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EDITORIAL

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Key Points:
- We compare the citation impact across hydrology journals in order to help clarify the robustness and meaning of journal impact factors
- A small number of highly cited papers have a large influence on the journal impact factor, especially for the smaller journals
- Reducing the obsession on citation impact enables focusing more on enhancing the quality and broader impacts of hydrologic science

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The citation impact of hydrology journals

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Abstract We examine a suite of journal-level productivity and citation statistics for six leading hydrology journals in order to help authors understand the robustness and meaning of journal impact factors. The main results are (1) the probability distribution of citations is remarkably homogenous across hydrology journals; (2) hydrology papers tend to have a long-lasting impact, with a large fraction of papers cited after the 2 year window used to calculate the journal impact factor; and (3) journal impact factors are characterized by substantial year-to-year variability (especially for smaller journals), primarily because a small number of highly cited papers have a large influence on the journal impact factor. Consequently, the ranking of hydrology journals with respect to the journal impact factor in a given year does not have much information content. These results highlight problems in using citation data to evaluate hydrologic science. We hope that this analysis helps authors better understand journal-level citation statistics, and also helps improve research assessments in institutions and funding agencies.

1. Motivation

Journal impact factors are widely cited, used, and misused across the academic landscape [*Seglen*, 1997; *Amin and Mabe*, 2004; *Simons*, 2008; *Alberts*, 2013; *Reich*, 2013; *Casadevall and Fang*, 2014; *Verma*, 2015; *Lariviere et al.*, 2016]. It is rare in a presentation on publishing, whether to authors, librarians, or administrators, that a question or comment on the journal impact factor does not come up. The journal impact factor was originally developed to judge the quality of journals [*Garfield*, 1999, 2006], and now its use is much more widespread. Academic institutions and funding agencies use the journal impact factor to judge individual scientists (e.g., to check if they are publishing in the top journals), and authors use the journal impact factor to decide where to publish [*Simons*, 2008; *Alberts*, 2013; *Verma*, 2015]. The obsession with journal impact factors occurs, in part, because the academic community uses impact factors to make decisions on hiring, promotion, tenure, and funding.

We compare the citation impact across six leading hydrology journals in order to help clarify/illuminate the robustness and meaning of journal impact factors. Our overall intent in writing this Editorial is to help authors determine if the citation impact of different hydrology journals can guide where they decide to publish, and also to provide authors with information that they can use to improve research assessments in their institutions and in their funding agencies.

2. Data and Methods

We analyzed data from the Web of Science (Clarivate Analytics), from 1996 to 2016, for six leading hydrology journals: *Advances in Water Resources* (*AdWR*), *Hydrology and Earth System Sciences* (*HESS*), *Hydrologic Processes* (*HP*), *Journal of Hydrometeorology* (*JHM*), *Journal of Hydrology* (*JoH*), and *Water Resources Research* (*WRR*).

Data were obtained from the Web of Science on 7 May 2017, and hence, the results reflect the content of the Web of Science database at this point in time. Because the Web of Science database is continually updated, the results may differ if citation data are obtained at a future date; however, any differences are likely to be small for analyses calculated over similar time windows [*Lariviere et al.*, 2016].

The key metrics that we consider are:

1. The time series of the number of papers published in each journal, to provide information on the productivity of hydrology journals.

2. The journal-level Hirsch- (or *h*-) indices, to provide information on both the productivity and citation impact of journals [*Hirsch*, 2005; *Braun et al*., 2006]. The *h*-index is the number of publications *h* that have at least *h* citations each, and the *h*-median is the median of the citation counts of the articles cited at least *h* times.
3. The journal impact factor. The *n*-year journal impact factor for a given year *y* is the ratio of citations in all papers published in year *y* in all indexed journals divided by research papers published in a particular journal in the previous *n* years. The journal impact factor focuses more on the citation impact than the *h*-indices because it normalizes citations by the number of publications. In the statistics presented here, we do not make any restrictions on publication type; thus, our analysis is similar to a new metric proposed by Elsevier [*da Silva and Memon*, 2017]. The journal impact factor calculations presented here differs from the official journal impact factors. Clarivate calculates their official journal impact factor from a different, proprietary database that includes additional citations. Moreover, Clarivate applies undocumented rules to define which articles are included in the journal impact factor calculation. The official journal impact factor is usually larger than that inferred from citations in the Web of Science.
4. The probability distribution of citation statistics. This analysis was recently suggested by a group of editors to circumvent problems with the journal impact factor calculations [*Lariviere et al*., 2016].
5. The age of cited papers, to determine the suitability of different citation windows.

