

## **Variations in satellite-derived precipitation estimates and atmospheric circulation over Africa**

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**Abstract** Temporal and spatial variability of precipitation estimates are compared to features of the atmospheric circulation for the African continent. The precipitation estimates are primarily based on cold cloud top duration obtained from METEOSAT 6 data, and are refined using an optimal interpolation of observed precipitation, surface topography, and numerical model forecasts of wind and relative humidity. These precipitation estimates are produced operationally at the Climate Prediction Center (CPC) for the United States Agency for International Development (USAID), in support of the drought monitoring efforts for the African continent as a part of the Famine Early Warning System (FEWS) activity. The NCEP Climate Data Assimilation System (CDAS) analyses of atmospheric fields are used to determine the flow regimes for selected cases. The temporal and spatial variability of the model analyses for monthly periods are examined to determine the possible dynamic links with precipitation anomalies for the African continent. Extreme precipitation events during the 1997 ENSO event are examined to evaluate differences in circulation patterns.

### **INTRODUCTION**

Estimates of accumulated precipitation for 10-day periods are prepared operationally in real time for the portion of the African continent south of 20°N. These estimates are derived from METEOSAT 6 Infra-Red (IR) data, Global Telecommunication System (GTS) precipitation observations, and Global Data Assimilation System (GDAS) analyses of wind and relative humidity (Herman *et al.*, 1997).

Here we examine the dynamics of the circulation for the anomalously dry Sahelian growing season during August 1997 compared to the relatively normal period during August 1995, and the extreme flooding event that affected extensive areas of Somalia and Kenya during October and November 1997.

### **METHODOLOGY**

An initial estimate of convective precipitation is calculated from the cold cloud duration obtained from METEOSAT 6 IR data using a threshold temperature of

## Diff Precipitation Estimates (mm) Aug 97 - 95

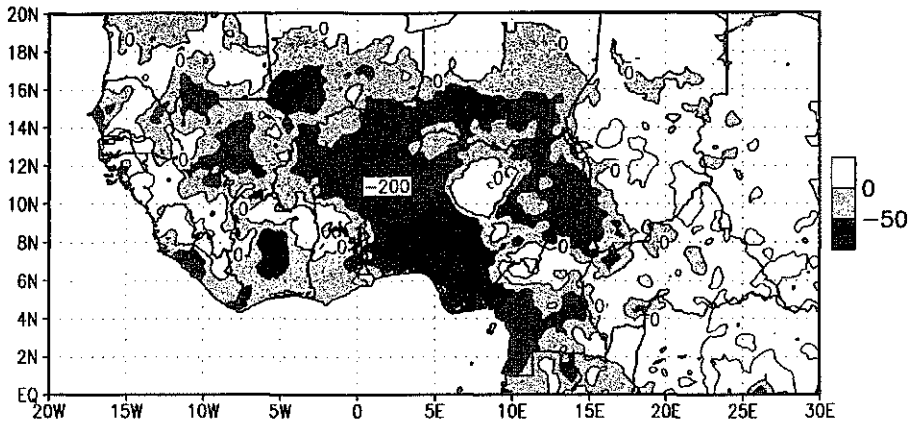


Fig. 1 Difference field for estimated precipitation for August 1997–August 1995 (mm).

235 K. Using the GOES Precipitation Index (GPI) developed by Arkin & Meissner (1987), an average rainfall rate of  $3 \text{ mm h}^{-1}$  is assigned for the occurrences of cloud top temperatures at or below this threshold. An estimate of the orographic rainfall, calculated at locations over which the cloud top temperature ranges from 235 to 275 K, is computed as the dot product of the gradient of the wind and the gradient of orography, multiplied by the relative humidity. An optimal interpolation scheme involving cost minimization functions (Thacker, 1988), is utilized to fit the GTS observations of precipitation with this initial estimate, resulting in a gridded estimate of convective and orographic precipitation at a resolution of  $0.1 \times 0.1$  degree.

