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# MONSOON SYSTEMS AND CONTINENTAL RAINFALL OVER EQUATORIAL AFRICA

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Since at least the 1950s a very simplistic view of the African monsoon has prevailed. In this view, the Intertropical Convergence Zone migrates northward into West Africa in the boreal summer and southward into southern Africa the austral summer, "following the sun". The rainfall is assumed to be coupled with this north-south migration of the ITCZ, so that the ITCZ scenario is used to explain such phenomena as the seasonal cycle, the length of the wet and dry seasons, and even interannual variability (Fig. 1). Over West Africa the monsoon is assumed to be produced by a layer of moist air coming off the tropical Atlantic. The ITCZ marks the meeting of this air with the hot desert "harmattan". Rainfall occurs only where the layer is deep enough to sustain convection. Thus, the rainfall maximum occurs several degrees of latitude equatorward of the surface ITCZ.

Our work on West Africa has produced a very new picture of the "monsoon" (Fig. 2). In this picture, the ITCZ is effectively decoupled from the tropical rainbelt. The main rainfall is instead associated with a region of strong ascent lying between the cores of the African Easterly Jet (AEJ-North) in the mid-troposphere and the Tropical Easterly Jet (TEJ) in the upper troposphere. The width of the rainbelt is equivalent to the distance between the cores; the intensity of the rainbelt is roughly proportional to the intensity of the ascent. Interannual variability results from changes in the width, latitudinal location and intensity of the rainbelt.

More recent work has focused on climate and interannual variability in the equatorial region and the southern-hemisphere extra-tropics of Africa. This is the region with rainy seasons in the two transition seasons and drier seasons in the extreme seasons. Our early work has documented a southern hemisphere, mid-tropospheric easterly jet (termed the AEJ-South) (Fig. 3) that appears to play a role analogous to that in the northern hemisphere. However, the situation is much more complex here than in West Africa, where there is an expansive land mass and uniform terrain. West African climate shows very little zonal asymmetry. Zonal asymmetry is pronounced over the eastern half of the continent, especially in the tropics. This is because of the complex terrain in the eastern and western extremities of the equatorial region, the low-lying central basin, and the varying proximity to the Atlantic and Indian Oceans across the east-west expanse of this region. Zonal asymmetries in the dominant dynamic controls also complicate the situation. Notably, the October-November rainy season is generally dominant in the west, while the March-April-May season is dominant in the east.

One point of similarity with West Africa is that the development of the rainy season follows this core of ascent as the jets migrate north and south with the seasons. In the western equatorial region the ascent and tropical rainbelt lie between the cores of the AEJ-South and the TEJ (Fig. 4), which is quite weak in the main rainy season months of March and October. In the eastern equatorial region the ascent and rainbelt lie between the cores of the two mid-level easterly jets (AEJ-N and AEJ-S). The ascent tends to be anomalously weak in the dry years and anomalously strong in the wet years.

The zonal asymmetry in climate is accompanied by zonal asymmetry in interannual variability. The controls on interannual variability vary markedly in the east-west direction. To the west, the control by the Atlantic is stronger; the control by the Indian Ocean increases steadily eastward. The role of the oceans also varies seasonally. The dominant ocean influence in the first rainy season (March-to-March) is the Pacific, especially the El Nino/la Nina phenomenon. The dominant influences in the second rainy season (October-November) are equatorial Atlantic and Indian Ocean SSTs.

Another outcome of our work both for West and equatorial Africa is the demonstration that the ITCZ is not the harbinger of rainfall. The seasonal of the ITCZ does correlate with the seasonal migration of rainfall over the continent. This is but a coincidental association. The ITCZ is essentially decoupled from the main regions of ascent and the main regions of rainfall. The assumed ITCZ-rainfall association has prevailed for a long time, causing the focus to be on surface features of climate and weather in the context of understanding interannual variability and forecasting. First and foremost, our work is showing that the processes controlling African climate are those in the upper atmosphere. Much more attention must be paid to the upper-level flows, how they are influenced by ocean and land surface processes and how they relate to interannual variability.

