Detecting multiscale carbon controls across different nutrient deposition scenarios in a Mediterranean tree-grass ecosystem

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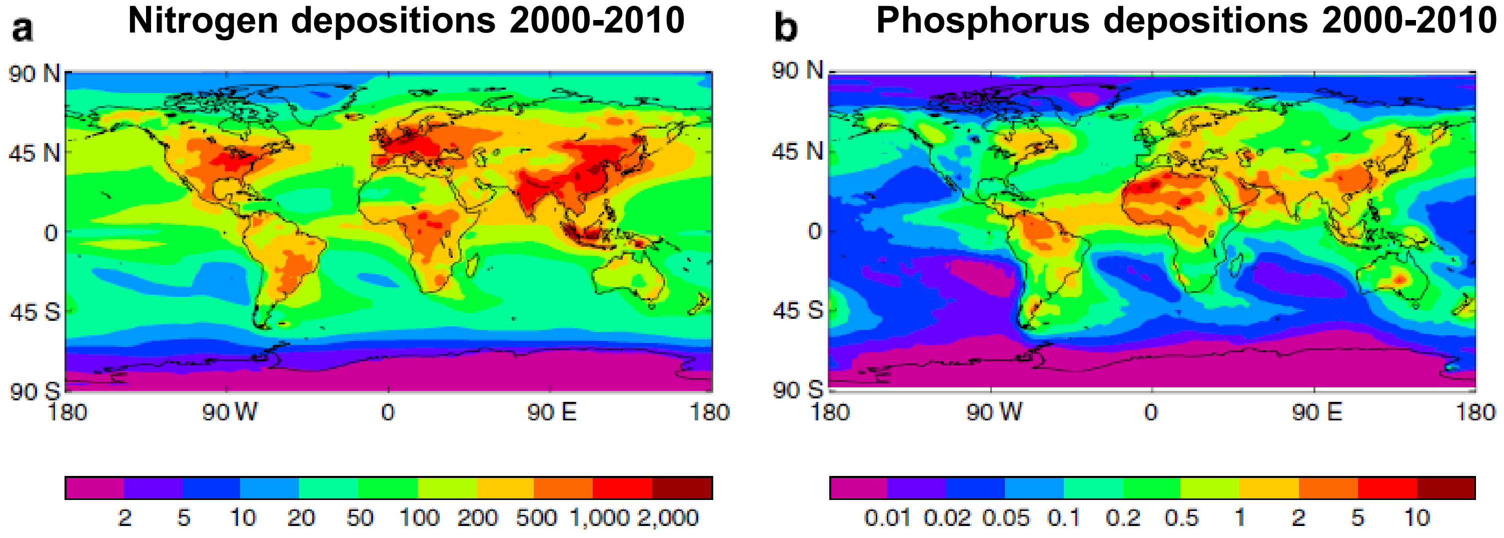
1. Motivation

Future anthropogenic nutrient deposition

- Terrestrial ecosystems are important carbon sink
- Semi-arid ecosystems play an important role for interannual variability and trend of CO_2 uptake
- Still not too well represented in models

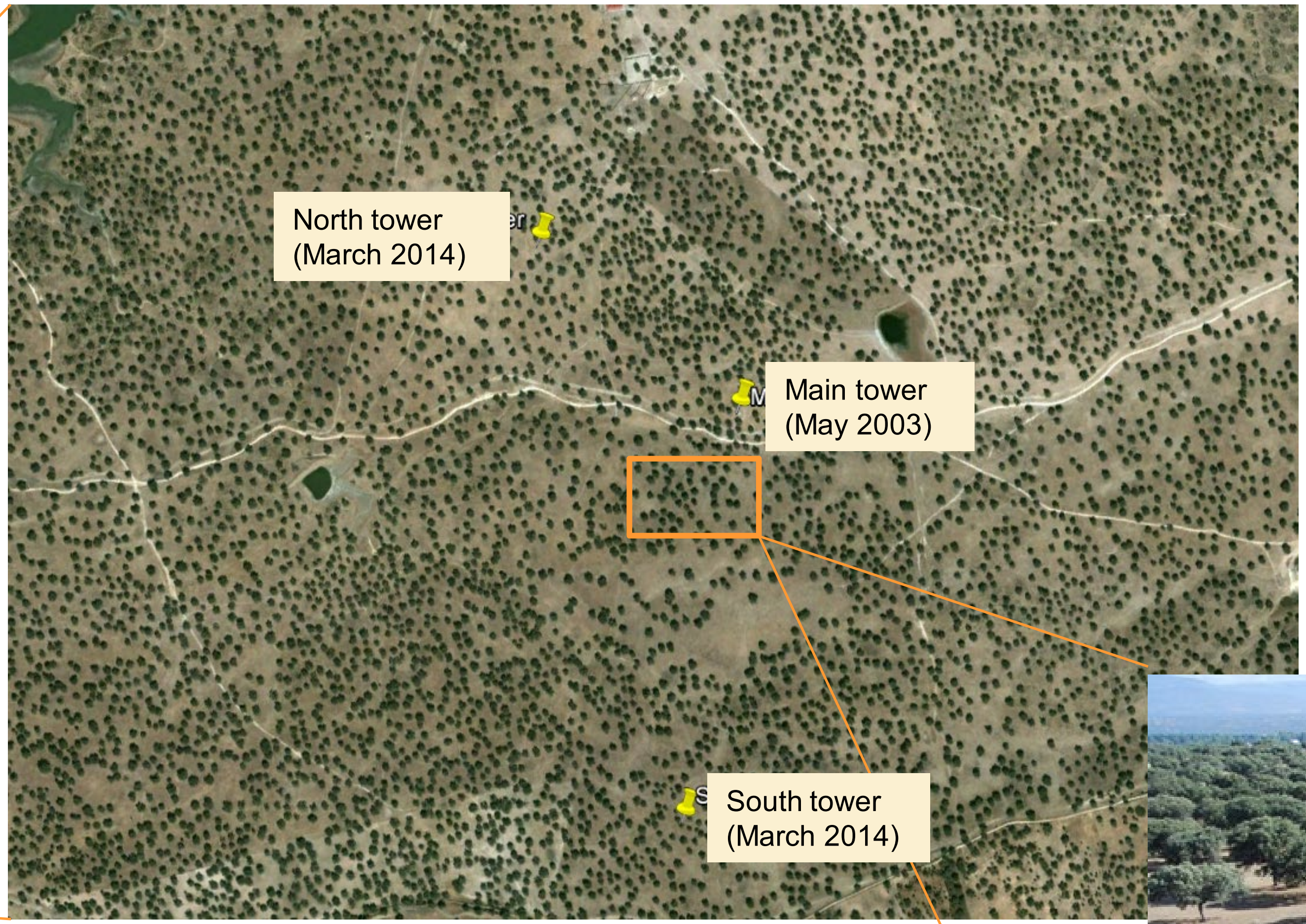


Atmospheric depositions (mg m^{-2} y^{-1}) (Peñuelas 2013)

- Phosphorus and its relation with Nitrogen are crucial for functioning of the carbon cycle
- Human activities alter N:P ratio in atmosphere and ecosystems

2. Site and Data

Majadas de Tiétar



650 mm yearly precipitation


Dehesa at Majadas de Tiétar, Extremadura, Spain (Carrara 2022)

- Semi-arid tree-grass ecosystem ("dehesa") in Western Spain
- 3 EC sites above canopy, 3 subcanopy

