Vertical gradient of gravity (VGG) in earth sciences: Significance and applicability

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MICROGRAVIMETRY

VGG in FREE AIR EFFECT (FAE)

NEAR SURFACE GEOPHYSICS VOLCANO GEODESY

IF IN SITU VGGS ARE NOT AVAILABLE: PREDICTION OF VGG FIELD (VALUES)

MODELLING THE CONTRIBUTION OF TOPO-MASSES TO VGG

- High resolution (a few meters) high accuracy (10 cm) DTM
- Correct choice of constant reference topo-density
- Numerical volumetric Newtonian integration by means of Toposk software

PREDICTED VGG FIELD



PREDICTED VGG FIELD

Deviates strongly from constant normal FAG in (alpine/volcanic) areas of prominent rugged topo-relief



UVGG measurements with relative gravimeter in tower mode

PREDICTED VGG FIELD

Fairly well approximates true in-situ VGGs in areas of prominent rugged topo-relief

IN SITU VERIFICATION TEIDE (TENERIFE), ETNA (SICILY)





IMPROVEMENTS TO VGG PREDICTION

correction for man-made structures
 local in-situ DEM improvement

ETNA VOLCANO MONITORING (GRAVIMETRIC) NETWORK: REFINED VGG PREDICTION AND IN SITU VERIFICATION

gravitational effect (on VGG) of road-side walls at relative points
 gravitational effect (on VGG) of buildings (refugio) at absolute points



ETNA DRONE-PHOTOGRAMMETRY DEM AND PREDICTED VGG REFINEMENT



ETNA VOLCANO MONITORING NETWORK:PIZZI DENERI OBSERVATORYREFINED VGG PREDICTION AND IN SITU VERIFICATION(PDN 2847m)

□ drone-flown photogrammetry (res 50 cm, vert.acc. 10 cm) to improve the inner-most zone DEM for topographic contribution to VGG computation



IN SITU VERIFICATION OF PREDICTED VGG FIELD



SIGNIFICANCE AND APPLICATIONS – MICROGRAVIMETRY



Gal				
0.045	FREE AIR			
0.035	CORRECTION			
0.025				
0.015		Correction (reduction)		
0.005		for gravimeter sensor height		
-0.005		Sensor height 25 cm		
-0.015		VGG vs FAG		
-0.025		(FAE difference)		
-0.035				
-0.045		ETNA		
-0.055				

ETNA VOLCANO: NE-RIFT 2002 ERUPTION

(PIANO PROVENZANA SKI RESORT DESTROYED)

SIGNIFICANCE AND APPLICATIONS VOLCANO GRAVIMETRY

high vertical displacements at NER (2002) – 2 m
 high time-lapse gravity changes at NER (2002) – 350 mjuGal

Point	Vertical	Predicted VGG	Expected deviation
	displacement (m)	(µGal/m)	(µGal)
LZ	-2.16	-371	135
DG	-2.329	-357	113
СО	-1.403	-374	92

Table 1. Expected deviation in free-air correction as a result of difference between predicted VGG and normal free-air gradient (-308.6 µGal/m) multiplied by observed vertical displacement at three selected benchmarks of the NE-rift gravity-deformation monitoring

MICROGRAVIMETRY

VGG in DEFORMATION-INDUCED TOPOGRAPHIC EFFECT (DITE)

VOLCANO GEODESY

VOLCANO GRAVIMETRY

surface deformation

 indicates pressure and volume changes
 gravity changes
 indicate mass and density changes

METHODOLOGY



 $\Delta g^{\text{DITE}} \equiv \Delta g^{\text{FAE}} + \Delta g^{\text{TDE}}$, defining equation

 $\Delta g^{\text{DITE}}(P) \approx \gamma_{\text{N}} \Delta h(P) + [a^{\text{T}*}(P^*) - a^{\text{T}}(P)]$

numerical realization

FAG-DITE

APPROXIMATION

BCFAG-DITE APPROXIMATION

 $\Delta g^{\text{DITE}}(P) \approx \gamma_{\text{N}} \Delta h(P) + 2\pi G \varrho_0 \Delta h(P) = [\gamma_{\text{N}} + 2\pi G \varrho_0] \Delta h(P) = BCFAG * \Delta h(P)$

 $\Delta g^{\text{DITE}}(P) \approx \gamma_{\text{N}} \Delta h(P)$

WE HAVE STUDIED THE NATURE OF DITE BY NUMERICAL SIMULATIONS

of deformation fields of various shapes imposed over various topo-relief shapes

THE NATURE OF DITE SPANS FROM NORMAL-FREE-AIR-LIKE TO BOUGUER-LIKE

DITE CONCLUSIONS

The nature of DITE varies between normal-free-air-like and Bouguer-like depending on the shape and horizontal extent of the deformation field and on the shape of the relief over which it is exposed (in most cases it is closer to Bouguer-like)
 The most accurate numerical realization of DITE is the "geDITE"

 $\Delta g^{\text{DITE}}(P) \approx \gamma_{\text{N}} \Delta h(P) + [a^{\text{T}*}(P^*) - a^{\text{T}}(P)]$

It requires the deformation field known in areal form
 if vertical displacments are known only on benchmarks, two approximations of DITE are available: BCFAG-DITE and FAG-DITE
 FAG-DITE approximation suits only in special cases of very narrow spiky deformation fields over cone-shaped steeper relief
 in all other cases BCFAG-DITE suits better

THANKS FOR YOUR ATTENTION AND CU OUT THERE

Teide summit (Tenerife island) 3718 m asl