A ground based gravity network for monitoring water mass movements in the Classical Karst region

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UNIVERSITÀ DEGLI STUDI DI TRIESTE

dipartimento di matematica e geoscienze

1) Motivation/Hydrological outline

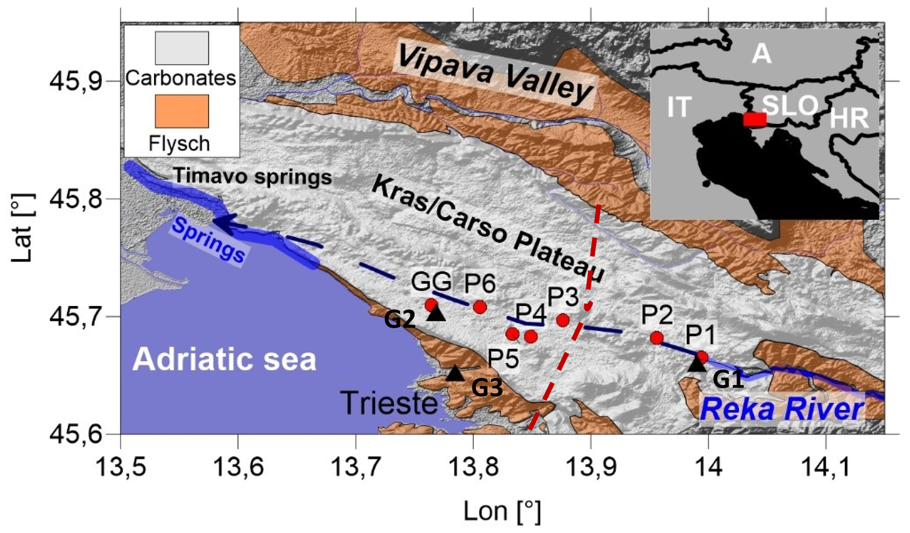

Figure 1: Geologic Map of the Classical Karst area (outlines of geology after Jurkovšek et al. 2016). The main caves along the underground stream (blue dotted line) of the Reka river are reported with red circles. Black triangles report location of the gravity instruments. Red dashed line marks approximately the boundary between upper and lower parts of the system

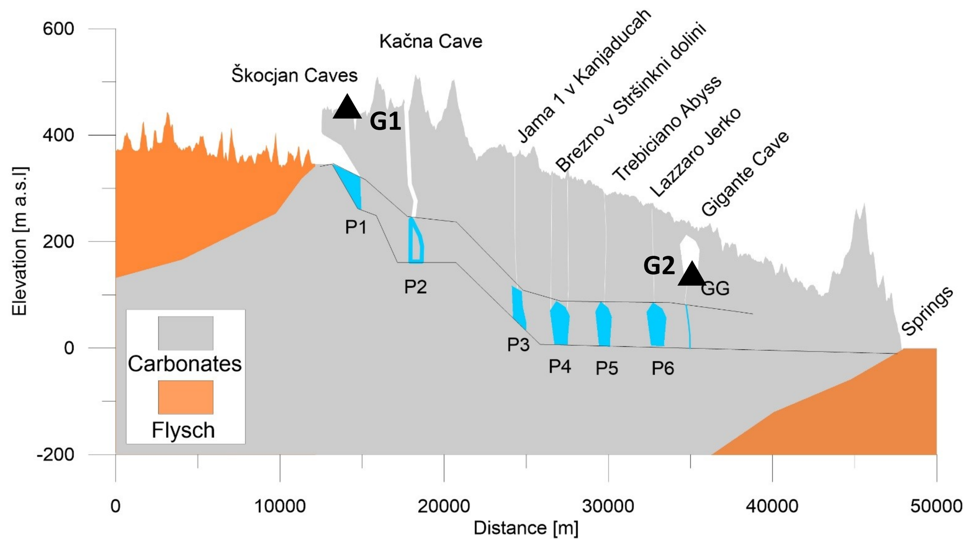

Figure 2: Geologic section along the main water path of the Reka. Blue line reports the water level increase during Reka flood events. G1 and G2 report the location of the two gravity meters.

