



# Biomass and Soil Moisture simulation and assimilation in Hungary in the framework of ImagineS project

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# Outline



- **ImagineS project (2012-2016)**
- **Surfex and LDAS (Land Data Assimilation System)**
  - ISBA-A-gs in SURFEX
  - Data assimilation: Extended Kalman Filter
- **Validation**
  - 1D (against in-situ measurements from Hegyhátsál)
  - 2D (against satellite data)
  - Agricultural utilization
  - Drought indicators



# ImagineS



- **Implementation of Multi-scale Agricultural Indicators Exploiting Sentinels**
- **EU-FP7 project: <http://fp7-imagines.eu>**
- **Period: 40 month (Nov. 2012. – June 2016. )**
- **8 Institutions (Fr, Sp, Be, UK, Hu), From this 2 SME**
- **Aims:**
  - Improve the retrieval of basic biophysical variables coming from PROBA-V and LandSat-8 for Copernicus Global Land Service.
  - Assimilation of these satellite data into Surface model → monitoring of the evolution of the vegetation and the soil.
  - Demonstrate the added value of this products for the community of users



# Surfex model



## • SURFEX (SURface EXternalisée) 7.3

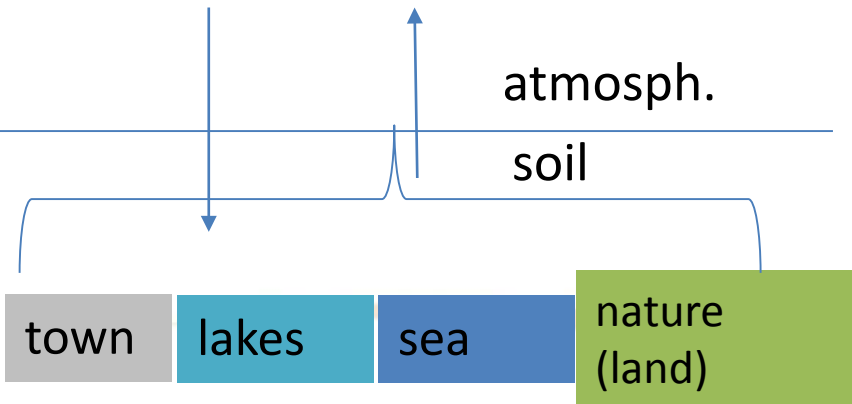
Surfex :

- Soil-Vegetation (ISBA)
- Town (TEB)
- Lakes, Sea, Sea ice
- Surfexa Boundary Layer (SBL)

- Runs only over nature tile
- Nature tile is separated 12 patches (grassland, C3, C4 plants, deciduous tree .... etc)
- Soil processes with ISBA scheme + photosynthesis model - > ISBA-A-gs (3-layer Force-Restore scheme)
- Prognostic eq. for the evolution of  $T$ ,  $w$ , intercepted  $w$
- Evolution of the vegetation (photosynthesis  $\leftrightarrow$  mortality)

ECOCLIMAP II

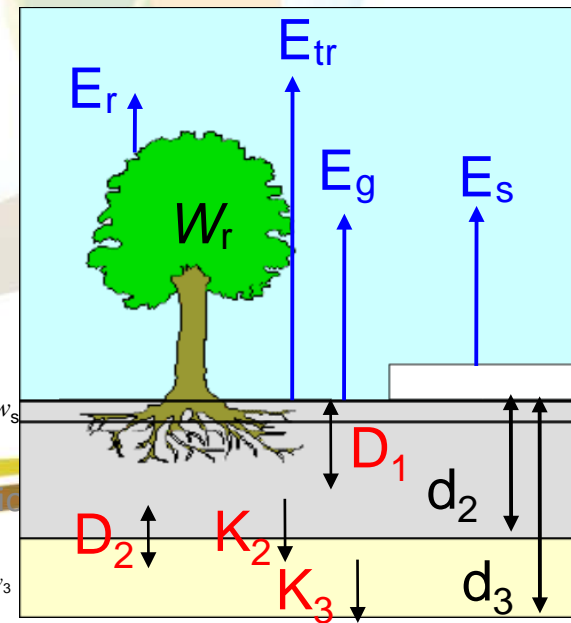
Atmospheric forcings ( $u, v, T, q, P, \text{rad.}$ )



### ISBA Force – Restore scheme:

Temp. change = net radiation - latent and sensible heat – towards its mean value

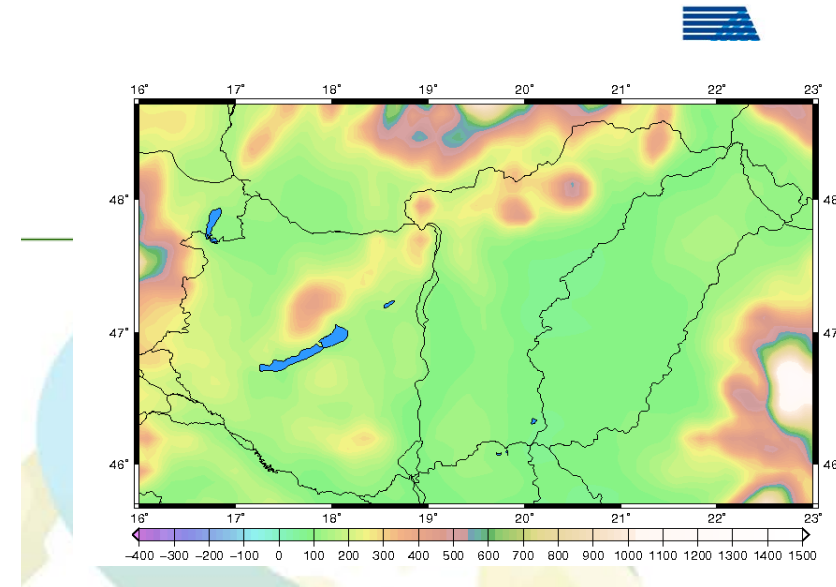
Soil Moisture change = precip. - evap. - diffusion - drain



- Surfex was run over Hungary with 8 x 8 km resolution, 24 h forecast with 6 h outputs freq.
- Atmospheric forcings come from ALADIN NWP model (air temperature, humidity, wind speed, precipitation) + LandSAF long and short wave radiation
- Run with offline mode -> no influence to the atmosphere

## OUTPUTS:

- LAI (Leaf Area Index)
- WG2 (Volumetric soil moisture content)
- GPP (Gross Primary Product), NEE (Net Ecosystem Exchange)
- ETR (Evapotranspiration), LE (Latent Heat Flux)



## VALIDATION:

- 1D (against in situ measurements of Hegyhátsál)
- 2D (against satellite)
- agricultural utilization: simm. biomass vs. yield statistics (National measurements, WOFOST crop model)



