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An Atlas of Objectively Analyzed Atmospheric Cross Sections 1973-1980

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This atlas is dedicated to the memory of Professor Christopher Riegel, Chairman of the Meteorology Department, San José State University, who died while this work was in progress.

Preface

Atmospheric variability over time scales greater than one month is conceptually simplified and readily recognized from vertical cross-sections of zonal-monthly mean data. The reduction to two dimensions, latitude and height, explicitly eliminates all zonal waves but implicitly retains their effects on the thermal-pressure fields and the dynamically related zonal wind fields. This atlas contains 96 examples, spanning all latitudes in both the northern and southern hemispheres and two decades in pressure, from 1000 to 10 mb. Four analyses, representing each month from January 1973 through December 1980, are arranged on facing pages for convenient visual comparisons. The upper pair depicts the potential virtual temperature (see text for definitions) and the observed zonal wind velocity. The lower pair depicts the virtual temperature and the geostrophic zonal wind velocity. Each variable is contoured at a close interval to facilitate visual estimates of stability and vorticity via their gradients.

The analyses are generated and contoured by objective computer methods from just one data source: *in situ* measurements from the conventional rawin-radiosonde system. This choice of data limits the cross-sections to pressures ≥ 10 mb and to heights of 30 ± 2 km. This disadvantage is more than offset by the fact that the data are synoptic, reported at fixed pressure levels, and can be checked for internal consistency. Throughout the development of the computer programs, our philosophy was to use simple methods wherever possible to reproduce the quality of hand analyses. The methods used to process and to analyze the data are discussed in the following text.

Although the analyses are independently made at constant pressure levels (the mandatory levels) the cross-sections are drawn with geopotential height as the ordinate. With this ordinate we can observe the seasonal expansion and contraction of the earth's atmosphere, especially that of the polar stratosphere, an important phenomenon we tend to forget by the repeated use of the standard atmospheric heights as an ordinate. Also, the quasi-biannual cycle can be identified and studied directly from successive cross-sections. During these 8 years it differs quite markedly from that found in a prior 8 year period, 1957–1964 by Newell, *et al*, (1972).

I. Introduction

The challenge in atmospheric analysis is to extract from a nonuniformly distributed set of observations, including representative and nonrepresentative signals plus systematic and random errors, a uniformly distributed set of representative values. The analysis method, subjective or objective, may not distinguish between nonrepresentative signals and errors, but generally, the former are more troublesome than the latter and will be considered here separately.

Atmospheric measurements, especially those of wind velocity and temperature, are influenced by a broad spectrum of internally propagating waves. In addition to the slowly moving, large scale waves whose amplitudes and phases can be determined from radiosonde observations, separated 300 km in space and 12 hr in time, there are many faster moving, smaller scale waves which cannot be resolved by conventional data. Special high resolution measurements are required to detect them, but it is apparent that they are ubiquitous. For example, precision radar tracking of radiosonde balloons with high frequency data recording (Danielsen and Duquet, 1967) indicates that waves whose vertical wavelenghts range from 1 to 4 km contribute velocity deviations, often circularly polarized, of 2 to 5 $m\ s^{-1}$ and temperature deviations of 1 to 2 K. This and subsequent studies show that occasionally they exceed these typical values by as much as a factor of three. From the earth's surface to $\sim$30 km (10 mb) these velocity and temperature deviations, which represent signals, often unwanted signals, definitely exceed the errors in rawin- and radiosonde measurements.

Eliminating these unwanted signals would be simple if radiosonde measurements of temperature and pressure were combined with radar tracking (rather than radio signal intensity) and all measurements were recorded at 10 to 20 Hz. Then, the waves would be resolved vertically and could be objectively removed by Fourier filtering. Unfortunately, conventional data are recorded only once per minute and temperature frequencies are transmitted and recorded intermittently, transmission being shared with relative humidity and calibration frequencies.

In a crude attempt to obtain representative large scale wind velocities, 2 min average velocities are computed below 7 km and 4 min averages at all higher elevations. Since radiosonde balloons rise at $\sim 5 \pm 1$ $m\ s^{-1}$, even a 4 min average does not remove the effects of waves whose vertical wavelengths are 1 to 4 km. Conversely, the tracking data do not provide enough information to adequately resolve them and therefore to permit one to remove them by vertical filtering.

In synoptic analyses the filtering remains the responsibility of the analyst. And, indeed, it is a formidable problem. On the other hand, in monthly mean analyses temporal averaging itself is an effective filter. Short vertical waves tend to be omnipresent and randomly distributed in a set of twice daily measurements, made over a monthly period. These contributions effectively cancel one another leaving smoothly varying mean profiles. Furthermore, adjacent stations yield similar profiles which vary slowly and smoothly with distance.

To those familiar with the accuracies of radiosonde measurements these results probably are not surprising. Although it is far from a state-of-the-art measuring system, the radiosonde has proven to be a very reliable, accurate and inexpensive system. One would expect the accuracy of monthly mean temperatures to depend mainly on the measurement accuracy which includes relative and systematic errors. The former are small, usually < 0.2 K. Values as large as $\pm$ 1 K are quoted for the latter but direct comparisons with radar tracking suggest that such errors are rare. With radar tracking the geometric heights above a curved earth can be derived independently of the thermodynamic measurements. These can be converted to geopotential heights as a function of time and compared directly to the geopotential heights computed from the measurements of pressure, temperature and relative humidity as a function of time. Results of a recent study by Danielsen, Hipskind and Gaines (1980) indicate that inaccuracies in the pressure rather than in the temperature measurements dominate the radiosonde errors. The percentage error in pressure becomes large above 30 km where the total pressure decreases below 10 mb. Above this altitude the reduction in thermal conductivity also makes the thermistor subject to radiational errors. Their combined effects limit the reliability of radiosonde measurements to the lowest 30 km of the atmosphere.

However, if one considers current atmospheric measuring systems, *in situ* and remote, active and passive, the rawin-radiosonde system still offers the most reliable, homogeneous set of measurements for the troposphere, and the lower and middle stratosphere. In effect, they remain the standard for calibration of new sensors. In recognition of these attributes and the extensive data base, we chose to restrict our analyses exclusively to rawin- radiosonde data. The analyses and error rejection methods are completely objective. They are the product of numerous tests and comparisons with hand analyses. The goal, to reproduce by relatively simple objective methods the quality of hand analyses, has been achieved. Although the analyses extend to 10 mb, the number of radiosonde balloons which survive the cold temperatures of the winter pole is significantly reduced. Therefore, due to nonrepresentative sampling the 10 mb analyses in the vicinity of the winter pole are least reliable.

II. Error rejection and monthly averaging

Data for the analyses were obtained from the rawin-radiosonde tape library of the National Center for Atmospheric Research (NCAR).

The data, initially collected at the National Meteorological Center (NMC) of the National Oceanic and Atmospheric Administration (NOAA), include synoptic observations received twice daily from both hemispheres. A complete report includes mandatory and significant level data, but not all reports are complete. Often only mandatory data are received at NMC from Asiatic and some southern hemispheric stations. In addition to being the most complete subset of data, only mandatory levels include enough information to permit a hydrostatic error analysis.

Because the data are processed, coded, transmitted, etc., a small but nonzero percentage of errors is introduced. Since the mandatory data, at fixed pressure levels, include geopotential heights, temperatures, dew point depressions, wind directions and speeds, the heights and temperatures can be checked for internal consistency. The method developed here permits distinguishing between an isolated temperature or height error. It cannot be applied to significant level data because only the pressure, temperature and dew point depression are reported. Lacking explicit height information one cannot distinguish between a temperature or pressure error. Our monthly mean computations are restricted, therefore, to mandatory level data only. Error detection depends upon the sign of two consecutive height differences. A temperature error is identified when both have the same sign, while a height error is identified by opposite signs.

Geopotential heights are computed by integrating the hydrostatic approximation

$$\frac{\partial p}{\partial z} = -\rho g \tag{1}$$

where p and ρ are the total pressure and density and g is the acceleration of gravity. Since density is not measured directly, it is eliminated by means of the equation of state, which relates p and ρ to the temperature T and the appropriate gas constant for the mixture. Rather than dealing with a variable gas constant it is customary to assume only the gas constant R for dry air and adjust the temperature for the presence of water molecules in the mixture, thus the equation of state becomes

$$p = \rho R T_v \tag{2}$$

where T_v is the virtual temperature defined by

$$T_v = T(1 + 0.61\chi_v) \tag{3}$$

where χ_v is the specific humidity, i.e., the ratio of the density of water vapor to the total density ρ. In effect, the virtual temperature exceeds the actual temperature to account for the less dense water molecules in the mixture. In the dry stratosphere the difference between T_v and T is negligible, but it can approach 5 K in the lower moist tropical atmosphere. Therefore in our hydrostatic tests we first convert T to T_v by computing χ_v from the dew point or frost point temperatures.

Then, let $z_i(r)$ denote the reported geopotential height at mandatory pressure level i and $z_{i+1}(c)$ denote the computed height at the next higher level (lower pressure), computed from (1), (2) and (3) by assuming a linear variation in virtual temperature between the two levels,

$$z_{i+1}(c) = z_i(r) + \frac{R}{g}\left(\frac{T_{v_i}(r) + T_{v_{i+1}}(r)}{2}\right)\ln\frac{p_i}{p_{i+1}} \tag{4}$$

Equation (4) evaluated from i =1 to 16 represents a column matrix of computed heights from which we subtract the column of reported heights $z_{i+1}(r)$, yielding a column matrix of differences, δ_{i+1}'s. If the reported heights and virtual temperatures are correct, the δ's will differ from zero only where the layer mean temperatures differ from the linear aproximation. No organized pattern of δ's is expected but can occur by chance so a threshold δ_T must be assigned to permit detection of coding, transmission, or other errors. The threshold specified here is

$$|\delta_T| = 4\left(\frac{z_{i+1} - z_i}{\overline{T}_{v_{i,i+1}}}\right)_{STDATM} \tag{5}$$

When the magnitude of two consecutive δ's exceed (5), they are examined for signs. If both signs are positive (negative), $T_{v_{i+1}}$ is too warm (cold) and is rejected from the computation. Conversely, if the signs are reversed, z_{i+1} is rejected. No attempt is made to correct the errors. This objective error rejection method identified and rejected as errors the same values detected by an analyst examining plotted temperature and height profiles.

Occasionally, two consecutive levels contain errors or there is an error in both height and temperature at one level. Under these circumstances the error rejection method described above does not apply, but any point exceeding the criterion is flagged as are the points above and below it. After completing the computations of the means and standard deviations on the first pass, the complete set of flagged data is re-examined. Deviations from the mean height and virtual temperature are then compared to their respective standard deviations, σ. Data are rejected when the deviation exceeds 3 σ in magnitude. After this check is completed, new means and standard deviations are computed and the number of observations included in each mean is recorded.

We found it necessary to check each radiosonde observation for errors in the reported station elevation and location. To do this, a complete survey was made of all reporting stations between 1973 and 1981. Any changes in elevation and/or location were flagged. Also, the survey was scanned to locate changes in block or station number for the same location and elevation. All flagged stations were then compared to a master list obtained from NMC. When discrepancies were found, the heights were converted to surface pressure using a standard atmosphere. These values were compared to the reported surface pressures and the discrepancies were elimated.

To identify and reject errors in the reported wind direction and speed we computed wind shears between successive mandatory levels and compared them to a threshold value. Probable error detection is based on shears exceeding the threshold, while data rejection is based on a sign reversal when two consecutive shears exceed a larger threshold. Shears as large as $5 \times 10^{-2} s^{-1}$ are observed in association with hyperbaroclinic zones, usually folded tropopause zones, in the upper troposphere. However, when large shears of this type occur, they are imbedded in a larger scale baroclinic field of the same sign. A shear reversal in the adjacent layers is not expected, certainly not a reversal of similar magnitude. Conversely, a miscoded wind direction or wind speed at one mandatory level is expected to produce a shear reversal in the layers above and below the error. Our initial test threshold is set at $1.5 \times 10^{-2} s^{-1}$ for the u and v components separately. When one or more shears exceed this threshold, the winds contributing to the shears are flagged. If two successive shears exceed twice the threshold and have opposite signs, the wind common to the two shears is rejected, i.e., both u and v components are rejected. As with the thermodynamic data, the winds which have been flagged on the first pass as possible errors, but not rejected, are compared to the first pass means and rejected if the deviation exceeds 3 σ.

At the time of computing monthly means we intended to screen for errors but not to filter individual observations with respect to height.

The criteria were intentionally set to screen out major errors and we relied on temporal filtering to reduce the effects of minor errors. Based on our experience gained by analyzing the monthly mean winds, we now prefer to apply a smaller shear threshold, rejecting two successive shears of opposite sign whose magnitudes exceed $10^{-2}s^{-1}$. We expect no significant change in the mean zonal winds, especially after zonal averaging. On the other hand, we do anticipate improved accuracy in the mean meridional winds. Since $\overline{v}$ is very small, the standard deviation σ_v is large. Thus, it takes a rather large error to exceed three standard deviations. Also, because $\overline{v}$ is small an error in v makes a larger percentage error in $\overline{v}$ than a comparable error in u makes in $\overline{u}$.

III. Zonal averaging of monthly means

If radiosonde stations were uniformly distributed over the earth, zonal averaging would require no special consideration nor would the subsequent analyses. In fact, the stations and their measurements are relatively densely packed on most northern hemisphere continents and widely separated over the major oceans. Consequently, care must be taken to determine representative zonal-monthly means. Since zonal averaging eliminates longitudinal waves, when the sampling is uniform and representative, we expect smoothly varying distributions with respect to latitude and pressure. Also, we expect the latitudinal height gradients to be in quasi-geostrophic balance with the observed $\overline{u}$ and the virtual temperature gradients to be in quasi-geostrophic balance with $\partial\overline{u}/\partial z$. In addition, the pressure, virtual temperature and height fields should be in hydrostatic balance. In view of the fact that we will use these wind relationships in subsequent analyses to compensate for nonuniformly distributed data, we concentrate first on producing smoothly varying $\overline{u}$ distributions.

We use overlapping latitudinal strips to assure smoothly varying $\overline{u}$ versus latitude but do not assign the means to the central latitude of each strip. Tests conducted with a central location showed that significant phase errors are generated in the southern hemisphere where the radiosonde density is sparse between midlatitude land masses and Antarctica. Instead, we compute the mean latitude of the stations which contribute to each mean quantity. This method eliminates phase errors but has the disadvantage of yielding nonuniformly spaced mean data. To convert to a uniform grid spacing at each pressure level, the data are fitted by cubic splines from pole to pole with the constraint that first derivative equals zero at both poles. Since the poles are singular points, $\overline{u}$ is set to zero at both poles.

A total of 33 strips are used. Of these 31 are 11.25° latitude in width, which overlap the adjacent strip by 5.625°. The remaining 2 represent polar caps extending 5.625° from the pole. Zonal means are computed for each strip, but at high latitudes in the southern hemisphere the mean latitude of two adjacent-overlapping strips is often the same because they contain the same stations. Therefore, they contribute only one point to the cubic splines. A set of uniformly spaced values is then interpolated from the cubic splines. Several of these $\overline{u}$ distributions were expanded in series of Legendre polynomials and the series were truncated at successively smaller latitudinal wave numbers to determine whether latitudinal filtering was necessary. None was deemed necessary, but at high latitudes in the southern hemisphere vertical filtering was found to be essential. A vertical Fourier filter was designed to remove oscillations with wavelengths shorter than 6 km at 500 mb, increasing to 9 km at 50 mb. The filter is applied only to southern hemispheric profiles south of latitude 50° S. Also, a cosine transition function assures a smooth trend from unfiltered data north of 50° S to the filtered data south of 60° S.

Unlike $\overline{u}$ which is zero at the poles, $\overline{z}$ and $\overline{T}_v$ must be available for spline fitting. If pole values are missing, we use Stokes' circulation integral to provide a reliable estimate

$$\oint \oint \varsigma \, dA = \oint u dx \qquad (6)$$

where ς is the vertical component of the relative vorticity, dA is the differential polar area and dx is positive eastward. The differential area $dA = R_e^2 \sin\theta d\theta d\lambda$ and the zonal differential distance $dx = R_e \sin\theta d\lambda$ are functions of the earth's radius R_e, colatitude θ and longitudinal angle λ. When integrated over the polar cap to colatitude θ

$$\bar{\zeta} = \frac{\bar{u}_\theta}{R_e}\left(\frac{\sin\theta}{1 - |\cos\theta|}\right) \tag{7}$$

We approximate $\bar{\zeta}$ by the geostrophic vorticity,

$$\bar{\zeta} \simeq \frac{\nabla^2 g\bar{z}}{\bar{f}} \tag{8}$$

and replace the Laplacian by its finite difference approximation, which yields

$$\bar{z}_{pole} = \bar{z}_\theta - \frac{\bar{f}R_e}{4g}\left(\frac{\sin\theta}{1 - |\cos\theta|}\right)\theta^2\bar{u}_\theta \tag{9}$$

In (8) and (9) the Coriolis parameter $f = 2\omega\cos\theta$ includes the angular rotation speed of the earth, ω. When θ is a small angle (relative to the north pole) or $\pi - \theta$ is a small angle (relative to the south pole), $|f| \sim 2\omega$ and then (9) is equivalent to extrapolating $\bar{z}$ poleward with a parabola whose slope geostrophically balances $\bar{u}$ at θ and is zero at the pole. Similarly, when $\overline{T}_v$ is missing at either pole

$$\overline{T}_{v_{pole}} = \overline{T}_{v_\theta} - \frac{\bar{f}R_e}{4g}\left(\frac{\sin\theta}{1 - |\cos\theta|}\right)\theta^2\left(\frac{\Delta\bar{u}}{\Delta z^*}\right)_\theta \tag{10}$$

where

$$\Delta z^* = -\frac{R}{g}\Delta \ln p \tag{11}$$

The wind shear is evaluated by finite differencing cubic splines which are fitted vertically at the mandatory levels. Δz^* is assigned a value of 4 mK^{-1}

which translates to 1 km when $\overline{T}_v = 250K$, since $\Delta z = \overline{T}_v \Delta z^*$. Boundary conditions for the splines are zero second derivatives at p = 10 and 1000 mb.

IV. Least squares analysis of zonal-monthly means

Having determined a smoothly varying $\overline{u}$ field, we use them to influence both the height and virtual temperature analyses by minimizing the following integral

$$I = \int_0^A \left[w_z \left(\overline{z}^o - \overline{z}^A \right)^2 + w_u \left(\frac{R_e f \overline{u}^o}{g} - \frac{\partial \overline{z}^A}{\partial \theta} \right)^2 \right] dA \qquad (12)$$

where the superscripts o and A denote observed and analyzed, respectively. This is a variation of the method proposed by Sasaki, (1958). In particular, the Coriolis term in our equation appears in the numerator of the second term rather than the denominator. The first term forces the analyzed heights toward the observed, the second forces their slopes toward a geostrophic balance with the observed winds. We desire neither extreme, wanting instead to use the winds as a vectoral guide to suppress nonrepresentative oscillations in the observed heights as we do in hand analyses. In turn, the desired conditions depend on the relative weights to be assigned, i.e., to w_z and w_u. These weights, inversely proportional to the standard deviations in $\overline{z}$

and $\overline{u}$, were assigned initial values based on error estimates and then the resulting height profiles were compared to hand analyses. Final weight assignments were made by these comparisons at selected pressure levels.

Before minimizing (12) we express the analyzed heights in terms of a finite series of Legendre polynomials

$$\overline{z}^A = \sum_{n=0}^{N} a_n P_n(\mu) \tag{13}$$

where $\mu = \cos\theta$. The derivative

$$\frac{\partial \overline{z}^A}{\partial \theta} = -\sum_{n=0}^{N} a_n \frac{\partial P_n}{\partial \mu}(1-\mu^2)^{1/2} \tag{14}$$

the differential area

$$dA = 2\pi R_e^2 \sin\theta d\theta = -2\pi R_e^2 d\mu \tag{15}$$

and the integral limits convert (12) to

$$I = 2\pi R_e^2 \int_{-1}^{1} \left[w_z \left(\overline{z}^o - \sum_{n=0}^{N} a_n P_n \right)^2 + w_u \left(\frac{R_e f \overline{u}^o}{g} + \sum_{n=0}^{N} a_n \frac{\partial P_n}{\partial \mu}(1-\mu^2)^{1/2} \right)^2 \right] d\mu \tag{16}$$

Setting $\partial I / \partial a_k = 0$ for $k = 0 \; to \; N$ generates a set of $N+1$ dependent equations which can be solved for the a_n's by matrix inversion.

However, if the weights are independent of latitude, we can take advantage of the orthogonality of the Legendre polynomials and solve directly for the coefficients,

$$a_n \simeq \frac{\sum_{j=1}\left(w_z P_n \overline{z}^o - w_u \frac{R_e f \overline{u}^o}{g} \frac{\partial P_n}{\partial \mu}\left(1-\mu^2\right)^{1/2}\right)_j}{\frac{2}{2n+1}\left(w_z + w_u n(n+1)\right)} \tag{17}$$

The approximation is necessary because (17) involves a summation rather than an integral. Sufficient accuracy is obtained when the j's correspond to the Gauss points with their appropriate Gaussian Quadrature weights. A total of 64 points is used in these computations. Also, since w_z and w_u are independent of latitude, only their ratio is important. When $w_z \gg w_u$, the solution is qualitatively similar to that obtained when $w_u \gg w_z$, but the amplitude of the former exceeds that of the latter. This result implies that the observed winds are systematically subgeostrophic, i.e., although $\overline{u}_g - \overline{u}^o$ is small, the ageostrophic contributions accumulate in the latitudinal summation to produce a significant difference in the amplitude of the height profiles. Part of the difference can be accounted for by the centripetal acceleration $\frac{\overline{u}^2}{R_e}\frac{\cos\theta}{\sin\theta}$, a spherical coordinate term which is usually neglected in the meridional equation of motion. When $\overline{u} > 0$, a larger than geostrophic height gradient is required to turn the air parallel to the curved earth. However, numerical evaluations indicate that this centripetal term is not of sufficient magnitude to account for the ageostrophic components. Similarly, $\frac{\partial \overline{v}}{\partial t}$ is too small; therefore, only the nonlinear terms $\frac{\partial}{\partial y}\left(\overline{v'v'}\right)$ and $\frac{\partial}{\partial p}\left(\overline{v'w'}\right)$, which arise from zonal-temporal averaging, are viable candidates.

We could force these terms to zero by increasing the ratio of w_u to w_z, but this generates a hydrostatic imbalance between the independently derived $\overline{z}$ and $\overline{T}_v$ distributions. The latter are determined at each mandatory level, separately, as are the heights by minimizing the integrated square of the deviations. Thus (12) to (17) apply to $\overline{T}_v$ by replacing $\overline{z}$ with $\overline{T}_v$ and $\overline{u}^o$ with $\frac{\Delta \overline{u}^o}{\Delta z^*}$. Since $\overline{z}$ and $\overline{T}_v$ are derived independently, with wind and wind shear contributing to the least-squares solution, there is no assurance that the analyzed fields are in hydrostatic balance.

It might be argued that $\overline{z}$ and $\overline{T}_v$ at all levels be solved for simultaneously by minimizing a double integral of area and pressure, with hydrostatic balance imposed as a vertical constraint. This problem and its solution are made difficult because the weights w_z and w_u must vary with height. We preferred the simplicity of independent solutions, using hydrostatic balance as a criterion for selecting the best solution.

After obtaining the cross-section plots for the entire dataset, it was seen that some of the solutions in the upper levels (above 70 mb) near the south pole were quite noisy. The difficulty was most apparent in the southern hemisphere winter especially the months of July and August, when, as mentioned before, the extreme cold temperatures and high zonal wind speeds are at the limit of the radiosonde system's measuring capability. The problem was traced to the original zonal mean calculations where the cubic spline interpolation made some spurious excursions when given sparse and/or badly distributed data. A change was made to the processing program whereby vertical extrapolation was performed using a linear least-squares fit if the data was missing at 70 mb and above in the latitude strips south of 50° S. Nineteen months out of the total of 96 were reprocessed with this technique, and the resulting solutions were considerably improved.

The cross-sections at this stage looked quite good individually, but the month to month variability, particularly in the south polar region, was thought to be more a reflection of the relatively poor data sampling in that region, rather than a measure of the actual atmospheric variability. For this reason we decided to apply a temporal filter to the final fields. A Fourier decompostion was performed and by looking at the percentage of variance explained by each wavenumber, three test truncations were chosen: wavenumbers 32, 24 and 16, corresponding to periods of 3, 4, and 6 months, respectively. (The truncations were made such that all periods including the truncation period and longer were retained). The wavenumber 16 solution was quite smooth, but the data in the tropics and northern hemisphere were strongly modified as well, indicating that signal was being lost. Truncation at wavenumber 32 had the desired effect of making little change in the data dense regions, but seemed to provide inadequate smoothing where needed. It was decided that setting the cuttoff at wavenumber 24 provided the best balance of smoothing the noise with minimal effect on the signal. That is the solution presented in this report.

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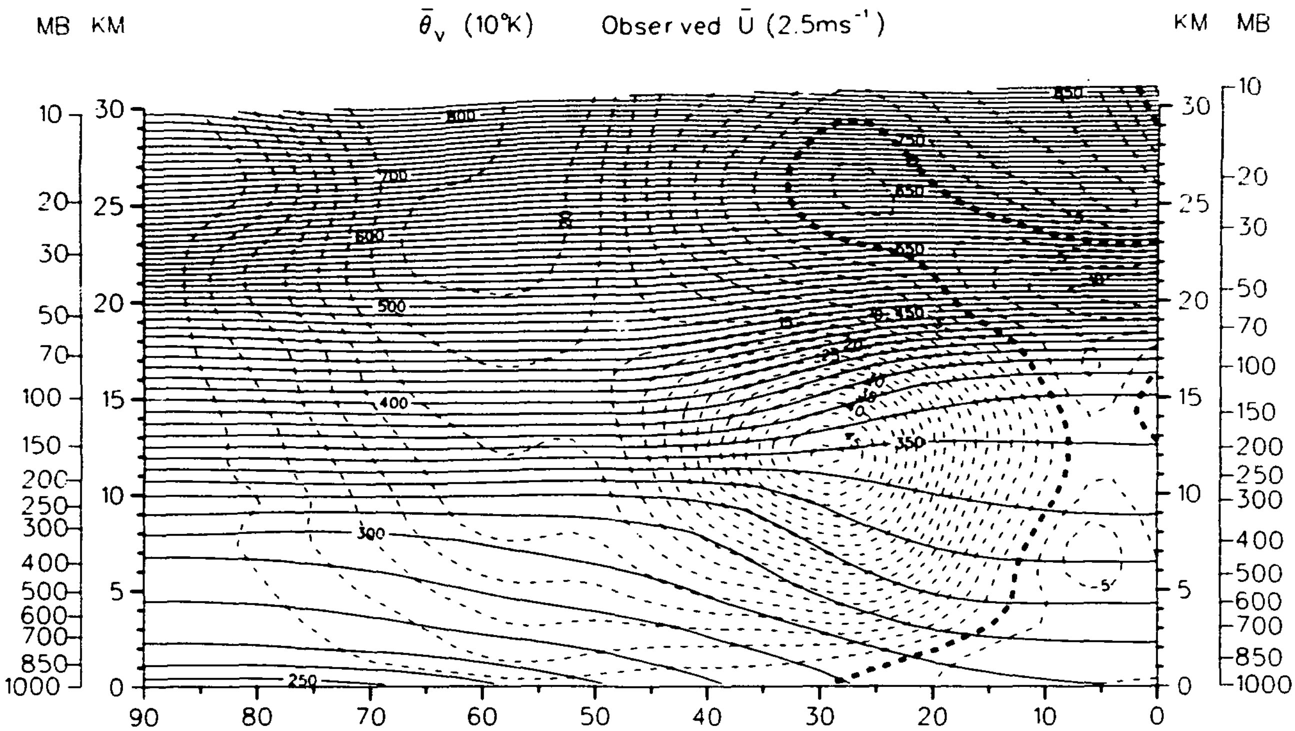
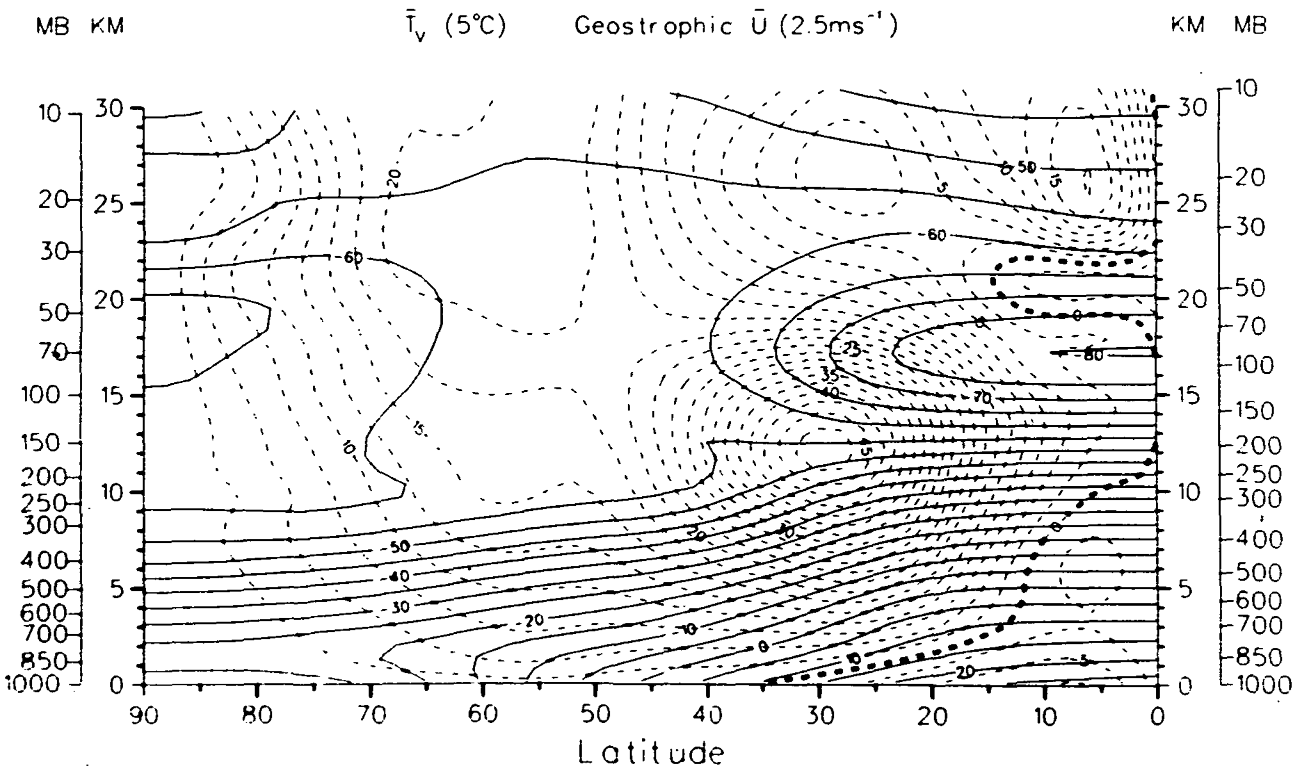
MONTHLY CROSS SECTIONS

NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JANUARY 1973





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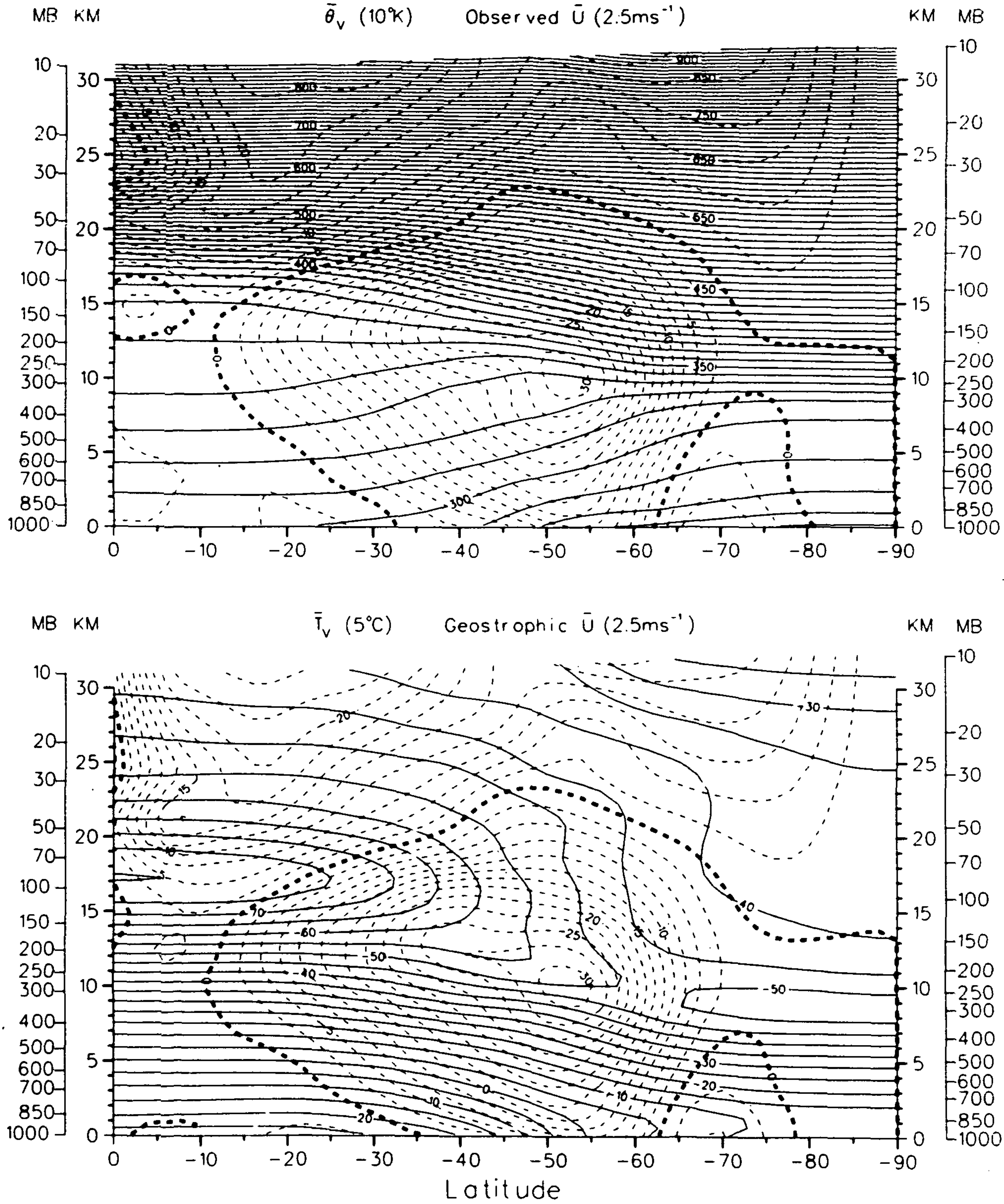
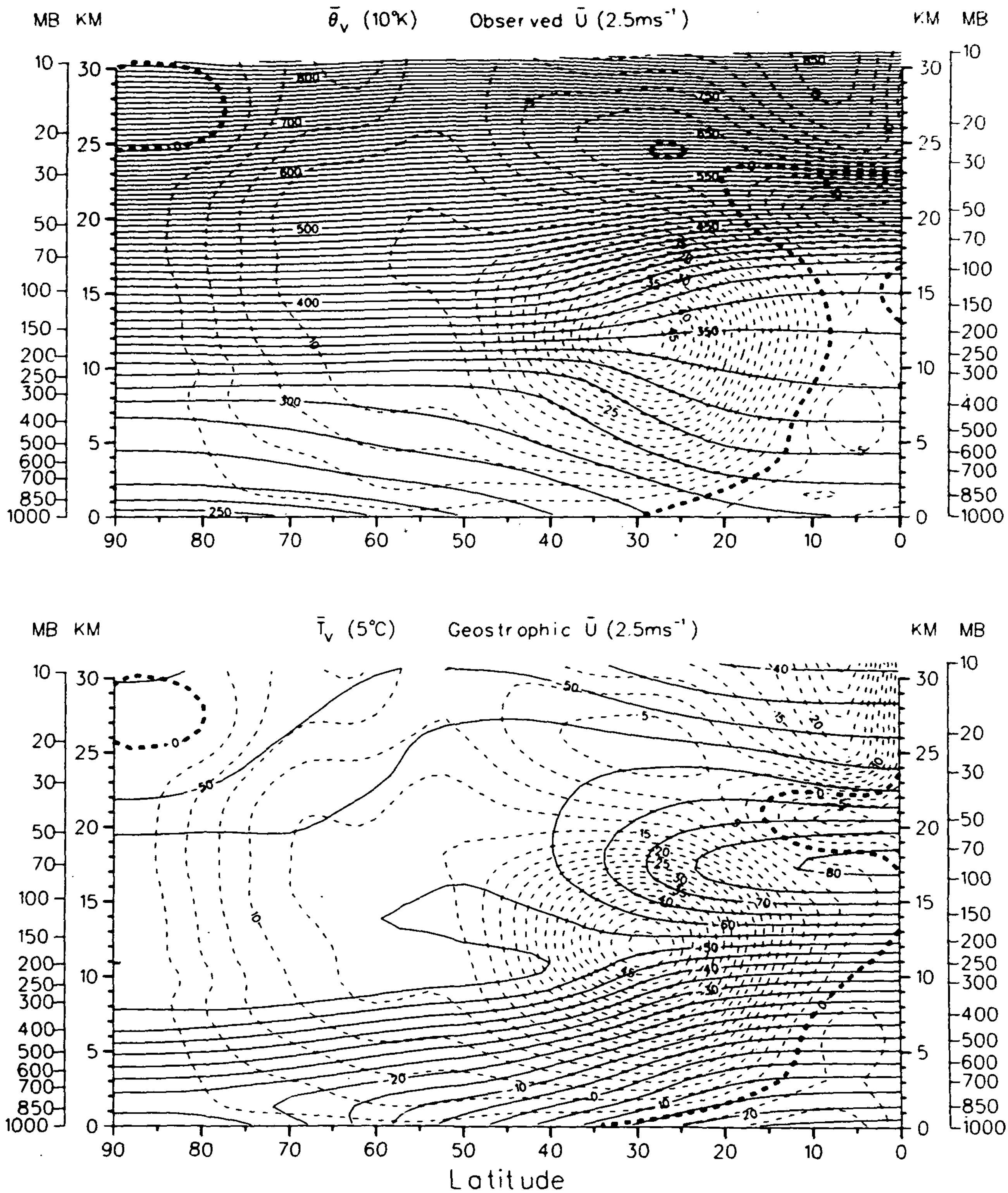
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JANUARY 1973



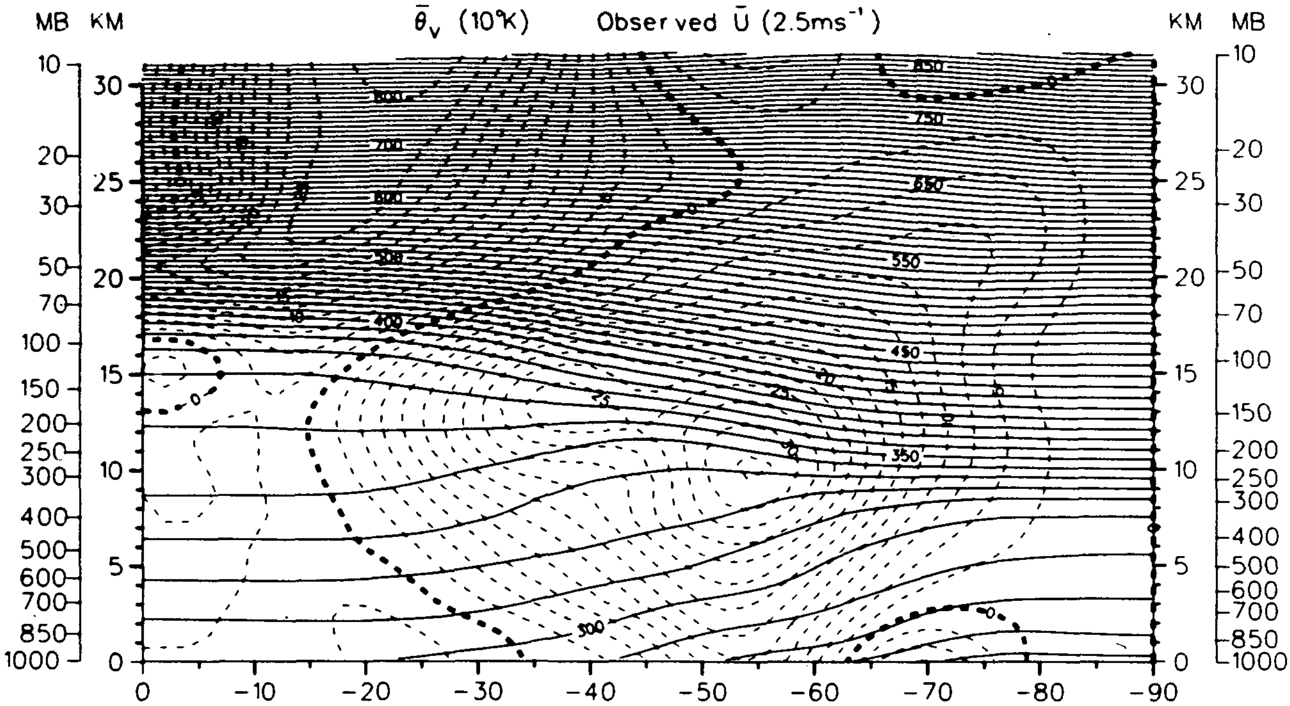
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

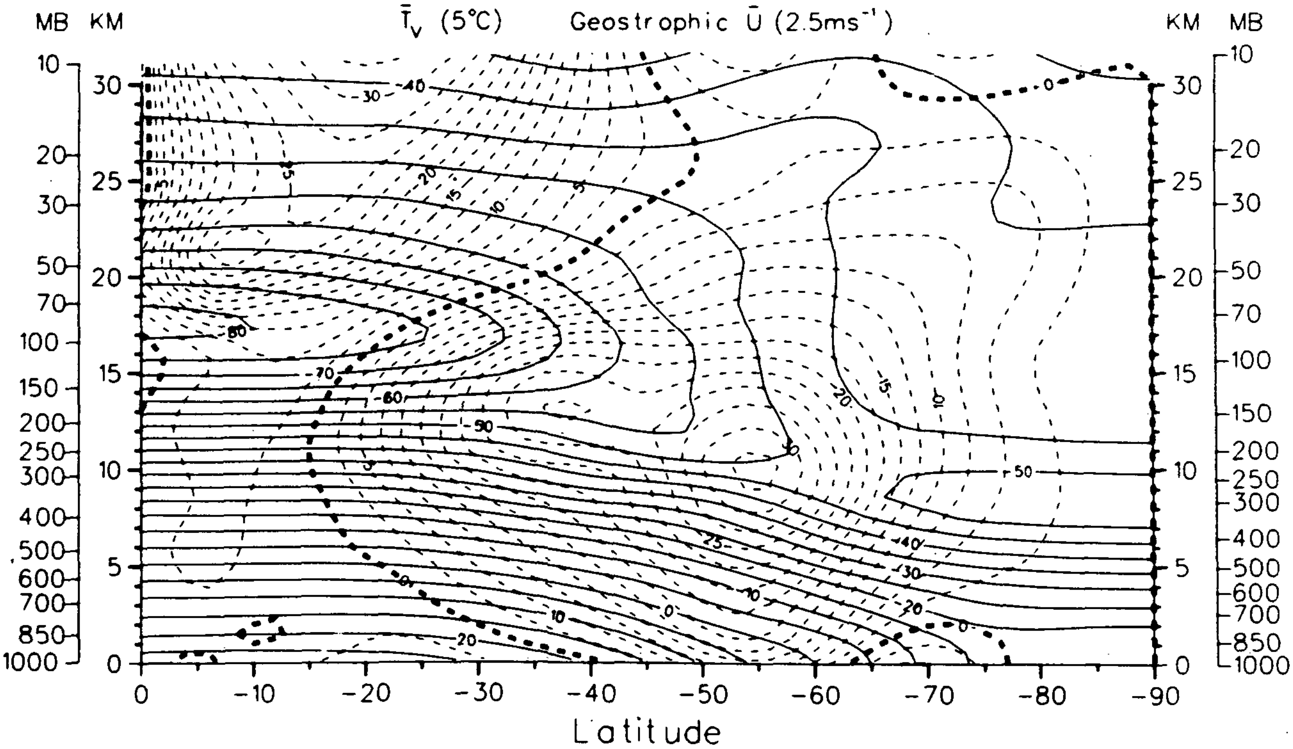
FEBRUARY 1973



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

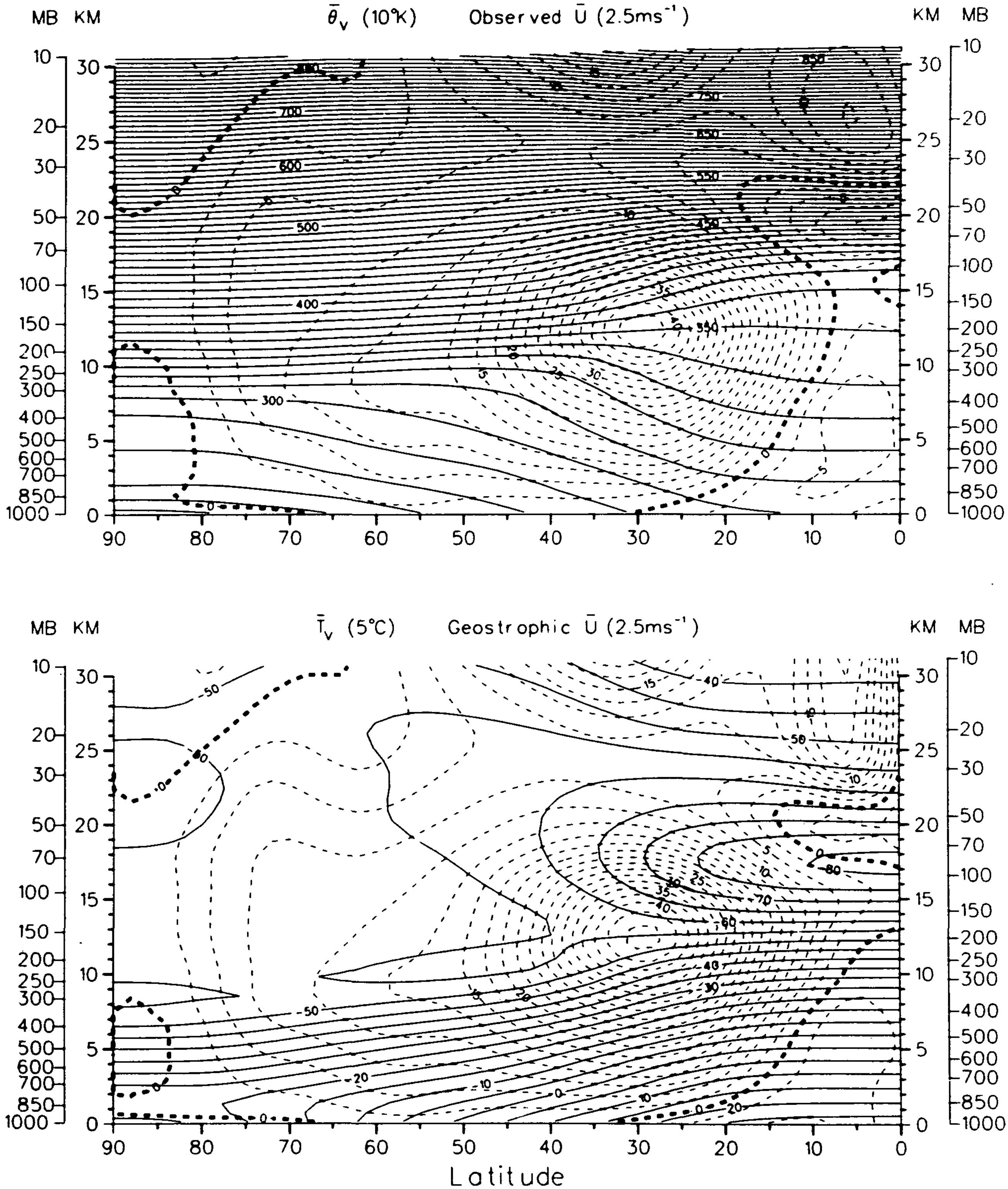
FEBRUARY 1973





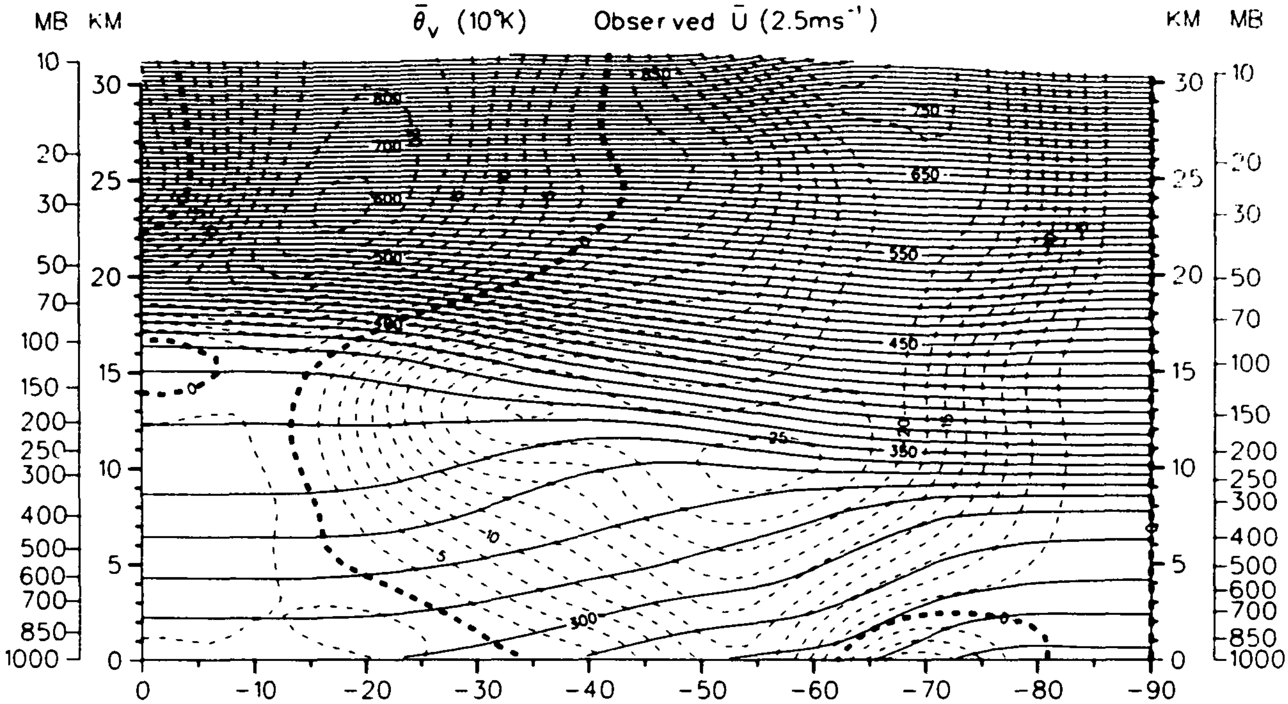
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

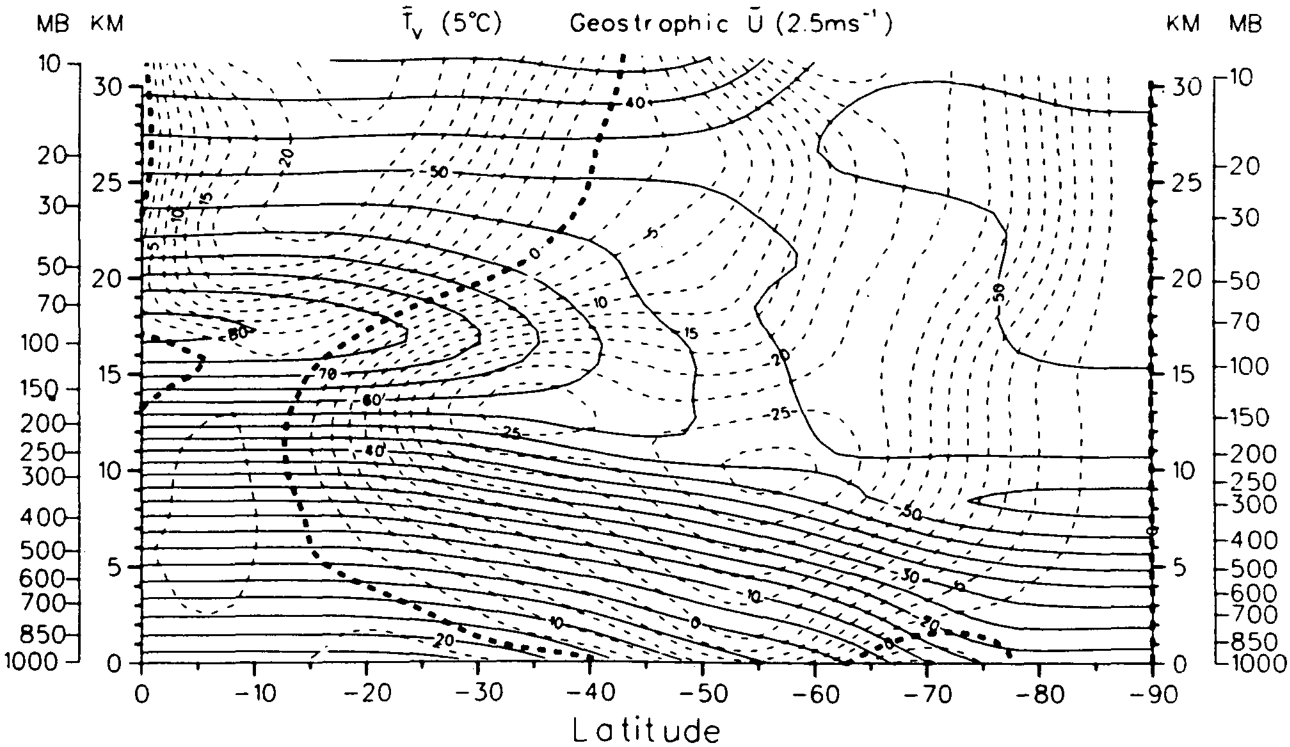
MARCH 1973



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

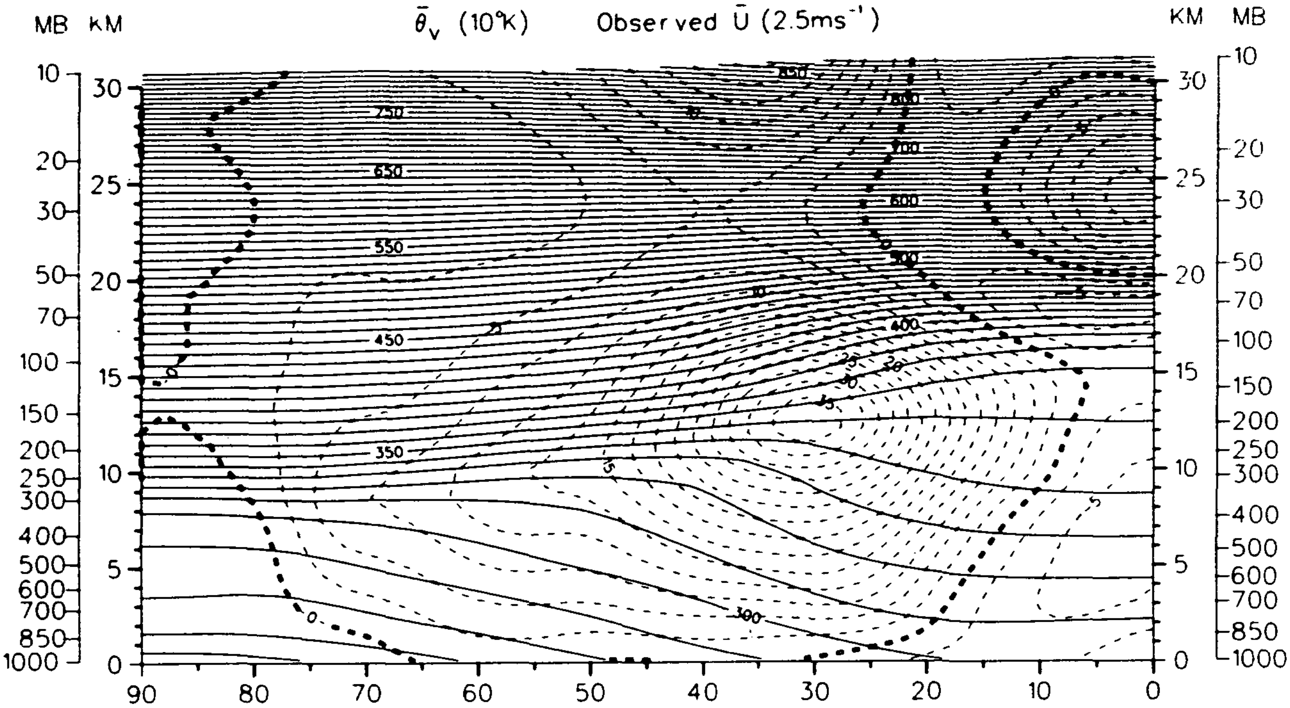
MARCH 1973

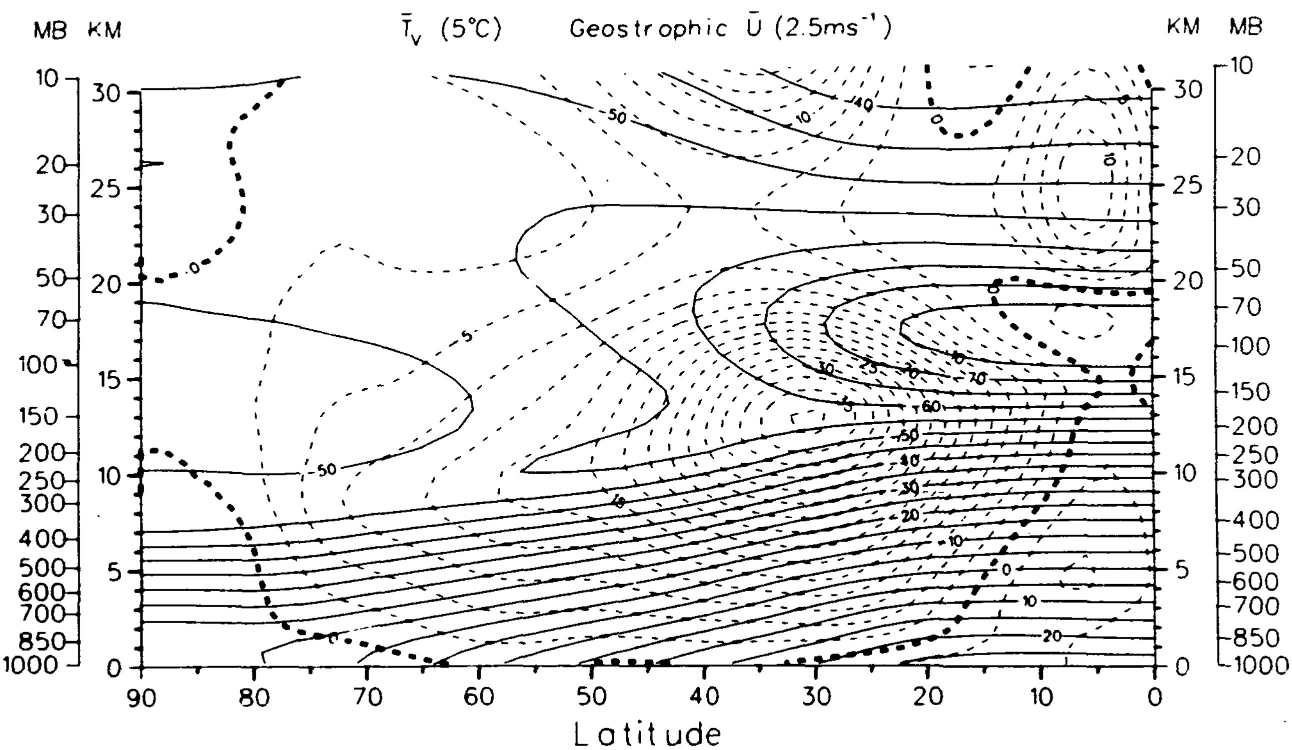




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

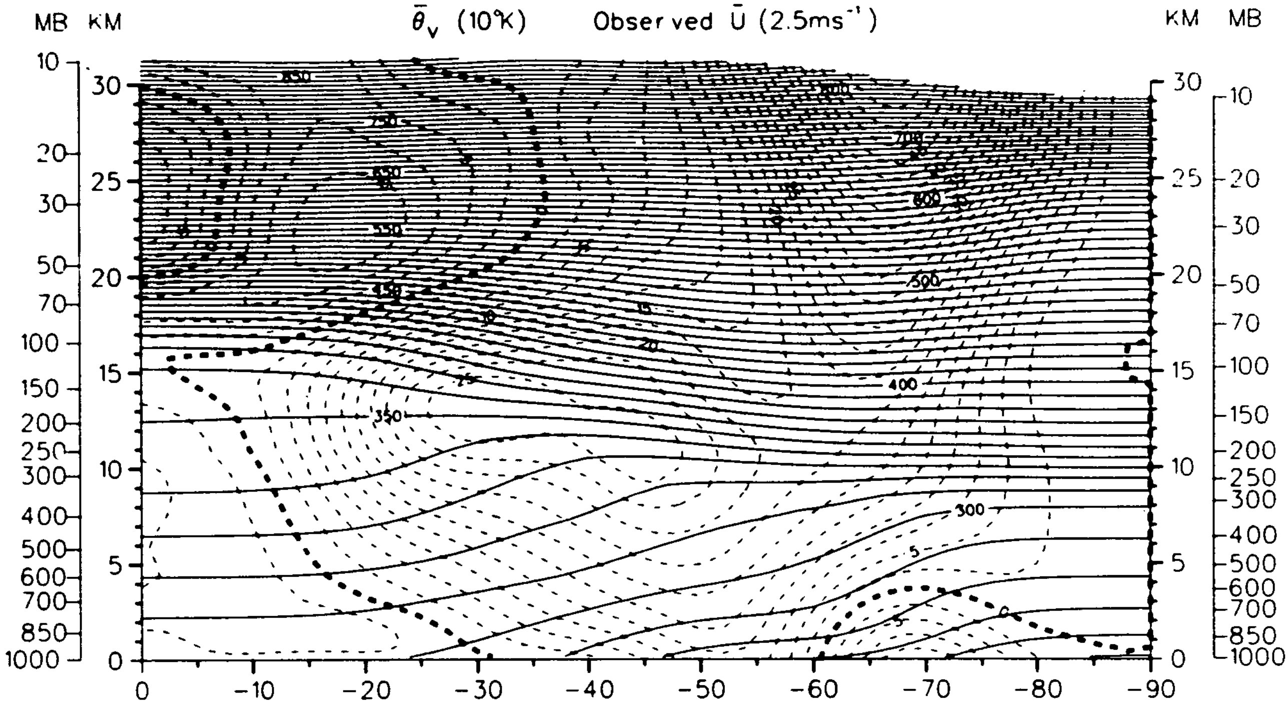
APRIL 1973

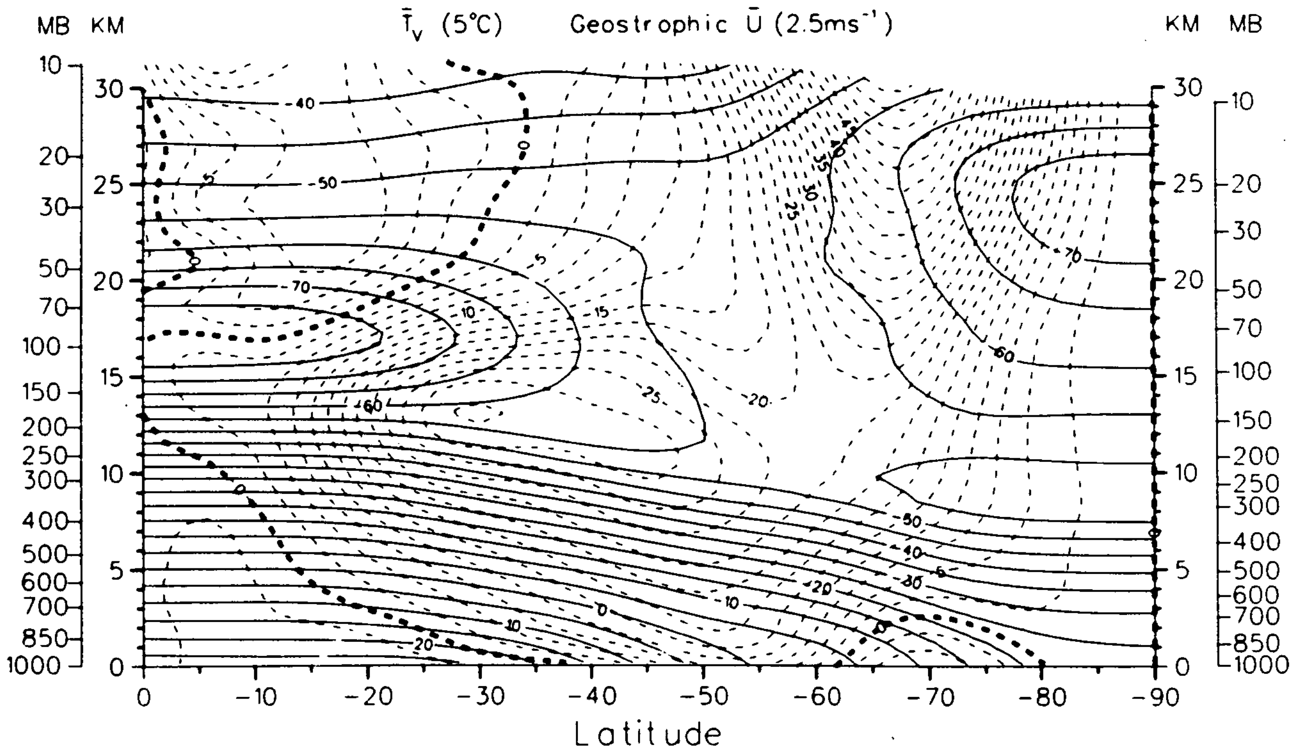




SOUTHERN HEMISPHERIC ZONAL–MONTHLY MEANS

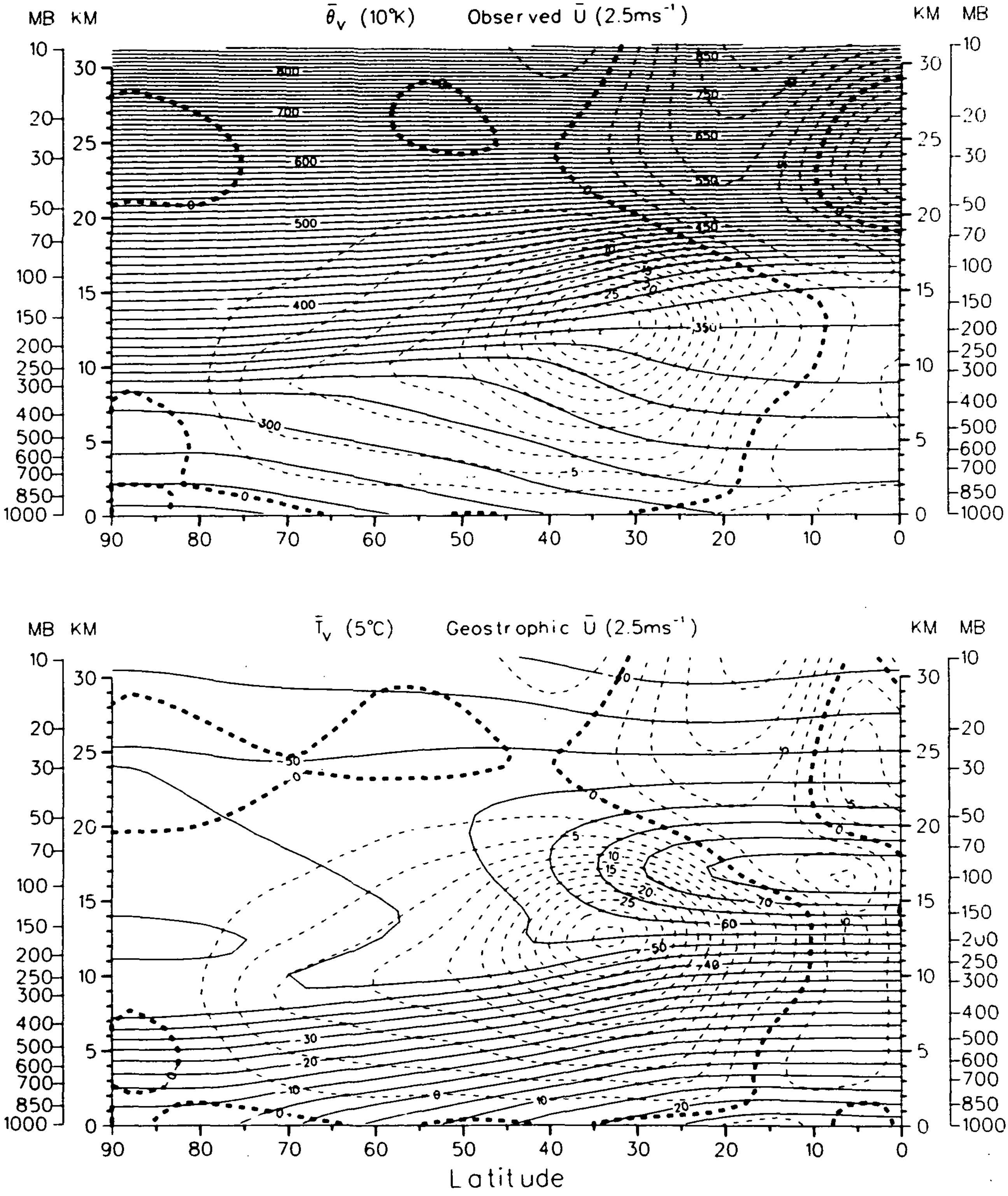
APRIL 1973





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

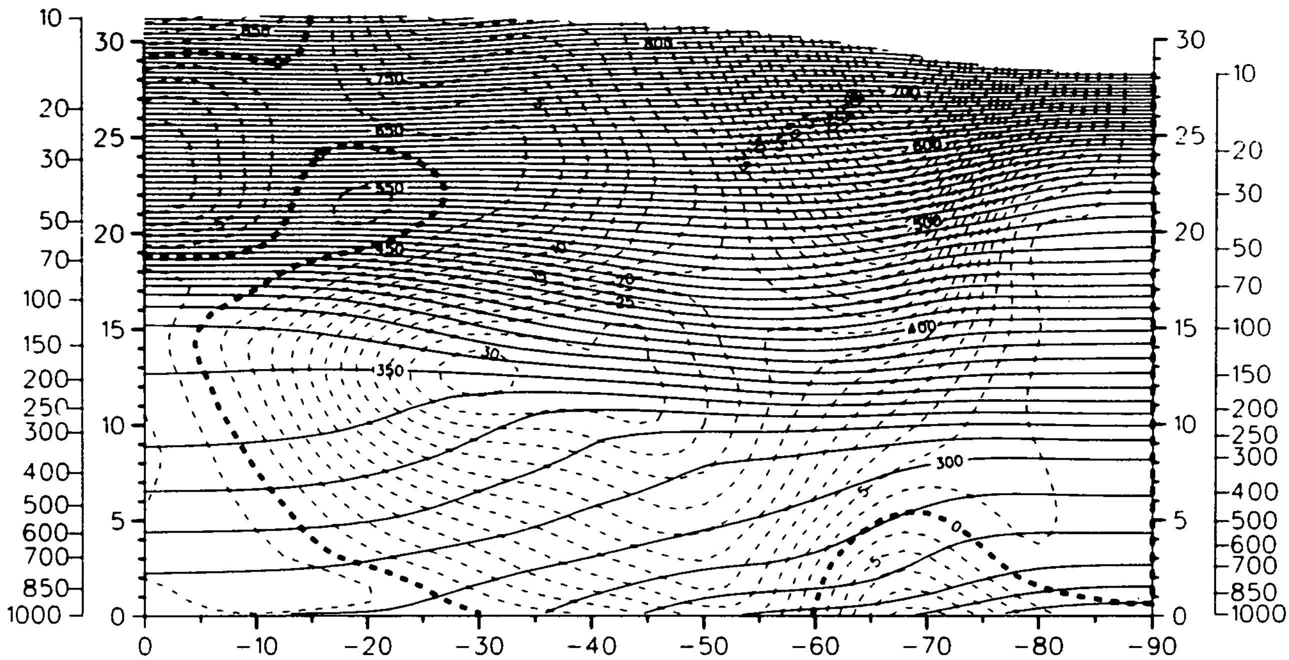
MAY 1973



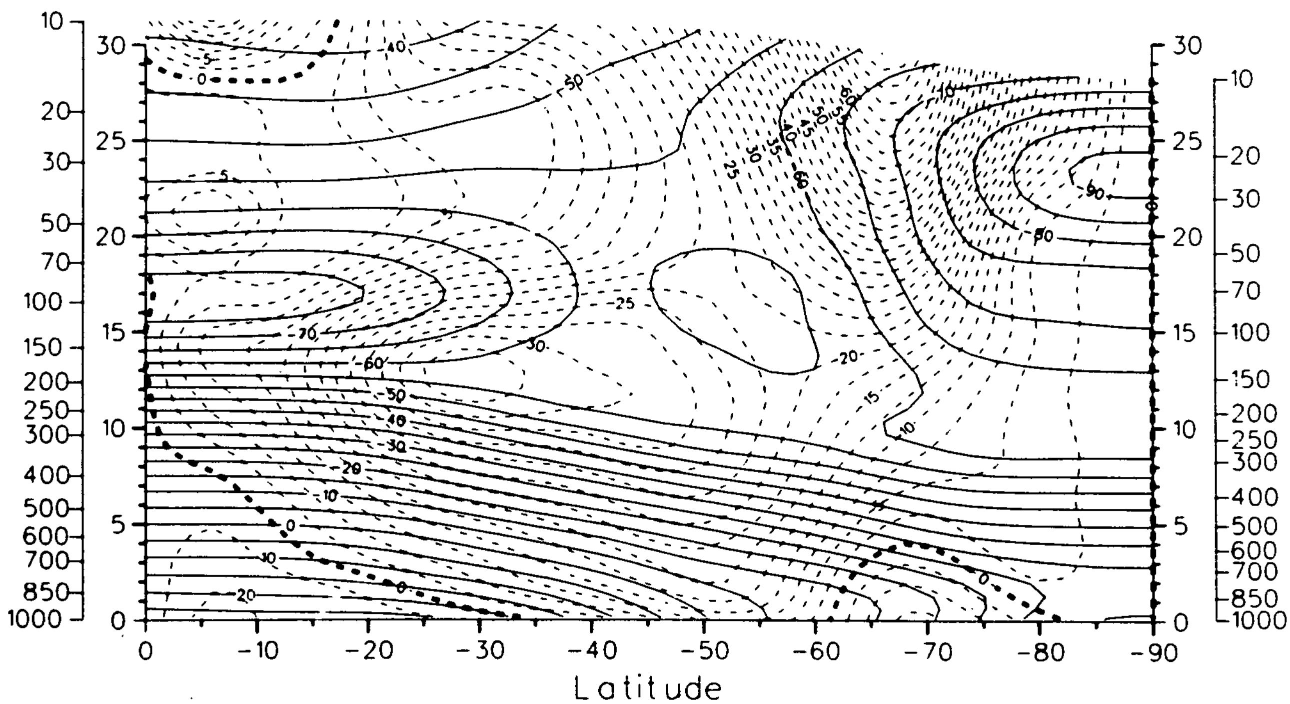
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

MAY 1973

$\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1})

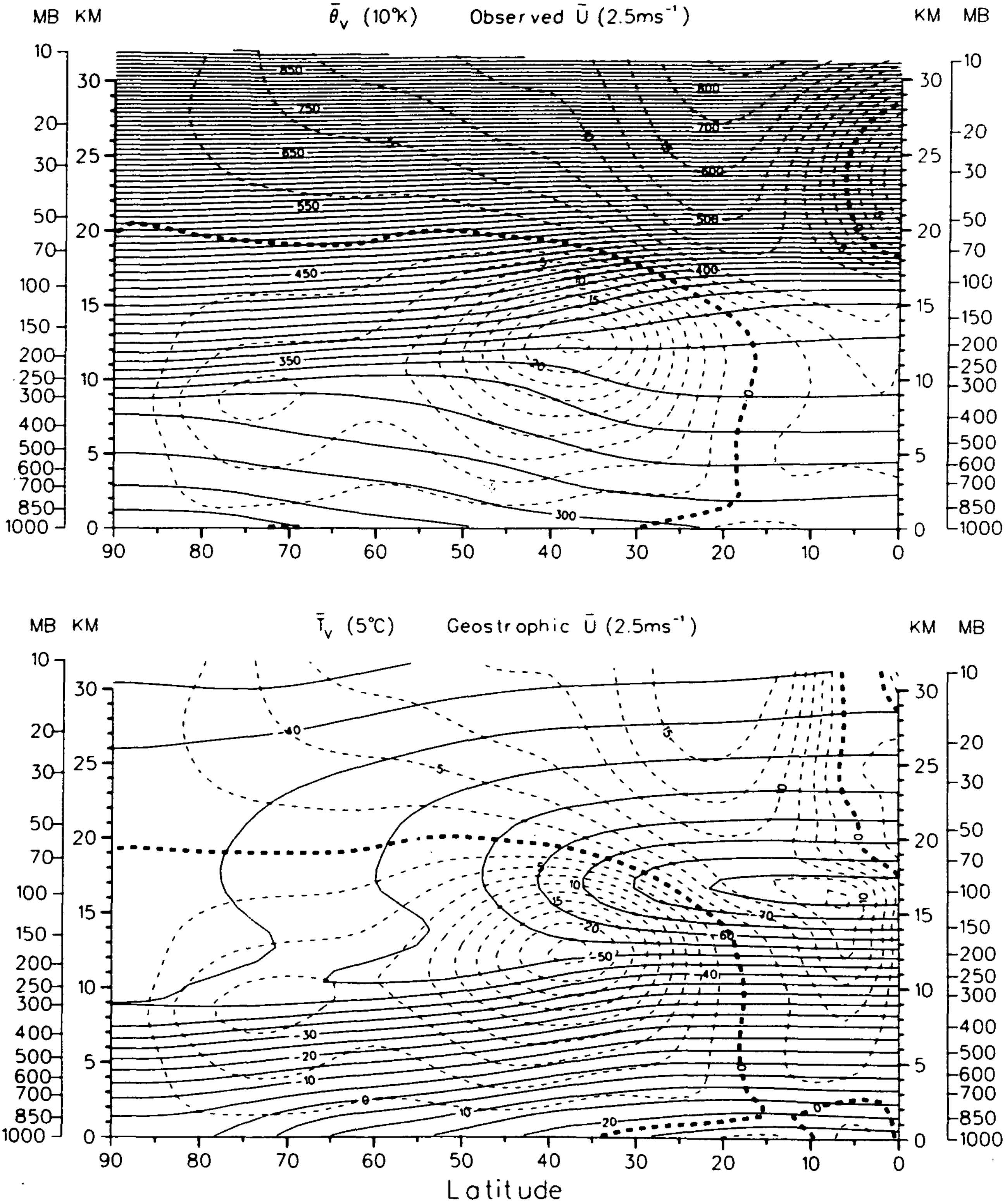


$\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1})



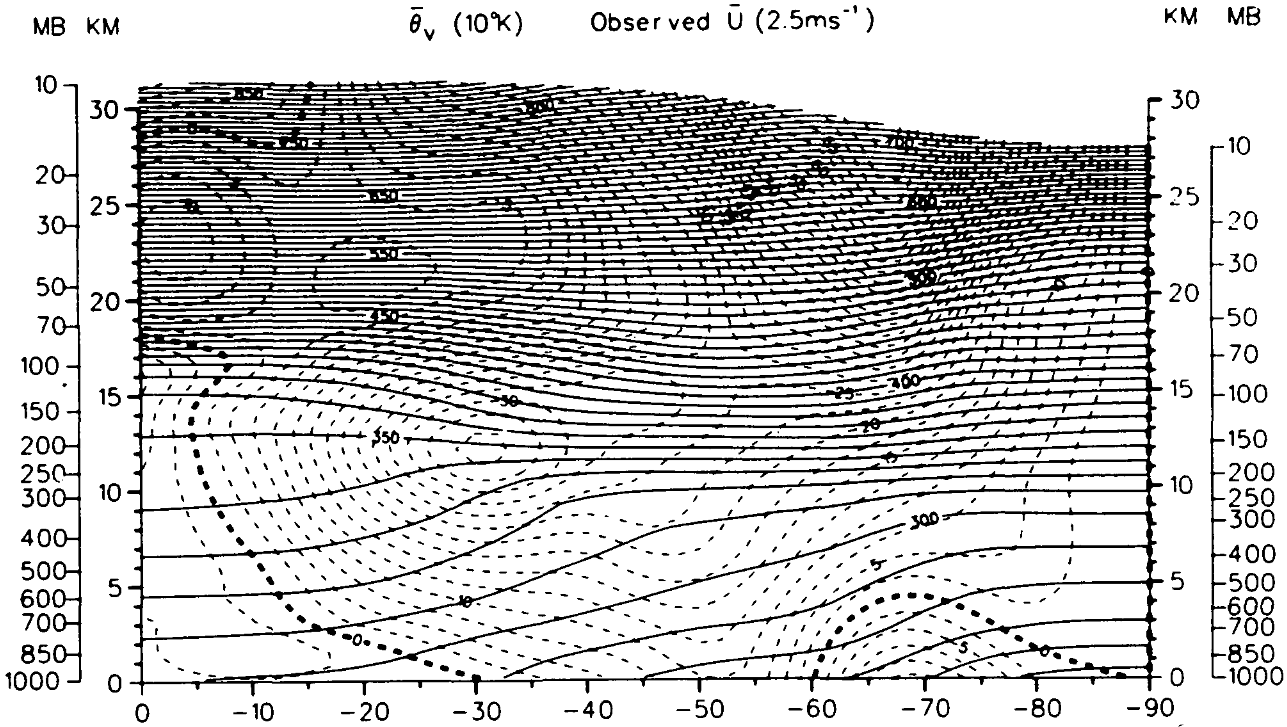
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

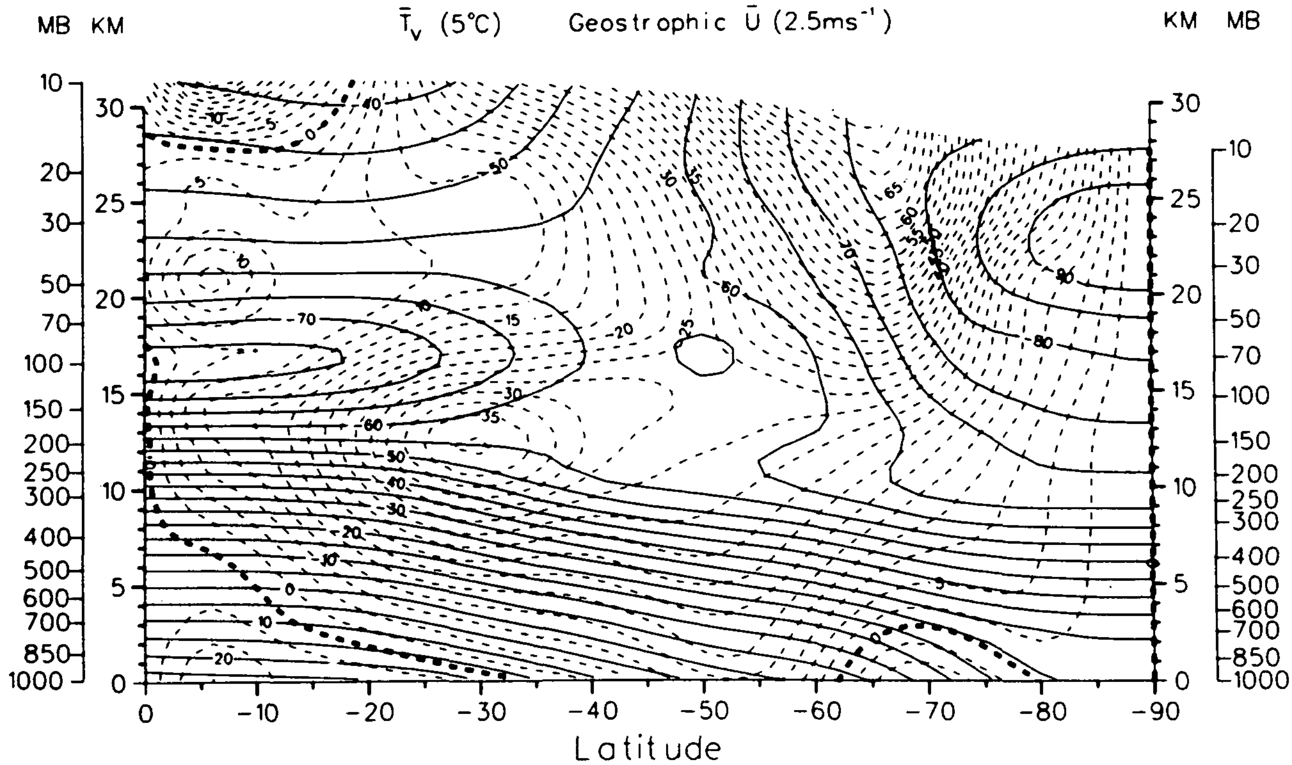
JUNE 1973



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

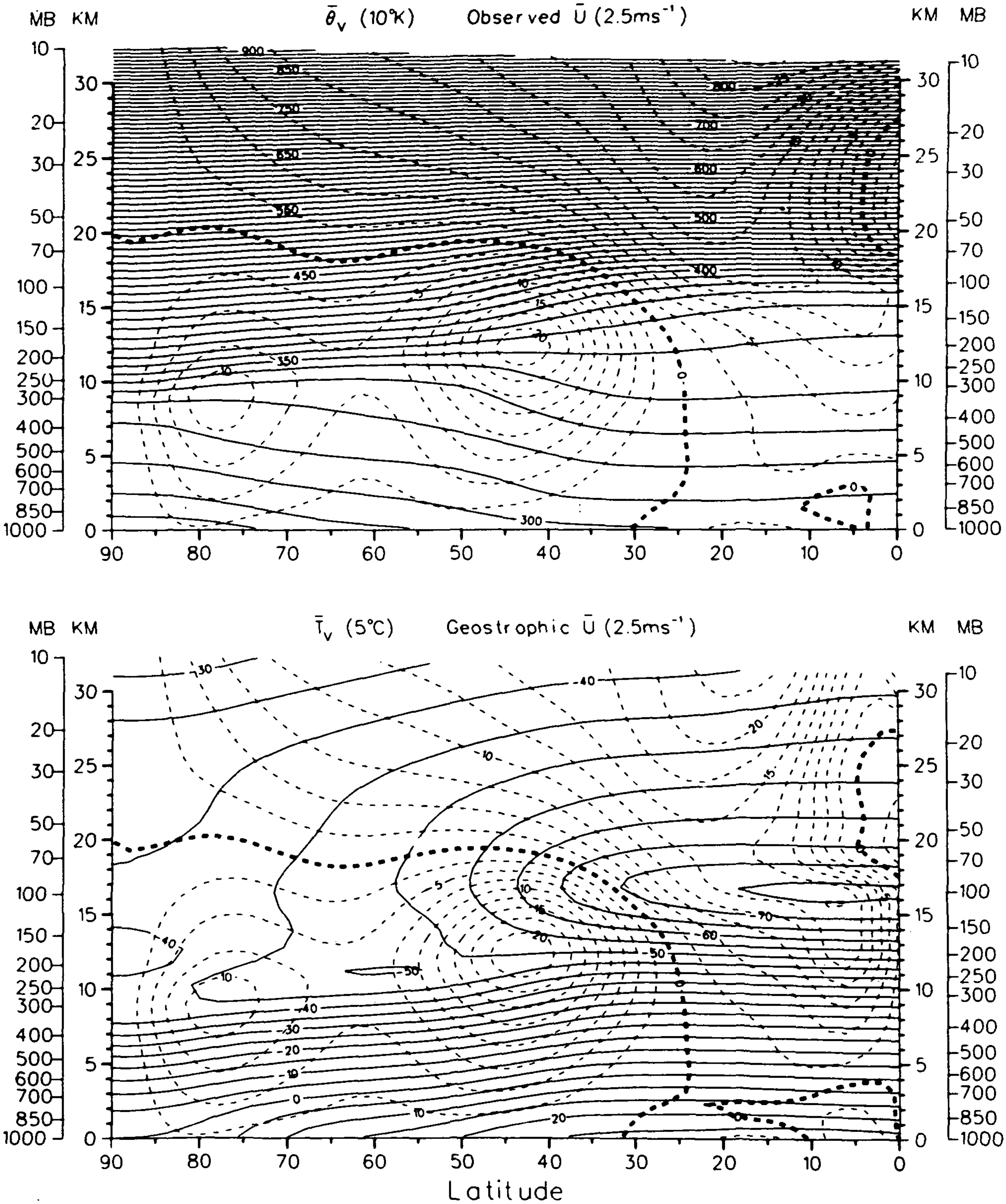
JUNE 1973





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JULY 1973



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

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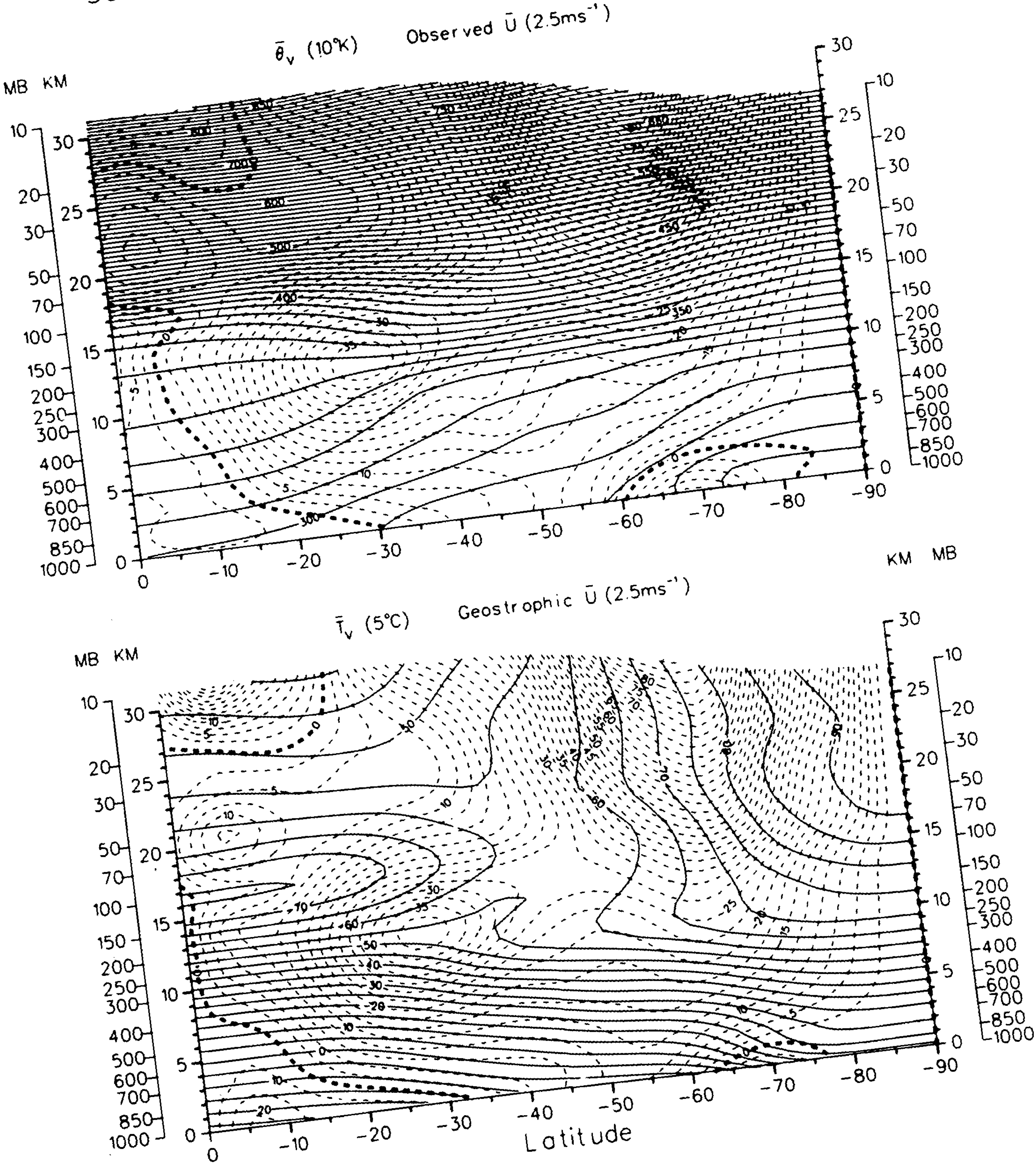
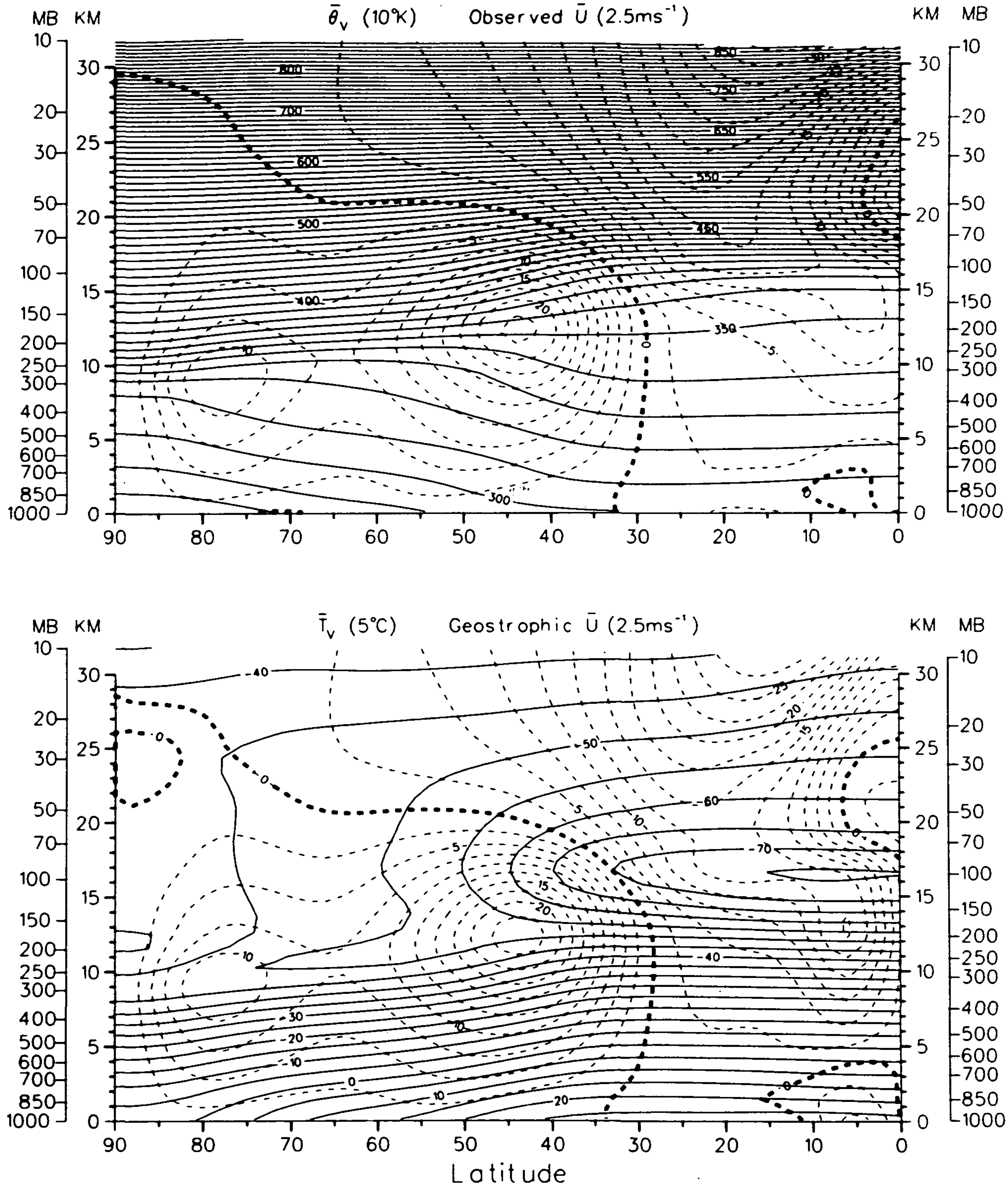
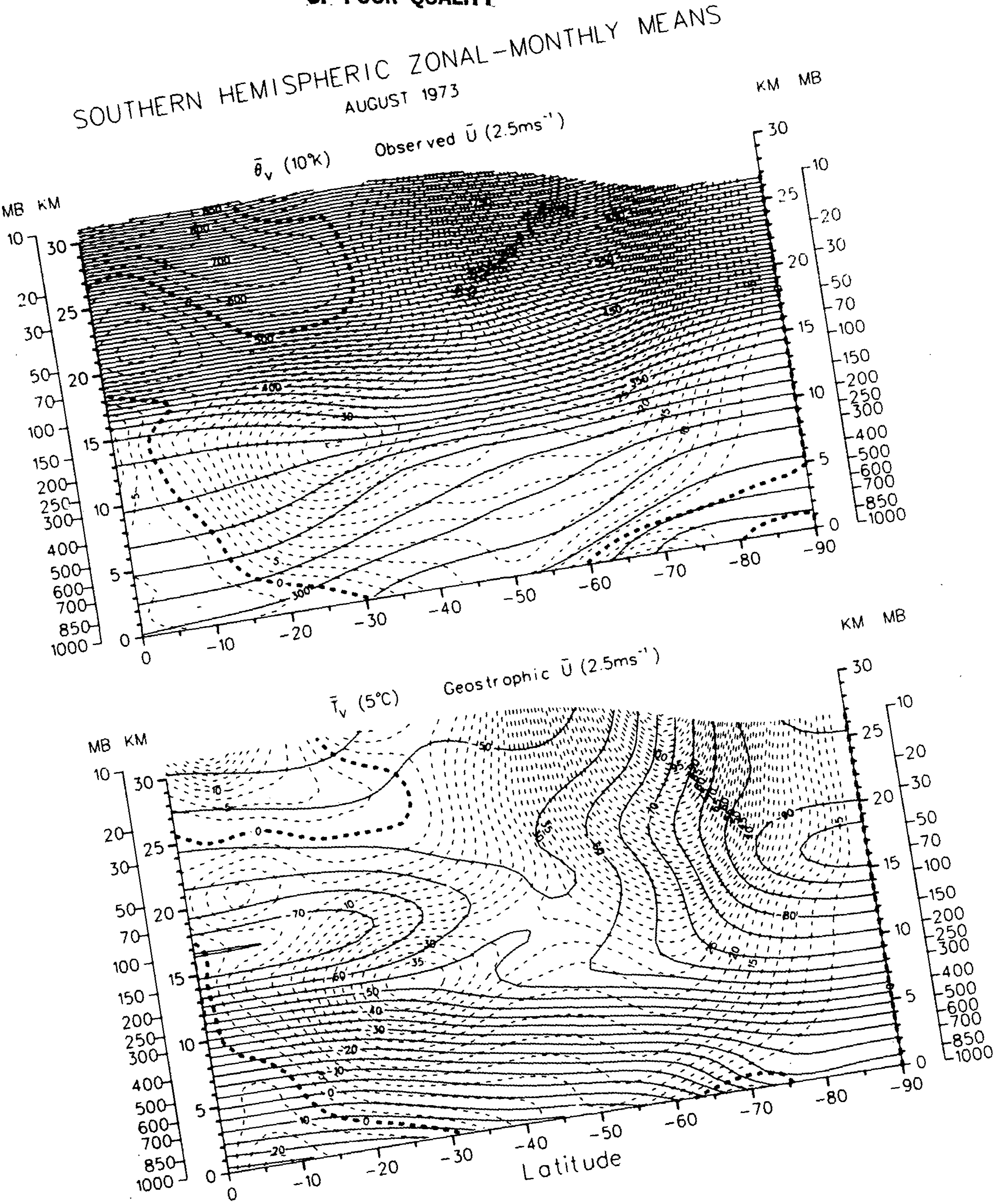


NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

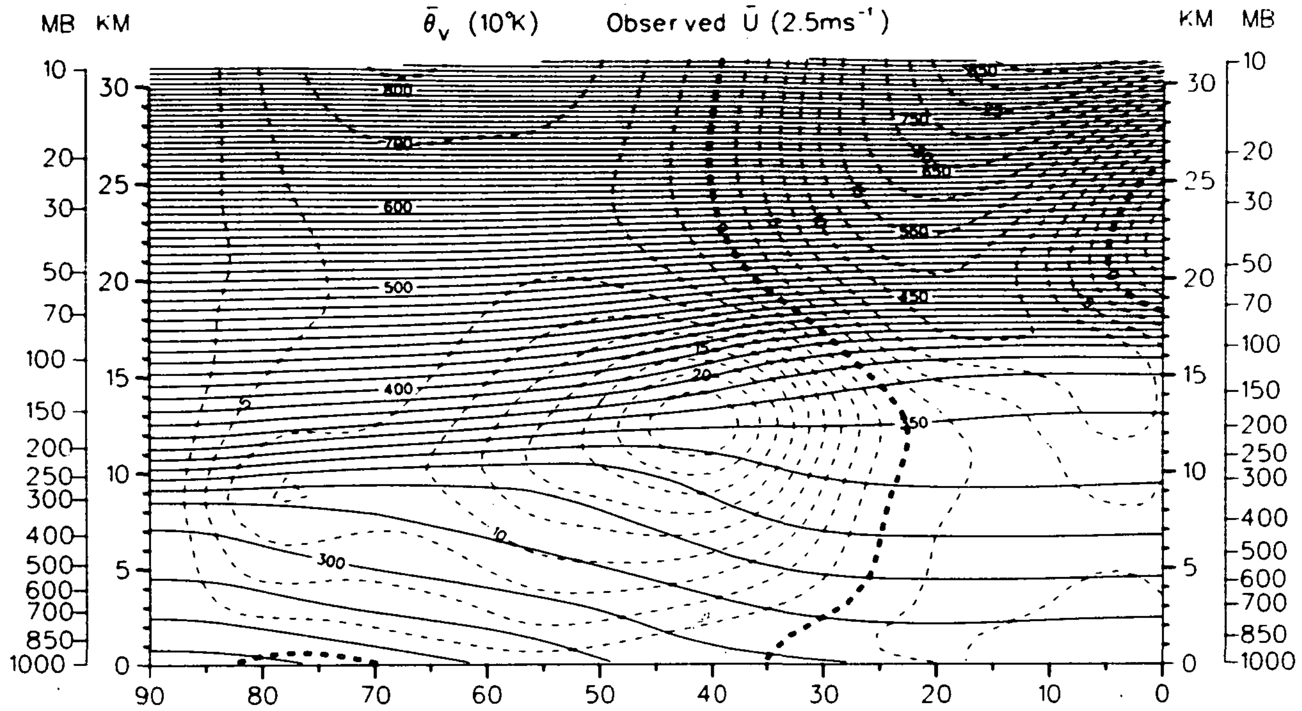
AUGUST 1973

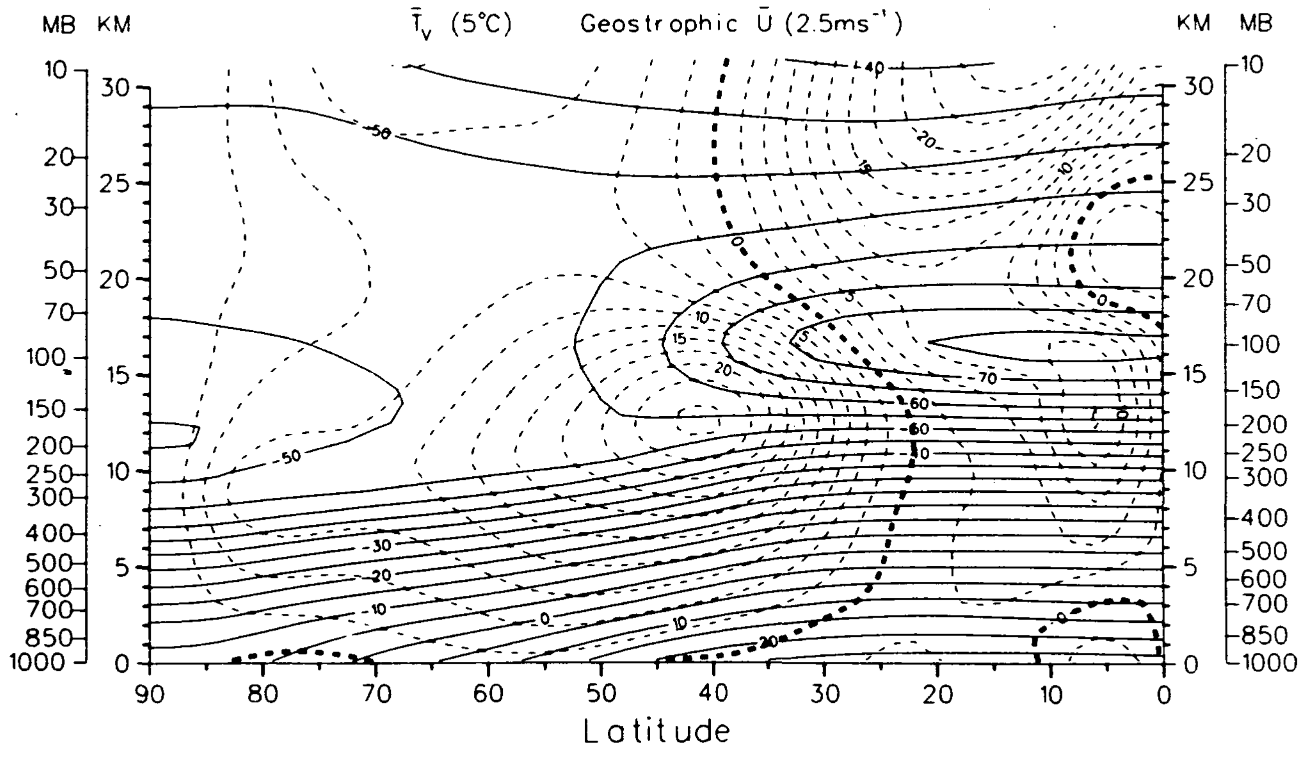



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS
AUGUST 1973
$\bar{\theta}_v$ (10°K)
Observed $\bar{U}$ (2.5ms^{-1})
MB KM
KM MB
$\bar{T}_v$ (5°C)
Geostrophic $\bar{U}$ (2.5ms^{-1})
Latitude
0 -10 -20 -30 -40 -50 -60 -70 -80 -90

NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

SEPTEMBER 1973

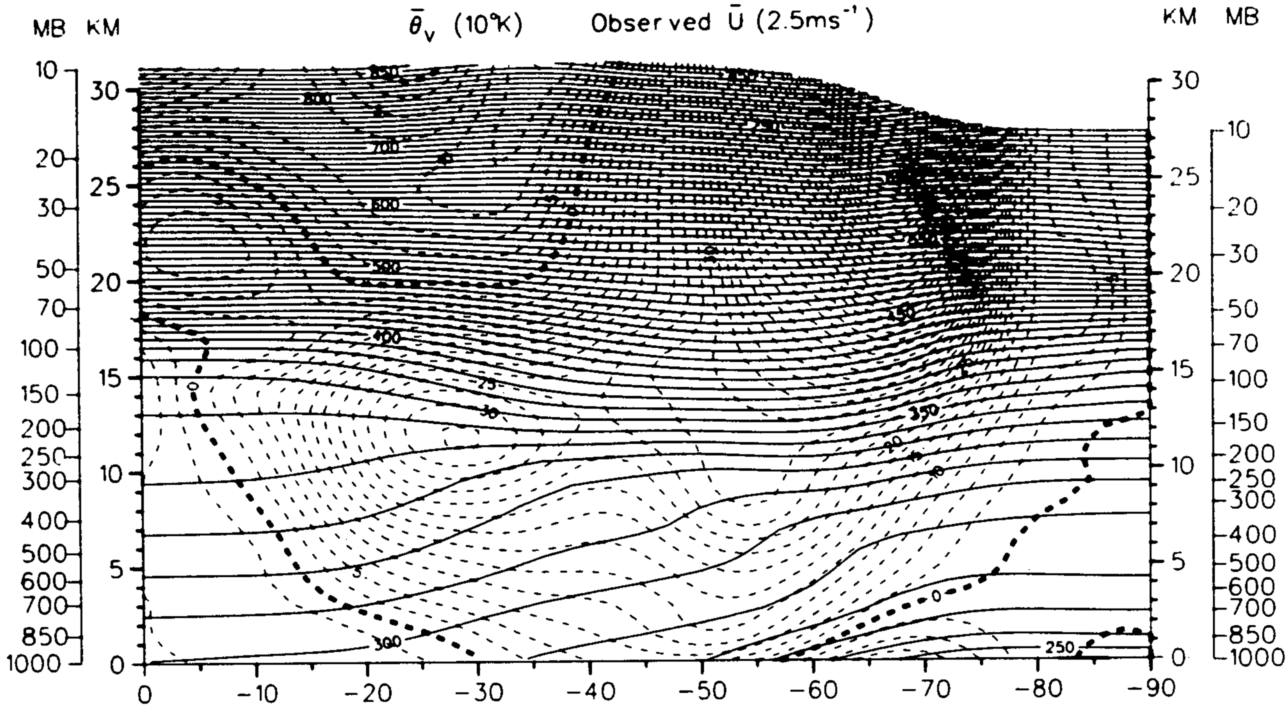




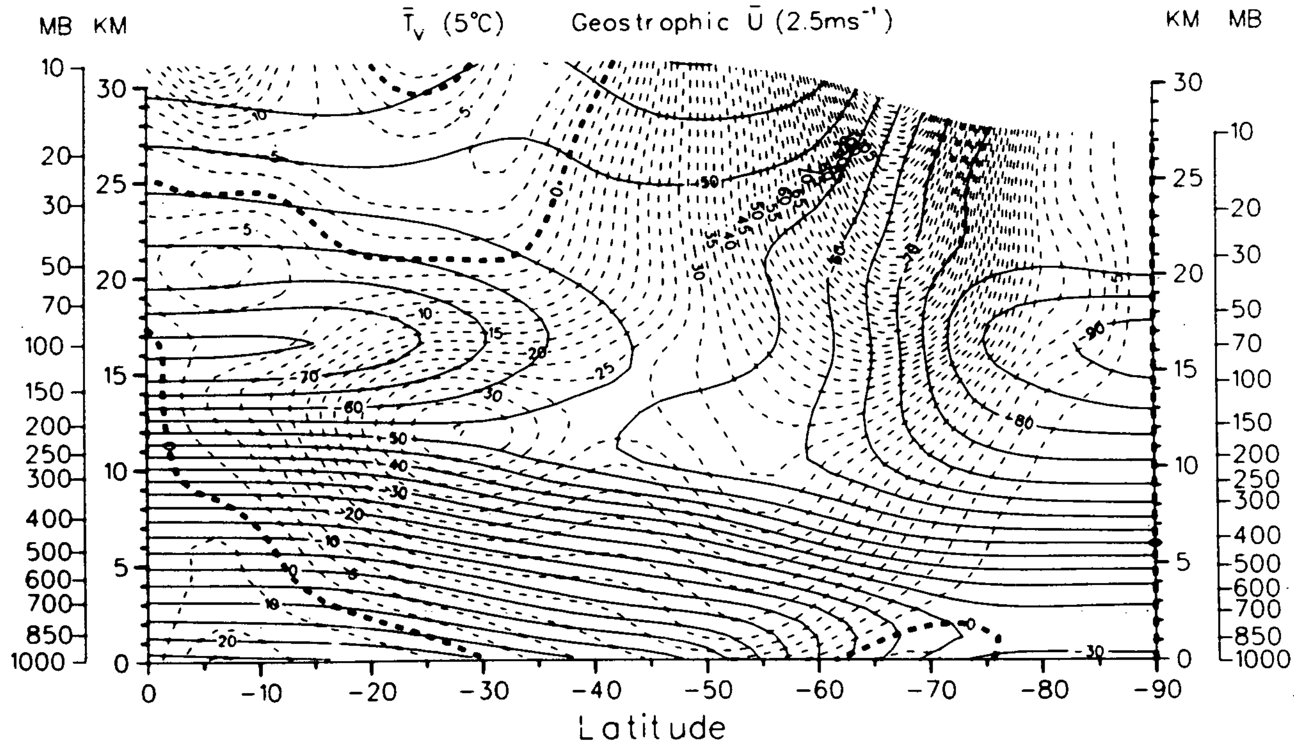
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

SEPTEMBER 1973

$\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1})

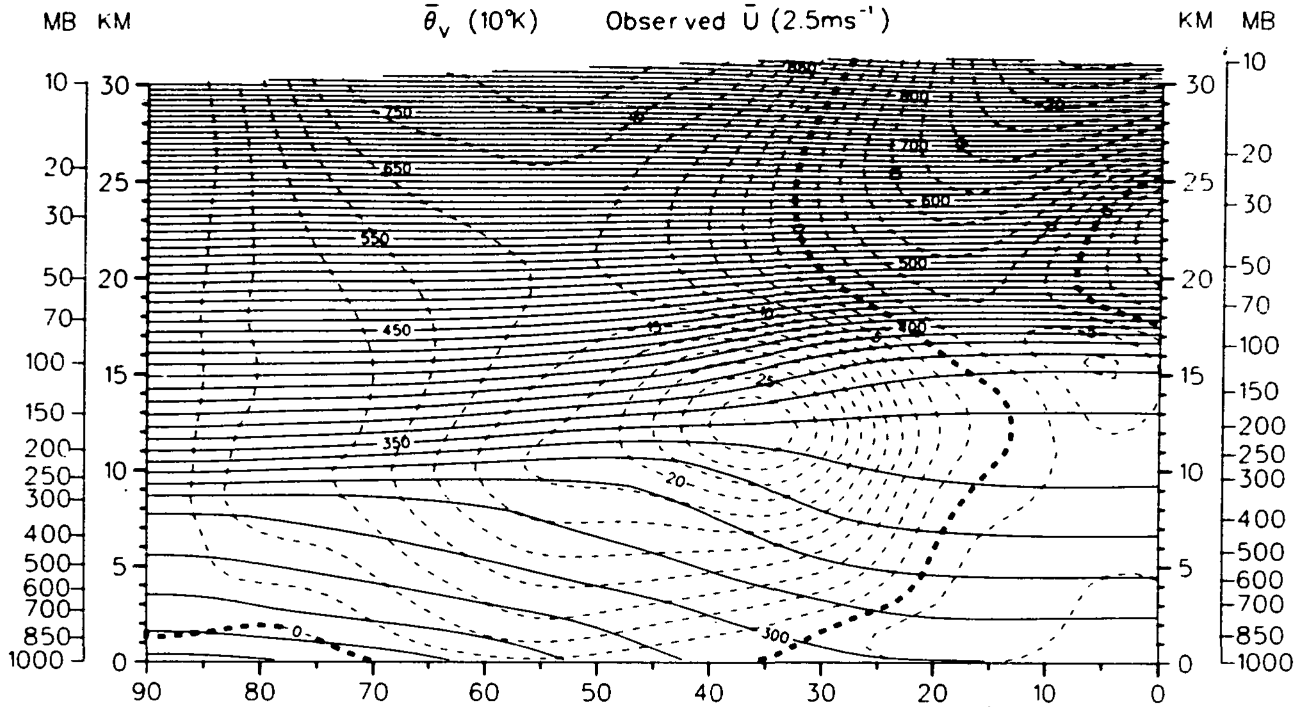


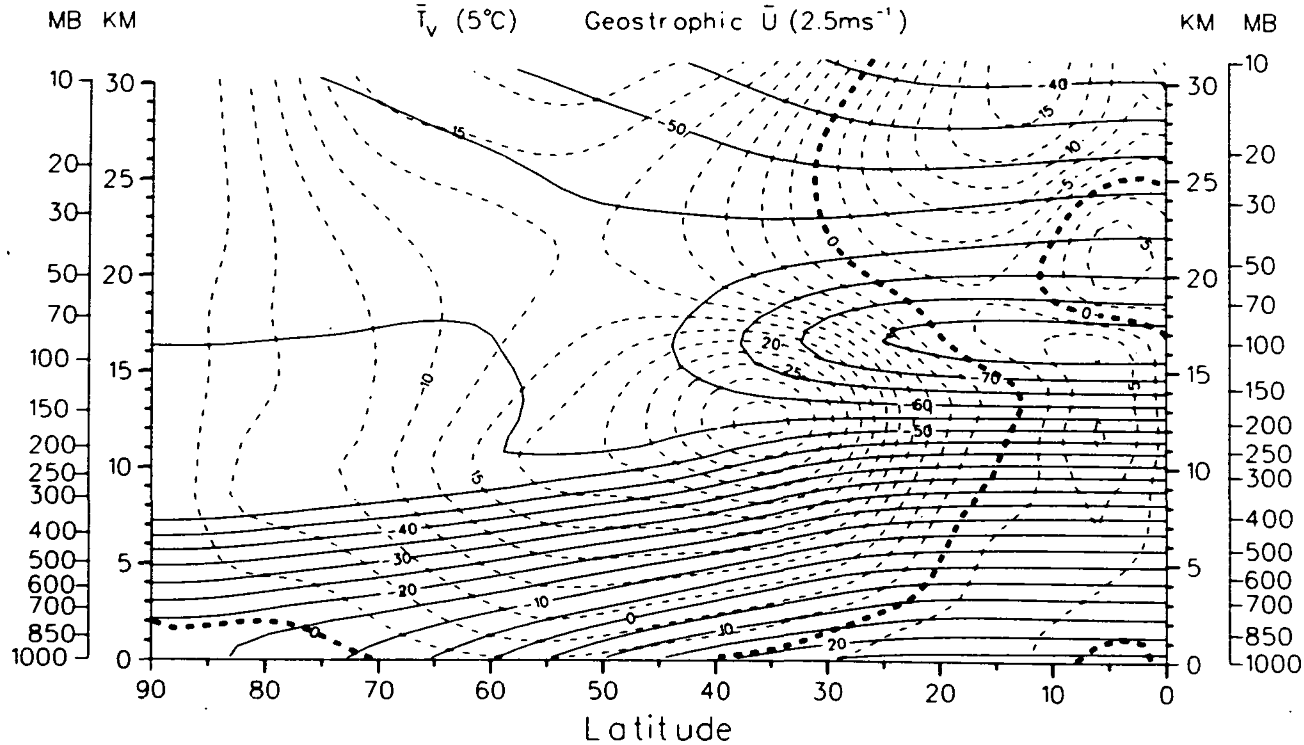
$\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1})



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

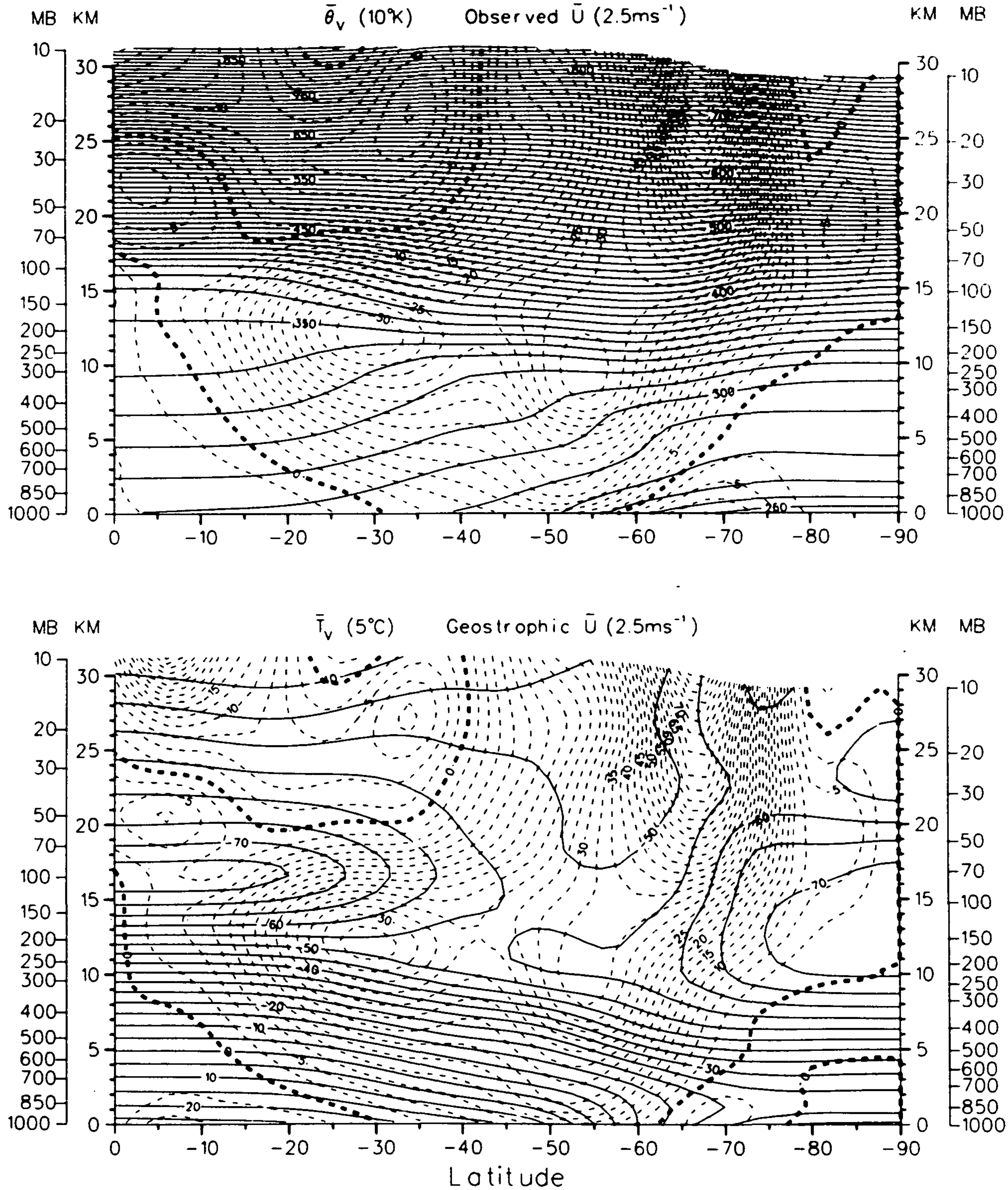
OCTOBER 1973





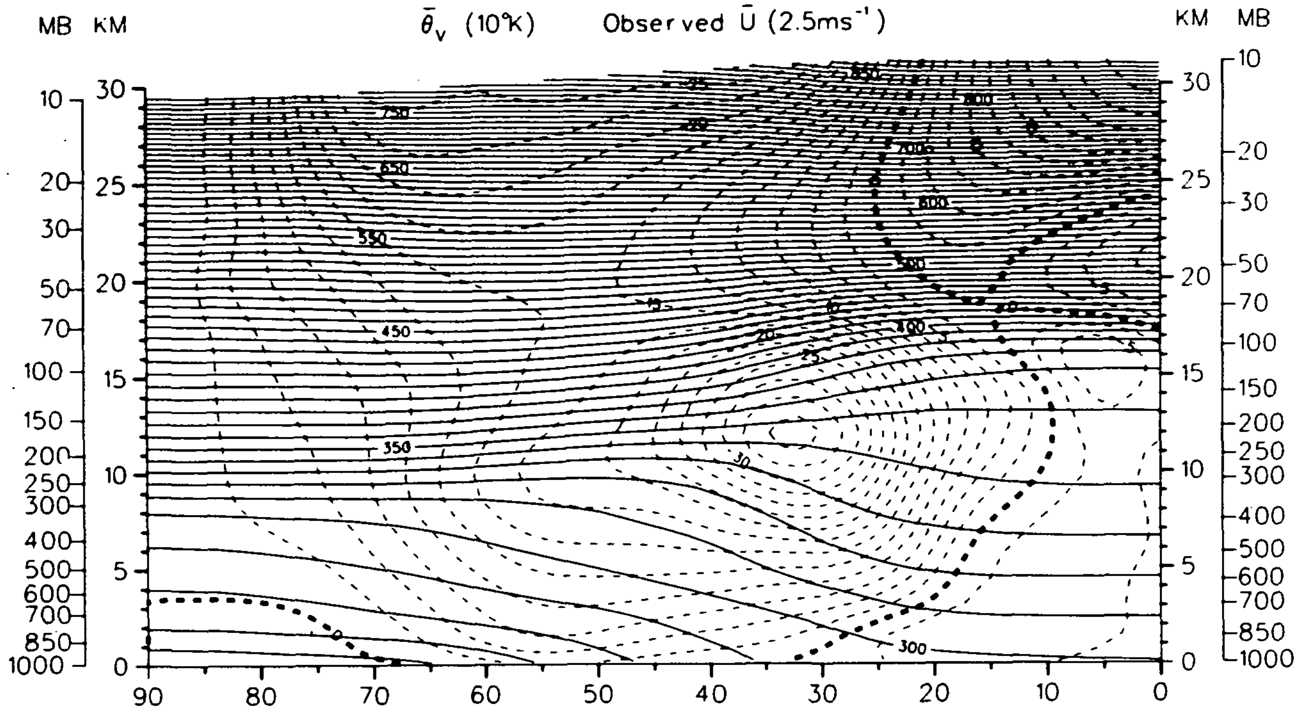
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

