# Normalised representation of terrestrial vegetation response to extreme weather events

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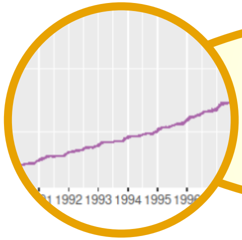
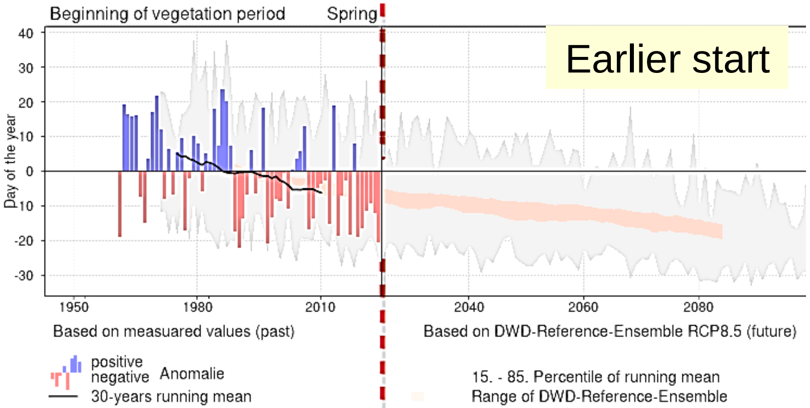
https://renovables.blog/en/ecosystem/Tundra-flora-and-its-importance-for-animal-life/

# Vegetation response to climate change

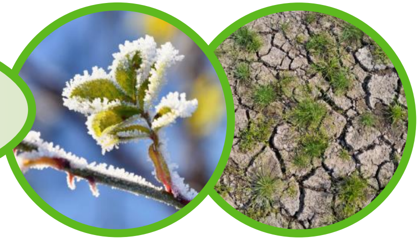



Burning fossil fuels raises $CO_2$ levels, causing global warming

Rising frequency of extreme weather events

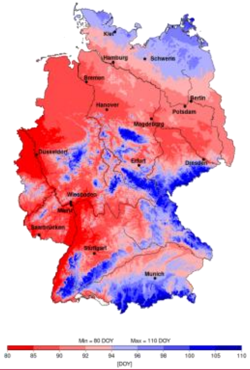



Adaptation of terrestrial vegetation to climate changes



Accumulated temperatures

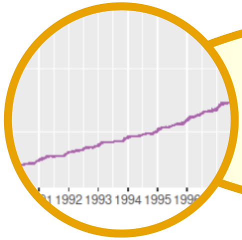
https://www.dwd.de/EN/climate_environment/climateatlas/climateatlas_node.html



How can we observe and analyse terrestrial vegetation response?

https://www.freepik.com/free-photo/drought_28944337.htm

# Vegetation response to climate change

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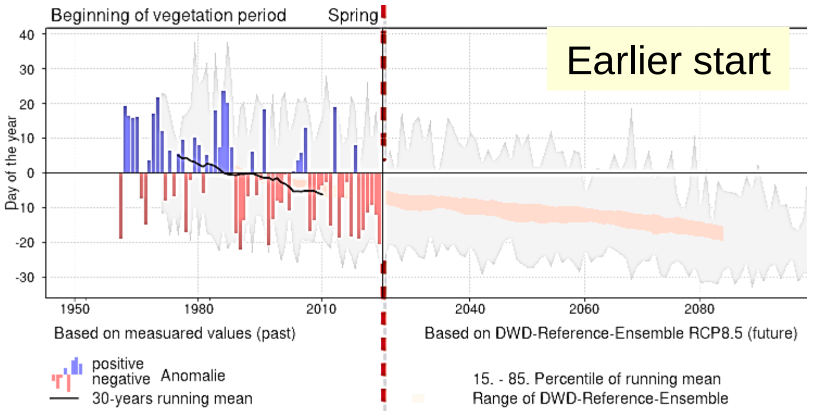
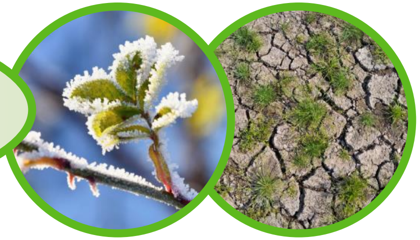



Adaptation of terrestrial vegetation to climate changes



https://www.dwd.de/EN/climate_environment/climateatlas/climateatlas_node.html


**Problems:**
Existing methods for vegetation activity identification need to be adapted to climate change

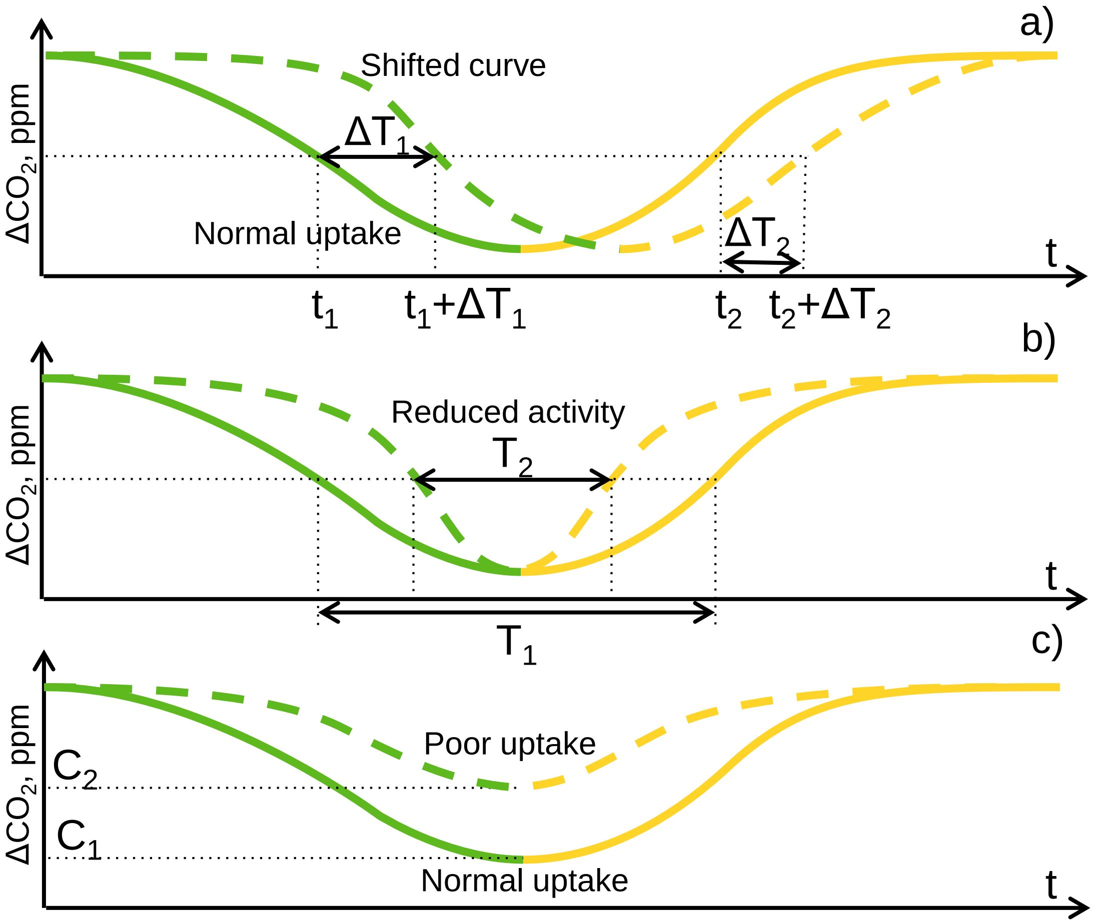
New indices, methods for identification of vegetation activity required

https://www.freepik.com/free-photo/drought_28944337.htm

# Potential impact of weather extreme events on

Due to deviations in the seasonal cycle and the impact of extreme weather events, changes in photosynthetic activity can be conceptually described with:

