GGOS INFORMATION MODELS: ANALYSIS OF INTERRELATIONS BETWEEN OBSERVATION TECHNIQUES AND THE EARTH GRAVITY FIELD

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1. INTRODUCTION

Global Geodetic Observation System (GGOS) is the scientific research project of the International Association of Geodesy (IAG) and its subsidiary bodies. This project comprises research on numerous geophysical phenomena such as earthquakes, floods and volcanic eruptions. The project consists of three main pillars:
- geometry and kinematics;
- rotation of the Earth;
- Earth's gravitational field.

These three pillars are linked together and with a reference frame. This dependence is shown in Figure 1. There are many relationships and linkages between the pillars.
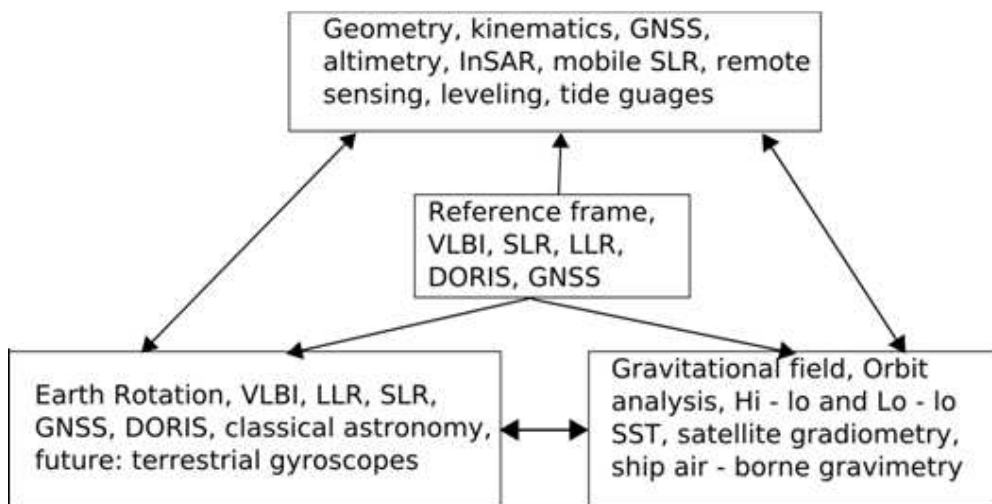

Fig. 1. GGOS pillars.

Each pillar of GGOS concerns a considerable number of mutually related entities such as different objects, processes, phenomena, as well as theories, methods, algorithms and observational data, and also investigators, analysts, etc.

Information on the state and behavior of instances of these entities, in the form of their attribute values and relationships, is the basic goal and result of the investigations and should be available for any further analyses and interpretations in different forms, planning new experiments, development of theories. Proper consistency, integration and coordination of projects and interoperability of participants are demanded. All these things encompass a specific information structure of GGOS, which in detailed detection and description, such as (Drewes, 2005), (Rothacher, 2005), (Neilan et al., 2005) and (Plag et al., 2006), is necessary for effective realization of the project in many aspects. Therefore, the purpose of this case study is presenting an overall conceptual model for such structures, both as to its content and description formalism.

