VERIFY General Assembly

WP3 - Co-responsibles

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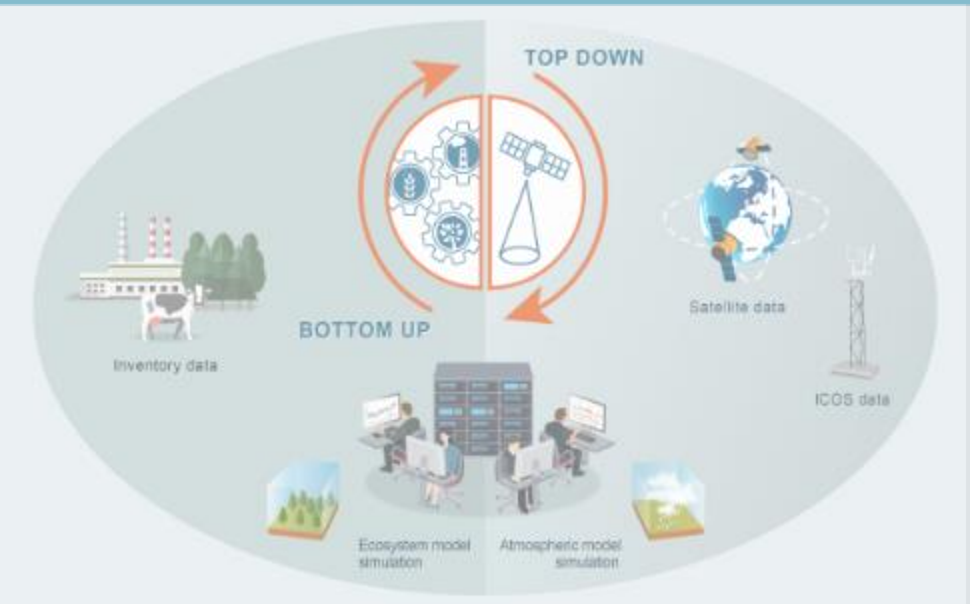
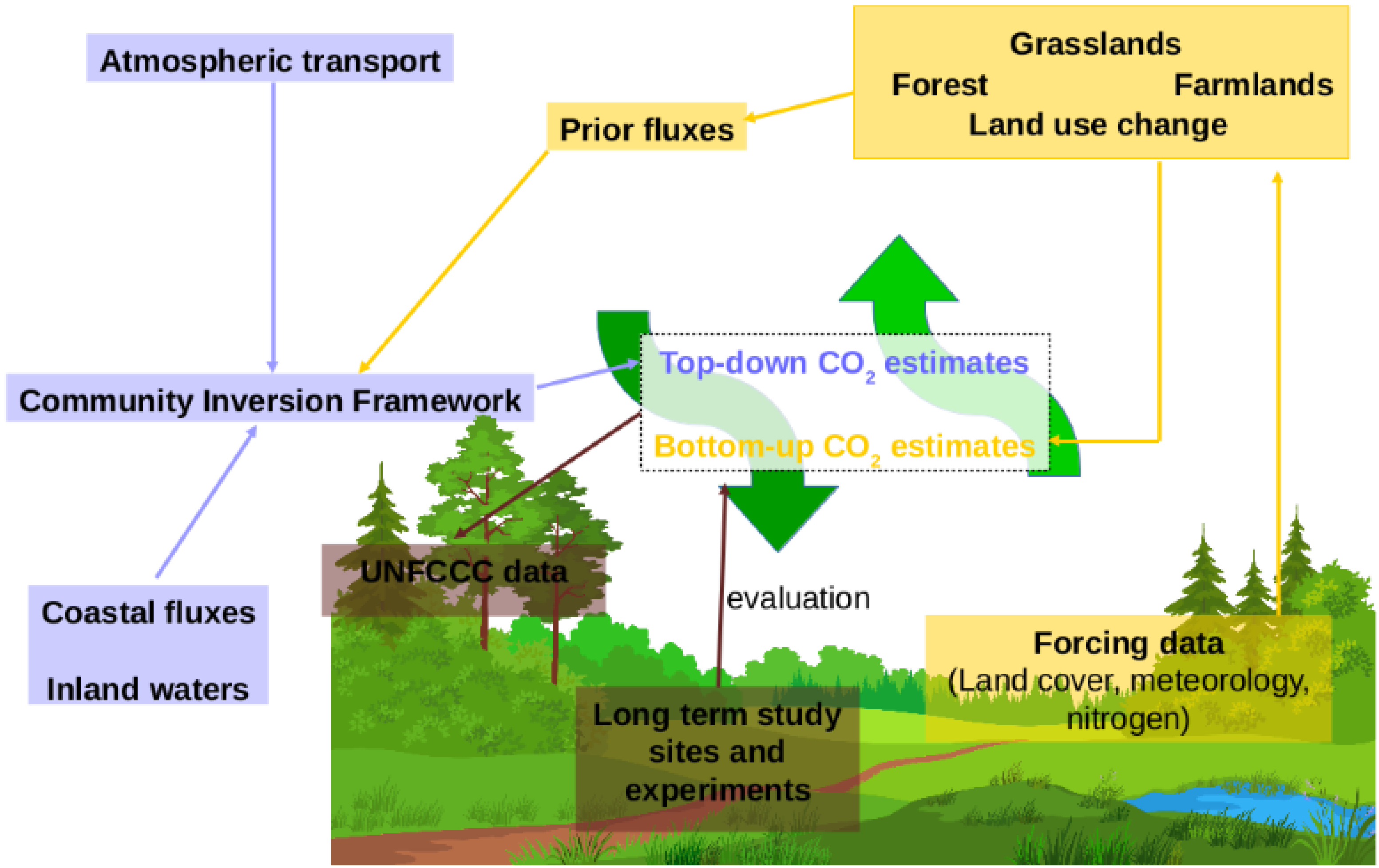
May 9th -11th , 2022



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776810

WP3 “CO2 land Pre-operational system”

Pre-operational system for CO_2 fluxes from terrestrial ecosystems



WP3 – MAIN TASKS !

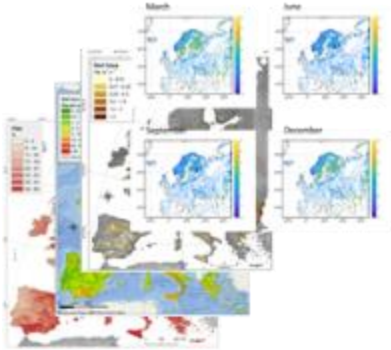
- T3.1: State-of-the-art Driving & Evaluation datasets
- T3.2: Bottom-up budget of terrestrial CO2 fluxes using a few complementary models (statistical or process-based).
- T3.3: Europe-wide Inversions of NEE using in situ & satellite CO2 data and high-resolution transport models.
- T3.4: Develop new multi-data model fusion strategies to investigate CO2 budgets and trends;
  ⇒ Specific focus on Eastern Europe.

WP3-Toward operationalisation

Modeling system consolidation

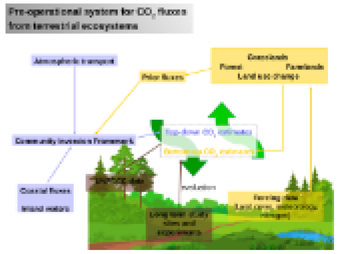
T3.1

Preparation of forcing
- Meteo forcing
- Land cover
- Atmospheric CO2
- Soil



T3.2

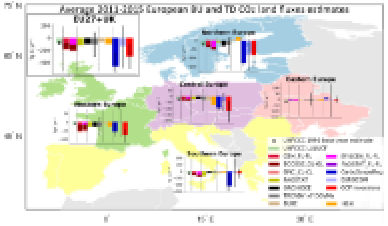
Running Bottom-up models
- process-based
- data-driven



T3.3

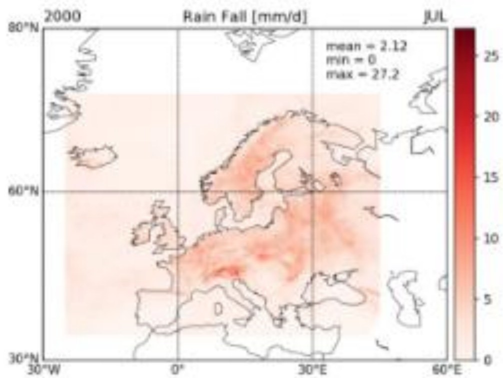
Running Top-down models
- CSR
- CIF

T3.4



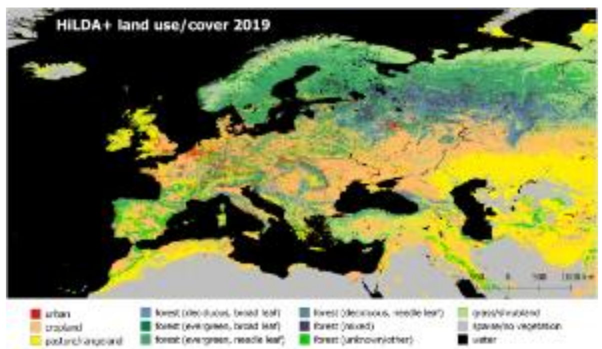
WP3-Key input data sets for ecosystem models

High Res. Meteorology



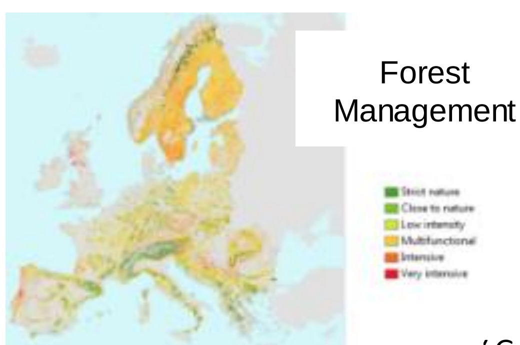
- Now based on ERA-5land
- Around 11 km resolution
- Biased corrected with CRU monthly data (Prec, Temp.,..)

Land Cover (HILDA+)



- Mix several data sets (CCI, FAO, CORINE,...)
- Covers 1900 - 2019
- 1 km resolution ; yearly

Ecosystem management data

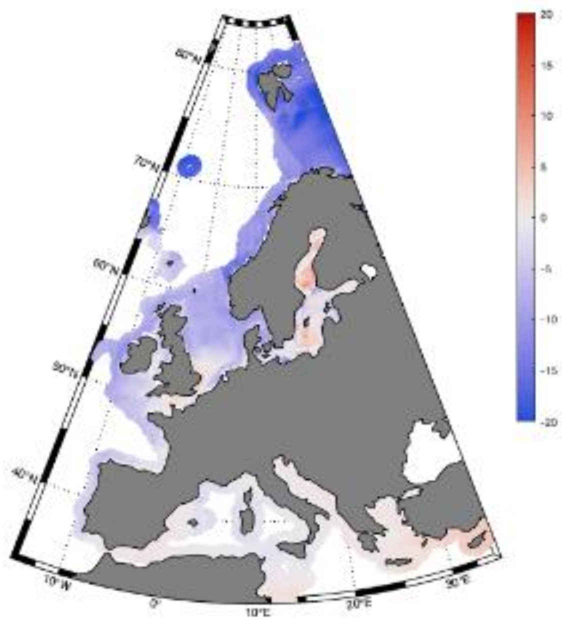


- Forest management
- N deposition, N fertilisation
- Crop management data
- …..