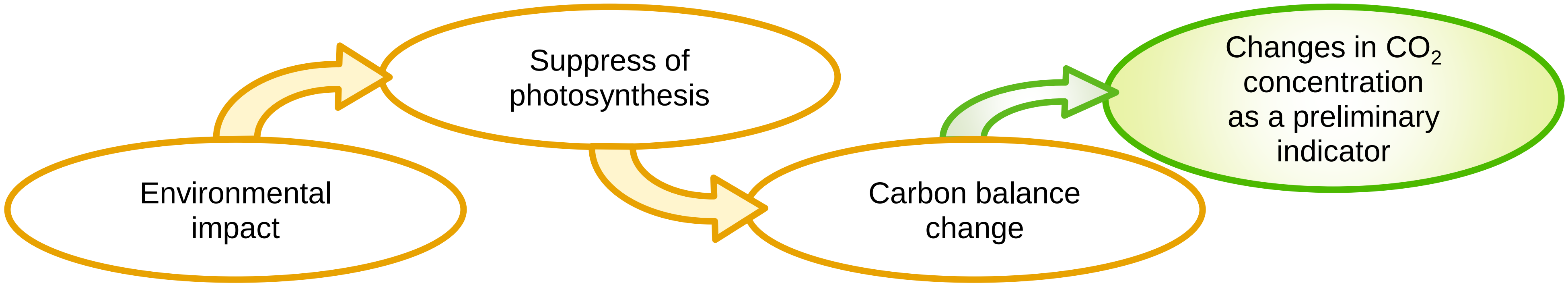
- a shift in the start and/or end of the active $CO_2$ fixation phase (Fig. a)
- a change in the duration of the active $CO_2$ fixation phase (Fig. b)
- a change in the strength of $CO_2$ fixation (Fig. c)




*Simultaneous changes to one or more parameters are possible*

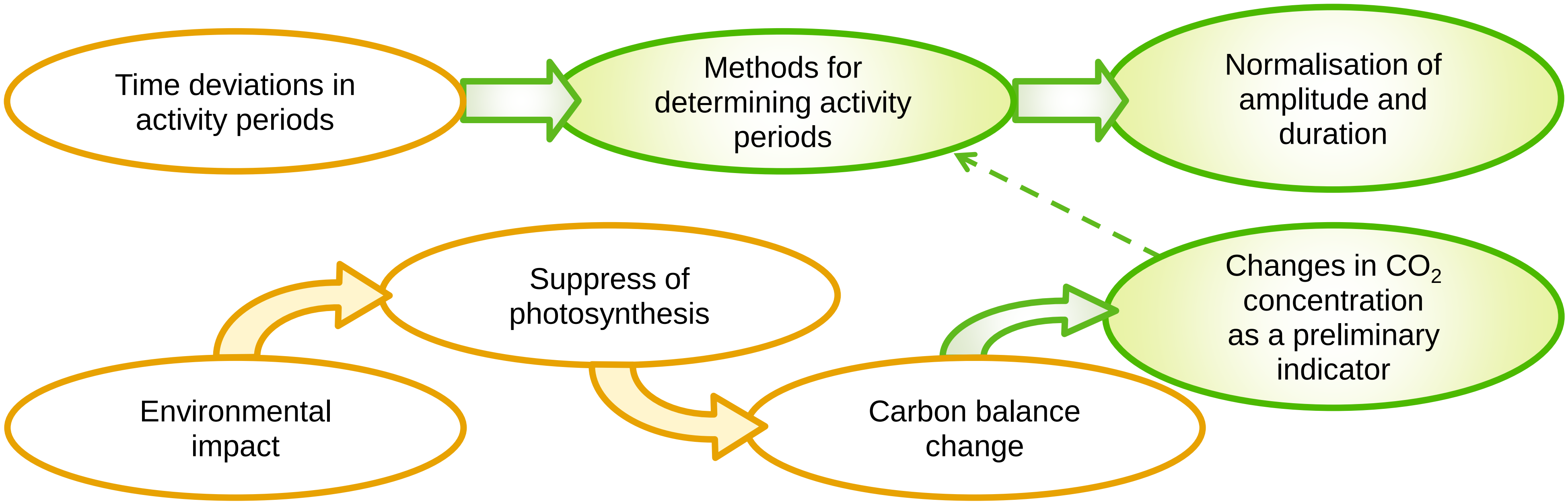
# Workflow for identification of vegetation activity

Do $CO_2$ concentration changes reflect **ecosystem response** to extreme events **via photosynthesis**?

