Detecting the impact caused by oak lace bug (*Corythucha arcuata*, Say 1832) in pedunculate oak forests of the Pannonian Plain

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Background

The oak lace bug (*Corythucha arcuata*, Say 1832), native to North America, **is a new invasive species in Central Europe**, spreading rapidly and causing damage on foliage, primarily of oak trees, potentially jeopardizing the long term health and stability of natural oak forests. Since it was first recorded in Northern Italy in 2000, the lace bug has spread to most of the countries in South-East and Central Europe and in recent years the infestation has gained momentum (map below). In 2013 it was first recorded in Croatia and Hungary, affecting the valuable pedunculate oak forests of the Pannonian Plain. Damage to the leaves caused by the oak lace bug, as a result of leaf-sucking, **negatively affects leaf photosynthesis**.

Materials and Methods

To detect the impact caused by oak lace bugs we used:

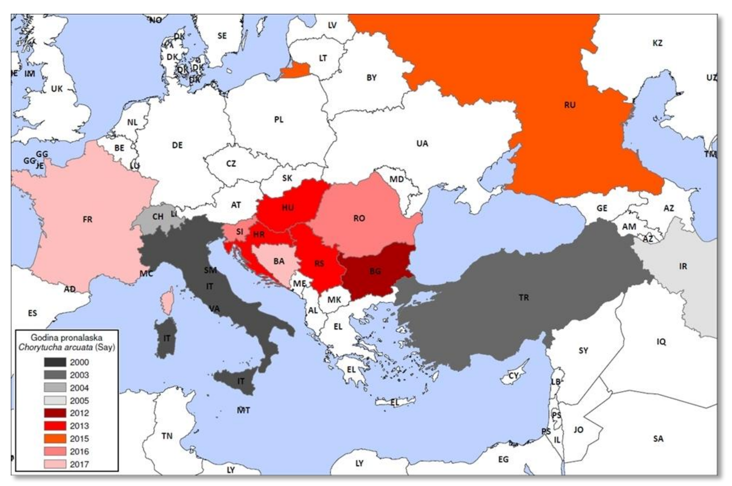
- **NDVI from C006 MOD13Q1 and MOD09Q1** with 250 × 250 m spatial and 16-day and 8-day temporal resolution, derived from the measurements of the MODIS sensor on board satellite Terra. Processing was performed using the quality flag and Julian day information included in the datasets based on the work of *Kern et al.* (*2016*). From MOD13 NDVI we created a dataset with 8-day temporal resolution. MOD09 NDVI were interpolated to an equidistant Julian grid, as well.
- **Land cover type** information based on the **IGBP classification of the C006 MCD12Q1** dataset (2001-2016) and **CORINE 2012**.
- **Forest species information** (*HNFD, 2010*)

To discriminate the early discoloration from the effect of the weather we used:

- **Daily mean temperature and precipitation sums** from the FORESEE database (*Dobor et al., 2015*), based on the E-OBS 17e dataset (*Cornes et al., 2018*), resampled to the grid of the MODIS data.
- Daily mean **Soil Water Content** of the **ERA5 reanalysis** dataset, at the 3[rd] & 4[th] depth of 0.28-2.89m.