The authors' concept of GGOS information structure is shown in Fig. 2, with the use of the Unified Modeling Language (UML). UML is widely used in conceptual modeling of information systems and its comprehensive presentation is given among others in (Booch et al., 2002).
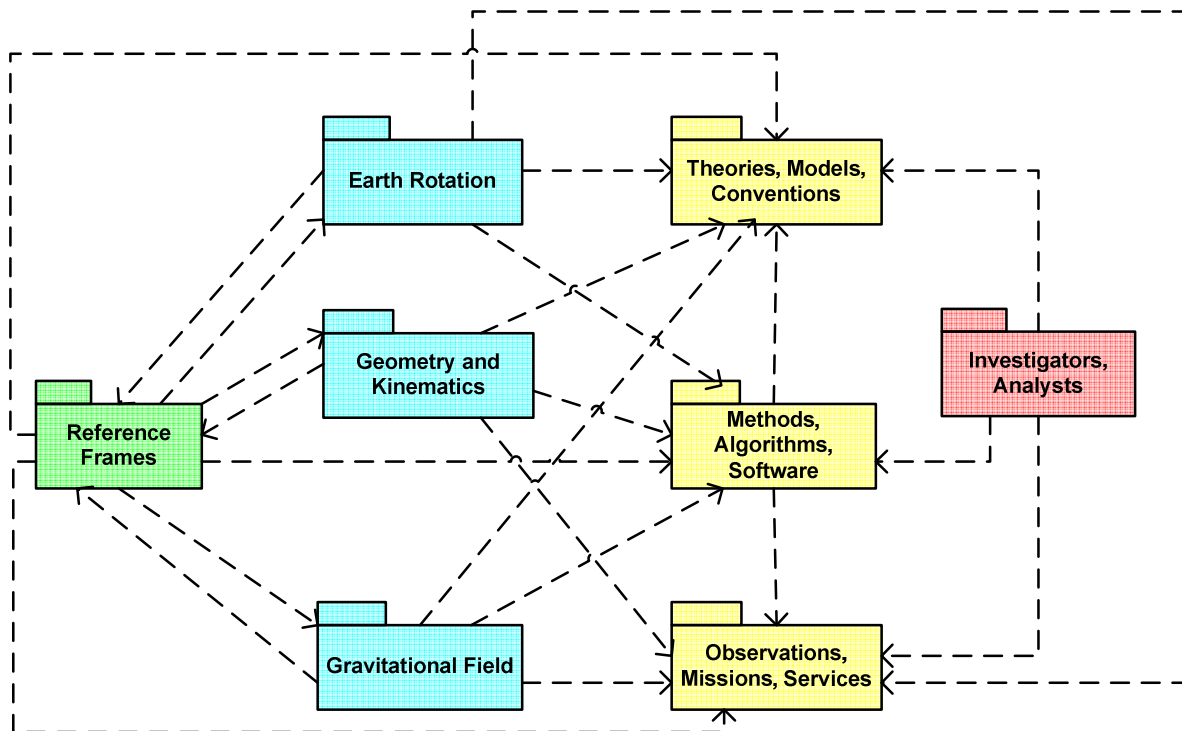

Fig. 2. GGOS packages.

2. REFERENCE SYSTEMS AND FRAMES

Reference system is a set of theoretical definitions and model descriptions, which are required to define, among the others, the scale, origin and orientation of axes of the coordinate system used. There are celestial and terrestrial reference systems. The celestial reference systems are used for extraterrestrial features which set the precise location of the axis of rotation of the Earth. The terrestrial reference system is related to this axis. The terrestrial and celestial reference frame are presented in details by Kryński (2004).

The present Conventional Celestial Reference System (CCRS) adopted by the IAU is the International Celestial Reference System (ICRS).

This system is realised as International Celestial Reference Frame (ICRF) through Very Long Baseline Interferometry (VLBI) measurements to extragalactic objects and as such is maintained by the International Earth Rotation and Reference Systems Service (IERS). The observations made with the HIPPARCOS satellite at optical wavelengths allow to materialize ICRS through the HIPPARCOS celestial frame (Fig. 3).

Quite similarly, the present Conventional Terrestrial Reference System (CTRS) accepted by the International Union of Geodesy and Geophysics (IUGG) is the International Terrestrial Reference System (ITRS), which is realised through International Terrestrial Reference Frame (ITRF). ITRF is maintained by space and terrestrial measurement techniques. The mass centre of the Earth is the origin of CTRS coordinates.

