

## Fluid dynamics of the monsoon

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**Abstract.** The monsoonal regions of the world are characterized by a seasonal reversal in the direction of winds associated with the excursion of the equatorial trough (or the ITCZ) in response to the variation in the latitude of maximum insolation. This monsoonal circulation is a planetary scale phenomenon. However, the associated precipitation is critically dependent on the organization of the cumulus clouds (typically a few kilometers in horizontal extent) over the scale of synoptic vortices (typically a few hundred kilometers in horizontal extent). Thus modelling of the seasonal transitions and intraseasonal fluctuations requires an understanding of the fluid mechanics of these three scales of organizations and their interactions. The present paper is an attempt to outline the current state of understanding of these phenomena.

**Keywords.** Monsoon; tropical circulation; intertropical convergence zone; atmospheric instabilities.

### 1. Introduction

Over certain regions of the tropics, the wind blows in opposite directions in summer and winter. For instance, over the Arabian Sea, the wind at low levels blows from the southwest in the summer and from the northeast in the winter. Such a seasonal reversal in the direction of the wind is traditionally known as the monsoon. The Arabs first discovered the monsoon over the Arabian sea. In fact the word monsoon is derived from the Arabic word *mausam* for a season. Thus the essence of monsoon is seasonality.

Around the first century B.C. when India moved from pre-history to history, other traders from the Mediterranean world became aware of these winds and used this knowledge in planning their voyages. Ships travelling from Alexandria, which was then the entrepot of the Mediterranean world, would wait for the southwest monsoon to be established and then set sail for the west coast port of Bharukachchha (modern Broach). The northeast monsoon of the winter season would take these ships back. At this time Indians were involved in extensive trade with the Golden Isles of Jawa, Sumatra and Bali, which supplied the spices which were then sold to the Romans at enormous profits (Thaper 1966). Thus it is likely that they were also aware of the monsoon over the Bay of Bengal.

The monsoon is by no means restricted to the Indian region and the surrounding oceans. Ramage's (1971) delineation of the monsoonal regions of the world using a criterion based on the seasonality of winds shows the monsoon to be a planetary scale phenomenon (figure 1). As the famous astronomer Edmond Halley observed