CMUG Deliverable

Number:	**D3.1c**
Due date:	**March 2013**
Submission date:	**16 April 2013**
Version:	**0.4**

Climate Modelling User Group

Deliverable 3.1c

Technical note on
CMUG Cross ECV (Fire/Soil Moisture/LandCover) Assessment Report

Centers providing input: MPI-M

Version nr.	Date	Status
0.1	15 March	Initial document
0.4	16 April 13	Final changes made (RS)

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CMUG ECV Soil moisture Assessment Report

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1 INTRODUCTION

Fire is an important Earth system process that impacts climate through various processes. At the same time fire itself is controlled by climate and thus forms a potential feedback mechanism within the Earth System. The assessment of this feedback requires global fire models that take into account climate as a driver of fire occurrence and at the same time simulate fire initiated climate relevant processes such as the emissions of greenhouse gases into the atmosphere.

Global fire models are typically evaluated with satellite based fire products that cover a multiyear timespan. However, satellite products are representative for present day conditions and burned area crucially depends on the prevailing meteorological conditions. Global climate models often do not have the means to represent these meteorological conditions, which makes an evaluation difficult. Discrepancies between geographical patterns of model and observations might be a result of an insufficient representation of the fire process itself or might be caused by a biased meteorological forcing. This is just one example, there are a number of reasons why perfect agreement between model and observations cannot be expected.

Functional relationships between independent variables of the climate system circumvent the dependency of the results on the meteorological forcing data and the climate state. For fire occurrence such a relationship is suggested between soil moisture and burned area. Fire occurrence depends on the soil moisture status, whereas a fire does not directly affect the soil moisture. Moreover, while the geographical patterns will change with varying climate the relationship between burned area and its drivers will remain the same and is therefore highly valuable to assess the model performance.

The purpose of the present study is to investigate a potential relationship between soil moisture and burned area exploiting possibilities of new observational data. A novel fire model (SPITFIRE) as part of the Max-Planck-Institute for Meteorology Earth System Model (MPI-ESM, Giorgetta et al., 2012) will be confronted with this observational based relationship. This analysis is part of the overall evaluation of the newly implemented fire model in the MPI-M ESM.

2 DATA

2.1. Meteorological Forcing

The land vegetation model JSBACH can be used in various setups, including fully coupled simulations in the MPI-M Earth System model including interactive Carbon-Cycle calculations and standalone simulations with prescribed meteorological forcing data. For the present study we used model simulations that were forced with observed meteorological data.

Meteorological forcing data (air temperature and humidity, shortwave and longwave incident radiation, precipitation, and surface wind speed) for 1860 to 2010 were derived from CRU-NCEP (CRU-NCEPv4, N. 2011. Available from: http://dods.extra.cea.fr/ data/p529viov/cruncep/), and were aggregated to the T63 resolution (~1.8° to 1.8°) of the MPI-ESM grid at daily resolution.

2.2. Burned Area

As precursor dataset for the fire CCI the Global Fire Emission Database (GFED, version 3) was chosen (van der Werf *et. al.*, 2010, Giglio *et. al.*, 2010). GFEDv3 reports burned area for the time period 1997 – 2010 on a monthly basis with a spatial resolution of 0.5 x 0.5 deg. For the comparison with JSBACH the burned area was mapped to the current model standard grid resolution of T63 (~1.8 degree x 1.8 degree).

2.3. Soil Moisture

Here we used soil moisture datasets processed in D3.1b. The datasets comprise two remote sensing products, including the recently released multidecadal soil moisture data record developed by partners from the ESA CCI soil moisture team (ECV_SM v0.1). The different datasets are described in detail in D3.1b.

Table 1: List of used datasets in the present study (from D3.1b)

Dataset	*Version*	*Timeperiod*	*References*
VUA AMSR-E soil moisture	V0.5	07/2002 – 10/2011	Owe et al., 2008
ESA ECV Soil Moisture (ECV_SM)	V0.1	11/1978 – 12/2010	Liu et al., 2011; Liu et al., 2012

The Soil Moisture datasets were harmonized and processed, including spatial regridding and temporal filtering, to be directly comparable to soil moisture simulated in the vegetation model JSBACH on a resolution of T63 (~1.8 x 1.8 degree)

2.4. Land Cover

The land cover data from the ESA GlobCover project is used as an observation pre-cursor (http://ionia1.esrin.esa.int/). It is distributed with the GFEDv3 burned area product. In an initial assessment the land cover classification is used to discriminate between burned areas in grass and tree covered regions.

