The IASI dryness vegetation index (IASIDVI) and its application to the 2017 heat-wave in Southern Italy

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Outline

1

Methodology

- Emissivity Based Index
- Dryness Vegetation Index

2

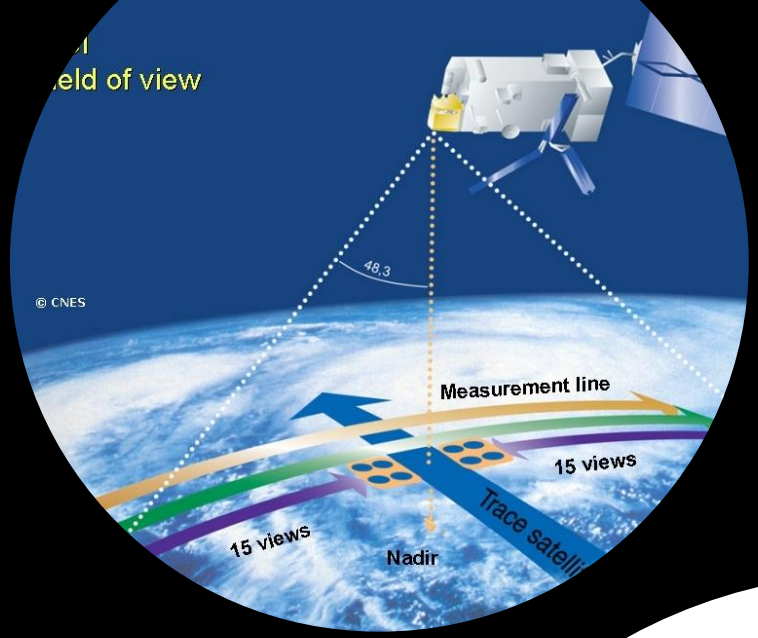
Case Study

- 2017 heat-wave

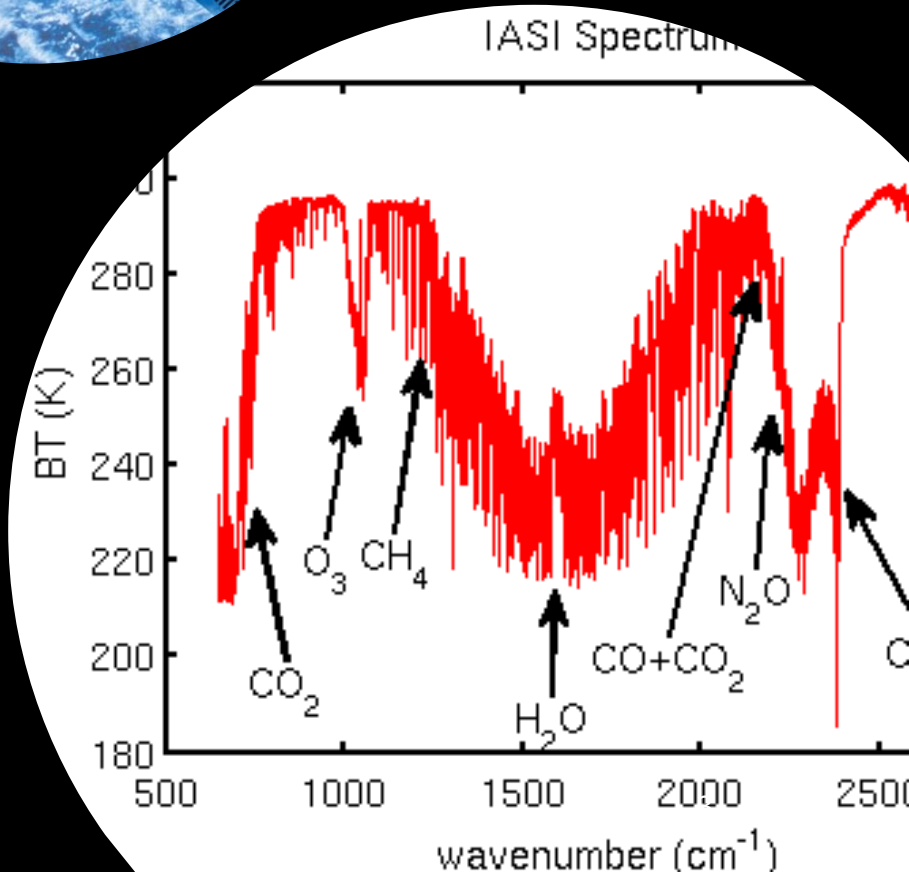
3

Conclusion and future developments

IASI (Infrared Atmospheric Sounding Interferometer)



- This work is based on IASI data which give us the possibility to simultaneously retrieve surface and the thermodynamical parameters
- This capably has been underexplored until now mainly on the side of surface properties.



- IASI is a Michelson Interferometer measuring the spectral distribution of the atmospheric radiation covering the Spectral range 15.5 to 3.62 µm with a sampling rate of 0.25 cm^{-1}
- developed at CNES/EUMESAT http://smsc.cnes.fr/IASI/
- IASI has been designed for operational meteorological soundings with a very high level of accuracy (specifications on Temperature accuracy: 1K for 1 km and 10 % for humidity) being devoted to improved medium range weather forecast.
- It was successful launched on board of EUMETSAT METOP-A on 19 October 2006 and it is in the operational status since 30 November 2006. Second and third IASI are on board of METOP-B (2012) and METOP-C (2018)

G. Masiello et al. 7th SALGEE Workshop

Motivations

Vegetation and soil moisture stress can be estimated using

- Field measurements
- Meteorological data
- Remote sensing

At present, it is widely used NDVI (Normalized Differential Vegetation Index) and air temperature (Ta) measured close to the surface

- NDVI is normally obtained from satellite observations
- Ta from in situ observations or meteorological networks

Drawbacks

- Lacking spatial and temporal consistency
- NDVI is not capable of distinguishing between arid soil and senescent vegetation
- Ta is not directly linked to soil moisture

We developed a methodology coherent and consistent both spatially and temporally estimating parameters from hyperspectral infrared measurements (IASI)

Emissivity contrast Index (ECI) estimation

- Infrared Emissivity contrast has been used to discriminate the state of vegetation
- $\delta\varepsilon = Max(Channel\ Emissivity) - Min(Channel\ Emissivity);$
- We define the Emissivity Contrast Index (ECI) as **$1 - \delta\varepsilon$**, ECI varies in range [0,1] , the endpoint 1 is the limit of wet green vegetation (black body), 0.7 that of dry arid soil;
- For water **ECI ≅1** greater than
  - > **Green vegetation** greater than
    - > **Senescent (dry)** vegetation greater than
      - > **Bare soil**.

Surface and dew point Temperature's difference Ts-Td

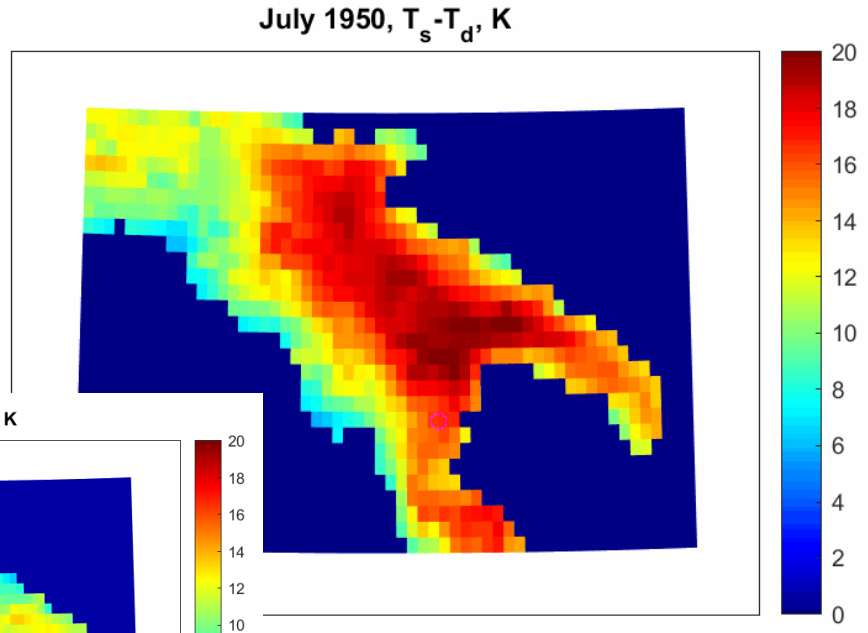
The Dew point temperature (Td) close to the surface is more directly related to the evapotranspiration processes of the surface.

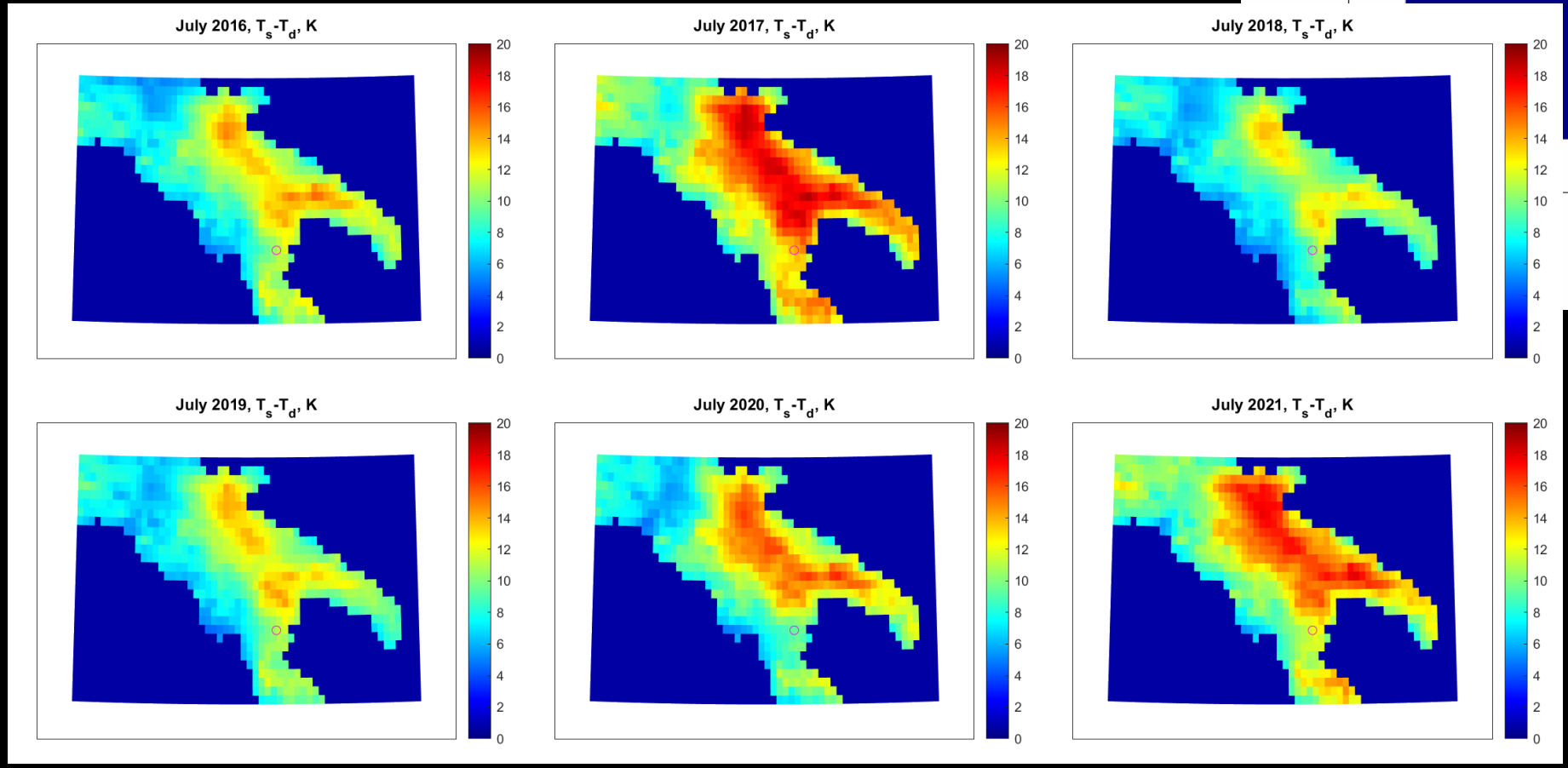
The difference between Surface temperature (Ts) and Td close to it is directly related to the loss of water vapour from surface and vegetation.

