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A comparison of Indian and African monsoon variability at different time scales

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Abstract

A review is given of the summer monsoon systems in Africa and India, and of their comparison at different time scales. Features of the circulation are described first, including the main respective meteorological centres of action controlling the annual cycle of the rain bands over these two regions. The main elements of the atmospheric intraseasonal variability are then presented, which controls in particular the onset of these two monsoon systems. Then the sensitivity of these two monsoon systems to oceanic and continental surface conditions in the context of interannual variability is discussed and compared. Consequences in term of predictability are commented. Finally, the Intergovernmental Panel on Climate Change (IPCC4) scenarios of the future climate over these two regions are presented. ***To cite this article: S. Janicot, C. R. Geoscience 341 (2009).***

Résumé

Une comparaison de la variabilité des moussons indienne et africaine à différentes échelles de temps. Un bilan des connaissances est présenté sur les systèmes de mousson d'été boréal en Afrique et en Inde et sur leur comparaison à différentes échelles de temps. Les grands traits de ces circulations atmosphériques sont tout d'abord décrits, incluant les principaux centres d'action météorologiques respectifs contrôlant le cycle saisonnier des pluies sur ces deux régions. On décrit ensuite les éléments principaux de la variabilité atmosphérique intrasaisonnière, conditionnant, en particulier, la mise en place de ces deux systèmes de mousson. Puis la sensibilité de ces deux systèmes de mousson aux conditions de surface océanique et continentale dans le contexte de la variabilité interannuelle est discutée et comparée. Les conséquences en terme de prévisibilité sont commentées. Enfin, les scénarios climatiques du 4e rapport du GIEC sur ces deux régions sont présentés. ***Pour citer cet article : S. Janicot, C. R. Geoscience 341 (2009).***

Keywords: Monsoon systems; Intraseasonal variability; Africa; India; Interannual variability; Climate change; Predictability

Mots clés : Systèmes de mousson ; Variabilité intrasaisonnière ; Afrique ; Inde ; Variabilité interannuelle ; Changement climatique ; Prévisibilité

1. Introduction

The livelihood of over 60% of the world's population depends upon the monsoons, of which the Asian

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summer monsoon is the largest. The monsoons (which mean ‘‘season’’) are directly controlled by the annual course of the sun and represent in the tropics the most important phenomena in the seasonal cycle. Local agriculture and water resources can be greatly affected by the timing and the intensity of this event which brings, during some months, most of the total annual rainfall. Actually, while the main component of the monsoon is highly regular as it occurs every year, anomalies in the resultant rainfall total and in the daily distribution can be high, and impact greatly on crop yields. These anomalies are present at all time scales: intraseasonal (meaning here fluctuations of less than 90 days), interannual, decadal and multidecadal, and more or less expected in the climate change scenarios. They are controlled both through internal atmospheric dynamics and by oceanic and continental anomalies on local, regional or global scales, including complex scale interactions. In consequence, accurate and useful prediction of the monsoons is presently difficult to provide.

In this article, we focus on the Africa–India monsoon sectors during the northern summer. These two monsoon systems have been shown to share common temporal ranges in their fluctuations, being linked to common or contrasted climate processes. Various investigations using proxi data and recent climate models have demonstrated that both African and Asian monsoons have been very sensitive to paleoclimate fluctuations due to the variation of astronomical factors. For instance, it has been shown that these two monsoons were stronger or weaker during the mid-Holocene at 6000 BP or the Last Glacial maximum at 21,000 BP, respectively, providing higher or lower precipitation, respectively, during northern summer over the northern subtropical latitudes of Africa, India and East Asia [5]. In the following, we present over the present the main features of these monsoon systems variability from intraseasonal to multidecadal time scales and we detail the associated climate mechanisms. Then we analyse the climate change scenario for the 21st century.

2. Annual cycle of the monsoon systems and monsoons onset

Fig. 1 shows on the upper panel (left) the averaged July–September mean sea level pressure and 1000 hPa wind fields. Due to the contrast in the thermal capacity of the land surface and the ocean, the hot land masses in the northern hemisphere are located in a low pressure area (extending to 10°S in Central Africa) while high pressures, located over the oceans outside of the equatorial band, correspond to the subtropical anticyclones of Azores in the northern tropical Atlantic, and of Santa Helena and Mascareignes in the southern tropical Atlantic and Indian oceans, respectively. The large-scale cross-equatorial pressure gradient induced leads to southerly transequatorial low-level winds which bring a high content of moisture from the ocean to the land areas. When crossing the equator, these ‘‘trade’’ winds pass from an easterly to a westerly component and become the monsoon winds. They converge in the low-pressure areas with dry winds coming from the northeast and form a cyclonic circulation. The lower panel (left) of Fig. 1 shows half of the difference in the pressure and wind fields between the summer and the winter. This computation enables one to characterize the annual cycle of these low-level fields. It enhances the cross-equatorial pressure contrast seen on the upper panel, but the wind field is very similar to the summer one over the Indian Ocean and the Asian sector. This highlights the very large-scale character of the monsoon phenomena in this area. In the Atlantic–Africa sector, the signal is limited north of the equator, showing the more continental scale of the African monsoon.

Fig. 1 also shows the mean summer atmospheric circulation at 700 hPa (bottom right panel) and at 200 hPa (top right panel). At 700 hPa, the circulation is highly contrasted between the Asian and the African monsoon. The high thickness character of the Asian monsoon circulation is highlighted by the maintenance of a clear cyclonic circulation at this level, while over Africa the low-level monsoon circulation has been replaced by a high pressure cell and an anticyclonic circulation controlling northeasterly winds over the Sahara and easterly winds over West Africa. This circulation corresponds to the top of the Saharan heat low and is associated with divergent winds inducing, in particular, a northerly return flow at this level. The mean easterly winds maximum over West Africa corresponds to the so-called African Easterly Jet, an unstable jet in which easterly waves develop and can trigger the initiation of mesoscale convective systems [66]. At 200 hPa level, a high geopotential height belt extends from East Asia to Africa controlling easterly winds on its southern border, the so-called Tropical Easterly Jet [33]. This is the sign of the continental scale monsoon system and of the associated meridional Hadley-type circulation transporting high energy air from the monsoon areas towards the southern hemisphere [60].

The large-scale extension and strength of such monsoon circulations is explained by the large release of latent heat by convective systems within this