A Giant Step: from Milli- to Micro-arcsecond Astrometry
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Direct contribution of the surface layers to the Earth's dynamical flattening

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Abstract. The global dynamic flattening (H) is an important quantity in research of rotating Earth. Precession observations give $H_{obs} = 0.0032737 \approx 1/305.5$. We recalculate the geometrical flattening profile of the Earth interior from potential theory in hydrostatic equilibrium. Results coincide with that of Denis (1989). We derive expression for H to the third-order accuracy and obtain $H_{PREM} = 1/308.5$. This matches similar studies, in which there is a difference about 1% between this and the observed value. In order to understand where this difference comes from, we replace the homogenous outermost crust and oceanic layers in PREM with some real surface layers data, such as oceanic layer (ECCO) , topography data (GTOPO30), crust data (CRUST2.0) and mixed data (ETOPO5). Our results deviate from the observed value more than H_{PREM}. These results verify the isostasy theory indirectly and may imply that the "positive" effects from such as mantle circulation associated with the density anomalies maybe larger than thought before.

Keywords. reference systems, standards, magnetic fields, Earth, methods: analytical

1. Introduction

The global dynamic flattening (H) is an important quantity in research of rotating Earth. It can be related with the luni-solar precession, nutation(18.6 yr terms), tilt-over mode and so on. From observations, the value of H is approximately 1/305.5 (Dehant, 1997). But the H of PREM model (Dziewonski, 1981) is about 1/308.8 at the first order accuracy. There is about 1% difference between them, which is an interesting question we discuss in this paper.

We recalculate the geometrical flattening profile of the Earth interior from potential theory at 3rd accuracy. The flattening profile matches that of Denis (1989). We obtain the dynamic flattening at the 3rd accuracy by using the geometrical flattening profile. Comparing our results with the others, we find that adopting a high order accuracy can reduce the difference between H_{PREM} and H_{obs} , but the effect is too small to remove the difference.

At the same time, we note that the oceans and lands are distributed uniformly in the PREM model. The real oceans and lands are distributed nonuniformly obviously. What effect the real oceans and land make?

2. Dynamic flattening of modified Earth model with real surface layers (ocean and topography)

According to the depth range of each real surface layers model, we construct three Earth models with real surface data form PREM, ECCO, GTOPO30 as follows: (a)

PREM without 5.615 km depth surface layer(PREM_NS_5) + real ocean data(ECCO) + real topography data (GTOPO30); (b) PREM without 10.376 km depth surface layer(PREM_NS_10) + real ocean and topography data (ETOPO5); (c) PREM without 70.137 km depth surface layer(PREM_NS_70) + real crustal data (CRUST2). We assume simply that the shapes and so on of PREM_NS_5 and PREM_NS_10 in our model are as the same as in PREM. The following table shows all the results.

Model	A 10^{37} $kg \cdot m^2$	B 10^{37} $kg \cdot m^2$	C 10^{37} $kg \cdot m^2$	1/H
PREM(Full)	8.0115651	8.0115651	8.0376170	308.52
PREM_NS_5	7.9966287		8.0226249	
ECCO(KF049f)	0.0132681	0.0128369	0.0125290	
GTOPO30	0.0008458	0.0006980	0.0005578	
PREM+E+G	8.0107426	8.0101637	8.0357116	318.14
PREM_NS_10	7.9788034		8.0047331	
ETOPO5	0.0312185	0.0305047	0.0300231	
PREM+ETOPO5	8.0100220	8.0093081	8.0347563	320.22
PREM_NS_70	7.7087284		7.7336553	
CRUST2	0.3008642	0.3008114	0.3017731	
PREM+CRUST2	8.0095926	8.0095399	8.0354284	310.70

3. Discussion

The mass of surface layer is less than 0.1% of the whole Earth. But the real surface layer can reduce the global dynamic flattening from 1/308.53 to 1/318.14 (about 3%). It is a large effect, because the surface layer is the outermost layer of the Earth.

H deviates more with the depth of surface layer displaced by real data being deeper, untill somewhere deeper than 10.376 km under the mean sea level. The value of H of the deepest model C is enlarged and deviates less than the above two models. The isostasy theory can explain why this is happening and our results provide an indirect evidence for the theory of isostasy.

The effects from nonuniform distribution of oceans and lands are “negative”. They make H deviate from the observed value even further. Although the theory of isostasy can explain the difference among the three models, there is still a difference between H and the observed value. This may imply that, in order to balance the “negative” effect from real oceans and lands, the “positive” effectssuch as the mantle circulation associated with the density anomalies maybe larger than what was thought before.

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