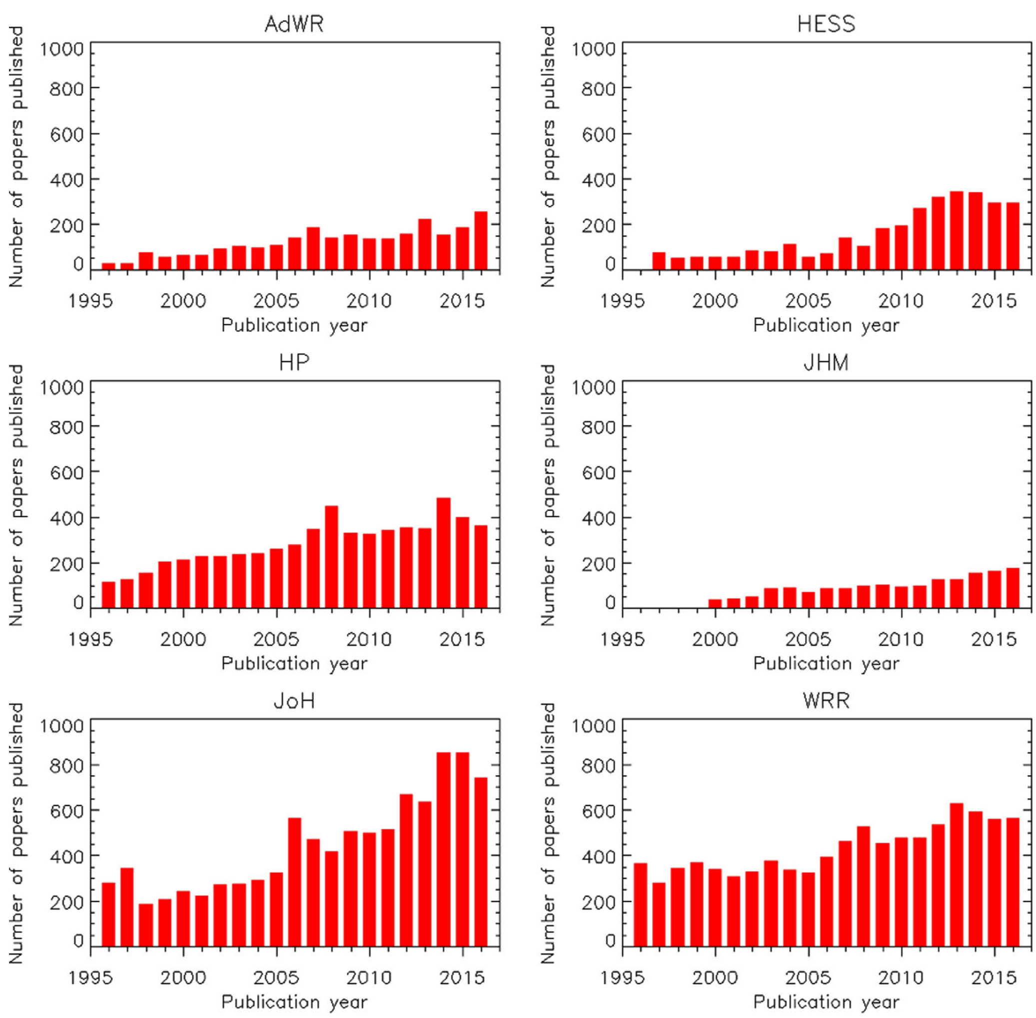

Figure 1. Time series of the number of papers published in hydrology journals (1996–2016).

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We also evaluate the robustness of the journal impact factor for these hydrology journals in two ways. First, we use bootstrapping methods to estimate the uncertainty around the collection of papers published in the citation window. Specifically, we resample (with replacement) from the collection of m papers published in the citation window for a given year, and we recompute the impact factor using the random sample of m papers. We repeat this exercise 1000 times and compute the 5th and 95th percentiles. Second, we evaluate the robustness of the journal impact factor by ranking the m papers published in the citation window in terms of the number of citations, and compute the fraction of citations in year y from the 1, 2, 5, and 10 most highly cited papers.

3. Results

The time series of the number of papers published in each journal (Figure 1) shows the growth of the journals over the period 1996–2016. In recent years, *JoH* was the largest journal, publishing more than 500 papers per year, whereas *AdWR* and the *JHM* are the smallest journals, publishing less than 200 papers per year. The number of papers published by *WRR* has increased more slowly than other journals over the past 20 years.

The journal-level Hirsch- (or *h*-) indices (Figure 2) depend on the size and citation distribution of journals. We expect a strong relation between journal size and the *h*-indices if the authors' publishing preferences are entirely random. Such expectations are supported in Figure 2, where the largest hydrology journals (*JoH* and *WRR*) also have the highest *h*-indices. There are also cases where the *h*-indices are more homogenous than could be expected from journal size alone. For example, the *HP* *h*-indices are similar to other journals that publish fewer papers (*AdWR*, *HESS*, and *JHM*), and the JHM *h*-indices are similar to other journals that publish more papers (*AdWR*, *HP*, and *HESS*). The *h*-indices are much more homogenous across journals in the time period since 2006.

