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Wind gradients at meteor heights over mid-latitude stations

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Abstract. The gradients of amplitude and phase of diurnal and semidiurnal components of zonal and meridional winds in the height intervals of 80–90 km and 90–100 km are studied using the meteor wind radar data collected at Atlanta (34°N, 84°W) during the period August 1974–March 1978. The results are compared with those at Adelaide (35°S, 139°E). It is found that the gradients vary in an opposite manner between the two height intervals.

Keywords. Meteor winds; amplitude and phase gradients; diurnal and semidiurnal components; mid-latitudes.

1. Introduction

Radar tracking of ionized trails of meteors yields accurate and systematic information on upper atmospheric winds in the height region 80–100 km. The use of this method for investigating various phenomena such as turbulence, tides and diffusion in the upper atmosphere at these heights was pioneered by Greenhow and Neufeld (1956, 1959) and the results obtained so far at various places in the world have been reviewed by Hocking (1985) and Forbes (1985). Recently, the meteor radar technique has been made more powerful and sophisticated to achieve maximum height resolution of order 1 km to study the height variation of neutral wind parameters in detail (e.g., Revah *et al* 1967). Observations carried out at many places indicate that gradients in wind amplitude and phase could be as high as 4 msec^{-1} km^{-1} and 12° km^{-1} respectively over a height range 85–95 km (Elford and Robertson 1953; Greenhow and Neufeld 1955). The seasonal and annual variation of wind gradients has been extensively studied by Greenhow and Neufeld (1955, 1956) at Jodrell Bank, England. They report that the magnitude of wind gradient varies between 1·5 and 0·4 msec^{-1} km^{-1} during winter and summer months in the height region 85–95 km. In a comparative study between meteor winds and ionospheric drifts, Muller (1968) observed the height gradients of wind amplitude and phase of 1·06 msec^{-1} km^{-1} and 4·7° km^{-1} respectively. By analyzing the meteor wind data for Adelaide for the period 1967–69, Ahmed and Devara (1979) reported that gradients of amplitude and phase of semidiurnal wind component varied markedly between 80 and 90 km, and 90 and 100 km height intervals.

An attempt has been made in this paper to study the variation of wind gradients over mid-latitude stations in the altitude range 80–100 km which contributes the information on propagational characteristics of wave phenomena prevailing at those altitudes. For this purpose, diurnal and semidiurnal components of zonal

(EW) and meridional (NS) winds between 80 and 100 km over Atlanta (34°N, 84°W) obtained using the Georgia Tech radio meteor wind facility during the period August 1974–March 1978 are analysed to obtain information on gradients of amplitude and phase in the height intervals of 80–90 km and 90–100 km. The results are compared with those at Adelaide (35°S, 139°E), almost geographically symmetric station. The details of the analysis, results achieved and conclusions drawn are presented below.

2. Data and analysis

The data of monthly mean amplitude and phase of diurnal (24 hour) and semidiurnal (12 hour) components of EW and NS winds at 80, 90 and 100 km for Atlanta for the period August 1974–March 1978 are available. The details of the radar facility used and the mathematical procedure followed for estimating the amplitude and phase of diurnal and semidiurnal components from the hourly mean meteor wind values have been described by Roper (1975, 1978). The differences in amplitude and in phase were computed between the heights 80 and 90 km, and 90 and 100 km for diurnal and semidiurnal components of EW and NS winds. The gradients so obtained for each month were averaged for respective months and mean values for all January months, February months etc over the 44-month period (August 1974–March 1978) are utilized for studying the behaviour of wind gradients of amplitude and phase of EW and NS winds in the 80–90 km and 90–100 km height intervals over a mid-latitude station.

3. Variation of height gradients over different months

3.1 *Diurnal amplitude*

The monthly mean variations in the gradients of amplitude of diurnal component of EW and NS winds in the 80–90 km and 90–100 km height intervals are shown in figure 1 for Atlanta (A,B,C,D) and Adelaide (a,b,c,d). It is clear from figure 1 that the gradients of EW and NS winds are positive in the 90–100 km height interval and negative in the 80–90 km height interval throughout the year at Atlanta. In the case of Adelaide (figure 1a & b) although the EW wind gradient in both the height intervals appears to be swinging between positive and negative values, it is negative during most of the months in the 80–90 km height interval. Also, the variations in the gradients at Atlanta and Adelaide for the height interval 80–90 km follow each other for most of the months. The results of Atlanta clearly show that the diurnal oscillation is damped (negative amplitude gradient) between the levels 80 and 90 km, and amplified (positive amplitude gradient) between the levels 90 and 100 km.

