REQUEST FOR A SPECIAL PROJECT 2017–2019

MEMBER STATE: Sweden………………………………………………………………...…

Principal Investigator[1]: Wilhelm May…..……………………………………………….……

Affiliation: Centre for Environmental and Climate Research, Lund University…

Address: Sölvegatan 37….……………………………………………………..……

SE-223 62 Lund, Sweden…..……………………………………….……

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E-mail: wilhelm.may@cec.lu.se……..……………………………………..……

Other researchers:

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Project Title:

Coupling and feedbacks between soil moisture and two dominant monsoon systems for present and future climates……..…………..……

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _________________	
Starting year: (Each project will have a well-defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2017	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2017-2019: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2018.)		**2017**	**2018**	**2019**
High Performance Computing Facility	(units)	6,000,000	12,000,000	18,000,000
Data storage capacity (total archive volume)	(gigabytes)	15,000	30,000	45,000

*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): 07-06-2016……………………………

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.

Principal Investigator: Wilhelm May……………………………………………………

Project Title: Coupling and feedbacks between soil moisture and two dominant monsoon systems for present and future climates…………………

Extended abstract

The overall objective of the project is to investigate the role of soil moisture for the variability of two of the most dominant monsoon systems, i.e., the West African Monsoon (WAM) and the Indian Summer Monsoon (ISM), for present-day and future climate conditions. In particular, the project will investigate the physical processes governing the coupling and feedbacks between soil moisture and the two monsoons and assess the contributions of the future changes in soil moisture to the overall future changes in the variability and the mean state of these monsoons in response to the projected increases in the anthropogenic climate forcing. The project will extend the analysis of the role of soil moisture to the atmospheric monsoon flows, studying how the local effects of soil moisture combine with the remote effects, and investigating the physical mechanisms coupling the local variations to the variability of the large-scale monsoon flows.

The vision of the project to generate new knowledge on the coupling between soil moisture and several, both local and remote, aspects of the two monsoon systems, at a variety of time scales, ranging from sub-seasonal to seasonal via annual to multi-decadal and century time scales. This knowledge will allow us, by highlighting the role of soil moisture for the two monsoon systems, to emphasize the need for incorporating anthropogenic land use changes and dynamical changes in vegetation in climate models to obtain reliable projections of future changes not only in the regions affected by these monsoons but also in other parts of the globe.

A number of specific simulations will be performed with the latest version of the state-of-the-art global climate model EC-Earth, both configured as the atmospheric component only and as interactively coupled atmosphere-ocean-sea ice model. In some of these simulations the soil moisture will be interactively coupled to the atmosphere, in others the soil moisture will be prescribed. These specific simulations will enable us to address several scientific research questions, which govern the specific scientific objectives of the project:

1. to describe the characteristics of the WAM and ISM according to observations,
2. to assess the quality of the simulation of the WAM and ISM by EC-Earth,
3. to analyse the coupling and feedback between soil moisture and the WAM and ISM under present-day climate conditions,
4. to evaluate the coupling and feedback between soil moisture and the WAM and ISM under future climate conditions, and
5. to quantify the contributions of the future soil moisture changes to the overall future changes of the WAM and ISM.

The project is linked to the Land Surface, Snow and Soil moisture Multimodel Intercomparison Project (LS3MIP; Seneviratne et al. 2014), which addresses the role of land processes and feedbacks in climate change simulations. LS3MIP is one project on the extensive list of MIPs within the Coupled Model Intercomparison Project phase 6 (CMIP6; Eyring et al. 2015), which is the largest ever coordinated international effort on climate modelling, and will provide the climate scenarios to be utilized in the next assessment report by the Intergovernmental Panel on Climate Change (IPCC).

Several sets of simulations with the latest version of the state-of-the-art global climate model EC-Earth (Hazeleger et al. 2012) will be at the core of the project. In the latest version, the EC-Earth atmosphere-ocean-sea-ice coupled climate model (AOGCM) combines the ECMWF IFS (cycle 36) atmospheric general circulation model (AGCM) with the NEMO (version 3.6) ocean model and the LIM (version 3) sea-ice model. This means that the individual models have been updated compared to the previous version of EC-Earth, but most importantly the horizontal and/or vertical resolutions have been increased. The horizontal resolution of IFS is increased from T159 to T255 (corresponding to grid point distances of approx. 130 km to approx. 80 km) and the number of vertical levels is increased from 62 to 91. The number of vertical levels of NEMO is increased from 42 to 75, while the horizontal resolution is unchanged, ranging between 1/3° round the equator and 1° over the rest of the globe. IFS includes the H-TESSEL land surface model (Balsamo et al. 2009), incorporating land surface hydrology. Within the project, 12 climate simulations will be performed, 10 with the AGCM and two with the AOGCM (see Table 1). In these simulations the temporal development of the anthropogenic climate forcing is prescribed according to observations until 2014 and according to one of the new set of scenarios to be used in CMIP6, following the concept of shared socioeconomic pathways (O'Neill et al. 2014). One of the high forcing scenarios will be used, as this is likely to give strong signals compared to climate noise. Additional simulations with varying initial conditions will be performed for some of the simulations with the AGCM to generate ensembles of these experiments.