WP3-New input data sets for Inversions

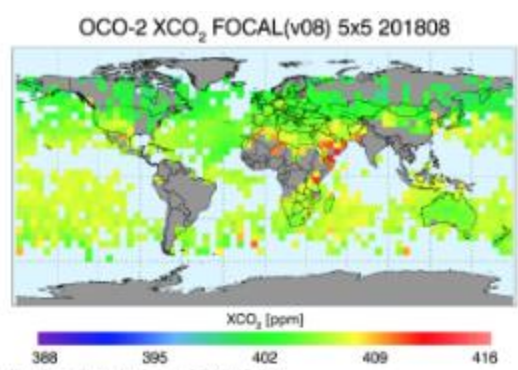
Coastal ocean fluxes

Air-Sea CO_2 Flux / gC m^{-2} yr^{-1}



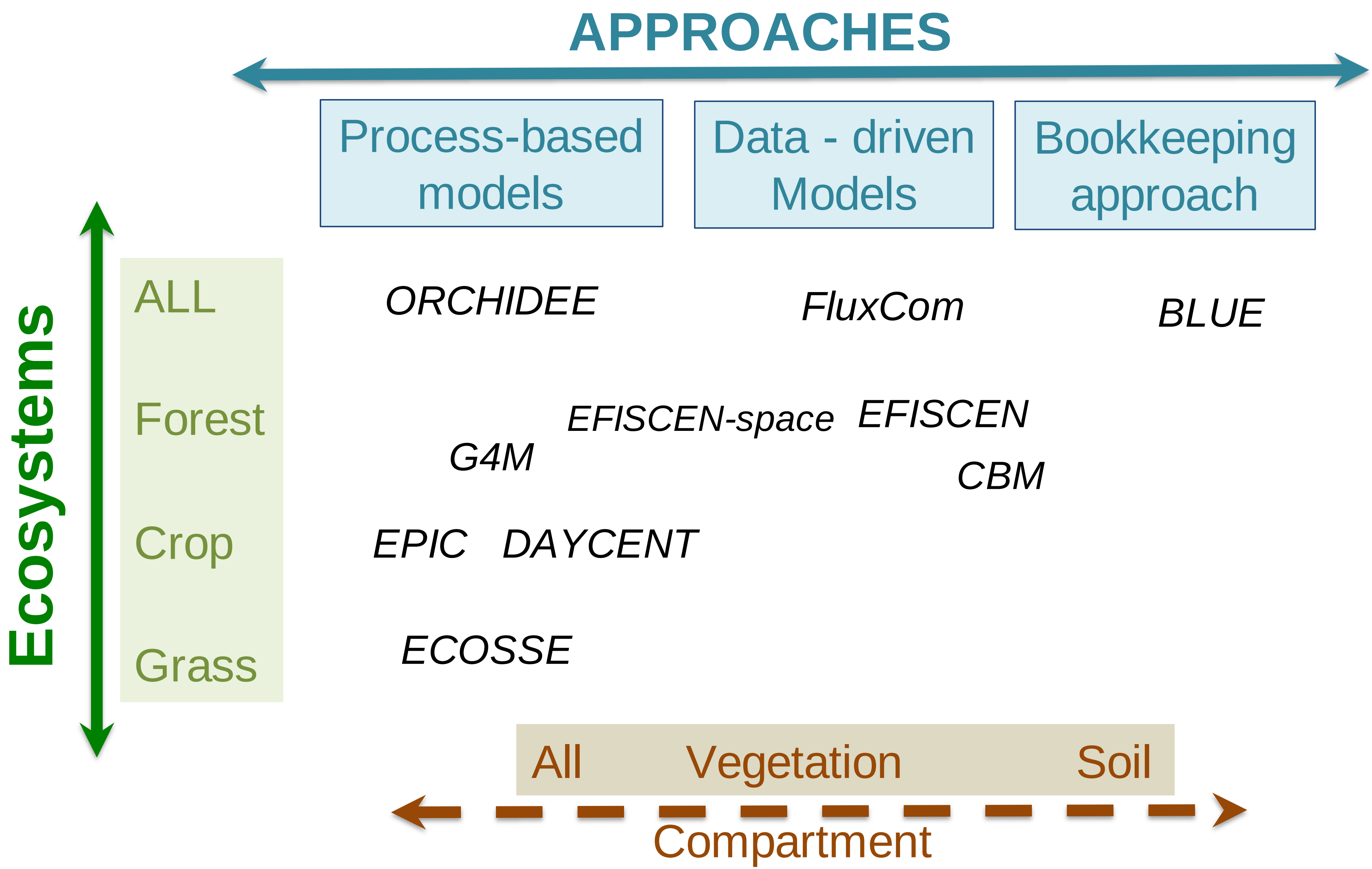
- ➢ Data driven approach (pCO2) using a Random Forest
- ➢ Predictors: Temp, Chlorophyll, Mix Layer depth, ice,
- ➢ Sinks:
  - ○ North, Central North, Baltic
- ➢ Sources
  - ○ South, Baltic, Mediterranee

XCO2 atm. data : Ground-based & Satellite



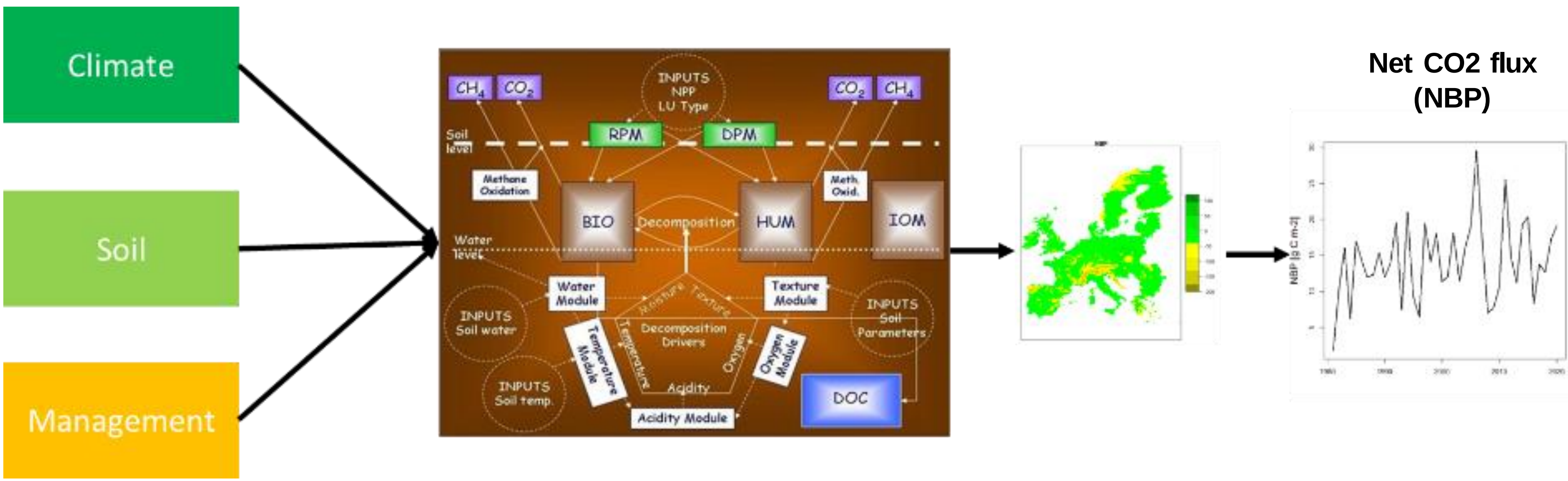
- ➢ Several campaign in Russia (FTIR) used to calibrate OCO-2 - XCO2 retrievals
- ➢ To be used by the inversions

WP3 – BOTTOM-UP BUDGEST OF CO_2 FLUXES



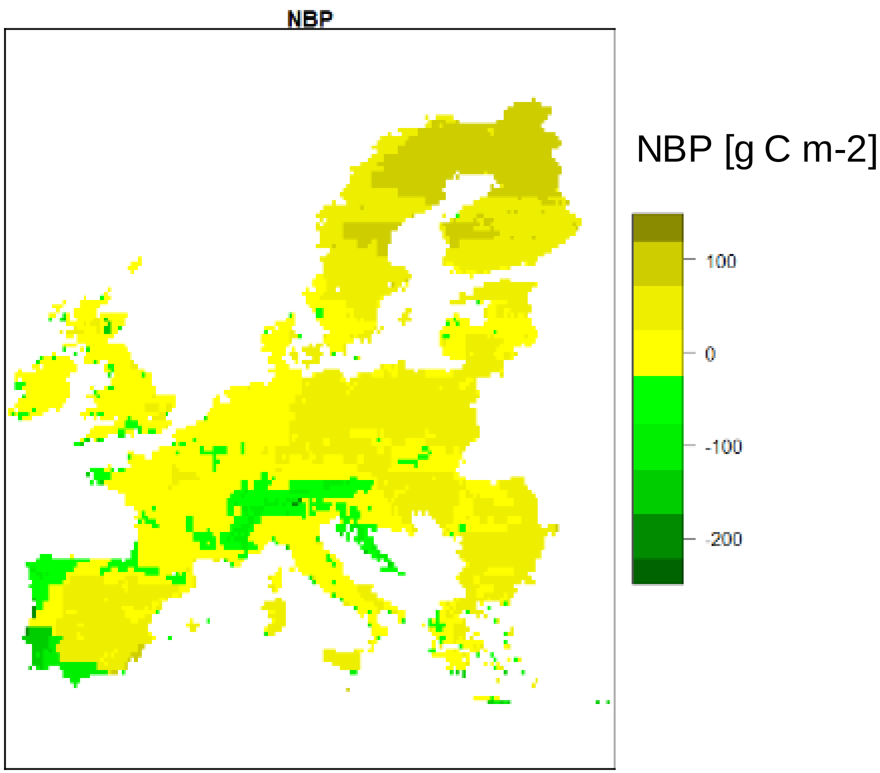
WP3 – GRASSLAND / CROPLAND

Set up of a bottom-up model approach
Example: ECOSSE model

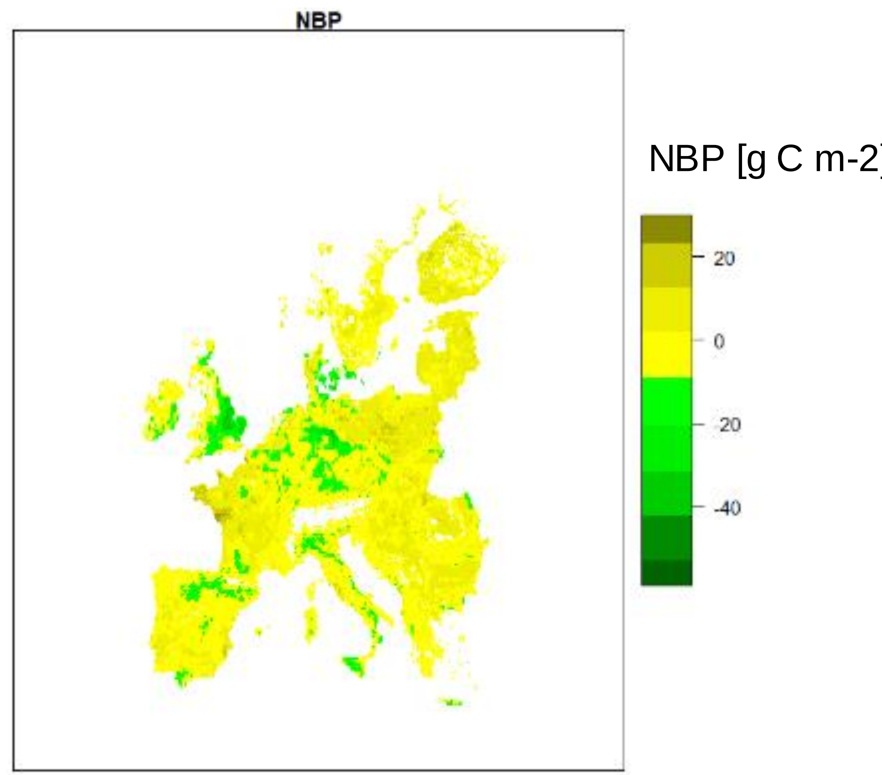


WP3 – GRASSLAND / CROPLAND

ECOSSE - NBP (Crop)

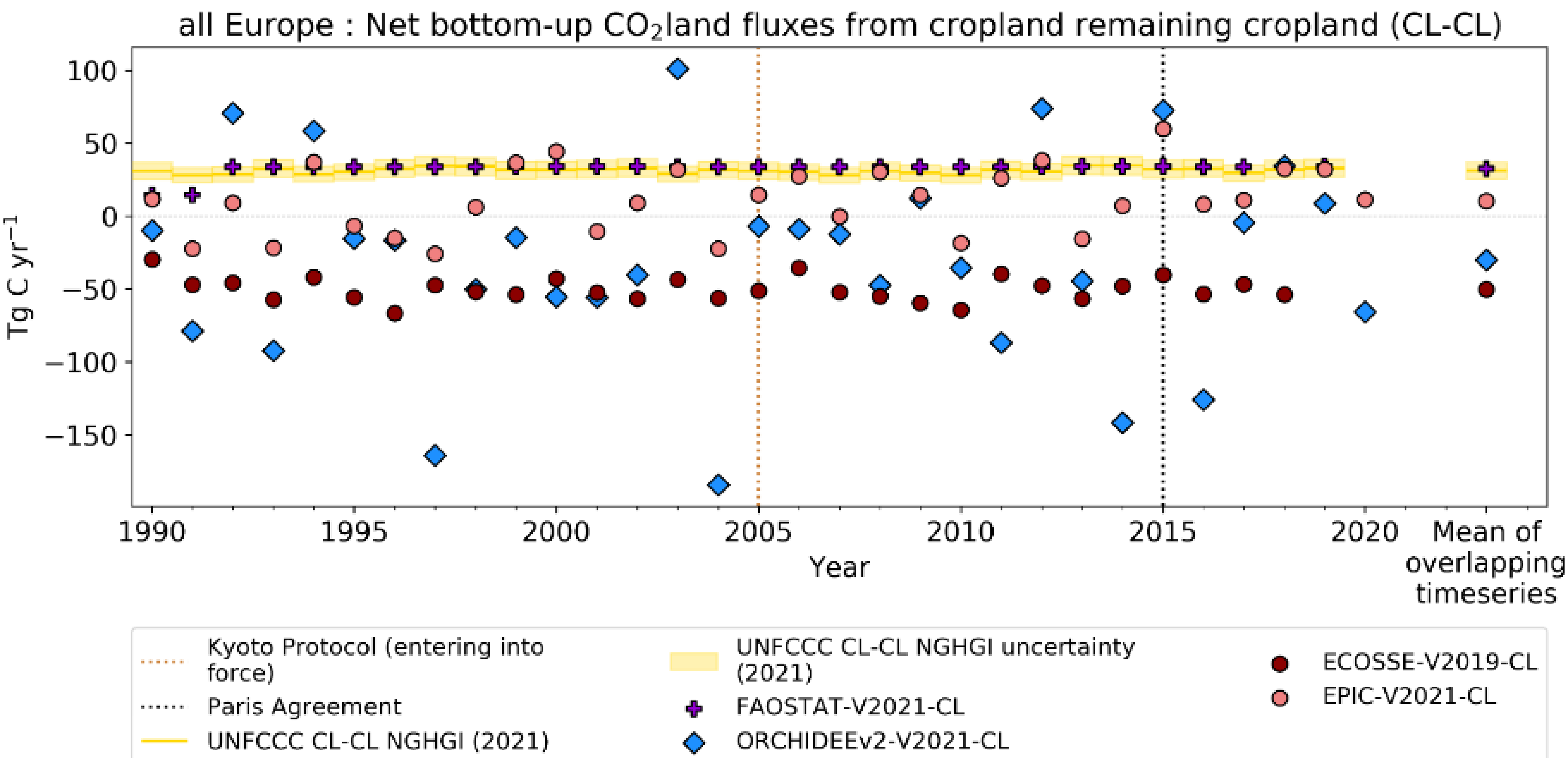


EPIC - NBP (Crop)