ITRF is defined through many solutions related to various epochs (ITRF88, ITRF89, ITRF2000). Individual solutions are developed on the basis of the VLBI, Lunar Laser Ranging (LLR), Satellite Laser Ranging (SLR), Global Positioning System (GPS) and Doppler Orbit Determination and Radiopositioning Integrated on Satellite (DORIS) observation techniques. The above definitions and examples of the systems are taken from the IERS Conventions (2003).

Both ITRF and ICRF are important in determining the Earth Orientation Parameters (EOP), which consist of the x and y coordinates of the Earth pole, the data on precession and nutation, and the difference of time UT1 - UTC.

The reference system consists of a reference frame (datum) and a coordinate system. The reference frame is defined through a network of stations, which positions in a given coordinate system come from observations (class CD_Datum, from ISO19111). The system of coordinates (class CS_CoordinateSystem, from ISO 19111) is defined as a function assigning an ordered set of numbers (coordinates) to any given point in space, (Fig. 4, 5).

Single Coordinate Reference System (CRS) consists of the datum and the coordinate system. As datums there are particular ITRF, ICRF and Hipparcos frames. Among different reference systems, the geodetic systems (class CS_GeodeticCRS) and temporal ones (class TM_TemporalCRS) are very important for GGOS.
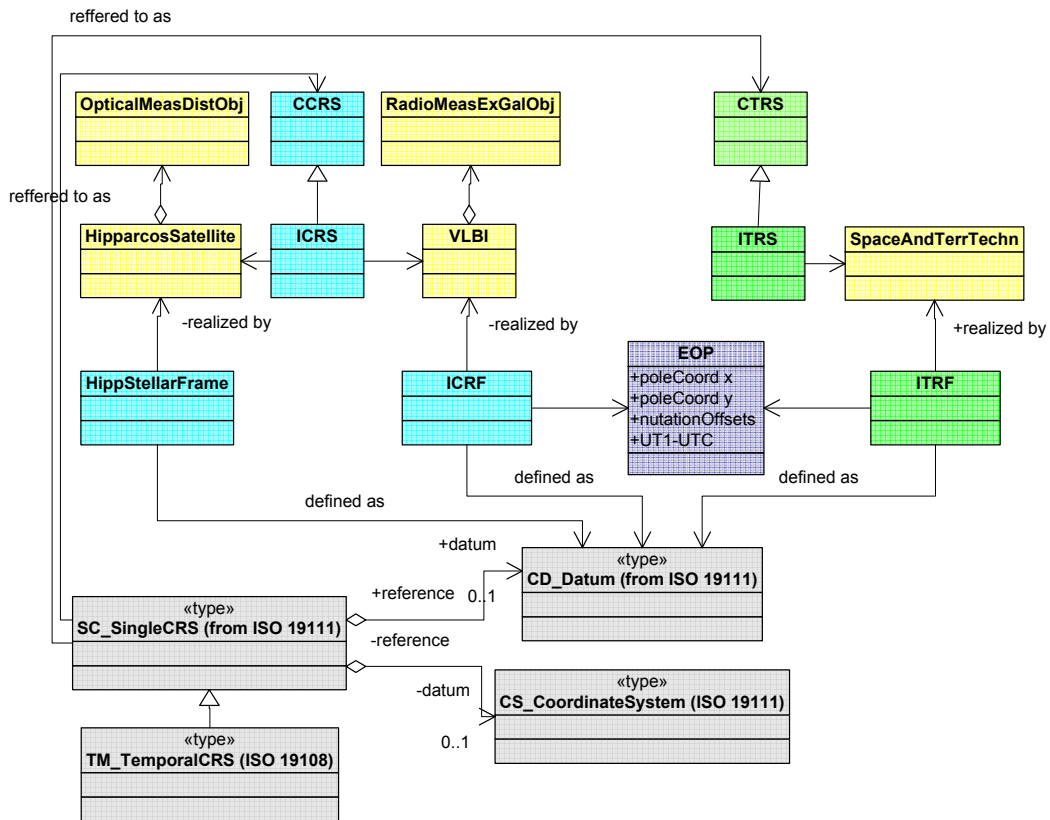
Fig. 3. Reference systems and frames.

