Report of Activities of the IAG/ETC Working Group 6 «Solid Earth Tides in Space Geodetic Techniques»

Harald Schuh
University of Technology Wien
Austria
hschuh@luna.tuwien.ac.at

1. Introduction

The **IAG/ETC Working Group 6 'Solid Earth tides in space geodetic techniques'** was established at the XIIIth International Symposium on Earth Tides, Brussels, July 1997. The general goal of the WG is to strengthen the links between researchers of the tidal community and those who work in space geodetic techniques. The cooperation shall take place in both directions:

- The tidal experts provide precise models for the displacements of observation sites on the Earth's crust due to the tides and for the tidal variations to the gravitational field of the Earth.
- The space geodetic techniques are used to validate and possibly to improve the tidal models, e.g. the tidal parameters.

For the investigation of the solid Earth tides it is necessary to take also into account other geophysical influences, e.g. those of the oceans, of the atmosphere and of the pole-tide. Thus, oceanic and atmospheric loading, oceanic and atmospheric effects on the geopotential and the pole-tide are regarded by the WG, too.

Chairman, members and correspondents of WG 6 (status August 2000) are:

Chairman: Harald Schuh (DGFI, München, since April 2000 TUW, Wien)
Members: Per-Helge Andersen (NDRE, Kjeller)
Trevor Baker (POL, Bidston)
Veronique Dehant (ROB, Brussels)
Richard Eanes (UTEX, Austin)
John Gipson (GSFC, Greenbelt) (till 1999)
Ruediger Haas (OSO, Onsala)
P.M. Mathews (Univ. Madras, Chennai)
Jürgen Mueller (TUM, München)
Richard Ray (GSFC, Greenbelt)
Hans-Georg Scherneck (Chalmers Univ. of Techn., Göteborg)
Oleg Titov (Univ., Sanct-Petersburg)
Correspondents: Duncan C. Agnew (Scripps Inst. of Oceanography, La Jolla)
Richard Biancale (CNES, Toulouse)
Karen Bruyninx (ROB, Brusells)
Robert C. Bostrom (Univ. of Washington, Seattle)
Jean Chapront (PO, Paris)
Shailen Desai (JPL, Pasadena)
Robert Dill (DGFI, München)
Olivier Francis (ROB, Brusells)
Pascale Gegout (IPG, Strasbourg)
Michael Gerstl (DGFI, München)
Michael B. Heflin (JPL, Pasadena)
Maria Mareyen (BKG, Potsdam)
Jürgen Neumeyer (GFZ, Potsdam)
Ron Noomen (TU, Delft)

Markuu Poutanen (FGI, Masala)
Burghard Richter (DGFI, München)
Judit G. Ries (UTEX, Austin)
Ernst Schrama (TH Delft)
Tonie M. VanDam (NOAA, Boulder)
Peter Varga (GGRI, Sopron)
John Wahr (Univ. Colorado, Boulder)
Robert Weber (TUW, Wien)
Pascal Willis (IGN, Paris)
Wu Bin (IGG, Wuhan)
Xi Qinwen (State Seism. Bur., Beijing)
Kahled Zahran (Univ., Karlsruhe)

2. Terms of Reference (ToR)

The following Terms of Reference (ToR) were agreed upon by the members of WG 6 on Oct., 24th, 1997:

1. Extension of the recommendations concerning the tidal influences given in the IERS Conventions (1996) to facilitate their practical use for space geodetic techniques.
2. Evaluation and comparison of the potential of different space geodetic techniques to monitor tidal effects and to determine tidal parameters. Techniques such as VLBI, SLR, LLR, GPS and GLONASS, DORIS and PRARE, satellite altimetry will be covered.
3. Determination of parameters of the tidal models by space geodetic techniques. This requires a priori corrections due to atmospheric and oceanic influences on the Earth‘s surface and on the geopotential and precise models for tidal influences on the Earth orientation parameters. The effect of pole-tide has also to be considered. The results will have to be compared and interpreted.

3. Activities of Working Group 6 from 1997 till 2000

Activities for the **1. Term of Reference** started in February 1998 by establishing subgroups which worked on ‘supplements‘ to the IERS Conventions (1996). The goal was to work on an extension of the recommendations concerning the tidal influences given in the IERS Conventions (1996) to facilitate their practical use for space geodetic techniques. Dennis D. McCarthy, editor of the IERS Conventions (1996), was informed.

These are the subgroups with the chairpersons given in bold:

Chapter 6 of the IERS Conventions (1996) ‘Geopotential‘

- Effect of Solid Earth Tides (**Eanes**, Dehant, Mathews, Ray,...)
- Solid Earth Pole Tide (**Andersen**, Müller, Schuh, ...)
- Treatment of the Permanent Tide (**Mathews**, Dehant, Eanes, ...)
- Effect of the Ocean Tide (**Ray**, Eanes, Baker, Müller, Scherneck, ...)
- Conversion of tidal amplitudes defined according to different conventions (**Dehant**, Gipson,...)

Chapter 7 of the IERS Conventions (1996) ‘Site Displacement‘

- Local Site Displacement due to Ocean Loading (**Scherneck**, Baker, Haas, Müller, ...)
- Effects of the Solid Earth Tides (**Dehant**, Gipson, Haas, Mathews, Schuh, Titov, ...)
- Rotational Deformation Due to Polar Motion (**Andersen**, Müller, Schuh)
- Antenna Deformation (**Haas**, Schuh, Titov, ...)
- Atmospheric Loading (**Gipson**, Baker, Haas, MacMillan, Scherneck, Schuh, Titov, Vauterin)
- Postglacial Rebound (**Ray**, Scherneck, ...)

