Show cases on Land Surface Analysis: Hands-on Applications of LSA SAF Products

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Abstract

Show cases on land surface analysis focus on hands-on examples of usage of LSA SAF products in operational framework and in showing users benefits of using these satellite products in their daily routine (e.g. duty forecasters). They focus on satellite detection of land surface temperature, vegetation and shortwave radiation. They cover a wide variety of attractive applications for expert end-users, e.g., detection of urban heat islands, monitoring heat waves, detection of vegetation anomalies and use of shortwave radiation for validation studies. Show cases integrate LSA SAF products with other data sources such as NWP data and in-situ ground measurements.

We illustrated usage of selected LSA SAF products. Besides showing their practical applications in operational framework, we also aimed to make a comparison between MSG and METOP-based product. By doing this, one is able to imagine the benefits of future MTG-based products that will have even higher spatial resolution than METOP and higher temporal resolution than MSG. Show cases are intended for a broad community of expert as well as occasional users.

INTRODUCTION

There are many fields where selected LSA SAF products could be put to good use in meteorology and meteorology related services, e.g., operational meteorology, validation studies, agrometeorology, cooling/public heating, electric power industry and road management. In this paper, we focused on shortwave radiation (for verification of meteorological models), land surface temperature applications (heat waves, urban heat islands, icy roads and roads) and vegetation/drought monitoring. Featured show cases were prepared by Slovenian Environment Agency and some of them were also published on the LSA SAF website.

APPLICATIONS OF LSA SAF PRODUCTS

Validation of shortwave solar radiation

Instantaneous values of shortwave radiation over land are important for several applications including verification of NWP models as well as solar power plant applications. We compared hourly average of shortwave radiation at the ground based on satellite measurements, i. e., LSA SAF downward surface shortwave flux (DSSF) against forecast from operational NWP model ALADIN operated at Slovenian Environment Agency. Figure 1 illustrates the case for 19 June 2017 when NWP model forecast is very good and DSSF serves for confirmation of high quality NWP forecast, while Fig. 2 illustrates how valuable are satellite DSSF data in cases when NWP forecast deviates from reality – in this particular case due to poor cloud cover forecast (case shown for 6 June 2017). In such cases when forecasts deviate from reality, DSSF data are extremely important for decision makers in solar power plant applications for up to 2-3 hours in advance as well as for the NWP developers for further NWP model improvements.

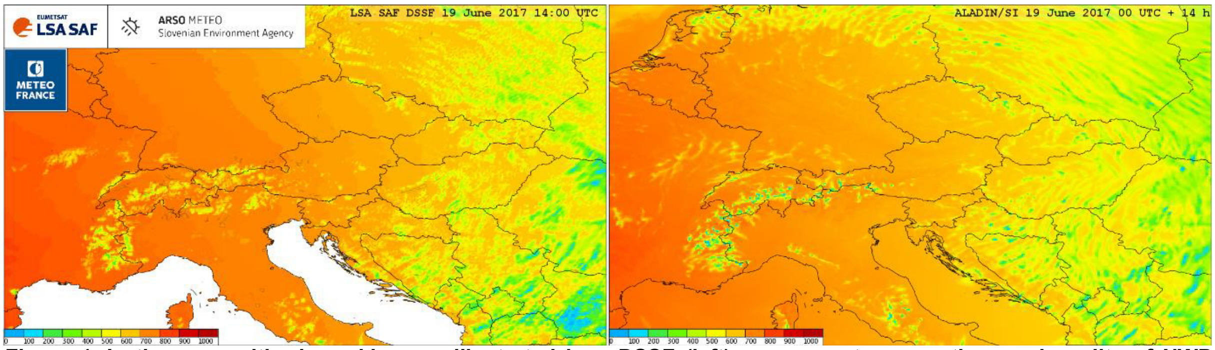

Figure 1: **In the case with clear skies, we illustrated how DSSF (left) can serve to prove the good quality of NWP forecast (right).**