The practical realization of the reference system as a frame is datum, as shown on Fig. 6. The parameter values for the origin, scale and orientation of datum, are derived from observations. Datum has a number of attributes:

- anchor (secondary), which describe how a string of characters;
- realization epoch, which is the date on which the date has been set;
- domain of validity, given the scope of applicability;
- scope.

Datum may have many subtypes such as vertical datum, engineering datum, image datum and geodetic datum, which may be used in particular issues of GGOS.
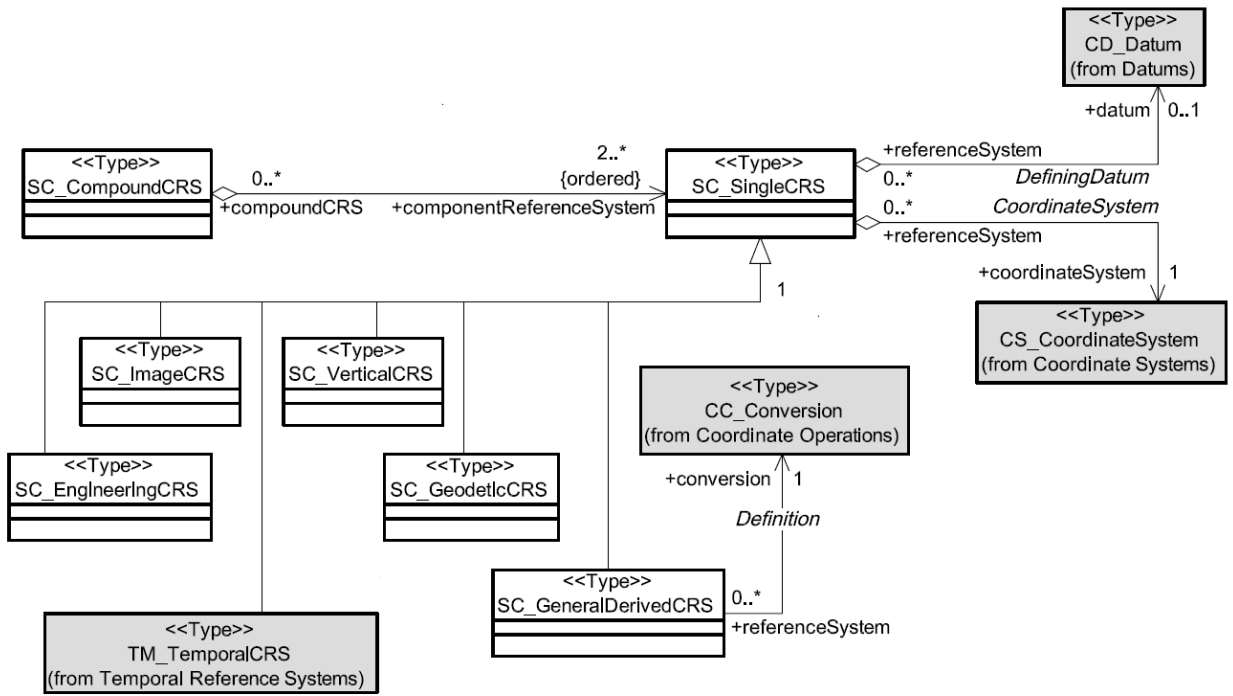
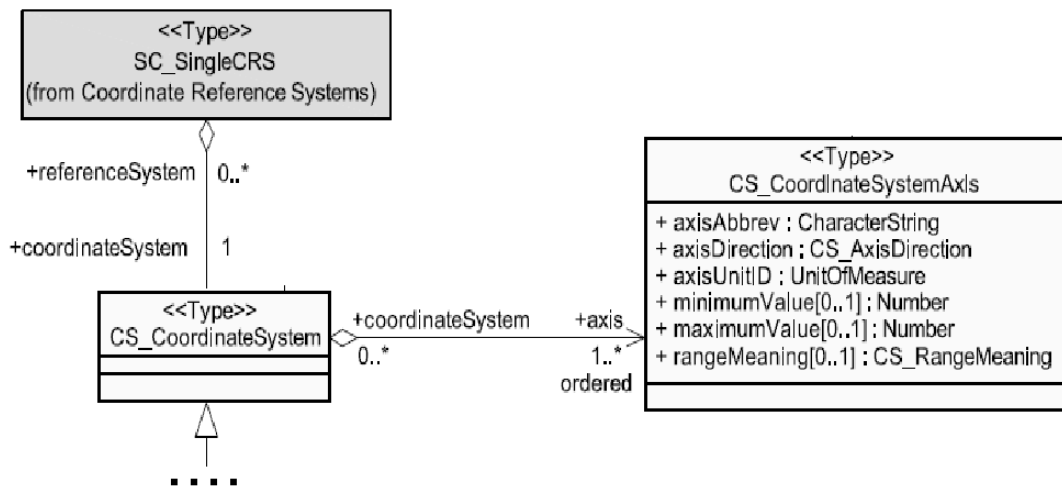Fig. 4. Coordinate reference system (ISO 19111, 2007).