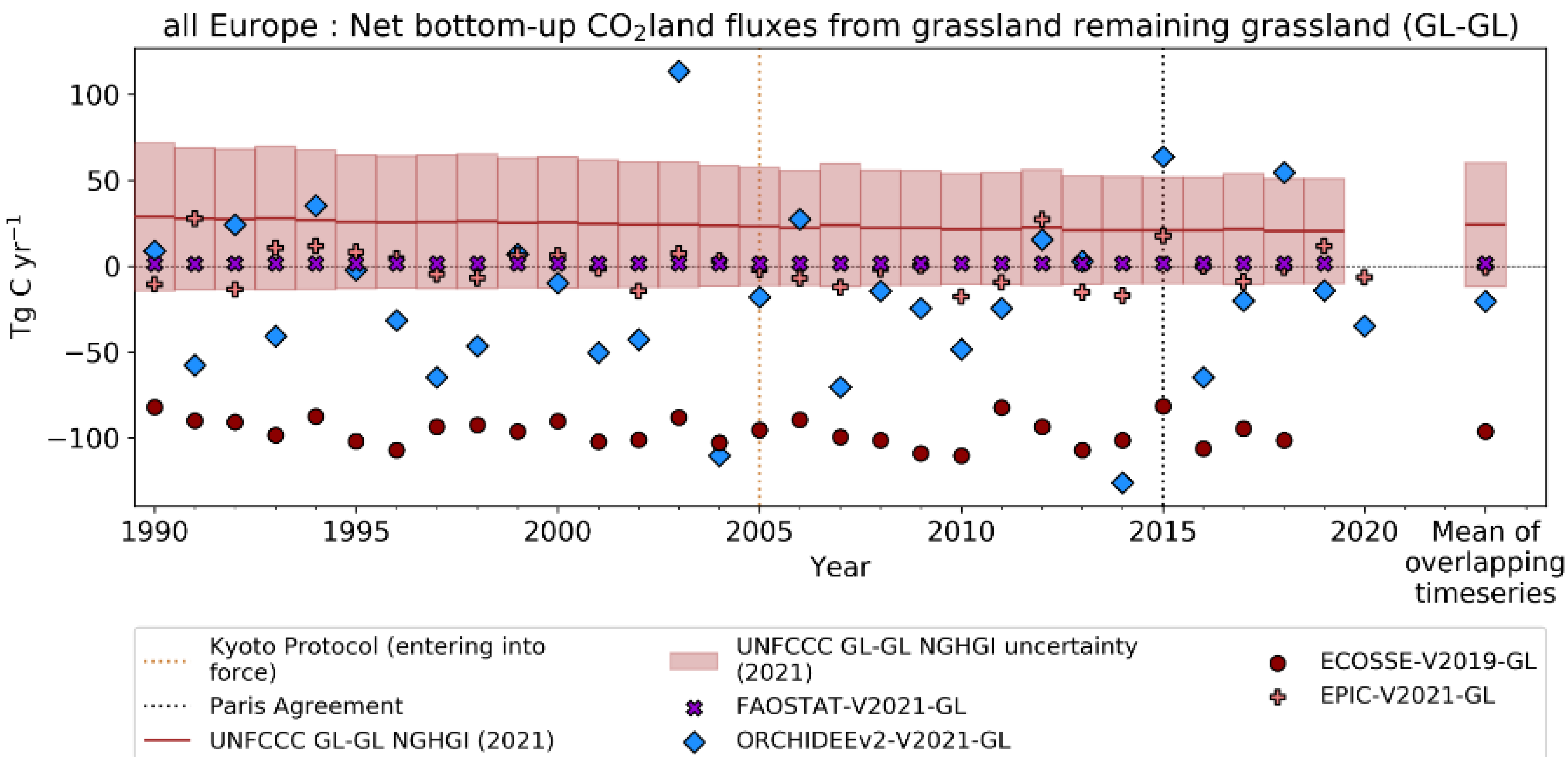


⇒ Spatial differences between the models !

WP3 – GRASSLAND / CROPLAND



WP3 – GRASSLAND / CROPLAND



WP3 – GRASSLAND / CROPLAND

Conclusions

- ➢ Process based models provide additional information about the distribution of the fluxes
- ➢ The process-based models show a higher variability
- ➢ There is a higher data demand and increased uncertainty (better information about management is required)
- ➢ The models estimate lower C fluxes (stronger sink) (compared to UNFCCC and FAOSTATS)

Bottom up high-resolution forest carbon assessment

presented by Sara Filipek (WEnR)

Contributors:
Mart-Jan Schelhaas
Bas Lerink
Gert-Jan Nabuurs

WP3 – FOREST ECOSYSTEMS

EFISCEN-Space model

- High-resolution model
- European forest resources simulator
- Empirically based (tree-wise observations from NFIs) – currently 15 countries
- Uses climate sensitive growth functions
- Harvest patterns derived from repeated NFI observations
- Coupled with Yasso15 mineral soil model

Outputs:

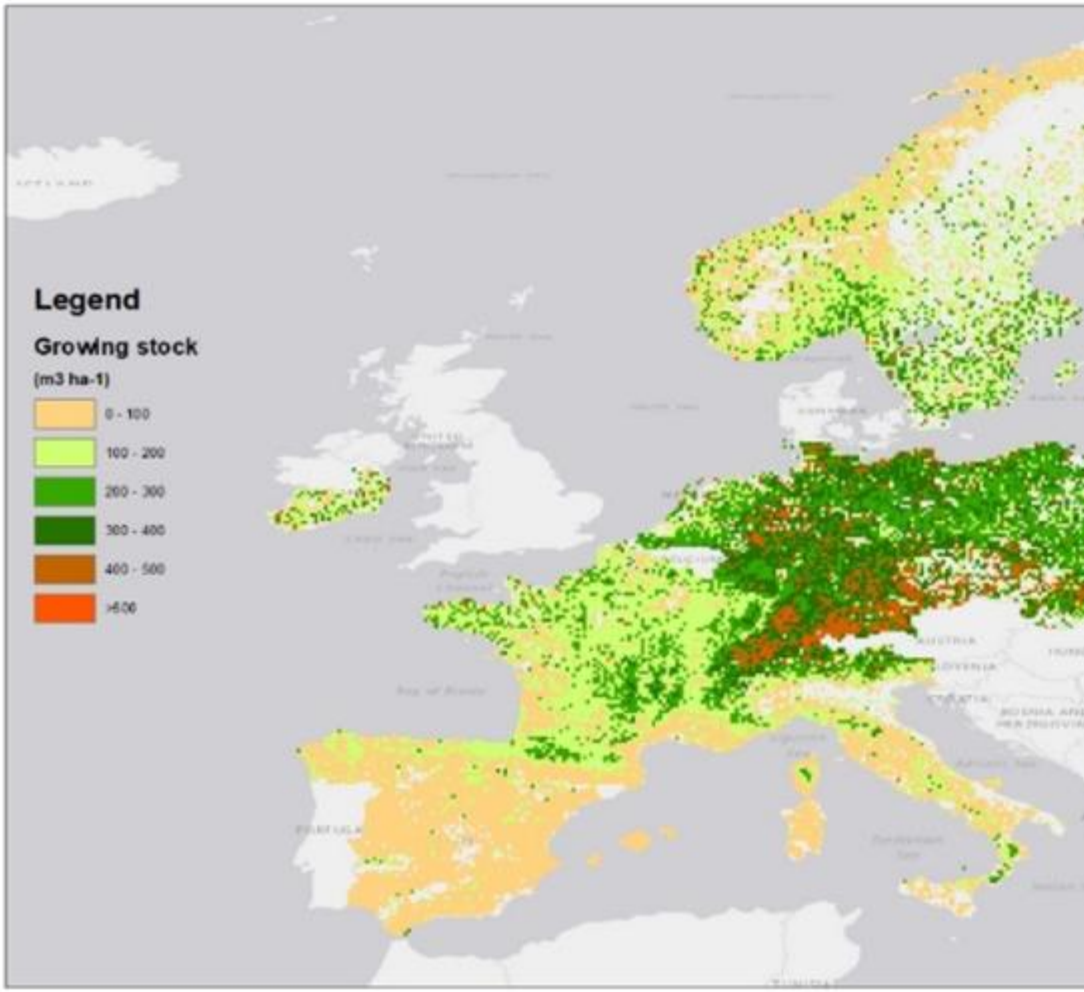
- Growing stock, harvest
- NEP, NBP
- Soil organic carbon

