Response to Referee #1

Authors' response to general comments:

This paper performs a comparison of the ecological impacts of two extreme climatic events, the 2003 and 2010 heatwaves, which registered the strongest temperature anomalies in central France and western Russia, respectively. These two heat waves were unprecedented at the 500-yr scale and have redrawn the maps of record breaking temperatures in Europe, as one of the authors has shown in previous works (Barriopedro et al., 2011).

The authors acknowledge that the strong and innovative points of this work could be more clearly emphasized:

1) **Climatic vs. Ecological extremes**: There is much debate about whether an extreme climatic event always implies an extreme response by ecosystems. Smith (2011) has shown that this is not always the case, and proposed a new framework to assess extreme ecological responses to climate extremes. So far, to our knowledge, no studies have performed this type of assessment in what heat waves are concerned. Here we show that vegetation activity was markedly affected, well below the corresponding climatological range of variability. This analysis allows us to further assess how different types of vegetation responded to the heatwave, and it is shown that in the case of 2010, agricultural and managed areas did not exhibit an extreme ecological response.

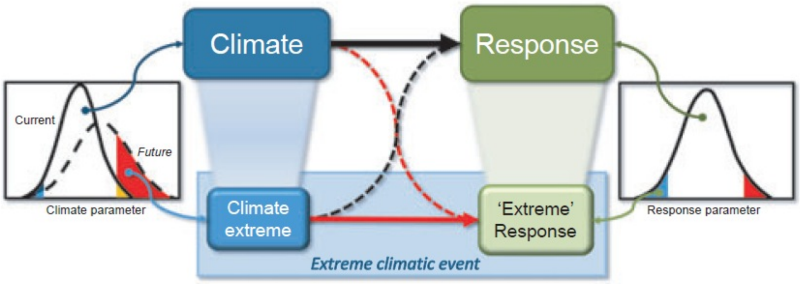


Fig 1 from Smith, M. D.: An ecological perspective on extreme climatic events: a synthetic definition and framework to guide future research, J. Ecol., 99, 656–663, 2011.

2) **Heatwave or Heatwave preceded by dryness** : Even when a single extreme event is considered, there are several indirect factors that may affect vegetation response. In the case of heatwaves, temperature and soil moisture are known to be tightly coupled and reinforce each other. This physical coupling may or may not be responsible for differentiated responses of vegetation to the extreme climatic event, i.e. the heatwave. We know that both heatwaves (2003 and 2010) were preceded by dry conditions that can have a complex effect. On one hand, dry conditions help to amplify the extent and amplitude of the summer heatwaves. On the other hand, from the ecological perspective, a prolonged dry period can impinge stress on the vegetation dynamics even before the extreme heatwave strikes. Thus, although we focus

preferentially on the heatwave periods, we are also interested in the antecedent climatic conditions that led to both episodes. In this regard we attempt to disentangle the impacts of high temperatures and soil moistures on ecosystems i.e.: is NPP reduced due to high temperatures (thus higher respiration) or to water stress (thus less photosynthetic activity), or both? With this approach, we show (Fig. 9) that temperature and water stress drive an extreme ecological response in the case of the 2003 heatwave, while in the case of the 2010 event, temperature appears to be the main driver of the extreme ecological response. To the best of our knowledge no previous publications had assessed simultaneously both heatwaves in respect to these different variables showing the distinct role played by temperature and precipitation/soil moisture on vegetation response in 2003 and 2010.

RC 1: The choice of "selected" French and Russian regions for summary numbers is confusing and does not connect well to the reader interest in what those numbers look like for the entire drought-stricken regions.

AR1: Following the framework proposed by Smith (2011), and explained above, we have concentrated our efforts into analyzing those regions where vegetation health was effectively affected. Since we are interested in assessing the ecological impacts of the heatwaves, rather than the heatwave events per se, the regions presenting marked decreases in NPP in each year were selected. Further on, in Figures 6 and 7, we show that in fact these regions correspond roughly to the centers of very high temperature (and not drought) conditions.