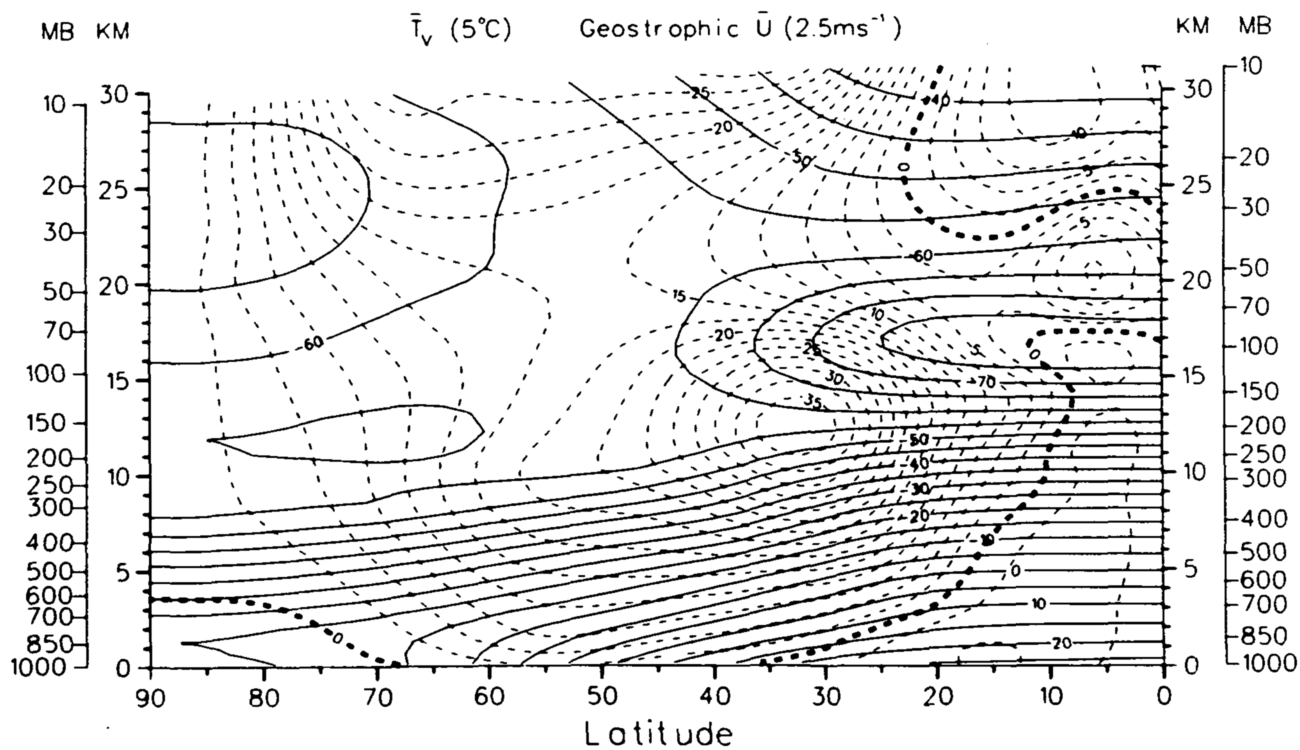
OCTOBER 1973



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

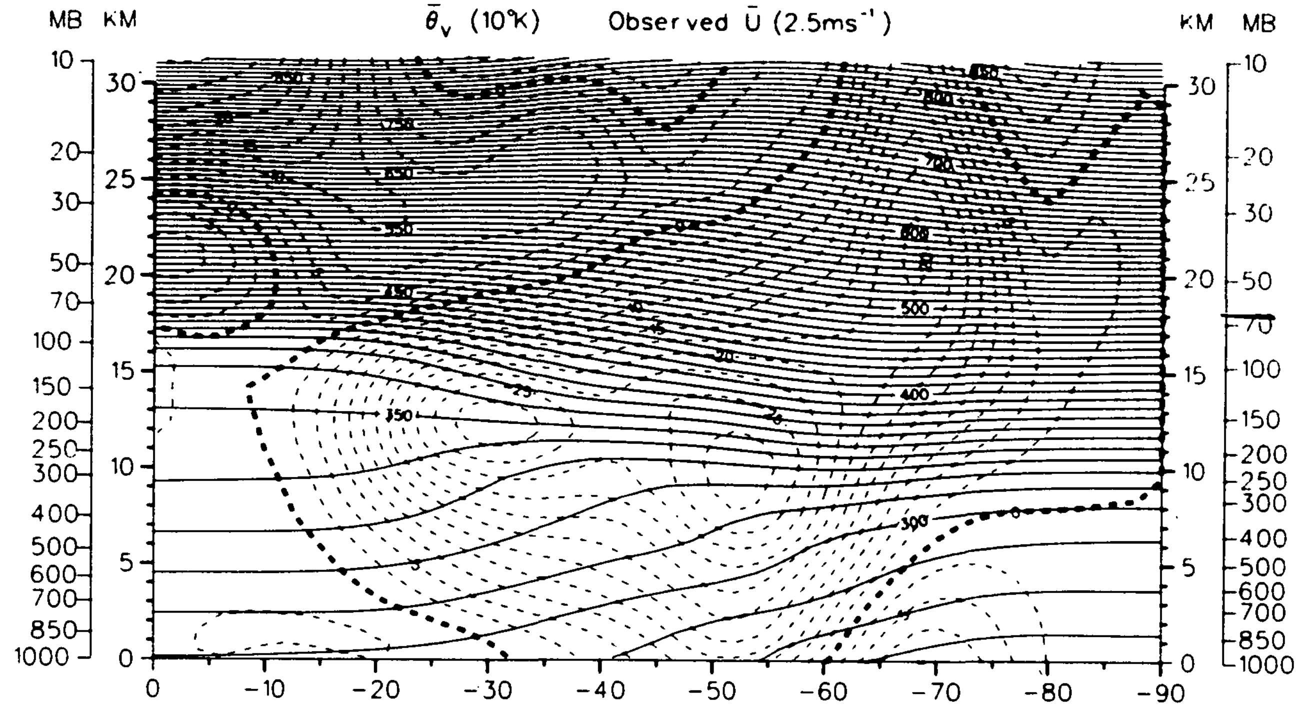
NOVEMBER 1973

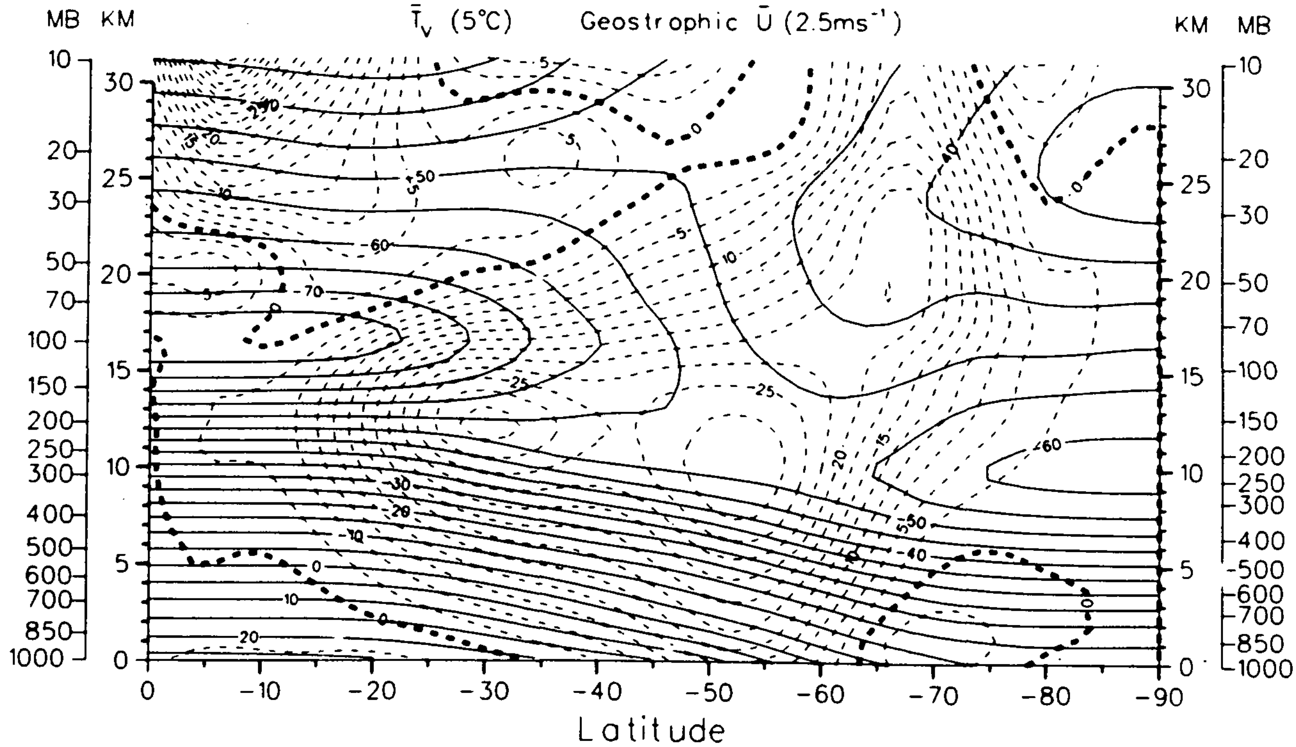




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

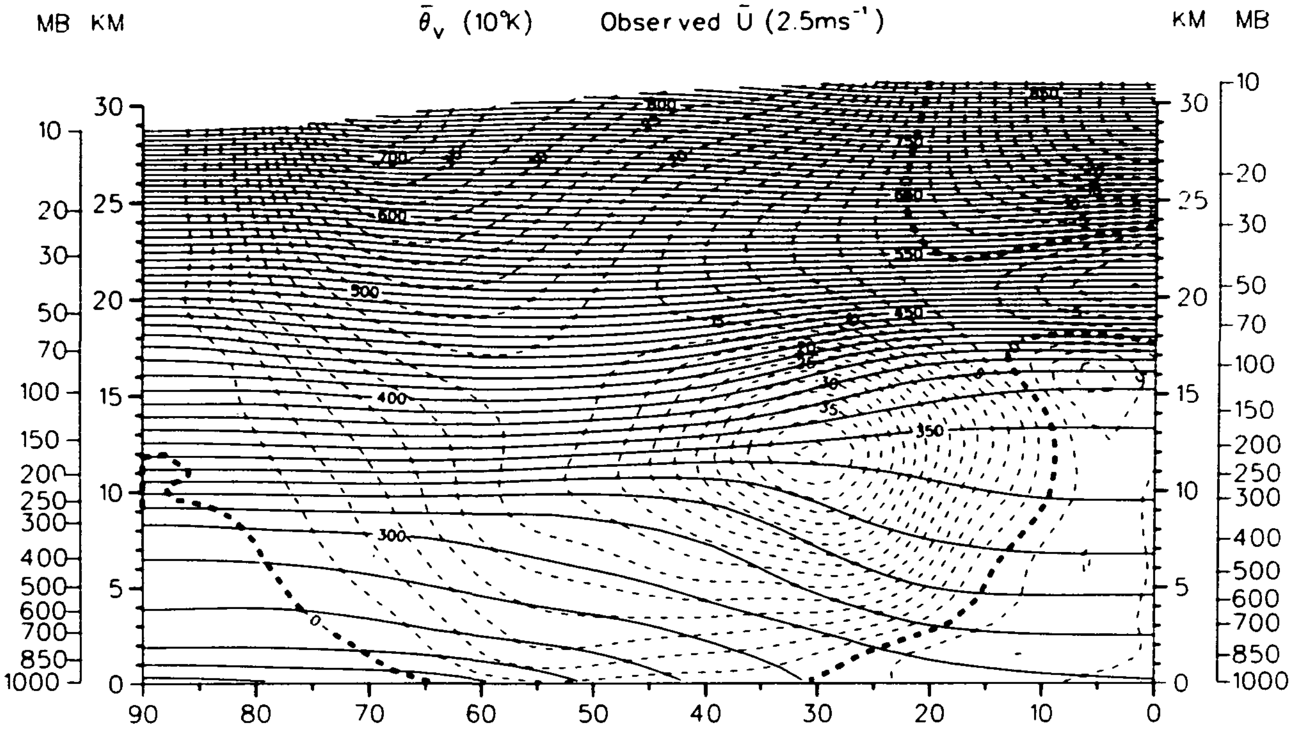
NOVEMBER 1973

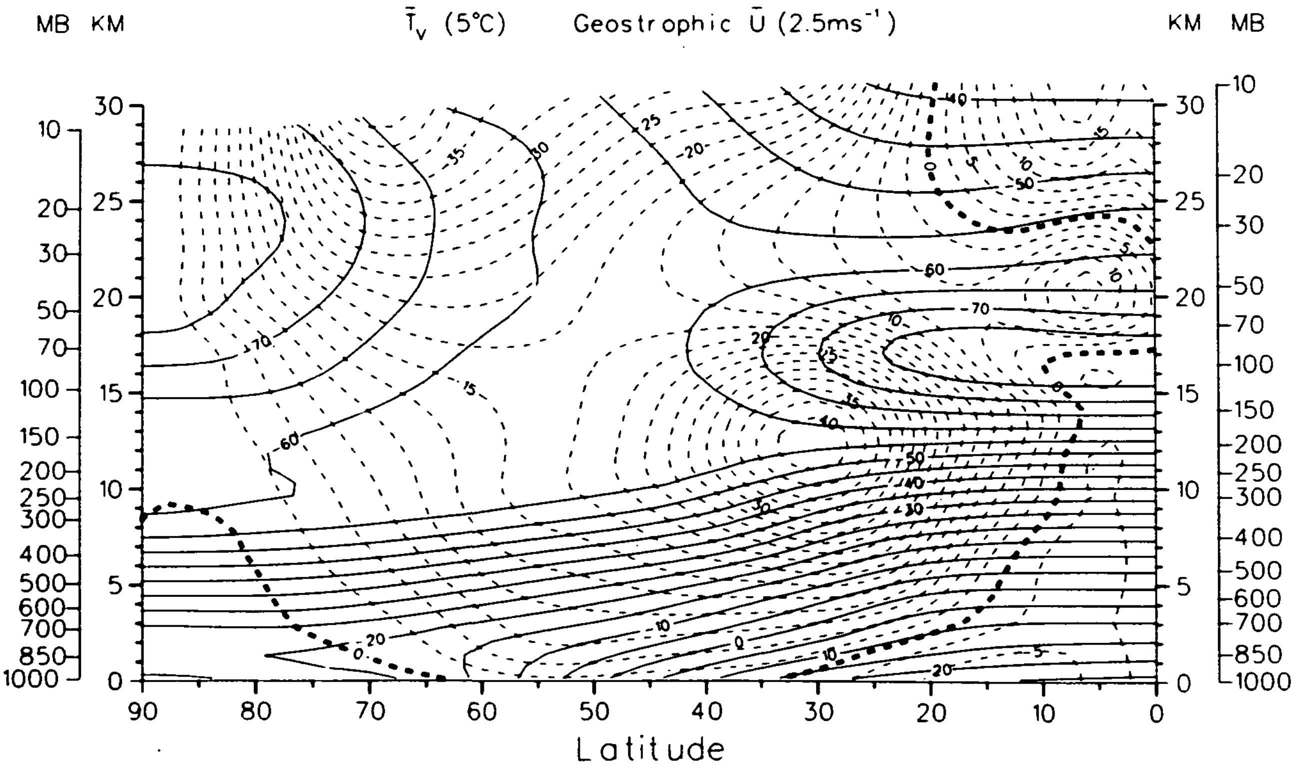




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

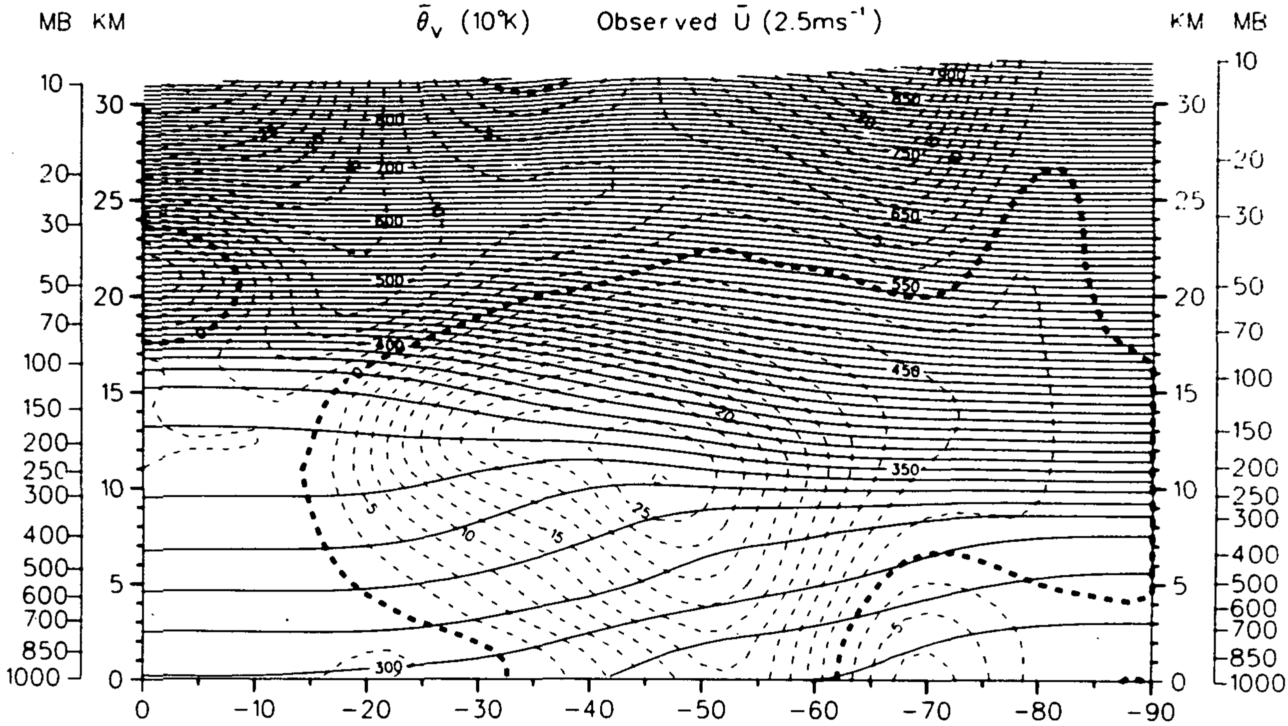
DECEMBER 1973

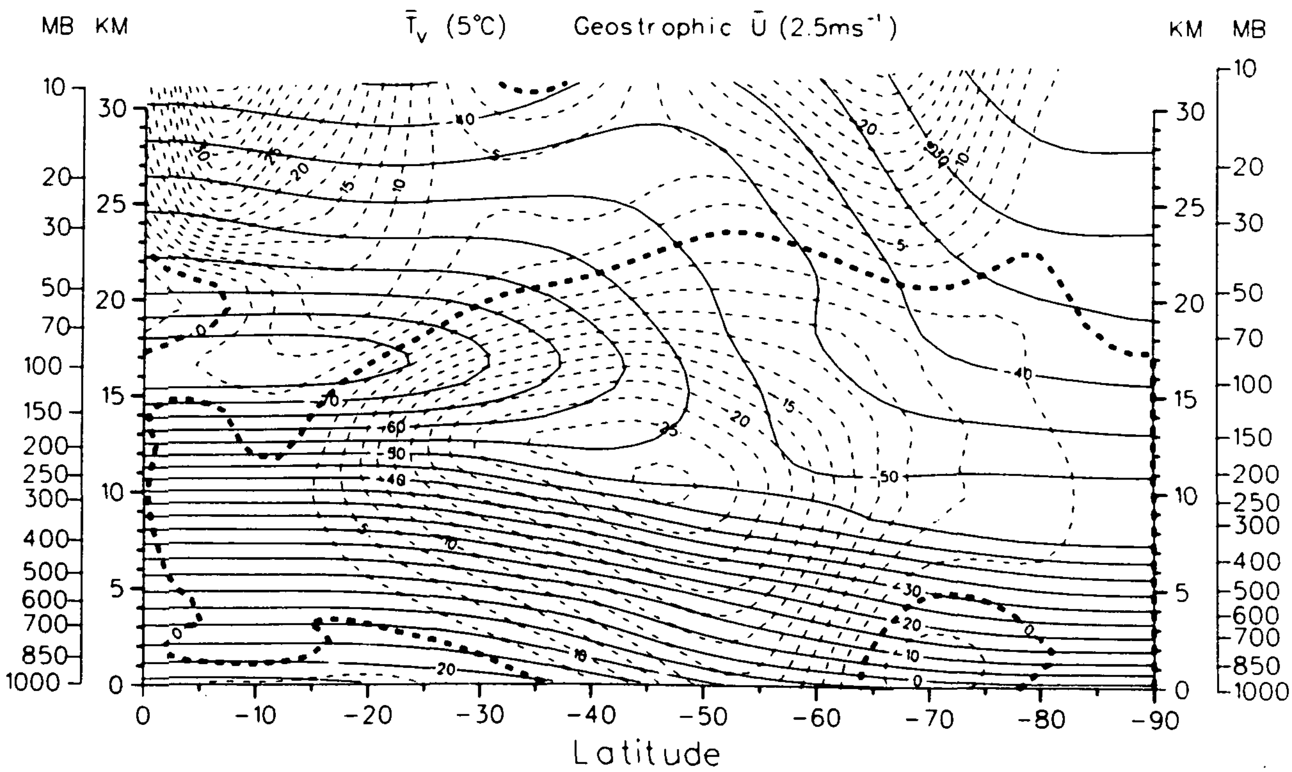




SOUTHERN HEMISPHERIC ZONAL–MONTHLY MEANS

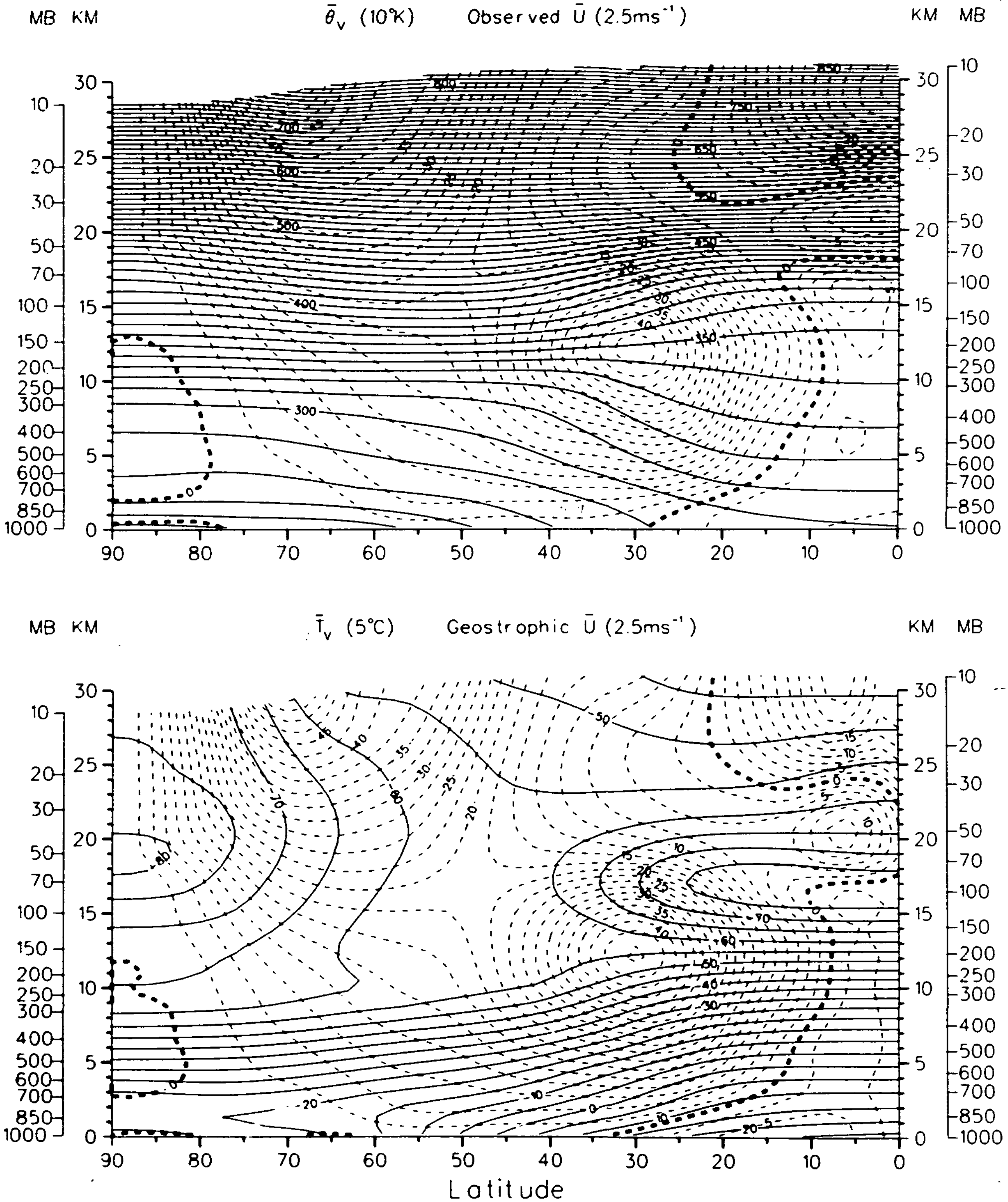
DECEMBER 1973





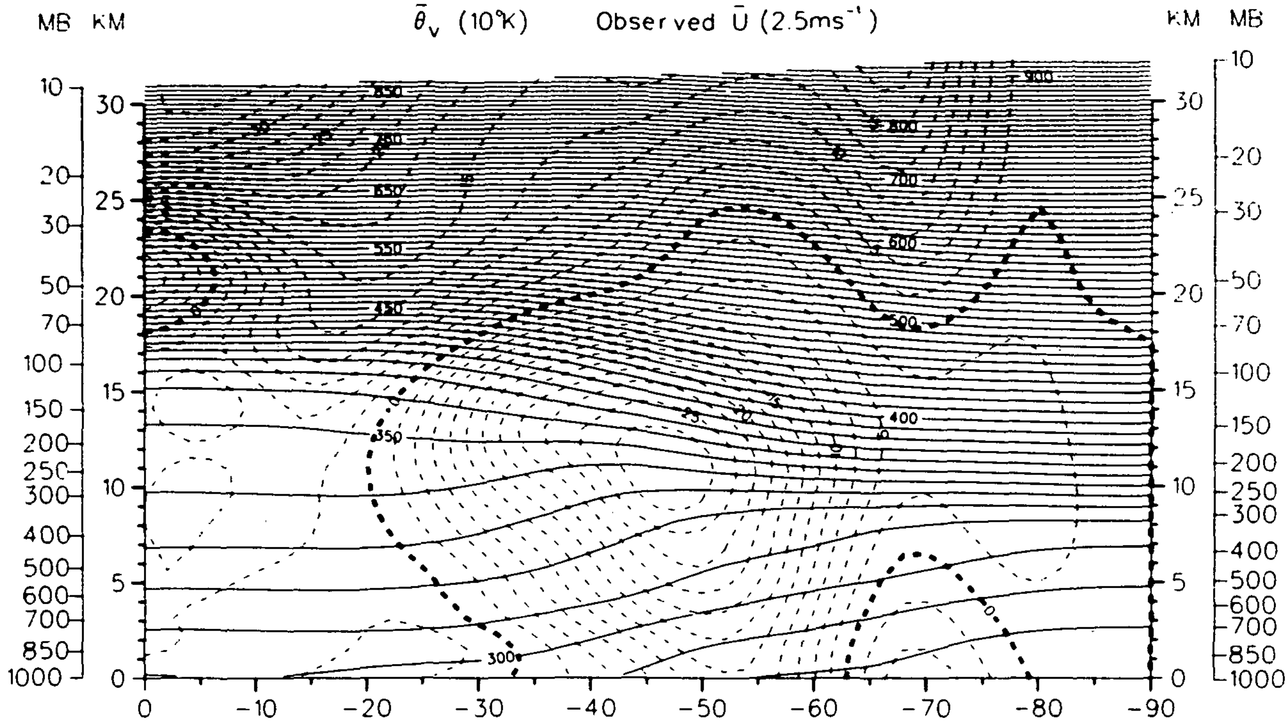
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

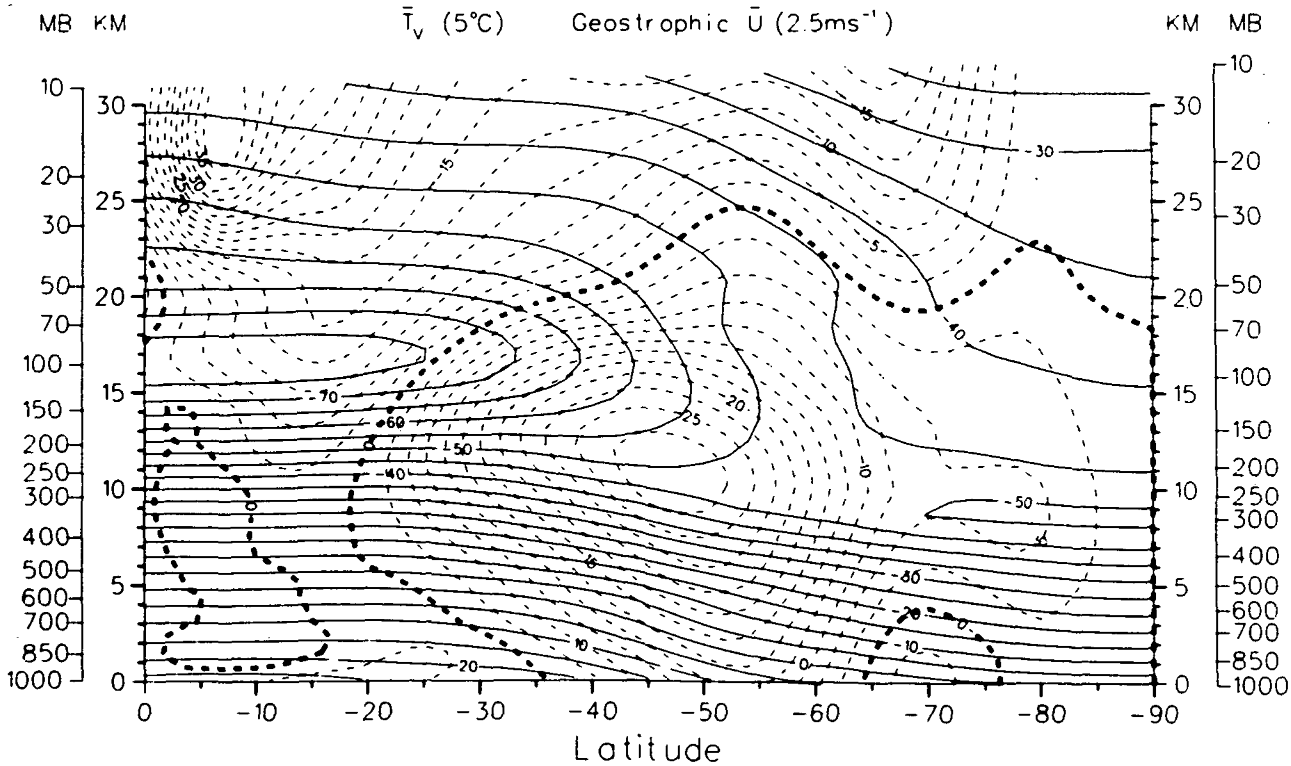
JANUARY 1974



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

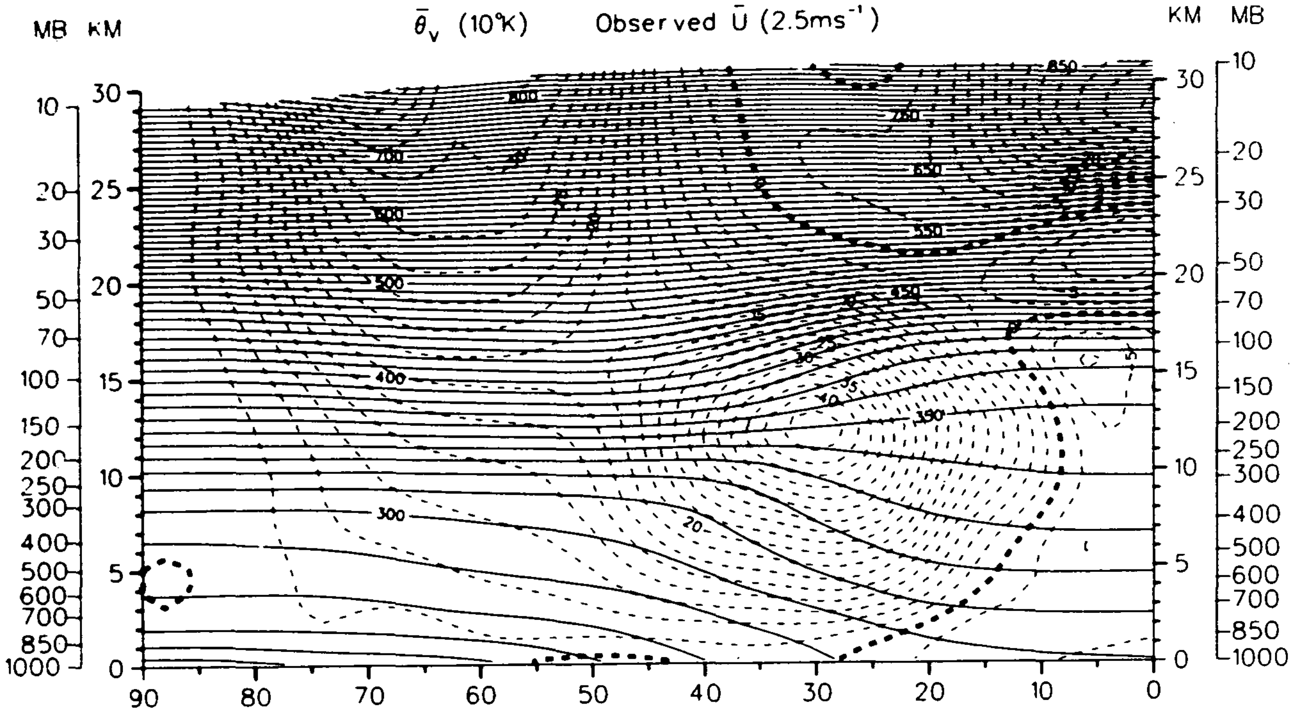
JANUARY 1974

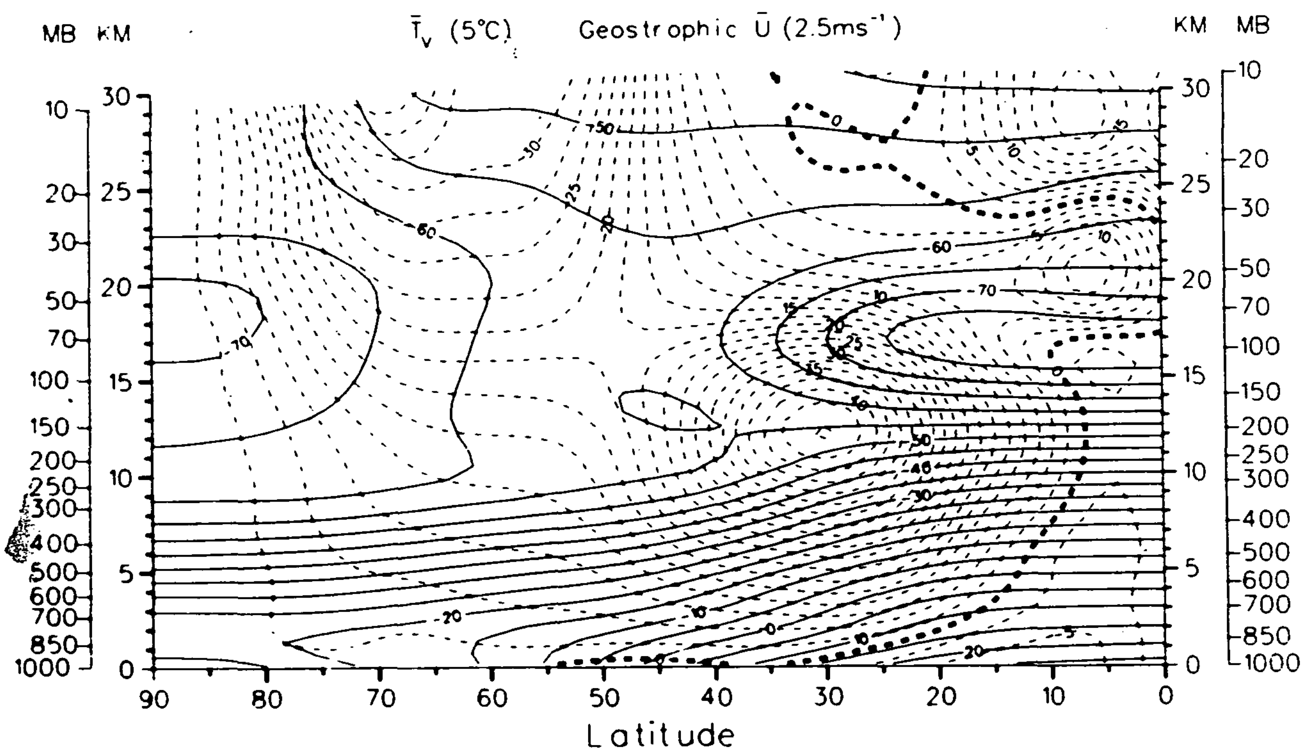




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

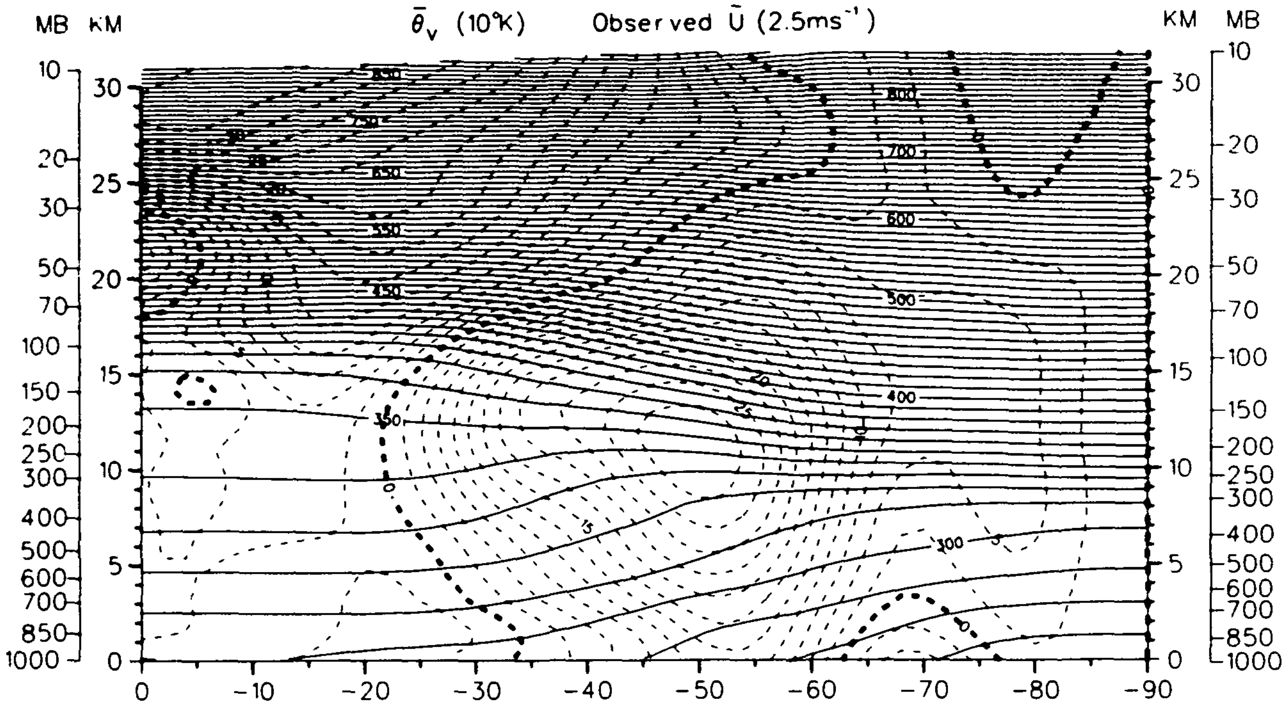
FEBRUARY 1974

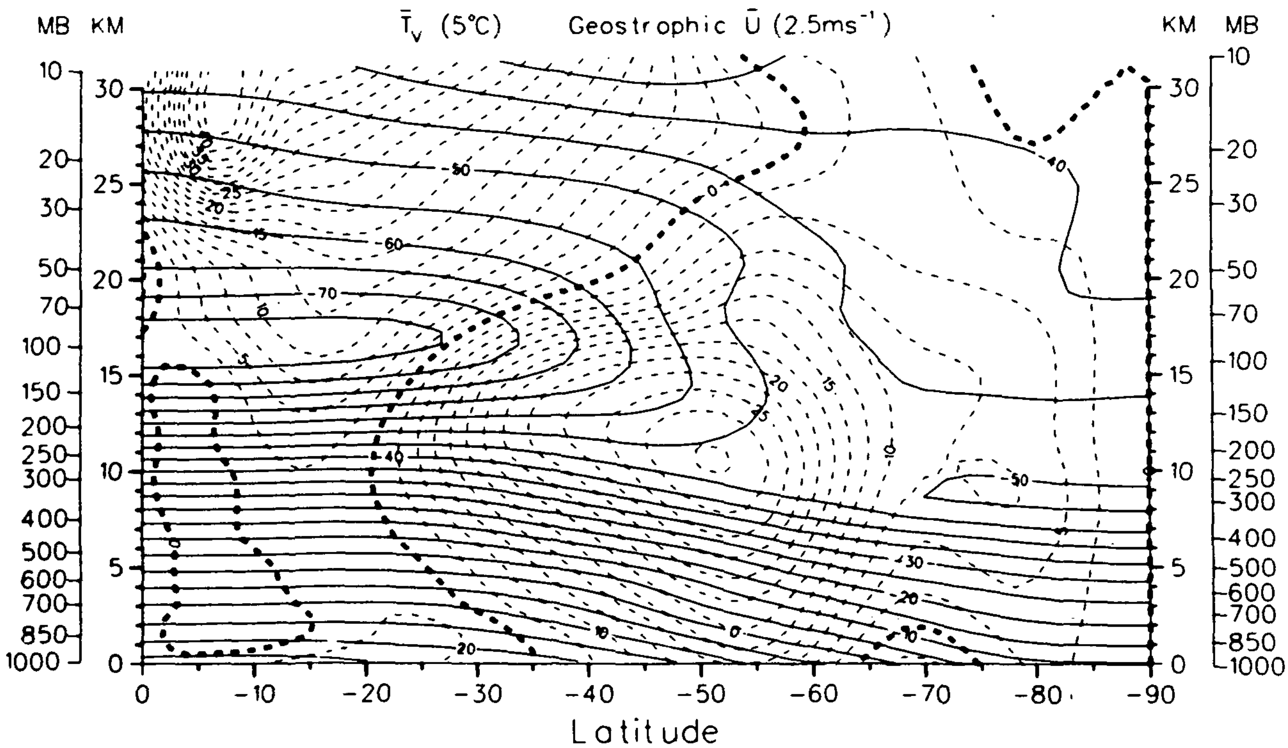




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

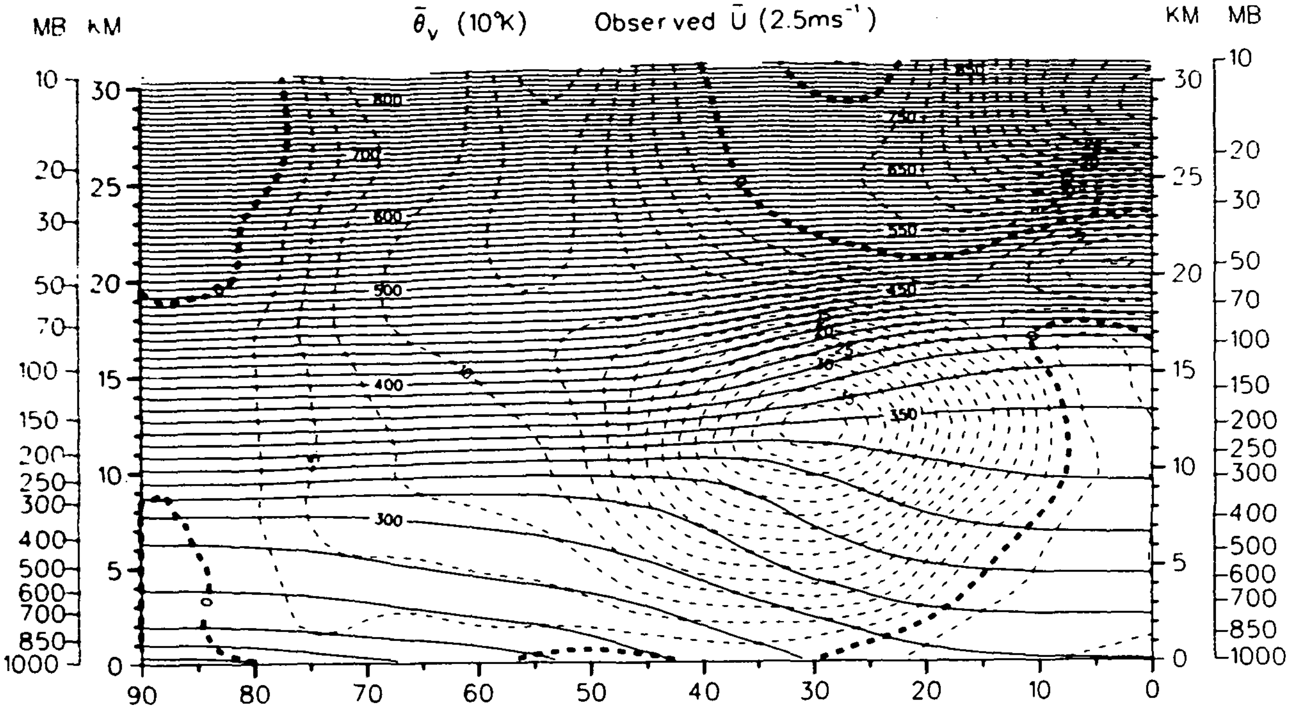
FEBRUARY 1974

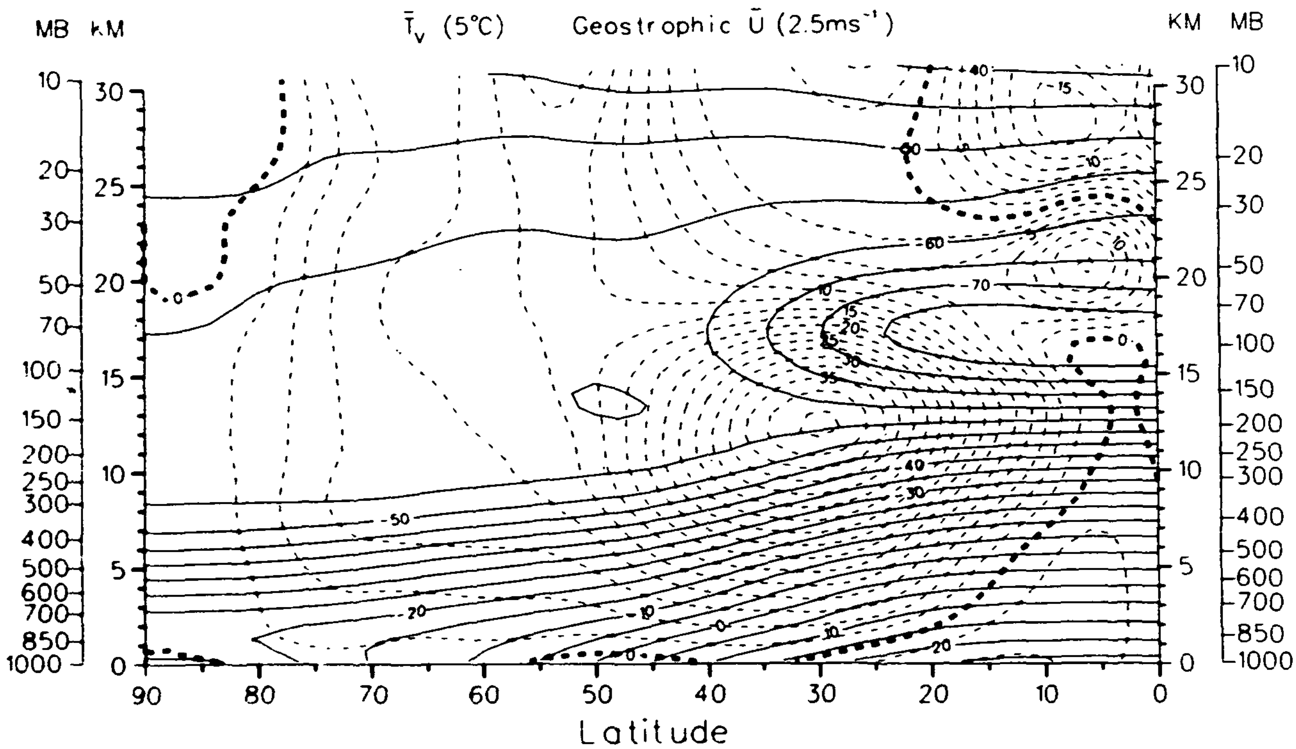




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

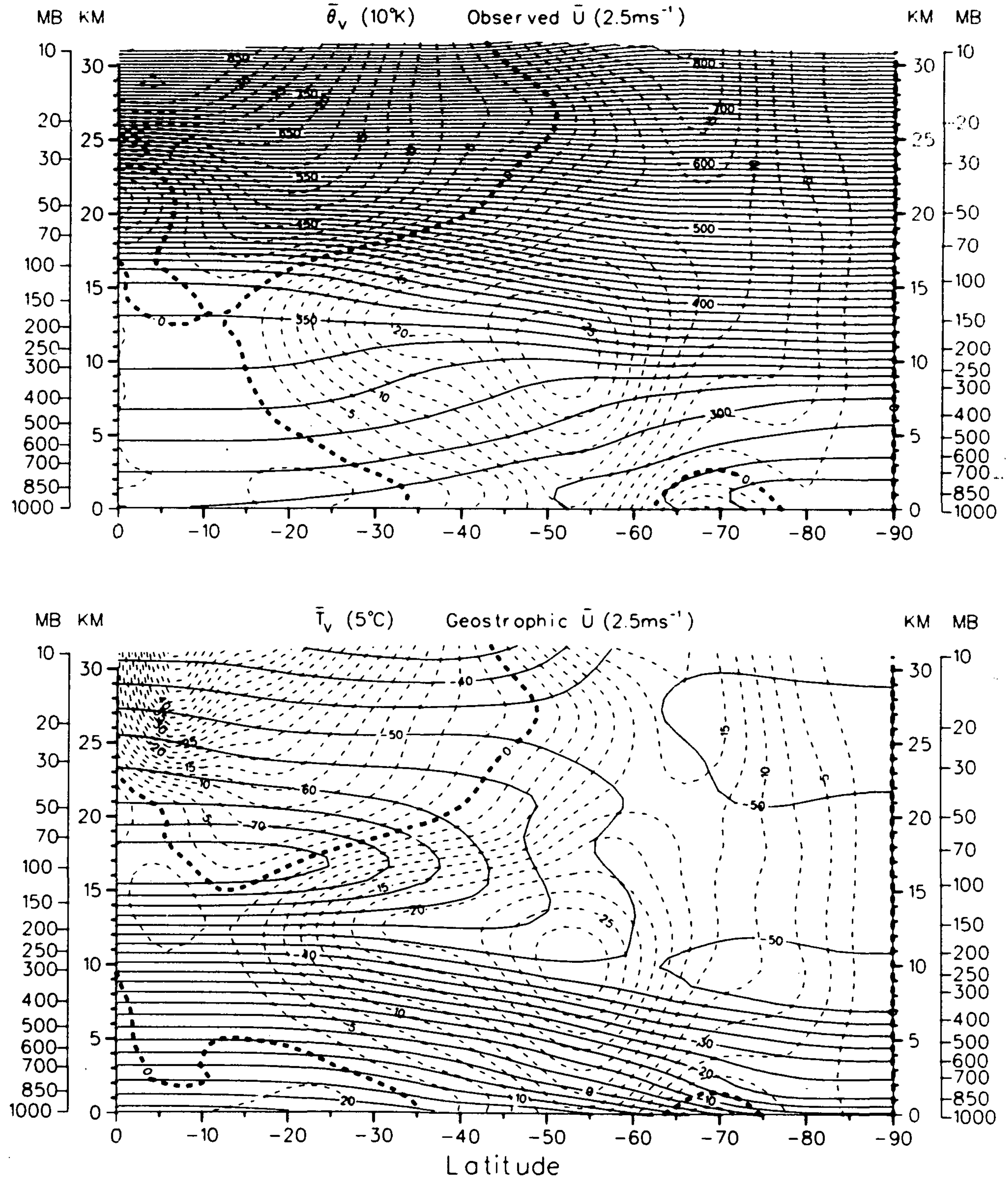
MARCH 1974





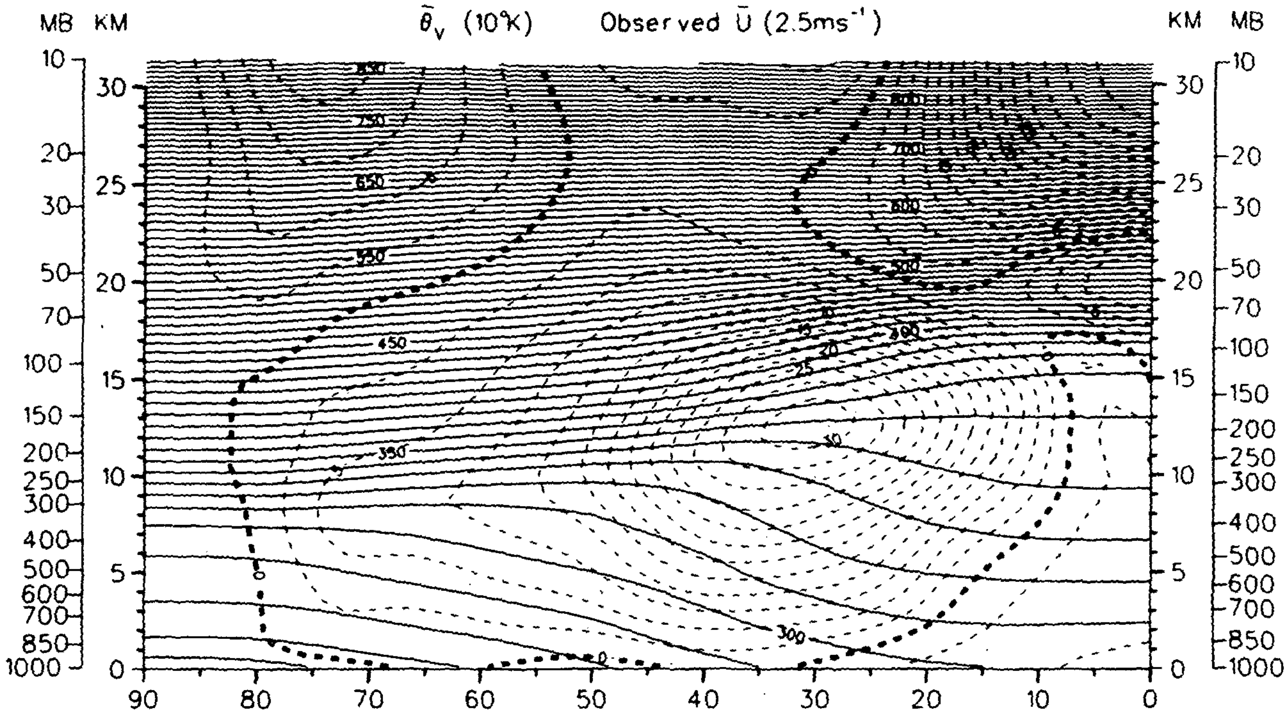
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

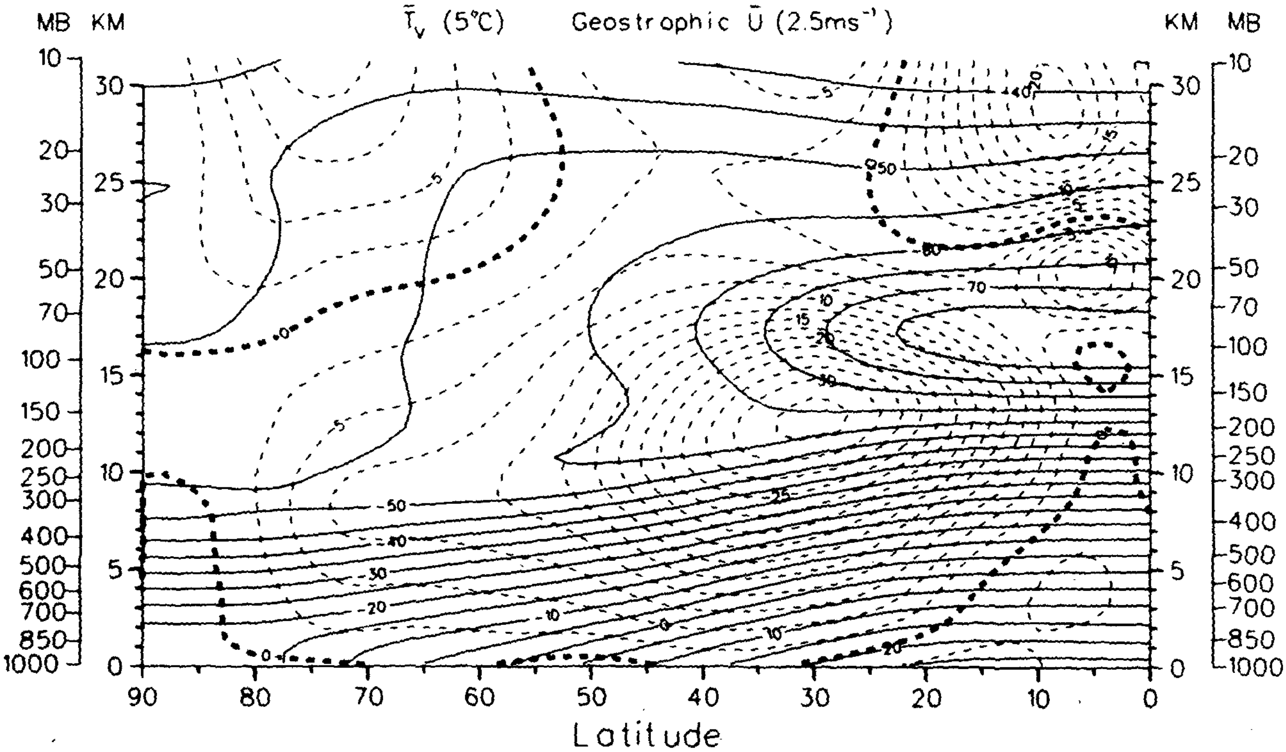
MARCH 1974



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

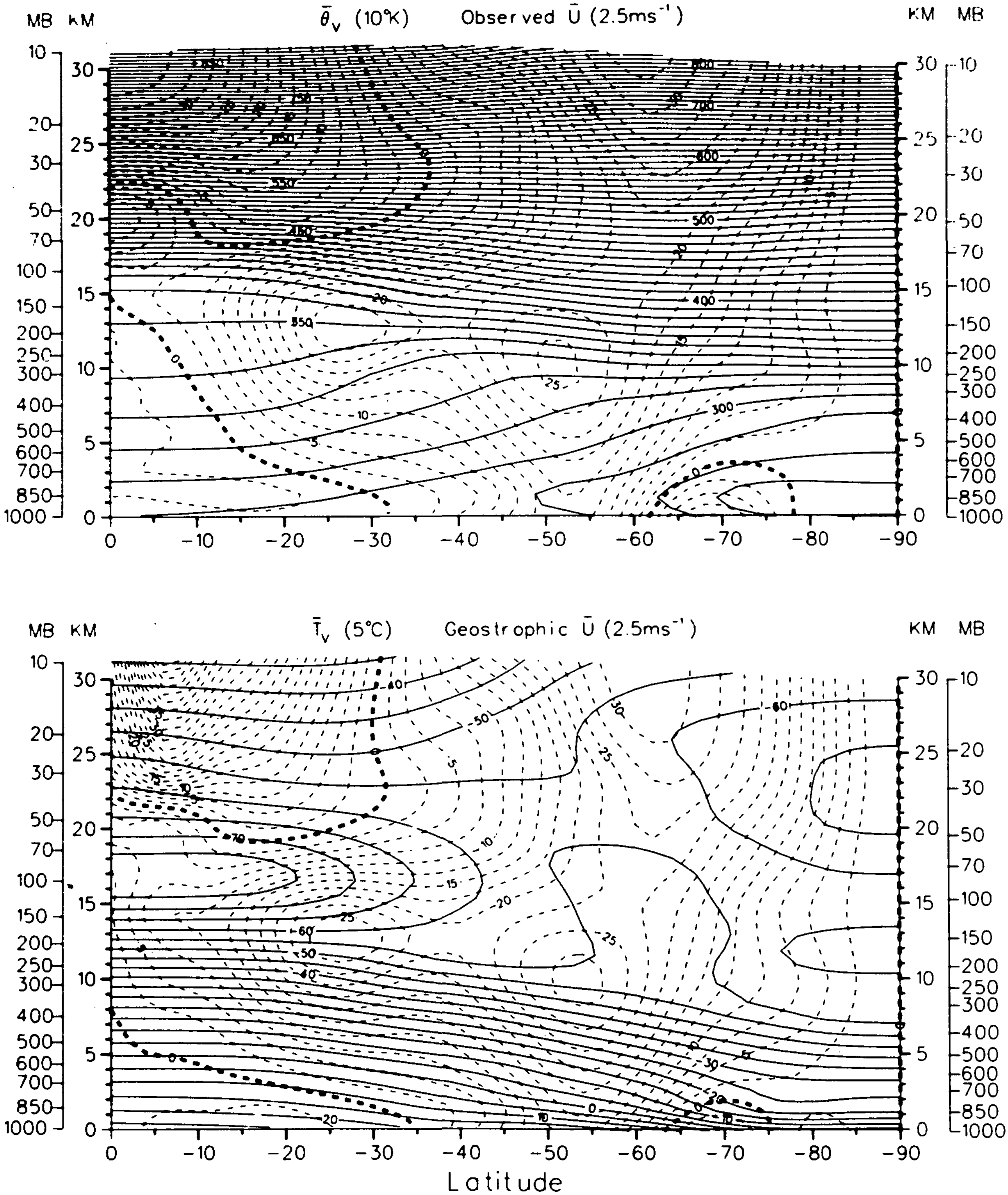
APRIL 1974





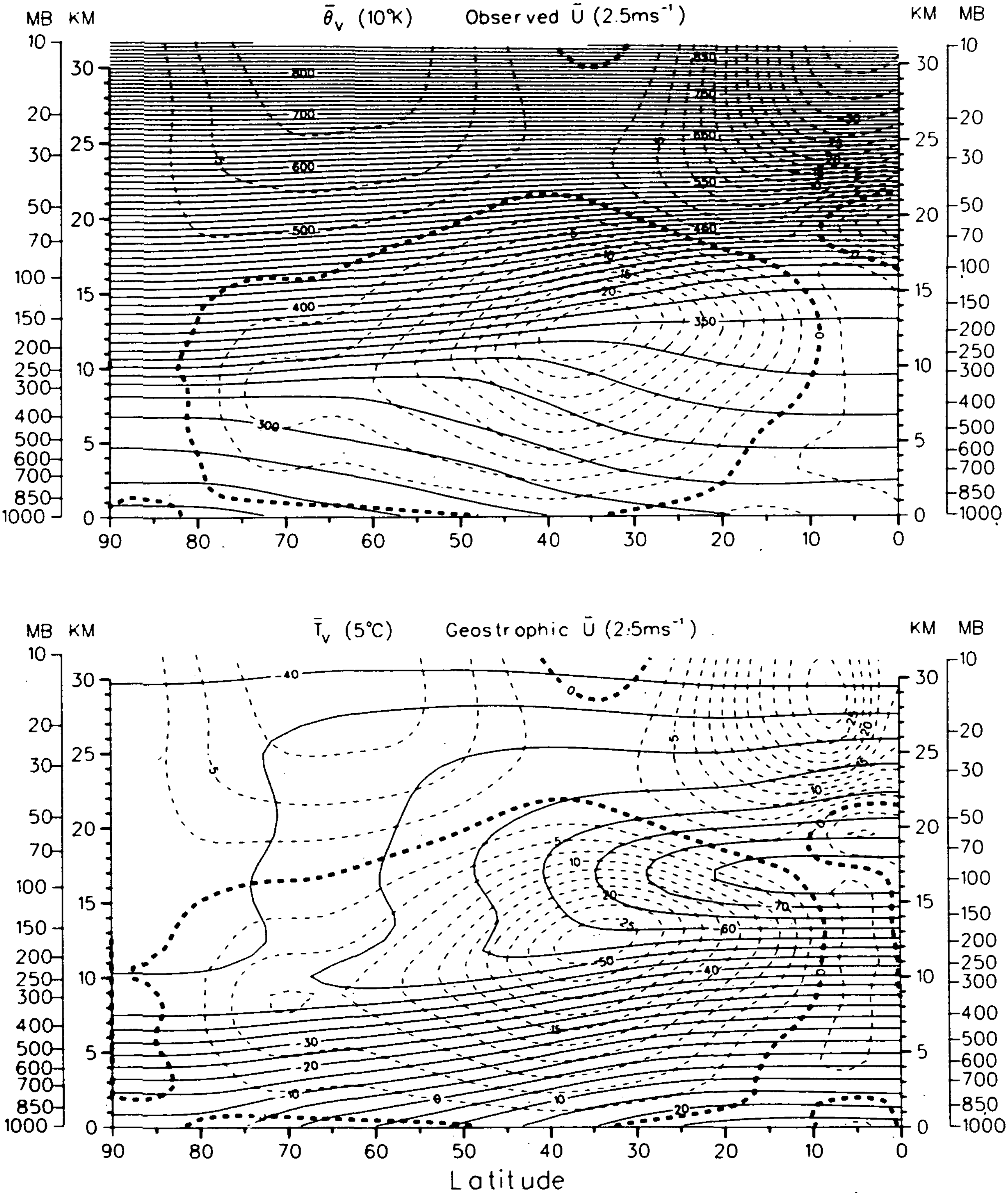
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

APRIL 1974



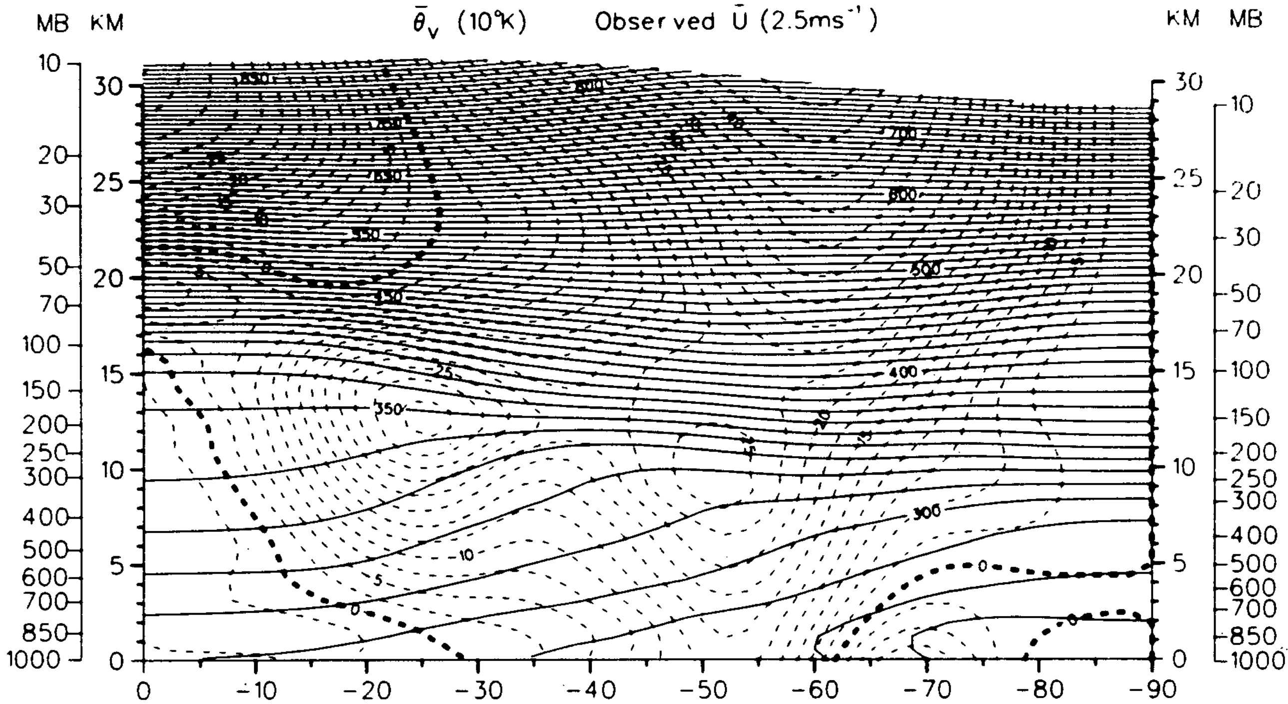
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

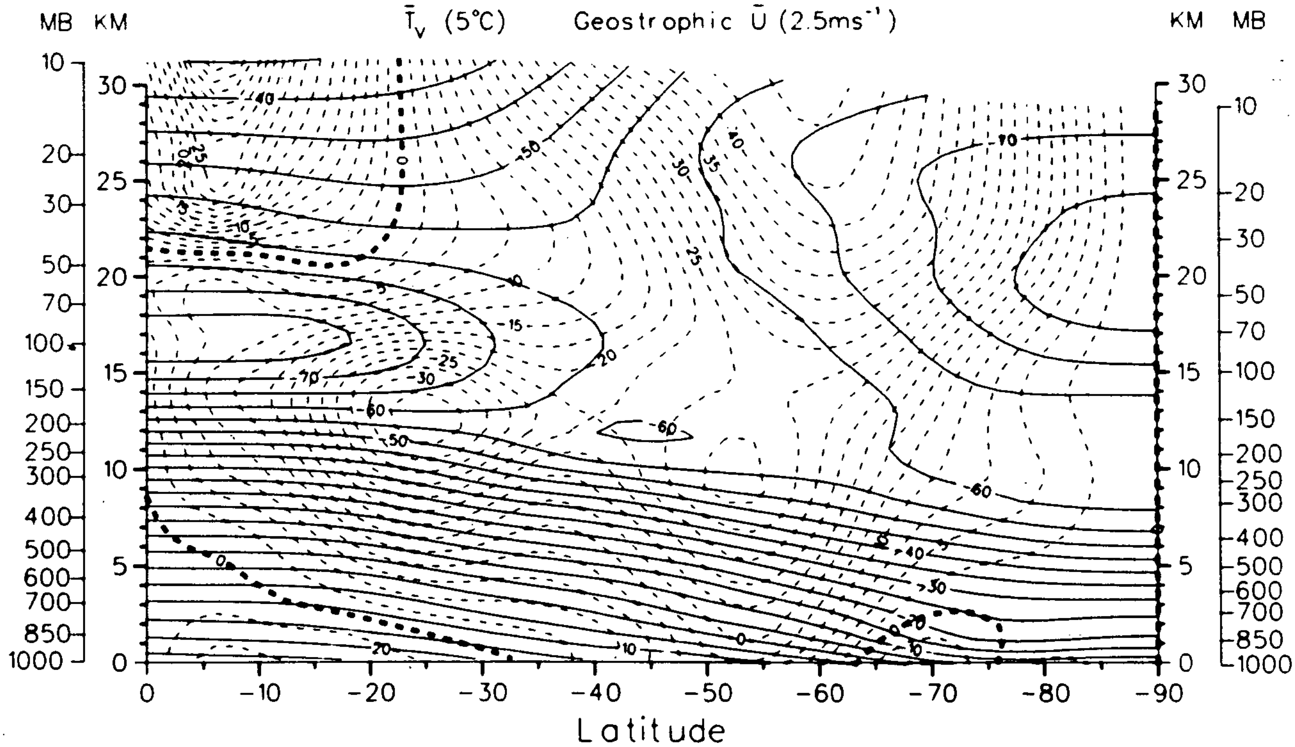
MAY 1974



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

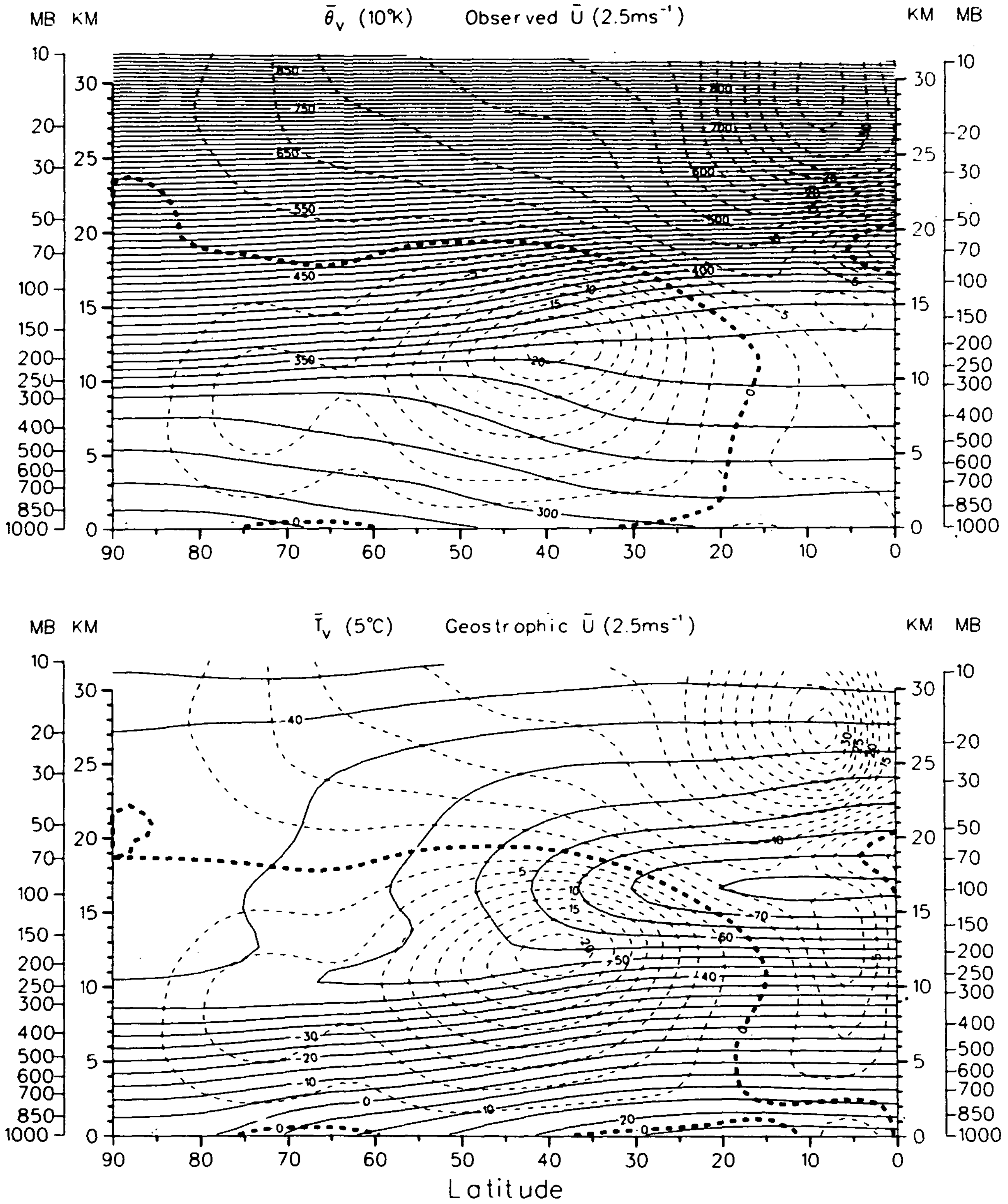
MAY 1974





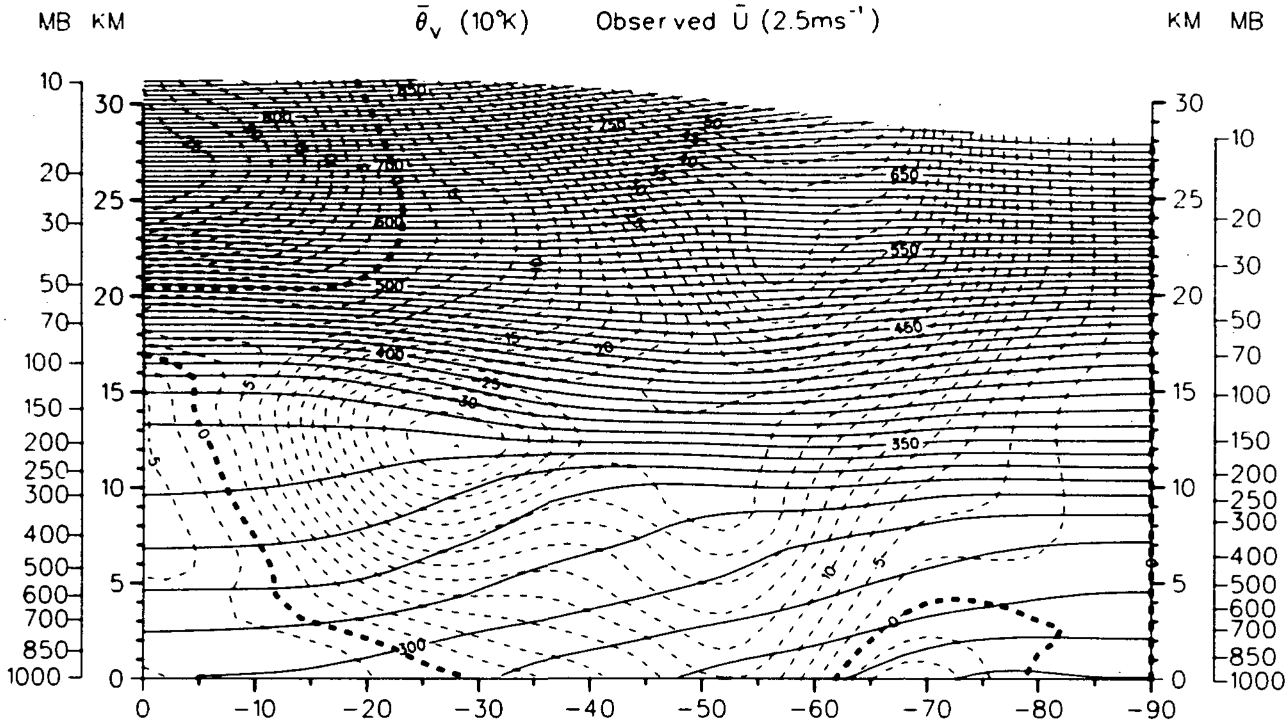
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

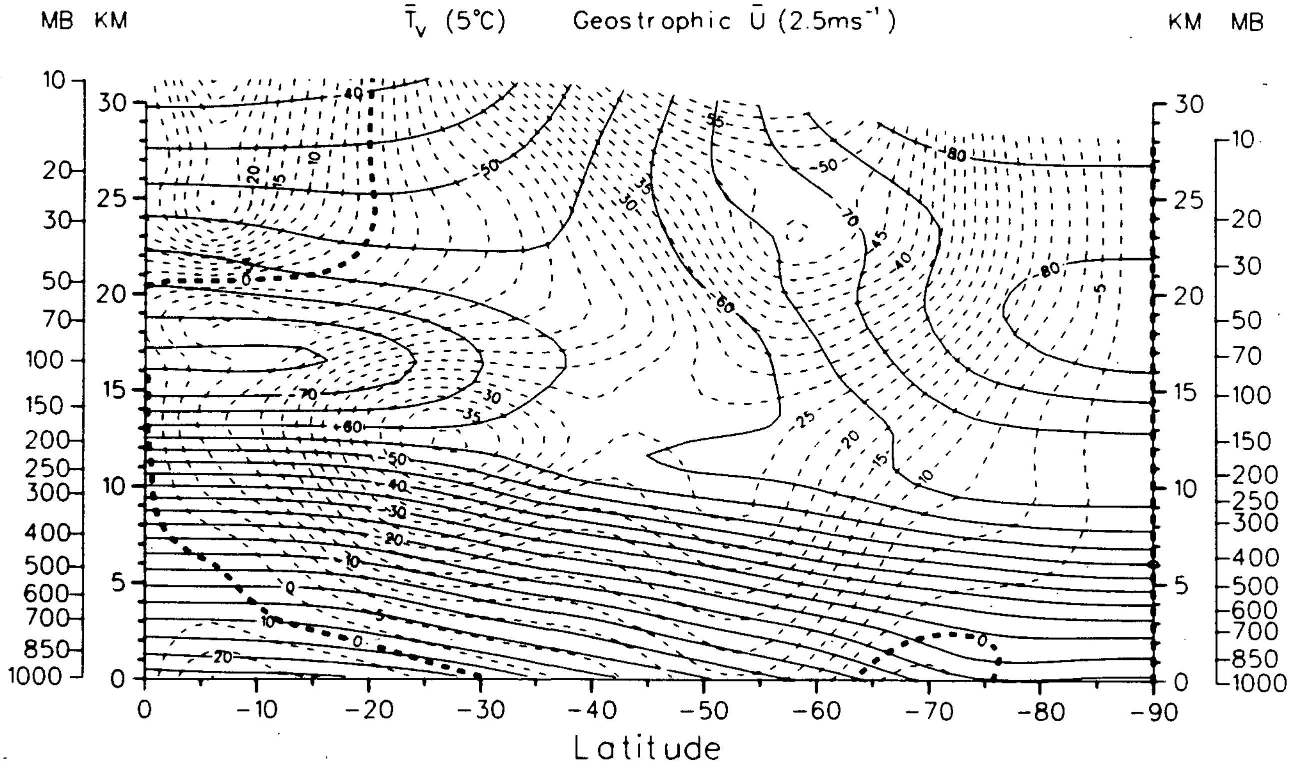
JUNE 1974



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JUNE 1974





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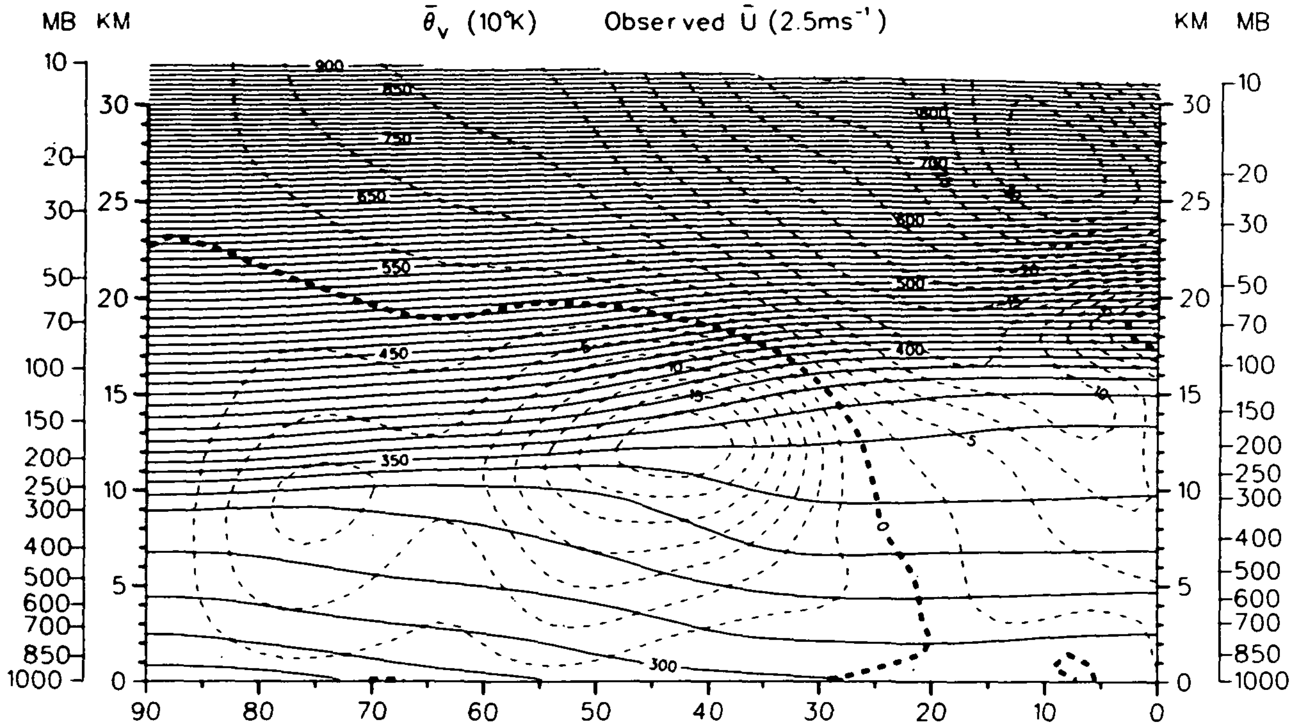
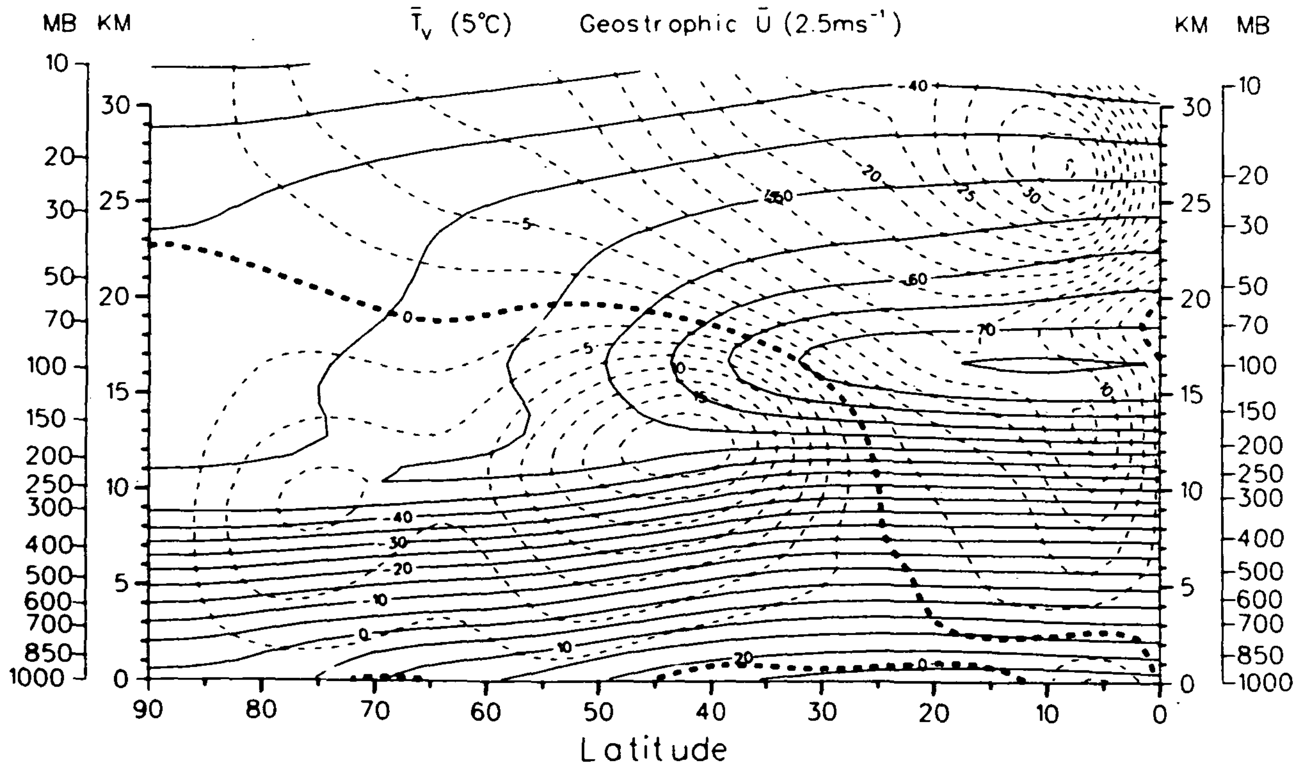
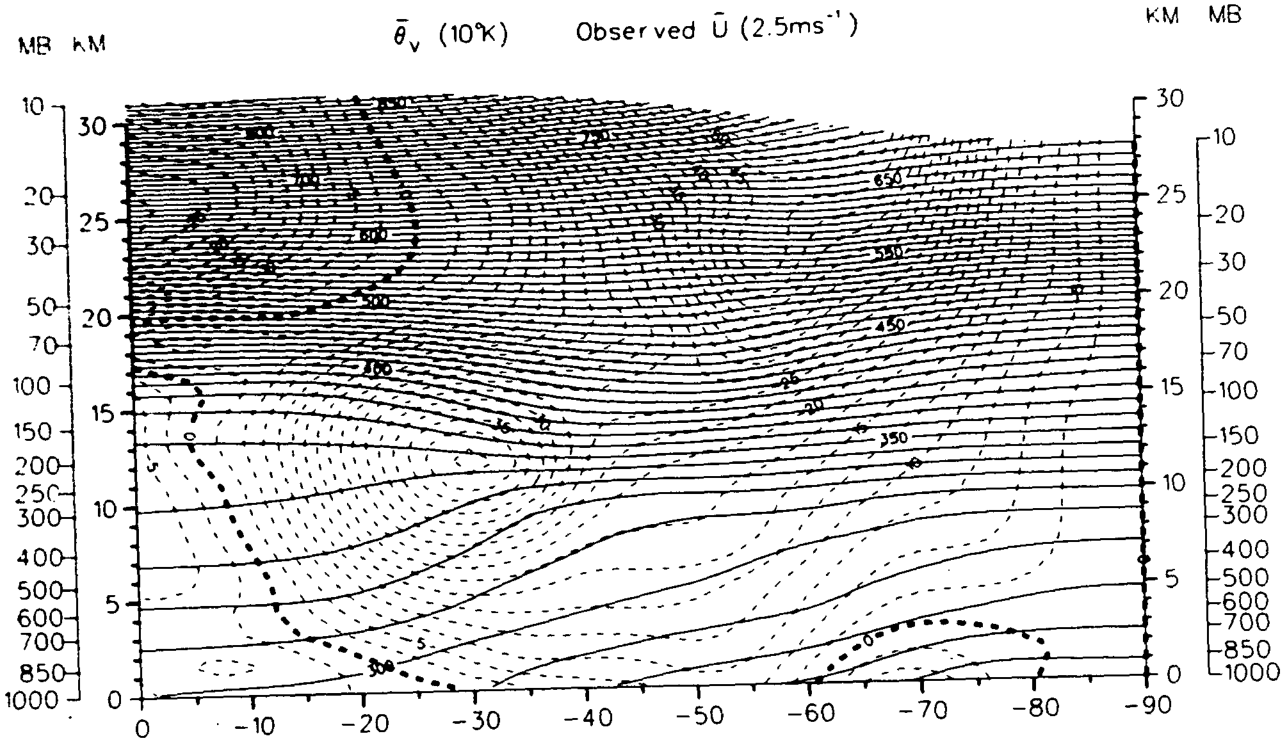
JULY 1974

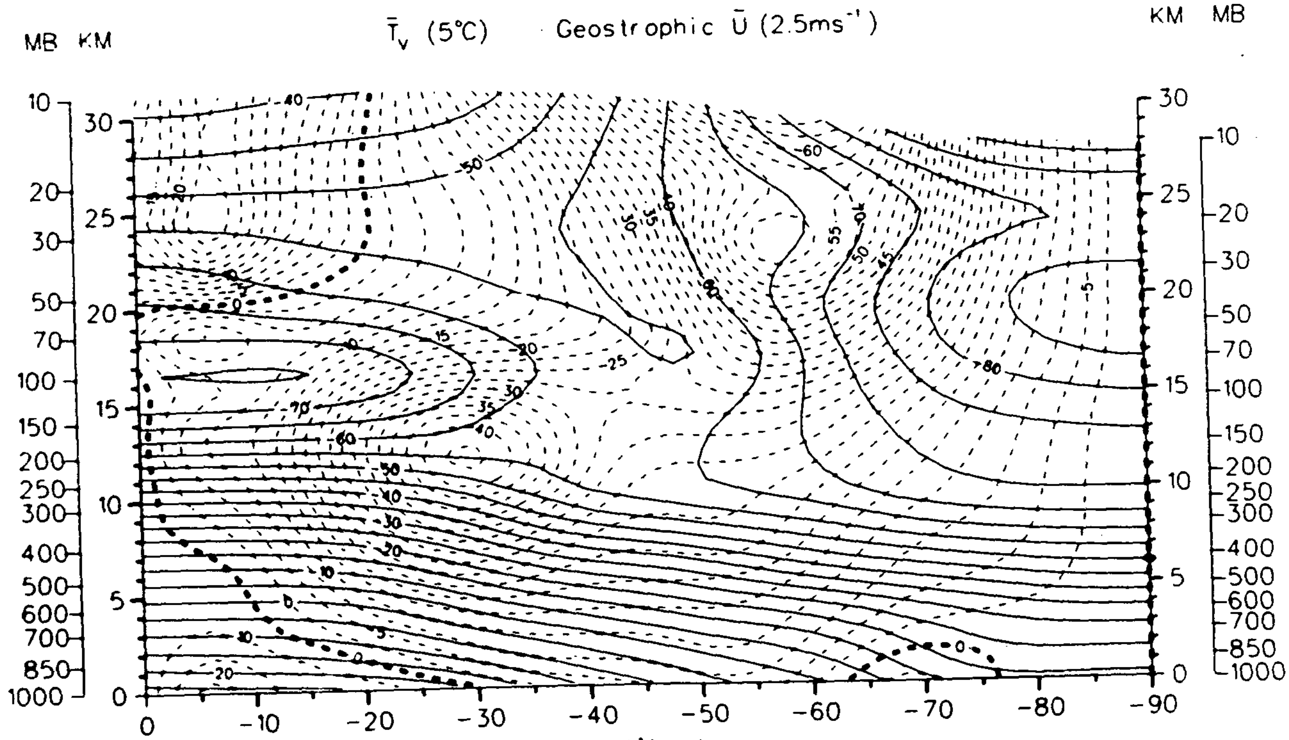




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

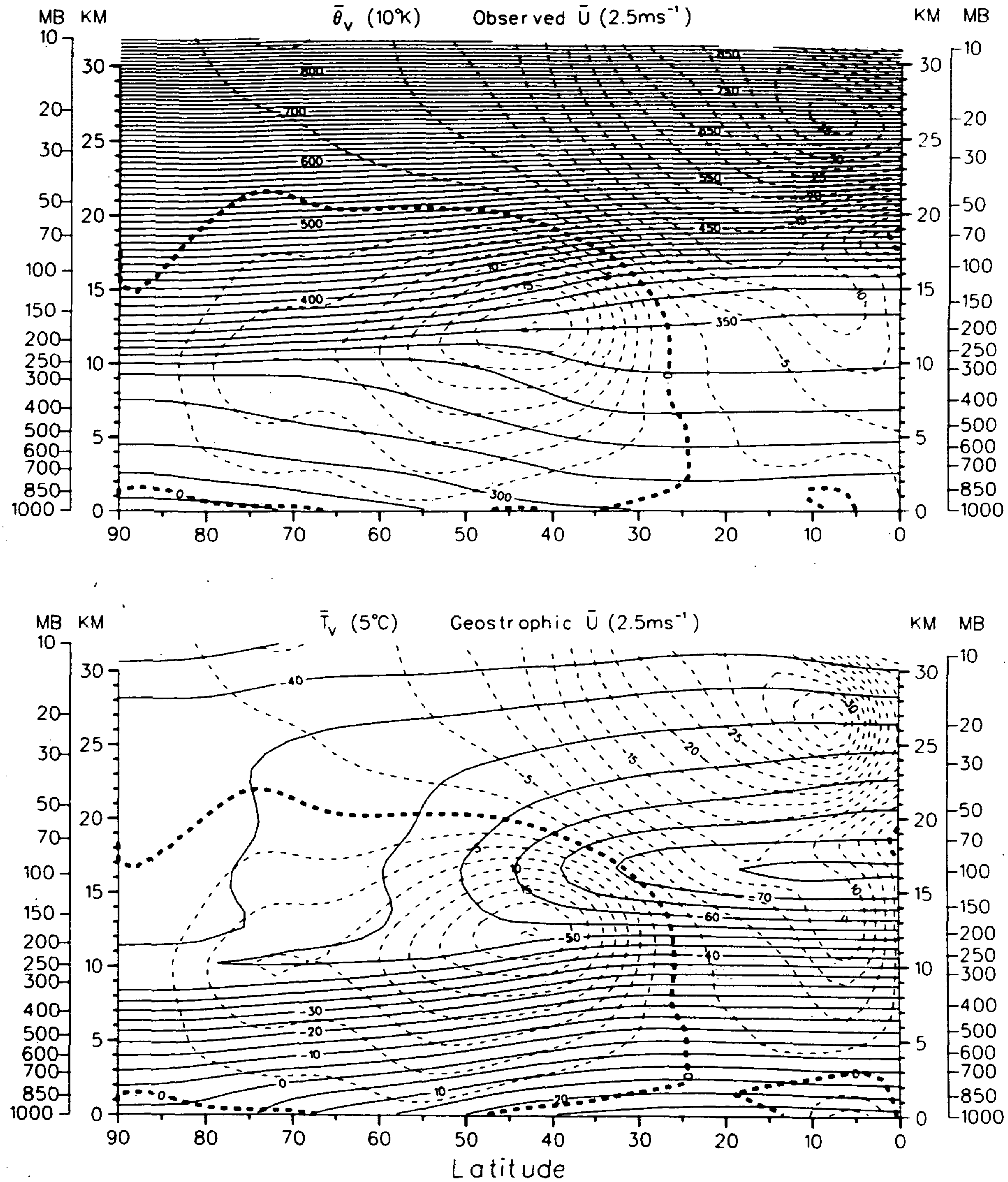
JULY 1974





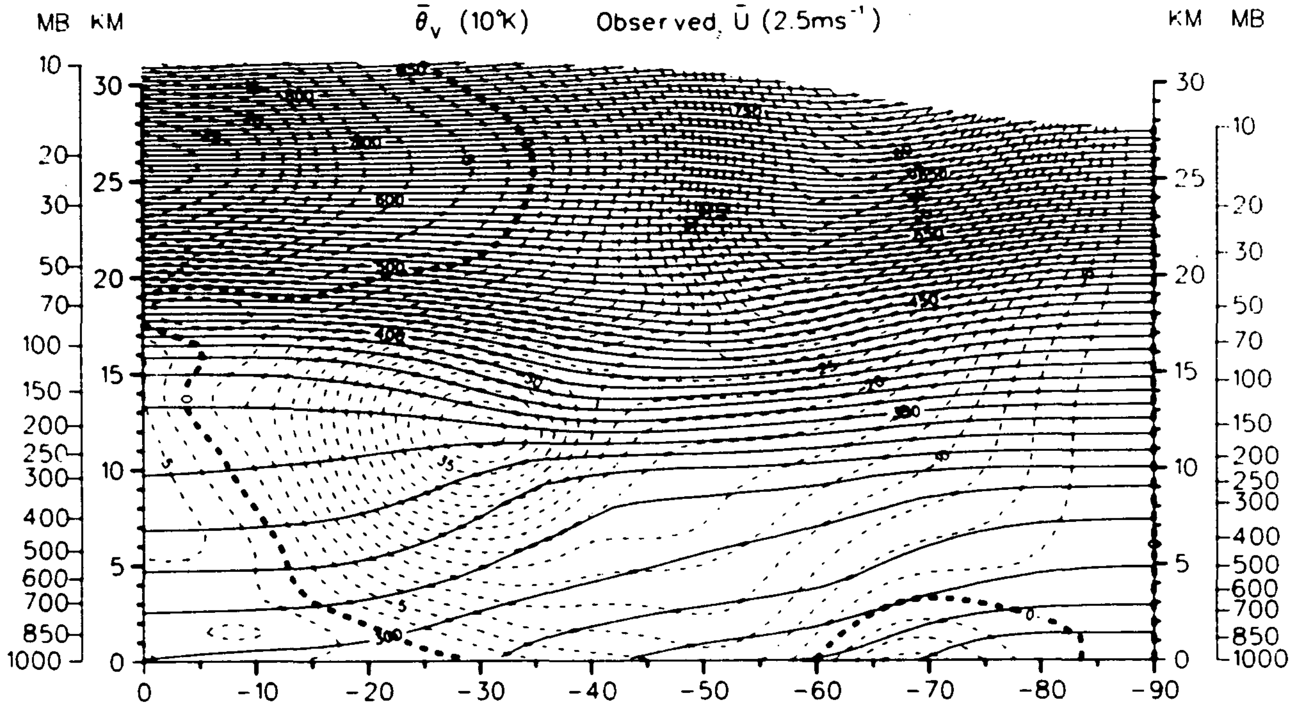
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

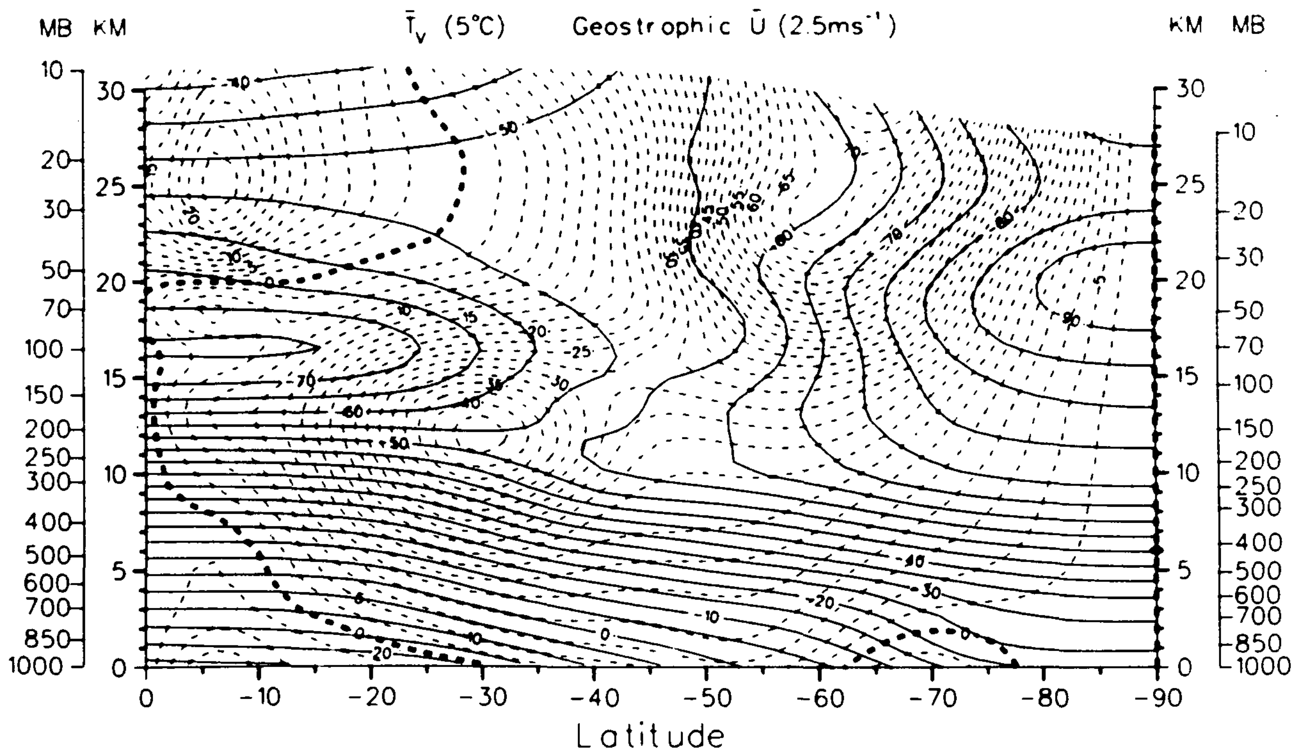
AUGUST 1974



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

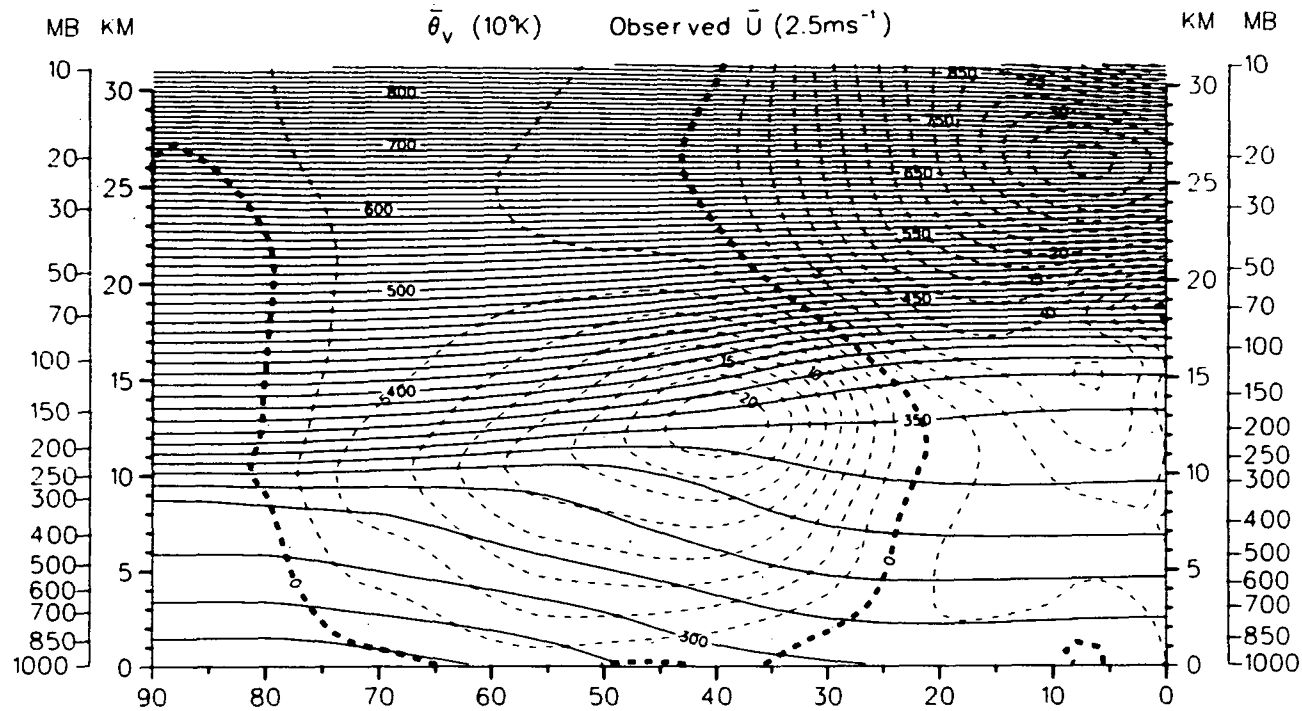
AUGUST 1974

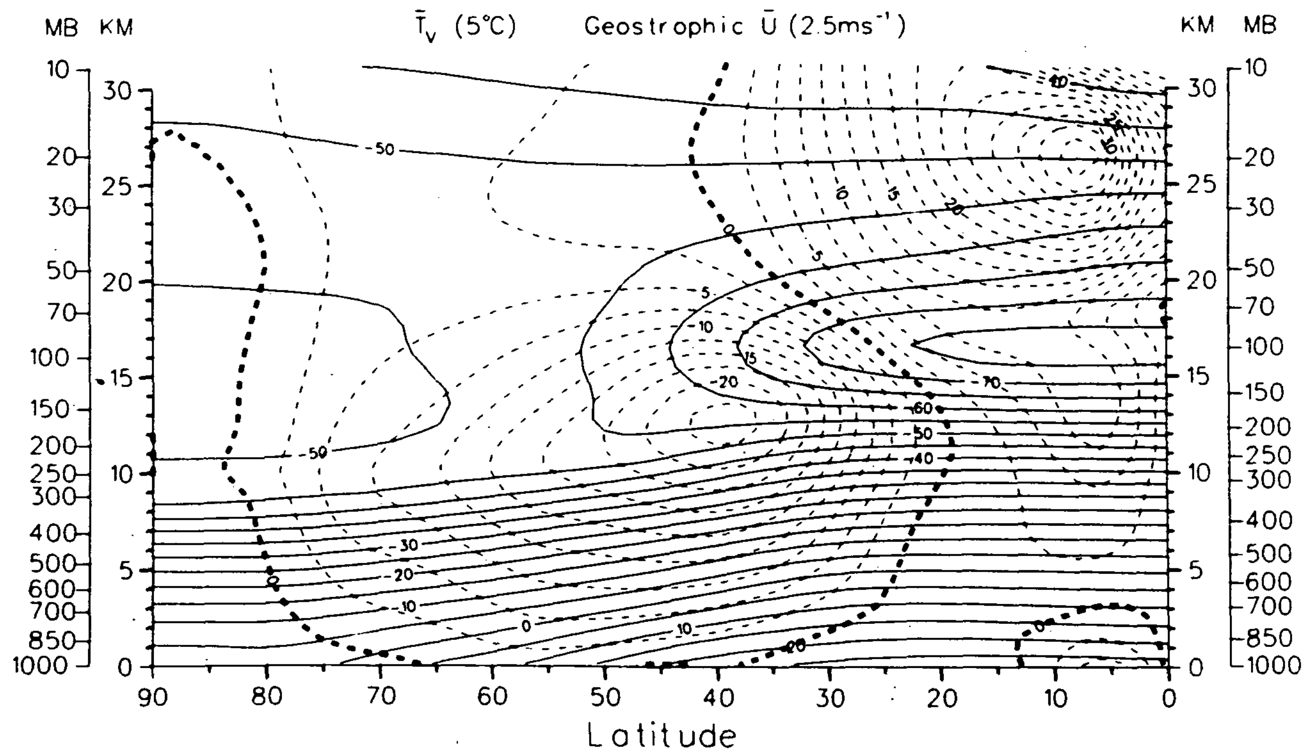




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

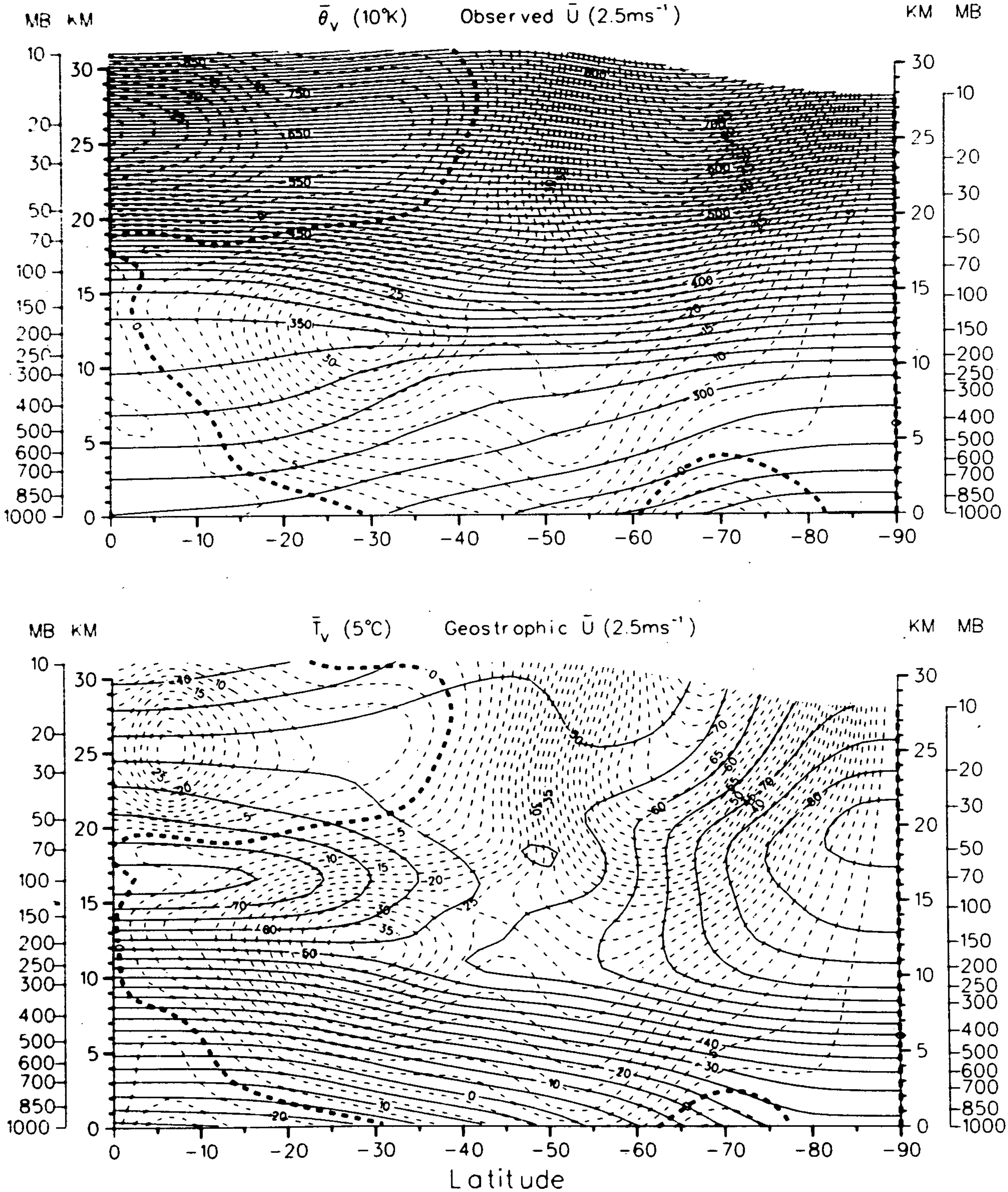
SEPTEMBER 1974





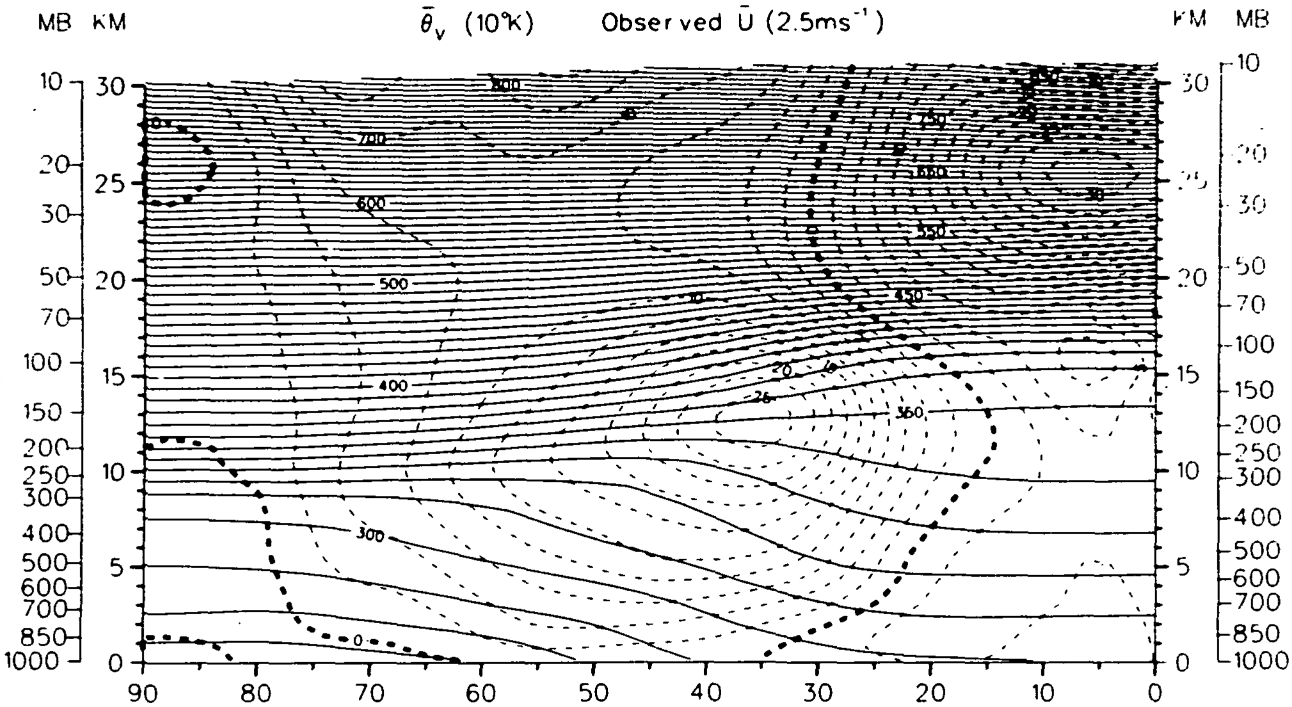
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

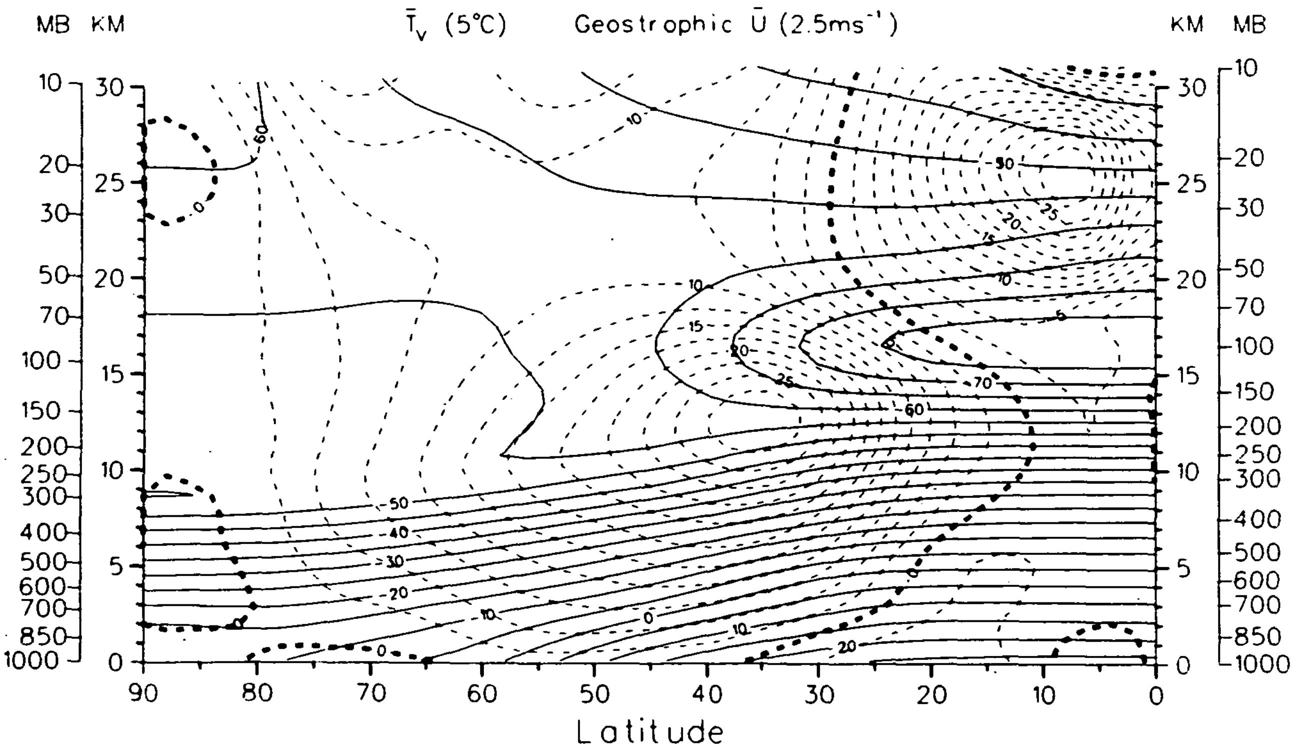
SEPTEMBER 1974



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

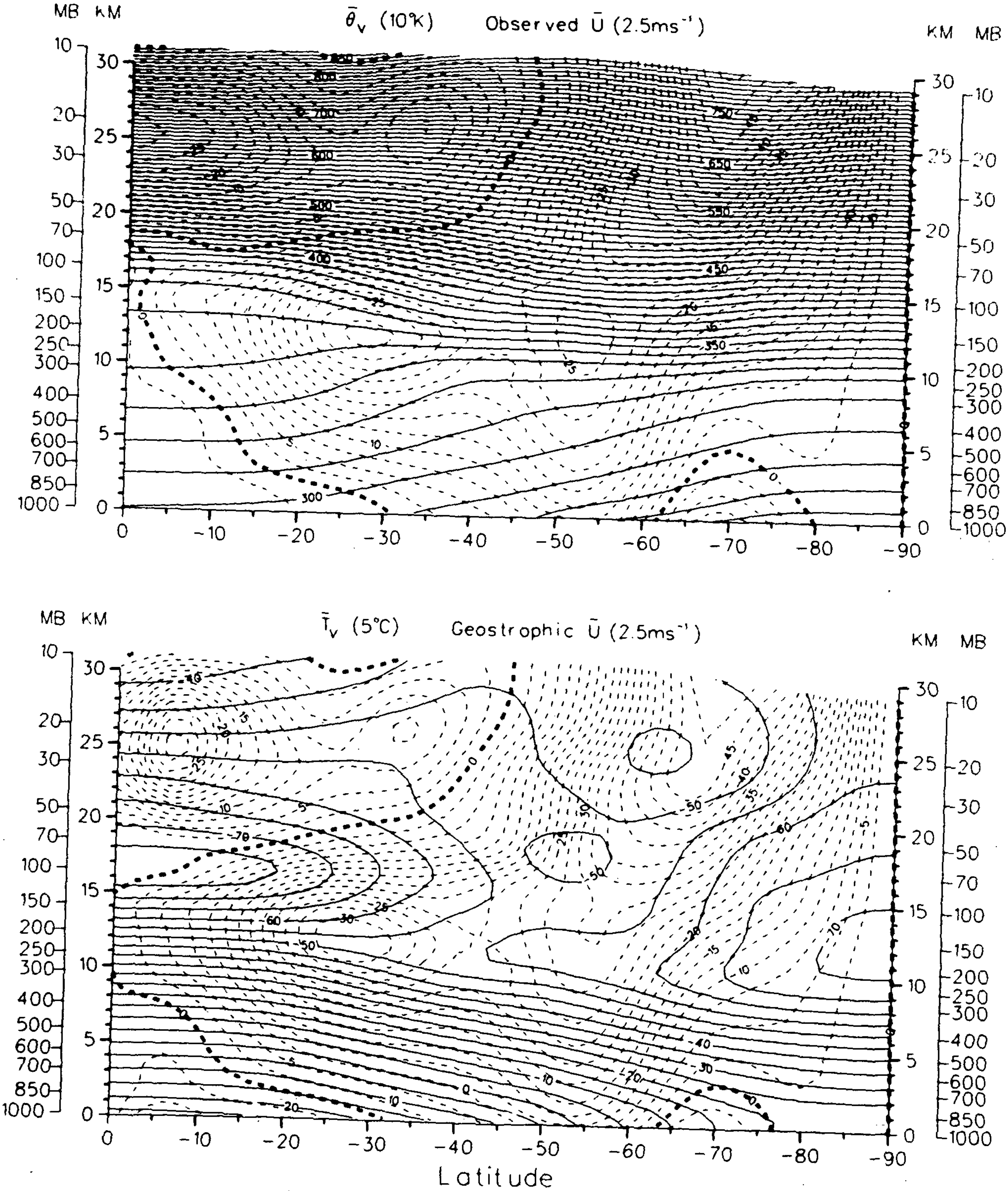
OCTOBER 1974





SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

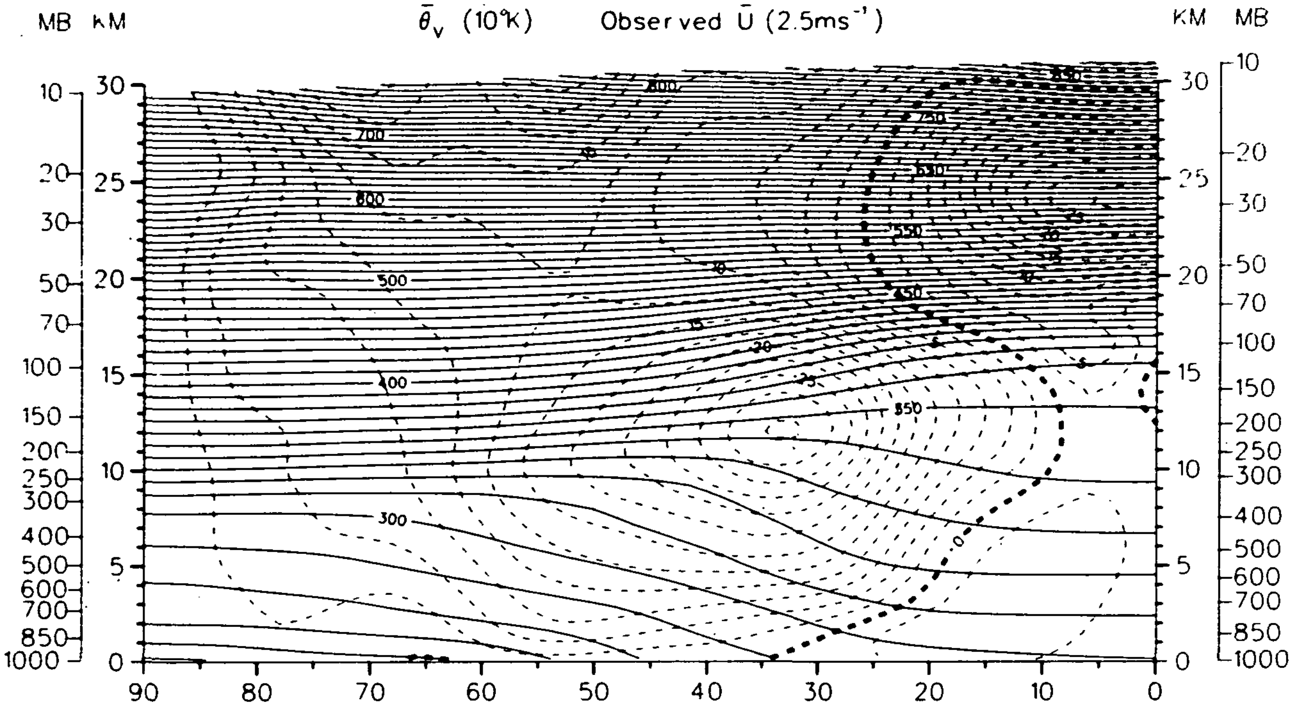
OCTOBER 1974



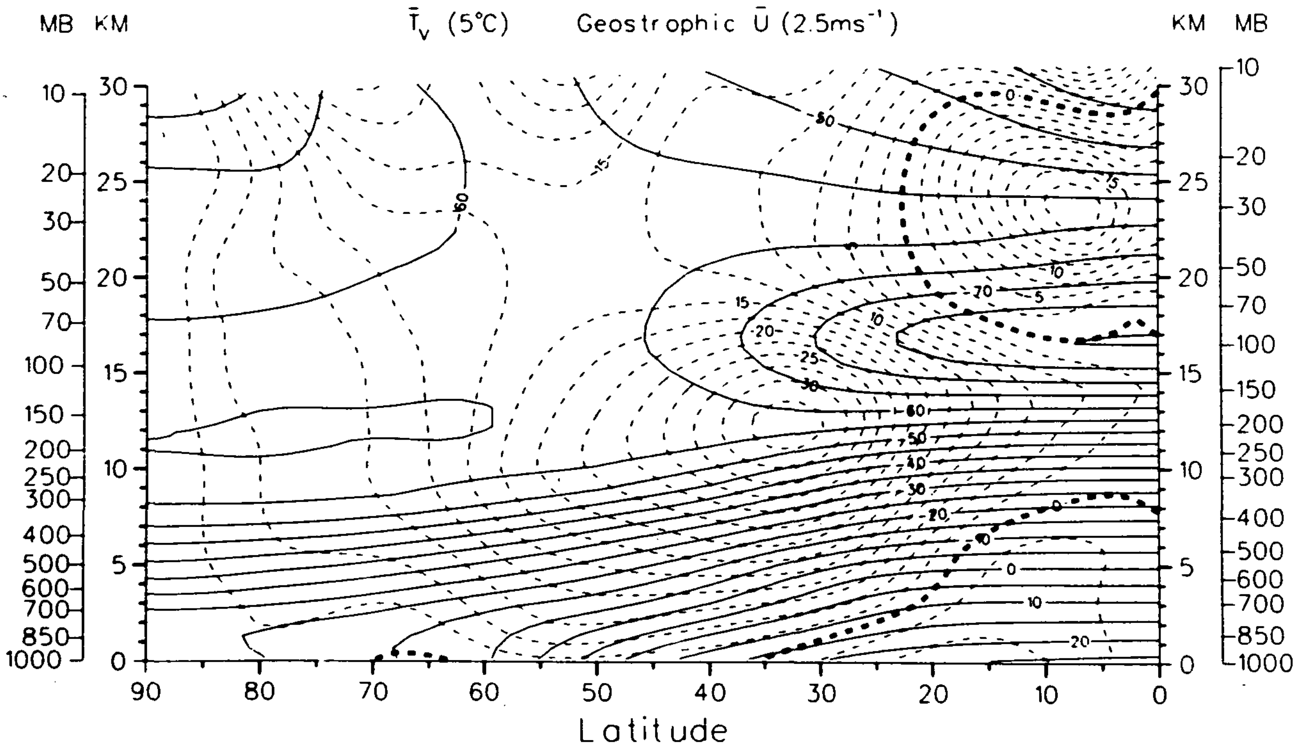
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

NOVEMBER 1974

$\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1})



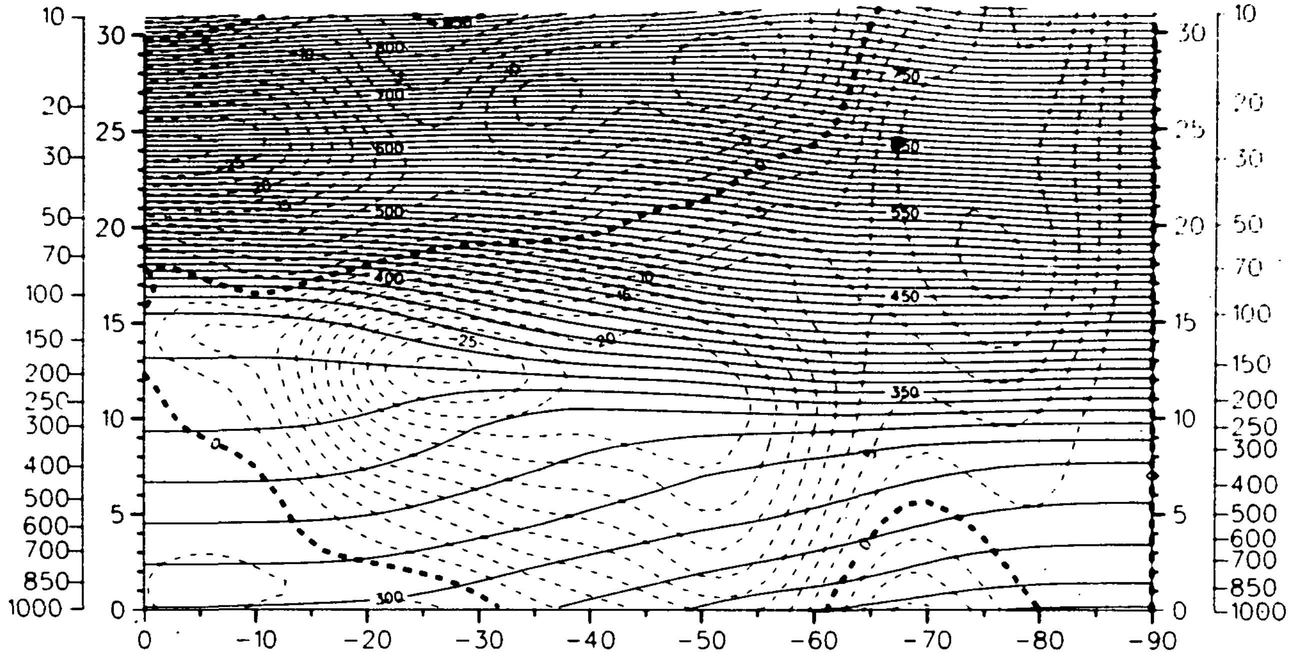
$\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1})



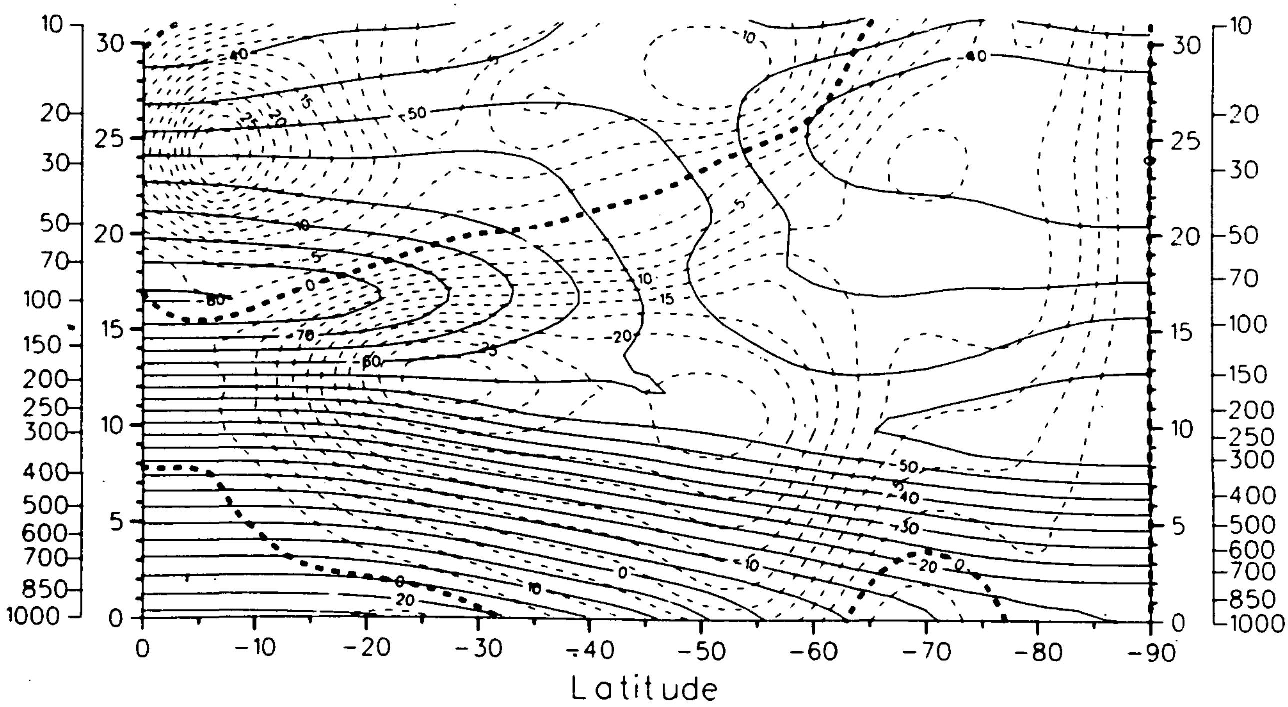
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

