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	2014………………………………………….……
Project Title:	Go Beyond Current Limitations of Climate Predictions over Land
Computer Project Account:	spitales……………………………….……
Principal Investigator(s):	Andrea Alessandri…………..……
	…………………………………………………….……
Affiliation:	ENEA……………………………………….……
Name of ECMWF scientist(s) collaborating to the project (if applicable)	…………………………………………………….…… …………………………………………………….……
Start date of the project:	4 April 2013…………………….……
Expected end date:	31 December 2015…………….……

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)	1.6 million	1118727	2.2 million	2032440
Data storage capacity	(Gbytes)	11000	3302	25000	24166

Summary of project objectives
(10 lines max)

The main object of the project is to improve forecast quality of the new generation Coupled Global Circulation Models (CGCMs) over land. The plan is to perform sensitivity experiments by using the EC-Earth CGCM for retrospective forecasts and by focusing on three key aspects of the land surface-vegetation potential contribution on predictability: 1) sensitivity to initialized vegetation for seasonal predictions; 2) improved consideration of unconstrained parameters through perturbation of soil field capacity and/or surface resistance to evapotranspiration; 3) exploratory effort on the sensitivity of the decadal forecasts to vegetation initialization.

Summary of problems encountered (if any)
(20 lines max)

Initial and boundary conditions for the seasonal experiment were produced by IC3 as part of a joint effort for the SPECS project, where ENEA is partner. We initially planned to use as the control hindcast for our seasonal experiment an experiment run by IC3 using the same model and the same land, atmosphere and ocean boundary conditions, with constant Leaf Area Index (LAI). An accurate analysis of the data revealed that there was a mismatch of sea-ice initial conditions. That is, we used in our perturbed hindcast five different initial conditions for the sea-ice, whereas the IC3 experiment considered only one unperturbed sea-ice initial condition For this reason, we had to re-run the control experiment but using all the sea-ice members in order to be consistent with our perturbed hindcasts. This caused an increment in the use of computing resources for this year with respect to the original estimate of about 750000 SBUs. Therefore, the total SBUs allocated may not be enough to run all the members of the decadal hindcast experiment and we might have to request additional resources.

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

State-of-the-art Earth System Models (ESMs), like EC-Earth (Hazeleger et al. 2012), still lack an appropriate treatment of vegetation, able to take into account the effects of vegetation variability on actual land cover (Weiss et al. 2012). Experiments performed during the first year of the project with the original release of EC-Earth evidenced weak sensitivity of model results to vegetation changes. This can be attributed to the fact that vegetation fractional coverage are assumed to be constant in time in the original formulation of the land surface model in EC-Earth (HTESSEL; Balsamo et al. 2009). The effective vegetation cover is a key variable in ESMs as it affects biophysical parameters such as surface resistance to evapotranspiration, soil field capacity and albedo. It can vary seasonally and at interannual time-scales as a function of leaf-canopy growth, phenology and senescence. Land Surface Models in ESMs must be able to appropriately represent vegetation phenomena to provide ESMs the land surface influence required in climate modeling and climate projection. To address this issue we designed a modified version of the code to allow vegetation fractional coverage to change as a function of Leaf Area Index (LAI) for both low and high vegetation. To this aim a Lambert-Beer (LB) formulation (Smith et al. 2011) of the vegetation densities has been introduced in HTESSEL with the expression as follows:

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$Cveg_{l,h}=[1-\exp(-k\, LAI_{l,h})]^{\alpha}$

where k=0.5, α=1 and the subscripts $_{l,h}$ indicate low and high vegetation components, respectively.
Effective vegetation fractional covers are given by:

$Ceff_{l,h}=Cveg_{l,h}*A_{l,h}$

where $A_{l,h}$ are the climatological vegetation fractional covers. The time-varying $Ceff_{l,h}$ are used to rescale evapotranspiration, roughness length, field capacity and albedo (snow over high vegetation fraction). Furthermore, the exponential dependence of $Cveg_{l,h}$ on $LAI_{l,h}$ has the overall effect of reducing vegetation fractional covers.

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1. Experiments setup

~~1.~~

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The novel parameterization has been included in EC-Earth v2.4 and used for both (i) seasonal prediction and (ii) historical centennial experiments (Table 1). The resolution is T159L62 for the atmosphere and the ORCA1 grid for the ocean. In total, two long historical runs and two hindcasts have been performed with the objective to evaluate model sensitivity to vegetation seasonal and inter-annual variability.

