Ph.D. Candidate

Robert William Kingdon

Graduate Academic Unit

Geodesy & Geomatics Engineering

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

January 13, 2012

2:00 p.m.

ADI Studio (Room HC 25)
Head Hall

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Examining Board:

Dr. Petr Vanicek (Geodesy & Geomatics Eng.)	Co-Supervisor
Dr. Marcelo Santos (Geodesy & Geomatics Eng.)	
Dr. Peter Dare (Geodesy & Geomatics Eng.)	
Dr. Sanjeev Seahra (Math & Stats)	
Dr. Karl Butler (Earth Sciences)	Chairperson

External Examiner:
Dr. Spiros Pagiatakis
Dept. of Earth & Space Science and Engineering
Faculty of Science and Engineering
York University

The Oral Examination will be chaired by:
Dr. Ed Biden, Dean of Graduate Studies

BIOGRAPHY

Universities attended:

2008-2012	**Doctor of Philosophy candidate,** University of New Brunswick
2005-2008	**Master of Science in Engineering,** University of New Brunswick (Transferred from the MScE to the PhD program effective May 1, 2008)
2000-2005	**Bachelor of Science in Engineering (Geodesy and Geomatics)** University of New Brunswick

Publications:

Kingdon, R., P. Vaníček, A. Ellmann, M. Santos, and R. Tenzer (2005). "Toward an improved orthometric height system for Canada." *Geomatica*, Vol. 59, No. 3, pp. 241–249.

Nievinski, F., K. Cove, M. Santos, D. Wells, and R. Kingdon (2005). "Range-Extended GPS Kinematic Positioning using Numerical Weather Prediction Model." *Proceedings of the Institute of Navigation 61st Annual Technical Meeting*. Cambridge, M.A., U.S.A., June 27–29, 2005, pp. 902–911.

Santos, M., P. Vaníček, W.E., Featherstone, R. Kingdon, B.-A. Martin, M.Kuhn and R.Tenzer (2006). "Relation between the rigorous and Helmert's definitions of orthometric heights." *Journal of Geodesy*, Vol. 80, No. 12, pp. 691–704. doi: 10.1007/s00190-006-0086-0.

Ellmann, A., P. Vaníček, M. Santos, and R. Kingdon (2006). "Interrelation between the geoid and orthometric heights." *Proceedings of the 1st International Symposium of the International Gravity Field Service "Gravity Field of the Earth",* Ed. R. Forsberg and A. Kilicoglu. Istanbul, Turkey, August 28–September 1, 2006. pp. 130–135.

Kingdon, R., C. Hwang, Y.-S. Hsiao, and M. Santos (2007). "Gravity Anomalies from retracked ERS and GeoSat Altimetry over the Great Lakes: Accuracy Assessment and Problems." *Terrestrial, Atmospheric and Ocean Sciences*, Vol. 19, No. 1–2, pp. 93–102, doi: 10.3319/TAO.2008.19.1-2.93(SA).

Kingdon, R., P. Vaníček, and M. Santos (2009). "Modeling topographical density for geoid determination." *Canadian Journal of Earth Sciences*, Vol. 46, No. 8, pp. 571–585, doi: 10.1139/E09-018.

Kingdon, R., P. Vaníček, and M. Santos (2011). "Effects of hypothetical complex mass-density distributions on geoidal height." *Geodesy for Planet Earth*, Eds. S. Kenyon, M. Pacino and U. Marti. International Association of Geodesy IAG2009 "Geodesy for Planet Earth" Scientific Assembly, Buenos Aires, Argentina, 31 August–4 September, 2009. *International Association of Geodesy Symposia*, Vol. 135, Springer, New York (in press).

Kingdon, R., and P. Vaníček (2011). "Poisson downward continuation solution by the Jacobi method." *Journal of Geodetic Science*, Vol. 1, No. 1, pp. 74-81, doi: 10.2478/v10156-010-0009-0.

Vaníček, P., R. Kingdon, M. Santos (2011). "Geoid vs. quasi-geoid: a case of physics versus geometry." *Contributions to Geophysics and Geodesy* (in review).

Kingdon, R., P. Vaníček, M. Santos, and A. Ellmann (2012). "Efficient correction of Helmert orthometric heights for terrain and density effects." *Computations and Geosciences* (in preparation).

ADVANCES IN GRAVITY BASED HEIGHT SYSTEMS

Abstract

In order to have physical meaning, a height system must have some relation to the Earth's gravity field. Of the height systems that do, orthometric heights match best without intuitive understanding of height. The orthometric height of a point is the distance travelled along a plumbline from that point to the geoid, and can be arrived at either directly from leveling and gravity observations or indirectly by converting geodetic heights to orthometric heights using a geoid model. This dissertation investigates recent advances in orthometric height determination, to find out whether orthometric height determinations can meet modern accuracy requirements. Persistent barriers to improving orthometric height accuracy have been the impossibility of fully modeling topographical density effects, the lack of suitable numerical methods, and the lack of sufficient data.

The problem is addressed in six articles. The first two deal with direct calculation of orthometric heights, providing a practical implementation of a rigorous theory of orthometric heights able to deliver sub-centimetre accuracy in most cases, and showing that numerical errors in this process can be kept below the one centimetre level. The next two articles address the problem of the unknown density distribution in geoid determination, describing a framework for including the full three-dimensional effect of topographical density, and demonstrating that existing laterally-varying density models can provide sub-centimetre results in most areas. Vertical density variations neglected in such models are only expected to reduce accuracy to a few centimetres in mountainous areas. The fifth article demonstrates a new method for downward continuation of gravity anomalies, one of the largest numerical barriers to accurate geoid determination. The final article evaluates satellite altimetry as a source of gravity data over lakes, finding it promising but in need of further refinement.

The ultimate conclusion is that precise orthometric heights can be now determined in most areas, given suitable data, while in some especially challenging areas errors of several centimetres must be accepted.