NOVEMBER 1974

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB

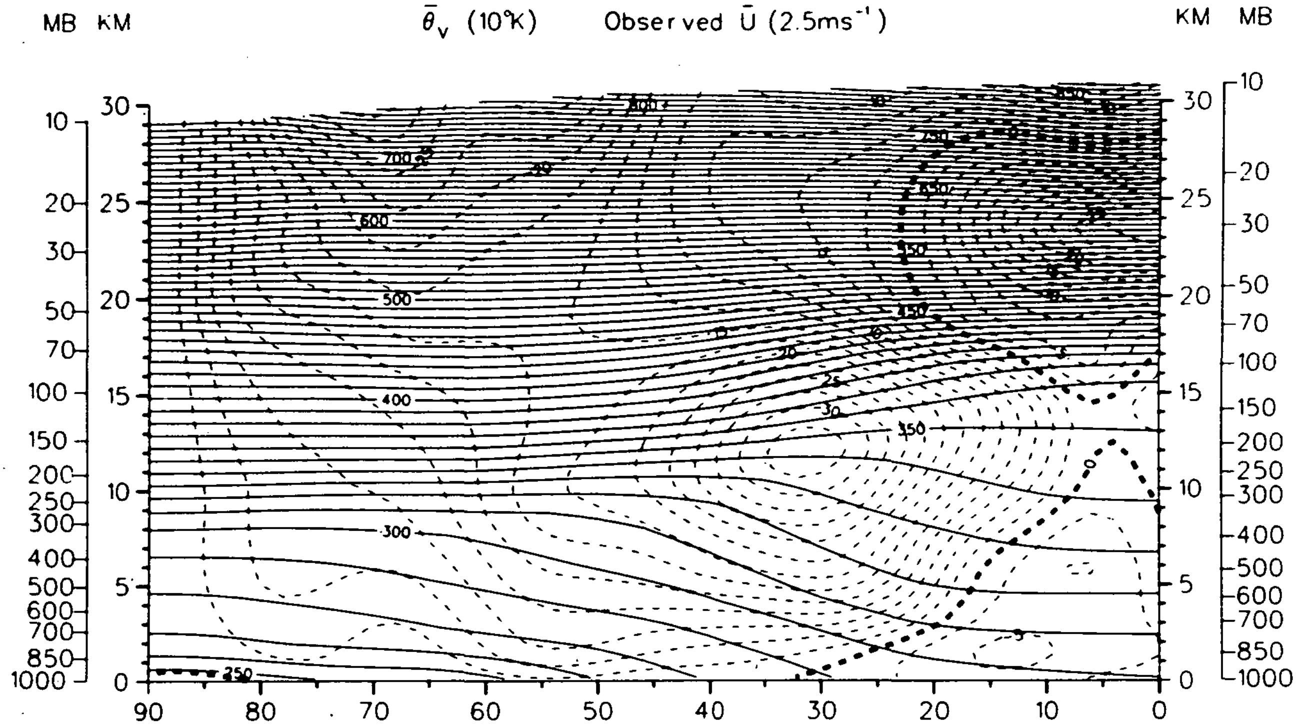


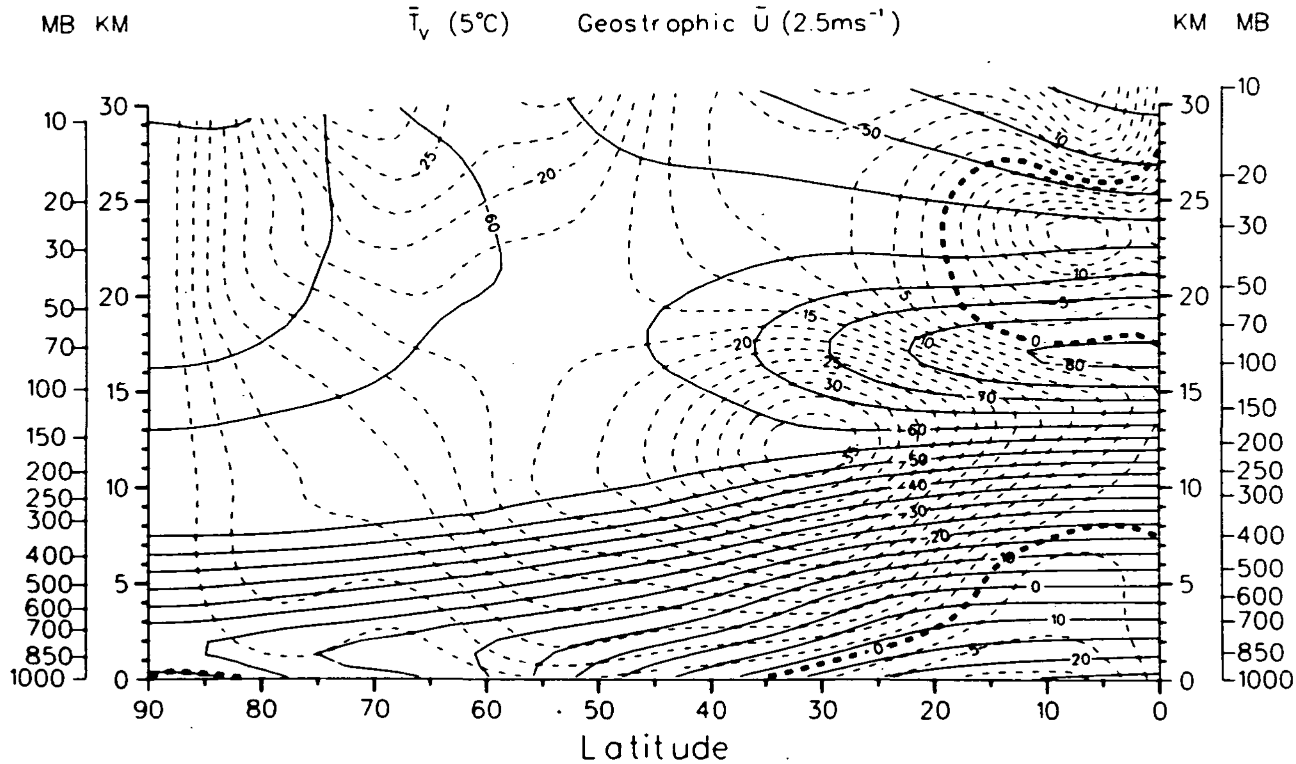
MB KM $\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1}) KM MB



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

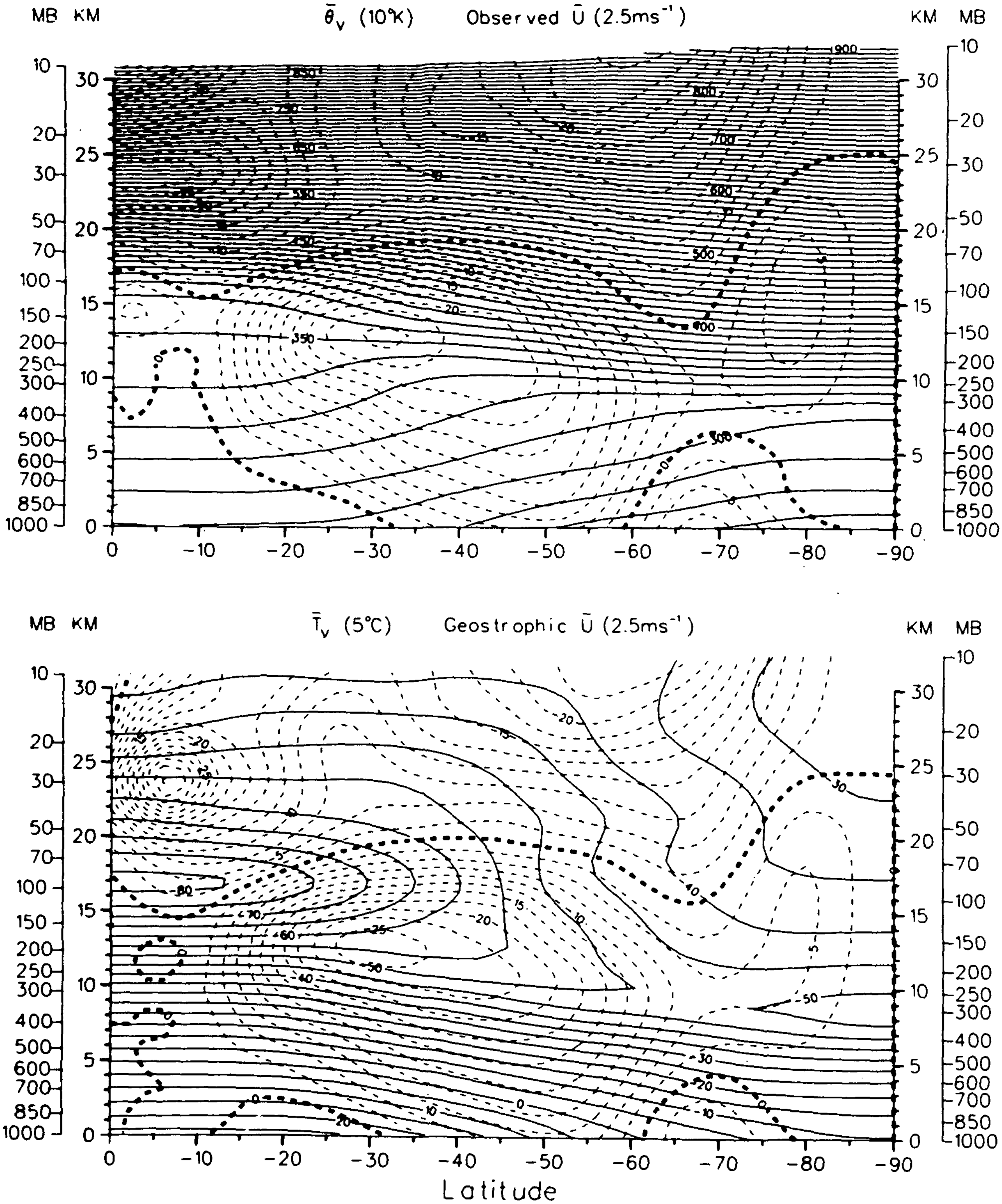
DECEMBER 1974





SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

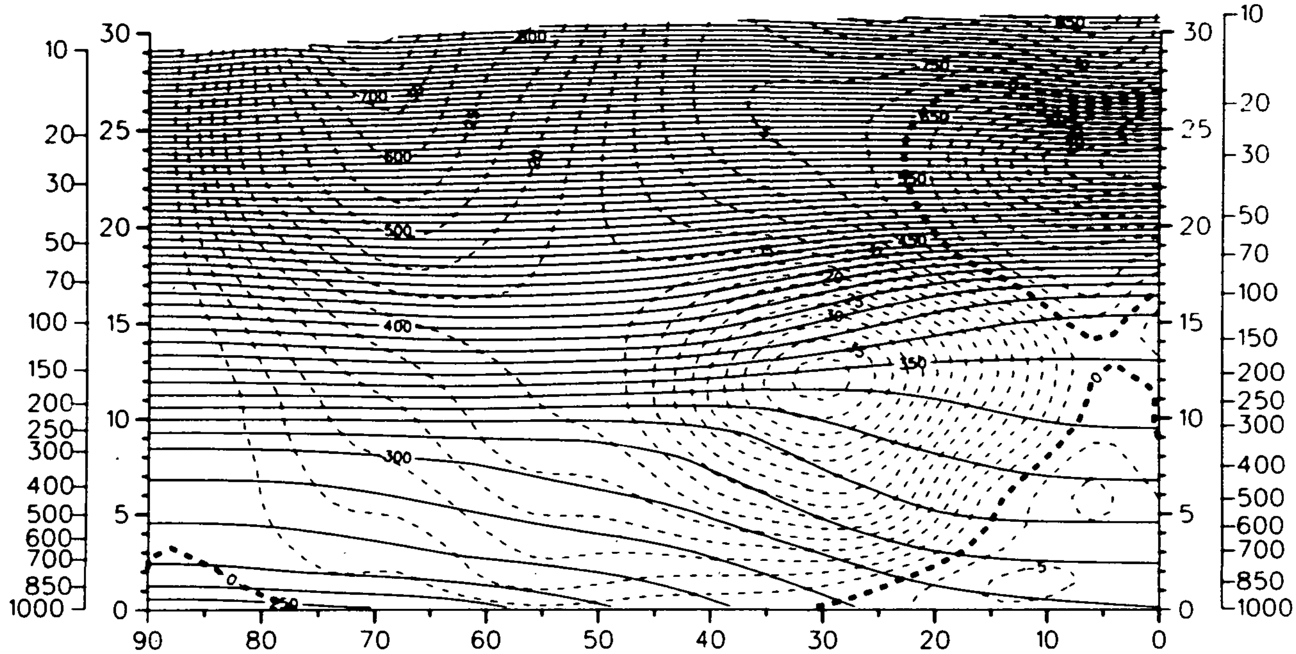
DECEMBER 1974



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JANUARY 1975

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB



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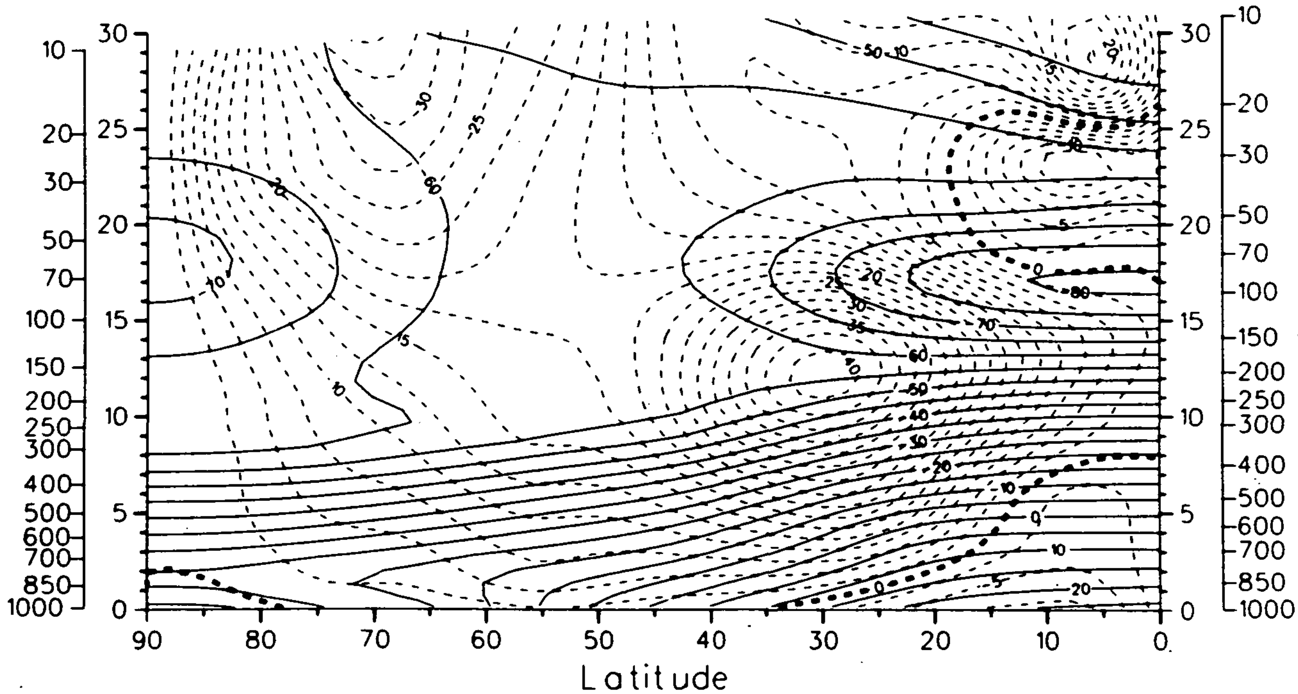
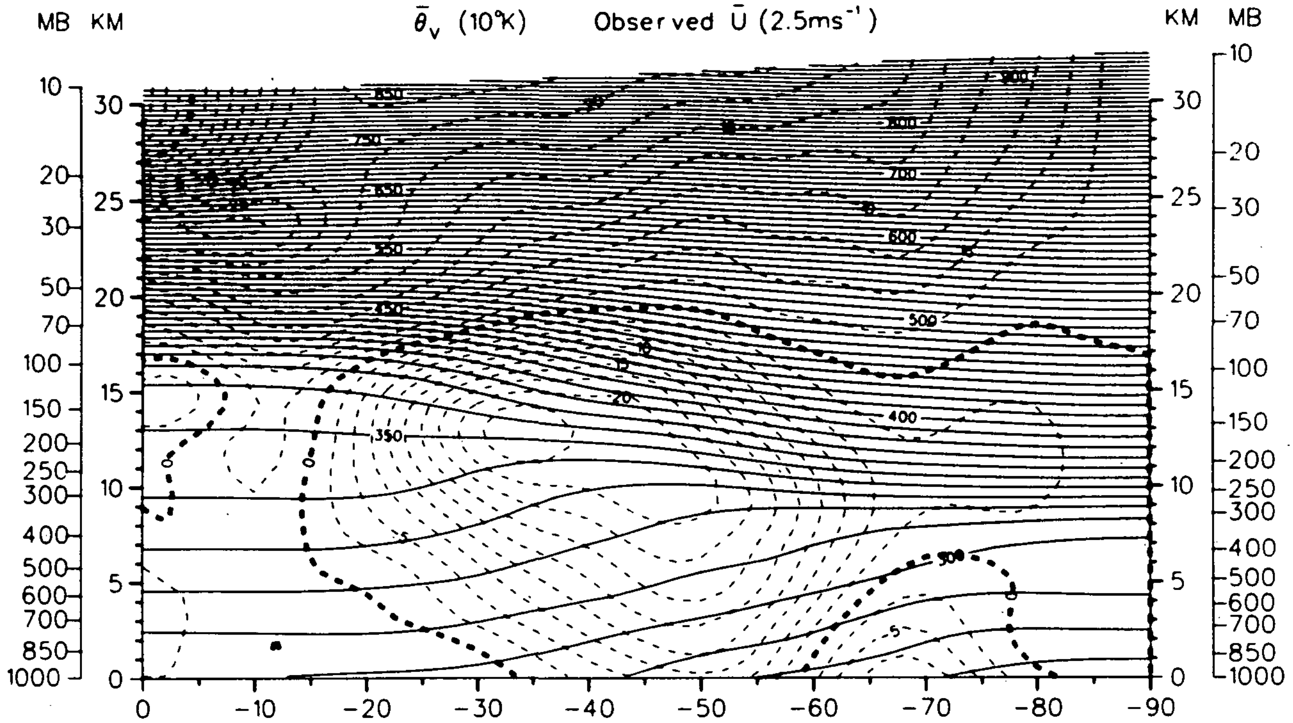
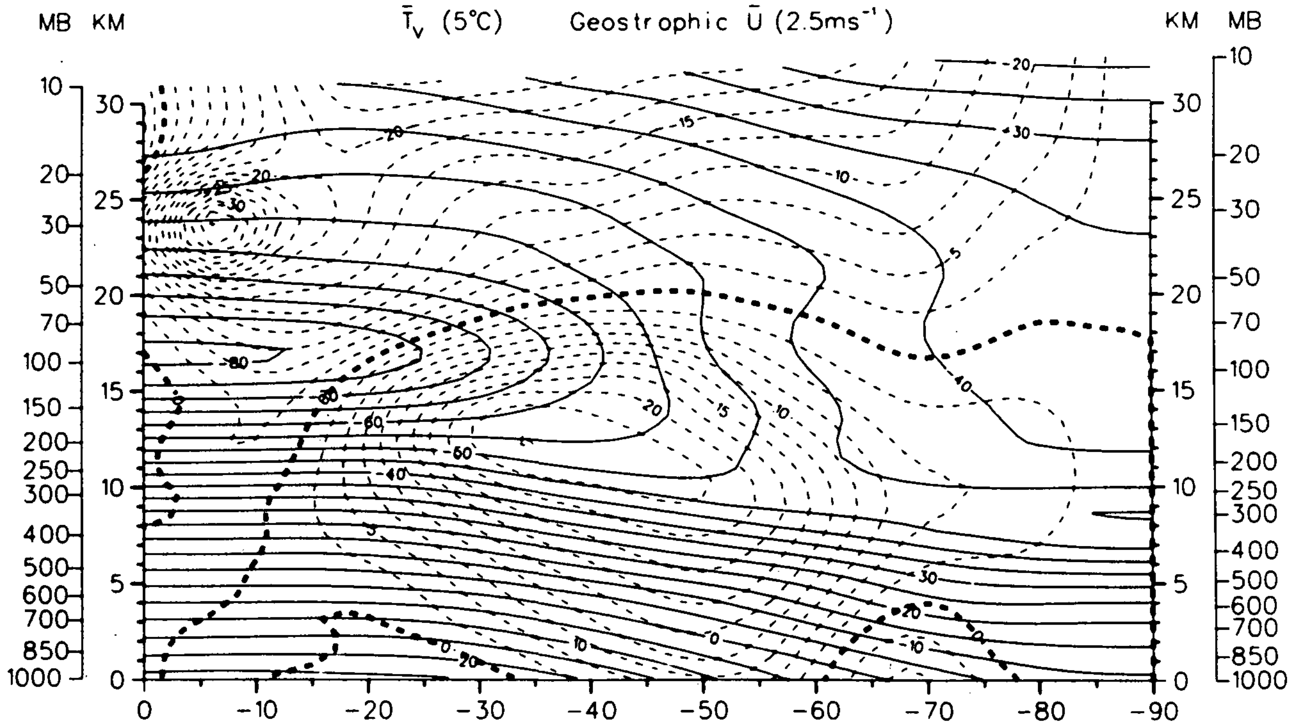


SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

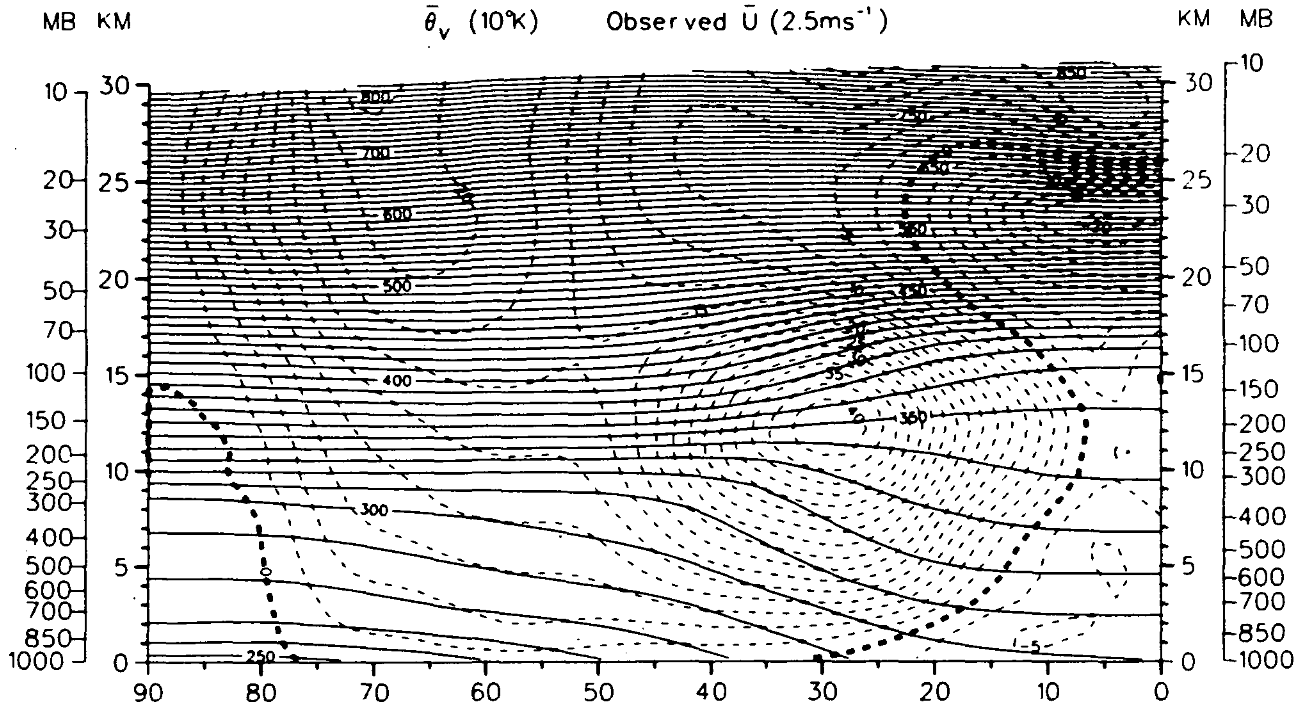
JANUARY 1975

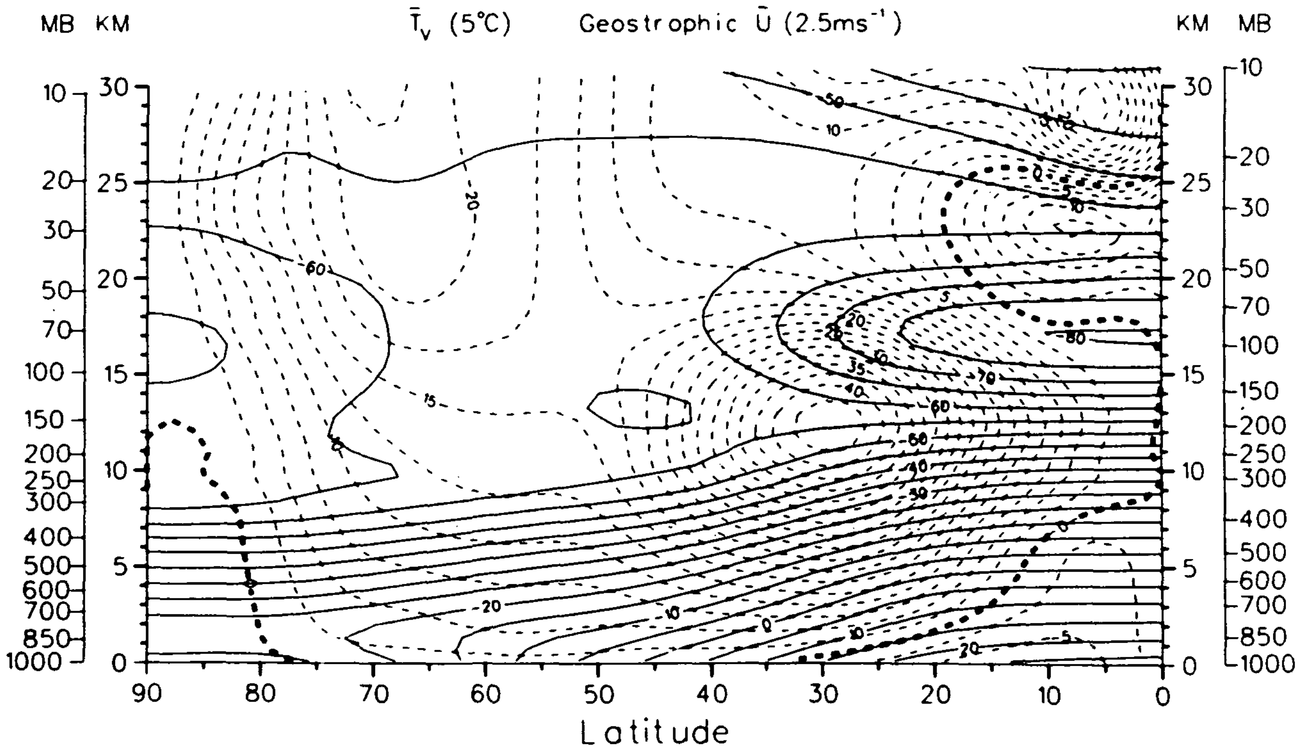




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

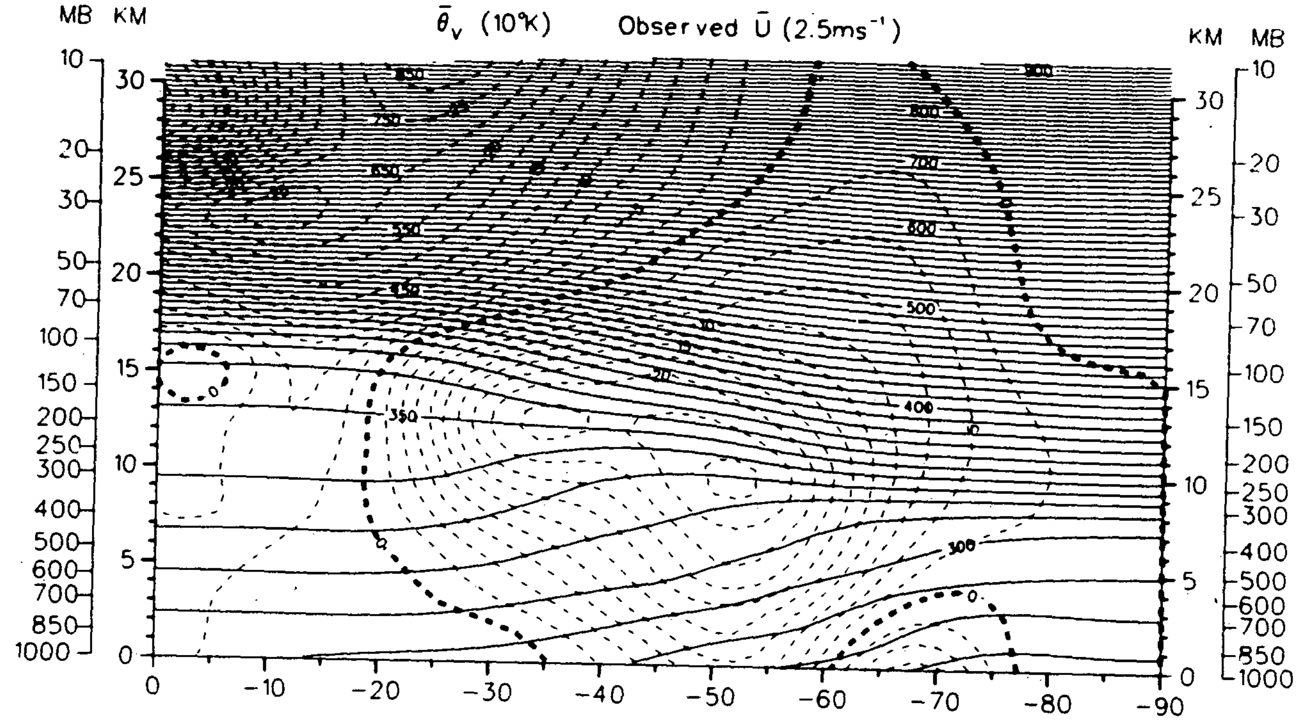
FEBRUARY 1975

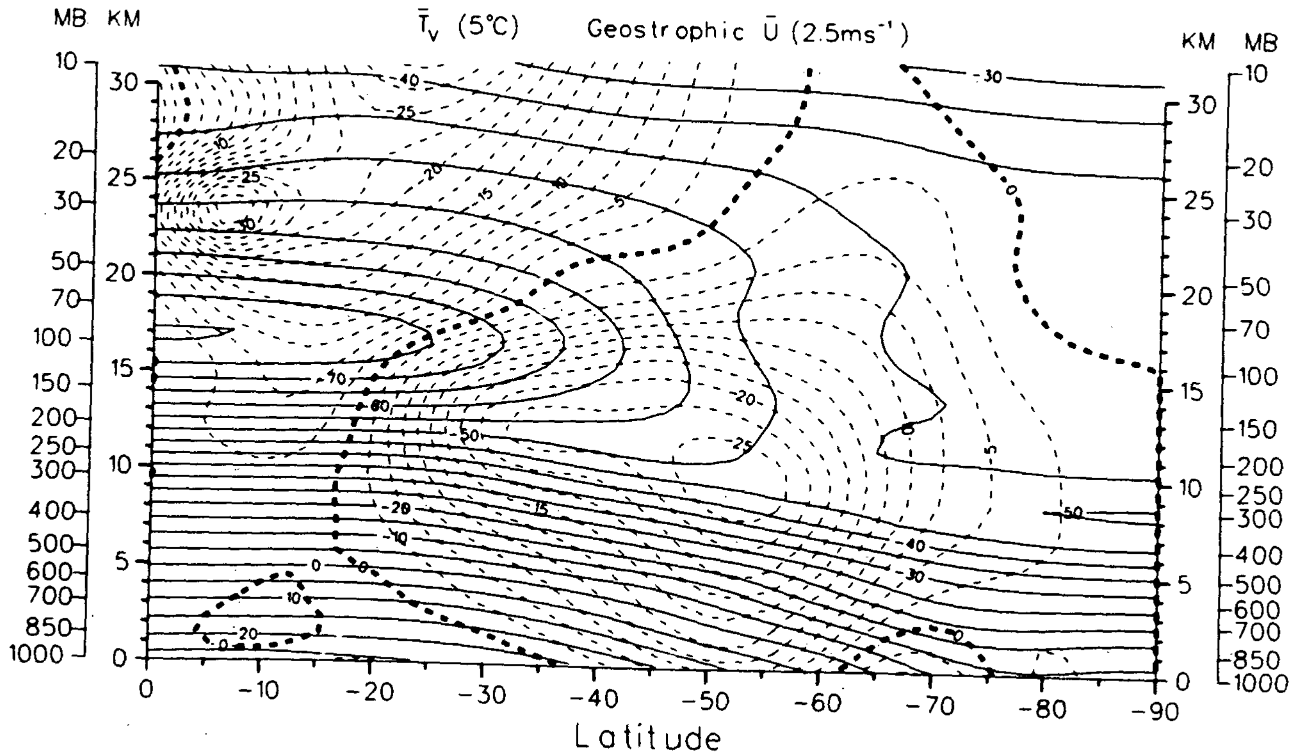




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

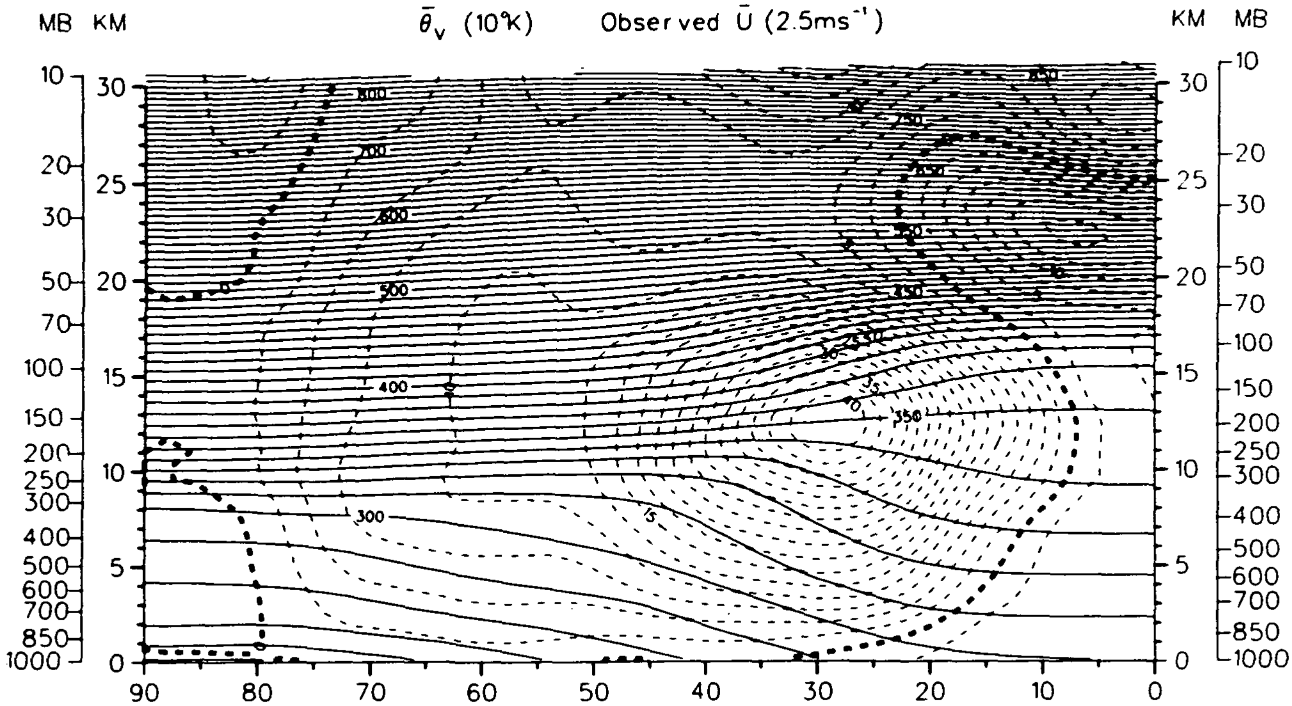
FEBRUARY 1975

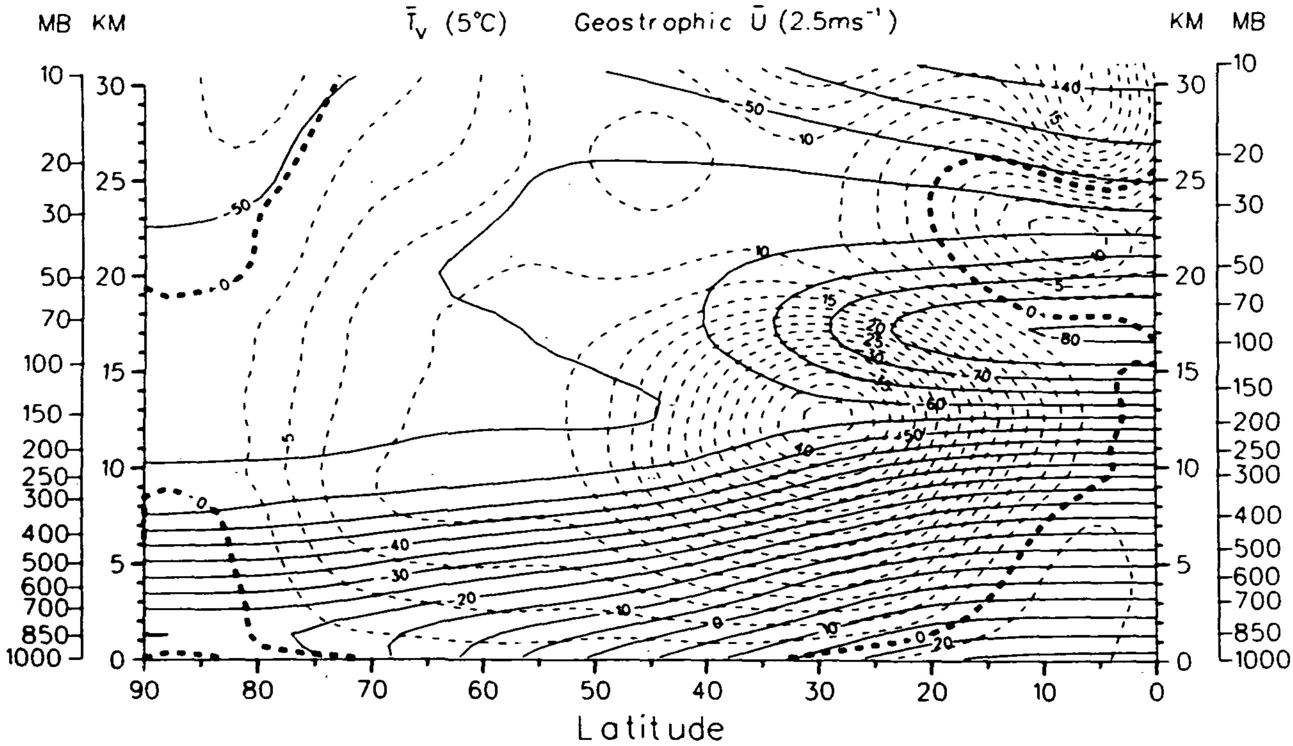




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

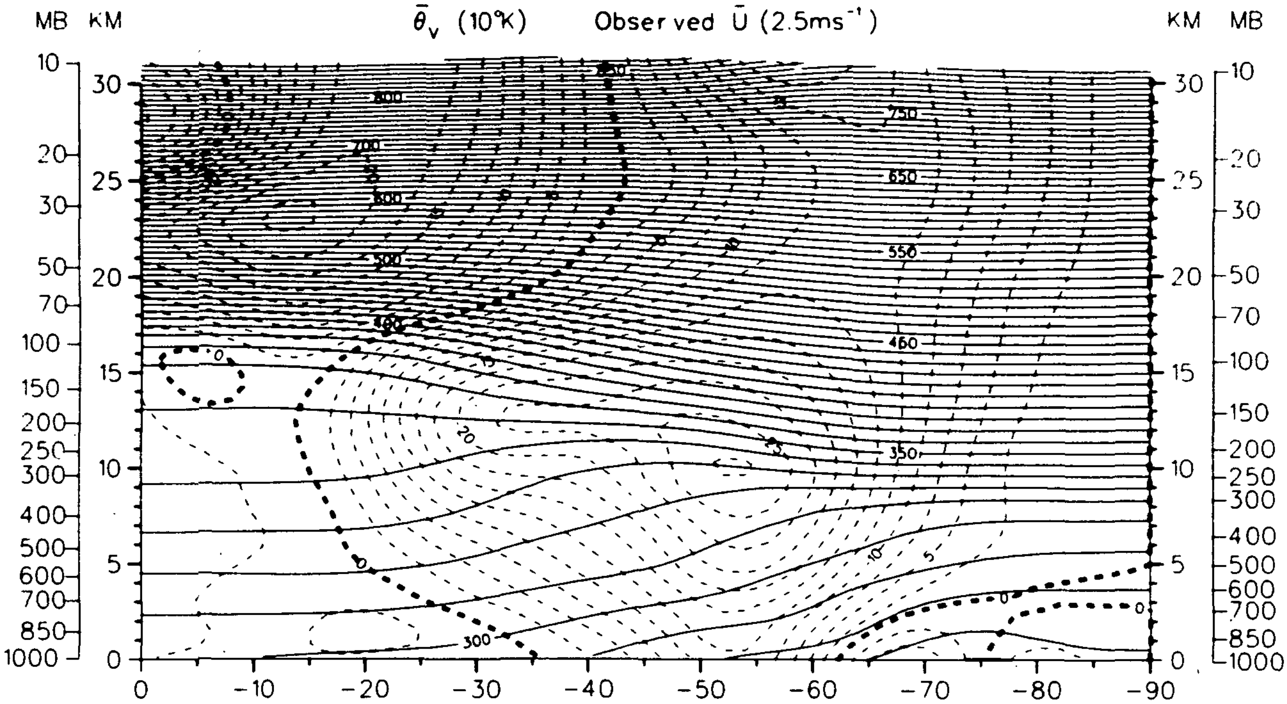
MARCH 1975

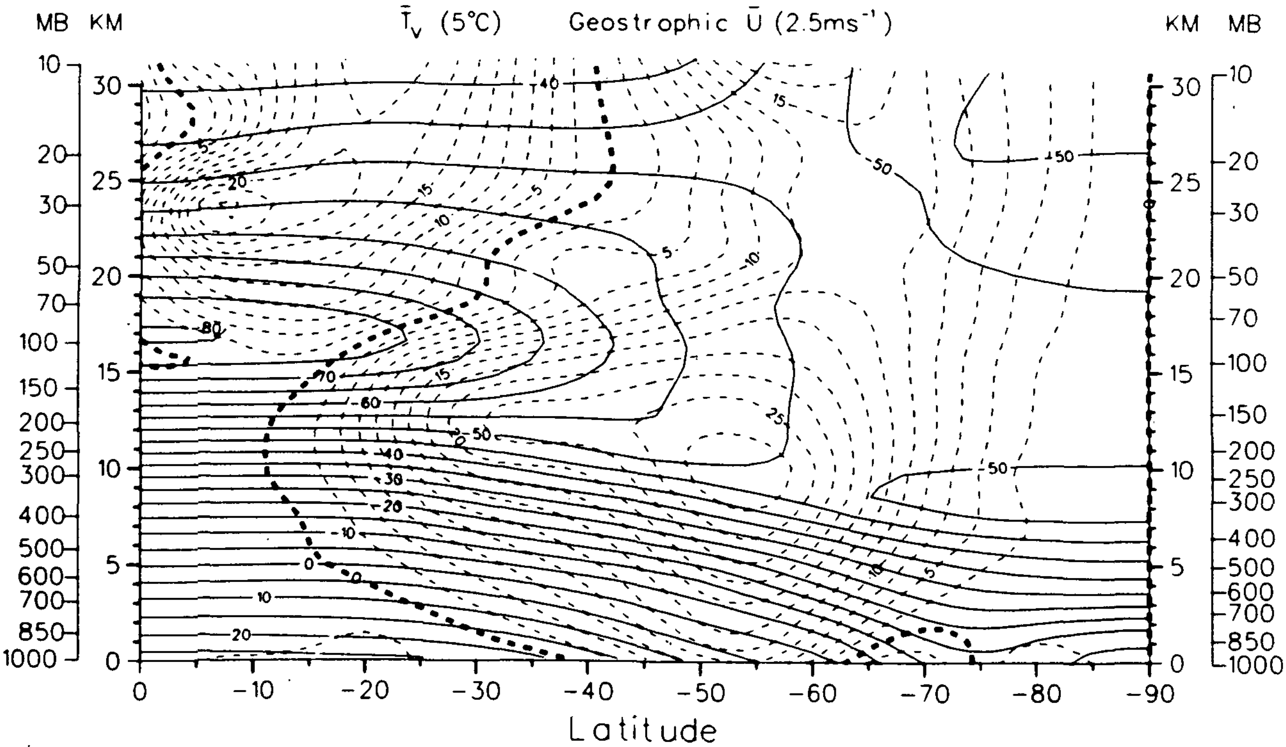




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

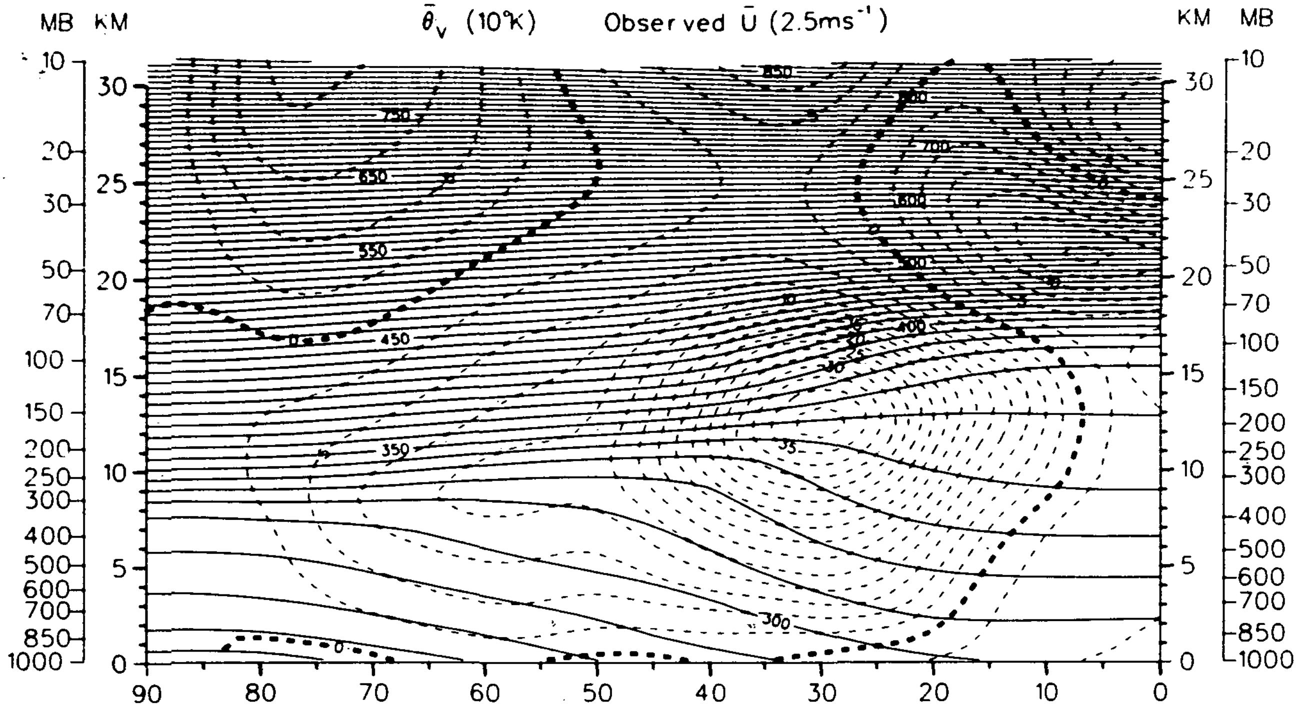
MARCH 1975

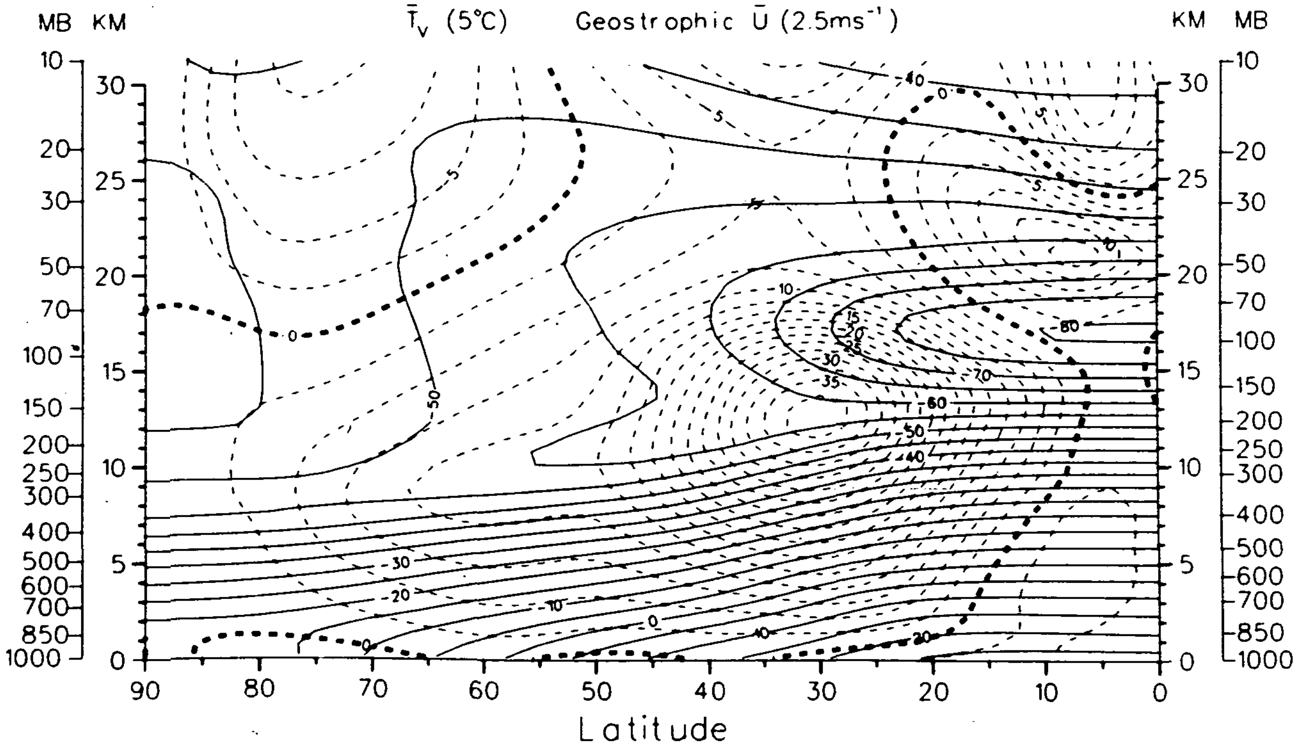




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

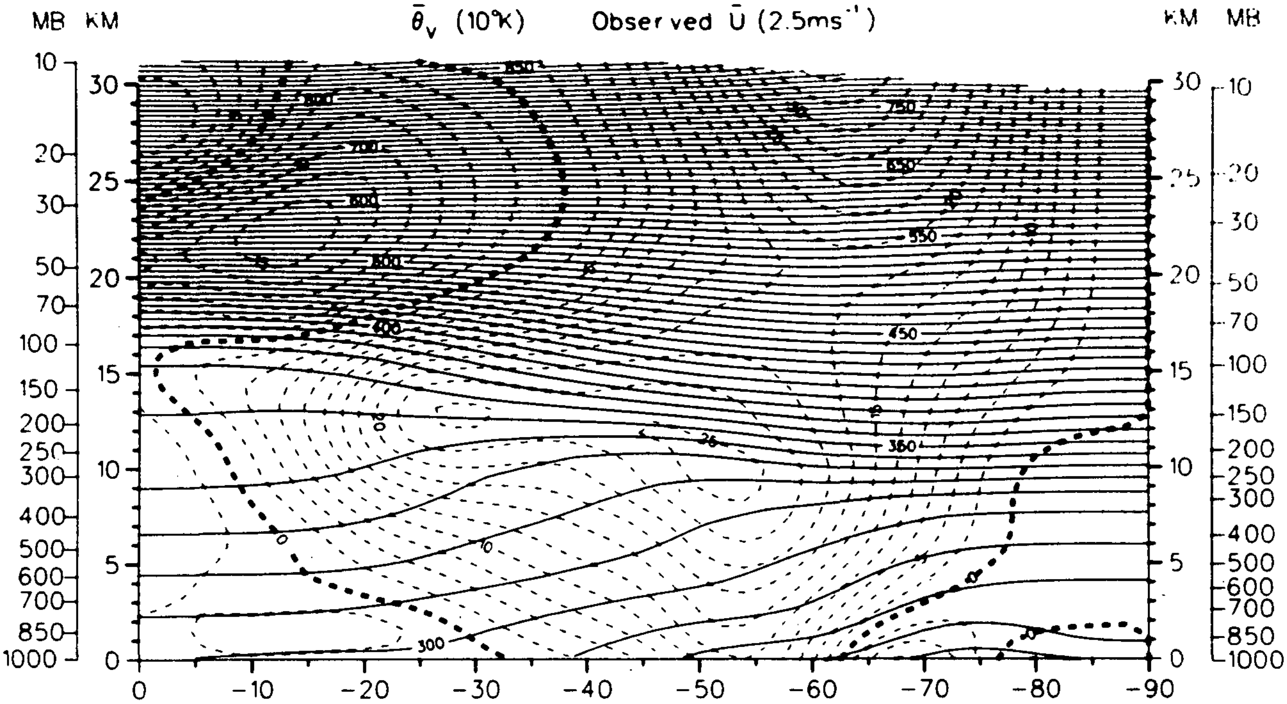
APRIL 1975

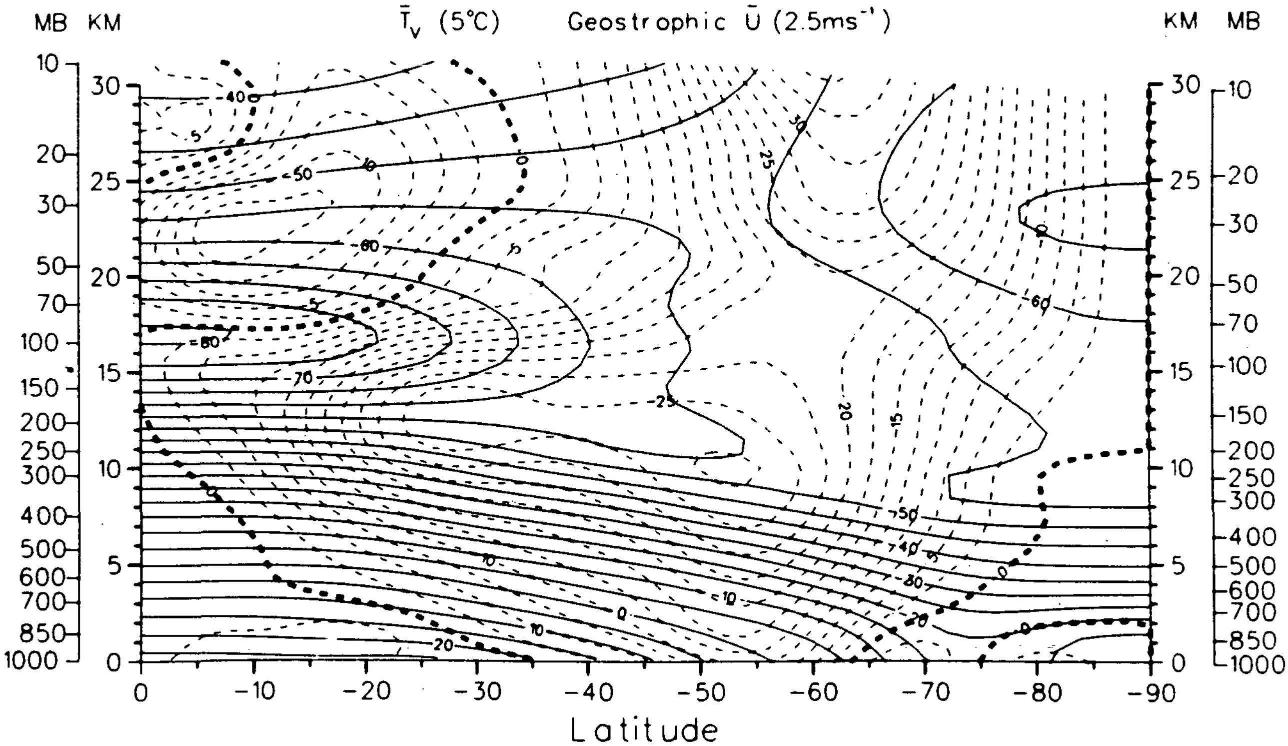




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

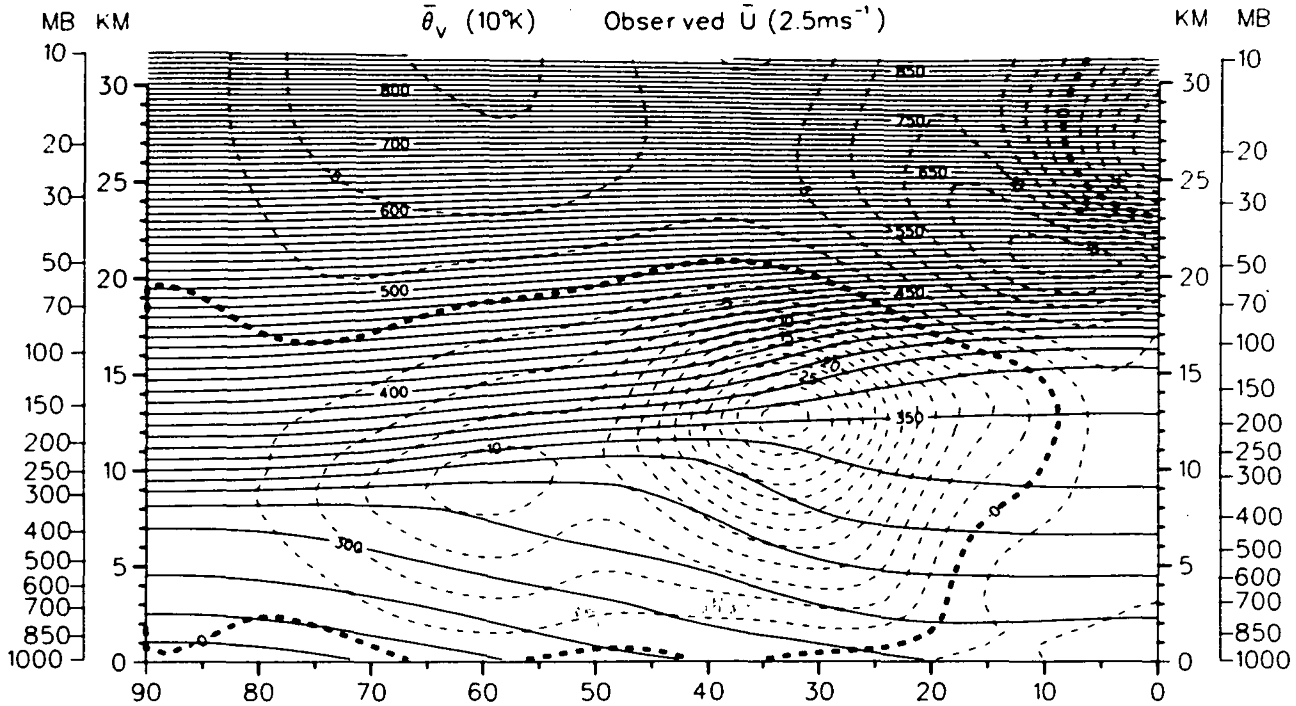
APRIL 1975

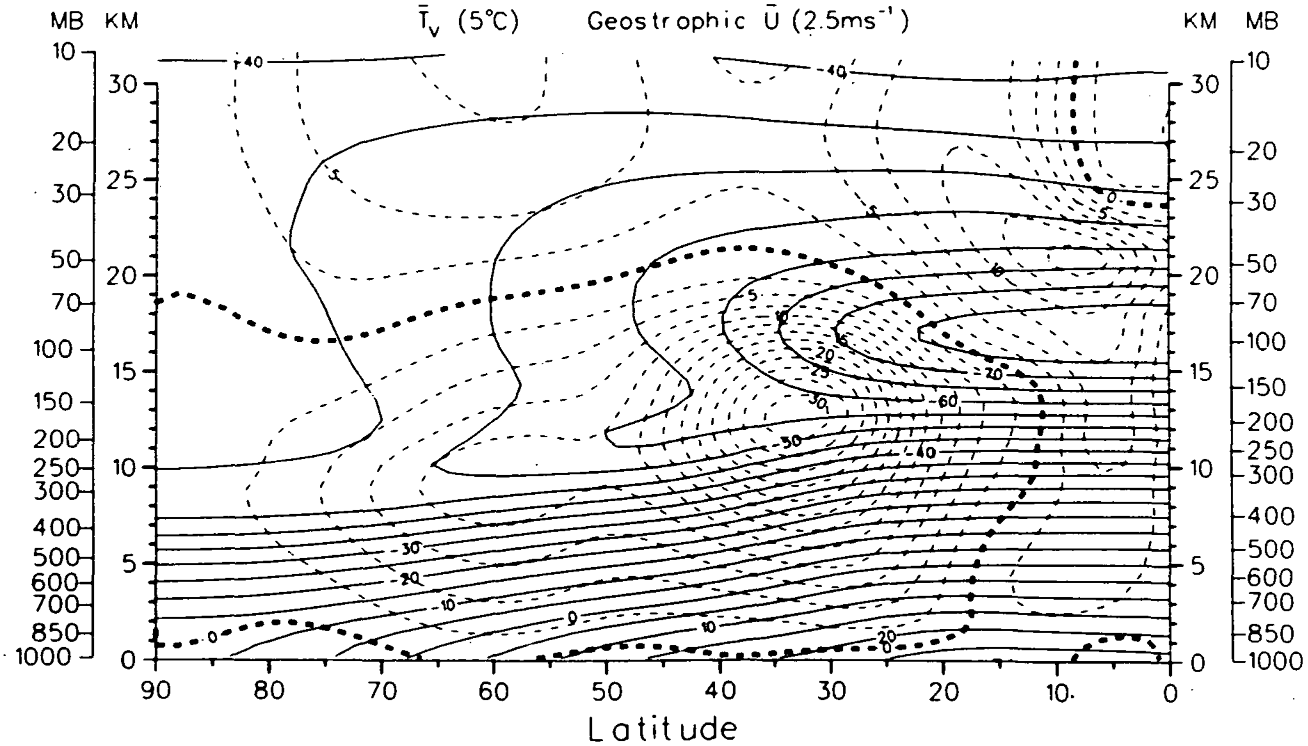




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

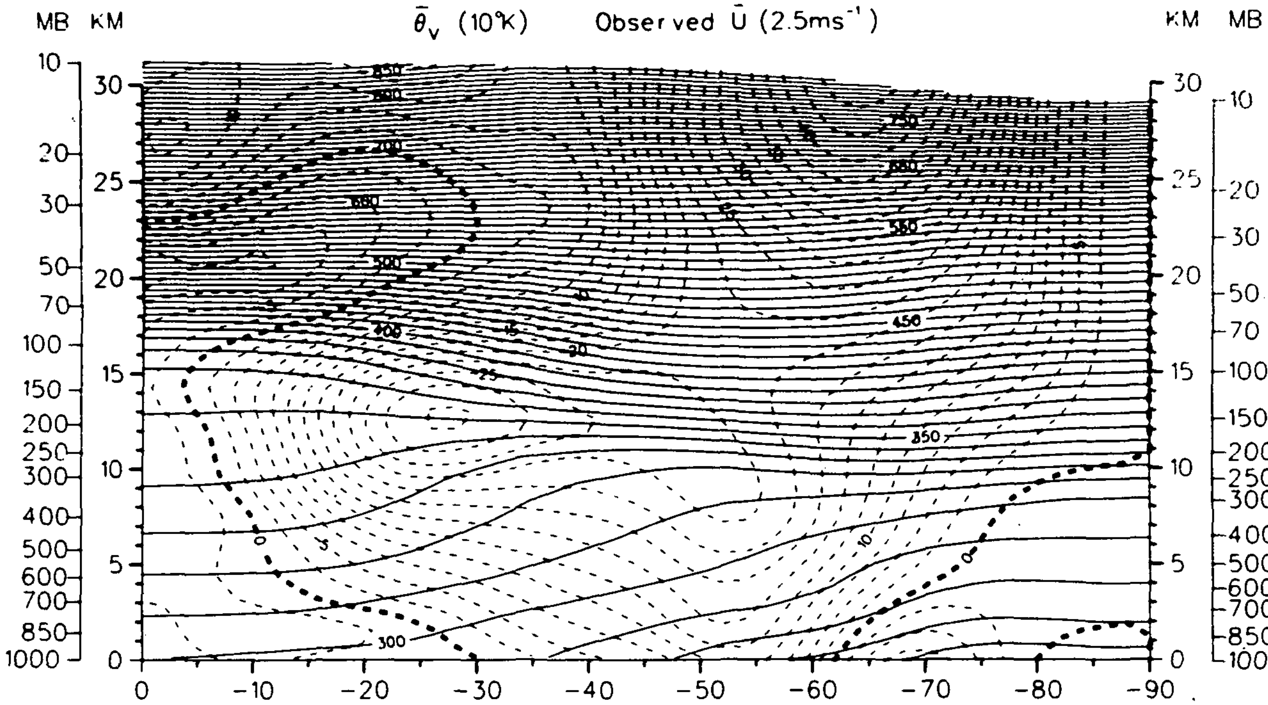
MAY 1975

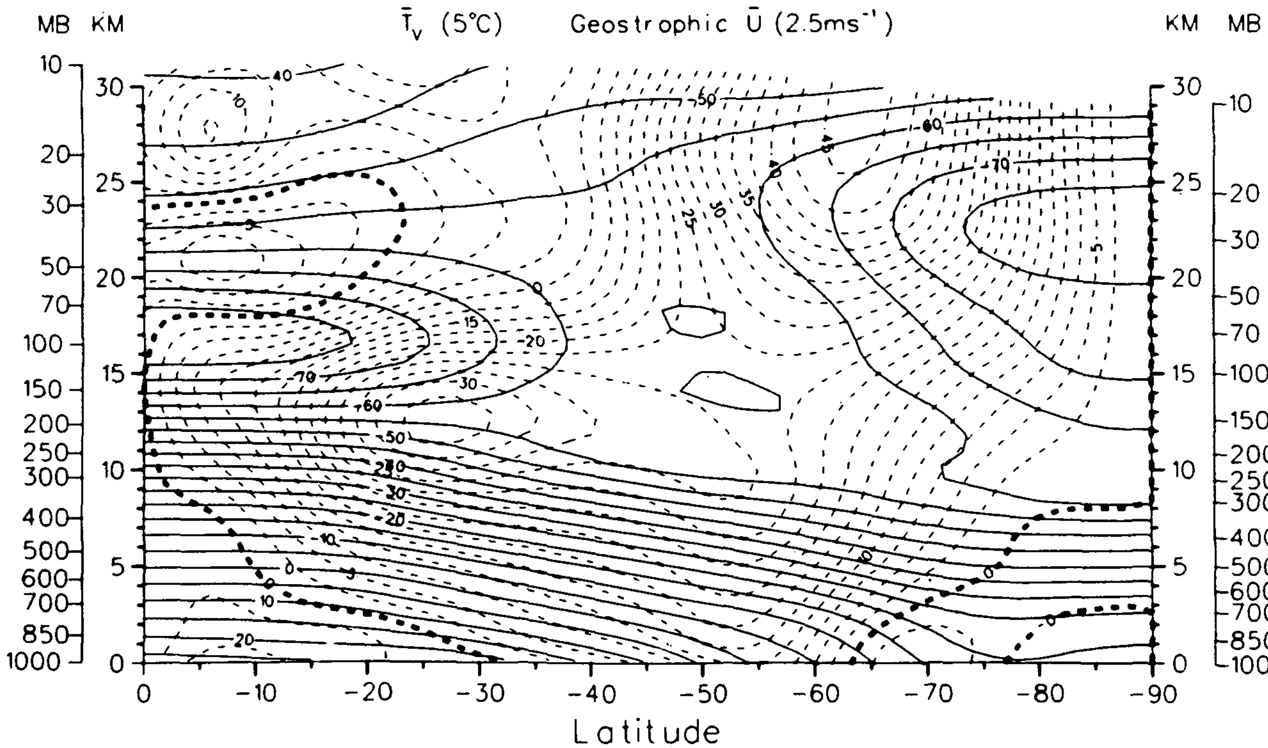




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

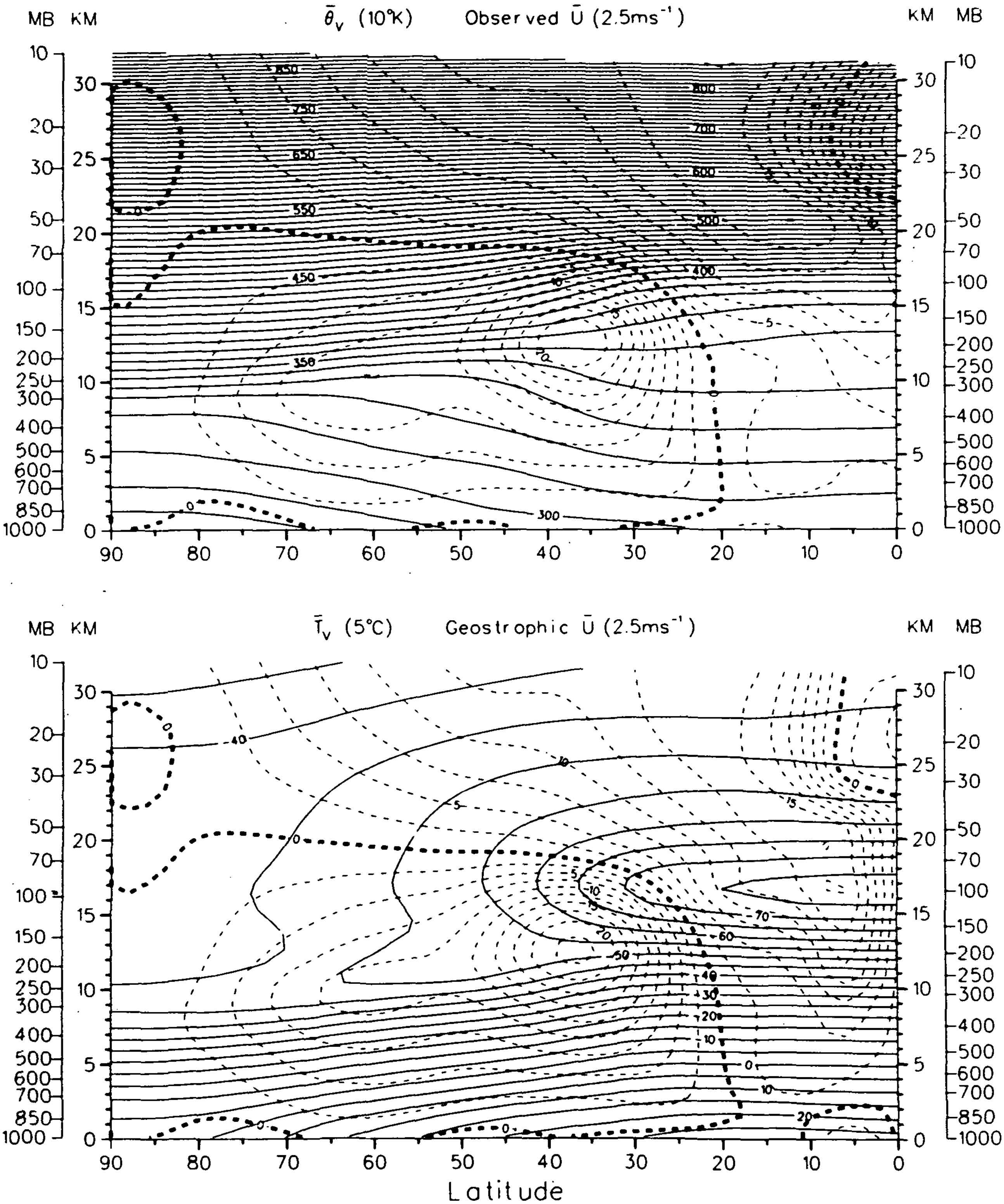
MAY 1975





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JUNE 1975



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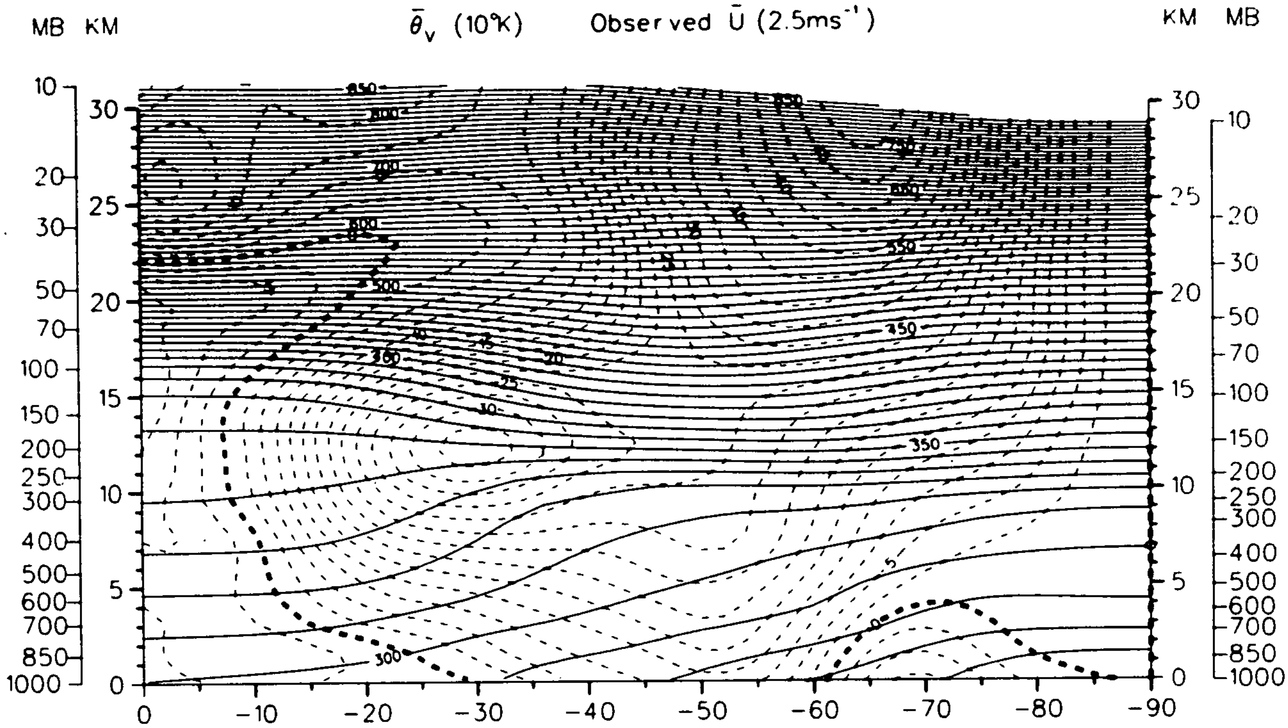

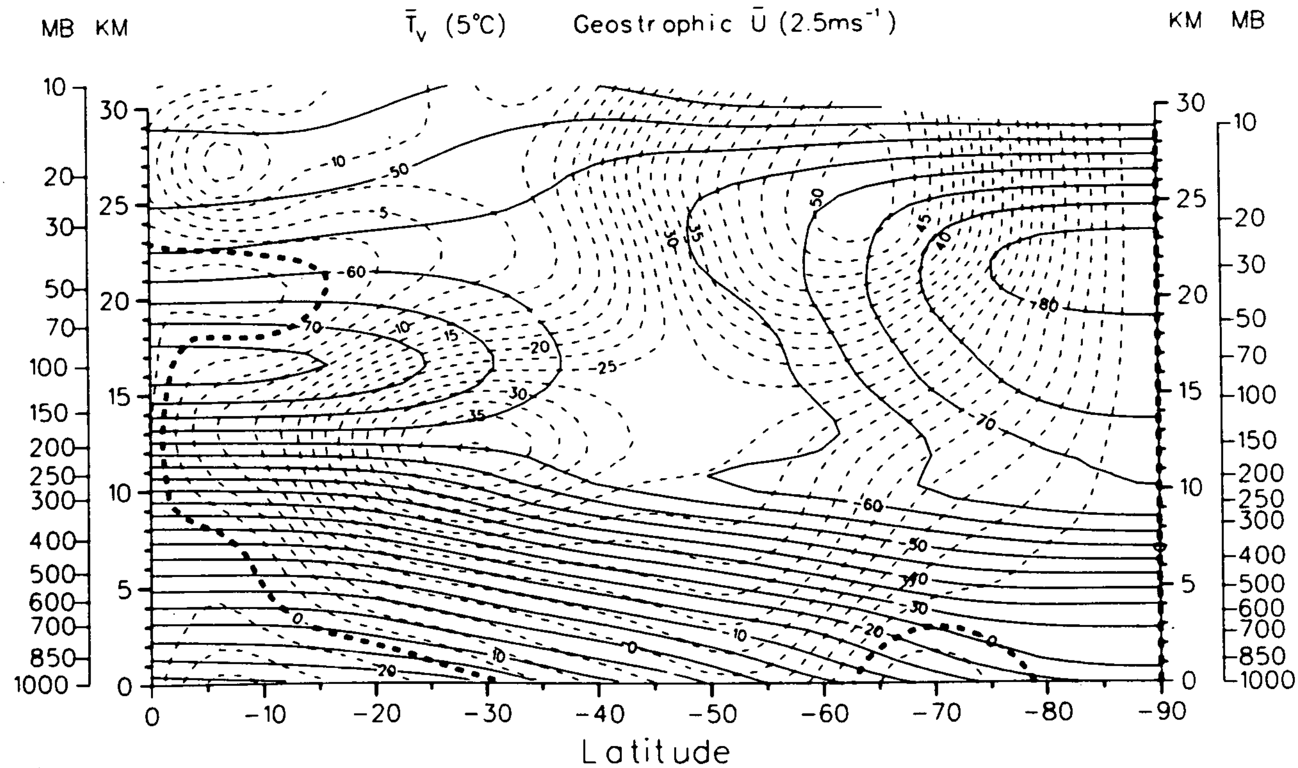

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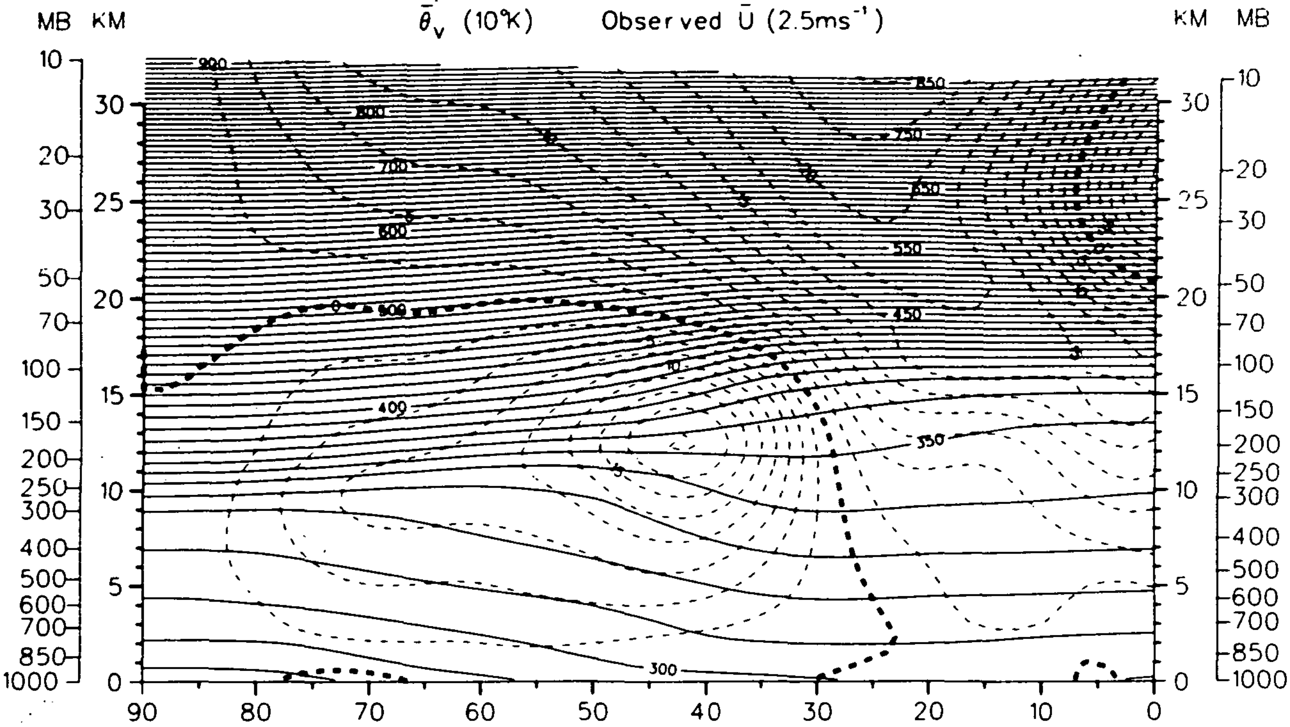

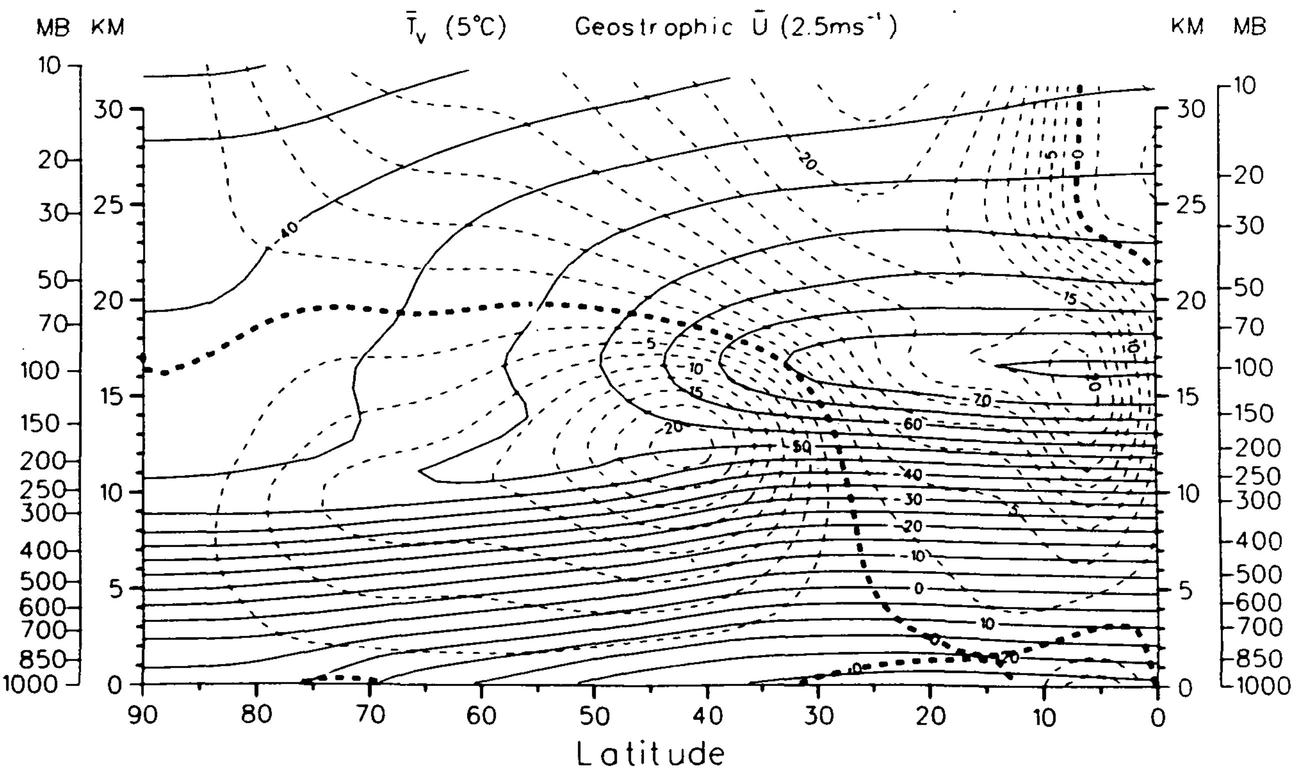

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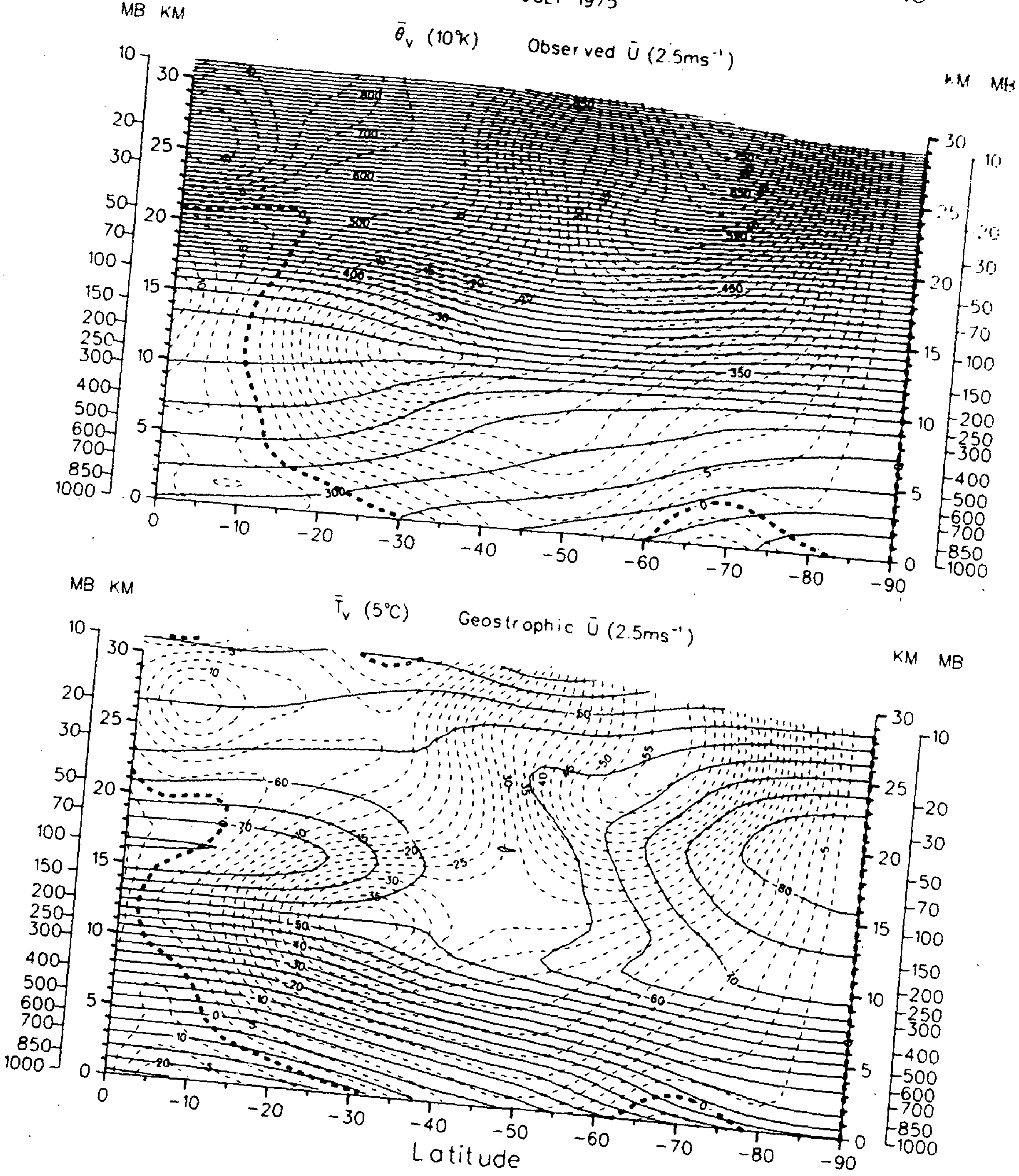
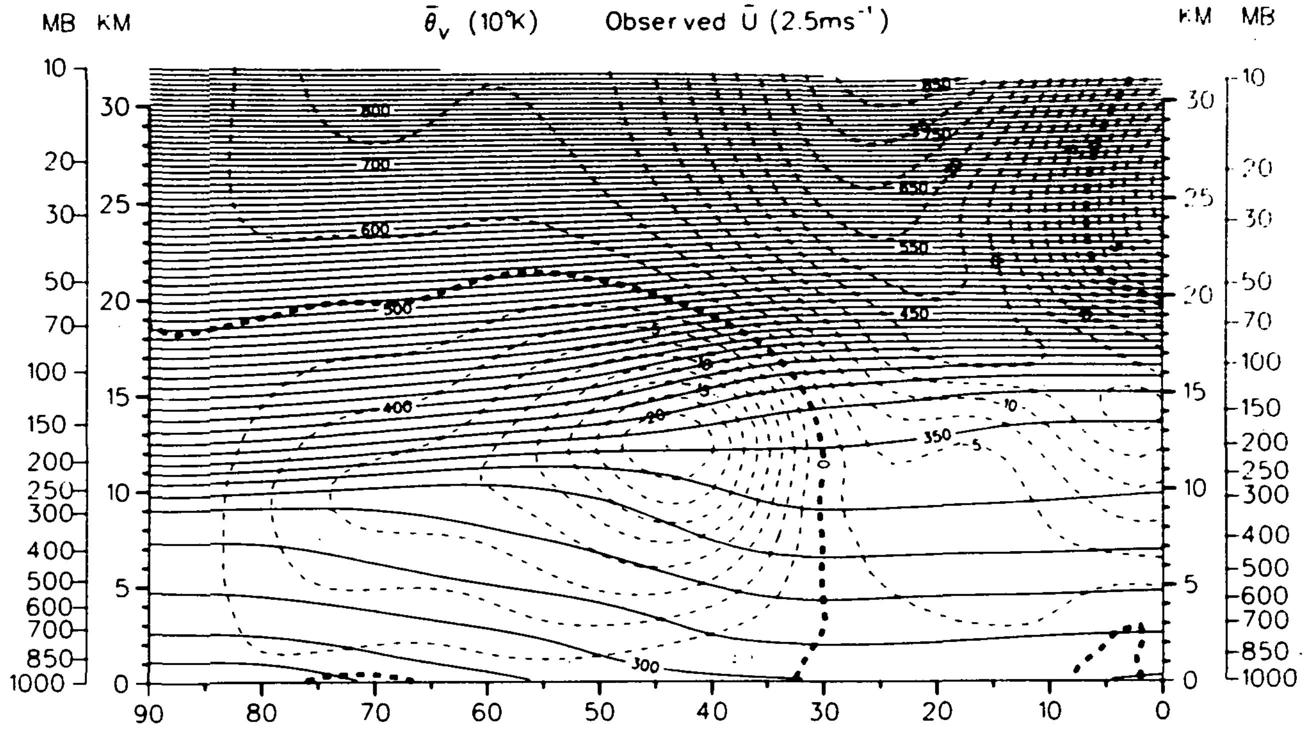


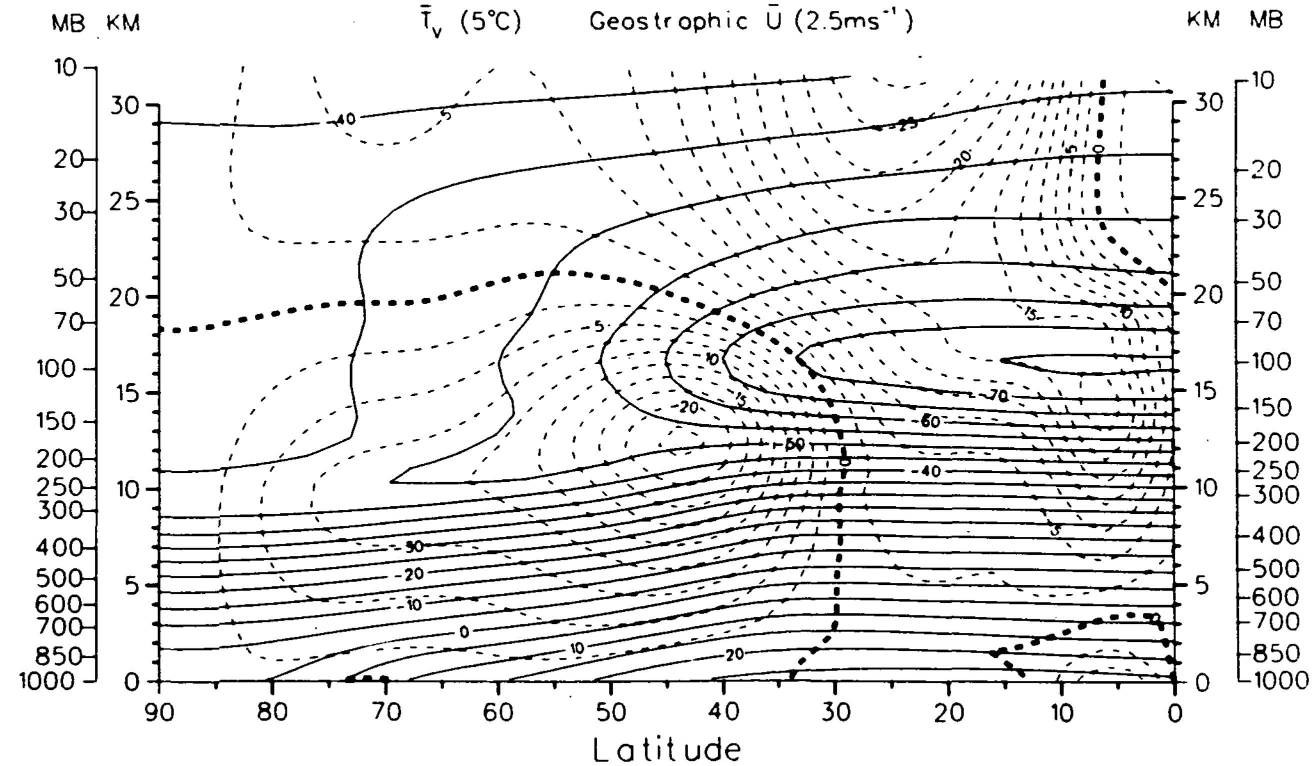
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

AUGUST 1975

$\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1})



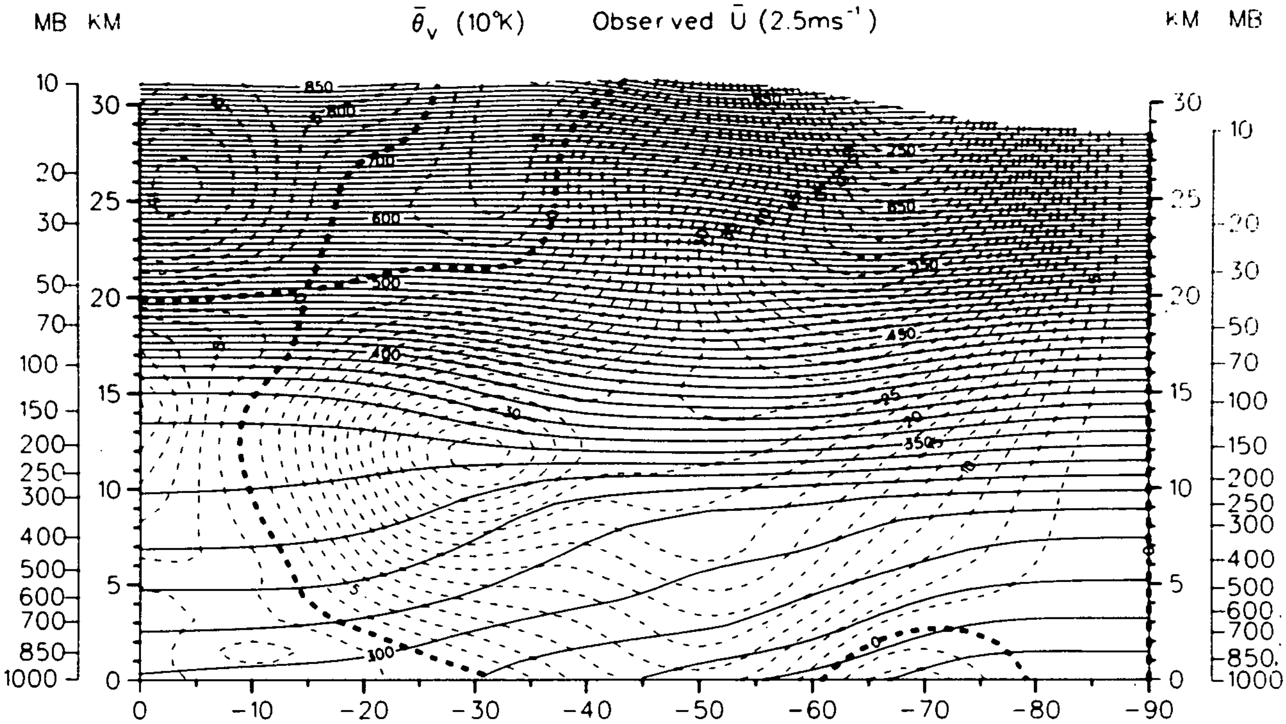
$\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1})



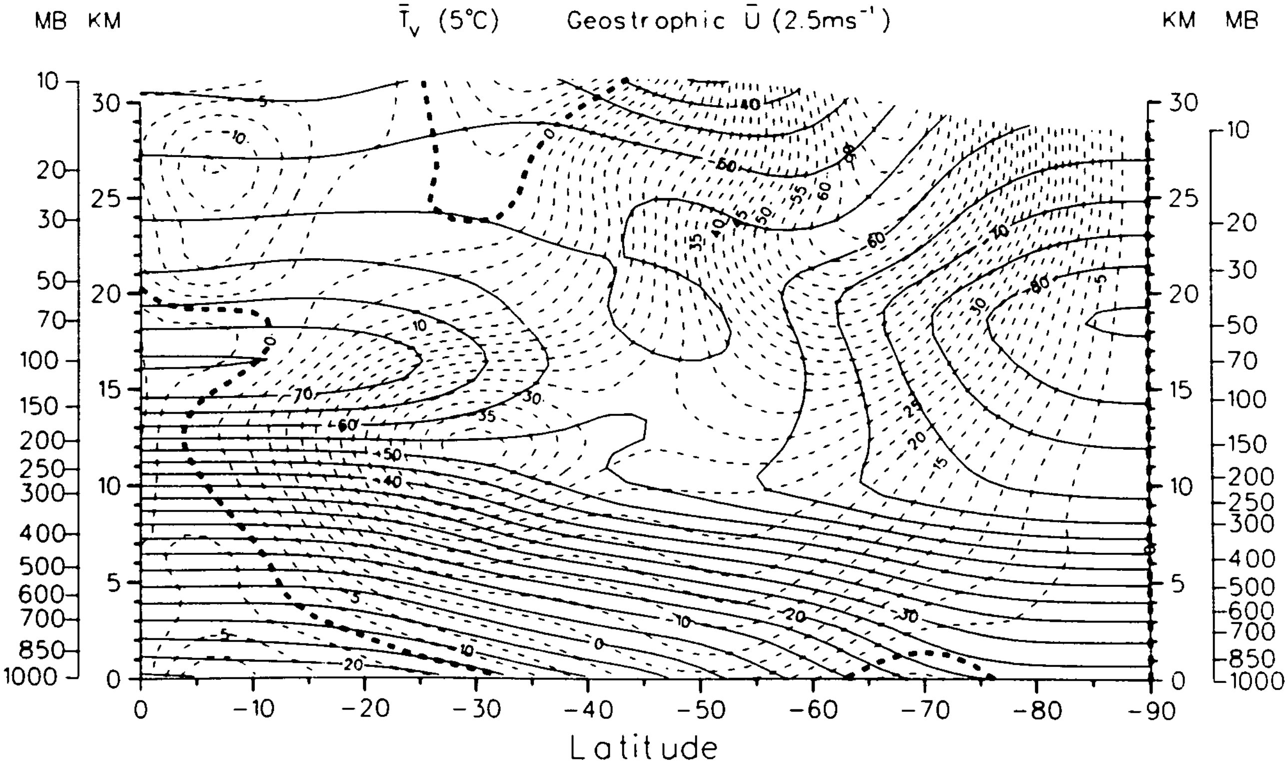
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

AUGUST 1975

$\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1})

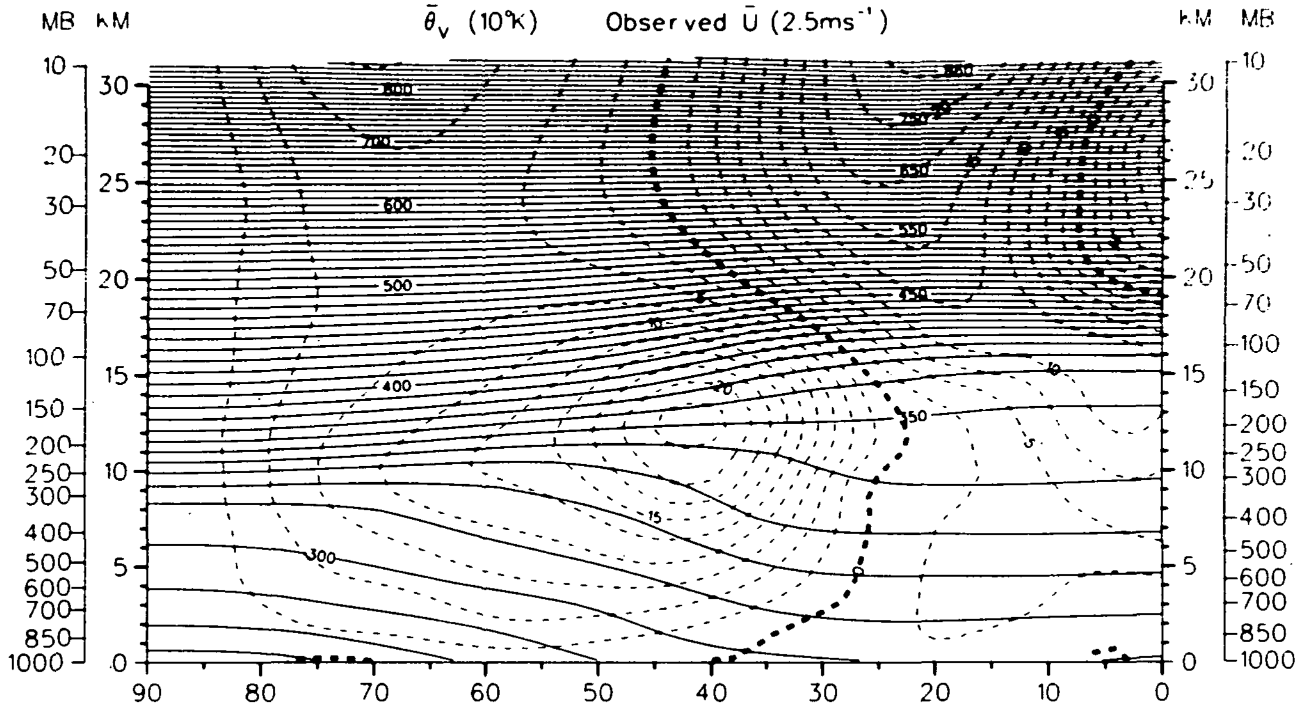


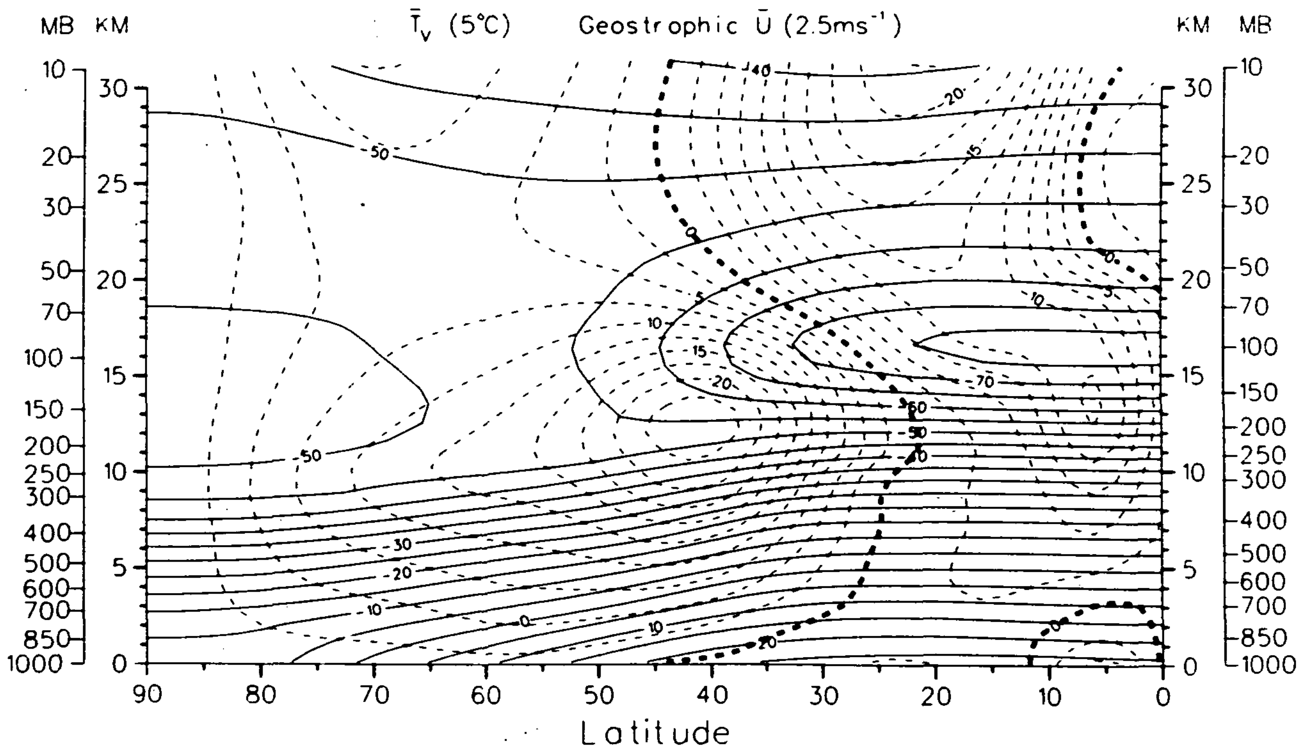
$\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1})



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

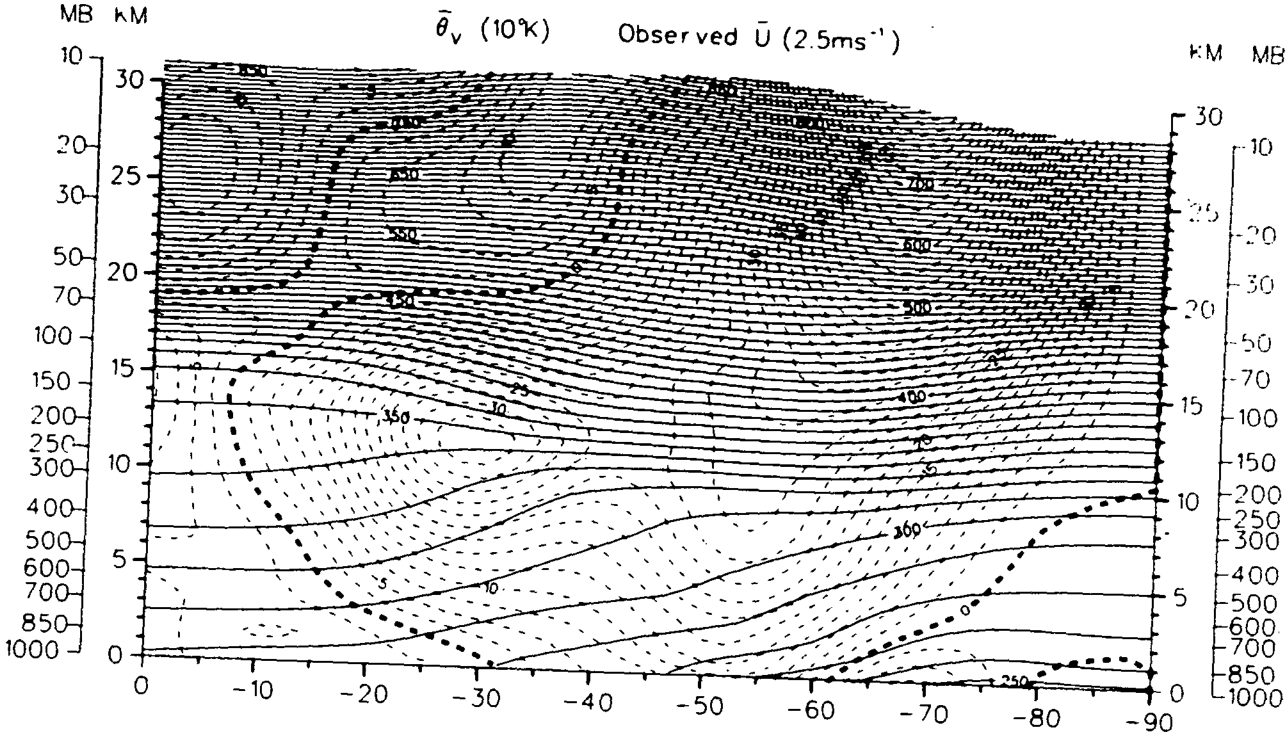
SEPTEMBER 1975

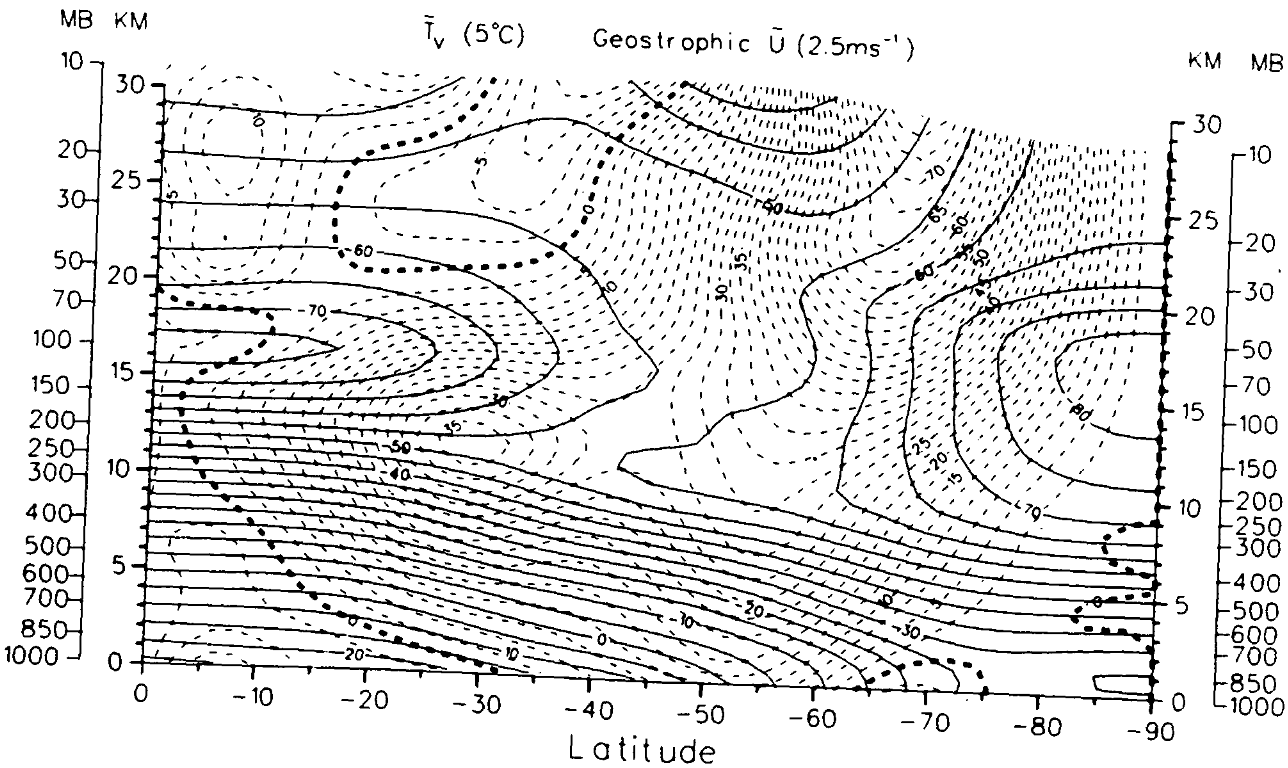




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

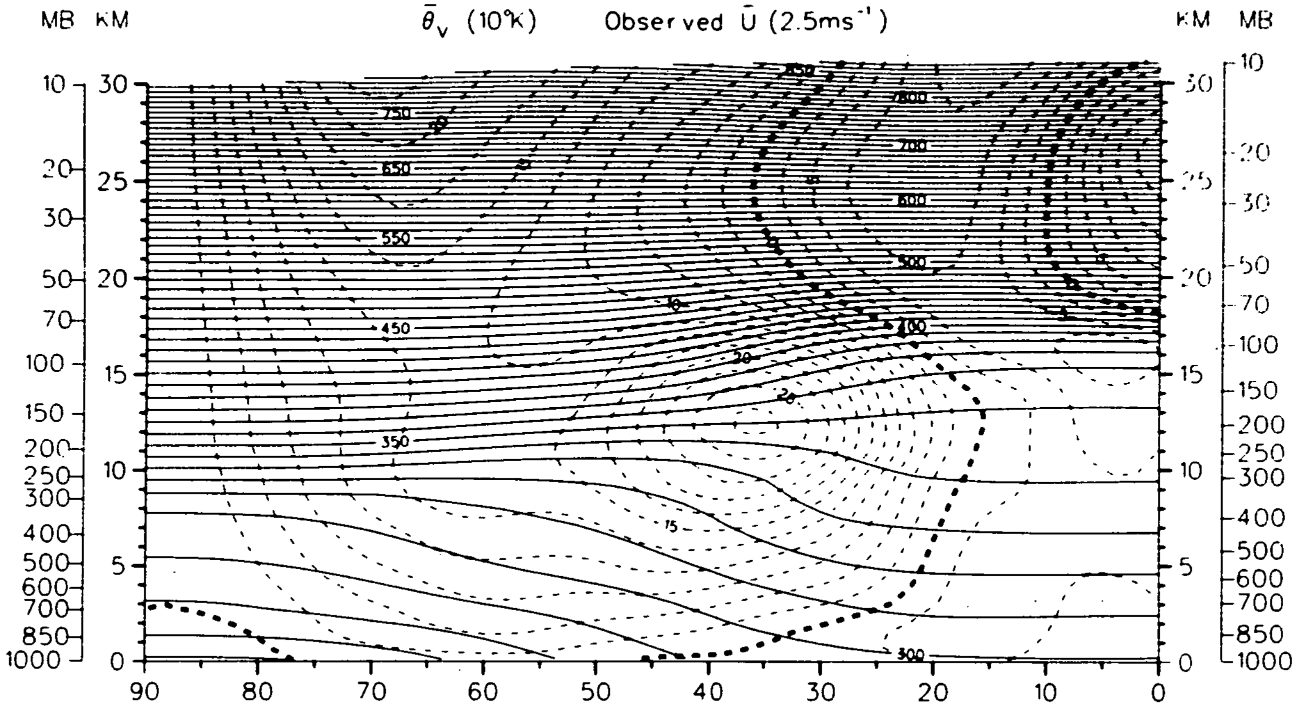
SEPTEMBER 1975

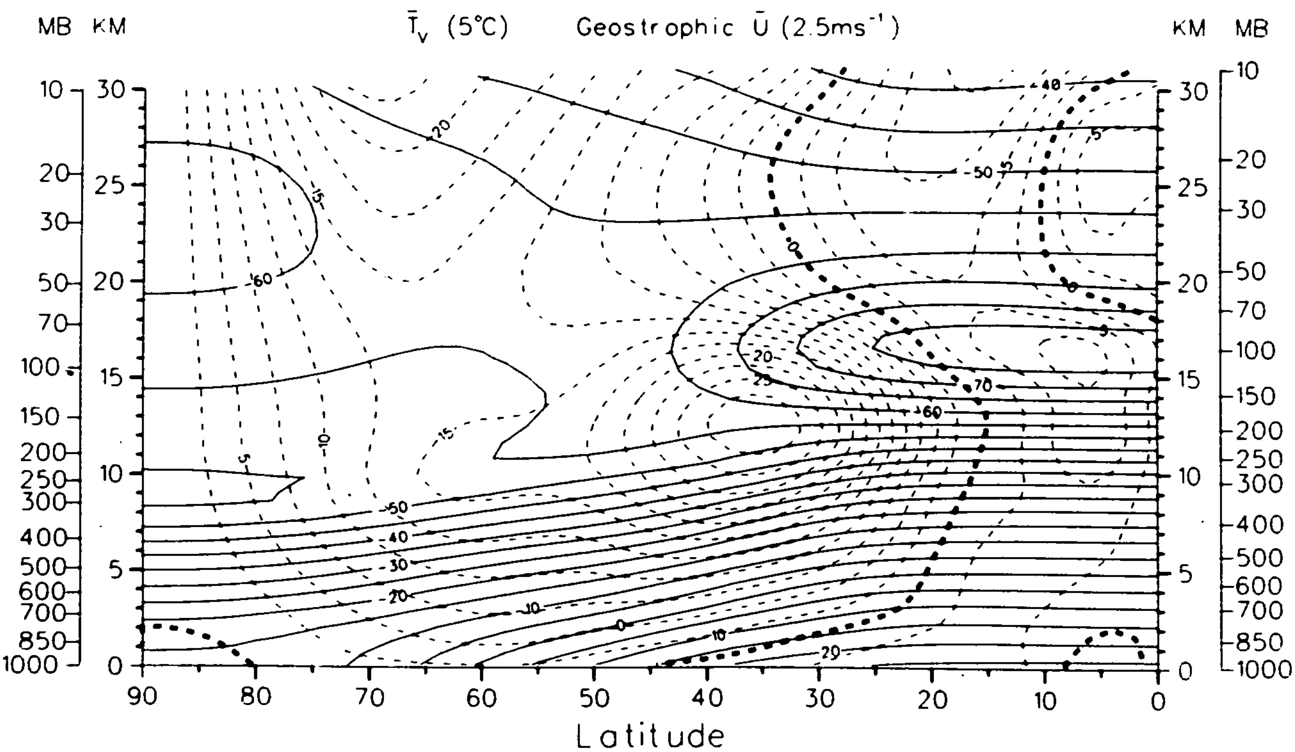




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

OCTOBER 1975





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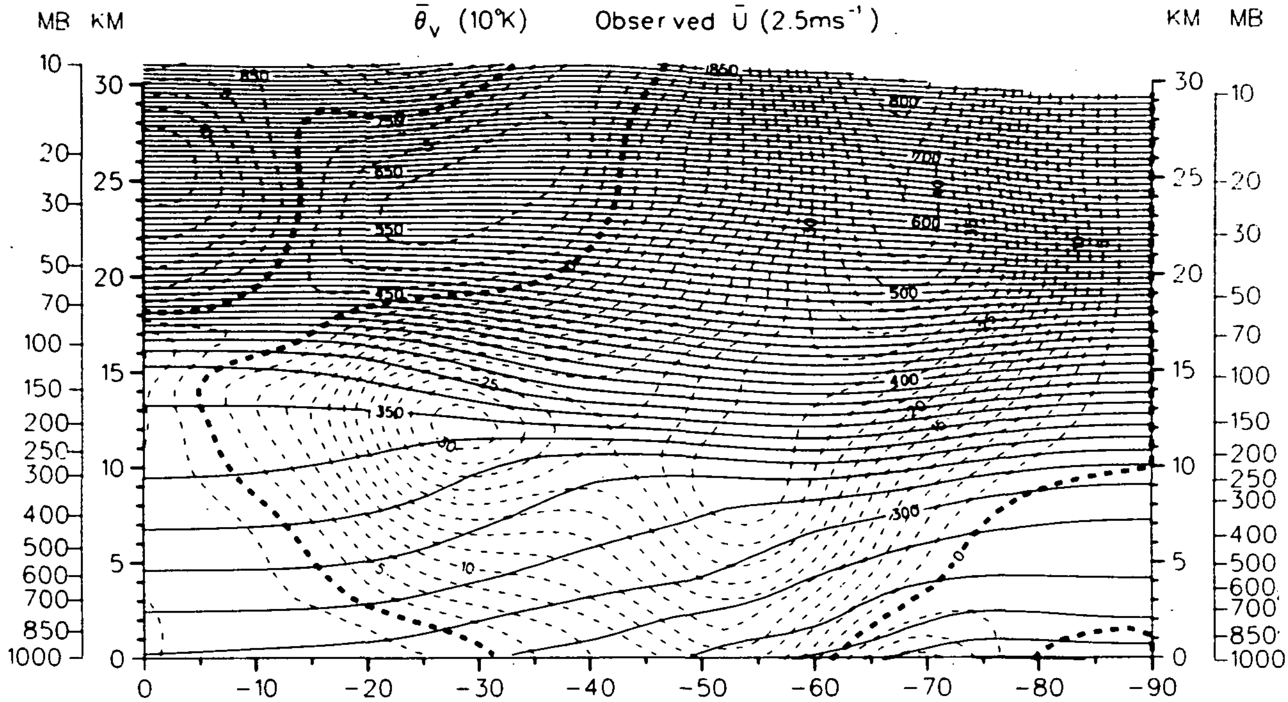
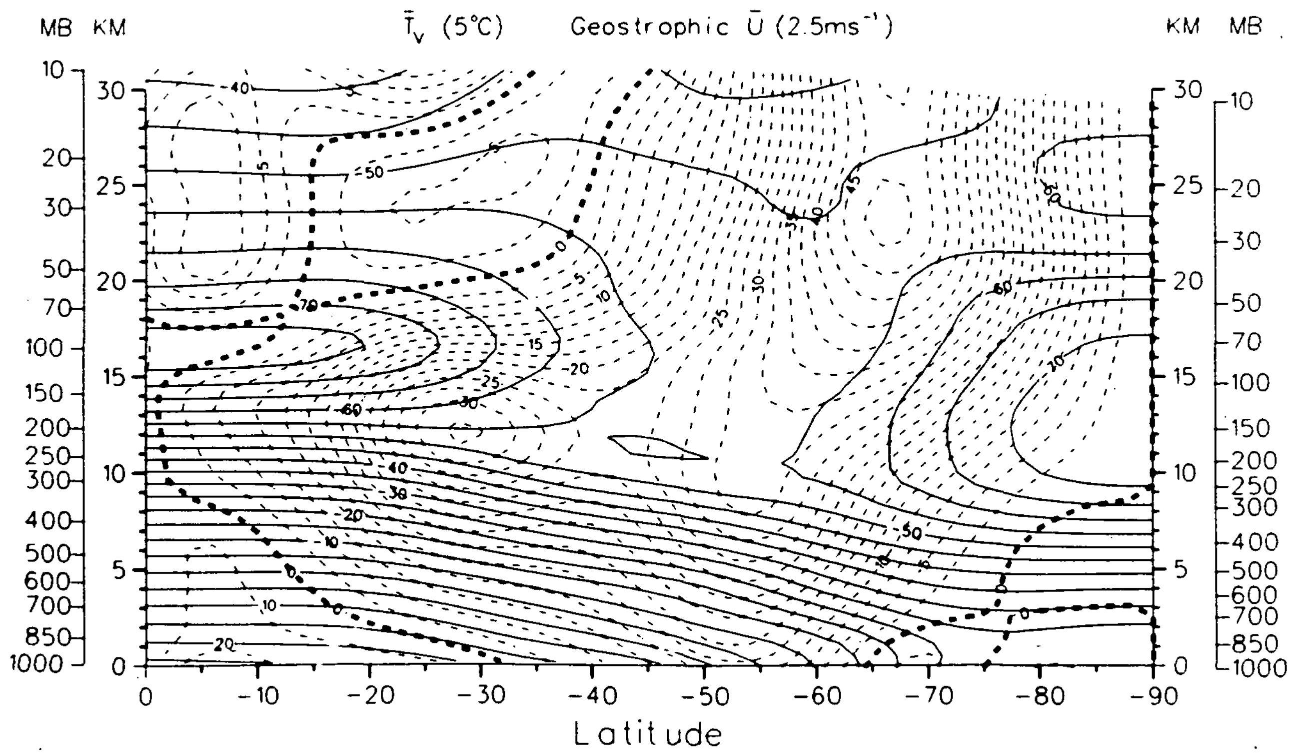
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

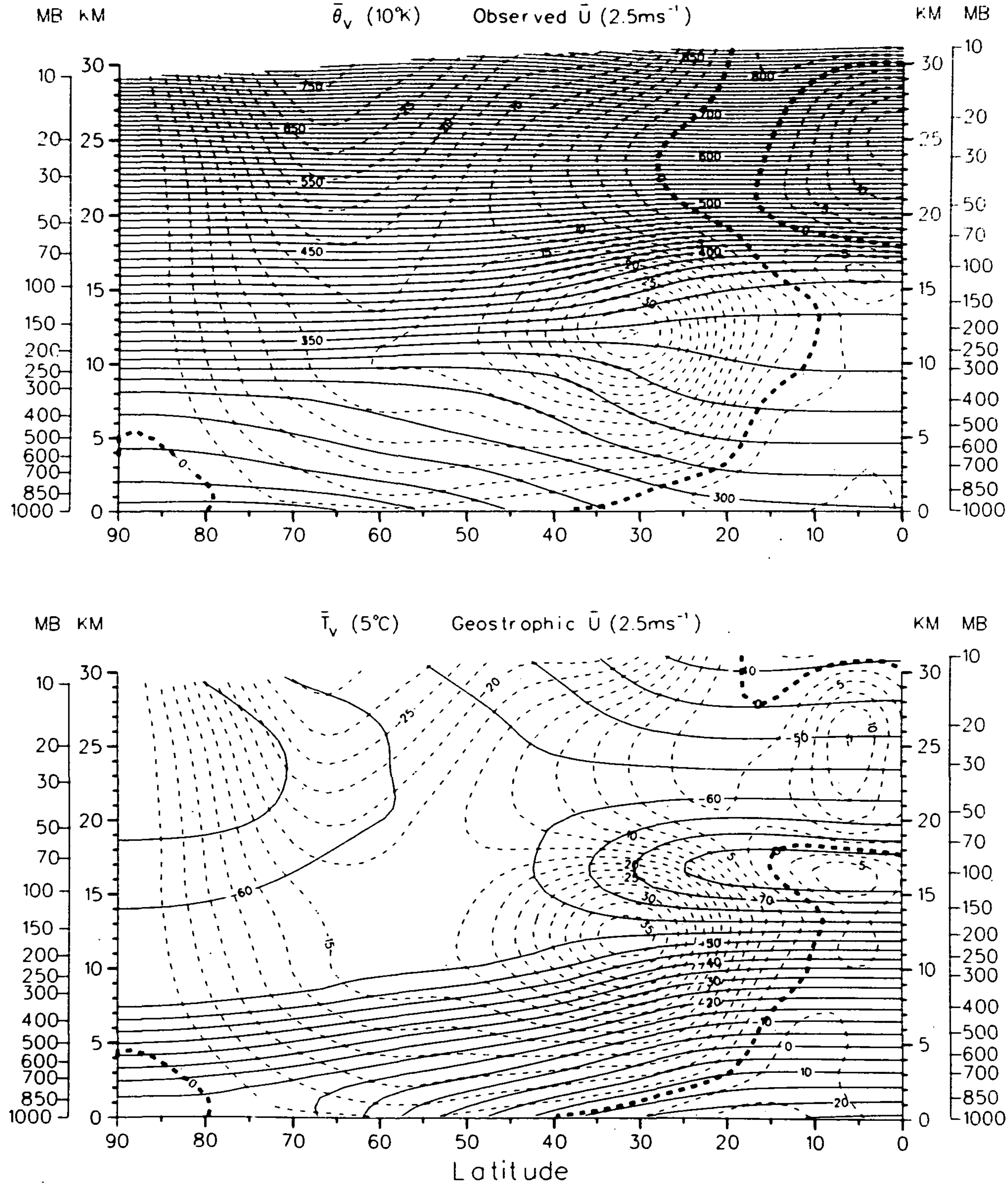
OCTOBER 1975





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

NOVEMBER 1975



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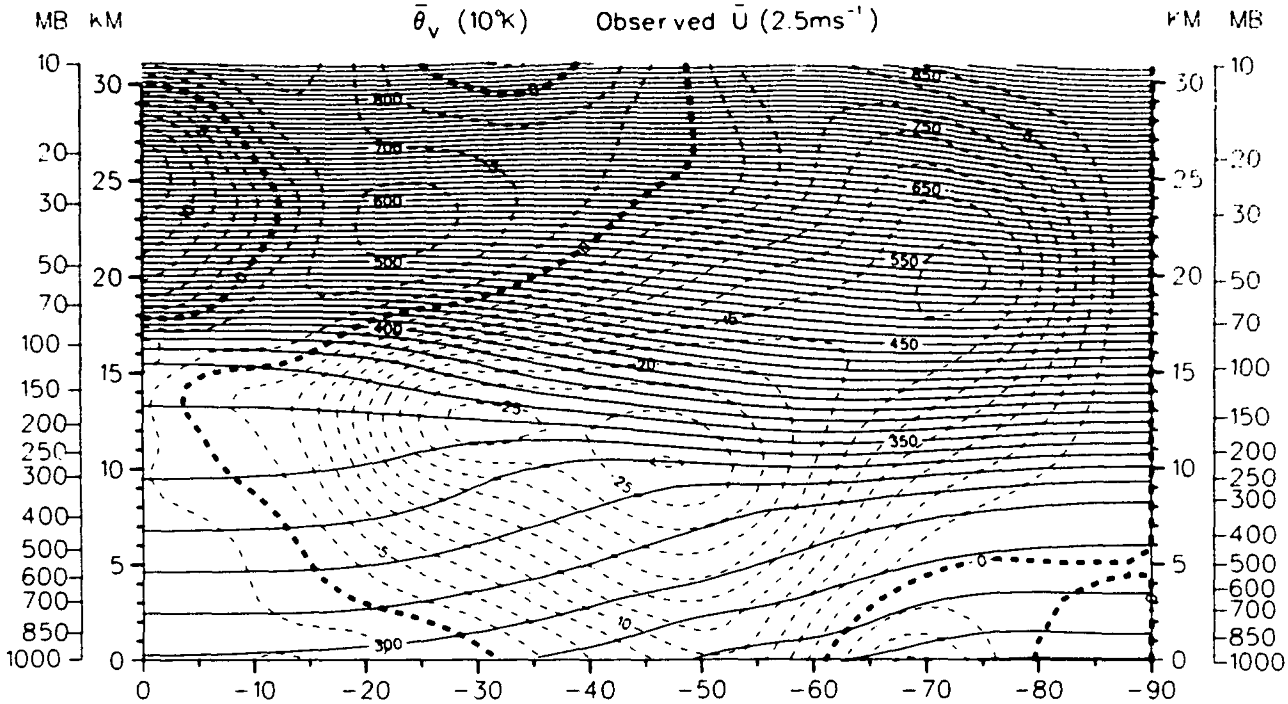
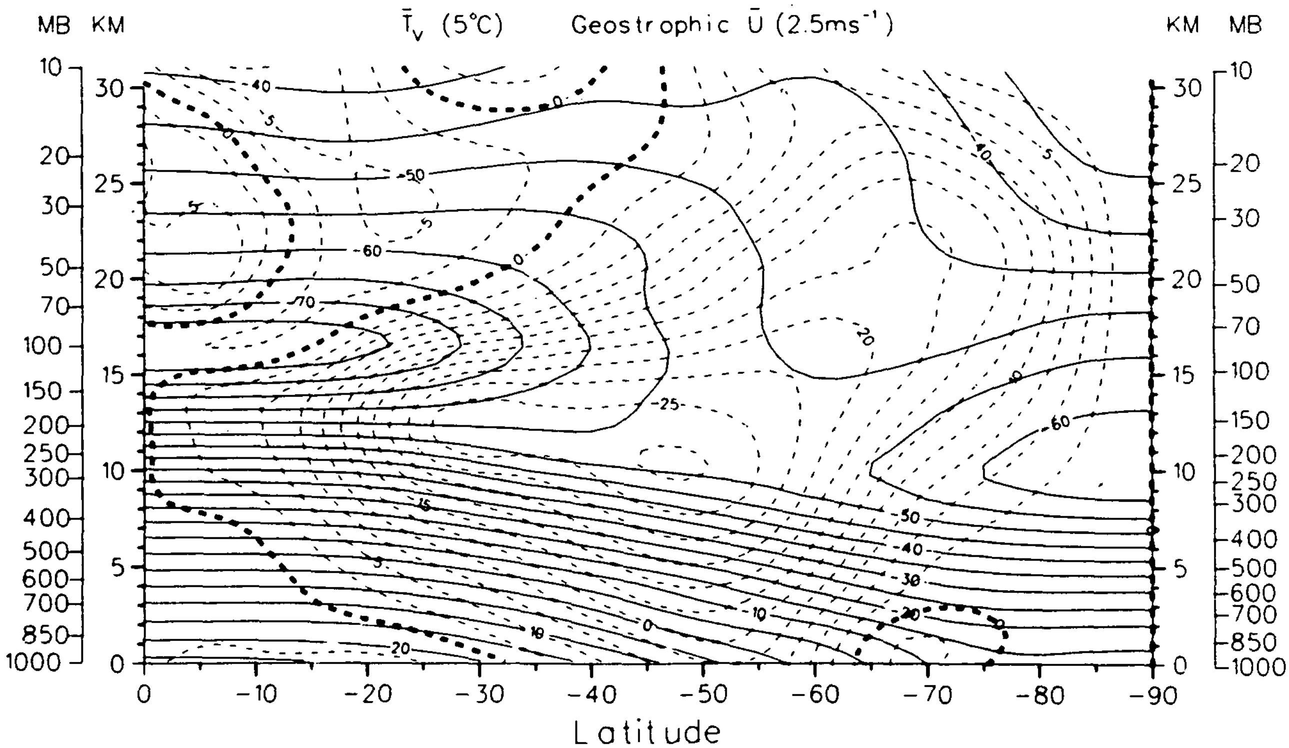
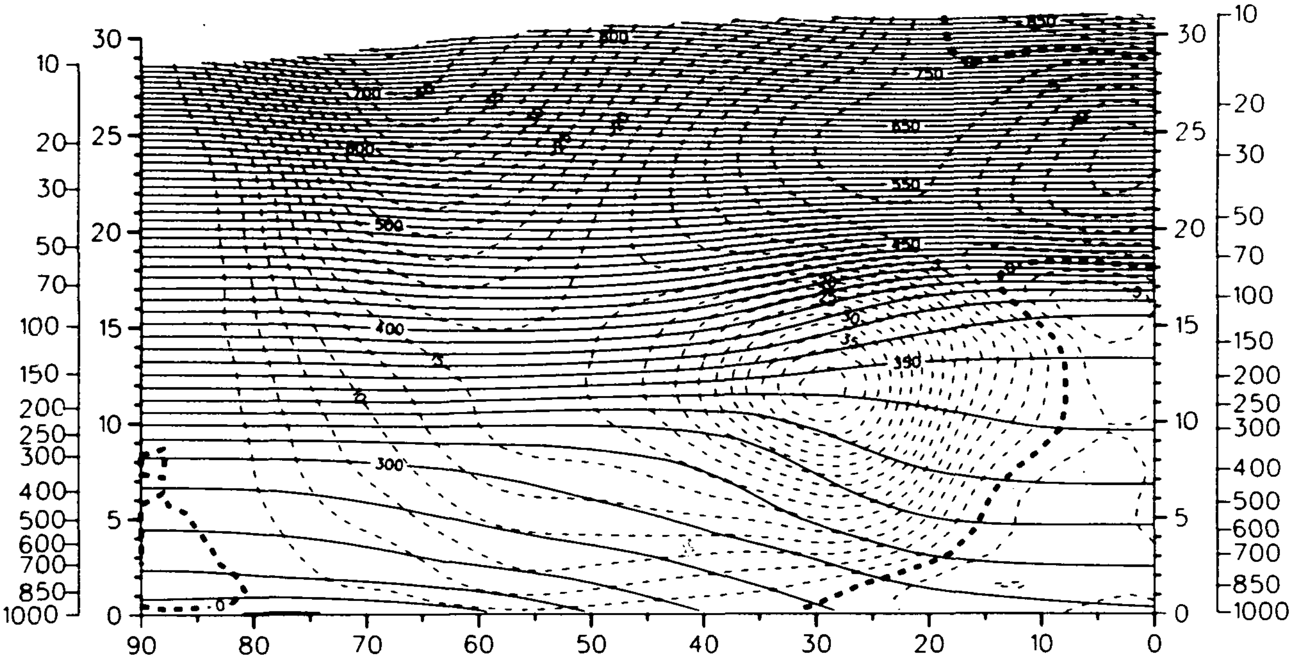




