COMBINATION OF GOCE TRF GRAVITY GRADIENT DATA BY COLLOCATION FOR REGIONAL GRAVITY FIELD RECOVERY : A CASE STUDY IN FRANCE

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OUTLINE

1. **DATA AND METHODOLOGY**

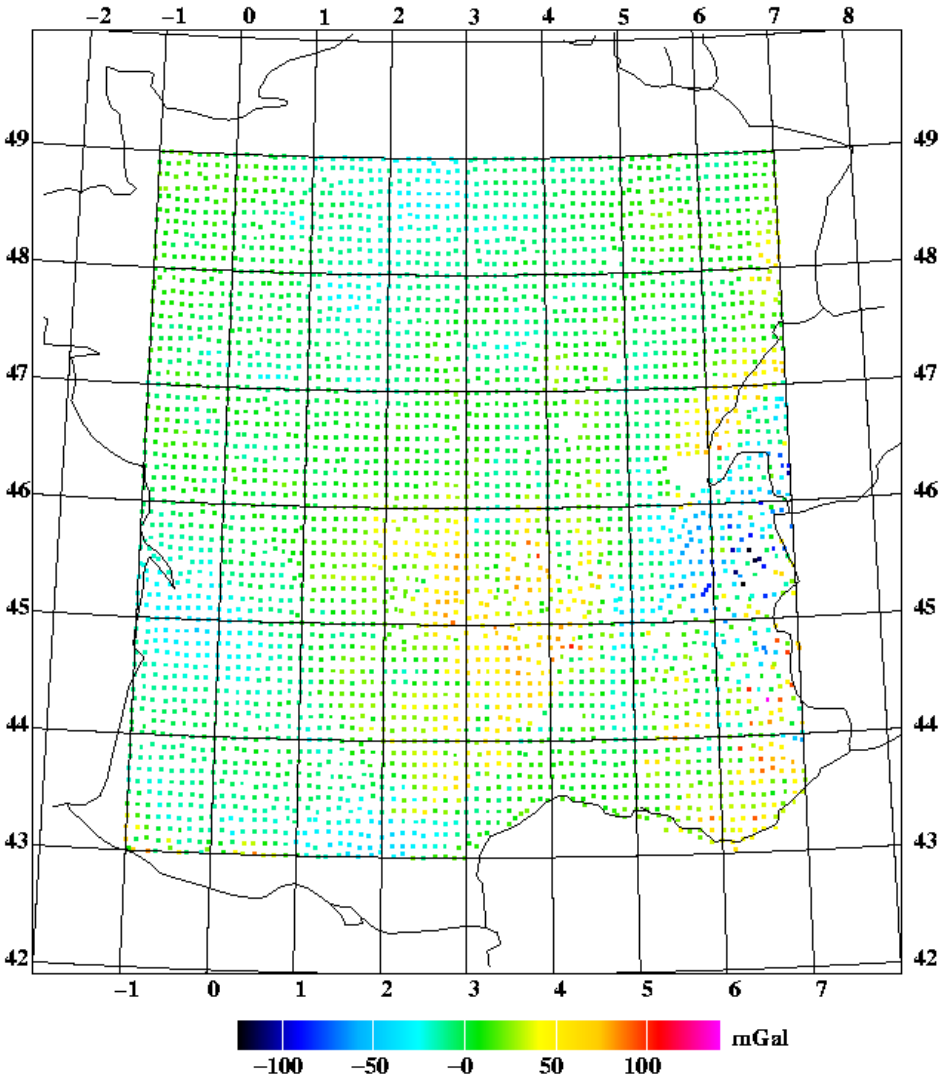
   a. Ground Truth Data
   b. GOCE Gravity Gradient Anomalies