The greater this difference, the faster the surface and vegetation lose their moisture

Ts-Td is a “Vegetation Dryness Index”

Ts-Td, ERA5 - LAND
July (1950-2021)





φ-IASI

- To retrieve geophysical parameters from IASI measurements we developed a retrieval methodology we call the φ-IASI package based on optimal estimation
- We use the full IASI spectrum (all the 8461 channels) to retrieve simultaneously, the State vector

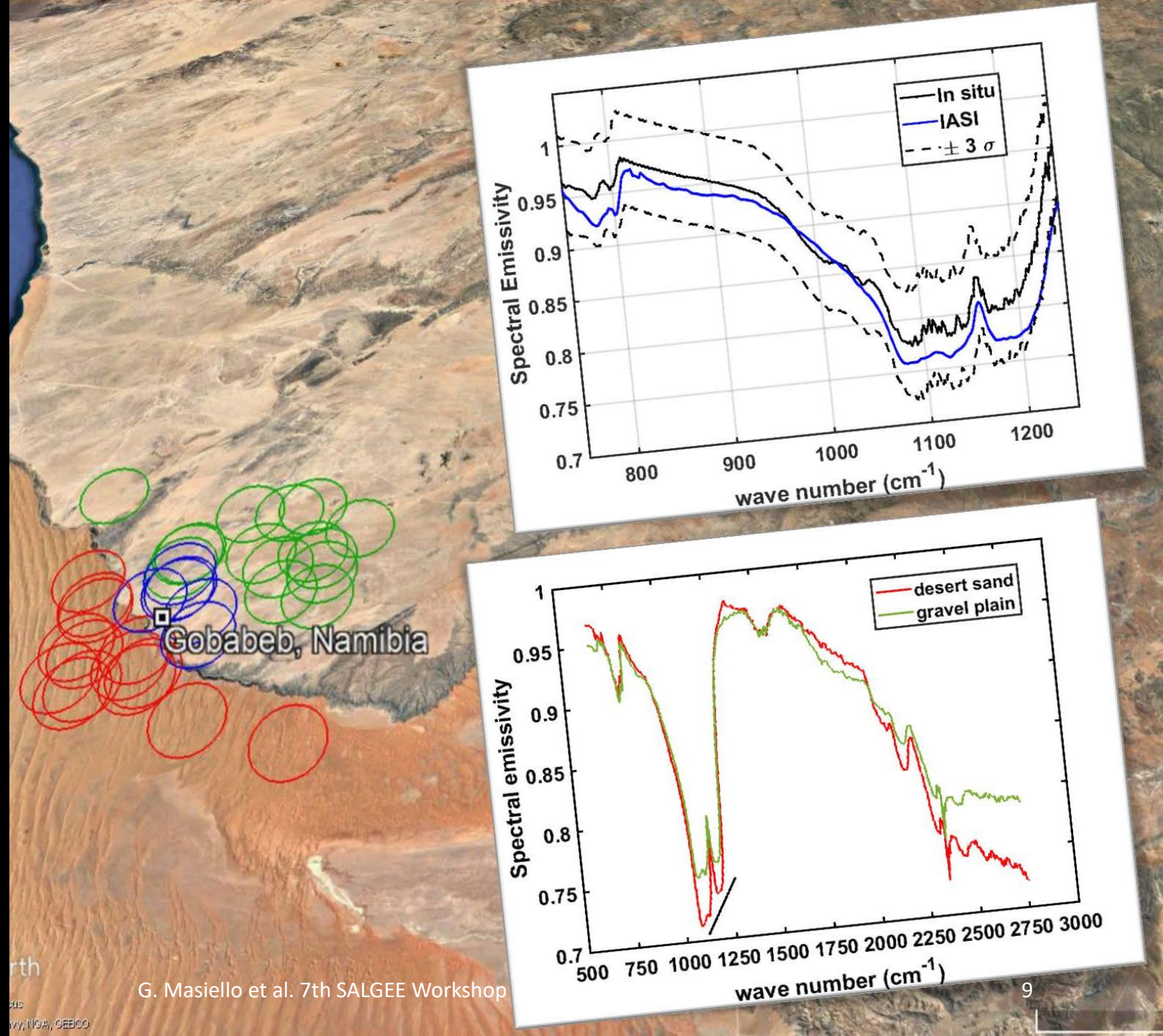
$$\mathbf{V} = (T_s, \mathbf{T}, \mathbf{Q}, \mathbf{O}, \mathbf{D}, \mathbf{q_{CO2}}, \mathbf{q_{OCS}}, f_{N2O}, f_{CO}, f_{CH4}, f_{SO2}, f_{HNO3}, f_{NH3}, f_{CF4}, pc_{\epsilon})$$

- Surface temperature Ts, Atmospheric profiles of Temperature T(p), Water vapour q(p), Ozone, HDO, CO2, and OCS;
- Scalar scaling factors for the column amount of CO, N2O, CH4, SO2, HNO3, NH3, and CF4
- PC scores for surface emissivity spectrum ϵ_σ

- Liuzzi et al. (2016). JQSRT, doi:10.1016/j.jqsrt.2016.05.022.

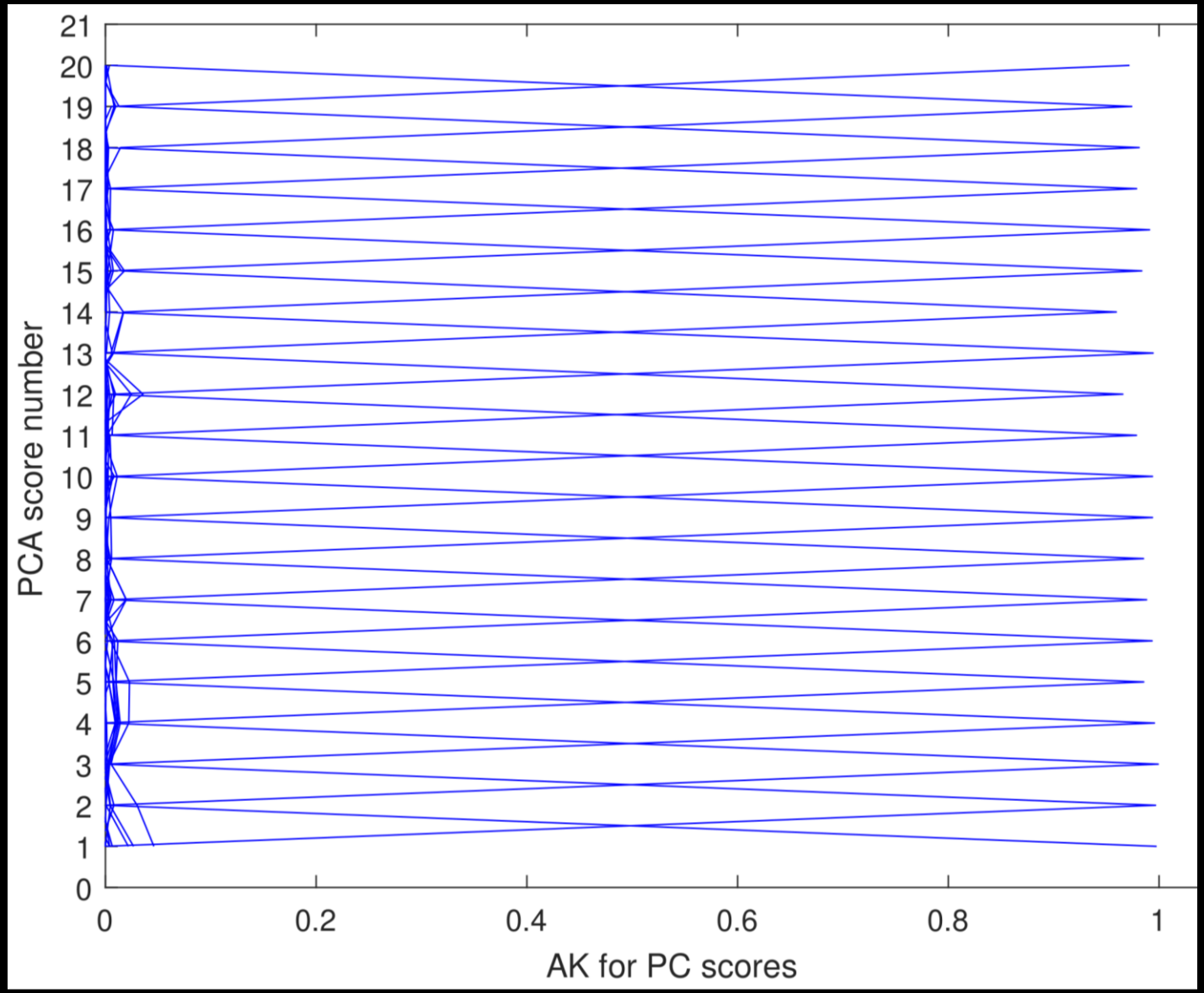
Emissivity spectrum

- IASI spectrum co-located with Gobabeb, Namibia station.
- Ancillary information ECMWF
- Masiello et al. Remote Sens. 2018 https://doi.org/10.3390/rs10060976



Averaging Kernel

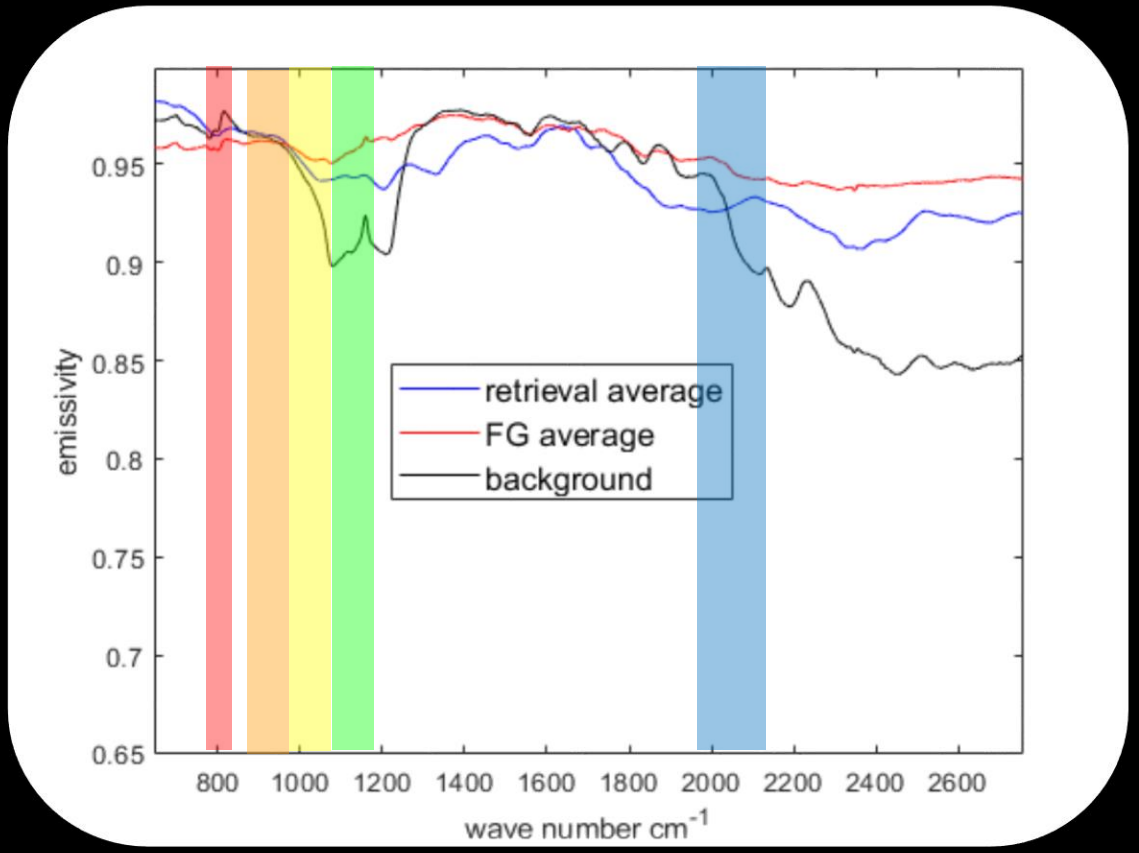
- Emissivity spectrum is retrieved simultaneously using 20 PCA scores.
- Figure shows the Averaging Kernels (AK) for the t = 20 PC scores used to represent the emissivity spectrum.
- AK is that it is nearly one at each PC score. The degrees of freedom are in fact 19.71, very close to the value of 20, which corresponds to a retrieval for which the twenty PC score were fully resolved by the data.
- **20 DOF**