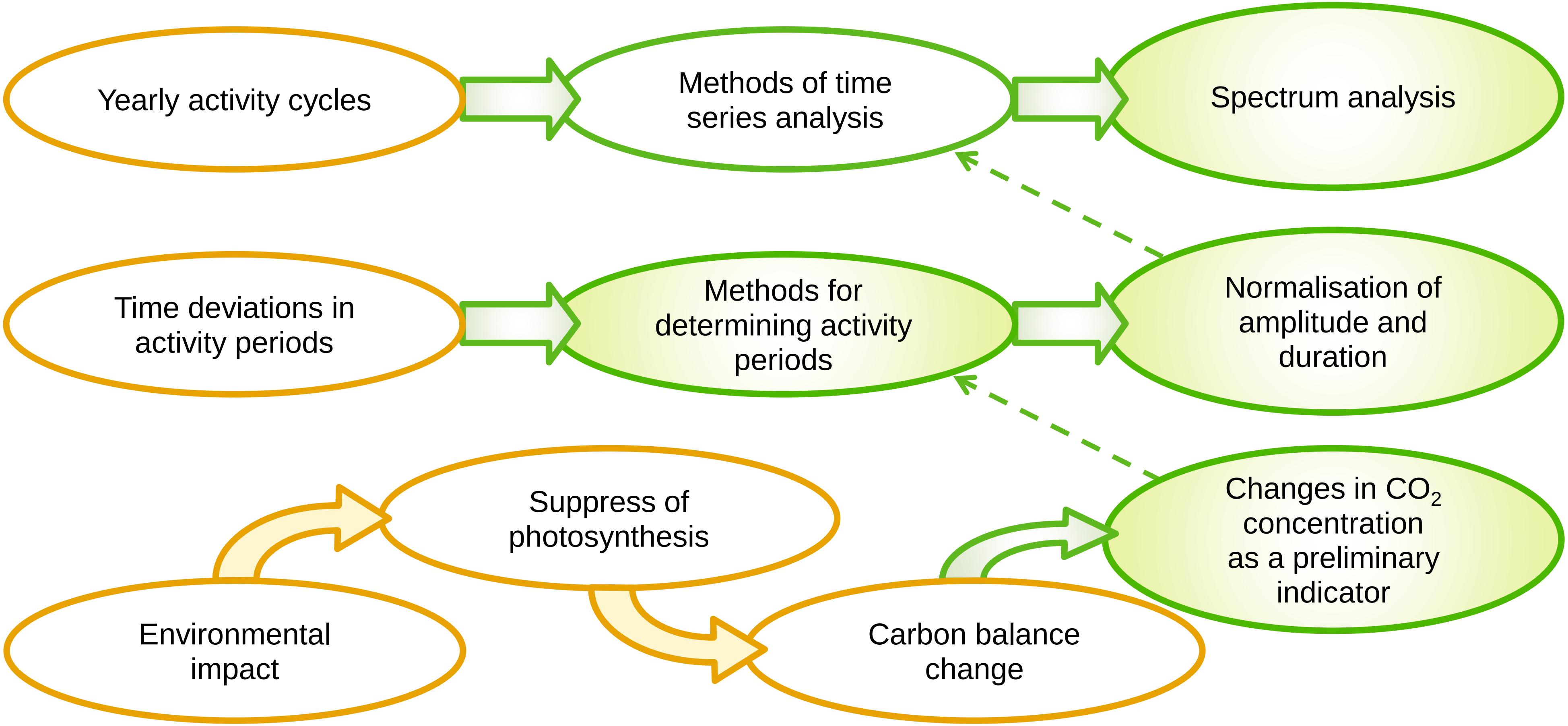


# Workflow for identification of vegetation activity

## An integrated conceptual representation of photosynthetic activity magnitude and duration



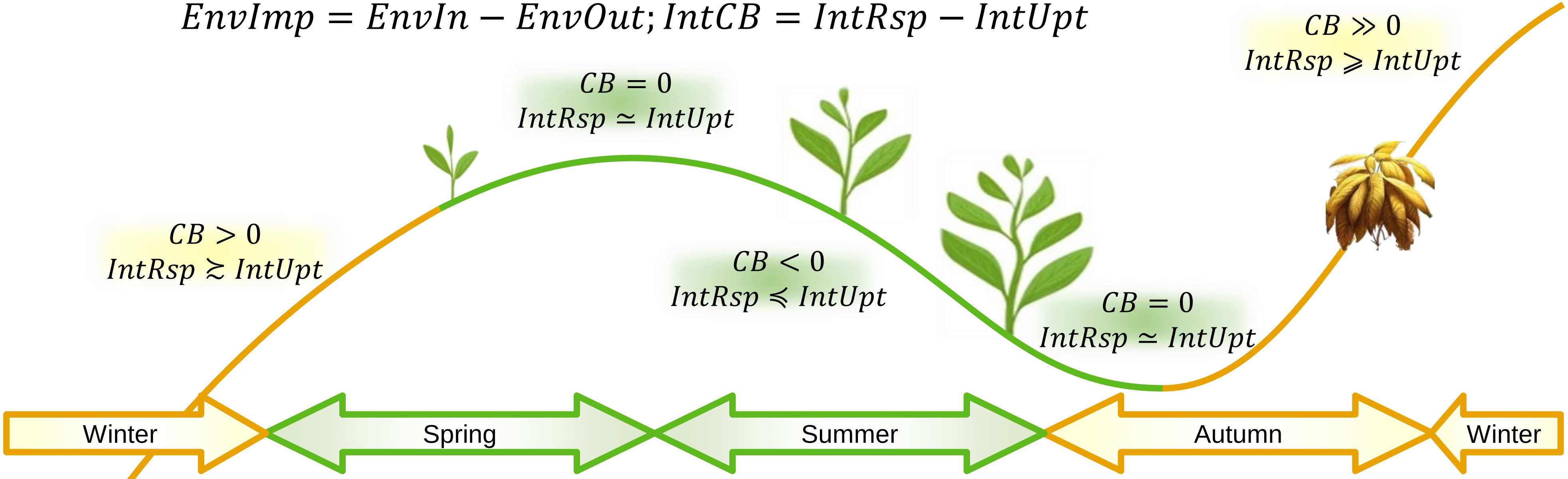
# Workflow for identification of vegetation activity

