VERIFY GA meeting

WP3 – Verification methods for terrestrial CO_2 sources and sinks and carbon stocks

March 14, 2019

ECMWF

Reading, UK

Presenters

Pete Smith & Philippe Peylin

(Matthias Kunert & Matthew Macgrath)

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

WP3 – Main objectives M1-M12

➔ **Provide land CO2 budgets for Europe (including uncertainties and improved understanding of key processes and drivers)**

- T3.1: Collect/provide all driving data needed by the models
- T3.1: Creates a sharing platform to make the data available
- T3.2: ecosystem models; 2018 = Ramp up year
  ➔ preliminary data for all contributors
- T3.3 : regional Atmospheric inversion for Europe
  - First results done by MPI-JENA
  - Development of the Community Inversion Framework
- T3.4: Research needs to reduce uncertainties: case of East Europe

T3.1 – COLLATE STATE-OF-THE-ART DRIVING DATA

- **T3.1.1** Climate data
- **T3.1.2** Land use
- **T3.1.2** Land management
- **T3.1.3** Soil properties
- **T3.1.3** Soil erosion
- **T3.1.4** Flux data sets
- **T3.1.5** Cropland management
- **T3.1.6** Grassland management
- **T3.1.7** Forest management
- **T3.1.8** Nitrogen deposition
- **T3.1.9** Fresh water fluxes
- **T3.1.9** River exports
- **T3.1.10** Coastal ocean CO2 fluxes
- **T3.1.11** Other lateral fluxes

Data available

Work in progress (data will be completed or improved)

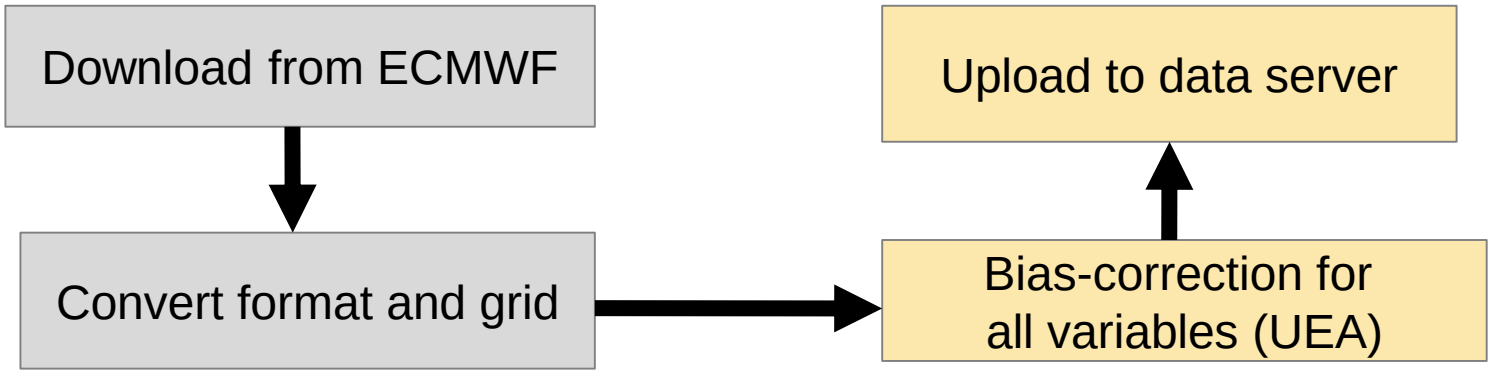
Data not yet available

T3.1.1 – CLIMATE DATA

Requirements

- Operational data set – Near Real Time **(up to year – 1)**
- Multiple decades
- **High resolution**
- **Variables :** surface air relative humidity ; surface solar radiation downwards ; surface thermal radiation downwards ; 10 metre wind speed ; 10 metre wind direction ; 2 metre temperature ; surface pressure ; snow fall water equivalent ; total precipitation

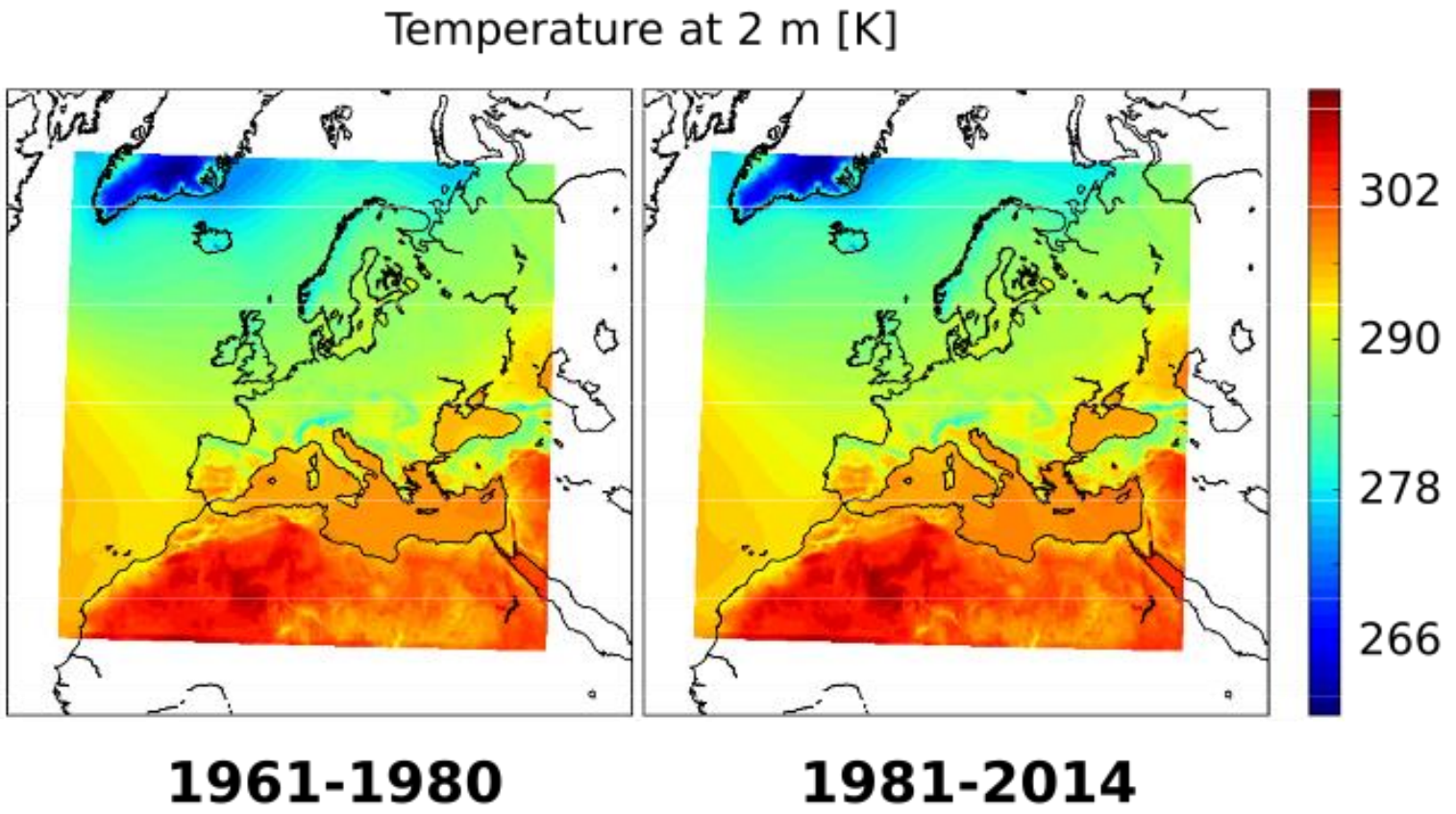
Procedure



T3.1.1 – CLIMATE DATA

Selection from UERRA project: HARMONIE / v1
(« Uncertainties in Ensembles of Regional ReAnalyses)

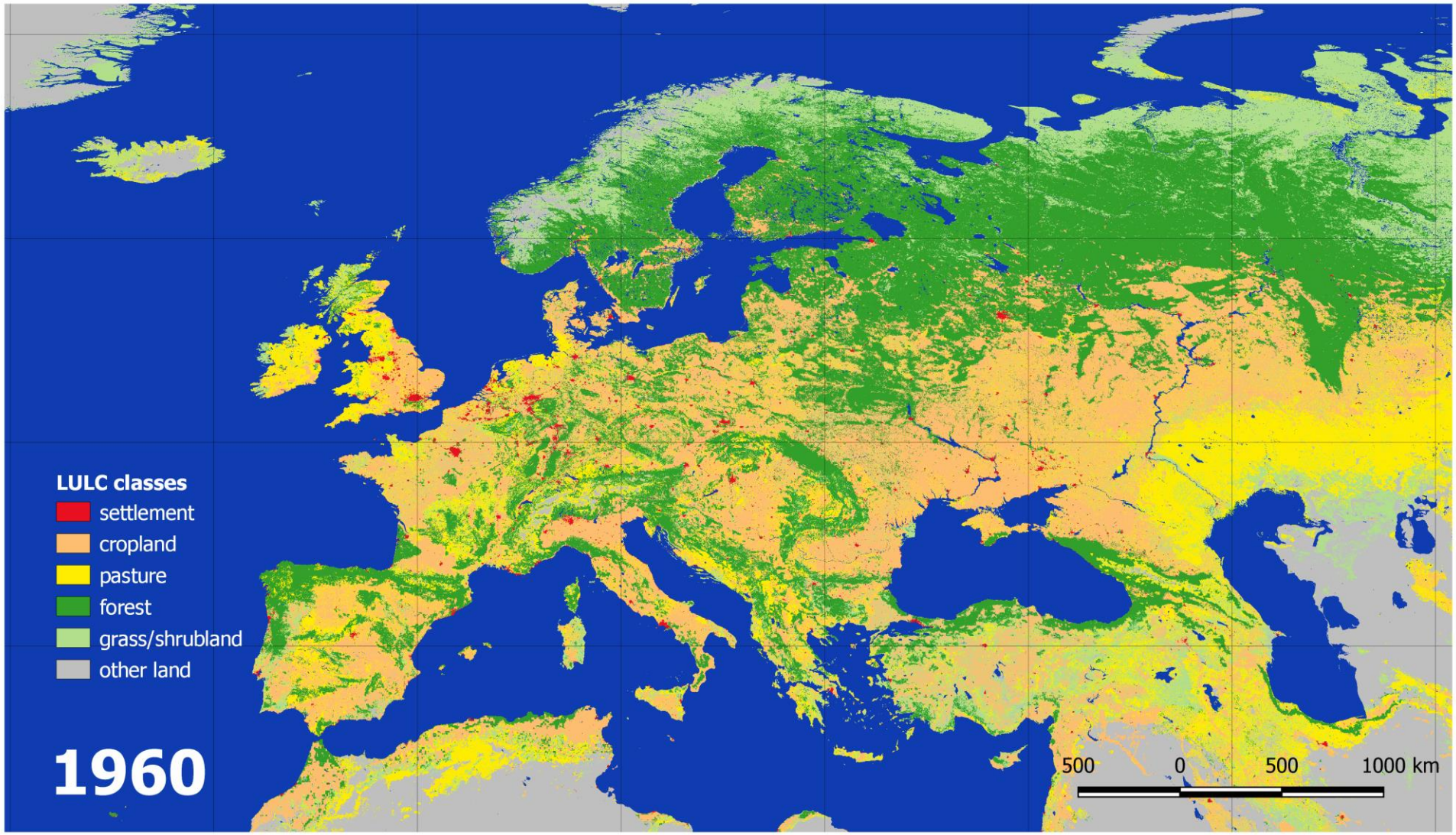
➔ **Available 1961-2018, 3-hour resolution ; 11 km spatial res.**



Land cover change over Europe / globe

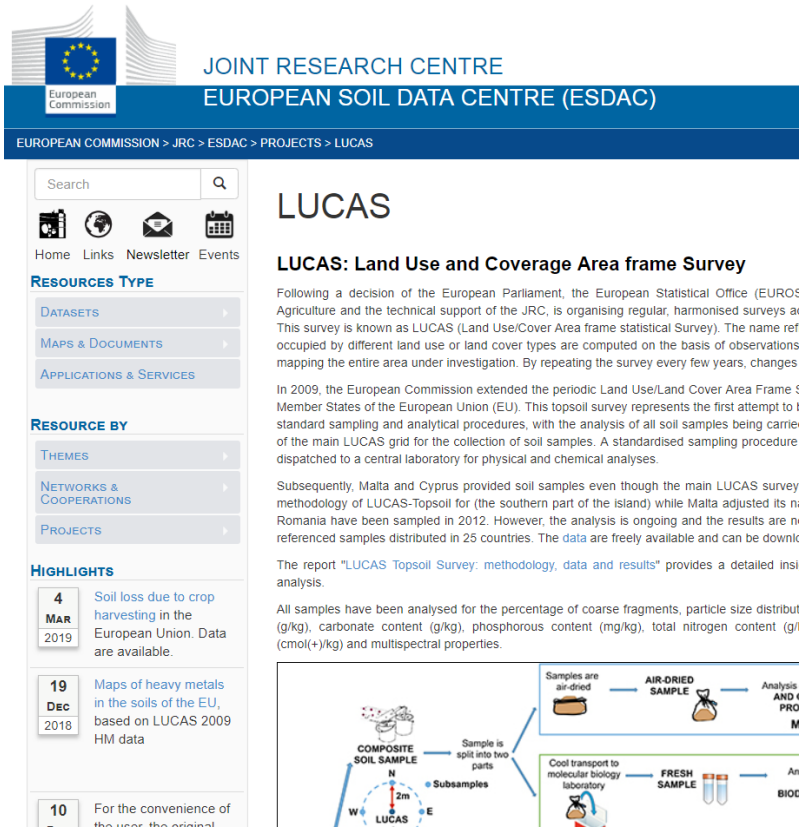
➔ Synthesis using: Satellite / FAO / Regional data

