ΜΕΤΕΩΡΟΛΟΓΙΑ.— **Trends and Quasi-Biennial Pulses in the Temperature Field of the Stratosphere During the Period 1957 - 1972,** *by Christos S. Zerefos**. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἠλία Γ. Μαριολοπούλου.

A B S T R A C T

The mean temperature of the 30 - 50 mb isobaric layer was found to drop to the south of 60°N by about 2°C during the period 1957 - 1972. Superimposed on this trend are quasi - biennial pulses. The stratospheric temperature fluctuations are examined for northern latitude circles, ranged from 20°N to the pole and were restricted to the warmer months of the year because during these months, radiative equilibrium is known to exist in that layer.

The present work is concerned with a surprisingly high trend and obvious quasi - biennial pulses found in the mean temperature of the lower stratosphere during the sixteen - year period 1957 - 72. I started investigating the time - latitude distribution of the 30 - 50 mb thickness during the warmer months of the year, when the stratosphere is known to be in radiative equilibrium, in searching possible solar influences on that layer. The thickness of that isobaric layer was chosen as an objective representative of its mean temperature. These thicknesses were computed from mean monthly heights of the 30 mb and 50 mb isobaric surfaces from data kindly supplied by Barbara Kriester of the Berlin stratospheric group, as well as from data tabulations published in *Meteorologische Abhandlungen.*

The time - latitude distribution of the thickness of the above mentioned layer, averaged over the four months June, July, August and Septemper, is shown in figure 1. Numbers to the right correspond to the latitude circles under study and dashed lines are least square trend lines to be discussed in the following text.

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From figure 1 we can easily see that quasi - biennial oscillations are evident in the mid - low - latitude lower stratosphere, similar to the well known curius cycle observed in the equatorial circulation system at the stratonull level (see for examble Webb [**2**]). It looks as if, moving north-

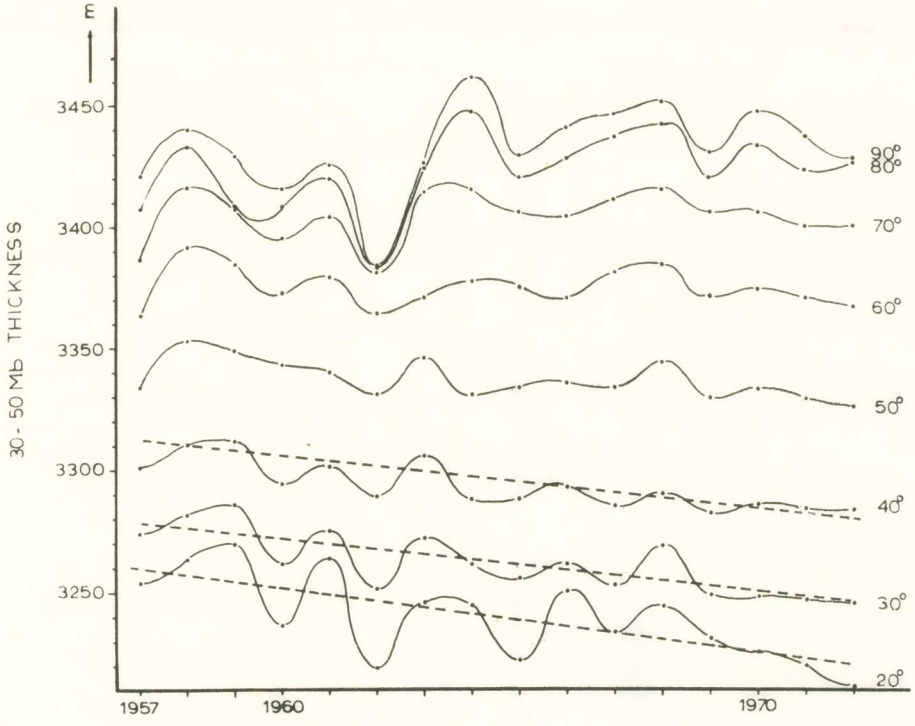

Fig. 1.

wards, this oscillation is changed to a quasi 3 - year pulse which is evident to the north of about 50°N, Angell and Korshover [**3**] examining 12-month running means of 50 mb temperatures, at a few number of stations whose location ranged from 80°N to 80°S, discussed the world wide appearance of that spectacular atmospheric oscillation.

Returning to figure 1 we can say that, since total solar heating rate alone can explain the mean monthly stratospheric temperatures during the warmer half year with a standard error of less than 2°C (Hering et al. [**1**]), several speculations can be drawn on possible radiative causes of the biennial pulses observed. We presently leave this observational evidence as a fascinating problem for feature research.

