Contributions of satellite laser ranging to the studies of Earth tides

IAG/ETC WG6 SLR subgroup report

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Satellite laser ranging (SLR) contributes to the studies of Earth tides in the following aspects:

1. Determination of potential love number k2 by analyzing related tidal parameters from satellite orbit perturbations
2. Determination of Love number h2 and l2 by analyzing tidal displacements of SLR sites.
3. Determination of tidal geocenter variations.

SLR observable, the range from a satellite in orbit to a station, is a function of tidal displacements of site and tidal geopotential variations, which perturbate the position of a satellite in its orbit. Hence the signals of tidal variations in satellite position and station position can be recovered from SLR data analyzing. For example, for K1 tide wave, solid Earth tide causes the variation of Lageos inclination 43 meters with the period of 1050 days and maxim radial site displacement 0.08 meter with diurnal period compared with 4 meters in inclination and 0.015 meter in maxim radial site displacement by ocean tide. It is worth to note that SLR is a such technique that is used to determine not only the Love number h2 and l2 from the site tidal displacements but also the Love number k2 from the orbit tidal perturbations, which is quite different from the VLBI or gravimeter.

In order to obtained the high precise Love numbers from SLR analyzing, sophisticated models, especially the ocean tide models are crucial because the solid Earth, ocean and atmosphere affect the geopotential variations and site displacements at same frequency associated with any tide constitute. Although using SLR to derived displacement Love numbers h and l is less precise than VLBI, it has proven from recent studies that SLR is a more precise tool to determine potential Love number k2 with high precision from semi-diurnal period to 18.6 year.

In precise SLR data analyzing, second and third solid Earth tide model, and ocean tide model at least up to 6th degree and order must be included for precise orbit determination. Second degree solid Earth tide to geopotential variations and displacements with liquid core flattening correction and ocean tidal displacement correction must be applied. Polar tide correction is advisedly to add to geopotential and site displacement. Permanent tide effects on geopotential and site displacement are important when objectives are to determine the gravity model including SLR data and to realize the terrestrial reference frame using SLR data.

With enhancement the global distributed SLR station tracking network and centimeter or better precision of ranging measurement, the tidal variations in the geopotential and coordinates of stations have been recovered by SLR technique more accurately. These tidal variations contain all of the solid Earth, oceanic and atmospheric tide contributions and provide a unique method to directly to estimate Love number independently from traditionally ones. By adopting the recent ocean tide model and some small corrections of atmospheric tides, SLR data can be used to estimated the second degree Love numbers for the semi-diurnal (M2,S2), diurnal (K1,O1), monthly (Mm, Mf) and 18.6 year waves. The geocenter tidal variations can also be recovered by parameterized estimation from SLR data analyzing.

In recent years, partly excited by recently important results of ocean tide studies from satellite altimetery and Earth tide studies from VLBI, SLR community has been very active in studying the Earth tide. As an important base, more precise ocean models (e.g. CSR3.0) and ocean tide displacement models (e.g. HGS's

model) were used for precise orbit determination in SLR data analyzing which made it possible to extend the studies of tidal parameter determination to the Love numbers determination. There we try to give a brief summery directly related to the topics of SLR subgroup of WG6 after 1997.

1) Watkins and Eanes (1997) studied Geocenter tidal variations. Their solution using nearly 18 years of Lageos data indicated 'geocenter motions at few millimeter level compare well with predicted values from theoretical ocean models and from TOPEX/Poseidon radar altimetry'

2) After Ray et al (1996), the earth tide phase lag was re-studied for M2 and K1 by Wu et al (1999) using SLR or satellite tracking data with phase lag(M2)=0.16±0.09 and phase lag(K1)=0.06±0.12 (degree)

3) Cheng et al (1997) using multi-satellite SLR data, Peng (1998) and Peng and Wu (1999) using Lageos SLR data studied 18.6 year Love number k2 and phase lag and had the following results:

By Cheng ea al k2=0.3265 , phase lag=0.62 (degree)
By Peng and Wu k2=0.3152(0.0070) phase lag=3.1(2.0) (degree),

4) Wu et al (1997,1999) studied how to precisely determine semi-diurnal and diurnal Love number k2. Using tidal parameter results of SLR and satellite tracking data with the following result:

k2				
M2	S2	K1	O1	
0.3017	0.3014	0.2573	0.2968	SLR (delta h2 corrected)
(0.0004)	(0.0004)	(0.0013)	(0.0029)	
0.3019	0.3022	0.2581	0.2961	SLR (delta h2 =0)
0.302	0.302	0.256	0.298	Wahr model
0.3012	0.3012	0.2574	0.2975	IERS recommended

5) Wu et al (1999) and Peng et al (1999) studied solid Earth tidal displacement Love number h2 and l2 by SLR and by both gravity tide results and SLR result with the result:

h2				
M2,	S2,	K1,	O1	
0.6062	0.6114	0.5234	0.6024	SLR combined
(0.0004)	(0.0004)	(0.0013)	(0.0029)	
0.606	0.599	0.502	0.618	SLR
(0.001)	(0.004)	(0.002)	(0.002)	
0.600	0.592	0.512	0.612	Haas and Schuh (VLBI)
0.6078	0.6078	0.5232	0.6026	IERS recommended

l2= 0.071(0.001)M2, 0.069(0.002)S2, 0.065(0.002)K1, 0.095(0.002)O1

6) Wu et al (1999) studied the Love number k2 at Mm and Mf waves using SLR and the variation of length of day and obtained:
k2=0.3032+i0.0028 (Mf),0.3026+i0.0012 (Mm), SLR
k2=0.3083-i0.0100 (Mf),0.3014-i0.0010 (Mm), LOD

Further prospects: Previous researches, especially in recent four years, SLR have demonstrated that it is a one of the most useful techniques for the studies of Earth tides. Different from the long history of the ground gravimetric tidal ones, SLR just began to contribute the precise Earth tides research for a short time. There are left many detail problems to be refined and solved. One of the most limitations using SLR to study solid

Earth tide mainly exists in sparse SLR data acquisition, error of ocean tide models. With the advancement of SLR hardware, SLR data accumulation, more precise orbit determination of SLR tracking satellites and the more precise oceanic and atmospheric tide models, SLR will be a powerful tool to study the Earth tides.

Recent publications

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4. Peng B.B and B. Wu Acta Geodaetica et Cartogrphica Sinica (in Chinese),1999 in press
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