Karina Winkler, Richard Fuchs, Martin Herold

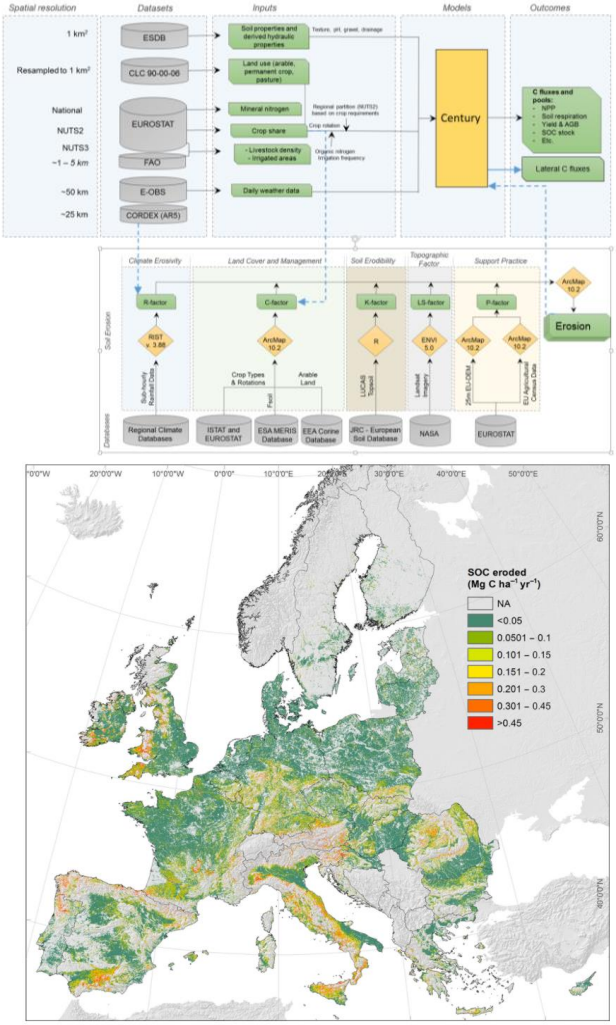


T3.1.3 – Soil properties and Soil Erosion

Soil properties: ESDAC (European Soil Data Center)



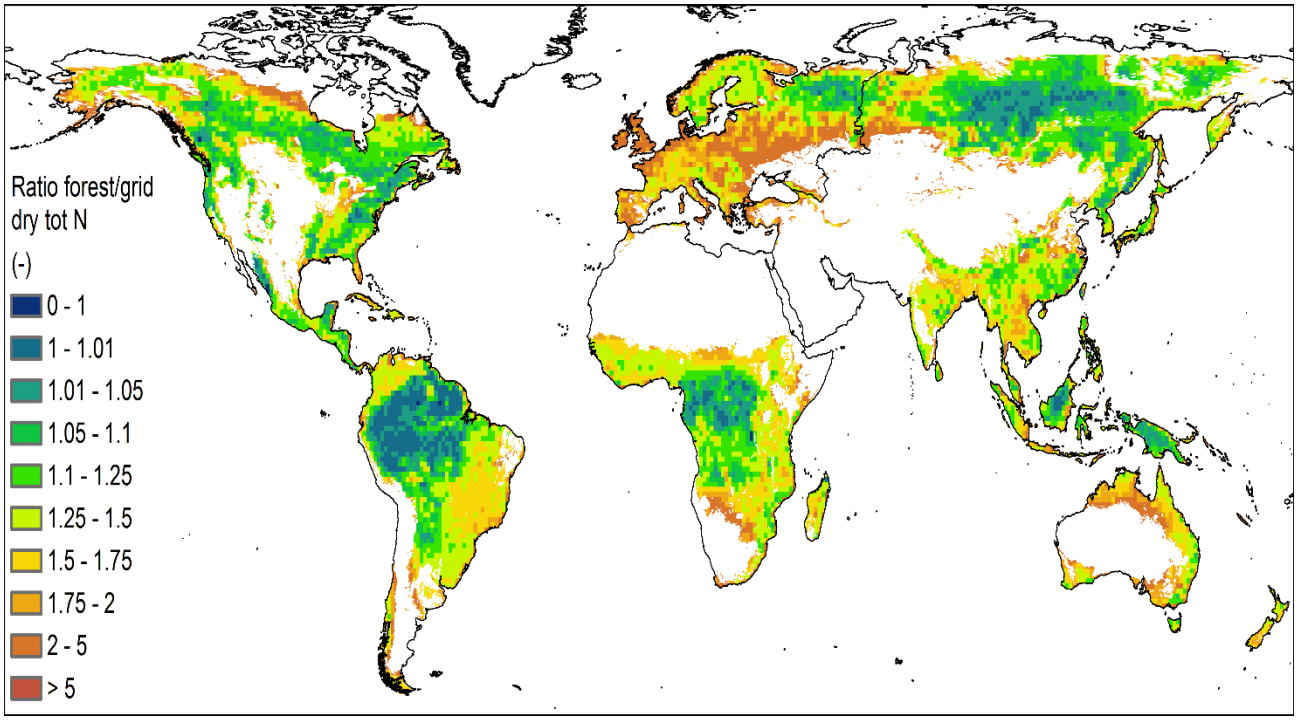
Erosion: Derived datasets from the C-erosion model framework



T3.1.8 – Nitrogen deposition data

Available data:

- Observational based only for wet deposition in Europe and North America
- Observation 'derived' dry deposition is very uncertain
- Gridded maps mostly rely on models
- Ensemble model results generally better performance.

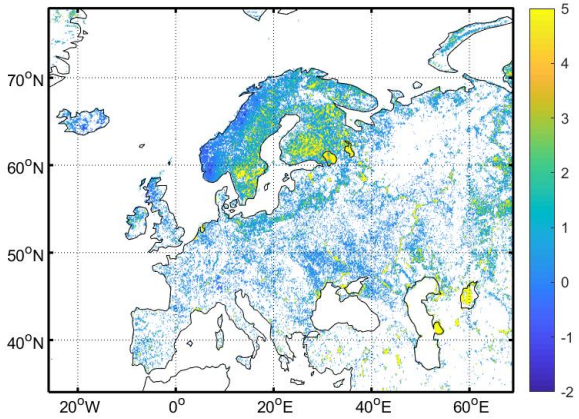


EMEP model (Schwede et al, 2018; David Simpson). Global model that delivers ecosystem (forest) specific deposition of nitrogen deposition.

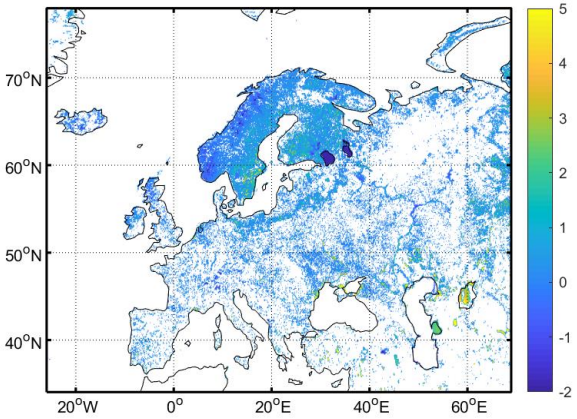
T3.1.8 – Fresh water Fluxes

Monthly seasonality in lake CO_2 emissions at 0.1°

March

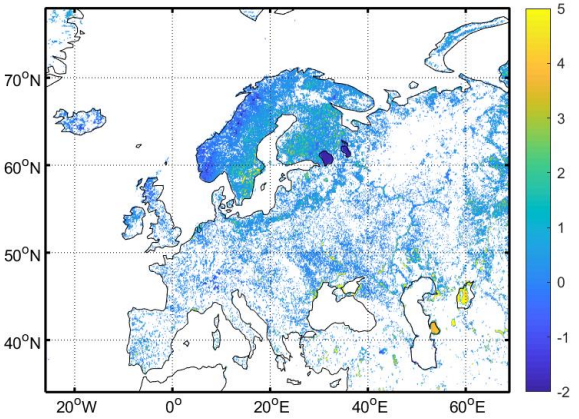


June

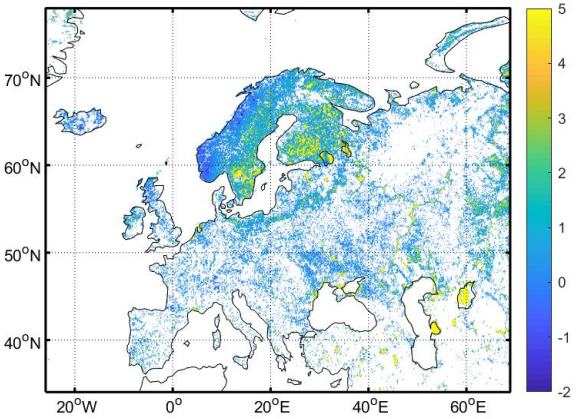


Lake CO_2 emissions [g m^{-2*} $month^{-1}$]
*refers to total area (terrestrial+aquatic)

September



December



Annual emissions from European lakes:
56.6 Tg CO_2-C yr^{-1}

T3.2 – BOTTOM UP BUDGET OF TERRESTRIAL CO2 FLUXES

- **T3.2.1: High-resolution model simulation of the net annual carbon fluxes over Europe (M1-M48)**
  - **Process-based ecosystem models**
    - **All ecosystems: ORCHIDEE**
    - **Ecosystem specific: ECOSSE, EPIC, EFISCEN**
  - **Data – driven statistical model : FLUXCOM**
  - **Book-keeping land use model (BLUE)**

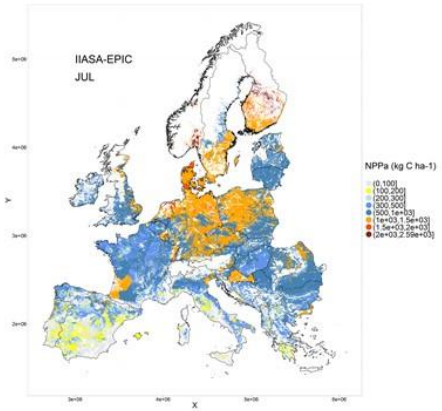
- T3.2.2: Analysis of the main drivers of the European carbon sink (M13-M36)

- T3.2.3: Evaluation of model simulations & contribution to a pre-operational bottom-up system (M13-M36)

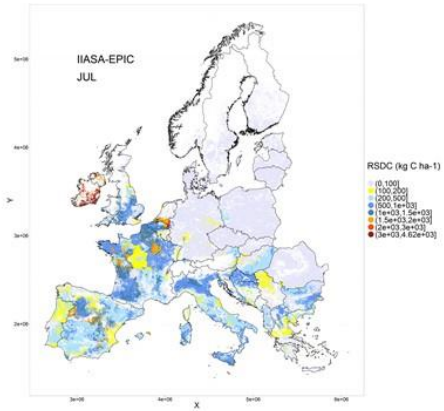
T3.2.1 – HIGH-RESOLUTION MODEL SIMULATION OF THE NET ANNUAL CARBON FLUXES OVER EUROPE

