Strategies to remove hydrological effects in continuous gravity time series

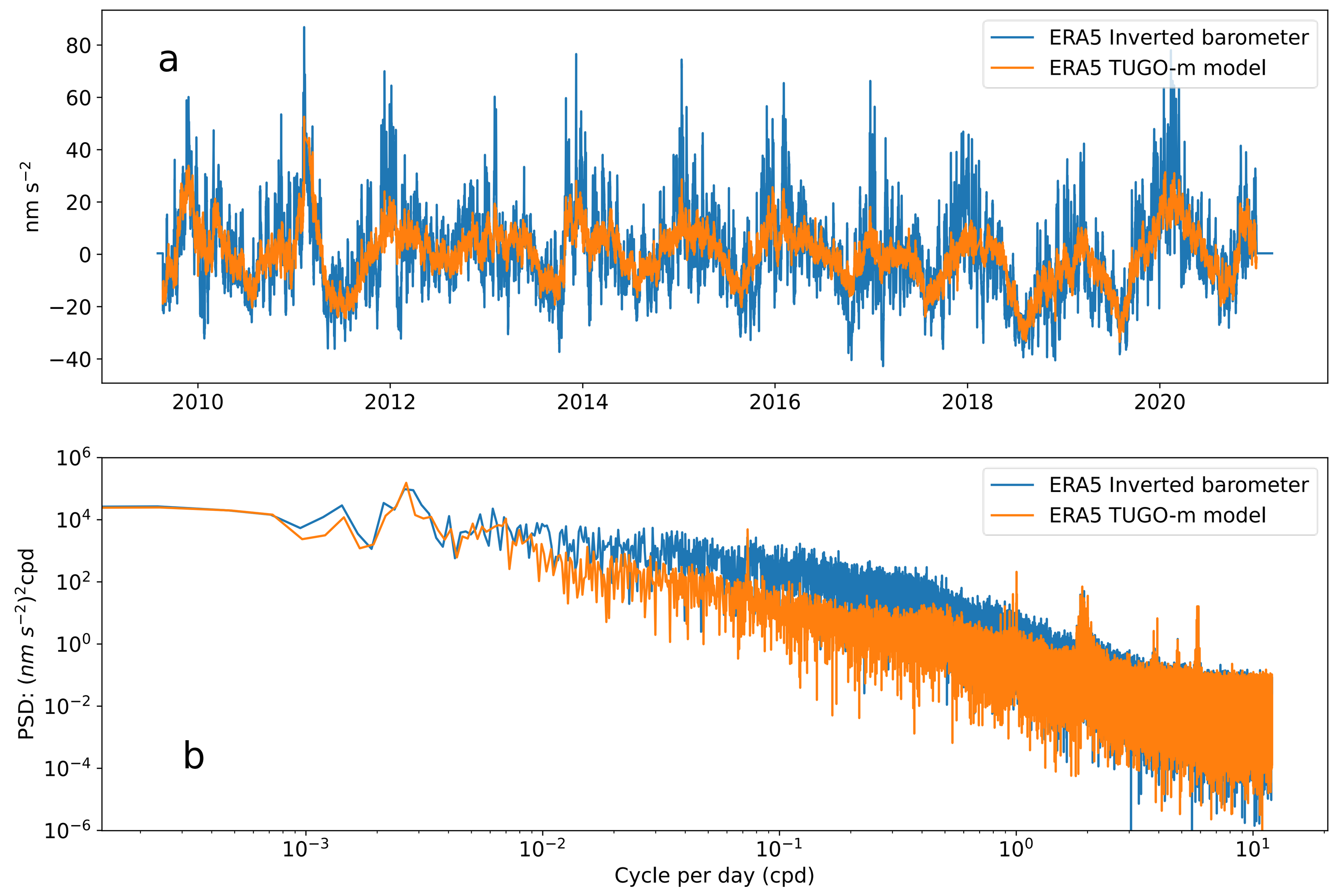
Maxime Mouyen

Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, SE-41296, Sweden.

