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TOTAL OZONE AND TEMPERATURE VARIATIONS IN THE LOWER STRATOSPHERE AND RELATED TELECONNECTIONS IN THE MEDITERRANEAN AREA

By

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Abstract: *Monthly and daily total ozone and 100 mb temperature correlations and telecorrelations at Cagliari, Messina and Athens are investigated. It was found that 100 mb temperature and total ozone were better correlated on a monthly than on a daily basis and related suggestions are given. Horizontal advection and vertical motion were found to be almost exactly opposite with respect to the 24 - hour ozone and 100 mb temperature changes. During the summer the above correlations were found to be fairly high both on a monthly and on a daily basis, resulting to an interannual variation of the ozone - temperature correlation coefficient. The summer high correlation could be explained assuming that the variation of both ozone and 100 mb temperature caused by meridional advection in this area under study have probably the same sign during that season. Total ozone telecorrelations were found to be higher during the winter. These telecorrelations displayed a rather weak longitudinal dependence. Yearly total ozone and 100 mb temperature correlations and telecorrelations did not differ from the 11 - year period (1960 - 1970) correlation at the 5 % level.*

INTRODUCTION

According to the classical photochemical theory, first formulated by Chapman (1930), the presence of atmospheric ozone is due to photodissociation and recombination processes. Following the classical theory, the photochemical distribution of atmospheric ozone will depend on the availability of the solar UV - radiation as well as on atomic and molecular concentrations of the various gases involved in the photodissociative and recombination processes. The photochemical theory predicts a maximum ozone concentration between 25 - 35 km height, a latitude ozone gradient with maximum values in low latitudes and minimum values at high latitudes, and a seasonal variation with ozone maximum in the summer and minimum in the winter hemispheres. However, observational material showed that total ozone and its vertical distribution display a high - latitude maximum during the spring and a minimum in autumn.

The discrepancy between the photochemical prediction and the actual space and time ozone distribution led to a modification of the «classical» theory which incorporated thereon the effects of air motions (see for example, PROBAKARA, 1963). In several papers (BREWER, 1949, DOBSON, 1956 et al.) it was suggested that the meridional circulation in addition to the photochemical processes might be responsible for the space and time distribution of atmospheric ozone.

Presently it is accepted that only a small fraction of atmospheric ozone, mainly that found above 30 km height, is in photochemical equilibrium. Ozone in the lower stratosphere, transported there by large scale descent of the air with which it is mixed, is well shielded by the ozone above it. Since a small amount of ozone is found in the troposphere and the photochemical equilibrium region is above about 30 km, total ozone variations will be related to perturbations in the middle and lower stratosphere. Indeed, total ozone content was found to be fairly well correlated with stratospheric temperatures (DUTSCH, 1963, KULKARNI, 1968, FIGUEIRA, 1972 and others) as well as with various meteorological

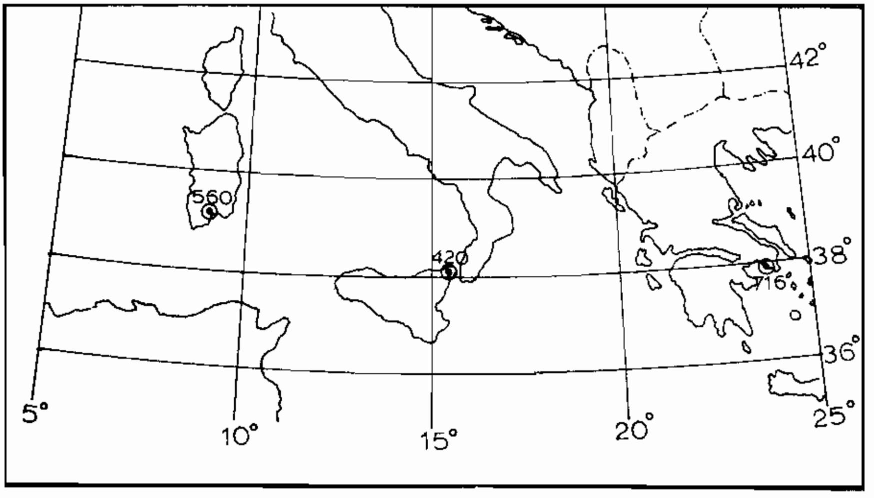


Fig. 1

parameters of the upper troposphere and lower stratosphere (KULKARNI. 1963, et al.). The complicated scheme of the mutual ozone- temperature interrelations, was recently discussed by Dütsch (1971).