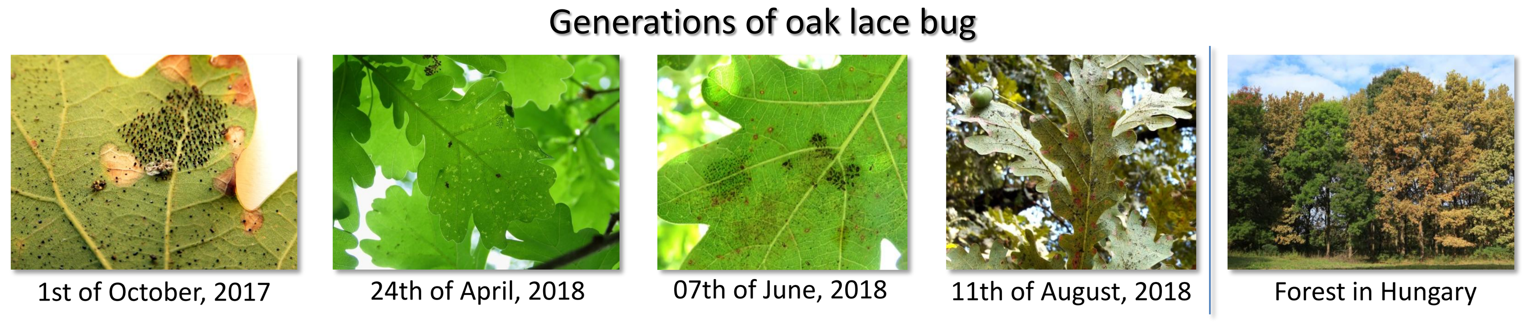
Ground observations

- First outbreaks of oak lace bug (OLB) within the Carpathian-Basin in Croatia and Hungary were recorded in 2013 (*Csóka et al., 2013; Hrašovec et al., 2013*).
- The oak lace bug, after overwintering behind the bark of the tree, has 3-4 generations during the year from April until October.
- Damage to the leaves becomes pronounced in the second part of the vegetation season as early discolouration.
- In Europe, OLB has no natural enemy yet.
- Negative biotic factor jeopardizing the health of oak stands, of many oak species.
- Impact on reproduction: negatively affects the quality of the seeds (*Franjevic et al., 2018*).
- Its spread and outbreaks might be promoted by the milder winters of the last years in the region.



The first records of the oak lace bug in the countries of Central Europe

Generations of oak lace bug



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Acknowledgments

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RESULTS

Investigating the spread at South Hungary, in 2018

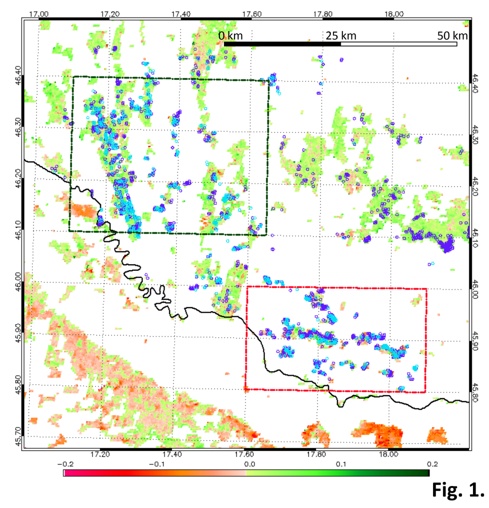


Fig. 1. NDVI anomaly of forested pixels in 06-13 of September, 2018.

Selecting pixels:

- Pixels of *Quercus robur* and *Q. petraea* with $share_{forest}$ > 80%
- Pixels of *Q. robur* with $share_{forest}$ > 80% and $share_{Q.\ robur}$ >75%

Determining two sub-areas:

- Partially infected area (n=139)
- uninfected area (n= 385)

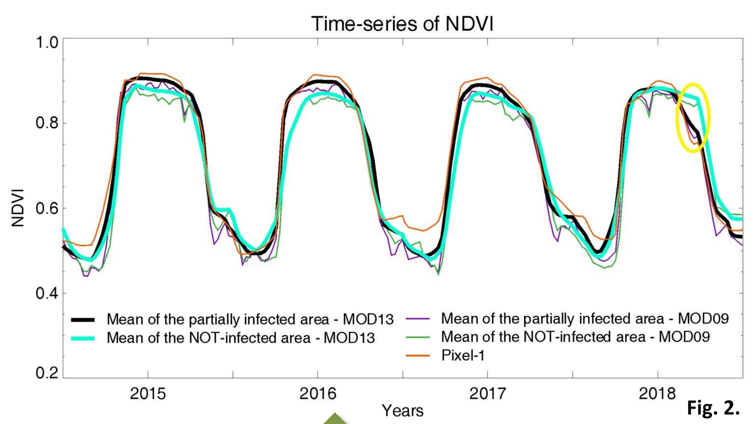


Fig. 2. Mean MOD09 and MOD13 **NDVI time-series** of the partially infected and uninfected areas, based on the selected pixels. One single pixel is also indicated.

Fig. 3. Mean MOD13 NDVI values of the partially infected and un-infected forested areas for different 8-day long periods, based on the selected pixels. **Short-time trends** are also indicated.

