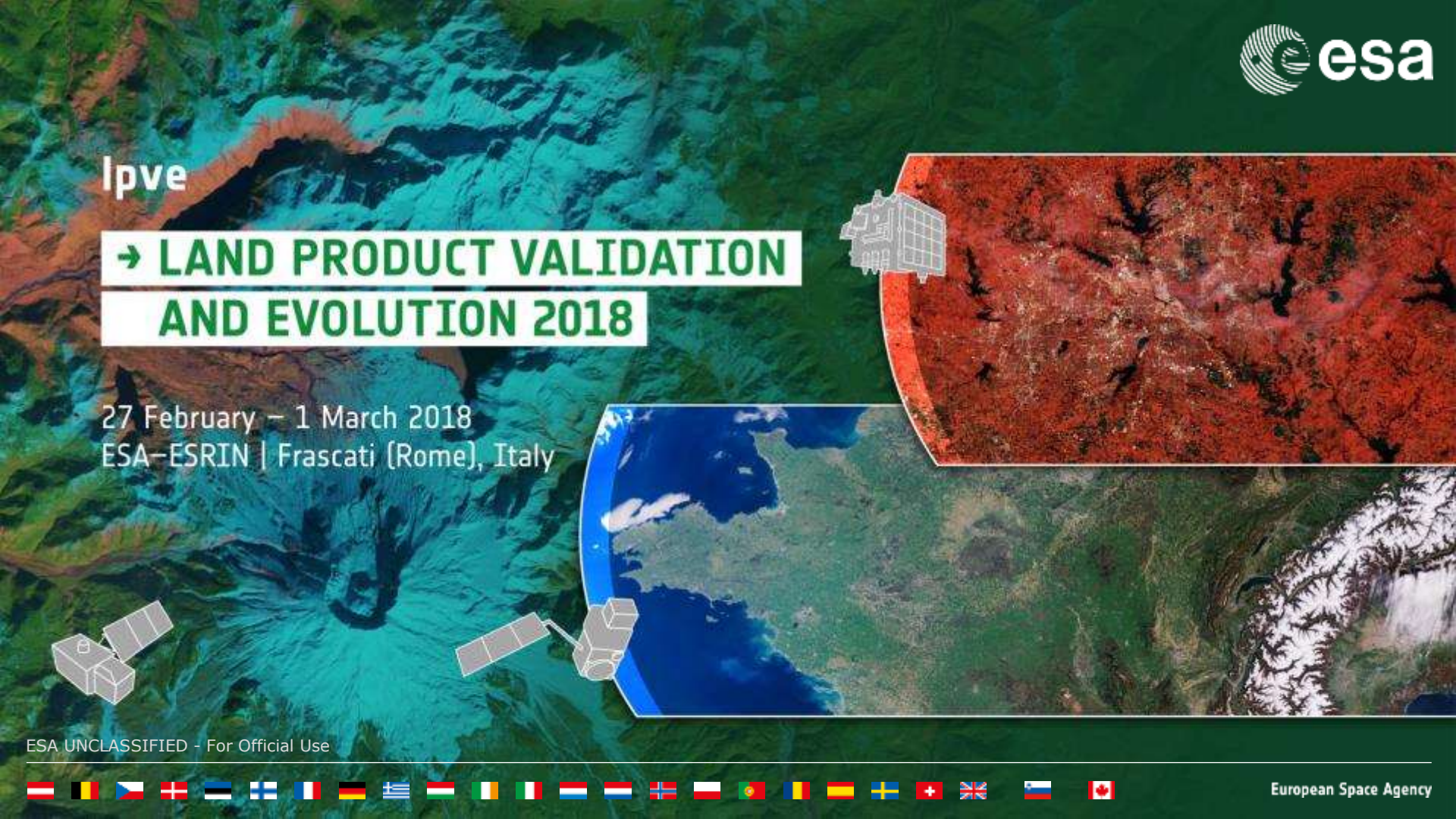


Else Swinnen[1], Roel Van Hoolst[1], Rebecca Thomas[2], Colin Prentice[2], Sara Vicca[3], Manuela Balzarolo[3], Ivan Janssens[3]

TerrA-P

Estimation of GPP and NPP from Sentinel-3 data starting from first principles

Objectives

DEFINITION

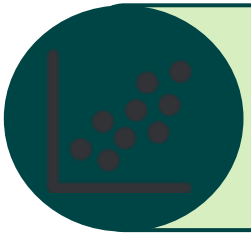
The P-model developed by Imperial College London (ICL) is used as a basis for the Gross Primary Productivity (GPP).