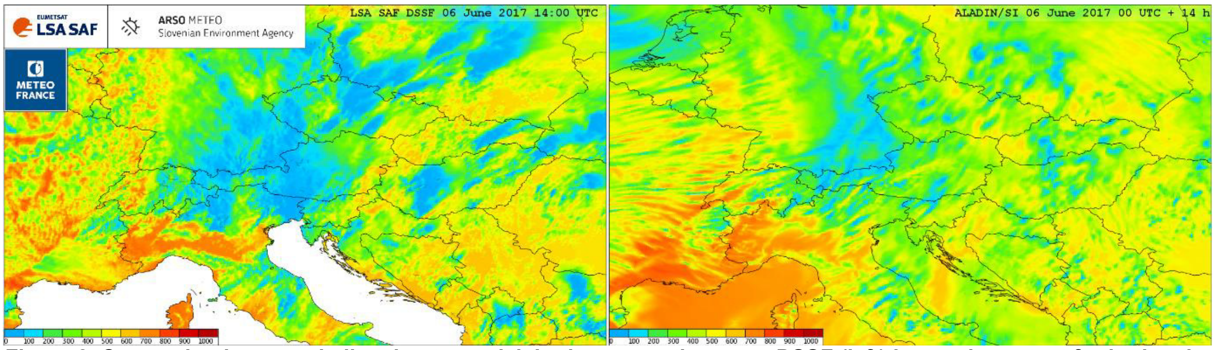

Figure 2: **Convection is more challenging to model. In the convective case, DSSF (left) is very important for both solar energy applications and NWP verification (right).**

Heat waves

Southern Europe experienced a severe heat wave that the media referred to as »Lucifer« in early August 2017. Air temperatures exceeded 40°C in many parts of Southern Europe. In recorded history, this was the fourth heat wave in Slovenia with air temperatures above 40°C. Three out of four cases occurred in the last 15 years. The LSA SAF land surface temperature (LST) product from MSG proved to be particularly well suited to monitor ground conditions and to locate the hottest areas during the »Lucifer« heat wave. Although satellite-retrieved LST is not identical to air temperature measured 2 meters above ground, the areas where both quantities reach their maximum are often identical (Fig. 3).

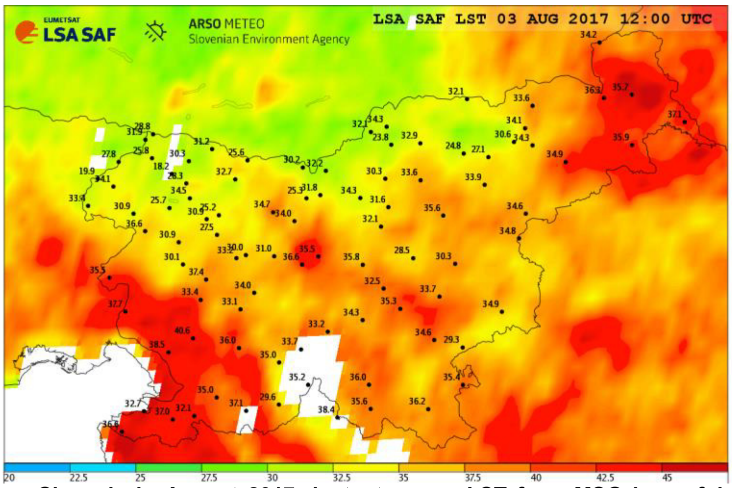

Figure 3: **Heat wave over Slovenia in August 2017: instantaneous LST from MSG is useful to locate hottest areas during the heat wave and complements air temperature data from ground observations network (recorded values are plotted on the image).**

LSA SAF DLST (Derived Land Surface Temperature) is a 10-day product. Temporal compositing and modelling of the diurnal temperature cycle results in representative and spatially continuous maps of LST, which are a very helpful indicator of past weather conditions. This allows us to identify regions affected by heat waves and droughts. It is particularly good for quick agrometeorological/climatological analyses and has little issues with cloudiness.

Imagery in Fig. 4 displays minimum temperature and temperature amplitude obtained from DLST median composites of two consecutive 10-day periods in August 2017. The first period from 1-10 August 2017 was dominated by a strong heat wave over most of southern Europe, which is clearly reflected by very high minimum temperatures and high temperature amplitudes. In the second period (11-20 August 2017), the summer heat wave already receded from Italy and southeastern Europe, but it still remained very warm in the southern part of the Iberian Peninsula.