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The seasonal hindcast experiment has been performed with prescribed LAI to assess the sensitivity of seasonal forecasts to the new vegetation cover representation based on Lambert-Beer formulation. The observationally-based LAI data has been obtained from a novel dataset based on the third generation GIMMS and MODIS satellite observations (Zhu et al. 2013). The LAI dataset was suitably pre-processed (monthly averaged, interpolated, gap-filled) to use it in the land surface scheme of EC-Earth (HTESSEL). Initial conditions for the atmosphere, land, ocean and sea-ice are taken from Du et al. 2012 and Guemas et al. 2014. The period of the experiment, 28 years (1982-2010), is constrained by the availability of the observational LAI dataset. The control experiment has been run with constant LAI.
For the two historical centennial simulations EC-Earth has been run coupled with LPJ-Guess from pre-industrial conditions (1850-on). The aim of the long historical runs is, after a 50 years spin-up, to evaluate model climatology and the ability of the model to adequately represent the 20th century surface climate change. The difference between the perturbed and the control experiment is that in control the new LB parameterization has been switched off and vegetation densities are constant in time.

Comment [Andrea AI4]: La parte decadal mettiamola nei future plans per dire che questa analisi preliminare ci ha fatto decidere per potential predictability experiment cosi' come dici tu

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Table 1. Overview of seasonal and decadal experiments.

Acronym	**Experiment**	**Vegetation density parameterization**	**Start dates**	**Forecast length**	**Members**	**Period**
hind_seas_pert	EC-Earth v2.4, prescribed observational LAI	LB	1st May, 1st November	7 months	10	1982-2010
hind_seas_cont	EC-Earth v2.4, constant LAI	Constant	1st May, 1st November	7 months	10	1982-2010
hist_pert	EC-Earth v2.4, coupled to LPJ-Guess	LB	-	-	-	1850-2010
hist_contEC-Earth v2.4 coupled with LPJ-GuessConstant---1850-2010						

2. Results

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2.1. Seasonal hindcasts

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The performance of 1-month lead forecasts of the modified model is evaluated by taking as the reference the ERA-INTERIM reanalysis (Dee et al., 2011) for 2m-temperature and the GPCP satellite-based precipitation observations (Adler et al. 2003). Fig. 1 shows the difference of the correlations with observed 2m-temperature between hind_seas_pert and hind_seas_cont for the 1-month-lead ensemble-mean DJF seasonal forecasts. For each grid point, we tested the null hypothesis of getting as high or higher correlation differences simply by chance through a Monte Carlo bootstrap method (1000 repetitions). Since we are mostly interested in the evaluation of the effects of the new parameterization on land-atmosphere interactions, only land areas are shown. Overall, the performance of hind_seas_pert is better than control, especially in the northern hemisphere. Experiment hind_seas_pert displays increased correlations over all the boreal forests, in particular Canada, West US and Russia. Significant improvements are also evident over Great Plains in North America, Europe, India and the Sahel. In the southern hemisphere the difference pattern is patchy, with positive differences in some regions, which tend to be compensated by negative values in other areas.

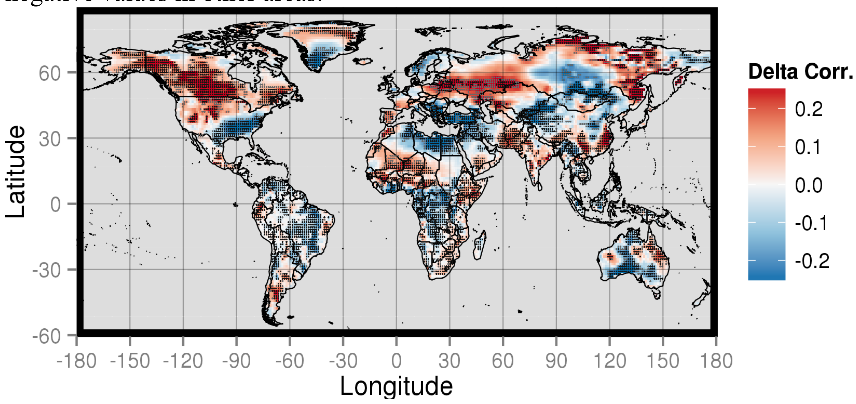

Fig. 1. Differences of correlation with ERA-INTERIM for T2M with respect to control, DJF. Areas which passed a significance test at 10% (black) and 20% (grey) levels are dotted.

Fig. 2 shows the difference of the correlations with observed precipitation between hind_seas_pert and hind_seas_cont for the 1-month-lead ensemble-mean DJF seasonal forecasts. The improvements of the perturbed hindcast are evident over most of the regions individuated for 2m-temperature, although the pattern is more patchy.

