SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2017
Project Title:	Go Beyond Current Limitations of Climate Simulation and Projection over Land
Computer Project Account:	spitales
Principal Investigator(s):	Alessandri Andrea
Affiliation:	ENEA (Italy) (other affiliation: KNMI, Netherland)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	……………………………………………………………… ………………………………………………………………
Start date of the project:	1 January 2016
Expected end date:	31 December 2018

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	4 million	4013545	5 million	0
Data storage capacity	(Gbytes)	50000	2080	50000	2204

Summary of project objectives

(10 lines max)

The objectives of this special project are (i) develop a process-based albedo parameterization in EC-Earth, (ii) validate and assess the effects of the new albedo scheme on the simulated climate during the last Century historical period and (iii) evaluate the interactions and feedbacks of the interactive albedo in the future climate projections (CMIP6).

The couplings and feedbacks of the newly introduced interactive albedo will be assessed together with the interactions with the changes of water availability (soil moisture and snow) as well as changes in land cover/land use types.

Summary of problems encountered (if any)

(20 lines max)

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Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

During the second reporting period of the project, in collaboration with colleagues of Stockholm University and SMHI, a new albedo scheme has been developed in EC-Earth based on a lookup-table approach. At first, the values for each vegetation type have been adapted from Houldcroft et al., (2009) where the albedo values were derived for the JULES Plant Functional Types (PFTs) classification (Best et al., 2011). However, using the look-up table values derived from Houldcroft et al., (2009) (hereinafter CTRL experiment) produced a global overestimation of surface albedo with respect to MODIS observational data (Fig. 1a), leading to significant cold biases in surface temperature (Fig. 2a). This motivated us to continue the development of the albedo parametrization in EC-Earth by re-estimating the look-up table values of albedo specifically for the PFTs considered in the land-surface model included in IFS (HTESSEL; Balsamo et al., 2009). The look-up table has been recomputed using percent (%) cover thresholds to identify MODIS grid-points dominated by (i.e. representative of) each PFT considered in HTESSEL. The %thresholds have been iteratively adjusted for each PFT in order to identify enough grid points for robust averaged-value estimation and also based on experience-oriented judgement when needed. Look-up table values of albedo have been estimated for each PFT and for each of the four short-wave bands considered in IFS radiation code (visible and near infrared for both diffuse and parallel beams) by averaging the MODIS albedo over grid-points that are representative of each vegetation type. Similarly, soil albedo values for each soil type and for each short-wave band have been estimated using averaged MODIS values over points classified as bare soil.

Both the revised and the CTRL albedo schemes also include the modifications for desert albedo discrimination developed during the previous reporting period (first 6 months of the project) and the enhanced vegetation sensitivity described in Alessandri et al. (2017).

The effects of the improved albedo parameterization have been analyzed on a set of historical simulations with both AMIP-type (using HadISST SST and sea ice [Rayner et al. 2003] from the CMIP6 forcing dataset input4MIPs) and coupled (using NEMO 3.6 ocean model) setup spanning 28 years (1982-2009) with the latest available version (v3.2) of EC-Earth (see Table 1 for a summary of experiments performed). In all simulations, the vegetation LAI variability is prescribed from the LAI3g dataset based on the third generation GIMMS and MODIS satellite observations (Zhu et al., 2013).

Experiment name	Albedo parameterization
MODIS AMIP	Climatological snow-free albedo from MODIS
CTRL AMIP	Albedo lookup table from Houldcroft et al., (2009)
MODIF AMIP	Newly computed lookup table estimated from MODIS data
MODIS coupled	Climatological snow-free albedo from MODIS
CTRL coupled	Albedo lookup table from Houldcroft et al., (2009)
MODIF coupled	Newly computed lookup table estimated from MODIS data

Table 1. Summary of experiments performed.

In the MODIS experiments the albedo is prescribed from satellite-derived MODIS monthly climatology (Morcrette et al. 2008). For CTRL experiments, albedo is assigned for each vegetation class from lookup table values adapted from Houldcroft et al. (2009). On the other hand, in MODIF the albedo has been specifically re-estimated from satellite MODIS data for each vegetation and soil type considered in HTESSEL. For brevity, we will describe in the following only the analysis of the results of the coupled simulations that are also well representative of the results for the corresponding AMIP experiments.