# Data assimilation in SURFEX



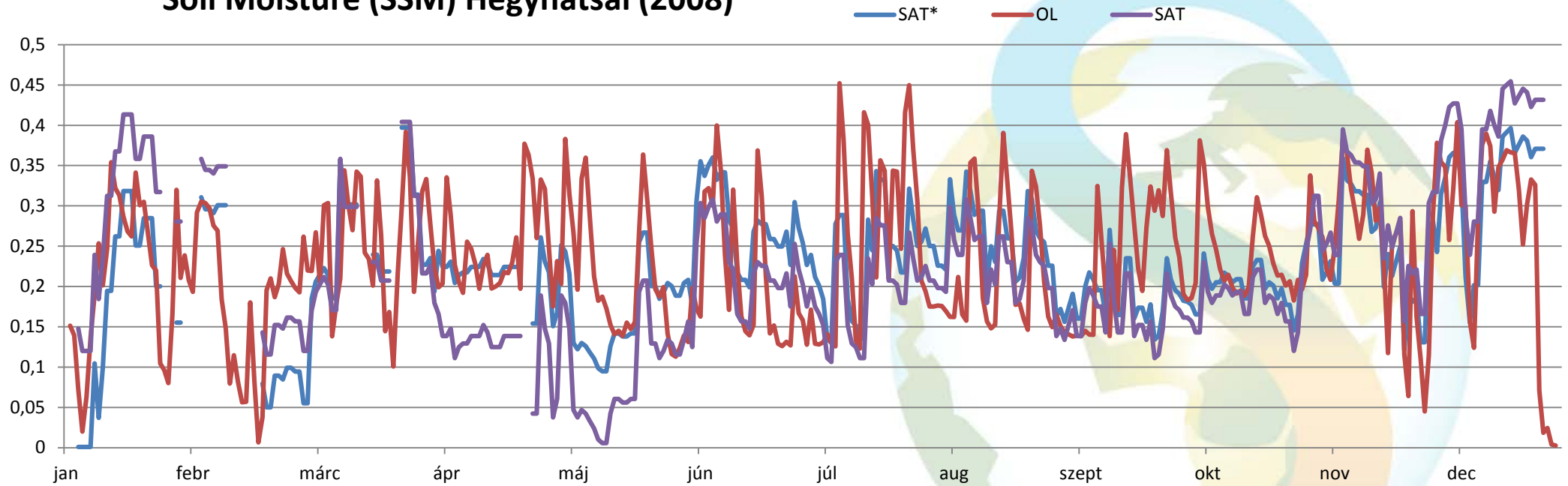
- Improve the accuracy of initial fields: LAI and Soil Moisture satellite obs. are assimilated (downloaded from <http://land.copernicus.eu/>)
  - LAI: SPOT-VEG (till may 2014) and PROBA-V (from may 2014) 1km res. 10 days sampling.
  - SWI (Soil Water Index) [0,1]: MetOp. ASCAT 10 km res. 1 day sampling.  $SSM = SWI \cdot (W_{max} - W_{min}) + W_{min}$  and  $W_{max}$  and  $W_{min}$  derived from the model climatology
- ASCAT SSM and model climatology SSM have different BIAS, interannual variability => ASCAT SSM need to rescaled by **CDF matching technique** (removes differences between satellite observations and model data by ensuring statistical consistency)

## Linear matching:

$$SSM'_{sat} = p_1 + p_2 \cdot SSM_{sat} \quad \text{where} \quad p_1 = \overline{SSM_{mod}} - p_2 \cdot \overline{SSM_{sat}} \quad p_2 = \frac{stdev(SSM_{mod})}{stdev(SSM_{sat})}$$



### Soil Moisture (SSM) Hegyhatsal (2008)

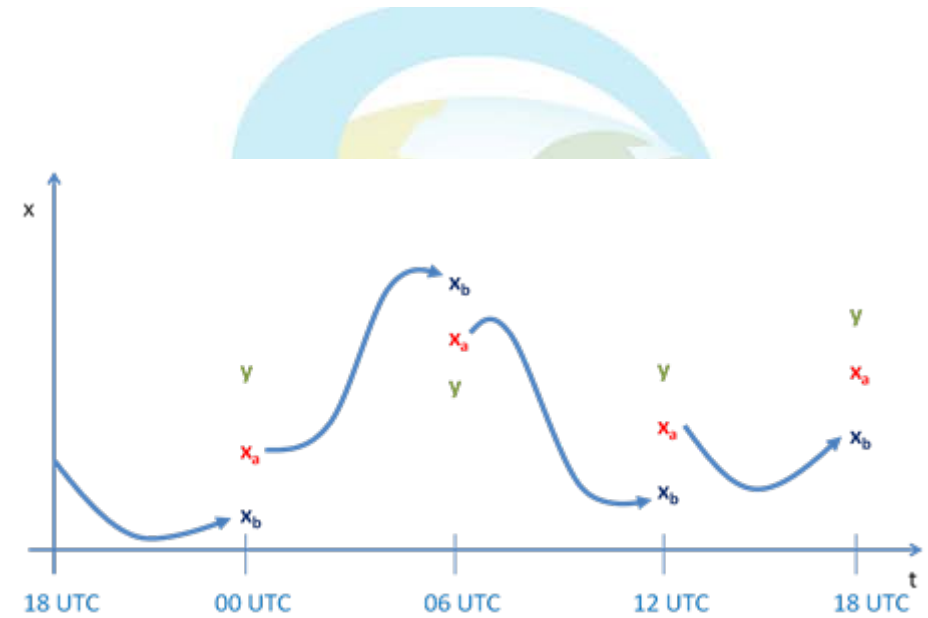




# EKF assimilation



- Goal: improve the initial fields => Data assimilation
- In data assimilation the satellite obs. are considered (LAI, SSM) + background (earlier forecast) + dynamics of the atmosphere.
- To produce analysis (LAI, WG1, WG2) at the initial time as close as possible to the obs.



