ANALYSES AND FORECAST OF DROUGHT HAZARDS

Julia Stoyanova

National Institute of Meteorology and Hydrology (NIMH), Bulgaria

Outline

1. Introduction to drought problem
2. Meteorological processes that shape terrestrial drought
3. Basic methods & principles in land surface analysis and forecasts
4. Satellite techniques & LSASAF products for monitoring land surface conditions of drought related hazards
5. Applications of LSA SAF products

1. Introduction to drought problem

Drought is a High Impact Weather phenomena

Spectrum of High Impact Weather effects

extreme in amplitude

tropical cyclones, intense winds, wind gusts, heavy convective precipitation

prolonged 'regimes'

droughts, heat-waves *or cold-spells*

These features are a challenge to define, let-alone predict, because they represent the aggregate of interactions between planetary waves (possibly remotely-forced) and smaller spatio-temporal scale variability including land – atmosphere coupling.

1. Introduction to drought problem

- The central theme in the definitions of a drought is the **concept of a water deficit**.
- A drought is difficult to define because of the need to specify the component(s) of the hydrologic cycle affected by the water deficit and the time period associated with the deficit.

- How the definitions of a drought are related to specific components of the hydrologic cycle and how precipitation deficits are related to drought ? The effects of precipitation deficits are propagated with progressively duration of delay through the *(Figure 1)*:
  - surface-runoff,
  - soil-moisture,
  - streamflow, and
  - ground-water components of the hydrologic cycle respectively.
- From this perspective, precipitation can be considered to be the **carrier** of the drought signal, and streamflow and ground-water levels can be considered to be the last indicators of the occurrence of a drought.

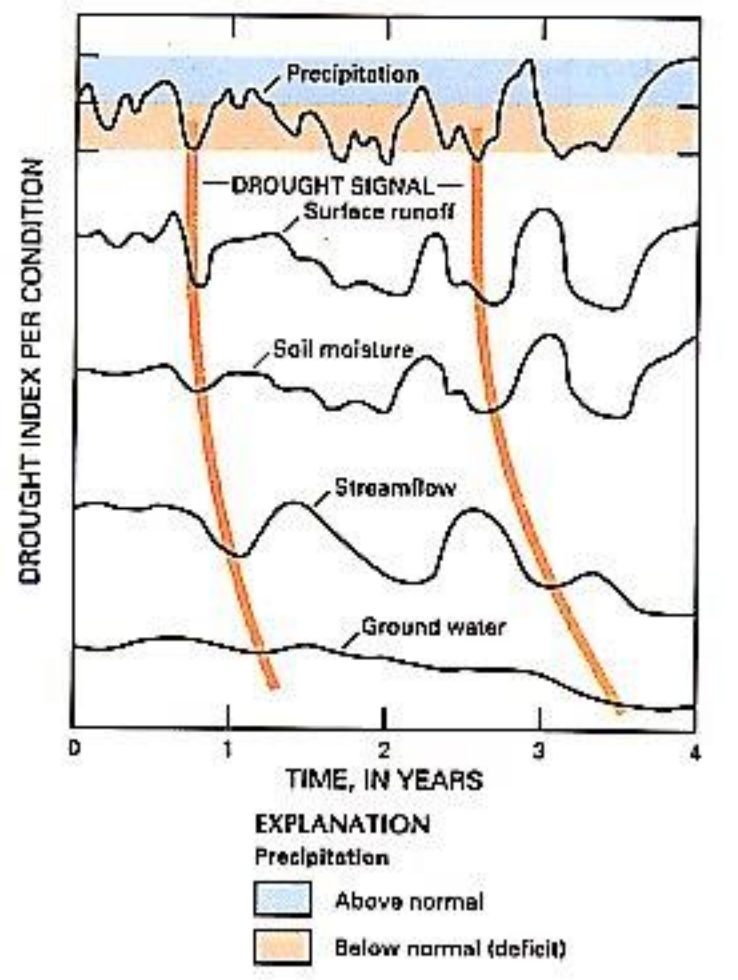


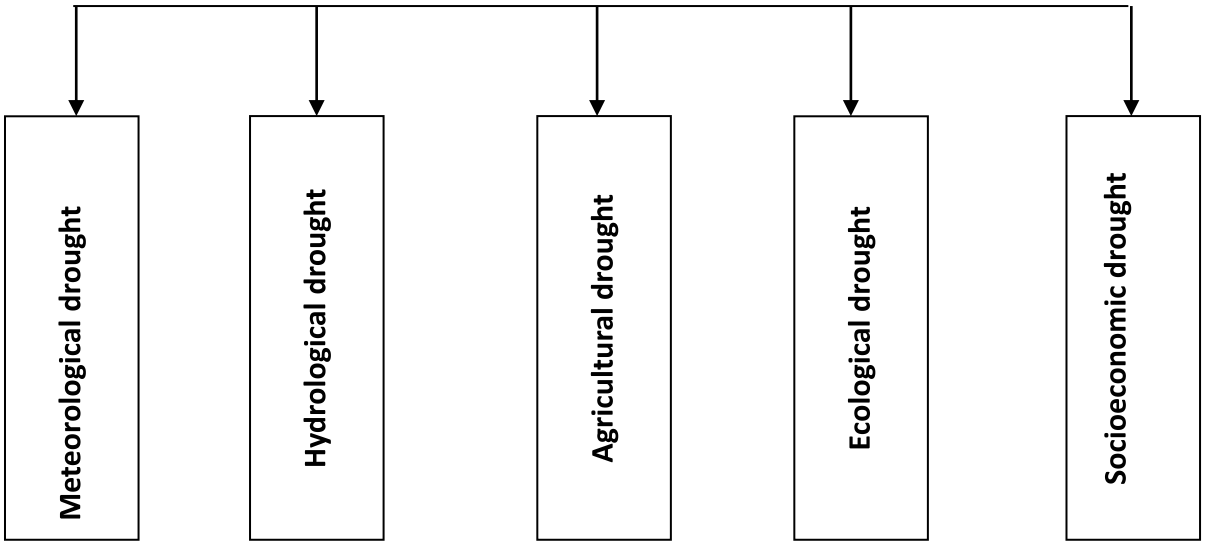
Figure 1. *Propagation of precipitation defecits through other components of the hydrologic cycle. (Modified from Changnon, 1987).*

Spectrum of drought (*with accent on vegetation season*)

Drought is an event-driven extreme, which do not necessarily occur every year at a given location.
A drought is a complex phenomenon that can be defined from several perspectives.

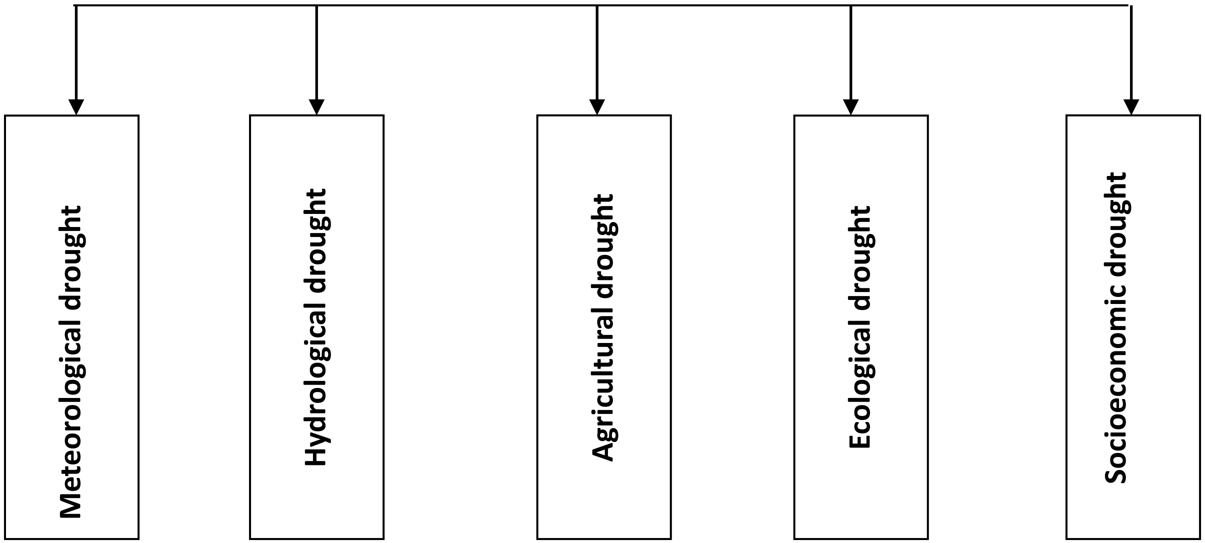
- **Meteorological drought**
  usually defined as a significant negative deviation from mean precipitation
- **Hydrological drought**
  a deficit in the supply of surface and sub-surface water (run-off, water levels)
- **Agricultural drought**
  a combination of meteorological and hydrological droughts resulting in reduced supply of moisture levels for crops)
- **Ecological drought**
  reflected by ecosystem functioning
- **Socioeconomic drought**
  combination of the above droughts leading to undesirable social and economic impacts

Therefore Drought is part of the natural climate variability and can be observed in all climate regimes. Unlike aridity, drought is a temporary abnormal phenomenon, usually characterized by lower than average water availability for the population or for the environment.



The role of the forecasters is to account for the climatic factors associated with drought,

- especially the description of the local climate in areas that have precipitation deficits.
- Than these factors should be related to atmospheric circulations beyond the local area that governs the drought reveals.
- Finally, possible causes of drought-related atmospheric circulations and the relation of these causes to non atmospheric factors have to be described and forecasted.



A key operational : Atmospheric drought signals analysis

- Precipitation - *Drought commonly is perceived to be an abnormally long period without precipitation or associated with weather systems that result in only minimal precipitation. The strongest drought signals are recognized during seasons when substantial precipitation is expected but fails to fall.*
- Temperature - *Droughts, and particularly summer droughts, generally are associated with higher than normal surface-air temperatures.*
- Atmospheric water vapor - *Droughts commonly are referred to as "dry" in the sense that not only does less precipitation fall, but also the air is drier than usual. Relative humidity is a commonly used measure of atmospheric water vapor.*
- Atmospheric circulation patterns - *A drought is associated with* ***persistent or persistently recurring circulations that produce little or no precipitation*** *and is not associated with any discernibly unique feature of the individual daily circulation patterns.*

These factors, however, only provide descriptions of the atmosphere during a drought.

They do not answer the question:

Why do these drought-related circulations arise, and why do they recur more frequently than in normal years?

↓

The search for causes of atmospheric drought signals *goes far beyond the immediate area affected by drought.*

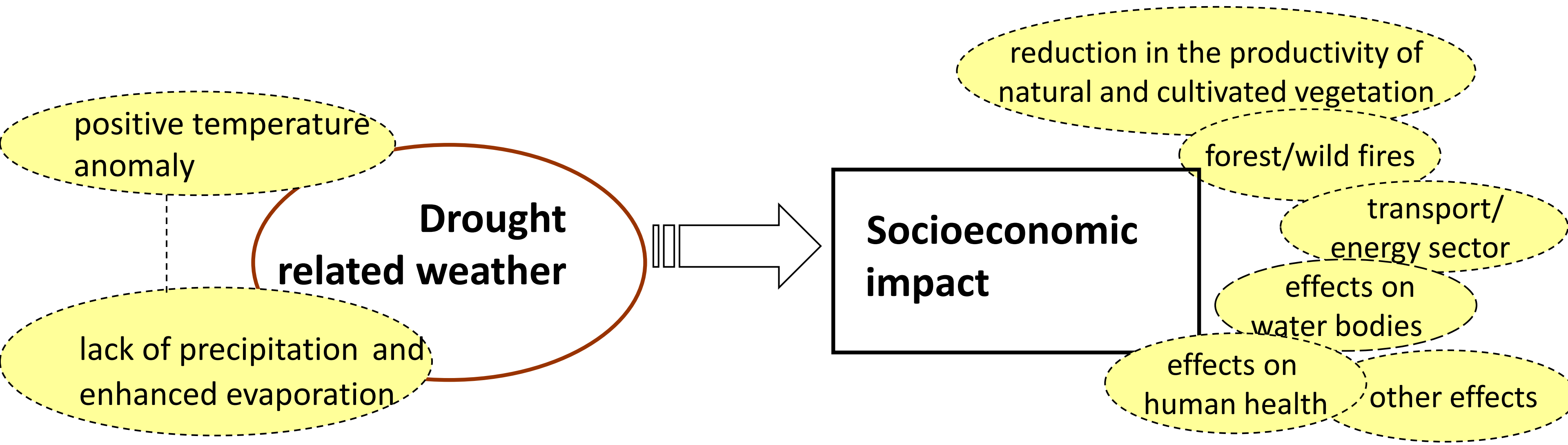
- ✓ Climate anomalies - *Recurrent periods of less than normal precipitation are best described as climate anomalies, not weather anomalies. A climatic perspective on drought is a global, or at least a hemispheric, perspective that includes interactions between the atmosphere and its ocean and land boundaries.*
- ✓ **Anomalous surface-boundary conditions commonly have been cited as being principal factors in causing and maintaining a drought. The key question to answer in drought analysis and forecast is what caused the boundary anomaly that provides an important understanding of the global aspects of drought-producing processes.**
  - Atmosphere and ocean boundary
  - Atmosphere and land-surface boundary

  SST anomalies are important in determining the atmospheric-heating variations due to the ocean surface, and soil-moisture anomalies are important in regulating the evapotranspiration and, consequently, the latent heating over land.

What is the significance of drought forecast?

- There is a process to continue to provide quality services by pursuing a more centralized forecasting approach and increasing the automation of forecasts via NWP.
- Specifically, automation of “routine weather” forecasts would be increased to allow forecasters to concentrate their efforts on “high impact weather” *(Sills 2009).*

Drought as a High Impact Weather phenomena



Extreme events are easy to recognize but difficult to define, as the concept of “extremeness” is strongly dependent on Context

DAILY NEWS 10 October 2003

European heatwave caused 35,000 deaths

By Shaoni Bhattacharya

At least 35,000 people died as a result of the record heatwave that scorched Europe in August 2003, says an environmental think tank.

The Earth Policy Institute (EPI), based in Washington DC, warns that such deaths are likely to increase, as “even more extreme weather events lie ahead”.

The EPI calculated the huge death toll from the eight western European countries with data available. “Since reports are not yet available for all European countries, the total heat death toll for the continent is likely to be substantially larger,” it says in a statement.

France suffered the worst losses, with 14,802 people dying from causes attributable to the blistering heat. This is “more than 19 times the death toll from the SARS epidemic worldwide”, notes the EPI.

Silent killer

August 2003 was the hottest August on record in the northern hemisphere. But projections by the Intergovernmental Panel on Climate Change predict more erratic weather, the EPI notes. By the end of this century, the average world temperature is projected to climb by 1.4 to 5.8°C.

"Lucifer" heat waves could become regular summer occurrence

https://www.cbsnews.com/news/lucifer-heat-wave-europe-regular-summer-occurrence-climate-change-study/

Unusually high temperatures are being recorded across an area spanning much of Spain and Portugal, southern France, Italy, the Balkans and Hungary.

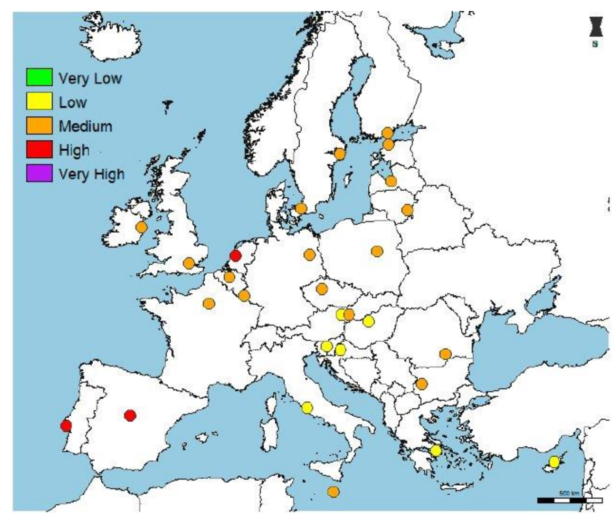


Figure 1. The risk levels of the Heatwave Hazard Index (HWHI) in the capitals of the 28-EU Member States during the 18-year sub-period 1980–1997. The color keys indicate the five HWHI risk-levels.

Morabito et al., 2017

Why drought is so significant for Mediterranean?

- **Southern Europe will experienced droughts coinciding with an increased demand for water, which, in combination with wildfires threatening entire regions, will affect agriculture and major industries.**
  - According to the **5th Assessment Report** of **IPCC (2014)** climate change is already a reality.
  - **Paris Agreement 2015**, the Parties to the United Nations Framework Convention on Climate Change are now committed to adaptation and mitigation policies that are both vital to manage risks and contain emissions and the magnitude of climate change.
- **Weather and climate services for mitigation and adaptation to climate change**
  - Adaptation and mitigation both require integrated weather and climate information services built on solid scientific foundations – including observations, forecasts, warnings based on real-time qualification of extreme events against climatology, climate projections and impact assessments.
  - Therefore, NMSs are best placed to deliver to decision makers and users in each country, following WMO guidelines, relying on the ECMWF numerical weather prediction and on EUMETSAT for space-based observations.
- **The challenge for NMSs** is not only to further develop forecasts and early warnings but also to work with other institutions involved in disaster reduction to meet the expectations of governments, citizens and industries.

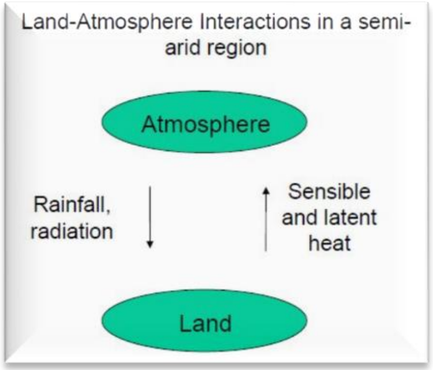
Reference: *EUMETSAT Strategy - Challenge 2025*
EUMETSAT in a changing world. EUMETSAT edition, December 2016, EUM COR.02B

“hot spots’’ of land-atmosphere coupling

Regions where Soil Moisture most impacts the atmosphere are transitional zones between dry and wet climates

→ For present climate: also the **southern Europe/ Mediterranean region** have been identified as such regions *(Zhang et al., 2008).*

→ These **“hot spots”** of land–atmosphere coupling is expected to be modified with shifts in climate regimes for instance due to climate change.



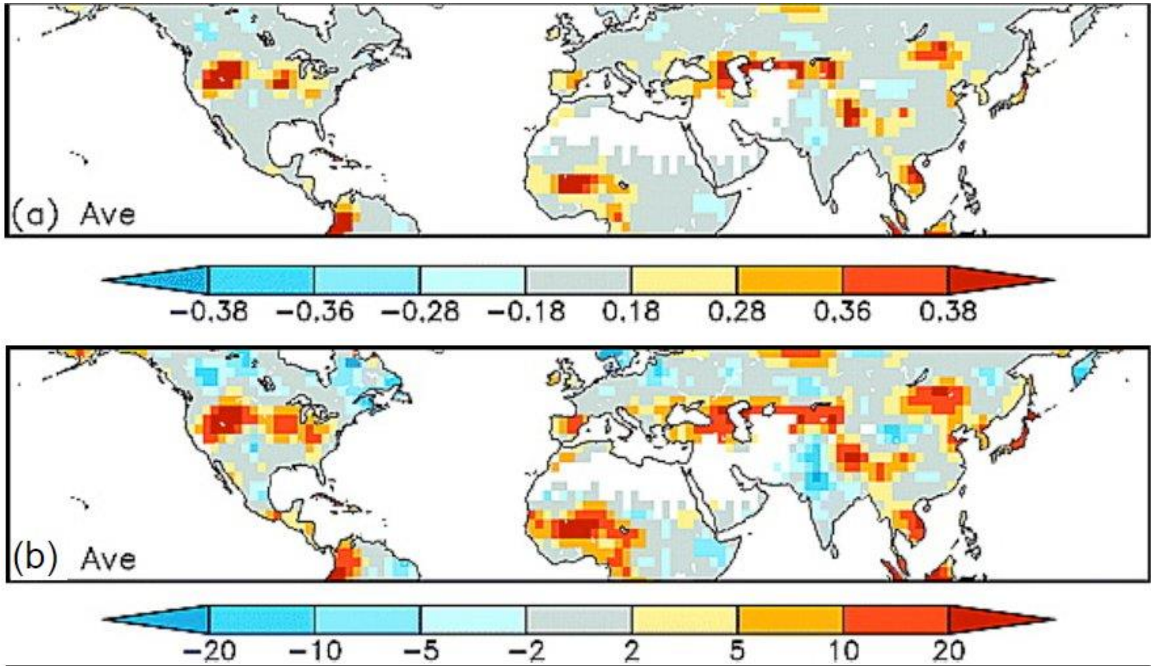
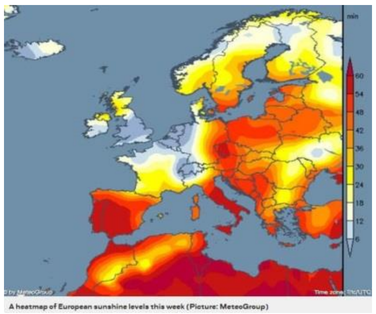


Fig. 2.6. *Quantifying land-atmosphere coupling through (a) correlations of monthly soil moisture anomalies leading CMAP precipitation anomalies by 1 month calculated using MJJ soil moisture and JJA precipitation and averaged across three land-surface models and (b) the percentage of variance of monthly precipitation anomalies due to soil moisture feedback calculated using JJA soil moisture and precipitation averaged across three land-surface models. Figures from Zhang et al., 2008.* (*Koster et al., 2004*)

Meteorological phenomena related to drought hazards

Vegetation season dryness in Mediterranean region has different manifestations: heat waves, agricultural/ ecological soil moisture deficit, fire weather, declined yield of agricultural field and Net Primary Productivity of forests, and increased risk to human health.

Heat waves

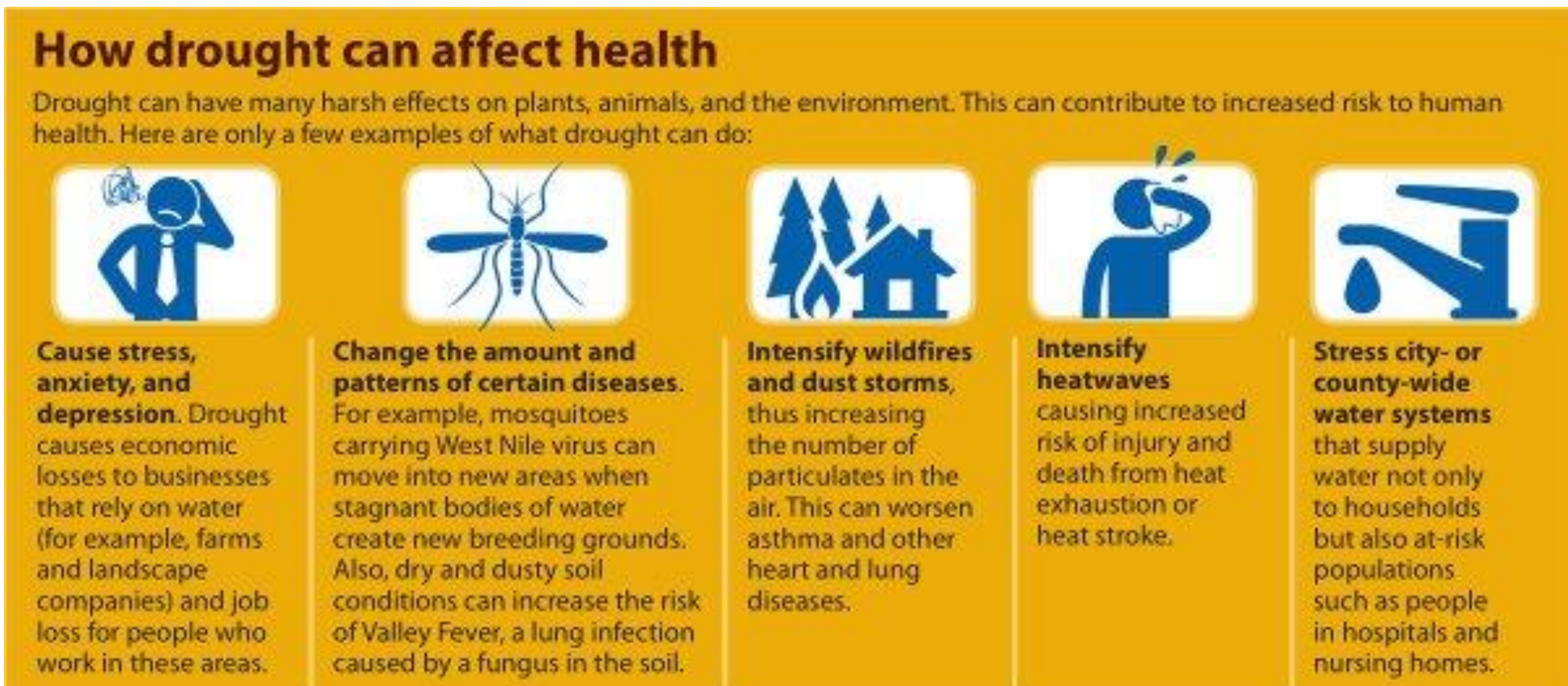


Soil moisture deficit

Wild/forest fires

Declined productivity

Human health



How drought can affect health

Drought can have many harsh effects on plants, animals, and the environment. This can contribute to increased risk to human health. Here are only a few examples of what drought can do:

Cause stress, anxiety, and depression. Drought causes economic losses to businesses that rely on water (for example, farms and landscape companies) and job loss for people who work in these areas.

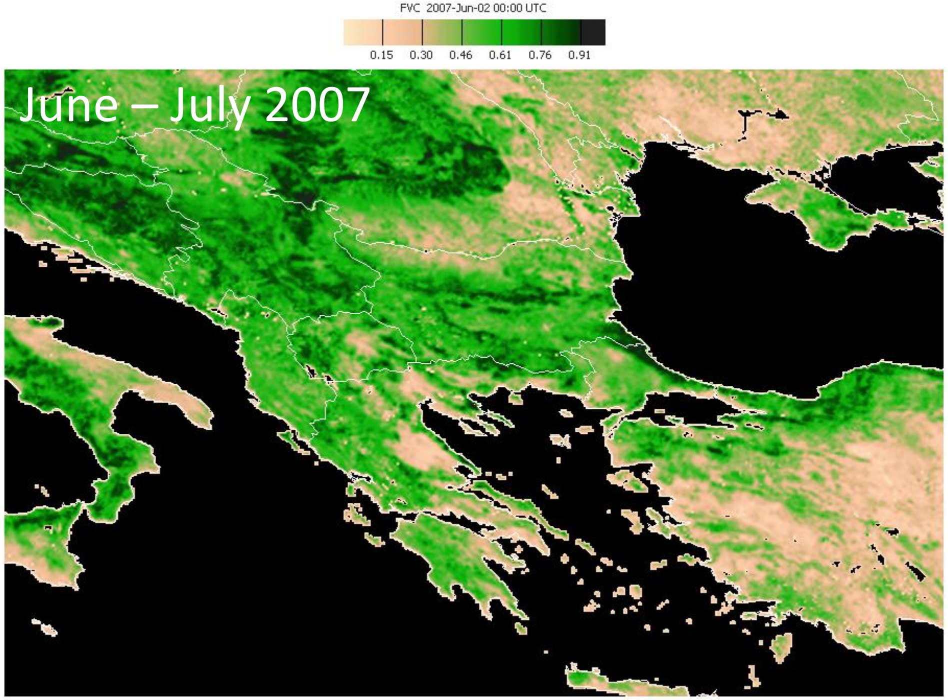
Change the amount and patterns of certain diseases. For example, mosquitoes carrying West Nile virus can move into new areas when stagnant bodies of water create new breeding grounds. Also, dry and dusty soil conditions can increase the risk of Valley Fever, a lung infection caused by a fungus in the soil.

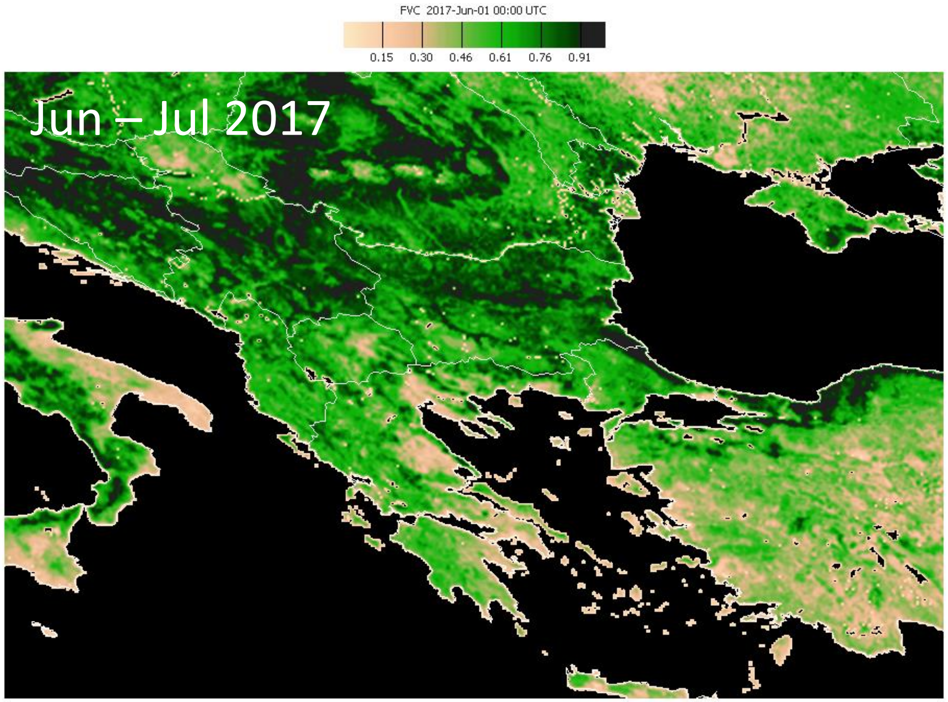
Intensify wildfires and dust storms, thus increasing the number of particulates in the air. This can worsen asthma and other heart and lung diseases.

Intensify heatwaves causing increased risk of injury and death from heat exhaustion or heat stroke.

