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

A B S T R A C T

The mean temperature of the 30 - 50 mb isobaric layer was found to drop by about 2^0C 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 - 1972. 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 (Hering et al. **1**), 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 *Meteorologisch Abhandlungen.*

The time-latitude distribution of the thickness of the above mentioned layer, averaged over the four months June, July, August and September, 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.

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

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the stratonull level (see for example Webb **2**). It looks as if, moving Northwards, this oscillation is changed to a quasi 3-year pulse which is evident to the North of about 50° N. The whole pattern indicates that possibly at the 50° N latitude zone, a filter is operating in the meridional direction, if we wand to link the mid-low-latitude quasi-biennial to the high latitude quasi- 3-year oscillations. Angell and Korshover (**3**) exa-

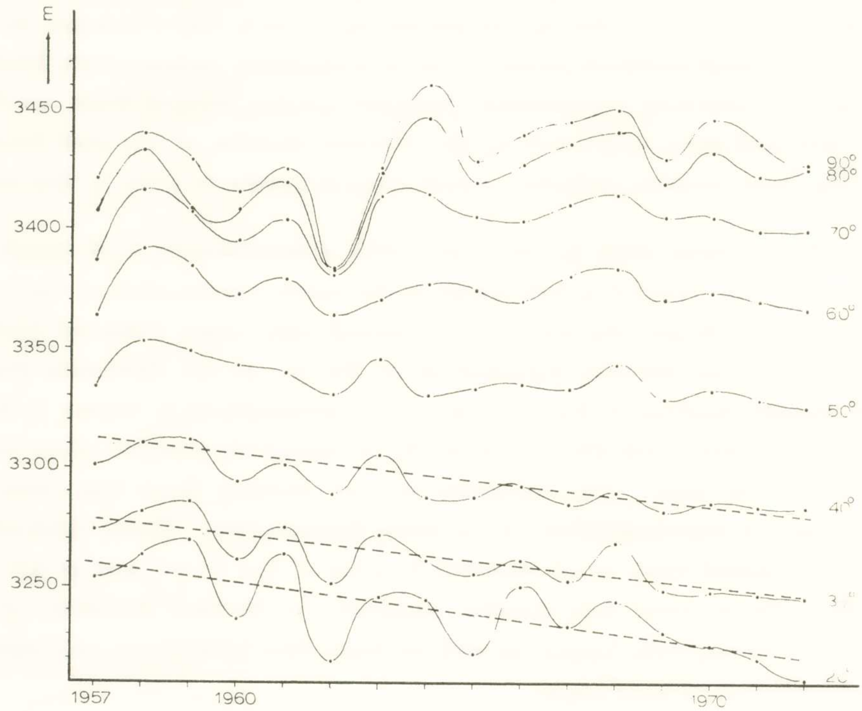

Fig. 1. Time-latitude distribution of 30 - 50 mbs thicknesses averaged over the months June, July, August and September, during the period 1957 - 1972. Dashed lines are trend least square lines.

mining 12-month running means of 50 mb temperatures, at a few number of stations, whose location ranged from 80° N to 80° S, were the first to discuss the worldwide 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 20° 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.

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. latitude. This trend was tested for its statistical significance by the well known Mann-Kendall procedure. The Mann-Kendall statistic τ is simply defined as $\tau = 4P/N(N-1) - 1$, where N is the number of observation used and P is the sum of the number of latter terms, whose values exceed 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 compensatory heating trend observed in the high latitude zone is found to be insignificant even at the .05 confidence level.

The cooling trend found in mid-low-latitudes, of approximately 2^0C/16-years, is found to be 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 - 1963. However, although this trend continued to persist in all latitudes between about 20° - 70° N, in the very high latitude zone (80° - 90°) 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 and air-ocean interactions, chemical composition changes, probable changes in solar radiation componets e.t.c. The field is widely open to arguments and there is need of great effort to be donne in

