Incorporating nonstructural carbohydrate dynamics in the ISBA biomass allocation scheme

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ISBA

ISBA: vegetation component of Surfex land surface model (Delire et al., 2020)
Coupled simulation of energy, water and carbon exchanges

Prognostic simulation of leaf area index (LAI)

- allows seasonal and spatial variation of vegetation (contrary to climatic LAI)
- feedback between surface fluxes and vegetation are reflected
- requires accurate biomass allocation scheme (BAS)

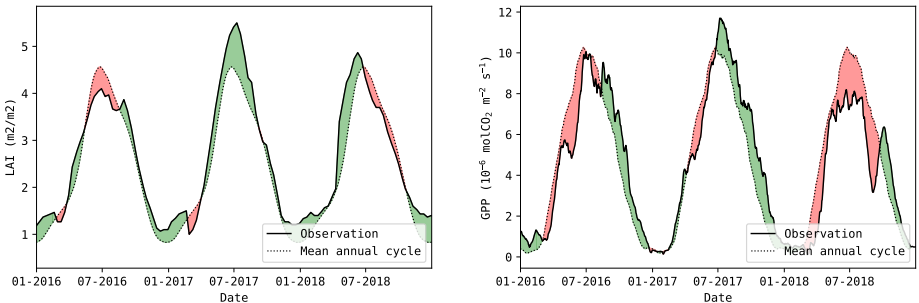


Figure 1: LAI and GPP timeseries in DE-Obe (Evergreen needleleaf forest), highlighted deviation from mean annual cycle

Prognostic LAI in ISBA

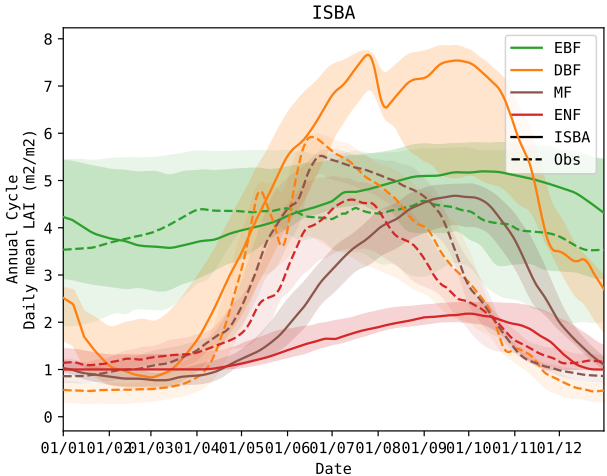
Issues with the prognostic LAI (De Pue et al., 2022)

- Delayed pattern
- Underestimation in spring
- Overestimation in autumn
- Feedback to ET, GPP, ...

Inherent to the BAS architecture

- Decoupled BAS runs, sensitivity tests

Note: *green* LAI

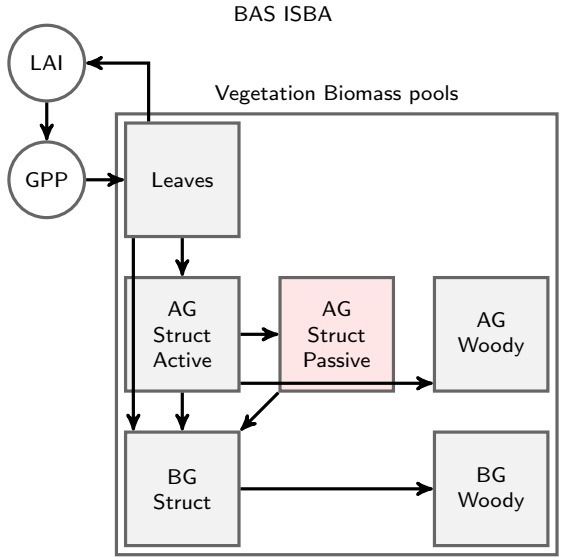


Biomass allocation in ISBA

All assimilated carbon directly to leafs
Trickles down to other biomass pools.