Pseudo emissivity channels for mapping

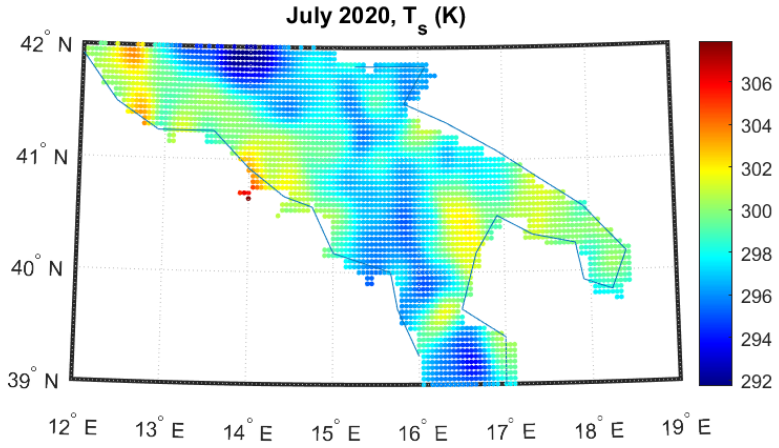
Starting from the IASI retrieved emissivity spectrum ε_σ, we compute the emissivity for the infrared pseudo-channels in table.

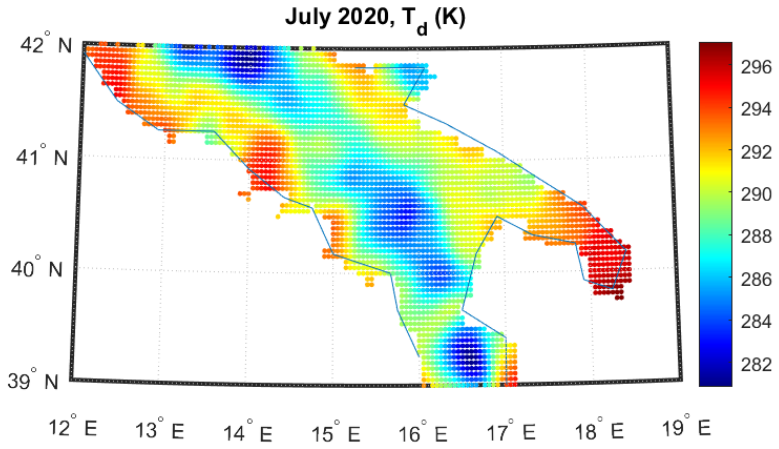
Among these channels, we calculate the emissivity maximum difference δε, and finally, we define the Emissivity Contrast Index (ECI): ECI=1-δε.

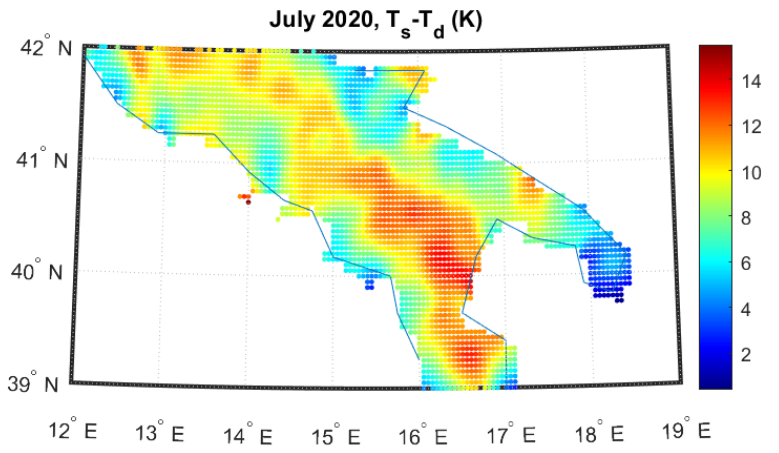


Pseudo Channels Range (cm^{-1})

800-830	900-1000	1000-1100	1100-1200	2000-2200
vegetation	vegetation	vegetation	Reststrahlen band of Quartz	Good to check high reflectivity on desert sand







IASIDVI index

- An original, unique, dryness vegetation index based on IASI
- IASI Dryness Vegetation Index (IASIDVI)
- To compute it needs **T(p)**, **Q(p)** profiles and surface Temperature **Ts**
- The dew point temperature close to the surface Td is straightforwardly calculated by combining IASI retrieved temperature **$T(p_0)$** and water vapor **$Q(p_0)$** close to the surface.

Region of Interest, south Italy

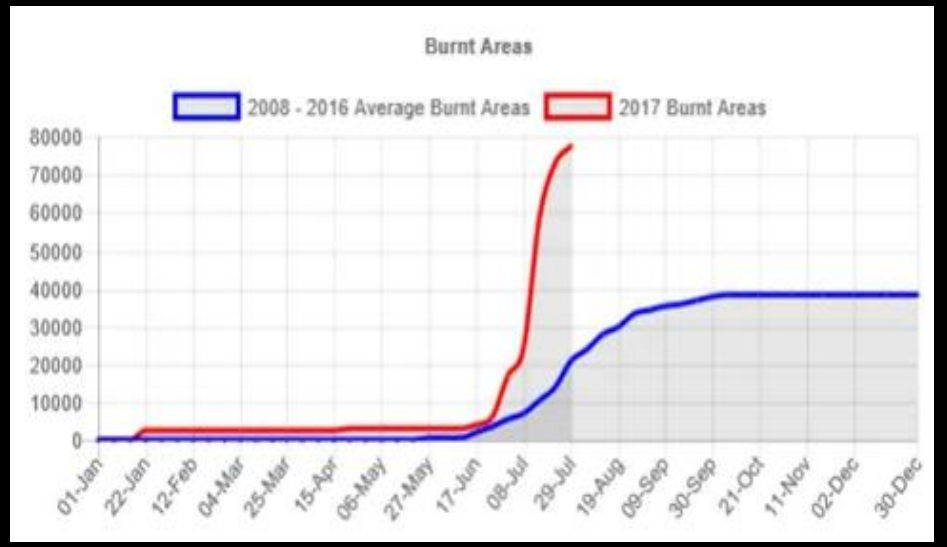
- The animation shows the region of interest and how IASI covers it in 5 days.
- From summer 2019, IASI is on board 3 satellites (MetOp-A, B and C)

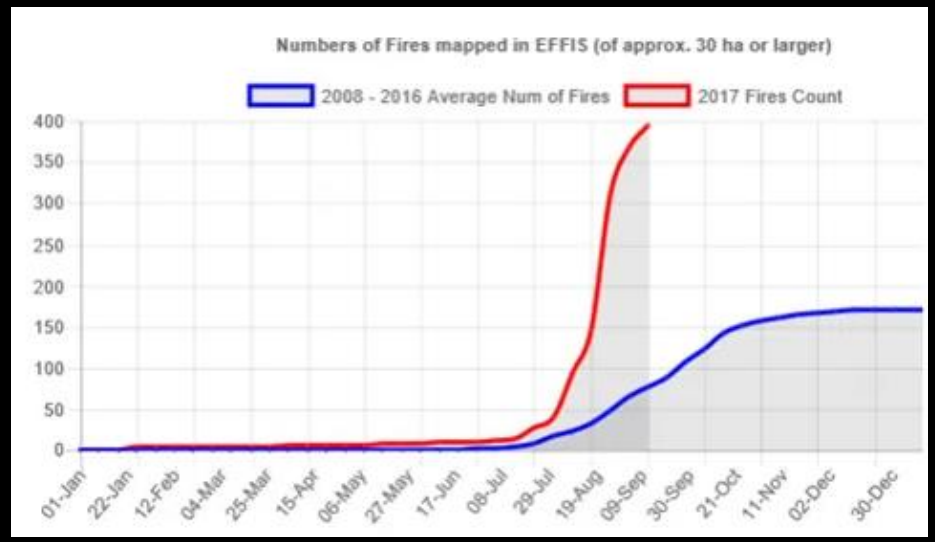
Why South Italy in 2017

- Drought
- The 2017 heat wave began in May and extended till October leaving the vegetation in an acute dry stress
- broad-leaf forests dried before than expected

Why South Italy in 2017

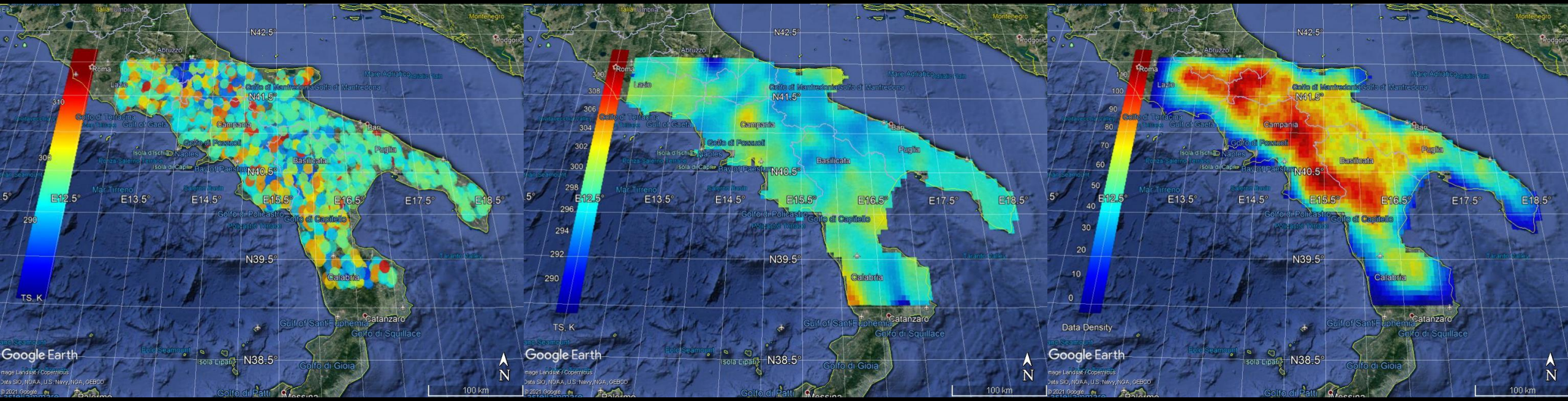
- Fires
- During the 2017 summer Southern Italy was concerned by some 400 wild fires, which destroyed some 800 km^2 of forest and vegetated areas. The biggest fires developed in the Campania district.
- the number of fires was unprecedented in the last 20 years





From Level 2 to Level 3

- IASI retrieved geophysical parameters (Level 2) are remapped on a regular grid with Optimal interpolation procedure averaging the results over a month (Level 3)
- Figure shows L2 (left) and L3 (middle) surface temperature for July 2017. Data density is shown in the right panel.



