DROUGHT MONITORING IN REGIONS WITH STRONG LAND-ATMOSPHERE COUPLING USING METEOSAT SAF

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8th SALGEE-LSASAF User Workshop
"Monitoring Drought Impacts on Vegetation & Feedback "
25 November 2024, Darmstadt, Germany

SALGEE

Drought monitoring in regions with strong land-atmosphere coupling using METEOSAT SAF

SAF products in use: Research, Applications, Operational use – Drought Dynamics

Outline

1. Drought as a complex high impact weather event
2. Land-atmosphere coupling: Vegetation as mediator of cause-consequence relations
3. Drought dynamics parameters
4. Research & Applications
5. Operational use

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1. Drought as a complex high impact weather event

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.

https://appliedsciences.nasa.gov/sites/default/files/2020-11/Drought_Part1.pdf

Types of Droughts

All droughts originate from "below normal" precipitation

- Meteorological Drought
- Agricultural Drought / Ecological
- Hydrological Drought
- Socioeconomic Drought

Duration

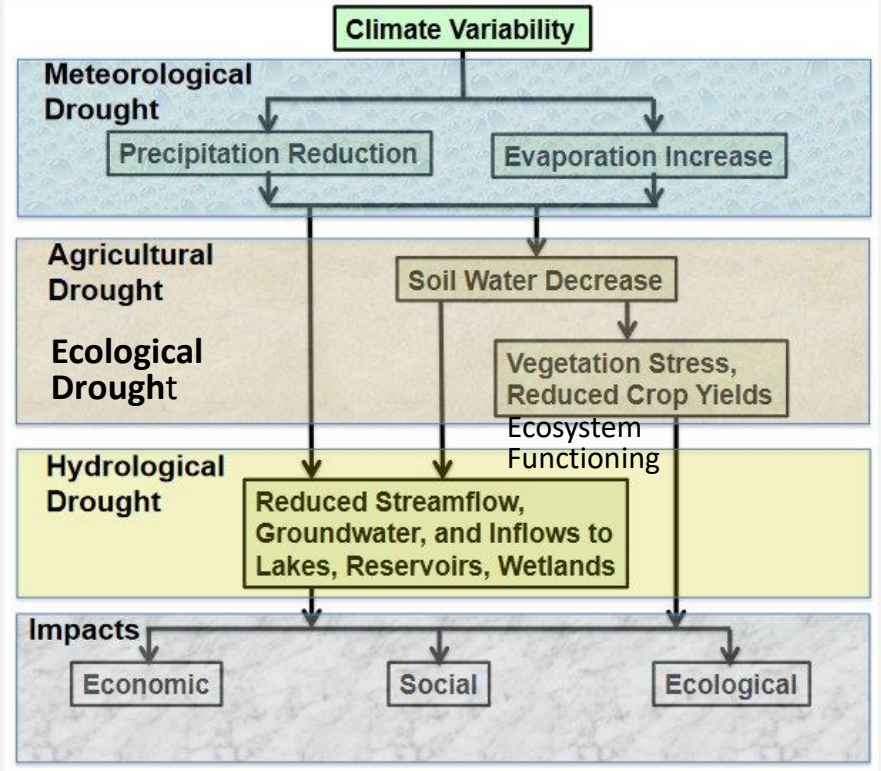


Image Credit: National Drought Mitigation Center

Wilhite, D.A.; and M.H. Glantz. 1985. Understanding the Drought Phenomenon: The Role of Definitions. *Water International* 10(3):111–120

Figure: Mehta, V.M., 2017: Natural Decadal Climate Variability: Societal Impacts. CRC Press, Boca Raton, Florida, 326 pp.

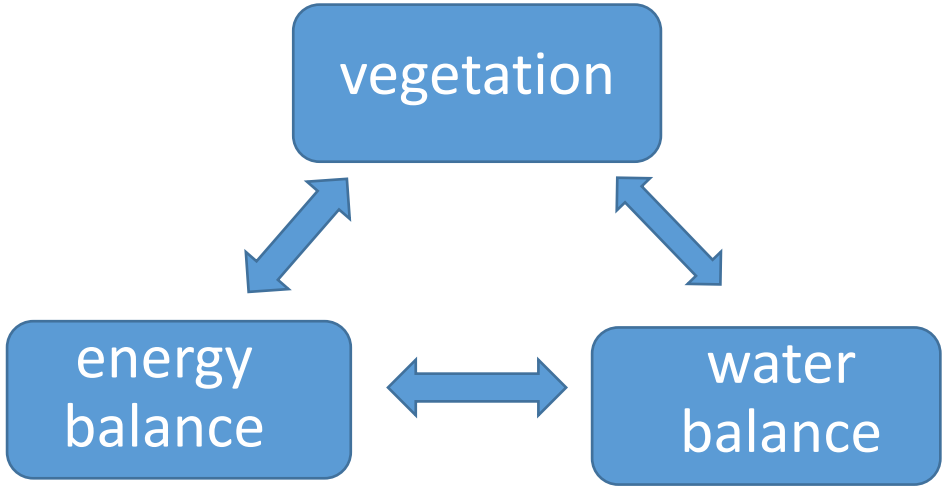
National Aeronautics and Space Administration

Applied Remote Sensing Training Program

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.

2. Land-atmosphere coupling: Vegetation as mediator of cause-consequence relations

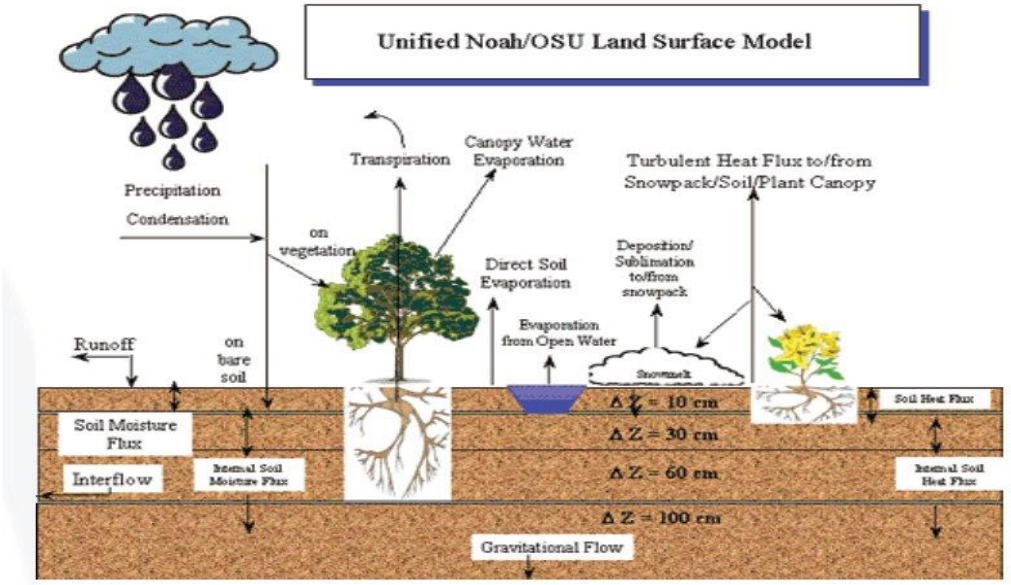
❑ 'Dry' anomaly impact on biogeophysical cycling



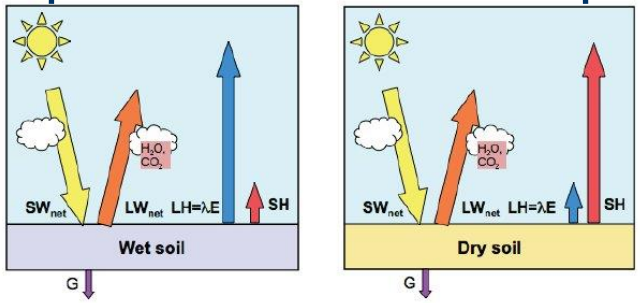
✓ Soil–vegetation–atmosphere feedbacks are particularly important in water-limited ecosystems.

