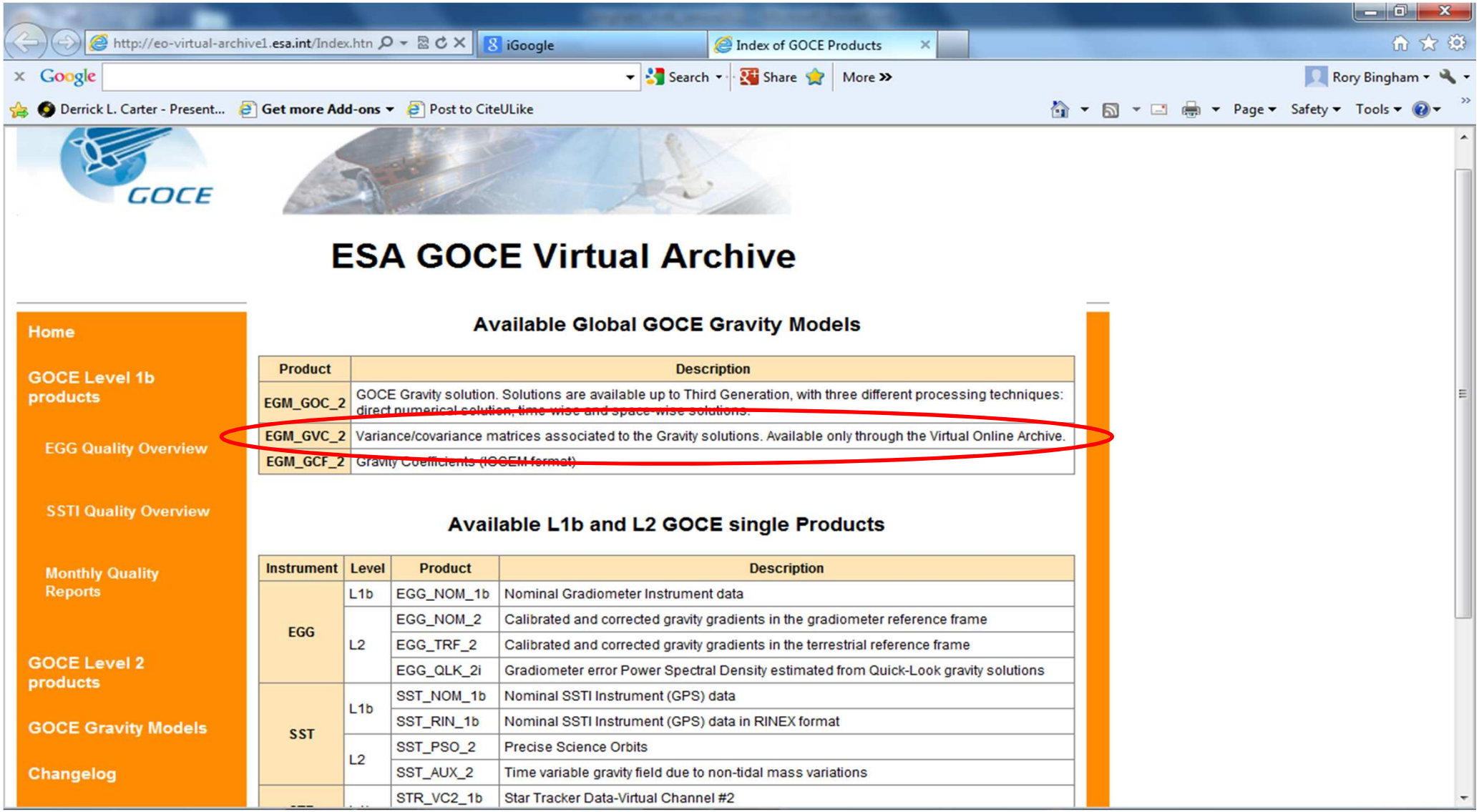
An introduction to the GOCE error variance covariance products: A user's perspective

Rory Bingham

Newcastle University

rory.bingham@ncl.ac.uk

The ESA GOCE Virtual Archive



The variance-covariance matrices

- Product EGM_GVC_2
- Eight full variance-covariance matrices: DIR1/2/3;TIM1/2/3;SPW1/2
- Available from virtual archive
- Ascii format with XML header
- Individual files for each order

					File size (GB)		
Model	**Filename: GO_CONS_EGM_GVC_2__***	**d/o**	**Order**	**Form**	***.TGZ**	***.TAR**	***.DAT**
DIR1	20091101T000000_20100110T235959_0001	240	I	e20.14	11	35	13
DIR2	20091101T000000_20100630T235959_0001	240	I	e20.14	11	35	13
TIM1	20091101T000000_20100111T000000_0002	224	B	e25.20	13		10
TIM2	20091101T000000_20100705T235500_0001	250	B	e25.20	20	52	16
SPW1	20091030T005757_20100111T073815_0001	210	B	e11.8	3	13	8
SPW2	20091031T000000_20100705T235959_0001	240	B	e11.8	5	22	13

Variance-covariance matrix file structure

GO_CONS_EGM_GVC_2__20091101T000000_20100705T235500_0001.TGZ (20.4GB)

GO_CONS_EGM_GVC_2__20091101T000000_20100705T235500_0001.HDR (0.6MB)

GO_CONS_EGM_GVC_2__20091101T000000_20100705T235500_0001.TAR (51.6GB)

GO_CONS_EGM_GVC_2__20091101T000000_20100705T235500_0001.IIH (0.6MB)

L+1 x GO_CONS_EGM_GVC_2__20091101T000000_20100705T235500_0001.M (<316MB)

M=1,..,L

Contents of IIH file:

product_type Variance-covariance matrix
modelname GO_CONS_EGM_GVC_2__20091101T000000_20100705T235500
earth_gravity_constant 3.9860044150000000E+14
radius 6.3781362999999998E+06
max_degree 250
errors formal
covariance_matrix_type full
sequence_number_entries 62997
C_002_000
C_003_000
C_004_000
C_005_000

Contents of data file:

meta_data_file_name
GO_CONS_EGM_GVC_2__20091101T000000_20100705T235500_0001.IIH
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number_entries 12172025
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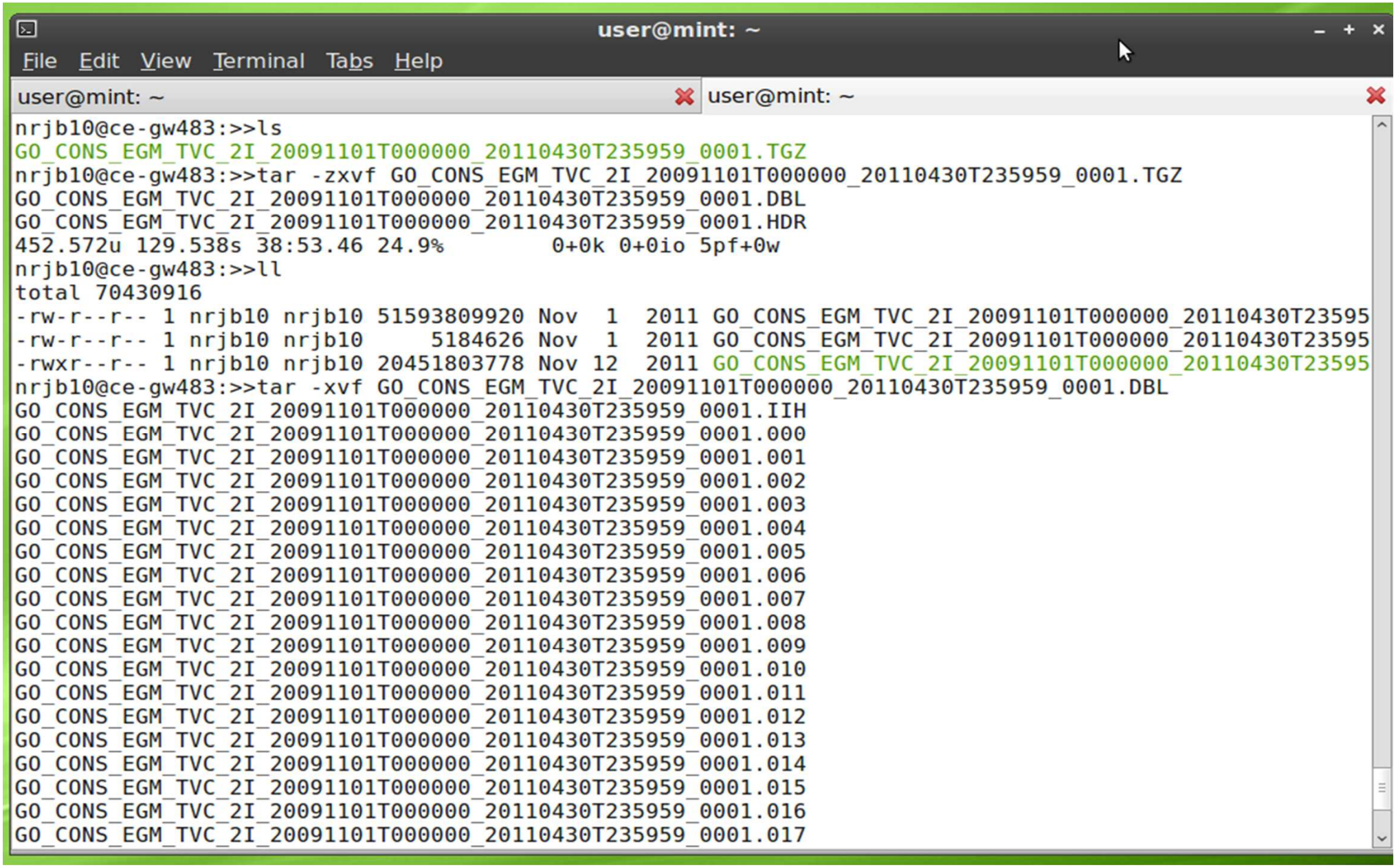
:
:
end data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GO_CONS_EGM_TVC_2I_20091101T000000_20110430T235959_0001.HDR
452.572u 129.538s 38:53.46 24.9% 0+0k 0+0io 5pf+0w
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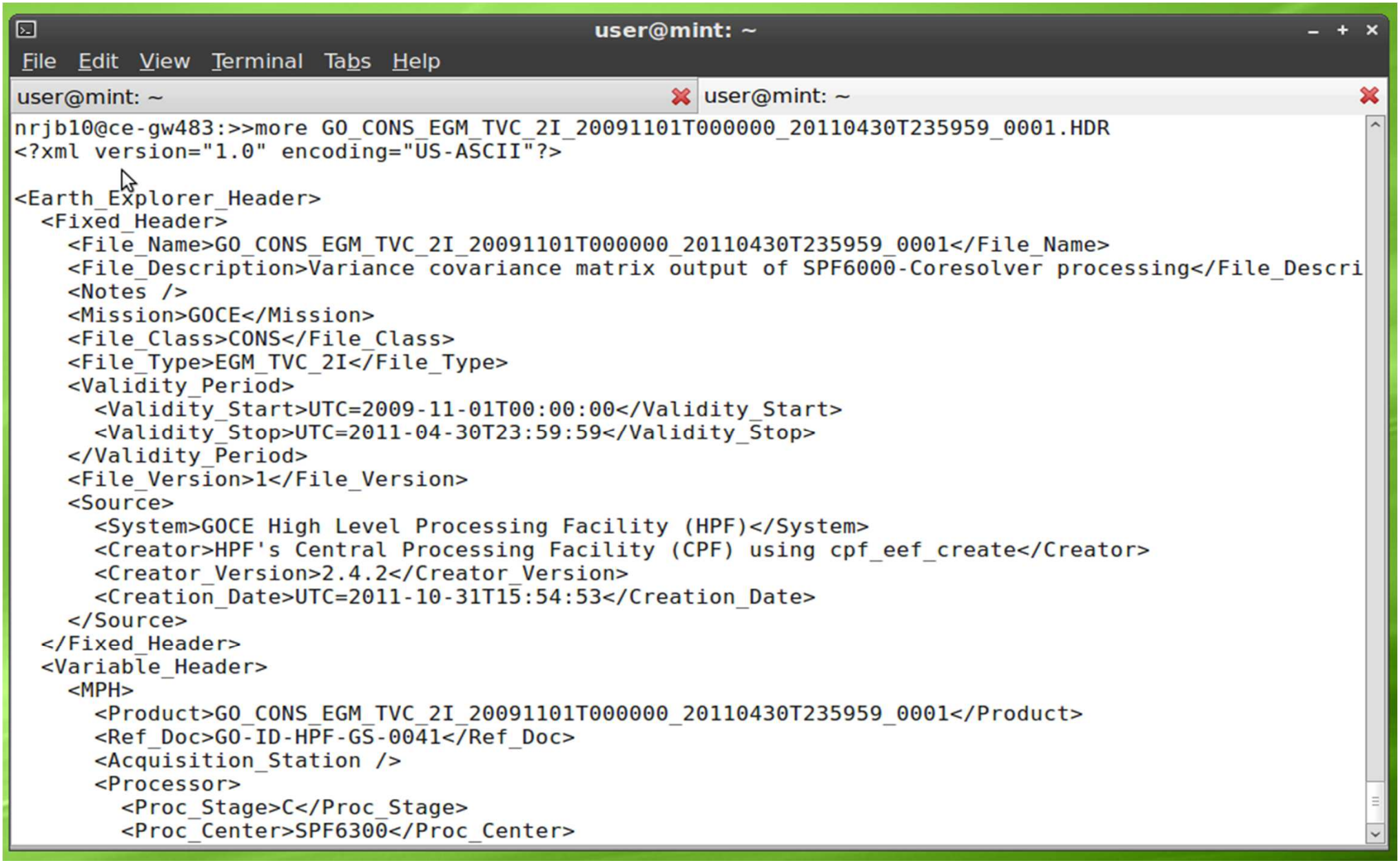
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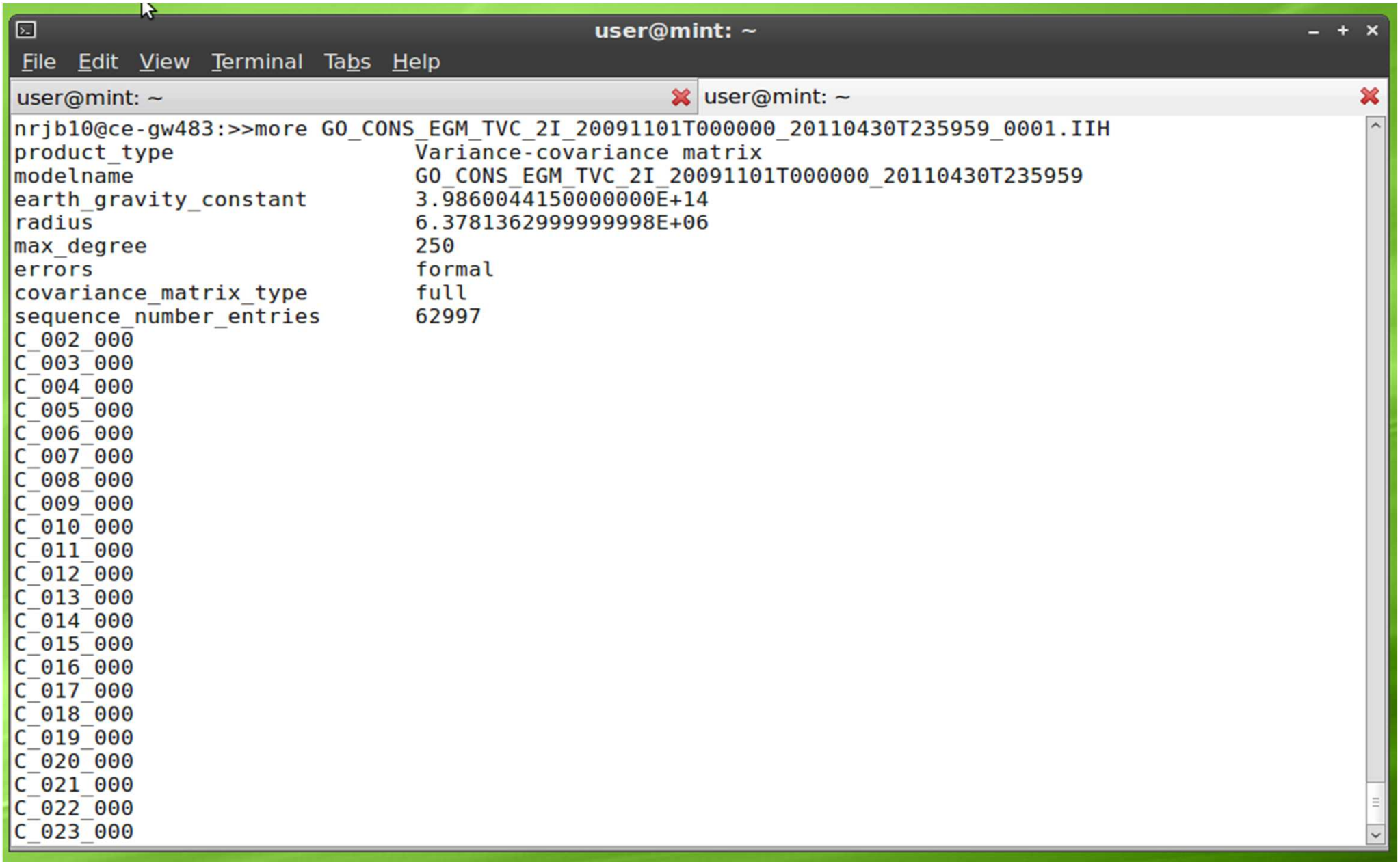
user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
nrjb10@ce-gw483:>>more GO_CONS_EGM_TVC_2I_20091101T000000_20110430T235959_0001.IIH
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modelname GO_CONS_EGM_TVC_2I_20091101T000000_20110430T235959
earth_gravity_constant 3.9860044150000000E+14
radius 6.3781362999999998E+06
max_degree 250
errors formal
covariance_matrix_type full
sequence_number_entries 62997
C_002_000
C_003_000
C_004_000
C_005_000
C_006_000
C_007_000
C_008_000
C_009_000
C_010_000
C_011_000
C_012_000
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C_016_000
C_017_000
C_018_000
C_019_000
C_020_000
C_021_000
C_022_000
C_023_000

Error propagation – geoid

The gridded geoid is given by

$$N(\phi,\lambda) = Y^T X$$

where

$$X = \{C_{lm}; S_{lm}\}_{l,m}$$

Spectral coefficients of gravity field

$$Y = \{f_{lm} P_{lm}(\sin\phi)\cos m\lambda;\ f_{lm} P_{lm}(\sin\phi)\sin m\lambda\}_{l,m}$$

and

$$f_{lm} = \frac{GM}{r\gamma}\left(\frac{R}{r}\right)^l$$

The corresponding error variance is given by

$$\sigma_N^2(\phi,\lambda) = Y^T \Gamma Y$$

where Γ is the variance-covariance matrix

Issues:

Size of Γ (13GB)

No. of operations

For one point: $\approx 3\text{Gflops} \approx 1\text{sec}$

1x1 degree global grid: 64800 points = 18hrs

0.5x0.5 degree global grid: 3 days

Error propagation – geoid

Full geoid error covariance matrix **C** for a global 1x1 degree grid:

$$C_{kh} = Y_k^{\ T} \Gamma Y_h$$
$$k, h = 360 \times (j-1) + i$$
$$i = 1,\ldots,360$$
$$j = 1,\ldots,180$$

For one entry: $\approx 3\text{Gflops} \approx 1\text{sec}$

1x1 degree global grid:
64800^2 entries = 0.5x64800x18hrs=67yrs!

18hrs for the error covariance associated with one point

Balmino software

- e_covhsmp for computing error variances: $\sigma^2(q) = \mathbf{Y}^{\mathrm{T}}\boldsymbol{\Gamma}\mathbf{Y}$

- e_covhs2p for computing error covariances: $\mathrm{cov}(q_1, q_2) = \mathbf{Y}_1^{\mathrm{T}}\boldsymbol{\Gamma}\mathbf{Y}_2$

$$\begin{bmatrix} \sigma^2(q_1) & \mathrm{cov}(q_1, q_2) \\ \mathrm{cov}(q_1, q_2) & \sigma^2(q_2) \end{bmatrix} = \begin{bmatrix} \mathbf{Y}_1^{\mathrm{T}}\boldsymbol{\Gamma}\mathbf{Y}_1 & \mathbf{Y}_1^{\mathrm{T}}\boldsymbol{\Gamma}\mathbf{Y}_2 \\ \mathbf{Y}_2^{\mathrm{T}}\boldsymbol{\Gamma}\mathbf{Y}_1 & \mathbf{Y}_2^{\mathrm{T}}\boldsymbol{\Gamma}\mathbf{Y}_2 \end{bmatrix}$$

  - q is any linear function of the gravity field coefficients
  - $\mathbf{Y}$ are the corresponding basis functions evaluated at grid points

- Written in fortran 90
- Employs partial sums and longitude regression to improve performance
- Only one row variance-covariance matrix needs to be held in memory (assuming full square matrix)

Balmino software

- Can compute error variances/covariances for:
  - geoid heights
  - free-air gravity anomalies Δg
  - gravity distrubances
  - radial gravity gradient
  - vertical gradient of Δg
  - equivalent water thickness (with load effects)

- Built in filters
  - Pellinen, Hanning, Gauss, cap-limited Gauss
  - tapering functions (by degree and/or order)

- Balmino, G., Efficient propagation of error covariance matrices of gravitational models: application to GRACE and GOCE, Journal of Geodesy, 83, 989-995 (2009).

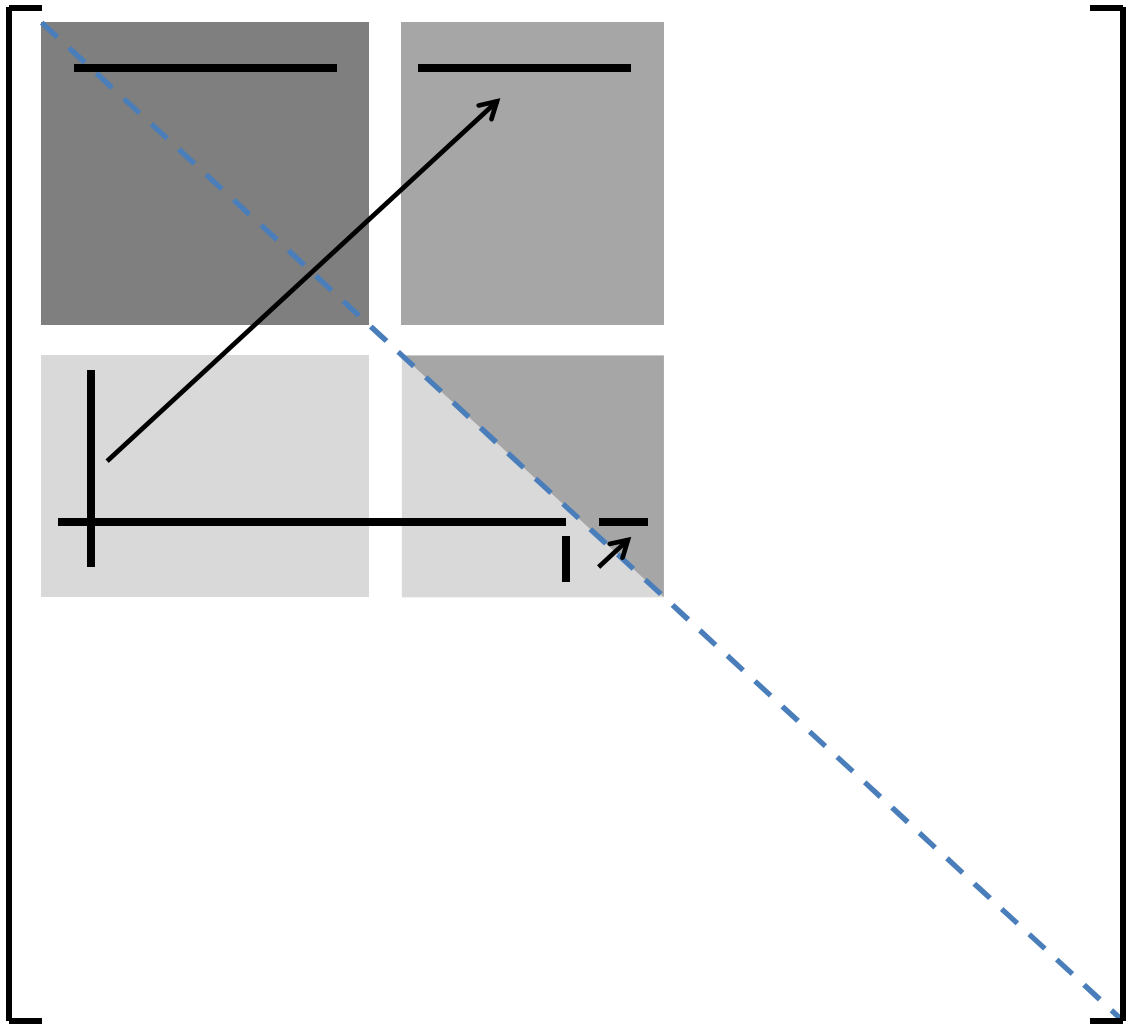
Issues with the variance-covariance matrix files

- Size!!!
- Format not compatible with Balmino routines
  - full square vcm; unformatted binary; sequential access; 1 row = 1 record
- Not in a consistent format:
  - DIR model interleave C_{lm} and S_{lm}
  - TIM/SPW model blocks C_{lm} and S_{lm}
  - SPW inc. C00,C10,C11,S11
- TIM1 VCM corrupted
  - "IIH" replaces "nnn" at random points
- *.DBL = *.TAR

Generating the variance-covariance matrix

- Read ascii file and write L-triangular matrix as unformatted binary; sequential access; 1 row = 1 record; single precision (30->13Gb)
- Generate square matrix
-

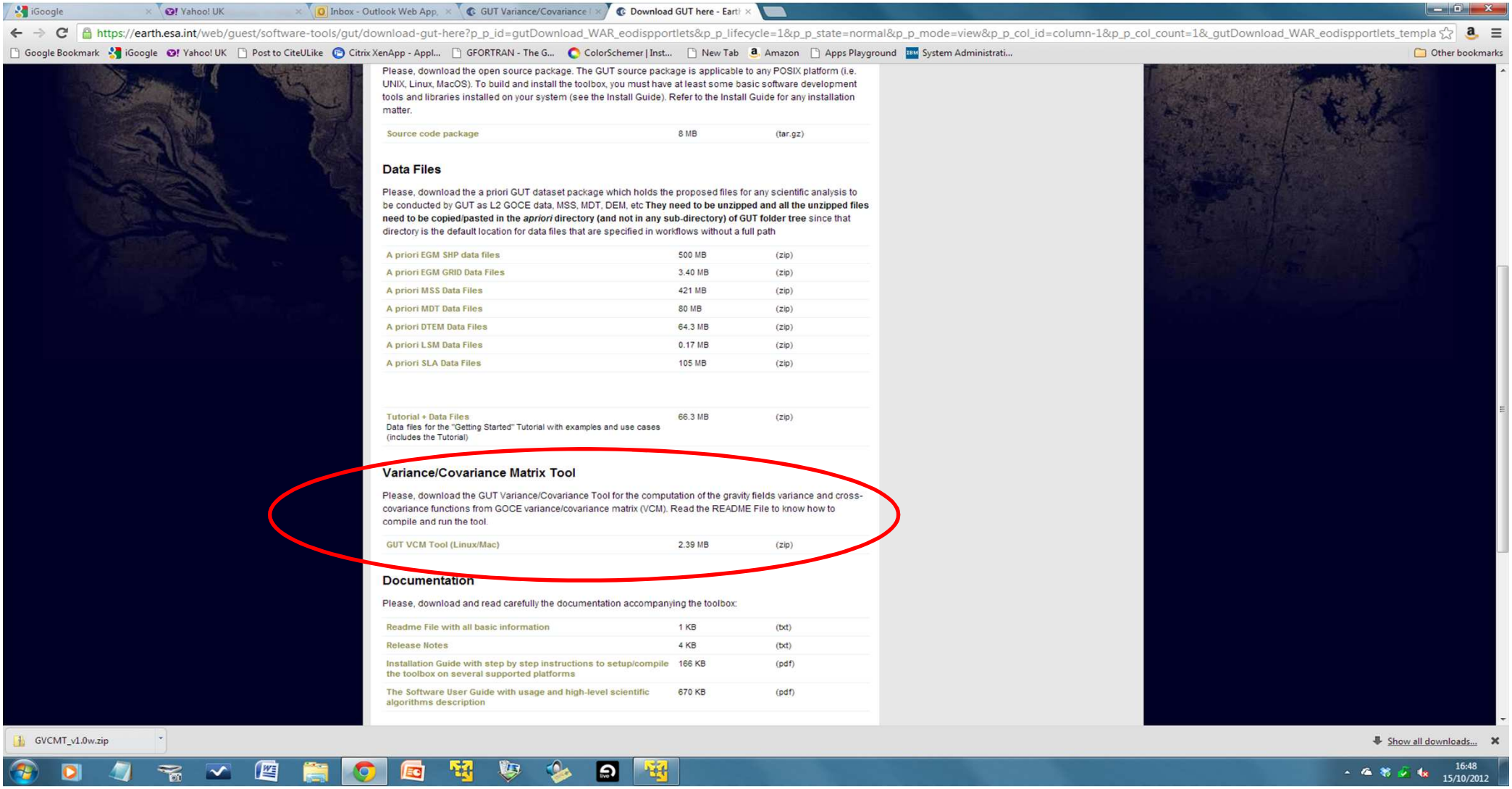
Generating the full variance-covariance matrix

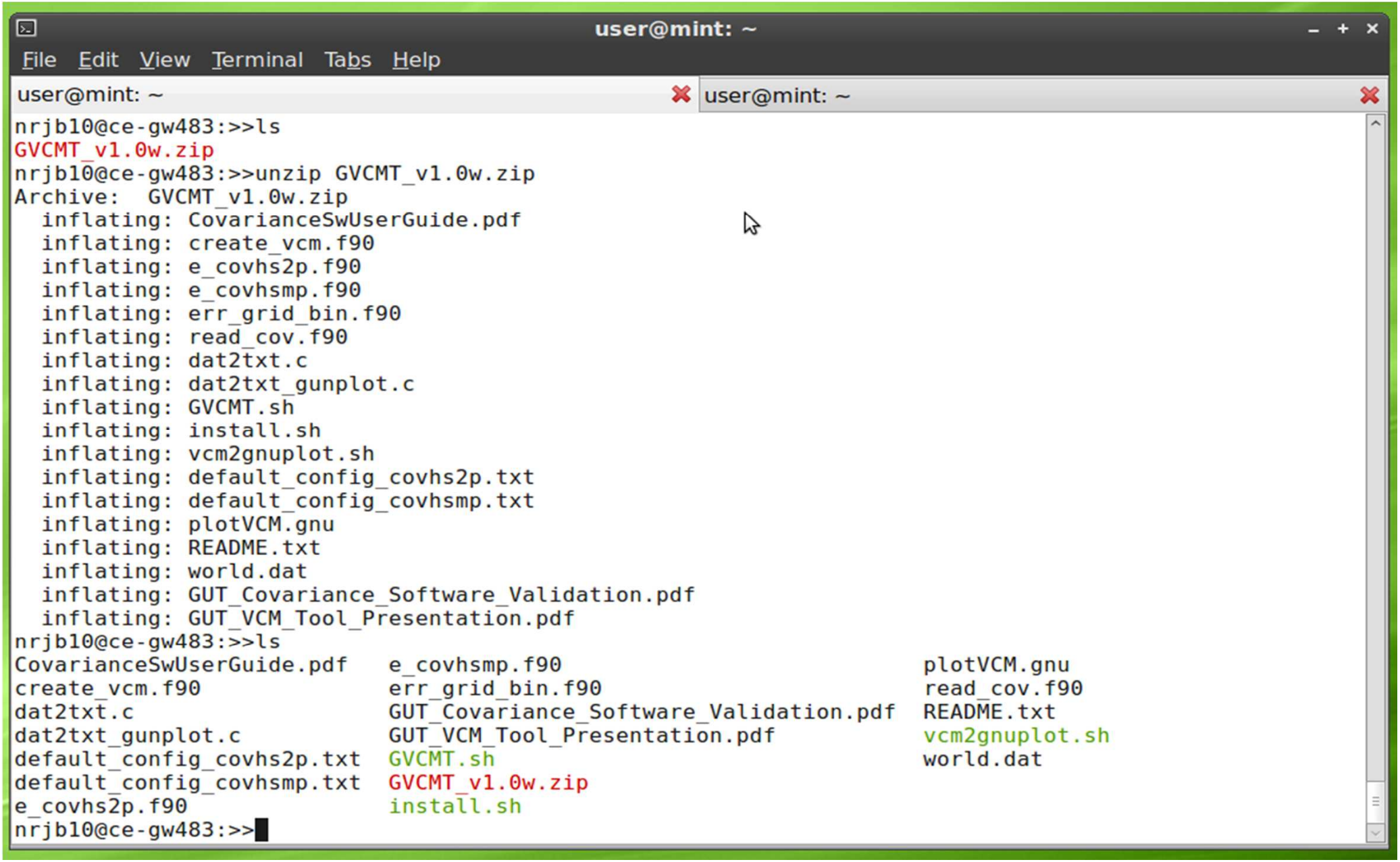


- Create blank direct access file
- Determine max block size within memory limits (user defined)
- Fill rectangular block from sequential file containing L-tri
- Read in rows of direct access file, append corresponding columns of rectangular block and write back to file from first row to last before new block
- Complete upper triangular part of rectangular block and write rows to direct access file.
- Repeat until complete (1GB ram = 13 loops