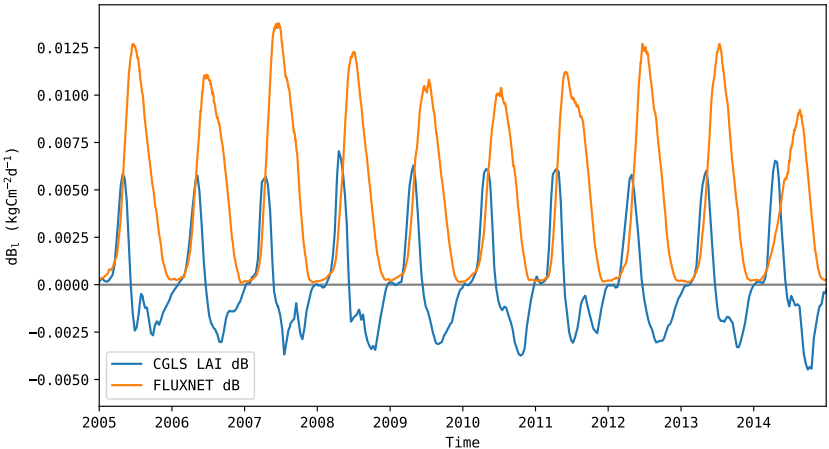
Simple scheme
No complex plant physiology is considered.

Ignores reserve dynamics in growing season.
No functional role of non-structural carbohydrates (NSC)



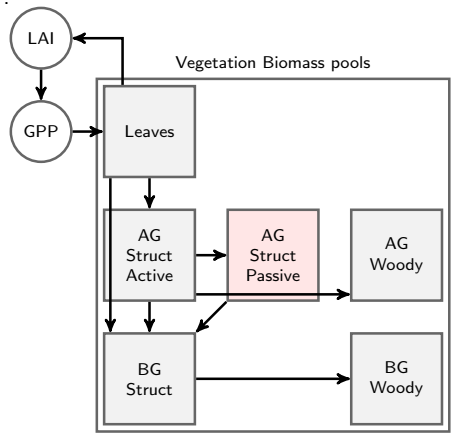
Reserve dynamics

Comparison net leaf biomass change (from RS LAI) vs Biomass from carbon assimiliation (from Eddy Covariance GPP)



BAS revision

- Current scheme: missing nonstructural carbon (NSC) dynamics



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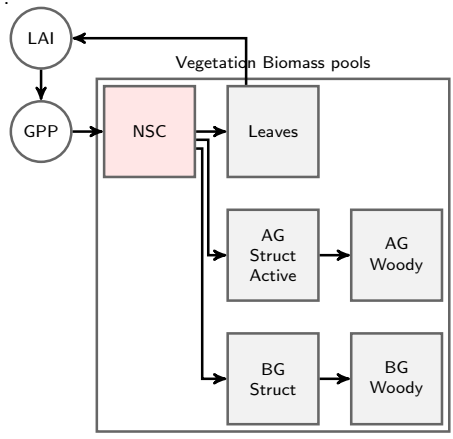

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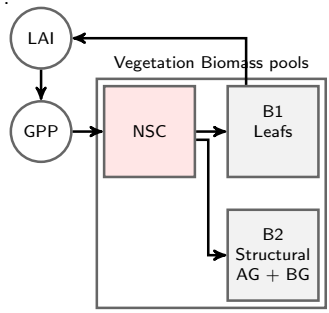

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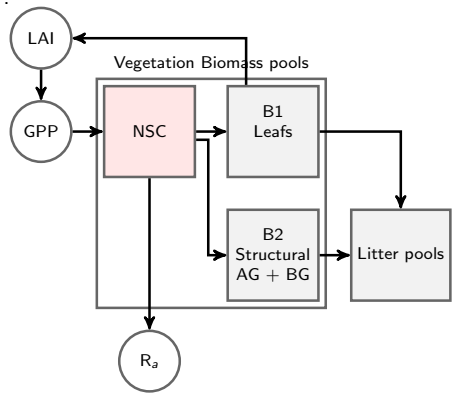
- Link with mortality and respiration



