A consistent link between drought and pulses of tree mortality across Europe

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ECOSYSTEM DYNAMICS AND
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Preamble

This document presents preliminary results from an ongoing research project that has not been published and thus not been peer-reviewed yet. We appreciate your interest in our research, but kindly ask you to take all results with a grain of salt, as they might be subject to changes.

Thank you!

Research questions

(1) Where across continental Europe did pulses of tree mortality occur?

(2) Are those pulses statistically related to drought conditions?

(3) Which regions are particularly sensitive to drought-related pulses of tree mortality?

Objectives

(1) We used high-resolution satellite-based maps of forest canopy mortality to identify pulses of tree mortality at annual resolution and at a spatial grain of 0.5 degrees.

(2) We following test for a robust statistical relationship between pulses of tree mortality and drought conditions as measured using three different drought indices: climatic water balance (CWB), precipitation anomaly (PREC) and vapor pressure deficit (VPD).

Objective 1: Pulses of tree mortality

- We use 30 m resolution forest disturbance maps covering the period 1987 to 2016 and created from Landsat satellite data in a previous study (Senf and Seidl, *in revision*).

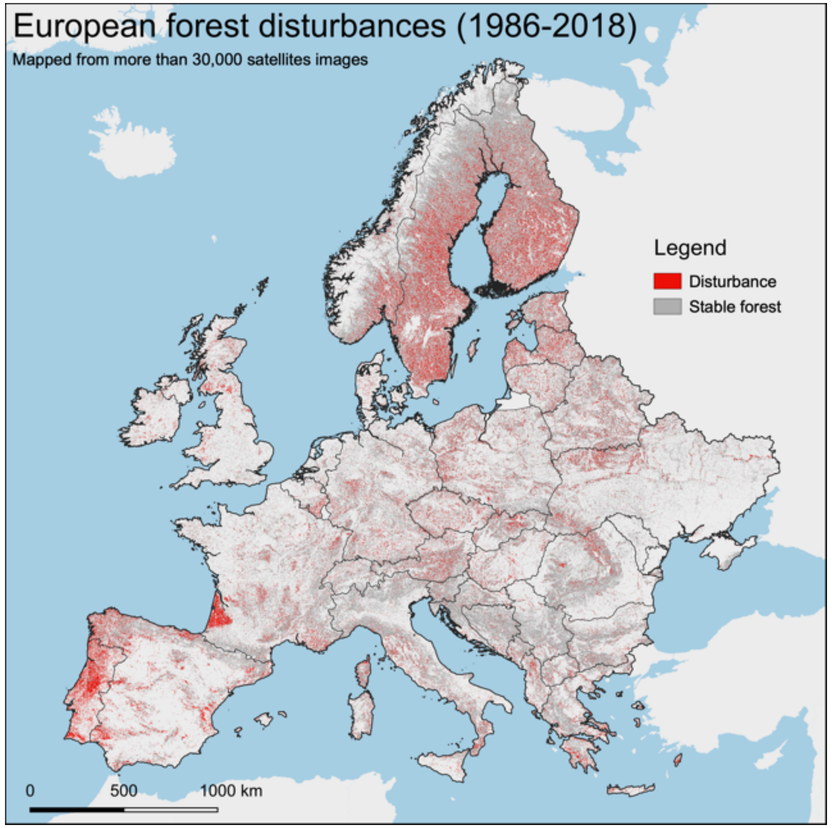

Fig. 1: Annual forest disturbance maps from Senf and Seidl (*in review*)