RC2: The Introduction is largely well written. However, it does not lead in to why the authors are doing what they are doing, given the previous research done already on the events. Later, this problem propagates as the analytical approach does not follow a logical flow.

AC2: We appreciate the overall appraisal by the reviewer on the quality of the introduction. Please see response to general comments. The authors will make an effort to improve the writing in order to clarify the analytical approach.

RC3: P15883L17: "Reanalyzes" → "Reanalysis"
AC: The text will be accordingly corrected.

RC4: P15883. It is good that the authors include a statement on how well MOD17 has done in previous studies. However, it is far from hidden that MOD17 has been shown to suffer in perhaps an even greater number of studies. This aspect should be addressed head on, rather than ignored, by the authors, as readers may immediately disregard their study because of a lack of trust in MOD17. MOD17A2 is even lesser known than MOD17A3.
AC4: MOD17 is an automated algorithm run by NASA using global datasets of remotely sensed imagery. The Numerical Terradynamic Simulation Group (NTSG)/University of Montana's

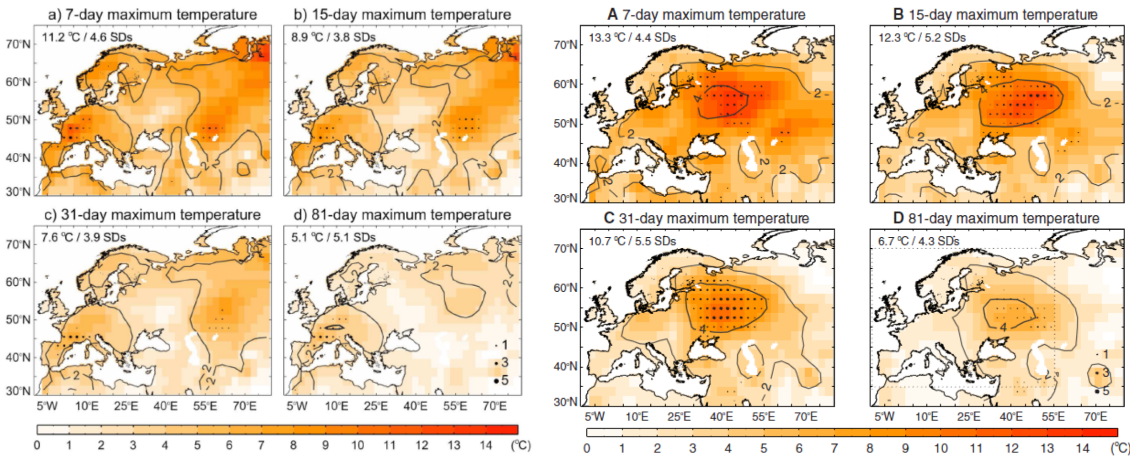
(UMT) has performed a number of improvements to the original dataset (Zhao et al, 2005; Zhao and Running, 2010), and has been providing the improved C5 MOD17 dataset, which has been shown to reproduce vegetation dynamics with satisfactory results, especially in mid to high latitudes (Running et al, 2004; Reeves et al, 2006; Turner et al., 2006).
As with most remote sensing products, it is to be expected that regional analyses of NPP using more detailed local information and calibrations will do better at representing local NPP, and a number of studies have found just that. However, when trying to look at global patterns and gradients, the current MOD17 operation is the best compromise we have yet found for an accurate global operation.

RC5: Some paragraph should be included on how the analyses were done given that all the datasets were of widely varying resolutions. Actually, in looking back, it appears that the authors did not do any combination analyses, though this seems like it would be useful.

AC5: In the first version of the paper the authors thought it would be easier to follow the analysis if the methodology was described along with the results. However, we acknowledge that describing the methodology in a separate section may improve the reading and understanding of the work. The section "Data" will be accordingly changed to "Data and Methods" and the methodology will be summarized in that section.

RC6: It is not clear why the authors separate western and Eastern Europe for analysis. It is not clear why 25E is the division. It appears that the authors did this to make their results look better, not really reflecting a Europe-wide drought in both years.

