1.Classification *INPE-COM.4/RPE*

C.D.U.: 551.524.77

2.Period

4.Distribution Criterion

internal ☐

external ☒

3.Key Words (selected by the author)

VERTICAL VELOCITY, TOPOGRAPHY

5.Report No.
INPE-1691-RPE/119

6.Date
March, 1980

7.Revised by
Antonio Divino Moura

8. Title and Sub-title

VERTICAL VELOCITY FORCED BY TOPOGRAPHY IN THE SOUTHERN HEMISPHERE

9.Authorized by

Parada
Nelson de Jesus Parada
Director

10.Sector *DME* Code

11.No. of Copies *09*

12.Authorship *Rubens Leite Vianello*
V. Brahmananda Rao

14.No. of Pages *15*

13.Signature of first author

15.Price

16.Summary/Notes

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17.Remarks *To be submitted to Monthly Weather Review.*

1691

VERTICAL VELOCITY FORCED BY TOPOGRAPHY IN THE SOUTHERN HEMISPHERE

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ABSTRACT

Vertical component of wind forced by topography in the Southern Hemisphere is calculated using the equation given by Saltzman and Irsch (1972). This equation contains the contribution of zonal deviations of wind in addition to the contribution of zonal mean. Results show that the vertical velocity forced by topography in the Southern Hemisphere is in general, comparable to that in the Northern Hemisphere. As in the case of the Northern Hemisphere, the zonal deviations of wind contribute significantly to the vertical velocity.

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1. Introduction

It is well known that asymmetries of the earth's surface force stationary waves. Longitudinal variations of mean meteorological elements such as precipitation and cloudiness, are strongly related to these waves. Orographic features of the earth's surface can account for some aspects of the stationary waves (Charney and Eliassen, 1949). Although a major part of the Southern Hemisphere is occupied by ocean, stationary waves are still produced by topography in some latitude belts, thus exerting important influence on the climate of these regions. For example, the Andes Mountains seem to affect substantially the climate of the South american Continent, especially the distribution of rainfall. Riehl (1978) suggested the existence of a trough on the east of Andes Mountains, in a way similar to the trough on the east of Rocky Mountains. In a recent study Satyamurty et al. (1979) substantiated Riehl's suggestion, using a primitive equation barotropic model with topography. Their results strongly support the existence of a trough on the lee side of Andes Mountains.

Yasunary (1977) showed the importance of continent-ocean configuration in the Southern Hemisphere on the pattern of cloudiness. He attributed the dominance of wave number 3, in the latitude belt 40^0-50^0 S to the presence of 3 continents,viz , S. America, Africa and Australia.

Using a two-layer quasi-geostrophic model, the authors have earlier studied the dynamics of stationary disturbances forced by topography in the Southern Hemisphere (Vianello and Rao, 1975). It was possible to explain only partially some of the observed features of stationary waves by topographic forcing. However, in that study, only the zonal mean wind was used in the forcing of topography. Saltzman and Irsch (1972) have shown that the terms which are usually neglected in the topographic forcing function, such as the ones associated with zonal deviations could also be important in the Northern Hemisphere. The purpose of the present note is to extend the study of Saltzman and Irsch III to the Southern Hemisphere with a view to see the importance of the terms which were not included in the above mentioned study of the authors.

Thus, we calculate the vertical velocity forced by topography in the Southern Hemisphere in a manner similar to the calculations of Saltzman and Irsch. The equation used to calculate the vertical velocity forced by mountains is

$$\overline{w}_s^{(M)} = u_{os} \frac{\partial h}{a \cos \phi \, \partial\lambda} + \left[u_{1s} \frac{\partial \bar{h}}{a \cos\phi \partial\lambda} + (v_o + v_1)_s \frac{\partial h}{a \, \partial\phi} \right] \qquad (1)$$

where subscript S indicates the value at the anemometer level and the superscript M denotes the mountain forcing. Bar represents a time average. Subscripts 0 and 1 represent average around a latitude circle and departure from it respectively, h is the topographic height above sea level and u and v are respectively the eastward and northward components of the wind. For a derivation of equation (1) see Saltzman and Irsch (loc.cit.). In our theoretical study mentioned earlier, we included only the first term on the right hand side of (1), neglecting the other terms.

