(not shown) indicate that the SMV often corresponds to cold upwelled MAW. However, it does not maintain its structure during RR96 as strongly as the other three vortices. Meandering southward shelf currents on its western side (Böhm et al., 1987) and the lack of topographic controls on its eastern side are probable explanation.

These four identifications illustrate the potentials of ESSE for quantitative three-dimensional and multivariate variability studies. In the present situation, the specifics of the geometry and horizontal covariances were such that the orthogonality constraint did not significantly alter the dominant physical patterns. In other cases, one may need subsequent analyses (e.g., factor or cluster analysis) to disentangle the physics from of the dominant decomposition. In addition, the three-dimensional multivariate variability of a feature often corresponds to groups of eigenvectors. For example, the three-dimensional modes 11 and 12 of Fig. 7 correspond to the ABV and IBV as modes 1 and 2 did, but they mainly account for salinity dominated variabilities (Fig. 6). From our experience, the number of modes required is often of the order of the product of numbers required for horizontal and vertical univariate EOFs. For example, the present 400 dominant modes explain 68.2% of the total 3D tracer variance; the 1000 dominant explain 87% of the variance. In passing, these numbers account for all possible realizations of the 3D mesoscale tracer variability. Because of the memory in time, only a portion of these eigenvectors is active at a given instant (e.g., mesoscale eddies are not everywhere at the same time).

#### *3.1.2. Dominant eigendecomposition of the three-dimensional PE error covariance matrix*

As outlined in Section A.1 (Eqs. (A12) and (A13)), the velocity responses corresponding to the dominant 3D tracer eigenmodes (Section 3.1.1) are computed first. Each tracer mode is dimensionalized and added to the initial tracer fields $\hat{\psi}_{trc}$. The resulting ensemble of unbalanced fields is adjusted by integrating the momentum equations for 2 model-days, keeping $T$ and $S$ fixed. Fig. 8 illustrates the velocity responses of these adjustment PE integrations (Section 2.3). The dimensional difference fields shown correspond to the tracer modes 1 to 4, and 10 to 13, that were plotted on Fig. 7. The specifics of the state $\hat{\psi}_0$ (e.g., density features) and topography (e.g., Ionian slope and basin between Pantelleria and Malta) strongly influence the flow responses to tracer perturbations. The barotropic transport responses usually have their largest amplitudes and gradients along the deep eastern side of the Ionian shelfbreak (e.g., compare Panels 1 and 11 with the others). The internal velocity anomalies of Panels (1–4) explain internal circulation variabilities corresponding to the largest-scales of the ABV, IBV, MCC and SMV, respectively. The internal velocity responses to tracer modes of shorter horizontal scales (e.g., Panels 10 and 13) clearly show that they are mainly subject to geostrophic constraints (the meridional internal velocity is not shown for this reason). The effects of the vertical tracer decomposition (Fig. 6) are also observed. The barotropic transport and internal velocity responses of Panels 11–12, which correspond to the second vertical tracer EOF ($T$ and $S$ in opposition, $S$ dominating), differ from that of Panels 1–2, which correspond to the first vertical tracer EOF ($T$ and $S$ in phase, $T$ dominating). This difference is especially striking for the transport responses, which adjust via baroclinicity, relief, diffusion and nonlinear effects (Section 2.3).