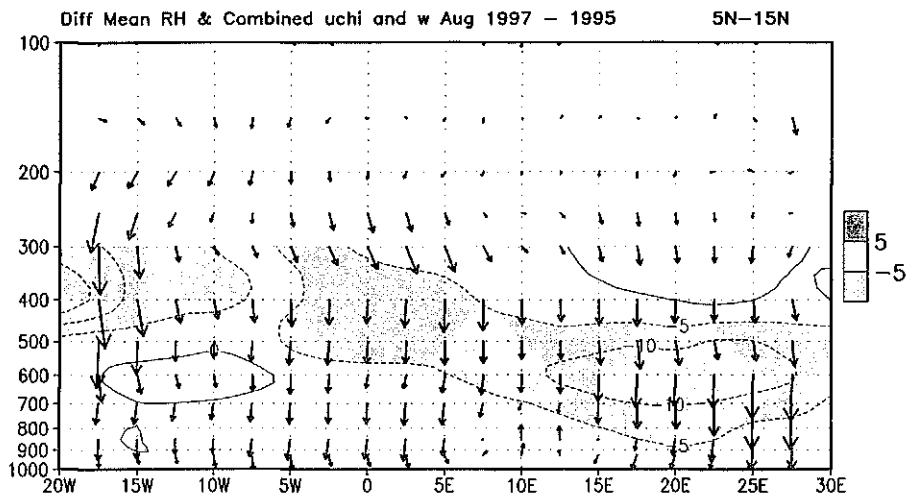
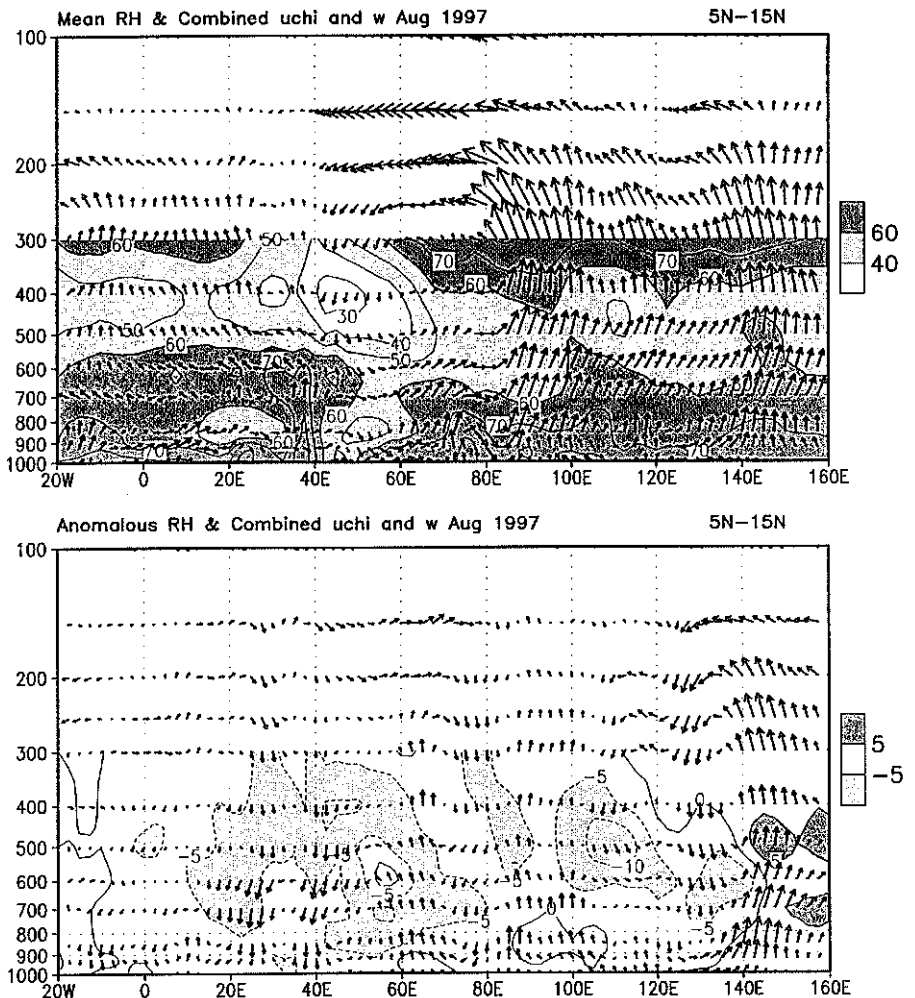


Fig. 2 Difference field for relative humidity and divergent circulation ( $5^{\circ}\text{N}$ – $15^{\circ}\text{N}$ ) for August 1997–1995, computed using CDAS. The divergent circulation is represented by vectors of combined vertical velocity and divergent zonal wind. Dashed contours (negative) for relative humidity difference in %.