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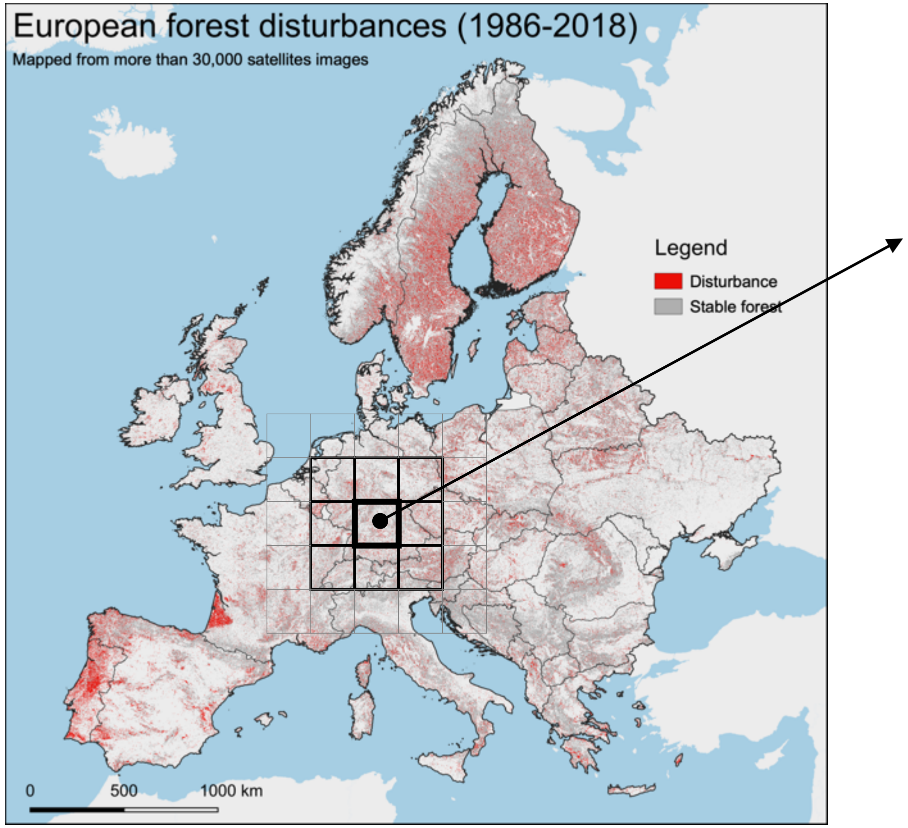

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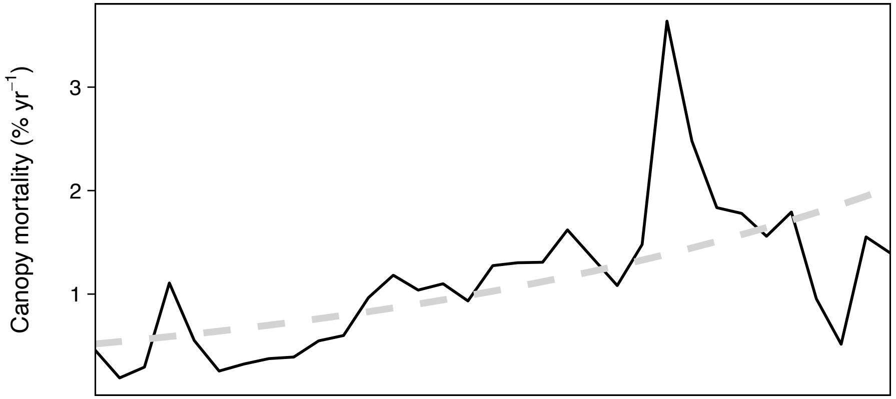

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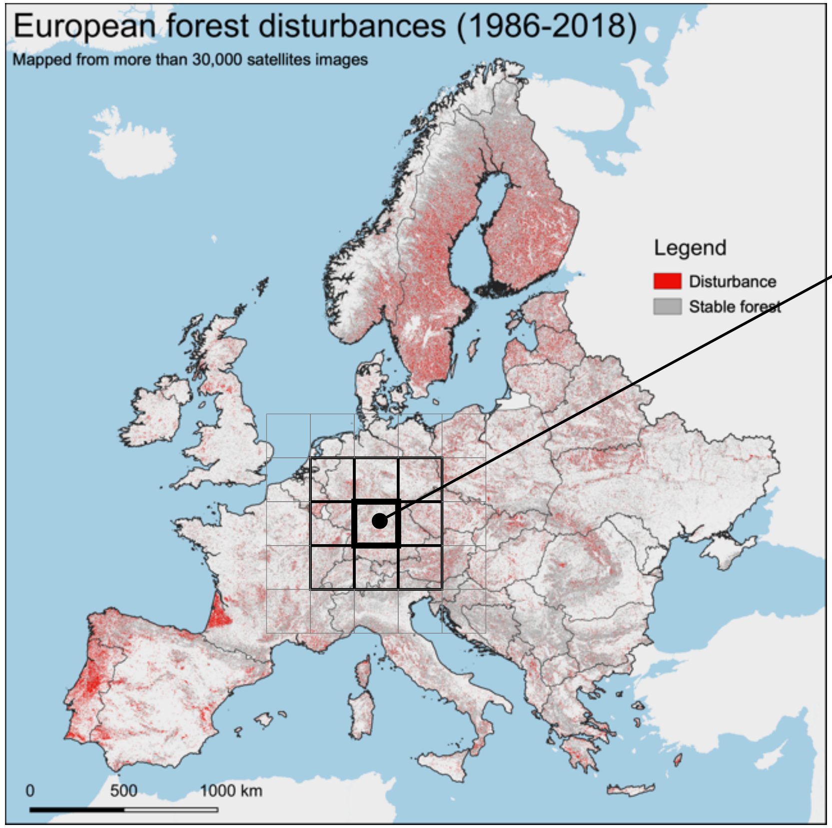
- For each grid cell we calculated the trend in canopy mortality rates.



