SALGEE experience in land surface analyses

BIOGEOPHYSICAL ASPECTS OF DROUGHT ASSESSMENT

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Overview

1. SALGEE Project of EUMETSAT in support to LSA SAF
   - Aim of the SALGEE initiative
   - Role & Objectives
   - Activities & SALGEE Workshops
2. Drought as a biogeophysical process
   - SVAT Modeling of soil moisture. Soil Moisture Availability /SMA/ Concept
   - Drought assessment by using LSA SAF products
3. Concluding remarks

EUMETSAT
LSA SAF Program

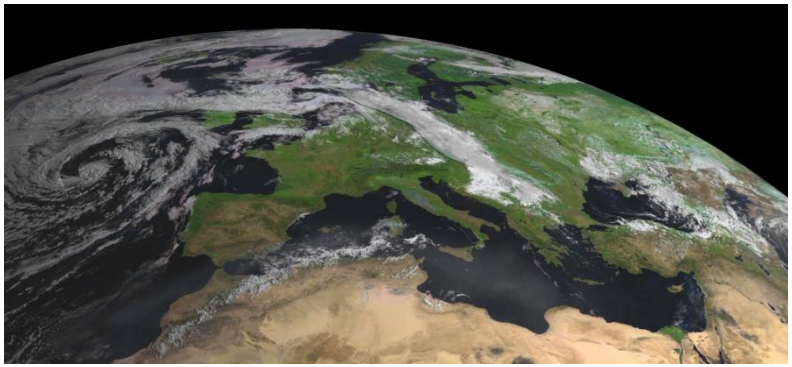
Land surface bio-physical parameters from large scale optical sensors in an operational way

The Land Surface Analyses Satellite Application Facility, LSA SAF has been especially designed to serve the needs of the meteorological community, particularly Numerical Weather Prediction (NWP). Nowadays, the LSA SAF program addresses a much broader community and operational applications.

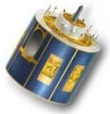
MSG capabilities for land surface remote rensing

Land Surface Monitoring

- The spectral and radiometric characteristics of MSG SEVIRI instrument enable observations of Land Surface parameters and processes.



MSG SEVIRI Data Applications



Spinning Enhanced Visible and Infrared Imager (SEVIRI):
12 spectral channels diapason in the VIS, NIR, MIR, IR spectral bands that are used for generation meteorological products for monitoring

- **Landscape water balance**
- **Surface energy balance**
- **Vegetation parameters**
- **Vegetation fires and carbon issue**

Land LSAF products and area of application

- **Weather forecasting and climate modelling**, requiring detailed information on the [illegible]ure and properties of land.
- **Environmental management and land u[illegible]** needing information on land cover type and land cover changes (e.g. provided by biophysical parameters or thermal characteristics).
- **Agricultural and Forestry** applications, requiring information on incoming/outgoing radiation and vegetation properties.
- **Natural hazards management**, requiring frequent observations of terrestrial surfaces in both the solar and thermal bands.
- **Climatological applications and climate change** detection, requiring long observations.
- (http://landsaf.meteo.pt/).

LSA SAF - MSG Meteorological Products based on SEVIRI data:

- Landscape energy balance
  LST, Albedo, DSLF/DSSF
- Surface water balance
  ET, Snow cover
- Vegetation parameters
  VFC, LAI, fAPAR
- Vegetation fires and carbon issue
  FRM, FRP

SALGEE, The **S**atellite **A**pplications in **L**and surface analyses **G**roup for **E**astern **E**urope *has been established in 2009 for gathering experts in the field of satellite meteorology to complement the activities of EUMETSAT Land Surface SAF for progression of using satellite Land Surface Analyses techniques and training in South Eastern and Eastern Europe (SEE) and other regions of interest regarding their application (CGMS-38, 2010) in conjunction with other source of information.*

http://www.eumetsat.int/Home/Main/AboutEUMETSAT/InternationalRelations/CGMS/CGMSPublications/index.htm

EUMETSAT SALGEE Project

in support to LSA SAF

Applying integrated approach for using satellite data in conjunction with ground observations and model outputs

SALGEE Project of EUMETSAT

- **Aim of the SALGEE initiative**

Support to LSA SAF activities in user services & training in Eastern Europe and other regions of interest to take full advantage of remotely sensed data on land, land-atmosphere interactions and biosphere applications.

- **Role & Objectives**

  ✓ Facilitate exchange of knowledge on integrated approach for using satellite data in conjunction with ground observations and model outputs.

  ✓ Coordinate research and operational activates in using MSG and EPS data for quantification of land surface processes as well as to facilitate the validation and use of LSA SAF products.

  ✓ Contribute to increase benefits from the satellite products in target region.

SALGEE Project of EUMETSAT

▪ Activities

✓ Fostering the use of satellite data in conjunction with other available information (e.g. NWP and Land Surface Model output, ground measurements, etc.)
✓ Establish mechanisms where scientists and user community provide feedback to product developers at EUMETSAT and LSA SAF.
✓ To support the use of new land surface analysis methods and operationally generated geophysical products.
✓ Develop training materials
✓ Support the implementation of EUMETSAT SAF Strategy related to climate monitoring and use of products for Terrestrial-Essential Climate Variables (T-ECV).
✓ Maintain a close cooperation with the LSA SAF, NOAA/NESDIS and NASA.
✓ Organise biennial international workshops to review and discuss progress.

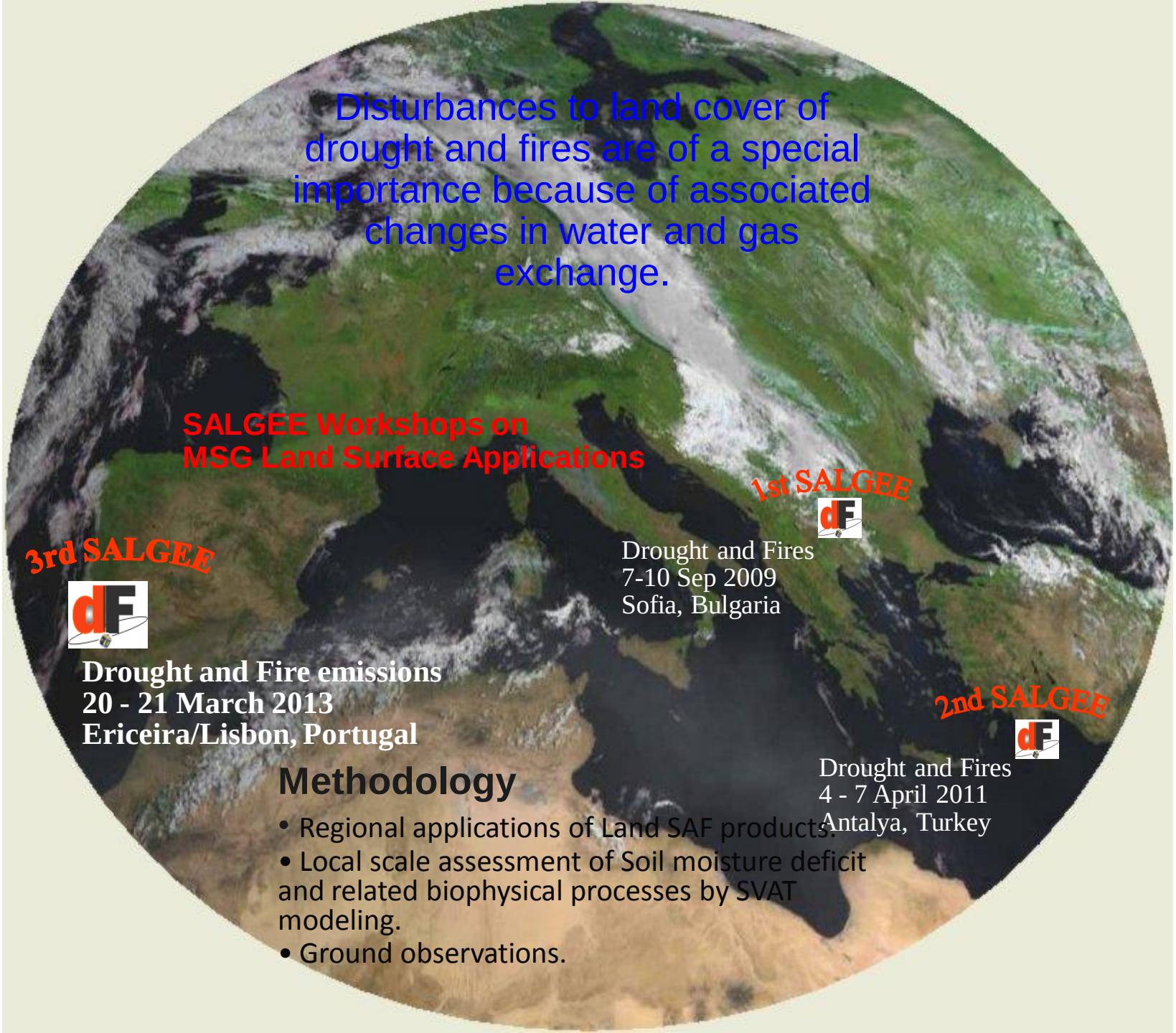
▪ SALGEE Workshops

✓ Sofia, 7-10 September 2009, Bulgaria, “Drought & Fires”
http://info.meteo.bg/conferences/EUMETSAT07092009
http://gofc-fire.umd.edu/implementation/Events/meetings/past.asp

✓Antalya, 4-7 April 2011, Turkey, “Drought & Fires”
http://www.eumetsat.int/Home/Main/DataProducts/HowtoUseOurProducts/WorkshopsAndCourses/SP_20100691324359 19?l=en

✓ Lisabon/Ericeira, 20 - 21 March 2013, Portugal, “Drought & Fire emissions”

SALGEE Workshops



Disturbances to land cover of drought and fires are of a special importance because of associated changes in water and gas exchange.