Multi-annual gravity time series offer a unique, non-invasive, way to monitor **mass redistributions within the earth**. However, for non-hydrological purposes, gravity time series **must be corrected from hydrological effects** to properly quantify mass redistribution involved in other geodynamic processes (volcanic activities, sedimentation). Such a **hydrological correction remains challenging.**

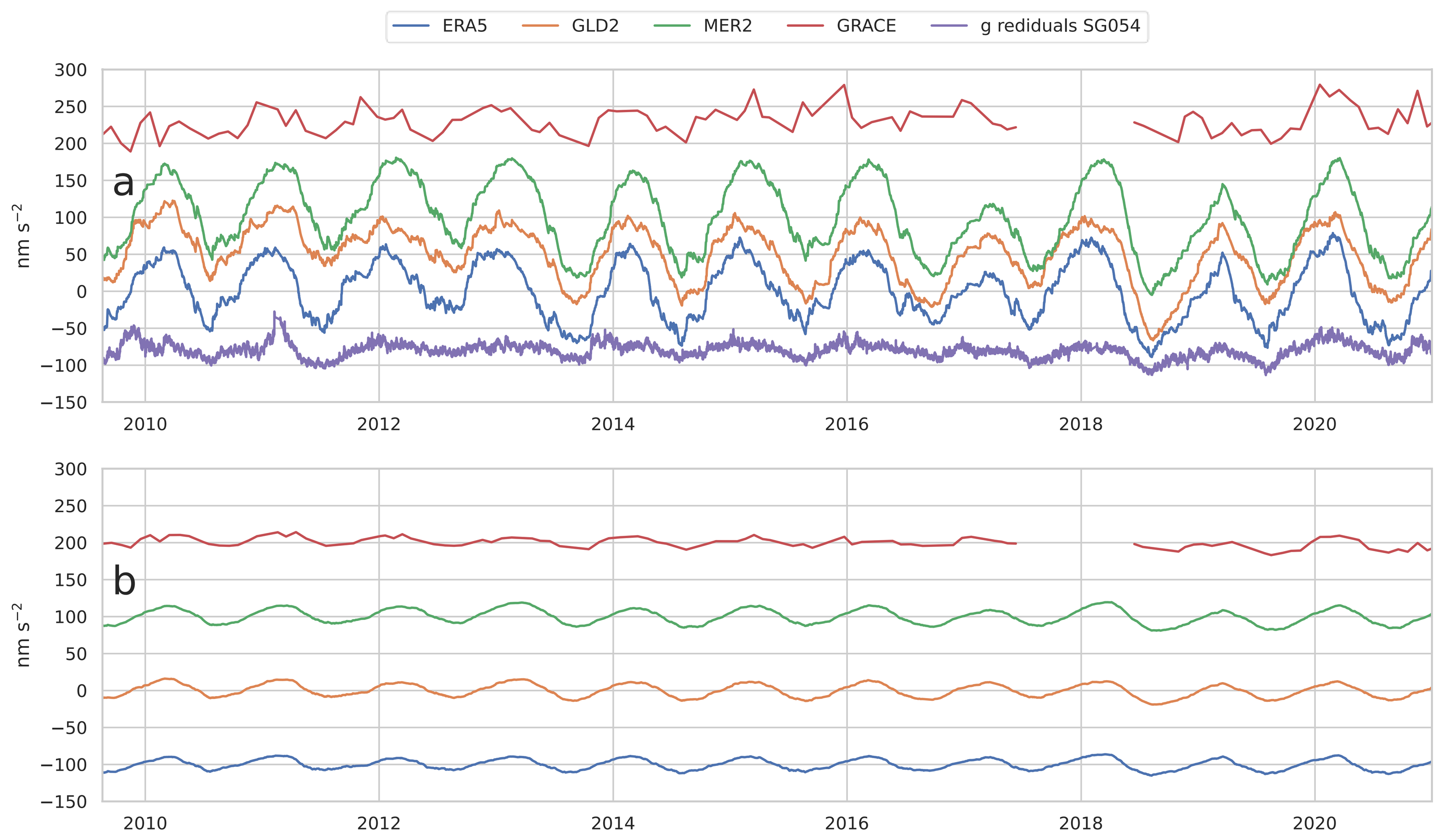
The objective of this work is to use a 11-years long gravity time series acquired by a superconducting gravimeter located at the Onsala Space Observatory (Sweden) for evaluating the **relative performance of hydrogravity models computed from three global hydrological models**, namely GLDAS2, MERRA2 and ERA5, provided by the EOST Loading Service (Boy, 2015) and local hydrological measurements. The interest of using IGETS level-3 and EOST Loading Service products is that our approach can be **easily applied to any superconducting gravimeter that belongs to the IGETS network.**