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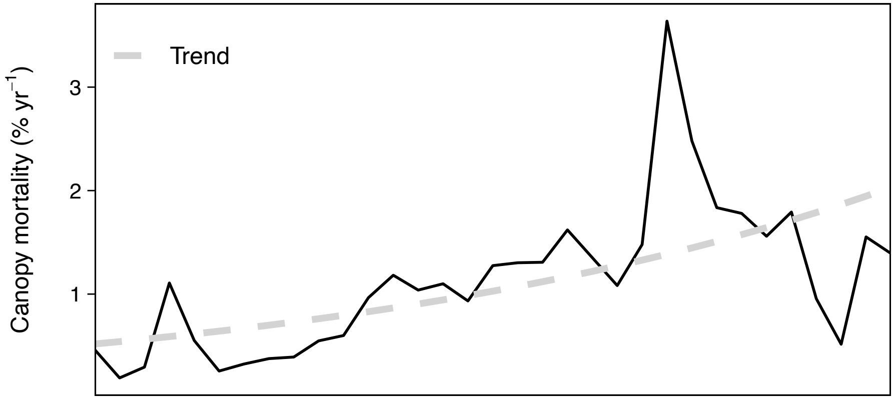

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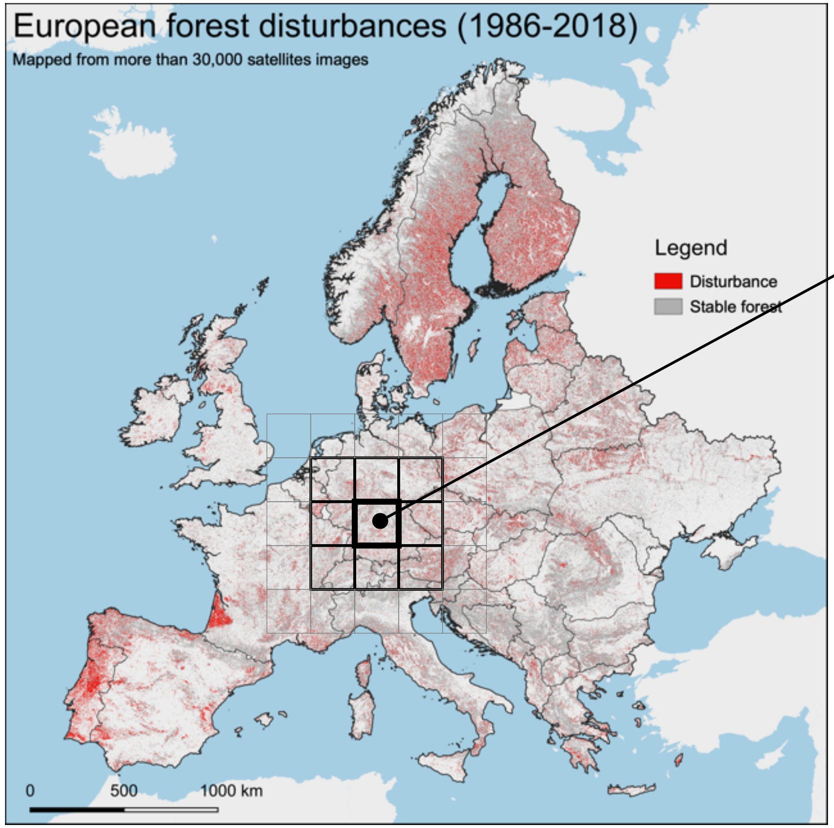
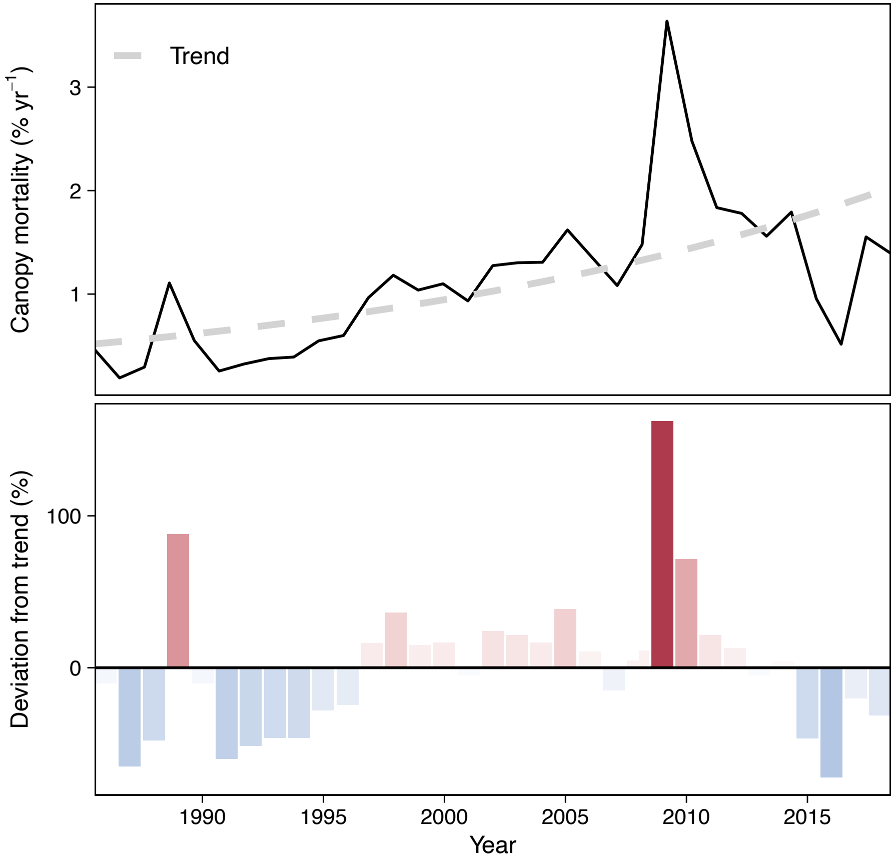