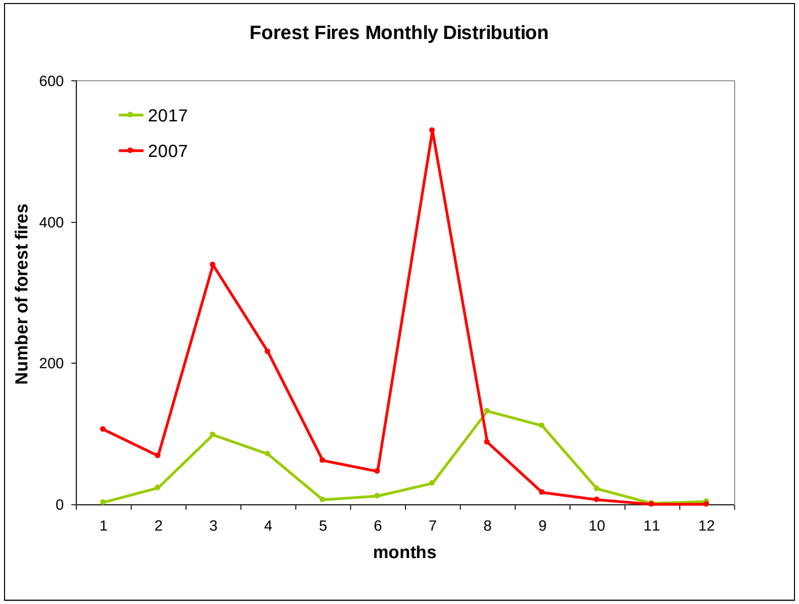
Stress city- or county-wide water systems that supply water not only to households but also at-risk populations such as people in hospitals and nursing homes.

Meteorological indicators alone are not enough to represent terrestrial drought across Europe.





LSA SAF Fraction of green Vegetation Cover (FVC)



- Satellite observations of land cover provide important information for vegetation cover state and in term the severity of drought related hazards.

Analyses and forecast of drought related hazards with accent on terrestrial drought

Understanding and forecasting drought is an important operational task. It calls for knowledge about:

- Processes of Land-Atmosphere interaction, principles and practices of Land Surface Analyses.
- Knowledge about terrestrial drought and how do it forms.
- Drought related hazards from a synoptic perspective (*precipitation anomalies, heat wave, fire weather*).
- Satellite techniques (*tools and products*) for operational assessment of land surface dry anomalies and related terrestrial hazards.

2. Meteorological processes that shape terrestrial drought

Land surface definition: The surface that comprises vegetation, soil (and snow)

Which are meteorological processes that shape the land surface state?

↓

Land-Atmosphere coupling: the exchange of water, energy and carbon within the Earth system.

How Vegetation Land Cover is defined from a physical point of view?

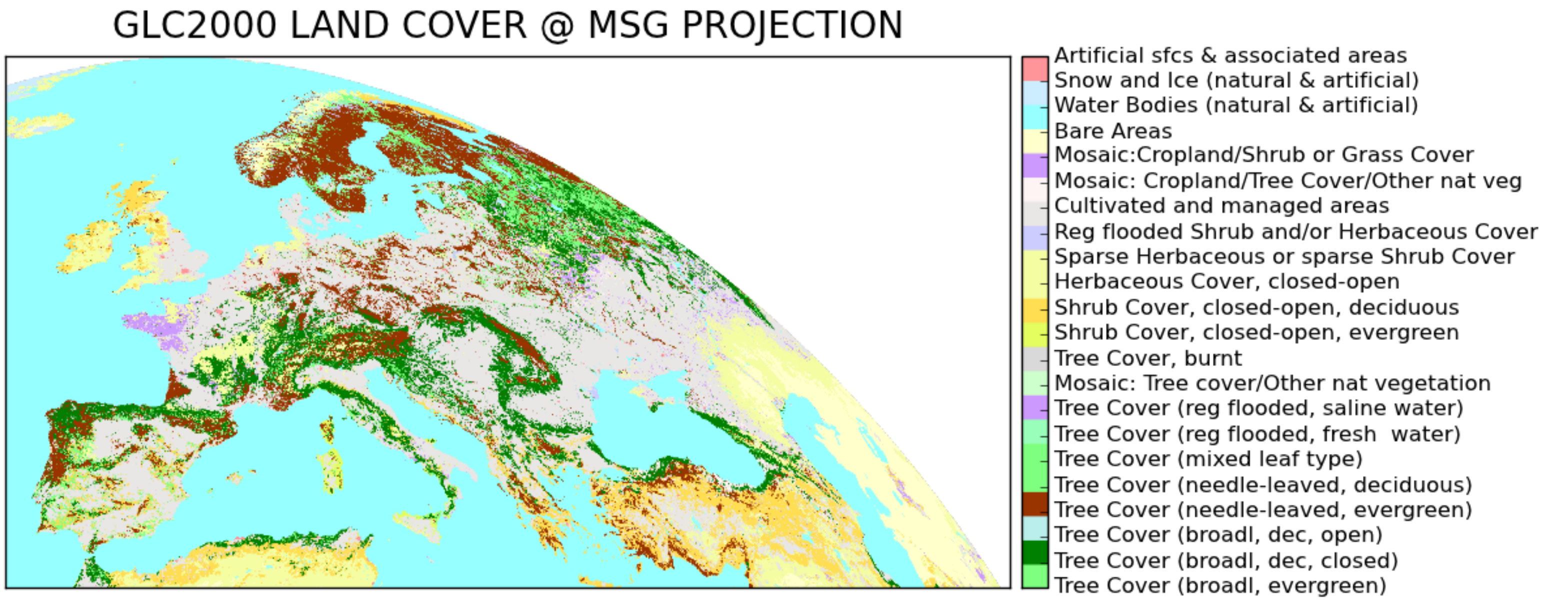
- **Land cover** is defined as the physical vegetation layer at the surface of the Earth.
- The Land cover structure and organization are at the **origin of the geographical repartition of heat-, carbon-, energy- flux exchanges**, which are at the bottom of atmosphere.

How Vegetation Land Cover is defined from a physical point of view?

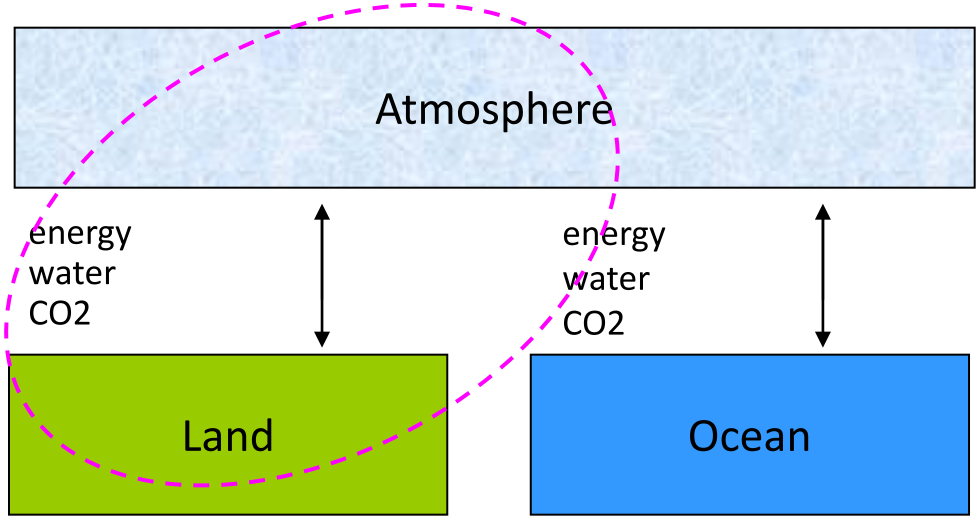
Various features of the Land Cover are important regarding the problem of High Impact Weather events like drought

- Vegetation Distribution and Structure
- Vegetation Biophysical Properties
- Vegetation State Characteristics, etc.

For region of Mediterranean we have a wide variety of climate and LS conditions



Role of land in the climate system ?



There is now strong evidences that the land surface influences weather and climate at a range of time scales from seconds to millions of years.

Biogeophysical processes regulate fluxes of:

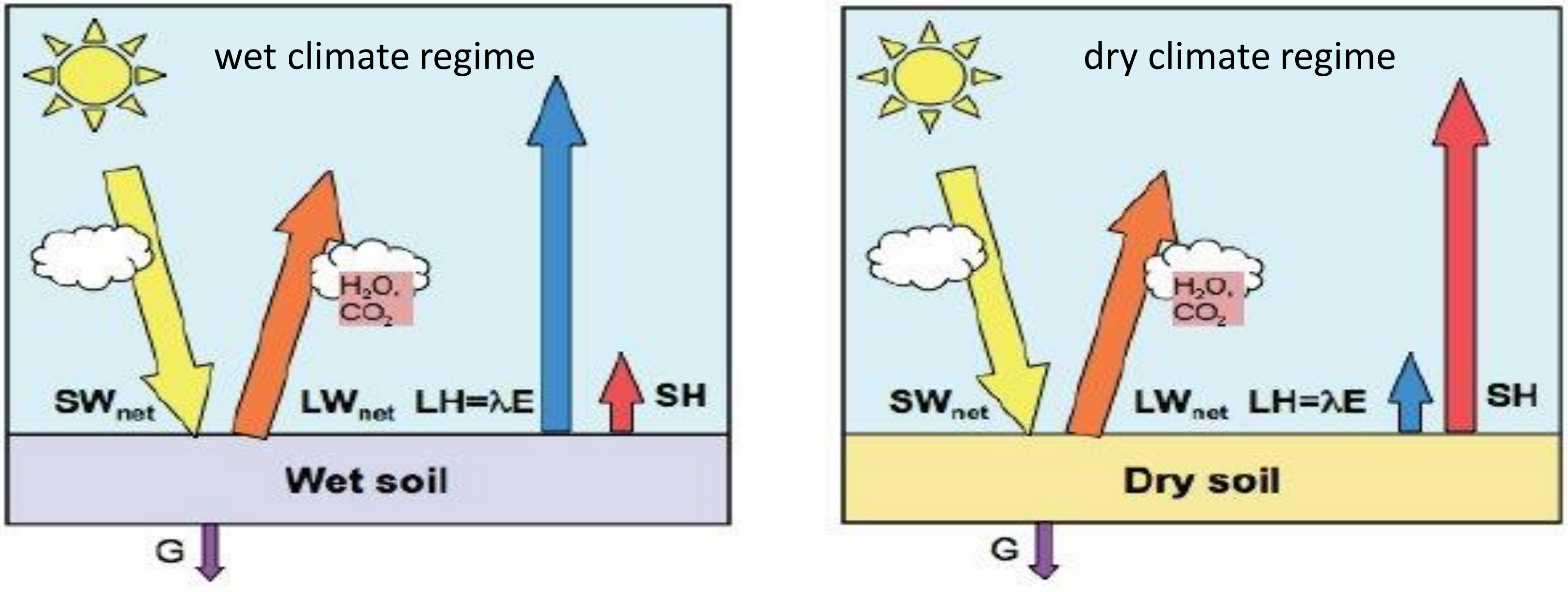
- momentum
- heat
- water
- gaseous components.

Analyses and forecast of meteorological processes on the land surface can be performed trough quantitative description of biogeophysical cycle.

Land-atmosphere coupling

Key parameters and meteorological processes

- **Land-Atmosphere coupling** is based on ecosystems functioning, which are at the bottom of atmosphere.
- Coupling of energy-water cycles is the bases of ecosystem functioning that is resulting in transformation of solar energy into the energetic fluxes of latent heat, **LE** and sensible heat, **H** towards atmosphere, and in the soil, **G**.



Seneviratne et al. (2011)

Vegetation as part of climate system

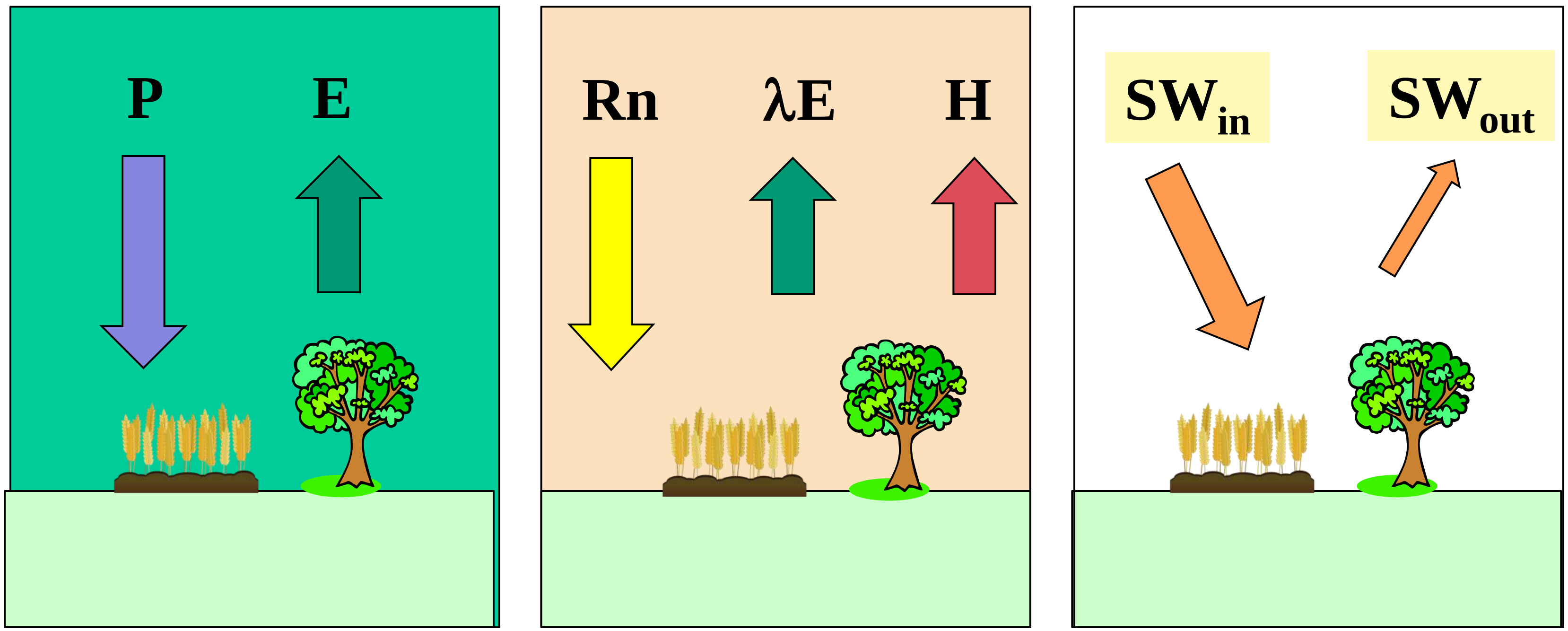
Coupling of energy-water cycles

Water

Energy

Evaporative cooling

Radiative budget



E=60%P

λE=50-60%Rn

Variations of α: 0.1-0.2

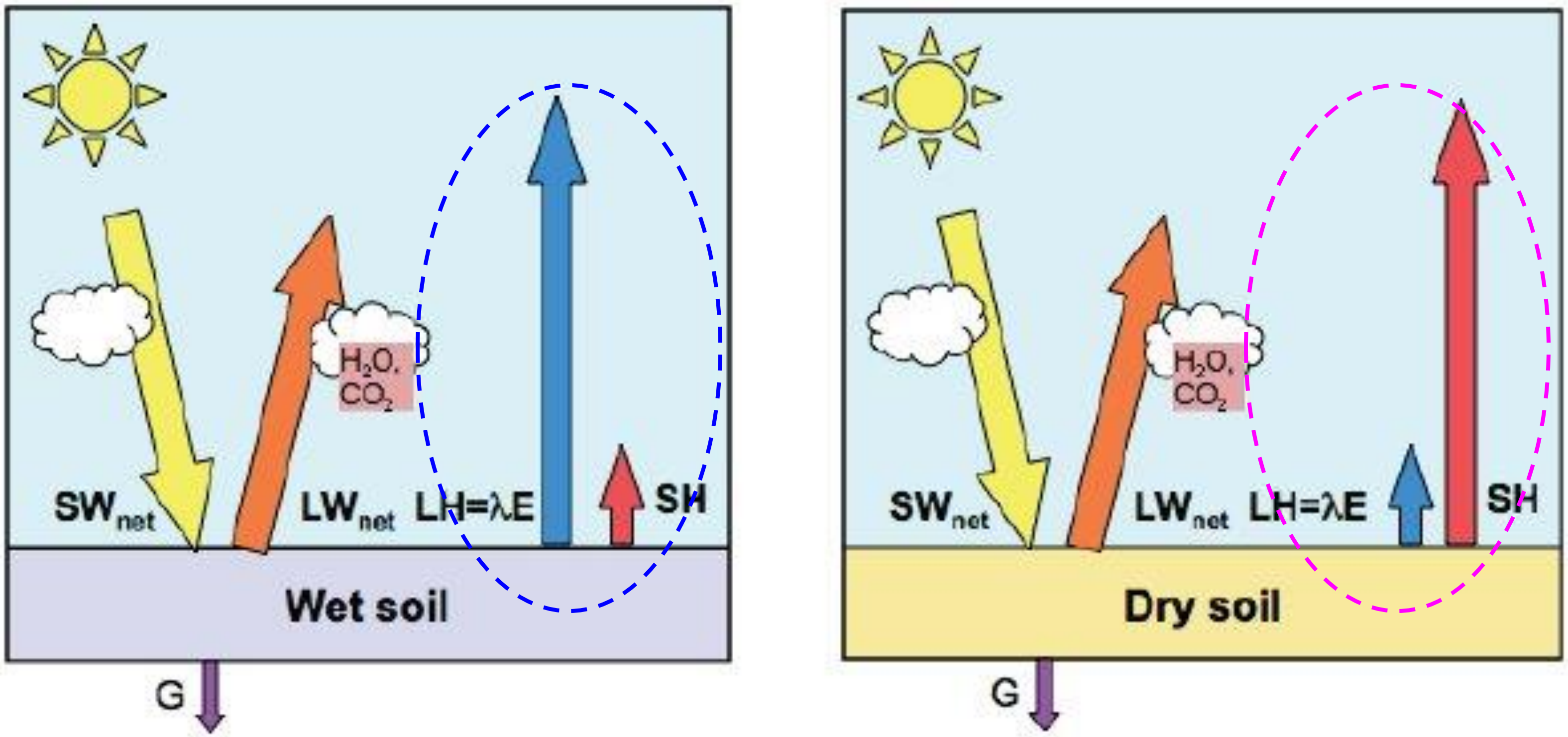
Natural and anthropogenic systems such as forests and crops have different behavior under heat waves conditions.

Teuling et al (2010)

Terrestrial drought

meteorological processes that shape the land surface state

The role of soil moisture in propagation of Mediterranean drought: Coupling of energy-water cycles at 'Dry'- 'Wet' soil



- The role of soil moisture in propagation of Mediterranean drought: Coupling of energy-water cycles at 'Dry'- 'Wet' soil is reflected by the proportion between **LE** and **H**.
- **A better description, understanding and modelling of soil moisture** and associated **land-atmosphere interaction would improve the predictability at both daily and sub seasonal scale.**

Effect of soil moisture, vegetation and land use on land surface state

Relation between soil media and atmosphere

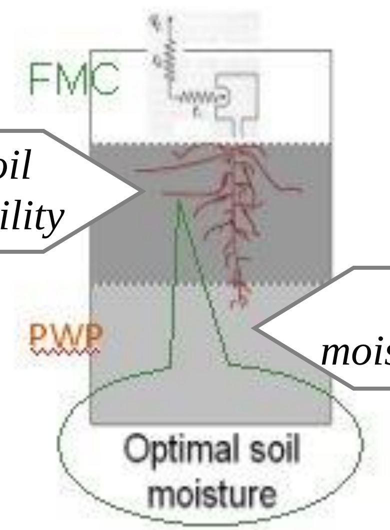
- For characterizing of coupling SM-atmosphere, the Soil Moisture Availability **(SMA)** to the vegetation cover is used.
- **SMA** is a measure of both: SM dynamics and vegetation functioning, which in turn is reflected by LS state indicators: Ts, LE, H, E, etc.

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

dry *wet*

At limiting SM conditions, the evapotranspiration from the plant community is restricted and controlled by soil.

Optimum of soil moisture availability



Limited soil moisture availability

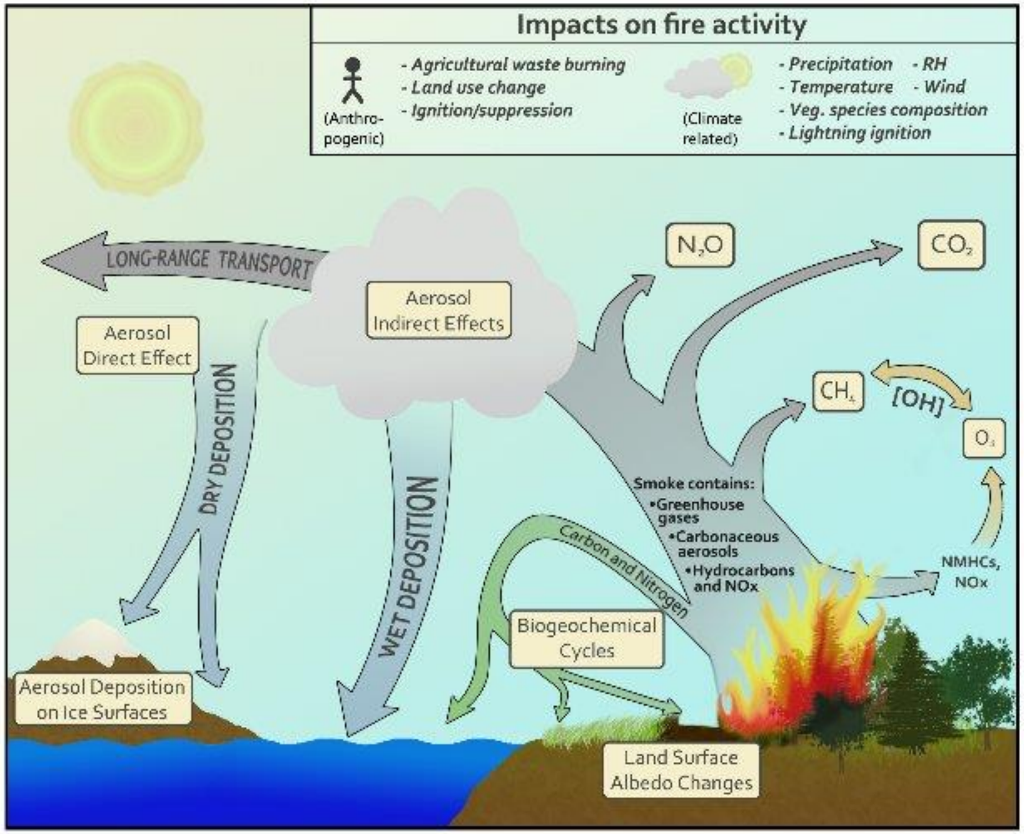
At non-limiting SM conditions, the evapotranspiration from the plant community is not restricted.

Soil Moisture (SM) available to plants is an important variable for evaluating vegetation transpiration; a key factor in ecosystem processes, as well as a basic parameter in mesoscale atmospheric circulation models and forecasting systems.

Land cover change effects and land surface state

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

- Changes in the land surface can influence regional- to global-scale climate on time scales from days to millennia.
  - Large-scale changes in key land surface characteristics *(albedo, roughness length, water-holding capacity, root depths, etc.)* lead to changes in climate and changes in the sensitivity of climate to other perturbations.
  - Changes in the surface at regional scales *(e.g. the Sahel, Amazonia, Mediterranean etc.)* influence regional climate.
- Land cover change is often related to **biomass burning during fire hazards**.



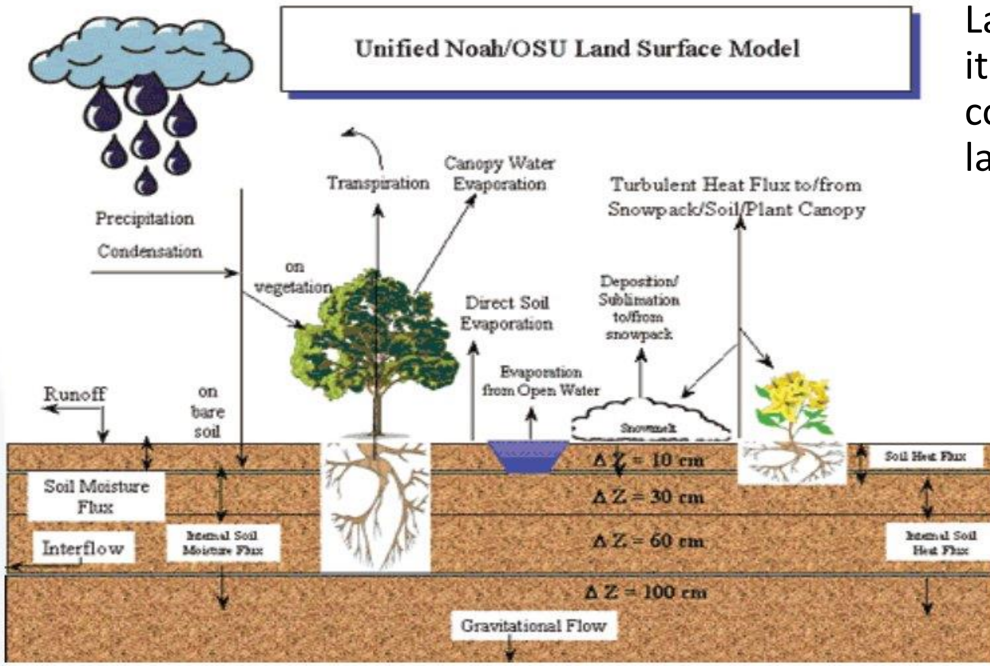
3. Basic methods & Principles in land surface analysis

- Meteorological modeling, LSMs
- Satellite observations
- EUMETSAT LSA SAF program
- EUMETSAT SALGEE Project

Meteorological modeling

Land Surface Models, LSMs

Parameterization of land-surface processes in NWP



Land surface is much smaller than the ocean but its significance is commensurable. Although it covers only 30% of Earth, the climate over the land surface is extremely important.

First generation models *(Manabe, 1969),* implying idealized land cover distribution, a globally constant soil depth and water-holding capacity, etc.

Second generation models *(Deardorff, 1978; Seller et al., 1997),* improving the physical representation of continental surface.

Third generation models, 'greening' of LSM *(Henderson-Sellers et al., 1995; Levis et al., 2000; Bergengren, 2001).*

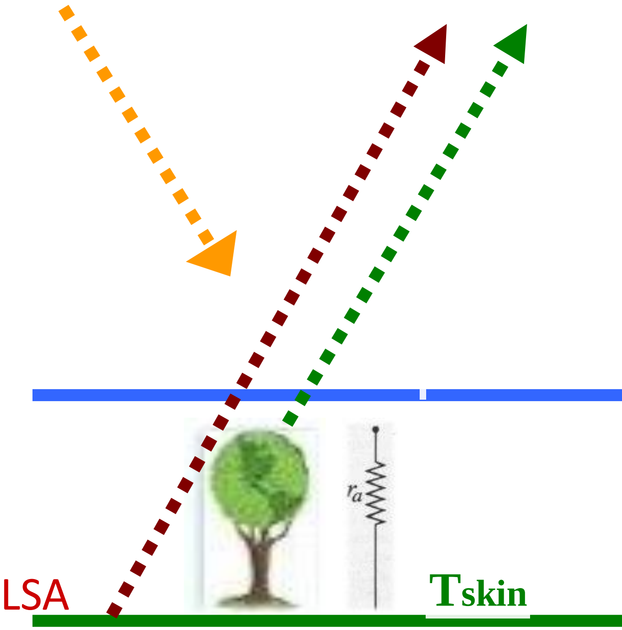
The challenges for Land Surface Modeling

- Capture natural diversity of land surfaces (heterogeneity) *via* simple set of equations
- Focus is given on elements which affect more directly weather and climate (*i.e. soil moisture, snow cover*).

Satellite observations

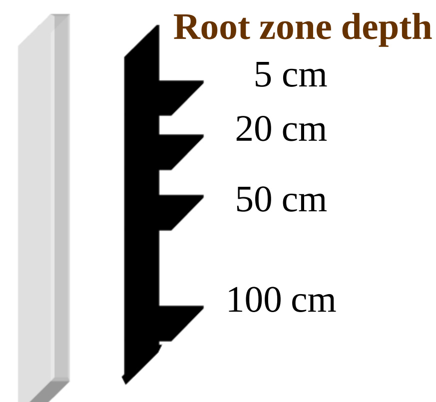
Remote sensing provides the best means to monitor changes in vegetation over a wide range of temporal scales over large areas.

- A number of MSG based LSA SAF products provide useful information for characterizing land surface state in cases of drought hazards and fires in the region of Europe.
- Given the high impact of drought and wild/forest fires on society, the implications of satellite information for the management and control of these phenomena by characterizing land surface conditions and issuing early warnings is an important operational task.



Limitations & Advantages of Meteosat based products for LSA

- Highest time frequency, especially valuable for land surface temperature estimation and fire detection, but lower spatial resolution of MSG.
- Cloudiness is a severe limitation factor.
- Microwave sounders are alternative solution (for LST, soil moisture retrievals).
- **For correct interpretation of vegetation state from satellite data, Land Surface Models and NWP models** are needed.