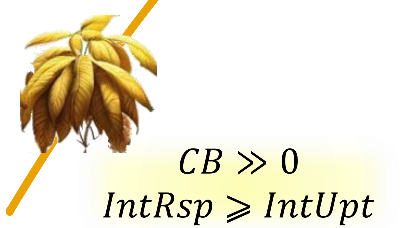


# Seasonal variations in ecosystem carbon balance (CB)

$$CB = EnvImp + IntCB$$

$$EnvImp = EnvIn - EnvOut; IntCB = IntRsp - IntUpt$$

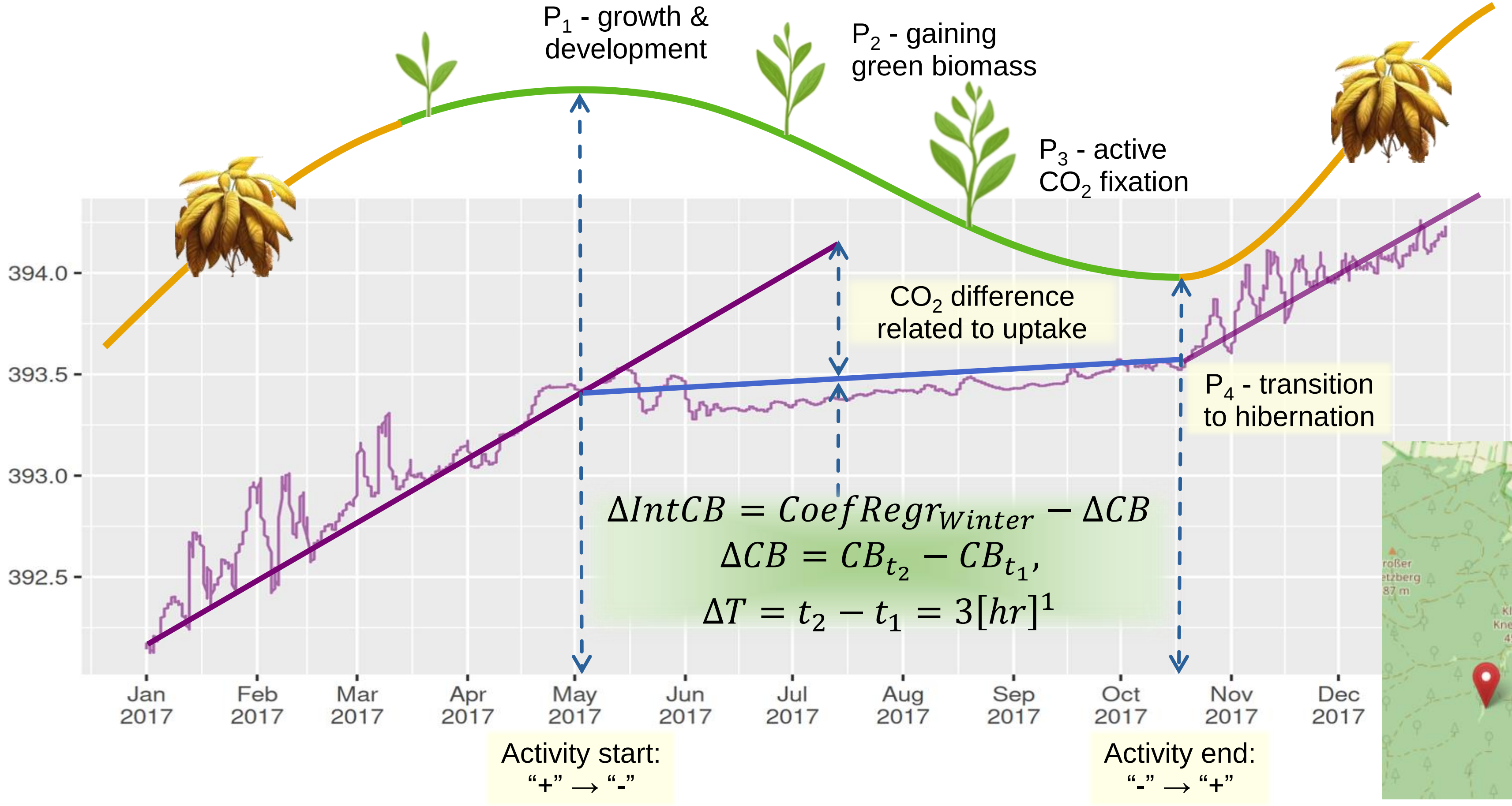



Components of external "Environmental" impacts (***EnvImp***) - carbon which is coming from (***EnvIn***) and is going to (***EnvOut***) the external environment.

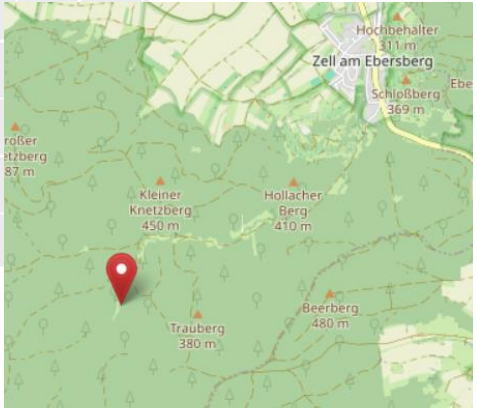
Components of the internal ecosystem's carbon balance ***IntCB*** are internal uptake - ***IntUpt*** and respiration - ***IntRsp***

# Identification of vegetation activity periods




$$\Delta IntCB = CoefRegr_{Winter} - \Delta CB$$
$$\Delta CB = CB_{t_2} - CB_{t_1},$$
$$\Delta T = t_2 - t_1 = 3[hr]^1$$

*NH non-evergreen forest*
*LC: Deciduous broadleaved*
*lon: 10.53082*
*lat: 49.94474*
*(near Zell am Ebersberg, Landkreis Haßberge, DE)*




[1]CAMS global inversion-optimised greenhouse gas fluxes and concentrations

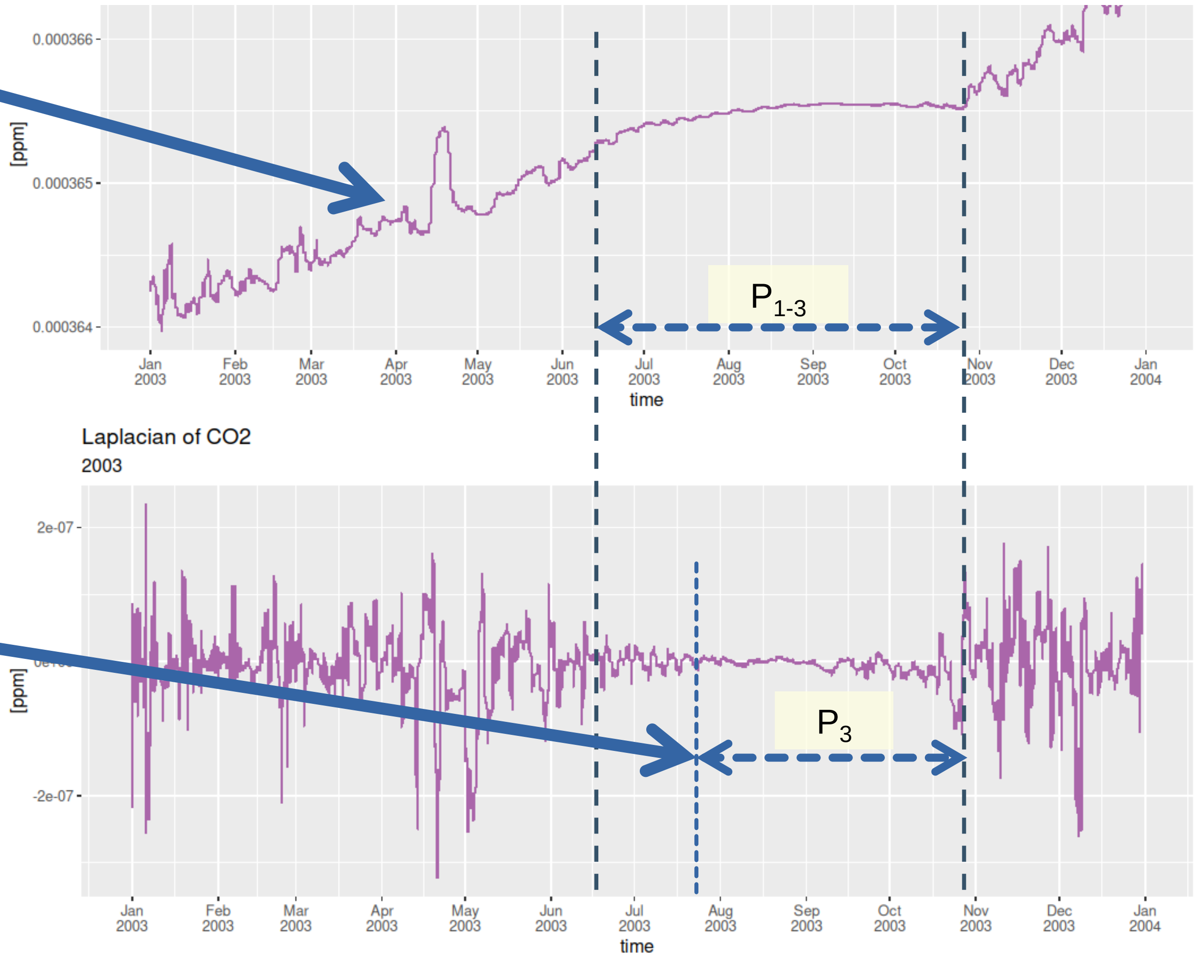
https://www.openstreetmap.org/search?lat=49.96552&lon=10.56305&zoom=15#map=15/49.96549/10.56305

# Identification of vegetation activity periods

- $CO_2$ concentration[1] reflects both external and internal changes in ecosystem carbon balance, while the $CO_2$ Laplacian primarily captures internal dynamics

- Active $CO_2$ uptake by vegetation corresponds to a decrease in the Laplacian (negative regression coefficient)

