Reviewer comments in italic — Author responses in normal text.

Referee # 1

General comments

The authors present an analysis of the effects of drought on ecosystem and leaf function in a Mediterranean cork oak savannah. Of particular value are the multi-faceted approach, which includes data on ecosystem gas exchange, leaf physics, soil moisture, and understorey plant performance for one moist year and the following drought year. The use of photosynthesis / stomatal conductance models to analyze the changing effects of environmental conditions on leaf function over the two years provides additional insight into the complexity of underlying regulatory processes.

Autors' response: We are very thankful for the appreciation of our manuscript and the approach to combine leaf physiological modeling with flux observations to infer regulatory processes of the *Quercus suber* (L.) trees facing drought conditions.

Specific comments

This manuscript is of particular value for the multiple aspects of ecosystem function that are compared between the moist year and the dry year. As a result, the authors are able to place changes in leaf function into the context of changing soil moisture, providing clear evidence for the importance of deep soil water for tree function and the impact of soil moisture draw-down on understorey vegetation. The manuscript also provides some important insights into leaf function. For instance, the observation that maximum carboxylation rate decreased despite only a small change in leaf temperature between the two years helps to constrain interpretation of how photosynthesis rates were down-regulated. Also of interest is the observation that T_{opt} *was actually lower in the hotter drier year, a surprising result given previous research showing that* T_{opt} *increases when leaves are grown at higher temperatures, indicating that water and other environmental factors must also play a role. Finally, the model-fitting process yielded insights into the complexity of regulating processes. In particular, the model was only able to correctly fit* GPP_o *and* ET_o *when both maximum carboxylation rate and the slope of the Ball-Berry function for stomatal conductance were allowed to vary, indicating that multiple physiological processes contributed to down-regulation of photosynthesis.*

Overall this is an excellent manuscript and I recommend that it be accepted.

Autors' response: The authors are thankful for the positive review and the recommendation for publication.

Technical corrections

I found two places where the author-year citation format seems to be used incorrectly:
p. 10388, line 5 : Costa e Silva et al. (2014) is written, where the correct format would be (Costa e Silva et al., 2014)
p. 10389, line 17: de Dios Miranda et al. (2009) is written, where the correct format would be (de Dios Mirand et al., 2009)

Autors' response: The citation format has been corrected in the revised manuscript.

Referee # 2

General comments

Reviewer comment: Accurately modelling drought impacts on ecosystem gas exchange is a major challenge, so these data are a welcome addition. However I do have a number of comments about the analysis that I believe should be addressed before final publication.

Authors' response: We are very thankful for the reviewer's evaluation of our manuscript. We have thoroughly studied the very constructive and detailed comments and revised the manuscript accordingly.

The principal comment is that I cannot see why the data have been analyzed with a single-leaf model when they are clearly whole-ecosystem data, including a vegetation canopy and soil fluxes. The leaf scale model has been fitted to canopy-top eddy covariance measures. It is not appropriate to model a system like this using a single leaf model. Some of the results may be ecosystem-level effects rather than changes in leaf-level parameters. I suggest that an ecosystem-scale model should be applied. In particular, non-canopy fluxes need to be considered, as does the role of the atmospheric boundary layer conductance.

We agree with the reviewer that ecosystem scale observations of gross primary productivity and transpiration can hardly be modeled with a simple leaf scale model if the observations are affected by other fluxes. Therefore, we tried to exclude all possible sources of interfering carbon and water fluxes for the modeling application:

- During the modeling period, understorey and soil water fluxes are small compared to the entire ecosystem fluxes (e.g., $\overline{ET_u}$ = 0.7±0.5 mmol m^{-2} s^{-1} compared to $\overline{ET_o}$ = 4.4±2.4 mmol m^{-2} s^{-1} for 2011, Fig. 4 b,c) and show no significant inter-annual differences (2012: $\overline{ET_u}$ = 0.7±0.4 mmol

m^{-2} s^{-1}), which can interfere the inter-annual comparison conducted in the manuscript.

- It is correct that changes in stem and branch transpiration of the tree layer have not been regarded here explicitly so that modeled stomatal conductance could be affected. However, stem and branch transpiration of *Quercus suber* (L.) trees are strongly reduced due to the thick cork bark protection and play not a significant role in total ecosystem transpiration.

- Like transpiration, understorey gross primary productivity is comparably small with respect to the entire ecosystem (e.g., $\overline{GPP_u} = 1.5 \pm 1.2$ compared to $\overline{GPP_o} = 10.8 \pm 3.0$ μmol m^{-2} s^{-1} for 2011, Fig. 6 b,c) and inter-annual differences are not significant (2012: $\overline{GPP_u} = 1.2 \pm 1.0$ μmol m^{-2} s^{-1}). The remaining carbon fluxes from soil, understorey and tree stem respiration have been excluded from the modeling by partitioning the observed net carbon fluxes beforehand so that an influence of changes in respiration on the modeling results are avoided.

Following the recommendations of the reviewer, we increased model complexity to a sun/shade leaf model as described in De Pury & Farquhar (1997). The separation into sunlit and shaded leaves via $f_s = [1 - \exp(-K \cdot LAI)]/[K \cdot LAI]$ with $K = G(\alpha) / \cos(\alpha)$ could directly derived by measured $G(\alpha)$ and LAI from Piayda *et al.* (submitted).
The influence of the atmospheric boundary layer on the transport from the Eddy Covariance sensor height to the leaf surface has been implemented via the aerodynamic conductance g_a (Appendix B, Eq. B8, B9, B12, and B13), which comes directly calculated from turbulence and wind speed measurements $g_a = u_*^2/u$ with the measured friction velocity u_*^2 and horizontal wind speed u. The necessary equations of the two-leaf model and the derivation of aerodynamic conductance are included into the revised manuscript.