Imperial College London

IMPLEMENTATION

VITO remote sensing implements the model on global MERIS and Sentinel-3 data.

vito remote sensing



VALIDATION

The models outcome is validated by the University of Antwerp using FLUXNET GPP and historical in-situ and biomass measurements + benchmark to similar global datasets

University of Antwerp

vito remote sensing

Requirements survey

Characteristic	Target Requirement/ Product Specification Proposed	 Requested
DEFINITION		
Products	GPP ABP, because there is too little in situ data to accurately produce BP or NPP	GPP ABP / NPP / BP
Units	GPP: g C/m²/day ABP: kg DM/ha/day	g C/m²/day and kg DM/ha/day
Further specification	GPP and ABP will be produced for C3 and C4 plants, without distinction of where they occur.	Distinction between C3 and C4 plants
Quality & uncertainty information	Quality flags Per-pixel uncertainties Accuracy assessment of products.	Quality flags Per-pixel uncertainties Information on accuracy of product
Timeliness	Within 3-5 days after acquisition	Within 3-5 days after acquisition
Periodicity	10-daily	10-daily (daily)
Spatial resolution	300 m Provide downsampled products	300 m (or lower)
ACCURACY		
Relative accuracy	20%	20%
Absolute accuracy	150 g C/m²/year	120-150 g C/m²/year

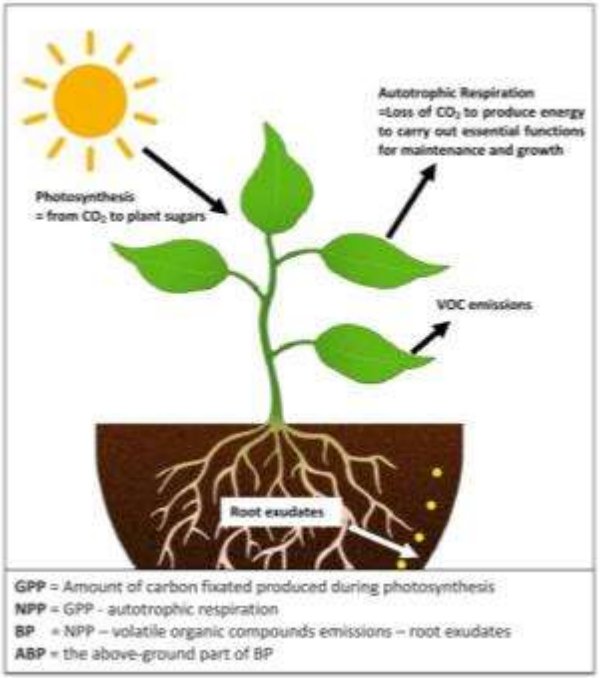
Outputs

GPP Gross primary production **– the rate of total carbon fixation (photosynthesis) by the ecosystem.**

- The most fundamental measure of primary production, as all ecosystem functions depend on it.
- GPP data are available from flux measurements – at time scales from half-hourly up to multi-annual – for some hundreds of locations worldwide (albeit with a bias towards temperate regions) and for crops as well as natural and managed ecosystems.

ABP Above-ground primary production **– the rate of production of plant matter, excluding roots.**

- A practically important measure, e.g. the production rate of forage for grazing animals, it is closely related to the production rate of timber for harvest
- It can be converted to estimates of crop yield.
- There are data on ABP: commonly on at the annual time scale, for many ecosystems, especially crops and managed forests but also for natural ecosystems.



