Foreword

Satellite geodetic positioning for geosciences (dedicated to Michele Caputo's 90th birthday)

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1 The outlook of the special issue

On 8 March, 2017, at the Accademia dei Lincei (Rome), a Symposium has been organized under the title “Satellite Geodetic Positioning for Geosciences”. This is one of a series of initiatives periodically dedicated to explore the scientific progresses of Geodesy and its interrelations with other sciences as Geophysics, Physics, Mathematics and so on. This year the focus has been on the advancements of satellite positioning and its impact on Geosciences.

On the other hand, since Prof. Michele Caputo, great Italian scientist and Academician, first class geodesist and outstanding pioneer geophysicist, was going to become 90 years old the following May 5th, this meeting was naturally dedicated to honour Prof. Caputo.

The program of the day has been conceived as a view, zooming on the contributions of positioning to Geosciences through all scales, from the global level, with the unification of the Earth Observations into a unique reference system, down to the local level, with the geodetic monitoring

of specific areas to study and predict natural and anthropic hazards.

The explored items, though not exhaustive, testify the significant activity of the Italian scientists and institutions in this particular scientific field.

As it can be inferred from the content of the Symposium, the presentations had a double purpose, i.e., to review the state of the art and to present new achievements in the various fields.

2 The figure of Michele Caputo

The polyhedral scientific personality of Michele Caputo was born in physical mathematics and grown at the school of Antonio Marussi. So, starting from the abstract tools of modern geometry, he made a short step into the geometry of the gravity field, which was the elective subject of the Trieste school.

From this to the functional modelling of the gravity field, to the distribution of masses inside the Earth and to the stresses they generate, to rheology, was Caputo's path finally landing to the elastic models of wave propagation within the Earth body and its free oscillations. In this way, Caputo has achieved a 360° vision of our sciences, such that of the motto “Measurements, Models and Methods” he has been able to cover all the aspects.

As for Measurements we recall (e.g. Caputo 1957, 1963, 1964, 1978a, b, 1979):

- The gravimetric campaign of Karakorum, in the frame of the Italian expedition of 1954.
- The photogrammetric determination of the surface of a liquid.
- The measurements performed with the long pendulums at the Grotta del Gigante (Trieste).

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- The marine gravity campaign in the Pacific and Indian oceans, within a project of the Scripps Institute.
- The geodetic control network across the Messina straits.
- The leveling in the Po valley, to monitor subsidence.
- The measurements of the tectonic motion of Campi Flegrei and of the area of Pozzuoli.

As for the Models we recall (e.g. Caputo 1963a, b, 1965a, b; Desio et al. 1961; Slichter et al. 1964, 1965):

- The gravity field model of the Earth, Moon and Venus.
- The Somigliana-Pizzetti gravity model in 3D extended to a 3 axes ellipsoidal geometry.
- Glaciological and oceanographic models.
- Dynamic models of seismic wave propagation in a dispersive medium with memory.
- The model of free oscillation of the Earth.
- Models for earthquake prediction.

As for the Methods we recall (e.g. Bozzi and Caputo 1968; Caputo et al. 1980):

- Application of methods of cluster analysis and pattern recognition.
- Application of stochastic methods, particularly using higher order spectra (e.g. the bispectrum).
- Applications of the analysis of dynamic systems.
- Spectral methods for the solution of elasticity equations for the sphere and computation of proper oscillation modes of the Earth.

However, a special attention should be given to the development and application of the concept of fractional derivative (Caputo 1969, 2015).

The definition was already present in mathematical analysis, as introduced by Sobolev based on Fourier transform theory, though Caputo has re-discovered it by using the Laplace transform. This approach is more suited to describe dynamic systems evolving in time.

In essence, after recalling the well-known properties of the Laplace transform

$$L(f) = \int_0^{+\infty} e^{-pt} f(t) dt; L(Df) = p \int_0^{+\infty} e^{-pt} f(t) dt, (f(0) = 0),$$

one can apply the concept of interpolating spaces, according to Lions-Magenes, to define for every real $z > 0$.

$$L(D^z f) = p^z L(f), (f(0) = 0).$$

With this new definition of the fractional derivative, Caputo has proposed a new form of the stress–strain relation, generalizing that of Knopoff, that reads.

$$\tau = I \int f_1(\cdot, z) D^z \text{Tr}(e) dz + 2 \int f_2(\cdot, z) D^z e dz.$$

This is called an elasticity model with distributed derivative orders; by suitably choosing f_1, f_2 Caputo shows how to build models of dissipative systems with memory.

Once conceived, such a general tool enabled Caputo to look for applications in other fields, where the theory of dynamic systems has a prominent role.

This is the case for instance of Economy and the theory of financial crises or Demography and Population Dynamics. So, after the year 2000 we can count 31 papers by Caputo in Economics and 15 papers in Demography (e.g. Kolari et al. 1996, 2002).

With such presupposes, we can only look forward for future interesting developments of Caputo's research.

