NERC Earth Observation Data Acquisition & Analysis Service (NEODAAS) support of Carbon Cycle Research.

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Abstract

The NERC Earth Observation Data Acquisition & Analysis Service (NEODAAS) provides satellite data and products for the UK research community. Capabilities offered include the reception, archiving, processing and analysis of satellite data, along with scientific research activities.

NEODAAS supports marine and atmospheric research and is currently extending services and expertise into Terrestrial, Polar and Earth Sciences. To develop these new areas we have started by identifying some difficulties researchers might face when using remote sensing data and this paper discusses how NEODAAS can support the research community at each of these points.

The contributions NEODAAS has made to carbon cycle research are briefly reviewed as well as the present areas we are pursuing to extend support to the terrestrial domain.

Keywords: *NEODAAS, Carbon Cycle, MODIS, SeaWiFS, AVHRR*

1. Introduction

NEODAAS is funded by the Natural Environment Research Council (NERC) to support UK research scientists with remote sensing data and information. The service is hosted at two sites: data processing is provided by the Remote Sensing Group at the Plymouth Marine Laboratory (PML); data reception and acquisition is provided by the Dundee Satellite Receiving Station at the University of Dundee (UoD).

The aim of the service is to provide scientific products that cannot be easily obtained elsewhere and in order to achieve we continually review the products offered and the research community requirements. NEODAAS has been providing remote sensing support to the marine community for several years and we are currently expanding into other domains.

This paper discusses the contributions that NEODAAS has done, or is planning to do, relevant to carbon cycle research. First, past, present and future satellites providing measurements relevant to carbon cycle are briefly reviewed pointing out which ones are already available through NEODAAS.

We also review the difficulties researchers might encounter when using satellite data and how NEODAAS can help to overcome them. Finally, NEODAAS contributions specific to the carbon cycle are presented including both present and planned services in marine and non-marine domains.

2. Remote Sensing and the Carbon Cycle

The study of the carbon cycle should be approached as an integrated system covering the land, ocean and atmospheric domains. Remote sensing offers a unique tool providing repetitive, consistent and global measurements that can be directly used to monitor changes in carbon pools or combined with models to improve our understanding of the process involved. Sensor capabilities range from active to passive sensors providing key measurements of fluxes and direct or indirect estimations of carbon stocks.

Optical remote sensing of visible and near-infrared provides observations core to carbon cycle studies such as land-cover change, disturbances, Leaf Area Index (LAI) and related biophysical processes and Ocean Colour (OC) that are related to biological activity.

Several international missions with ocean colour capabilities were launched in the late 1990s and have been providing exceptional data on marine productivity. These include the Ocean Color and Temperature Sensor (OCTS, Japan, 1996-1997), the Sea-viewing Wide Field-of-view Sensor (SeaWiFS, United States, 1997-present), two Moderate Resolution Imaging Spectroradiometers (MODIS, United States, Terra: 2000-present and Aqua: 2002-present) and the Medium Resolution Imaging Spectrometer (MERIS, European Space Agency, 2002-present) (McClain 2009). The long term AVHRR NDVI series has provided a fundamental record of vegetation responses to climate (Los et al 2005). This record has been extended and improved in resolution and frequency with the MODIS instrument onboard the Aqua and Terra (Barnes and Salomon 1993). The continuity of these data will be provided using the Ocean and Land colour Instrument to be carried on ESA's Sentinel-3 and the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the National Polar-Orbiting Environmental Satellite System (NPOESS) Preparatory Project (NPP) (Guenther et al. 2009).

Active remote sensing, such as Synthetic Aperture Radar (SAR) sensors and Light Detection and Ranging (LiDAR), has also proved very useful for carbon cycle studies. SAR provides a direct measurement of the biomass while LiDAR provides forest height from which biomass can be indirectly estimated with site-specific allometric relations. SAR sensors can operate day or night and penetrate through haze, smoke, and clouds. There are a number of radar satellites currently in operation including ALOS/PALSAR (L-band), ENVISAT/ASAR (C-band), TerraSAR-X (X-band), and Cosmo/SkyMed (X-Band). Several others are planned for launch within 5–10 years, including the ALOS follow-on mission (L-Band), the NASA DESDynI (L-band), and the European BIOMASS (P-band). LiDAR has emerged in the last few years as an innovative way of measuring biomass from satellite. Full waveform LiDAR has the unique capability of measuring the three-dimensional vertical structure of vegetation in great detail, providing more accurate estimate of the woody biomass (carbon stock) thus useful for carbon source and sink estimation (Dubayah et al. 2000). Despite not being designed specifically for vegetation characterization, current LiDAR satellite systems have proven useful for vegetation analysis (e.g. the Geoscience Laser Altimetry System (GLAS) onboard ICESAT, originally designed for monitoring ice dynamics, has been used for vegetation analysis. There is a follow on mission, ICESat-II to be launched 2010-2013, and lidar on DESDynI, is also planned for launch in the near future. Whereas LiDAR provides detailed forest structure information, spectral remote sensing is more sensitive to vegetation composition and phenology. Integration of LiDAR and spectral data thus provides a much more comprehensive view for understanding ecosystems.

NEODAAS is currently receiving, archiving, processing and mapping global data from multiple polar-orbiting sensors in near-real time, including MERIS, MODIS, SeaWiFS, ASAR and AVHRR. These are made available to users through a single portal as raw (level 0/1) data, geophysical or biological products (level-2) or mapped and composite data sets (level 3) available in near-real time or from the archive. Processing of a range of sensors (e.g. MODIS, MERIS and SeaWiFS) is important since cloud cover, sunglint and orbit/sensor swath characteristics all limit observation of the surface on a given day. The use of several sensors increment the possibilities to retrieve a valid pixel.