SALGEE Workshops on MSG Land Surface Applications

1st SALGEE

Drought and Fires
7-10 Sep 2009
Sofia, Bulgaria

2nd SALGEE

Drought and Fires
4 - 7 April 2011
Antalya, Turkey

3rd SALGEE

Drought and Fire emissions
20 - 21 March 2013
Ericeira/Lisbon, Portugal

Methodology

- Regional applications of Land SAF products.
- Local scale assessment of Soil moisture deficit and related biophysical processes by SVAT modeling.
- Ground observations.

Drought identification problem

- Although all types of droughts originate from a precipitation deficiency, it is insufficient to monitor solely this parameter to assess severity and resultant impacts *(World Meteorological Organization, 2006)*.
- Dryness or absence of rain is not enough to constitute a drought. Physiological & Physical signals of vegetation water stress are important.
- In common with other natural disasters, droughts vary widely in degree of severity, duration and areal extent.
- Unlike most other natural disasters, drought onset and termination is difficult to identify.
- The drought indicators should be monitored routinely to determine the drought extent and impacts.

Data and products of MSG satellites can be used for assessment of biophysical parameters related to the surface moistening conditions.

Drought in a changing climate

Due to the complex nature of drought its monitoring calls for a comprehensive and integrated approach, accounting for its specific regional and local reveals.

Joint International Activities

that make use of numerical modeling and satellite data in establishing Drought Information System *(early detection & monitoring):*

- Soil Moisture Anomalies
- Indicators optimazied for characterizing vegetation water stress
- Satellite observations and products.

Operational application of LSA SAF geophysical products

The goal of this study is to evaluate the capacity of LSA SAF products based on MSG SEVIRI data to reflect some physical aspects of terrestrial drought conditions related to biogeophysical cycle on the Earth's surface.

Drought as a specific state of biogeophysical cycle, characterized by a set of related parameters and their dynamics. The methodology includes two kind of approach:

1. SVAT modeling of soil moisture and its dry anomalies.
   Soil Moisture Availability /SMA/ Concept
2. Drought assessment by using LSA SAF products. *To reveal the information content of operational LSA SAF products, which are relevant for evaluation of land surface dry energy and water cycle anomalies).*

Local scale assessment of Soil Moisture Deficit and related biophysical processes

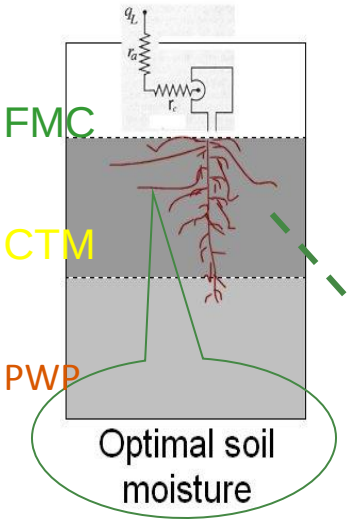
In this study, the evaluation of satellite products information content is performed by combine use with soil moisture deficit products derived by SVAT operational model at NIMH of Bulgaria, 'SVAT_bg'
(Stoyanova, J.S. & Georgiev, C.G., 2007; 2013).

Soil–Vegetation–Atmosphere–Transfer (SVAT) Model

The SVAT models are run by using data from meteorological observations, site specific soil and vegetation physical properties as well as local scale geopysical parameters, and thus can be used as a reference regarding the information content of satellite products for land surface analysis at local scale.

In our methodology the Soil Moisture Availability /SMA/ concept is used for assessing drought and related vegetation water stress.

Soil Moisture Availability Concept



Levels of SM availability

Field Moisture Capacity **(FMC)**

Capillarity tearing moisture **(CTM)**

Permanent wilting point **(PWP)**

- Non-limiting SM conditions, the evaporation from the plant community is not restricted and occurs at a potential level *PET* when the meteorological variables are the only determinants.

Physical meaning of drought severity

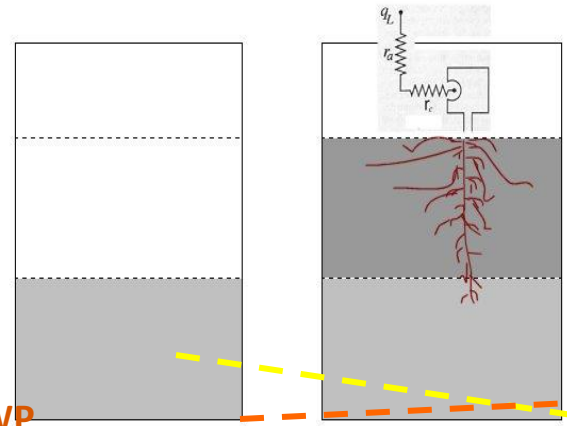
Optimum of soil moisture availability

Soil Moisture Availability /SMA/ to plants is an important variable for:

- Evaluating vegetation transpiration;
- A key factor in models of ecosystem and carbon cycle processes *(e.g. Friend and Kiang, 2005);*
- energy and water budgets of crop canopies,
- A basic parameter in mesoscale atmospheric circulation models *(Noilhan and Calvet, 1995)* and forecasting systems *(e.g. Fennessey and Shukla, 1999; Koster et al., 2004).*

SMA being the main determinant of plant systems development, at the same time might serve as information source for “warnings” for environmental constrains.

Soil Moisture Availability /SMA/ Concept



PWP

Restricted moisture availability

Optimal soil moisture

Levels of SM availability

Field Moisture Capacity **(FMC)**

Capillarity tearing moisture **(CTM)**

Permanent wilting point **(PWP)**

when AET is restricted, the status of initial SM deficit is defined as 'Dry'

Physical meaning of drought severity

No available moisture

The availability of moisture is restricted

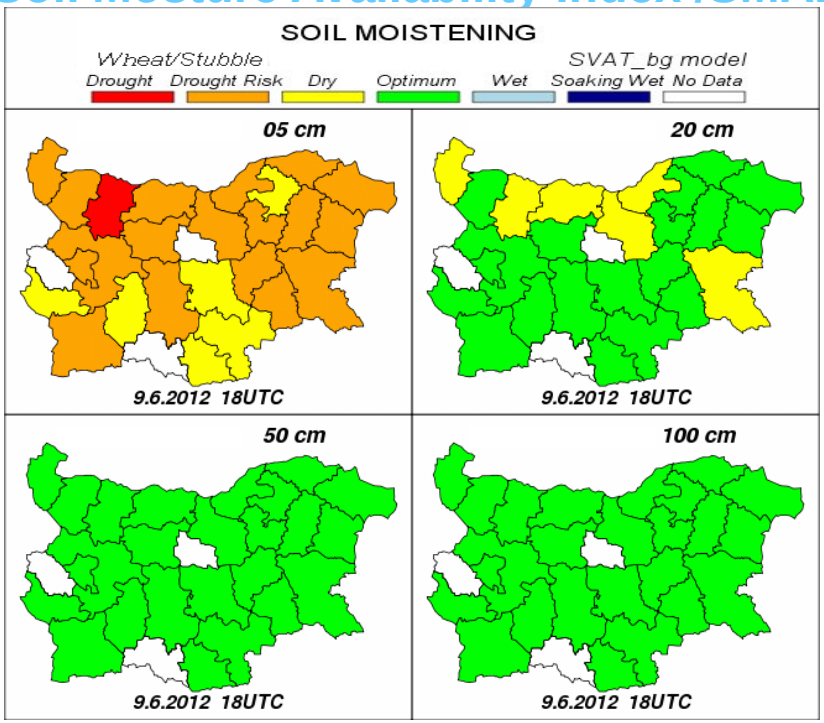
Optimum of soil moisture availability

• **Below PWP level**:
'Drought risk' and 'Drought' denote high SM deficit and prevented AET.
'Drought risk' and 'Drought' are distinguished depending on the duration of the period without rain.

• The maximum moisture content of capillaries in equilibrium with the force of gravity that is the field moisture capacity **(FMC)**
• Capillary tearing moisture **(CTM).** Below this moisture level, SMA sharply drops as a result of a salutatory alteration in soil moisture mobility and instead of its usual fluid state, the water movement to the evaporative soil surface becomes *via* water vapour.
• The permanent wilting point **(PWP)** is defined as the minimal of soil moisture that plant requires not to wilt.

OPERATIONAL APPLICATIONS based on the SMA concept

Soil Mosture Availability Index /SMAI/



- **Defined through a 6-level threshold scheme, based on 'SVAT_bg' derived SM on a site-scale.**
- **Reflects regional climate/soil/vegetation specificity.**
- **Operatively calculated for perennial grass /lucerne and cropped field / wheat on a daily basis.**
- **Assessment of soil moisture availability at top soil layer.**
- **Calculated for the 26 administrative regions of Bulgaria and visualized by colour-coded maps.**

