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

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Outline

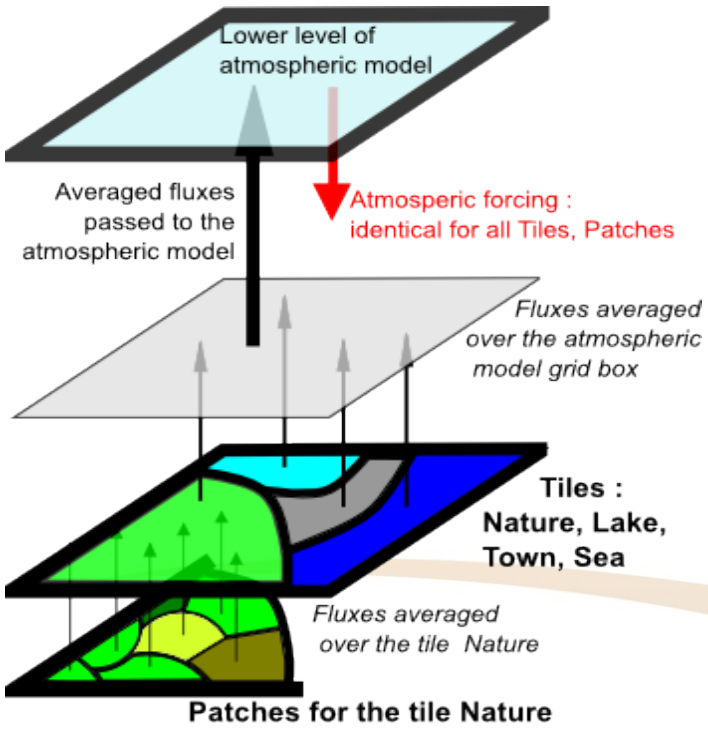
- **ImagineS project (2012-2016)**
- **LDAS (Land Data Assimilation System)**
  - ISBA-A-gs in SURFEX
  - Data assimilation: Extended Kalman Filter
- **Validation**
  - 1D (against in-situ measurements from Hegyhátsál)
  - 2D (against satellite data)
  - Agricultural utilization
  - Drought indicators

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 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

LDAS in Hungary

- **SURFEX (SURface EXternalisée) 7.3**



SURFEX tiling and coupling with an atmospheric model

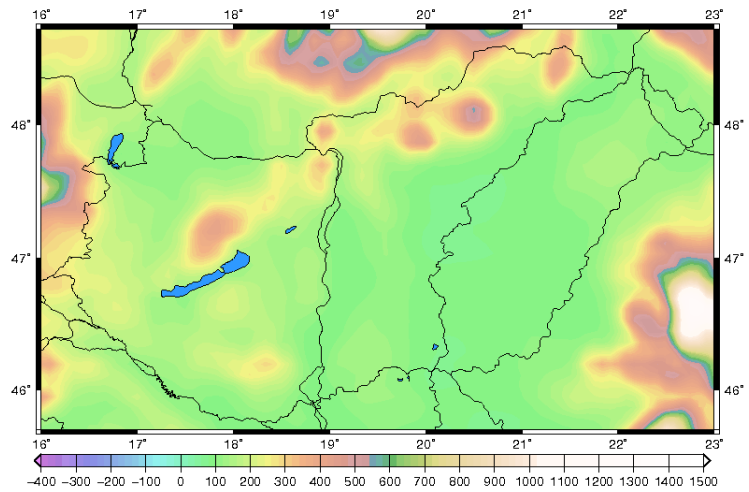
ECOCLIMAP II

- Runs only over nature tile
- Nature tile is separated 12 patches (grassland, C3, C4 plants , deciduous tree …. etc)

- ISBA + photosynthesis model - > ISBA-A-gs (3 layers Force-Restore scheme)
- Prognostic eq.-s for Biomass (photosyntesis ⇔ mortality) $B(t+dt)=B(t)+dB^{+}-dB^{-}$
  $dB^{+} \sim A_n / dt$ (A_n daily accum. assimilaton)
  $dB^{-} = B\{1-\exp(dt/\tau)\}$, $\tau \sim A_{n,fm}/A_{n,max}$ ($A_{n,fm}$ max. assim. of the prev. day., $A_{n,max}$ optimum value)
- Force-restore method for the evolution of T, w, intercepted w

Source: http://www.cnrm.meteo.fr/surfex/spip.php?rubrique8

• 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)