2. Data

To calculate $\overline{W}_s^{(M)}$, for summer and winter we used the following data: for the region between 0° and 25° S, zonal wind and meridional wind components for the periods December-February and June-August are obtained from Newell et al (1972) and for the region south of 30° S January and July values are taken from Jenne et al. (1971). The data of Newell et al, are the observed winds, while those of Jenne et al.are geostropic winds. Although the distribution of wind measuring stations is not what one would like to have, it appears to be satisfactory for the present study. Data for grid of 5^0 longitude and 5^0 latitude are obtained by interpolating linearly. Further, depending upon the height of the grid point, wind values are taken from 3 pressure levels, 1000 mb for points up to a height of 1000 m, 850 mb for points between 1000 and 2000 m and 750 mb for points above 2000 m (see Fig. 1). Topographic heights are obtained from Berkofsky and Bertoni (1955).

For calculating vertical velocity using equation (1), derivatives are replaced by centered finite differences. Vertical velocities are calculated for summer and winter separately at each grid point. These are plotted on charts and are shown in Figs. 2 and 3. In order to evaluate the importance of various terms in (1), longitudinal profiles of vertical velocity at 20^0 S, forced only by u_{os}, only by v_{os} and by all the components are shown in Fig. 4. Finally, the fields of vertical velocity in Figs. 2 and 3 are compared with the mean precipitation and cloudiness.

3. Results

A comparison of Figs. 2 and 3 with Figs. 1 and 2[*] of Saltzman and Irsch (loc. cit) reveals that vertical velocity is in general comparable in both the Hemispheres.

It can be seen in Figs. 2 and 3 that high values of $\overline{W}_s^{(M)}$ occur in the southern portion of South America with positive values (rising motion) on the west of Andes mountains and negative values (sinking motion) on the east. This feature agrees well with the distribution of cloudiness (Miller and Feddles, 1971) and with the mean

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[*] *In a recent paper by Lau (1979), it was mentioned that the values of* $\overline{W}_M^{(M)}$, *obtained by Saltzman and Irsch are actually in units of* 10^{-1} *cm* s^{-1} *instead of* 10^{-2} *cm* s^{-1}.

rainfall given in Berry et al (1973). This suggests the importance of topography on the distribution of precipitation in this region.

Manabe and Terpstra (1974) studied the effects of mountain on the global climate using a numerical model. Their model results show that the arid zone in South Pacific was limited up to South American coast in the simulation with mountains. On the other hand the simulation without mountains shows the penetration of arid zone in an unrealistic way into the continent. This agrees with our results, viz., that in the region surronding Andes mountains, vertical velocities are rather high showing the importance of topography.

Another region in South America, where some importance of topography could be seen is northeast Brazil. Further, pattern of vertical velocity in this region is different in summer and winter because of the change of wind direction and speed. However, the present study is limited by the grid size and finer details could not be obtained.

In the African Continent, there is a reasonable agreement between vertical velocity, cloudiness and precipitation particularly in winter, in the region of Madagascar Island and Central portion of southern part of the continent.

In the Australian Continent, again, there is some agreement between the field of vertical velocity and the field of precipitation and cloudiness, although topography does not seem to have important influence on the precipitation, at least on the scale used in this study.

Values obtained for latitudes south of 60^{o} S are not plotted in Figs. 2 and 3, in view of large errors associated with the finite differences of spherical coordinates (Shuman, 1970).

Finally, Fig. 4 shows the longitudinal profiles of $\overline{W}_s^{(M)}$ for 20^o S, forced by u_{os}, by v_{os} and by all the terms on the right hand side of equation (1). It can be seen that the fluctuation terms are as important as the mean term. A similar conclusion has been reached by Saltzman and Irsch (loc.cit.) for the Northern Hemisphere case. A theoretical study of stationary waves is underway which includes fluctuation terms in the topography forcing in addition to the term due to mean zonal wind.

Acknowledgements:

Thanks are due to Drs. A.D.Moura and S. Srivatsangam for going through the manuscript. This work was partially financed by Convenio nº B/28/079/019/00/00 - FINEP/CNPq - Climatologia.

REFERENCES

BERKOFSKY, L., and E.A. Bertoni, 1955: Mean topographic charts for the entire earth. *Bull. Amer. Meteor. Soc.,* 36 (7). 350-354.

BERRY, F.A.Jr., E. Bollay, and N.R. Beers, 1945. *Hand book of meteorology.,* McGraw-Hill book company INC New York. 967-969.

