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Validating future gravity missions via optical clock networks

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Stationary optical clocks show fractional instabilities below 10^{-18} when averaged over an hour, and continue to be improved in terms of precision and accuracy, uptime and transportability. The frequency of a clock is affected by the gravitational redshift, and thus depends on the local geopotential; a relative frequency change of 10^{-18} corresponds to a geoid height change of about 1 cm. This effect could be exploited for sensing large-scale temporal geopotential changes via a network of clocks distributed at the Earth's surface. The CLOck NETwork Services (CLONETS) project aims to create an ensemble of optical clocks connected across Europe via optical fibre links.

A station network spread over Europe, which is already installed in parts, would enable us to determine temporal variations of the Earth's gravity field at time scales of days and thus provide a new means for validating satellite missions such as GRACE-FO or potential Next Generation Gravity Missions. However, mass changes at the surface of an elastic Earth are accompanied by load-induced height changes, and clocks are sensitive to non-loading e.g. tectonic height changes as well. As a result, local and global mass redistribution as well as local height change will be entangled in clock readings, and very precise GNSS measurements will be required to separate them.

Here, we show through simulations how ice (glacier mass imbalance), hydrology (water storage) and atmosphere (dry and wet air mass) signals over Europe could be observed with the currently proposed/established clock network geometry and how potential extensions can benefit this observability. The importance of collocated GNSS receivers is demonstrated for the sake of signal separation.