Response to Referee #3

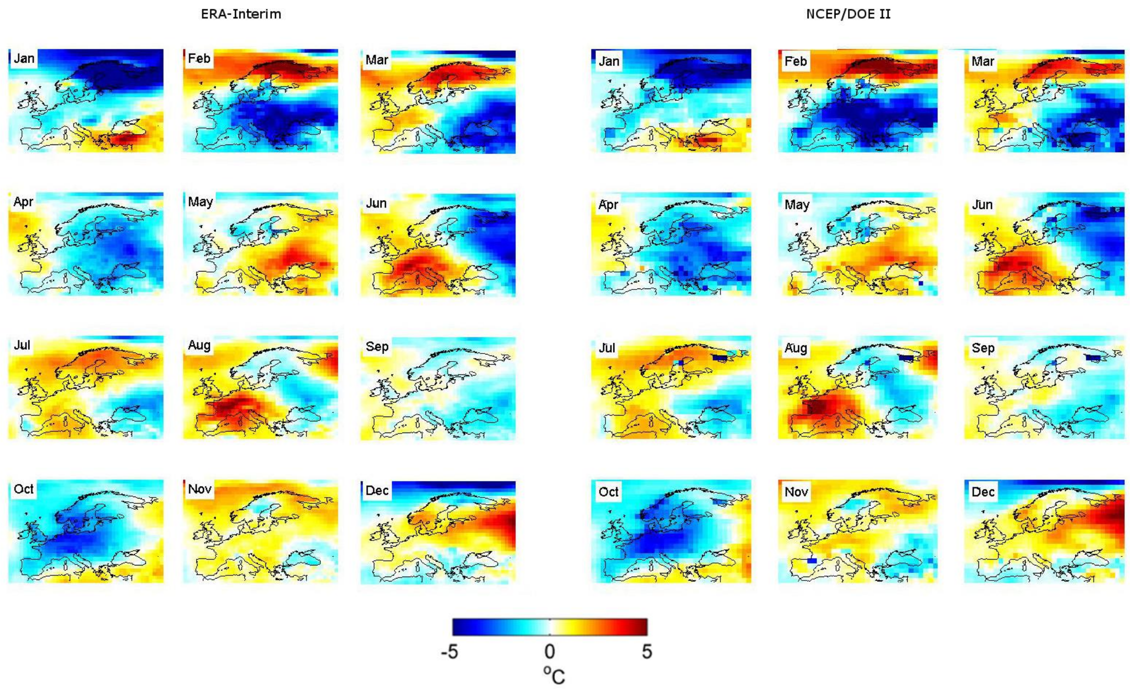
RC 1: However, I find the title a bit misleading because it only mentions NPP were also photosynthesis and soil moisture patterns etc. and their relation are part of the analysis. I would suggest "Analysing the spatio-temporal impacts of the 2003 and 2010 extreme heat waves on plant productivity in Europe".

AR1: We agree with the reviewer that the current title did not reflect the entire analysis. We have changed the title accordingly to the reviewer's suggestion.