3 MODEL

3.1. MPI-M ESM land surface vegetation model (JSBACH)

The model used in the present study is the land surface scheme of the MPI-ESM, JSBACH (Reick et al., 2012). The model is implicitly coupled to the atmospheric component of MPI-ESM (ECHAM6) and simulates all relevant land surface water, energy and carbon fluxes in an interactive manner (Figure 1). A new soil hydrology scheme with multiple layers for the zone until the bedrock allows for the simulation of soil moisture dynamics in varying depths. The soil layers have a thickness of dz=[0.065,0.254,0.913,2.902,5.9] [m]. As satellite observations provide soil moisture information for the upper few centimeters of the soil only, the new scheme allows for a comparison with the satellite data.

The present analysis uses version 2.03 of JSBACH (similar to the model version used in D3.1b) which is comparable to the model version which was used for the Coupled Model Intercomparison Project 5 (CMIP5) (Taylor et al., 2012). The only major difference between the CMIP5 model and the model version used in the present study is the inclusion of the new 5-layer soil hydrology scheme.

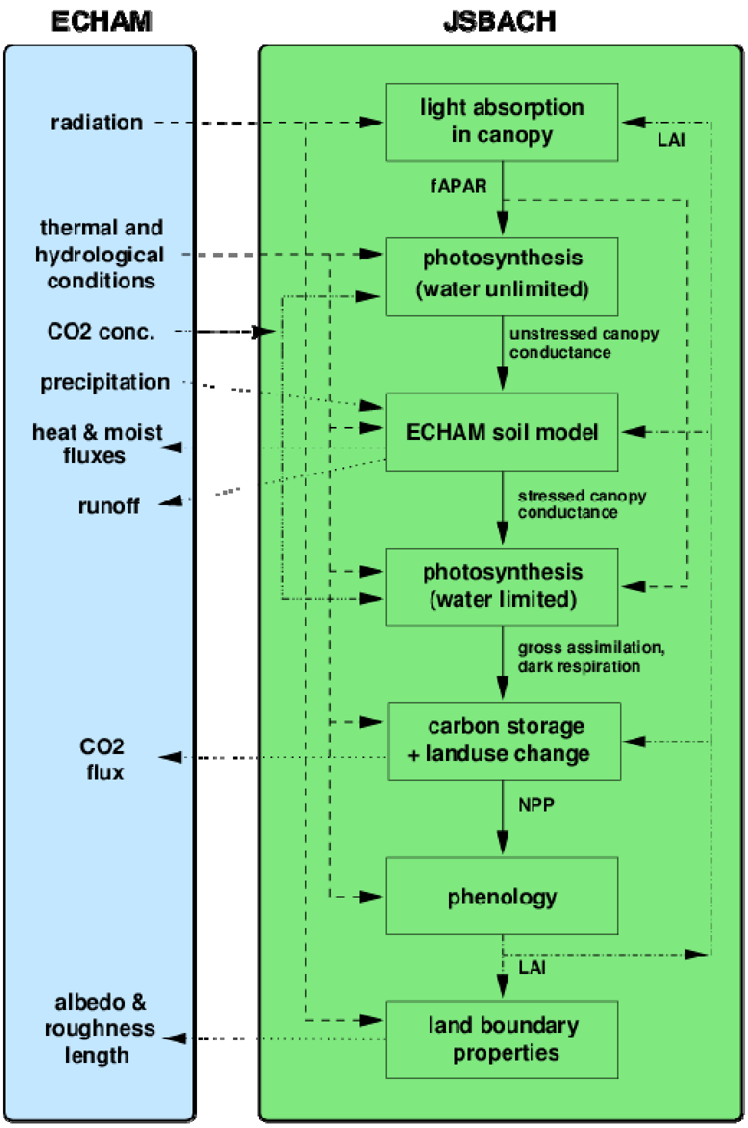

Figure 1: The components of the land vegetation model of the MPI-M Earth System Model (JSBACH).

3.2. MPI-M ESM fire model (SPITFIRE)

SPITFIRE (SPread and InTensity of FIRE) is a process-based fire regime model. It interacts with the land surface model through the usage of the meteorological and carbon stock related parameters and provides in return the burned area and fire carbon emissions on a daily time scale (Figure 2). The model includes explicit representation of ignitions and of the physical properties and processes determining fire occurrence, spread and intensity. It distinguishes the controls on the drying of different litter size classes from those on soil moisture and live fuel moisture, allowing the separation of processes with different time scales of response to atmospheric conditions. It also adopts a process-based formulation of the effects of fire on vegetation as a function of structural plant properties (Thonicke et al., 2010).