Model development

Model is based on **P-model** (Wang et al., 2017)

- Wang, H., I.C Prentice, W.M. Cornwell, T.F. Keenan, T.W. Davis, I.J. Wright, B.J. Evans and C. Peng (2017) Towards a universal model for carbon dioxide uptake by plants. *Nature Plants* **3**: 734–741.
- Online code repository (https://bitbucket.org/labprentice/)

Desirable attributes of the model:

- An explicit derivation from the standard Farquhar, von Caemmerer and Berry (FvCB) photosynthesis model, and a clear relationship to a well-established functional form for stomatal behaviour – both elements required for a prediction of GPP.
- A representation of physiological CO_2 effects on photosynthesis that is consistent with both the FvCB model and results from FACE experiments.
- No distinctions among plant functional types and biomes (except for the well-established differences between C_3 and C_4 plants), eliminating the need for spatial discontinuities induced by the use of a land-cover classification and look-up table.
- Demonstrated success in representing flux-derived GPP across different biomes at monthly time scales.

Extremely parameter-sparse, while achieving high accuracy.

Outputs with associated uncertainties

P-model: input data

- **fAPAR** per pixel and dekad or month: MERIS GVI data and Sentinel-3 (later).
- **Meteorological data** (ECMWF) daily total 'global' (solar shortwave) radiation and vapour pressure from ECMWF.
- **Remotely sensed LST** (GlobTemperature) daily temperature data to drive the model, including the calculation of vpd from actual vapour pressure.
- **Ambient partial pressure of CO_2**: a time-varying global average CO_2 mole fraction obtained from the monitoring station at Mauna Loa, Hawaii is converted to partial pressure units and used as input to the P model.
- **C_3 versus C_4 photosynthesis**

Validation: general

In situ data FLUXNET-2015

Data

- GPP: FLUXNET-2015
- ABP: Vicca et al., 2012; Campioli et al., 2015

Methods

- Between-site differences in average annual GPP (modeled GPP against in-situ GPP).
- Interannual variation in modelled GPP against in-situ observation of GPP (only for the years for which the remote sensed product matches observations).
- Seasonal variability in GPP at daily (considering mean or accumulated values over 24 hours), 10-daily and monthly time scales.

Benchmark with other global data sets

Data:

- MODIS (MOD17A2)
- Copernicus Global Land Service Lot1 GDMP

Methods

- Product completeness
- Spatial consistency analysis
- Global statstical analysis
- Temporal consistency analysis

P-model: current results

Model

Model calibration used monthly fAPAR based on combination of SeaWifs and MERIS GVI.

Model applied using:

- MERIS GVI (10-daily)
- Temperature data based on
  - ECMWF meteo data
  - GlobTemperature LST

Set of 122 sites:

- relatively homogeneous surrounding vegetation
- long measurement records
- quality

Validation

90 homogeneous sites selected from FLUXNET-2015

- 58 sites, for a total of 260 site years of data ECMWF
- 46 sites for a total of 227 sites years of data for LST estimates

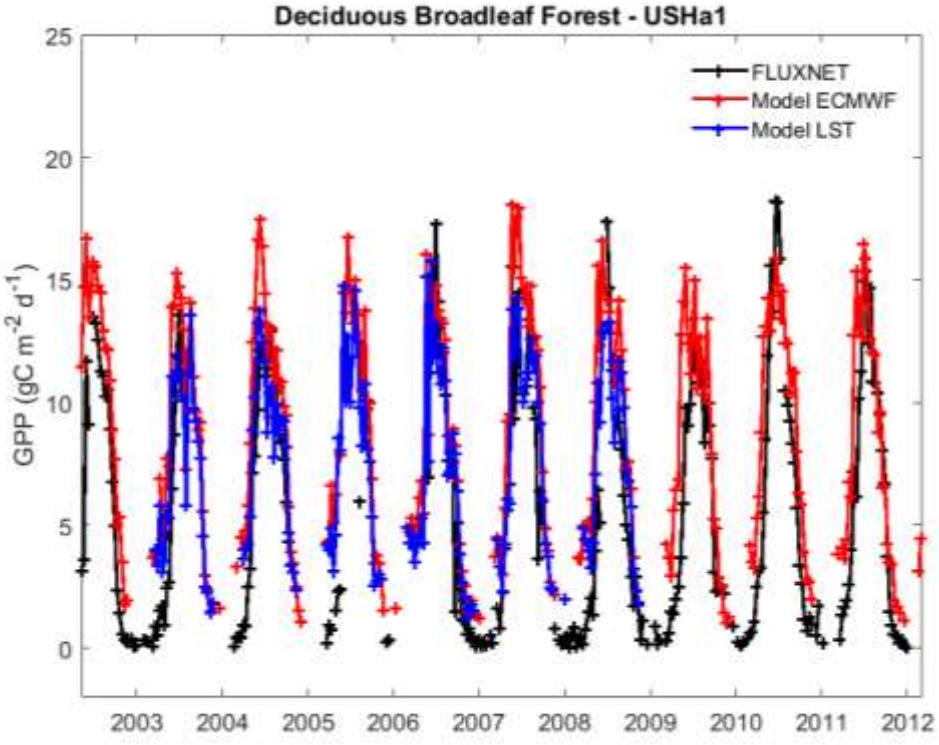
Different time steps: Seasonal (10 days) & annual

