Hydrol. Earth Syst. Sci. Discuss., 8, C189–C194, 2011
www.hydrol-earth-syst-sci-discuss.net/8/C189/2011/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Low-frequency variability of European runoff" *by* L. Gudmundsson et al.

L. Gudmundsson et al.

lukas.gudmundsson@geo.uio.no

Received and published: 28 February 2011

We would like to thank Reviewer #1 for the helpful comments and questions. We want to use these as an opportunity to clarify terminology, the interpretation, and some methodological aspects.

1 Terminology

Reviewer # 1 suggested to replace "fraction of low-frequency *variance* of runoff" with a more accessible term, e.g. "between-year variability".

Low-frequency *variability* is an established term in atmospheric science to describe slow fluctuations in the climate system. It is also a term typically used in time series

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

decomposition. The term “between-year variability” may be misleading (as also recognized by the reviewer) because it emphasizes the variability from one year to the next. In this study, low-frequency refers to variability on time-scales larger than one year, including inter-annual and decadal variations as well as trends. We therefore prefer to keep the term low-frequency variability despite its technical character. An alternative might be “long-term” variability.

In the manuscript we intended to use the following terminology:

1. “low-frequency variability” to describe the *general phenomenon* of temporal variability at scales longer than one year;
2. “low frequency runoff” for Q_{Long}, the low-frequency component the decomposed runoff *time series*;
3. “fraction of low-frequency variance” for the *proportion* (one value) of the total variance in the original runoff series that is contained in Q_{Long}.

Further we define *low-frequency variance* as “variance on time scales larger than one year” (p 1707, l. 25); and *high-frequency variance* as “variance on time scales shorter than one year” (p 1708, l.18).

We acknowledge that the term “fraction of low-frequency variance” is a bit technical and may disturb the flow of the text (to avoid this, we mainly used the variable name Φ_Q). However, for the reasons stated here, we hesitate to introduce new terms, but suggest to change the title of Section 4.1 from “Low-frequency variance” to “Fraction of low-frequency variance” and Section 4.2 from “Space-time patterns” to “Space-time patterns of low-frequency runoff”. In addition, the text will be carefully checked to ensure that the terms are used consistently and simplified/clarified where needed.

HESSD

8, C189–C194, 2011

2 Interpretation of patterns

Reviewer #1 suggested that many of the emerging patterns could be described more intuitively in terms of "within-year variability".

The focus of this paper are two different aspects of runoff variability on time-scales longer than one year: (i) Dominant space-time patterns of low-frequency runoff and (ii) the fraction of low-frequency variance of runoff. Our primary aim was to quantify these aspects and to provide some empirical evidence on factors that influence the emerging patterns.

The dominant *space-time patterns of low frequency runoff* appearers to be sufficiently explained by the close relation to dominant space-time patterns of low-frequency precipitation and temperature (Fig. 5).

By definition the *fraction of low-frequency variance of runoff* contains information on all other (seasonal and residual) time scales (see Eq. 2). However, it is not sensitive to the distribution of the variance within the shorter time scales. The "seasonal" as well as the "residual" component may have significant influence on Φ_Q. This is supported by Fig. 2, which shows that the amplitude of the three different components are actually of the same order of magnitude. We suggest to comment upon this phenomenon in detail when introducing Fig. 2.

To explain the large differences in Φ_Q we have been guided by the results of the correlation analysis (Table 1). Φ_Q can be discussed with respect to

1. *residual variance*: Here we adopt the perception of hydrological systems as filters. The question is what determines the strength of the filtering. The correlation analysis suggests that this filtering is stronger under dryer conditions (see p. 1716, l. 2 ff.).

2. *seasonal variance*: The amplitude of the seasonal cycle may have a large influ-

HESSD

8, C189–C194, 2011

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

ence on Φ_Q. The seasonal cycle of runoff is closely related to mean temperature. We discuss effects related to the seasonal cycle, including snow processes in Section 5.1 (see p. 1716, l. 5 ff.).

