Deliverables:

WP8000: Toolbox promo package

and

WP8000: Scientific paper

Ref:

GUTS Phase 3: GUT Development and Supporting Scientific Studies

Intended Extension to ESRIN/Contract No. 19568/06/I-OL

Coordinator: Per Knudsen (DTU)

Responsible partner: DTU

Prepared by Per Knudsen.

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Rev.	Date	Sections modified	Comments	Changed by
1	22-6-2011	All	None.	Per Knudsen
2	14-11-2001	1 and 3	Some imperfections/inconsistencies and various observations/request of clarifications have been corrected.	Per Knudsen

1. Introduction

As stated in the Statement of Work the purpose of WP8000: GUT Outreach and Promotion is to prepare material to be used for outreach. This material shall have as scope the promotion of the GUTv2 toolbox and be intended for didactic purpose.

The contractor shall prepare presentation material and a didactic demo of the toolbox's purpose and functionalities, to be used for special events like training workshop events. Furthermore, a toolbox training kit shall be produced which latter will be used for toolbox training sessions.

This material will be used to populate the ESA GUT web site, the purpose of which is to promote the output of this research and development activity. This web site will be released under the responsibility of ESA, whereas the contractor is required to produce the promotion content.

As stated in the Statement of work, an aditional important task is to produce one or more scientific publications to be submitted in a peer-reviewed journal with the findings and novelties of this project. GUT will be presented at conferences and workshops such as the GOCE User Workshop, the EGU meeting, and the ESA Living Planet Symposium.

Deliverables will be the toolbox demonstration package (promo presentation and didactic demo, training kit) and the peer-reviewed papers.

2. Deliverables

The following table presents the list of the deliverables of WP8000:

Name of Deliverable	Date	Responsible
WP8000: Toolbox promo package	T0+14 25-5-2011	DTU
WP8000: Scientific paper	T0+14 25-5-2011	DTU

Both deliverables are documented in this document

3. Result

WP8000: Toolbox promo package

The GUT promotion and demo materials have been prepared in collaboration with ESA. DTU has prepared poster presentations and presented GUT at scientific conferences: EGU in Vienna 2010, ESA LP in Bergen 2010, AGU in San Francisco 2010, GOCE WS in Munich 2011, and EGU in Vienna 2011. IPGP presented GUT at IUGG in Melbourne 2011.

Based partly on the poster presentation and the GUT Tutorials ESA prepared the promotion material (including the Training Kit as described in the Statement of Work) and carried out demonstrations of GUT at the ESA LP in Bergen 2010 and at the GOCE WS in Munich 2011.

DTU prepared the presentation of GUT at the "4th GOCE Workshop" as well as the manuscripts for the proceedings. In addition DTU participated in the press conferences at EGU in Vienna 6 April 2011. Those three presentations are enclosed in the Appendix

Presentations by GUT project participants at the "4th GOCE Workshop" in Munich:

1. *GOCE User Toolbox and Tutorial* by P. Knudsen,
2. *Impact of New, Accurate Geoid Information on Ocean State Estimation* by F. Siegismund,
3. *GOCE MDT combined with drifter info for improving ocean currents?* by M.-H. Rio,
4. *An initial estimate of the North Atlantic steady-state geostrophic circulation from GOCE* by R. Bingham ,
5. *Gravity Anomaly and Gradient Recovery from GOCE Gradient Data using LSC and Comparisons with Known Ground Data*. by C.C. Tscherning,
6. *A global Mean Dynamic Topography and Ocean Circulation Estimation using a Preliminary GOCE Gravity Model* by P Knudsen,
7. *An oceanographic assessment of the preliminary GOCE geoid models accurac*. by S. Mulet,
8. *On the accuracy of current Mean Sea Surface Models for the use with GOCE data* by O Andersen,
9. *Regional gravity modelling from a combination of GOCE and ground data* by I. Panet,

WP8000: Scientific paper

During this phase of the GUT project two scientific papers on GUT were written and accepted for publication in peer-reviewed journals. Those are:

1. Bingham, R., P. Knudsen, O. Andersen, and R. Pail, An initial estimate of the North Atlantic steady-state geostrophic circulation from GOCE, Geophys. Res. Lett., VOL. 38, L01606, 5 PP., 2011, doi:10.1029/2010GL045633.

   Abstract: The GOCE satellite mission was launched in 2009 and the first gravity models were released in July 2010. Here we present an initial assessment of the GOCE data in terms of the mean circulation of the North Atlantic. We show that with just two months of data, the estimated circulation from GOCE is already superior to a similar estimate based on 8 years of GRACE observations. This result primarily depends on the fact that the GOCE mean dynamic topography (MDT) is generally less noisy than that obtained from the GRACE data. It therefore requires less smoothing and so there is less attenuation of the oceanographic signal. Our results provide a strong validation of the GOCE mission concept, and we anticipate further substantial improvements as the mission progresses.

2. Knudsen, P., R. Bingham, O. Andersen, M.-H. Rio, Enhanced Mean Dynamic Topography and Ocean Circulation Estimation using GOCE Preliminary Models, J. of Geodesy, 2011, DOI 10.1007/s00190-011-0485-8.

