HESS Review Criteria

Principal criteria	Excellent (1)	Good (2)	Fair (3)	Poor (3)
Scientific significance: Does the manuscript represent a substantial contribution to scientific progress within the scope of Hydrology and Earth System Sciences (substantial new concepts, ideas, methods, or data)?		Substantial and impressive new datasets, and broadens applications of ERT methods.		
Scientific quality: Are the scientific approach and applied methods valid? Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)?		I am not familiar with ERT methods, but the presentation and discussion of methods, data, and results felt appropriate, though at times difficult to understand without detailed prior knowledge of the method.		
Presentation quality: Are the scientific results and conclusions presented in a clear, concise, and well-structured way (number and quality of figures/tables, appropriate use of English language)?			Writing has many small spelling/grammar/typo issues, and structure of sentences and paragraphs is often not clear. This paper could probably be much shorter.	

Does the paper address relevant scientific questions within the scope of HESS?

Yes. Seasonal variation in subsurface water flow processes in complex karst systems.

Does the paper present novel concepts, ideas, tools, or data?

Yes. Significant, comprehensive, multi-year, multi-instrument dataset, and expanded applications of ERT methods. The data will be made freely available.

Are substantial conclusions reached?

Somewhat. The ERT data supported a commonly-accepted model of karst aquifer functioning, and provided detailed information describing the flow patterns sustaining cave drip discharge. The authors hope that this data will support modeling, but it is not clear whether enough generalizable information is provided to support modeling in other karst systems or only in this specific location. If a semi-permanent ERT installation is needed to detect preferential flow paths in every aquifer we wish to model, the costs are likely too high to make it feasible.

Are the scientific methods and assumptions valid and clearly outlined?

Based on my limited familiarity with ERT methods, yes.

Are the results sufficient to support the interpretations and conclusions?

Based on my limited familiarity with ERT methods, yes.

Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

Based on my limited familiarity with ERT methods, yes.

Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Based on my knowledge of the literature, yes.

Does the title clearly reflect the contents of the paper?

Yes.

Does the abstract provide a concise and complete summary?

Yes.

Is the overall presentation well structured and clear?

Somewhat. The paper is quite long, and would therefore benefit from a clearer organizational structure to emphasize each section's key points. The writing is also sometimes convoluted, and had many spelling & grammar errors and typos.

Is the language fluent and precise?

Somewhat. Many sentences would benefit from being streamlined, and in some cases the sentence structure implies things that the authors probably did not intend.

Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Yes.

Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

The text would benefit from a thorough copy-edit.

The introduction in particular uses needlessly complex language to describe the basic functioning of karst aquifers and the role of the epikarst. An additional figure here would probably help.

The figures are generally very strong.

A few clarifying edits are suggested, particularly for Fig. 2 and Fig. 15.

For readers not familiar with ERT methods, a very brief introduction to the general concept and to the factors affecting resistivity (low resistivity = higher conductivity = higher permeability, higher water content, more conductive material...etc.) would be helpful.

Are the number and quality of references appropriate?

Yes.

Is the amount and quality of supplementary material appropriate?

Yes.

Comment:

General comments

This review will focus on the structure, context, and implications of the paper with respect to karst hydrogeology, rather than on specific comments on ERT methods and analysis, as I am not well-acquainted with ERT techniques.

This paper presents and makes freely available valuable data from long-term, high-resolution geophysical monitoring of groundwater flow patterns in a karst system. These data support well-accepted conceptual models for infiltration and recharge processes in karst systems, particularly with respect to the role of the epikarst. The authors do not put forward new conceptual models, but present the data and their analyses and conclusions in high-quality, detailed, well-developed figures, which are a major highlight of the paper. However, the overall quality of the writing and the organization of the paper lack clarity and concision. The paper would benefit from thorough, streamlining-focused editing, and from clearer explanations of the underlying concepts and assumptions the study is

based on. Additionally, the authors propose one specific interpretation of the ERT data, but their analysis might benefit from considering what other interpretations would be possible, and what hydrogeologic data would be needed to test competing interpretations against each other and against additional data. Finally, although the dataset being presented is extremely impressive and valuable, it is unclear how generalizable the results are to other karst systems. The authors suggest that their analysis may be useful for future modeling efforts, and while they will certainly be invaluable in efforts to model this specific system, it is not clear that they can support modeling in other locations, particularly since the methods needed to reproduce this type of study elsewhere are quite costly and time-intensive. If the three source region types (D1, D2, D3) can be more clearly defined and if they can be generalized to exist in other karst systems, it would be highly beneficial if the authors provided a set of metrics that could be used to identify these types of source regions in other karst systems in the absence of high-resolution ERT surveys.