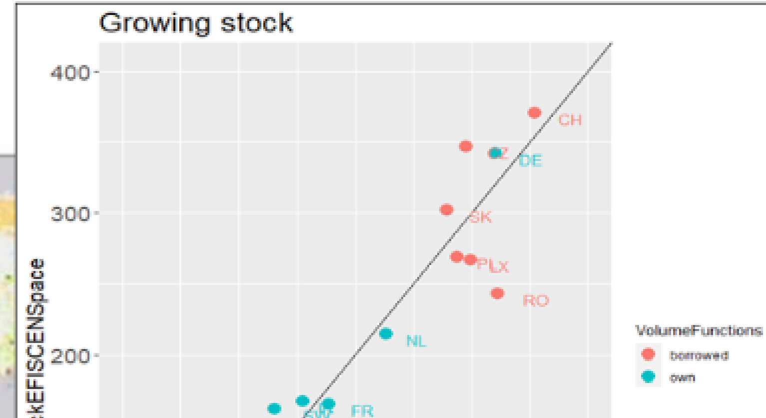
RESULTS

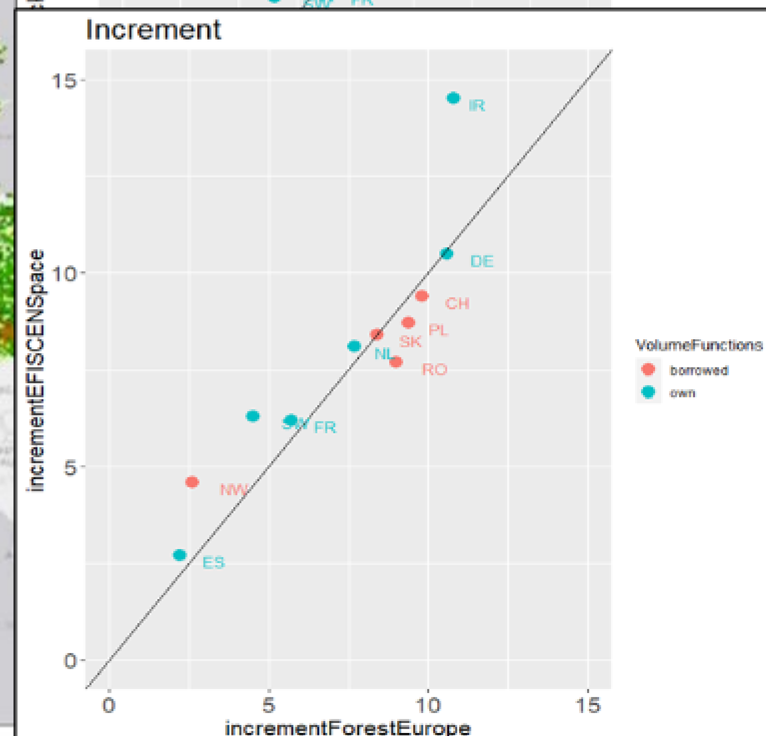
Baseline simulations of 15 countries

WP3 – FOREST ECOSYSTEMS

Growing stock

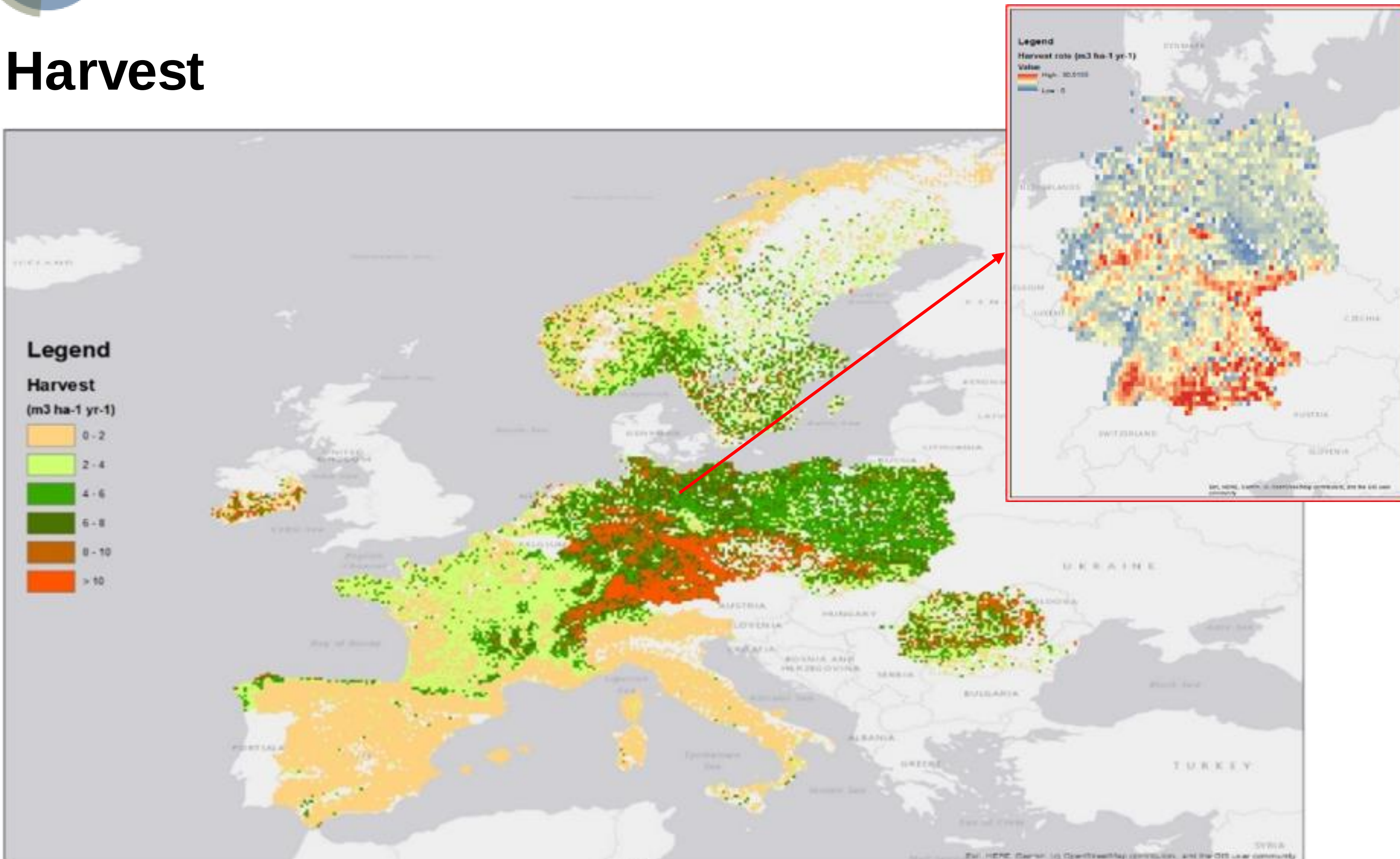






WP3 – FOREST ECOSYSTEMS

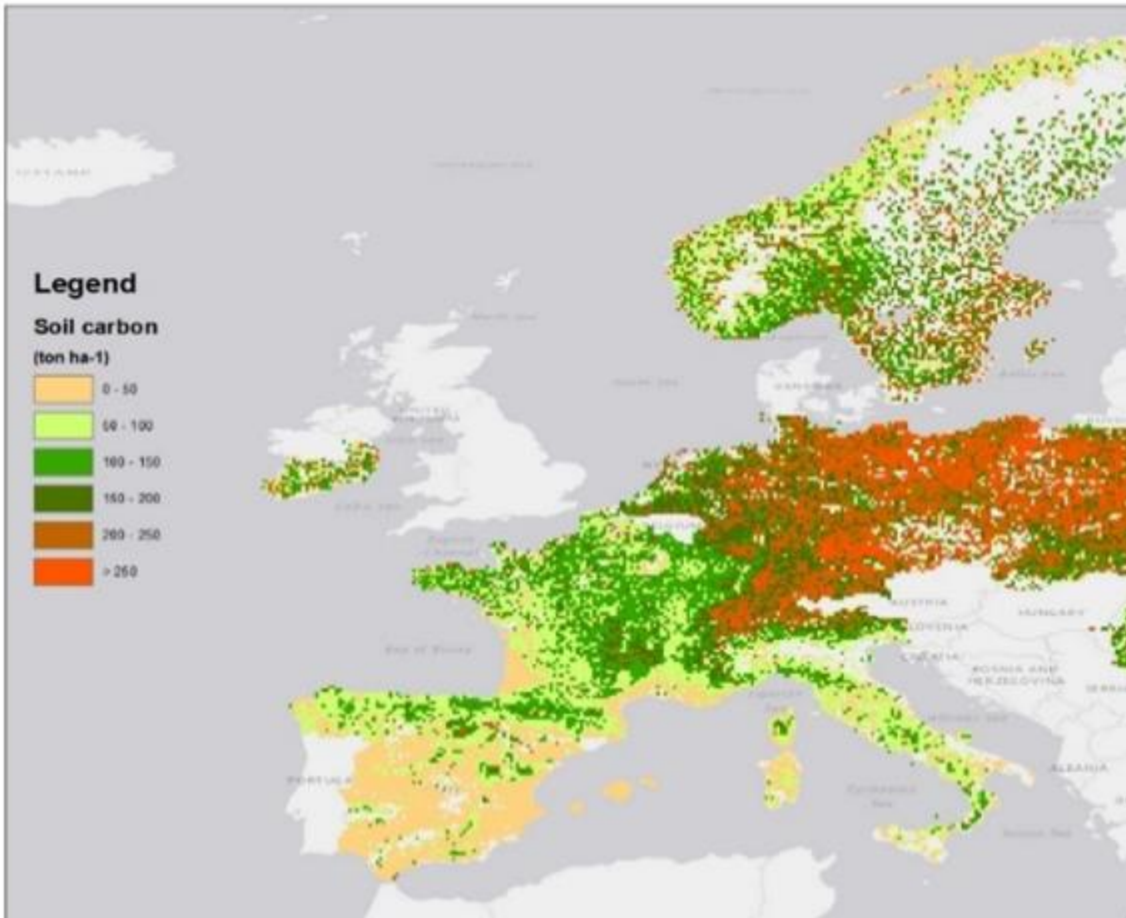
Harvest

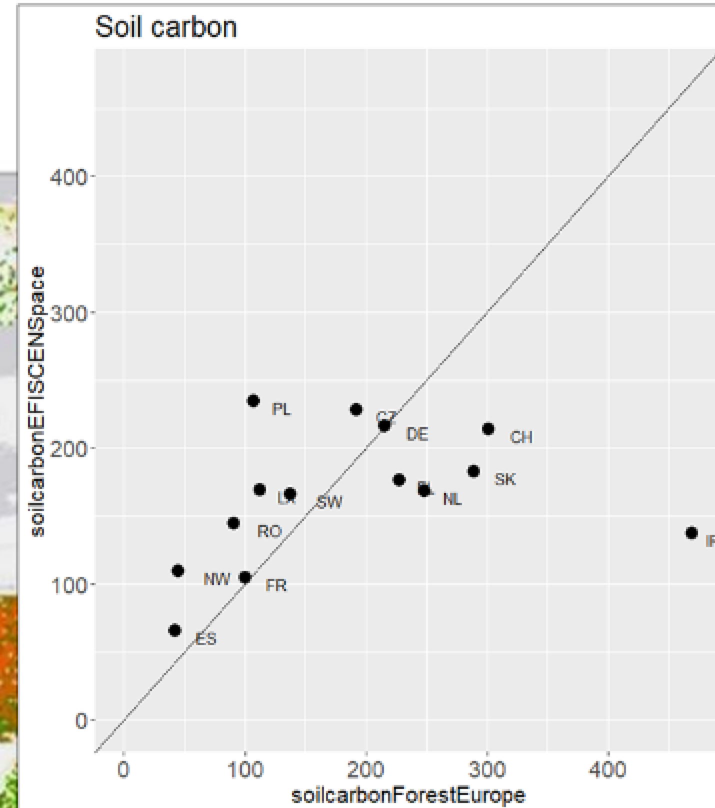


WP3 – FOREST ECOSYSTEMS

Mineral soil carbon

(spin up based on litterfall rates)

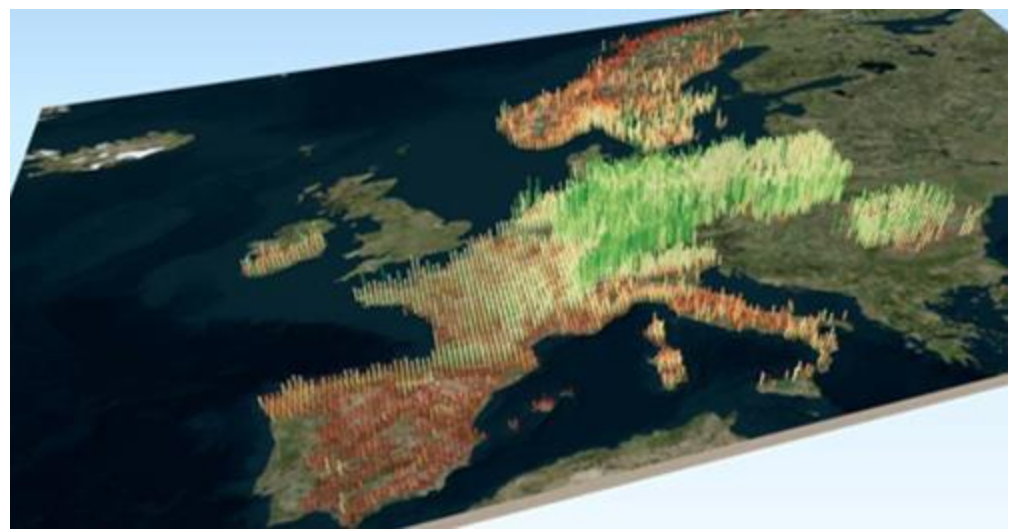




WP3 – FOREST ECOSYSTEMS

Conclusions

- We made great progress towards a new generation of EU-scale models
- Great potential for validation of national reporting (e.g., CRFs)
- Great potential to expand (forest structure indices, biomass, carbon, deadwood, biodiversity, HWP, forest disturbances, impacts of climate change)
- More NFIs data...



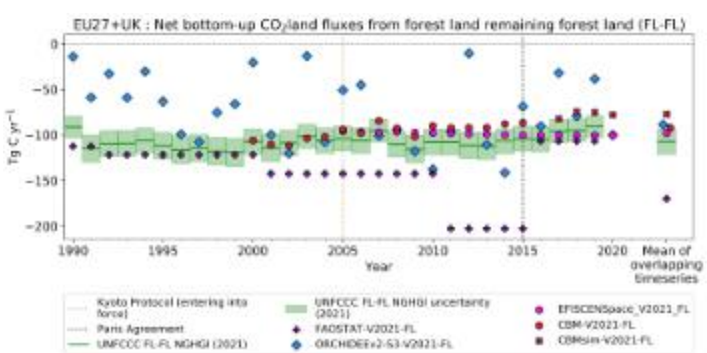
Important for regional fluxes in inversion system

WP3 – FOREST ECOSYSTEMS : Other models

- Other models where also used in VERIFY !
  - CBM - data driven model (similar to EFISCEN)
  - ORCHIDEE / G4M process based model
- As well as FAO data estimates !

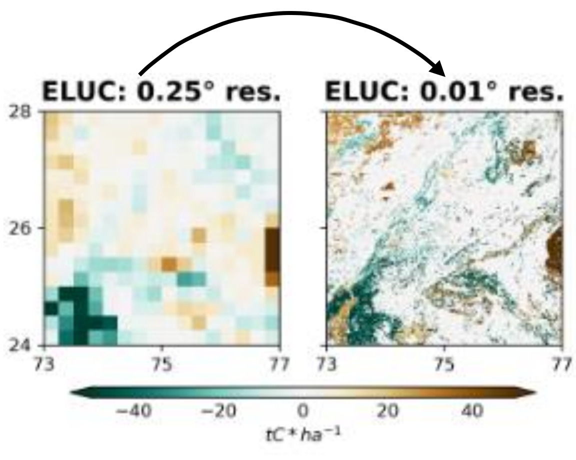
⇒ Significant differences that need to be resolved !

- Synthesis in WP5 still use the different estimates
  (See summary talk (P. Peylin) for a few comparisons)



WP3 – LULUC FLUXES - BLUE MODEL

- BLUE: Bookkeeping model for estimating CO2 fluxes from LULCC, e.g., expansion of agricultural land, wood harvest, regrowth
- Implementation of new, higher res. LULCC information (HILDA+) in BLUE



25x higher information!