Colour coded threshold scheme of SM availability

Physical meaning of drought severity

No available moisture for > 5 days

No available moisture

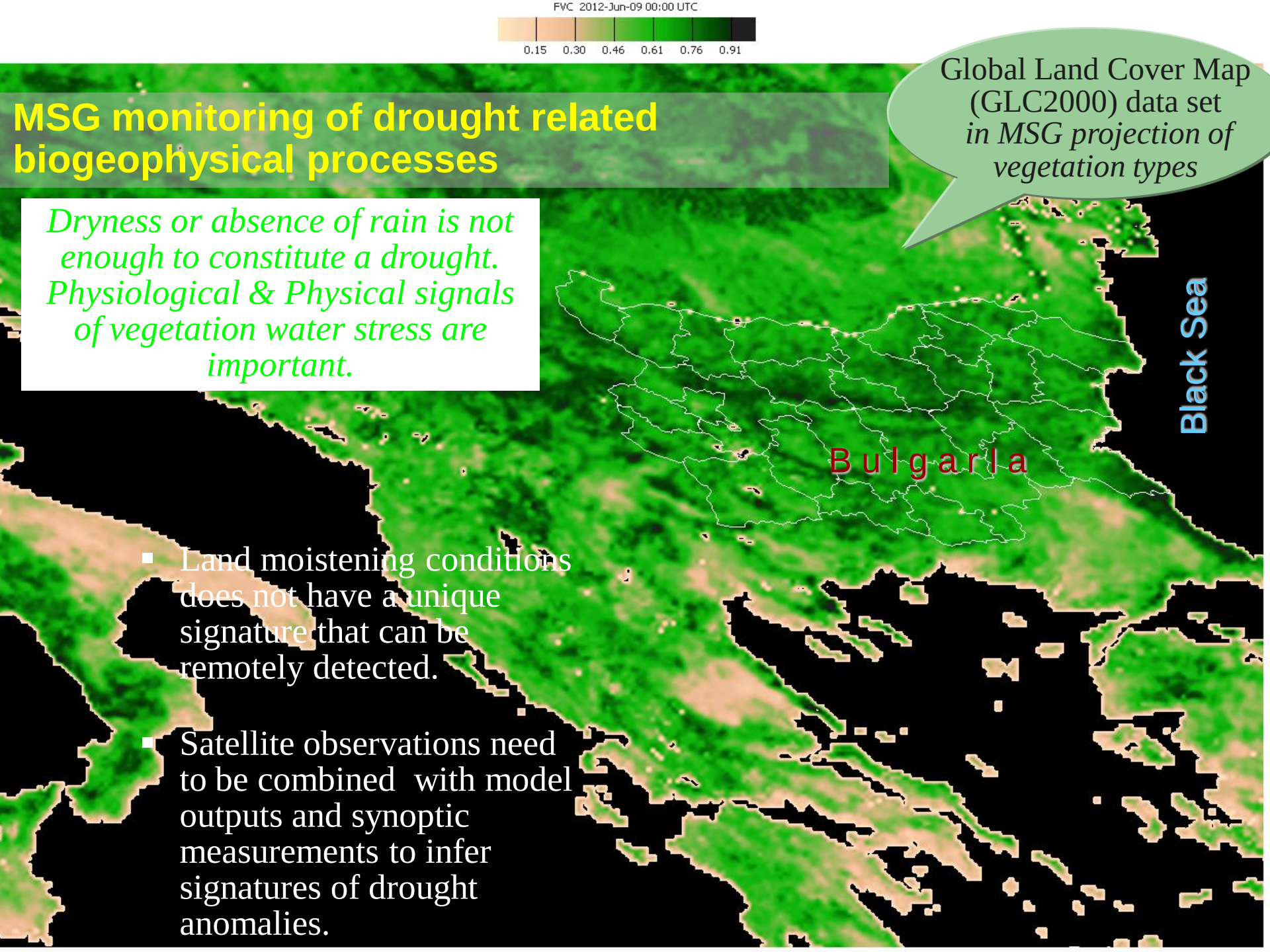
The availability of moisture is restricted

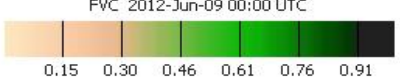
Optimum of soil moisture availability

Soil moisture at field moisture capacity

Over moistening > Field moisture capacity

No data


FVC 2012-Jun-09 00:00 UTC
0.15 0.30 0.46 0.61 0.76 0.91
MSG monitoring of drought related biogeophysical processes
Global Land Cover Map (GLC2000) data set in MSG projection of vegetation types
Dryness or absence of rain is not enough to constitute a drought. Physiological & Physical signals of vegetation water stress are important.
Black Sea
Bulgaria
Land moistening conditions does not have a unique signature that can be remotely detected.
Satellite observations need to be combined with model outputs and synoptic measurements to infer signatures of drought anomalies.



MSG monitoring of drought related biogeophysical processes

Global Land Cover Map (GLC2000) data set *in MSG projection of vegetation types*

- Based on the spatial and temporal resolution of geostationary MSG satellites, pixel values of LSA SAF biophysical products are used for evaluation of land surface drought conditions and related anomalies in:
  - Energy cycle
  - Water cycle
- The evaluation of satellite products is performed by combine use with SVAT model output and ground observations (as references).

Satellite observations
LST 1200, FVC, ET1200

Black Sea

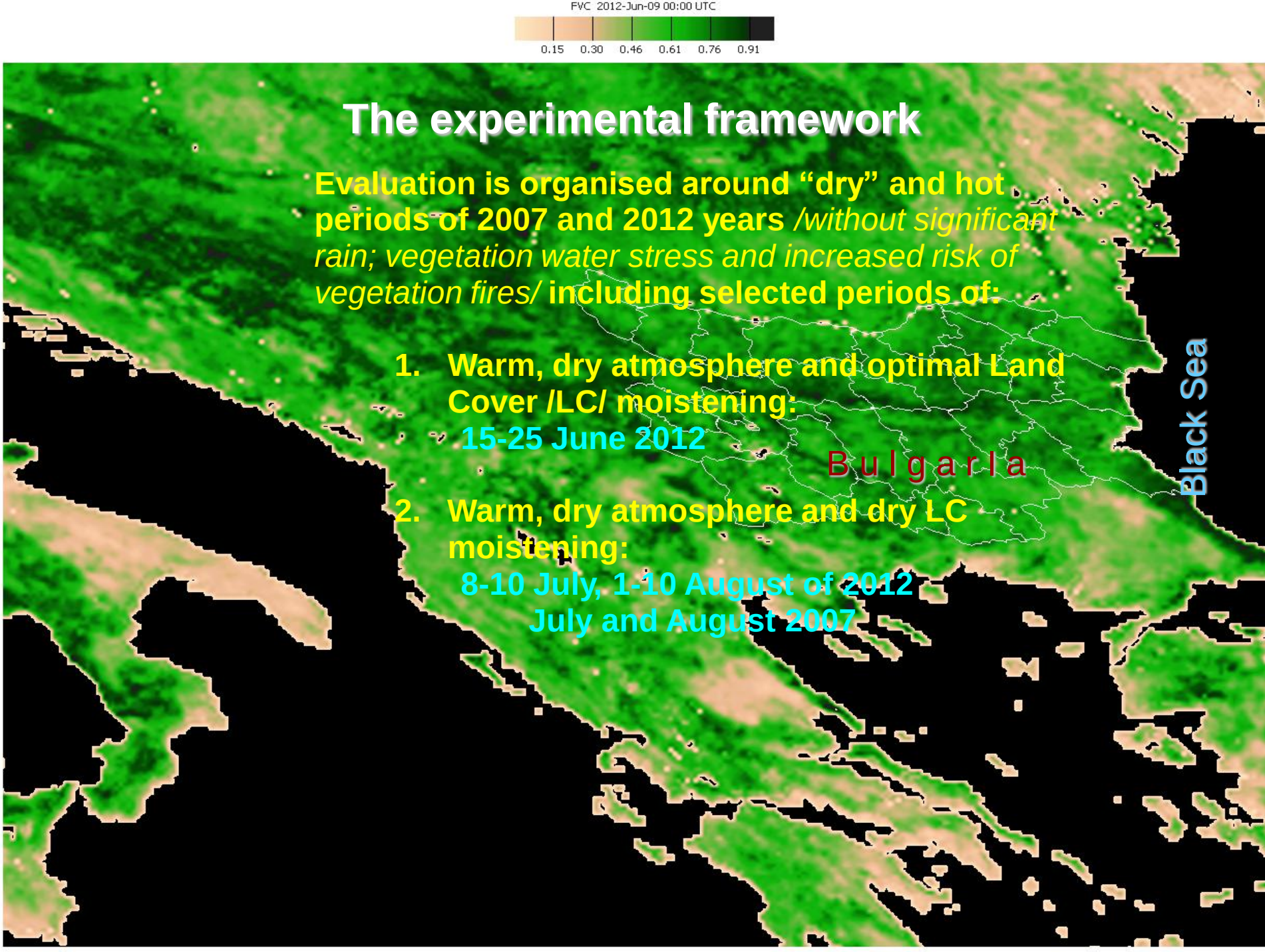
Bulgaria

Synoptic observations

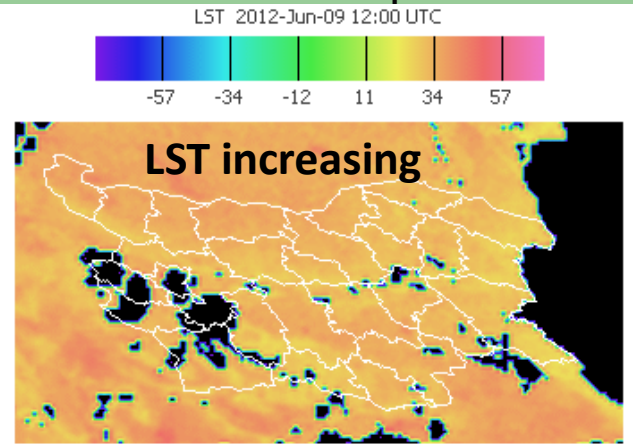
Land model *SVAT_bg/*
Soil & Vegetation

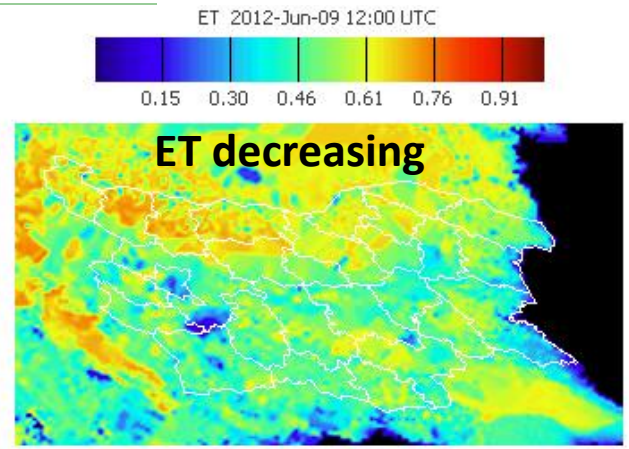
Blended parameters
between satellite and ground observations

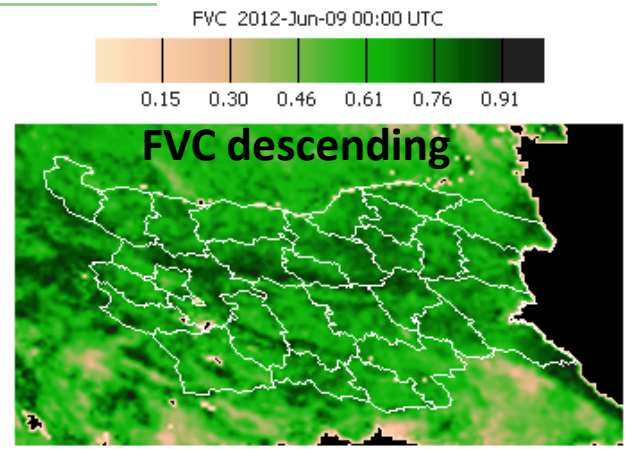
- Land moistening conditions does not have a unique signature that can be remotely detected.
- Satellite observations need to be combined with model outputs and synoptic measurements to infer signatures of drought anomalies.


