The Danish National Report 2007 – 2011

International Association of Geodesy (IAG)

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Edited by

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Introduction

In the four year period 2007 – 2011 Danish Geodesy has developed further as reflected in the reporting below of central national and international geodetic research and activities.
Utilization, building and investigation of the national and international geodetic space infrastructure is a striking feature for the main activities and this is done in close cooperation with many national and international institutions.

A markedly organizational change was the merging by January 1st , 2007 of the National Space Centre, including the department of Geodesy and the department of Geodynamics with the Technical University of Denmark (DTU) forming a new National Space Institute (DTU Space) now housing most of the geodesy research in Denmark and again reflecting the increasing overlap between geodesy and space research.

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Geodetic Activities and Research 2007 - 2011

Since 2007 the **Department of Geodesy** has been affiliated with DTU Space, the National Space Institute at the Technical University of Denmark. The main objectives remain to be research in the field of Geodesy with a special focus on positioning and reference frames as well as in Earth Observation where we focus on the use of radar altimetry for estimation of marine geodetic quantities and monitoring of sea level. During the transfer to DTU Space we merged with the Geoinformatics group expanding our activities to include research in surveying and mapping as well.

Along with the geodetic research we carry out practical tasks for the National Survey and Cadastre (KMS). Those tasks are mainly focused on operating permanent GNSS stations and tide gauge stations in Greenland and on development of the geodetic infrastructure such as realizing new reference frames in Denmark, Greenland and the Faeroe Islands. Furthermore, we advise KMS on issues related Navigation and Mapping. In addition, we also carry out government consultancy of other agencies such as the Danish Agency for Science, Technology and Innovation and Asiaq - the Greenland Survey. In 2007, we launched a new education Geomatics Engineering as a focus line on the Mathematical Modelling and Computation master programme at DTU.

During the last 4 year period the Department of Geodesy has been involved in many cutting edge research projects where new methodologies for studying and monitoring the impacts of climate change have been developed. Furthermore, methodologies for using new satellite based techniques for both climate monitoring as well as strengthening the infrastructure have been developed.

Positioning and reference frames

The research activities related to positioning and reference frames have mainly been focusing on Greenland and on how the melting of the ice sheet may influence the stability of the reference frame realisation. For that purpose data from permanently operating GNSS stations is being analysed to detect crustal movements caused by the changes in the load of the ice sheet masses. The estimated movements have been compared to estimates of ice mass loss derived from GRACE gravity data. For Denmark another study on climate adaptation is being carried with a special focus on sea level rise and its effects along the Danish coastline. Here uplift due to postglacial rebound is modelled using historical precise levelling in combination with GPS data from permanent station.

We continue to operate, maintain and develop a number of high class permanent GNSS stations in Greenland. Those stations are equipped with stable monuments, external frequencies and met sensors and contribute to the IGS networks for reference frame realization. Most of the stations supply hourly data and some combined GPS and Glonass data. In addition to GNSS, we operate tide gauges at three of those sites. The vertical reference points are connected to the nearby GNSS station using precise levelling.
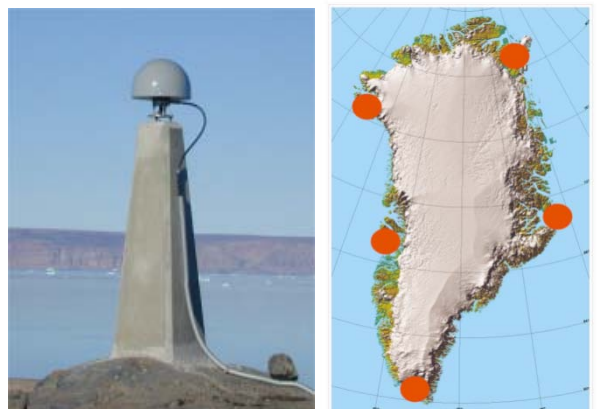
The data from the permanent GPS stations have been used to study uplift due to mass loss of the Greenland ice sheet. Greenland's main outlet glaciers have more than doubled their contribution to global sea level rise over the last decade. Recent work has shown that Greenland's mass loss is still increasing. Here we show that the ice loss, which has been well-documented over southern portions of Greenland, is now spreading up along the northwest coast, with this acceleration likely starting in late 2005. We support this with two lines of evidence. One is based on measurements from the Gravity Recovery and Climate Experiment (GRACE) satellite gravity mission, launched in March, 2002. The other comes from continuous Global Positioning System (GPS) measurements from three long-

term sites on bedrock adjacent to the ice sheet. The GRACE results provide a direct measure of mass loss averaged over scales of a few hundred km. The GPS data are used to monitor crustal uplift caused by ice mass loss close to the sites. The GRACE results can be used to predict crustal uplift, which can be compared with the GPS data. In addition to showing that the northwest ice sheet margin is now losing mass, the uplift results from both the GPS measurements and the GRACE predictions show rapid acceleration in southeast Greenland in late 2003, followed by a moderate deceleration in 2006. Because that latter deceleration is weak, southeast Greenland still
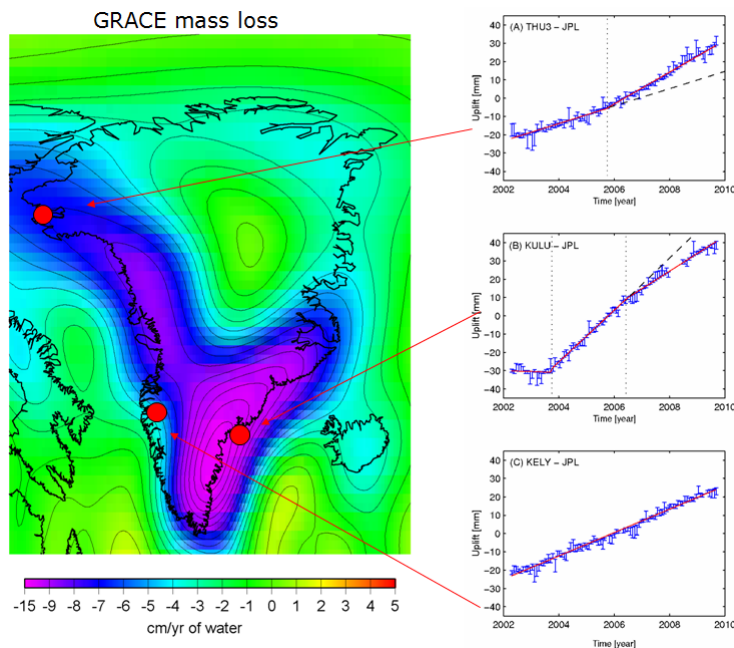

appears to be losing ice mass at a much higher rate than it was prior to fall 2003. In a more general sense, the analysis described here demonstrates that GPS uplift measurements can be used in combination with GRACE mass estimates to provide a better understanding of

ongoing Greenland mass loss; an analysis approach that will become increasingly useful as long time spans of data accumulate from the 51 permanent GPS stations recently deployed around the edge of the ice sheet as part of the Greenland GPS Network (GNET).