3.2 *Semidiurnal amplitude*

The monthly mean variations in the gradients of amplitude of semidiurnal component of EW and NS winds in the 80–90 km and 90–100 km height intervals

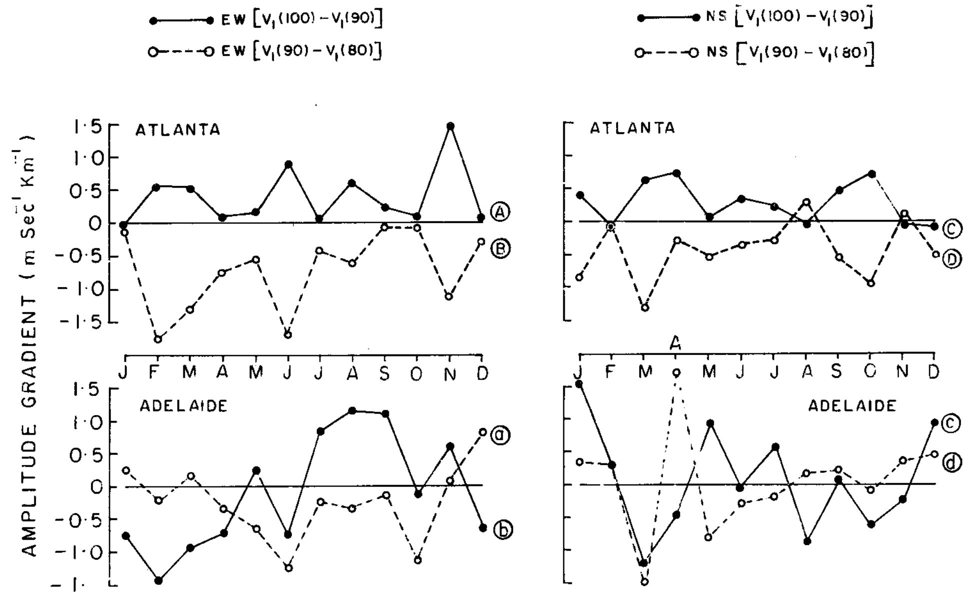

Figure 1. Monthly variations in gradients of amplitude of diurnal component of zonal and meridional winds for Atlanta (A,B,C,D) and Adelaide (a,b,c,d).

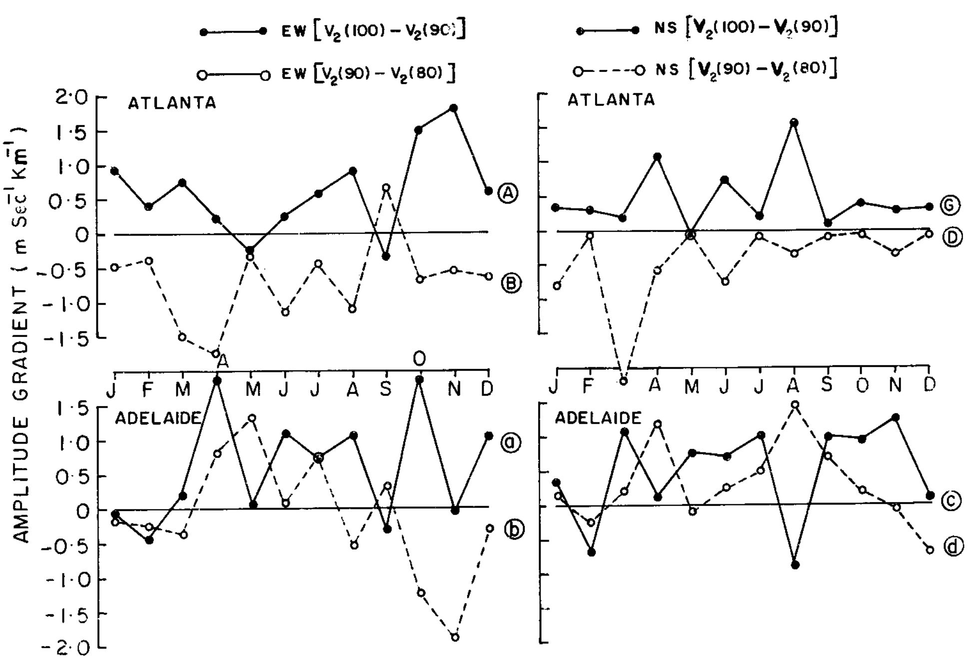

Figure 2. Same as figure 1 for semidiurnal component.

