



Conference Abstract

Behind the Spatio-Temporal Variation in Spectral Chlorophyll Fluorescence of Boreal Species

Paulina Rajewicz[‡], Chao Zhang[‡], Jon Atherton[‡], Shari Van Wittenberghe[§], Anu Riikonen[‡], Troy Magney^{||}, Beatriz Fernandez-Marin[¶], Jose Ignacio Garcia Plazaola[#], Albert Porcar-Castell[‡]

[‡] Optics of Photosynthesis Laboratory, Institute for Atmospheric and Earth System Research/Forest Sciences, Viikki Plant Science Center, University of Helsinki, Helsinki, Finland

[§] Laboratory of Earth Observation, University of Valencia, Valencia, Spain

^{||} Department of Plant Sciences, University of California, Davis, Davis, United States of America

[¶] Department of Botany, Ecology and Plant Physiology, University of La Laguna, Tenerife, Spain

[#] Department of Plant Biology and Ecology, University of the Basque Country, Bilbao, Spain

Corresponding author: Paulina Rajewicz (paulina.rajewicz@helsinki.fi)

Received: 11 Feb 2025 | Published: 28 May 2025

Citation: Rajewicz P, Zhang C, Atherton J, Van Wittenberghe S, Riikonen A, Magney T, Fernandez-Marin B, Garcia Plazaola JI, Porcar-Castell A (2025) Behind the Spatio-Temporal Variation in Spectral Chlorophyll Fluorescence of Boreal Species. ARPHA Conference Abstracts 8: e149326.

<https://doi.org/10.3897/aca.8.e149326>

Abstract

Boreal forests constitute about one-third of all the global forest area (Brandt et al. 2013). Capturing a significant portion of global atmospheric CO₂ (Beer et al. 2010, Thurner et al. 2016, Thurner et al. 2013), boreal forests play a key role in the global carbon cycle (Anav et al. 2015). However, monitoring photosynthetic activity in these forests is difficult with traditional greenness or vegetation indices, particularly due to the dominance of evergreen species and thus relatively little seasonal variation in greenness (Magney et al. 2019). Fortunately, emerging studies suggest that chlorophyll-a fluorescence (ChlF) can improve our ability to track photosynthetic processes in evergreen-dominated ecosystems (Walther et al. 2016, Magney et al. 2019). However, the relationship between ChlF and photosynthesis (or at a larger scale, between Sun-Induced Fluorescence, SIF, and gross primary productivity, GPP) is dependent on various factors, both physical and physiological. Therefore, to fully interpret the information provided by ChlF, it is crucial to develop a thorough understanding and quantitative framework of the mechanisms linking ChlF measurements to photosynthesis at various scales.

In our study performed at SMEAR-II Hyttälä forestry field station (61° 31' North 24°17' East, southern Finland) and published in 2023 (Rajewicz et al. 2023), we established what factors affected spatial variation in spectral ChlF among leaves in a boreal forest and whether these effects vary over time (spring recovery of photosynthesis). Simultaneously, we also established what factors affect temporal variation in spectral ChlF and whether these effects differ between species and across the canopy light gradient (different canopy positions).

We investigated a range of factors potentially driving variation in leaf spectral ChlF across three dominant Boreal evergreen species and different light environments (spatial variation), as well as during the period of spring recovery of photosynthesis (temporal variation). Measurements were conducted on two conifers—Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* L.)—and the broadleaf shrub, lingonberry (*Vaccinium vitis-idaea* L.). The focus on evergreen species, combining conifers and broadleaf species, facilitated a deeper understanding of the relationships between foliar traits and ChlF over time, particularly regarding the influence of leaf morphology and light gradient within the canopy. Data collection occurred biweekly from February to July 2017, encompassing 10 measurement points. Alongside leaf spectral ChlF, leaf samples were analyzed to retrieve a wide range of traits:

1. Photosynthetic traits (e.g., Fv/Fm, maximum quantum yield photochemistry, and NPQS, sustained non-photochemical quenching);
2. Morphological traits (e.g., Specific Leaf Area, SLA); and
3. Foliar pigment traits (e.g. Cab, total chlorophyll a + b, and Zea/Cab, zeaxanthin to chlorophyll a + b ratio). Moreover, Digital Hemispherical Photography (DHP) was used to assess the light environment and its spatio-temporal dynamics.