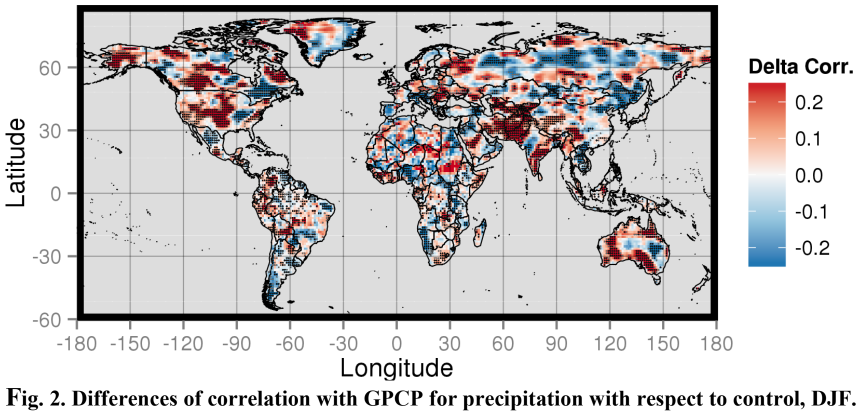

Fig. 2. Differences of correlation with GPCP for precipitation with respect to control, DJF. Areas which passed a significance test at 10% (black) and 20% (grey) levels are dotted.

Correlation differences for 2m-temperature in JJA are shown in Fig. 3. Significant improvements are observed over Europe, central Asia, the Great Plains of North America, Argentina, Nordeste and high latitudes forests (Alaska and Siberia).

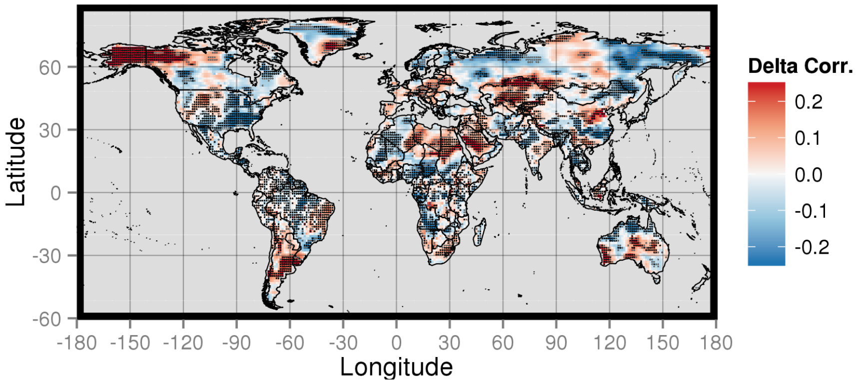

Fig. 3. Differences of correlation with ERA-INTERIM for 2m-temperature with respect to control, JJA. Areas which passed a significance test at 10% (black) and 20% (grey) levels are dotted.

Correlation differences for precipitation in JJA are shown in Fig. 4. Improvements are concentrated over South-Eastern Europe, central Asia, the Great Plains of North America, Alaska, Canada most of South America, Sahel and Russia.

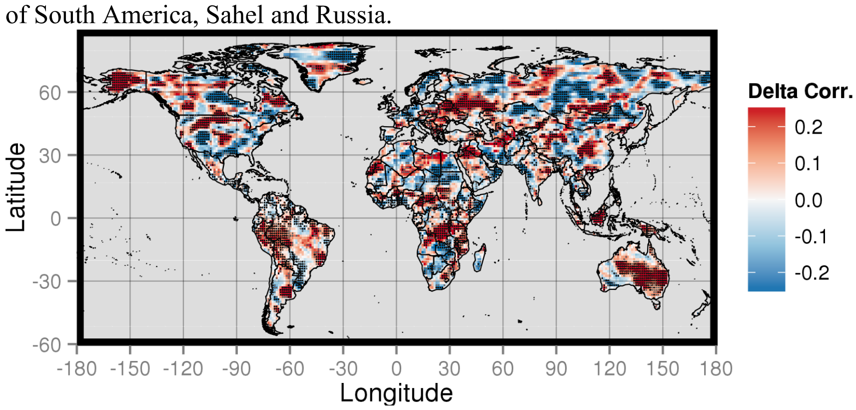

Fig. 4. Differences of correlation with GPCP for precipitation with respect to control, JJA. Areas which passed a significance test at 10% (black) and 20% (grey) levels are dotted.

Results of the seasonal hindcast experiment demonstrate the ability of the improved model to take into account the effect of realistic vegetation inter-annual variability on seasonal forecasts. A relevant outcome is a better prediction of cold winters (and associated snow) and summer heat waves (and the associated droughts).