Our activities have benefitted vastly from the collaboration in the international project Greenland Network - GNET. GNET is a major US project supported by NSF and lead by Mike
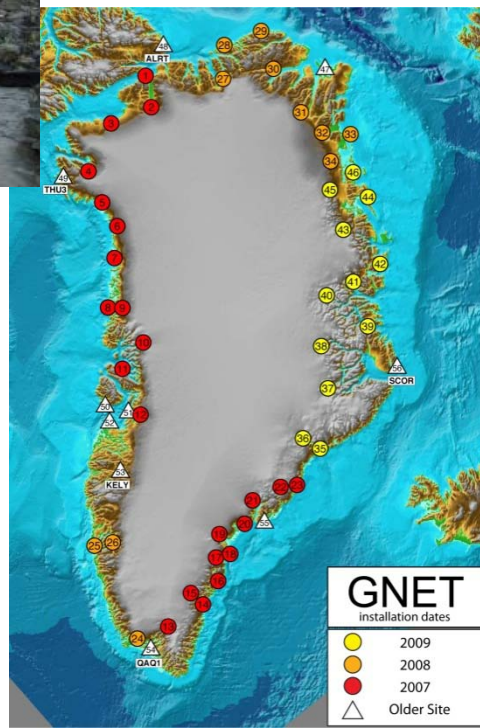
Bevis, Ohio State University. The objective of GNET is to study the vertical crustal movements caused by changes in the ice mass using GPS to better understand the impact of climate change and involve the installation of about 45 permanent GPS stations around Greenland. University of Luxembourg and University of Colorado contribute to the project as well. The installation of the station was carried out during 2007-2009 by UNAVCO with our assistance in both the planning and the field work phases. Some of the stations are established at facilities where electricity and communication are available but more than half of the stations are established in remote regions with none of those only accessible by helicopter. The remote stations are powered by solar panels and wind mills through batteries and need to be visited to acquire data from the receivers.
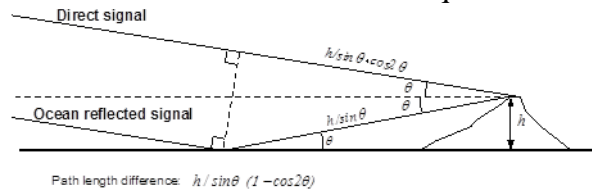
Schematic presentation of the direct and the ocean reflected GPS signal as observed by the receiver.

The direct signals from satellites in global satellite navigation satellites systems (GNSS), as GPS, GLONASS and GALILEO, constitute the primary signal source for positioning, navigation and timing from space. But also the reflected GNSS signals contain an important information content of signal travel times and the characteristics of the reflecting surfaces and structure.

The field-of-view at the observation site and the L1 and L2 receiving antenna array.

Ocean reflected signals from GNSS satellite systems reveal the mean height, the significant wave height and the roughness of the ocean. The estimated accuracy of the average surface height can be as low as 10 cm. For low elevations, the signals reveal the incoherent scatter process at the reflection zone. By using open-loop high-precision GNSS receivers, it is possible to provide the in-phase and quadrature components of the signal at high sample rates, which enables investigation of the spectral signatures of the observations.

The retrieval method consists of a radio occultation technique for the phase differences between the direct and reflected signal combined with a statistical method. Results are derived through a sequential Bayesian estimation method, where the retrieval algorithms are based on a particle filtering technique. The horizontal size of the probability density function, which uniquely describes the ocean reflection zone using the recursive particle filter method, is determined to have an extend of 200 to 500 meters for all observations used in the experiments.
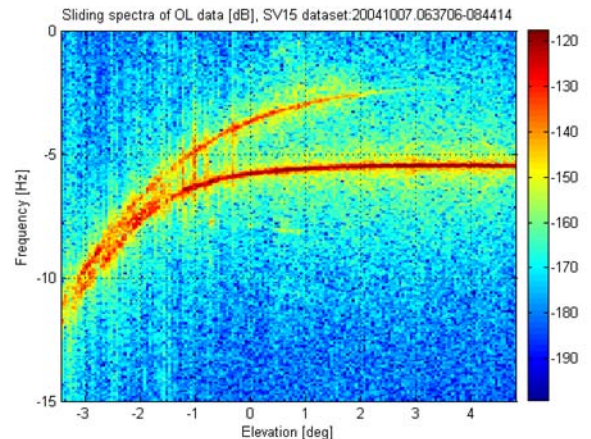
Figure: Sliding power spectra of the direct and ocean reflected GPS signal.

Earth Observation for Marine Geodesy

Our activities related to the use of satellite based Earth Observation have mainly been focused on improving the methodologies for deriving mean sea surface heights and marine gravity. Important global products such as the DNSC08 and the DTU10 series are results of those activities. Furthermore, the use of GOCE gravity fields for estimating mean dynamic ocean topography models has been investigated. Finally, the use of satellite altimetry for retrieving operational sea levels and for monitoring mean sea level has been studied.

Satellite altimetry continues to provide new information about the variations in the sea surface height that contribute to improvements of marine geodetic products such as the mean sea surface and the marine gravity field. During the reporting period we have continued to enhance the data processing using re-tracked data merged with enhanced corrections. Especially, the enhanced data from the ERS and the ENVISAT satellite missions together with the utilisation of ICESAT has improved the products in the coastal areas and in the Polar Regions. For the mean sea surface modelling the extension of the time period provided by JASON 2 has been important. The DNSC08 series of products has been made publically available and went into the computation of EGM08 models as well.

The DTU-10 is the latest release of the global high resolution suite of geophysical and geodetic fields from DTU space formerly the Danish National Space Center. In the DTU suite of fields all six fields (free air gravity, mean sea surface, mean dynamic topography, bathymetetry and error) have a spatial resolution of 1 minute by 1 minute covering all marine regions of the world including the Arctic Ocean up to the North Pole.