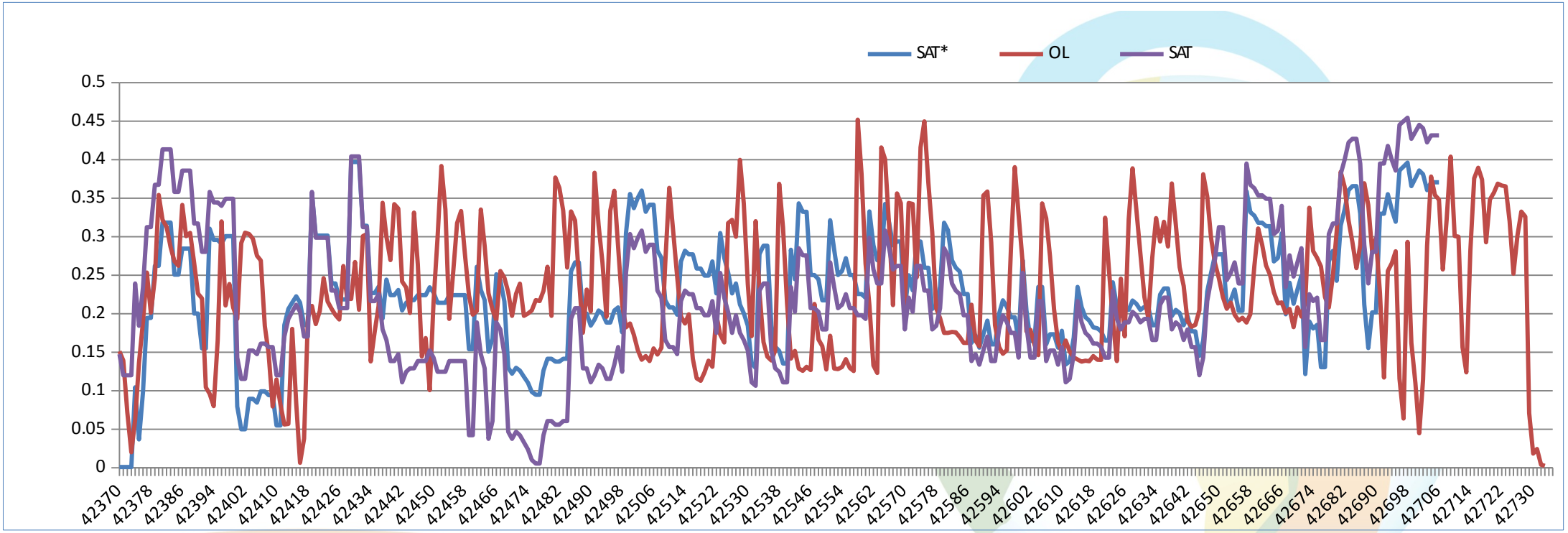
Data assimilation in SURFEX

- **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*(w_{max}-w_{min})+w_{min} 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:

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

Assimilation technique: **Extended Kalman Filter (EKF)** (for non-linear system):

$$X_a = X_f + K\,(y_o - H\,(x_f))$$

where: x is the model state vector (a means analysis, f means forecast), y is the observation vector, *H* is the non-linear observation operator, K is the Kalman gain.