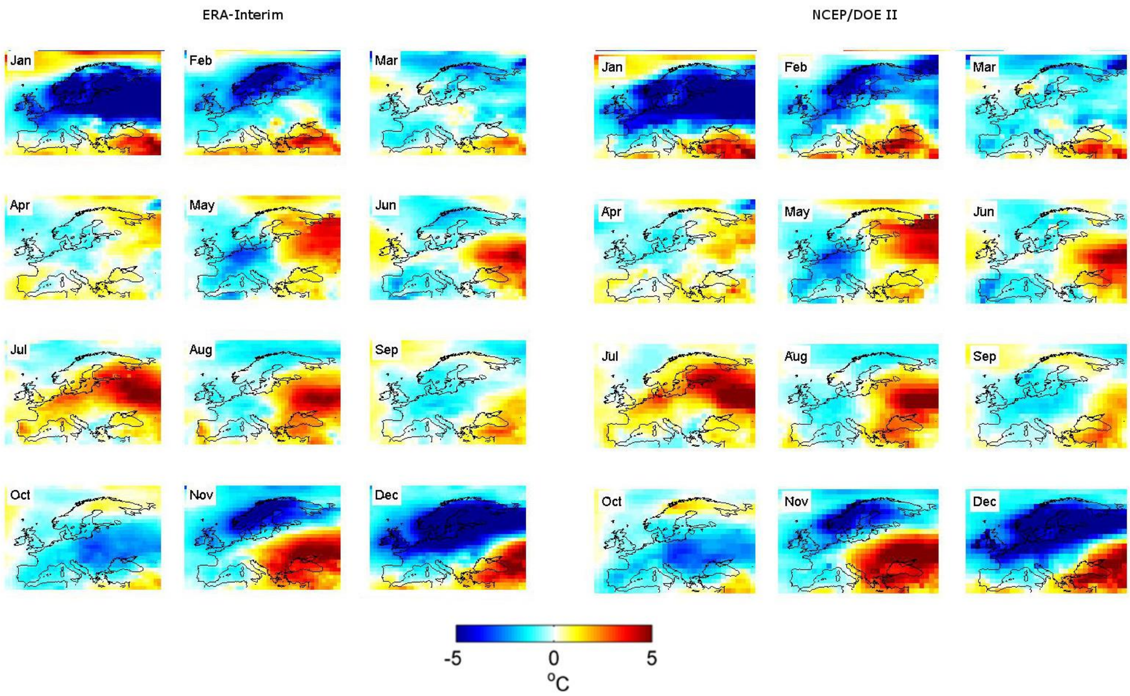
RC2: The analysis relies on the MODIS C5 MOD17 as well as A3 and A2 data series for the time 2000-2011. The analysis is therefore also dependant on the meteorological data used for the MODIS NPP product, the NCEP/DOE II reanalysis. However, for the identification of the climatic/meteorological conditions/anomalies the authors use ERA-interim and GPCC precipitation data. From my point of view it is not clear how consistent theses data are with NCEP. In the frame of CMIP 5 Sillmann et al. (2013) are comparing models to the different datasets used here. Especially, as the authors are focusing on spatio-temporal pattern some discussion about uncertainties arising from using different reanalysis products needs to be elaborated. This in particular true as the authors are using the data to identify the potentially different drivers of vegetation response. The question here would be, are these patterns in the ERA-Interim product consistent with the NCEP dataset?

AC2: We have chosen to use an independent dataset to assess climate patterns and their impact on vegetation dynamics to decrease the dependence of results on the algorithm's response to the data used to force the model (Running et al., 2004). However, we agree that in order to attribute vegetation response to certain climatic drivers with confidence, the consistency of the results using different Reanalyzes must be assessed. In fact, Zhao et al. (2006) have analyzed the sensitivity of MODIS NPP and GPP products to the Reanalyzes used to force the model, comparing results from NASA/DAO, ERA-40 and NCEP/DOE Reanalyzes. Their results show that the use of distinct datasets introduces substantial differences in GPP and NPP; however we must note that those differences are 1) mainly due to bias, and 2) that larger discrepancies are located in the tropical regions. Both of these issues should be substantially mitigated by the approach used here. On the one hand we use composite anomalies that tend to eliminate structural bias (issue #1), additionally we focus the entire analysis in mid-to-higher latitudes, avoiding the more problematic tropical regions (issue #2).