Specific comments

Please separate out the results from the discussion. Separating them would make the results much clearer and the paper easier to read.

We agree that a manuscript is usually more clear to the reader when results and discussions are separated in two sections. However, in this particular case we think that the manuscript gains clarity by drawing first the environmental conditions (section 3.1) and then separating it into a water related (section 3.2) and a carbon related (section 3.3, 3.4, 3.5) part. Both parts are consolidated finally in the model part (section 3.6).

How many locations were used to measure soil temperature and moisture? One location only, or many?

Soil temperature profiles (2, 4, 8, 16, 30, and 60 cm depth) were measured at two locations, an open and a tree-shaded location, two replicates each. Soil moisture profiles (5, 15, 30 and 60 cm depth) were measured as well at the open and tree-shaded locations but with 4 replicates each. The materials and method section of the revised manuscript was updated with this information.

In the leaf-level model, what is the aerodynamic conductance ga? Note that this conductance should be corrected by a factor of 1.37 when being applied to CO2 rather than H2O (eqn A12).

It is correct that CO_2 and H_2O have different diffusion coefficients, thus, conductances through the stomata (factor: 1.56) and through the leaf boundary layer (factor: 1.37) are different for both molecules. The transport from the leaf boundary layer to the measurement height of the Eddy Covariance tower is purely turbulence driven, thus, aerodynamic conductivity is equal for both molecules (e.g. Wang & Leuning, 1998). So far, the boundary layer conductance was not treated separately for CO_2 and H_2O, but only the observed aerodynamic conductance was used for both molecules (see above). To be more precise, the boundary layer conductance (including different factors for CO_2 and H_2O) was now included into the model explicitly according to Bonan et al. (2002). The model description in the appendix of the revised manuscript was extended by the full canopy conductance description.

How is Tleaf calculated? Tleaf is mentioned on p10378 but it is not clear if this is measured or modelled, or what methods were used to estimate it.

The leaf temperature is estimated using measured air temperature T_a and measured sensible heat flux H via $T_l = T_a + H/(g_a \rho_a c_p)$ with ρ_a being the density and c_p the heat capacity of the air. The inversion of sensible heat flux leads rather to an average surface temperature between leaf and soil because H originates from both. However, the soil was highly comparable in both years (with respect to moisture, understorey vegetation cover and environmental conditions during the modeling period, compare e.g., Fig. 5), so that we can address the differences between both years purely to changes in leaf temperature. The description of leaf temperature calculation is included in the revised manuscript in the data treatment section (section 2.6)

No information is given for how well the model fitted the data, nor are there errors given for the parameter estimates. Model fit statistics and parameter errors need to be given to assess the goodness of fit. For example, parameter standard errors might show us if the differences in parameter estimates between 2011 and 2012 are actually meaningful.

We agree that a goodness of fit needs to be given to display how well the modeled carbon and water fluxes fitted the observations. Therefore, in section 3.6 (p. 20,

l. 18) Nash-Sutcliffe model efficiencies were given as $\overline{\varepsilon_{GPP_o}} = 0.88$ and $\overline{\varepsilon_{ET_o}} = 0.95$ for 2011, and $\overline{\varepsilon_{GPP_o}} = 0.84$ and $\overline{\varepsilon_{ET_o}} = 0.90$ for 2012. The Nash-Sutcliffe model efficiency describes the goodness of fit with respect to correlation and to possible biases. According to the reviewers suggestion, we assessed the parameter uncertainty with respect to the measurements with bootstrapping (Efron & Tibshirani, 1993). The parameter uncertainty with respect to the model structure was not calculated, since the numerical estimation of the Hessian matrix delivered no reliable results due to discontinuous functions within the model and objective function. In the revised manuscript, uncertainty bands of the parameter standard error are drawn in Fig. 7 to display the significance of the described differences between both years. The stomatal conductance parameters m and D_0 were the only ones showing strongly overlapping uncertainty bands so that their inter-annual differences were declared as not significant in the revised text.

The actual values for the fitted parameters are not similar to values typically obtained from fitting to leaf data, which suggests there is a problem with applying the leaf-level model. For example, Ball-Berry model slopes m are typically around 8 to 10, whereas Figure 7 shows estimates of 20 to 60, which seems unrealistic. Similarly the T_{opt} for J_{max} is generally 30 degrees or above (Kattge & Knorr 2007) so the estimated values of 20 degrees seem very low and suggest further investigation is needed.

We are very glad for this advice of the reviewer, which caused us to go through all model equations. We found a unit error in the stomatal conductance description, which we corrected. The values for m are now much lower, ranging on average from about 10 to 15 mol mol^{-1}. It is correct that literature values range around 30 °C for the optimum temperature T_{opt} of J_{max} but some species also vary around 20°C (June *et al.*, 2004). However, after thorough revision of the model code, no bugs could be found and values for T_{opt} range on average between 20 to 25 °C. To our knowledge, no T_{opt} values for evergreen oak species are reported so far preventing direct comparison.