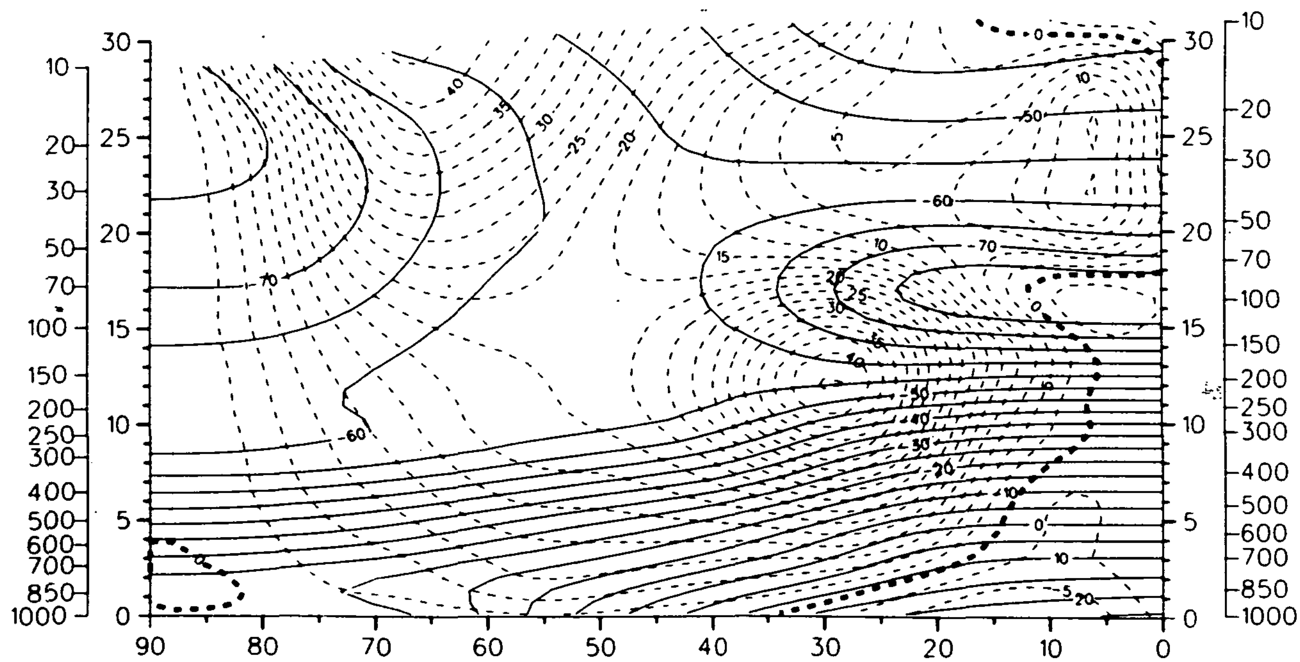
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

DECEMBER 1975

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB

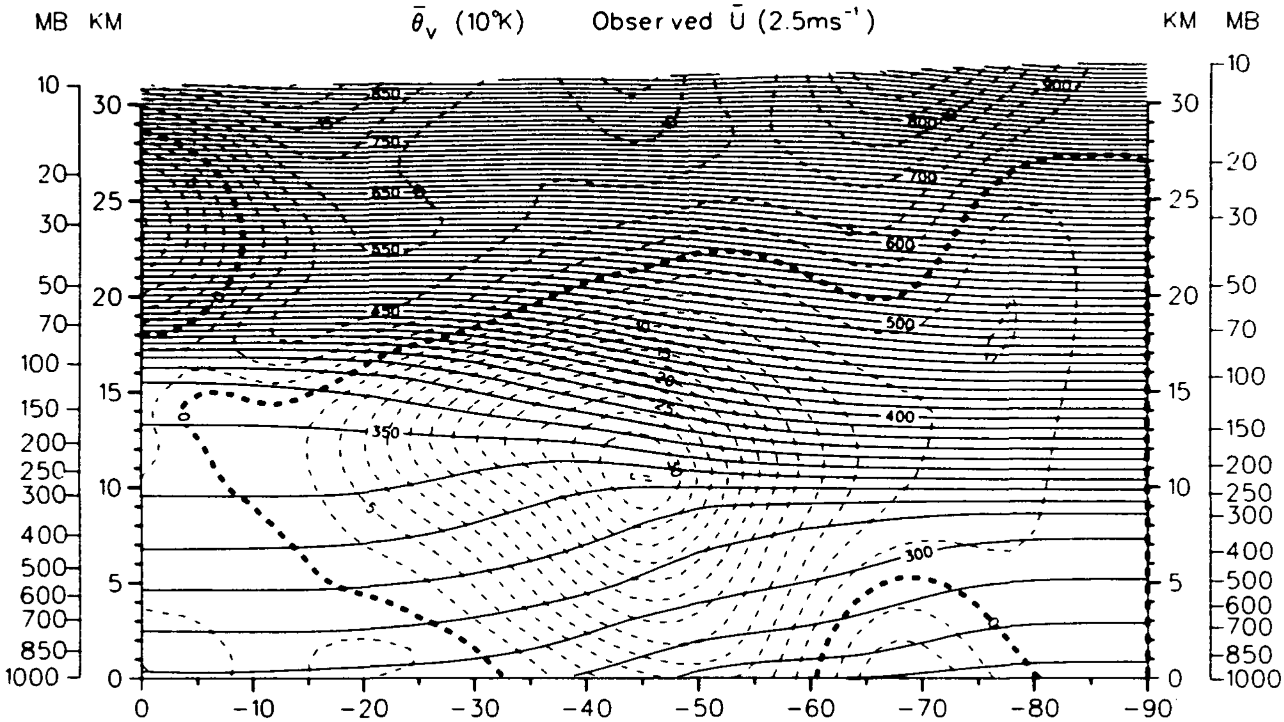


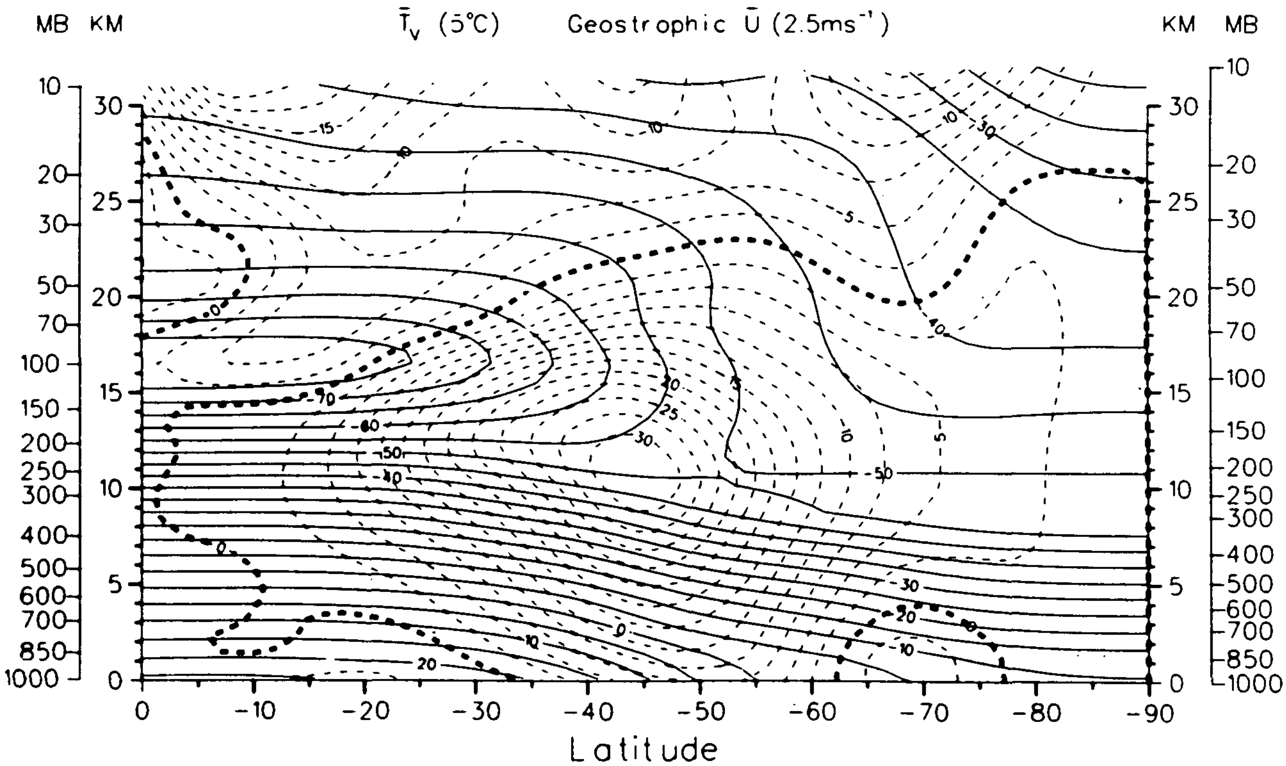
MB KM $\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1}) KM MB



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

DECEMBER 1975

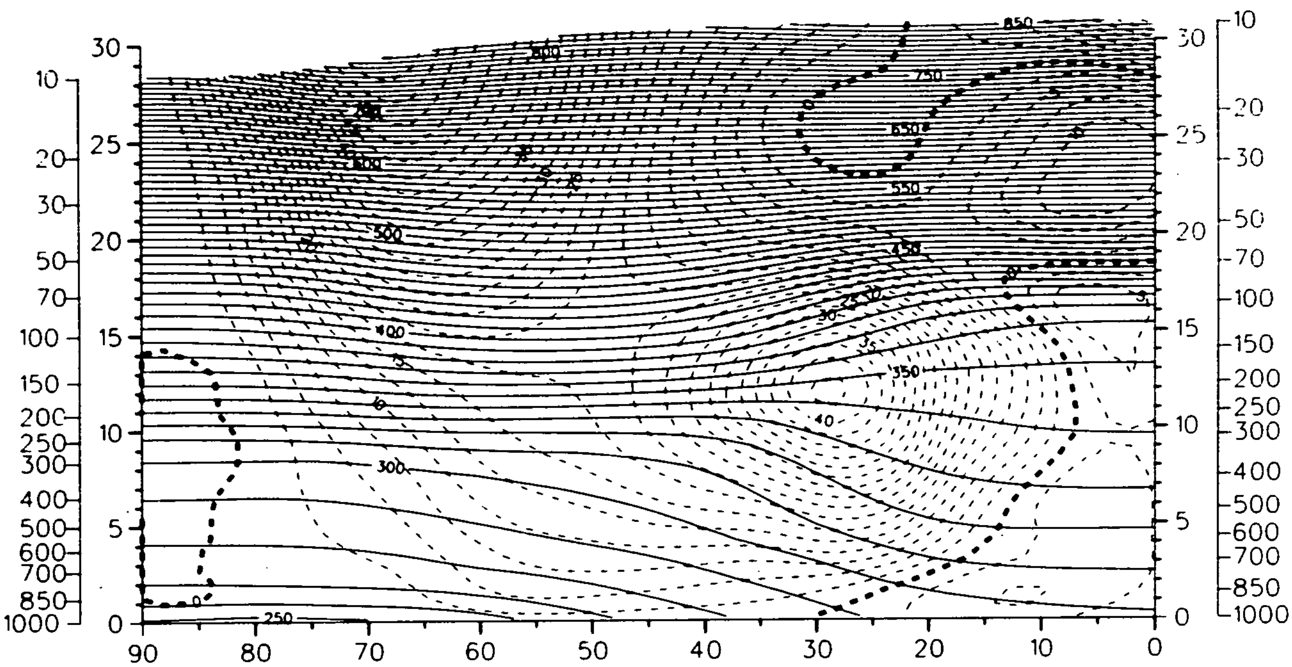




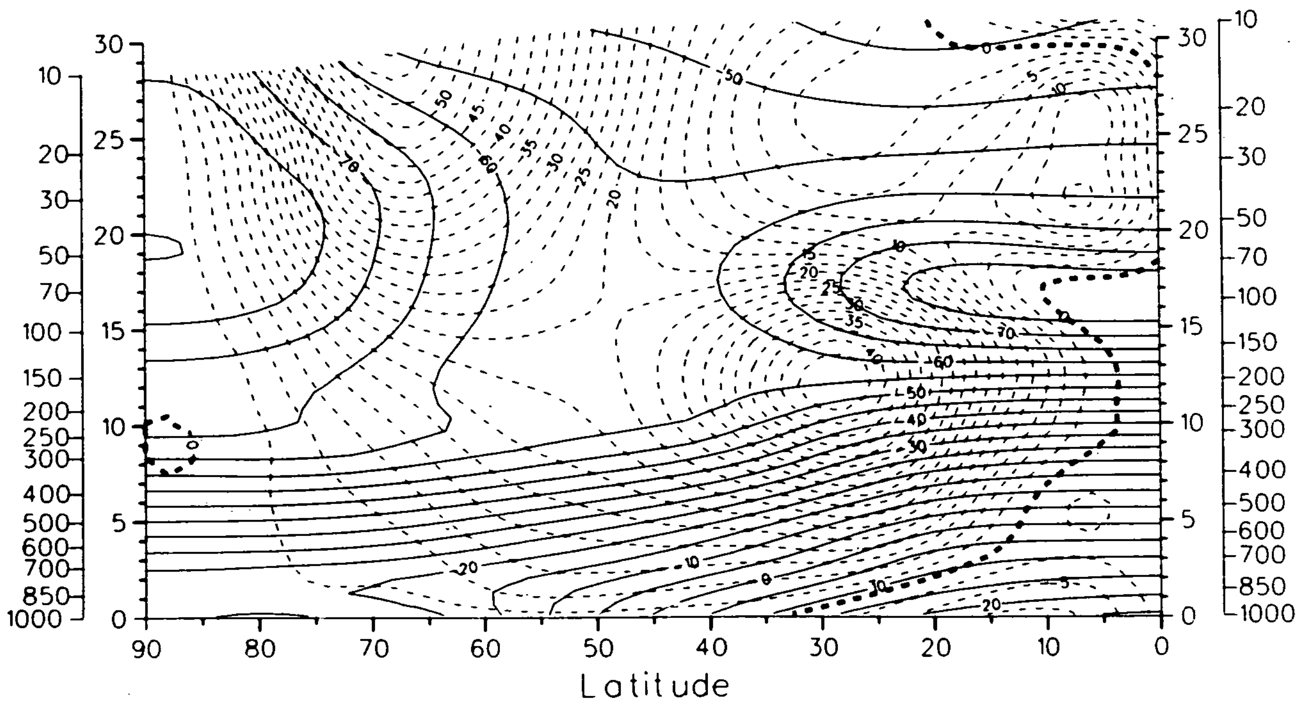
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JANUARY 1976

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB

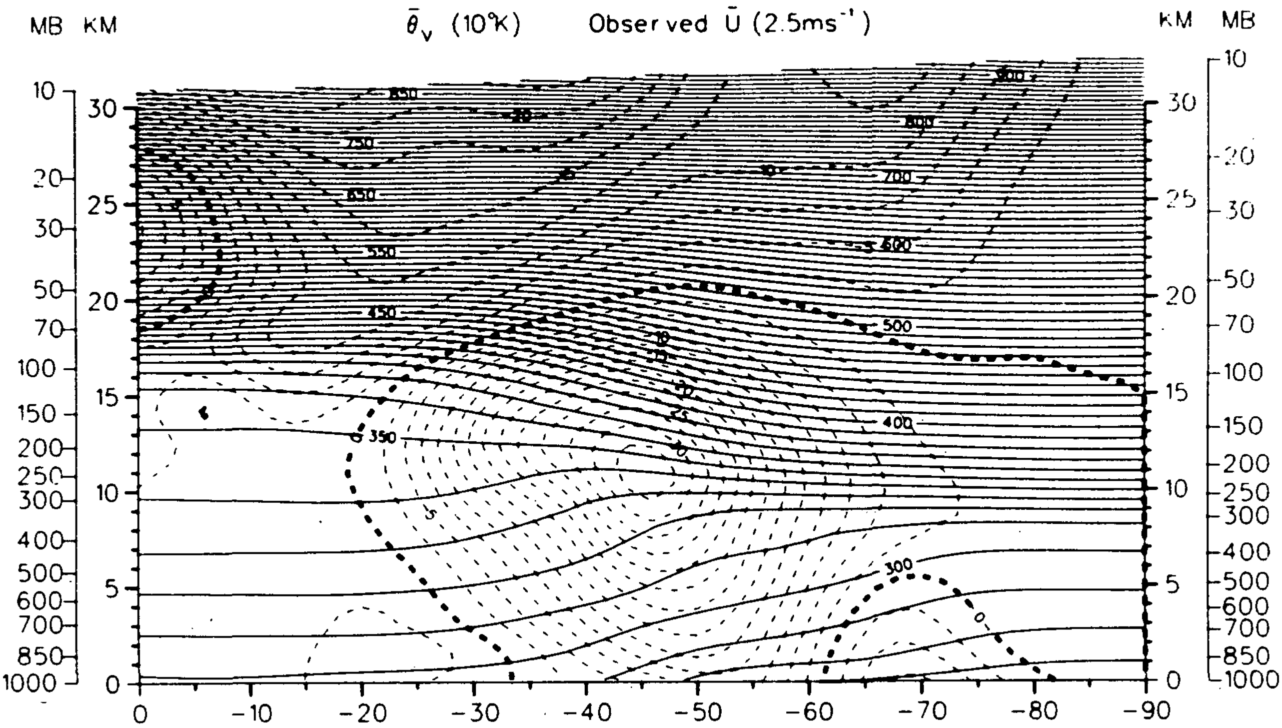


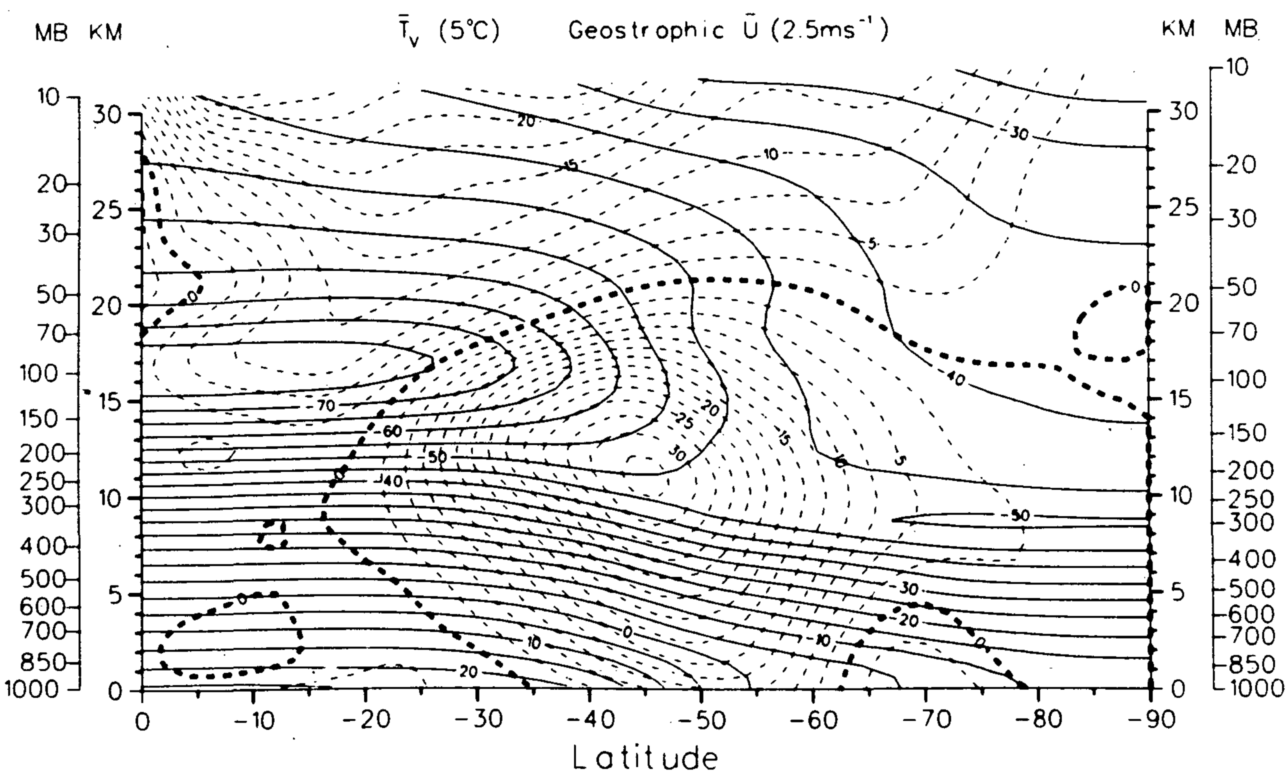
MB KM $\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1}) KM MB



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

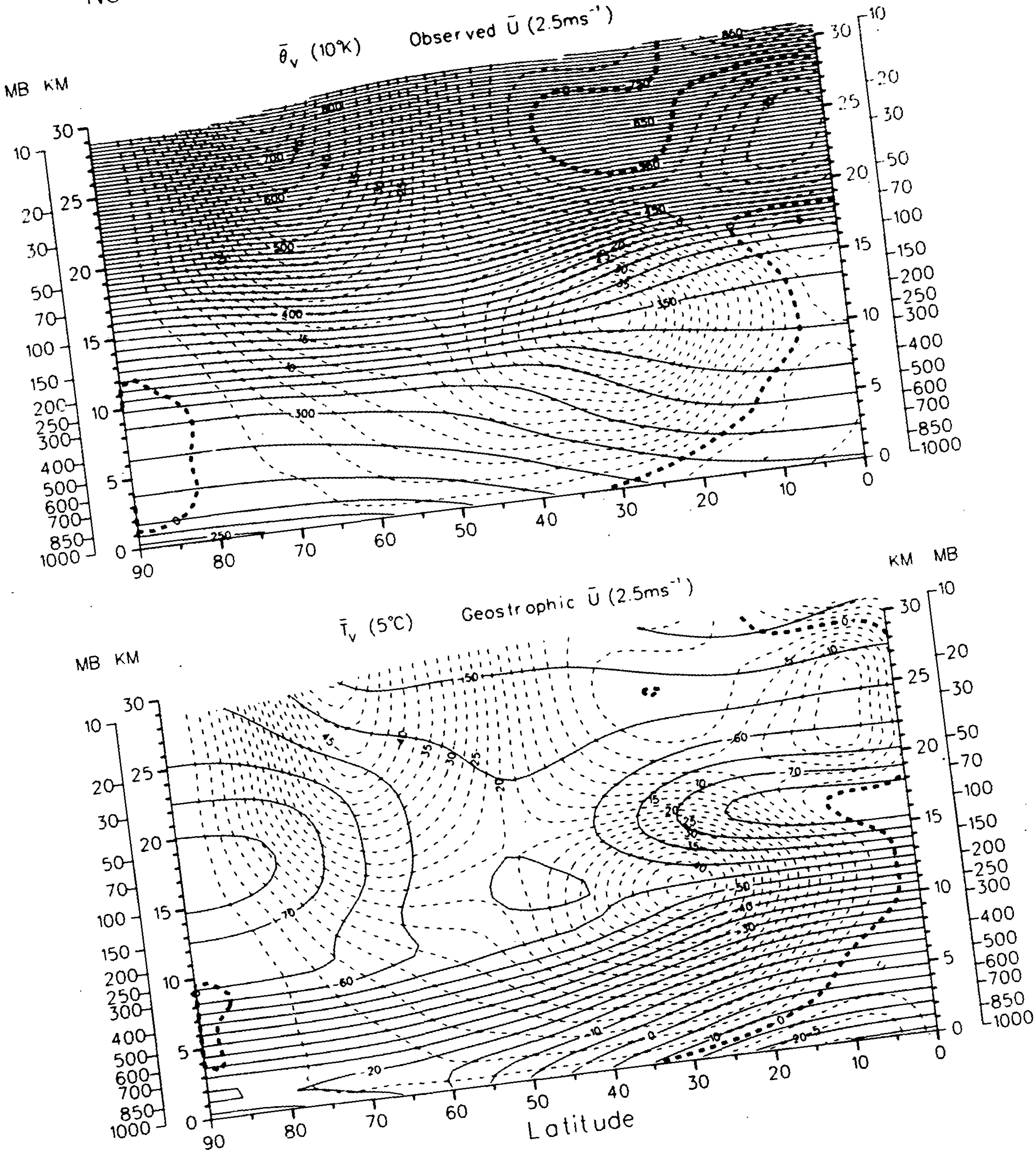
JANUARY 1976





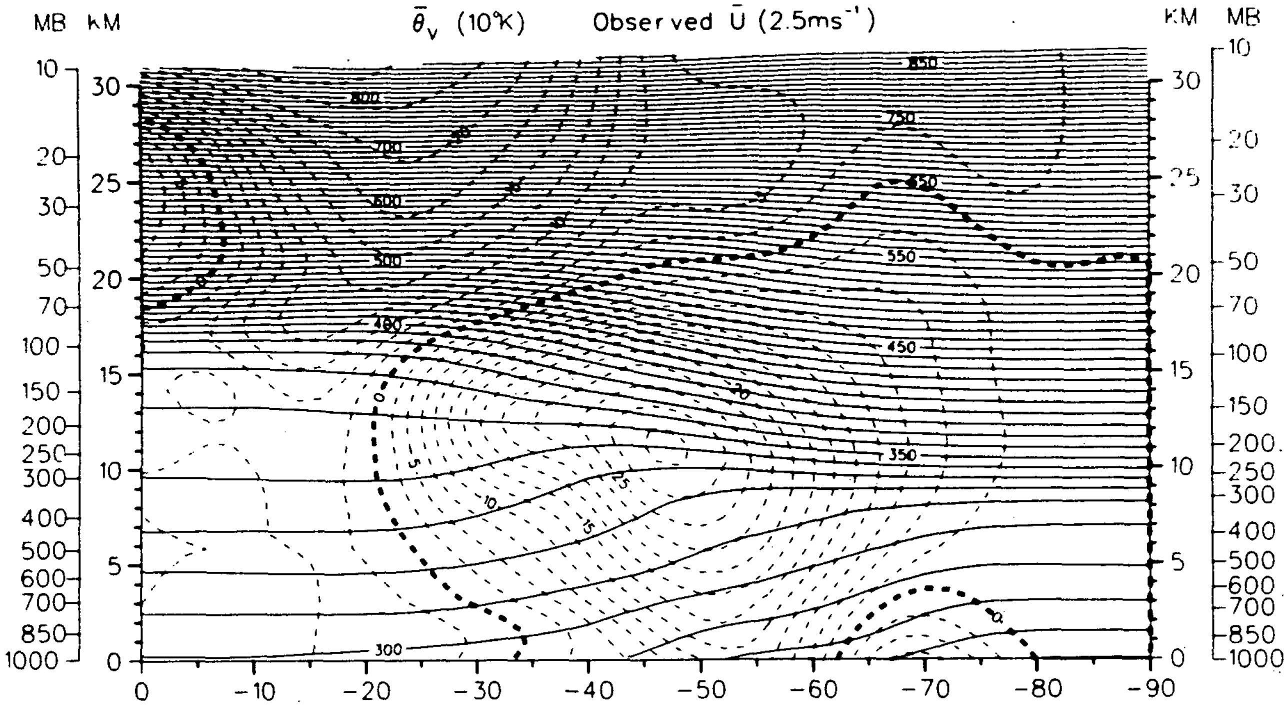
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

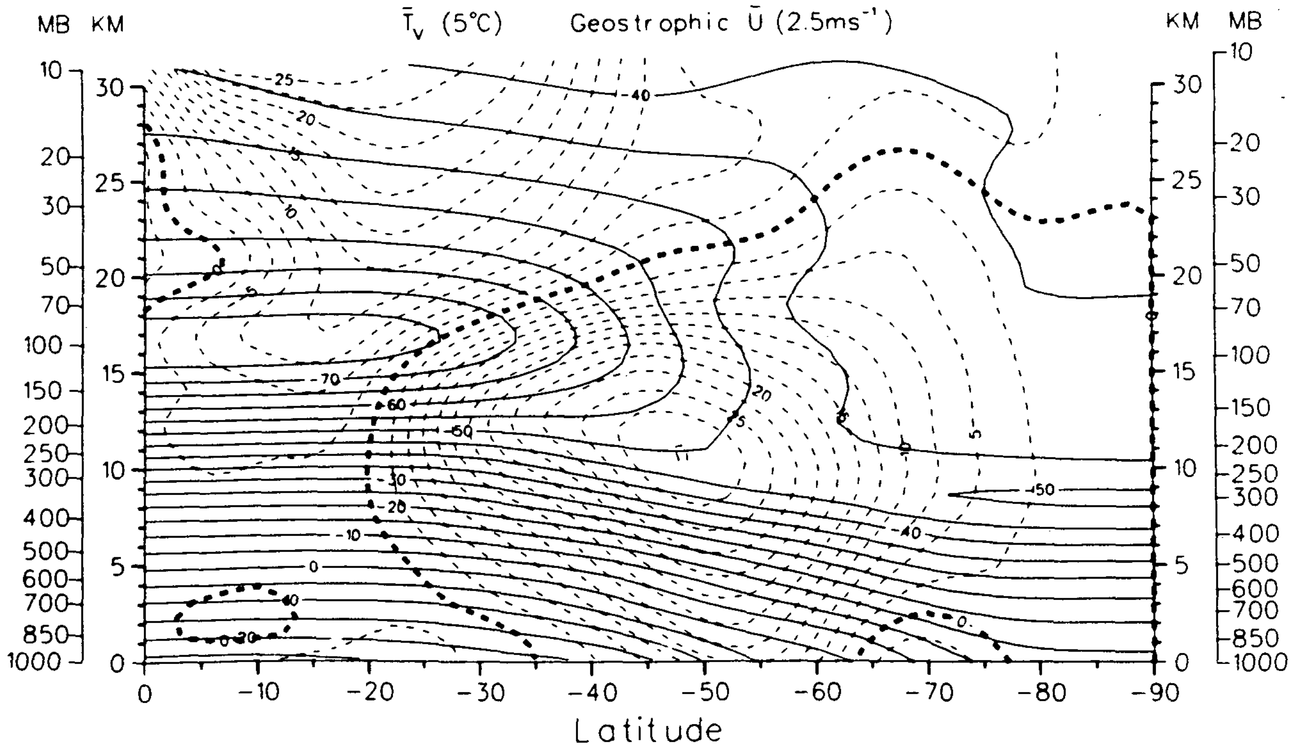
FEBRUARY 1976



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

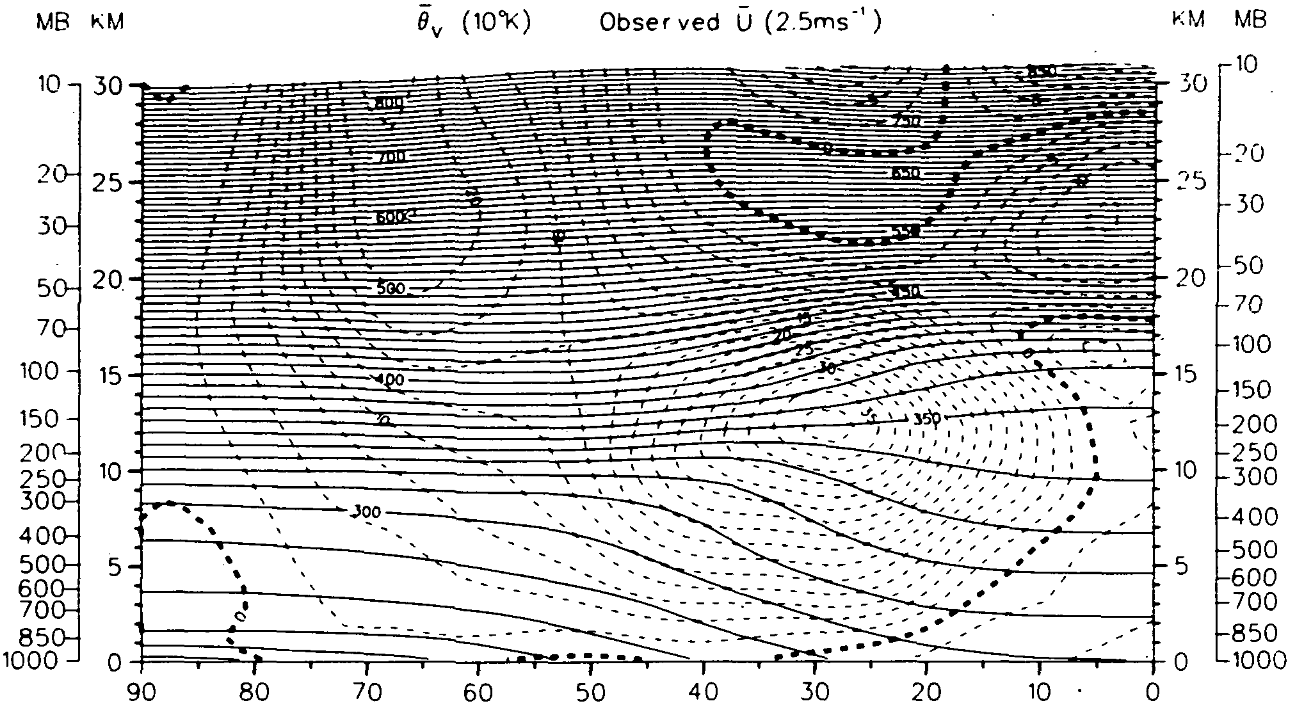
FEBRUARY 1976

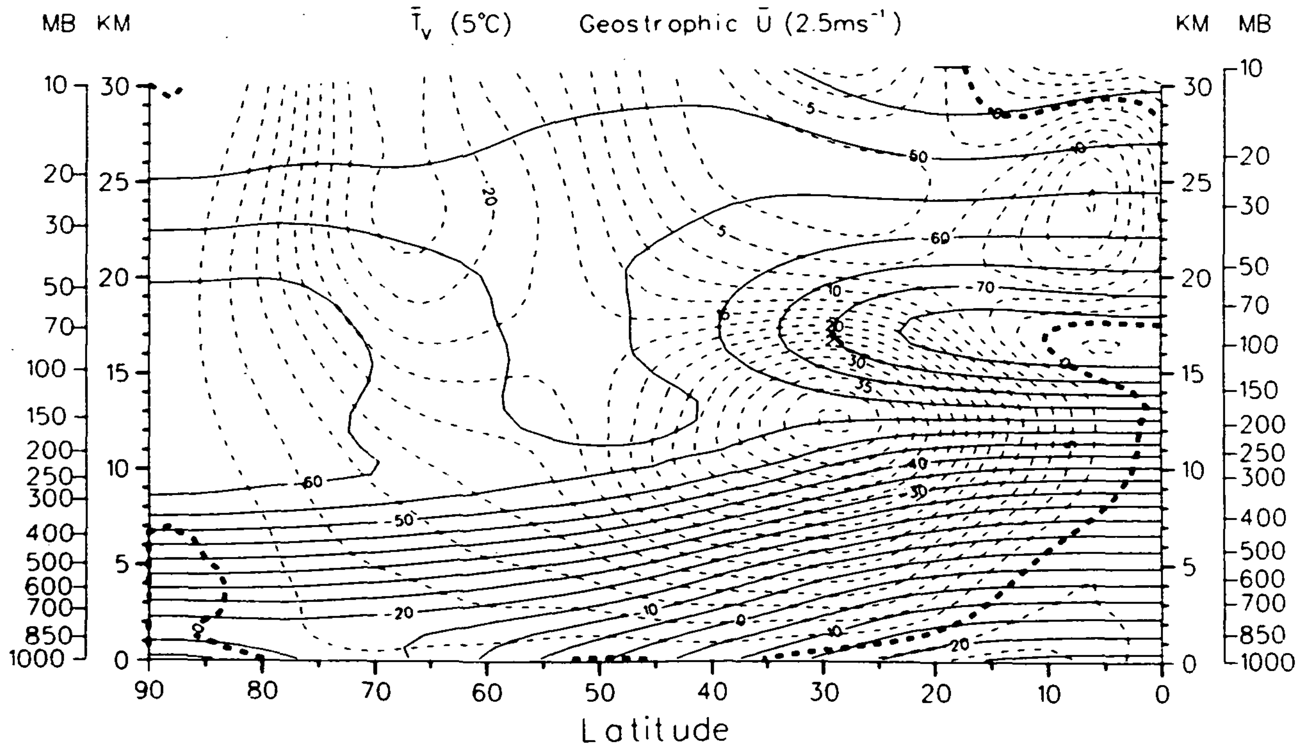




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

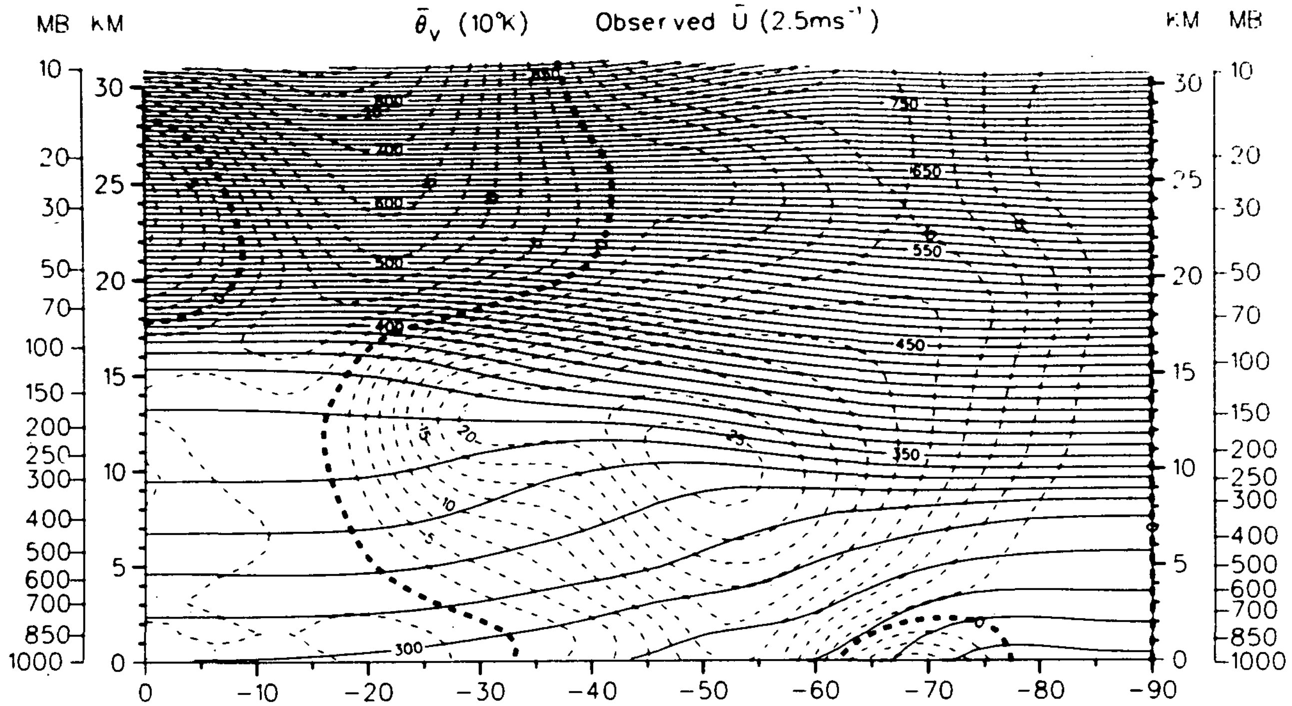
MARCH 1976

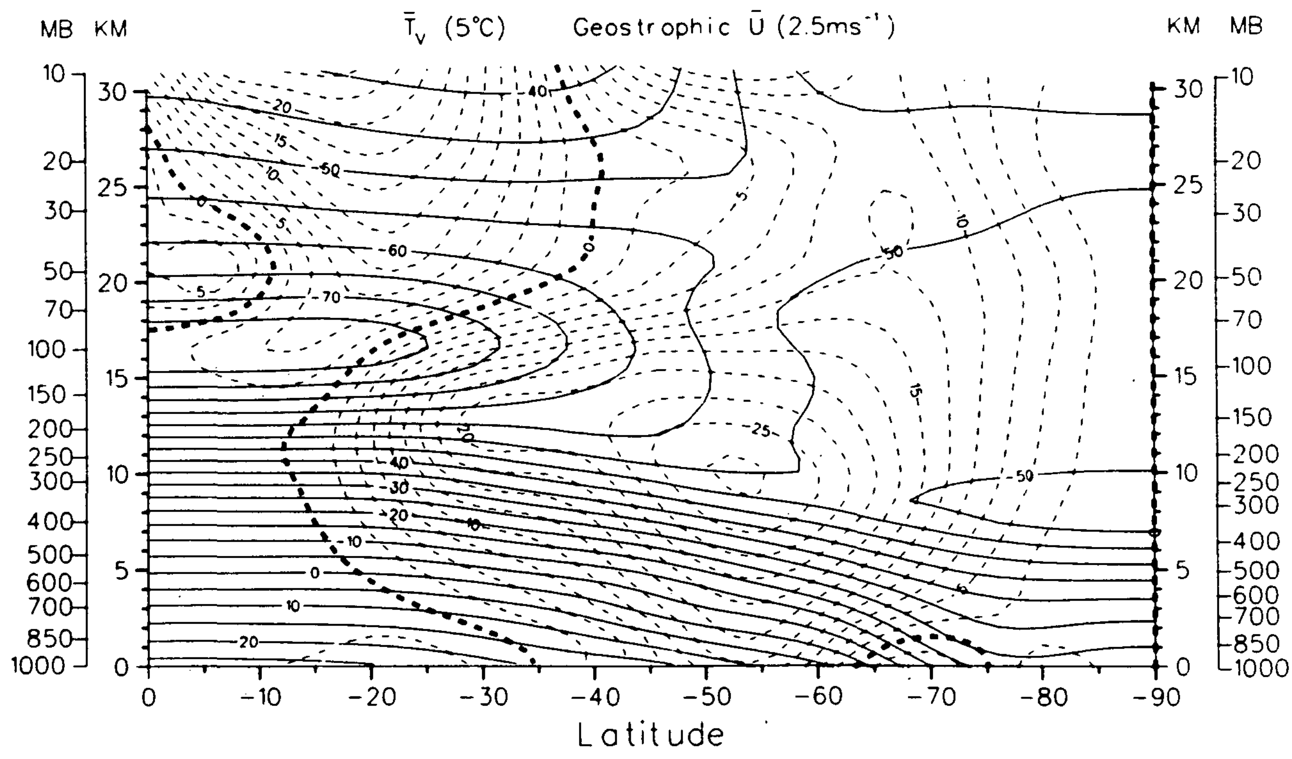




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

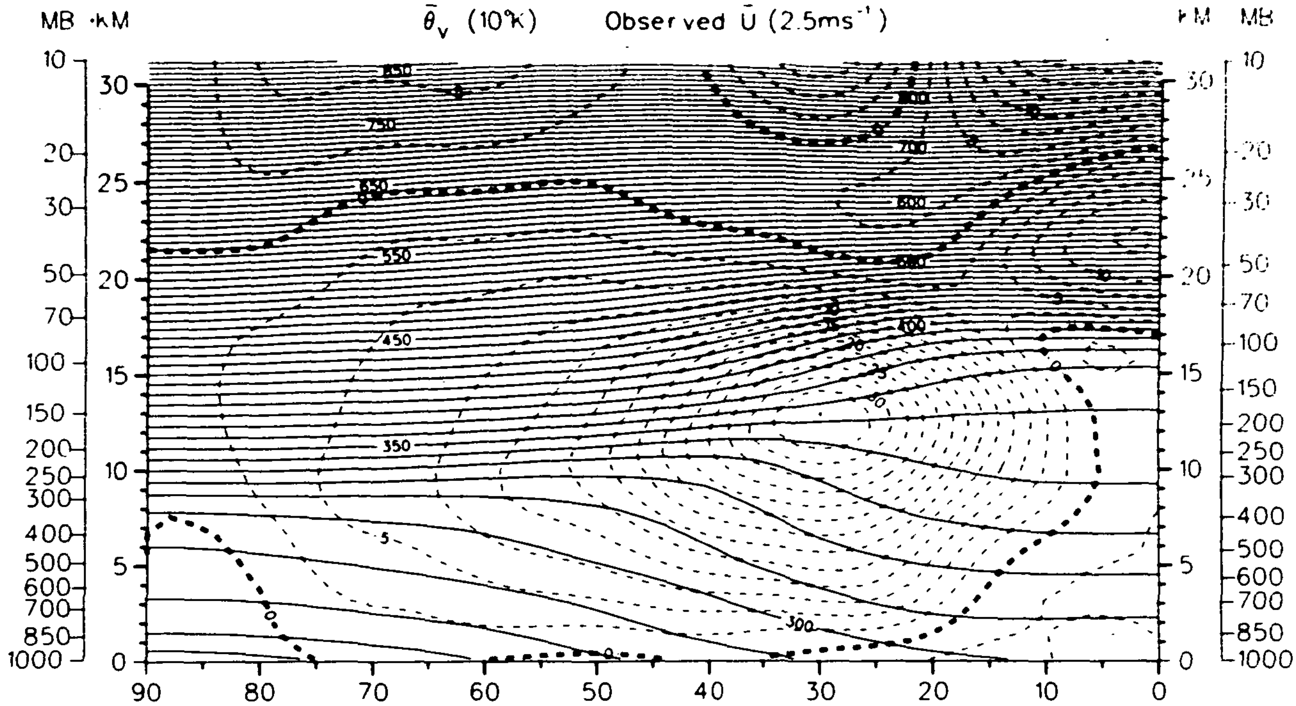
MARCH 1976

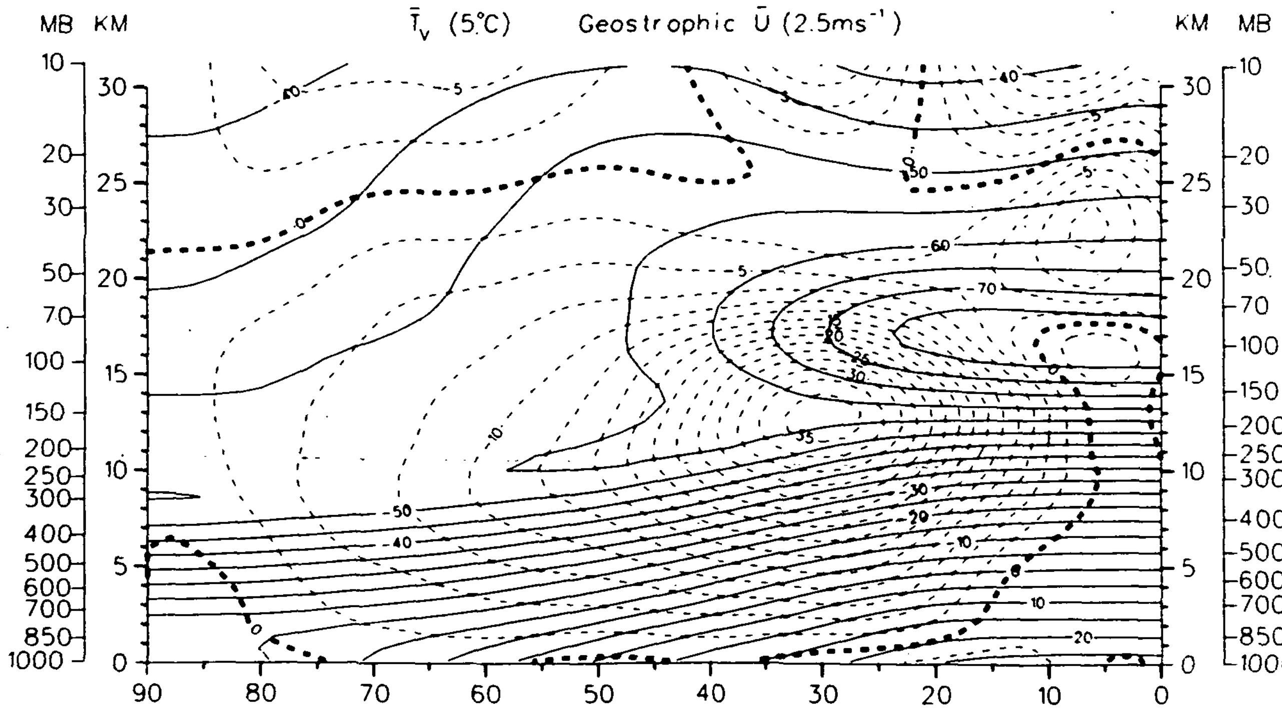




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

APRIL 1976





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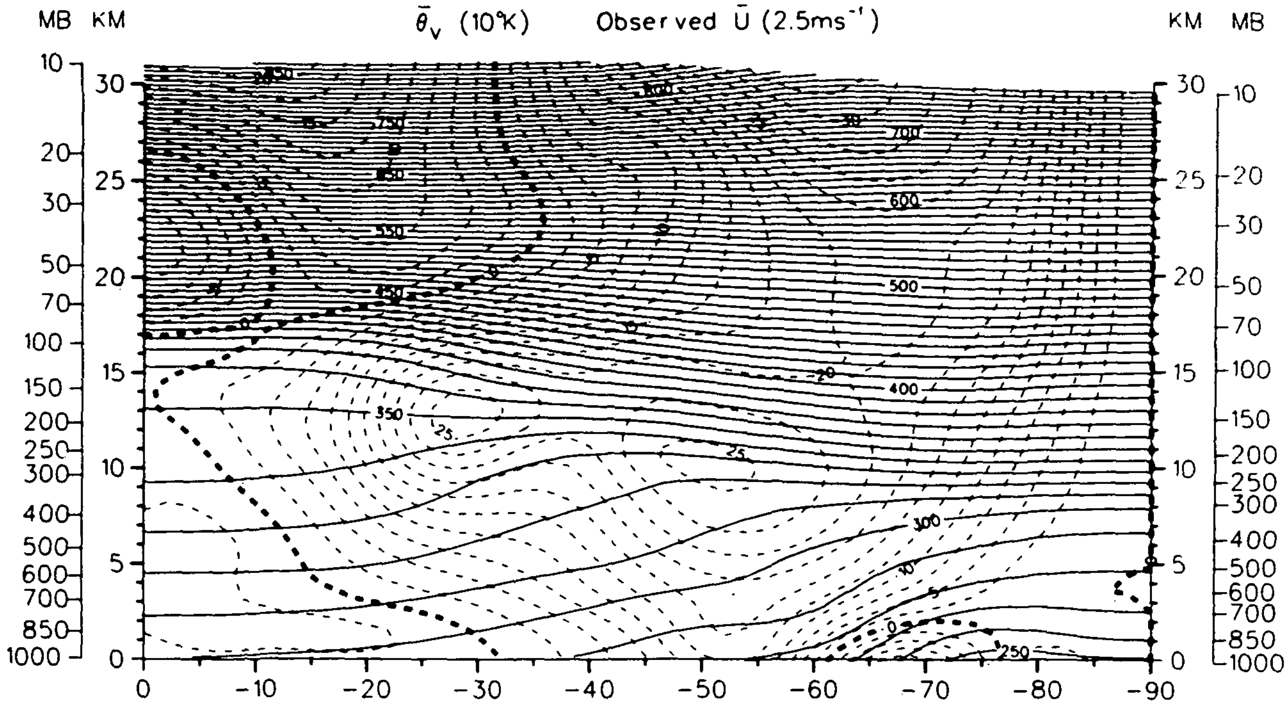
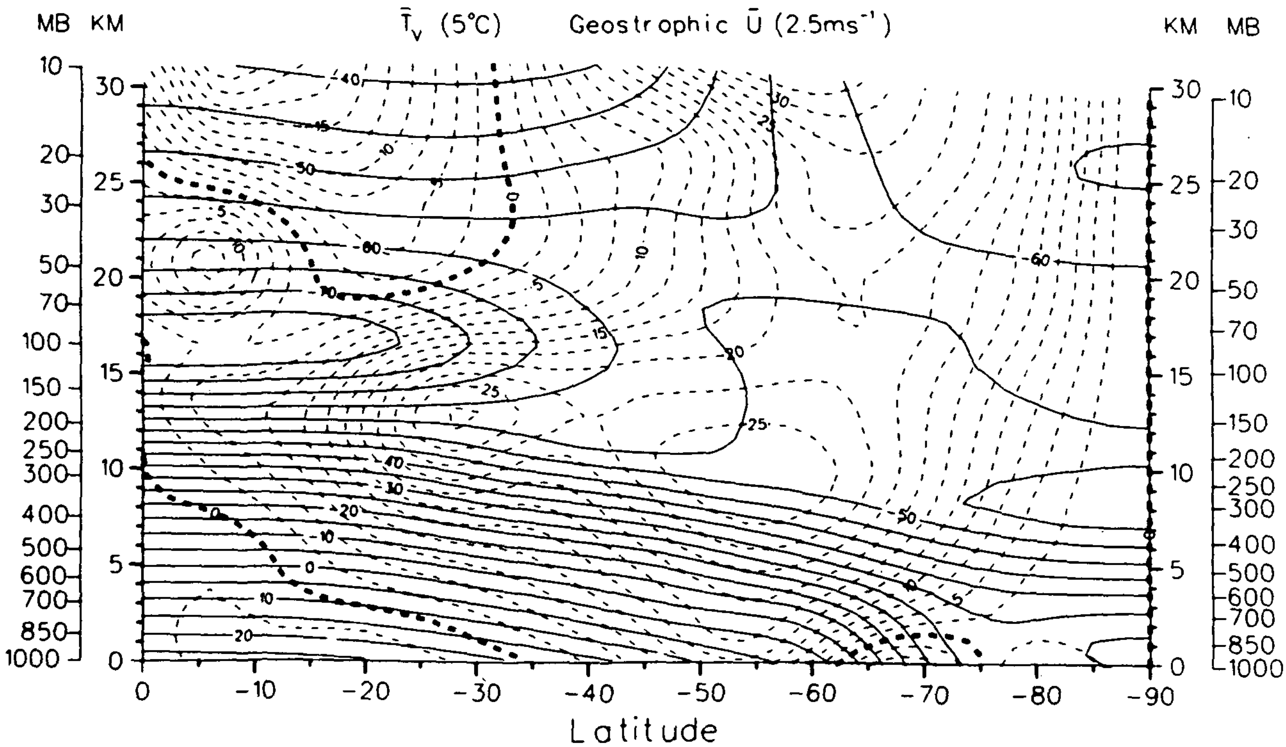
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

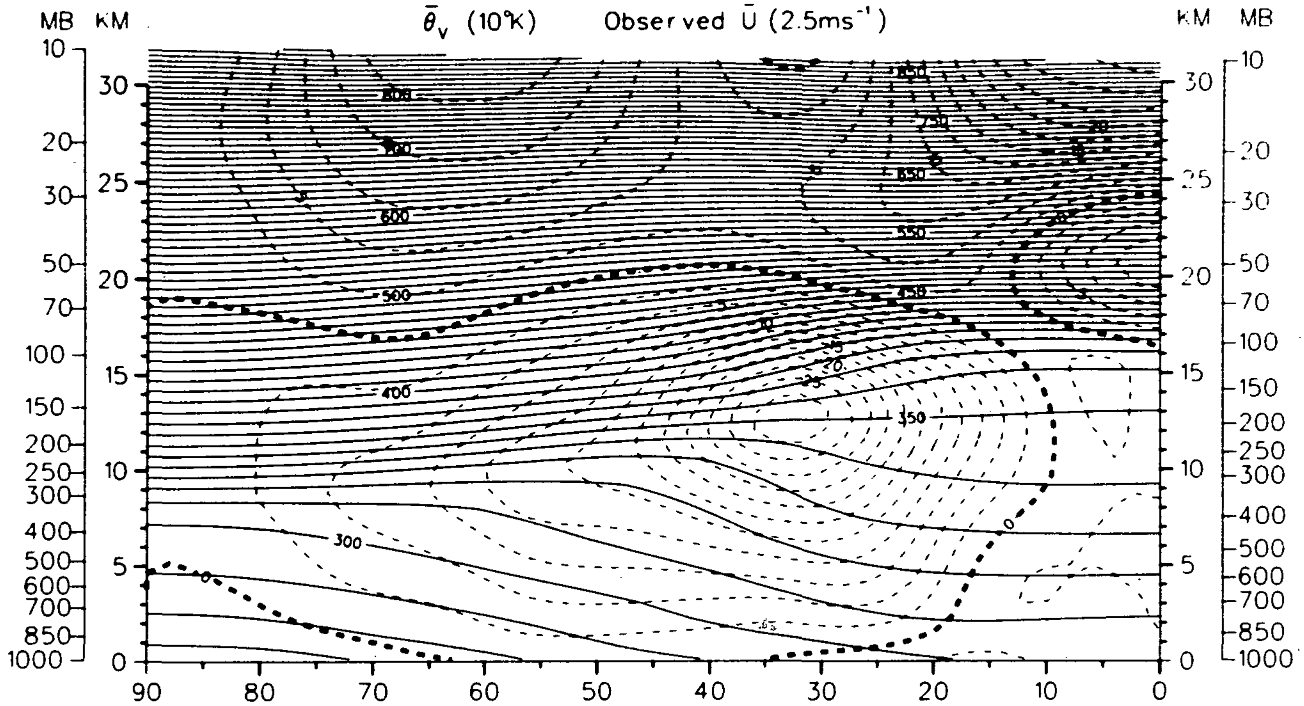
APRIL 1976

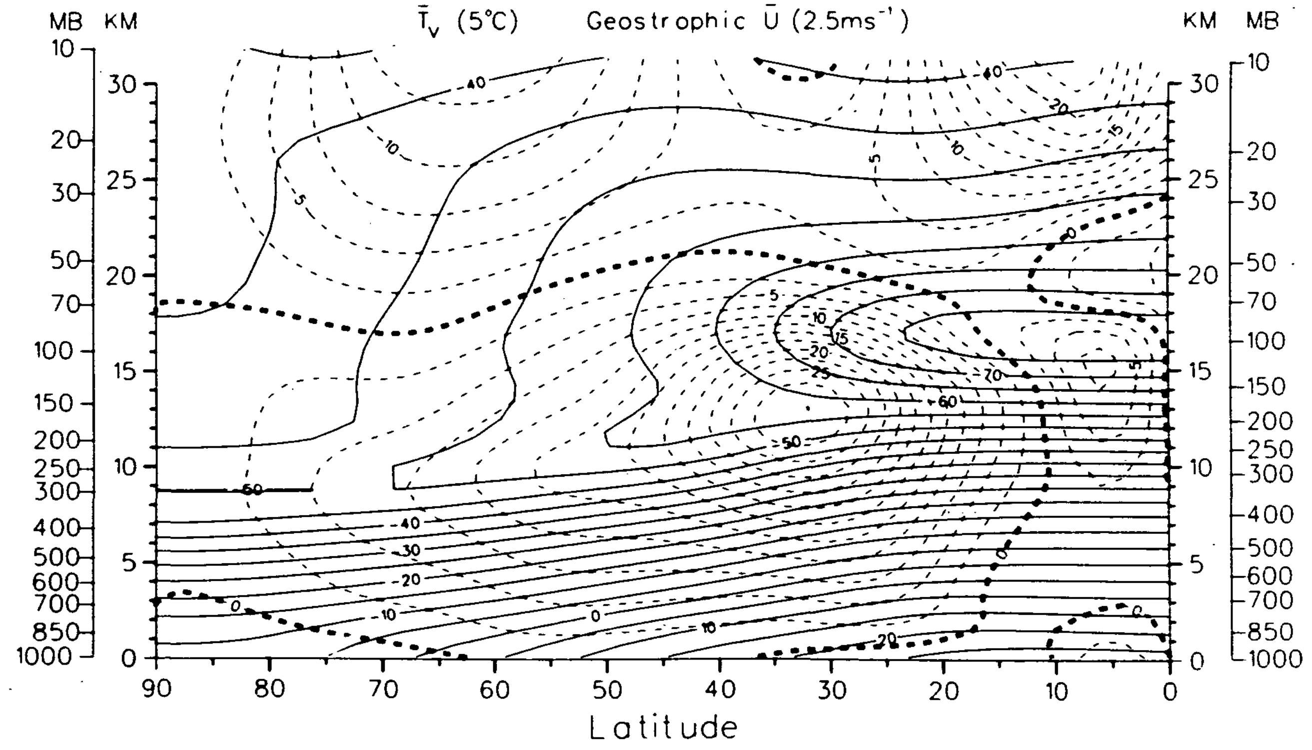




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

MAY 1976





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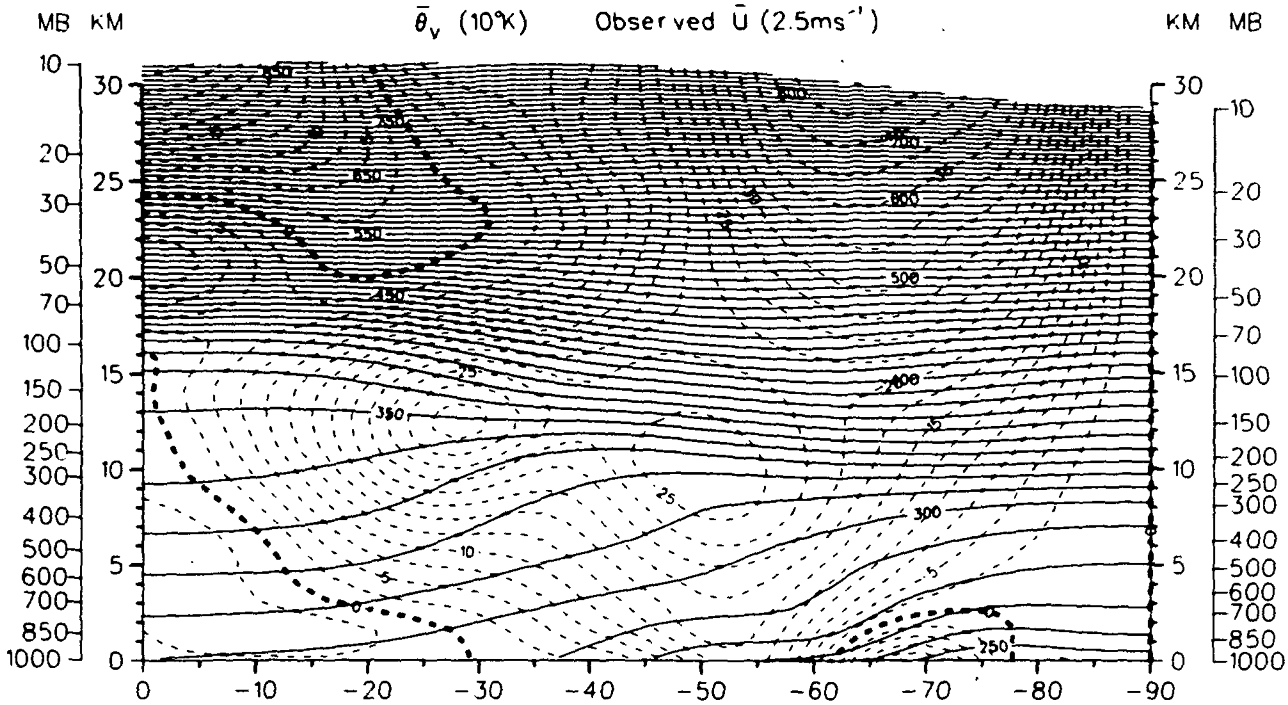
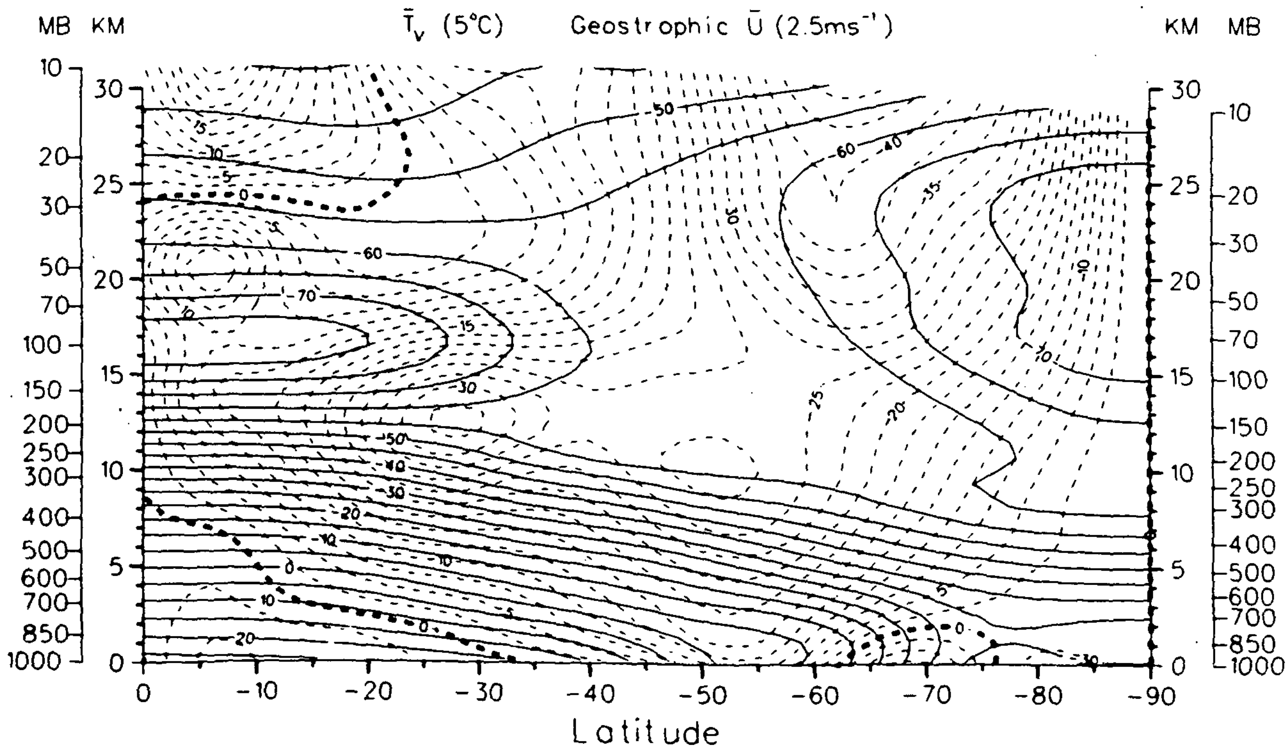
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

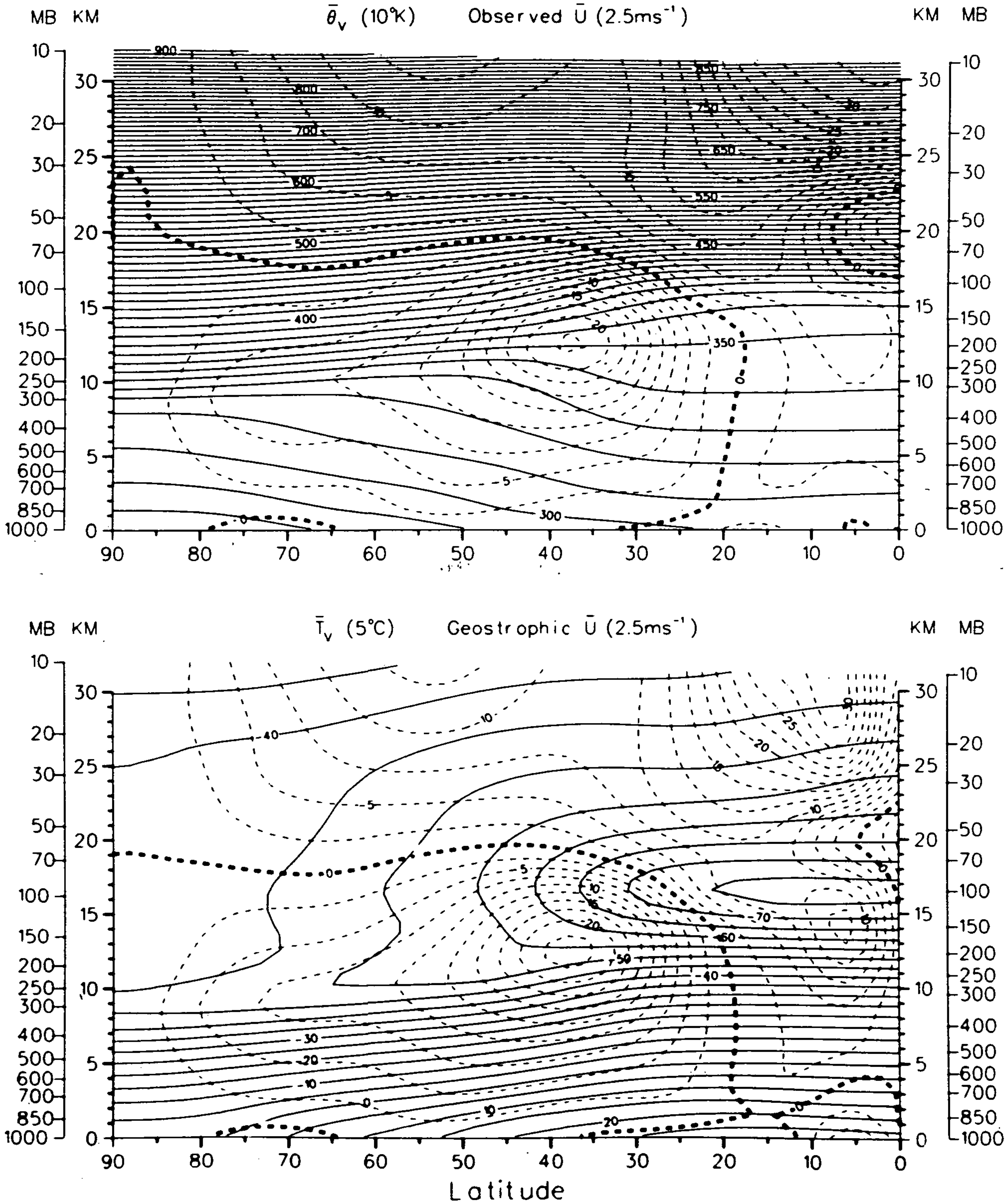
MAY 1976





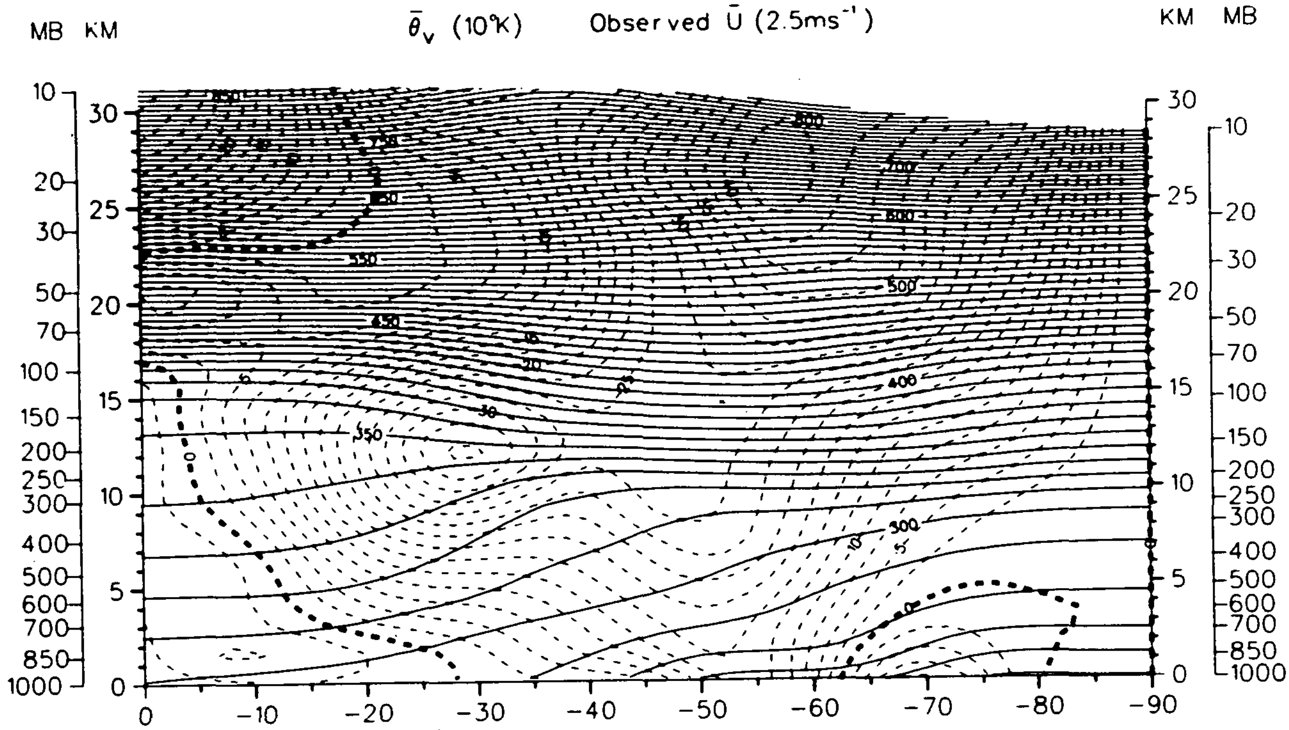
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

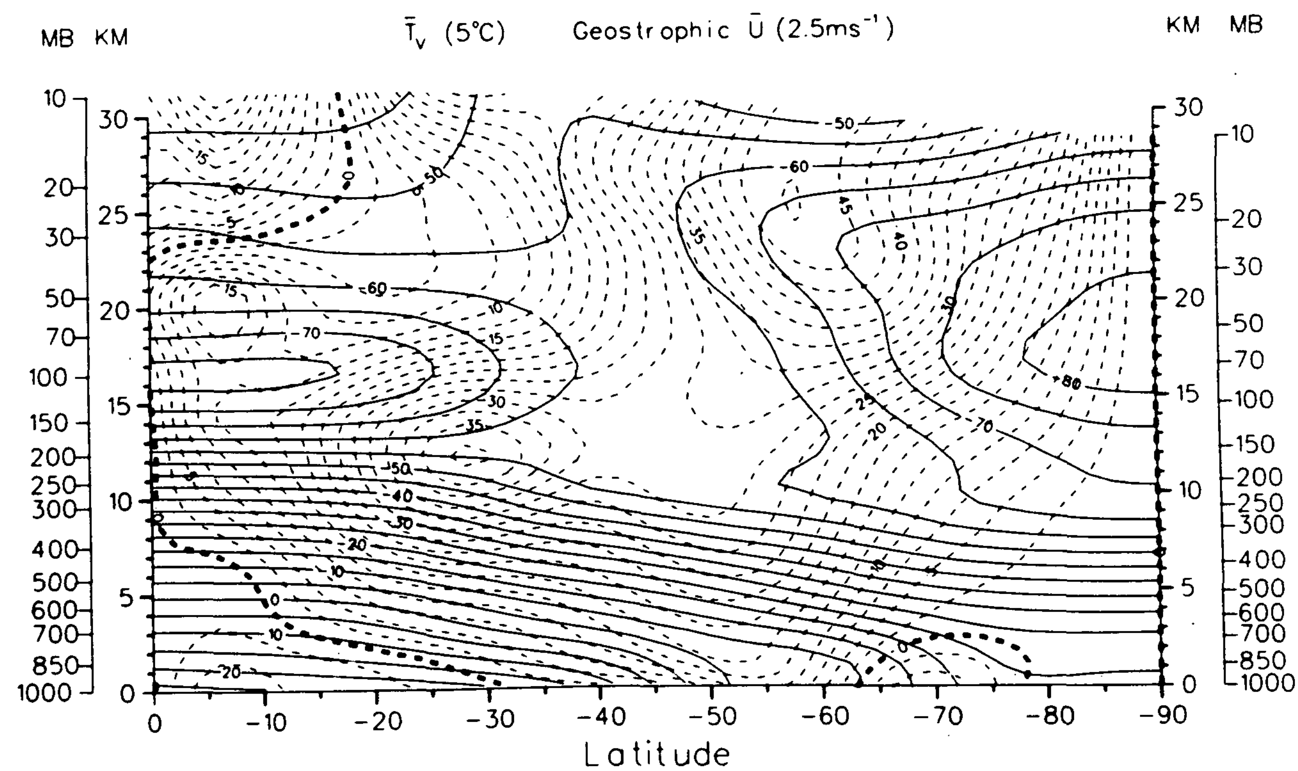
JUNE 1976



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

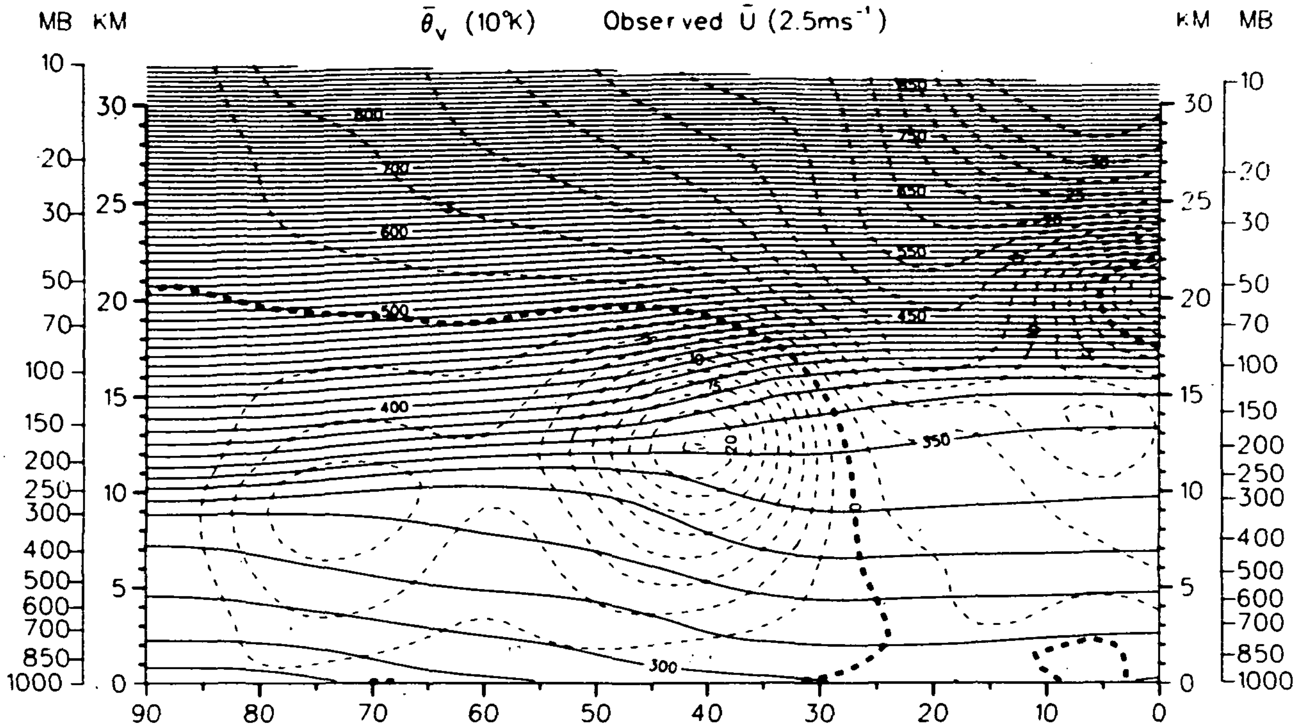
JUNE 1976

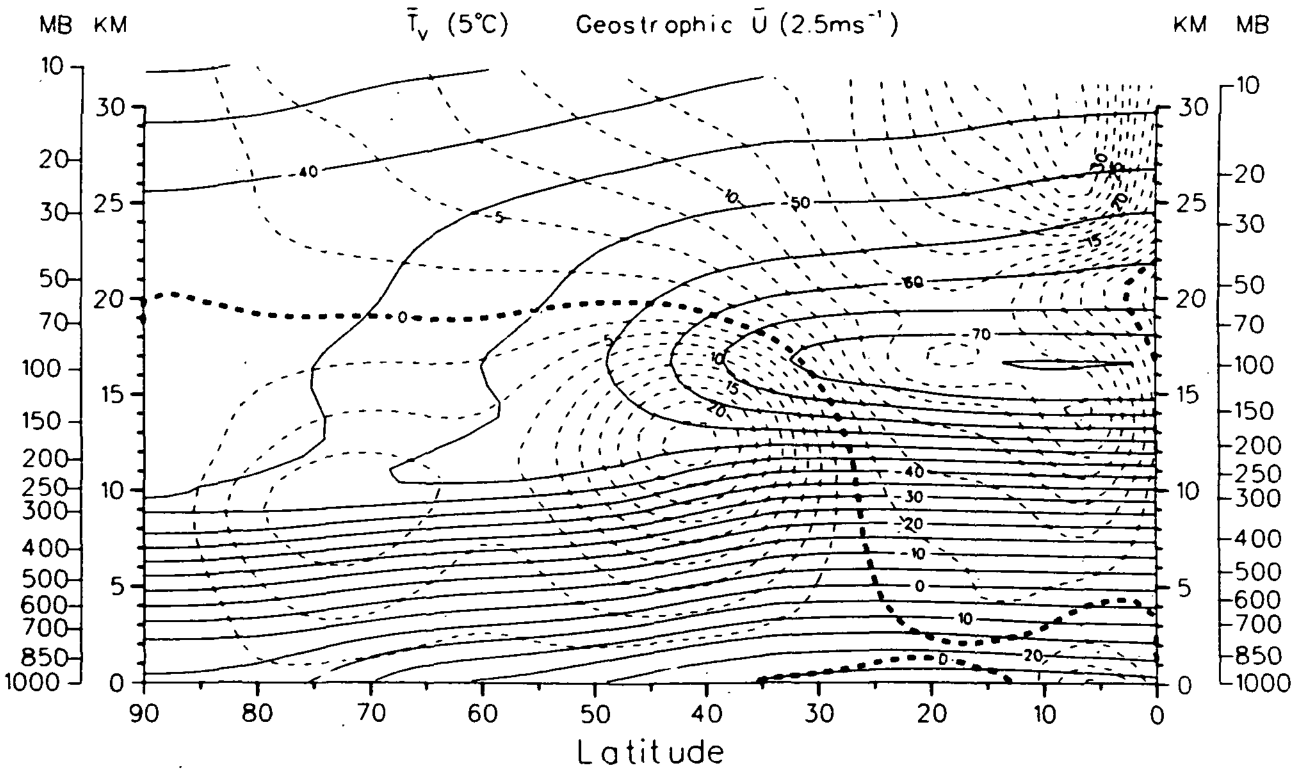




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JULY 1976

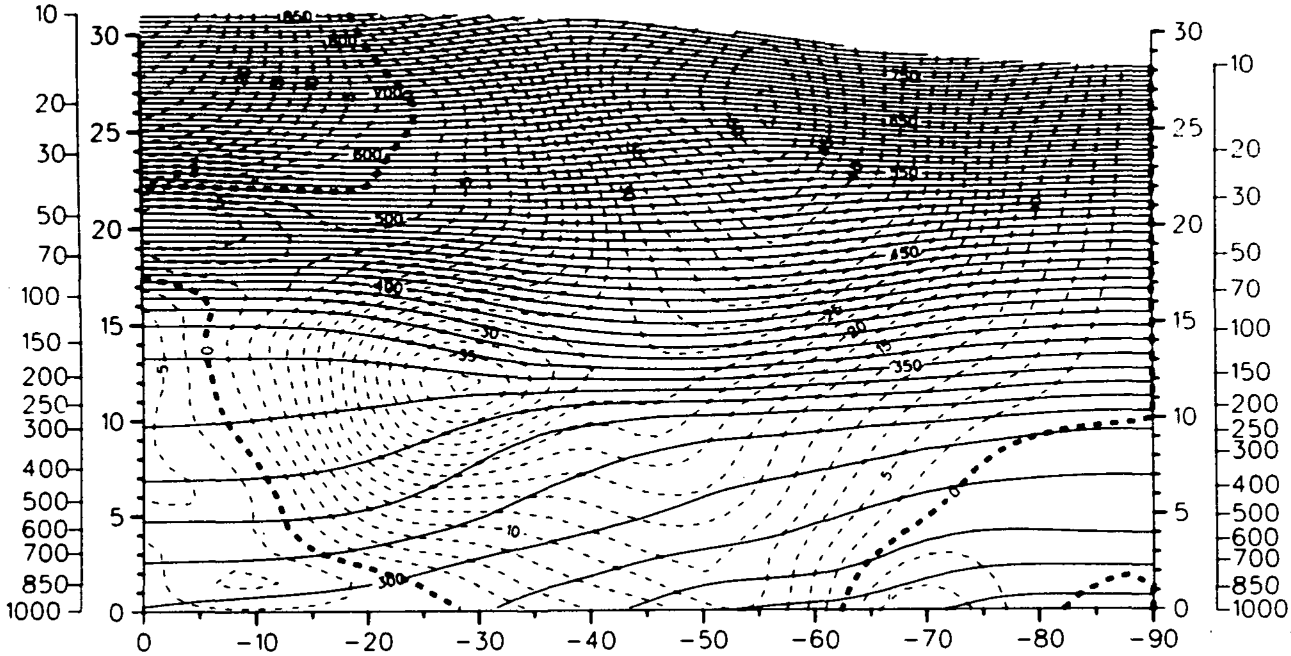




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JULY 1976

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB



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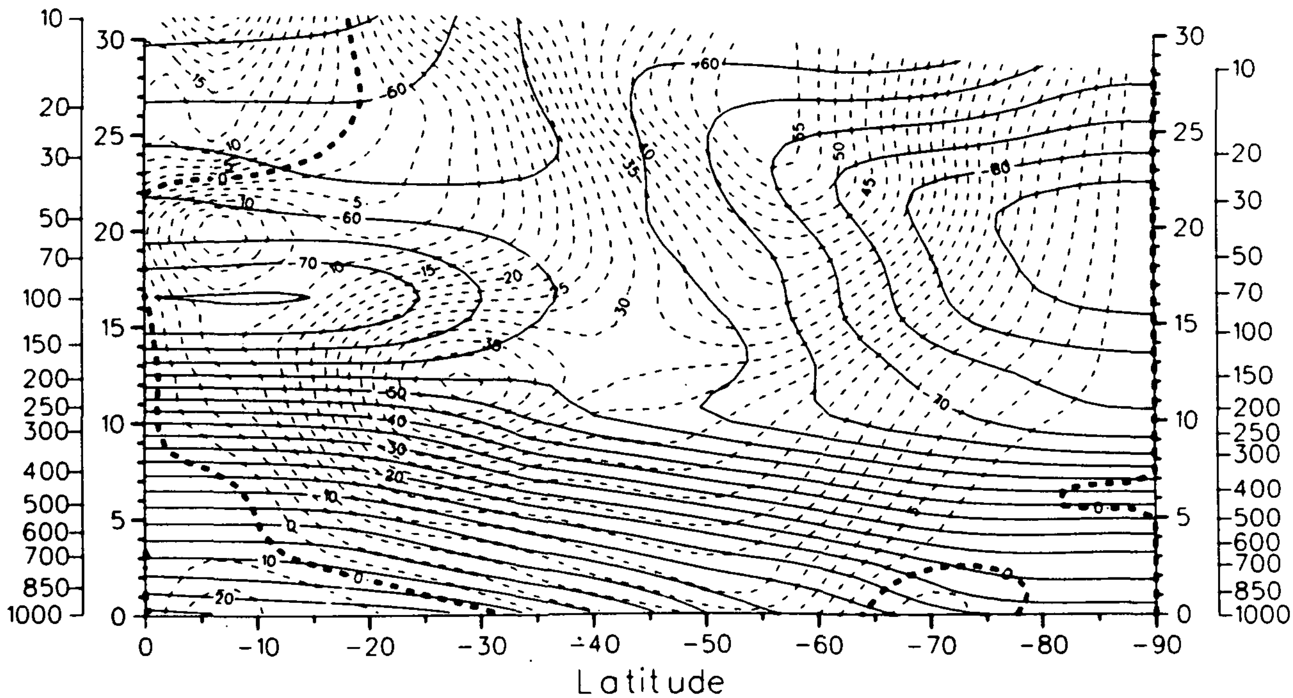
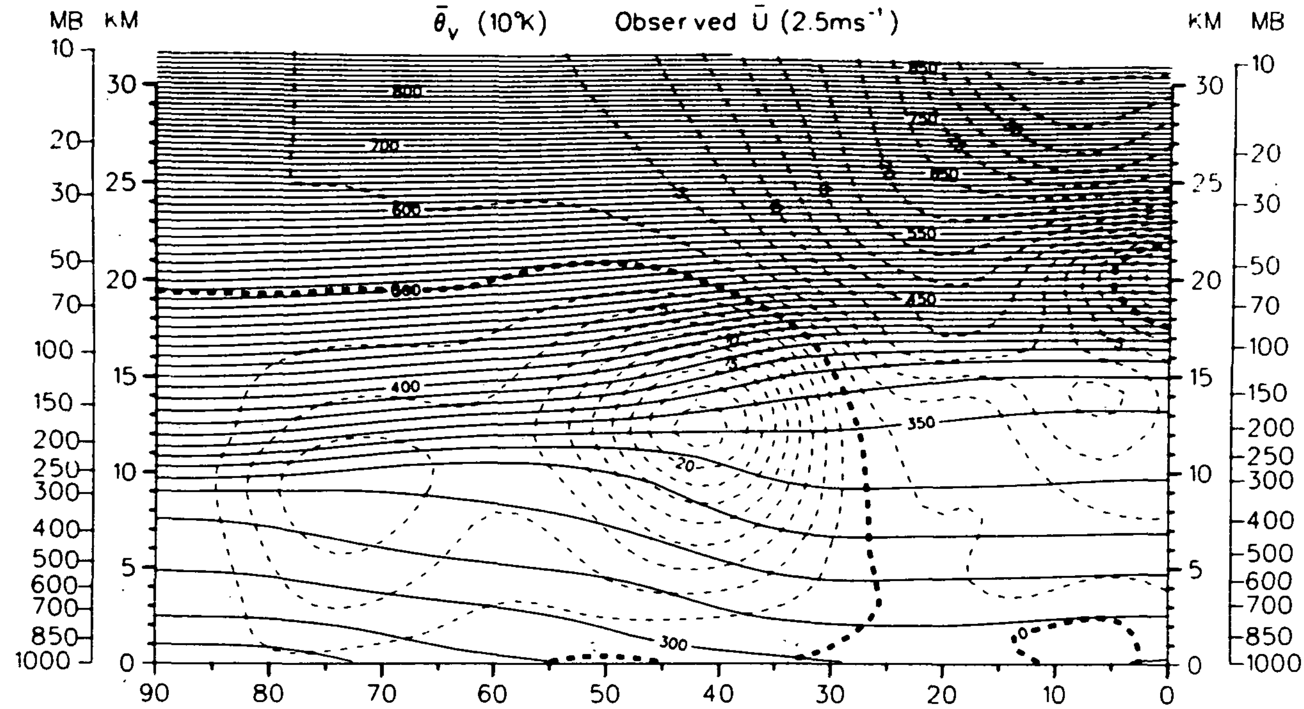
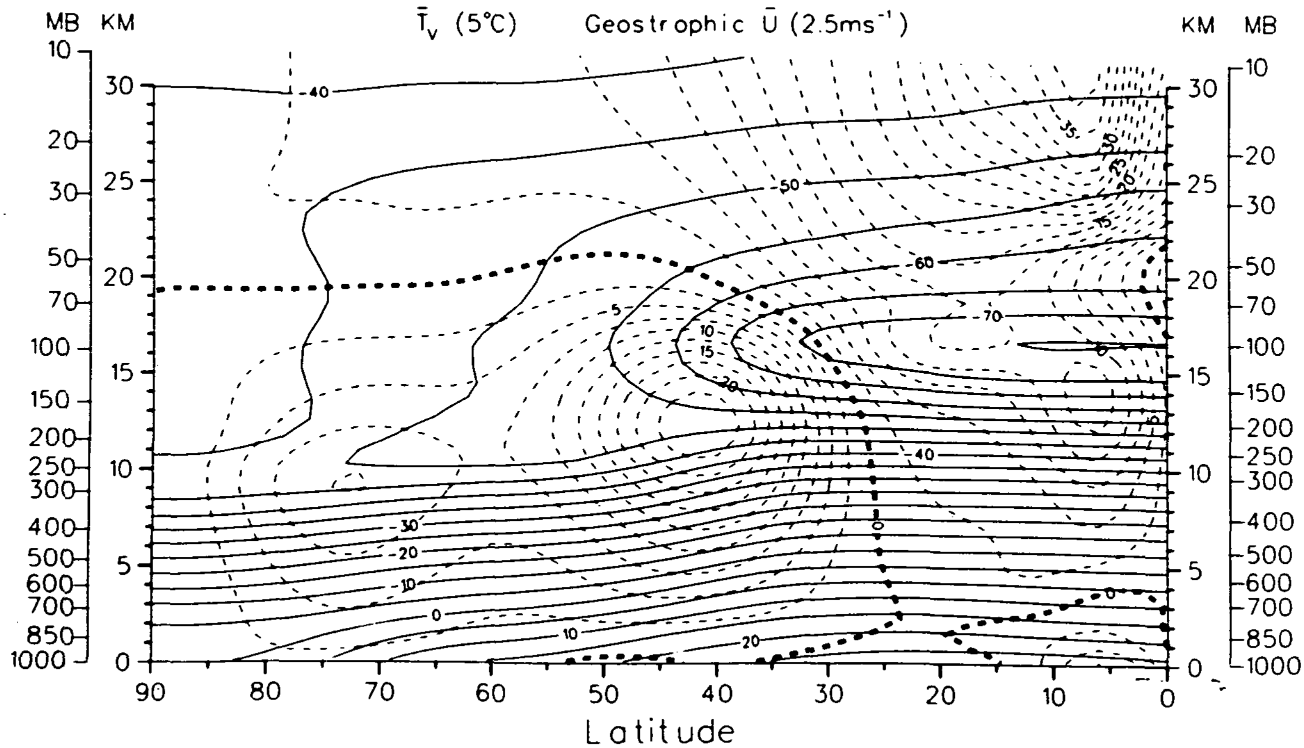


NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

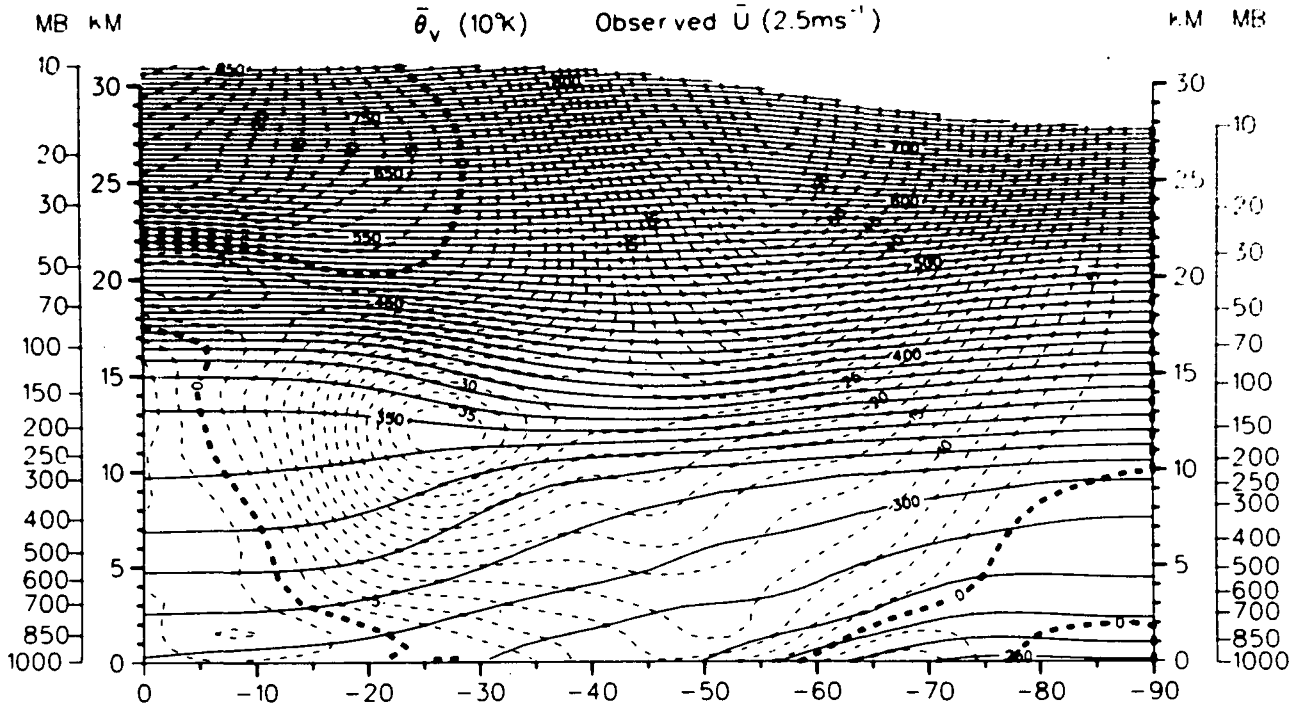
AUGUST 1976

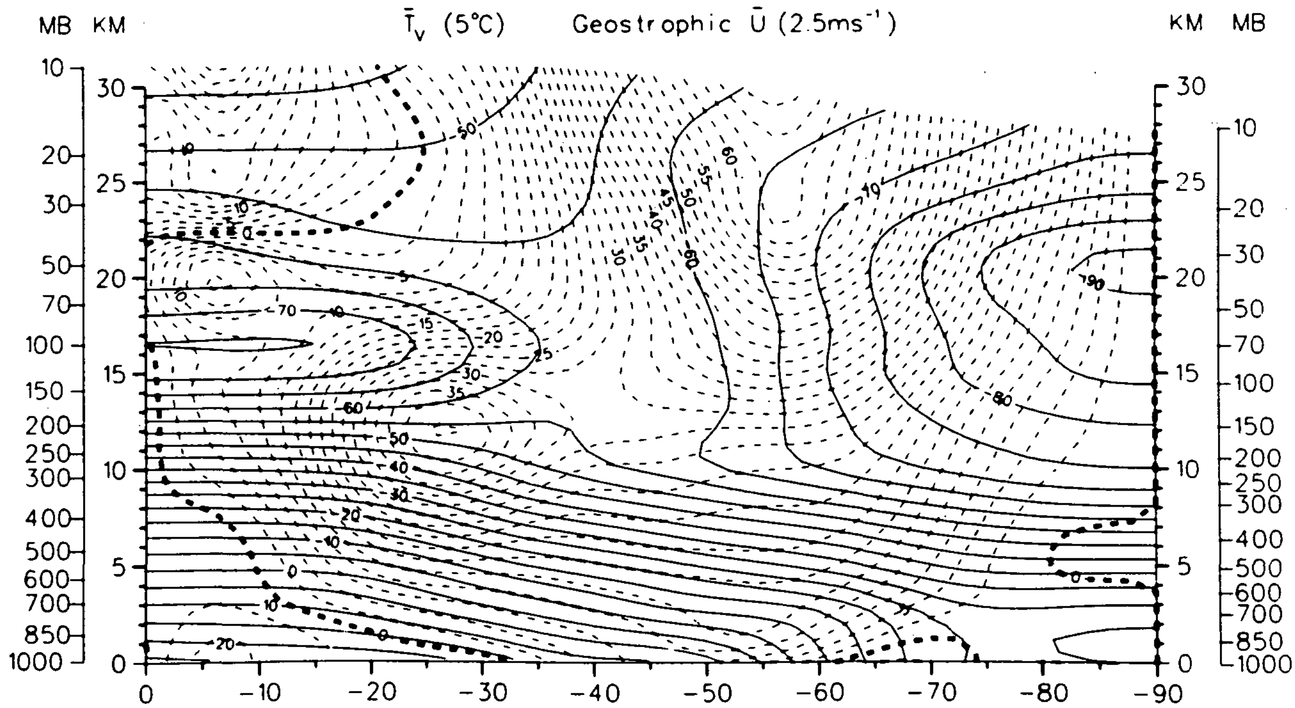




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

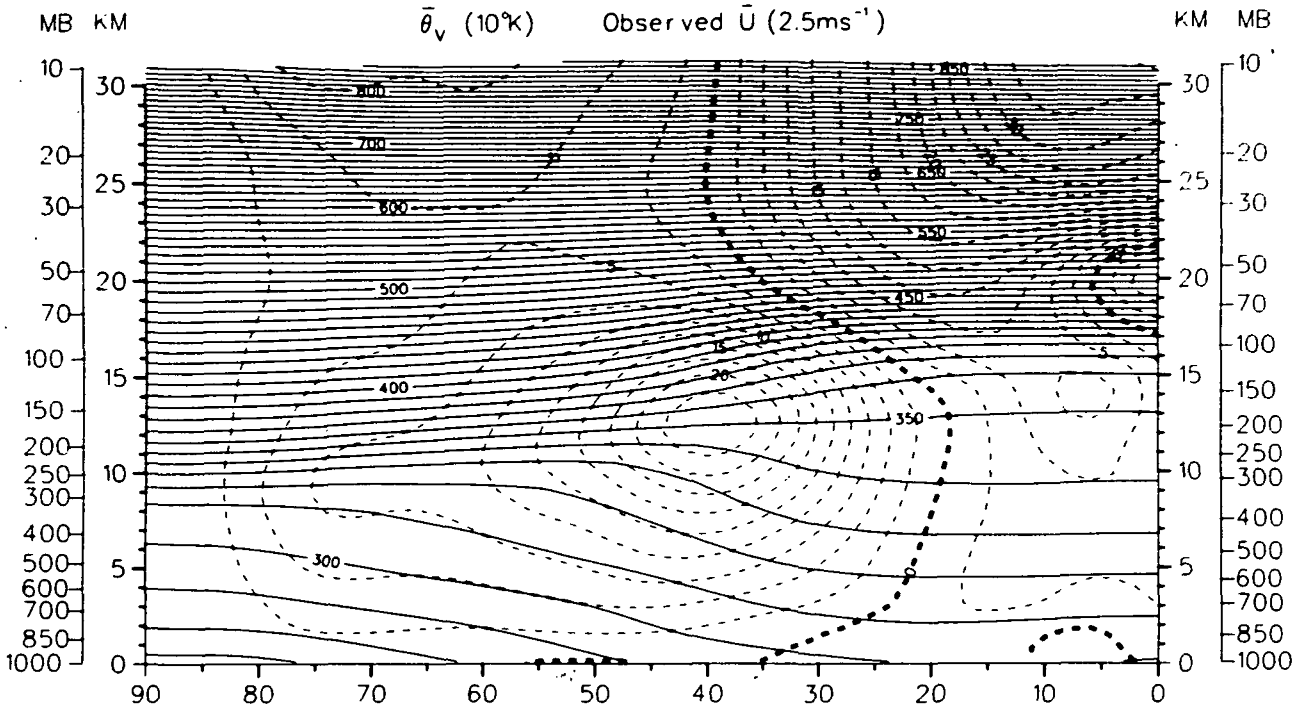
AUGUST 1976

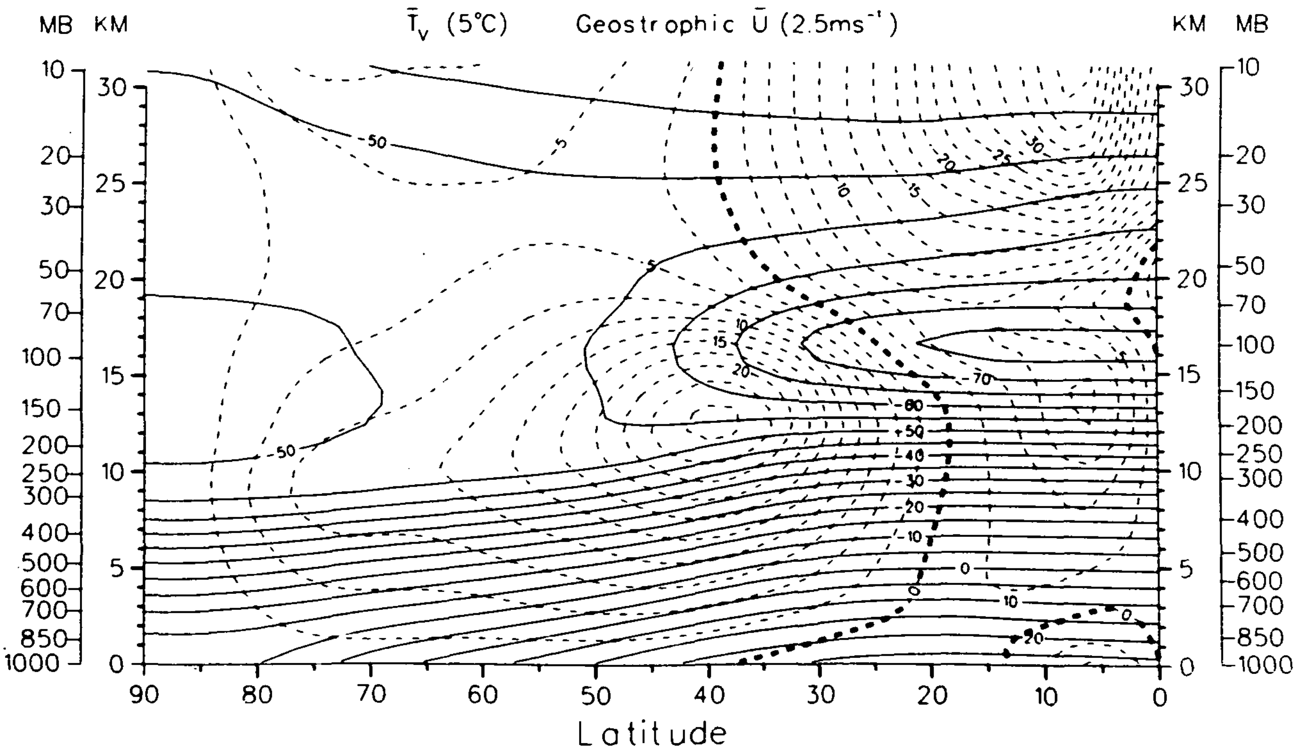




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

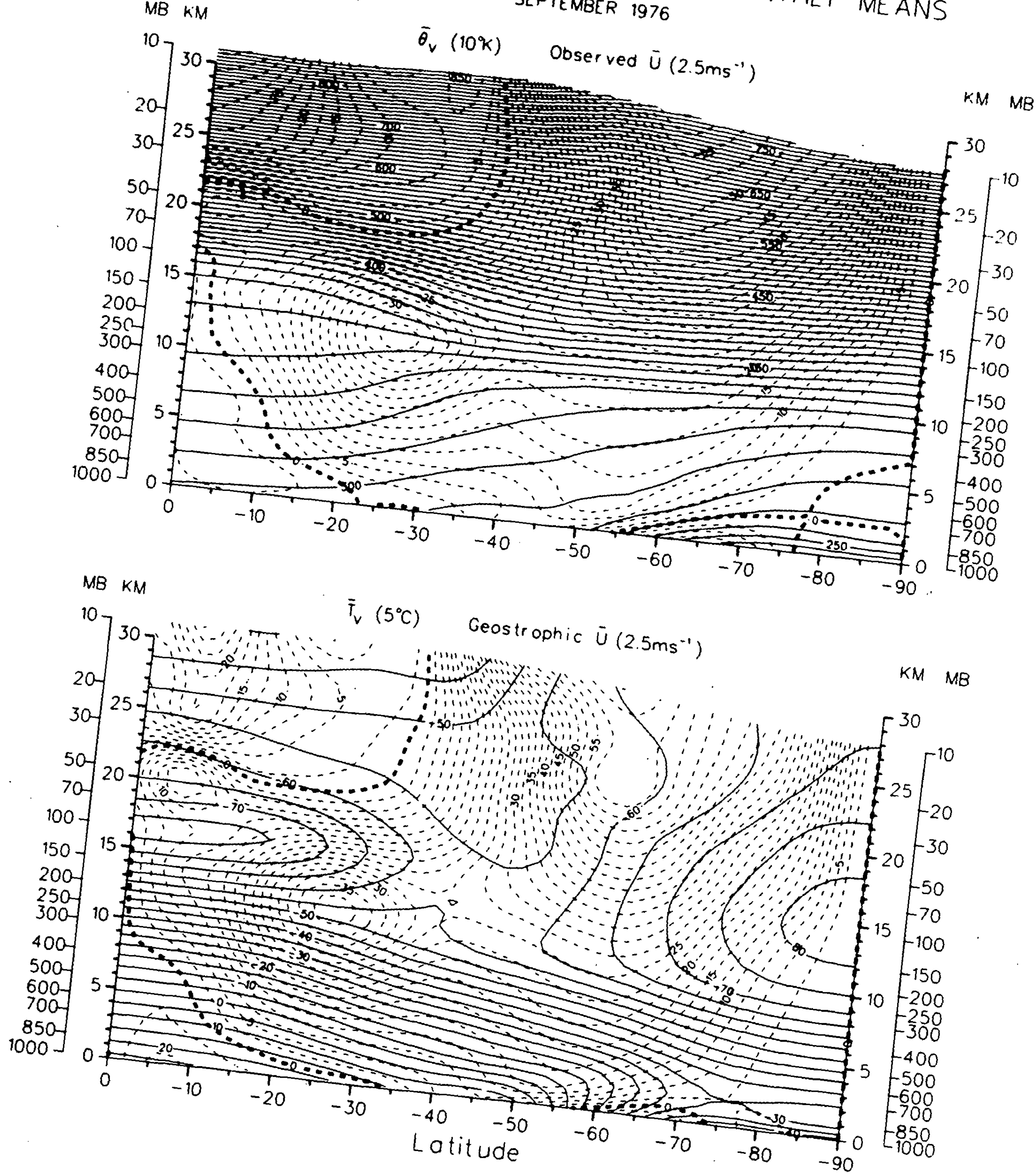
SEPTEMBER 1976





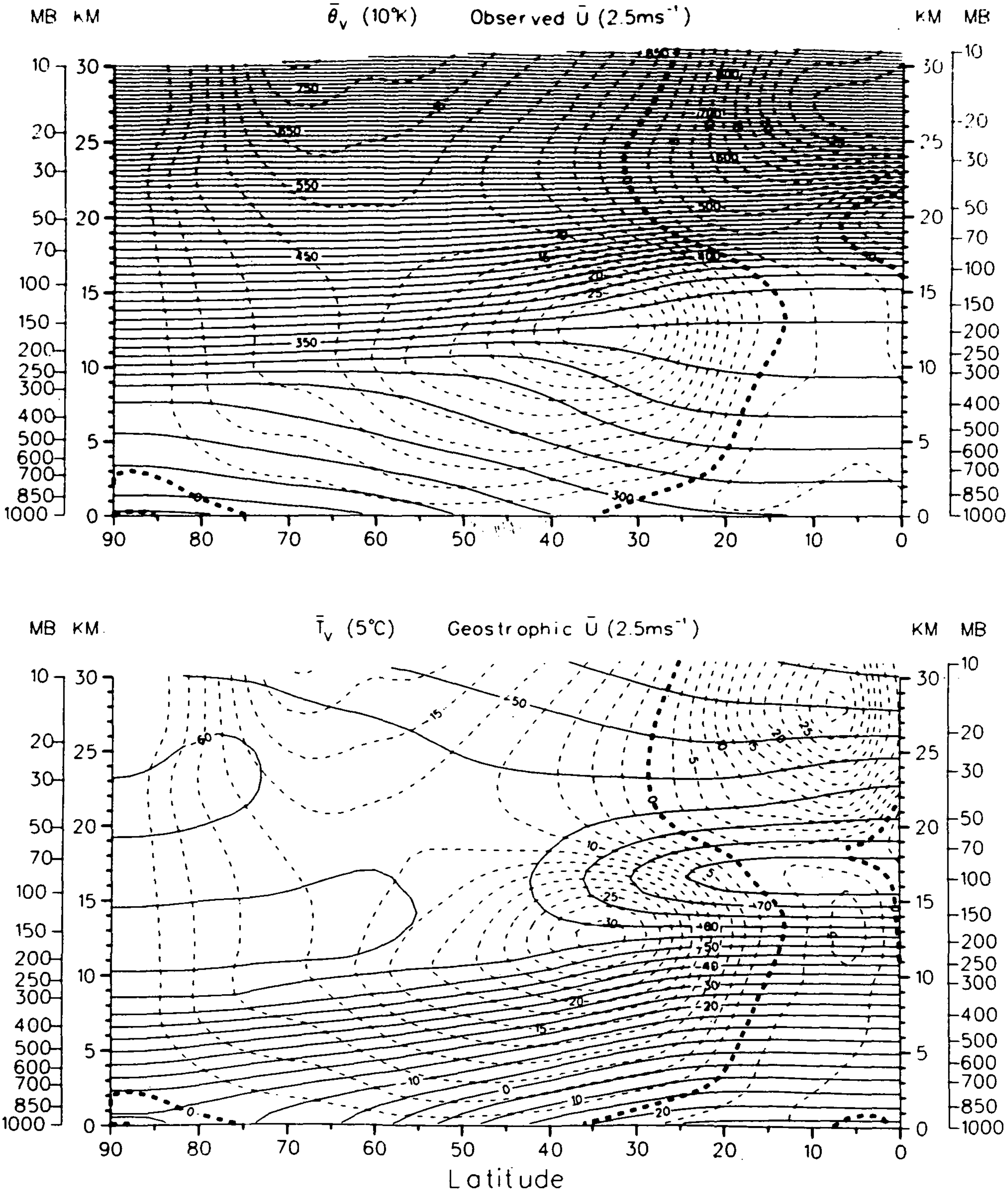
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

SEPTEMBER 1976



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

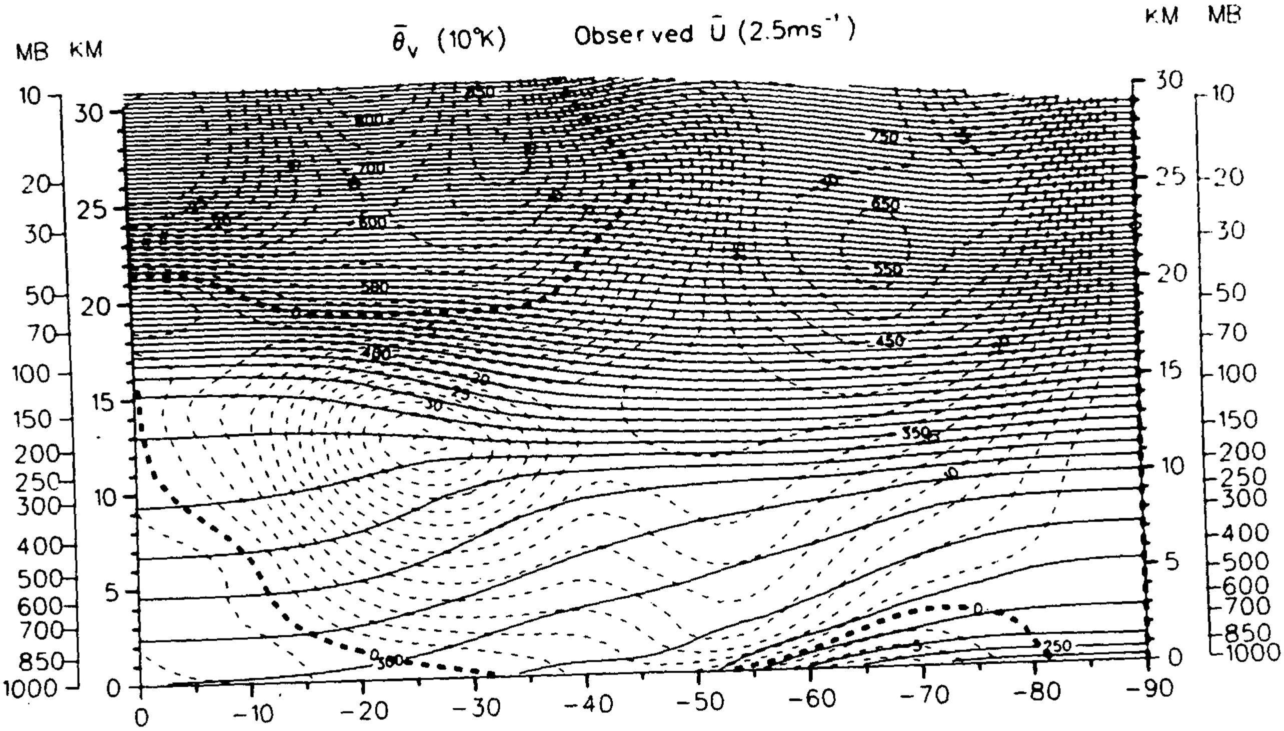
OCTOBER 1976



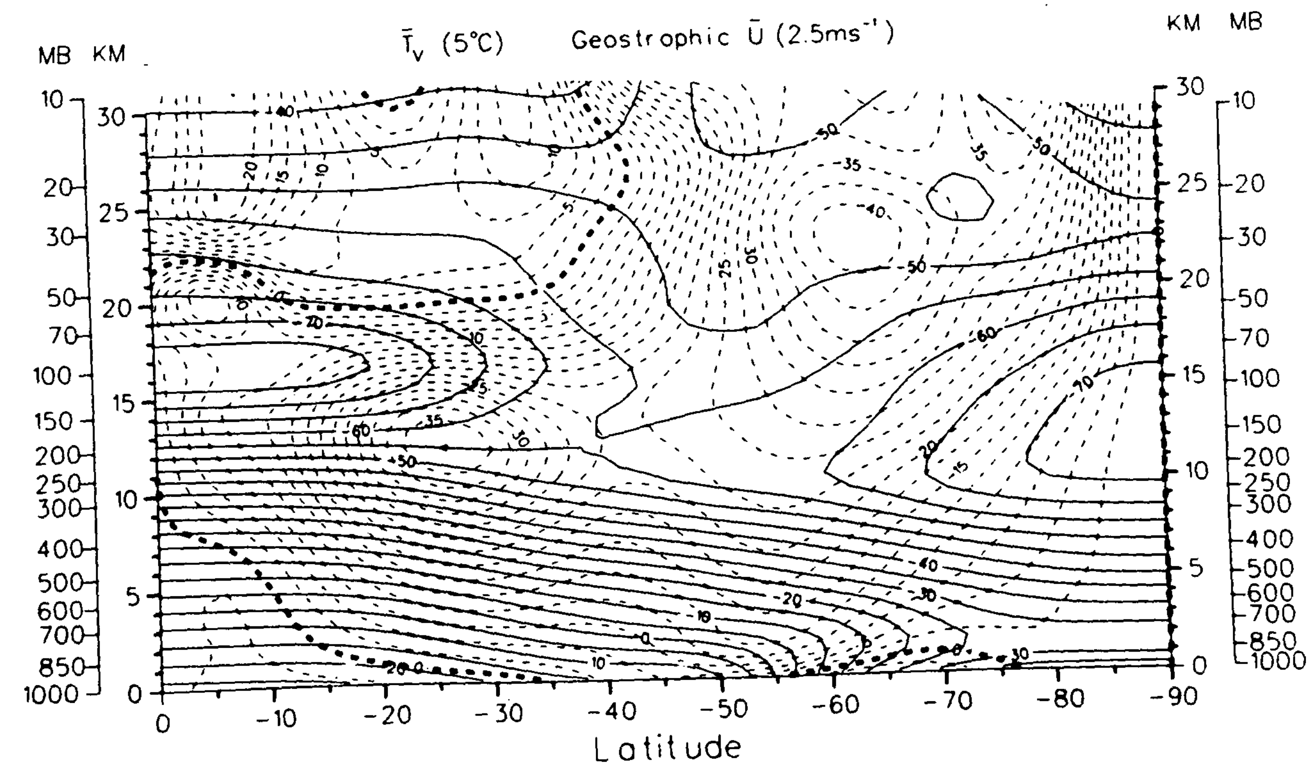
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

OCTOBER 1976

$\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1})

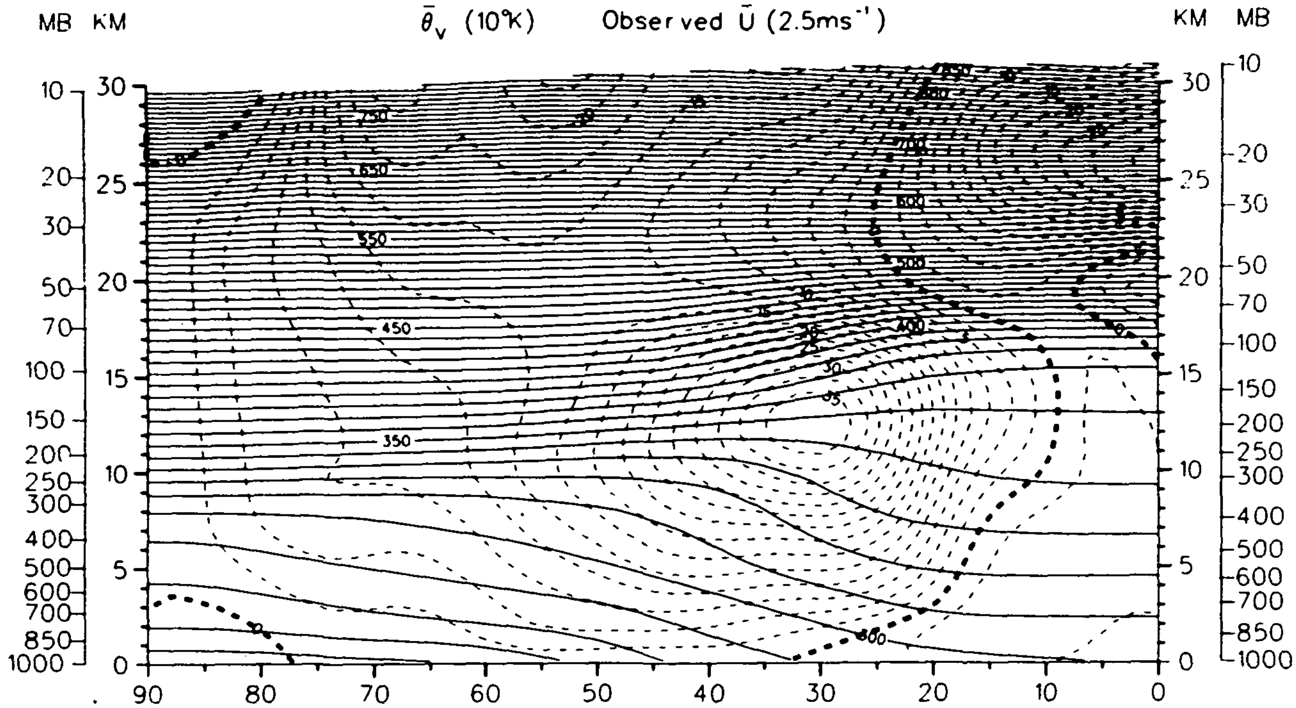


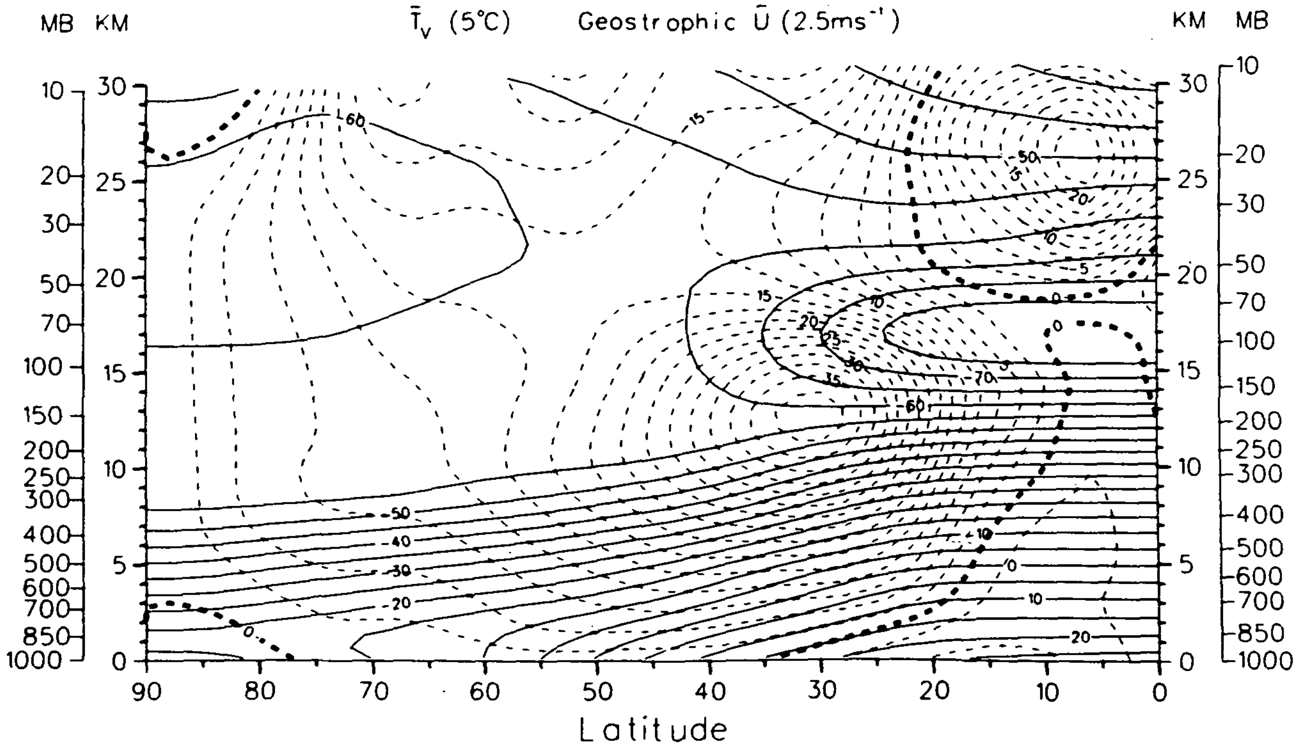
$\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1})