The time series of journal impact factors (Figure 3) provides context for the annual impact factors. The 2 and 5 year impact factors have increased over time for all hydrology journals, most notably for *HESS*. However, there is substantial year-to-year variability in the 2 year journal impact factors, most evident in the rapid increase in the 2 year impact factor for *AdWR* from 2013 to 2015, followed by a dramatic decrease in

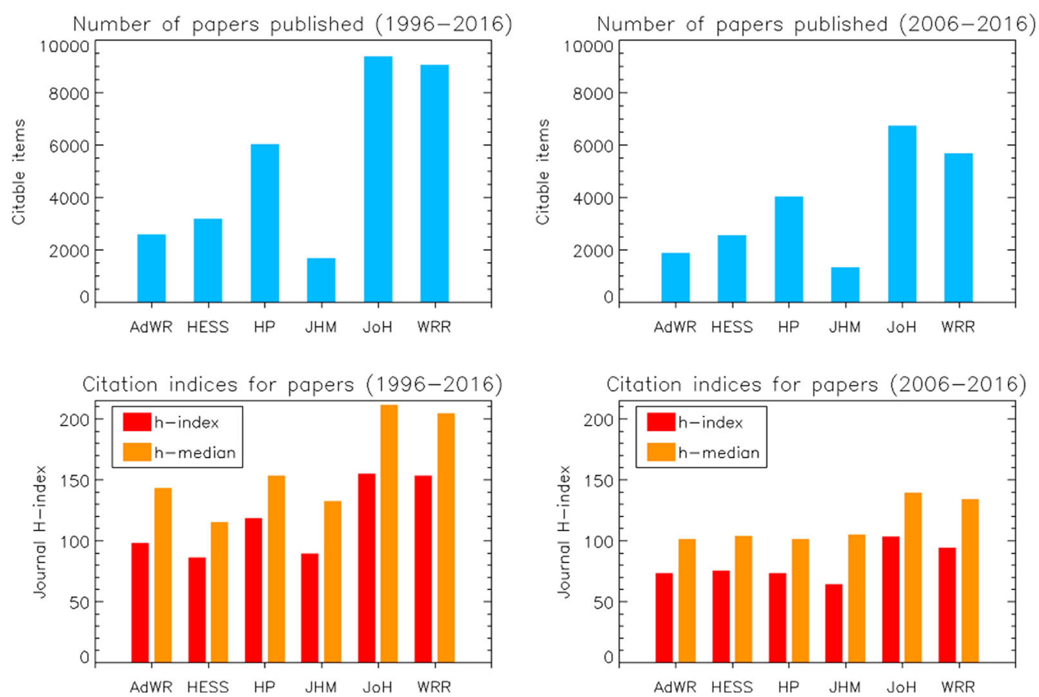

Figure 2. Comparison of the productivity and impact of hydrology journals, showing (top) the number of citable items published in each journal and (bottom) the *h*-index and the *h*-median citation statistics. The left and right set of plots show statistics for papers published since 1996 and 2006, respectively.

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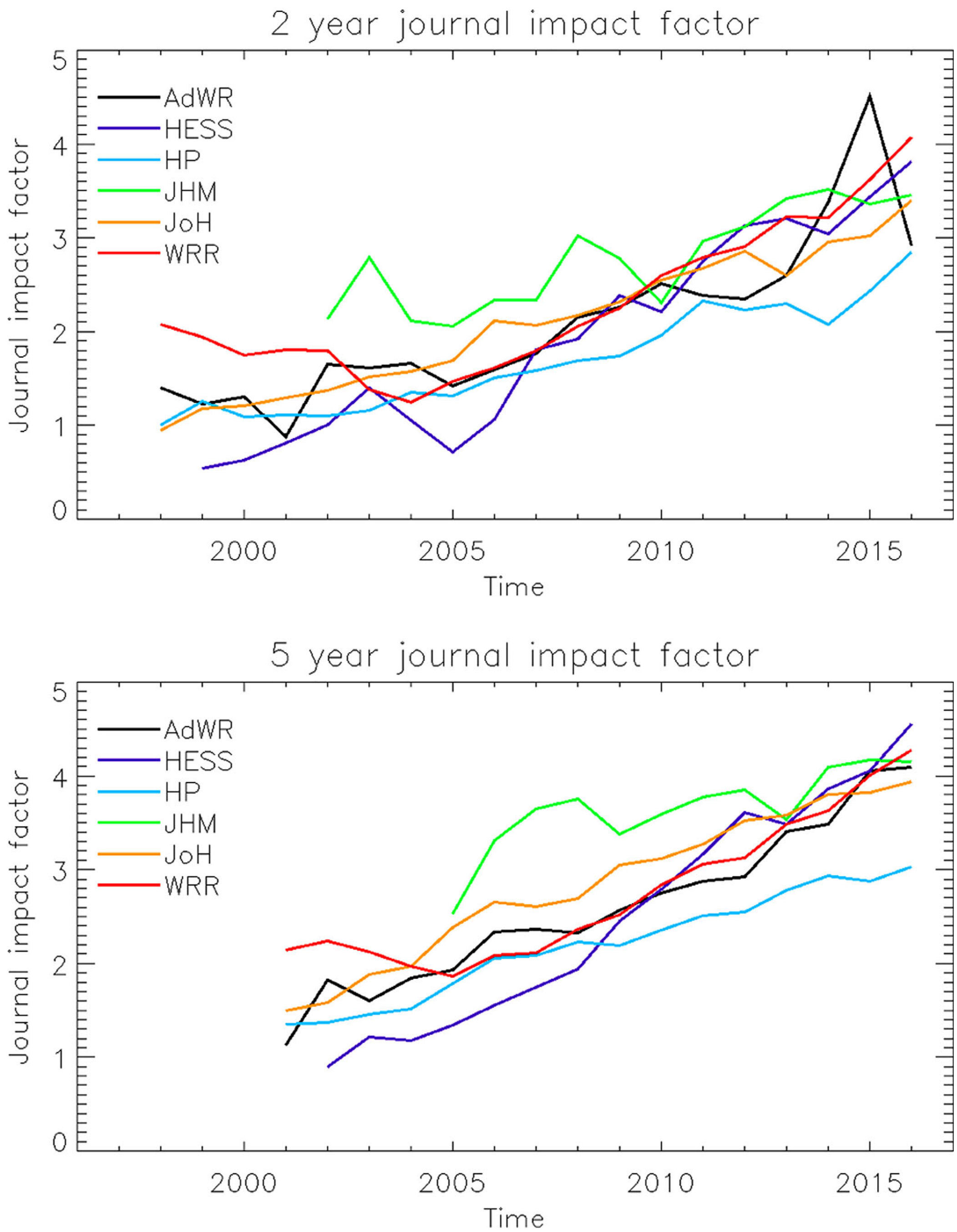