❑ land-atmosphere interaction process

Complex nature of land-atmosphere interaction driven by various biophysical and biochemical processes.



❑ Drought & Heat waves: produce high impact weather event



Regions where SM most impacts the atmosphere are transitional zones between dry and wet climates (*Koster et al., 2004*).

❑ "hot spots" of land-atmosphere coupling

→ For present climate: **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.

3. Drought dynamics parameters

The projected increase in extreme events and temperature will significantly influence the hydrological regimes

Drought Monitoring with Vegetation

Physiological & Physical signals of vegetation water stress

- Soil Moisture Anomalies (*water availability indicator*)
- Evapotranspiration (*water use indicator*)
- Land Surface Temperature (*plant water demand indicator*)
- Vegetation structural properties
- Vegetation Functioning/ Health

SAF products in use: Drought parameters should be monitored routinely to determine drought extent and impacts

RESEARCH: Numerical Analyses

Early detection of drought onset and monitoring of drought dynamics

Soil Moisture Availability, SMA

as a reference

(SVAT_bg model)

Physical analyses

spatial-temporal analyses of dry anomalies in energy & water cycle coupling

land surface state

- ✓ LSASAF LST
- ✓ LST anomaly
- ✓ H-SAF H-14, Soil Wetness Profile Index (SWI)

identification of vegetation water stress

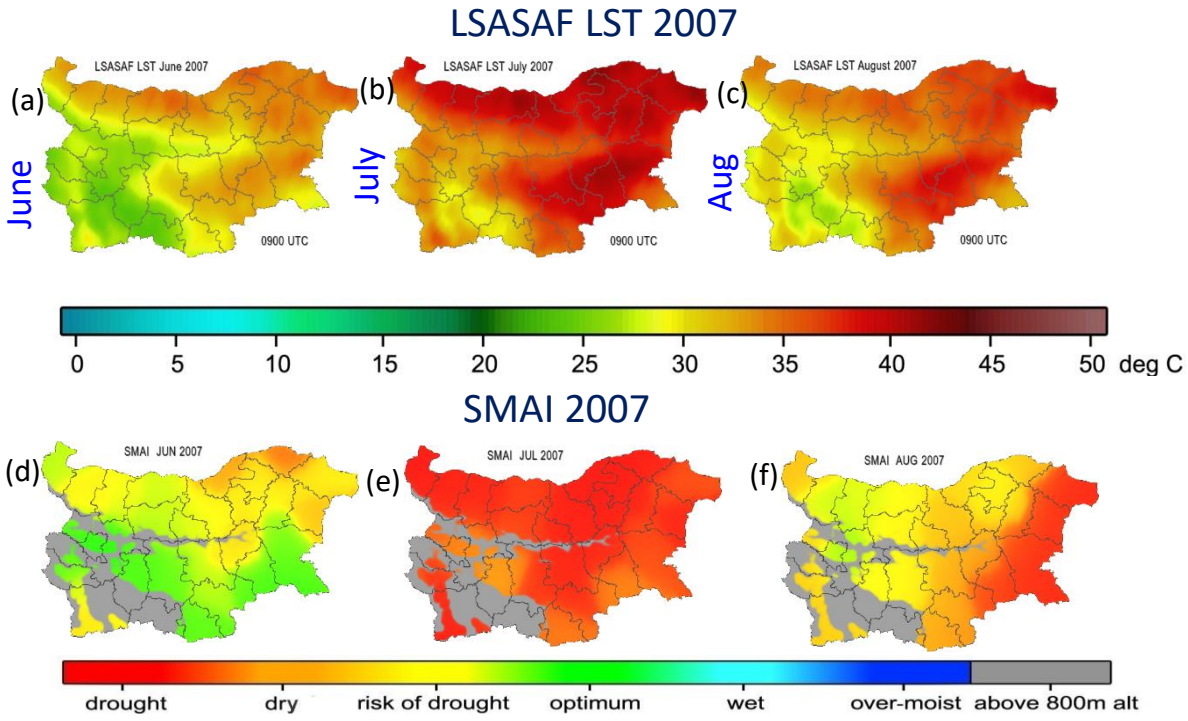
- ✓ METREF as a measure of PET (*atmosphere evaporative demand, AED*)
- ✓ DMETv.3 as a measure of AET
- ✓ (METREF-DMET) evapotranspiration deficit (ED)
- ✓ ESR (AET/PET) evapotranspiration stress ratio

Impacts assessment

4. Research & Applications

4.1. Meteosat LST as indicator of Land Surface Dry Anomalies in Climatic Aspect

- A synchronized behavior between LST and SMAI during dry spells is identified



Spatial distribution of monthly mean of LSASAF LST in 2007: (a) June;
Example: 2007 deficient precipitations from April up to the beginning of August.

Atmosphere, 2019

Region of applications:
SEE, Bulgaria, Mediterranean climate influence

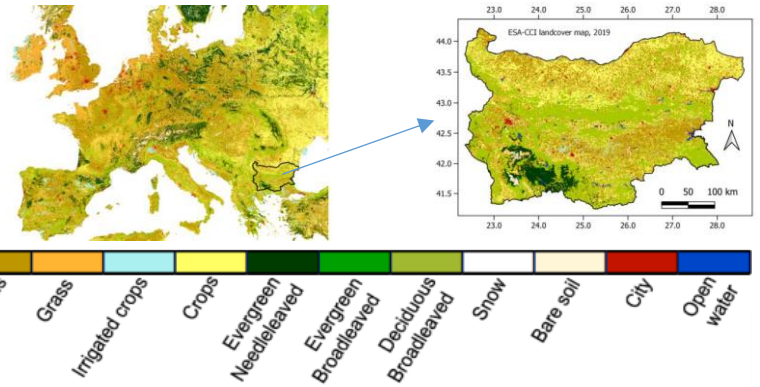
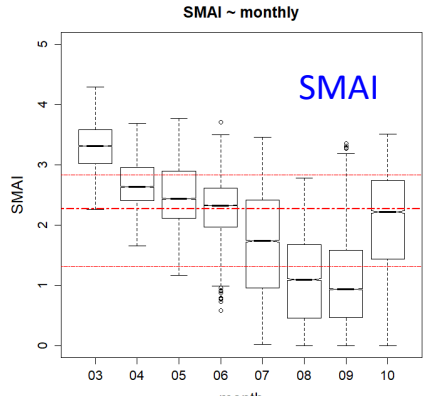
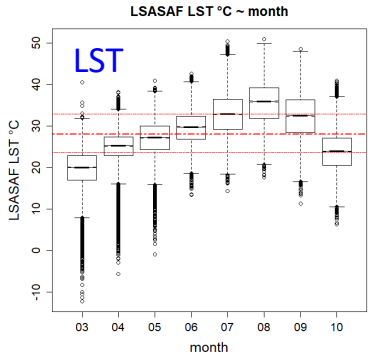


Figure 1. Target region on the background of the LC Types, ESA-CCI LC Map: a) Europe; b) Bulgaria, SE Europe.

