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EXPERIMENTS ON THE EFFECT OF TROPICAL ATLANTIC HEATING ANOMALIES UPON GCM RAIN FORECASTS OVER THE AMERICAS

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ABSTRACT - A series of real data experiments is performed with a general circulation model in order to ascertain the sensitivity of extended range rain forecasts over the Americas to the structure and magnitude of tropical heating anomalies. The emphasis is upon heat inputs over the tropical Atlantic which have shown particularly significant drying influences over North America in our prior simulations. The heating imposed in the prior experiments is compared to the condensation heating rates that naturally occur in the forecast model, and shown to be excessive by approximately a factor of two. Present experiments reduce the imposed anomaly by a factor of three, and also incorporate sea-surface temperature decreases over the eastern tropical Pacific Ocean. The new experimental results are in many ways consistent with our prior results. The dry North American response is statistically more significant than the South American response, and occurs at least as frequently in the different members of the experimental ensembles as in our prior experiments. The drying effect is accentuated by the presence of East Pacific cooling, but this does not appear to be the dominant influence. Over tropical South America, the Pacific and Atlantic modifications produce compensating influences, with the former dominating dominant, and allowing increased rainfall over the Amazon Basin.

RESUMO - Uma série de experimentos com dados reais, foi realizada com um modelo de circiulação geral, de modo, a verificar a sensitividade do prognóstico de precitação sobre as Américas, para a estrutura e magnitude das anomalias de aquecimento tropical. A ênfase é sobre o aquecimento sobre o Atlântico tropical, o qual tem mostrado significante influência de seca sobre a América do norte, em experimentos anteriores. O aquecimento imposto nos experimentos anteriores é comparado com a razão de aquecimento de condensação, que ocorre naturalmente no modelo de prognósticos e tem mostrado ser excessivo por um fator de dois. Os presentes experimentos reduzem a anomalia imposta por um fator de três e também incorpora um decréscimo na temperatura da superfície da água do mar sobre o Oceano Pacífico tropical leste. Os novos resultados são de muitas maneiras consistentes com nossos resultados anteriores.

INTRODUCTION

The purpose of this note is to describe the sensitivity of the response of a general circulation model to variations in the structure and magnitude of the tropical forcing. This work builds upon a series of real data experiments incorporating tropical heating modifications within the National Center for Atmospheric Research general circulation model (1985), et al. (1986), et al. (1987), et al. (1989a) and (1989) describe experiments in which the tropical heating of the East Pacific is modified within integrations of 10-36 days duration. et al. (1990-b) and Buja (1989) study the effect of varying tropical Atlantic heating in 30 days predictions.

The principal conclusions were that strong tropical latent heating events influence the regional tropical and extratropical circulation on time scales of 5 days and 10 days, respectively, and are evident globally after 30 days. In particular, modifications of tropical Atlantic heating have surprisingly strong and repeatable effects upon rainfall forecasts over North America (et al., 1990-b), but probably used unrealistically large tropical heating modifications. Two of our present goals are to investigate the typical strength of model tropical heating, and the model response to variations of the heating.

Section 2 describes the response of the vertical to the heating modifications, Section 3 summarizes conclusions.

CIRCULATION RESPONSE

Precipitation requires vertical ascent of humid air, and can be influenced by flow modifications which change the ascent rate, or modify the flow trajectories with respect to low level moisture sources. This section demonstrates that both processes appear to act in the present set of experiments.

Figures 1 and 2 display the vertical motion response, its T statistic, and significance analyses over South America for ensembles 2 and 3, respectively. Both ensembles display increased rising motion (negative values) over central and southern sections of South America, and increased subsidence (positive values) outside these regions. These patterns agree with the rainfall response of these regions, as depicted in Figs. 3 and 4 .

