Reply to referee #1

Thank you very much for reviewing the manuscript and your comments. Below, the reviewer comments are presented in italics and our responses follow in normal letters.

The topic of this paper is very interesting and relevant when analysing climate change. The publication covers a large spatial scale, thus spatially involves areas with very contradicting observed and projected precipitation (and temperature) trends. Common yearly, half-yearly and seasonal periods may miss important trends because of partly contradicting trends within those periods. Using fixed smaller periods like months does not solve such problems, but contributes to a better understanding of climatic trends. Relating found climatic trends to atmospheric circulation helps understanding causes for such developments.

- We appreciate these positive comments to our study.

<u>Specific comments</u>

P12802/L26: sources should be arranged in logic order, either by year of publication (2011 to 2007 or other way around) or author first letter (A to Z); comment relevant for whole paper

- We will correct this in the whole paper.

P03/L8: more precise is that variations occur on monthly and even shorter time periods, but a monthly resolution is an important step to higher temporal resolutions compared to previous studies

- Yes, we agree and we will comment on this both in the introduction and conclusions of the paper.

P03/L20: why that time frame? 2001 was 13 years ago, aren't there more up-to-date datasets available? (they are. . .). I'd suggest to update the time frame at least until 2010, also considering that the SynopVis GWL are available up to recent years.

- An extension of the study period beyond 2001 is unfortunately not possible, as the gridded and bias-corrected climatic data for temperature and precipitation from the WATCH-Forcing-Data (WFD) are based on the ERA-40 data and only available until 2001. For the more recent years WATCH-Forcing-Data-ERA-Interim (WFDEI) based on ERA-Interim data are available. However, due to differences in the reanalysis between ERA-40 and ERA-Interim, there are also offsets in some variables between the WFD and WFDEI. For a trend analysis, we would therefore hesitate to combine WFD and WFDEI data to allow for a longer time period. We prefer here to use the WFD, as it is one of the best available datasets for precipitation and temperature in Europe, due to its high spatial resolution and bias correction, well suited as a basis for the pan-European study presented here.

P05/L14ff: I understand the choice of dataset and time frame given here, but again, in terms of usability, 2001 is too far in the past to create useful up-to-data trend conclusions. For averages the time frame would be totally OK, but for trends it is outdated. Adding recent years may produce very different trend results. In case a prolonging of the time frame is not possible, recent developments (weakening of the NAO etc.) should at least be mentioned and discussed in the text, based on publications of recent years. Just as an example: there was a considerable April drying (and warming) in Central Europe since the 1990 (still continuing), which is not visible at all here, but is very relevant for agriculture, forestry etc. here due to its location at the beginning of the vegetation cycle (P10/L7). Also, drying signals in August may not be visible if including recent years with very high precipitation amounts in CE (2002, 2010 etc.; P10/L13).

- We agree that the used time frame is not optimal for a trend analysis on "recent" changes in European climate. However, as argued above, we judge the quality of the WFD dataset in terms of temperature and precipitation and the rather long period covered to be preferable as compared to using a more updated dataset with lower spatial resolution.

  We see the main message of this study not so much the actual climatic trends themselves (in terms of direction and magnitude), but rather in the following results (which are independent of the time period):

  - important spatial and temporal variability in climate variables is masked by seasonal or annual studies and potentially more information can be gained by using a higher temporal resolution,
  - local climatic variability and changes are caused by a combination of synoptic-circulation and within-type changes and neither of them alone can explain all climatic changes,
  - the relative importance of synoptic-circulation changes vs within-type changes varies in space and throughout the year.

  We will try to stress this motivation for our study more clearly in the paper and comment on the fact that the trends themselves are not up-to-date. In addition, we will comment on more recent changes in European climate and atmospheric circulation when discussing the results.

The SynopVis GWL has been applied already in various other studies, thus the performance of this classification method has been tested and compared to other circulation classifications before. References of those studies and their evaluation of the SynopVis method should be added.

- We found three more studies (Ducić et al., 2012; Hoy et al., 2013 and 2014), which we will reference including their evaluation of the SynopVis Grosswetterlagen. In the studies by Hoy et al., the SynopVis Grosswetterlagen were applied along one more classification as well as the NAO and found useful for studying the impact of synoptic types on European temperature (Hoy et al., 2013) and precipitation (Hoy et al., 2014).

Chapters 4.3 to 4.5 (fig. 3-5) explain well the developments described in chapters 4.1 and 4.2 (fig. 1). [only drawback is that results are not up-to-date, see previous comment]

It should be mentioned that months are, as seasons and other fixed temporal frames, artificially fixed periods within the annual cycle, and that strongest trends may occur at different positions within a 30day cycle and that opposing trends within a specific month may lead to only a weak or no signal, while strong developments are actually present.

- We agree and we will state this assumption and discuss the potential implications in the discussion section.

The definition of wet/dry CTs based on the annual mean precipitation of each CT (P19/L1) is critical, as CTs may behave very differently between the seasons. As an example: CTs with a rather easterly inflow are mostly drier than average precipitation amounts in Central Europe during the winter (also those defined as cyclonic), while the separation in anticyclonic and cyclonic works very well during the summer.

- In this study, we chose not to differentiate between anticyclonic and cyclonic types, as each type is associated with varying precipitation and temperature properties across Europe. We realize that precipitation and temperature properties associated with one synoptic type in a particular part of Europe can vary between seasons. However, we preferred to use a consistent grouping into predominantly wet and dry types throughout the year, as also the time of the year when atmospheric conditions transition from e.g. winter to summer conditions can vary. We will clarify the assumption and discuss the fact that local precipitation and temperature properties associated with one synoptic type can vary between seasons more explicitly when introducing the grouping into wet and dry types.

<u>References</u>

Ducić, V., Luković, J., Burić, D., Stanojević, G. and Mustafić, S.: Precipitation extremes in the wettest Mediterranean region (Krivošije) and associated atmospheric circulation types, Nat. Hazards Earth Syst. Sci., 12, 687-697, doi: 10.5194/nhess-12-687-2012, 2012.

Hoy, A., Sepp, M. and Matschullat, J.: Large-scale atmospheric circulation forms and their impact on air temperature in Europe and northern Asia, Theor. Appl. Climatol., 113(3-4), 643-658, doi: 10.1007/s00704-012-0813-9, 2013.

Hoy, A., Schucknecht, A., Mait, S. and Matschullat, J.: Large-scale synoptic types and their impact on European precipitation, Theor. Appl. Climatol. 116(1-2): 19-35, doi: 10.1007/s00704-013-0897-x, 2014.