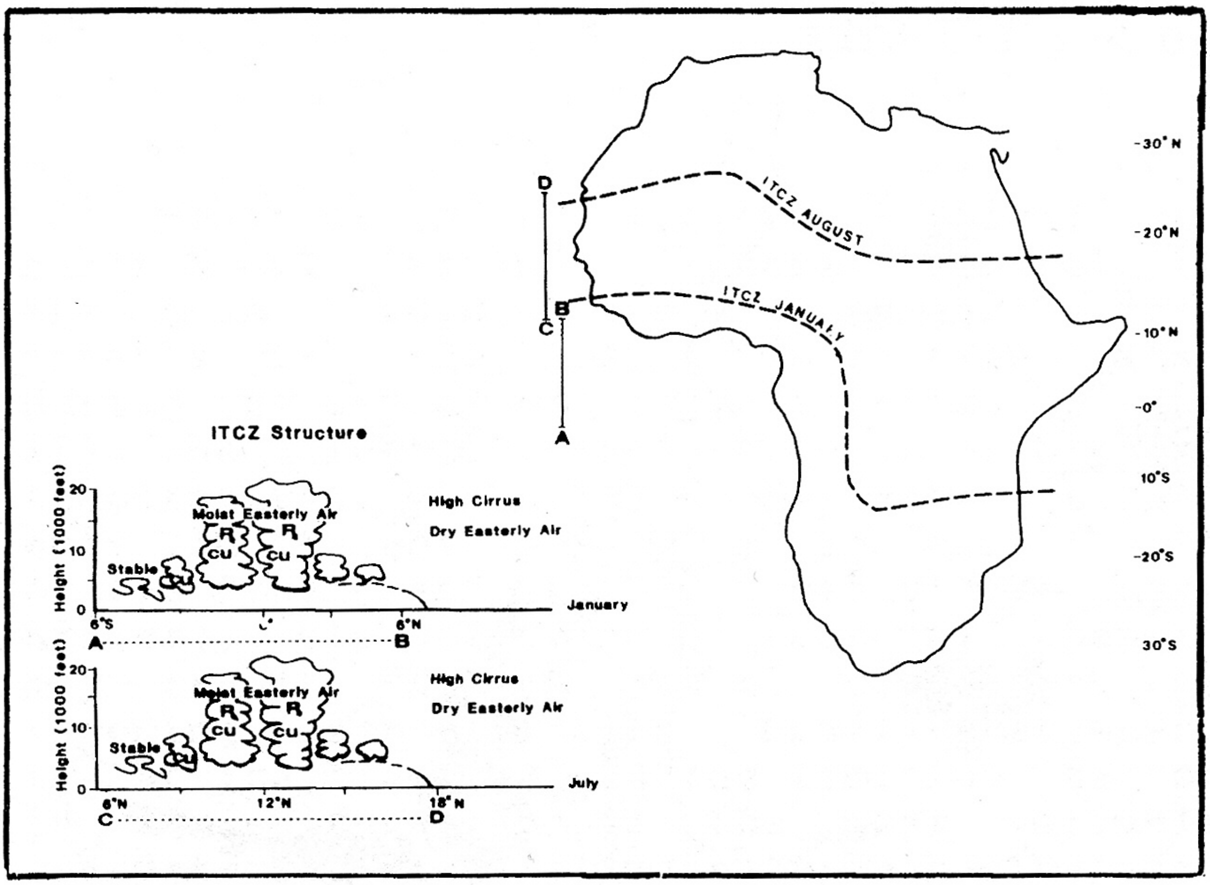


Fig. 1a The structure and position of the Intertropical Convergence Zone (ITCZ) over Africa in January and July/August, along with the classical picture of the structure of the monsoon layer.