Figures 5 and 6 display the same fields over North America for ensembles 2 and 3, respectively. Regions of increased subsidence accompany the areas of decreased rainfall displayed in Figs. 7 and 8 . The subsidence increases are not as significant from a statistical viewpoint as are the drying effects compare Fig. 5c with Fig. 7c and Fig. 6c with Fig. 8c . This implies that other drying influences may also act in the present cases. One possible source of these is presented in the 200 mb vector wind response displayed in Fig. 9 for the strongly forced ensemble 2. Each of these responses displays an anticyclone within the tropics and subtropics of the North Atlantic, and most responses have cyclonic maxima located in the mid-latitudes of the North Atlantic. These cyclonic response centers are denoted by heavy plus signs in Fig. 9.

There is substantial variability in the particular location of these cyclone response centers, but in all cases, they occur somewhere over the Atlantic Ocean, implying an eastward shift of the upper tropospheric storm track ordinarily located near the east coast of North America. Such a shift may produce a relatively dry air mass near the east coast, and probably contributes to the drying there, as previously suggested by Buchmann et al. (1990-b).

CONCLUSIONS

The circulation response suggests that increased subsidence, as well as unfavorable horizontal moisture transport are produced over the drier zones. The subsidence enhancement pattern is similar to the decreased rain pattern, but does not have as much statistical significance as the rain response. The storm track ordinarily found off the east coast of North America is displaced eastward by the present tropical modifications. The loss of moisture related to this horizontal flow displacement may also contribute to the rainfall decrease of the

Eastern United States.

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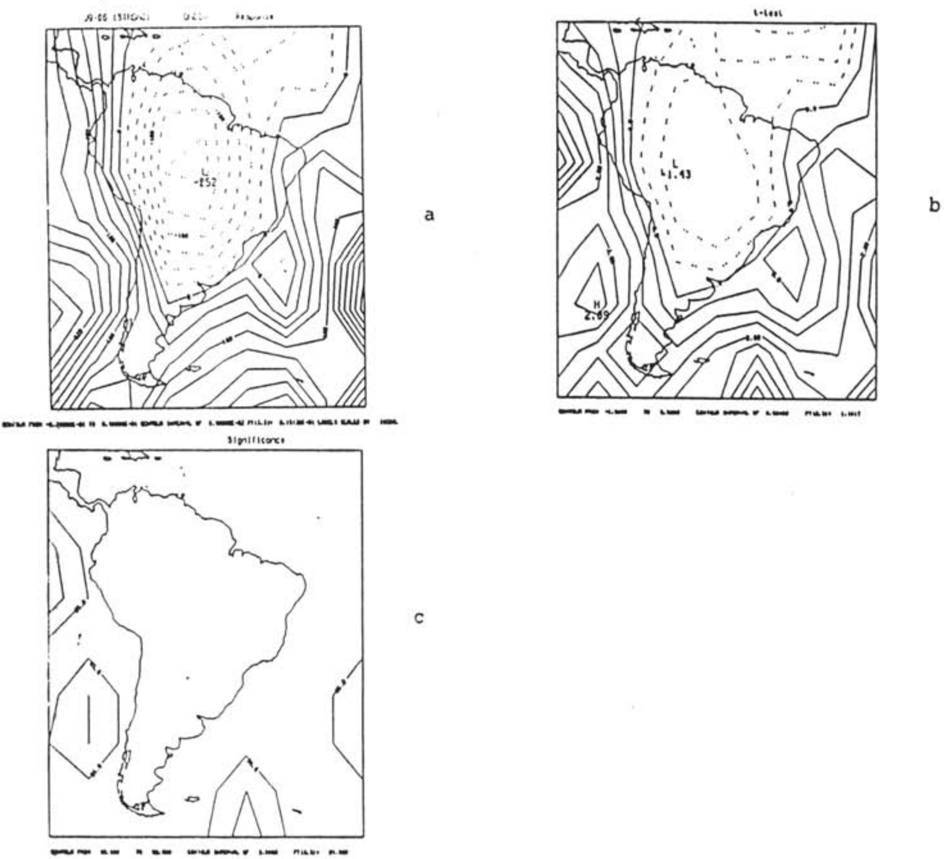


Fig. 1a - Ensemble and time averaged vertical motion response for ensemble 2. Contour interval is .4 x 10**-2 Pascal/s.