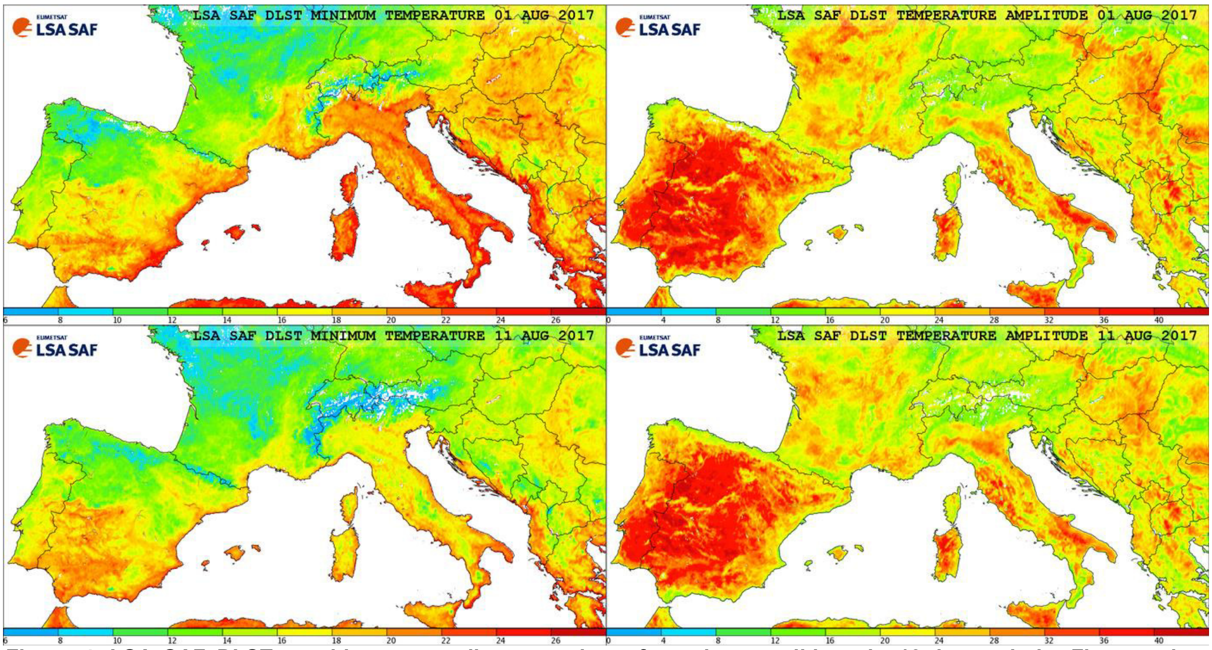

***Figure 4:* LSA SAF DLST provides an excellent overview of weather conditions in 10-day periods. Figures show minimum temperature (left) and temperature amplitude (right) displayed for 2017 heat wave over Southern Europe in 1-10 August 2017 (top) and 11-20 August 2017 (bottom).**

Urban heat islands

LST derived from geostationary and polar-orbiting meteorological satellites is very useful for monitoring and detecting urban heat islands. Madrid is one of the biggest metropolitan areas in Europe by population. It is located on the Meseta plateau in the centre of Spain and has a dry continental climate. Nights can get cold in winter and its location is favourable to study urban heat islands because of its dry climate (cloud free conditions are necessary in order to calculate land surface temperature from measurements in infrared spectrum).

Zoom over Madrid area reveals parts of the city with higher night-time LST for 5 December 2017 (see Fig. 5). The difference in LST between the centre of Madrid and the areas out of city was 5-6°C for the MSG product. METOP‘s image displays quite a similar temperature difference between central and outlying areas although it is possible to detect more spatial details from it because of METOP‘s higher spatial resolution. With the next generation of EUMETSAT’s geostationary satellites one will be able to obtain METOP-like spatial resolution with a high temporal frequency.

