Response to comments of Anonymous Referees

Our responses to the referee's comments are shown below in blue, with the reviewer's comments shown as normally black text.

Response to comments of Anonymous Referee #2 at the round1

This paper proposes a statistical drought prediction model based on atmospheric and oceanic variables. The authors first identify severe and extreme drought events based on the SPI3 and identify predictors for these events. Based on these, they build a drought prediction model and propose a drought outlook. The performance of the full chain is then illustrated in the case of four drought events in China.

General comment

I believe that this paper is a valuable contribution to the special issue. However, I believe that, in its current form, it is hard for the reader to follow and process the large amount of information it contains. For clarification, I would suggest reorganizing the paper. Indeed, some of the subsections in the Methods section bring little to the paper in their current state (especially subsections 3.4 and 3.5). I could suggest two ways (non-restrictive) to reorganize the Methods and Results sections. (1) The first suggestion would be to keep the current structure but making sure that the Methods section (a) is more detailed and explains even briefly all methods, including the computation of the SPI, the step-wise regression and the EOF analysis, and (b) excludes statements on what has been done (move to the Results section). (2) The second way could be to separate the paper by "themes" or "work steps" as listed at the end of the introduction: this way, the continuity between the steps could be easier to follow, and, for instance, the drought periods and predictors would be available to the reader to understand the steps of "structuring predictors" and "building the prediction model".

RESPONSE:

Thanks for your admiration about the scientific values of this manuscript. Actually, it is a new and valuable attempt of seasonal drought process prediction, which hardly appear in the previous study.

The most important issue to solve is the lack of clarification, especially in the Methods section and Results section. In the potentially revised version, we tend to choose the second way recommended, which separate the paper by "themes" or "work steps".

To achieve it, we will add a flow diagram map of model construction at the end of the Introduction section and give a brief introduction about the sequential procedures. Here they are. "*Considering that the conceptual model proposed consists of several important parts, a brief but general introduction about sequential procedures are shown (Fig. 1), prior to specified illustration from sect. 3 to sect. 8. In sect. 3, historical extreme and severe drought processes will be identified with 3-month SPI updated everyday (SPI3). Identified drought processes usually go through one or several dry/wet spells, in which precipitation deficit characteristics and circulation patterns varies. Therefore, process-split rules according to dry/wet spells in sect. 4 are designed to assign drought process segments to different dry/wet spells. Meanwhile, gridded values in the fields of 200 hPa/500 hPa HGT and SST are transformed into gridded values of Standardized Anomalies (SA) in sect. 5. Basically, maps of atmospheric/oceanic SA during drought process segments within the same dry/wet spells are the important inputs of predictor construction. After Empirical Orthogonal Function (EOF) analysis are conducted on these SA-based maps, the first leading EOF modes are used to build up predictors (sect. 5). Further, synchronous statistical relationship between SA-based predictors and SPI3 are calibrated with the method of stepwise regression in sect. 6. The National Centers for Environmental Prediction / National Center for Atmospheric Research (NCEP/NCAR) Reanalysis datasets and the NCEP Climate Forecast System Version 2 (CFSv2) operationally forecasted datasets are used to force the synchronous statistical relationship, respectively. Simulated and predicted 90-day prospective SPI3 time series are output of sect. 7. With the help of angle-based rules of drought outlook, simulated and predicted SPI3 time series are transformed to five kinds of drought outlook, which are easily accessible to end water managers.*"

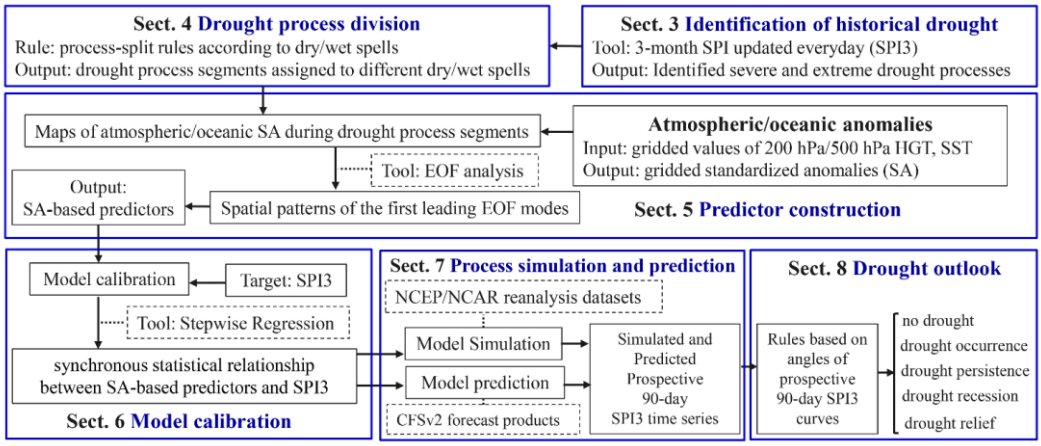

Figure 1. Brief introduction about sequential procedures of the drought prediction model construction

