A Comparison of Surface Geostrophic Winds with COADS Ship Wind Observations

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Introduction

It has been widely noted that changes in the application of different winds scales, principally the Beaufort wind scale, and other changes related to varying proportions of anemometer-measured winds versus Beaufort-estimated wind reports, changes in ship size, varying anemometer heights, etc. have introduced inhomogeneities in the COADS surface wind data set (Ramage 1987; Wright 1988; Cardone et al., 1990; Isemer and Hasse 1991). These biases tend to produce spurious trends in time series of the scalar magnitude of surface wind. An example of such spurious trends was documented by Ramage (1987) who investigated differences between the long-term means of wind speed and meridional sea-level pressure gradient with data from the region of the South China Sea for two different periods, 1950-79 and 1900-39. He pointed out a positive bias of about 1 ms^{-1} in the reported wind speed averaged over 1950-79 relative to 1900-39. Similar results have also been found in the Atlantic and North Pacific oceans, and in global means. A general conclusion reached by these authors is that the trends reflected in the reported wind data are artificially more positive (increasing along with time) than those reflected in contemporary changes of sea level pressure gradients or in comparison with physically-based models of changes in sea level imposed by increasing wind stress (Cardone et al. 1990).

Here we show a comparison of observed versus geostrophic wind changes for various latitude belts for the months of January and July. The period of record studied is 1950-1990, and we have also assessed differences in the wind variables between the subperiods 1950-79 (a climatological reference period which is often used), and 1979- 1990. The zonal component of geostrophic wind was obtained by applying a simple uniform finite difference scheme to the four-degree COADS monthly averaged sea-level pressure data.

Results

Figure 1 gives a measure of the association between the observed surface u-wind component and the corresponding geostrophic wind u-component for January and July. The correlations are very high in the zone extending from about 20°-60°N, generally exceeding r = 0.8. As one would expect, the correlations are typically higher in areas with sufficient data coverage (Fig. 2a), and are found to be relatively poor in much of the Southern Hemisphere (Fig. 2b). Time series of zonally averaged u and u_g wind anomalies for the period 1950-90 for January and July are presented in Figs. 3 and 4 for the main Northern Hemisphere westerly wind belt (top panels of Figs. 3 & 4), the Northern Hemisphere subtropics (middle panel), and a representative trade wind belt (bottom panels).

Increases are evident in both observed and geostrophic zonal mean winds, particularly over the last decade in both the trade and westerly wind zone, but there is little overall change in the subtropical belt. Table 1 gives a summary of the magnitude of the linear trends by four-degree latitude bands. Clearly, most of the increase in both observed and geostrophic zonal mean winds occurs during northern winter (January), primarily in the main westerly wind belt. A corresponding strengthening of the easterly trades is also evident south of about 30°N.

Most of the increase, however, takes place over approximately the past decade. The linear trends are statistically significant at the 5% level or better in the period 1979-90 over the latitudes from about 38°N-50°N and from about 20°N-28°N. We illustrate this further in Figs. 5 and 6, which show the mean zonal profiles of both u and u_g for the decade of the 1970s and 1980s. We conclude that at least with respect to the east- west component of surface wind, recent increases over selected latitude bands of the Northern Hemisphere are corroborated by similar changes in co-located zonal geostrophic wind changes derived from the reported sea-level pressures.

References

Cardone, V. J., Greenwood, J.G., and Cane, M.A., 1990: On trend in the historical marine wind data. *Journal of Climate*, **3**, 113-127.

Isemer, H.-J. and Hasse, L., 1991: The scientific Beaufort equivalent scale: Effects on wind statistics and climatological air-sea flux estimates in the North Atlantic. *Journal of Climate*, ***4***, 819-836.

Ramage, C.R., 1987: Secular changes in reported surface wind speeds over the ocean. *Journal of Applied Meteorology*, **26**, 525-528.

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Table 1. Summary showing latitudinal comparisons of zonal mean values (in m/s) and linear trend coefficients (in m/s/yr) of observed wind u-component and geostrophic wind u-component for the month of January for the period 1950-79 (top) and 1979-90 (bottom). Values of the t-statistic and its significance at different levels are shown at the bottom of each panel.