2. Site and Data

Fertilization experiment

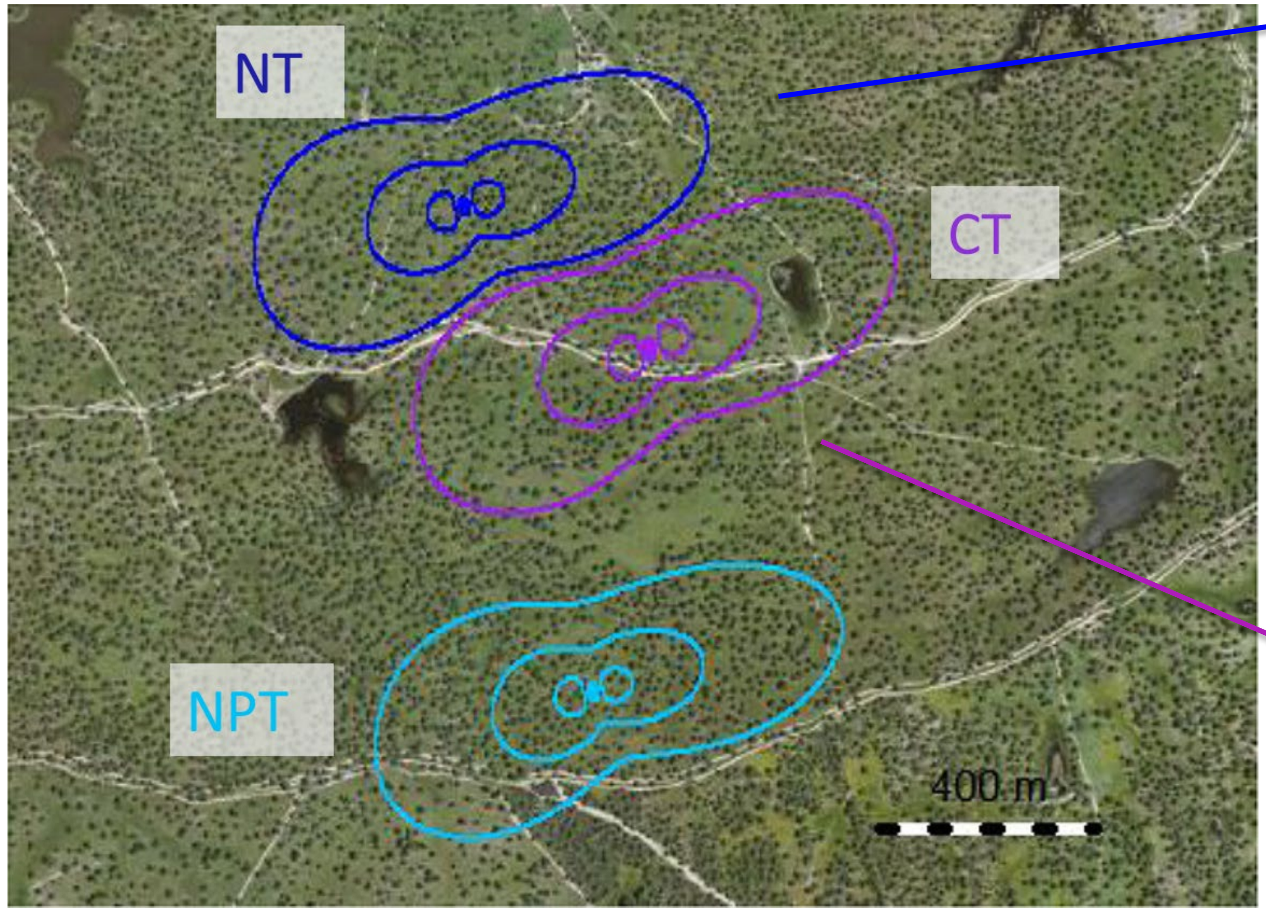


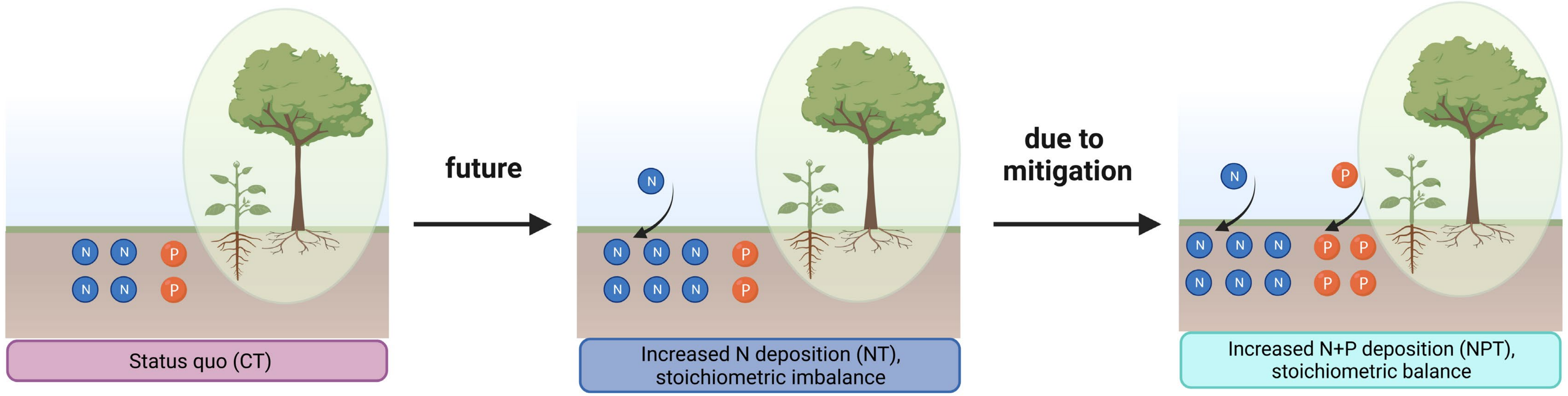
Fig.4: Flux towers and their footprints at Majadas de Tiétar measurement site (El-Madany et al. 2018)

North tower (footprint fertilized with Nitrogen)

Main tower/ Control tower

- Radiometric, biometeorological, flux and soil data
- 2016-2022
- 2015: Fertilization treatments with nitrogen (N) and nitrogen + phosphorus (NP)

3. Research questions



Q.1: How does nutrient availability change the variability of the CO_2-flux, vegetation and soil properties in a semi-arid tree grass ecosystem on different time scales?

→ H.1.1: We expect higher nutrient availability to increase the variability of the CO_2-flux, especially on longer time scales.

→ H.1.2: We expect that higher nutrient availability to affect more the biogenic drivers, where the grass layer has the dominant influence

Q.2: How does nutrient availability change the sensitivity of the CO_2 -flux to different environmental factors on short and long timescales?

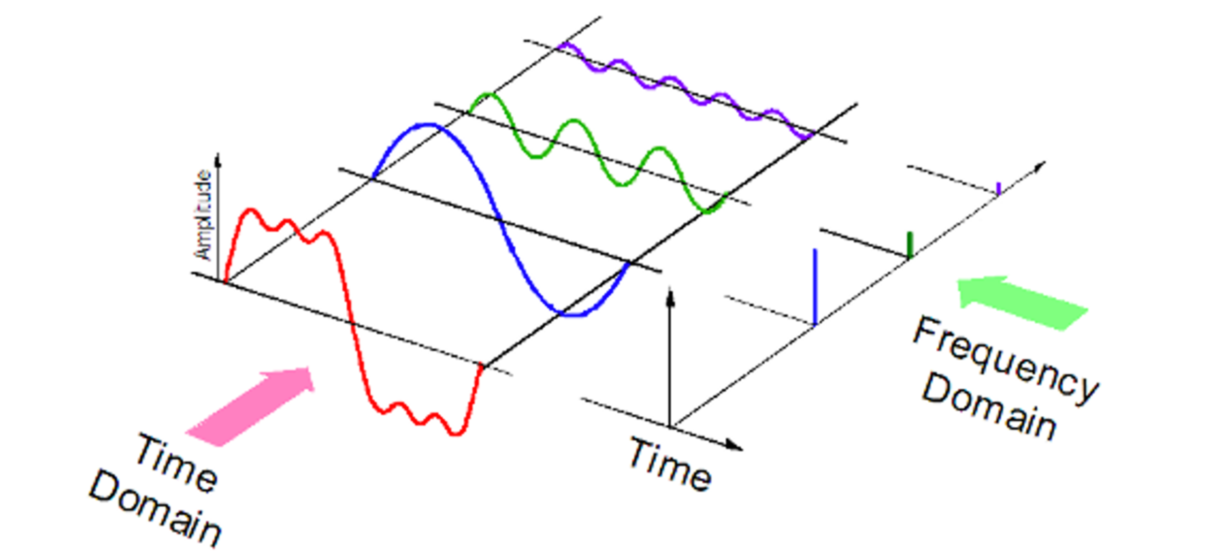
→ H.2: We hypothesize that on shorter time scales both fertilized plots become more sensitive to solar radiation, while on longer timescales all plots are more sensitive to water than sun.

4. Methods

4.1. Decomposition

Singular Spectrum Analysis (SSA)

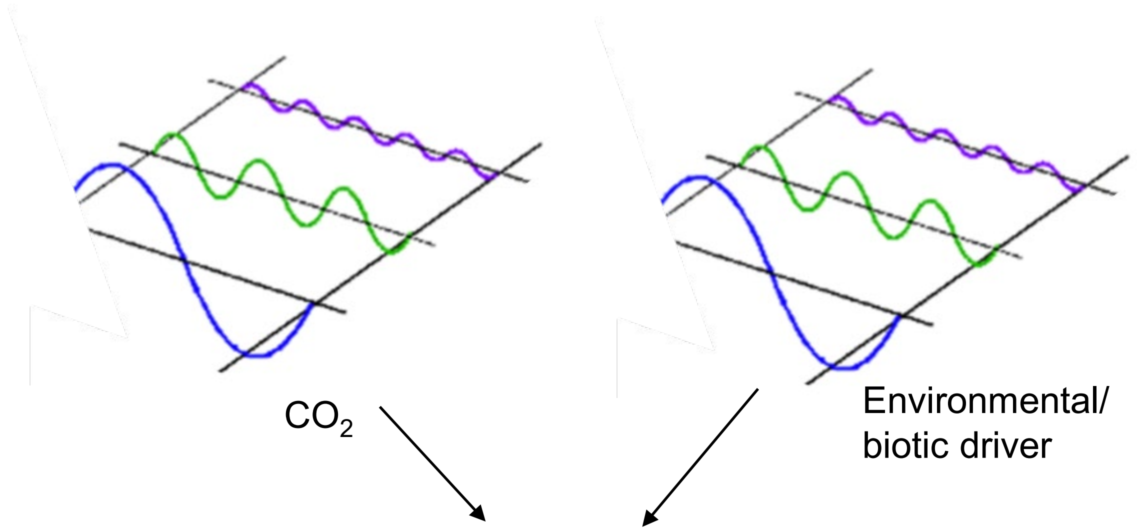
- Data-driven, non-parametric
- able to decompose a signal into (possibly) nonharmonic or aperiodic sub-signals
- Adequate for high-frequency measurements
- Implemented in R with Rssa-package by Nina Golyandina



Embedding → Singular Value Decomposition → Grouping:
- daily (2h-1.3 days)
- multiday and (2.7 -21.3 days)
- seasonal (15 – 366 days)

→ Reconstruction

4.2. Metrics of Mutual Information



Mutual Information (MI):

- Amount of information two variables X and Y hold in common → measures reduction of uncertainty in one variable given the knowledge of another
- Calculated with marginal and joint probability distributions
- **Relative mutual information (normalized)** is computed → comparability
- Possible to detect **leading and lagging** effects

CO2	CO_2	µmol m-2 s-1
H	Sensible heat	W m-2
LE	Latent heat	W m-2
AIR_PRESS	Air pressure	Pa
RH02	Relative humidity 2m	%
RH15	Relative humidity 15m	%
TA02	Temperature 2m	degree C
TA15	Temperature 15m	degree C
VPD	Water vapor pressure deficit	Pa
WIND_DIR	Wind direction	degrees
U*	Friction velocity	m s-1
SWDR	Short wave downward radiation	W m-2
LWDR	Long wave downward radiation	W m-2
PAR_{IN}	Incoming Photosynthetically Active radiation	umol m-2
POS0_PRIT	Photochemical reflectance index above trees	
POS0_NDVIT	Normalized Difference Vegetation Index above trees	
POS0_PRIG	Photochemical reflectance index above grass	
POS0_NDVIG	Normalized Difference Vegetation Index above grass	
SWC	normalized soil moisture content for top 20cm	
SHF_SUN	soil heat flux sun*	W m-2
SHF_SHD	soil heat flux shadow*	W m-2
TSOIL_SUN	soil temperature sun*	degreeC
TSOIL_SHD	soil temperature shadow*	degreeC