Kras/Carso Plateau

- Limestone plateau (600km²) between Italy and Slovenia (Figure 1).
- Contains a complex network of conduits, shafts voids fed by the autogenic recharge and allogenic input of the Reka River.
- Reka River sinks underground in the Škocjan Caves and continues its underground flow ~40km until Timavo Springs.
- Upper parts of the system:
  - Characterized by prevalently subsurface channelized flow (Figure 2)
  - Well known hydraulically (Gabrovsek et al., 2018), especially P1-P2 portion
- Lower parts of the system:
  - More complex network of channels.
  - Indirect evidences of water passage during Reka flood events (Braitenberg et al., 2019)

Contribution of gravimetry to Hydrology:

- Indicates presence of underground water paths were direct observation is not possible or scarce
- In combination with other hydrological constraints produce complete 4D picture of the underground water dynamics

2) Gravity Network in the Karst

ŠKOCJAN GRAVITY STATION (G1):

- Micro g Lacoste gPhone gravimeter
- Reading resolution 0.1microGal
- Drift <500microGal/month
- Included an autolevelling tripod for tilt correction
- Barometer and Temperature sensors included
- Output data: daily files @ 1s sampling rate
- Well known site hydrologically; with shallow water circulation and huge accumulation during flood events. Geometry of the caves and hydrographs are available.

GROTTA GIGANTE GRAVITY STATION (G2):

- Lacoste Romberg G gravimeter
- Reading resolution 1microGal
- Drift <1000microGal/month
- Barometer, Temperature sensors and co-located pendulums for tilt monitoring
- Output data: hourly files @ 1s sampling rate
- Very quiet place; less known hydrologically with respect to G1. Deep water circulation on several (?) conduits

UNIVERSITY GRAVITY STATION (G3):

- Lacoste Romberg D gravimeter
- Reading resolution 0.1microGal
- Drift <1000microGal/month
- Barometer, Temperature sensors
- Output data: daily files @ 1s sampling rate
- Reference site: the station is located on flysch, a non-karstified rock formation

3) Škocjan caves: hydraulics/simulations

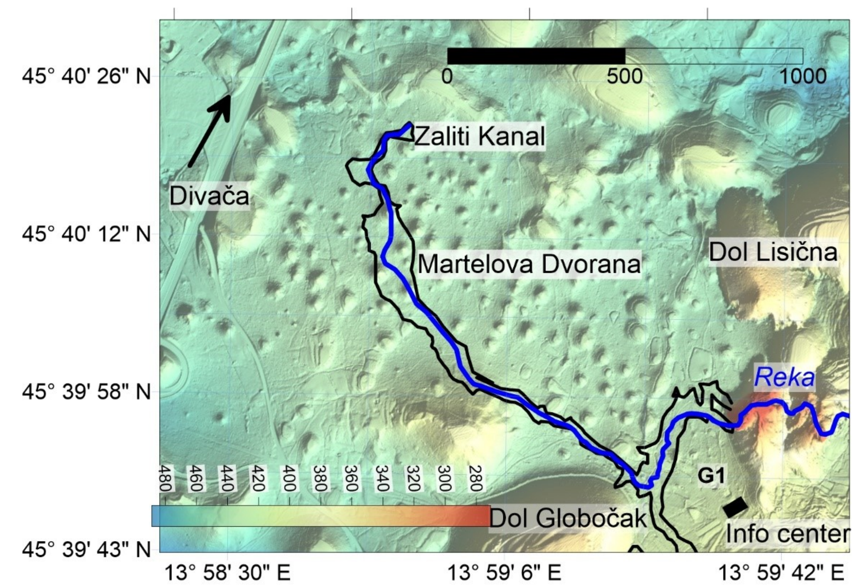

Figure 3: Map of the Škocjan cave area. DEM of the area. Black line: outline of the cave. Martelova Dvorana is a big hall inside the cave located before the Zaliti kanal which is a small conduit that drains the water out from the Škocjan caves system. The info center hosts the gravity station G1

- The Reka shows high discharge variations; 0.3 m^3 /s up to over 350 m^3/s during heavy precipitation events
- The conduit system cannot efficiently drain large discharge due to hydraulic restrictions (e.g. Zaliti Kanal Figure 3). → Huge water masses are stored in the epiphreatic voids of the aquifer during flood events.
- Škocjan Caves present such storage, where a vast amount of water is temporary stored during intense rain.
- The water level variation in the caves could reach 70m in the Martelova Dvorana (Figure 4a) and the accumulated water in the whole Škocjan caves system exceeds the $20{\cdot}10^6 m^3$