Changes in Zonal Average Surface Wind: U-component

January 1950-79

Lat	Observed			Geostrophic		
	mean	trend	T-test	mean	trend	T-test
62N	0	-0.07	-1.826	-0.12	-0.01	-0.213
58N	0.61	-0.06	-2.04	1.1	-0.17	-3.206
54N	1.23	-0.06	-1.572	1.55	-0.31	-2.566
50N	1.9	-0.01	-0.18	2.17	-0.01	-0.208
46N	2.6	0.02	0.671	3.36	0.02	0.481
42N	2.97	0.02	0.645	3.87	0	-0.058
38N	3.09	0.02	0.826	4.08	-0.03	-0.79
34N	3.19	0.01	0.597	3.7	0	0.002
30N	2.45	0	0.004	2.5	0.01	0.396
26N	0.46	0	0.004	-0.08	0.02	0.537
22N	-1.81	0	-0.186	-3.41	0	0.159
22S	-3.43	-0.03	-2.931	-4.63	0	0.019
26S	-2.69	-0.01	-0.689	-3.27	-0.04	-2.046
30S	-1.15	-0.01	-0.421	-1.42	-0.03	-1.401
34S	0.38	0.01	0.616	0.65	0.02	0.566
38S	2.22	0.04	2.477	3	0.03	0.634
42S	3.93	0.06	3.947	4.45	0.12	2.724
46S	5.19	0.06	3.897	5.57	0.07	1.202
50S	5.52	0.02	0.971	5.41	0.08	1.438
54S	4.15	0.04	1.348	4.22	0.06	0.767
58S	1.86	-0.01	-0.239	1.98	0.01	0.264
62S	0.15	-0.04	-1.493	0.55	0.01	0.319

when N=30, D.F.=28,

α = 0.25 0.10 0.05 0.025 0.01 0.005

τ_α = 0.683 1.313 1.701 2.048 2.467 2.763

Table 1. (Continued).