FVC 2012-Jun-09 00:00 UTC
0.15 0.30 0.46 0.61 0.76 0.91
The experimental framework
Evaluation is organised around “dry” and hot periods of 2007 and 2012 years /without significant rain; vegetation water stress and increased risk of vegetation fires/ including selected periods of:
1. Warm, dry atmosphere and optimal Land Cover /LC/ moistening:
15-25 June 2012
2. Warm, dry atmosphere and dry LC moistening:
8-10 July, 1-10 August of 2012
July and August 2007
Bulgaria
Black Sea

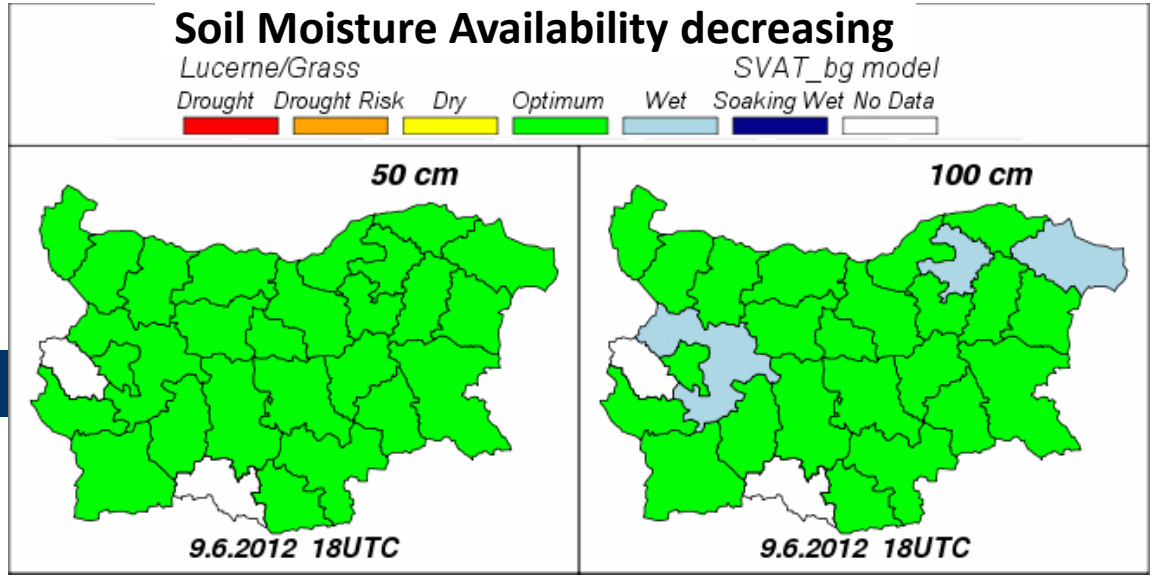
LSA SAF products



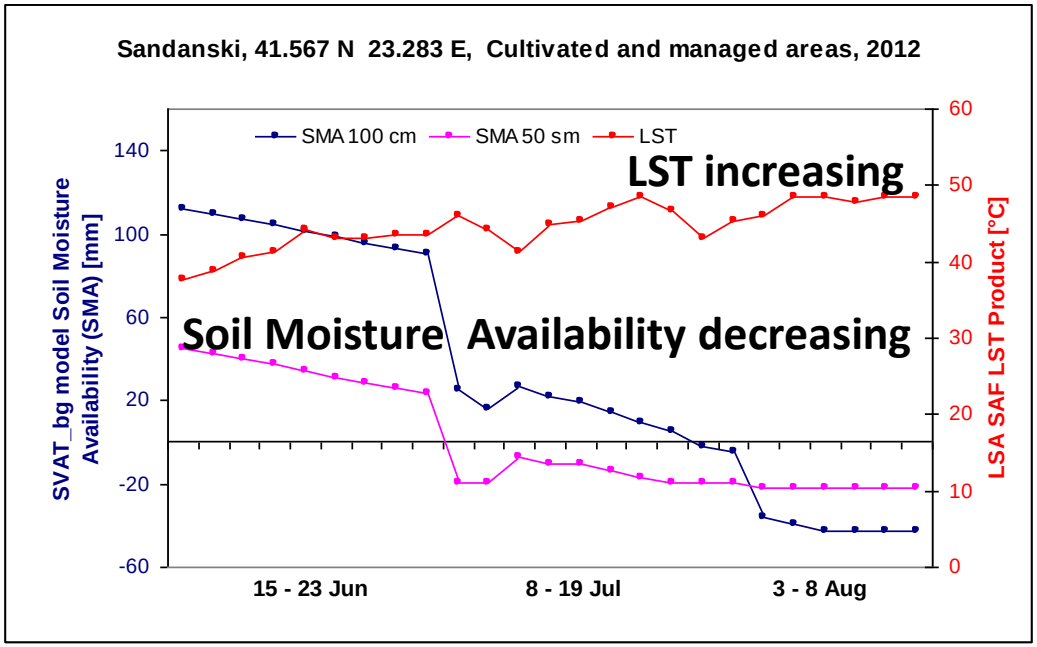




SVAT products

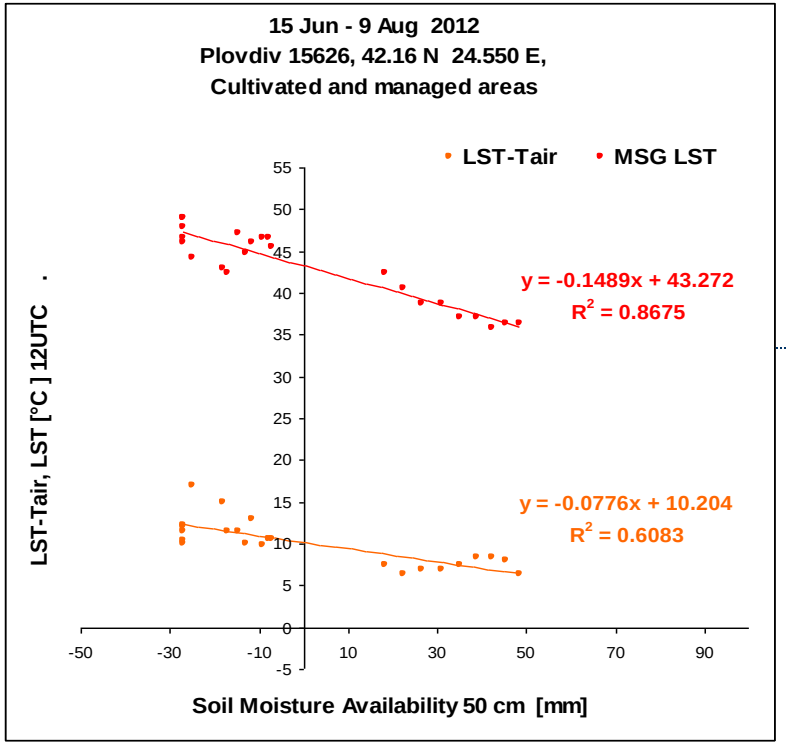


SMA depletion is accompanied by increase of LST, decrease of ET, decrease of FVC.



The difference (Tskin - Tair)

is a key parameter for characterization of heat and moisture fluxes between the land surface and the atmosphere and thus can provide **signals of vegetation water stress** .



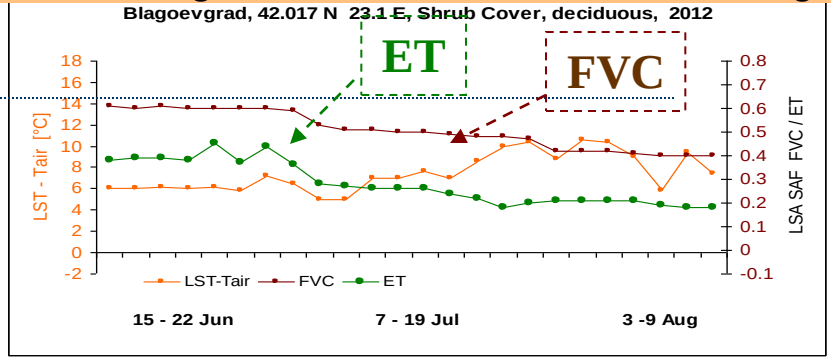
MSG LST_Tair difference increases along the strengthening of dry soil moisture anomaly:

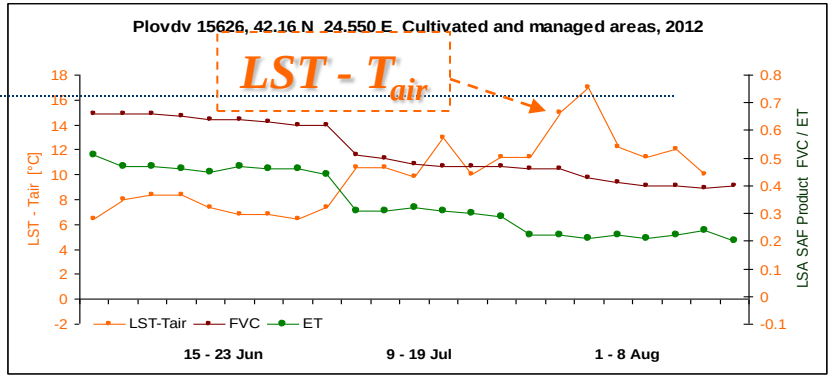
- being up to **10 ºC** in presence of available SM,
- increasing up to **18 ºC** after SMA depletion.

