Hydrological signals in the SG records at Moxa – a follow-up

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Abstract.

The existence of hydrological signals with their various sources in the records of the superconducting gravimeter (SG) at Moxa observatory is well known for several years. A part of this influence is directly related to rainfall affecting gravity from the short-periodic tides up to some weeks. The immediate (roof) area above the gravimeter which is thought to be a major source for this hydrological effect was covered with plastic foil in order to reduce effects. The results of this effort are presented.

1. Introduction

Hydrological signals in the records of the dual sensor superconducting gravimeter (SG) CD034 which operates at the Geodynamic Observatory Moxa, are known for a couple of years (e.g. Kroner, 2001). One characteristic of the hydrological influence is the occurrence of an immediate gravity decrease of several nm/s² associated with rainfall events (Fig. 1). A systematic change in gravity related to precipitation has not been found yet. Effects can widely vary even within one season: 14 mm of rainfall e.g. might produce a gravity effect of 7 nm/s², while 3 mm precipitation can result in a gravity decrease of 6 nm/s². The amplitude spectrum of the accumulated rain (Fig. 2) shows in which spectral bands a significant effect is to be expected in gravity. As can been seen from Fig. 2 the short-periodic tides (diurnal and higher periods) will clearly be affected by rain, but also strong effects should occur around 4, 10, 20, and between 30 and 40 days which will increase the noise in the gravity records and diminish the signal-to-noise ratio. Therefore, it is highly desirable to reduce this influence by any means. A fairly simple method for a reduction is to compute a regression coefficient between water level data of a 50 m deep borehole in front of the observatory and the gravity residuals. This procedure removes at least part of the hydrological effect (Kroner, 2001).



Fig. 1. Example of rainfall induced signals in gravity residuals. The gravity data were reduced with regard to earth tides, drift, polar motion and barometric pressure effects (3d-reduction+local regression coefficient). The precipitation given in grey corresponds to accumulated rain per event. The upper panel shows the local barometric pressure variation for comparison.

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During the last years a number of experiments have been carried out to enhance the understanding of the hydrological effects from different contributing areas in the near vicinity of the SG and to develop reduction algorithms (Kroner, 2001; Kroner & Jahr, 2006). Apart from this, additional hydrological sensors for continuous soil moisture and water level monitoring were installed in the gravimeter vicinity. From one experiment in which the roof area above the gravimeter was irrigated it could be demonstrated that a non-negligible effect comes from changes in the water mass in this volume which consists of soil and gravel. To get an estimate of the effect due to rainfall events from this area it was assumed that one third of the total amount of precipitation runs off, one third evaporates and one third percolates. By applying this simple rule of thumb gravity variations of some nm/s² originate solely from this area (Fig. 3). From this follows, if it were possible to avoid or reduce changes in the amount of water stored in the roof area, the total of the hydrologicallyinduced effects in gravity could be reduced and the signal-to-noise ratio in the gravity data improved.



Fig. 2. Amplitude spectrum of the accumulated precipitation per event, 01/01/2001-12/07/2005.



Fig. 3. Estimate of gravity effect caused by rainfall on roof area, 01/01/2001-12/07/2005. Periods with snow are excluded.

2. Coverage of roof surface

Bsed on the result of the irrigation experiment and the estimate of the hydrological effect originating from the roof area, in summer 2004 a project was started to cover the roof area. The first step was to remove all the vegetation from weeds up to small trees. After this the area had to be provided with a slope and the surface had to be levelled off with an excavator, among other things getting rid of a 0.5 to 1 m high hump in the middle of the roof. At the same time bigger roots and larger rocks were removed. Due to bad weather and a slippery surface work had to stop in September and could only be continued in summer 2005. Due to the long break the roof once more was covered with vegetation which thus had to be removed for cond time. After the preparation of the surface was finished a 4 cm thick layer of gravel (density: 1660 kg/m³) was put onto the roof which should help to avoid damage of the plastic foil by remaining small rocks. The major part of the roof then was covered with plastic foil of 1 mm thickness. Only a small part in the back which directly borders to the rock, in which the observatory is built, was left uncovered due to the rocky and unequal surface. Fig.

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4 gives an impression of the roof area before work was begun and afterwards. The total area which is covered by foil since September, 7^{th} 2005 amounts to 311 m². At the location of the SG the surface is 6 m above the instrument, at its lowest point, 13 m to the west the surface has a height of 3.6 m above the gravimeter.



Fig. 4. Upper panel: Impressions of the roof area before work was started and after removal of vegetation; bottom panel: Putting gravel on the flattened suface and final condition of surface.

The additional mass of about 40 t on the roof produced a gravity decrease of 19 nm/s² in the record of the lower sensor of the SG and of 19.7 nm/s² in the data of the upper sensor (Fig. 5). The order of magnitude of the effect could be recovered in an estimate considering the dimensions and the geometry of the area with respect to the SG and assuming a gravel layer of homogeneous thickness.

Fig. 6 shows the gravity residuals before and after the roof was covered. For comparison the accumulated precipitation per rain event and the soil moisture changes on the roof directly above the SG in a depth of 0.3 m and 1.0 m are given. The soil moisture variations are monitored with TDR probes (TRIME-EZ). The sampling rate is 15 min. From the change in the soil moisture signatures it becomes clear that the foil screens the roof surface against short-term hydrological variations as intended, hopefully also against part of the long-term variations. Before the coverage most rain events produced clear soil moisture variations mostly in the data of the upper probe. At the same time also effects in the gravity residuals can be found. After the roof coverage practically no fluctuations exist in the soil moisture data which can be related to rain. The results are not so unambiguous with regard to gravity. We still have a gravity decrease related to rain events as expected because most of the area from which precipitation induced effects originate is still the same. The question is whether the size of the gravity decrease is now noticeably reduced or not. In the short period of data that is available after the roof coverage, we have e.g. rain events of 12 and 15 mm which produce a decrease in gravity of 5 mm/s² and rain events of 4.5 mm which result in a gravity change of



Fig. 5. Decrease in gravity residuals due to additional mass on roof; — lower sensor, — upper sensor.



Fig. 6: Comparison of gravity residuals before and after the roof was covered with foil and accumulated precipitation per rainfall; the upper two curves show soil moisture changes in a depth of 0.3 and 1.0 m on the roof directly above the location of the SG. The decrease in gravity in the second half of December 2004 and between mid-February and mid-March is caused by snow.

2.5 nm/s². The general impression is that of a slight reduction of the gravity effects, but truth to tell the time span is still much too short for a meaningful assessment. The winter period (December 2005 until end of March 2006) can not be taken into account since the snow load remains the same independent of the roof coverage.

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3. Conclusions

With the coverage of the roof surface at Moxa observatory it is intended to prevent esp. short-term hydrological fluctuations which affect the observations with the superconducting gravimeter situated directly below. This should lead to an improved signal-to-noise ratio. The clear diminishing of the soil moisture fluctuations to practically no variation shows the effectiveness of the coverage which results in an almost constant amount of water stored in the gravel and soil volume on the roof when periods of a few hours up to some weeks are considered. Whether the roof coverage is as effective as expected with regard to gravity is not clear yet since the period of observation after the covering took place is still too short.

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