2. **RESULTS**

3. **CONCLUSION**

Ground Truth Data

Terrestrial free air gravity anomaly data



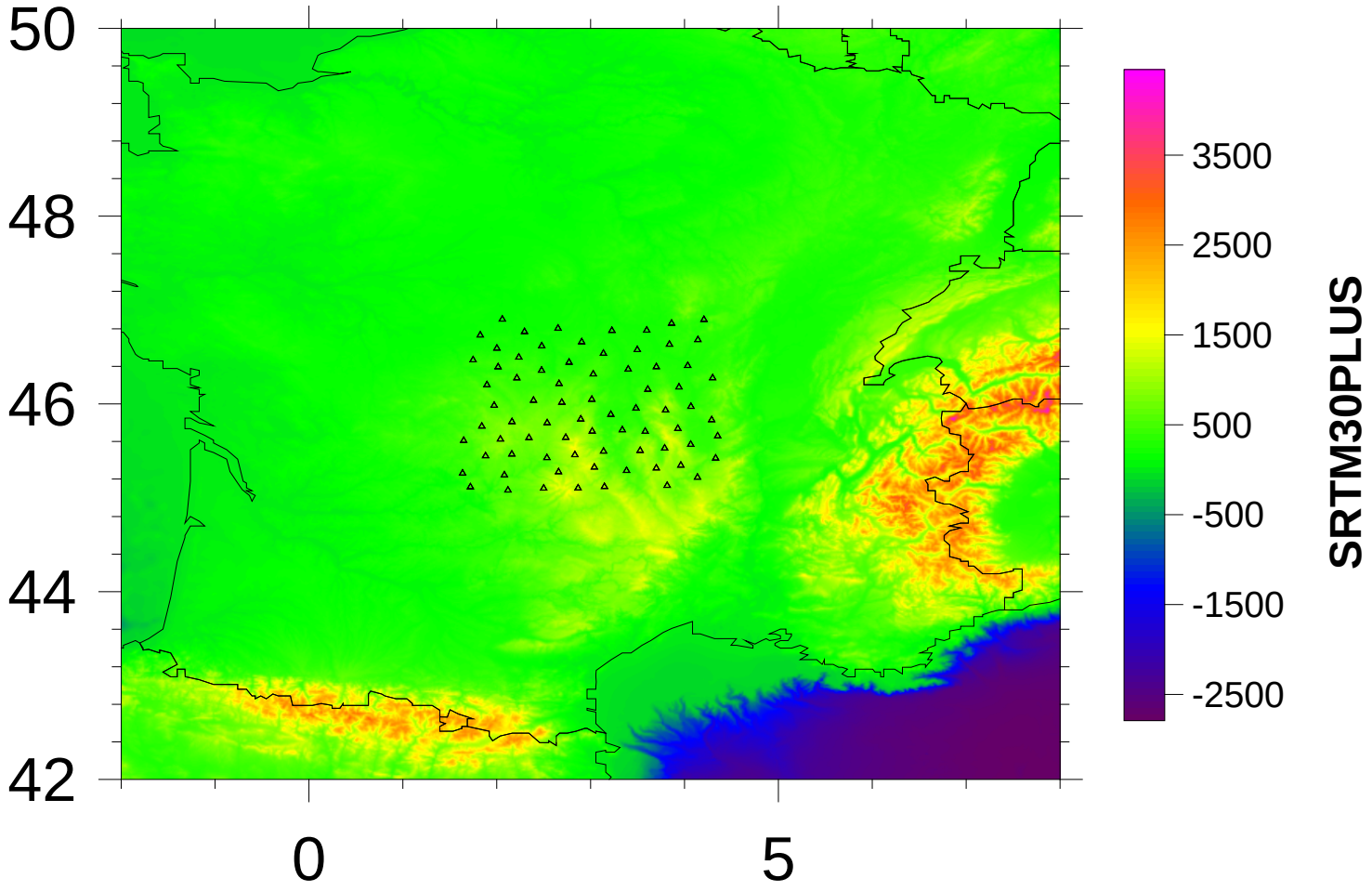
Selected at 0.1º x 0.125º (~ 10 km) resolution

Quasi-geoid comparison area, Auvergne, France

Relatively moderate mountainous area

The accuracy of gravity values : 0.25~0.75 mGal (Duquenne, 2007)

Ground Truth Data : GPS/leveling data



Accuracy of GPS/levelling data: 3.2 cm (linked to the French national levelling network (normal height system).
(Yildiz et al., 2012, Journal of Geodetic Science).