1 - GRAVITY DATA



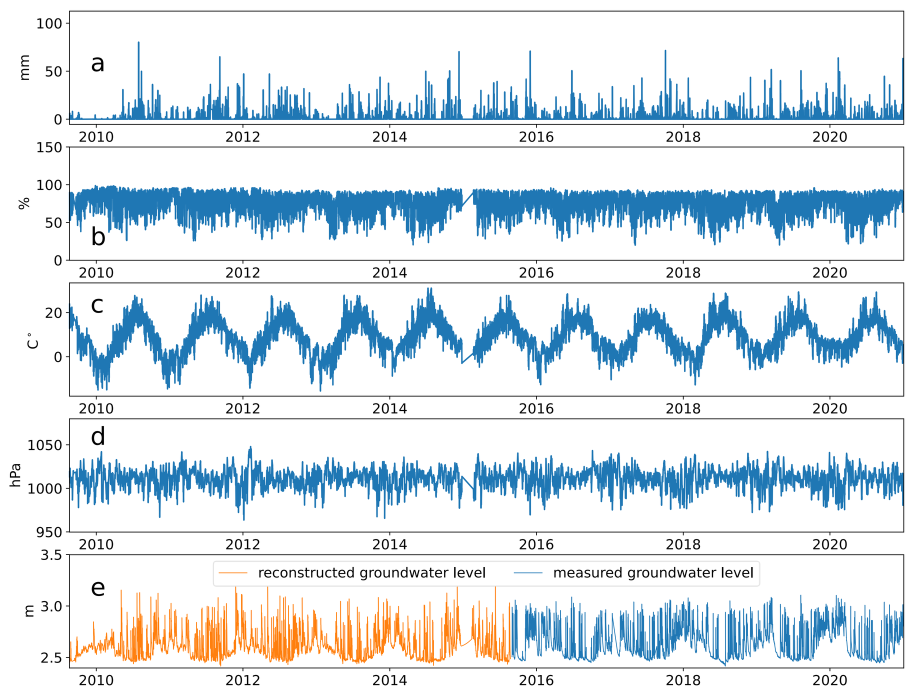
Gravity residuals with an atmospheric loading correction using ERA5 and assuming an inverted barometer ocean response or a dynamic ocean response (TUGO-m model) to the air surface pressure, a) in the time domain, b) in the frequency domain.