5. First Results

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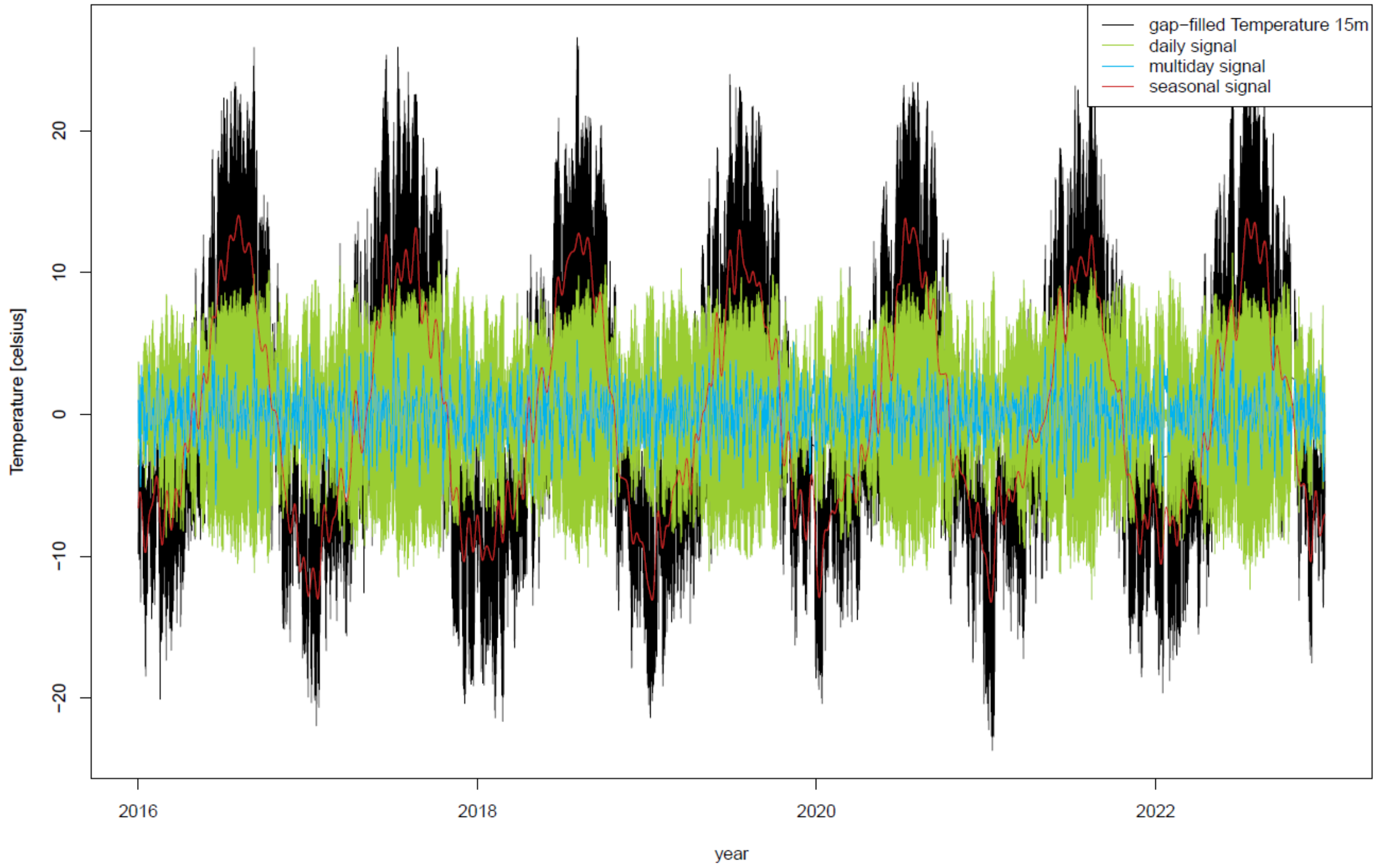
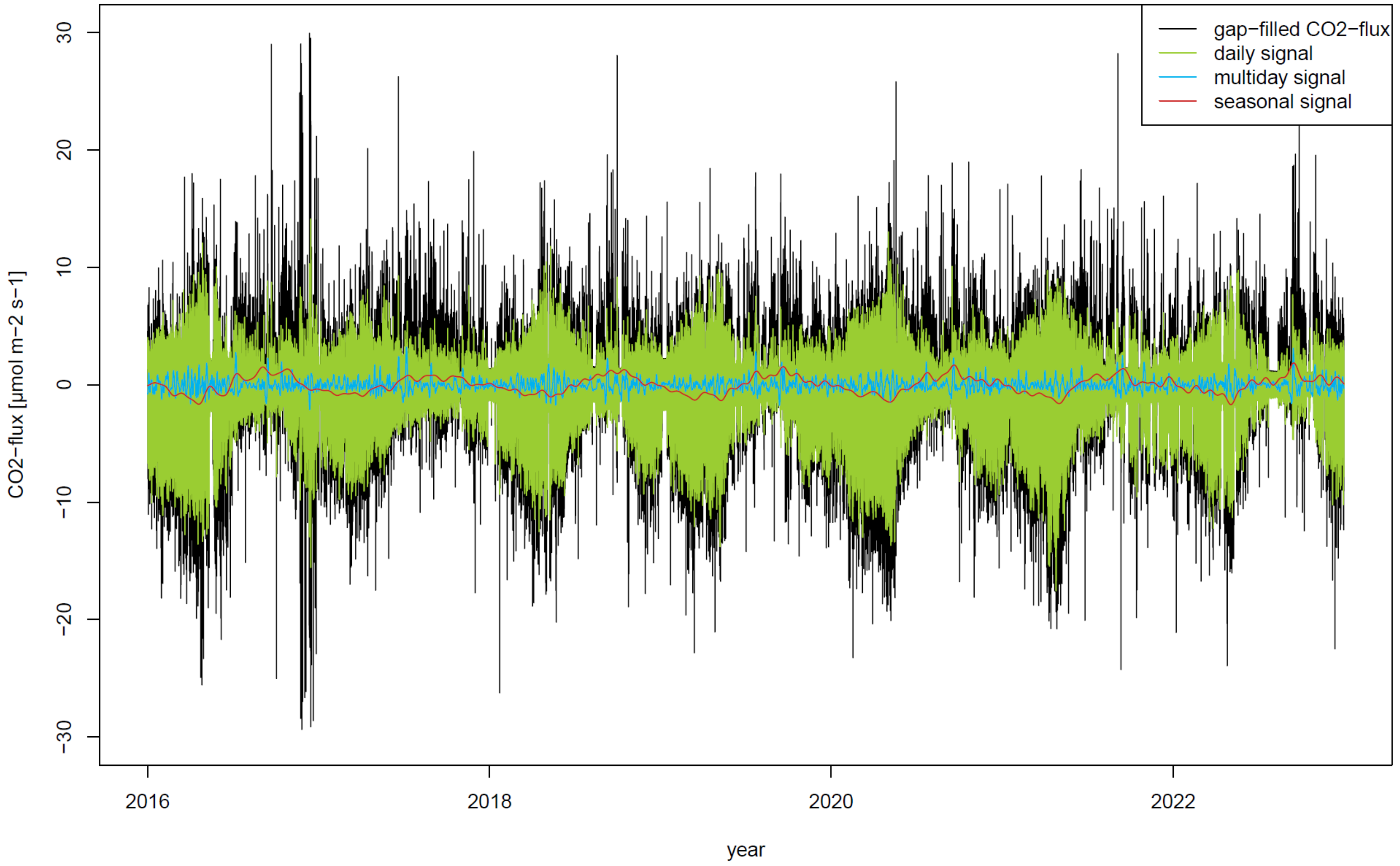
Reconstructed time series – 2016-2022

Temperature



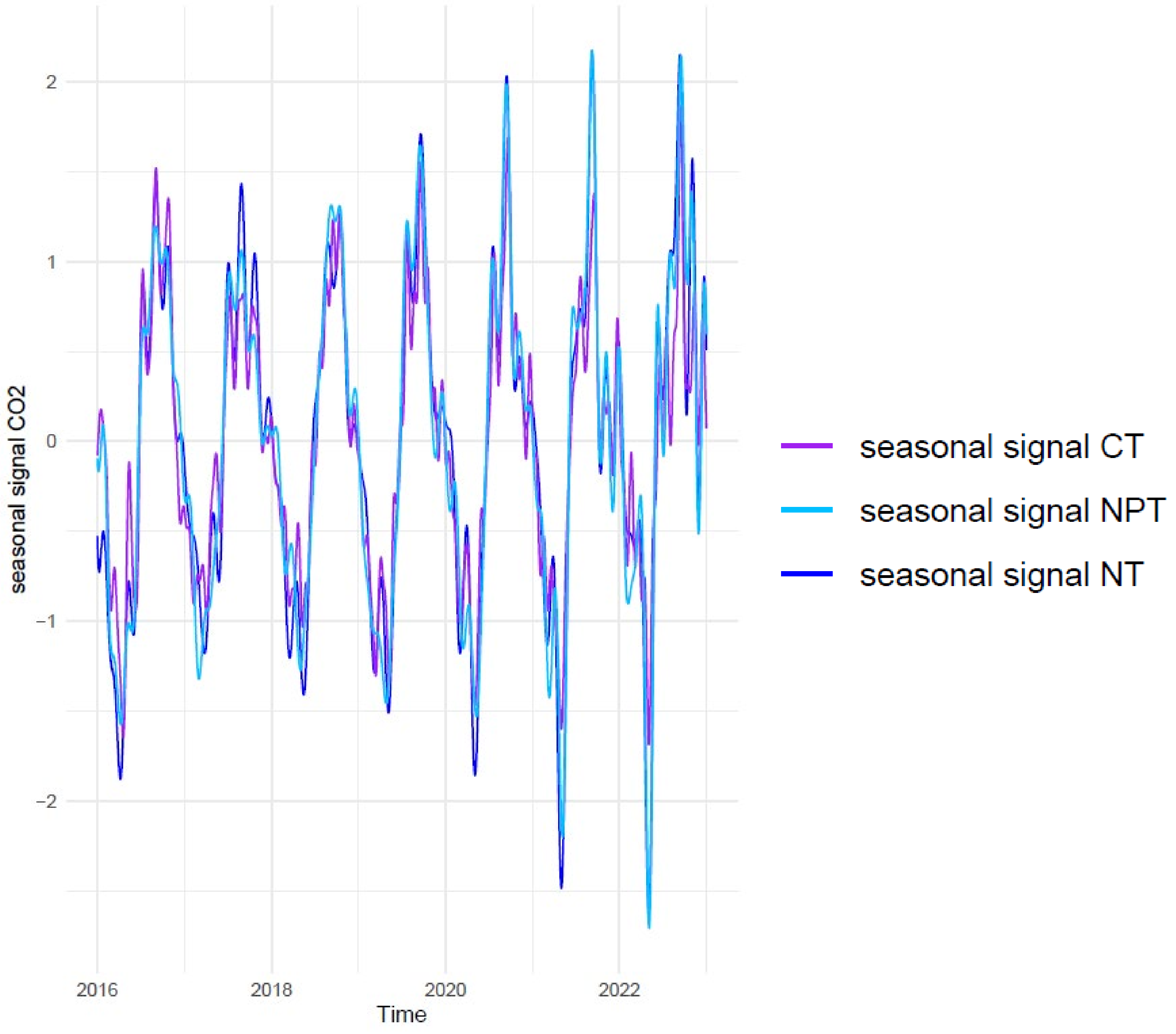
CO_2-flux (CT)