Number	Simulation	Model configuration	Sea surface temperatures	Soil moisture	Period of simulation
1	AP-PO-I	AGCM	Prescribed (observations)	Interactive	1979-2014
2	AP-PO-P1	AGCM	Prescribed (observations)	Prescribed (AP-PO-I; method 1)	1979-2014
3	AP-PO-P2	AGCM	Prescribed (observations)	Prescribed (AP-PO-I; method 2)	1979-2014
4	AP-PO-P3	AGCM	Prescribed (observations)	Prescribed (AP-PO-I; method 3)	1979-2014
5	AP-PO-PO	AGCM	Prescribed (observations)	Prescribed (observations)	1979-2010
6	CP-I-I	AOGCM	Interactive	Interactive	1951-2014
7	CF-I-I	AOGCM	Interactive	Interactive	2015-2100
8	AP-PM-I	AGCM	Prescribed (CP-I-I)	Interactive	1979-2014
9	AP-PM-P	AGCM	Prescribed (CP-I-I)	Prescribed (CP-I-I)	1979-2014
10	AF-PM-I	AGCM	Prescribed (CF-I-I)	Interactive	2071-2100
11	AF-PM-P	AGCM	Prescribed (CF-I-I)	Prescribed (CF-I-I)	2071-2100
12	AF-PM-PP	AGCM	Prescribed (CF-I-I)	Prescribed (CP-I-I)	2071-2100

Table 1: Model simulations, specifying the model configuration, the treatment of the sea surface temperatures and of the soil moisture, respectively, as well as the period of simulation

The simulations differ by the degree to which the oceans or land surface are interactively coupled with the atmosphere, enabling feedbacks between the atmosphere and the oceans or between the atmosphere and the land surfaces, or the lower boundary conditions, i.e., the sea surface temperatures (SST) and/or soil moisture, are prescribed.

Various aspects of the WAM and ISM will be considered, applying suitable diagnostics, with two focus areas. These are, on one hand, the interaction between local variations of the two monsoons with the respective large-scale monsoon flow and the interaction between the sub-seasonal variability and the mean state of the respective monsoon system on the other. The work in the project will be organized in five research themes, corresponding to the specific scientific objectives mentioned above:

RT1; The characteristics of the WAM and ISM according to observations and their simulation by EC-Earth

The characteristics of the WAM and ISM will be described using different suitable observational data sets, i.e., ERA-Interim (Dee et al. 2011) for the large-scale structure of the monsoons and near-surface temperatures, ERA-Interim/Land (Balsamo et al. 2015) for the soil moisture or GPCP (e.g., Huffman et al. 2009) for precipitation. Simulation AP-PO-I (#1) will be used to assess the quality of the simulation of these aspects of the WAM and the ISM by EC-Earth. This simulation is chosen for two reasons: SST are prescribed according to observations and the land surface is interactively coupled to the atmosphere. Using observed SST ensures that errors in simulated SST do not influence the simulation of the two monsoon systems, while the full coupling with the land surface is expected to give the most realistic simulation of the two monsoons.

RT2; The prescription of soil moisture and the coupling and feedbacks between soil moisture and the WAM and ISM for present-day climate

Several approaches for prescribing soil moisture will be tested in simulations AP-PO-P1, P2 and P3 (#2, #3 and #4). Two will apply the nudging technique based on monthly means of soil moisture. Following Douville et al. (2016), in one of the approaches only the three lower soil-layers of H-TESSEL are nudged towards the prescribed soil moisture and the uppermost layer is interactively coupled to the atmosphere. In the second approach all four layers are nudged towards the prescribed soil moisture. The third method will follow the LS3MIP-protocol, where as in Seneviratne et al. (2013) climatological annual cycles of the soil moisture are directly prescribed to H-TESSEL. The most appropriate method, i.e., the method, which maintains the largest fraction of the variability and doesn't introduce any inconsistent energy fluxes at the surface, will be determined by comparing the three simulations with simulation AP-PO-I (#1).

