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Assessment of NGGM Concepts for Sustained Observation of Mass Transport in the Earth System

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Climate change is one of the biggest societal challenges today, and understanding the underlying processes, which are most frequently related to mass transport in the Earth system, are a key element of Earth observation. Observing the gravity field of the Earth from space is the only available tool to observe and monitor mass distribution and mass transport in the system Earth consistently and globally. Such observations enable the quantification of the global water cycle and closure of the global water budget, melting of ice sheets and glaciers, determination of ocean circulation, mass contributions to sea level change, and constraining the geophysical and earthquake modelling. The value of such observations was proven by the GRACE and GOCE and is now continued by the successfully launched GRACE Follow-On mission. Consolidated science and user needs have be derived in an international initiative under the umbrella of IUGG, and the need for sustained observation of mass transport from space is also expressed by a corresponding IUGG resolution.

In recent years various future mission concepts for observing mass transport in the system Earth, which can fulfil the ambition requirements of Earth science disciplines asking for mass transport observations with higher temporal and spatial resolutions as it can be achieved nowadays, have been performed. In the ESA-project "Additional Constellation and Scientific Analysis Studies of the Next Generation Gravity Mission (ADDCON)", by means of extensive numerical closed-loop mission simulations the achievable performance of so-called Bender constellations of two satellite pairs flying in different inclined orbits are analysed, and innovative methods of data exploitation are being developed. Currently we are investigating, in cooperation with a Chinese study team, the benefit of adding a third and fourth pair to the constellation. An alternative concept of high-precision ranging between high- and low-flying satellites is currently investigated in the frame of a national German project. Since such a constellation observes mainly the radial component of gravity-induced orbit perturbations, the error structure is close to isotropic and significantly reduces artefacts of along-track ranging low-low formations (GRACE, GRACE-Follow-On) such as the typical striping patterns.

This high-low concept was proposed in March 2018 by a group of European scientists with the support of technological and industrial partners as Earth Explorer 10 mission to ESA, and is considered as precursor for a future sustained gravity-based mass variation observing system from space. The name of this mission is MOBILE (Mass variation OBservIng system by high-Low inter-satellitE links).

In this context one of the main research questions is the optimum parameterization of the spatial-temporal signal content provided by these mission constellations, and simultaneously the reduction and/or mitigation of temporal aliasing. By means of co-parameterization of daily long-wavelength gravity fields, a significant amount of non-tidal temporal aliasing can be prevented, and it could be shown that such a strategy might help to avoid the use of external atmosphere and ocean models for a-priori dealiasing. Additionally, explicit parameterization strategies of ocean tide signal were investigated.

In this contribution, based on full-fledged numerical closed-loop simulations with realistic error assumptions different mission constellations (Bender double-pair, multi-pairs, precise high-low tracking) are assessed and compared, especially regarding their overall performance, their dealiasing potential, and recovery performance of short-periodic gravity signals. The performance of the constellations and associated processing strategies is also analysed in view of their capabilities to retrieve gravity field information with short latencies to be used for societally relevant service applications, such as water management, groundwater monitoring, and forecasting of droughts and floods.