



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

**Istituto Nazionale di Geofisica
e Vulcanologia**

AOO INGV

Protocollo Generale - U

N. 0015984

del 07/11/2019



il Direttore

Gestione WEB

Ai Direttori di Dipartimento

Ai Direttori di Sezione

Al Dott. Salvatore GAMBINO

Al Responsabile del Centro Servizi Contabilità e Bilancio

Al Responsabile del Centro Servizi per il coordinamento delle attività

a supporto della Ricerca

Alla Segreteria della Presidenza

Oggetto: Pubblicità atti

Si notifica in copia l'allegata Delibera n. 218/2019 del 11/10/2019 – Allegato V al Verbale n. 08/2019 concernente: Cooperation Agreement tra Centre National de La Recherche Scientifique (CNRS), Universite de Montpellier, Istituto di Istruzione Secondaria Superiore Benedetto Radice di Bronte e Istituto Nazionale di Geofisica e Vulcanologia (INGV).

Dott. Giovanni TORRE



Delibera n. 218/2019

Allegato V al Verbale n. 08/2019

Oggetto: Cooperation Agreement tra Centre National de La Recherche Scientifique (CNRS), Universite de Montpellier, Istituto di Istruzione Secondaria Superiore Benedetto Radice di Bronte e Istituto Nazionale di Geofisica e Vulcanologia (INGV).

IL CONSIGLIO DI AMMINISTRAZIONE

- VISTO il Decreto legislativo 29 settembre 1999, n. 381, concernente la costituzione dell'Istituto Nazionale di Geofisica e Vulcanologia (INGV);
- VISTO il Decreto Leg.vo 25/11/2016, n. 218, concernente "Semplificazione delle attività degli Enti Pubblici di Ricerca ai sensi dell'art. 13 della Legge 7/08/2015, n. 124";
- VISTO lo Statuto dell'INGV, approvato con Delibera del Consiglio di Amministrazione n. 372/2017 del 9 giugno 2017, come modificato con Delibere del Consiglio di Amministrazione n. 424/2017 del 15 settembre 2017 e n. 501/2017 del 21 dicembre 2017, pubblicato sul Sito WEB istituzionale (Avviso di emanazione pubblicato sulla Gazzetta Ufficiale della Repubblica Italiana - Serie generale - n. 27 del 2 febbraio 2018), in particolare, l'art. 8, comma 6, lettera f), il quale prevede che il CdA "*omissis....delibera la partecipazione a società, fondazione e consorzi, nonché la stipulazione di accordi con organismi nazionali, europei e internazionali*";
- VISTO il Regolamento di Organizzazione e Funzionamento dell'INGV, emanato con Decreto del Presidente n. 45/2018 del 21/2/2018, pubblicato sul Sito WEB istituzionale, in particolare l'art. 39, il quale disciplina le *Collaborazioni con soggetti esterni*, stabilendo al primo comma che: "*I rapporti di collaborazione nell'attività di ricerca tra l'Ente e soggetti pubblici e privati, italiani e stranieri sono regolati attraverso contratti aventi come riferimento di massima la seguente tipologia: protocolli d'intesa, accordi di programma quadro, convenzioni operative*";
- VISTO il Regolamento del Personale emanato con Decreto del Presidente n. 118/2018 del 14/05/2018, pubblicato sul Sito WEB istituzionale;
- VISTO il Regolamento di Amministrazione, Contabilità e Finanza, emanato con Decreto del Presidente n. 119/2018 del 14/05/2018, pubblicato sul Sito WEB istituzionale;
- VALUTATA l'opportunità di procedere alla sottoscrizione del Cooperation Agreement tra Centre National de La Recherche Scientifique (CNRS), Universite de Montpellier, Istituto di Istruzione Secondaria Superiore Benedetto Radice di Bronte e Istituto Nazionale di Geofisica e Vulcanologia (INGV);
- CONSIDERATO che le Parti, con il presente Cooperation Agreement, istituiscono una cooperazione a livello internazionale, finalizzata alla realizzazione di una installazione congiunta, in foro, di un clinometro ottico, realizzato dal laboratorio "GEOSCIENCES Montpellier" dell'Università di Montpellier, insieme ad un clinometro AGI Lily di proprietà INGV-OE, presso



un sito di proprietà dell'Istituto di Istruzione Secondaria Superiore Benedetto Radice, in località Bronte (CT);

- CONSIDERATO che l'attività da espletare rientra tra i compiti scientifici e istituzionali dell'INGV;
- VISTI i pareri favorevoli del Direttore di Sezione e del Direttore di Dipartimento,

DELIBERA

L'approvazione dello schema del Cooperation Agreement tra Centre National de La Recherche Scientifique (CNRS), Universite de Montpellier, Istituto di Istruzione Secondaria Superiore Benedetto Radice di Bronte e Istituto Nazionale di Geofisica e Vulcanologia (INGV), allegato alla presente quale parte integrante e sostanziale (all.1).