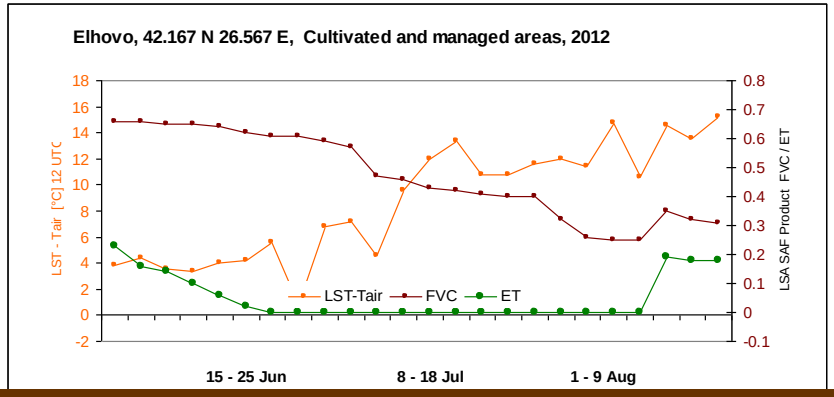
Time evolution: MSG FVC – MSG ET – (MSG LST – Tair)

Dry soil reduce the vegetation cover and its functioning

ET decreases along to LST/LST-Tair increase



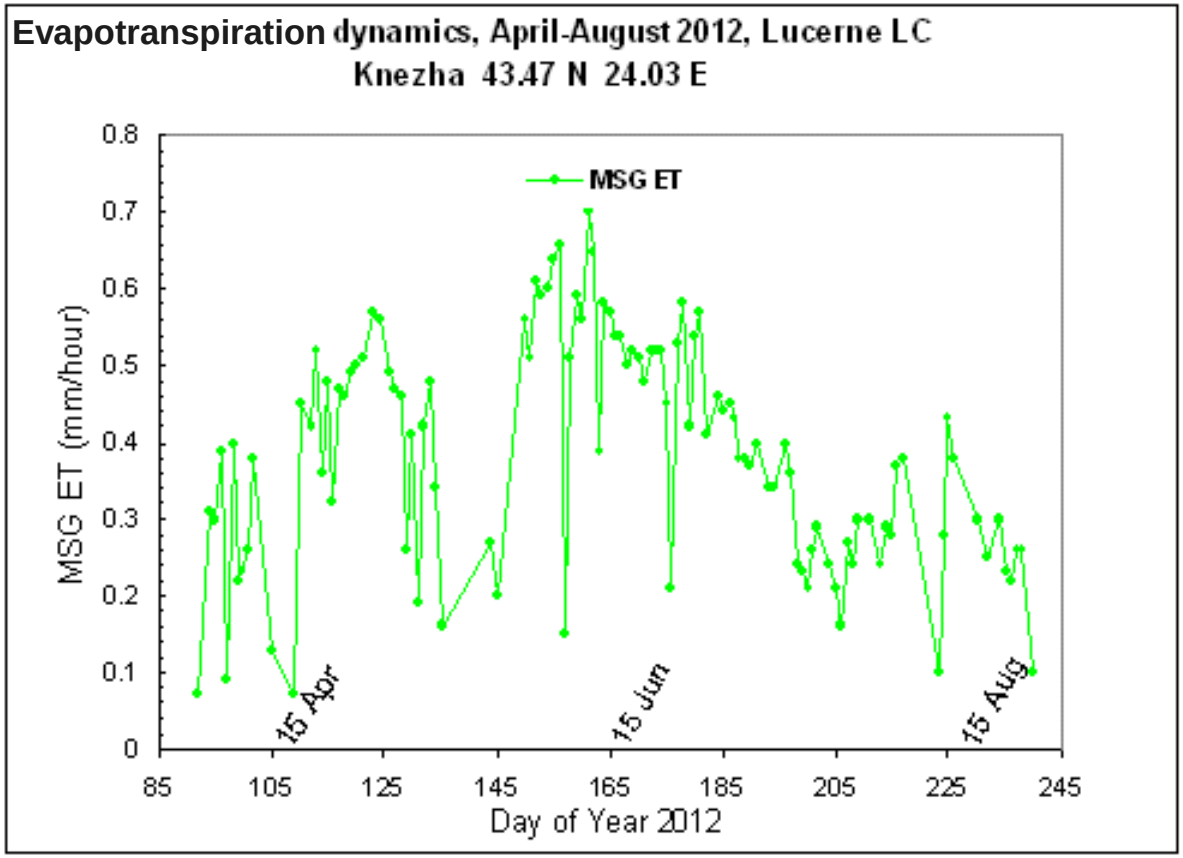


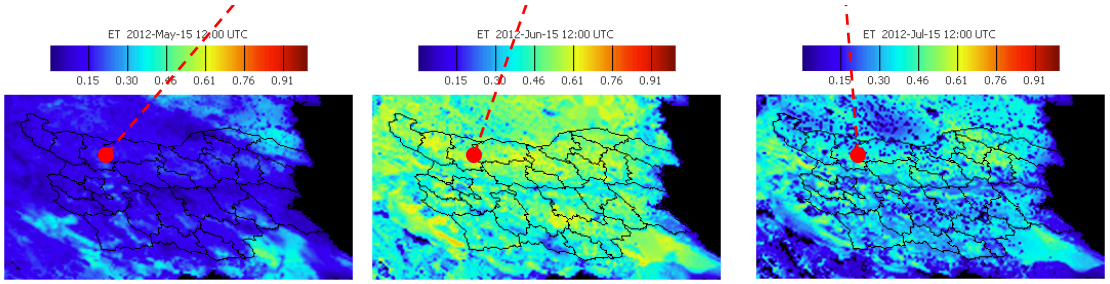


During the period of the heat waves 2012

Along the gradual SMA depletion

Evapotranspiration as seen by MSG ET





15 May 15 Jun 15 Jul

LSA SAF ET product

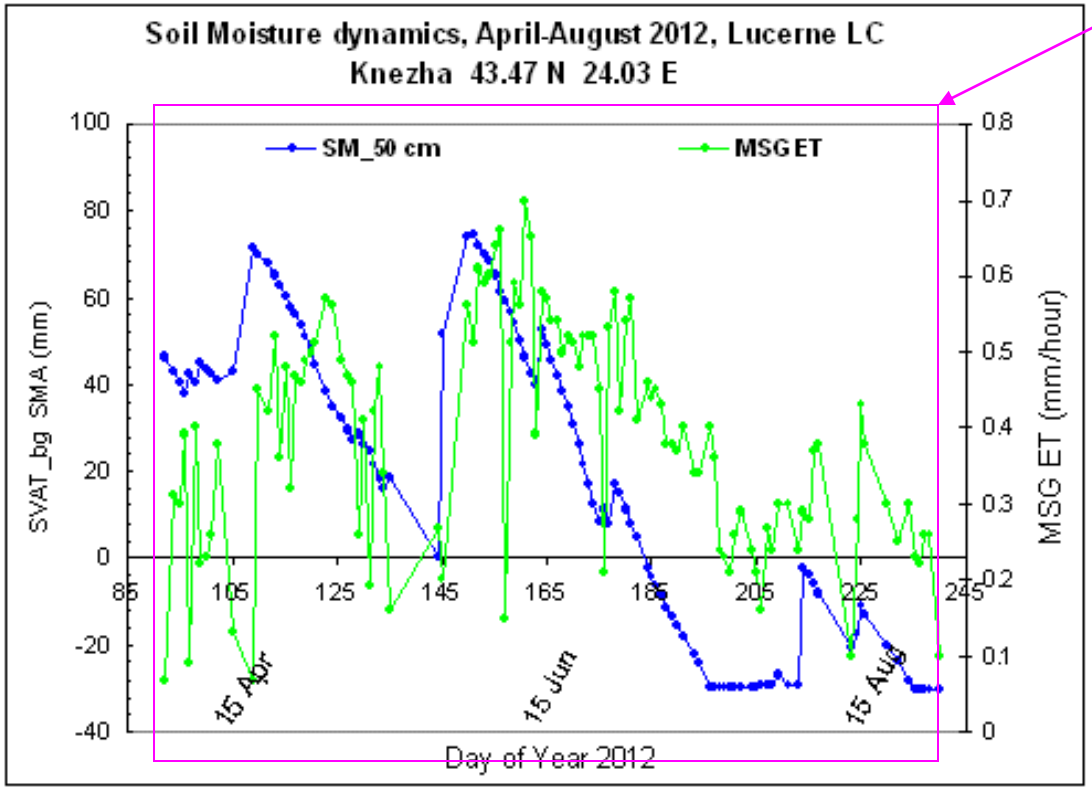
- **Land - atmosphere interaction:**
  - ✓ Governs the vegetation functioning,
  - ✓ Is reflected by dynamics of evapotranspiration */more exactly by LE/* during the growing season.

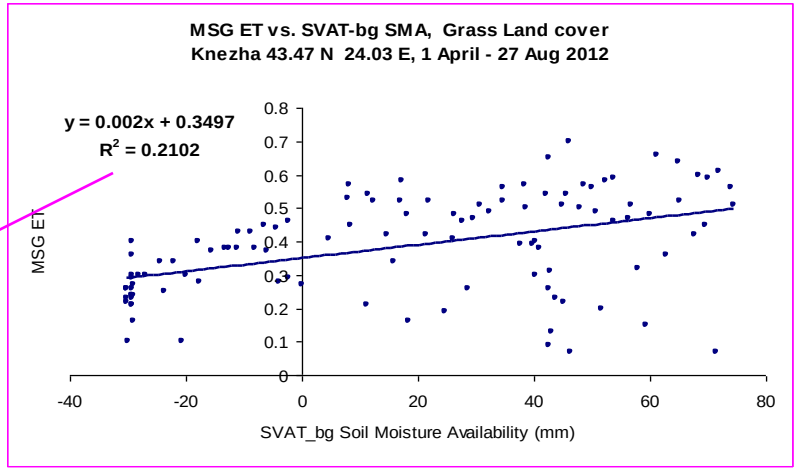
- The evapotranspiration **seasonal** evolution can be monitored by LSA SAF MSG ET product:
  - ✓ The ET reaches its maximum values at the beginning of the summer (around 15 June) when both maximum solar energy and maximum soil moisture availability are present.