Assimilation technic: **Extended Kalman Filter (EKF)**

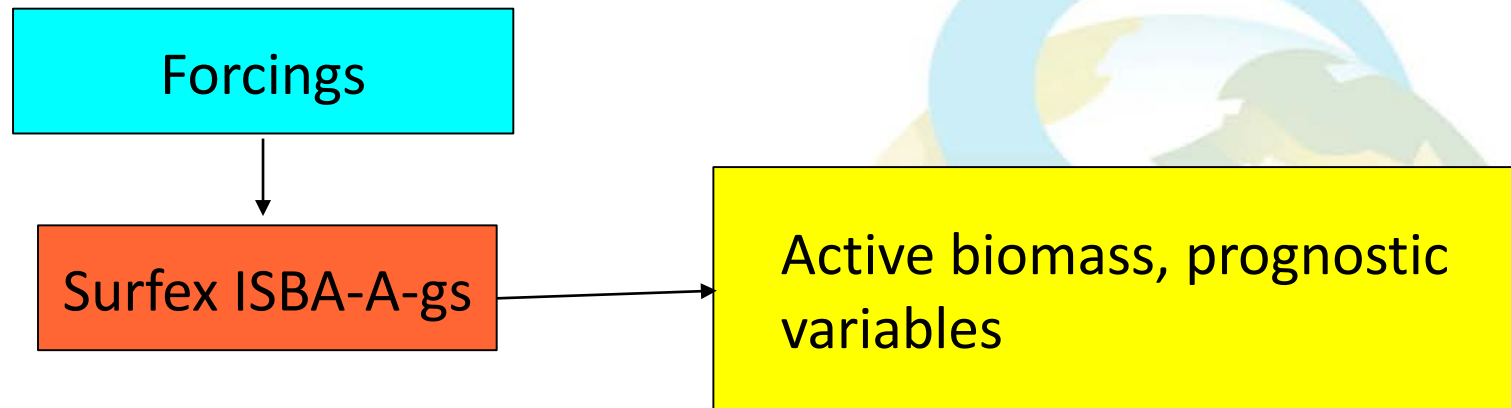




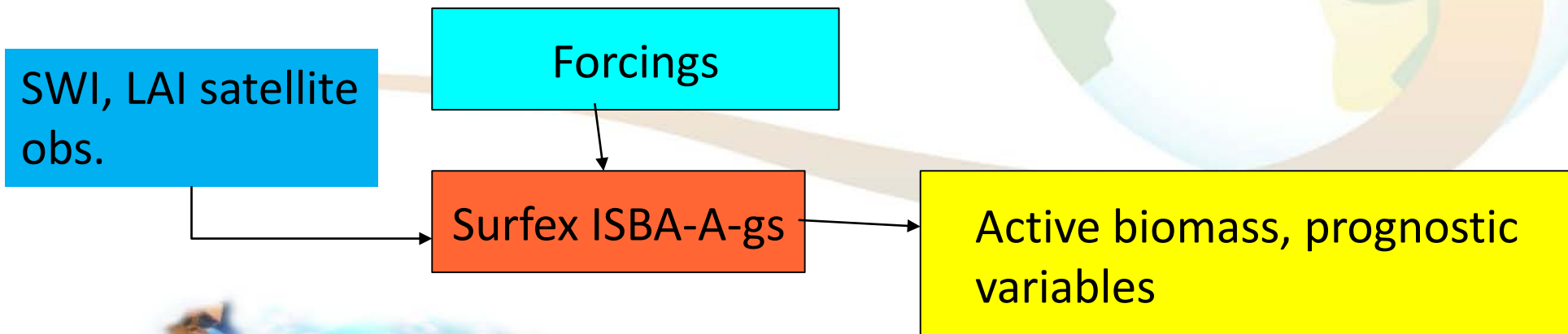
# Model runs



- Surfex run **without data assimilation** for 2008-2015 (Openloop)

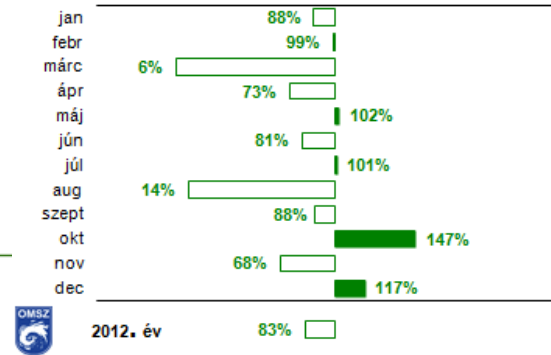


- Surfex run **with data assimilation** for 2008-2015





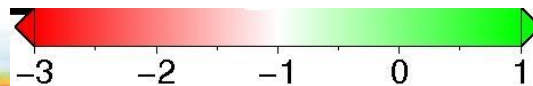
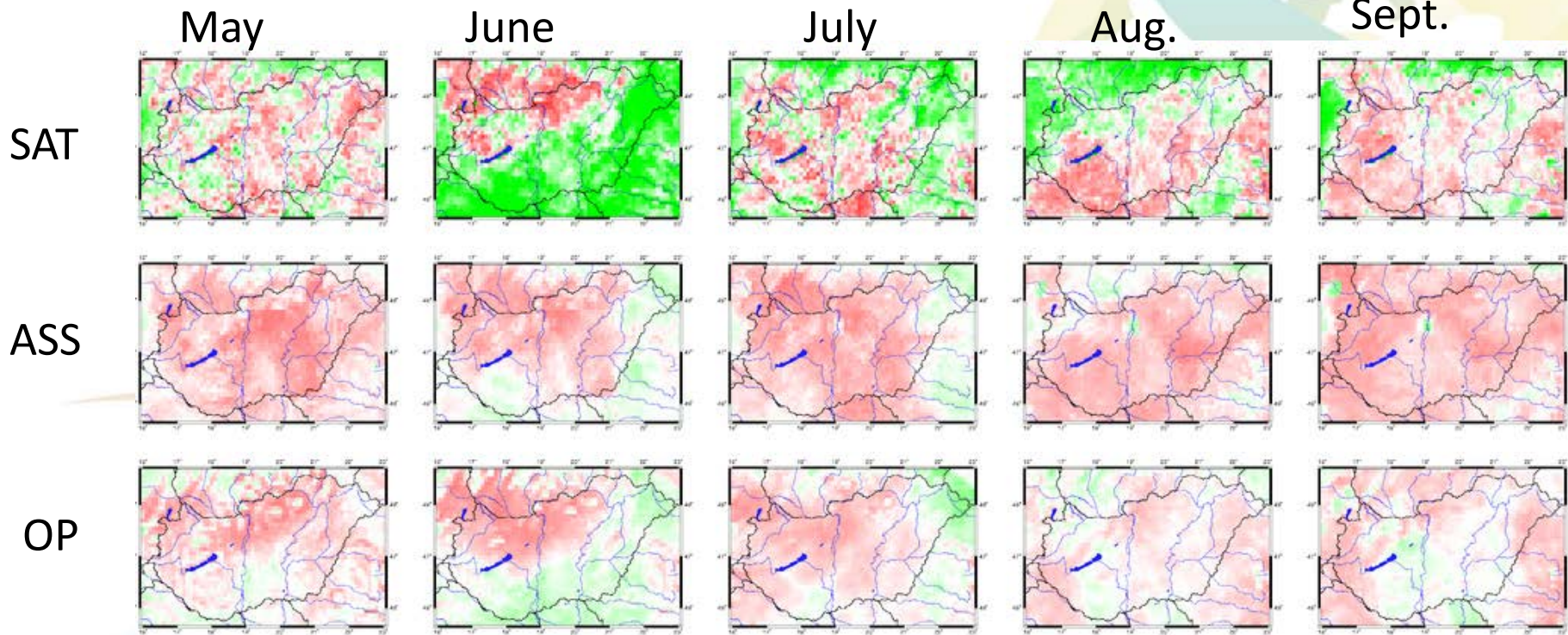
# RESULTS (2D)