All these fields are available for free download from ftp.space.dtu.dk/pub/DTU10.
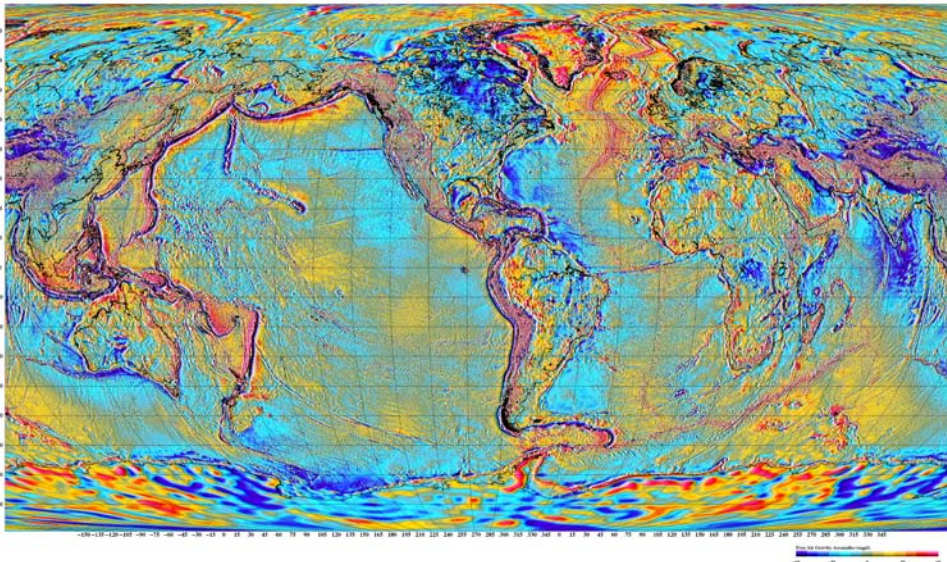
The use of GOCE gravity fields for deriving mean dynamic ocean topography models has been studies in a European collaboration supported by various EU and ESA supported projects coordinated by us. The studies have been carried out as joint Geodetic and Oceanographic projects. An important outcome has been the GOCE User Toolbox supported by ESA which may be used for combining GOCE data with a mean sea surface into a dynamic topography applying different strategies for filtering.
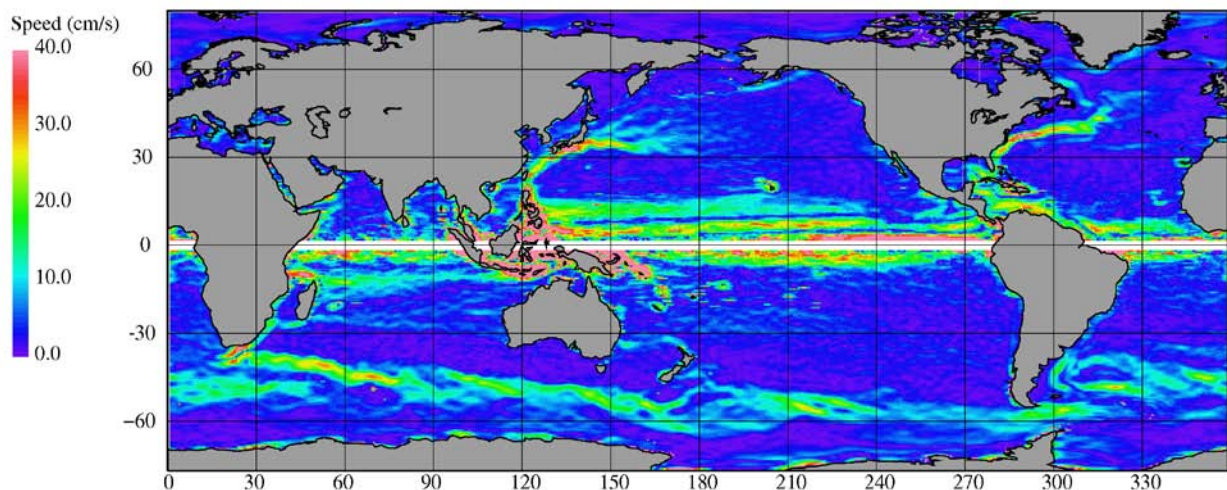
Figure showing the ocean surface geostrophic current speed from Mean Dynamic Topography model based on GOCE.

Government consultancy

As mentioned above we carry out practical tasks for the National Survey and Cadastre (KMS). Those tasks are mainly focused on operating permanent GNSS stations and tide gauge stations in Greenland and on development of the geodetic infrastructure such as realizing new reference frames in Denmark, Greenland and the Faeroe Islands. During the reporting period we assisted KMS in defining a new reference system for the Faeroe Islands. The reference frame is realized in ITRF2005 and transferred to ETRS89. The height system is referenced to current mean sea level. At Nordic level we have been chairing the NKG working group Positioning and Reference frames and contributed to the joint Nordic effort to realize a common reference frame in ITRF2005. Furthermore, we advise KMS on issues related Navigation and Mapping. In addition, we also carry out government consultancy of other agencies such as the Danish Agency for Science, Technology and Innovation and Asiaq - the Greenland Survey.

Education

The transfer to DTU Space and the merge with the Geoinformatics group formed the basis for expanding our activities to include research in surveying and mapping as well. In 2007, we launched a new education Geomatics Engineering as a focus line on the Mathematical Modelling and Computation master programme at DTU. Geomatics Engineering cover in addition to Geoinformatics and Geodesy also Navigation and Earth Observation.
At diploma level we teach student on the civil engineering education surveying and mapping. In Greenland, we contribute to the Arctic Technology education as well.

The work of the **Geodynamics Department, National Space Institute, DTU** has continued in the 4-year period to be a healthy mix of in-house research, mainly in the area of physical geodesy, airborne geodesy and cryosphere research, with numerous field campaigns nationally and internationally. Government work continues through several re-organizations to focus on gravity networks and geoid, advice and data collection related to UNCLOS (UN Laws of the Seas), especially in the polar areas, and advice and research of sea-ice and ice sheet changes in Greenland.

Gravity network and geoid activities

A new gravity network has been established in Denmark as part of the modernization of the national geodetic reference networks by KMS (National Survey and Cadastre). The new "5D" network of some 50 points has been measured with Scintrex gravimeters and tied to a number of absolute gravity points, measured both by FG5 and A10 absolute gravimeters. A new A10 gravimeter was purchased in 2008 to support this work, as well as to measure at points in the GNET US-Danish-Luxembourg new GPS network in Greenland to monitor ice load changes. The A10 works satisfactory now, after more than a year of hardware teething problems with several equipment returns to the manufacturer.

Gravity measurements in Greenland have been initiated to survey as many GNET points as possible within logistic and economic constraints, and to improve the gravity network in cities, airports and remote stations. The GNET A10 measurements will be repeated on a 2-5 year cycle, to monitor point gravity changes along with GRACE and height changes, especially to better understand the GIA process.

Absolute gravity measurement at GNET site in East Greenland

Geoid determination continued through the period, with new software modules added to the GRAVSOFT software system, developed in cooperation with University of Copenhagen. A joint Nordic data base supports Nordic and North Atlantic geoid computations. Specific geoid projects have included support for major engineering projects (bridges), new marine geoids, and a new national geoid of the Faeroe Islands. In addition a number of international research or geoid consultancy tasks have been carried out, often hand in hand with airborne gravity surveys.