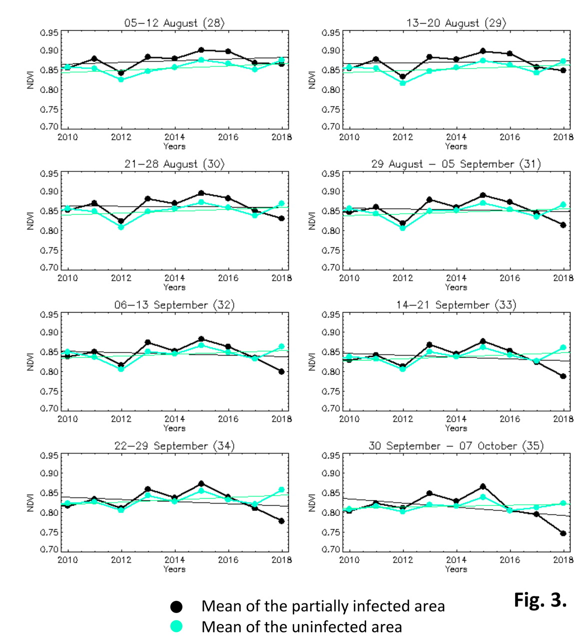


Fig. 3.

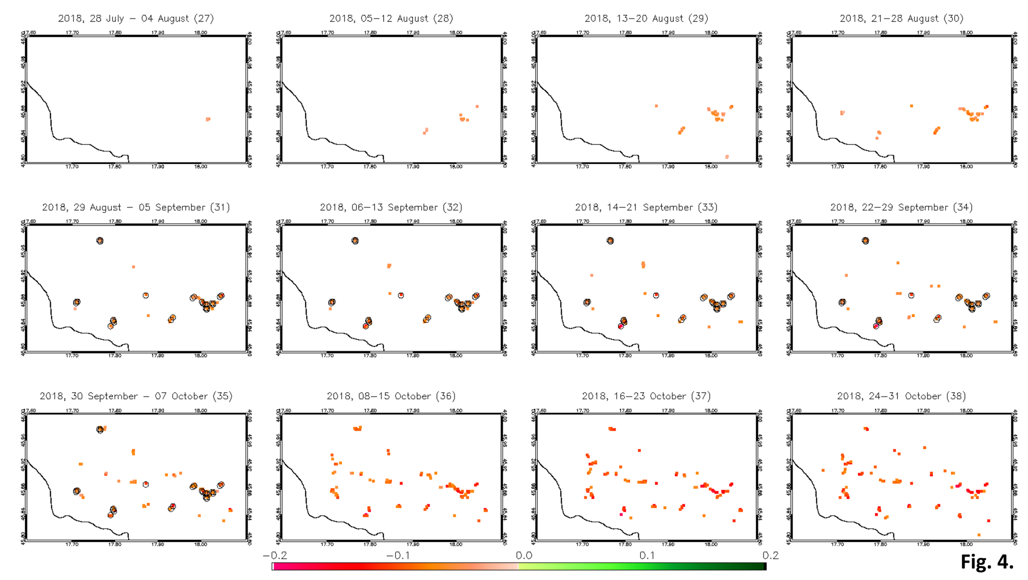


Fig. 4. MOD13 NDVI anomalies of those pixels in each 8-day periods in 2018, which had a **new record minimum value** relatively to 2000-2017.

Pixels having constantly a minimum values during 29 of August – 07 of October in 2018 are indicated with black circles.

(During 2013-2015 there were no such pixels at all).

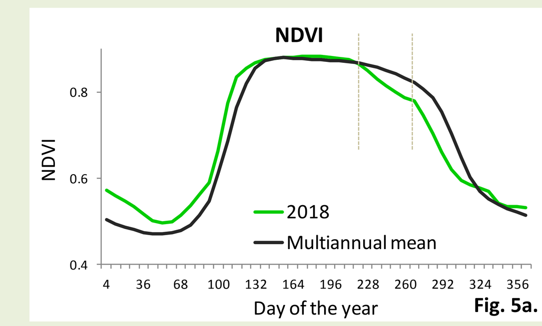
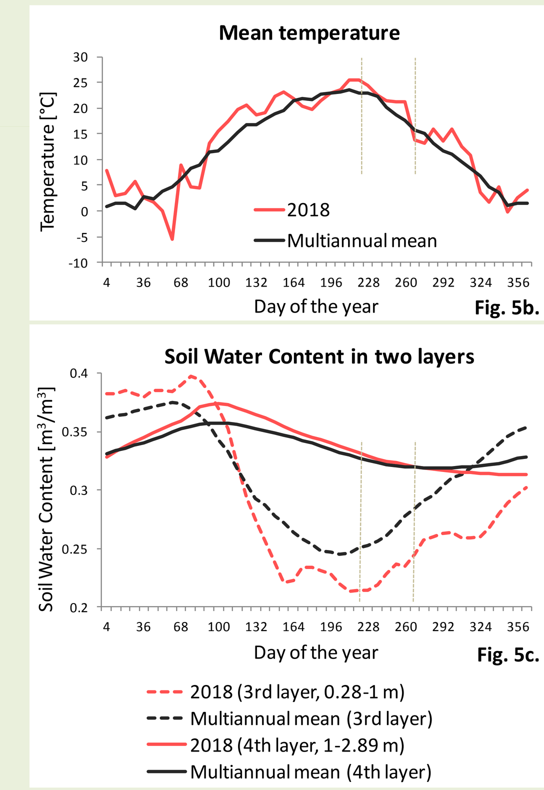