Vegetation functioning

in relation to Soil Moisture Availability

/'SVAT_bg'/





✓ As a measure of SM conditions, SMA from 'SVAT_bg' model is used in parallel to ET.

role of SM in initiation and propagation of drought

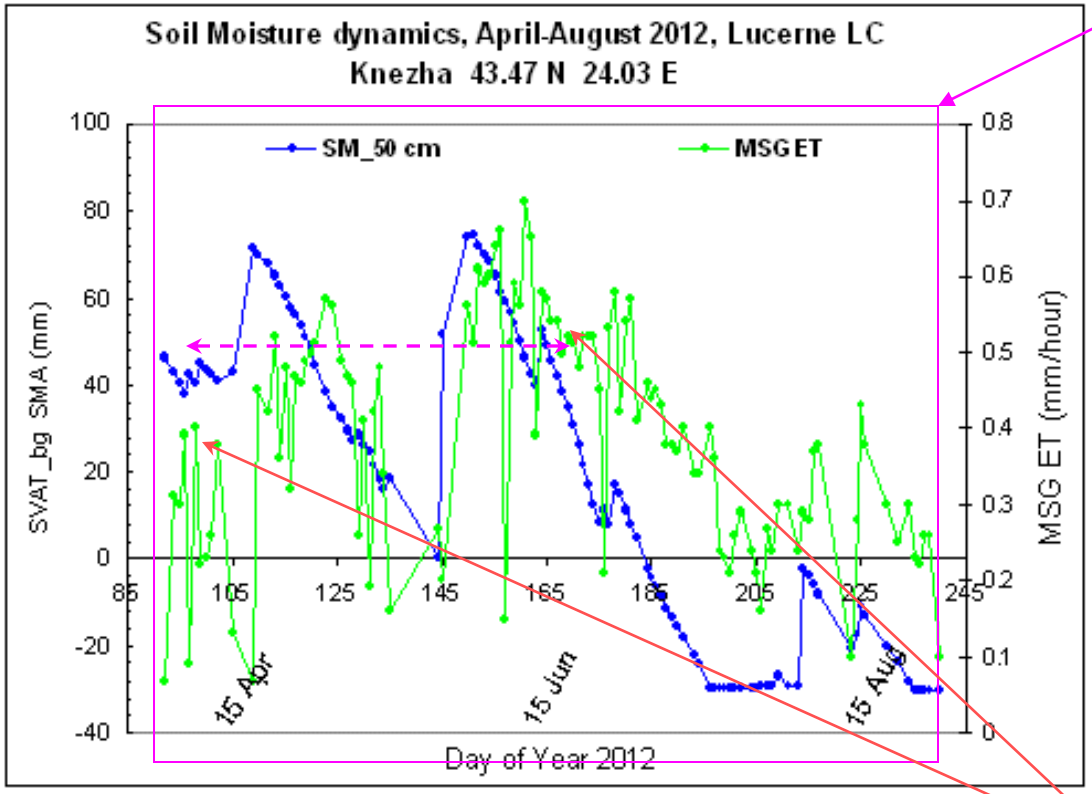
- The evapotranspiration dynamics is driven by the solar energy and soil moisture availability.

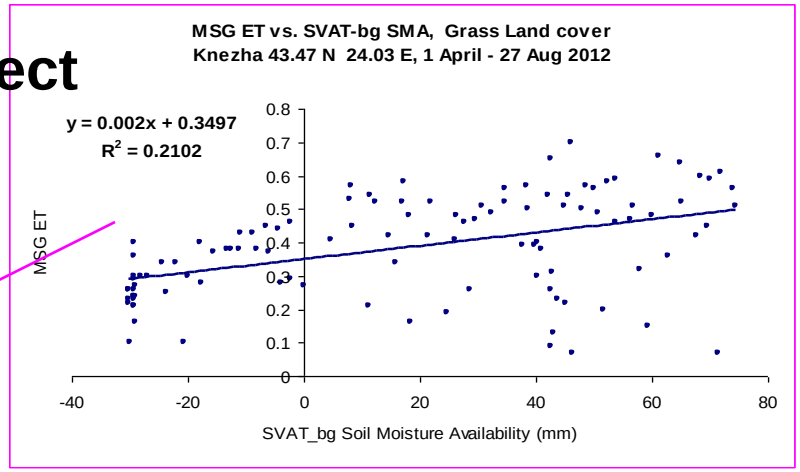
- The ET reaches maximum values at the beginning of the summer (around 15 June) when both maximum solar energy and maximum soil moisture availability are present.

- The dependence of ET to SMA over the whole growing season is week.

LSA SAF ET product capabilities to reflect SMA dynamics & drought conditions

Evaluation by 'SVAT_bg' model as a reference





- The dependence of ET to SMA over the whole growing season is week.

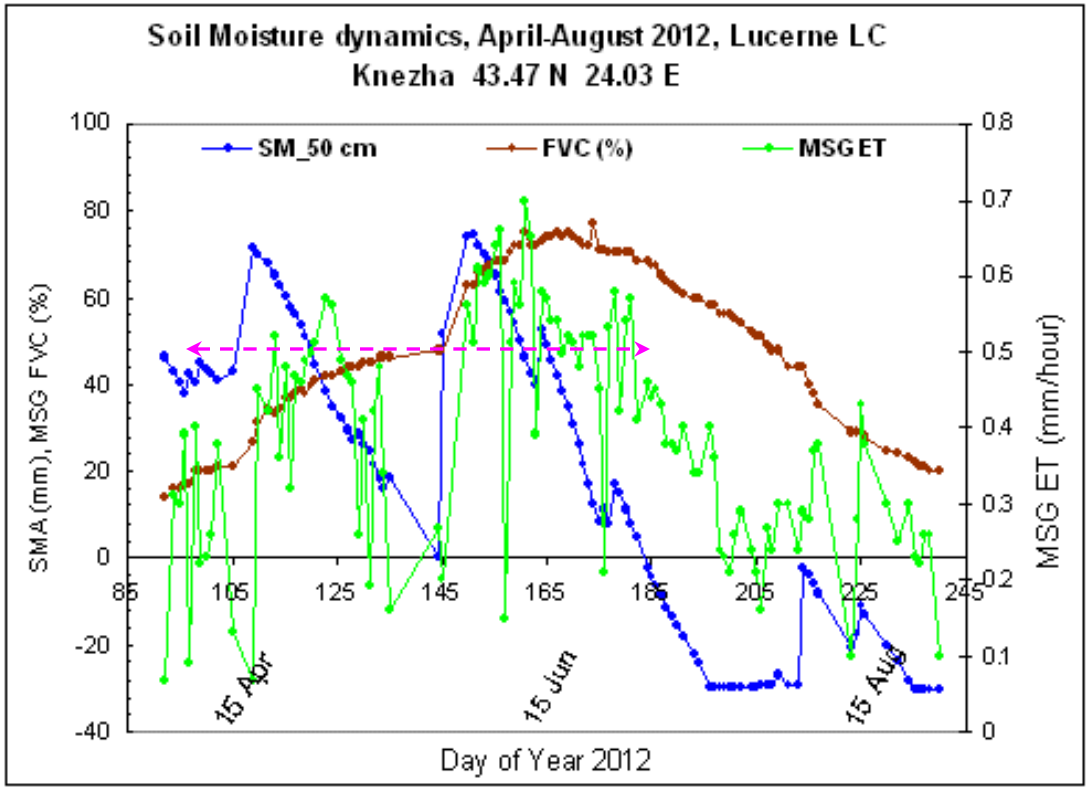
Vegetation functioning

in relation to Soil Moisture Availability

/'SVAT_bg'/

- Among April and June at the same level of SMA, the ET is more intensive in June.

SMA and structural vegetation characteristics as seen by MSG FVC dynamics



- Among April and June at the same level of SMA the ET is more intensive in June.

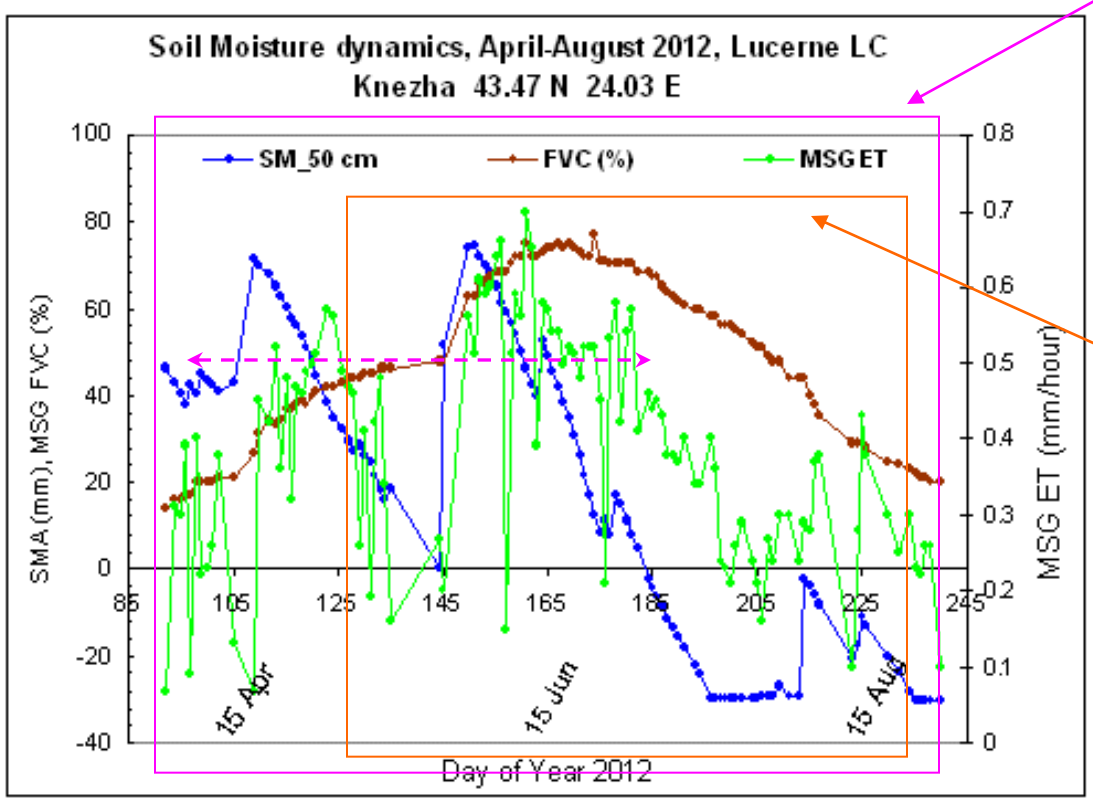
In addition to the solar energy and soil moisture availability, the Fraction of Vegetation Cover is the parameter, that influences the ET.