EPIC model – testing outputs for July 2017

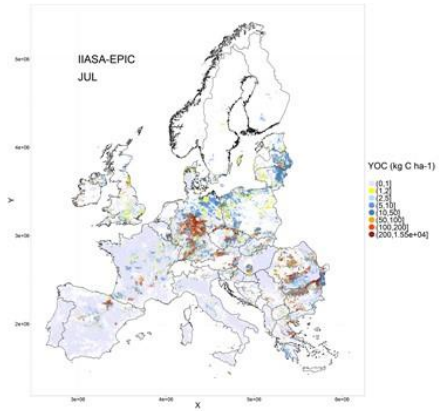
NPP above-ground



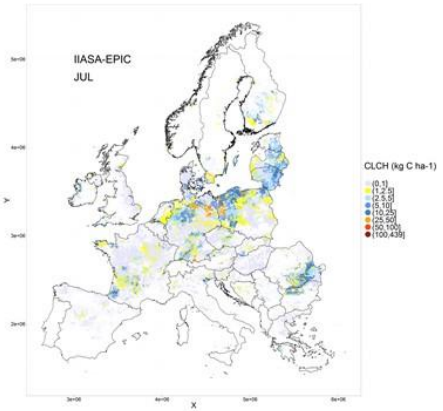
+ Carbon in crop residues



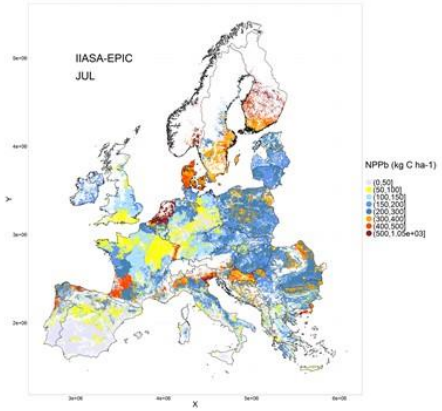
- Carbon in water erosion



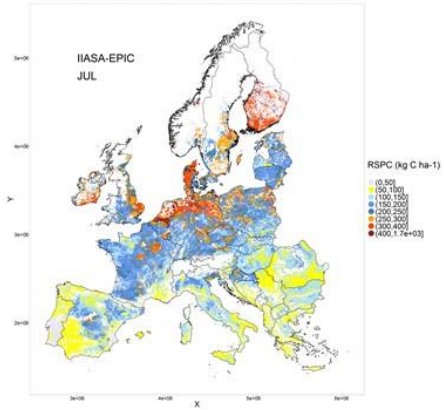
- Leached soluble carbon



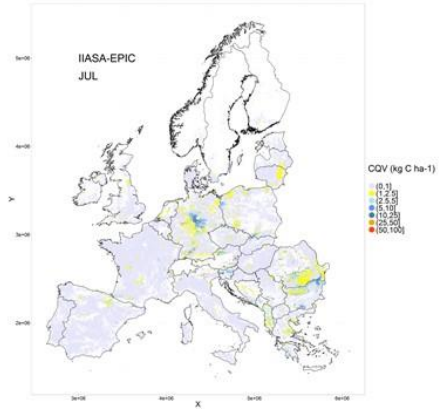
NPP below-ground



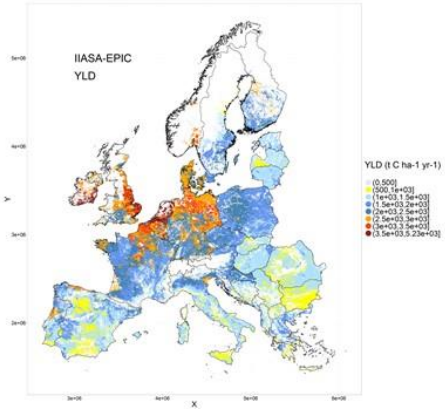
- Heterotrophic respiration



- Carbon in runoff



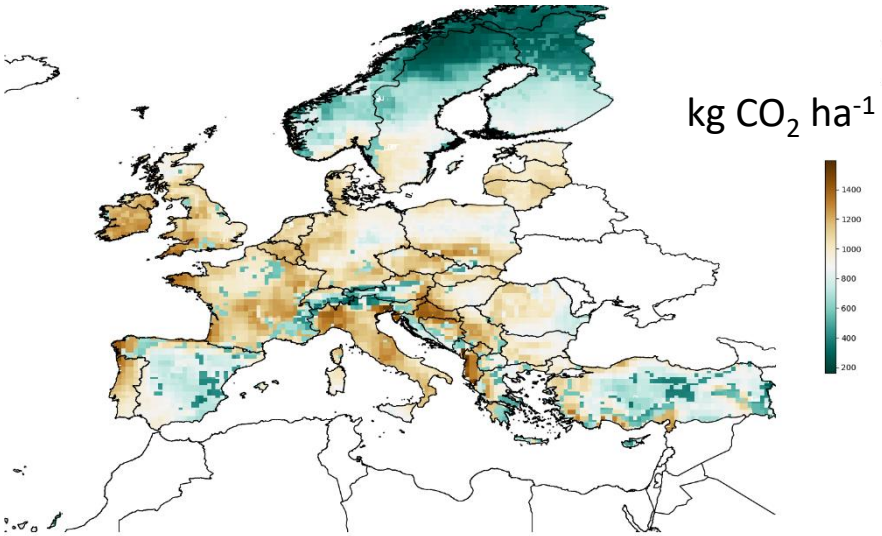
- C embedded in harvest (annual)



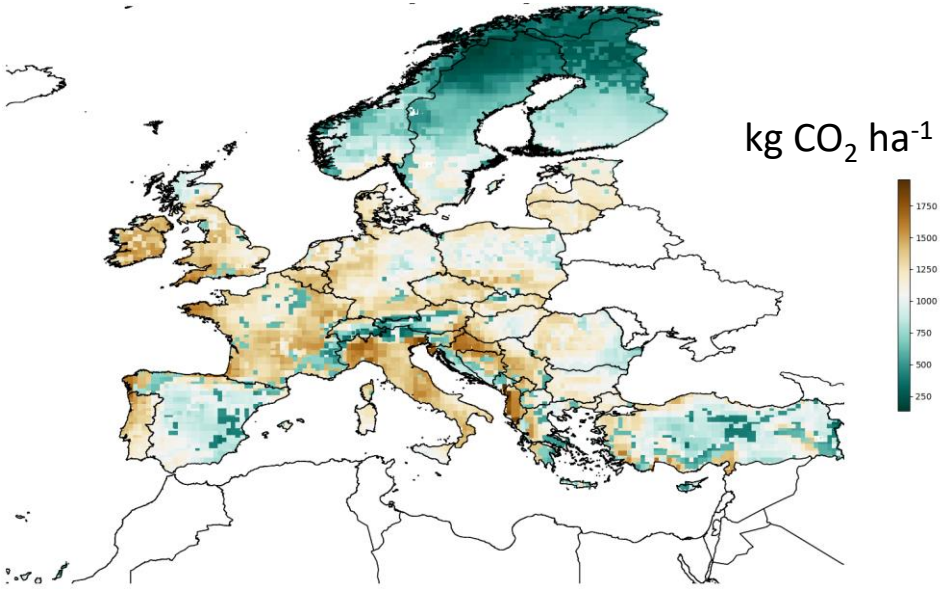
T3.2.1 – HIGH-RESOLUTION MODEL SIMULATION OF THE NET ANNUAL CARBON FLUXES OVER EUROPE

Preliminary results of ECOSSE model (annual average 2005-2015)

Cropland (only apply fertilizer demand)

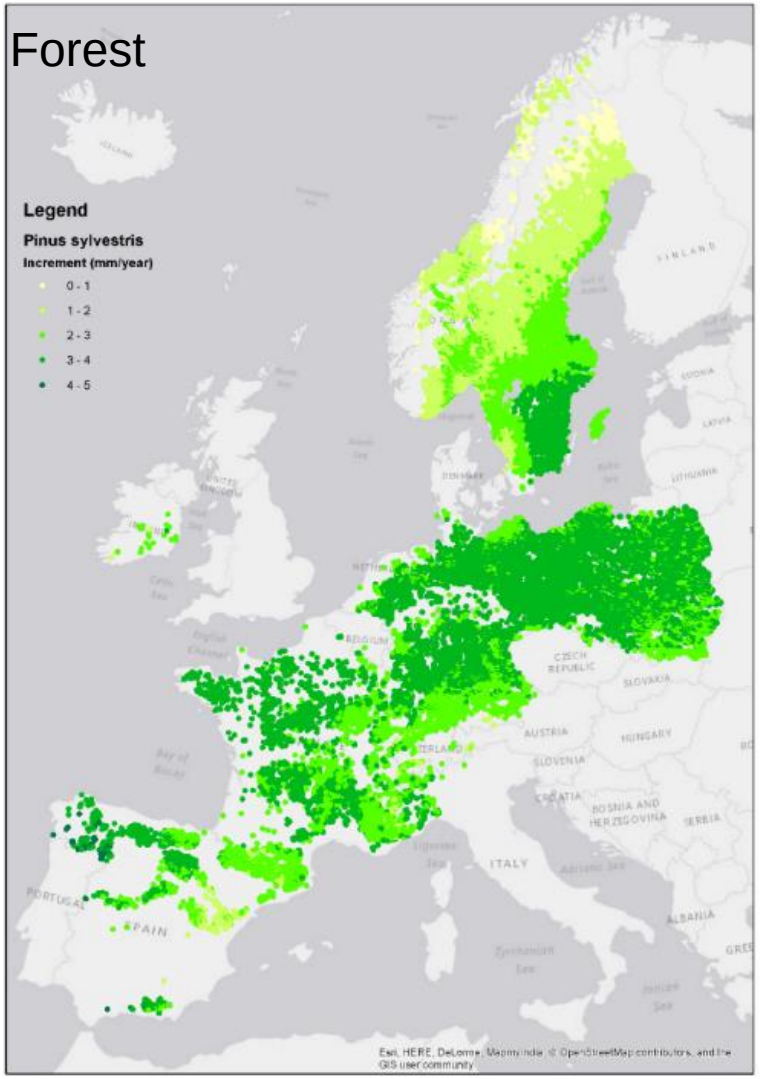


grassland (without management)

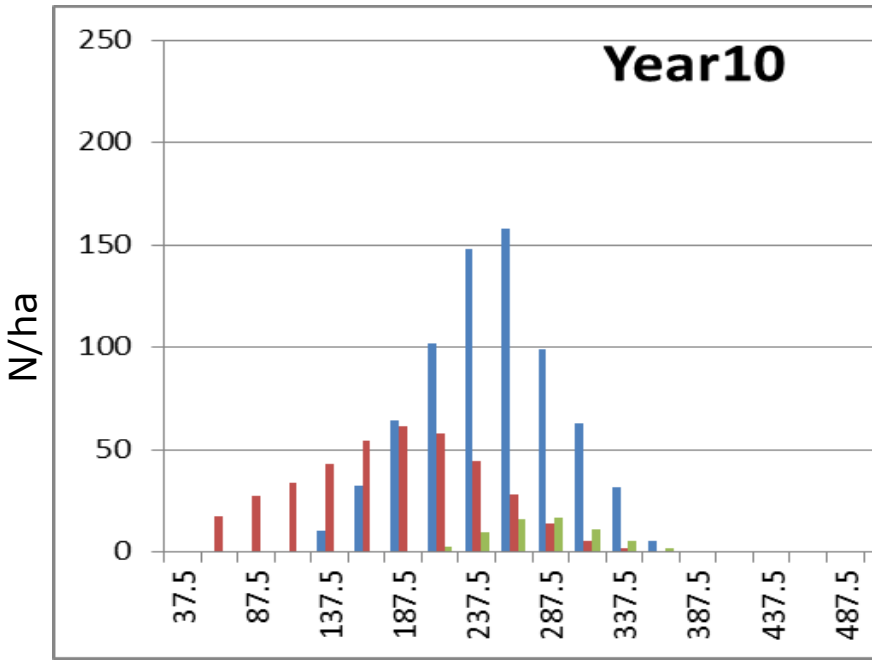


UNIVERSITY OF ABERDEEN

T3.2.1 – EFISCEN forest ecosystem model

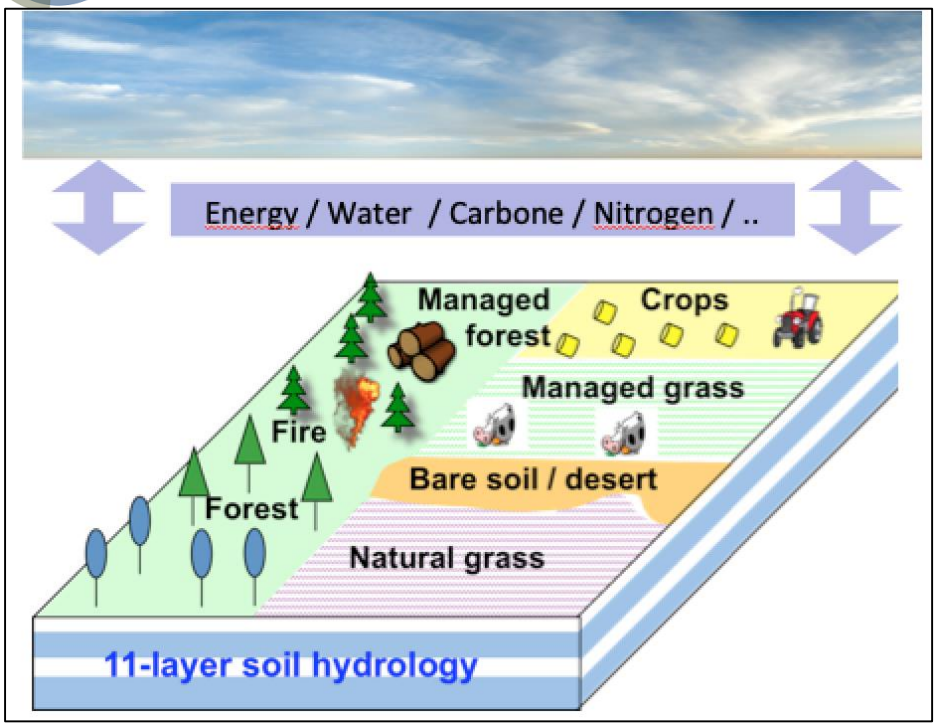


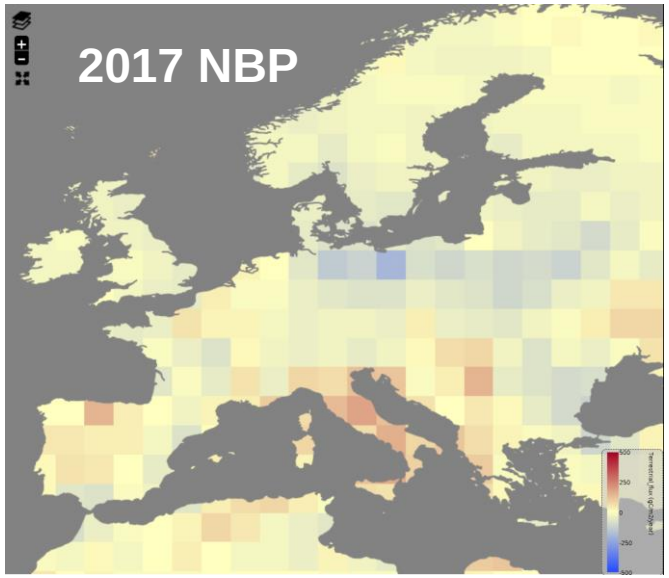
Empirical diameter class model. Climate sensitive, density dependent growth function (Schelhaas et al. 2018)