- Openloop offline run 2008-2015
- Assimilation run 2008-2015

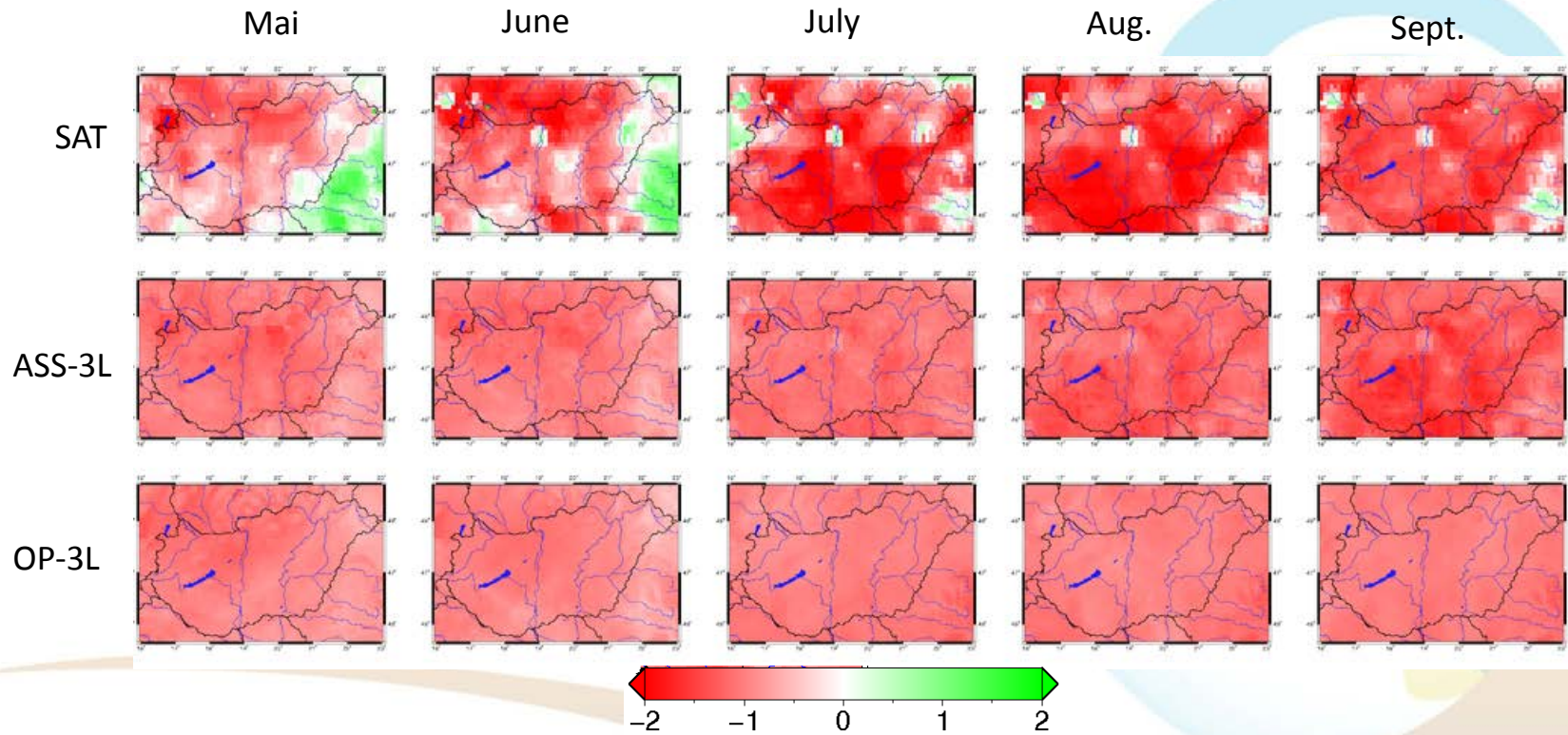
$$AnoX = \frac{X - \langle X \rangle}{stddev(X)}$$

Inter-annual variability of LAI for 2012 (extreme dry)





Root-zone soil moisture anomalies in 2012 (AnoWG2 (models) and AnoSWI10 (satellite))