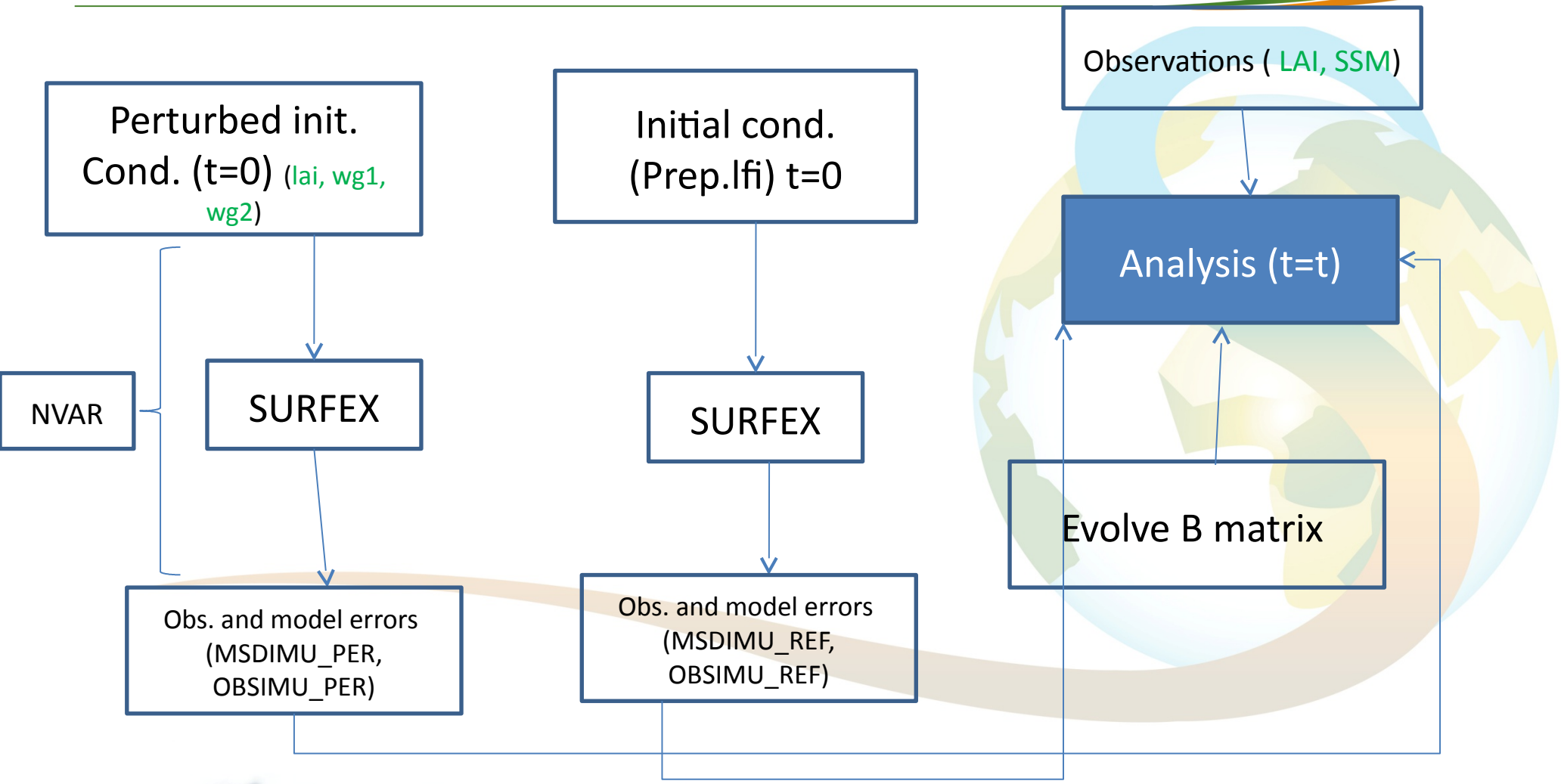
$$K = BH^T(HBH^T+R)^{-1}$$

$$H = \frac{\partial y_t}{\partial x_0}$$

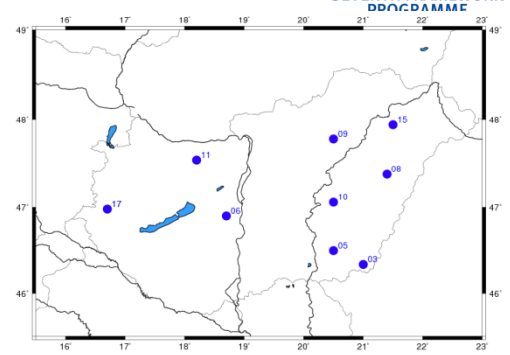
$$H_{ij} = \frac{\partial y_i}{\partial x_j} \approx \frac{y_i(x+\delta x_j) - y_i(x)}{\delta x_j}$$

-**H**: Jacobian matrix of the observation operator (Taylor expansion of *H* obs. operator, tangent linear hipotesis)
-The elements of the Jacobian matrix

EKF Flow charts



LDAS products



http://fp7-imagines.eu/

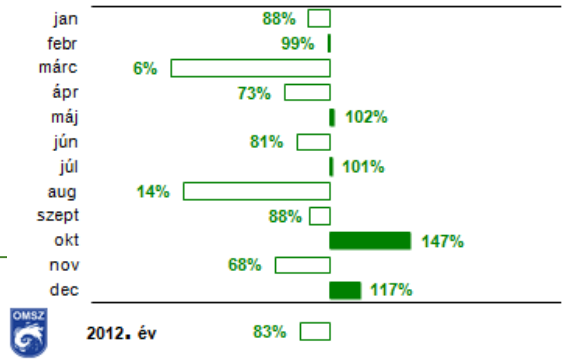
Free download data: 9 straw cereals Hungarian points for 2008-2013:

- 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)

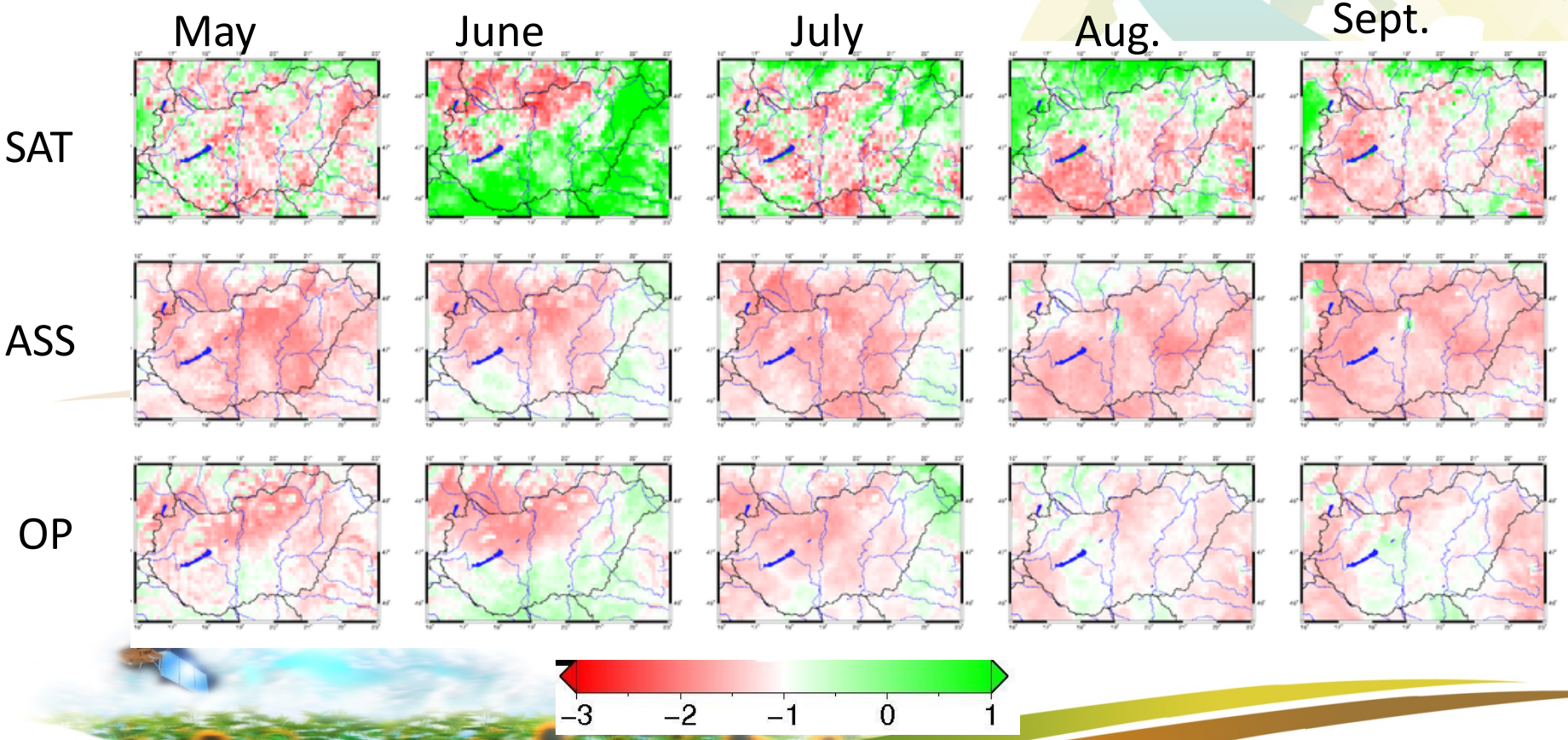
RESULTS (2D)