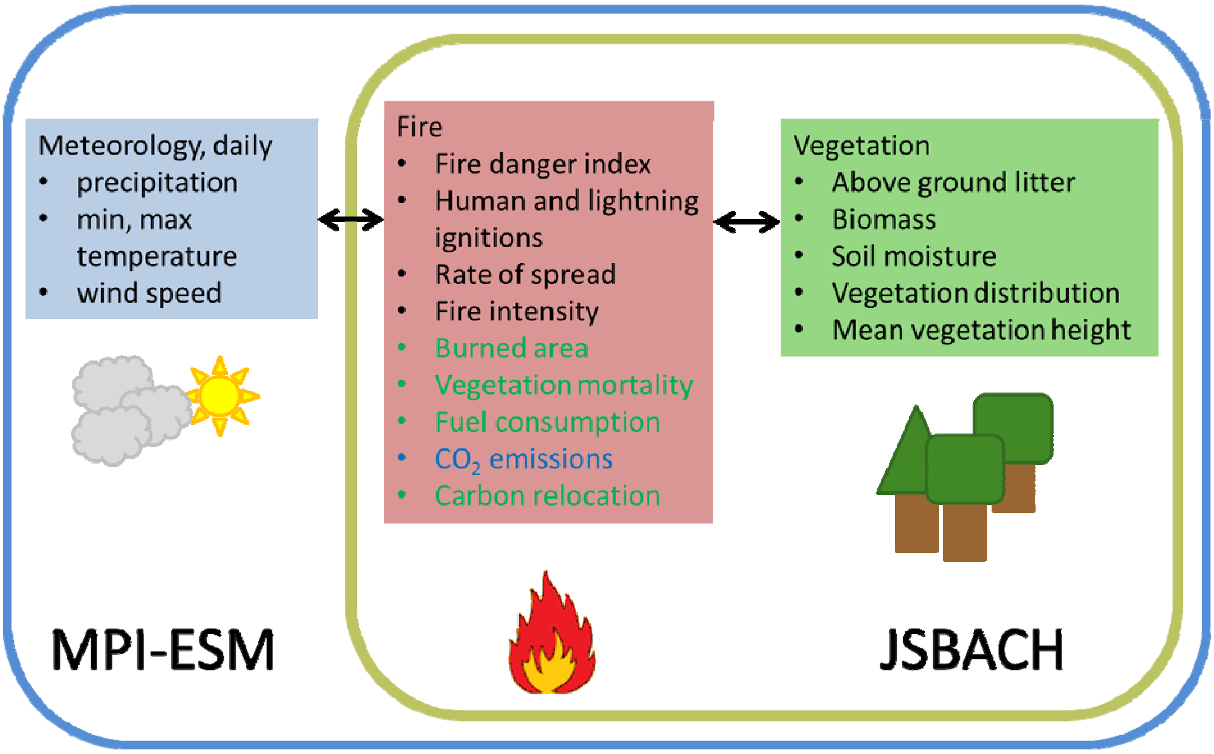

Figure 2 : Implementation of the fire model SPITFIRE in JSBACH

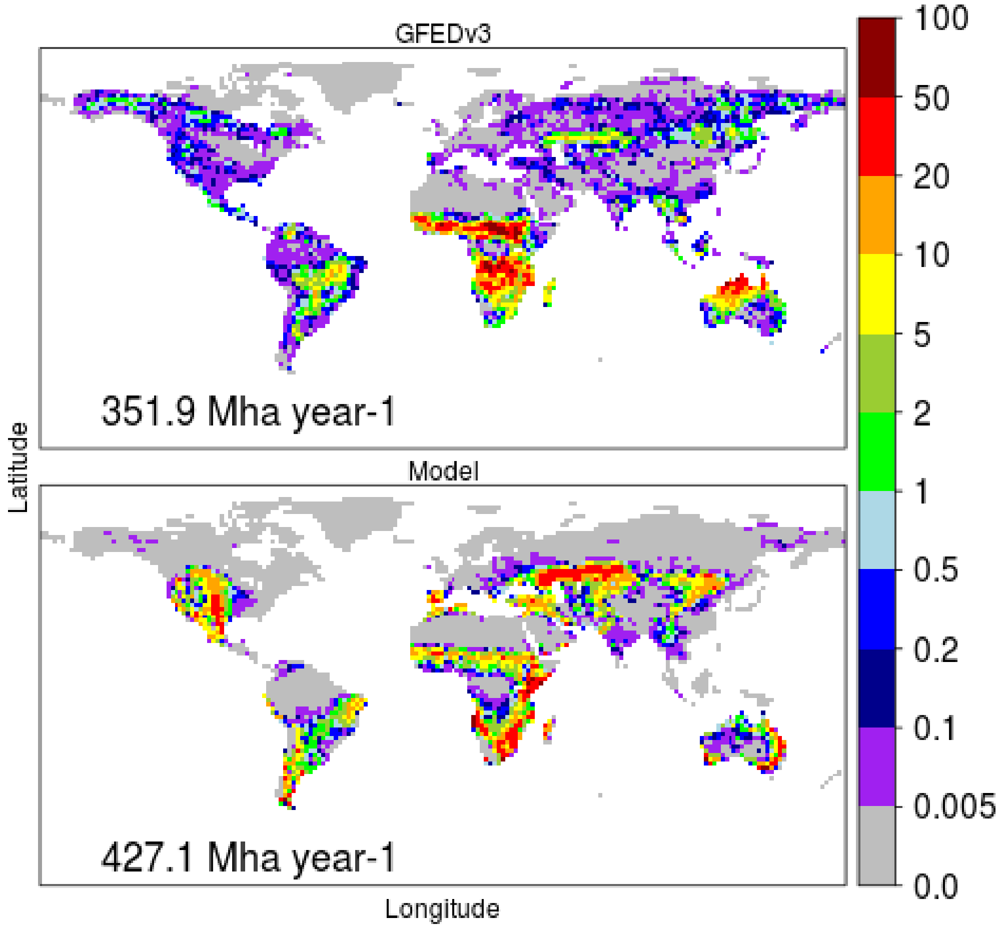

Figure 3: Simulated (Model) and observed burned (GFEDv3) burned area for the time period 1997-2005 [fraction of gridbox burned per year in %].

For present day (1997 – 2005) conditions the model simulates an annual burned area of 427 Mha with maximum burning in Africa, Central Asia, Australia and North and South America (Figure 3).

4 RESULTS

Figure 4 shows the relationship between monthly soil moisture and burned area as derived from the observational datasets and from the model results. Both the model and the observational data derived relation show a strong functional relationship between the higher percentiles of burned area and soil moisture. For low soil moisture the burned area is low, it peaks for medium soil moisture and decreases again for increasing soil moisture. This reflects that fire occurrence is a function of fuel availability and fuel moisture. Fires do not occur in regions where not enough fuel is available to burn (fuel limitation) and in regions in which the fuel is too moist to be ignited (moisture limitation). Fuel limitation