*GEO*detic *D*ata assimilation and *ES*timation of references for climate change *InvE*stigation. An overall presentation of the French *GEODESIE* project.

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Overview *A*

Many major indicators of climate change are monitored with space observations (sea level rise from satellite altimetry, ice melting from dedicated satellites, etc.). This monitoring is highly dependent on references (positions and velocities of ground observing instruments, orbits of satellites, etc.) that only geodesy can provide. The current accuracy of these references does not permit to fully support the challenges that the constantly evolving Earth system gives rise to, and can consequently limit the accuracy of these indicators. For this reason, in the framework of the Global Geodetic Observing System (GGOS), stringent requirements are fixed to the International Terrestrial Reference Frame (ITRF) for the next decade: an accuracy at the level of 1 mm and a stability at the level of 0.1 mm/yr. This means an improvement of the current quality of ITRF by a factor of 5-10.

Improving the quality of the geodetic references is an issue which requires a thorough reassessment of the methodologies involved. The most relevant and promising method to improve this quality is the direct combination (Combination at Observation Level – COL) of the space-geodetic measurements used to compute the official references of the International Earth Rotation and Reference Systems Service (IERS). The GEODESIE project aims at (i) determining highly-accurate global and consistent references (time series of Terrestrial Reference Frames and Celestial Reference Frames, of Earth's Orientation Parameters, and orbits of Earth's observation satellites) and (ii) providing the geophysical and climate research communities with these references, for a better estimation of geocentric sea level rise, ice mass balance and on-going climate changes. Time series of sea levels computed from altimetric data and tide gauge records with these references (orbits of satellite altimeters, Terrestrial Reference Frames and related vertical velocities of stations) will also be provided.

The geodetic references will be essential bases for Earth's observation and monitoring to support the challenges of the century. The geocentric time series of sea levels will permit to better apprehend (i) the drivers of the global mean sea level rise and of regional variations of sea level and (ii) the contribution of the global climate change induced by anthropogenic greenhouse gases emissions to these drivers. All the results and computation and quality assessment reports will be available on the Website of the project.

This project, funded by the French Agence Nationale de la Recherche (ANR) for the period 2017-2020, will be an unprecedented opportunity to provide the French Groupe de Recherche de Géodésie Spatiale (GRGS) with complete simulation and data processing capabilities to prepare the future possible arrival of space missions such as the European Geodetic Reference Antenna in SPace (E-GRASP) and to significantly contribute to the GGOS with accurate references.

Project Team *B*

The team of the GEODESIE project is made of 24 people from six different institutes/laboratories.

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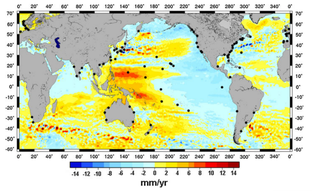
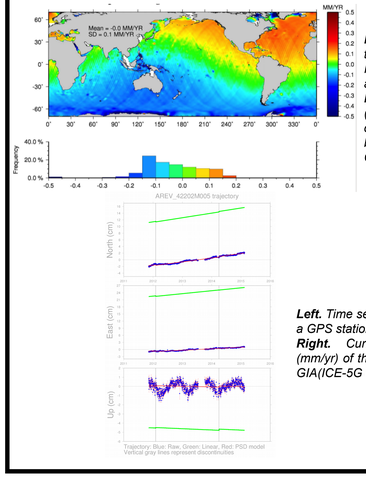
Geodetic References and Geosciences *C*

« The current scientific and societal user requirements are demanding in terms of accuracy, resolution, latency and reliability, and the requirements are expected to increase in the future. The GGOS products must have sufficient accuracy, temporal and spatial resolution, and latency to meet these requirements, which can be achieved by meeting the most demanding requirements. [...] In order to have a frame at least an order of magnitude more accurate than the signal to be monitored, the terrestrial reference frame should be accurate at a level of 1 mm and be stable at a level of 0.1 mm/yr. » ***[Plag & Pearlman, 2009].***

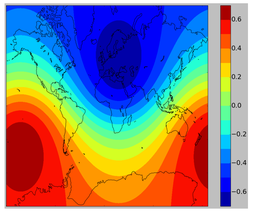
Geodetic references are essential, not only for the sea level rise monitoring and understanding, but also for Astronomy, Geophysics, etc.