ECI & IASIDVI

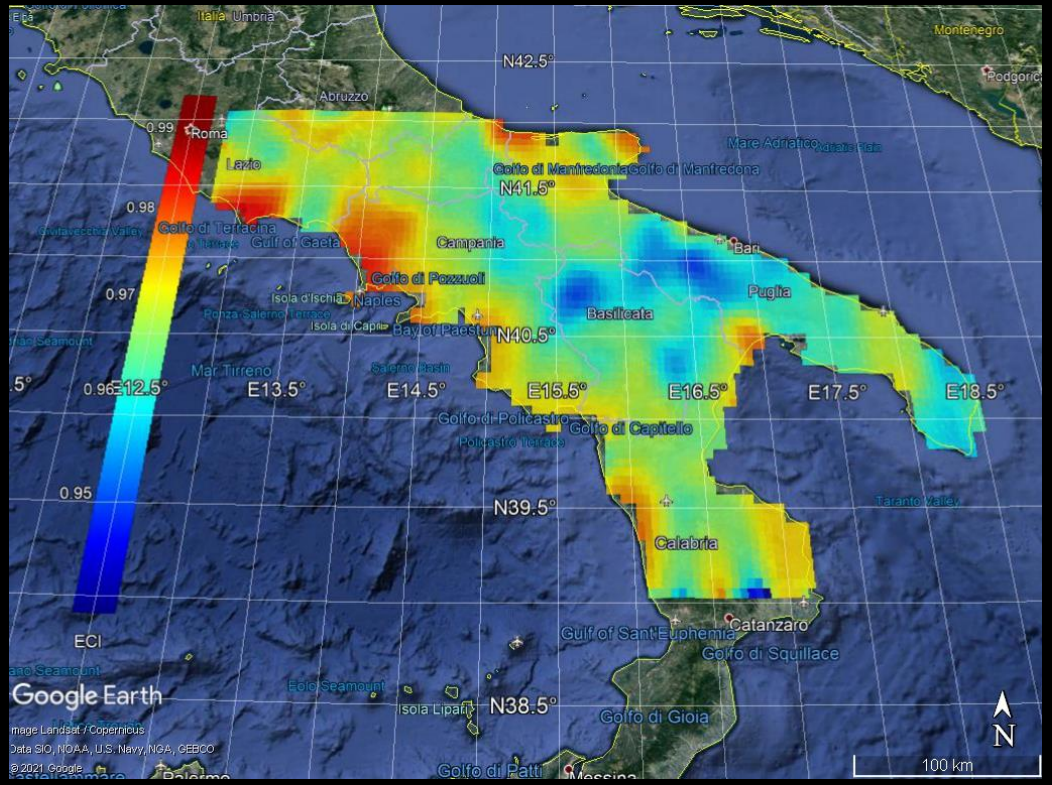
July 2017

The ECI is larger in the coastal regions, while it shows smaller values in the inland regions where there are forests.

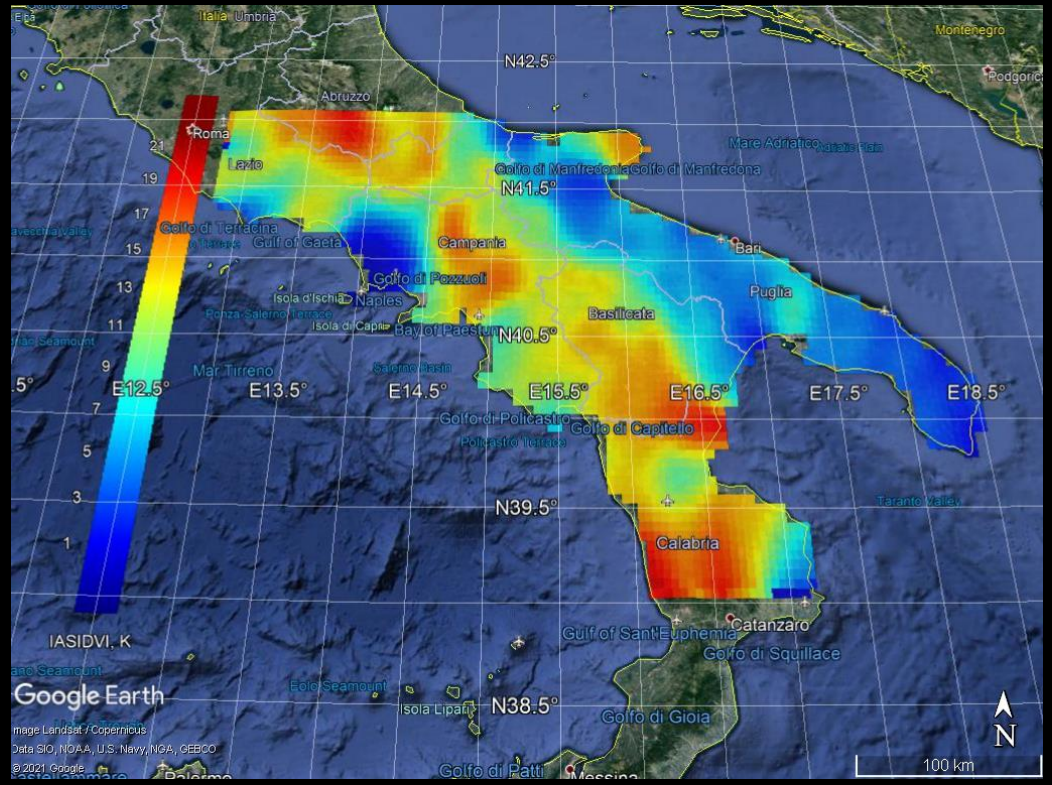
IASIDVI close to the Vesuvius mountain is ~0 K

A further confirmation that the fires of 2017 were arson

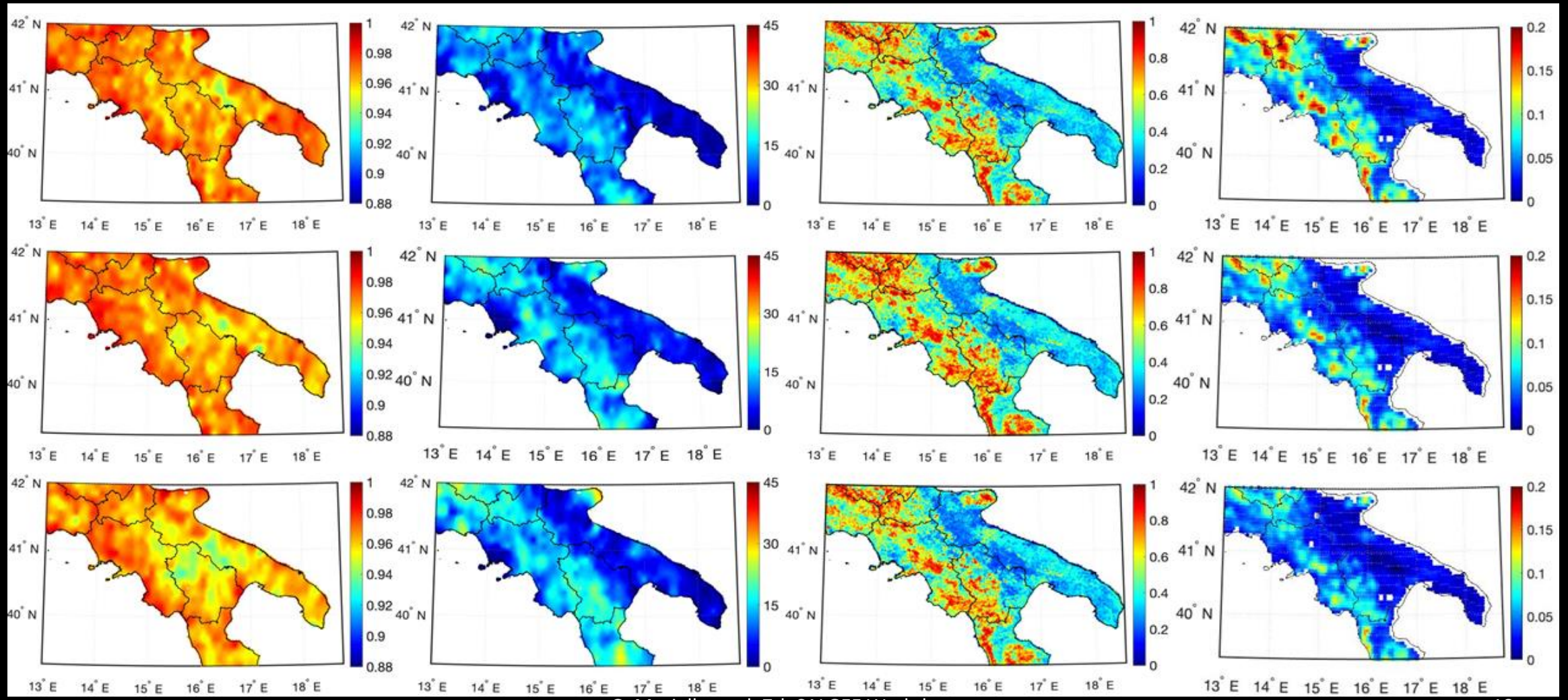
ECI



IASIDVI



Summer 2017, Indices



NDVI

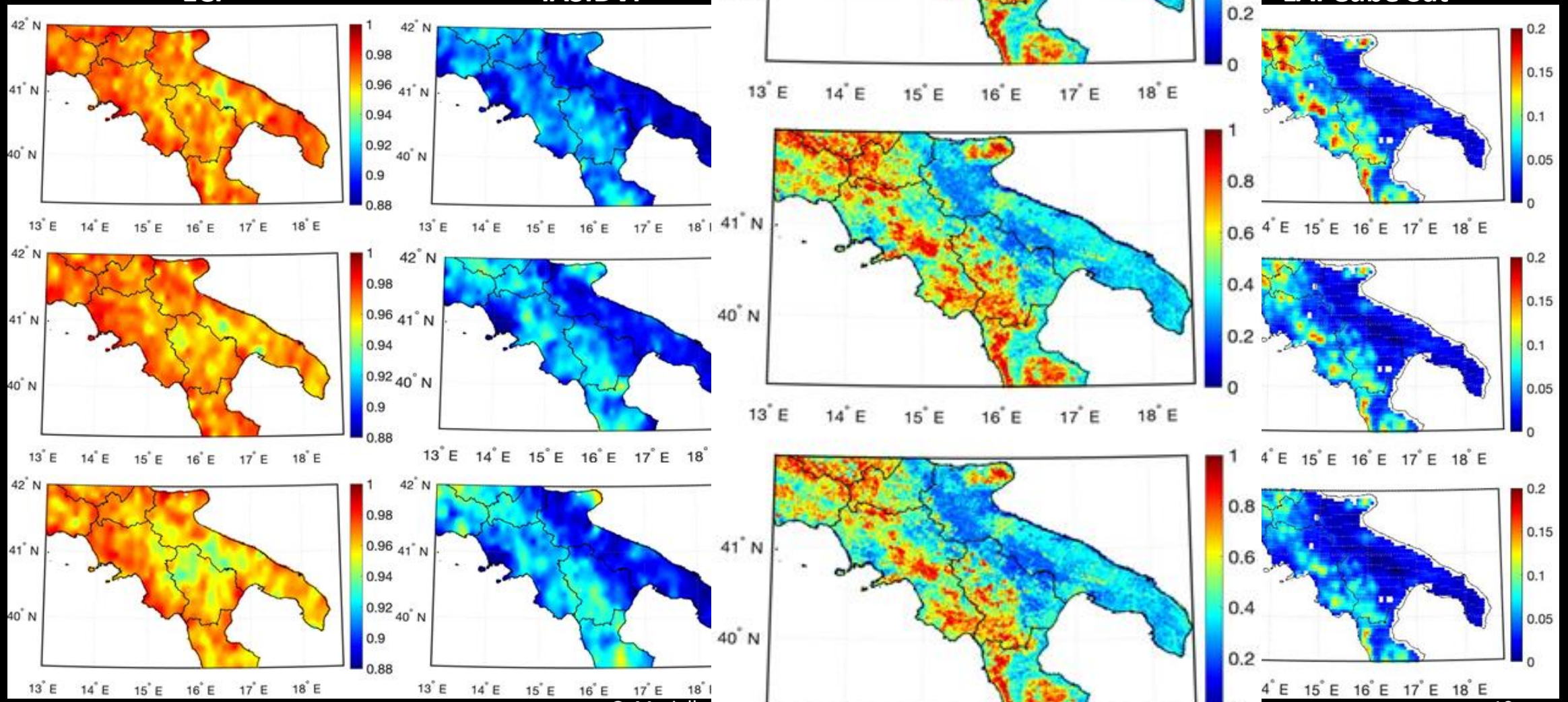
No noticeable differences as the summer months pass