Horizontal and vertical ozone transfer in middle and high latitudes, is now well known to be connected with the occurence of depressions and anticyclones (see for example TABA, 1961, SEKIGUCHI, 1972 and others). Advection and vertical motions accompanied by horizontal divergence and convergence were suggested to explain some significant correlations found between short - term total ozone and temperatures chauges in the upper troposphere and lower stratosphere (KULKARNI, 1963).

The present work is an acconnt to both long and short term total ozone and lower stratosphere temperature correlation at about the 38⁰ deg. latitude circle in the area defined by the meridians 09⁰ E to 24⁰ E, namely for the stations Cagliari (39⁰ 15′ N, 09⁰ 3′ E, Messina (38⁰ 12′ N, 15⁰ 33′ E) and Athens (37⁰ 54′ N, 23⁰ 48′ E) (see figure 1).

2. DATA USED

Monthly and Daily total ozone amount data at Cagliari and Messina were taken from the «Ozone Data for the World» for the period 1960 - 1971. Mean monthly temperatures at the 100 mb level were taken from the «Monthly Climatic Data for the World» for Cagliari (1965 - 1971) and Messina (1965 - 1966). Daily radiosonde, observations for Cagliari were taken from the «Northern Hemisphere Data Tabulations». Monthly and daily radiosonde data for Athens, were taken from «Bulletin Mensuel Climatologique», kindly supplied by the National Meteorological Service of Greece.

3. MONTHLY AND DAILY TOTAL OZONE AND 100 - MB TEMPERATURE CORRELATIONS.

Day to day ozone changes are at least as large as the long-term ozone variations. Correlation studies between total ozone and lower stratospheric temperatures showed that on a seasonal basis correlations were generally lower than on a day to day basis (KULKARNI, 1968) the correlation being positive throughout the year (DUTSCH, 1963). Kulkarni suggested that the mechanisms responsible for day to day changes are quite different from those responsible for the seasonal changes in both ozone and lower stratospheric temperatures. Dütsch (1963) found that the ozone - temperature correlation was greater during the cold season than during the summer, an effect which was attributed to the decrease in the intensity of vertical motions from winter to summer and possibly to the different sign of ozone and temperature variations caused by meridional advection during the warm part of the year.

Similar results were found by KULKARNI (1968) for Brisbane but not at Aspendale for which the best correlation was found to occur during the summer. SEKIGUCHI (1972) in order to explain an interannual variation of the ozone - lower stratosphere temperature correlation postulated a phase shift between the annual ozone and temperature distributions.

Our first task was to investigate the above mentioned features of the correlation between ozone and temperature in the lower stratosphere at Cagliari for which rather complete total ozone and 100 mb temperature data were available to us. The correlation coefficient between mean monthly total ozone and 100 mb temperature for the period 1965 - 1971 (76 pairs) was found to be + 0.683. This correlation was reduced to + 0.332, when based on 213 pairs of daily total ozone and 100 mb temperatures for the year Dec. 1968 to Nov. 1969.

Although both correlation coefficients are different from zero at a better than the 1 % level and positive, they are however exactly the opposite of what was to be expected from the previous work discussed above, i.e. lower correlations are found on a short - term than on a long - term basis.

Next we considered monthly and daily ozone - temperature correlations obtained at Cagliari for the four seasons of the year, which are shown in Table I.

TABLE I

Total ozone and 100 - mb Temperature Correlations

Cagliari	Winter	Spring	Summer	Fall
Daily Corr.	+ 0.121 (61)	— 0.248 (52)	+ 0.562 (29)	+ 0.261 (68)
Monthly Corr.	+ 0.539 (17)	+ 0.016 (19)	+ 0.710 (21)	+ 0.418 (19)

From Table I it appears that significant (at the 1 % level) correlations are found only during the summer season. The general rule of positive total ozone - 100 mb temperature correlation is not confirmed during the spring. However an interannual change of the correlation coefficient is found both for the daily and for the monthly correlations. This could resulted from a phase shift between the annual total ozone and 100 - mb temperature distribution as it was postulated by Sekiguchi (1972), but we shall become at this point later on. Before ending this paragraph we should mention that monthly mean ozone - 100 mb temperature at Messina was found to be + 0.830, but because of incomplete daily and monthly data no further discussion is dedicated on it.

4. Mechanism of local short - term temperature and ozone changes.

In the following lines we shall study the local three dimensional temperature and ozone changes during a short time interval, namely in 24hours.