Specific comments

Location	**Comment**
Abstract lines 26-30	Consistent abbreviations should be used for the three types of hydrologic source region dynamics - the main text uses D1, D2, D3, but the abstract uses (i), (ii), (iii).
Abstract line 31	The connection between the drip discharge spots and the source regions imaged using ERT methods should be made clear. Are the source region being imaged connected to specific drip discharge monitoring points, or to general types of observed drip discharge patterns? Specific examples of how this study could be used to support modeling should be provided in the main text to support this claim. It may also be worthwhile to mention the possible implications for improved understanding of speleothem formation (and therefore for paleoclimate studies) in the abstract.
Section 1 lines 37-54	The section describing the upper layers of karst systems and the associated infiltration and recharge dynamics needs to be clearer. As a reader already familiar with karst systems, I found it difficult to understand what the authors were trying to describe - I suspect it would therefore be almost incomprehensible to readers not already well-versed in the subject. This is particularly important given the unfortunately non-standard terminology used by different authors in describing karst systems above the water table. What is referred to in this paper as the “infiltration zone” (based on Mangin 1974?) is in other cases referred to as the “transmission zone” (Williams 2008) or the “unsaturated zone” (Goldscheider & Drew 2007). Additionally, because the terms “vadose zone” and “unsaturated zone” are also used in porous aquifers, it may not be clear to readers what exactly the authors mean by these terms. For example, in some texts, the terms “unsaturated zone” or “vadose zone” in karst *do not include the epikarst and the soil*, but in other texts, including this paper, the terms “unsaturated zone” and “vadose zone” are used to refer to everything above the water table. It would be helpful as well to choose either “unsaturated zone” or “vadose zone” and use a single term continuously throughout the paper. A simple figure could easily clarify this section - something like Fig. 2 from: Doerfliger et al. Water vulnerability assessment in karst environments: a new method of defining protection areas using a multi-attribute approach and GIS tools (EPIK method). *Environmental Geology* **39,** 165–176 (1999) or Fig. 3 from: Bakalowicz, M. The epikarst, the skin of karst. *Karst Waters Institute Special*

	Publication **9,** 16–22 (2004).
Section 1 lines 58 &74	These are important points and should be emphasized.
Section 1 section starting line 79 & section starting line 87	The order of these sections should be reversed - first ERT should be introduced, then examples of ERT studies in karst should be given.
Section 1 line 99	This is exciting and should be emphasized. It could potentially be moved to the beginning of the introduction? Also, "permanently installed" suggests that the ERT installation will be left in place and that data will continue to be collected in the future. Is this in fact the case? If yes, it should be explicitly stated, since this will be an exciting ongoing data source.
Section 2	The description of the system is clear and helpful, and the accompanying figure is clear and provides relevant context.
Section 2 line 122	The term "decametric" is uncommon in English (it is primarily used to describe radio wavelengths). In this case, is it intended to mean that each layer is ~10 m thick? If so, specify.
Section 2 line 128	Sinkhole and doline do not always mean the same thing. In this case the formation in question appears to be more of a typical sinkhole.
Section 2 line 137	The phrase "tiny underground river" is subjective - it would be helpful to specify an estimated discharge range.
Section 2 line 144	"Detrimentally affects" is subjective. Does detrimental imply increased erosion? Damage to man-made access structures? Specify.
Figure 1a	The Lomme River is difficult to see because it is so faint and small. The blue line and text indicating the river should be thicker.
Section 3	This section is excellent - clear descriptions and extremely helpful accompanying figures.
Figure 2	There is a great deal of valuable information that is overall very well presented. The stereograms and rose diagrams especially are helpful. However, the figure would benefit from some clarification since it is so information-dense: - Include S and N indicators on the cave cross-section. - PWD3 is not shown - there should be some indication, even if only in the caption, of where it is. - Line 175 seems to discuss layers on the southern side of the cave, but the diagram only shows these layers (50-53) visible on the northern roof. - Part C is difficult to read - does the meter-ruler indicate the location of the borehole? Is there a difference between the left and right sides? What are the overlaid numbered beds meant to indicate? And how exactly are the layers in Part C connected to the layers in the cave shown in Part A? See comments on Fig. 15 as well. - In the caption, spell out that S0 refers to bedding planes.
Section 4	Fig. 1 seems to show steps descending into the sinkhole. This should be mentioned