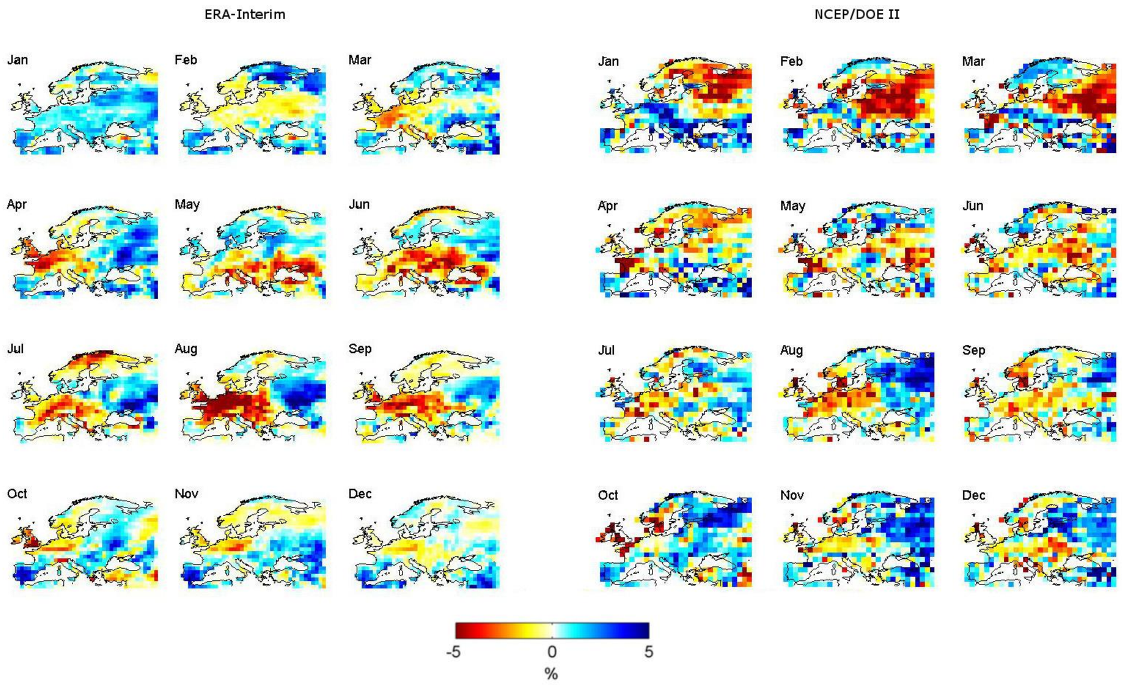
Nevertheless, we have compared temperature anomalies for NCEP and ERA-Interim for the two years (see figures below). Despite some differences, the patterns and the magnitude of the anomalies are quite similar. One must keep in mind that the two datasets are provided at different spatial resolutions – ERA-Interim at 0.75º (Dee et al., 2011) and NCEP/DOEII at 2º (Kanamitsu et al., 2002) – which by itself leads to discrepancies between results. This is particularly relevant for the case of soil moisture content, since the two Reanalyzes define distinct soil layers (4 layers in ERA-Interim and 2 layers in NCEP/DOEII) which do not allow a direct comparison. Here we show the comparison of the first layer of each dataset because they correspond approximately to the same depth (between 0-7cm for ERA-Interim and 0-10cm for NCEP/DOEII). In both years, differences are larger during winter months (Jan-Mar), while during spring and summer months, the drying patterns over the regions considered are similar.



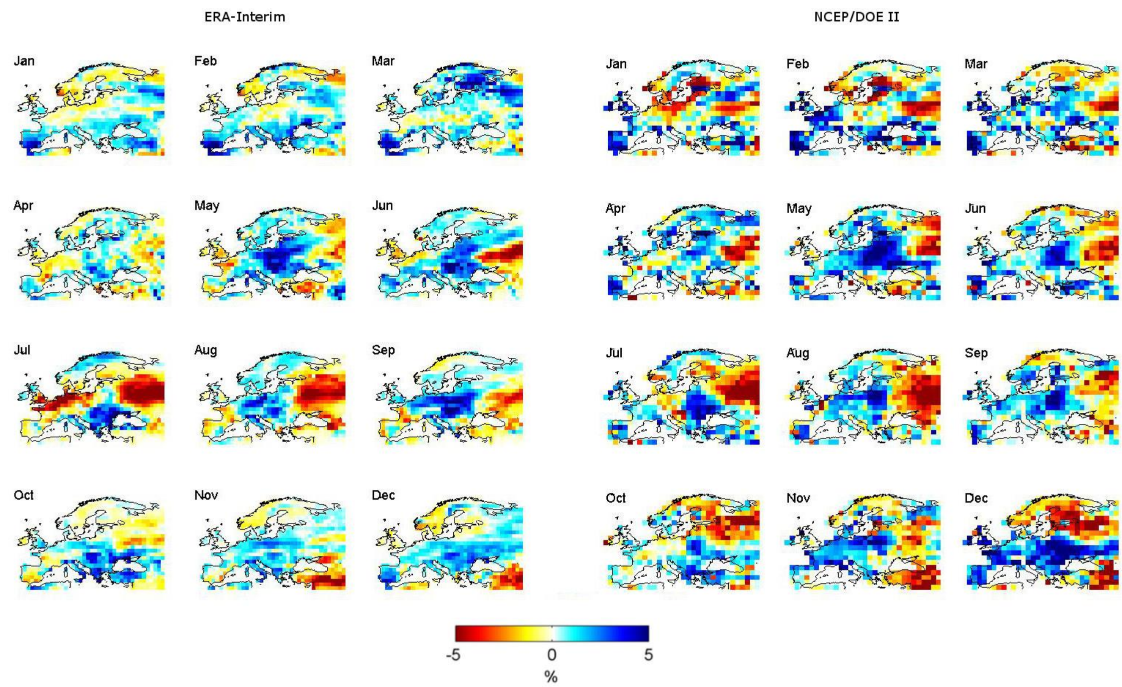
Monthly temperature anomalies in 2003 computed using ERA-Interim and NCEP/DOEII Reanalyzes.