The potential temperature Θ in the lower stratosphere can be considered to be conserved during the air motion in a short time period (say in 24 hours). Thus the total differential $\frac{d}{dt} = \frac{\partial}{\partial t} + \vec{V}.\ \text{grad} + + W \frac{\partial}{\partial z}$ ($\vec{V}$ = horizontal wind vector, W = vertical air velocity (positive upwards) and z the vertical coordinate) applied to Θ must satisfy the equation:

$$\frac{d\Theta}{dt} = 0$$

Using pressure as the vertical coordinate and because $\Theta = T\ (Po/P)^{\frac{Cp-Cv}{Cp}}$ we can easily get the local temperature change on an isobaric level at any fixed point, which is found to be:

$$\left(\frac{\partial T}{\partial t}\right)_p = -\vec{V}.\ \text{grad}\ T - \omega \frac{T}{\Theta} \frac{\partial \Theta}{\partial p} \qquad (1)$$

where $\omega = dp/dt$ (the p - velocity) and $\left(\frac{\partial T}{\partial t}\right)$ means the time derivative of temperature at constant pressure and constant geographical coordinates.

A similar expression to (1) can be found in the case of local change in the ozone mixing ratio q on an isobaric level above fixed geographical coordinates, assuming that q is conserved during a short time period, namely that $dq/dt = 0$. The equation is:

$$\left(\frac{\partial q}{\partial t}\right)_p = -\vec{V}.\text{grad}q - \omega \frac{\partial q}{\partial p} \qquad (2)$$

From equations (1) and (2) it follows that during a given time interval we can divide local temperature and ozone changes at a given station into two components: one due to horizontal advection and another due to vertical motion. The resultant local temperature or ozone change is smaller in magnitude than either of the corresponding horizontal and vertical components, their signs being opposite to each other. In the case of local total ozone changes, SEGIKUCHI (1972) found after a simple manipulation of equation (2) that

$$\frac{\partial \Omega}{\partial t} = - <\vec{V}>.\text{grad}\,\Omega + <\omega>\Delta q \qquad (3)$$

where $<\vec{V}>$ and $<\omega>$ are the mean horizontal wind vector and the mean vertical p - velocity, Ω is the total ozone amount and Δq the difference between the ozone mixing ratio above about 30 km and that below about the 100 mb level ($\Delta q \simeq 8\ \mu g/g$).

From the above mentioned expressions (1) and (3), it seemed reasonable to investigate the interrelations between the horizontal and vertical ozone and temperature change components at Cagliari. Horizontal ozone gradients were computed from data for Cagliari and Messina, and temperature gradients were computed from Cagliari and Athens radiosonde data. All calculations were based on daily observations during the one year period Dec. 1968 to Nov. 1969. Calculated quantities at Cagliari are as follows:

1. Temperature and ozone 24 - hour changes as a result of horizontal advection at the 100 mb level ($-\vec{V}$.gradT and $-\vec{V}$.grad Ω respectively).

2. Differences between the 24 - jour local temperature change observed (δT) and the temperature change due to horizontal advection at the 100 level, i.e (δT) + $\vec{V}$.grad T.

3. Differences between the 24 - hour local total ozone change observed ($\delta\Omega$) and the ozone change as a result of horizontal advection at the 100 mb level, i.e. ($\delta\Omega$) + $\vec{V}$.grad Ω.

Differences in 2) and 3) are considered to be estimates of the 24 - hour temperature (or ozone) changes due to vertical motion.

Figure 2 shows monthly mean values of $-\vec{V}$. grad T, $\vec{V}$.grad Ω, (δT) + $\vec{V}$.grad T and ($\delta\Omega$) + $\vec{V}$.grad Ω, for the year Dec. 1968 to Nov. 1969. From that figure it appears that a strong counteraction exists between the mean monthly by vertical motion and by horizontal advection 24 - hour ozone or temperature changes respectively. The counteraction between the 24 - hour ozone change components strengthens during the winter and early spring while regarding temperature