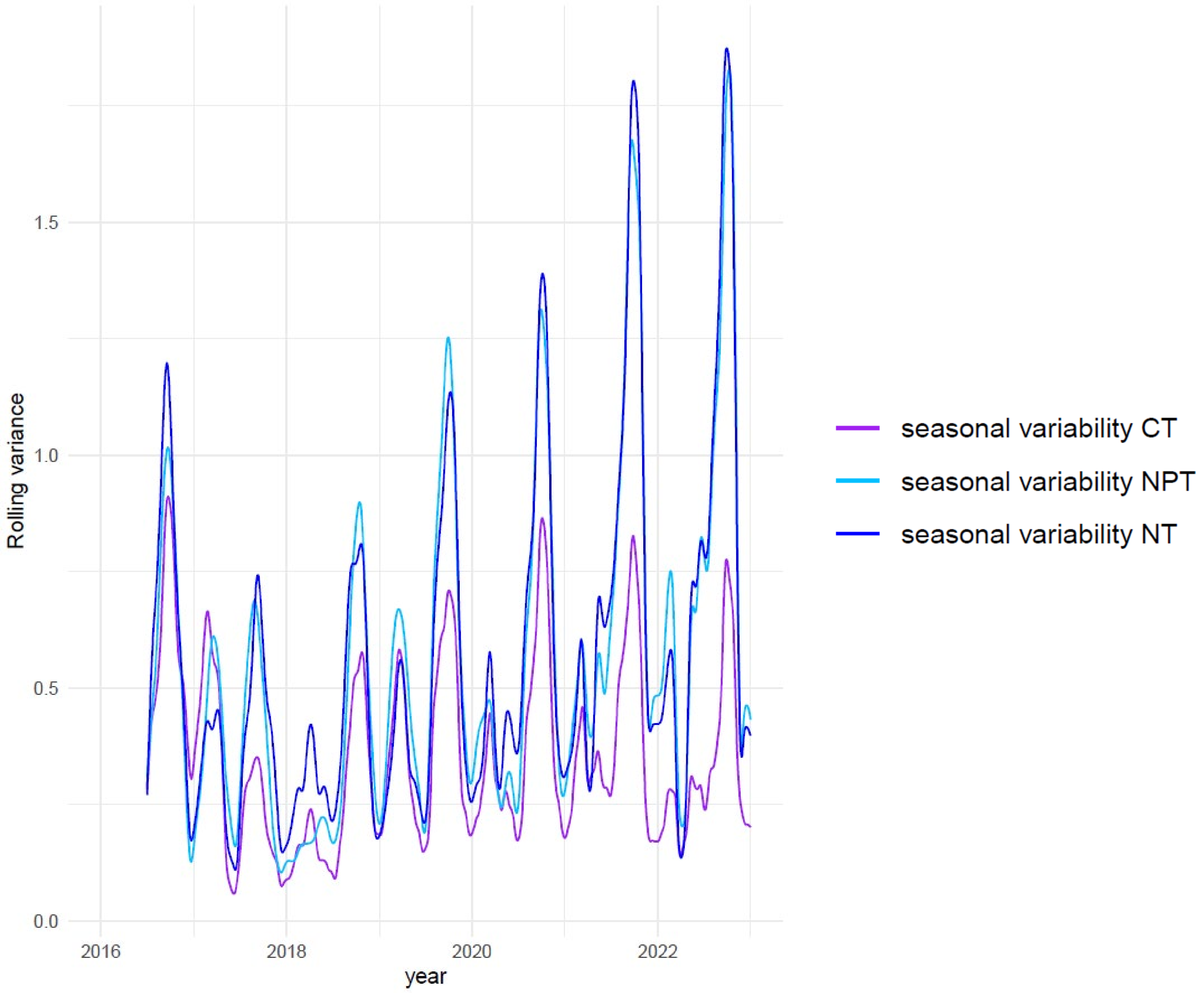


Q.1 change of variability

5. First Results

Reconstructed time series – variability of **CO_2-flux**





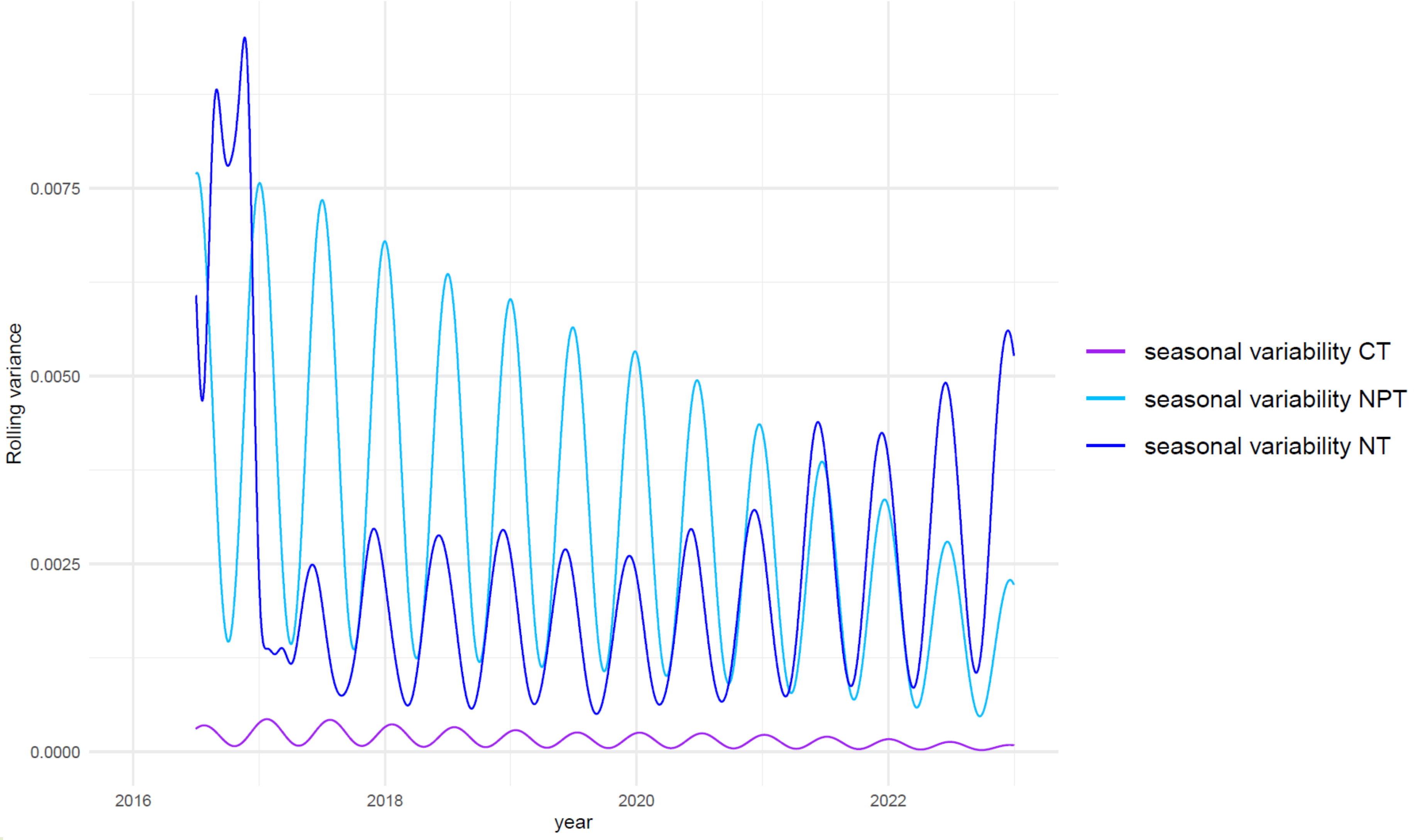
Q.1 change of variability

- variability of the CO_2-flux on seasonal scale increases at both fertilized plots
- at CT no change in variability

