南東アラスカにおける重力と地面上昇の年率の比について

佐藤忠弘 [1], 三浦哲 [1], 太田雄策 [1], 藤本博巳 [1], 稲津大祐 [1], W. Sun [2], 菅野貴之 [3],
C.F. Larsen [4], A.M. Kaufman [4], R.J. Motyka [5], J.T. Freymueller [4]
1. 東北大理学研究科・地震噴火予知研究観測センター,
2. 中国科学院大学院・数理地球物理学中央研究所, 3. 東京大学・地震研究所,
4. アラスカ大学フェアバンクス校・地球物理研究所, 5. アラスカ大学南東校・芸術科学学部

On the ratio of the gravity change rate to the uplift rate in Southeast Alaska

T. Sato [1], S. Miura [1], Y. Ohta [1], H. Fujimoto [1], D. Inazu[1], W. Sun [2], T. Sugano [3],
C.F. Larsen [4], A.M. Kaufman [4], R.J. Motyka [5], J.T. Freymueller [4]
[1] *Research Center for Prediction of Earthquakes and Volcanic Eruptions, Tohoku University,*
[2] *Key Laboratory of Computing Geodynamics, Graduate University of Chinese Academy of Science,*
[3] *Earthquake Research Institute, University of Tokyo,* [4] *Geophysical Institute, University of Alaska Fairbanks,*
[5] *School of Arts and Sciences, University of Alaska Southeast.*

Base on the intensive GPS surveys carried out in Southeast Alaska (SE-AK) by a group of University Alaska Fairbanks (UAF), they found that SE-AK shows very rapid uplift rates exceeding 30 mm/yr. The origin of this rapid uplifting is considered to be mainly caused by the GIA (Glacial Isostatic Adjustment) due to the deglaciation of the post-little ice age (LIA) ices, which covered the SE-AK area with thickness up to 1.5 km at the maximum (Larsen et al., 2004 and 2005). Geodynamic modeling for the observed uplift signals with the extreme rates and a priori knowledge of ice load changes require the presence of a thin lithosphere of 60–70 km thick and a low asthenospheric viscosity at the order of 3.7×10^{18} Pa s. Sato et al. (2010) reevaluated the viscoelastic parameters beneath the SE-AK based on the GPS vertical velocity rates combining the data sets previously published in 2005 with the additional data for the uplift rates compiled recently and an improved model for the present-day ice melting (PDIM) by Larsen et al. (2007), and they obtained a viscosity value slightly larger than the previous estimation by Larsen et al. (2005). The most probable reason for the difference in the viscosity values is considered to be the difference in the magnitude of the estimated PDIM effects in respective studies.

In order to study the effects of the glacier changes in SE-AK precisely by adding the new data sets, we conducted a US-Japan cooperative observation project called ISEA during the four years from April 2005 to March 2009 (Miura et al., 2007). Under the framework of the ISEA project, we carried out the absolute gravity (AG) measurements at 6 sites (see Fig.1) with an absolute gravimeter (FG5#211) in and around the Glacier Bay ice field during three years from 2006 to 2008. The AG measurements should contribute to study the GIA process because the gravity observation is sensitive to the present-day ice mass changes. Therefore, combining the gravity data with the displacement data could give us useful information to improve the estimation of the effects of the PDIM, consequently to improve the estimation accuracy of viscoelastic parameters. At the two sites of BRM and HNSG, the AG measurements were also done in 1978 (about 20 years ago) by a group of IGPP, Scripps Institute at UCLA, Sun Diego. We have confirmed that the previous observations are on the lines respectively estimated at the two sites using our recent AG data.

We will introduce here the following two topics based on the AG measurements. One is the results for the estimations of the mean thickness of the glaciers in the Glacier Bay area and other is the results for the comparison of the observed ratios of the gravity rates to the uplift rates and the predicted ratios.

For the mean thickness of the glaciers in SE-AK, we have obtained 500 to 600 m. For the AG site at MGVC that locates at the edge of the Mendenhall glaciers, the mean thickness estimated from the AG data is consistent with that obtained from the radar measurements.

For the ratio of the gravity rate dg' (unit: μGal/yr) and the uplift rate du' (unit: mm/yr), it is known a relation of dg'=(F+B)du' between these two rates, where F is the Free-air gradient (-0.308 μGal/mm) and B is the Bouguer gradient (+0.154 μGal/mm) that is due to the flow of heavy mantle material into the rebound area (Wahr et al., 1995). Using these, we obtain a value of -0.154 μgal/mm as the coefficient of F+B. Wahr et al. (1995) pointed out that the coefficient B is almost constant for a wide range of the viscous profiles and lithospheric thicknesses. We examined the ratio of dg'/du' in SE-AK using our observations at the 6 AG sites. The viscous portions of the gravity rate and of the uplift rate were estimated by correcting for the PDIM effects to the respective observational rates. We call here the ratio estimated using these corrected rates as "viscous ratio (VR)". Our results indicate that the estimated VRs are sensitive to the distance between the gravity and GPS sites, because of the large spatial gradients in the uplift rates in SE-AK. For example, quite recently, the uplift rate at BCT5 was analyzed using the data obtained during the period from 2007 to 2010. BCT5 is a GPS site which is much close to the AG site GBC1 than the GUS2 GPS site used in the previous estimation. The distances from GBC1 are 11 km and 660 m for GUS2 and BCT5, respectively. Using the uplift rate at BCT5 instead of GUS2 changes the VR at GBC1 from -0.28 μGal/mm to -0.21 μGal/mm. Compared with the VR values obtained at other sites, the later is much consistent in magnitude than the former.

We have obtained -0.17+/-0.12 μGal/mm as a mean value for the VR averaged over the 6 AG sites. Although it is still within the error range, the observed mean VR is slightly smaller than -0.154 μGal/mm proposed by Wahr et al. (1995). However, our computation results indicate that the observed mean VR is consistent with a value of -0.171 μGal/mm estimated from the gravity and uplift rates at the early stage of the GIA responses to the deglaciation of the LIA ices, and the predicted VRs show a tendency that increases as time goes by.

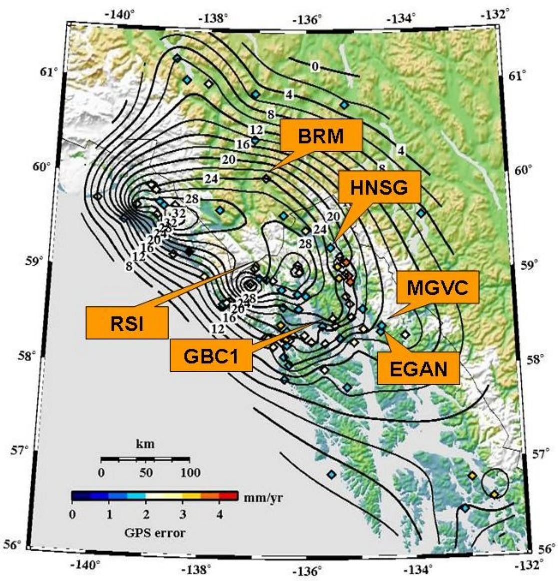

Fig.1. 6 AG sites of the ISEA Project and a counter map for the distribution of uplift rates obtained from the GPS observations at 91 sites in SE-AK.

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