- $CO_2$ fixation start identified when both regression signs - the $CO_2$ concentration and the Laplacian become negative




[1] CAMS global inversion-optimised greenhouse gas fluxes and concentrations

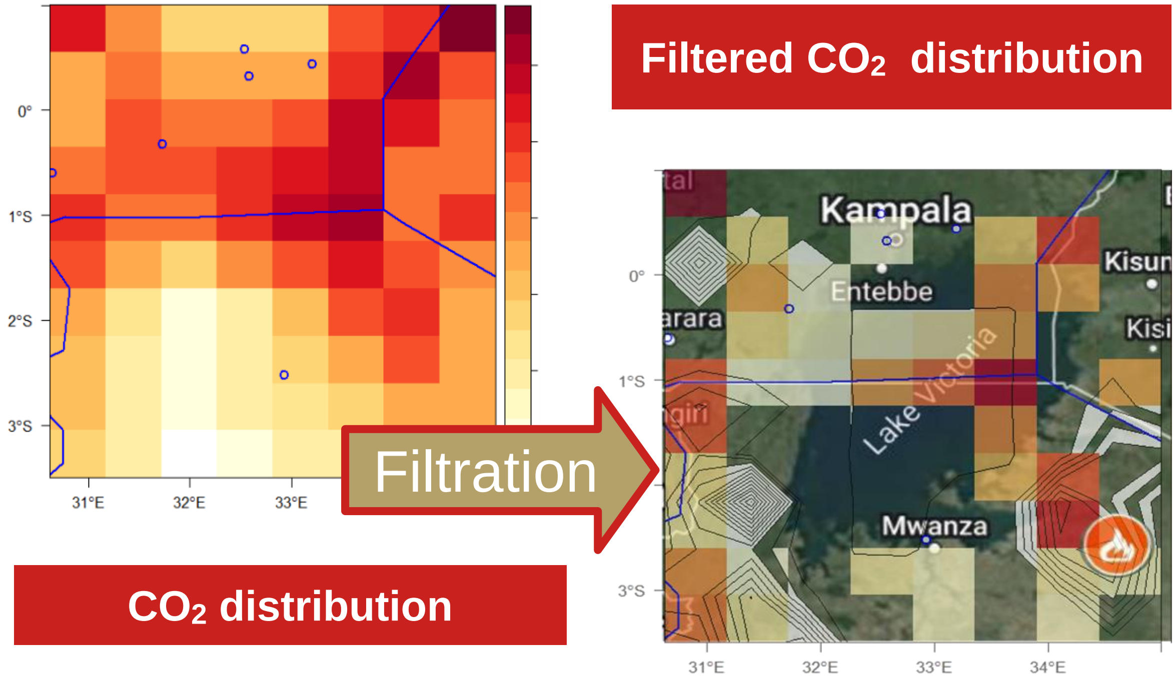
# Digital filtration with Laplacian filter

$$F(CB)=\sum_{i=1}^{i=8}\left(CB_0-CB_i\right)\Rightarrow\nabla(CB)=\begin{vmatrix}-1 & -1 & -1\\ -1 & 8 & -1\\ -1 & -1 & -1\end{vmatrix};\ CDC_{filtered}=\begin{bmatrix}CDC_4 & CDC_3 & CDC_2\\ CDC_5 & CDC_0 & CDC_1\\ CDC_6 & CDC_7 & CDC_8\end{bmatrix}\times\begin{bmatrix}-1 & -1 & -1\\ -1 & 8 & -1\\ -1 & -1 & -1\end{bmatrix}$$

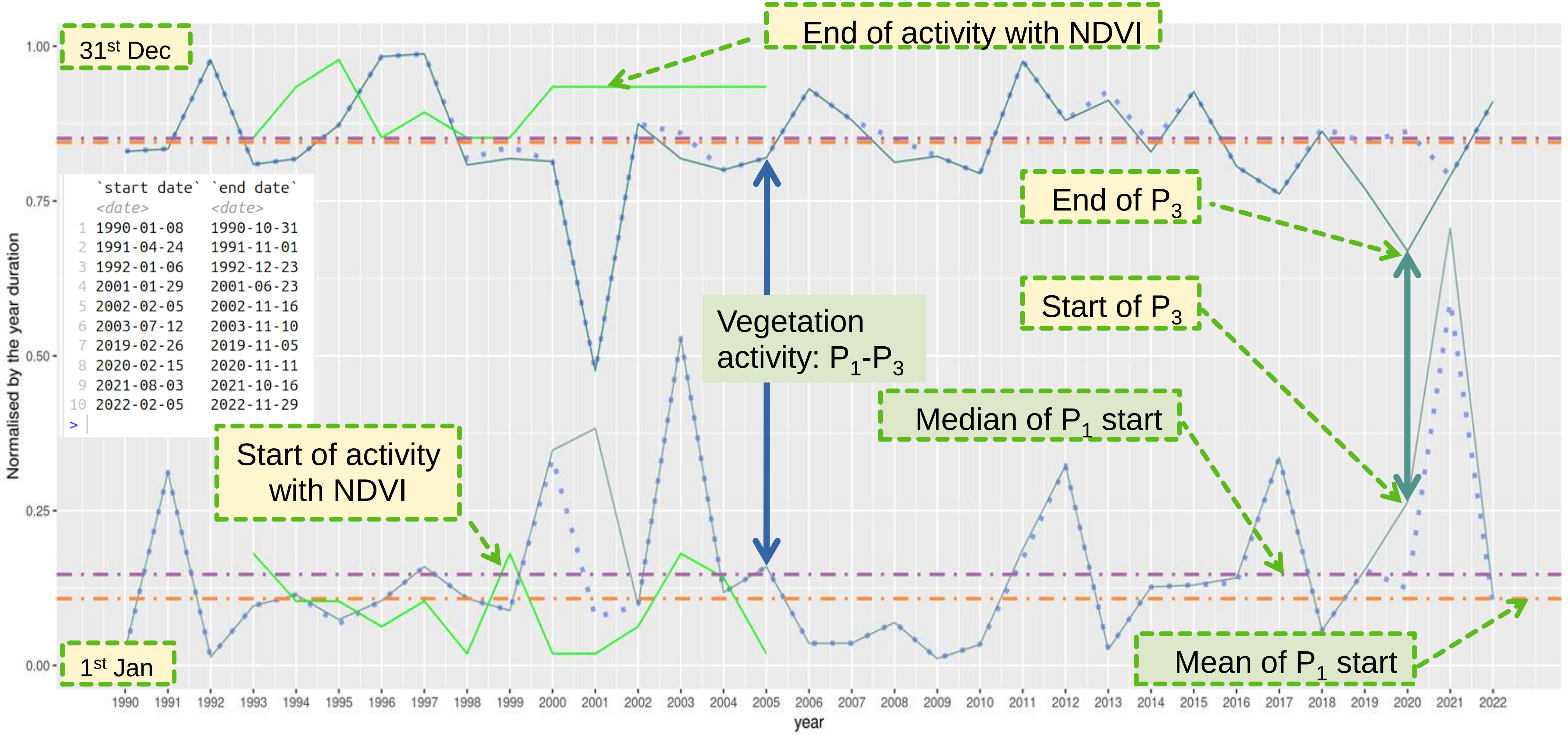
The Laplacian filter detects sudden intensity transitions in the image and highlights the edges.