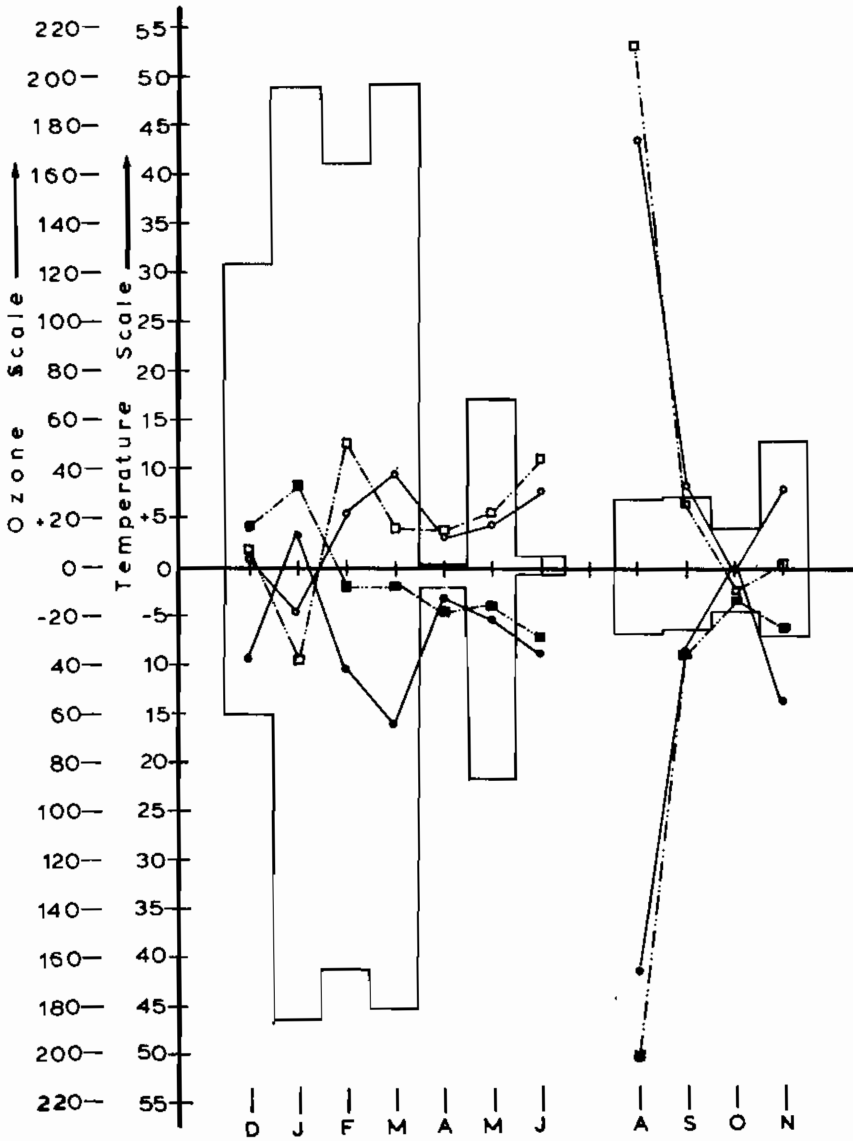


Fig. 2

changes horizontal advection and vertical motion compensate each other much more during the month of August than during the other months (no July radiosonde data were available in these calculations).

Table II shows the correlation coefficients between the 24 - hour ozone and temperature change components for the one year period Dec. 1968 - Nov. 1969, at Cagliari.

TABLE II

Ozone and temperature 24 - hour change components

Cagliari	(δT)	$-\vec{V}$.grad T	$(\delta T) + \vec{V}$.grad T
$(\delta\Omega)$	+ 0.160 (156)	— 0.047 (96)	+ 0.063 (81)
$-\vec{V}$.grad Ω	+ 0.193 (137)	+ 0.022 (93)	— 0.257 (80)
$(\delta\Omega) + \vec{V}$.grad Ω	— 0.160 (129)	— 0.144 (90)	+ 0.176 (77)

From Table II it appears that corresponding temperature and ozone 24 - hour change components are positively correlated, although correlation coefficients are insignificant at the 1 % level and the advective ozone and temperature changes are almost independent of each other. However, considering the 5 % significance level we can see from this table that (δT) with $(\delta\Omega)$ and $(\delta T) + \vec{V}$.grad T with $(-\vec{V}$.grad $\Omega)$ are significantly correlated the later negatively in agreement with what was to be expected.

Table III shows the correlation coefficients between the ozone 24 - hour change components as well as their correlations with the local 24 - hour temperature change at Cagliari for the four seasons of the one year period Dec. 1968 - Nov. 1969.