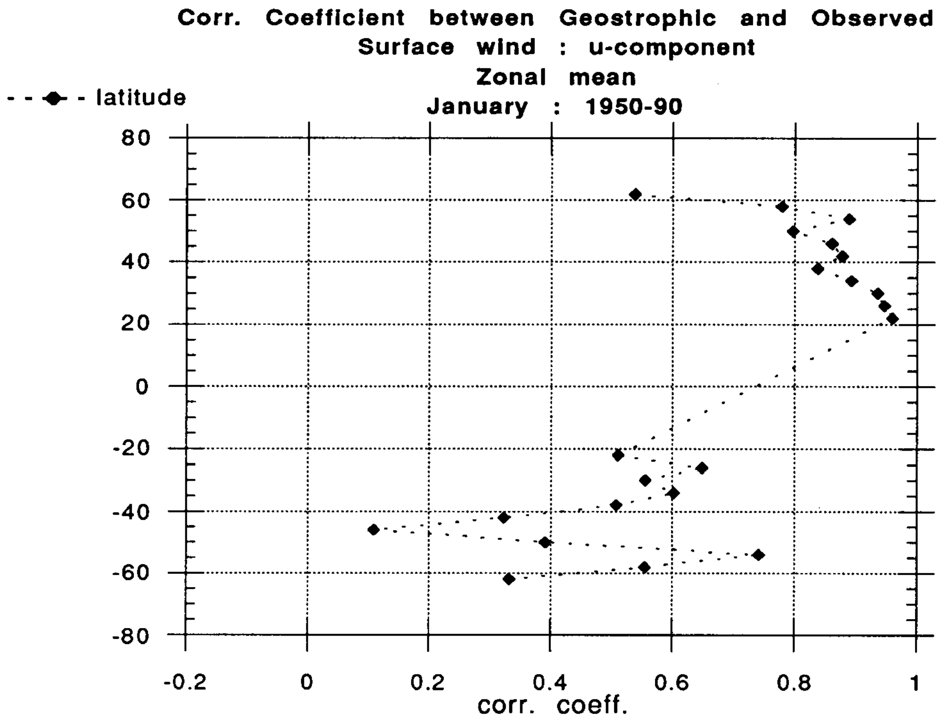
January 1979-90

Lat	Observed mean	Observed trend	Observed T-test	Geostrophic mean	Geostrophic trend	Geostrophic T-test
62N	0.02	0.13	0.865	0.93	-0.05	-0.261
58N	0.74	0.21	1.154	0.81	0.17	0.806
54N	1.5	0.31	2.11	1.66	0.3	1.233
50N	2.53	0.36	3.415	3.52	0.38	1.963
46N	3.35	0.35	4.803	4.44	0.38	4.025
42N	3.56	0.31	5.471	4.36	0.43	4.928
38N	3.43	0.19	2.697	3.84	0.32	3.329
34N	3.26	0.01	0.127	3.4	0.02	0.181
30N	2.42	-0.16	-1.557	2.57	-0.22	-1.676
26N	0.34	-0.27	-2.794	-0.29	-0.38	-3.164
22N	-2.17	-0.31	-4.786	-3.94	-0.44	-4.677
22S	-3.77	-0.06	-1.111	-4.8	-0.18	-2.718
26S	-2.87	-0.01	-0.15	-3.62‘	0.1	1.769
30S	-1.18	-0.01	-0.224	-1.25	0.102	1.727
34S	0.72	0.01	0.153	1.17	0.01	0.04
38S	2.73	0.04	0.685	4.03	-0.2	-1.313
42S	4.48	0	0.004	6.64	0	-0.021
46S	5.57	0.02	0.364	7.16	-0.03	-0.229
50S	5.53	0.05	0.672	6.91	-0.24	-2.11
54S	4.4	-0.03	0.355	5.51	-0.08	-0.729
58S	1.83	-0.01	-0.073	2.64	0.02	0.129
62S	-0.9	0.02	0.259	0.45	0.05	0.558

when N=12, D.F.=10,

α = 0.25 0.10 0.05 0.025 0.01 0.005

τ_α = 0.700 1.372 1.812 2.228 2.764 3.169



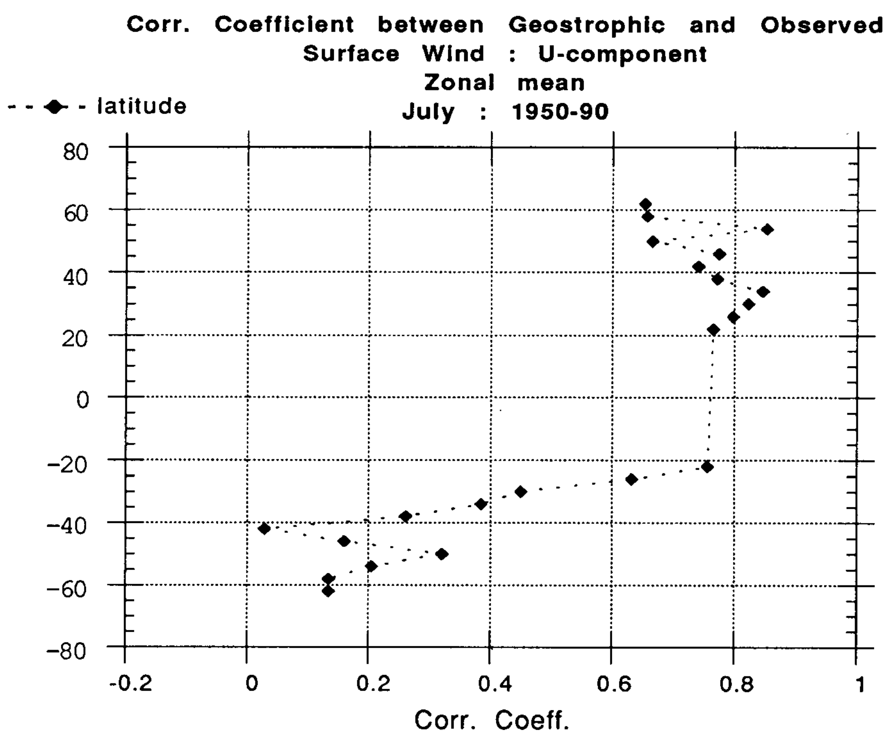


Figure 1. Zonal profile of the correlation between time series of zonally averaged annual means of the observed wind u-component and the corresponding time series of the zonal component of mean geostrophic wind for January and July over the period 1950-90.