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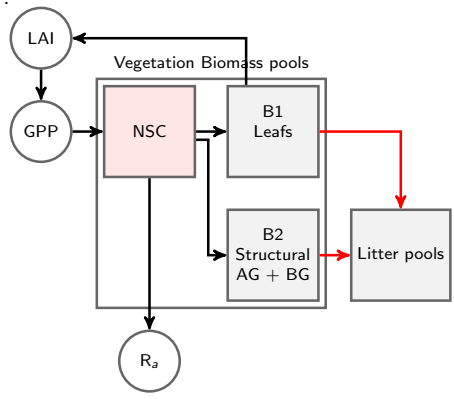

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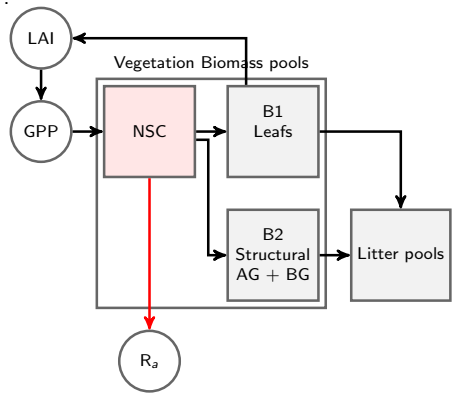

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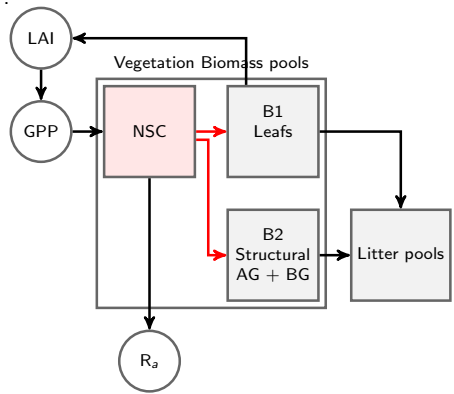

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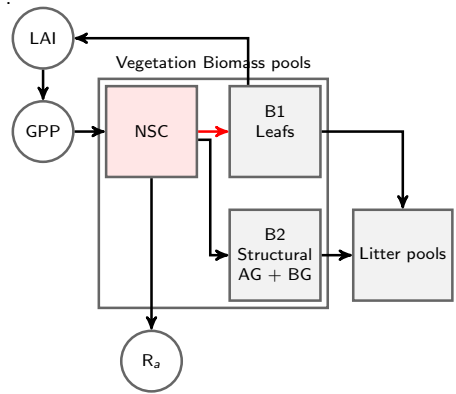


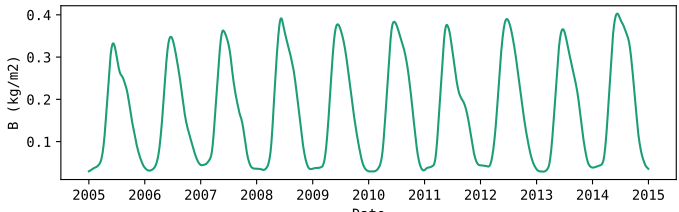
NSC Parametrization strategy
Data from ICOS sites

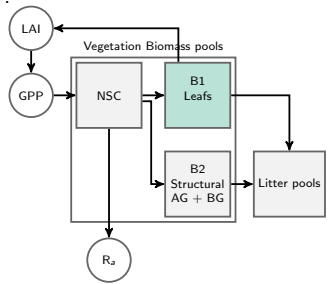
- GPP: eddy covariance observations
- LAI: remote sensing product

Allocation NSC → B2: proportional to GPP
Only missing element:
Allocation of NSC → B1