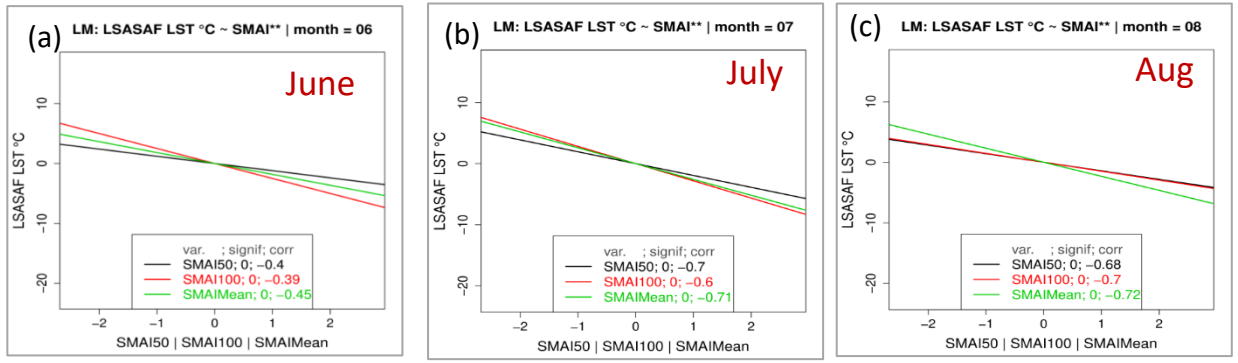
- ✓ The lower the SMAI (i.e. increased drought severity) the higher LST.
- ✓ Accumulated terrestrial drought leads to increased land surface temperature, as in July 2007.





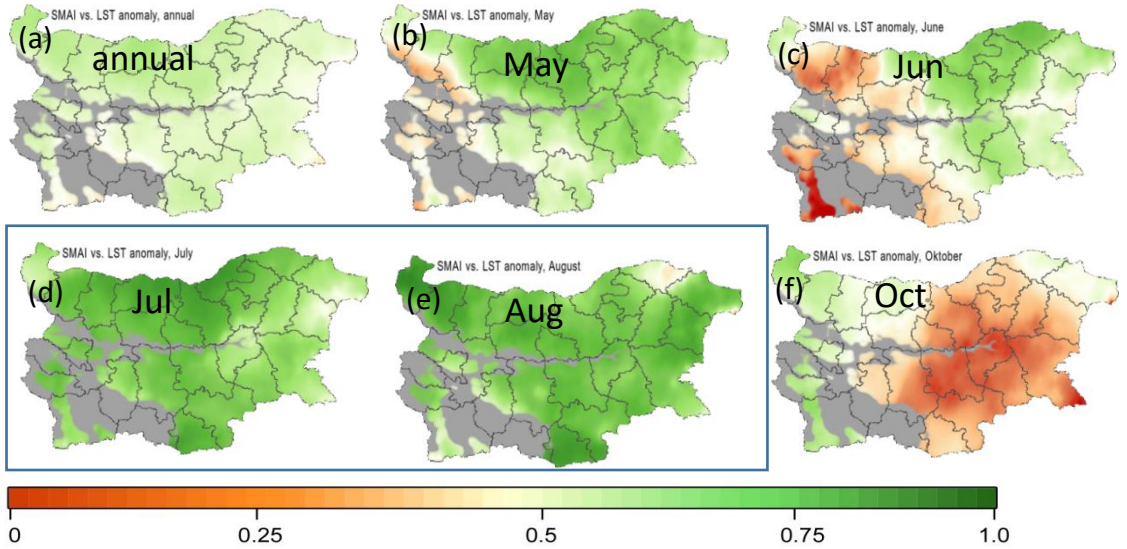
4.1. Meteosat LST as indicator of Land Surface Dry Anomalies in Climatic Aspect

❑ Land Surface Temperature positive anomalies correspond to negative soil moisture availability anomalies (*regional evaluation over Bulgaria, site-scale analyses around SYNOP stations*)



Negative linear regression models of the relationship between LSASAF LST anomalies and SMAI (for 50 cm, black; 100 cm, red; Mean, green) for: (a) June, (b) July, (c) Aug over Bulgaria. Monthly means (2007-2018).

❑ Spatial-temporal variability of correlation between LST & SMAI anomalies



Spatial distribution of correlation between the monthly mean anomalies of root zone SMAI and LSASAF LST (MSG retrieval) over Bulgaria for (a) whole growing season; (b) May; (c) June; (d) July; (e) August; (f) October. Anomalies towards (2007-2018).

Conclusion: The strong negative relationship between the anomalies of Soil Moisture Availability and Land Surface Temperature during dry periods highlights the value of LST retrievals from IR satellite observations in providing climatic information of drought occurrence and severity.

High LST is both a cause and the product of dry periods.

And mediate the evapotranspiration dynamics.

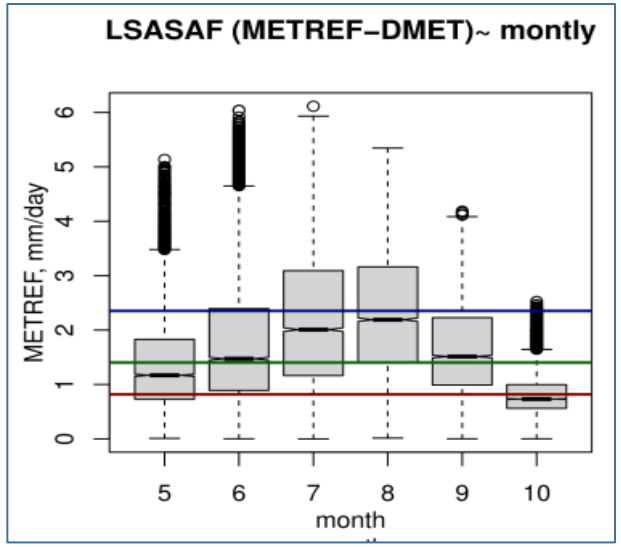
Atmosphere, 2019

4.2. Drought dynamics in terms of Evapotranspiration metric

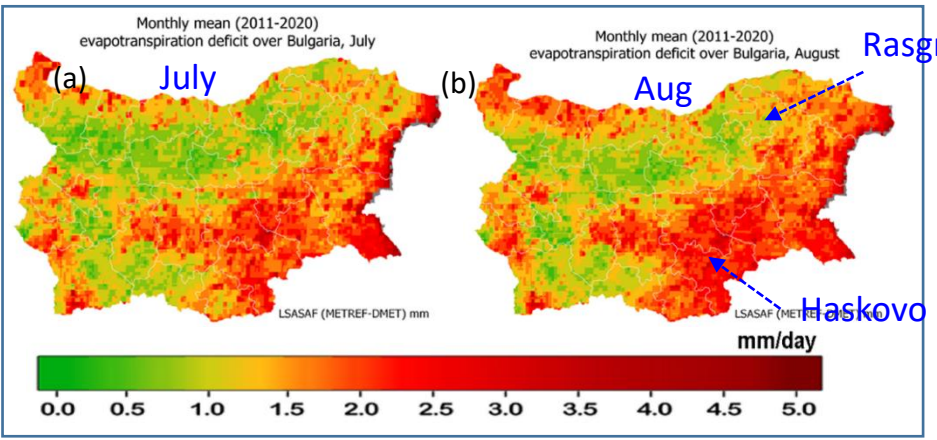
Land, 2023

❑ Evapotranspiration deficit (ED)

✓ Growing season dynamics of Meteosat derived ED (PET-AET) for the domain of Bulgaria

