# Reply to discussion on 'A reduced-order model for the regeneration of surface currents in Gorgan Bay. Iran [Journal of Hydroinformatics 20(6), 1419–1435, https://doi.org/10.2166/hydro.2018.149]' by Georgios M. Horsch and Nikolaos Th. Fourniotis

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We are pleased to learn that the hydrodynamic reduced-order model (ROM) for the regeneration of surface currents in Gorgan Bay, Iran, presented in our research article, entitled 'A ROM for the regeneration of surface currents in Gorgan Bay, Iran' and published in the Journal of Hydroinformatics in 2018 (Kheirabadi *et al.* 2018), is of interest to the readers of this journal.

As Horsch and Fourniotis concluded in their discussion, the results of the MIKE3 FM model applied to wind induced flow in Gorgan Bay correspond to the model introduced by Csanady (1973), that demonstrated surface currents to be windward in shallower areas but leeward in deeper areas of a lake, causing an *S*-shaped cross-flow on the free surface. To support these findings, a ROM was developed by linking the MIKE3-FM model with proper orthogonal decomposition (POD) to simulate the wind induced surface currents in Gorgan Bay, Iran (Kheirabadi *et al.* 2018). In a discussion on our paper, Horsch and Fourniotis inquired whether these same features (i.e., the expected *S*-shape salient features of wind-induced flow in the bay) that are present in the ROM results can be applied to supplement the criterion used to assess whether the ROM results are adequate.

In response to this inquiry, it should be noted that one of the main aims of the application of POD is to extract the most dominant features of the data obtained by numerical simulations or field measurements (Feng *et al.* 2011; Noori *et al.* 2019a). POD effectively compresses (or summarizes) huge quantities of data to extract the most useful information about the physical processes of the target parameter (Kostas *et al.* 2005; Noori *et al.* 2019b). These features include both the spatial and temporal characteristics of the simulated data (Noori *et al.* 2017). In our study, POD is used to develop the surface current ROM in Gorgan Bay using Equation (12), while Equations (5) and (13) are used to calculate the dominant spatial and temporal features of the surface currents, respectively. It should be noted that the most dominant spatial features of the surface currents could confirm Csanady's (1973) theory. However, only the temporal features of surface currents were presented in Kheirabadi *et al.* (2018).

In response to the inquiry, we have calculated the dominant spatial features of the surface currents, as shown in

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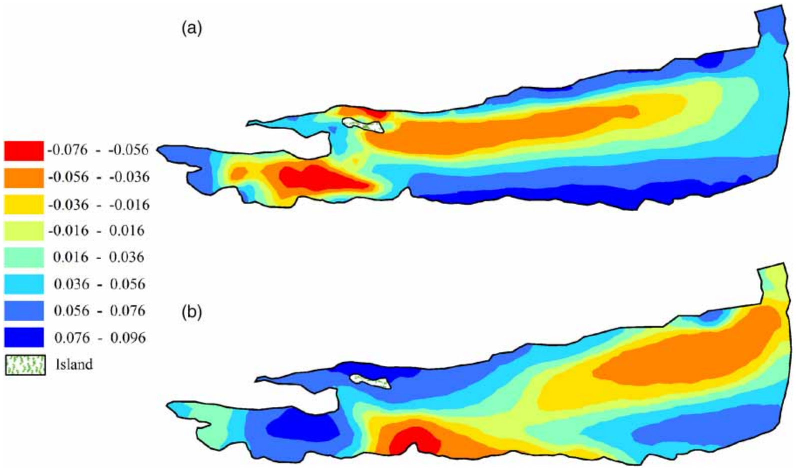


**Figure 1** | (a) The first and (b) second spatial features of surface velocity (*U*) in Gorgan Bay, Iran.

Figure 1, for surface velocities *U* in the *x*-direction in Gorgan Bay, Iran. As described in Kheirabadi *et al.* (2018), the dominant spatial features were calculated as a linear combination of eigenvectors and snapshots. The first spatial feature corresponds to the first eigenvalue, and represents about 65% of the spatial variation of *U* in the bay (Kheirabadi *et al.* 2018). The second spatial feature corresponds to the second eigenvalue, which maintains about 10% of the system energy for *U* in the bay. As the first two spatial features conserve about 75% of the system energy, these features alone can be considered to effectively represent the physical conditions of the system; thus, only these results are presented in Figure 1 for *U*.

The first spatial feature of *U* indicates strong windward currents in the bay's nearshore waters as discussed by Csanady (1973), especially alongside the south shore, as confirmed in Figure 6 of Ranjbar & Hadjizadeh Zaker (2018). In addition, Figure 1 reveals weak leeward currents in the middle of the bay where the mean depth is increased. Although Figure 1 shows strong windward currents in the bay's nearshore waters, some nearshore regions contain weak leeward currents as well; this corresponds to the second spatial feature of *U*. Therefore, this feature does fully support Csanady (1973) theory. Note that the second spatial feature of *U* maintains only about 10% of the total system energy. Therefore, this feature is less important for detecting the dominant physical characteristic of *U* in comparison to the first spatial feature in the bay.

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