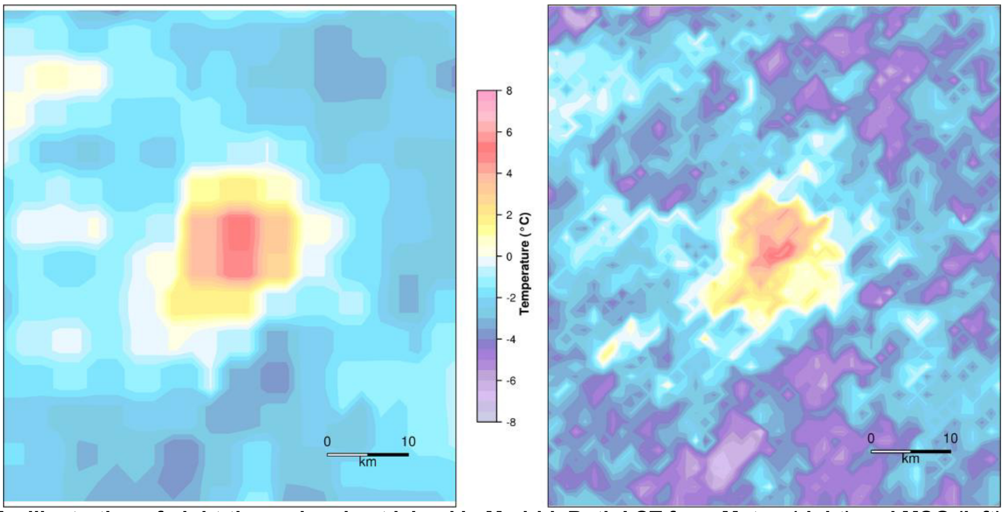

Figure 5: **An illustration of night-time urban heat island in Madrid. Both LST from Metop (right) and MSG (left) are able to indicate temperature gradient between city centre and outlying areas.**

Nowcast in temperature inversion situations

A typical winter weather situation with a pronounced temperature inversion developed in late December 2017 over Slovenia. Temperature inversion formed only over deeper basins and some valleys with maximum temperatures at around 1500 metres above sea level. Above valley and basin floors moderate west winds caused the mixing of the atmosphere which resulted in higher temperatures.

LST and analysis performed by Slovenian Meteorological Nowcasting System (MetNS) were compared with in-situ temperature measurements on the morning of 25 December 2017. Additionally, the figure displays which in-situ air temperature measurements at 5 cm are assimilated in the model (shown as black dots). The comparison between LST and MetNS revealed what benefits LST can offer in the scope of nowcasting when used together with a nowcasting system (see in Fig. 6).

Satellite image is clearly beneficial in areas with a lower density of in-situ measurement sites, particularly in the mountainous regions. In snow-covered areas satellite LST has an advantage at evaluating land surface temperature as the model relies on the air temperature to estimate land surface temperature. Finally, LST is also useful for identification of local weather characteristics that are not represented in the model when in-situ measurements are located on the edge of the local-scale weather pattern. These weather patterns had a crucial impact on the development of the local temperature inversion, which in turn is very important for a correct assessment of areas with a risk of icy roads.

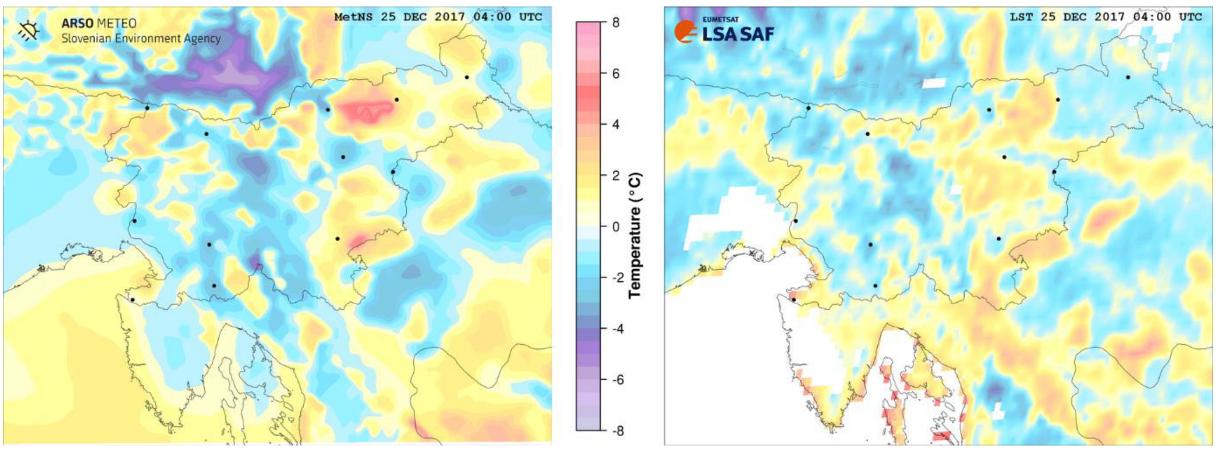

Figure 6: **A case of temperature inversion in diverse topography is presented. MetNS analysis (left) is compared against satellite LST (right).**

In these specific weather situations, LST is of great help for nowcasters when data are available (only in cloud-free situations). In this sense, satellite LST complements nowcasting products, which are available at all times, both in cloud-free and cloudy situations. For custom-tailored products, e.g., identification of icy roads at temperatures around freezing point the LST product has a potential to be useful in assessing road safety.

