GOCE User Toolbox
introduction and demo

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Presented at the 1st International GOCE Solid Earth Workshop,
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A global Mean Dynamic Topography and Ocean Circulation Estimation using GOCE Gravity Models

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Rory Bingham, Newcastle University
Marie-Helene Rio, CLS

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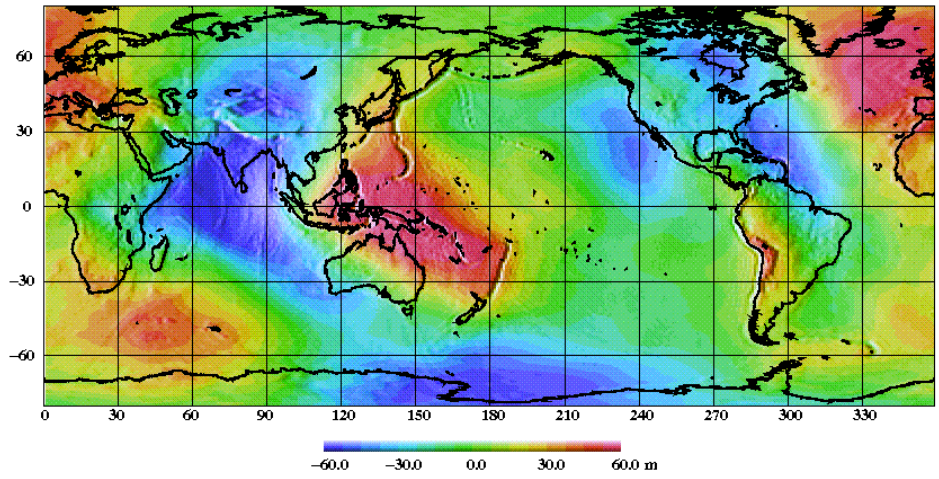
GOCE Geoid (rel.1 DIR):



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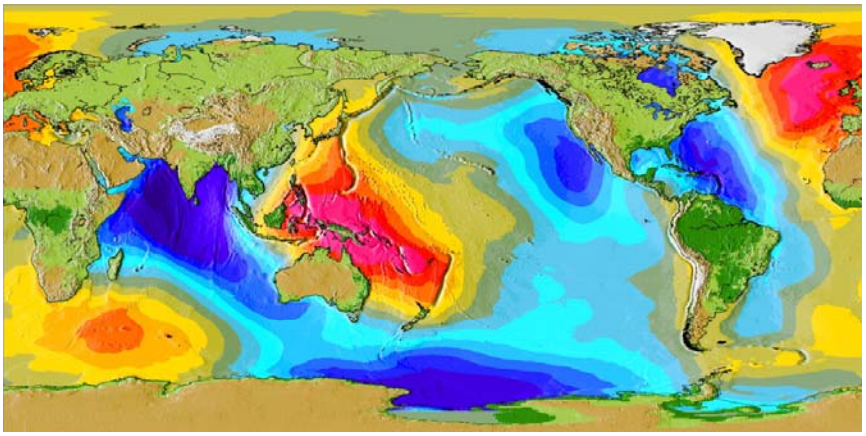
Mean Sea Surface:



DTU10MSS is available at: http://www.space.dtu.dk

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Computation of a MDT

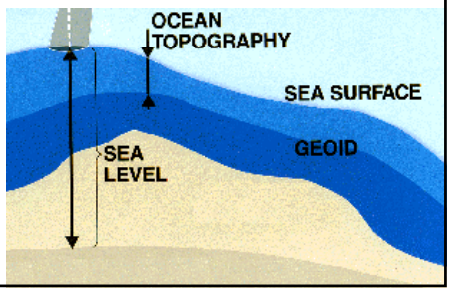
Basically, the Mean Dynamic Topography is obtained as:

MDT = MSS - Geoid

Important to ensure consistency in

- Reference frame
- Tidal system

MSS = Geoid + MDT



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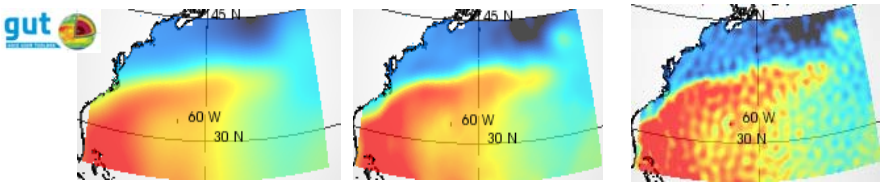
On filtering

A filtering of the MSS-Geoid residuals is needed to remove omission geoid errors due to the truncation of the spherical harmonic expansion.



2.0 **1.0** **0.5**

Test filtering with a quasi-gaussian function with half-width at half-max values of 2.0, 1.0 and 0.5 degrees.

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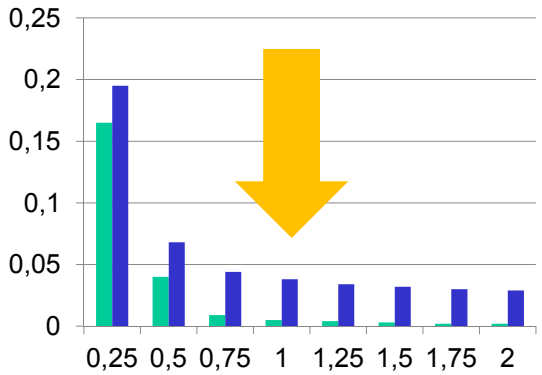
Optimize filtering



Standard deviations of quantities after filtering with a quasi-gaussian function with half-width at half-max values varying from 0.25° to 2.0° computed in a region covering 10<φ<50 and 140<λ<220 in the North Pacific.

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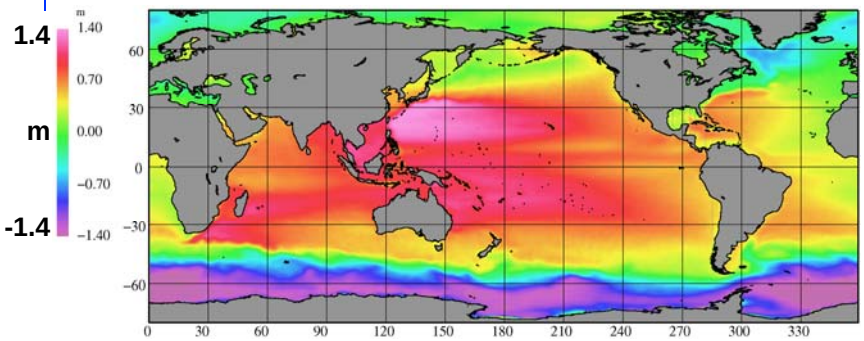
Results - MDT:



The GOCE MDT (r.1 DIR) display the well-known features with enhanced resolution and sharpened boundaries.

Compute surface geostrophic currents (*u,v*) to enjoy details

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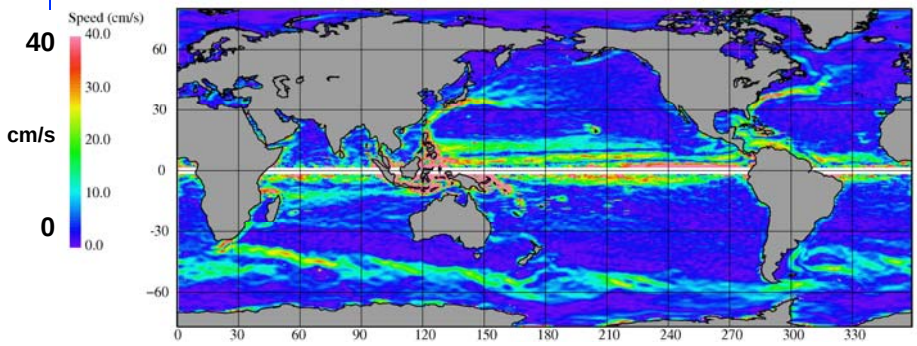
Geostrophic Current Speed:



The surface geostrophic currents display the well-known flow features associated with the major current systems,

Also, finer details (minor currents and fronts) are displayed !