MSG capabilities for land surface remote sensing

MSG SEVIRI Data Applications

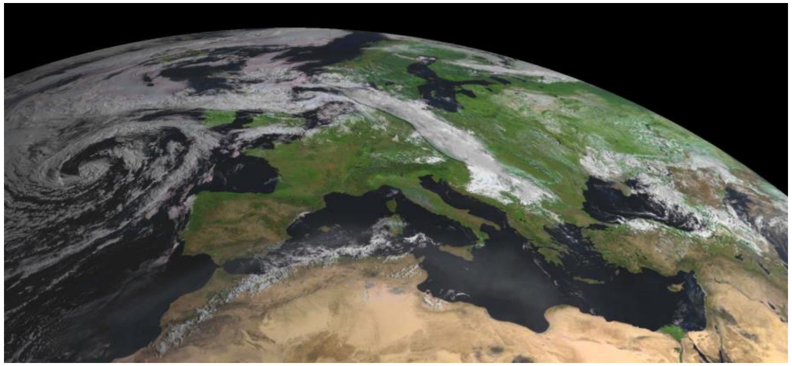
Land Surface Monitoring

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

Spinning Enhanced Visible and Infrared Imager (SEVIRI):

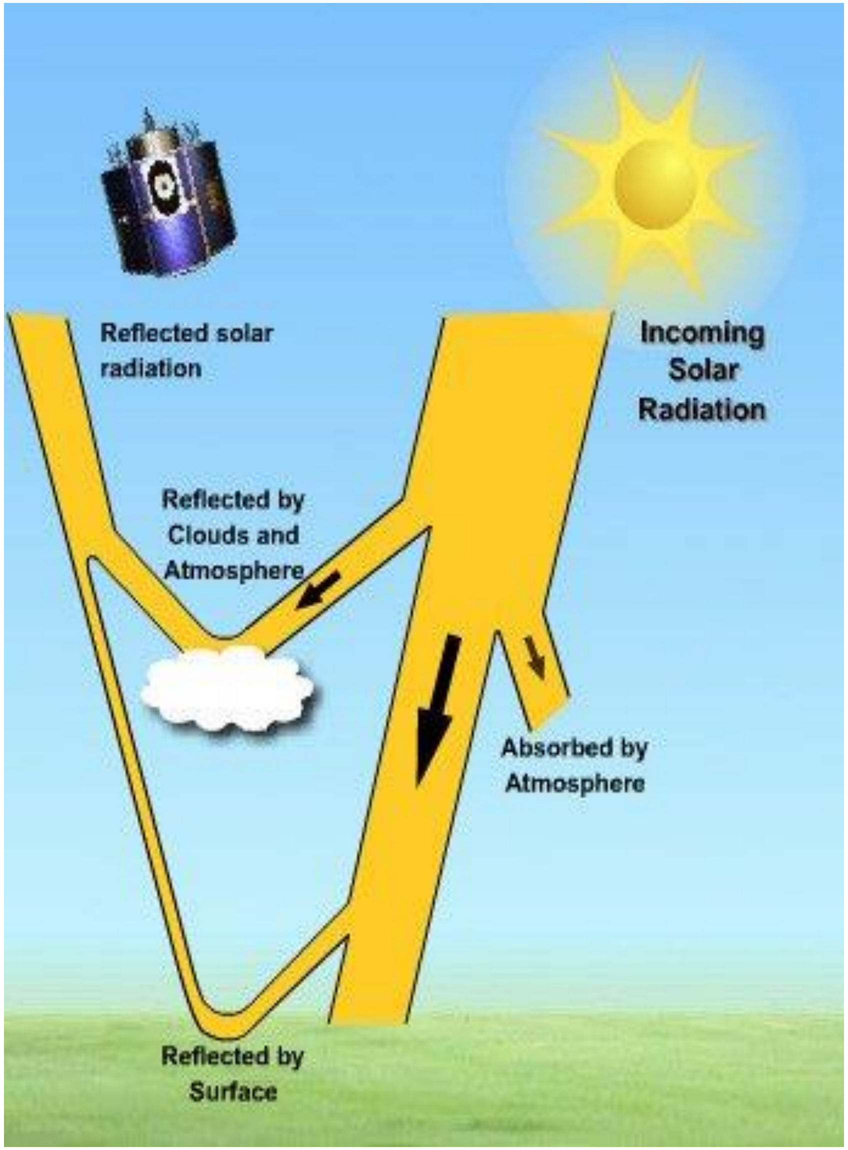
12 spectral channels diapason in the VIS, NIR, MIR, IR spectral bands that are used for generation meteorological products for monitoring

- Some components of landscape water balance
- Surface energy balance
- Vegetation parameters
- Vegetation fires and carbon issue

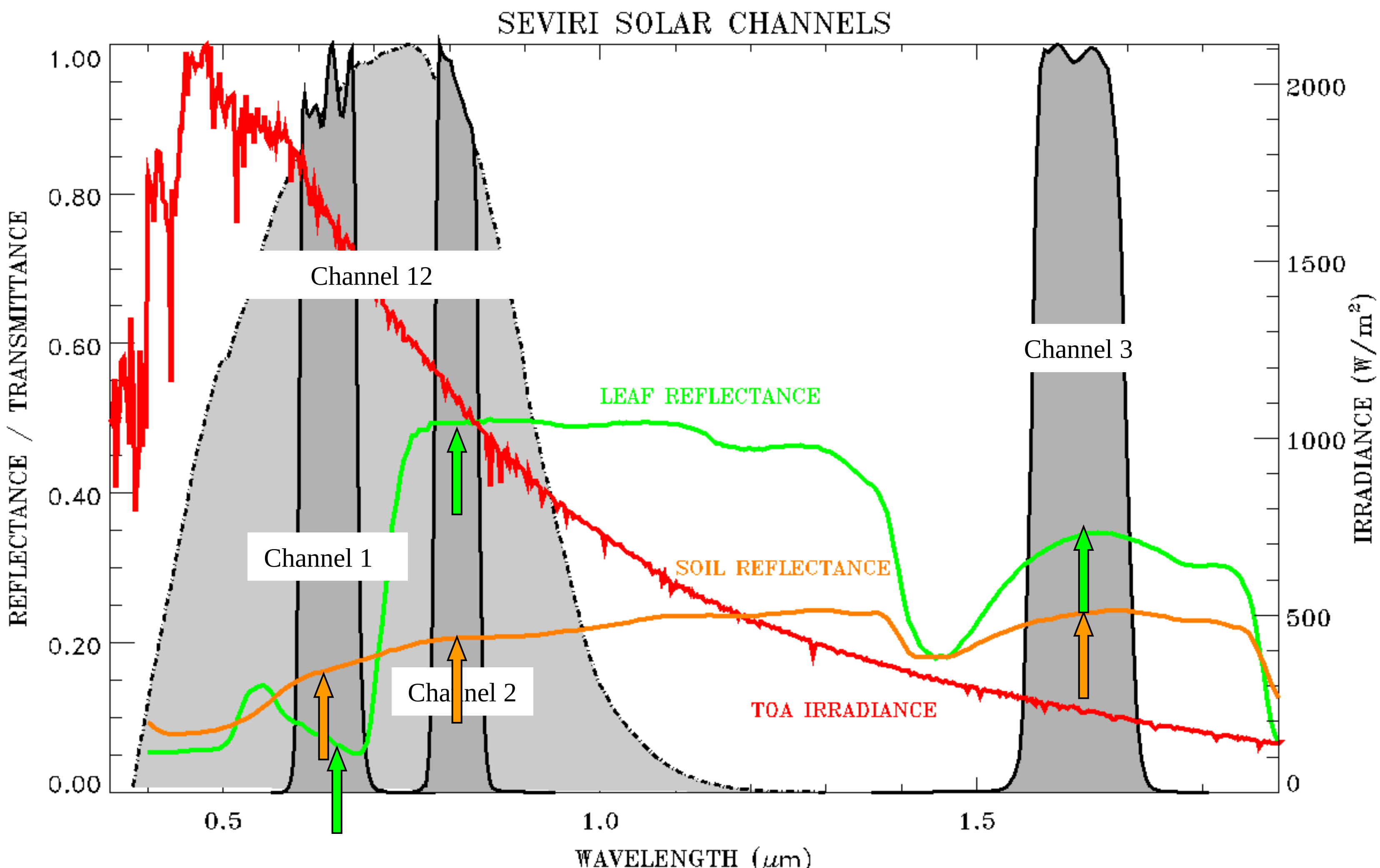


Satellites measure specific spectral characteristics of vegetation

- The Sun is the main source of energy in the earth-atmosphere system.
- Vegetation & non-vegetated surfaces have unique spectral signatures in different channels. They can be associated with:
    - the phase of vegetation life cycle,
    - health and status,
    - identification of individual vegetation cover types,
    - identification of changes in typical spectral signatures indicating stress conditions.



Spectral characteristics of vegetation in Visible band



Low sensitivity to leaf reflectance by VIS 0.6 channel

Sensitivity to leaf reflectance by NIR 1.6 channel

High sensitivity to leaf reflectance by VIS 0.8 channel

Solar energy spectrum
Source: EUMETSAT

Zwatz-Meise, V. (2004)

EUMETSAT LSA SAF Program

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.

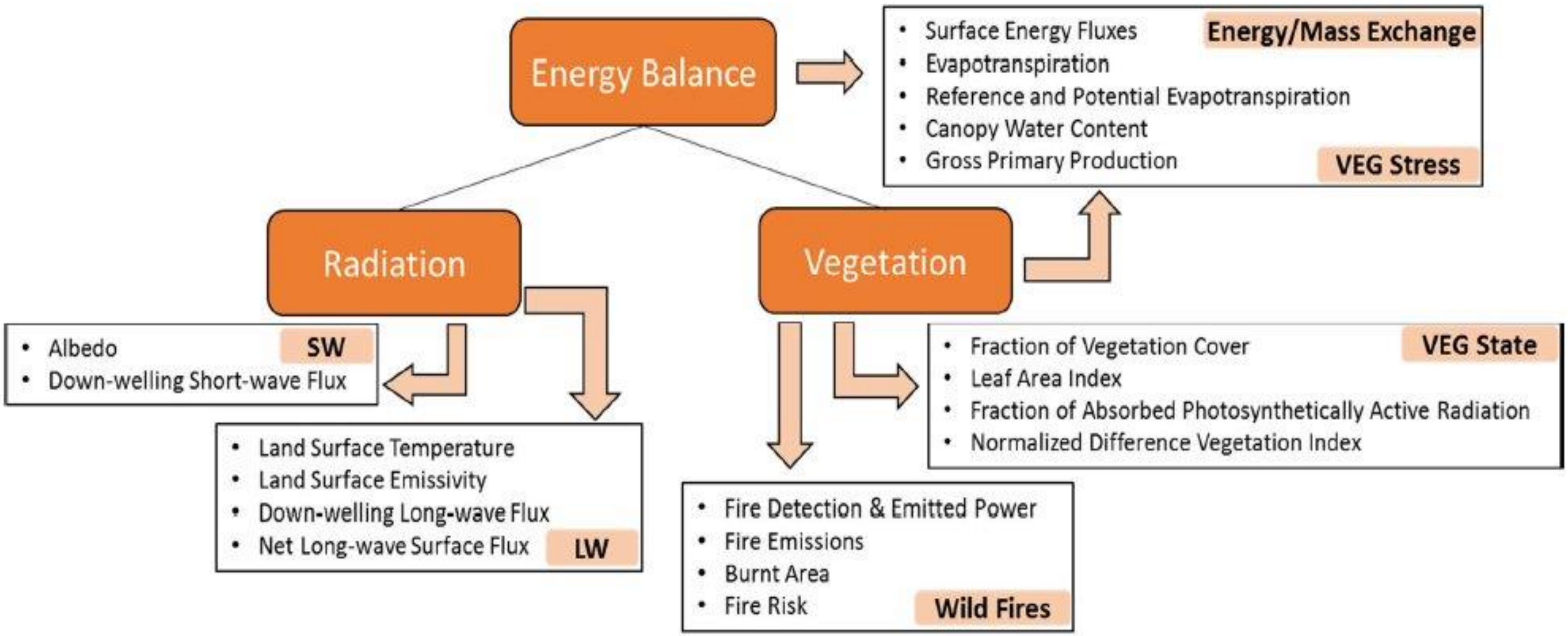
http://www.eumetsat.int/website/home/Satellites/GroundSegment/Safs/index.html

LSA SAF Land Surface Analysis

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

Land-SAF Products Organization

The scope of Land Surface Analysis Satellite Applications Facility (LSA SAF) is to increase benefit from EUMETSAT Satellites (MSG and EPS) data related to:



EUMETSAT SALGEE (*Satellite Applications for Land surface analyses Group for south Eastern-eastern Europe*) Project

Objectives of the SALGEE initiative: For 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 *(established in 2010).*

To foster integrated approach for research and operational activates in meteorology/ climatology in support to the quantification of biogeophysical and biochemical cycles and related land surface processes, in combination with info from in situ data, model outputs and satellite observations.

New comers 2019:
Austria, Poland, Switzerland, Iran, Jordan, Palestine

SALGEE Role & Activities

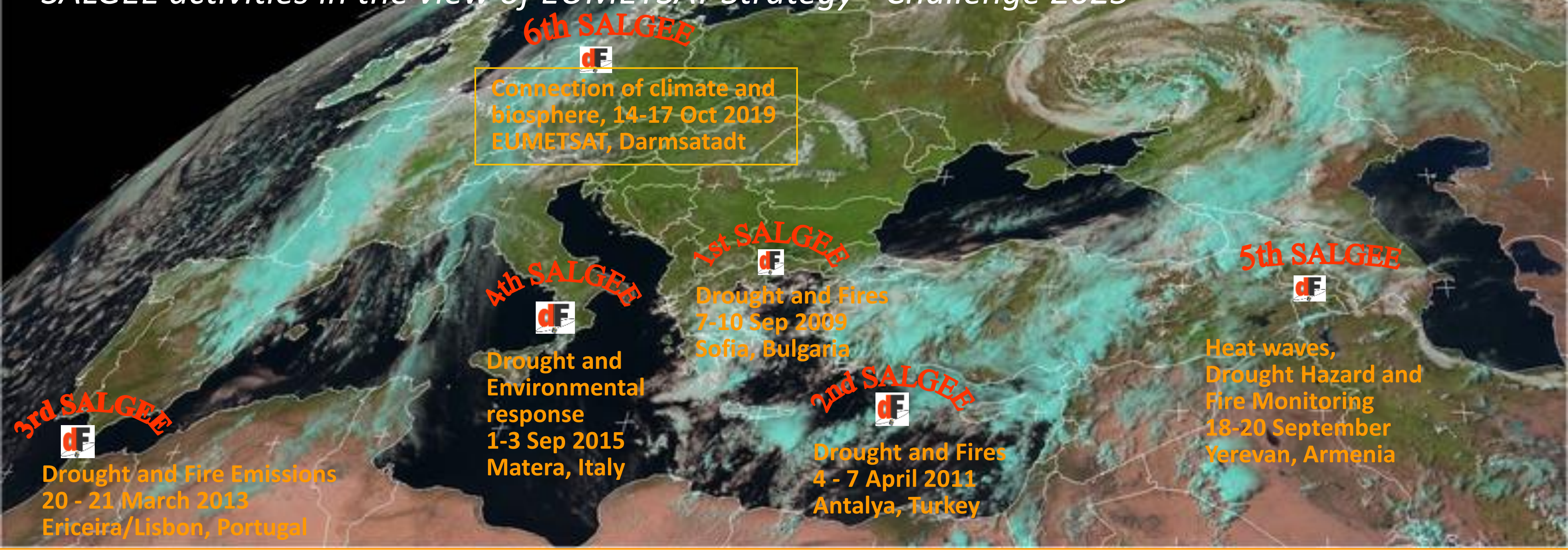
- ○ Assist the LSA SAF in communicating with NMSs on the use of satellite data and products for the purpose of LSA
- ○ Gathering experts & Exchange of knowledge
- ○ CDOP-3 (2017-2022)

Counties which have been involved in the activities of SALGEE and/or participated in the workshops.

SALGEE Experience on MSG Land Surface Applications

Drought Problem, Fire hazard as a main SALGEE Topics

SALGEE activities in the view of EUMETSAT Strategy - Challenge 2025



1st Workshop, Sofia, 7-10 September 2009, Bulgaria, “MSG Land Surface Applications: Drought & Fires”,
http://info.meteo.bg/conferences/EUMETSAT07092009
http://gofc-fire.umd.edu/implementation/Events/meetings/past.asp

2nd Workshop, Antalya, 4-7 April 2011, Turkey, “MSG Land Surface Applications: Drought & Fires”
http://www.eumetsat.int/Home/Main/DataProducts/HowtoUseOurProducts/WorkshopsAndCourses/SP_

3rd Workshop, Lisabon/Ericeira, 20 - 21 March 2013, Portugal, “MSG Land Surface Applications: Drought & Fire emissions”

4th Workshop, Matera, Italy 1 - 3 September 2015, “MSG Land Surface Applications: Drought and Environmental response”
https://www.cnr.it/it/evento/14133

5th Workshop, Yerevan, Armenia 18 - 20 September 2017, “MSG Land Surface Applications: Heat waves, drought hazard and fire monitoring”
https://www.cnr.it/it/evento/14133

4. LSA SAF satellite products for monitoring land surface conditions of drought related hazards

- Radiative skin temperature, LST
  - Soil moisture indicator
  - (LST-T2m) as water stress in crop/vegetation & drought indicator
- Fraction of Vegetation Cover, FVC
- Evapotranspiration, ET
- Fire risk, FRM

Needs for a set of functional and structural vegetation characteristics, because Drought is a complex event-driven climate extreme

LSA SAF products access and processing

Available both in near real time and off-line:

- EUMETCast
- LSA_SAF_Archive
- FTP

The LSA SAF products are operationally disseminated via EUMETCast in HDF5 format.

- *For qualitative analyses, products are used in image format.*
- *Digital values can be inferred at MSG pixel resolution.*

https://landsaf.ipma.pt/en/

GEO Polymorphic Clo... Състояние на земнат...

EUMETSAT LSA SAF LAND SURFACE ANALYSIS

Home | About | Products | Get Data | Help&Support | News&Media | Account

Vegetation Monitoring and Locating Drought Impacted Areas

Fraction Vegetation Cover indicates the state of vegetation

Satellite biogeophysical products developed in the frame of LSA SAF

Latest News

Heatwave strikes Europe — July 10, 2019

June ends with sweltering temperatures across Europe

Vegetation Response Variability from Meteosat — June 11, 2019

How do land and climate type as well as irrigation affect vegetation signal from space?

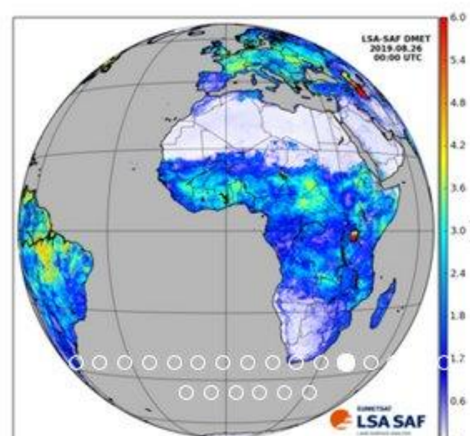
New version of MSG Evapotranspiration products — June 7, 2019

A new version of MSG Evapotranspiration products (instantaneous and daily) has been released (LSA-311 and LSA-312).

A User Tool to Aid Exploitation of LSA SAF Products — June 3, 2019

How to aggregate evapotranspiration data from LSA SAF files quickly?

Latest Products



Land Surface Temperature – LSA System

MSG LST can refer to an average effective LST, which is the radiative skin temperature over land derived from clear-sky thermal IR radiation.

Operational since Jan 2005. The algorithm uses a number of Input parameters derived from SAF satellite products and NWP data.

Inputs: Land Sea Mask + LandCover (GLC2000)

- FVC ← LSA SAF
- Cloud Mask ← NWC SAF (SEVIRI + ECMWF)
- TCWV ← ECMWF
- **Tb (SEVIRI 10.8 & 12.0 μm)**

Clear Sky Algorithm
IR 10.8μm and 12.0μm
general split window channels

Non-Clear

Pixel NOT Processed

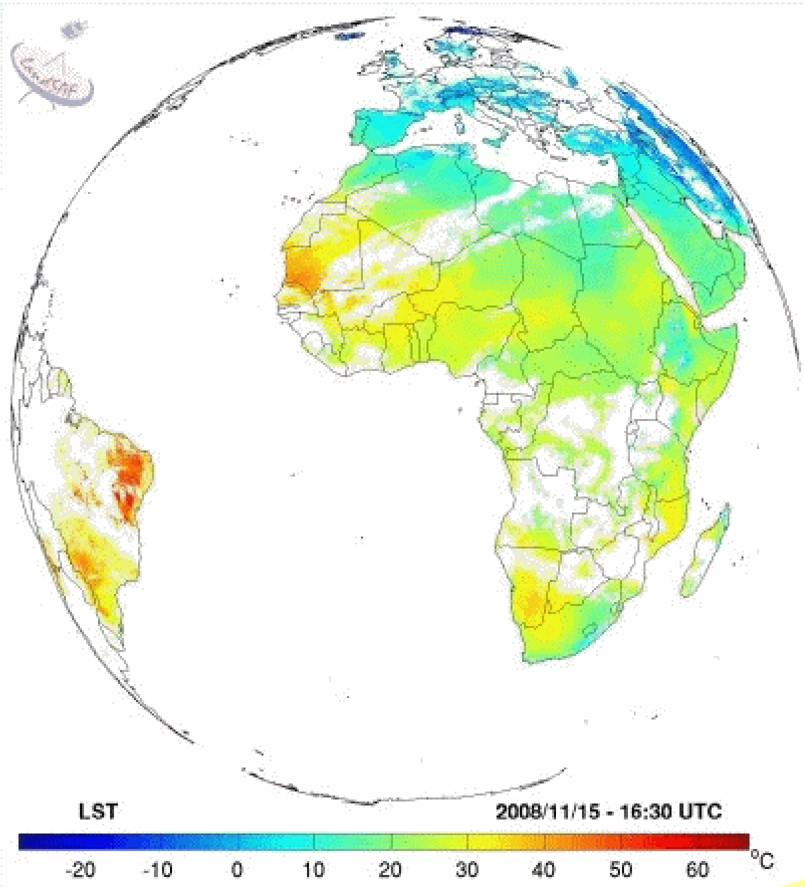
MSG - Projection

15-min Frequency

LST & Quality Control

LSA SAF Land Surface Temperature (LST)

the physical temperature of the Earth's surface



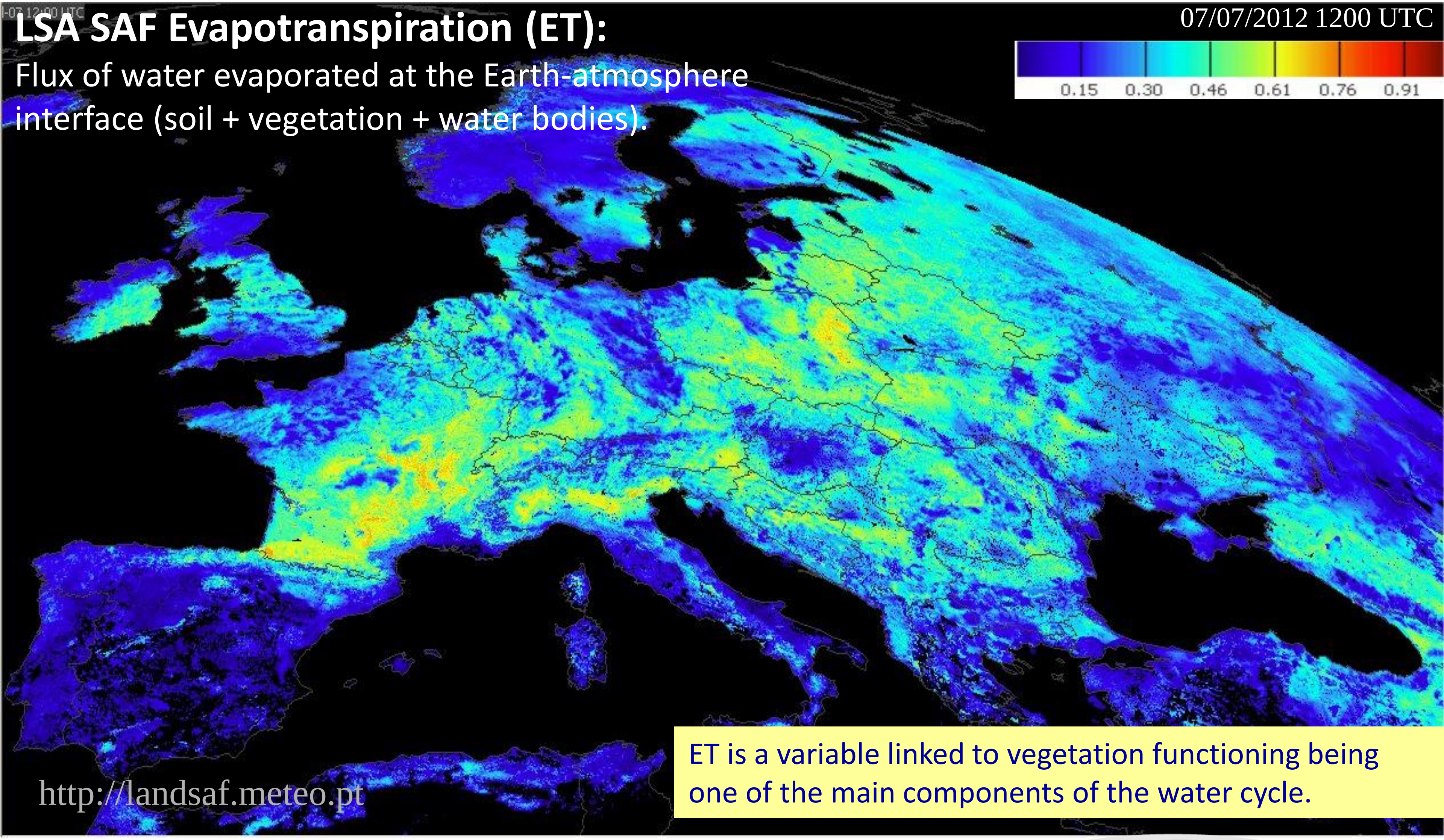
Space variability of LST is modulated by surface properties like vegetation density and soil moisture.

LST is one of the **key variable**s in the physics of land-surface processes on regional/global scales; As a functional parameter in main biogeophysical processes of energy-water-carbon balances it combines **the effects of all surface-atmosphere interactions.**

Being related to the energetic and water cycles, LST derived by satellite data, can be used as a **key parameter in drought analysis**.

LSA SAF Evapotranspiration (ET):

Flux of water evaporated at the Earth-atmosphere interface (soil + vegetation + water bodies).



ET is a variable linked to vegetation functioning being one of the main components of the water cycle.

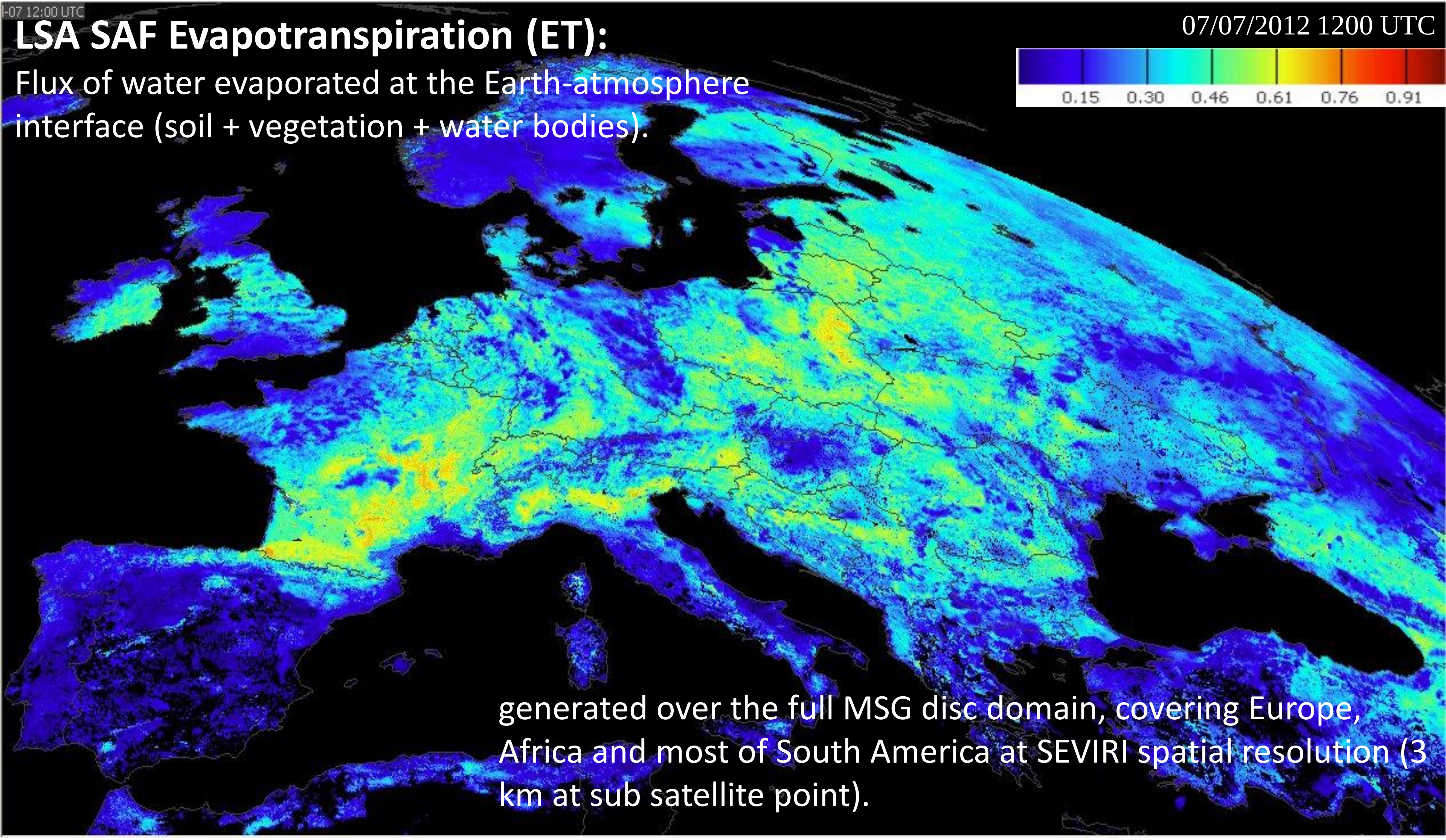
Associated with the latent heat flux (LE), a key link between the energy and water cycles, of importance in:

Application

- ✓ Weather forecasting
- ✓ Global climate monitoring
- ✓ Water management
- ✓ Agriculture
- ✓ Ecology

LSA SAF Evapotranspiration (ET):

Flux of water evaporated at the Earth-atmosphere interface (soil + vegetation + water bodies).



generated over the full MSG disc domain, covering Europe, Africa and most of South America at SEVIRI spatial resolution (3 km at sub satellite point).

Algorithm

1. ECMWF SVAT scheme *(Viterbo and Beljaars, 1995; van den Hurk et al., 2000),* ECOCLIMAP database.
2. Since 20 February 2019 updated algorithm distributed for MSG disk.