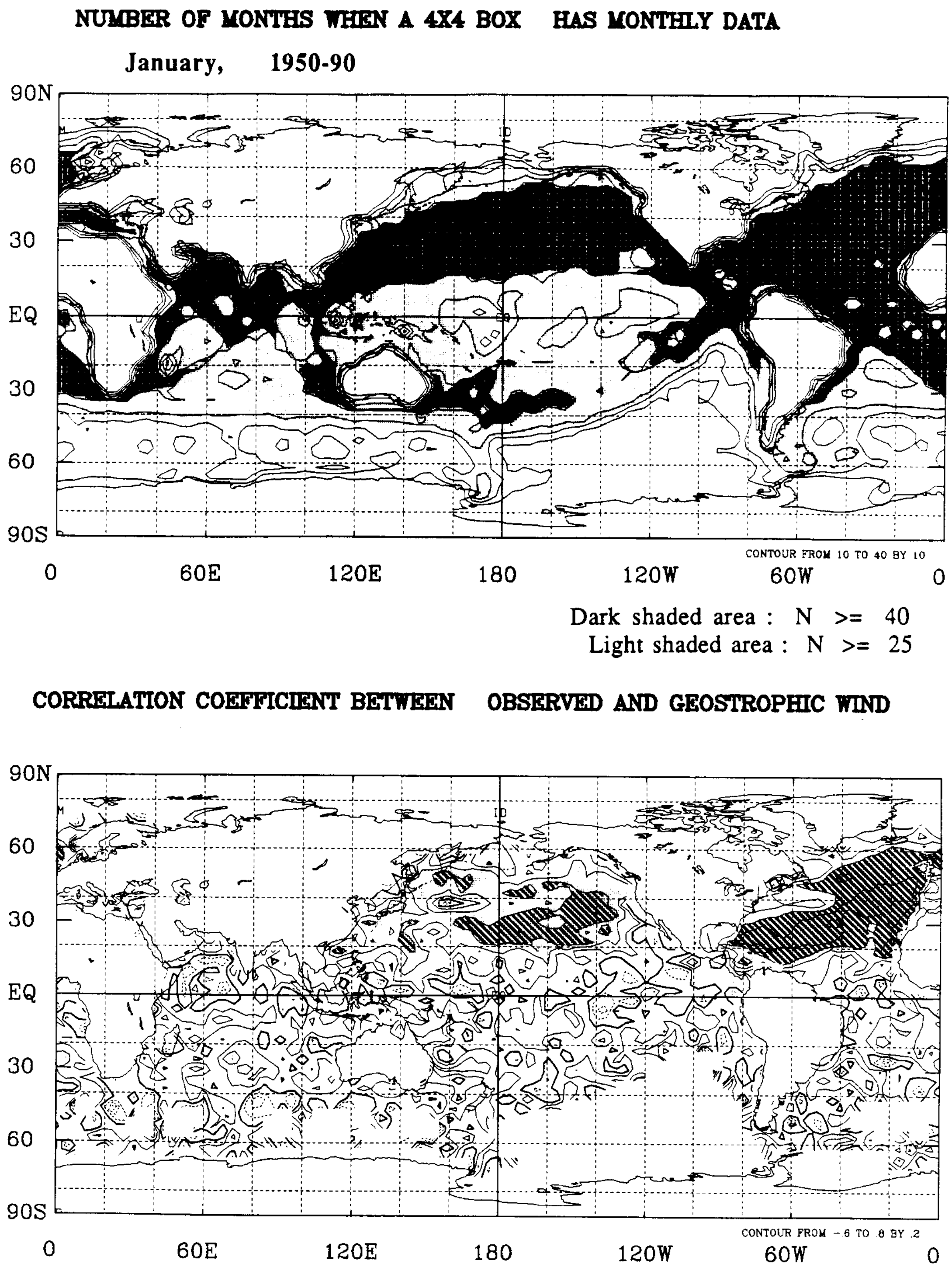


Figure 2. Map showing the spatial distribution of a) monthly wind observations in four-degree boxes for January; and b) values of the correlation of u vs. u_g. Light and dark shaded areas correspond to $N \geq 25$ yr and $N \geq 40$ yr, respectively for panel (a); and to $r \geq 0.51$ and $r \geq 0.62$, respectively, for panel (b).