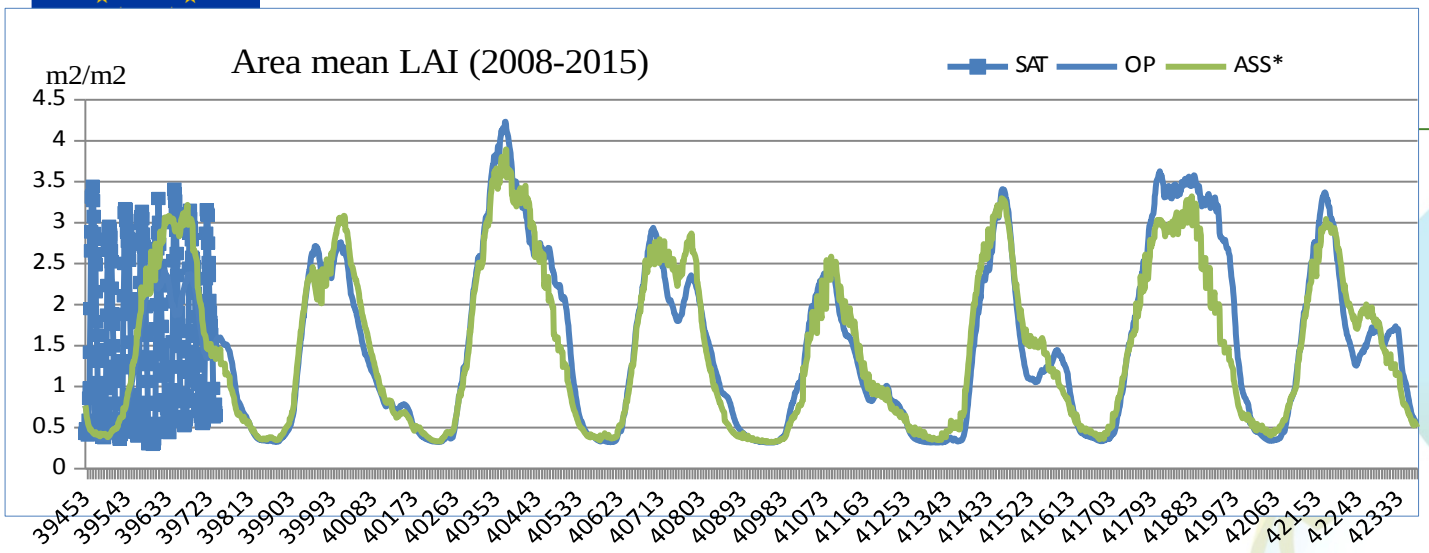
- Openloop offline run 2008-2015
- Assimilation run 2008-2015

$$AnoX = \frac{X - < X >}{stdev(X)}$$

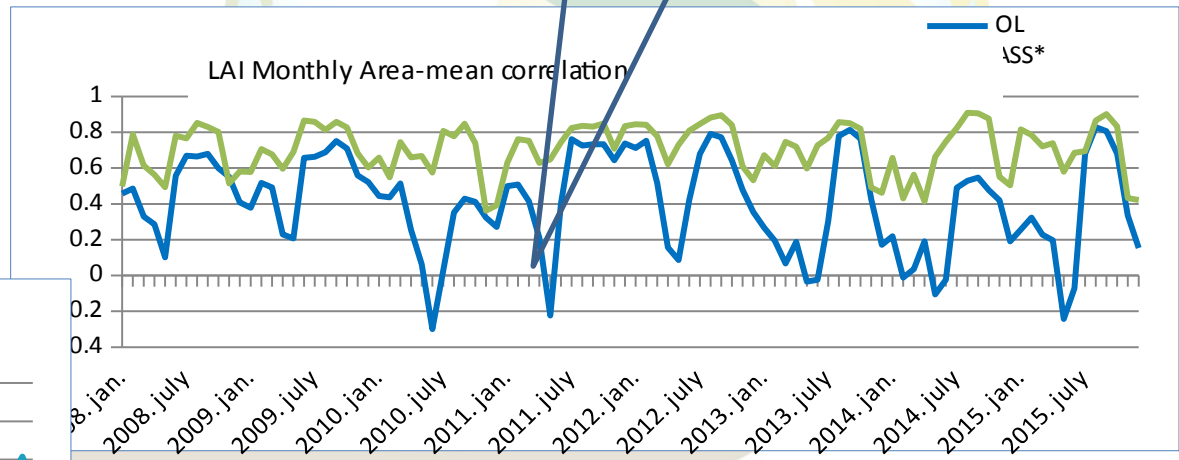
Inter-annual variability of LAI for 2012 (extremly dry)