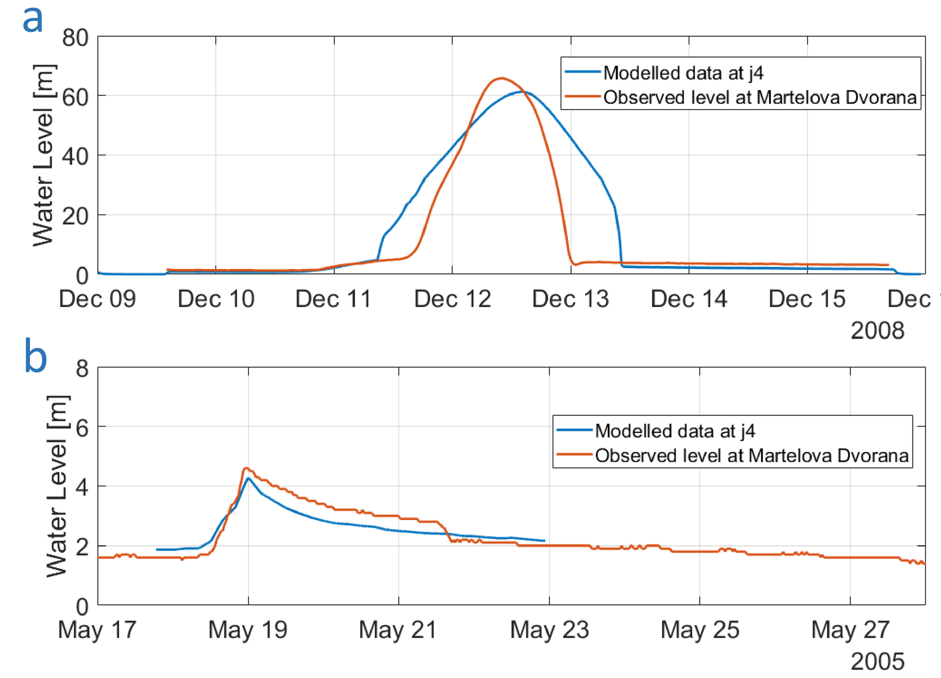

Figure 4: 4D- Hydraulic simulations in the Škocjan cave. a) rare event with Q_{peak}>250m^3/s; b) typical seasonal event (Q_{peak}=60m^3/s). The hydraulic model is obtained by solving the Saint-Venant eqs., given the geometry of the cave and an input hydrograph. The model outcome is controlled at Martelova, where continuous recording of the water level is available.

4) Škocjan caves: gravity observations (G1)

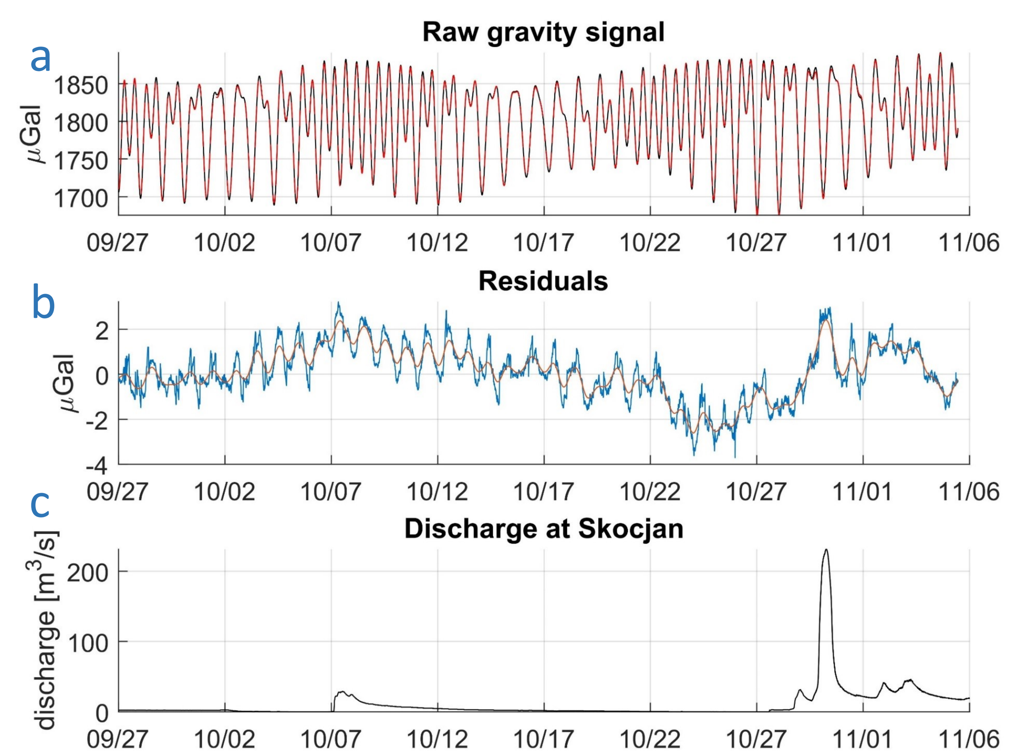

Figure 5: Observed gravity variations at Škocjan caves (G1) October-November 2018. a) raw gravity data (black line); predicted ET signal (red) b) Gravity residuals after removing ET and pressure effects c) observed level of Reka river at Škocjan