	in the site description. Were the steps constructed for this study? Does the general public have access to the interior of the sinkhole?
Section 4.1 lines 220-221	Clarify how humidity data will contribute to understanding infiltration dynamics, or move this sentence to right before line 269.
Section 4.2 line 226	Some indication of what the normal climate and precipitation patterns for this region are should be made earlier, in the site description.
Section 4.2 line 266	At some point *before* discussion of ERT results and/or expected patterns, there should be a brief description of what factors generally increase resistivity, and what factors generally decrease resistivity, so that readers not familiar with ERT methods have a frame of reference for this type of statement (see comments on Section 7.2 as well).
Section 4.2 line 283	Define "shaft flows".
Section 4.2 line 290	Clarify that PWD1 and PWD2 and spatially located close together, not close in terms of similar flow patterns.
Section 4.2 lines 307-314	Emphasize this section.
Section 4.2 line 326	Make a *brief* summary of the primary findings of the study (one sentence).
Section 5	I am not very familiar with ERT methods, and so did not give detailed comments for this section.
Figure 6	The caption for this figure should include what the letters (A-D) indicate, and what the primary differences between DD and GD datasets are. It should also spell out DD and GD rather than using abbreviations.
Figure 7	The red lines and numbers indicating where in time each resistivity image belongs are extremely helpful. These data could be powerfully visualized using a simple time-lapse animation (a GIF would work well) of the resistivities. This can be done very easily with several freely available software options (see one example of the step-by-step process here: http://www.spacelapse.net/en/Astrophotography_Tutorials/Convert_Single_Photos_to_a_Timelapse_Movie.html). Such an animation could be posted as supplementary material when the article is published online, and would give a compelling image of the subsurface dynamics over time.
Section 7.1 lines 575	Include possible options for distinguishing between the two types.
Figure 8	Very nice. Include a brief description of the characteristics of each region in the caption.
Figure 10	This is an excellent figure - very clear and detailed. Include descriptions of each numbered region in the caption.

Section 7.2 line 640-641	Something to this effect should be explained much much earlier in the paper, in the introduction.
Section 7.2.1 line 691	This sentence needs to be reversed - the increased pore water conductivity is a result of the drought, not the opposite.
Section 7.2.1 lines 699-707	Is it possible to disentangle the effects of fresh rainwater mixing from the effects of increased saturation? If not, how significant is the uncertainty introduced by the different conductivities of rain & pore waters?
Section 7.2.2 line 734	Is the fracture drip discharge at PWD1 from a different fracture than the one identified az zone #8 on Fig. 10? It is important to spell this out. Is it assumed that if drip discharge could be monitored from the #8 fracture zone, it would follow a similar pattern to PWD1? The descriptions make it unclear how D1 type regions differ from D3 type regions - they are both fractured regions? Is D3 intermediate between D1 (quick response to precip) and D2 (damped response to precip)? Why does PWD1 correlate with D1 type if it is measuring fracture drip discharge? One would think it should correlated with D3 type? In the text, PWD1 is listed as correlated with D1 regions, but in Fig. 15, PWD1 is shown as correlated with the D3 fractured region. Which is correct? Also, it is possible to estimate *rates* of recharge for each different type of region? Is it thought that these three types exist in other karst systems as well?
Section 7.2.2 line 739	Clarify the use of the term "subsurface." Is this intended to indicate near-surface regions? It is more commonly used to indicate everything below the surface, so the meaning should be made explicit.
Section 7.2.2 line 751	This type of general principle for interpreting ERT data should be listed out in one section nearer the beginning of the paper, or at the very start of the analysis section.
Section 7.2.2 line 778	Again, is the drip discharge at PWD2 & PWD3 coming from the same layers as those identified by ERT analysis as type D2? Or are they following similar behavior patterns but not coming from the same units? This should be explicitly stated.
Section 7.2.2 line 791-797	In this paragraph, does "the fractured region" correspond to D3 type? And does "surface layers" correspond to D1 type? Is the primary difference between D1 and D3 that the response to rainfall is more short-lived in D3?
Section 7.2.3 line 875	The preceding section seems to reject both possible causes of the increased resistivity after rainfall. What might then be responsible?
Section 7.3 line 886	The previous sentences indicate that the epikarst does *not* act as a buffer, but this sentence states that the epikarst *does* act as a buffer. Clarify.
Figure 15	This is an excellent overview/summary figure. The seasonal variation indicators are particularly helpful. However, in combination with Fig. 2 it is confusing. Fig. 2 seems to indicate that the ERT transect is next to the cave, but Fig. 15 seems to indicate that the cave is directly below the ERT transect. Which is correct? Both figures should be revised to be consistent with each other. The caption for Fig. 15 should also be much more detailed, with brief summaries of the D1, D2, and D3 dynamics, and the PWD1, 2, and 3 dynamics.

Section 8	This section is overall clear and concise. The phrasing in this section could be adapted to clarify some of the previous sections.
Section 8 lines 939-943	It would be good to think about how the interpretations drawn from ERT data could be further tested hydrologically. Are there other possible interpretations? Could different interpretations be tested against each other? What additional data could support or counter these interpretations?

Technical corrections

There are many small typos, spelling errors, and grammar issues. This paper would benefit from a purely copy-editing oriented revision. A few of the most obvious ones are listed below:

l. 17 carbonate
l. 39 soil joined with the epikarst
l. 54 agree on the dichotomy of matrix and conduit
l. 114 the Charlesmont Limestone, which includes
l. 115 member acts as
l. 117 system ends when
l. 189 three groups of joint orientations
l. 251 Penman-Monteith
l. 256 homogeneously
l. 534 inflection
l. 740 Klimchouk (2004), defining
l. 787 This indicates delayed