CHARNEY, J.G. and A. Eliassen, 1949: A numerical method for predicting the perturbations in middle-latitude westerlies. *Tellus* 1. 38-54.

JENNE, R.L., H.L. Cretcher, H.van Loon and J. Taljward, 1971 climate of upper air. Southern Hemisphere-Vector mean geostrophic winds. NCAR IN/STR - 58, vol. III.

LAU, N.C., 1979: The observed structure of tropospheric stationary waves and the local balance of vorticity and heat. *J. Atmos. Sci.,* 36,996-1016.

MANABE,S. and T.B. Terpstra:1974: The effect of mountains on the general circulation of the atmosphere as identified by numerical experiments. J. Atmos. Sci., 31, 3 - 42.

MILLER, D.B. and R.G. Feddles, 1971: Global atlas of relative cloud cover 1967/1970. NOAA/USA Washington D.C.

NEWELL, R.E., J.W. Kidson, D.G. Vicente and G.J. Boer, 1972: The general circulation of the tropical atmosphere and interactions with extratropical latitudes. vol.1. The MIT Press, 258 pp.

RIEHL. H., 1978: New features of global climatology revealed by satellied derived oceanic rainfall maps. *Bull. Amer. Meteor. Soc.,* 59(5). 645-646.

SALTZMAN, B. and F.E. Irsch, 1972:Note on the theory of topographically forced planetary waves in the atmosphere. *Mon. Wea. Rev.* 100 (6)441-444.

SATYAMURTY, P., R.P. Santos and M.A.M. Lemes, 1979: On the stationary trough generated by the Andes. Accepted in *Mon. Wea. Rev.* (Available from INPE, C.P. 515, 12 200. São José dos Campos, SP. Brasil).

SCHUMAN, F.G. 1970: On certain truncation errors associated with spherical coordinates. *J. Appl. Meteor.* 9. 564-570.

VIANELLO, R.L. and V.B.Rao, 1975: A theoretical study of the continental elevation influence on the stationary harmonics in the Southern Hemisphere. (Available from INPE. C.P. 515, 12 200 São José dos Campos. SP. Brasil).

YASUNARI, T., 1977: Stationary waves in the Southern Hemisphere mid-latitude zone revealed from image brightness charts. *J.Meteor. Soc. Japan* 55(3) 274-285.

FIGURE LEGENDS

Fig. 1 - Pressure levels used at different grid points.

Fig. 2 - Total vertical velocity (10^{-2} cm S^{-1}) - summer.

Fig. 3 - Same as Fig. 2 for winter.

Fig. 4 - Longitude profiles of vertical velocity at 20^0 S. The Contributions of u_{os}, v_{os} and total vertical velocity for winter. Lower fig. shows the smoothed topography at 20^0 S.