Fig. 5a-c. However, **the meteorological conditions** of the area showed a slight positive temperature anomaly, but also a positive one in soil moisture between 1-2.89m. Investigating the effects of temperature, precipitation and soil moisture (both in layer 3 and 4) on the state of the vegetation in August and September during 2000-2018, we found **relationship only in case of the soil moisture at layer 4** (1-2.89m) (Fig. 6).

It means, neither the positive temperature anomaly, nor the positive soil moisture anomaly could not contribute to the NDVI decrease in August at such an extent, with a maximum -0.045 NDVI.



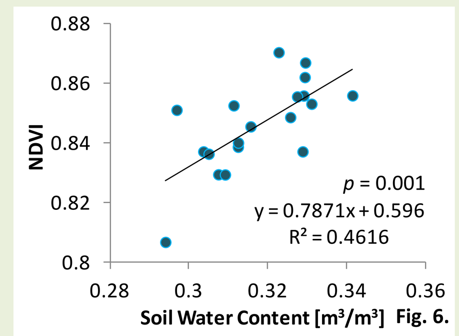
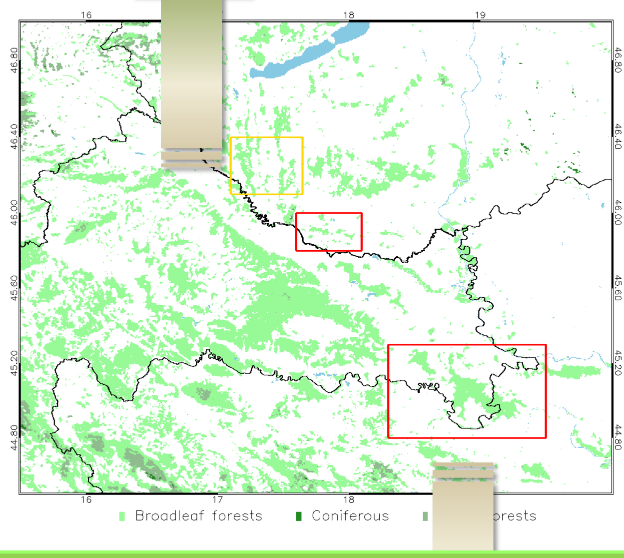


Fig. 6. **Relationship between mean soil water content** (at 1-2.89m) during 5[th] of Aug. until 5[th] of Sept. **and mean NDVI** during 21[th] of Aug. until 5[th] of Sept.



Conclusions

- NDVI derived from **MOD09 provides more detailed phenology** to pixel based studies.
- The **presence and spread of OLB in Croatian** forests **since 2015 is clear, its impact is significant**.
- However, other effects might also contribute to the negative NDVI anomaly of the other tree species.
- The oak lace bug might be present in the southern Hungarian forests as well since 2016.
- The infection of the pest **effecting larger forested areas** started at South Hungary as well, its impact **can be clearly observed in 2018**. However, the decreasing NDVI has to be dealt with caution, since it can be also due to weather or to other disturbances (or in September to the start of the senescence).
- **The anomalous weather alone is not able to trigger such high NDVI decrease.** Moreover, the still NOT infected area encountered very similar weather, but a higher than average NDVI.