- Important flood events: October-November 2018 (Figure 5) and January-February 2019 (Figure 6).
- The gravity observations have been reduced for Earth Tides (ET; not using site specific tidal coefficients) and pressure effects.
- The gravity residuals for the 2018 event show periodic signals due to a non perfect correction of ET. In any case an increase in the gravity is seen. 2019 event amplitude is over 40μGal
- Preliminary simulations of the gravity variations, derived from the hydraulic model, confirm the amplitude of the observed gravity transient.
- From our estimates over $20{\cdot}10^6$ m^3 of water are temporarly stored in the system

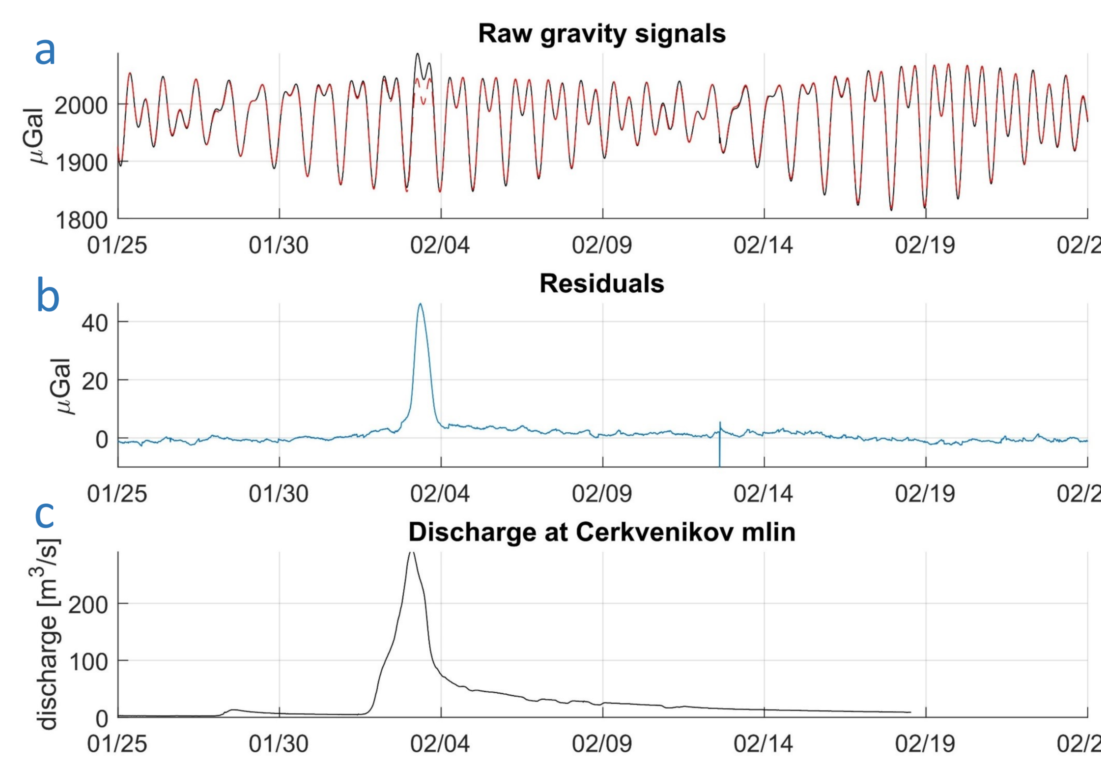

Figure 6: Observed gravity variations at Škocjan caves (G1) January-February 2019. a) raw gravity data (black line); predicted Earth Tide signal b) Gravity residuals after removing the ET and pressure effects c) observed level of Reka river at Cerkvenikov mlin

5) Conclusions /Perspectives

- Three gravity stations have been installed in the Karst area: G1 near Škocjan caves where circulation is shallow and channelized. Here gravimetry proves to be an important complement to classical hydrological prospections providing a more complete water mass balance.
- Škocjan cave site proved the potential of gravimetry to explore less known sections of the system. Similar to Škocjan there are other caves in the upper parts of the system (in Figure 1 from P2 to P3)
- G2 shows lower amplitude signals w.r.t. Škocjan, as expected from the hydrological context. Detailed analysis should be done in future.

References

1. Braitenberg C., Pivetta T., Barbolla D. F., Gabrovsek F., Devoti R., Nagy I. (2019). Terrain uplift due to natural hydrologic overpressure in karstic conduits. *Scientific Reports*, 9:3934, 1-10.
2. Gabrovšek, F., Peric B., Kaufmann, G. (2018). Hydraulics of epiphreatic flow of a karst aquifer. *Journal of hydrology*, 560, 56-74.
3. Jurkovšek B., Biolchi S., Furlani S., Kolar-Jurkovšek T., Zini L., Jež J., Tunis G., Bavec M., Cucchi F. (2016). Geology of the Classical Karst Region (SW Slovenia–NE Italy), *Journal of Maps*, 12:sup1, 352-362

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