are displayed in figure 2 for Atlanta (A,B,C,D) and Adelaide (a,b,c,d). Figure 2 (A & a) clearly shows that the gradient of EW wind is positive in the 90–100 km height interval throughout the year except during May and September at Atlanta;

January, February and September at Adelaide. The same gradient is negative in the 80–90 km height interval in all the months except September at Atlanta while it is swinging between positive and negative values at Adelaide. Figure 2 (C & D) points out that the gradient of semidiurnal component of NS wind at Atlanta is positive in the 90–100 km height interval and negative in the 80–90 km height interval throughout the year. At Adelaide, this gradient is positive for both the height intervals except during February and August in the 90–100 km height interval; February and December in the 80–90 km height interval.

3.3 *Diurnal phase*

The month-to-month mean variations in the gradients of phase of diurnal component of EW and NS winds in the 80–90 km and 90–100 km height intervals are displayed in figure 3 for Atlanta (A,B,C,D) and Adelaide (a,b,c,d). It can be seen that the variations in the gradients of phase of EW and NS winds at Atlanta and Adelaide are erratic and at times follow each other in both the height intervals.

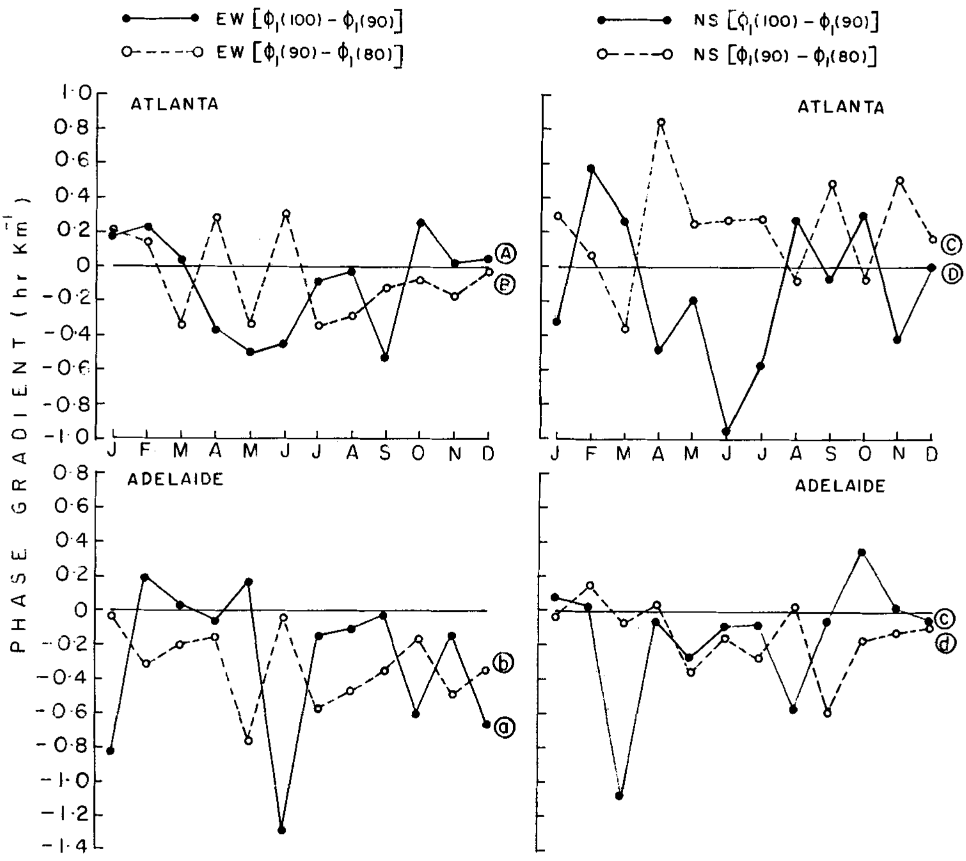

Figure 3. Monthly variations in gradients of phase of diurnal component of zonal and meridional winds for Atlanta (A,B,C,D) and Adelaide (a,b,c,d).

Also, it is evident from figure 3 (a,b,c,d) that the nature of variation of gradient in the 80–90 km interval is almost opposite to that in the 90–100 km interval.