ECI **IASIDVI** **LAI Cube Sat**

June

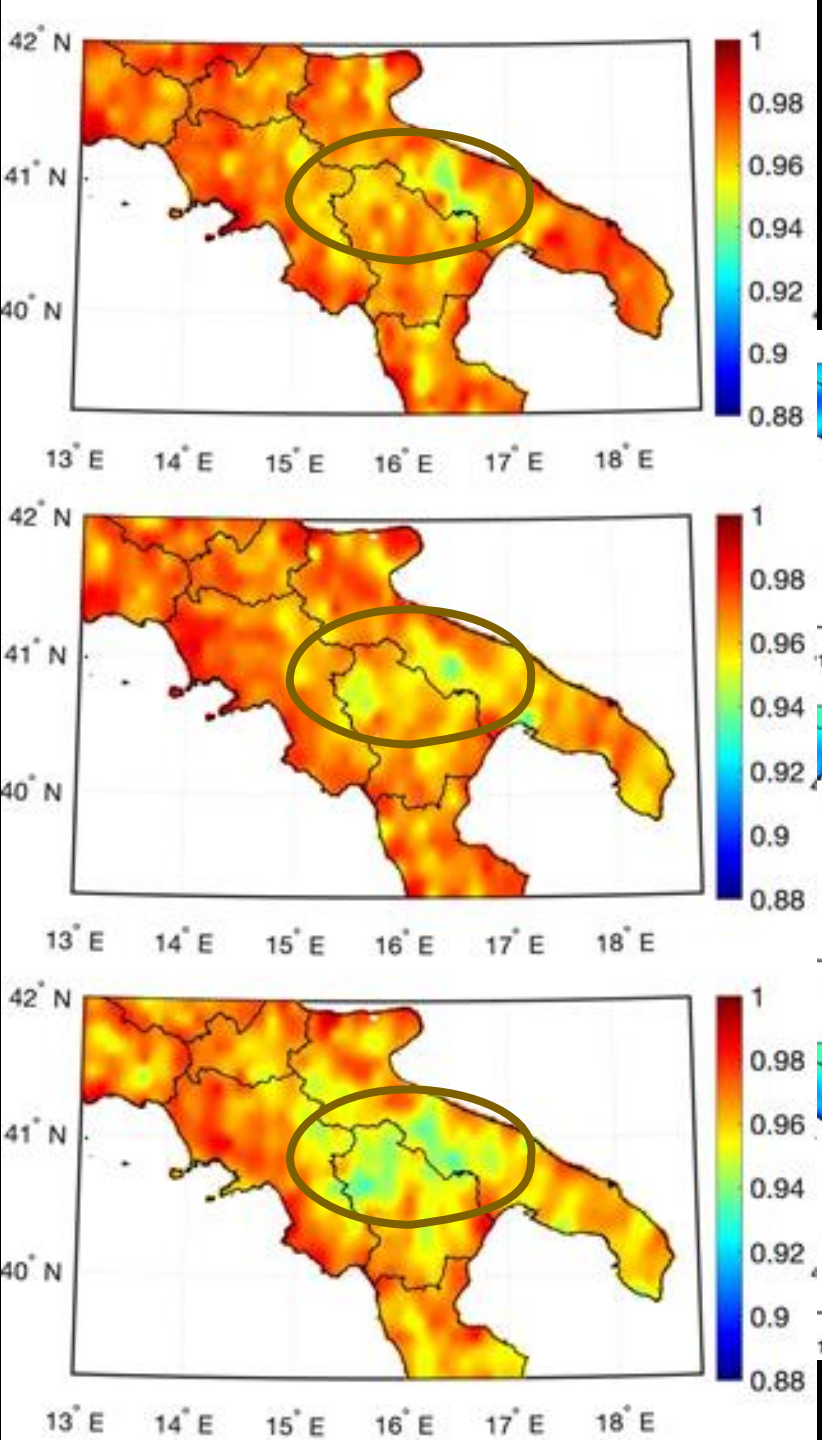
July

August

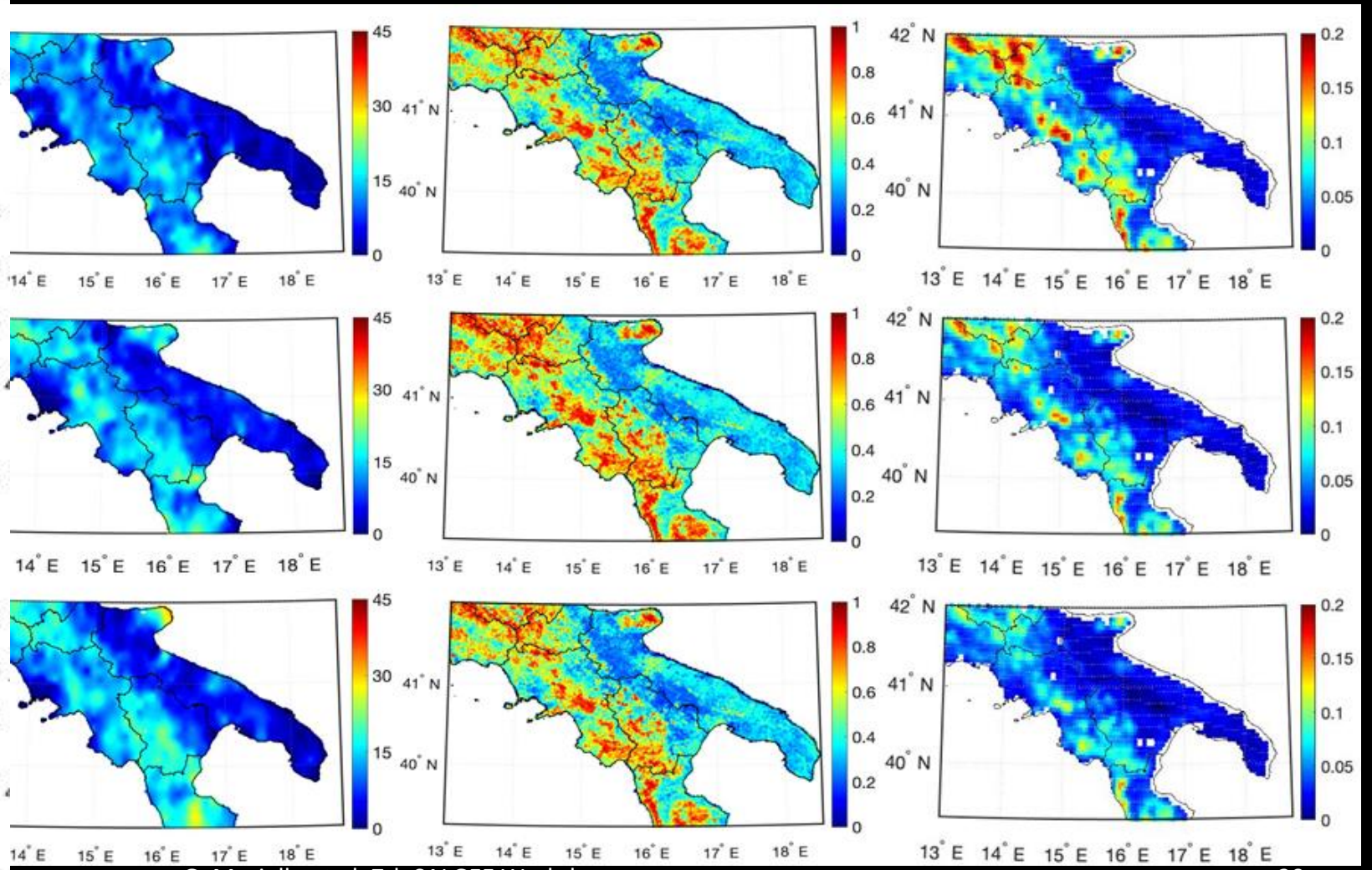


ECI

decreases during the summer in correspondence of the cultivated fields.
It distinguishes between bare soils and dry vegetation



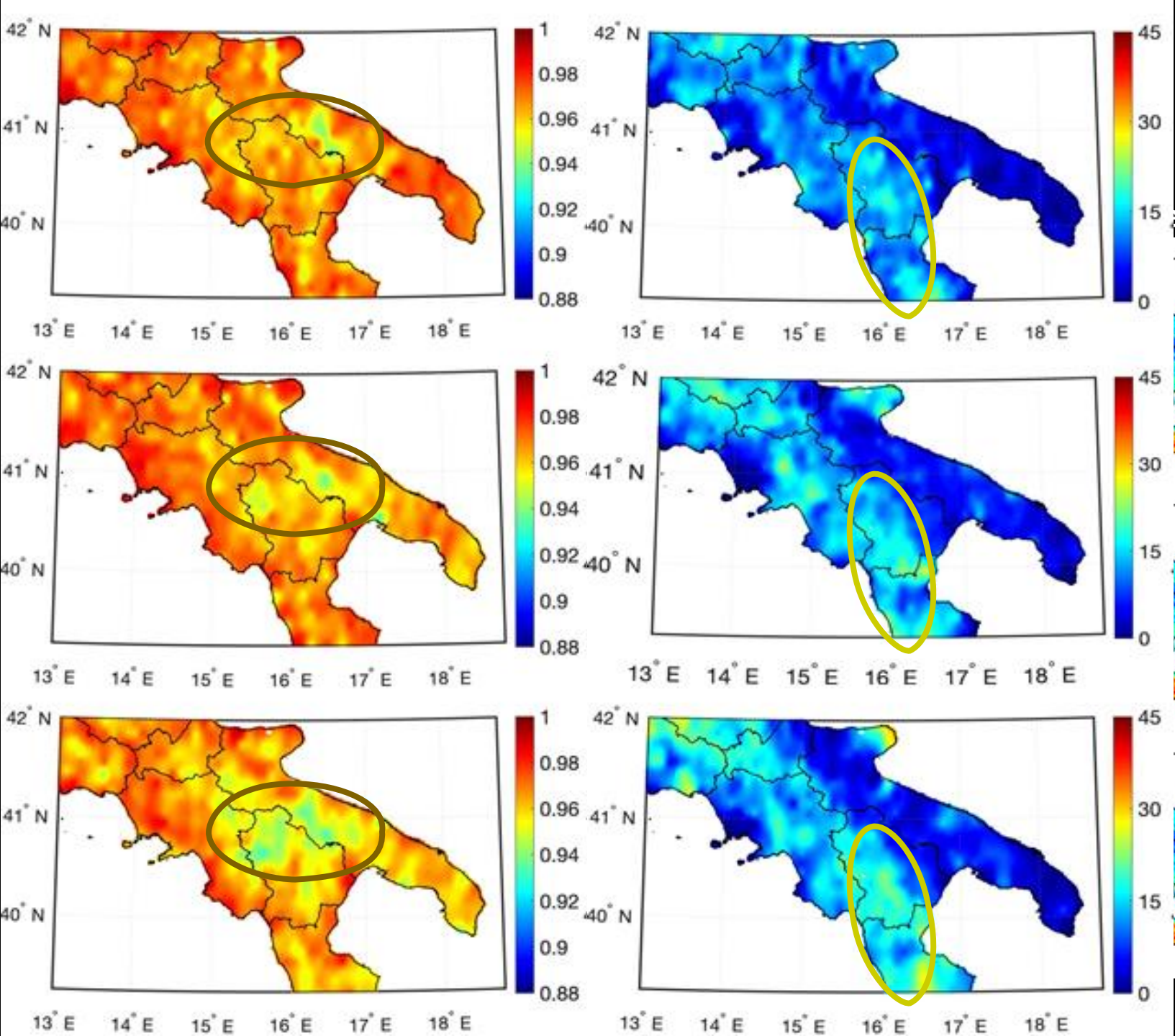
IASIDVI **NDVI Cube Sat** **LAI Cube Sat**