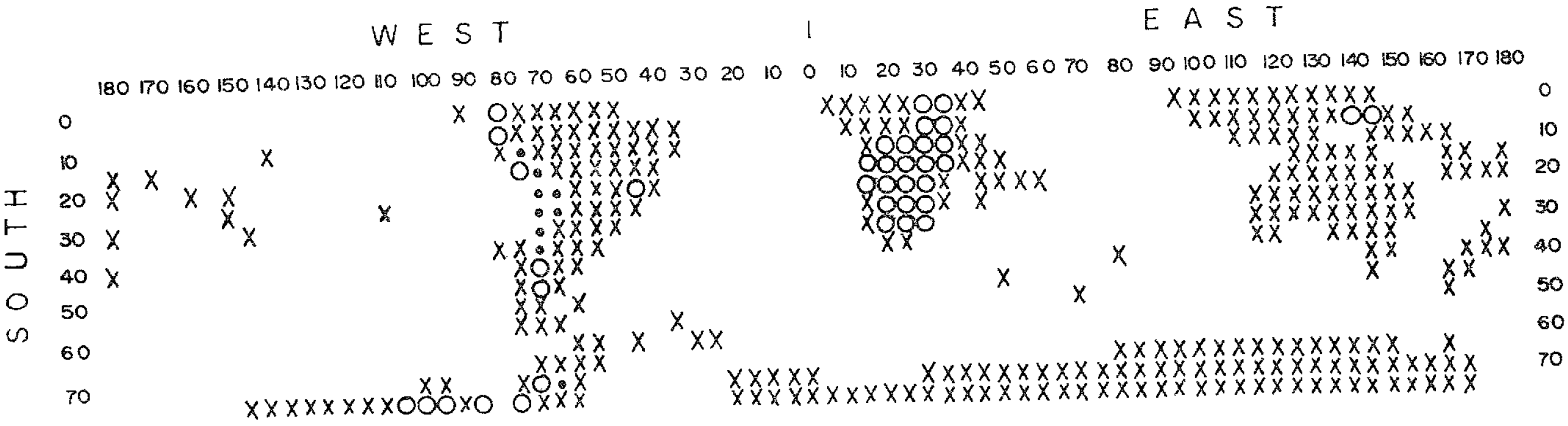
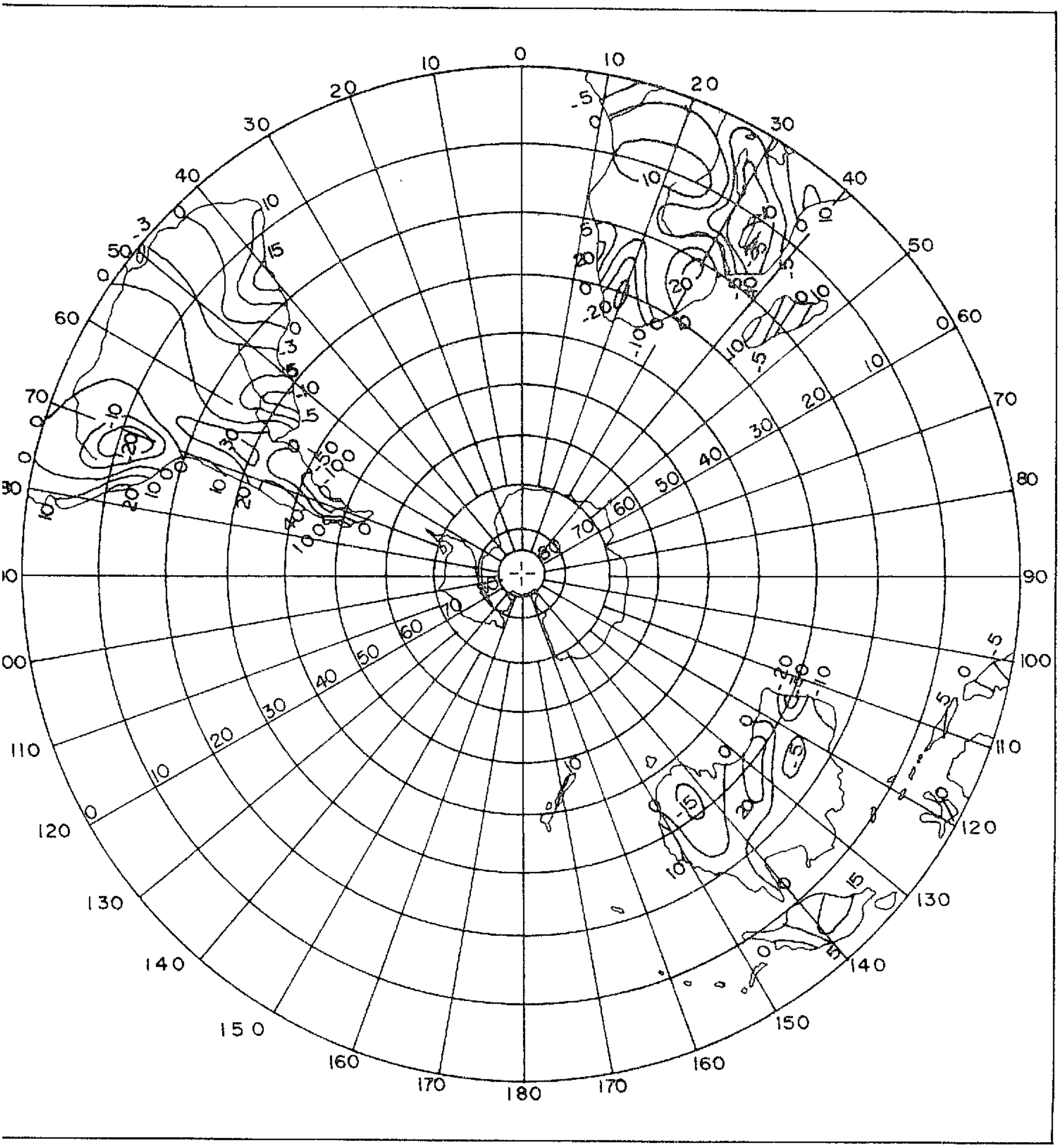

