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Implementation of a two-way coupled atmosphere-ocean wave modeling system for assessing air-sea interaction (solicited: Young Scientist Award Lecture)

Georgios Varlas (1,2)

(1) Department of Geography, Harokopion University of Athens (HUA), El. Venizelou Str. 70, 17671 Athens, Greece, (2) Institute of Marine Biological Resources and Inland Waters, Hellenic Centre for Marine Research (HCMR), 46.7 Km Athens-Sounio avenue, 19013 Anavissos, Attica, Greece

The idea that the fluid layer surrounding Earth should be considered as a single system at short and longer spatiotemporal scales is nowadays dominant among scientific society. However, the complex mechanisms of atmosphere-ocean interaction are still understudied. To narrow this gap, it is essential to implement modeling systems that couple atmosphere and ocean. In this study, a new two-way coupled atmosphere-ocean wave modeling system named CHAOS (Chemical Hydrological Atmospheric Ocean wave System) is introduced, aiming to unveil the impact of sea state on atmospheric properties and vice versa. The newly developed system consists of two components. The first component consists of the Advanced Weather Research Forecasting (WRF-ARW) model and two sub-components to resolve chemical (WRF-Chem) and hydrological (WRF-Hydro) processes, while, Wave model (WAM) is the second component. The two components are coupled using the OASIS Model Coupling Toolkit (OASIS3-MCT) that enables them to communicate and exchange the information required to refine their simulation results. CHAOS has been tested in a high-impact cyclonic system over the Mediterranean Sea comparing one-way and two-way coupled simulations to assess air-sea interaction (neglecting the chemical and hydrological capabilities in these experiments). The analysis of results showcases that the encapsulation of ocean waves in the atmospheric surface layer processes modifies the characteristics of atmospheric flow which, in turn, determines the ocean wave generation. A remarkable finding is that the coupling of the two systems foremost increases the air-sea momentum, enthalpy and moisture transfer affecting the formation of the cyclonic system. The interaction along air-sea interface is also reflected in the vertical structure of troposphere and its properties. The results are statistically assessed against in-situ and remotely sensed data. CHAOS in two-way coupling mode presents an overall improvement of the forecast skill up to 20% over the sea, also having a positive impact on atmospheric predictability over the land. Moreover, in operational mode for one year, two-way coupling offers improvement up to 6%. A particularly understudied phenomenon in air-sea interaction that this study approaches is the effect of rain on sea state and its feedback to atmospheric conditions. To that end, a new parameterization scheme assuming rain-induced sea surface roughness was incorporated in CHAOS. The simulation of hurricane Sandy (2012) over the Atlantic Ocean employing the new scheme indicates that the rain-on-sea state effect increases sea surface roughness attenuating both the atmospheric flow and the ocean wave growth.