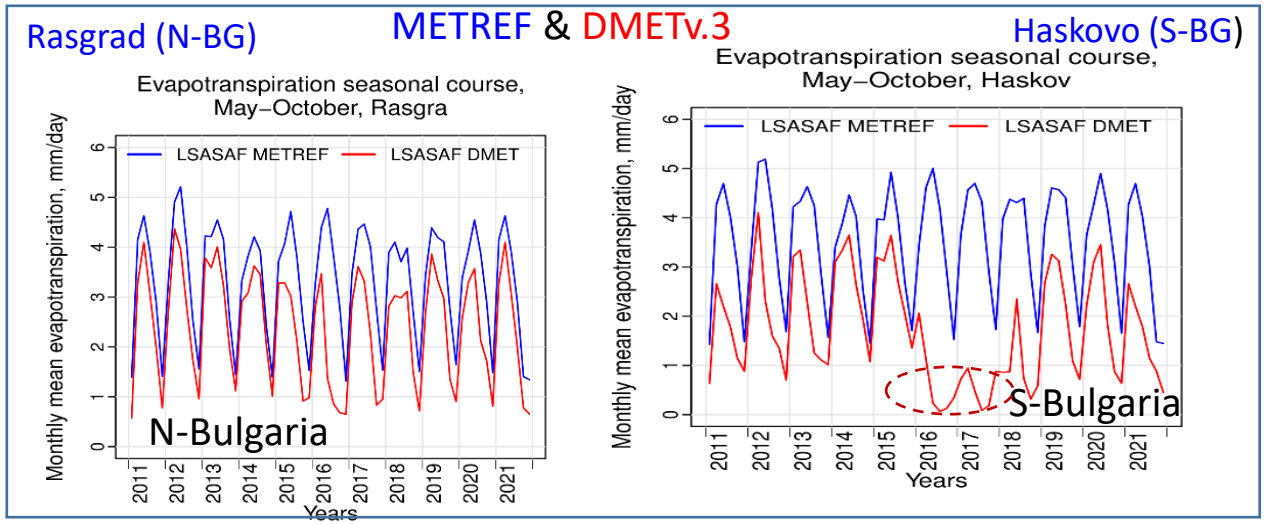


✓ Spatial-temporal distribution of the ED over Bulgaria Monthly means (2011-2020): (a) July; (b) Aug



❑ Vegetation water stress (ESR = AET/PET)

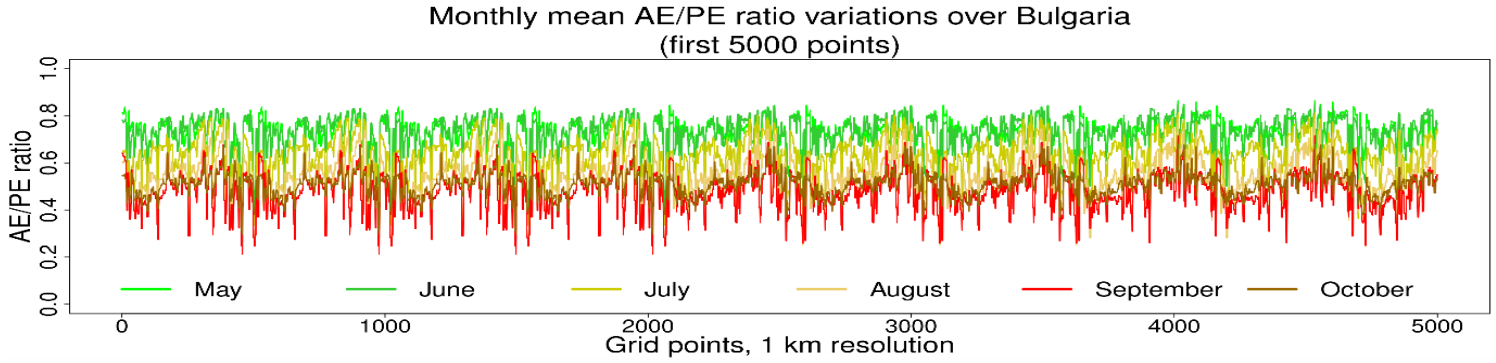
✓ Local effects on the spatial-temporal variability of PET & AET, daily basis



seasonal courses from year to year implicitly underline the role of **micrometeorological conditions** and **SM deficit.**

✓ Evolution of AET/PET ratio in line with SMA during growing season

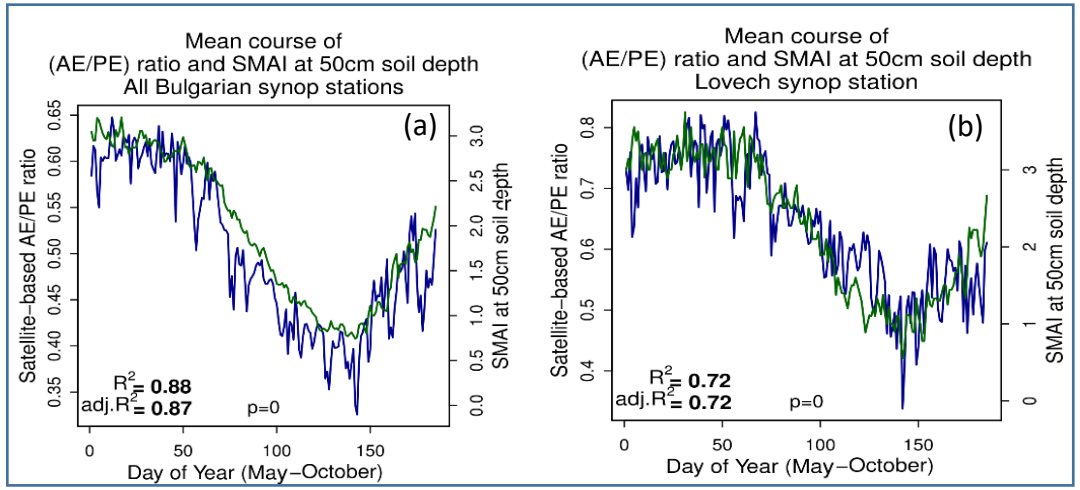
- The dynamics of satellite derived ESR from May (green) to Aug, Sep (red) indicates progressive water stress from spring to the autumn over Bulgaria
- Thus reflects vegetation physiological response during the growing season



4.2. Drought dynamics in terms of Evapotranspiration metric

❑ Vegetation water stress (ESR, AET/PET)

✓ Spatiotemporal consistency between ESR and SMA (R2 ~ 0.88 – 0.54; p=0 for SYNOP regions)



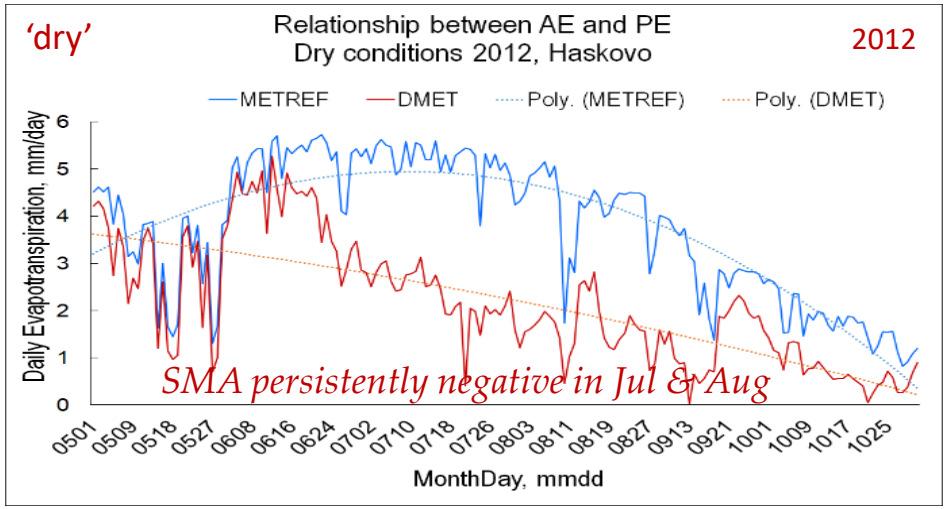
Comparison between time series (May-October) of satellite ESR (blue line) and SMAI from Bg_SVAT (green line): (a) mean from SYNOP stations in Bulgaria; (b) station in N-BG.