Fig. 1b) T-statistic for response depicted in Fig. 1a. Contour interval is 1/2.

Fig. 1c)Probability that the response depicted in Fig. 1a is statistically significant. Contour interval is 3% and only values of 95% and higher are analysed.

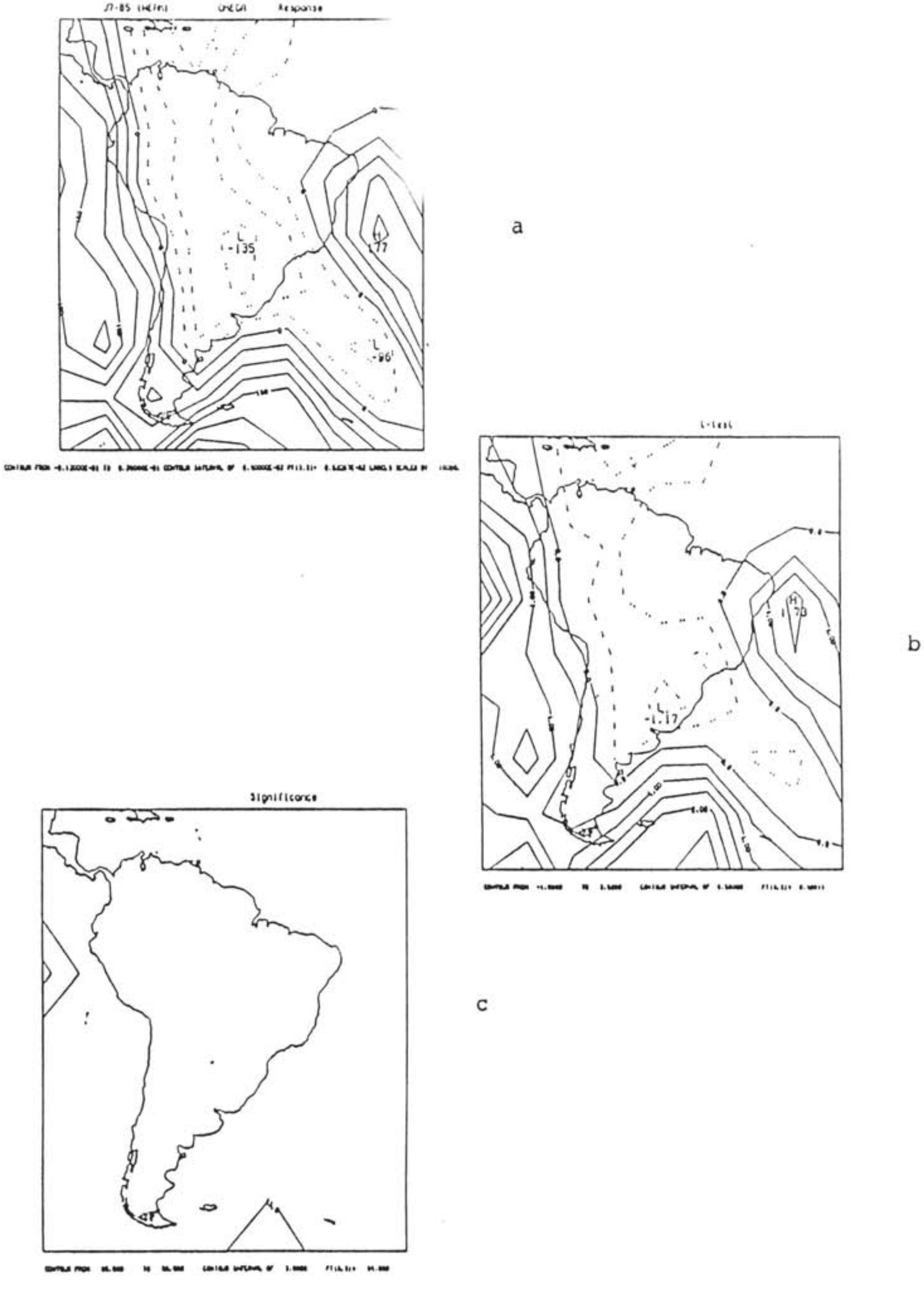
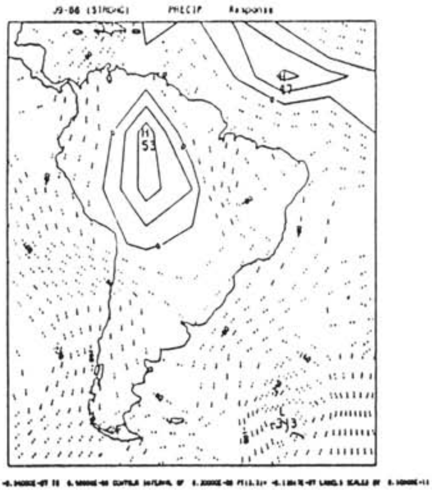
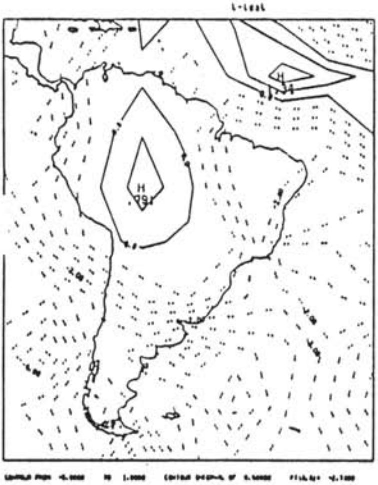