Generating the variance-covariance matrix

- Read ascii file and write L-triangular matrix as unformatted binary; sequential access; 1 row = 1 record; single precision (30->13Gb)
- Generate square matrix as direct access file
- Convert direct access file to sequential access
- First two steps have now been combined into one operation
- Process validated using Balmino simulated VCM
- Conversion to int*2 (Christian) reduces file size to approx 6.5 GB


iGoogle
Yahoo! UK
Inbox - Outlook Web App
GUT Variance/Covariance
Download GUT here - Earth
https://earth.esa.int/web/guest/software-tools/gut/download-gut-here?p_p_id=gutDownload_WAR_eodispportlets&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&p_p_col_id=column-1&p_p_col_count=1&_gutDownload_WAR_eodispportlets_templa
Google Bookmark
iGoogle
Yahoo! UK
Post to CiteULike
Citrix XenApp - Appl...
GFORTRAN - The G...
ColorSchemer | Inst...
New Tab
Amazon
Apps Playground
System Administrati...
Other bookmarks
Please, download the open source package. The GUT source package is applicable to any POSIX platform (i.e. UNIX, Linux, MacOS). To build and install the toolbox, you must have at least some basic software development tools and libraries installed on your system (see the Install Guide). Refer to the Install Guide for any installation matter.
Source code package 8 MB (tar.gz)
Data Files
Please, download the a priori GUT dataset package which holds the proposed files for any scientific analysis to be conducted by GUT as L2 GOCE data, MSS, MDT, DEM, etc They need to be unzipped and all the unzipped files need to be copied/pasted in the apriori directory (and not in any sub-directory) of GUT folder tree since that directory is the default location for data files that are specified in workflows without a full path
A priori EGM SHP data files 500 MB (zip)
A priori EGM GRID Data Files 3.40 MB (zip)
A priori MSS Data Files 421 MB (zip)
A priori MDT Data Files 80 MB (zip)
A priori DTEM Data Files 64.3 MB (zip)
A priori LSM Data Files 0.17 MB (zip)
A priori SLA Data Files 105 MB (zip)
Tutorial + Data Files 66.3 MB (zip)
Data files for the "Getting Started" Tutorial with examples and use cases (includes the Tutorial)
Variance/Covariance Matrix Tool
Please, download the GUT Variance/Covariance Tool for the computation of the gravity fields variance and cross-covariance functions from GOCE variance/covariance matrix (VCM). Read the README File to know how to compile and run the tool.
GUT VCM Tool (Linux/Mac) 2.39 MB (zip)
Documentation
Please, download and read carefully the documentation accompanying the toolbox:
Readme File with all basic information 1 KB (txt)
Release Notes 4 KB (txt)
Installation Guide with step by step instructions to setup/compile the toolbox on several supported platforms 166 KB (pdf)
The Software User Guide with usage and high-level scientific algorithms description 670 KB (pdf)
GVCMT_v1.0w.zip
Show all downloads...
16:48
15/10/2012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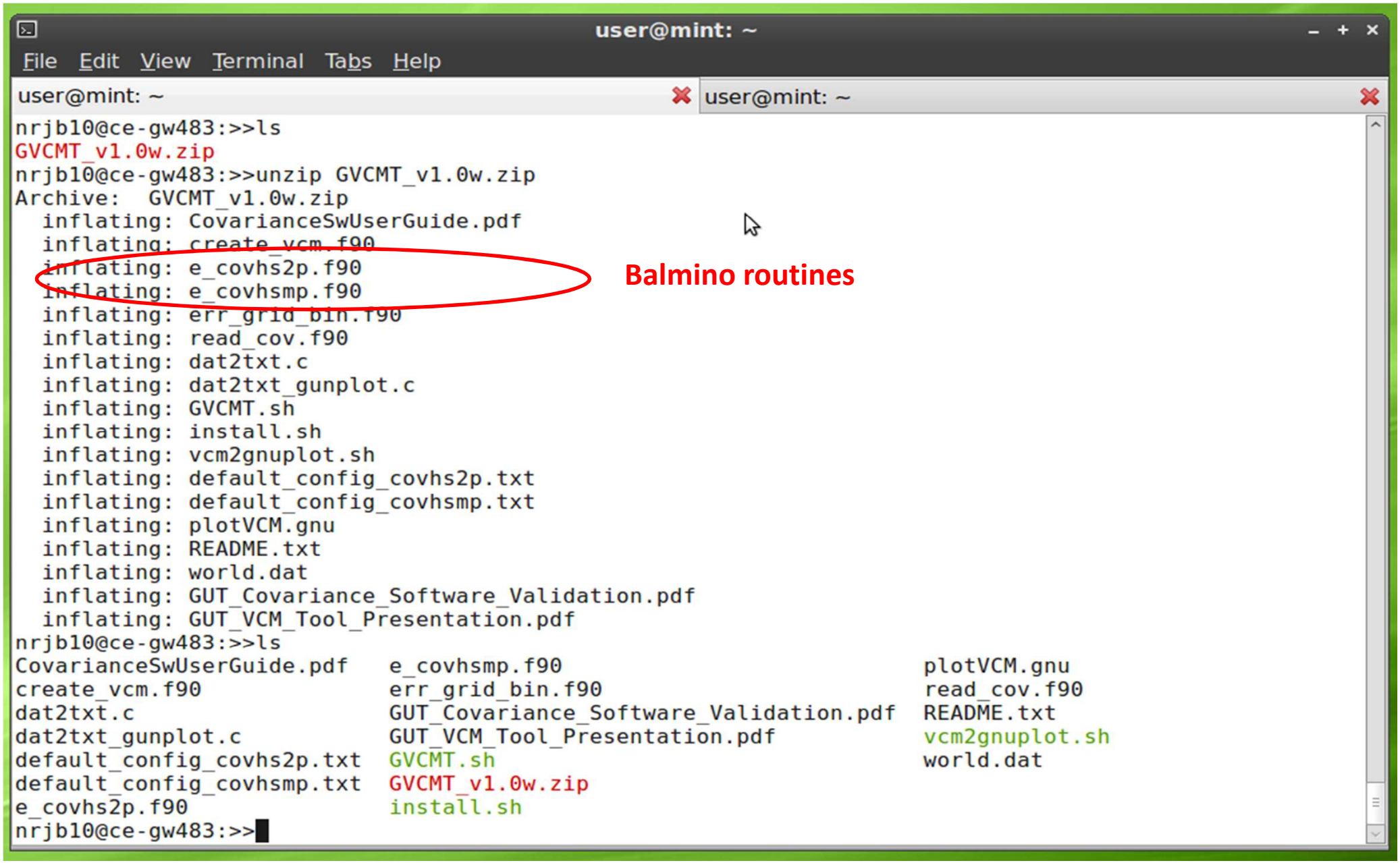
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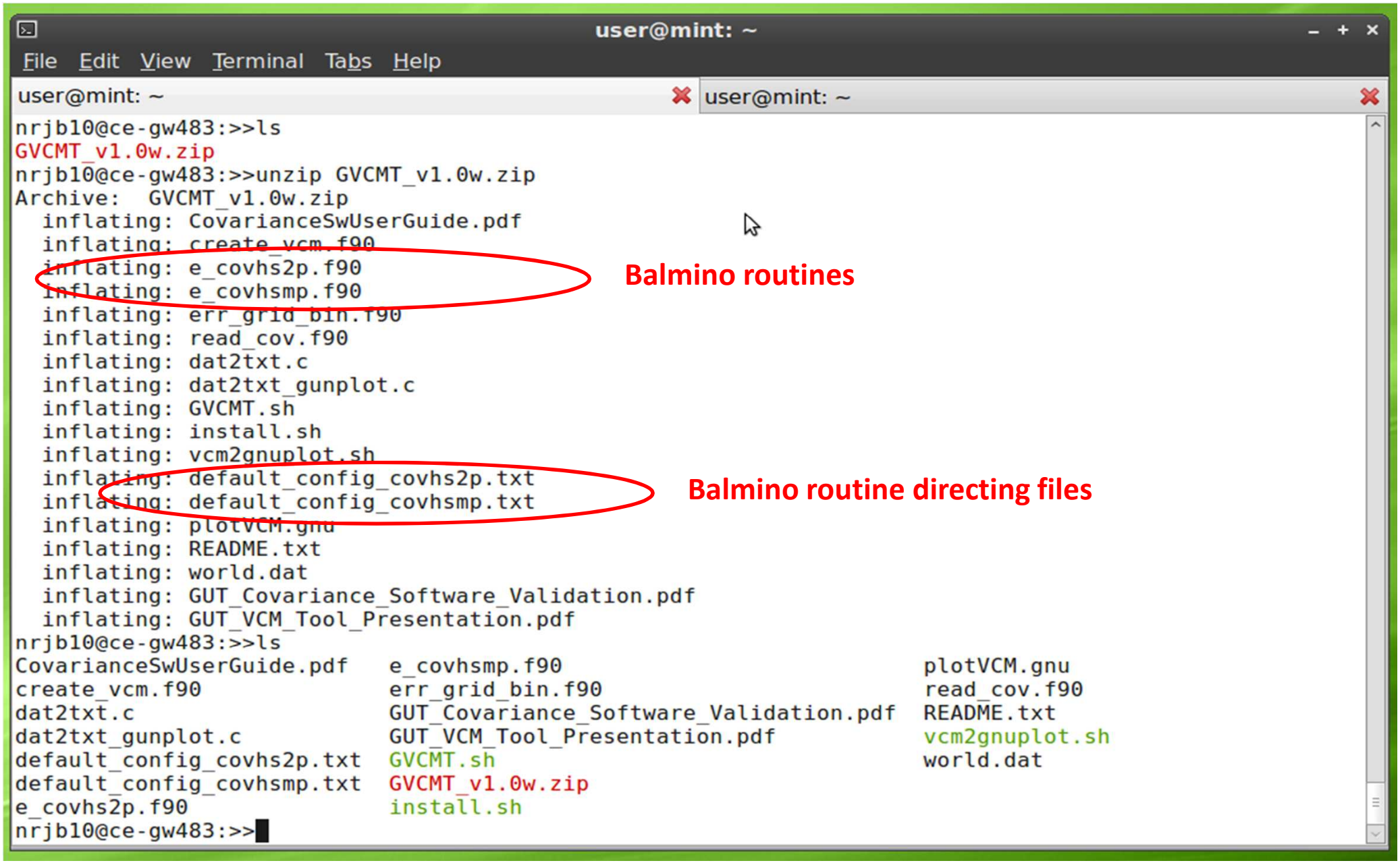
Balmino routines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GVCMT.sh
GVCMT_v1.0w.zip
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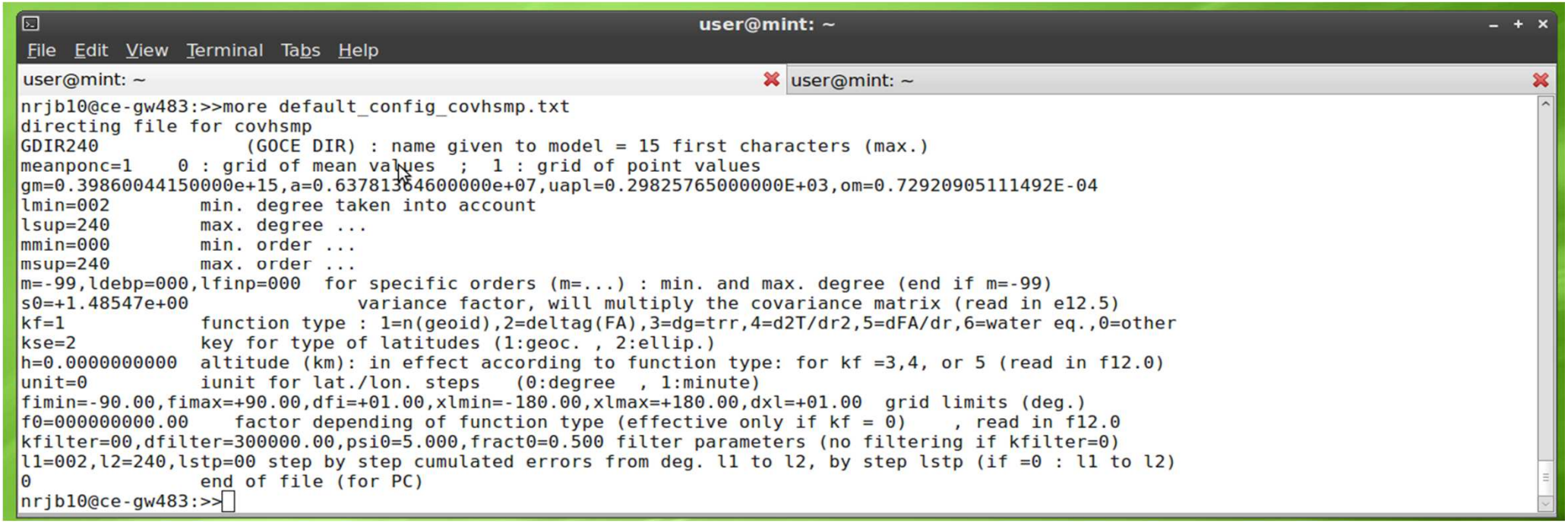
Balmino routines
Balmino routine directing files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File Edit View Terminal Tabs Help
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user@mint: ~
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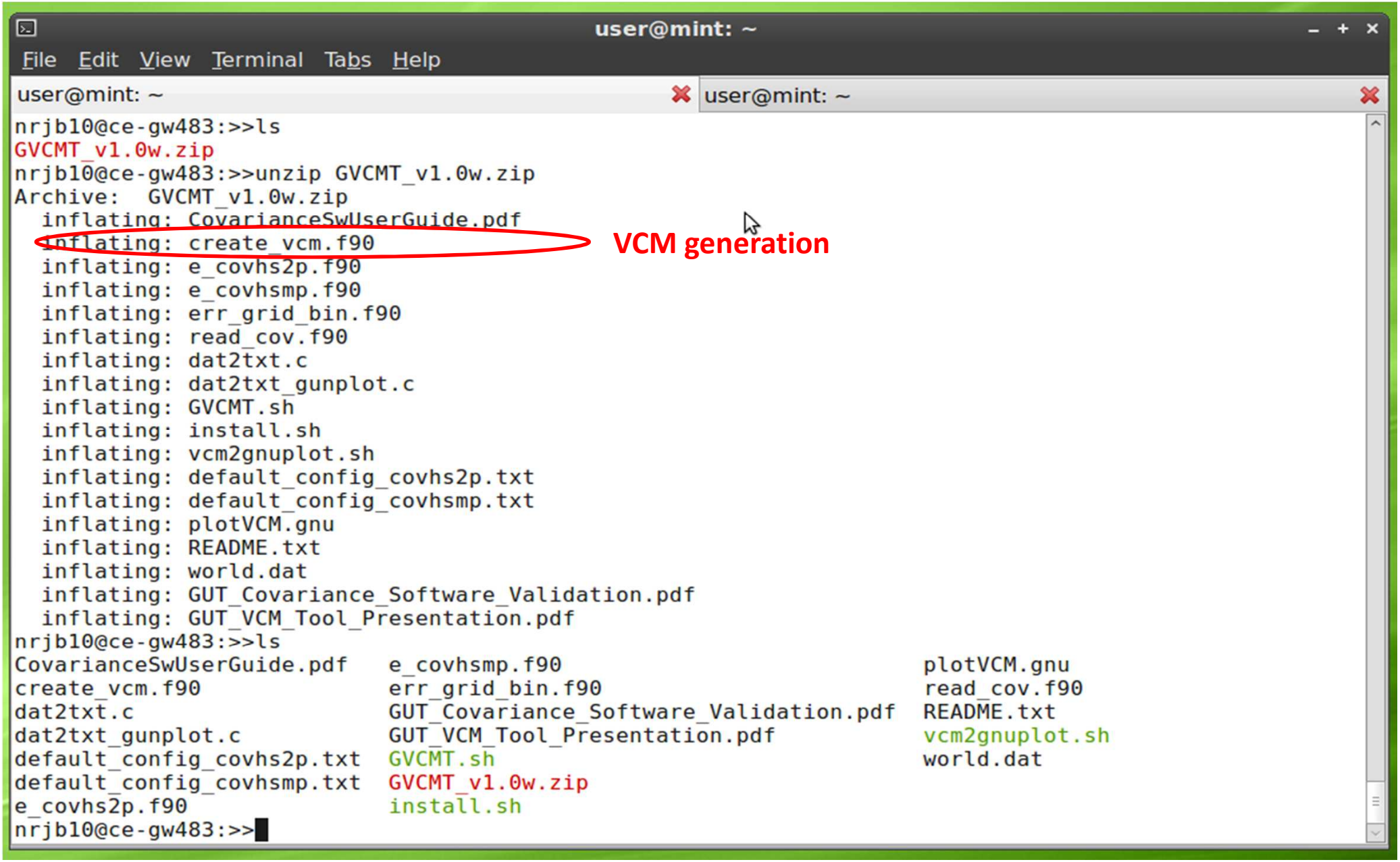
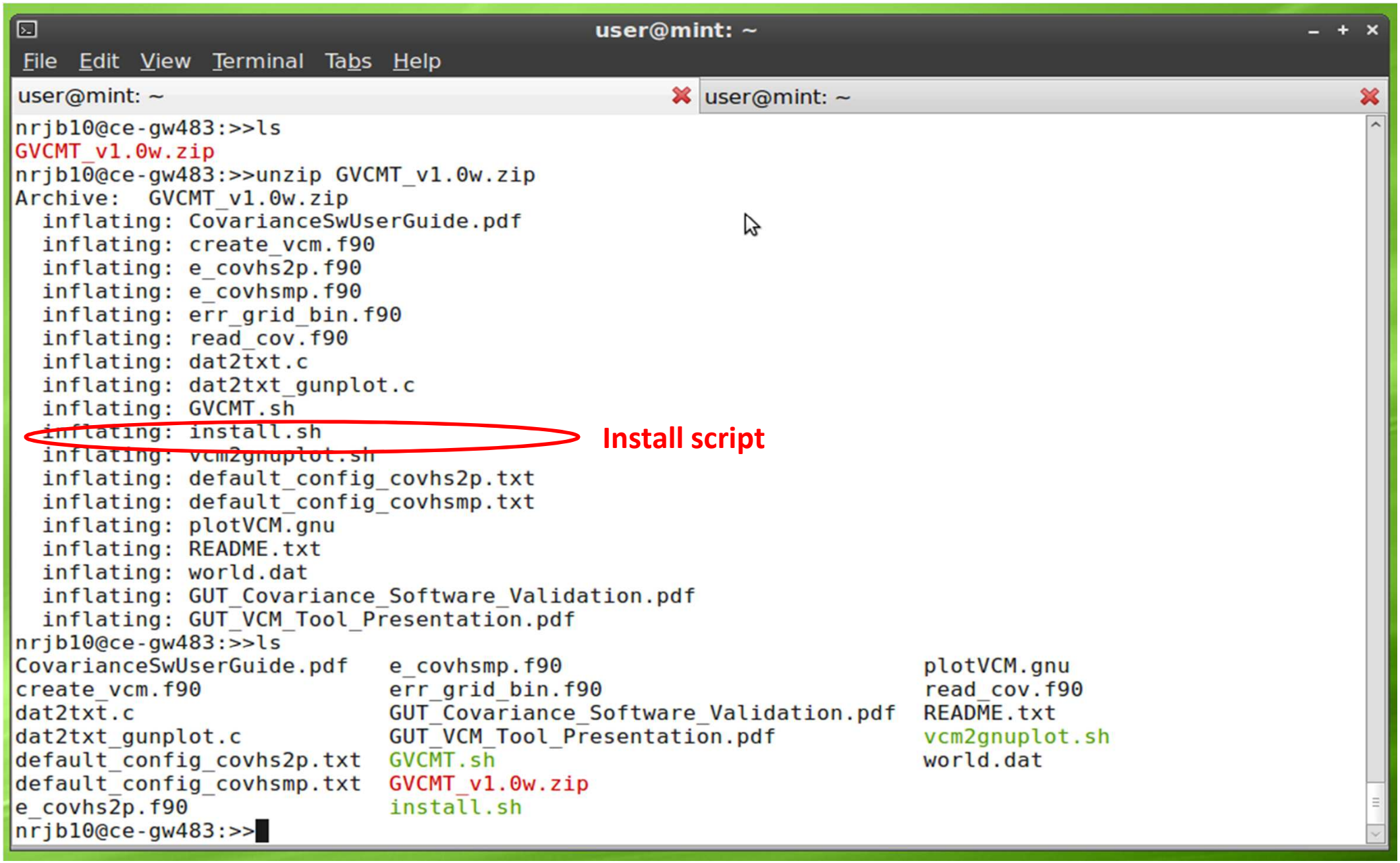
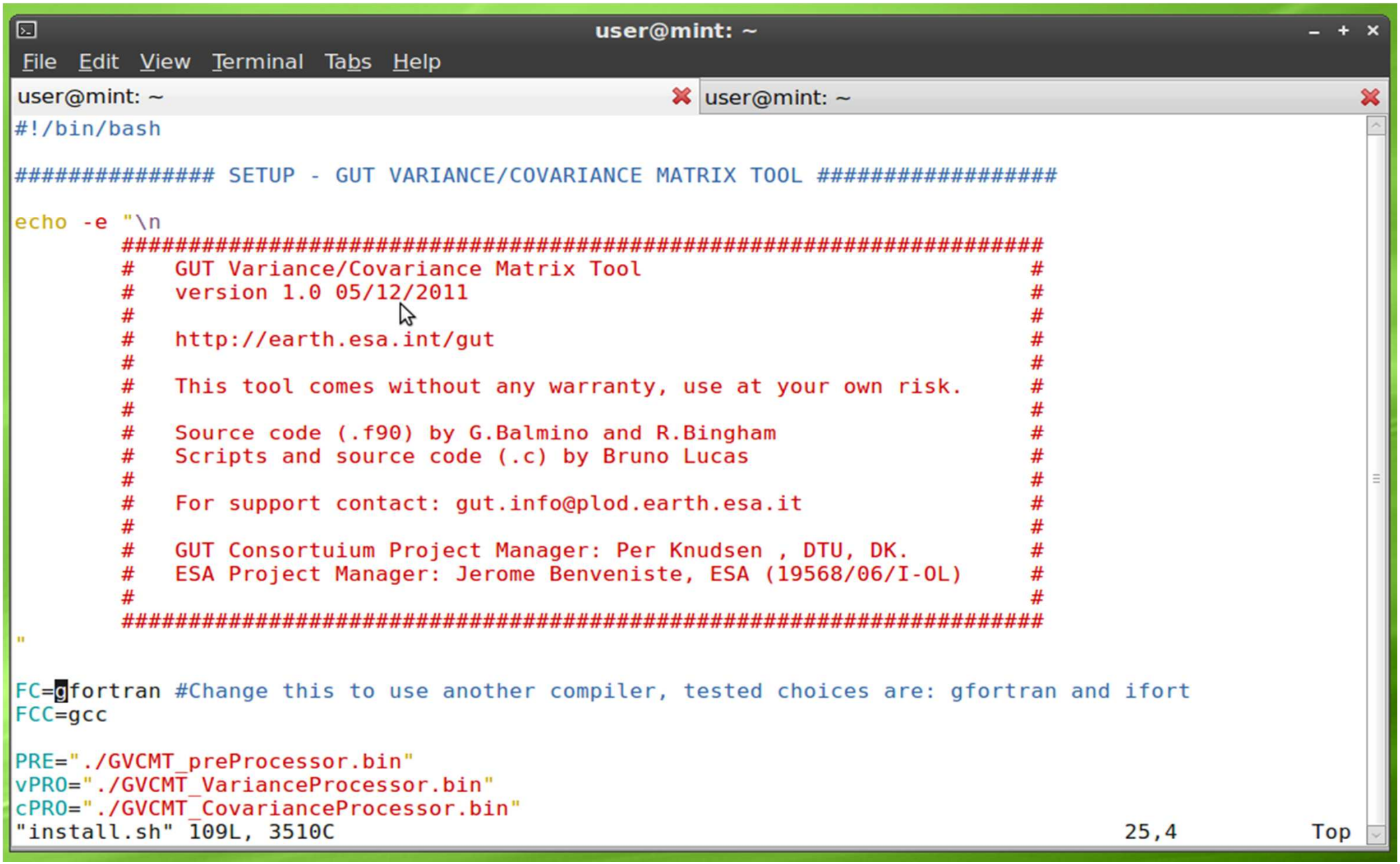
directing file for covhsmp
GDIR240 (GOCE DIR) : name given to model = 15 first characters (max.)
meanponc=1 0 : grid of mean values ; 1 : grid of point values
gm=0.39860044150000e+15,a=0.63781364600000e+07,uapl=0.29825765000000E+03,om=0.72920905111492E-04
lmin=002 min. degree taken into account
lsup=240 max. degree ...
mmin=000 min. order ...
msup=240 max. order ...
m=-99,ldebp=000,lfinp=000 for specific orders (m=...) : min. and max. degree (end if m=-99)
s0=+1.48547e+00 variance factor, will multiply the covariance matrix (read in e12.5)
kf=1 function type : 1=n(geoid),2=deltag(FA),3=dg=trr,4=d2T/dr2,5=dFA/dr,6=water eq.,0=other
kse=2 key for type of latitudes (1:geoc. , 2:ellip.)
h=0.0000000000 altitude (km): in effect according to function type: for kf =3,4, or 5 (read in f12.0)
unit=0 iunit for lat./lon. steps (0:degree , 1:minute)
fimin=-90.00,fimax=+90.00,dfi=+01.00,xlmin=-180.00,xlmax=+180.00,dxl=+01.00 grid limits (deg.)
f0=000000000.00 factor depending of function type (effective only if kf = 0) , read in f12.0
kfilter=00,dfilter=300000.00,psi0=5.000,fract0=0.500 filter parameters (no filtering if kfilter=0)
l1=002,l2=240,lstp=00 step by step cumulated errors from deg. l1 to l2, by step lstp (if =0 : l1 to l2)
0 end of file (for PC)
nrjb10@ce-gw483:>>

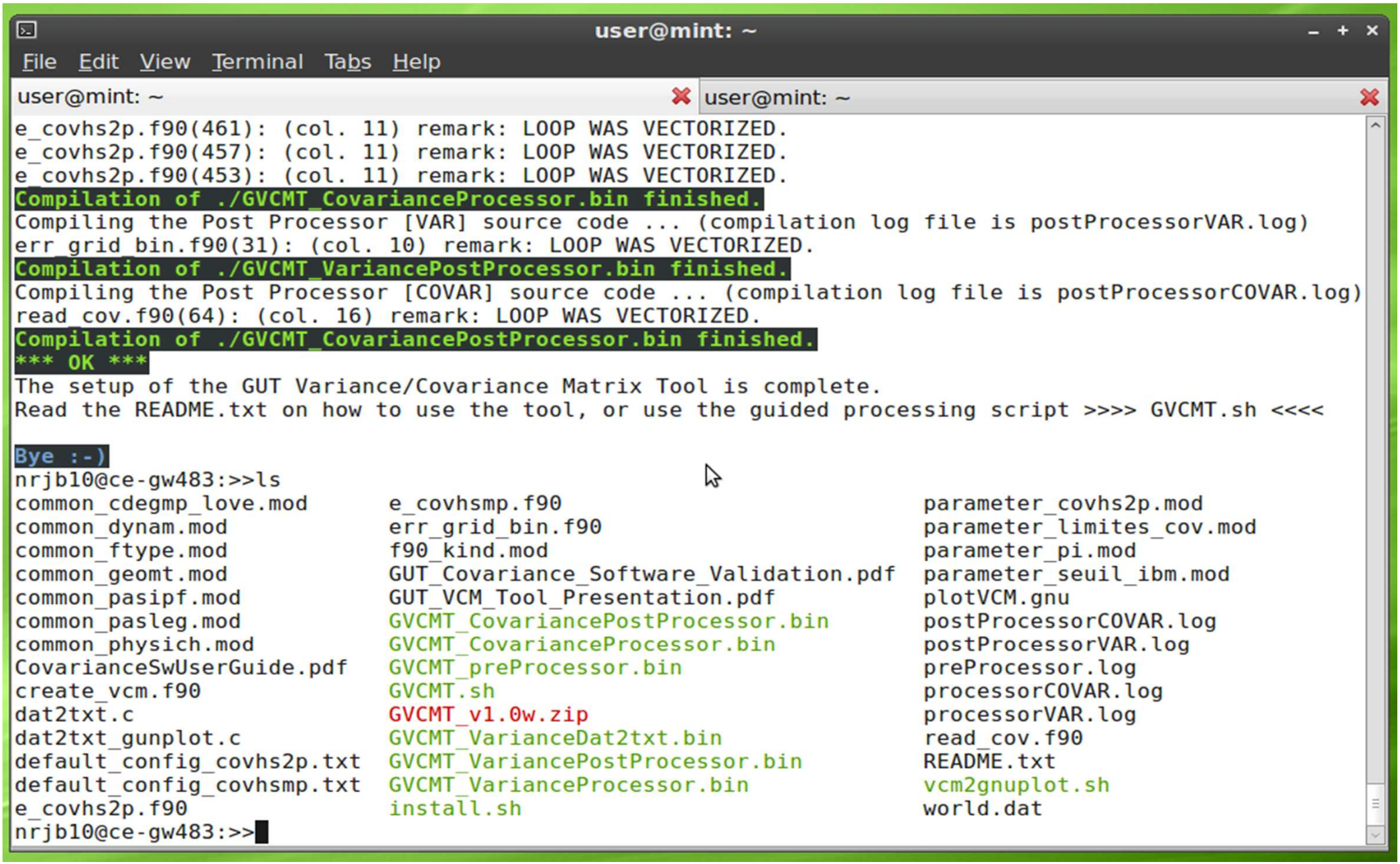
covhsmp: the directing file

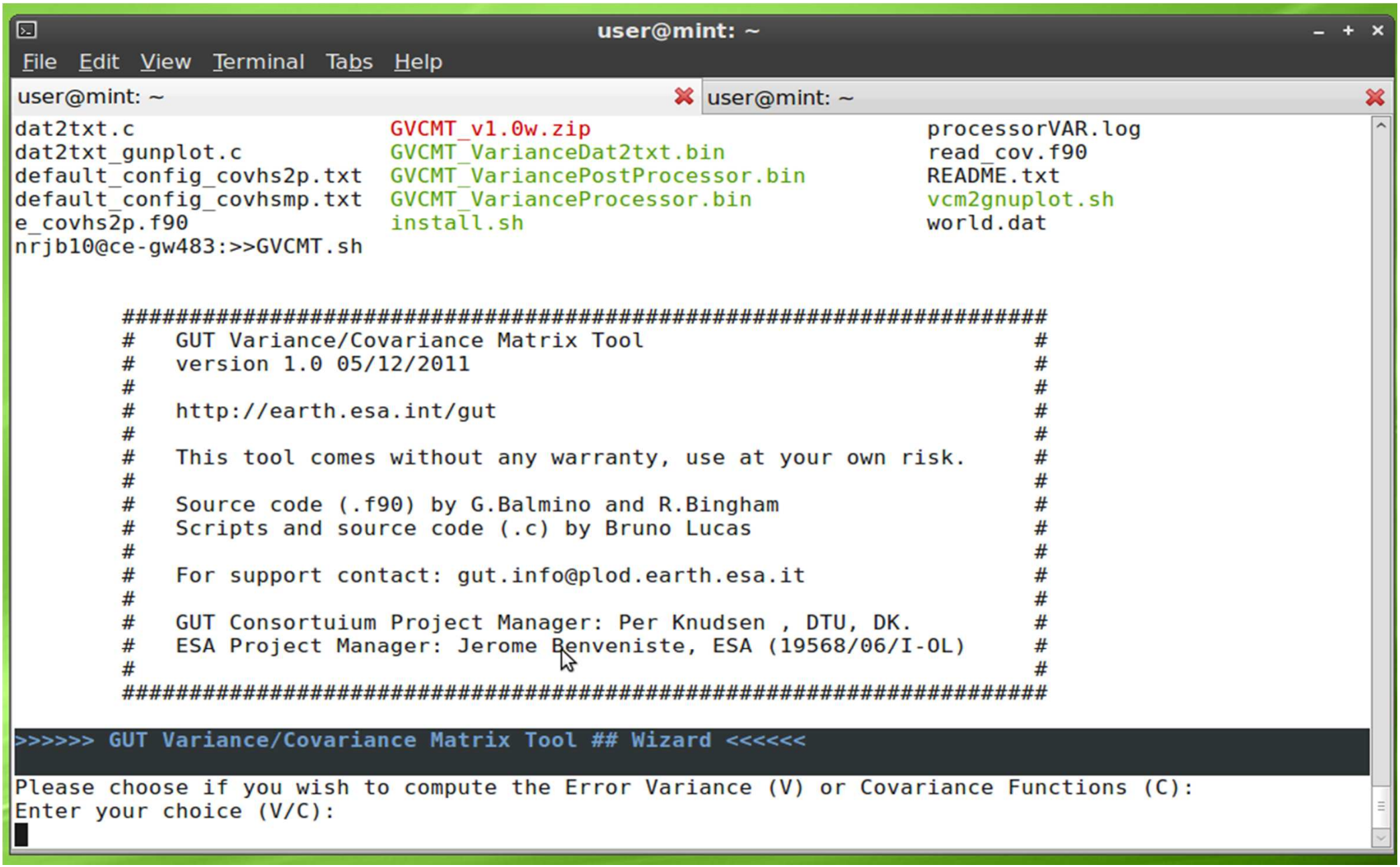
GDIR240 (GOCE DIR) : name given to model = 15 first characters (max.)
meanponc=1 0 : grid of mean values ; 1 : grid of point values
gm=0.39860044150000e+15,a=0.63781364600000e+07,uapl=0.29825765000000E+03,om=0.72920905111492E
-04
lmin=002 min. degree taken into account
lsup=240 max. degree ...
mmin=000 min. order ...
msup=240 max. order ...
m=-99,ldebp=000,lfinp=000 for specific orders (m=...) : min. and max. degree (end if m=-99)
s0=+1.48547e+00 variance factor, will multiply the covariance matrix (read in e12.5)
kf=1 function type : 1=n(geoid),2=deltag(FA),3=dg=trr,4=d2T/dr2,5=dFA/dr,6=water eq.,0=other
kse=2 key for type of latitudes (1:geoc. , 2:ellip.)
h=0.0000000000 altitude (km): in effect according to function type: for kf =3,4, or 5 (read in f12.0)
unit=0 iunit for lat./lon. steps (0:degree , 1:minute)
fimin=-90.00,fimax=+90.00,dfi=+01.00,xlmin=-180.00,xlmax=+180.00,dxl=+01.00 grid limits (deg.)
f0=000000000.00 factor depending of function type (effective only if kf = 0) , read in f12.0
kfilter=00,dfilter=300000.00,psi0=5.000,fract0=0.500 filter parameters (no filtering if kfilter=0)
l1=002,l2=240,lstp=00 step by step cumulated errors from deg. l1 to l2, by step lstp (if =0 : l1 to l2)
0 end of file (for PC)

