Reply to S. Zechmeister-Boltenstern, bdg-8-C2372-2011

…it is not absolutely clear, whether it is the aim of this paper to describe and explain C-fluxes by isotopic signatures (as stated in the abstract and introduction) or whether the paper focuses on explaining measured isotopic signatures by a range of possible underlying processes (large parts of the paper and conclusions). These two approaches should be distinguished more clearly. It would also help if the three aspects mentioned above would be addressed right at the beginning to avoid confusion amongst readers from other scientific areas.

→ The aim of this paper is both explaining and interpreting C-fluxes by isotopic signatures and understanding how a range of underlying processes change these isotopic signatures. This aim has been already stated in the Abstract:
"In this review we provide an overview of an emerging picture of plant–soil–atmosphere C fluxes, as based on C isotope studies, and identify processes determining related C isotope signatures."
However, we have tried to make this point clearer by adding a sentence towards the end of the introduction:
"However, as the isotopic signatures of carbon compounds transported in the plant–soil–atmosphere system do not necessarily remain unchanged during transport, it is important to know all relevant processes involved in generating and altering theses signatures."
Furthermore, we added a paragraph at the beginning of section 3:
"The process of C transport in the plant itself is not assumed to fractionate against the 13C-isotopologues of the transported compounds. However, temporal changes in C allocation and metabolic processes along the transport pathways can strongly affect this relationship between environmental conditions and δ13C. For example, it has been observed that phloem sucrose is 13C-enriched in the trunk compared to the twig phloem of trees (e.g. Brandes et al. 2006; 2007). It is likely that metabolic processes associated with phloem transport but not the transport (such as phloem loading or phloem transport; 5 in Fig. 1) itself is responsible for these patterns. Since phloem-allocated sucrose is the main carbon source for all processes in non-green plant parts, spatial variations in □13C along the plant axis and the processes involved need to be taken into account when interpreting respiratory isotope signals. Moreover, transport dynamics determine the coupling of the isotope signals above- and belowground and thus an understanding of the underlying processes is crucial to interpret carbon isotope signals on the ecosystem scale."

A separate methods chapter could help during reading and at the same time highlight new promising techniques. This section could also be critical about some fields of application: e.g. maybe there are some parts of the plant-soil-atmosphere continuum, where natural abundance measurements are difficult to interpret and will not help our understanding in the future, as there always are too many incoming and outgoing processes affecting the signal of a certain pool …and possible ways out of this dilemma (inhibitors?, GMOs?). Alternatively there could be a subject index of methodologies with short definitions and an indication of advantages and possible limitations.

→ Also according to the suggestion of the other reviewer we now have created a separate section on stable isotope methodologies (new section 6), where we have tried to address these points.

Some longer chapters of the paper could gain from subheadings. At least it should be clear from the first sentence, or even the first words of a paragraph what this paragraph is going to deal with. A simple rearrangement of words could help. (See specific comments)

→ Due to reasons of uniformity we have refrained from introducing subheadings in some chapters. However, we have tried to start each paragraph with a sentence describing its content. Wherever we thought it might help, we have rearranged the respective sentences.

The figures are very good but they should be explained in more detail in the text, especially Fig. 4. More references to Fig. 4 should be made in the chapters where the respective components are described. Fig. 1 is especially useful and clear, a similar figure for soil-related processes would be very instructive.

→We found it difficult to find the right places in the text where to mention Fig. 4, other than at the end, without raising the reader's expectations too high of what he or she might see there. Therefore, we have included the numbers of the chapters describing the respective processes in the figure. We also thought about the suggestion to add a figure for soil processes according to Fig. 1. But this figure would have been just a cut out / zoom in of Fig. 4, where all relevant soil processes covered in this review are displayed. Therefore we did not add an additional figure on soil processes.

Specific comments:

P3627 line 8-25. This section is overlapping with section 3.4 and 3.5. If you decide to leave the order please make clear the difference.

→ The focus here is on photosynthetic carbon isotope fractionation, whereas it is on transport processes in section 3. We have tried to make that clear by rearranging the sentence to: "High variations of photosynthetic carbon isotope fractionation in C3 species over the day, between days and over the growing season were recently revealed by direct online isotope measurements under field conditions,…".