NSC dynamics at ICOS site

RS LAI to estimate leaf biomass evolution
Green leafs





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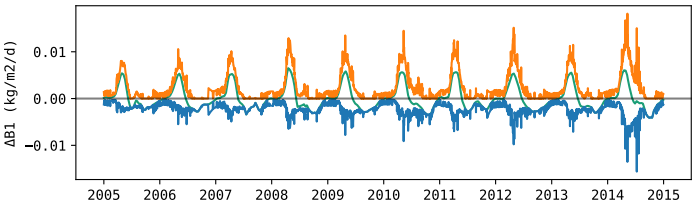
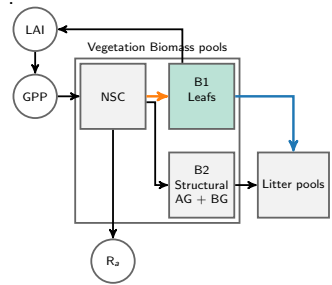
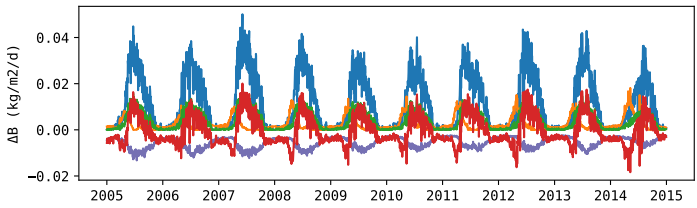
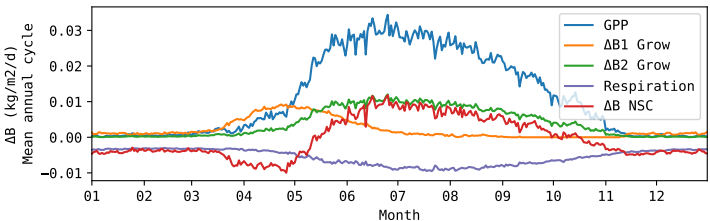


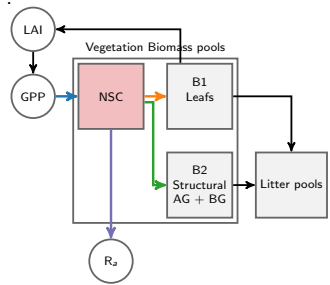


NSC dynamics at ICOS site

Resulting allocation







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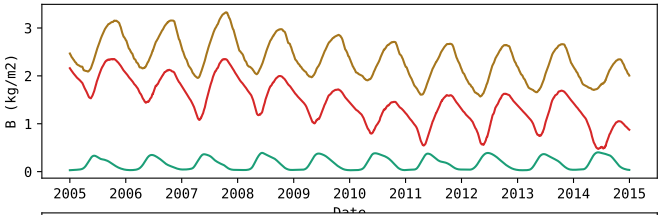
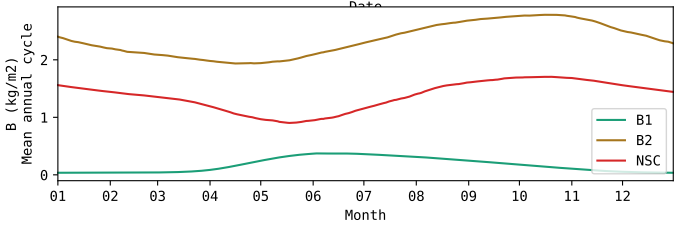
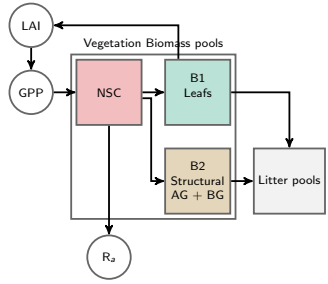
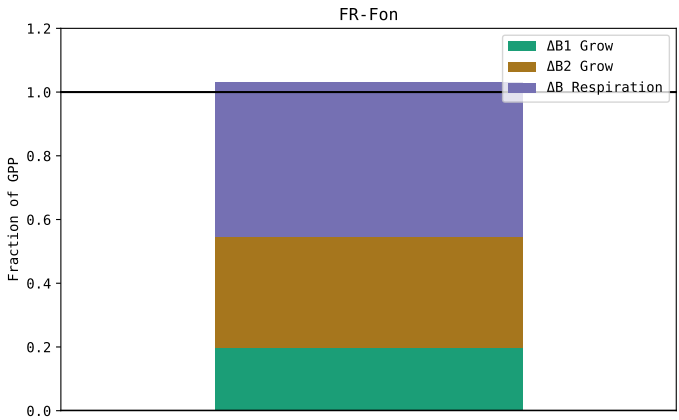


