Satellite orbits, mission analysis and applications

Contact: dr. ir. P.N.A.M. Visser
Astrodynamics and Space Missions
Faculty of Aerospace Engineering

E–mail: P.N.A.M.Visser@tudelft.nl

The Astrodynamics & Space Missions group at the Faculty of Aerospace Engineering is one of the leading centers in the world for precise orbit determination. Our group is regularly selected by the European Space Agency (ESA) to compute precise orbits for their satellites.

To compute our orbits we use and co-develop software from the NASA Goddard Space Flight Center and the DLR German Space Operation Center. We use state-of-the-art models for density in the atmosphere and the gravity field. We maintain our own infrastructure of servers to efficiently process the terrabytes of data coming from the satellite sensors. With our expertise and facilities we have improved the accury of many satellite orbits down to the cm level.

Not only do we understand the environment of the satellite, we also look at the applications of the satellites. The orbits computed by our group are used to measure ocean currents, sea level rise and in support of measuring the effect of earthquakes, for example in Sumatra and Japan.

Examples of satellite missions the group has been working on include the geopotential missions CHAMP, GRACE, GOCE and Swarm, the altimeter missions TOPEX/Poseidon, ENVISAT and CryoSat-2, and the lunar mission SELENE.

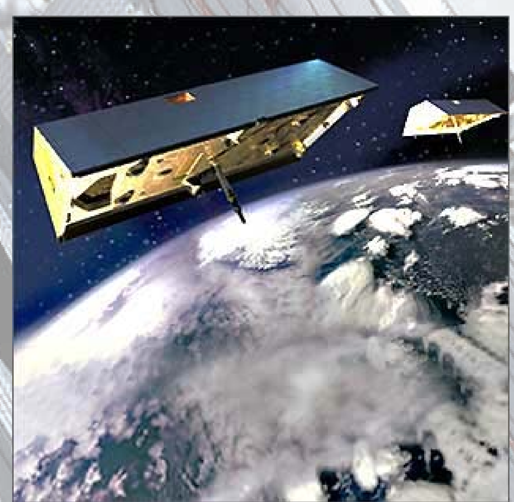
CHAMP (Jul 2000 - Sep 2010)

Thales Alenia Space: precise orbit determination. Accelerometer and GPS and SLR tracking data from the German CHAMP mission were used to develop and test software eventually to be used by the GOCE ground segment. We were involved in an international comparison campaign, showing that at the time (2003) the most precise orbits were computed in Delft.

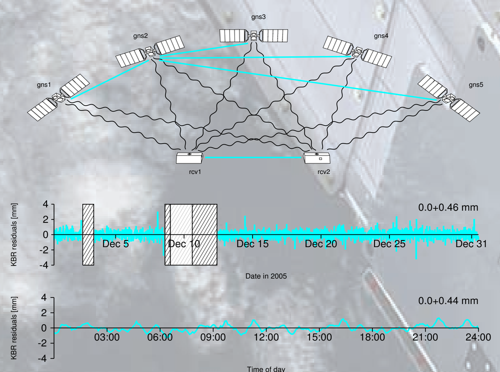
Institute	RMS	Mean	σ
TU Delft/AS	3.60	1.31	3.36
Texas/CSR	4.43	0.04	4.42
TU Munich	4.61	1.78	4.26
Potsdam/GFZ	4.81	0.75	4.76
NASA/JPL	5.31	2.51	4.68
CNES/GRGS	6.80	3.35	5.92
NewCastle Univ	7.44	-0.59	7.42
Univ. Bern	13.56	2.55	13.33
ESA/ESOC	16.83	2.64	16.63
Colorado/UCAR	17.35	4.68	16.71

Consistency between Satellite Laser Tracking (SLR) range measurements and CHAMP orbits computed (cm).