✓ At high SMAI (May, June), ESR ~ 0.7-0.8 and higher - ***NO vegetation water stress***

✓ At low SMAI - ***High vegetation water stress, ESR*** below 0.5 reaching 0.0

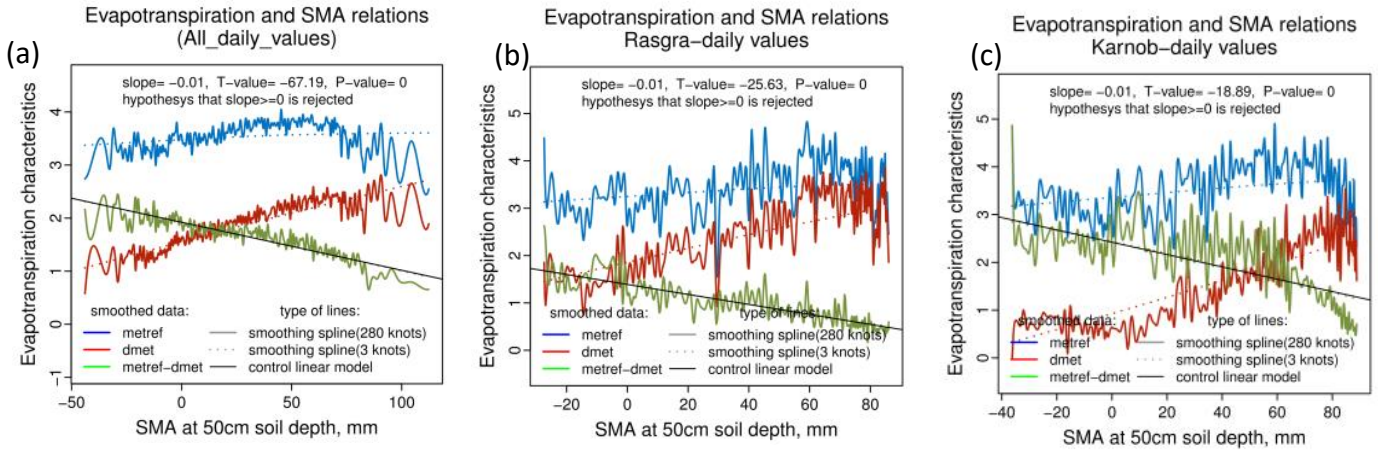
Land, 2023

✓ Complementary behaviour of regional PET-AET dependences



With surface drying and associated decrease of AET, a complementary mechanism is established to increase PET;

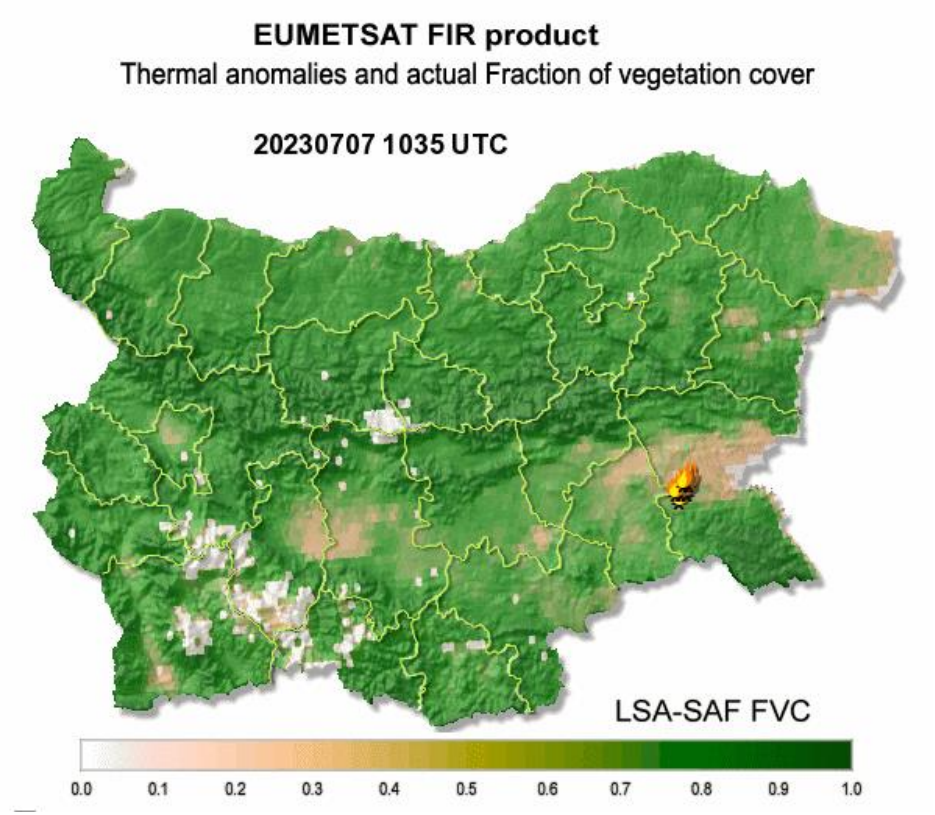
complementary relationship still in spring/early summer



The complementary relationship between PET (METREF), AET (DMETv.3) and the ED deficit (*in terms of Bouchet hypothesis*) as drought indicator for: (a) the entire Bulgaria landmass; (b) Rasgrad in NE Bulgaria; (c) Karnobat in SE Bulgaria**. Evapotranspiration deficit (green line) approximated by linear regression model (black line).**

4.3. Drought impact on vegetation structural properties

- Monitoring dynamics of fraction of vegetation cover (FVC) from space can depict the relation between drought and fire occurrence
  (superimposed thermal anomaly detected by SEVIRI MPEF FIR product)



Conclusion: Temporal and spatial dynamics of biophysical parameter FVC provides information for the changes of the amount of green vegetation distribution and thus may serve as a reference for the location and the extend of live vegetation dryness.

Since live vegetation (fuel) dryness favors wild fires occurrence and spread, operational use of LSASAF FVC product on a regional scale as a background of satellite detections of thermal anomalies can provide an instant view of biomass burning in the landscape environment.

Fires occur at areas with low FVC (0.2-0.4), mainly at low-level parts.