One plot

ORCHIDEE Process-based global model





Ongoing Improvement

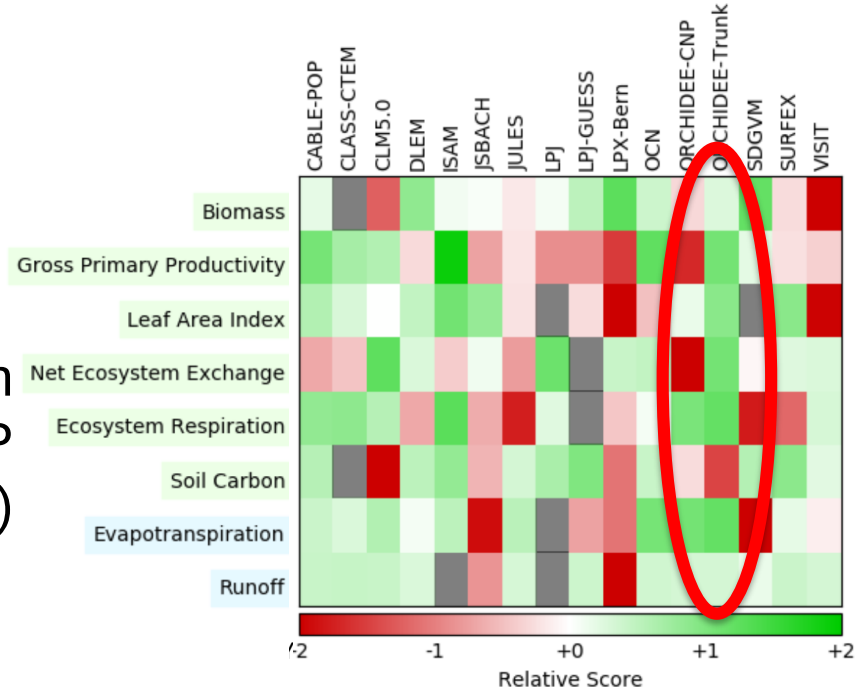
Forest dynamic

Gross transition

Cropland

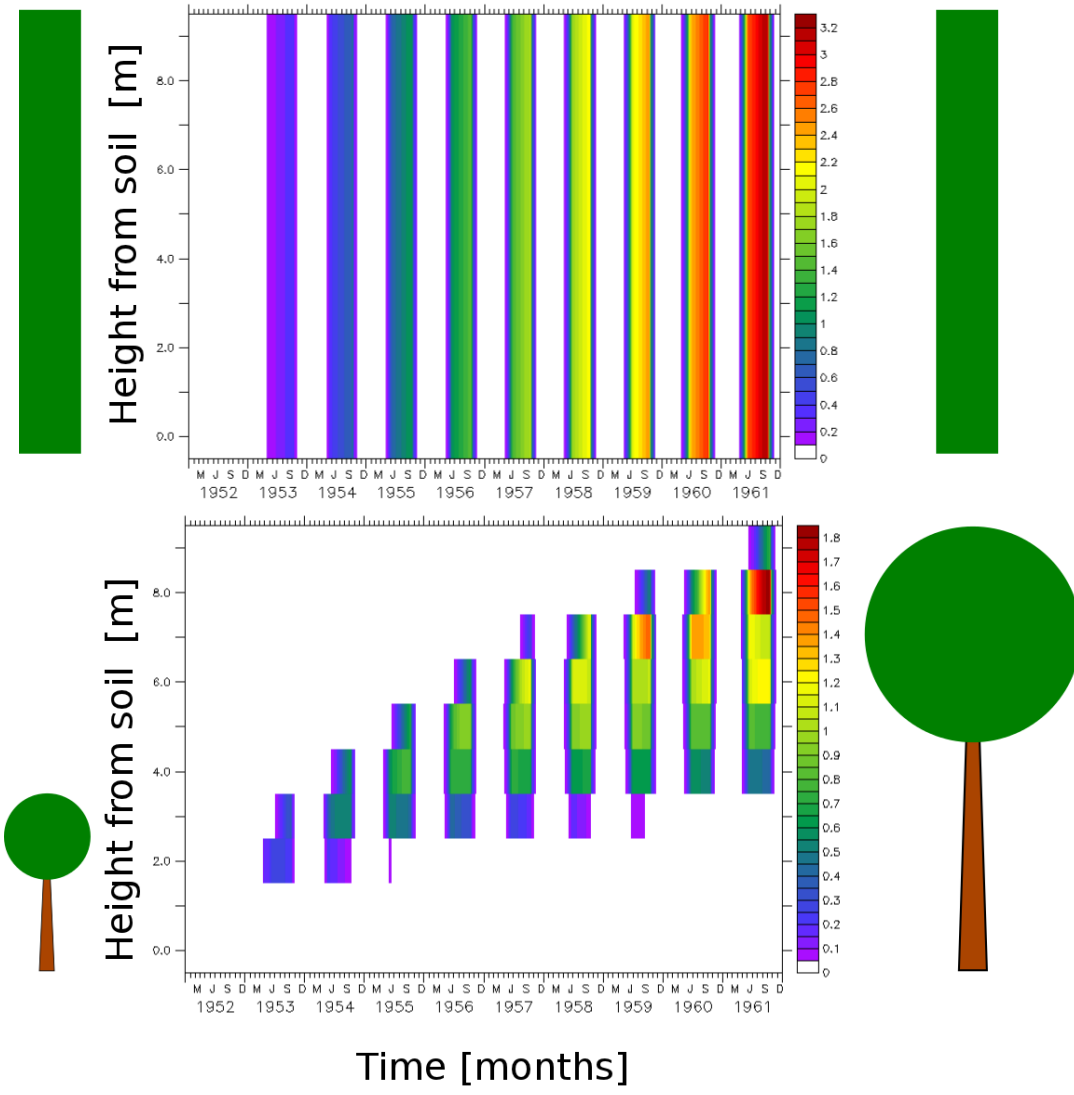
Grass Management

Evaluation within GCP (TRENDY)



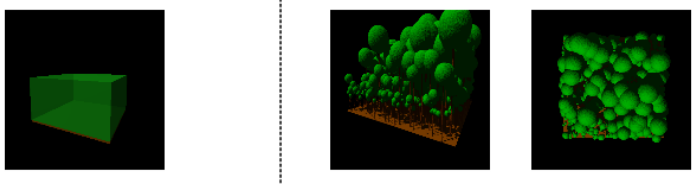
ORCHIDEE global ecosystem model

- **Moving away from the big leaf**
- Canopy structure drives
  - Light adsorption
  - Photosynthesis
  - Albedo
  - Hydraulic architecture
- Enables structural forest management rules (e.g., thinning)
- **Inclusion of nitrogen cycle**



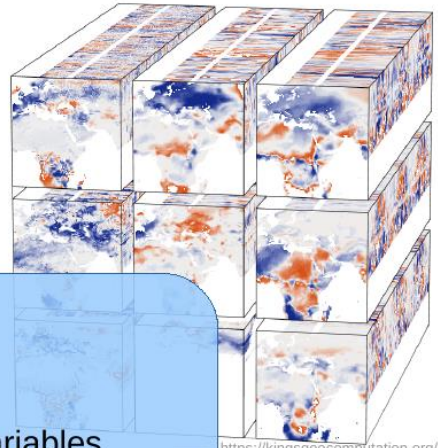
Big leaf

Canopy structure with varying diameter classes



Data – driven approach (MPI-BGC)

https://www.adzine.de/



https://kingsgeocomputation.org/2017/05/08/big-data-for-geoscience-the-earth-system-data-cube/

Site-level gas exchange
and ancillary measurements
+ machine learning
+ global gridded explanatory variables

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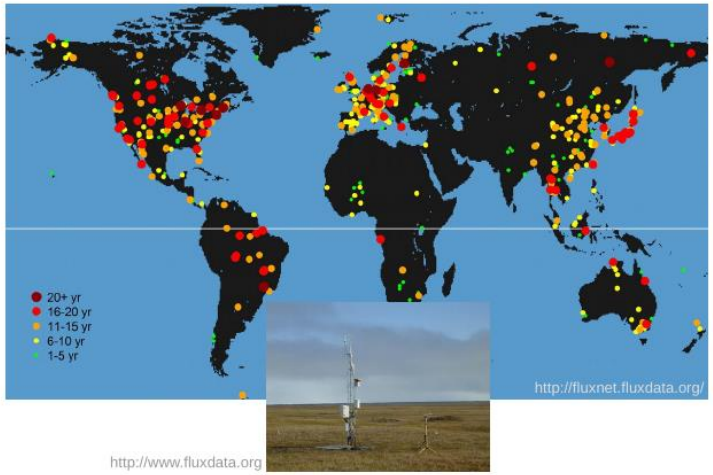
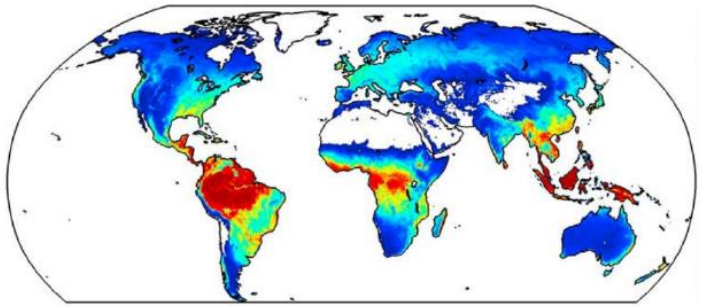
global data-driven estimates of carbon fluxes



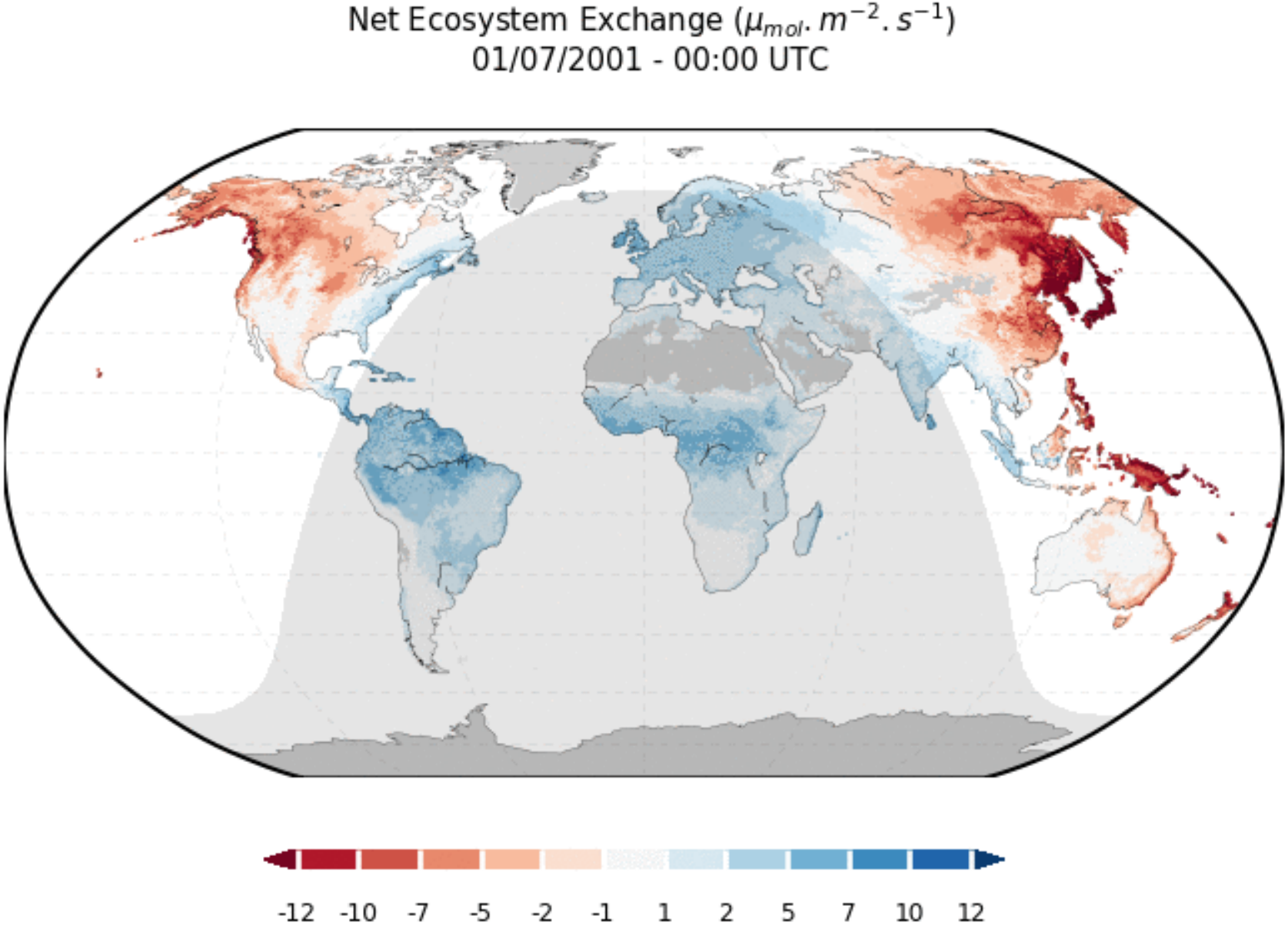
http://www.fluxdata.org

GPP [gC/m2/yr]