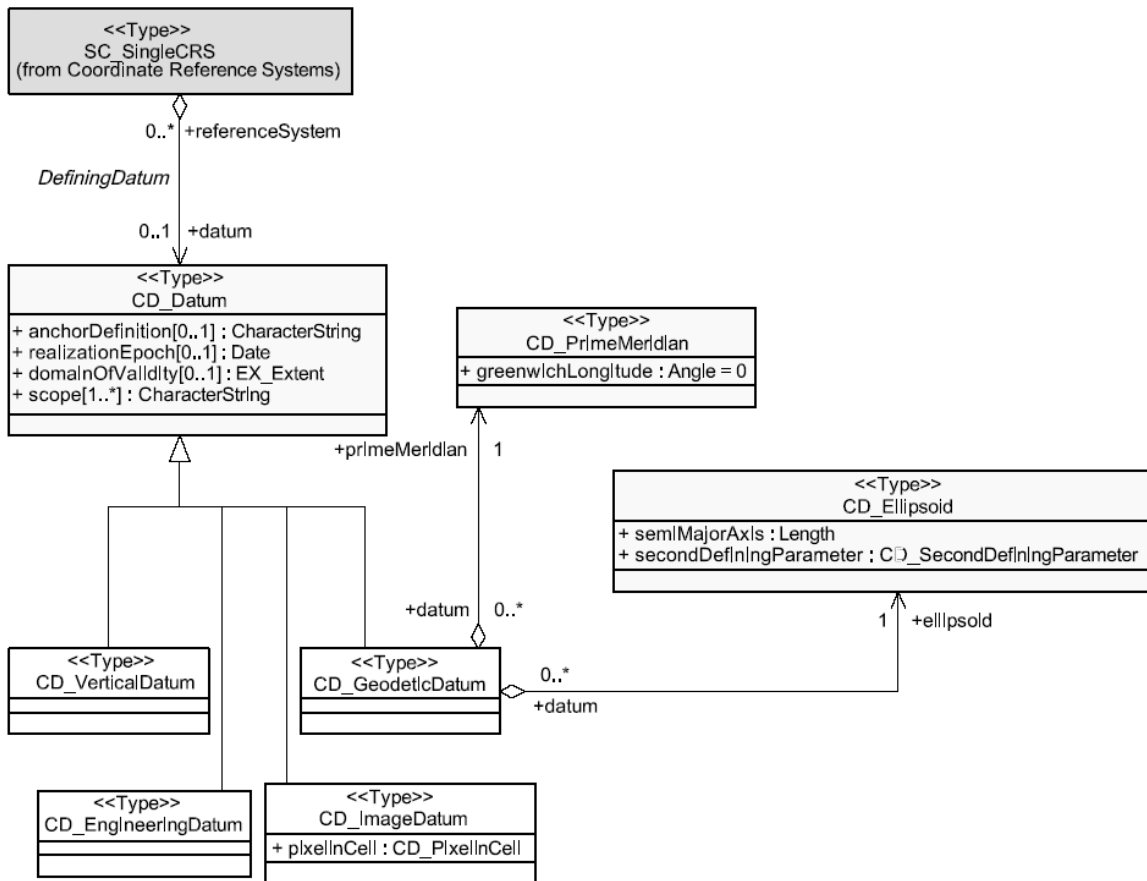Fig. 5. Coordinate system in UML class diagram.