Investigating the progress in Croatia, since 2013

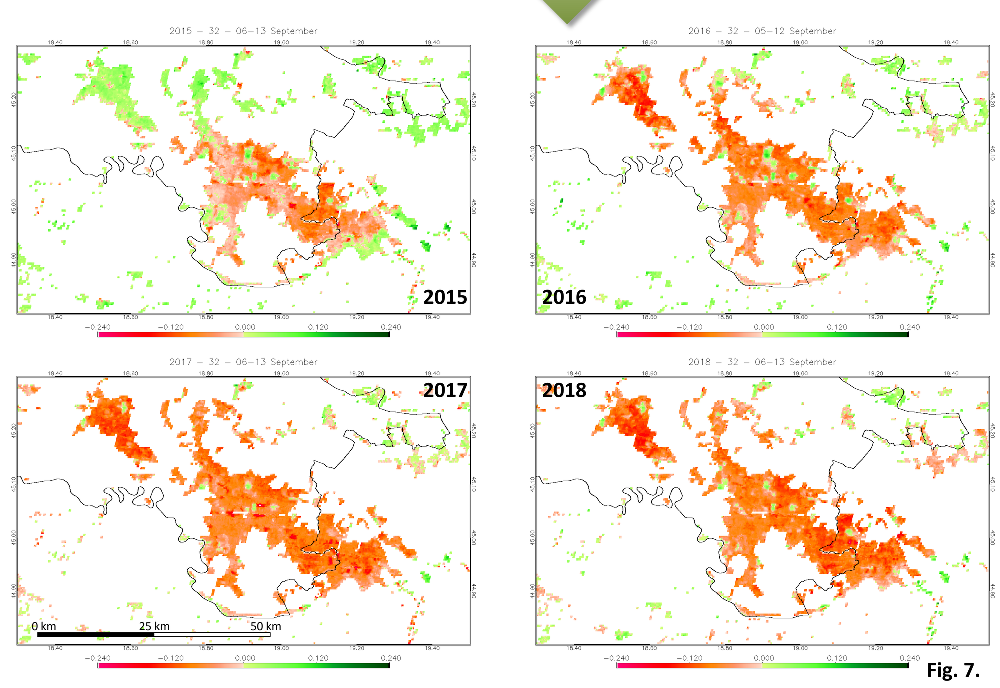


Fig. 7. **Maps of MOD13 NDVI anomalies of the Slavonian forest (in Spačva basin)** in Croatia between 2015-2018, during 06-13, September. The spread and the progress of the infection is also visible,

Anomaly was calculated for the period of 2000-2012 (pre-oak lace bug period).

The anomaly of this period at the beginning of September is still not the consequence of the senescence.

Questions

- Consequences?
- Further future spread?

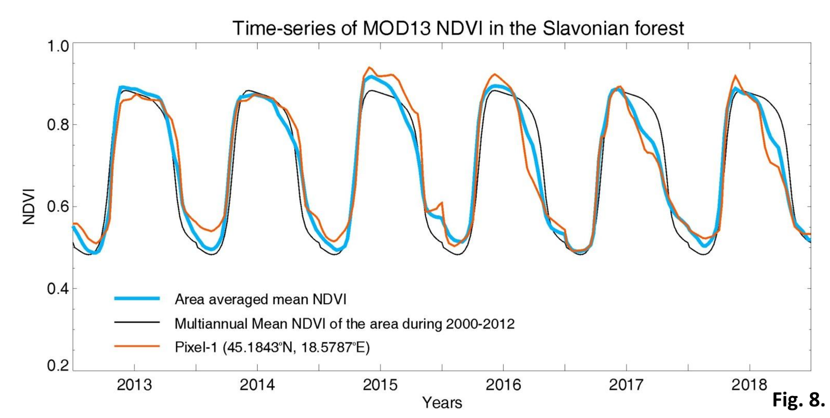


Fig. 8. **Mean MOD13 NDVI time-series of the Slavonian forest** (blue), based on the selected pixels of oak trees. Multiannual mean (black) during 2000-2012 (pre-oak lace bug period), and one single pixel is also indicated (red). The difference between the area averaged mean and the multiannual mean were:

	5-12, Aug	13-20, Aug	21-28, Aug	29-05, Sept	06-13, Sept
2018	0.037	0.055	0.071	0.081	0.084
2017	0.070	0.077	0.080	0.081	0.081

Fig. 9. **Comparison of the histograms of the NDVI anomalies for oak trees** (red, n = 6450) **and for all other broadleaf species** (black, n = 6521) within the Slavonian forest during August-September 2015-2018. (NDVI anomalies are calculated for the pre-lace bug period of 2000-2012). The figures clearly show the outbreak of oak lace bug in 2015, and its increasing effect on oaks during the next years. However, other species also show increasing negative anomaly, which can be due to weather, other pests (like Chalara ash die-back) or remaining presence of oaks within those forests.