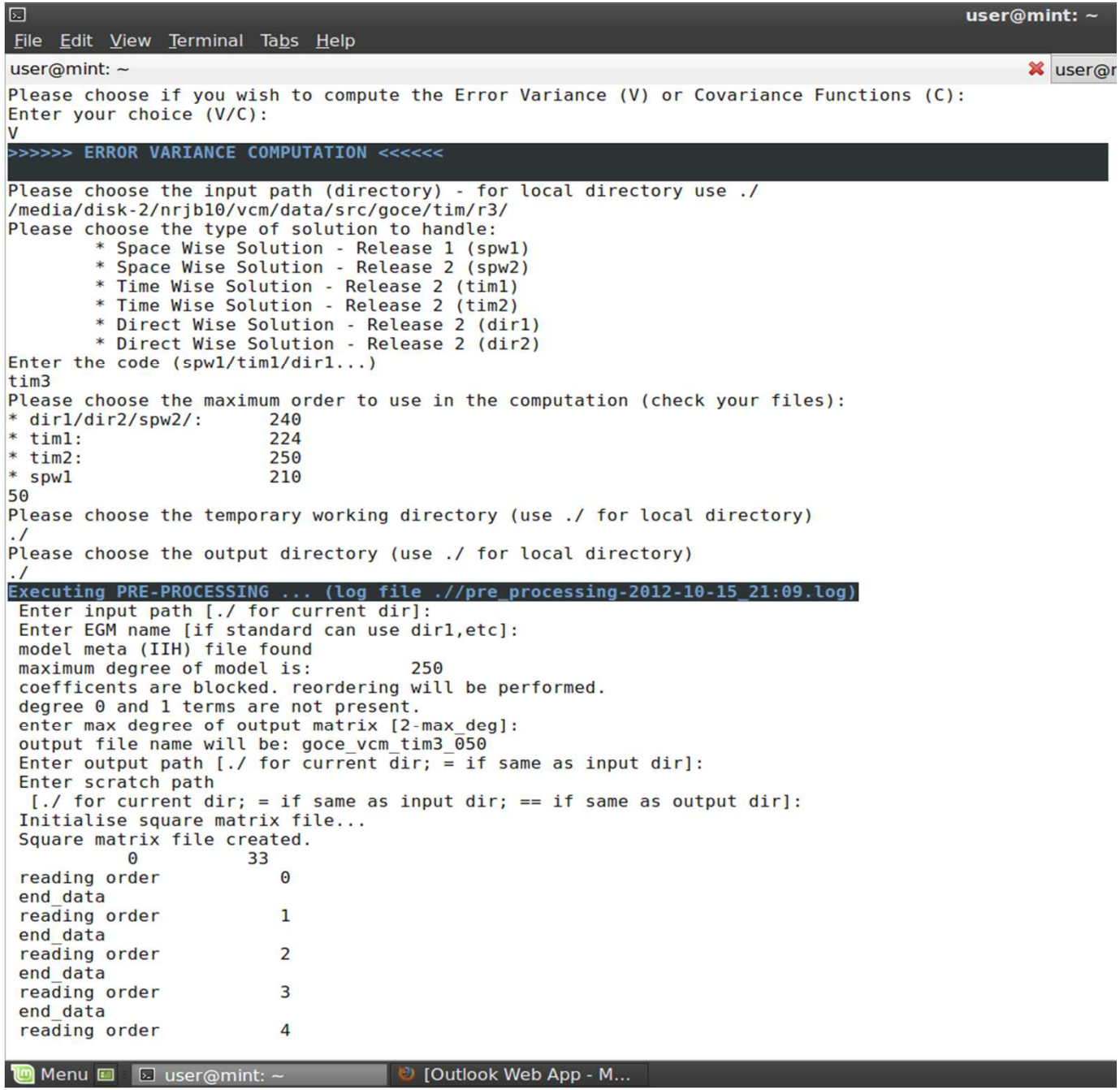

user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
nrjb10@ce-gw483:>>ls
GVCMT_v1.0w.zip
nrjb10@ce-gw483:>>unzip GVCMT_v1.0w.zip
Archive: GVCMT_v1.0w.zip
inflating: CovarianceSwUserGuide.pdf
inflating: create_vcm.f90
inflating: e_covhs2p.f90
inflating: e_covhsmp.f90
inflating: err_grid_bin.f90
inflating: read_cov.f90
inflating: dat2txt.c
inflating: dat2txt_gunplot.c
inflating: GVCMT.sh
inflating: install.sh
inflating: vcm2gnuplot.sh
inflating: default_config_covhs2p.txt
inflating: default_config_covhsmp.txt
inflating: plotVCM.gnu
inflating: README.txt
inflating: world.dat
inflating: GUT_Covariance_Software_Validation.pdf
inflating: GUT_VCM_Tool_Presentation.pdf
nrjb10@ce-gw483:>>ls
CovarianceSwUserGuide.pdf
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
GVCMT.sh
GVCMT_v1.0w.zip
install.sh
plotVCM.gnu
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
nrjb10@ce-gw483:>>
VCM generation

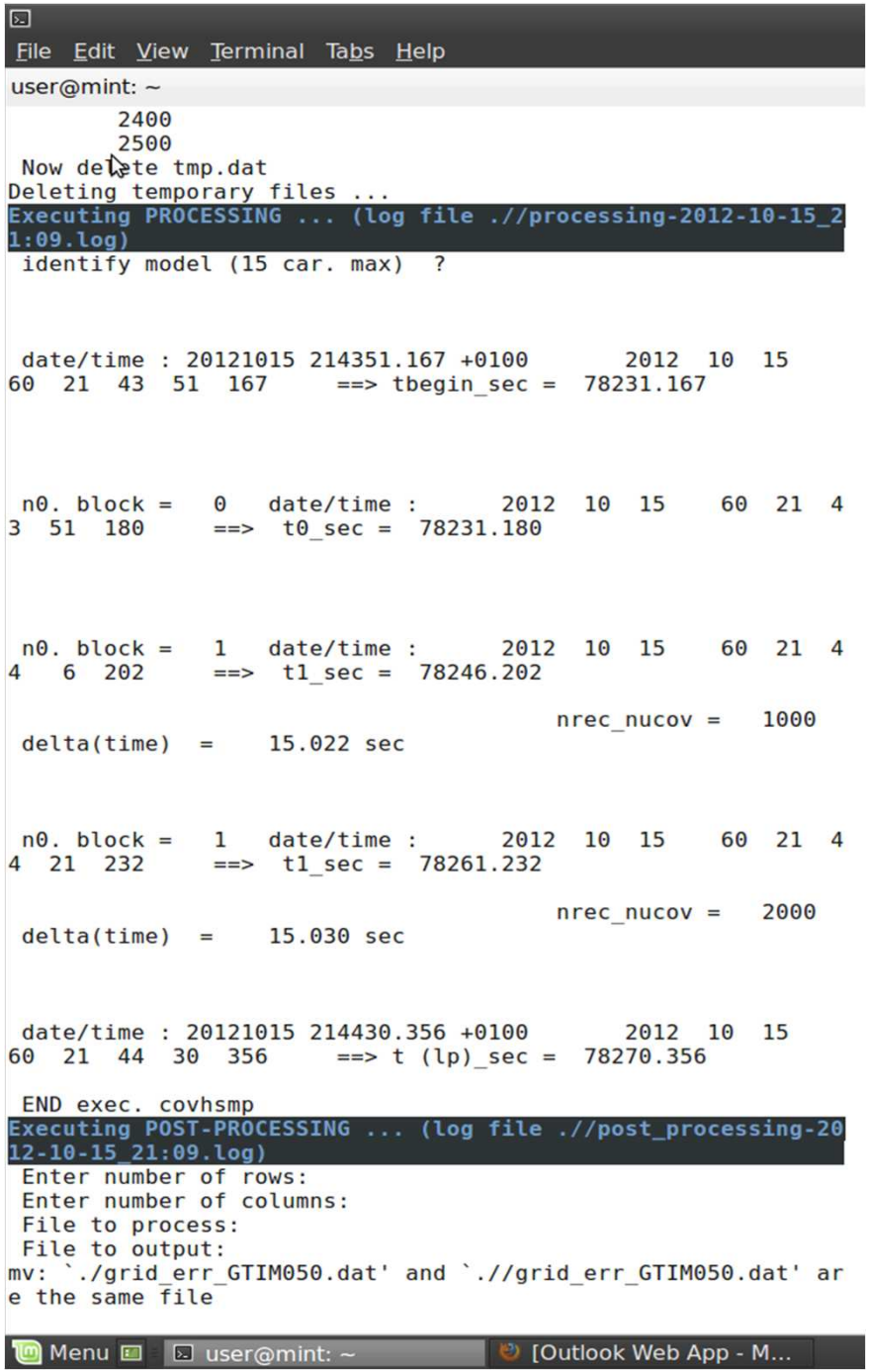

user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
nrjb10@ce-gw483:>>ls
GVCMT_v1.0w.zip
nrjb10@ce-gw483:>>unzip GVCMT_v1.0w.zip
Archive: GVCMT_v1.0w.zip
inflating: CovarianceSwUserGuide.pdf
inflating: create_vcm.f90
inflating: e_covhs2p.f90
inflating: e_covhsmp.f90
inflating: err_grid_bin.f90
inflating: read_cov.f90
inflating: dat2txt.c
inflating: dat2txt_gunplot.c
inflating: GVCMT.sh
inflating: install.sh
Install script
inflating: default_config_covhs2p.txt
inflating: default_config_covhsmp.txt
inflating: plotVCM.gnu
inflating: README.txt
inflating: world.dat
inflating: GUT_Covariance_Software_Validation.pdf
inflating: GUT_VCM_Tool_Presentation.pdf
nrjb10@ce-gw483:>>ls
CovarianceSwUserGuide.pdf
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
GVCMT.sh
GVCMT_v1.0w.zip
install.sh
plotVCM.gnu
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
nrjb10@ce-gw483:>>

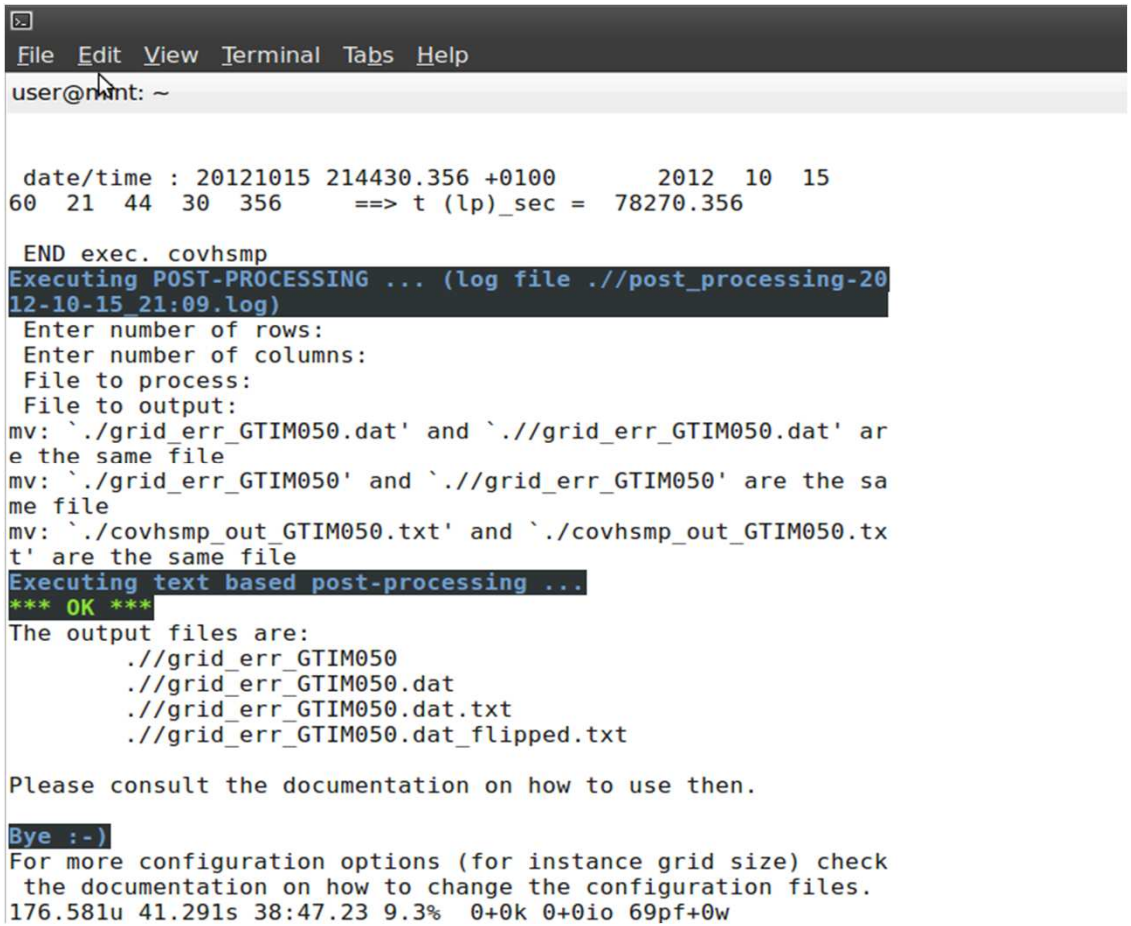

user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
#!/bin/bash
############### SETUP - GUT VARIANCE/COVARIANCE MATRIX TOOL ##################
echo -e "\n
###
GUT Variance/Covariance Matrix Tool
version 1.0 05/12/2011
# #
http://earth.esa.int/gut
# #
This tool comes without any warranty, use at your own risk.
# #
Source code (.f90) by G.Balmino and R.Bingham
Scripts and source code (.c) by Bruno Lucas
# #
For support contact: gut.info@plod.earth.esa.it
# #
GUT Consortuium Project Manager: Per Knudsen , DTU, DK.
ESA Project Manager: Jerome Benveniste, ESA (19568/06/I-OL)
# #
###
"
FC=gfortran #Change this to use another compiler, tested choices are: gfortran and ifort
FCC=gcc
PRE="./GVCMT_preProcessor.bin"
vPRO="./GVCMT_VarianceProcessor.bin"
cPRO="./GVCMT_CovarianceProcessor.bin"
"install.sh" 109L, 3510C
25,4
Top

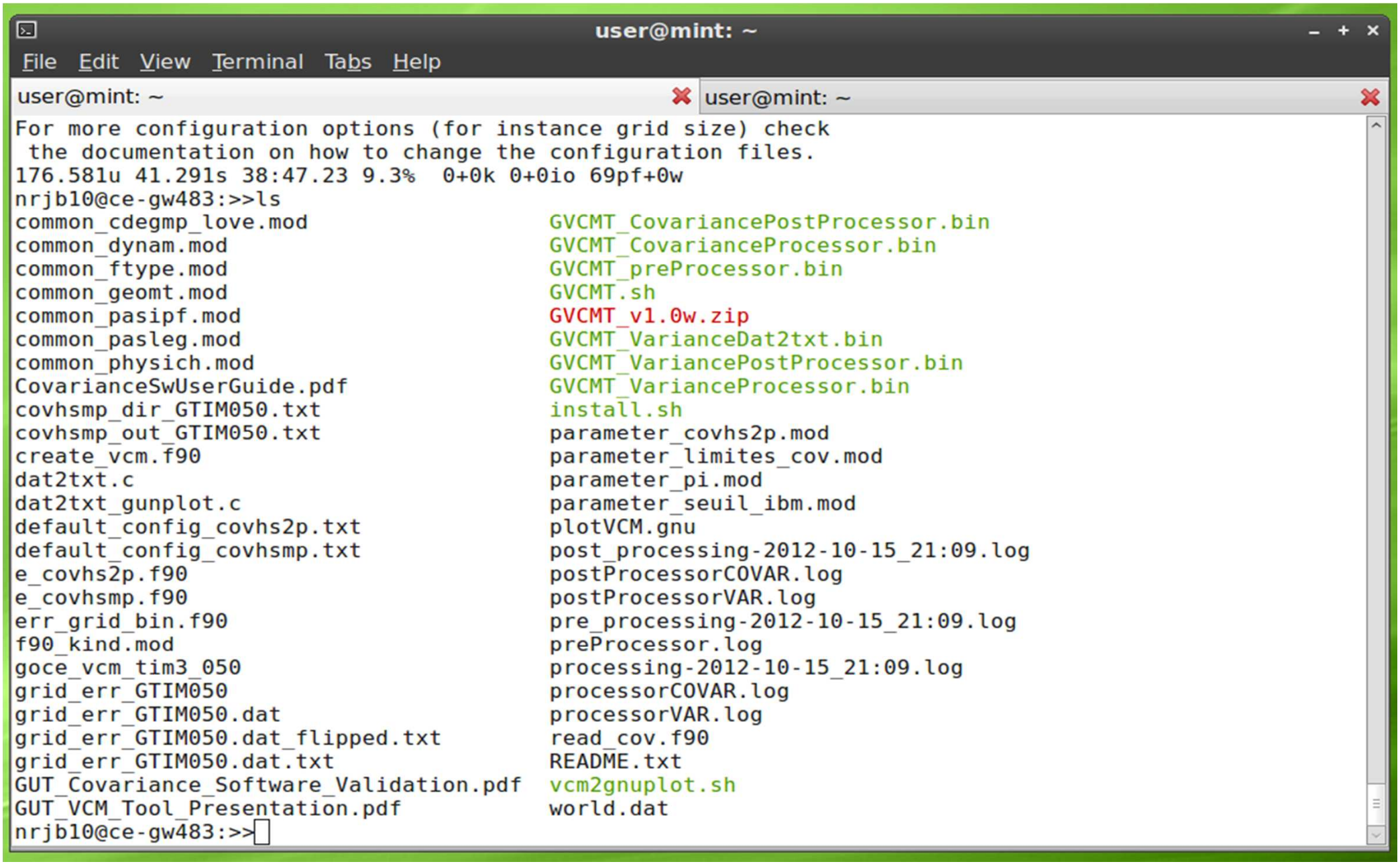

user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
e_covhs2p.f90(461): (col. 11) remark: LOOP WAS VECTORIZED.
e_covhs2p.f90(457): (col. 11) remark: LOOP WAS VECTORIZED.
e_covhs2p.f90(453): (col. 11) remark: LOOP WAS VECTORIZED.
Compilation of ./GVCMT_CovarianceProcessor.bin finished.
Compiling the Post Processor [VAR] source code ... (compilation log file is postProcessorVAR.log)
err_grid_bin.f90(31): (col. 10) remark: LOOP WAS VECTORIZED.
Compilation of ./GVCMT_VariancePostProcessor.bin finished.
Compiling the Post Processor [COVAR] source code ... (compilation log file is postProcessorCOVAR.log)
read_cov.f90(64): (col. 16) remark: LOOP WAS VECTORIZED.
Compilation of ./GVCMT_CovariancePostProcessor.bin finished.
*** OK ***
The setup of the GUT Variance/Covariance Matrix Tool is complete.
Read the README.txt on how to use the tool, or use the guided processing script >>>> GVCMT.sh <<<<
Bye :-)
nrjb10@ce-gw483:>>ls
common_cdegmp_love.mod
common_dynam.mod
common_ftype.mod
common_geomt.mod
common_pasipf.mod
common_pasleg.mod
common_physich.mod
CovarianceSwUserGuide.pdf
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
f90_kind.mod
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
GVCMT_CovariancePostProcessor.bin
GVCMT_CovarianceProcessor.bin
GVCMT_preProcessor.bin
GVCMT.sh
GVCMT_v1.0w.zip
GVCMT_VarianceDat2txt.bin
GVCMT_VariancePostProcessor.bin
GVCMT_VarianceProcessor.bin
install.sh
parameter_covhs2p.mod
parameter_limites_cov.mod
parameter_pi.mod
parameter_seuil_ibm.mod
plotVCM.gnu
postProcessorCOVAR.log
postProcessorVAR.log
preProcessor.log
processorCOVAR.log
processorVAR.log
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
nrjb10@ce-gw483:>>

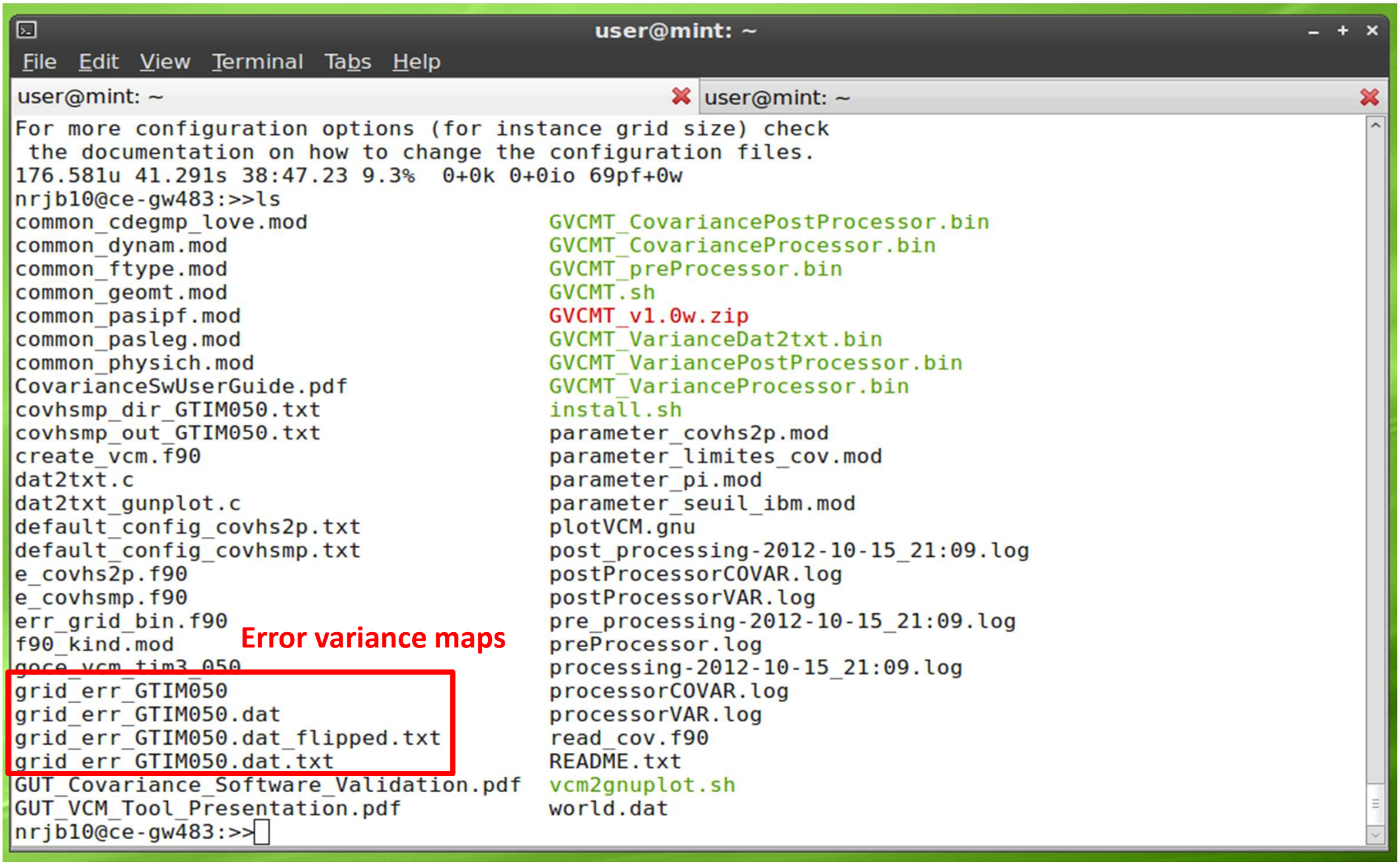

user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
nrjb10@ce-gw483:>>GVCMT.sh
GVCMT_v1.0w.zip
GVCMT_VarianceDat2txt.bin
GVCMT_VariancePostProcessor.bin
GVCMT_VarianceProcessor.bin
install.sh
processorVAR.log
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
GUT Variance/Covariance Matrix Tool
version 1.0 05/12/2011
http://earth.esa.int/gut
This tool comes without any warranty, use at your own risk.
Source code (.f90) by G.Balmino and R.Bingham
Scripts and source code (.c) by Bruno Lucas
For support contact: gut.info@plod.earth.esa.it
GUT Consortuium Project Manager: Per Knudsen , DTU, DK.
ESA Project Manager: Jerome Benveniste, ESA (19568/06/I-OL)
>>>>>> GUT Variance/Covariance Matrix Tool ## Wizard <<<<<<
Please choose if you wish to compute the Error Variance (V) or Covariance Functions (C):
Enter your choice (V/C):

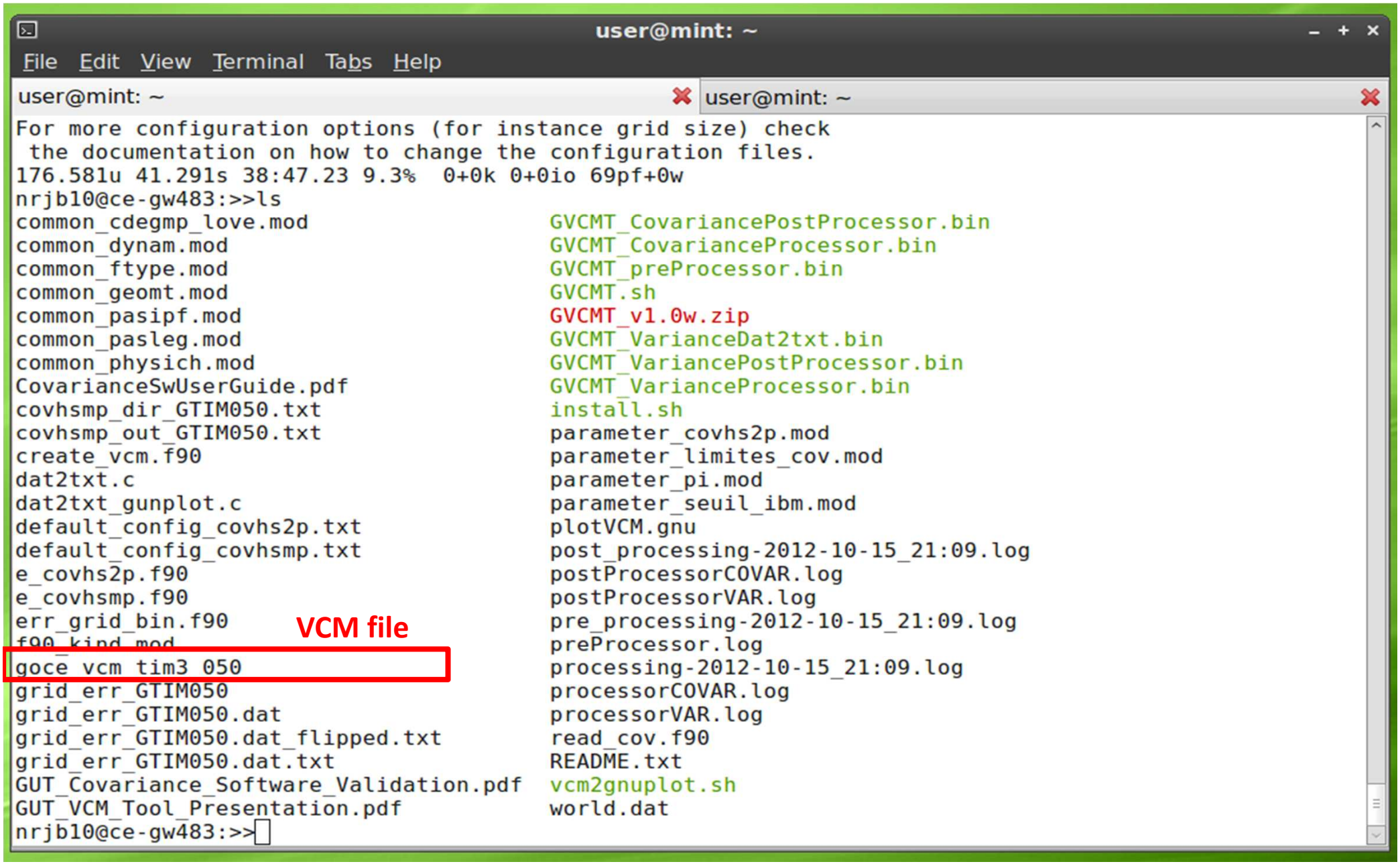

user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
Please choose if you wish to compute the Error Variance (V) or Covariance Functions (C):
Enter your choice (V/C):
V
>>>>>> ERROR VARIANCE COMPUTATION <<<<<<
Please choose the input path (directory) - for local directory use ./
/media/disk-2/nrjb10/vcm/data/src/goce/tim/r3/
Please choose the type of solution to handle:
* Space Wise Solution - Release 1 (spw1)
* Space Wise Solution - Release 2 (spw2)
* Time Wise Solution - Release 2 (tim1)
* Time Wise Solution - Release 2 (tim2)
* Direct Wise Solution - Release 2 (dir1)
* Direct Wise Solution - Release 2 (dir2)
Enter the code (spw1/tim1/dir1...)
tim3
Please choose the maximum order to use in the computation (check your files):
* dir1/dir2/spw2/: 240
* tim1: 224
* tim2: 250
* spw1 210
50
Please choose the temporary working directory (use ./ for local directory)
./
Please choose the output directory (use ./ for local directory)
./
Executing PRE-PROCESSING ... (log file .//pre_processing-2012-10-15_21:09.log)
Enter input path [./ for current dir]:
Enter EGM name [if standard can use dir1,etc]:
model meta (IIH) file found
maximum degree of model is: 250
coefficents are blocked. reordering will be performed.
degree 0 and 1 terms are not present.
enter max degree of output matrix [2-max_deg]:
output file name will be: goce_vcm_tim3_050
Enter output path [./ for current dir; = if same as input dir]:
Enter scratch path
[./ for current dir; = if same as input dir; == if same as output dir]:
Initialise square matrix file...
Square matrix file created.
0 33
reading order 0
end_data
reading order 1
end_data
reading order 2
end_data
reading order 3
end_data
reading order 4
Menu
user@mint: ~
[Outlook Web App - M...