ET, mm/h

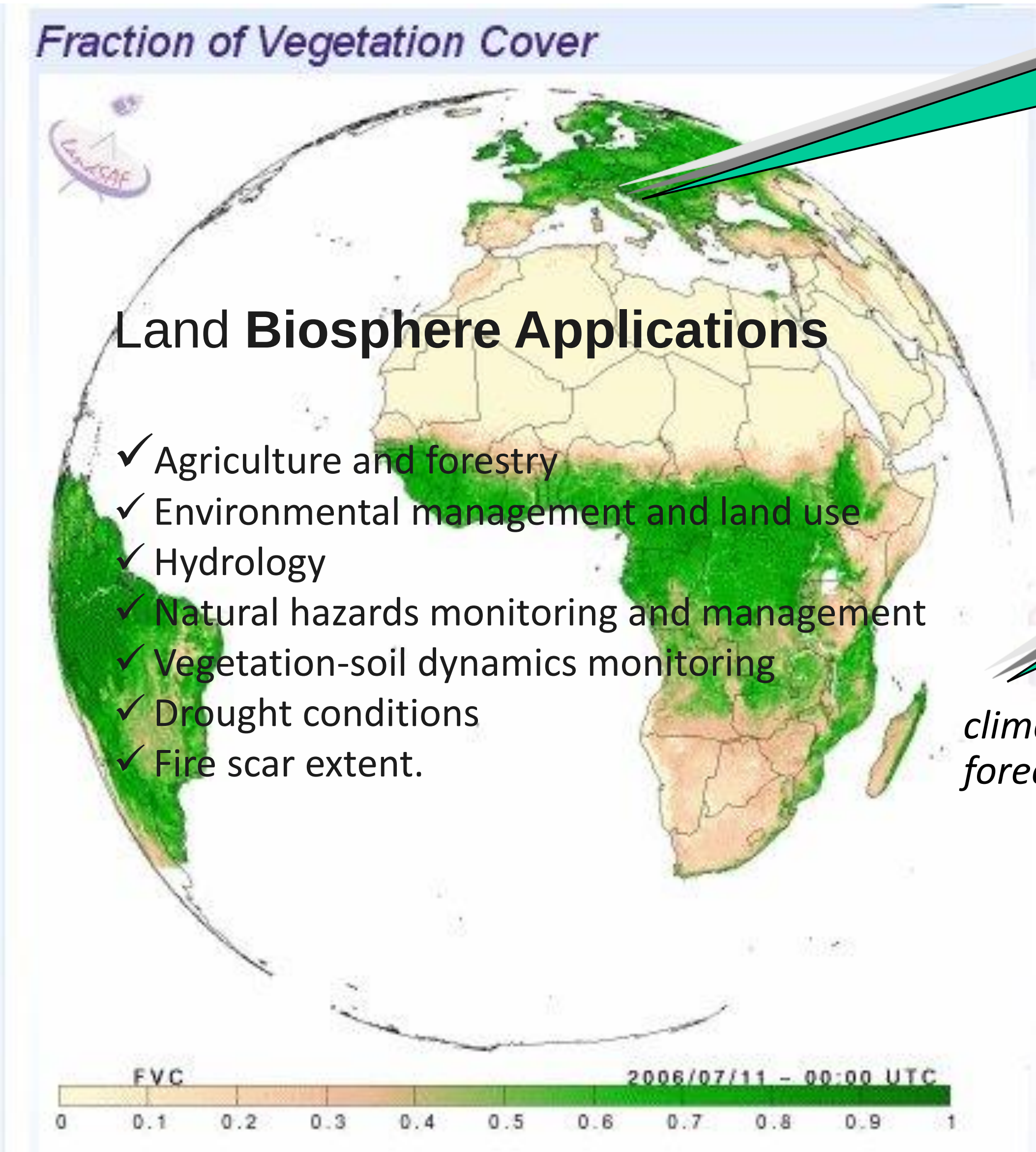
30-min, HDF5 format

MSG spatial resolution

Input

- DSSF, DSLF, AL from MSG
- Auxiliary data (air temperature and humidity, wind speed, atmospheric pressure) from ECMWF.

LSA SAF Fraction of Vegetation Cover



Land **Biosphere Applications**

- ✓ Agriculture and forestry
- ✓ Environmental management and land use
- ✓ Hydrology
- ✓ Natural hazards monitoring and management
- ✓ Vegetation-soil dynamics monitoring
- ✓ Drought conditions
- ✓ Fire scar extent.

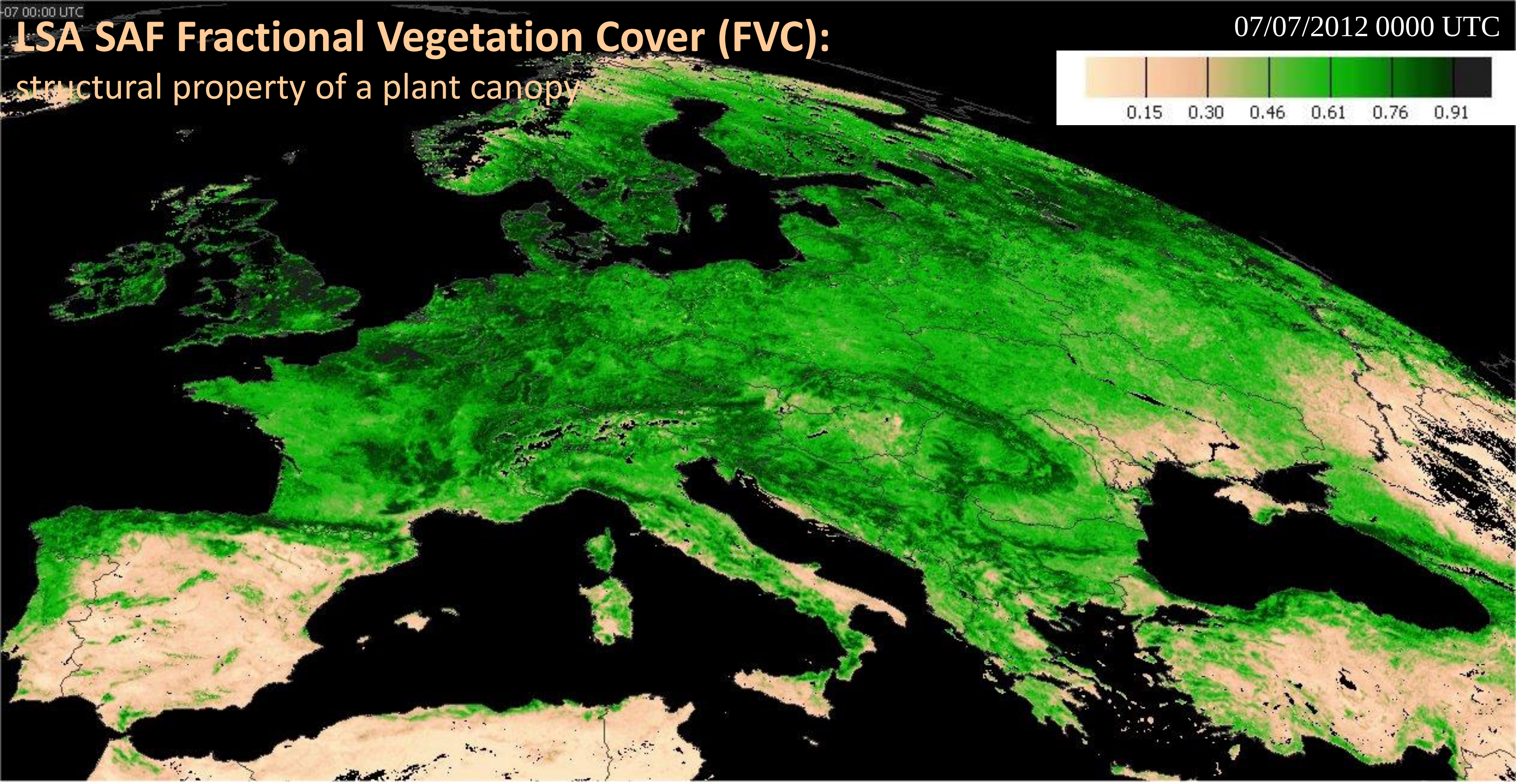
FVC accounts for the amount of vegetation distributed in a horizontal perspective.

FVC is mandatory for a thorough description of land surface processes in the surface parameterisation schemes.

climate and weather forecasting models

LSA SAF Fractional Vegetation Cover (FVC):

structural property of a plant canopy



Algorithm

Derivation of subpixel vegetation fractions at a global scale *(García-Haro et al. 2005a, 2005b).*

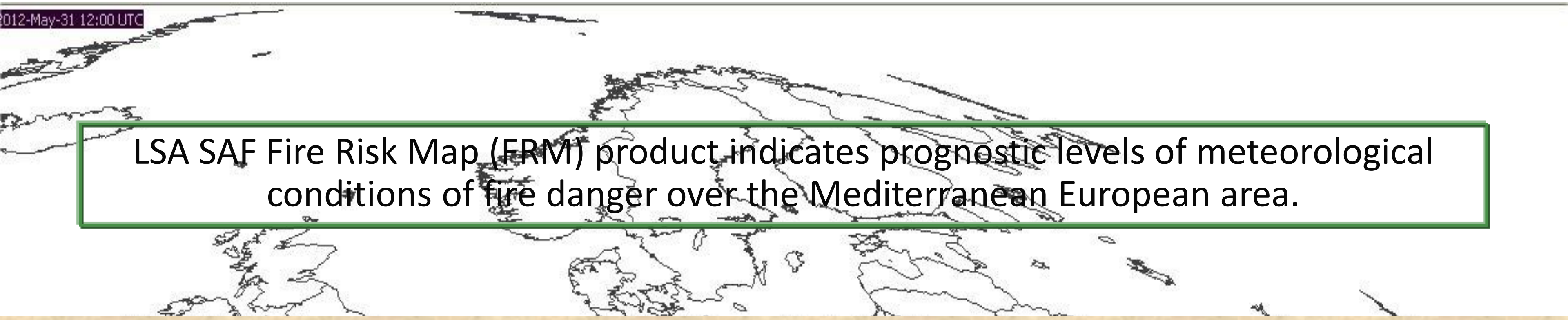
FVC (0 % - 100 %)
(daily, HDF5 format)

MSG spatial resolution

Input

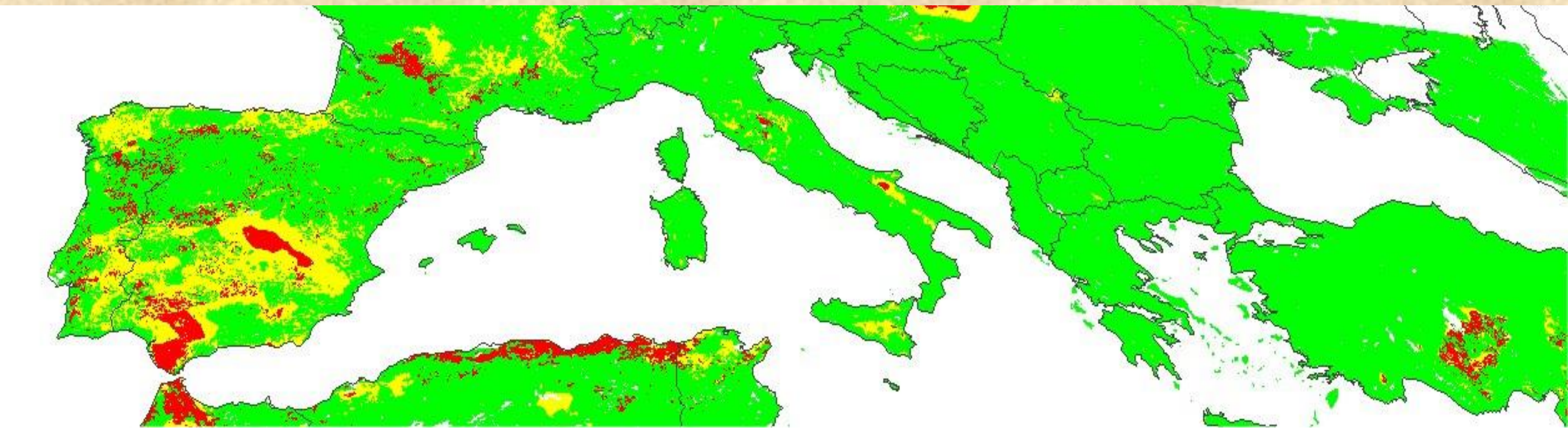
- Three short-wave channels (VIS 0.6µm, 0.8µm, NIR 1.6µm)
- Normalized reflectance of a parametric BRDF model *(Roujean et al. 1992)*

LSA SAF FRM for Meteorological Fire Risk evaluation over Europe



LSA SAF Fire Risk Map (FRM) product indicates prognostic levels of meteorological conditions of fire danger over the Mediterranean European area.

Input: ECMWF forecasts of meteorological parameters (temperature at 2 m, relative humidity, wind velocity at 10m and cumulated precipitation in 24 h) to compute the set of six fire indices CFFWIS. Classes of fire danger are obtained by combining, at each MSG pixel, daily values of fire weather index (FWI) with vegetation status for the vegetation classes as derived from GLC2000.

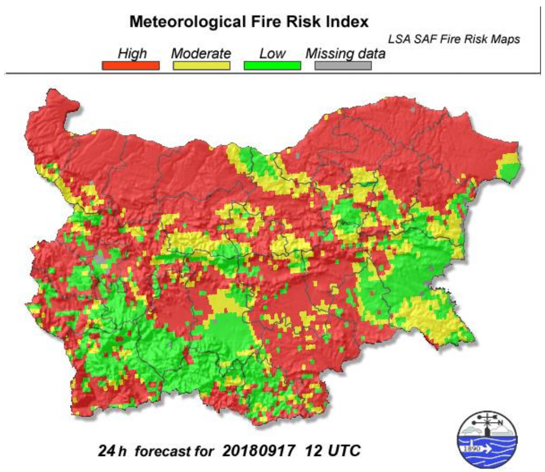


http://landsaf.meteo.pt/algorithms.jsp;jsessionid=ABD11E8E94E225D481C24BDE588ECDC2?seltab=18&starttab=18

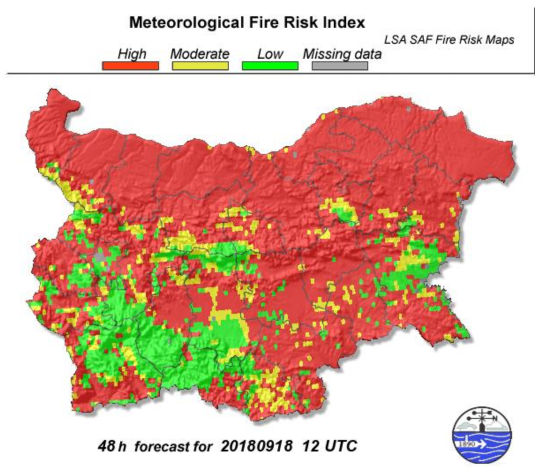
Fire Risk over over Eastern Mediterranean

LSA-SAF FRM product

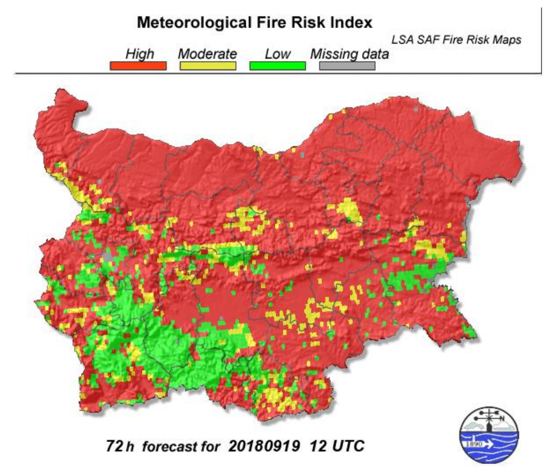
24h forecast



48h forecast



72h forecast



Output

- The product indicates prognostic levels of fire danger over the eastern European area (Bulgaria).
- The algorithm computes the set of components of the Canadian Forest Fire Weather Index System (*van Wagner, 1987)* for the following 24h, 48h and 72h.

5. Applications of modeling & LSA SAF products for analyses and forecast of drought related hazards

For analyses and forecast of drought over **Europe, Africa and Latin America** various meteorological and biogeophysical parameters and their dynamics are considered (as outputs of numerical models and satellite observations):

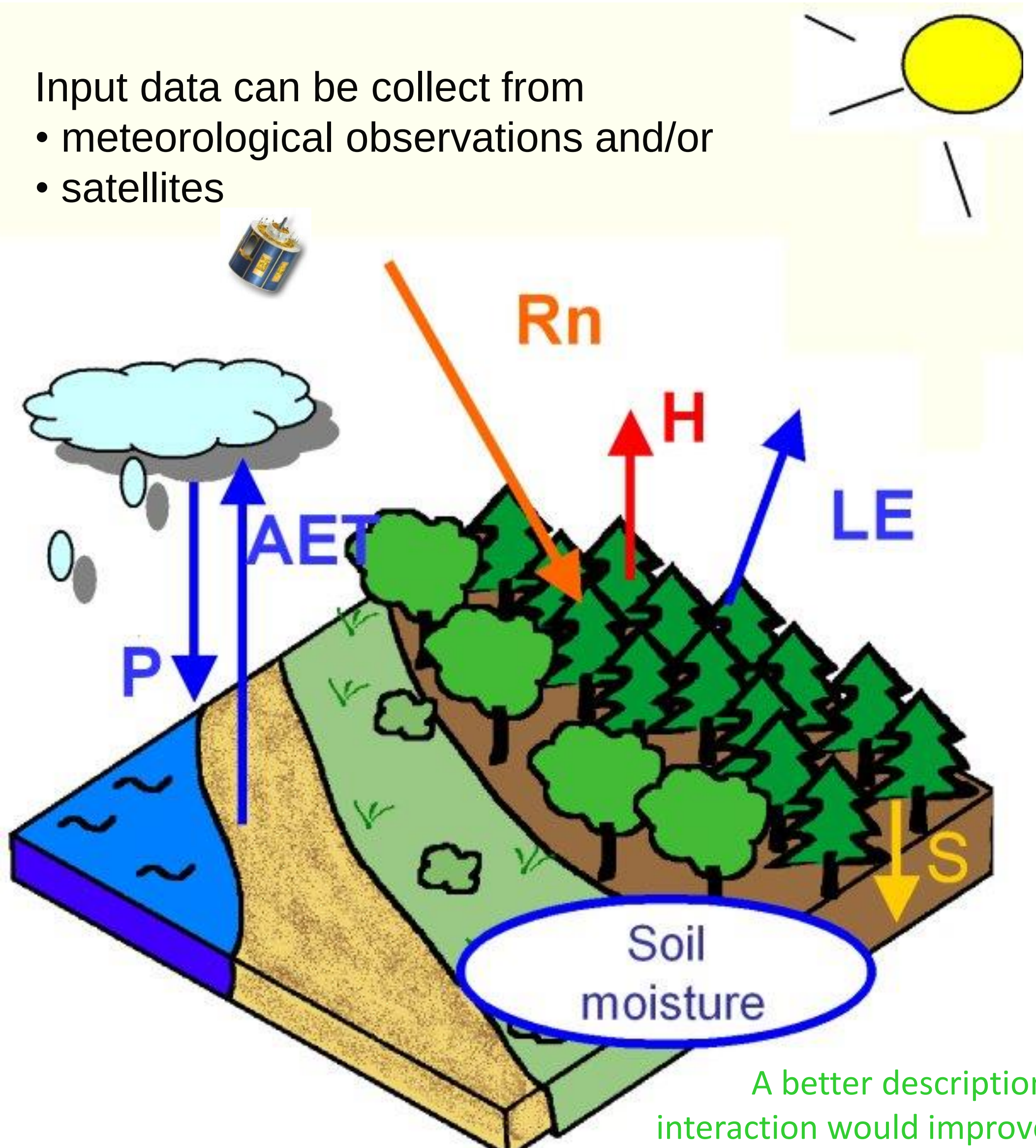
- Tmax and heat waves *(atmosphere)*
- Soil Moisture Anomalies *(land surface)*
- Indicators optimized for characterizing vegetation water stress *(vegetation)*
    - Land surface state dynamics reflected by satellite products
    - Blended parameters between satellite and ground meteorological observations.

○ Soil Moisture Anomalies

Meteorological modeling

Biophysical aspects of drought

Input data can be collect from
• meteorological observations and/or
• satellites



Soil-Vegetation-Atmosphere-Transfer Model ('SVAT_bg')

1D (vertical) geo-referenced meteorological scheme at NIMH of Bulgaria, 'SVAT_bg', incorporates the main physical mechanisms of soil-vegetation-atmosphere interface

INPUT

- Site specific soil and vegetation physical properties,
- Site and *spp.* specific vegetation physiology,
- Meteorological driving parameters,
- Geopysical driving parameters.

OUTPUT

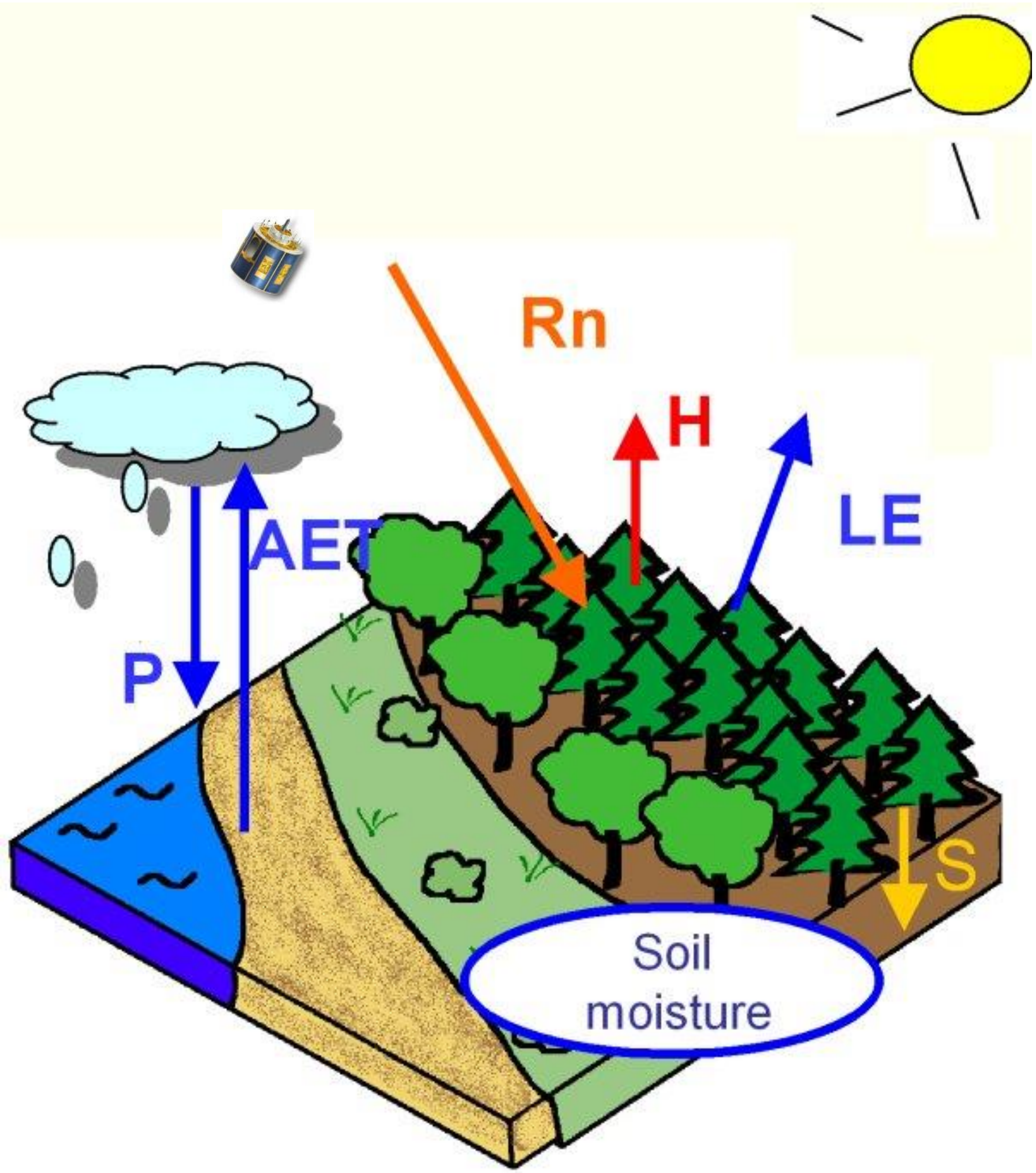
Data for land surface analyses:

- **Soil moisture conditions along root zone depth,**
- Evapotranspiration,
- Plant canopy temperature.

A better description, understanding and modelling of the land-atmosphere interaction would improve the predictability at both daily and sub seasonal scale.

Meteorological modeling

Biophysical aspects of drought



Land Surface state & Anomalies

Meteorological operational products are developed

- **Index of soil moisture availability in root zone depyh, 5, 20, 50, 100 cm.**
- **Soil Moisture Deficit of Fire danger index (SMDIFD).**
- Risk of over moistening.

Satellite observations

https://landsaf.ipma.pt/en/newsmedia/news-show-cases-2/heatwave-strike

ed GEO Polymorphic Clo... Състояние на земнат...

EUMETSAT LSA SAF LAND SURFACE ANALYSIS

Home About Products Get Data Help&Support News&Media Account

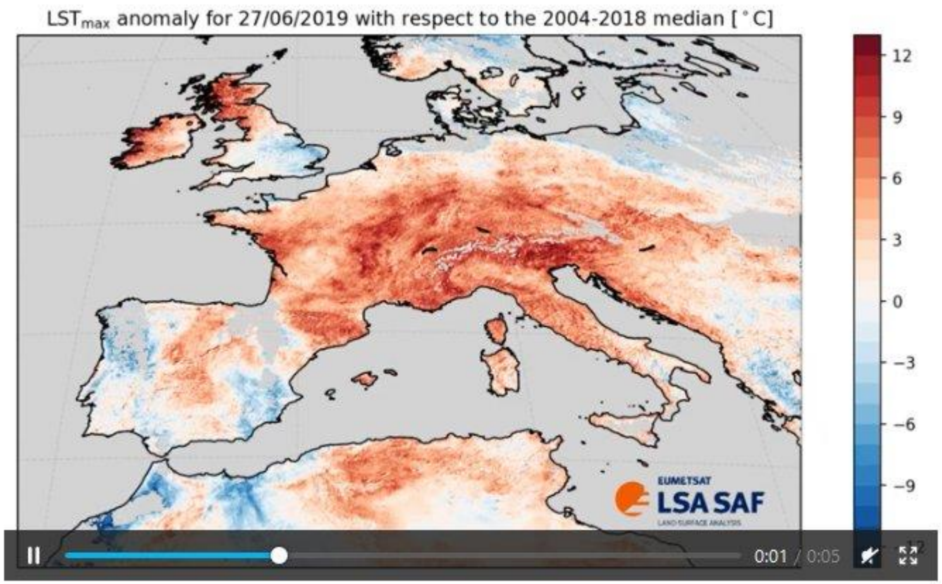
- **LST as an indicator of heat waves**

Heatwave strikes Europe

June ends with sweltering temperatures across Europe

Central Europe felt an intense heatwave at the end of June. The animation shows the daily maximum land surface temperature anomalies for the time period between 24 of June and 2 of July 2019. The reference period is taken here as the 2004-2018 median. In some regions in France and Spain, temperatures were 12°C above normal and over Germany exceeded 15°C. Continental Portugal had below average temperatures north of the Montejunto-Estrela mountain range, while the south showed slightly above normal temperatures.

The LST is estimated from thermal infrared radiances measured by the SEVIRI instrument onboard the Meteosat Second Generation (MSG). Estimates are provided every 15 minutes since 2004 (find more about LSA SAF LST data record here). The values represent the land surface radiative temperature, which differs from the 2m air temperature measured by conventional weather stations. Satellite land surface temperature can only be measured in clear sky conditions, since clouds are opaque to infrared radiation (detailed information on how LSA SAF LST is estimated from MSG observations can be found here).



← Previous Article – Back to Overview – Next Article →

LSA SAF System maintained in cooperation with: deimos

Physical mechanisms underlying European summer heat waves

Three large-scale mechanisms have been identified as fundamental factors in producing summer HWs in Europe:

a) persistent anticyclonic circulation anomalies (i.e. atmospheric stability)
b) sea surface temperatures (SSTs) in the North Atlantic, Mediterranean and/or Indian Ocean
c) anomalous **land surface conditions (e.g. drought)**

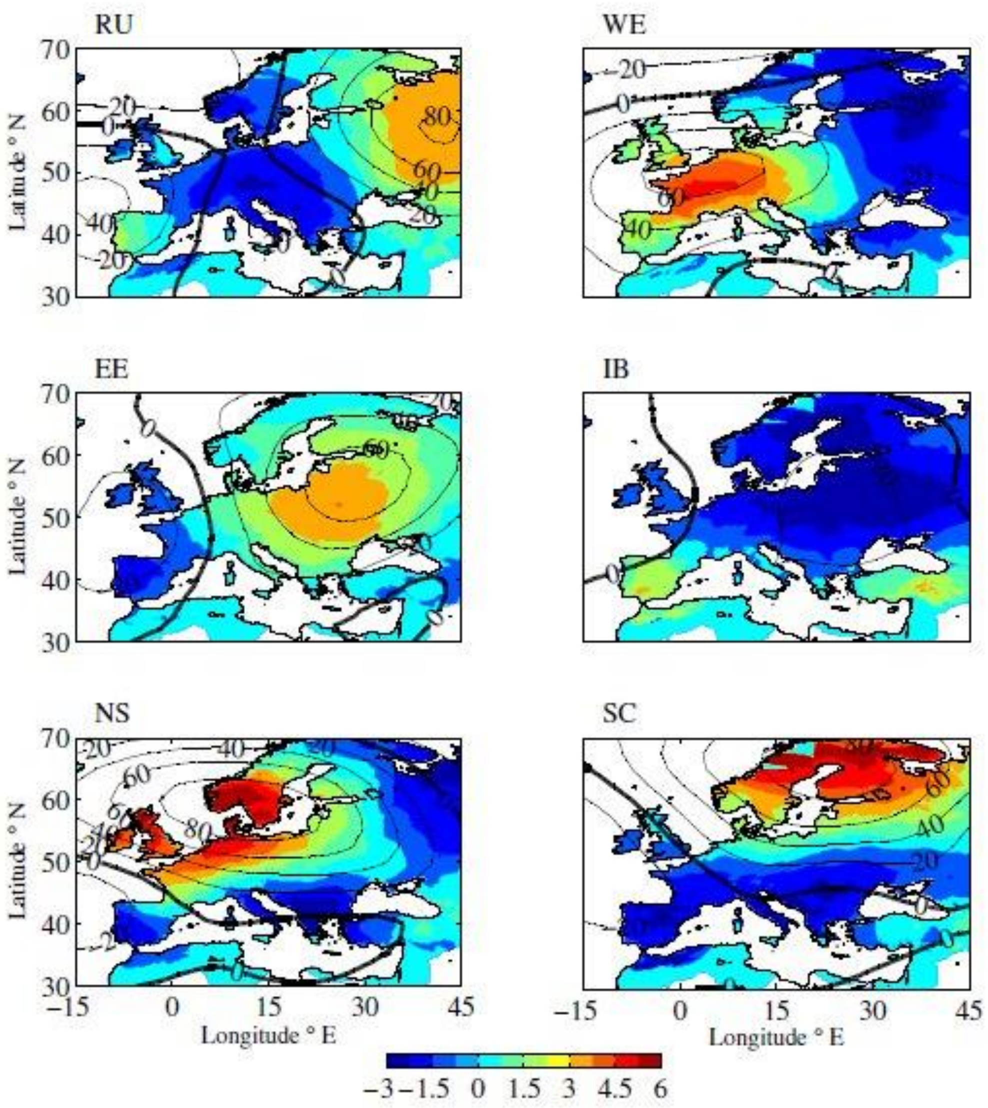
The large-scale effects of blocking anticyclonic circulation alone is not sufficient for such a temperature anomaly in 2003, others factor play a role as the:

- SST and land-atmosphere interactions
- Possible teleconnections with tropics.