Fig. 2) As in FIg. 1 for ensemble 3.



a



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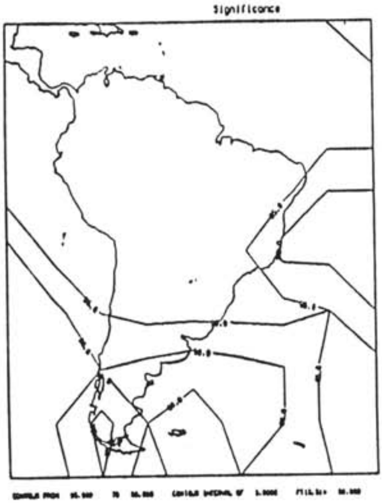


c

Fig. 3a - Ensemble and time averaged precipitation response for ensemble 2. Contour interval is 2x10xx-8 m/s.

Fig. 3b - T-statistics for response depicted im fig. 3a. Contour interval is 1/2.

Fig. 3c - Probability that the response depicted in fig. 3 is statistically significant. Contour interval is 3% and only values of 95% and higher are analysed.

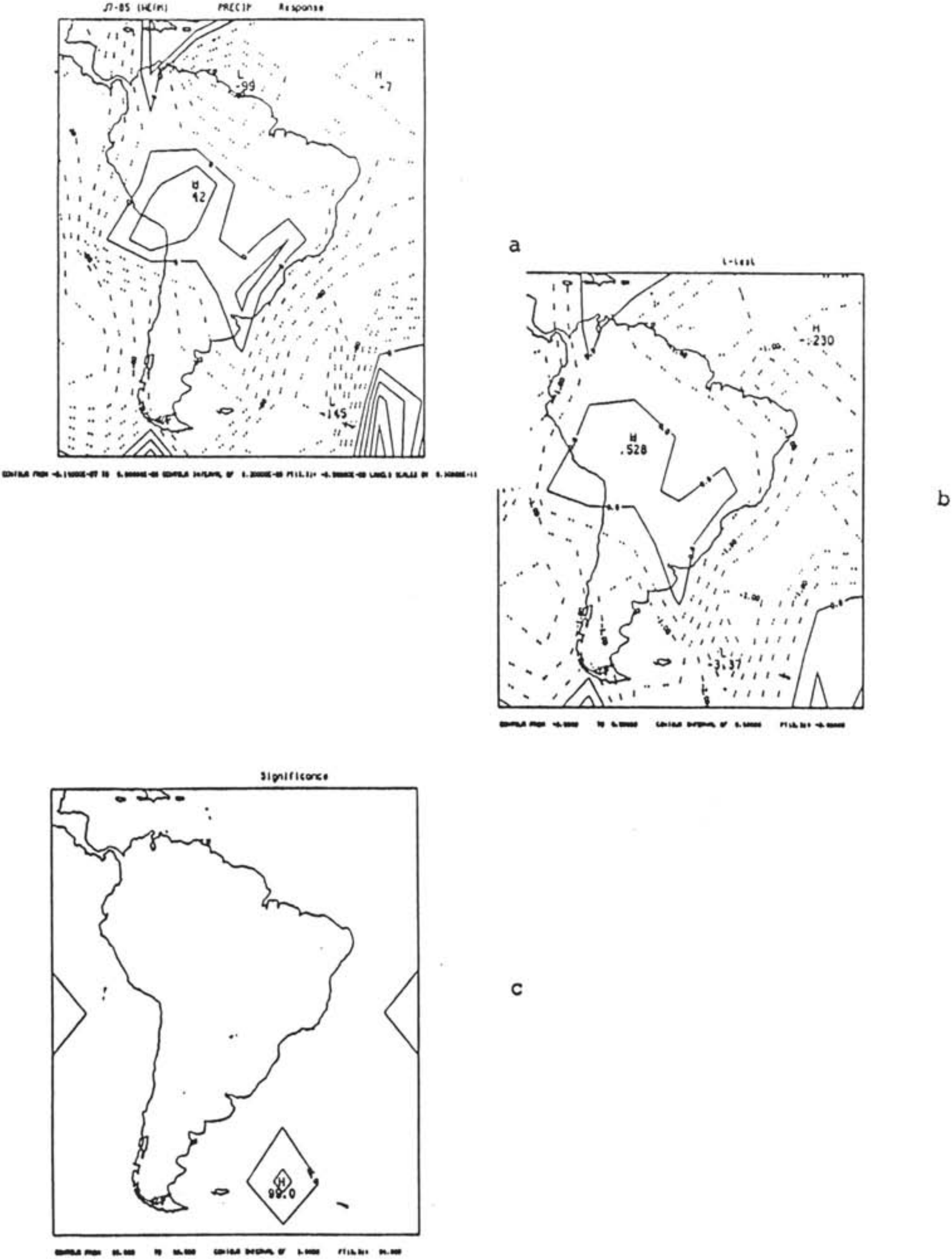