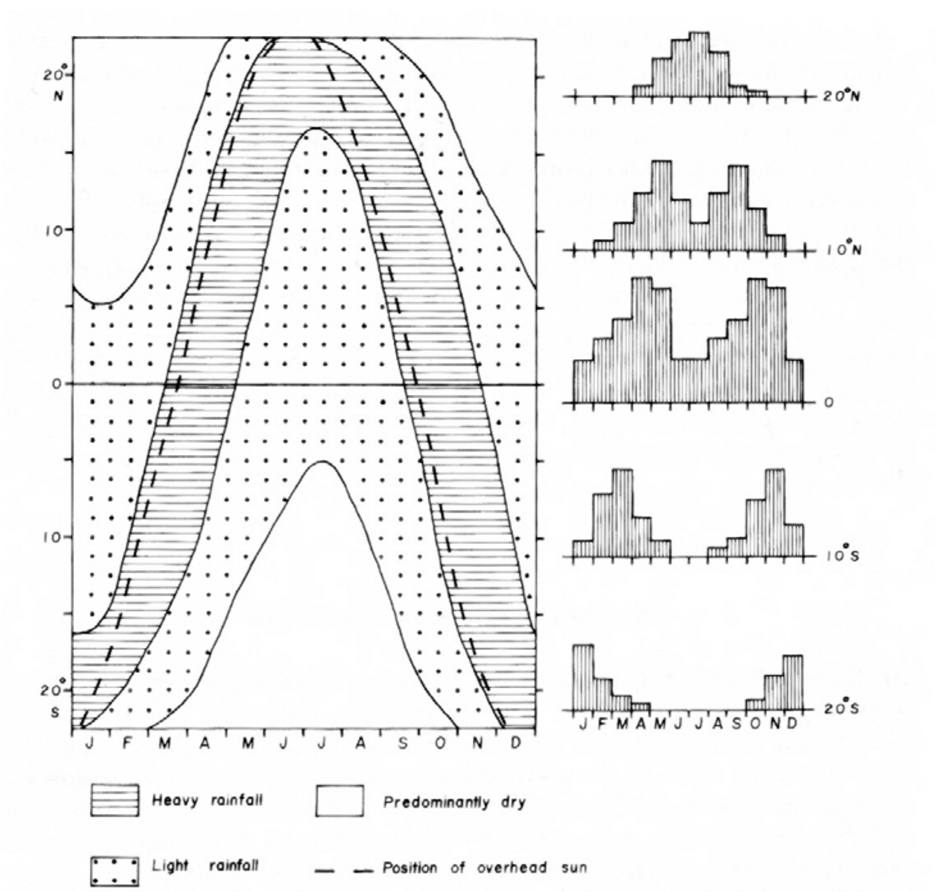


Fig. 1b A simplified model of season rainfall distribution over tropical continents, based on the ITCZ migration. Left: latitudinal movement of precipitation zones. Right: station models at various latitudes.