DATA AND METHODOLOGY

GOCE Gravity Gradient Anomalies

Gravity field quantities are derived by LSC in Local North Oriented Frame (LNOF)

GOCE TRF gravity gradient data in LNOF (GOCE EGG_TRF_2)

(Covering 13 months, from 2009 to 2010) are used

GOCE gradient data only of good quality are used taking into account flags for outliers

The GOCE TRF gradient data selected at 0.09º x 0.125º resolution (overlaps the area by 1ºx 1º)

GOCE Gravity Gradient Anomalies

The data downloaded from GOCE Virtual Online Archive are the gravity gradients of the Earth potential (V).

The gravity gradient anomalies (Tzz, Txx, Tyy and Tyz) corresponding to the anomalous potential (T) are obtained

$$T=V-U$$

U : GRS80 normal potential.

GOCE Gravity Gradient Anomalies

Four of the GOCE gravity gradient anomalies

Tzz

Txx

Tyy

Tyz

are used separately or in combination.

Txy and Txz are known to be poorly estimated or replaced by the estimates from global Earth geopotential models.

Least Squares Collocation (LSC)

- **LSC uses spherical approximation in local/regional applications, but NOT when evaluating an EGM.**

- **Data preprocessed by subtracting EGM2008 to degree 60 and Residual Terrain Modeling (RTM) restored afterwards for the comparison with ground truth data.**

- **Covariance functions estimated from reduced terrestrial free air anomalies.**
  (GRAVSOFT program EMPCOV).

- **Analytic model determined (COVFIT).**

- **LSC used for prediction, bias-estimation (without cross-overs !) and error-estimation (GEOCOL18)**