Our analysis indicates that the improved parameterization with more realistic albedo values for each vegetation type in MODIF allows to overcome major albedo biases (Fig. 1b) compared to CTRL (Fig. 1a). The realistic albedo values for each vegetation type lead to a significant reduction of the albedo in MODIF compared to CTRL in several areas (Fig. 1c), correcting for most of the large scale overestimation that was diagnosed for CTRL (Fig. 1a).

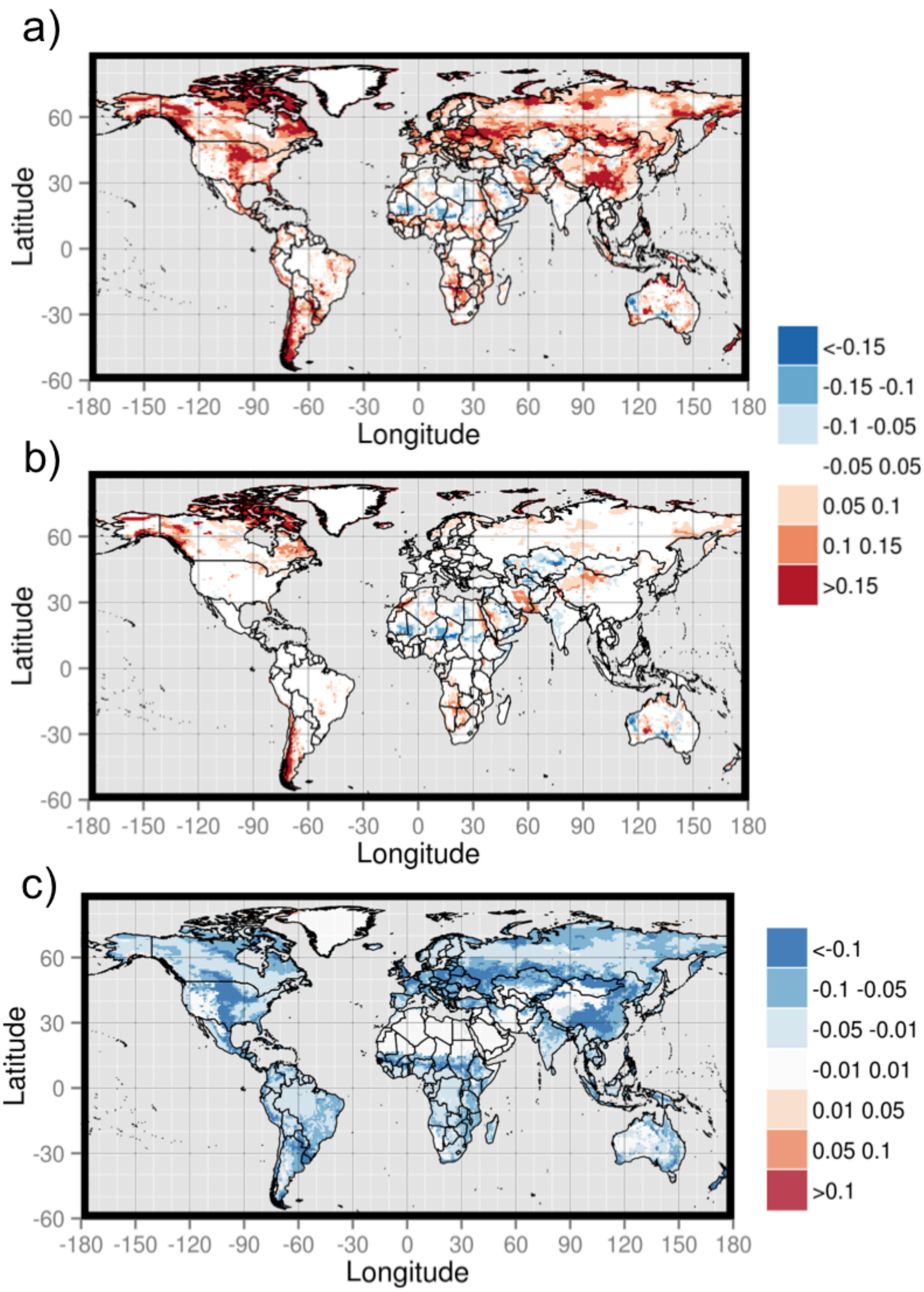

Figure 1: Boreal summer (June-July-August) difference of albedo with respect to MODIS experiment (i.e. prescribed climatology of snow-free albedo) for (a) CTRL and (b) MODIF. In (c) is the MODIF minus CTRL difference.