WEST
EAST
SOUTH
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
0 10 20 30 40 50 60 70
X – 1000mb
O – 850 mb
• – 700mb

FIG. 1


0
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160
150
140
130
120
110
100
90
80
70
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10
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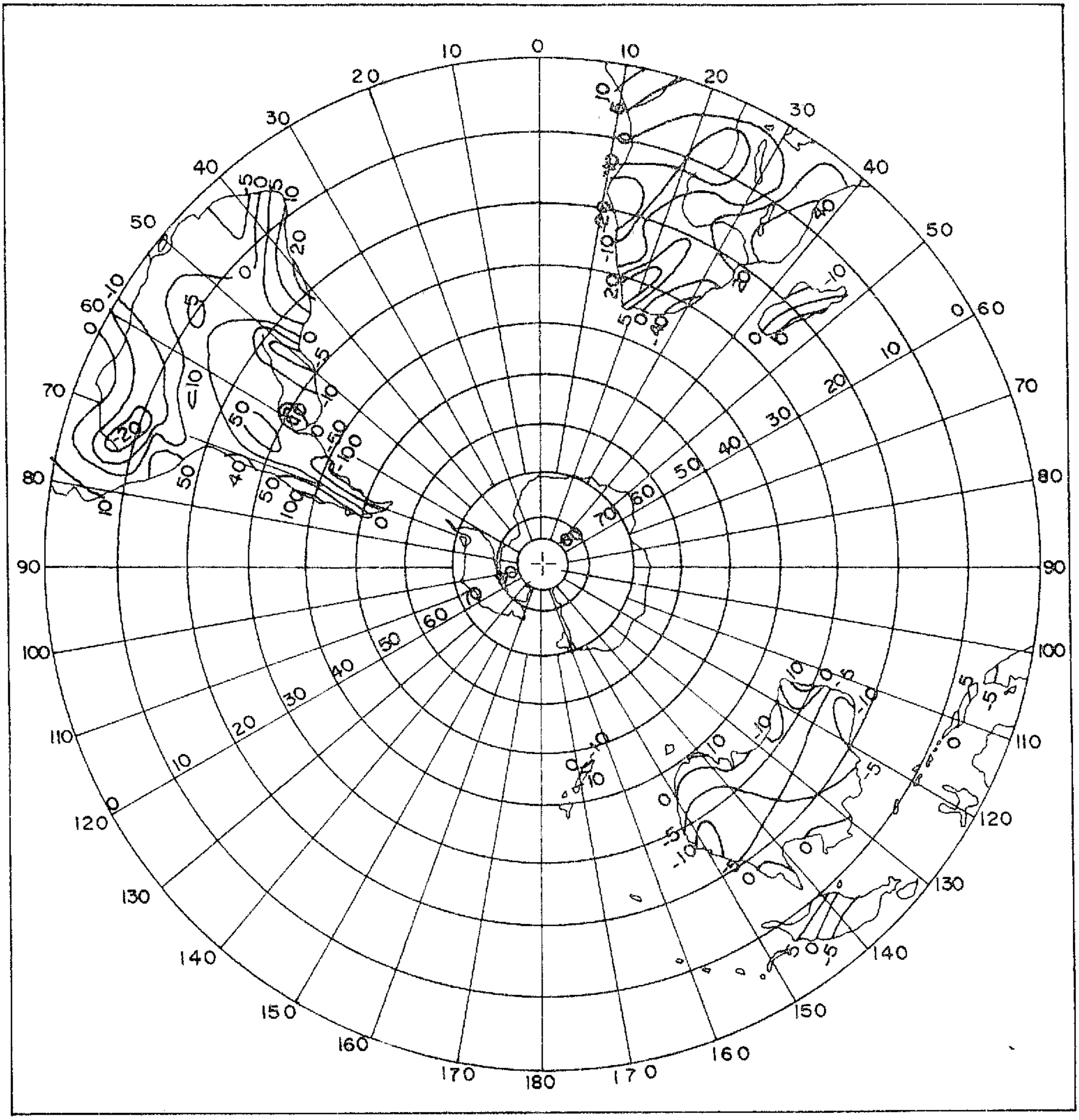
-5
-3
-10
-20
-50
-100
15