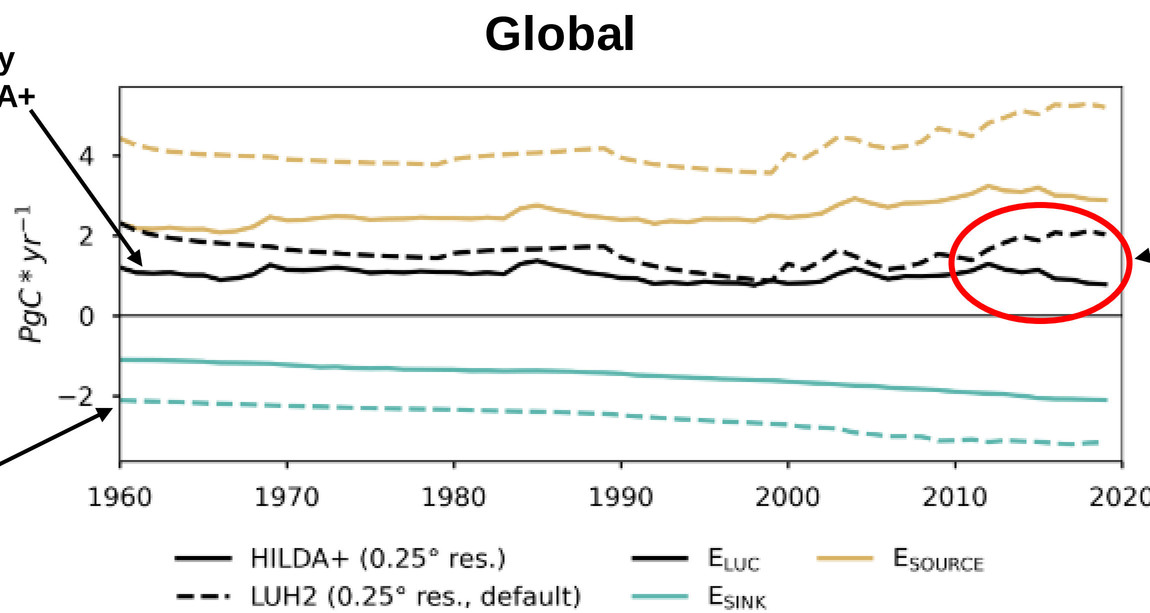
Effects of resolution on ELUC estimates due to successive transitions

- Uncertainty evaluation and better detection of gross sinks and sources

Ganzenmüller et al. (in press, ERL)

WP3 – LULUC FLUXES - BLUE MODEL

(1) ELUC substantially lower based on HILDA+



(2) Diverging trends in recent years (see also GCB2020 vs. GCB2021)

(3) Larger gross sinks and sources with LUH2, (main reason: implementation of shifting cultivation in LULCC data)

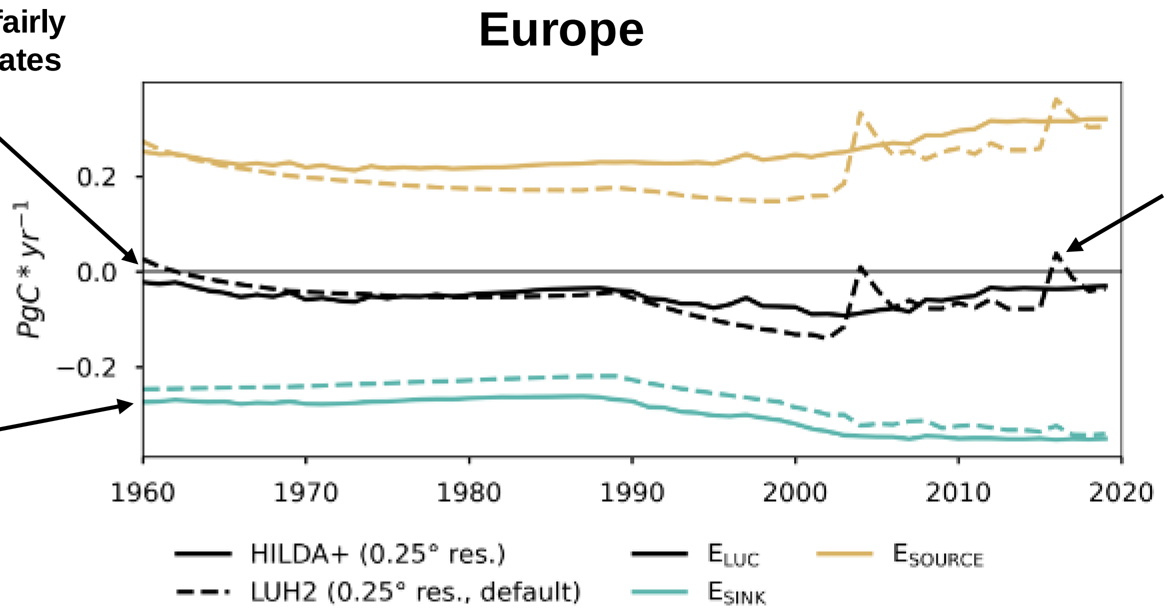
Ganzenmüller et al. (in press, ERL)

WP3 – LULUC FLUXES - BLUE MODEL

(1) ELUC matches fairly well between estimates (but larger spatial differences)

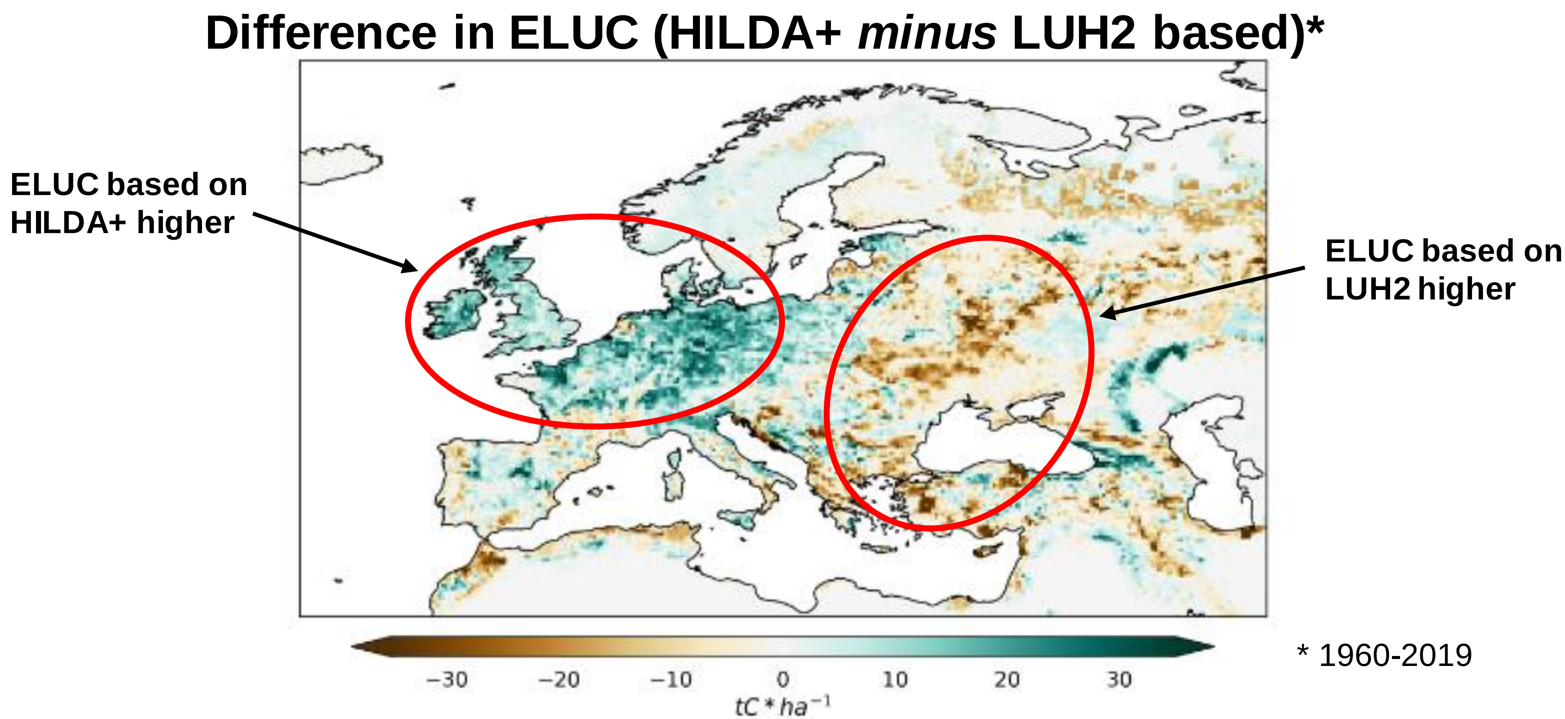
(2) Potential data artifacts from LUH2

(3) Slightly larger gross sinks and sources with HILDA+



Ganzenmüller et al. (in press, ERL)

WP3 – LULUC FLUXES - BLUE MODEL



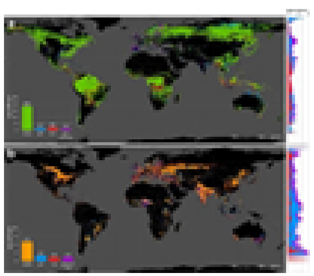
* 1960-2019

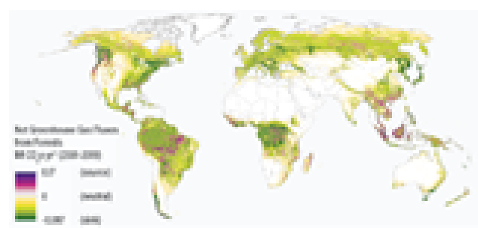
Ganzenmüller et al. (in press, ERL)

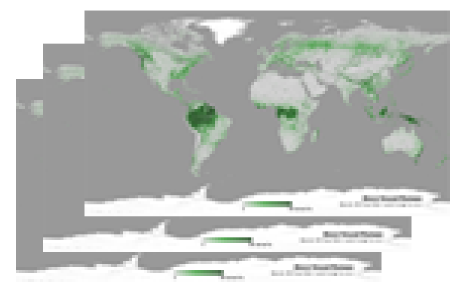
Land use, biomass and AFOLU

Contribution by Wageningen University team (in close collaboration with KIT & GFZ)

1. Annual land use change 1960-2020 (HILDA+, Winkler et al. Nature Coms)
2. EO-based biomass estimation for modeling and towards spatially-explicit AFOLU GHG inventories (Papers: Araza-RSE / Harris-Nature-CC)
3. Special study: data quality and comparison for Eastern Europe (paper by Karina Winkler in preparation)







WAGENINGEN UNIVERSITY & RESEARCH

KIT

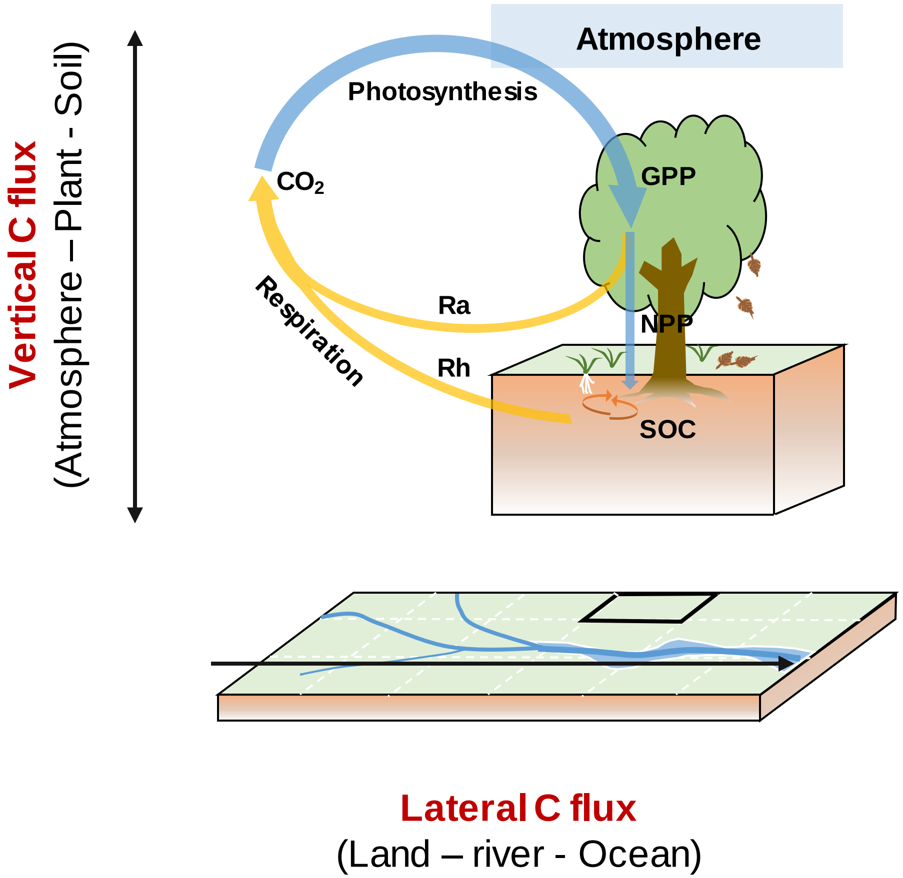
GFZ Helmholtz-Zentrum POTSDAM

WP3 – LATERAL FLUXES

Lateral carbon transfer: Budget, trends & impact on the terrestrial carbon budget of Europe