The main results from Table III are summarized as follows:

1) During all seasons the large negative correlation between the 24 - hour ozone change due to horizontal advection and vertical motion, reflects the strong compensation between these terms, which was also evident when monthly mean values were computed (figure 2).

2) The local ozone change in 24 hours is much more affected by vertical motions than by horizontal advection during all seasons, because correlation coefficients between $(\delta\Omega)$ and $(\delta\Omega) + \vec{V}$.grd Ω are positive and significant (excepting summer) at the 1 % level.

3) The effect of ozone change due to horizontal advection on local

ozone 24 - hour change although positive is negligible in winter and summer. However during the transition periods of spring and autumn, (δΩ) and its change by horizontal advection are rather significantly coupled.

TABLE III

	(δΩ)	$-\vec{V}$.grad Ω	(δΩ) + $\vec{V}$.grad Ω	(δT)
		WINTER		
(δΩ)	1	+ 0.012 (37)	+ 0.496 (30)	+ 0.179 (43)
$-\vec{V}$.grad Ω		1	— 0.990 (37)	+ 0.265 (33)
(δΩ) + $\vec{V}$.grad Ω			1	— 0.302 (32)
		SPRING		
(δΩ)	1	— 0.337 (40)	+ 0.500 (40)	+ 0.161 (35)
$-\vec{V}$.grad Ω		1	— 0.989 (40)	+ 0.261 (34)
(δΩ) + $\vec{V}$.grad Ω			1	— 0.305 (31)
		SUMMER		
(δΩ)	1	+ 0.039 (22)	+ 0.199 (22)	+ 0.045 (26)
$-\vec{V}$.grad Ω		1	— 0.979 (22)	— 0.128 (19)
(δΩ) + $\vec{V}$.grad Ω			1	+ 0.164 (19)
		FALL		
(δΩ)	1	— 0.378 (59)	+ 0.515 (59)	+ 0.229 (52)
$-\vec{V}$grad Ω		1	— 0.986 (59)	+ 0.001 (51)
(δΩ) + $\vec{V}$grad Ω			1	+ 0.008 (48)

4) ($\delta\Omega$) and (δT) are positively correlated in all seasons. During the fall (δT) seems to be not related to the short - term ozone change components. During winter and spring the local 24 - hour temperature change at 100 mbs is positively correlated to $-\vec{V}.\text{grad}\,\Omega$ and negatively correlated to $(\delta\Omega) + \vec{V}.\text{grad}\Omega$, this correlation is reversed during the summer and is about zero during the fall.

5. Monthly and daily total ozone and 100 mb temperature teleconnections between Cagliari, Messina and Athens.

Since all three stations under study are located near the 38⁰ deg. parallel, and since no significant longitudinal dependence on the ozone and lower stratospheric temperature correlation is expected, it seemed worthwhile to calculate correlation coefficients using upper - air data at Cagliari and Athens and total ozone data at Cagliari and Messina.

Figure 3 (a) shows isolines of the correlation coefficients for all seasons between 100 mb mean monthly temperatures at Athens and mean monthly total ozone at Messina and Cagliari where we used data for the period 1960 - 1971. Figure 3 (b) shows the same isolines but correlation coefficients were based on daily observations during the period Dec. 1968 to Nov. 1969.

From fig. 3 it appears that moving from Athens towards Cagliari correlations become generally lower, a fact which is possibly connected to the longitudinal dependence of ozone on meteorological conditions (Vassy, 1965).

On a monthly basis there is no interannual variation of the correlation coefficients but in fig. 3 (b) it is evident that on a short - term (daily) basis rather high (and significant) tele-correlations occur both in winter and summer. Tele - correlations are higher on a short - term basis than on a monthly basis during the colder part of the year probably due to the fact that ozone strongly depends on meteorological conditions. However, during the summer season monthly correlations even exceed the daily ones (fig. 3(a)).

The summer high correlations found both on a short - term and on a monthly basis was quite surprising since it is well known that vertical motions during that time of the year are decreased. It is probable that at the three stations under study the variation of both ozone and temperature caused by meridional advection have the same sign during the summer season. Also if a longitudinal dependence of ozone and