   Abstract: The Gravity and steady state Ocean Circulation Explorer (GOCE) satellite mission measures Earth's gravity field with an unprecedented accuracy at short spatial scales. In doing so, it promises to significantly advance our ability to determine the ocean's general circulation. In this study, an initial gravity model from GOCE, based on just two months of data, is combined with the recent DTU10MSS mean sea surface to construct a global mean dynamic topography (MDT) model. The GOCE MDT clearly displays the gross features of the ocean's steady state circulation. More significantly, the improved gravity model provided by the GOCE mission has enhanced the resolution and sharpened the boundaries of those features compared with earlier satellite only solutions. Calculation of the geostrophic surface currents from the MDT reveals improvements for all of the ocean's major current systems. In the North Atlantic, the Gulf Stream is stronger and more clearly defined; as are the Labrador and the Greenland currents. Furthermore, the finer scale features, such as eddies, meanders and branches of the Gulf Stream and North Atlantic Current system are visible. Similar improvements are seen also in the North Pacific Ocean, where the Kuroshio and its extension are well represented. In the Southern hemisphere, both the Agulhas and the Brazil-Malvinas Confluence current systems are well defined, and in the Southern ocean Antarctic Circumpolar Current appears enhanced. The results of this preliminary analysis, using an initial GOCE gravity model, clearly demonstrate the potential of the GOCE mission. Already, at this early stage of the mission, the resolution of the MDT has been improved and the estimated surface current speeds have been increased compared to a GRACE satellite-only MDT. Future GOCE gravity models are expected to build further upon this early success.

In addition the GUT project participants individually contributed to the Proceedings of the GOCE Workshop held in April 2011 in Munich.

Appendix.

Content of this Appendix:

1. GOCE User Toolbox and Tutorial by Knudsen. Powerpoint presentation presented at the 4th GOCE Workshop 2011, and
2. GOCE User Toolbox and Tutorial by Knudsen and Benveniste. Paper published in the proceedings of the 4th GOCE Workshop 2011,
3. GOCE in Ocean Modelling by Knudsen. Presented at the press conference in Vienna 6 April 2011.

GOCE User Toolbox and Tutorial

Per Knudsen
DTU Space

GUT contributors

The GUT Core Group :

- J. Benveniste, S. Dinardo, D. Serpe, B.M. Lucas, R. Floberghagen, A. Horvath (@esa),
- P. Knudsen, O. Andersen, M. Herceg (@space.dtu),
- M.-H. Rio, S. Mulet, G. Larnicol (@cls),
- J. Johannessen, L.Bertino (@nersc),
- H. Snaith, P. Challenor (@noc.soton),
- K. Haines, D. Bretherton (@nceo), C. Hughes (@pol),
- R.J. Bingham (@newcastle), G. Balmino (@orange.fr),
- S. Niemeijer, I. Price, L. Cornejo (@stcorp),
- M. Diament, I Panet (@ipgp),
- C.C. Tscherning (@ku.dk),
- D. Stammer, F. Siegismund (@uh), T. Gruber (tum),

GUT developments

The GOCE User Toolbox has been developed through 3 ESA supported projects:

- GUTS developing user requirements and algorithm specifications,
  + trade-off studies on data processing, eg filtering,
- GUTS#2 developing GUT and Tutorials v.1,
  + software for GOCE error covariances,
- GUTS#3 developing GUT and Tutorials v.2,
  + study of geoid and MSS error covarances.

Input from the EU supported GOCINA and GOCINO projects.

User requirements

The toolbox supports the use of GOCE data in Geodetic, Oceanographic and Solid Earth studies.

Basic requirements:

- Computation of global, gridded geoid heights at a given, user-specified, degree and order of the spherical harmonic expansion (i.e., at a given spatial resolution)
- Computation of geoid heights at a given spatial resolution (i.e. specified degree and order of the spherical harmonic expansion) at a given point or list of points (e.g. unstructured grid, transect)

User requirements

Specific requirements for generation of MDT:

- Provision of a priori MSS, MDT and Geoid data on a grid
- Computation of a 'GOCE' MDT (MSS-GOCE geoid) at a given spatial resolution, on a given structured or unstructured grid
- Filtering of MSSH consistent with a specific harmonic degree geoid height field expansion.

What is GUT?

The GOCE User Toolbox is a compilation of tools for the utilisation and analysis of GOCE Level 2 products.

The GUT package includes:

- The source package for building on UNIX/Linux/Mac
- Binary packages for Linux and Windows that include BratDisplay
- The GUT Algorithm Description and User Guide
- The GUT Tutorial
- The GUT Install Guide (applicable to ALL packages).

A set of a-priori data and models are made available as well.

What is GUT?

