REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: Portugal

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Project Title: Using Earth Observations to constrain land-atmosphere interactions

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2018-2020: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	2500000	2500000	2500000
Accumulated data storage (total archive volume)[2]	(GB)	4000	7000	10000

***An electronic copy of this form must be sent via e-mail to**:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date): 4 July 2017

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.
[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

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Project Title: Using Earth Observations to constrain land-atmosphere interactions

Abstract

Processes occurring at the land surface impact weather and climate variability. We propose that constraining land-atmosphere exchanges using Earth Observations (EO) will enhance current weather forecasts skill of near-surface fields, such as temperature, and improve the realism of present day climate models leading the way to increase climate change projections reliability. The project will focus on three main components: (i) development of key processes in the land surface model HTESSEL (ii) use of EO data to constrain model parameters, and (iii) weather forecasts and climate simulations. The weather forecasts tests will be performed with the ECMWF IFS and the climate simulations with the EC-EARTH model.

Motivation

Land surface is an important component of the Earth System (ES) and, consequently, of numerical weather prediction (NWP) and climate models. It controls the partitioning of available energy at the surface between sensible and latent heat, the partitioning of available water between evaporation and runoff, and carbon exchanges. There is increasing evidence of land surface's impact on climate (Alkama and Cescatti 2016), with changes in the land surface influencing regional-to global-scale climate from hours to millennia. The role of land surface in the ES has been investigated through observation-based studies (e.g. Teuling et al. 2017) and modelling studies (e.g. Dutra et al. 2012 ; Prodhomme et al. 2016). While observations provide the fundamental basis to understand the different processes and feedbacks, these need to be complemented by modelling studies that allow weather forecasts and climate simulations. Both lines of work are needed to advance our understanding of the role of the land surface in the ES and the computational resources requested in this project are essential to test the developments.

Feedback processes between surface and atmosphere are of major importance for the ES. The increased variability of summer temperatures in Europe (Schar et al. 2004) is mainly due to feedbacks between the land surface and the atmosphere (Seneviratne et al. 2006). On shorter time-scales, the land surface and its initial conditions are a source of sub-seasonal to seasonal predictability (e.g. Paolino et al. 2012; Prodhomme et al. 2016) and NWP skill (de Rosnay et al. 2004). However, current climate models revealed limitations in representing the recent hot summer of 2010 (Barriopedro et al. 2011).

Despite the relevance of land surface in the ES, there is a large-uncertainty arising from the representation of land-atmosphere exchanges of water, energy and carbon. This stems from the turbulent nature of these exchanges, spatial heterogeneity and temporal variability of the land-surface, which are difficult to observe (Coenders-Gerrits et al. 2014) and differ among models (Schellekens et al. 2016). These processes are represented in weather and climate models via conceptual models, i.e. parameterizations. These are strongly dependent on parameters, either observed or effective, which tend to be poorly constrained. Although there has been a steady improvement in land surface models (Pitman 2003), current state-of-the-art surface models still struggle to represent turbulent exchanges (Best et al. 2015), with implications in simulating extremes, such as drought frequency (Ukkola et al. 2016) or heatwaves (Kala et al. 2016).

The emergence of Earth Observations (EO) in the last two decades has enhanced our understanding of land surface dynamics (e.g. Künzer et al. 2015). EO data can help closing the gap between in-situ point observations and the grid-cell size models (from 1 to 100km), as well as to provide unique spatial sampling. The land surface temperature (LST) is a prime example: it can be estimated from polar and geostationary satellites with a high temporal and spatial frequency (Trigo et al. 2011). Moreover, LST is a key variable for land surface, as it controls the longwave emission and the turbulent exchanges of water and energy. However, in current models, LST shows large discrepancies with EO data (e.g. Trigo et al. 2015 ; Wang et al. 2014). These can be associated with numerous issues, such as deficient surface parameters or model formulations (e.g. Beljaars et al. 2017).

One area requiring attention is the uncertainty analysis: it is fundamental in environmental sciences, as it allows modelers and, ultimately, end users to identify uncertainties in model structures, drivers and prior estimates of parameters (Pappenberger; Beven 2006). Model uncertainty also provides guidance on processes and parameterizations which could be enhanced via parameter optimization, fundamental to explore the potential of EO data for model constraint. There are recent examples of land surface model calibrations applied to NWP (e.g Jr. et al. 2013; Orth et al. 2016; Orth et al. 2017). These works showed the potential to constrain the models using in-situ and EO data. However, the use of EO LST has not been fully explored in an integrated dual parameter-state data assimilation framework (Evensen 2009 ; Moradkhani et al. 2005) nor has there been a seamless approach integrating such advances in weather forecasts and climate modeling.

Considering the significant computations requirements to perform NWP and climate simulations, the computational resources requested in this project are fundamental to assess the current models deficiencies in terms of LST representation and testing of the model developments in both NWP and climate mode.

Workplan

The work will be organized in 3 main tasks to evaluate the current state of the models and their evolution in terms of weather forecast and climate using EO data and conventional observations. Evaluation will include the model developments and constrain to assess the added value of the use of EO data in constraining land-atmosphere exchanges and their impact on the model climate and weather forecasts skill.

Task 1. In this first task land-only (stand-alone or offline) simulations with the ECMWF land surface model HTESSEL will be carried out to test several developments including: (i) increased vertical resolution of the soil and (ii) new soil moisture root zone extraction based on a bulk root zone depth. This will be performed on a regional-scale at high resolution (initially over selected regions, e.g Iberia at about 5 km) to be compared with the LST from LandSAF. Further developments and testing will include a careful model parameters uncertainty estimation and optimization.

Task 2. In this second task, the development in task 1 will be tested in the full ECMWF IFS. These will include long simulations (at least 1 annual cycle) with nudged atmosphere above the boundary layer and medium-range weather forecast focusing on transition seasons.

Task 3. This last task will focus on climate simulations using the EC-EARTH model. Several multi-decadal simulations will be carried out with prescribed SST’s and sea-ice to assess the impact of the model developments in terms of current climate variability. In a second phase, future scenarios also with prescribed SST and sea-ice will be carried out to evaluate the impact of the model changes in terms of climate change projections.

This work will benefit from a close interaction with researchers at ECMWF in the coupled process team, the EC-EARTH consortium and the Portuguese weather Service IPMA.

Resources

The resources are based on the following estimates:

- Stand-alone simulations: T255, 35 years: approximately 3.000 SBU and 50 GB storage. These simulations are computationally cheap, but require some storage. 10 to 20 simulations are envisaged each year.

- Atmosphere nudging: T255, 137 levels, 1 year: approximately 30.000 SBU and 200 GB data. Up to 10 simulations are envisaged each year with a cost of about 300.000 SBU and 2TB of data.

- Atmospheric medium-range weather forecasts: TCo399 30 days: 140.000 SBU and 100 GB. Up to 6 months of simulations are envisaged year with a coast of about 840.000 SBU and 600 GB of data.

- Climate simulations: T255, 90 levels with 1 year: approximately 20.000 SBU and 40 GB data. Up to 100 years simulations are envisaged each year with a coast of about 2.000.000 SBU and 4TB of data.

Not all simulations and configurations will be carried out each year, and the requested SUB of 2.500.000 per year will cover most of the required computational resources in each year. The storage will be managed to only keep important simulations while temporary testing and extra output will be removed after the analysis.

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