2 - HYDROGRAVITY MODELS

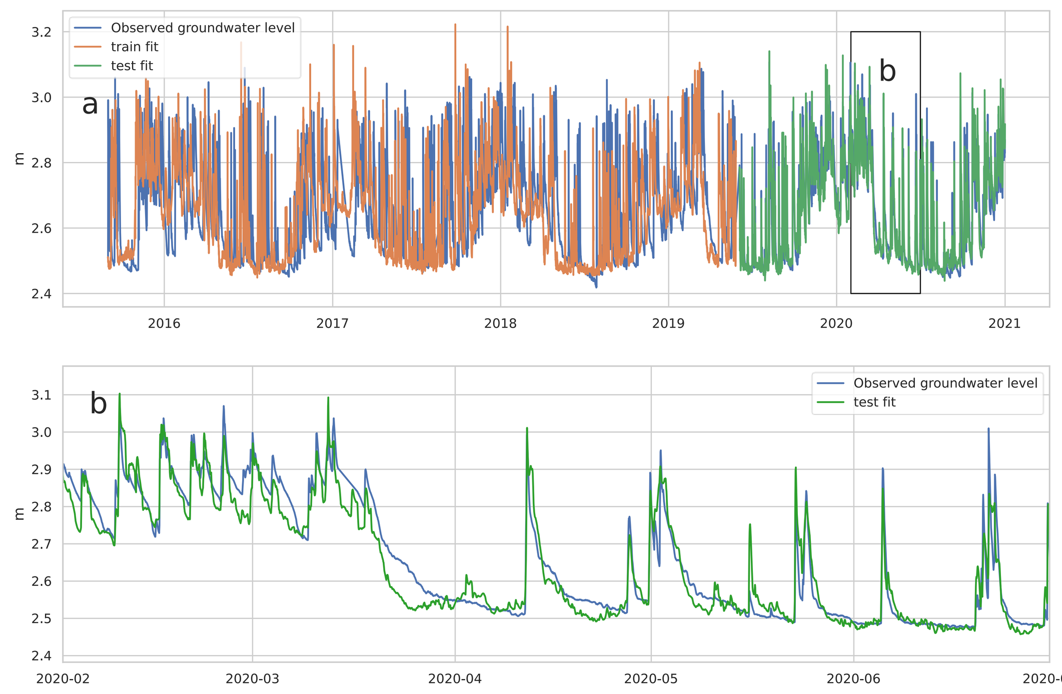


Hydrological products the EOST loading service used in this study, with their a) local, b) non-local contribution to the gravity measured at the location of the SG054 gravimeter. The scale of the y-axis is kept identical to facilitate the comparison of each signal. In a) we also add the SG054 gravity residuals, which should only contain hydrological effects

