Time Variable Gravity Field: Using Future Earth Observation Missions for High Frequency De-Aliasing

Thomas Gruber, Thomas Peters

Institute for Astronomical and Physical Geodesy,Technical University Munich, Germany

1 Introduction

The main objective of the future gravity field mission GOCE is the improvement of the static gravity field for wavelengths down to about 70 km by several orders of magnitude with respect to the current knowledge. CHAMP and GRACE have slightly less ambitious goals and aim at the determination of the static and time dependent gravity field for the long and medium wavelengths. Each mission has its own characteristics and contributes significantly to the overall goal. Due to the fluid and atmosphere dynamics in, on and above the Earth's surface, variations in the gravity field occur with time scales between a few hours and decades. The signals of these time variations of the gravity field are significantly above the sensitivity of the gravity field missions for wavelengths down to approximately 500 km. Therefore, if we want to determine the static gravity field with the prospected accuracy, the time variable effects in the gravity field have to be determined independently in order to be able to correct the observations beforehand. Up to now only models of the atmosphere, the oceans and the continental water, which only partly based on real observations are available to determine the time variable effects. Investigations for the atmospheric component have shown, that the accuracy of the atmospheric model parameters is not sufficient to compute atmosphere induced gravity field variations as correction for the static gravity field. With the sensors on ENVISAT and other Earth observation satellite missions, the first time an observation based approach to compute the oceanic and atmospheric mass variations and their impact on the gravity field can be developed. The extended abstract provides an overview of the scientific issues, the analysis methods and the missions and sensors applicable for atmospheric and oceanic mass de-aliasing. In summary the following tasks have to be investigated:

- Oceans: Determination of the steric (not mass related) effect over the oceans in order to reduce altimetric derived sea surface variations to real oceanic mass variations. The steric effect is computed by the ocean temperature and its salinity.
- Atmosphere: Computation of atmospheric mass variations from observed vertical pressure, temperature and humidity profiles.
- Combination of atmospheric and oceanic contributions for global gravity field analysis with special emphasis on the inverse barometer assumption.

2 Scientific Issues and Analysis Methods

2.1 Ocean

Altimeter data are providing the sea surface height above a reference surface. Variations of sea surface heights are caused by real water mass variations due to wind stress for example and by the so-called steric effect changing only the volume of water due to temperature and/or salinity changes. The issue is to develop methods for separating the real mass and the steric effects in the altimeter observations on a global scale. The individual processing tasks are:

- Computation of representative sea surface height maps for specific time periods from altimeter data taking into account the orbit characteristics and the applied altimeter corrections. Specific care must be given on mass related altimeter range corrections like tidal effects, in order to be compatible with the further processing of gravity field variations and their application in the gravity field modelling (e.g. gradiometer corrections). If necessary specific altimeter range correction terms have to be replaced or removed.
- Correlation of sea surface temperature maps with the altimeter maps. A careful space-time correlation of both fields must be done, because the satellite sensors for both parameters (radiometer, altimeter) cover different areas simultaneously. Methods have to be developed to perform the space-time interpolation of altimeter maps or sea surface temperature maps (or both) in order to make them compatible for the estimation of the steric effect.
- Ocean salinity data have to be acquired from other sources. For the near future salinity models from oceanographers are applicable. In the time-frame of the GOCE mission also the ESA Earth Explorer opportunity mission SMOS is planned to be in orbit, which will provide observations of the ocean salinity. At this time the only model data in the overall approach can also be replaced by satellite observations.

The combination of sea surface temperature and salinity to compute the steric height effect can be done with well known mathematical models. By subtracting this effect from the full altimeter signal the mass effect in the oceans can be determined.