Figure 3. Trends in the impact of different journals: (top) 2 year impact factor and (bottom) 5 year impact factor.

2016. The peak for *AdWR* in 2015 occurs because ~30% of the 2015 *AdWR* citations come from the 27 papers in the *AdWR* 35 year anniversary issue that was published in 2013. Another interesting observation is that the impact factors were much higher for *JHM* than for other hydrology journals in the first decade of its existence; however, in recent years, *JHM* has an impact factor more similar to other hydrology journals. The initially high impact factor simply reflects the growth of a new journal [*Seglen*, 1997], where a few highly cited papers are normalized by a small number of in-window publications. The large year-to-year variability in Figure 3 means the journal impact factor in a given year should be interpreted cautiously.

Sampling analysis reveals substantial uncertainty in the 2 year impact factors (Figure 4): the uncertainty in journal impact factors is most pronounced for the smaller journals (Figure 4, left column), and a small number of highly cited papers have a large influence on the journal impact factor (Figure 4, right column). An interesting example is for *JHM*, where the 10 most highly cited papers contributed to more than 50% of the citations when *JHM* first started in 2003, and a single paper contributed 20% of the 2009 *JHM* citations. The substantial year-to-year variability and uncertainty in the impact factor calculations means that ranking hydrology journals by impact factor is not statistically meaningful (i.e., there is no leading hydrology journal on this basis).

The probability distribution of citation statistics (Figure 5) is remarkably similar across journals. For example, *AdWR*, *JHM*, *JoH*, and *WRR* all have a similar fraction of highly cited papers (in these journals ∼10% of papers have greater than 50 citations for the period 2006–2016). While some differences in citation distributions among journals are noteworthy—for example, *WRR* has a slightly smaller fraction of seldom-cited papers,