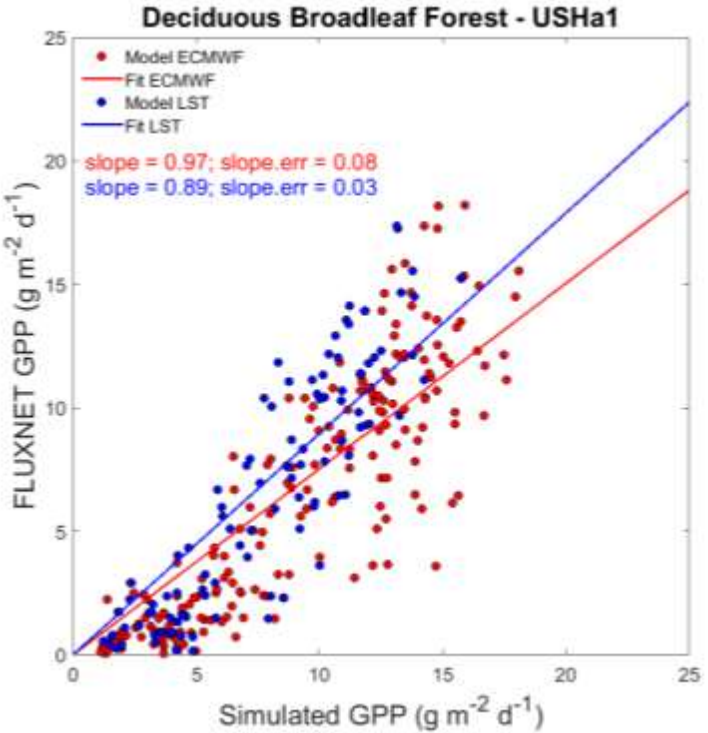
Sites, PFT, climate

Meteorological forcing

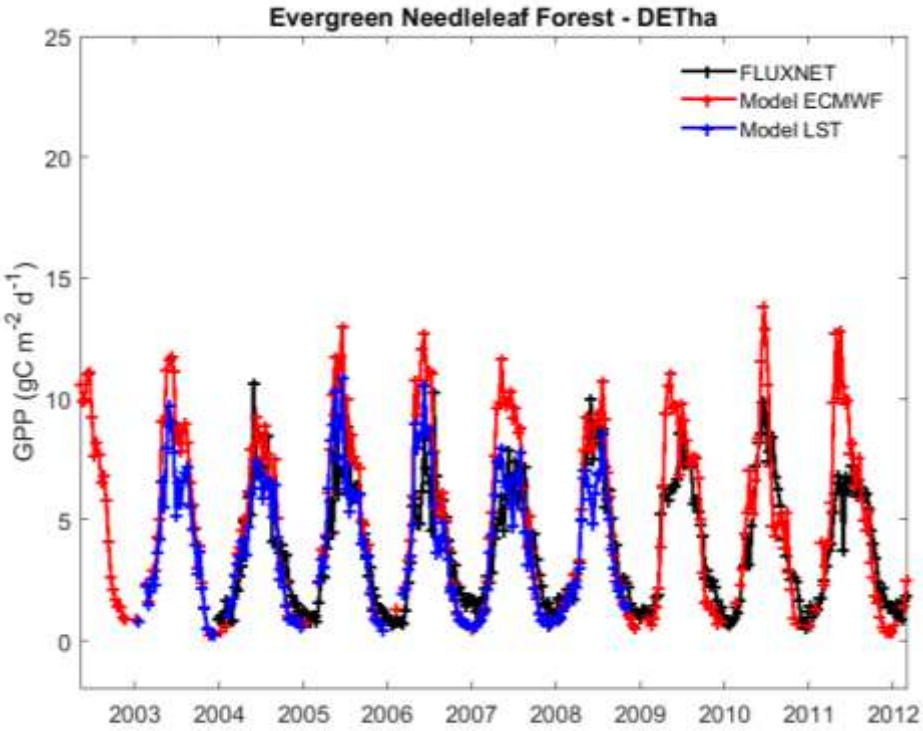
Ecological functions

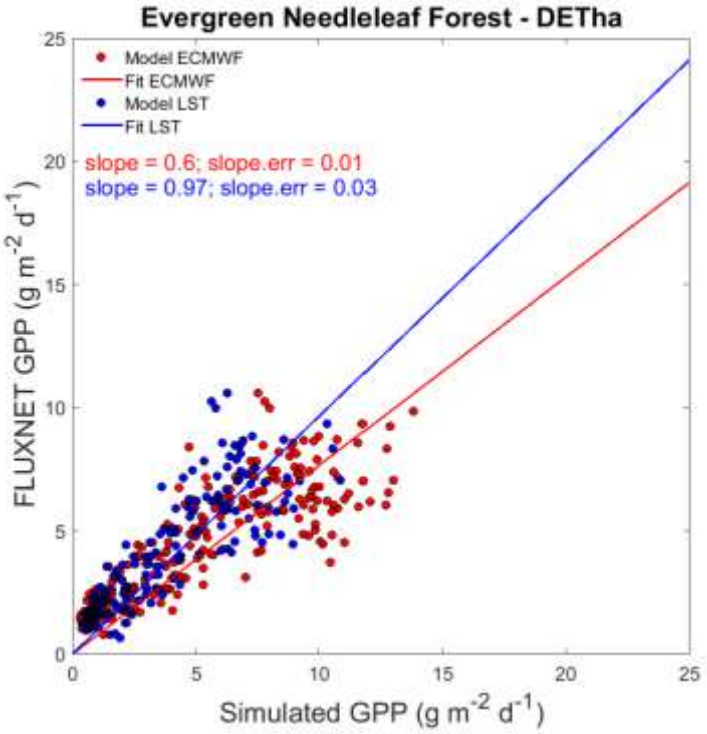
Validation with in-situ data



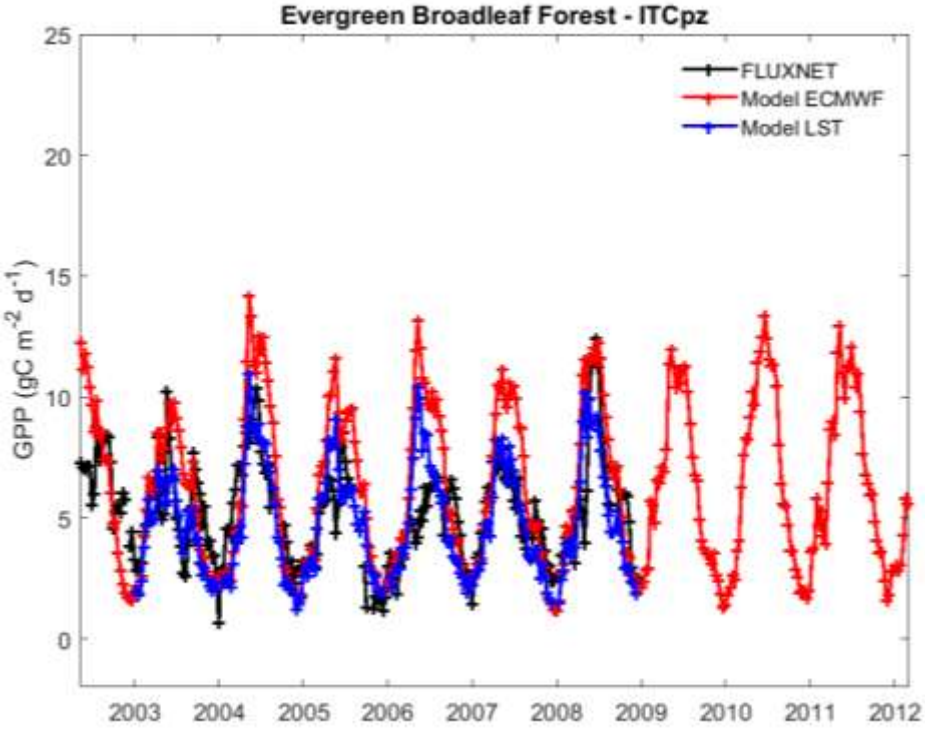


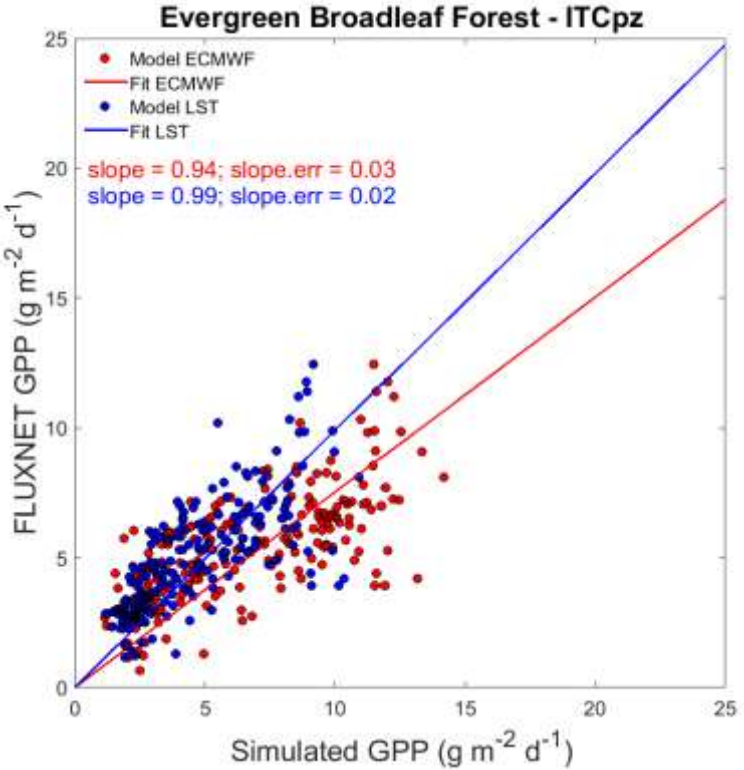
Validation with in-situ data

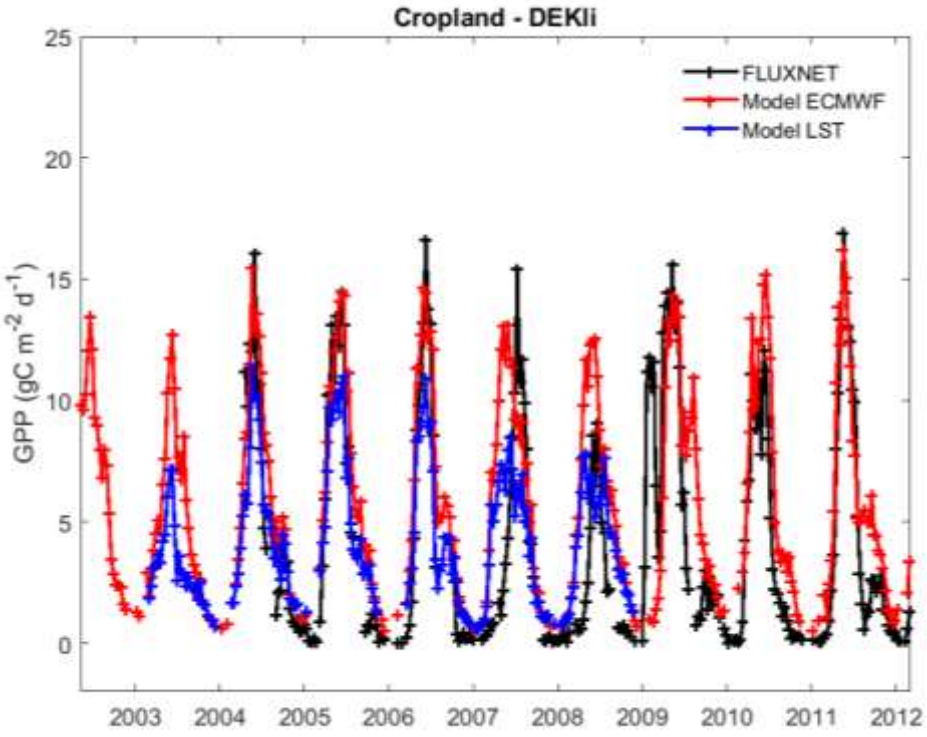




Validation with in-situ data