P. Regnier, **H. Zhang**, R. Lauerwald, C. Gommet, K. van Oost, B. Guenet, P. Ciais

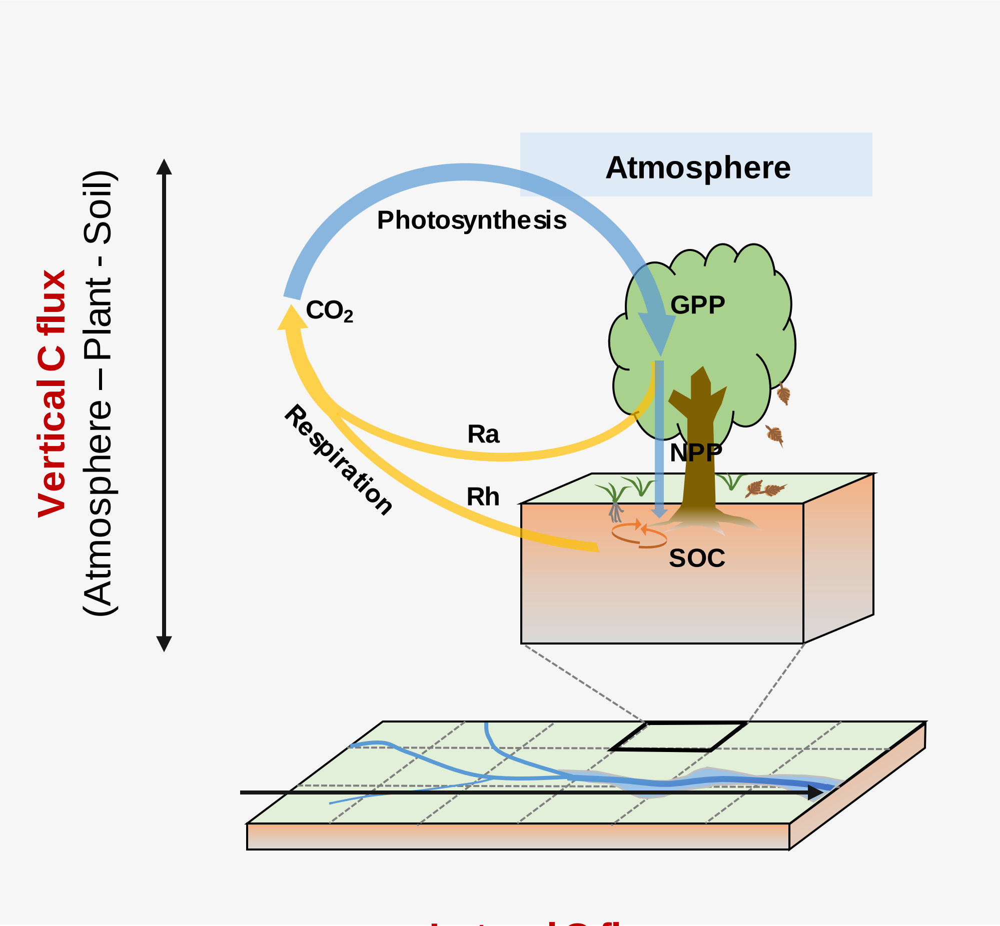
Objectives



- Implement lateral C transfers (driven by leaching & erosion) into a global land surface model
- Quantify the magnitude & trends of regional lateral C transfers
- Explore the impacts of global change on lateral C transfers
- Explore the effects of lateral C transfers on the land C budget

See, Regnier et al. The Land-to-Ocean loops of the Global Carbon Cycle, Nature 603, 2022 for a perspective

OBJECTIVES



Lateral C flux
(Land – river - Ocean)

- Implement lateral C transfers (driven by leaching & erosion) into a global land surface model (ORCHIDEE-Clateral)**
- Quantify the magnitude & trends of regional lateral C transfers
- Explore the impacts of global change on lateral C transfers
- Explore the effects of lateral C transfers on the land C budget

** Lauerwald et al., GMD, 2017; Zhang et al. JAMES, 202
Gommet et al., ESD, 2022; Zhang et al. ESDD, in revision

See, Regnier et al. The Land-to-Ocean loops of the Global Carbon Cycle, Nature 603, 2022 for a perspective

APPLICATION

- **Study area** : Europe
- **Period** : 1901-2014

Model-data comparison

Units: g C m^{-2} yr^{-1}

Variable	ORCHIDEE-Clateral	Previous estimates
Soil POC loss rate	0.55	0.49-0.67*
Soil DOC loss rate	1.59	0.91-1.73**
CO_2 evasion from inland waters	2.3	2.0***

Estimates from ORC-Clateral are within the range of previous estimates
see Zhang et al. ESDD, in revision for (much more) detailed evaluation, incl. GPP, NPP, NBP, SOC

* Borelli et al., 2018; Ciais et al., 2008; Mayorga et al., 2010 ** Ludwig et al., 1996; Ciais et al. 2008, Li et al., 2019; Mayorga et al., 2010 *** Lauerwald et al., 2015

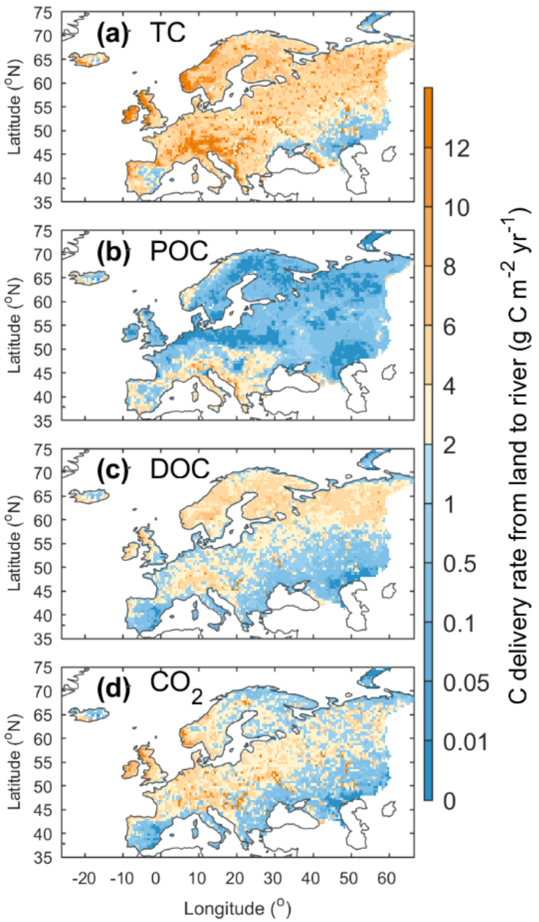
Attribution - Simulation under different global change scenarios

Zhang et al. submitted

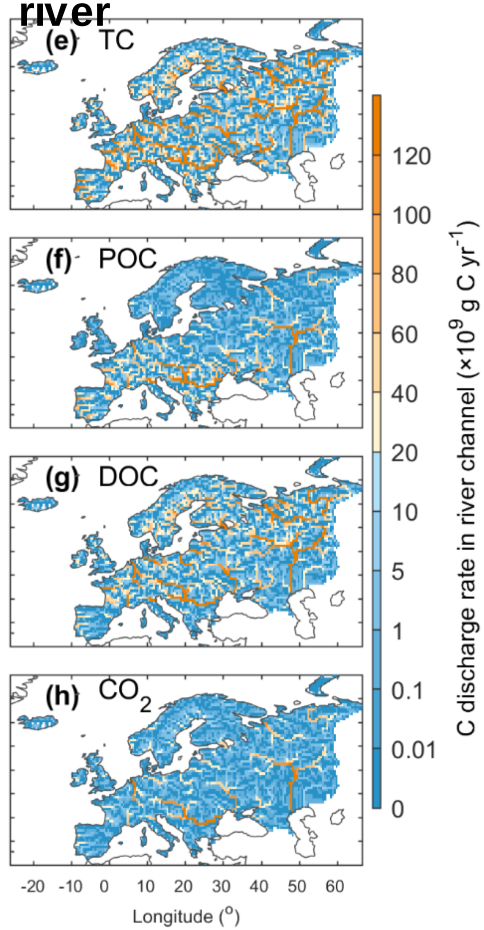
No.	Scenarios	Climate data	Atmospheric CO_2 concentration	Land cover	Lateral C transfer
1	Climate+CO_2+LUC	1901-2014	1901-2014	1901-2014	Yes
2	Climate+CO_2	1911-2014	1911-2014	$AVE_{1901-1910}$	Yes
3	Climate	1911-2014	$AVE_{1901-1910}$	$AVE_{1901-1910}$	Yes
4	No C-lateral	1911-2014	1911-2014	1911-2014	No

SPATIAL VARIABILITY (PRESENT-DAY)

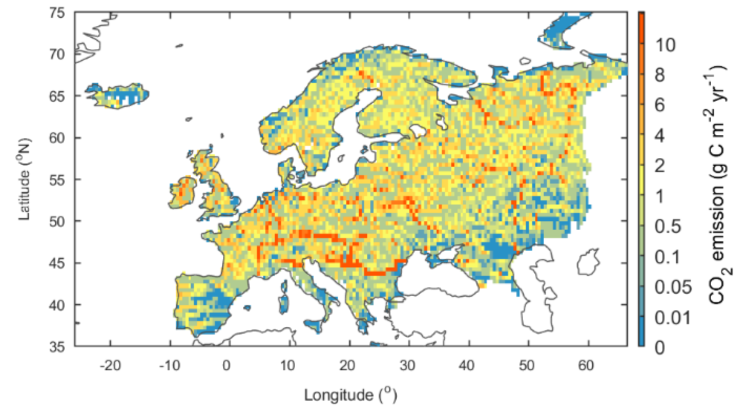
C loss to river



C discharge in river



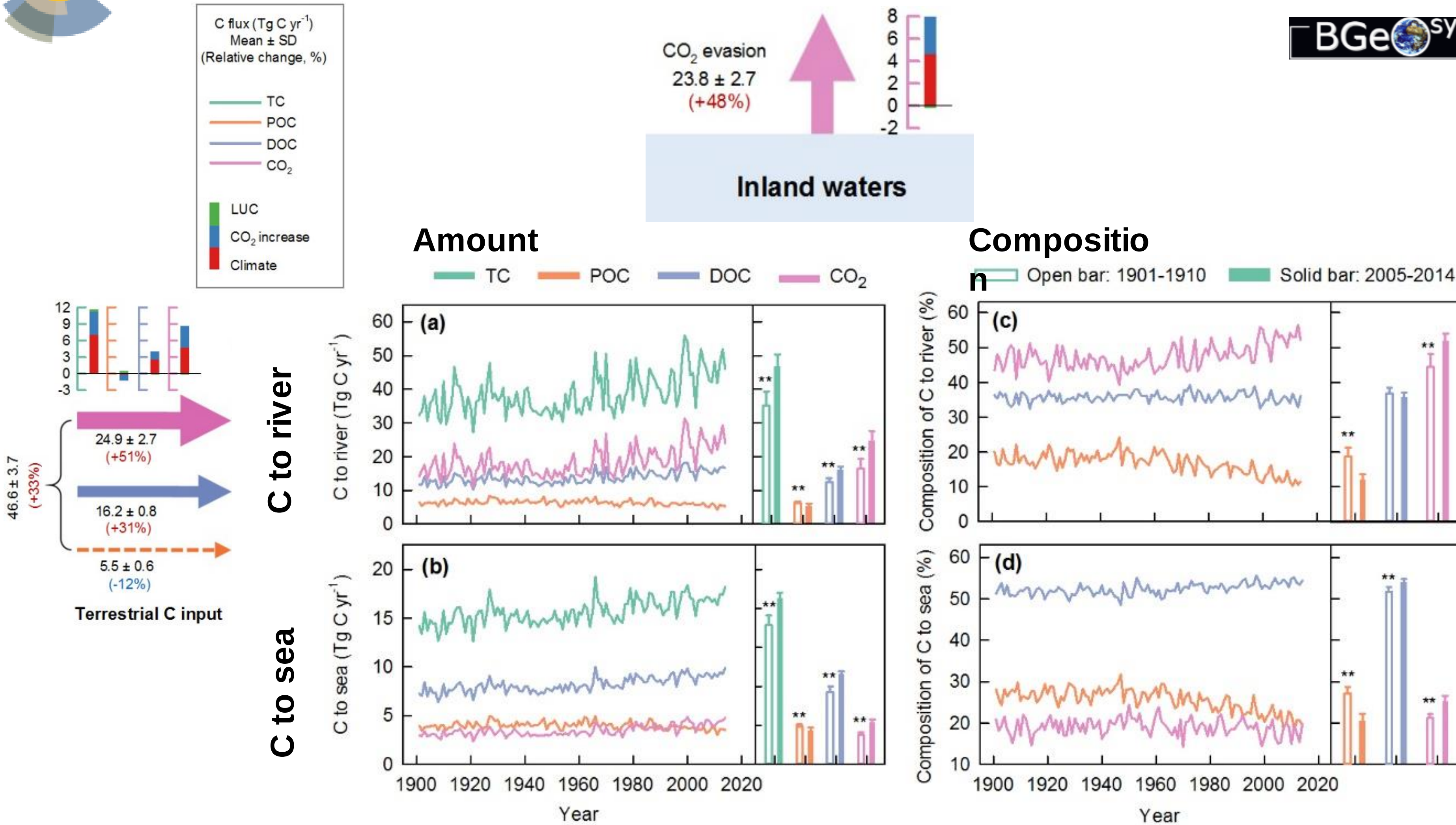
CO_2 evasion



TC: total C delivery ($POC+DOC+CO_2$)

Zhang et al. submitted

TRENDS IN LATERAL C FLUXES, ATTRIBUTION



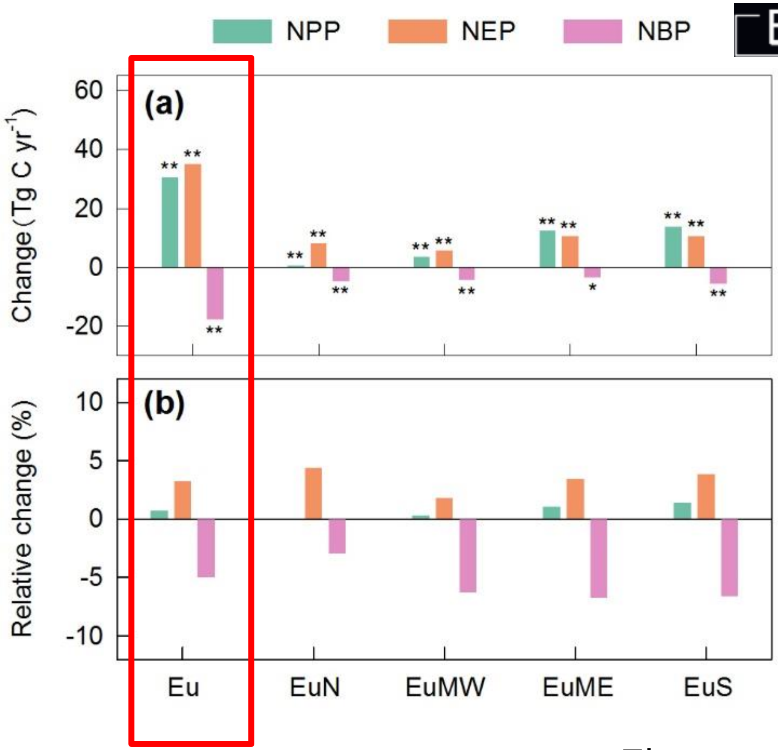
Zhang et al. submitted

Simulated trends in lateral C deliveries over Europe are overall consistent with previous (YET SCARCE) studies based on observations