The addition of several mechanisms - such as atmospheric stability, sea surface temperature anomaly and drought - led to the very exceptional 2003 heat waves with a temperature up by 12.5 °C with respect to climatological observations realised between 1971-2000 *(Levinson and Waple, 2004).*

Triggered by large-scale atmospheric forcings, Mediterranean regional heat waves are often amplifed by surface preconditioning, **such as negative soil moisture anomalies and vegetation state "** *(Stéfanon et al, 2012; 2013).*

Heat waves classication over Europe



Six heatwave patterns obtained by hierarchical clustering algorithm for the Euro-Mediterranean region:
(a) Russian cluster (**RU**),
(b) Western Europe cluster (**WE**),
(c) Eastern Europe cluster (**EE**),
(d) Iberian cluster (**IB**),
(e) North Sea cluster (**NS**) an
(f) Scandinavian cluster (**SC**).

Daily maximum temperature anomaly are in colour and expressed in deg K and isolines are the 500-hPa geopotential height anomaly.

Triggered by large-scale atmospheric forcings, Mediterranean regional heat waves are often amplifed by surface preconditioning, **such as negative soil moisture anomalies and vegetation state**.

Stéfanon et al. (2013)

In this classification scheme there is no definite pattern of HW for South-Eastern Europe (SEE).

Quantification of drought hazards effects

Identification of drought response over Eastern Mediterranean:

→ Soil Moisture (SM) deficit, characterized by Soil Moisture Availability (SMA) to vegetation cover according SVAT_bg.
→ LSA SAF Land surface temperature (LST) in conjunction with the MSG products of FVC and ET.
→ Blended parameter: Temperature difference between land surface and atmosphere (2m air temperature).
→ LSASAF FRM and its updated versions
→ NWP models output: ECMWF estimates

Local reveals of large-scale processes: Bulgaria, southeastern Europe

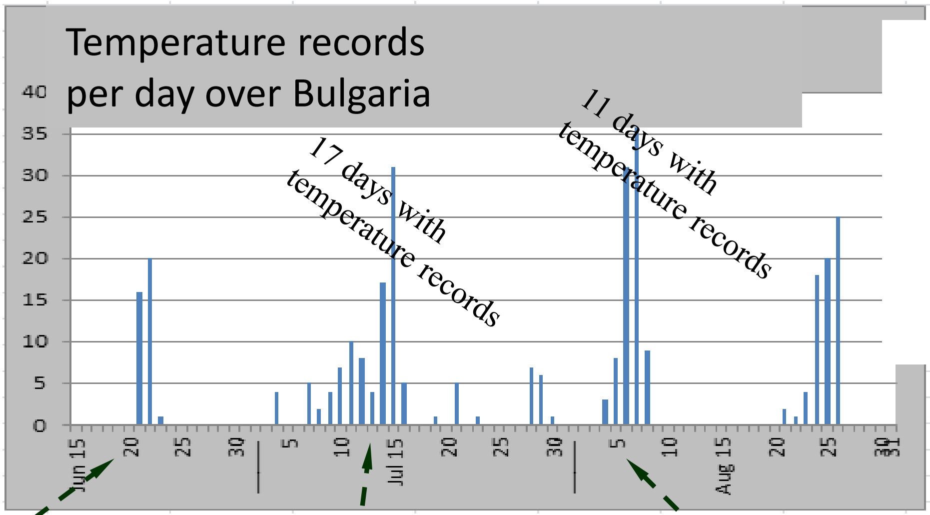
- **A task of operational meteorology:** To evaluate the land surface state during heat waves and drought by using biogeophysical moistening- and thermal- parameters to determine the potential effects of SM deficit.
- **Climatic applications:** LST, FVC, FRP-Pixel products

• 1. Heat wave episodes over SEE

Synoptic evolution: summer heat waves in Bulgaria during 2012

Persistent anticyclonic circulation anomalies over SEE

- **Mid-level ridge** over Southeastern Europe.
- **High pressure at the surface**, or evolution from cyclonic to anticyclonic over Bulgaria.

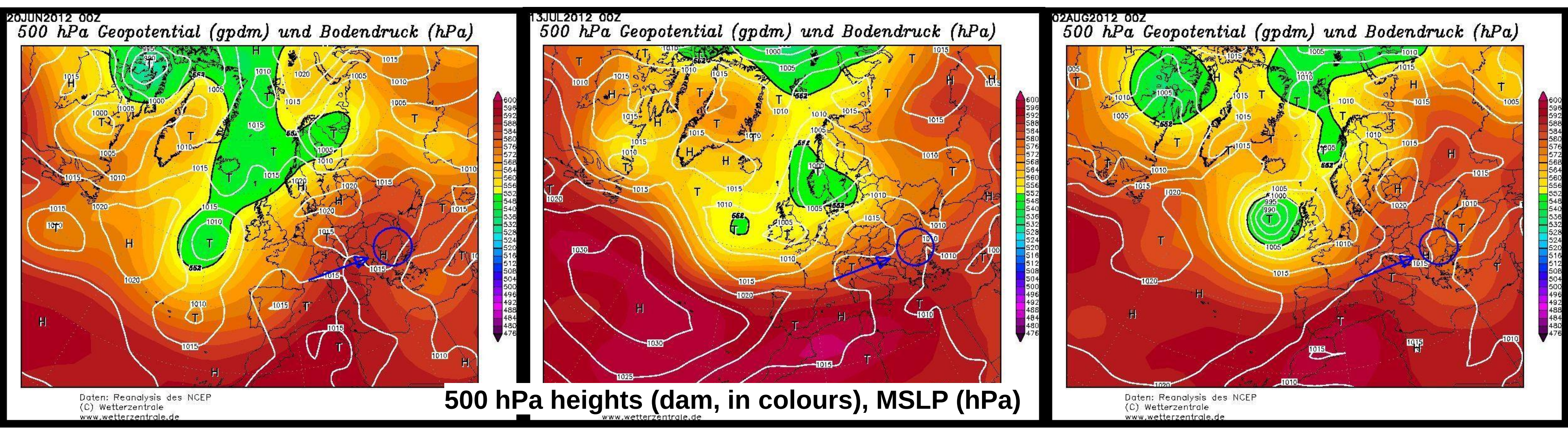


Transport of hot and dry air-masses from North Africa over the Balkans : temperature records and meteorological drought.

20 June 2012

13 Jul 2012

2 Aug 2012



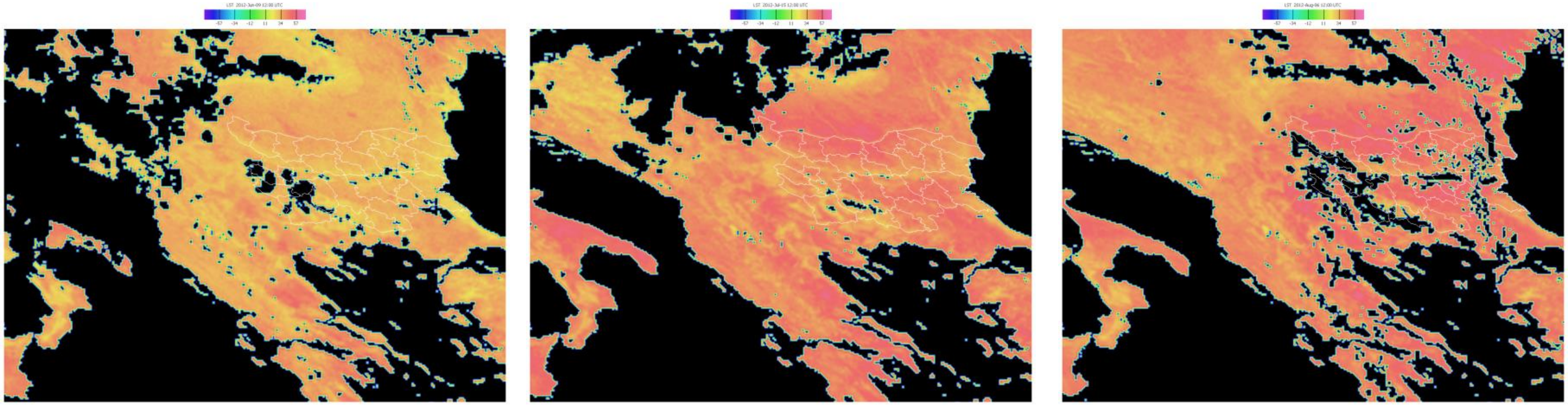
500 hPa heights (dam, in colours), MSLP (hPa)

Contributed by Mariana Popova

Land surface state: Effect of soil moisture, vegetation, and land use

LSA SAF LST product in image format over the Eastern Mediterranean

LST 1200 UTC



15- 23 Jun → 9-19 Jul → 3-8 Aug 2012

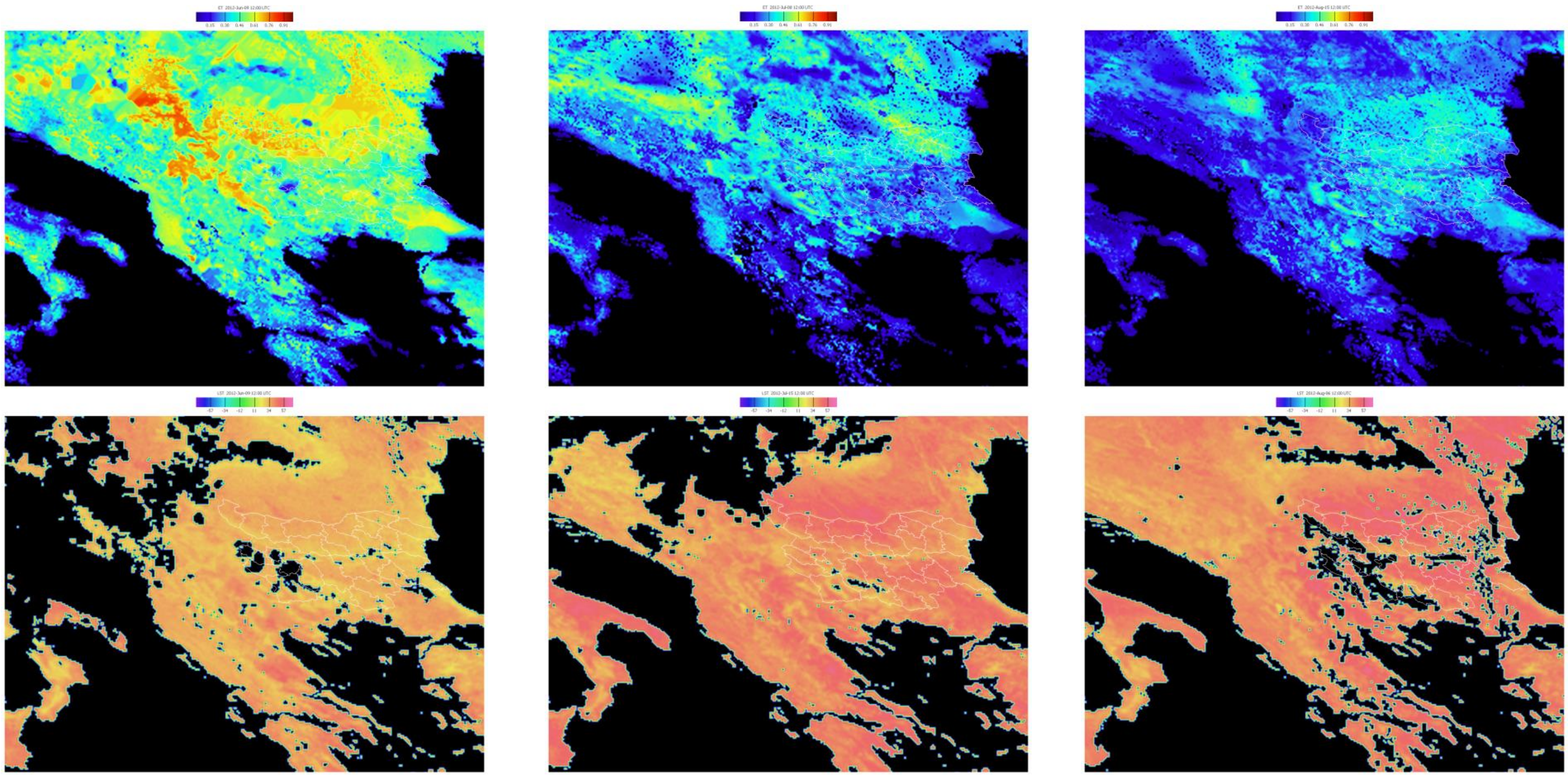
- There is no rain during the selected summer periods of 2012.
- MSG LST is progressively increasing.
- In conditions of meteorological drought, this is associated with soil moisture decrease.

What is the related response of vegetation functional and structural features to drought ?

LSA SAF products in image format over the Eastern Mediterranean

ET

1200 UTC



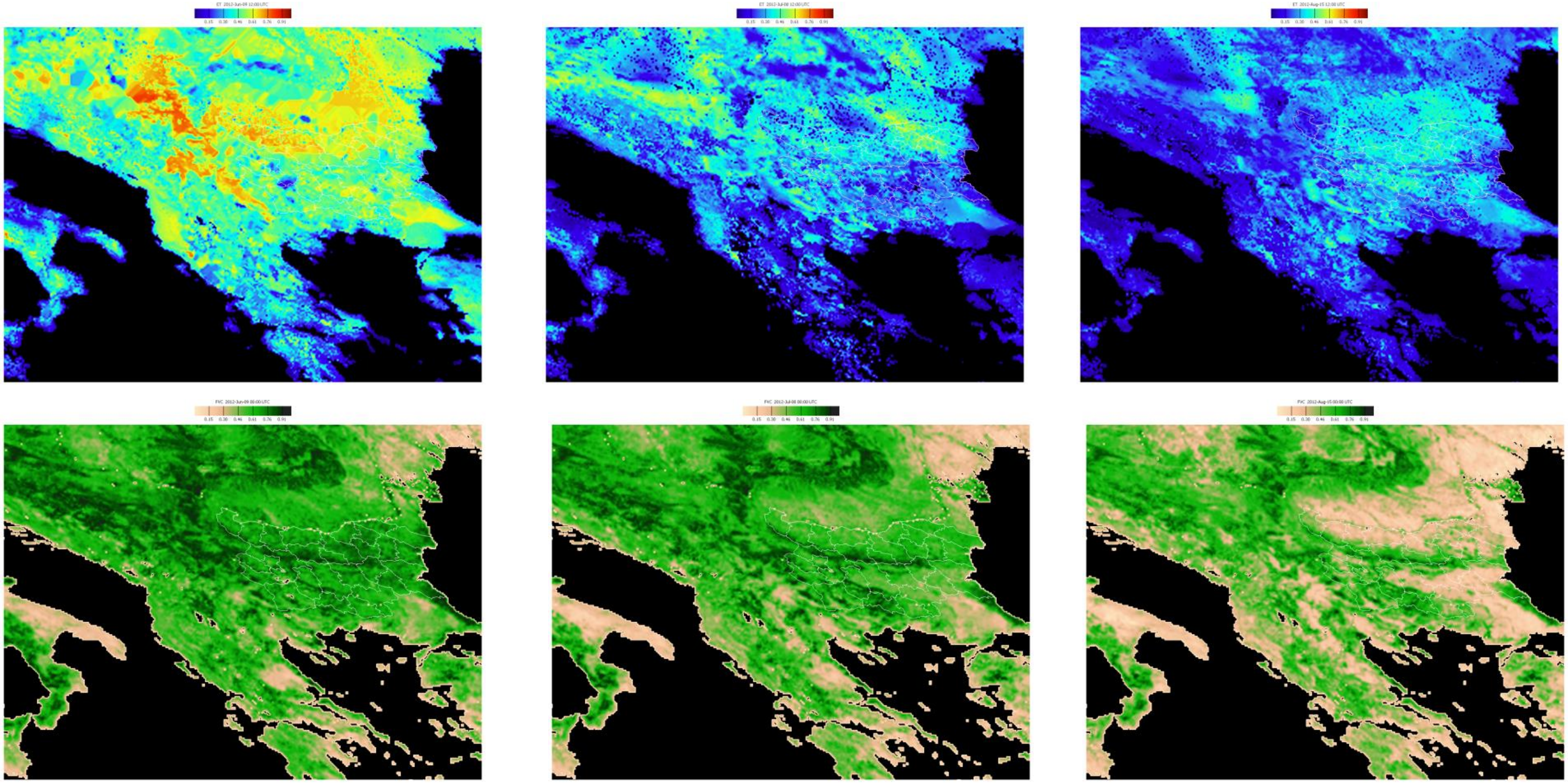
LST

15- 23 Jun → 9-19 Jul → 3-8 Aug 2012

Accumulated drought is associated with decrease of Evapotranspiration (the satellite image becomes dominantly blue).

Drought as seen in LSA SAF ET, FVC products

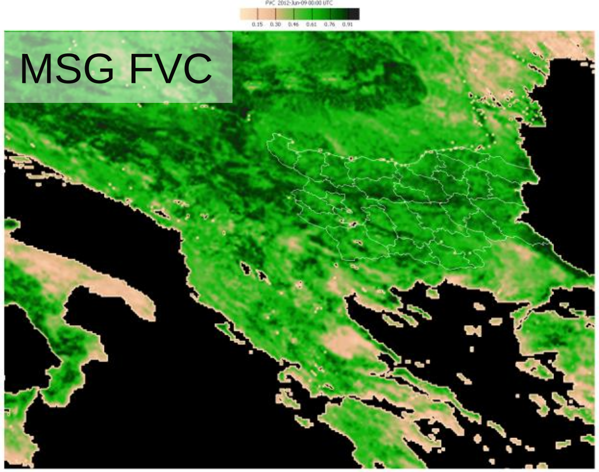
ET 1200 UTC

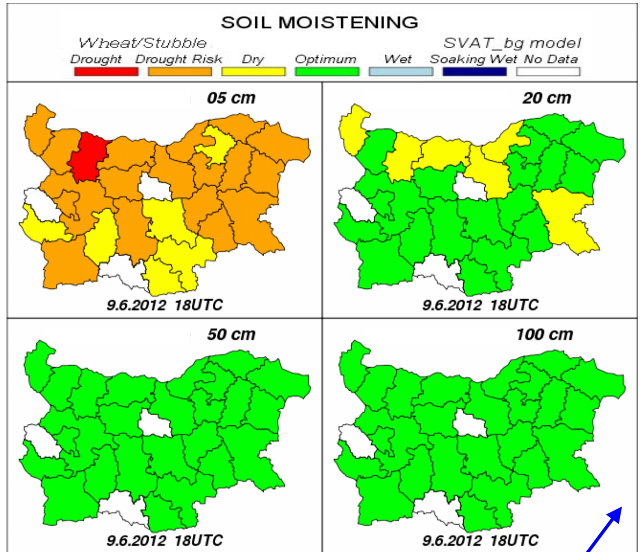


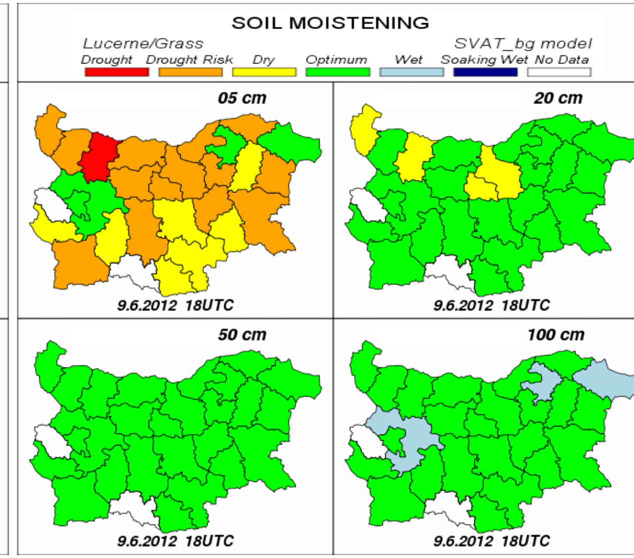
FVC

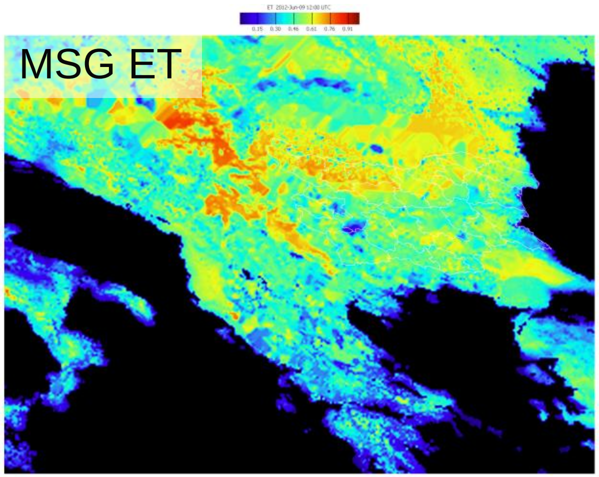
15- 23 Jun → 9-19 Jul → 3-8 Aug 2012

Accumulated terrestrial drought is associated with decrease of evapotranspiration and decline of vegetation cover seen by MSG.

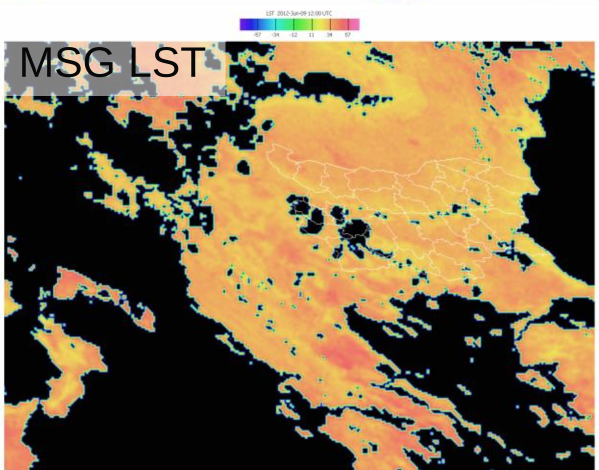


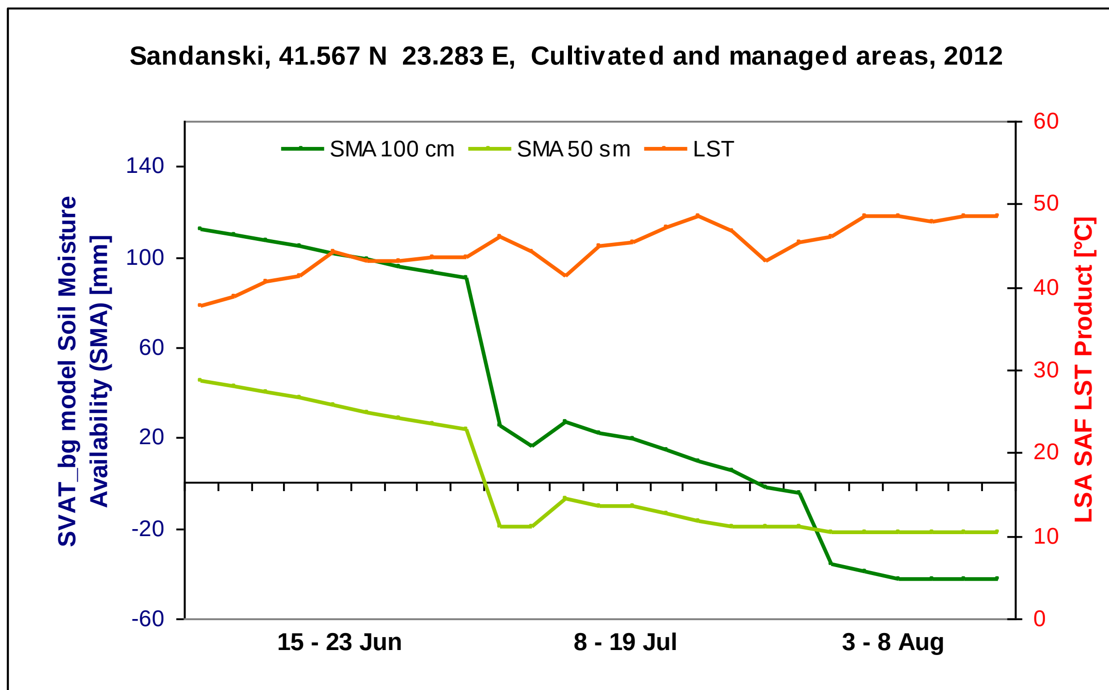






Satellite & SVAT products in image format:
SMA depletion is accompanied by decrease of FVC, decrease of ET, increase of LST.





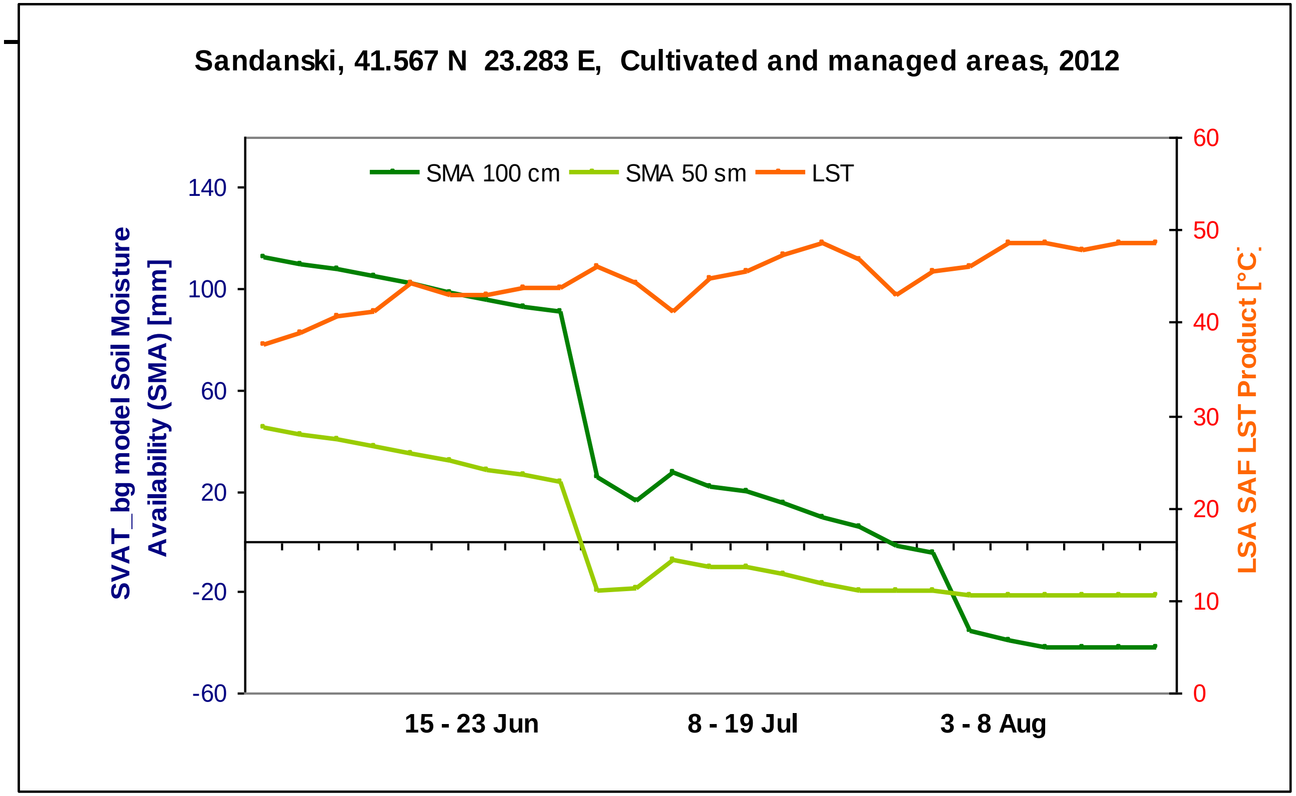
Blended time series: MSG satellite products in digital values & SVAT products

ROLE OF SOIL MOISTURE DURING HEAT WAVES

The soil moisture decrease (in conditions of meteorological drought), which is accompanied by steadily increase of LST.

MSG pixel values of LSA SAF LST product at locations of the synoptic stations are inferred and considered along with the 'SVAT-bg' model Soil Moisture Availability (SMA) products.

