Future satellite gravity missions

Activities in the French scientific community and in relevant agencies

Activities in France related to satellite gravity missions cover the following topics: satellite gravity data processing and gravity modelling for CHAMP, GRACE and GOCE missions, science usage of the current satellite gravity products, future satellite gravity missions studies, and accelerometer development.

1. CHAMP, GRACE & GOCE missions

1.a - Missions preparation and gravity field determination

Over the past few decades, France has developed expertise in the determination of gravity field models from satellite data. The CNES/GRGS group in Toulouse participates in the processing of data from CHAMP and GRACE. Through a cooperation with the GFZ Potsdam, the GRGS produces global gravity solutions, called EIGEN, that are made available to the users community, both for the static and time-varying gravity fields. For instance static models are commonly used for orbit computation for space altimeter missions. Time variable models such as the 10-day EIGEN-GRGS-RL02 models are widely distributed in view of research on surface mass transfers.
Having led or been involved in several mission proposals to CNES or ESA based on the concept of a space-based gradiometre (projects GRADIO and Aristoteles), the French scientific community was well placed to promote and participate in the ESA GOCE mission when it was selected. The CNES/GRGS team is part of the GOCE High-Level Processing Facility of the European GOCE Gravity Consortium, and is in charge of the computation of a global gravity model from GOCE by the direct approach. This involves the manipulation of large quantities of data and the calculation of many parameters. The processing chains for this task have been developed specifically by the CNES/GRGS team.

France is also developing an expertise in regional gravity field modelling, an approach that appears interesting for science use of satellite gravity data. We are testing different approaches such as the direct inversion of GRACE data for regional recovery of equivalent water heights on grids (at DTP team, Toulouse), and the development of wavelet representations of the gravity field to derive locally refined gravity models, in combination with surface measurements (at Institut Géographique National IGN, Marne-la-Vallée and Institut de Physique du Globe IPGP, Paris). This also contributes to the ground validation of the satellite gravity products.

1.b - Science usage of satellite gravity products

In the context of the GOCE mission, the FROG bureau (French Resources Organization for GOCE) was created to facilitate communication and coordination of the potential user community for GOCE data, and more generally, satellite gravity data. This bureau is based at Institut de Physique du Globe de Paris.

We developed algorithms for geophysical signal extraction from the GRACE and GOCE data, and for their geodynamic interpretation. Capable of taking into account the specific spatial and temporal characteristic of the different gravity sources, wavelets proved to be an efficient tool for this purpose, for both static and the time-varying gravity fields as shown by our studies in the Pacific and in the Sumatra areas. We also apply Empirical Orthogonal Functions to isolate signals related to water displacements and inter-annual climatic signals. Finally, we developed a regularized least-squares inversion approach to estimate the water storage from various reservoirs from GRACE.

At the national level, the SEEGOCE proposal (Solid Earth Exploration with GOCE) was selected by ESA in the context of the ESA's call for the GOCE data processing. This proposal involves several research laboratories in France and Belgium, and is led by IPGP. It comprises four parts: the validation of the GOCE products by comparison with surface data and by the computation of regional geoid models, the study of the Earth's inner structure from the GOCE data, the evaluation of gravity field variations from the gradients, and geophysical time variable signals detection, such as earthquakes signals.

2. Future satellite gravity missions

The Micromega project is on-going at CNES, and aims at studying the feasibility of a future gap filler satellite gravity mission, for launch around 2014. This project benefits from the experience and past proposals related to satellite gravity by the CNES/GRGS team (concepts proposed by Georges Balmino).

In the context of the Micromega Phase 0 preparation, preliminary studies have been carried out since mid-2008 by the Micromega Mission Team, a study group gathering French researchers in geosciences, ONERA and CNES members, chaired by Isabelle Panet (IGN).

The Mission Team gathered support from the international community of users of satellite gravity data in the form of support letters from 15 key-researchers in the different fields of application (geodesy, solid Earth, hydrology, glaciology, ocean dynamics, sea level), from GGOS's Space Missions Working Group and from the IAG. These letters also contributed to a science report that was put together to summarize the user's needs for future satellite gravity data, and is attached to this document. The conclusions underline as an essential requirement, to avoid a gap in data acquisitions. Needs for an increased spatial resolution and for the reduction of aliasing have also been expressed. This advocates for a GRACE type mission (Low-low satellite-to-satellite tracking) with some focused improvements.

In parallel, simulations have been carried out by the CNES/GRGS team of Richard Biancale, to test different missions configurations. Analytical covariance analysis have been performed on the Manege software, for GRACE-type range and range-rate simulations, for various inclinations, altitudes and inter-satellite distance. Numerical simulations (Gins/Dynamo software) introducing aliasing errors have been done for one couple of satellite, for two couples in two different planes (inclinations 90° and 70°), for radial wheel and pendulum configuration with 2 satellites and for the oblique wheel with 3 satellites. The best case is obtained with two couples of satellites in two different planes. Indeed, the two inclinations considerably reduce the meridian artefacts. The pendulum configuration with 2 satellites is a very good alternative, less expensive and performing very well except for the lowest SH degrees. Finally, the inclined or radial wheels are interesting solutions, but show the configuration is more difficult to maintain due to the atmospheric drag.

The Micromega mission was selected as a priority mission by the TOSCA (CNES' consultative body representing the French Earth science community) and CNES' Scientific Programmes Committee during the Future Science Missions workshop (Séminaire de Prospective Scientifique) organised by CNES at Biarritz in March 2009. Following this decision, the start of the Micromega Phase 0 (pre phase A study) is scheduled for autumn 2009. This study, conducted by the PASO department at CNES (André Laurens and colleagues) will carry out a full technical study of the most realistic scenarii. It is anticipated that this will be an international collaborative project and as such, the CNES is open to proposals from partner agencies to participate in this phase 0 study.

3. Instrumental developments

The DMPH team of ONERA has developed a expertise in spatial accelerometry and designed the accelerometers on-board the CHAMP, GRACE and GOCE satellites. Specific developments have been carried out, in order to build dedicated instruments for those missions. Not only a very demanding precision has been achieved, but these instruments are also very compact and less sensitive to the vibrations and to the thermal environment. They contribute to the science data, and also to the control system for the formation flight of the GRACE satellites. The current experience from the GOCE mission shows the excellent performance of the accelerometers of the gradiometer.

The DMPH team also has an expertise in non-linear optic and on-board laser sources, which could be useful for an inter-satellite laser link.

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