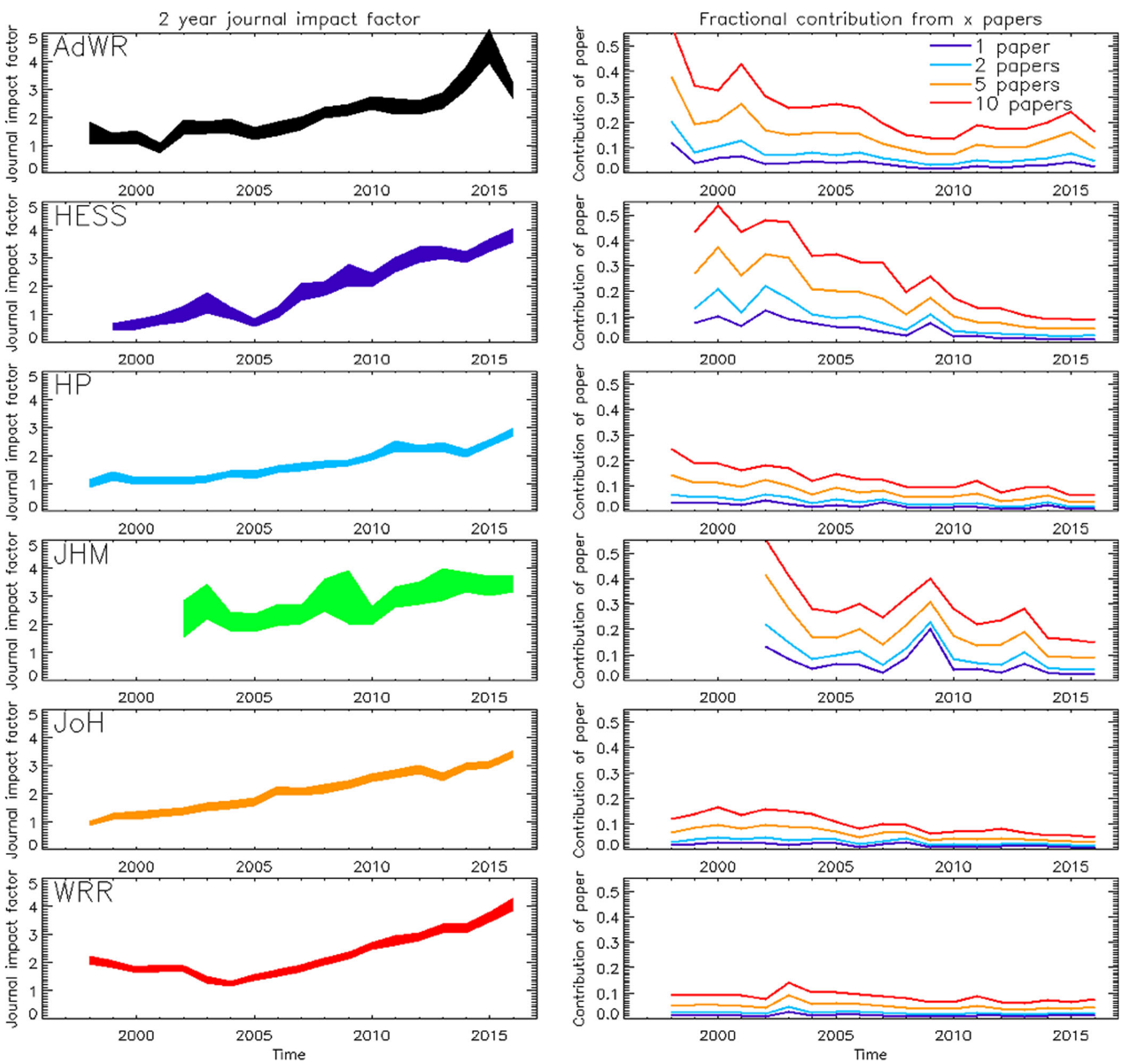

Figure 4. Uncertainty in the impact factor time series for each journal. (left column) The 5% and 95% confidence limits obtained by resampling the papers published in the 2 year impact factor window. (right column) The fraction of citations from 1, 2, 5, and 10 most highly cited papers in the 2 year impact factor window.

e.g., papers with less than 10 citations—inter-journal differences are never very pronounced. Such homogeneity in citation statistics suggests that useful papers will be recognized no matter which leading hydrology journal publishes them.

The distribution of the age of cited papers in individual years (Figure 6) helps explain the volatility of the impact factor. Peaks in citations clearly persist from year to year, especially for the smaller journals (e.g., *AdWR* and *JHM*). For example, the age distribution of articles cited from *AdWR* peaks at 1 year in 2014, at 2 years in 2015, and at 3 years in 2016. This behavior occurs because of the special *AdWR* 35 year anniversary issue published in 2013. Interestingly, in 2016, the *AdWR* 35 year anniversary issue is outside the 2 year citation window and hence does not contribute to the 2016 two year impact factor (see the dramatic drop in the 2016 *AdWR* impact factor in Figure 3). Similar behavior is evident for *JHM*, where the age distribution of articles cited in 2014, 2015, and 2016 peaks at 7, 8, and 9 years, respectively (Figure 6). This behavior can actually be traced all the way back to 2010 where a large fraction of citations can be attributed to papers published 3 years earlier. For *JHM*, the persistence in citations can be attributed to a single 2007 paper that contributed 27–45% of the citations during the years 2010–2016 (see Table 1). The large influence of individual issues (*AdWR*) and individual papers (*JHM*) again calls into question the robustness of annual journal impact factors for comparing journals.

The summary of the age distributions (Figure 7) describes both how quickly articles gain attention and the long-lasting impact of published papers. *HESS* articles tend to gain attention more quickly than the other hydrology journals, likely because *HESS* articles are made available to the community as discussion papers

