Remote Sensing of Environment 137 (2013) 84–93

Contents lists available at SciVerse ScienceDirect

Remote Sensing of Environment

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

Carbon cycling of European croplands: A framework for the assimilation of optical and microwave Earth observation data ☆

Andrew Revill *, Oliver Sus [1], Brian Barrett [2], Mathew Williams

School of GeoSciences and National Centre for Earth Observation, University of Edinburgh, Edinburgh, United Kingdom

ARTICLE INFO

Article history:
Received 21 January 2013
Received in revised form 30 May 2013
Accepted 1 June 2013
Available online 12 July 2013

Keywords:
Crop carbon cycling
Agriculture Remote Sensing
Crop modelling
LAI retrieval
Data assimilation

ABSTRACT

Worldwide, cropland ecosystems play a significant role in the global carbon (C) cycle. However, quantifying and understanding the cropland C cycle are complex, due to variable environmental drivers, varied management practices and often highly heterogeneous landscapes. Efforts to upscale processes using simulation models must resolve these challenges. In this study we show how data assimilation (DA) approaches can link C cycle modelling to Earth observation (EO) and reduce uncertainty in upscaling. We evaluate a framework for the assimilation of leaf area index (LAI) time-series, derived from EO optical and radar sensors, for state-updating a model of crop development and C fluxes. Sensors are selected with fine spatial resolutions (20–50 m) to resolve variability across field sizes typically used in European agriculture (1.5–97.6 ha). Sequential DA is used to improve the canopy development simulation, which is validated by comparing time-series of net ecosystem exchange (NEE) predictions to independent eddy covariance observations at multiple European cereal crop sites. From assimilating all EO LAI estimates, results indicated adjustments in LAI and, through an enhanced representation of C exchanges, the predicted at-harvest cumulative NEE was improved for all sites by an average of 69% when compared to the model without DA. However, using radar sensors, being relatively unaffected by cloud cover and more sensitive to the structural properties of crops, further improvements were achieved when compared to the combined, and individual, use of optical data. Specifically, when assimilating radar LAI estimates only, the cumulative NEE estimation was improved by 79% when compared to the simulation without DA. Future developments would include the assimilation of additional state variables, such as soil moisture.

© 2013 The Authors. Published by Elsevier Inc. All rights reserved.

1. Introduction

Agricultural intensification over the past 40 to 50 years, achieved by 'Green Revolution' technologies and an increase in cropland area (Foley et al., 2005), has resulted in an approximate doubling in world grain harvests (Tilman et al., 2001). Through changes to carbon (C) storage and emissions, associated with management activities, croplands also provide opportunities for climate change mitigation (Power, 2010). The European Union (EU-27), with around half of the land area occupied by croplands (EU, 2009), presents a mosaic of crop varieties, phenologies and growth periods due to spatiotemporal variations in soil and climatic conditions, together with local and regional production requirements. The resulting broad range of cropland management techniques (e.g. tilling intensity, use of fertilisers and irrigation) causes uncertainty when generalising the impact of specific activities on crop C budgets (Osborne, Saunders, Walmsley, Jones, & Smith, 2010).

There is considerable uncertainty involved in quantifying C dynamics, particularly when identifying whether, and under what conditions, landscapes act as sources or sinks for C (Quaife et al., 2008). Flux towers provide measurements of net ecosystem exchange (NEE) at local scales (~1 km^2) via eddy covariance (EC) technique (Baldocchi, 2003), which directly measures biosphere–atmosphere CO_2 exchanges. However, complex terrain and heterogeneous spatial distributions of vegetation within the sensor 'footprint' undermine assumptions of the EC technique, introducing uncertainty (Hollinger & Richardson, 2005). Furthermore, towers are sparsely distributed and data-gaps are always present. Therefore, a complete analysis of crop C dynamics and yield relies on simulations using process-based models, often linked to C flux observations for validation. The models require reliable input parameters, including management interventions, plant traits, meteorological driving data and soil properties at points within the model domain. Therefore parameter estimates are the largest source of model uncertainty (Launay & Guerif, 2005) and a particular challenge is to derive these parameters across the model spatial and temporal domains.

☆ This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

* Corresponding author at: Crew Building, Kings Buildings, University of Edinburgh, Edinburgh EH9 3JN, United Kingdom. Tel.: +44 131 650 5103.
E-mail address: a.revill@sms.ed.ac.uk (A. Revill).
[1] Present address: Centre de Recerca Ecològica i Aplicacions Forestals, Universitat Autònoma de Barcelona, Spain.
[2] Present address: Department of Geography, University College Cork, Cork, Ireland.

0034-4257/$ – see front matter © 2013 The Authors. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.rse.2013.06.002

Earth observation (EO) data can be combined with models to provide objective updates of state variables describing crop condition over landscape scales. This model–data fusion can be achieved via data assimilation (DA) algorithms, which assume that estimates from neither observations nor models are perfect but a combination of the two, weighted by a specified uncertainty, will produce more realistic model updates (Williams, Schwarz, Law, Irvine, & Kurpius, 2005). Researchers have demonstrated how DA can link regional-scale models with moderate spatial resolution EO sensors (250 m to 1 km, e.g. de Wit & van Diepen, 2007; Sus, Heuer, Meyers, & Williams, 2012; Wu et al., 2012). These sensors have high temporal resolutions (daily to weekly) that can capture the key developmental stages of crop growth (Launay & Guerif, 2005). However, this spatial resolution is typically insufficient for retrieving biophysical variables at field sizes <25 ha (Doraiswamy et al., 2004), which are typical in Europe. Smaller fields require finer resolution sensors (e.g. SPOT-HRV, 20 m), which is at the expense of lower temporal resolution that potentially leads to gaps in acquisitions during critical growth stages. Moreover, cloud cover affects the availability of optical EO imagery, resulting in further reductions in observations. The spatial/temporal resolution trade-off can be addressed by also using Synthetic Aperture Radar (SAR) sensors. SAR provides fine-scale data and is unaffected by cloud cover. Furthermore, as optical instruments are sensitive to biochemical properties of crops, SAR sensors are more responsive to crop water content and structural elements, such as the size and shape of leaves (Shang, McNairn, Champagne, & Jiao, 2009).