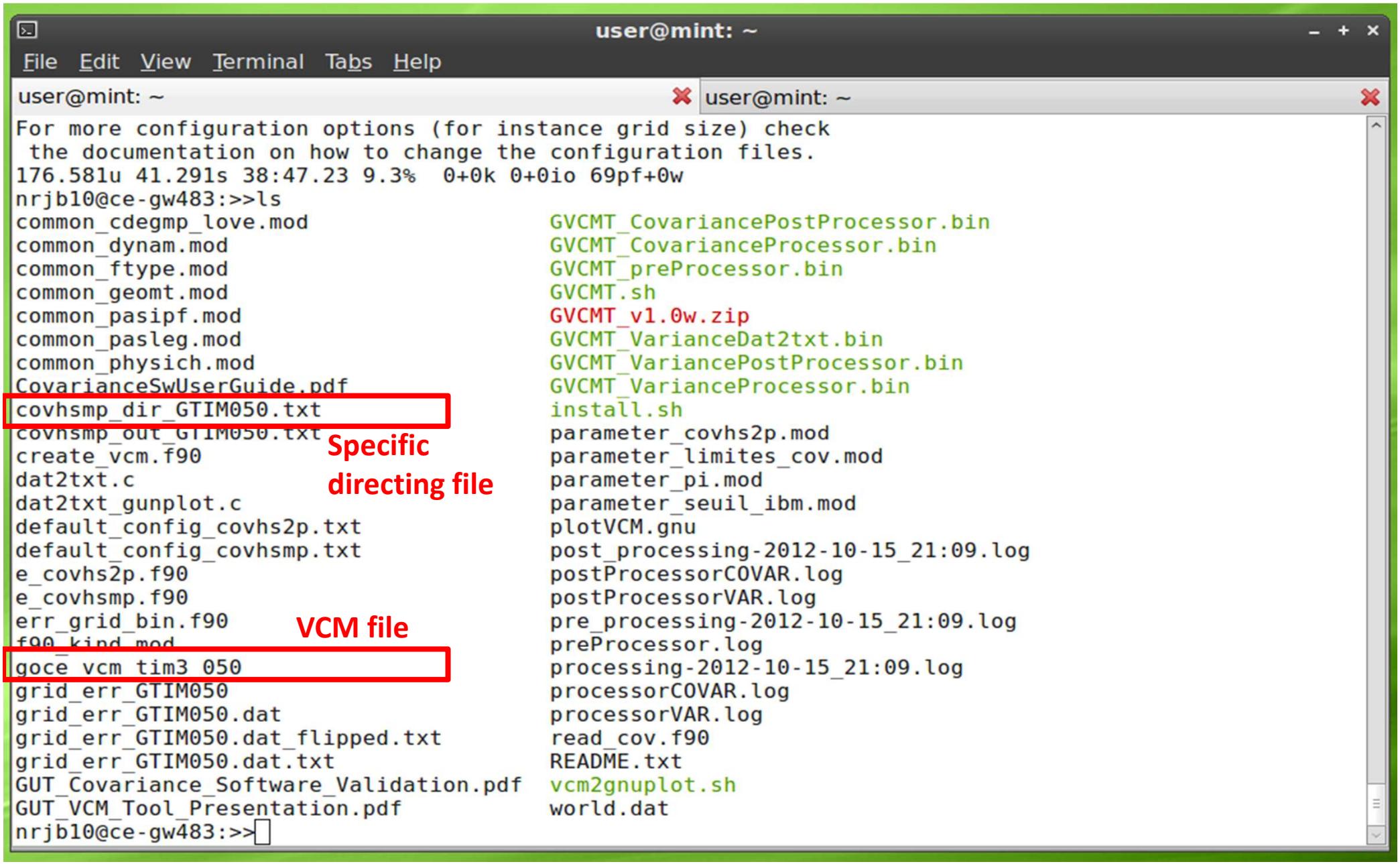

File Edit View Terminal Tabs Help
user@mint: ~
2400
2500
Now delete tmp.dat
Deleting temporary files ...
Executing PROCESSING ... (log file .//processing-2012-10-15_21:09.log)
identify model (15 car. max) ?
date/time : 20121015 214351.167 +0100 2012 10 15 60 21 43 51 167 ==> tbegin_sec = 78231.167
n0. block = 0 date/time : 2012 10 15 60 21 43 51 180 ==> t0_sec = 78231.180
n0. block = 1 date/time : 2012 10 15 60 21 44 6 202 ==> t1_sec = 78246.202
nrec_nucov = 1000
delta(time) = 15.022 sec
n0. block = 1 date/time : 2012 10 15 60 21 44 21 232 ==> t1_sec = 78261.232
nrec_nucov = 2000
delta(time) = 15.030 sec
date/time : 20121015 214430.356 +0100 2012 10 15 60 21 44 30 356 ==> t (lp)_sec = 78270.356
END exec. covhsmp
Executing POST-PROCESSING ... (log file .//post_processing-2012-10-15_21:09.log)
Enter number of rows:
Enter number of columns:
File to process:
File to output:
mv: `./grid_err_GTIM050.dat' and `.//grid_err_GTIM050.dat' are the same file
Menu
user@mint: ~
[Outlook Web App - M...


File Edit View Terminal Tabs Help
user@mint: ~
date/time : 20121015 214430.356 +0100 2012 10 15
60 21 44 30 356 ==> t (lp)_sec = 78270.356
END exec. covhsmp
Executing POST-PROCESSING ... (log file .//post_processing-2012-10-15_21:09.log)
Enter number of rows:
Enter number of columns:
File to process:
File to output:
mv: `./grid_err_GTIM050.dat' and `.//grid_err_GTIM050.dat' are the same file
mv: `./grid_err_GTIM050' and `.//grid_err_GTIM050' are the same file
mv: `./covhsmp_out_GTIM050.txt' and `./covhsmp_out_GTIM050.txt' are the same file
Executing text based post-processing ...
*** OK ***
The output files are:
.//grid_err_GTIM050
.//grid_err_GTIM050.dat
.//grid_err_GTIM050.dat.txt
.//grid_err_GTIM050.dat_flipped.txt
Please consult the documentation on how to use then.
Bye :-)
For more configuration options (for instance grid size) check the documentation on how to change the configuration files.
176.581u 41.291s 38:47.23 9.3% 0+0k 0+0io 69pf+0w


user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
For more configuration options (for instance grid size) check
the documentation on how to change the configuration files.
176.581u 41.291s 38:47.23 9.3% 0+0k 0+0io 69pf+0w
nrjb10@ce-gw483:>>ls
common_cdegmp_love.mod
common_dynam.mod
common_ftype.mod
common_geomt.mod
common_pasipf.mod
common_pasleg.mod
common_physich.mod
CovarianceSwUserGuide.pdf
covhsmp_dir_GTIM050.txt
covhsmp_out_GTIM050.txt
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
f90_kind.mod
goce_vcm_tim3_050
grid_err_GTIM050
grid_err_GTIM050.dat
grid_err_GTIM050.dat_flipped.txt
grid_err_GTIM050.dat.txt
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
GVCMT_CovariancePostProcessor.bin
GVCMT_CovarianceProcessor.bin
GVCMT_preProcessor.bin
GVCMT.sh
GVCMT_v1.0w.zip
GVCMT_VarianceDat2txt.bin
GVCMT_VariancePostProcessor.bin
GVCMT_VarianceProcessor.bin
install.sh
parameter_covhs2p.mod
parameter_limites_cov.mod
parameter_pi.mod
parameter_seuil_ibm.mod
plotVCM.gnu
post_processing-2012-10-15_21:09.log
postProcessorCOVAR.log
postProcessorVAR.log
pre_processing-2012-10-15_21:09.log
preProcessor.log
processing-2012-10-15_21:09.log
processorCOVAR.log
processorVAR.log
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
nrjb10@ce-gw483:>>


user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
For more configuration options (for instance grid size) check
the documentation on how to change the configuration files.
176.581u 41.291s 38:47.23 9.3% 0+0k 0+0io 69pf+0w
nrjb10@ce-gw483:>>ls
common_cdegmp_love.mod
common_dynam.mod
common_ftype.mod
common_geomt.mod
common_pasipf.mod
common_pasleg.mod
common_physich.mod
CovarianceSwUserGuide.pdf
covhsmp_dir_GTIM050.txt
covhsmp_out_GTIM050.txt
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
f90_kind.mod
goce_vcm_tim3_050
grid_err_GTIM050
grid_err_GTIM050.dat
grid_err_GTIM050.dat_flipped.txt
grid_err_GTIM050.dat.txt
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
nrjb10@ce-gw483:>>
Error variance maps
GVCMT_CovariancePostProcessor.bin
GVCMT_CovarianceProcessor.bin
GVCMT_preProcessor.bin
GVCMT.sh
GVCMT_v1.0w.zip
GVCMT_VarianceDat2txt.bin
GVCMT_VariancePostProcessor.bin
GVCMT_VarianceProcessor.bin
install.sh
parameter_covhs2p.mod
parameter_limites_cov.mod
parameter_pi.mod
parameter_seuil_ibm.mod
plotVCM.gnu
post_processing-2012-10-15_21:09.log
postProcessorCOVAR.log
postProcessorVAR.log
pre_processing-2012-10-15_21:09.log
preProcessor.log
processing-2012-10-15_21:09.log
processorCOVAR.log
processorVAR.log
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat


user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
For more configuration options (for instance grid size) check
the documentation on how to change the configuration files.
176.581u 41.291s 38:47.23 9.3% 0+0k 0+0io 69pf+0w
nrjb10@ce-gw483:>>ls
common_cdegmp_love.mod
common_dynam.mod
common_ftype.mod
common_geomt.mod
common_pasipf.mod
common_pasleg.mod
common_physich.mod
CovarianceSwUserGuide.pdf
covhsmp_dir_GTIM050.txt
covhsmp_out_GTIM050.txt
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
f90_kind.mod
goce_vcm_tim3_050
grid_err_GTIM050
grid_err_GTIM050.dat
grid_err_GTIM050.dat_flipped.txt
grid_err_GTIM050.dat.txt
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
GVCMT_CovariancePostProcessor.bin
GVCMT_CovarianceProcessor.bin
GVCMT_preProcessor.bin
GVCMT.sh
GVCMT_v1.0w.zip
GVCMT_VarianceDat2txt.bin
GVCMT_VariancePostProcessor.bin
GVCMT_VarianceProcessor.bin
install.sh
parameter_covhs2p.mod
parameter_limites_cov.mod
parameter_pi.mod
parameter_seuil_ibm.mod
plotVCM.gnu
post_processing-2012-10-15_21:09.log
postProcessorCOVAR.log
postProcessorVAR.log
pre_processing-2012-10-15_21:09.log
preProcessor.log
processing-2012-10-15_21:09.log
processorCOVAR.log
processorVAR.log
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
nrjb10@ce-gw483:>>
VCM file


user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
For more configuration options (for instance grid size) check
the documentation on how to change the configuration files.
176.581u 41.291s 38:47.23 9.3% 0+0k 0+0io 69pf+0w
nrjb10@ce-gw483:>>ls
common_cdegmp_love.mod
common_dynam.mod
common_ftype.mod
common_geomt.mod
common_pasipf.mod
common_pasleg.mod
common_physich.mod
CovarianceSwUserGuide.pdf
covhsmp_dir_GTIM050.txt
covhsmp_out_GTIM050.txt
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
f90_kind.mod
goce_vcm_tim3_050
grid_err_GTIM050
grid_err_GTIM050.dat
grid_err_GTIM050.dat_flipped.txt
grid_err_GTIM050.dat.txt
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
nrjb10@ce-gw483:>>
GVCMT_CovariancePostProcessor.bin
GVCMT_CovarianceProcessor.bin
GVCMT_preProcessor.bin
GVCMT.sh
GVCMT_v1.0w.zip
GVCMT_VarianceDat2txt.bin
GVCMT_VariancePostProcessor.bin
GVCMT_VarianceProcessor.bin
install.sh
parameter_covhs2p.mod
parameter_limites_cov.mod
parameter_pi.mod
parameter_seuil_ibm.mod
plotVCM.gnu
post_processing-2012-10-15_21:09.log
postProcessorCOVAR.log
postProcessorVAR.log
pre_processing-2012-10-15_21:09.log
preProcessor.log
processing-2012-10-15_21:09.log
processorCOVAR.log
processorVAR.log
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
Specific directing file
VCM file

user@mint: ~

File Edit View Terminal Tabs Help

user@mint: ~ | user@mint: ~

```
nrjb10@ce-gw483:>>more default_config_covhsmp.txt
directing file for covhsmp
GDIR240             (GOCE DIR) : name given to model = 15 first characters (max.)
meanponc=1    0 : grid of mean values  ;  1 : grid of point values
gm=0.39860044150000e+15,a=0.63781364600000e+07,uapl=0.29825765000000E+03,om=0.72920905111492E-04
lmin=002         min. degree taken into account
lsup=240         max. degree ...
mmin=000         min. order ...
msup=240         max. order ...
m=-99,ldebp=000,lfinp=000  for specific orders (m=...) : min. and max. degree (end if m=-99)
s0=+1.48547e+00               variance factor, will multiply the covariance matrix (read in e12.5)
kf=1             function type : 1=n(geoid),2=deltag(FA),3=dg=trr,4=d2T/dr2,5=dFA/dr,6=water eq.,0=other
kse=2            key for type of latitudes (1:geoc. , 2:ellip.)
h=0.0000000000   altitude (km): in effect according to function type: for kf =3,4, or 5 (read in f12.0)
unit=0           iunit for lat./lon. steps   (0:degree  , 1:minute)
fimin=-90.00,fimax=+90.00,dfi=+01.00,xlmin=-180.00,xlmax=+180.00,dxl=+01.00  grid limits (deg.)
f0=000000000.00    factor depending of function type (effective only if kf = 0)    , read in f12.0
kfilter=00,dfilter=300000.00,psi0=5.000,fract0=0.500 filter parameters (no filtering if kfilter=0)
l1=002,l2=240,lstp=00 step by step cumulated errors from deg. l1 to l2, by step lstp (if =0 : l1 to l2)
0                end of file (for PC)
nrjb10@ce-gw483:>>
```

Default config file

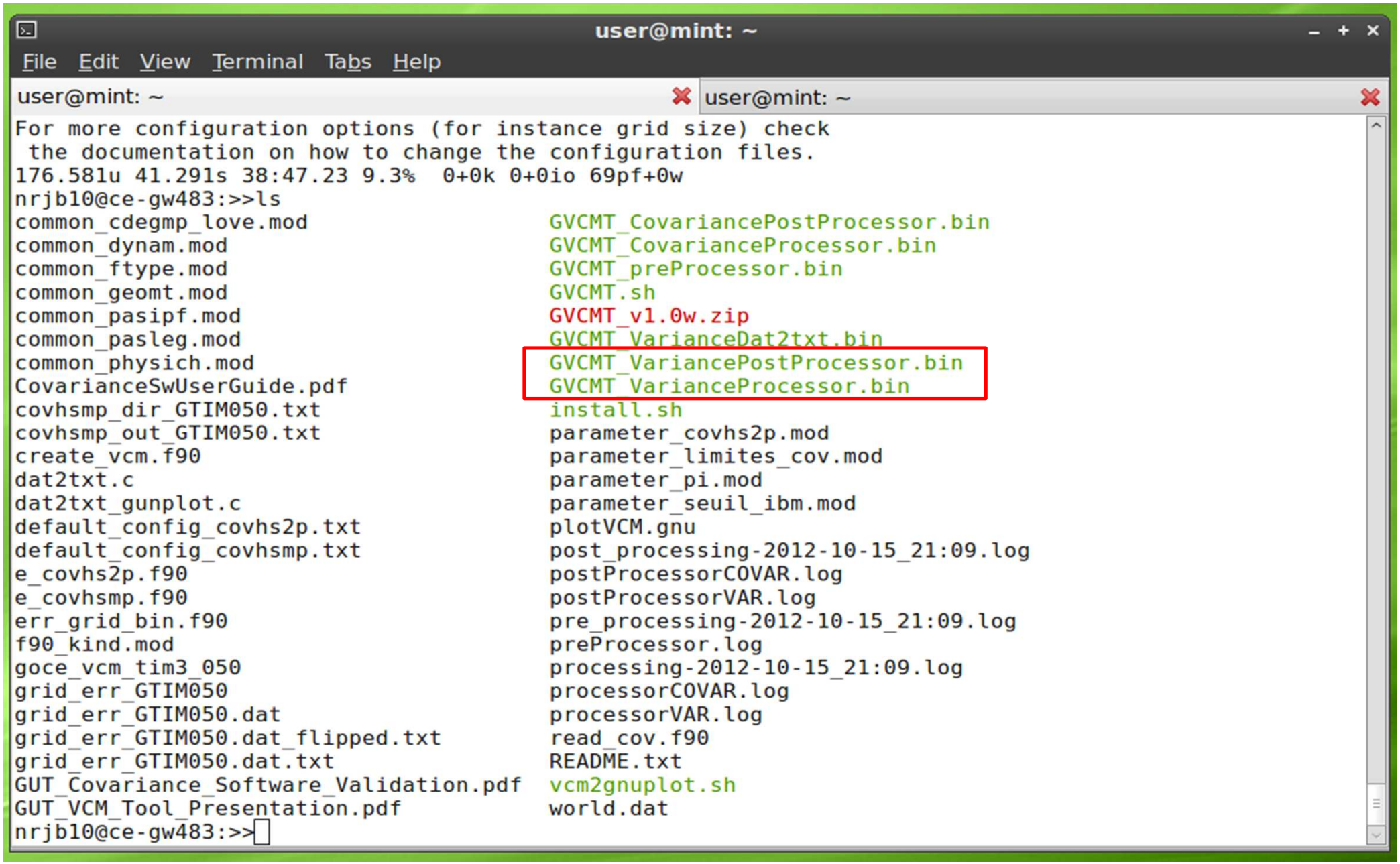
user@mint: ~

File Edit View Terminal Tabs Help

user@mint: ~ | user@mint: ~

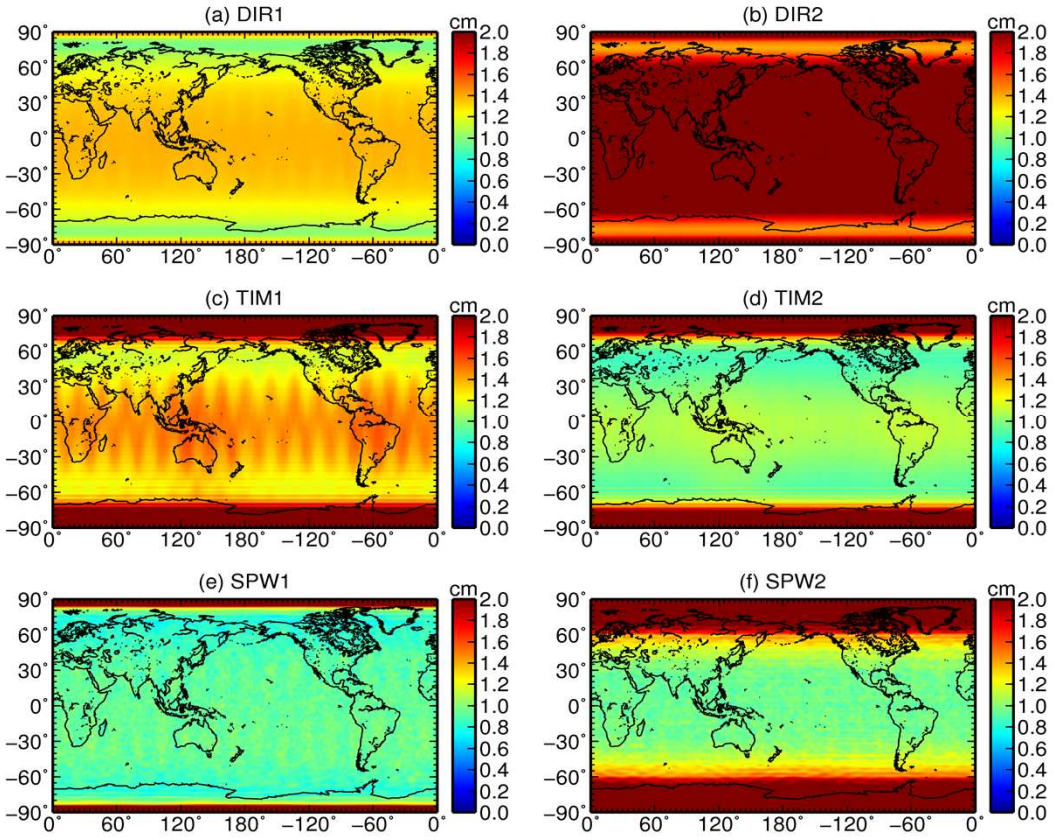
```
nrjb10@ce-gw483:>>more covhsmp_dir_GTIM050.txt
directing file for covhsmp
GTIM050             (GOCE DIR) : name given to model = 15 first characters (max.)
meanponc=1    0 : grid of mean values  ;  1 : grid of point values
gm=0.39860044150000e+15,a=0.63781364600000e+07,uapl=0.29825765000000E+03,om=0.72920905111492E-04
lmin=002         min. degree taken into account
lsup=050         max. degree ...
mmin=000         min. order ...
msup=050         max. order ...
m=-99,ldebp=000,lfinp=000  for specific orders (m=...) : min. and max. degree (end if m=-99)
s0=+1.48547e+00               variance factor, will multiply the covariance matrix (read in e12.5)
kf=1             function type : 1=n(geoid),2=deltag(FA),3=dg=trr,4=d2T/dr2,5=dFA/dr,6=water eq.,0=other
kse=2            key for type of latitudes (1:geoc. , 2:ellip.)
h=0.0000000000   altitude (km): in effect according to function type: for kf =3,4, or 5 (read in f12.0)
unit=0           iunit for lat./lon. steps   (0:degree  , 1:minute)
fimin=-90.00,fimax=+90.00,dfi=+01.00,xlmin=-180.00,xlmax=+180.00,dxl=+01.00  grid limits (deg.)
f0=000000000.00    factor depending of function type (effective only if kf = 0)    , read in f12.0
kfilter=00,dfilter=300000.00,psi0=5.000,fract0=0.500 filter parameters (no filtering if kfilter=0)
l1=002,l2=050,lstp=00 step by step cumulated errors from deg. l1 to l2, by step lstp (if =0 : l1 to l2)
0                end of file (for PC)
nrjb10@ce-gw483:>>
```

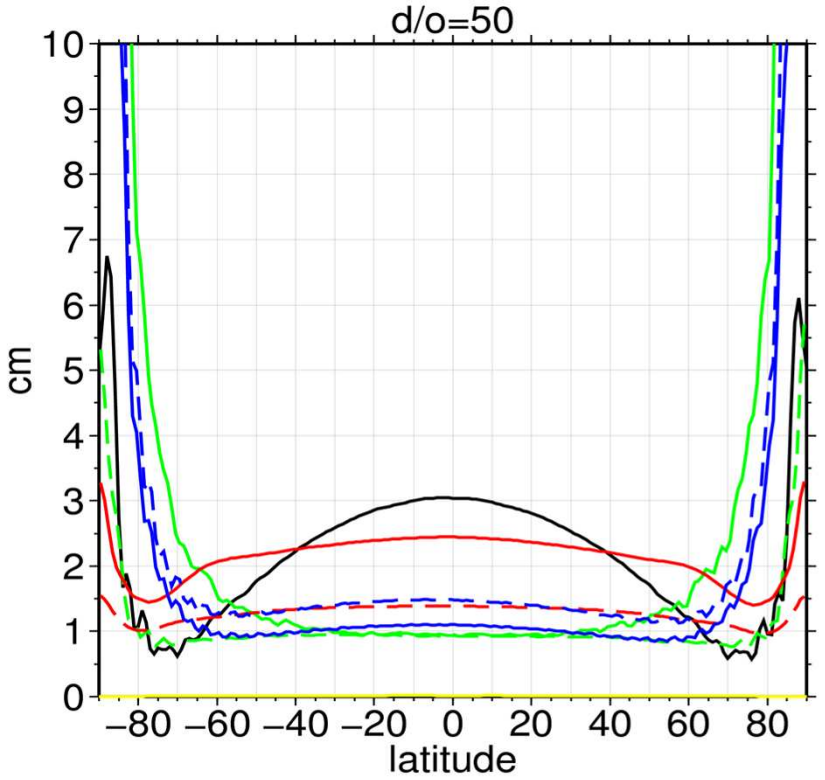
Specifc config file


user@mint: ~
File Edit View Terminal Tabs Help
user@mint: ~
user@mint: ~
For more configuration options (for instance grid size) check
the documentation on how to change the configuration files.
176.581u 41.291s 38:47.23 9.3% 0+0k 0+0io 69pf+0w
nrjb10@ce-gw483:>>ls
common_cdegmp_love.mod
common_dynam.mod
common_ftype.mod
common_geomt.mod
common_pasipf.mod
common_pasleg.mod
common_physich.mod
CovarianceSwUserGuide.pdf
covhsmp_dir_GTIM050.txt
covhsmp_out_GTIM050.txt
create_vcm.f90
dat2txt.c
dat2txt_gunplot.c
default_config_covhs2p.txt
default_config_covhsmp.txt
e_covhs2p.f90
e_covhsmp.f90
err_grid_bin.f90
f90_kind.mod
goce_vcm_tim3_050
grid_err_GTIM050
grid_err_GTIM050.dat
grid_err_GTIM050.dat_flipped.txt
grid_err_GTIM050.dat.txt
GUT_Covariance_Software_Validation.pdf
GUT_VCM_Tool_Presentation.pdf
GVCMT_CovariancePostProcessor.bin
GVCMT_CovarianceProcessor.bin
GVCMT_preProcessor.bin
GVCMT.sh
GVCMT_v1.0w.zip
GVCMT_VarianceDat2txt.bin
GVCMT_VariancePostProcessor.bin
GVCMT_VarianceProcessor.bin
install.sh
parameter_covhs2p.mod
parameter_limites_cov.mod
parameter_pi.mod
parameter_seuil_ibm.mod
plotVCM.gnu
post_processing-2012-10-15_21:09.log
postProcessorCOVAR.log
postProcessorVAR.log
pre_processing-2012-10-15_21:09.log
preProcessor.log
processing-2012-10-15_21:09.log
processorCOVAR.log
processorVAR.log
read_cov.f90
README.txt
vcm2gnuplot.sh
world.dat
nrjb10@ce-gw483:>>