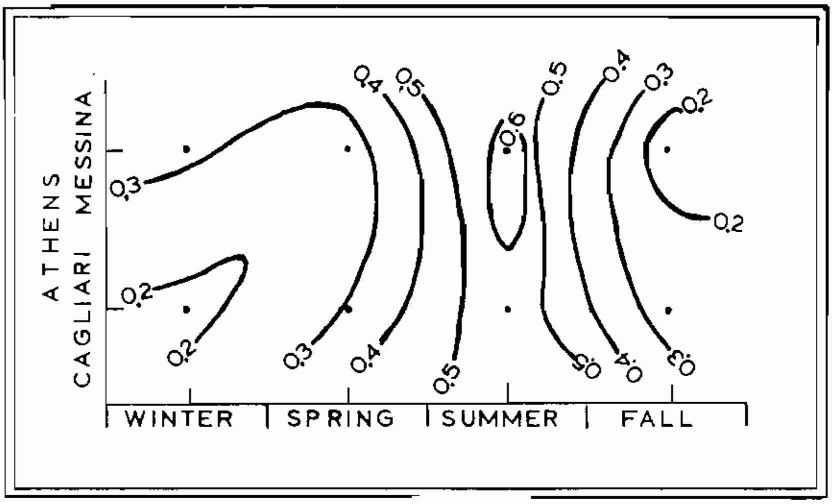
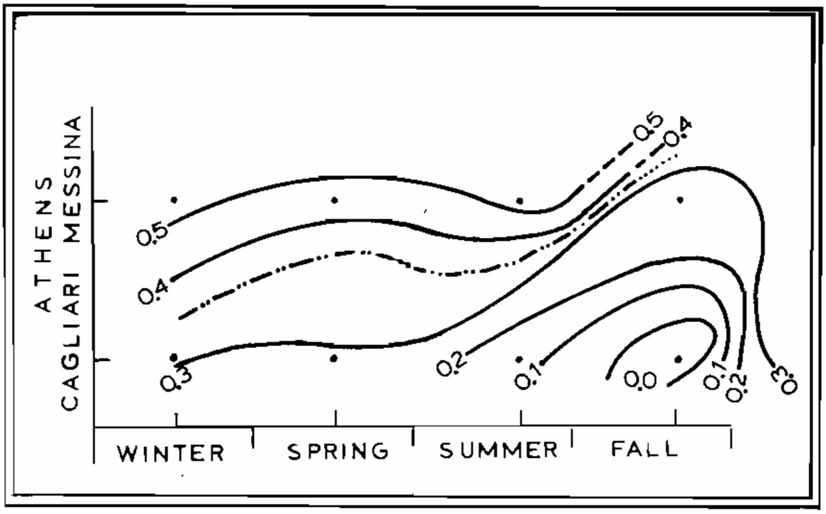


Fig. 3 (a) Monthly telecorrelations between total ozone at Cagliari and Messina and 100-mb temperature in Athens



(b) Daily teleeorrelations between total ozone at Cagliari and Messina and 100-mb temperature in Athens

temperature gradients exists the contribution of both advective and dynamic changes with respect to correlation could possibly explain the observed findings of this paragraph and paragraph 3, i.e. the dissappearance of the interannual change when telecorrelations are considered.

Regarding the daily correlation coefficient between ozone at Cagliari and ozone at Messina the following figures appeared:

TABLE IV

Cagliari Messina	Winter	Spring	Summer	Fall
	+ 0.729 (77)	+ 0.598 (85)	+ 0.077 (93)	+ 0.399 (83)

From table IV it is evident that total ozone at Cagliari and Messina have their best correlation during the winter which is probably due to the higher standard deviations observed at that time of the year.

Telecorrelations between ozone and 100 - mb. temperatures at all three stations under study based on monthly values are shown in Table V, together with the period during which data were available to us. (Subscripts are the initials of the stations' name).

TABLE V

Monthly ozone - 100 mb temperature correlation coefficients

	T_A	T_C	T_M
Messina Ω	+ 0.650	+ 0.709	+ 0.830
Period	1960 - 71	1965 - 71	1965 - 66
Cagliari Ω	+ 0.551	+ 0.683	+ 0.734
Period	1960 - 71	1965 - 71	1965 - 66

Table V confirms the results discussed previously in the text. This table is to be considered rather representative since yearly ozone temperature correlation coefficients were found to be not different from the correlation coefficient obtained for the period as a whole.