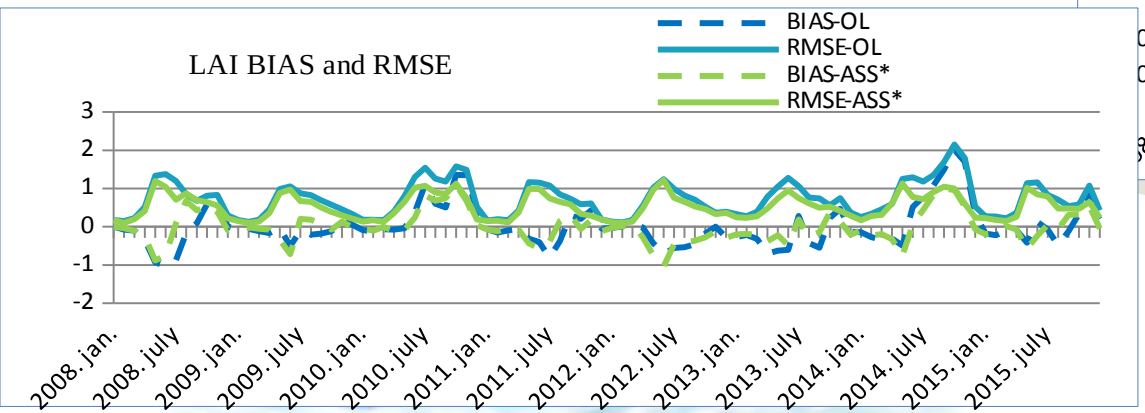


Statistics (LAI)