These estimates are prepared operationally at the CPC for 10-day periods. For the comparisons made here, the three 10-day estimates of precipitation for each month are summed to provide an estimate for the month. Gridded normals of precipitation, used in the comparisons which follow, are obtained from the CPC Climate Assessment Data Base (CADB) monthly station normals for the period from 1961 to 1990.

The CDAS (Kalnay *et al.*, 1996) monthly mean analyses of atmospheric quantities are used to determine anomalous circulation patterns associated with the precipitation anomalies over Africa. These monthly mean analyses are prepared using the 6 hourly CDAS analyses run operationally at CPC at the end of each month.

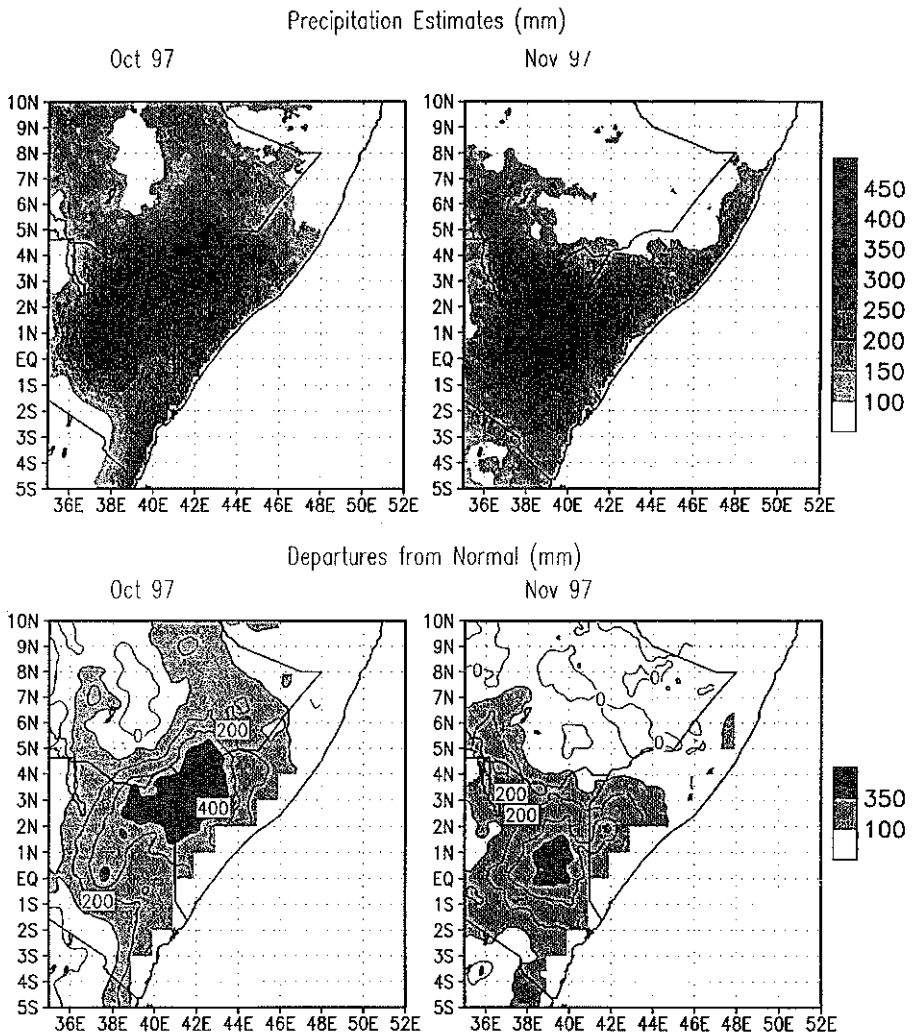


**Fig. 3** Mean (top) and anomalous (bottom) relative humidity and divergent circulation (5°N–15°N) for August 1997, computed using CDAS. The divergent circulation is represented by vectors of combined vertical velocity and divergent zonal wind. Dark (light) shading for positive (negative) and solid (dashed) contours for positive (negative) for relative humidity anomalies in %. Anomalies are departures from 1979–1995 means.

## SAHEL, AUGUST 1997

The growing season for the Sahel during 1997 featured below normal precipitation during August (*Climate Diagnostics Bulletin*, 1997) compared to August 1995, when relatively normal amounts of rainfall were observed over the region; rainfall during August 1997 ranged from 50 to over 200 mm less (Fig. 1).