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

NOVEMBER 1976





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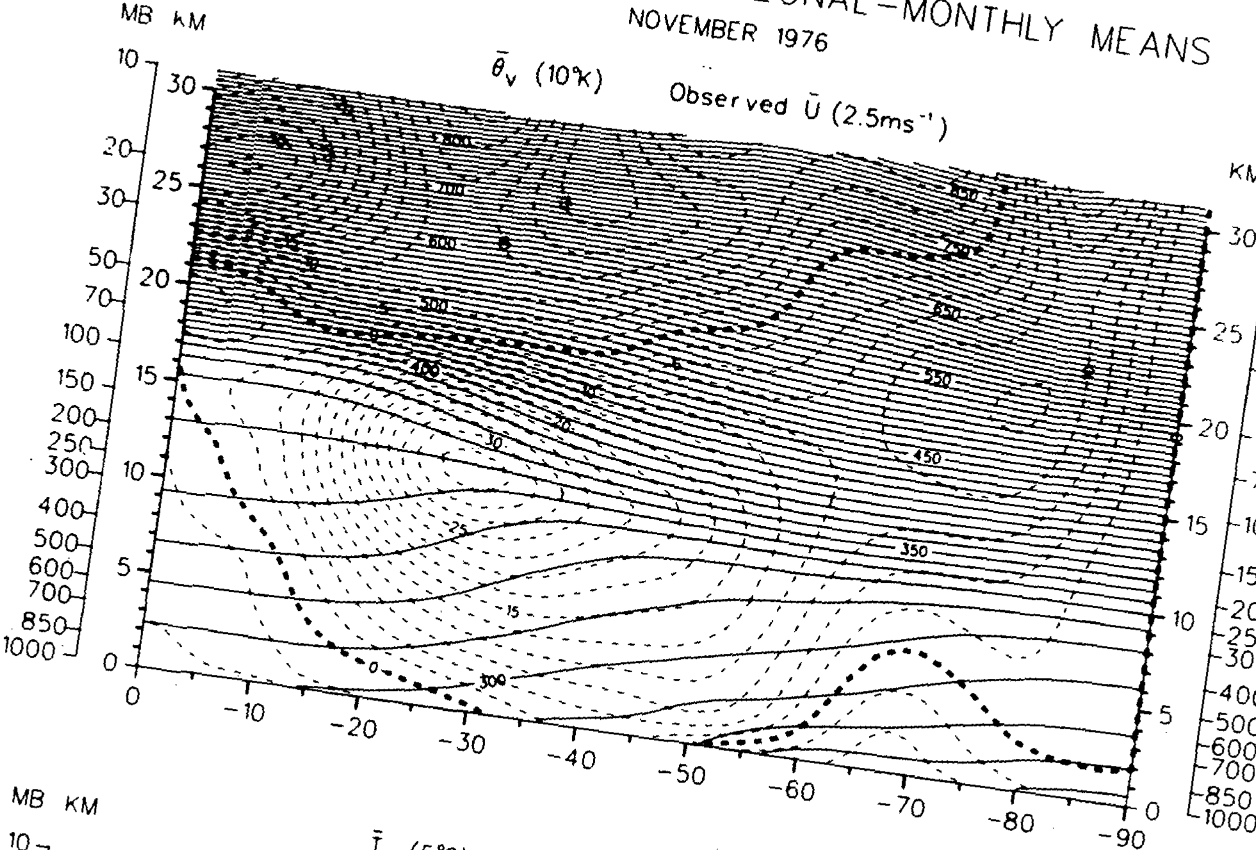
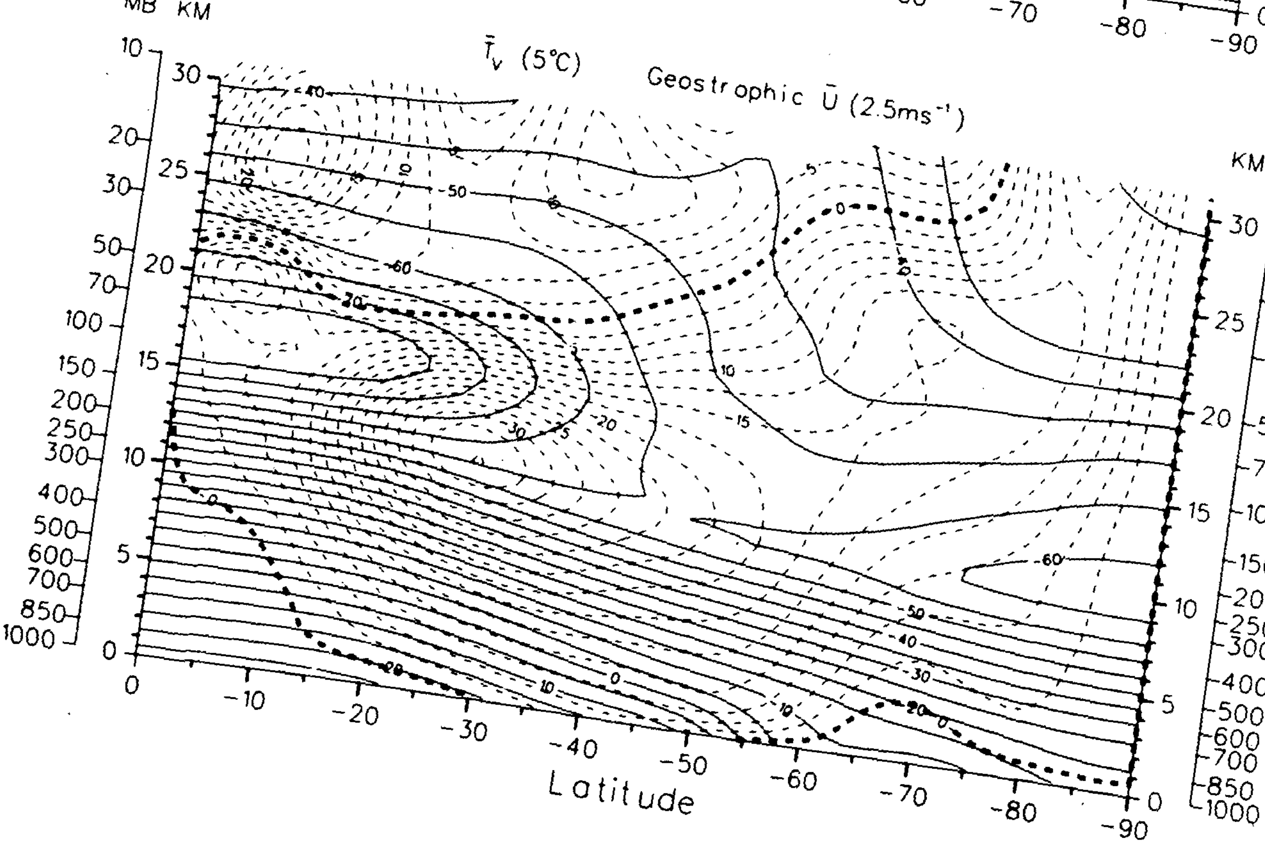
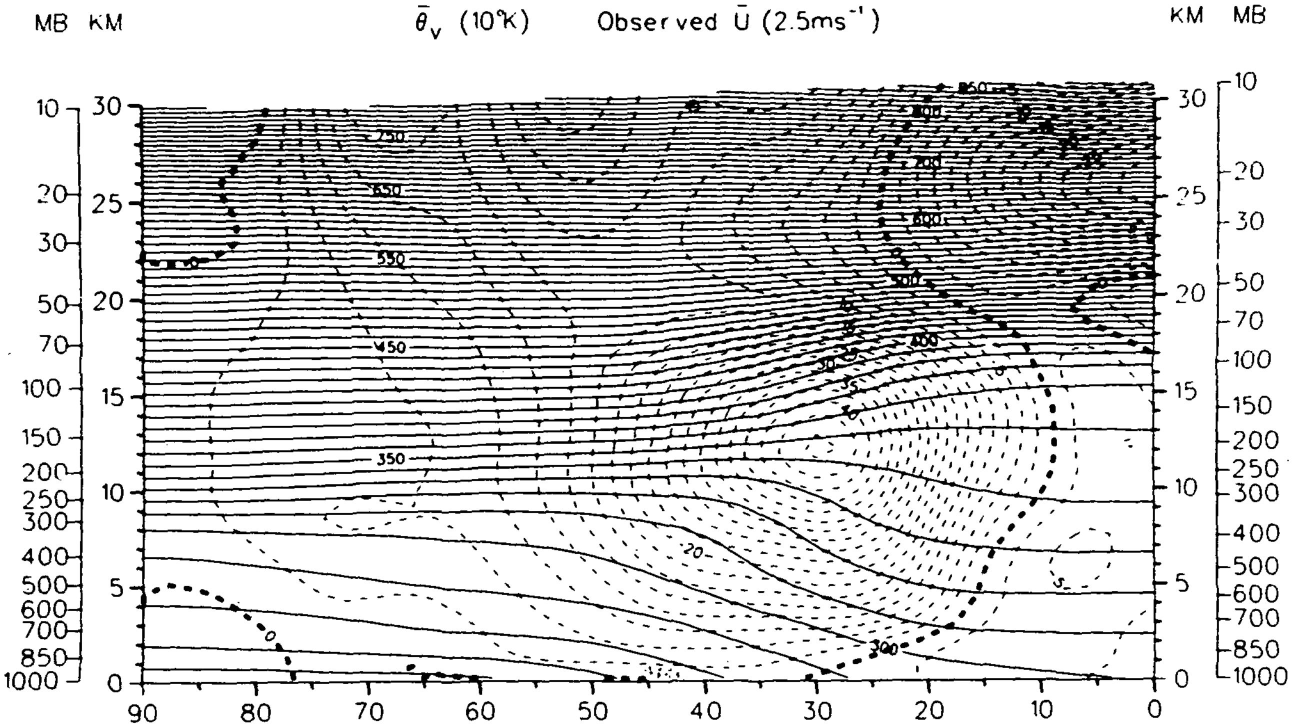
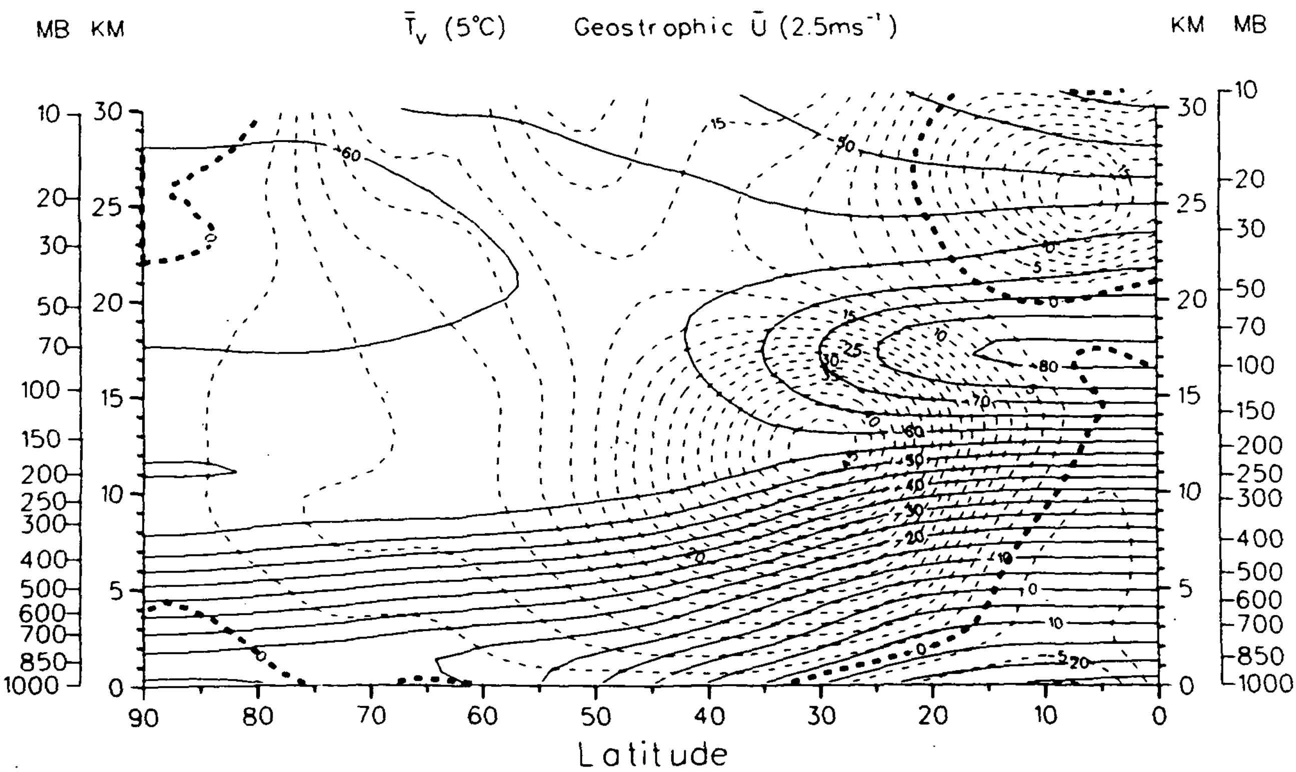




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

DECEMBER 1976





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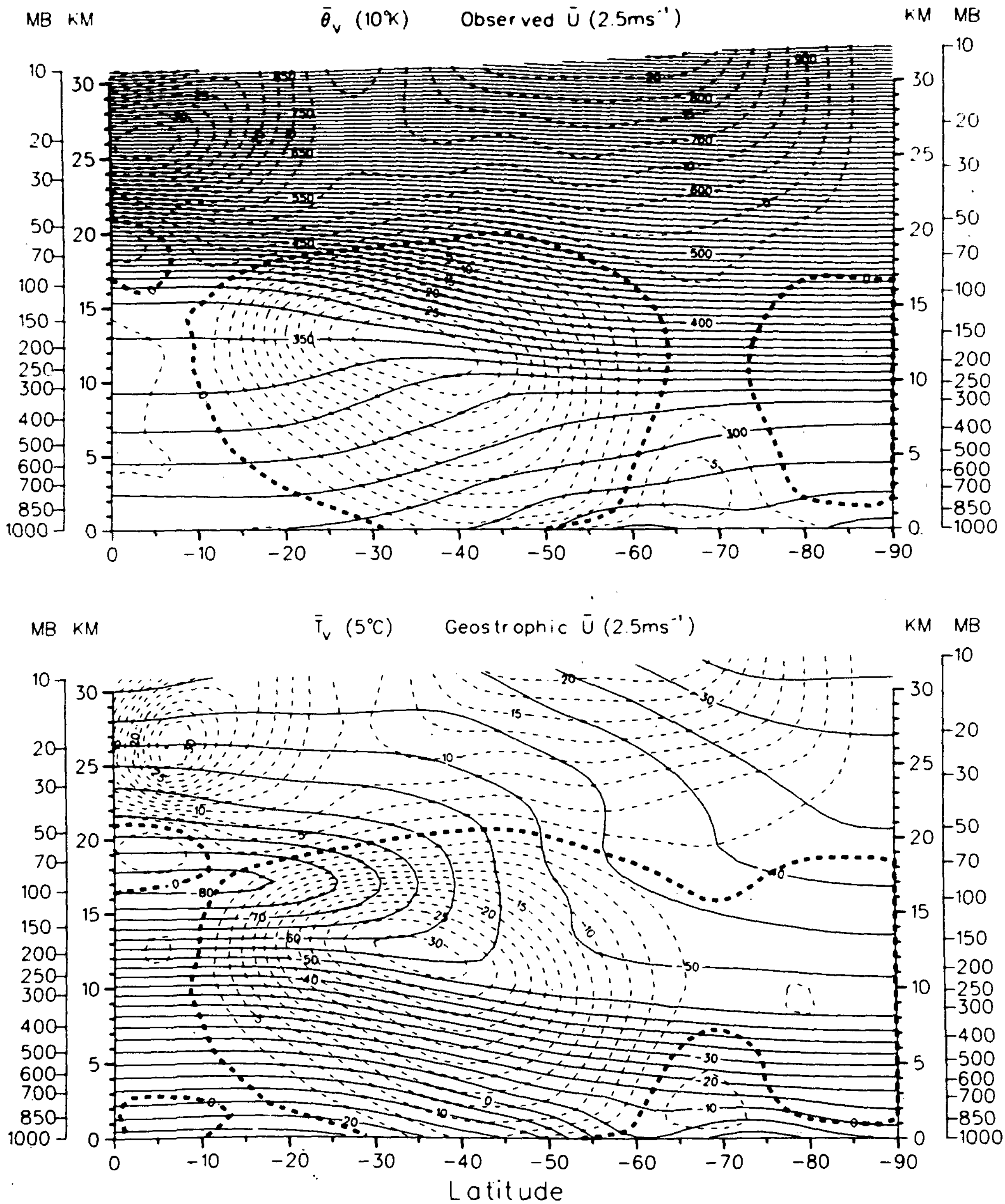
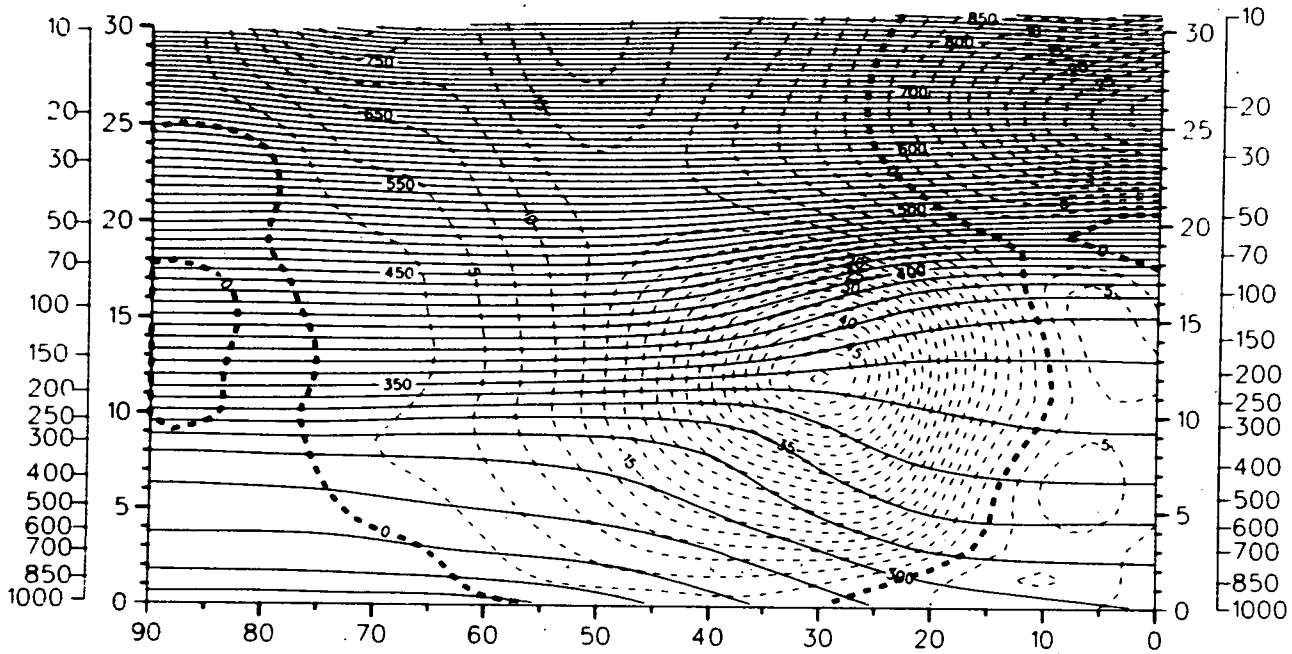


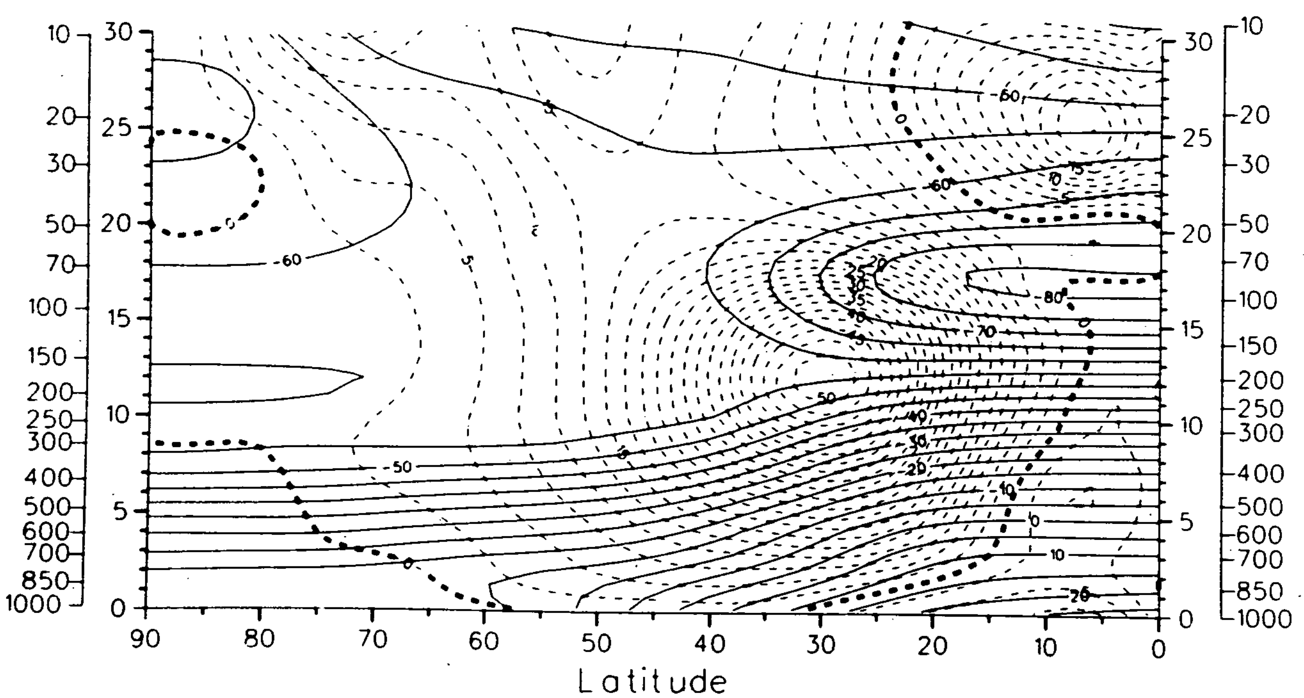
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JANUARY 1977

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB

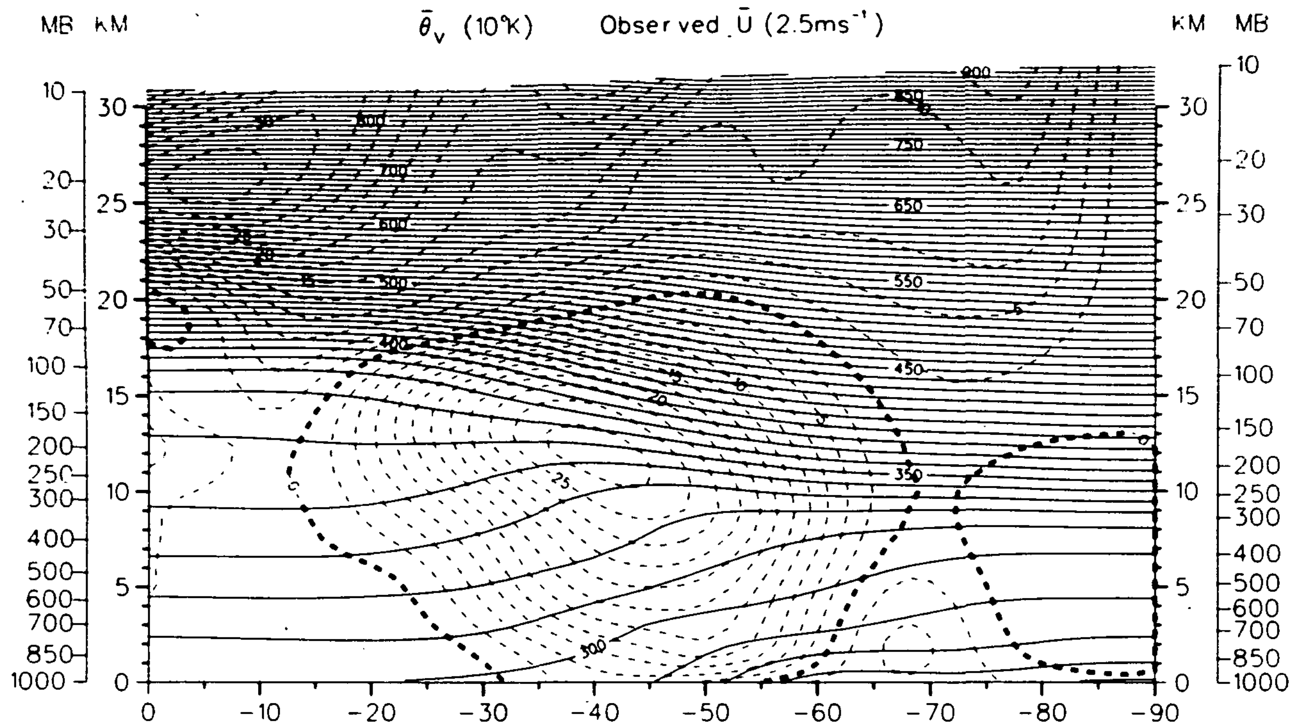


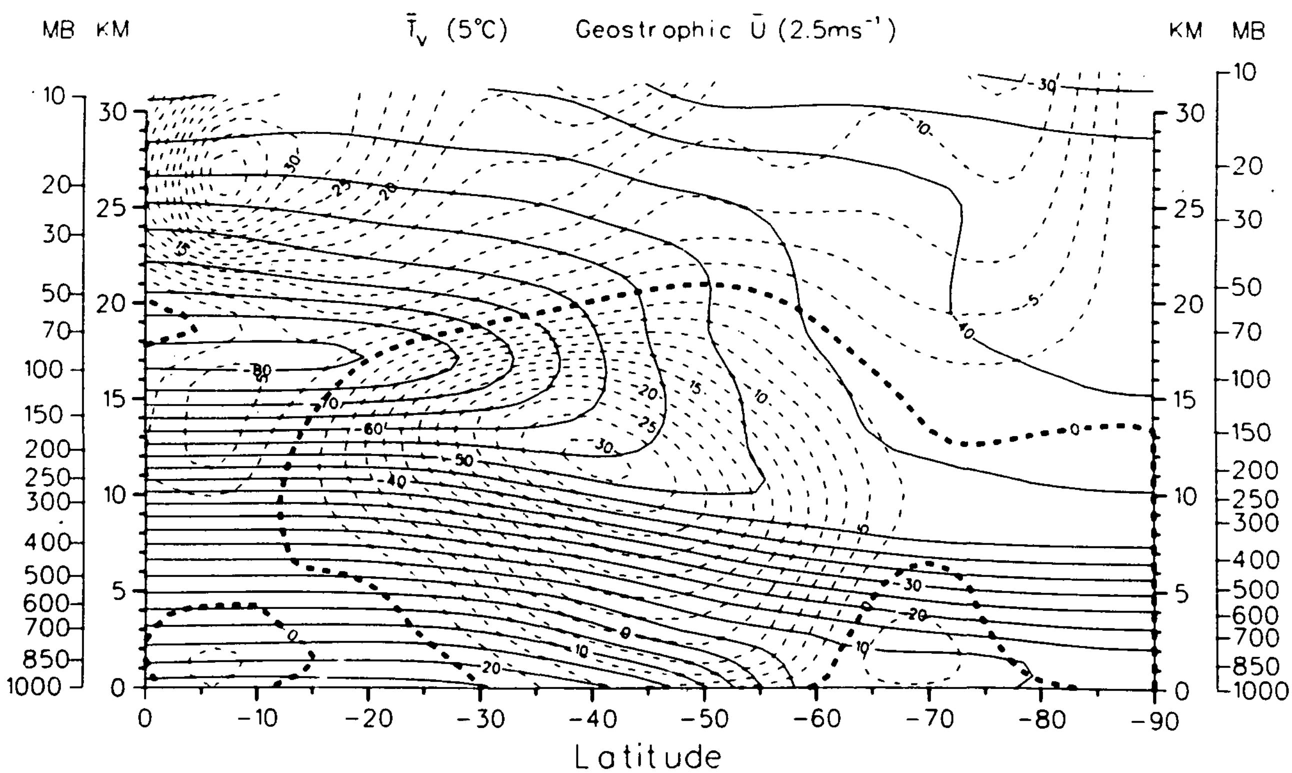
MB KM $\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1}) KM MB



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JANUARY 1977





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

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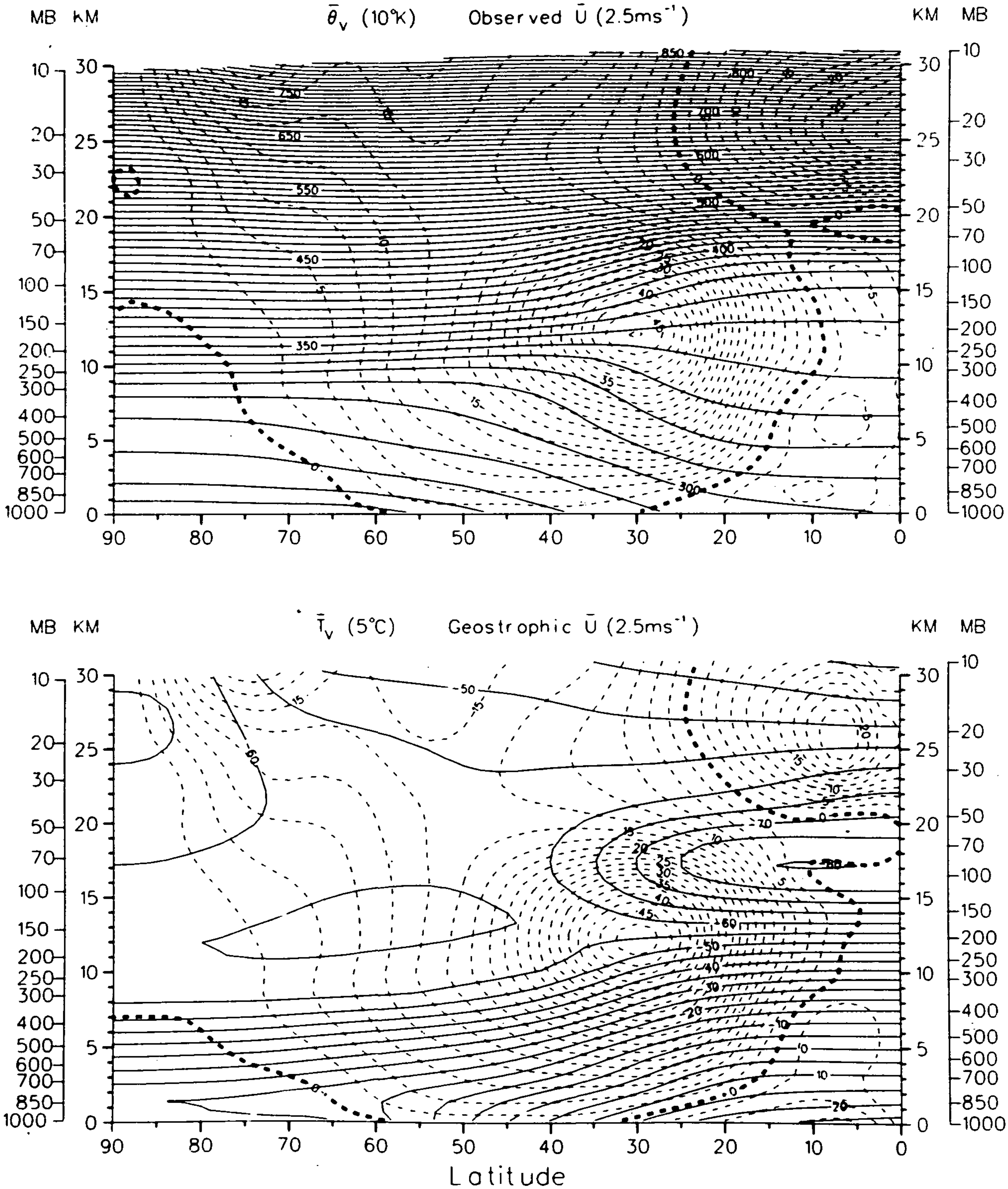

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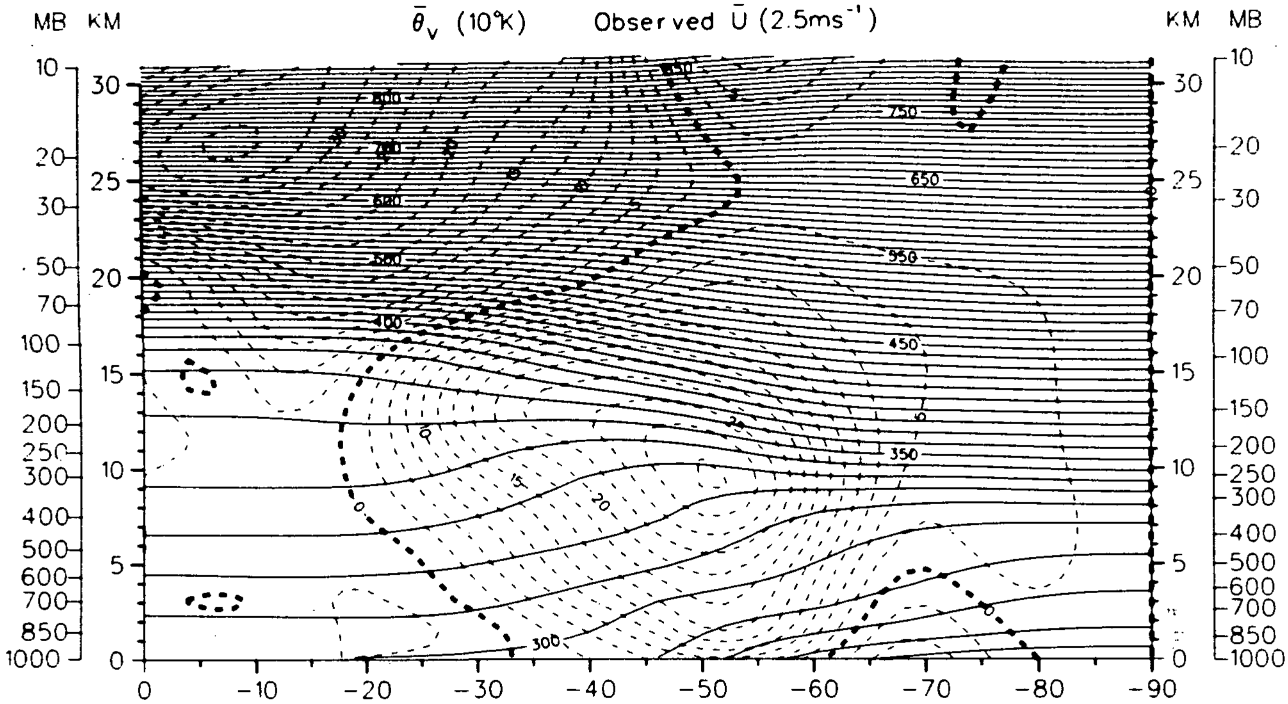
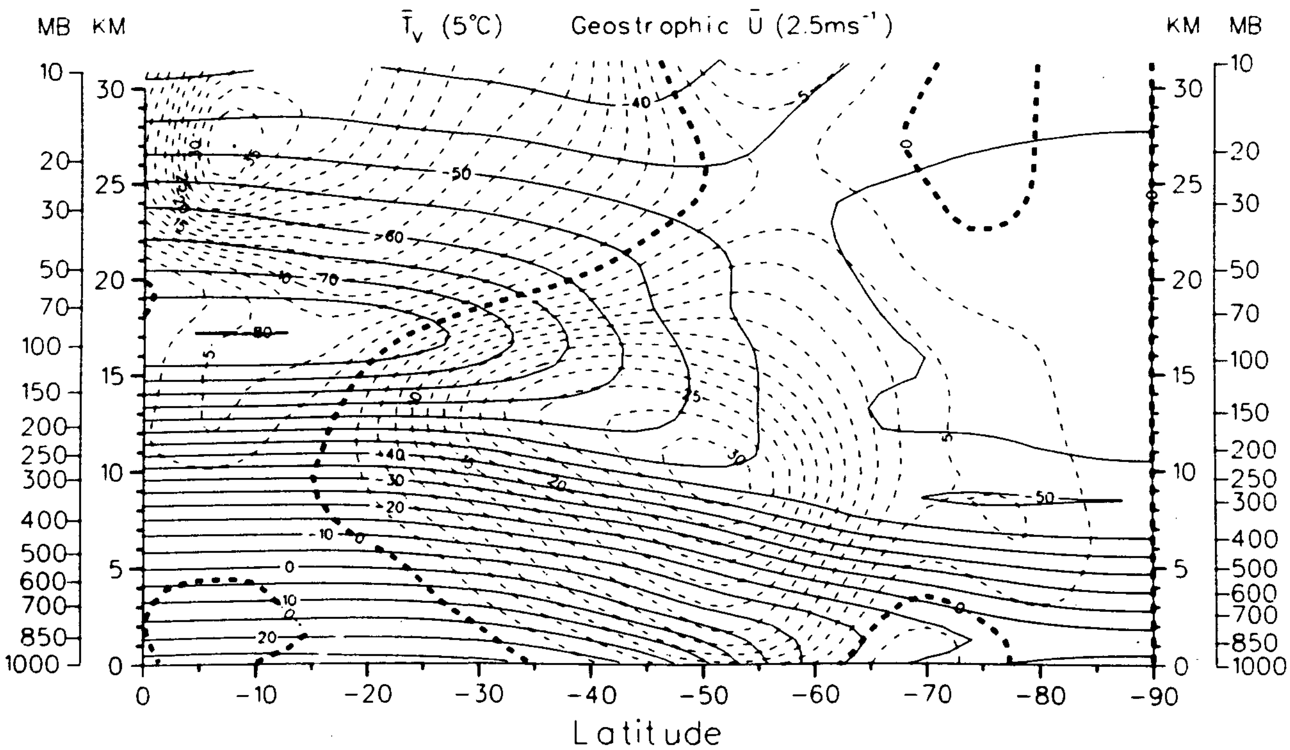
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

FEBRUARY 1977





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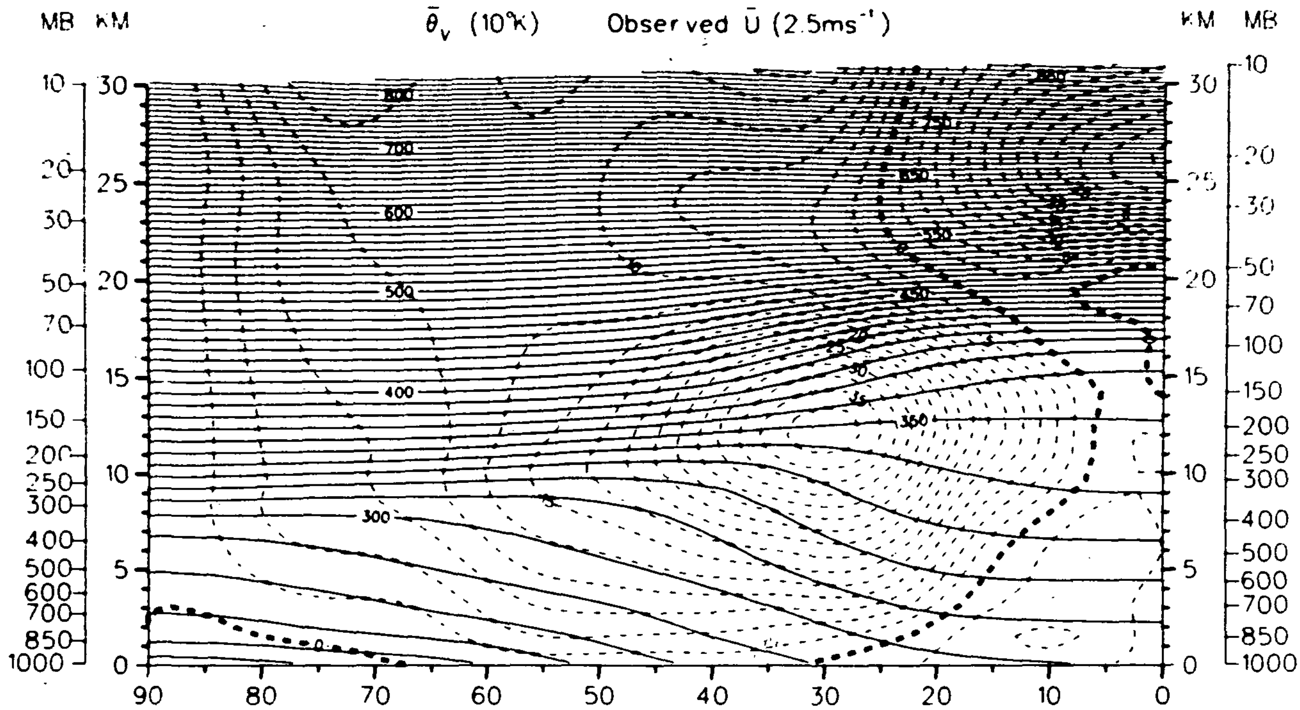
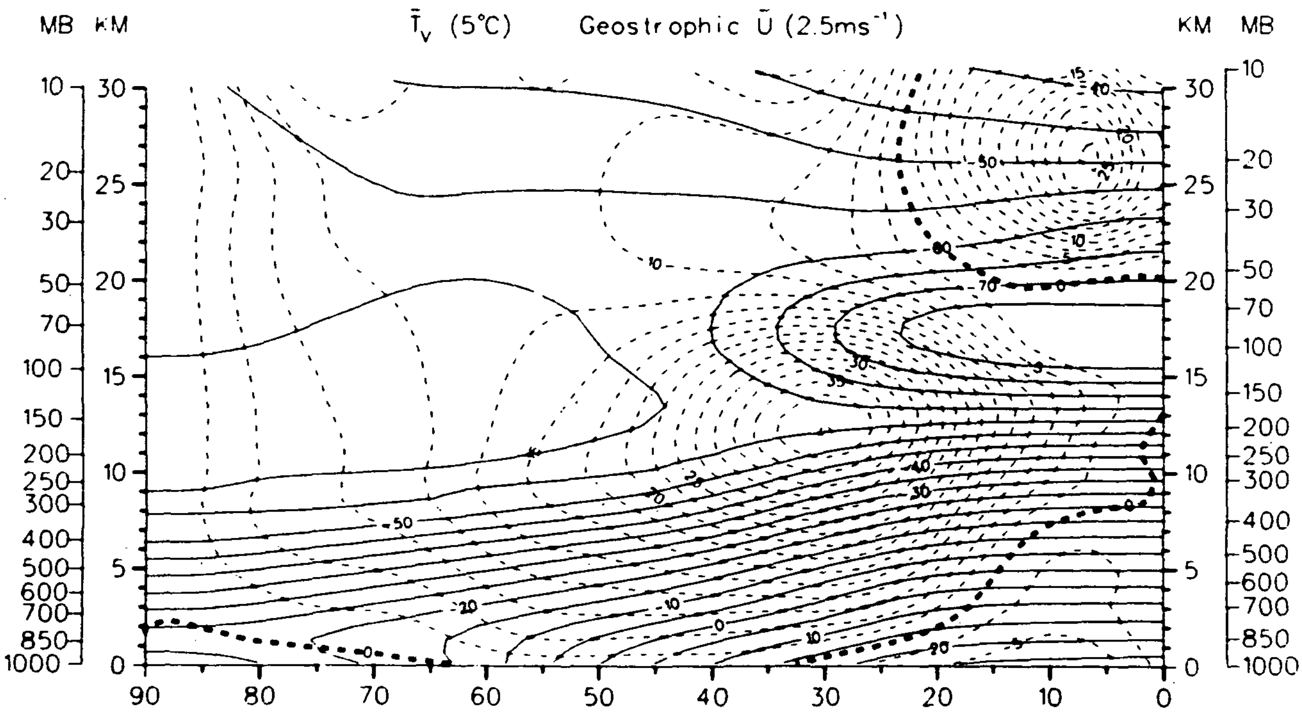
MARCH 1977





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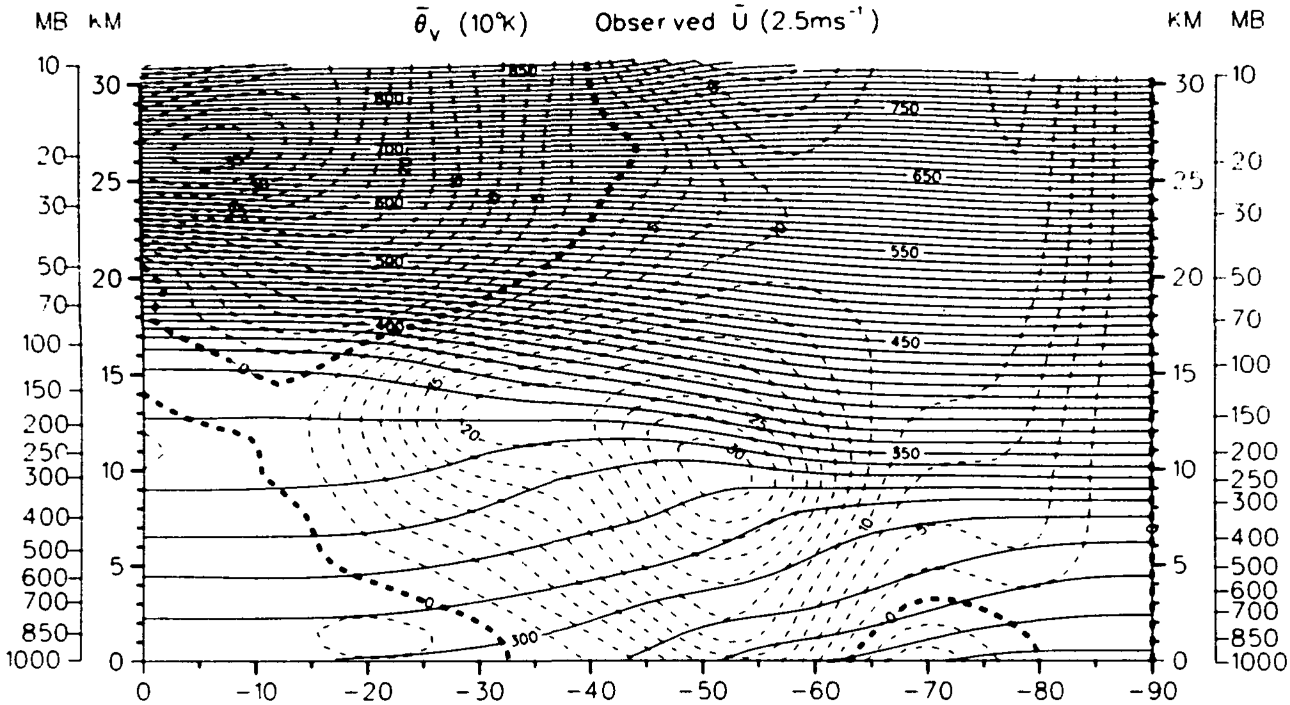

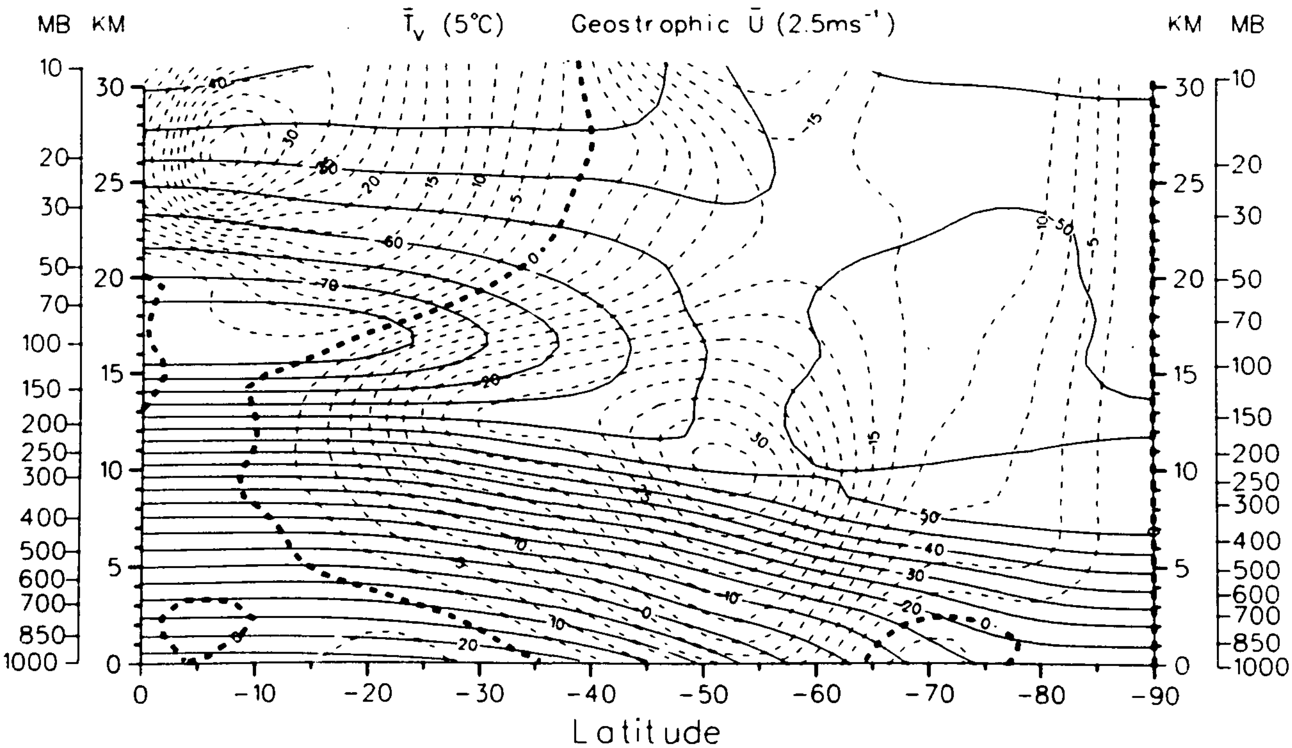

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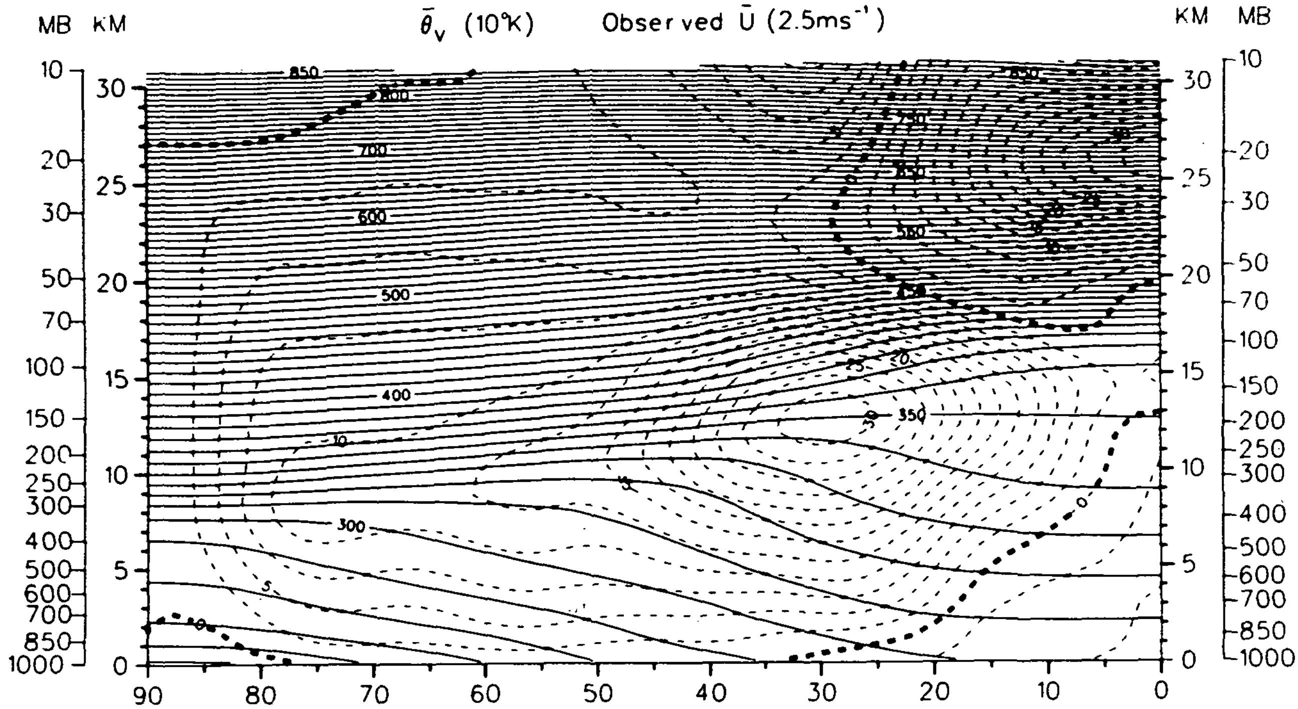
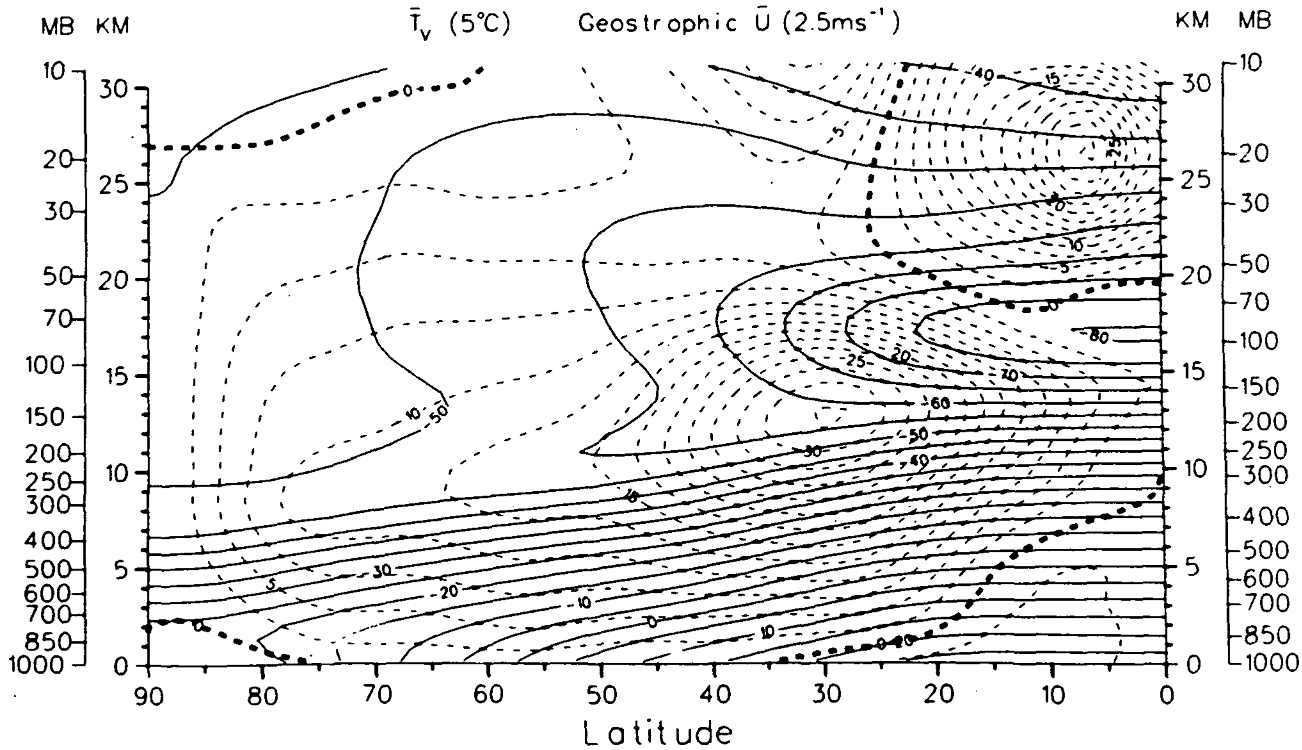
APRIL 1977





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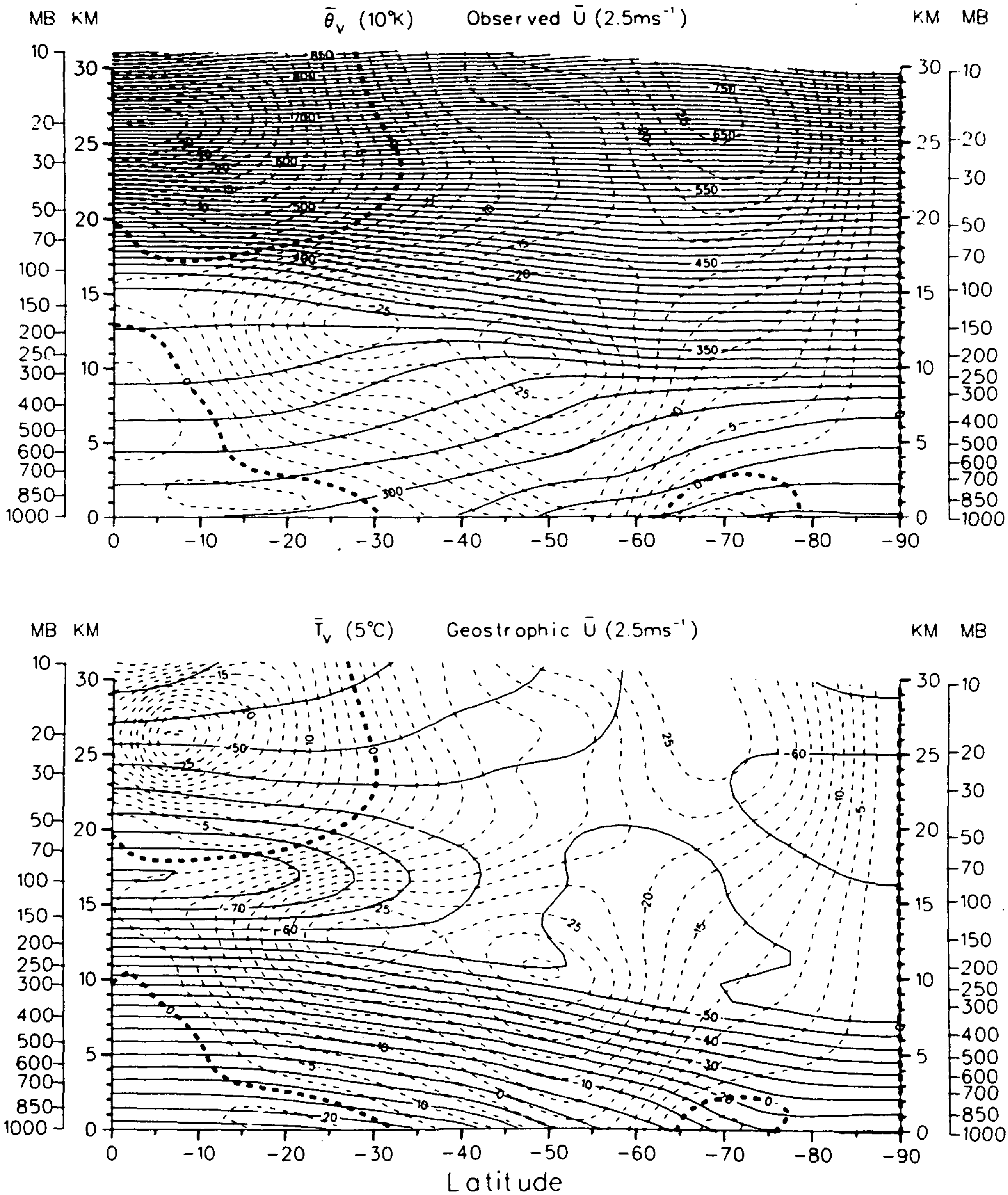

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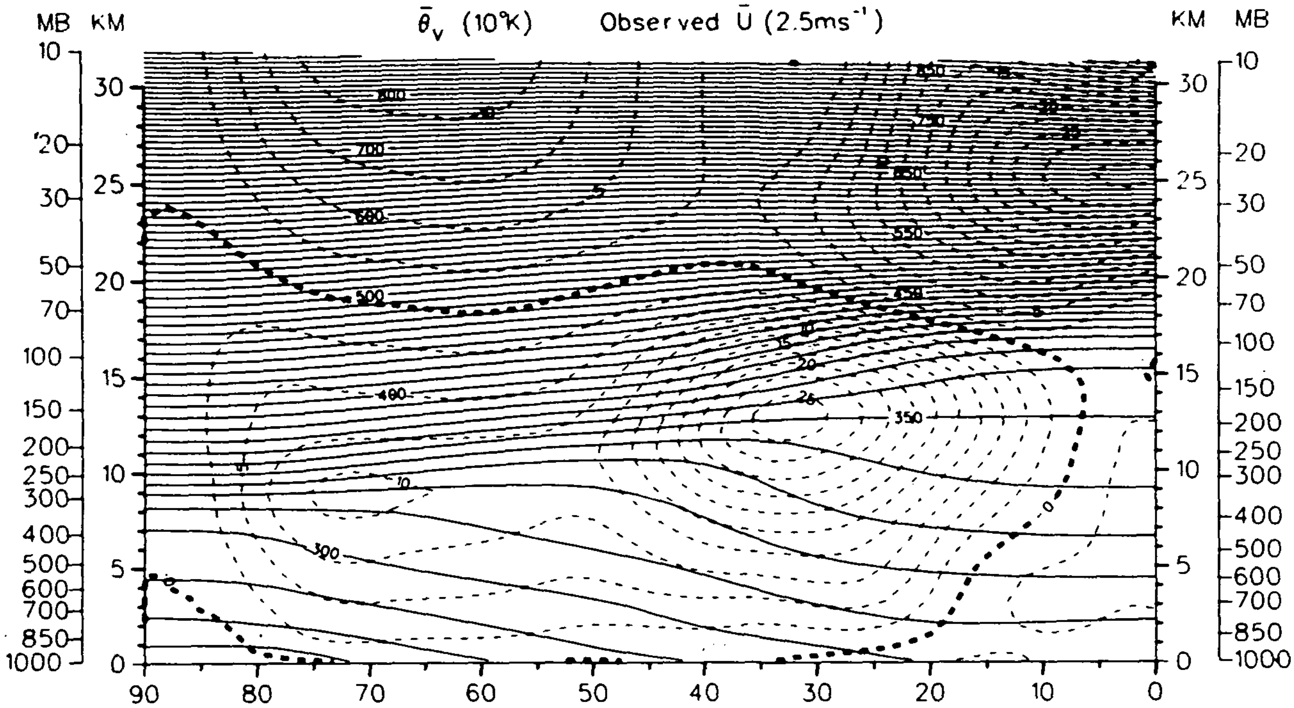
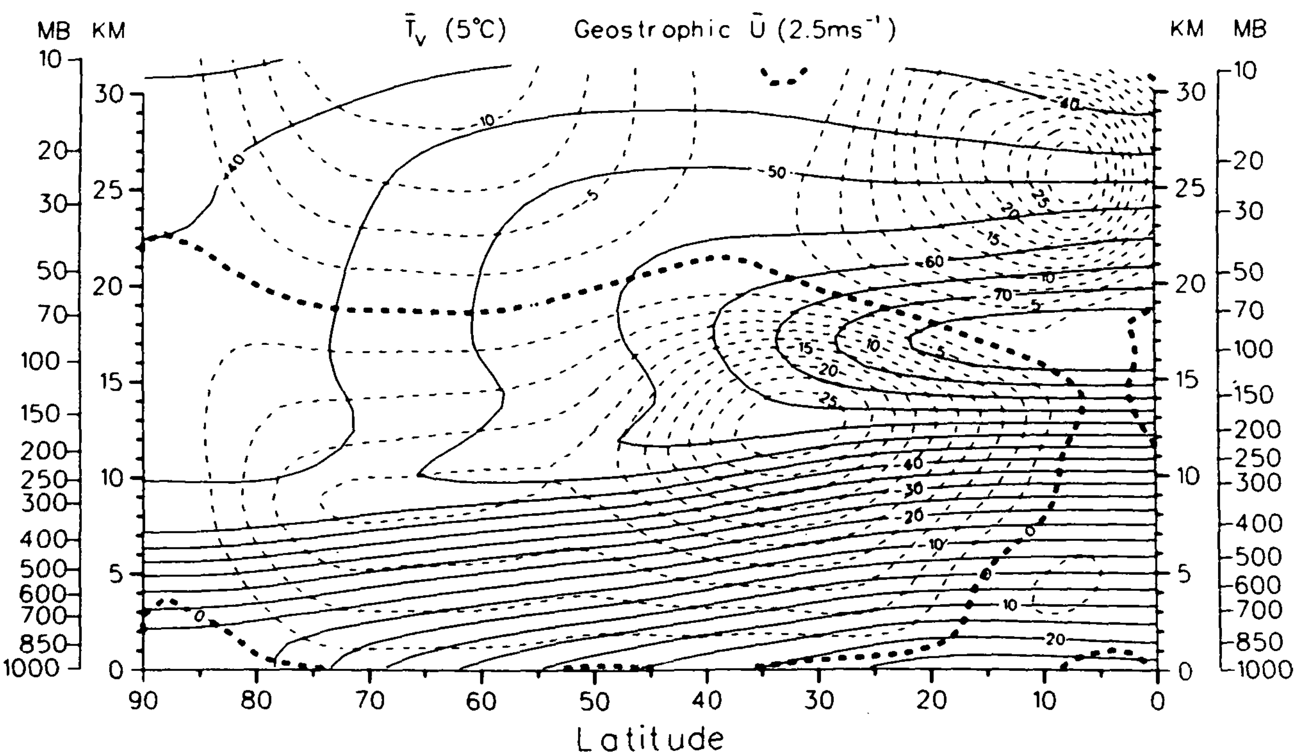
MAY 1977





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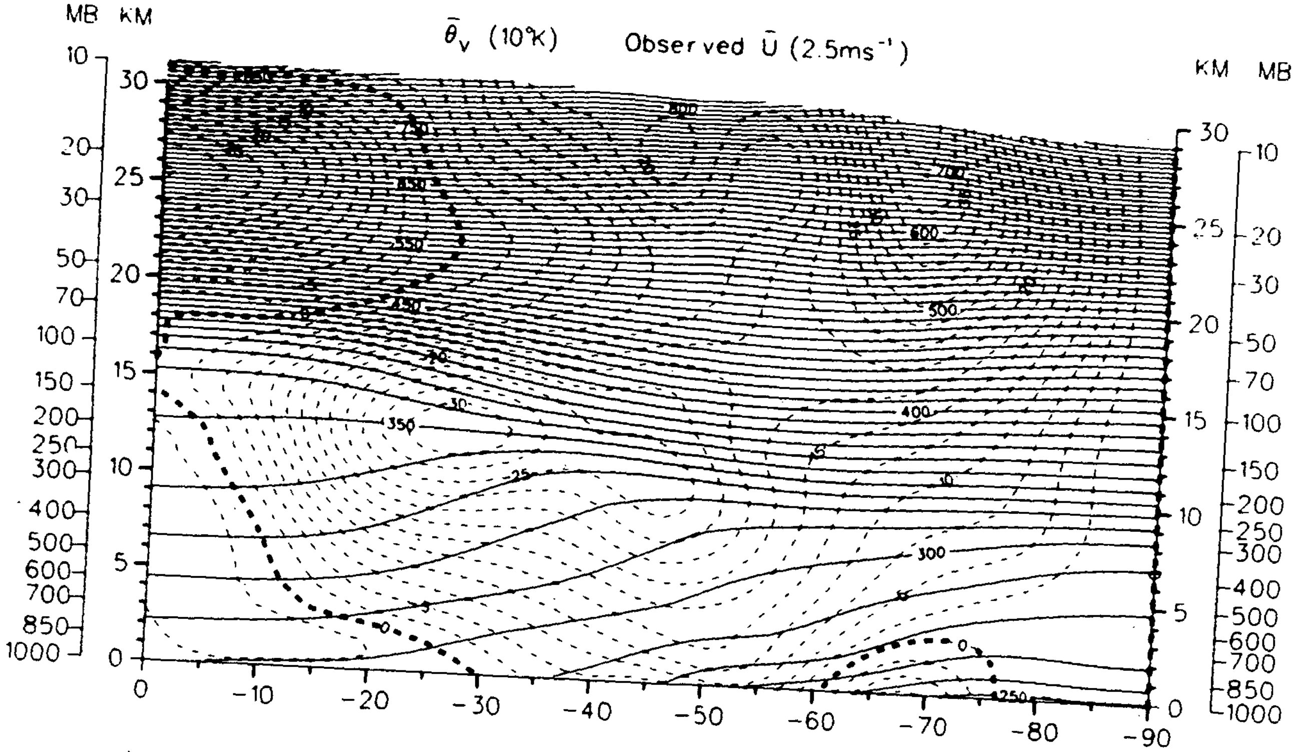
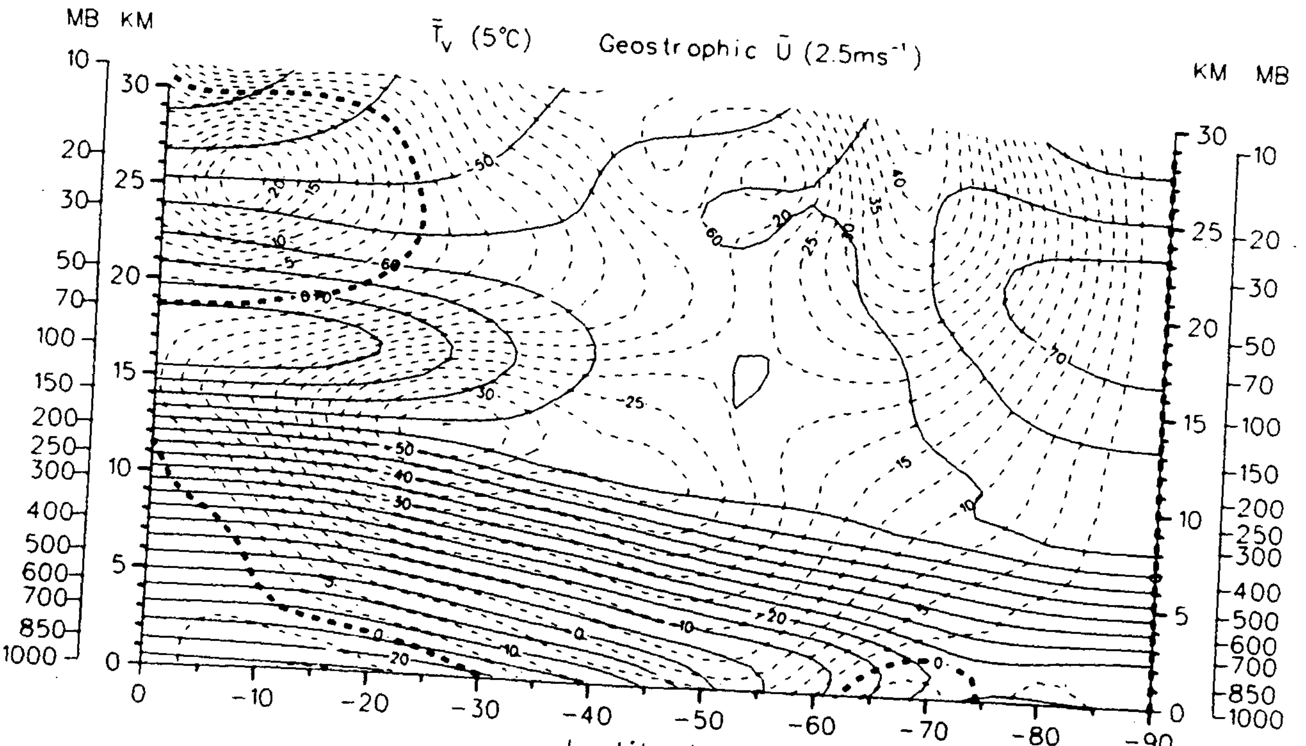
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

MAY 1977





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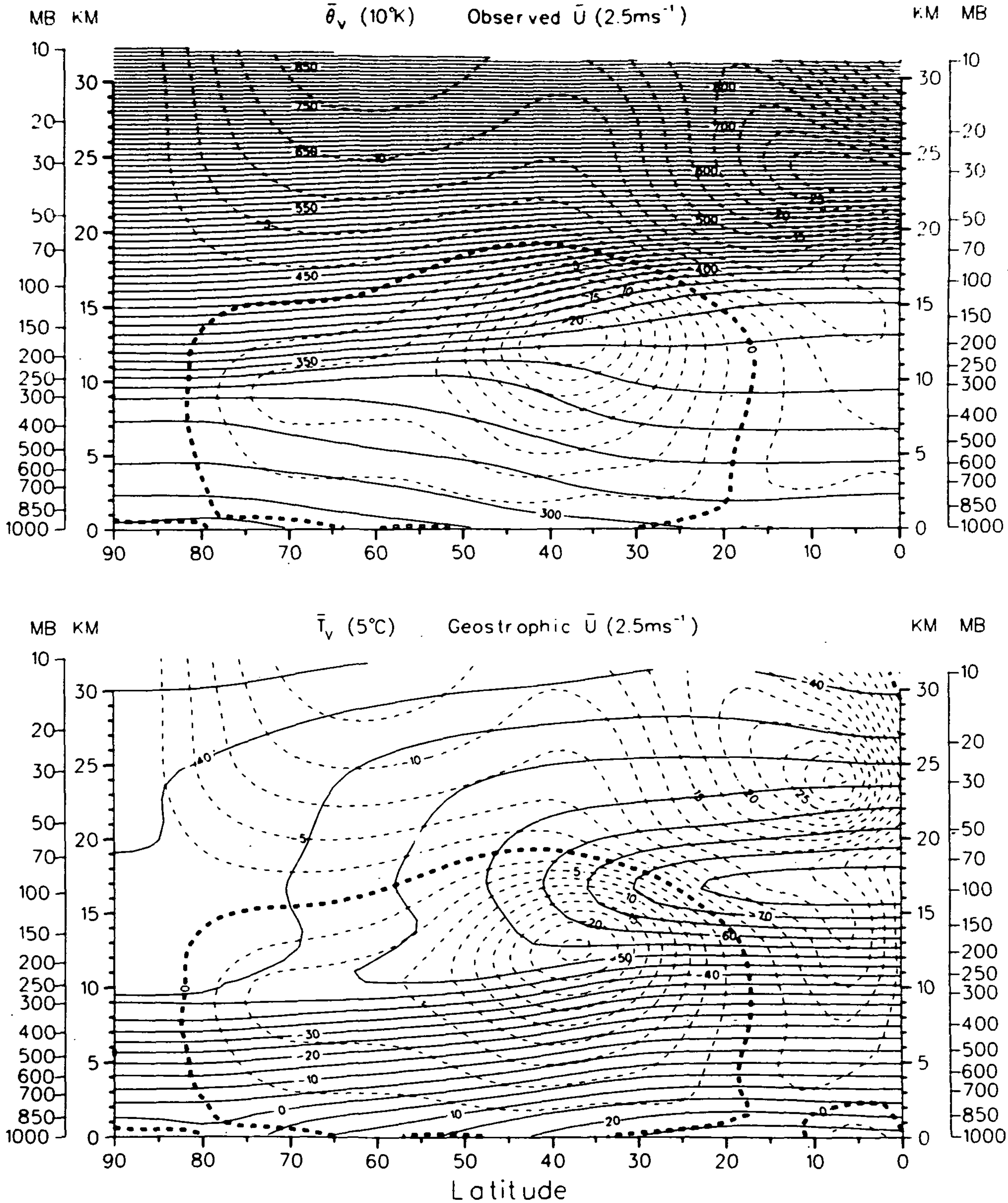
JUNE 1977



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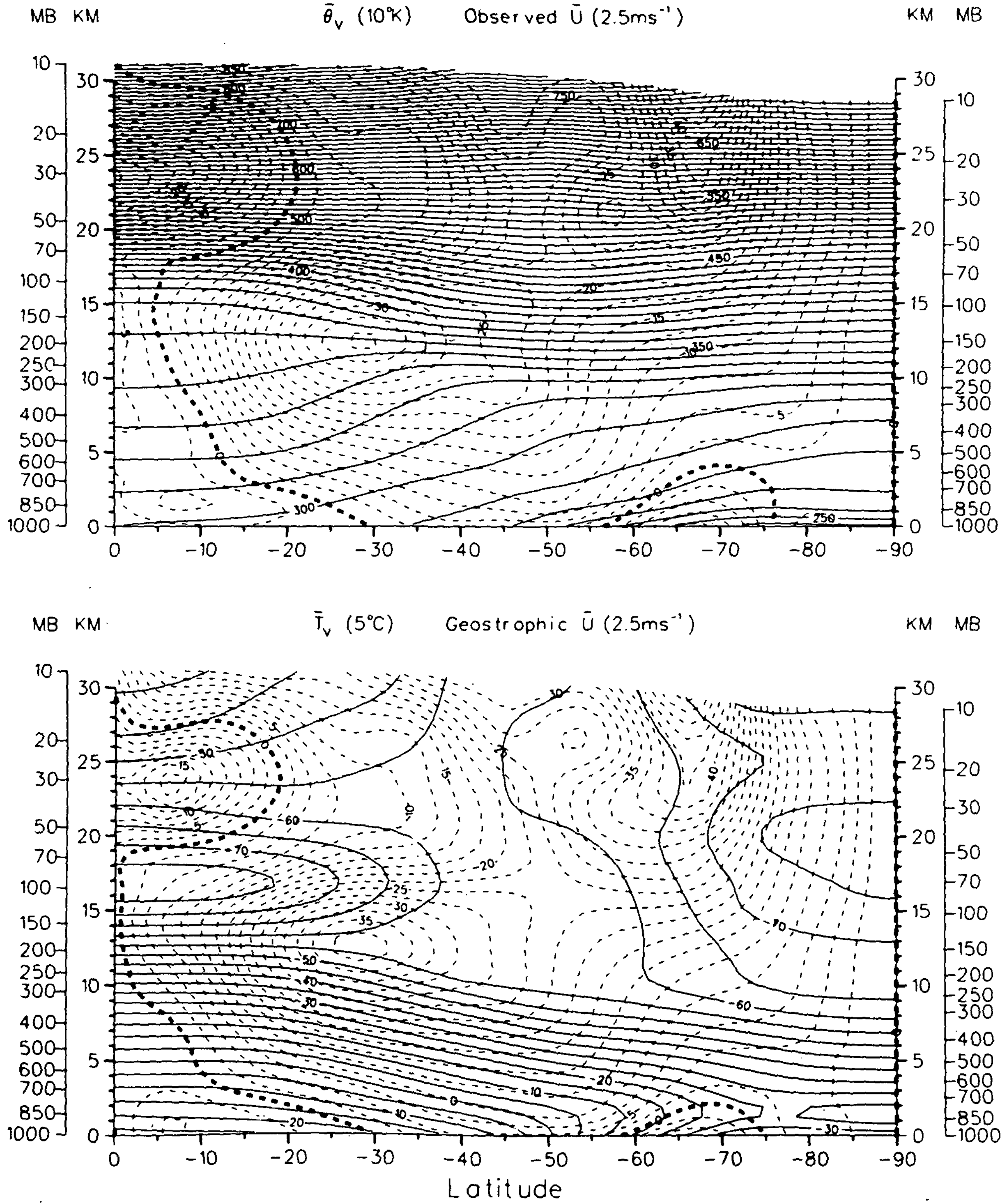
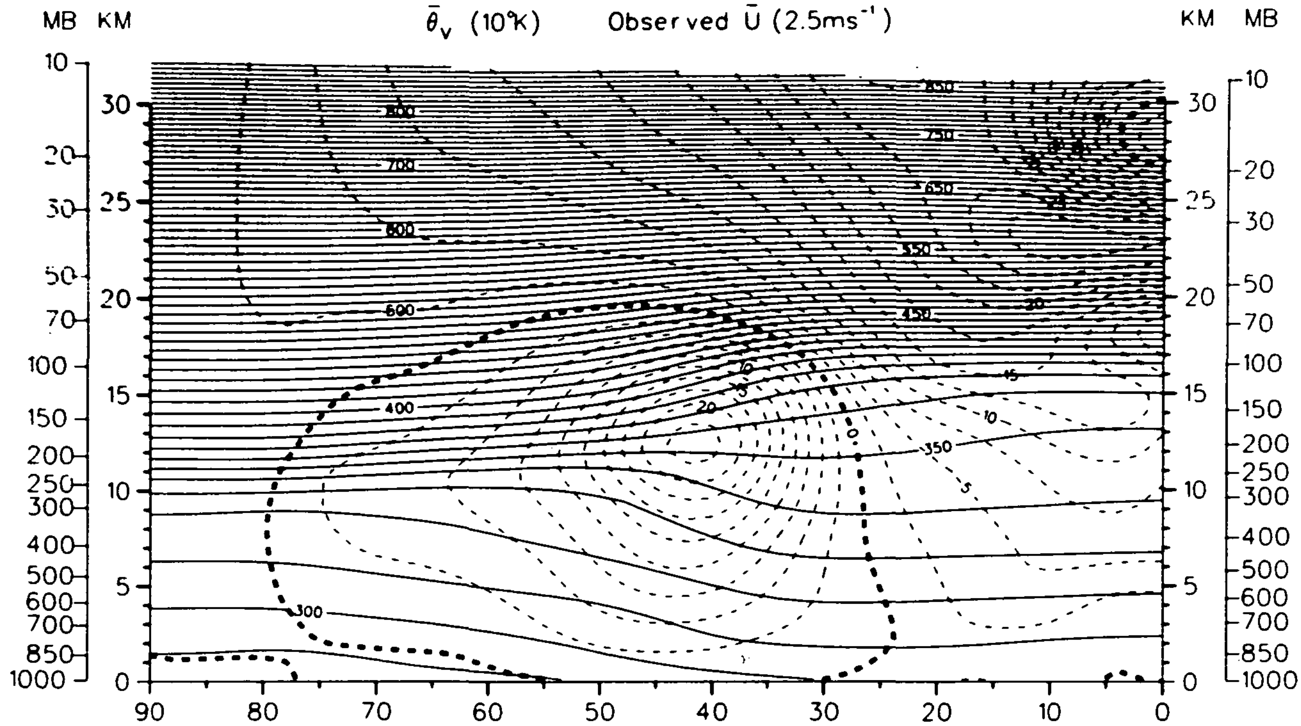
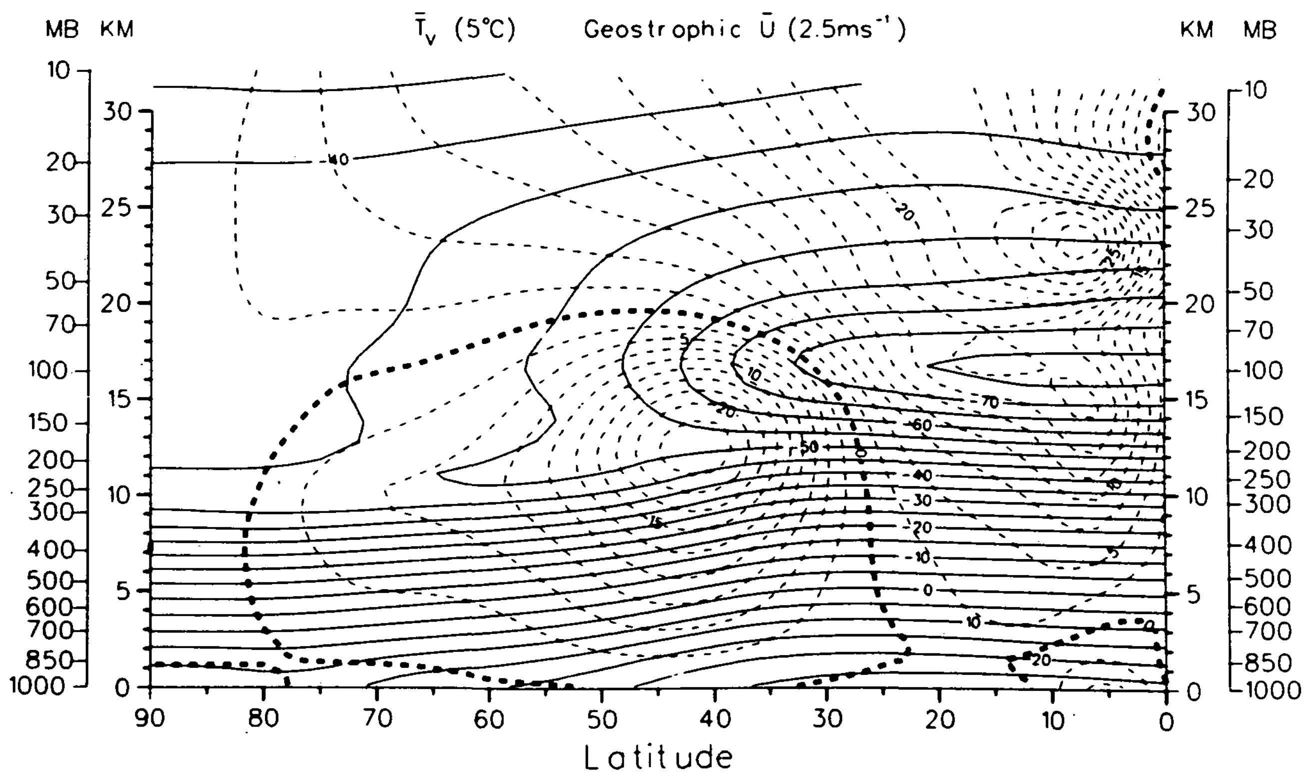
JUNE 1977



NORTHERN HEMISPHERIC ZONAL–MONTHLY MEANS

JULY 1977





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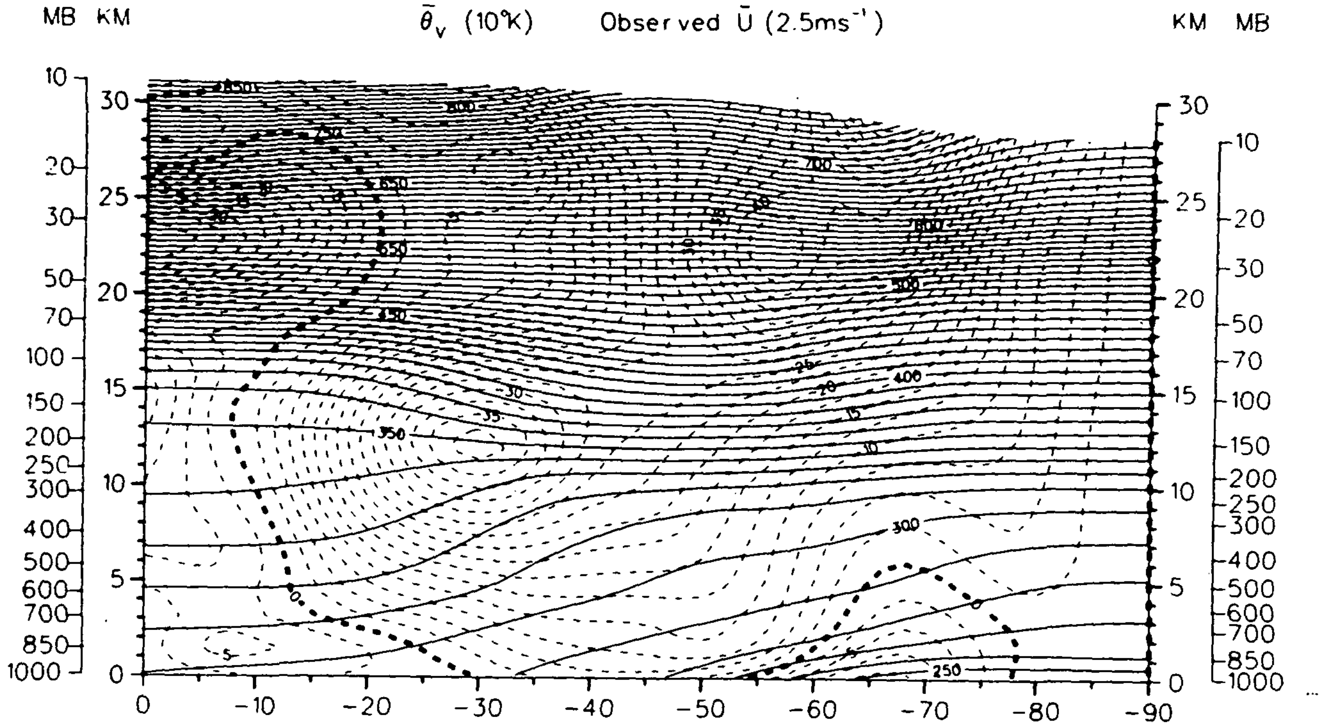
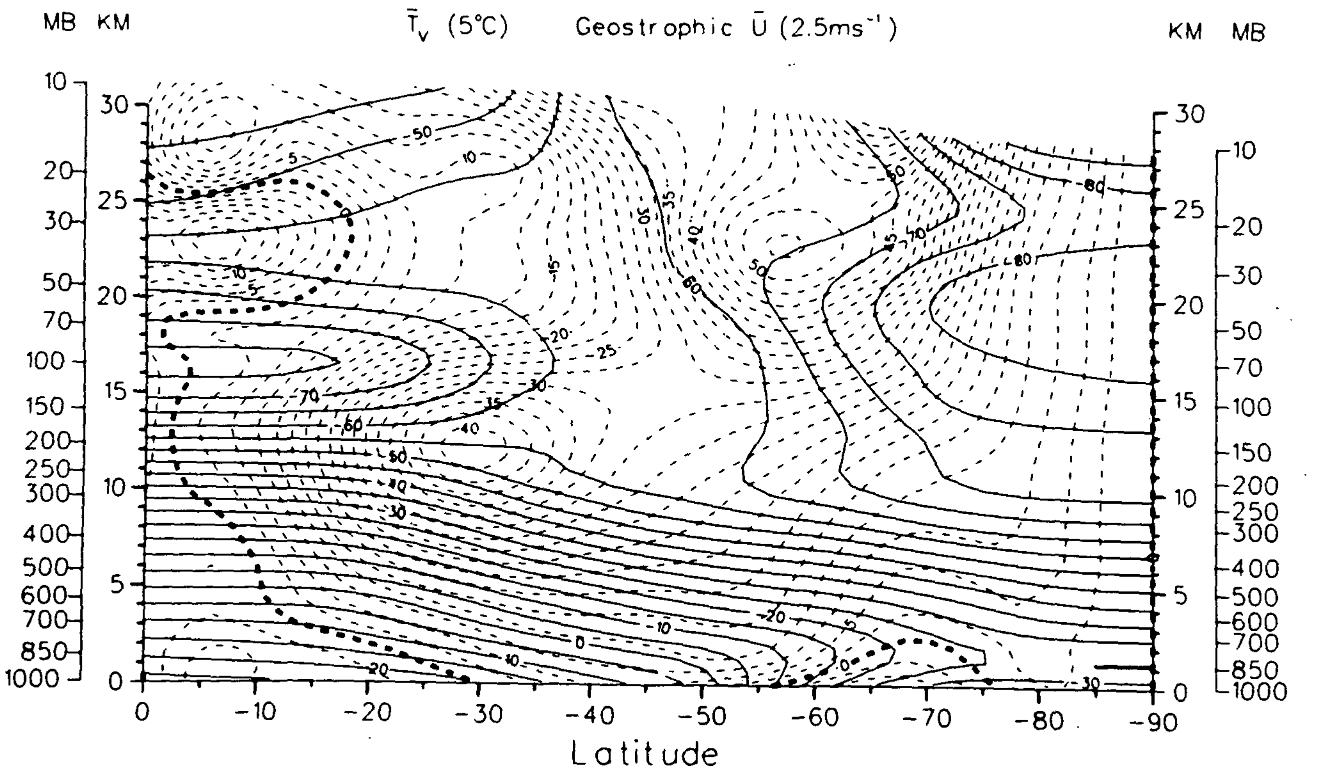
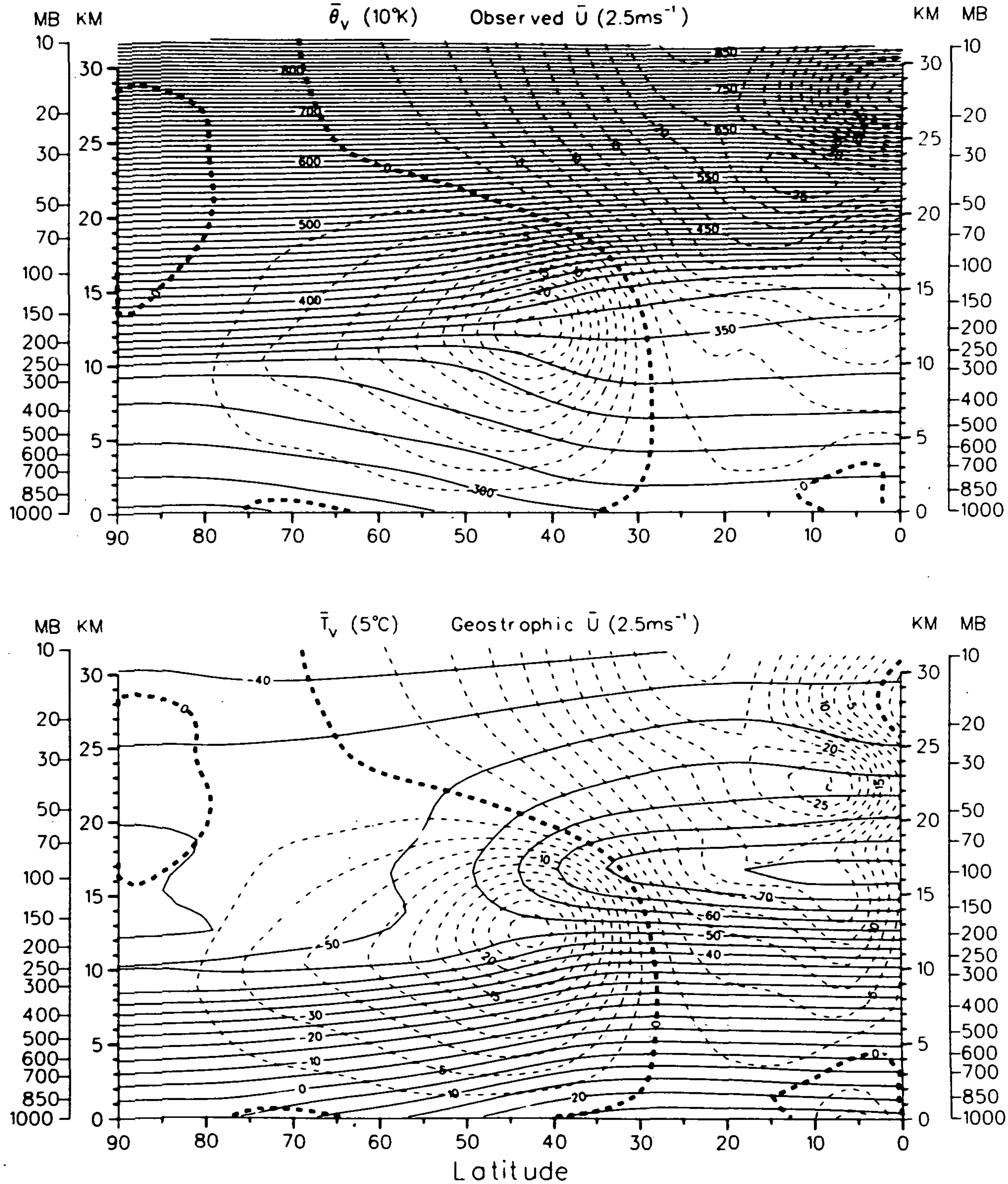
JULY 1977





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

AUGUST 1977



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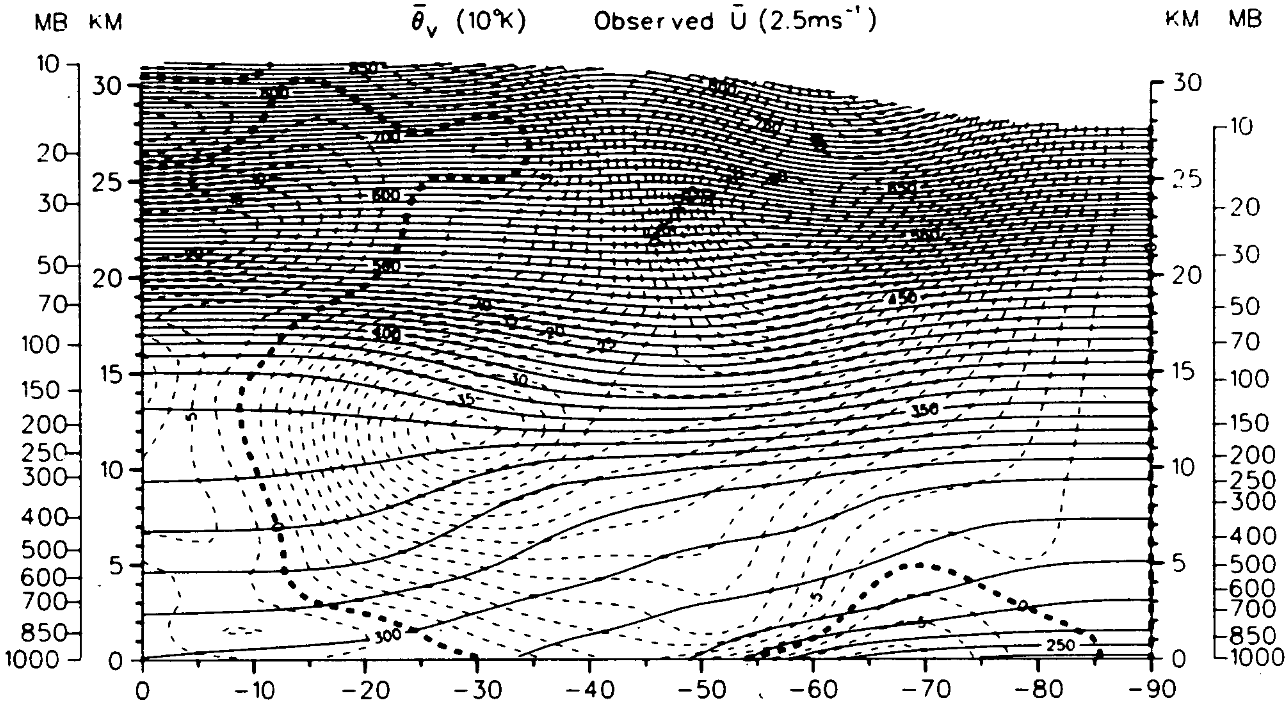
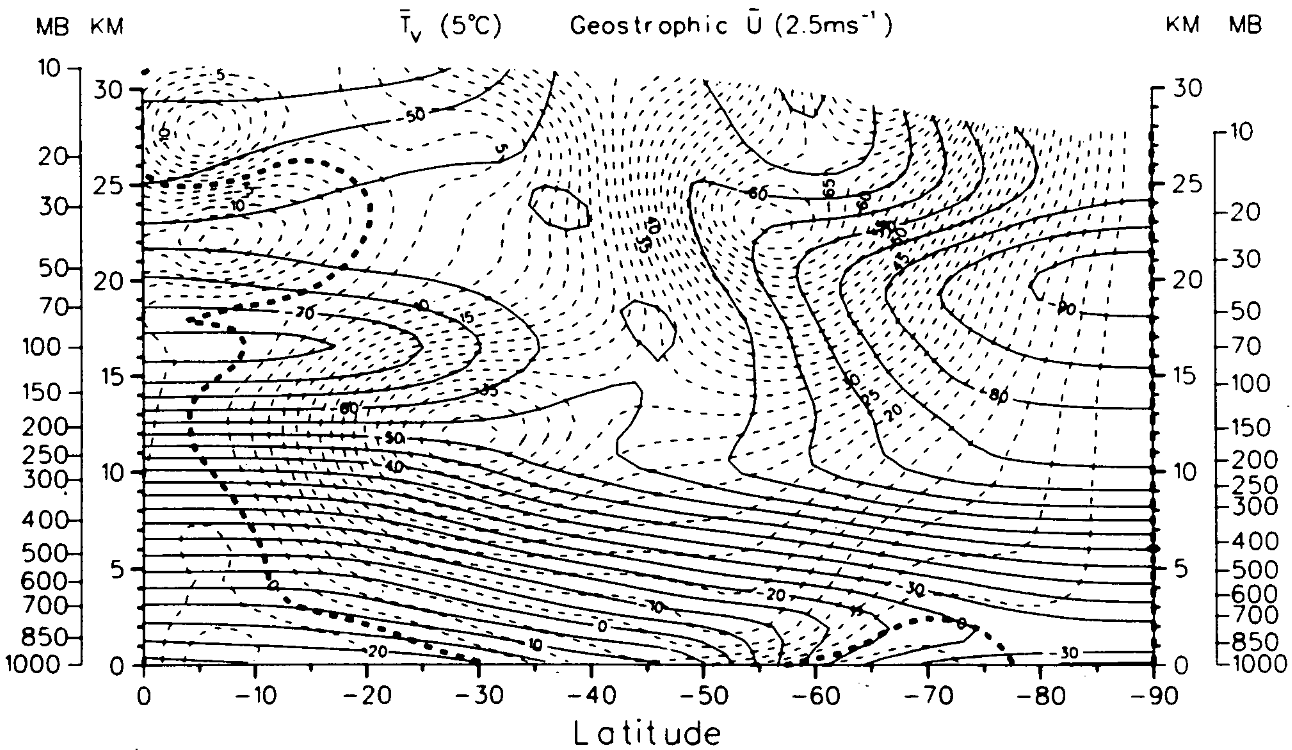
AUGUST 1977





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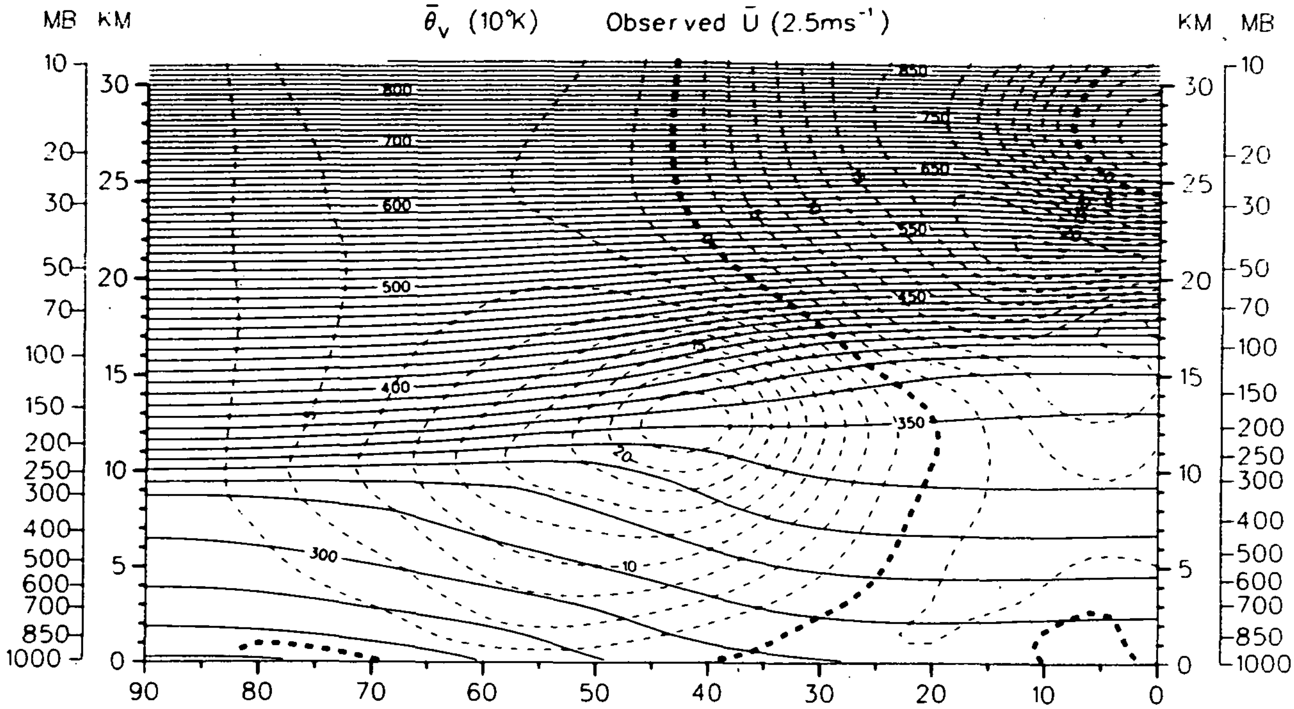
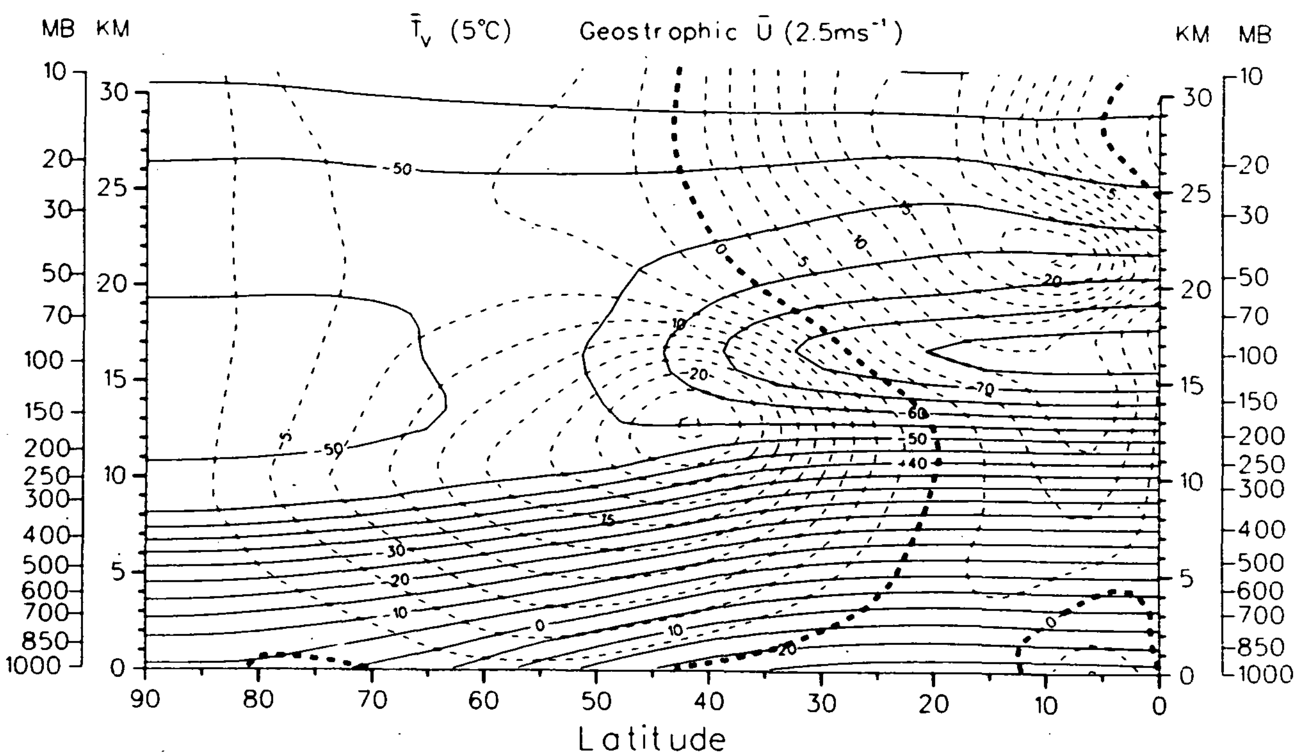
SEPTEMBER 1977





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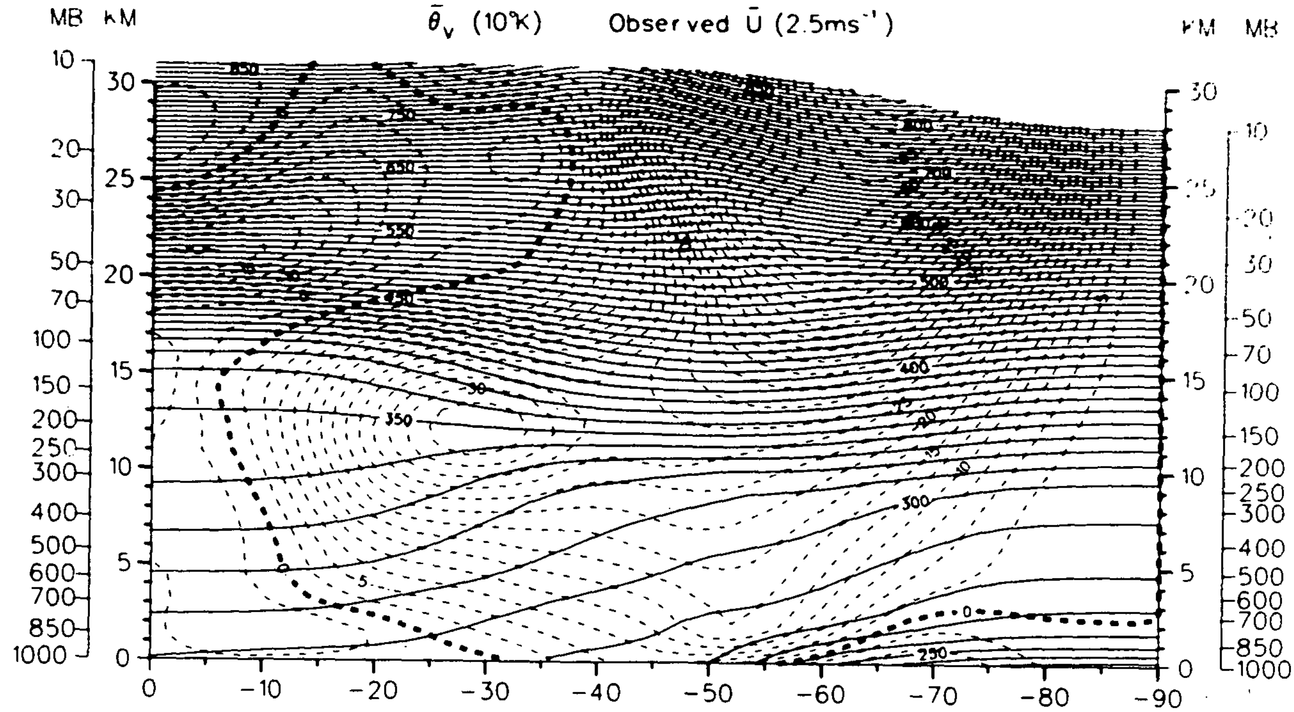
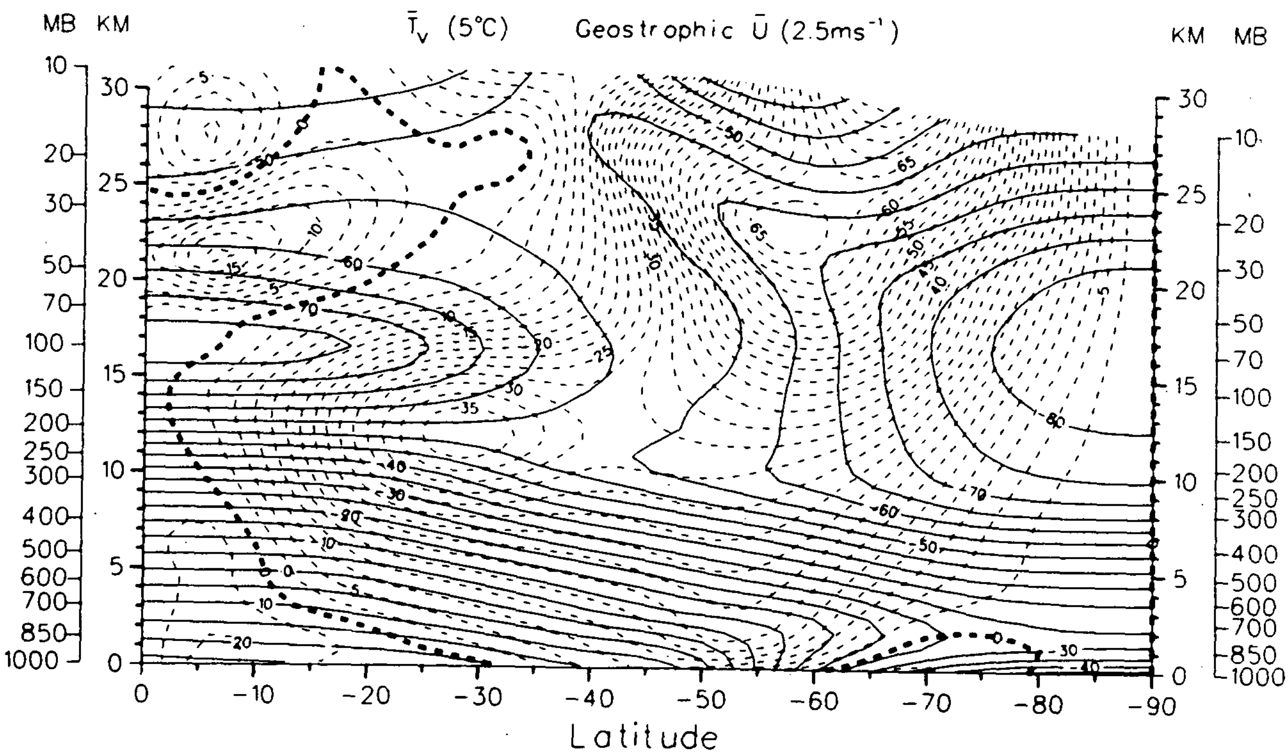
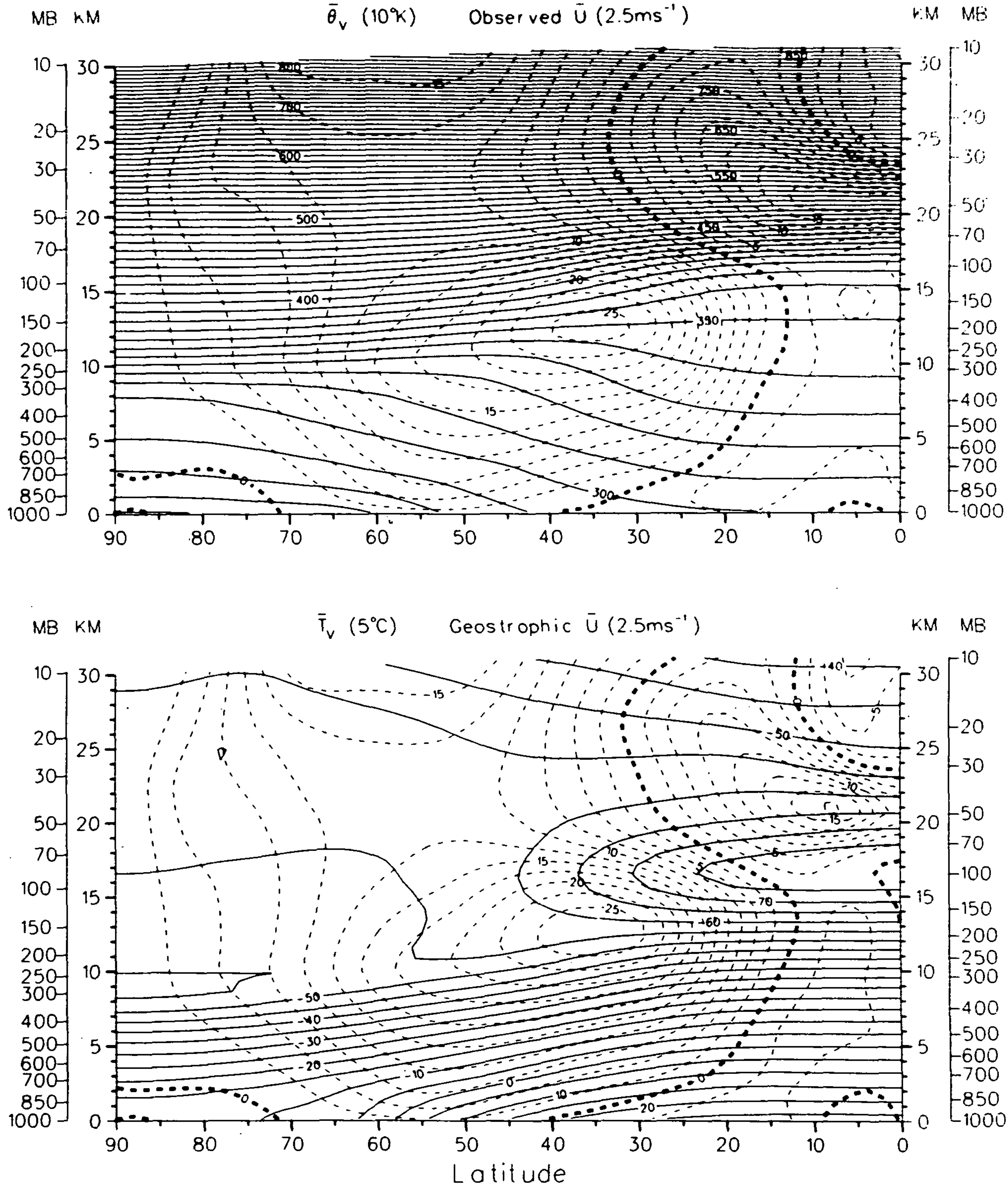




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

OCTOBER 1977



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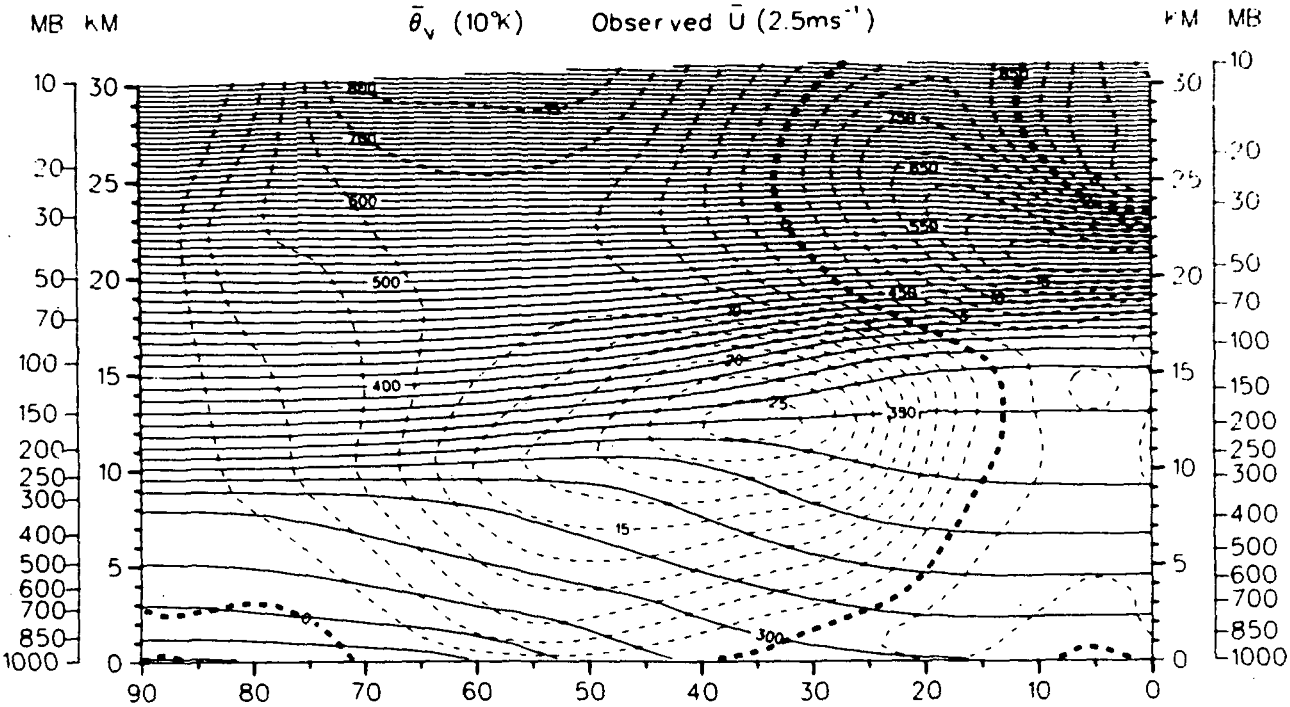
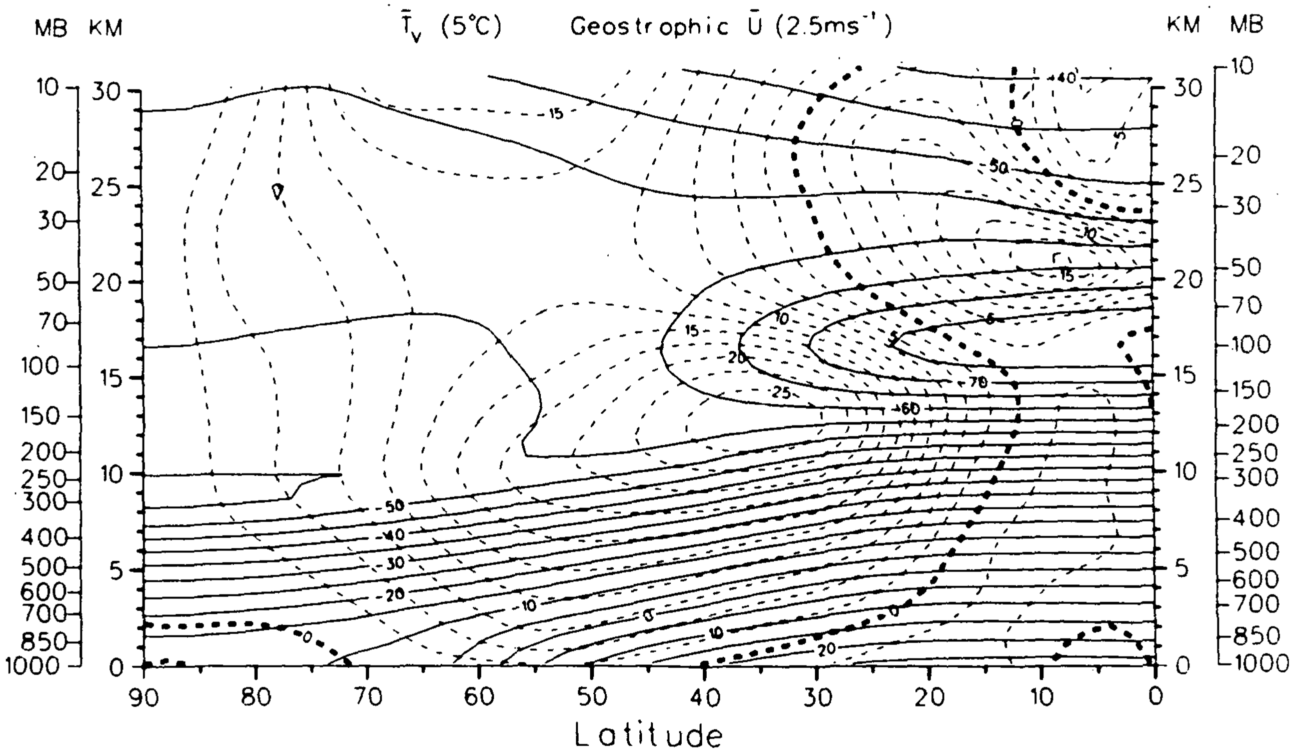
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

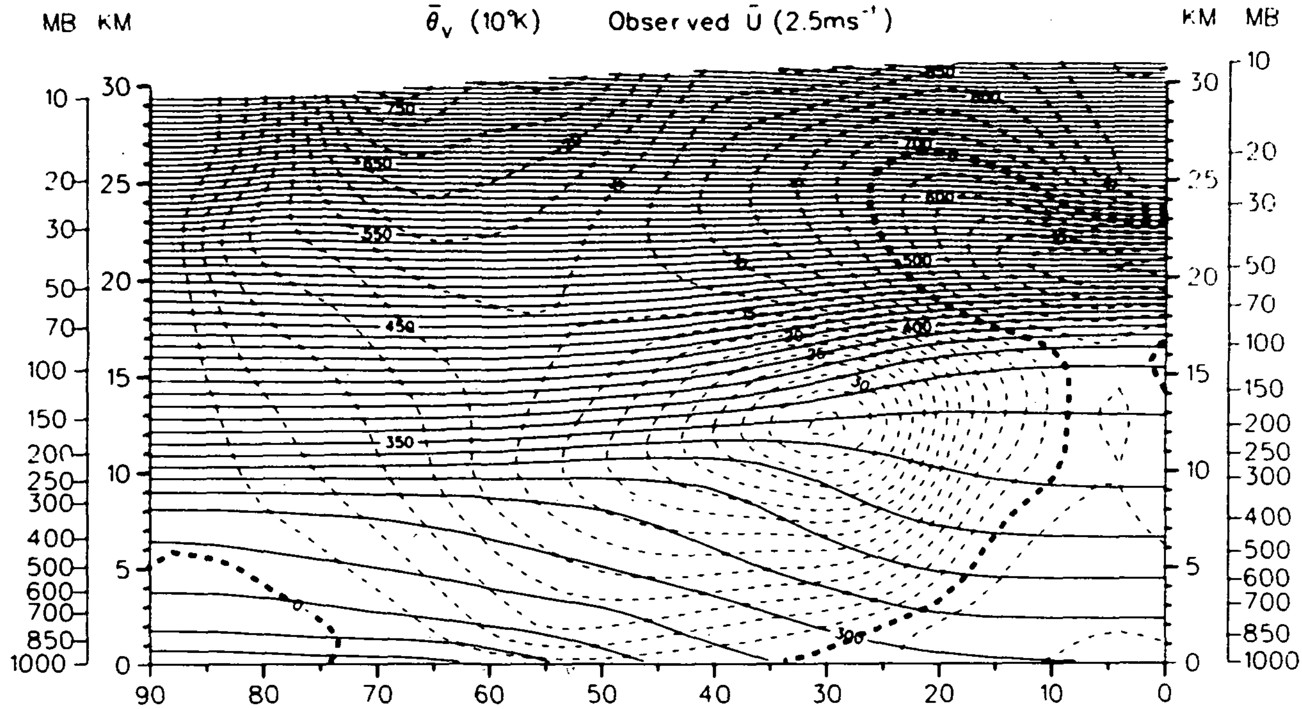
OCTOBER 1977

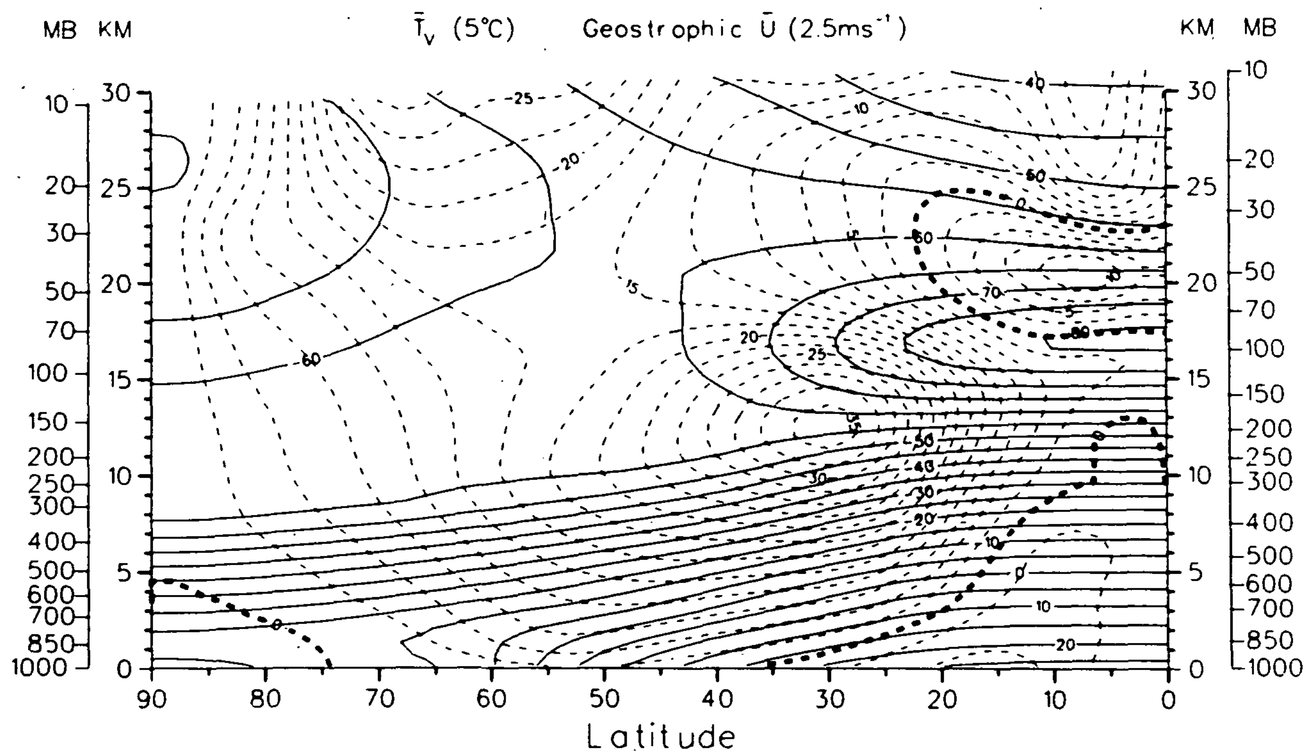




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

NOVEMBER 1977





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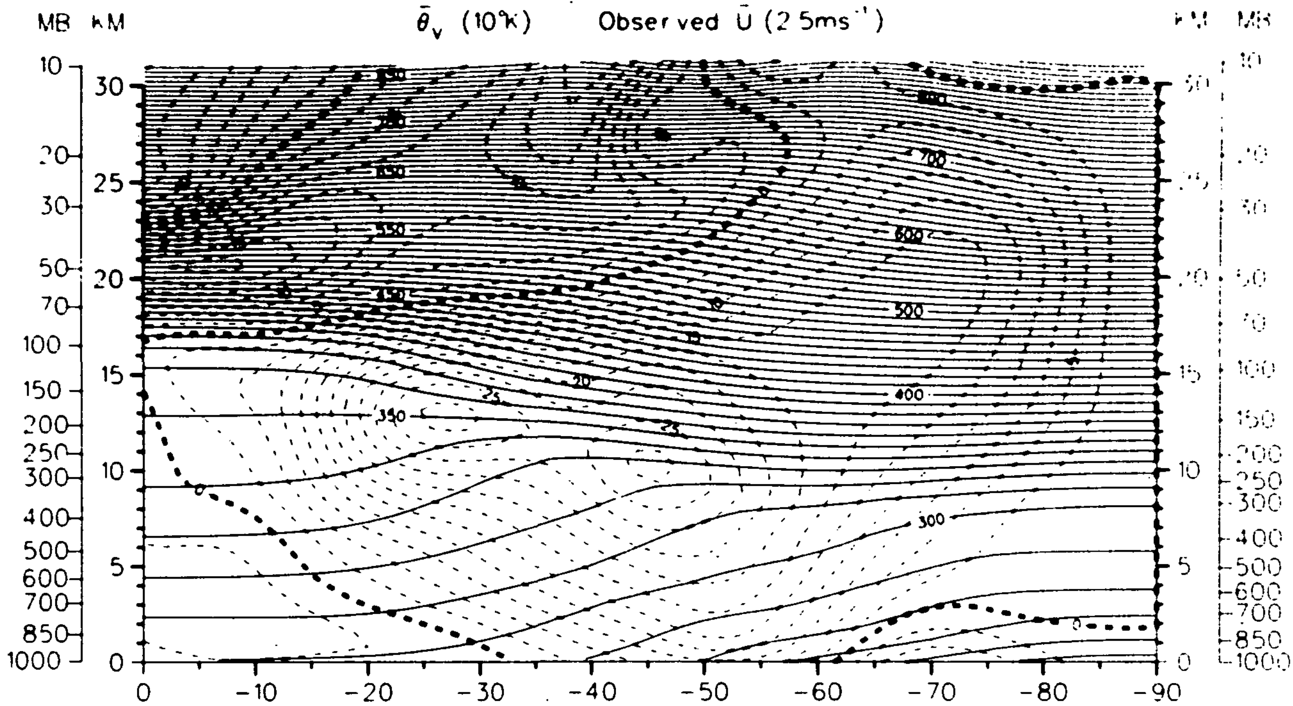
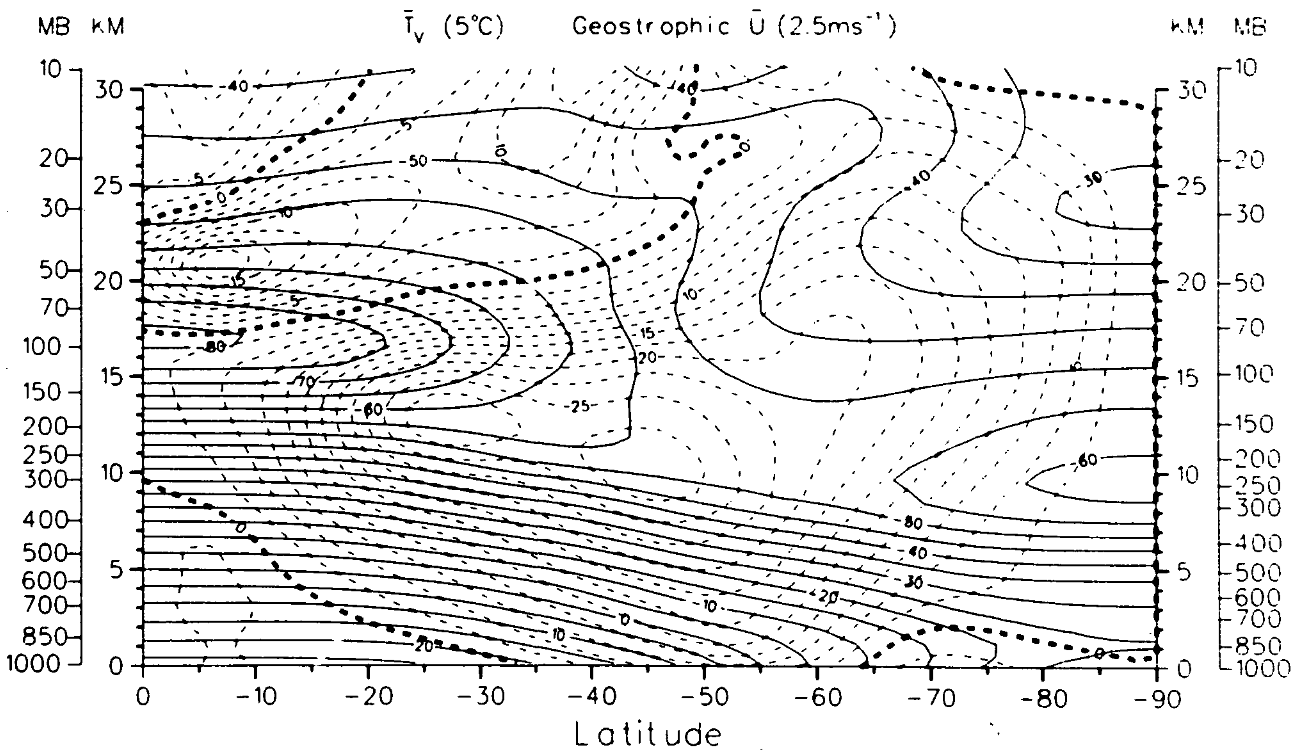
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