The feedback between the soil moisture and the two monsoon systems under present-day climate conditions (1979-2014) in EC-Earth will be analysed by relating the simulation AP-PO-I to the simulation with prescribed soil moisture using the most appropriate method, AP-PO-PX. This is because differences in the characteristics of the two respective monsoon systems between the two simulations are associated with the impact of the atmosphere on the land surface in simulation AP-PO-I (with the interactive coupling between the land surface and the atmosphere). The simulation AP-PO-PX, on the other hand, only incorporates the coupling of the atmosphere to the land surface. As part of this analysis, the strength of the feedback will be quantified for different aspects of the monsoon systems (see Seneviratne et al. (2010) and references therein for the diagnostics of soil moisture coupling and feedbacks).

In contrast to simulation AP-PO-PX, in the simulation AP-PO-PO (#5) soil moisture is prescribed according to observations (ERA-Interim/Land; Balsamo et al. 2015). The comparison between these two simulations will reveal, to which extent the coupling between the land surface and the two monsoon systems is affected by potential errors in the simulation of soil moisture in EC-Earth.

RT3; The influence of SST-errors on the simulation of the WAM and ISM by EC-Earth

Simulations CP-I-I (#6) and CF-I-I (#7) incorporate both the interactive coupling between the oceans and the atmosphere and the interactive coupling between the land surface and the atmosphere. The full coupling between the different components of the climate system is needed for simulating the future climate in response to increases in the anthropogenic climate forcing. These simulations provide the SST and soil moisture data that will be prescribed in the simulations in RT4 and RT5 (see below).

The simulation with the coupled atmosphere-ocean-sea-ice version of EC-Earth, simulation CP-I-I, is likely to be affected by errors in the SST (e.g., Wang et al. 2014). The influence of these errors on the simulation of the WAM and ISM by EC-Earth will be determined by comparing simulation AP-PM-I (#8), where the prescribed SST originate from the simulation CP-I-I, with simulation AP-PO-I, where observed SST are prescribed. The simulation AP-PM-I is used here, because it, consistent with simulation AP-PO-I, does not incorporate the interactive coupling between the oceans and the atmosphere. Knowledge on the influence of SST-errors on the simulation of the two monsoon systems is relevant, as the SST, which will be prescribed in the simulations in RT4 and RT5, originate from simulations with EC-Earth.

RT4; The coupling and feedbacks between soil moisture and the WAM and ISM for future climate

Consistent with RT2, the feedback between the soil moisture and the two monsoon systems in EC-Earth will also be analysed under future climate conditions (2071-2100). This will be done by relating the simulation AF-PM-I (#10) with interactive soil moisture to the corresponding simulation with prescribed soil moisture, AF-PM-P (#11). In this case, the differences in the characteristics of the two monsoon systems between the two simulations are linked to the impact of the atmosphere on the land surface in simulation AF-PM-I (with the interactive coupling between the land surface and the atmosphere). The simulation AF-PM-P, on the other hand, only incorporates the coupling of the atmosphere to the land surface.

RT5; The contributions of future soil moisture changes to the overall future changes of the WAM and ISM

In order to quantify the contributions of the future soil moisture changes to the overall future changes in the different characteristics of the WAM and ISM, the differences between the simulations AF-PM-P (#11) and AP-PM-P (#9) will be related to the differences between the simulations AF-PM-P and AF-PM-PP (#12). This will lead to the anticipated result, because the differences between the simulations AF-PM-P and AF-PM-PP are associated with the future changes in soil moisture alone, while the differences between the simulations AF-PM-P and AP-PM-P are caused by a combination of the soil moisture changes and other changes in response to the projected increases in the anthropogenic climate forcing. The latter are, for instance, changes in the large-scale monsoon flows in association with changes in the Hadley circulation or the Walker circulation or, in the case of precipitation, an increase due to the enhanced atmospheric water content in a warmer climate. The contributions of the future changes in soil moisture to the overall changes in the characteristics of the WAM and ISM will be quantified by means of anomaly correlation coefficients (indicating the similarity between corresponding anomaly patterns) and be means of linear regression analysis (relating the magnitude of the overall local change to the magnitude of the change caused by the soil moisture changes; see May et al. (2015) for details).

Within the three years of the requested special project the work related to RT1, RT2 and RT3 and, partly, the work related to RT4 will be undertaken.

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