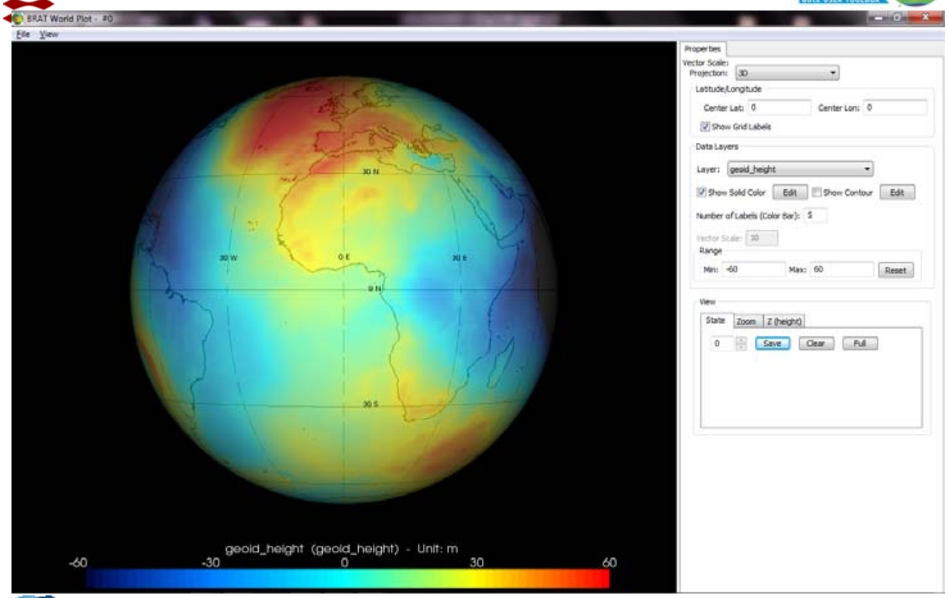
GUT is a command line processor :

C:\gut geoidheight_gf -InFile egm_dir_r1.HDR -R 0.0:360.0,-80.0:80.0 -I 0.125:0.125 -DO 200

C:\BratDisplay geoid_heights.nc

```
C:\GUT_test>gut geoidheight_gf -InFile egm_dir_r1.HDR -R 0.0:360.0,-80.0:80.0 -I
 0.5:0.5 -DO 200
INFO:    Specified Maximun Degree and Order : 200
INFO:    Calculating Geoid Height ...
INFO:     ... Done

C:\GUT_test>BratDisplay geoid_height.nc

C:\GUT_test>_
```

Meta data included in the xml/nc files

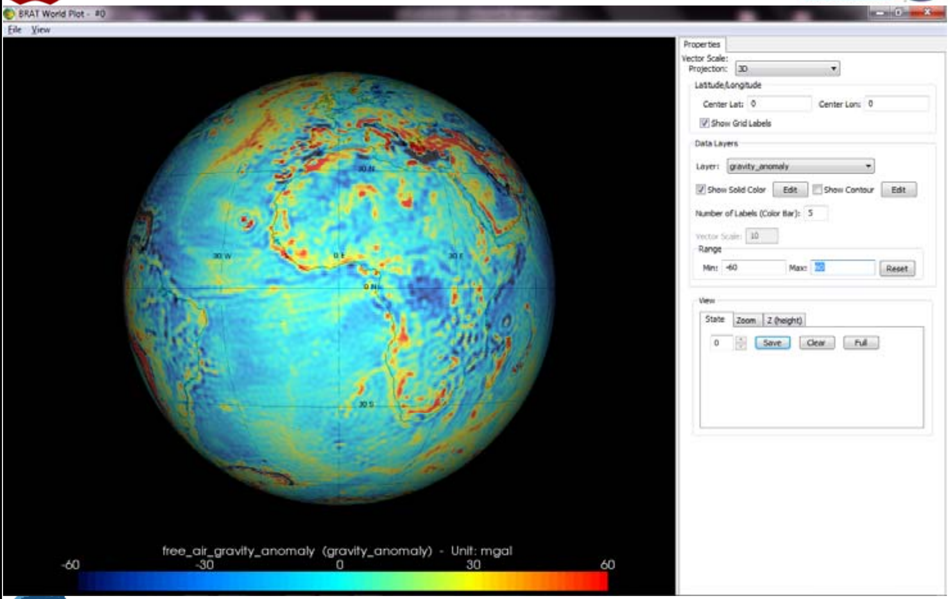


What is GUT?

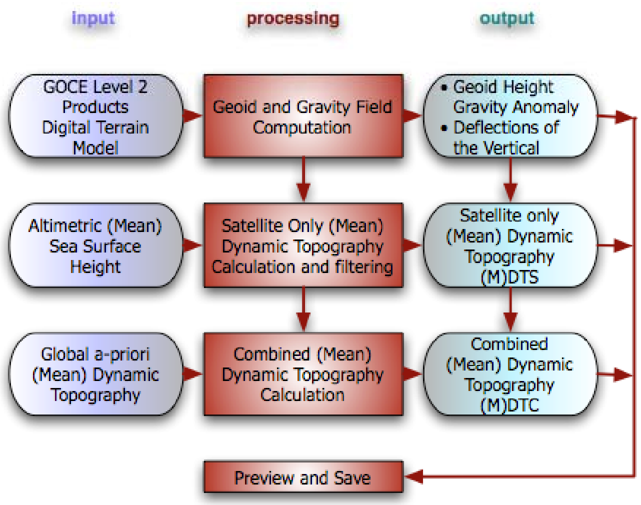
GUT has help / man functionality

```
C:\GUT_test>gut --man geoidheight_gf

Synopsis  : Extract a set of spherical harmonic potential coefficients
            (and GM, R, tide system) from file and calculate the height
            of the geoid on a chosen Grid with a specified expansion of
            the geopotential. The Grid can be specified in one of
            several ways. The default is a global 1x1 degree grid on
            the GRS80 ellipsoid with the potential expanded to the
            degree and order defined by the input file.

Arguments :
       -InFile input_file_name
            Input file containing the geopotential.

       -Gf input_grid_file      (option 1 of 3)
            Specifies the file that defines the output Grid. This can
            be any file from which GUT can extract a grid. Note, this
            includes the ellipsoid.
   OR
       -Af input_grid_file      (option 2 of 3)
            Specifies the file that defines the latitude and longitude
            axes of the output Grid. This can be any file from which
            GUT can extract a grid. The -Ellipse flag can be used to
```