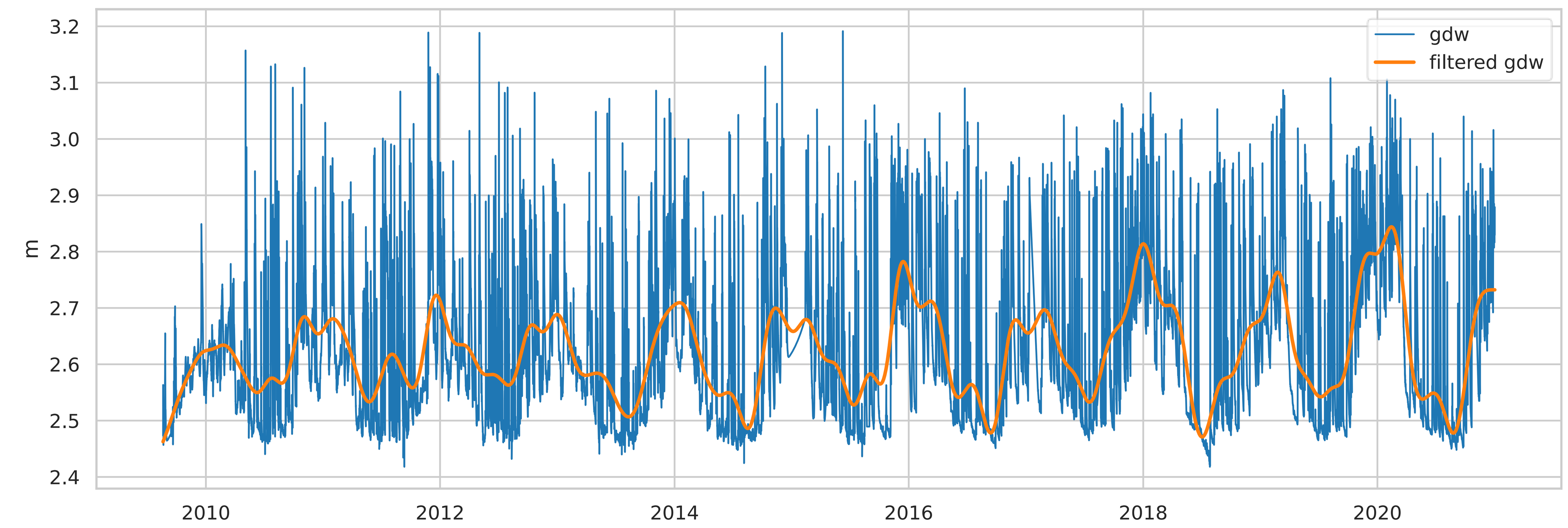
3 - LOCAL HYDROLOGY



Hydro-meteorological data used in this study. a) 24h-cumulative rainfalls. b) Relative humidity of the air. c) Air temperature. d) Air pressure. e) Groundwater level variations.



Train and test fits to the groundwater level data obtained with the artificial neural network b) Close-up on the test fit, where the algorithm predicts groundwater level variations.

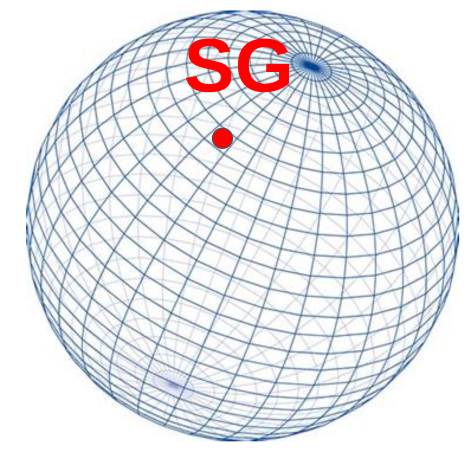


Raw and low-pass filtered (cut-off frequency = 1/90 days−1) in situ groundwater measures next to the SG054.