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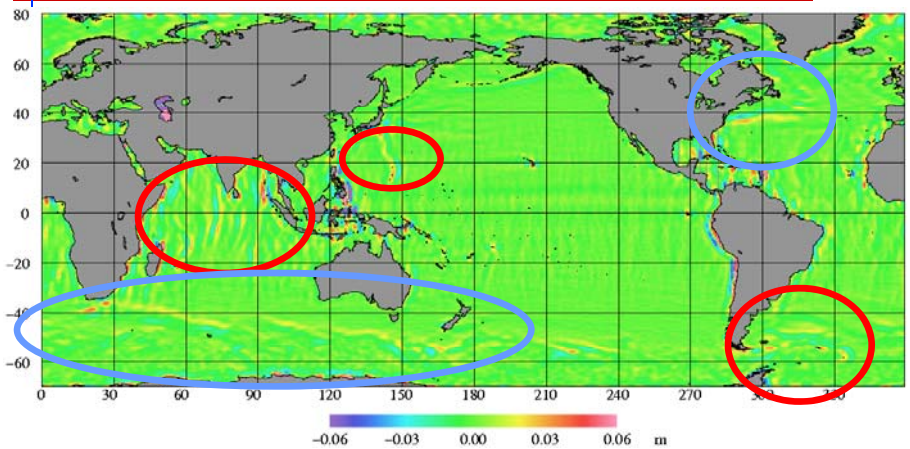
More on filtering:



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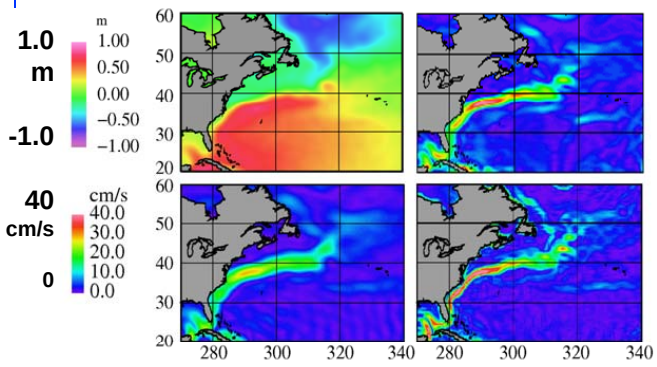
Gulf Stream:



The GOCE derived current speeds (r.3 TIM) show enhanced structures compared to a GRACE derived MDT (lower left).

Good agreements with Maximenko (2009) (lower right)

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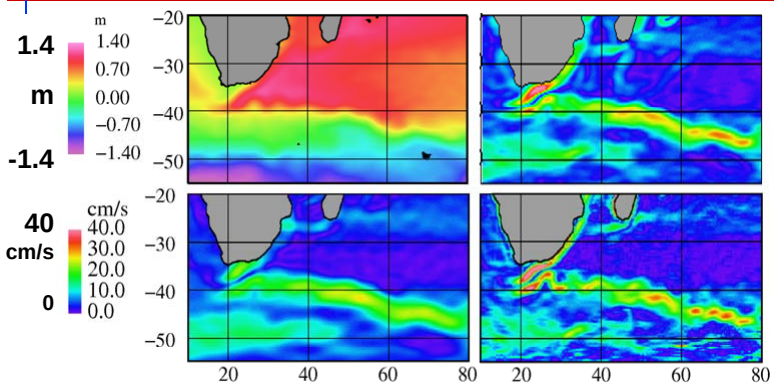
Aghulas:



The GOCE MDT and derived current speeds (r.3 TIM) (upper left and right)

Speeds from a GRACE derived MDT (lower left)

Speeds from Maximenko (2009) (lower right)