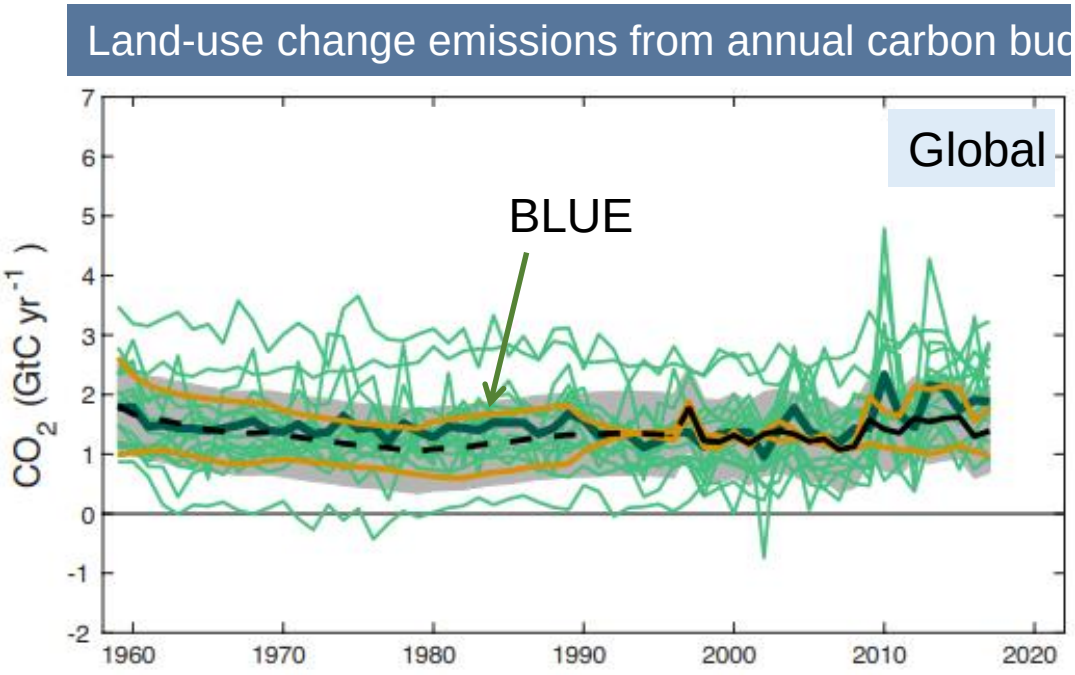
Jung et al., 2011, JGR

Data – driven approach (MPI-BGC)

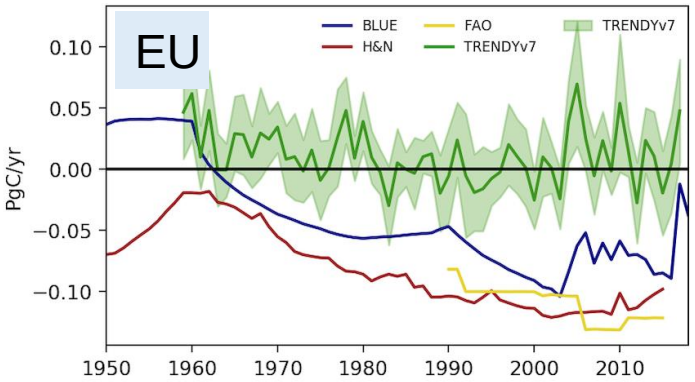


Bookkeeping simulations of land use emissions

Model: BLUE (“bookkeeping of land use emissions”)
Status: annual update as part of GCP’s annual global carbon budget
resolution: annual, 0.25 degrees (→ country-level)



- Bookkeeping models
  (BLUE usually higher than Houghton & Nassikas)
- Bookkeeping mean
- DGVMs
- DGVM mean



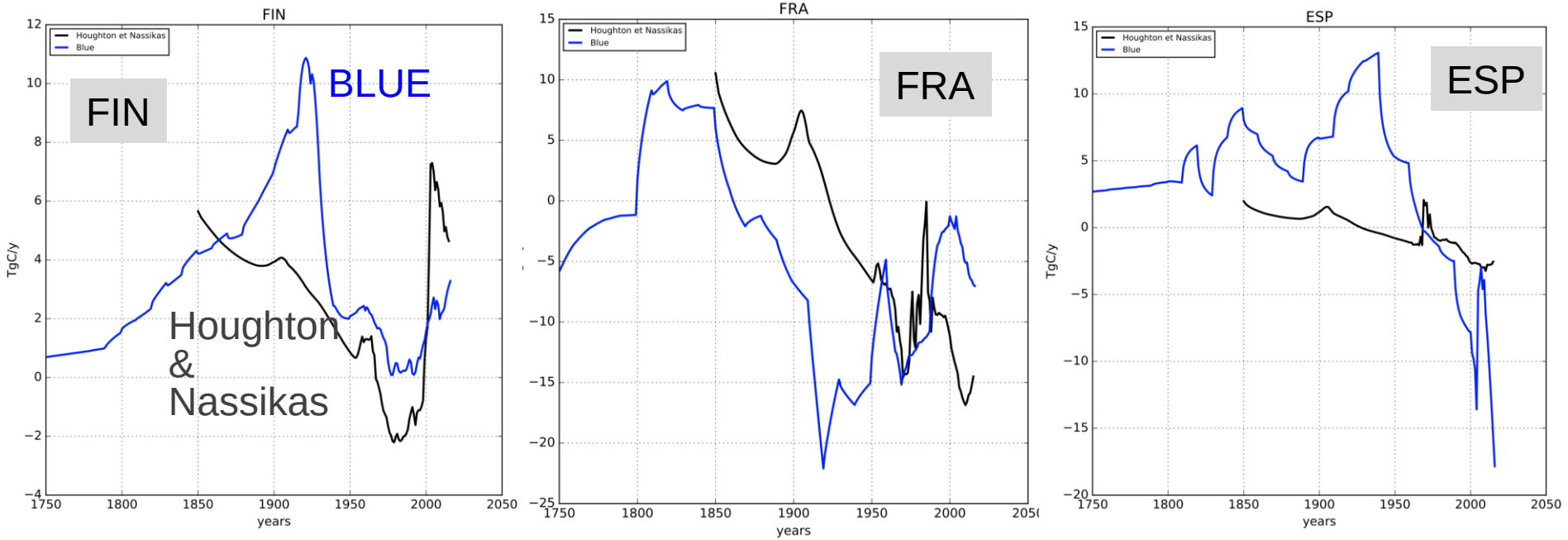
LeQuéré et al., *ESSD*, 2018

Figure: Ana Bastos

Bookkeeping simulations of land use emissions

Model: BLUE (“bookkeeping of land use emissions”)
Status: annual update as part of GCP’s annual global carbon budget
resolution: annual, 0.25 degrees (→ country-level)

Examples of current, default, version of BLUE: Finland, France, Spain (flux in TgC/year)



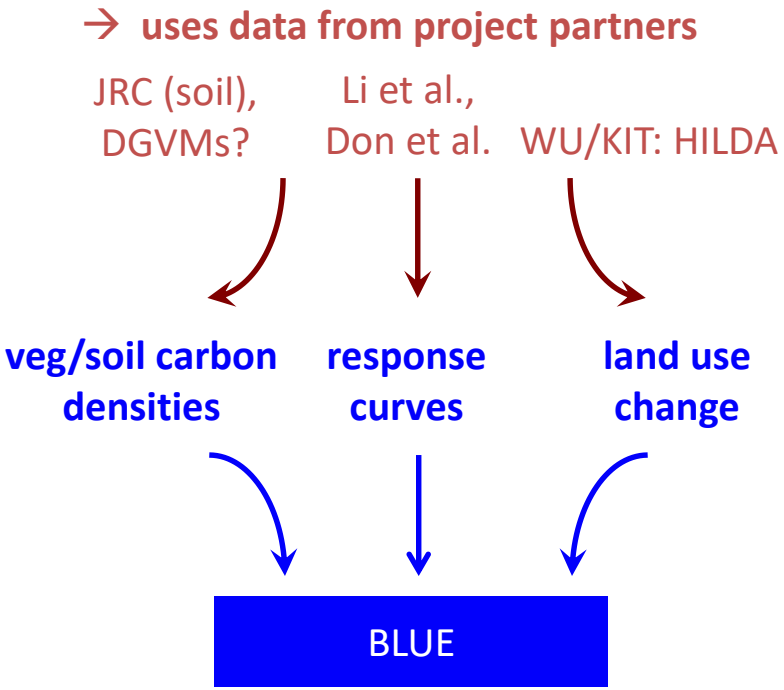
Europe ≠ global: mostly sink, not source; intense agricultural & forestry management (including forest species changes); peat matters; region-specific plant functional types

Figures: J. Nabel

Bookkeeping simulations of land use emissions

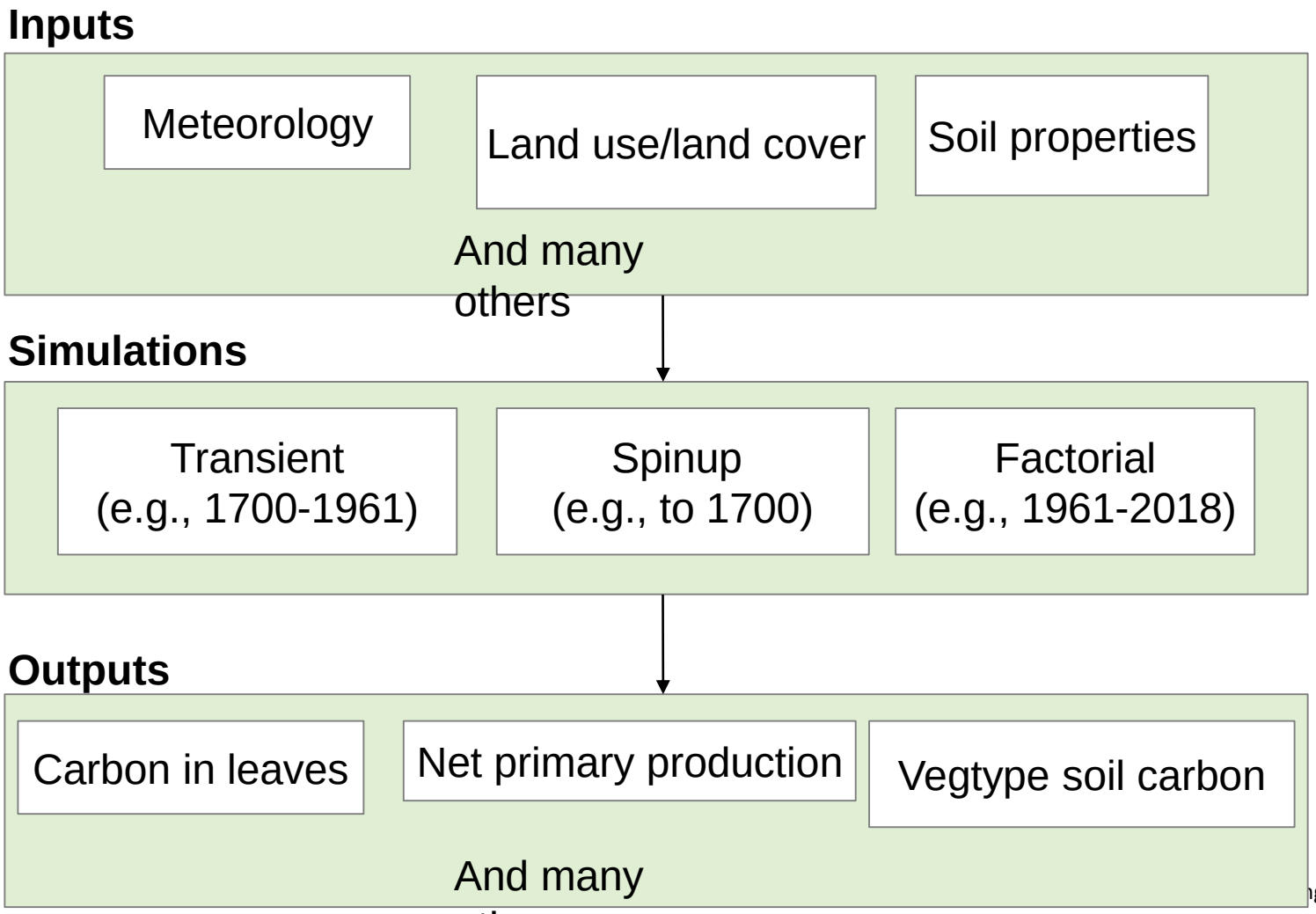
Model: BLUE ("bookkeeping of land use emissions")
Status: annual update as part of GCP's annual global carbon budget
resolution: annual, 0.25 degrees (→ country-level)

- Plans for VERIFY WP3 (starting fall):
  - incorporate observational data where possible to account for Europe's specificities



Common protocol established …

- A generalized method to create comparable outputs between models
- Primarily applicable to process-based ecosystem models
- Used when possible by other model families

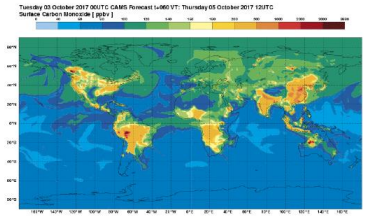


T3.3 – INVERSIONS OF NEE

- T3.3.1: Regional inversion system (M1-M48)
- T3.3.2: Community Inversion Framework (M1-M48)
- T3.3.3: Potential for satellite CO2 observations to improve regional NEE inversions (M13-M48)

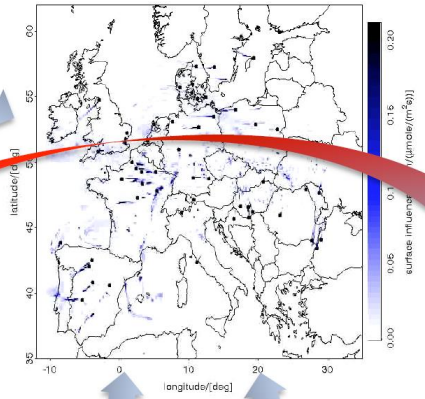
T3.3.1 – REGIONAL INVERSION SYSTEM

Top-down inversions at regional scale using the CarboScope-Regional system

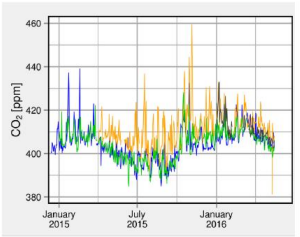


lateral boundary condition

regional atmospheric transport

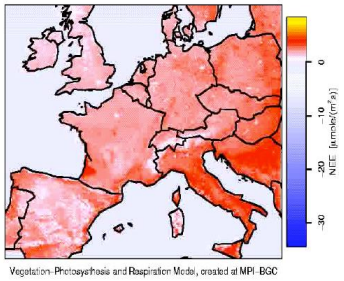


simulated concentrations

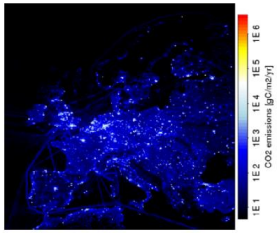


Minimization of differences by flux optimization

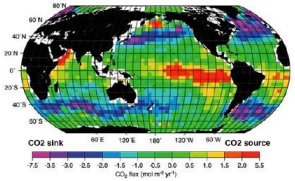
prior biosph. fluxes + error cov.