Vegetation and drought monitoring

LSA SAF Fraction of vegetation cover (FVC) represents the fraction of green vegetation covering a unit area and is very helpful for monitoring the current state of vegetation. Figure 7 displays FVC over Europe in June-August 2017 together with differences from the reference state of vegetation over the same period. Negative anomaly from the reference vegetation (FVC average in years 2004-2012) indicates conditions with less green vegetation. This highlights a situation with damaged vegetation which often implies drought conditions.

FVC is very useful for locating drought impacted areas and in general for detection of any kind of damage on vegetation, e.g., forest fires, hail and glaze ice. One can observe drought impacted areas from the FVC anomaly images: Iberian peninsula, Italy, France (middle/late summer) and Balkan peninsula (late summer). Additionally, it is possible to notice areas of burnt forest in central Portugal caused by massive forest wildfires in June 2017.

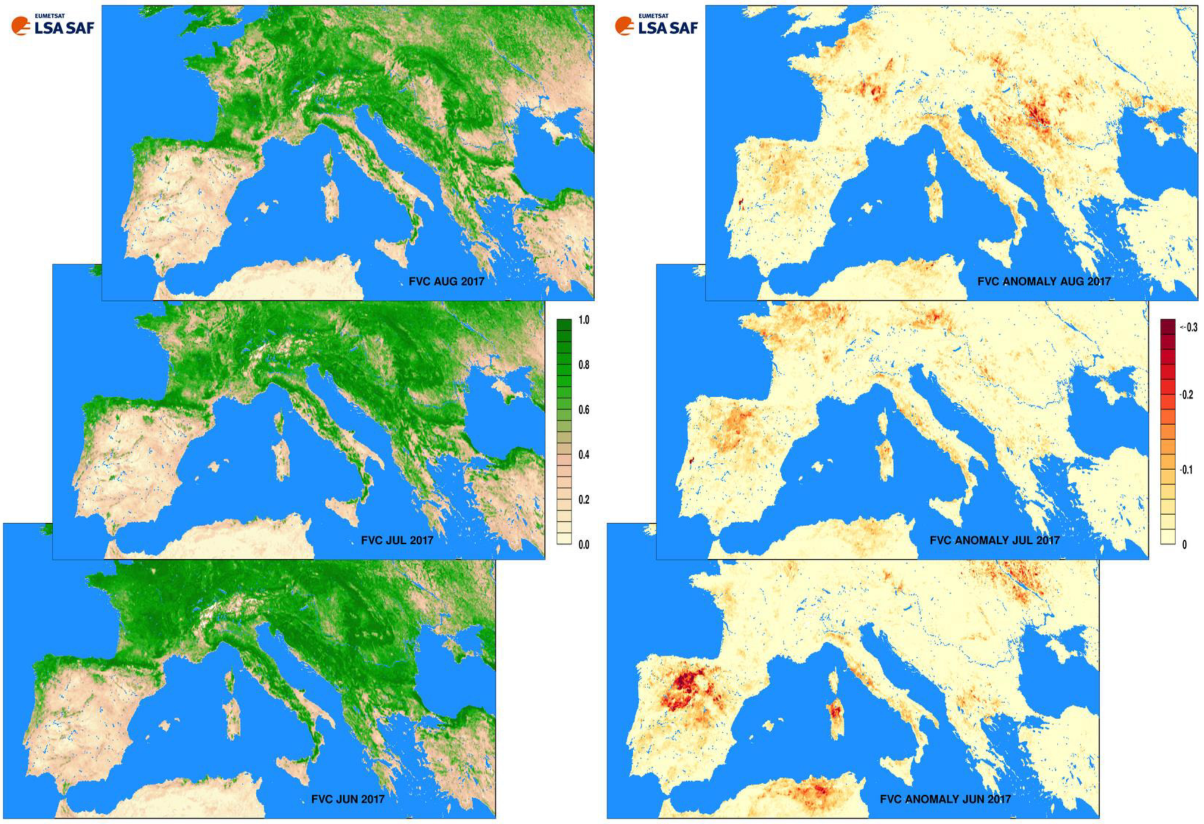

Figure 7: **FVC (left) and FVC anomaly (right) are shown for June-August 2017 over Europe. Only negative values of anomalies are indicated in the FVC anomaly images.**