GUT may also compute gravity anomalies and deflections of
the vertical



Workflows



Computation of a MDT

Use the GUT workflow: spatialmdt_gf

-InShpFile EGM.HDR   -InSshFile MSS.nc

-R 280.0:320.0,25.0:45.0 -I 0.125:0.125

-DO 240

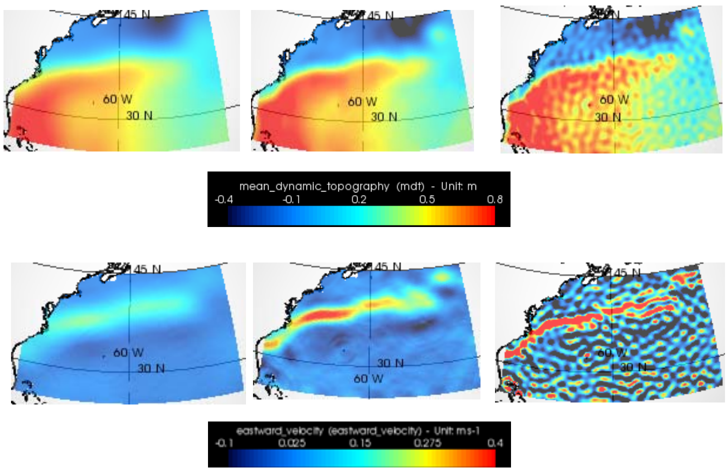
-Ftg 1.0

The workflow ensure consistency in

- Grids
- Reference frame
- Tidal system

Perform filtering considering a land mask using a user specified filter wrt type and width.

Demo: Filtering using 2.0, 1.0, and 0.5



Filter types

-F[filter_type] filter_scale

- -Fg: Gaussian with given Half-Width at Half-Maximum (HWHM = 1.1774 sigma)
- -Ftg : Truncated Gaussian (- at a radius of 3 sigma)
- -Fsc : Spherical Cap
- -Fhan : Hanning
- -Fham : Hamming
- -Fbox : Pill Box

Both isotropic and simple anisotropic.

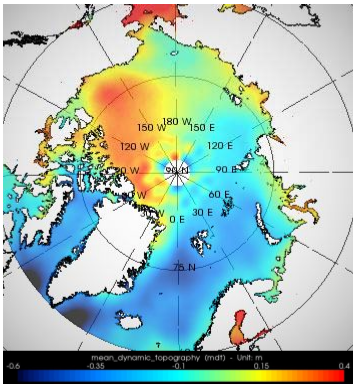
Also Spectral filtering through spherical harmonic expansion.

Summary:

- GUT is an advanced professional package of functions that support R&D in the use of GOCE EGM data,
- Most required functionalities are implemented in GUT
- User testing and validation of software and GOCE EGM data are ongoing

- Still need to implement:
  - Error covariances
  - Use of gradients

Demo at the posters



GOCE USER TOOLBOX AND TUTORIAL

Per Knudsen [1] and Jerome Benveniste[2]

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[2]*European Space Agency – ESRIN, Frascati, Italy.*

Abstract
The GOCE User Toolbox GUT is a compilation of tools for the utilisation and analysis of GOCE Level 2 products. GUT support applications in Geodesy, Oceanography and Solid Earth Physics. The GUT Tutorial provides information and guidance in how to use the toolbox for a variety of applications. GUT consists of a series of advanced computer routines that carry out the required computations. It may be used on Windows PCs, UNIX/Linux Workstations, and Mac. The toolbox is supported by The GUT Algorithm Description and User Guide and The GUT Install Guide. A set of a-priori data and models are made available as well. GUT has been developed in a collaboration within the GUT Core Group.

The GUT Core Group:
- S. Dinardo, D. Serpe, B.M. Lucas, R. Floberghagen, A. Horvath (ESA),
- O. Andersen, M. Herceg (DTU),
- M.-H. Rio, S. Mulet, G. Larnicol (CLS),
- J. Johannessen, L.Bertino (NERSC),
- H. Snaith, P. Challenor (NOC),
- K. Haines, D. Bretherton (NCEO),
- C. Hughes (POL),
- R.J. Bingham (NU),
- G. Balmino,
- S. Niemeijer, I. Price, L. Cornejo (S&T),
- M. Diament, I Panet (IPGP),
- C.C. Tscherning (KU),
- D. Stammer, F. Siegismund (UH),
- T. Gruber (TUM),

Background
The Gravity and Ocean Circulation Experiment - GOCE satellite mission is a new type of Earth observation satellite that will measure the Earth gravity and geoid with unprecedented accuracy. Combining GOCE geoid models with satellite altimetric observations of the sea surface height substantial improvements in the modelling of the ocean circulation and transport are foreseen. No ocean circulation products are planned to be delivered as level-2 products as part of the GOCE project so that a strong need exists, for oceanographers, to further process the GOCE level-2 geoid and merge it with Radar Altimetry. The primary requirement of oceanographers is to have access to a geoid and its error covariance at the highest spatial resolution and accuracy possible, although required resolution depends on application. For effective use of the geoid data, knowledge of the error covariance is mandatory.

