# Numerical study of the role of land–air–sea interactions for the northeasterly monsoon circulations over Indian Ocean during INDOEX

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**One of the principal objectives of the Indian Ocean Experiment (INDOEX) was to study the aerosol transport from the Indian subcontinent to the pristine oceanic environment. The underlying hypothesis for INDOEX is that, during the northeasterly monsoon, the intruding aerosols and other anthropogenic pollutants can entrain into the Inter Tropical Convergence Zone (ITCZ) and the Equatorial Indian Ocean and finally into the clouds. The altered clouds influence the radiative transfer processes at the regional and possibly global scale. The driving mechanism for the regional transport was the boundary layer circulation. In this study, it was hypothesized that the circulation pattern, which affects the regional transport, was strongly influenced by the land–air–sea interactions. To test this, a zonally symmetric version of a primitive equation numerical weather prediction model, called the Advanced Regional Prediction System (ARPS), was used. A number of numerical experiments were performed for a 2-D domain ranging from 14°N to 16°S centered over 76°E. In the experiments, the influence of land–sea interaction (differential heating), topography (Western Ghats), and the thermal gradients (SST and land surface temperature) on the coastal circulations over Equatorial Indian Ocean were studied. Results indicated a strong land–air–sea interaction and feedback teleconnection between the local and large scale features. Interestingly, the model generated land influence to the order of 1000 km offshore in the simulation domain, consistent with different observations. Results suggest that the oceanic environment in the northeast monsoon over Arabian Sea and the Indian Ocean can display significant diurnal variability and heterogeneity due to topography and surface temperature gradients, and that the local features have interactive feedback on the large scale circulations and transport.**

THE genesis of this study lies in a major multi-national field experiment: Indian Ocean Experiment (INDOEX) that was conducted during the northeasterly monsoon of 1999. INDOEX had several objectives focused towards developing a comprehensive analysis of the interactive role of radiation, clouds, and the aerosol transport leading to a better understanding of the regional scale radiative forcing for climate change. The hypothesis was, during the northeast (NE) monsoon, not-so-clean continental air parcels can be transported towards the Inter Tropical Convergence Zone (ITCZ) and alter the cloud–radiative properties. Thus, one of the pivotal components linked with this experiment was to understand, how the air parcels and aerosols could be circulated over the marine environment, and how the ITCZ dynamics related with the atmospheric chemistry and cloud formation. More details about the experimental plan can be found at http://www-indoex.ucsd.edu as well as from Ramanathan *et al.*[1]

The NE monsoon, compared to the southwest monsoon, is however traditionally a lesser studied system. This is principally because the southwest monsoon affects a large continental landmass and has climatic and economic significance. Considering this paucity of information, for INDOEX, four ship-based studies have been conducted prior to the 1999 field program. The first of these was in January 1995 (ref. 2), second in January 1996 (ref. 3), third was in January 1997 (ref. 4) and the fourth in February 1998 (ref. 5). Of these, the first two cruises collected data principally on the latitudinal variation of radiation, and aerosol and trace gas characteristics over the Indian Ocean[6]. The 1997 and 1998 cruises over the Indian ORV *Sagar Kanya* additionally focused on the thermodynamic structure of the marine troposphere. One consistent feature that was proposed from all the four data sets relates to the signature of a strong continental land mass influence on the marine environment to the order of hundreds of kilometers offshore. The observations of Rhoads *et al.*[2] suggested strong influence of continental effect till about 2°N. This influence was seen in all the trace species and aerosol characteristics. Similar land influence was observed in the western Indian Ocean region during the 1996 cruise[3]. These observations went beyond the realms of traditional land–sea breeze circulations and had necessitated the numerical experiment summarized in this

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