

Interactive comment on “Earth’s Critical Zone and hydrogeology: concepts, characteristics, and advances” by H. S. Lin

Anonymous Referee #2

Received and published: 10 June 2009

The paper of Hery Lin on the “Earth’s Critical Zone and hydrogeology: concepts, characteristics, and advances” is a timely and important contribution to the science of terrestrial processes and systems as well as to the discussion on the challenges in terrestrial research for the 21st century. It points out the necessity of an integrated approach that needs to be embedded in a holistic perception of the interaction between the different compartments of the Earth’s system. Specifically the paper addresses the interaction between the CZ concept and the recently emerged new discipline “hydrogeology”.

Although I am convinced that the critical zone is an excellent concept to point out the importance of this thin layer (compared to the Earth’s diameter) embracing the Earth,

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I feel that there is a need for a clear definition of what exactly the Critical Zone is referring to. In the paper there are many tentative descriptions of what a CZ is or is not, but still a clear formulation is missing and in my opinion it is needed in order to provide a consistent discussion throughout the paper. Is the CZ an holistic framework for integrating studies of water, soil, rock, air and biotic resources in terrestrial environments (line 2, page 3418), a platform for synergetic collaboration across disciplines (line 16, page 3418) or is it the heterogeneous near surface environment in which complex interactions involving rock, soil, water, air and living organisms regulate the natural habitat and determine availability of life sustaining resources (line 5, 3422). In the first definition it is not a natural system whereas in the last one it is. Yet another definition can be found at line 23, page 3430 where the CZ is defined as the zone where all humans live and where population growth, urbanization, and industrialization all have put increasing pressure on the CZ. The author should use a consistent definition of CZ throughout the paper and then derive the research needs and scientific questions. I propose to provide a definition of CZ at the end of section 2.1 and to work with this definition throughout the paper.

The paper is very long and I think it can be shortened without losing much of its messages. The paper suffers a bit from the fact that it wants to present both the concepts, characteristics and advances for the Critical Zone (and CZ research/science) and hydrogeology and at the same time it aims at addressing and discussing the link between both of them. It might be better to focus on either the Critical Zone, the relevant scientific questions, the methods and approaches needed to solve these questions and its links with other disciplines (hydrogeology being one of them) or to focus on hydrogeology and the role CZ can play in advancing this field of research. Focussing on the Critical Zone has a major advantage as it will allow identifying the contribution needed from all geoscience disciplines rather than from hydrogeology alone. In addition, it would be good to point out the new elements added in the discussion and presentation of hydrogeology with respect to other publications on this topic.

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Specific comments:

It would be useful to the readers to set CZ in a perspective with respect to ongoing activities of establishing ecological, hydrological and environmental observatories worldwide and to work out the difference and eventual overlaps between the different approaches underlying these observatories. It would also be good to address briefly the actual state of the three Critical Zone Observatories established in the US since 2007. This might be helpful to better understand the underlying approaches and the observation strategies implemented at these sites. What are the lessons learned and what are the future developments in terms of modelling and monitoring?

In addition to addressing the issue of geological and biological cycles (section 2) it may be more important to stress that geological and biological processes operate at different spatial and temporal scales rather than focussing on the cyclic nature. In addition to better defining the spatial extent of the CZ it would be good to consider a better definition of the key temporal scales relevant for the main processes in the CZ.

The term coupled systems is not really addressed in this section. It would be good to elaborate more on this issue by specifically addressing how the various subsystems of the CZ are coupled and which processes and feedbacks mechanisms are involved. Why is it e.g. important to couple systems and what are the challenges and deficits in our understanding. Interesting issues are e.g the effect of changing groundwater levels on the energy balance at the soil surface and its impact on local meteorology (e.g. Maxwell and Kollet, 2008), the coupling between the subsurface environment and river systems (Sophocleous M, 2002) or the interaction between the atmosphere and terrestrial ecosystems (E.g. Pielke et al., 1998).

Also in section 2.2.1 the author states that the formation of the CZ is mainly attributed to the impact of geological and biological activity. However, the CZ is also the result of past and present human activity (e.g. land use change from forest to agricultural land) or the presently ongoing climate change in many regions of the world. In addition

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we are dealing with feedback mechanisms and complex interactions between the different compartments. As the CZ is the skin of the Earth, these activities and complex feedback mechanisms are more likely to shape the future of this zone rather than the geological processes occurring at larger time and space scales. It should also be made more explicit in how far e.g. tectonic processes (section 2.2) are relevant for processes occurring in the CZ.

In the discussion on heterogeneity and hierarchical patterns it would be useful to start off with presenting the types and scales of heterogeneity encountered in the CZ. These scales may include the local scale, the field/hillslope scale, the catchment and regional scale. At each scale specific heterogeneities are occurring. At the local scale, heterogeneities may e.g. be determined by variability in physical/chemical/biological properties whereas at the catchment scale variability and patterns in soils and vegetation may be more typical. By using these scales one automatically includes a horizontal component in the presentation of the CZ which is important especially when one wants to focus on water as the key driver for many processes in the CZ.

An important element of the CZ is the presence of interfaces between two or more compartments. The role of these interfaces in understanding the interactions and feedbacks between the different compartments and their regulatory impact on many processes and compartments of the Earth system (e.g. land surface atmosphere interaction; soil-groundwater-river interaction) is essential and should deserve more attention in terms of defining research questions for these interfaces. Perhaps it would be good use the presence of key interfaces in CZ as a part of its definition and uniqueness.

I propose to start the section 3 with the fundamentals of hydrogeology (now 3.2) and then present the characteristics and its links to CZ science. The paper would benefit from a more explicit definition of Critical Zone science. What is the CZ science and which disciplines does it cover?

Some of the important features of hydrogeology (line 16, page 3437) are not really

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unique to this discipline such as “opening the black box of the soil system by closely examining soil structural heterogeneity and soil distribution pattern in the landscape, rather than treating soil as a simple homogeneous layer” or viewing the soil as a living entity. These assets belong to many soil science disciplines. In the scientific questions, the author refers to landscape water but does not really define what he means by this. Is landscape water the water that does not enter the soil profile and is lost by surface runoff to the river system, or is it the water that is contained in surface water systems? A clarification would be helpful to the reader. As mentioned above, research on the role and importance of interfaces between the hydrosphere (e.g. rivers, groundwater) and the soil appears to me an important asset of hydrogeology.

The summary and conclusion are very general and would benefit from a more focussed and specific formulation of key steps or actions that need to be taken in order to achieve advancements in our understanding of the functioning of the CZ. The establishment of a global alliance for monitoring-mapping-modeling is one of these steps that need to be taken but most likely not the only one.

References:

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