Fig. 6. Datum in UML.

3. MODEL OF THE GRAVITY FIELD

Gravity field is an important pillar within the GGOS. Geoid, the gravity anomalies, deviations of vertical and other functions of the gravity field are key figures for the global geodetic reference system used in the practical measurements. Earth's gravity field changes not only in space but also in time. Any change in the distribution of air masses, masses of water in the oceans, as well as masses of groundwater in the Earth's interior lead to short term, seasonal, annual and centurial variations in the gravity field and the associated changes in the geoid. The global models of the Earth's gravity field began with the era of satellite observations which allowed for determining global reference system. A conceptual model of gravity is shown on Fig. 7. The class GravityField may have the following attributes (not shown on the figure):
- value of the normal potential;
- value of the disturbing potential;
- vector of acceleration force of gravity;
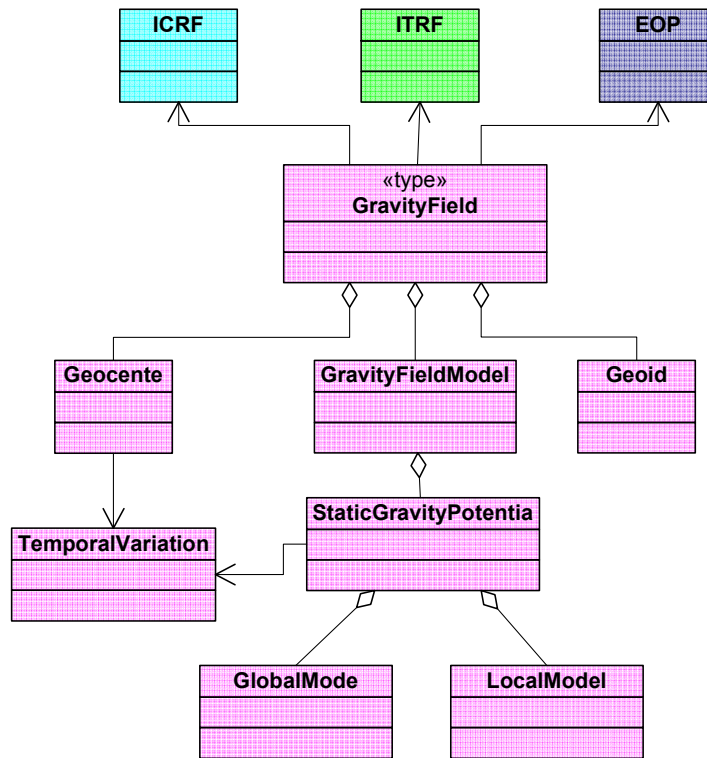- value of the deviation of vertical in a given point.

Fig. 7. Model of gravity field.

4. GEODETIC OBSERVATION TECHNIQUES

Geodetic observation techniques can be divided into space observation techniques and terrestrial observation techniques. Space techniques include: VLBI, satellite altimetry, SLR, Global Navigation Satellite Systems (GNSS), Interferometric Synthetic Aperture Radar (InSAR), LLR, and gravimetric missions like CHAMP, GRACE, GOCE, observation satellites in orbit, SST, DORIS.

