Science of the Total Environment 556 (2016) 1–11

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

A multi-sites analysis on the ozone effects on Gross Primary Production of European forests

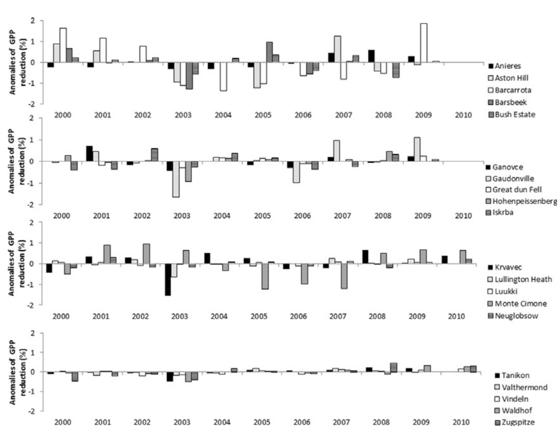
C. Proietti [a], A. Anav [b,c], A. De Marco [b], P. Sicard [d], M. Vitale [a,*]

[a] Department of Environmental Biology, Sapienza University of Rome, Piazzale Aldo Moro, 5, 00185 Rome, Italy
[b] Italian National Agency for New Technologies, Energy and the Environment (ENEA), C.R. Casaccia, Via Anguillarese 301, 00123 S. Maria di Galeria, Rome, Italy
[c] University of Exeter, College of Engineering, Mathematics and Physical Sciences, Exeter, UK
[d] ACRI-HE, 260 route du Pin Montard BP234, 06904 Sophia Antipolis-cedex, France

HIGHLIGHTS

- Assessment of the surface O_3 effects on Gross Primary Production (GPP)
- GPP is negatively related to O_3 concentration and positively to O_3 fluxes
- Temperature and relative humidity were the most important factors controlling GPP.
- Key role of the Soil Water Content in the Mediterranean regions.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 30 December 2015
Received in revised form 24 February 2016
Accepted 26 February 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Tropospheric ozone
Gross Primary Production
MODIS
Random Forests Analysis
AOT40
Ozone fluxes

ABSTRACT

Ozone (O_3) is both a greenhouse gas and a secondary air pollutant causing adverse impacts on forests ecosystems at different scales, from cellular to ecosystem level. Specifically, the phytotoxic nature of O_3 can impair CO_2 assimilation that, in turn affects forest productivity. This study aims to evaluate the effects of tropospheric O_3 on Gross Primary Production (GPP) at 37 European forest sites during the time period 2000–2010. Due to the lack of carbon assimilation data at O_3 monitoring stations (and vice-versa) this study makes a first attempt to combine high resolution MODIS Gross Primary Production (GPP) estimates and O_3 measurement data. Partial Correlations, Anomalies Analysis and the Random Forests Analysis (RFA) were used to quantify the effects of tropospheric O_3 concentration and its uptake on GPP and to evaluate the most important factors affecting inter-annual GPP changes. Our results showed, along a North-West/South-East European transect, a negative impact of O_3 on GPP ranging from 0.4% to 30%, although a key role of meteorological parameters respect to pollutant variables in affecting GPP was found. In particular, meteorological parameters, namely air temperature (*T*), soil water content (SWC) and relative humidity (RH) are the most important predictors at 81% of test sites. Moreover, it is interesting to highlight a key role of SWC in the Mediterranean areas (Spanish, Italian and French test sites) confirming that, soil moisture and soil water availability affect vegetation growth and photosynthesis especially in arid or semi-arid ecosystems such as the Mediterranean climate regions.

* Corresponding author.
E-mail address: marcello.vitale@uniroma1.it (M. Vitale).

http://dx.doi.org/10.1016/j.scitotenv.2016.02.187
0048-9697/© 2016 Elsevier B.V. All rights reserved.

Considering the pivotal role of GPP in the global carbon balance and the O_3 ability to reduce primary productivity of the forests, this study can help in assessing the O_3 impacts on ecosystem services, including wood production and carbon sequestration.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Tropospheric ozone (O_3) is an important atmospheric pollutant and climate forcer, i.e. the third most important greenhouse gas (Ramaswamy et al., 2001; IPCC, 2013). The majority of surface O_3 formation is produced by photochemical reactions involving methane (CH_4), volatile organic compounds (VOCs) and NOx (Chameides et al., 1988; Monks et al., 2014). Ground-level O_3 have risen by approximately 60–100% since pre-industrial revolution in the Northern Hemisphere (Vingarzan, 2004; Sitch et al., 2007).

Among common air pollutants, O_3 is considered one of the most important in affecting forest health conditions (Karnosky et al., 2003; Paoletti, 2006). Several studies reported the adverse O_3 impacts at different scales, from cellular to ecosystem level (Ashmore, 2005; Sarkar et al., 2010). A reduction in primary metabolism at cellular and leaf level (e.g. alterations of RuBisCO content and activity, reduction of CO_2 assimilation) cause a reductions in leaf area and biomass at whole-plant level, which constitutes the basis for O_3-induced reductions in ecosystem Net Primary Productivity (NPP) (Ashmore, 2005; Fares et al., 2013). A meta-analysis performed by Wittig et al. (2007, 2009), compared northern temperate trees exposed to ambient O_3 concentration (a daytime mean concentration of approximately 40 ppb) with those exposed to charcoal-filtered air revealed that O_3 caused a reduction of net photosynthesis and tree biomass, by 11% and 7%, respectively. The impact of tropospheric O_3 on European vegetation has been also quantified by Anav et al. (2011) through a land surface model (ORCHIDEE) at high spatial resolution (30 km) coupled with a chemistry transport model (CHIMERE) for the whole year 2002, showing a reduction in yearly Gross Primary Production (GPP) of about 22% and in Leaf Area Index (LAI) of 15–20%. Moreover, it should be taken into account that plant response to O_3 is modified by environmental change like temperature, precipitation and soil moisture availability. Growth of some tree species could be affected by the interactive effects between ozone and drought stress (Hayes et al., 2015).