Part II: Geoid Errors

Geoid errors: d/o=50





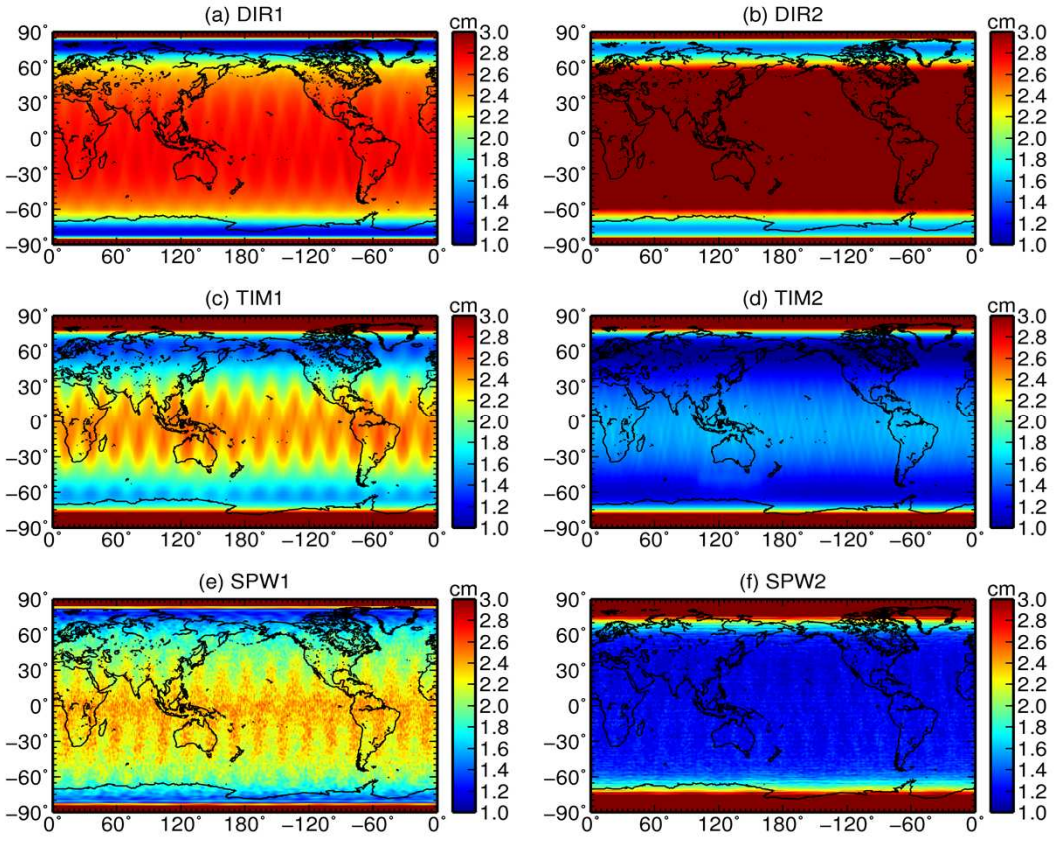
DIRECT SIMULATED

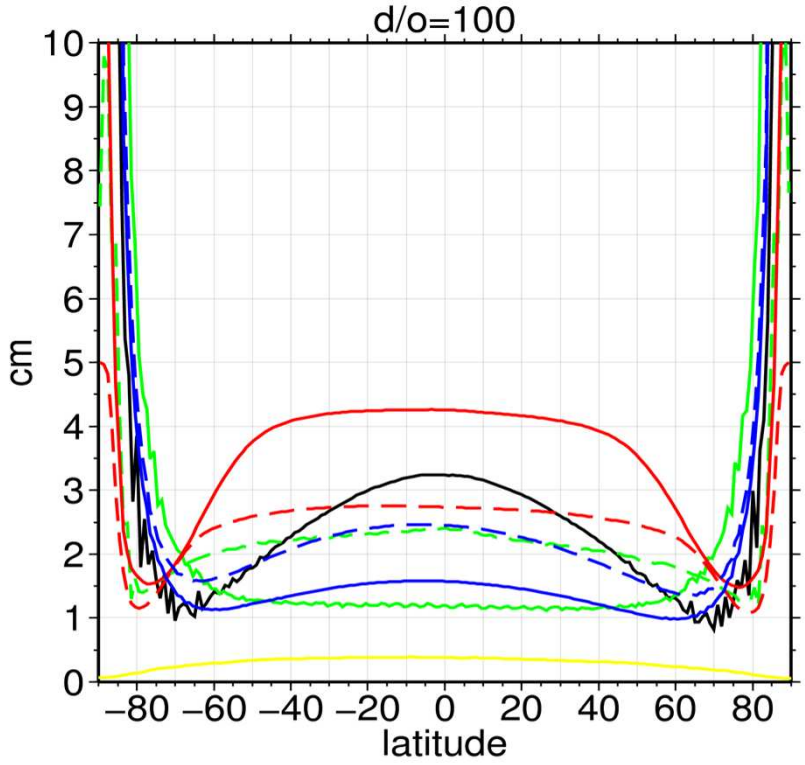
TIMEWISE GRACE

SPACEWISE

1st gen dashed

Geoid errors: d/o=100





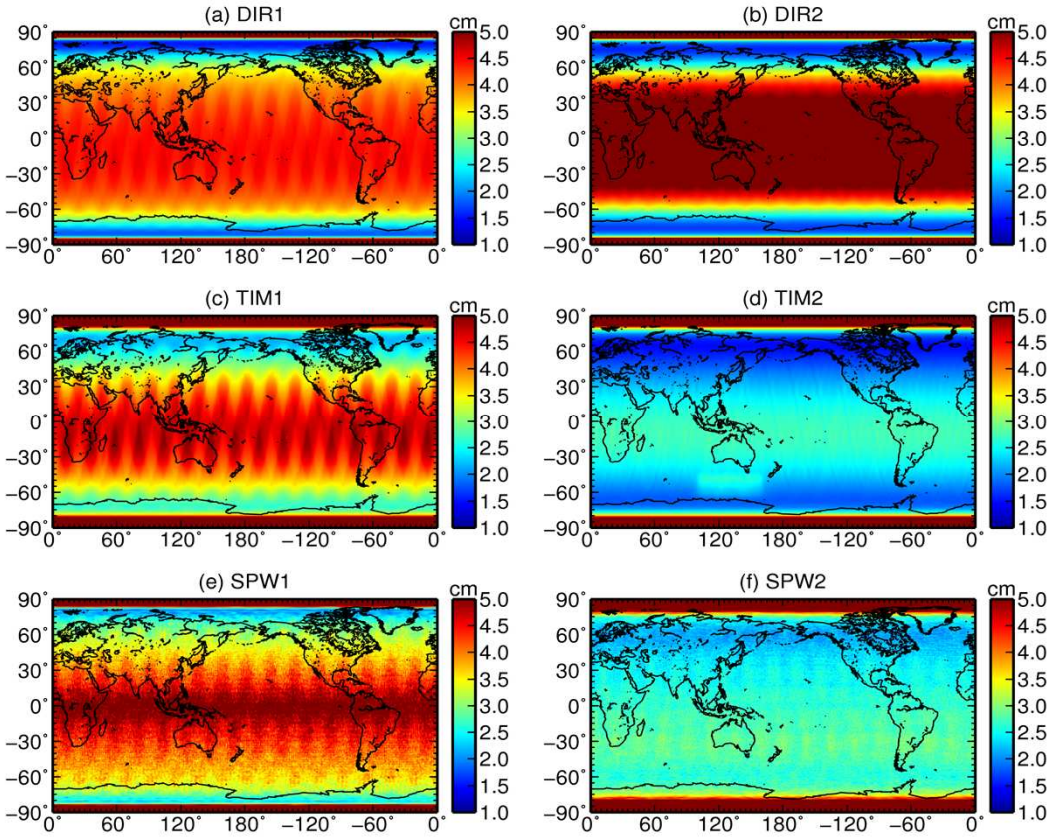
DIRECT SIMULATED

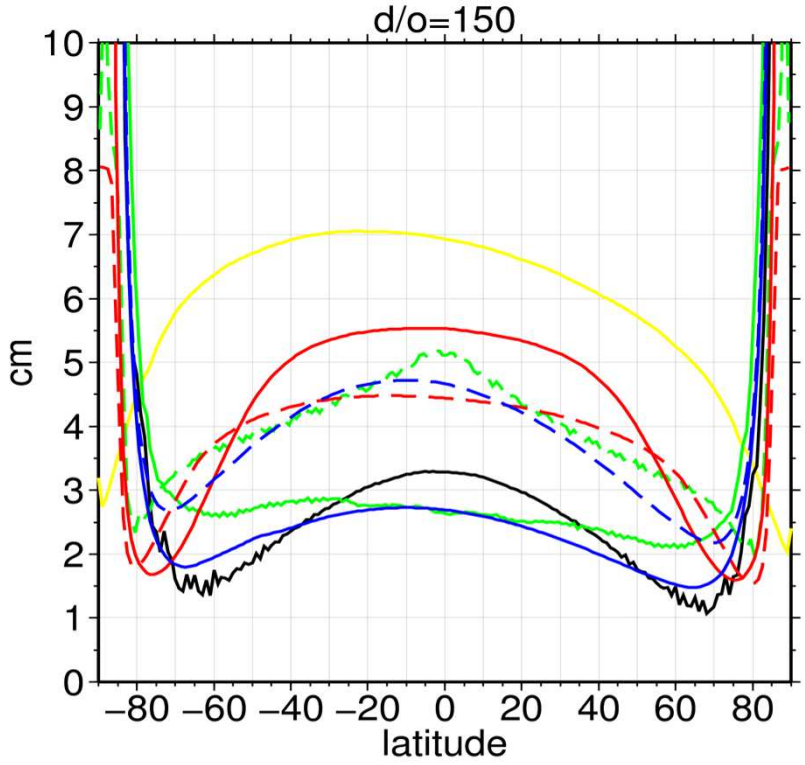
TIMEWISE GRACE

SPACEWISE

1st gen dashed

Geoid errors: d/o=150





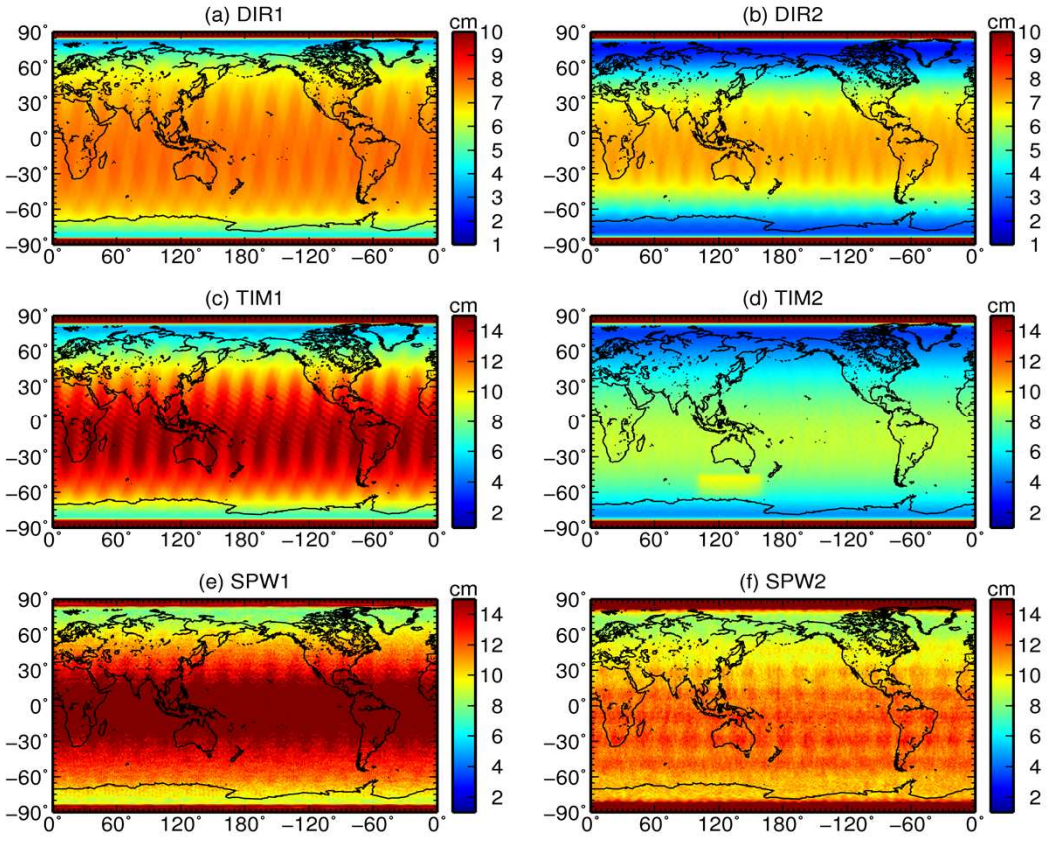
DIRECT SIMULATED

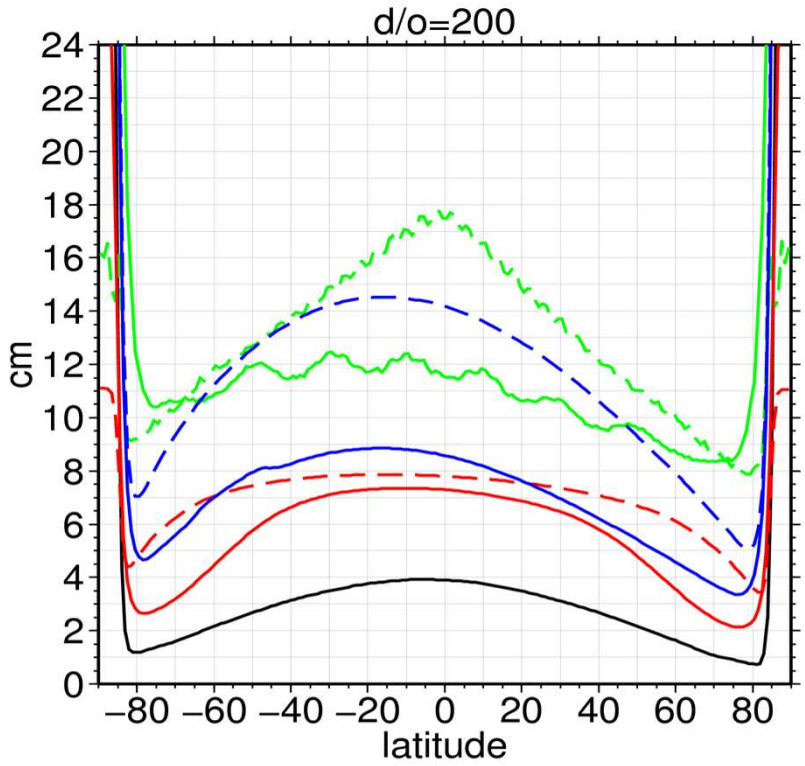
TIMEWISE GRACE

SPACEWISE

1st gen dashed

Geoid errors: d/o=200





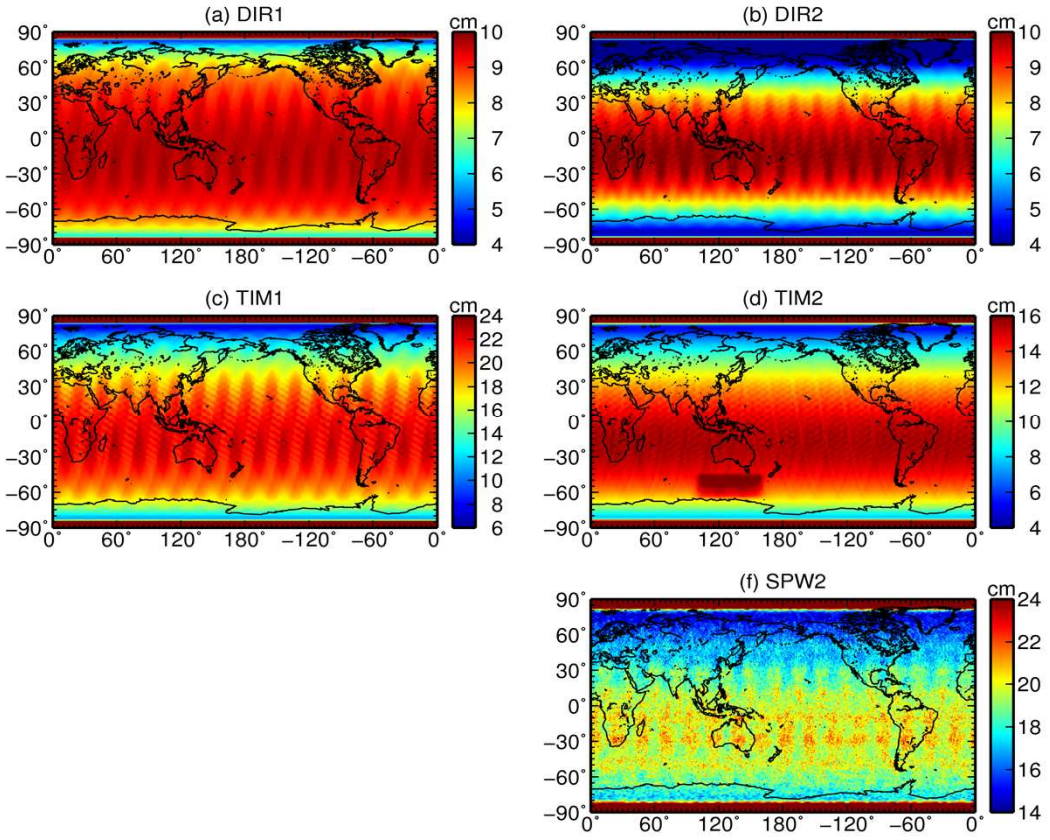
DIRECT SIMULATED

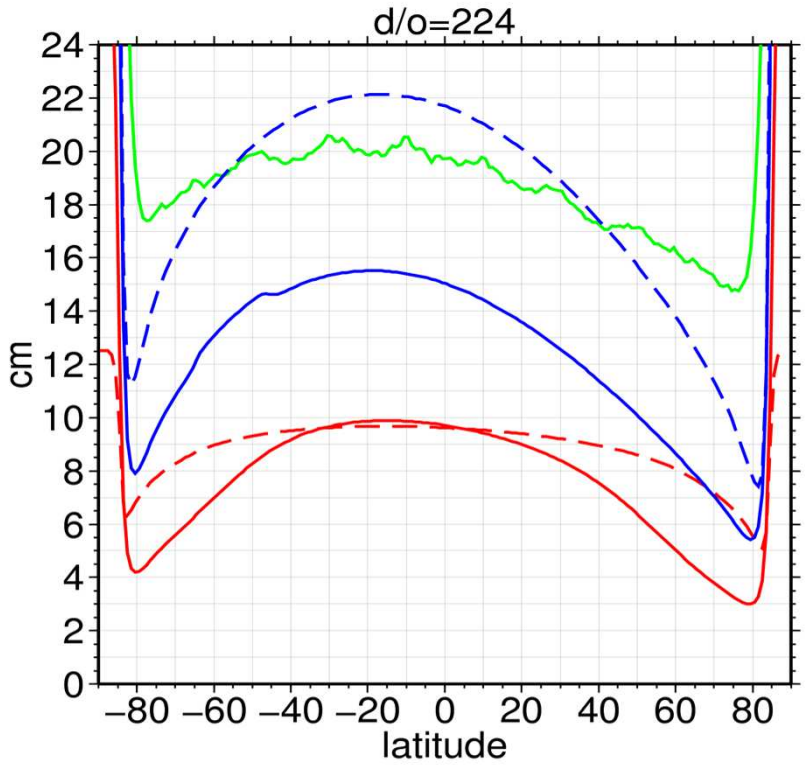
TIMEWISE

SPACEWISE

1st gen dashed

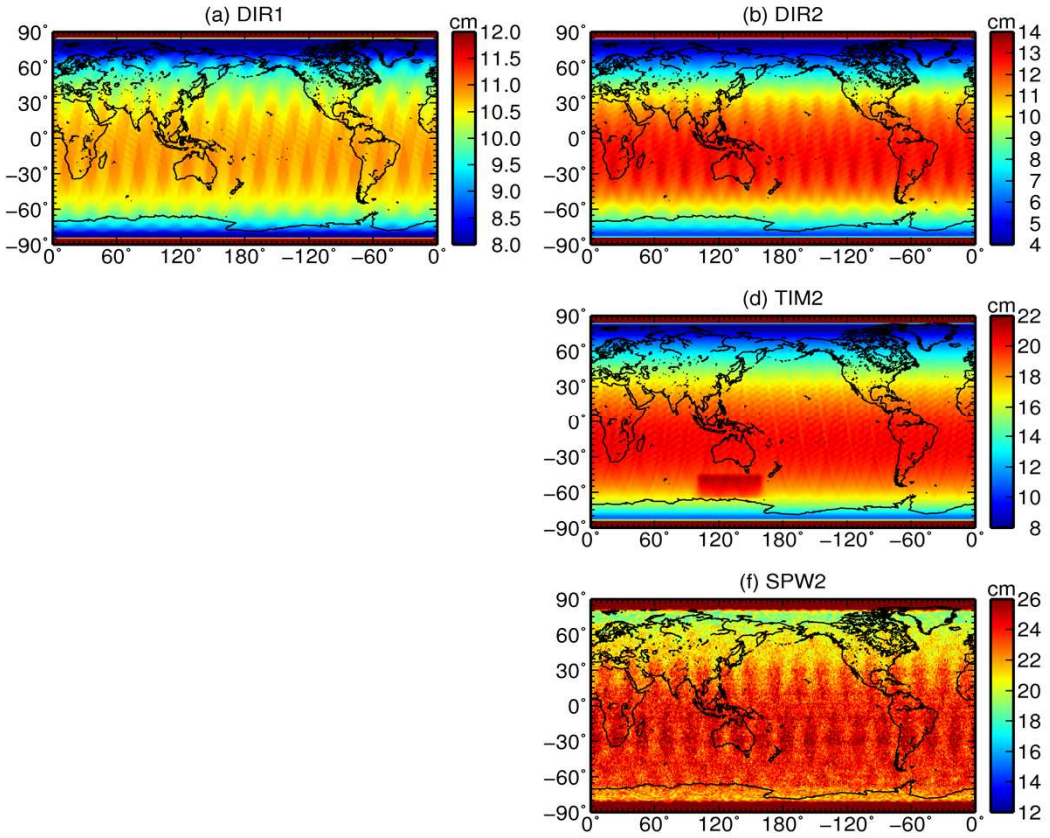
Geoid errors: d/o=224

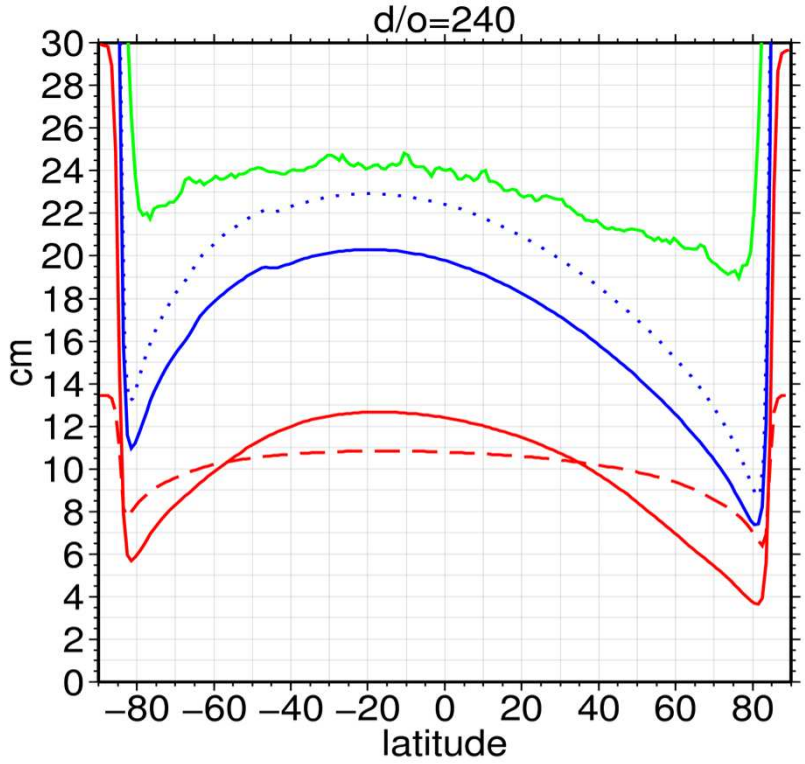




DIRECT
TIMEWISE
SPACEWISE
1st gen dashed

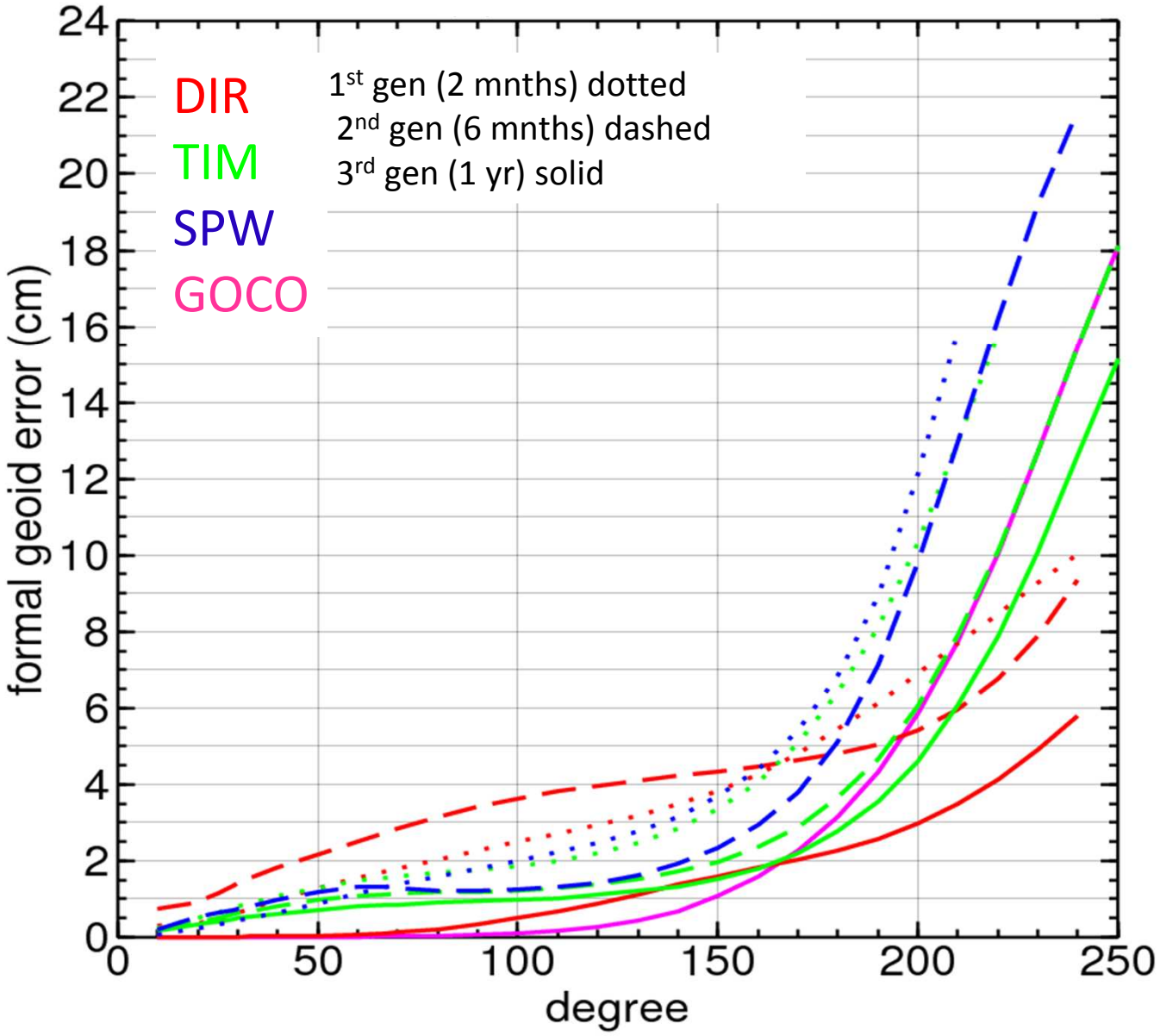
Geoid errors: d/o=240



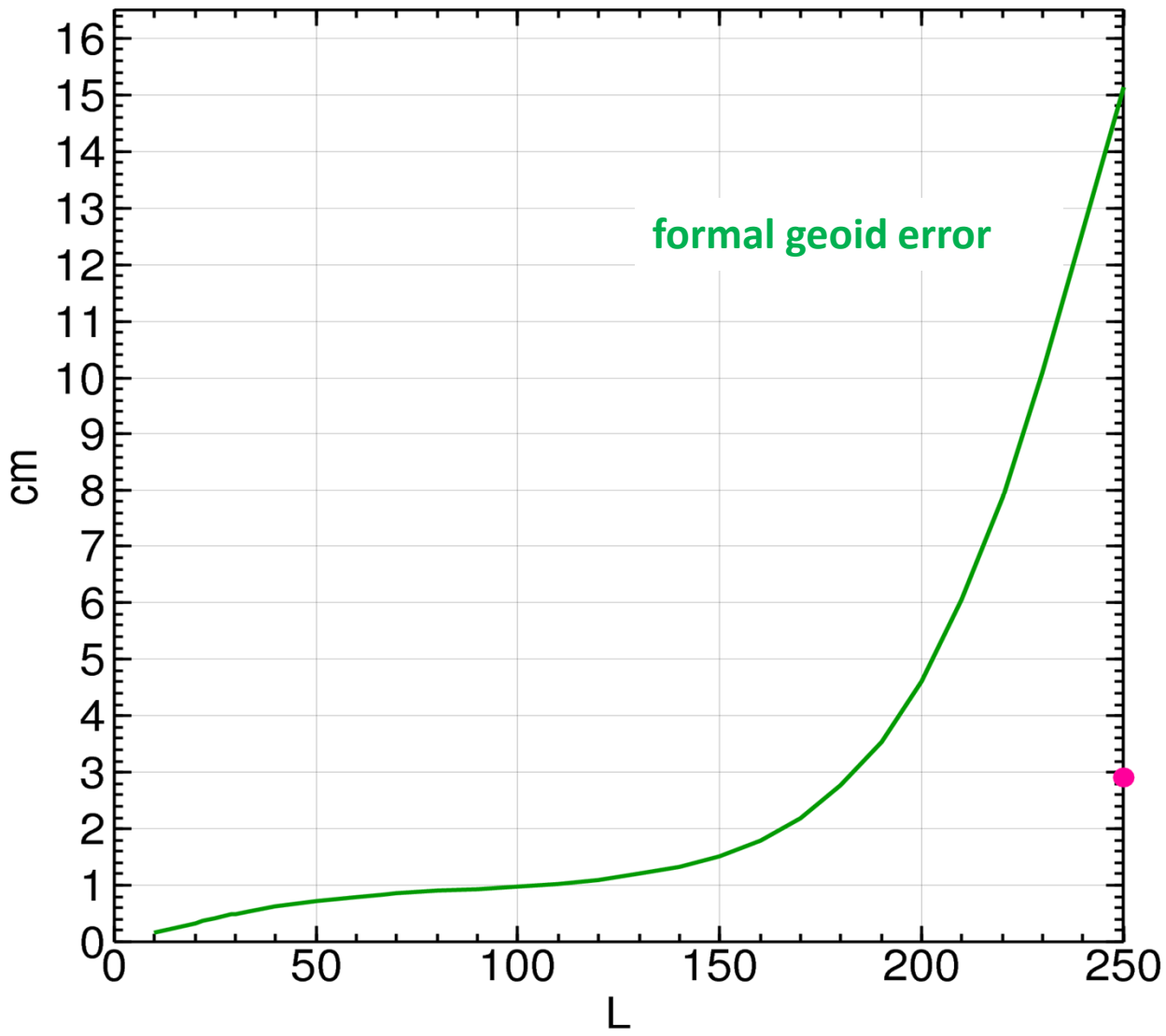


DIRECT
TIMEWISE
SPACEWISE
1st gen dashed

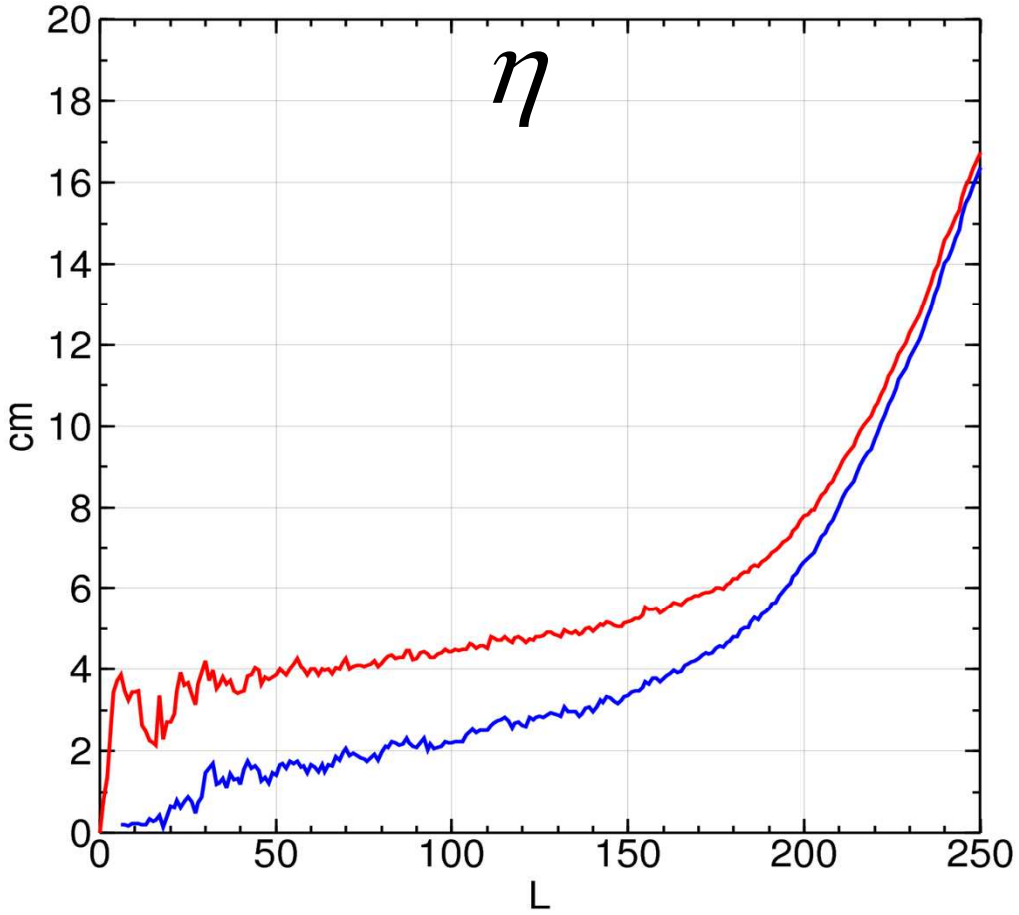
Formal geoid errors

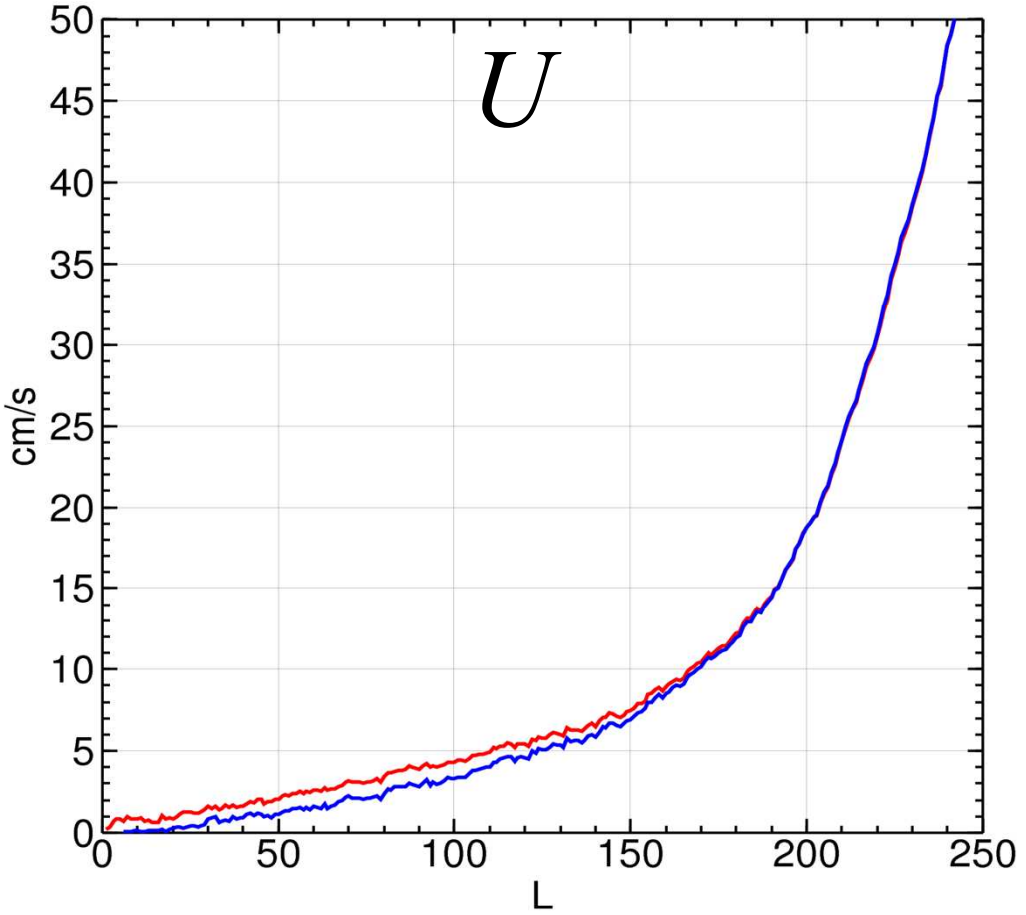


Formal geoid error over North Atlantic



Heuristic errors as a function of *L*





$$\hat{E}_L^{\eta} = \overline{\langle \eta_L - \hat{\eta}_L \rangle}^{NA}$$

Upper error bound:
Corrected for omission error
Includes error in external ref. (Niiler)

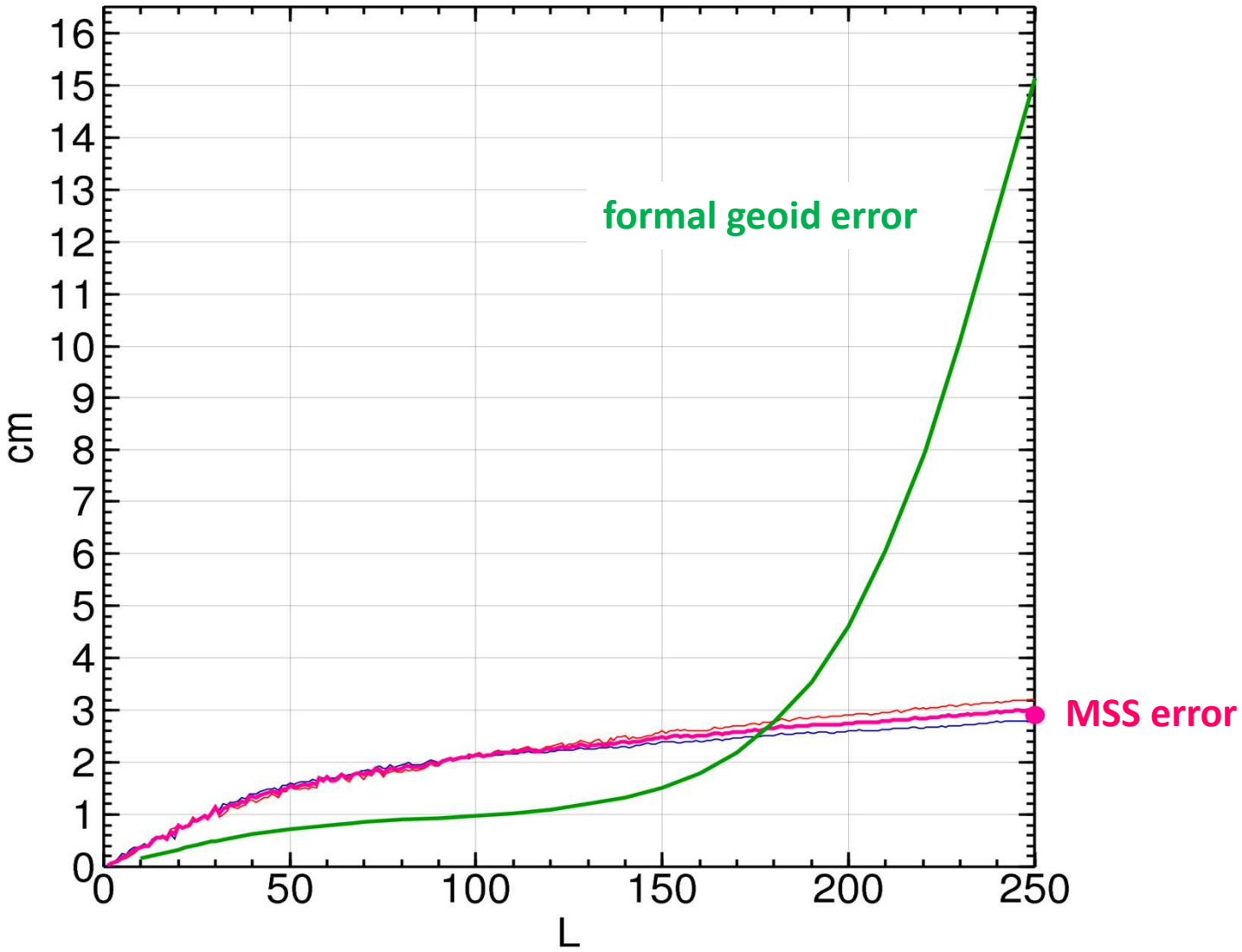
$$\hat{E}_L^{U} = \overline{\langle U_L - \hat{U}_L \rangle}^{NA}$$

$$\overline{E}_L^{\eta} = \overline{\langle \eta_L - \overline{\eta}_L \rangle}^{NA} - E_f^{\eta}$$