AC6: There is nothing magic with the 25ºE separation longitude. The division of Europe into the Eastern and Western sectors follows from the spatial coverage of the two heat waves, as described in Barriopedro et al. (2011) in Fig. 1 and Fig. S7:



Spatio-temporal evolution of the 2003 (left panel) and 2010 (right panel) summer temperature for (A) 7-day, (B) 15-day, (C) 31-day, and (D) 81-day average periods in absolute magnitude (color) and relative do SD (contour lines); corresponding to Fig. S7 and Fig. 1 from Barriopedro, D., Fischer, E. M., Luterbacher, J., Trigo, R. M., and García-Herrera, R.: The hot summer of 2010: redrawing the temperature record map of Europe, Science, 332, 220-224, 2011.

The 2003 event affected mainly Western Europe (particularly central and southern France), while the 2010 was centered on Eastern Europe (including most western Russia). As mentioned in the response to general comments, these two outstanding events were responsible for record breaking temperatures on the 500-yr scale. In particular, for Western Europe, previous to 2003, record breaking temperatures had been registered in the 1500s (Fig. 3 in Barriopedro et al., 2011). Although previous studies have stressed the contribution from dry conditions in amplifying the summer heatwave (Seneviratne et al., 2006; Barriopedro et al., 2011) the fact remains that we were not constrained by the spatial pattern of the drought prior to the heatwave.
Furthermore, analyzing separately NPP anomalies over the two sectors provides information about the impact on the European scale of each of the two heatwaves. In fact, Fig. 1a reveals that in spite of both years presenting very low NPP anomalies on the European scale, in 2003 eastern European sector presents average NPP (anomaly close to zero), and the same happens to western Europe in 2010. Thus, the very low NPP anomalies registered in Europe in each of the two years were due to quite localized events of great magnitude that coincided on the seasonal scale with the periods of very high temperatures (and not with the prolonged dry conditions). Fig 1a is then complemented with Fig 1b, which allows constraining even further the regions more highly impacted by the heatwaves. However, the authors would like to point that the spatial integration of NPP anomalies (Fig.1a) is relevant for applications such as the economic assessment of the impact of the two events.

RC7: Fig 2. Make the seasonal median black line thicker. It is not clear which one it is (one would expect it to be somewhere in the middle of the percentiles, but it appears to be at the bottom. Fig 2. Perhaps labeling it a-f, instead of a-b, would help the reader follow which descriptions correspond to which sub-figures.
AC7: the line will be accordingly corrected and the panels renamed.

RC8: It is not clear why the authors used both MOD17A2 and MOD17A3, rather than just one. Both basically show the same spatial patterns, which comprise nearly all of the figures/results. It would be interesting if some comparison were made, with concrete conclusions explaining differences.
AC8: We are interested in assessing the impact of a localized event in time (heatwave). The annual dataset does not allow understanding whether the anomalous values of NPP by the end of the year were due to the prolonged dry conditions, the relatively brief heatwave, or any other event during that year. Only by looking into the seasonal dynamics are we able to assess the different contributions of the dry conditions and the heatwaves.
In fact, when analyzing Figures 4 and 5, it is possible to see that during some periods of the corresponding year, the regions severely affected by the heatwave had average to above average productivity. It becomes evident that the periods with greater decreases in carbon uptake by ecosystems are the ones corresponding to very high temperatures.
For a complete description of the differences between NPP and PsN, please see Running et al. (2004).

RC9: The results are really just a bunch of maps showing what we already know, little else.
AC9: The authors disagree with the reviewer and consider that this work provides novel understanding of the ecological impacts of the two heat waves, as already mentioned in response to general comments.
In particular, we want to emphasize that results show that the ecological impact of extremely high temperatures during a heat wave varies from ecosystem to ecosystem and may be indirectly driven by other physical variables, and by their coupling. This means that one should

be aware that a wide diversity of ecological responses may be found whenever a heat wave of a given magnitude occurs.
Nevertheless, the authors agree that results could be better summarized and will make an effort to simplify some of the maps.

RC10: Discussion. Poorly written. This is basically just Results-continued. Very little tie back to the literature.

AC10: the authors agree that Discussion section could be improved and will make an effort to make it more clear and concise.