P3636 line 16-17 please reword, this sentence is difficult to understand.

→ Reworded to: "…2) released as exudates and allocated to soil microorganisms in the rhizosphere…".

P3637 line 15-16 please specify (how do earthworms access plant exudates?)

→Changed to: "It has been shown with ^{13}C-pulse labeling that also soil macrofauna (e.g. earthworms) may quickly incorporate plant exudates as a C source in addition to above- and belowground plant litter inputs, probably by incorporating ^{13}C-labeled microorganisms (Ostle et al., 2007)."

Ad 3.3. Carbon losses via plant and rhizosphere respiration and BVOC emissions
The knowledge presented in this chapter is strongly compressed and it demands considerable expertise in the field to follow the somewhat jumpy explanations. I suggest

separately treating the VOC part and to include more general information in order to help the reader following the red thread of the chapter. I also suggest to move rhizosphere and especially mycorrhizal respiration to Chapter 4 (belowground C turnover).

→ We have rearranged this chapter, and added more information on BVOC. We hope that the read thread is visible now. We have also moved rhizosphere respiration to Chapter 4.1.

Ad 3.4 Temporal C allocation patterns
I suggest rearranging the words, which puts the main topic of each paragraph in the front, eg: P 3641 line 1: Diel variations in soil respiration are temperature (and moisture) independent…… Correlation-based studies in separate sentence

→ Here we could not completely follow the suggestion, as starting the sentence with "Diel variations in soil respiration are temperature (and moisture) independent…" would have made a different statement (as this is currently not clear and under debate). However, we have rearranged the paragraph to:
"Also the $\delta^{13}C$ of soil CO_2 efflux has been shown to exhibit diel variations (e.g. Kodama et al., 2008; Bahn et al., 2009; but see Betson et al., 2007). However, from correlation-based flux studies it is not consistently clear to which extent they are temperature- (and moisture-) independent and thus possibly related to rapid allocation of C from recent photosynthesis to respiration (Tang et al., 2005; Bahn et al., 2008; Subke and Bahn, 2010; Vargas et al., 2010; Philipps et al., 2011). It is also not clear to which extent these diel variations of $\delta^{13}C$ of soil CO_2 efflux reflect the number of processes potentially involved, …".

P 3641 Line 16: Initial growth and respiration are supplied from storage C in seeds…..in both annual and perennial plants……..

→ Done.

Chapter 4.1 Heterotrophic soil respiration
This chapter is very short concerning the wealth of knowledge, the importance of the process in the global C cycle and the fractionation effects. If you include such a chapter (in spite of the self-limitation mentioned above) mechanisms such as a biotic/abiotic "regulatory gate hypothesis" of C mineralization, the effects of nutrients and nutrient stoichiometry on Rh, and effects of different microbial "carbon use efficiency" of fungi versus bacteria, should be mentioned.

→We have moved the rhizosphere respiration part from Chapter 3.3 to here and have renamed the Chapter to "Rhizosphere respiration". At the end of this chapter, we briefly mention heterotrophic soil respiration in contrast to autotrophic respiration, building a bridge to the following chapters, where SOM turnover, isotopic fractionation and microbial processes are covered. Given the length of the review already at this stage and the fact that "classical" heterotrophic soil respiration processes have been reviewed extensively elsewhere, we refrained from extending this section more.

Chapter 4.3 Fractionation due to microbial metabolism
Here the studies of E.A. Hobbie on mycorrhizal fractionation should be included

→We agree that Hobbie has provided much information on the potential fractionation of mycorrhizae, especially when ^{15}N is concerned. Of special interest is the recent paper he co-authored in 2009 using position-specific labeling in glucose which we have now included in the text:
"For example, the use of positional labeling of carbon in glucose has given metabolic insight into carbon pathways in mycorrizhae (Scandellari et al., 2009)."

P 3656 line 15 What do you mean by "unrecognizable organic matter", do you mean "completely humified organic matter"?

→Yes, we changed the text accordingly.

P 3663 line 1: meshwork?

→Changed to "…complex network of interlinked carbon transformation and transport processes…".

P 3663 line 19: do you mean "secondary" ion mass spectrometry?

→ Yes, in the original Word version it was correct, must have been truncated during the generation of the pdf. Now moved to the new section 6 on methodology.