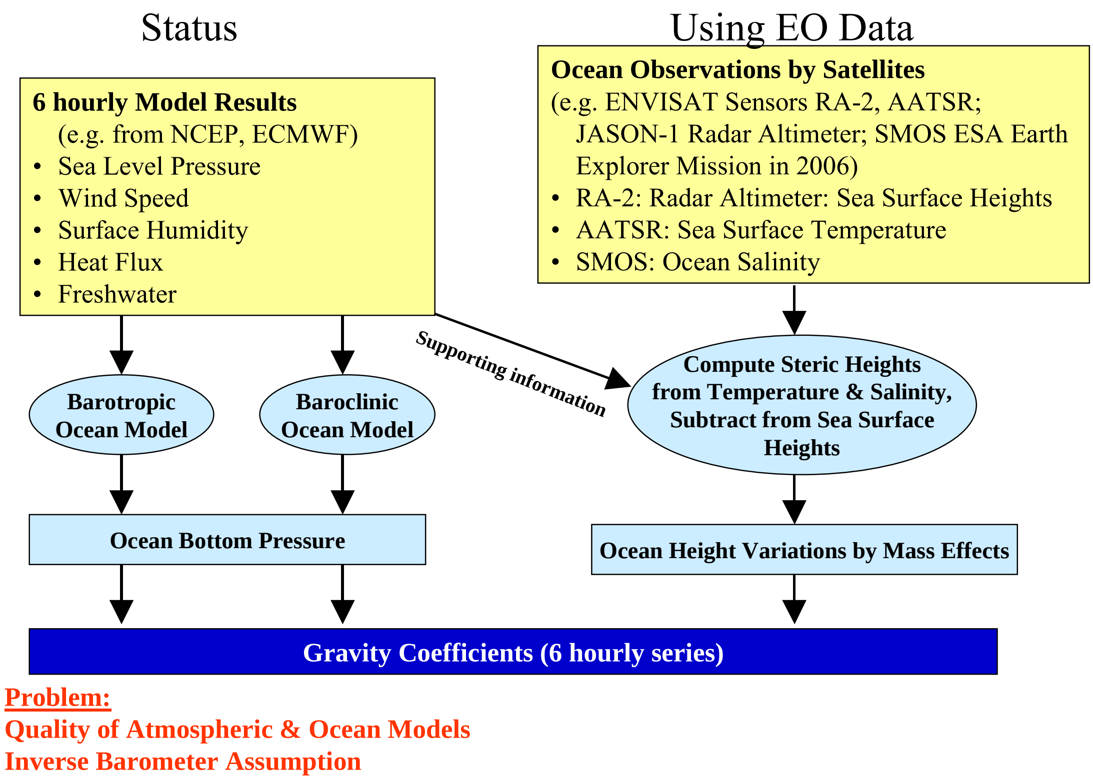

Fig. 1 De-Aliasing Concept Oceans

2.2 Atmosphere

Gravity field variations induced by atmospheric mass variations are apparent in different time-scales (from hours to seasons). They can be computed in a simplified approach from the surface pressure. This approach is not sufficient for the gravity field missions, because it does not take into consideration the distance of the attracting atmospheric masses from the satellites. Therefore the vertical structure of the atmospheric pressure plays an important role. Methods to use vertical profiles of pressure, temperature and humidity (water), observed by satellite sensors, which could replace the model data (at least partly) have to be developed. The individual processing tasks are:

- Combination of atmospheric observations from different sensors in different areas with different vertical resolutions in order to derive maps of vertical profiles for pressure, temperature and humidity. Limb and nadir observations have to be combined such that global maps for specific time intervals are available. Methods for data sampling and interpolation have to be developed for the atmospheric parameters.
- A mathematical model for the computation of the gravity effects from the vertical structure of the atmosphere has to be developed and tested. Comparisons with results based on data from atmospheric models (e.g. ECMWF) have to be performed in order to test one against the other for the purpose of determining the time variable gravity field effect.

