Exploiting the scale invariance feature of the critical behaviour of soil moisture dynamics

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Recently we have proposed a novel approach dealing with soil moisture organization on the basis of concepts of the percolation theory and the renormalization group method (Di Domenico et al., 2007). When in a physical system a geometrical phase transition occurs showing a critical behaviour, it is possible to observe the onset of scale-invariance.

The soil moisture spatial patterns show a behaviour similar to phase transition processes when changing, in their seasonal time dynamics, from spatially random to spatially connected appearances as conditions become wetter. Such phenomenon is driven by the onset of lateral redistribution, which provides the conditions for the growth of the contributing areas.

Working on the Agri catchment (southern Italy), we demonstrated that such phase change shows critical point behaviour. In addition, the value of the critical probability seems to be an intrinsic characteristic of a catchment, being insensitive to renormalization (rescaling), as well as to model parameterization.

The aim of this work can be summarized into three goals:

1. to evaluate the generality of the methodology by considering other soil moisture data sources;
2. to explore the relationship between geomorphologic indices and critical point;
3. to assess the role of renormalization in problems of optimal monitoring scales.

In order to assess the generality of the methodology we decided to perform further applications on other river basins. Indeed, we considered the soil moisture data provided by the hydrological model TOPMODEL-based land-surface-atmosphere transfer scheme (TOPLATS) on the Red and Arkansas basins in the south-central United States (Crow and Wood, 2002). From the 1 km grid covering the entire 575000 km^2 Red and Arkansas basins, we selected several sub-basins, then we processed one year of daily soil moisture maps. We verified the critical behaviour and we determined the critical probability for each sub-basin.

With respect to point 2, it is worth to believe two different processes driven by the morphology of the catchment and experiencing scale invariant behaviour being related. Thus the relationship between critical point and morphologic features of drainage basin, such as bifurcation and elongation ratio, fractal dimension and informational entropy has been investigated. Critical point tends to be lower for basins with more organized morphological structures.

Finally, we investigated the possibility of taking advantage of the scale invariance feature in the definition of the monitoring scale of soil moisture. The maximum pixel size at which rescaled soil moisture maps show the same critical point should be the upper limit of monitoring (or ensemble scheming) scale.

References

Crow, W. T. and Wood, E. F., The value of coarse-scale soil moisture observations for regional surface energy balance modelling, Journal of Hydrometeorology, 3, pp. 467–482, 2002.

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