Fig 4 - As in fig. 3, for ensemble 3

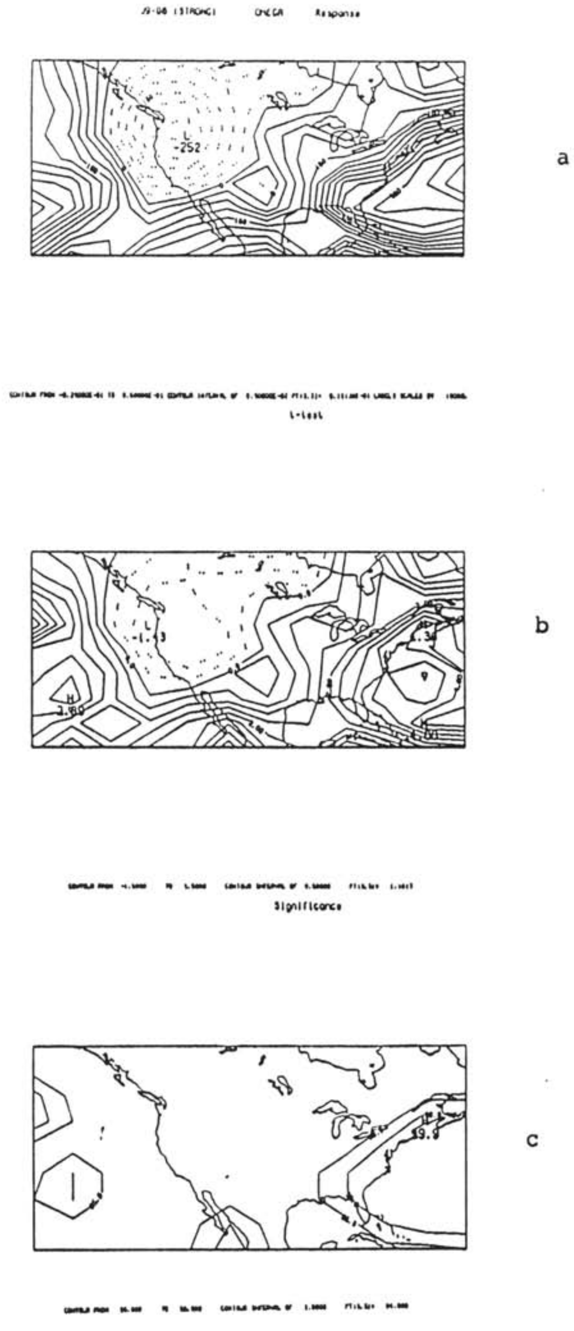


Fig. 5) As in Fig,. 1 for North America.

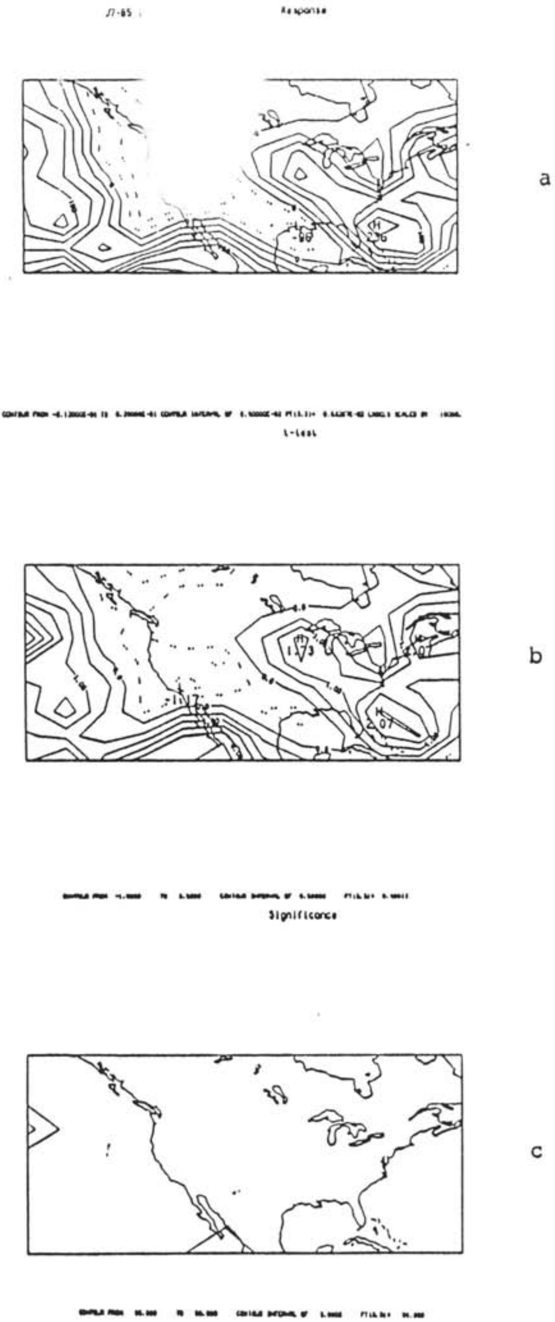
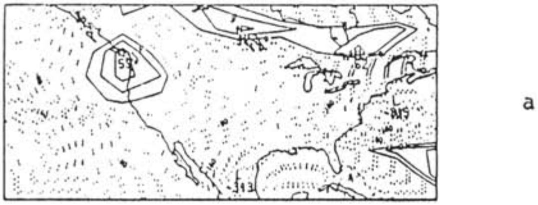
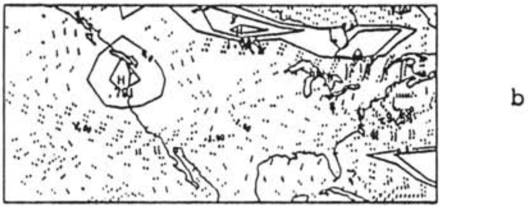