Fjord height and tide measurement in Greenland to support geoid determination

Airborne gravity and lidar surveys

The Geodynamics Department continues to develop and improve our airborne survey methodology. Large-scale lidar and radar surveys have been done 2007-2009 in connection with the International Polar Year (IPY), to determine sea-ice thickness as well as ice sheet monitoring. These surveys have been done as part of EU projects (mainly Damocles), ESA projects (CryoSat cal/val campaigns) and national projects (Greenland ice sheet monitoring and GreenArc national IPY ice camp north of Greenland).
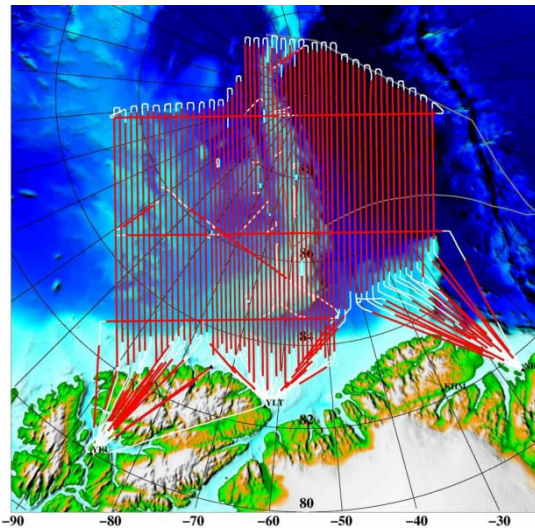
Long-range airborne survey tracks north of Greenland – LOMGRAV2009

Airborne gravity surveys include major surveys of Indonesia (Kalimantan, Sulawesi, Papua), in cooperation with Bakosurtanal and NGA, several surveys in the North Sea and Baltic regions carried out in cooperation with BKG, Germany, and a complete survey of Nepal, in cooperation with the Nepal Survey Dept and NGA. Together with National Ressources, Canada, a major airborne gravity and magnetic project was carried out north of Greenland and Ellesmere Island 2009, to support both Danish and Canadian UNCLOS programmes. The UNCLOS Arctic programme used a long-range DC3 aircraft, capable of covering areas beyond the North Pole. The DC3 airborne programme has since 2010 continued in Antarctica with major surveys in the Antarctic Peninsula and East Antarctica, in cooperation with several national programs (Argentina, Chile, UK, Norway), University of Texas (ice radar) and NGA.

DC3 aircraft at Troll Station, Antarctica for during ICEGRAV 2011 airborne geophysics

To enhance the airborne research and give higher redundancy in field operations, new scanning lasers, IMU's and a new gravimeter – Chekan AM – has been acquired during the period.

Satellite-based research

The research has focused on use of satellites such as GRACE, ICESat, Envisat and CryoSat. The monitoring of the ice sheets, determination of sea ice thickness, gravity field and ocean dynamic topography in the Arctic Ocean has been a special focus for this research, and a.o. supported by an ESA study (ArcGICE) and EU-projects. Operational kinematic GPS research has also continued, especially to support airborne and marine activities. A post.doc. from Wuhan University has visited as part of this research, and has been applied a.o. to a global marine cruise (Galathea-3), where the department participated with a gravimeter and GPS/lasers capable of measuring ocean heights.

Danish naval vessel in Solomon Islands during around-the-world science trip. DTU-Space operated laser and GPS to measure sea-surface topography and waves, and gravimeter to check global gravity grids.

Government work

The Geodynamics Department support the national UNCLOS programme through consultancy on sea-ice conditions and geophysical data collections and –interpretations. This work involves major icebreaker cruises in the Arctic Ocean (LOMROG 2007 and 09), on-ice activities supported by helicopters (2006-9) and the earlier mentioned LOMGRAV aerogeophysical survey. Other national

activities include support to the Greenland self-rule government for sea-ice conditions (satellite data and survey flights) as well as general geodetic and geophysical consulting.

During 2007 – 2011 the company **AJ Geomatics** has been involved in various projects on geodesy and positioning mainly in cooperation with geodetic government organizations in Denmark, Norway, and Germany.

In the period from 2007 to 2009 AJ Geomatics worked with the Norwegian Mapping Authority on development of a regional ionosphere model for Norway based on GNSS data from the SATREF network of permanent GNSS stations. Contributions to other research projects with the Norwegian Mapping Authority were also carried out for instance data analyses for the EPINOL project on EGNOS Performance In Northern Latitudes.
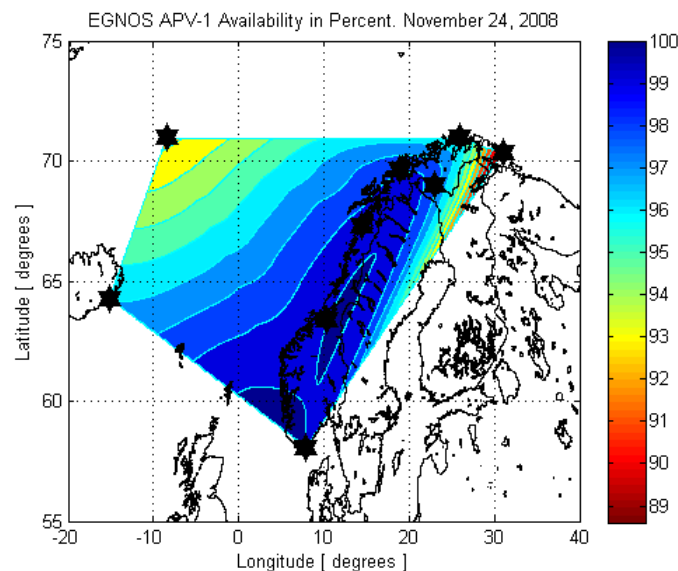
EGNOS APV-1 availability in percent, interpolated for parts of Norway and the Norwegian Sea. From Jensen et al. (2009).

With the National Survey and Cadastre in Denmark, AJ Geomatics worked on the development and initial operation of a Norm RTK services. The implementation of the Norm was initiated by the National Survey and Cadastre to make sure GNSS RTK service providers in Denmark for instance operate in the correct national geodetic reference frame.

Geodetic foundation for the fixed link across Fehmarnbelt
During 2009 – 2011 the main project for AJ Geomatics was establishment of the geodetic foundation for the Fehmarnbelt Fixed Link (bridge or tunnel) to be established between Germany and Denmark across the Fehmarnbelt, a 20 km stretch of water of the Baltic Sea. Contracted by Femern A/S and Rambøll Denmark, AJ Geomatics worked on management, coordination, testing and quality control of all parts of the geodetic foundation for the large infrastructure project.

