Introducing a daily updated Leaf Area Index in AROME-Hungary

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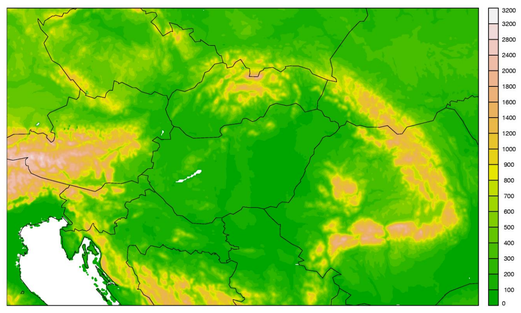
Background

OMSZ has been involved in the simulation and assimilation of vegetation properties since 2008. During two EU-funded projects (Geoland2 and ImagineS) a Land Data Assimilation System (LDAS) was applied to monitor the above-ground biomass, surface fluxes (carbon and water) and the associated root-zone soil moisture at the regional scale in quasi real time. In this system the Surfex model is used (in offilne mode), which applies the ISBA-A-gs photosynthesis scheme to describe the evolution of vegetation. An Extended Kalman Filter (EKF) method is used to assimilate Leaf Area Index (LAI, from SPOT/Vegetation and Proba-V) and Soil Wetness Index (SWI, from ASCAT/Metop) satellite measurements. Simulations were compared to observations (LAI and soil moisture satellite measurements) over the whole country and also at a selected site in West Hungary (Hegyhátsál), results show that the LDAS system is capable to simulate the evolution of vegetation with an acceptable accuracy (Tóth and Szintai, 2021).

SURFEX land surface model

The SURFEX model was used to simulate in offline-mode the Leaf Area Index over the model domain of AROME-Hungary (2.5 x 2.5 km resolution). In SURFEX each surface grid point is separated into 4 different tiles: nature, sea, lake and town, but here only the nature tile was used. The nature tile is further divided into 12 patches according to the vegetation or surface types: bare soil, rock, permanent snow, deciduous tree, coniferous tree, broadleaf evergreen tree, C3 crops, C4 crops, irrigated crops, grassland, tropical grassland, parks and gardens. The nature tile is simulated with **ISBA** (Interaction between Soil, Biosphere and Atmosphere) scheme, which contains a photosynthesis model, **ISBA-A-gs**. This model is suitable to describe the evolution of the vegetation. The biomass is a prognostic variable. Growing of biomass is due to photosynthesis (CO_2 assimilation) while the decline can be due to soil moisture stress or senescence. The model takes into account the soil moisture stress in the photosynthesis.

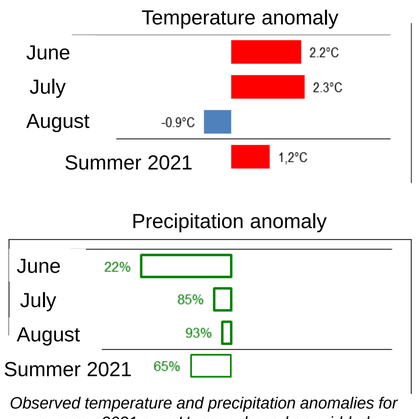
The ISBA 3-layer soil scheme is used (surface 0-1 cm, root zone 0-2 m and deep soil 2-3 m). The soil prognostic variables (temperature, water content and intercepted water content) are calculated with the force-restore method.



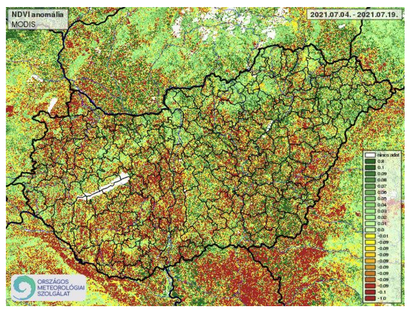
Domain and orography of the operational AROME-Hungary model.

Time period of interest – Summer 2021

Our first aim was to investigate the impact of LAI change on the weather forecast produced by AROME-Hungary. For this study the summer of 2021 was chosen. In 2021 a cold spring was followed by very hot and dry summer. During July and August a severe drought occurred over Southern Hungary and Northern Serbia, and consequently maize fields over large areas were significantly underdeveloped (irrigation is very limited in the region).



Observed temperature and precipitation anomalies for summer 2021 over Hungary based on gridded observations.