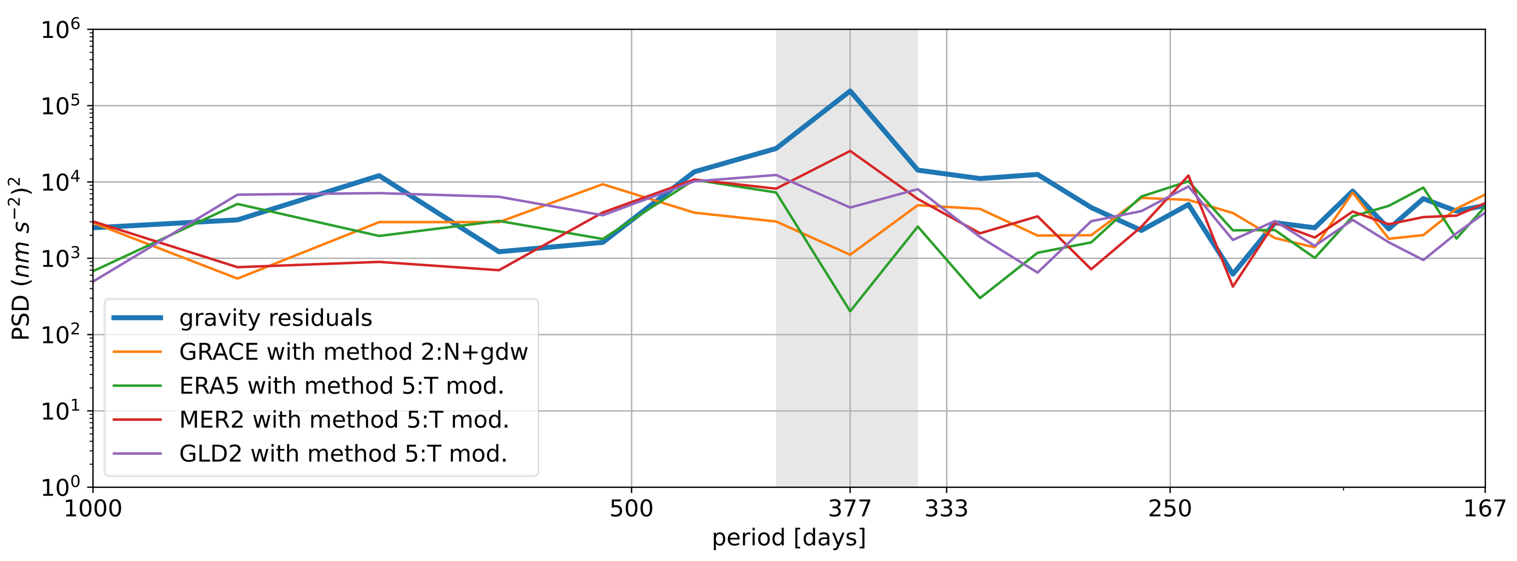
4 - METHOD

The models and local hydrological data are combined following **five different approaches** and subtracted to the gravity residuals, with the aim to **minimize its PSD in the seasonal band**, often using a scale factor.

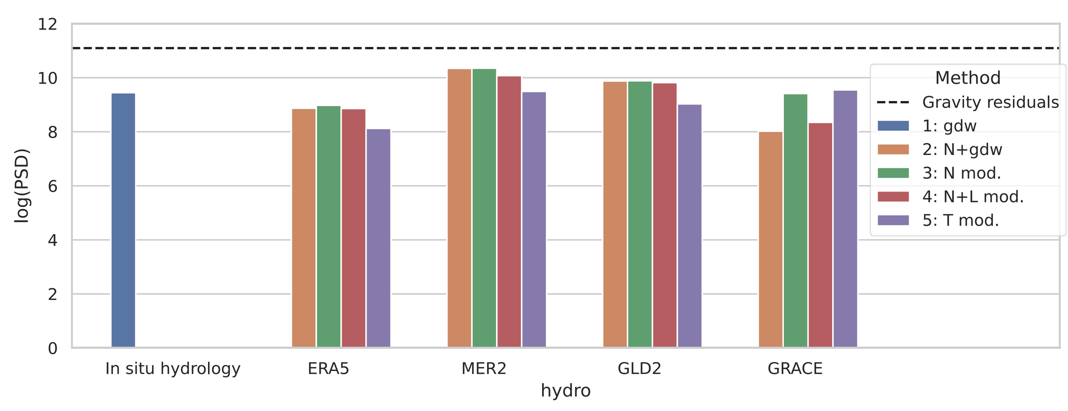
1. $g_{hydres} - \mathbf{k}h_{gdw}$
2. $g_{hydres} - (M_{Non-local} + \mathbf{k}h_{gdw})$
3. $g_{hydres} - M_{Non-local}$
4. $g_{hydres} - (M_{Non-local} + \mathbf{k}M_{Local})$
5. $g_{hydres} - \mathbf{k}M_{Total}$



