Onshore GNSS Monitoring Tide Variations

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Introduction

Monitoring of sea level and its changes is a major interest for the geosciences community, since it provides important indications for global climate change. In the past few centuries, tide gauges is the primarily monitoring method. Satellite altimetry is the dominant technology in the last three decades. Tide gauges are, however, affected by land surface changes. This makes it difficult to use traditional tidal gauges for sea level studies that construct active areas and applications related to global ocean volume changes. This makes it difficult to use traditional tidal gauges to study regional sea level changes. Fortunately, GNSS stations were established near many tide stations. It not only provides crustal deformation at the location of the site, but also continuously receives reflected signals from the sea surface. It is a "by-product".

These years, with the rapid progress of global navigation satellite systems such as BDS, Glonass and Galileo, coupled with the increasing number of continuously operating reference stations (CORS) around the world, multi-GNSS monitoring tidal variations has become possible in present. Its purpose is mainly to increase the inversion result time resolution. The tidal level inversion resolution is limited by the number of sea surface signals, multi-GNSS greatly increased the number of inversion points, thus improving the inversion results of the main tidal wave components.

Methods

In the study of the observed water level, mainly for H. it needs to ensure that the received reflected signal comes from the sea surface. The azimuths and elevation angles are chosen so that the sensing zones are on water. In order to get the height of the water surface to the center of the antenna phase (H), the SNR data are translated to linearization, and the direct signals are removed by the low-order polynomial. These SNR residuals are modeled as

$$\delta = A\cos\left(\frac{4\pi H}{\lambda}\text{sine} + \phi\right)$$

Where λ is the wavelength of the GPS, and e is the satellite elevation angle. Since the data is not equally spaced, use the Lomb-Scargle cycle diagram to extract frequency f . High vertical reflection is obtained by

$$H = \lambda f / 2$$

Where H is the reflection height, not the actual water level. When calculating the reflection is high, only the wavelength is considered, for different bands of different satellites. Figure 1 shows the results of the spectrum analysis from different SNR of different satellites. Figure 2 shows screenshot of first Fresnel zones for MAYG.

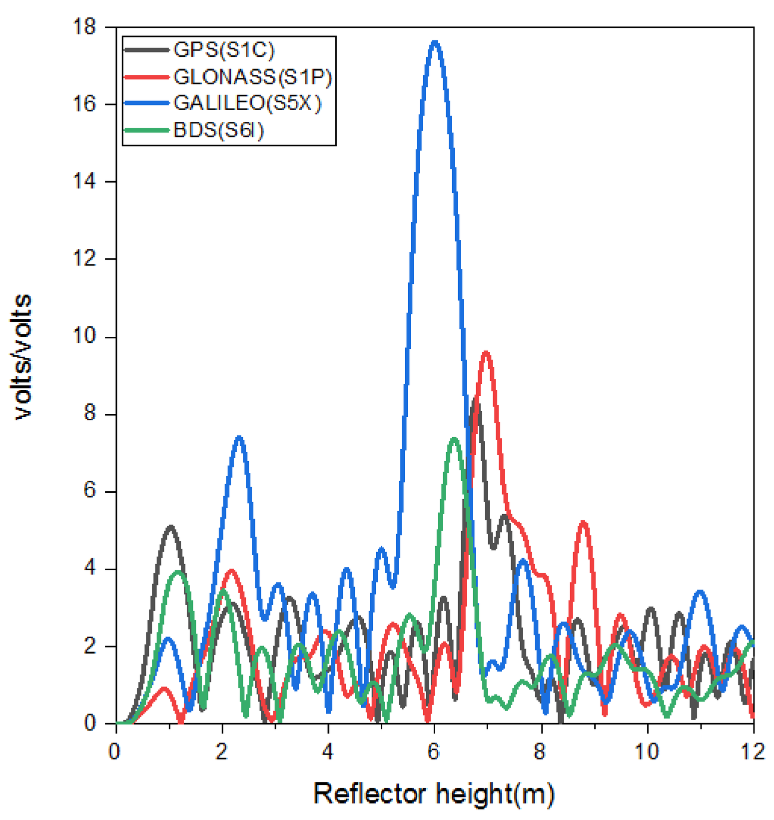

Fig. 1. the results of the spectrum analysis from different SNR of different satellites.

