Preface

Dedicated lectures on Advanced Geodesy (*Höhere Geodäsie*) at Vienna University of Technology (erstwhile *k.k. Polytechnisches Institut*) were originated in 1857 by Josef Herr, at that time Professor of Applied Geometry (*Praktische Geometrie*) and later also of Advanced Geodesy and Spherical Astronomy (*Höhere Geodäsie und Sphärische Astronomie*). Since those early days of Advanced Geodesy in Vienna, research topics have been manifold and broad, being revolutionized with the advent of computers and satellites in the second half of the twentieth century. This development certainly strengthened the value of studies dealing with atmospheric effects in geodesy. For instance, in 1969 Kurt Bretterbauer, predecessor of Harald Schuh as Chair of Advanced Geodesy, wrote his dissertation on refraction issues in Advanced Geodesy, stating in the first sentence of the introduction to the thesis that we are living at the bottom of a sea, the'air-sea' (*Wir leben auf dem Grunde eines Meeres*, *des Luftmeeres*). The substance of this quote should not be underrated, as many atmospheric effects have counterparts in the oceans, e.g., atmospheric and oceanic loading of the solid Earth, excitation of Earth rotation, or variable gravitational effects due to density variations in both fluids. While there are no antennas at the ocean bottom to receive signals from satellites or extragalactic radio sources, systems with receivers and transponders at the sea surface exist as well as sensors located at the bathymetry.

Ever since Johannes Böhm completed his Ph.D. thesis on tropospheric path delays of Very Long Baseline Interferometry (VLBI) observations in 2004 supervised by Harald Schuh, the research group on Advanced Geodesy at Vienna University of Technology has been very active in investigating atmospheric effects in space geodesy. Johannes Böhm's thesis laid the foundation for the Vienna Mapping Functions 1 (VMF1) and the Global Mapping Functions (GMF), which were published in 2006 and can be used to map tropospheric delays from the zenith to arbitrary elevations. In the wake of this work, numerous research and Ph.D. projects were stimulated by issues relating to tropospheric delays, e.g., the determination of long-term trends in zenith delays determined from VLBI observations (Ph.D. thesis by Robert Heinkelmann, finished in 2008) or the retrieval of precipitable water with Global Navigation Satellite Systems (GNSS)—a topic that has been primarily dealt with in projects led by Robert Weber with Ph.D. theses, e.g., by Elisabeth Klaffenböck in 2005 or Ana Karabatic in 2011.

Under the supervision of Harald Schuh, Thomas Hobiger completed his Ph.D. thesis on the determination of ionospheric parameters from VLBI observations in 2005. His study marks the starting point of research on ionospheric effects in space geodesy, and was continued by Sonya Todorova (Ph.D. in 2008), Mahdi Alizadeh, Nina Magnet, and Claudia Tierno Ros.

A diversification of research topics beyond the field of atmospheric delays arose when the Austrian Science Fund (FWF, *Der Wissenschaftsfond*) approved project *GGOS Atmosphere* in October 2008. GGOS is the Global Geodetic Observing System of the International Association of Geodesy (IAG), aimed at the consistent treatment of geokinematics (i.e., the shape of the Earth), the gravity field of the Earth, and Earth rotation. In accordance with those pillars, *GGOS Atmosphere* allowed funding of three scientists dealing with atmospheric loading (Dudy Wijaya), atmospheric effects on gravity (Maria Karbon), and atmospheric excitation of Earth rotation (Michael Schindelegger). Additionally, Vahab Nafisi and Matthias Madzak addressed the refinement of ray-tracing through numerical weather models. All scientists in project *GGOS Atmosphere* consistently used data from numerical weather models of the European Centre for Medium-Range Weather Forecasts (ECMWF) for the determination of the respective products.

Since 2002, Johannes Böhm has been giving these lectures on *Atmospheric effects in space geodesy* at the Vienna University of Technology. Supported by the input of the research staff of Advanced Geodesy, these lectures present both theoretical foundations as well as recent results achieved in the field. Consequently, with all the expertise available, we decided to write a book based on the contributions of various members of the research group. Instead of simply compiling numerous papers, the plan was to publish a textbook with a consistent and homogeneous description of atmospheric effects that can be used for lectures, primarily in geodesy courses.

The first chapter (Geodetic and Atmospheric Background) by Böhm et al. provides introductory information for the other chapters in the textbook, summarizing gas laws and meteorological parameters or phenomena for the troposphere, as well as ionization processes for the ionosphere. More specifically, the second chapter (Ionospheric Effects on Microwave Signals) by Alizadeh et al. discusses delays (and phase advances) of signals from space geodetic techniques in the ionosphere, and how they are treated in the analysis of the observations. Analogously, in the third chapter (Path Delays in the Neutral Atmosphere), Nilsson et al. report about signal delays in the neutral atmosphere. In both cases, ionosphere and neutral atmosphere, the emphasis of the book is on atmospheric effects on space geodetic observations and how they can be reduced or mitigated to get the best possible geodetic results in terms of station coordinates or Earth orientation parameters. However, the contributions do not deal with the reverse applications, that is the use of space geodetic observations for the determination of atmospheric parameters in the first place, e.g., maps of water vapor or Total Electron Content. "Atmospheric Pressure Loading" by Wijaya et al. describes atmospheric loading of the solid Earth by changing surface pressure and its implication on geometric space geodetic techniques, while in the fifth chapter

(Atmospheric Effects on Gravity Space Missions) Karbon et al. report about atmospheric effects on gravity missions in space. Again, atmospheric loading shows up as an indirect effect for gravity determination. Finally, Schindelegger et al. provide a detailed summary of atmospheric excitation of Earth rotation in "Atmospheric Effects on Earth Rotation".

For the sake of completeness, we want to list here the atmospheric effects in space geodesy which are not covered by the book: presently there is no review of tropospheric delays affecting Interferometric Synthetic Aperture Radar (InSAR) observations and how they can be mitigated. Furthermore, we do not deal with atmospheric drag on satellite orbits, nor do we describe thermal deformation of VLBI telescopes or other monuments that carry space geodetic antennas. However, those topics are kept in mind and will be eventually added to a new edition of the book at some time in the future.

The development of the book was quite a challenge, and we are sure that there are some bugs (hopefully not too many). Thus, we will be very happy to receive comments and feedback (positive and negative) so that we can further improve the description of atmospheric effects in space geodesy.

Vienna, December 2012

Johannes Böhm
Harald Schuh

Springer

http://www.springer.com/978-3-642-36931-5

Atmospheric Effects in Space Geodesy
Böhm, J.; Schuh, H. (Eds.)
2013, XVII, 234 p., Hardcover
ISBN: 978-3-642-36931-5