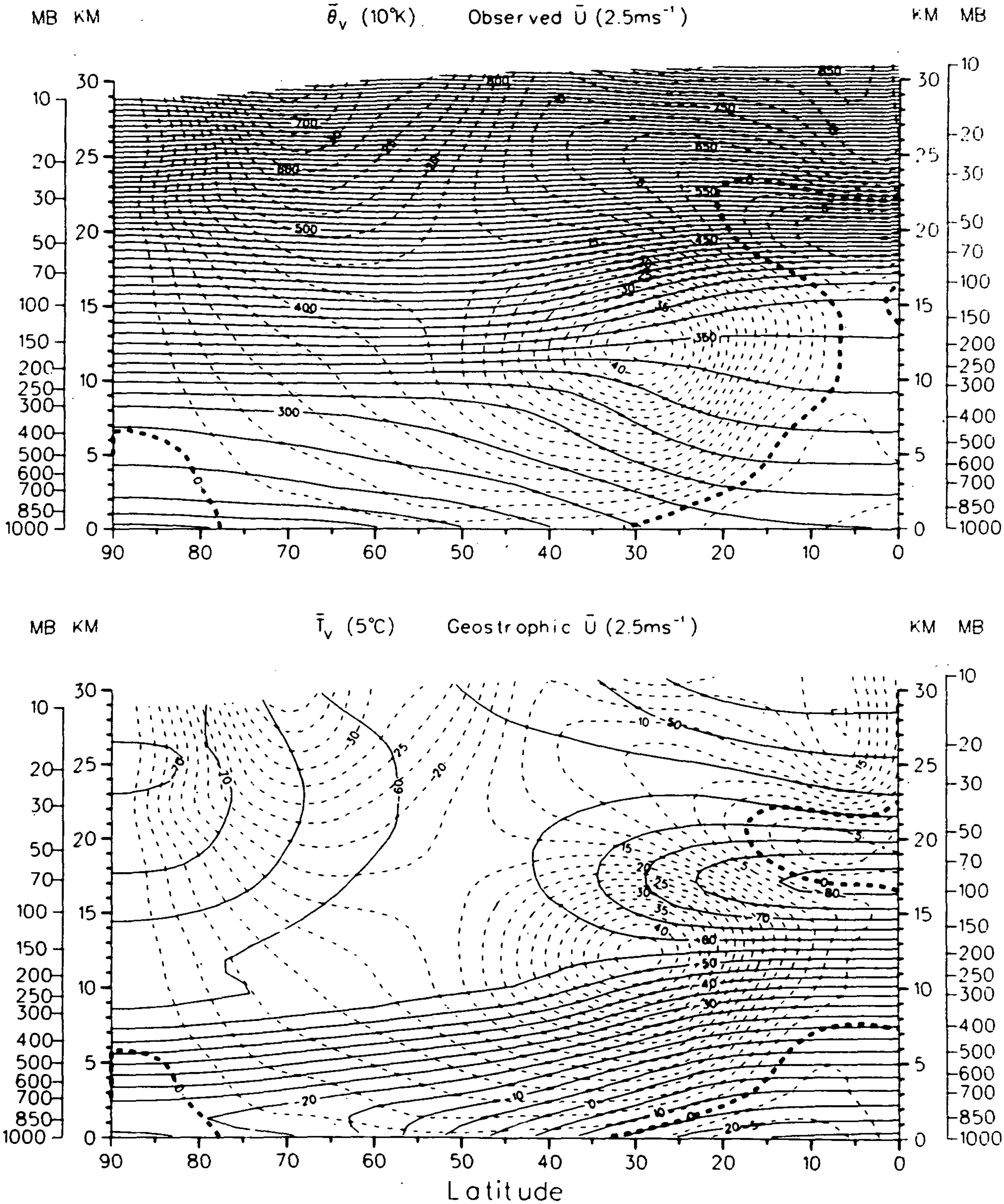
NOVEMBER 1977





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

DECEMBER 1977



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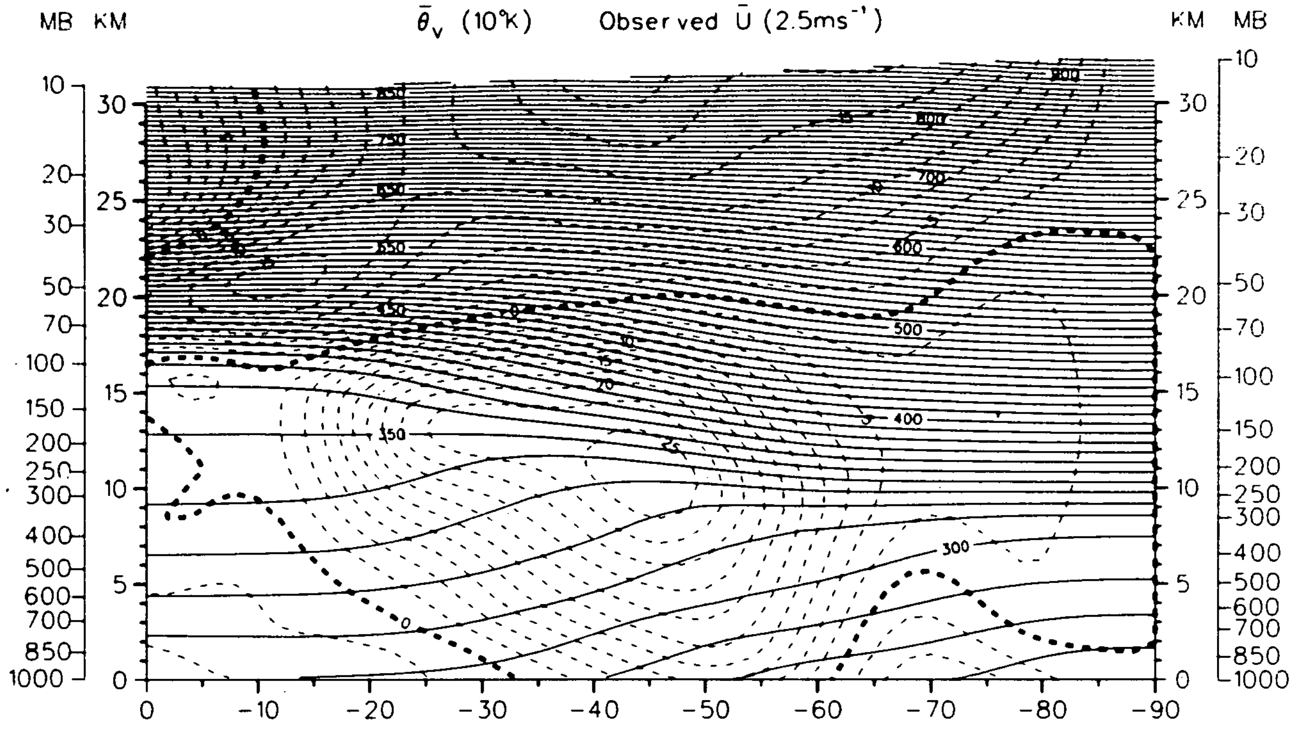
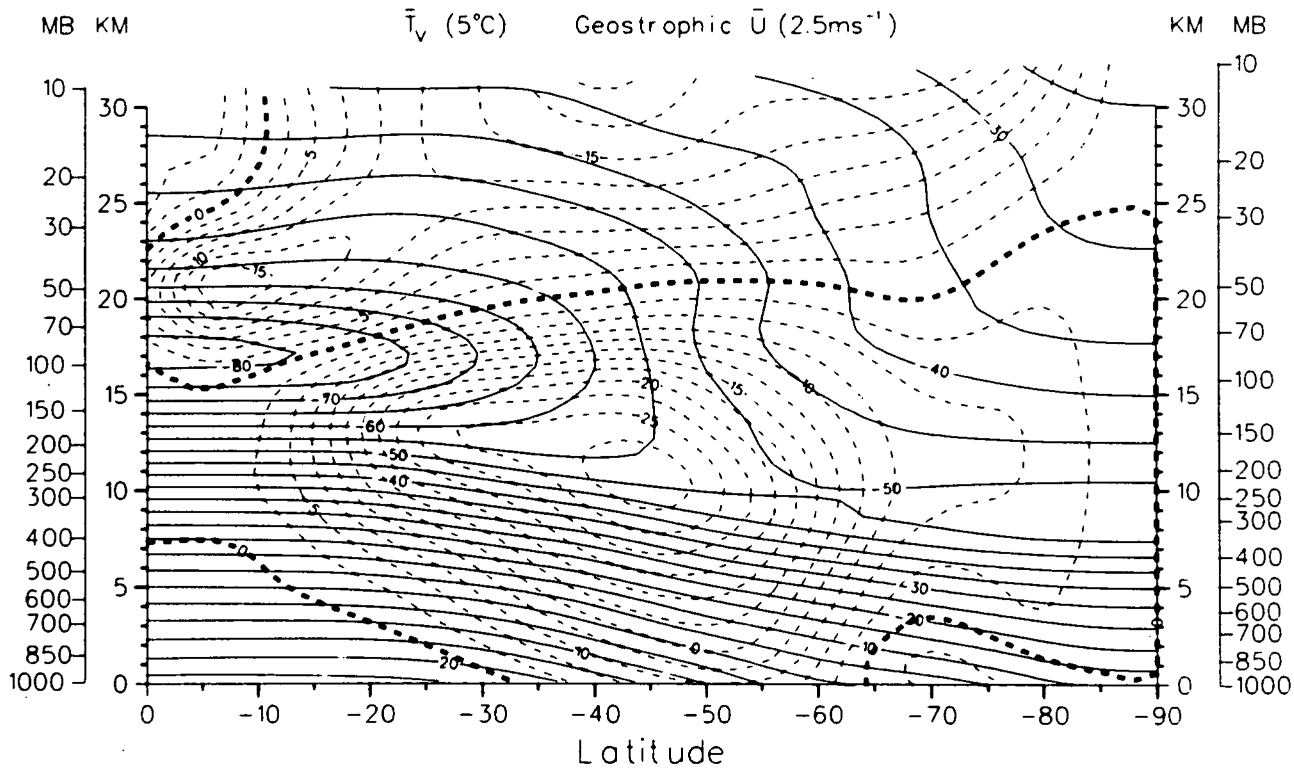
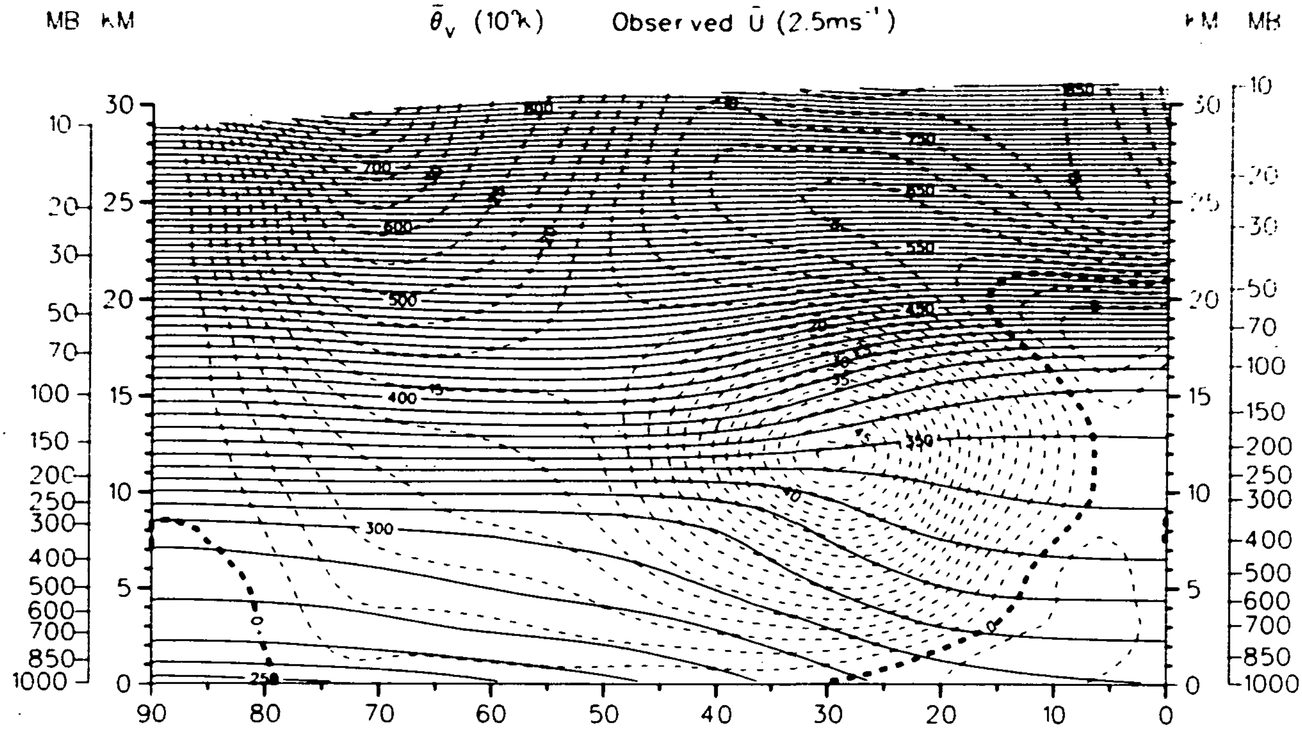
DECEMBER 1977

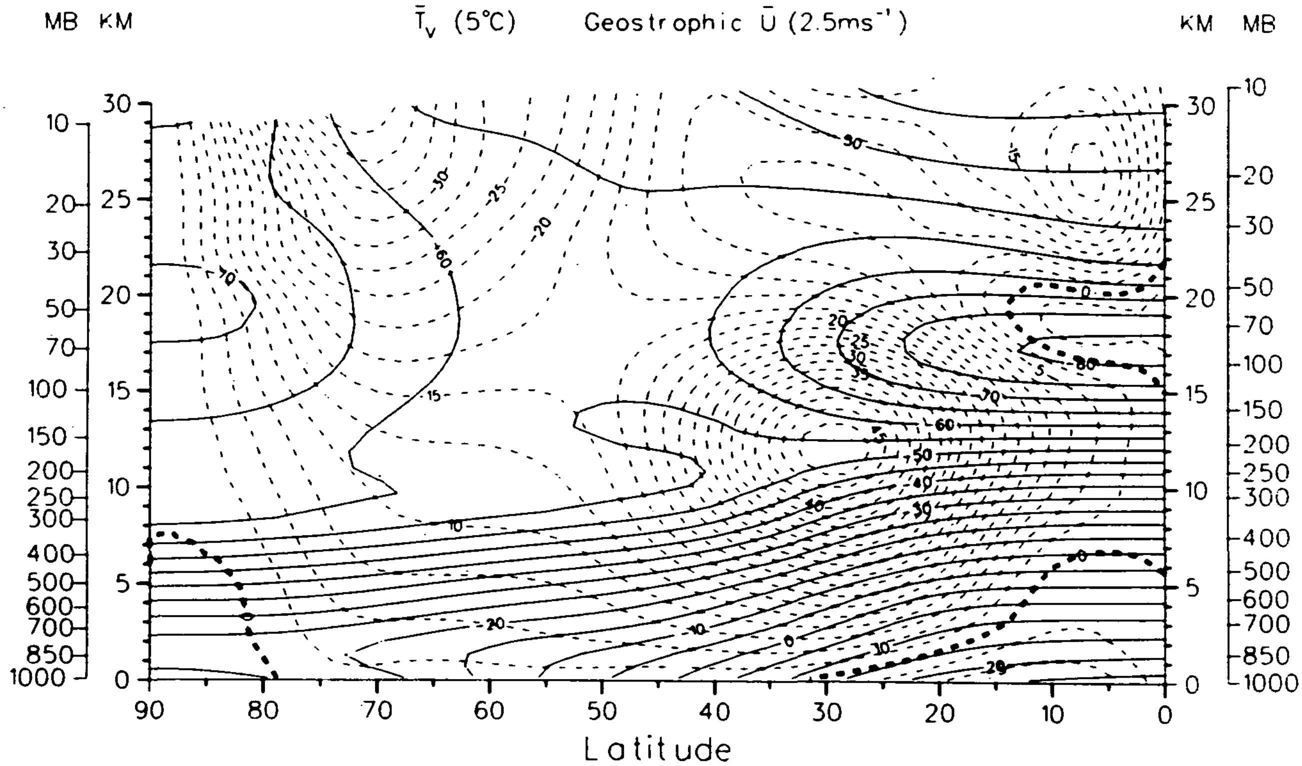




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

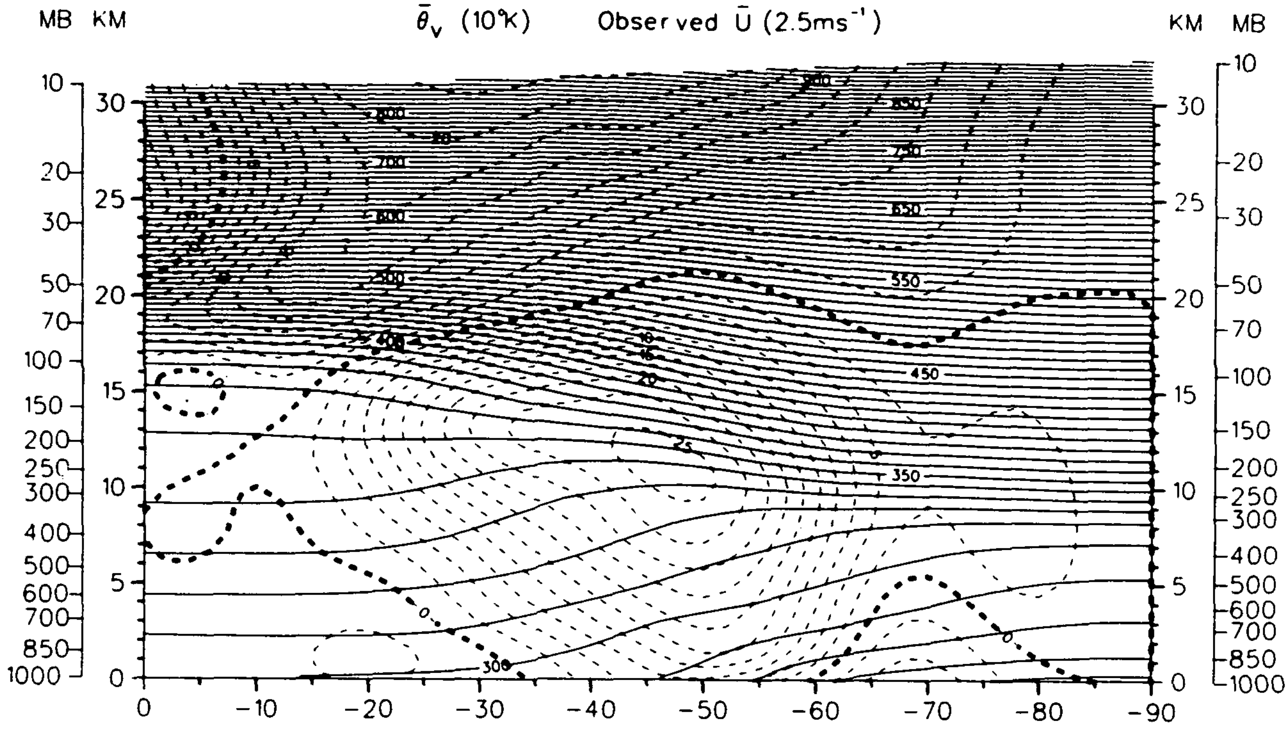
JANUARY 1978

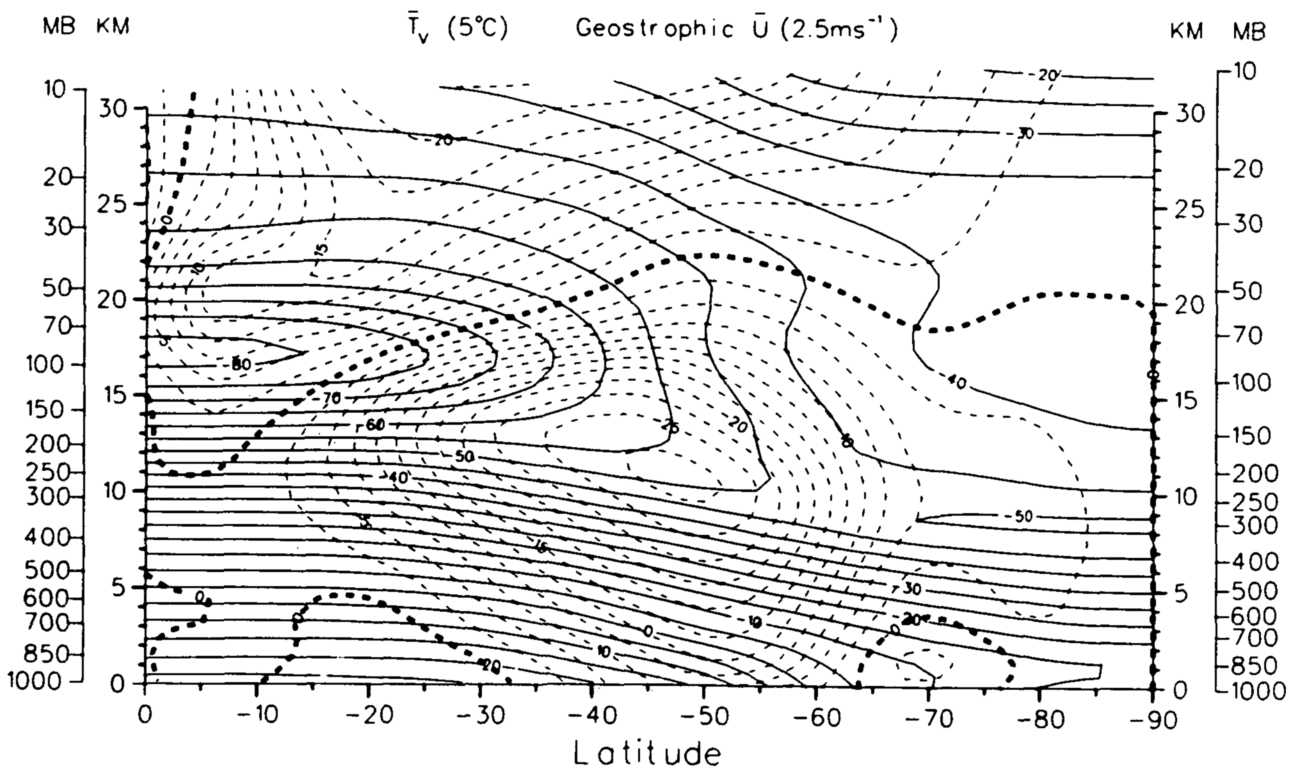




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

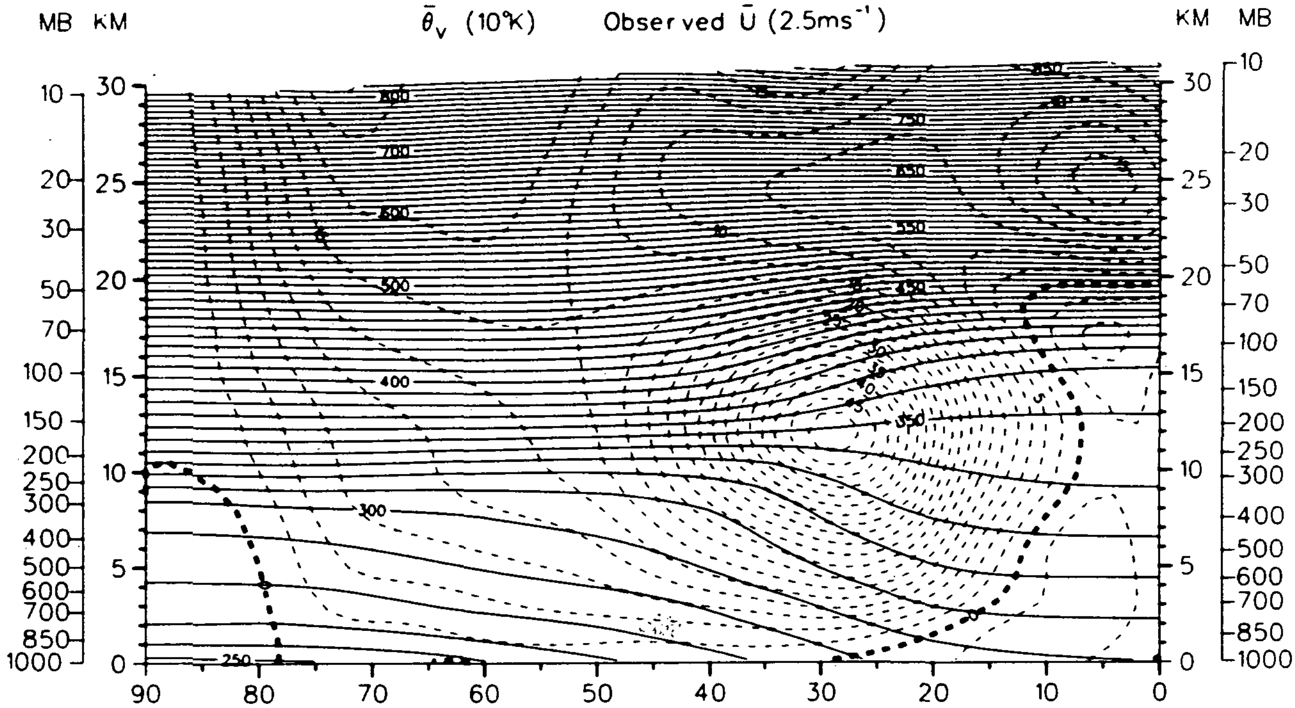
JANUARY 1978

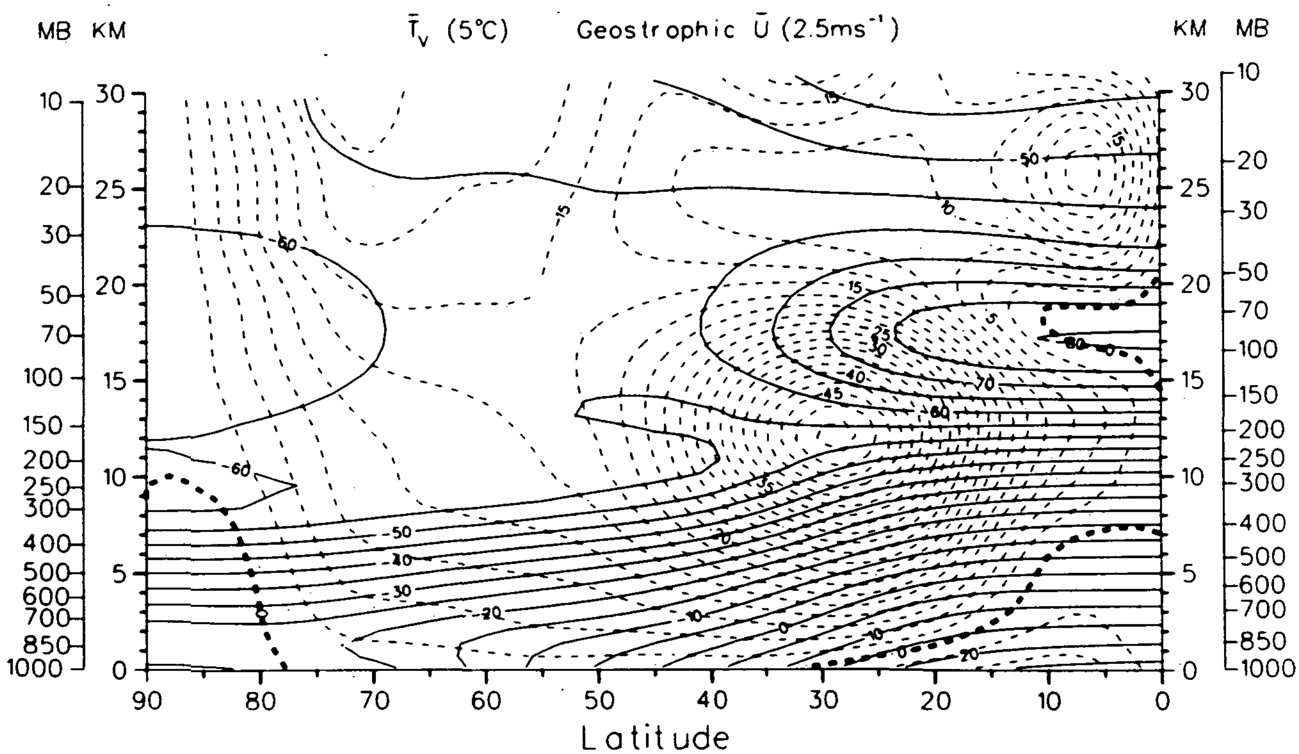




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

FEBRUARY 1978





SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

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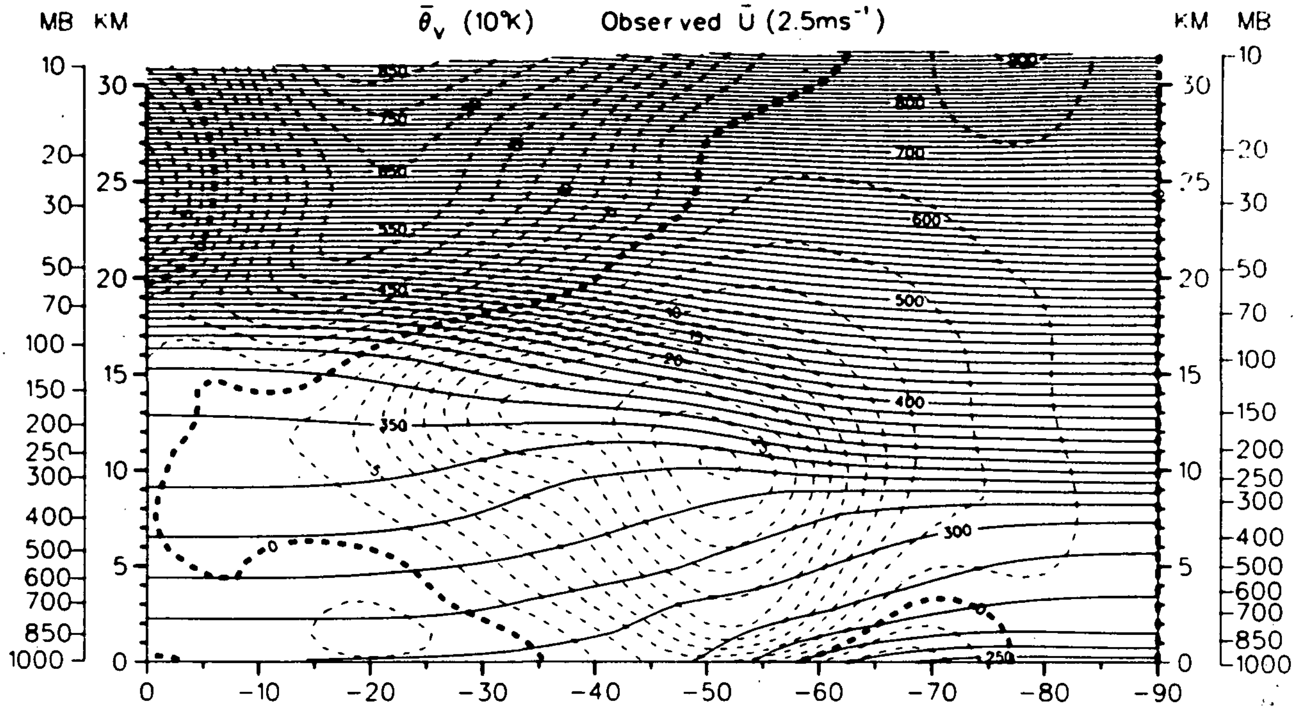
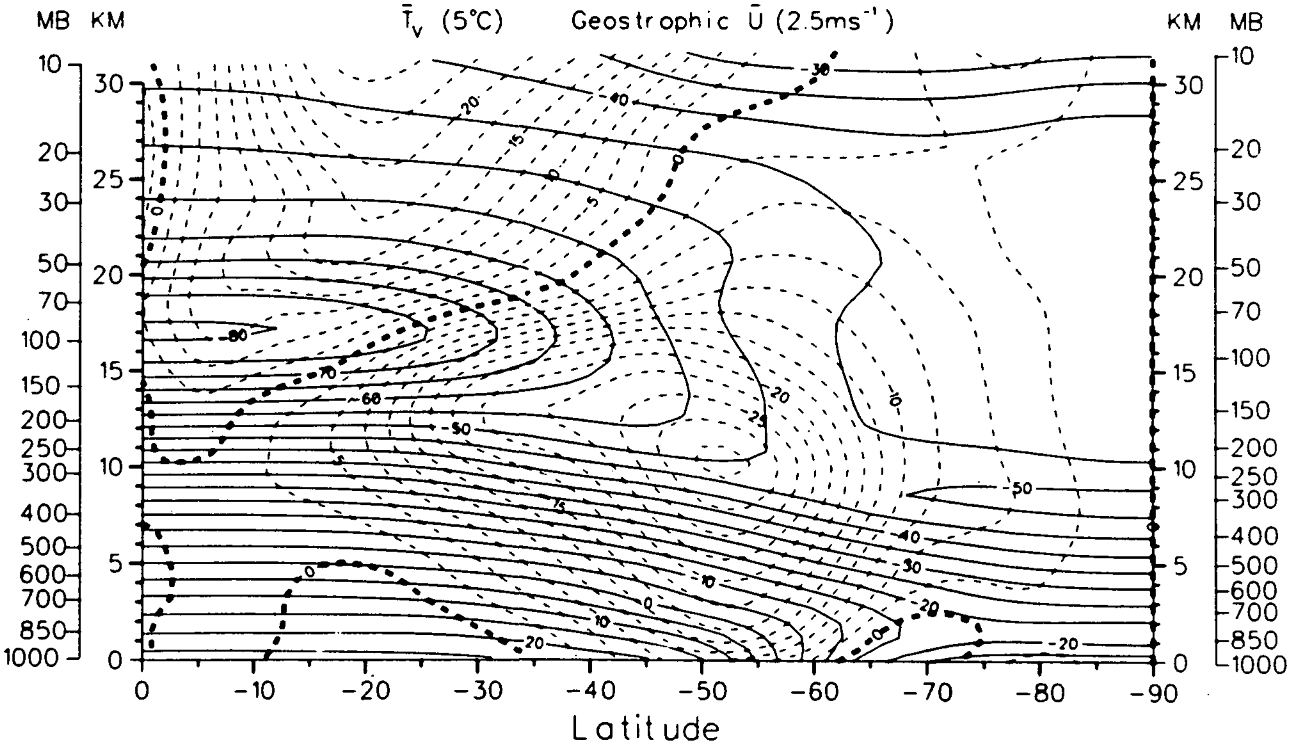
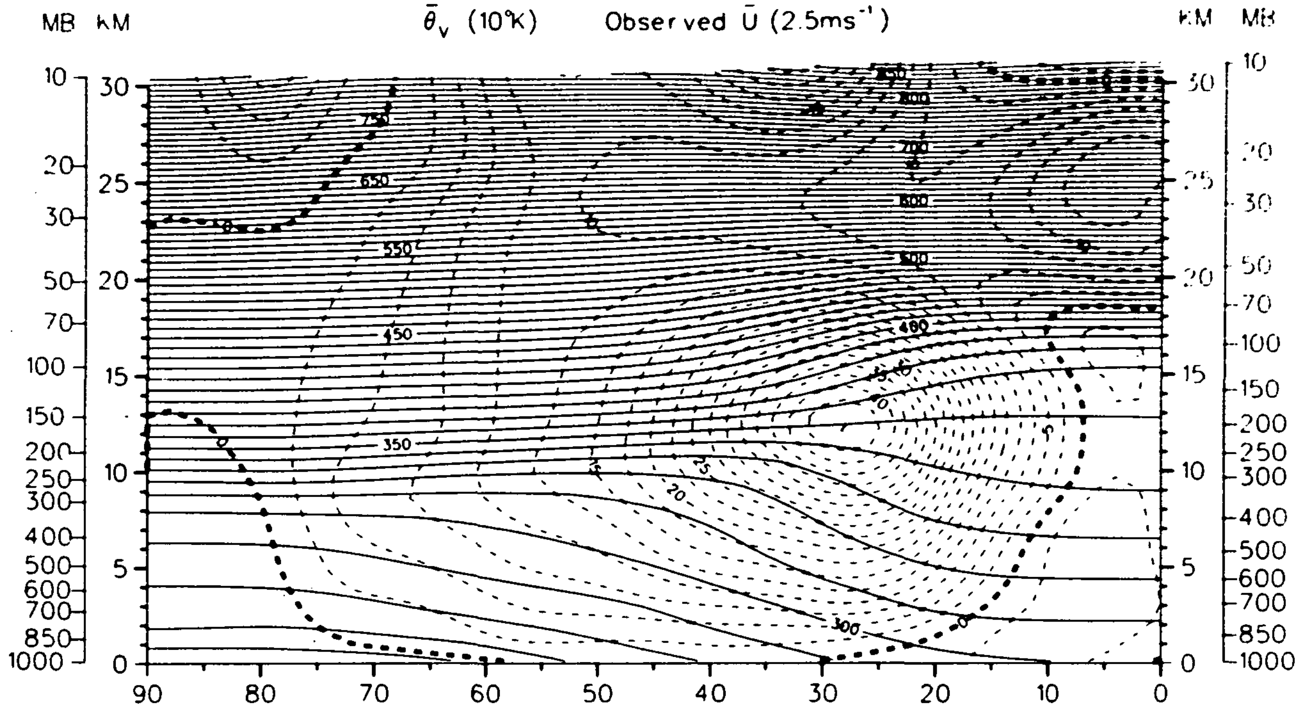
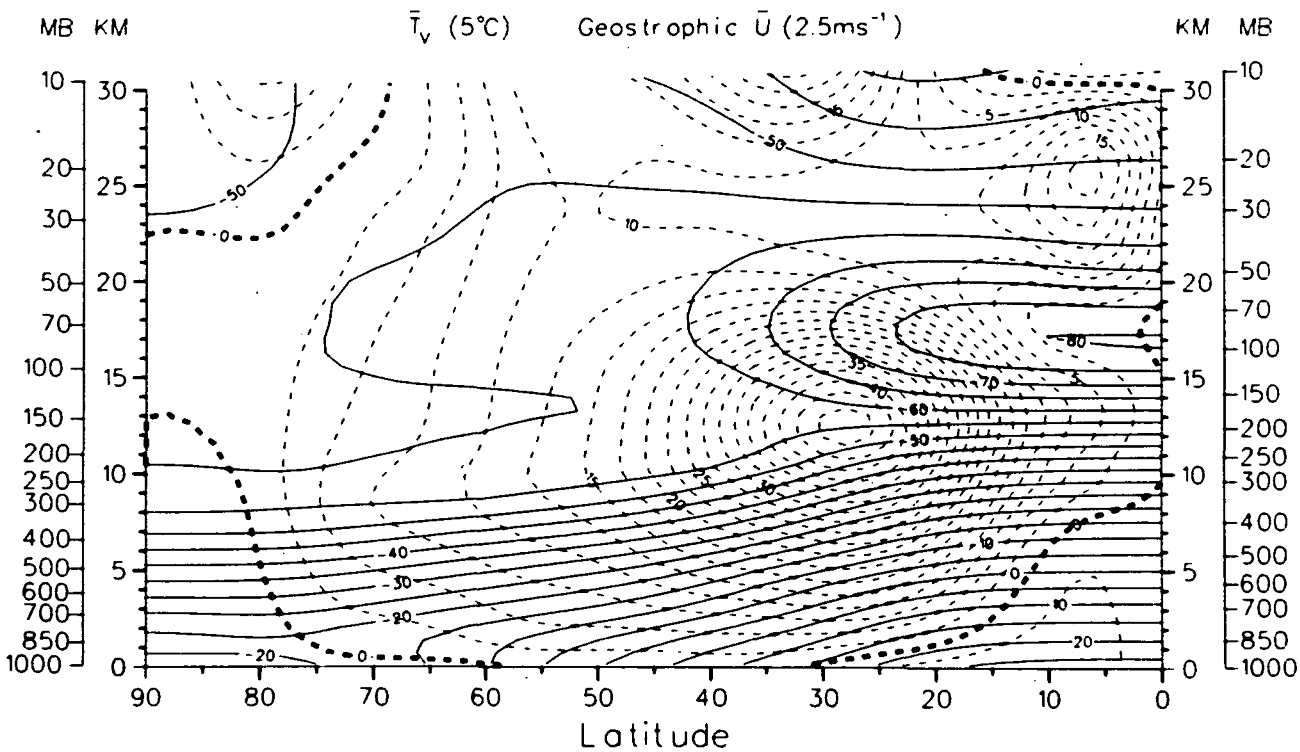




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

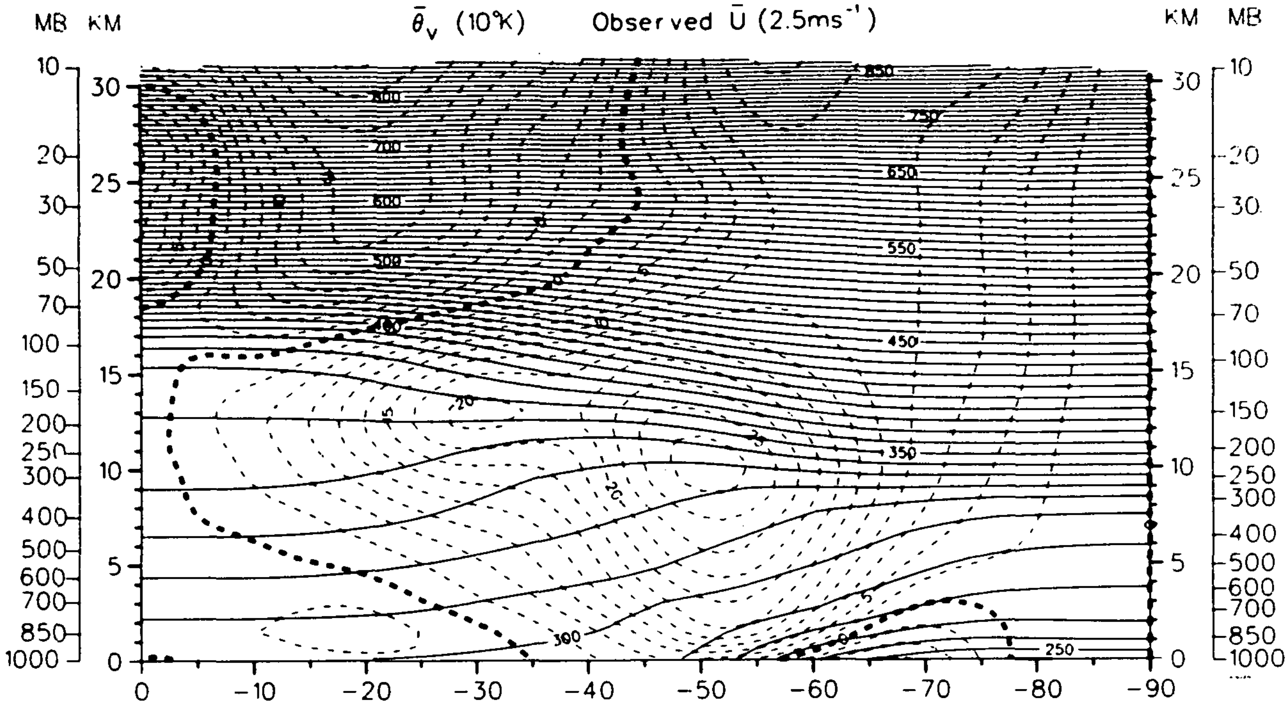
MARCH 1978

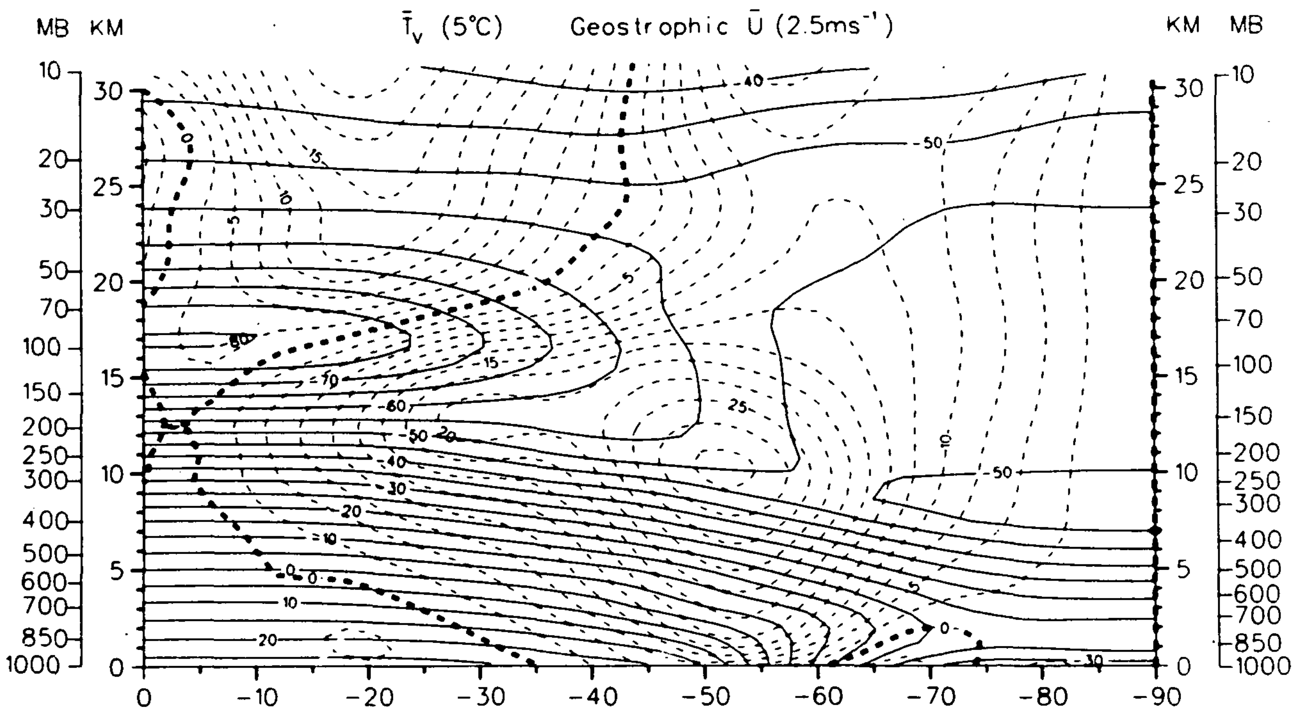




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

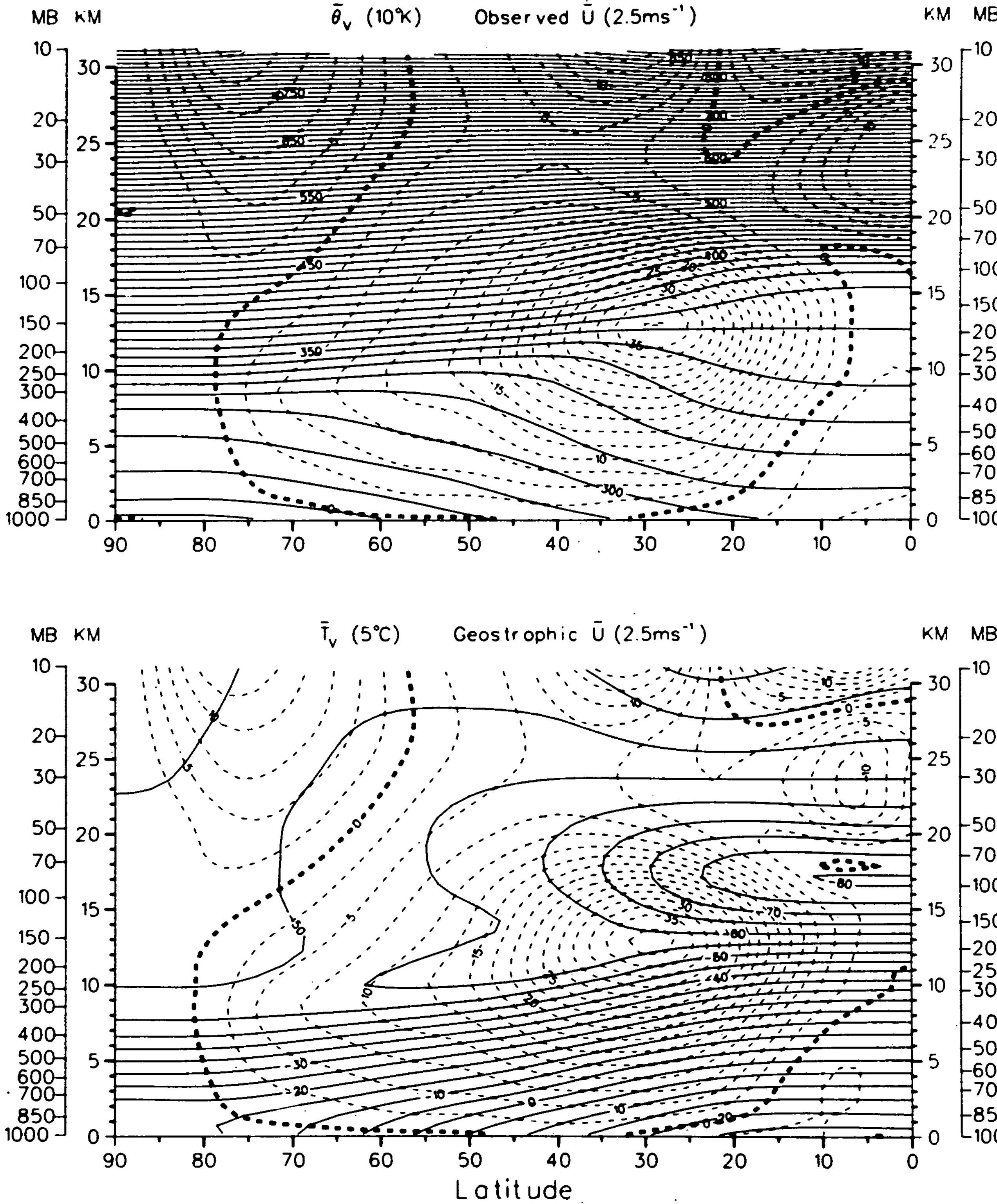
MARCH 1978





NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

APRIL 1978



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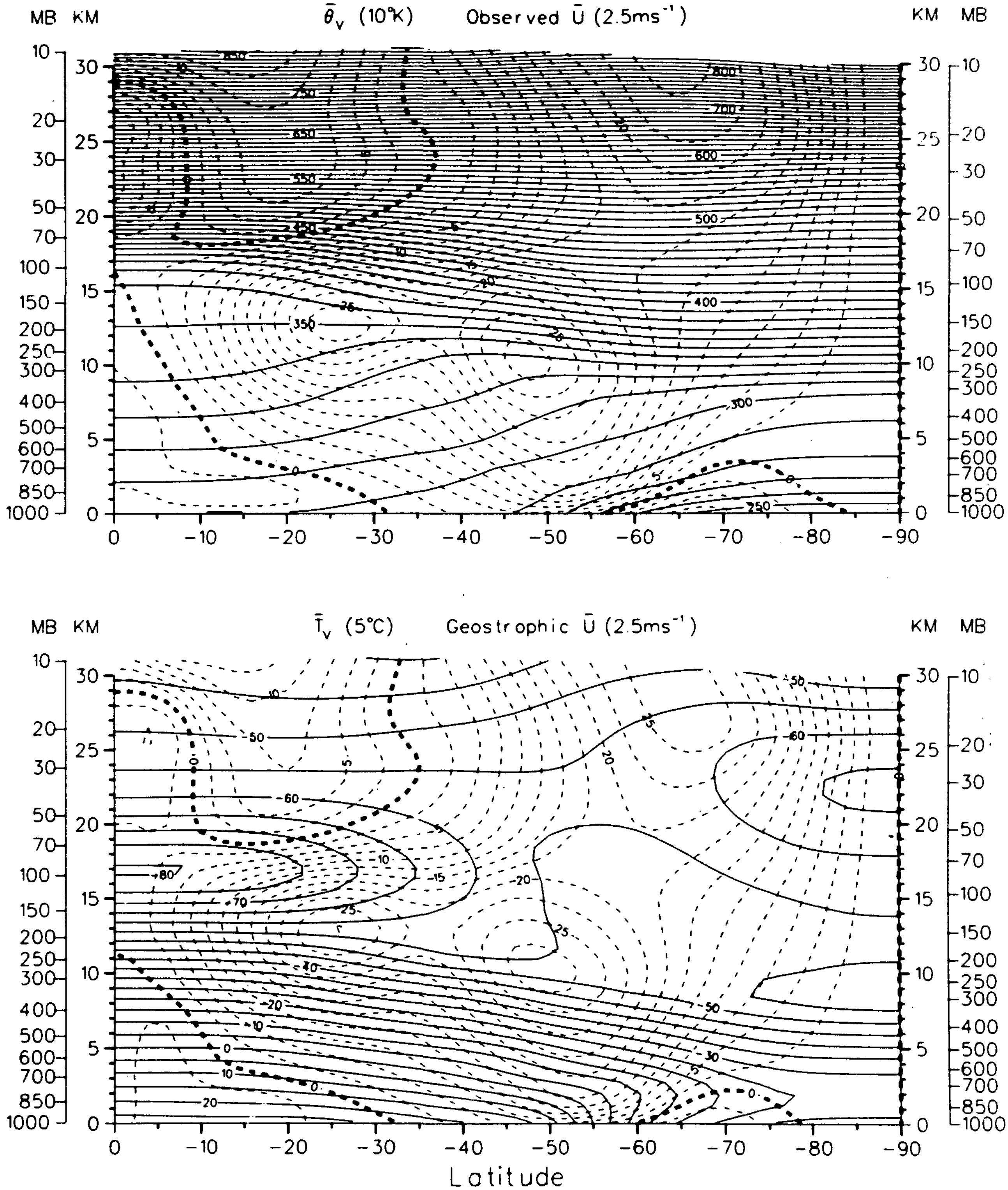

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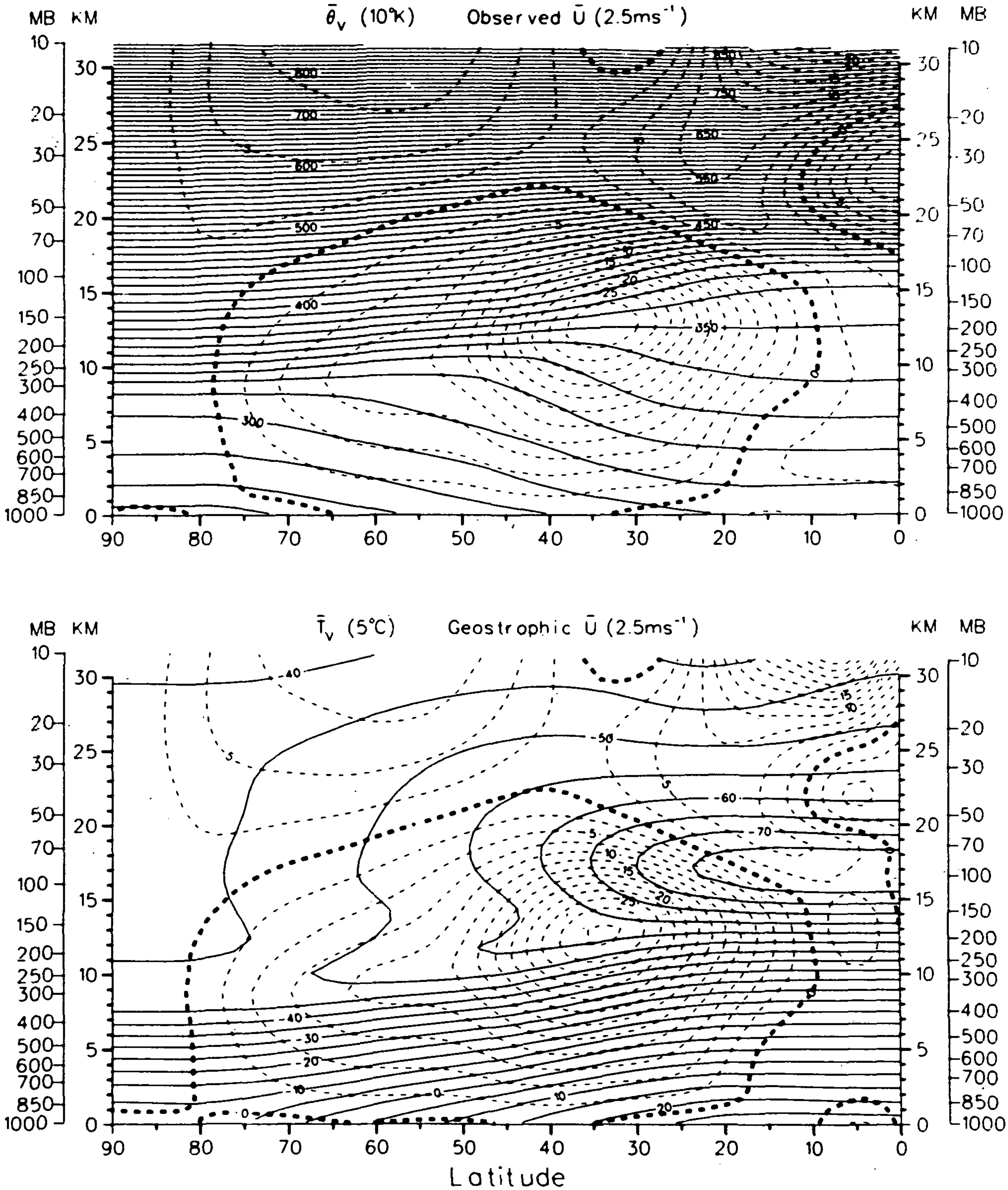

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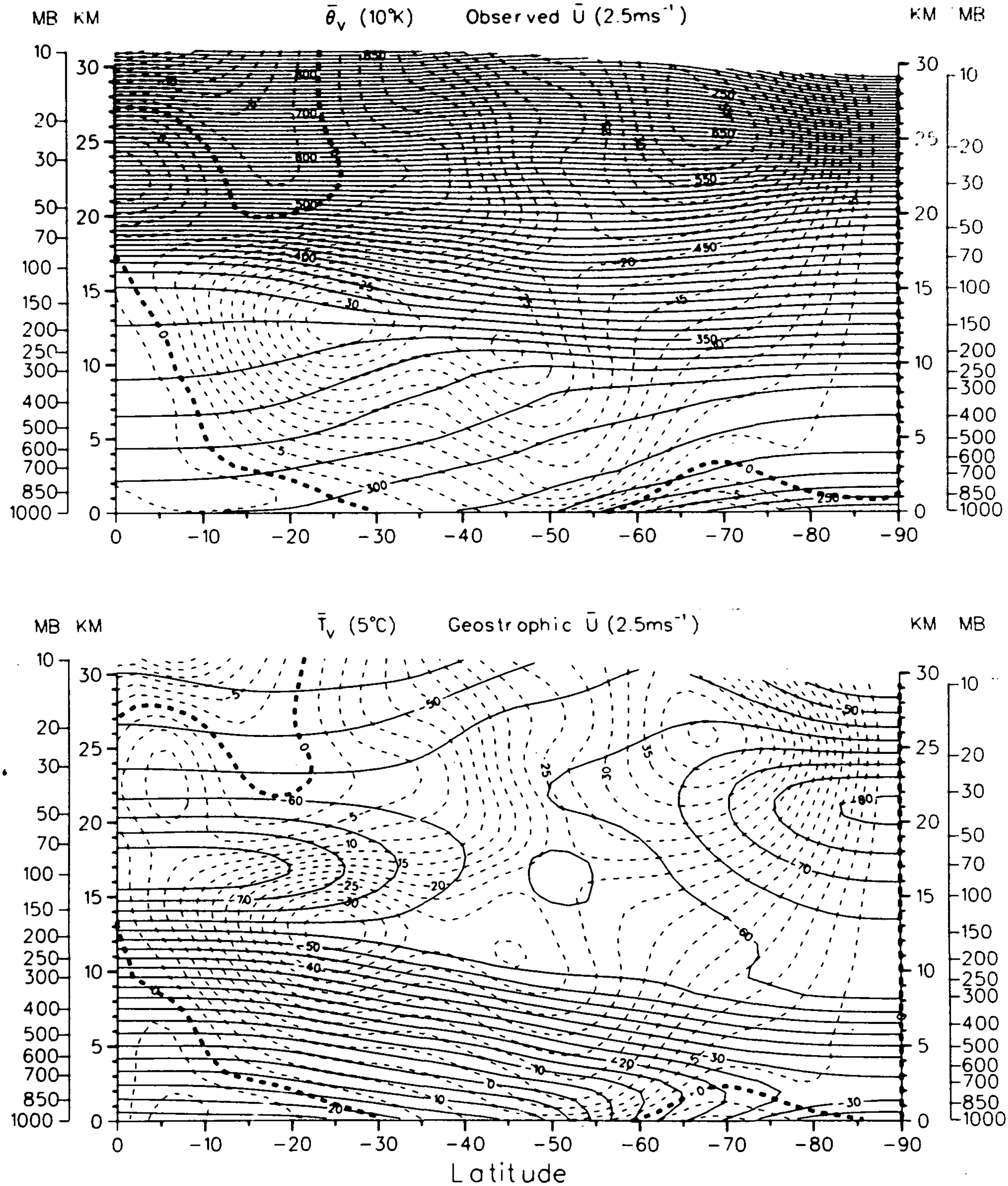
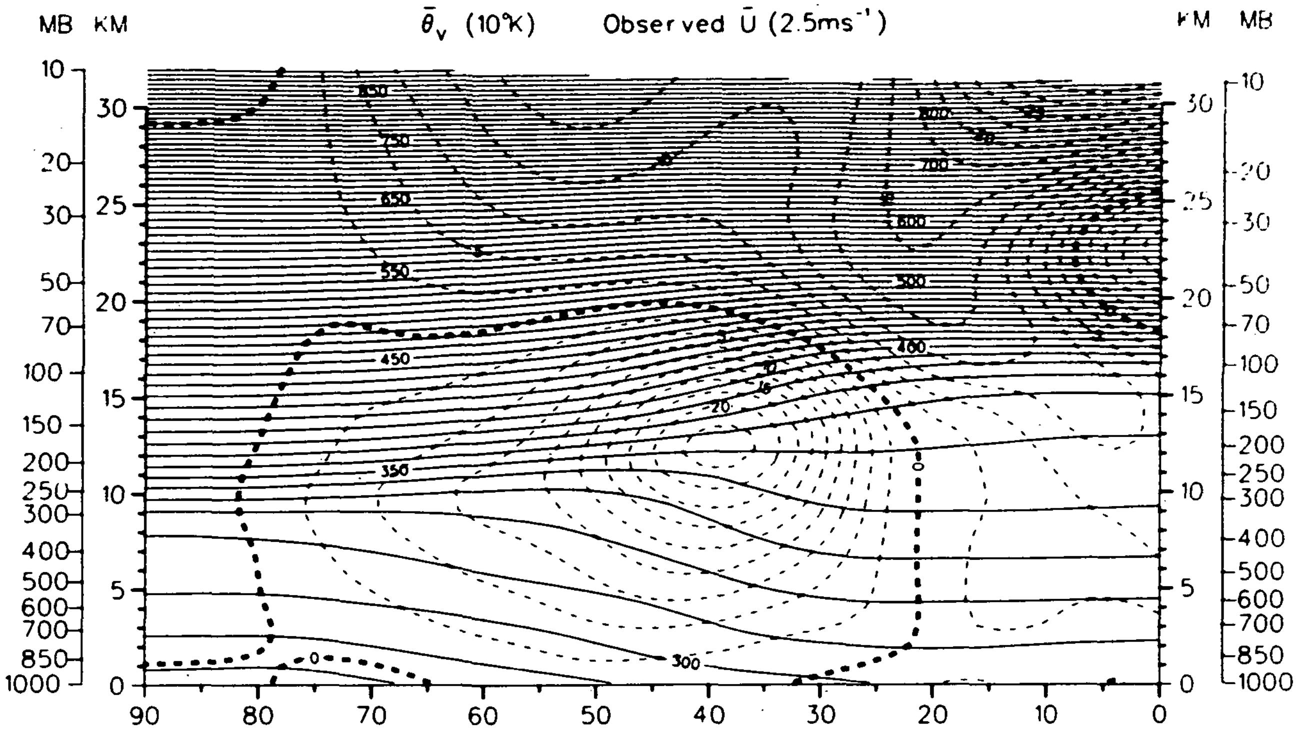
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

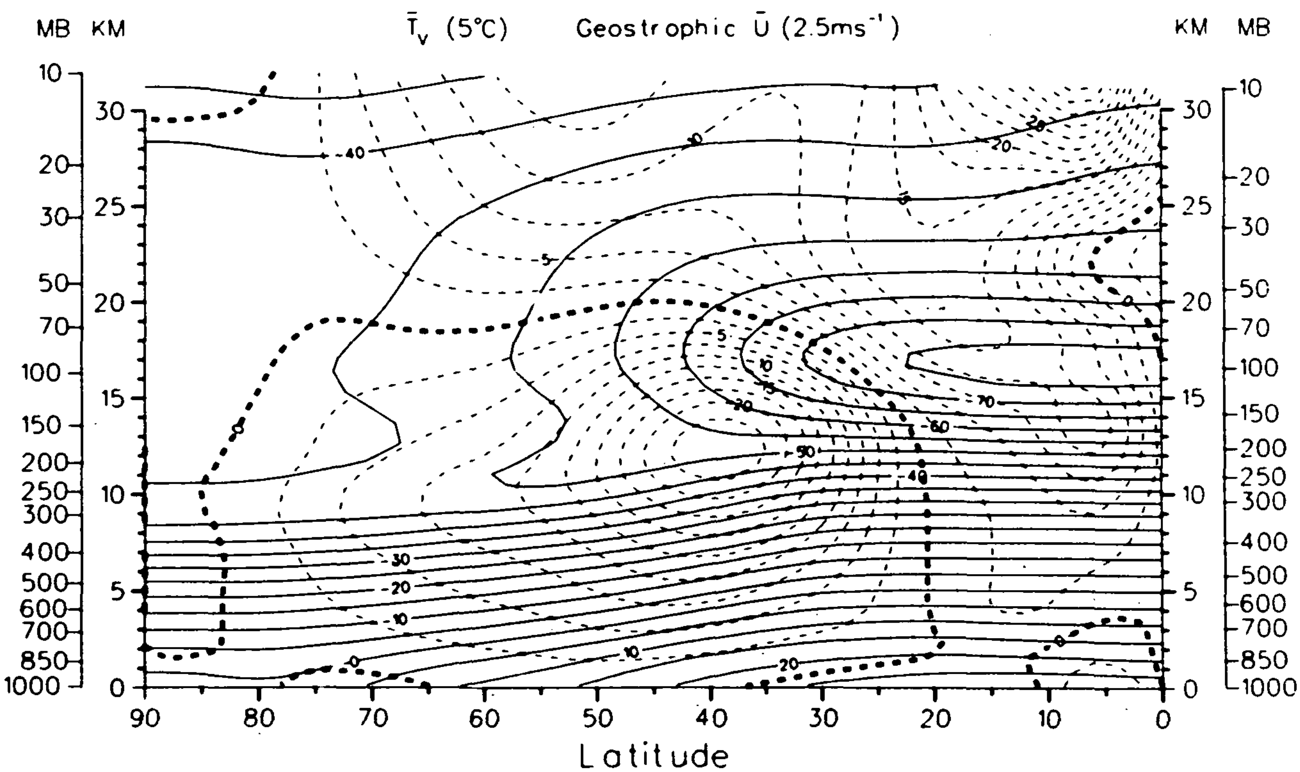
MAY 1978



NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JUNE 1978





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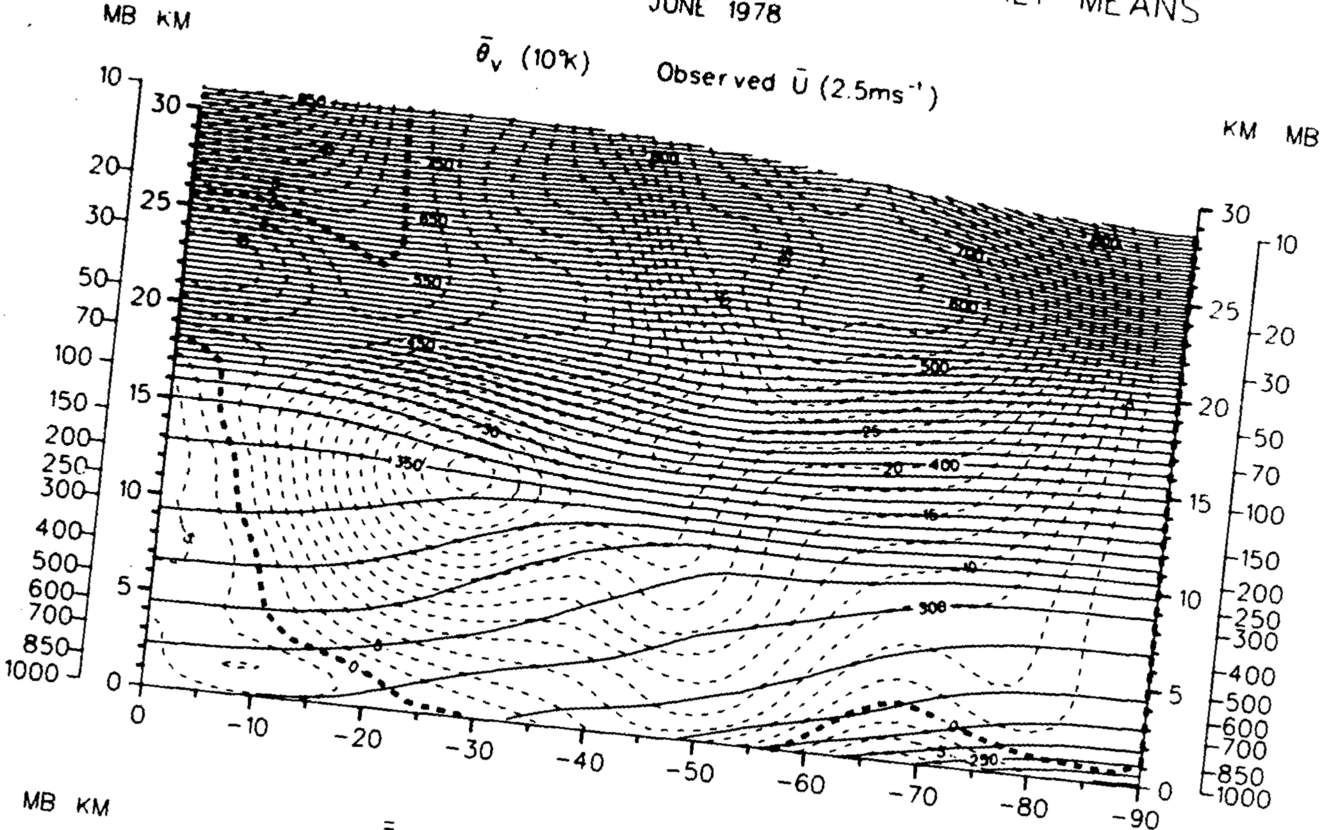

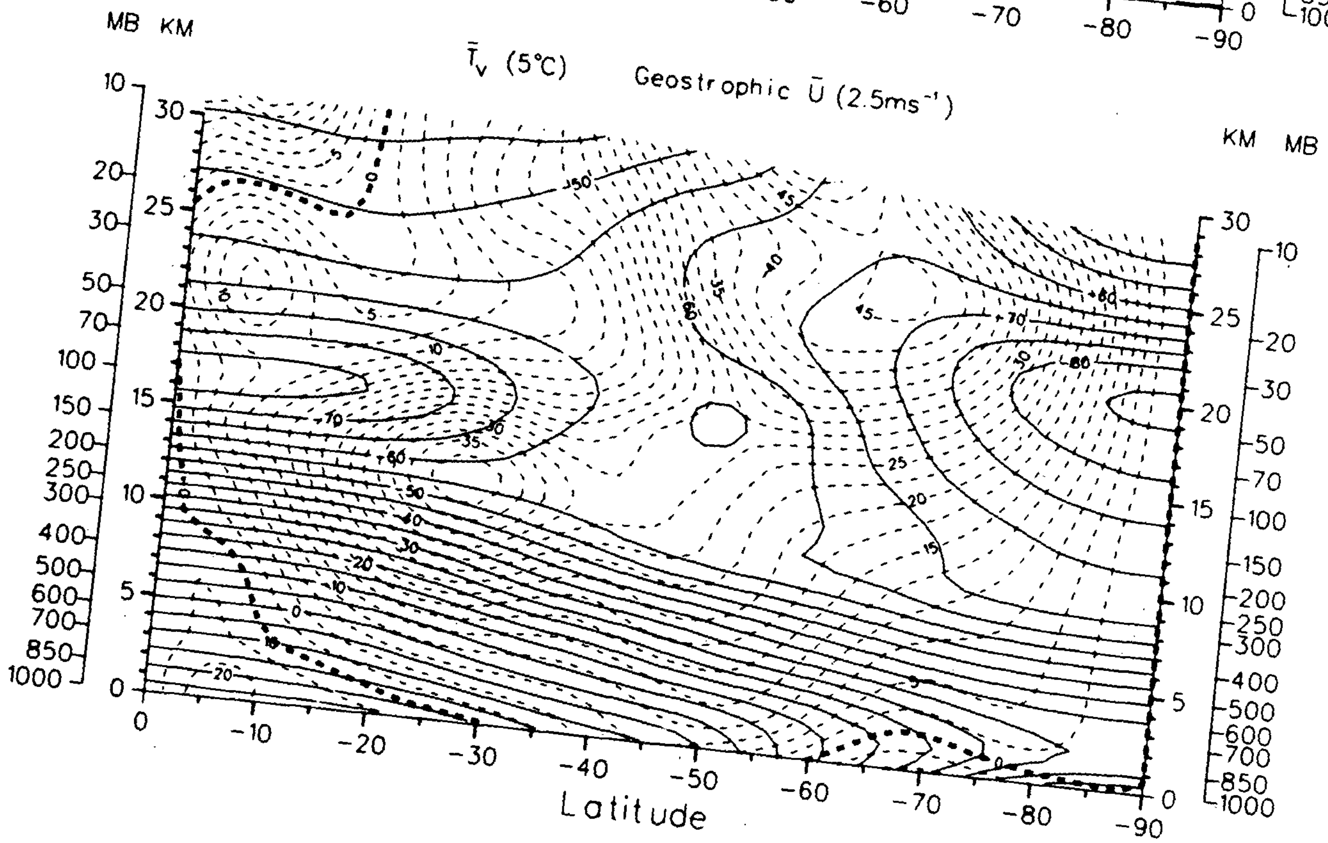

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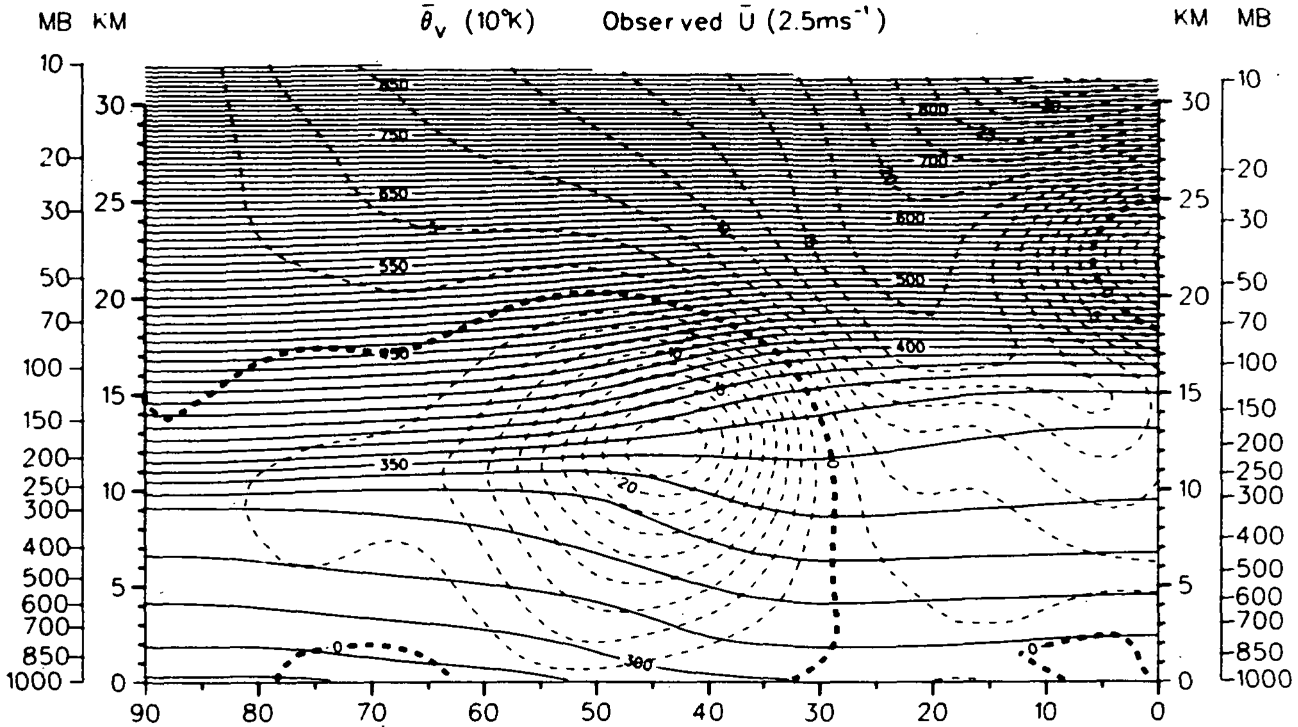

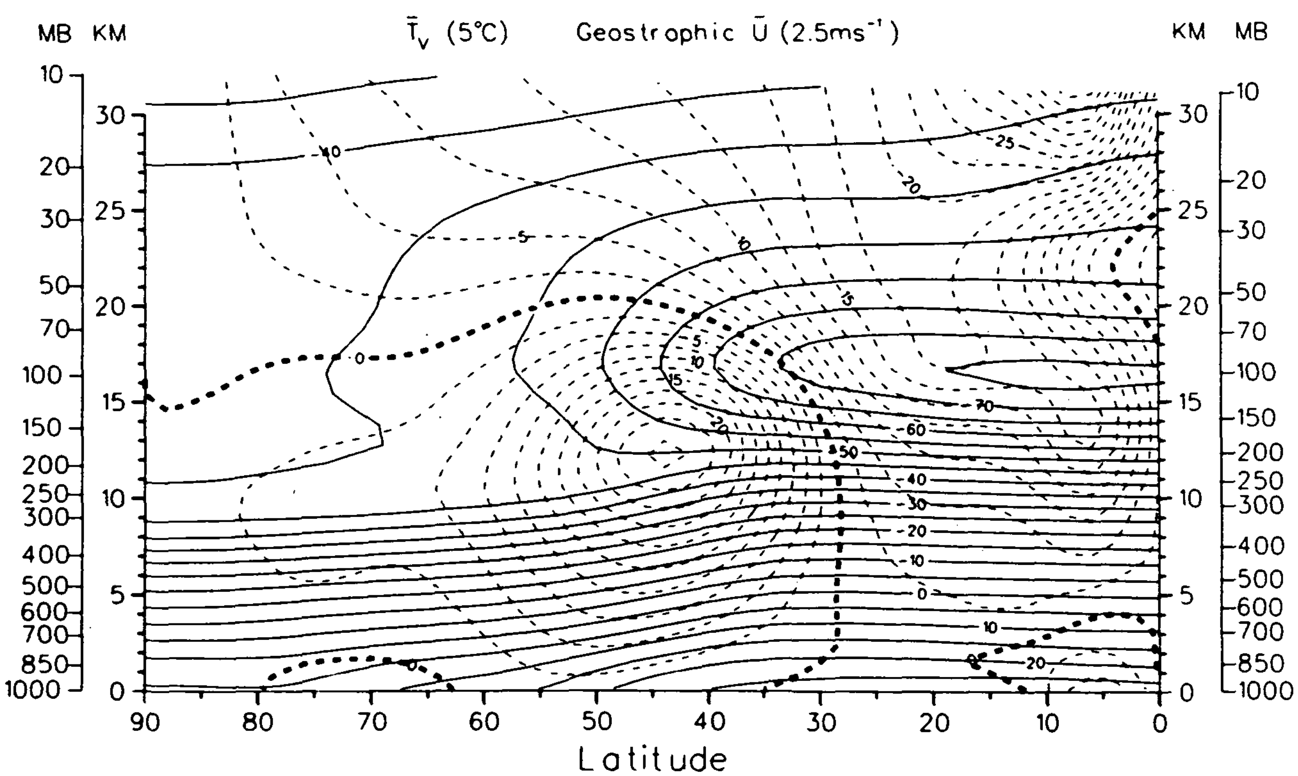

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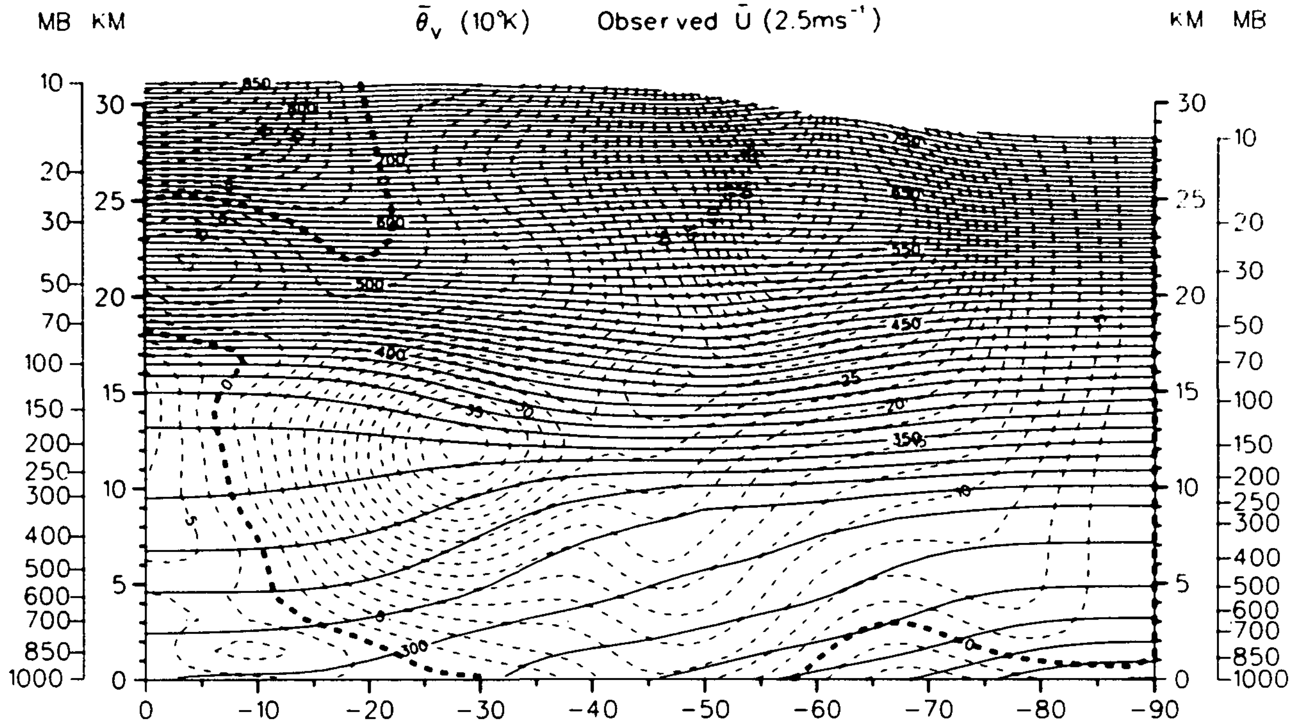
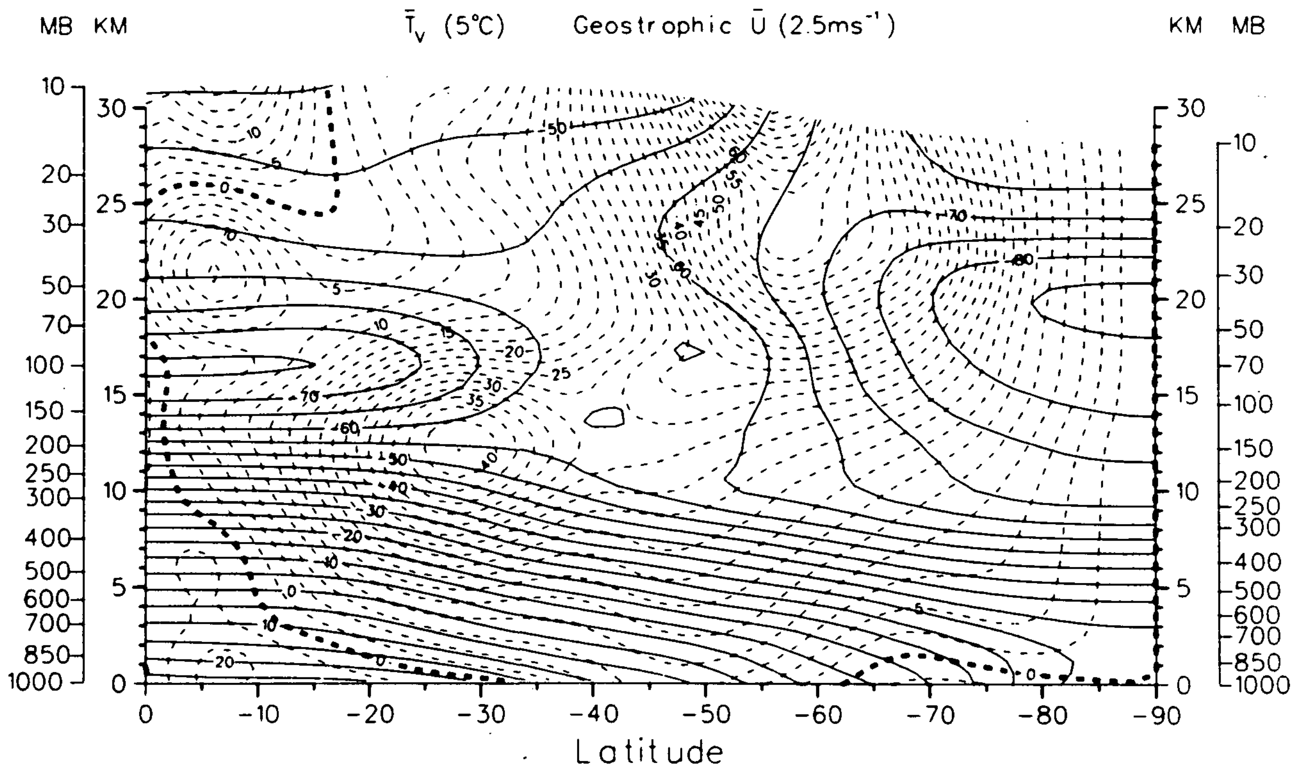
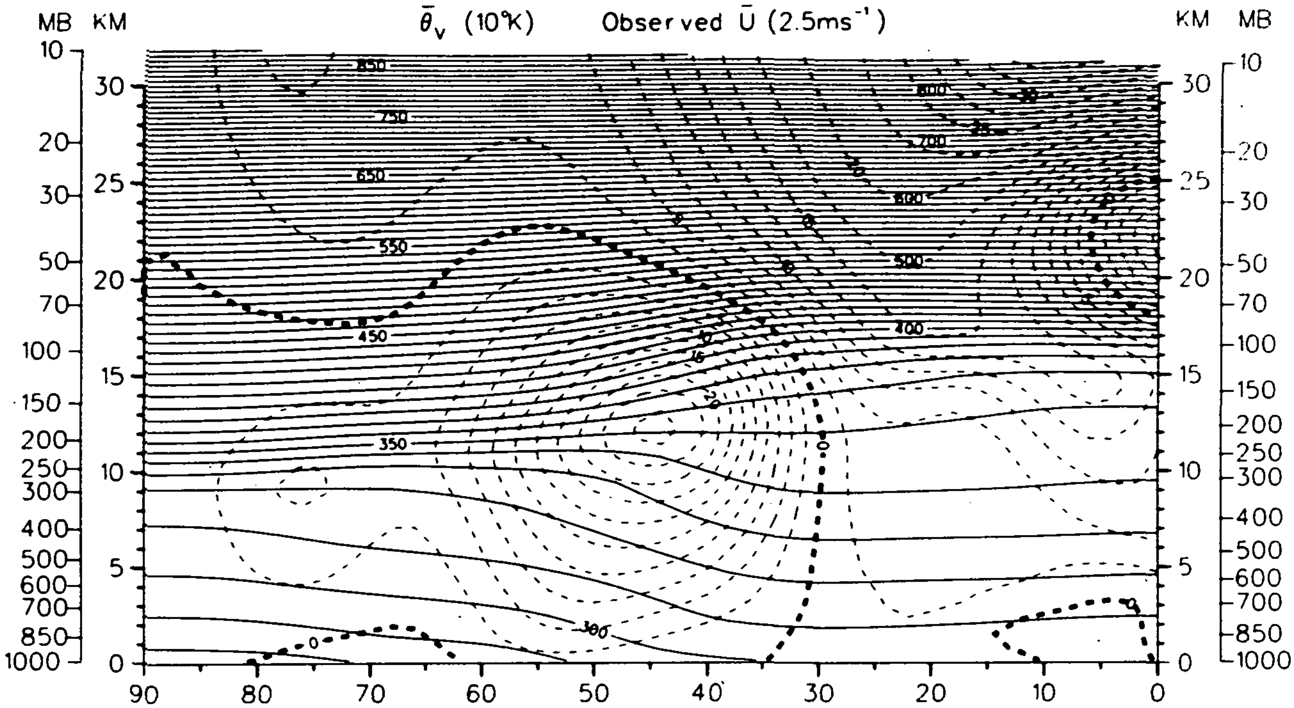
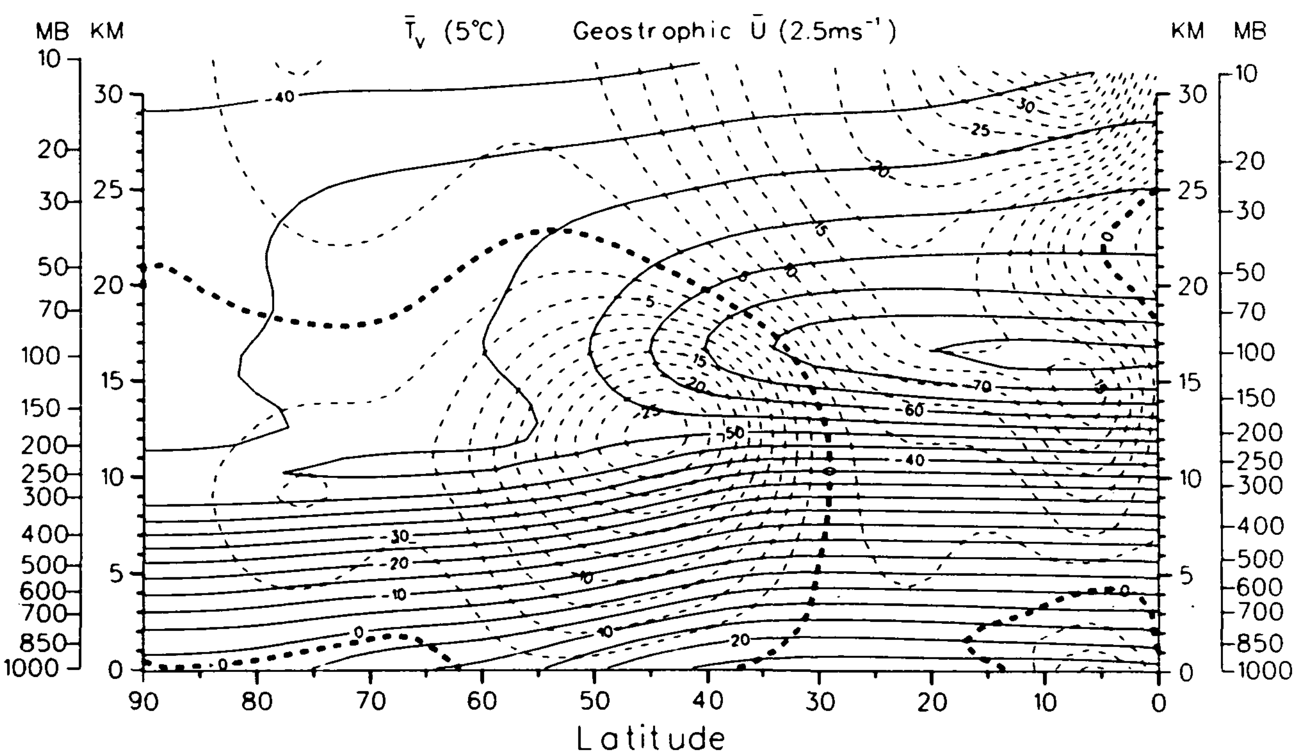




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

AUGUST 1978





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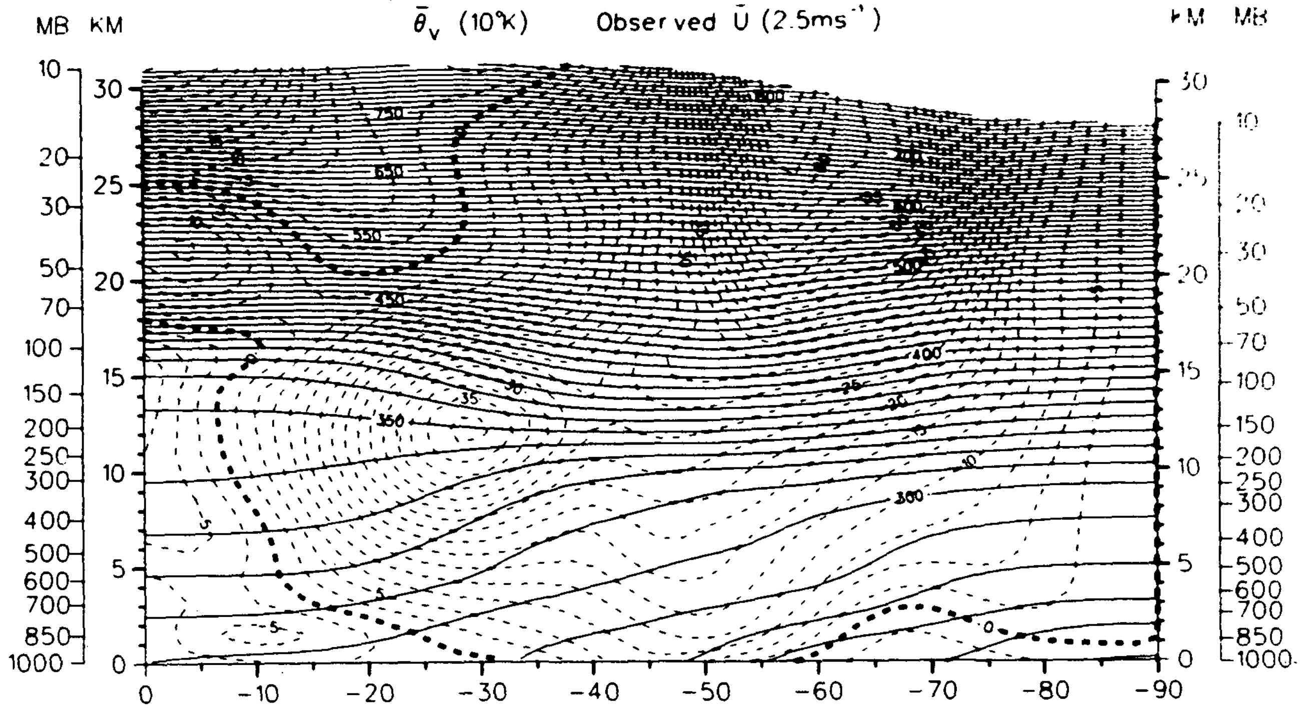
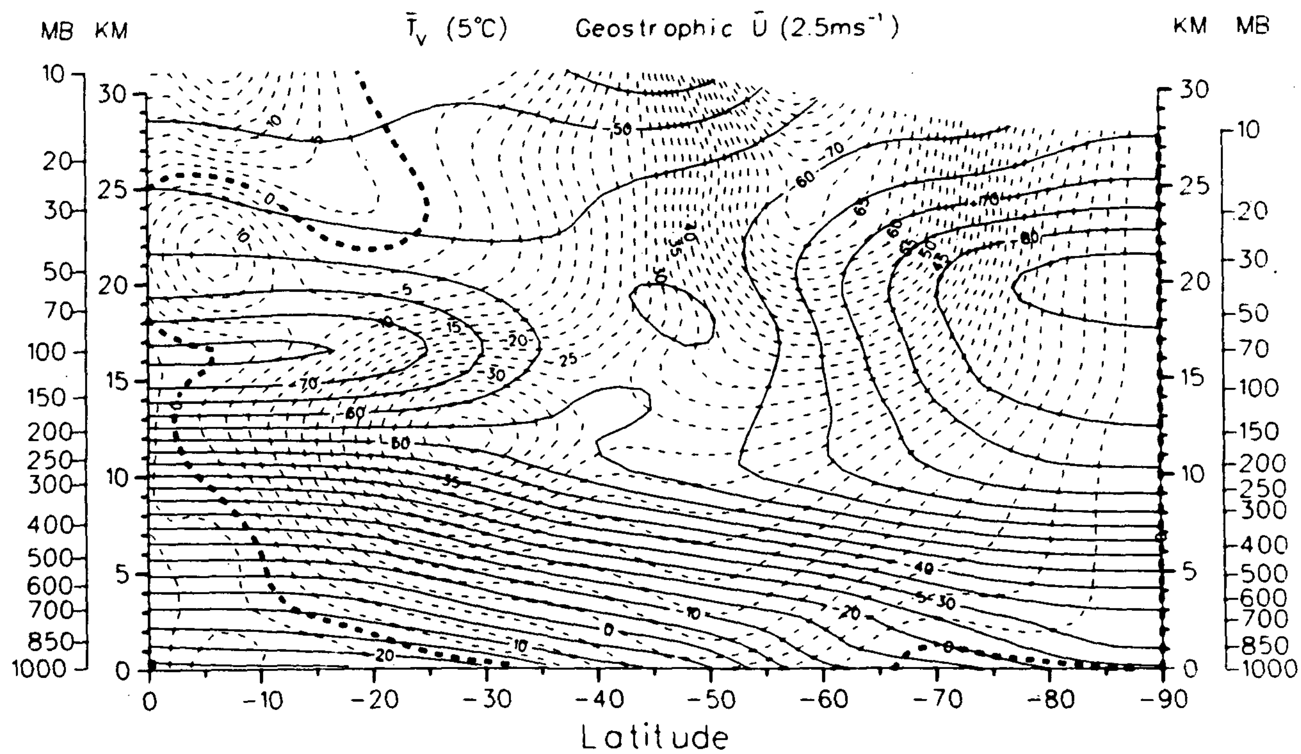
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

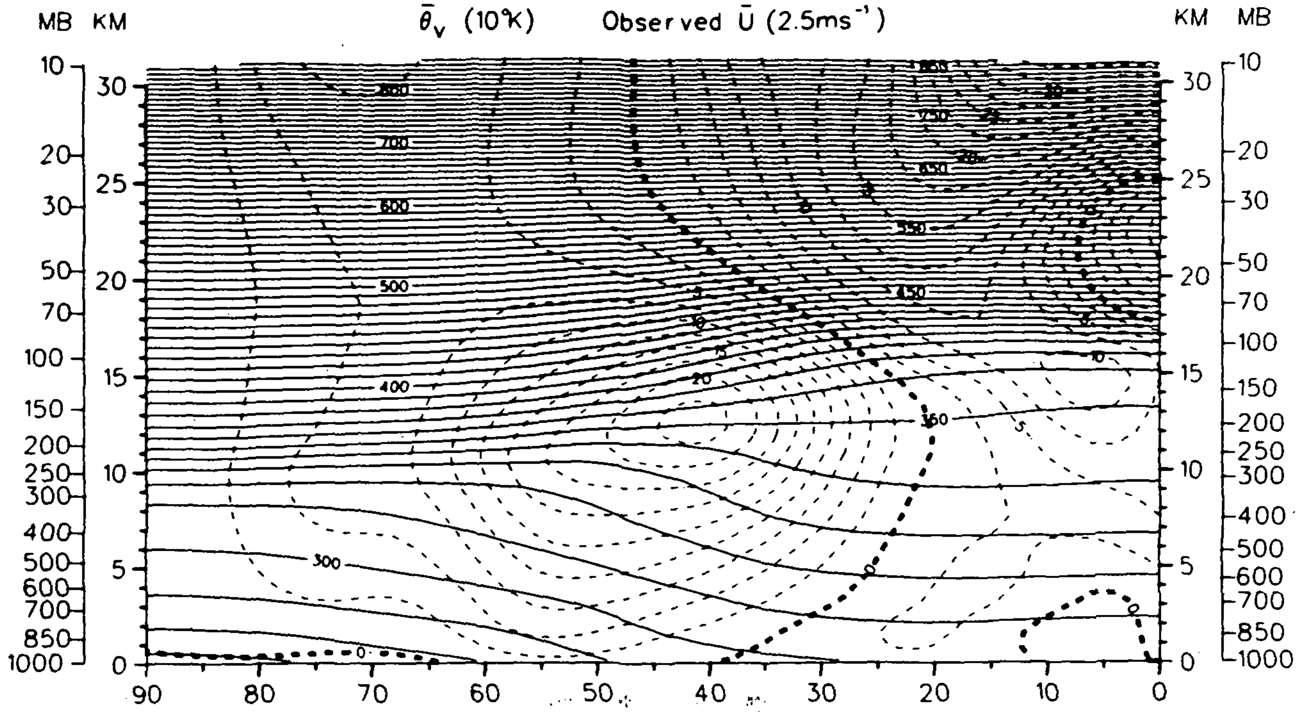
AUGUST 1978

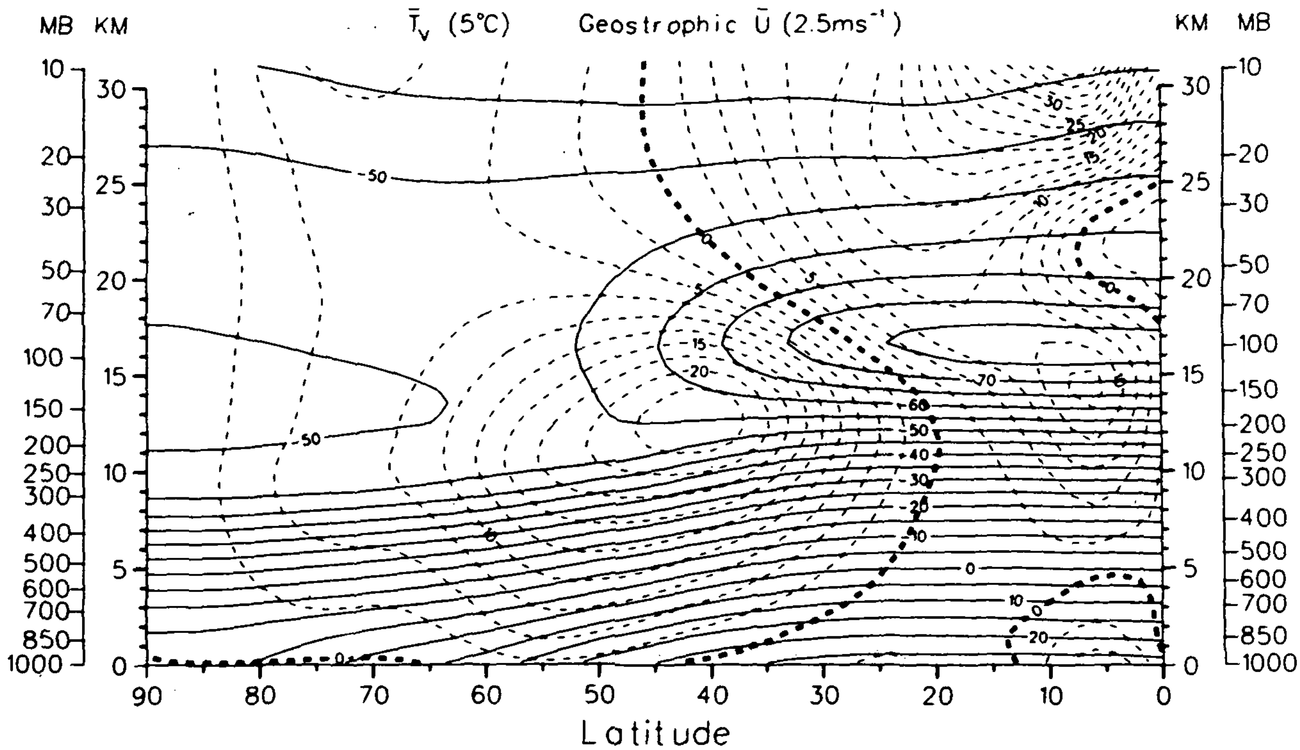




NORTHERN HEMISPHERIC ZONAL–MONTHLY MEANS

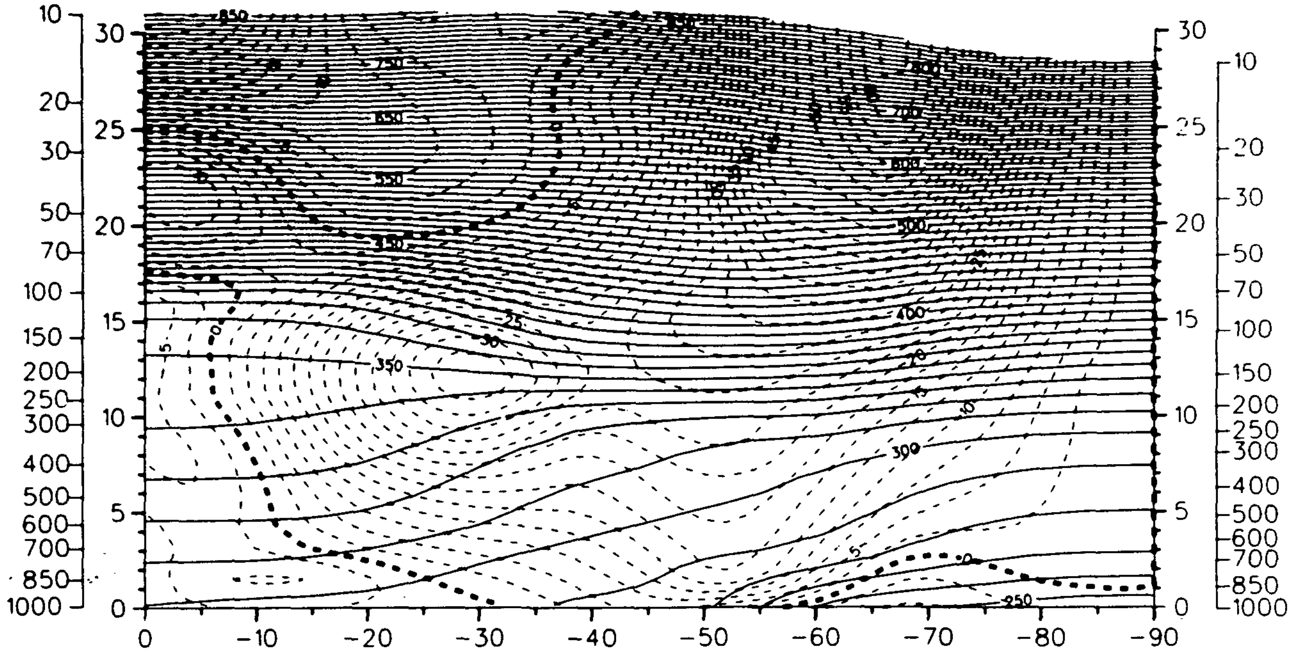
SEPTEMBER 1978

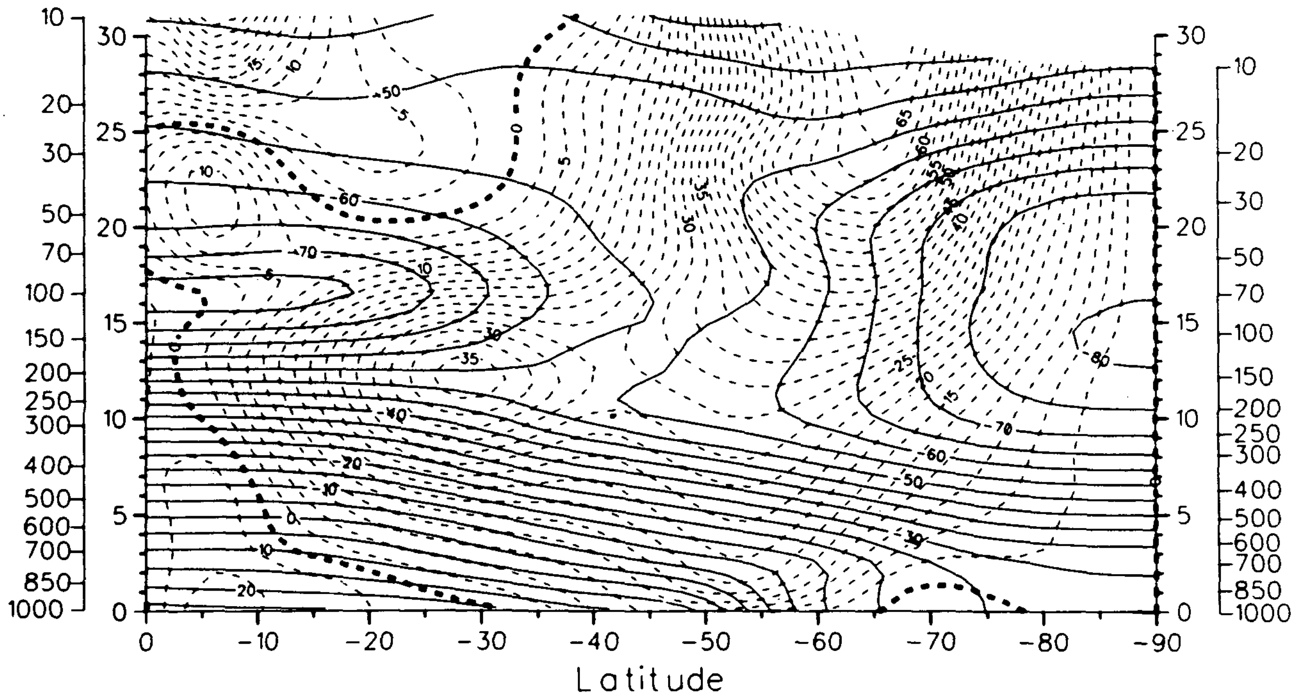




SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

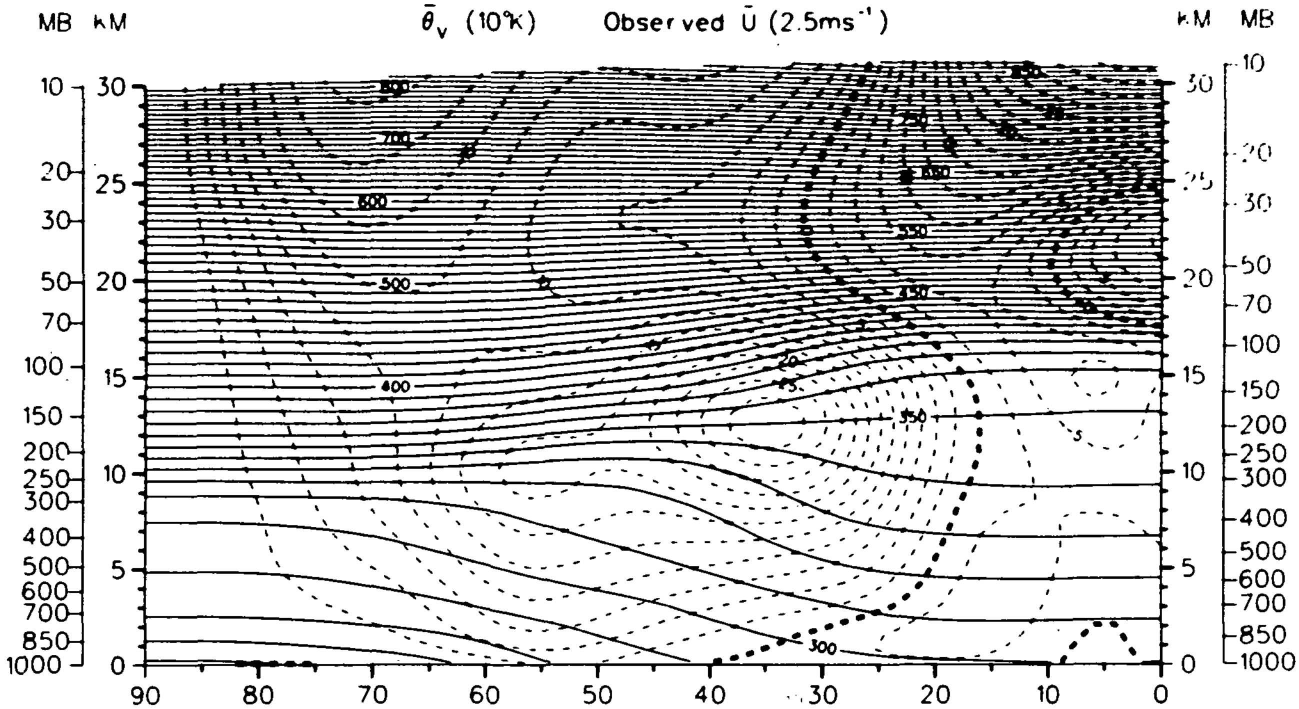
SEPTEMBER 1978

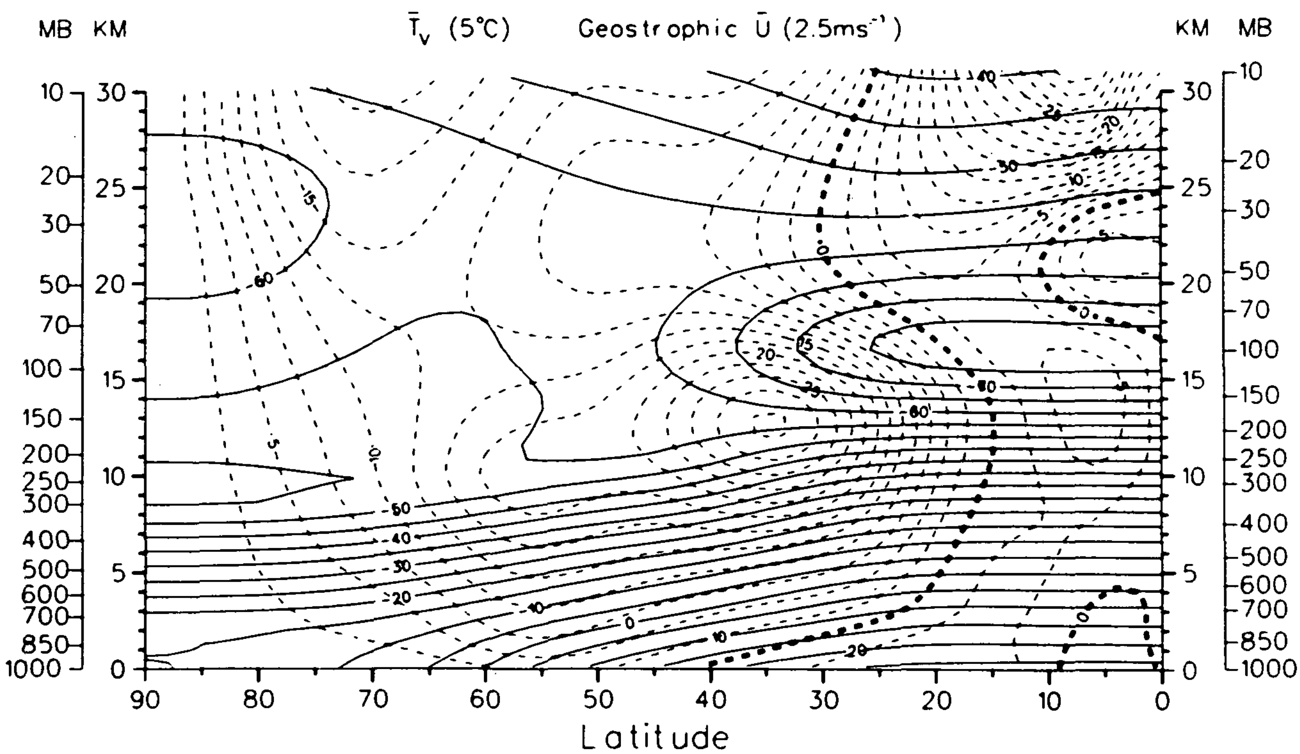




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

OCTOBER 1978





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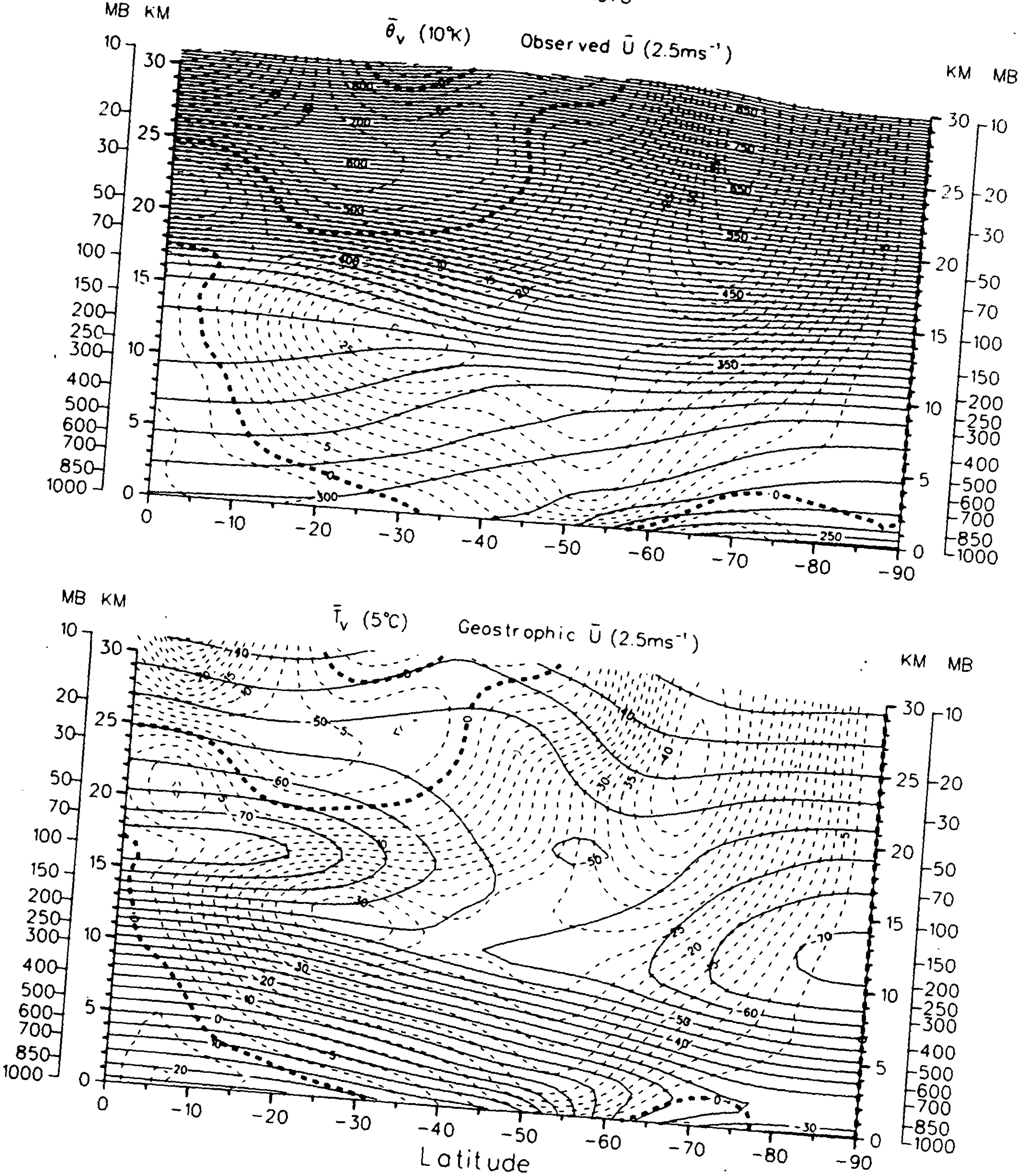

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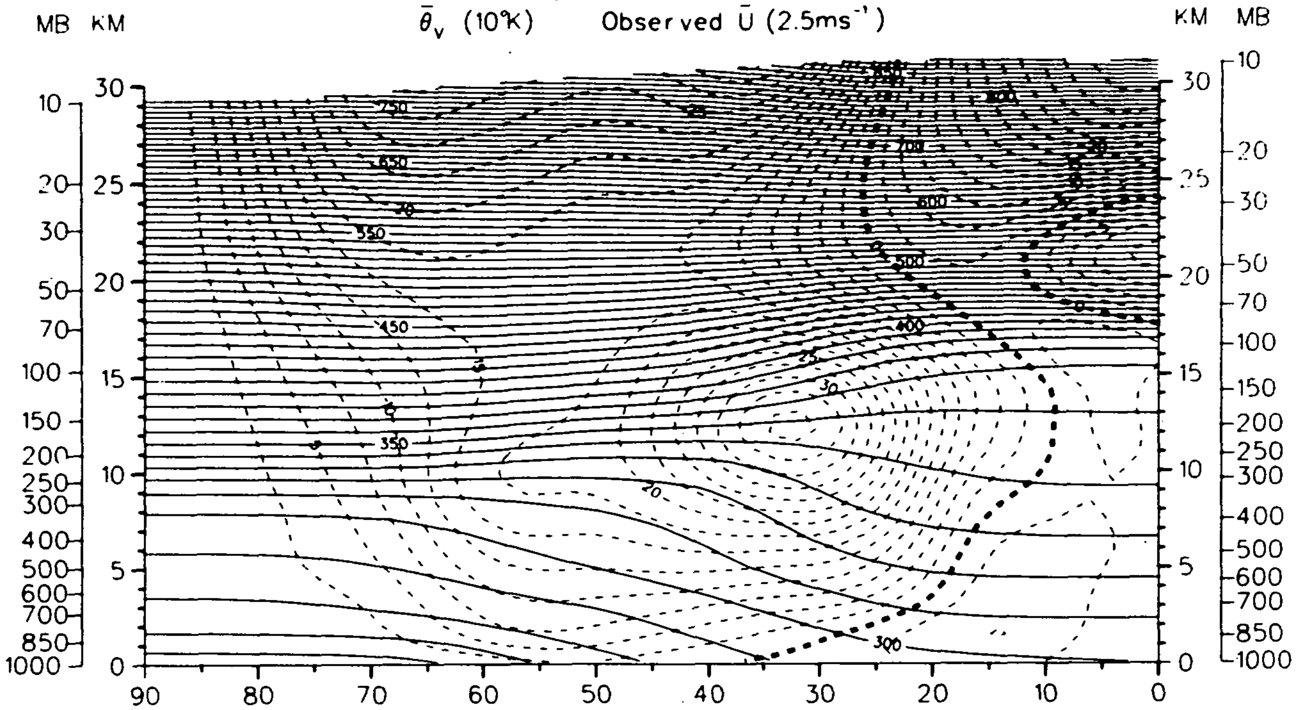
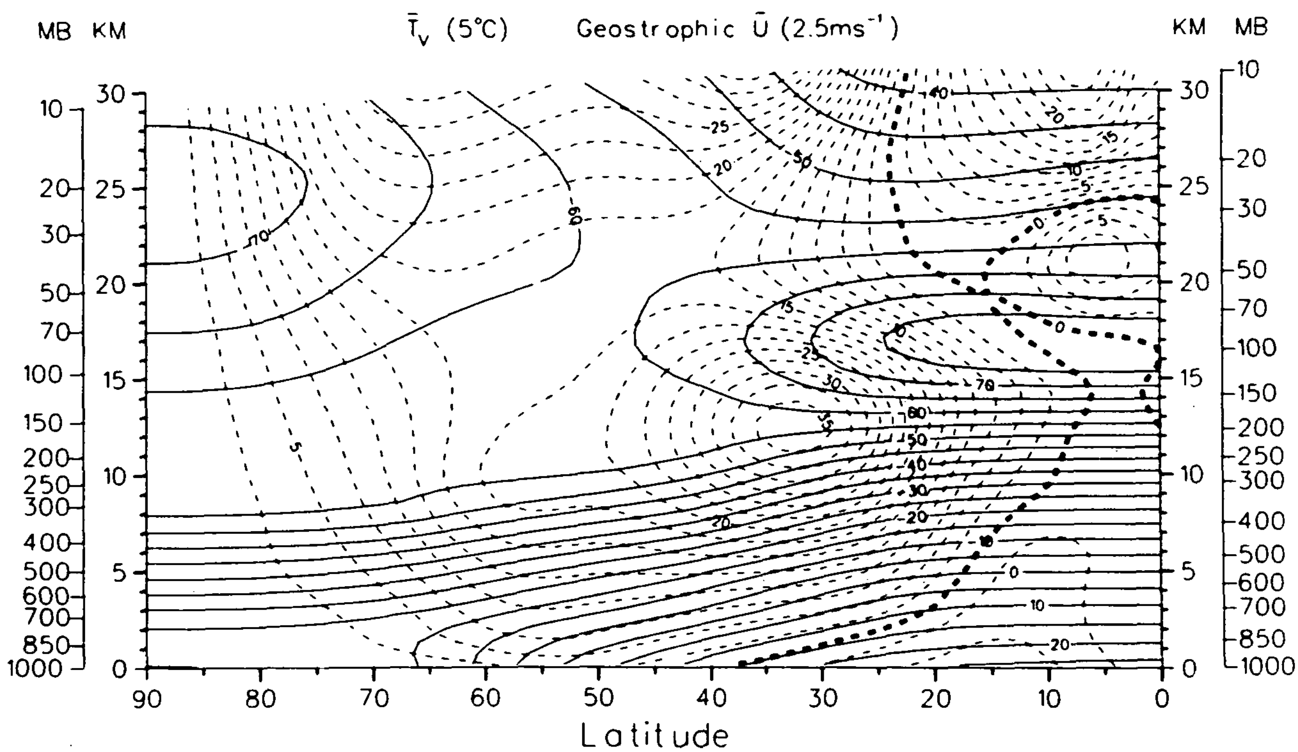
NOVEMBER 1978





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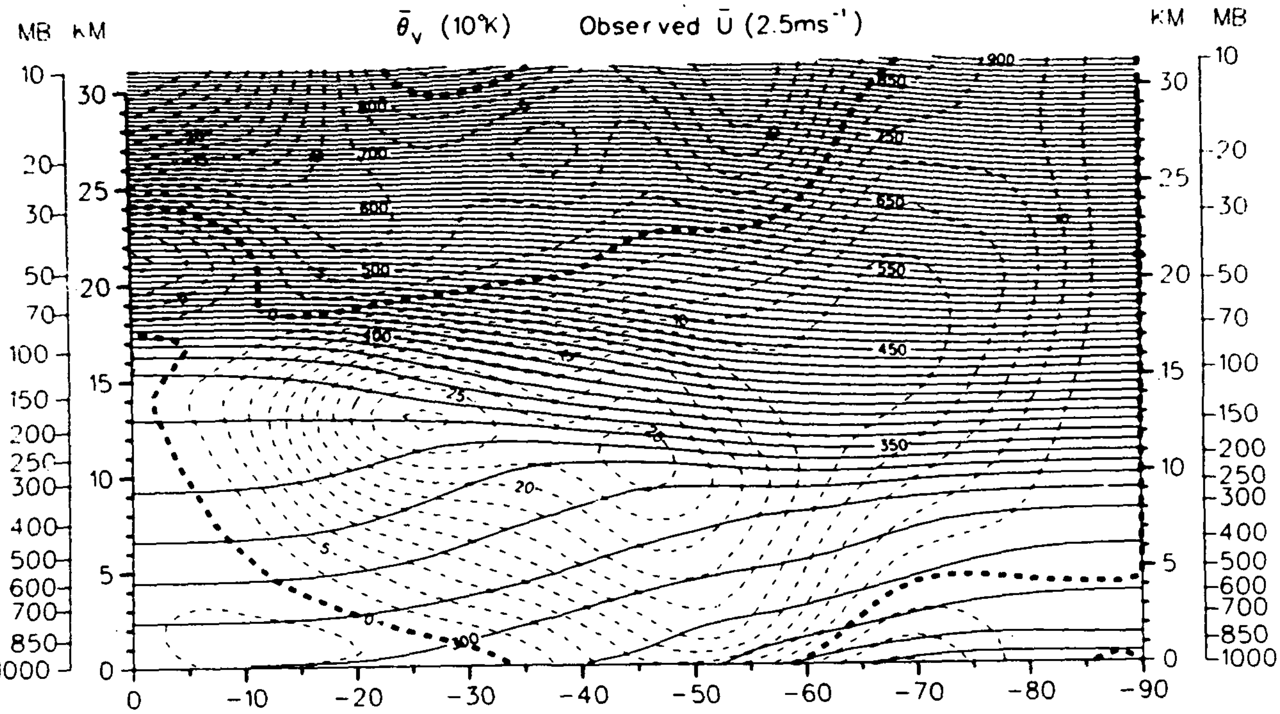
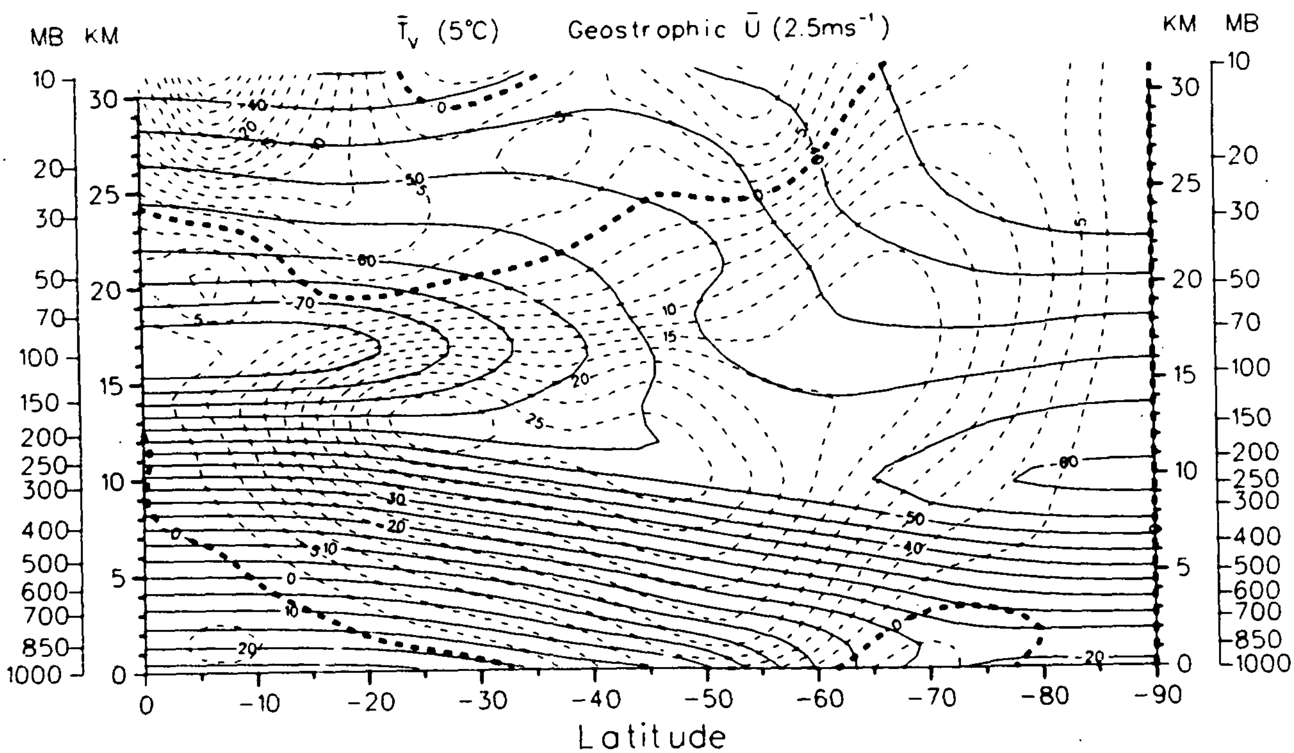
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