Viene dato mandato al Presidente dell'INGV alla sottoscrizione definitiva dell'atto in questione.

Letto, approvato e sottoscritto seduta stante.

Roma, 11/10/2019

La segretaria verbalizzante
(Dott.ssa Maria Valeria INTINI)

IL PRESIDENTE
(Prof. Carlo DOGLIONI)

Cooperation agreement

BY AND BETWEEN

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, a public scientific and technological establishment, having its registered office at 3 rue Michel-Ange, 75794 Paris Cedex 16, France, SIREN n° 180089013, NAF code 7220Z, represented by its President and CEO, Mr Antoine Petit, who has delegated signing authority for this agreement to Mr Jérôme Vitre, Regional Delegate of Délégation Occitanie Est, hereinafter referred to as "CNRS",

UNIVERSITE DE MONTPELLIER, a public scientific, cultural and professional establishment, SIREN n° 130 020 548, APE n° 8542 Z, having its registered office at 163 rue Auguste Broussonnet, 34090 Montpellier, France, represented by its President, Mr Philippe AUGÉ, hereinafter referred to as "UM",

The CNRS and UM, hereinafter referred to as the "Establishments", are acting in their own name and on behalf of the laboratory "GEOSCIENCES Montpellier" (GSM), Joint research unit n°5243, directed by Mr. ILEDEFONSE, hereinafter referred to as the "Laboratory"; being specified that UM mandates the CNRS to sign this agreement.

Party of the first part,

AND

Istituto Nazionale Geofisica e Vulcanologia, having its registered office at Via di Vigna Murata 605 - 00143 Roma, ITALY, represented by its President Prof. Carlo DOGLIONI, hereinafter referred to as the "INGV",

Party of the second part,

AND

Istituto di Istruzione Secondaria Superiore Benedetto Radice, a state technical institute, having its registered office at via Sarajevo, 1, 95064 Bronte CT, ITALY, its director, Ms Maria Pia CALANNA, hereinafter referred to as the "Owner" or "ISRADICE",

Party of the third part,

The Establishments and INGV are hereinafter referred to individually as the "Party" and jointly as the "Parties".

Recitals:

The Laboratory possesses skills in the field of Geodesy, Geophysics and instrumentation. In particular:

- the Establishments are the owner of the following monitoring device: *an optical borehole tiltmeter made in the framework of the MIRZA project. This instrument has been designed to have a high resolution (2 nanorad) and a low long term (drift about 2 microrad/yr);*
- the Laboratory is a member of a research project "MIRZA" in the frame of which the device is also used.

The INGV possesses skills in the field of Geodesy, Geophysics and Volcanology. In particular, INGV is the owner of the following monitoring device: *a Lily Borehole tiltmeter.*

Moreover and for the implementation of the study described in appendix 1 jointly performed by the Parties, the said monitoring devices will be installed in ISRADICE, hereinafter referred to as the "Owner".

Therefore, the Parties decide to conclude this cooperation agreement, hereinafter referred to as the "Agreement".



The following has been agreed upon:

Article 1 – Definitions

In this agreement, the following capitalized terms shall have the respective following meanings:

Affiliate: Affiliate of a Party means any and all legal entity that controls, or that is directly or indirectly controlled by, said Party, to wit when said Party directly or indirectly holds over 50% of said legal entity's share capital; or over 50% of the voting rights of the shareholders or partners of said legal entity.
Affiliates of the Parties are listed in Appendix 3.

Agreement: means this research collaboration agreement, its annexes and its possible amendments.

Confidential information : means any and all information and/or data, in any form and of any nature whatsoever, that is disclosed by a Party to one or several other Parties under the Agreement, subject to the disclosing Party having clearly and unambiguously stated its confidential nature. Each Party acknowledges that other Parties' Own Knowledge shall constitute Confidential Information.

Own Knowledge: means the information and technical and/or scientific knowledge and/or any other type of information, in any form, patentable or not and/or patented or not, as well as any rights relating hereto, belonging to a Party or held by this Party before the effective date of the Agreement and/or developed or acquired by it outside the scope of the Study. The Parties' Own Knowledge at the effective date of the Agreement are specified in the Appendix 2 hereto.

