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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Hydrological Signals in Tilt and Gravity Residuals at Conrad Observatory (Austria)" *by* Bruno Meurers et al.

Anonymous Referee #1

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Review of "Hydrological Signals in tilt and gravity residuals at Conrad Observatory, Austria, by Meurers et al. This paper investigates the effects of precipitations on gravity and tilt recordings. Although precipitations are now well known (but difficult to model) effects, their influence on tilts or strains remains a poorly unexplored field, which deserves attention, especially in karst areas. This paper would deserve publication in HESS, but suffers presently from shortcomings and requires a major revision. General comments: Before providing detailed comments, I provide here the two most important points:

1. This paper provides a too detailed description of the processing of gravity and especially, tilt data. HESS is dedicated to hydro(geo)logy, hence, all the details of the SG processing are pure routine, the authors should just provide the basics and refer

to previous works, while I'm not sure that the whole discussion on the atmospheric pressure admittance of the tiltmeters is relevant. The authors could publish technical challenges into a more technical journal.

2. The discussion of the observed hydrogeological effects deserves more details. An important point is a decrease in gravity during precipitations that is immediately followed by an increase in gravity. If I see correctly, on 2016-07-11, Fig 4 shows the decrease, which is rather small comparing to the increase following just after, as shown by Figure 3 (same e.g. just before 2017-09-22 Fig 3). My interpretation is that during rainfall, gravity decreases because water is stored just above the gravimeter, and after while water percolates under the instrument (see similar effects in Watlet et al., WRR 2020). Of course, the response to rainfall probably depends on the degree of saturation of the saturated/unsaturated zones. Even if the authors do not dispose of groundwater measurements, they could build a simplistic model, to estimate the degree of saturation. A nice, original piece of information is provided by the tiltmeters: do they react more to the water stored immediately above the station, or more when water is supposedly underneath the gallery? Do you see a similar effect with snow, or not? As far as I can see, the snow does not affect tilts, hence we can rule Newtonian or load effects that would deform the rock around the gallery. Can you better quantify the effects of rain on gravity and tilts? Of course, there are admittances, but it is a general rule? Are there events obeying more the rule than others do? Are the responses of tilts and gravimeter perfectly proportional? So, elaborate, please.

Detailed comments

L10 An SG monitors changes in gravity

L11: add a blank: 5.5 m

L14: You should already mention the cavity effect, this is (unfortunately) an important effect

L20: unclear: what is exactly the difference between Newtonian and loading effects on tilts?

L25: in»at all spatial. . .

L27: loading: provide references

L30: add volcanoes

L34: You should mention the pioneering papers of Baker & Lennon and King & Bilham, both in Nature, 1973 (same remark on L179)

L41: complex infiltration process: mention that Conrad is a karstic area, where everything is expected to be even more complicated than in other hydrogeological contexts.

Section 2: provide a topographic map around the Conrad Observatory, showing the tunnel.

L48: I'd say: "Trafelberg at an elevation of 1050 m."

L53: there is no indication of the karstification, like e.g., sinkholes easy to detect?

L59: refer also to Van Camp, Meurers et al., J Geod 2016.

L63: What is "long one end"? Elaborate.

L71: in»at one end. . .

L72: 0.7x250: where does this '0.7' come from? "5.5 m/2 base": what does the "2" mean?

L73-74: "and an example can be given": strange sentence. Anyway, in my opinion, this belongs to useless technical details. In this paper, you should just mention than thermal effects are negligible (and this is especially true during rainfall, lasting only a few days in the worst case, while thermal effects would play a role only at longer periods or during maintenance).

L78-80: I do not understand the message. What is the relationship between the 50-100 m length and the resonances?

L103: "Thies": use the same wording as for Anton Paar: "A disdrometer (Thies). . .."

L109: nearby: provide an actual distance.

Section 3: too detailed, esp. for gravity.

L157: pole»polar

Section 4: the discussion on pressure is too detailed and somehow confusing.

L170: 5% of the tidal signal: do you mean that the observations are within 5% of the model? In that case, does the cavity effect play a role? Clarify, please.

L170: "much less data": provide the actual duration of both SG and tilt series.

L176: "However": what's exactly the link between the one-century old paper of Michelson, and the ocean loading at CO?

L181: calibrations errors: the tiltmeters are not at the same place, and have different baselines. Hence, they (probably?) undergo quite different cavity effects, and therefore, this may explain the differences, is it? Can you discuss this?

L194: sensor box: of LTS?

L194-203: this paragraph is not very clear and again, what is the relevant information for this study?

L213: temperature increase: I suppose that "temperature change" is more appropriate.

L214: the faster. . . faster": I do not understand. What is the message?

L219: why do we observe differences between the SG and tilt barometers? Different transfer functions? Also, why not directly comparing the barometers rather than working on the admittances?

L221: no idea about the steady change?

Section 5: could please better explain the Newtonian effect on tilts? Is it just due to a mass attracting more a side of the tiltmeter than the other side? It would be nice, perhaps in the introduction, to explain the different causes of tilts: Newtonian, loading (causing the crust to tilt), and infiltration in fissure and changes in pore pressure, and so on.

L261: the weak air pressure admittance. . .I do not understand your point. And, why is this admittance weaker than NS?

L265: looking at Figure 8 I see blue dots: it means rain, esp. before 12h or after 23h: could you explain, please?

L268-269: use UTC, avoid am and pm

L281: see also Watlet et al, WRR 2020.

L283-284: rather than charge and discharge I'd use "degree of saturation"

L285: do you mean the gravel layer above the concrete ceiling of the gallery? Unclear.

L288: Eventually: do you mean "perhaps"?

L293-294: "in advance": looking at the figure it's not so clear Could you quantify (e.g. by computing moving correlation)?

L308-310: I do not see your point: what's the relevancy of this information?

L314: gravity effects: but, your calculation of the rainfall admittance shows that you (nearly) perfectly model the Newtonian effects on gravity; unclear sentence.

L323: scale»scales

L329-335: you may quote Tenze et al., Bollettino di Geofisica Teorica ed Applicata, 2012

L330: which array?

L348-349: I do not understand: what is the link between the physics, hydrology and the cavity effect?

Figure 1: specify units on the vertical axis.

Figure 6: specify: modelled gravitational effect.

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