3 A short chronology

1927	May 5, birth in Ferrara
1950	First master degree in mathematics on differential exterior calculus and Grassmanian Algebras
1954	Second master degree in physics on particles and plasma physics.
Called by Antonio Marussi at the university of Trieste.
Works on tensor calculus and theoretical cartography.
Photogrammetry for liquid surfaces.
1959	Called by the University of California (UCLA)
Works on gravimetry, marine gravimetry.
Stress state of the Earth interior compatible with the gravity field.
Theoretical and practical work on Earth tides, by using the pendulums of Grotta del Gigante.
Study of the free oscillations of the Earth; frequency splitting.
1965	Definition of derivatives of fractional order and corresponding elastic waves theory.
Studies on the problem of gravity absorption by matter, using solar eclipse data.
1967	Full professor of Geodesy at the university of Bologna.
Publication of the book “The gravity field of the Earth, from classical and modern Methods”, by Academic Press.
1974/76	President of I.N.G. (Istituto Nazionale di Geofisica). Works on seismology; application of pattern recognition theory to seismic risk assessment (cooperation with Kellis Borough).

- 1976 Called by Edoardo Amaldi to cover the chair of seismology at the University of Rome. Feltrinelli Award of the Accademia dei Lincei. Project to monitor the geodynamics of the Messina Straits. Measurements for the subsidence of the Po valley. Construction of stochastic/non linear earthquake models.
- 1979 Full member of the Accademia dei Lincei.
- 1983/1987 Harris Professor of Geophysics at Texas A/M University. Now Professor Emeritus.
- 1984 Publication of the Catalog of the Tsunamis of the Italian Coasts in Atti dell'Accademia.
- 1987 Publication of the monograph "Sismologia e segnali precursori dei terremoti".
- 1991 A special mention of the paper "What may Geodesy do for the studies of seismicity and of the rheology of the Earth?" presented at a symposium of the Accademia dei Lincei in honor of Antonio Marussi.
- 1997/on A series of researches on economical subjects (cooperation with F. Forte) by applying pattern recognition and dynamic systems theory with operators representing phenomena with memory.
- 2001/on A series of researches on demographic and biologic subjects, applying dynamic systems to the evolution of populations with memory.
- Professor Emeritus at the Sapienza University of Rome.

References

- Bozzi Zadro M, Caputo M (1968) Spectral, bispectral analysis and Q of the free oscillations of the earth. *Suppl Nuovo Cimento Ser I* 6:67–81
- Caputo M (1957) Rilievo fotogrammetrico della superficie di un liquido in moto in una canaletta sperimentale. *L'Energia Elettrica* 34(4):3–5
- Caputo M (1963a) Free modes of layered oblate planets. *J Geophys Res* 68(2):497–503. <https://doi.org/10.1029/JZ068i002p00497>
- Caputo M (1963b) Gravity in space and the dimensions and mass of the Earth. *J Geophys Res* 68(15):4595–4600. <https://doi.org/10.1029/JZ068i015p04595>
- Caputo M (1964) Glaciology. In: Marussi A (ed) *Geophysics of the Karakorum*. E. J. Brill, Leiden, pp 242
- Caputo M (1965a) The minimum strength of the Earth. *J Geophys Res* 4(15):955–963
- Caputo M (1965b) On the shape, gravity field, and strength of the Moon. *J Geophys Res* 70(16):3993–4003. <https://doi.org/10.1029/JZ070i016p03993>
- Caputo M (1969) *Elasticità e Dissipazione*. Zanichelli, Bologna
- Caputo M (1978a) Problems and advances in monitoring horizontal strain. In: *Proceedings of the 9th Conference: an Intern. Symposium on the applications of geodesy to geodynamics*, October 2–5 1978, Dept of Geodetic Science, Ohio State University, Rept., 280:103–110
- Caputo M (1978b) 2000 years of geodetic and geophysical observations in the Phlaegrean Fields near Naples. *Geophys* 56:319–328
- Caputo M (1979) Two thousand years of geodetic and geophysical observation in the Phlegrean Fields near Naples. *Geoph J of the Royal Astron Soc* 56(2):319–328. <https://doi.org/10.1111/j.1365-246X.1979.tb00167.x>
- Caputo M, Fabrizio M (2015) A new definition of fractional derivative without singular Kernel. *Progr Fract Diff Appl* 1(2):73–85. <https://doi.org/10.12785/pfda/010201>
- Caputo M, Harrison JC, vonHuene R, Helfer MD (1963) Accuracy of gravity measurements off the coast of southern California. *J Geophys Res* 68(10):3273–3282. <https://doi.org/10.1029/JZ068i010p03273>
- Caputo M, Keilis Borok V, Oficerova E, Ranzman E, Rotwain II, Solovieff A (1980) Pattern recognition of earthquake-prone areas in Italy. *Phys Earth Planet Inter* 21:305–320
- Desio A, Marussi A, Caputo M (1961) Glaciological research of the Italian Karakoram expedition 1953–1955. *Snow and Ice Commission, IAHS, Publ. No. 54*. pp 224–232
- Kolari J, Caputo M, Wagner D (1996) Trait recognition: an alternative approach to early warning systems in commercial banking. *J Bus Finance Acc* 23(1996):1415–1434
- Kolari J, Glennon D, Shin H, Caputo M (2002) Predicting large US commercial bank failures. *J Econ Bus* 54(4):361–387. [https://doi.org/10.1016/S0148-6195\(02\)00089-9](https://doi.org/10.1016/S0148-6195(02)00089-9)
- Slichter LB, MacDonald GJF, Caputo M, Hager CL (1964) Report of earth tides results and of other gravity observations at UCLA. *Communications de l'Observatoire Royal de Belgique, 69, Marées Terrestres*, 124–134
- Slichter LB, Caputo M, Hager CL (1965) An experiment concerning gravitational shielding. *J Geophys Res* 70(6):1541–1555