REGIONAL QUASIGEOID AND SEA SURFACE TOPOGRAPHY MODEL IN THE ANTARCTIC AREA

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Abstract. The basic purpose of the given work is the construction of the gravimetric quasigeoid from gravimetry data and Sea Surface Topography (SST) model based on altimetry data from 6 satellite missions for the total period of 15 years for the Antarctic region limited by 50°S by latitude. Another goal is further study of the special harmonic functions called by multipole potentials that goes back to ideas of J.K. Maxwell (1881) in his famous treatise for geoid solution and SST model over the large continental and marine areas. Gravimetric quasi-geoid and SST model are used then for the comparison with available independent data from 5 tide-gauges stations of the Australian levelling network which are led to the conclusion on the 10 cm level of accuracy of discussed models in the places of location of these stations (Mawson, Davis, Casey, Macquarie Island, Heard Island) and the corresponding network points.

This study occurs in 2008 during the International Polar Year 2007/2008 since airborne data are found in the ADGRAV database for better covering of the Antarctic continent of gravimetry data. Surprisingly, but only one existing file (“Vostok Lake”) has included elevations for airborne data without any success for other ones. Briefly review of the situation with measurements and gravity field determination can be found in (Scheinert et al., 2008) where airborne regional quasi-geoid was built.

Because marine and land gravity database for Antarctic area is updating in BGI and ADGRAV databases and offshore data are added by KMS99 and KMS01 $2'\times2'$ gravity anomalies from the inversion of satellite altimetry the quasigeoid determination together with SST model based on the gravimetry data was assessed to be important. Additionally to ~ 20000000 KMS (Andersen, Knudsen, 1998) free air anomaly Δg we found the 303486 point Δg BGI marine, 103565 point ADGRAV marine Δg, 9681 BGI continental Δg, and 79574 point ADGRAV continental Δg (a number of non-repeated data are given). Other kind of initial data is 111428429 satellite altimetry observations from six altimetry missions ERS-1, ERS-2, TOPEX/POSEIDON, GFO, ENVISAT, JASON-1 in the time-period 1992-2007 yr.

Taking into account large area of interest which take place from 90°S to 50°S by latitude and from –180°W to 180°E by longitude and also for the saving of computation time was accepted decision to use for the geoid determination $6' \times 12'$ mean gravity anomalies values instead of smaller grid.