Cropland - DEKli
FLUXNET
Model ECMWF
Model LST
GPP (gC m-2 d-1)
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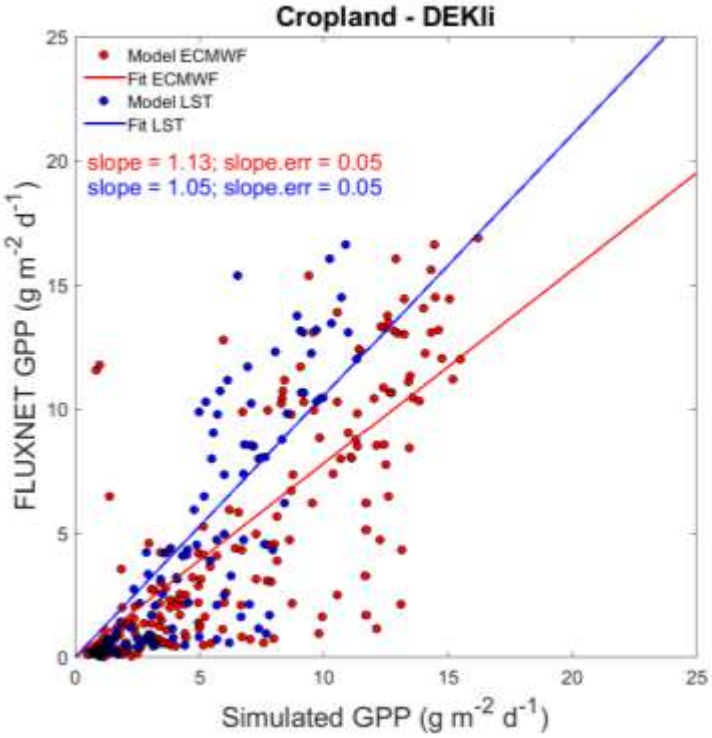
Cropland - DEKli
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Model LST
Fit LST
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FLUXNET GPP (g m-2 d-1)
Simulated GPP (g m-2 d-1)
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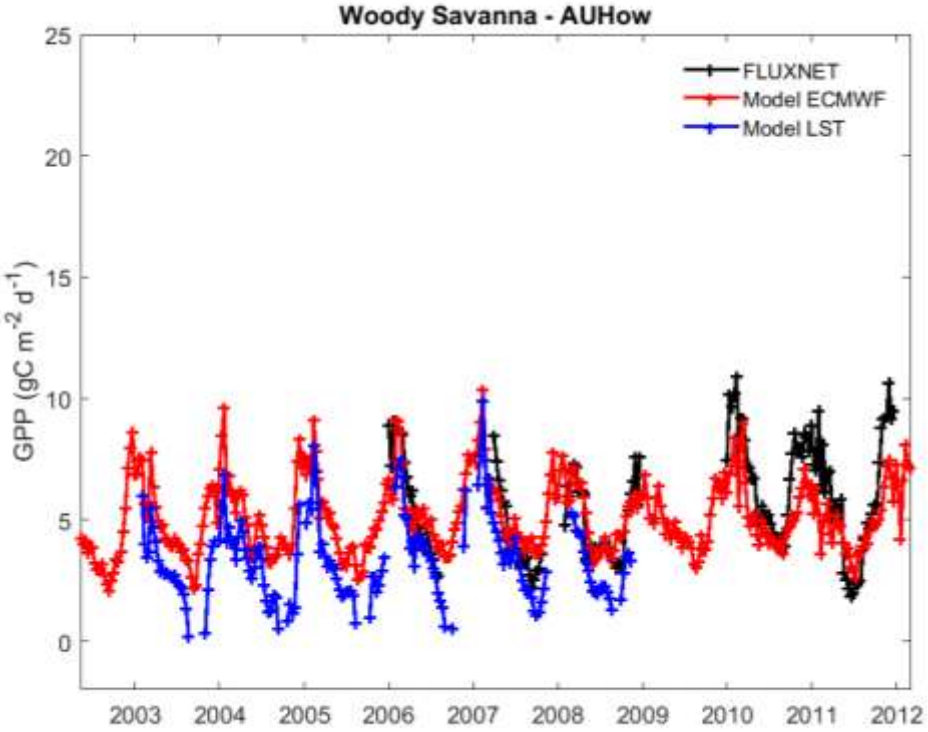