Results: means any and all information, technical and/or scientific knowledge, patented or not, patentable or not, including know-how, software, plans, sketches, drawings, formulae or any and all type of information, in any form, and all the rights relating hereto, developed within the frame of the Study.

Article 2 – Purpose

The Parties hereby decide to conduct a joint study, entitled: "Assessment of performance of an optical borehole tiltmeter", hereinafter referred to as the "Study". The corresponding work program is described in the scientific and technical appendix (Appendix 1).

The purpose of the Agreement is to set out the terms and conditions under which the Study will be performed. The Parties shall make every effort to ensure its due and proper progress in accordance with its obligation of due care.

Article 3 – Modalities of implementation of the Study

3.1 SCIENTIFIC MANAGERS

Scientific managers of the Parties, are :

- For the Establishments: Mr. Jean CHERY (jean.chery@umontpellier.fr), researcher in the Laboratory;
- For INGV: Mr. Salvatore GAMBINO (salvatore.gambino@ingv.it).
- For ISRADICE: Ms Maria Pia CALANNA (ctis01100x@istruzione.it).

3.2 MEETINGS, REPORTS

Meetings may be held every at least once a year and/or upon the request of one of the Scientific managers and/or upon request of one of the Parties. Each meeting will be subject of a report.



Moreover, scientific reports on the data obtained from the monitoring devices will be regularly drafted by the INGV and the Laboratory's Scientific managers.

It has been agreed by the Parties that INGV and the Establishments shall grant to ISRADICE the right to use the said scientific reports for educational and non-commercial purposes only.

Article 4 – Modalities of occupation of ISRADICE's property

4.1 OBLIGATIONS OF THE OWNER

The Owner undertakes to:

- allow the installation of both monitoring devices in its property (hereinafter referred to as the "site") and to provide to the Partners any needed information, security rules and/or applicable regulations under which they shall comply in the site;
- make available a dedicated place where a computer will be installed for collecting and storage of data obtained by monitoring device owned by the Establishments;
- grant access of its server to the Laboratory so that data stored in the computer may be remotely accessible.

4.2 OBLIGATIONS OF THE INGV AND THE ESTABLISHMENTS

The INGV and the Establishments undertake to:

- use its monitoring device in the Owner's site solely for the purpose defined in the present Agreement.
- regularly send to ISRADICE scientific reports on the data collected in the site.

4.3 MONITORING DEVICE INSTALLATION

The site owned by ISRADICE is localised in via Sarajevo, 1, 95064 Bronte CT, ITALY.

In order to implement the Project, the Parties agree to drill boreholes (approximate depth: 25 m / approximate diameter: 120 mm) in the site. Afterwards, the monitoring device (i.e. tiltmeters) will be installed in the drilling.

The Parties undertake to inform each other in case of any help from third parties that they may need for drilling and/or installing its monitoring devices.

Article 5 – Financial arrangements

Each Party shall support its cost of the Study.

The occupation of the ISRADICE's property is concluded free of charge.

In particular, the Establishments have received funding from INSU-CNRS for travels and consumables in the frame of the Study.

Article 6 – Confidentiality - Publications

6.1 CONFIDENTIALITY

Each Party undertakes to refrain from publishing or disclosing, in any manner whatsoever, the confidential information (Own Knowledge included), belonging to the other Party, of which it may become aware during



negotiation and/or performance of this Agreement. This undertaking shall remain effective for three (3) years as from the termination or expiry date of this Agreement.

The Parties are no longer bound to commitments of this article 6.1 insofar as they can prove that the confidential information :

- is publicly available without an infringement having been committed by them;
- has been received lawfully from a third party;
- was already in their possession prior to the conclusion of this Agreement;
- has been developed independently and in good faith by members of their staff that did not have access to the Own Knowledge;
- has been disclosed pursuant to court order;
- has been disclosed by the Party from which it originates;
- has been used or disclosed with the written consent of the Party from which it originates.

In particular, the Parties hereby agree to disclose information on Own Knowledge to third parties when it is necessary for the installation of the monitoring devices in the site mentioned in Recitals.

6.2 RESULTS

Any and all draft publication or communication on the Results, by either Party, shall be subject, during the term of this Agreement, and for two (2) years following its expiry date, to the prior written authorization of the other Parties which shall provide notice of its decision within a maximum thirty (30) days deadline as from the date of the request. At the end of said deadline and in the absence of a reply, authorization shall be deemed to have been given.

The other Parties shall be entitled to delete or change certain details, which, if disclosed, would be liable to compromise the industrial and commercial use, in optimum conditions of the Results. Such deletions or changes shall not affect the scientific value of the publication.