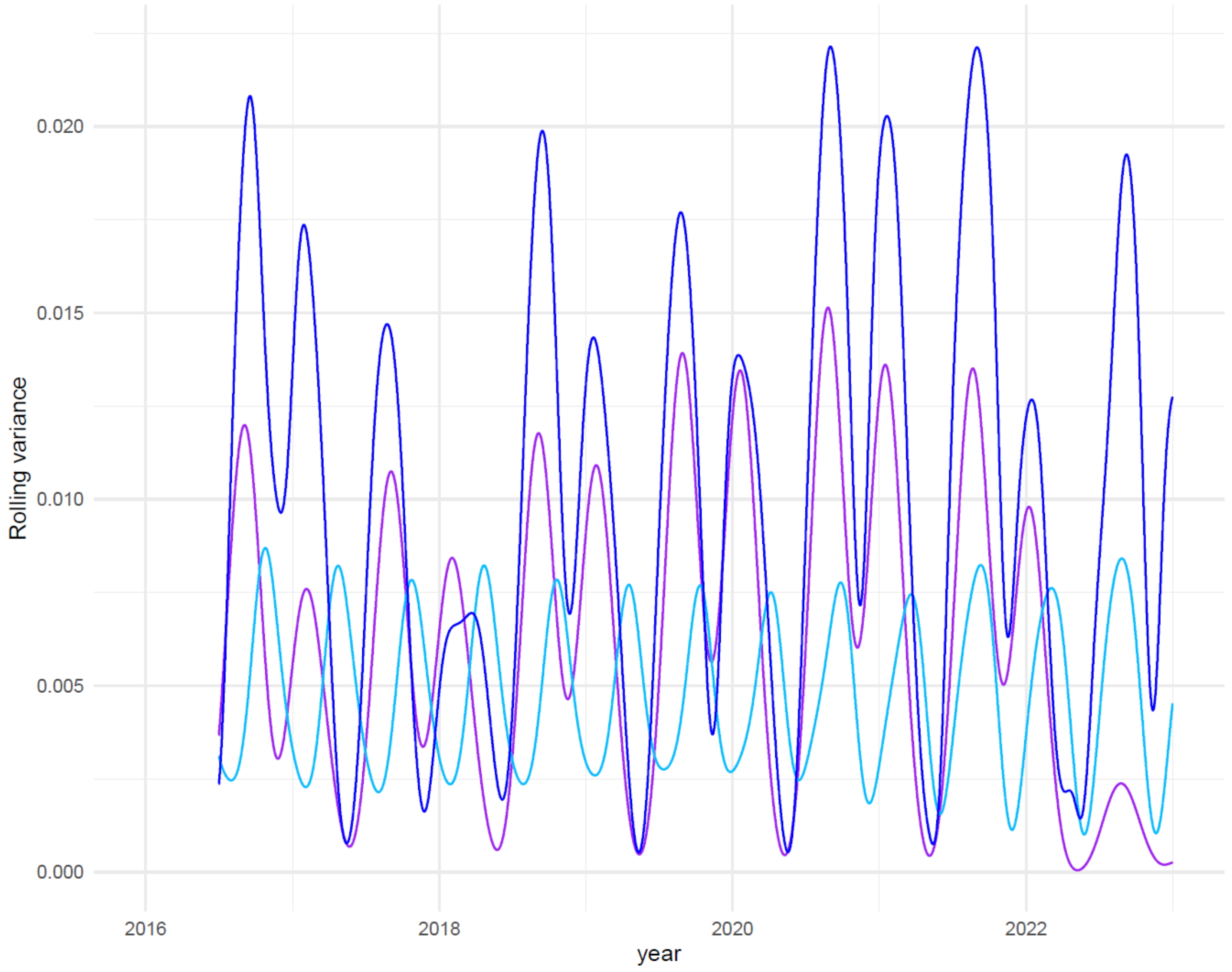
5. First Results

Reconstructed time series – **NDVI variability**

Tree layer



Grass layer



Q.1 change of variability

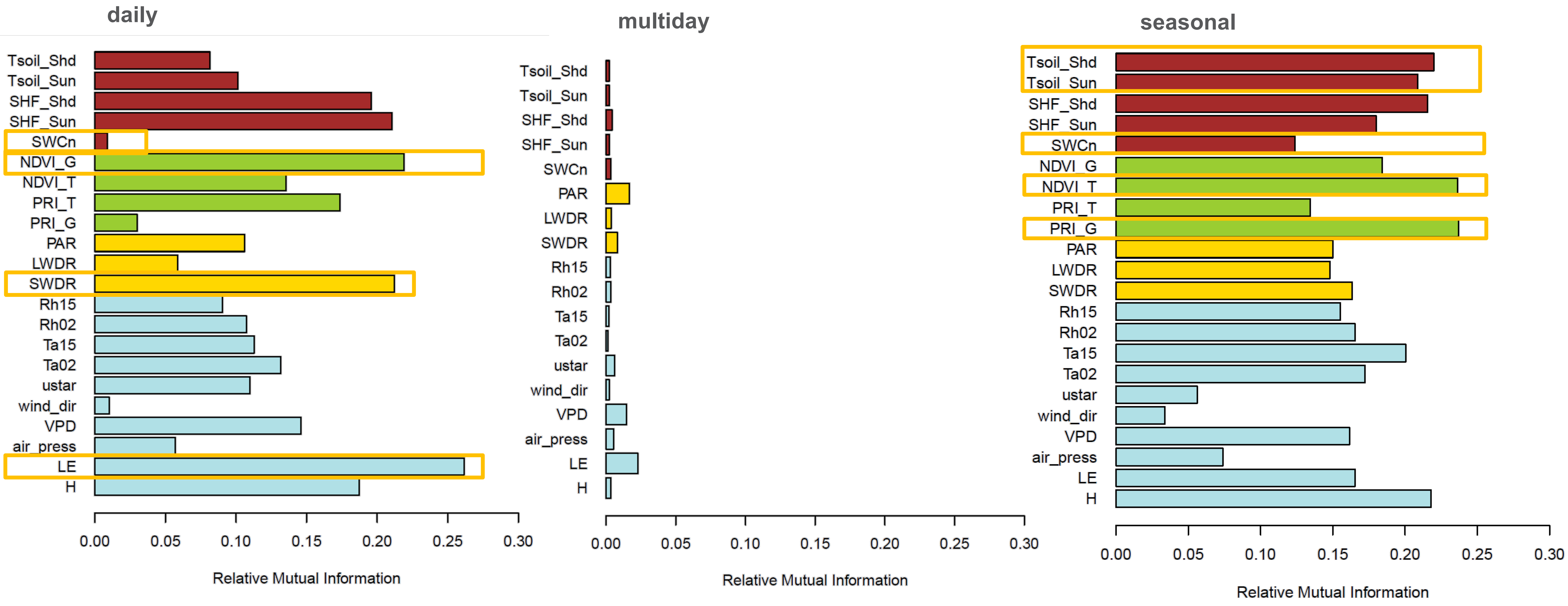
- Tree layer NDVI variability decreases at NPT, increases at NT
- Grass layer NDVI variability highest at NT, lowest at NPT, no trend

5. First Results

NDVI: “greenness” of the vegetation

PRI: “efficiency of photosynthesis”