Published: https://lsa-saf.eumetsat.int/en/news/news/2024/06/21/vegetation-state-and-fire-occurrence-1/

4. Research & Applications

4.4. Vegetation malfunctioning

Disturbances in Conifer forest functioning, SE Bulgaria

Patch wilting of conifer forests in the lower forest belt in Bulgarian (Eastern Mediterranean) after heavy snow conditions in 2015, causing damages of trees. Broken trees are affected by disease (2016, 2017) and start to become dry due to *Corolla infections.*

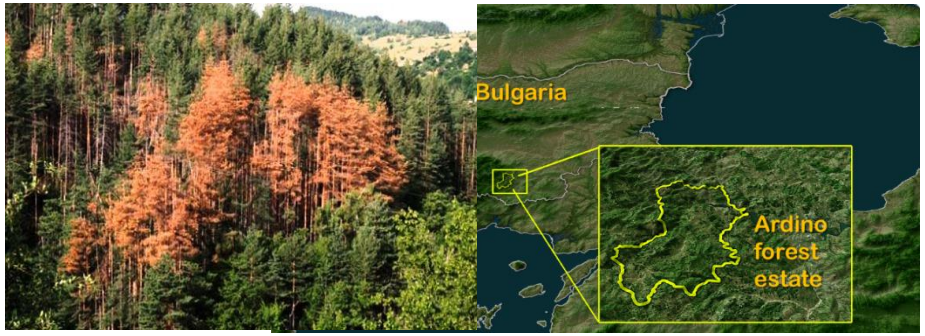
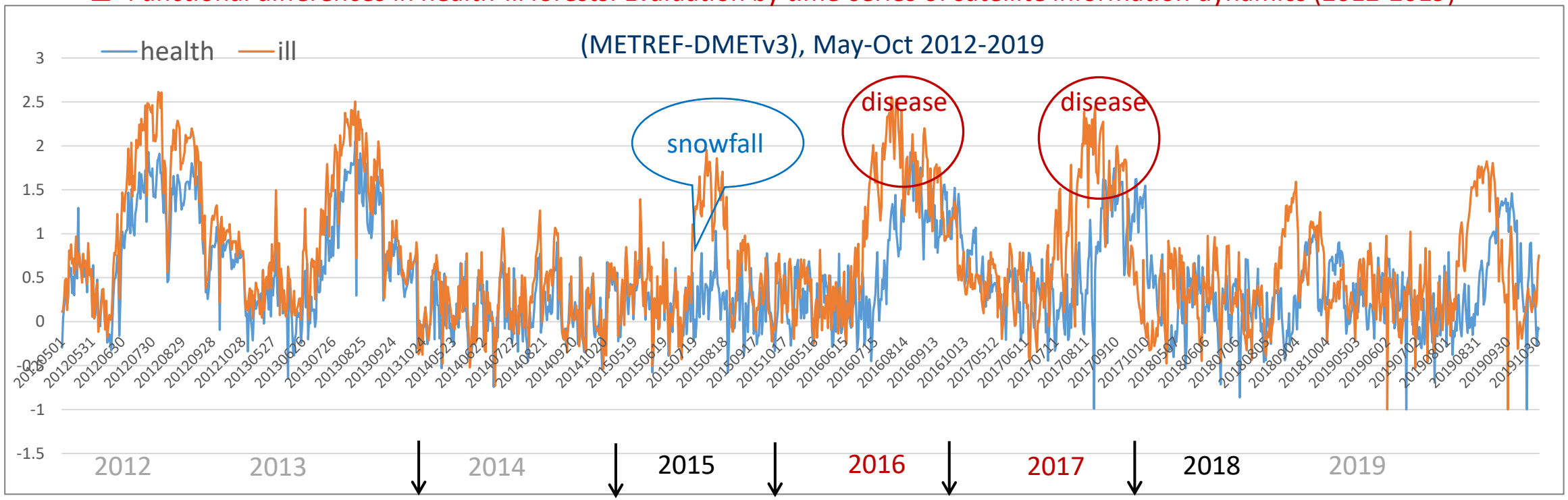


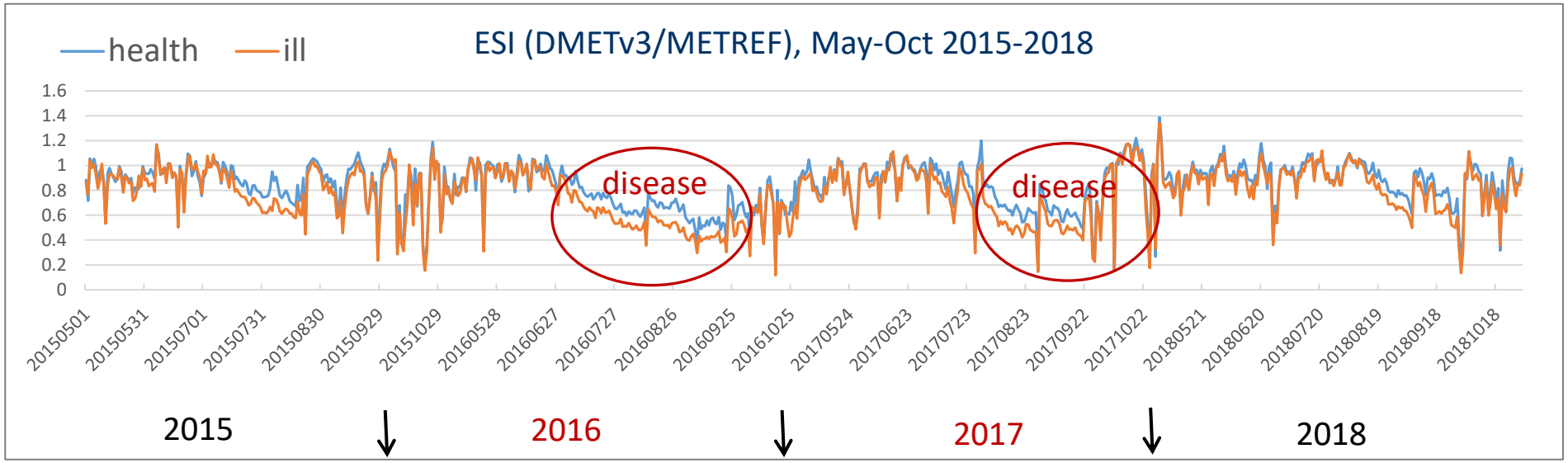
Photo of affected by disease forest is provided by State Forest Agency

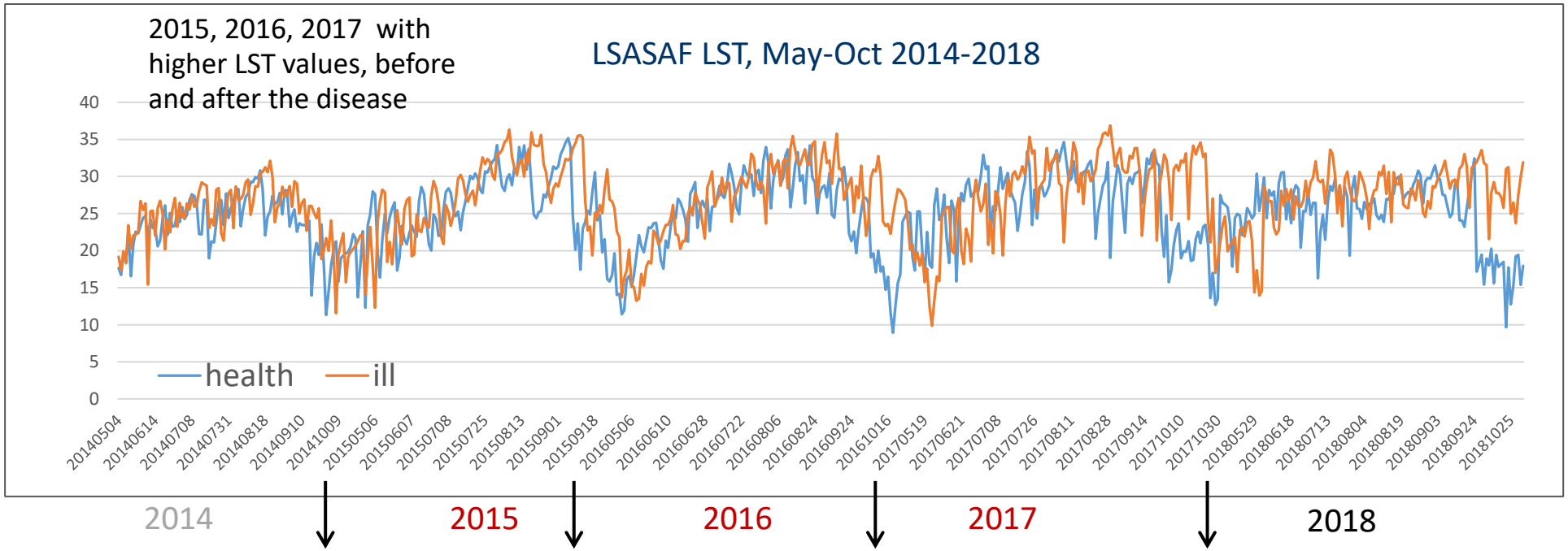
- ✓ Site scale analyses/comparison for a selected health and ill forest in the target region of Ardino
- ✓ For diagnoses: Evaluation of water stress *via* METREF & DMETv3 differences, ESI (Evapotranspiration Stress Index), LST, HSAF H-14
- ✓ Test period: before – during – after disease (2012-2019)