Fig. 6) As in Fig. 5 for weaker tropical forcing, ensemble 3.

JJ-86 (STRCAC) PRECIP Response



t-test



Significance

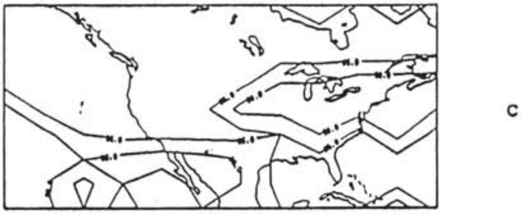


Fig 7 - As in fig. 3, for ensemble 3

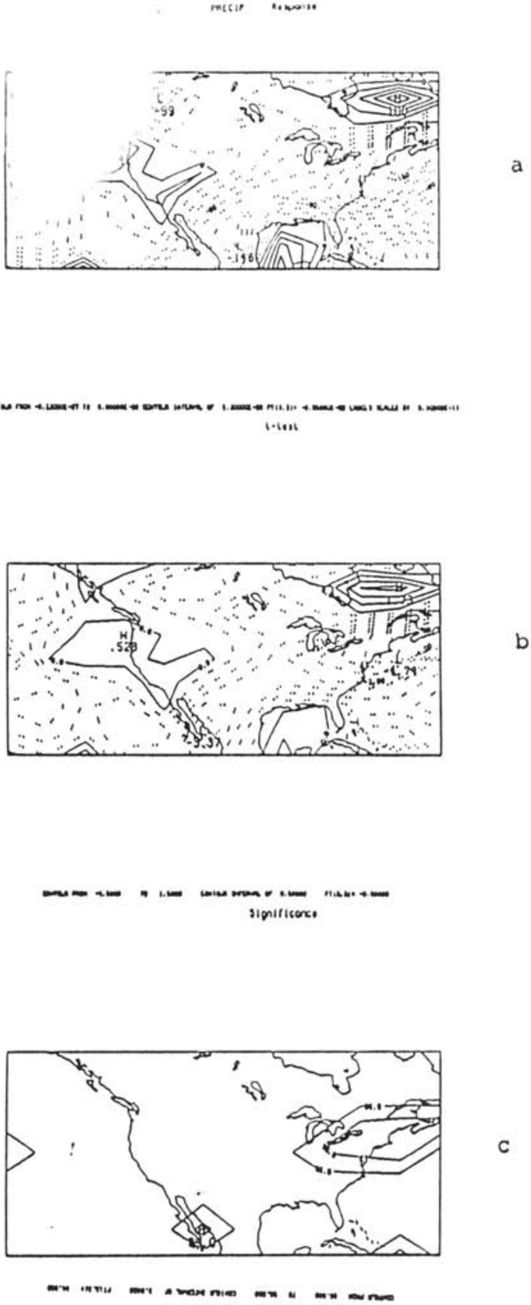


Fig 8 - As in fig. 7, for weaker tropical forcing, ensemble 3