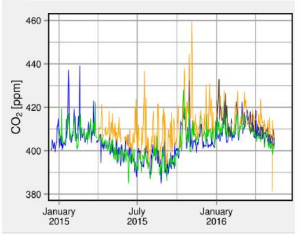
anthropogenic emissions



ocean fluxes

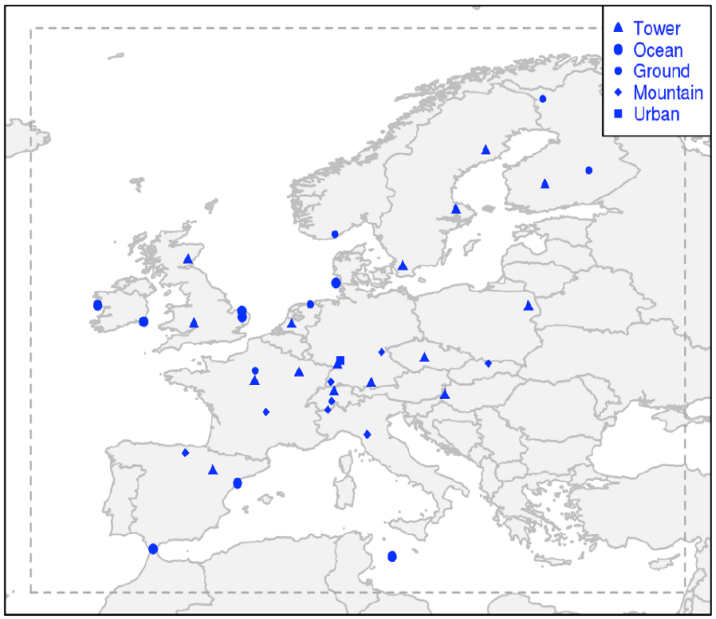


observed concentrations



T3.3.1 – REGIONAL INVERSION SYSTEM

Atmospheric observations:



- 41 atmospheric stations (2017) (Continuous measurements and analysed flask samples)
  Datasets: ICOS, pre-ICOS, ObsPack GV+ v4.0
- Only 11:00-16:00 local (mountain: 23:00-04:00)

CO_2 Model-data mismatch error in ppm (for weekly time scales)

Ocean	Ground	Mount.	Tower	Urban
1.5	2.5	1.5	1.5	4

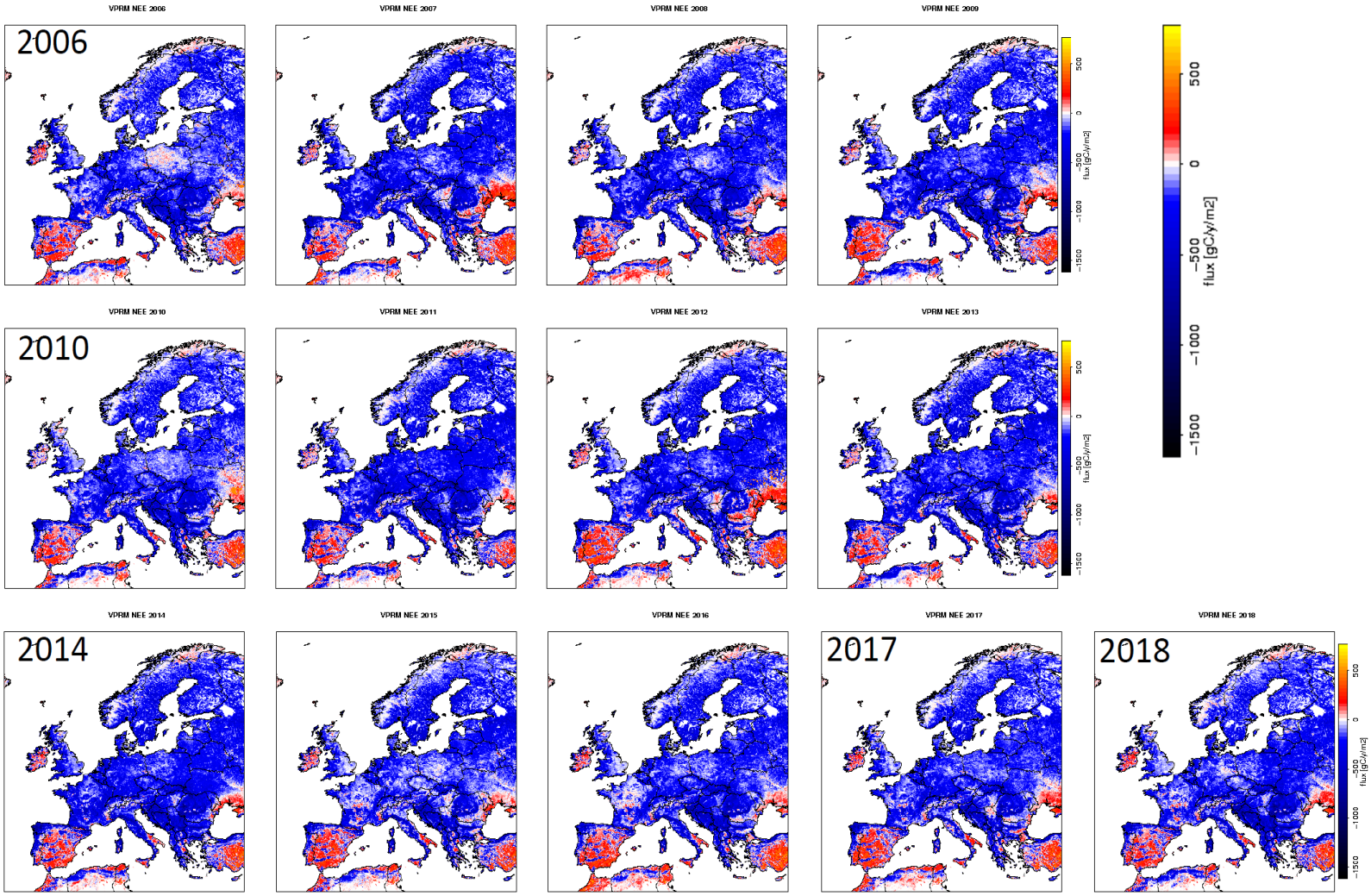
Prior error structure (derived from differences prior fluxes – flux observations):

- Diagonal: 2.3 µmoles/m^2/s (daily fluxes, 0.5x0.5 ° lat-lon)
- error correlations: 30 days, 100 km

=> error inflation needed to obtain consistency with global inversions
0.3 GtC/yr for annual and domain wide aggregated prior error

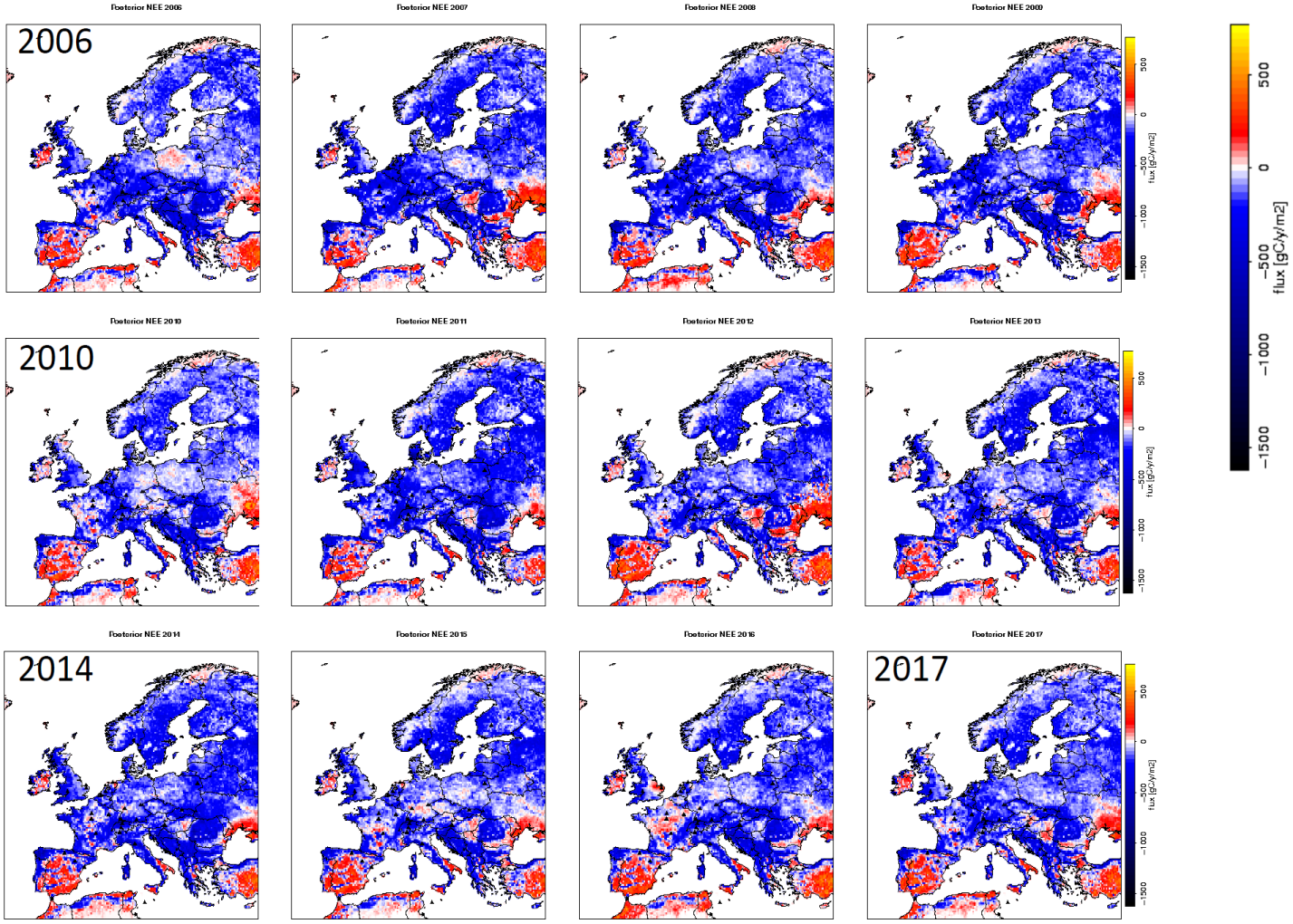
T3.3.1 – REGIONAL INVERSION SYSTEM

A priori NEE (2006-2018):



T3.3.1 – REGIONAL INVERSION SYSTEM

Inversion results NEE (2006-2017):



Plans for 2019:

- **Inversion update using 2018 data (Expected summer 2019)**
- **Posterior uncertainty Estimation**
  - Using ensembles
  - Using different inversion settings
- Ready to use different prior flux fields
- Prepare data stream to users
- **New inversions from other Transport Models with CIF**

T3.4 – Research needed to reduce NEE uncertainties: the case of Eastern Europe

- T3.4.1: Reanalysis of national forest inventory data and high-resolution satellite forest cover change data in Eastern Europe (M1-M36)
- T3.4.2: Ground based measurement of column CO2 to assess quality of satellite data (M12-M30)
- T3.4.3: Use of Carbon Cycle data assimilation systems (M12-M36)
- T3.4.4 Analysis of NEE and carbon balance of Eastern Europe (M24-M48)

