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Analysis of multi-seasonal meteorological pathways to reduced forest NDVI in Europe in 2000–2020

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Productivity of Europe's temperate forest regions is strongly influenced by meteorological conditions and their interannual variability, including seasonal variations of temperature (*T2m*) and precipitation (*P*) and short-term extreme events. Understanding the occurrence of individual events of reduced forest productivity therefore requires knowledge at the interface of atmospheric science and forest ecology. While numerous recent studies focused on the forest ecosystem perspective of such events, the preceding evolution of basic meteorological parameters such as *T2m* and *P* has not yet been analyzed systematically. The purpose of this study is thus to provide an atmospheric science perspective on such events in Europe in 2000–2020. To this end, we examine the meteorological evolution in the year prior to events of reduced forest productivity in June–August (JJA), by considering the trajectory of normalized 90-day *T2m* and *P* anomalies from the ERA5 reanalysis in their phase space. The events have been identified based on normalized difference vegetation index anomalies ($NDVI'$) at 0.05° resolution. Furthermore, a pragmatic approach is developed to coarse-grain the events to the 0.5° scale of ERA5.

From a set of event characteristics we identify different event types. One event type (F_{drop}) is found to feature a pronounced $NDVI'$ drop over JJA, while a second type (F_{low}) exhibits consistently negative $NDVI'$ throughout JJA. Well-known forest damage occurrences are identified as F_{drop} events, e.g., in the Balkans in 2000, in central Europe in 2003, and in northern Europe in 2018. Wide-spread F_{low} events are identified for the first time in 2014. They occur most prominently in 2019 and 2020 in regions already affected by F_{drop} events in 2018. The multi-seasonal meteorological history of F_{drop} events in the *T2m*–*P* phase space is characterized by exceptionally dry conditions already in the early growing season and increasingly warm summer conditions. In some contrast, F_{low} events emerge after two consecutively hot-dry summers. During these events, anomalies of *T2m* and *P* are less extreme than during F_{drop} events, suggesting the involvement of forest legacy and secondary disturbances (e.g., fire, insects).

In future work, we will validate the reduced forest productivity events with already existing datasets of forest disturbances in Europe and expand the analysis of these events' meteorological history more quantitatively. Also, we aim at further refining the event classification according to

the spatiotemporal variability of their meteorological history to better understand the meteorological impact on forest productivity in Europe.