The geodetic foundation of the Fehmarnbelt Fixed Link includes establishment of four new geodetic grade permanent GNSS stations to form the basis for the reference frame, realization of the ITRF2005 in the Fehmarnbelt area, definition of a map projection, leveling campaigns for definition of mean sea level in the Fehmarnbelt and realization of a local height system, development of a geoid model and fit to the reference frame and the height system, derivation of transformation parameters between ITRF2005 and the national reference frames of Germany and Denmark, development of a software for coordinate transformations, and finally establishment of an RTK service for precise positioning and navigation in the area.

The work was carried out in close cooperation with several organizations for instance the National Survey and Cadastre, Denmark (KMS), AXIO-NET GmbH in Germany, the Danish National Space Institute (DTU-Space), the Land Survey Office of the State of Schleswig-Holstein in Germany, the Federal Agency for Cartography and Geodesy in Germany (BKG), and Allsat GmbH Network and Services in Germany.

Permanent GNSS station of Femern A/S near the coast of the Fehmarnbelt. Antenna mast for data communication is located directly north of the GNSS pillar. Photo: A. Jensen.

University of Copenhagen, Niels Bohr Institute

Staff: C.C.Tscherning and M.Veicherts. PhD-students: H.Skourup, J.Jakobsen,(finished 2010) and S.L.Sandberg Sørensen.

The main activity in the period has been the work within ESA's Gravity and Ocean Circulation Explorer mission's (GOCE) High Level processing System (HPF). We have contributed to two areas

(1) Calibration of the GOCE gravity gradients using ground data (see Arabelos et al.,2007 and Bouman et al. 2008)

(2) Preprocessing of data used in the so-called "Space-wise" approach, (see Micgliaccio et al., 2007, 2010).

An overview of the use of Least-Squares Collocation is given in Tscherning (2010), and the use of reduced point-masses or multipole functions is discussed initially in Tscherning et al. 2010.

The computation of error covariances have been studied both for ground point values and spherical harmonic coefficients in cooperation with D.Arabelos (University of Thessaloniki), (see Arabelos et al., 2007, Arabelos & Tscherning, 2008) and we have studied the contribution of new Earth Global Gravity Field Models (EGM) to geoid determination, (see Arabelos & Tscherning, 2010).

The GRAVSOFT package of programs (Forsberg & Tscherning, 2008) is widely used, and it has been upgraded to have a more user-friendly interface (Nielsen et al. 2008, 2010). We have weakly requests for the package which is developed in cooperation with DTU-Space, and used at International Schools for the determination of the Geoid.

The mapping of sea-ice has been studied in an ESA project, (see Forsberg et al. 2007) and resulting in a PhD-thesis (Skourup, 2010).

Geoid determination has been investigated in Pakistan using various data types, (see Sadiq (2019, 2010).

Research in GNSS has been on ionospheric efffects (see Yuan et al. 2008), and on multipath in a PhD-thesis (Jakobsen, 2010).

The use of satellite radar altimetry in coastal areas has been studied in (Madsen et al. 2007 and Tscherning et al. 2009).

Publication 2007 - 2010

Publication 2007-2010 for Niels Bohr Institute

Arabelos, D., R.Forsberg and C.C.Tscherning: On the a-priori estimation of error-covariance functions. A feasibilty study. Geoph. J. Int., idoi:10.1111/j.1365-246X.2007.03460.x. 2007.

Arabelos, D., C.C.Tscherning and M.Veicherts: External calibration of GOCE SGG data with terrestrial gravity data: A simulation study. IAG Proceedings 130, pp. 337-344, Springer Verlag, 2007.

Arabelos, D.N., R.Forsberg and C.C.Tscherning: On the a-priori estimation of collocation error-covariance functions. A feasibility study. Geoph.J.Int., doi: 10.1111/j.1365-246X.2007.03460x, 2007.

Arabelos, D. and C.C.Tscherning: Error-covariances of the estimates of spherical harmonic coefficients computed by LSC, using second-order radial derivative functionals associated with realistic GOCE orbits. J.Geodesy,DOI 10.1007/s00190-008-0250-9, 2008.

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Knudsen, P., and C.C.Tscherning: Error characteristics of dynamic Topography models derived from altimetry and GOCE gravimetry. IAG Proceedings 130, pp. 3-10, Springer Verlag 2007.

Madsen, K.S., J.L.Hoeyer and C.C.Tscherning: Near-coastal satellite altimetry: Sea surface height variability in the North Sea – Baltic Sea area. GRL, Vol. 34, L14601, doi:10:1029/2007GL029965, 2007.

Nielsen,J., C.C.Tscherning, T.R.N.Jansson, R.Forsberg: Development of a Python interface to the GRAVSOFT gravity field programs. Symposium "Geodesy for Planet Earth", Buenos Aires, Aug. 31-Sept. 4, 2009, IAG Proceedings, pp. 325-330, Springer Verlag 2010.

Sadiq,Muhammad, C.C. Tscherning and Zulfiqar, Ahmad: An estimatetion of the height system bias parameter No using Least Squares Collocation from observed gravity and GPS/leveling data. StudiaGG, Vol. 53, pp. 375-388, 2009.

Sadiq,Muhammad, C.C. Tscherning and Zulfiqar, Ahmad:Regional gravity field model in Pakistan area from the combination of CHAMP, GRACE and ground data using least squares

Publication 2007-2010 for AJ Geomatics

Jensen, A. B.O., Hermsmeyer, D., Huck, B., Rüffer J., and Skjellerup, P. (2011). Positioning System for the Fixed Link Across Fehmarnbelt. Accepted for *GPS World*. In Press.

Jensen, A.B.O. and Mitchell, C. (2011). GNSS and the Ionosphere – What's In Store for the Next Solar Maximum. *GPS World – Innovation*, February, 2011.

Jensen, A.B.O. and Sicard, J.-P. (2010). Challenges for positioning and navigation in the Arctic. *Coordinates*. Vol. 6, October 2010, pp. 10-13.

Jakobsen, J., Knudsen, P., and Jensen A.B.O. (2010). Analysis of Local Ionospheric Time Varying Characteristics with Singular Value Decomposition. *Journal of Geodesy*. 85(7): 449-456.

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Ouassou, M., Jensen, A., Kristiansen, O. (2009). Use of Statistics to Improve a Grid Based Single Shell Layer VTEC Model. *Proceedings of the 13th IAIN World Congress*, Stockholm, 27-30 October 2009. Published by the Nordic Institute of Navigation.

Jensen, A.B.O. and Ovstedal, O. (2008). The Effect of Different Tropospheric Models On Precise Point Positioning in Kinematic Mode. *Survey Review*. Vol. 40, No. 308 pp. 171-187. April 2008.

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Jensen, A.B.O. (2010). GPS og Galileo. *KVANT – Tidsskrift for Fysik og Astronomi,* nr. 3, oktober 2010.