3. Difficulties when using Remote Sensed Data

Several studies have identified the flaws of use of remote sensing in applied contexts and the requirement of a closer collaboration between remote sensing and other communities (Roughgarden and Matson 1991, Plummer 2000, Newton et al 2009). Recently, Newton et al (2009) examined the use of remote sensing in the context of landscape ecology in papers published in Landscape Ecology between 2004-2008. The review showed that only 36% of the 438 research papers explicitly mentioned remote sensing and most of them used it for thematic mapping purposes while 75% did not provide any assessment of uncertainty or error in the classification or mapping used. We believe that this is due to the challenges that the use of remote sensing data impose on novice users and it is these scientists we aim to support through NEODAAS.

The main challenges faced by novice users can be categorized as *(1) Lack of technical expertise:* this involves both the technical knowledge to process the data and the necessary software, which often requires expensive licences. *(2) Insufficient knowledge* of the products available and/or their limitations: some users might unknowingly use products that are not optimal to their needs or not considering the uncertainties involved and their implications. *(3) Lack of adequate equipment or time in critical situations*: in time critical situations, such as during field campaigns, remote sensing data can be crucial to decide sampling areas or strategies or to do quick comparisons with in situ instruments. Field campaigns tend to be short and intense so it would be ideal to have data processed elsewhere and quickly accessible on-line. *(4) Lack of resources* to implement and maintain operational services: Most projects are time-limited due to funding constraints. Rarely will a project be able to operationalise the scientific algorithms produced so that the rest of the scientific community can benefit from this work.

NEODAAS aims to support the research community by providing services that target these points: (1) Provision of data in a unified format: NEODAAS data are provided at standard projections and in a format easily accessible by commonly used software packages (e.g. GeoTIFF) (2) Provision of a set of basic products on-line and specific products on request with advice on their availability and limitations of use. (3) On-line access for near real time products: As the service comprises satellite data reception, final products can be provided rapidly: e.g. MODIS products can be available in less than 2 hours and data from AVHRR in less than 30 minutes. (4) NEODAAS has highly automated operational systems (Shutler at al. 2005).

4. NEODAAS Service

The main contributions in terms of carbon cycle research are discussed in the following sections.

4.1 Marine Services

NEODAAS Plymouth has developed a number of novel ocean colour algorithms including higher resolution (500 m) chl-a estimation from MODIS (Shutler et al., 2007), primary productivity from MODIS (Smyth et al., 2005) and inherent optical properties (IOP) from MODIS, SeaWiFS and MERIS using the PML IOP model (Smyth et al., 2006).

In the future ocean colour data will be obtained from instruments such as VIIRS. NEODAAS will also investigate ocean colour from Indian and Chinese instruments that would “fill the gap” if SeaWiFS or MERIS and Aqua-MODIS should fail.

4.2 Non-marine services

In order to extend our services to non-marine areas we have identified three categories of services and investigation we aim to follow:

− Mapping: Carbon fluxes between atmosphere and land are controlled mainly by changes in biomass density, soil carbon and land use. Satellite data offer spatially and temporally consistent estimates of forest cover and land use change, one of the large uncertainties in the global carbon cycle. NEODAAS data will provide information on the state of the land cover so that current land cover maps can be validated and/or updated. These data provide detailed spatial patterns and variations in ecosystem processes, as well as information on the temporal changes.

− Monitoring: There are now more than three decades of satellite data available in a wide range of spatial, spectral and temporal resolutions from different sensors. For instance, satellite data from Landsat (high resolution/ low revisit time) since 1972 and AVHRR/NOAA (low resolution/ high frequency) since 1979. Other instruments such as MODIS (since 2000 on board Terra) provide daily global data at medium resolution (500m). These data allow detection of spatio-temporal vegetation responses. NEODAAS will offer long time series of these data to monitor phenology and to explore implications for the carbon cycle, such as changes in Net Primary Production. Most operational products currently available are global in coverage and hence rely on generic algorithms that can be applied to different biomes. We anticipate that the algorithms used to derive these global products can be refined by adapting them to specific areas, initially to UK, improving their accuracy by including the prior knowledge about the land cover and simultaneous measurements of the atmospheric conditions.

− Modelling: Models require information on a number of properties used to characterize the state of the land-surface and atmosphere system as well as reference values to validate the outputs. Earth Observation data provides a unique means to collect these data at the required temporal and spatial scale. NEODAAS will explore the requirements of these models both in terms of data (input parameters) and format in order to provide accurate and easy to use datasets to the modelling community. An optimal strategy for Earth observation involves integrating data and models: here, data uncertainties become as important as the data values themselves (Raupach et al. 2005). NEODAAS will direct effort to provide products with estimated uncertainties so that they can be fed into the models and used with a sound knowledge of its limitations.

5. Conclusions

Satellite remote sensing offers a unique tool to retrieve key measurements to monitor and study the carbon cycle. A range of passive and active sensors are currently collecting an increasing amount of data extremely useful for a research community that is having to adapt quickly to new techniques. The NEODAAS "mission" is to support UK research scientists in this task, facilitating the access to data and creating new added-value products.

The service has proven very useful in the marine domain. The main services and investigations we aim to follow in non-marine areas have been identified as well as the key points in which researchers need support. In the near future we expect to provide accurate land products with uncertainties that can be used both to monitor and model the carbon cycle and to improve our understanding of the underlying processes.

Acknowledgements – *NEODAAS is funded by the NERC..*

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