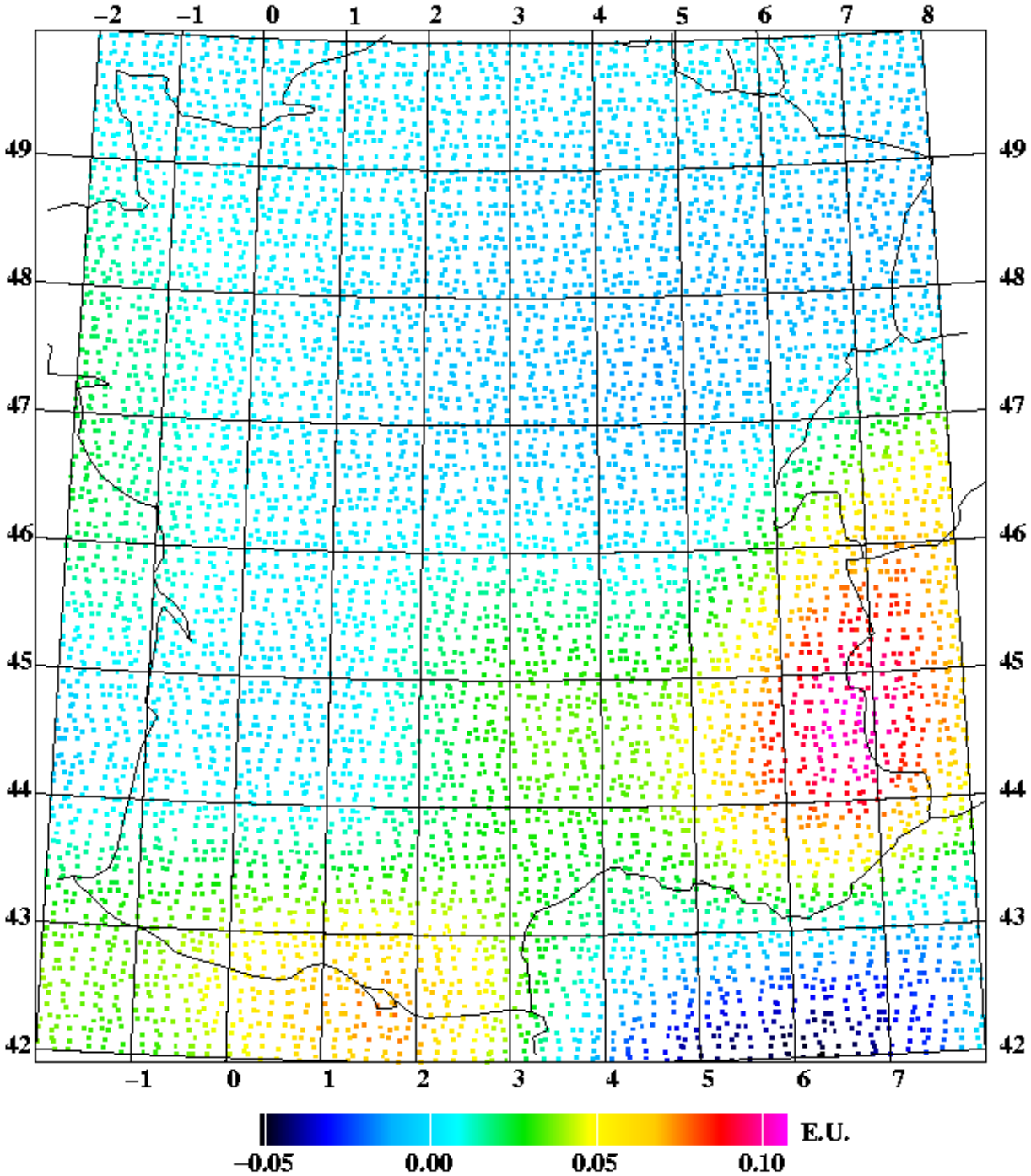
Residual Terrain Modelling

Terrain effects are subtracted, computed by the residual terrain modeling (RTM) method (Forsberg, 1984).

SRTM30 PLUS (Earth Topography at 30'' spacing) elevation model (Becker et al., 2009) are used over the area bounded in latitude by 35^{o} - 57^{o} and longtitude by -9^{o} – 15^{o} with respect to a mean elevation surface 1^{o} of resolution.

RTM effects on GOCE gravity gradients

	RTM on T_{zz}	RTM on T_{xx}	RTM on T_{yy}	RTM on T_{yz}
Mean	0.014	-0.006	-0.008	0.004
STD	0.026	0.01	0.018	0.022
Max	0.11	0.029	0.03	0.049
Min	-0.051	-0.05	-0.06	-0.07



RTM Effects on Tzz at GOCE satellite altitude

Maximum values are obtained for Tzz

Statistics of terrestrial point free-air gravity anomalies (mgal)

Nu.of Data 3819	Δg	$\Delta g - \Delta g_{EGM}$	$\Delta g - \Delta g_{EGM} - \Delta g_{RTM}$
Mean	3.6	-8.0	-2.4
Std.	24.8	24.2	13.0
Max	139.6	115.4	80.0
Min	-124.2	-149.5	-74.6

Std. is 52% of the origional

Statistics of quasi-geoid heights at GPS/leveling points (meters)

Nu.of Data 75	ζ	$\zeta - \zeta_{EGM}$	$\zeta - \zeta_{EGM} - \zeta_{RTM}$
Mean	49.55	0.41	-0.26
Std.	1.47	0.76	0.46
Max	52.15	1.9	0.81
Min	46.78	-0.80	-0.99

Std. is 31% of the origional

Statistics of GOCE Tzz

Eötvös (E.U.)=Eötvös unit = $10^{-9}s^{-2}$

Nu.of Data 7212	T_{zz}	$T_{zz} - T_{zz}^{EGM}$	$T_{zz} - T_{zz}^{EGM} - T_{zz}^{RTM}$
Mean	0.12	-0.0029	-0.017
Std.	0.17	0.05	0.038
Max	0.50	0.18	0.11
Min	-0.21	-0.17	-0.13

Std. is 22% of the origional

Statistics of GOCE Tyy

(E.U.)