Accordingly, the enhanced albedo representation leads to a significant improvement of the global summer-mean (JJA) climatology of surface temperature with respect to ERA-Interim reanalysis (Berrisford et al., 2007; Fig. 2b). In particular, the cold bias is significantly reduced over the Euro-Asian domain, Africa, Australia and South America (Fig. 2b-c). On the other hand, the warming in MODIF (Fig. 2c) has mixed results over North America, leading to too high temperature over Great Plains and continental central-northern U.S and Canada.

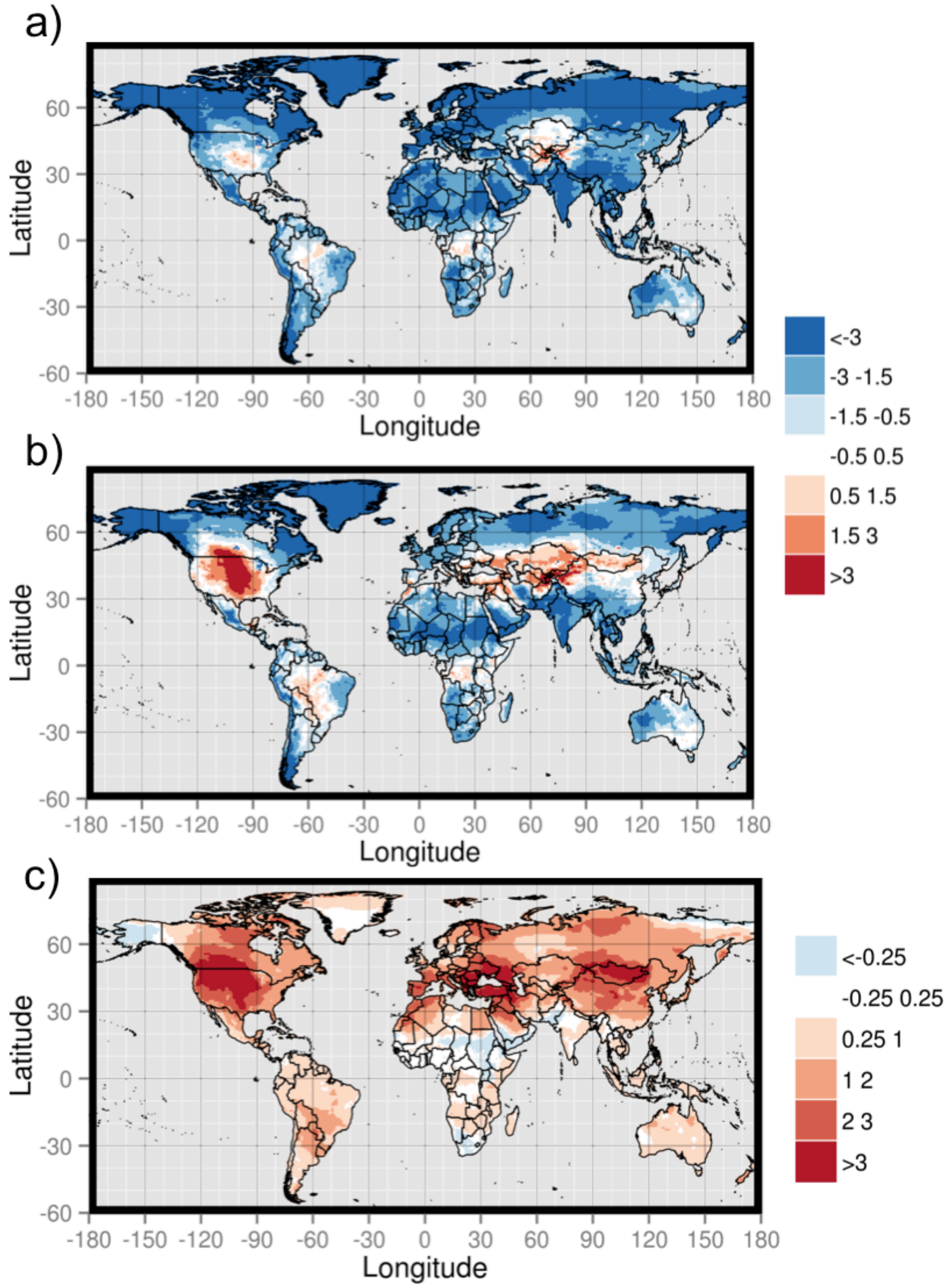

Figure 2: Boreal summer (June-July-August) bias of 2m temperature computed with respect to ERA-Interim reanalysis for (a) CTRL and (b) MODIF. In (c) is the MODIF minus CTRL difference.

Interestingly, the novel parameterization in MODIF improves considerably the Boreal summer (JJA) precipitation considering as reference the GPCP satellite-based data (Adler et al., 2003; Fig. 3b). Remarkably, the too low monsoon precipitation in CTRL (Fig. 3a) is improved considerably in MODIF (Fig. 3b) with an increase over the Indian, the south-east Asian and the western Africa monsoon domains (Fig. 3c). The described increase of precipitation over the monsoon domains that follows the reduction of the albedo over the same areas (Fig. 1c) is consistent with the Charney's albedo mechanism of positive feedback on rainfall over subtropical and tropical regions (Charney et al. 1977).