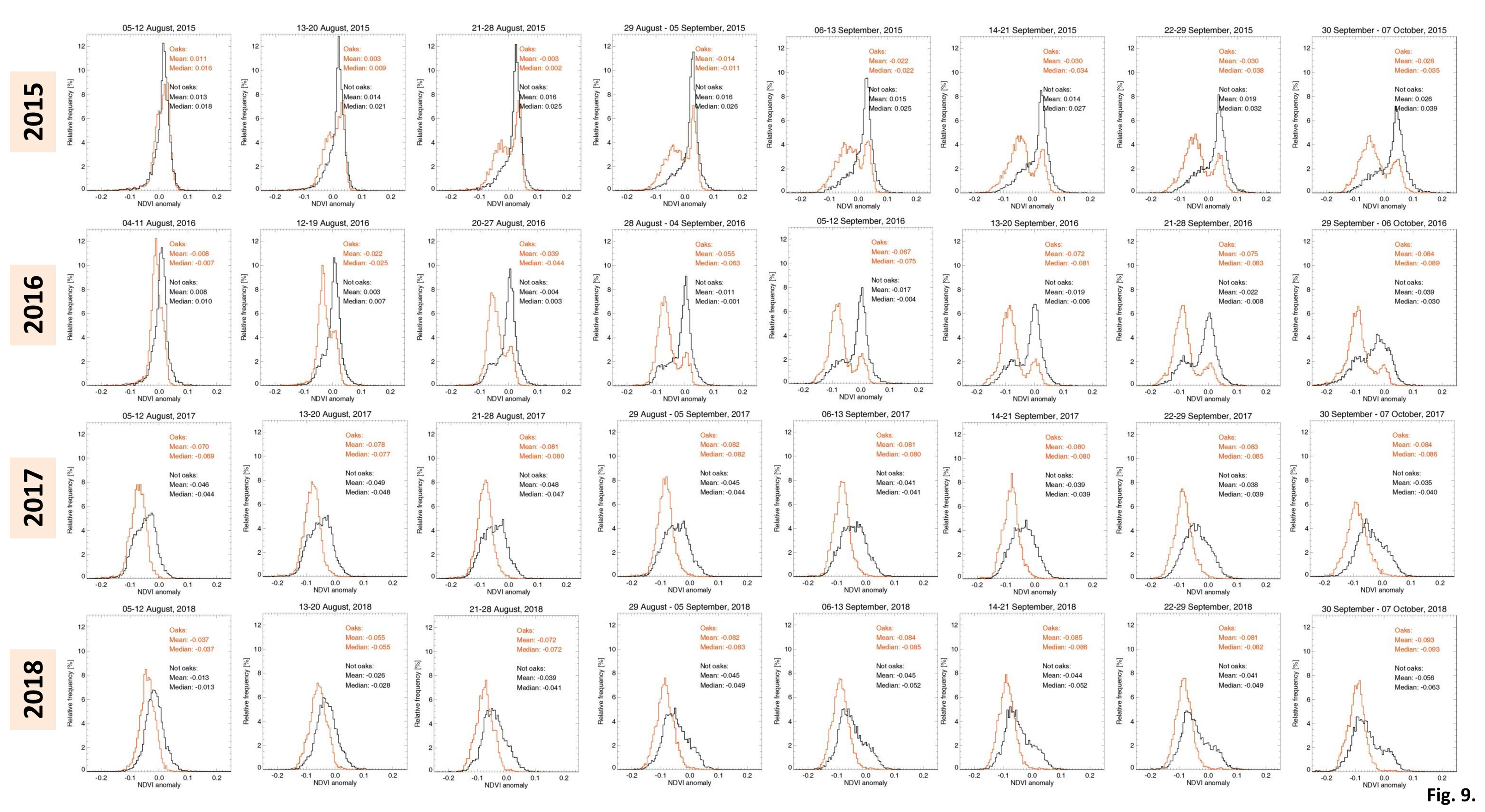


Fig. 9.