GRACE (Mar 2002 - 2019)

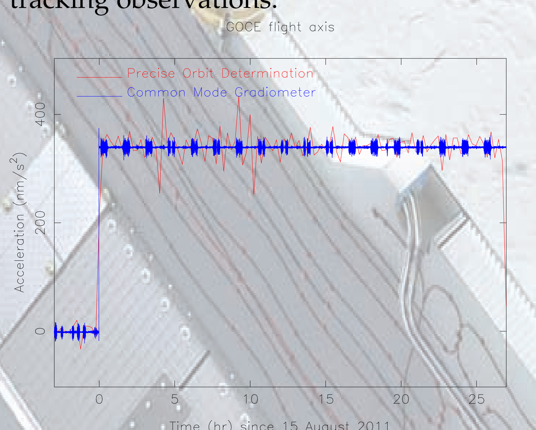


MicroNed/MISAT: relative positioning by GPS. The distance can be computed with a precision of about 0.5 mm for the US/German GRACE satellites which trail each other at a distance of about 200 km.

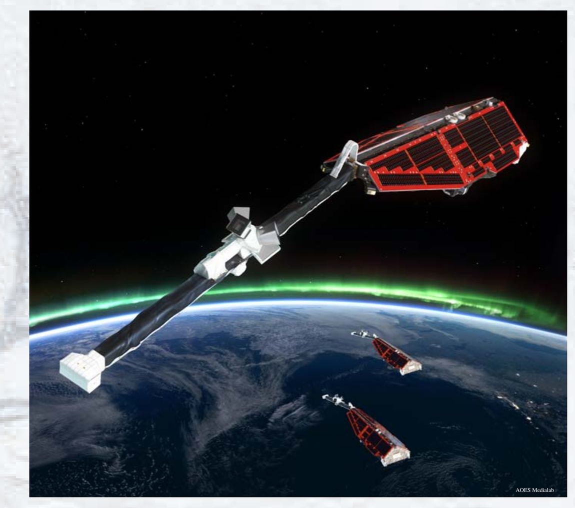


GOCE (Mar 2009 - 2013)

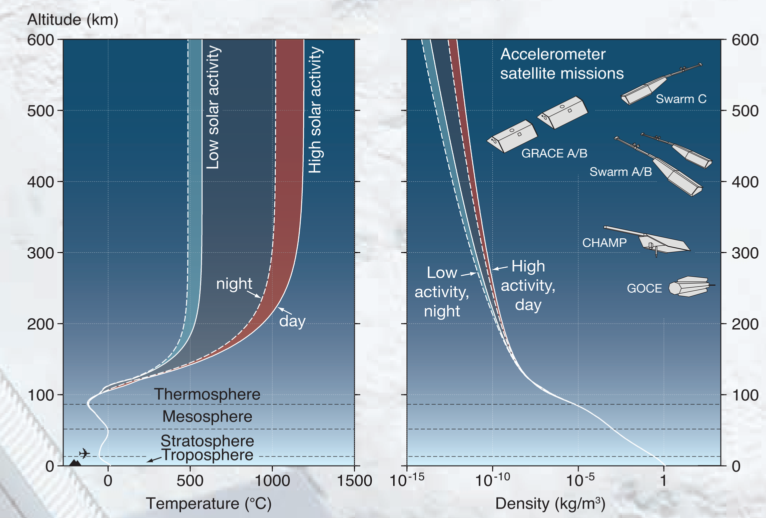
ESA High-Level Processing Facility: verification of accelerometers. Non-gravitational accelerations, including maneuvers, can be determined at a level of a few nm/s^2 from GPS satellite tracking observations.



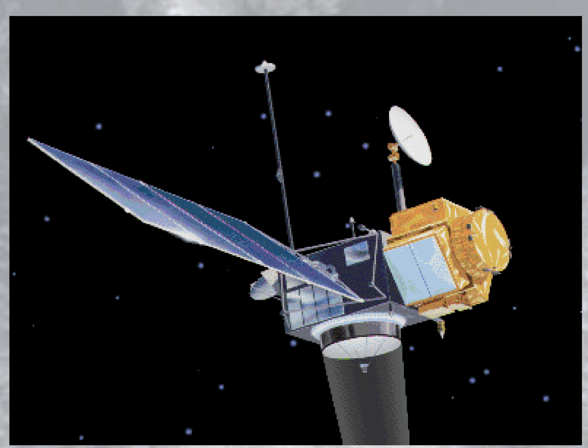
Swarm (Early 2013 - 2018)