Jensen, A.B.O., Andersen, O. B., og Sørensen, P. B. (2009). Galathea og GPS – undervisningsmateriale for gymnasier og hf. *Virtuel Galathea 3.*

Conferences, lecturing and committees

During 2007 – 2011 Dr. Anna B.O. Jensen has been lecturing the course "Satellite Positioning" every year at the Technical University of Denmark, she has supervised master and Ph.D. students, and has been a member of several evaluation committees and review bodies.

Dr. Jensen has also been involved in arranging conferences, most significantly the *13th IAIN World Congress* in Stockholm, Sweden, October 2009, and the *3rd International Colloquium on Scientific and Fundamental Aspects of the Galileo Programme* in Copenhagen, Denmark, September 2011. She has acted as session chair at several other conferences, and has during the four years contributed with presentations and papers to a number of conferences and meetings.

During 2006 – 2009 Dr. Jensen was a member of the board of the Nordic Institute of Navigation, and since 2008 Dr. Jensen has been a member of GNSS Scientific Advisory Committee of the European Space Agency.

Presentations and lectures

Geodesy and Reference Frames, course for GeoForum Danmark, Lyngby, Denmark, December 2010.

Positioning System for Fehmarnbelt Fixed Link. Geodätische Woche 2010, Cologne, Germany, October 2010.

GPS, Presentation for Youth in Science and Technology. Lyngby, Denmark, October 2010

Positioning System for Fehmarnbelt Fixed Link. Allsat Open 2010, Hannover, Germany, June 2010.

EGNOS Performance in Northern Latitudes. Presented at the 13th IAIN World Congress, Stockholm, October 2009.

GNSS. Lecture at the Nordic Course on Geographic Information, arranged by the National Survey and Cadastre – Denmark for the armed forces in the Nordic countries. Copenhagen, Denmark. September 2009.

EPINOL – EGNOS Performance in Northern Latitudes. Seminar at the Norwegian Mapping Authority. Honefoss, Norway. June 2009.

Solar Activity and GPS Surveying. Presentation at seminar by the Danish Association of Map and Survey Technicians. Ry, Denmark. April 2009.

GPS etc. Lecture at Nykøbing Gymnasium (secondary high school). Nykøbing Falster, Denmark. Marts 2009.

Artic Positioning Issues. Presentation at the e-Navigation Conference by the Nordic Institute of Navigation, Bergen, Norway, March 2009.

Solar Activity. Presentation at the GeoNordland-2009 conference by GeoForum Norway, Bodø, Norway, February 2009.

Monitoring EGNOS quality at Northern Latitudes. Presentation at SATREF User Conference, Norwegian Mapping Authority, Hønefoss, Norway, December 2008.

GPS, Galileo and GLONASS. Presentation for the employees at Thrane & Thrane, Lyngby, Denmark, November 2008.

Best practice with RTK for land surveying, course for the Danish Association of Chartered Land Surveyors. Fredericia, Denmark, October 2008.

Regulation of RTK Services in Denmark. Presentation at the 48th Meeting of the Civil GPS Service Interface Committee, Savannah, Georgia, USA, September 2008.

A Norwegian Ionosphere Model based on GPS Data. Presentation at the High Precision Navigation and Positioning Conference by the Nordic Institute of Navigation, Oslo, June 2008.

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Forsberg, René; Strykowski, Gabriel
Geoid model for the Fehmarn Belt connection. - Copenhagen : DTU Space, 2010 (p. 10) Type: Report

Forsberg, René; Skourup, Henriette
Geoid, mean sea level and ice thickness in the Arctic Ocean from GRACE and ICESat
Type: Talk / Oral presentation Note

Forsberg, René; Skourup, Henriette; Hvidegaard, Sine Munk
Geoid, mean sea level and ice thickness in the Arctic Ocean from ICESat, GRACE and airborne measurements
Type: Talk / Oral presentation Note

Forsberg, René; Skourup, Henriette; Tscherning, C.C.
Geoid, mean sea level and ice thickness in the Arctic Ocean from GRACE and ICESAT
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Geoid, mean sea level and ice thickness in the Arctic Ocean from ICESAT, GRACE and airborne measurements
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Skourup, Henriette; Forsberg, René
Geoid, sea-level and vertical datum of the Arctic – Improved by ICESat and GRACE
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Larsen, T.B.; Andersen, M.L.; Nettles, M.; Elosegui, P.; Ahlstrøm, Andreas P.; Davis, J.L.; de Juan, J.; Ekström, G.; Forsberg, René; Hamilton, G.S.; Khan, Shfaqat Abbas; Stearns, L.A.; Stenseng, Lars
Glacial earthquakes in Greenland
Presented at: Geophysical Research Abstracts, 2008 Type: Conference contribution, Conference abstract

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Presented at: Gravity Field of the Earth – 1st meeting of the International Gravity Field Service. Ankara, 2007
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Forsberg, René; Olesen, Arne Vestergaard
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Type: Workshop / Seminar Note

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Gravity field separation and mapping of buried quaternary valleys in Lolland, Denmark using old geophysical data
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Gravity geoid and geophysics – from data to models : Strategimøde Dept. of Geodynamics
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Strykowski, Gabriel; Madsen, K. M.; Schmidt, K. E.; Reinhold, A.; Hoppe, W.; Gitlein, O.; Timmen, L.; Forsberg, René
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Sørensen, Louise Sandberg; Stenseng, Lars; Simonsen, Sebastian S.; Forsberg, René; Kildegaard Poulsen, Stine; Helm, Veit
Greenland Ice Sheet Changes from Space Using Laser, Radar and Gravity
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Sørensen, Louise Sandberg; Forsberg, René
Greenland ice sheet mass loss from GRACE data
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Stenseng, Lars
Grønland rundt med POF'en : Foredrag i Dansk Geofysisk Forening
Type: Lecture given outside DTU

Andersen, Ole Baltazar; Knudsen, Per; Berry, P.; Mathers, L.; Freeman, J.; Kenyon, S.; Trimmer, R.