Our results revealed that the spatial variation in spectral ChlF was influenced by different factors throughout the spring recovery period of photosynthesis. Notably, leaf morphology (represented by SLA) and the local light environment (GLI) stood out as continuous and strong contributors, showing a consistent and significant correlation with ChlF variation across the entire study period. This baseline, time-independent element in ChlF magnitude indicates that foliar factors, such as SLA and potentially other factors influenced by GLI, should be considered when interpreting ChlF variations. Meanwhile, temporal variation in spectral ChlF was influenced by different factors across leaves within the forest. For exposed needles and lingonberry, ChlF magnitude followed seasonal patterns of NPQS, while shaded needles exhibited a compensatory relationship between NPQS and PQS.

In this study, we highlighted the complex nature of factors influencing spectral ChlF across space and time, suggesting that no single factor should be considered in isolation. Consequently, more long-term, comprehensive studies are needed to provide comparable ChlF data across species, light environments, and biomes. Although focused on boreal forests, our findings can encourage similar research in other biomes. By integrating ground-based physiological observations with ecosystem modeling, our study offers a framework for understanding species-level responses and their implications for

forest function and resilience. The inclusion of spectral ChlF in monitoring networks like eLTER or ICP Forests would enhance our ability to track ecosystem responses to global change. Moreover, incorporating species-specific physiological diversity into predictive models of forest carbon cycling will improve accuracy in forecasting forest carbon sequestration and resilience under climate extremes, informing forest management and conservation strategies.

Keywords

Boreal forest, Chlorophyll fluorescence, Photosynthesis

Presenting author

Paulina Rajewicz

Presented at

POSTER

Conflicts of interest

The authors have declared that no competing interests exist.

Disclaimer: This article is (co-)authored by any of the Editors-in-Chief, Managing Editors or their deputies in this journal.

References

- Anav A, Friedlingstein P, Beer C, Ciais P, Harper A, Jones C, Murray-Tortarolo G, Papale D, Parazoo NC, Peylin P, et al. (2015) Spatiotemporal patterns of terrestrial gross primary production: A review. *Rev. Geophys.* 53 (3): 785-818. <https://doi.org/10.1002/2015RG000483>
- Beer C, Reichstein M, Tomelleri E, Ciais P, Jung M, Carvalhais N, Rödenbeck C, Arain MA, Baldocchi D, Bonan G, Bondeau A, Cescatti A, Lasslop G, Lindroth A, Lomas M, Luysaert S, Margolis H, Oleson K, Rouspard O, Veenendaal E, Viovy N, Williams C, Woodward FI, Papale D (2010) Terrestrial Gross Carbon Dioxide Uptake: Global Distribution and Covariation with Climate. *Science* 329 (5993): 834-838. <https://doi.org/10.1126/science.1184984>
- Brandt JP, Flannigan MD, Maynard DG, Thompson ID, Volney WJ (2013) An introduction to Canada's boreal zone: ecosystem processes, health, sustainability, and environmental issues. *Environmental Reviews* 21 (4): 207-226. <https://doi.org/10.1139/er-2013-0040>
- Magney T, Bowling D, Logan B, Grossmann K, Stutz J, Blanken P, Burns S, Cheng R, Garcia M, Köhler P, Lopez S, Parazoo N, Raczka B, Schimel D, Frankenberg C (2019) Mechanistic evidence for tracking the seasonality of photosynthesis with solar-induced

fluorescence. *Proceedings of the National Academy of Sciences* 116 (24): 11640-11645. <https://doi.org/10.1073/pnas.1900278116>

- Rajewicz P, Zhang C, Atherton J, Van Wittenberghe S, Riikonen A, Magney T, Fernandez-Marin B, Plazaola JIG, Porcar-Castell A (2023) The photosynthetic response of spectral chlorophyll fluorescence differs across species and light environments in a boreal forest ecosystem. *Agricultural and Forest Meteorology* 334. <https://doi.org/10.1016/j.agrformet.2023.109434>
- Thurner M, Beer C, Santoro M, Carvalhais N, Wutzler T, Schepaschenko D, Shvidenko A, Kompter E, Ahrens B, Levick S, Schimmlius C (2013) Carbon stock and density of northern boreal and temperate forests. *Global Ecology and Biogeography* 23 (3): 297-310. <https://doi.org/10.1111/geb.12125>
- Thurner M, Beer C, Carvalhais N, Forkel M, Santoro M, Tum M, Schimmlius C (2016) Large-scale variation in boreal and temperate forest carbon turnover rate related to climate. *Geophysical Research Letters* 43 (9): 4576-4585. <https://doi.org/10.1002/2016gl068794>
- Walther S, Voigt M, Thum T, Gonsamo A, Zhang Y, Köhler P, Jung M, Varlagin A, Guanter L (2016) Satellite chlorophyll fluorescence measurements reveal large-scale decoupling of photosynthesis and greenness dynamics in boreal evergreen forests. *Global Change Biology* 22 (9): 2979-2996. <https://doi.org/10.1111/gcb.13200>