2B.1 MEAN STATE AND WAVE DISTURBANCES DURING PHASES I, II, AND III OF GATE BASED ON ERA-40

Andreas H. Fink[1]*, Dayton G. Vincent[2], P. M. Reiner[1], and Peter Speth[1]
[1] University of Cologne, Cologne, Germany; [2]Purdue University, West Lafayette, Indiana, USA

1. INTRODUCTION

From 15 June to 23 September 1974, the international field program GATE (GARP Atlantic Tropical Experiment) was held over the tropical region encompassing western Africa and the eastern Atlantic Ocean. The scientific objectives of GATE's Central Program were to examine the interactions between a variety of scales of organized convective systems and the large-scale flow, and to improve numerical models and, thereby, numerical weather prediction (Kuettner 1974). Four scales of motion were defined for GATE: A, B, C, and D, which range from the large (including synoptic) – scale A to the cumulus cloud scale D.

One of the goals of the present paper is to use the recently-available European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis dataset, known as ERA-40 (1957-2002), to conduct a comprehensive investigation of the large-scale (A-scale) circulation patterns (primarily mean state and African easterly wave disturbances, AEWs) during all three phases of GATE (Phase I: 26 June–16 July; Phase II: 28 July–17 August; Phase III: 30 August–19 September 1974). Another goal of this paper is to place GATE results in a long-term perspective by comparing them to a set of climatological features, both over West Africa (land) and the adjacent eastern Atlantic Ocean (water), where a special A/B-scale ship array was located. Since about the 1970s, it has been established that there are two east-west tracks along which AEW vortices propagate, one located between 16° and 20°N and the other located between 7° and 11°N. The kinematic, thermodynamic, and moisture environments of AEW disturbances along the northern track have not been investigated in depth, especially for the three enhanced observing phases of GATE. Therefore a third goal of this paper is to conduct a thorough diagnosis of the northerly AEW vortices during Phases I, II, and III.

2. DATA AND AEW ANALYSIS TECHNIQUE

ERA-40 belongs to the second generation reanalysis benefiting from many improvements and new developments in the data assimilation scheme, resolution, dynamics, physics, and formulation of land-surface processes in the background forecast model. With respect to the quality of ERA-40 fields during the GATE period, two of the most salient features are: 1) a unique set of dense upper-air information (e.g., cloud drift winds, radiosondes, dropwindsondes, flight-level aircraft data) over the data-sparse West African and East Atlantic Tropics and 2) the three-dimensional variational analysis scheme 3D-Var that combined the background forecast and observations to the analysis every hour. Thus, the use of ERA-40 during GATE formed a unique opportunity to study synoptic-scale processes over West Africa and the adjacent eastern Atlantic Ocean.

The three-step subjective manual AEW tracking method employed in this paper is the same as that used by Fink and Reiner (2003). In brief, AEW episodes and the approximate longitudinal position of AEW troughs were identified from two sets of longitude-time (Hovmoeller) diagrams of temporal anomalies of the meridional wind component: one at 700 hPa averaged between 7° and 13°N, the other at 850 hPa averaged between 17° and 23°N. In a second step, a northerly and southerly center of cyclonic inflow at or close to the previously identified trough longitudes were localized from six hourly streamline maps of 2–6-day bandpass-filtered wind at 850 hPa. Only in case of ambiguity, maps of 2–6-day bandpass-filtered relative vorticity at 700 hPa were also consulted to diagnose the coordinates of the paired vortex

3. RESULTS

In the present analysis, the AEW tracks for all three phases of GATE will be discussed. In order to conserve space, only Phase III tracks are shown in Fig. 1a. As in many of the previous studies, two distinct tracks are visible, especially over land. The northern and southern AEW disturbances propagate simultaneously westward as twin vortices. The only case of a single vortex propagation occurred during Phase I (not shown) and solely during Phase III, a merging of two paired vortices is evident in our analysis. Figure 1a also shows four regions (shaded boxes), two over land and two over water, which were used for the computation of areal averages of several variables.

One important result is that the activity of the northern waves at about 20°N was, in contrast to the southern waves at about 9°N, already quite strong during Phase I. At the same time, the low-level monsoonal flow, the heat low, and the upward motion in the northern desert zone were strongest. In contrast, the midtropospheric African easterly jet (AEJ) and the related horizontal shear instabilities were strongest during Phase III. The AEJ is also found at the lowest altitude over land during Phase III and it extends out to the Atlantic Ocean without changing its height and strength. These factors are associated with the well-known peak in the activity of AEWs in the southern wet zone during Phase III. The different activity of the northern and southern waves during Phase I and Phase

* *Corresponding author address*: Andreas H. Fink, Institute of Geophysics and Meteorology, University of Cologne, Kerpener Str. 13, 50923 Köln, Germany; e-mail: fink@meteo.uni-koeln.de