IMPACT ON TERRESTRIAL C BUDGET

- Lateral C delivery to river is 18±10% of NBP in Europe
- Lateral C transfer reduces land C sink (NBP) in Europe by 5% on average

NPP: Vegetation net primary production
NEP: NPP – Rh (heterotrophic respiration)
NBP: NPP – Rh – Disturbance (harvest, lateral C transfer)



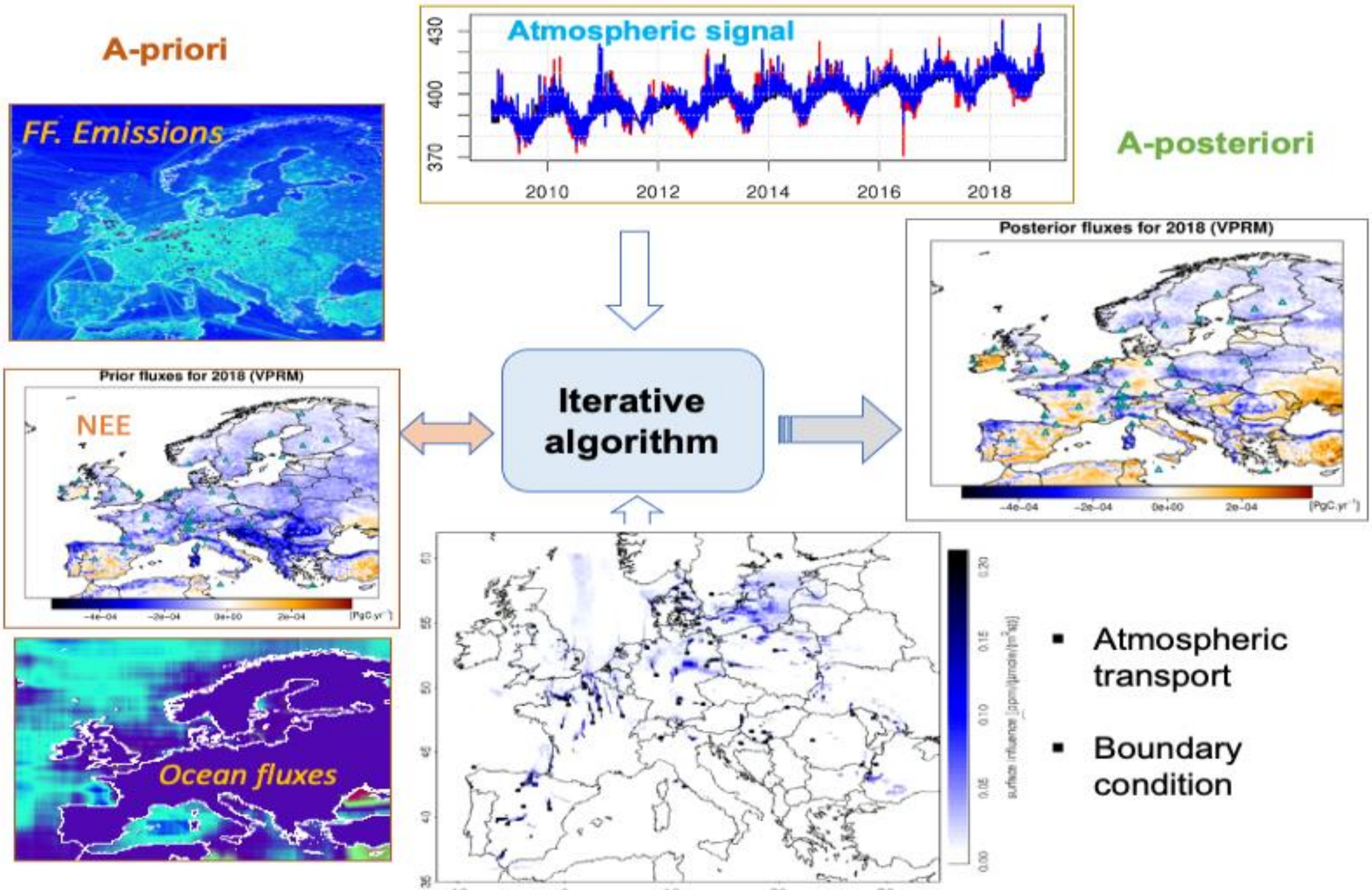
Zhang et al. submitted

Conclusions

- Lateral C delivery (LCD) in Europe increase **by 33 %** over 1901-2014 (DOC & CO_2: increase; POC: decrease), which suggests a significant anthropogenic perturbation. CO_2 evasion has increased by **48 %**, indicating a decrease in the stability of the river C.
- Change in LCD is mainly due to climate change (**62%**) & CO_2 increase, LUC is a secondary factor, except in Southern Europe
- LCD impacts land C budget in various ways, and leads to a notable decrease in net land C sink (NBP)

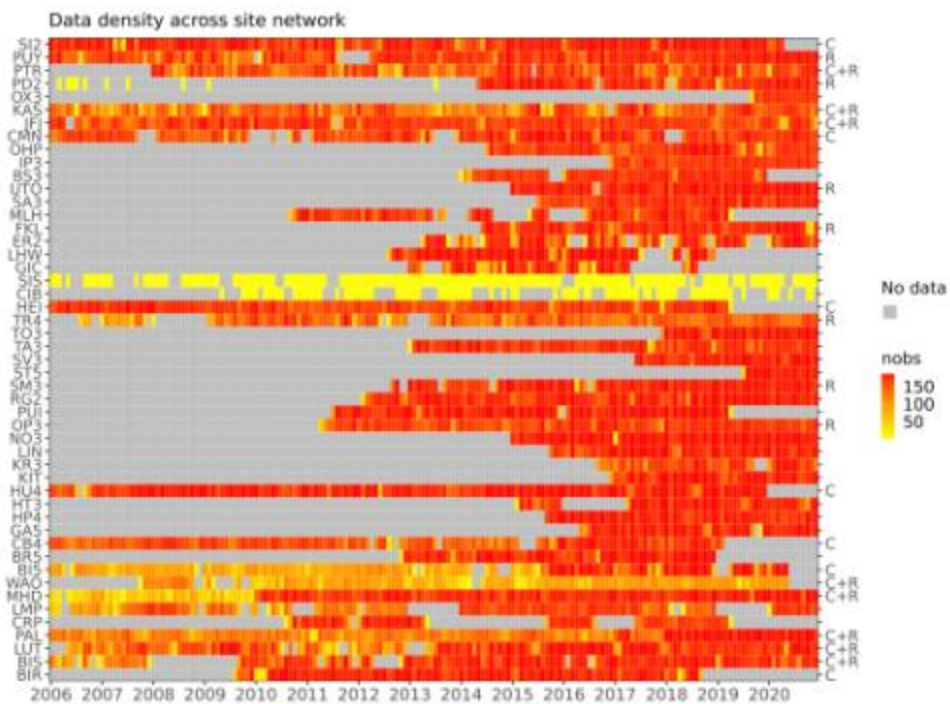
NEE estimates derived from Jena CarboScope-Regional inversion system (CSR)

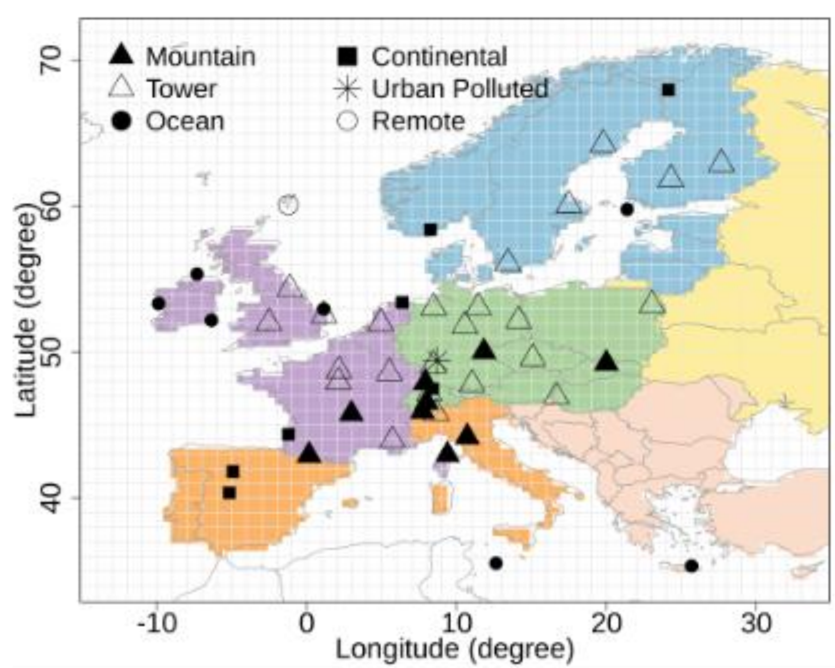
CarboScope-Regional Inversion (CSR)



Atmospheric data

- Datasets from 49 sites provided by ICOS, pre-ICOS, and NOAA site network
- Data coverage variable over years (2006-2020), remarkably improved since ICOS established (on heatmap, left)
- Weekly model-data mismatch errors are assumed from 0.5 to 4 (ppm) based on station types (on map, right)
- Subsets of sites: C (coverage over full period), R (coverage over recent 5 year period)





A-priori flux models

Flux type	Biogenic fluxes (NEE)				Ocean fluxes		Emissions
Model	VPRM	FLUXCOM	ORCHIDEE	SiBCASA (- 2018)	Mikaloff	CarboScope	COFFEE (EDGAR_v4.3 + BP + Carbon Monitor)
Spatial resolution (deg.)	0.08 x 0.125	0.5 x 0.5	0.5x0.5	0.5 x 0.5	5 x 4	5 x 4	0.1 x 0.1
Temporal resolution	hourly	hourly	3-hourly	hourly	monthly-climatology	6-hourly	hourly

Spatial NEE estimates (2020)

Optimized fluxes:

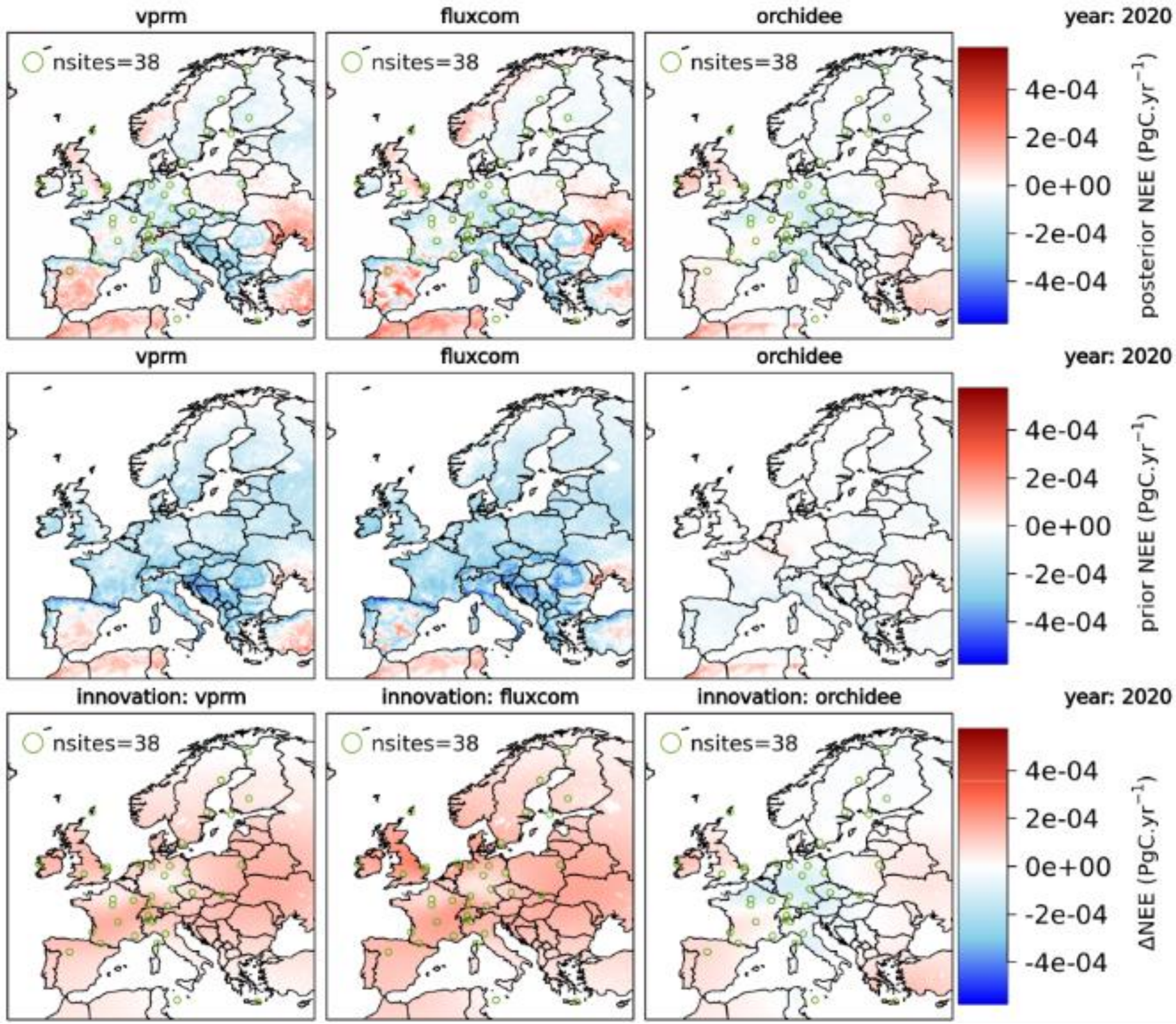
consensus over models on nearly net sink