Nu.of Data 7213	T_{yy}	$T_{yy} - T_{yy}^{EGM}$	$T_{yy} - T_{yy}^{EGM} - T_{yy}^{RTM}$
Mean	-0.09	0.004	0.013
Std.	0.08	0.036	0.028
Max	0.15	0.1125	0.11
Min	-0.29	-0.1033	-0.07

Std. is 35% of the origional

Statistics of GOCE Txx

(E.U.)

Nu.of Data 7214	T_{xx}	$T_{xx} - T_{xx}^{EGM}$	$T_{xx} - T_{xx}^{EGM} - T_{xx}^{RTM}$
Mean	-0.033	-0.0016	0.0047
Std.	0.09	0.027	0.02
Max	0.18	0.09	0.07
Min	-0.25	-0.12	-0.07

Std. is 22% of the origional

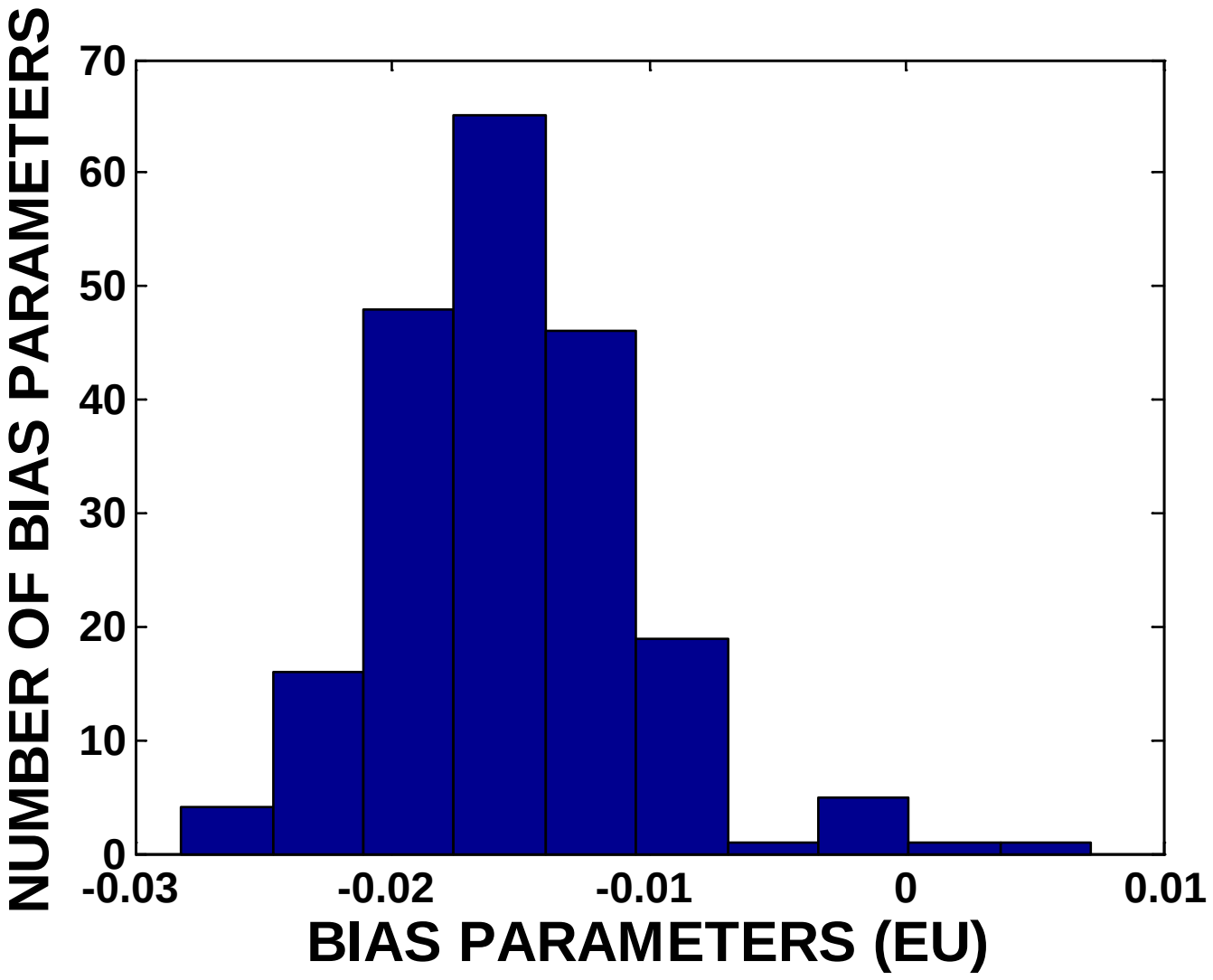
Statistics of GOCE Tyz

(E.U.)

Nu.of Data 7214	T_{yz}	$T_{yz} - T_{yz}^{EGM}$	$T_{yz} - T_{yz}^{EGM} - T_{yz}^{RTM}$
Mean	0.054	-0.002	-0.007
Std.	0.11	0.04	0.03
Max	0.30	0.11	0.09
Min	-0.24	-0.14	-0.10

Std. is 27% of the origional

BIAS ESTIMATION



RESULTS

Use of Tzz with/without bias

	Free Air Gravity Anomaly (mgal)				Quasi-Geoid (m)		
Input Data		Mean	Std.	Error	Mean	Std.	Average Error
Tzz	Predictions	-0.2	13.6	9.4	0.4	0.5	0.5
	Differences	-2.2	11.6		-0.6	0.2	
Tzz+ bias	Predictions	-0.9	11.0	9.5	0.5	0.48	0.5
	Differences	-1.5	9.9		-0.8	0.189	

RESULTS

Seperate use of GGs

	Free Air Gravity Anomaly (mgal)				Quasi-Geoid (m)		
Input Data		Mean	Std.	Error	Mean	Std.	Average Error