❑ Functional differences in health-ill forests: Evaluation by time-series of satellite information dynamics (2012-2019)



❑ Functional differences in health-ill forests: Evaluation by time-series of satellite information dynamics



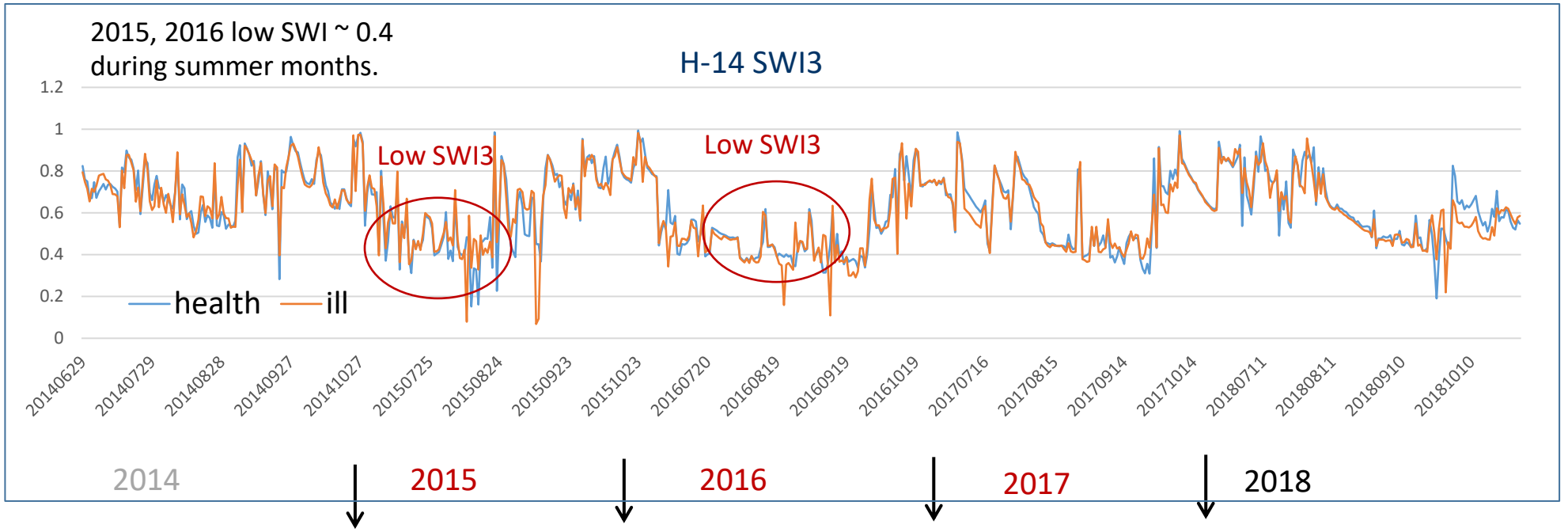


The concept adopted is applied to capture differential functional response of diseased/water stressed compared with health forest sites.

- ✓ Higher difference between METREF and DMET corresponds to a higher water stress according ESI
- ✓ Higher water stress for 2016, 2017 (Jul, Aug), i.e. during the observed *Corolla infections* attack.

- ✓ 2015, 2016, 2017 with higher LST values, before and during the disease, being higher at ill forest.

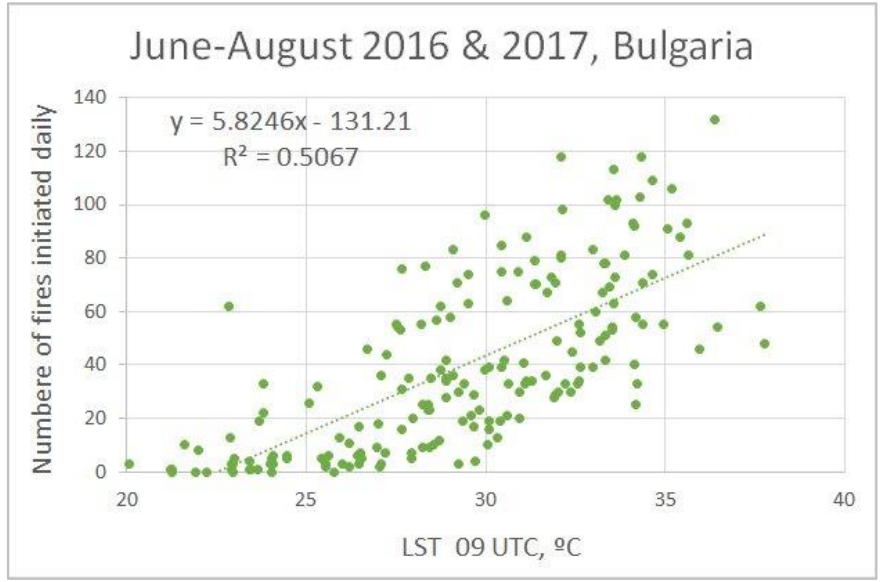
✓ Synergetic effects of decease and drought analyzed in the view of the H-SAF H-14 root zone Soil Wetness Profile Index (SWI) dynamics

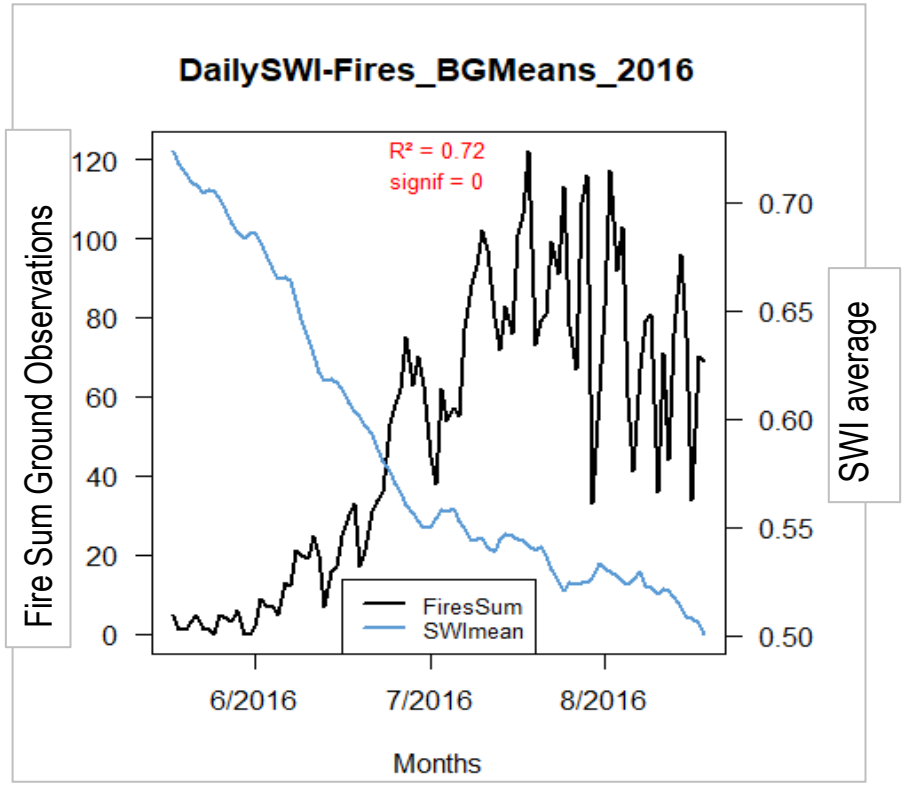


Summary: Signals of combined effect from ecological drought and disturbances by *Cofolla* infection, both related to water stress and forest cover desiccation are successfully evaluated by SAF products.