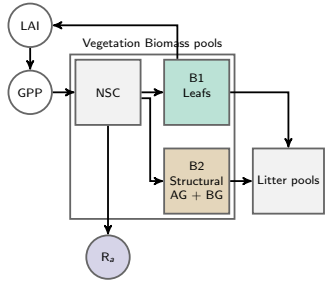




NSC dynamics at ICOS site

Partitioning





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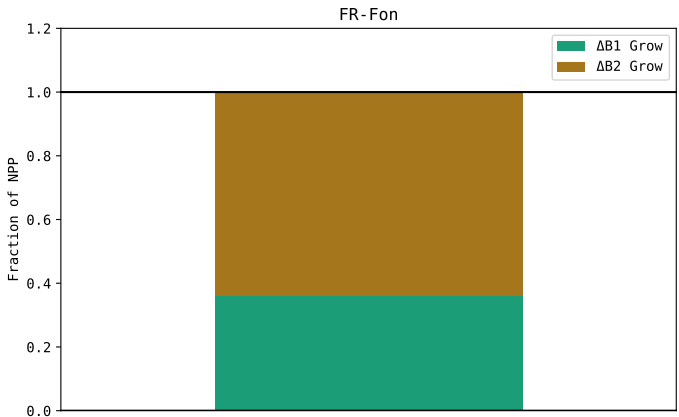
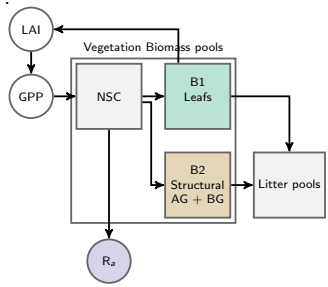




NSC machine learning

Use data from ICOS stations to train & test NSC allocation module
Main drivers of current ISBA BAS:

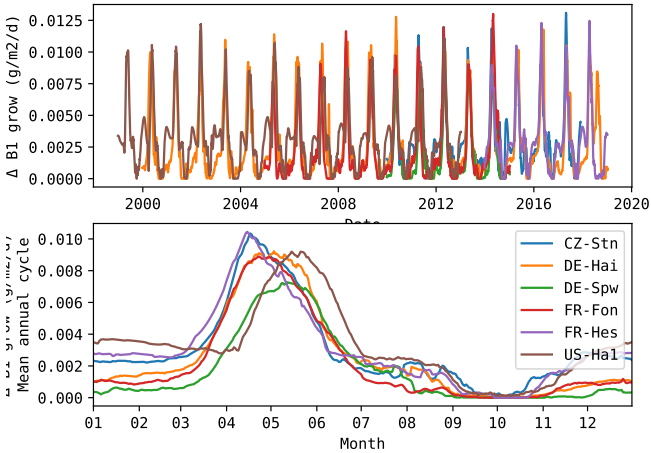
- Daily max and total carbon assimilation rate
- Optimal carbon assimilation rate
- Leaf biomass

Extend this with additional variables (climatology and anomalies):

- Atmospheric forcing (temperature, radiation, vapor pressure, etc.)
- Soil moisture
- Soil temperature
- Running day-degrees
- ...