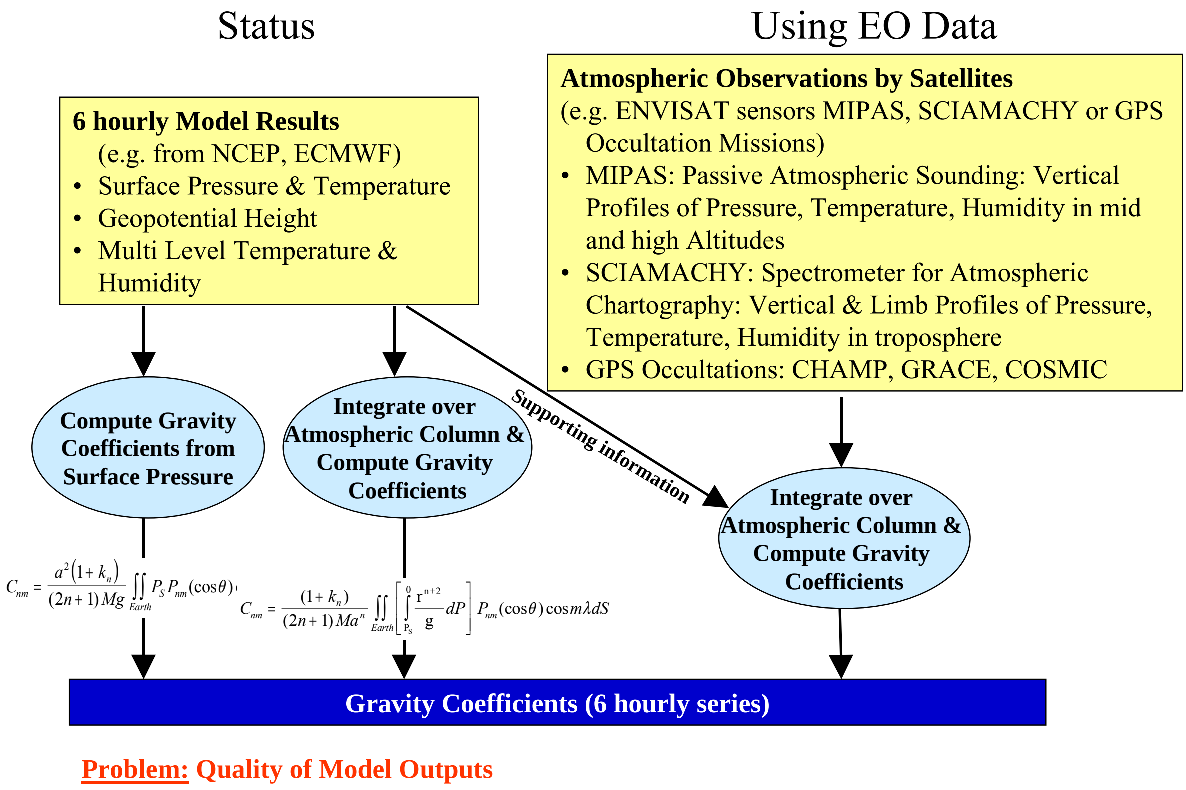

Fig. 2 De-Aliasing Concept Atmosphere

3 Combination

The mass variation contributions from the atmosphere and the oceans can not be regarded separately, because of the dynamic response of the oceans to atmospheric mass changes (inverse barometer effect). Therefore a combined approach for the determination of atmosphere/ocean gravity field variations has to be developed. This task includes:

- Investigations on the inverse barometer response of the oceans due to atmosphere and development of a regional strategy for the combination. Investigations can be performed by a correlation analysis of altimetric sea surface height changes with atmospheric surface pressure changes.
- Development of Software to compute the combined atmospheric and oceanic mass variation effects on the gravity field, according to the results of the previous investigations.
- Development of Software to compute corrections for the time variable gravity field for CHAMP and GRACE data processing and for GOCE gradiometric observations.

4 Related Earth Observation Missions

The ENVISAT mission with several sensors could play a key role to model high frequency mass variations from atmosphere and oceans. The MIPAS and SCIAMACHY instruments provide vertical profiles of atmospheric pressure, temperature and humidity in the mid and high altitudes by different techniques in different views. The radar altimeter (RA-2) and the radiometer (AATSR) provide in-situ sea surface height and sea surface temperature observations usable for modelling oceanic mass effects. In addition the future SMOS mission by ESA (planned to be launched in 2007) will provide ocean salinity, which represents the third parameter required for separating the steric and mass effects in the oceans. For atmospheric profiling also the CHAMP and GRACE missions and specifically the planned US/Taiwanese COSMIC multi-satellite mission can provide significant contributions for atmospheric de-aliasing. All these missions carry GPS receivers for limb sounding. The COSMIC mission could provide about 500 vertical atmospheric profiles per days.

5 Conclusions

Earth observation data from other satellite missions could be of major interest for modelling the high frequency atmospheric and oceanic mass variations. These variations currently are computed from model data, which are to some extent not sufficient in accuracy due to missing observations in large areas (e.g. Southern oceans). The combination of model and in-situ data together probably will be the best way to determine the high-frequency mass variations, which are essential for the determination of the static gravity field from CHAMP, GRACE and GOCE observations.