In the case of Athens 100 mb temperatures telecorrelation with total ozone at Messina, the computed z statistic of the correlation coefficients based on every year and on 11 - years is plotted in figure 4, the horizontal line indicating the 5 % significance limit. In no

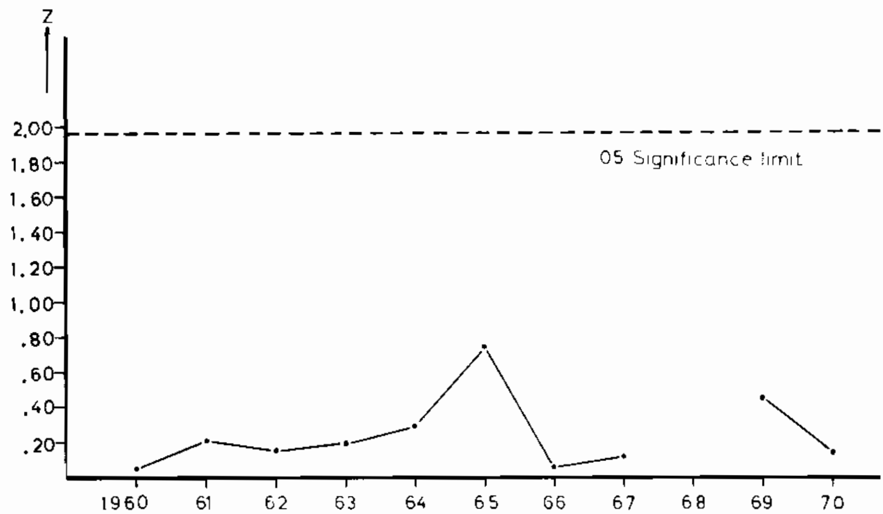


Fig. 4

year this statistic exceeded the 5 % level, or in other words yearly correlation coefficients and the correlation coefficient obtained during the 11 - year period do not differ significantly.

Conclusions

The present work confirms the relation of atmospheric ozone with the temperature field in the lower stratosphere found by other workers which were based on independent data. However some new interesting features of this relation are to be discussed in the following lines.

Total ozone and 100 - mb temperature at Cagliari were found to be better correlated on a monthly than on a daily basis. This finding was not expected from the previous work done, discussed in the introduction. It is possible that on a daily basis ozone change takes place at higher than the 100 - mb level. This suggestion is supported also by the poor correlation found between $\delta\Omega$ and δT at the 100 mb level (tables II and 111), and is found in agreemeut with Kulkarni's (1968) suggestion that the middle stratosphere plays an important role in ozone changes on a short - term basis.

Total ozone change in 24 - hours was found to be much more affected by the ozone change due to vertical motions than by the ozone change by horizontal advection in agreement with Sekiguchi's (1972) findings. Horizontal advection and vertical motion strongly compensate each other with respect to the 24 - hour ozone and 100 - mb temperature changes.

An interesting result was that corresponding temperature and ozone 24 - hour change components are positively correlated, although this correlation was found to be insignificant at the 1 % level. However when a time lag of one day was used between the 24 - hour corresponding ozone and temperature components, this lagged correlation was found to be satisfactorily significant. This supports the speculation that short - term ozone changes take place at a higher than the 100 - mb level in the middle stratosphere. Unfortunately no complete (say 10 mb or 20 mb) data were available to us at that time in order to check the above discussion.

Although day to day changes are possibly different from those responsible for seasonal changes, it was found that during the summer the ozone and 100 - mb temperature are fairly well correlated both on a monthly and on a daily basis. This fact resulted also to an interannual variation of the ozone temperature correlation coefficient with peaks in winter and summer. The positive correlation during the winter was to be expected because of the enhanced atmosphere circulation during that time of the year. However the summer high correlation could possibly be explained assuming that in the area under study (centered at 38^0 deg. latitude) the variation of both ozone and temperature caused by meridional advection have probably the same sign during that season.

The ozone - 100 mb temperature correlations between stations located at about the same latitude but a few degrees longitude apart (Cagliari - Messina - Athens) although positive, all showed a weak longitudinal dependence. Regarding total ozone correlation between Cagliari and Messina the best correlation between them was found, as was to be expected, during increased air motions (winter) and the worst correlation was found in summer due to the decrease in the intensity of air motions during that season. All tele-correlations were found to be quite stable and yearly correlations did not differ from the 11 - year period correlation at the 5 % level.