Increased drought stress in a warmer climate is predicted over large parts of Europe (Bates et al., 2008; Blenkinsop and Fowler, 2007; Lehner et al., 2006) and this can lead to a protective effect against ozone through stomatal closure (*Populus* spp.; Silim et al., 2009) and reduced ozone uptake (*Fagus sylvatica*, Löw et al., 2006); however O_3 can induce slow or less efficient stomatal control (Paoletti and Grulke, 2005), which might confound this effect. Consequently, there is an urgent need to improve our knowledge on the impacts of O_3 on the carbon cycle. This aim can be achieved by combining GPP estimates with O_3 measurements data. However, although worldwide many measurement stations exist for O_3 (e.g. World Data Centre for Greenhouse Gases, WDCGG) as well as for GPP estimates (FLUXNET, Baldocchi et al., 2001; Friend et al., 2007; Aubinet et al., 2012), only in few of them O_3 and GPP are simultaneously measured/estimated. Nevertheless, new global GPP dataset at high spatial resolution (1 km) have been released and these products, suitable for monitoring ecological conditions, natural resources and environmental changes, up to date have never been linked to O_3 measurements data (e.g. WDCGG, Airbase). For this reason, we are aiming to link GPP satellite retrievals with ground O_3 measurements at 37 station data across Europe. Among different available observation-based GPP dataset, we used MODIS (Collection5 MOD17; Zhao et al., 2005) because of its high spatial resolution (1 km) that allows the extraction of GPP data close to the O_3 monitoring stations and because of its ability in detecting disturbances like drought (Zhao and Running, 2010) or stresses (including O_3) on vegetation (Anav et al., 2015a). Thus, we can assess how seasonal and inter-annual changes in GPP are related to changes in O_3 concentrations and uptake. In particular, we considered the relationships between GPP, AOT40 (Accumulated dose Over a Threshold of 40 ppb, UNECE, 2010) and PODy (Phytotoxic Ozone Dose over a threshold of y nmol m^{-2} s^{-1}). AOT40 is an exposure-based metric and represents the European standards for estimating the potential risk of forests due to O_3, whereas PODy is a flux-based metric representing the effective absorbed O_3 dose through stomata.

Key questions of the study are:

- What are the effects of tropospheric O_3 concentration and uptake on GPP of dominant forest-types growing at 37 sites scattered along Europe?
- What are the most relevant environmental factors controlling seasonal and inter-annual GPP changes?

To disentangle these questions, statistical techniques based on partial correlation analysis, anomalies analysis and Random Forests Analysis (RFA) were used to understand the role of O_3 in affecting GPP variability.

2. Materials and methods

2.1. Study area and dominant tree species

We investigated the O_3 effects on GPP at 37 European sites scattered across the four European bio-geographic areas (Boreal; Atlantic/Temperate; Continental/Temperate; Mediterranean; Fig. S1) in order to consider different environmental conditions (i.e. meteorology, topography, soil conditions, water availability) and tree species. Basic information about sites characteristics, dominant tree species and available time-series were reported in supplementary material (Table S1).

Whereas possible, tree species occurrence was given by the site managers, otherwise a high resolution tree species map for European Forests was used (European Forest Institute, see Tröltzsch et al., 2009; Brus et al., 2011).

2.2. Data collection

2.2.1. Meteorological data, soil type and ozone concentrations

Meteorological parameters, as daily mean temperature (T, °C), daily volumetric soil water content (SWC, m^3 m^{-3}) and daily Photosynthetically Active Radiation (PAR, J m^{-2}) were provided by the most recent global atmospheric re-analysis (ERA-Interim) produced by European Centre for Medium-Range Weather Forecasts (ECMWF) over the time period 2000–2010 (Dee et al., 2011). Daily relative humidity (RH, %) was calculated from temperature data according to Buck (1981). In particular, temperature data allowed to calculate partial and saturation vapour pressure leading to a relative humidity estimations.

Soil texture is divided into 16 soil categories in according to the Food and Agriculture Organization of the United Nations soil dataset (Pásztor et al., 2011) with a spatial resolution of 5′; wilting point (WP) and field capacity (FC) were estimated for each soil category.

Measured hourly O_3 concentration data (in ppb), were provided by Scientific/administrative Responsible of the 37 test sites through the World Data Centre for Greenhouse Gases (WDCGG) and European Environment Agency (EEA) website as reported in Table S1. Further details about ozone monitoring sites are available in Supplementary Material (Table S2).

Download English Version:

https://daneshyari.com/en/article/6323013

Download Persian Version:

https://daneshyari.com/article/6323013

Daneshyari.com