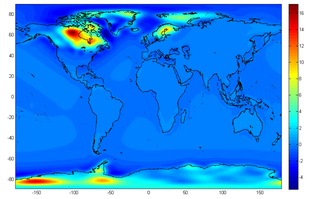


Spatial trend patterns in sea level from satellite altimetry data over 1993-2009. A uniform trend of 3.2 mm/yr has been removed. Locations of some tide gauges are indicated by black dots [Meyssignac et al., 2012].



Left. *effect on regional sea level trends of the transition from ITRF2008 to ITRF2014 [Beckley et al., 2016].*
Right. *Errors in vertical velocities (mm/yr) computed with the errors in origin rates of ITRF2008 estimated by Wu et al. [2011], following Collilieux & Wöppelmann [2011].*





Left. *Time series of positions (cm) of a GPS station (itrf.ign.fr).*
Right. *Current vertical velocity (mm/yr) of the ground resulting from GIA(ICE-5G model).*

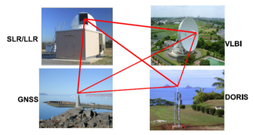
Objectives and Issues *D*

The GEODESIE project aims at:

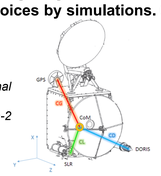
- demonstrating all the potentialities of direct combinations of space-geodetic observations to derive the geodetic references needed to support the challenges in Earth's observation and monitoring, by taking into account all the data available since the advent of space geodesy and all the possible links between the four space-geodetic techniques (GNSS, DORIS, LLR-SLR and VLBI), in a specific data assimilation framework;
- providing references to the geophysics, oceanography and climate research communities;
- providing as well time series of geocentric sea levels, computed from altimetric data and tide gauge records with the references (orbits, terrestrial reference frames and related vertical velocities of stations);
- strengthening the position of the team (and, by extension, of the French Groupe de recherche de géodésie spatiale – GRGS) as an international leader expert on combinations at the observation level;
- Preparing the future arrival of space missions such as GRASP and E-GRASP.

Issues that the project will address:

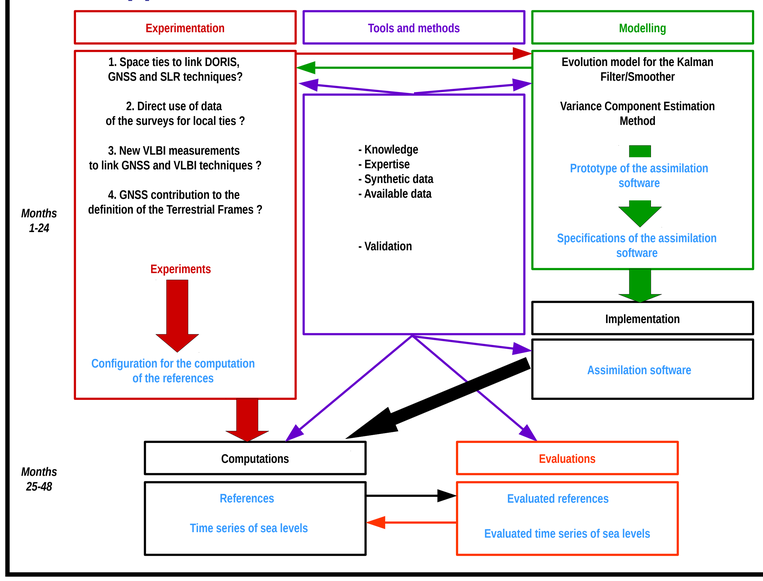
- **Space data.** All the space-geodetic data available since the beginning of the eighties. Standards and models required over the whole period.
- **Links between techniques and frame definition.** Use of space ties provided by the multi-technique satellites. Direct use of the data of the topometric surveys processed to compute local ties. Use of the new types of measurements VLBI/GNSS. Possible contribution of the GNSS to the definition of the terrestrial frames.
- **Data assimilation.** Method ? Stochastic modelling/evolution ? Data weighting ?
- **Evaluation of references.** Validation of all technical and scientific choices by simulations. Complete evaluation of the computed references with external data and models.



Left. *Local tie [Altamimi, personal communication, 2016].*
Right. *Space tie on Jason-2 [Zoulida et al., 2015].*



Global Approach *E*



Data *F*

IDS IGS INTERNATIONAL GNSS SERVICE IVS ILRS

Miscellaneous *F*

The GEODESIE project is the project ANR-16-CE01-0001 of the French ANR. See http://www.agence-nationale-recherche.fr/?Project=ANR-16-CE01-0001 for the official abstract.

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The GEODESIE project is on the Web: geodesie-anr.ign.fr.

The GEODESIE project is also on Twitter: @GEODESIE_ANR.