Review of Zocatelli et al

Spatial moments of catchment rainfall: rainfall spatial organisation, basin morphology, and flood response

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Summary

The paper defines scaled spatial rainfall moments, using flow distance as a spatial coordinate, and defines a catchment-scale storm velocity. Zocatelli et al show that scaled spatial moments of catchment rainfall are useful for explaining moments of runoff transport time. They use examples with observed rainfall data to quantify and discuss the spatial moments, and conduct a sensitivity analysis.

Main Points

1. *"In this paper, the rainfall spatial organization is analysed with respect to the flow distance, i.e. the distance along the runoff flow path from a given point to the outlet."* The authors need to make explicit what is the rationale for this choice – i.e., the assumption that distance is a useful surrogate for travel time (variations in celerity can be neglected), and that this travel time (and its variation) is an important determinant of hydrograph response (hydrodynamic dispersion can be neglected)

2. *"the river network geometry plays a central role in the structure of the catchment dampening properties"*
   This statement is unclear to me; a reader might infer that the network is always a dominant factor in determining the damping. The work of Woods and Sivapalan (1999) and Viglione et al (2010) (hereafter V2010) both show that network geometry dominates only in some cases.

3. *Equations (3) & (5).*
   The positive and negative signs of covariance terms of V2010 contain much the same information as scaled rainfall moments being greater or less than unity. Equations (3) & (5). Do the variables δ_1 and δ_2 or Δ_1 and Δ_2 correspond to variables in V2010? Which ones? Are they are generalisations of components of the moments of network travel time described in Woods and Sivapalan (1999; Appendix C3)? Zocatelli et al (hereafter Z2011) need to make clear the significance of Equations (3) & (5) in relation to what was already done.

4. *"The computation of the catchment-scale storm velocity …"*
   It appears that a time derivative of δ_1 is needed for this computation. Plate 1 indicates that δ_1 includes significant noise which would need to be smoothed before a useful derivative could be computed. A comment on this might be useful in the paper.

5. *Equation (9)*
   V2010's Equation (19) is an equivalent expression for the same quantity given in Equation (9), but V2010 separates the term into additive contributions from network geometry and rainfall variability, while Z2011 provide a separation into multiplicative factors. What is the advantage of writing the expression in the form of Equation (9) instead? The interpretations, in terms of the effects on timing of rain falling near to, or far from, the catchment outlet, seem to be exactly the same.
   Compare these two equations for what is, I believe, the same quantity in the special case that all rain runs off and hillslope transport is not separated out from river channel transport:

$$E(T_n) = \underbrace{\frac{D_{x,y}}{v}}_{\text{En1}} + \underbrace{\frac{\mathrm{cov}_{x,y}(D, R_t)}{v \cdot R_{x,y,t}}}_{\text{En2}}$$

V2010 Eq (19)

$$E(T_c) = \frac{\int_0^{T_s}\left[\int_0^A r(x,y,t)d(x,y)dA\right]dt}{AT_sP_0v} = \frac{P_1}{P_0v} = \Delta_1 g_1 \frac{1}{v}$$

Z2011 Eq (9)

To what extent is Z2011 simply a relabelling of the terms in V2010? Is it correct to say that

$$\Delta_1 = 1 + \frac{\mathrm{cov}_{x,y}(D, R_t)}{D_{x,y}.R_{x,y,t}}$$

What do the authors consider to be the advantages and disadvantages of taking a spatial moment approach as opposed to the mean-covariance approach of V2010? Perhaps this should be addressed in the Discussion or Conclusions.

6. *"One should note that the storm velocity has no influence on E(Tq)."*
   This statement needs a little qualification before it can be accepted. It depends on many of the assumptions made previously (e.g. the neglect of runoff generation processes, the assumed time-invariant celerity).

7. *"The role of catchment scale storm velocity is represented by the term of Cov(Tr, Tc)."*
   The authors needed to provide some justification for, or elaboration of, this statement.

8. *Equation (15)*
   It seems that the authors make use of a connection between g_1 Δ_1 and some covariance terms. What are these relationships? This would assist readers trying to understand how this work relates to V2010.

9. *"Details about the application of the model to the individual events, its calibration and its verification are reported in the relevant papers"*
   A very brief summary of the adequacy of the model verification is needed here; e.g. did it work equally well on all 5 catchments?

10. *Plate1 and Plate 2*
    The time series for δ_1, δ_2 and velocity include fluctuations of several different magnitudes and timescales. It is not clear which fluctuations are significant, and which are a consequence of measurement uncertainty when using radar rainfall. Some kind of uncertainty analysis would be very helpful. For example, if these time series for δ_1, δ_2 and velocity were computed 50 times, each time with a different realisation of "noise" added to each radar rainfall field, which features of the time series in Plates 1 and 2 would remain?

11. *"it seems that the intriguing overlapping between the theoretical analysis represented by Eq. (19) and the empirical results represented by Eq. (21) needs to be substantiated"*
    The theory of V2010 provides guidance on how to explore counter-intuitive results of this type, and I think it should be applied here. For example, is there a correlation between hillslope residence time and flow distance? Is it large enough to explain the timing shifts?
    I think that the authors need to provide more justification to support the results, since they are somewhat unexpected. Can the authors confirm that if the hillslope residence time is reduced to very near zero, the slope of the line in Figure 4a changes from 0.33 to a value near 1.0?
    The 0.91 slope in Figure 4b was quite unexpected for me, in the light of the 0.33 slope for the previous case. The authors could assist the reader by providing a discussion of the spatial and temporal variability of the modelled surface runoff generation, and giving an indication of the relative amounts of runoff generated by surface and subsurface pathways. Again, the theory of V2010 could be usefully applied, rather than leaving the reader with an unexplained conundrum.

Minor comments

12. *P 5813*
    Spelling of Skojen – should this be Skøien?

13. *"This paper builds upon and generalizes the work presented in Wood and Sivapalan (1999)"*
    Wood should be Wood**s**.

14. *Equation (15)*
    Several terms are not defined. E.g. Var[T] D R P(x,y)

15. *Equation (16)*
    You defined V(t) as being the catchment scale storm velocity, and then later use the same phrase to describe Vs. Surely the same phrase can't mean two different things? What is the relationship between V(t) and Vs? Is Vs the time-average of V(t)?

16. *Equation (17)*
    has a misplaced "-" sign: it should be between the two covariance terms.