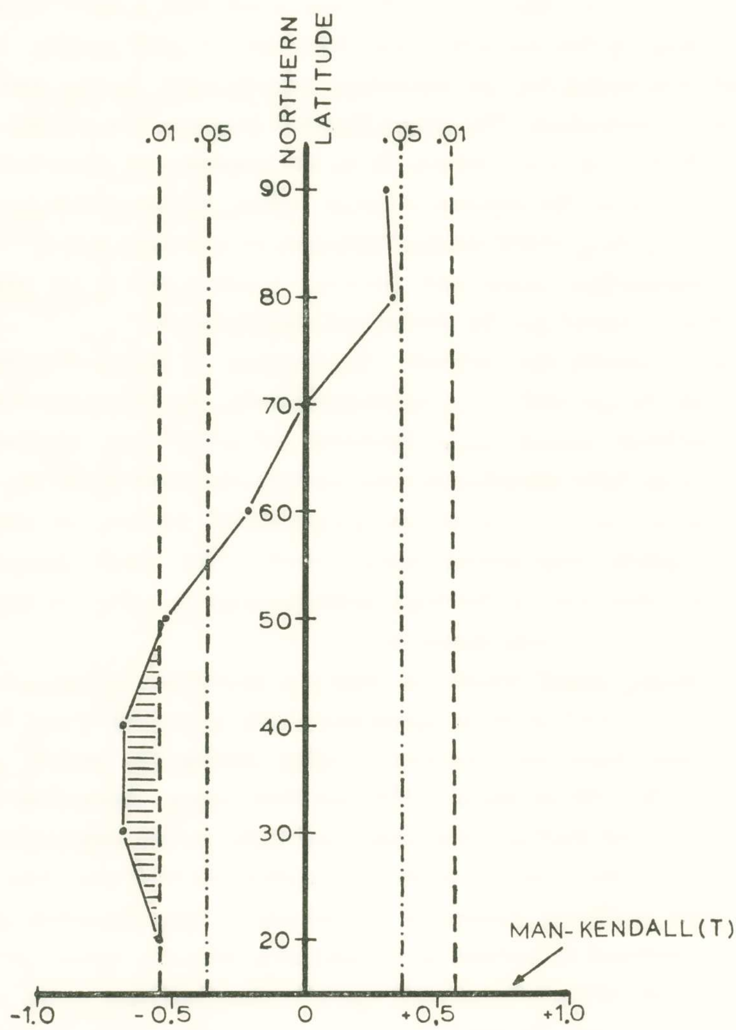

Fig. 2. A Test of statistical significance of trends observed in figure 1 (see text).

order to get further insight to the above mentioned temperature changes, which undoubtedly take place in the bulk of the atmosphere in our days.

ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν μελέτην ἐξητάσθησαν αἱ μεταβολαὶ τοῦ πάχους τοῦ στρώματος ἐκείνου τῆς στρατοσφαίρας, τοῦ περιλαμβανομένου μεταξὺ τῶν ἰσοβαρικῶν ἐπιφανειῶν 30 mb καὶ 50 mb, εἰς ὁλόκληρον τὸ βόρειον ἡμισφαίριον καὶ δὴ κατὰ τὴν περίοδον 1957 - 1972. Ἡ ἀνάλυσις τῶν ἀπὸ ἔτους εἰς ἔτος μεταβολῶν τοῦ πάχους τοῦ στρώματος τούτου περιωρίσθη εἰς τοὺς θερμοὺς μῆνας Ἰούνιον, Ἰούλιον, Αὔγουστον καὶ Σεπτέμβριον, ὅτε, ὡς γνωστόν, ἡ στρατόσφαιρα εὑρίσκεται εἰς ἰσορροπίαν ἀκτινοβολίας (Hering κ. ἄ., 1967). Τὸ πάχος τοῦ στρώματος 30 - 50 mb δέον ὅπως θεωρηθῇ ὡς ἀντιπροσωπευτικὸν τῆς μέσης θερμοκρασίας τοῦ στρώματος τούτου. Εὑρέθη ὅτι εἰς τὰ νοτιώτερα τῶν 50° Ν πλάτη, ἡ μέση θερμοκρασία τοῦ ὑπὸ μελέτην ἰσοβαρικοῦ στρώματος ἐπιδεικνύει σχεδὸν διετεῖς κυμάνσεις, ἀναλόγους πρὸς τὰς διετεῖς κυμάνσεις τοῦ ζωνικοῦ ἀνέμου εἰς τὴν τροπικὴν στρατόσφαιραν, αἵτινες δὲν ἔχουσιν εἰσέτι ἑρμηνευθῆ ὡς πρὸς τὴν φυσικὴν αὐτῶν αἰτίαν. Ὡσαύτως, διὰ τοῦ στατιστικοῦ ἐλέγχου τῶν Mann-Kendall, εὑρέθη στατιστικῶς σημαντικὴ κλιματικὴ τάσις (Trend) εἰς τὴν μέσην θερμοκρασίαν τοῦ ἀνωτέρω ἰσοβαρικοῦ στρώματος, ἐφ᾽ ἧς ἐπιπροστίθεται ἡ ἀνωτέρω ἀναφερθεῖσα διετὴς κύμανσις. Εἰς τὰ πλάτη, τὰ περιλαμβανόμενα μεταξὺ τῶν παραλλήλων 50° καὶ 20° βορείου πλάτους, ἡ ἀνωτέρω κλιματικὴ τάσις συνίσταται εἰς ψῦξιν τοῦ ὑπὸ μελέτην ἰσοβαρικοῦ στρώματος κατὰ 2 βαθμοὺς Κελσίου ἐντὸς τῆς ὑπὸ μελέτην περιόδου.

Τὰ εὑρήματα τῆς παρούσης μελέτης ἐπιβεβαιοῦν προγενέστερα τοιαῦτα διὰ τὴν τροπόσφαιραν, εἰς τὸ κείμενον δὲ ἀναφέρονται διάφοροι φυσικαὶ αἰτίαι, αἵτινες εἶναι ἱκαναὶ ὅπως προκαθορίσωσιν τὰς κλιματικὰς μεταβολάς, τὰς ὁποίας ὑφίσταται ἡ στρατόσφαιρα κατὰ τὰ τελευταῖα ἔτη.

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