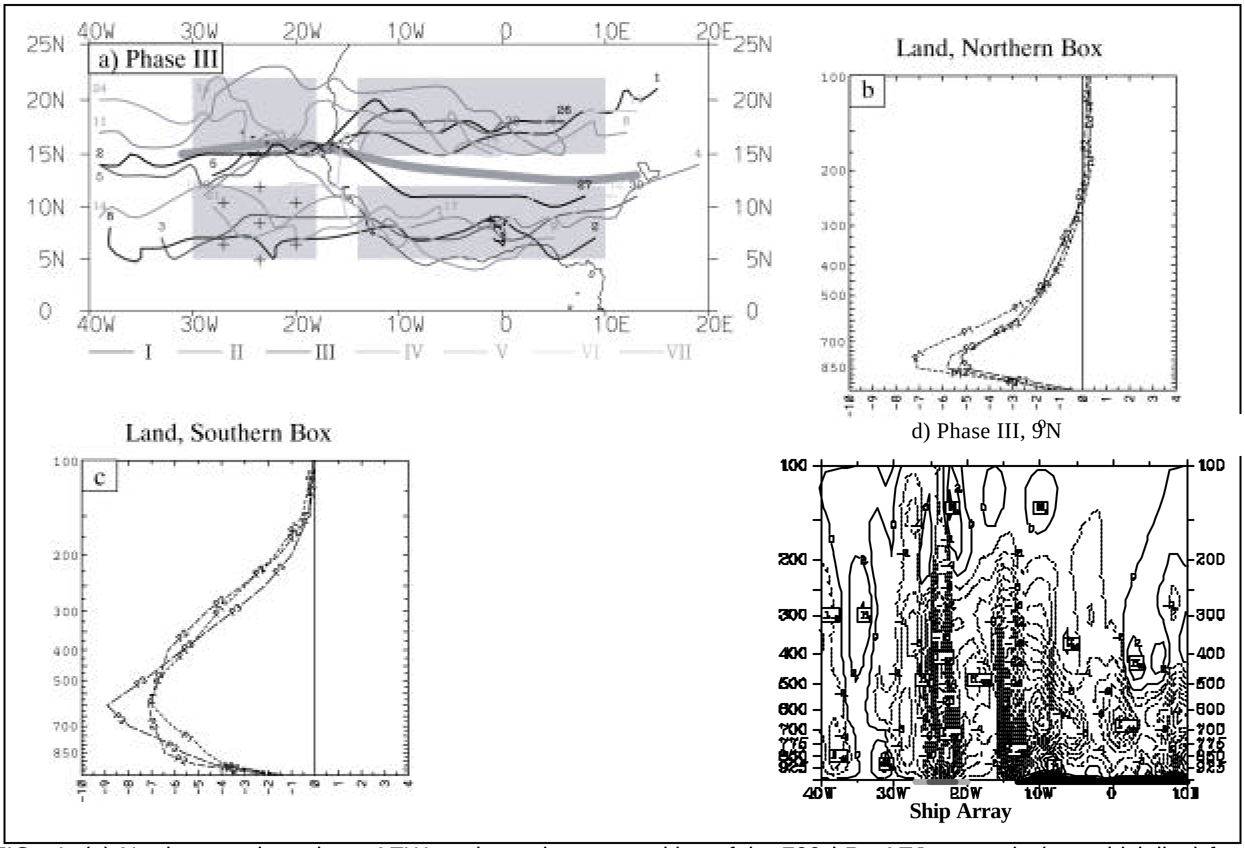

FIG. 1. (a) Northern and southern AEW tracks and mean position of the 700-hPa AEJ core axis (gray thick line) for Phase III. (b) and (c): Vertical profiles of vertical motion (omega) in 10^{-2} Pa s^{-1}, horizontally averaged over land (14°W–10°E) for northern (15°N–22°N) and southern (5°N–12°N) boxes, respectively, for all three phases. (d) Zonal cross sections of the vertical motion (omega) in contour intervals of 2 x 10^{-2} Pa s^{-1} along 9°N

III, respectively, is reflected in the vertical motion fields over the northern and southern land boxes (cf. Fig. 1a for box locations). Peak upward motion occurs at 775 hPa in the northern box during Phase I, while rising motion peaked at 600 hPa in the southern box during Phase III (Figs. 1b and 1c).

During all three phases of GATE, the upward motion over the GATE ship array (cf. Fig. 1d) was much stronger throughout the troposphere than in the climatological means (not shown). In this context, it is interesting to note that ERA-40 divergence fields revealed a mid-level outflow layer at 500 hPa over the ship array during GATE Phases II and III, that was not evident in the 30-yr ERA-40 climatology (not shown). Thompson et al. (1979) attributed the divergence peaks at 500 and 250 hPa to outflow regions from two distinct groups of convective cloud tops over the A/B-scale ship array in Phase III. Thus, it seems reasonable to assume that the cluster of more than a dozen ship upper-air stations in this small portion of the eastern Atlantic Ocean ITCZ led to a much more realistic analysis of the vertical motion field and the ERA-40 analyses in this region are likely a good testbed for convective and boundary layer parameterizations in numerical models.

More detailed information, including a Phase-to-Phase intercomparison of the barotropic and baroclinic instabilities associated with the AEJ and the monsoon heat low, as well as AEW energetics will shortly be published in Fink et al. (2004). A preprint of the manuscript is available at: http://www.meteo.uni-koeln.de/meteo.php?show=De_In_Pr_230_0.

4. REFERENCES

Fink, A. H., and A. Reiner, 2003: Spatio-temporal variability of the relation between African easterly waves and West African squall lines in 1998 and 1999. J. Geophys. Res., 108(D11), 4332, doi:10.1029/2002JD002816.

Fink, A. H., D. G. Vincent, P. Reiner, and P. Speth, 2004: Mean state and wave disturbances during Phases I, II, and III of GATE based on ERA-40. Mon. Wea. Rev., in press.

Kuettner, J. P. 1974: General description and central program of GATE. Bull. Amer. Meteor. Soc., 55 (7), 712–719.

Thompson Jr. , R. M., S.W. Payne, E.R. Recker, and R.J. Reed, 1979: Structure and properties of synoptic-scale wave disturbances in the intertropical convergence zone of the eastern Atlantic Ocean. J. Atmos. Sci., 36, 53–72.