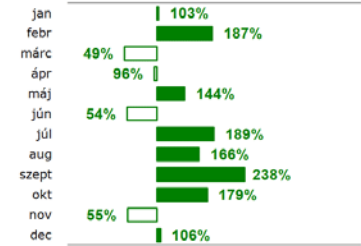




# LAI soil moisture anomalies in 2014 (very moist year)



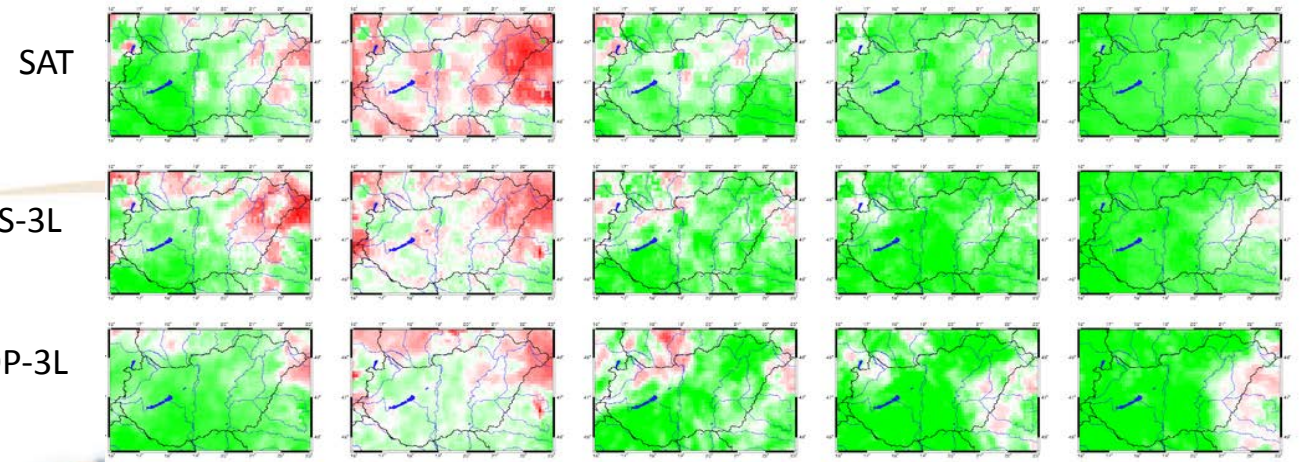
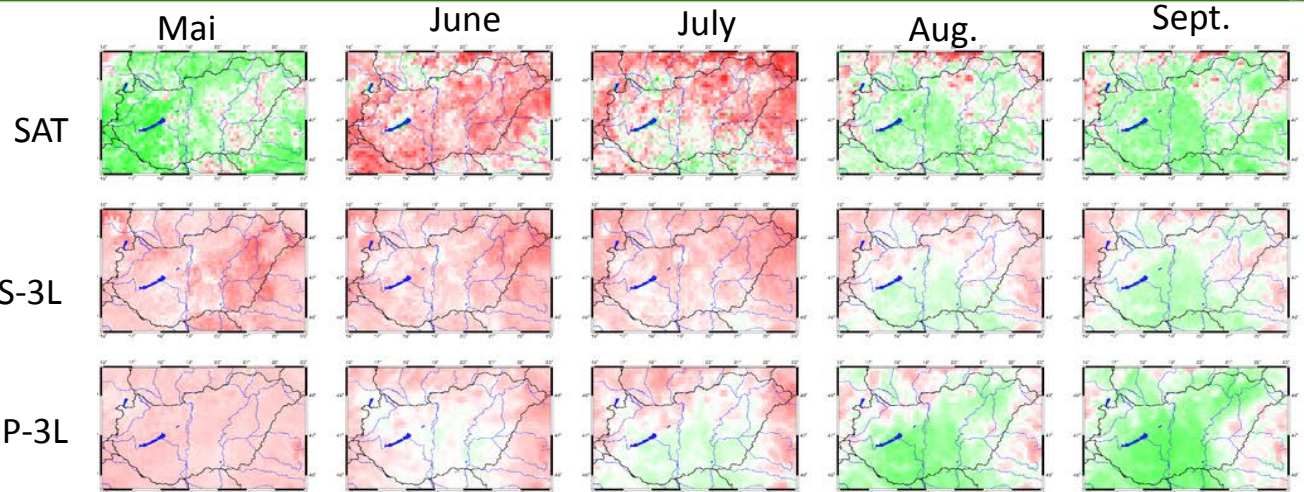
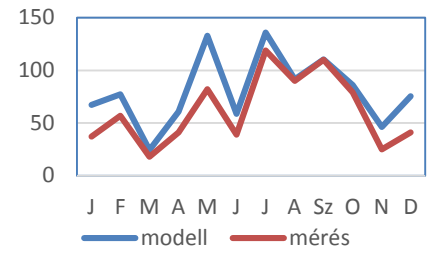
WORK  
AE