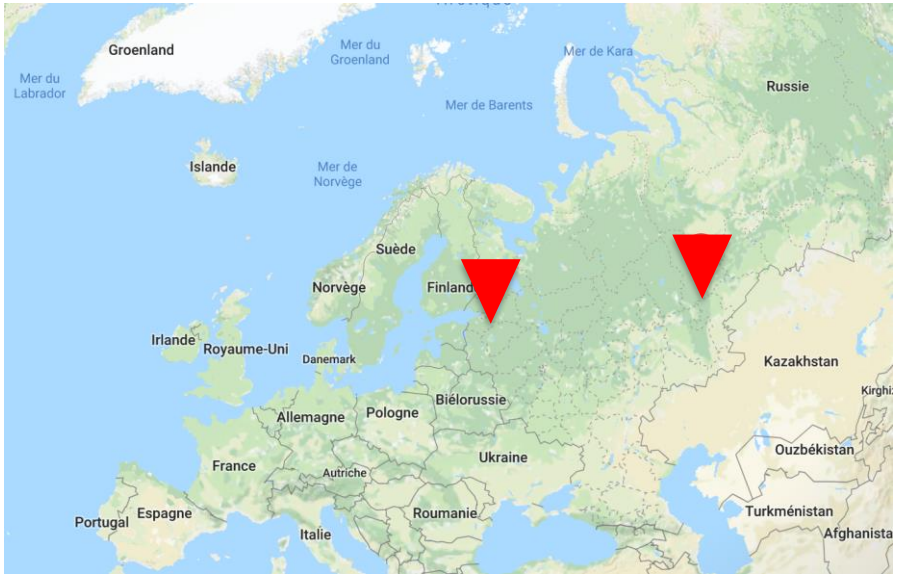
T3.4.2 – Ground based measurement of column CO_2 to assess quality of satellite data

- Two COCCON (Collaborative Carbon Column Observing Network) spectrometers have been calibrated and tested at KIT
- The spectrometers entered Russia in August 2018 using a Carnet ATA custom document
- Russian partners performed successful test measurements
- The extension of the Carnet ATA until May 2020 is in progress

T3.4.2 – Ground based measurement of column CO2 to assess quality of satellite data

- Mar – Apr 2019St. Petersburg city campaign (supporting NO2 measurements with DOAS planned by Russian partners)

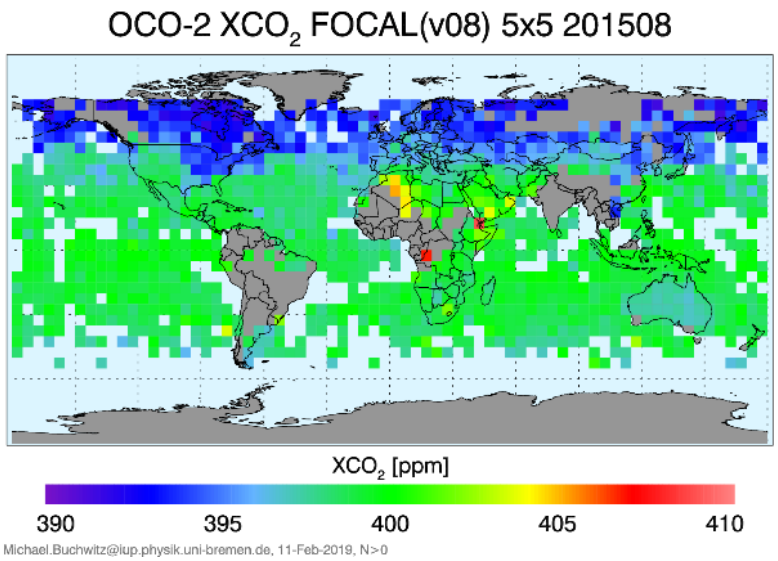
- May 19 – Apr 20 Simultaneous Measurements in St Petersburg and Yekaterinburg

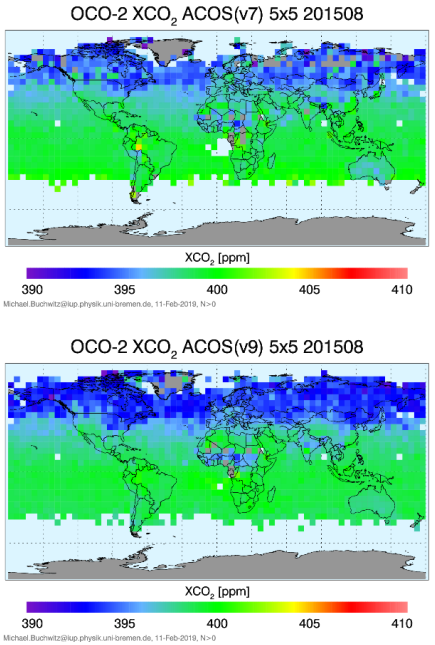


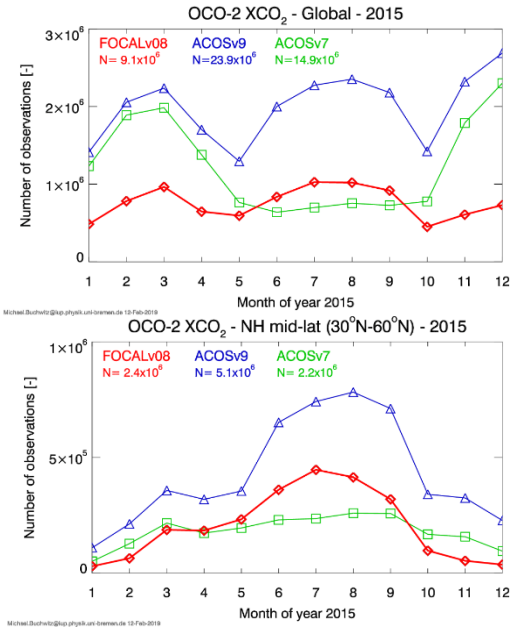
T3.4.4 – XCO2 DATA – SPECIFIC CALIBRATION FOR EASTERN EUROPE

Comparison with NASA/ACOS products:

- FOCAL v08 is sparser and somewhat noisier, esp. in comparison with latest NASA product v9







Data quality via comparison with TCCON:

- Systematic error: 0.58 ppm (site-to-site bias); random: +/- 1.5 ppm (1-sigma, single obs.)

See also **poster** „OCO-2 XCO_2 retrievals using the FOCAL algorithm“

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WP3 – Status of Deliverables / Milestones

DEL n°	DEL Title	Leader	Due date	Status	Comments
D3.1	First - State-of-the-art database	UNIABDN	14	To be completed	First version

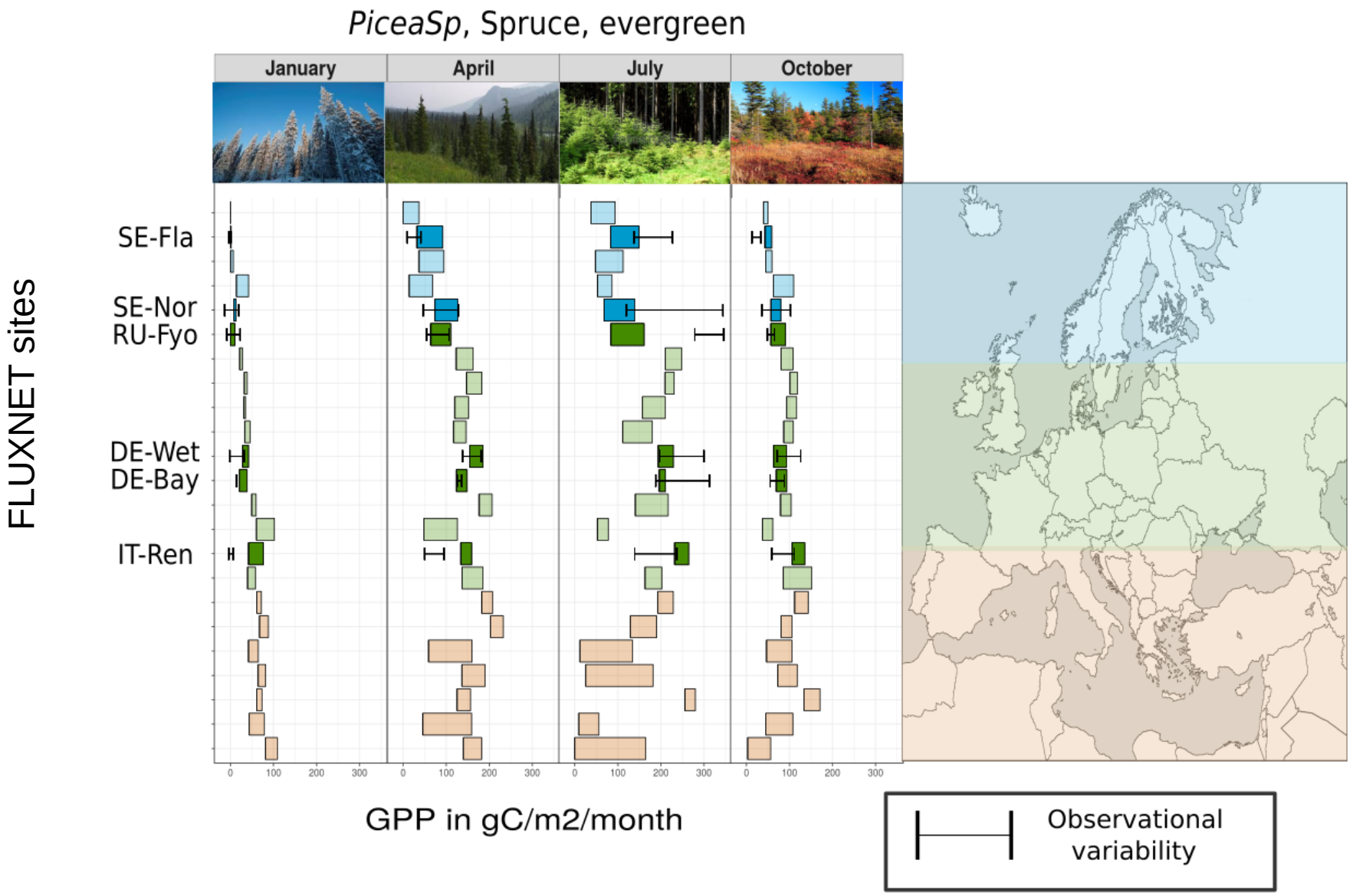
n°	MIL Title	Leader	Due date	Status
MS12	First yearly compilation of driver datasets	**MPG**	**31/01/19**	Achieved
MS13	Common protocol to simulate the carbon balance of European ecosystems	**UNIABDN**	**30/11/18**	Achieved
MS19	Compilation of statistical and environmental data for bottom-up models	**UNIABDN**	**30/04/18**	Achieved

Thank you….

WP3 – Main objectives until M24

- T3.1.8: Stitching together existing and new regional/global MMF-TAD maps (Canada, USA, UK, Sweden, Norway, Asia, Europe) to produce global maps + a journal article (**M13-M24**)
- T3.2.1: CBM runs will be non-spatial explicit for 2019 (Nuts2 level) (**M13-M24**)
- T3.2.1: ECOSSE runs for croplands and grassland will be provided as daily time series for Europe (0.25 degree resolution) (**M13-M24**)
- T3.3.1: Inversion update using 2018 data (**M13-M19)**
- T3.3.1 : Posterior uncertainty Estimation (using ensembles and using different inversion settings) and ready to use different prior flux fields (**M13-M24**)
- T3.3.1 : Prepare data stream to users (**M13-M24**)

ORCHIDEE – model evaluation



WP3 – Main objectives until M24

- T3.4.2: St. Petersburg city campaign (supporting NO2 measurements with DOAS planned by Russian partners) (**M14-M15**)
- T3.4.2: Simultaneous Measurements in St Petersburg and Yekaterinburg (**M16-M28**)
- Task 3.4.4: XCO_2 from OCO-2, optimized for Europe, for task „Analysis of NEE and carbon balance of Eastern Europe“: Data analysis (e.g., comparison with NASA products), algorithm improvements, processing of more data (**M13-M24**)

WP3 – Main objectives until M24

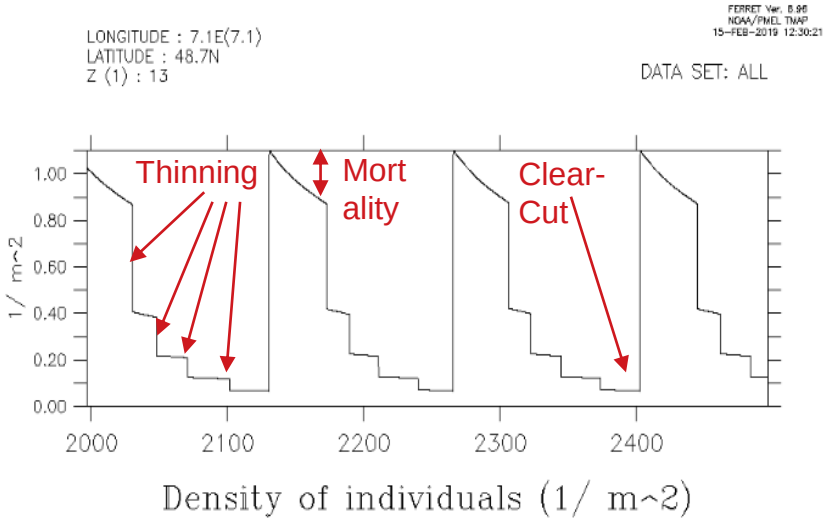
- Complete data collection/improve quality of data sets
- Establish and improve the data platform
- Provide improved results for the different models
- Provide results for Europe using the regional inversion system

T3.2.1 – High-resolution model simulation of the net annual carbon fluxes over Europe Objectives

- Bottom-up for CO2 emissions using a complementary models
- Models are informed by various data streams through model data fusion or direct use of key observational constraints
- Output data include NEE, atmospheric CO_2, nutrient availability and land use/management change

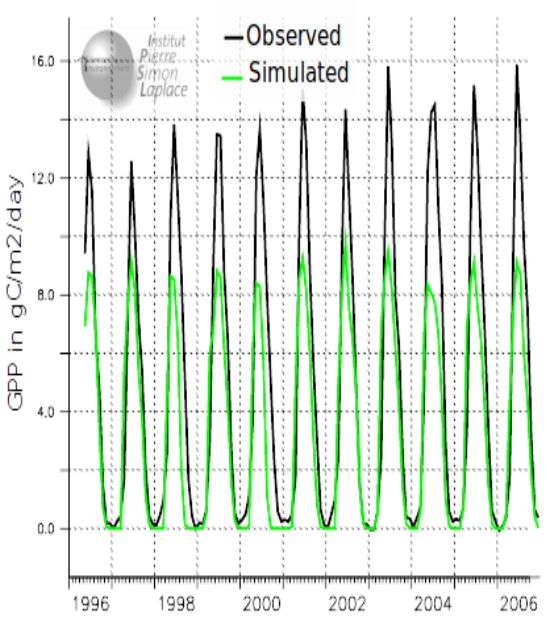
ORCHIDEE – Site evaluation

- 500-year simulations
- 7 tree species
- 3 forest management
- 22 European FLUXNET sites
- For evaluation, simulate <u>every</u> species on <u>every</u> site



For each site, GPP, NEE, R_{eco} are evaluated.