- We derived the residuals as measure of excess (red) and deficit (blue) mortality.





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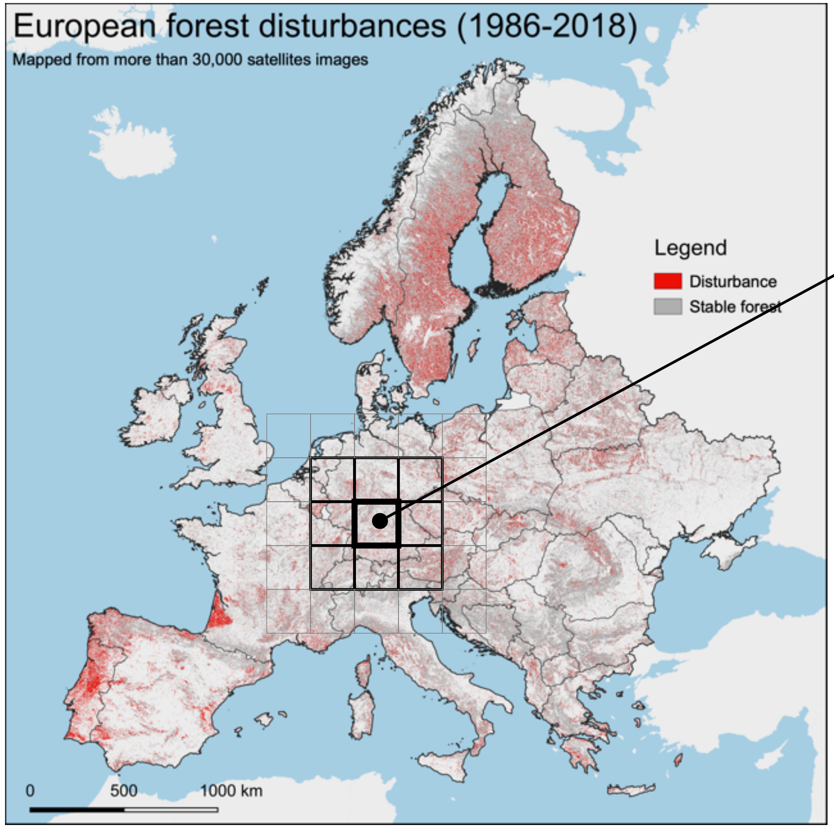
- A mortality pulse was finally defined as a grid cell and year with excess mortality compared to the long-term trend.