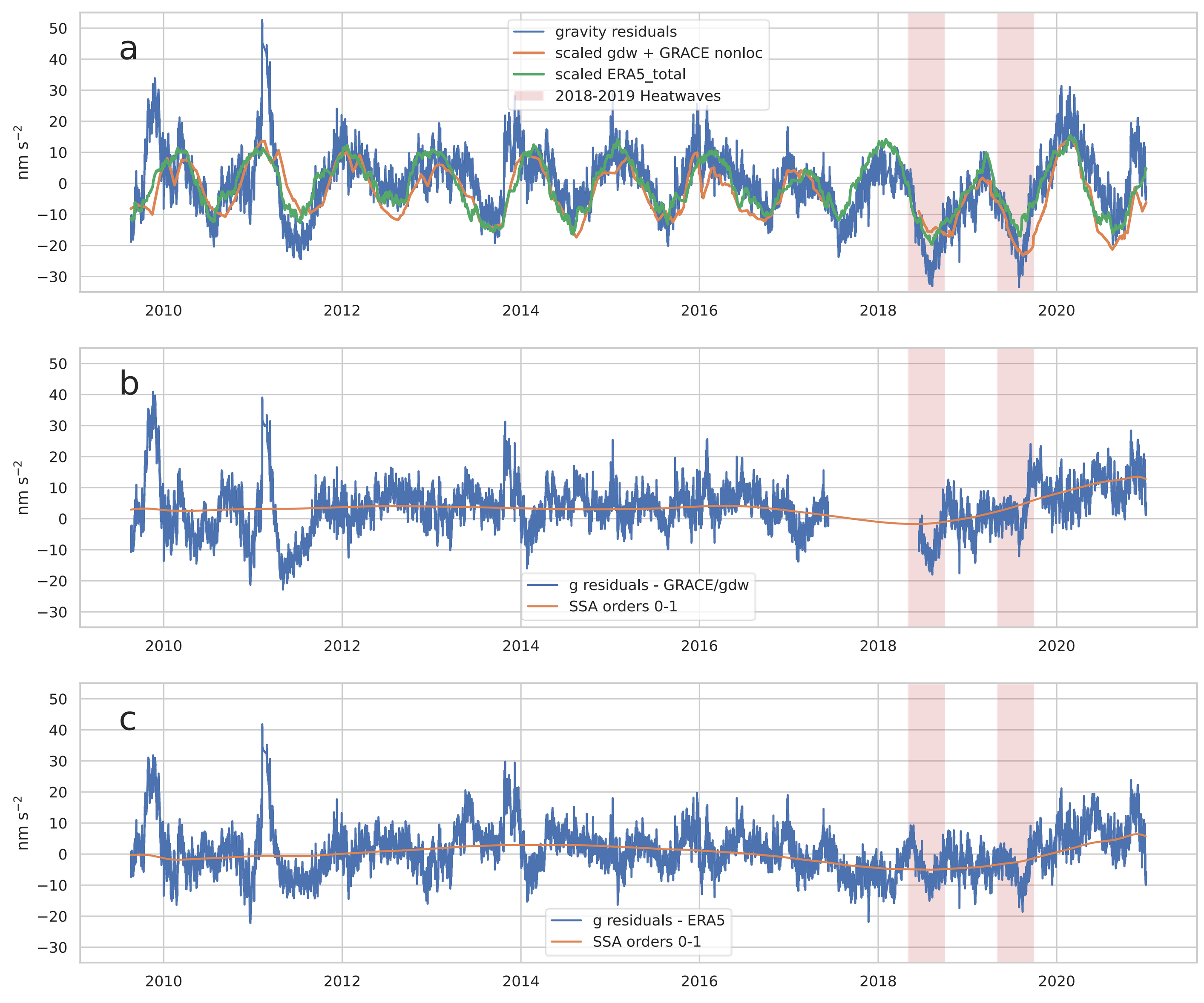
5 - RESULTS



PSD in the seasonal band for the gravity residuals without hydrological corrections and with the best hydrological corrections for each product. The vertical gray band spans the periods between 346 and 415 days



Mean power spectrum density (PSD) in the for periods between 346 and 415 days, where the gravity residuals without hydrological corrections show the largest power after removing the hydrological contribution using the different methods given in Section 4.



The figure to the left shows that **GRACE (b) and ERA5 (c)** best represent hydrological effects measured by Onsala's superconducting gravimeter, followed by GLDAS2 and MERRA2. Local groundwater measurements are only useful to GRACE-derived hydrogravity model. One specificity of Onsala though is that **local hydrological effect remain very small relative to non-local ones.**

All models **underestimate** the amplitude of the gravity decrease during the **northern Europe heatwave in summers 2018 and 2019.** This latter effect shall be investigated in other superconducting gravimeters affected by the northern heatwave (e.g in Belgium, Finland, Germany).