AnoLAI

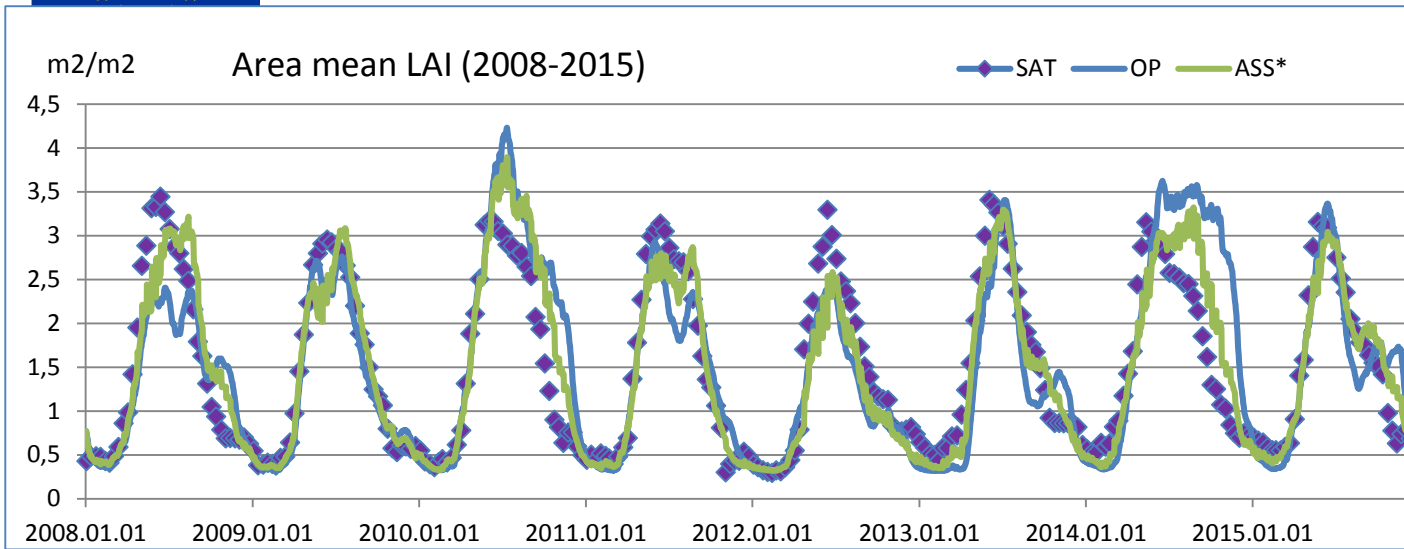
AnoSWI10 /  
AnoWG2

2014. precip

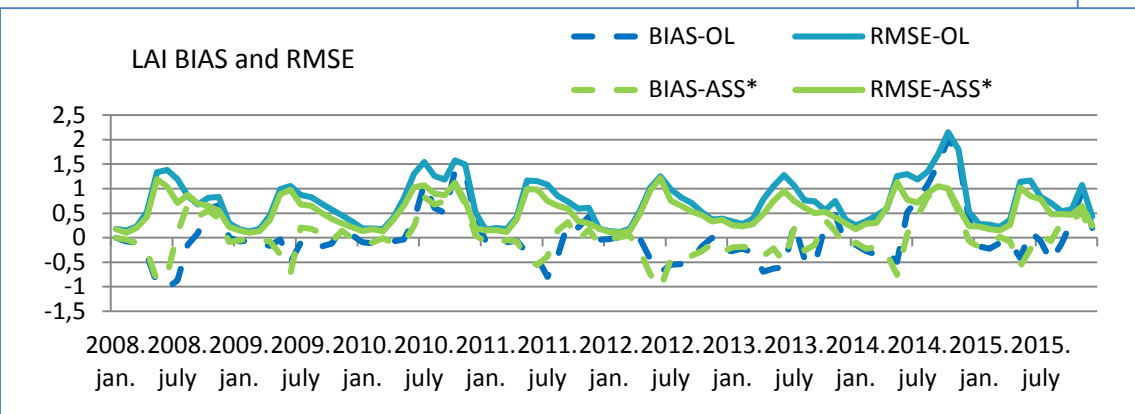
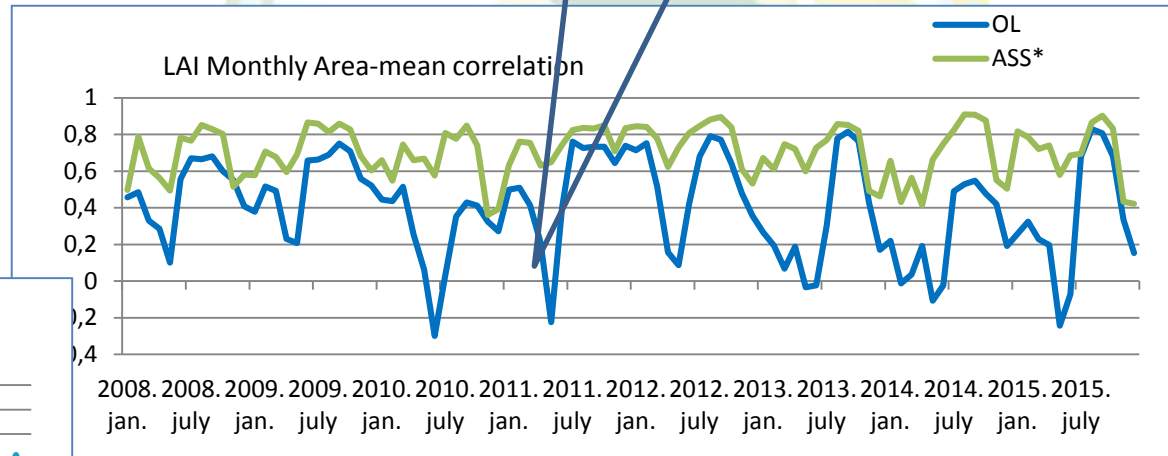




# Statistics (LAI)



Low correlation for OL runs at every spring, early summer period



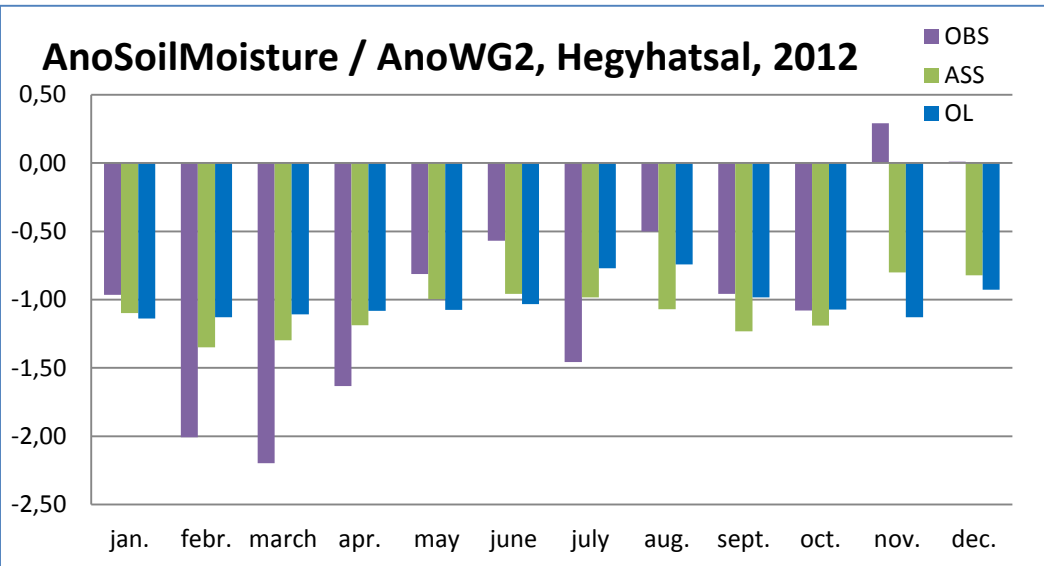
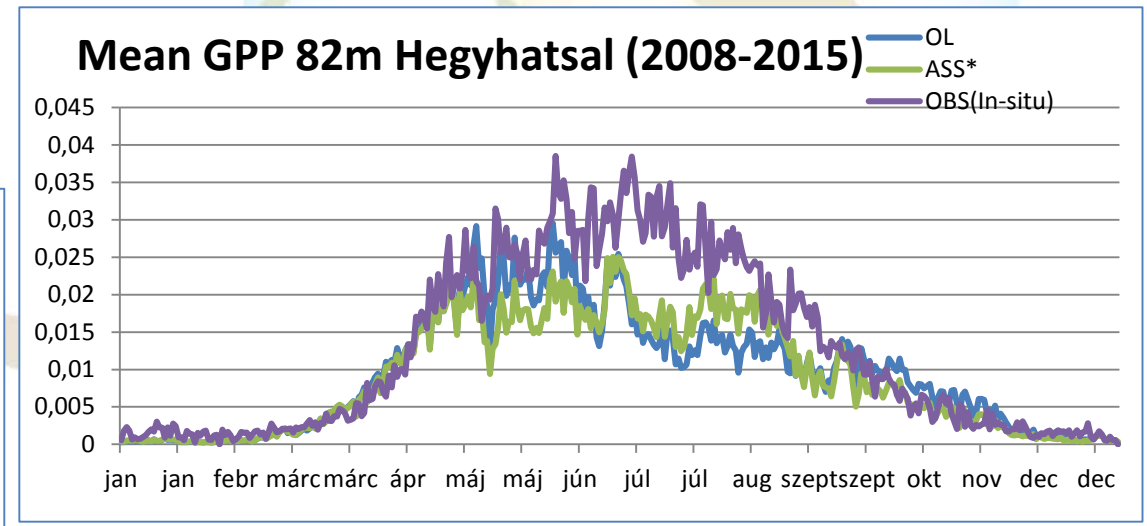
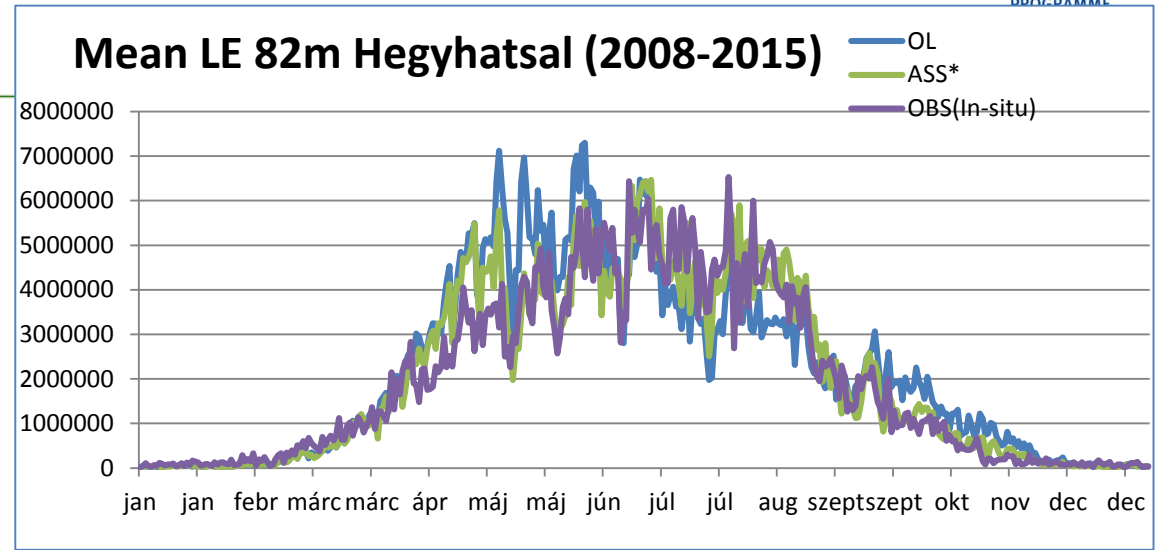


