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DIRECTIONAL DEPENDENCE OF ZONAL AND MERIDIONAL WIND CORRELATION COEFFICIENTS

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ABSTRACT

Evidence is presented which suggests that the spatial correlation coefficients of zonal and meridional wind components decay most slowly with increasing separation, in directions that depart slightly from those expected assuming geostrophic flow in a horizontally homogeneous and isotropic atmosphere. The consistency between studies in four different geographical areas indicates that at least a part of the departures may be global in character, but further examination of data from other parts of the world is needed to confirm this.

INTRODUCTION

Quantitative measures of the spatial variation of meteorological elements are useful for many applications, including (a) objective analysis and data assimilation, (b) the design of observational networks, and (c) assessment of the similarity to the real atmosphere of model simulations. A commonly used measure is the two-point correlation coefficient. This note focuses upon the correlation coefficients of zonal and meridional wind components.

HOMOGENEOUS, ISOTROPIC, GEOSTROPHIC CASE

It is well established that the two-point correlation coefficients (r_u, r_v) of zonal and meridional winds depend not only upon the separation of the points, but also upon the orientation of the line joining the points. On the assumption that the geopotential field is homogeneous and isotropic, and that the wind is geostrophic, it may be shown (Buell 1960) that r_u (r_v) decays most slowly with increasing separation in the west-east (north-south) direction, and most rapidly in the north-south (west-east) direction. The dependence of the correlation coefficients upon separation (d) and orientation (Θ) may be expressed diagrammatically by means of contours of r_u and r_v, in a (d, Θ) coordinate system. The homogeneous, isotropic, geostrophic constraint corresponds to the schematic contour pattern of Fig. 1(a). The few correlation coefficient contour patterns available in the literature for different geographical areas (Buell 1960, 1972; Alaka and Elvander 1972; Ramanathan et al. 1973; Seaman 1975) agree approximately with the above pattern. Objective analysis schemes in several analysis centres incorporate the homogeneous, isotropic and geostrophic constraint on the correlation coefficients r_u and r_v used for statistical interpolation.

EVIDENCE OF SYSTEMATIC DEPARTURES

The purpose of this note is to point out departures from Fig. 1(a), which are common to all the reports cited above, but which do not appear to have been remarked upon or explained. These departures, illustrated schematically in Figs 1(b) and 1(c), consist of slight rotations (ϕ_u, ϕ_v) to both patterns from the orientations in Fig. 1(a). The zonal coefficient decreases most slowly with separation along a WSW-ENE axis (northern hemisphere), or along a WNW-ESE axis (southern hemisphere). The meridional component decreases most slowly along a SSW-NNE axis (northern hemisphere), or along a NNW-SSE axis (southern hemisphere).

The approximate magnitudes of ϕ_u and ϕ_v, measured from diagrams in the references cited above, are shown in Table 1 together with details of geographical region, level and season. All the zonal component patterns and two of the three meridional patterns are consistent with Figs 1(b) or 1(c). The meridional component pattern at zero lag, shown by Buell (1972), is oriented very close to north-south, but it is of interest that his corresponding distance-time patterns, at both lag and lead times from one to three days, exhibit the small clockwise rotation of Fig. 1(b).

Table 1 Summary of wind component spatial correlation coefficient contour patterns appearing in the open literature (see text and Figs 1(b) and 1(c) for explanations of ϕ_u and ϕ_v (degrees)).

Reference	Region	Level, Season	ϕ_u	ϕ_v
Buell 1960, Fig. 3 Buell 1972, Fig. 4	North America	300 mb winter* 500 mb (season not stated)	25	0
Alaka and Elvander 1972, Fig. 1	Caribbean	850 mb summer 200 mb summer	10	not shown
Ramanathan et al. 1973, Fig. 2	India	500 mb winter	15	10
Seaman 1975, Fig. 1(a)	Australia	500 mb winter	10	20

* Patterns stated to be similar for other levels and seasons

More detailed examination of Australian wind data from 1962 to 1972, at 500 and 200 mb in summer and winter (Seaman and Gauntlett 1980), using the Marquardt (1963) non-linear least squares fitting algorithm to construct contours of r_u and r_v, indicates that in this region the observed departures of the type shown in Fig. 1(c) are unlikely to have arisen from sampling fluctuations (see Table 2 for means and standard