Accordingly, when it comes to specified sections, we will illustrate methodology and results as follows:

3 Identification of drought processes

3.1 Three-month SPI updated everyday

3.2 Drought process identification and grade classification

4 Drought process division according to dry/wet spells

5 Predictor construction

5.1 Atmospheric and oceanic standardized anomalies

5.2 The first EOF leading modes of SA

5.3 Pattern-based predictor construction

6 Model calibration

6.1 Synchronous statistical relationship

6.2 Rolling calibration year by year

7 Drought process simulation and prediction

7.1 Model forcing

7.2 Drought processes simulated by the NCEP/NCAR reanalysis datasets

7.3 Drought Processes predicted by the CFSv2 forecast datasets

8 Drought outlook

8.1 Angle-based rules

8.2 Simulated and predicted results

Additionally, subsections 3.4 and 3.5, which bring little to the original version, will be simplified and illustrated in section 5.1 and section 6.1 in the potentially revision paper.

We think the potentially revised version will be improved a lot and easy for readers to follow and process it.

Major comments and general questions

- Introduction: Even if it becomes clear early in the paper, I think it should be stated that the droughts studied are restricted to meteorological droughts.

RESPONSE:

We will add illustration about drought types in the first paragraph of the Introduction section, which are as follows: “In the present study, drought prediction is restricted to meteorological drought, which is associated with long-term precipitation deficit.”

- Section Methods: I was missing descriptions of the computation of the SPI, the EOF analysis, as well as of the step-wise regression used to build the prediction model. These could simply be described in very brief sentences.

RESPONSE:

Thank you for this comment. Actually, lacking the description of SPI3 computation is also pointed out by Referee#1. In the potentially revised version, we will add brief but important description about the computation of the SPI, the EOF analysis and the step-wise regression where necessary. Relevant main description designed for the revised version is as follows.

(1) SPI calculation

“SPI3 was used as the drought index for seasonal drought recognition and prediction in this study, and the period for SPI3 calculation is 1979–2014. Traditionally, the SPI3 set is moving in the sense that each month a new value is determined from the previous 3 months (McKee and Kleist, 1993). To obtain seasonal drought processes at the one-day timescale, we chose to update SPI3 everyday, which was also recommended by the World Metrological Organization (2012). Compared with the traditional method, the essential difference is that the interval for SPI3 calculation has been extended from 12 months to 365 days, while the moving window has changed from one month to one day. However, no changes happen to relevant mathematic procedures. Specified illustrations and details about how to calculate SPI3 updated everyday are shown as Fig. 3.”

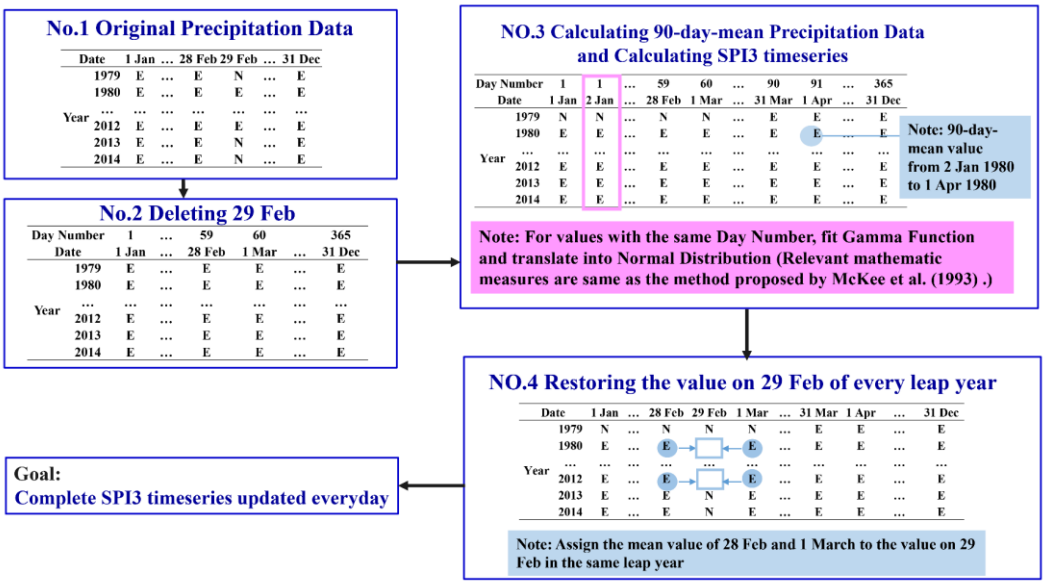

Figure 3. Illustration of calculating SPI3 updated everyday. The letter "E" represents value existence, while the letter "N" represents no relevant data.