occurs naturally in dry regions were low soil moisture prevents vegetation build up, but can also occur for higher soil moisture through anthropogenic influence, previous burns or herbivory In addition ignitions can be a limiting factor, these additional limiting factors explain why the functional relationship only gets apparent for the higher percentiles of burned area.

The VUA AMSR-E results differ from the ESA ECV Soil Moisture results for high soil moisture values (> 0.6). In case of the AMSR-E data high soil moisture values coincide with vegetation burning, in the ESA ECV dataset soil moistures higher 0.5 do not occur. Further inspection of the relation showed that this signal stems from high latitude boreal regions. In these regions the AMSR-E dataset reports soil moisture that is higher compared to other observational based products and probably biased high (see also analysis in D3.1b). The model results and the relationship based on the ESA ECV Soil Moisture product compare reasonable well with peak burned fraction for soil moisture between 0.15 and 0.25.

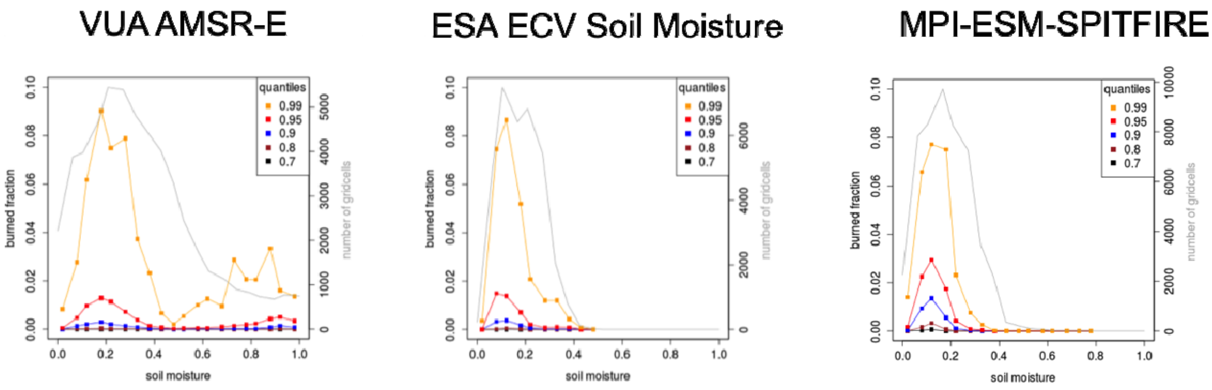

Figure 4: Relationship between soil moisture and burned area derived for all landcover classes.