If the information set forth in the publication or communication is required to be protected as industrial property, either Party may postpone the publication or communication for a maximum period of twelve (12) months as from the date of the other Party's request.

Said publications and communications shall refer to the contribution made by each Party to the realisation of the Study.

6.3 EXCEPTIONS

This article shall not prevent:

- either the obligation binding on each of the persons involved in the Study to submit an activity report to the establishment which he/she reports to, provided this communication does not constitute a disclosure within the meaning of industrial property legislation;
- or defence of theses by researchers, whose scientific work relates to the purpose of this Agreement, with such defence being organised whenever necessary so as to guarantee the confidentiality of certain results of the work conducted pursuant to the Study, whilst complying with the effective university regulations;
- the Establishments to grant access for research purposes of the data obtained in the frame of this Agreement to its partners of the MIRZA project (especially, Aquitaine Electronique and the research unit n°8001 LAAS-CNRS) and to Mr Pierre BRIOLE (researcher in the joint research unit CNRS / Ecole Normale Supérieure n°8538 "LG-ENS").

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6.4 USE OF THE NAMES OF THE PARTIES

Each Party undertakes not to use the name, logo and/or brand name of the other Party (and its laboratories) or of one of its agents, in the frame of the use or exploitation of the Results originating from the Agreement, in particular for promotional purpose, whatever the medium used (video, advertising brochure, press kit, etc.) without the prior written consent of the Party concerned.

Article 7 – Ownership of the Own Knowledge and of the Results

In principle, it has been agreed by the Parties that this article shall only apply for INGV and the Establishments

7.1 OWN KNOWLEDGE

INGV and the Establishments shall be the sole owner of its Own Knowledge.

In particular, both Parties' respective monitoring devices (mentioned in Recitals) and its eventual amelioration during the performance of the Agreement, remain the property of the said Parties.

Other Party shall receive no rights, under this Agreement, over this Own Knowledge, subject to article 8 hereinafter.

7.2 RESULTS

Both Parties hereby agree that the Results generating from the Study are not meant to be patentable. Otherwise, they shall meet without undue delay in order to set out the proportion of co-ownership and the valorisation strategy of the said patentable results.

Moreover, both Parties hereby agree that they shall be the owner of data obtained from its respective device. Notwithstanding, both Parties grant to each other access rights to its data for the performance of the Study and for academic and non-commercial activities (i.e research and teaching activities) outside the scope of the Study.

Results that do not constitute data obtained from devices, shall be equally owned by both Parties.

Article 8 – Use and exploitation of the Own Knowledge and of the Results

In principle, it has been agreed by the Parties that this article shall only apply for INGV and the Establishments

8.1 USE OF OWN KNOWLEDGE

Both Party grant to each other the right to use its Own Knowledge solely for the proper performance of the Agreement and for the latter's validity period.



8.2 USE OF THE RESULTS FOR RESEARCH

Both Parties may freely, and without valuable consideration, use the Results for their own research requirements, with the exclusion of any industrial and/or commercial activity.

8.3 INDUSTRIAL AND COMMERCIAL USE

8.3.1 Industrial and commercial use of the Results

Prior to any direct or indirect industrial and/or commercial use of the Results jointly owned by both Parties, an agreement setting forth, notably, financial terms, shall be signed by the said Parties.

8.3.2 Use of Own Knowledge for the industrial and/or commercial use of the Results

Should the use of the Results by either Party require use of the prior know-how or patents held, either fully or partly, by the other Party, the latter shall endeavour, subject to the rights granted to third parties, to allow the said use. The terms and conditions of use of Own Knowledge shall be subsequently established contractually, on a case-by-case basis.

Article 9 – Term

9.1 Notwithstanding its signature date, the Agreement shall become effective as from its date of signature by the Parties and shall remain effective for a term of three (3) years.

9.2 It may be renewed at the end of this term by means of an amendment signed by the Parties specifying, in particular, the purpose of this extension, and the terms and conditions for its financing.

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9.3 Notwithstanding expiry or termination of the Agreement under the conditions set forth in article 10 hereof:

- the undertakings made in article 6 shall remain in force during the term provided in said article; and
- subject to any provisions to the contrary contained therein, the undertakings made in article 8 of the Agreement remain effective in force until the expiry of the rights and obligations related to it.

Article 10 – Termination

10.1 CONDITIONS OF THE TERMINATION

This Agreement may be automatically terminated by either Party in the event of the other Party's breach of one or several of the obligations set forth in its various clauses. Termination shall only become effective two (2) months subsequent to the sending, by the aggrieved Party, of a registered letter with acknowledgment of receipt setting forth the reasons for the complaint, unless during this period, the defaulting Party were to have complied with its obligations, or were to present proof of an obstacle representing a case of force majeure.

