

Interactive comment on “Tracking the direct impact of rainfall on groundwater at Mt. Fuji by multiple analyses including microbial DNA” by Ayumi Sugiyama et al.

Anonymous Referee #1

Received and published: 26 April 2016

This paper makes the point that groundwater mean ages integrate a range of transport times in subsurface waters at Mt. Fuji. In particular, they use unique tracers, including microbial community composition, to demonstrate rapid transport during storm events. They also use the δ stable isotopes to identify the elevation range of source waters during these events, and distinguish temporal responses of shallower and deeper components of the groundwater. A main point of the paper is that microbial DNA can provide a new tracer that has unique information about the sources and flushing of groundwater.

General comments: This is an interesting paper that has novelty in the use of microbial DNA changes to infer groundwater sources. It also reports responses of groundwater and runoff chemistry to extreme precipitation events and what can be learned from

C1

chemical versus DNA changes.

As written, the paper was very difficult to follow. This is not just a problem of language (which needs improvement), but also of structure. For example, the introduction introduces the special case of Mt. Fuji in the middle of a series of paragraph that talk about different methods used to trace groundwater flow times. For the reader, it would be much easier to follow if the authors first introduced the overall problem (using chemical and isotopic properties to separate groundwater and streamflow into sources that have a range of residence times), and why Mt Fuji is a good laboratory to test new methods (including DNA). Then a description of the methods that have been applied to trace groundwater flow and estimate residence times, including their shortcomings (i.e. they only provide averages in most cases). Then how extreme events can be used in concert with these methods to indicate the rate and magnitude of response (i.e. the current study).

Two issues I found I did not fully understand in this study. First, the stable isotopes of water in precipitation will likely differ for high rainfall events from long term averages (i.e. they should be heavier at all elevations). These are given in Table 1, but it was not really clear to me how the conclusions about where the water was coming from were based on actual rainfall measurements during the storm events at the various elevations.

Second, Table 1 shows that dissolved O₂ levels are still about 80% of saturation in the deep aquifer. Yet the Archea being flushed out are obligate anaerobes. One could take this to mean that there are anaerobic ‘pockets’ that are not measured under average conditions, and only get flushed out when there is an extreme event. This would be supported if there were a strong decline in DO (and an increase in Na⁺) in the waters that have high Archea – is that the case? If not, are there other supporting data indicating that these waters are flushing out cracks?

In summary, I think this paper has novel elements, but it needs editing for clarity and

C2

structure, as well as language to be publishable. The Wei et al. paper (and others indicating piston flow water residence times/flows) should be introduced first, when discussing the site itself, rather than very late in the paper, so that the reader does not get confused about the flow paths and water sources (at least what was initially thought) for G1-G4. What is the source for the arrows indicating flow direction in Figure 1?

It was hard for me as a reader to keep these sites and their differences straight – perhaps the name could be changed to include more information .e.g. G1 could be Spring1- 0m, G2 could be Groundwater well 1- and give depth, etc. That would help the reader remember that one is a deep well, one a shallow well, etc.

Specific comments:

Page 2, Line 12. The term “runoff processes of groundwater” seems a little strange (to a non-hydrologist). I think of runoff as a process mostly associated with overland flow (i.e. not groundwater). Perhaps a less confusing expression of the same idea could be “Effect of rainwater on groundwater”

Page 2, Line 23. Start of the sentence should read “Our ongoing microbiological study. . .”

Page 2, Line27. “ This depth is far below the lava layer that was taken to be a substantial pool of groundwater.” I do not understand this sentence. If there is a lava layer closer to the surface, why could that not be the source of warmer water and thermophiles? Also, I think what is meant here is that the lava layer formed a barrier to infiltration and thus provided the base for an aquifer? There should be a reference given for the geotherm at Mt. Fuji.

Page 3, line 30. “Groundwater discharge was measured”. Does this mean the spring waters sampled? Is the assumption that all groundwater eventually leaves as springs? IN figure 1, it is almost impossible to understand where G1 - G4 are in relation to each other. It is only in the figure caption that we know these are either spring water or

C3

shallow wells.

Page 4, lines 9-13. The authors should mention if there was any treatment to remove DOC from water (and if not, what the DOC concentration range was). Organic C has been shown to affect the analysis (see REF).

Page 4, line 19-20. Please spell out acronyms (TDC, CARD-FISH) the first time they are used.

Page 5, line 23. “ We studied four rainfall events from 2012 to 2014 at the foot of Mt. Fuji.” Did the rain only fall at the foot of Mt Fuji, or do you mean that you sampled springs and rivers at the foot of Mt Fuji? Probably precipitation intensity varied with altitude – were the measurements of rainfall amount given made at the base of Mt. Fuji?

Can you give an estimate of the volume of groundwater compared to the volume of rainfall? (Even based on the average residence time and the annual rainfall?) It seems the largest events are flushing a large fraction of the groundwater out – does that make sense compared to the other estimate based on ‘average’ conditions?

Page 6, line 6. At what elevation was the isotopic composition of rainwater measured? In Table 1 it is indicated that rainwater was measured at several elevations. Obviously it is heavier than the groundwater, so the inference is that most groundwater source is at higher elevation? If the rain water is measured only at the foot of Mt. Fuji, this can tell us about ‘local’ sources versus groundwater sources, but if there was also a high amount of rainfall at high elevation that would perhaps not be distinguishable?

Figure 2. caption - “the number gives the average value of the variable”. Average over what time scale (most seem outside the range of measurements in the figure?)

Supplemental material. I think not all readers of Biogeosciences will be familiar with the use of hexadiagrams (they are new to this reviewer). Perhaps the authors could add a brief definition to the figure caption.

C4