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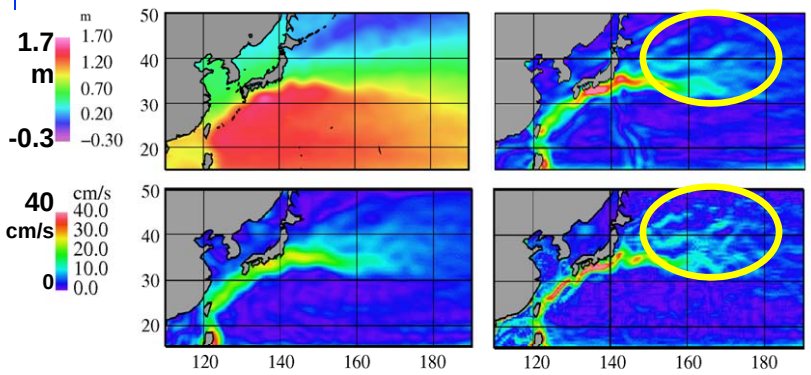
Kuroshio:



The GOCE MDT and derived current speeds (r.3 TIM) (upper left and right)
Speeds from a GRACE derived MDT (lower left)
Speeds from Maximenko (2009) (lower right)

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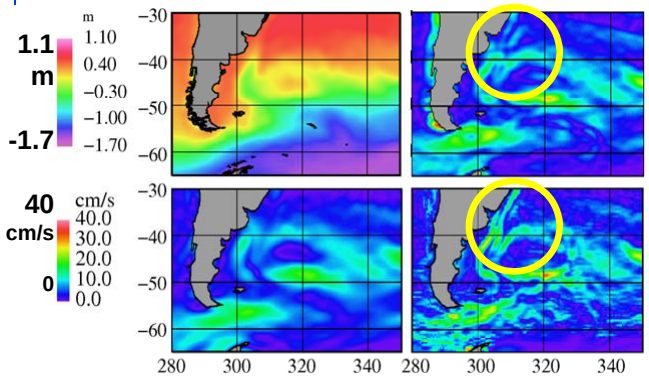
Brazil-Malvinas Confluence:



The GOCE MDT and derived current speeds (r.3 TIM) (upper left and right)
Speeds from a GRACE derived MDT (lower left)
Speeds from Maximenko (2009) (lower right)

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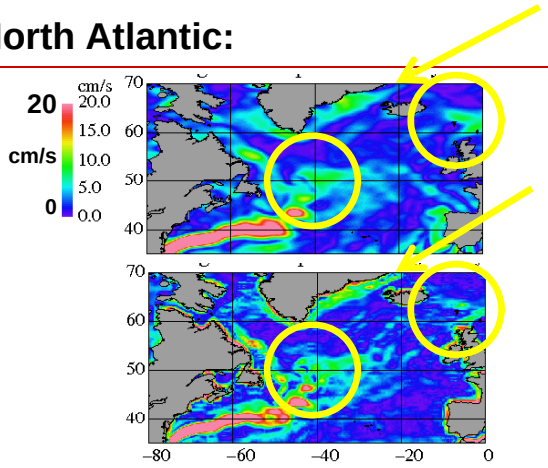
North Atlantic:



The GOCE (r.3 TIM) derived current speeds show details about local current systems as well (upper).

Also in good agreement with Maximenko (2009) (lower)

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Summary:

The results of this analysis clearly demonstrate the potential of the GOCE mission in ocean modelling:

- the resolution of the MDT has been improved
- the estimated surface current speeds have been increased - also minor currents and fronts are shown

Near future:

- improve filtering – combined solutions – full ECV matrix,
- more validation with oceanographic MDTs

Thanks to ESA for the GOCE User Toolbox

GOCE User Toolbox and Tutorial

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GUT contributors

The GUT Core Group :

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- 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.

