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Identifying areas with similar temporal behaviour from MERIS time series in the Gulf of Bothnia, the northern Baltic Sea

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Coastal waters are subject to ongoing long-term developments, cycles of varying lengths, and random variations. Assessments of water quality should not be based only on temporally sparse sampling and inter-annual comparisons of periodical data, but also on their temporal behaviour as an entity. In the latter approach, regions having similar inter- and intra-annual temporal pattern are classified together, regardless of the differing levels of the observed parameter.

Altogether 4600 time series, containing MERIS reflectance data R(443), R(520) and R(665) and one band ratio R(681) / R(620), were formed for the Gulf of Bothnia, covering the ice free periods of 1.6.-30.9. in 2004-2011. We were only interested in the fluctuation of the reflectance time series and the data was standardized before further processing. Dynamic time warping (DTW) was used to measure the dissimilarity between the standardized time series, which were clustered in order to find areas having similar temporal character. In partitional clustering, a random initial centroid time series is selected for each cluster, which is then adjusted according to the selected centroid function to find coherent clusters. With DTW, a specific DTW barycentric averaging (DBA) is commonly used for this purpose.

An appropriate configuration for DTW and clustering was searched by evaluating the clustering results with two cluster validity indices. Two key settings in DTW are 1) step pattern, which defines how the minimum distances between the observations are searched, and 2) time window, which constrain the allowed time difference between the observations to be compared. The performance of two step patterns, symmetric2 and symmetricP1, and three time windows, 1, 7 and 21 days, were tested. The clustering result may vary due to randomness in the selection of the initial centroid time series. The stability of the repeated clustering was evaluated by Variation of Information –index (VI). With this metric, symmetricP1 step pattern performed slightly better than symmetric2. Longer time windows produced more unstable clustering results. The distances between time series are small, and wide time windows further diminish the differences between them, thus making the clustering unstable. Allowing a certain amount of temporal distortion is however desirable, and because the VI showed satisfactory results also with seven days' time window, it was selected for further computation. A silhouette index were used to evaluate the appropriate number of clusters (k). The most coherent clusters were formed with k=4 or k=6.

As result, four rational and spatially coherent macro-areas with different temporal behaviour were identified. They reflect the surface layer circulation pattern of the Gulf of Bothnia, rivers with fresh water input and terrestrial washed-out materials being among the most recognisable phenomena. All the studied spectral bands and the band ratio R(681) / R(620) formed clusters of the same shape, despite that their mean values over eight years were spatially different. In all, the results indicate the potential of using time series clustering also in coastal remote sensing studies.