Looking for a qualitative assessment along the latitudinal gradient.



T3.2.1 – High-resolution model simulation of the net annual carbon fluxes over Europe - Progress

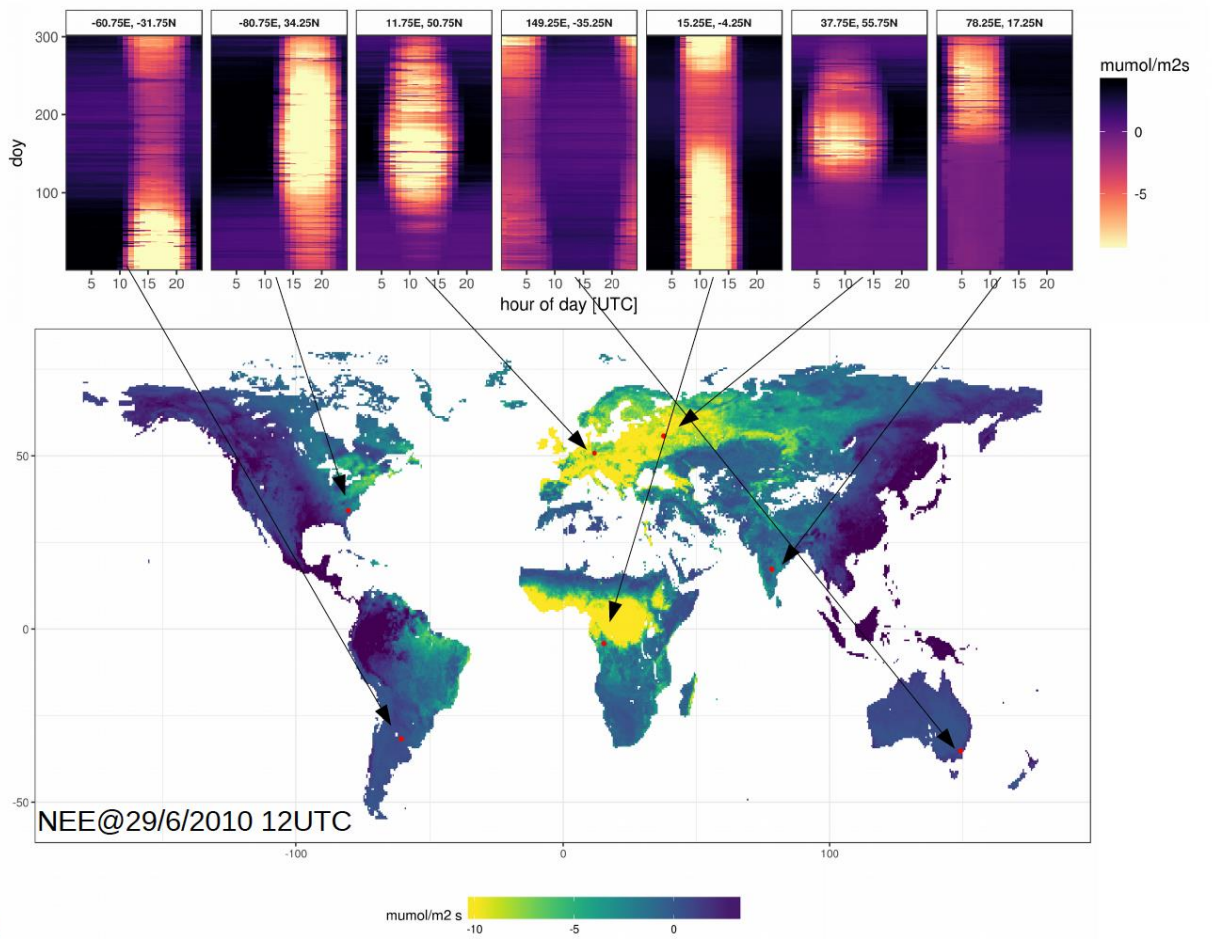
- CBM runs will be non-spatial explicit for 2019 (Nuts2 level), and spatial explicit from 2020.
- Preliminary, not validated ECOSSE results are available for cropland and grasslands. Improved results at the end of 2019
- Results of ORCHIDEE runs will be available soon

Data – driven approach (MPI-BGC)

Based on Bodesheim et al. 2018

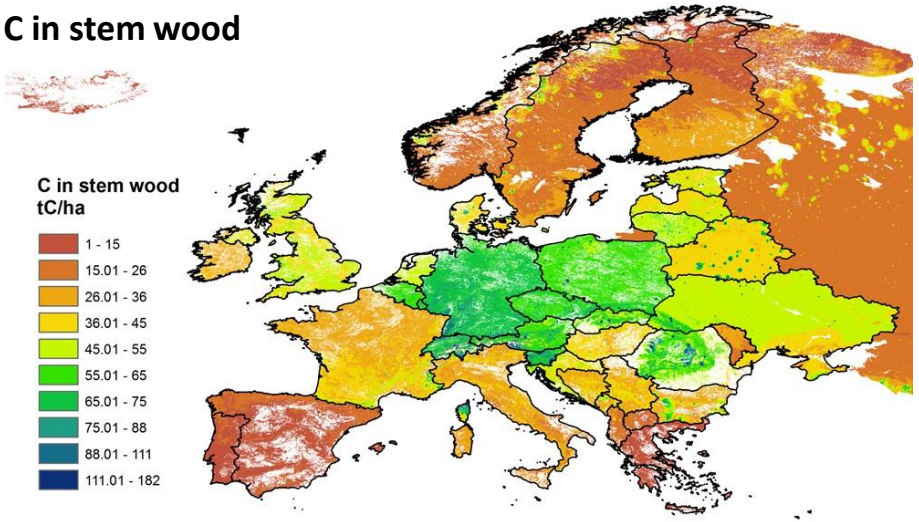
➔ hourly NEE / GPP using hourly meteo data from ERA5.

➔ 0.5° spatial resolution for the period 2008-2017

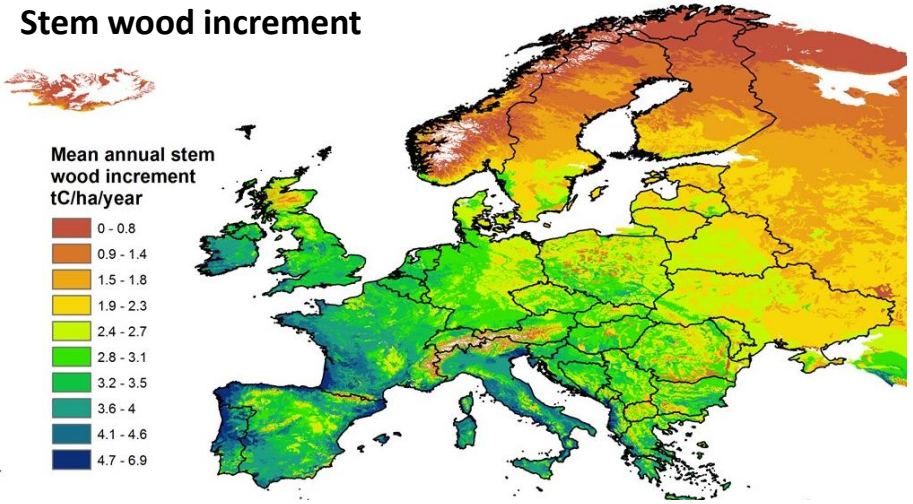


G4M model – testing outputs for year 2015

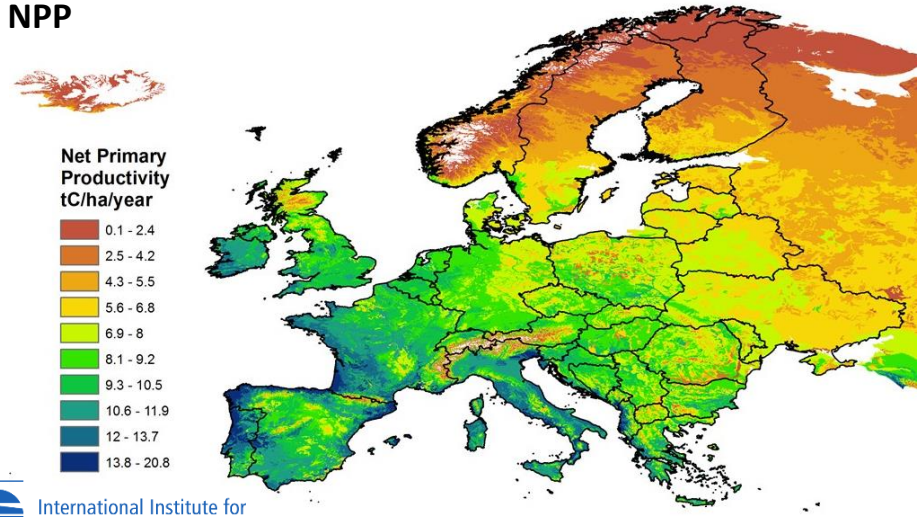
C in stem wood



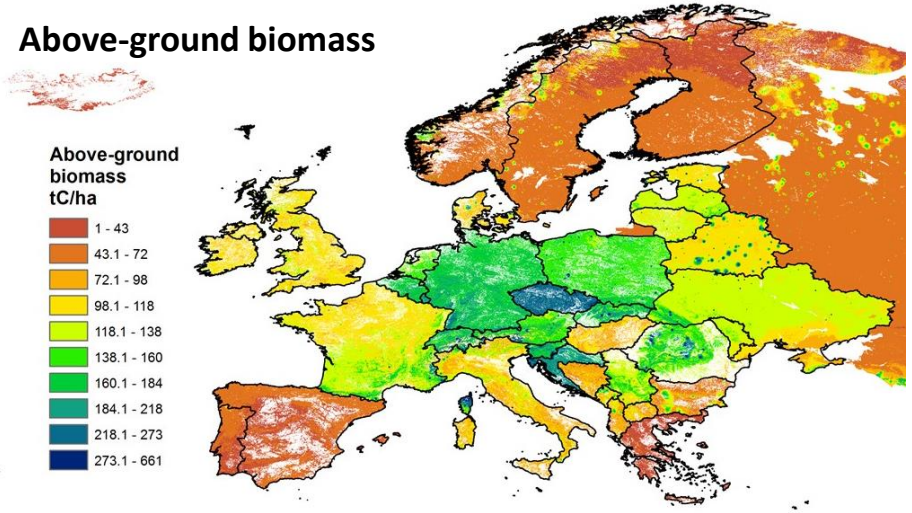
Stem wood increment



NPP



Above-ground biomass



T3.4.2 – GROUND BASED MEASUREMENT OF COLUMN CO2 TO ASSESS QUALITY OF SATELLITE DATA - Background

- Carbon fluxes in Russia are highly uncertain and not well constrained by measurements. Satellite measurements lack ground-based validation in this region.

- Within Verify ground-based column measurements will be performed in Russia to provide data for a) satellite validation and b) flux estimates from the city of St Petersburg and the land biosphere.

T3.4.4 – Research needed to reduce NEE uncertainties: the case of Eastern Europe - Progress

UBremen satellite contributions to VERIFY:

- XCO_2 from OCO-2, optimized for Europe, for task „Analysis of NEE and carbon balance of Eastern Europe“
  - Information to access 1st data set (see above) provided in Oct. 2018
- UBremen also contributes with ground-based observations in Russia via Task 3.4.2

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WP3 – Status of Milestones

MIL n°	MIL Title	Leader	Due date	Status	Comments
MS20	Compilation of atmospheric observations and uncertainties for Inversions	CEA	6		WP3, WP4
MS21	Design of the CIF and plan for its development	CEA	6		WP2,WP3, WP4
MS31	Draft uncertainty framework ready	WU	12		WP2,WP3, WP4
MS34	Derivation of prognostic framework	NILU	12		WP2,WP3, WP4
MS39	Annual update of the Global Carbon Budget	CEA	12		WP2,WP3, WP4,WP7