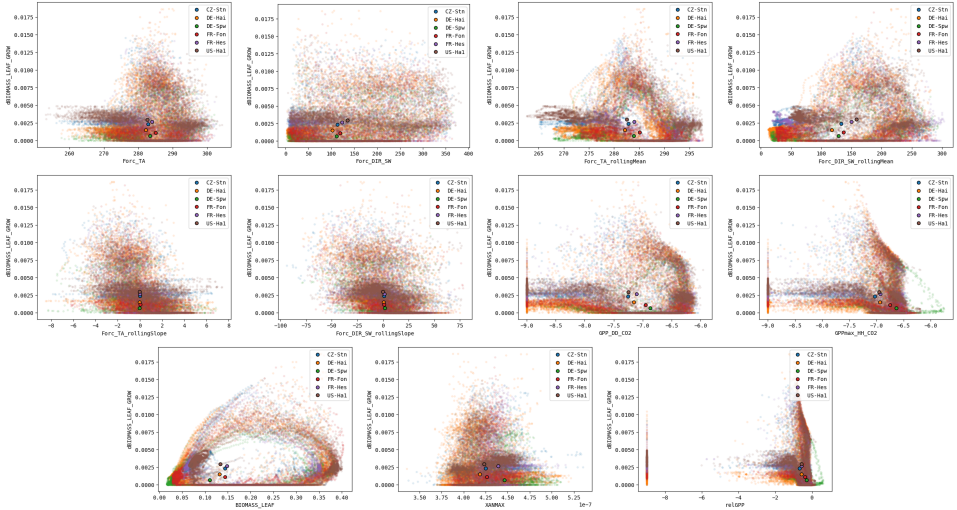
NSC machine learning

NSC dynamics at ICOS sites (DBF sites for illustration)



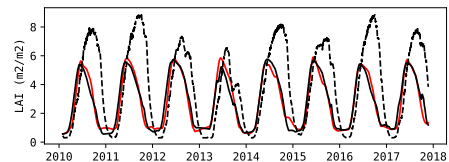
NSC machine learning

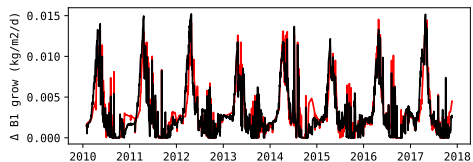
Combine with predictor variables



NSC machine learning

Preliminary results:
LAI at CZ-Stn ICOS station, using random forest trained with data from other DBF stations.





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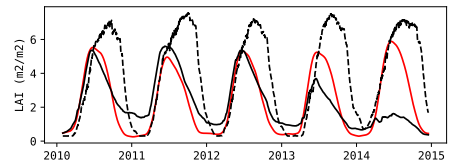

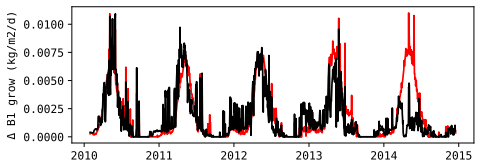

Conclusions

- ISBA BAS needs incorporation of NSC dynamics for accurate prognostic LAI
- Revision proposed, main objective: leaf biomass improvement
- Simplified scheme allows to estimate NSC dynamics from GPP and LAI observations
- Preliminary results show potential of ML to simulate NSC allocation

Open questions

- Realistic NSC biomass pool?
- Applicability accross biomes?
- Ability to model legacy effects in vegetation?
- Large scale, composit understory/canopy
- Specific Leaf Area (SLA)
- Remote sensing LAI quality (impact snow cover)
- Biomass 2: improve allocation (using other data sources)
- Transferability ML trained on obs to model?

Thank you for your attention
Questions?

References I


De Pue, Jan et al. (2022). "Local-scale evaluation of the simulated interactions between energy, water and vegetation in ISBA, ORCHIDEE and a diagnostic model". In: *Biogeosciences* 19.17, pp. 4361–4386.


Delire, Christine et al. (2020). "The global land carbon cycle simulated with ISBA-CTRIP: Improvements over the last decade". In: *Journal of Advances in Modeling Earth Systems* 12.9, e2019MS001886.


McCree, KJ et al. (1970). "An equation for the rate of respiration of white clover grown under controlled conditions.". In: *Prediction and measurement of photosynthetic productivity. Proceedings of the IBP/PP Technical Meeting, Trebon,[Czechoslovakia], 14-21 September, 1969*. Wageningen: PUDOC.