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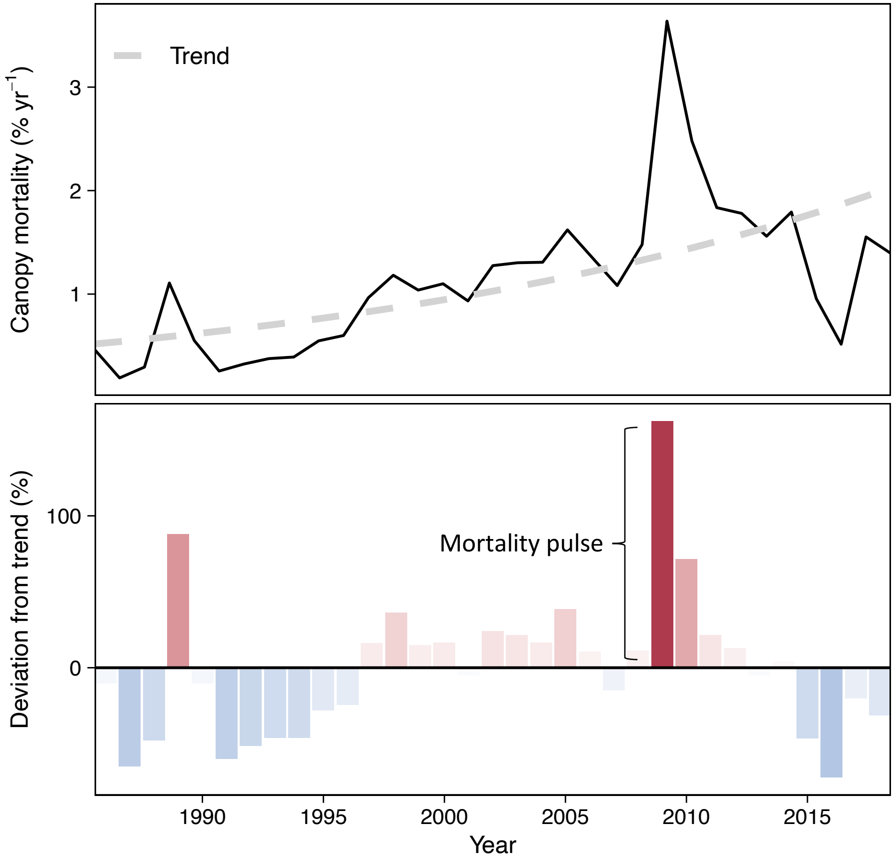

