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An epidemiological assessment of stomatal ozone flux-based critical levels for visible ozone injury in Southern European forests

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Southern forests are at the highest ozone (O_3) risk in Europe where ground-level O_3 is a pressing sanitary problem for ecosystem health. Exposure-based standards for protecting vegetation are not representative of actual field conditions. A biologically-sound stomatal flux-based standard has been proposed, although critical levels for protection still need to be validated. This innovative epidemiological assessment of forest responses to O_3 was carried out in 54 plots in Southeastern France and Northwestern Italy in 2012 and 2013. Three O_3 indices, namely the accumulated exposure AOT40, and the accumulated stomatal flux with and without an hourly threshold of uptake (POD1 and POD0) were compared. Stomatal O_3 fluxes were modelled (DO_3SE) and correlated to measured forest-response indicators, i.e. crown defoliation, crown discoloration and visible foliar O_3 injury. Soil water content, a key variable affecting the severity of visible foliar O_3 injury, was included in DO_3SE. Based on flux-effect relationships, we developed species-specific flux-based critical levels (CLef) for forest protection against visible O_3 injury. For O_3 sensitive conifers, CLef of 19 mmol m-2 for P. cembra (high O_3 sensitivity) and 32 mmol m-2 for P. halepensis (moderate O_3 sensitivity) were calculated. For broadleaved species, we obtained a CLef of 25 mmol m-2 for Fagus sylvatica (moderate O_3 sensitivity) and of 19 mmol m-2 for Fraxinus excelsior (high O_3 sensitivity). We showed that an assessment based on PODY and on real plant symptoms is more appropriated than the concentration-based method. Indeed, POD0 was better correlated with visible foliar O_3 injury than AOT40, whereas AOT40 was better correlated with crown discoloration and defoliation (aspecific indicators). To avoid an underestimation of the real O_3 uptake, we recommend the use of POD0 calculated for hours with a non-null global radiation over the 24-h O_3 accumulation window.