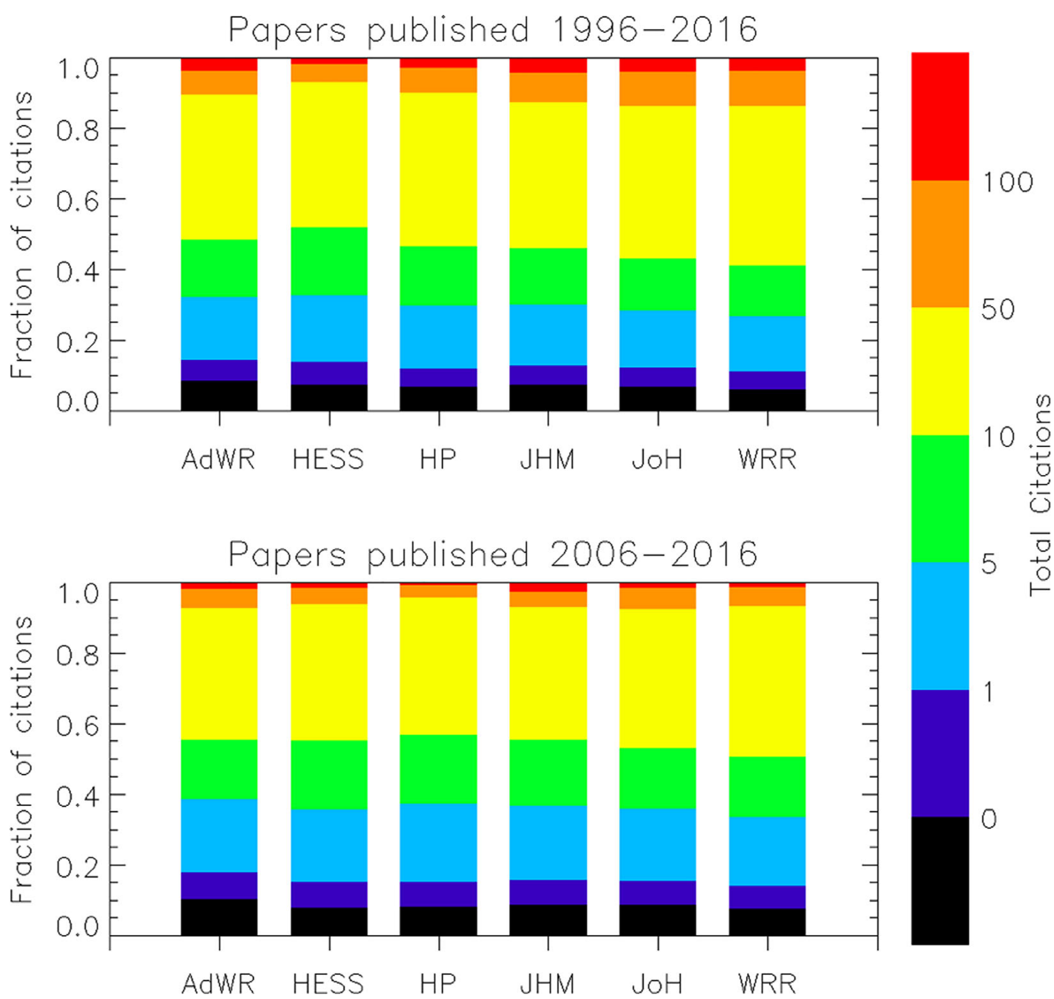

Figure 5. Comparison of the distribution of citations among hydrology journals: (top) papers published since 1996 and (bottom) papers published since 2006.