NOVEMBER 1978

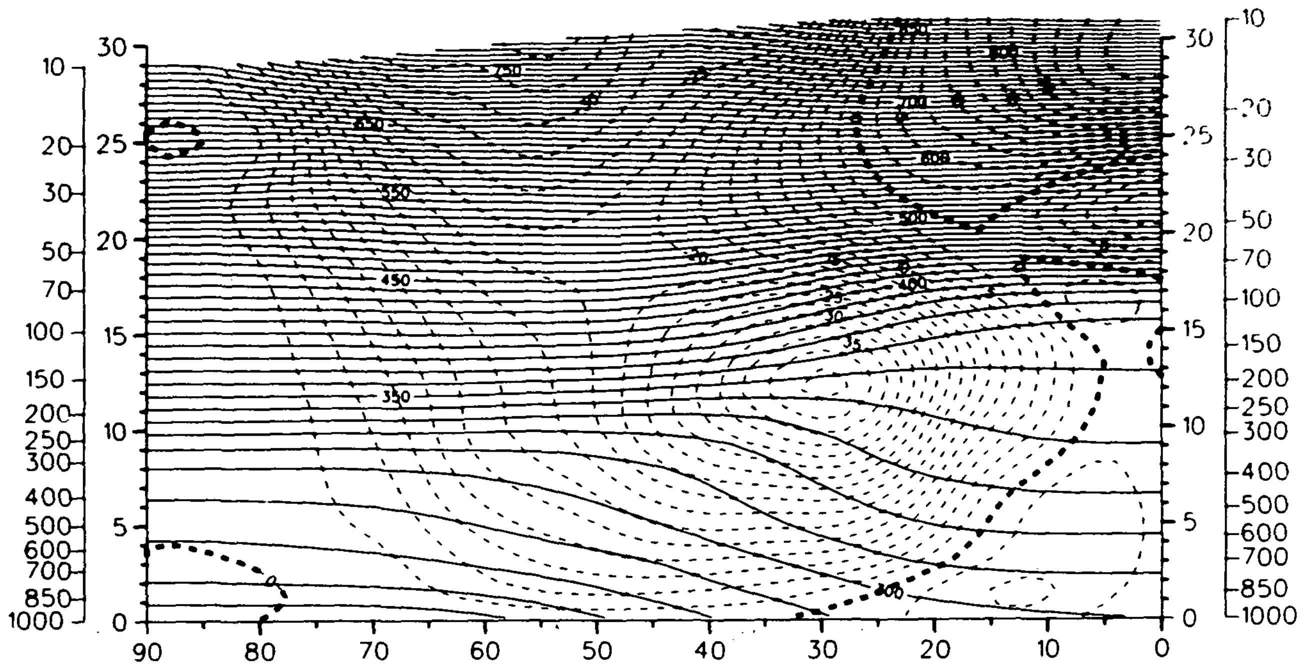




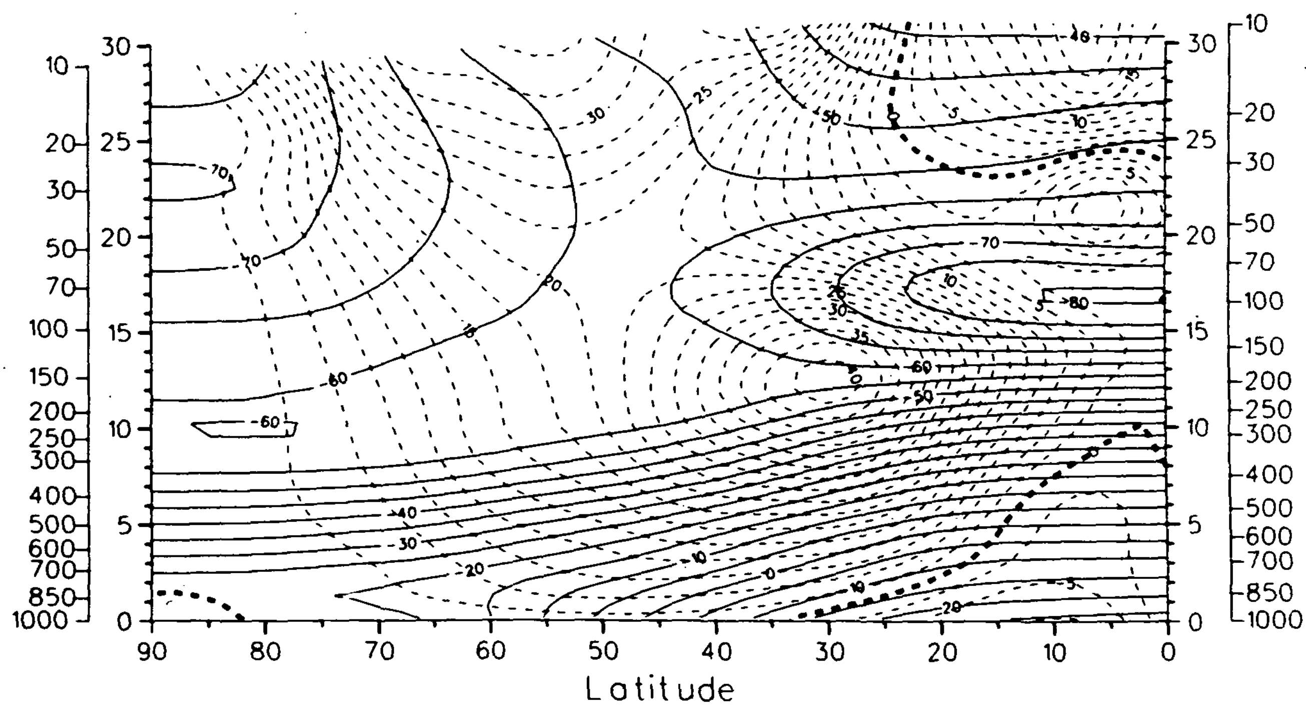
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

DECEMBER 1978

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB

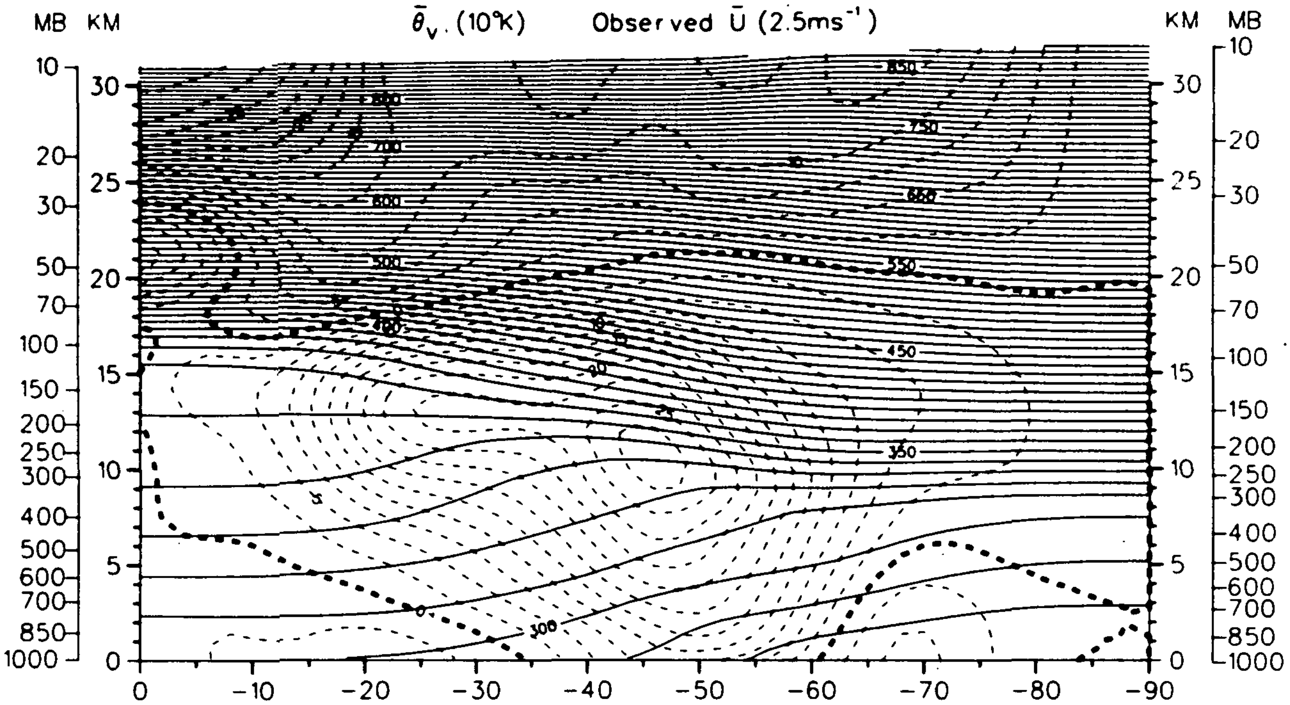


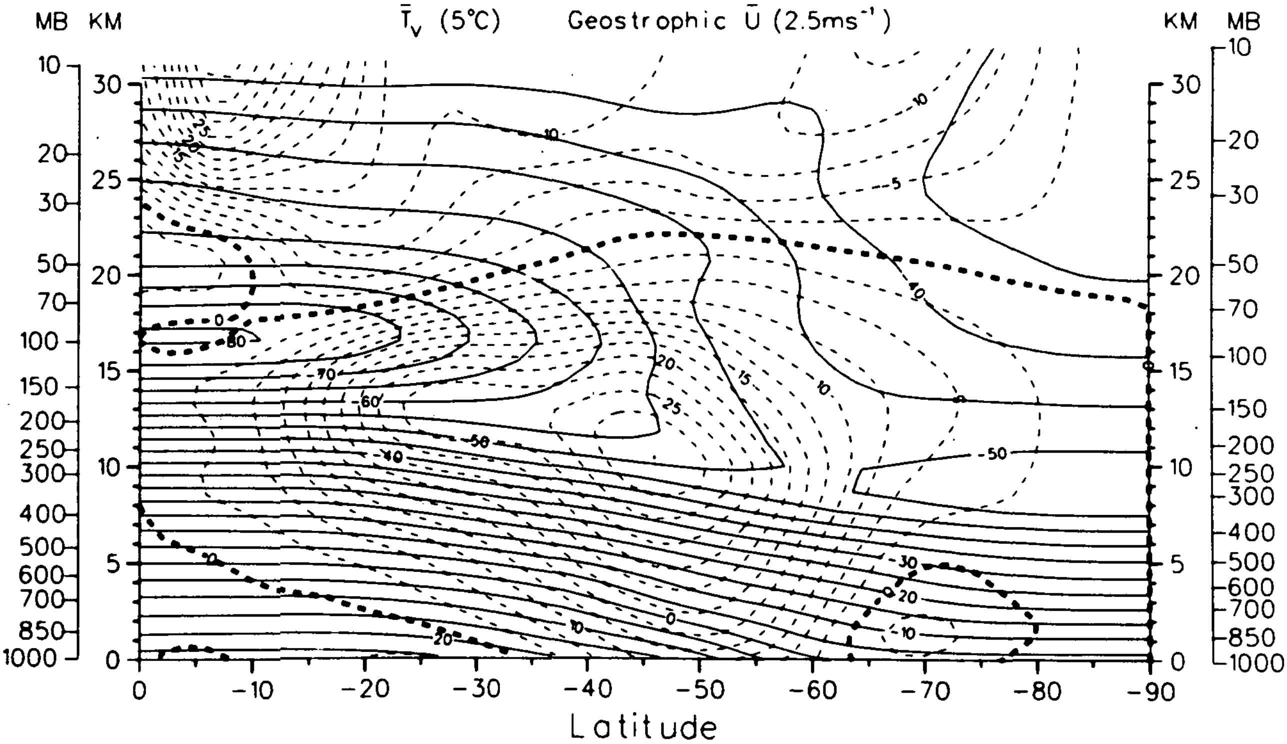
MB KM $\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1}) KM MB



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

DECEMBER 1978

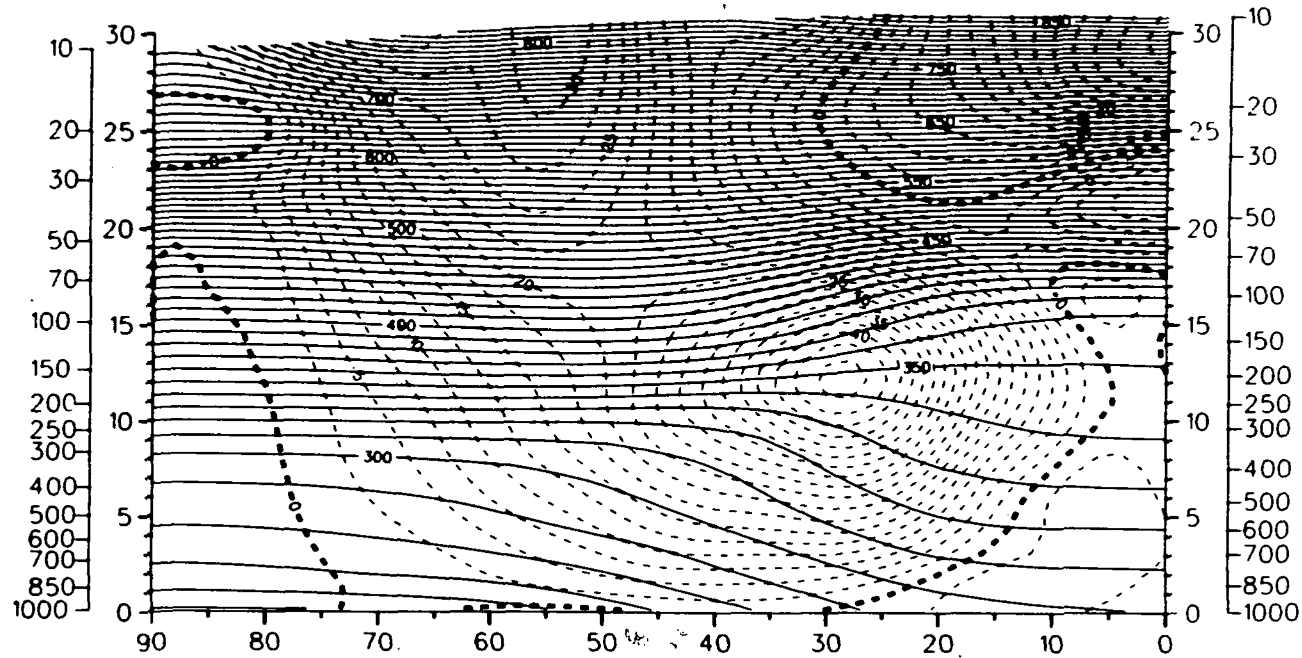




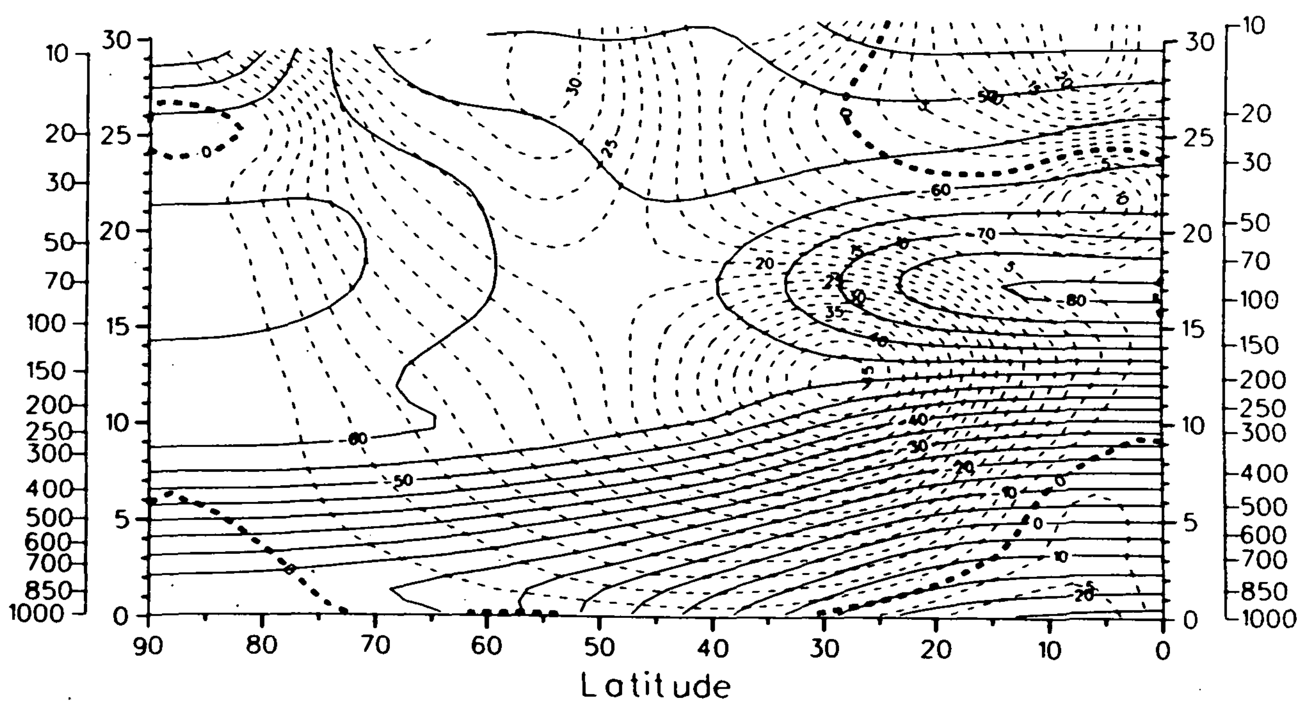
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JANUARY 1979

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB

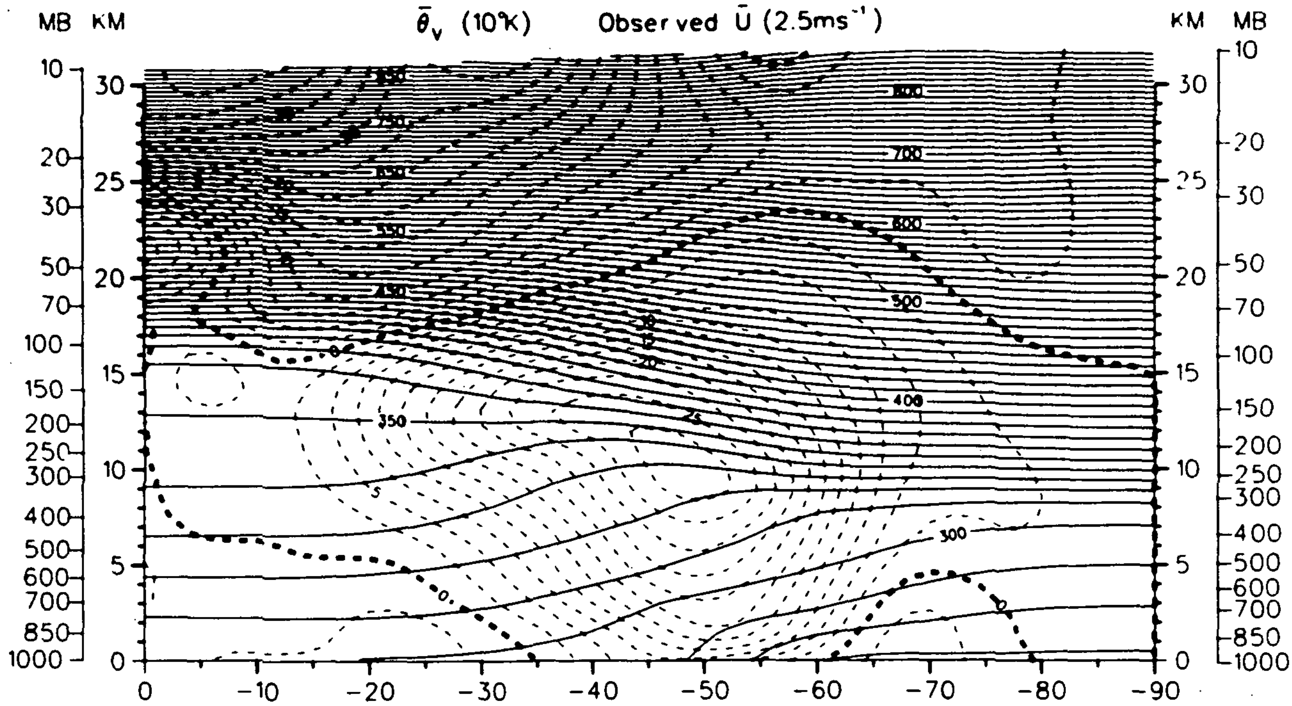


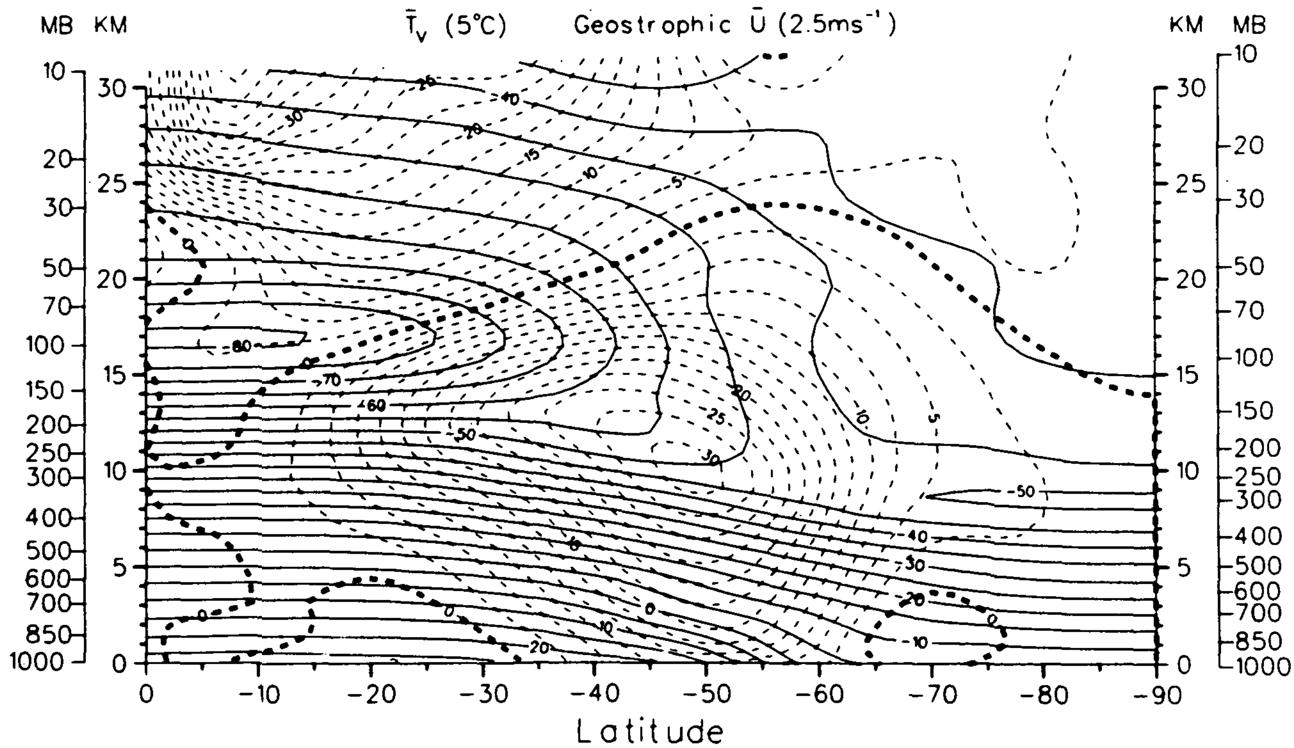
MB KM $\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1}) KM MB



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

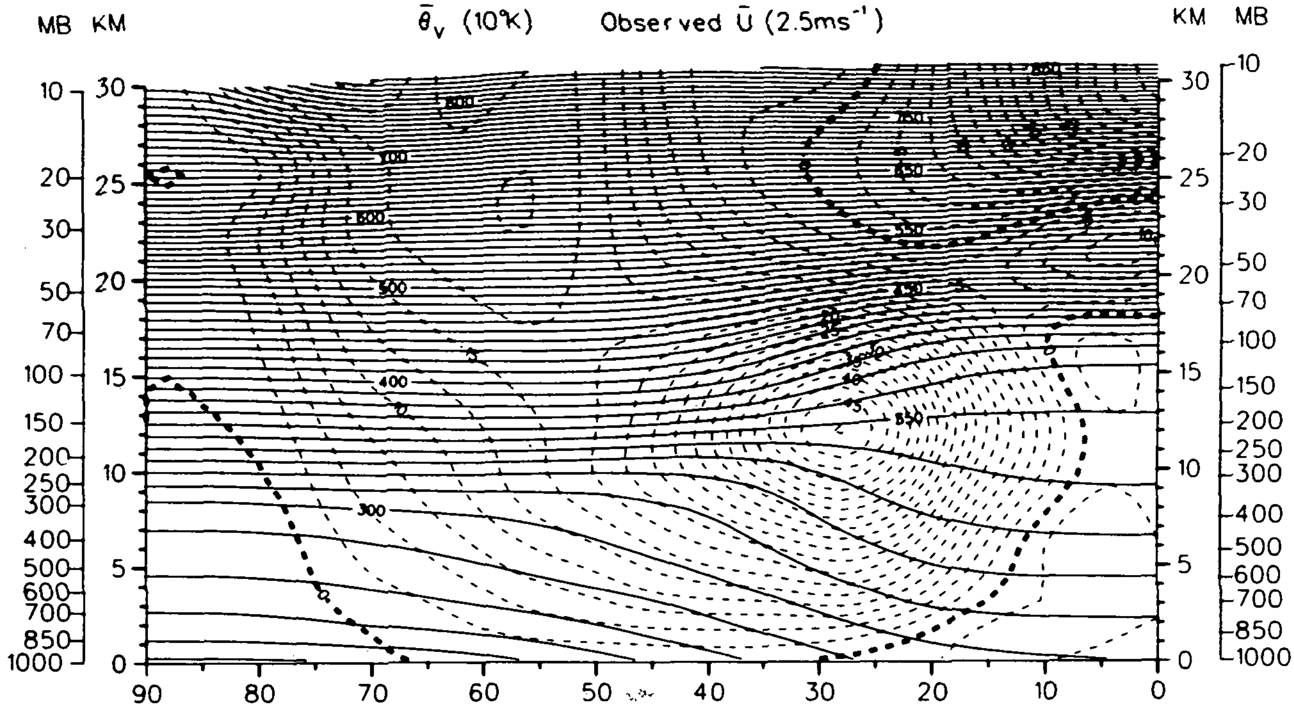
JANUARY 1979

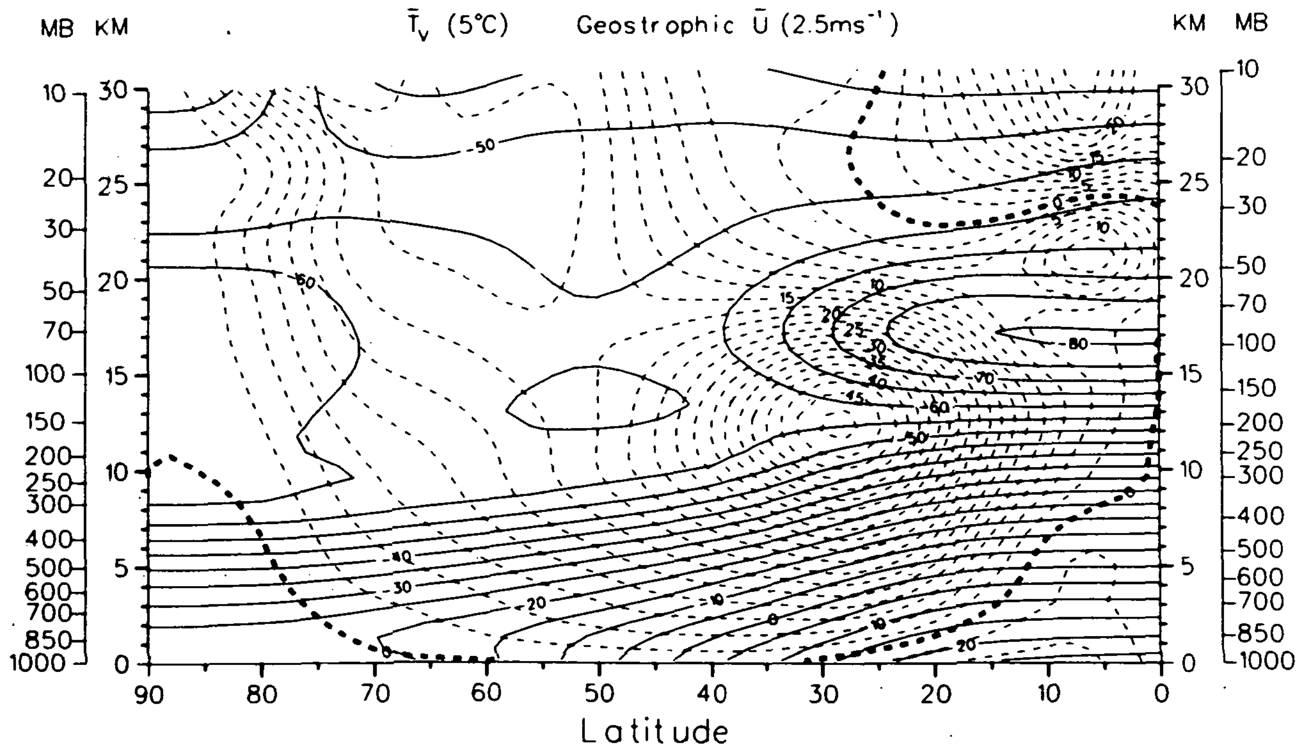




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

FEBRUARY 1979





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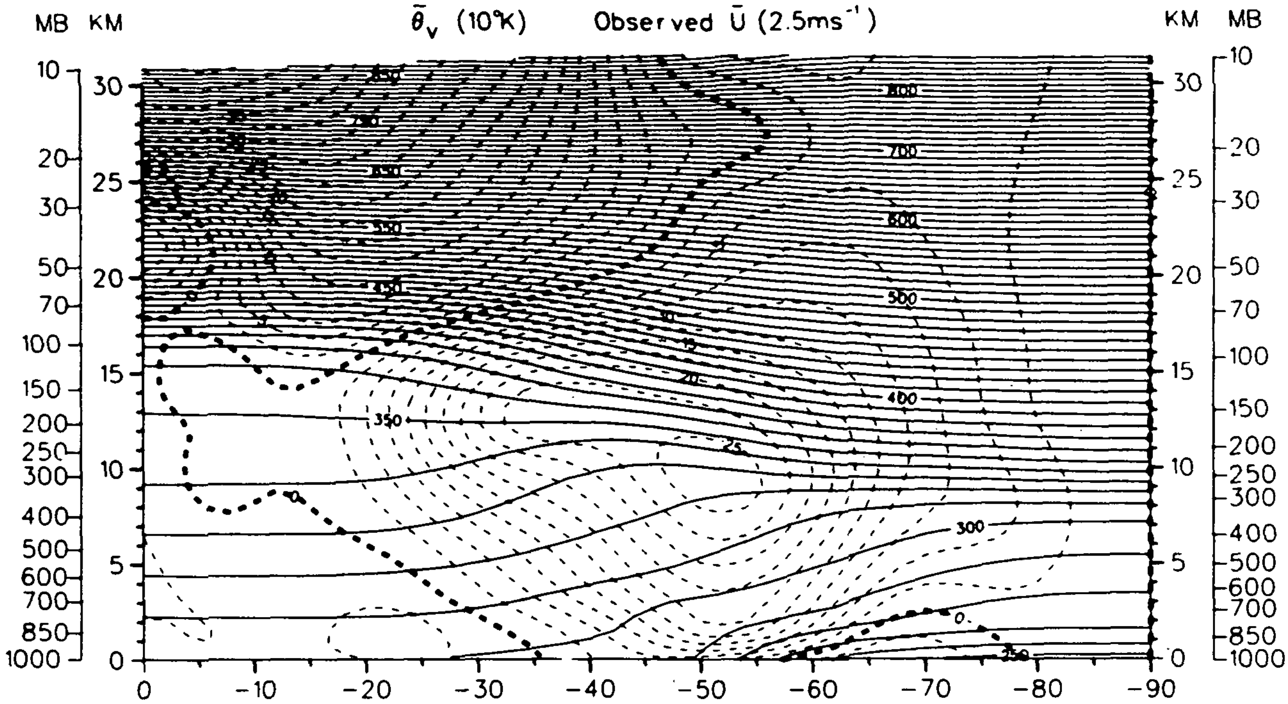
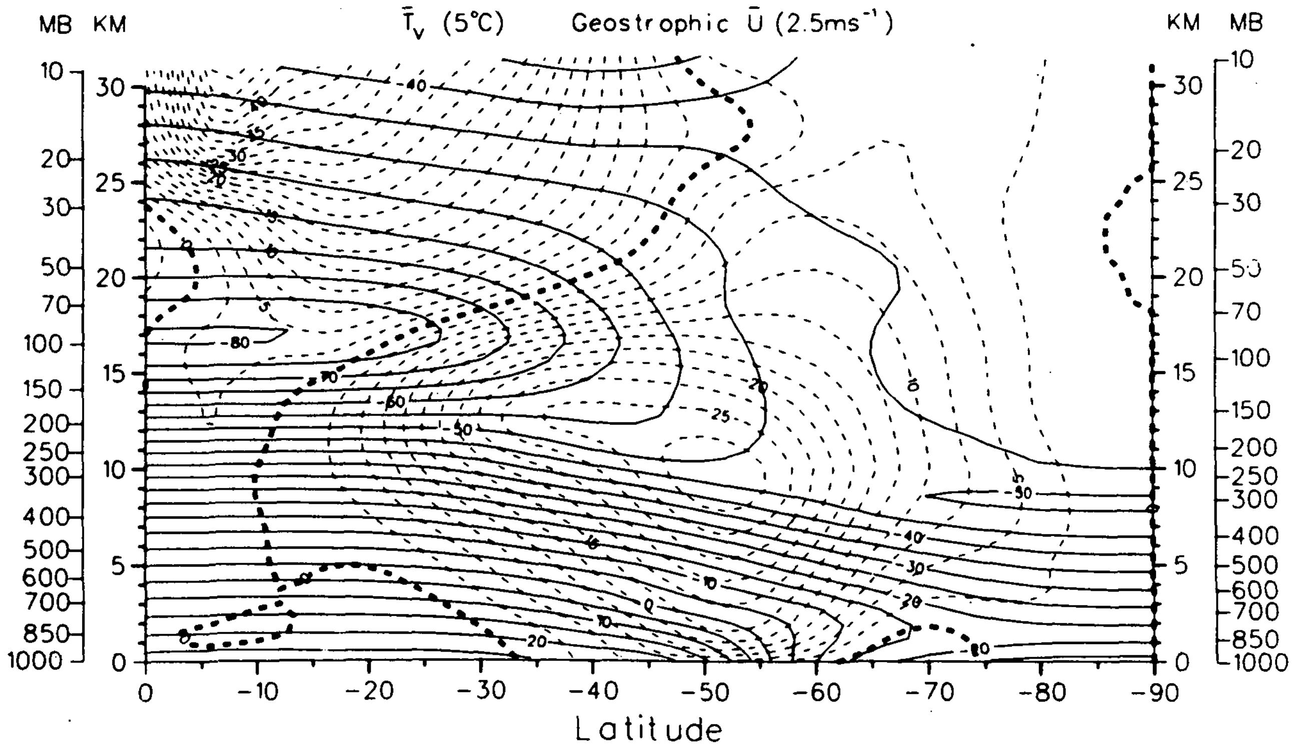
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

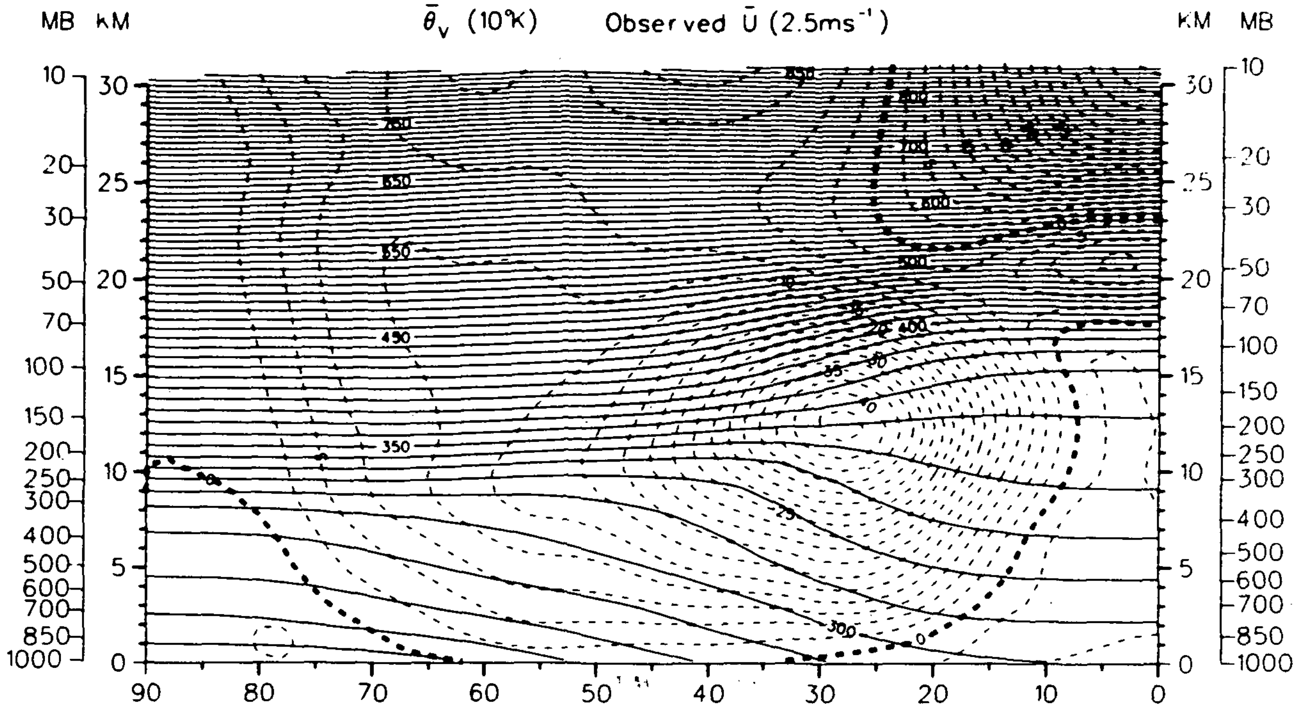
FEBRUARY 1979

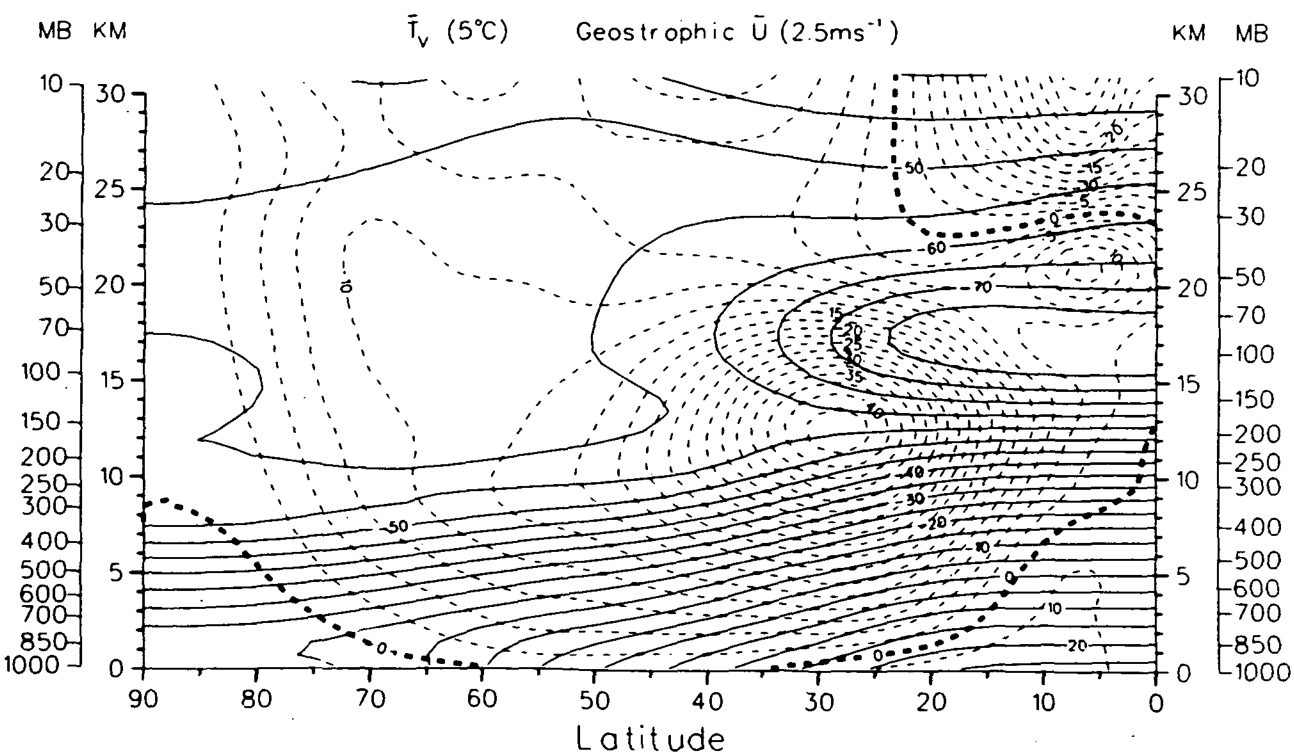




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

MARCH 1979

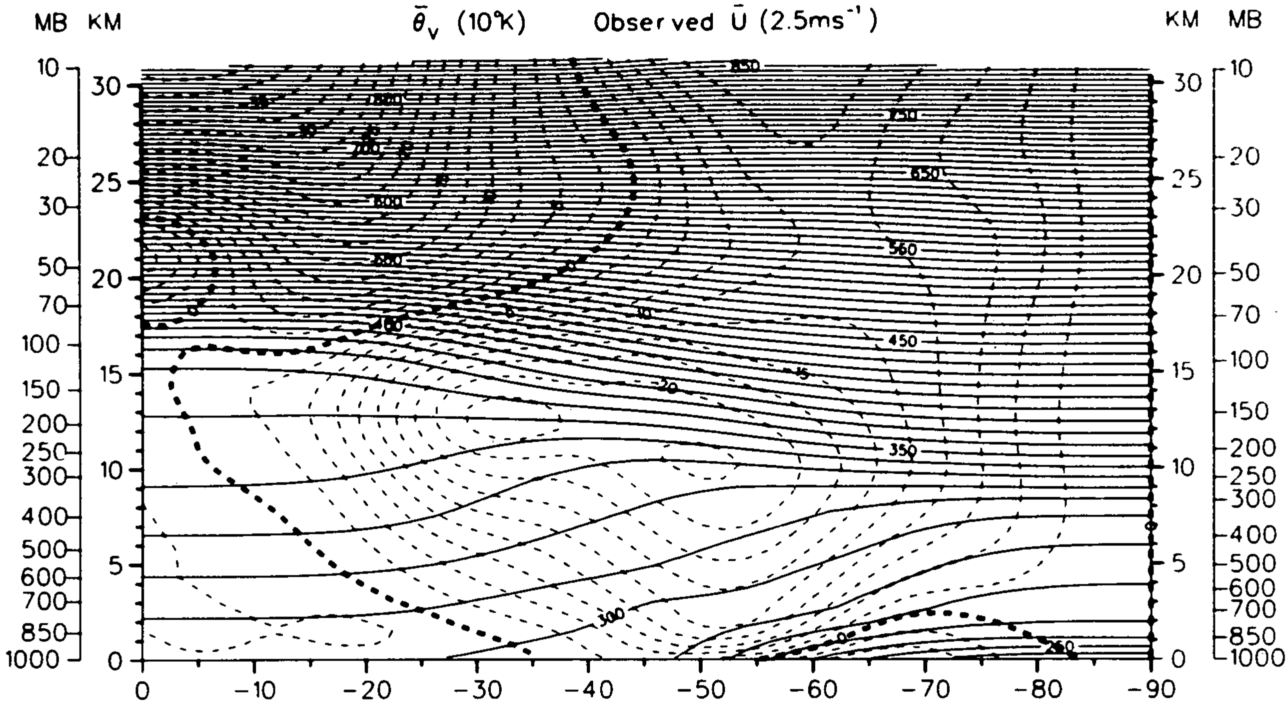




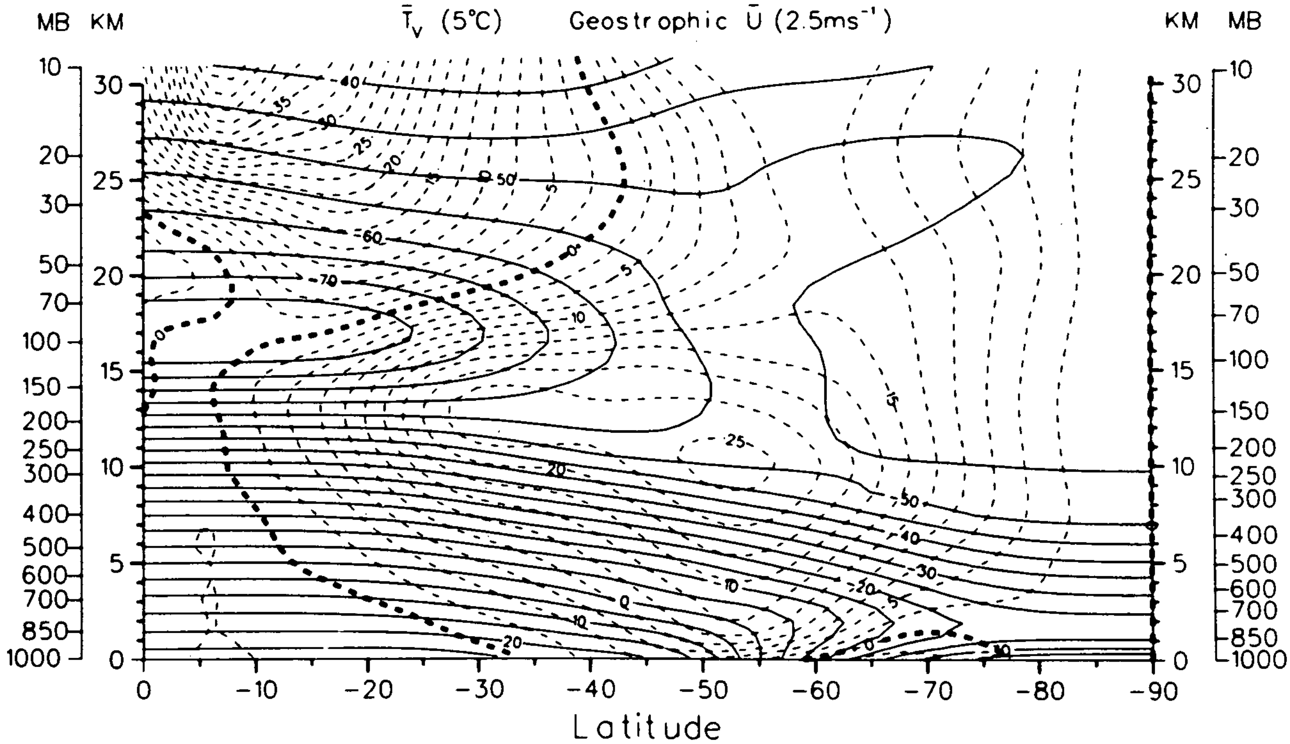
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

MARCH 1979

$\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1})

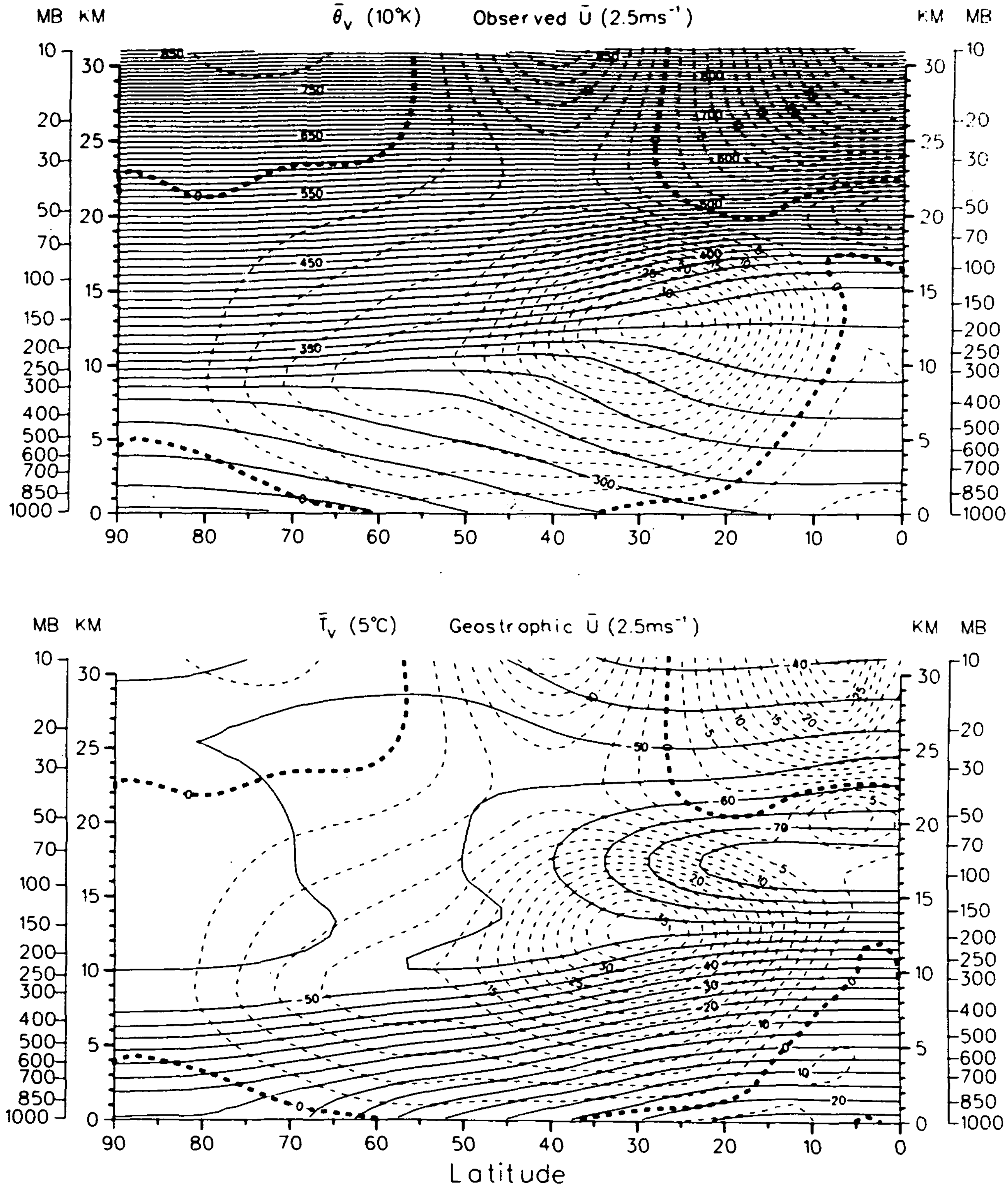


$\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1})



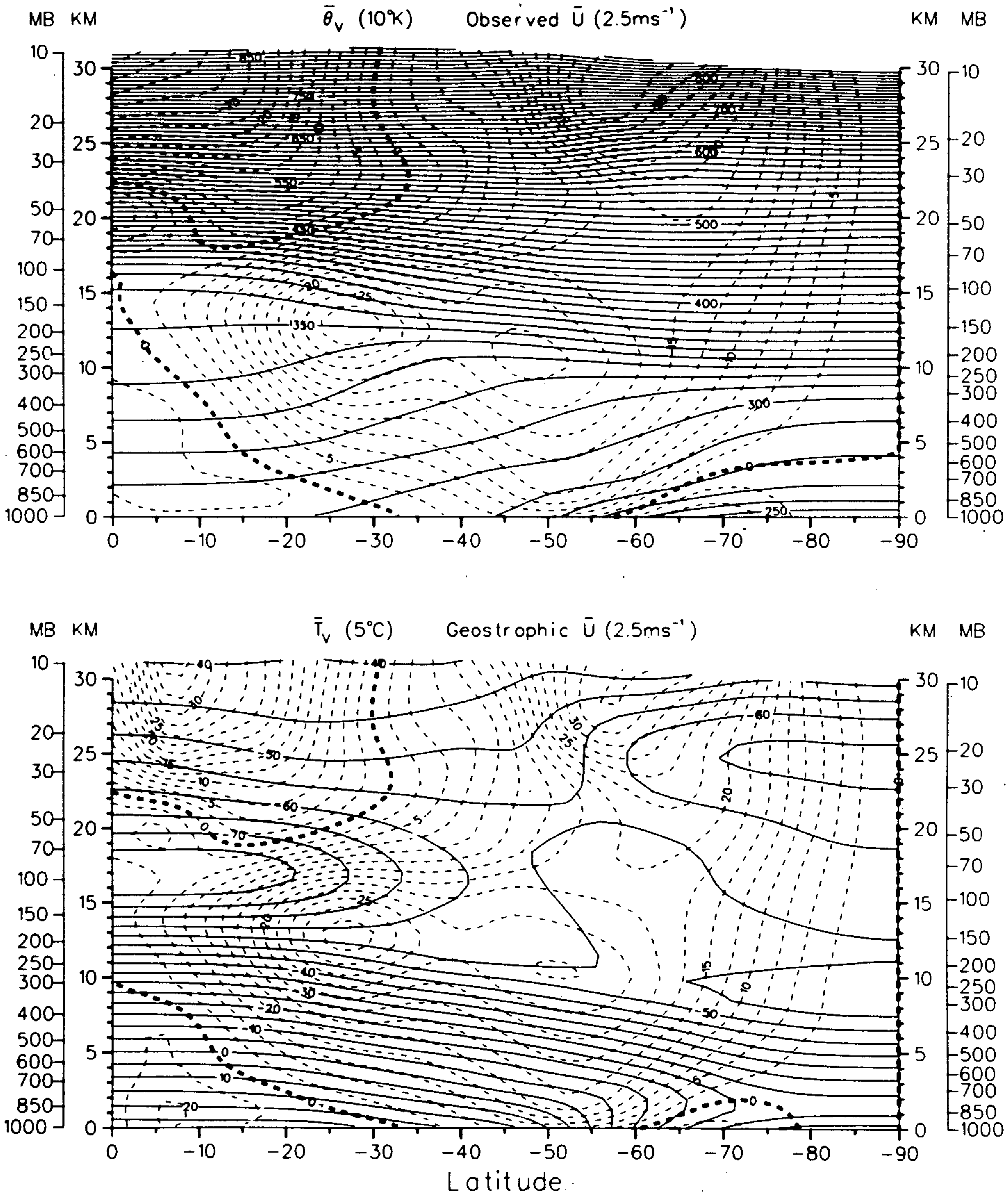
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

APRIL 1979



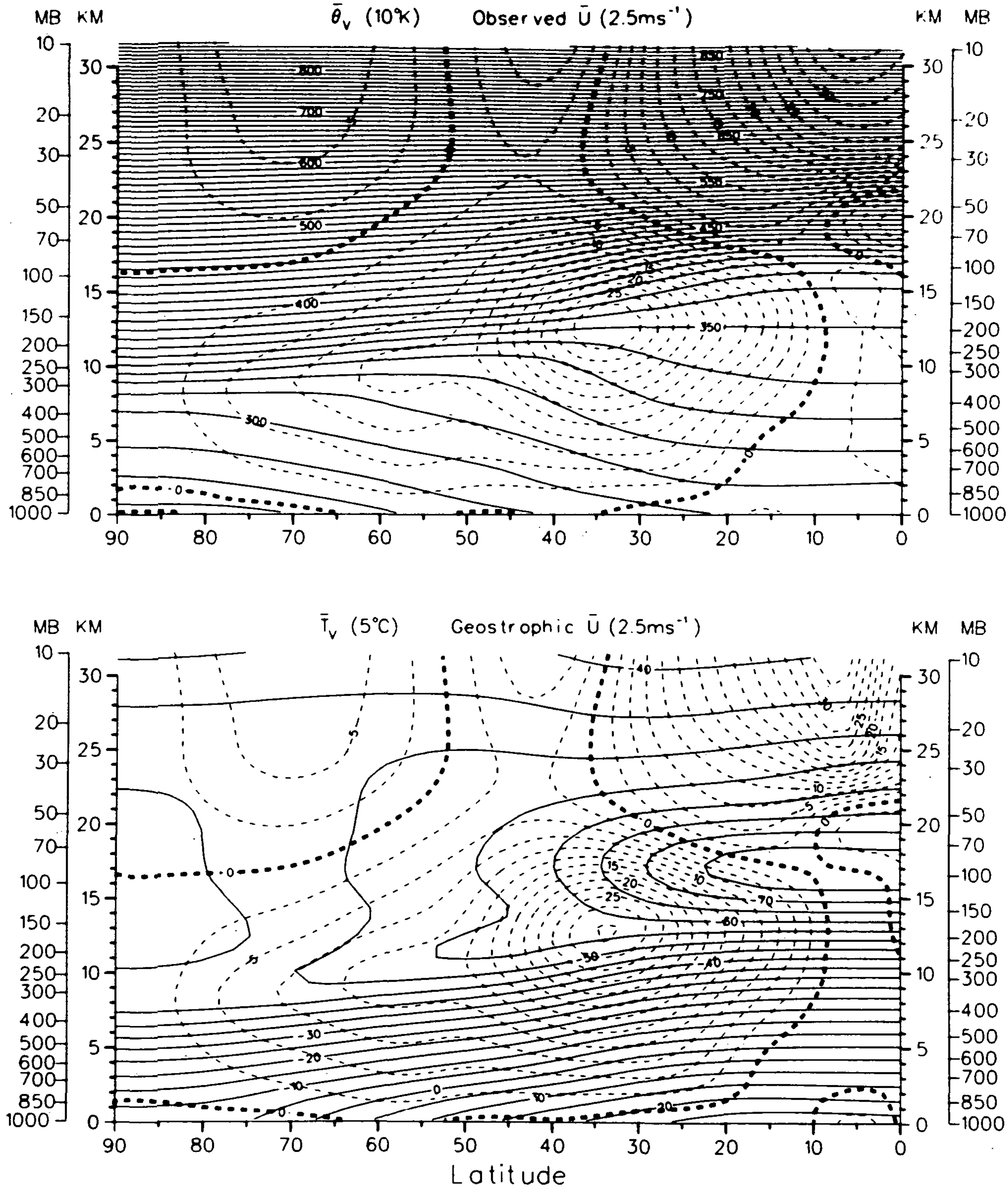
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

APRIL 1979



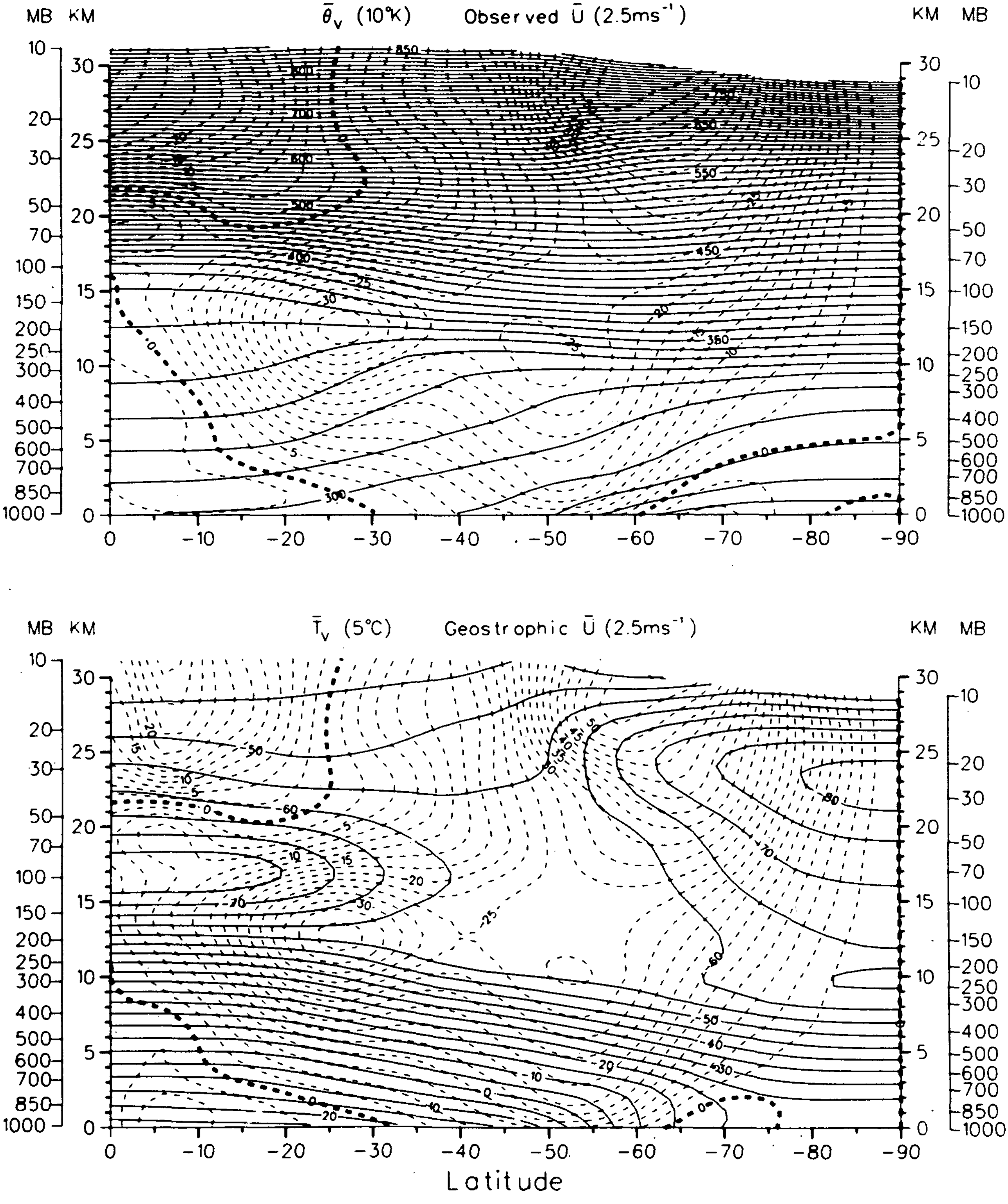
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

MAY 1979



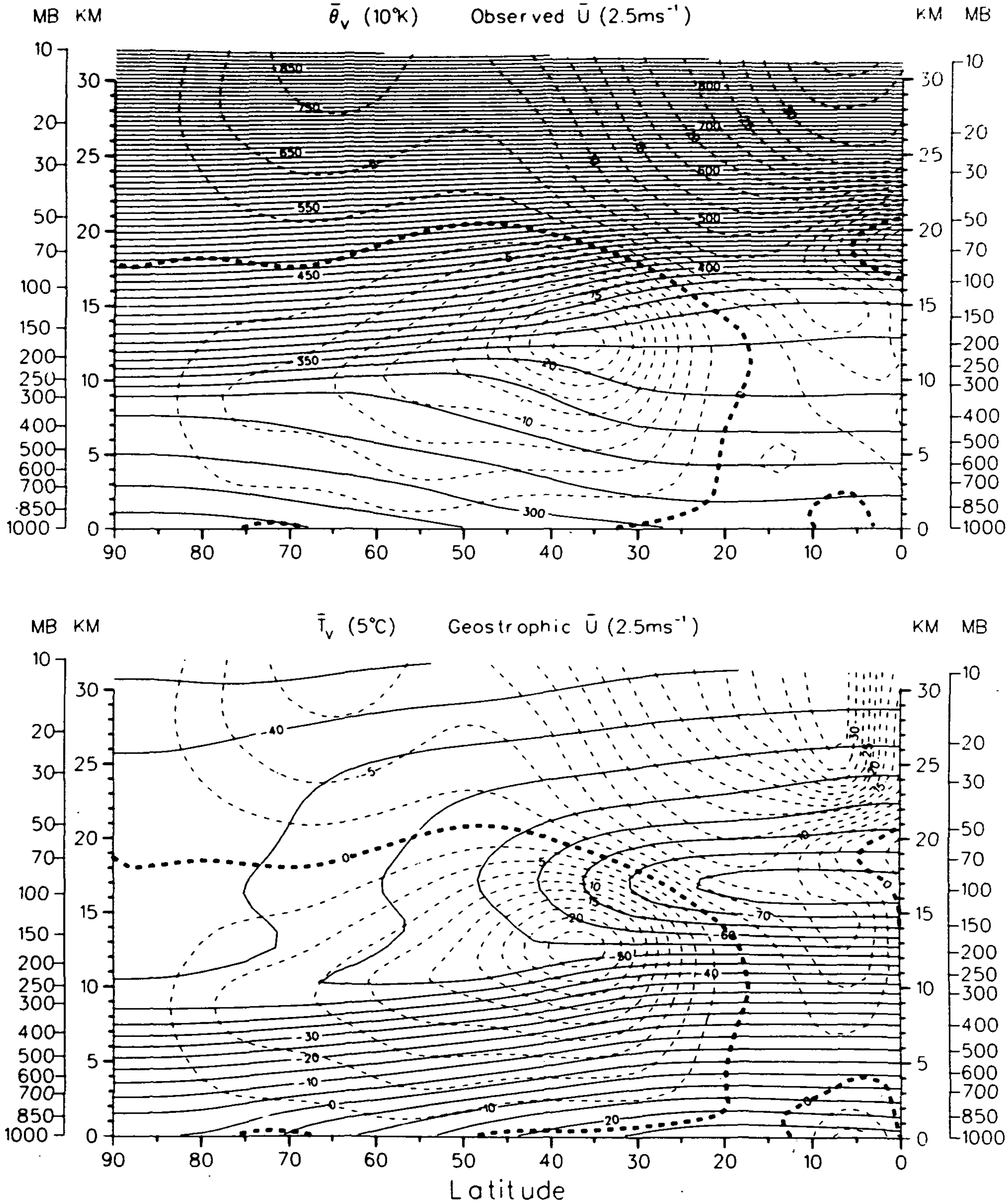
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

MAY 1979



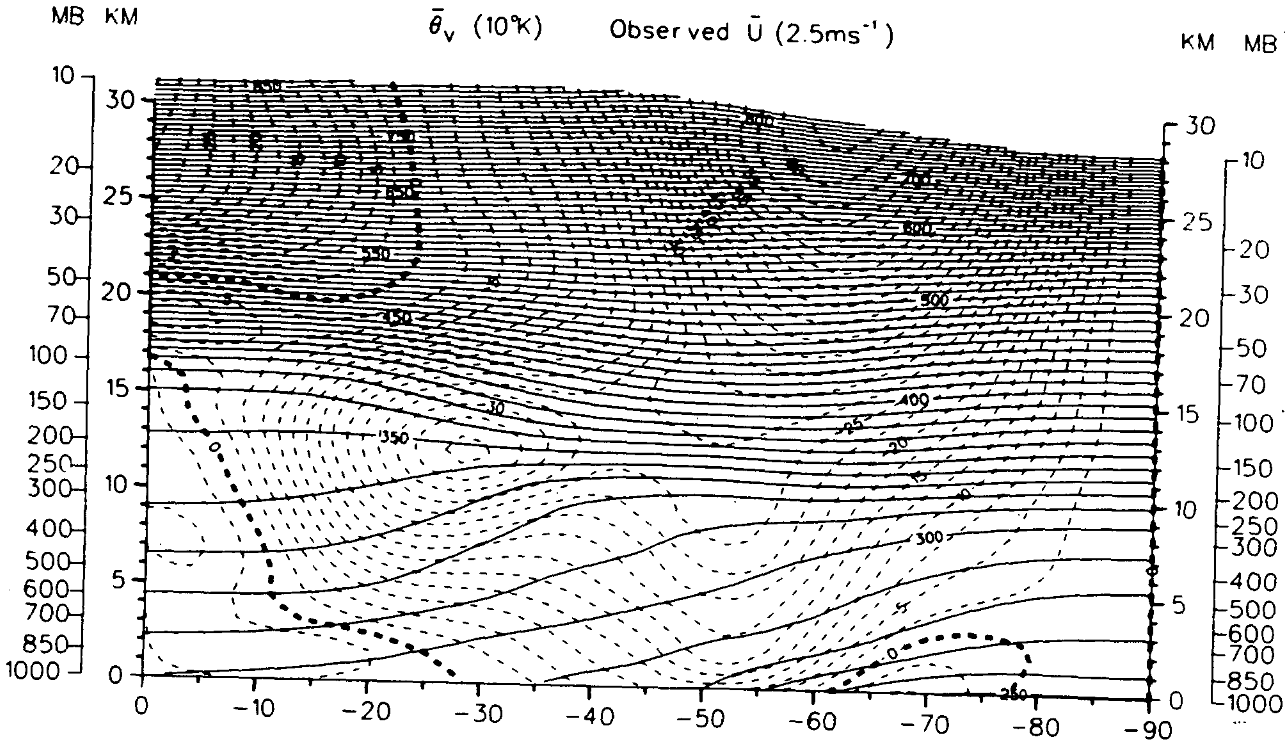
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

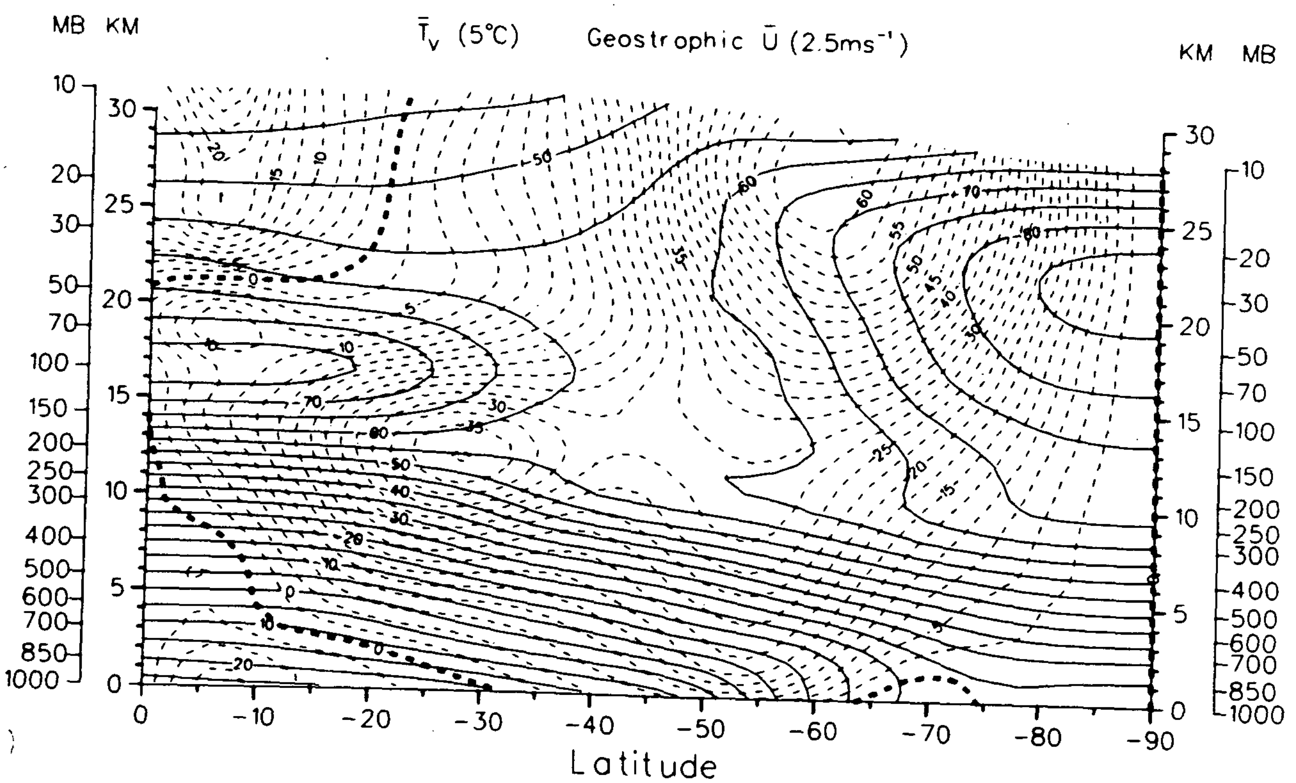
JUNE 1979



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JUNE 1979

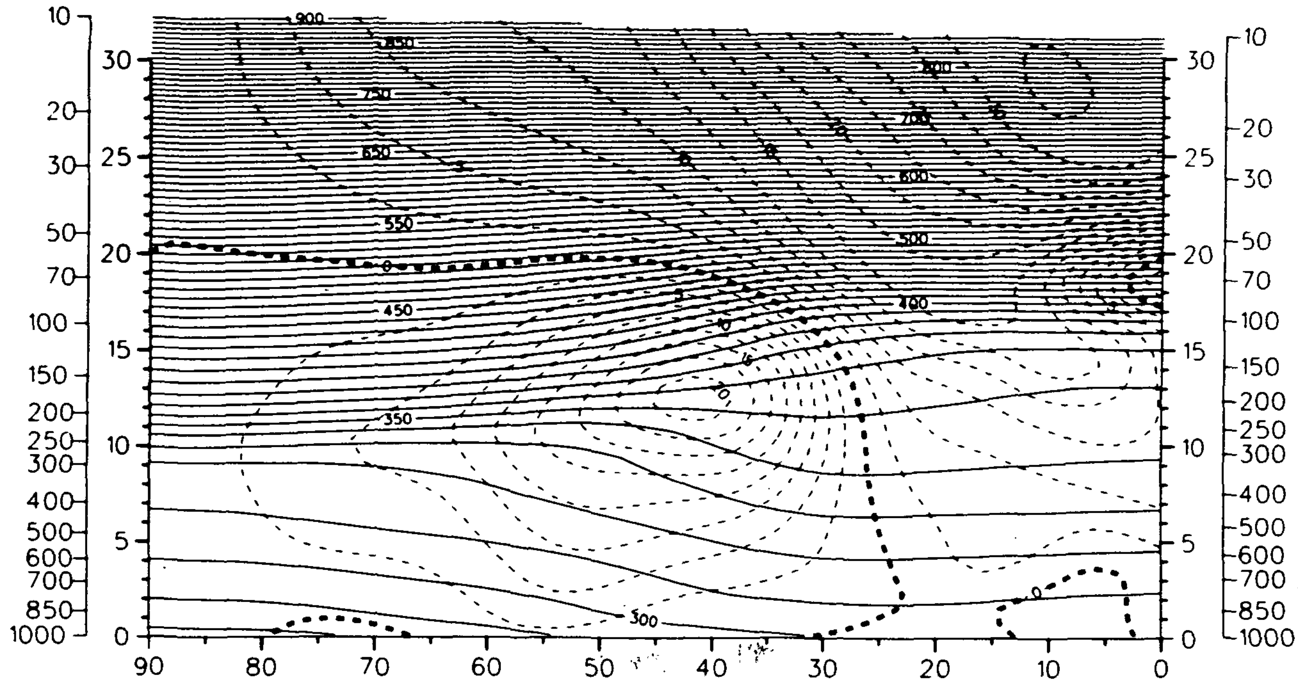




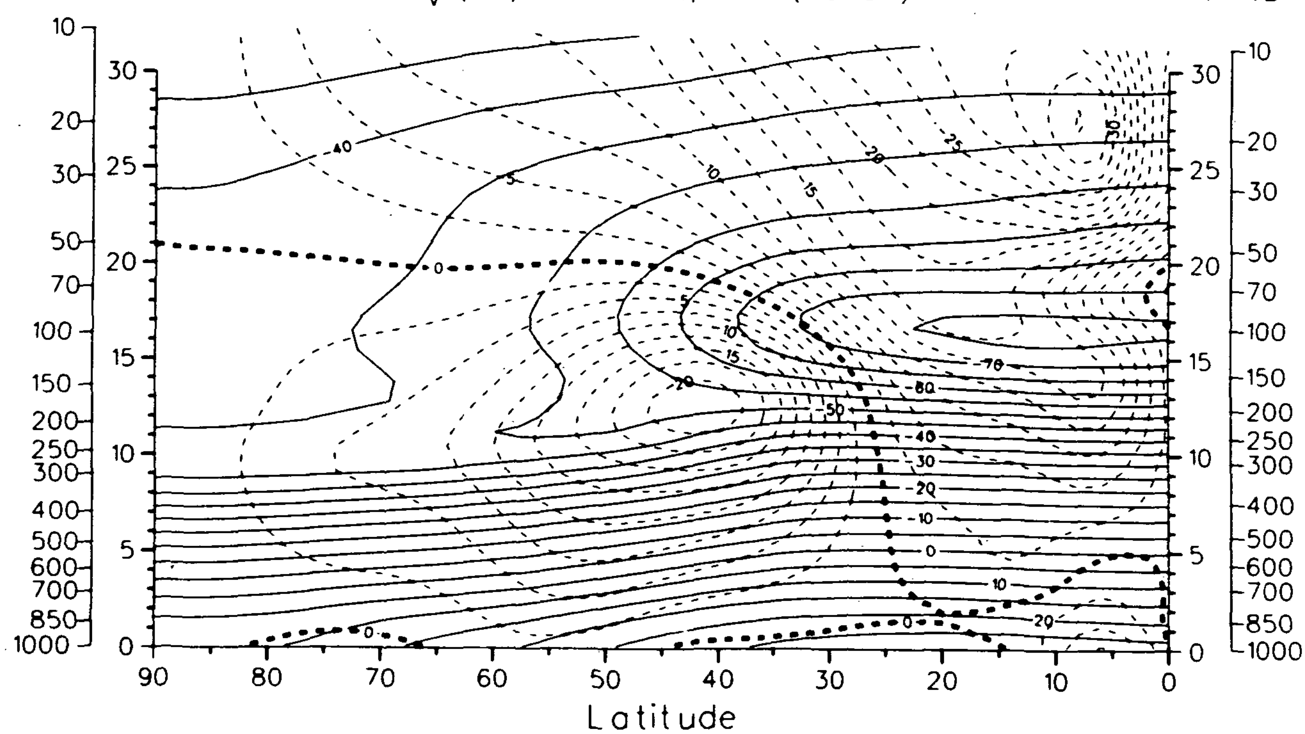
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

JULY 1979

MB KM $\bar{\theta}_v$ (10°K) Observed $\bar{U}$ (2.5ms^{-1}) KM MB

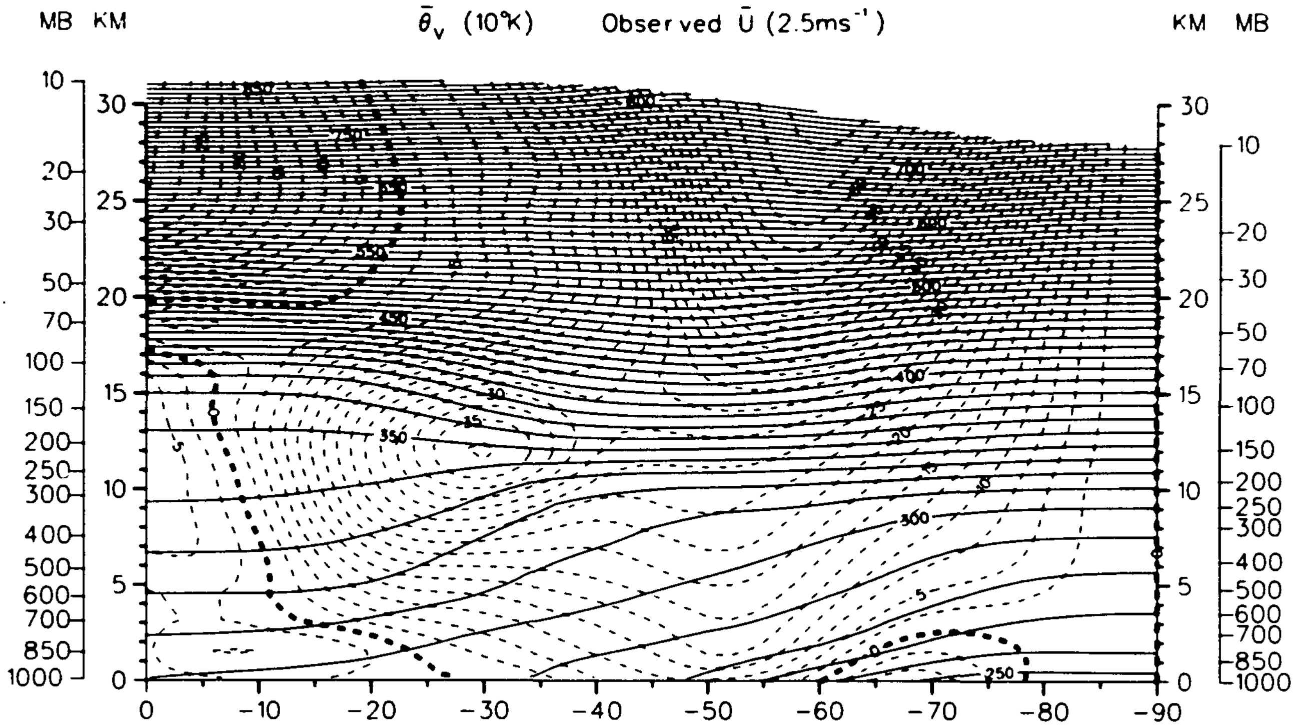


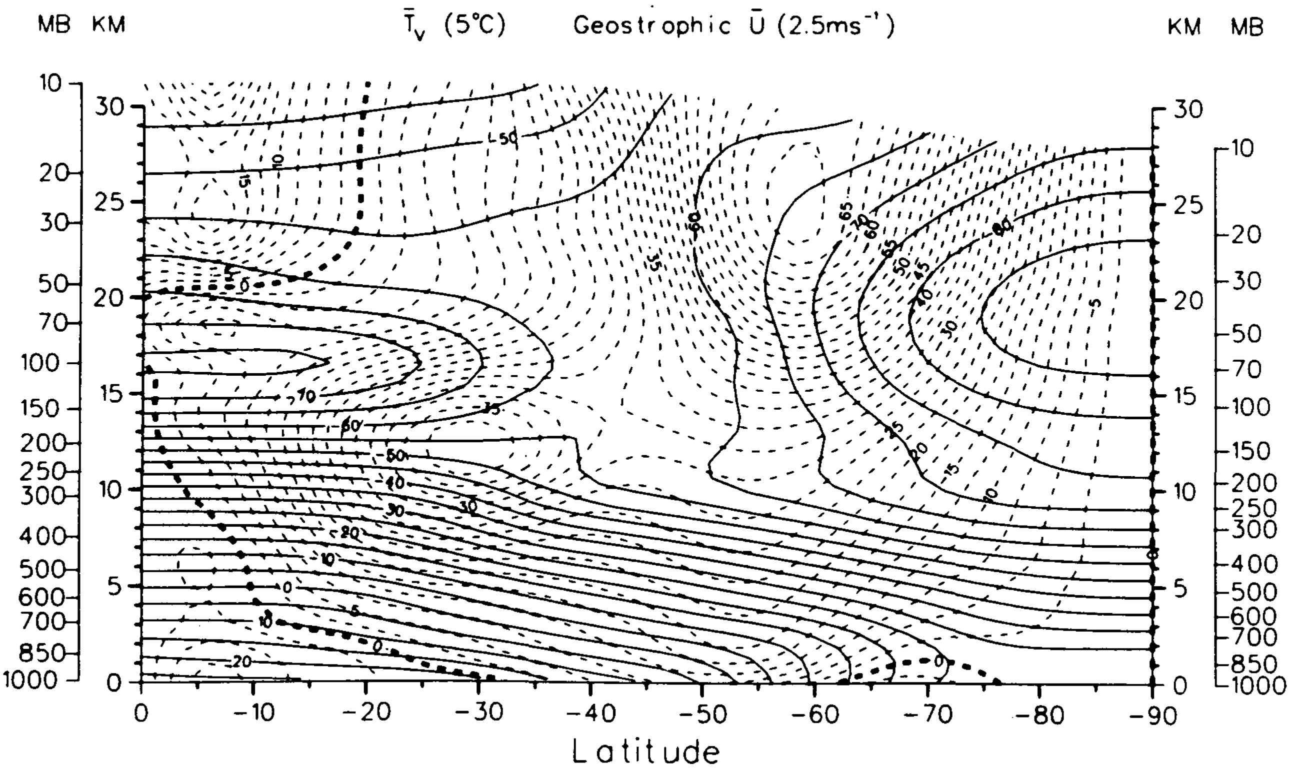
MB KM $\bar{T}_v$ (5°C) Geostrophic $\bar{U}$ (2.5ms^{-1}) KM MB



SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

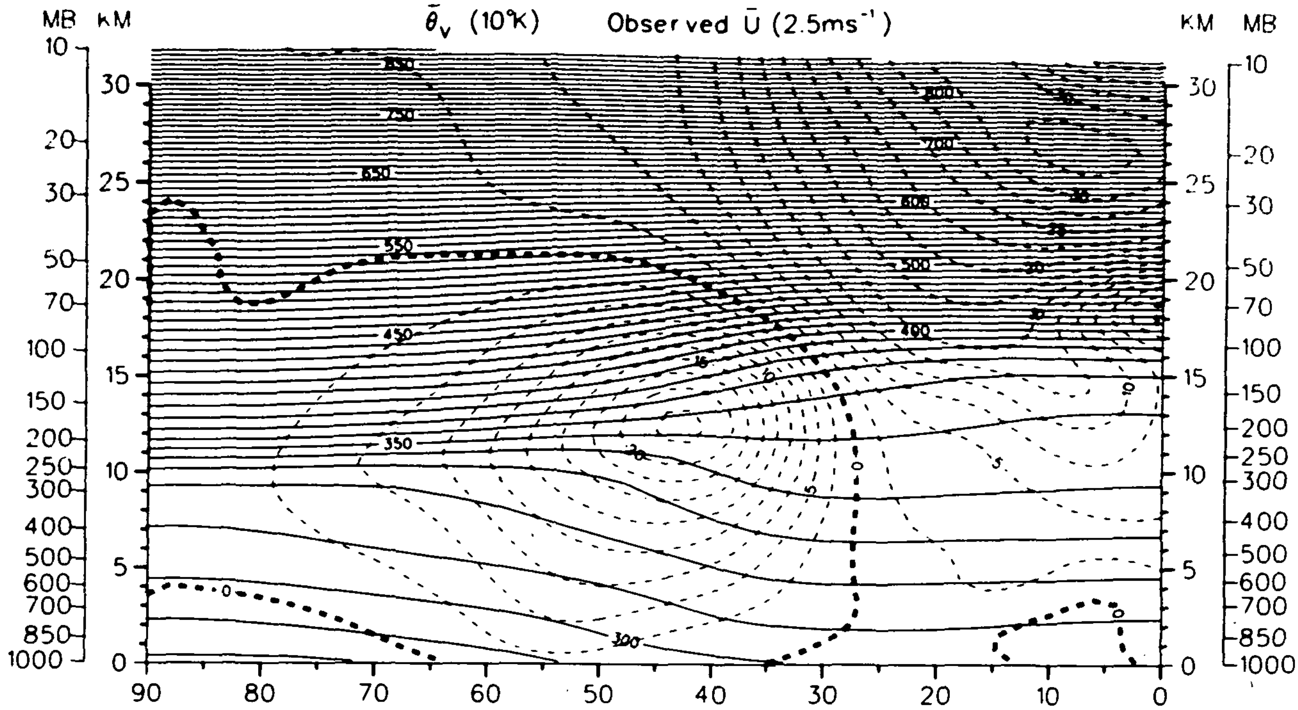
JULY 1979

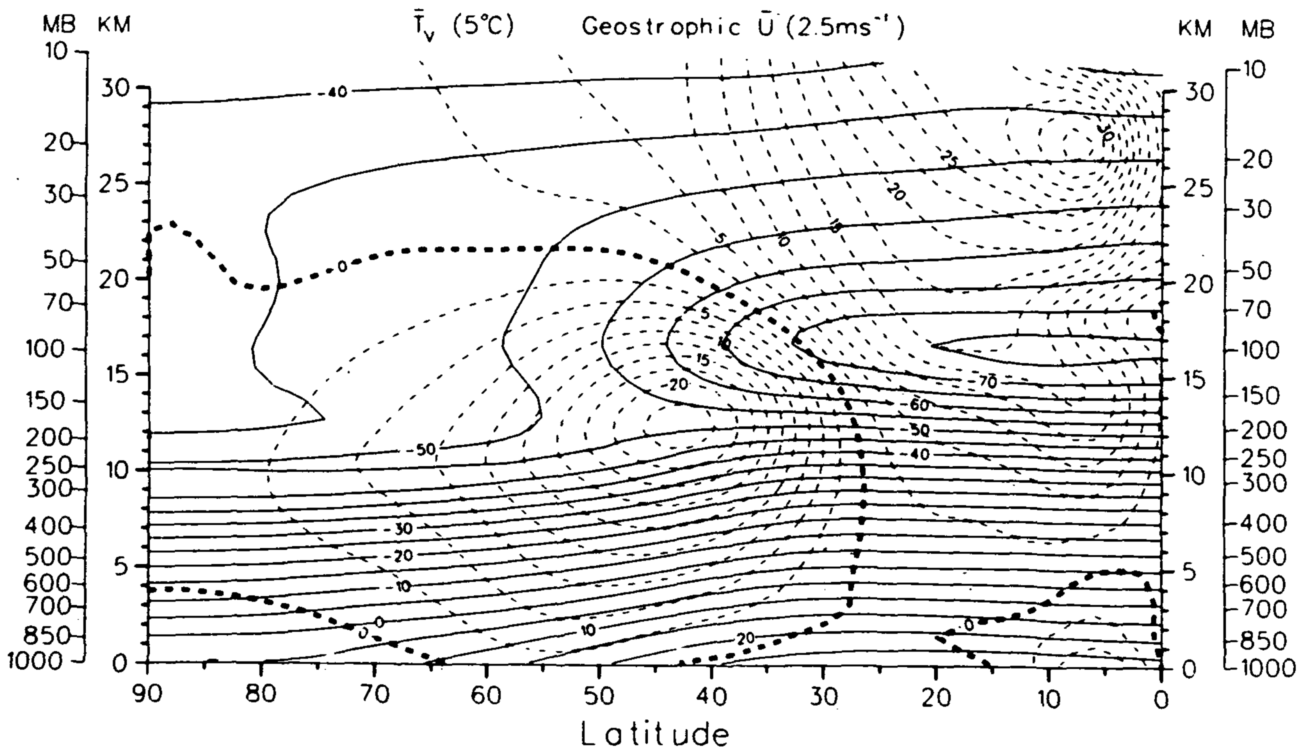




NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

AUGUST 1979





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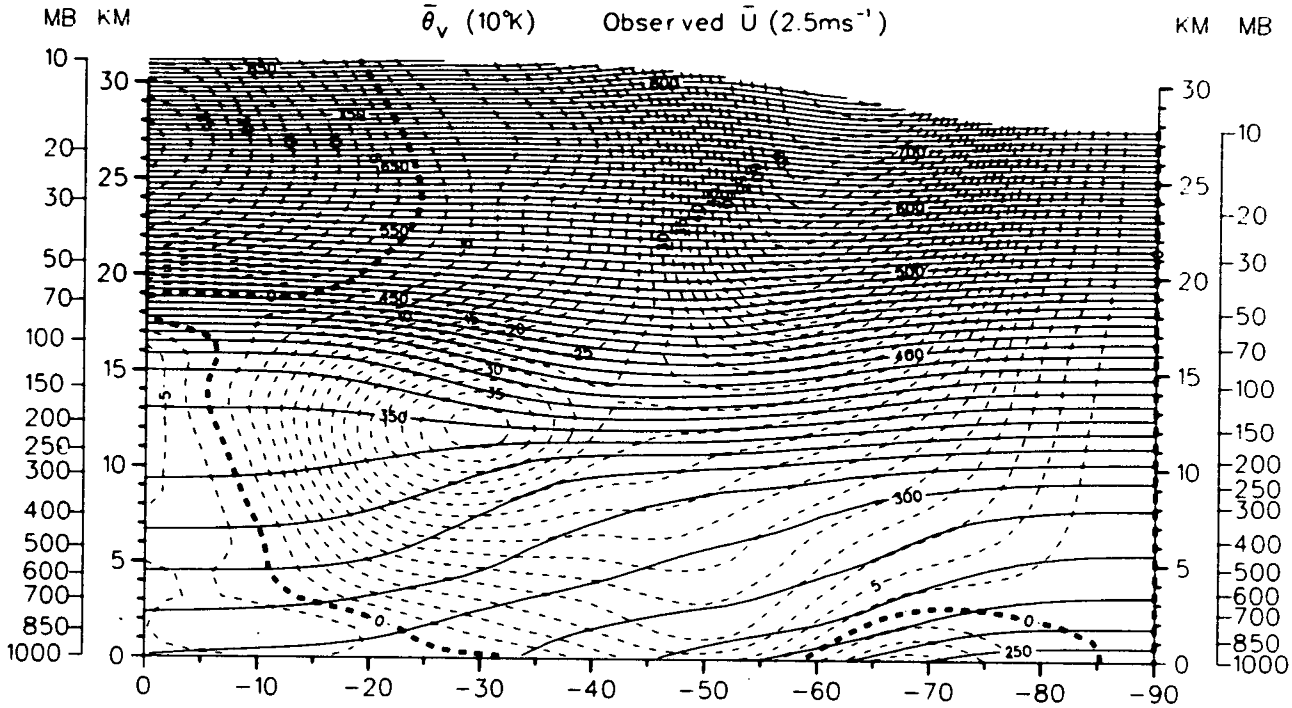

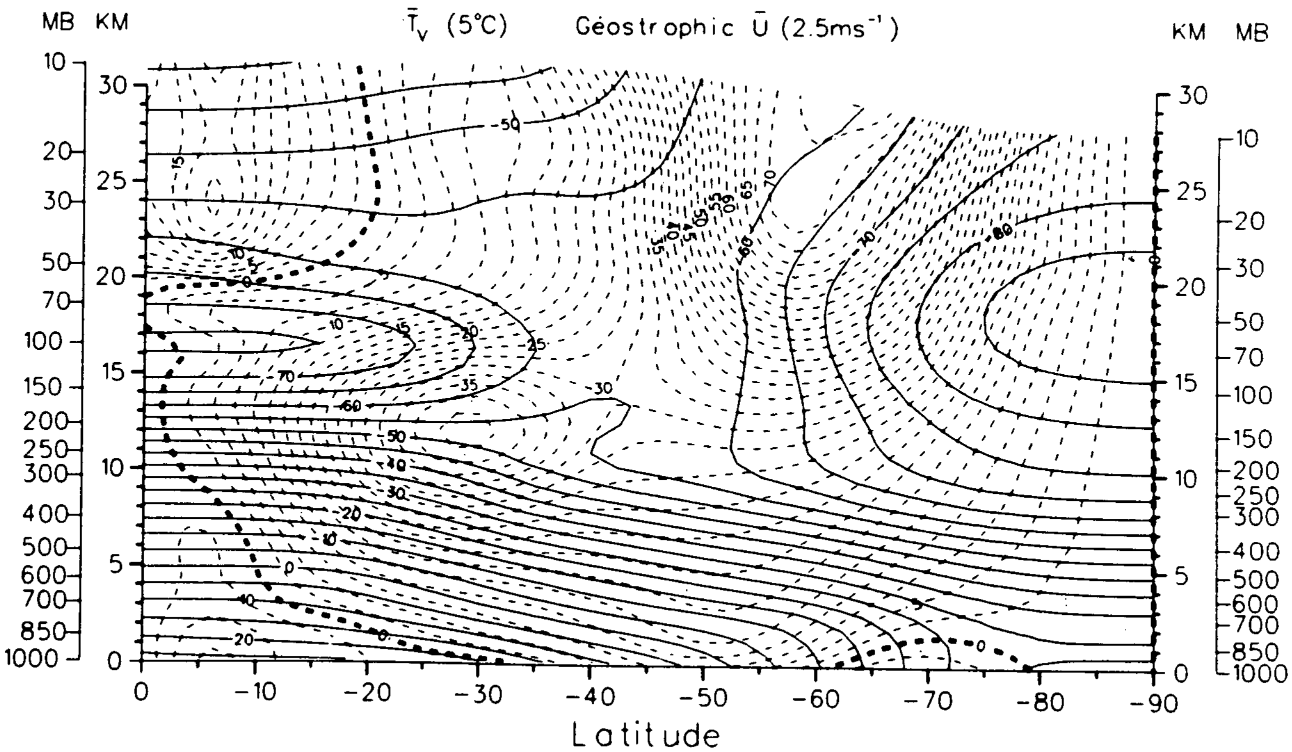

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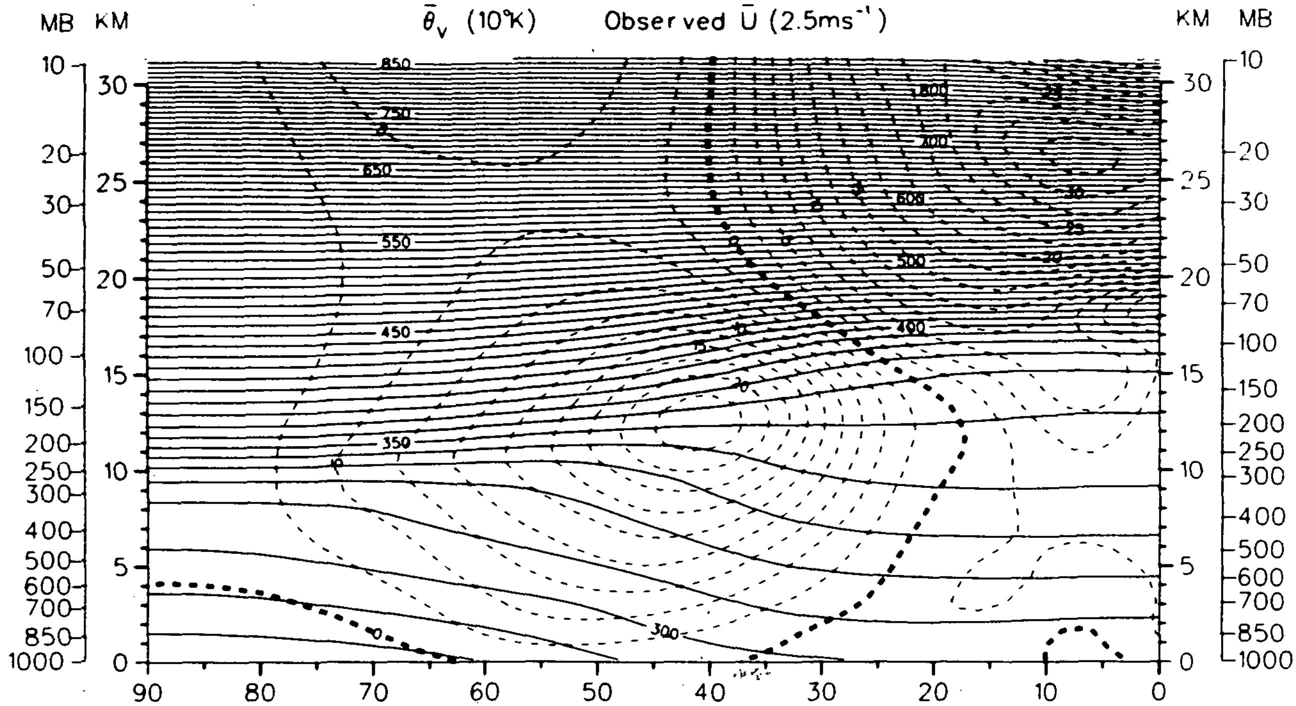
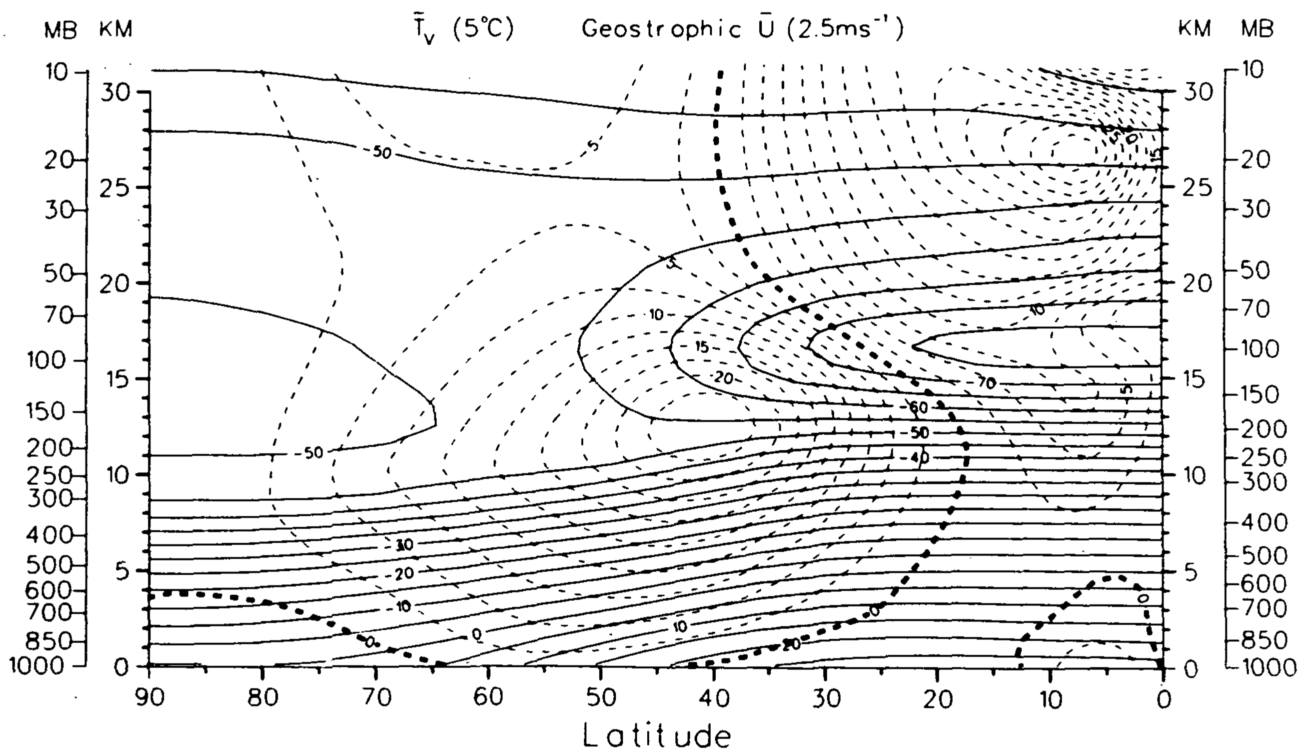
SEPTEMBER 1979





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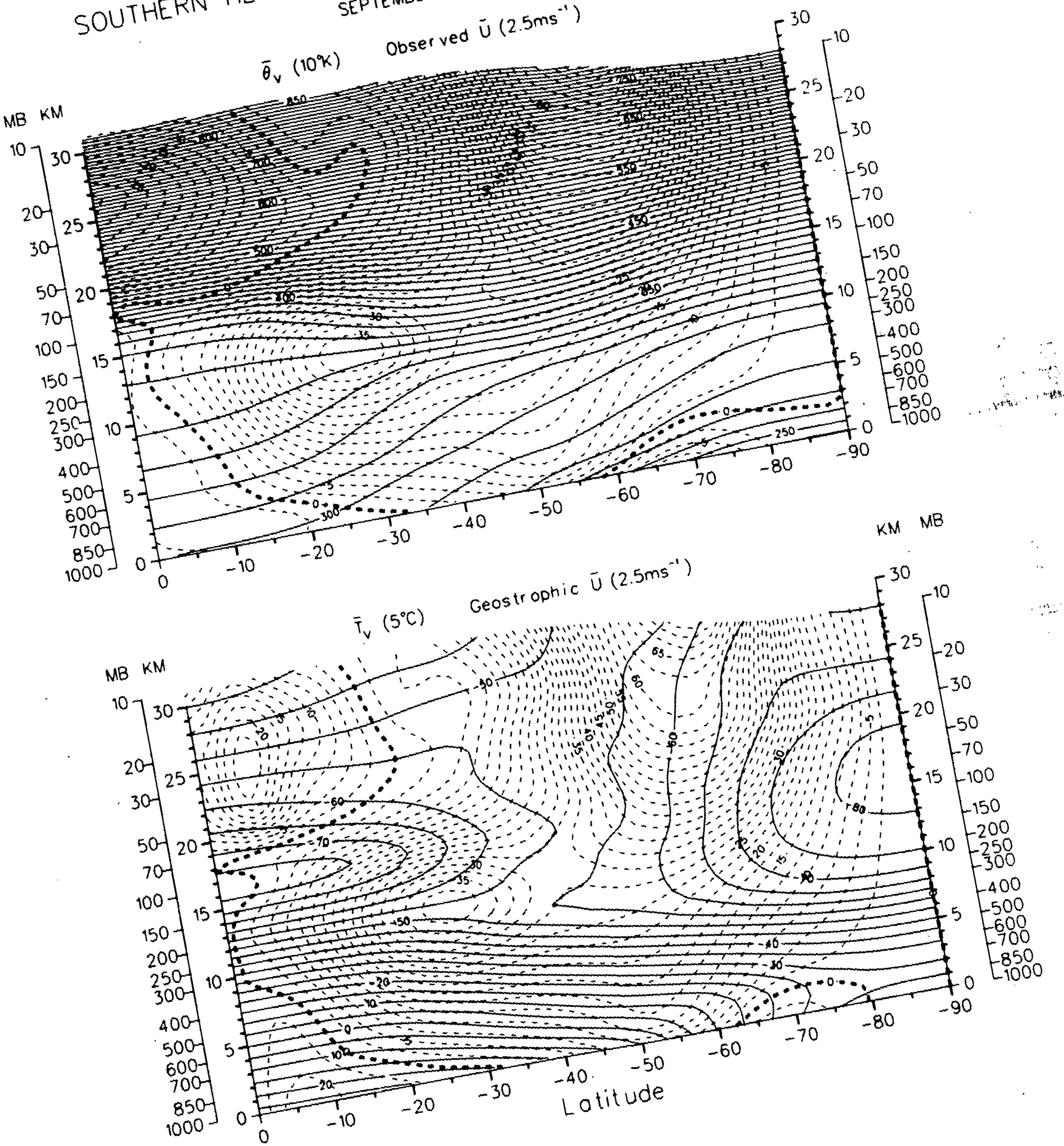

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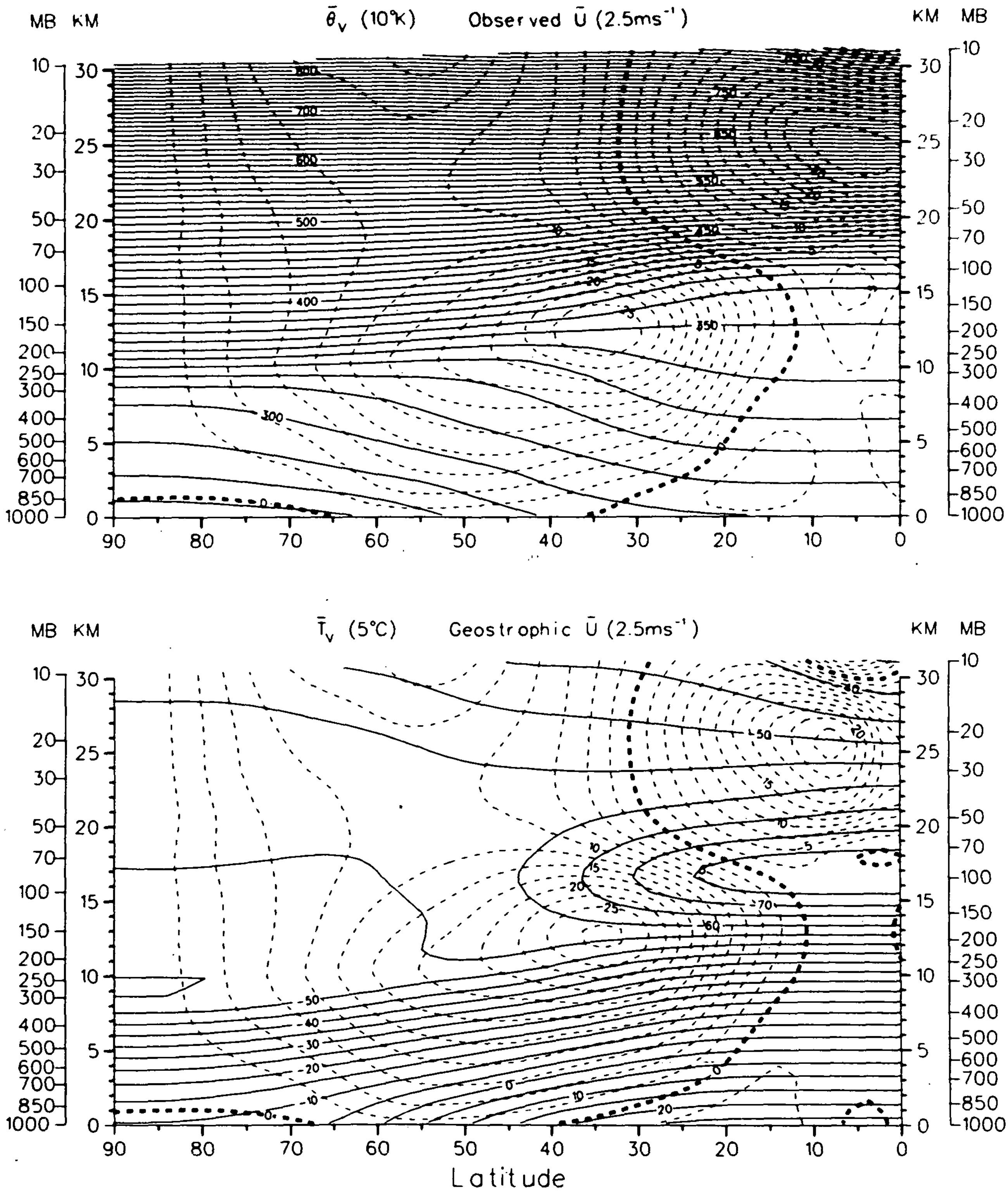

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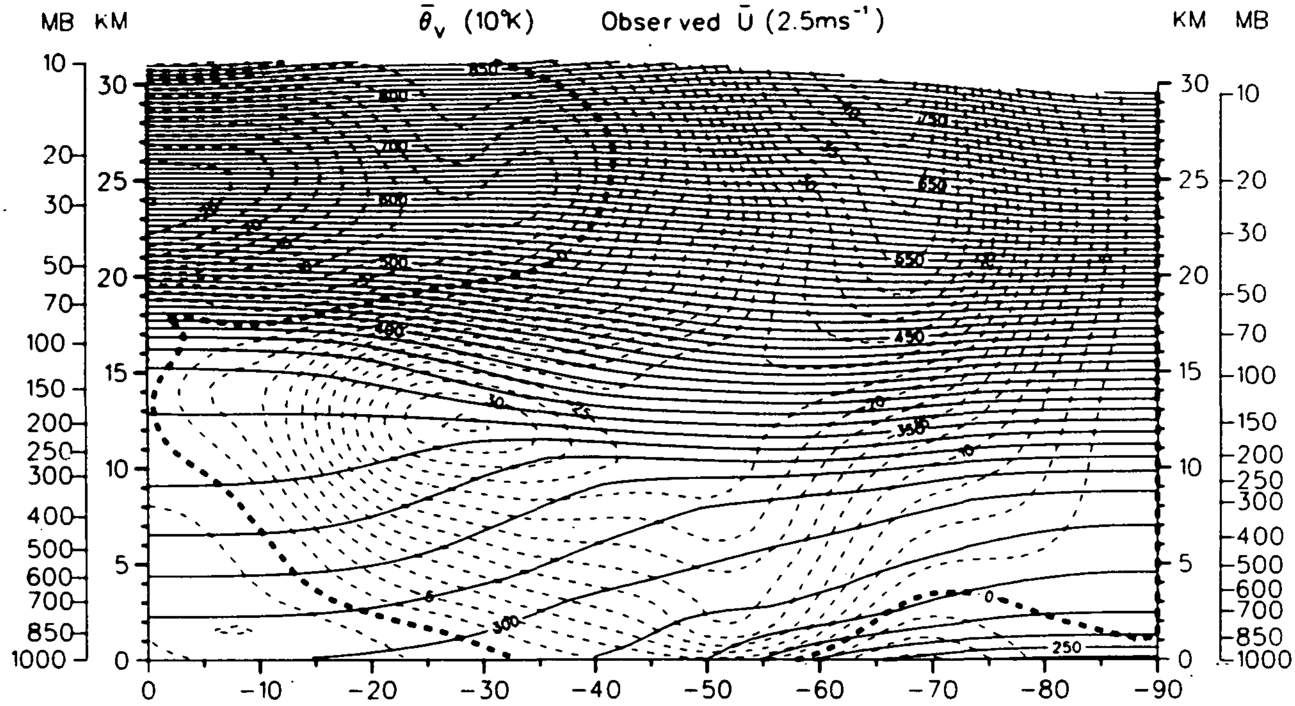

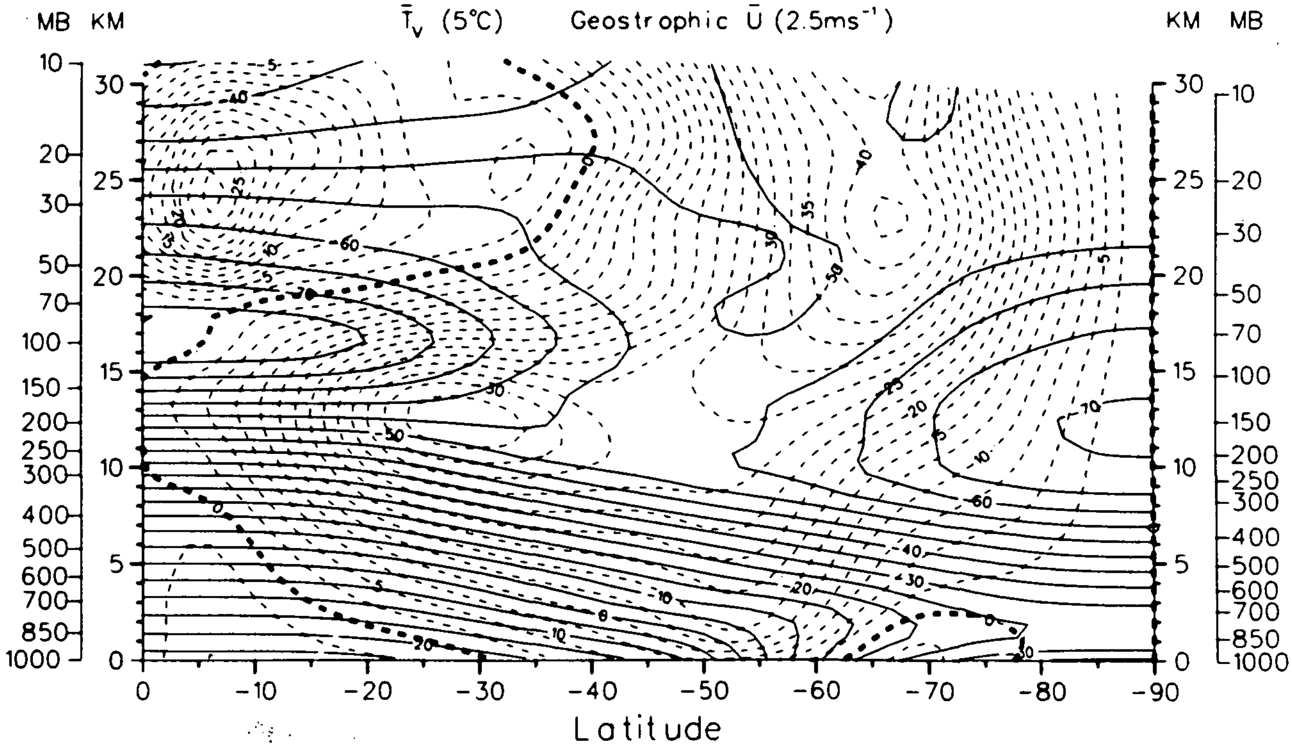

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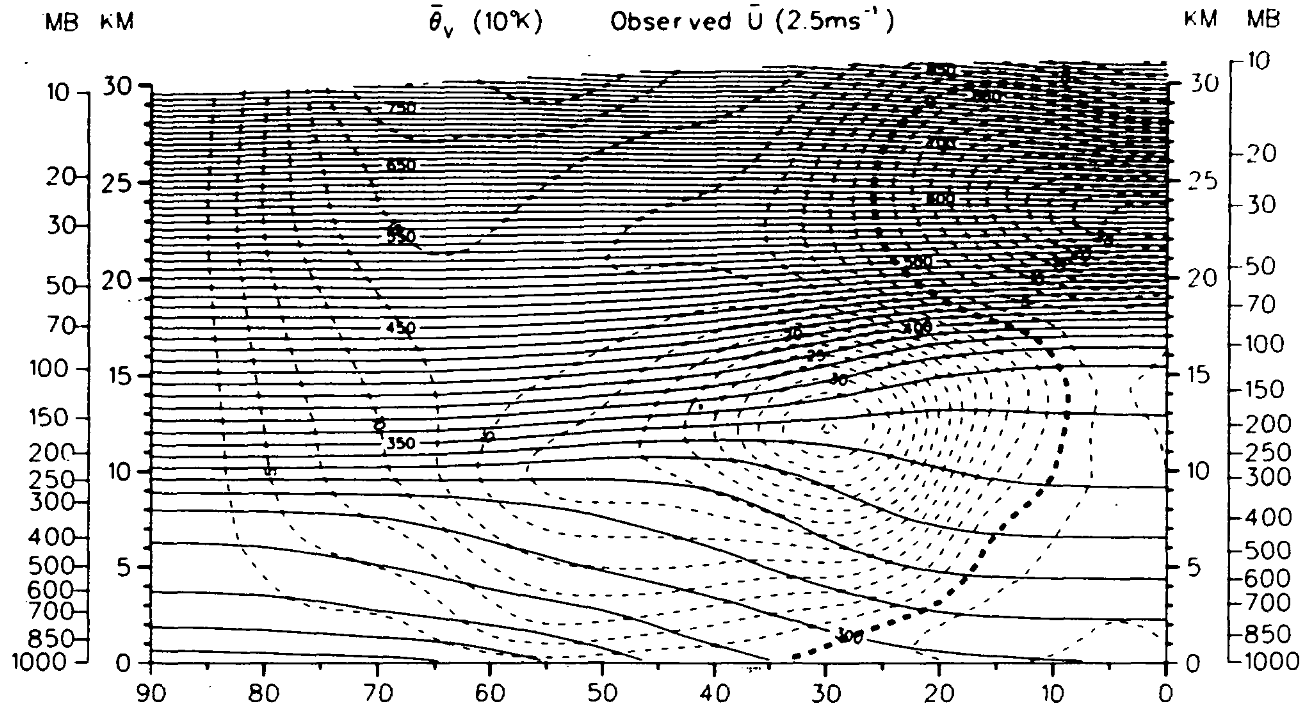
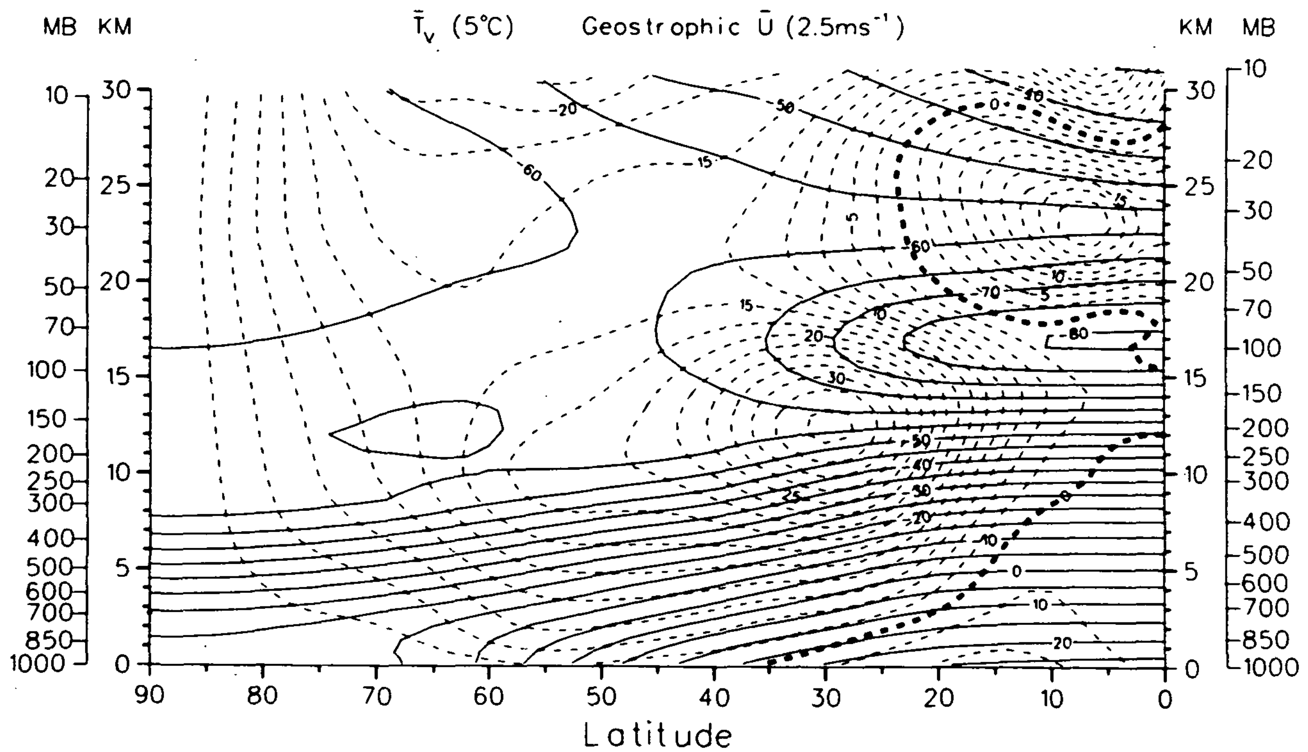
NOVEMBER 1979





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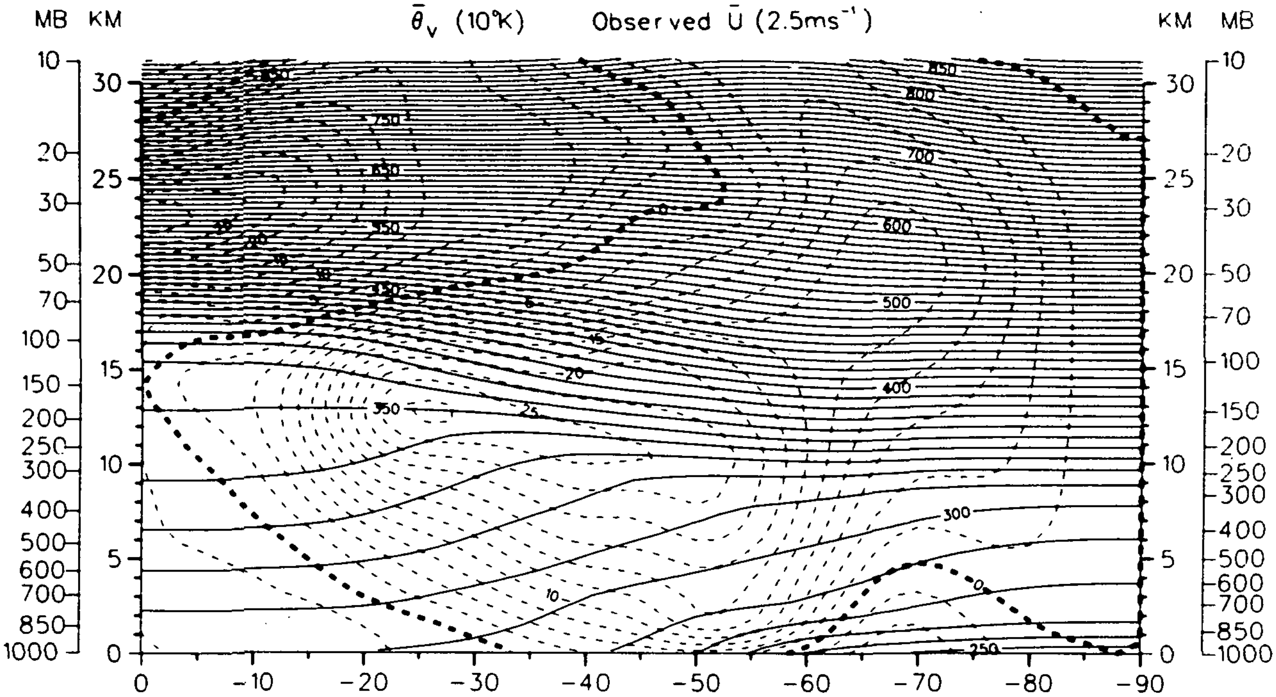

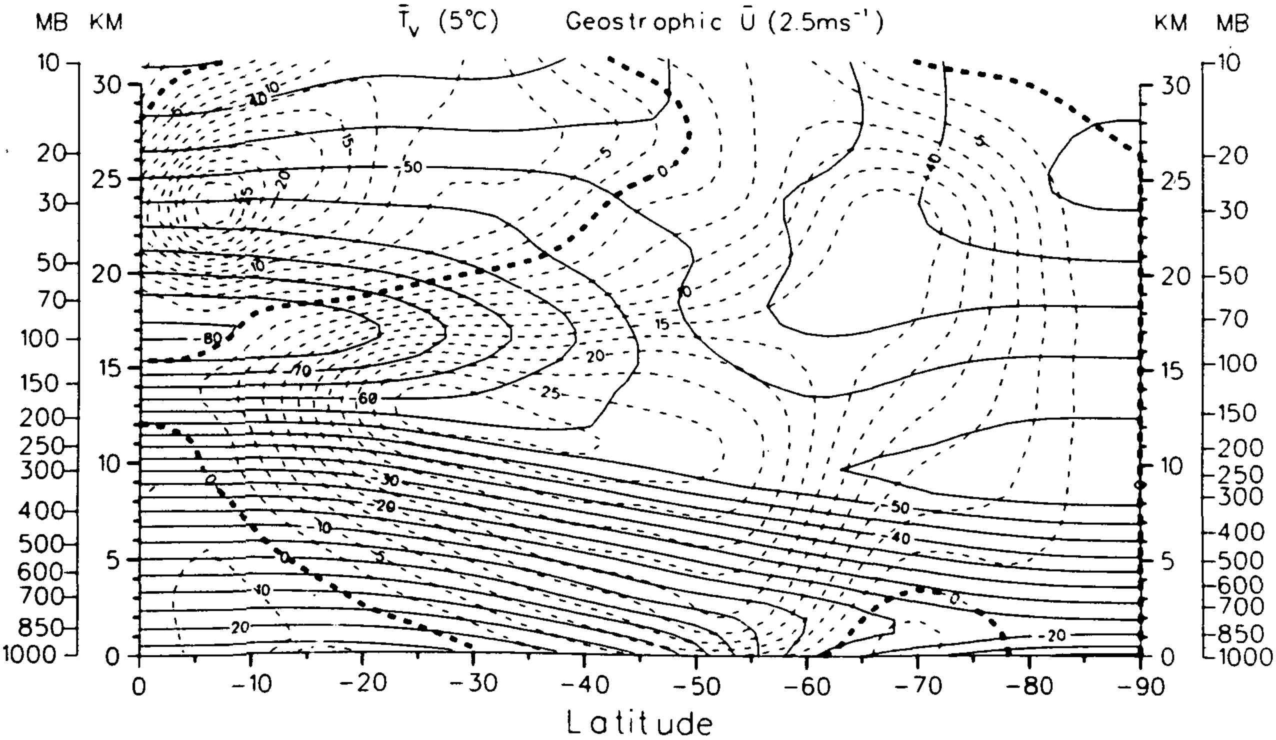

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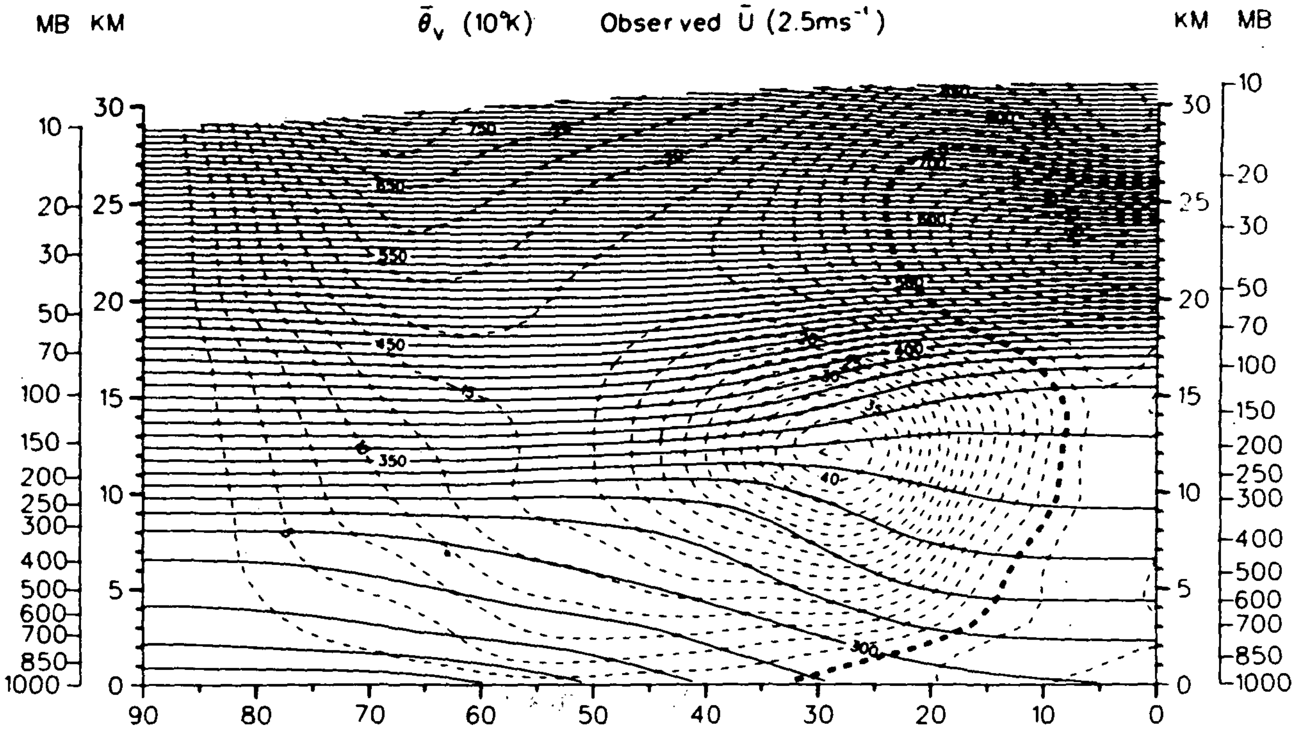