Lower error bound:
Corrected for filter attenuation
Does not include error not removed by filter

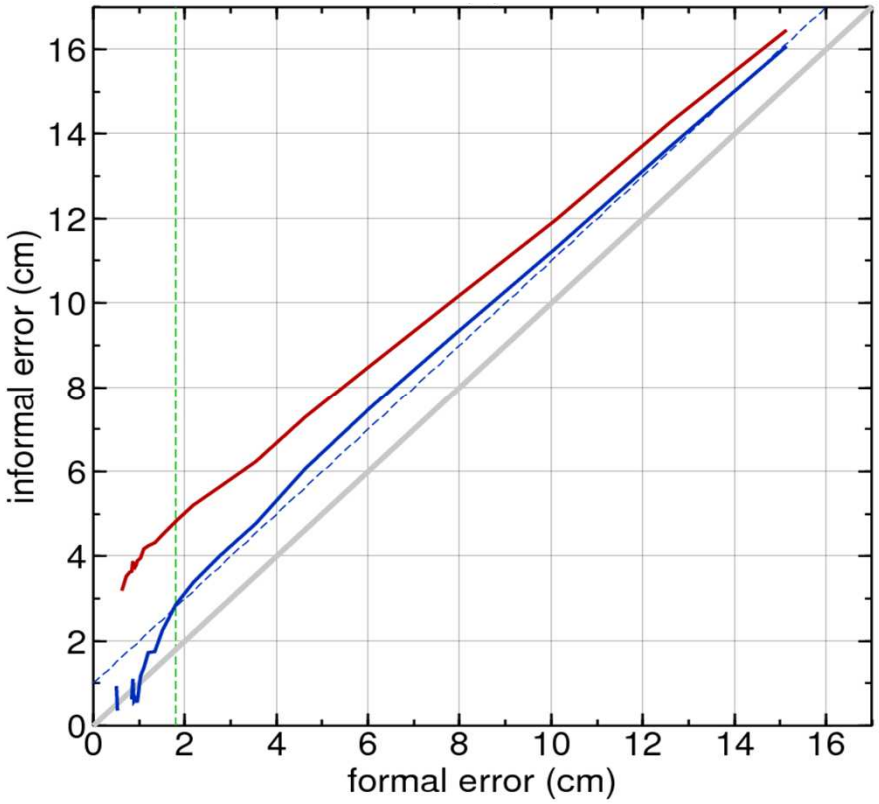
$$\overline{E}_L^{U} = \overline{\langle U_L - \overline{U}_L \rangle}^{NA} - E_f^{U}$$

An MDT error budget for the North

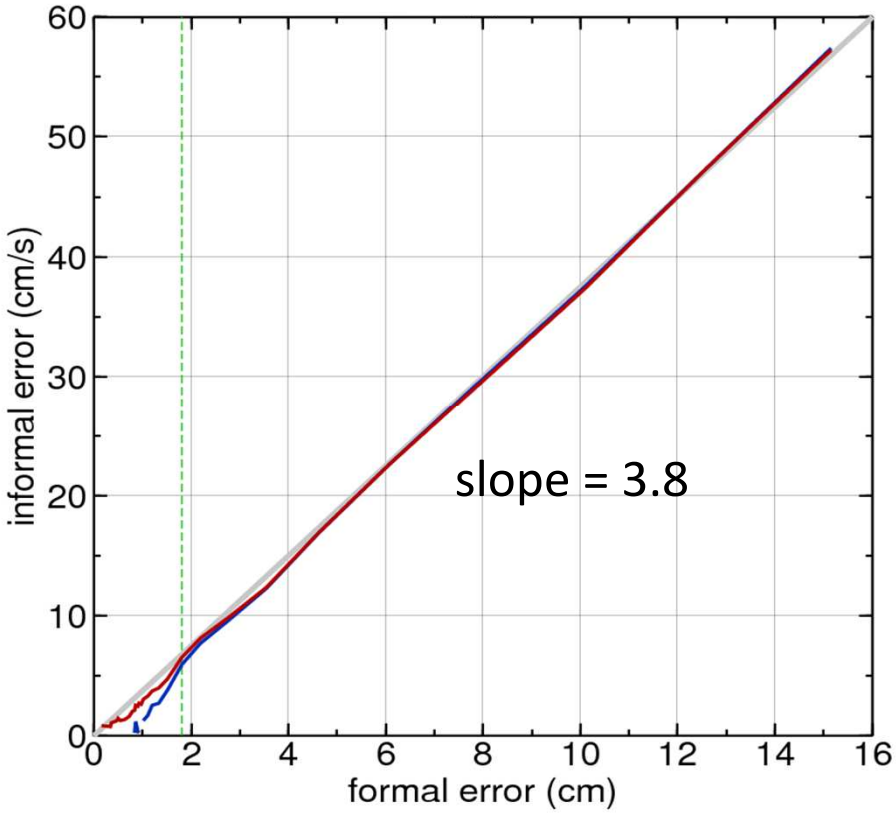


Informal vs. formal errors (TIM3)

η



U

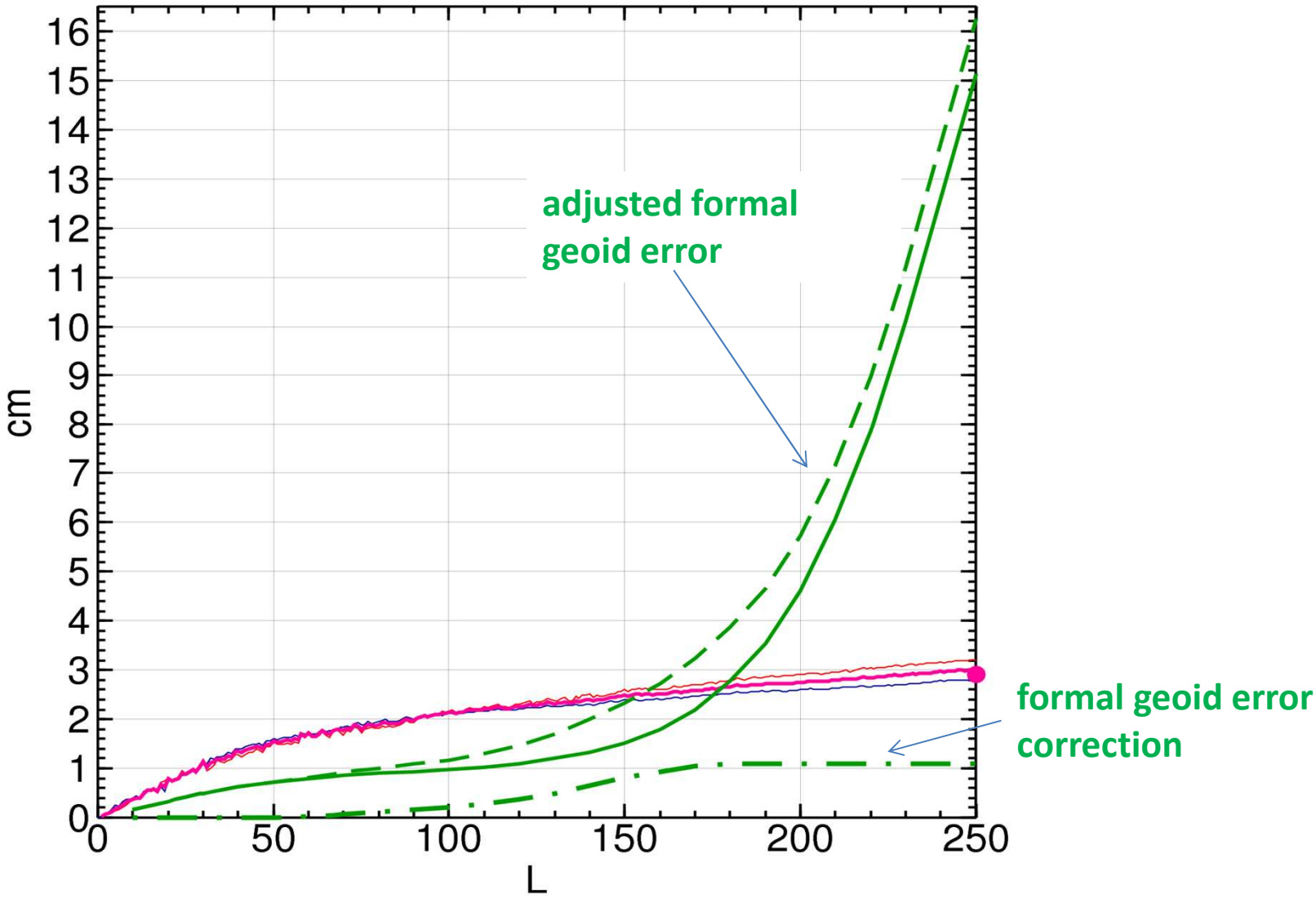


Upper bound informal error

Lower bound informal error

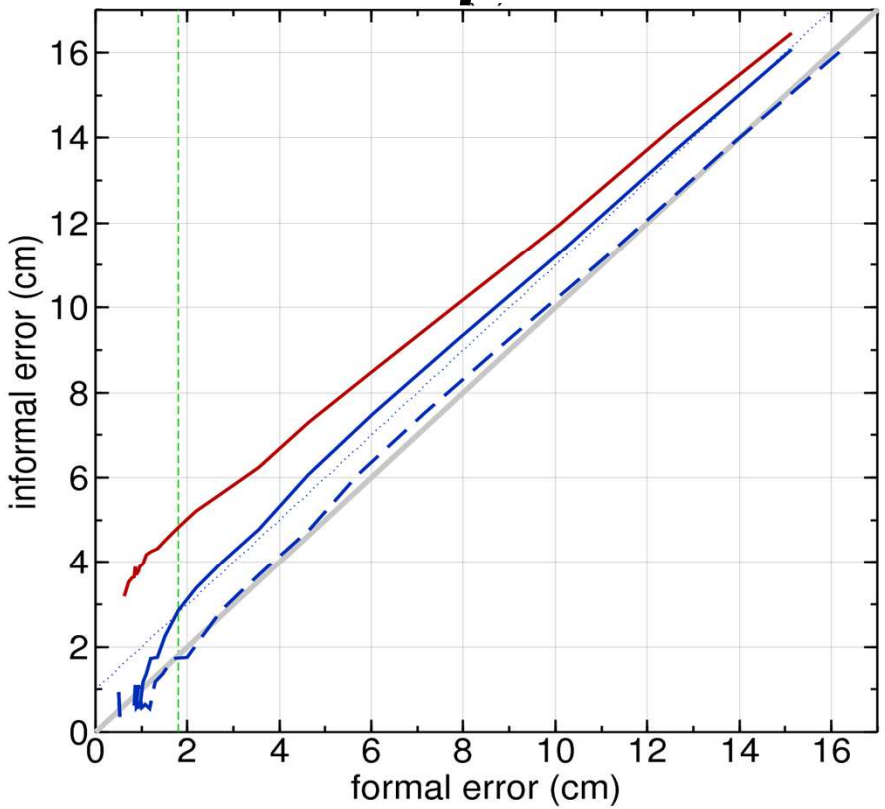
Both corrected for MSS contribution

An MDT error budget for the North

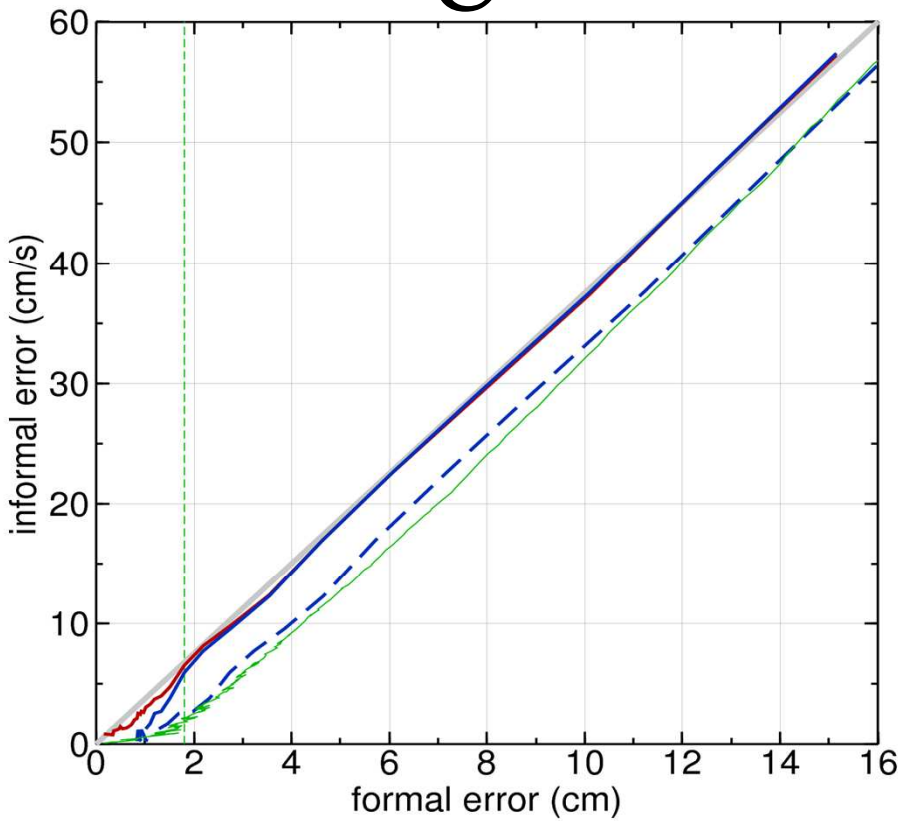


Informal vs. formal errors (TIM3)

η



U

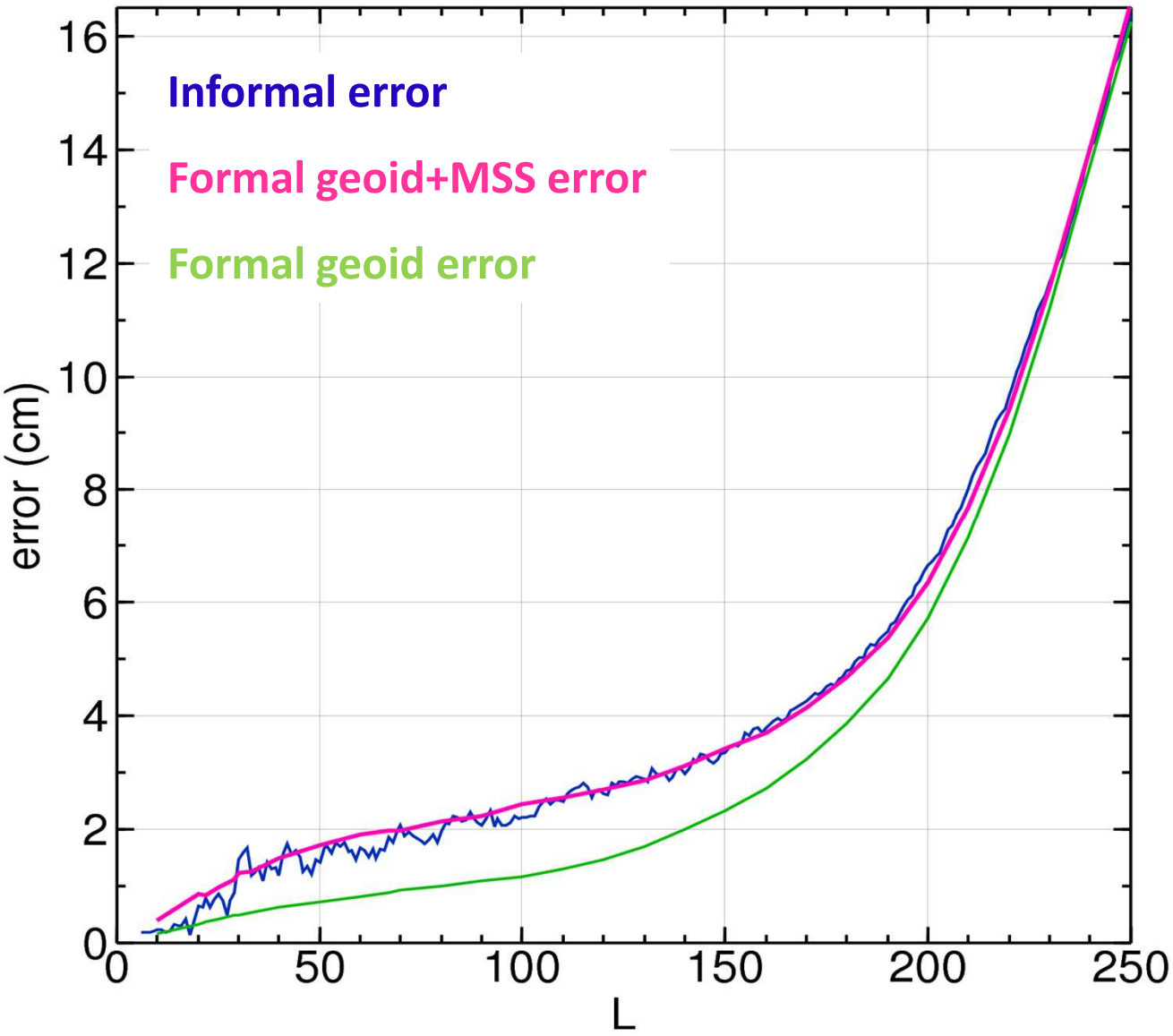


Upper bound informal error

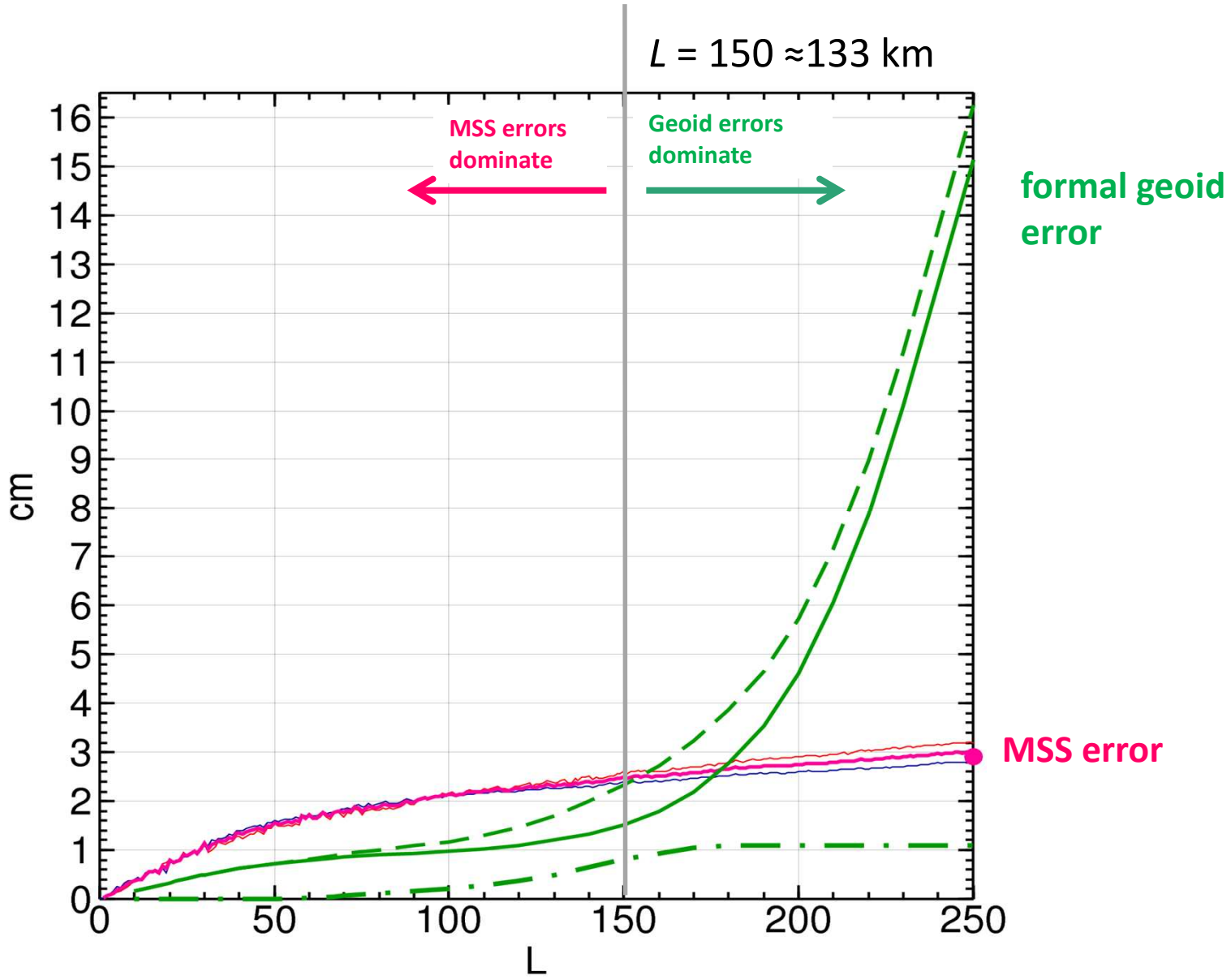
Lower bound informal error

Both corrected for MSS contribution

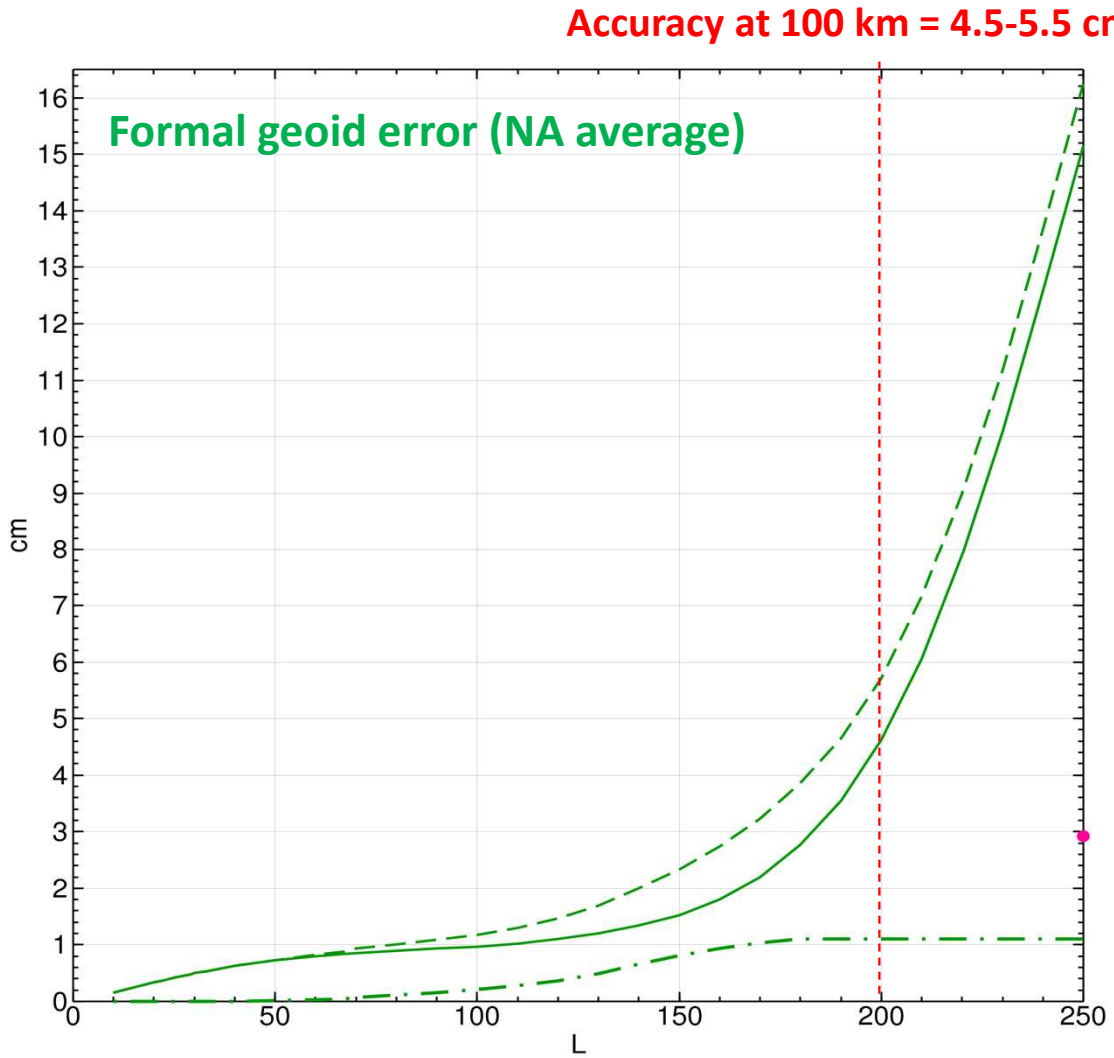
Inter-comparison of error estimates



An MDT error budget for the North Atlantic



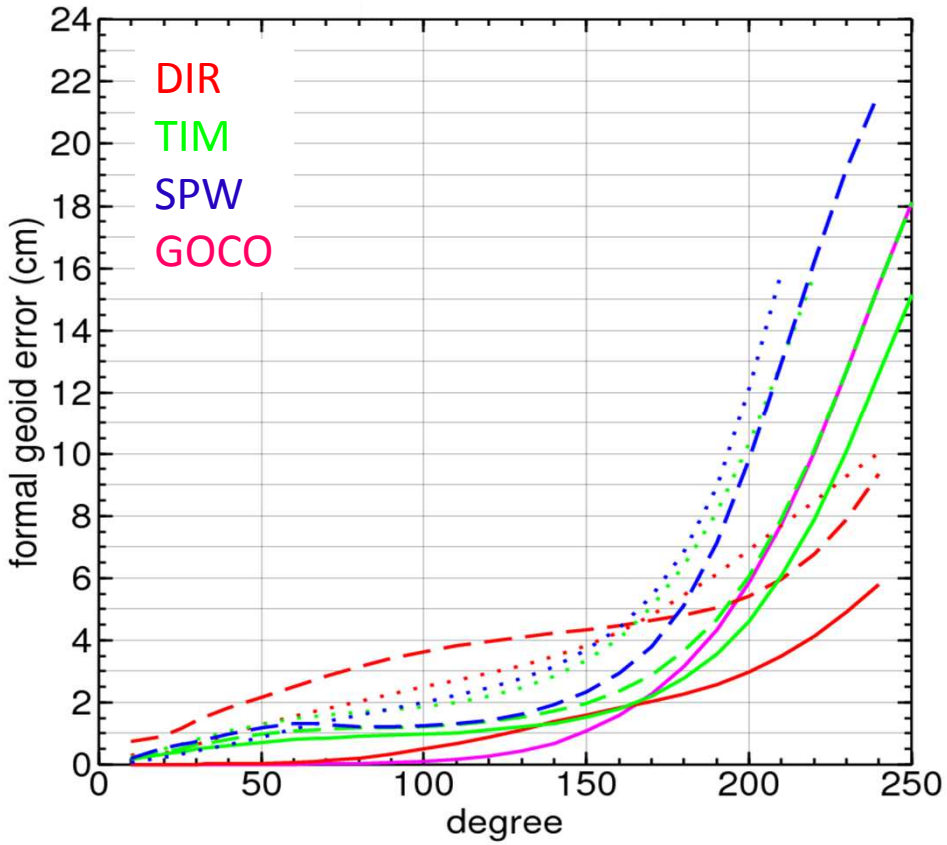
The issue of geoid commission error



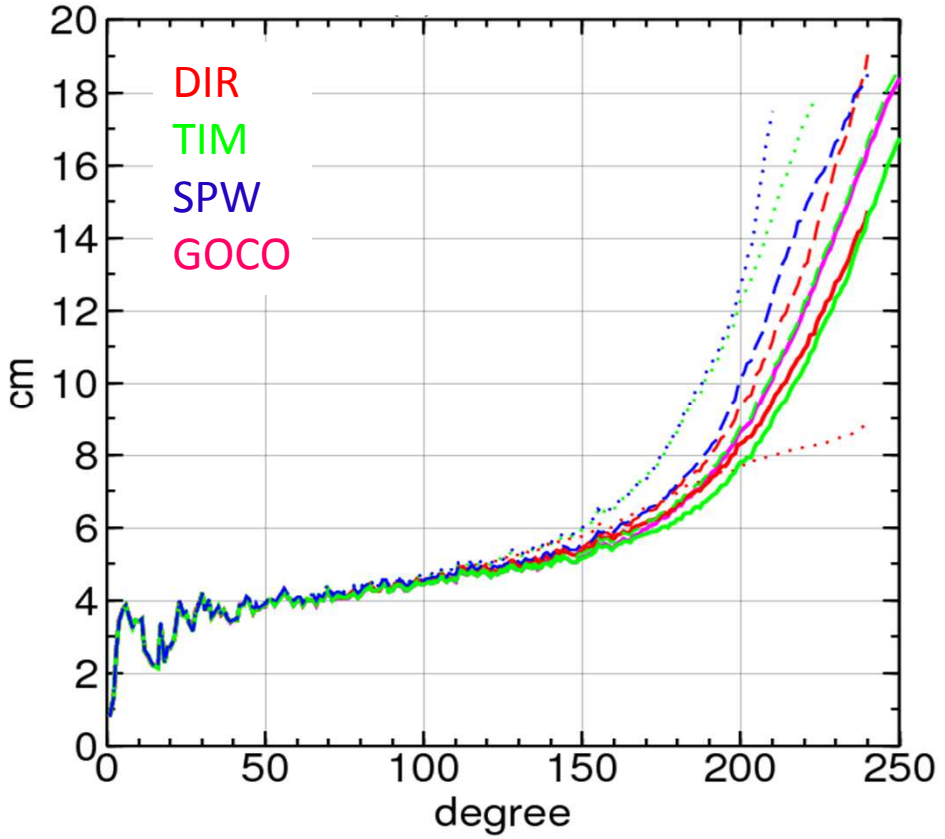
GOCE is still someway short of the desired accuracy of 1 cm at 100 km