Contrasting the divergent circulation patterns for the month of August during 1995 and 1997, the difference field implies lower relative humidity and increased sinking motion over the Sahel during August 1997 (Fig. 2). This anomalous circulation pattern over the Sahel during August 1997 is consistent with below



**Fig. 4** Estimated precipitation (mm) for October 1997 (*top left*), and November 1997 (*top right*), and precipitation departure from normal (mm) October 1997 (*bottom left*), and November 1997 (*bottom right*). Positive anomalies depicted with shading. Anomalies are departures from 1961–1990 means.

normal precipitation, and may also be related to weaker than normal easterly waves and reduced tropical storm activity in the Atlantic during 1997 (Bell, 1997).

In addition, strong El Nino conditions were present in the Pacific which were associated with anomalous circulation patterns throughout the tropics. The pattern of anomalous sinking motion and drier than normal conditions over the Sahel seems to be part of a larger scale pattern that extended from Africa eastward to Indonesia (Fig. 3, bottom).

### SOMALIA AND KENYA, OCTOBER AND NOVEMBER 1997

Record amounts of precipitation fell during late October and November 1997 over most of the southern portions of Somalia, and the coastal and northern portions of

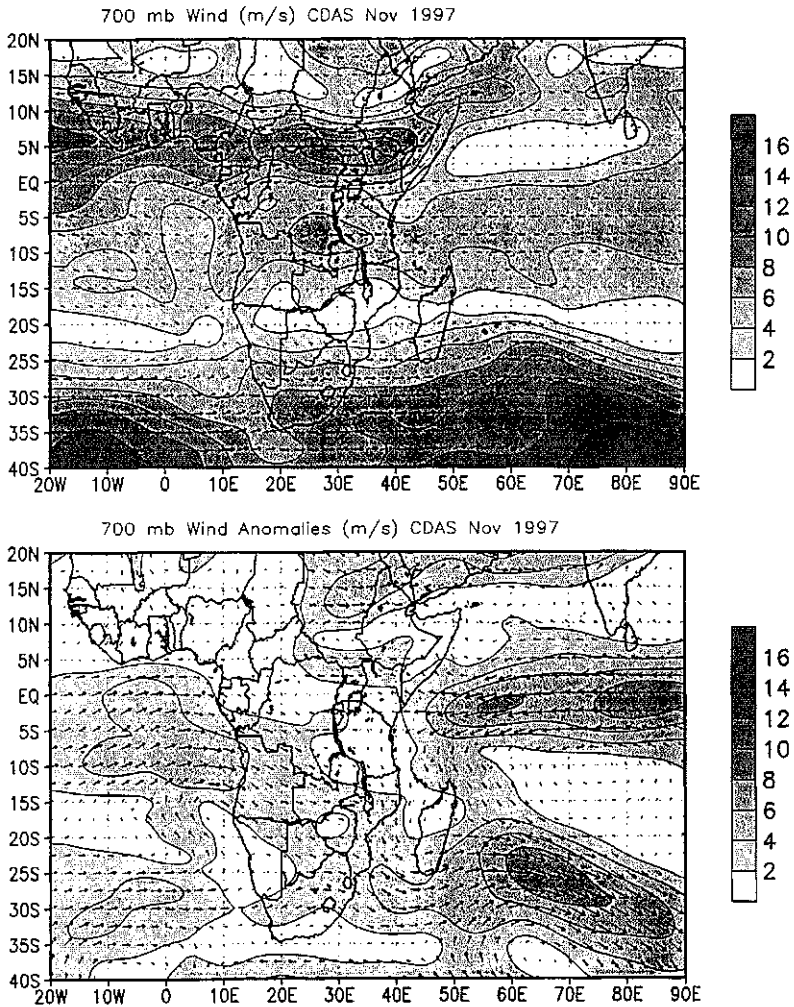
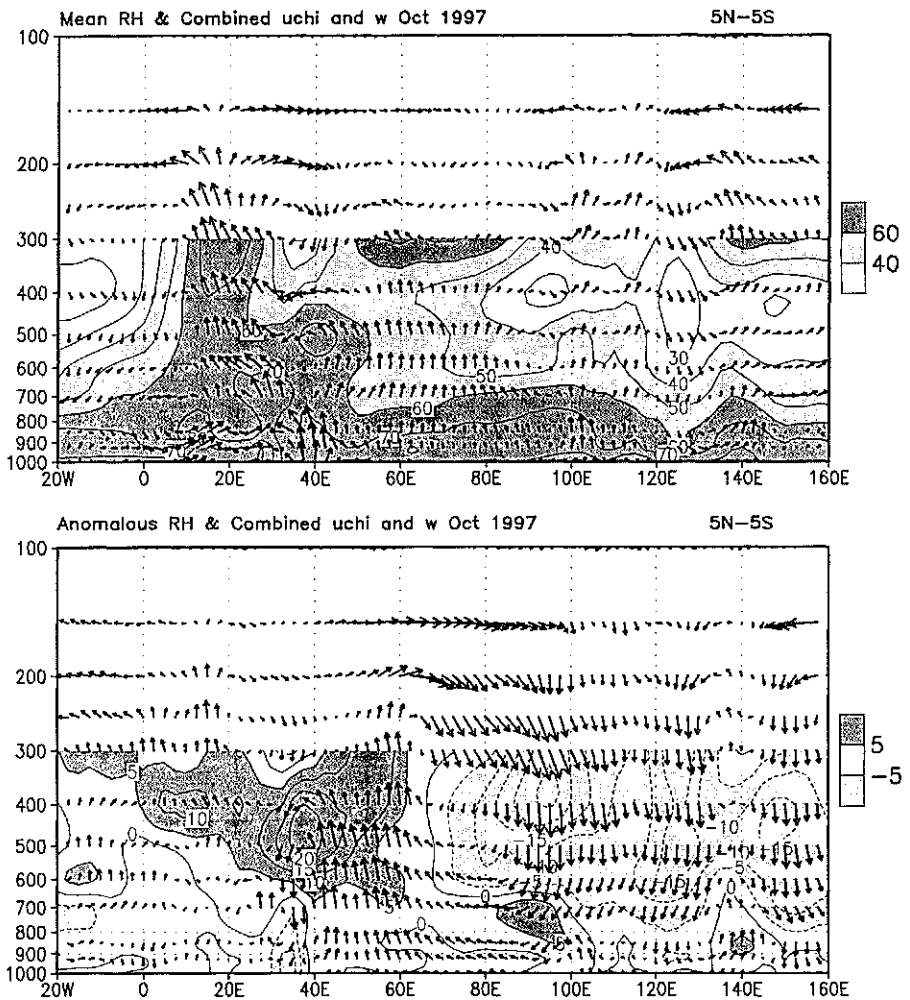