It convolves an image and acts as a zero-crossing detector that determines the edge pixels.

*Savytska, Y., Smolii, V., and Weitzel, N. Near real-time preliminary detection of carbon dioxide source and sink areas using a Laplacian filter, [Accepted in ESD], 2024.*

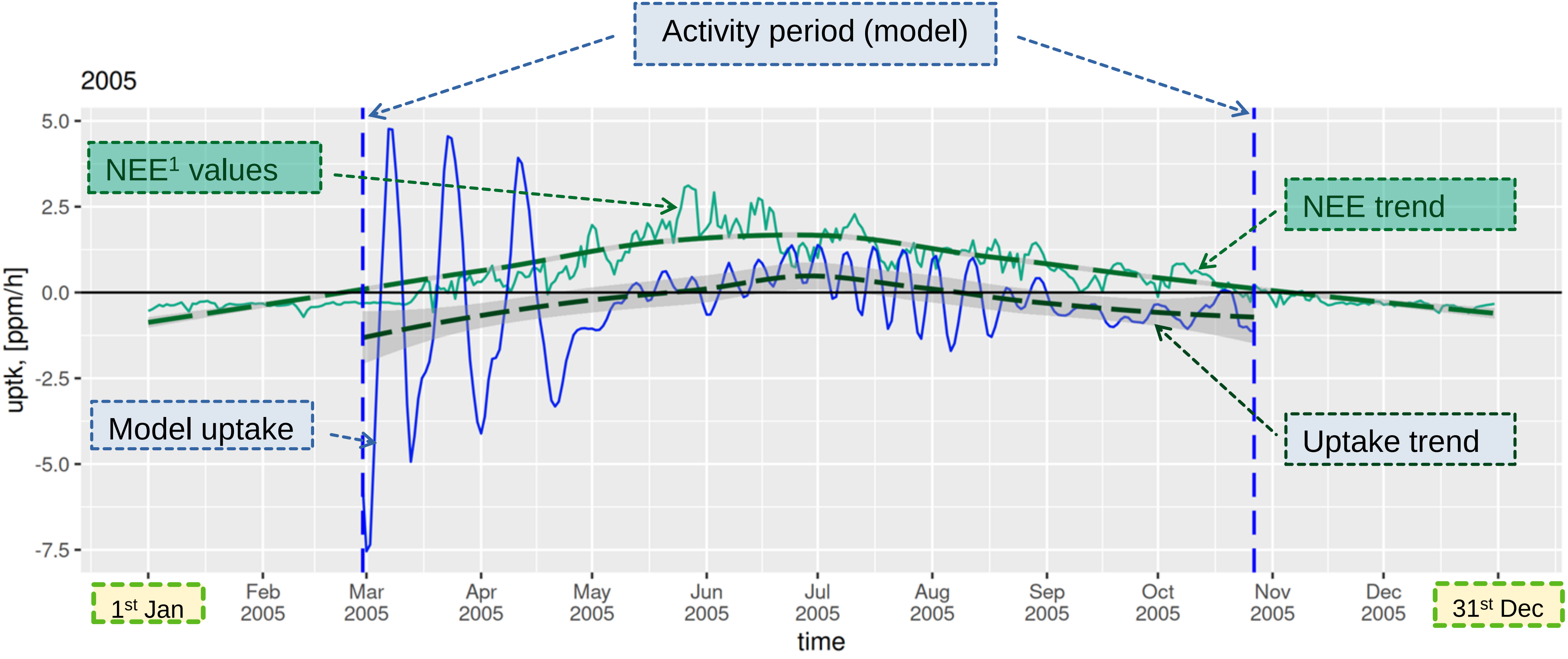


# Identified vegetation activity periods



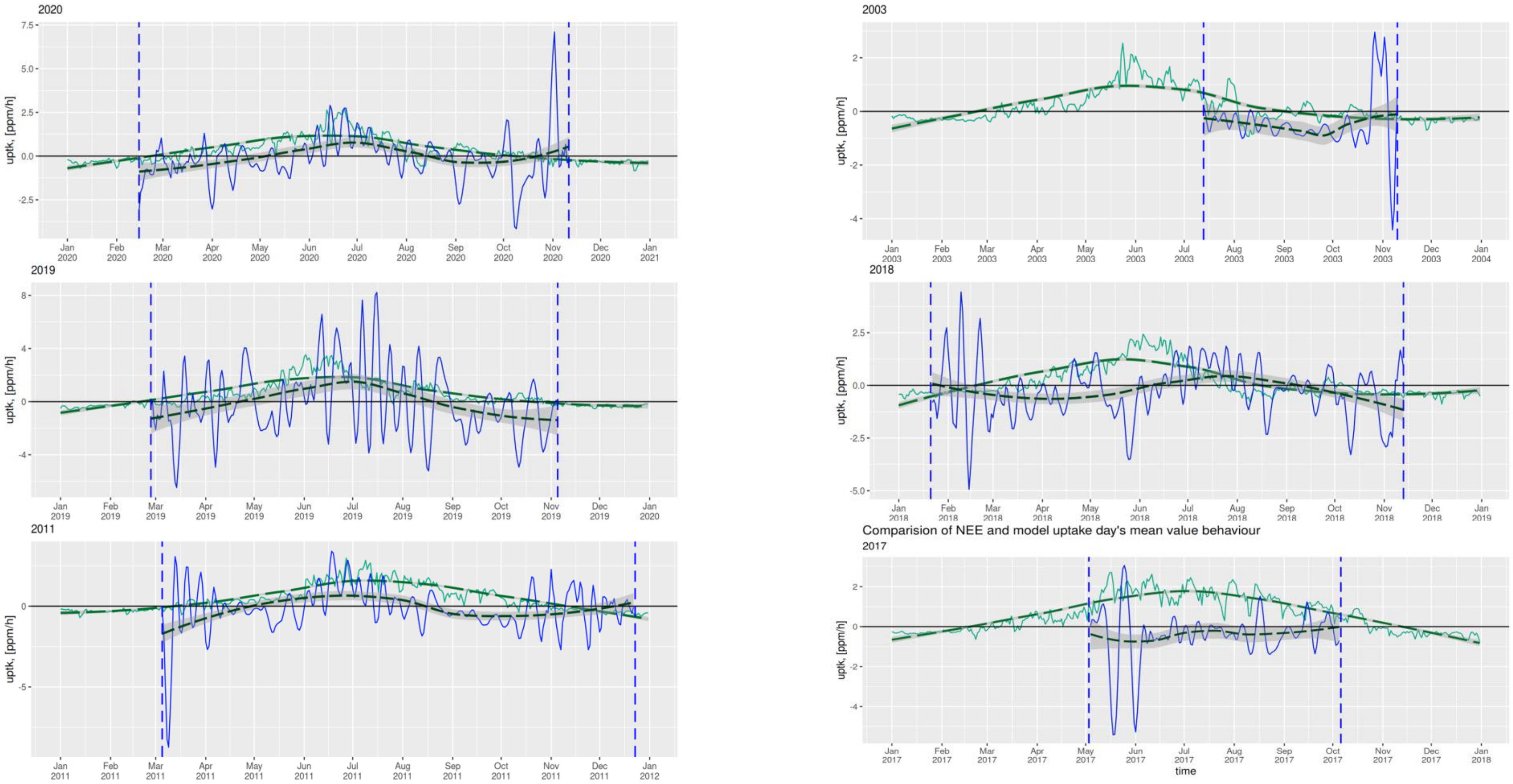

| | `start date` | `end date` |
|---|---|---|
| | <date> | <date> |
| 1 | 1990-01-08 | 1990-10-31 |
| 2 | 1991-04-24 | 1991-11-01 |
| 3 | 1992-01-06 | 1992-12-23 |
| 4 | 2001-01-29 | 2001-06-23 |
| 5 | 2002-02-05 | 2002-11-16 |
| 6 | 2003-07-12 | 2003-11-10 |
| 7 | 2019-02-26 | 2019-11-05 |
| 8 | 2020-02-15 | 2020-11-11 |
| 9 | 2021-08-03 | 2021-10-16 |
| 10 | 2022-02-05 | 2022-11-29 |