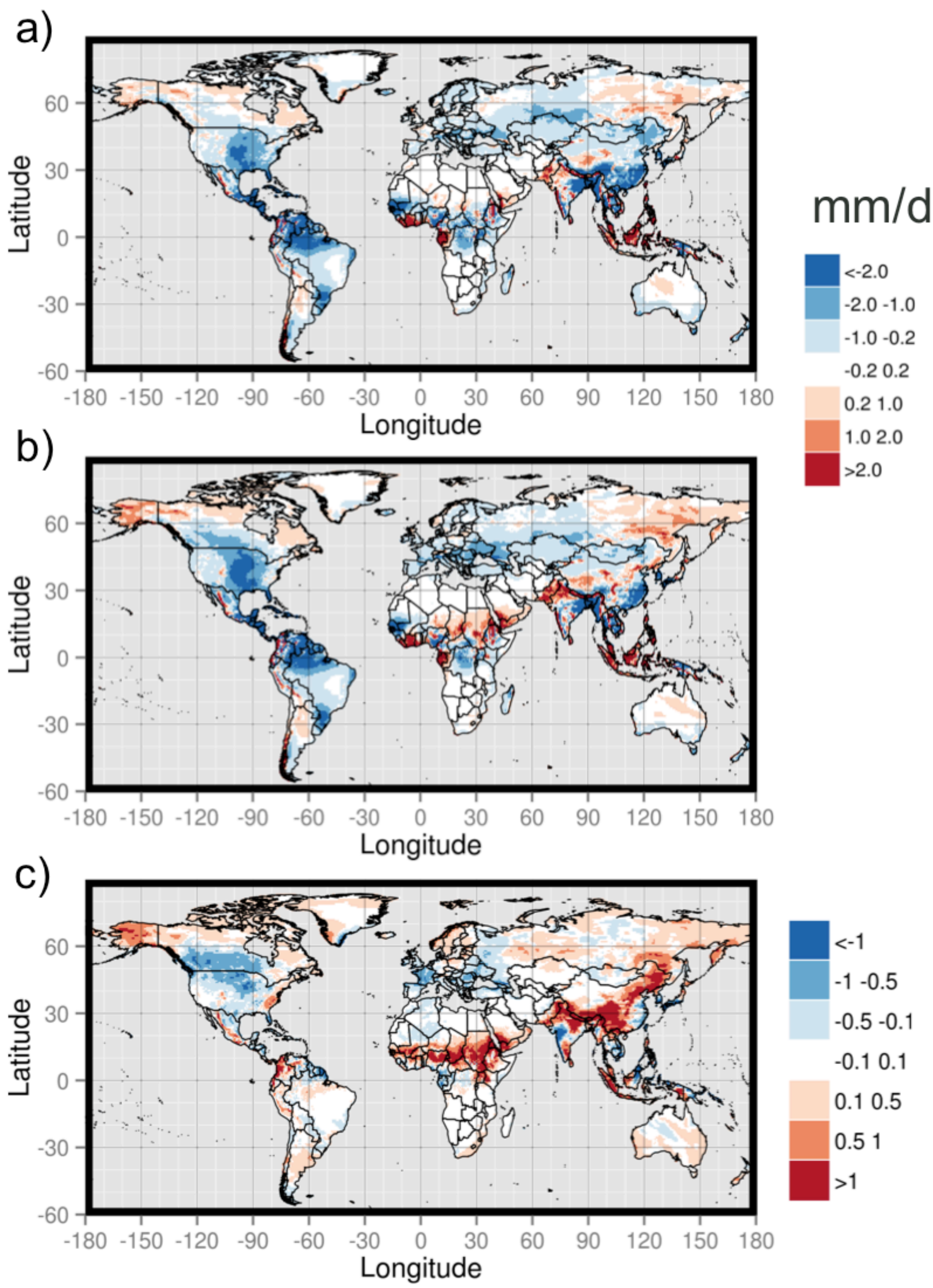

Figure 3: Same as Figure 1 but for total precipitation. Biases are computed with respect to GPCP satellite-based data.

References:

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A. Alessandri, F. Catalano, M. De Felice, B. Van Den Hurk, F. Doblas Reyes, S. Boussetta, G. Balsamo, P. Miller (2017), "Multi-scale enhancement of climate prediction over land by increasing the model sensitivity to vegetation variability in EC-Earth", In Press. Climate Dynamics. DOI: 10.1007/s00382-016-3372-4

Balsamo, G., A. Beljaars, K. Scipal, P. Viterbo, B. van den Hurk, M. Hirschi, and A. K. Betts, 2009: A revised hydrology for the ECMWF model: Verification from field site to terrestrial water storage and impact in the integrated forecast system. J. Hydrometeor. , 10 , 623–643, doi:10.1175/2008JHM1068.1.

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Houldcroft C. J., Grey W. M. F., Barnsley M., Taylor C. M., Los S. O., North P. R. J., 2009: New Vegetation Albedo Parameters and Global Fields of Soil Background Albedo Derived from MODIS for Use in a Climate Model, J. Hydrometeorol., 10, 183-198.

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Rayner, N. A.; Parker, D. E.; Horton, E. B.; Folland, C. K.; Alexander, L. V.; Rowell, D. P.; Kent, E. C.; Kaplan, A. (2003) Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century J. Geophys. Res.Vol. 108, No. D14, 4407 10.1029/2002JD002670