Within the ESA supported GUT Specifications project, the user requirements for GUT associated with geodetic, oceanographic and solid earth applications were consolidated. For all applications the absolute minimal requirement of the toolbox includes the computation of geoid heights from the set of spherical harmonic coefficients at a given user-specified harmonic degree and order. For oceanographic applications the key quantity to be computed is the mean dynamic topography which basically is the height of the mean sea surface relative to the geoid. For this application GUT provide the tools for converting the mean sea surface and the geoid into the same geodetic system and for carrying out the needed filtering to compensate for the different resolution capabilities of the two surfaces. Furthermore, a-priori mean dynamic topography models derived from e.g. ocean circulation models, may be used.

To facilitate use in the oceanographic community and the solid earth community the GUT needs to include a number of standard geodetic functionalities as well as functionalities that are more specific to the two fields. The input for GUT will come both from the HPF, mostly in the form of the coefficients of a spherical harmonic expansion and the full variance-covariance matrix for these coefficients, and from auxiliary input for the SSH, MSSH, MDT, and perhaps an a priori MDT. Enough of these auxiliary fields need to be included so that the user can use the toolbox without the need to find these fields. In addition to these inputs some meta data is required concerning the tide system and model used, the atmospheric and ocean corrections made, etc.

Functionalities
In the following a complete list of wanted functionalities will be given. Some of these are vital inclusions in the toolbox while others are perhaps not as vital or perhaps very cumbersome in their need for computing power.

Geodetic functionalities
In a variety of geophysical studies information associated with the Earth's gravity are used in form of geoid heights, gravity anomalies or deflections of the vertical. Those quantities may be represented in the

nodes along a profile, in a grid or in discretely located points. Associated with such quantities error covariance information may be needed. Hence, the following functionalities are required:

- Computation of global, gridded geoid heights or gravity anomalies at a given, user-specified, degree and order of the spherical harmonic expansion.
- Computation of geoid heights at a given spatial resolution and a given point or list of points.
- Option to replace geoid heights by deflections from the vertical.
- Computation of geoid heights covariance for any pair of points on the sphere or the computation of a full covariance matrix for a given maximum degree and order of the spherical harmonic expansion.
- Computation of geoid cumulative height errors and error covariances at a given spatial resolution on a global regular grid or for a list of points.
- Covariance error matrix within chosen degree/order range for commission and omission error.
- Option to include the omission errors for the GOCE gravity field.
- Regional geoid solutions starting from the global products.

Oceanographic functionalities

The primary oceanography variable of interest to be provided by the tool box is the dynamic topography resulting from the difference between altimetric measurements and the geoid model. Altimetric MSSH fields or time-varying SSH fields would be auxiliary input data set fields from which a consistently filtered mean dynamic topography (and associated mean geostrophic circulation) need to be computed by the toolbox. This leads to the following functionalities:

- Interpolation of external MSSH on any regular grid or at given points.
- Spatial filtering of MSSH consistent with a specific harmonic geoid height field expansion.
- Change of reference system for the geoid and/or MSSH.
- Computation of a ‘GOCE’ MDT at a given spatial resolution.
- Computation of altimetric time-varying absolute dynamic topography.
- Provision of a priori MSSH, MDT and Geoid data on a grid
- Provision of tools to produce a global description of a combination of these a priori gridded fields in spherical harmonics
- Computation of altimetric absolute geostrophic velocities.
- Covariance error matrix within chosen degree/order range for commission and omission error for mean dynamic surface topographies.
- Option to include the omission errors for the MDT and the associated geostrophic surface currents.

Solid earth functionalities

The commonly used quantity in solid earth studies is gravity anomalies and associated error information. Hence, the main required functionalities are covered by general functionalities described above. However, on land the quantities may be needed on the surface of the earth. Hence, a few additional functionalties are required:

- Computation of geoid heights, gravity anomalies or deflections of the vertical at a given, user-specified, degree and order of the spherical harmonic expansion at the surface of the terrain.
- Computation of geoid cumulative errors and error covariances associated with the above at a given spatial resolution on a global regular grid or for a list of points.
- Covariance error matrix within chosen degree/order range for commission and with the option of including the omission errors for the GOCE gravity field.

Additional functionalities

In addition to the functionalities given above the toolbox will need to be able to handle:

- Auxiliary fields given by the user, this includes SSH, MDT, etc. but the ability for the user to introduce another set of spherical harmonic coefficients and the variance-covariance matrix should also exist.
- Compute differences between GOCE geoid and external geoids / ‘GOCE’ MDT and external MDT / between absolute altimetric geostrophic velocities and in situ geostrophic velocities.
- Determine the parameters in a priori degree variance model for the modeling of the gravity field a priori spectrum.
- Derive a degree variance model for the MDT and determine statistical properties of the MDT and its associated geostrophic surface currents.
- Derive an optimal filter for the low pass filtering of the altimetric MSSH and/or the MDT.
- Previewing. A need exists for the user to be able to do a quick preview when using the toolbox to find some quantity.

