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Discussions

# *Interactive comment on* "The Future of Earth Observation in Hydrology" *by* Matthew F. McCabe et al.

**Matthew F. McCabe et al.**

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We thank Prof Kummerow for his thoughtful interactive comment. A number of important points are raised in this review, particularly regarding the issue of integrating the diverse data sets and sources that are emerging into a "coherent global framework". This is most definitely a community challenge, but as the reviewer implies, it is beyond the scope of this paper to address. However, it is an important point that requires some comment in a revised version. A number of other excellent points are raised in the review, and we respond to these individually below.

p. 7, line 10: The notion that we need a more appropriate error analysis before we can merge multiple sensors into a coherent framework is often repeated and yet to be implemented. Since this is a large part of what the paper is advocating for the future,



the authors should emphasize the critical need to advance this field rather than simply stating it as a necessity.

[Response] The purpose of Section 2.1 is to highlight some of the challenges and knowledge gaps in remote sensing that require community attention. The particular challenge of multi-sensor integration and error characterization is a key example of these challenges. In revising the paper, we can certainly draw stronger attention to this issue, as we agree that it is a critical element of any comprehensive observation strategy.

p. 29, line 22: Google's Earth Engine was developed by Google and follows Google's rules. Without a coordinating body in global hydrology, it becomes difficult to reproduce something like this.

[Response] Agreed. But it is also difficult to imagine the scientific community organizing themselves and then funding an initiative to replicate such a framework. Whether it is necessary to do so, given that these systems are relatively easy to access and (currently) not especially restrictive, is also a consideration. There are examples of private-public partnerships that seek to reproduce some of the same functions as Google Earth Engine and Amazon Web Server (see discussion on EODC p.30, line 15) which may serve as a model should these commercial facilities prove unsuitable for scientific application.

p. 34, line 27: The fallacy here is that it assumes that if SpaceX develops a very cheap launch vehicle, then NASA would launch its satellites on it. That is probably not the case. NASA would continue to develop new technologies that in its early stages, might be just as expensive as before.

[Response] Hopefully, NASA will continue to develop new technologies, as the commercial sector are unlikely to invest the significant resources required to do this: a point mentioned in our paper. However, in terms of delivering satellites into space and re-provisioning ISS, NASA is already utilizing commercial sector expertise, and this model seems likely to expand.

p. 30, line 22: Storage can get very large. While commercial vendors often discard old data which generates little revenue, this has never been the case in Earth Sciences. It again goes back to the question of funding data storage that belongs to the community rather than an "agency".

[Response] Yes, this is an important point, and there are examples within our own scientific communities where this has been done poorly. Further highlighting the importance of data archiving and stewardship can be addressed in a revised version of the paper. With the rise of AI and machine learning approaches, the importance of a long record of "training data" may be an incentive to effectively archive historical observations.

Abstract, line 10: The real time, high resolution video capabilities are surely new, but equally important for cloud development are the newly available JMA and NOAA 1min. geostationary data with 1 km resolution. CMA even has 60m resolution geostationary data with 30 sec. resolution. Given the size and speed with which clouds naturally evolve, it is not clear to me that 10 m data with 30 frames per second would revolutionize our understanding of clouds. I can better see the utility in tracking small scale, fast flows. In any case some careful rewording here would help.

[Response] Noted and we can revise the text (n.b. the HD video is on the order of 1m, not 10m). Perhaps "understanding" can be changed to "monitoring".

p. 6, line 5: Eliminate "radiative" – just visible and NIR frequencies is enough.

[Response] Noted

p. 6, line 6: It is now GOES-16 and authors should probably mention Himawari-8 as well. They do the same thing.

[Response] Noted



p. 9, Line 16: Doppler radars are good for judging speeds and rotation of convective elements. They don't do anything for rainfall estimation. I suggest that the author drop "Doppler" or replace it with "polarimetric".

[Response] Noted

p. 14, Line 5: Section 2 discussed variables independently. The author mentions that integration and a more holistic approach is necessary – but emergent capabilities and technologies are not the answer. They merely add observations. The text is not very clear here.

[Response] We agree that more observations will not directly resolve the issues raised in Section 2. The purpose of Section 3 (Emergent Capabilities and Technologies) is not to provide answers to these issues. A better transition paragraph to this section will be attempted in a revised version.

p. 14, line 11: The text starts out boldly predicting hydrology 50 years from now. The paper, however, focuses on things that are real today and probably represents the next 10-15 years. Perhaps that would be a better into?

[Response] The introductory line is definitely not intended to impart any bold or long term predictions of hydrology. Perhaps the comparison to the developments and improvements in our transportation system is not the clearest analogy. We will review this. Our focus is certainly more on the near-term (5-10 year horizon), highlighting technologies that for the most part have emerged within the last few years, but which we believe have the potential to play a much larger role in EO strategies and in advancing the EO landscape.

p. 14: Line 33: Perhaps Japan should be mentioned as well.

[Response] Noted

p. 18, line 25: The balloon section needs a few more caveats. Since high altitude balloons have been around for a long time, and the authors fail to make a case that commercial balloons for telecom would somehow change their utility or cost, some argument for why we might see a resurgence of balloon-based observing systems should be put forth.

[Response] The argument here is that commercial enterprises (i.e. Google and Facebook) have active programs exploring the use of manoeuvrable high-altitude balloons and/or autonomous planes. This is driven by commercial motives for the most part. Whether our community can leverage this for scientific purposes remains unclear. We can more clearly articulate this in a revision if necessary, as well as some of the caveats.

p. 18, line 32: “constructed” instead of “constructing”.

[Response] Noted

p. 21, line 19: perhaps the authors need to still remind readers that while passive systems in the VIS/IR are quite feasible, the power needed by active sensors still limits these systems today.

[Response] Noted

p. 23, line 5: I think the authors could come up with a better example here. Rain gauge records are often protected for various geopolitical reasons. It is not clear to me that the rain gauge records from the Congo have not been released simply because nobody in the office has a smartphone.

[Response] Noted. The political and bureaucratic issues are also worth highlighting.

p. 24, line 12: The authors might want to include CoCoRAHs https://www.cocorahs.org/ Which, on a given day, receives roughly 7000 daily rain gauge reports) from citizen scientists.

[Response] Thank you and noted.

p. 25, line 20: Perhaps it is worth noting that the “entire country” was the Netherlands



and that this would not work for countries like the US where many rural areas do not have nearly enough cell phone towers to apply this technique.

[Response] Noted.

p. 27, line 3: Commercial aircraft started making turbulence measurements as well. See Sharman et al., Description and Derived Climatologies of Automated In Situ Eddy Dissipation-Rate, 2014. Appl. Met. and Clim., 53, 1416-1432

[Response] Noted and we will include this reference.

p. 27, line 25. The same issue pointed out in the abstract.

[Response] Noted and we will highlight some additional aspects where HD Video may be better suited.

p. 33, line 4: The risk averse nature of space agencies is true. The rationale is the authors’ interpretation. I would argue that they are risk averse because it takes so long to reach a scientific consensus. The PI led missions have very short time frames – similar to industry. Perhaps pointing out that facility type missions are risk averse while PI missions can be much more nimble is a better way of expressing this.

[Response] Noted.

p. 35, line 20: At least NASA is shifting into smaller missions via Earth Ventures. This should be acknowledged although it is equally true that NASA’s mission would probably not support a much greater emphasis in small Earth Venture missions.

[Response] Noted. ESA (and other agencies) are also pursuing smaller missions which we can further highlight. The issue of cost versus quality (i.e. commercial radiometric requirements are probably not as strict those from space agencies) is an important element of this discussion.

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