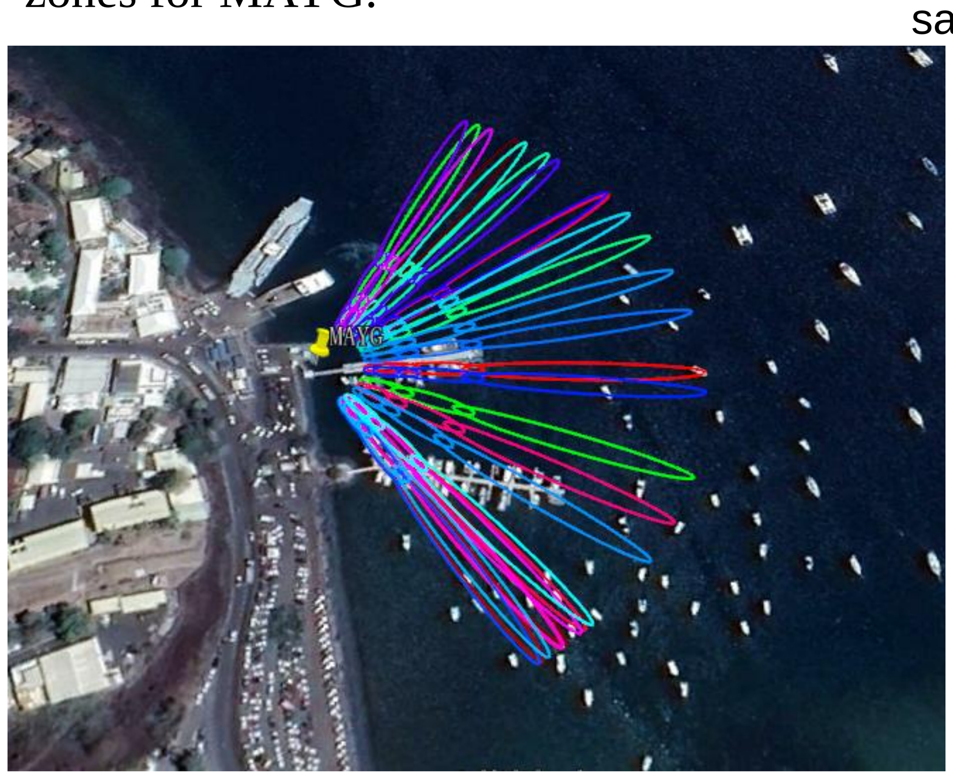

Fig. 2. the screenshot of first Fresnel zones for MAYG, and elevation angles of 5°, 9°, 13°, and 18°projected on a Google Earth image. An H_R value of 6 m was used.

Results

Monitoring tidal variations by the onshore multi-GNSS in this article, MAYG is one of the Multi-GNSS Experiment (MGEX) stations in Mayotte, France. The co-located tide gauge station is Dzaoudzi with about several meters far from the MAYG station, with sampling rate of 1 min are provided by the Intergovernmental Oceanographic Commission (IOC). The elevation angle used in this study is 5 to 18 degrees. Evaluate the terrain around the site by map, to ensure that the reflected signal comes from the sea, not what else. Therefore, a satellite orbit between 20 and 170 degrees azimuth is selected for calculation. Table 1 lists the detailed correlations and values of RMSE, four satellite systems derived results. Figure 3 shows the 7 day sea level change time series. Figure 4 is a selection of SNRs with better inversion results, each satellite system to jointly invert. Four satellite systems are derived and the results are in good agreement.

