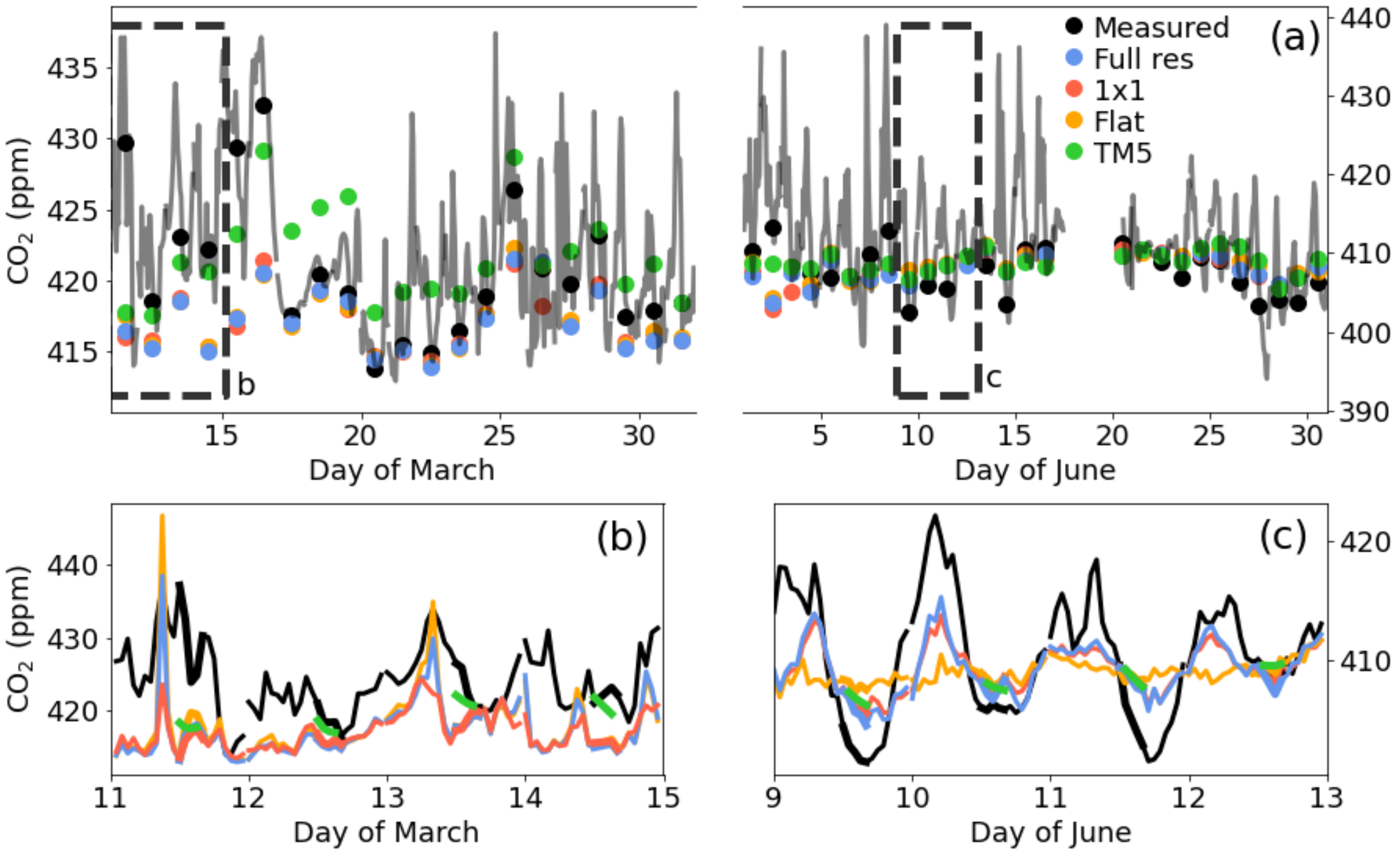


Simulations of TM5, WRF-STILT,
and WRF-STILT (coarsened/flattened flux)

Lutjewad CO_2 mole fractions (data courtesy of RUG)



Cabauw CO_2 mole fractions (data courtesy of TNO)



Summary

- CTE-HR fluxes for Europe now available for 01/2017-03/2022
- Many CC anomalies represented already (without optimization)
- Evaluation against ICOS CO_2 mole fractions suggests:
  - CTE-HR performs nearly as well as optimized fluxes from CTE
  - TM5 performs nearly as well as WRF-STILT for transporting them
- In measured CO_2 mole fractions:
  - 85-90% of variability is due too synoptic variations at scales captured by TM5
  - This is true even for a non-background site like Cabauw, Netherlands
  - the remainder is due to (FF) “plumes”, captured better* by WRF-STILT
  - diurnal variability of fluxes is too large to ignore

Next steps

- WRF-CHEM in CTDAS (Sander, Liesbeth, Friedemann) will be used to *transport* and *evaluate* CTE-HR fluxes in near real-time, also part of PARIS EU proposal.
- Auke van der Woude will work to formally merge CTE global fluxes with CTE-HR European fluxes
- Activity/statistical data and weather/other proxy concept to be expanded globally using CTSF (see presentation Joram)
- Anne-Wil van den Berg works on OpenIFS transport of CO_2, together with Etienne Tourigny and Iria Ayan at BSC, Spain.
  - Use of EC-Earth4 framework from OpenIFS runs, together with python NetCDF reader, and CT Europe global CO_2 fluxes. Also part of CORSO EU proposal
- Separate funded projects to add CO, NO_x, O_2, and $\delta^{13}C$ to CT Europe