

## **Final Report**

Special Study Group 4.191: Theory of Fundamental Heights Systems

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Christopher Jekeli  
Laboratory for Space Geodesy and Remote Sensing Research  
Ohio State University  
Columbus, Ohio

This Special Study Group was proposed and approved at the I.U.G.G. General Assembly in Birmingham, July 1999, to consider the fundamental role of vertical control and height systems in view of the modern reference system. As geodetic control throughout the world relies increasingly on satellite positioning techniques, vertical datums and height systems take on a new significance as they become an integral part of global and local reference systems. Although no longer the exclusive origin for heights, the vertical datum nonetheless remains a traditional reference for the most intuitive systems of heights, the orthometric (and normal) heights (above mean sea level). As such, these heights continue to be relevant in geodesy, as well as related mapping, geospatial, and geographic information systems. Maintaining vertical datums, connecting different regional datums, defining a world vertical datum, and establishing vertical control within a datum are still important aspects that are actually becoming more significant as increasing accuracy is achieved in related geodetic control. The geoid also, of course, is intimately connected with the vertical datum and height systems and thus the latter are relevant to other disciplines such as oceanography, hydrology, and geodynamics that make ever more demands on an accurate geoid. Especially, as geoid determination and geodetic control now consider the time-varying aspects associated with geodynamics and anthropogenic phenomena, the maintenance of vertical control and datums assumes a new temporal significance that must be addressed by the geodetic community.

The objectives of the Study Group were defined as follows:

1. To consider the fundamental definition and realization of the geoid, with full recognition of temporal and general relativistic effects, for the purpose of establishing a global reference for geopotential heights and time systems.
2. To investigate height systems, including the role of the geopotential, and their utility for different geodetic, geophysical, and engineering applications that are current and that are projected in the year 2020 (and beyond). What accuracies will be needed, what height systems will be

useful, how will heights from different measurement systems be consolidated into a uniform frame? How should the vertical dimension be treated in terms of reference systems within the context of three-dimensional geodesy?

3. To determine if the IAG should establish recommendations for the future definitions of height systems for geodetic control and geophysical and engineering applications.

4. To determine (and recommend) if existing IAG-affiliated services should be expanded to provide information specific to vertical data.

The membership was compiled from organizations and individuals who have worked on or who have a close interest in promoting the objectives of the Study Group, as follows

Regular Members

Vassilios D. Andritsanos (Greece)  
Claude Boucher (France)  
Milan Bursa (Czech Republic)  
Hermann Drewes (Germany)  
Matt Higgins (Australia)  
Christopher Jekeli (USA), chair  
Steve Kenyon (USA)  
Urs Marti (Switzerland)  
Markku Poutanen (Finland)  
Fausto Sacerdote (Italy)  
Michael Sideris (Canada)  
Dave Zilkoski (USA)

Corresponding Members

Michael Bevis (USA)  
René Forsberg (Denmark)  
Erwin Groten (Germany)  
Cheinway Hwang (Taiwan)  
Bill Kearsley (Australia)  
Roberto Luz (Brazil)  
André Mainville (Canada)  
Ilias Tziavos (Greece)  
Martin Vermeer (Finland)  
Phillip Woodworth (United Kingdom)  
Georgia Fotopoulos (Canada)  
Christopher Kotsakis (Greece)

More details on the Objectives and Membership can be found on the Internet Web Site specifically created for this Study Group:

[www-ceg.eng.ohio-state.edu/~cjekeli/ssg4-191.htm](http://www-ceg.eng.ohio-state.edu/~cjekeli/ssg4-191.htm)

Clearly, the group is heavily interrelated with other structural entities of the International Association of Geodesy, including special study groups and commissions and special commissions of other sections.

Progress of the Study Group

One may say that the objectives of the Study Group were only partially fulfilled to the extent of providing a base from which to continue work in the future. Several important symposia and

conferences related to vertical datums either specifically, or as part of geodetic theory and application were well represented by and included contributions from the membership of the Study Group. These include

1. International Symposium on Gravity, Geoid and Geodynamics 2000 , Banff, Alberta, Canada, 31 July – 4 Aug 2000;
2. World Height System Workshop, Prague, 7-9 November 2000;
3. IAG Symposium, Vertical Reference Systems, Cartagena, Columbia, 20-23 Feb 2001;
4. EGS XXVI General Assembly, Nice, France, 25-30 March 2001;
5. IAG Scientific Assembly, IAG-2001, Budapest, Hungary, 2-8 September 2001;
6. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002
7. V Hotine-Marussi Symposium On Mathematical Geodesy, Matera, Italy, June 17 - 21, 2002;
8. International Gravity and Geoid Commission - GG2002, Thessaloniki, Greece August 26-30, 2002;
9. Weikko A. Heiskanen Symposium in Geodesy, Columbus, Ohio, 1-4 Oct 2002;
10. EGS-AGU-EUG Joint Assembly, Nice, France, 06 - 11 April 2003.

Relevant programs for these meetings, including proceedings for some, are provided on the SSG web site.

The Web Site also includes a compendium of vertical datums as well as information on access to GPS/orthometric height data sets for many countries around the world. This together with a bibliography that lists relevant publications provide a basis for further studies.

### Summary

While the work of the group has been rather inhomogeneous, attempts have been made to provide at least a focus for activities related to height systems and vertical datums via the internet site. Many open questions remain, as enumerated under the objectives above. The temporal aspects of height systems, the appropriate tidal system definition, the geodynamic effects (e.g. post-glacial rebound), the adoption of a world vertical datum, and other questions related to more local practical issues of using heights for geospatial data bases have been addressed with varying detail and require further study. No continuation of the Study Group is recommended at this time, especially because the topic has many related applications that fit in a variety of new purviews under the re-structured IAG. However, it is hoped that the study of height systems may continue to remain a focus of attention within the IAG under suitable auspices.