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

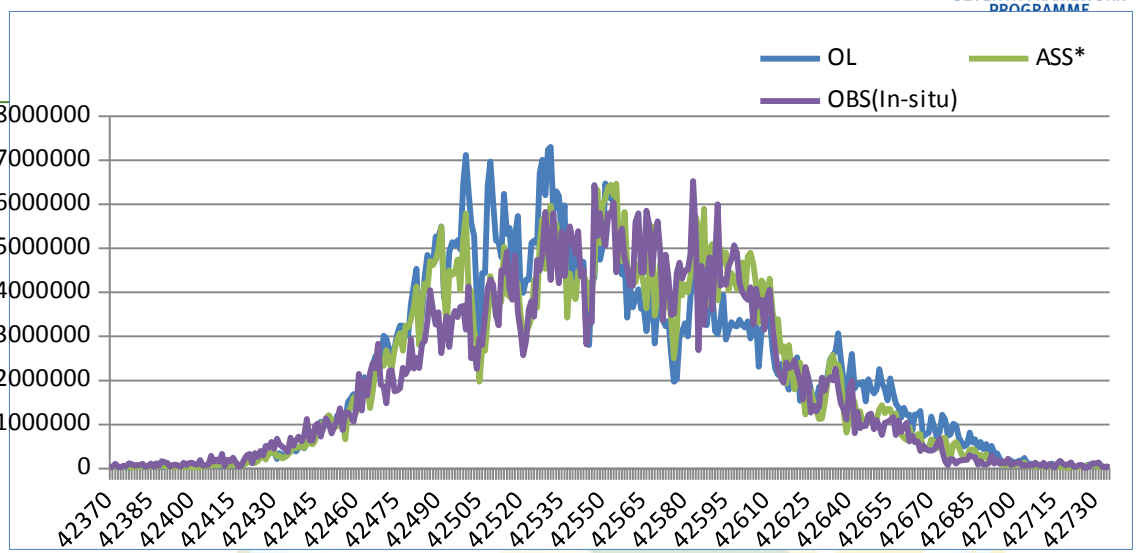


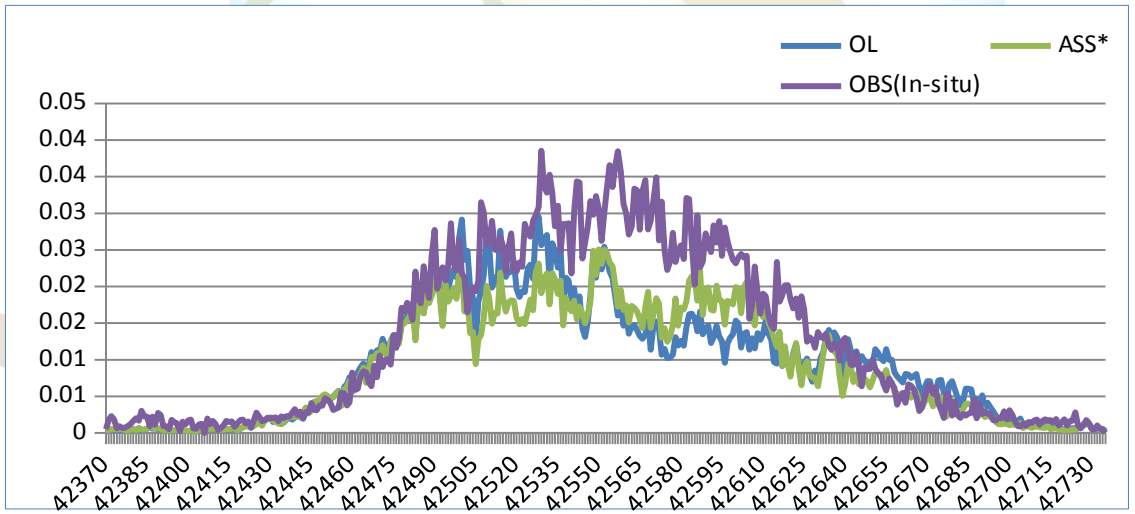


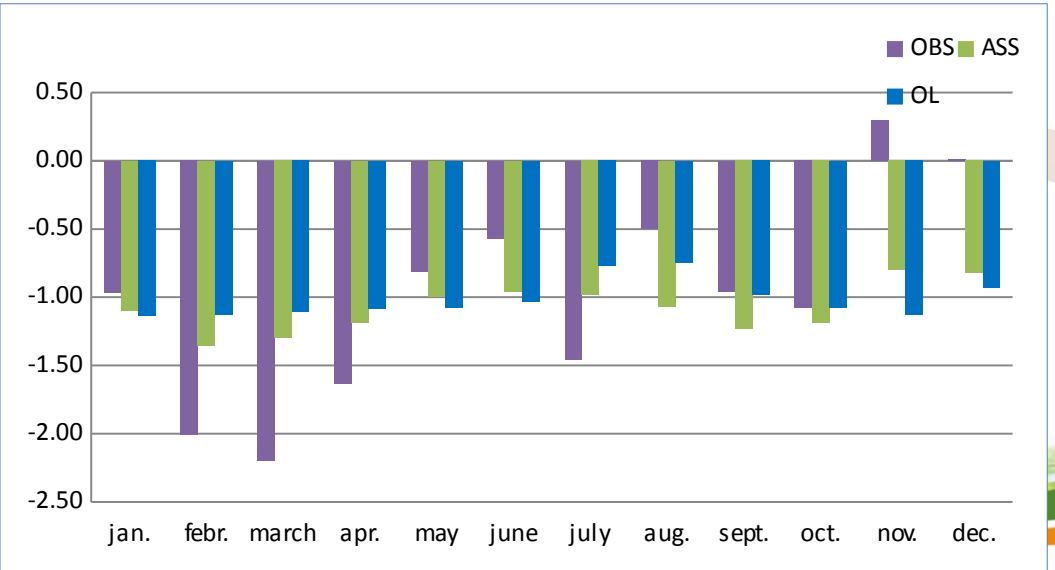
Results (1D)

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)