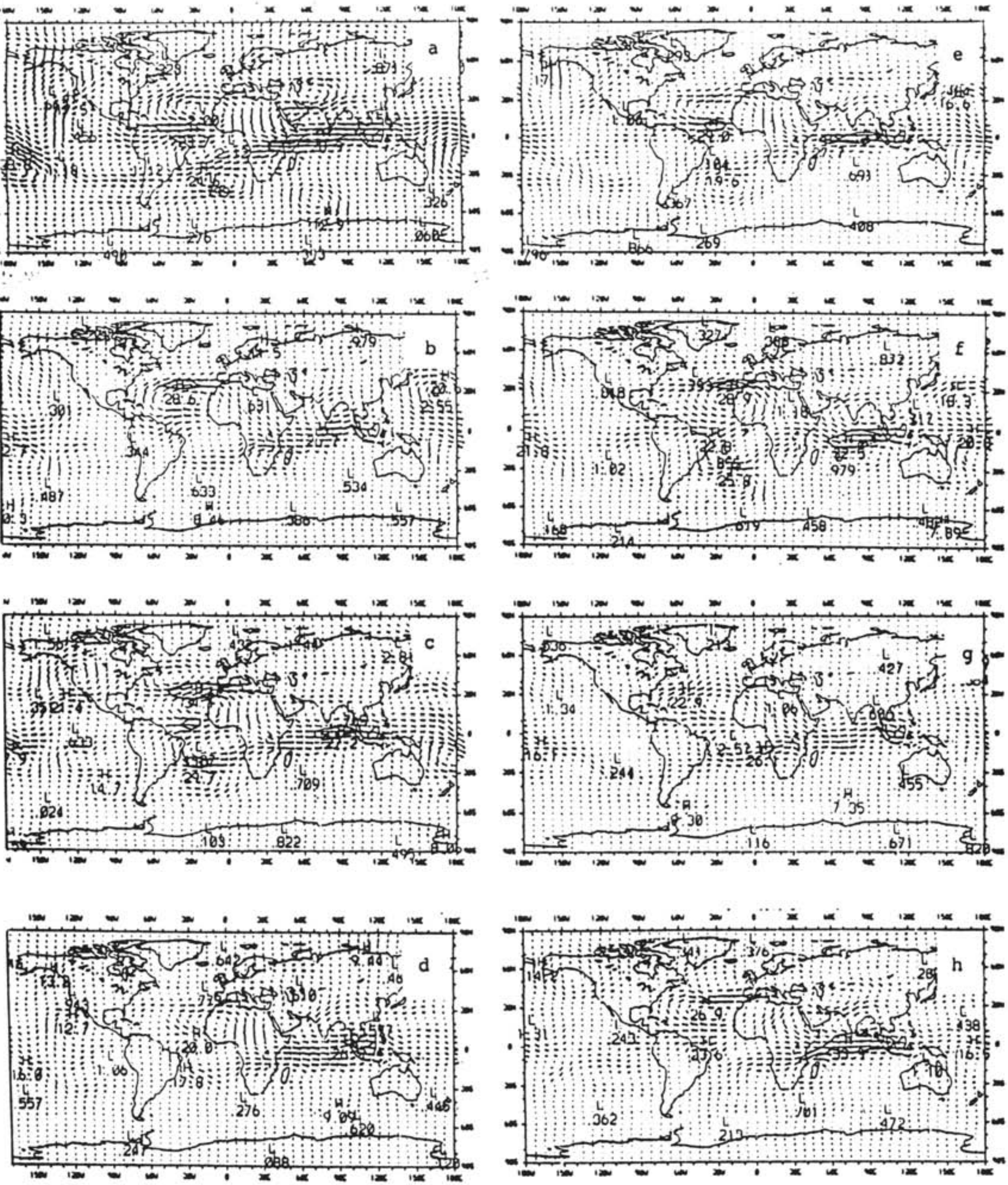


Fig. 9 - Time averaged 2mb vector wind response in ensemble 2 (experiment-control) for :
(a) 1977, (b) 1978, (c) 1979, (d) 1980, (e) 1981, (f) 1982, (g) 1983, (h) 1984. Peak vectors are approximately 25 m/s in each panel.