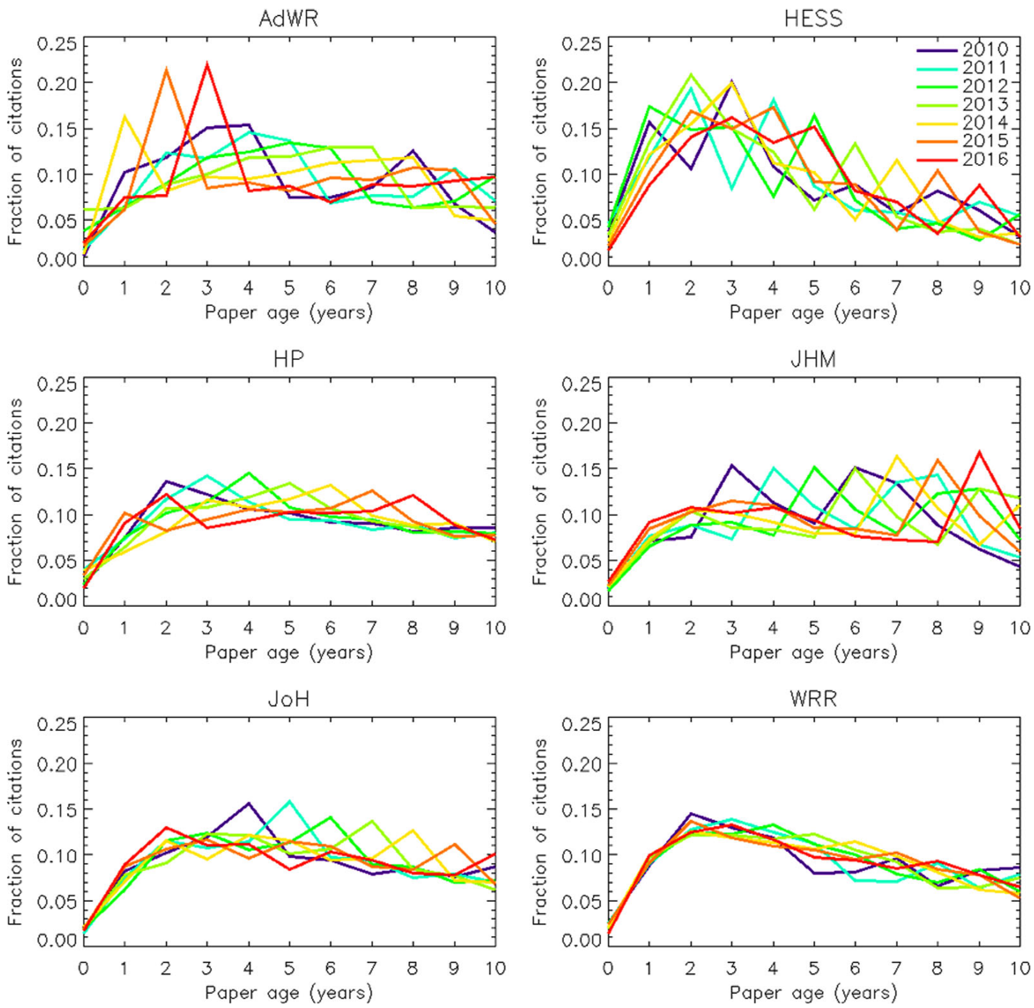

Figure 6. Fraction of papers cited of a given age within the previous 10 years, shown for papers cited in 2010–2016.

as soon as the articles are submitted (this is the temporal bias discussed by *Seglen* [1997]). More generally, papers published in hydrology journals tend to have a long-lasting impact, and a large fraction of papers are cited after the 2 year window used to calculate the journal impact factor.

4. Discussion

Our analysis highlights the disciplinary character of hydrology journals and the limitations with using journal impact factors for research assessment. Specifically, it is unreasonable to ask if hydrologists are publishing in journals with a high impact factor (e.g., journals with an impact factor above 5.0). Our results show that a large fraction of citations occur after the time window used to calculate the 2 year impact factor (Figure 7), suggesting that the 2 year journal impact factor, by itself, does not meaningfully quantify the citation impact of hydrology journals. More importantly, our results show that the 2 year impact factor is still below 5.0 for all leading hydrology journals (Figure 3). Assigning zero value to papers published in journals with

Table 1. Citations of *JHM* Papers Published in 2007

Year Papers Cited	2010	2011	2012	2013	2014	2015	2016
Most highly cited paper	150	143	197	260	319	362	393
Total citations	482	533	590	663	813	799	881
Fraction	0.31	0.27	0.33	0.39	0.39	0.45	0.45