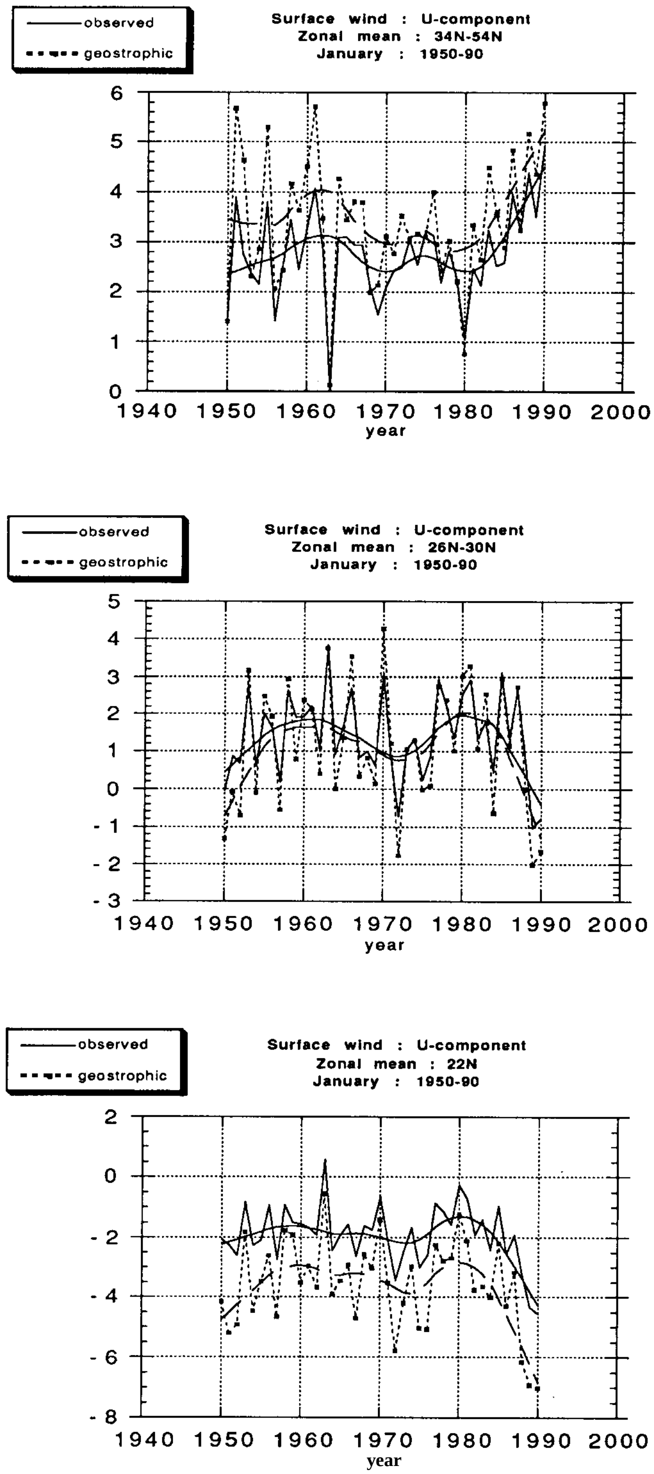


Figure 3. Time series of January zonally averaged observed wind u-component together with the corresponding values of the zonal component of geostrophic wind for three latitudinal belts comprising the Northern Hemisphere westerly and trade wind belts (top and bottom graphs) and the subtropical belt of light zonal winds (middle graph).