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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

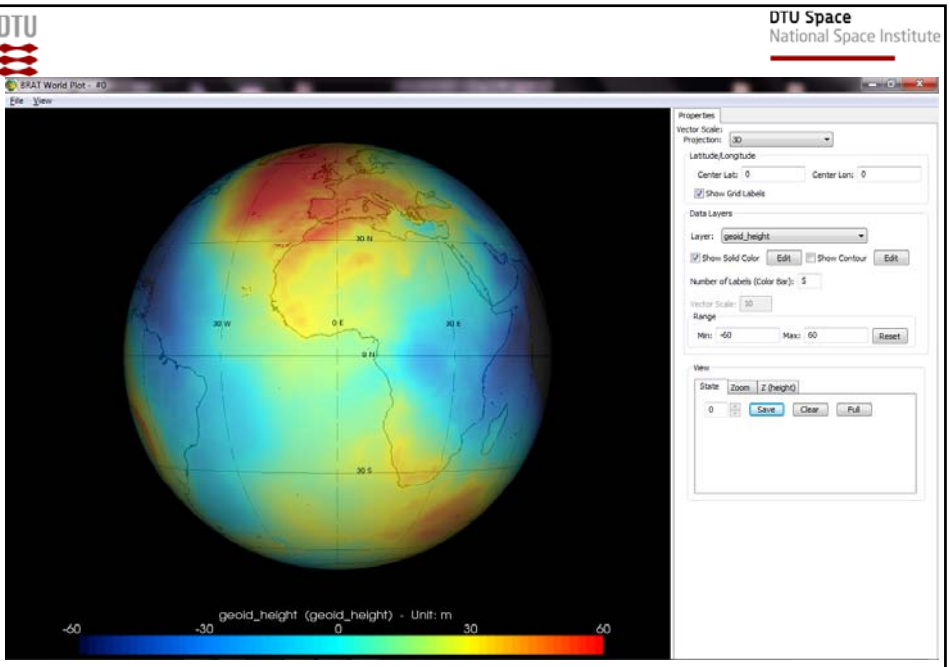
C:\BratDisplay geoid_heights.nc

```
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 Maximum 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



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What is GUT?

GUT has help / man functionality

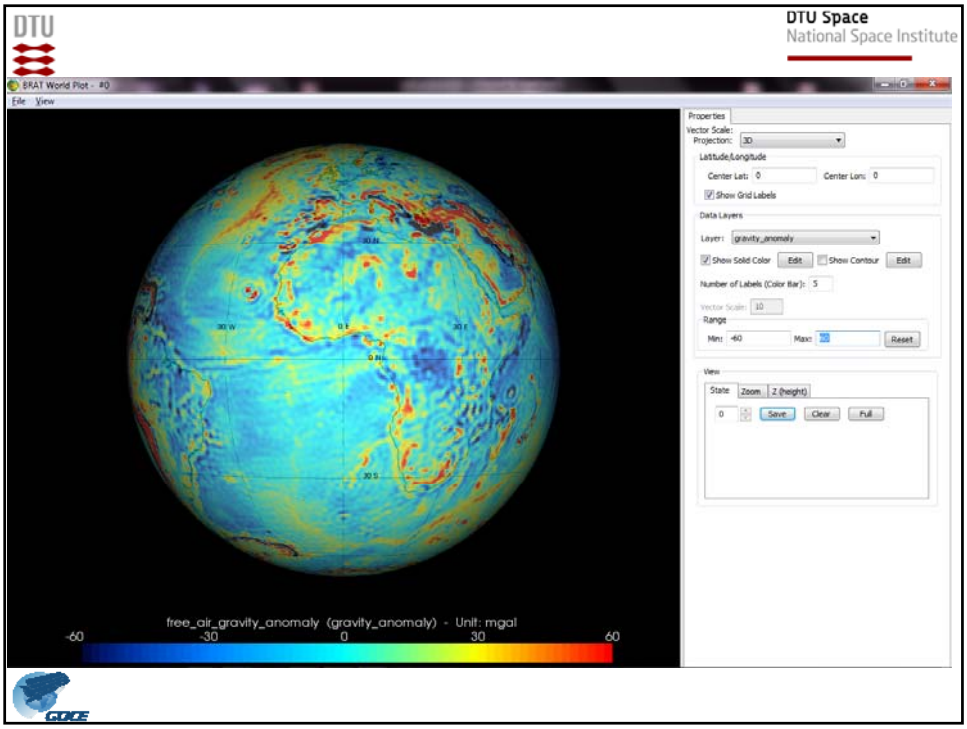
```
C:\GUT_test>gut --man geoidheight_gf

