



reccap-2

ESA Climate Space – RECCAP2

Project Scientific highlights (PSH) 30 09 2026

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Article published in Nature Geoscience, August 2026

Su, Y., Xu, Y., Zhang, X., Makowski, D., Pellissier-Tanon, A., Francini, S., Shi, T., Yu, K., Liu, S., Chen, H., Li, H., Chang, J., Chen, S., Yin, C., Besic, N., Brandt, M., Viana-Soto, A., Kowalski, K., Senf, C., d'Aspremont, A., & Ciais, P. (2026). *Disturbance characteristics and forest properties regulate surface warming and recovery across Europe*. **Nature Geoscience**. <https://doi.org/10.1038/s41561-026-02071-5> NG

This study provides a high-resolution, Europe-wide assessment of how forest disturbances affect **local surface temperature and its subsequent recovery**. By combining Landsat-derived summer land-surface temperature with the 30-m European Forest Disturbance Atlas, the analysis shows that recently disturbed forests are on average **1.70 °C warmer in summer than nearby undisturbed forests** located 100–500 m from disturbance edges. Disturbance severity, reflecting the amount of vegetation and canopy loss, emerges as the strongest control on warming, together with disturbance patch size. Needleleaf forests warm more strongly than broadleaf forests, while plantations show substantially larger warming than natural forests, demonstrating that forest structure and management strongly regulate the local climatic consequences of disturbance. NG NG

The study combines satellite observations with a **difference-in-differences framework and machine-learning attribution** to isolate the disturbance signal from background climatic variability. Disturbances occurring during 2019–2023 were analysed using Landsat temperature observations from 2018–2024, while forests disturbed in 2014 were followed for ten years to quantify thermal recovery. The results show an important resilience of European forests: **more than 82% of disturbance-induced surface warming disappears within ten years**, although recovery is slower following severe disturbances. Natural forests recover more rapidly and completely than plantations, and broadleaf forests generally recover faster than needleleaf forests. NG NG

The work also provides direct information for **climate-smart forest management**. Model experiments show that reducing disturbance severity can lower post-disturbance warming by about **0.10–0.51 °C**, while reducing disturbance patch size produces cooling of up to approximately **0.54 °C**. A hypothetical shift from needleleaf to broadleaf forest would reduce warming by a median **0.11 °C across Europe**, with effects exceeding 0.5 °C in some northern regions. These results indicate that avoiding unnecessarily large and severe canopy openings, maintaining structurally complex forests, and considering species composition can help limit the local warming caused by disturbances, while recognizing that forest management must simultaneously address biodiversity, regeneration, adaptation and wood production. NG NG

The study is particularly relevant to **ESA Climate Space RECCAP2**, illustrating how high-resolution Earth Observation can be extended beyond carbon-stock monitoring to quantify the **biophysical climate effects of forest disturbances**. The research was directly supported by the **ESA Climate Change Initiative RECCAP2 project** and by the new **ESA Climate Space RECCAP2 project**, together with the ANR AI4Forests programme. NG(1) The combination of long-term Landsat observations, the European disturbance record and Sentinel-1 information on canopy structural change demonstrates how satellite observations can identify where forests are most vulnerable to disturbance-driven warming and evaluate their capacity to recover. This adds an important new dimension to RECCAP2 assessments: disturbances not only alter forest carbon stocks and sinks, but can also create a substantial and persistent **local thermal footprint**, with consequences for forest resilience and climate adaptation.

Article published in Nature Geoscience, June 2026

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Kowalski, K., Viana-Soto, A., Brandt, M., Ciais, P., De Keersmaecker, W., Fensholt, R., Pugh, T. A. M., Xu, Y., & Senf, C. (2026). *Accelerating biomass loss from forest disturbances across Europe*. *Nature Geoscience*, 19, pages 1132–1138. <https://doi.org/10.1038/s41561-026-02032-y>

This study delivers the **first spatially explicit, satellite-based quantification of aboveground biomass (AGB) losses from both natural disturbances and harvesting across all European forests** over the period 1985–2023. By integrating long-term Landsat disturbance observations with high-resolution biomass maps derived from Earth Observation, the study estimates that European forests lost **6.5 ± 0.8 Pg of aboveground biomass** during the last four decades. Most importantly, it reveals a **45.6% increase in biomass losses after 2018**, driven by climate-induced disturbances such as bark beetle outbreaks, windstorms and drought impacts occurring in Europe's biomass-rich temperate forests.

The study demonstrates that biomass losses are increasing faster than disturbance area alone would suggest. In particular, the sensitivity of biomass loss to disturbance has risen sharply in temperate forests since the mid-2010s, indicating that even relatively small increases in disturbance area can now produce disproportionately large carbon losses because disturbances increasingly affect forests with high biomass stocks. These findings provide new evidence that climate change is fundamentally altering disturbance regimes and weakening the capacity of European forests to function as an effective carbon sink.

The work highlights the unique contribution of **ESA Earth Observation** to continental carbon monitoring. By combining the European Forest Disturbance Atlas with high-resolution satellite-derived aboveground biomass products, the study establishes an operational framework for translating observed forest disturbances into biomass and carbon losses across Europe. These advances directly support the objectives of the **ESA Climate Space RECCAP2** project by improving observation-based assessments of forest carbon dynamics, strengthening the monitoring of disturbance impacts, and providing critical information for evaluating the resilience of Europe's forest carbon sink under accelerating climate change.