An Explanatory Supplement to the IERS Conventions (1996) Chapters 6 and 7 was elaborated which was

published as *DGFI Report 71*:

http://www.dgfi.badw.de/dgfi/DOC/report71.pdf (1999).

The activities for the **2. and 3. Term of Reference** started in summer 1999. New subgroups were established in September 1999, now to evaluate the different space geodetic techniques with respect to their potential to monitor tidal effects and to determine tidal parameters. The subgroups were also open for non-members of the WG. The following questions were addressed by the subgroups:

1. Which tidal effects have to be considered in the particular space technique?
2. How is the 'permanent tide problem' handled?
3. What is the capability of the particular space technique to investigate tidal effects (including oceanic and atmospheric tides) and to determine tidal parameters, e.g. the Love numbers?
4. What are the newest results?
5. What are the limitations?
6. What are the future perspectives?

Each subgroup presented its results in a draft report between 1 and 15 pages before the ETS2000 in Mizusawa and it was agreed that the final report should be finished till end of 2000. Subgroups for ToR 2 and 3 are:

WG 6/1 (VLBI): **R. Haas**, P.-H. Andersen, O. Titov, H. Schuh, P.M. Mathews, V. Dehant
WG 6/2 (SLR: **Wu Bin**, R. Eanes, J. Müller, P.-H. Andersen
WG 6/3 (LLR): **J. Müller**, J. Chapront, J.G. Ries, J. Williams
WG 6/4 (GPS/GLONASS): **R. Weber**, T. van Dam, K. Bruyninx, P.-H. Andersen, T. Baker, M. Rothacher, H.-G. Scherneck
WG 6/5 (DORIS): **R. Biancale**, J.G. Ries, P. Willis
WG 6/6 (Satellite Altimetry): **S. D. Desai**, R.D. Ray, E.J.O. Schrama

Results of the work of the subgroups on different space geodetic techniques

- all space geodetic techniques provide interesting information about tidal effects;
- comparison of the treatment of tidal effects in different software packages revealed considerable discrepancies (e.g. between GPS software packages, between VLBI software packages, between LLR software packages, ...);
- new results for the tidal parameters were obtained for:
  VLBI: h, l (for individual tides and also for tidal bands: semi-diurnal, diurnal, long-period, second degree and third degree, including phase lags, *Haas and Schuh, 1996; Schuh and Haas, 1998*)
  DORIS: h_2, k_2 (*R. Biancale, 2001*)
  LLR: secular tidal acceleration, lunar tidal parameters, h_2, l_2 (*Müller and Tesmer, 2000*)
  SLR: k_2, h_2 incl. phase lags (for M_2, S_2, K_1, O_1) (*Wu Bin et al., 2001*)
  GPS: planned
  Sat. Altimetry: h_2 for four tides (*Ray et al., 1995*), ocean tidal models

For the work on the Terms of Reference and to achieve the results briefly summarized above three meetings of WG6 took place from 1997 till 2000, additionally to several thousands of email communications. Each of the meetings was attendend by about 20 participants.

1st Meeting, during EGS, Nice, April 23rd, 1998

2nd Meeting, during IUGG, Birmingham, July 22nd, 1999

3rd Meeting, during EGS, Nice, April 26th, 2000

4. Outlook

The following questions for the future of Working Group 6 were risen:

- What else should the WG 6 deliver? (bibliography related to tidal effects **and** space geodetic techniques?)
- What could be future activities after ETS2000?
- Should WG 6 finish its activities, continue in the present form, continue with different or
- additional goals?

The following proposals for future tasks of WG 6 were made:

- Cooperation with the analysis coordinators of the new IAG international services, e.g. IGS, IVS, ILRS, IDS, ... and the Working Groups which exist within these services,
- Comparison of tidal parameters obtained from the different techniques,
- Comparison of results obtained by space geodetic techniques and ground-based tidal measurements.

5. References

Explanatory Supplement to the IERS Conventions (1996) Chapters 6 and 7, ed. by H. Schuh, *DGFI Report 71*: http://www.dgfi.badw.de/dgfi/DOC/report71.pdf, 1999.

Final Report of the IAG/ETC Working Group 6 for the years 1997-2000, ed. by H. Schuh, with contributions by Biancale, Desai et al., Haas et al., Müller et al., Weber et al., Wu Bin et al., BIM, 2001.

Haas, R. and Schuh, H.: Determination of frequency dependent Love and Shida numbers from VLBI data. Geophys. Res. Lett., Vol. 23, No. 12, 1509-1512, 1996.

Müller, J. and Tesmer, V.: Investigation of Tidal Effects in LLR. subm. to Journal of Geophysical Research, 2000.

Ray, R.D. et al.: Geometrical Determination of the Love number h_2 at four tidal frequencies. Geophys. Res. Lett., Vol. 22, No. 16, 2175-2178, 1995.

Schuh, H. and Haas, R.: Earth Tides in VLBI Observations. Proc. of the 13th International Symp. on Earth Tides, Brussels, 1997, ed. by B. Ducarme and P. Paquet, Série Géophysique, Obs. Royal de Belgique,

101-110, 1998.