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



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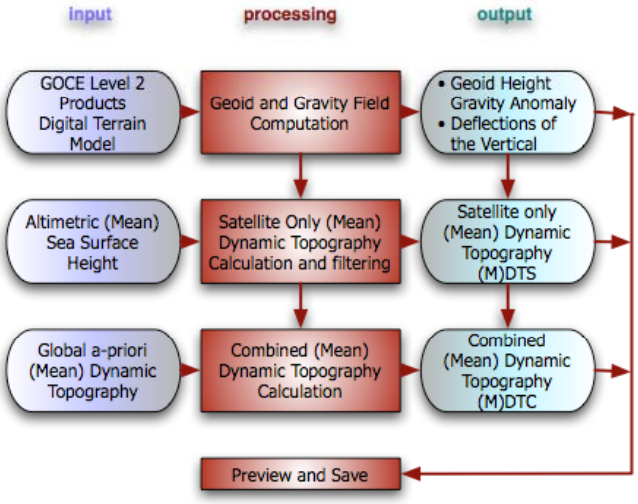
Workflows



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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.

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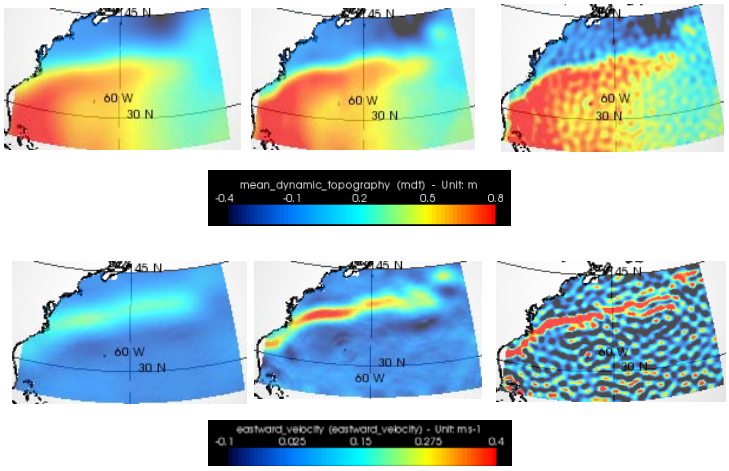
Demo: Filtering using 2.0, 1.0, and 0.5



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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.

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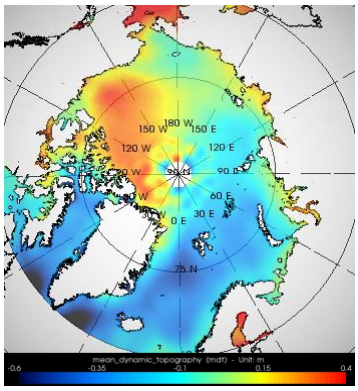
Summary:

- 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 to follow



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GUT demo:

```
Geoid - d/o 200 and 100:
gut geoidheight_gf -InFile egm_tim_r1.HDR -R -10.0:40.0,30.0:60.0 -I 0.25:0.25
BratDisplay geoid_height.nc
rename geoid_height.nc geoid_tim1_200.nc

gut geoidheight_gf -InFile egm_tim_r1.HDR -R -10.0:40.0,30.0:60.0 -I 0.25:0.25 -DO 100
BratDisplay geoid_height.nc
rename geoid_height.nc geoid_tim1_100.nc

gut subtract_gf -InFileLhs geoid_tim1_200.nc -InFileRhs geoid_tim1_100.nc -OutFile geoid_tim1_dif.nc
BratDisplay geoid_tim1_dif.nc


Gravity anomalies - d/o 200 and 100:
gut gravityanomaly_gf -InFile egm_tim_r1.HDR -R -10.0:40.0,30.0:60.0 -I 0.25:0.25 -DO 200
BratDisplay gravity_anomaly.nc
rename gravity_anomaly.nc gravity_tim1_200.nc

gut gravityanomaly_gf -InFile egm_tim_r1.HDR -R -10.0:40.0,30.0:60.0 -I 0.25:0.25 -DO 100
BratDisplay gravity_anomaly.nc
rename gravity_anomaly.nc gravity_tim1_100.nc

gut subtract_gf -InFileLhs gravity_tim1_200.nc -InFileRhs gravity_tim1_100.nc -OutFile
    gravity_tim1_dif.nc
BratDisplay gravity_tim1_dif.nc
```

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GUT demo:

```
Gravity anomalies - TIMr3 - TIMr1:
gut gravityanomaly_gf -InFile GO_CONS_EGM_GOC_2__20091101T000000_20110430T235959_0001.HDR -
     R 10.0:40.0,30.0:60.0 -I 0.25:0.25 -DO 240
BratDisplay gravity_anomaly.nc
rename gravity_anomaly.nc gravity_tim3_240.nc

gut subtract_gf -InFileLhs gravity_tim3_240.nc -InFileRhs gravity_tim1_200.nc -OutFile
     gravity_tim_dif.nc
BratDisplay gravity_tim_dif.nc


Gravity anomalies - TIMr3 - DIRr3:
gut gravityanomaly_gf -InFile GOCE_dir_r3.gfc -R -10.0:40.0,30.0:60.0 -I 0.25:0.25 -DO 240
BratDisplay gravity_anomaly.nc
rename gravity_anomaly.nc gravity_dir3_240.nc

gut subtract_gf -InFileLhs gravity_tim3_240.nc -InFileRhs gravity_dir3_240.nc -OutFile
     gravity_dif.nc
BratDisplay gravity_dif.nc
```

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GUT demo:

```
Bouguer anomalies:

gut adapt_gf -InFile GUT_ACE2_BATHY_5M.nc -OutFile dem.nc -R -10.0:40.0,30.0:60.0 -I 0.25:0.25
BratDisplay dem.nc

gut exportgravsoft_gf -InFile dem.nc -OutFile dem.grd
gut scale_gf -InFile dem.grd -OutFile bugl.nc -Scale 0.112 -PQ gravity_anomaly
gut import_gf -InFile bugl.nc -T tide-free -PQ gravity_anomaly
BratDisplay bugl.nc

gut landmask_gf -InFile dem.nc -OutFile demw.nc -Substitute 0
BratDisplay demw.nc

gut exportgravsoft_gf -InFile demw.nc -OutFile demw.grd
gut scale_gf -InFile demw.grd -OutFile bugw.nc -Scale 0.043 -PQ gravity_anomaly
gut import_gf -InFile bugw.nc -T tide-free -PQ gravity_anomaly
BratDisplay bugw.nc

gut subtract_gf -InFileLhs bugl.nc -InFileRhs bugw.nc -OutFile bug.nc
BratDisplay bug.nc

gut exportgravsoft_gf -InFile gravity_tim3_240.nc -OutFile gravity.grd
gut scale_gf -InFile gravity.grd -OutFile gravity.nc -Scale 1.0 -PQ gravity_anomaly
gut import_gf -InFile gravity.nc -T tide-free -PQ gravity_anomaly
gut subtract_gf -InFileLhs gravity.nc -InFileRhs bug.nc -OutFile buggrav.nc
BratDisplay buggrav.nc

gut filter_gf -InFile buggrav.nc -OutFile buggravf.nc -Ftg 1.0 -ResFile buggravr.nc
BratDisplay buggravf.nc
BratDisplay buggravr.nc
```