The exercising of this right of termination shall not discharge the defaulting Party from having to comply with its contractual obligations until the effective termination date, subject to any loss suffered by the aggrieved Party as a result of the early termination of the Agreement.

10.2 EFFECTS OF THE TERMINATION

In the event of early termination of the Agreement, the Parties shall meet to discuss, in particular, the status of the Study and its development.

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In all events of either the expiry or termination of this Agreement, either Party undertakes to return all the documents and sundry materials to the other Party, which the latter may have provided to it, at the latter's request, without retaining copies thereof.

Article 11 – Obligation of information

Upon the occurrence of an event which could jeopardise the performance of the Agreement, the Parties undertake to inform the other one, by registered letter with acknowledgment of receipt, within ten (10) calendar days from the occurrence of said event, and to meet to decide on appropriate ways of taking action.

Article 12 – Liability and insurance

12.1 DAMAGE TO THE PARTIE'S PROPERTY

The materials and equipment provided by one Party to the other, or financed by this Party pursuant to a specific agreement, shall remain the property of said Party. Consequently, each Party shall be liable for the damage to the materials, facilities and machinery which it owns, including the materials entrusted to the other Party and the materials being tested, during the conducting of the Study, even if the other Party is responsible for the damage, with the exception of gross or intentional negligence by the latter.

12.2 EMPLOYEES OF THE PARTIES

Pursuant to the Study, the employees of either Party, who shall continue to be paid by their employer, may be called upon to work in the other Party's premises. Said staff shall then comply with the by-laws of the host establishment and with the technical instructions concerning the materials. However, these employees stay under the hierarchical authority of their employer.

Thus, as regards the staff whom it pays, each Party shall continue to be responsible for all the employer's social security contributions and tax obligations, and shall exercise, vis-à-vis the staff, all administrative management responsibilities (grading, promotion, discipline, etc.).

The Parties shall both provide cover for their respective employees as regards industrial accidents and occupational diseases without prejudice to any and all actions against liable third parties.

12.3 DAMAGE TO THIRD PARTIES

Each Party bears, as far as it is concerned, the financial consequences of the civil liability it incur under common law, due to the personal injury or material damages to third parties during the work carried out for the performance of the Study, within the frame of the Agreement.

12.4 INSURANCE

Each Party states it has subscribed to an insurance policy or is insured by the State, or acts as its own insurer to cover the damages it might cause within the frame of the performance of the Agreement.

Article 13 – Miscellaneous

13.1 INTUITU PERSONAE

The Agreement is executed *intuitu personae*. Consequently, no Party is authorised to transfer all or part of the rights and obligations hereunder to a third party without the prior and written agreement of the other Party.

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13.2 SUB-CONTRACTING

Is considered the sub-contractor of a Party only the natural person or legal entity linked to said Party, by a business contract in respect of which it performs a part of the work, purpose of the Agreement, and/or carries out supplies in compliance with the specifications peculiar to this research.

Neither Party may subcontract part of the services with which it is entrusted in order to perform this Agreement without the other Party's written authorisation. Each Party shall remain solely liable vis-à-vis both the other Party and third parties for the due and proper furnishing, by its subcontractor(s), of the services entrusted to the latter.

13.3 ENTIRETY OF THE AGREEMENT

This Agreement, together with its appendices, sets forth the entirety of the Parties' obligations taken within the frame defined in preamble. It cancels and replaces all agreements and documents, written and oral, drawn up and exchanged during the negotiation period.

However, it will not affect the rights and obligations arising from agreements concluded previously between the Parties and the purpose of which is separate from the Agreement's one.

13.4 INVALIDITY OF A CLAUSE

Should one or several provisions of this Agreement be held to be invalid, or found to be so in application of a treaty, legislation or regulations, or even subsequent to a final legal decision from a Court having jurisdiction, the other provisions shall retain all their effect and scope.

In this case, the Parties could sign an amendment, the purpose of which being the replacing of the invalid provisions whilst complying, insofar as possible, with their intention when this Agreement was signed, as well as the purpose and the spirit of the latter.

Article 14 – Governing law, disputes

This Agreement is governed by the law of the country where the defendant is domiciled, i.e. Laws of France or Italy.

In the event of a dispute regarding the validity, the performance or the termination of the Agreement, the Parties shall endeavour, before any other remedy, to settle their disagreement out-of-court. Were the disagreement to persist, it shall be filled in the defendant's domicile competent courts, i.e. in the French or the Italian jurisdiction.