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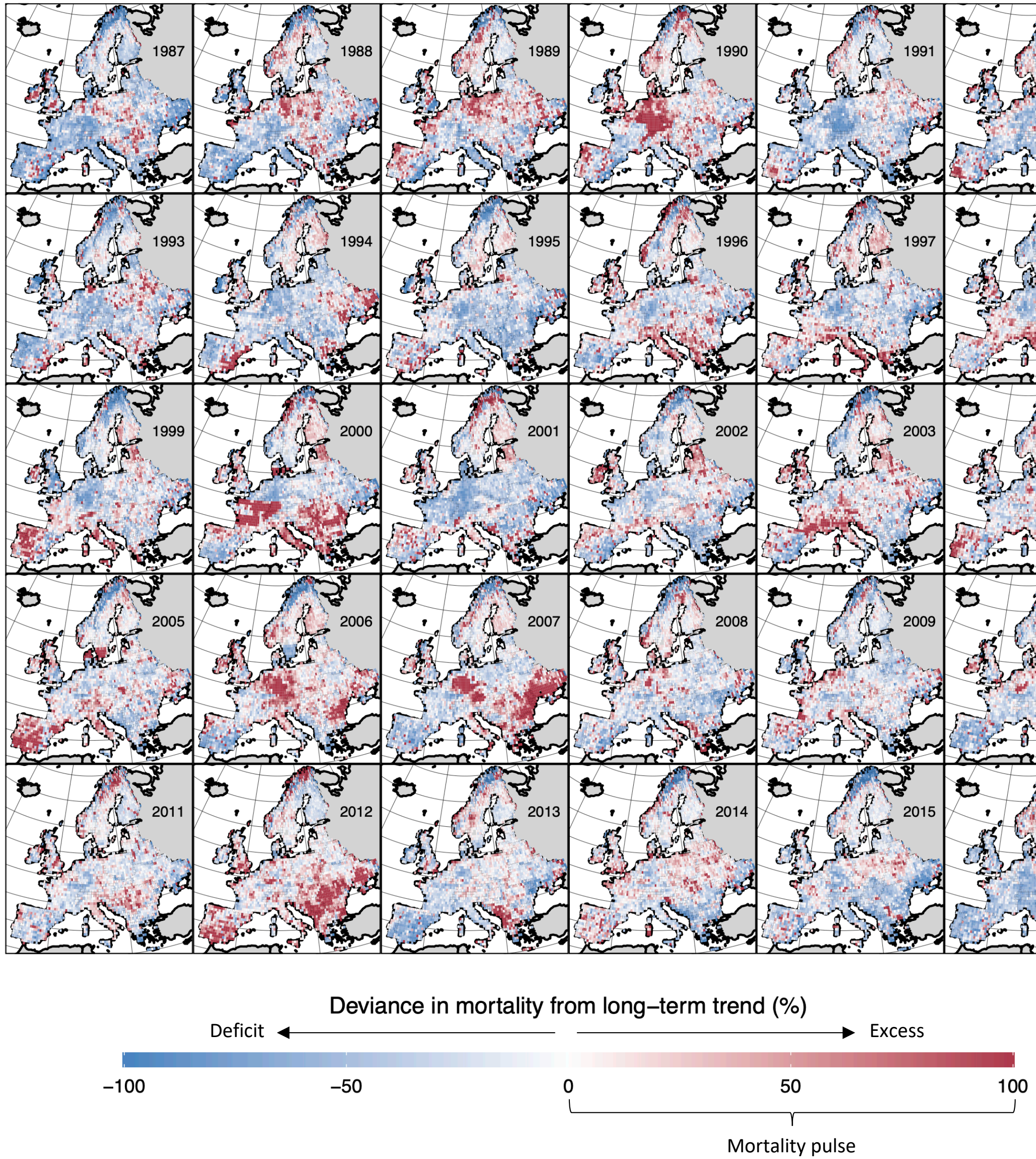

Fig. 2: Annual maps of forest mortality pulses (i.e., excess mortality compared to long-term trend) across the European continent.