Assessment of formal errors

Formal geoid errors



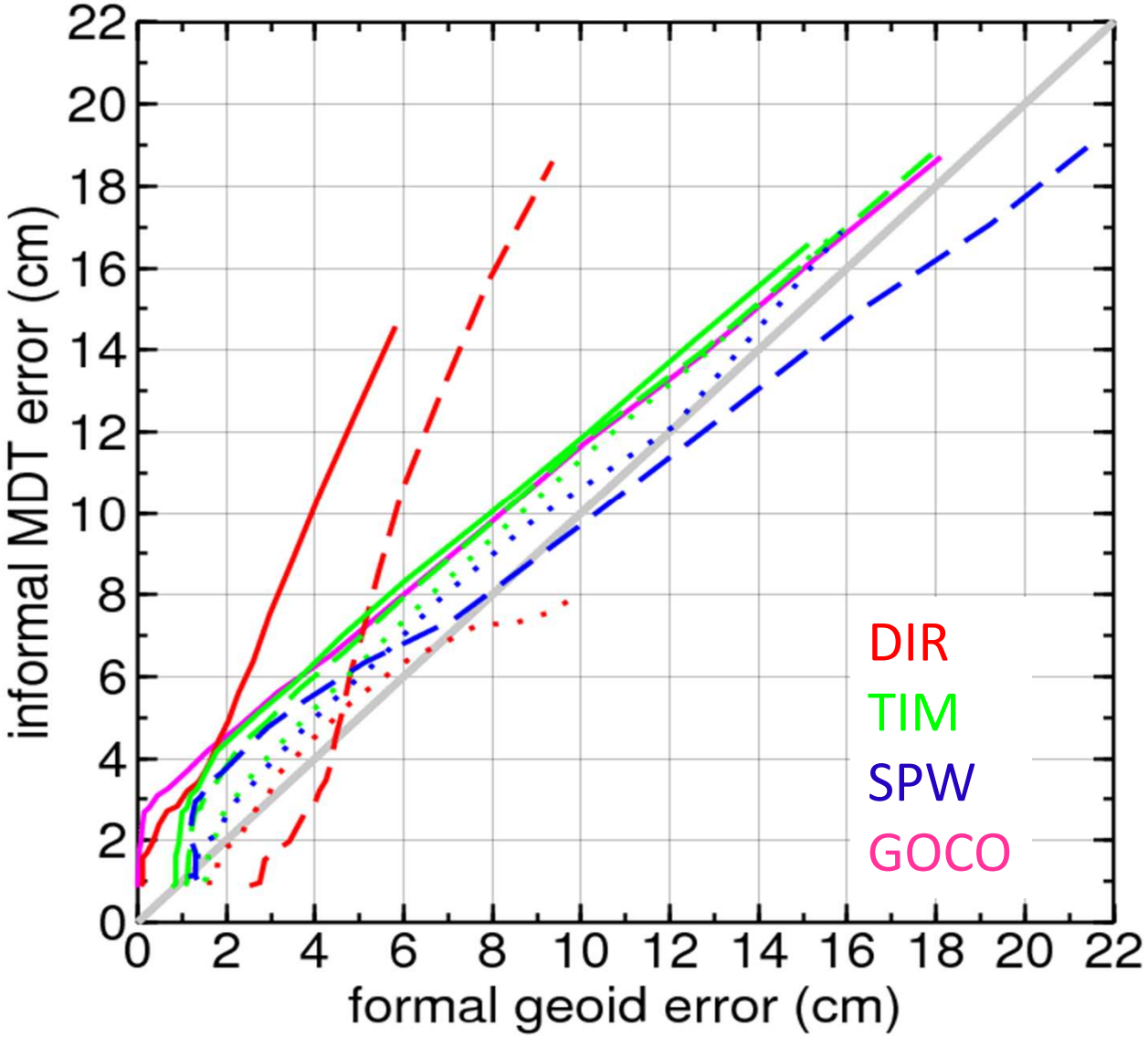
Informal MDT errors



- Relative magnitudes of formal geoid errors (left) and informal MDT errors (right) similar
- Except for 2nd and 3rd direct method solutions
- 1st DIR solution least noise – external data

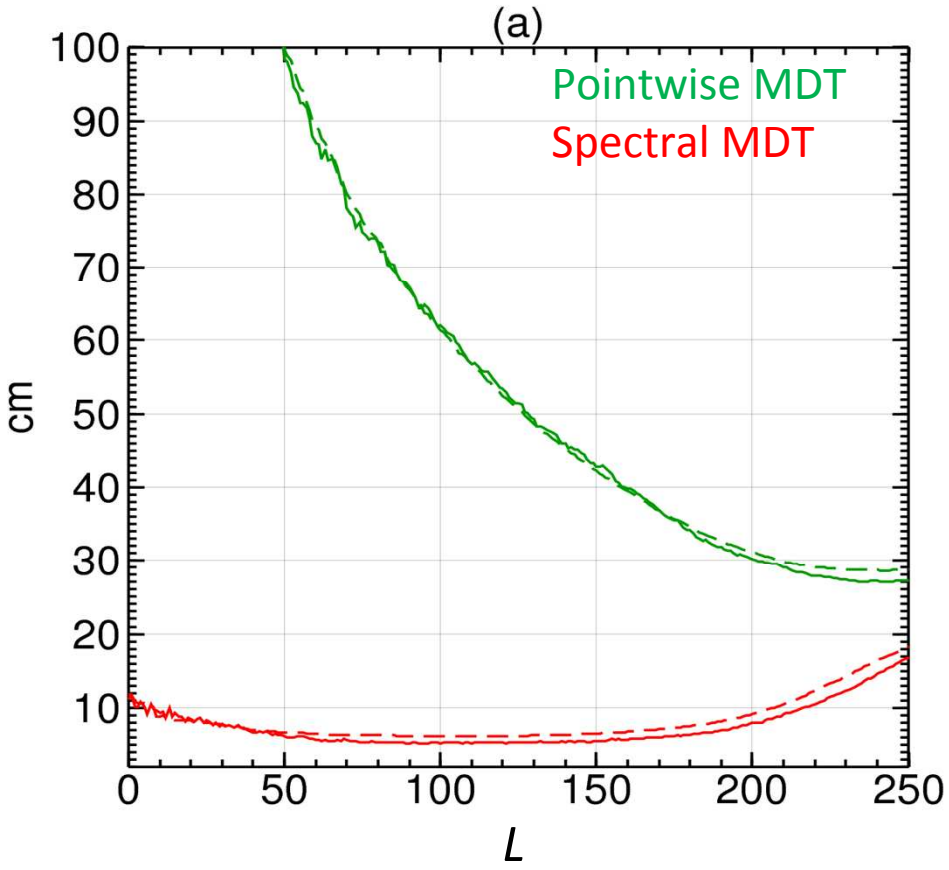
(GOCE solution: 1st gen (2 mnths) dotted; 2nd gen (6 mnths) dashed; 3rd gen (1 yr) solid)

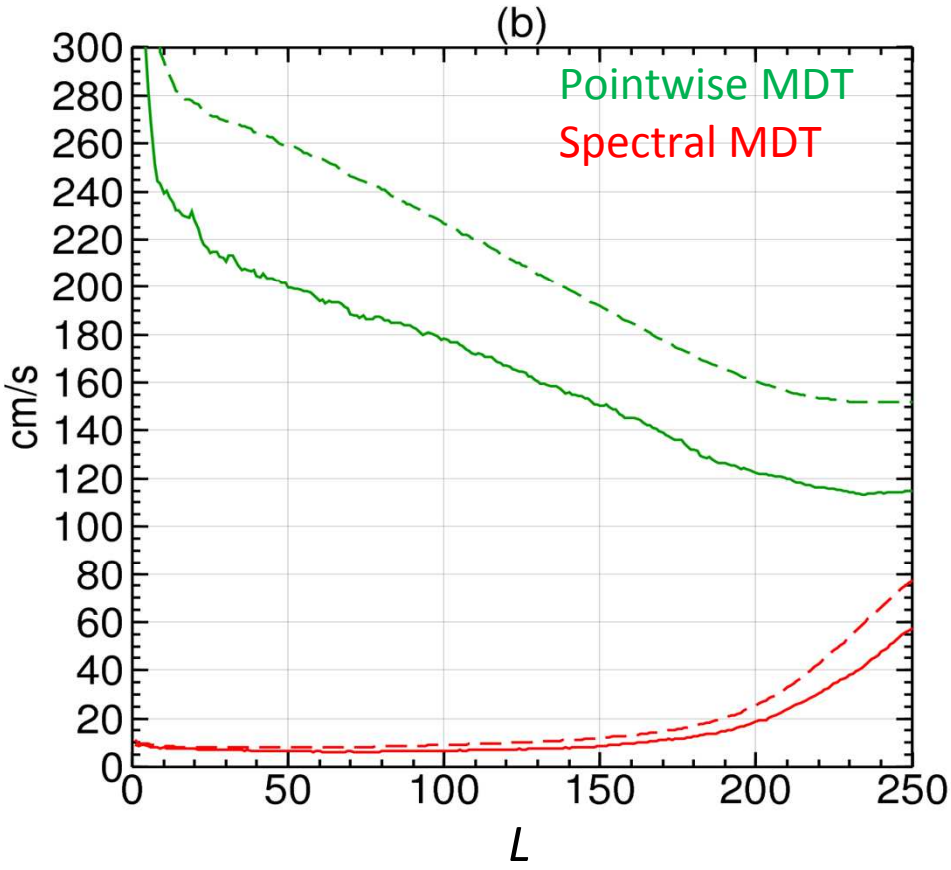
Assessment of formal errors



1st gen (2 mnths) dotted
2nd gen (6 mnths) dashed
3rd gen (1 yr) solid

Pointwise vs. Spectral methods





An estimate of MDT and GCS error as a function of d/o truncation (*L*) computed over the North Atlantic (solid) and globally (dashed).

Part III: Geoid Error Covariances

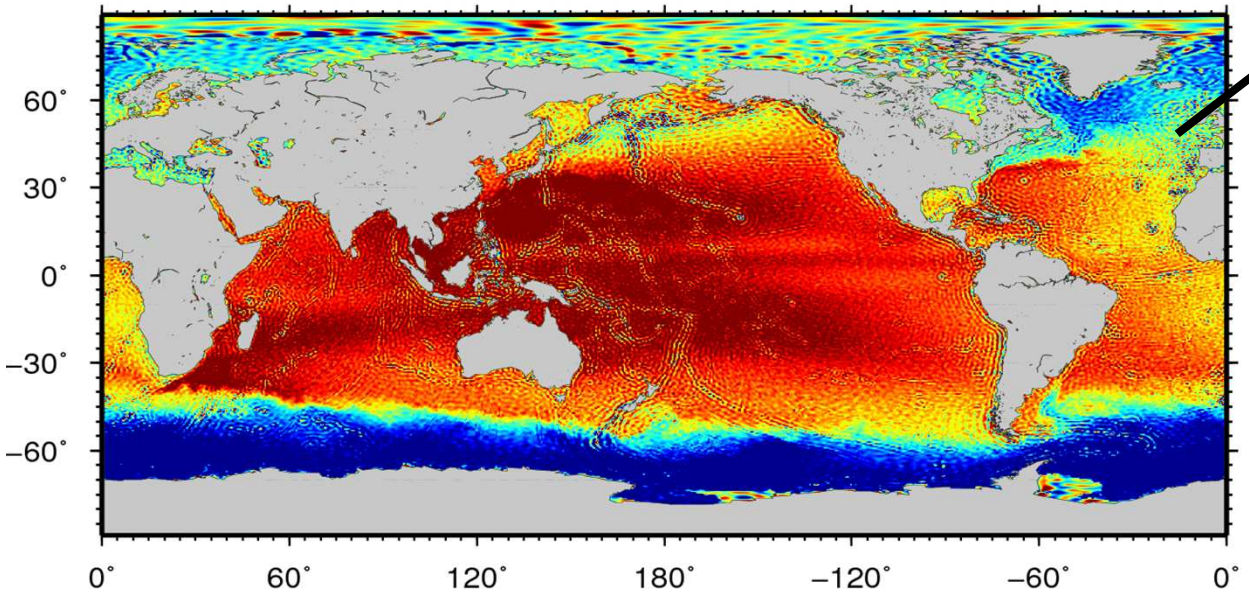
covhs2p: the directing file

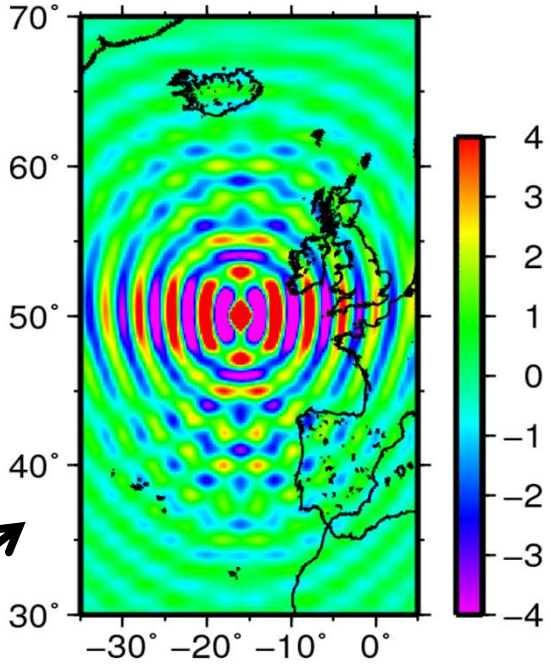
directing file for covhs2p
GDIR240 (GOCE DIR model) : name given to model = 15 first characters (max.)
typgrid=0 0 : direct access 1 : sequential (binary files)
meanponc=1 0 : grid of (pseudo) mean values ; 1 : grid of point values
gm=0.39860044150000e+15,a=0.63781364600000e+07,uapl=0.29825765000000E+03,om=0.72920905111492E-04
lmin=002 min. degree taken into account
lsup=240 max. degree ...
mmin=000 min. order ...
msup=240 max. order ...
m=-99,l_beg=000,l_end=000 for specific orders (m=...) : min. and max. degree (end if m=-99)
s0=+1.00000e+00 variance factor, will multiply the covariance matrix (read in e12.5)
kf=1 function type : 1=n(geoid),2=deltag(FA),3=dg=trr,4=d2T/dr2,5=dFA/dr,6=water eq.,0=other
kse=2 key for type of latitudes (1:geoc. , 2:ellip.)
h=+0.000000000 altitude (m): in effect according to function type (if kf=3, 4 or 5), read in f12.0
iunit=0 iunit for lat./lon. steps (0:degree , 1:minute)
fimin=+20.00,fimax=+80.00,dfi=+01.00,xlmin=-060.00,xlmax=+030.00,dxl=+01.00 (limits of inner zone Z in deg.)
H=lath=020,K=lonk=020 window size : half-height, halh-width (in number of grid points)
f0=1.0000000000 factor depending on function type (effective or not) , read in f12.0
kfilter=00,dfilter=300000.00,psi0=5.000,fract0=0.500 filter parameters (no filtering if kfilter=0)
l1=001,l2=240 computation for degree between l1 and l2 (eventually: reduction of cov. matrix)
dpsi=01.000000 stepsize (in degree) for tables of covariance functions) , read in f9.0
kverif=0 key for verification by "brute force" at a few points (if cov. matrix fits in core), 0: no
interp_ex=1 key for testing the interpolation procedure (if DA file), 0: no; 1:yes, for pair below
zi_lat=+40.50,zi_lon=+000.50,v_lat=+48.50,v_lon=+003.50 pair of points (1 in Z ; 2 in W [1]) for interp.
0 end of file (for PC)

Error Covariance Functions

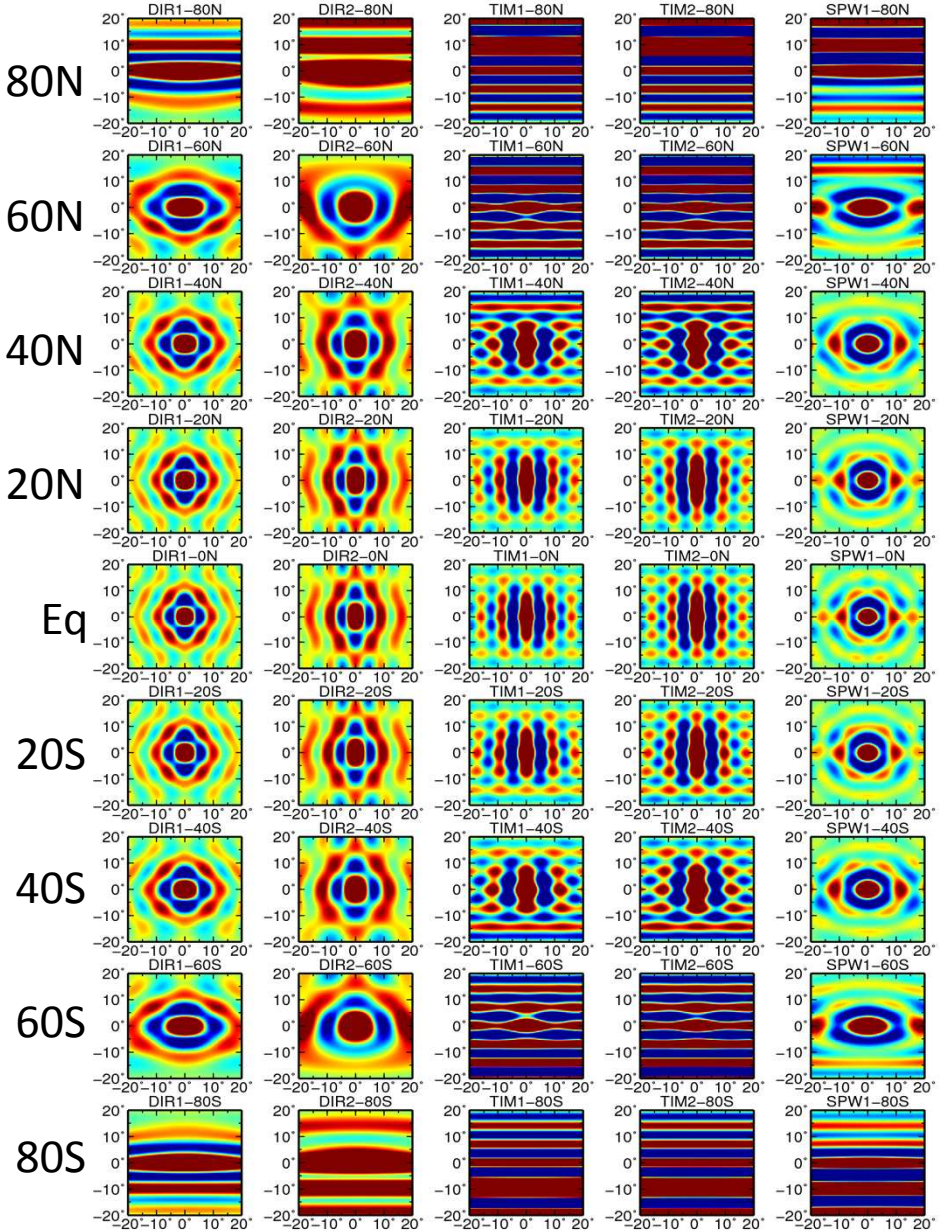
- Calculate error covariance function in 40x40 degree window for every point on a global 1x1 degree grid
- Expect functions to be zonally homogenous
- Form zonal mean ECF for each latitude
- At each latitude compute skill of zonal mean ECF in accounting for the variance in actual ECFs along line of latitude

$$S = 100 \times \left(1.0 - \frac{\left\langle f - \bar{f} \right\rangle}{\left\langle f \right\rangle} \right)$$



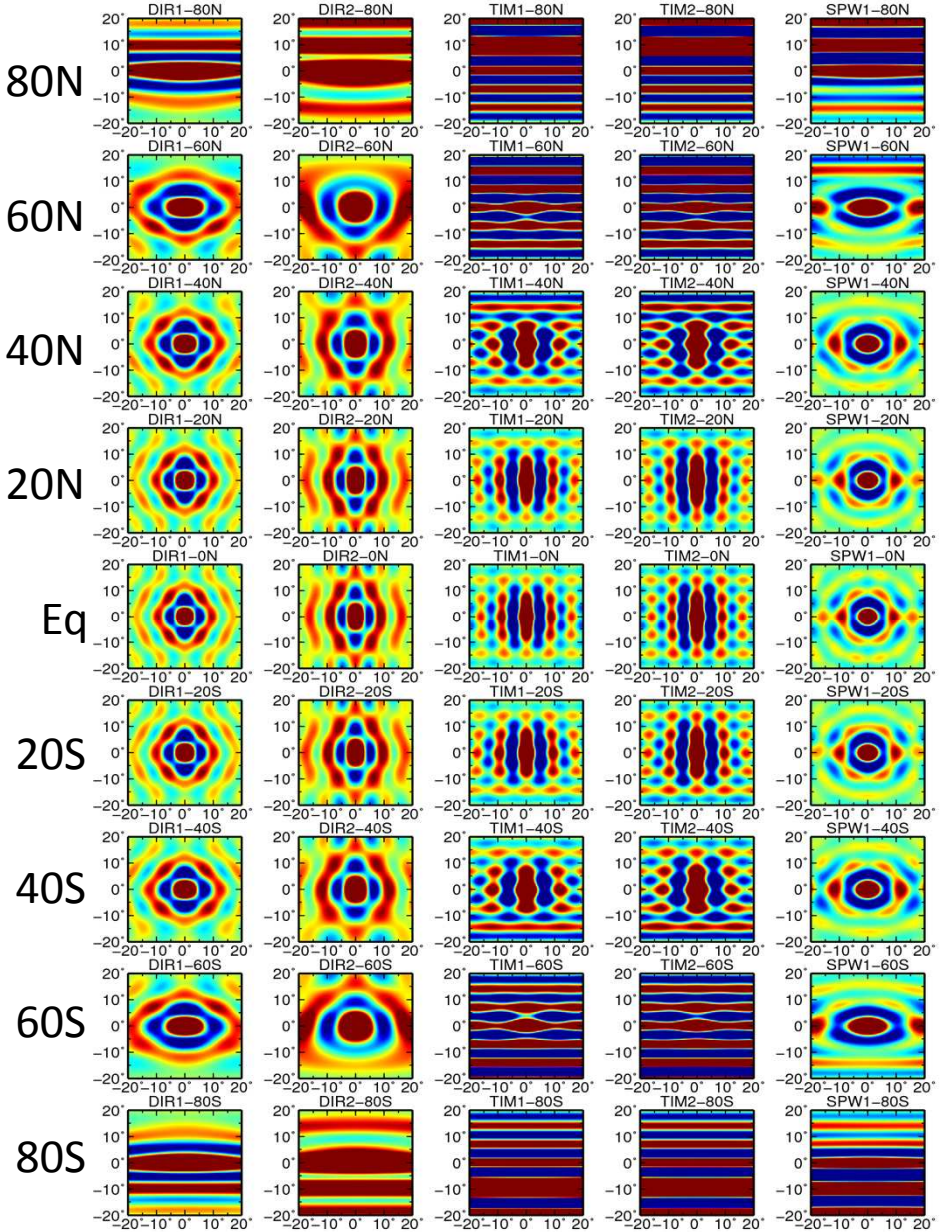


Zonal mean ECFs: d/o=50



- Calculate error covariance function in 40x40 degree window for every point on a global 1x1 degree grid
- Expect functions to be zonally homogenous
- Form zonal mean ECFs for each latitude

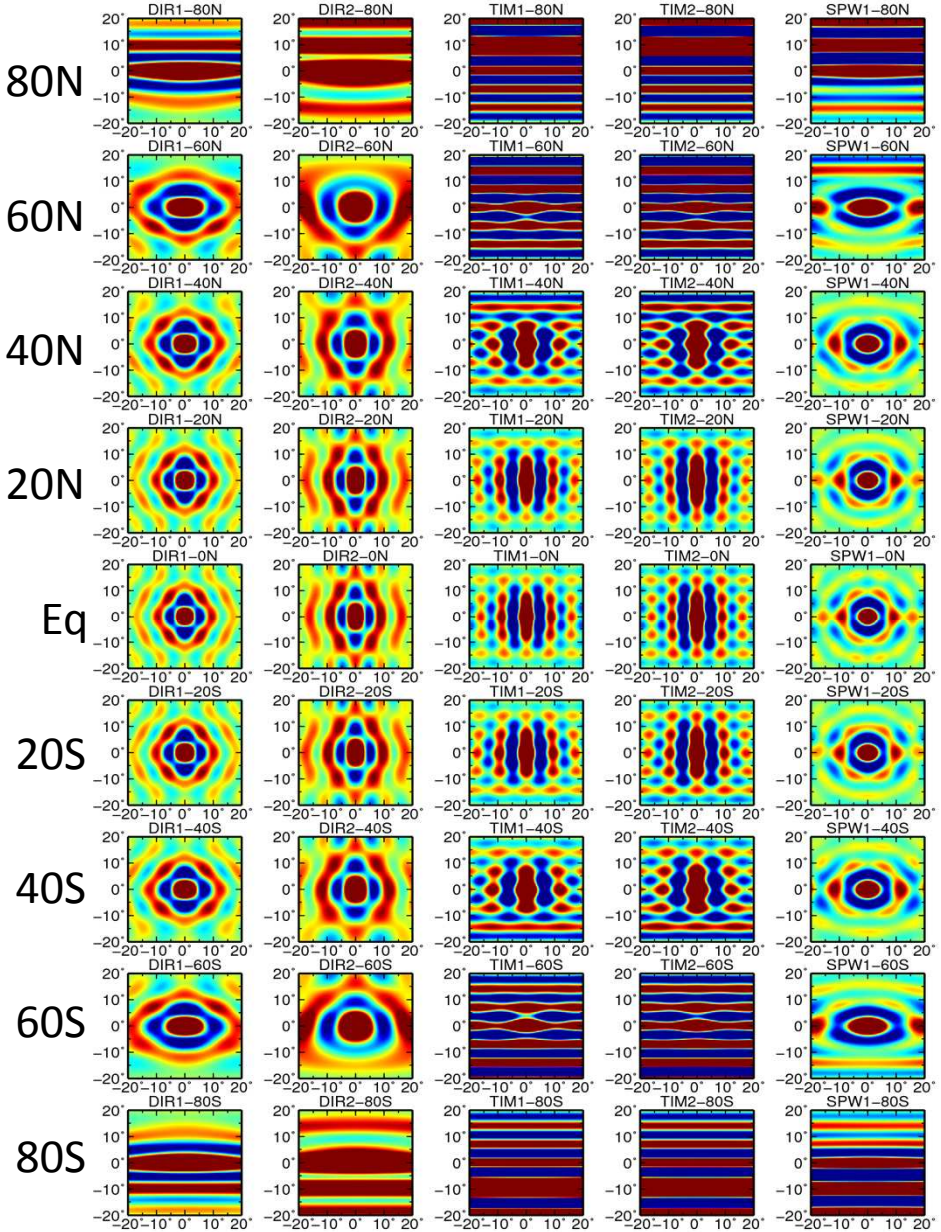
Zonal mean ECFs: d/o=50

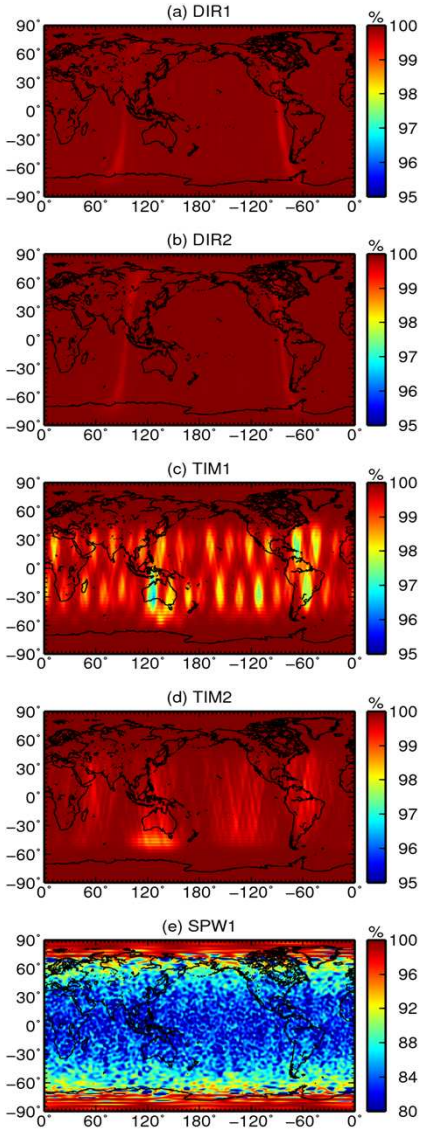


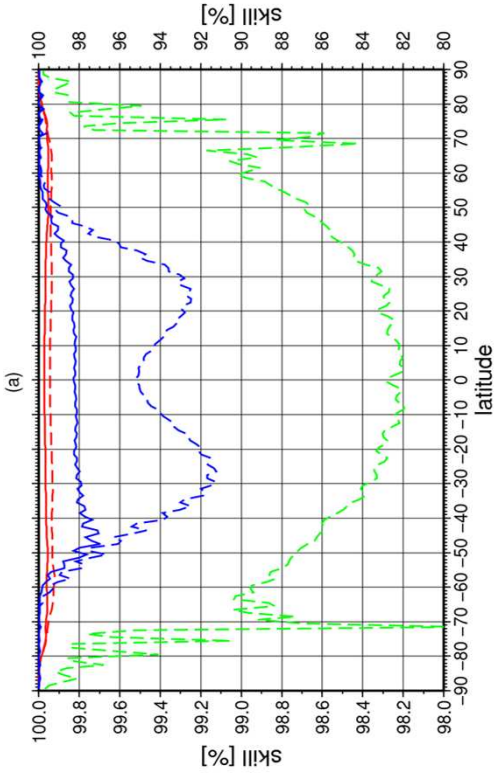
- Calculate error covariance function in 40x40 degree window for every point on a global 1x1 degree grid
- Expect functions to be zonally homogenous
- Form zonal mean ECFs for each latitude
- At each latitude compute skill of zonal mean ECF in accounting for the variance in actual ECFs along line of latitude

$$S = 100 \times \left(1.0 - \frac{\left\langle f - \bar{f} \right\rangle}{\left\langle f \right\rangle} \right)$$