3.4 *Semidiurnal phase*

Figure 4 depicts the monthly mean variations in the gradients of semidiurnal component of EW and NS winds in the 90–100 km and 80–90 km height intervals for Atlanta (A,B,C,D) and Adelaide (a,b,c,d). The magnitudes of gradients at Atlanta are small compared to those at Adelaide. Also, it appears that there is an appreciable change in the gradients of phase for semidiurnal components of EW and NS winds at Adelaide.

3.5 *Seasonal and annual variation of height gradients*

The seasonal and annual mean gradients of amplitude and phase of diurnal and semidiurnal components of EW and NS winds at Atlanta for the 90–100 km and 80–90 km intervals are presented in table 1. For purposes of comparison, results of

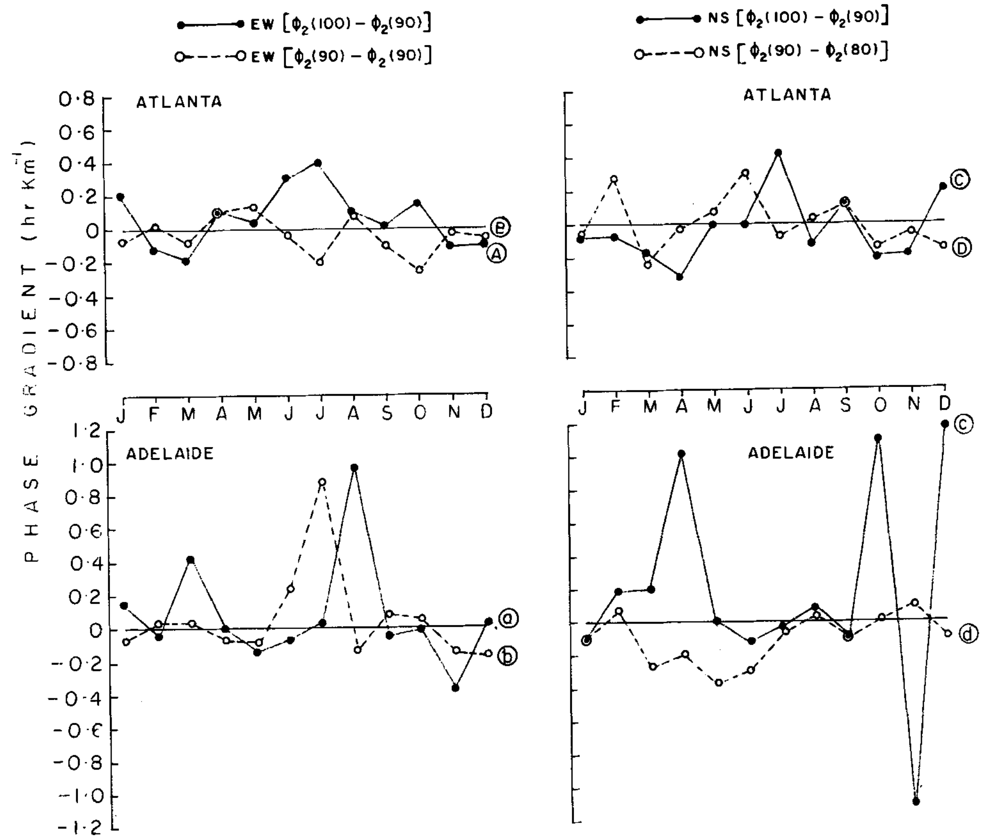

Figure 4. Same as figure 3 for semidiurnal component.

Table 1. Seasonal and annual mean variation in gradients of amplitude (m sec^{-1} km^{-1}) and phase (hr km^{-1}) of diurnal (V_1, θ_1) and semidiurnal (V_2, θ_2) components of zonal (EW) and meridional (NS) winds for the height intervals 80–90 km and 90–100 km.