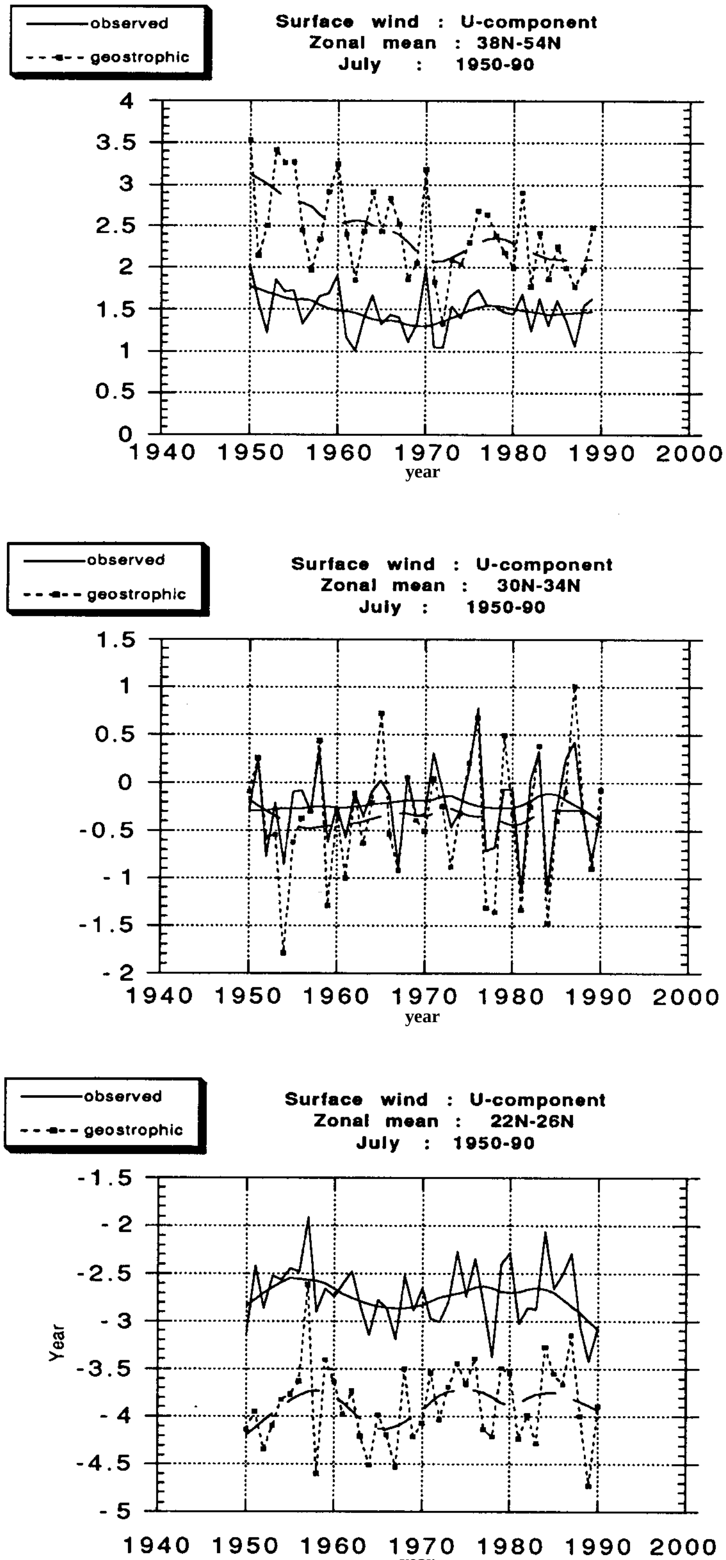


Figure 4. Same as Fig. 3, except for the month of July.