# Model validation with net ecosystem exchange (daytime)



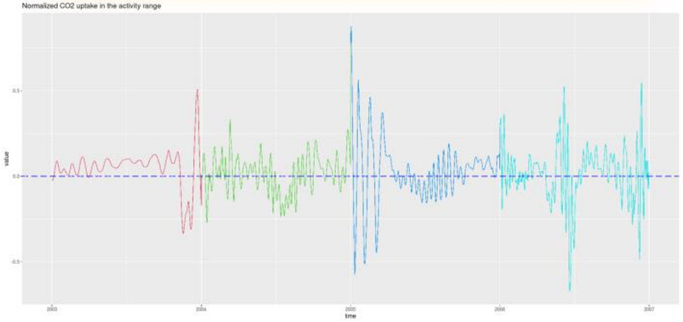

[1] Nelson, J.A., et al., 2023. FLUXCOM-X-BASE. https://doi.org/10.18160/5NZG-JMJE

# Model validation with net ecosystem exchange (daytime)

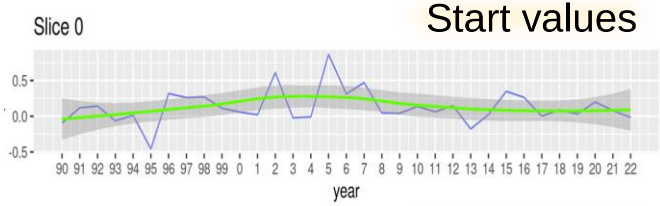


# Normalised uptake data in the time slices

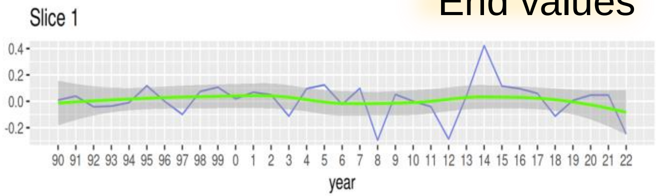
Normalised data of 2003-2006 set



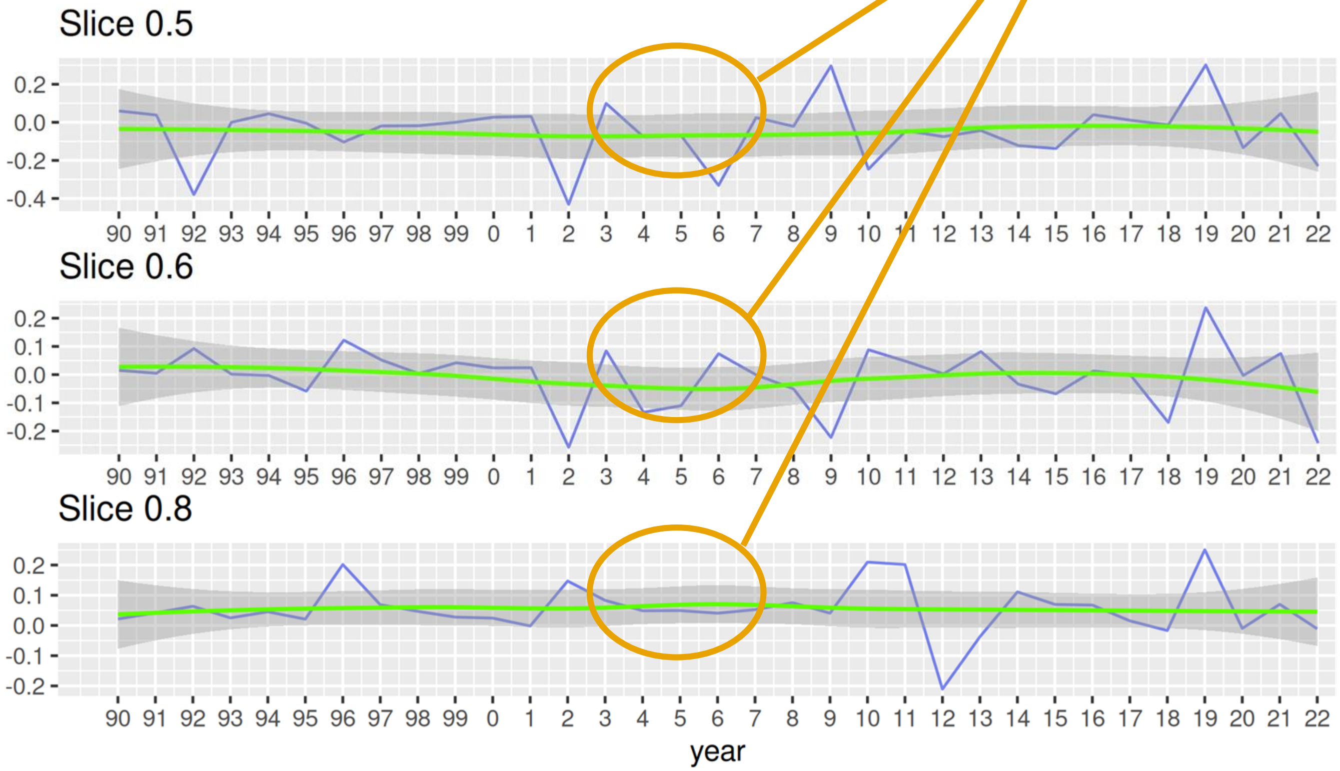

Start values



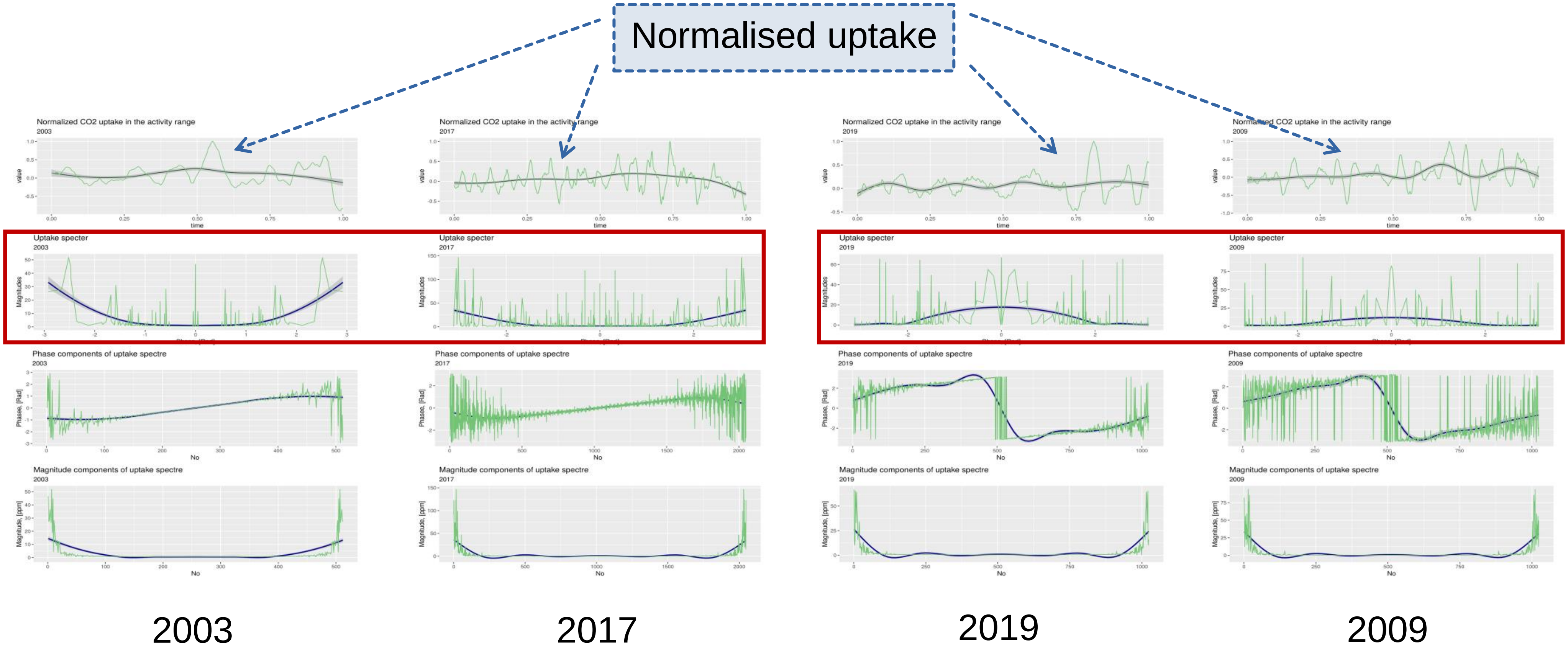

End values



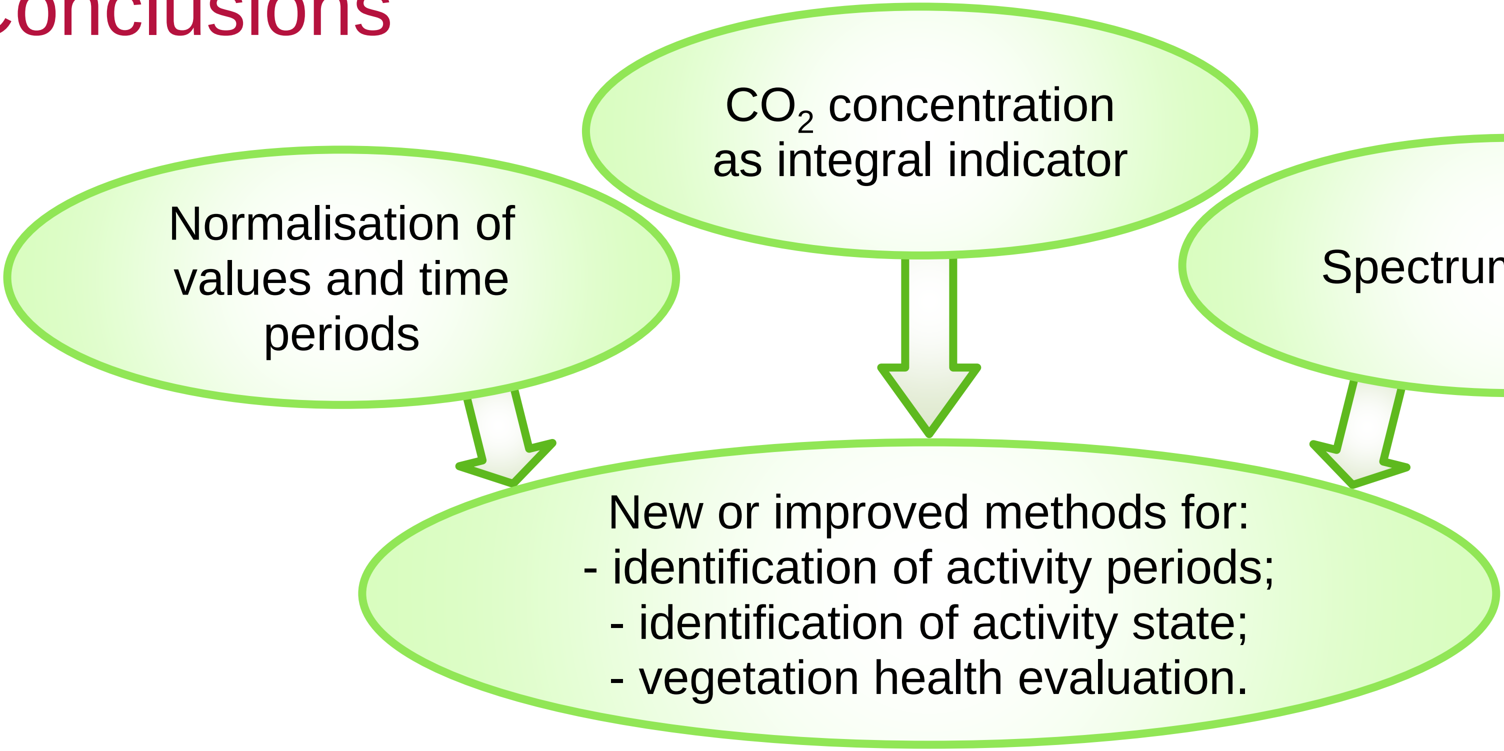




# Spectrum of normalised uptake, U- and n-type



# Conclusions




## To do:

- compare the responses of different vegetation types;
- compare the responses of the same vegetation type at different locations;
- detailed analysis of spectra patterns…

# Outlook

We would like to apply the first presented results and questions at this session for our next step of exploring the ***terrestrial vegetation response to extreme weather events.***

Further discussion could be about the ***methods of vegetation activity identification*** and their improvement under the extreme weather impacts and/or other aspects of climate change with ***digital filtration and spectral analysis of the $CO_2$ signal***.

We will be glad to get feedback and discuss related topics via: ***section link***, ***email link***.

# Acknowledgments

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Alexander von HUMBOLDT STIFTUNG

Philipp Schwartz initiative

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

All analysis is performed:

- R version 4.3.3 (20240229 ucrt) "Angel Food Cake" Copyright (C) 2024
- The R Foundation for Statistical Computing RStudio 2024.12.0+467 "Kousa Dogwood"

bawü.social/spacybawü.social/spacy

bsky.app/profile/past2futureclimate

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