The GOCE User Toolbox

The GOCE User Toolbox GUT is a compilation of tools for the utilisation and analysis of GOCE Level 2 products. GUT support applications in Geodesy, Oceanography and Solid Earth Physics. The GUT Tutorial provides information and guidance in how to use the toolbox for a variety of applications. GUT consists of a series of advanced computer routines that carry out the required computations. It may be used on Windows PCs, UNIX/Linux Workstations, and Mac.

The toolbox is supported by The GUT Algorithm Description and User Guide and The GUT Install Guide. A set of a-priori data and models are made available as well.

Hence, the GUT package includes

* The source package for building on UNIX/Linux/Mac
* Binary packages for Linux and Windows that include BratDisplay (v2.0.0b)
* The GUT Algorithm Description and User Guide
* The GUT Tutorial
* The GUT Install Guide (applicable to ALL packages).

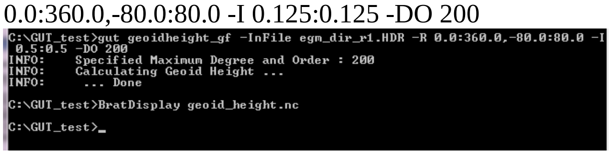
The a-priori data package gut-apriori.zip is available as well.

GUT use GOCE data associated with the following GOCE-L2 products:
EGM_GCF_2: Spherical harmonic series in ICGEM format
EGM_GEO_2: Grid with geoid heights in Grid format
EGM_GAN_2: Grid with gravity anomalies in Grid format
EGM_GVE_2: Grid with east-west vertical deflections in Grid format
EGM_GVN_2: Grid with north-south vertical deflections in Grid format
EGM_GVC_2: Variance-covariance matrix file of the spherical harmonics coefficients
These products will be stored in XML format, except for the Variance-Covariance Matrix (Internal HPF VCM format)

In addition GUT uses auxiliary data such as MSS and errors, MDT, DEM in NetCDF format (COARDS/CF standard).

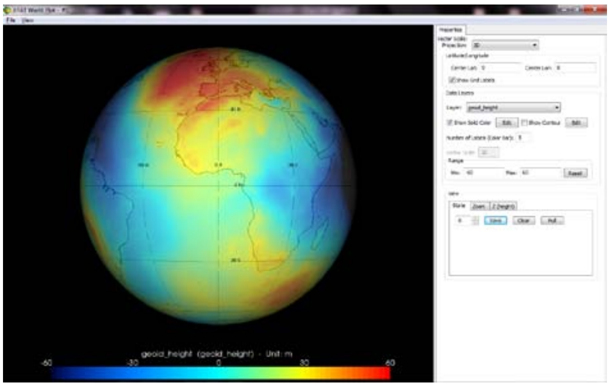
GUT is a command line processor. Its output may be exported and visualised using the ESA Basic Radar Altimetry Toolbox BRAT (http://earth.esa.int/brat).

GUT is a command line processor. An example is the following command that will make GUT compute the geoid in a specified region to a specified maximum harmonic degree and order. That is:
C:\gut geoidheight_gf -InFile egm_dir_r1.HDR -R 0.0:360.0,-80.0:80.0 -I 0.125:0.125 -DO 200

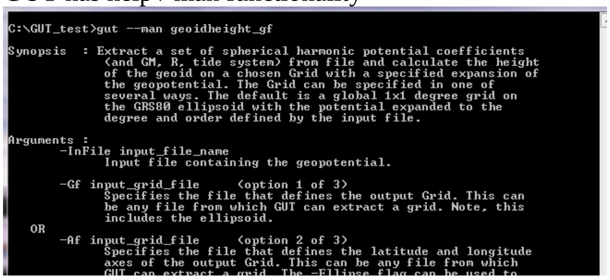


```
C:\GUT_test>gut geoidheight_gf -InFile egm_dir_r1.HDR -R 0.0:360.0,-80.0:80.0 -I
 0.5:0.5 -DO 200
INFO:    Specified Maximum Degree and Order : 200
INFO:    Calculating Geoid Height ...
INFO:     ... Done

C:\GUT_test>BratDisplay geoid_height.nc

C:\GUT_test>_
```