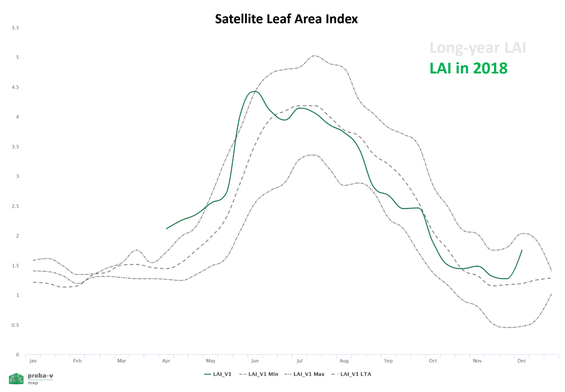
Observed NDVI anomaly for July 2021
(red colours indicate underdeveloped vegetation)

Photos of underdeveloped maize fields from Southern Hungary

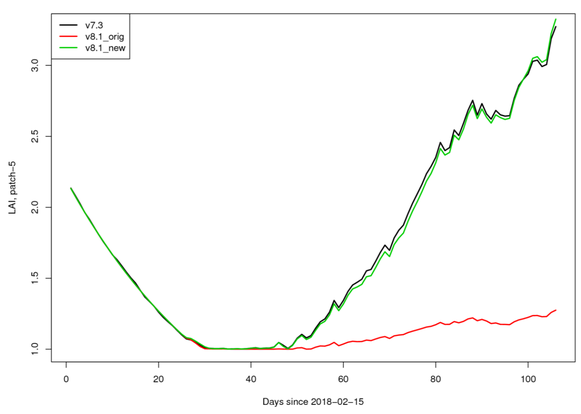
SURFEX_v8.1 offline was run in "open loop" mode, i.e. without data assimilation using atmospheric forcings derived from AROME forecasts. The run was started in summer 2020 using climatological LAI values and then vegetation was computed prognostically until August 2021. LAI from this simulation was used to run AROME for a selected day (see box on the right).

Simulation of coniferous forests in SURFEX

Patch-5 in SURFEX is representing coniferous (needle leaf) forests. During our experiments we have noted a significant change in the LAI simulation of patch-5 between SURFEX_v7.3 and SURFEX_v8.1 (which is the latest version of the model). Simulated LAI of coniferous forests was significantly lower in SURFEX_v8.1 than in SURFEX_v7.3 for the same period and with the same atmospheric forcing. After personal communication with SURFEX developers it turned out that the specific leaf area index was significantly decreased (from 13.3 m2/kg to 5 m2/kg) between the two model versions which causes the lower LAI values. When using the original value in SURFEX_v8.1 we get similar values than in SURFEX_v7.3 which is closer to reality (see figures below). In all the results shown here we used this modified version of SURFEX_v8.1.



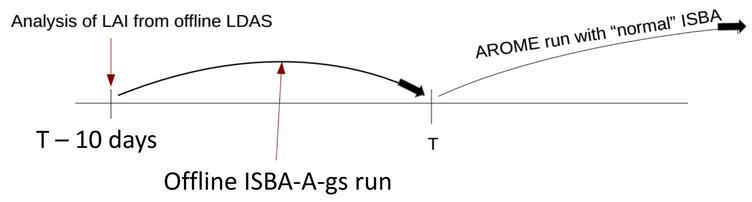
Yearly evolution of the observed Leaf Area Index (LAI) over coniferous forests in the East Carpathian mountains. Data derived from the Proba-V satellite. Grey lines: minimum, maximum and mean over the period 1999-2013; green line: year 2018.



Evolution of LAI in SURFEX_v7.3 (black), in the original SURFEX_v8.1 (red) and in the modified SURFEX_v8.1 (green) over coniferous forests in the East Carpathian mountains between 15 February and 31 May 2018.

Daily updated vegetation in AROME-Hungary

In current state-of-the-art NWP models Leaf Area Index (LAI) is considered as an external parameter where monthly values are derived from long-term averages. Such an approach is not capable of describing vegetation anomalies e.g. during severe droughts, when LAI values (especially over non-irrigated grasslands and croplands) could be considerably lower than long-year averages of the selected month. A solution for this inaccuracy could be to implement satellite observed vegetation parameters in the NWP model. The main difficulty with such an approach is that high resolution (e.g. that of Sentinel) satellite vegetation products have a time lag of 10-15 days. To overcome this the following is planned: satellite vegetation observations are assimilated in an offline land data assimilation system which is capable to deliver a soil and vegetation state analysis 10 days prior the actual date (T-10d). From T-10d we integrate the offline surface model with prognostic vegetation until the current date; and the resulting vegetation state (at time T) could be merged with the operational analyses of AROME.



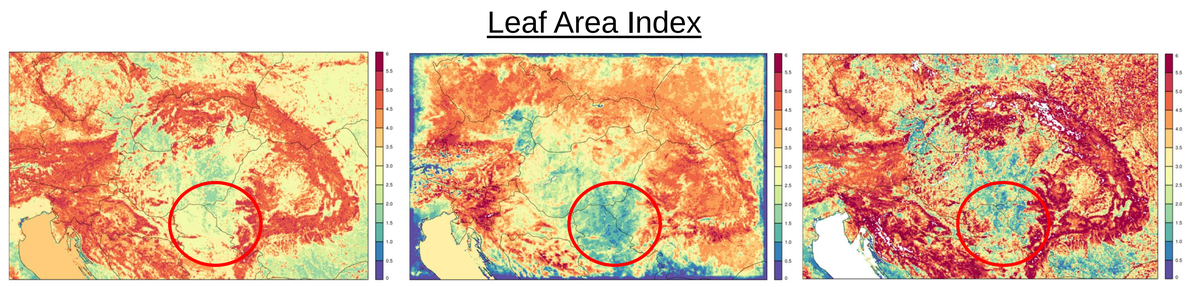
This system is currently under development at OMSZ. In the box below a first result is shown, where the offline SURFEX system is running without satellite data assimilation in "open loop" mode.