Gradient	Spring	Summer	Autumn	Winter	Annual
EW [V_1 (90)–V_1(80)]	−1·29 (−0·11)	−0·90 (−0·70)	−0·62 (0·25)	−0·54 (0·37)	−0·84 (−0·05)
EW [V_1 (100)–V_1(90)]	0·39 (−1·0)	0·35 (0·10)	0·32 (0·70)	0·49 (−0·28)	0·39 (−0·12)
NS [V_1 (90)–V_1(80)]	−0·57 (0·27)	−0·44 (−0·40)	−0·40 (0·08)	−0·42 (0·35)	−0·46 (0·08)
NS [V_1 (100)–V_1(90)]	0·44 (−0·49)	0·22 (0·47)	−0·38 (−0·47)	0·09 (0·72)	0·28 (0·06)
EW [V_2 (90)–V_2(80)]	−1·24 (0·05)	−0·67 (0·72)	−0·40 (−0·51)	−0·59 (−0·71)	−0·72 (−0·11)
EW [V_2 (100)–V_2(90)]	0·49 (0·56)	0·22 (0·64)	0·53 (0·99)	1·16 (0·35)	0·60 (0·64)
NS [V_2 (90)–V_2(80)]	−0·96 (0·38)	−0·33 (0·23)	−0·15 (0·79)	−0·37 (−0·20)	−0·45 (0·30)
NS [V_2 (100–V_2(90)]	0·55 (0·18)	0·33 (0·86)	0·71 (0·36)	0·39 (0·57)	0·49 (0·49)
EW [ϕ_1 (90)–ϕ_1(80)]	0·03 (−0·22)	−0·13 (−0·44)	−0·18 (−0·32)	0·001 (−0·28)	−0·07 (−0·32)
EW [ϕ_1 (100)–ϕ_1(90)]	−0·03 (0·05)	−0·36 (−0·43)	0·10 (−0·25)	0·09 (−0·54)	−0·10 (−0·29)
NS [ϕ_1 (90)–ϕ_1(80)]	0·18 (0·03)	0·27 (−0·27)	0·11 (−0·24)	0·32 (−0·09)	0·22 (−0·14)
NS [ϕ_1 (100)–ϕ_1(90)]	0·13 (−0·36)	−0·58 (−0·15)	0·18 (−0·09)	−0·24 (0·01)	−0·13 (−0·15)
EW [ϕ_2 (90)–ϕ_2(80)]	0·02 (−0·007)	−0·04 (0·35)	−0·10 (0·06)	−0·01(−0·11)	−0·03 (0·07)
EW [ϕ_2 (100)–ϕ_2(90)]	−0·07 (0·13)	0·25 (−0·05)	0·09 (0·30)	−0·008 (−0·06)	0·07 (0·08)
NS [ϕ_2 (90)–ϕ_2(80)]	0·003 (−0·14)	0·09 (−0·22)	−0·01 (−0·0003)	−0·05 (0·01)	0·01 (−0·09)
NS [ϕ_2 (100)–ϕ_2(90)]	−0·18 (0·47)	−0·14 (−0·06)	−0·01 (0·38)	−0·02 (0·01)	−0·09 (0·20)

Adelaide (with paranthesis) are also presented in table 1 and the most striking event is that at Atlanta, the seasonal mean height gradients of amplitude and phase of both diurnal and semidiurnal components in the 80–90 km and 90–100 km intervals are opposite to each other except for diurnal component of EW wind during summer and winter; semidiurnal components of NS and EW winds during autumn and winter. The annual mean height gradient also showed similar behaviour except for phase of diurnal component of EW wind. Any such systematic variation is not seen at Adelaide.

4. Discussion

The variations observed in the height gradients of amplitude and phase of the neutral wind components over the height intervals of 80–90 km and 90–100 km are discussed in relation to the atmospheric oscillations. In general, the height variations of wind amplitude and phase at meteor heights can be described by means of the propagational aspects of tidal energy from troposphere to upper atmosphere. The seasonal variations in the height gradients of amplitude and phase observed in the present study are considered to be due to the variations in vertical wavelength and corresponding dominant modes of diurnal and semidiurnal tides over Atlanta and Adelaide as explained by Ahmed and Roper (1983). The opposite trends of variation observed in the gradients of amplitude and phase of diurnal and semidiurnal components of EW and NS winds in the 80–90 km and 90–100 km intervals suggest the formation of amplitude node at 90 km which indicates reflection of tidal energy associated with a phase reversal at 90 km.

5. Conclusions

Analysis of the meteor wind data for Atlanta and Adelaide showed that the gradients of amplitude and phase of diurnal and semidiurnal components of EW and NS winds are positive in the 90–100 km height interval and negative in the 80–90 km height interval at Atlanta whereas at Adelaide they swing between positive and negative values. This suggests that the formation of amplitude node at 90 km is a more regular feature at Atlanta than at Adelaide, a southern hemisphere station with very nearly the same latitude as that of Atlanta. Inter-comparison of the available mid-latitude meteor wind radar results at closer height intervals may provide further understanding of the problem.

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