2.2. Historical 1850-2010 simulations

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Fig. 5 shows the 2m-temperature change between the end (1980-2010) and the beginning (1910-1940) of the century for observations (a), control (b) and perturbed (c) historical runs in DJF. Observations are taken from CRU (Harris et al. 2014). The perturbed experiment reproduces much better the temperature change signal with respect to control in the northern hemisphere. Therefore the improved model is able to take into account vegetation effects in modulating temperature change on long time scales.

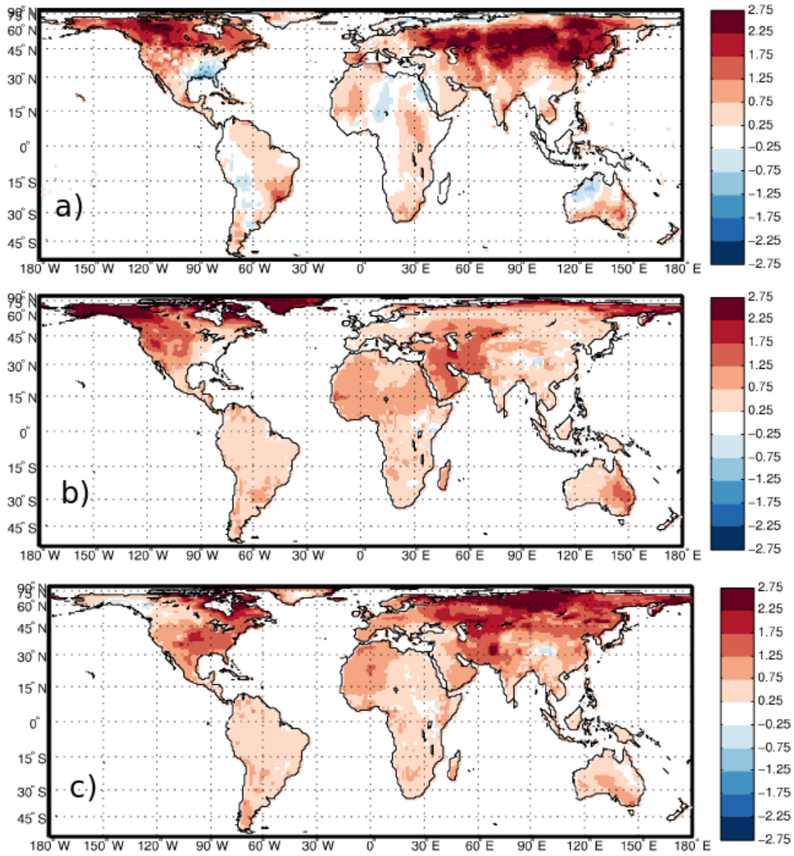

Fig. 5. 2m-temperature change between the end (1980-2010) and the beginning (1910-1940) of the century for observations (a), control (b) and perturbed (c) historical runs.

Comment [Andrea Al6]: Future plans

References

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and skill of EC-Earth simulations. Clim. Dyn., 39, 2733-2746.

- 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, 2013.

List of publications/reports from the project with complete references

- Catalano F., Alessandri A., De Felice M., and Doblas Reyes F., 2014: Effect of realistic vegetation variability on boreal winter seasonal forecasts in EC-Earth. In preparation.
- Catalano F., Alessandri A., De Felice M., and Doblas-Reyes F. J., 2014: Effect of realistic vegetation variability on seasonal forecasts. EGU General Assembly 2014, Vienna (Austria), 27 April - 2 May 2014.
- Alessandri A., Catalano F., and De Felice M., 2014: Improving sensitivity to vegetation variability in the EC-Earth Earth System Model. EGU General Assembly 2014, Vienna (Austria), 27 April - 2 May 2014.

Summary of plans for the continuation of the project

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Comment [Andrea Al7]: I future plans saranno in primo luogo I decadal hindcasts e le sue analisi. Inutile prendere impegni extra qui. Poi se facciamo alter cose tanto meglio…

-We'll further analyze and possibly improve the novel parameterization of the vegetation densities.
-In order to improve the robustness of the analysis of the seasonal hindcasts, if additional resources will become available we'll try to possibly extend the number of members.
-The analysis of the historical simulations evidenced a substantial positive drift in the LAI generated by LPJ-Guess after the onset of the coupled EC-Earth simulation initialized from observationally-based forcing. This is most likely due to the discrepancy between the observed state and the model-preferred climatology and prevents us to use a real predictability set up at this stage. Therefore, the decadal hindcast experiment setup will be configured as a potential predictability exercise. It will use prescribed LAI variability as it is saved from the historical run (hist_pert) for the perturbed experiment and a prescribed constant value of LAI for the control. The reference state will be provided by experiment hist_pert, which is therefore chosen as the hypothetical "model world" to be forecasted.