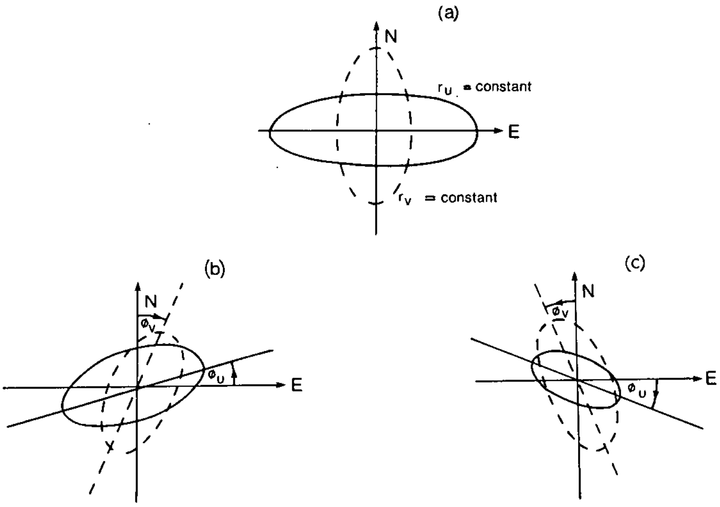

Fig. 1 Schematic illustrations of a typical zonal component (full line) and meridional component (dashed line) correlation coefficient contour, for (a) geostrophic flow in a homogeneous, isotropic atmosphere, (b) coefficients in the northern hemisphere, and (c) coefficients in the southern hemisphere.

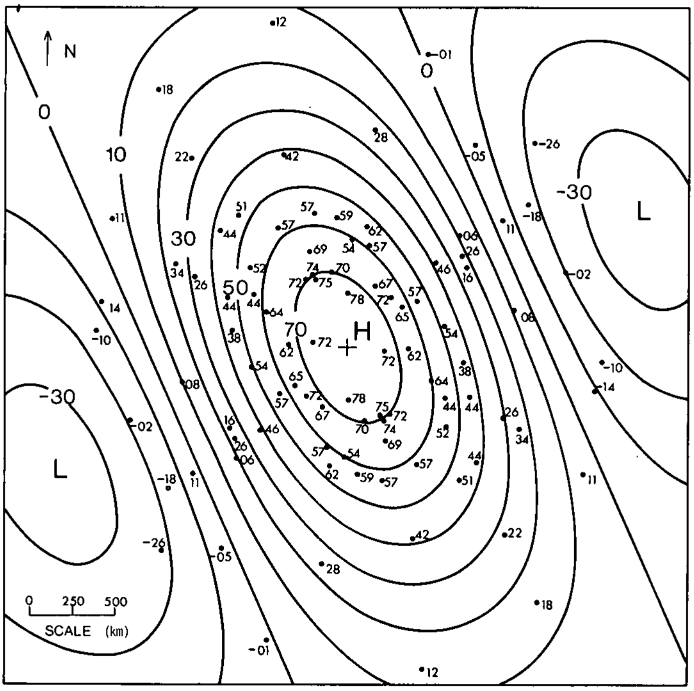

Fig. 2 Contours for the Australian region of the 500 mb winter meridional correlation coefficient function

$$r_v(d,\theta) = Z[1 - b_2^2 d^2 \cos^2(\theta - \phi)]\exp(-0.5 b_2^2 d^2)$$

where d and θ denote great circle separation and orientation, and z, b_2 and ϕ are fitting constants. Correlation coefficients are shown with the preceding decimal point omitted. (After Seaman and Gauntlett 1980) errors of ϕ_u and ϕ_v, obtained by the above objective procedure, and Fig. 2 for a typical fitted pattern.) The standard error estimates are a by-product of the least squares algorithm, and assume the validity of a Taylor series expansion in the neighbourhood of the solution. However, significance tests using a Monte Carlo technique also indicated that the non-zero values of ϕ_u and ϕ_v were unlikely to have arisen from sampling errors.

Table 2 Fitted values and standard errors of ϕ_u and ϕ_v (degrees) based upon eleven years of data from Australian upper wind stations.

	ϕ_u	ϕ_v
500 mb winter	11.5 (2.4)	23.7 (1.9)
500 mb summer	10.9 (1.1)	14.5 (2.3)
200 mb winter	7.3 (2.0)	21.5 (2.3)
200 mb summer	10.1 (1.8)	24.1 (2.0)

In none of the northern hemisphere reports listed in Table 1 is the role of sampling error specifically mentioned, and in all cases the contour patterns appear to have been manually drawn. Buell (1960) shows the correlation coefficients on which his contours are based, from which it is clear that the southwest-northeast tilt of his zonal component pattern is amply justified by the data. In the other reports insufficient information is available to assess the effects of manual subjectivity. Nevertheless, the qualitative consistency between the three northern hemisphere studies and the Australian results (taking into account the opposite hemisphere), suggests a contributory effect and underlying cause that are global rather than local in character.

CONCLUDING REMARKS

In view of the limited geographical areas so far sampled any conclusions of a global nature clearly must be tentative, and it is hoped that this note may encourage further analysis of wind data from different parts of the world. It appears both from the references previously cited and from Schlatter (1975, Table 5), that unpublished correlation coefficients of both wind and geopotential are probably already available for levels, seasons and regions additional to those for which contour patterns have appeared in the open literature.

An obvious additional question is whether it is inhomogeneity, anisotropy or ageostrophy that is primarily responsible for the observed departures from Fig. 1(a). The effects of the first two factors might be investigated by analysis of geopotential correlation coefficients, along the lines indicated by Buell (1971).

It should also be emphasised that the correlation coefficients in all the studies cited are based on deviations from a climatological mean. The conclusions therefore do not necessarily apply to deviations from a numerical prediction in an analysis-forecast cycle.

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