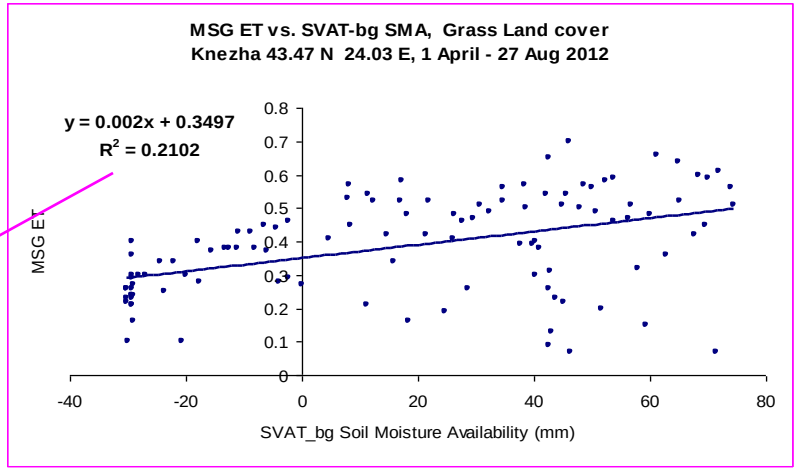
The Fraction of vegetation cover

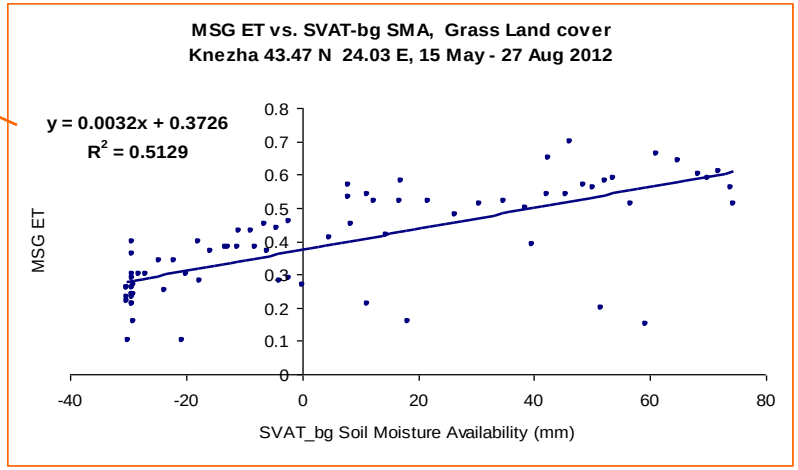
LSA SAF FVC product shows vegetation cover 20 % in the beginning of April and 60 % in the end of June that leads to different evapotranspiration at the same SMA conditions.

Vegetation functioning:

in conformity with structural vegetation characteristics as seen by MSG FVC







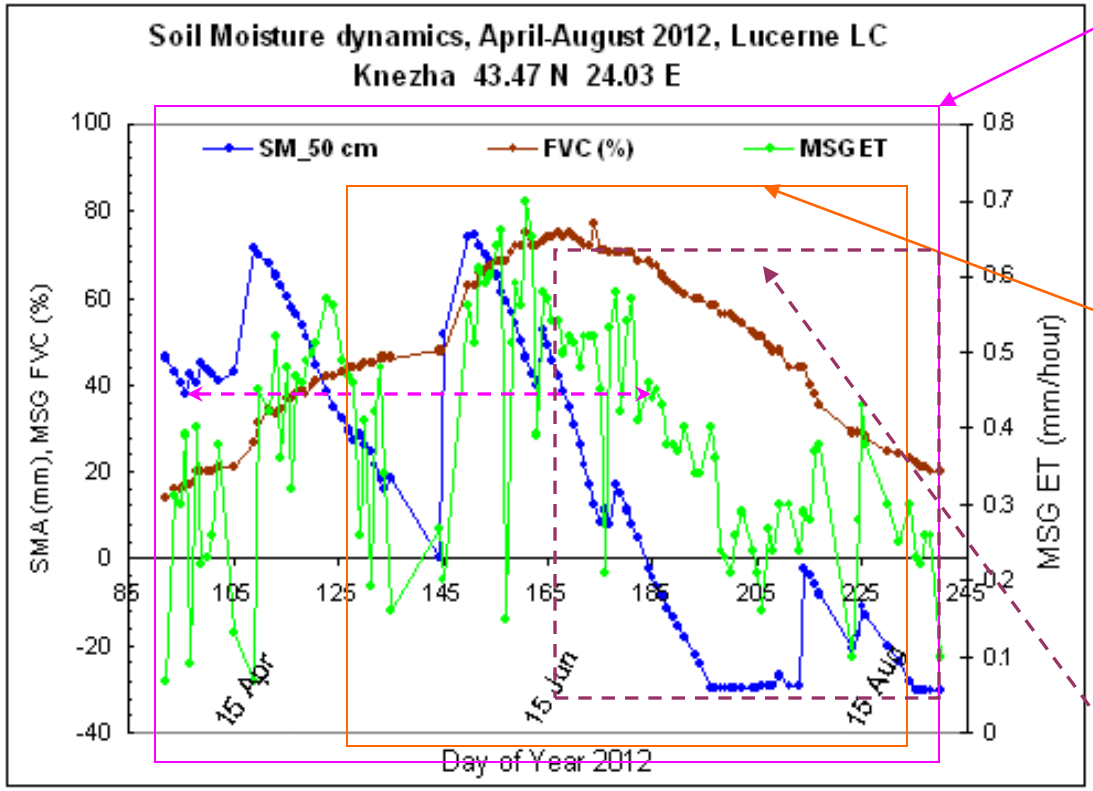
- Among April and June at the same level of SMA the ET is more intensive in June.

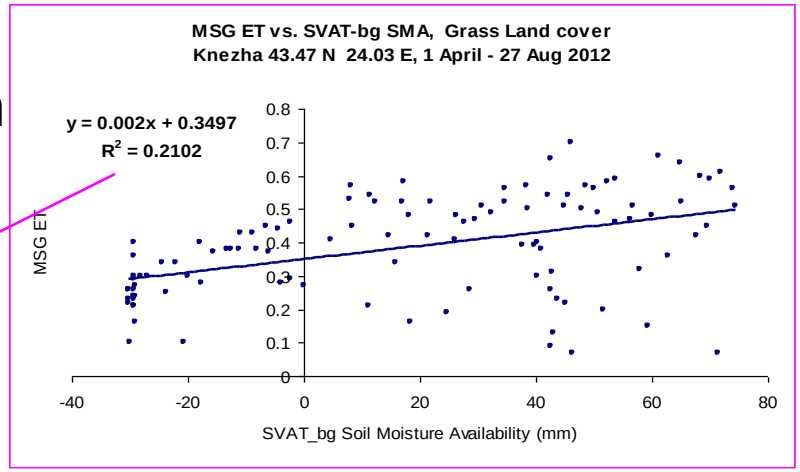
In addition to the solar energy and soil moisture availability, the Fraction of Vegetation Cover is the parameter, that influences the ET.

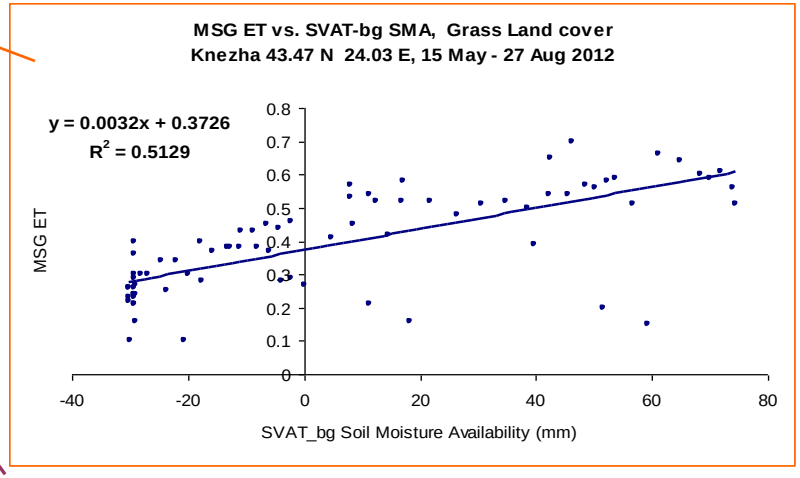
The dependence of ET to SMA increases to correlation coefficient 0.51 for the period after 15 May, when the FVC reaches 40 % as derived by LSA SAF FVC.