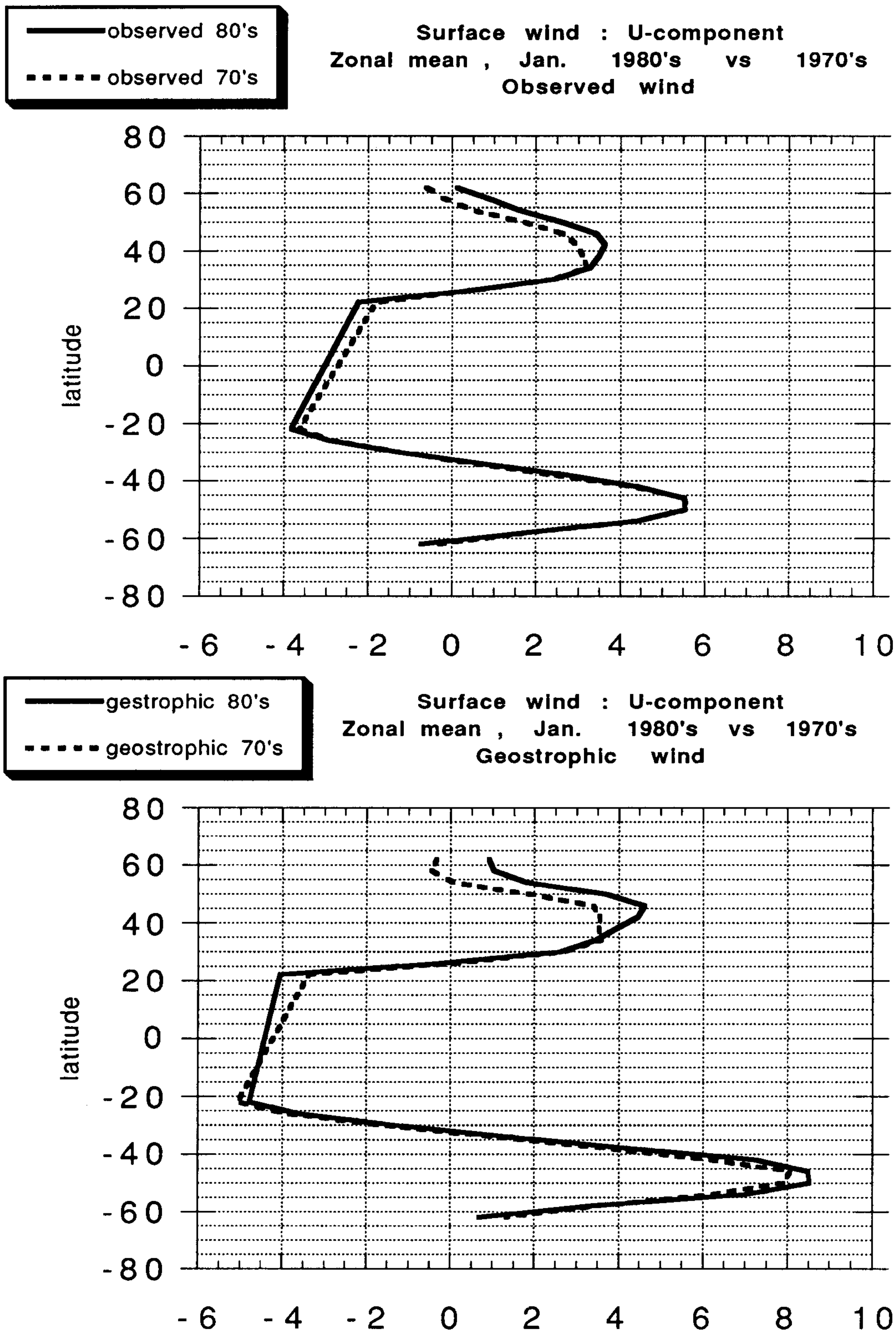
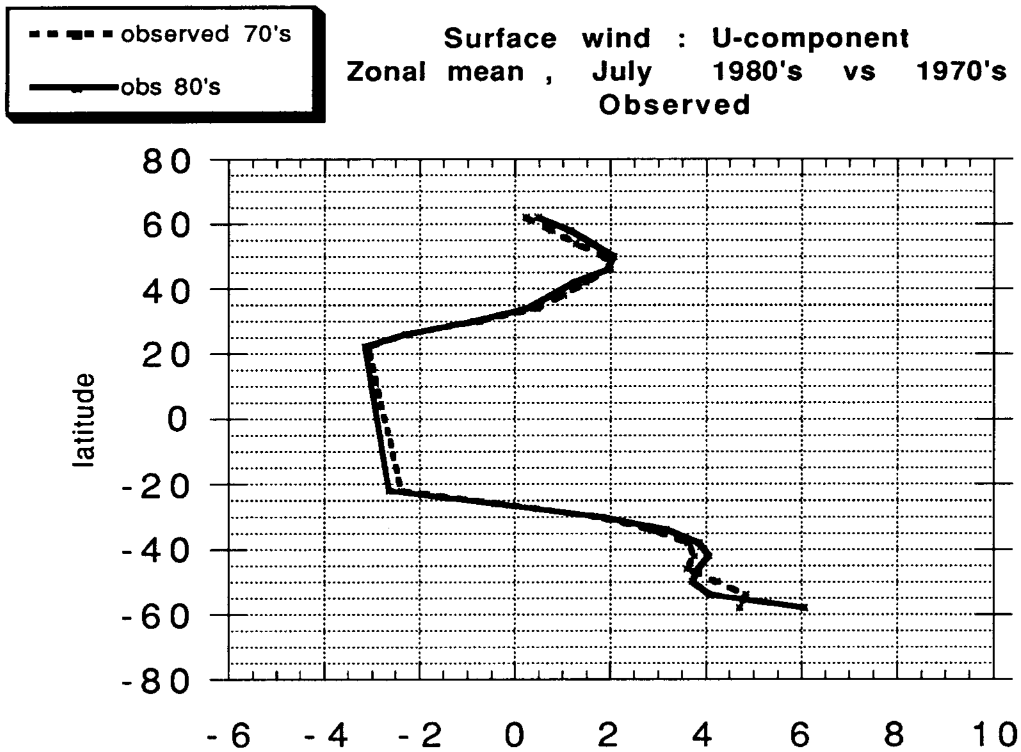