(2) the EOF analysis

"Empirical Orthogonal Function (EOF) analysis (Wilks, 2011) is introduced to decompose spatio-temporal dataset of drought-related atmospheric/oceanic SA into spatially stationary coefficients (leading modes) and time-varying coefficients (principal component). In the same dry/wet spell, the EOF analysis is conducted on atmospheric/oceanic SA from all severe drought process segments and all extreme drought process segments respectively. The identical work of EOF analysis is applied to all the four dry/wet spells."

(3) the step-wise regression

"To build statistical models, the method of stepwise regression is introduced. Stepwise regression (Afifi and Azen, 1972) is a method of fitting multiple regression models, in which a predictive variable is considered for addition to or subtraction from the set of explanatory variables based on statistically significant extent or loss. In the present study, it is used to build the synchronous statistical relationship between all 90-day-accumulated SA-based predictors and the prediction target SPI3."

- Lines 112-114: Could you please explain why you chose the first date of the period as the beginning for the drought period? Couldn't that lead to overestimating the duration of the droughts, and subsequently influence the selection/use of predictors?

RESPONSE:

Yes, we could explain the reason for extended drought processes. Actually, due to the timescale of SPI3, the SPI3 value on the start date of an identified drought process actually reflects drought-inducing precipitation information 90 days before it. It also corresponds to the situation that the SPI3 value is firstly less than -0.5 and the severe drought indeed comes, which is as much as important as those during the identified drought processes. Therefore, to extract drought-related atmospheric/oceanic anomalies more comprehensively, the start date of the drought process is extended to 90 days before it, prior to the drought process division. We think it is also necessary and is important part of extended drought processes, despite the overestimated drought duration and subsequently influence on the selection of predictors.

Originally, Lines 112-114 are unclear and easily result in misunderstanding. To make it clear and logically improved, we will rewrite relevant sentences in the potentially revised version for clarity.

- Line 142: Are these the circulation pattern variables used in the building of the model? If so, it could be worth emphasizing them throughout the Methods section when appropriate.

RESPONSE:

Yes, they are. Actually, the term "atmospheric and oceanic anomalies", which is also expressed as "large-scale circulation patterns", is specified as "200 hPa/500 hPa HGT and SST". Since these three terms express the same meanings, we have emphasized them throughout the Methods section where appropriate.

- Lines 148-150: in my opinion, these lines state analyses that have been carried out and do not really inform on the methodology itself. A brief sentence describing the EOF analysis could be useful here. Knowing the severe and extreme drought process segments at this stage could help towards a more pragmatic description of the method.

RESPONSE:

The descriptive text in Lines 148-150 was used to explain reasons rather than describe methods and approaches. We will remove the statement components in the potentially revised version. Besides, brief introduction and application about the EOF analysis will be also added in this section.

In terms of "Knowing the severe and extreme drought process segments at this stage", we took two measures to show this information. First, we will add a general flow diagram, in which "Knowing process segments is previous to the EOF analysis" will be expressed. Second, in the potentially revised version, sect. 4 "Drought process division according to dry/wet spells" will be prior to sect. 5 "Predictor construction". This measure followed the comment of "Theme-work steps", in which the continuity between the steps could be easier to follow.

- Lines 162-163 (also see previous comment): The sentence "All the atmospheric and oceanic predictors from all the dry/wet spells were adequately used for model calibration, which reflected drought-related information as integrally as possible." Does not seem to be supported by anything at this stage. I would suggest moving it to the Results section if appropriate, or reformulating the sentence.

RESPONSE:

Thank you for pointing out it. The original idea is to express that it involves drought-related information as integrally as possible, despite one simple stepwise regression equation. Actually, this sentence is not supported and seems unnecessary in this part. We will remove this sentence in the potentially revised version. Additionally, in Lines 314-321 of Discussion section in the original version, we have also expressed it.

- Section 3.6: I would have liked the authors to explain the advantage of this method over the methods found in the literature. In addition, I think this subsection needs some clarifications.

RESPONSE:

Compared with methods of drought outlook in the literature, the method itself does not show extremely obvious or significant advantages. However, in the present study, the angle-based drought outlook is an innovative and valuable attachment products for end water managers, because it is more convenient and comprehensive compared with predicted prospective SPI3 time series.