Mutual information between CO_2-flux and its drivers – CT

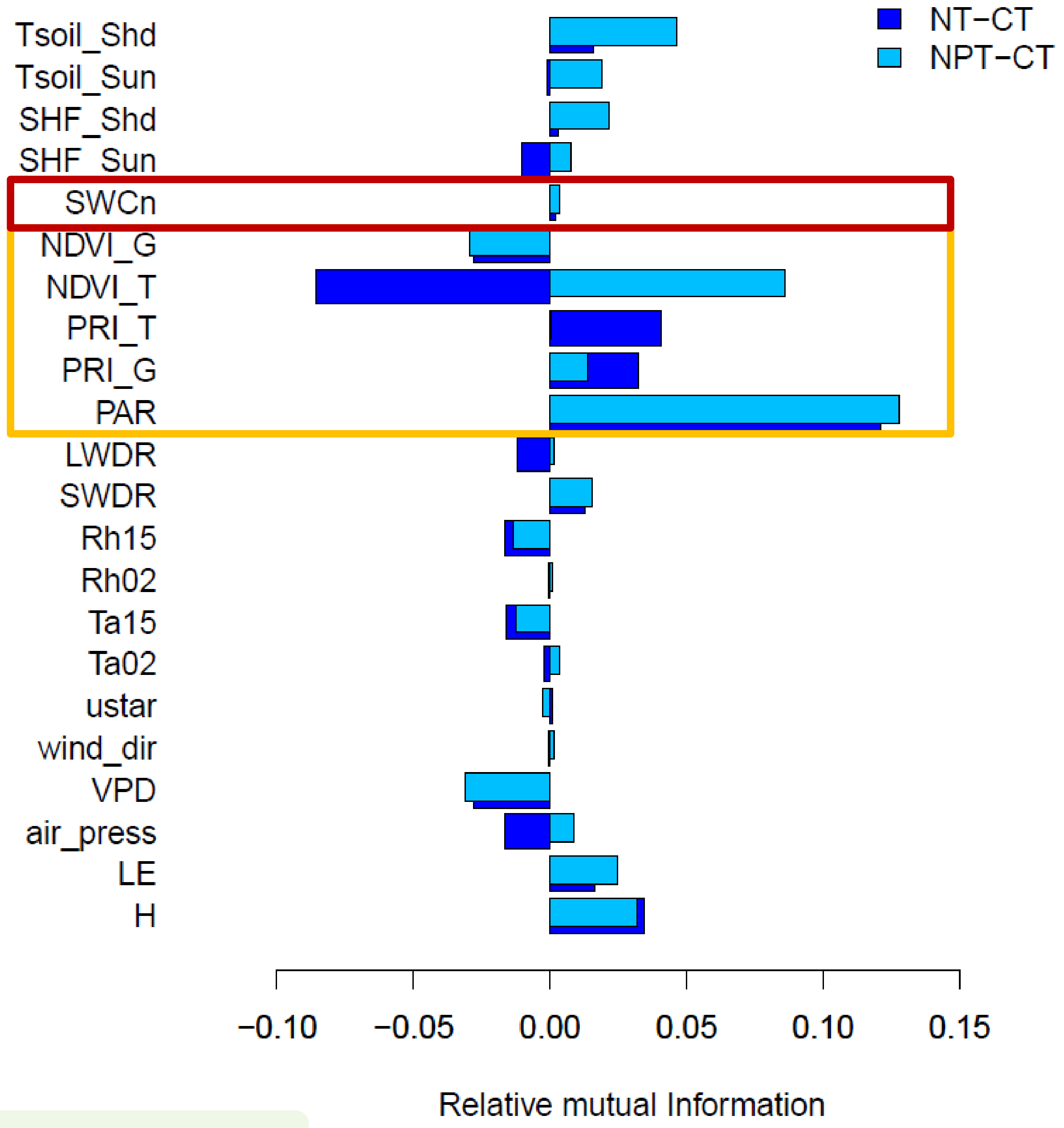


Q.2: drivers of the CO_2-flux

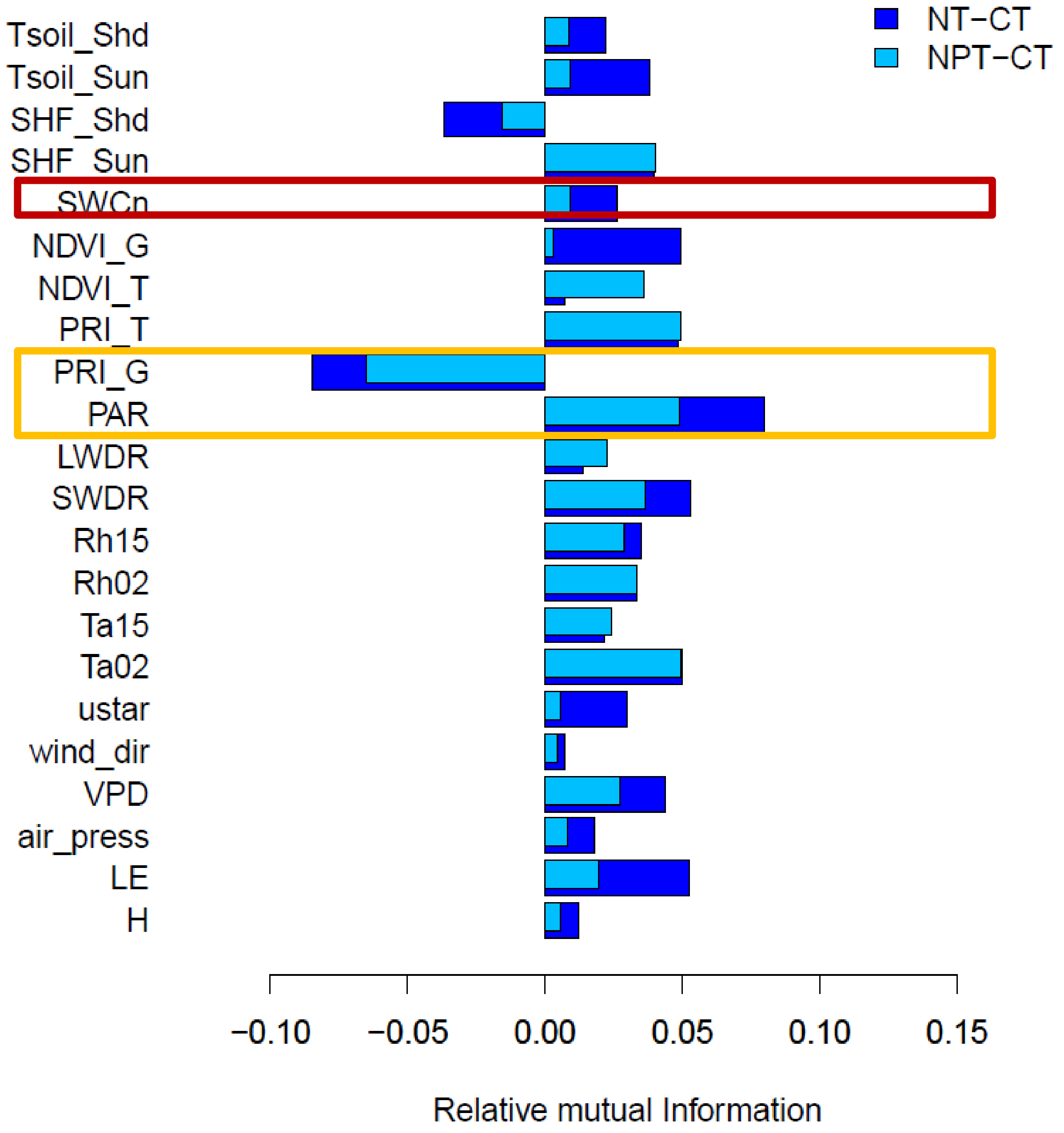
5. First Results

Mutual information – differences between towers

daily



seasonal



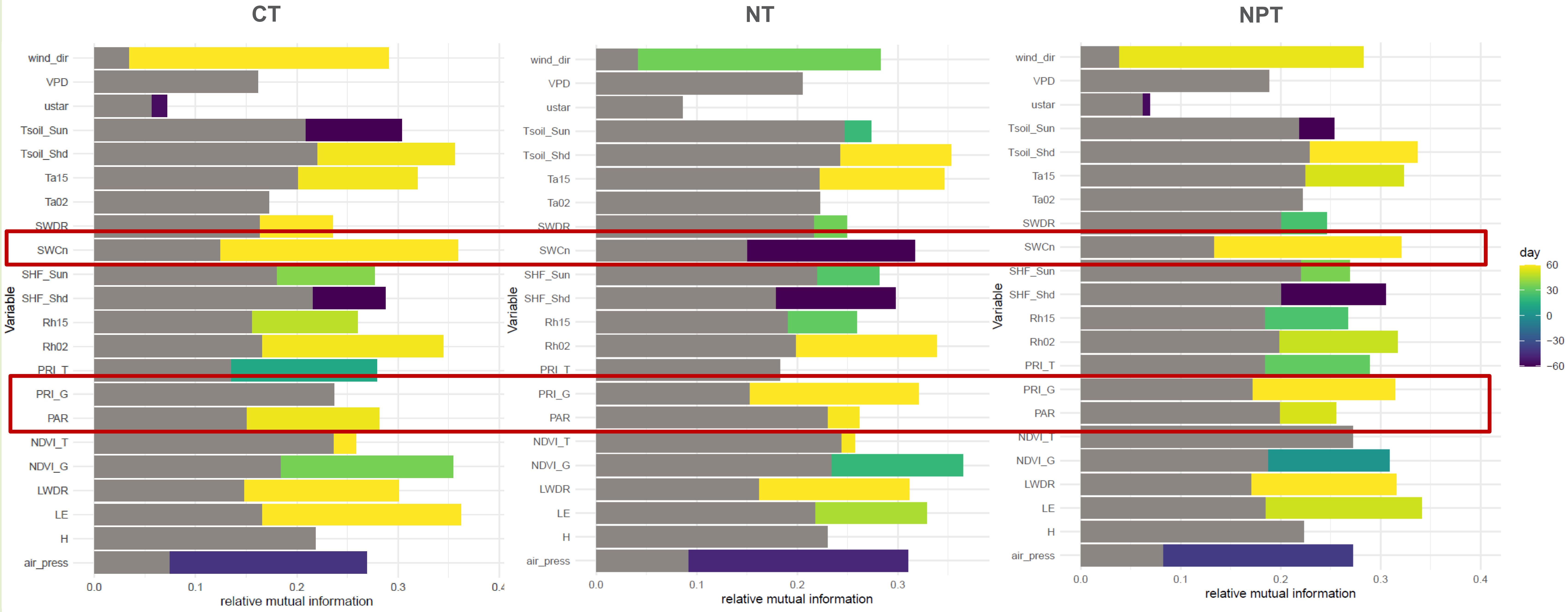
Q.2: drivers of the CO_2-flux

5. First Results

MI – leading and lagging effects – seasonal scale

Positive values (green/yellow) mean that the **driver is leading the CO_2 -flux**

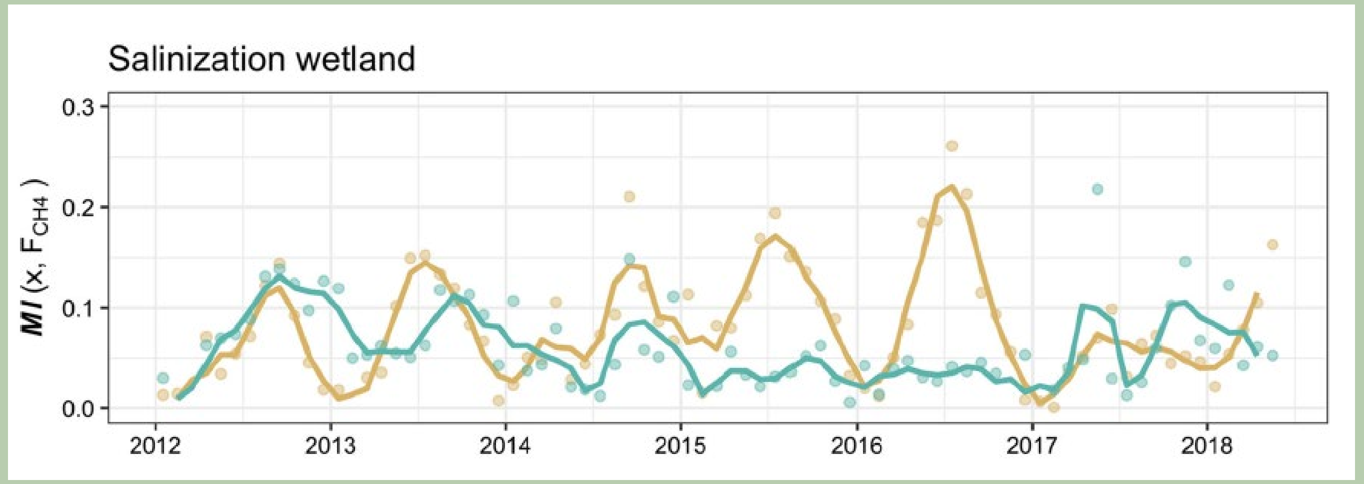
Negative values (blue) mean that the **CO_2 -flux is leading its driver**



Q.2: drivers of the CO_2-flux

6. Next steps

- **Calculate monthly MI** between CO_2-flux and most important drivers
- Compare how the MI changes over time at differently fertilized plots

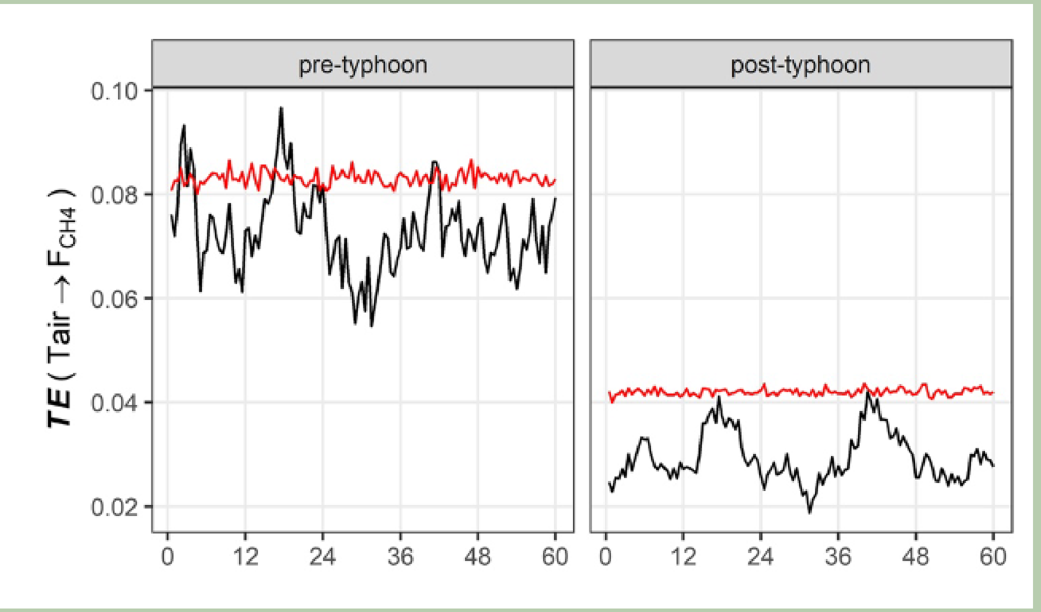


Chamberlain et al 2020: 681

Monthly relative MI shared between GEP and FCH4 (green) and Ta and FCH4 (yellow) in a wetland

Q.3: How do different N:P balances alter the effect heatwaves have on the drivers of the carbon flux?

Calculate **transfer entropy** = form of conditional MI
→ Compare information flow between (important) drivers and CO_2 flux before and after a heatwave event



Relative transfer entropies (TE) from T_{air} to FCH_4 before and after a super typhoon event in 2018 (Liu et al, 2022)

8. Summary and Outlook

Q.1: How does nutrient availability change the variability of the CO_2-flux, vegetation and soil properties in a semi-arid tree grass ecosystem on different time scales?

→ Seasonal variability of CO_2 increased within the investigation period at both fertilized plots
→ NDVI variability increases at NT and decreases at NPT on the tree layer

Q.2: How does nutrient availability change the sensitivity of the CO_2 -flux to different environmental factors on short and long timescales?

- SWDR is important at daily and SWC+Tsoil become much more at seasonal scale
- Considering leading and lagging SWCn and Tsoil become important at all time scales
- sensitivity and leading/lagging of SWC are similar between NPT and CT, but not NT
- PRI_G becomes an important drivers at daily and seasonal scales for fertilized sites but not CT

Thanks for your attention!

