Workshop di consultazione della comunità scientifico/applicativa sulla missione ESA NGGM/MAGIC



# Deep interior properties and dynamics, Natural resources

Multiscale imaging of potential field sources

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## DISTAR Università di Napoli Federico II

- Maurizio Fedi : Magsat anomalies in Europe; methods for crustal models of density and magnetization, at different scales, data from comprehensive models
- *Giovanni Florio*: methods for crustal models of density and magnetization, at different scales
- *Maurizio Milano*: EMMP data analysis, CHAMP and SWARM data modelling; multiscale methods
- Umberto Riccardi: variazioni altimetriche del livello del mare dati Jason 3; ciclo idrologico in Africa dati Grace

## **MULTISCALE ANALYSIS**

*Multiscale analysis* consists in studying the source properties from the field at a set of different altitudes or, in other words, in the 3D space

*Multiscale modeling* help obtaining potential field models across a broad range of scales, so yielding a better definition of the source parameters .

In fact, single-scale models often do not interface well with each other across wide ranges of scales.

In particular, critical and useful approximations made at one scale frequently break down completely at other scales.



## MULTISCALE ANALYSIS OF POTENTIAL FIELD SATELLITE DATA

Bulding a multiscale potential field dataset

Multiridge/scaling function analysis of the multiscale dataset

Depth to deep crustal sources/kind of source/Mass Fast Estimation

### **MULTISCALE METHOD**



#### **GEOMETRIC APPROACH**

(Fedi et al., 2009)

REDUCED EULER EQUATION

$$(z - z_0)\frac{\partial F_q}{\partial z} = -N_q F_q,$$
$$(x - x_0)\frac{\partial F_q}{\partial x} = -N_q F_q,$$



Figure 3. The multiridge geometric method. Vertical sections of the first vertical derivative of the total field produced by the following simple sources (in magenta): (a) horizontal cylinder, (b) thin dike, and (c) contact. The sources are magnetized by induction only, with inclination of 60° and source azimuth of 90°. Ridges R<sub>c</sub> (red solid lines),  $R_{\rm H}$  (yellow solid lines), and  $R_{\rm H}$  (white solid lines) intersect at the center or top of the source (x<sub>0</sub> = 0 m; z<sub>0</sub> = 15 m). Upward continuation-levels range from 0 to 25 m, with 1-m vertical steps.



#### FAST MASS ESTIMATION (Fedi, 2007)

$$W_{g1}(\overline{\mathbf{r}}_0) = \left| \frac{\gamma M z}{(z - \overline{z}_0)^2} \right|_{z = -\overline{z}_0} = \frac{\gamma M}{4\overline{z}_0}$$

## MULTISCALE ANALYSIS OF CRUSTAL STRUCTURES





## **AEROMAGNETIC/SATELLITE DATASET**

EMMP at 100 km of altitude







## MULTISCALE ANALYSIS OF CRUSTAL STRUCTURES





Milano M., Fedi M. and Fairhead J.D., 2016

## **MULTIRIDGE ANALYSIS**



100 km altitude





For each profile the highest resolution was searched to have the clearest definition of the ridges

1<sup>st</sup> order derivative for profile p1 2<sup>nd</sup> order derivative for profiles p2, p4, p6 3<sup>rd</sup> order derivative for profiles p3 and p5

## MULTIRIDGE ANALYSIS (AEROMAGNETIC DATA)

Seismic sections LT-7, LT-2, LT-4, CEL01.

**Ridges** correspond to the TESZ region

Depth values retrieved: 37 - 42 km

Depth values retrieved by choosing the bestfit straight lines to the ridges, in a least-square sense



Milano M., Fedi M. and Fairhead J.D., 2016

#### **DEFINING THE KIND OF SOURCE**



#### The homogeneity degree *n* may be computed



 $n \cong -0.8$  $h \cong 40 / 45 \ km$ 

The depth values obtained by the scaling function method agree with the depth estimates obtained with the geometric method.

The estimated homogeneity degrees can be interpreted as typical for finite fault or sill structures. These kinds of idealized models can be adopted for explaining the most complex features of the morphology of an interface or a basement.

### 3D MODEL OF THE MOHO BOUNDARY BENEATH THE TESZ



#### Gravity field from GOCE satellite data in the TESZ region 25. 25° 20° 30 g 15; 20° ß 15 Α В 55° . 55° 55. 55° altic basin Relarus Polis 1assif Free-air gravity field 50. Bohemian massif <sup>50°</sup> Bouguer gravity field 50° 50° Carpat Pannonian basin 45° 45' 45° 45° 35 25° 20° 25° 20 60 80 60 80 100 120 140 160 180 -20 0 40 Moho depth model BB OB PDDB PB OTB (Pastorutti and Braitenberg, 2019) km

40

35

45

50

### SIMPLIFIED SYNTHETIC MODEL OF TESZ SUTURE ZONE





Gravity gradient

#### **CRUSTAL SOURCES**

Multiridge analysis of gravity synthetic model of the TESZ region

#### **GRAVITY FIELD PRODUCED BY A TESSEROID MODEL OF THE MOHO**



### **CRUSTAL SOURCES**

Multiridge analysis of gravity synthetic model of the TESZ region

## GRAVITY FIELD GENERATED BY A TESSEROID MODEL OF THE MOHO



#### **CRUSTAL SOURCES**

Multiridge analysis of gravity synthetic model of the TESZ region



Phase F	9	Science Impact Quantification	
Phase E2	8	Validated and Matured Science	
Phase E1	7	Demonstrated Science	
Phase B, C, D	6	Consolidated Science and Products	
Phase A	5	End-to-End Performance Simulations	
Phase 0	4	Proof of Concept	
(Pre –) Phase 0	3	Scientific and Observation Requirements	
Pre – Phase 0	2	Consolidation of Scientific Ideas	
Pre – Phase 0	1	Initial Scientific Idea European Space Agency	

Is an E2E simulator in place and are the most important processes and input parameters (including uncertainty estimates) properly represented?	Partly
Is an error propagation model in place allowing the rigorous computation of uncertainties (e.g. accounting for co-variant error effects) for measurements and observations?	
Has a set of realistic test scenarios been established and are they scientifically justified?	Space: yes Time: not yet
Is the simulator tested and validated and applied for the predefined set of scenarios?	Space: yes Time: not yet
Are all assumptions of the performance simulator documented and critically discussed?	yes
Has the robustness of the simulator been demonstrated against independent observations (e.g. campaign data)?	yes
Is a draft instrument calibration strategy available and properly described?	
Is there a demonstrated interest of users?	yes
Is there a first evaluation of (simulated or measured data) in applications?	Partly