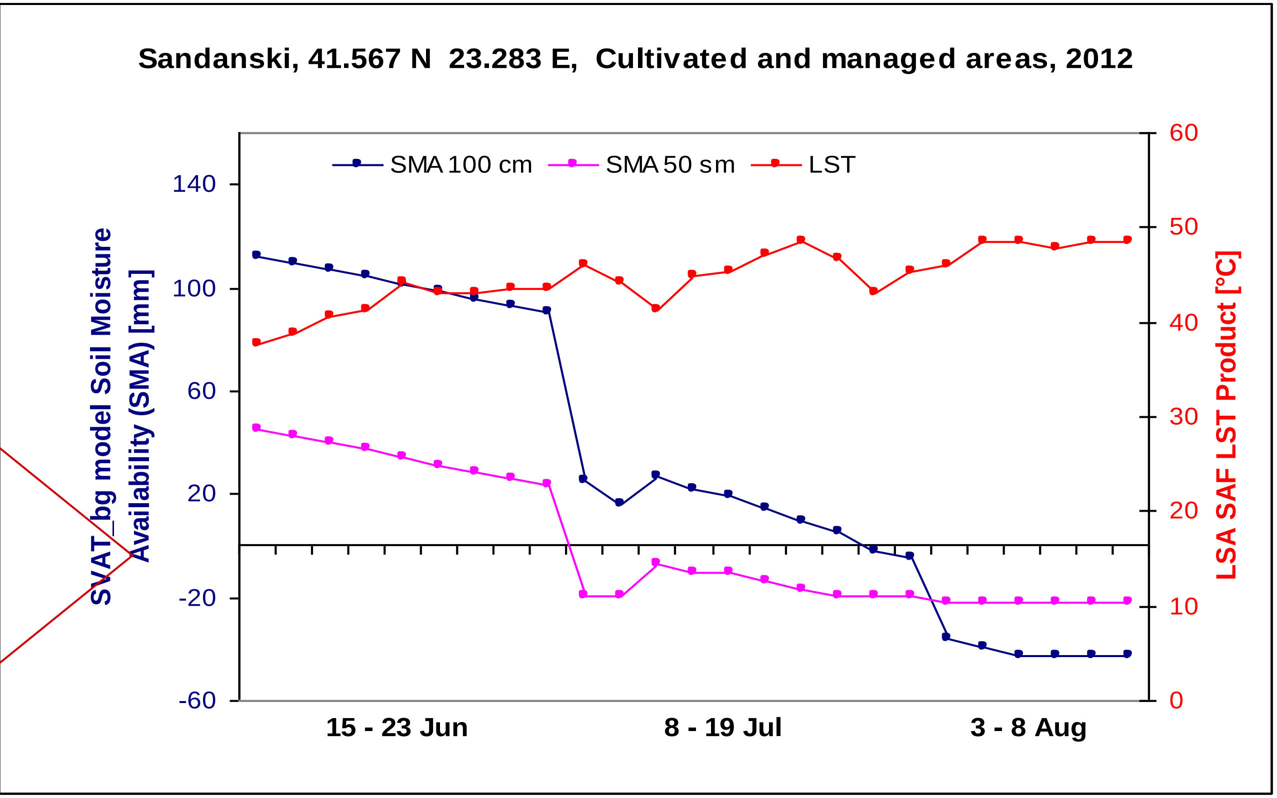
Synoptic station Sandanski, Jun-Aug 2012



Blended time series: MSG satellite products in digital values & SVAT products

As a moist soil surface dries out, more of the incoming solar energy is reflected, and a larger fraction of the absorbed energy is used to heat the air and soil. The heat flow into the soil increases at first, then decreases as the soil becomes very dry. ***This results in higher land surface temperatures (Ts), which also influence the rate of drying and evapotranspiration.***

The soil moisture decrease (in conditions of meteorological drought) leads to SMA depletion, which is accompanied by steadily increase of LST.



Is the increase of MSG LST

- a cause of the drought

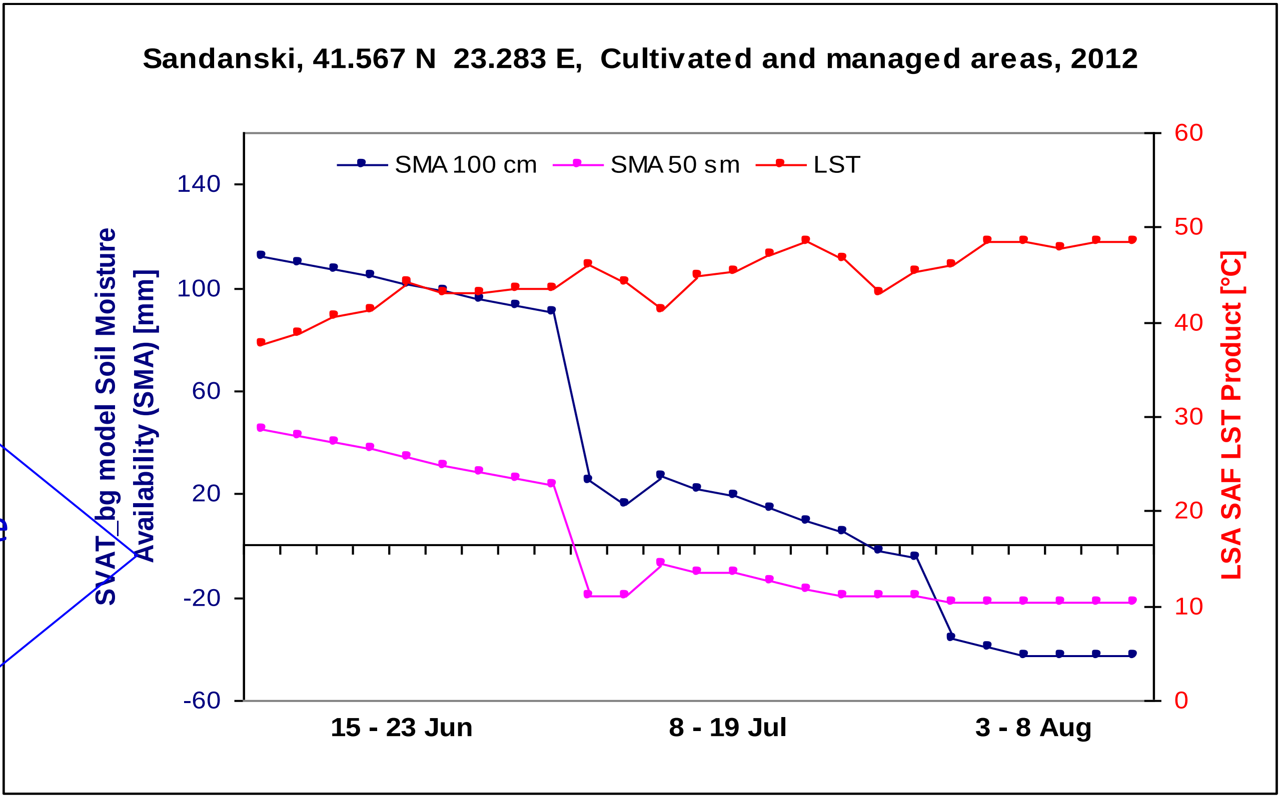
or/and

- a product of the drought?

Blended time series: MSG satellite products in digital values & SVAT products

As a moist soil surface dries out, more of the incoming solar energy is reflected, and a larger fraction of the absorbed energy is used to heat the air and soil. The heat flow into the soil increases at first, then decreases as the soil becomes very dry. ***This results in higher land surface temperatures (Ts), which also influence the rate of drying and evapotranspiration.***

The soil moisture decrease (in conditions of meteorological drought) leads to SMA depletion, which is accompanied by steadily increase of LST.



The high LST is both a cause and a result of the land surface - atmosphere interaction during the dry periods.

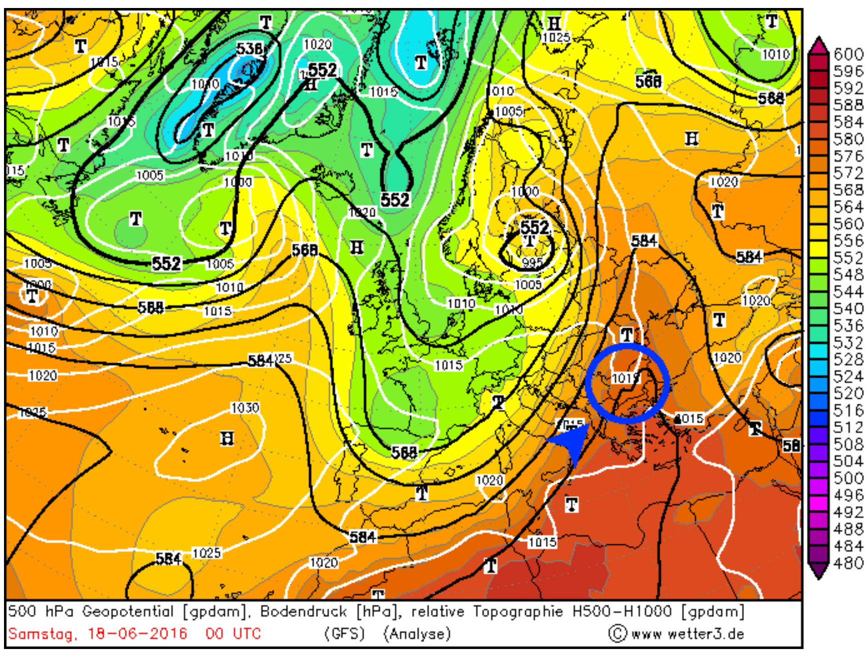
Heat wave episodes over SEE in 2016

Late spring heat waves 17-19/20-21 June 2016

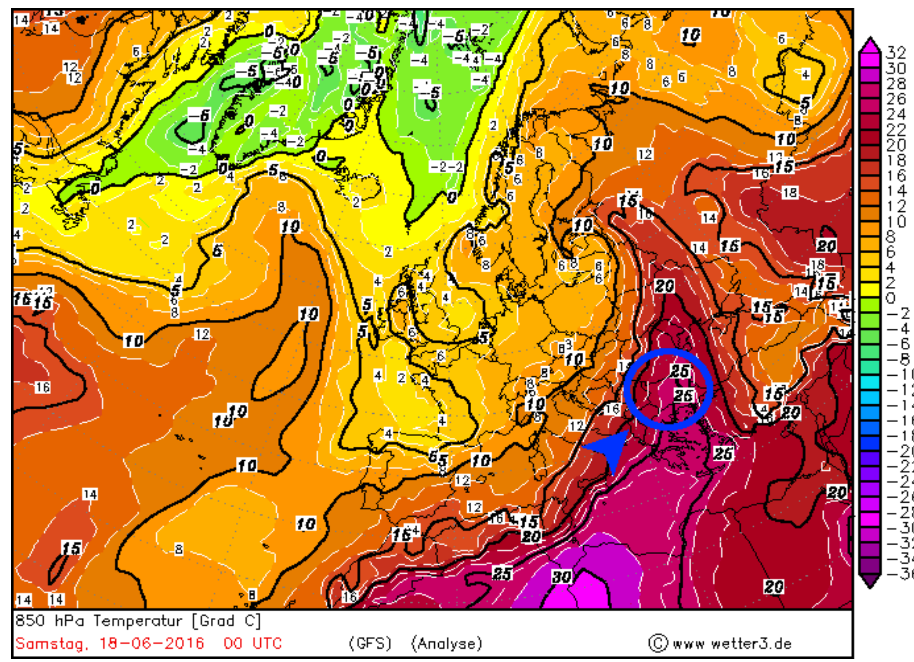
At upper- level a ridge from south builds up over the Balkans. The relative geopotential in the layer 500-1000 hPa strongly increased.

Accordingly the air from the surface up to the middle troposphere has warmed up.

500 hPa heights (black) **surface pressure** (white) relative topography 500-1000 hPa (colour)



500 hPa Temperature

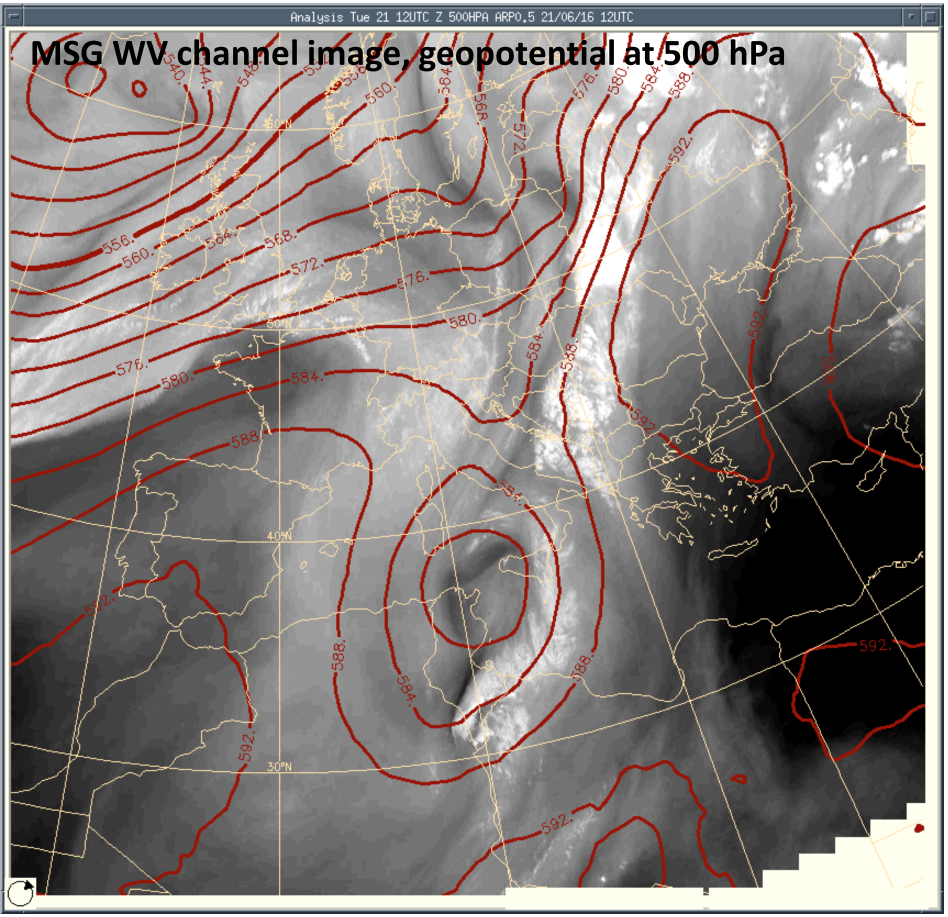


Contribution: Mariana Popova

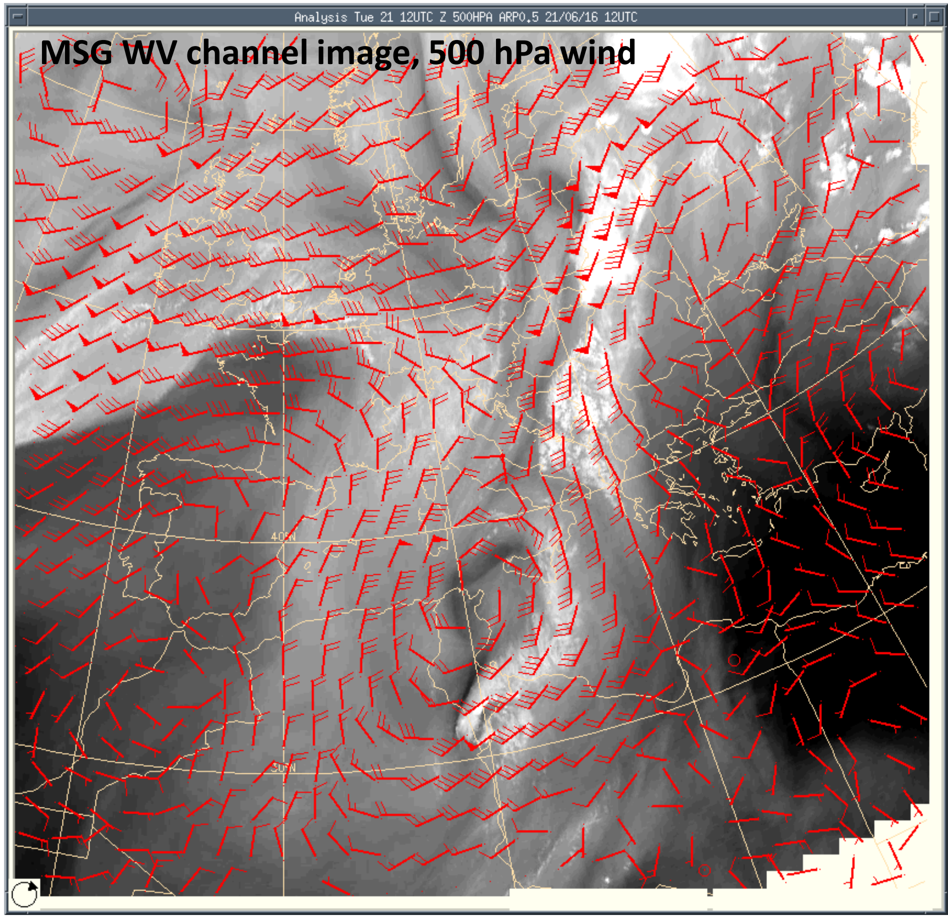
Late spring heat waves 20-21 June 2016

Diagnosis

Atmosphere: Large scale circulation patterns



There is anticyclonic circulation over the Balkans in blocking regime over the Central Mediterranean and North Africa.



Persistent south-westerly flow in the middle and lower troposphere is present over the Balkans.

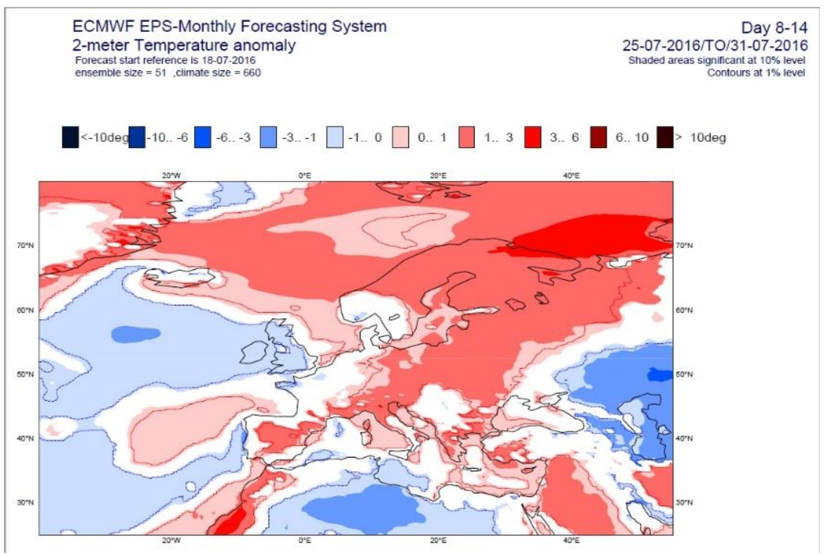
Contribution: Christo Georgiev

NWP forecasts: Summer heat wave 30 July – 1 August 2016

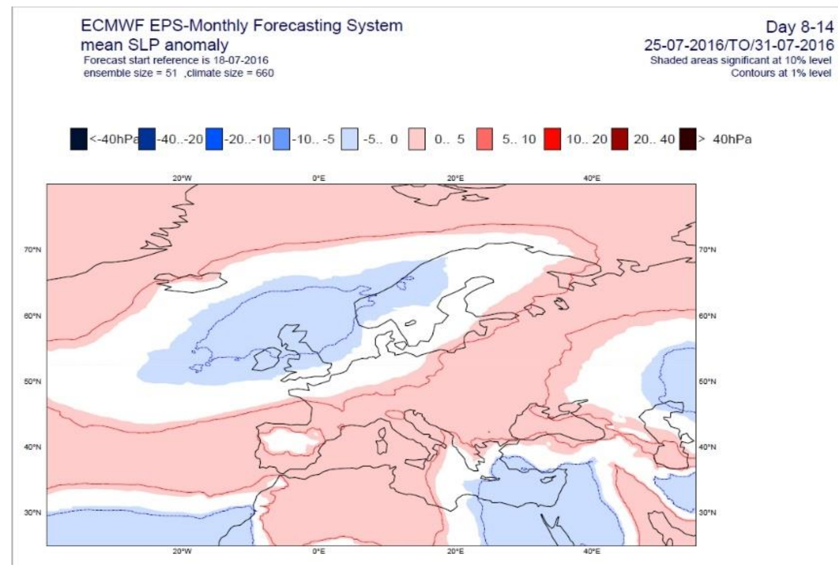
The lack of precipitations, especially in the east part of Bulgaria, lead to the increase of meteorological drought. There were no extreme heats, the highest temperatures were on 14th July, up to 36°- 38°, Sandanski 39° (the monthly record for July is 45.2 °C).

ECMWF weekly forecasts

The heat wave as seen in the weekly averaged forecasts of ECMWF from 18 July 2016 (about 7-8 days before is happened).



Temperature anomaly valid for 25–31 July



Surface pressure anomaly valid for 25–31 July

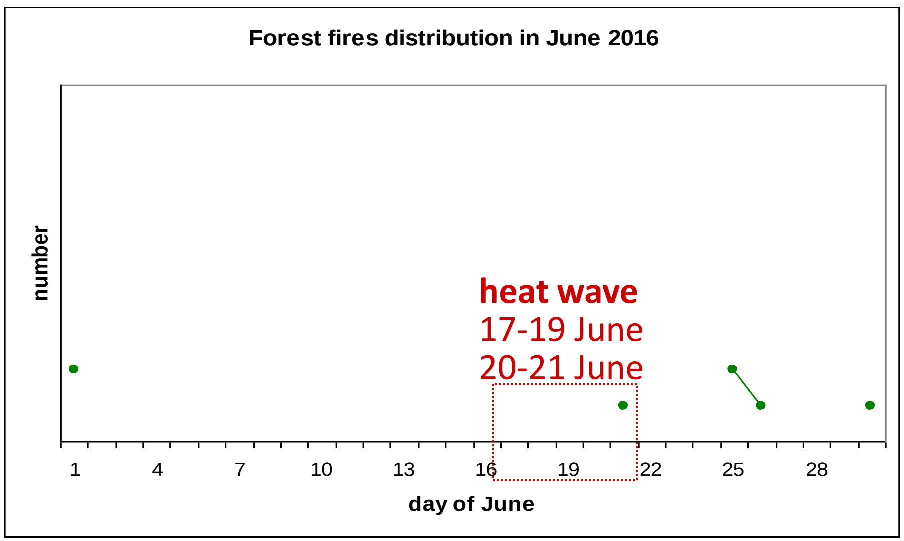
Contribution: Mariana Popova

Heat wave - vegetation state analyses to diagnose/predict fire risk

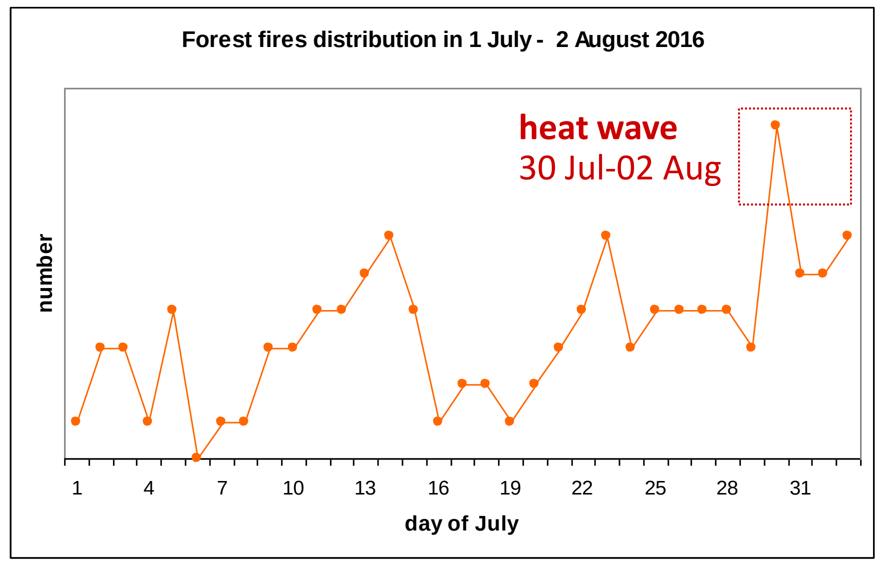
Heat wave effects:
- Increased meteorological fire risk
- No dry land surface anomalies
- Single forest fires only

Heat wave effects:
- Increased meteorological fire risk
- Increased soil moisture deficit/vegetation dryness
- Terrestrial drought accelerates synoptic conditions for fire risk
- Increased number of forest fires

Graph of forest fires in June 2016
State Forest Agency, Bulgaria



Graph of forest fires in July- 2 Aug 2016
State Forest Agency, Bulgaria



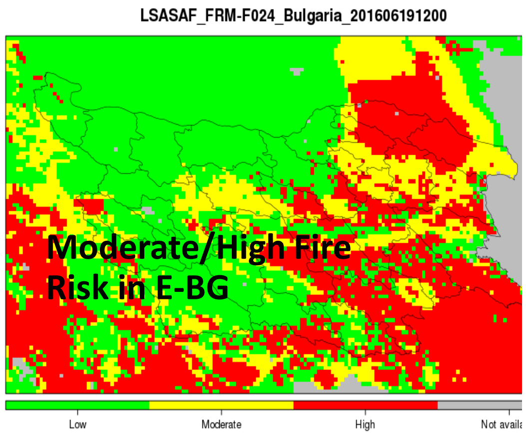
Satellite information provides a tool for diagnosis of land surface state/drought, fire risk & thermal anomalies detection and helps in issuing early warnings

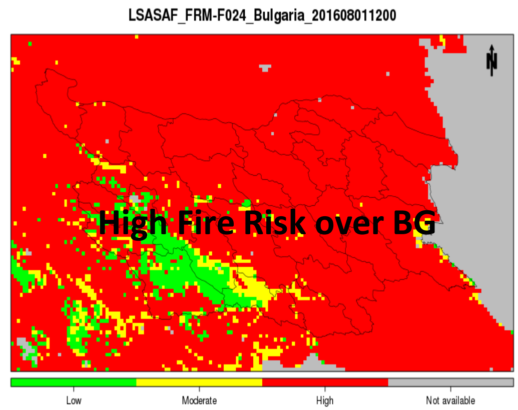
2. Terrestrial drought and fire risk

Meteorological (Atmosphere) risk & Terrestrial drought in 2016

Spring: 17-19 June 2016 | Summer: 30 Jul - 02 Aug 2016

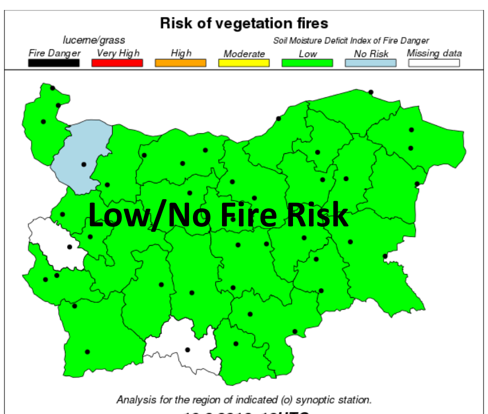
Atmosphere: Fire weather forecasts (according LSA SAF FRM product)

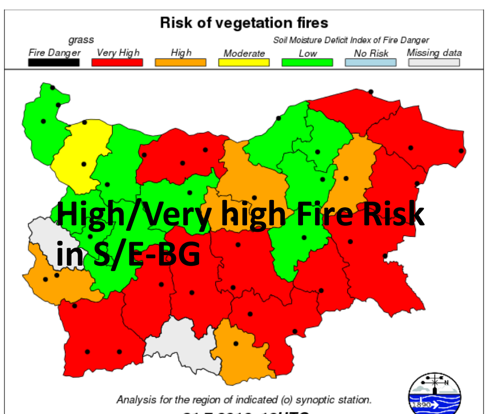




Land surface state impact : Fire danger according SMDIFD

Soil Moisture Deficit Index of Fire danger (SMDIFD) based on SVAT model output

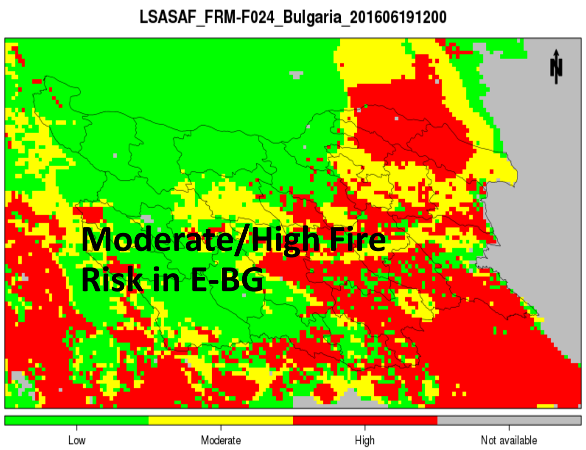


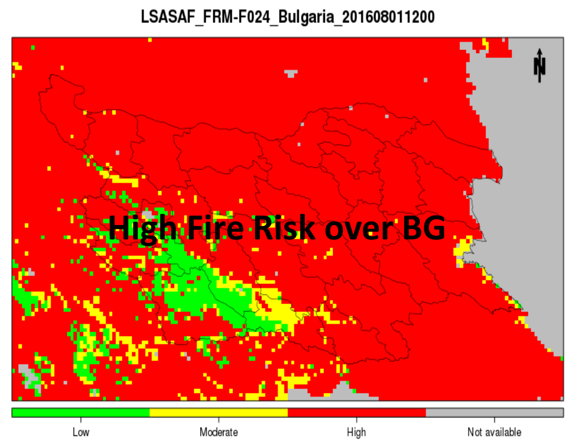


Meteorological (Atmosphere) risk & Terrestrial drought in 2016

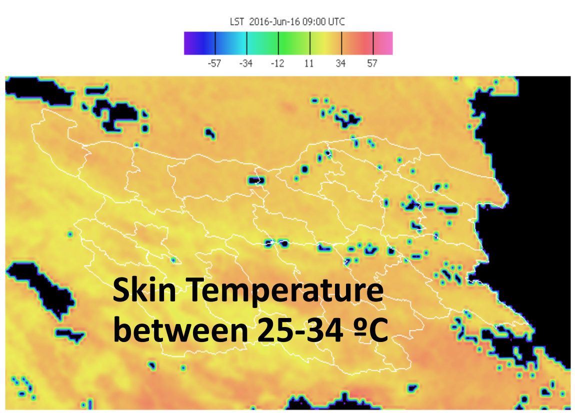
Spring: 17-19 June 2016 — Summer: 30 Jul - 02 Aug 2016

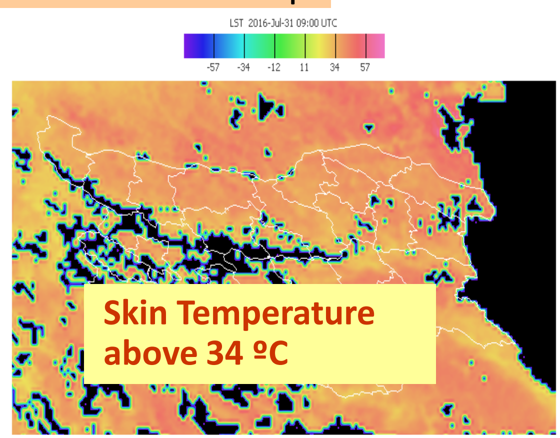
Atmosphere: Fire weather forecasts (according LSA SAF FRM product)





Land surface state impact: LSA SAF LST maps





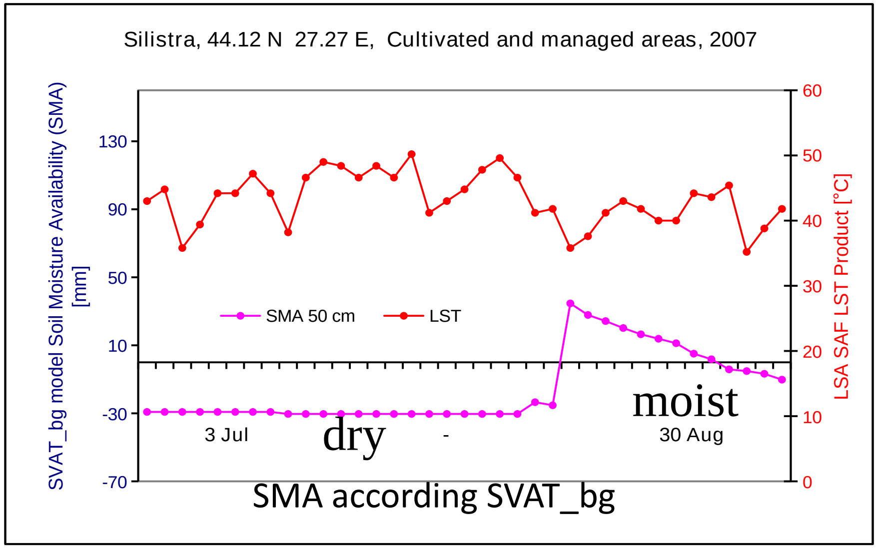
Land surface state during heat waves in 2007 and 2012

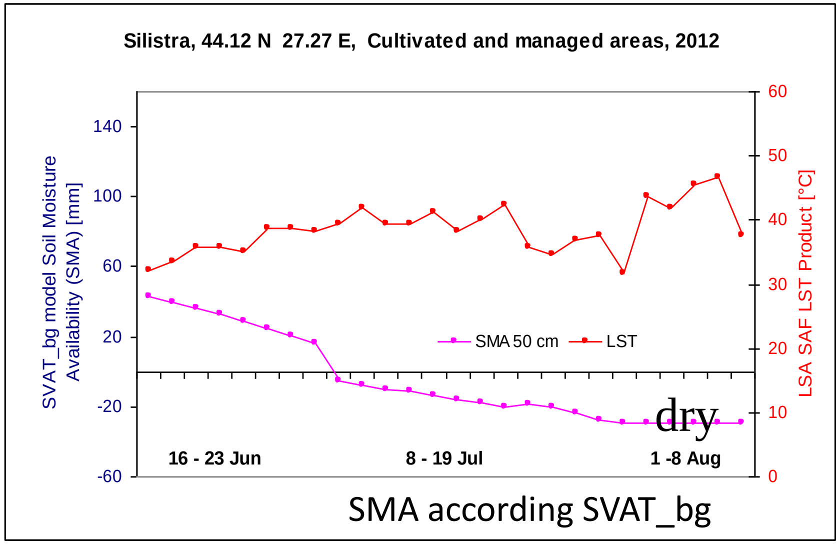
The evolution is illustrated by the land surface temperature and soil moisture conditions.