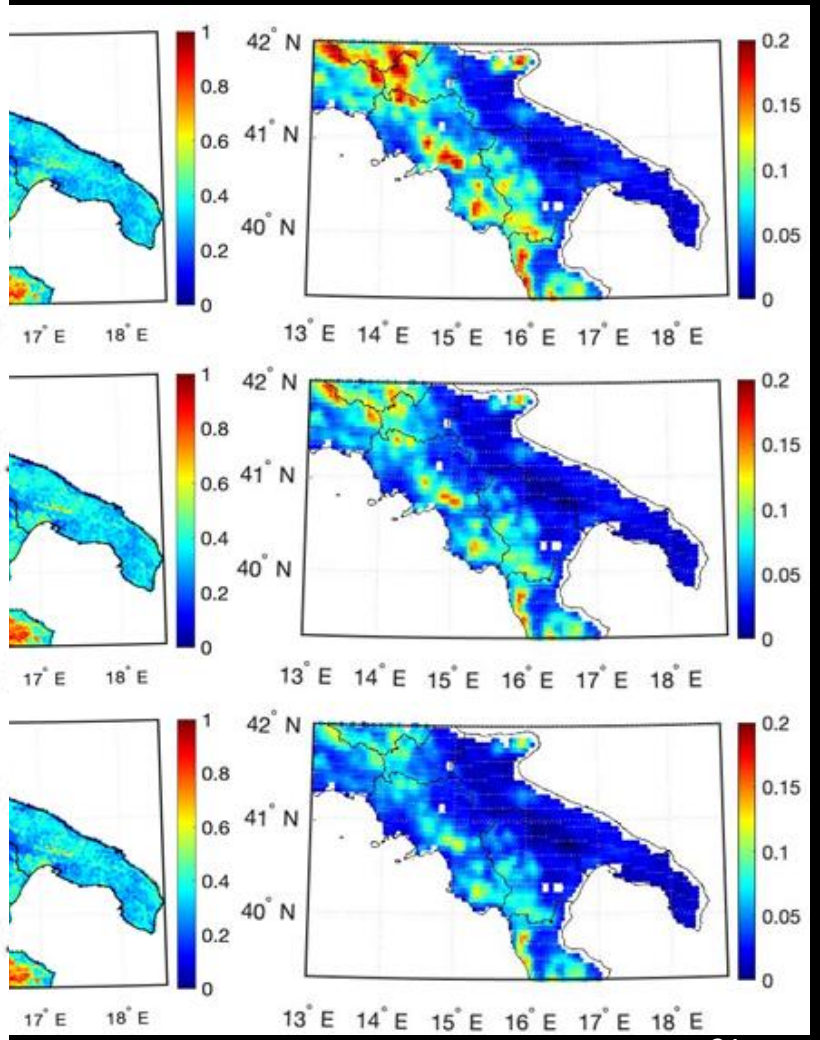


IASIDVI

increases during the summer on the Apennines forests

e Sat **LAI Cube Sat**





LAI

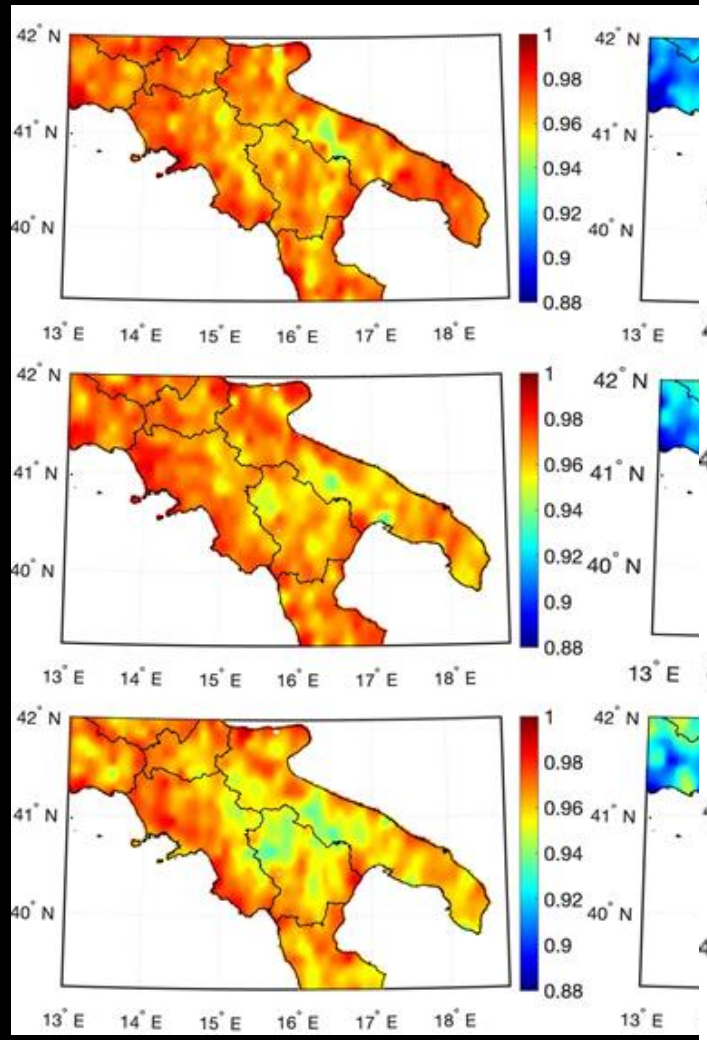
decreases during the summer on the Apennines forests