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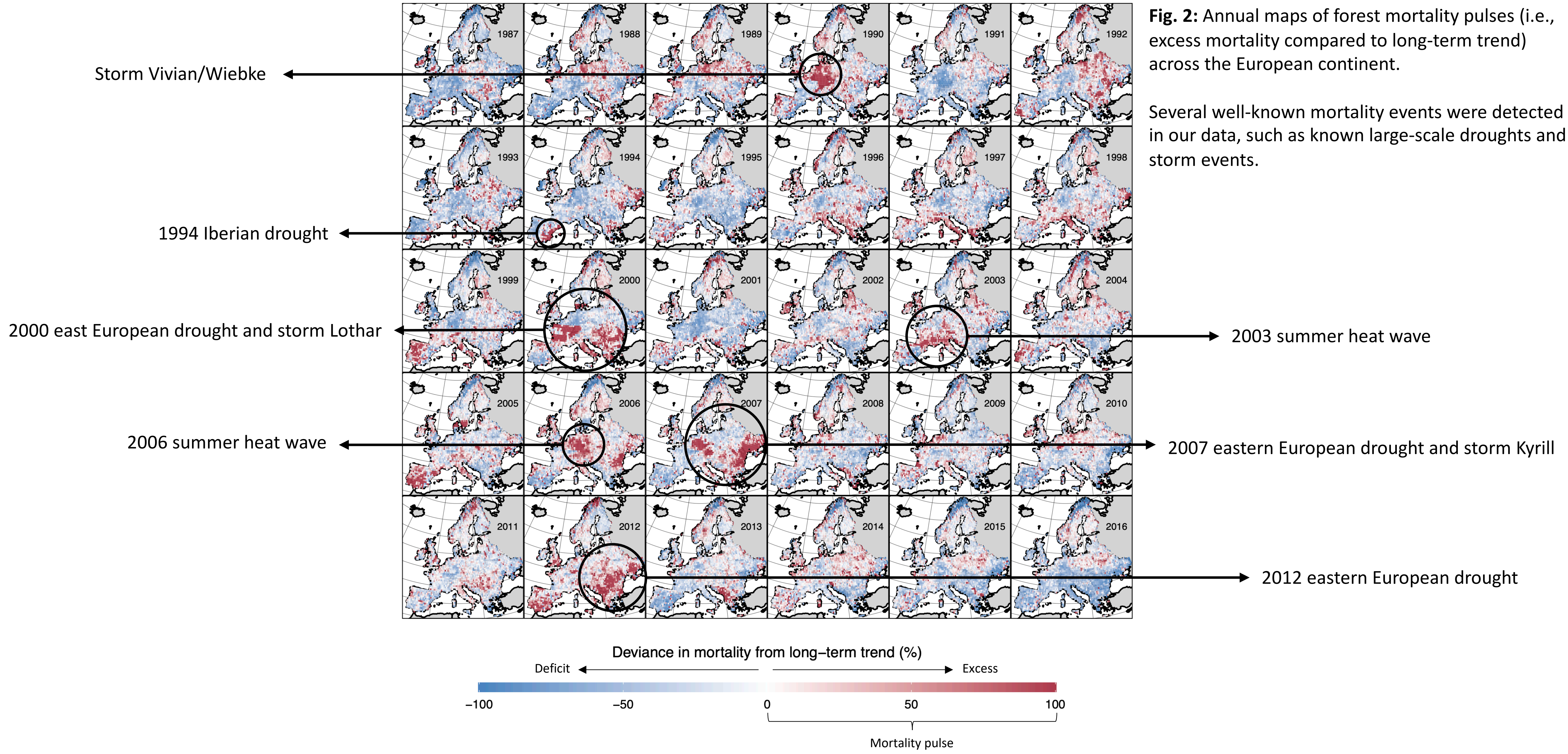

Fig. 2: Annual maps of forest mortality pulses (i.e., excess mortality compared to long-term trend) across the European continent.

Several well-known mortality events were detected in our data, such as known large-scale droughts and storm events.

Objective 2: Link to drought

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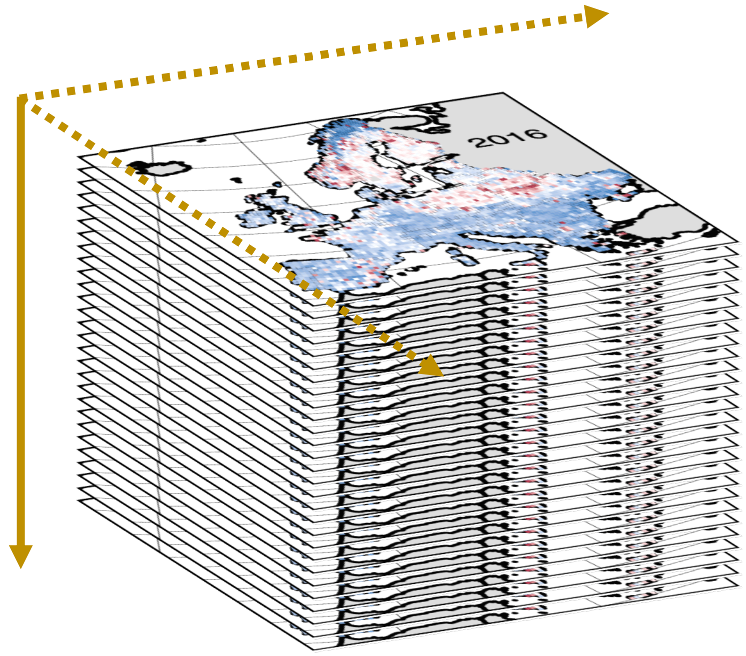