Fig. 5 Mean (top) and anomalous (bottom) 700 mb winds ( $\text{m s}^{-1}$ ) for November 1997, computed using CDAS. Anomalies are departures from 1979-1995 means.

Kenya (Fig. 4). Departures from normal ranged from 200 to 450 mm each month, resulting in disastrous flooding in both Somalia and Kenya.

A two-month period of persistent anomalous low and mid-tropospheric easterly flow (Fig. 5) over the North Indian Ocean advected anomalously moist and highly unstable air over the Indian Ocean into equatorial eastern Africa. Enhanced upward motion over coastal and inland portions of Kenya and Somalia contributed to the persistent and heavy precipitation (Figs 6 and 7). In addition, sea surface temperature anomalies of  $+1^{\circ}\text{C}$  prevailed along the coast of Somalia during October and November, which may have contributed to increased low-level moisture and instability in coastal sections of the region.



**Fig. 6** Mean (*top*) and anomalous (*bottom*) relative humidity and divergent circulation ( $5^{\circ}\text{S}$ – $5^{\circ}\text{N}$ ) for October 1997, computed using CDAS. The divergent circulation is represented by vectors of combined vertical velocity and divergent zonal wind. Dark (light) shading for positive (negative) and solid (dashed) contours for positive (negative) anomalies for relative humidity in %. Anomalies are departures from 1979–1995 means.