During the period of the heat waves, along the gradual SMA depletion, LST increases

2007 is extremely dry in July

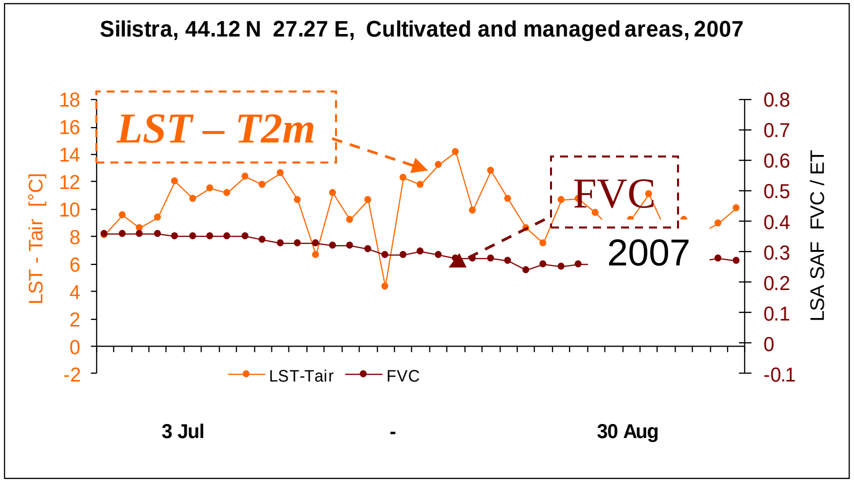
2012 is dry in July



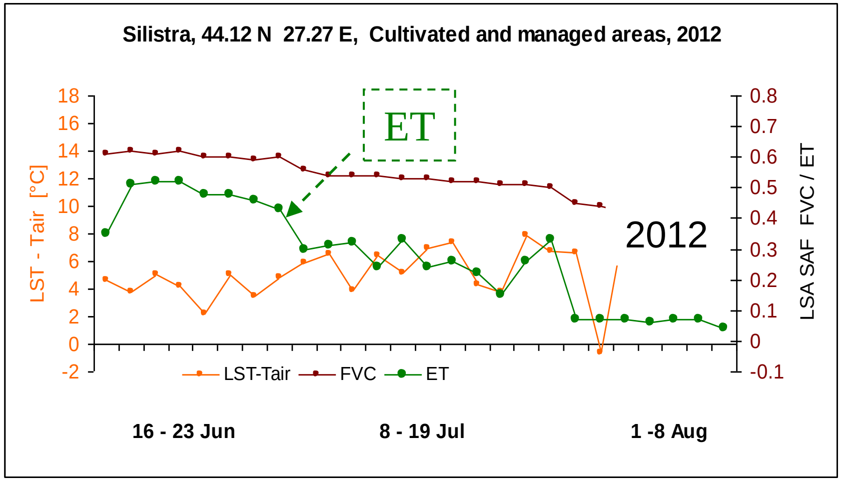


Drought accelerates the effect of meteorological conditions; LST becomes higher in July 2007.

Behavior of vegetation characteristics during heat waves in 2007 and 2012



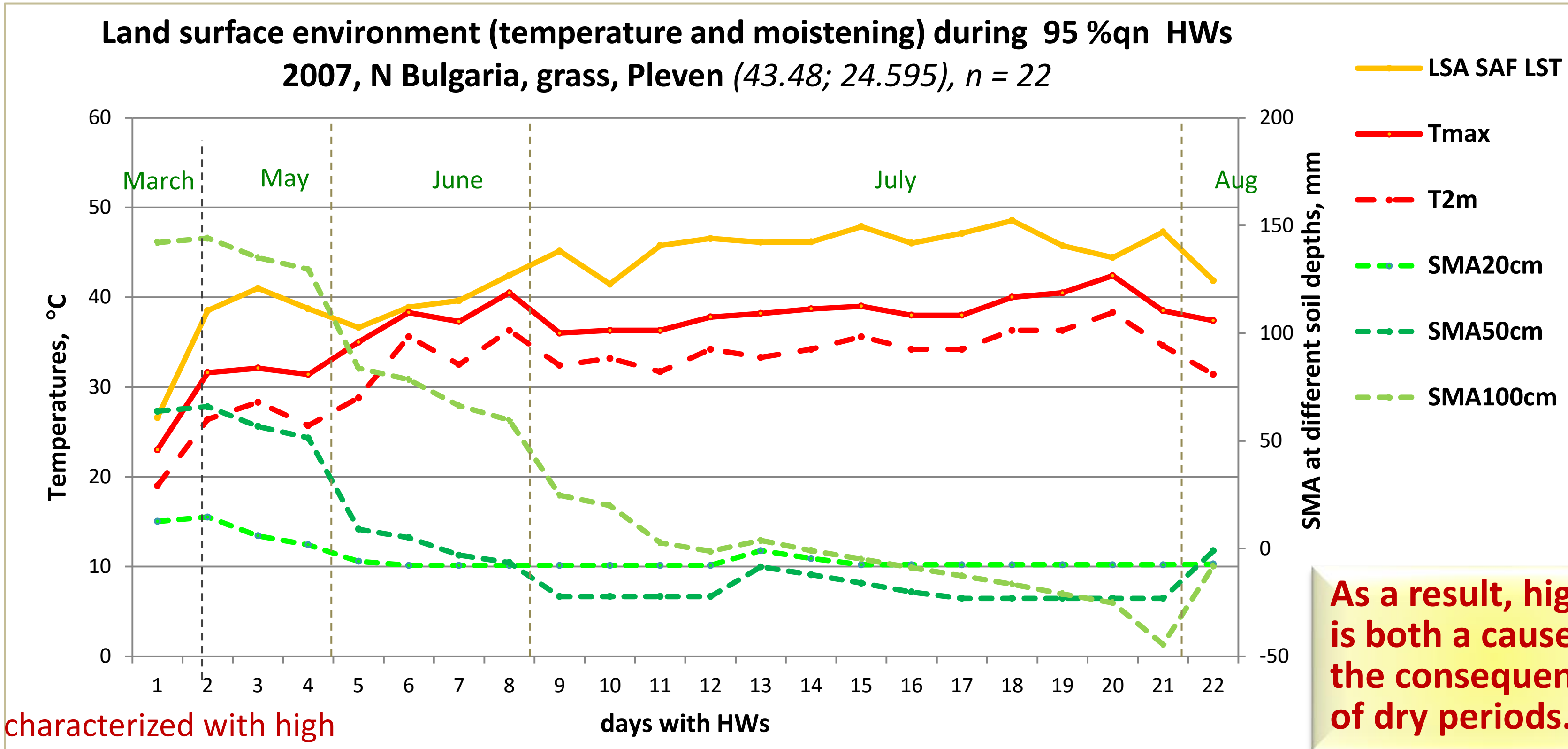
During the heat waves in 2007, FVC becomes lower, and (LST-T2m) becomes higher along with the fully exhausted SMA (compared to 2012).



ET decreases along to the (LST-T2m) increase.

The evolution is driven by the land-air temperature difference and vegetation characteristics (FVC, ET). Land surface state is modulated by the site-specific microclimate and vegetation characteristics.

Land surface state evolution during extreme fire activity in July 2007, E-Mediterranean



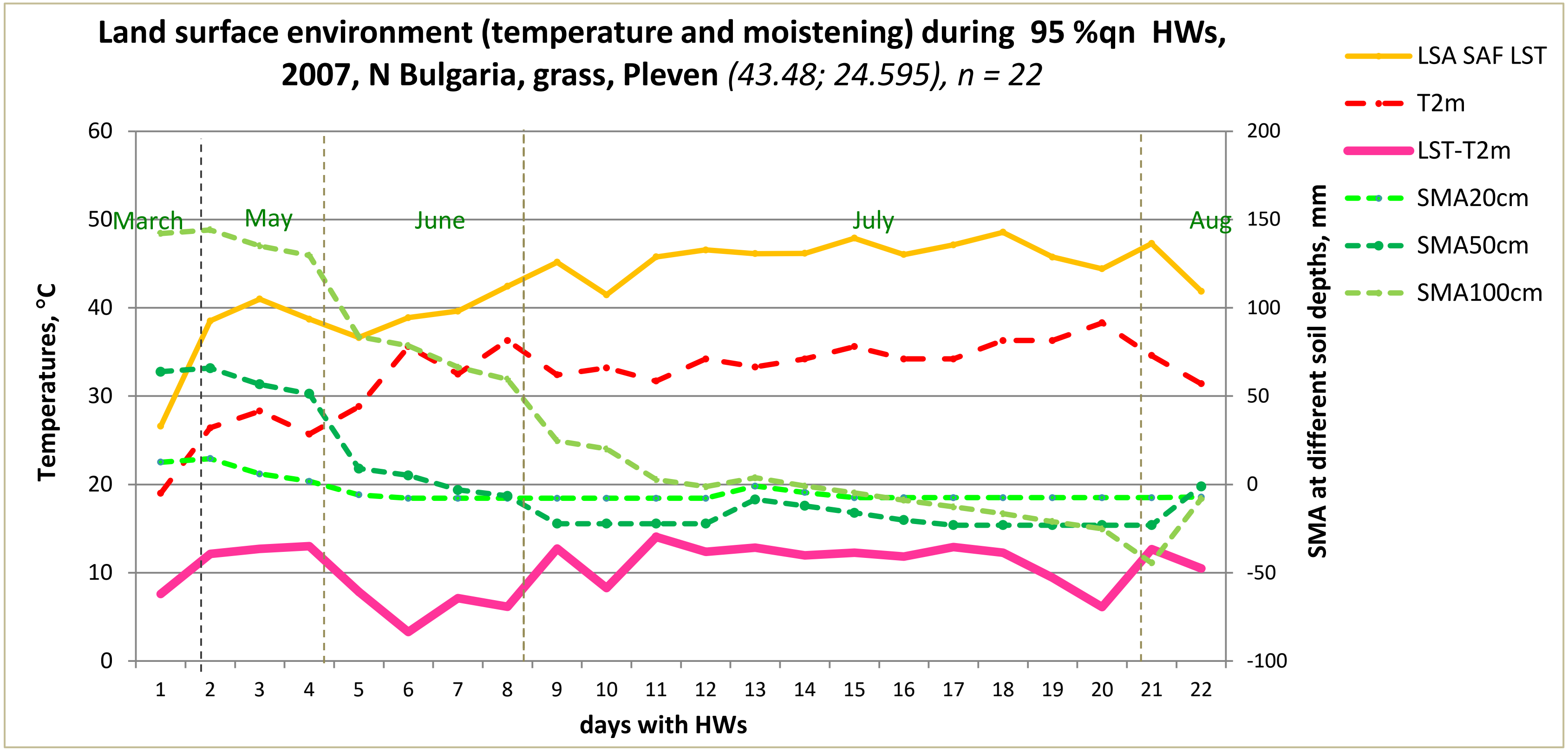
As a result, high Ts is both a cause and the consequence of dry periods.

2007 is characterized with high temperatures and records, enhanced fire risk, a peak of fire activity, being the second in ranking (after 2000).

Soil moistening characterized by SMA during 95 %qn HW episodes of 2007 along with temperature environment.

- Steadily depletion of SMA along root zone with increasing LST, Tmax, T2m.
- The SM decrease (in conditions of meteorological drought) leads to SMA depletion and reduced evaporative cooling of the land surface, which is accompanied by steadily increase of LST.

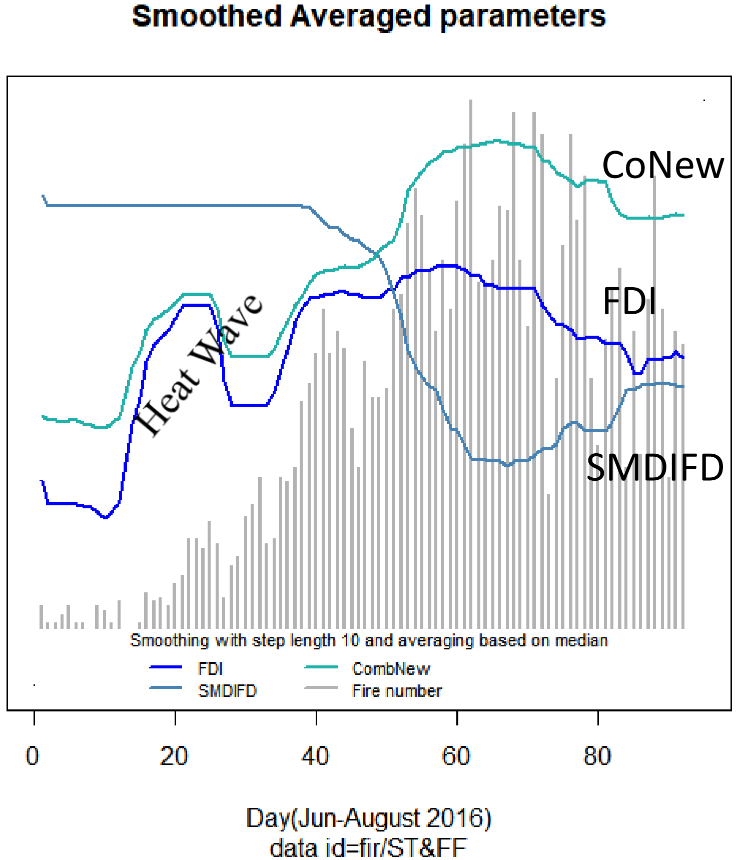
Land surface state evolution during extreme fire activity in July 2007, E-Mediterranean



The quantification of land surface state is performed *via* the blended parameter 0900 UTC (LSA SAF LST-T2m) (*magenta*) during HW episodes in spring (March, May), in summer (June, July, August) of 2007

The skin-air temperature difference during periods of HWs has a definite course depending on: season (e.g. land cover developed), SMA and its depletion along the root zone depth.

3. Fire risk forecast: Significance of land surface state impact



Smoothed averaged course of FDI, SMDIFD, CoNew FRIs along with fire activity (grey bars) June-August of 2016

To characterize dynamics of fire risk in late spring and summer, the performance of three types of Fire Risk Indexes (FRIs) are compared:

○ LSASAF FRM (*based on FWI*)

○ Fire Danger Index (FDI), the new version of FRM product

○ SMDIFD (*based on Soil Moisture Deficit*);

○ Complex New (*based on FDI & SMDIFD*).

The performance of FRIs is evaluated on the background of observed fire activity:

○ Increased fire activity is related to enhanced fire risk according *CoNew and SMDIFD (*the higher fire activity the lower *SMDIFD)*.

○ FDI is almost similar at heat waves in spring and during maximum of fire activity in August.

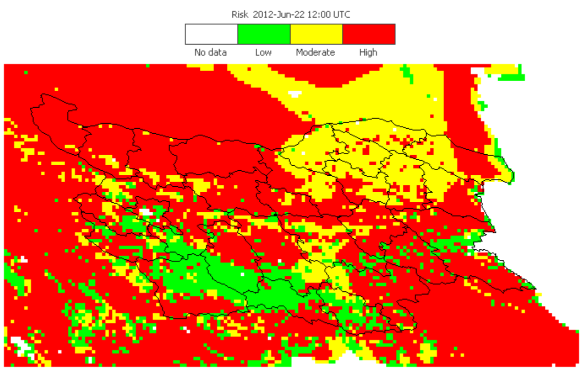
Assessment of fire weather risk alone is not enough for accurate fire risk forecast. It calls for land surface state analyses.

Stoyanova et al., 2018

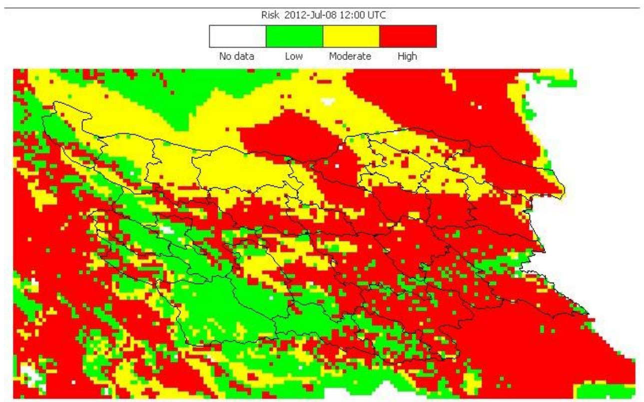
Diagnosiss of fire weather conditions

Fire weather index as a measure of Meteorological Fire Risk
LSA SAF Fire Risk Map /FRM/

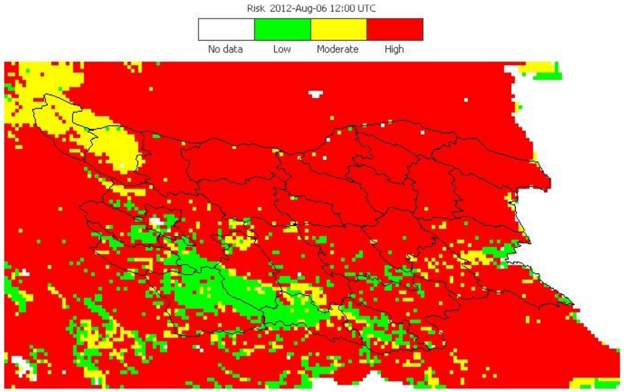
Not much difference of FRM in HW from June to August



22 June 2012



8 July 2012



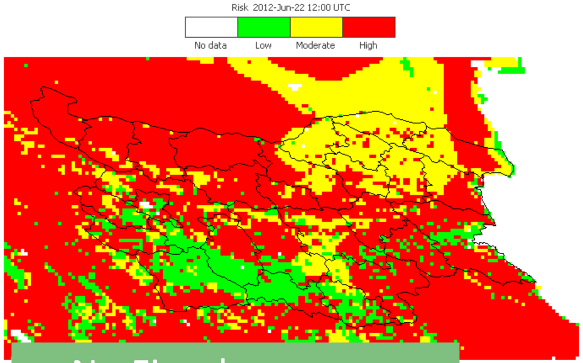
6 August 2012

15-23 Jun 9-19 Jul 3-8 Aug 2012

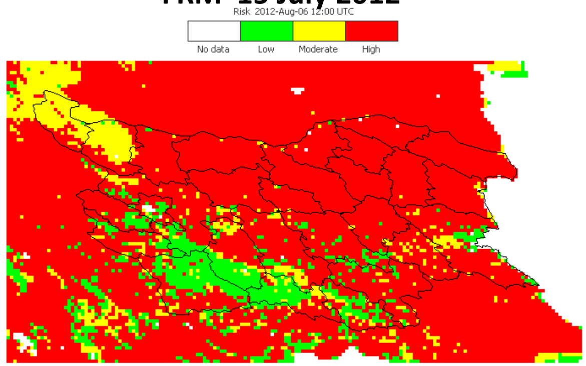
Periods of heat weaves (HW) over Bulgaria
(Eastern Mediterranean) during the summer of 2012

Diagnosis of vegetation dryness and fire weather conditions

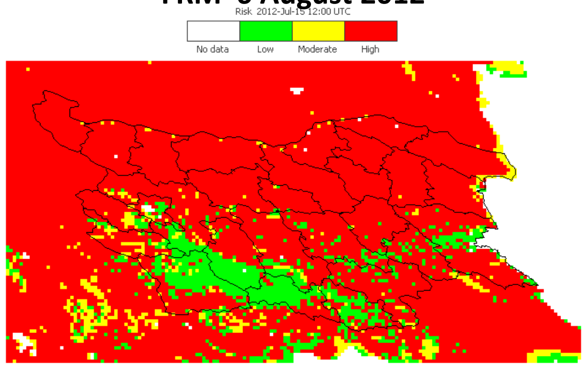
FRM 22 June 2012



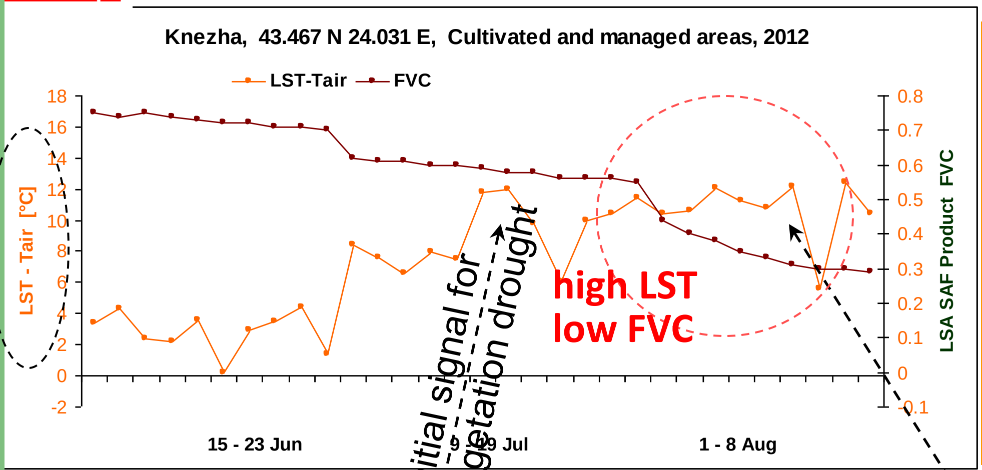
FRM 15 July 2012



FRM 6 August 2012



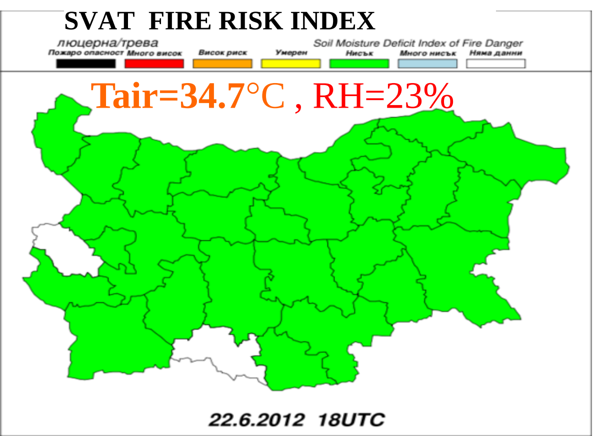
- No Fire danger according to SVAT model-derived Fire Risk Index, SMDIFD.
- MSG data do not provide signals for vegetation drought: FVC > 0.7.
- ***No forest fires***

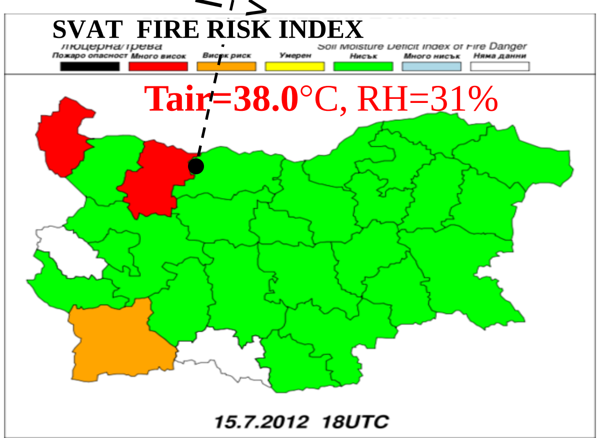


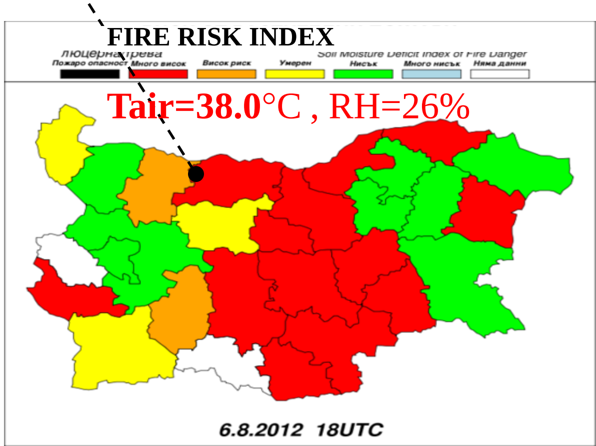
6 August 2012

- The high fire risk in FRM is confirmed by the SMDIFD.
- MSG data give widespread persistent signals for vegetation water stress:
- FVC decreasing ~ 0.3
- LST increases to 50.2°C

9 forest fires reported.







Land Surface impact on fire risk

Combined assessment of terrestrial drought and atmospheric conditions for efficient fire risk forecast

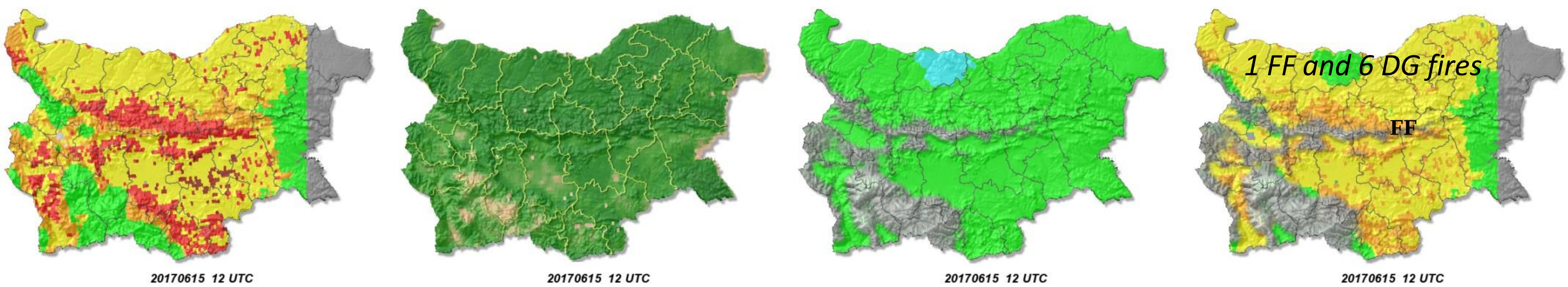
- Fire risk in Mediterranean is strongly linked to the land-atmosphere coupling processes.
- For improving diagnoses and forecast of wild/forest fires risk it is essential, the use of information for both:
  - meteorological conditions and
  - soil moisture deficit (SMD) in the root zone.
- A Complex Fire Risk Indexes (Complex FRI) for risk rating is recommended to combine the effect from both media – atmosphere and land surface.
- Additionally the vegetation state can be characterized by the LSA SAF daily (FVC) product. Increased fire risk is often related to fire occurrence at dry grass (DG) or forest fires (FF), confirmed by National fire data-base.