FIG. 2:



0
10
20
30
40
50
60
70
80
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100
110
120
130
140
150
160
170
180
-5
-10
-20
-50
-100

FIG. 3:

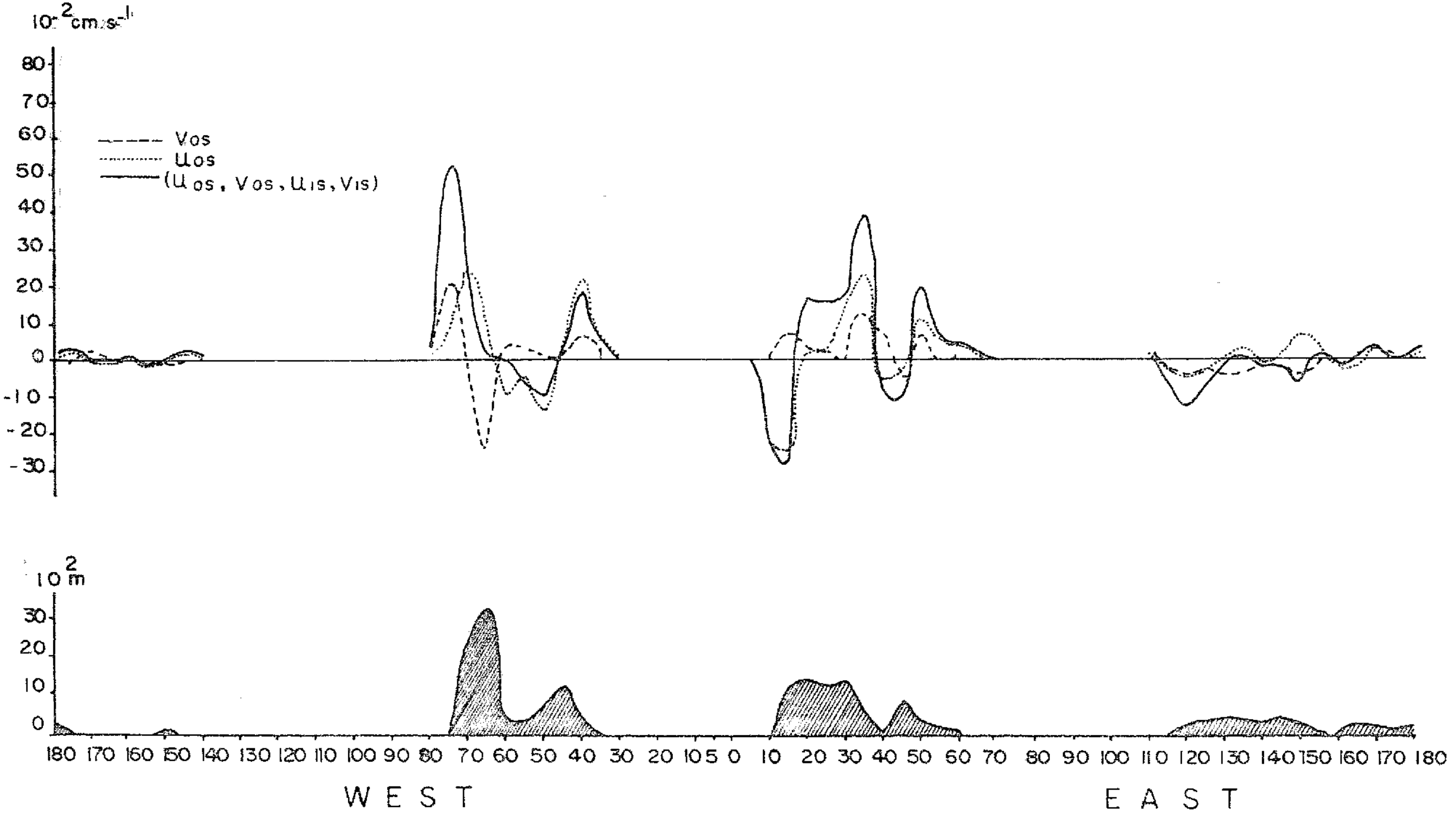
10^2 cm s^-1
80
70
60
50
40
30
20
10
0
-10
-20
-30
Vos
Uos
(Uos, Vos, U1s, V1s)
10^2 m
30
20
10
0
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 5 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
WEST
EAST

FIG. 4