# Results (1D)



In-situ measurements of Hegyhátsál.  
Data are available from two levels:

- 3 m height over a grassland area (valid for only the grassland patch):
  - LAI (weekly)
  - Soil Moisture (daily) (derived from 10-30 cm depth)
  - Carbon fluxes: GPP, Reco and NEE (daily)
  - Water flux: Latent Heat (LE) (daily)
- 82 m height (valid for the whole grid-point):
  - Carbon fluxes: GPP and NEE (daily)
  - Water flux: LE (daily)

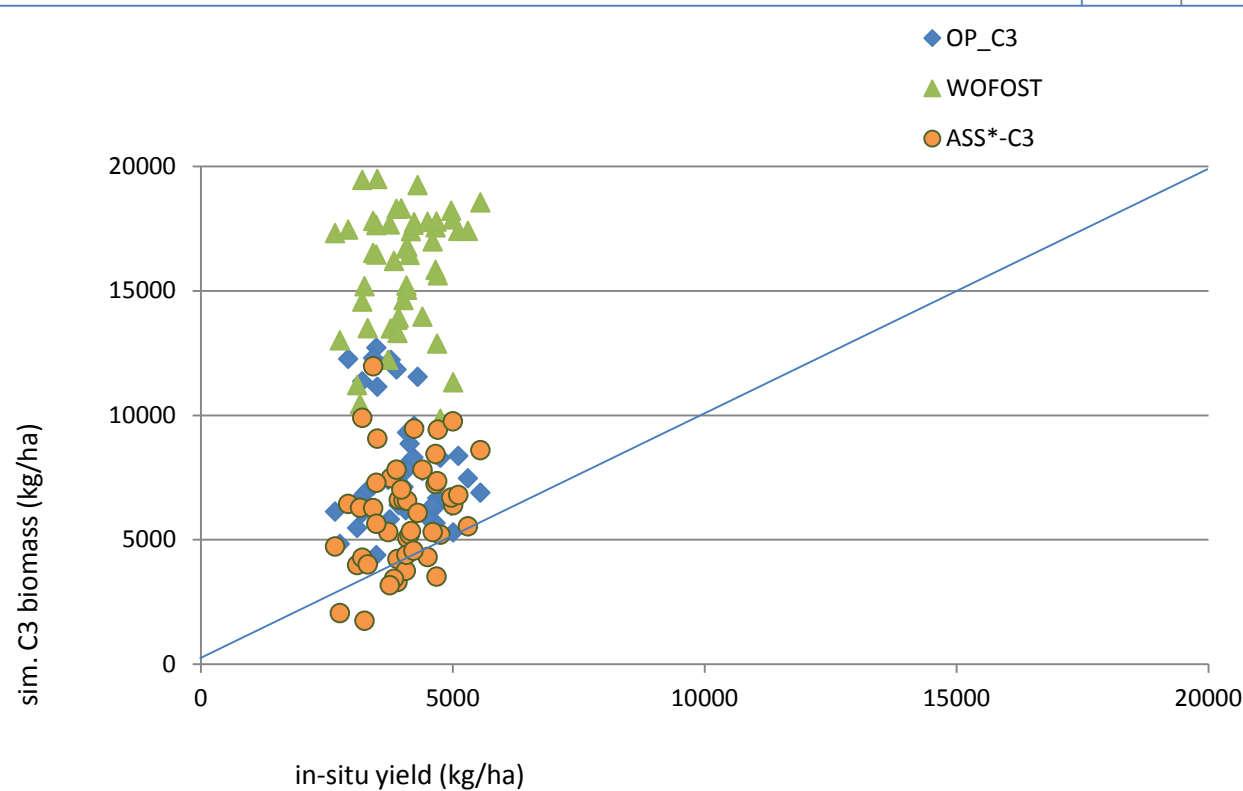
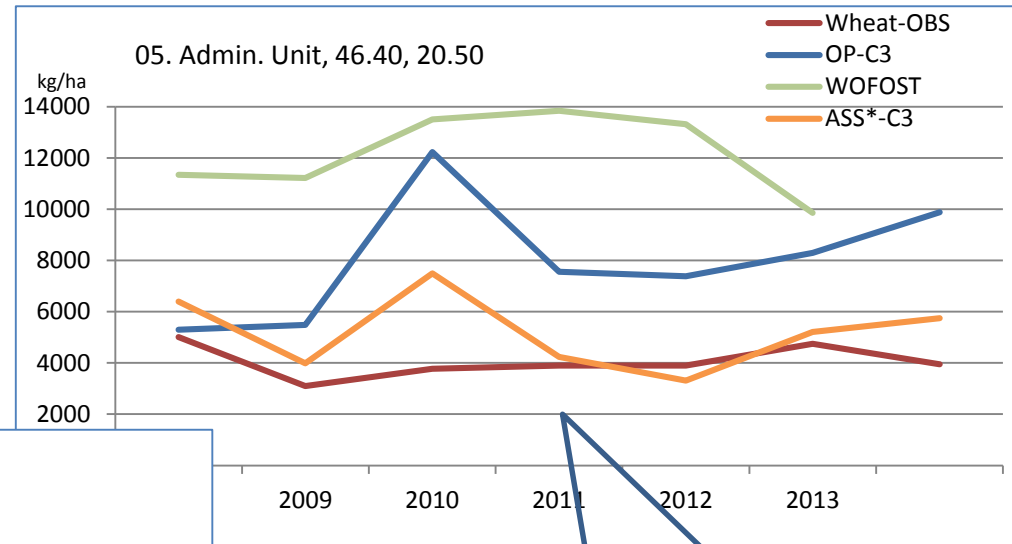