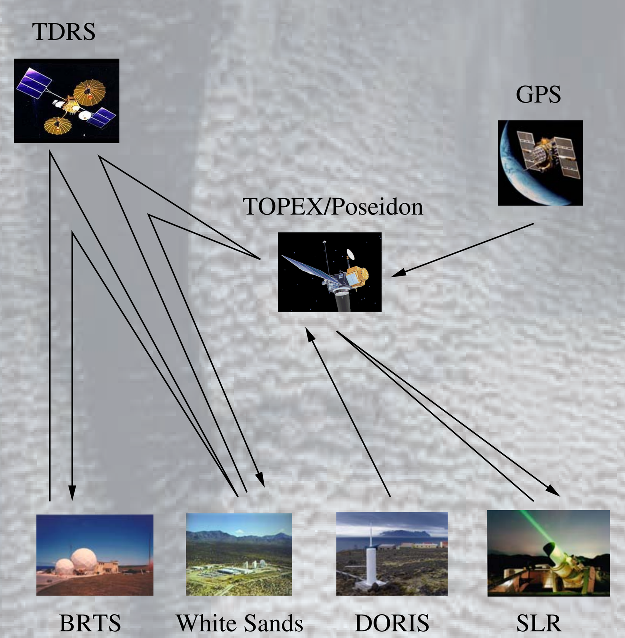
ESA Level2 Processing System: data processing for the *Swarm* geomagnetic field mission. More and more low-flying satellites are being equipped with GPS receivers and accelerometers which measure minute atmospheric drag and solar radiation forces. We will be responsible for the precise orbit determination of the three satellites, the calibration of the accelerometers and the derivation of the neutral density and winds from the aerodynamic accelerations sensed by the accelerometers.



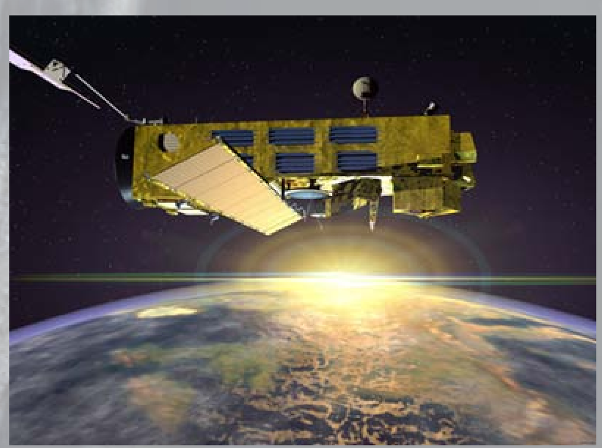
TOPEX/Poseidon (Aug 1992 - Jan 2006)



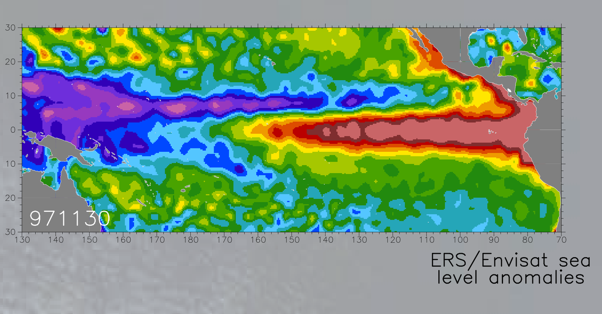
ESA: precise orbit and gravity field determination using GPS, SLR, DORIS and TDRSS observations. Orbits computed with GPS, SLR or DORIS observations are consistent at the 1 cm level in the height direction. Even with the relatively sparse tracking by the geostationary satellites of the Tracking and Data Relay Satellite System (TDRSS), a precision level of around 10 cm could be achieved for the height direction.

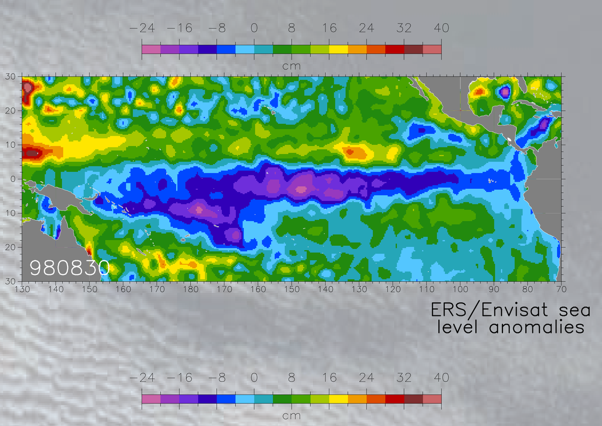


ENVISAT (Mar 2002 - Apr 2012)