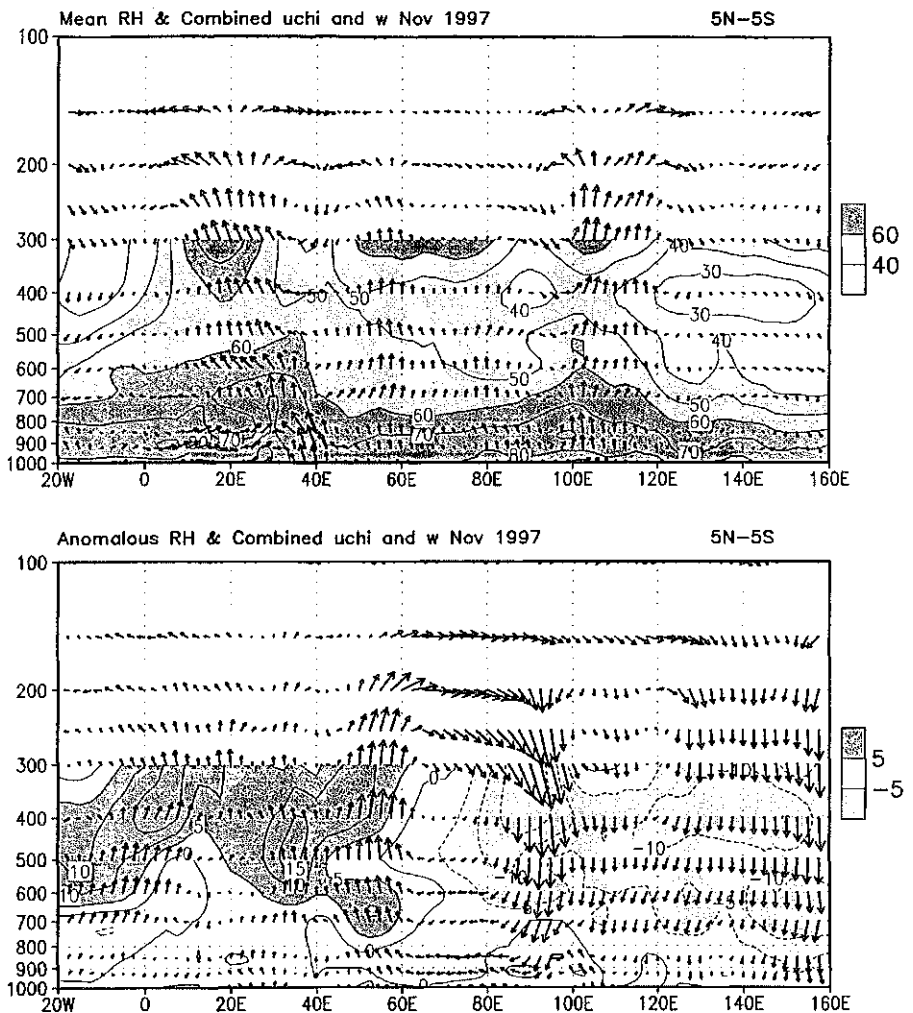


Fig. 7 Mean (top) and anomalous (bottom) relative humidity and divergent circulation (5°S-5°N) for November 1997, computed using CDAS. The divergent circulation is represented by vectors of combined vertical velocity and divergent zonal wind. Dark (light) shading for positive (negative) and solid (dashed) contours for positive (negative) anomalies for relative humidity in %. Anomalies are departures from 1979-1995 means.

As in the case for the Sahel, we see that the pattern over eastern equatorial Africa may be part of a larger scale pattern associated with the very strong ENSO conditions. Anomalous sinking accompanied by drier than normal conditions dominated Indonesia and the central and eastern Indian Ocean. This suppression of convection in a region of normally high rainfall probably contributed to a reversal in the east-west direct circulation cell that covers the Indian Ocean-Indonesia region, thus contributing to enhancing the rainfall over the normally dry regions of eastern equatorial Africa.

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## REFERENCES

- Arkin, P. A. & Meisner, B. N. (1987) The relationship between large-scale convective rainfall and cold cloud over the Western Hemisphere during 1982–84. *Mon. Weather Rev.* **115**, 51–74.
- Bell, G. D. (1997) Atmospheric Conditions Associated with the 1997 North Atlantic and North Pacific Hurricane Season, *Special Climate Summary 97/4*. [Available from the Climate Prediction Center, 4700 Silver Hill Road, Stop 9910, Washington DC 20233-9910, USA.]
- Climate Diagnostics Bulletin* (1997) no. 97/8, Figure E4. [Available from the Climate Prediction Center, 4700 Silver Hill Road, Stop 9910, Washington DC 20233-9910, USA.]
- Herman, A. et al. (1997) Objectively determined 10-day African rainfall estimates created for famine early warning systems. *Int. J. Remote Sens.* **18**, 2147–2159.
- Kalnay, E. et al. (1996) The NCEP/NCAR 40 year re-analysis project. *Bull. Am. Met. Soc.* **77**, 437–471.
- Thacker, W. C. (1988) Three lectures on fitting numerical models to observations. GKSS 87/E/65, GKSS-Forschungszentrum, Geesthacht, Germany.