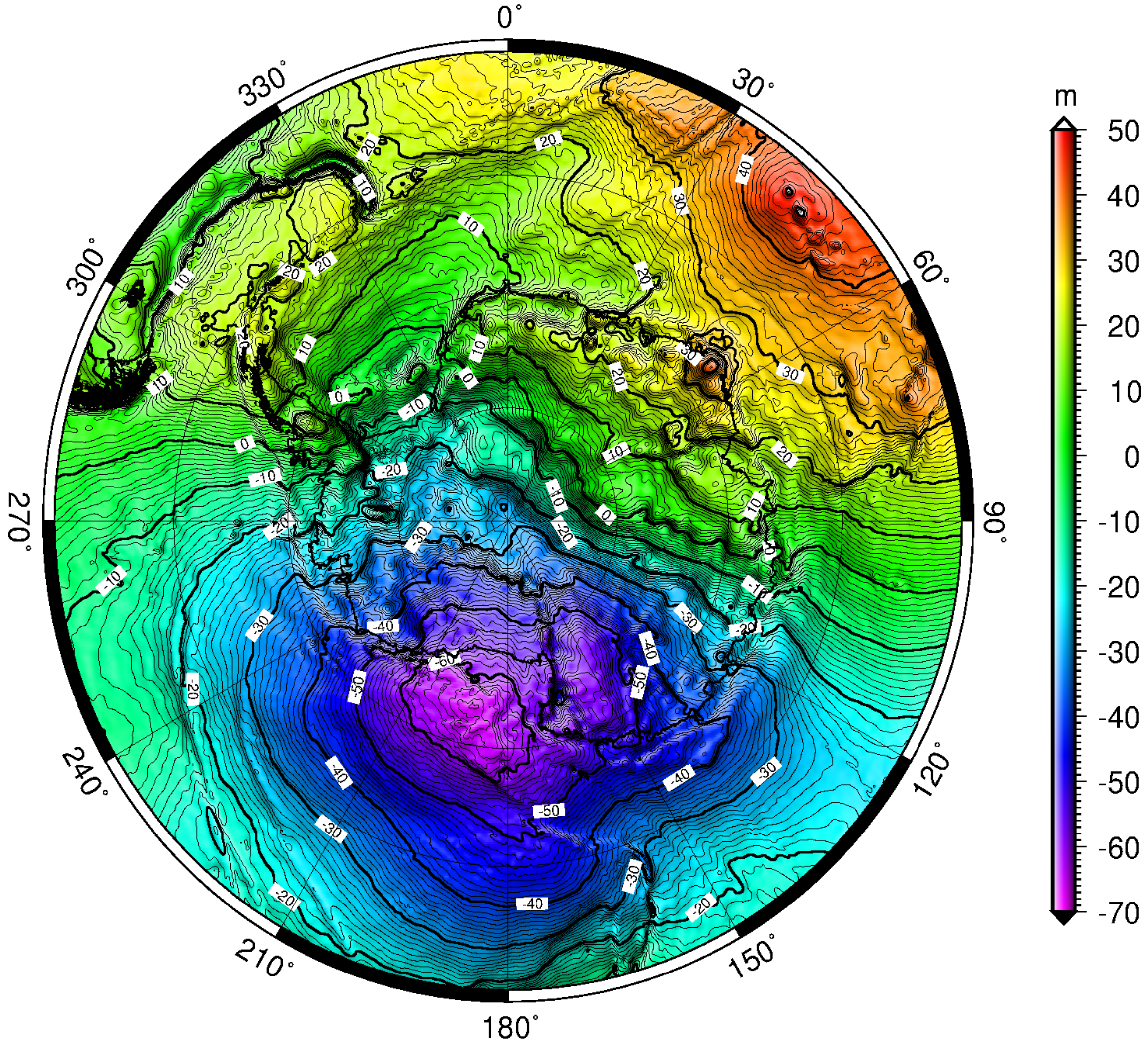

Fig.1. Gravimetric quasi-geoid [m] solution based on the KMS, BGI, and ADGRAV free air anomalies Δg

The gridded $6' \times 12'$ mean gravity anomalies were calculated based on all data sets of Δg where continental data gaps are filled by the EGM96 gravity field anomalies Δg. The obtained set of 718200 gridded free air gravity anomalies Δg was transformed into Faye gravity anomalies Δg_F derived from the GEBCO DTM topography model. For the geoid determination were accepted the well-known "remove-compute-restore" technique (Forsberg, Tscherning, 1981). Residual gravity field for the SMA solution was obtained in the way of the removing EIGEN-CG01C global gravity model up to degree 360 from the Faye anomalies (terrain corrected free-air gravity anomalies). Quasi-geoid solution was based on the SMA approach or sequential multipole analysis (Marchenko, 1998; Marchenko, et al., 2001) applying the direct approximation of the gridded $6' \times 12'$ mean gravity anomalies by the series of potentials of radial multipoles restricted by accuracy of approximation 5 mGal. After restoring of the EIGEN-CG01C gravity model the total number of 20152 of radial multipoles provides the gravimetric quasi-geoid in Fig.1. Resulting gravimetric quasi-geoid is adopted as reference surface for the SST modelling since in this area the mean sea surface heights data are not coincide with geoid heights (by definition) and have differences from -2.5 m up to 1.5 m. Therefore we choose such strategy assuming that GPS/Levelling data in the different places with tide-gauges in Antarctica should be referred to the one vertical system, defining by means of geoid computation the obtained numerical value of the geopotential $W_{0\text{Antarctic}} = 62636862.76\,\mathrm{m}^2/\mathrm{s}^2$. It has to be pointed out that adopted W_0 by the IAG and IUA worldwide value is $W_0 = 62636856.0 \pm 0.5\,\mathrm{m}^2/\mathrm{s}^2$ (Groten, 2004).

