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A novel toolbox for accurate thalweg determination in riverbed profiling and Salt Wedge Intrusion length extraction

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The thalweg is the riverbed's lowest continuous path. It profoundly influences river processes, including sediment transport, channel morphology, aquatic habitats, and water quality. It plays a vital role in flood dynamics, navigation, and holds administrative and political significance as it may represent the legal boundary between entities like states. Accurate thalweg determination is crucial for various applications. This study introduces an innovative thalweg determination approach using the ETICO (EstuarIO Thalweg Identification Code) software, part of EstuarIO project within the Copernicus Marine Service Evolution Project led by CMCC (Centro Euro-Mediterraneo sui Cambiamenti Climatici). ETICO serves as the basis for quantifying salt wedge intrusion (SWI) length, which threatens local economy and ecosystem health in estuarine transitional zones.

ETICO is a Python3 highly adaptable tool meeting user-specific requirements for inputs, algorithm parameters, and outputs. It incrementally constructs the thalweg through NetCDF bathymetry and a user-defined origin, analysing a sliding window neighborhood. Next point selection relies on three criteria: 1) *Depth-based:* In the neighborhood, the highest values are selected with adjustable tolerance. 2) *Direction-based:* given *d* (last direction), candidates within the range [d-90, d+90] are assigned a score. Greater similarity to *d* yields a higher score. 3) *Trend-based:* Considering the direction of last *n* movements (defaulting to 10), allowed directions are narrowed to a 90-degree angle bisected by the trend. Scores are then furtherly updated. The highest-scored point is elected as next point. Iterations continues until no eligible candidates remain (each point in the window is either on incompatible direction, inland or already visited). Criteria 2 and 3 only act after an initialization phase. In literature, few algorithms for thalweg computation are documented, among which Moretti and Orlandini 2023 and Zhou et al. 2021. Concerning the latter, selection criteria allows preventing loops. The resulting thalweg is employed to determine the SWI length, moving from mouth to head, along the thalweg by analysing salinity values provided by an unstructured grid model using the same bathymetry. This approach leverages the tendency of highest salinity points to concentrate on the riverbed, thus reducing the analysis to the sole bottom layer. Threshold value for the target length is set to 1psu.

The tool underwent validation on five branches of Po (Dritta, Gnocca, Goro, Maistra, Tolle) and Danube (Chilia 1 to 3, George, Sulina). Bathymetric data originates from merging EMODnet 100m dataset with local multibeam surveys (Po case) or satellite (Danube), interpolated on regular grids

with 10 and 100 m resolutions respectively. ETICO successfully faced challenges provided by complex geomorfologies (meanders, marshed and floodplains), and sections with constant values compensating incomplete bathymetry. In these instances, It exhibited strong adaptability while maintaining efficient execution, even with constrained computational resources. Comparison with manually traced GIS-derived thalwegs revealed higher accuracy and notable improvements in calculating SWI length during the second stage.

Concluding, this study sets the stage for advancements in SWI length identification. Its validity was tested on Po and Danube rivers, but a wider dataset is a scheduled future improvement, besides the development of automated calibration of the algorithm parameters.