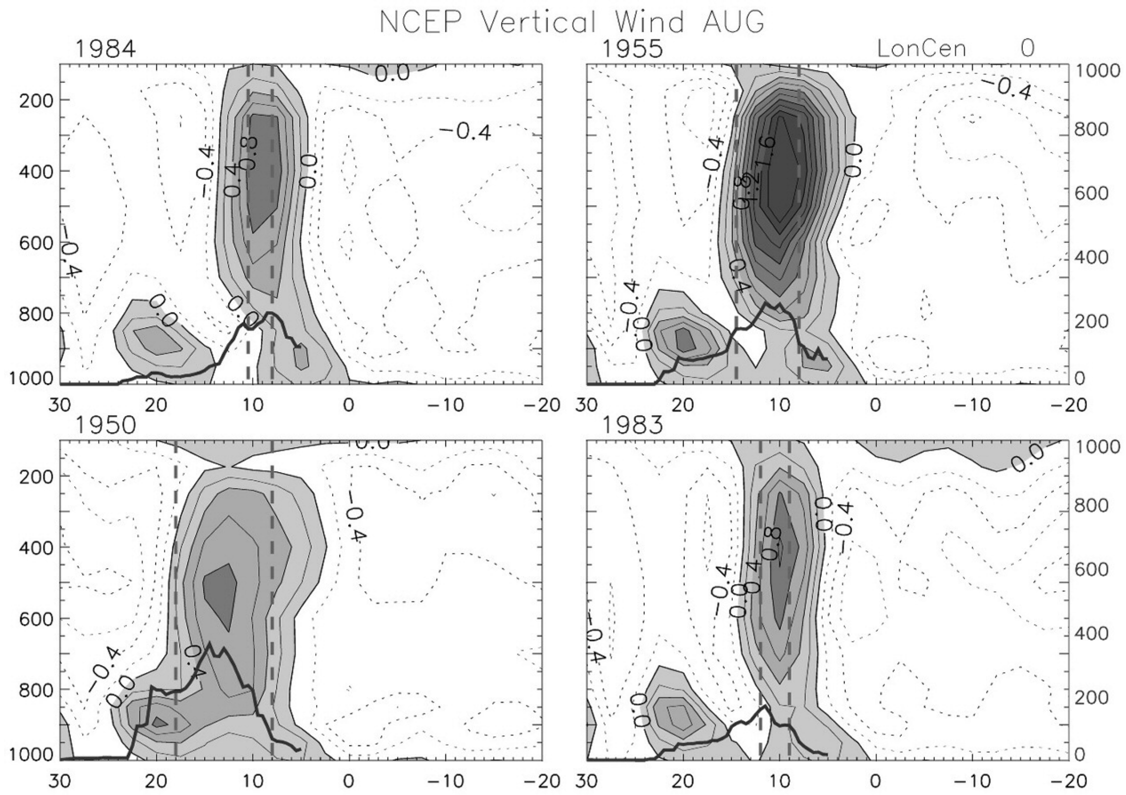


Fig. 2 Mean vertical motion over West Africa in August for the four years 1950, 1955, 1983 and 1984. Contours are in ms-1; areas of ascent are shaded. Mean rainfall as a function of latitude is indicated at the bottom; rainfall in mm/mo is indicated on the right hand axis. The vertical dashed lines indicate the axes of the AEJ (left) and TEJ (right).

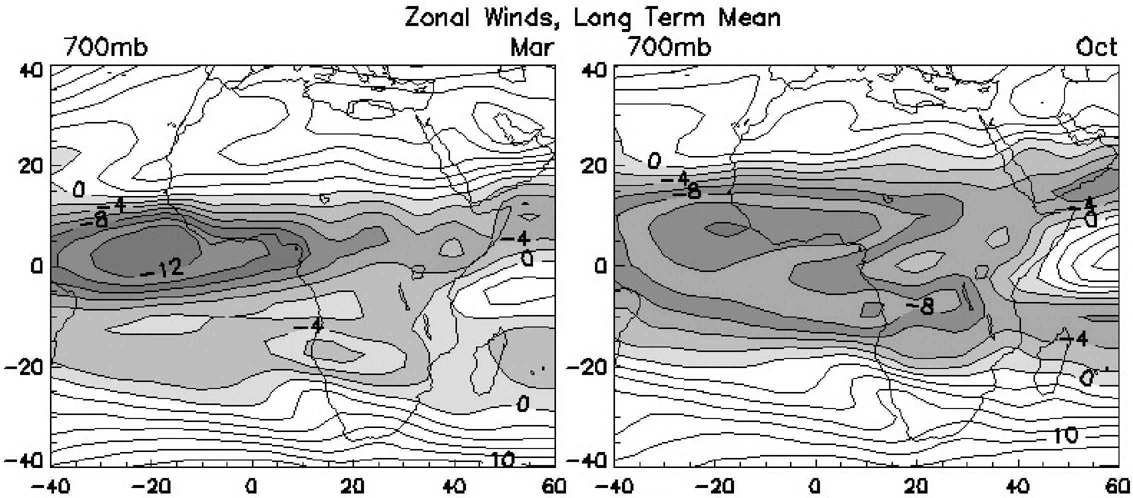


Fig. 3 Mean zonal winds ($ms^{-1}$) at 700 mb over Africa in March and October.