3. *long-term variance*: Storages such as large lakes and ground-water systems, may respond on time scales longer than one year, amplifying low-frequency fluctuations. Our data do not allow insights into to this phenomenon. Therefore, we opted not to comment upon this in the discussion and rather focused on the effects of storage on the modification of fluctuations on shorter time scales (see item 1 of this list)).

We suggest to restructure/clarify the discussion of Φ_Q with respect to the three terms mentioned above.

3 Detailed comments

3.1 p.1708, l. 9: "Accordingly"

Accordingly refers to the spectral representation underlying the idea of describing hydrological systems as low-pass filters. We will clarify this in the revision.

3.2 p.1710, l. 23: LOESS kernel and parameterization

1. *Kernel*: the "tricubic weight function" (p.1710, l. 20) used is standard for many kernel applications in time series smoothing and we thus suggest not to add additional information.
2. *Kernel-parameterization*: The main objective of applying the STL algorithm is the separation of low-frequency fluctuations (Q_{Long}) from fluctuations on other time

HESSD

8, C189–C194, 2011

Interactive Comment

scales. This can in principle be achieved by many other methods. However, we opted to use STL as an ready available algorithm (the "stl" function in the software "R") because its efficient implementation. The separation of Q_{Resid} and Q_{Seas} is only a by-product of the STL algorithm, but it's parameterization influences Q_{Long} and therefore deserves attention.

The STL algorithm principally allows to identify seasonal cycles that change with time. For each month (e.g. the series of all Januaries) STL applies a LOESS smoothing to identify slowly varying changes in the monthly mean. The LOESS parameter λ_{Seas} determines how large these changes in the mean annual cycle are allowed to be. In this study we assume the annual cycle to be stationary (to guarantee that no low-frequency fluctuations are lost) and set the kernel-parameterization accordingly. The text mentions (p.1710, l. 23) that $\lambda_{Seas} = 10n + 1$, where n is the length of the input series (here $n = 12\, months * 37\, years = 444\, months$). Accordingly $\lambda_{Seas} = 4441$ and thus much larger than the length of each seasonal subseries (e.g. series of Januaries), having 37 entries.

3.3 p. 1712 (including l.2 and Fig. 3): ISOMAP

We acknowledge that this section may not be explained sufficiently to readers that are not familiar with techniques such as Principal Component Analysis (PCA) or Multidimensional Scaling (MDS) and their application in climate science. Generally it is difficult to decide the level of details needed when introducing a method that is closely related to methodologies that ware well established in this field (as a paper needs to balance brevity and detail). In the present paper we opted to introduce ISOMAP by highlighting its main differences to MDS (or PCA), following the traditional ISOMAP literature.

We suggest to await the comments of the other reviewers and the editor before we

HESSD
8, C189–C194, 2011

conclude on this issue.

3.4 p.1713, l. 10: “Terminology”, influence of snow

We elaborate on our choice of terminology in Section 1 of this document. In the discussion section (see p 1716, l. 5) we do argue for the influence of snow processes on Φ_Q which is also mentioned by Reviewer #1. Hopefully this will become clearer to the reader following the clarifications to be made (see Sections 1 and 2 of this document).

3.5 p. 1713, l. 25: Why are the fraction of low-frequency variance of runoff and rainfall not correlated?

In the results section we report the results of our empirical investigation. A potential explanation is elaborated in the first sentence of the discussion section (p 1715, l.6): “The fact that Φ_Q is on average larger than and not correlated to Φ_P and Φ_T, supports the hypothesis that the fraction of low-frequency variance of runoff is controlled by catchment processes [...]”

3.6 p. 1717, l.19: “Interpretation of patterns”, “Terminology”

Based on the arguments made earlier (Sections 1 and 2 of this document), we prefer to keep the focus on low-frequency variability in the discussion.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 1705, 2011.

HESSD

8, C189–C194, 2011