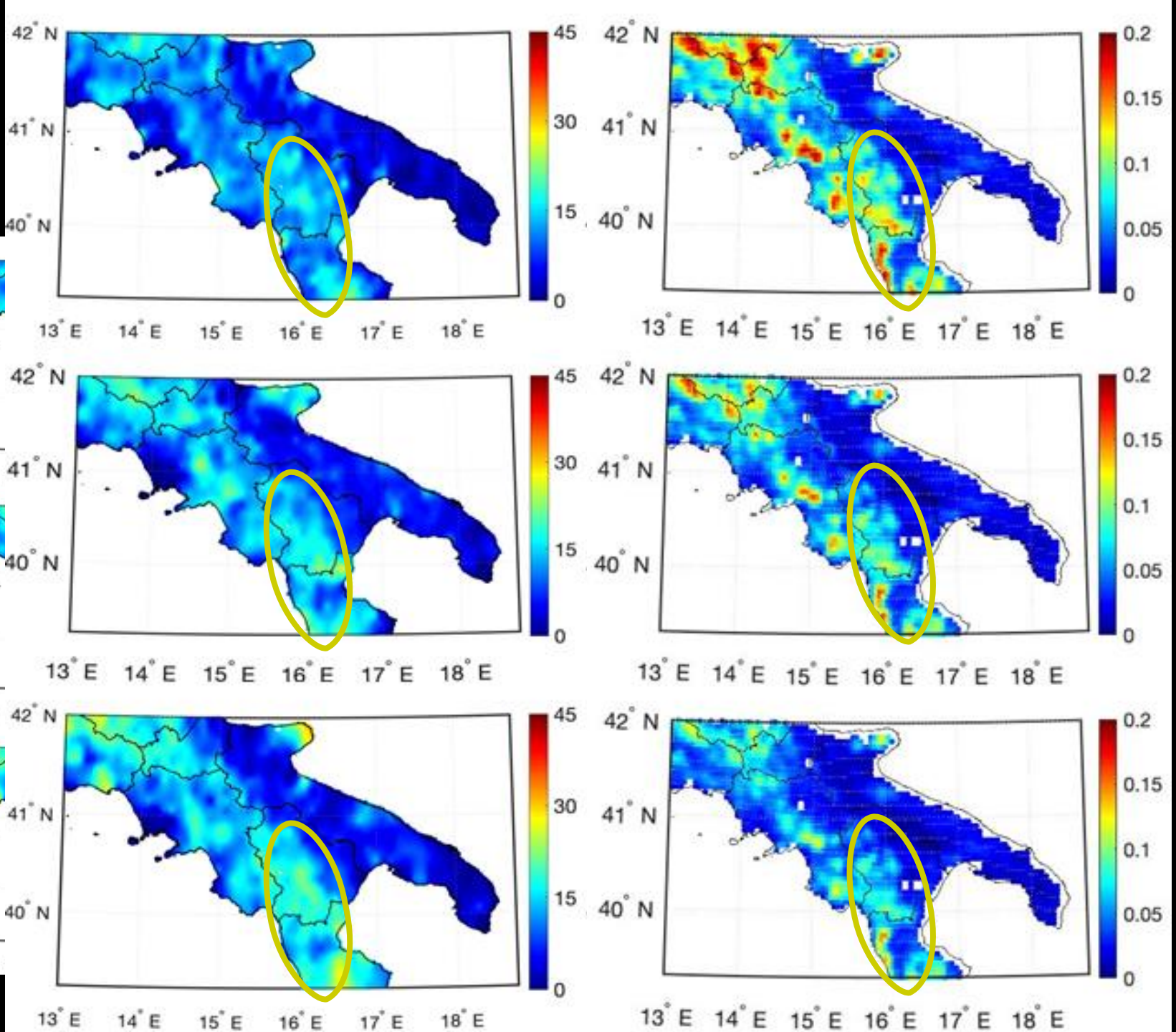
ECI

June

July

August





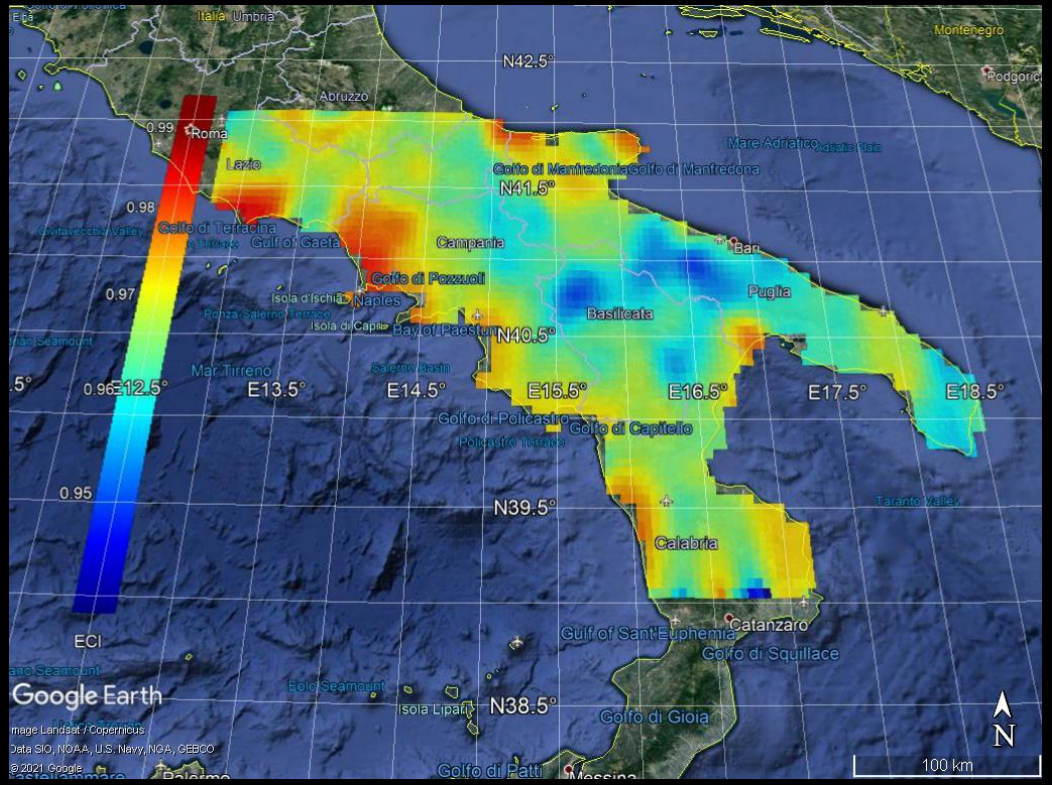
ECI

The ECI is larger in the coastal regions, while it shows smaller values in the inland regions where there are forests.

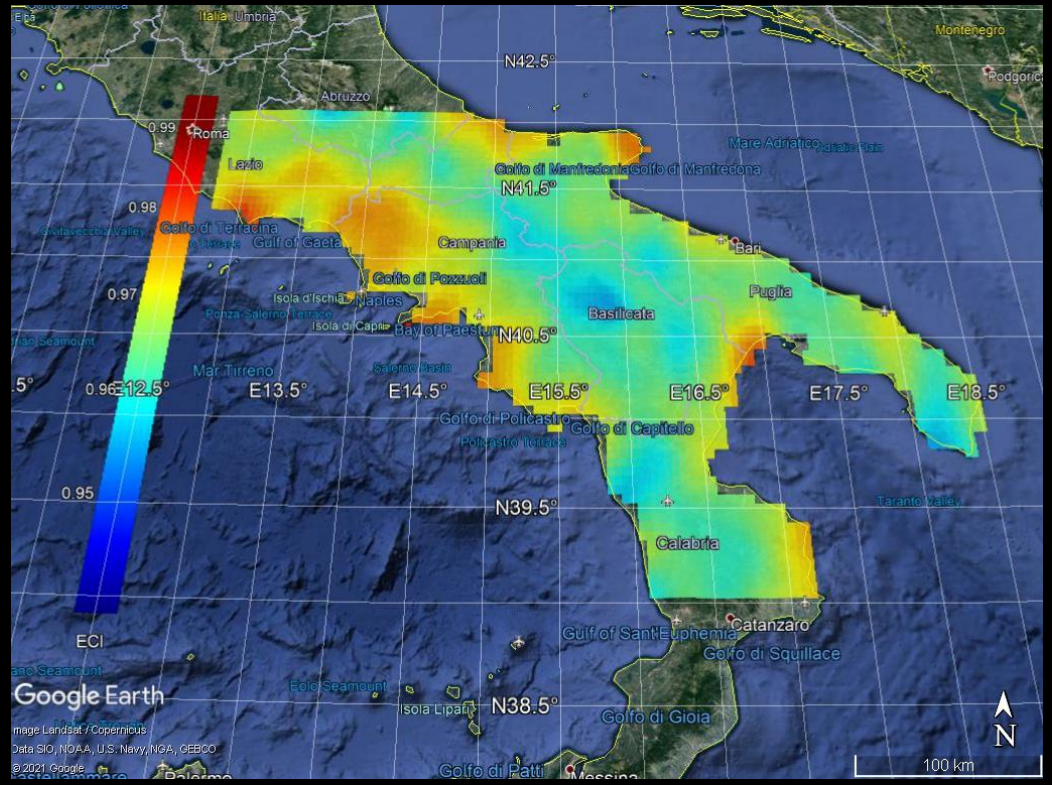
Comparing the two years, ECI shows both its highest and lowest values in 2017.

Inland regions experienced larger water stress during 2017.

July 2017



July 2020



IASIDVI

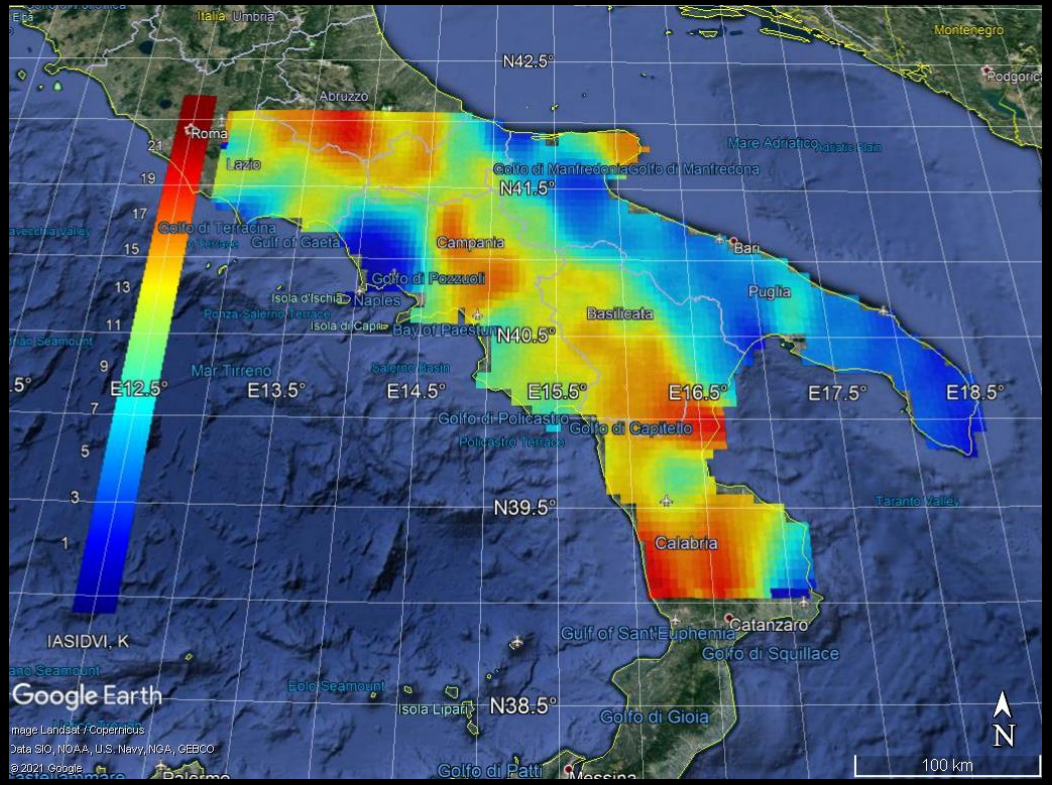
This intense water stress is more evident when IASIDVI is compared.

In July 2017 IASIDVI for Inland Forests is 8K greater than in 2020.

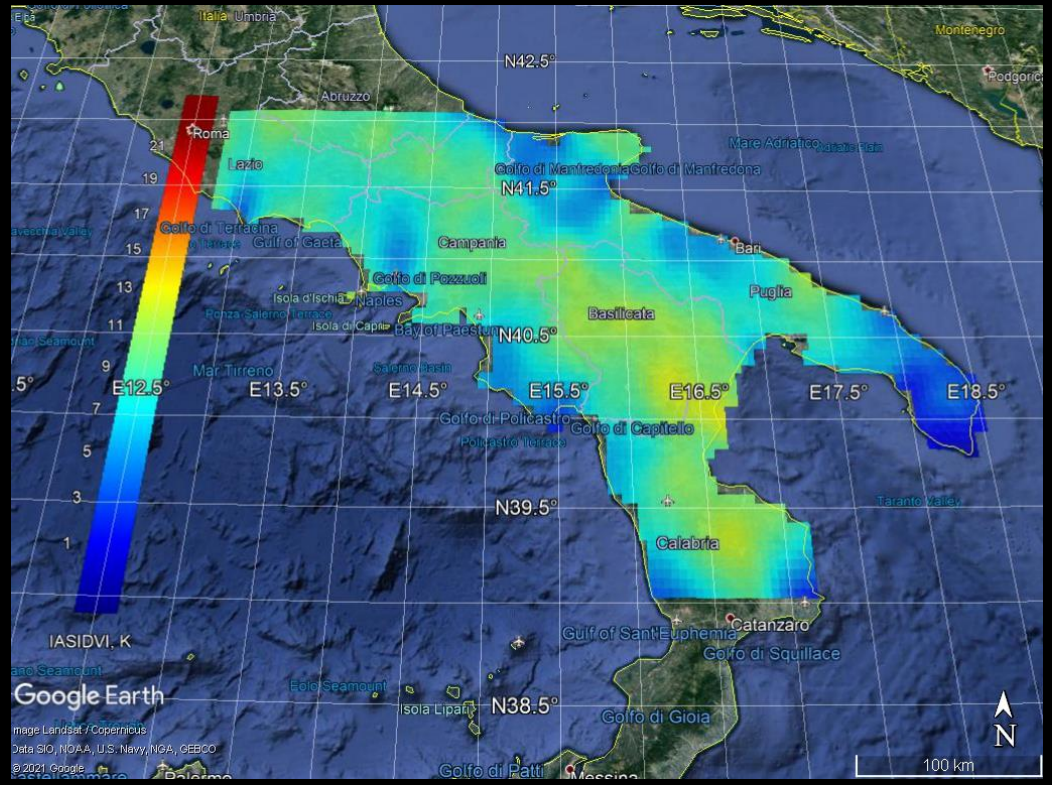
IASIDVI close to the Vesuvius mountain is ~0 K in 2017 and it increased in 2020.