Zhu, Z., Bi, J., Pan, Y., Ganguly, S., Anav, A., Xu, L., Samanta, A., Piao, S., Nemani, R. R., and Myneni, R. B., 2013: Global Data Sets of Vegetation Leaf Area Index (LAI)3g and Fraction of Photosynthetically Active Radiation (FPAR)3g Derived from Global Inventory Modeling and Mapping Studies (GIMMS) Normalized Difference Vegetation Index (NDVI3g) for the Period 1981 to 2011, Remote Sens., 5, 927–948.

List of publications/reports from the project with complete references

A. Alessandri, F. Catalano, M. De Felice, B. Van Den Hurk, F. Doblas Reyes, S. Boussetta, G. Balsamo, P. Miller (2017), "Multi-scale enhancement of climate prediction over land by increasing the model sensitivity to vegetation variability in EC-Earth", In Press. Climate Dynamics. DOI: 10.1007/s00382-016-3372-4

Summary of plans for the continuation of the project

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Building on the results of the simulations, analysis, and verification performed during the first 18 months of the project we plan to finalize the development of a process-based albedo parametrization in EC-Earth. The enhanced model will be used to assess the effects on the simulated climate during the last century historical period and used to evaluate the interactions and feedbacks of the albedo in the future climate projections (CMIP6). We plan to evaluate the couplings and feedbacks of the newly introduced interactive albedo together with the interactions with the changes of water availability and the changes in land cover/land use types.