Techniques, which are related to the ground, and therefore directly related to the effects of the Earth's gravity field, include gravimetric measurements (absolute and relative, air borne and sea borne), leveling, astrometry, and tide gauges. Their classification in terms of UML is shown on Fig. 8.
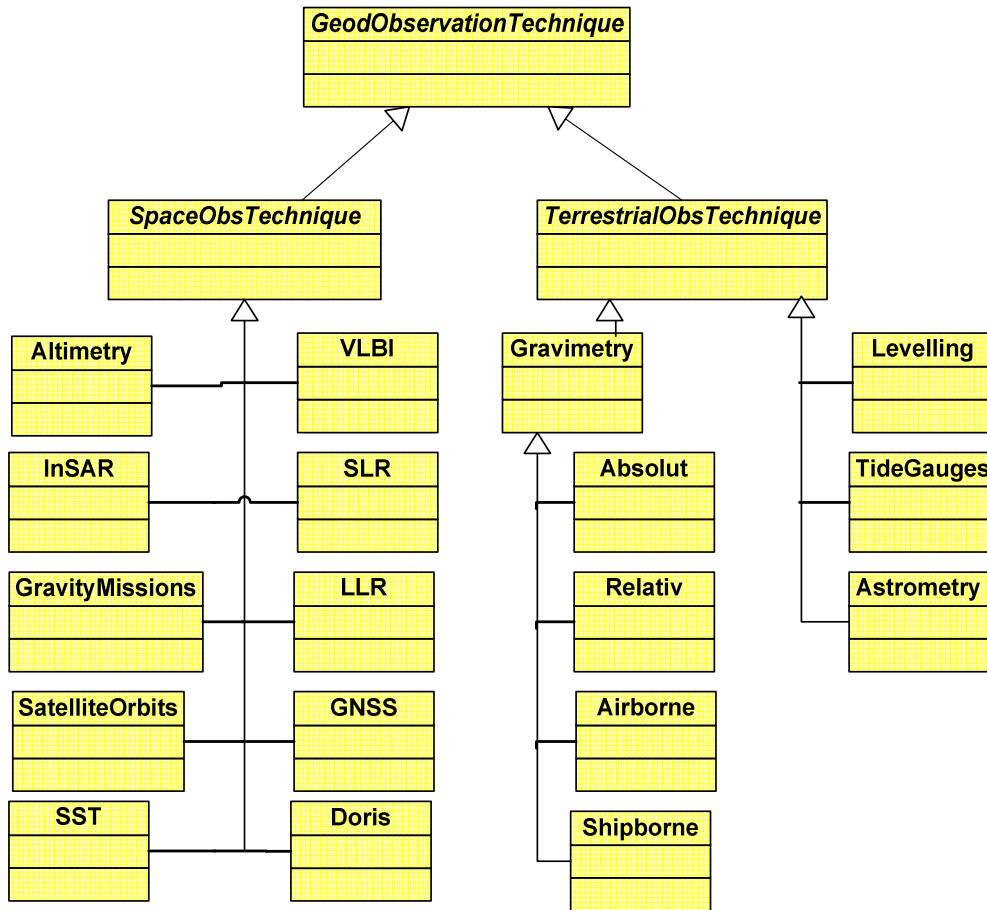
Fig. 8. Types of observation techniques.