From another aspect, the extended moving window of SPI3 calculation contributes to the application of drought outlook. In the previous studies on drought outlook, a common but distinct feature is the one-month moving window of drought indices, resulting in loss of sub-month drought information. However, in the present study, partly beneficial from the one-day moving window of SPI3, prospective 90-day SPI3 time series can be predicted. Accordingly, drought outlook can be performed. It can be updated real-time and provide more accurate discriminations about drought development. It is hard for previous methods of drought outlook to provide similar prospective drought prediction information.

Last but important, drought outlook in the original subsection needs deep clarifications. Similar comments were also made by Referee#1. In the potentially revised version, we will make considerably important changes to make it brief and clear. Despite no much revisions on the Figure and Table in the subsection, the original text has been reorganized into three paragraphs, which are namely "how to describe drought development", "general classifications of drought outlook" and "how to calculate angles and conduct angle-based drought outlook". Basically, we hope to make readers easily understand the method.

- Figure 8: could you please further detail the legend for Table 8? I believe "above table" should be changed to below. Could you describe what should be read in each column? More specifically, the column "Asses." seems to indicate when the simulation and observation agree. If this is correct, the "yes" entry for 30/6/2009 should be "-", and the "-" for 11/4/2011 should be "yes".

RESPONSE:

Yes, we can. We have followed your comments and will make relevant changes in the revised version. We will replace "above table" with "below table". We will add relevant brief illustrations about the abbreviation "Simul.", "Obs." and "Asses." in the table caption. Besides, the column "Asses." actually indicate when the simulation and observation agree, and the assessments on 30/6/2009 and 11/4/2011 will be corrected in the potentially revised version. Corresponding revision have been made in the revised version.

- Lines 287-288: Is this observation based on a visual inspection of Figure 10?

RESPONSE:

Yes, this is. The original description is not rigorous indeed. In the potentially revised version, it will be described in a more rigorous approach as follows: "*As shown in Fig. 10 (b), predicted curves performed worse than the simulated curves near the peak of the 2011 East China drought, since the prospective observation tendency is rising rather than decreasing. However, in the other three droughts, the predicted curves can indicate the drought development to different degree, and they resemble the simulated results quite well. For example, operationally reforecast curves can indicate phases of occurrence, persistence, and relief during the 2009/2010 drought in Southwest China (Fig. 10 (a)).*" However, only the visual inspection is not enough. In addition to this qualitative comparison, quantitative comparison of drought outlook will be shown in sect. 8 "Drought outlook" of the potentially revised version. Additionally, comparison of predicted, simulated and observed SPI3 curves with the evolution of predicted prospective periods was shown in the third issue of Discussion section.

- Tables 8 and 9: It seems that the prediction model performs better when forecasting the 2009/2010 drought in Southwest China than in simulating it. Why do you think this happens?

RESPONSE:

We think it lies in unbelievable uncertainties despite slightly better model performance. For example, the prediction model performs worse when forecasting the 2014 North China drought than in simulating it in the original table 8 and 9. The essential difference between simulated and predicted results is forced by reanalysis data or operationally forecast data. The results based on reanalysis data is the upper limitation of the latter one. Even if forecasted results sometimes perform better, it is connected with uncertainties.

Minor comments

- Throughout the paper, citations were sometimes organized based on alphabetical order and sometimes based on year of publication. These should be consistent.

RESPONSE:

Thank you for pointing out this problem. We have made them uniform on the basis of alphabetical order (first) and year ascending order (secondary). For example, "(Yoon et al., 2012;Mo and Lyon, 2015;Dutra et al., 2013;Dutra et al., 2014)", which is the citation in Lines 33-34 of the original version, has been adjusted into "(Dutra et al., 2013;Dutra et al., 2014;Mo and Lyon, 2015;Yoon et al., 2012)".

- L.32: The full name of SPI is "Standardized Precipitation Index".

RESPONSE:

We will replace the previous term with "Standardized Precipitation Index".

- L.69: Please explain the abbreviation "SA", as it has not been explained before in the text (only in the abstract).

RESPONSE:

We will add the full name "Standardized Anomalies" as a brief explanation in this position.

- Section 3 Methods: I would recommend changing the titles of subsections 3.1 to 3.6. The titles should reflect what is presented in the sections, i.e. here methods and techniques, and therefore should avoid action verbs (using, divide, apply,…). In my opinion, action verbs can be misleading and can make the reader expect results.

RESPONSE:

Thank you for pointing out these inappropriate expression. We have followed your comments to avoid action verbs and made description clear and simple. The sub sections designed for the potentially revised version are as follows:

3 Identification of drought processes

3.1 Three-month SPI updated everyday

3.2 Drought process identification and grade classification

4 Drought process division according to dry/wet spells

- Lines 147 and 303: “spatial-temporal” and “spatio-temporal” are used in these two sentences.

RESPONSE:

We will replaced the term “spatial-temporal” with the term “spatio-temporal” in the revised version.