Stoyanova et al., 2018

Examples of land surface state impact on fire risk

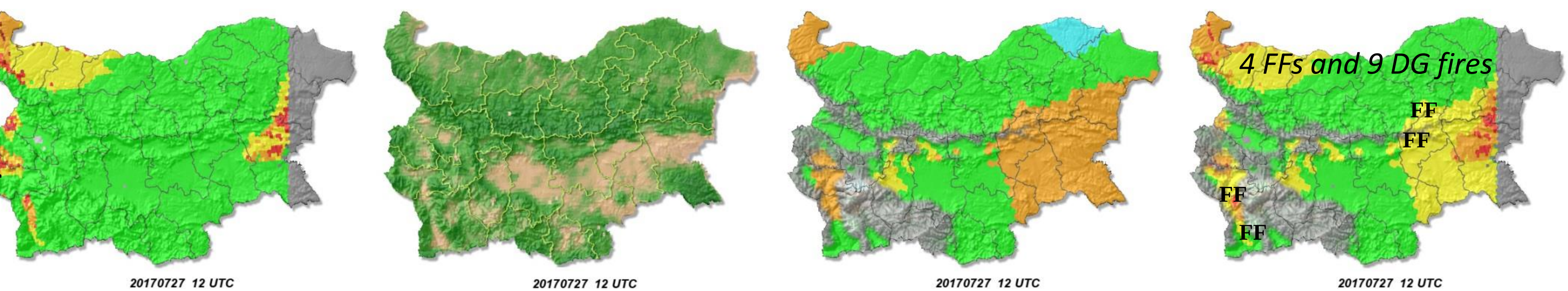
FDI | FVC | SMDIFD | Complex FRI

June 2017

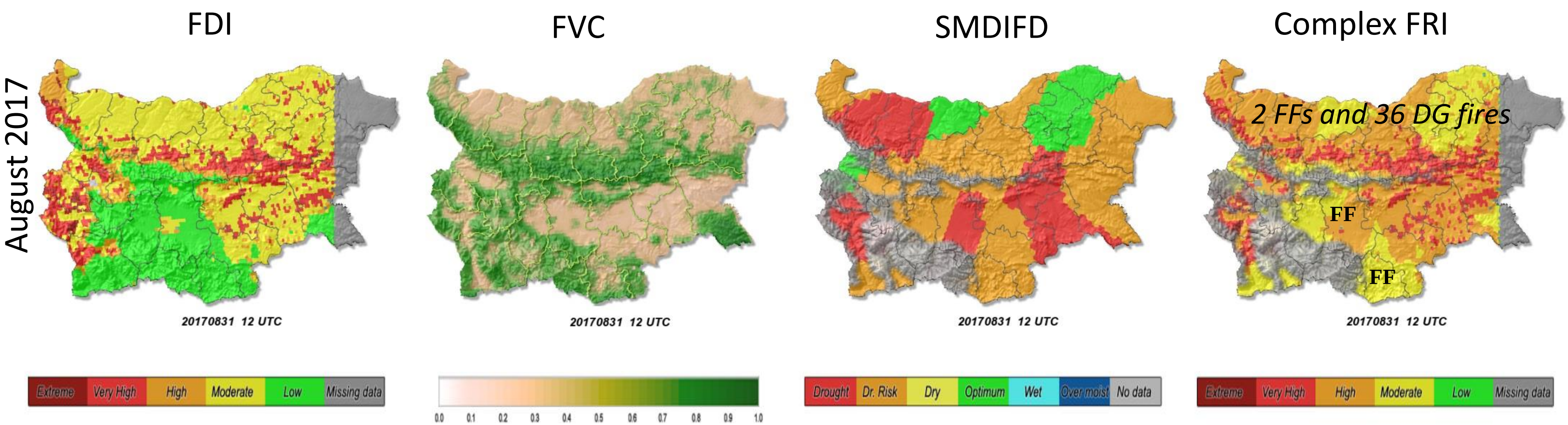


Because of heat waves meteorological fire risk increases according to FDI. FVC indicates fully covered land surface, there is optimal soil moistening and a low SMDIFD. The Complex FRI provides more realistic assessment: Lower risk that corresponds to the actual situation of a very small (2ha) forest fires FF and small dry grass DG burning.

July 2017



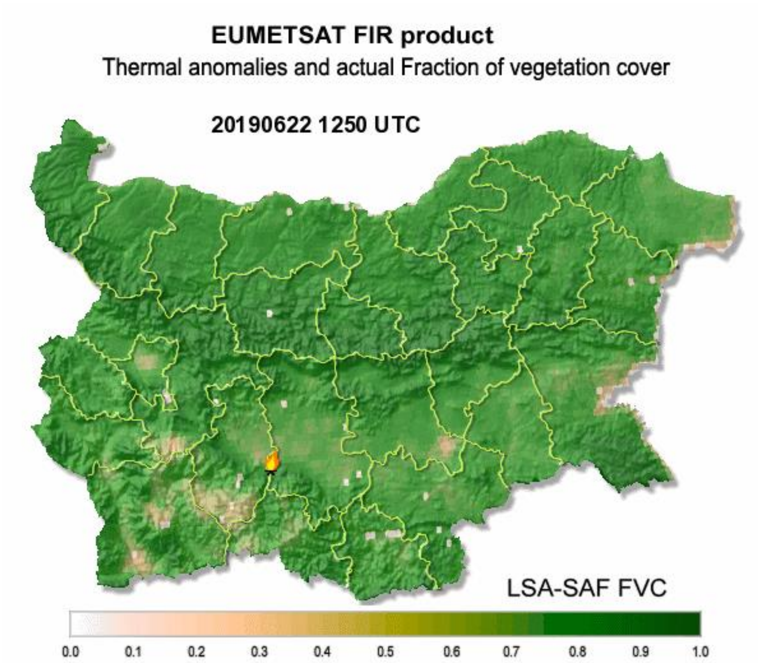
FDI is ‘green’ over the most part of the country, FVC starts to decline and SMD increases in some regions; this is reflected by a higher risk at these locations according SMDIFD, and a higher Complex FRI. There is an increased fire occurrence on these locations.

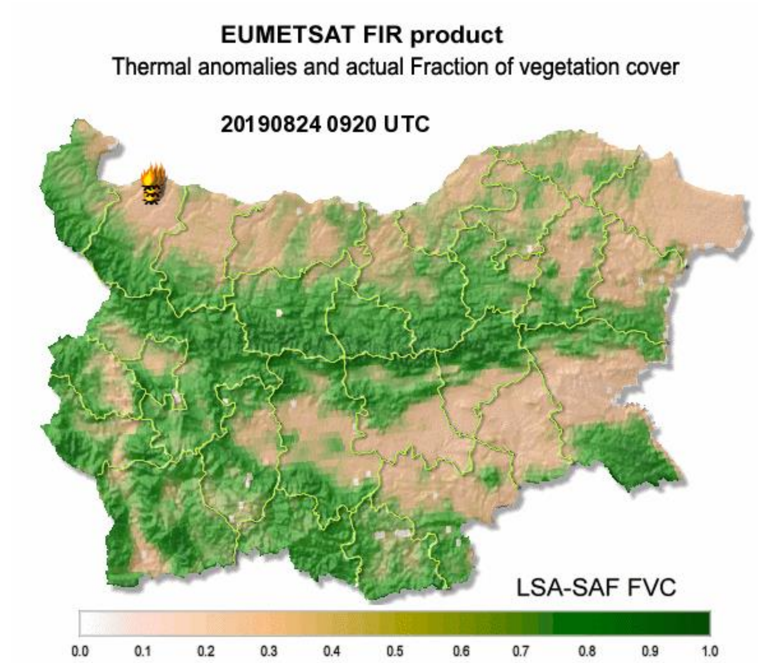


In August, drought becomes severe , FVC continue to decline, SMDIFD is increasing for great part of the country; even in case of low meteorological fire risk (‘green’ FDI in south-western part) there is an increased Complex FRI and a lot of fires.

Stoyanova et al., 2018

• Advanced meteorological product of fire risk and fire detection: Vegetation state and wild fires occurrence

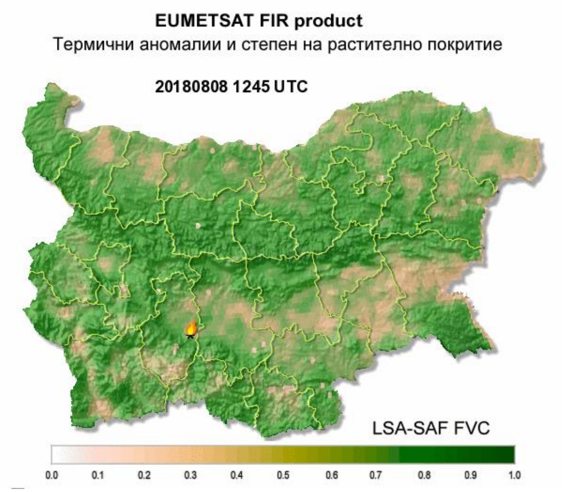




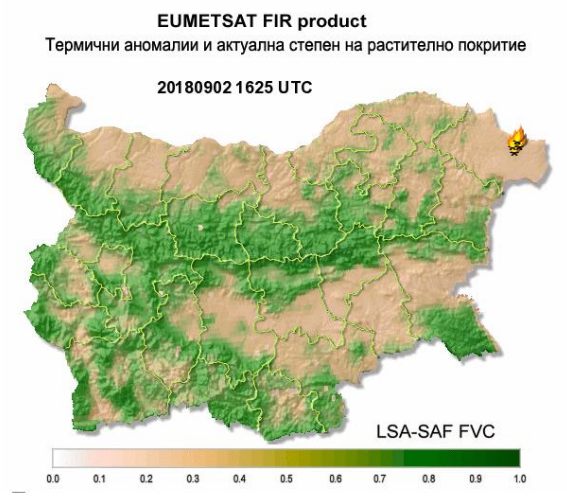
- Development, propagation and severity of a wild fire depends on LS state conditions.
- Advanced products for visualization of fire detection and LS state are recommended.
    - Along with decreases of fraction of vegetation cover the satellite detected thermal anomalies (potential wild fires) increases.

Vegetation Cover Dynamics & Wild fires

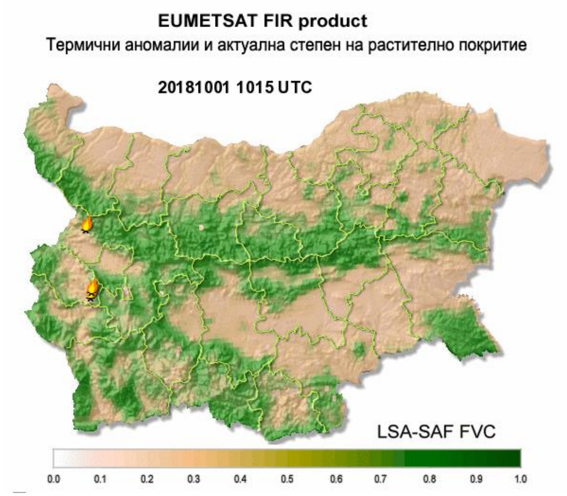
August 2018



September 2018



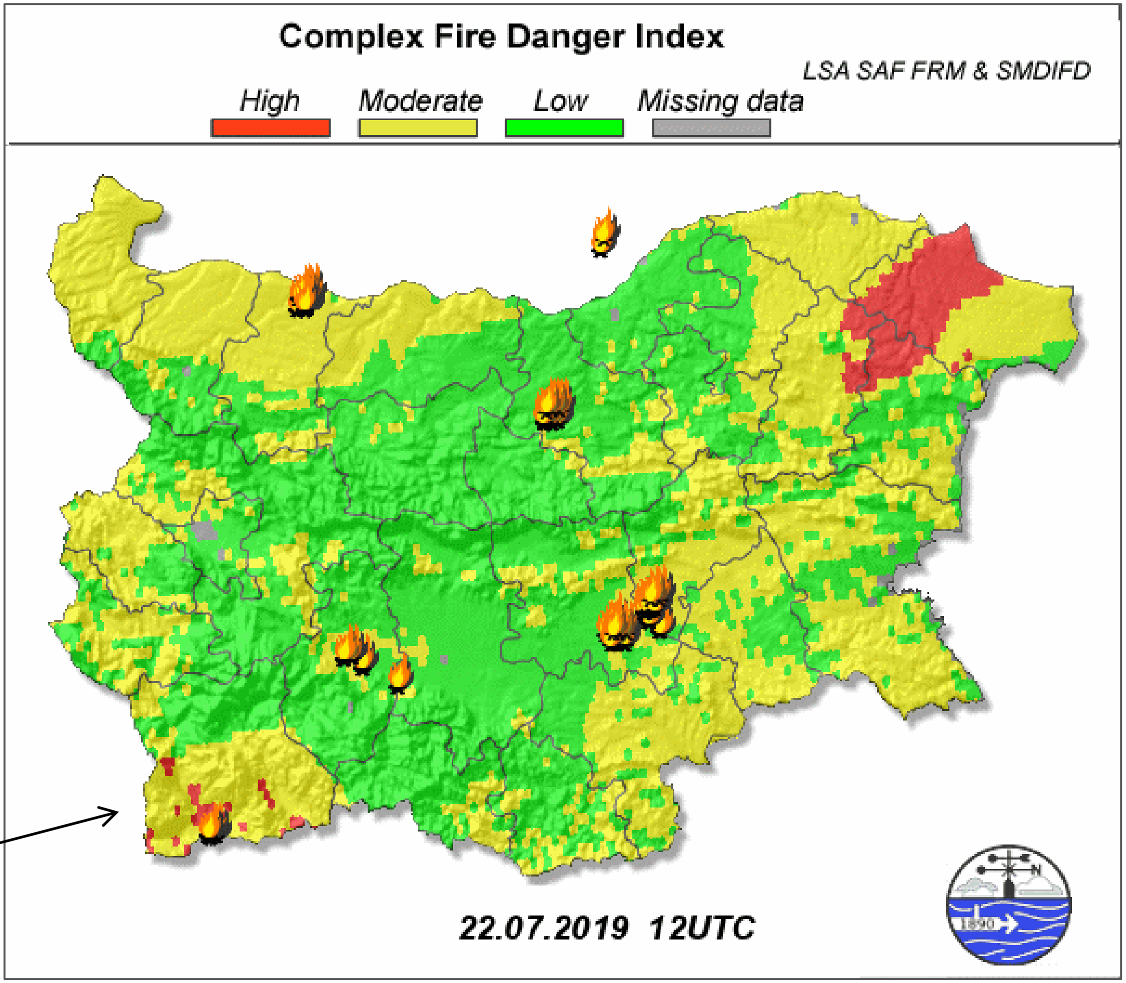
October 2018



Dry vegetation cover favors the wild fire development.

- **Advanced meteorological product of fire risk and fire detection: Complex assessment of fire risk and wild fires occurrence**

A Complex index of fire risk developed at NIMH: combines meteorological fire risk (according LSA SAF FRM, Canadian Fire Weather Warning System, https://landsaf.ipma.pt/en/products/fire-products/frm) and land surface state (according Soil Moisture Deficit Index of Fire Danger)



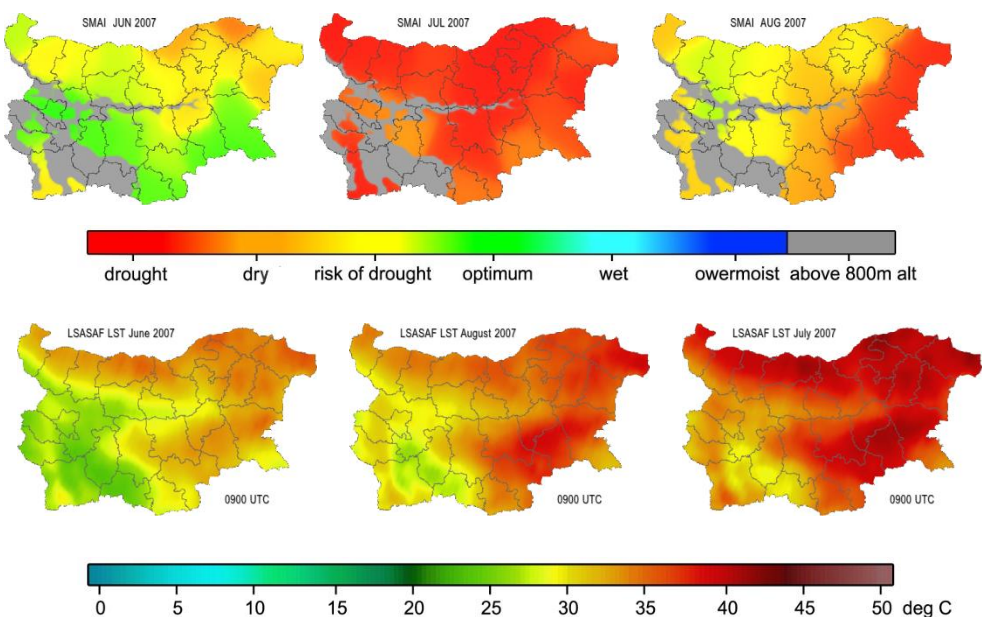
- Increased number of potential fires at environment of high fire risk.
- At environment of high fire risk fires are persistent.
- **Advanced products facilitate fire risk forecast.**

4. A climatic perspective of LSASAF products application

• Spatial-temporal variability of land surface dry anomalies

A climatic perspective means that a drought needs to be understood in terms of time and space statistics. A knowledge of the causes of a drought cannot provide an a priori description of the specific sequence of dry and wet days or any other similar daily details about a drought. Such day-to-day changes in precipitation, temperature, wind, and so forth are defined as weather, not climate.

Soil moisture availability index (SMAI) and LST



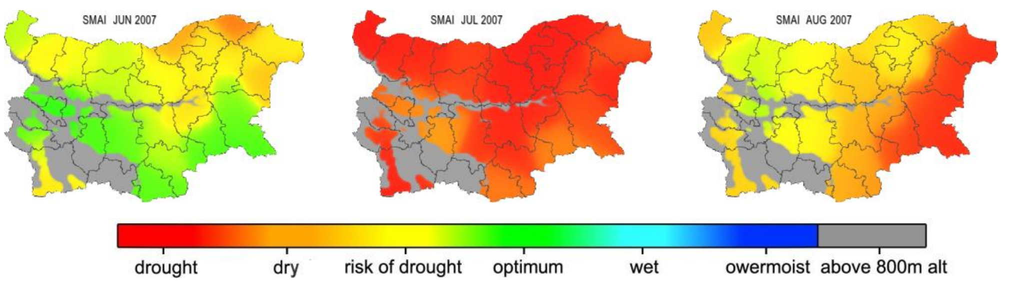
Category	SMAI color-coding
Drought	Red
Drought risk	Orange
Dry	Yellow
Optimum	Green
Wet	light blue
Overmoistening	dark blue

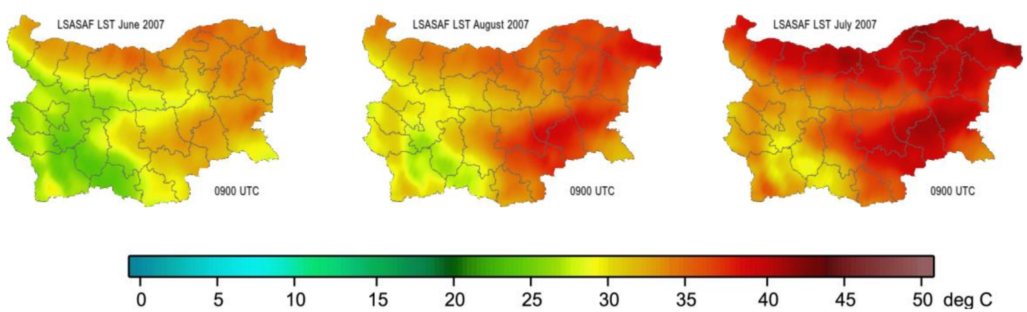
Color-coded maps for each one of SMAI and LST indexes (monthly means, 2007-2018) are developed to depict the consistency in spatial-temporal variability between the two indexes.

Spatial distribution of monthly mean SMAI over Bulgaria in 2007 for: (a) June; (b) July; (c) August, and of LSASAF LST for: (d) June; (e) July; (f) August. (2007-2018) mean values are used.

• Spatial-temporal variability of land surface dry anomalies in climatic aspect

SMAI and LST in ‘dry’ conditions





Spatial distribution of monthly mean SMAI over Bulgaria in 2007 for: (a) June; (b) July; (c) August, and of LSASAF LST for: (d) June; (e) July; (f) August. (2007-2018) mean values are used.

Biogeophysical insight by
Meteosat observations and SVAT modeling

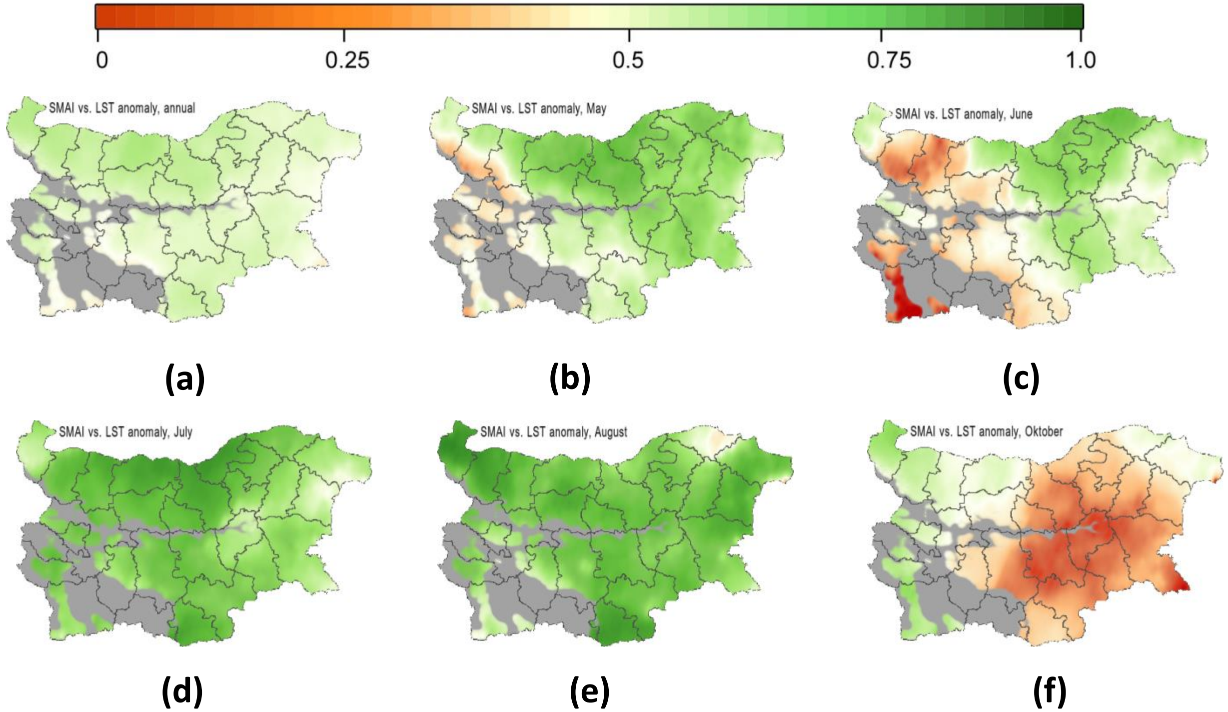
Category	SMAI color-coding
Drought	Red
Drought risk	Orange
Dry	Yellow
Optimum	Green
Wet	light blue
Overmoistening	dark blue

Qualitative comparison of the color maps reveals a good agreement between the spatial distributions of the two indexes:

- for the regions with low SMAI indicating for dry conditions, LST values according the MSG based satellite product are high.
- The lower SMAI (i.e. increased drought severity) the higher LST.

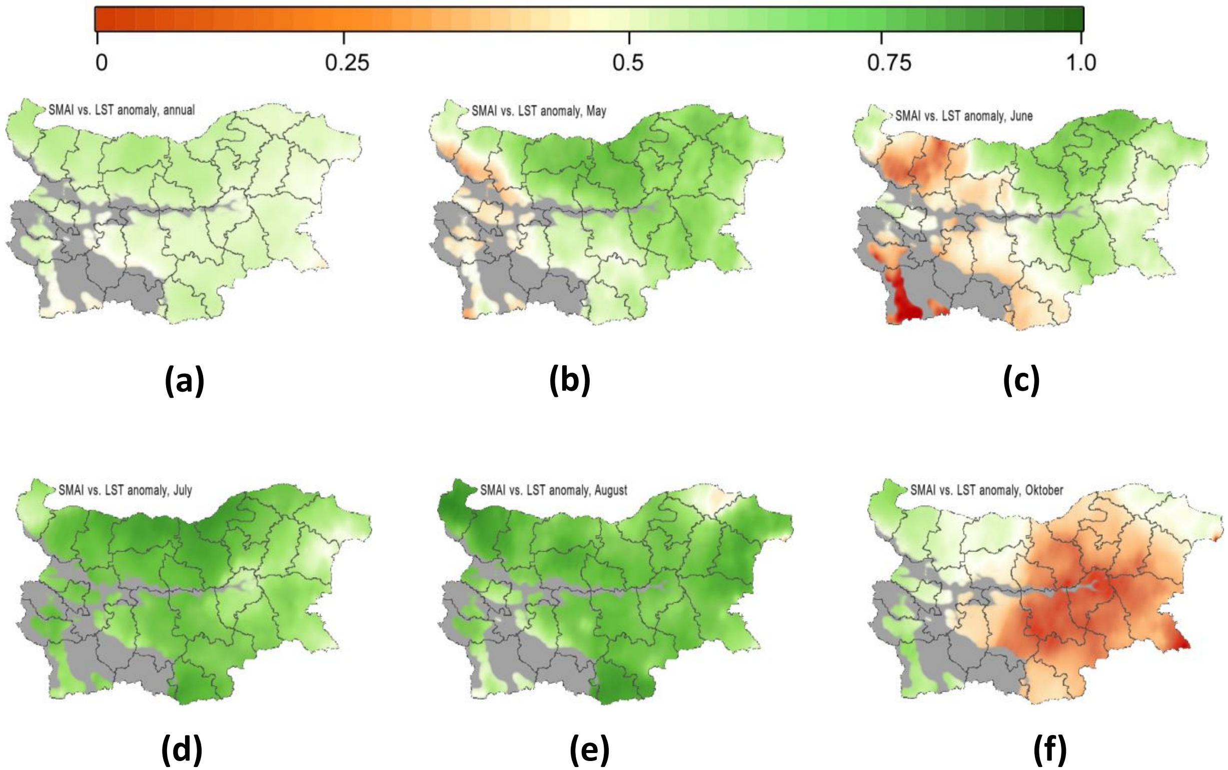
- # Spatial variability of correlation between SMAI and LST anomalies

Color-coded maps for each one of indexes anomalies (monthly/annual means) are developed to depict the consistency in spatio-temporal variability between the two indexes.



Spatial distribution over Bulgaria of correlation between the monthly mean anomalies of root zone SMAI and LSASAF LST (MSG retrieval) for: **(a)** whole growing season; **(b)** May; **(c)** June; **(d)** July; **(e)** August; **(f)** October. Anomalies are calculated towards (2007-2018) period. Mountain regions above 800 m altitude are excluded with a mask.

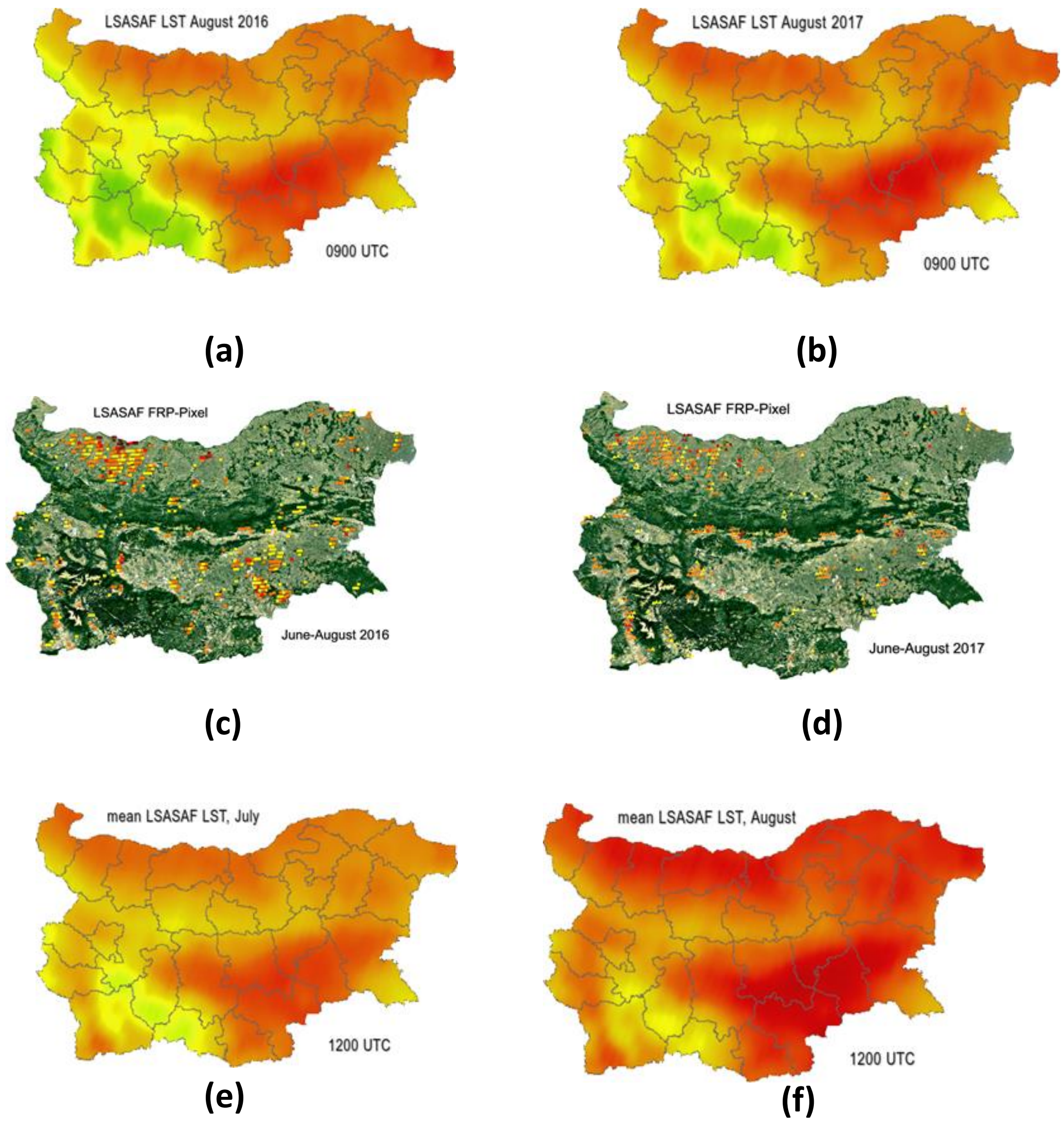
• Spatial variability of correlation between SMAI and LST anomalies



Spatial distribution over Bulgaria of correlation between the monthly mean anomalies of root zone SMAI and LSASAF LST (MSG retrieval) for: **(a)** whole growing season; **(b)** May; **(c)** June; **(d)** July; **(e)** August; **(f)** October. Anomalies are calculated towards (2007-2018) period. Mountain regions above 800 m altitude are excluded with a mask.

- On a mean annual bases **(a)** the increasing dry anomalies are related to increase of land surface temperature anomalies. The color map indicates correlations above moderate, r = -0.45 on mean annual bases.
- A strong correlation between the anomalies of the two indexes in July and August **(d), (e)** (coefficients mostly around --0.8, maximum -0.84).
- The behavior of LST closely corresponds to the drought severity as indicated by SMAI for the whole country, the lower SMAI, the higher LST.

• Sensitivity comparative analyses of drought related fire activity



- Fires in Mediterranean are mainly caused by human activities related to agricultural practices.
- In this relation identification of regions most vulnerable to biomass burning is of importance regarding some prevention activities.
- MSG LST product very well indicates the most sensitive areas to wild fires: Large number of fire detections in the northwestern, southwestern and southeastern parts of Bulgaria correspond to areas of highest LST.

Land surface state and probable fire occurrence: Monthly mean LSASAF LST 0900 UTC for: **(a)** August 2016; **(b)** August 2017. Accumulated thermal anomalies detections by LSA SAF FRP-Pixel product for: **(c)** June-August 2016; **(d)** June-August 2017. Monthly mean (2007-2018) LSASAF LST 1200 UTC values for: **(e)** July; **(f)** August.