A further confirmation that the fires of 2017 were arson

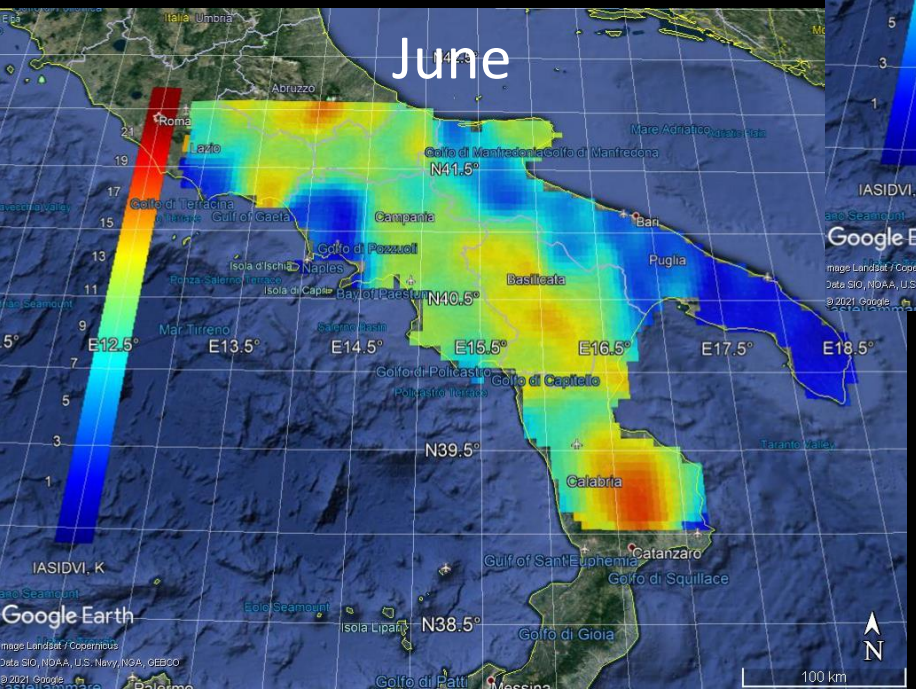
July 2017

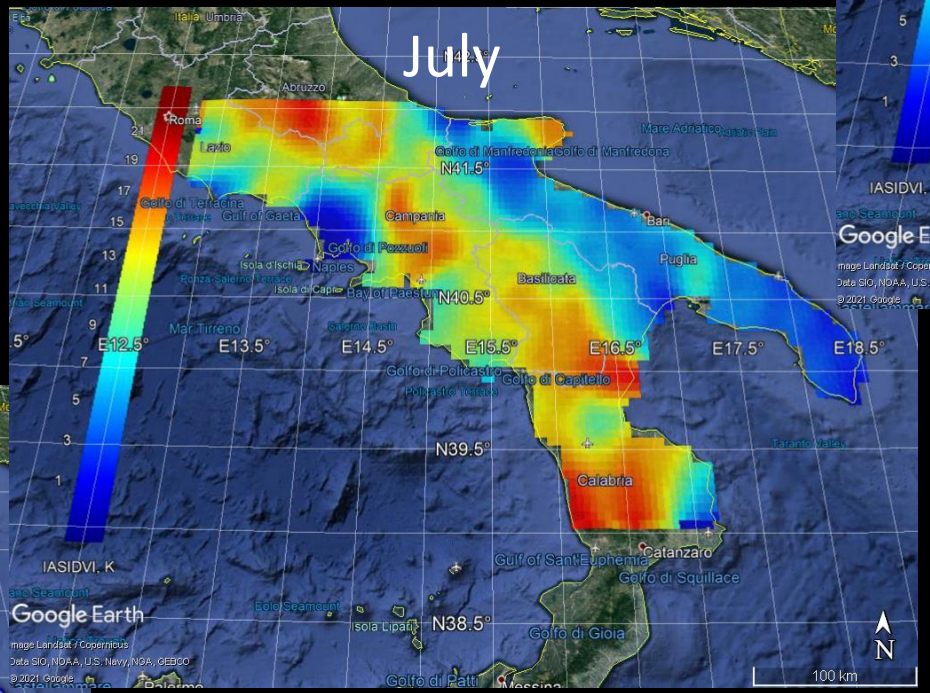


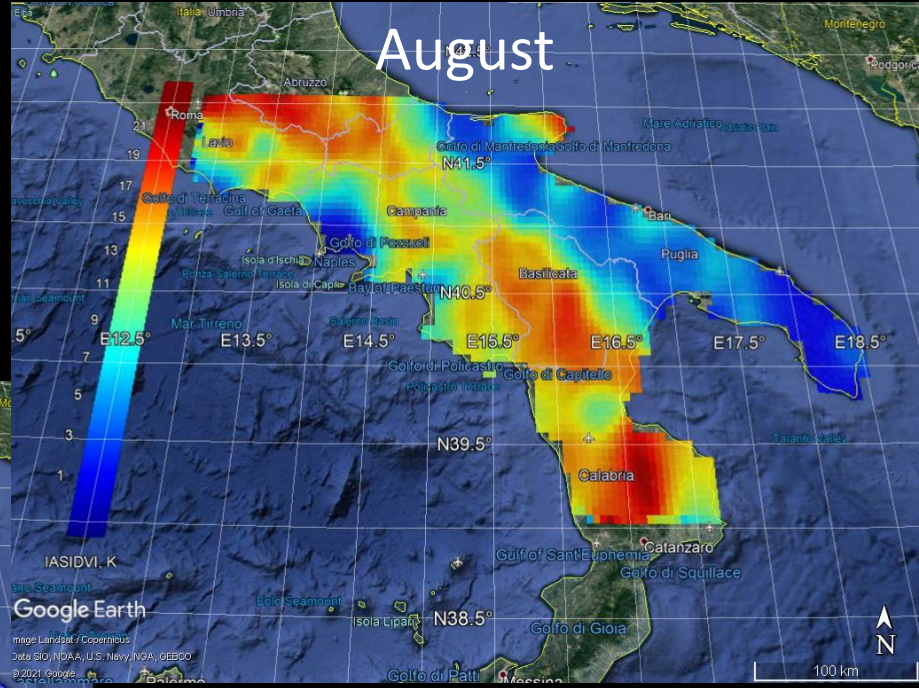
July 2020



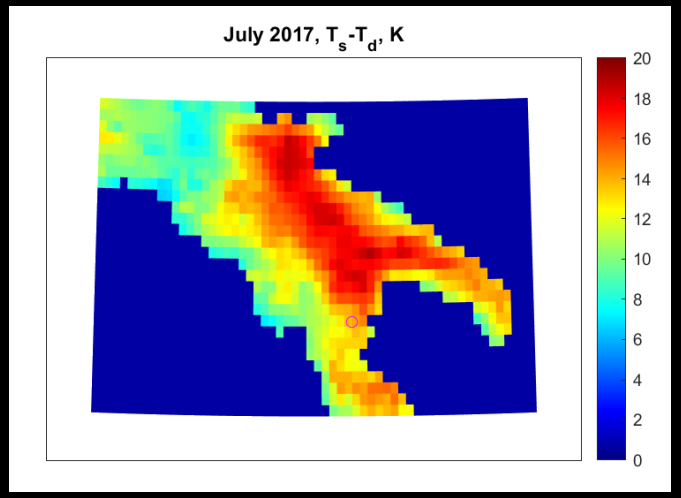
IASIDVI, summer 2017

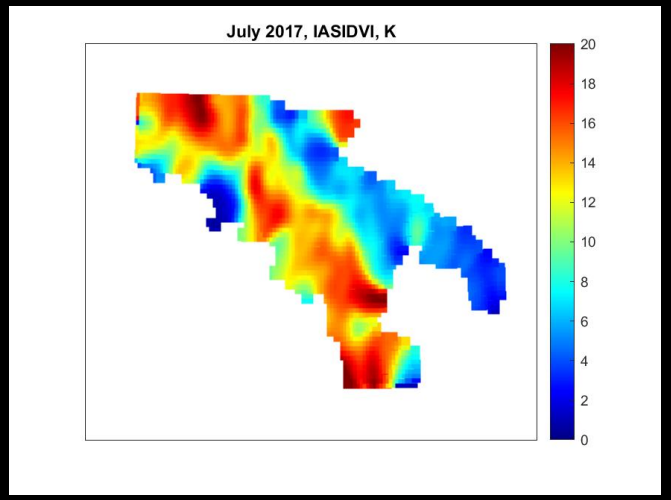


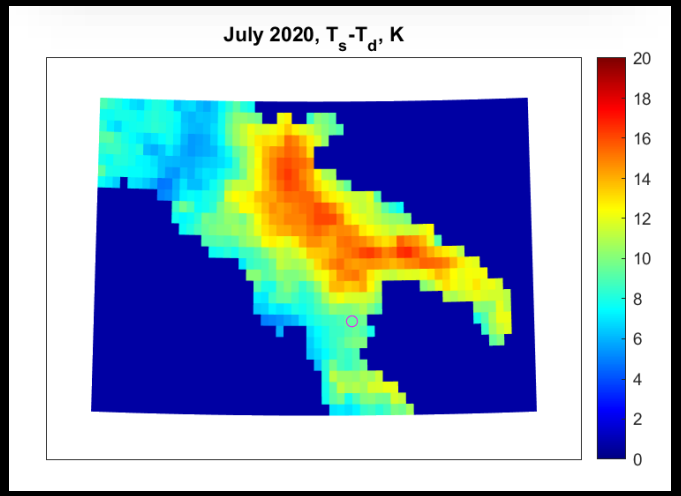


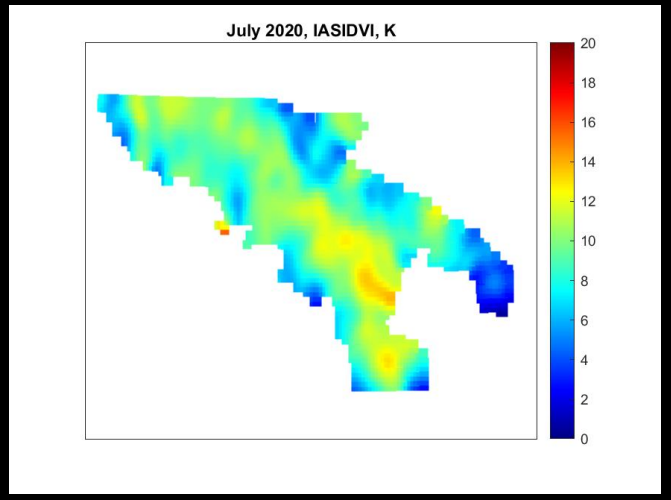


- during the summer of 2017 the IASIDVI grew throughout the region with the exception of southern Puglia









ERA5 v/s IASI

Differences in the geographical distribution and we think that IASI is more reliable in terms of what we know of the climatology of that region

Conclusions

- We developed thermodynamics indices for drought and forest fire derived from hyperspectral Infrared measurements
- Indices are coherent and consistent both spatially and temporally
- Emissivity contrast Index (ECI) can distinguish between bare soil and dry vegetation.
- The original IASI Dryness Vegetation Index (IASIDVI) is effective in defining dry-stress for vegetation.

Future developments

- Validation Campaign.
  - We already measured in July, September 2020 and July 2021
  - We deployed a long list of instrumentations in a Forest of Farnetto (Fagacee Quercus) a native oak of southern Italy that in recent years shows evident signs of deterioration
- We are investigating IASIDVI and ECI synergy with other ordinary indices and ground based measurements

Altitude

Instrument	Parameter
SEVIRI	
	ECI
IASI	
	IASIDVI
	ECI
Elicopter - ISAFOM, 1	
	NDVI,…
UAV - ISAFOM, 1	
	NDVI, ….
UAV - ISAFOM, SPA Lab	
	NDVI, …
PAR-FluorPen FP100	Chlorophyll fluorescence
MINI-PAM	Chlorophyll fluorescence
LI-6400	Gases exchange
Scholander Camera	Leaves Water potential
Spettrometer Laser	CO2
Profiler	Soil properties

Acknowledgments

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Prof. Dr. Carmine Serio
Prof. Dr. Guido Masiello

Submission Deadline: 31 January 2022

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Land surface monitoring plays a significant role in the study of climate change and global warming. Even though in situ measurements represent the most accurate way to measure surface parameters, they lack in spatial and temporal resolution. For this purpose, satellite data provide a global coverage and higher temporal resolution with very accurate retrievals of land parameters such as surface temperature and emissivity. Land surface parameters from remote sensing are incredibly attractive for applications in different environmental fields, such as land use/change, monitoring of vegetation and soil water stress, and early warning and detection of forest fires and drought. Typically, monitoring of land cover changes is based on the definition of vegetation indices, exploiting the surface information provided by the spectral channels in the visible and the infrared.

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