Article 15 – Notifications

All notifications, communications, formal notice laid down by the Agreement shall be deemed to have been validly delivered if sent to the following addresses:

- For INGV :
INGV - Osservatorio Etno
Piazza Roma, 2
95123 – Catania – ITALY
E-mail : aoo.catania@pec.ingv.it
- For the Establishments:
CNRS Délégation Régionale Occitanie Est
Service Partenariat et Valorisation – réf. CNRS n°194563



1919 route de Mende
34293 Montpellier Cedex 5, FRANCE
Email: DR13.valorisation@cnrs.fr

- For the ISRADICE :
Ms Maria Pia CALANNA
Istituto di Istruzione Secondaria Superiore Benedetto Radice
via Sarajevo, 1, 95064 Bronte CT, ITALY
Email: ctis01100x@istruzione.it

Article 18 – Appendices

This Agreement consists of this core text and the following appendices :

- Appendix 1 (Description of the Study)
- Appendix 2 (INGV and the Establishments' Own Knowledge)
- Appendix 3 (Affiliates of the Parties)

In case of conflicts between the appendices and the core text of this Agreement, the latter shall prevail.

Done in Montpellier, in three originals,

For the Establishments
Mr Jérôme VITRE Regional Delegate Date:

For INGV
Mr Carlo DOGLIONI President Date:

For ISRADICE
Ms Maria Pia CALANNA Director Date:

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Appendix 1 – Description of the Study

1) Context

Volcanic hazards can be studied by a large variety of geophysical and geochemical methods. Because source pressure variation in the magma chamber deforms the whole volcanic structure, the shape variation associated to volcanoes inflation and deflation can be measured by ground-deformation measurements such as GPS displacements (e.g. Fukushima et al., 2005; Peltier et al., 2009), InSAR displacements (e.g. Yun et al., 2006), levelling (e.g. Ojibbo et al., 2004), tilt (e.g. Anderson et al., 2010; Gambino et al., 2014), strain (e.g.: Sturkell et al., 2013) or gravimetry data (e.g. Poland and Carbone, 2016). In order to link these measurements to the source process at depth, models of different complexities can be used, starting from simple spherical sources (Mogi, 1958; McTigue, 1987) to complex finite elements models with complex source geometries (e.g. Camacho et al. 2011).

A particular interest of volcano-geodesy is the possibility to assemble all kind of geodetic measurements into deformation models (e.g. Geirsson et al. 2014). Indeed, a given geodetic tool provides a specific component of deformation or mass transfer that can be compared to the prediction of a single model. This feature reinforces the interest of volcano monitoring by different geodetic systems having various capabilities in term of spatial and temporal coverage and also different precisions. For example, InSAR displays excellent spatial coverage but not a continuous monitoring, while GPS provides a continuous recording of the 3D motions of a limited amount of ground markers. Among these instruments, horizontal and vertical tiltmeters have a great power in term of tilt resolution: commercial and scientific tools display 10^{-8} - 10^{-10} rad resolution over a short-period. To used at their best capacity, they are usually installed at depth in order to shadow atmospheric and subsurface disturbances (e.g. Wyatt & Berger, 1980).

Because a 10^{-9} tilt occurring over a 1km length baseline corresponds to 1 μ m of vertical motion, this method has the capability to detect tiny deformations (e.g. Boudin et al. 2008 ; Jacob et al., 2010). However, the local character of the measurement (measuring baselines from 1cm to 500m, see Agnew, 1986 for a review) induces a great sensibility to local strain disturbance (hydrology, local subsidence) and also plagues data with unavoidable instrumental drift. To counteract this effect, long baseline tiltmeters have been developed that display very low drift (e.g. Boudin et al., 2011, Lesparre et al. 2016), but these instruments need special facilities (mines, tunnel), preventing their extensive deployment on volcanoes or industrial geological reservoirs. By contrast, borehole tiltmeters display larger drift rates due to their smaller baseline but can be installed as a network (Jahr et al., 2006; Warpinski et al., 1997). Because the ultimate goal of volcano-geodesy is often to provide reliable information about source process, signal redundancy is mandatory to constrain key source parameters such as position, geometry and volume change history. Such a network strategy has been very valuable to detect novel kind of source process at depth by geodetic means, especially in the case of unexpected features like transient motion (e.g. Miller et al, 2002). For this reason, we chose to put a special effort on borehole tiltmeters development (since 2012) and the associated inverse problem formulation (since 2015).

