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Hydrology and Earth System Sciences Discussions

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Interactive Comment

Interactive comment on “The spatial variability of snow water equivalent” *by* T. Skaugen

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Editor comments. The Editor has three principle comments on the paper: 1.) “The assumption of ergodicity is dubious and wrongfully applied due to i) the precipitation process has a constant covariance, then it is not ergodic and ii) SWE is calculated by summation of the underlying precipitation process. Even if precipitation is stationary, then the integrated process is not stationary and, naturally non-ergodic. It is also pointed out that temporal variability of precipitation is too large to represent the spatial variability at such small scales as 2 km”. Reply: We have made the approximation that there is a constant (p 1470, l.7) covariance between the stochastic fields of units (not in actual daily precipitation which would be arbitrary sums of units), and it has been discussed in the paper as the average temporal correlation over total number of events (p.1476, l.14). This is, in the authors view compatible with an assumption of ergodicity. Let us assume an ensemble of innumerable points within the area of interest had the same marginal distribution of positive precipitation. If all the statistics (also covari-

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ance) are invariant for subsets of the time series within the ensemble, the ensemble is ergodic (J.C. Davies, Statistics and data analysis in geology, 2.nd. edition, 1986, p.259). So, the covariance function should not be a function of which subset is studied. The assumption of constant covariance is equivalent of stating that the covariance is also independent of temporal lag, or as stated in the paper, of representing the lag-dependent covariance with its temporal mean. It is very difficult to see how this can be incompatible with the assumption of ergodicity.

The second point comments on that the integrated process (summation of stochastic unit fields to make the distribution of SWE) is non-ergodic. Of this I agree. It is only the units that are assumed to be ergodic (and only for the purpose of guessing at the parameters of y). The units are obviously considered stationary (although, again, not daily precipitation which would be arbitrary sums of units), but arbitrary sums of units is, due to correlation, non-ergodic. Finally, in regard to the discussion on ergodicity. As mentioned in my reply to R#1, the ergodicity assumption is a relatively small part of the paper, and not an intrinsic part of the model. The main part of the work is to estimate the spatial distribution of the sums and differences of correlated stochastic fields. The ergodicity assumption came into play only when, in the application of the model, we needed to make a guess of the parameters of the spatial distribution of the units.

Temporal vs spatial variability. The variability of the time series is too large to be representative of spatial variability of small scales 2 km. I agree with this point, and if the difference was substantial, we would probably overestimate the spatial variance, as the covariance, in the accumulation phase represents a positive contribution to the spatial variance (see equation 3 and Figure 1.) It is possible that the correlation coefficient c (which is a tuned parameter and not estimated from data) compensates for this, and that it really should be higher. A paragraph with this discussion can be inserted in the revised manuscript.

2.) “The gamma distribution can only be summed when we have independent gamma distributions with identical scale parameter”. Reply: Agreed, and a major part of the pa-

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per (section 2) is devoted to this problem which was dealt with in the following manner: Trough, for example, the equations 2 and 3, and the assumption of a constant covariance between the stochastic unit fields, we could determine the mean and the variance of the sum. We can easily determine new values of the shape “n*ny”, and scale “alfa” parameter from the mean and the variance, where n is the number of stochastic unit fields in the sum. These new values of “ny” and “alfa” (equations 7 and 8) are the parameters of independent stochastic fields, termed Y in the paper, since we have the condition that the variance of the sum of the Ys is the sum of the individual variances of Y. The Ys are kind of dummy variables, in that their parameters change after each new summation. The point is that we, at any time, can claim that the spatial distribution of SWE can be modelled as the sum of independent (although fictitious) stochastic fields Y.

3.) “The spatial distribution of melt is assumed identical to that of snowfall. This is dubious due to the different meteorological processes involved”. Reply: I agree that this is a weak point as indeed there are quite different meteorological processes at work, which is duly pointed out in the paper (p.1473, l.1). There are no data available to the author’s knowledge on the spatial distribution of snowmelt, and certainly not applicable for the methodology of using units as presented here in this paper. However, inspired by literature (Essery and Pomeroy, 2004, cited in the paper) the same distribution was chosen for accumulation and melt. The spatial distribution of daily melt, measured on fixed time intervals (say, daily) is obviously non-stationary. The proposed method takes that into account in the way that different number of units (typically increasing in spring) gives different spatial distributions of melt, thus mimicking a non-stationary process. The very good agreement between simulated and observed CDF (Fig.7), in late spring (28 May) shows that the assumption of using identical distributions of the units of melt and accumulation does not weaken the performance of the model.

Finally I would like to mention a point I find curious. Nobody has commented on the, what I find, very favourable comparisons of the proposed model with observed data and with models operationally used in many countries. In my view these comparisons strongly supports the proposed model.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 4, 1465, 2007.