High resolution Global gravity field from retracked 2-Hz ERS-1 altimetry
Type: Talk / Oral presentation Note

Bauer-Gottwein, Peter; Andersen, Ole Baltazar; Leiriao, S.; He, X.
Hydrograv - Improving Hydrological Models with Ground-Based and Space-Borne Time-lapse
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Type: Talk / Oral presentation

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Ice in the Sea
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Type: Talk / Oral presentation

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Project
Presented at: 3rd International GOCE User Workshop. Frascati, 2007
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International standards on data quality description
Type: Talk / Oral presentation

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Larsen, Rasmus; Nielsen, Allan Aasbjerg; Arngren, Morten; Hansen, Per Waaben
Kernel based subspace projection of hyperspectral images
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Kernel empirical orthogonal function analysis of 1992-2008 global sea surface height anomaly data
Presented at: MultiTemp. Mystic, Connecticut, USA, 2009
In: MultiTemp : , 2009Type: Conference paper published in book/proceeding

Nielsen, Allan Aasbjerg
Kernel methods in change detection based on generalised multivariate difference images
Type: Talk / Oral presentation Note

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Kernel parameter dependence in spatial factor analysis
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Kinetic Line Voronoi Operations and Their Reversibility
In: Lecture Notes in Computer Science, vol: 6290, p. 139-165 (2010). Type: Journal article

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Hendricks, Stefan; Stenseng, Lars; Helm, Veit; Hanson, Susanne; Haas, Christian
Ku-Band radar penetration into Snow over Arctic Sea Ice
Presented at: EOS Trans. AGU, 2009, Article no. C52B-08 Type: Conference contribution, Conference abstract

Hvidegaard, Sine Munk
Laser måling af indlandsis og havis for klimaovervågning
Type: Talk / Oral presentation

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Least Squares Adjustment: Linear and Nonlinear Weighted Regression Analysis
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Reeh, Niels; Christensen, Erik Lintz; Hanson, Susanne; Kristensen, Steen Savstrup; Stenseng, Lars
Lens-shaped ice body (superimposed ice?) detected by radio echo-sounding of a West Greenland ice-margin sector
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Local to Regional Hydrological Model Calibration for the Okavango River Basin From In-Situ and Spaceborne Gravity Data
Type: Talk / Oral presentation

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Type: Talk / Oral presentation Note

Barbosa, S. M.; Knudsen, Per; Andersen, Ole Baltazar
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Presented at: EGU 2007. Vienna, Austria, 2007 Type: Conference contribution, Poster presentation

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Luftbåren laserscanning til støtte af klima- og miljøovervågning.
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Luftbårne Observationer i Danmarks Rumcenter
Type: Talk / Oral presentation

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Marine gravity from satellite altimetry
Type: Workshop / Seminar Note

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Mass change of the Greenland ice sheet from GRACE and a climatological-glaciological model
Type: Workshop / Seminar Note

Forsberg, René; Skourup, Henriette; Laxon, S.; Steele, M.; Maslowski, W.; Drange, H.;
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Mean dynamic topography of the Arctic Ocean from altimetry and geoid compared to
oceanographic models.
Presented at: IUGG07 Symposium JGS001. Perugia, 2007 Type: Conference contribution, Poster
presentation

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Type: Talk / Oral presentation Note

Forsberg, René
Med isen i hånden : CryoSat aktiviteter i Grønland og Polhavet
Type: Workshop / Seminar

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Merging GRACE gravimetry, satellite altimetry and in-situ data for Terrestrial water storage and flood monitoring ; EGU2007 G3-1WE2O-001
Type: Talk / Oral presentation

Bondo, Torsten; Enghoff, Martin Andreas Bødker; Svensmark, Henrik
Model of optical response of marine aerosols to Forbush decreases
In: Atmospheric Chemistry and Physics, vol: 10(6), p. 2765-2776 (2010). Copernicus GmbHType: Journal article Note

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Model-based satellite image fusion
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Modeling the UT effect in global distribution of ionospheric electric fields
In: Journal of Atmospheric and Solar - Terrestrial Physics, vol: 70(2-4), p. 637-645 (2008). PergamonType: Journal article

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Modelling non linerar shallow water tides from multi mission satellite altimetry
Type: Talk / Oral presentation Note

Friis-Christensen, Eigil; Forsberg, René; Lauritsen, Sune Nordentoft
Monitoring and climate predictions
In: DTU Climate Change Technologies : Recommendations on accelerated development and deployment of climate change technologies ; 4.1.A - 1 ed. - Kgs. Lyngby : Technical University of Denmark (DTU), 2009Type: Book chapter

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MSS improvements and errors
Type: Workshop / Seminar Note

Nielsen, Allan Aasbjerg
Multi-temporal images and semi-automatic map updating
Type: Talk / Oral presentation

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Naufragés de la Banquise
In: GEOexpedition (2007). Type: Journal article

Forsberg, René; Skourup, Henriette; Kenyon, S. C.; Laxon, S. W.; Jakobsson, M.
New Arctic Gravity Field Grids with Applications for Oceanography and Bathymetry
Presented at: AGU fall meeting, session OS43, 2007 Type: Conference contribution, Poster presentation

Skourup, Henriette; Olesen, Arne Vestergaard; Forsberg, René; Schäfer, U.; Liebsch, G.; Ihde, J.
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report. - Copenhagen : DTU Space, 2008 (p. 8) Type: Report

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Nye metoder til geobranchen
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Observationer af havis
Type: Talk / Oral presentation

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Observations of the annual cycle of sea ice – In situ measurements of sea ice in the Transpolar
Drift, Arctic Ocean
Presented at: DAMOCLES 4th General Assembly. Sopot, Poland, November 27. – 28., 2008, 2008
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Gitlein, O.; Timmen, L.; Müller, J.; Denker, H.; Mäkinen, J.; Bilker-Koivula, M.; Pettersen, B. R.;
Lysaker, D. I.; Svendsen, J. G. G.; Breili, K.; Wilmes, H.; Falk, R.; Reinhold, A.; Hoppe, W.;
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Strykowski, Gabriel; Forsberg, René
Observing Absolute Gravity Acceleration in the Fennoscandian Land Uplift Area
Presented at: TG – SMM. Saint Petersburg, Russia, 2007 Type: Conference contribution, Poster
presentation

Andersen, Ole Baltazar; Olesen, Arne Vestergaard; Forsberg, René; Strykowski, Gabriel; Cordua,
Knud Skou; Zhang, X.
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Presented at: IAG International Gravity Symposium. Chania, Greece, 2008
In: Gravity, Geoid and Earth Observation ; 135 / Editor: Mertikas, Stelios P. : Springer, 2010
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Ocean tides in GRACE monthly averaged gravity fields ; EGU2007 G9-1WE4O-004
Type: Talk / Oral presentation

Knudsen, Per; Andersen, Ole Baltazar; Knudsen, O.P.
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Type: Talk / Oral presentation

de Juan, Julia; Elosegui, P.; Nettles, M.; Davis, J. L.; Larsen, Tine B.; Ahlstrøm, Andreas P.;
Andersen, M. L.; Ekstrom, G.; Forsberg, René; Hamilton, G. S.; Khan, Shfaqat Abbas; Schild, K.
M.; Stearns, L. A.; Stenseng, Lars
Ocean tides modulation of flow at Helheim Glacier, East Greenland, observed using GPS
Presented at: EOS Trans. AGU, 2009, Article no. C11A-01 Type: Conference contribution,
Conference abstract