To reduce instrumental and environmental noise associated to borehole tiltmeters, our group has therefore developed a strategy for (1) providing low drift and low cost instrument (ANR RiskNat LINES 2009-2013) and (2) developing a inverse problem strategy to combine tilt, GPS and InSAR observation. This two-fold project is about to be completed:

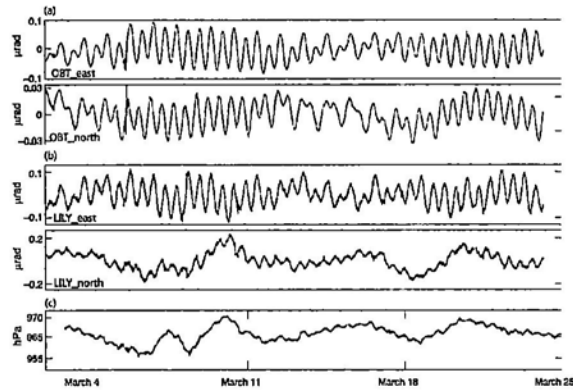
- We developed a new optical sensor (Seat et al., 2012) embedded into a novel kind of pendulum tiltmeter (Chawah et al. 2015). The performance of this instrument has been evaluated with the colocation of two tiltmeters (our prototype and a LILY tiltmeter from Jewell Instrument TM). As shown by figure 1, the determination of Earth tides is better achieved for the optical tiltmeter, that embeds a patented sensor configuration to auto-correct most of instrumental and environmental disturbance (Chéry et Collard, 2013). For example, the tilt signal is free of atmospheric pressure contamination and Laser diode wavelength variation. We pursued this instrumental improvement thanks to a collaborative project supported by the Fond Unique Inter-ministériel (FUI MIRZA 2015-2018). A small company (Aquitaine Electronique) is now able to produce the first prototype of a borehole tiltmeter devoted to high-precision reservoir monitoring. In the framework of this FUI project, a pre-commercial tiltmeter will be installed at the end of 2018 in the salt withdrawal site of Vauvert (Gard, see Raucoules et al. 2011).

Figure 1:

a : east and north tilt signal recorded by the optical tiltmeter (Chawah et al. 2015);

b : east and north tilt signal recorded by the LILY tiltmeter;

c: atmospheric pressure record at LSBB underground facility;



- We provided a tilt inversion methodology in order to jointly determine the strain source and instrumental parameters during inflation/deflation of geologic reservoirs or volcanoes (Furst et al. 2019). Figure 2 illustrates the ability of the methodology to recover both the volume variations in time (a and b) and the tiltmeters drift rates (c). This methodology is based on a global optimization method (Mohammadi & Saïac, 2003; Furst, 2018) allowing to deal with the non-linear character of the physical problem leading to a robust joint inversion of data.

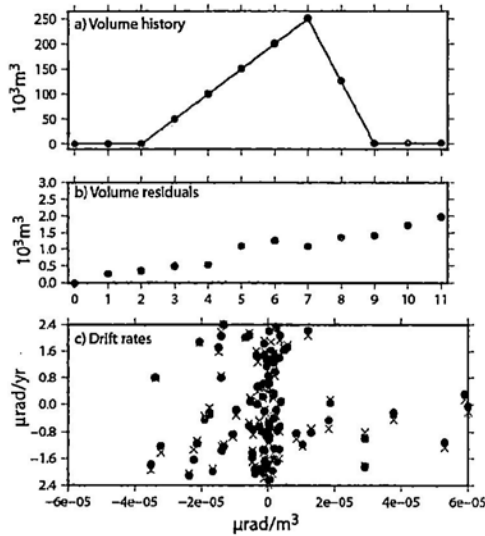


Figure 2: a) Optimal history of volume variations from the inversion process (red dots and line) compared to the target history (black line). b) Difference between the modeled volume variations and the target values. c) Drift rates from the inversion (red crosses) compared to the target drift rates (black dots).

We now propose to pursue this research with installing one optical tiltmeter and one commercial tiltmeter on Etna volcano in order to test the capability of these instruments to detect small deformation events and also evaluate the drift rate of the tiltmeters. The co-location of these instruments will allow to

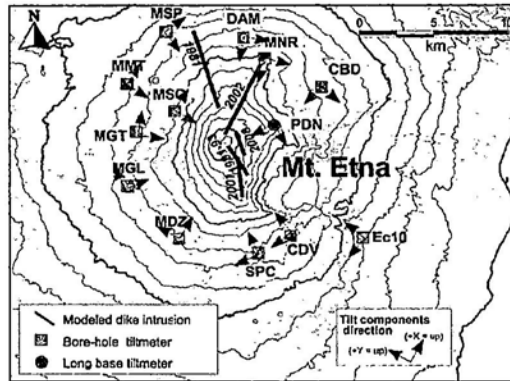
compare their respective drift. In addition to this instrumental effort, we will also combine available geodetic data on Mount Etna (provided by INGV Catania) as a test for our inverse problem methodology.