# Crop estimation



Simulated C3 BIOMASS vs. measured yield and vs. WOFOST for 2008-2013



Good agreement between LDAS BIOMASS and yield, except for 2010 (extreme wet year)

Correlations:  
OP: -0.13 (without 2010: 0.28)  
ASS\*: 0.25 (without 2010: 0.56)  
WO: 0.15 (without 2010: 0.32)



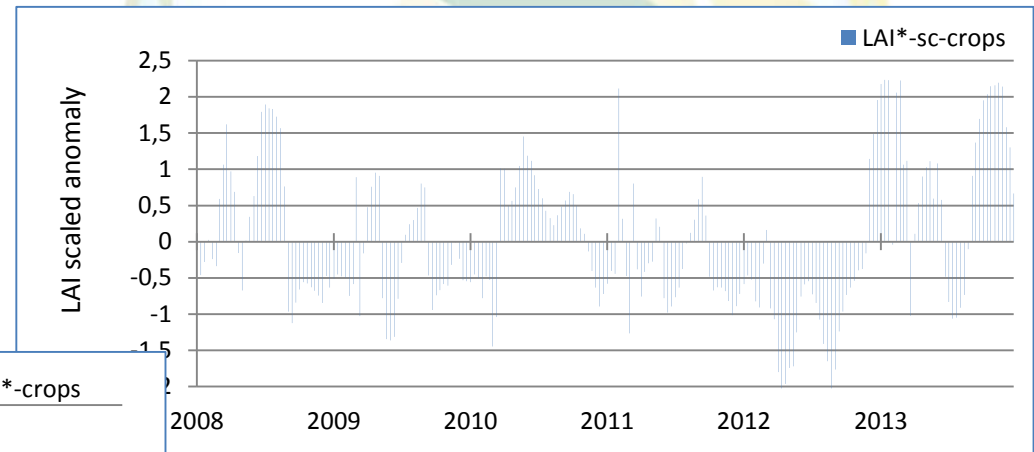
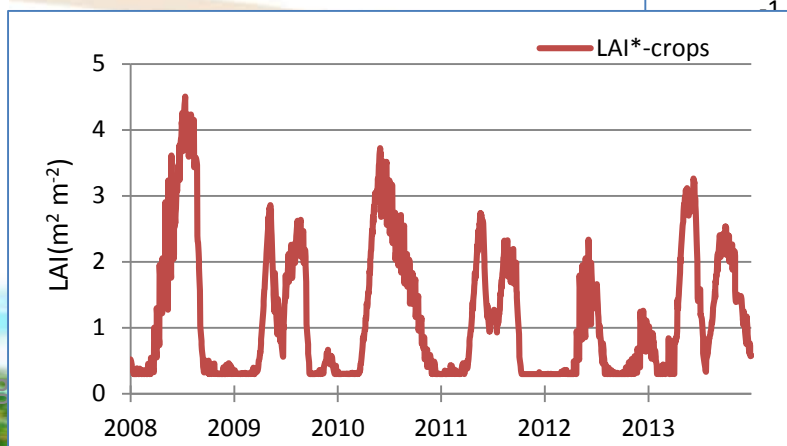
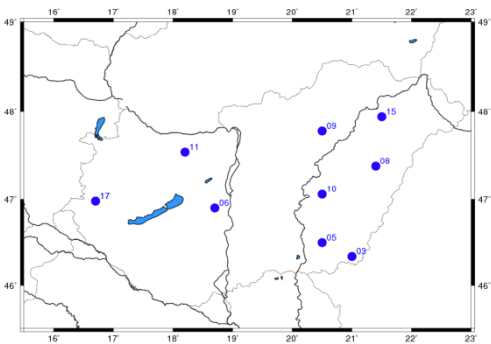
# LDAS products

<http://fp7-imagines.eu/>

Free download data: 9 straw cereals  
Hungarian points for 2008-2013:

- daily data: GPP, LAI, Evaporation, NEE, SWI, Above-ground biomass anomaly
- drought indicators for 10-day period: AnoLAI, AnoSWI and AnoAGB

+ 45 straw cereals and 48 grassland points from France (Meteo France)  
+ 85 sites from the globe (ECMWF)



**LDAS PRODUCTS**

ImagineS provides products derived from the regional LDAS operated over France by [Meteo-France](#) and over Hungary by [IMMSE](#), and the global LDAS, operated by [ECMWF](#), over the globe. They are presented in the [ACRIS](#), and are provided in ASCII csv format files. All practical information are given in the [Product User Manual](#). They are all freely accessible after [registration](#).

The **global LDAS products** are calculated over 85 sites of crops and grassland scattered around the globe. They include a set of variables derived from the analysis (i.e. the land surface model simulation after the assimilation of satellite-derived products). For each site, the daily and the 10-daily products are sets of 21 files corresponding to:

- 7 variables: Leaf Area Index (LAI), root zone soil moisture, surface soil moisture, evapotranspiration, Net Ecosystem Exchange (NEE), Gross Primary Production (GPP), and Above Ground Biomass (AGB)
- 3 product types: time series, drought indicator and anomaly index.

The **regional LDAS products** are calculated for 45 straw cereal sites and 48 grassland sites in France, and for 9 straw cereal sites in Hungary. They include:

- daily time series of Leaf Area Index (LAI), root zone soil moisture (SWI), evapotranspiration, Net Ecosystem Exchange (NEE), Gross Primary Production (GPP), and Above Ground Biomass (AGB) anomaly (% difference w.r.t. the 2008-2013 mean at the same date)
- 10-daily time series of drought indicators. A drought indicator is a scaled anomaly index of a variable for a particular 10-day period (from January to December) with regard to its standard deviation over the 2008-2013 period. The variables are the LAI, the SWI and the AGB.

The added value of the assimilation of satellite products on vegetation biomass simulations is evaluated over France using reference agricultural yearly statistics of fodder production and straw cereal yields ([Agreste](#)), and compared to the output of the [WOFOST](#) model implemented currently within the [MAESTRO Crop Growth Monitoring System](#) of JRC. The assimilation of LAI triggers a dramatic improvement of the correlation between the simulated biomass and the observations, and the ImagineS regional LDAS outperforms the WOFOST model. Further Details are given in the [Validation Report over France](#). Similar comparisons have been performed over Hungary. The results are given in the [Validation Report](#).

Simulated above-ground biomass (kg m<sup>-2</sup>) of straw cereals vs Agreste statistics of yield, over 45 administrat...





# Aftreer the project



- Use Surfex assimilation for drought monitoring (more indexes) and forecasting (based on monthly and seasonal ECMWF atmospheric forcings)
- Adaptation of Surfex 8 with diffusion soil scheme (with 11 soil layers)
- Assimilation of Sentinels data
- Find end-users

<http://fp7-imagines.eu>