Using the BratDisplay the geoid is visualized.
C:\BratDisplay geoid_heights.nc

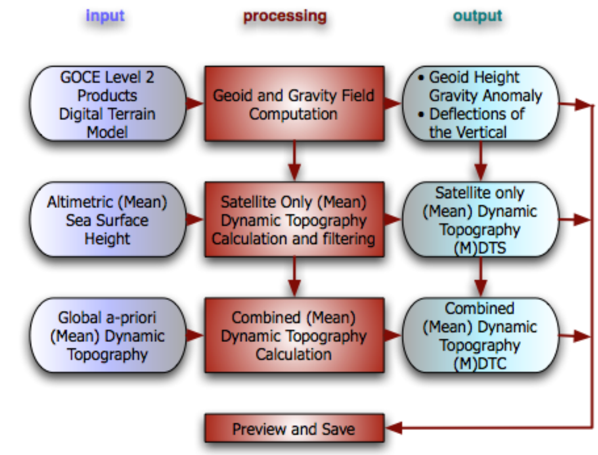


GUT has help / man functionality



```
C:\GUT_test>gut --man geoidheight_gf

Synopsis  : Extract a set of spherical harmonic potential coefficients
            (and GM, R, tide system) from file and calculate the height
            of the geoid on a chosen Grid with a specified expansion of
            the geopotential. The Grid can be specified in one of
            several ways. The default is a global 1x1 degree grid on
            the GRS80 ellipsoid with the potential expanded to the
            degree and order defined by the input file.

Arguments :
       -InFile input_file_name
            Input file containing the geopotential.

       -Gf input_grid_file     (option 1 of 3)
            Specifies the file that defines the output Grid. This can
            be any file from which GUT can extract a grid. Note, this
            includes the ellipsoid.
   OR
       -Af input_grid_file     (option 2 of 3)
            Specifies the file that defines the latitude and longitude
            axes of the output Grid. This can be any file from which
```

Workflows combine series of funcionalities for e.g. computing a MDT:

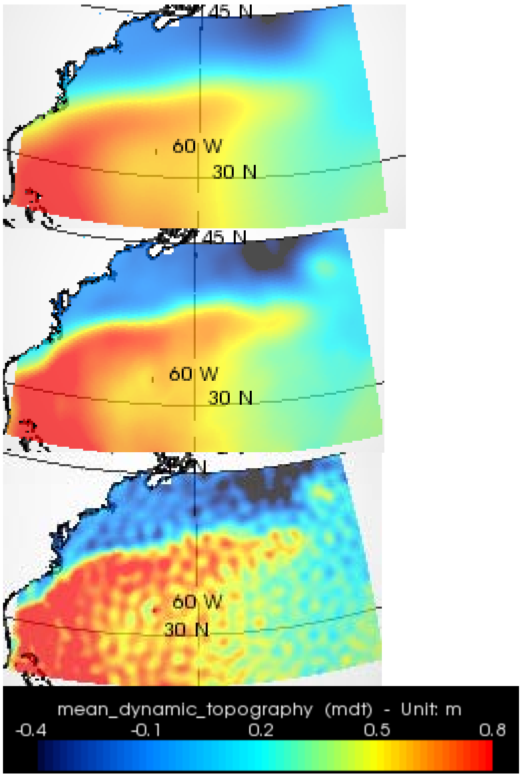


Use the GUT workflow for computing a MDT: spatialmdt_gf
-InShpFile EGM.HDR   -InSshFile MSS.nc
-R 280.0:320.0,25.0:45.0 -I 0.125:0.125
-DO 240
-Ftg 1.0

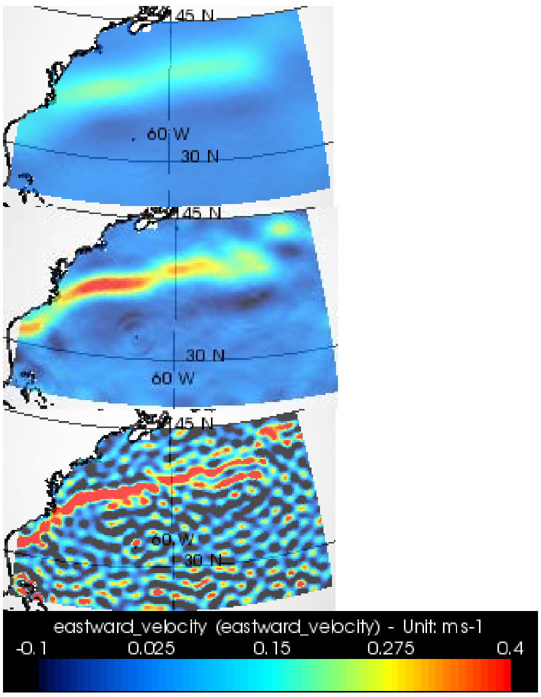
The workflow ensure consistency in
- Grids
- Reference frame
- Tidal system

Furthermore GUT perform filtering considering a land mask using a user specified filter wrt type and width.

An example is shown below where MDTs have been computed using different filters having half-width lengths of 2.0, 1.0, and 0.5 degrees.



Also geostrophic current components may be computed. Below are shown the east-west cunts associated with the MDTs above.



GUT has implemented several filters:
-F[filter_type] filter_scale
-Fg: Gaussian with given Half-Width at Half-Maximum (HWHM = 1.1774 sigma)
-Ftg : Truncated Gaussian (- at a radius of 3 sigma)
-Fsc : Spherical Cap
-Fhan : Hanning
-Fham : Hamming
-Fbox : Pill Box
Both isotropic and simple anisotropic.
Also Spectral filtering through spherical harmonic expansion.

Applications of the Variance-covariance Matrix require additional software not included in GUT. The software has been developed by Georges Balmino and made available to the community. Those applications require heavy computational resources. In the current version of GUT documentation and tutorial they are not supported.

Future Work
The GUT will be further developed through a collaborative effort where the scientific communities participate aiming on an implementation of remaining functionalities facilitating a wider span of research in the fields of Geodesy, Oceanography and Solid earth studies.

