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# Assimilation of remote sensing data to monitor the terrestrial carbon cycle: The carbon observatory of geoland

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I- Introduction

geoland is carried out in the context of GMES, a joint initiative of European Commission (EC) and European Space Agency (ESA), which aims to build up a European capacity for Global Monitoring of Environment and Security by the year 2008. geoland is designed to fundamentally support this initiative, focusing on the GMES priorities "Land Cover Change in Europe", "Environ-mental Stress in Europe", and "Global Vegetation Monitoring". The Observatory of Natural Carbon fluxes of geoland (ONC) will provide a pre-operational global accounting system, dealing with the impact of weather and climate variability on soil and vegetation carbon fluxes and stocks. ONC will deliver a unique tool to evaluate the inter-annual variability of the terrestrial carbon cycle at global and regional scales. The scientific understanding of natural terrestrial carbon fluxes will be improved, in support of the implementation of the Kyoto protocol. ONC will provide the scientific and observational basis on natural terrestrial fluxes which may be used in the context of international negotiations and carbon sequestration policies. IGBP, IGOS-P, PIK, and GCP are declared users of ONC. It is likely that the knowledge gained on the natural fluxes will be used in atmospheric transport studies based on remotely sensed atmospheric CO2 concentration. The products of ONC will permit to improve the atmospheric inversions and, over some regions, to help constrain the uncertainties of the anthropogenic sources. The HALO project, led by the European Center for Medium range Weather Forecast (ECMWF), will optimise the interactions of ONC with other GMES integrated projects: http://www.ecmwf.int/research/EU_projects/HALO/.

II- Objectives of geoland/ONC

The overall objective of ONC is to demonstrate the feasibility of monitoring vegetation-atmosphere CO2 exchange at the global scale, on daily to seasonal and inter-annual time scales. In situ meteorological measurements and different satellite remote sensing sources of information will be integrated by implementing and using assimilation techniques in global land surface models. At the end of the project ECMWF will be able to propose a near-operational system analysing land biospheric CO2 fluxes with a spatial resolution of about 50 km. Global or continental-scale land data assimilation systems (LDAS) have been developed in the last few years to characterise the surface energy and water budget, including changes in soil water and snow mass. The pioneering effort, coordinated by NASA, brings together a large community of meteorologists and hydrologists and runs currently in real-time, for the globe (GLDAS, at ij degree resolution) and North America (NLDAS, at 1/8 degree resolution). In Europe, ONC will provide a pre-operational global LDAS dealing with carbon accounting issues. Some ONC partners (ECMWF, KNMI, Météo-France, Alterra) are involved in the European LDAS (ELDAS) project which has created a daily data set spanning the year 2000 and the European continent. LDAS systems are able to collect all available remote sensing and in-situ information to create precipitation and surface radiative field, together with near-surface meteorology from atmospheric data assimilation centers. These fields are used to force state-of-the-art land-surface models, producing as output surface energy and water fluxes, soil water and snow mass. Uncertainty estimates can be obtained from varying the forcing and/or using different land-surface models. LDAS outputs document best estimates of the fields governing the surface-atmosphere interface; in particular, the soil moisture and snow mass fields can be used as initial conditions for weather prediction and monthly to seasonal forecasts. So far, LDAS systems have not addressed carbon fluxes. However, a number of land surface models used in numerical weather prediction and climate studies now include photosynthesis and respiration modules coupled with biomass allocation schemes. For example, ISBA-A-gs (Calvet et al. 1998, Calvet and Soussana 2001) at Météo-France (the French weather service) and ORCHIDEE (Krinner et al. 2003) at LSCE (a French research center of the Commissariat à l’Energie Atomique and of the Centre National de la Recherche Scientifique) are interactive vegetation models able to simulate the leaf area index and the vegetation biomass. Furthermore ORCHIDEE includes the slow carbon reservoirs of the soil and the dynamics of ecosystems after disturbance. ONC will build on the modelling expertise of Météo-France and LSCE to implement a carbon LDAS at ECMWF.

## III- Implementing ONC

The integration of in situ and satellite measurements at ECMWF will be made by using assimilation techniques in global land surface models. ONC will collect the remote sensing products provided by the geoland “Biogeophysical Parameters” core service and the atmospheric forcing provided by ECMWF. In order to integrate the existing approaches and to deliver an assessment based on independent modelling results, two land surface models will be used: 1) the operational scheme TESSEL (Beljaars and Viterbo 1999, van den Hurk et al. 2003), used in the ECMWF numerical weather forecast model, modified to describe an interactive vegetation (based on ISBA-A-gs, Météo-France); 2) a carbon-water-energy land surface scheme, fitted with carbon dynamics in biomass and soil pools, and with ecosystem dynamics (LSCE). The assimilation system will then be run at the global scale with both carbon models. The assimilated output fields will be checked against global observations of different nature, such as eddy covariance networks, long term ecological time series, forest and soil carbon inventories, or satellite products that were not used at first in the assimilation procedure. The spatial resolution considered in this project is about 1/2 degree. At this rather coarse spatial resolution, few homogeneous grid-cells are observed. A solution is to account for the sub-cell heterogeneity by simulating distinct water and energy budgets in the same grid-cell for the main surface types which are likely to be found (for example bare soil, forests, crops or grasslands). This tiling strategy will be also applied to the remote sensing data which will be aggregated for each tile. The end-product of the system will be a near real-time analysis of biospheric CO2 fluxes, released by ECMWF every 3 or 6 months. The other products of the service will consist of water and energy fluxes, biomass and soil moisture estimates which are fully compatible with CO2 exchange. The vegetation-atmosphere CO2 exchange depends on many biophysical factors. In particular, the leaf area index, the above-ground biomass, the soil carbon storage, the soil water content and the surface water flux, condition the CO2 flux. All these quantities will be produced at the same time by the physically-based model used by ONC. Constraining the vegetation biomass and the soil water content by using remote sensing products will permit to consolidate the estimation of the CO2 flux.

## IV- Conclusion

The main goal of geoland/ONC is to build a GMES near-operational service at ECMWF, able to monitor the natural terrestrial carbon fluxes at a global scale, together with consistently analysed soil moisture, water vapour fluxes, leaf area index and carbon stocks. ONC will build on past research projects and existing expertise in modelling (TESSEL, ISBA-A-gs, ORCHIDEE, at, respectively, ECMWF, Météo-France, LSCE).

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