Zonal mean ECFs: d/o=50







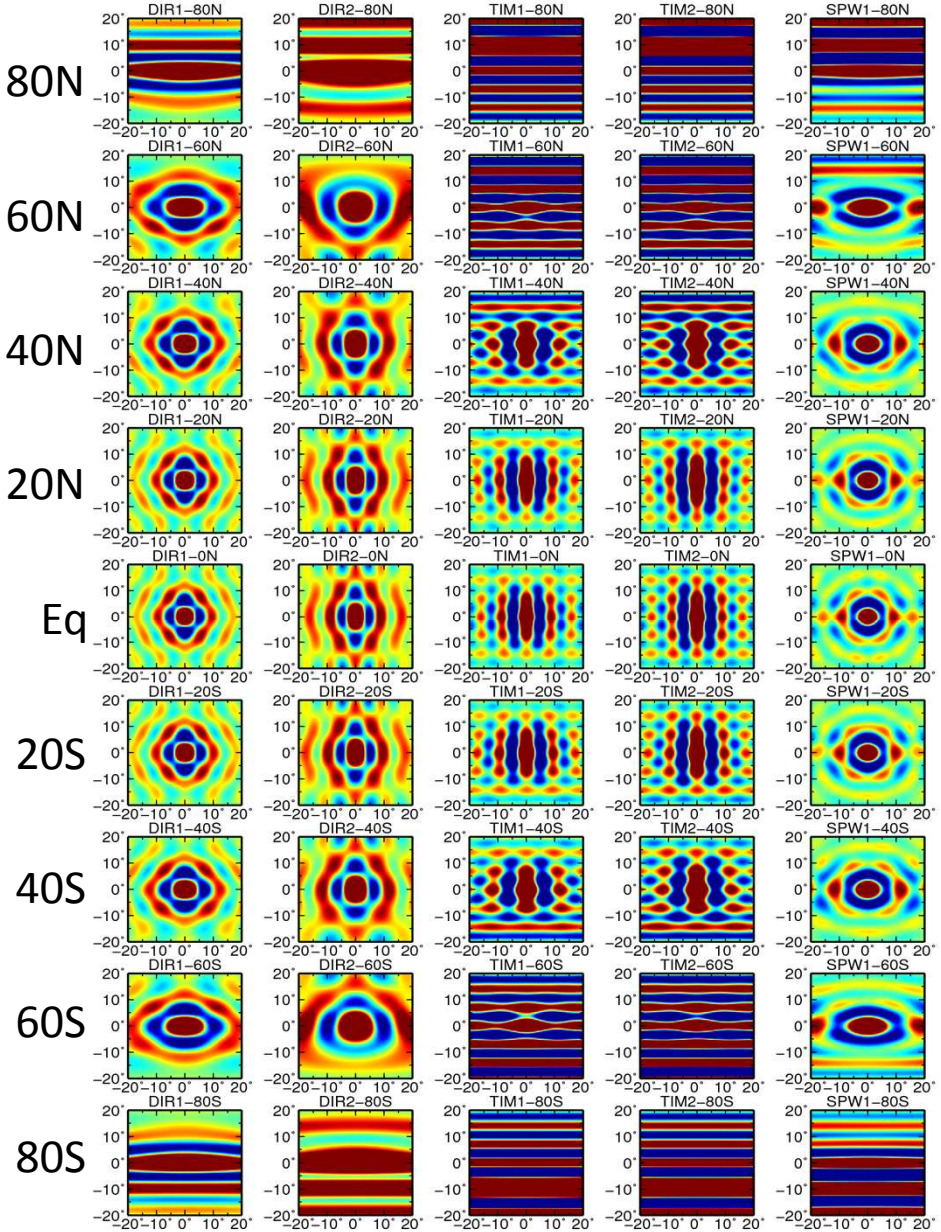
DIRECT

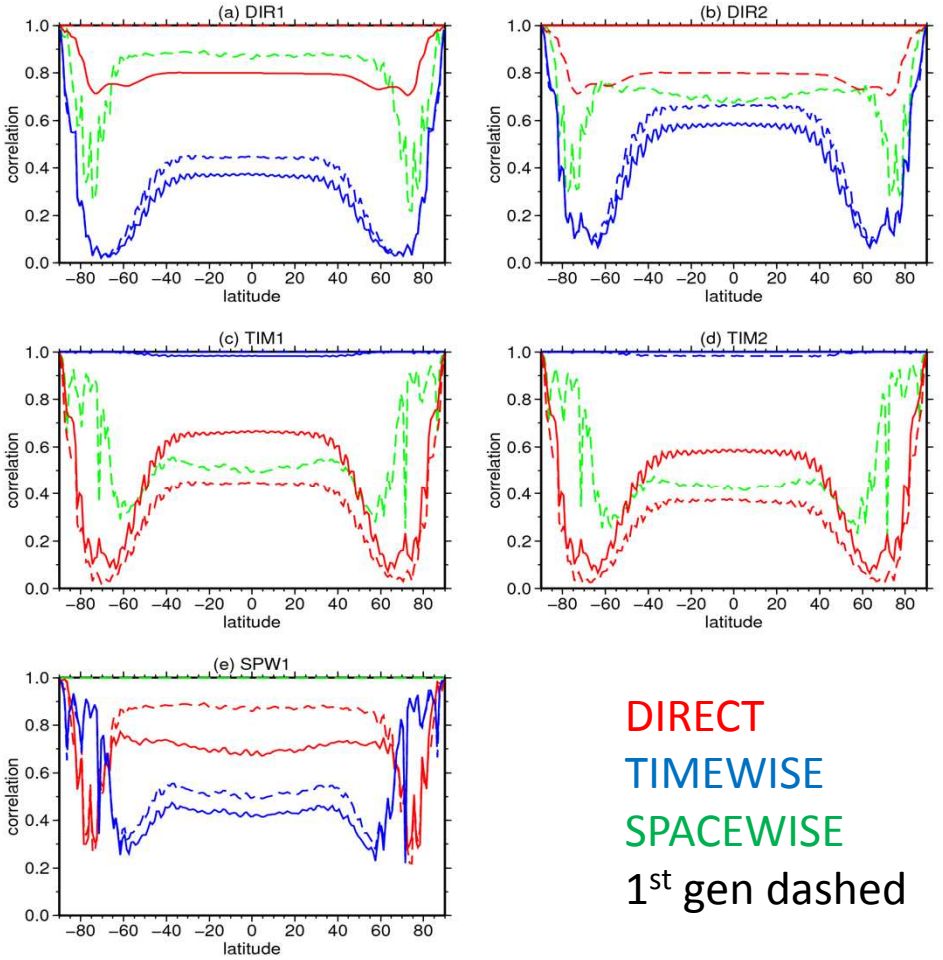
TIMEWISE

SPACEWISE

1st gen dashed

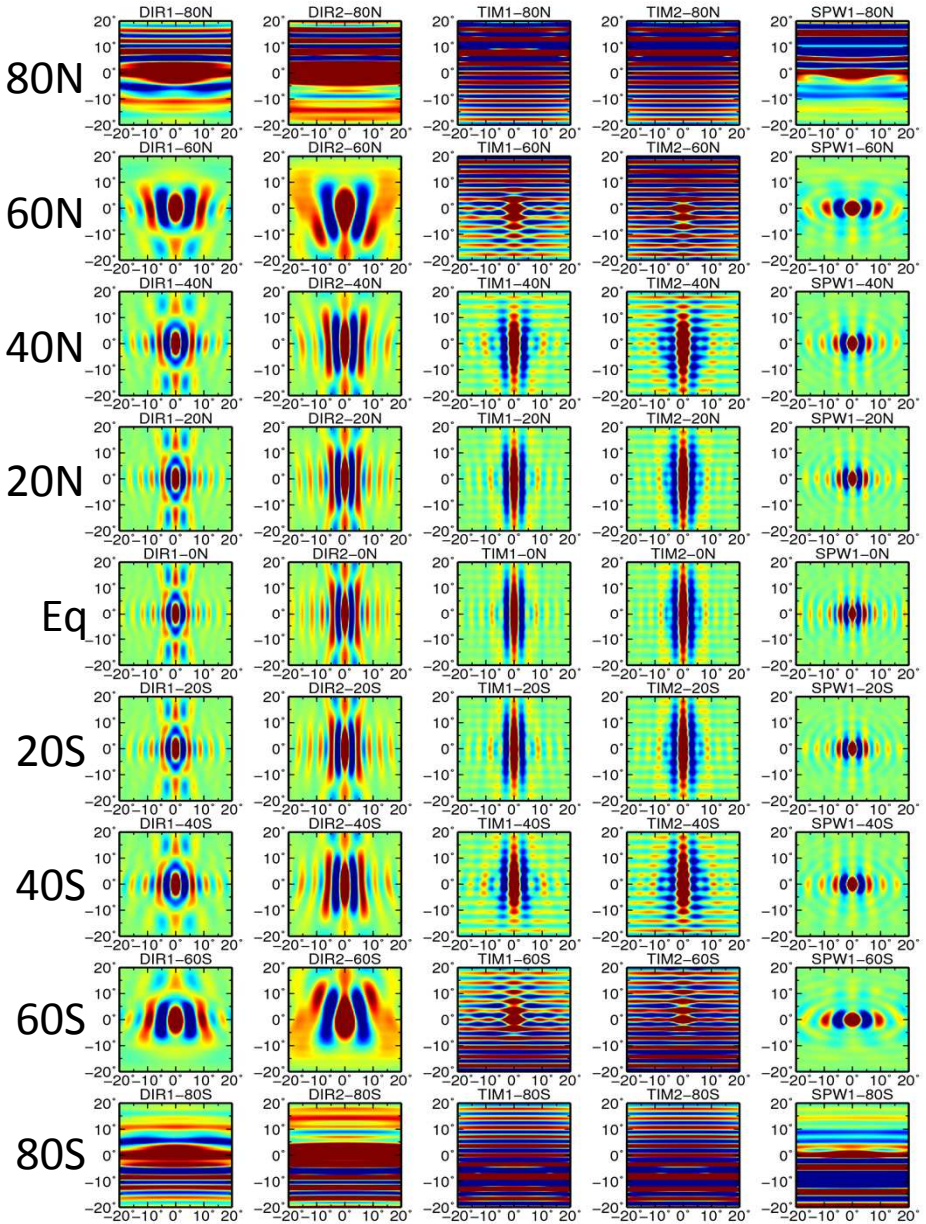
Zonal mean ECFs: d/o=50



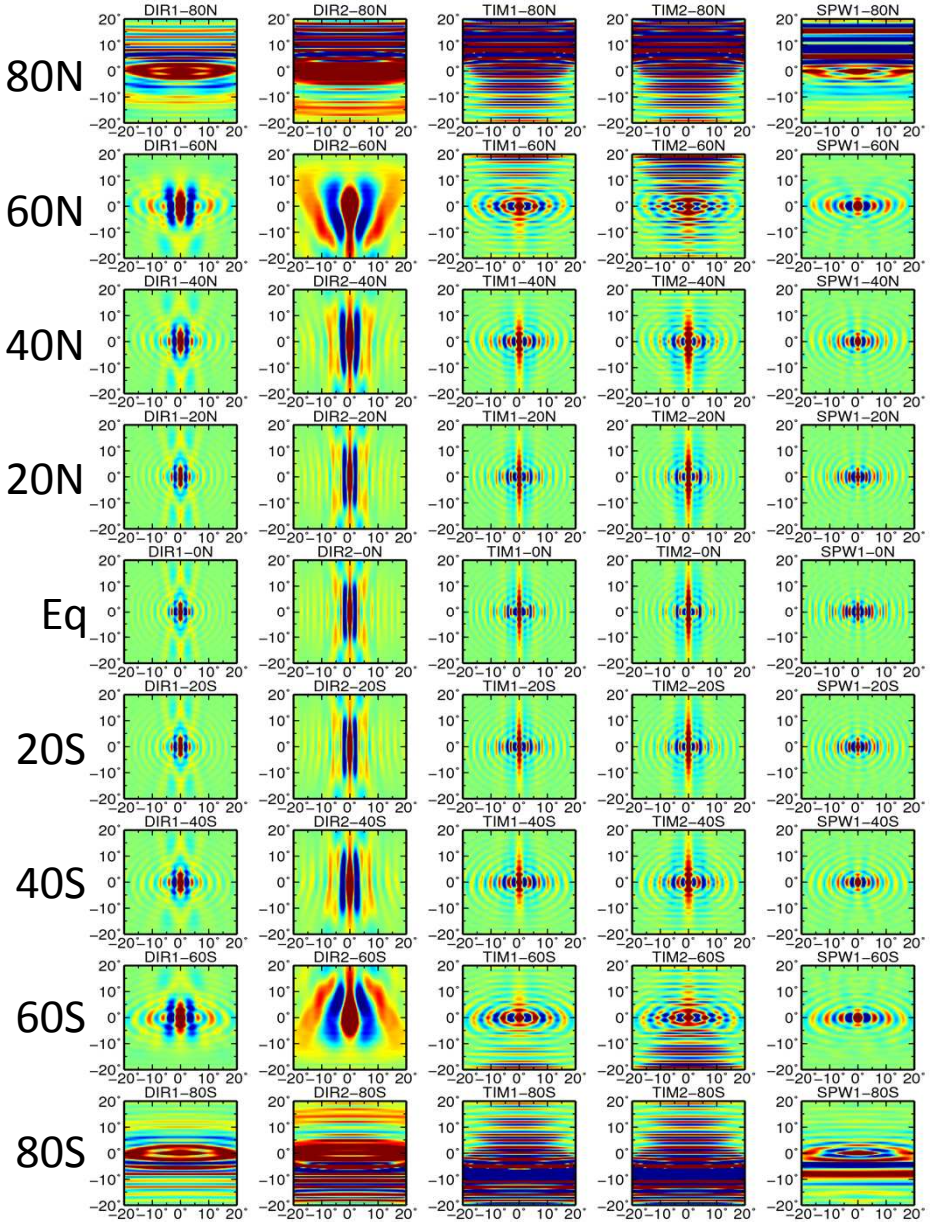


DIRECT
TIMEWISE
SPACEWISE
1st gen dashed

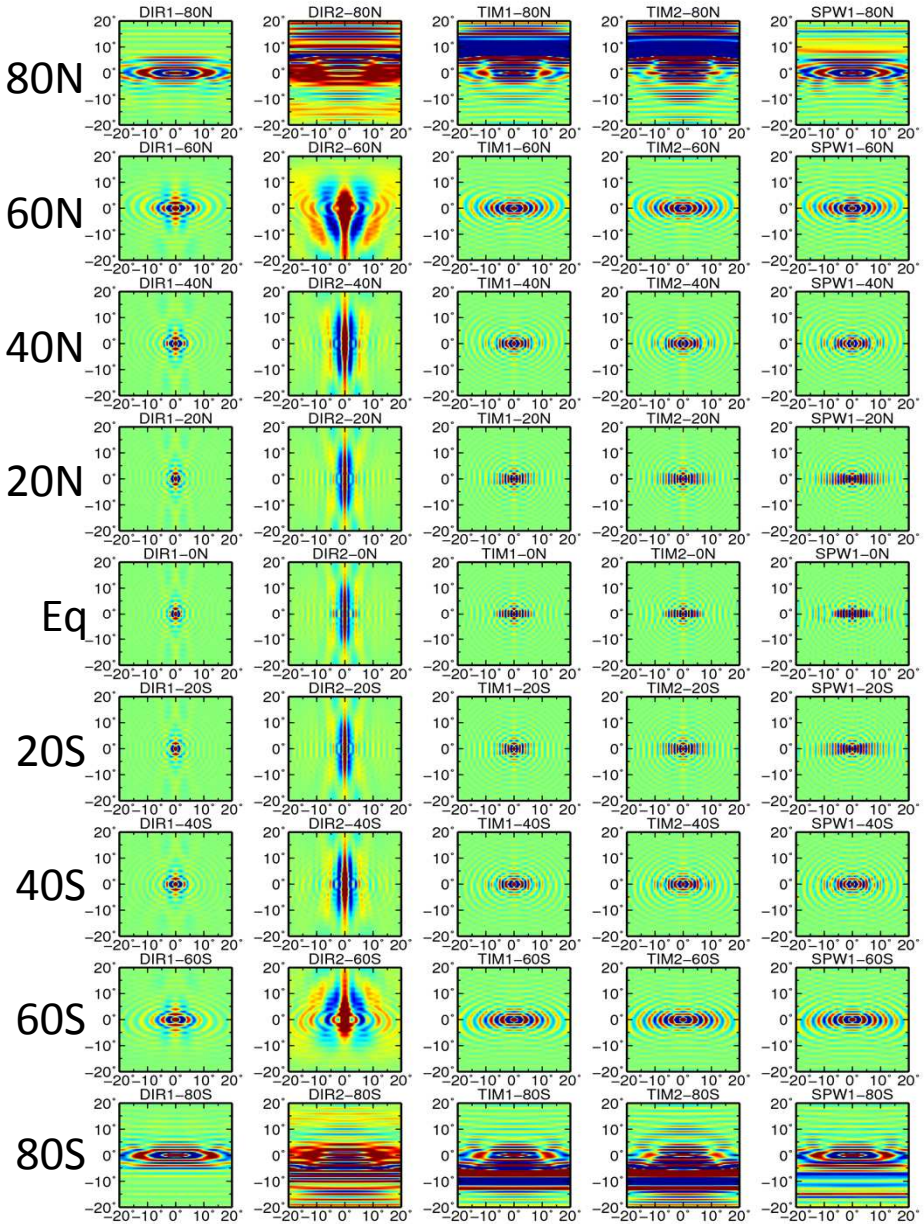
Zonal mean ECFs: d/o=100



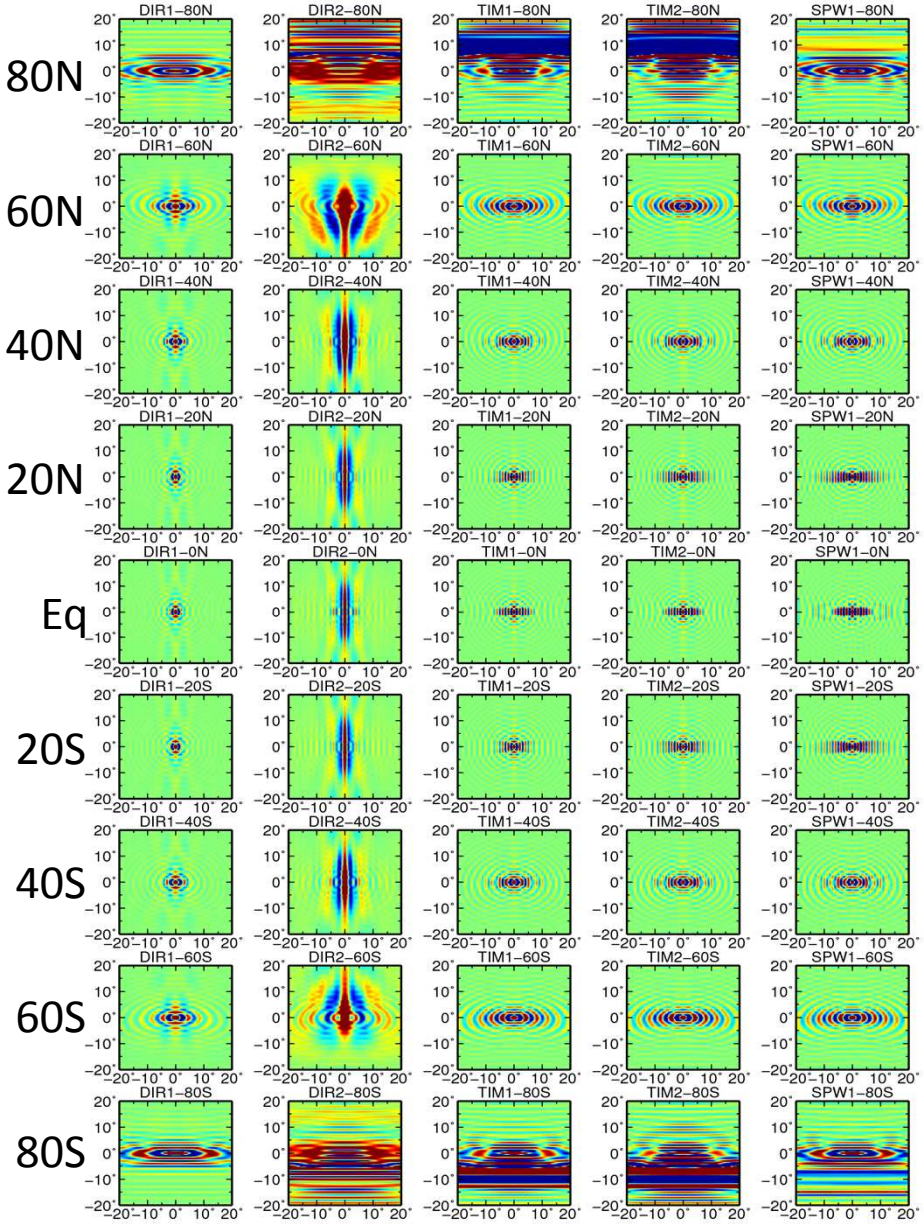
Zonal mean ECFs: d/o=150

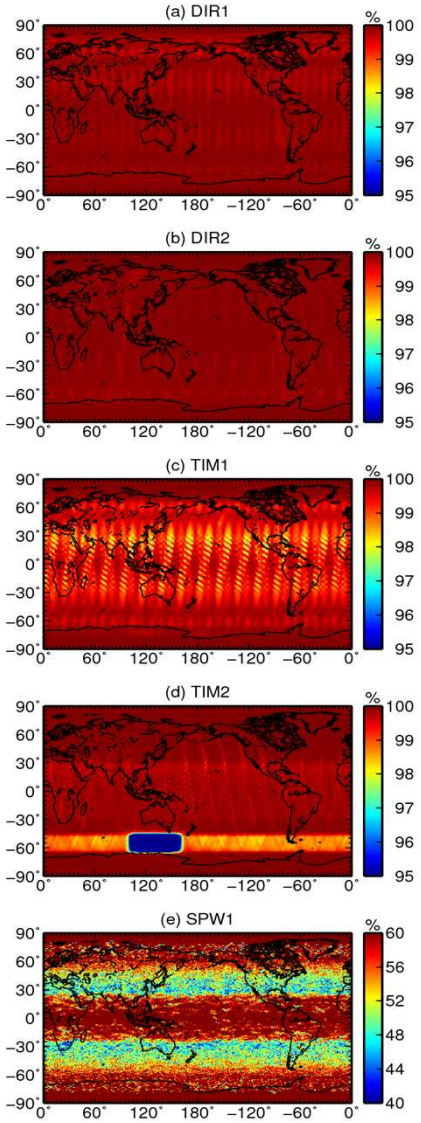


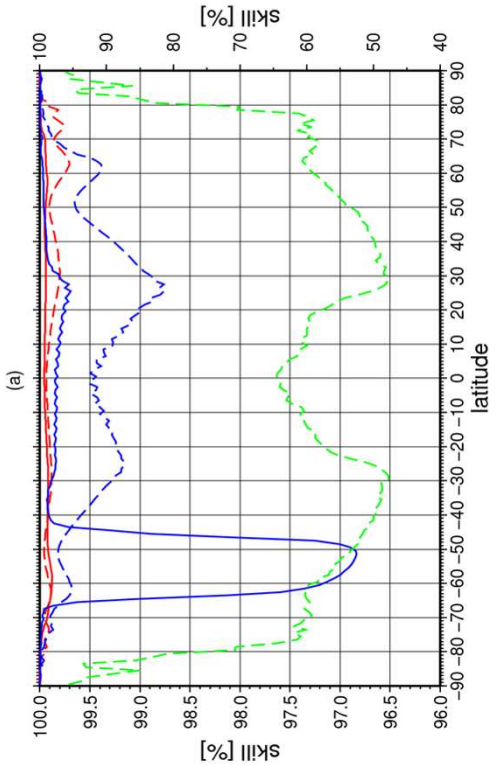
Zonal mean ECFs: d/o=200



Zonal mean ECFs: d/o=200







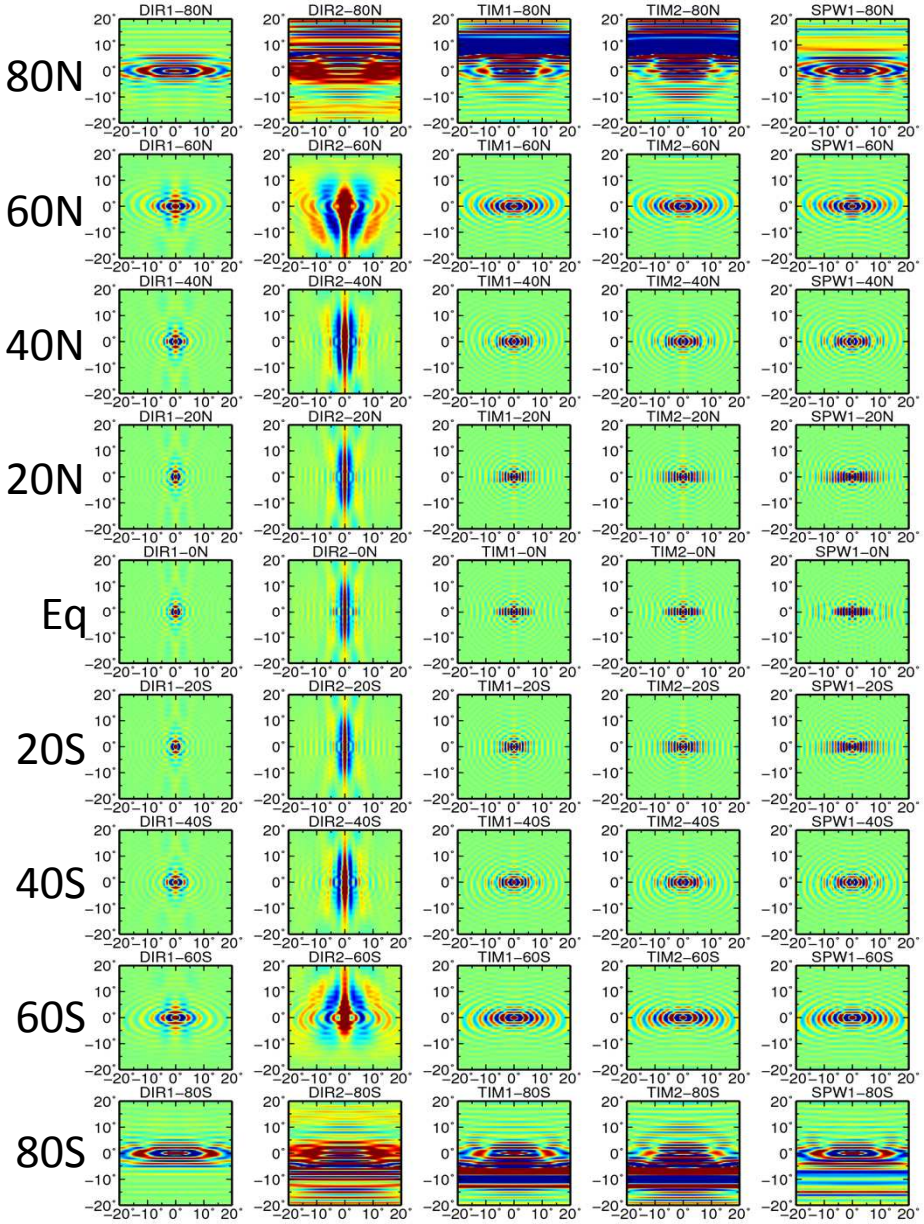
DIRECT

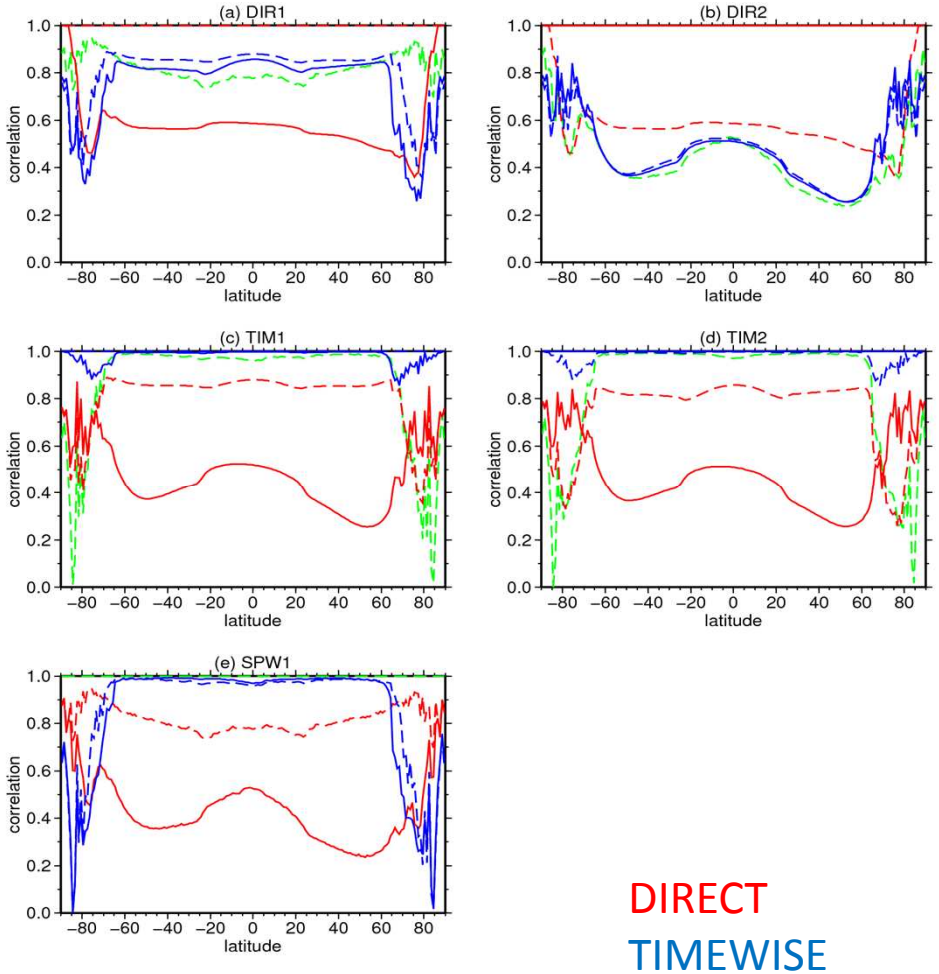
TIMEWISE

SPACEWISE

1st gen dashed

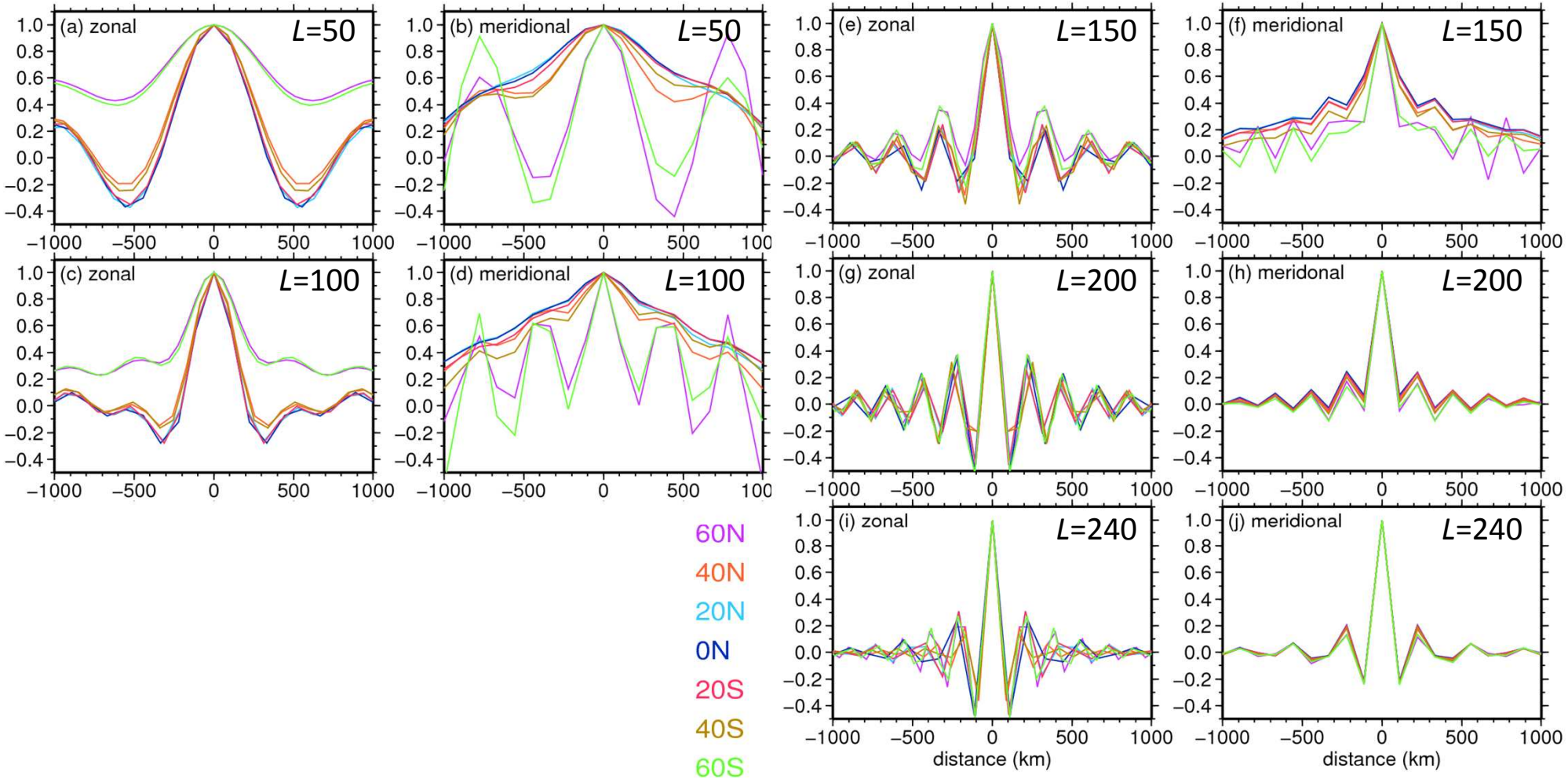
Zonal mean ECFs: d/o=200



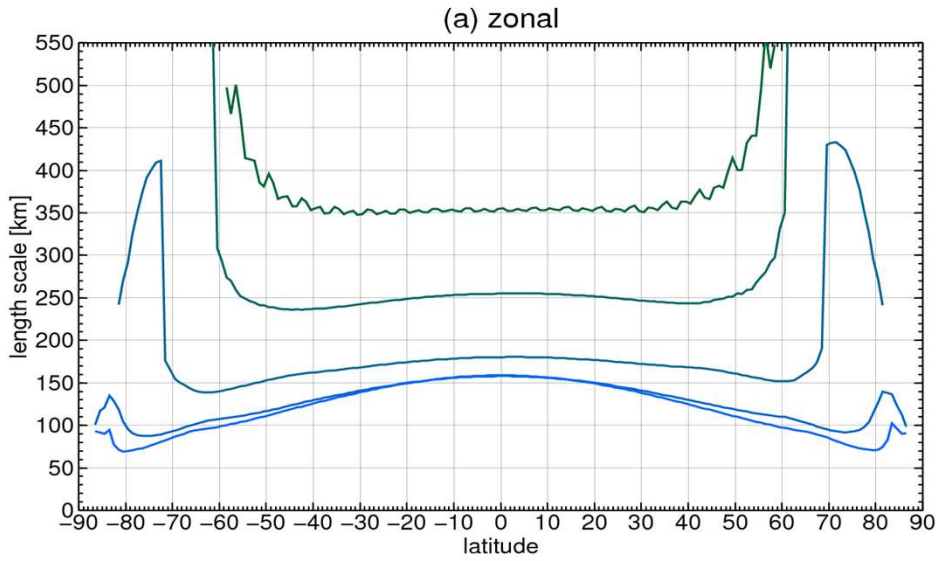


DIRECT
TIMEWISE
SPACEWISE
1st gen dashed

Error structure: Zonal and meridional ECF sections

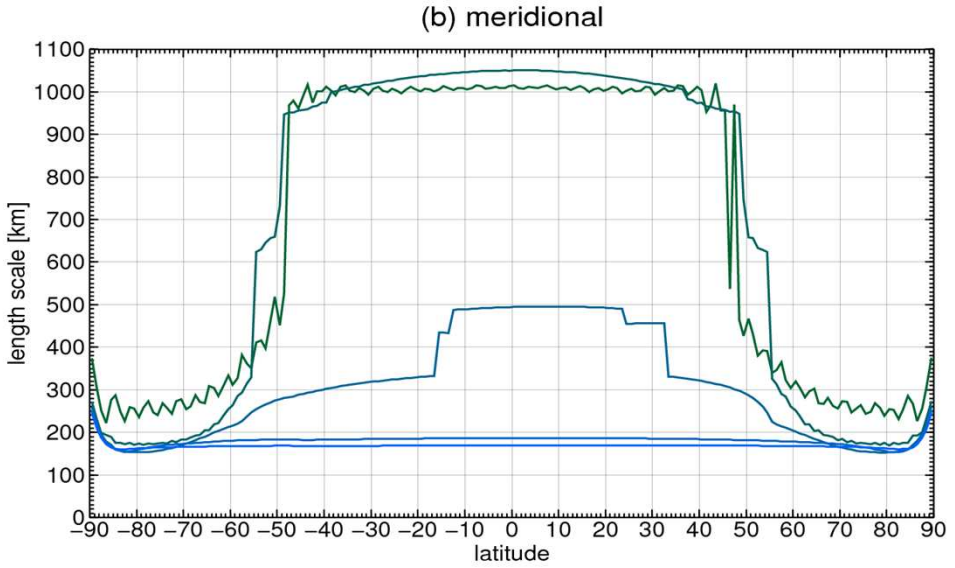


Error structure: Error correlation length scales



L=50

L=240



L=50

L=240