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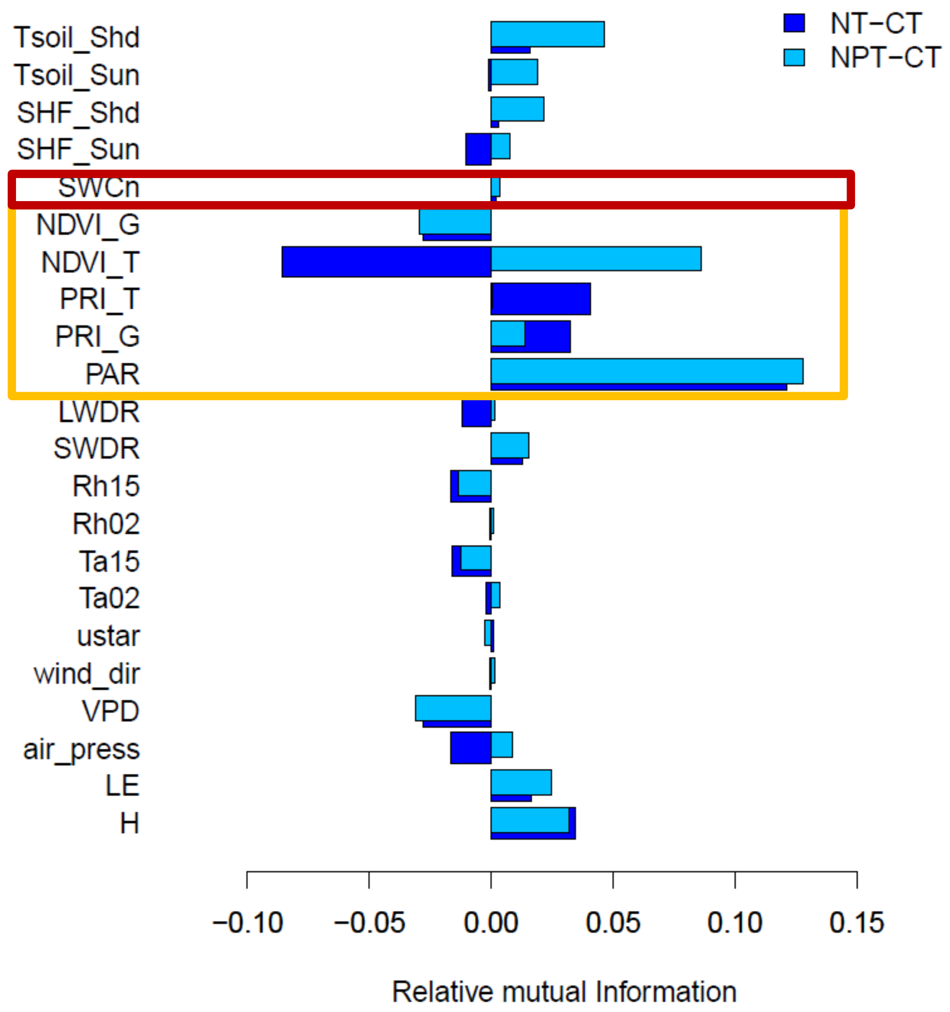
Penuelas 2022

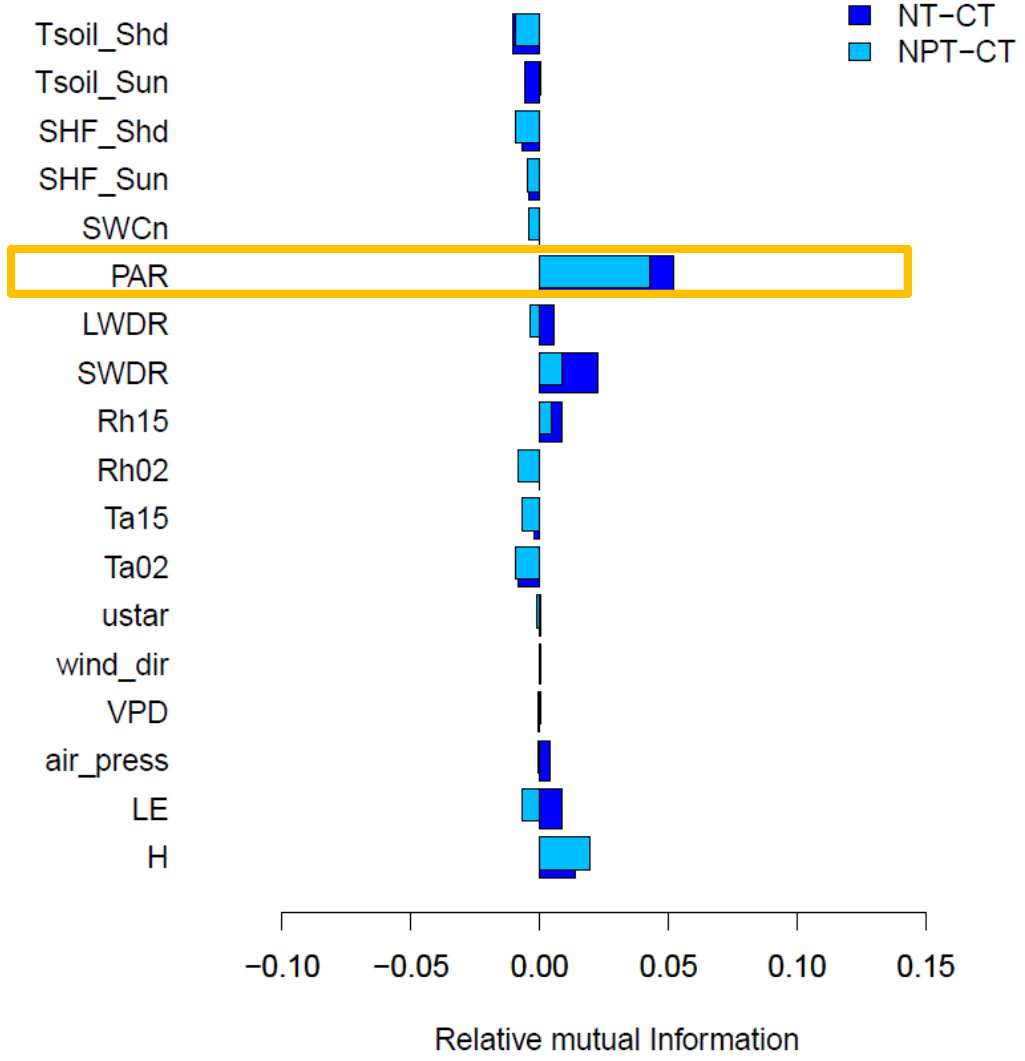
Supplementary material

5. First Results

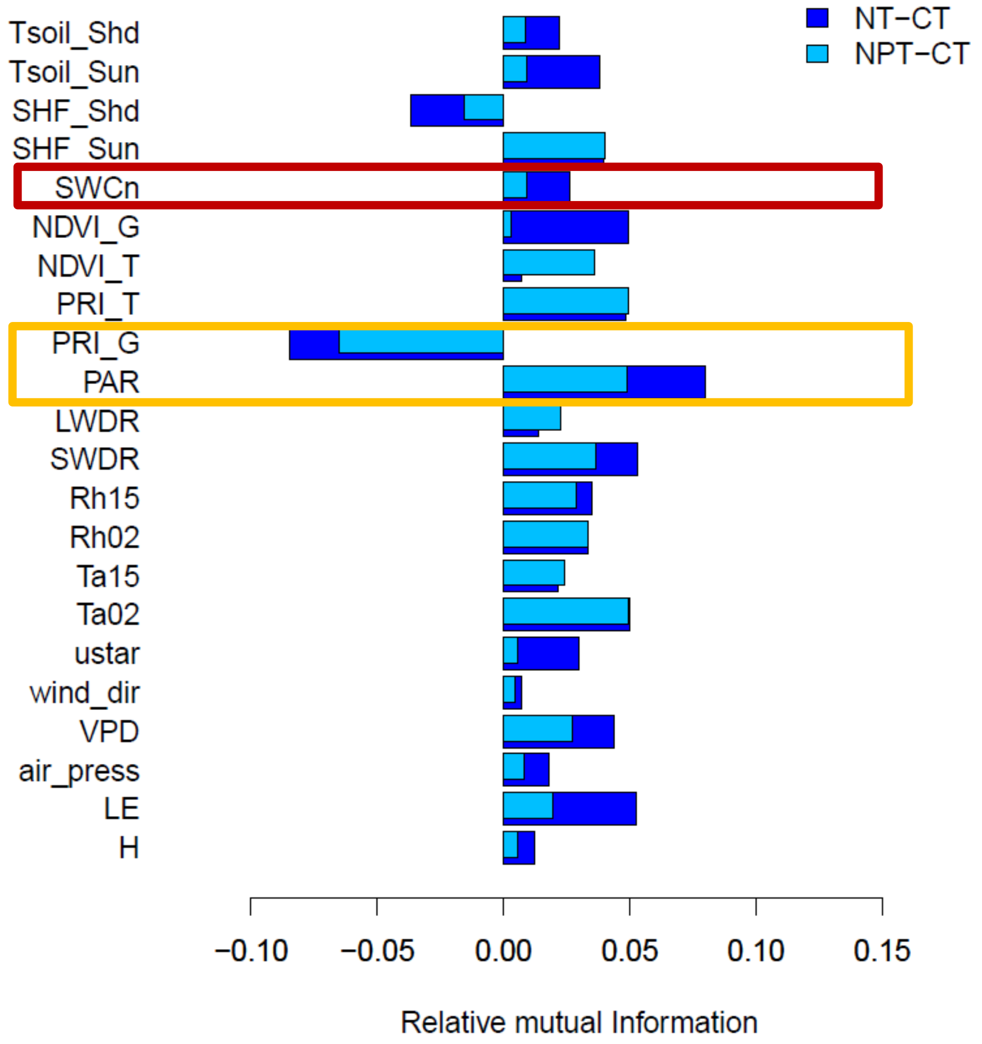
Mutual information – differences between towers