In this paper we demonstrate a framework for the assimilation of leaf area index (LAI) observations, retrieved from optical and SAR sensors, to update the simulated LAI of a process-based model of cereal crop C budgets for European landscapes. Our specific objectives were to: (1) determine the potential of the DA technique for improving the simulated daily NEE fluxes and the at-harvest cumulative NEE of wheat crops at the field-scale. The accuracy of the DA, when assimilating optical and SAR LAI estimates individually and synergistically, is evaluated by comparing model outputs to independent observations from flux towers at European sites. (2) Establish if the same methodology is applicable to a series of field sites across Europe, to improve the relationship between simulated and observed values, thereby providing a proof-of-concept for future spatial upscaling activities. Innovations of this study include the sequential DA of data derived from high resolution optical and SAR sensors, thus increasing the number of available observations. It is hypothesised that the multi-sensor approach improves the model performance at the field-scale by more effectively tracking the development of cereal crops, which is critical for seasonal carbon balances (Sus et al., 2010).

2. Data and methods

2.1. Study sites and data

This study investigates one winter wheat (*Triticum aestivum*) growing season at six different European field sites (Fig. 1). These sites were selected from the CarboEurope Integrated Project ecosystem database (CarboEurope-IP, www.carboeurope.org), which include those used by Sus et al. (2010) and Wattenbach et al. (2010). They are located in France (Auradé, Lamasquère and Grignon), Germany (Klingenberg and Gebesee) and Switzerland (Oensingen). As well as different management techniques, they also vary in latitude (43.5 to 51.1°N) and longitude (1.1 to 13.5°E) and show significant variations in temperature (annual average 6 to 11 °C) and precipitation (mean annual values from 327 to 1051 mm). Consequently, different growing periods were observed at each site, in terms of both the sowing dates and the overall length of the growing season (sowing to harvest), ranging from 245 to 346 days (Table 1). Field sizes vary from 1.5 to 97.6 ha, and the terrain across each field site can be considered level to very gently sloping.

Field data available from CarboEurope-IP included daily NEE flux measurements using the EC technique during the growing season at each site. These NEE flux data consisted of aggregates of half-hourly

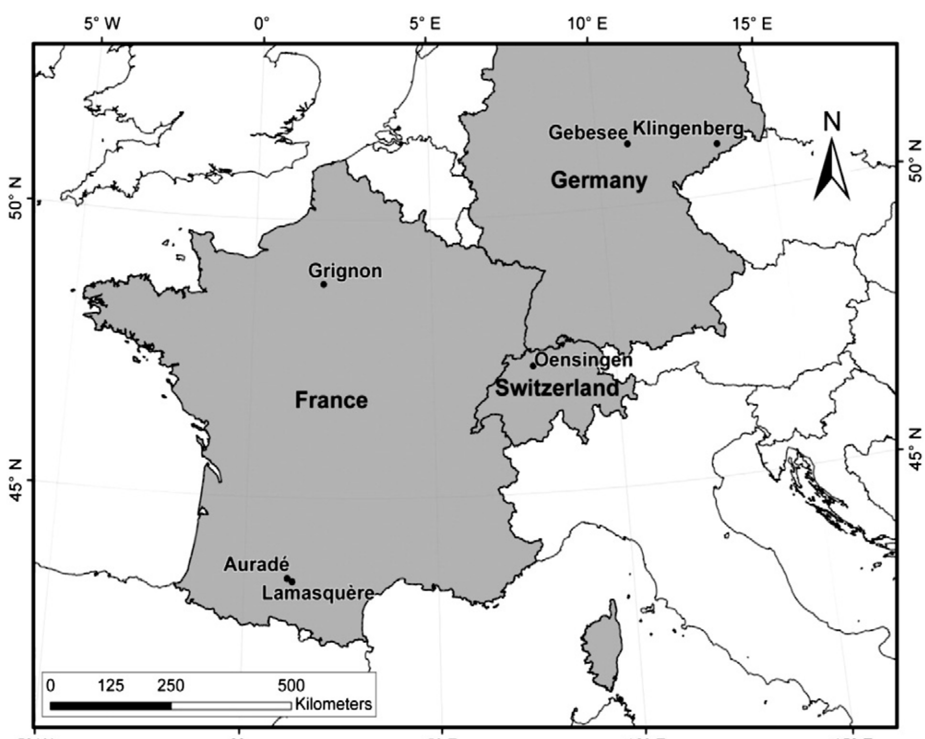

Fig. 1. Map showing the locations of the six European cropland sites.

Download English Version:

https://daneshyari.com/en/article/6347335

Download Persian Version:

https://daneshyari.com/article/6347335

Daneshyari.com