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Interpolation of hydrological time series via Dynamic Mode Decomposition

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The distribution and availability of water resources all around the world are strongly affected by climate change. To deal with any negative impact, the research community is asked to provide accurate information to guide adaptation and mitigation strategies. The effort is supported by the increasing availability of data, which is fueling studies about climate-related phenomena. A massive contribution comes from satellite technologies, which have evolved rapidly in the past few decades, and now provide data with improved spatial coverage and time resolution. However, an important issue related to this type of product is still represented by missing data. The gap between data, especially if long-lasting, breaks the continuity of the observations and limits further application of the time series. Different data-driven methods have been tested to bridge these gaps, and even to reconstruct the series in the past. A new viable approach could be represented by the dynamic mode decomposition (DMD), a data-driven model reduction technique that originated in the fluid dynamics community, capable of extracting coherent structures directly from spatiotemporal complex system data. The DMD method allows to automatically embed seasonal variations and capture trends in the data, for this reason, it is used for the detection of patterns, the extraction of reduced order models, and the prediction of time series based on previous observations. A suite of DMD algorithms is available to handle different applications. Here, we use different DMD algorithms and analyze their capability to reconstruct and interpolate time series of total water storage anomalies as provided by the Gravity Recovery and Climate Experiment (GRACE) satellite mission. The mission is focused on monitoring mass distribution changes on Earth through the measurement of Earth's gravity field variations. Changes in gravity detected by GRACE can be used to derive estimates of water distribution on the planet and hence provide pioneering data to draw an integrated global view of how Earth's water cycle is evolving. GRACE data are freely available and provided to the users as global matrices of centimeters of equivalent water thickness anomalies relative to a baseline mean. The native resolution is 3 degrees, but a matrix of scale factors can be applied to adapt the data on a global regular grid at a resolution of 0.5 degrees in both latitude and longitude. Data are available from April 2002 to the present, on a monthly scale, but the series is affected by some short-term gaps and a major interruption of approximately 1 year, due to the transition between the first GRACE mission, flown from March 2002 to October 2017, and the GRACE Follow-On (GRACE‐FO) mission launched in May 2018. In this study, the DMD method is applied to capture the hidden information embedded in the large amount of data collected by GRACE missions and then to use them to interpolate the

short-term gaps and bridge the larger one-year gap.