Figure 5. Zonal mean profiles of observed and geostrophic wind u-component for January for the 1970s and 1980s.



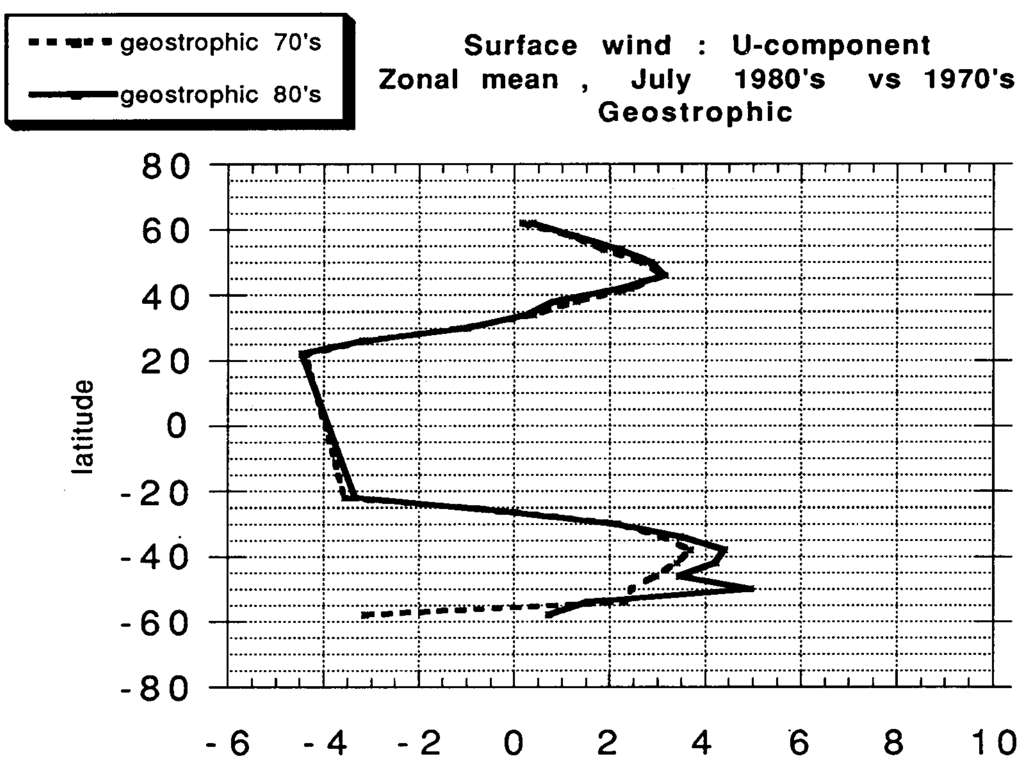


Figure 6. Same as Fig. 5, except for the month of July.