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With regard to figure 1, we can easily see that a surprisingly high trend is evident in the latitude zone between 20 and 50 deg. northern latitude. This trend was tested for its statistical significance by the well known Mann - Kentall procedure. The Mann - Kentall statistic τ is simly defined as $\tau = 4P/N(N-1) - 1$, where N is the number of observations used and P is the sum of the number of latter terms whose values exceed

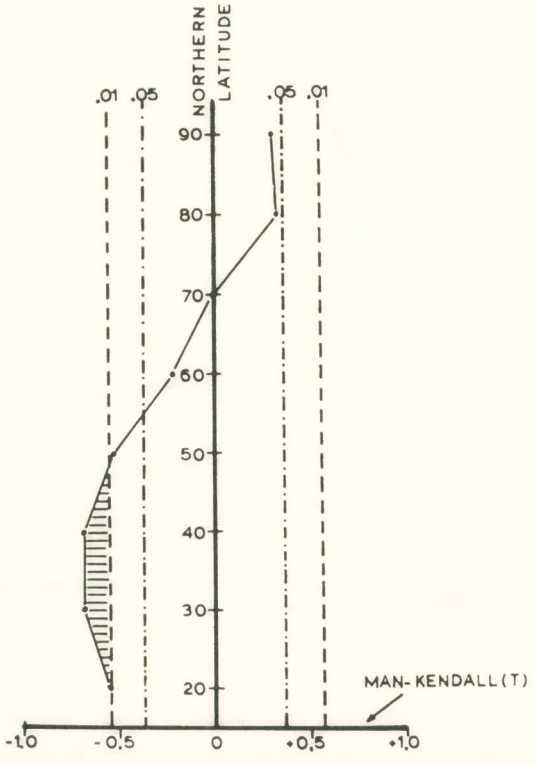

Fig. 2.

the consecutive variables under study. Inasmuch as τ is very nearly Gaussian, with zero expectation value and variance equal to $(4N+10)/9N(N-1)$, it can be easily tested for its statistical significance.

Figure 2 shows the latitude distribution of Mann - Kendall's τ together with its .05 and .01 confidence limits. As it appears from that figure, significant trends occur between 20^0 to 50^0 deg. northern latitude. The statistically significant total cooling observed in the 20 - 50 deg. latitude

zone amounts to about 40 geopotential meters, or about 2^0C during the sixteen year period under study. The small heating trend observed in the high latitude zone is found to be insignificant even at the .05 confidence level.

The cooling trend in the mid-low-latitudes, of approximately 2^0C/16-years, is in agreement with a cooling trend found in the atmosphere (between 1000 and 75 mbs) during the period 1958-63 by Starr and Oort [4] of about 0.6^0C per five years. According to these authors that strong cooling was observed both in the subtropics and at very high latitudes, and it must be pointed out that our data (fig. 1) show the same tendency during the period 1958-63. However, although this trend continued to persist in all latitudes between about 20^0-70^0N, in the very high latitude zone (80^0-90^0) it changed sign and a net, statistically insignificant, trend is found to occur after 1963. It looks as if these trends are parts of longer-term fluctuations in the free atmosphere.

A great variety of reasonable speculations can be proposed in searching an answer to the climatic trends and fluctuations discussed above. Among the factors affecting the atmospheric heat balance there are many kinds of changes in the atmosphere which could be responsible for that, air-ocean interactions, chemical composition changes, probable changes in solar radiation components e. t. c. The field is widely open to speculations and there is need of great effort to be donne in order to get further insight to the above mentioned temperature changes, which undoubtedly take place in the bulk of the atmosphere in our days.

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ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν μελέτην ἐξητάσθησαν αἱ χρονοσειραὶ τοῦ πάχους τοῦ στρατοσφαιρικοῦ στρώματος 30 - 50 mb κατὰ τὴν περίοδον 1957 - 1972, εἰς διά-

φορα πλάτη τοῦ βορείου ἡμισφαιρίου. Εὑρέθη ὅτι, νοτίως τῶν 60 μοιρῶν πλάτους, ἡ μέση θερμοκρασία τοῦ στρώματος τούτου ἀκολουθεῖ στατιστικῶς σημαντικὴν πτῶσιν, ἀνερχομένην εἰς 2 περίπου βαθμοὺς Κελσίου κατὰ τὴν ὑπὸ μελέτην περίοδον. Ἡ εὑρεθεῖσα ψῦξις τῆς κατωτέρας στρατοσφαίρας εὑρίσκεται ἐν συμφωνίᾳ πρὸς ἑτέρας πειραματικὰς διαπιστώσεις ἀναφερομένας εἰς τὸ κείμενον. Ἐπιπροσθέτως τῆς κλιματικῆς ταύτης τάσεως πρὸς ψῦξιν, εὑρέθησαν αἱ γνωσταὶ σχεδὸν · διετεῖς κυμάνσεις. Τὰ εὑρεθέντα ἀποτελέσματα ἀποκτοῦν ἔτι μεγαλυτέραν στατιστικὴν ἀξίαν λόγῳ τοῦ ὅτι ἐξήχθησαν ἐξ ὁμογενοῦς ὑλικοῦ προσεκτικῶς ἐπεξειργασμένου ὑπὸ τοῦ Πανεπιστημίου τοῦ Βερολίνου, ἀφοροῦν δὲ οὐχὶ εἰς μεμονωμένους σταθμούς, ἀλλὰ εἰς ὁλόκληρον τὸ ἡμισφαίριον. Αἱ εὑρεθεῖσαι κλιματικαὶ μεταβολαὶ ἀποτελοῦν πιθανῶς τμήματα μακρῶν διακυμάνσεων τῆς ἐλευθέρας ἀτμοσφαίρας

REFERENCES

1. W. S. Hering, C. N. Tuart and T. R. Borden, J. Atmos. Sci., **24** (1967), 402.
2. W. L. Webb, International Geophys Series, Vol. 9 (Chapt. 3), Academic Press, N. Y. and London, (1966).
3. J. K. Angell and J. Korshover, J Atmos. Sci., **21** (1964), 479.
4. V. P. Starr and A. H Oort, Nature, **242** (1973), 310.