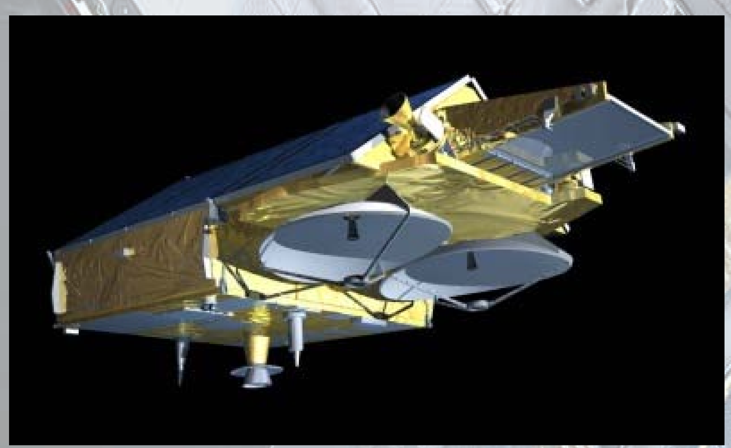


ESA, NOAA & national funding: precise orbit determination and altimeter data base system. The precision of the computed orbits has been improved from meter level in 1991 to cm level, significantly enhancing estimates of sea level heights. It is for example possible to identify the effect of tsunami's on sea level and the well-known climatological phenomenon El Niño (see below).

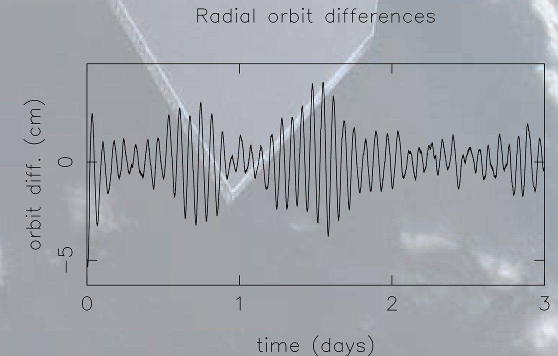




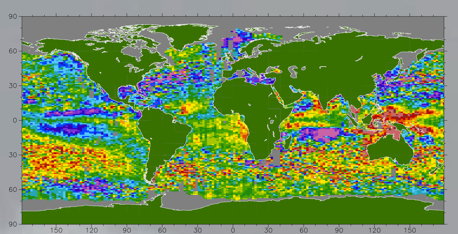
CryoSat-2 (Apr 2010 - 2015)



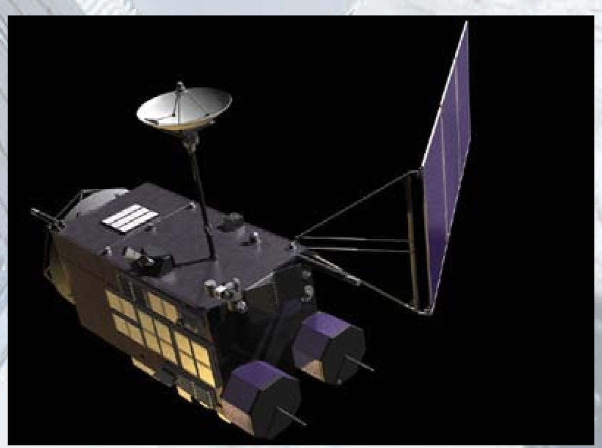
ESA: validation of precise orbit determination from SLR and DORIS observations and analysis of observations from new type of altimeter.
Radial orbit differences between orbit computed by CNES and Delft for 27-29 June 2010. The Root-Mean-Square is equal to 1.3 and 7.5 cm for the radial direction and 3-dimensionally, respectively.



This allows a clear identification of sea level variations: shown are the deviations for March 2011 with respect to the long-period mean.



SELENE (Sep 2007 - Jun 2009)



National funding: precise orbit determination and regional gravity field recovery from DSN tracking of Lunar orbiters. Precise orbit solutions for Lunar Prospector data allowed a more detailed observation in the gravity field of the so-called mascons.

Mare Serenitatis

Old solution — New solution