Frost exposure

A prolonged period of warmer-than-average weather over Europe in March and the first half of April 2017 came to a halt after polar air mass rapidly moved southwards from N/NE of the continent. This event resulted in one of the worst frost damage in recent years. It affected vegetation, which was already in bloom over larger areas of Central, Western and Eastern Europe. Particularly hard-hit were areas with fruit cultivation, e.g., apples, grapes, pears and cherries.

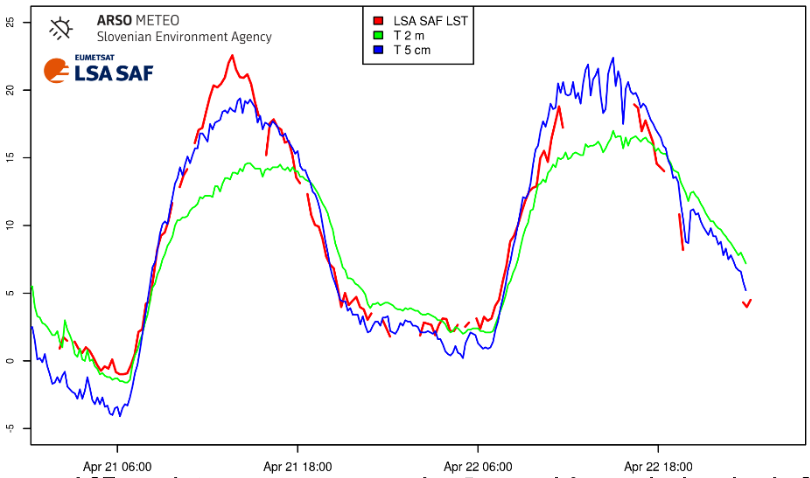

Figure 8: **Instantaneous LST vs. air temperature measured at 5 cm and 2 m at the location in SE Slovenia for 21-22 April 2017. Air temperature at 5 cm is quite comparable with satellite measurements.**

Air and ground temperature recordings from in-situ monitoring stations help identifying locations hit by the freezing temperatures. Air temperature is most commonly measured 2 metres above ground. This can be representative of frost exposure on many types of fruit trees, while air temperature closer to the ground is representative of various types of vegetables that grow on the ground. Figure 8 displays measured air temperature at two different altitudes from in-situ station in the coastal part of Slovenia (indicated as a black dot on the map) and the corresponding values of MSG LST for 21-22 April 2017. As can be seen from the figure, in-situ air temperature at 5 cm is quite comparable with satellite measurements, although there is a disagreement between the two for morning and noon values on 21 April 2017.