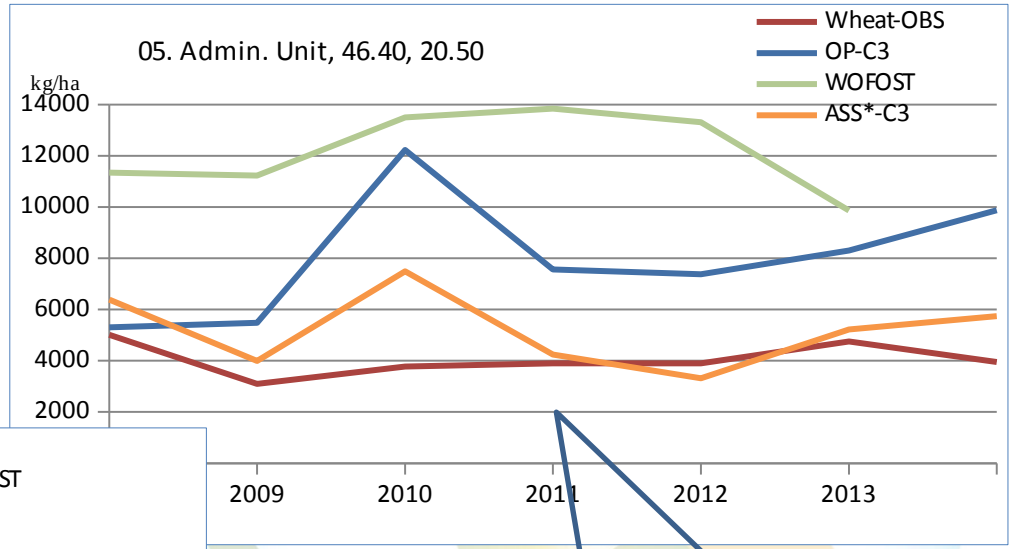


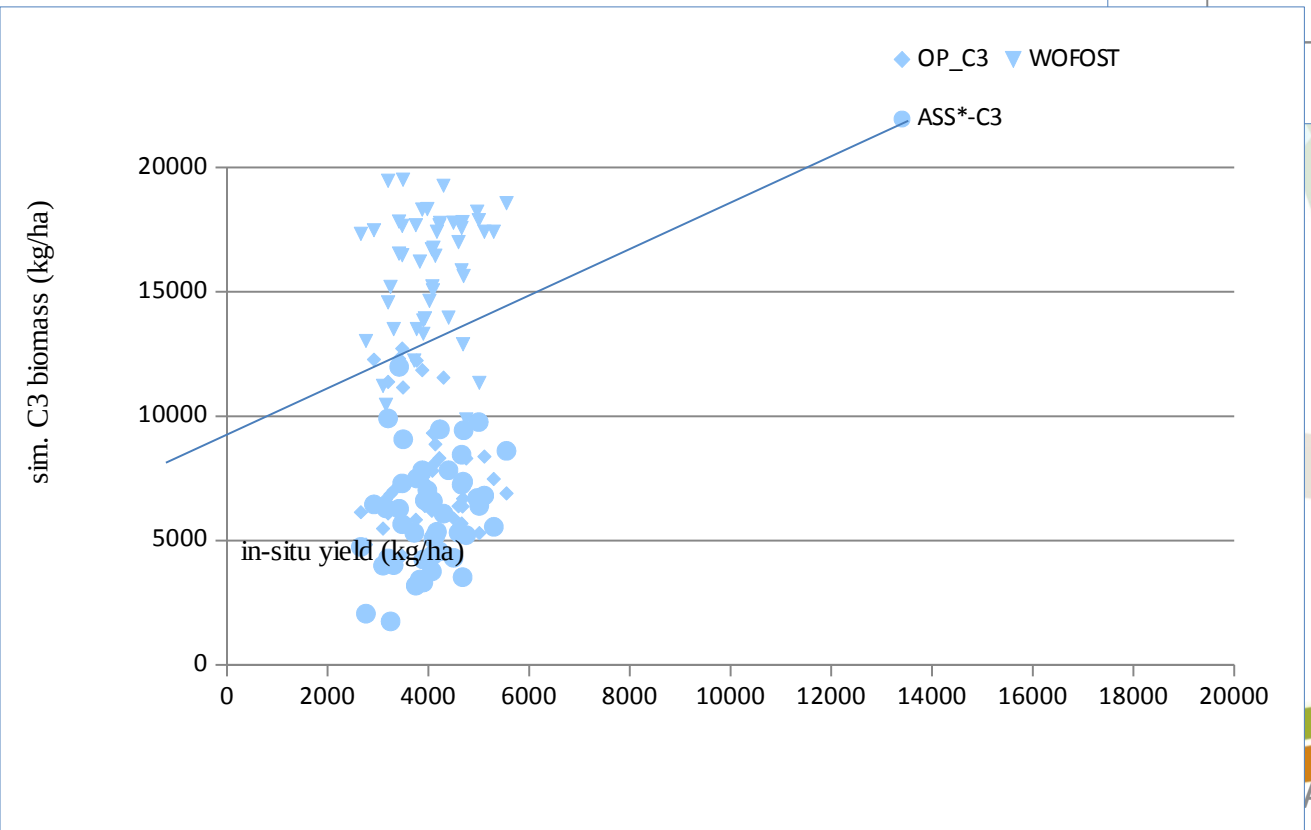




Crop estimation

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)

Till the end of the project

- Mini-workshop in Budapest in May 2016
- Final workshop in June 2016
- Find potential End-users!!!