Tzz	Predictions	-0.2	13.6	9.4	0.4	0.5	0.5
	Differences	-2.2	11.6		-0.6	0.2	
Txx	Predictions	1.4	14.9	10.2	0.08	0.9	0.6
	Differences	-3.8	14.4		-0.3	0.5	
Tyy	Predictions	0.4	12.2	10.3	0.5	0.5	0.6
	Differences	-2.7	13.9		-0.8	0.4	
Tyz	Predictions	-0.4	9.9	10.0	-0.4	0.2	0.6
	Differences	-1.9	20.1		0.1	0.6	

RESULTS

Combined use of GGs

	Free Air Gravity Anomaly (mgal)				Quasi-Geoid (m)		
Input Data		Mean	Std.	Average Error	Mean	Std.	Average Error
Tzz+ Tyy	Predictions	-0.7	13.1	9.3	0.4	0.4	0.5
	Differences	-1.6	11.1		-0.6	0.17	
Tzz + Tyy + Txx	Predictions	-1.2	13.5	9.2	0.46	0.42	0.5
	Differences	-1.2	11.2		-0.6	0.15	
Tzz + Tyy + Txx + Tyz	Predictions	-1.3	13.2	-	0.4	0.43	-
	Differences	-1.1	11.2		-0.6	0.147	

Conclusion –Prediction from GOCE GG

Tzz gives best results compared to other GG separately. STD: 11.6 mGal (gravity anomaly) and 20.4 cm (quasi-geoid)

Simultaneous bias parameter estimation for Tzz improves the STDs to 9.9 mgal and 18.9 cm.

The combination of four GOCE gravity gradients STDs 11.2 mGal and 14.7 cm.

Combination of four of the GOCE gradients does not improve the gravity anomaly prediction, compared to the use of Tzz only, whereas it improves the quasi-geoid prediction considerably.