Daily timescale



Multiday timescale

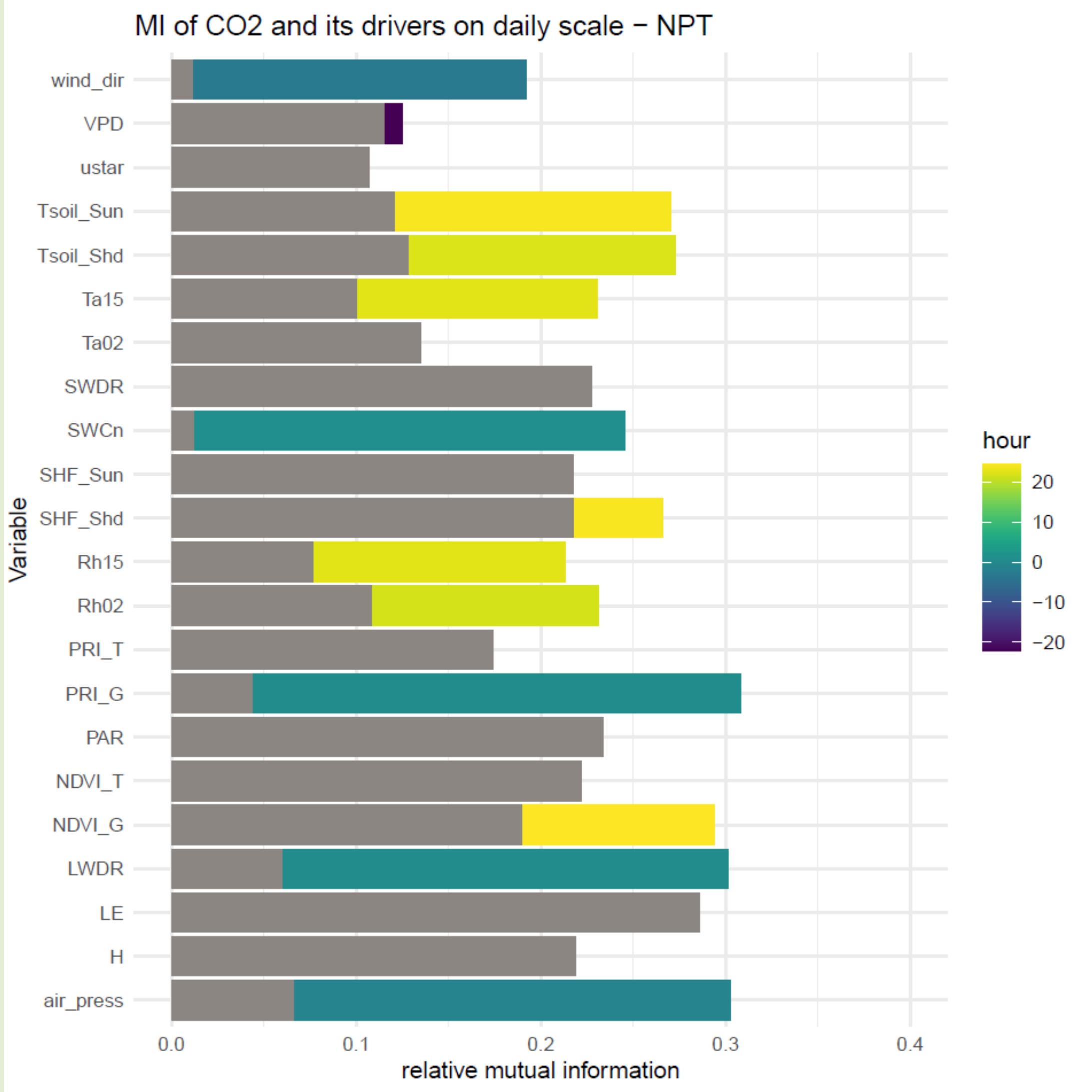


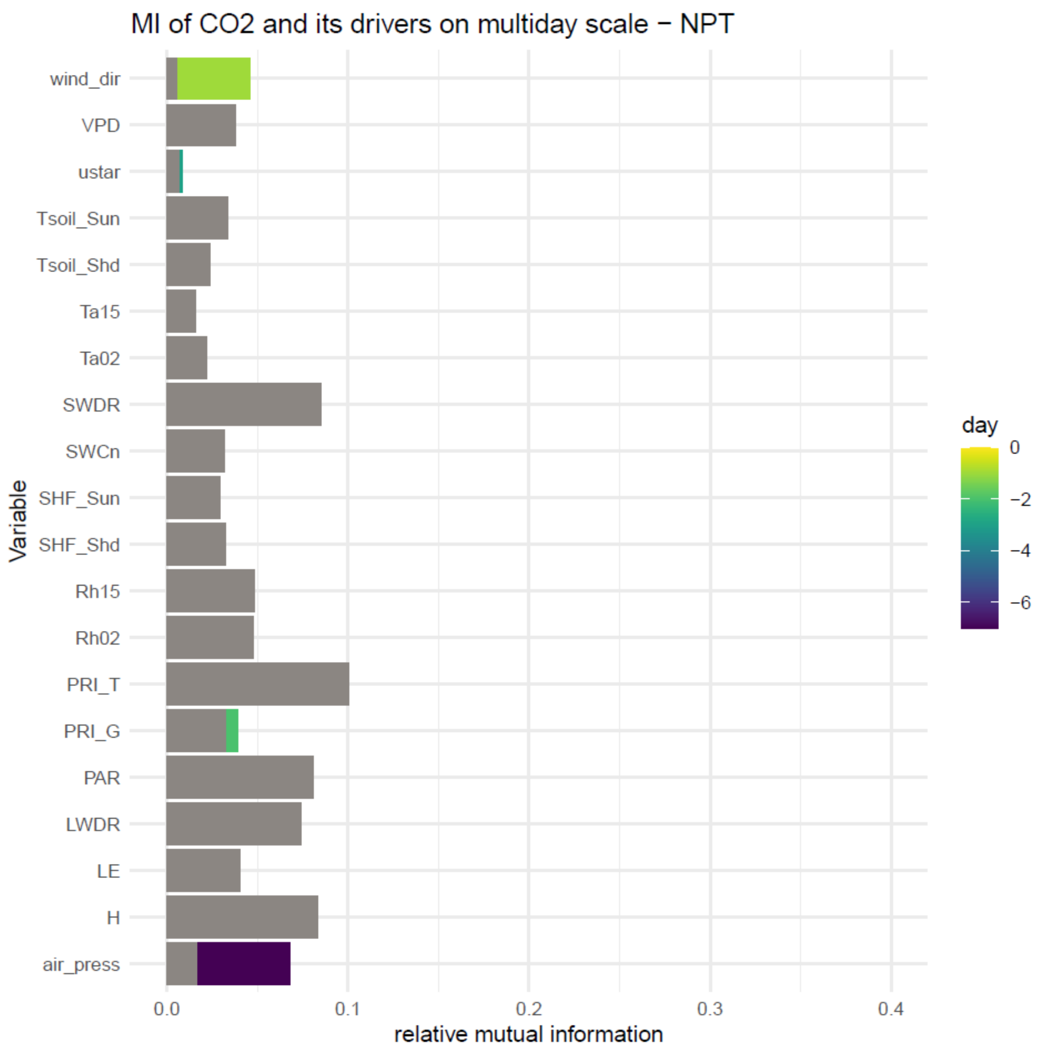
Seasonal timescale

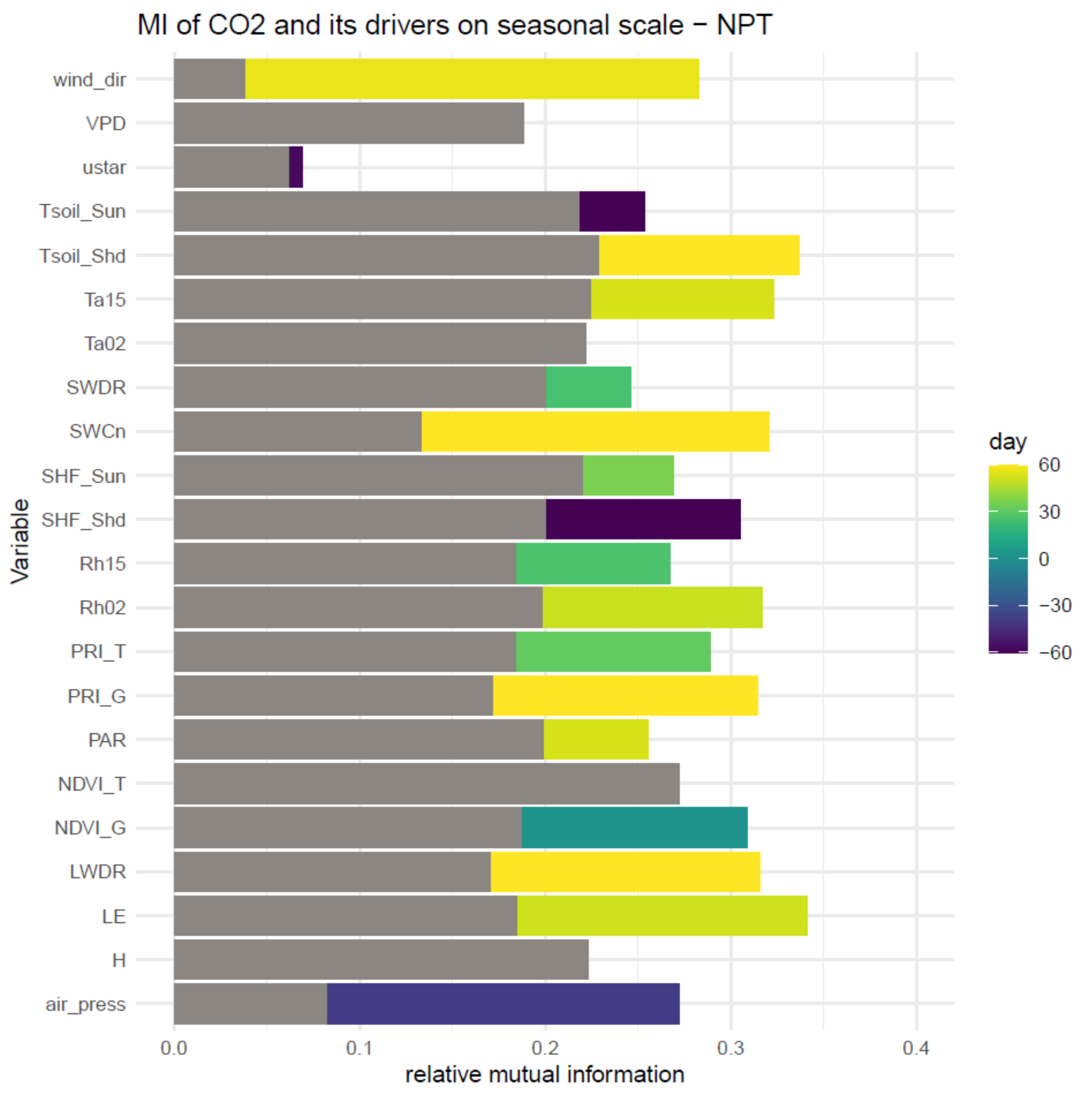
Q.2: drivers of the CO_2-flux

5. First Results

Mutual information – leading and lagging effects - NPT







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