ESA has published a new story on CCI Website

The paper has been picked up in a Nature Geoscience News Item: <https://doi.org/10.1038/s41561-026-02037-7>

Article published in Remote Sensing of Environment, August 2026

Viana-Soto, A., Mense, J. A., Kowalski, K., Pauls, J., Gieseke, F., & Senf, C. (2026). *Deep learning-based forest disturbance detection for Europe using Landsat time series*. *Remote Sensing of Environment*, 347, 115670. <https://doi.org/10.1016/j.rse.2026.115670>

This study implements two temporal deep learning models (TempCNN and 1D U-Net) for annual forest disturbance detection across all forests of continental Europe, using Landsat time series from 1985 to 2024 and a newly established reference dataset. Performance of both models for detecting forest disturbances was assessed using short temporal subsequences from the whole time series and compared them to existing approaches based on Random Forest. The 1D U-Net outperformed the TempCNN and Random Forest models across variable classification scenarios. The highest performance was achieved using the 5-year input window. Using the 1D U-Net model, annual forest disturbance maps at 30 m resolution were generated for Europe since 1985, with a total disturbed forest area of 48.5 Mha. Map validation using an independent validation dataset yielded an F1 score of 0.81 in spatial disturbance detection, with balanced commission and omission errors

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(18.4% and 19.8%, respectively), and less variability in commission and omission errors over time than previous maps and alternative models. Using a temporal convolutional architecture thus led to more consistent disturbance mapping across space and time compared to previous approaches. The proposed model is further designed to support updates as new observations arrive and to operate effectively with short temporal sequences, facilitating operational forest disturbance monitoring across Europe.

Article published in Global Ecology and Biogeography, August 2026

Zheleznyy, O., C. Senf, J. Boike, and D. Pflugmacher. 2026. Remote Sensing Reveals Post-Fire Forest Composition Shifts in Boreal Eastern Siberia. *Global Ecology and Biogeography* 35, no. 8: e70298. <https://doi.org/10.1111/geb.70298>

This study characterised post-fire vegetation across the forests of Eastern Siberia, one of the major wildfire hotspots, using Earth observation. With historical Landsat satellite imagery, the study identified 1863 wildfires in 1990–1994. Following, current fractional cover of five key boreal vegetation types was mapped across the study site using regression-based spectral unmixing of Sentinel-2 satellite imagery. From both datasets, differences in vegetation between burned and adjacent unburned areas were assessed, with particular focus on the effects of burn severity, proximity to the fire edge and average annual air temperatures. Thirty years following a fire, vegetation on more than 95% of burned area has recovered. Deciduous broadleaf forests maintained their composition even after high-severity fires, while coniferous trees were commonly replaced by early successional broadleaf species, especially further from the fire edge and in warmer annual air temperatures. In colder mountainous areas and sites with high burn severity, shrubby and herbaceous vegetation outcompeted broadleaf trees in the recovery process. The fraction of evergreen coniferous species decreased even after low-severity fires, whereas larch showed higher resilience; however, its recovery has been poorer in the southern parts of its range. The study concludes that post-fire recovery of East Siberian boreal forests is slow and is characterised by compositional shifts. Increasing frequency and severity of wildfires may pave the way for a permanent shift from coniferous to broadleaf forests in the warmer parts of Eastern Siberia.

Article published in Earth System Science Data, June 2026

Xing, Z., Li, X., Frappart, F., De Lannoy, G., Jagdhuber, T., Peng, J., Fan, L., Ma, H., Karthikeyan, L., Liu, X., Wang, M., Zhao, L., Liu, Y., & Wigneron, J.-P. (2026). An operational global L-band soil moisture and vegetation optical depth dataset from optimized 40° SMOS brightness temperatures for 2010–2024. *Earth System Science Data*, 18, 4047–4073. <https://doi.org/10.5194/essd-18-4047-2026>

This study develops a new operational global L-band vegetation optical depth (VOD) and soil moisture dataset, SMOS-IB, from optimized 40° SMOS brightness temperatures for 2010–2024. By harmonizing SMOS observations to a fixed incidence angle consistent with SMAP and applying the SMAP-IB retrieval framework, the study produces a long-term 25-km VOD record with reduced observational noise and improved consistency with independent vegetation indicators. The retrieved VOD showed strong spatial relationships with aboveground biomass ($R = 0.85$) and forest canopy height ($R = 0.90$), demonstrating its sensitivity to large-scale variations in woody vegetation structure and biomass. The study also provides the first temporal evaluation of L-band VOD against satellite-derived canopy water content, further supporting its ability to track vegetation water dynamics. The resulting 15-year VOD record therefore provides a valuable basis for monitoring long-term vegetation biomass and water-status changes and has strong potential for investigating

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forest carbon dynamics, disturbance- and drought-related carbon losses, and broader terrestrial carbon-cycle variability at regional to global scales.

ESA EEA Conference - Frascati 26-30th October

Abstract submitted

LULUCF case study for France : “Satellite observations and estimates in support of UNFCCC LULUCF inventories: insights from the French inventory” M. Juillard. Comparison of the inventory estimates with RECCAP2 products will be presented.

Top down bottom up reconciliation : “Reconciliation of top down and bottom up carbon budgets: an outlook on the recent weakening of the European land carbon sink” P. Ciais et al.