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ΠΕΡΙΛΗΨΙΣ

ΜΕΤΑΒΟΛΑΙ ΤΗΣ ΟΛΙΚΗΣ ΠΟΣΟΤΗΤΟΣ ΤΟΥ ΟΖΟΝΤΟΣ ΚΑΙ ΤΗΣ ΘΕΡΜΟΚΡΑΣΙΑΣ ΕΙΣ ΤΗΝ ΚΑΤΩΤΕΡΑΝ ΣΤΡΑΤΟΣΦΑΙΡΑΝ, ΩΣ ΚΑΙ ΣΧΕΤΙΚΑΙ ΤΗΛΕΣΥΝΔΕΣΕΙΣ ΕΙΣ ΤΗΝ ΠΕΡΙΟΧΗΝ ΤΗΣ ΜΕΣΟΓΕΙΟΥ

Ὑπὸ

ΧΡΗΣΤΟΥ ΖΕΡΕΦΟΥ καὶ ΑΝΤΩΝΙΟΥ ΜΠΛΟΥΤΣΟΥ

Συσχετίσεις μεταξὺ τῆς ὁλικῆς ποσότητος τοῦ ἀτμοσφαιρικοῦ ὄζοντος καὶ τοῦ πεδίου τῶν θερμοκρασιῶν εἰς τὴν κατωτέραν Στρατόσφαιραν, ἐρευνῶνται εἰς τὴν παροῦσαν ἐργασίαν διὰ τῆς χρήσεως τόσον τῶν ἡμερησίων ὅσον καὶ τῶν μηνιαίων ἀντιστοίχων στοιχείων, ἐκ τριῶν Μετεωρολογικῶν σταθμῶν τῆς περιοχῆς τῆς Μεσογείου.

Ἡ ὁλικὴ ποσότης τοῦ ὄζοντος καὶ ἡ θερμοκρασία εἰς τὰ 100 mb εὑρέθη ὅτι δίδουν καλυτέραν συσχέτισιν ἐὰν ληφθοῦν αἱ μέσαι μηνιαῖαι τιμαὶ ἀντὶ τῶν ἀντιστοίχων ἡμερησίων, γεγονὸς τὸ ὁποῖον δὲν ἀνεμένετο ἐκ τῆς ὑπαρχούσης βιβλιογραφίας.

Ὑποθέτομεν ὅτι, ἡ μέση Στρατόσφαιρα (ἀρκετὰ ἄνω τῶν 100 mb) διαδραματίζει πρωτεύοντα ρόλον εἰς τὰς βραχυχρονίους μεταβολὰς τοῦ ὄζοντος.

Ἡ 24ωρος μεταβολὴ τῆς ὁλικῆς ποσότητος τοῦ ὄζοντος, εὑρέθη ὅτι ἐξαρτᾶται πολὺ περισσότερον ἐκ τῆς κατακορύφου κινήσεως τούτου παρὰ ἐκ τῆς ὁριζοντίου μεταφορᾶς του.

Ἡ ὁριζόντιος μεταφορὰ καὶ αἱ κατακόρυφοι κινήσεις, εὑρέθη ὅτι ἀλληλοεξαρτῶνται ἰσχυρῶς, τόσον ὅσον ἀφορᾷ τὰς 24 - ώρους μεταβολὰς τῆς ὁλικῆς ποσότητος τοῦ ὄζοντος, ὅσον καὶ τὰς ἀντιστοίχους μεταβολὰς τῆς θερμοκρασίας τῶν 100 mb.

Κατὰ τὴν διάρκειαν τοῦ θέρους, τὸ ὄζον καὶ ἡ θερμοκρασία τῶν 100 mb δίδουν ἱκανοποιητικὴν συσχέτισιν καὶ διὰ τὰς μηνιαίας, ἀλλὰ καὶ διὰ τὰς ἡμερησίας τιμάς, ἂν καὶ ἡ ἀπὸ ἡμέρας εἰς ἡμέραν μεταβολή, ὡς ἐπροτάθη ὑπὸ ἄλλων ἐρευνητῶν, διαφέρει ἐξ αὐτῶν αἱ ὁποῖαι εἶναι ὑπεύθυνοι διὰ τὰς ἐποχικὰς μεταβολάς.

Εὑρέθη ἐπίσης ὅτι, ὑφίσταται τηλεσυσχέτισις, ἐξαρτωμένη ἐκ τοῦ γεω-

γραφικοῦ μήκους, μεταξὺ τοῦ ὄζοντος καὶ τῆς θερμοκρασίας, καὶ ὅτι αἱ ἐτήσιαι τηλεσυσχετίσεις εἰς τὴν ὑπὸ μελέτην περιοχὴν εἶναι περισσότερον σταθεραὶ κατὰ τὴν διάρκειαν τῆς περιόδου 1960 - 1971.