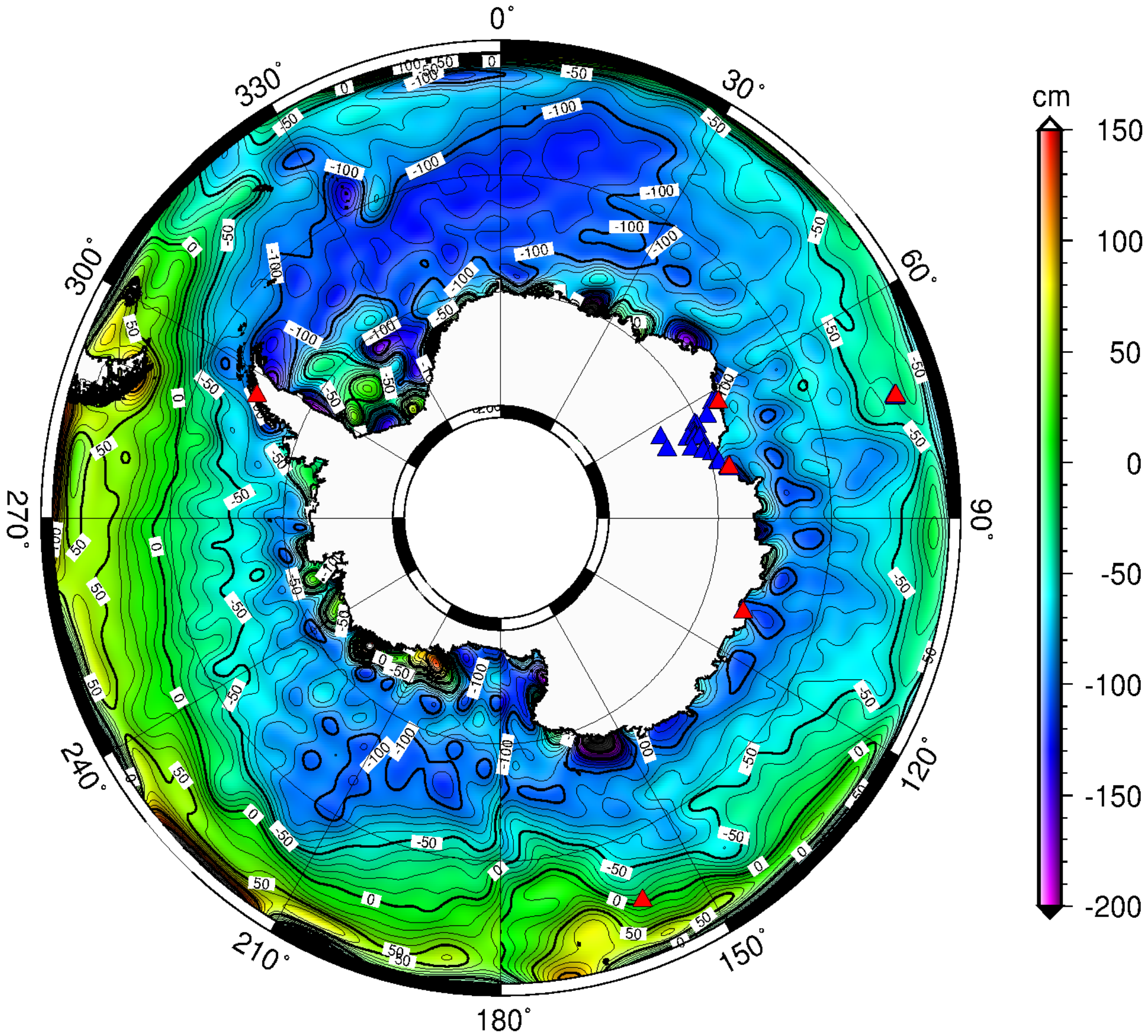

Fig.2. Sea Surface Topography model [cm] from altimetry SSH and gravimetric geoid heights (▲ is the Australian tide-gauge stations and Faraday/Vernadsky station)

Fig. 2 illustrates Sea Surface Topography model in the South-Antarctic area with Antarctic Circumpolar and Antarctic Sub-polar currents. Sea Surface Topography model was developed using in the first stage the gridding by static Kalman filter (or recursive least squares method) differences ΔSSH of SSH and geoid heights. Then after Gauss filtering of ΔSSH with the radius of average 55 km we get the SST or Sea Surface Topography model in the South-Antarctic area. It should be noted that geoid solution is obtained in the Zero Frequency Tide System (ZFTS). SSH AVISO data are given in the Mean Tide System (MTS). According to Rapp (1989) the independent comparisons is possible after transformation all geodetic functional to one tide system. In the following we transform from the MTS to ZFTS.

Table 1. Comparison of the constructed geoid and SST model in the Australian tide-gauge stations with measured H_{MSL} Mean Sea Level heights

Station	$H - H_{MSL} - \nu_{tide}$, m	N, m	SST, m	$N + SST$, m	$(H - H_{MSL} - \nu_{tide}) - (N + SST)$, m
Mawson	26.85	28.04	-1.01	27.03	-0.18
Davis	16.70	17.38	-0.62	16.75	-0.05
Casey	-18.26	-17.06	-1.11	-18.18	-0.09
Macquarie Island	-19.54	-19.18	-0.42	-19.61	0.07
Heard Island	39.60	39.81	-0.30	39.51	0.10

The independent comparison of the constructed geoid and SST model in the Australian tide-gauge stations with measured Mean Sea Level heights illustrates Table 1, where H is the ellipsoidal (geodetic) height observed by the use of GNSS, H_{MSL} is the measured Mean Sea Level height, ν_{tide} is the reduction of transformation from MTS to ZFTS, N is the geoid height, SST is the Sea Surface Topography model in the South-Antarctic area, $H - H_{MSL} - \nu_{tide}$ we assume as GNSS/Levelling data in the tide-gauge referred to the mean sea level height. The latter leads to the necessity of comparison with the sum $N + SST$ that means stationary sea surface topography with respect adopted ellipsoid expressed through geoid and SST model.

Conclusions

In summary we can conclude:

- The approximation of the regional gravity field in the Antarctic area was developed successfully by means of the non-orthogonal functions called by multipole potentials for geoid solution and SST model over the large continental and marine areas. All computations were made in the Zero Frequency Tide System.
- The geoid calculation makes available the numerical value of the geopotential $W_{0\text{Antarctic}} = 62636862.76\,\text{m}^2/\text{s}^2$ obtained for the study area.

- The stationary Sea Surface Topography model in the Antarctic area is built using the gridding by static Kalman filter or recursive least squares method with additional Gauss smoothing of differences between SSH and geoid heights.
- It is evident that the independent comparison of the constructed geoid and SST model in the Australian tide-gauge stations with measured Mean Sea Level heights leads to a good agreement with min deviation -0.18 m and max deviation +0.10 m with the approximate level of accuracy in the Antarctic marine regions about 10 cm.
- However for further improvement of these results the airborne and possibly GOCE data should be used that caused by major data gaps and weak places along the seashores due to satellite altimetry data in particular.

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