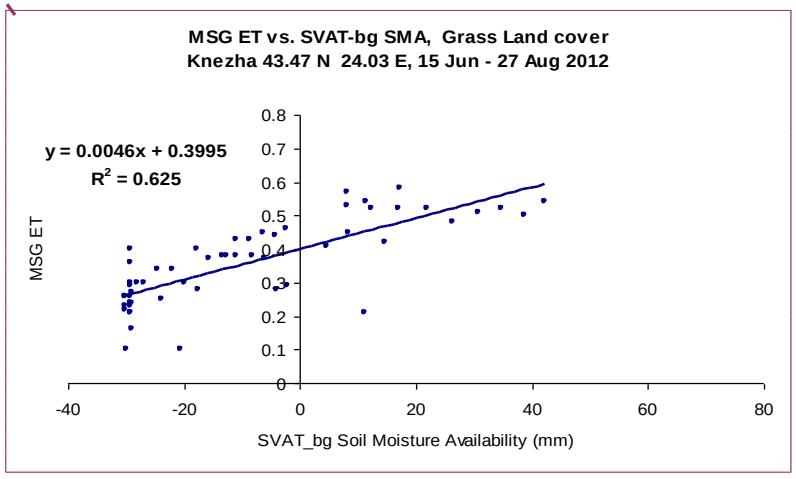
Vegetation functioning:

in conformity with structural vegetation characteristics as seen by MSG FVC







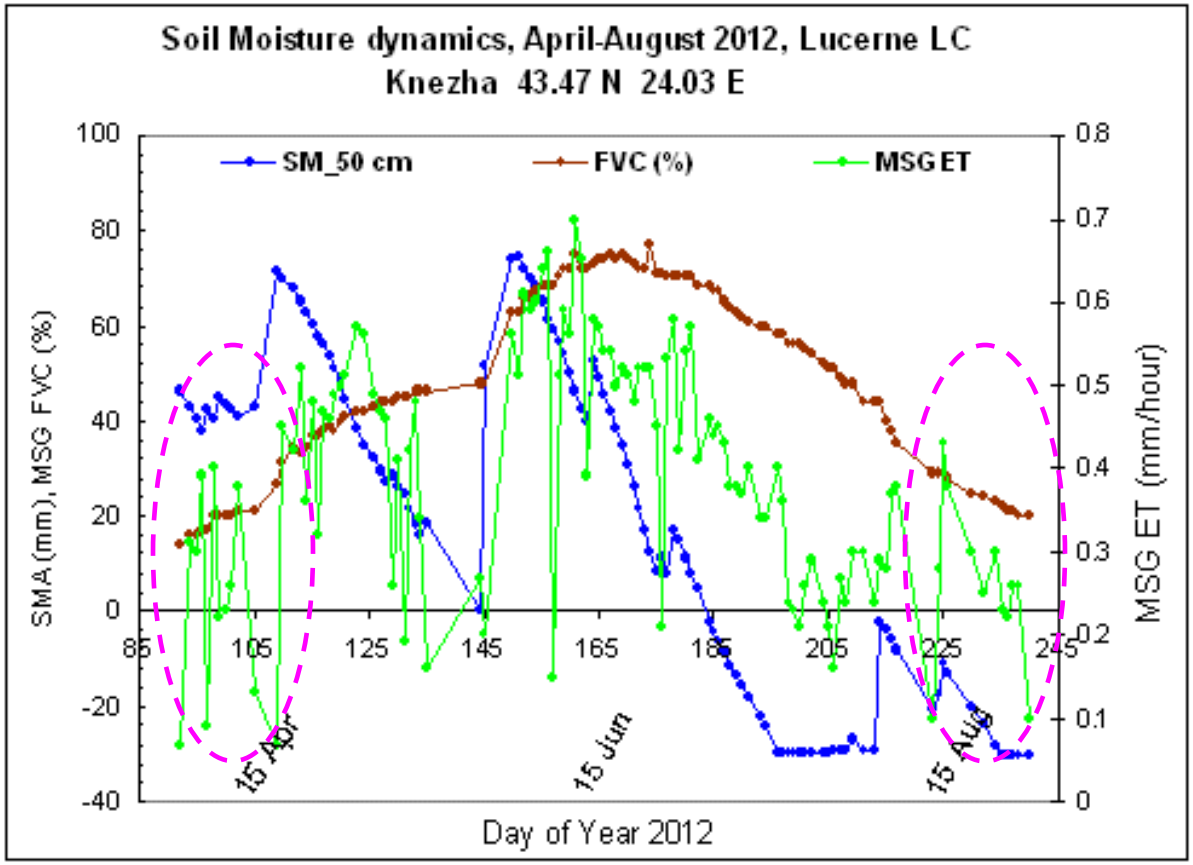


In addition to the solar energy and soil moisture availability, the Fraction of Vegetation Cover is the parameter, that influences the ET.

The dependence of ET to SMA strongly increases to correlation coefficient 0.62 for the period after 15 June, when the FVC reaches its maximum of 65 % as derived by LSA SAF FVC.

Vegetation functioning:

in conformity with structural vegetation characteristics as seen by MSG FVC

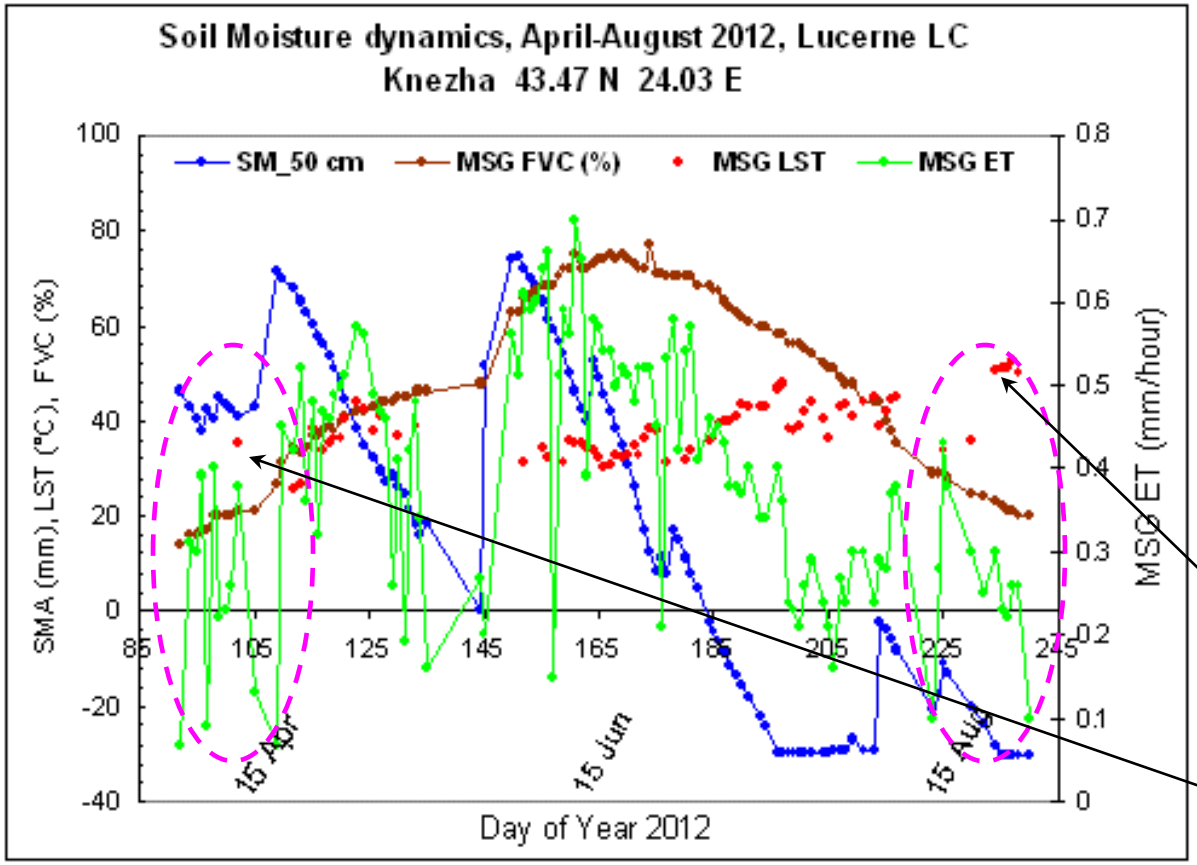


- Among April and August at quite different level of SMA and the same FVC, the ET in the beginning of April is as intensive as in the end of August.

- In addition to the solar energy, soil moisture availability and fraction of vegetation cover, surface skin temperature Ts is another functional vegetation characteristics that influences the evapotranspiration (LSA SAF ET).

Vegetation functioning:

in conformity with functional vegetation characteristics as seen by MSG LST



- Among April and August at quite different level of SMA and the same FVC the ET in the beginning of April is as intensive as in the end of August.

In addition to the solar energy soil moisture availability and fraction of vegetation cover, surface skin temperature Ts is another variable that influences the ET.

The Land Surface Temperature:

LSA SAF LST product shows LST 28 °C in the beginning of April and 45 °C in the end of August that results in the same evapotranspiration at the same FVC and quite different SMA conditions.

Concluding remarks

- LSA SAF products of functional (ET, LST) and structural (FVC) vegetation properties can reflect the physical aspects of energetic/water cycles and their “dry” anomalies:

  ✓ At the beginning of growing season (April) the SMA is high and it corresponds to high LSA SAF ET and low LST. In this time FVC starts to increase, reaching its maximum in June in line with the maximum of ET.

  ✓ In drought conditions during end-growing season, FVC can decrease up to its initial values from April. In this case, due to high LST in August (up to 45 °C), the ET increases sharply in case of SMA increasing (due to precipitation inputs).

  ✓ During the dry periods ET is steadily exosted in parallel to SMA , which finally becomes negative and as a result the ET stops.

- The study shows that these LSA SAF (ET, LST, FVC) products are suitable operational tools for monitoring initiation of water stress and propagation of drought .

Acknowledgments

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Processing and visualisation of the satellite products is performed by David Taylor HDF Viewer software, http://www.satsignal.eu.
Forest Agency of Bulgaria has provided information for actual forest fires.