Mioc, Darka; Anton, François; Gold, Christopher; Moulin, Bernard
On kinetic line Voronoi operations and finite fields
Presented at: Sixth International Symposium on Voronoi Diagrams, 2009. ISVD '09. DTU, 2009
In: Sixth International Symposium on Voronoi Diagrams, 2009. ISVD '09 : IEEE, 2009
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On the a priori estimation of collocation error covariance functions: a feasibility study
In: Geophysical Journal International, vol: 170(2), p. 527-533 (2007). Blackwell PublishingType:
Journal article

Vennerstrøm, Susanne; Christiansen, Freddy; Olsen, Nils; Moretto, T.
On the cause of IMF By related mid- and low latitude magnetic disturbances
In: Geophysical Research Letters, vol: 34(16) (2007). Amer Geophysical UnionType: Journal
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Presented at: Nordic Workshop on GIS and Health. Copenhagen, 2010 Type: Conference
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Knudsen, Per; Andersen, Ole Baltazar; Andersson, Toke Bech
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Presented at: 3rd International GOCE User Workshop. Francati, 2007
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Outline of a New Space-Domain Method of Forward Modeling
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Report for EGM07 Evaluation Group. Type: Report

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In: Journal of Geodynamics, vol: 43(2), p. 187-188 (2007). Pergamon-elsevier Science LtdType:
Journal article

Tocho, Claudia; Miranda, Silvia; Pacino, Maria Cristina; Forsberg, René
PRELIMINARY GEOID MODEL IN SAN JUAN PROVINCE: A CASE STUDY IN THE
ANDES
In: Boletim De Ciencias Geodesicas, vol: 14(3), p. 316-330 (2008). Univ Federal Parana, Centro
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Proceedings of the 15th General Meeting of the Nordic Geodetic Commission : Copenhagen, Denmark. May 29.-June 2., 2006 - DTU Space, 2008 (p. 240) Type: Report

Khan, Shfaqat Abbas; Wahr, J.; Dam, T.; Larson, K.M.; Francis, O.; Stearns, L.A.; Hamilton, G.S.
Rapid uplift in Greenland due to ongoing ice mass changes
Presented at: Geophysical Research Abstracts, 2008 Type: Conference contribution, Conference abstract

Nielsen, Allan Aasbjerg; Andersen, Ole Baltazar; Knudsen, Per
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Presented at: Danish Ocean Researchers' Meeting. Elsinore, Denmark, 2009
In: 15. danske havforskermøde, p. 116 , 2009Type: Conference contribution, Conference abstract

Andersen, Ole Baltazar; Knudsen, Per; Berry, P.; Kenyon, S.; Trimmer, R.
Refining Global Marine Gravity Prediction from Satellite and Ships. DNSC06 Global Marine Gravity Field and Associated Bathymetry
Presented at: ENVISAT Symposium 2007. Montreux, Switzerland, 2007
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Olesen, Arne Vestergaard; Forsberg, René
Regional airborne scalar gravimetry for geoid determination
Presented at: IUGG XXIV General Assembly. Perugia, Italy, 2007 Type: Conference contribution, Poster presentation

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Regional rumble: a seismological study of glacial earthquakes in Greenland
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Type: Conference contribution, Poster presentation

Joos, Gerhard
Registrierungsdienste für Geoelemente unter besonderer Berücksichtigung von Datenqualitätsmaßen
Type: Talk / Oral presentation

Gascard, J-C.; Offermann, M.; Hanson, Susanne
Report of 2007 deployment of ITPs, bouys, etc. from airborne deployment
In: The Sixth Framework Programme (2002-2006) ; D8.4-05b Type: Report

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Reportage fra TARA is lejer
Type: TV Interview

Olsen, Nils; Christiansen, Freddy; Jackson, A.
Reprocessing of POGO Satellite Data : Preliminary Results of some Experiments

Presented at: GEOSPACE Meeting. Abingdon, 2008 Type: Conference contribution, Poster presentation

Duplissy, J.; Enghoff, Martin Andreas Bødker; Aplin, K.L.; Arnold, F.; Aufmhoff, H.; Avngaard, M.; Baltensperger, U.; Bondo, Torsten; Bingham, R.; Carslaw, K.; Curtius, J.; David, A.; Fastrup, B.; Gagne, S.; Hahn, F.; Harrison, R.G.; Kellett, B.; Kirkby, J.; Kulmala, M.; Laakso, L.; Laaksonen, A.; Lillestol, E.; Lockwood, M.; Makela, J.; Makhmutov, V.; Marsh, N.D.; Nieminen, T.; Onnela, A.; Pedersen, E.; Pedersen, Jens Olaf Pepke; Polny, Josef; Reichl, U.; Seinfeld, J.H.; Sipila, M.; Stozhkov, Y.; Stratmann, F.; Svensmark, Henrik; Svensmark, J.; Veenhof, R.; Verheggen, B.; Viisanen, Y.; Wagner, P.E.; Wehrle, G.; Weingartner, E.; Wex, H.; Wilhelmsson, M.; Winkler, P.M.
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In: Atmospheric Chemistry and Physics, vol: 10(4), p. 1635-1647 (2010). Copernicus GmbHType: Journal article Note

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Results of the CryoSat Validation Experiment – CryoVEx-2003
Type: Talk / Oral presentation Note

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Zhang, Xiaohong; Forsberg, René
Retrieval of Airborne Lidar Misalignments Based on the Stepwise Geometric Method
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Skourup, Henriette; Forsberg, René; Sørensen, L. S.; Hanson, Susanne; Stenseng, Lars; Hvidegaard, Sine Munk
Satellite and Airborne data for change detection in the Arctic Cryosphere.
Presented at: IPY GeoNorth Conference. Yellowknife, 2007 Type: Invited conference contribution, Poster presentation

Hasager, Charlotte Bay; Andersen, Ole Baltazar
Satellite Eye for Galathea : Hjemmeside om Remote sensing og Galathea-3 ekspeditionen Type: Multimedia Learning Object

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Satellite eye for Galathea 3. Annual report 2007. - Roskilde : Forskningscenter Risø, 2008 (p. 17)
In: Risø-R-1626(EN) ; Risø-R-1626(EN) Type: Report Note

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Schedule of arrangements for air transport and lodging of individual participants, airfreight of equipment from primary departure bases : Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006),. - Copenhagen : DTU Space, 2008 (p. 10) Type: Report Note

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Sea Ice Conditions off NW and NE Greenland from Satellite Measurements, Airborne and In-situ data : Contract Report for Greenland Bureau of Minerals and Petroleum. - Copenhagen : DTU Space, 2008 Type: Report Note

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Sea Ice Freeboards and Snow Depths in the Arctic Based on Satellite Laser and Radar Altimetry
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