$$\sqrt{pulse_{it}} = (\alpha_0 + \alpha_i) + (\beta_0 + \beta_i) * \; drought_{it} + \epsilon_{pulse}$$ Temporal effect of drought on pulses

$$\epsilon_{pulse} = \mathrm{N}(0, \sigma^2)$$ Unobserved variation

$$\begin{pmatrix} \alpha_i \\ \beta_i \end{pmatrix} = \mathrm{MVN}(0, \Sigma_t)$$ Variation among grid cells

i = grid cell
t = year

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- We found a robust and consistent relationship between all three drought indices and pulses of tree mortality, with highest association using average drought values between Match and July (June for VPD).

Drought index	Effect size (95% CI)	R^2 (95% CI)	Observation period
CWB	-0.04 (-0.04 – -0.04)	0.13 (0.13 – 0.15)	March to July
PREC	-0.03 (-0.03 – -0.04)	0.13 (0.13 – 0.14)	March to July
VPD	0.03 (0.03 – 0.04)	0.13 (0.13 – 0.13)	March to June

Tab. 1: Average effect of the three drought indices on pulses of tree mortality.

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- We estimate that under strong drought (two standard deviations above normal), tree mortality increases on average by 14 % compared to the long-term trend.
- However, the effect size varied among grid cells, with several regions showing a substantially higher sensitivity of tree mortality to drought (e.g., Iberian peninsula).

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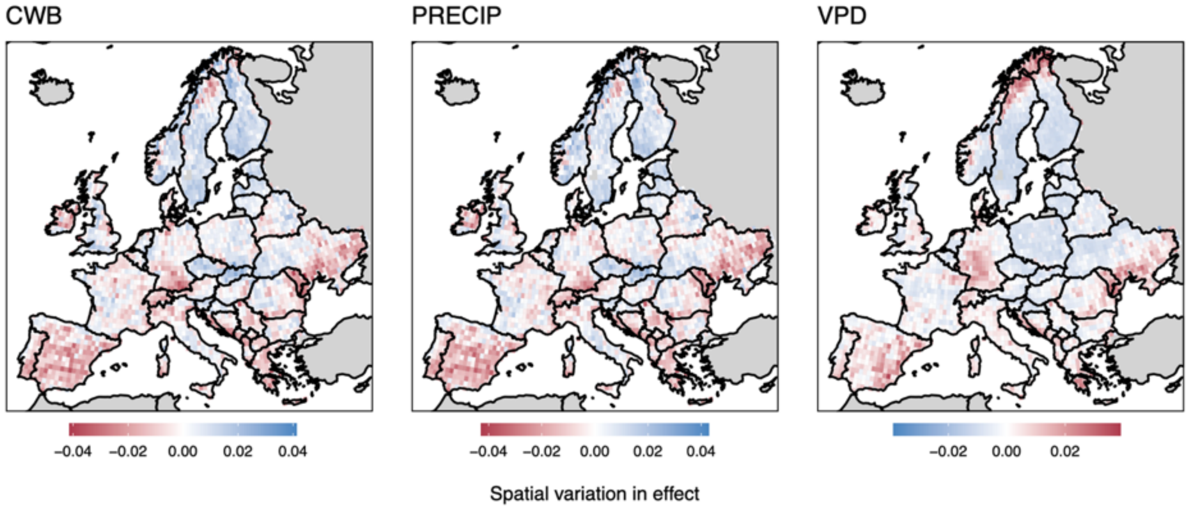

Fig. 3: Spatial variation in effect size. Reddish colors indicate a stronger effect of drought on mortality pulses.

Summary

(1) We present a novel yet simple approach of quantifying pulses of tree mortality from satellite-based forest disturbance maps.

(2) We show that across continental Europe there were several large-scale pulses of tree mortality over the past three decades.

(3) While some of the pulses are clearly unrelated to drought (e.g., storm events), there is a continental-scale consistent relationship between drought and pulses of tree mortality.

(4) However, there is wide spatial variation, with some regions characterized by a particular sensitivity of tree mortality to drought. Those include, among other, the Iberian peninsula, the Alps, and eastern/south-eastern Europe.

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