2) Work Program

2.1 Institute agreement and site selection. The initial phase of the project was done in July 2018 and April 2019 discussing the policy of collaboration and data exchange between Geosciences Montpellier and INGV Catania. Also, we selected the Bronte site for tiltmeters installation. This site on the west flank of the volcano is less disturbed by the tectonic motion associated to faulting than the sites of the east and south flanks as shown by seismicity and continuous GPS analysis (Aloisi et al. 2017).

Figure 3:

Borehole and long baseline tiltmeters installed on Mount Etna by INGV Catania (from Gambino et al. 2014)



2.2 Drilling and tiltmeters installation. We plan to drill 1 boreholes of 25m deep (120 mm of internal diameter) in the property of ISRADICE that already includes data transfer facilities. The drilling will be performed in summer 2019 by an operator contracted by INGV for geophysical instrumentation supervised by our team. The tiltmeters will be installed in the days following the drilling with the help of Aquitaine Electronique company, and will be in operation immediately.

2.3 Data analysis and inverse problem. The data will be daily acquired by a dedicated computer located at ISRADICE, then downloaded by ftp at Geosciences Montpellier. The time-frequency data processing will allow to separate slow events (tides, volcano inflation) from earthquakes. GPS, InSAR and tilt data will be processed using the codes developed at Geosciences Montpellier. Data assimilation and inverse problem will be performed using analytical forward models (Mogi 1958; Okada 1992) or Finite Elements models accounting for topographical change and variable rheological properties.

3) Reports

3.1 Tiltmeters comparison and drift estimate. Soon after an installation (usually a few months), a borehole tiltmeter stabilizes and its drift rate can be estimated by pass-band filtering. Because MIRZA tiltmeter and INGV instrument will be set at 25m depth in the same borehole, signal offset between the instruments should be purely instrumental and will give insights about the relative quality of the

tiltmeters. A publication involving french and italian partners about this comparison will be published in an international journal (such as J. of Geodesy, Geoph. J. Int., J. of Metrology).

3.2 Strain source analysis and inverse problem. Geodetic signal on Mount Etna have been used for decades and provided significant advances concerning the geometry and pressure evolution into the magma chamber and their related fissures and dykes (Patane et al. 2002). However, less has been done concerning the joint inversion of the available geodetic data on Etna. The newly developed approach (Furst et al. 2019) will be applied to a selected period showing both unrest and activity to determine the source of strain at depth but also the drift rate of all tiltmeters, on east and north components. Depending on the expected source geometry at depth, simple source model (Mogi, 1958), planar fissures (Okada, 1992) or more customized strain sources (finite element models) will be used to invert GPS, InSAR and tilt data. This part of work will be done in collaboration between french and italian partners, leading to a common publication implying all teams members.

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Appendix 2 – INGV and the ESTABLISHMENTS' Own Knowledge

For the Establishments (UMR 5243):

- A general knowledge in geophysics and a specific geodetic knowledge in geodetic tools such as GPS, InSAR, tiltmeters;
- A specific knowledge in crustal and reservoir deformation modeling using direct and inverse modeling tools;
- The capability to build and install a newly optical tiltmeter developed by Geosciences Montpellier and the partners of the MIRZA project;
- A borehole tiltmeter patent : Chéry J. et P. Collard (2012) Inclinomètre de forage à mesure triaxiale, brevet national et international (FR2987110 ; WO2013/124261);
- A thermo-mechanical software using Finite Element Method: Chéry J., et R. Hassani, (2018) ADELI : logiciel de modélisation thermo-mécanique, DI CNRS n°83580-01.

For INGV:

- A large and specific knowledge in tiltmeters on volcanoes that started in the 70s. In particular on Mt. Etna the permanent tilt network comprises 17 real-time monitored instruments installed in shallow boreholes and one fluid long-base instrument.
- INGV-OE tilt installations are the outcome of accurate instrument tests, site selection, drilling and sensor positioning in order to obtain a suitable matching of the instrument to the surrounding rocks.
- INGV-OE has produced tens of papers on ISI international journals about tiltmeters.

Appendix 3 – Affiliates of the Parties

For the CNRS: CNRS INNOVATION
 For the Establishments: SATT AxLR
 For INGV: None
 For ISRADICE: None