5. GEOID MODELING

The example of geoid modeling is presented in Fig. 9. Geoid, which is a zero-surface of constant potential, can be derived from the geopotential model. The shape of the geoid depends on the gravity field, which changes constantly in time. The gravity field model includes geoid undulations which are derived from the orthometric and ellipsoidal heights. Ellipsoidal heights depend on ellipsoid. Gravity field is defined by space observation techniques. A wide range of satellite and space-based measurements define the system of ICRF and ITRF. ICRF system is associated with the astrometry measurement. ITRF system is associated with reference ellipsoid, in which we can set the normal to ellipsoid and ellipsoidal height. There is the angle between normal to ellipsoid and normal to geoid called the deflection of the plumb line or of the verical. Deflection of the plumb line can be derived from astrometry measurements. Gravity field is also defined by gravimetric ground measurements. High precision levelling, which is carried out to determine orthometric heights, is also in relationship to the field of gravity.
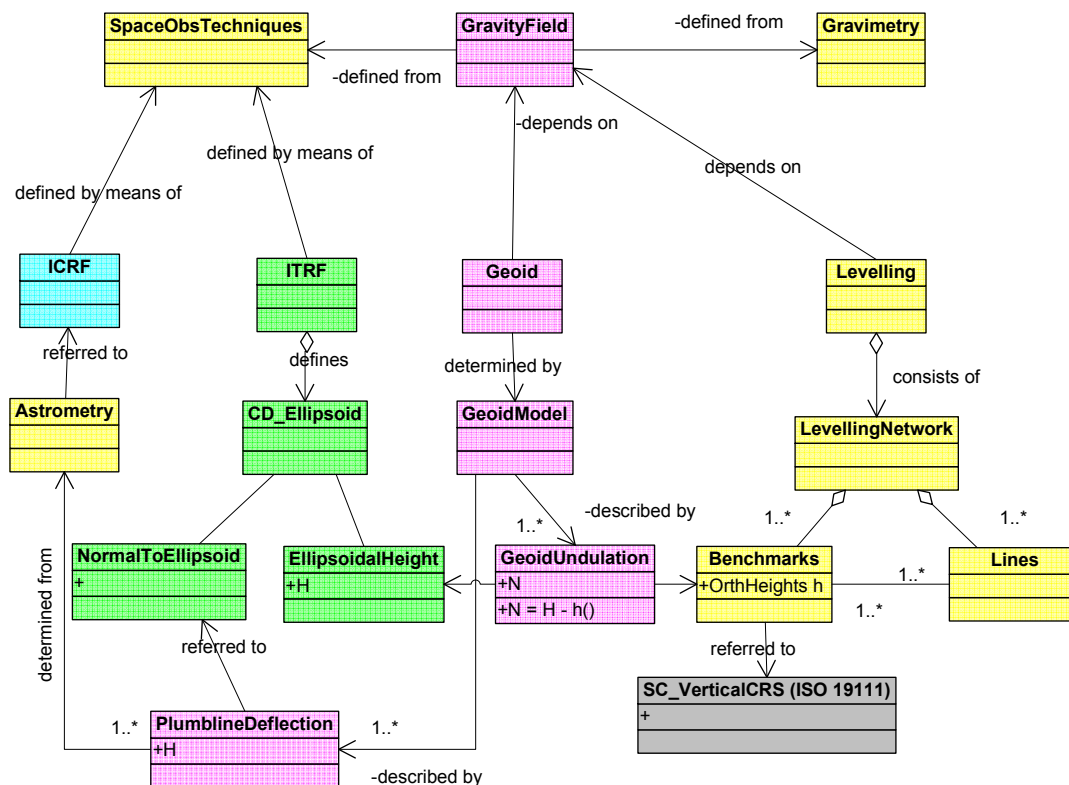
Fig. 9. Model of geoid.

6. CONCLUSIONS

Recognition, description and development of GGOS detailed information structure is of crucial importance for proper processing and interpretation of data, as well as for planning new experiments and missions. Means, such as UML, provide computerized and integrated analyses of data and coordinated management and cooperation.

The presented here UML diagrams, relevant to the Earth gravity field only, give just a general picture of a part of the problem, without any intention to give a final solution of the problem. So, any required more extensive and detailed elaboration of the model of the GGOS information system should follow the frame outlined in Fig. 2 and include contributions of specialists from a number of corresponding branches.

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