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Preface: Current perspectives in modelling, monitoring, and predicting geophysical fluid dynamics

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Abstract. The third edition of the international workshop "Nonlinear Processes in Oceanic and Atmospheric Flows" was held at the Institute of Mathematical Sciences (ICMAT) in Madrid from 6 to 8 July 2016. The event gathered oceanographers, atmospheric scientists, physicists, and applied mathematicians sharing a common interest in the nonlinear dynamics of geophysical fluid flows. The philosophy of this meeting was to bring together researchers from a variety of backgrounds into an environment that favoured a vigorous discussion of concepts across different disciplines. The present Special Issue on "Current perspectives in modelling, monitoring, and predicting geophysical fluid dynamics" contains selected contributions, mainly from attendants of the workshop, providing an updated perspective on modelling aspects of geophysical flows as well as issues on prediction and assimilation of observational data and novel tools for describing transport and mixing processes in these contexts. More details on these aspects are discussed in this preface.

This Special Issue is composed of 11 papers presenting the breadth of ideas and results discussed during the third edition of the international workshop "Nonlinear Processes in Oceanic and Atmospheric Flows". These articles illustrate exciting opportunities for multidisciplinary collaborations in the oceanic and atmospheric sciences and benefits from the interactions of these sciences with applied mathematics and nonlinear physics. The workshop was held thanks to the generous support of the United States Office of Naval Research (ONR and ONR Global) and the Spanish Severo Ochoa Programme.

Transport and mixing processes in fluid flows are crucially influenced by coherent structures and their characterization under different mathematical approaches. The understanding of these Lagrangian objects is a topic of intense research. Padberg-Gehle and Schneide (2017) discuss spatio-temporal clustering algorithms that have been proven to be effective for the extraction of coherent sets from sparse and possibly incomplete trajectory data. In particular the authors describe an unweighted, undirected network where Lagrangian particle trajectories serve as network nodes. Classical graph theory concepts are then employed to analyse the resulting network. The authors demonstrate the performance of their methodology in a simple kinematic model, the Bickley jet, as well as in data sets describing the Antarctic stratospheric polar vortex evolution.

Further characterizations of mixing in geophysical flows are given by Rypina and Pratt (2017), based on the trajectory encounter mass and the encounter volume. These quantities are introduced as a measure of the mixing potential of a flow. Regions characterized by a low encounter volume, such as the cores of coherent eddies, have a low mixing potential, whereas turbulent or chaotic regions characterized by a large encounter volume have a high mixing potential. The encounter volume diagnostic is applied in settings with increasing complexity: the Duffing oscillator, the Bickley jet, and the altimetry-based velocity in the Gulf Stream extension ocean region.

Understanding transport processes in simple kinematic models has helped to understand the essential ingredients of complex transport phenomena (Bower, 1991; Samelson, 1992; Samelson and Wiggins, 2006). In this Special Issue kinematic models are constructed by García-Garrido et al. (2017), retaining fundamental features of complex fluid parcel evolution during the polar vortex breakdown in September 2002 and its previous stages. The authors showed that the breaking and splitting of the polar vortex are justified by the sudden growth of a planetary wave and the decay of the axisymmetric flow.

Koshel and Ryzhov (2017) studied the kinematic model of an elliptic vortex evolving in a periodically strained background flow, to explore possible unbounded regimes. The authors demonstrated that, given superimposed periodic oscillations to the exterior deformation, the phase space region corresponding to the elliptic critical point experiences parametric instability leading to locally unbounded dynamics of the vortex. They also showed that, for specific values of the perturbation parameters, the parametric instability can be effectively suppressed.

Additional steps in the study of transport processes from data sets based on altimeter observations are considered in the paper by Prants et al. (2017). The authors study northward near-surface Lagrangian transport of subtropical waters in the Japan Sea. They document the presence of gates facilitating propagation of subtropical waters to the north and the findings are verified by some tracks of available drifters.

Curbelo et al. (2017) described 3-D transport processes in the stratospheric polar vortex (SPV) above Antarctica by using the Lagrangian descriptor function M. The authors provided new insights into the Lagrangian structure of the vertical extension of the stratospheric polar vortex and its evolution. They identify the appropriateness of 3-D mathematical objects such as normally hyperbolic invariant curves that support the characterization in the stratosphere of an invariant separatrix of several kilometres in depth.

Monroy et al. (2017) also study 3-D transport, but this time in the ocean, by addressing the problem of sinking particles in a realistic oceanic flow, with major energetic structures in the mesoscale. They focus on a range of particle sizes and densities appropriate for marine biogenic particles. By using a simplified equation of motion of small particles in a mesoscale simulation of the oceanic velocity field, they find that the influence of physical processes, such as the Coriolis force and the inertia of the particles, is negligible when compared with passive motion with the velocity of the flow and a constant added vertical velocity due to gravity. Nevertheless, the authors document and explain the emergence of inhomogeneities in the accumulated particle distribution on the sea floor even in this passive-transport setting.

Climatological studies considering winter precipitation over the Iberian Peninsula from 1979 to 2008 and their links to large-scale tropospheric mixing over the eastern Atlantic Ocean were addressed by Garaboa-Paz et al. (2017). The connections are established by means of finite-time Lyapunov exponents (FTLEs). The authors' study suggests that significant negative correlations exist between summer FTLE anomalies and winter precipitation over Portugal and Spain. Additionally, summer anomalies of the FTLE are correlated with the East Atlantic (EA) teleconnection index, confirming their role as a seasonal predictor for winter precipitation over the Iberian Peninsula.

Yu et al. (2017) studied uncertainties in coupled climate models produced by the choice of specific parameter values. The authors calibrated a parameter estimation procedure that projects observational information onto model parameters and tested it in a conceptual climate model that couples the stochastic atmosphere and a slow-varying ocean. This simple model study provides a guideline when real observations are used to optimize parameters in a coupled general circulation model for improving climate analysis and predictions.

Surface ocean currents contribute to the characterization of the Earth's climate. Knowledge of ocean surface velocities is a key and cross-cutting issue that impacts many societal challenges far beyond the research context of geophysical fluid dynamics. In this context Isern-Fontanet et al. (2017) presented a review of the current knowledge for retrieving ocean currents and provided a global and systematic view of the technologies available to this end in the upper ocean. They emphasized the available approaches to assimilate observations based on remote sensing techniques such as satellite measurements (sea surface height and sea surface temperature) and HF coastal radar into ocean models.

Finally, regarding remote sensing techniques, Basnayake et al. (2017) illustrate the utility of the variational destriping method to process ocean colour images. The authors show the accuracy of their approach from a benchmark data set which represents the sea surface temperature off the coast of Oregon, USA.

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