Monthly temperature anomalies in 2010 computed using ERA-Interim and NCEP/DOEII Reanalyzes.

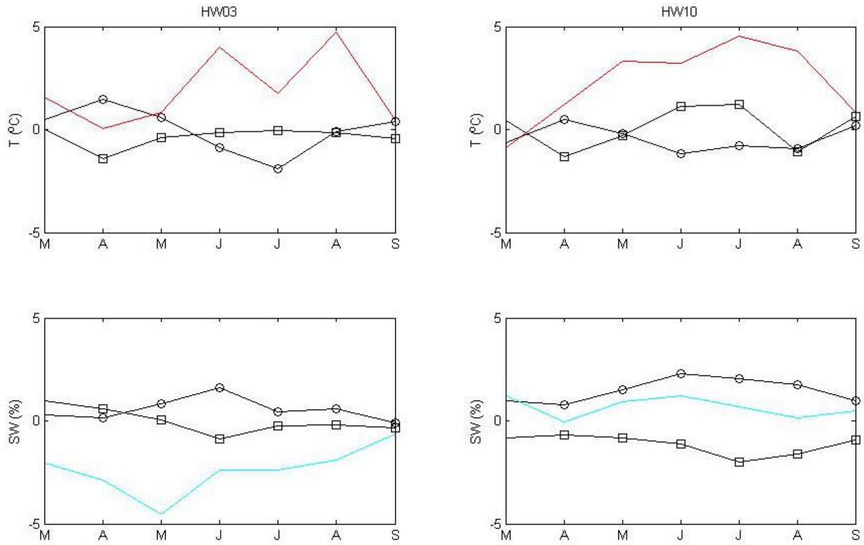


Monthly soil water content anomalies in 2003 computed for the first soil layer of ERA-Interim (0-7cm) and NCEP/DOEII (0-10cm) Reanalyzes.



Monthly soil water content anomalies in 2010 computed for the first soil layer of ERA-Interim (0-7cm) and NCEP/DOEII (0-10cm) Reanalyzes.

However, since the differences observed could lead to distinct results when analyzing the drivers of ecosystems' response, we also computed figure 9 using NCEP/DOEII temperature and soil moisture data:



As in Fig. 9 but using T_{anom} and SW at layer 1 (0-10cm) computed from NCEP/DOEII.

No appreciable differences are found regarding temperature anomalies, while in the case of soil moisture for the first layer, despite some differences being observed, results reinforce the main conclusion: that for HW03 temperature and soil moisture anomalies drive the extreme ecosystem response, while in HW10 only temperature anomalies are considered "exceptional".

Despite the fact that results do not differ substantially using the two datasets, we still consider more appropriate to rely on a climatological dataset that is independent of the one used to produce the data.

Dee, D. P.; Uppala, S. M.; Simmons, A. J.; Berrisford, P.; Poli, P.; Kobayashi, S.; Andrae, U.; Balmaseda, M. A.; Balsamo, G.; Bauer, P.; Bechtold, P.; Beljaars, A. C. M.; van de Berg, L.; Bidlot, J.; Bormann, N.; Delsol, C.; Dragani, R.; Fuentes, M.; Geer, A. J.; Haimberger, L.; Healy, S. B.; Hersbach, H.; Hólm, E. V.; Isaksen, L.; Kållberg, P.; Köhler, M.; Matricardi, M.; McNally, A. P.; Monge-Sanz, B. M.; Morcrette, J.-J.; Park, B.-K.; Peubey, C.; de Rosnay, P.; Tavolato, C.; Thépaut, J.-N. & Vitart, F. (2011) The ERA-Interim reanalysis: configuration and performance of the data assimilation system Quarterly Journal of the Royal Meteorological Society, John Wiley & Sons, Ltd., 137, 553-597

Kanamitsu, M.; Ebisuzaki, W.; Woollen, J.; Yang, S.-K.; Hnilo, J. J.; Fiorino, M. & Potter, G. L. (2002) NCEP/DOE AMIP-II Reanalysis (R-2) Bull. Amer. Meteor. Soc., Bulletin of the American Meteorological Society, American Meteorological Society, 83, 1631-1643.