Woody Savanna - AUHow
FLUXNET
Model ECMWF
Model LST
GPP (gC m-2 d-1)
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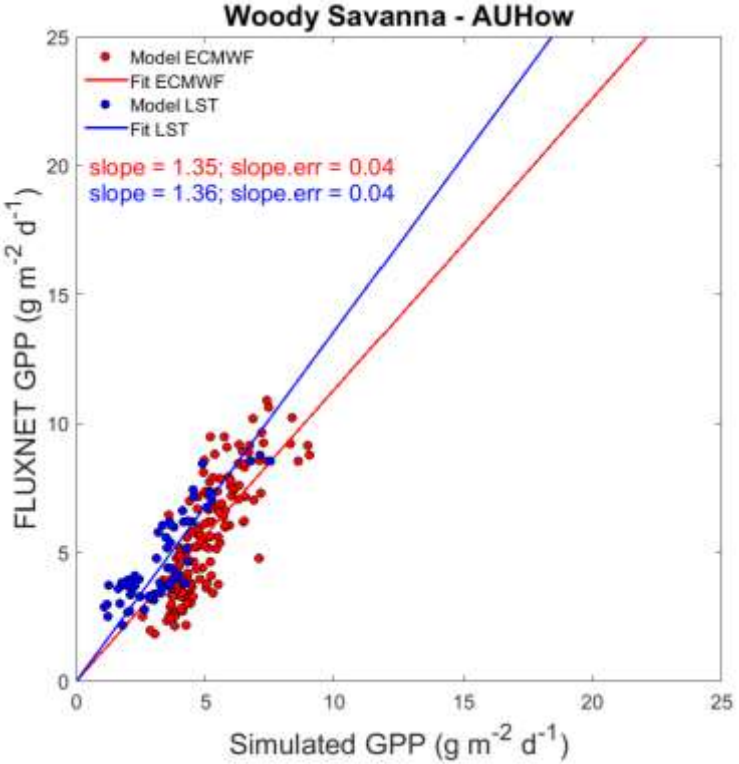
Woody Savanna - AUHow
Model ECMWF
Fit ECMWF
Model LST
Fit LST
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FLUXNET GPP (g m-2 d-1)
Simulated GPP (g m-2 d-1)
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Future developments

P-model

GPP:

- Recalibrate with MERIS GVI and TCI
- Remotely sensed soil moisture effect on GPP
- Remotely sensed digital elevation model or a remotely sensed surface pressure to account for the various atmospheric pressure effects on photosynthesis → improve GPP at high elevations

ABP

- Use global soils data reflecting the effect of soil fertility on the ratio of ABP to GPP.

Implementation

Implement the final P-model in a prototype processing chain to derive global estimates of GPP and ABP.

- MERIS: 2007 – 2008
- Sentinel-3: demonstrate on 2016 (?)

Validation

Validation at global scale including benchmark to MODIS GPP (MOD17A2) and CGLOPS1 GDMP

Thank you

https://terra-p.vito.be/

- ATBD v1
- User Requirements Survey
- Publication

Soon

- ATBD V2.1
- Validation report