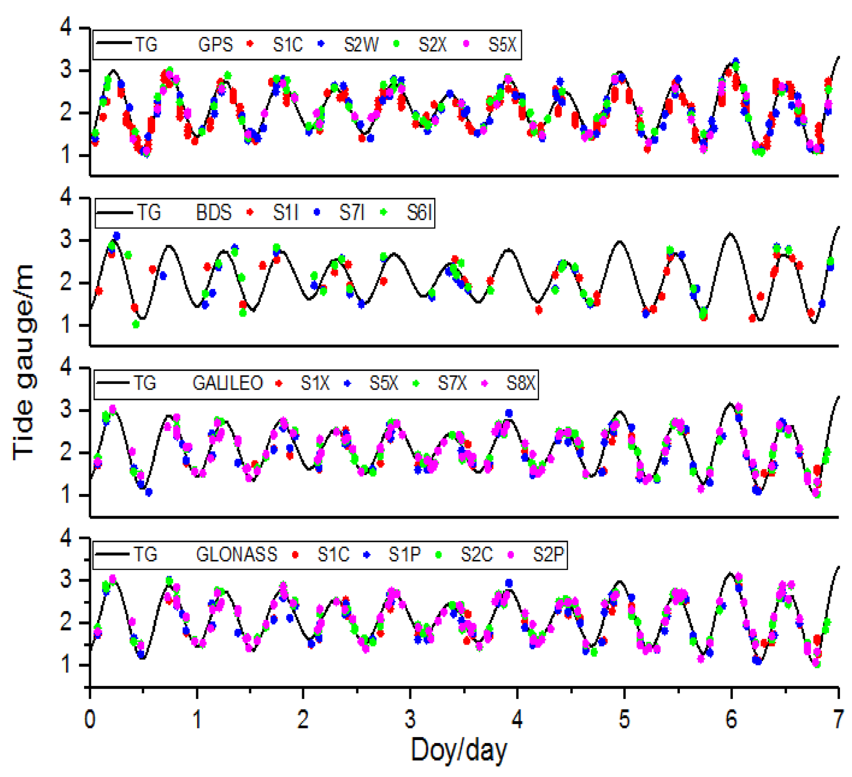

Fig. 3. Sea level changes from Four satellite systems and tide gauge observations

Tab. 1.Correlations and values of RMSE

Satellite systems	SNR type	RMSE	R
GPS	S1C	0.2923	0.9359
	S2W	0.2168	0.8930
	S2X	0.2027	0.9193
	S5X	0.2536	0.8874
BDS	S1I	0.3630	0.7445
	S7I	0.3914	0.7522
	S6I	0.3753	0.7962
GLONASS	S1C	0.3212	0.8480
	S1P	0.2793	0.8801
	S2C	0.2197	0.9061
	S2P	0.2145	0.9062
GALILEO	S1X	0.3216	0.7530
	S5X	0.2468	0.9062
	S7X	0.2801	0.8535
	S8X	0.2833	0.8708
Combine	S1C+S6I+S2P+S5X	0.2827	0.8757

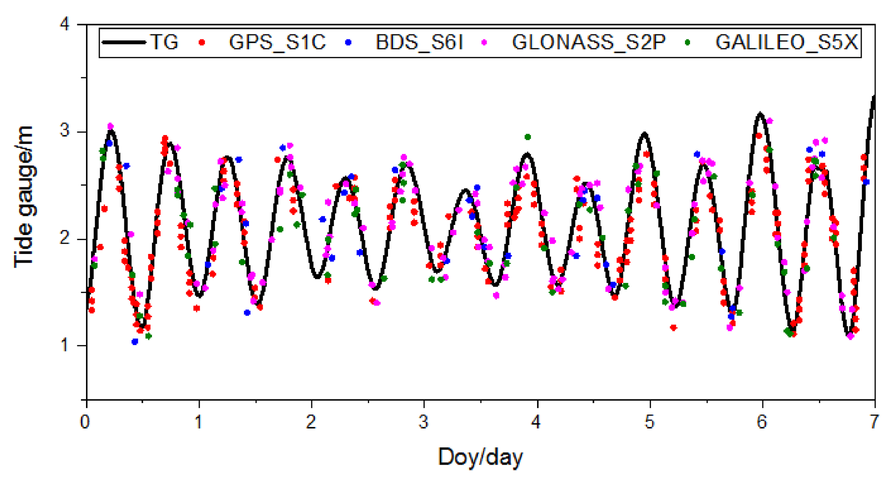

Fig. 4. Statistically optimal results, common inversion

Conclusions

Results show that the tidal variation from GNSS-IR have a good agreement with tide gauge, correlation coefficients of 0.74–0.94 and RMSEs of less than 0.39m, the best result of GPS-IR which was used S1C, Similarly, BDS-IR is S6I, Glonass-IR is S2P and Galileo-IR is S5X. This is only the result of a few days, as far as statistics are concerned. Statistically, these better results use SNR to jointly invert the tidal variation, correlation coefficients of 0.88 and RMSE of about 0.28m. The research verifies the feasibility and effectiveness of multi-GNSS-IR in monitoring the tidal variations. It has enriched the data sources and increased time resolution used by multi-GNSS for inversion of ocean tides, which has expanded the application of GNSS remote sensing in the ocean, especially in tidal analysis.

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