Running, S. W.; Nemani, R. R.; Heinsch, F. A.; Zhao, M.; Reeves, M. & Hashimoto, H. (2004) A Continuous Satellite-Derived Measure of Global Terrestrial Primary Production BioScience, 54, 547-560.

Zhao, M.; Running, S. W. & Nemani, R. R. (2006) Sensitivity of Moderate Resolution Imaging Spectroradiometer (MODIS) terrestrial primary production to the accuracy of meteorological reanalyses Journal of Geophysical Research: Biogeosciences, 111, G01002.

RC3: One of my main concerns for the paper is the role of the very different distribution of landcover types in the two regions see Teuling et al. (2010)? The fact itself is mentioned at page 15889 l8-14., but not discussed in detail! Did potentially higher percentage of forest in Russia impact on the magnitude of the impact? – Maybe only similar land-cover types should be compared if aggregated figures for Europe are given? Fig 3 (by the way the figure says CS for cultivated land the text below it says MCS) gives us a glimpse of the potential differences and the author note the very different response of cultivates areas on page 15889 and very nicely identify the influence of human interventions as a potential reason but don't go any further. Related to the effect of land-cover on the magnitude of the impact would be the role of the widespread fires in 2010 in Russia Shvidenko et al. (2011) which are a substantial source of dynamic in the carbon cycle. Again here the role of human intervention or better the lack of it might be a point to discuss.

AC3: The authors agree that the topic of the differentiated response of land-cover types is relevant, which led us to perform a separate analysis of annual and seasonal carbon uptake for each of the main land-cover types in Table 1 and Fig. 3. As mentioned in page 15889 l8-28, forests are the land-cover types more severely affected by the heatwave, presenting lower anomaly values. In both regions (HW03 and HW10) cultivated areas, despite presenting lower anomalies, are one of the main contributors to the integrated balance because they correspond to a large fraction of the area. However, HW10 has a larger fraction of forest cover (almost 40%) and, thus, forests are the first contributor to the integrated losses. We provide some further insights on the subject in response AC2 to referee #2 about the role of land cover in autotrophic respiration anoamlies.

We agree with the referee about the relevance of quantifying the impact of fires on the observed PsN anomalies, please see response to referee#2. In HW10, the widespread fires that affected Russia during summer led to decreases in NPP of 1.8TgC (more than 1% of the total). It is worth noting that these values correspond only to a decrease in the "ecosystem service" of carbon uptake provided by vegetation in those pixels in that year. We think this topic is worth being included in the revised version of the manuscript.

The topic of human intervention is highly relevant; however, the scarce information we possess about land management practices in those specific regions makes it highly speculative to draw conclusions about the human impact. The lower relative PsN anomalies registered in cultivated and managed areas may be due to human intervention, for instance in mitigating the effects of the preceding dry conditions. Furthermore, the areas considered are so large that it is most likely that land management practices differ significantly between pixels assigned to the same land-cover type. In this regard, we believe that the combination of our study with a socio-economic analysis of the impacts would be most interesting but that is beyond the goals of the present work.

RC4: I find it also difficult to understand if total impacts are given, like in the abstract p 15880 l 14-15, without the related areas. 94 TgC for 2010 is of course larger than 19 TgC but the area affected is also larger, these numbers lack some information about the magnitude of the impact on ecosystems.

AC4: The magnitude of the impact on ecosystems is presented as the NPP_{anom} fields in Fig. 1b. It is useful however, to quantify the overall impact in the area affected. As mentioned in page 15886 l16-20, the average magnitude of the impact over HW03 was -0.19 $kgCm^{-2}$ yr^{-1}, and in HW10, the average was -0.14 $kgCm^{-2}$ yr^{-1}.

However, we must note that the magnitude of the impact can be assessed in many ways, which depend on the goal of the study. In this case, since we are interested to analyze how extreme (in a statistical sense) the ecosystems' response was, we quantify the impact of the heatwave in relation to the annual mean (as in Fig. 1c) and as monthly departures from the climatological seasonal cycle (Fig. 2 and 3).

RC5: The
"Result" part of the paper is rather a "Result and Discussion" and the "Discussion and final remarks" reads like "conclusions". So I would recommend to either restructure the content by opening a discussion section or simply change the title of the sections.

AC5: The authors agree with the reviewer and have altered the title of this section to "Results and Discussion"