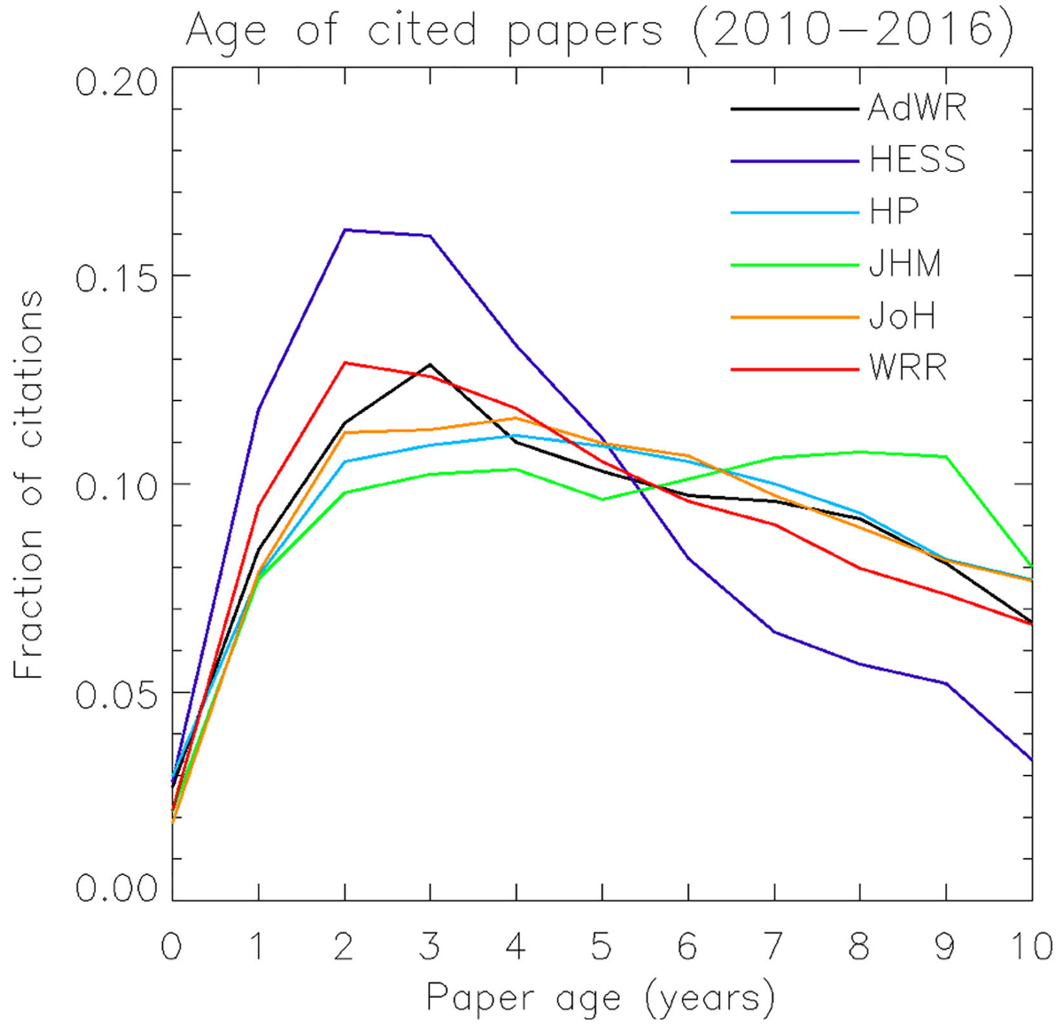

Figure 7. Summary of the age of cited papers (2010–2016).

an impact factor below 5.0 (as is done in some nations [*Alberts*, 2013]) restricts hydrologists from publishing in hydrology journals and potentially constrains the advancement of hydrologic science.

The misuse of journal impact factors for research assessment has received more widespread critique [*Alberts*, 2013; *Verma*, 2015]. Of concern is the pervasive and fallacious practice where academic institutions and funding agencies analyze journal impact factors to check if individuals are publishing in the top journals, and, by extension, to judge the quality of research output from individual scientists. This assessment is fallacious because journal impact factors depend on citations from individual papers, not the other way around [*Seglen*, 1997]. All journals have a large fraction of seldom-cited papers, and hence the quality of an individual paper cannot be determined based on where the paper is published [*Seglen*, 1997; *Rostami-Hodjegan and Tucker*, 2001; *Simons*, 2008; *Alberts*, 2013; *Verma*, 2015]. Moreover, the journal impact factor depends on the nature of the field—journal impact factors are higher in fields and journals that are young and rapidly expanding, in fields that are rapidly changing, and in fields where it is common to write articles that include a large number of coauthors and cite a large volume of previous work [*Seglen*, 1997; *Amin and Mabe*, 2004]. The disciplinary character of journal impact factors is often ignored in research evaluations. These considerations have motivated the American Society for Cell Biology to develop the Declaration on Research Assessment (DORA), http://www.ascb.org/dora/. DORA focuses on the scientific contributions of published papers, rather than where papers are published, in an attempt to reduce further misuse of journal impact factors for research assessment.

5. Conclusions

The analysis that we present in this Editorial provides a comprehensive assessment of the citation behavior of hydrology journals. Our main conclusions are:

1. The time series of 2 and 5 year impact factors is characterized by substantial year-to-year variability in impact factors. Analysis of the uncertainty in impact factors demonstrates that a small number of highly cited papers have a large effect on the journal impact factor, especially for the smaller journals. The substantial year-to-year variability and uncertainty in the impact factor calculations means the journal impact factor in a given year should be interpreted cautiously.
2. The probability distribution of citations is remarkably similar across journals. For example, *AdWR*, *JHM*, *JoH*, and *WRR* all have a similar fraction of highly cited papers, where ~10% of papers have greater than 50 citations. Such homogeneity in citation statistics suggests that useful papers will be recognized no matter which leading hydrology journal publishes them.
3. Papers published in hydrology journals tend to have a long-lasting impact, with a large fraction of papers cited after the 2 year window used to calculate the journal impact factor. Such citation behavior suggests that citation statistics should include those based on longer time windows than the 2 year impact factor.

The problems in using journal impact factors to evaluate hydrologic science motivate us to oppose the obsession with citation impact. Many organizations now recognize that the obsession with citation impact is hurting science and they are actively trying to improve the way that research is evaluated [*Alberts*, 2013; *Verma*, 2015]. There is greater awareness that the citation obsession discourages scientists from pursuing new areas of research that can take years to mature and publish, and, similarly, there is greater awareness that the citation obsession encourages scientists to work in fields that are populated with a large pool of people to reference new papers [*Alberts*, 2013]. There is also greater awareness that citation impact is very different from science impact, in the sense that citation impact represents utility rather than quality [*Seglen*, 1997] and that the utility of papers can take many years to be recognized (i.e., the sleeping beauties in science [*Van Raan*, 2004]). The DORA guidelines reduce pressure on authors to publish in journals that have a high impact factor [*Alberts*, 2013; *Verma*, 2015], which can, in turn, increase the focus on science advances and curtail questionable practices like citation coercion. In our opinion reducing the obsession on citation impact is necessary in order to enhance the quality and broader impacts of hydrologic science, and hence meet the high expectations that society has of hydrologists.

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