Biosphere models:

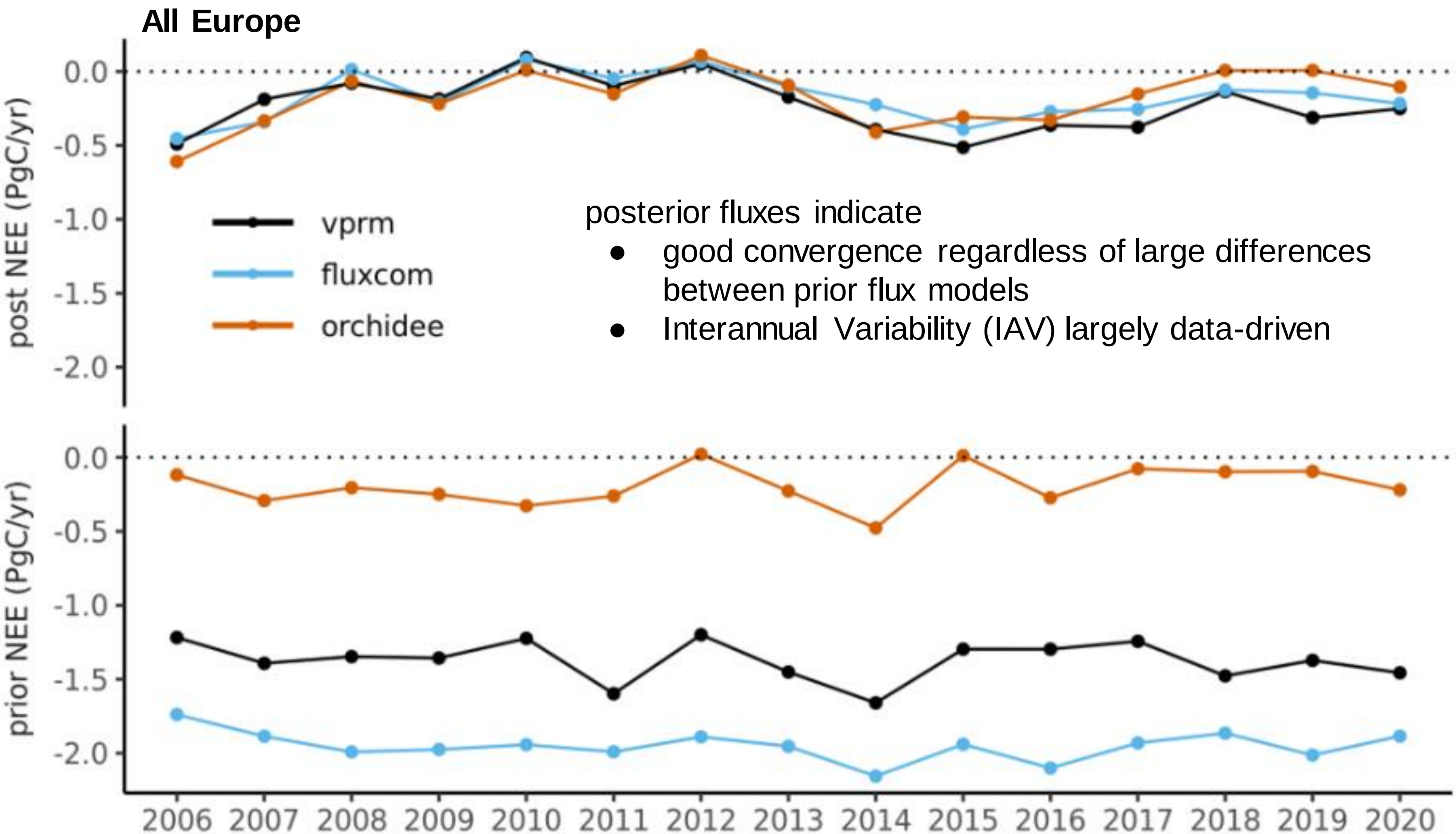
CO2 uptake overestimated by FLUXCOM and VPRM

Innovation of fluxes:

positive corrections dominating the inversions, except for central Europe with orchidee



NEE estimates 2006-2020

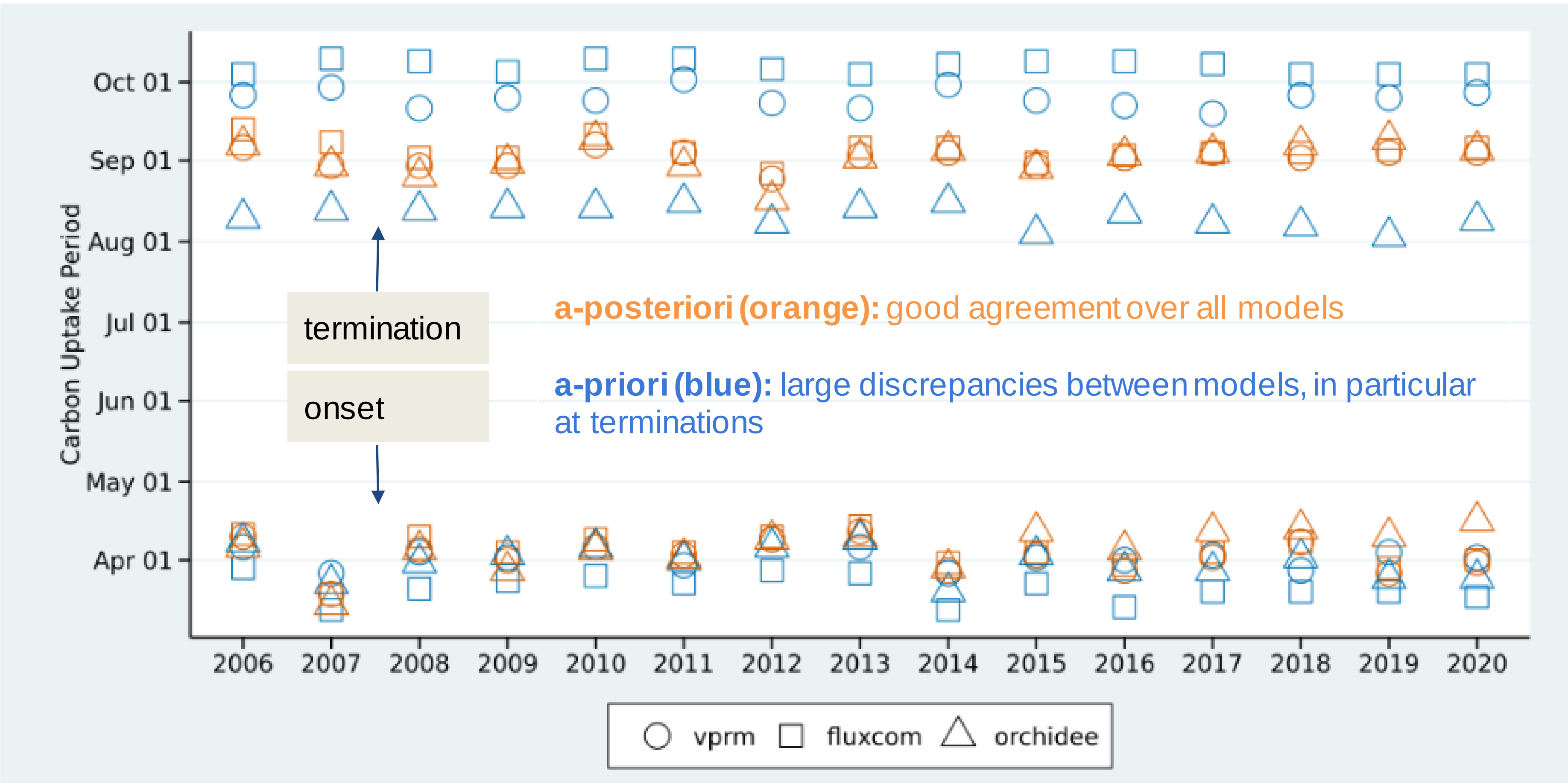


posterior fluxes indicate

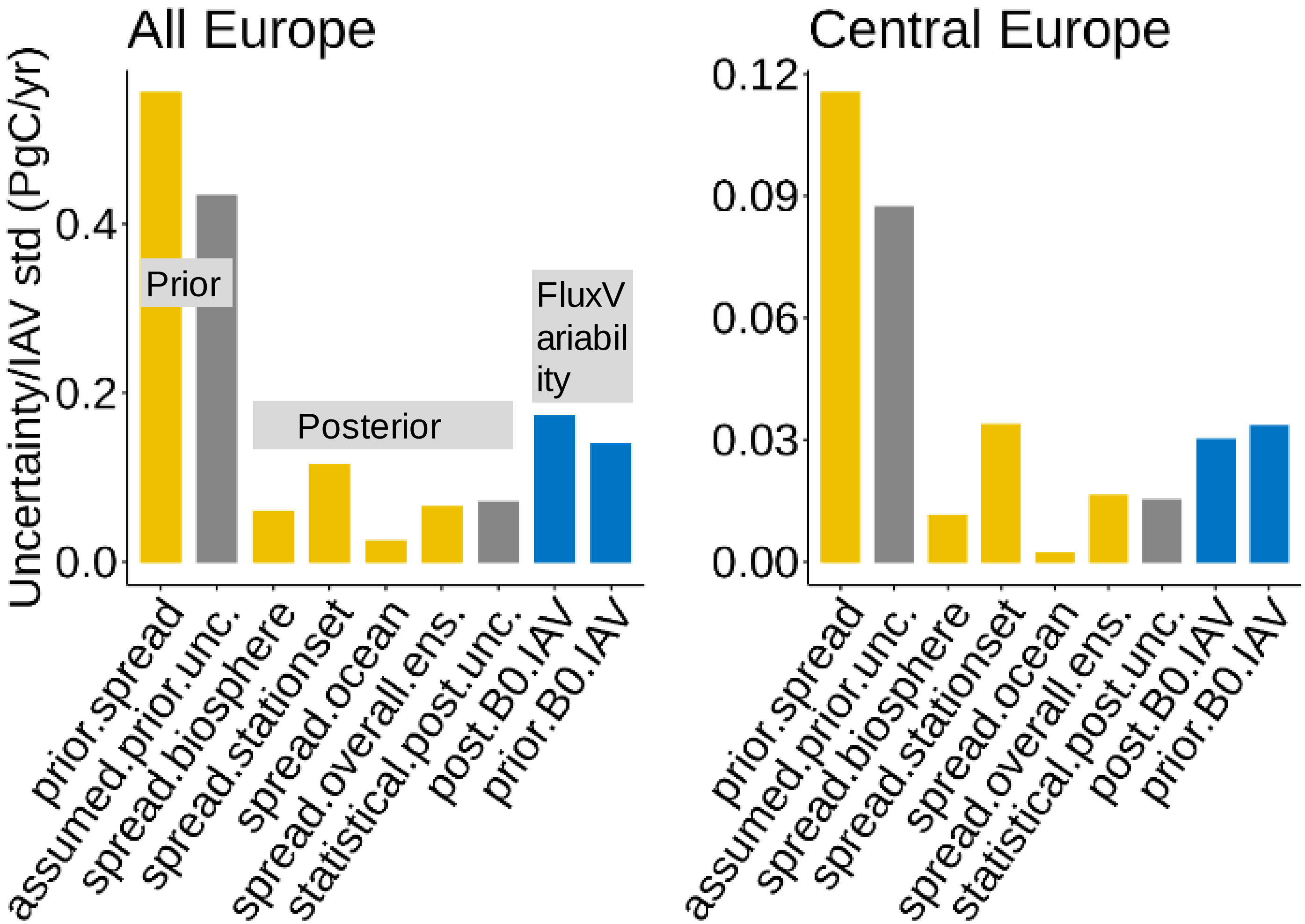
- good convergence regardless of large differences between prior flux models
- Interannual Variability (IAV) largely data-driven

Growing season variability

Carbon Uptake Period (CUP) calculated from the onset to termination based on the unique zero crossing points for flux estimates and the respective prior models over all Europe



Uncertainty analysis



Munassar et al. (2022, in review)

Concluding remarks

- ❖ The atmospheric signal is dominating in posterior fluxes
- ❖ Inversions indicate the importance of expanding site network to decrease the uncertainty of flux estimates
- ❖ **Next steps:**

Implementation of STILT footprints in CIF

Running CIF inversion and comparing to CSR (achievable until end of July)

Status:

CIF installed at DKRZ supercomputer

STILT footprints format provided to Antoine (for making compatibility with CIF)