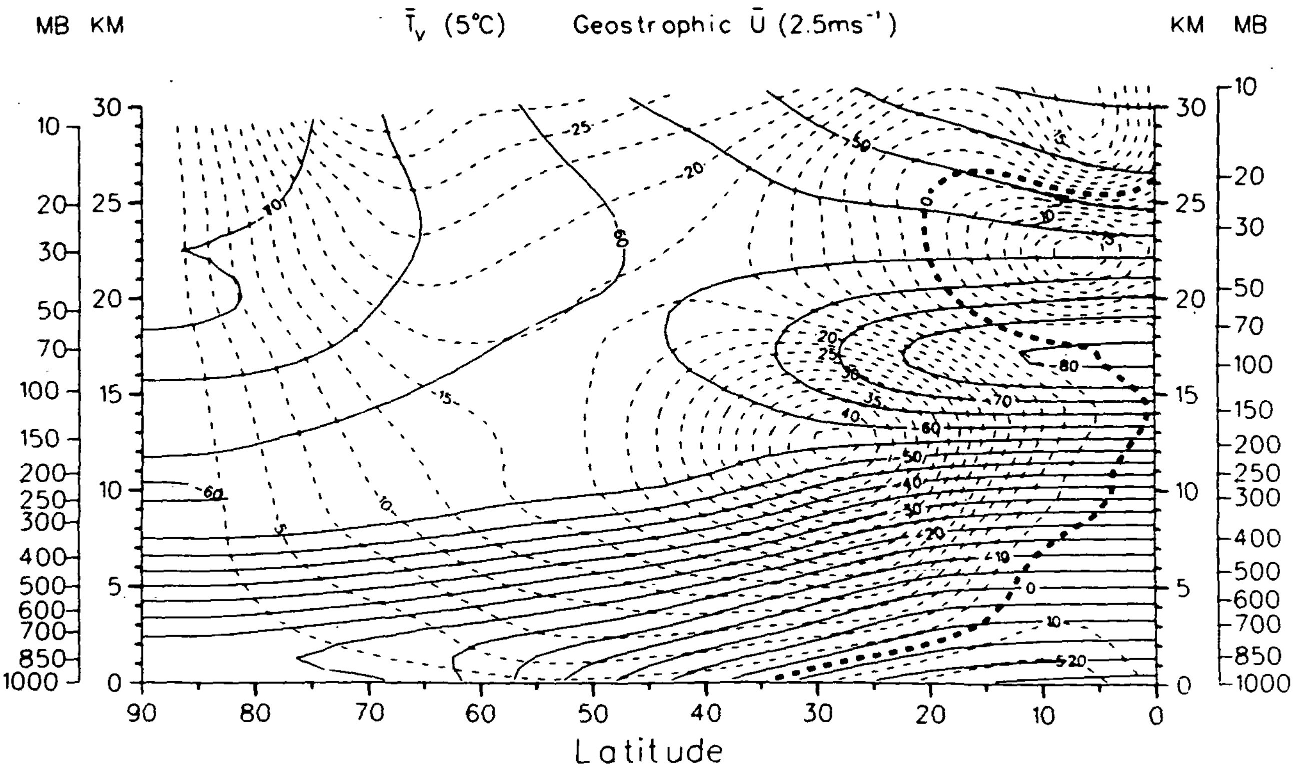

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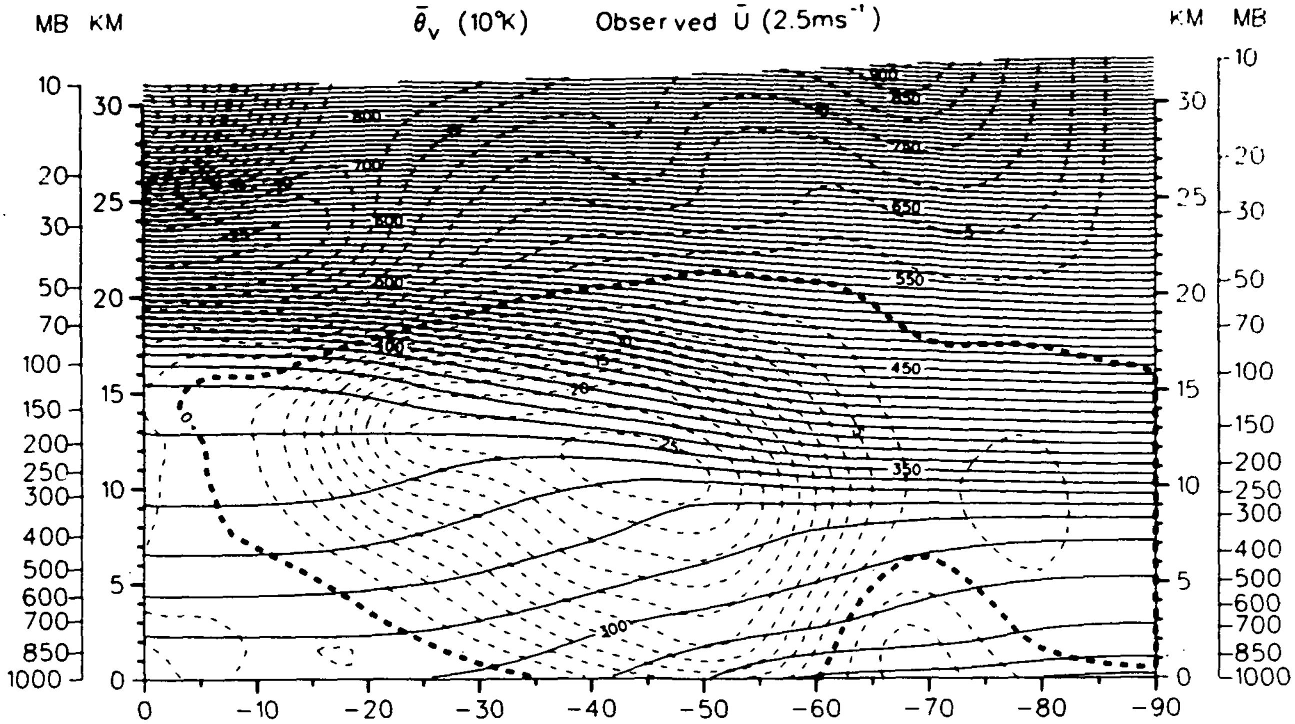
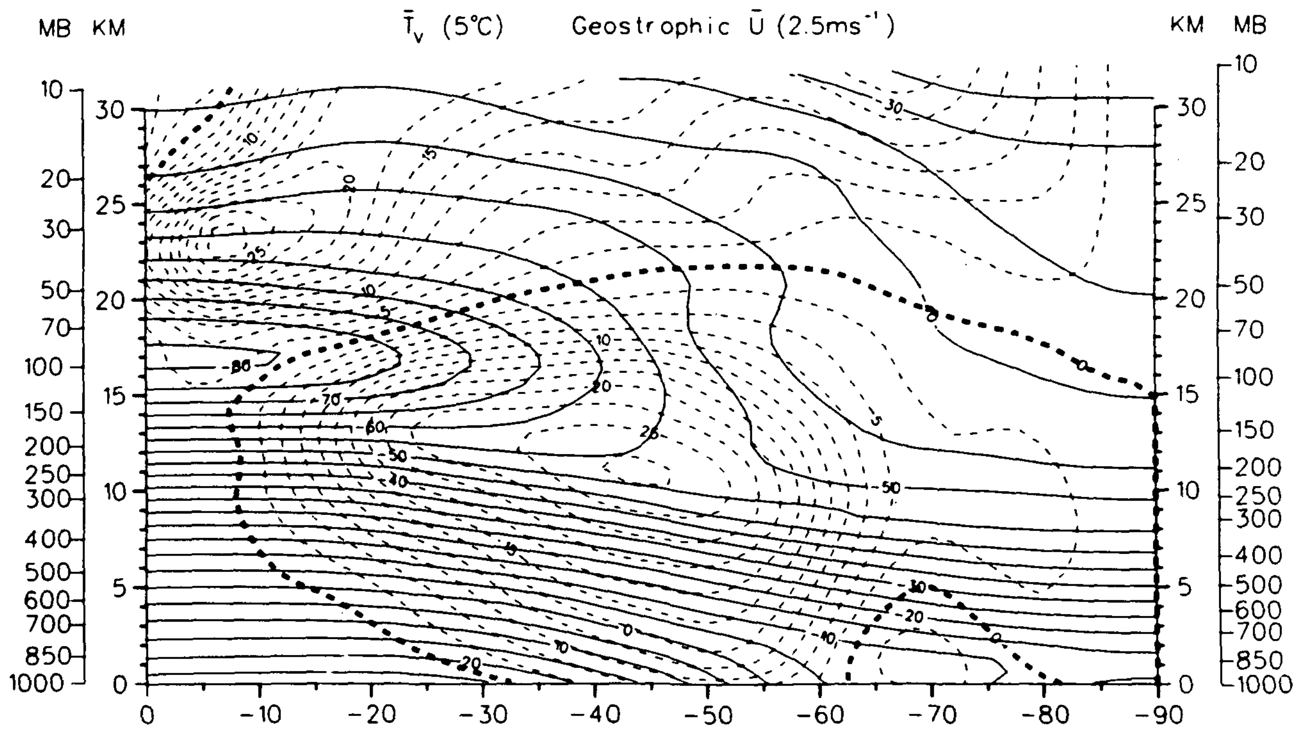
SOUTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

DECEMBER 1979





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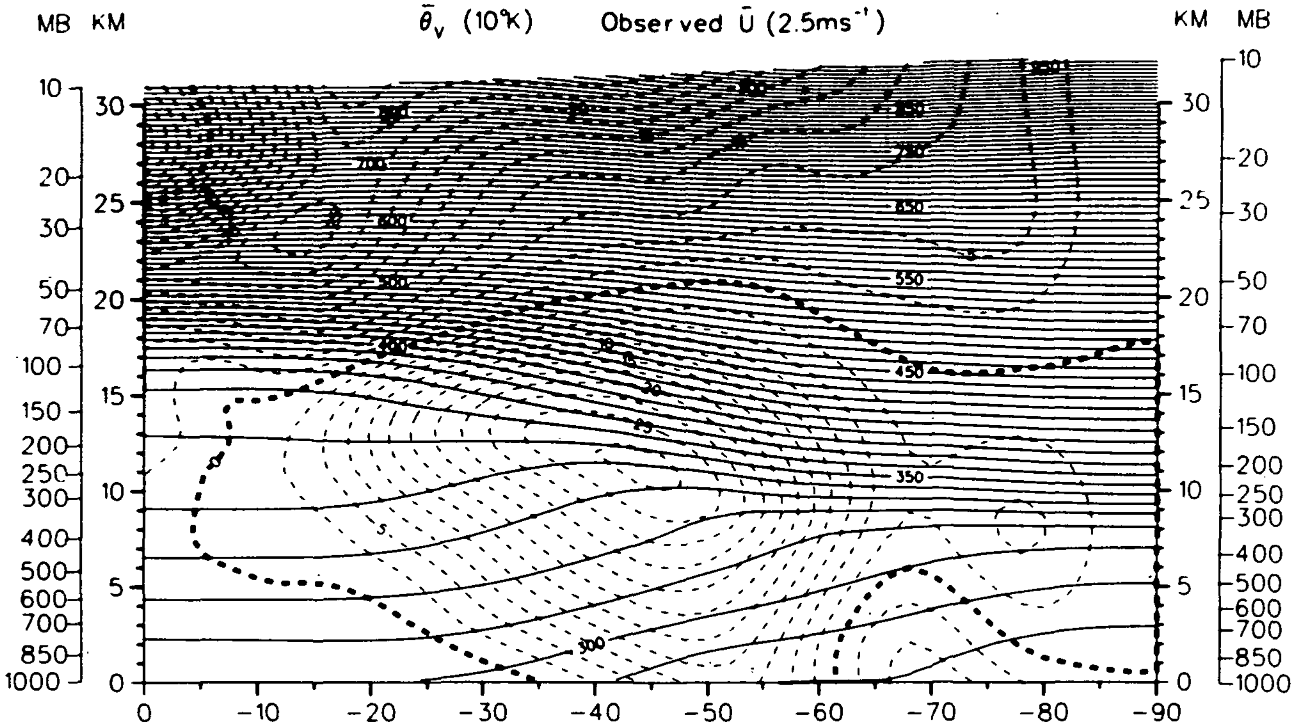
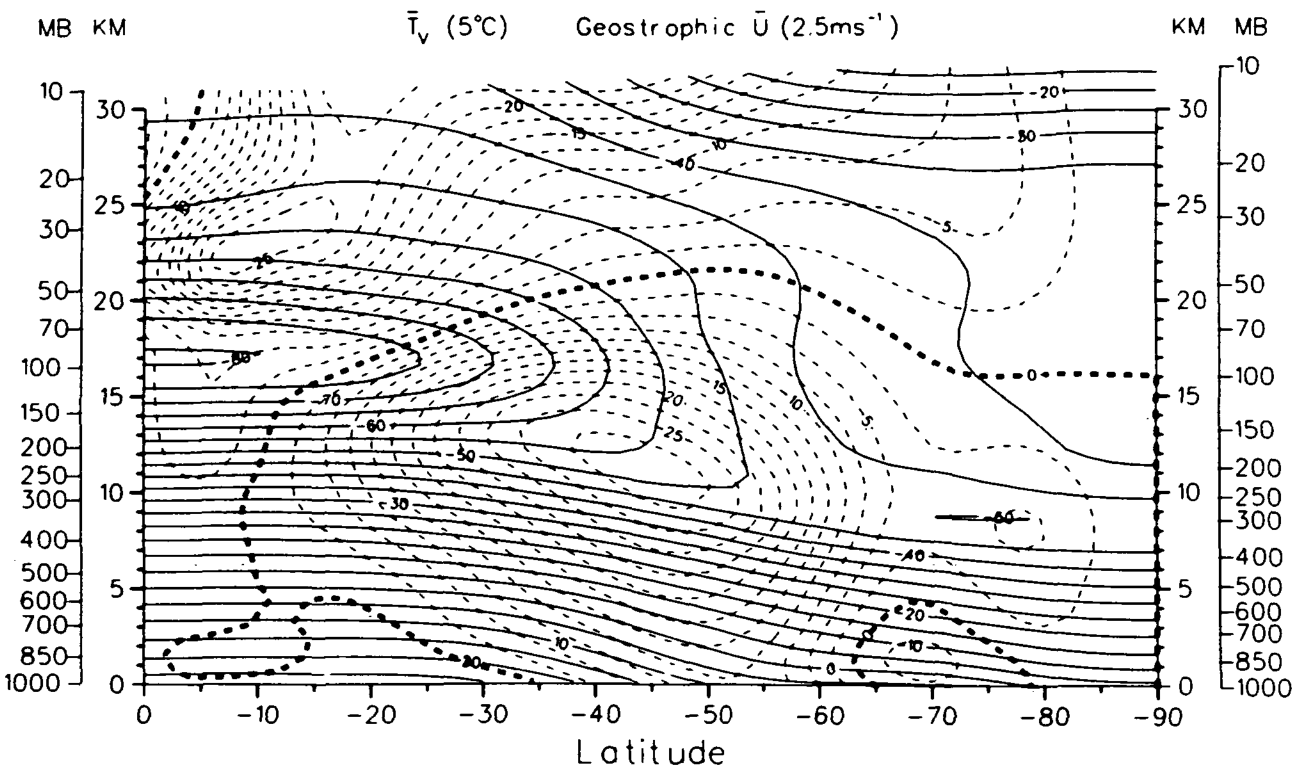
JANUARY 1980





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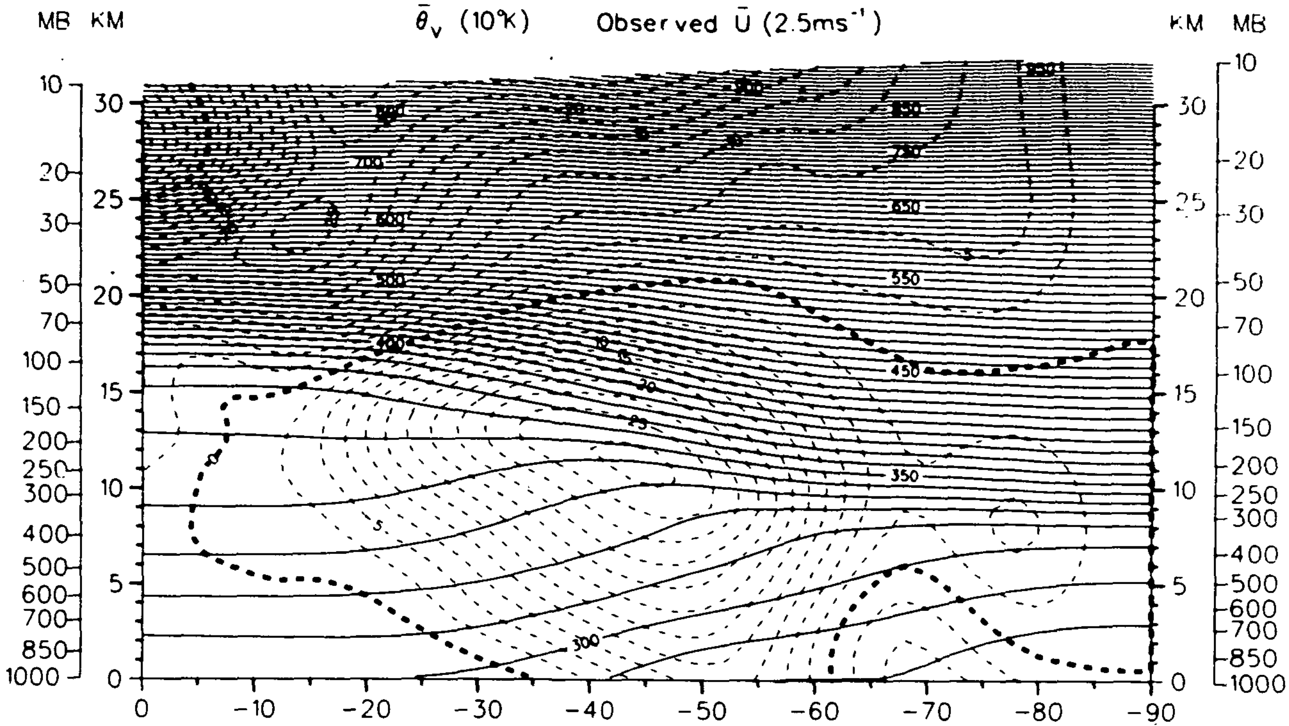

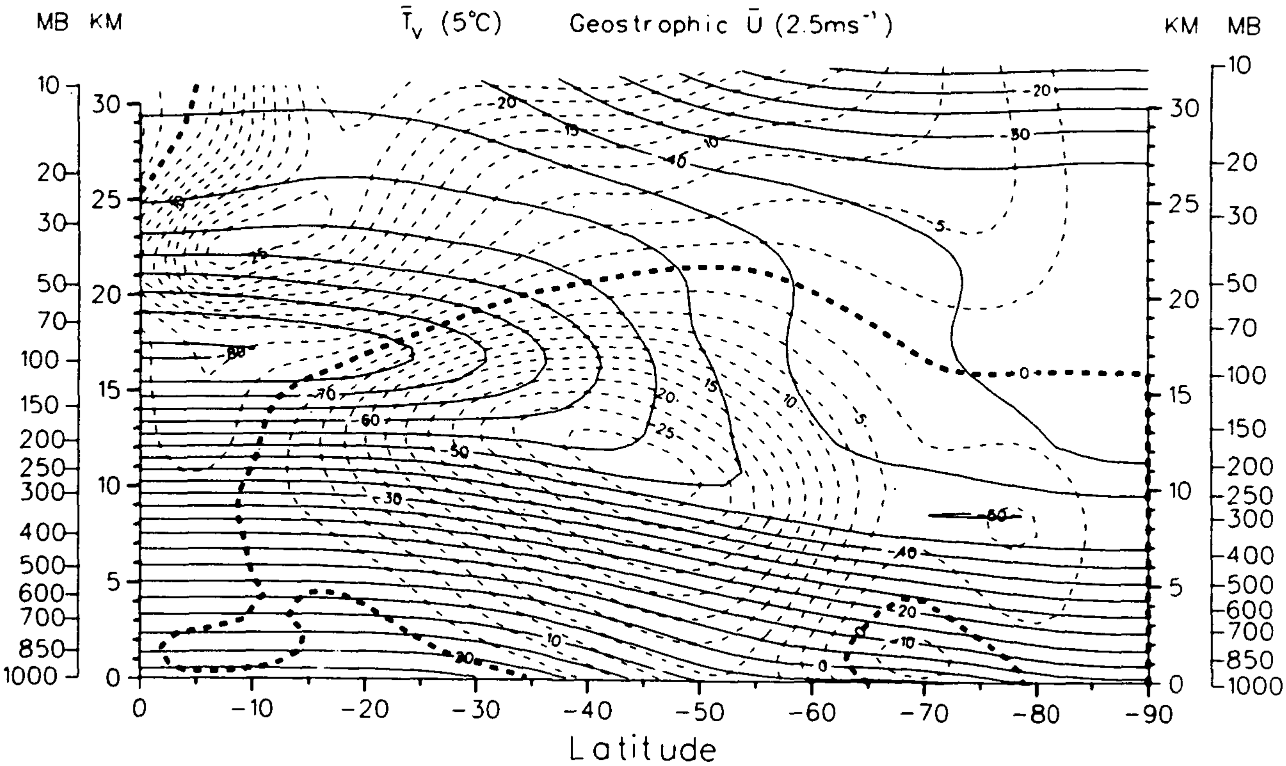

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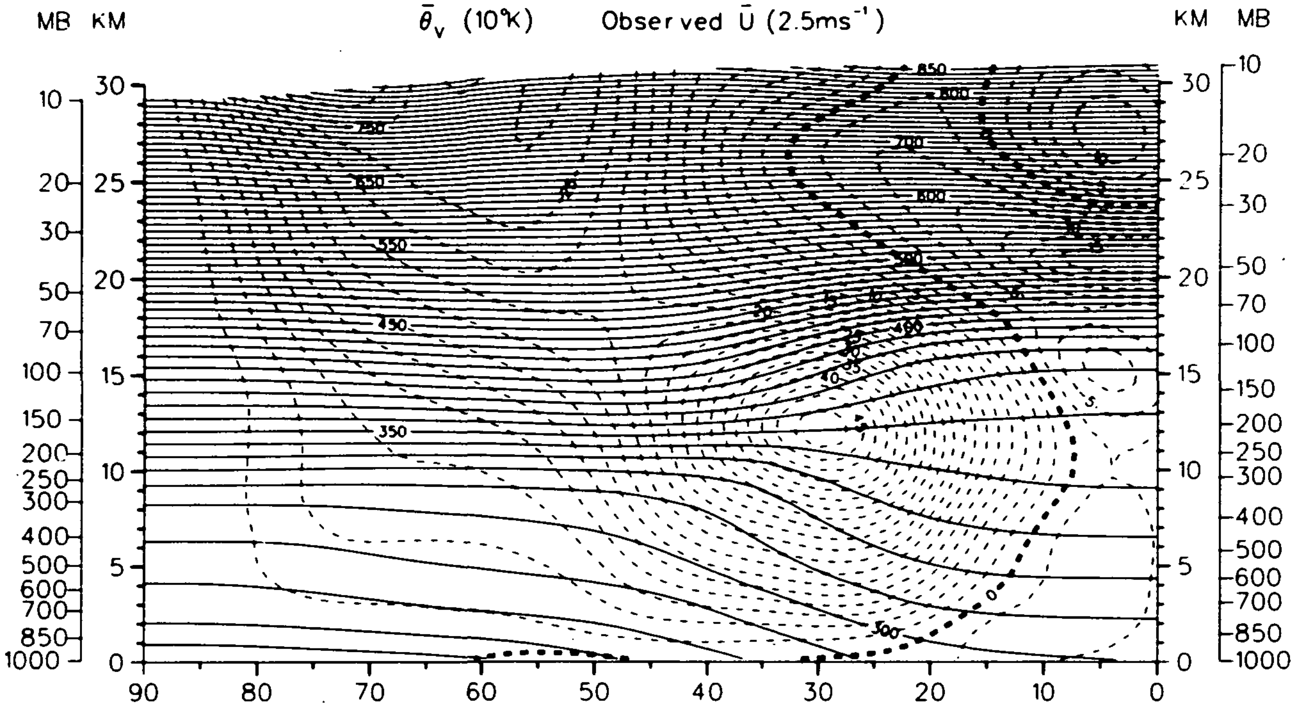
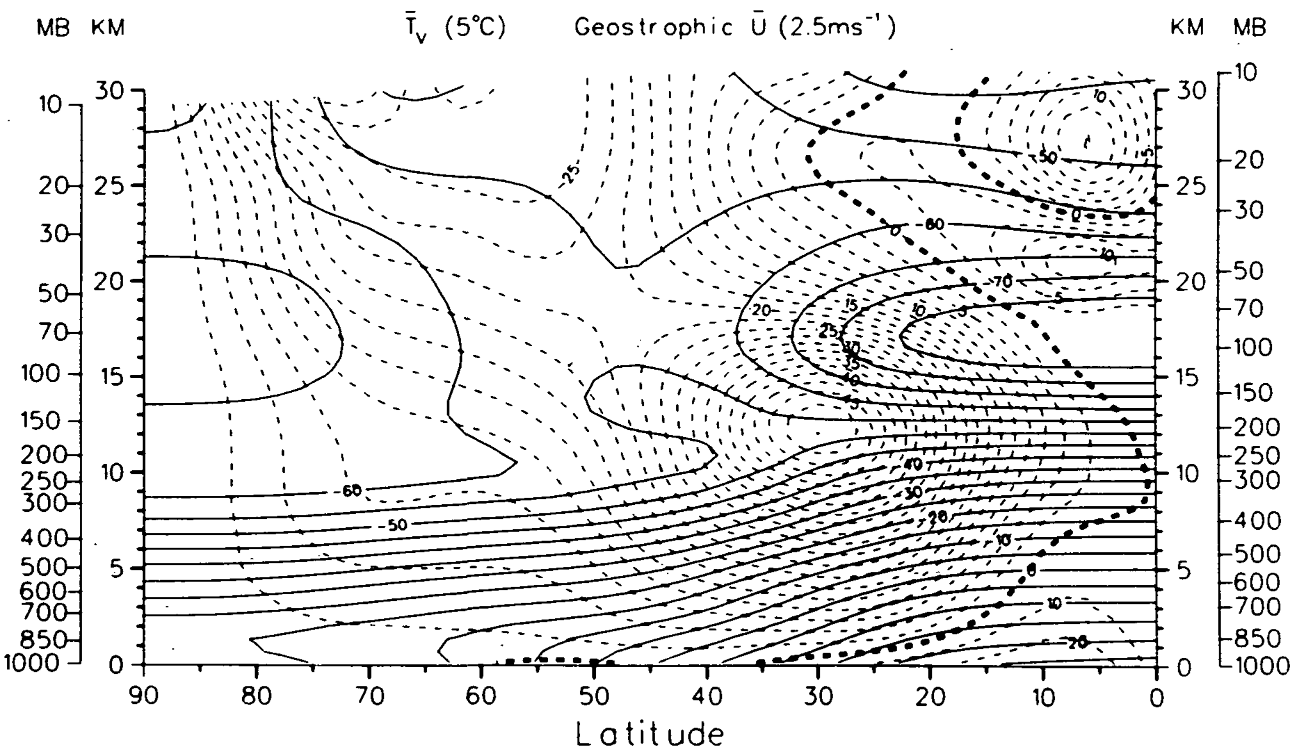
NORTHERN HEMISPHERIC ZONAL-MONTHLY MEANS

FEBRUARY 1980





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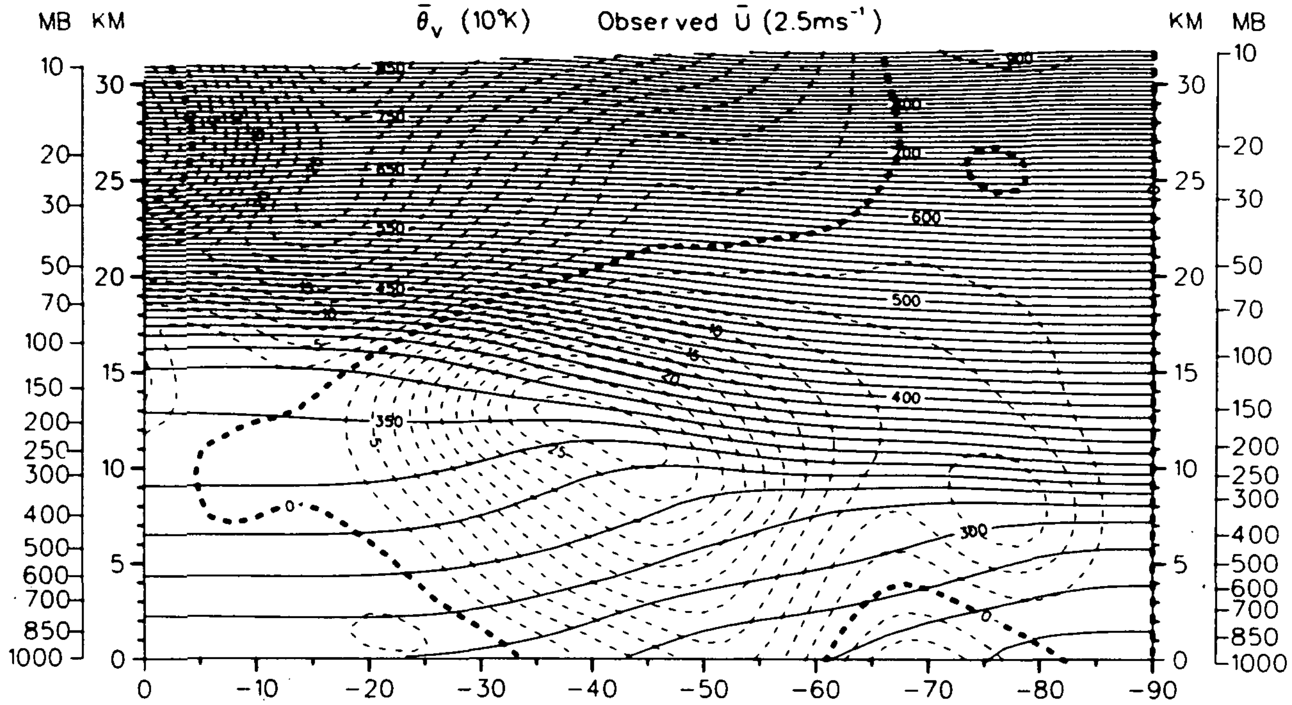

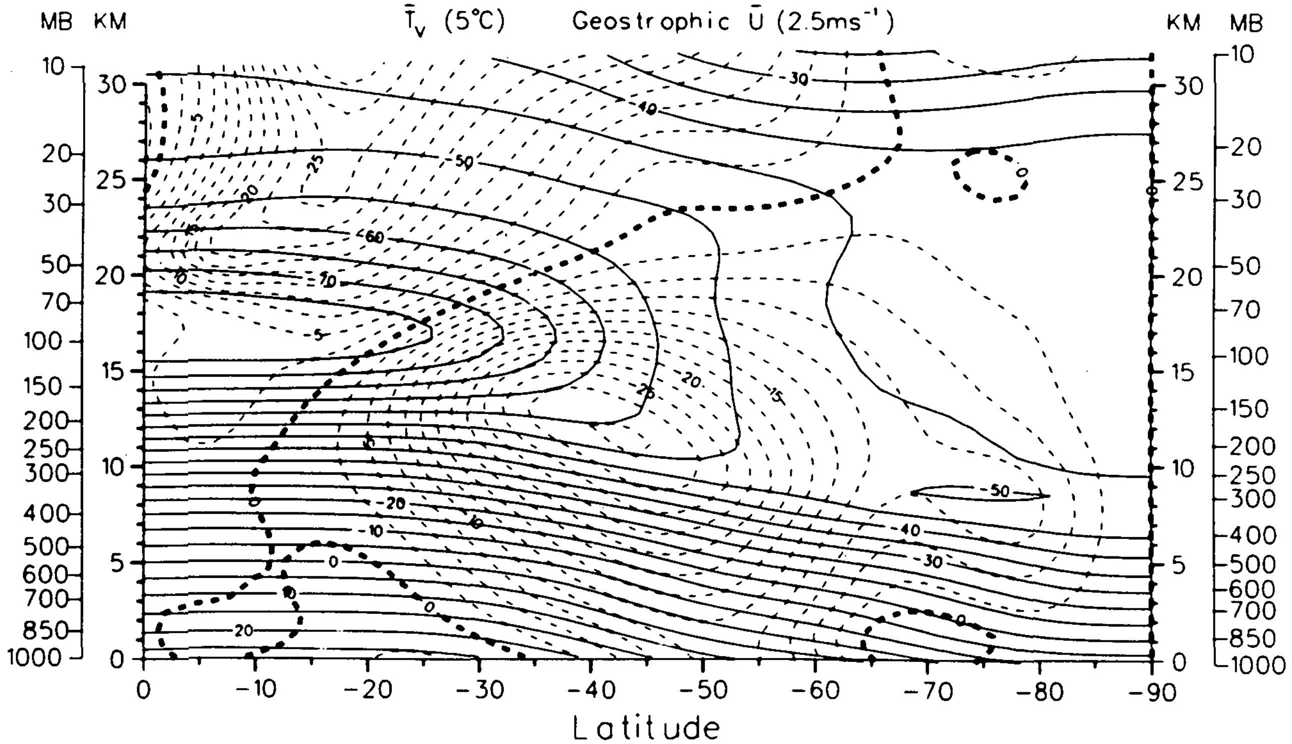

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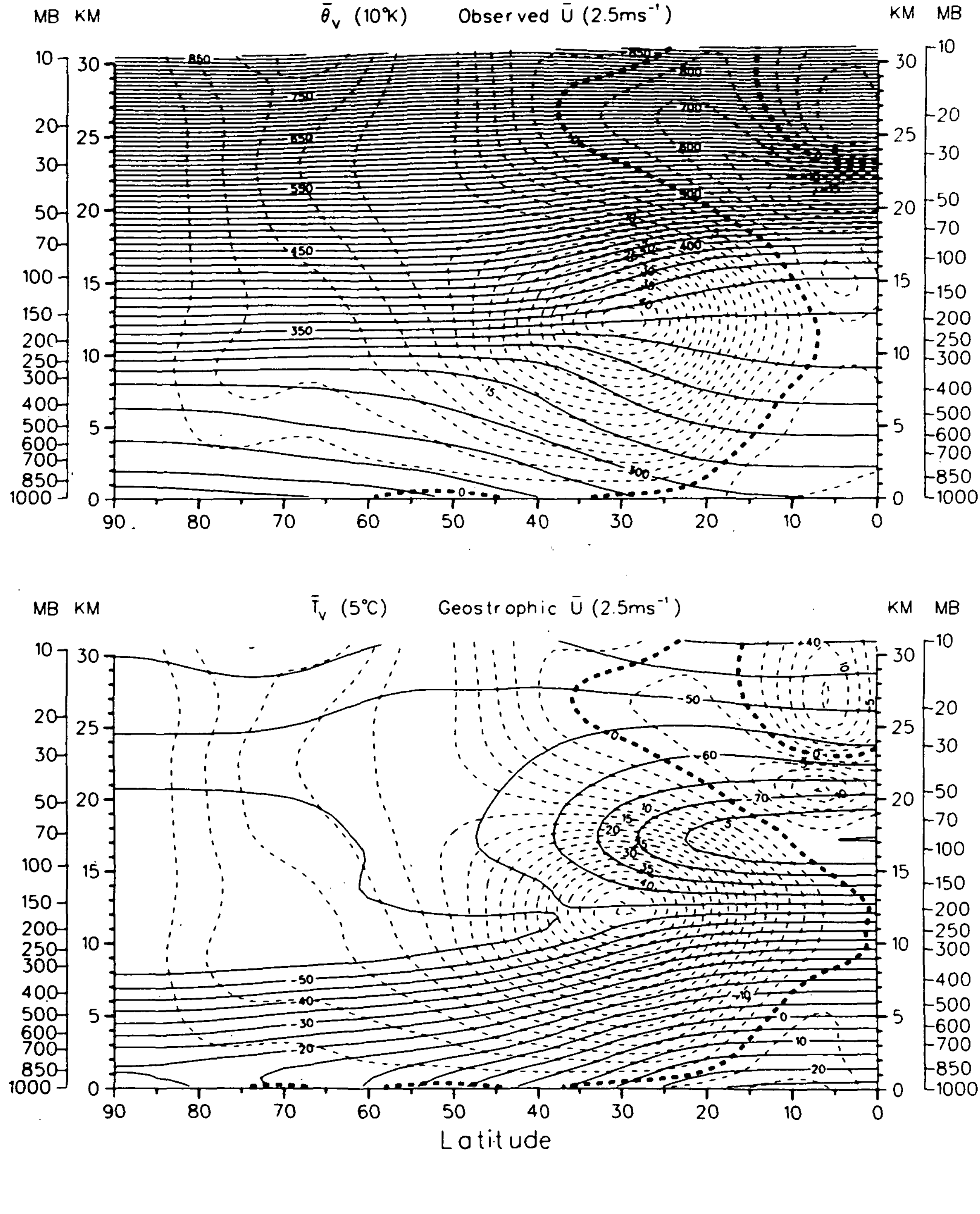
MARCH 1980



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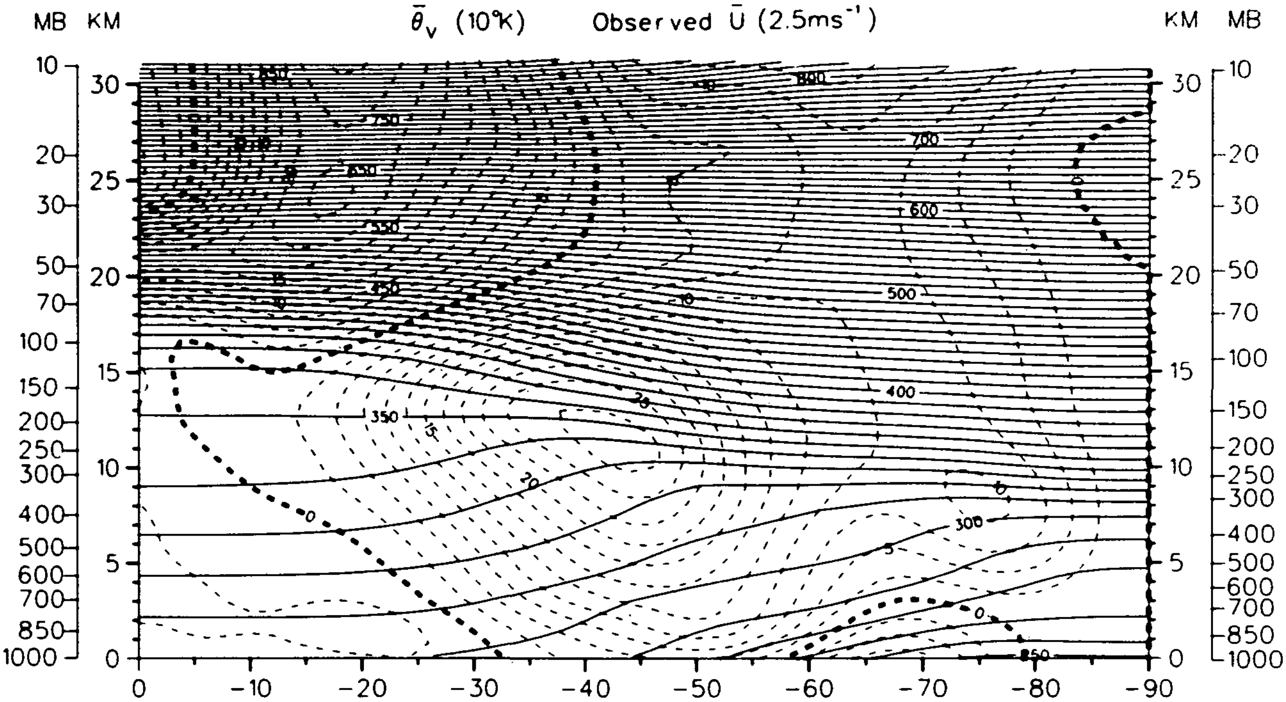

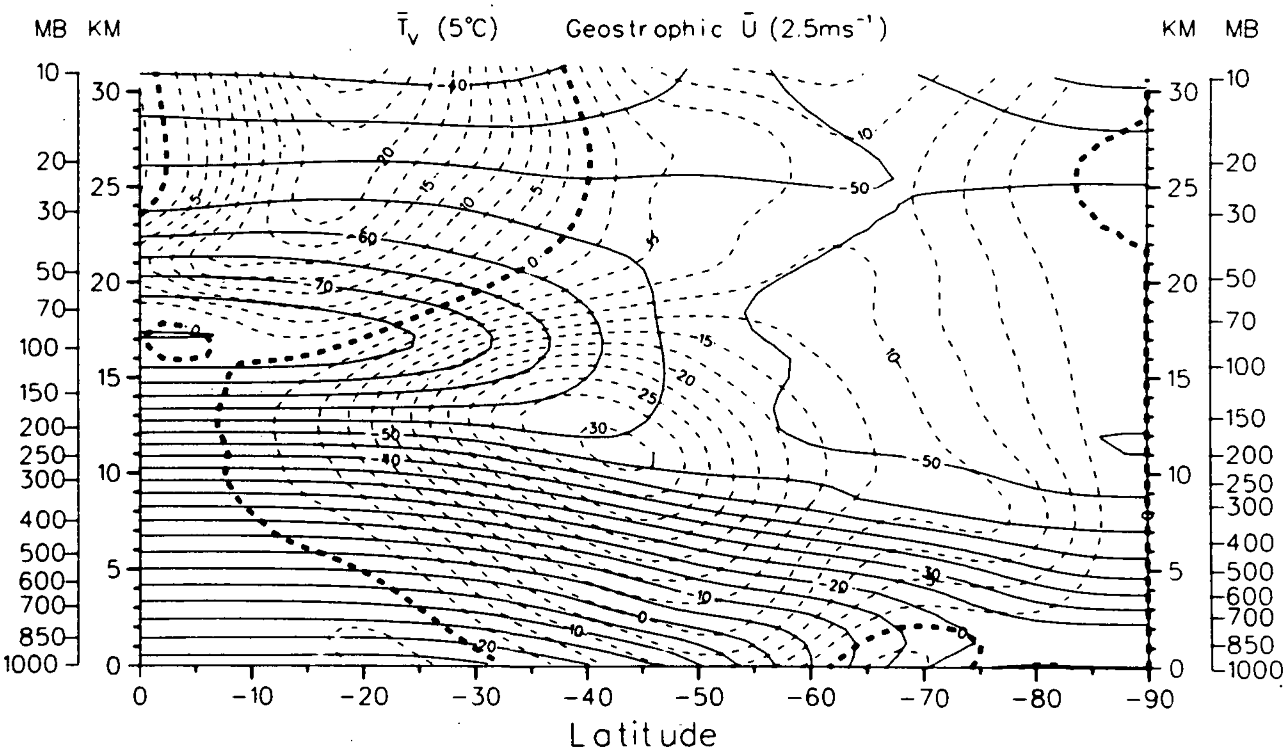

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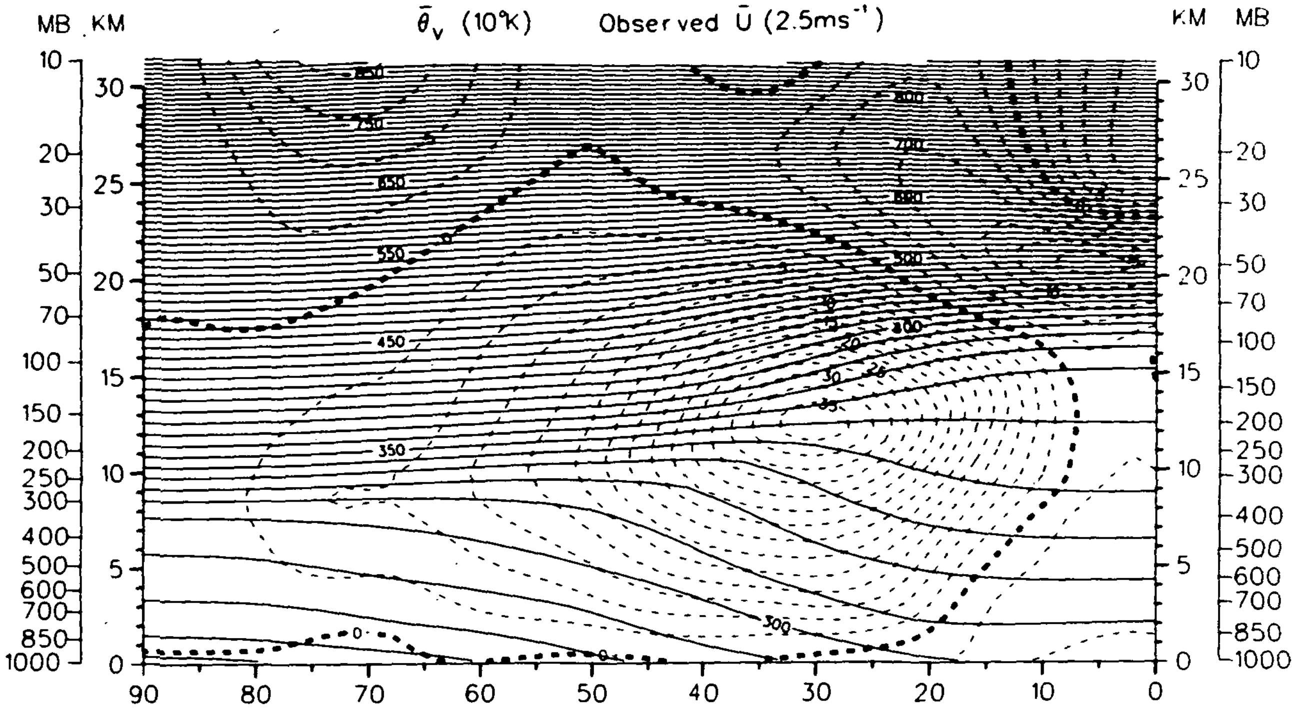

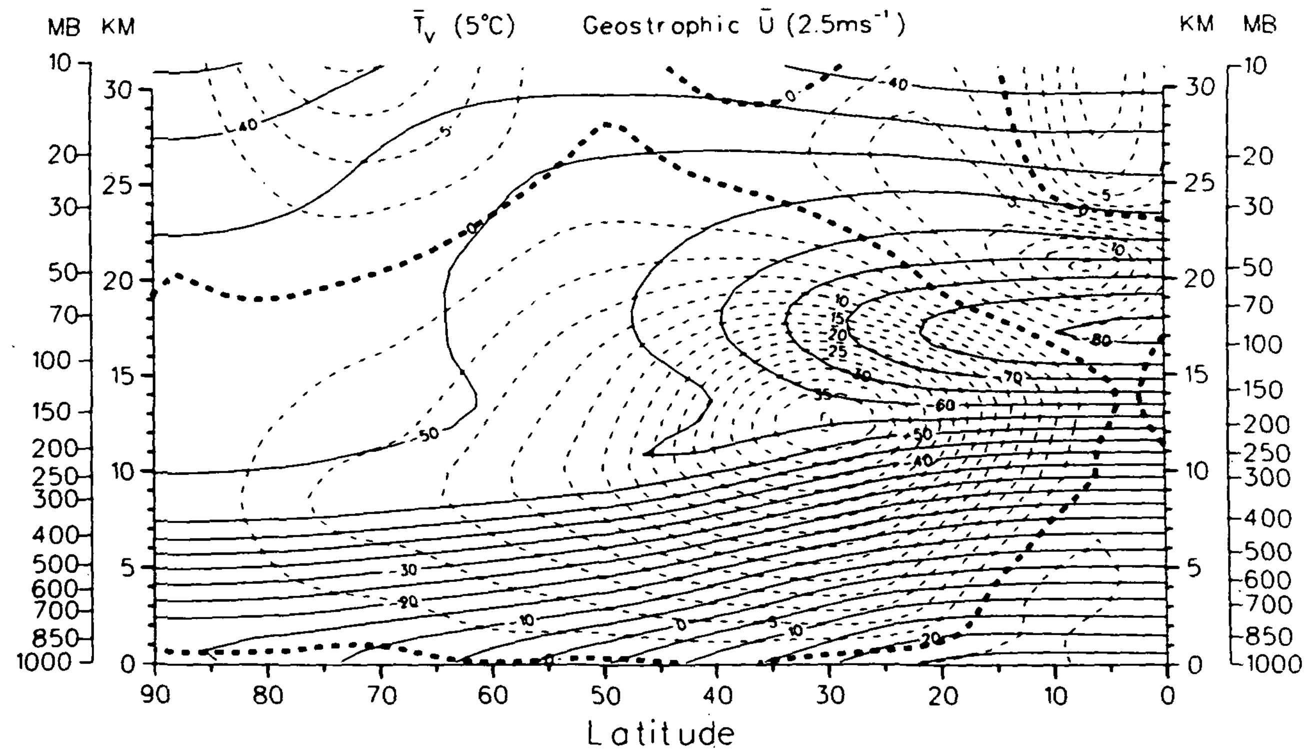

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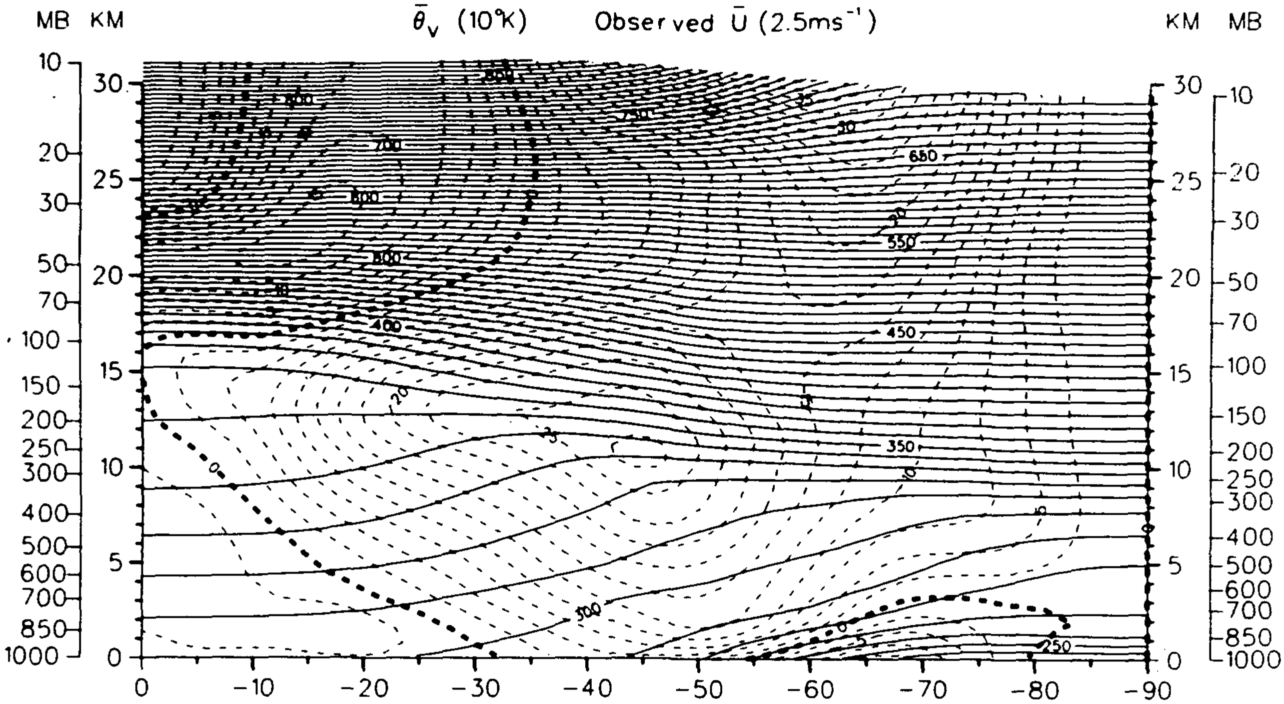

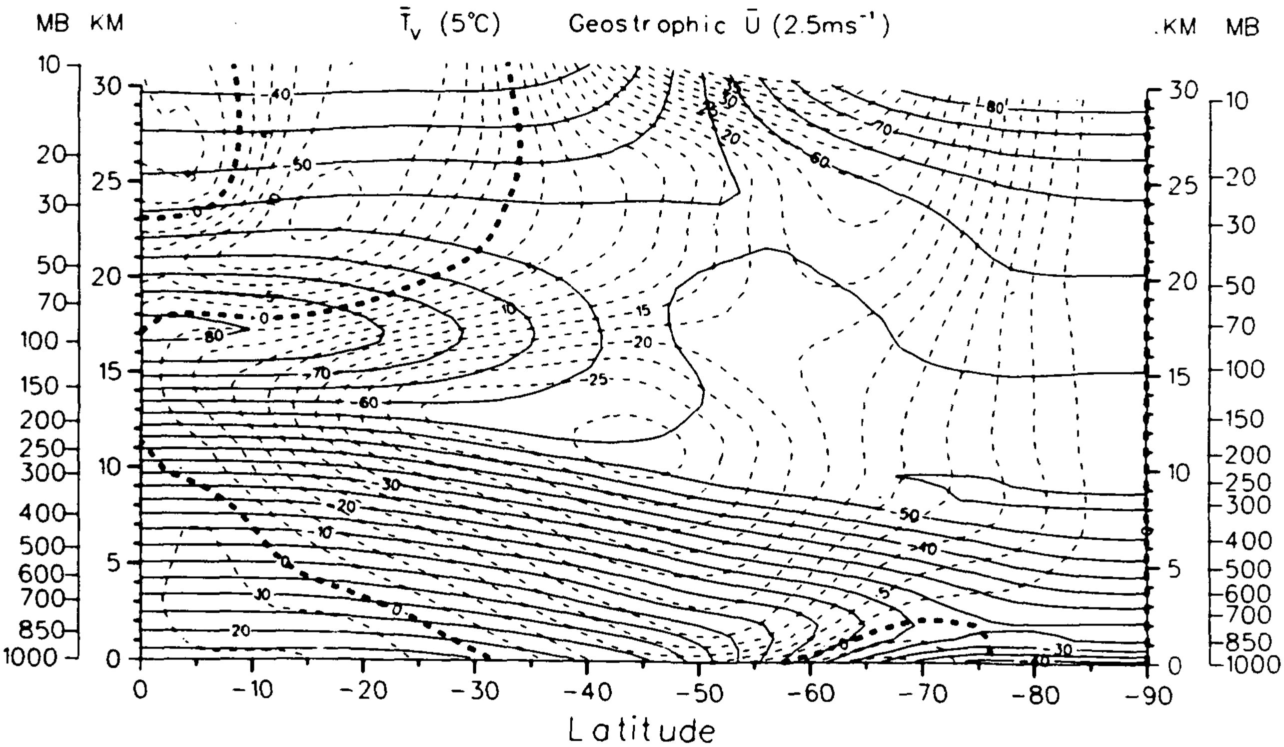

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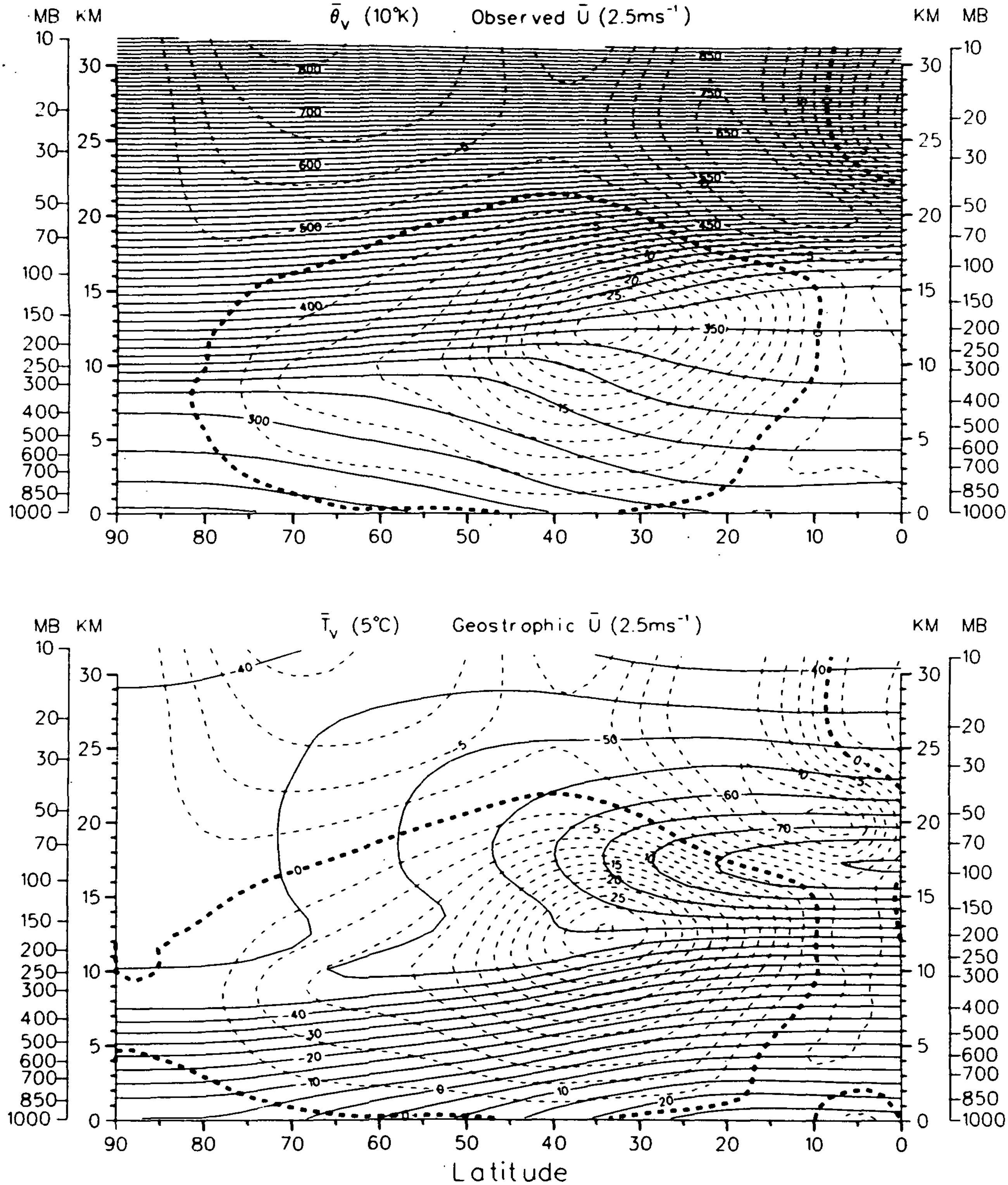

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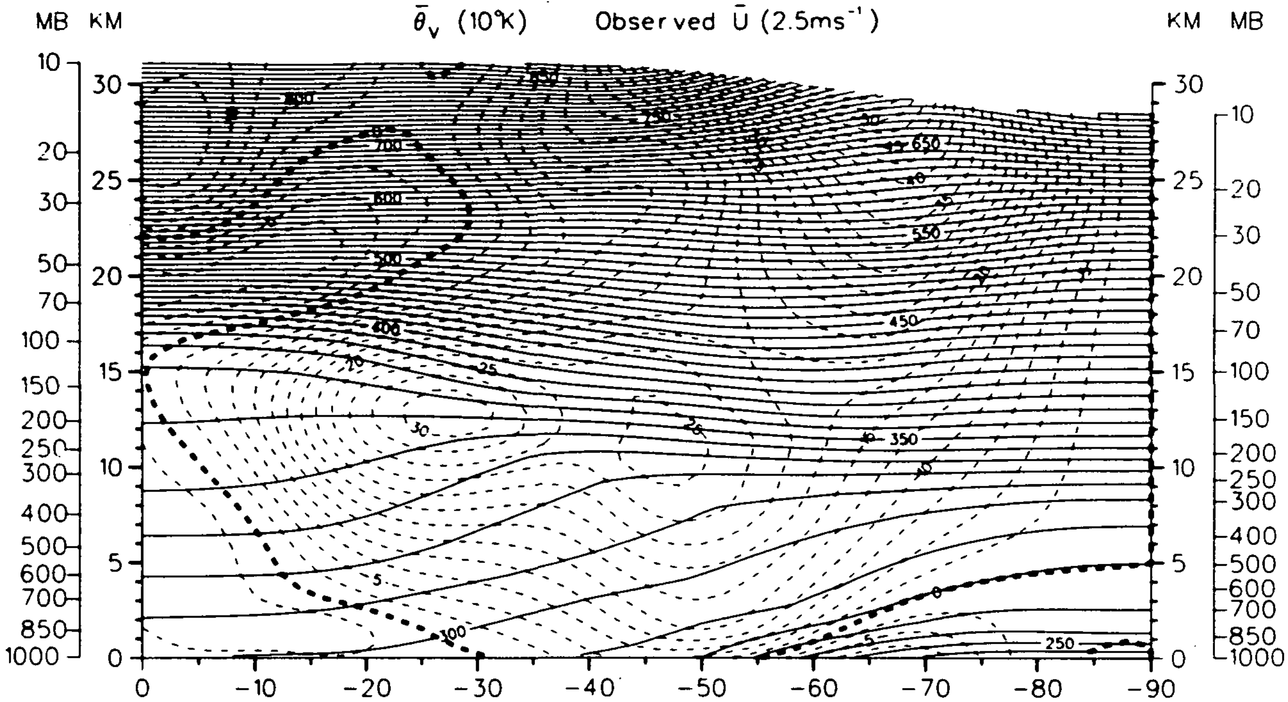

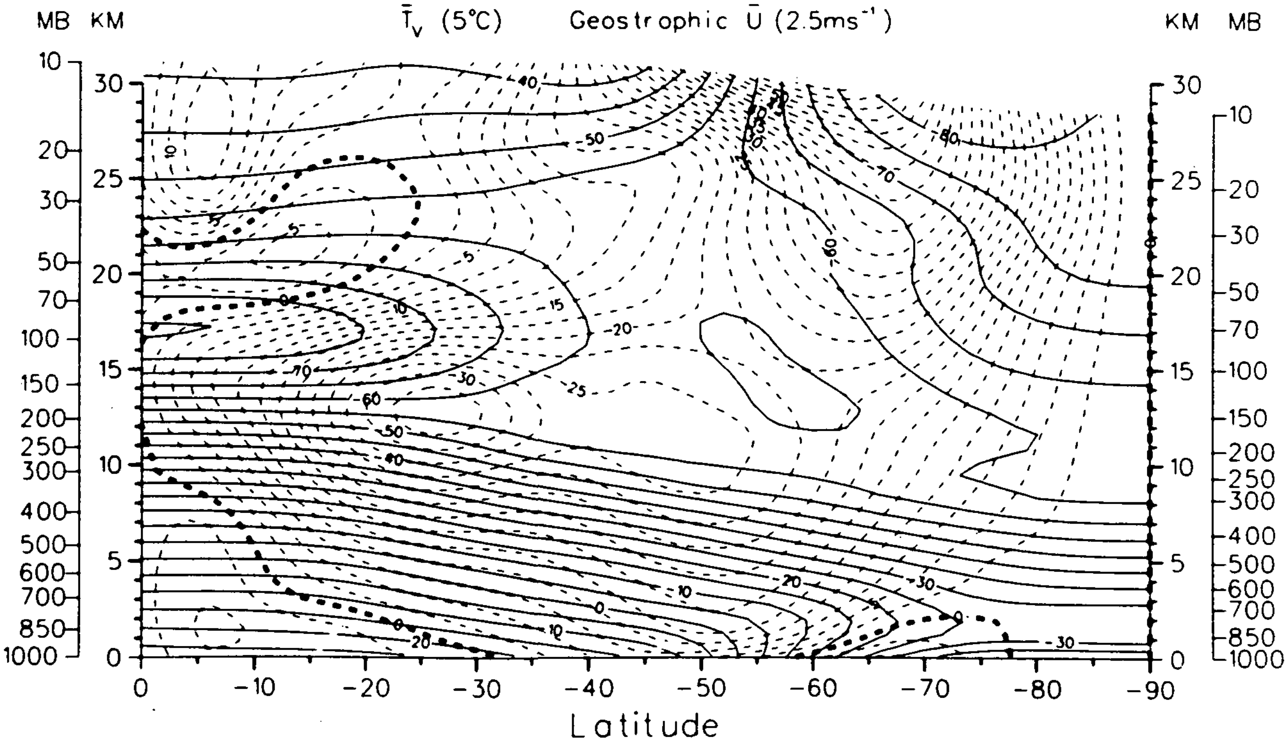

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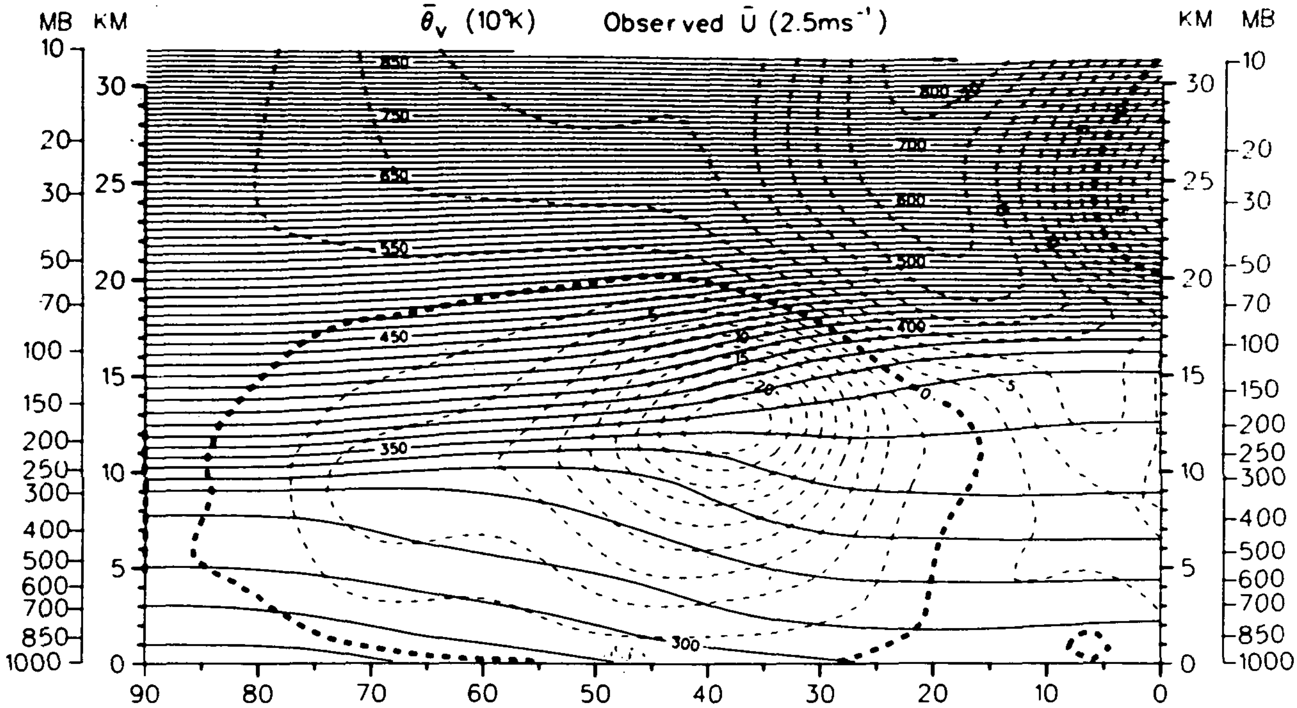

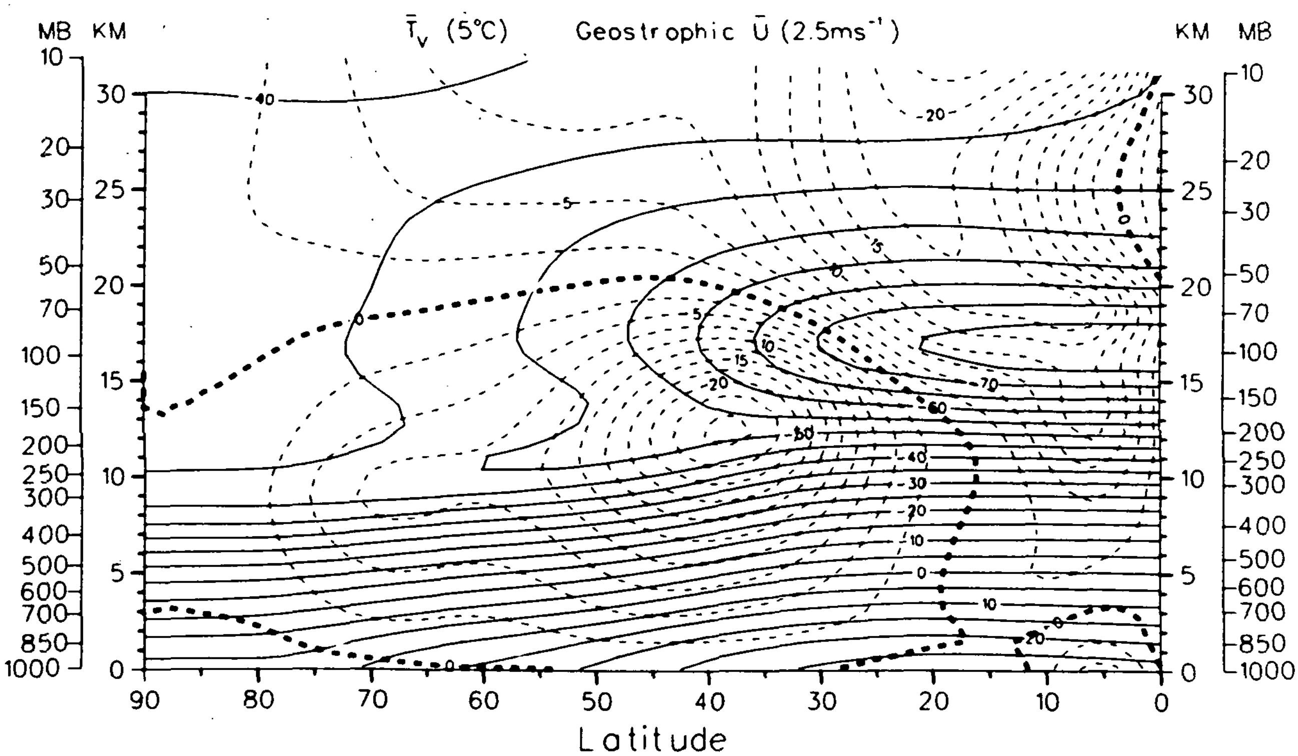

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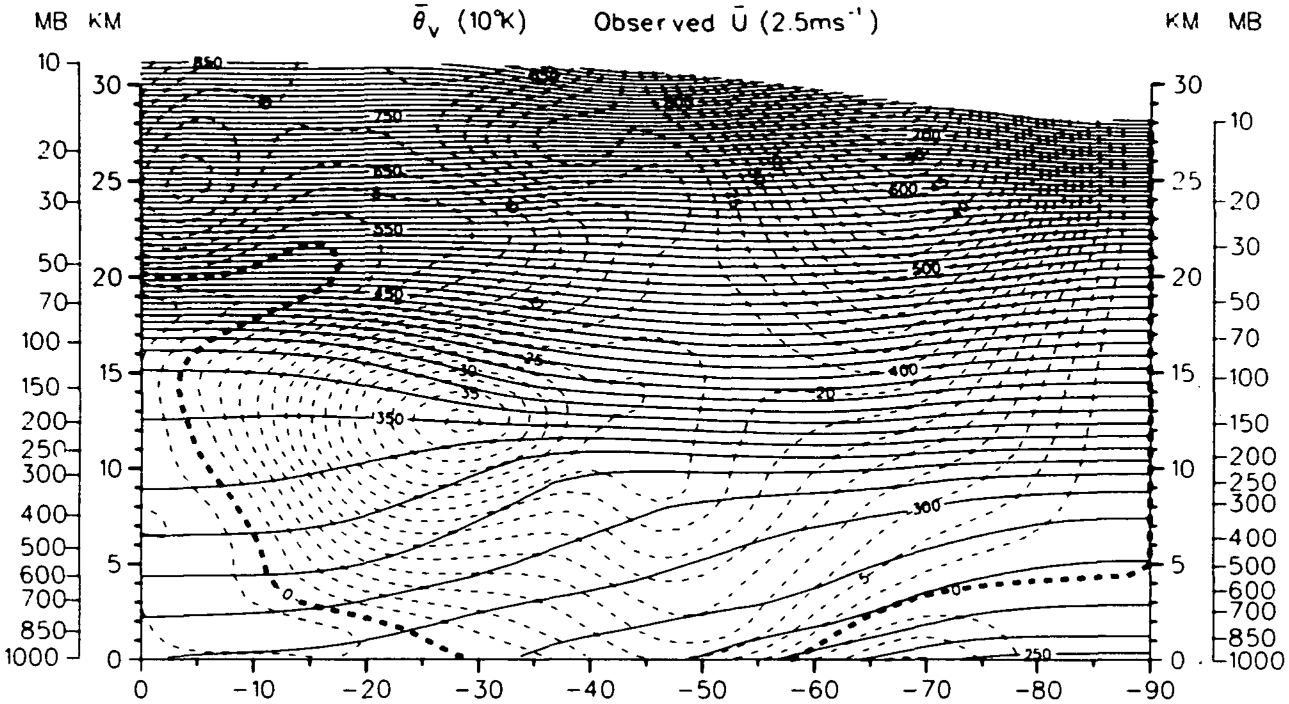

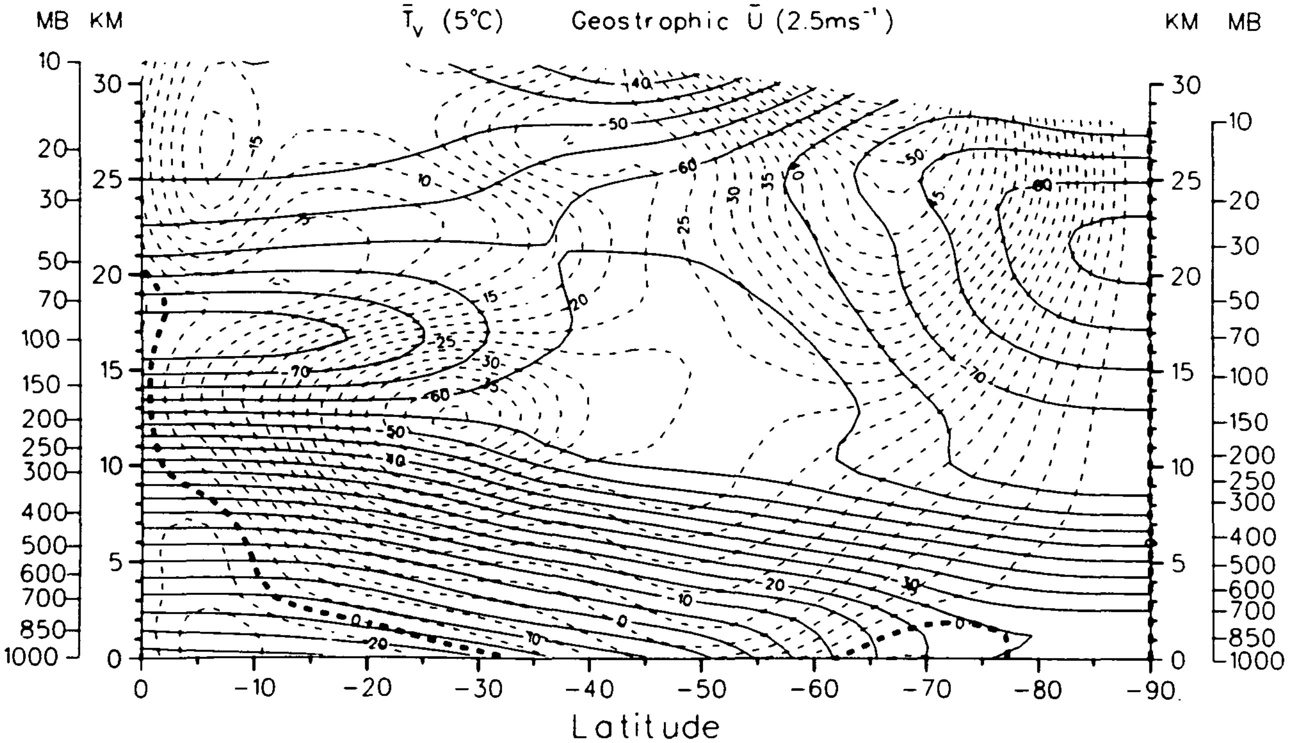

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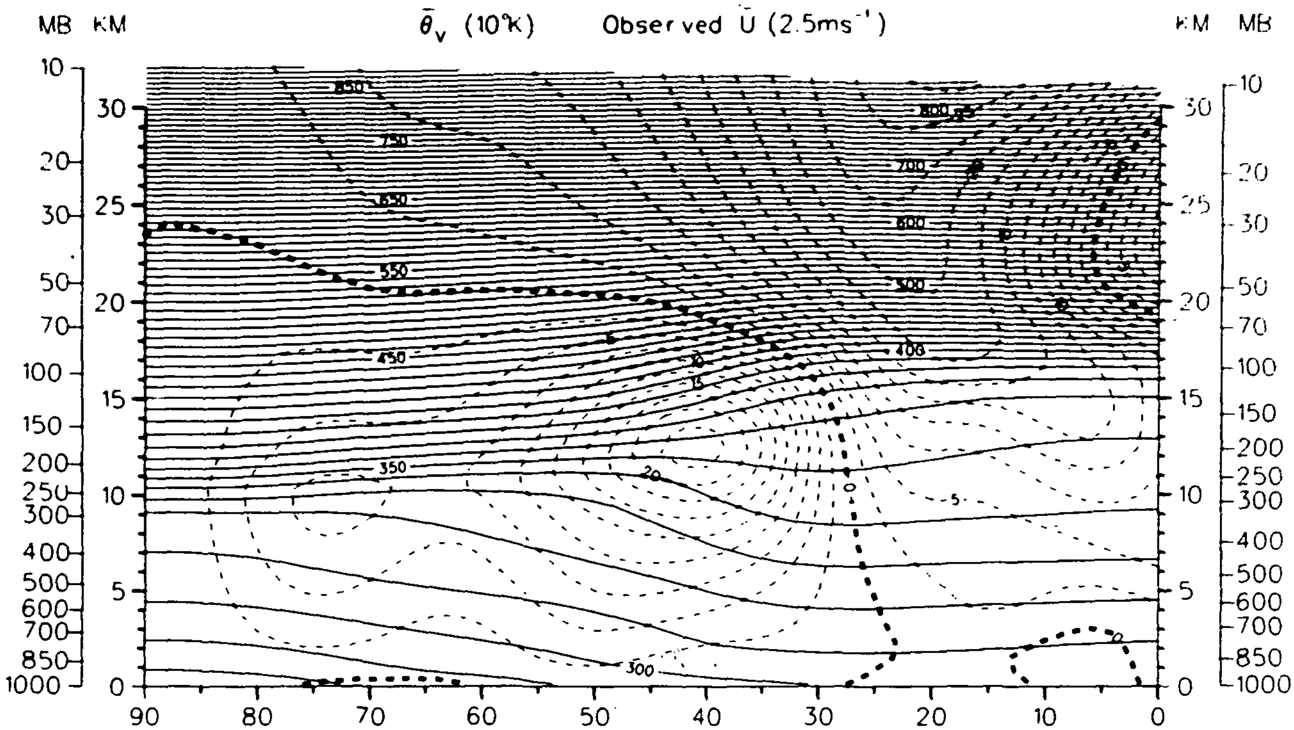

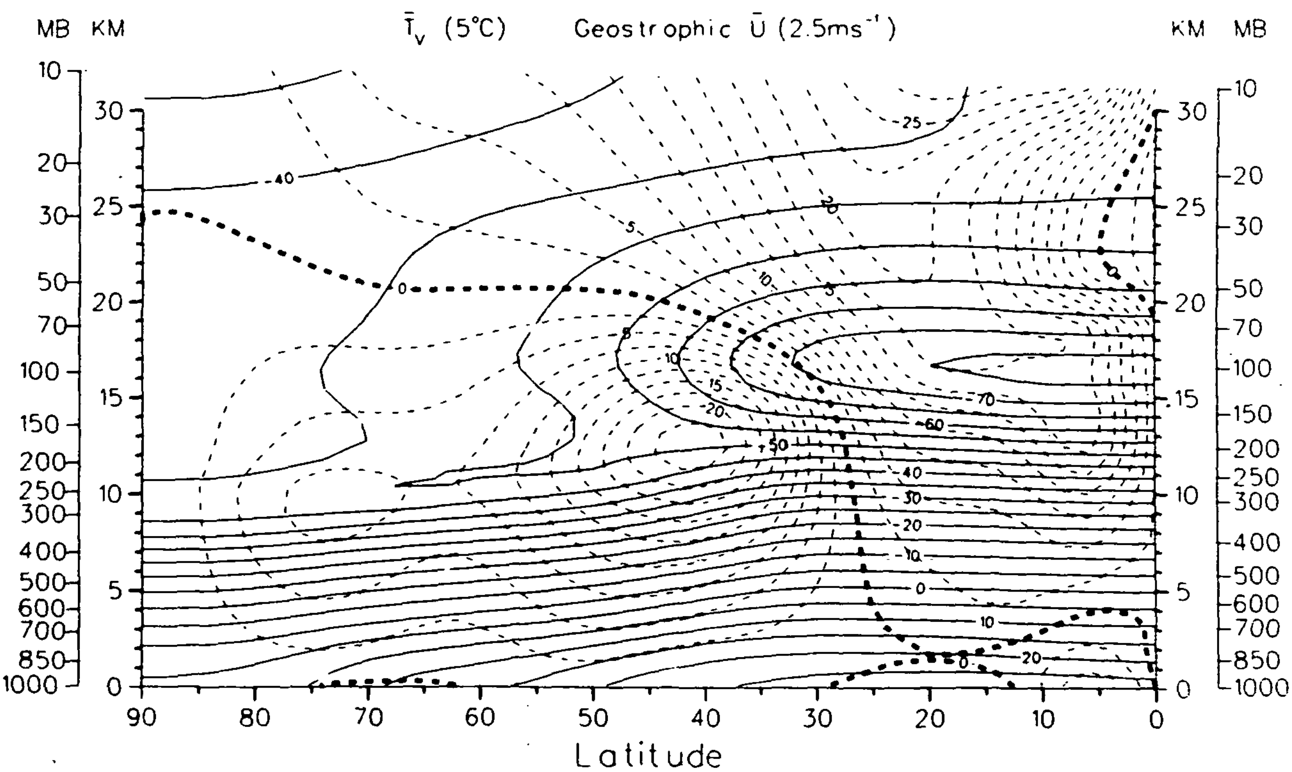

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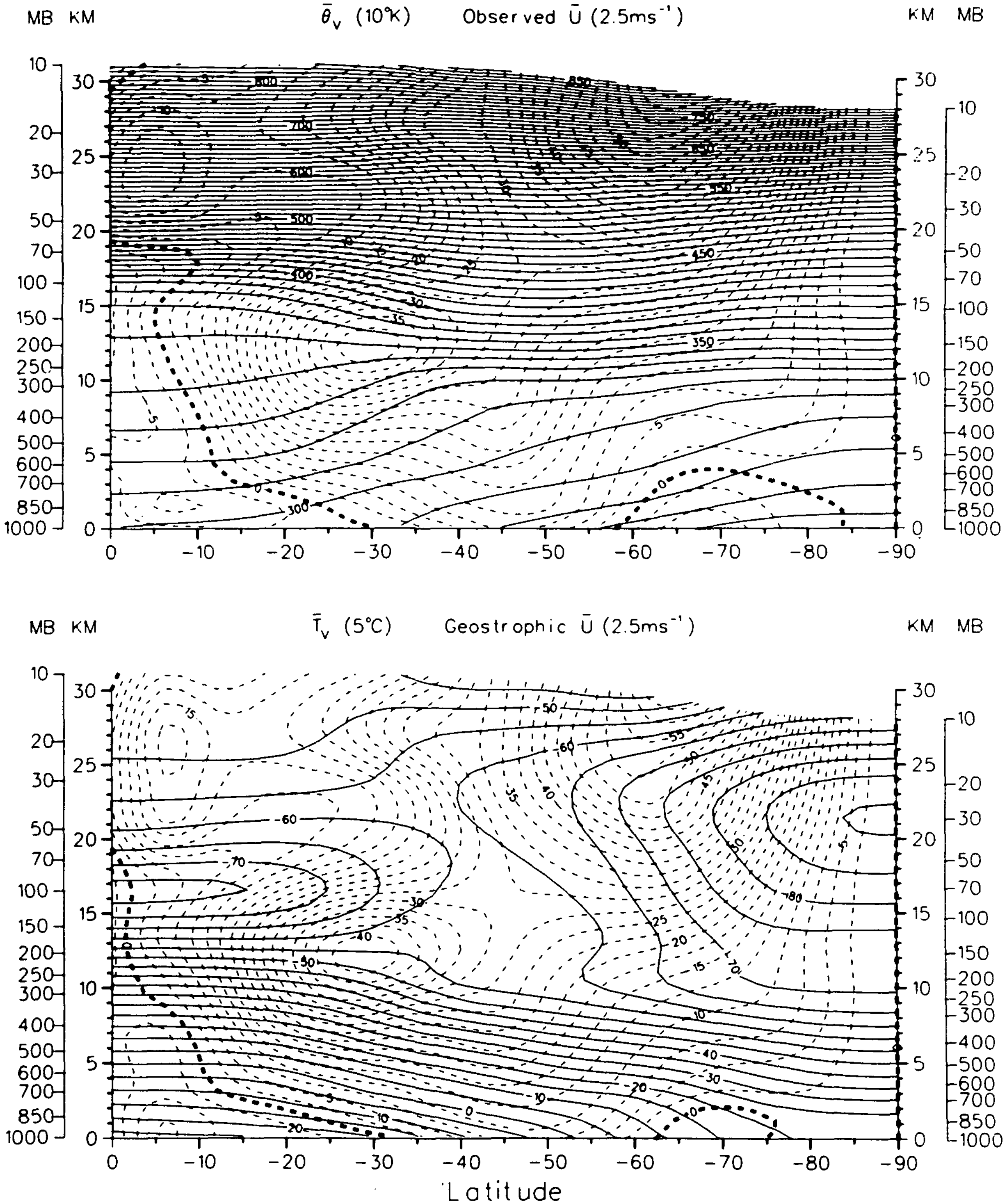

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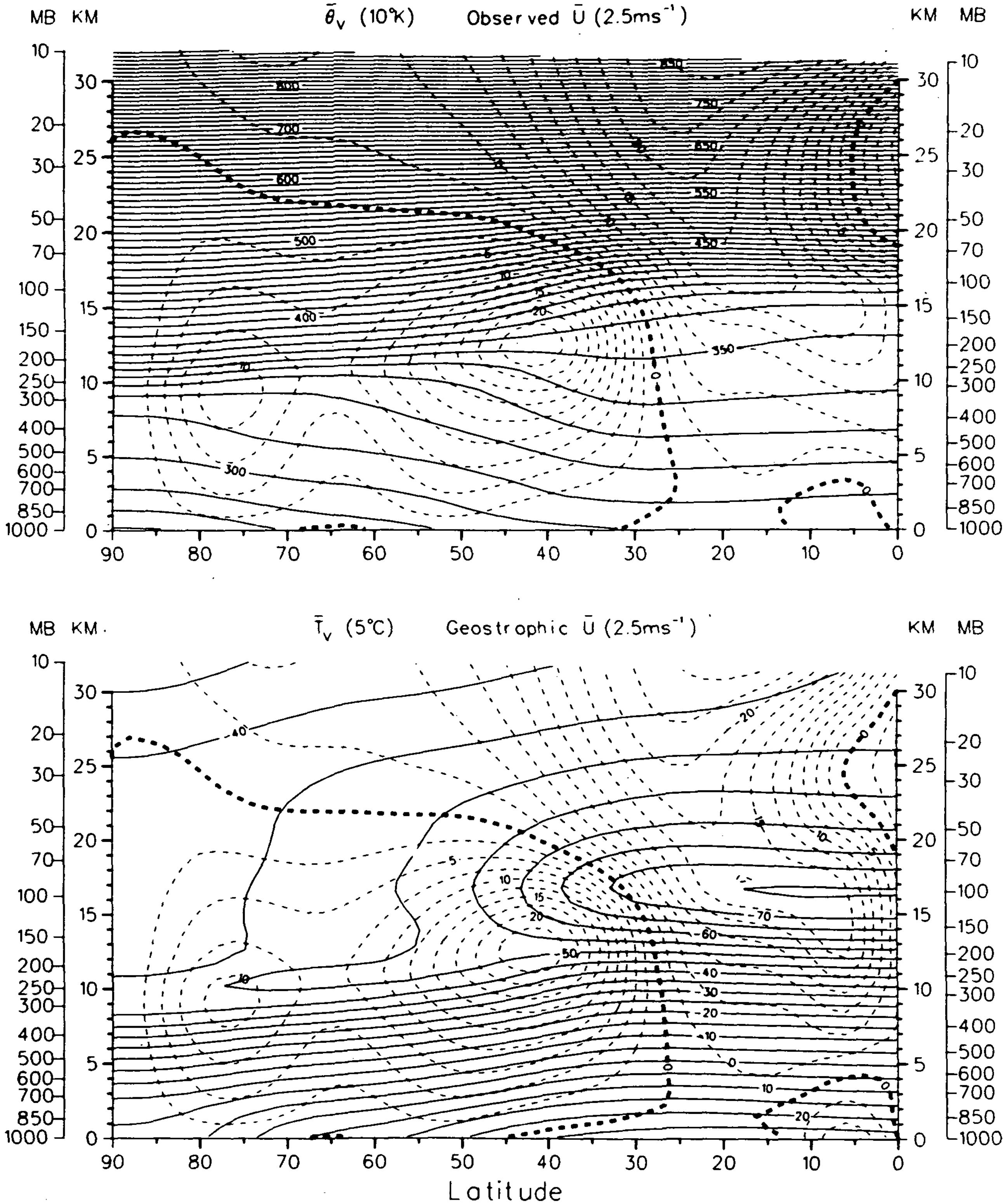

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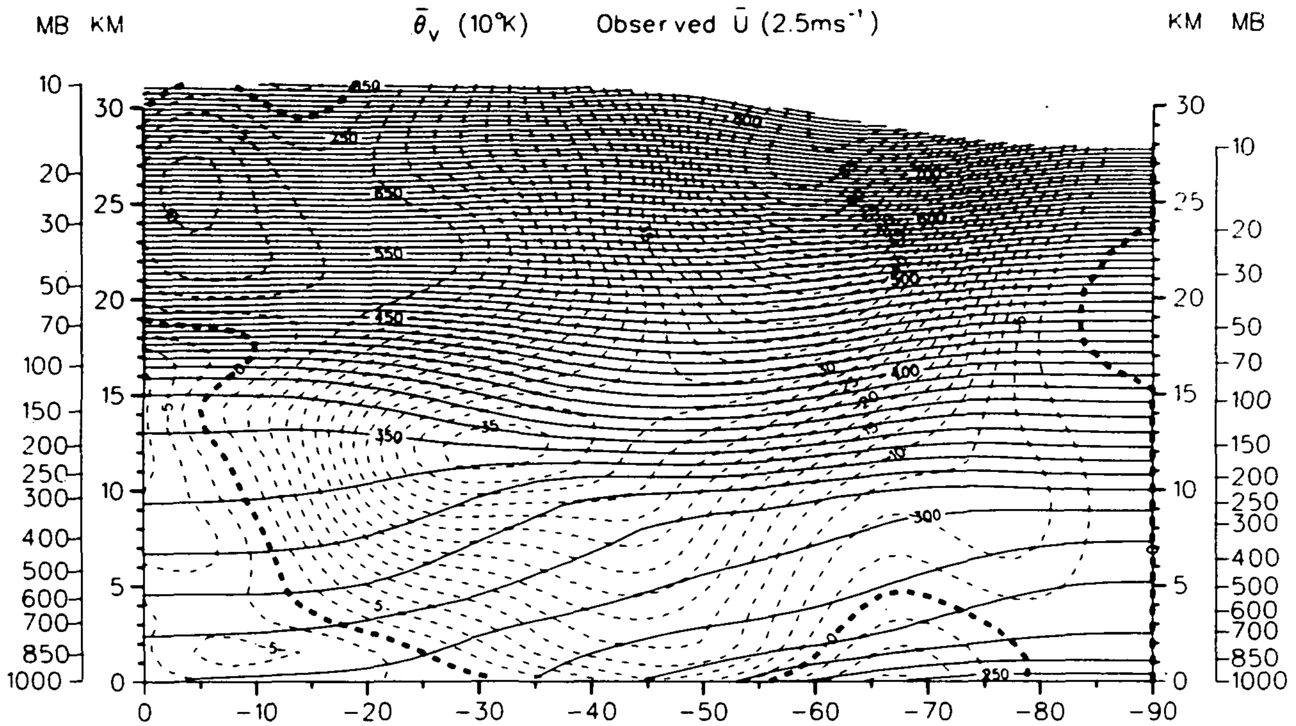

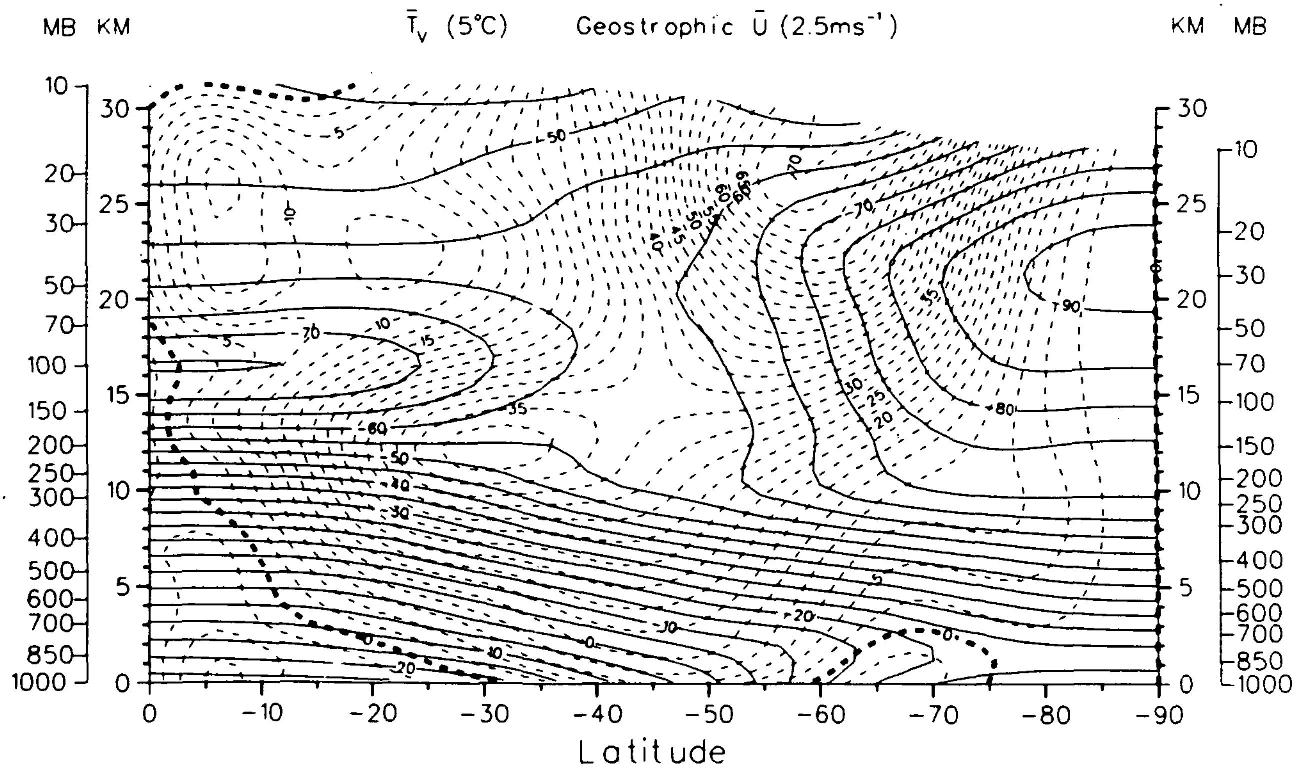

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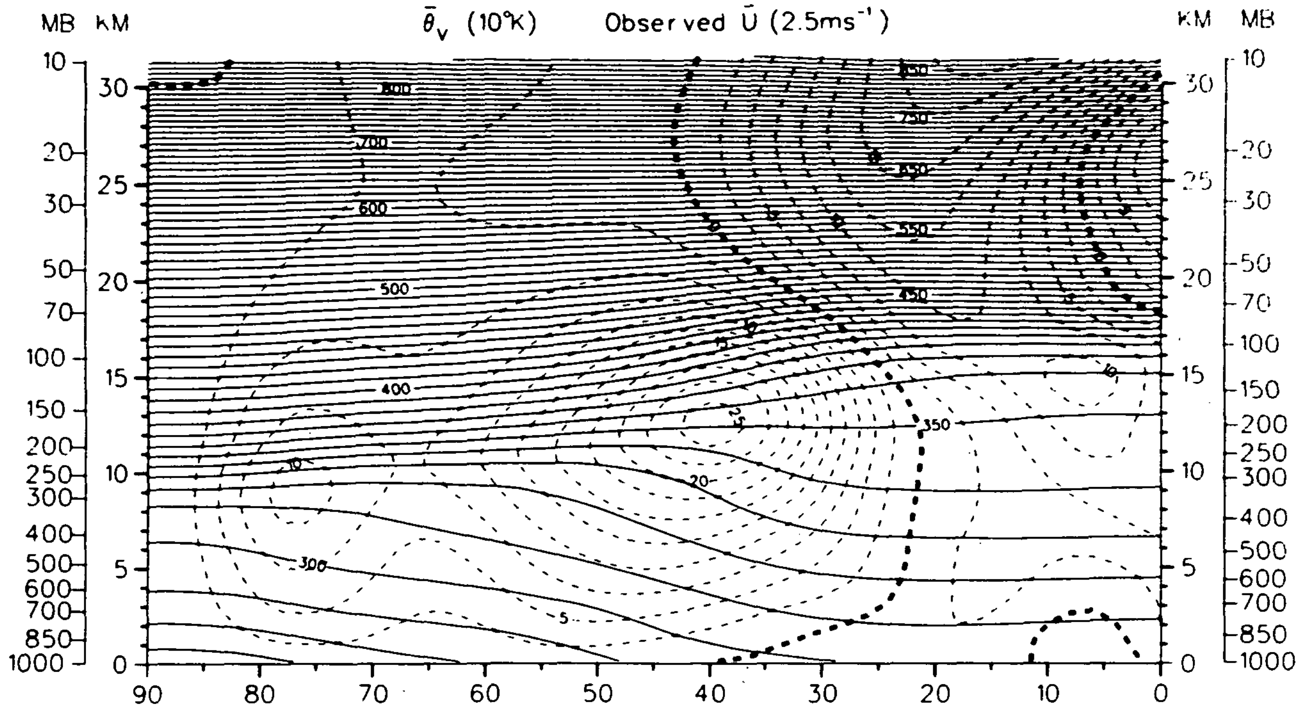

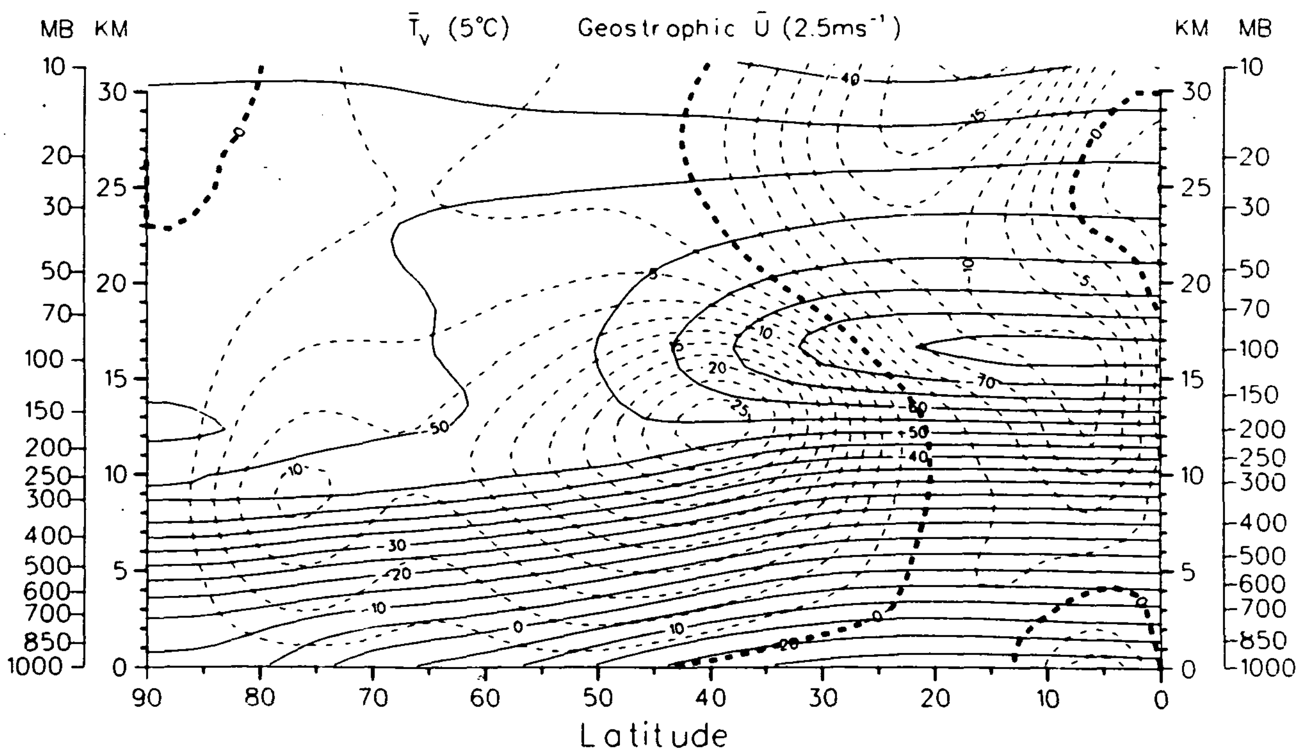

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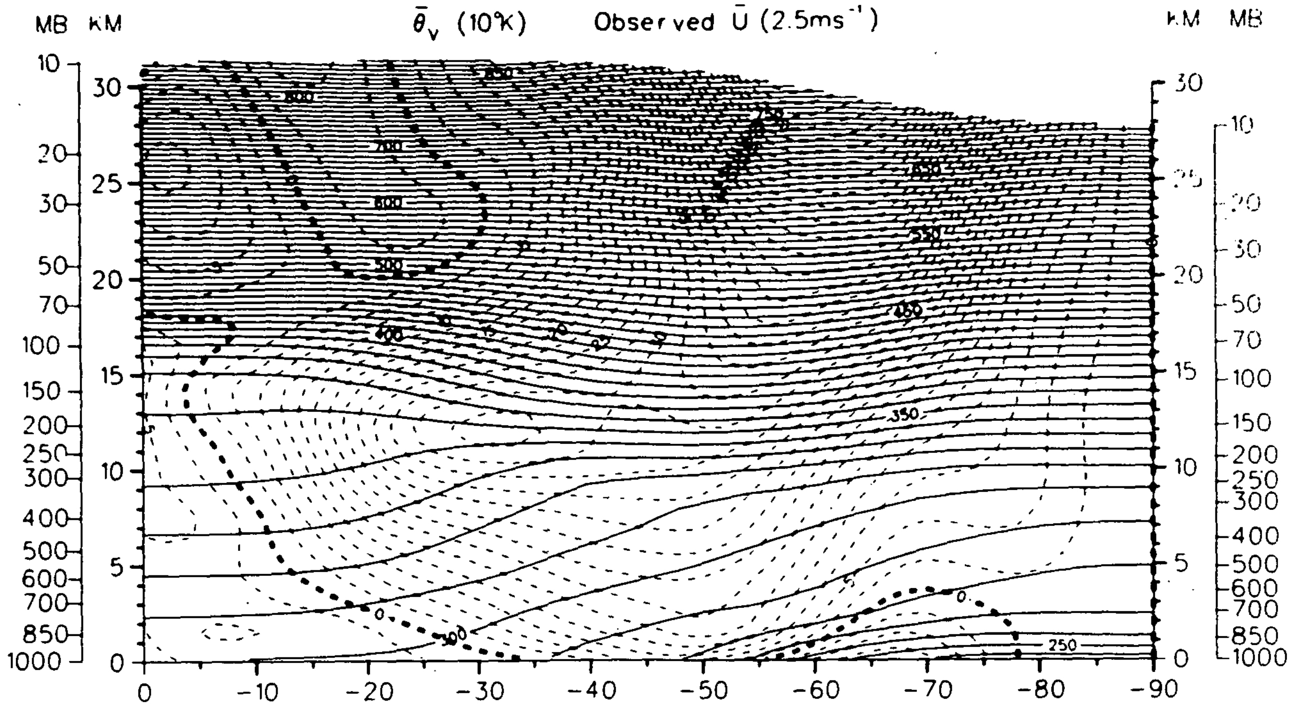
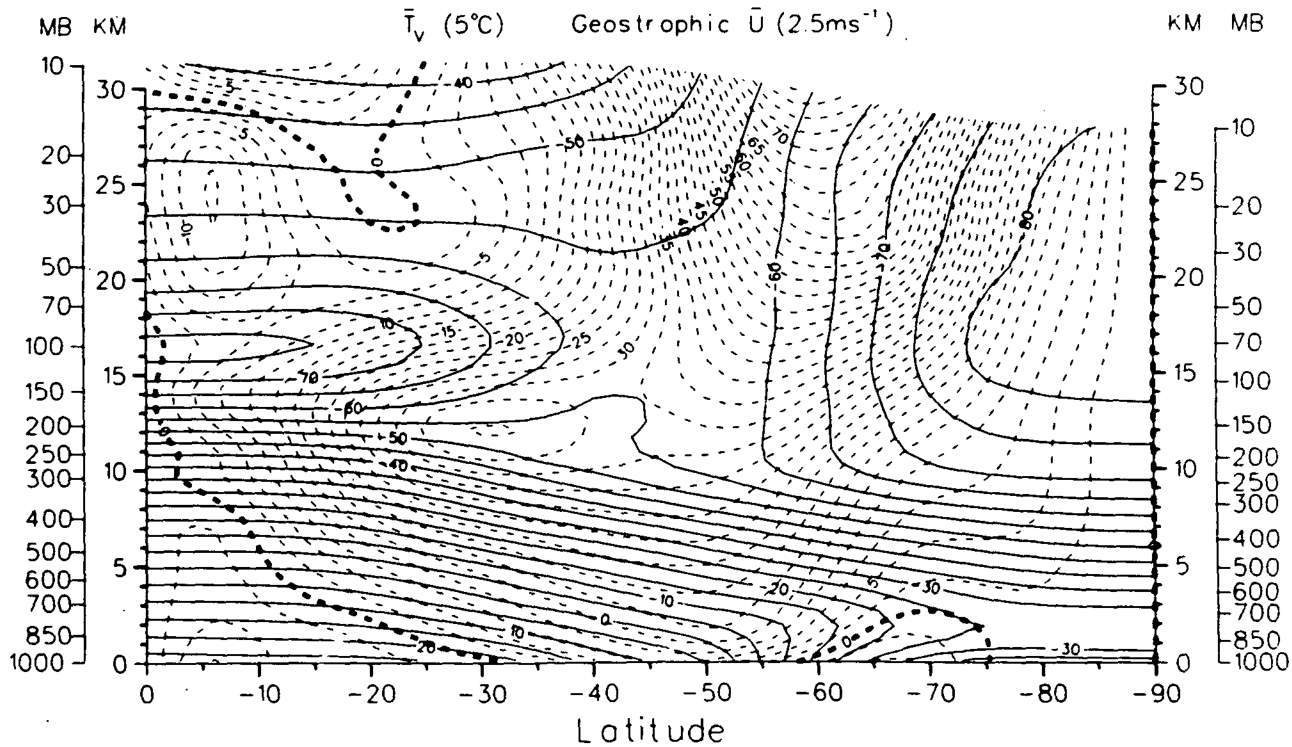
SEPTEMBER 1980





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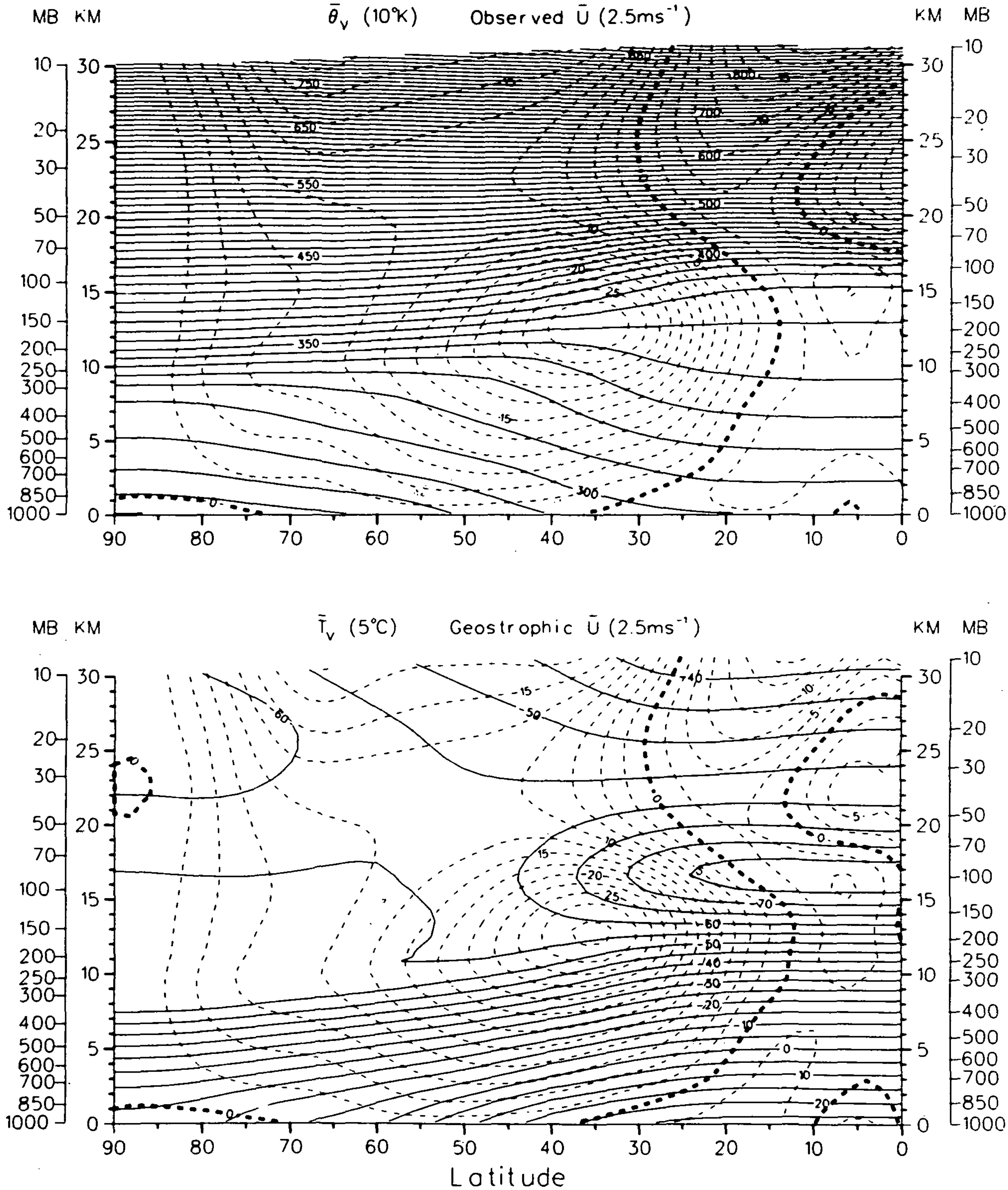

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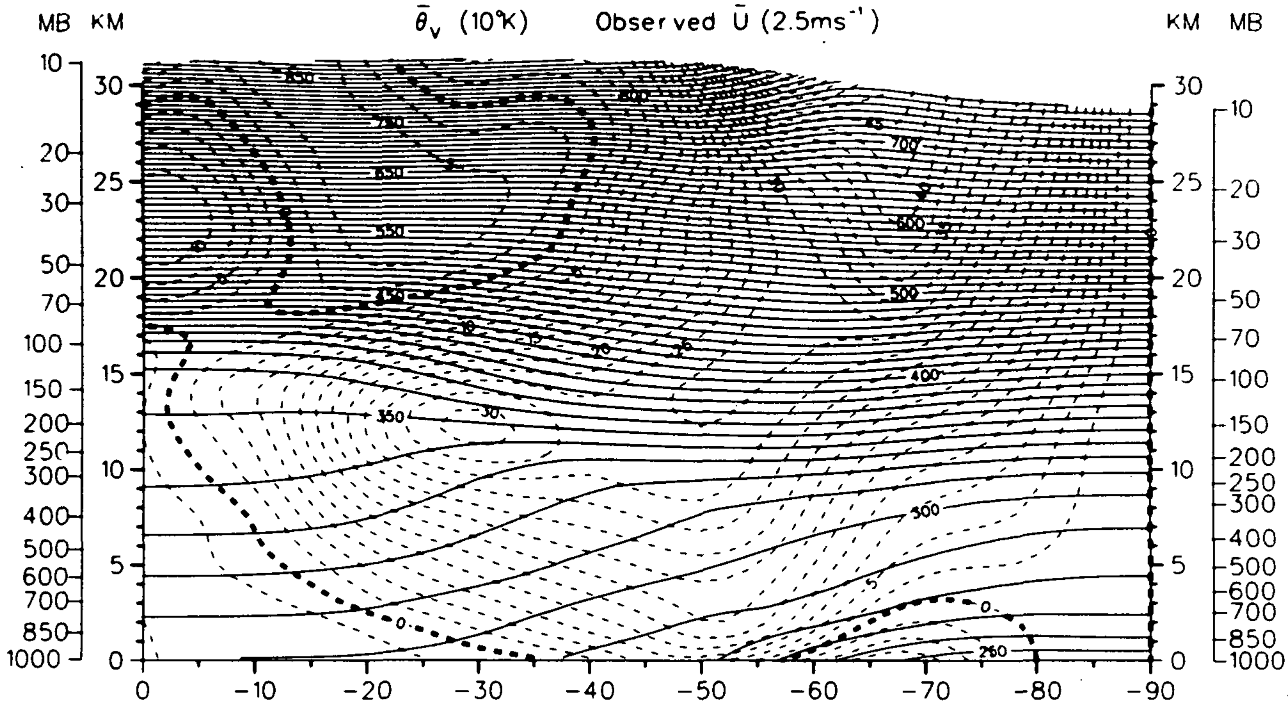

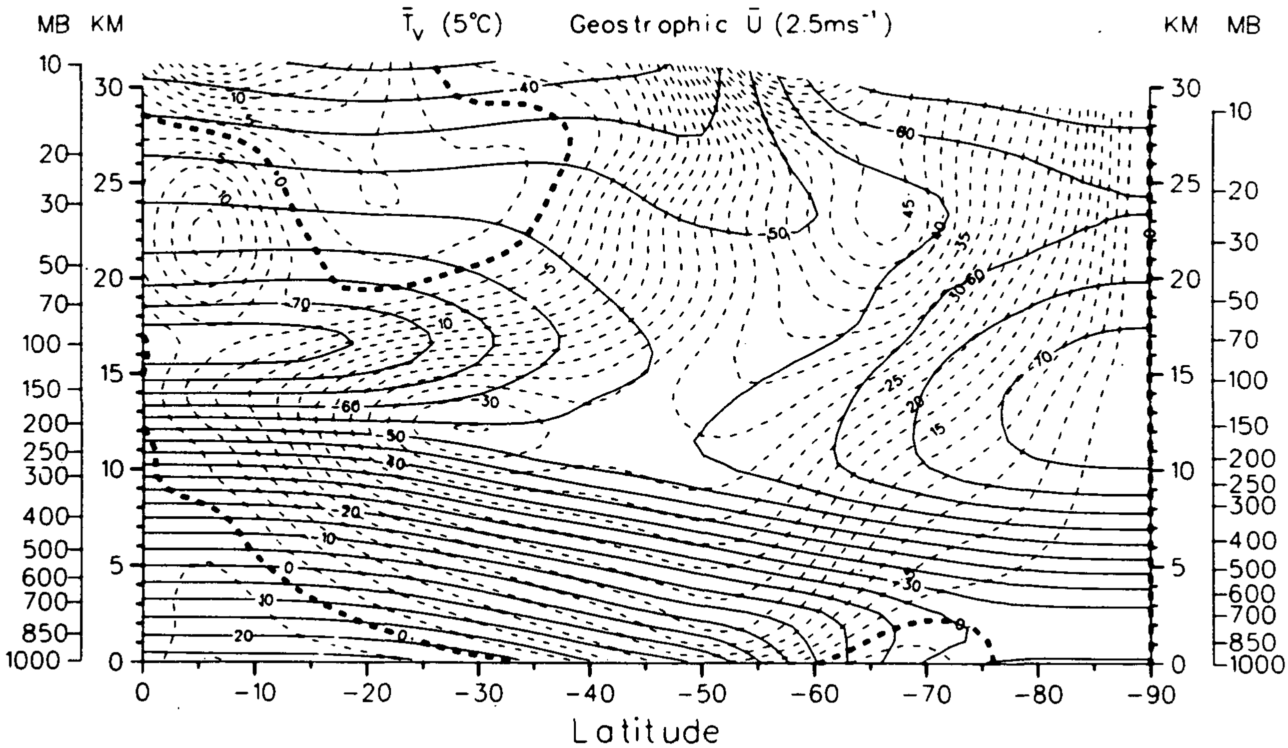

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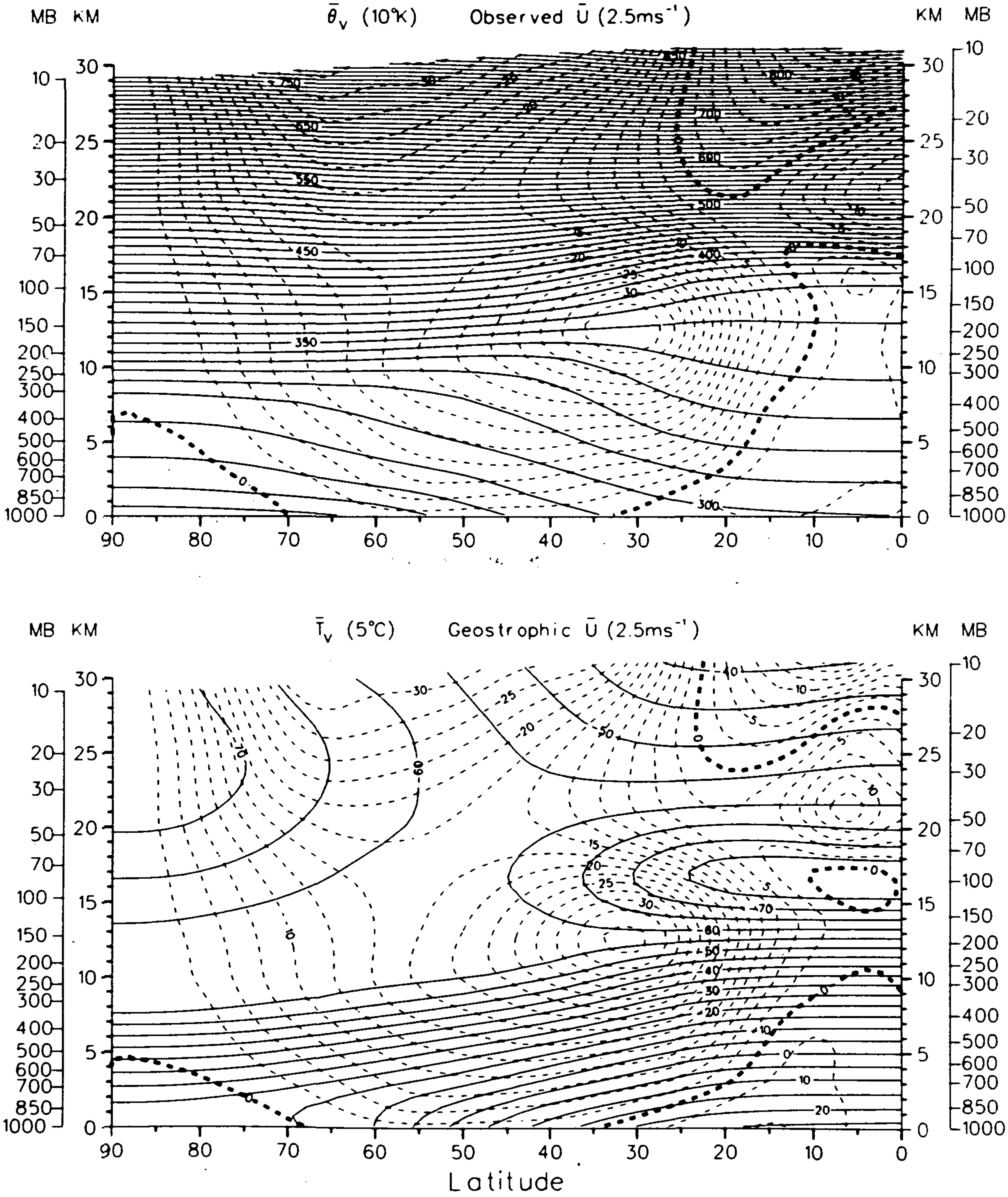

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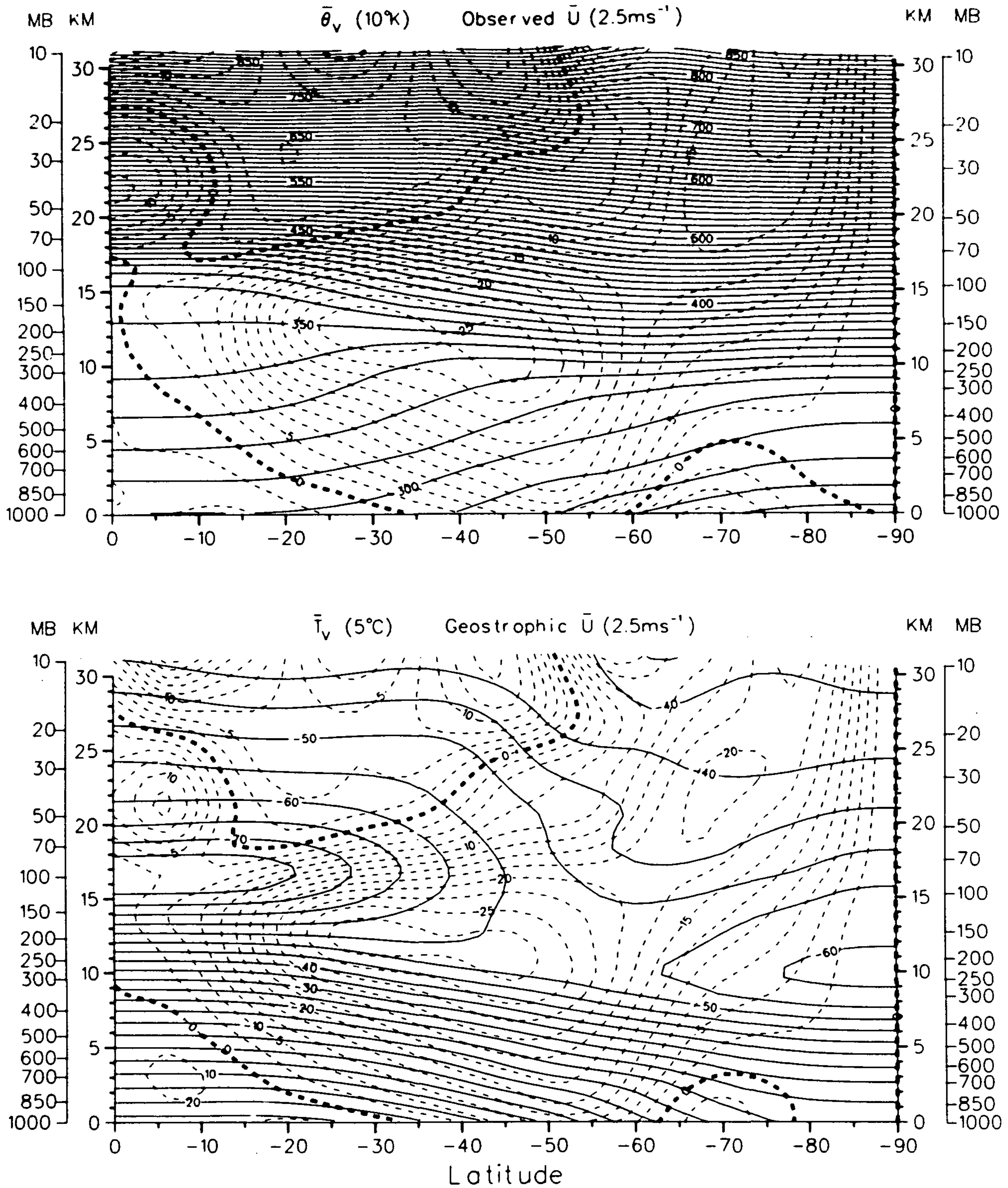

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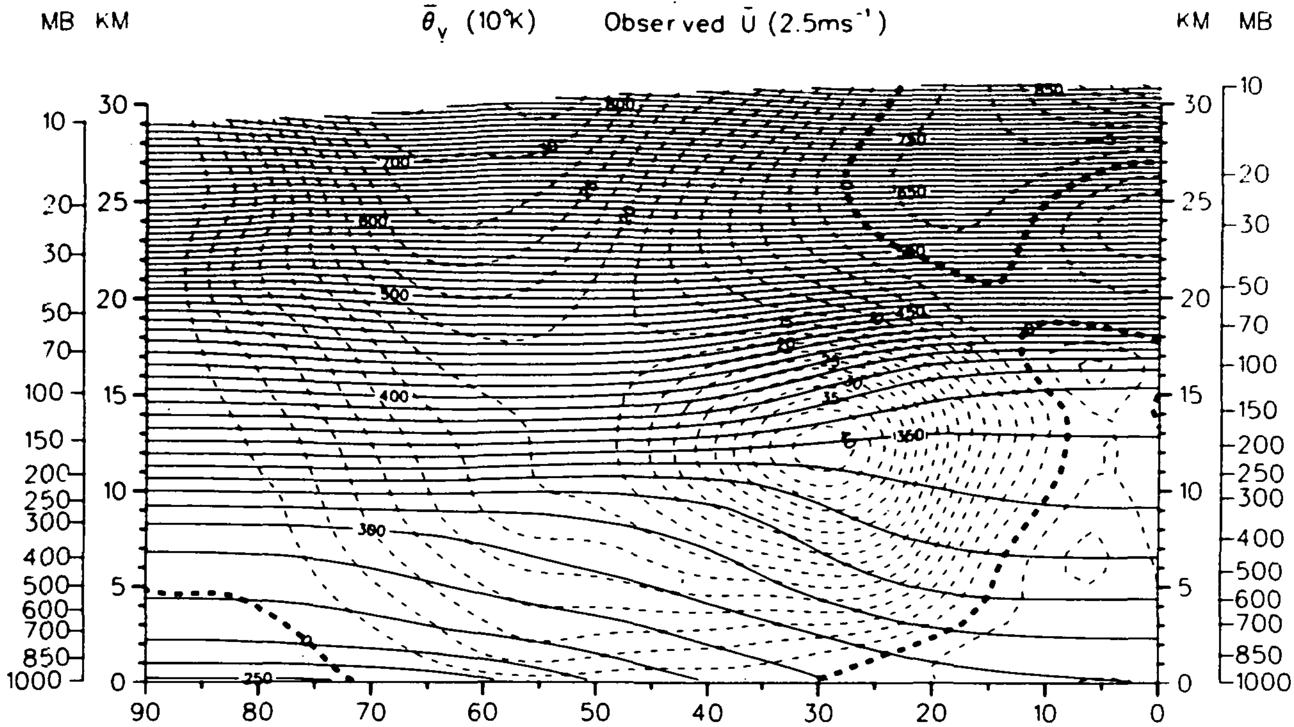

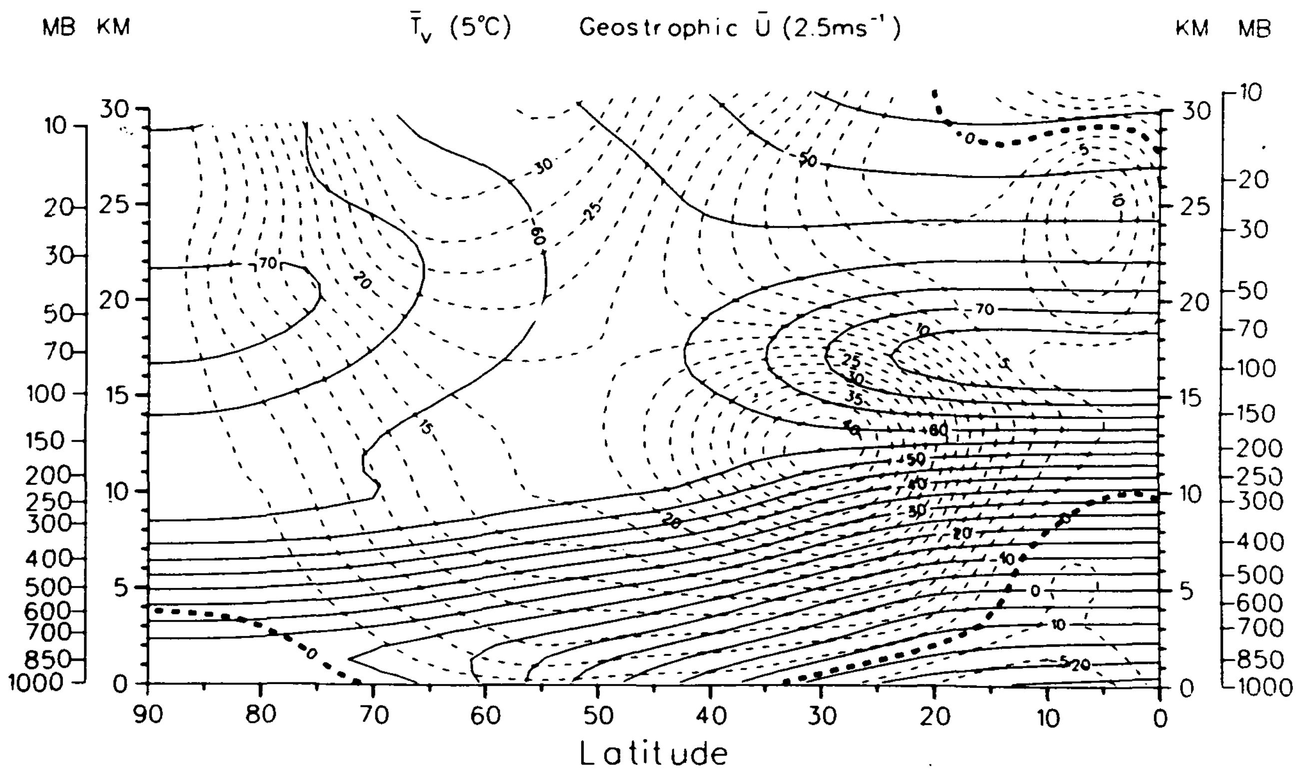

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