We further investigated the dependency of the relationship between soil moisture and burned area on the prevailing vegetation type. Therefore we only analysed grid cells dominated by either grass vegetation (Figure 5) or woody vegetation (Figure 6). The observations show a less peaked distribution in case only woody vegetation is considered compared to grass landcover. This implies that for woody vegetation fires do occur under higher soil moisture conditions compared to grass vegetation, which might be caused by higher tree cover for these moisture regimes.

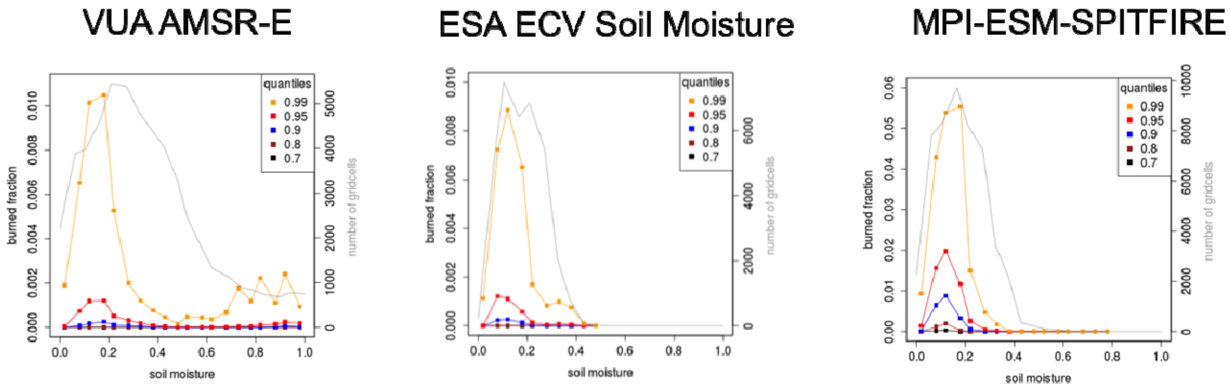

Figure 5 Relationship between soil moisture and burned area for grass vegetation types only.

The model results, however, do not reflect this different behaviour for the two different vegetation classes and show for woody and grass vegetation types very similar distributions.

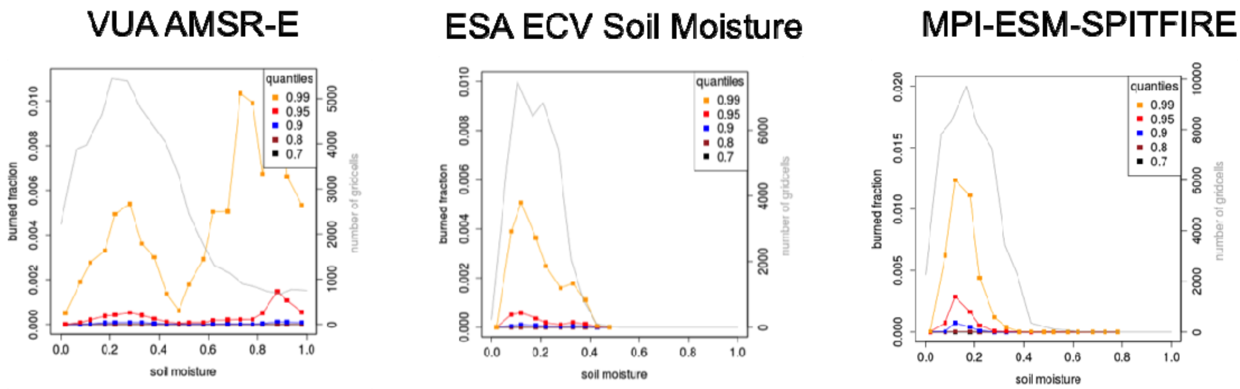

Figure 6 Relationship between soil moisture and burned area for woody vegetation types only.

This discrepancy might be solved in the model by varying the land cover specific moisture parameter that controls the fire spread rate (moisture of extinction) and differentiating stronger between woody and grass vegetation classes.

Overall the model shows a good agreement with the observational based relationship between burned area and soil moisture. This relationship forms a valuable tool to evaluate global fire models as it allows for an evaluation that is independent of possible model biases for soil moisture. This analysis evaluates the sensitivity of the fire model to moisture. While geographical patterns of fire occurrence are expected to change with changing climate, this relationship is expected to remain similar under different climatic conditions.

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