First results – AROME run for 15th July 2021

AROME-Hungary was run for a selected day (2021-07-15) in summer 2021 to investigate the impact of LAI on the weather forecast. The weather situation on this day was characterized by an anticyclone. Only few clouds appeared during the day over the AROME domain, while in the afternoon and evening hours some thunderstorms developed.

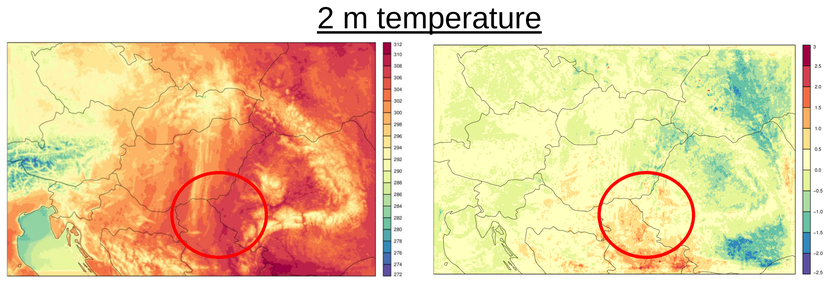
LAI values from the one year long "open loop" offline SURFEX ISBA-A-gs simulation were used in AROME-Hungary ("AROME-LAI" run) and the results were compared with the operational AROME run using climatological LAI computed from ECOCLIMAP v2.0. AROME-Hungary uses one patch in the nature tile of ISBA, consequently, in AROME-LAI the 12 patch output of the offline SURFEX ISBA-A-gs run had to be averaged to one patch. Apart from LAI, all model variables in the initial files (e.g. surface temperature and moisture) were identical in the two runs.

Leaf Area Index



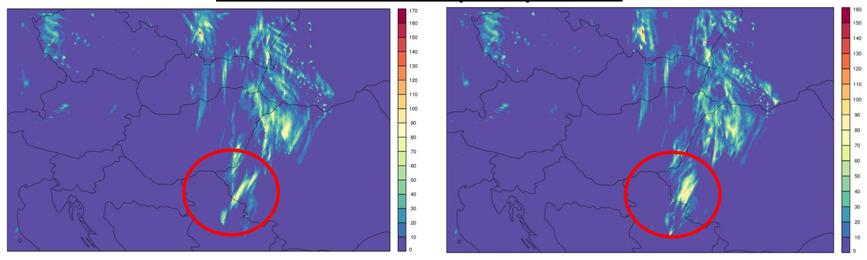
LAI values for 2021-07-15 as computed from the climatology files (left), from the offline SURFEX ISBA-A-gs run (middle) and from satellite observations (product from Sentinel-3 by Copernicus Land Service). Red circles indicate the area of interest which was affected by severe drought.

2 m temperature



2 m temperature forecast (in K) of AROME-LAI (+12h forecast valid for 12 UTC on 15th July 2021, left panel) and the difference from the operational AROME run (right; positive values indicate higher temperature in AROME-LAI). Red circles indicate the area of interest which was affected by severe drought.

30h accumulated precipitation



30h accumulated precipitation forecast (in mm) of AROME-LAI (valid for 06 UTC on 16th July 2021, left panel) and of the operational AROME run (right). Red circles indicate the area of interest which was affected by severe drought.

First results show that LAI can have an impact on the weather forecast produced by AROME in summer anticyclonic cases. Most affected variables are 2 m temperature and precipitation. In the AROME-LAI run, more accurate (lower) LAI values are causing 1-2 degrees higher 2 m temperatures over Northern Serbia.

Plans

In near future the following steps are planned with the aim of introducing a daily updated LAI in the operational AROME model at OMSZ: (1) assimilating LAI and SWI satellite observations in SURFEX offline; (2) using atmospheric forcings computed from interpolated measurements (synop and Radar); (3) running longer time periods with AROME with the daily updated LAI obtained from SURFEX offline.

Reference

Tóth, H., Szintai B., 2021: Assimilation of Leaf Area Index and Soil Water Index from Satellite Observations in a Land Surface Model in Hungary. Atmosphere 2021, 12(8), 944.

Acknowledgement

The discussion with Christine Delire, Clément Albergel and Jean-Christophe Calvet (Météo-France) on specific leaf area index in ISBA-A-gs is highly appreciated.