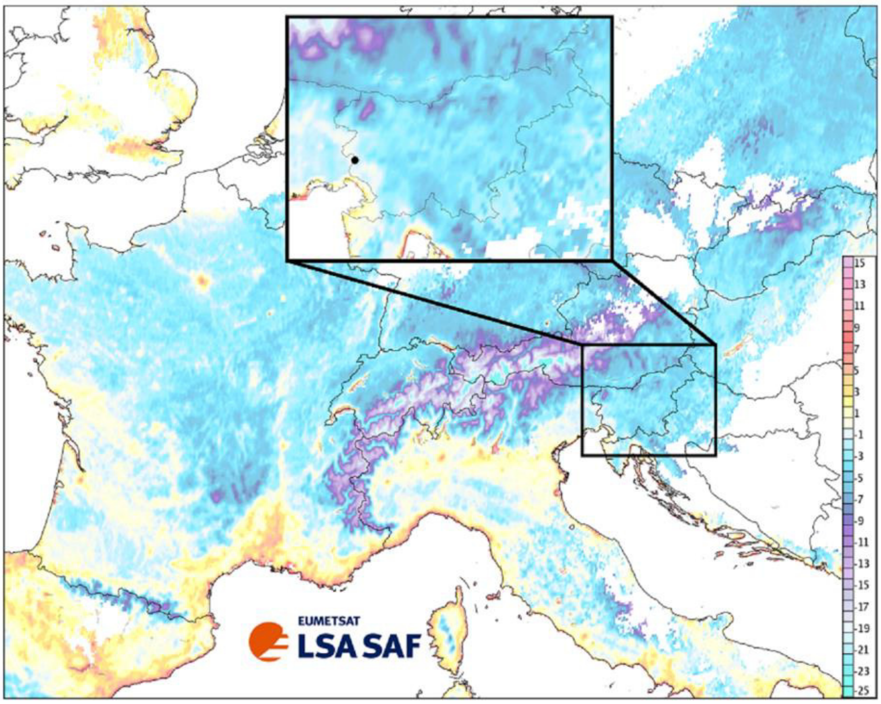

Figure 9: **Minimum LST indicates regions impacted by frost. Frost on 21 April 2017 is depicted over Europe with a zoomed-in area over Slovenia.**

LST is very useful to assess regional effects of frost on vegetation. For this purpose, we can study minimum temperature (shown for 21 April 2017 over Europe with a zoomed-in area over Slovenia in Fig. 9) and the duration of night-time frost exposure as a measure of frost severity in Fig. 10. We defined the latter as a number of hours when temperature fell below 0°C from 0 till 6 UTC. The two figures clearly indicate most of Slovenia experienced prolonged sub-zero temperatures on 21 April 2017 apart from the coastal areas. Satellite information helps differentiate areas with sub-zero temperatures from those with no frost exposure, particularly in areas with limited in-situ coverage.

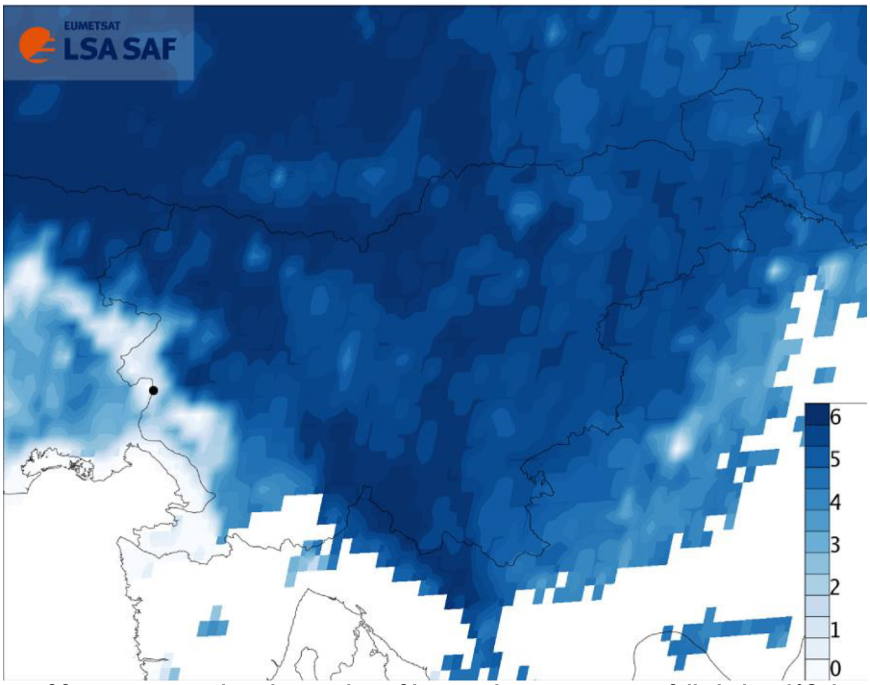

Figure 10: **Duration of frost exposure, i.e., the number of hours when temperature falls below 0°C, is a helpful indicator of frost severity. Frost severity is here defined as a number of hours when LST was below 0°C from 0 till 6 UTC.**

Frost damage depends to a high degree on the type and variety of plants grown locally as plants have a very different vulnerability to frost. Sensitivity to frost also depends greatly on the plant development, i.e., its phenological phase. So, to accurately assess regional effects of frost damage on vegetation one can combine local data (both type of plants and in-situ temperature) with satellite data to have a better understanding on the spatial extent of the frost exposure.

CONCLUSION

We illustrated some of many uses of LSA SAF products in operations. LSA SAF products are very important for Slovenian Environment Agency and some of them are already integrated in our operational framework. LSA SAF vegetation products (LAI and FVC) are employed in our drought monitoring set-up since 2011. We also see a potential for additional LSA SAF products to be integrated in our nowcasting system (e.g. LST).

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