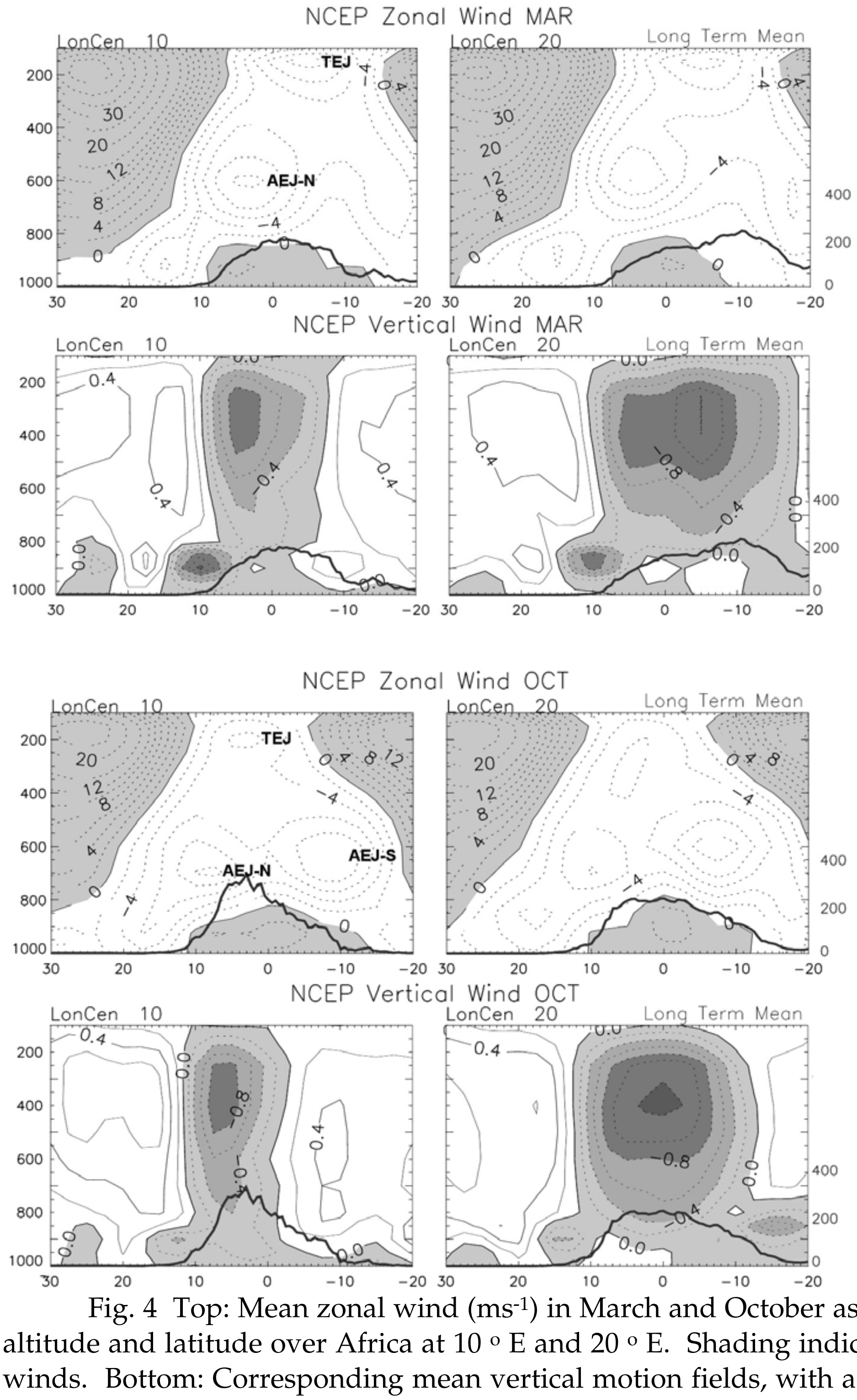


Fig. 4 Top: Mean zonal wind ($ms^{-1}$) in March and October as a function of altitude and latitude over Africa at 10 º E and 20 º E. Shading indicates westerly winds. Bottom: Corresponding mean vertical motion fields, with ascent shaded. Precipitation as a function of latitude is indicated at the bottom, with rainfall in mm indicated on the right hand axis.