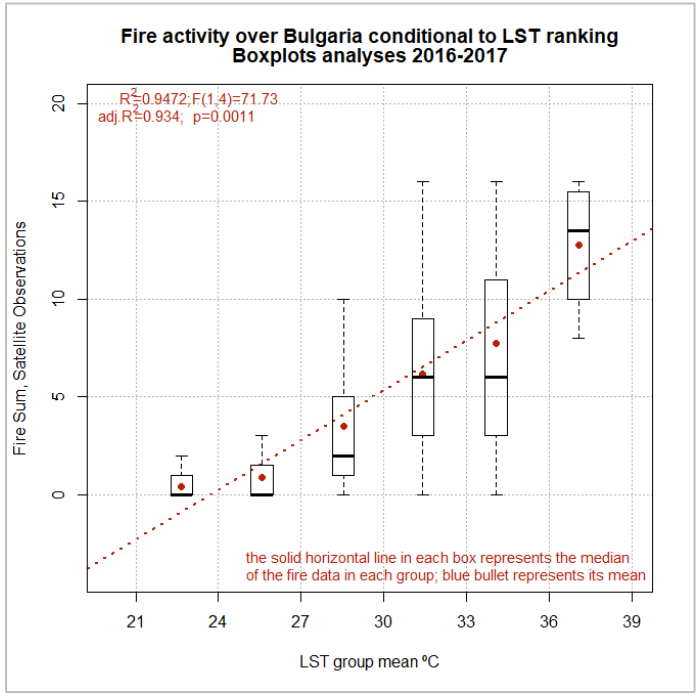
4.5. Vegetation dryness and fire activity on a short-term regional (*for details see the Poster)*

Close relationship between daily averaged values over Bulgaria of LSASAF LST at 09 UTC and the number of actual vegetation fires in 2016 and 2017.





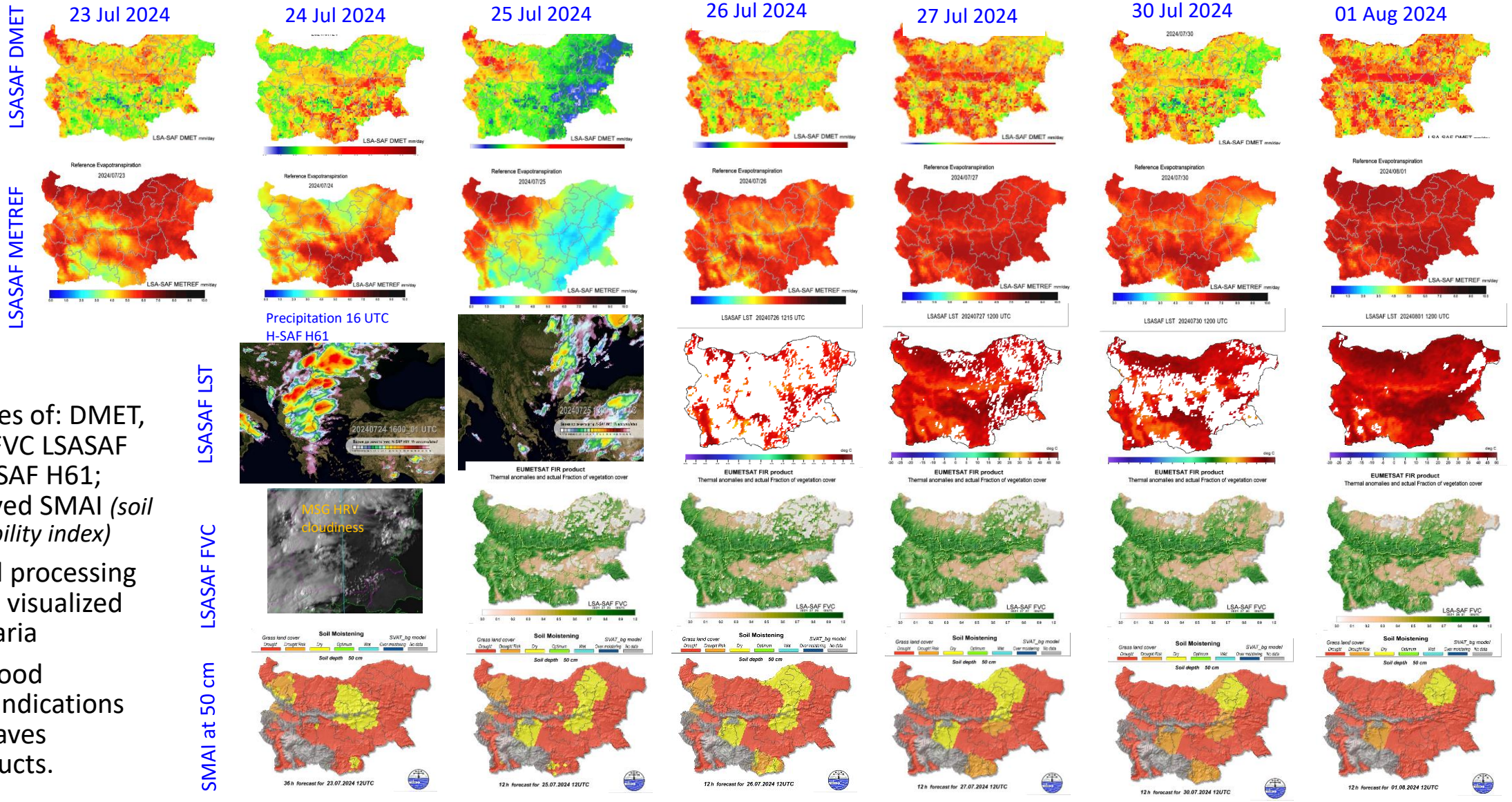
- ✓ Fire activity & HSAF SWI
- ✓ Regression models of fire sum conditional to LST ranking
- ✓ Fires accounted by ground observations & LSASAF FRP product
- ✓ Applying model to forecast fire sum over Bulgaria (first results).



5. Operational drought analyses at NIMH

Internal web page with operational NRT visualization of Atmosphere and Land Surface State

Heat wave, Drought & Vegetation dynamic: **2024 was the third dry and hot year in a row in Bulgaria**. The month of June was the hottest since 1930, and this year's drought was the longest, lasting more than three months. Example of high vegetation water stress indicated by LSASAF products, BG_SVAT SMA.



- ❑ Daily updates of: DMET, METREF, LST, FVC LSASAF products & H-SAF H61; BG_SVAT derived SMAI *(soil moisture availability index)*
- ❑ Operational processing and producing visualized maps for Bulgaria
- ❑ There is a good agreement in indications during heat waves between products.

Thank you for the attention.....

Acknowledgements:

The work is performed in the frame of EUMETSAT LSASAF CDOP-4 Project.