DTU Space
National Space Institute

GOCE for Ocean Circulation

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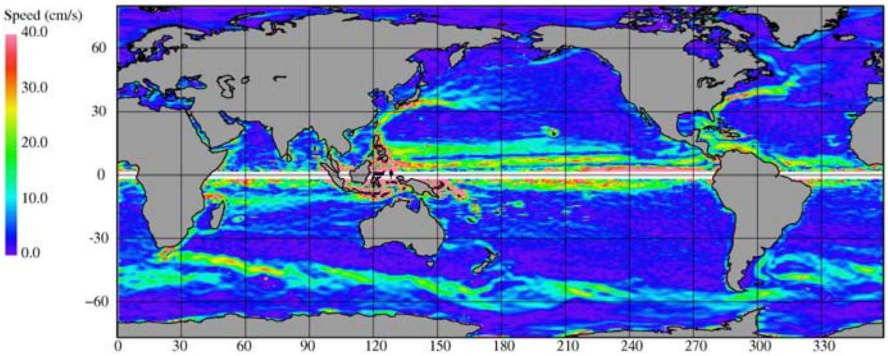
New Information:

Using data from GOCE we can now for the first time map details in the oceans mean currents accurately.



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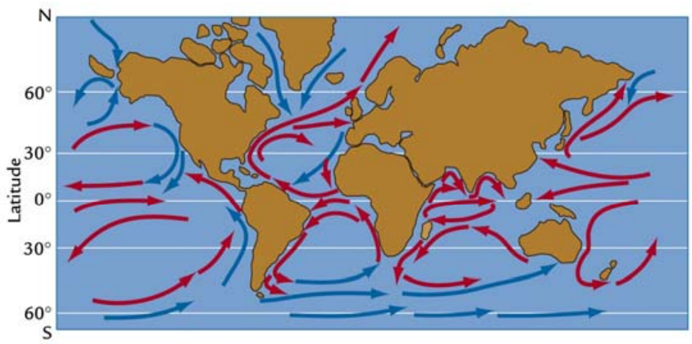
Importance:

The new information about the oceans mean currents (or steady ocean circulation) is important for the understanding of the oceans dynamics and heat transport.



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Importance:

The new information is to be fed into mathematical ocean models to better predict changes in the ocean circulation and heat transport due to e.g. Climate change.

Pespectives:

The new information about the mean circulation (or steady ocean circulation) may enhance application such as

- Forecasting of impact of climate change,
- Operational maritime services – ship routing, fishery, and
- Safety – disaster management – oil spill, pollution.



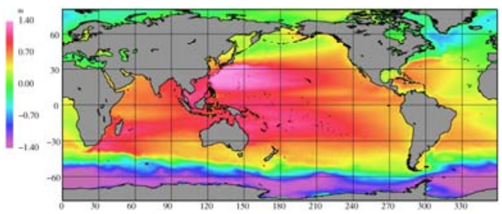
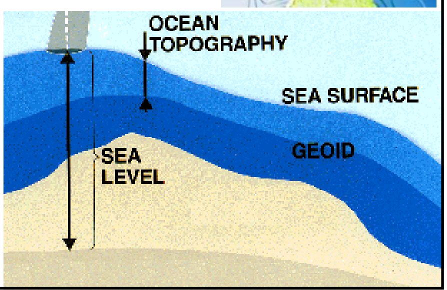

Satellite only observations

GOCE data is combined with Sea Surface Heights measured by Satellite Altimetry.

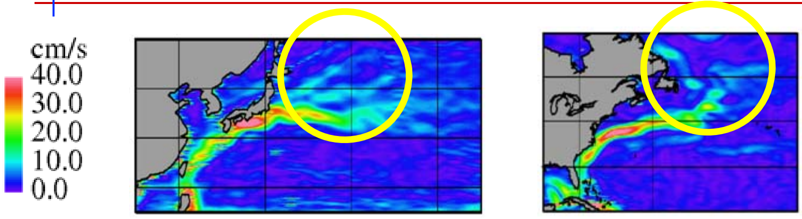
Global coverage!

The Ocean Topography is the key quantity.

The Geostrophic Surface Currents are derived from the Ocean Topography.

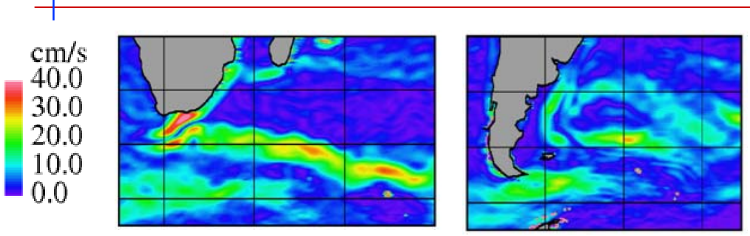




Examples:



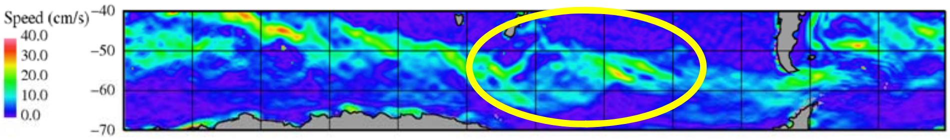
Kuroshio   Gulf Stream

Examples:



Aghulas   Brazil-Malvinas

Examples:



Antarctic Circumpolar Current

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Perspective:

The successful GOCE satellite mission is a important step forward in developing the satellite based observation system for monitoring the oceans.