During August 1983, there was a convergence of sensible heat fluxes around 85° E, in the lower levels due to strong westerly heat flux on west and easterly heat fluxes on east of 85° E. On the other hand, during July 1987, there was widespread westerly fluxes through the width of country and there was divergence of sensible heat fluxes over central parts of India. During July 1987, however, stronger easterly upper tropospheric flux values were observed.

Figs. 9 (a & b) show the longitudinal cross sections of vertical structure of zonal vapour fluxes (a) during August 1983 and July 1987 respectively. Similar to sensible heat fluxes, there was strong convergence of vapour fluxes during August 1983 around 85° E in the lower troposphere whereas during July 1987 there was vapour flux divergence over central parts of India in the lower troposphere.

These differences in structure of flux values are due to different circulation patterns which prevailed during August 1983 and July 1987. Convergence of zonal vapour flux in 1983 compared to the divergence in 1987 tie well in relation to the performance of monsoon rains in the two years.

5. Conclusions

The following conclusions can be drawn from this study:

(i) Vertically integrated meridional, sensible and latent heat flux values were generally southwards over the country in all seasons except over northeastern parts where the northerly fluxes were observed. Maximum sensible heat fluxes were observed during pre-monsoon season over northern parts of India and maximum latent heat fluxes were found over central parts of India during monsoon season. Large seasonal variations occur in association with the seasonal shifts of Hadley circulation and resemble meridional wind patterns over Indian region. However, seasonal variation of fluxes over low latitudes were different from the zonal pattern obtained from Oort (1971).

(ii) Eddy fluxes were one to two order lower than fluxes due to mean flow during all seasons. Similar to the fluxes due to mean flow, eddy fluxes were also mainly southwards over most parts of the country. The eddy fluxes were maximum in winter over northern latitudes and were practically negligible over low latitudes.

(iii) During monsoon seasons of 1983 (1987) sensible heat fluxes due to transient eddies were equatorwards (polewards) and these differences were perceptible during pre-monsoon season also. Northward mean fluxes were larger over Heat Bay area and western parts of India during 1983.

(iv) During 1983 the moisture flux shows convergence over India compared to divergence in 1987 which go well with the performance of monsoon during two years.

Acknowledgements

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References


Non-uniformity of the long-term trends in some tropospheric, stratospheric and mesospheric parameters

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- The long-term trends of oxygen-18 in the stratosphere and the mesosphere were examined over the period 1955-1985. The results indicate that the stratospheric oxygen-18 has shown a marked increase over the last 30 years whereas the mesospheric oxygen-18 has remained relatively constant. The observed changes are consistent with the expected changes due to the increased anthropogenic activities.

ABSTRACT: During the last 3 decades, the concentrations of greenhouse gases have increased in the troposphere and stratosphere. These are expected to produce warming in the troposphere and cooling at higher altitudes. Experimental observations of various atmospheric parameters were examined. It was noted that not all parameters showed monotonic trends. In some cases, the trends before and after about 1970-75 were opposite, or the trends developed only after 1970-75. The reason for this transition needs to be explored. A possible cause could be a more rapid increase of CFC concentrations in recent years. Also, effect of aerosol parameters, especially sea surface temperature changes before and after 1975, could be a possible cause, though this, in turn, may be related to increasing levels of greenhouse gases.

Key words - Greenhouse gases. Trends. CFC. Linkage. QBO, SST.

1. Introduction

Since regular measurements started in 1958, the concentration of atmospheric CO₂ has increased steadily from ~315 ppm in 1958 to ~350 ppm in 1988. Other greenhouse gases like methane, nitrous oxide, CFC compounds have also increased in recent years and all these are expected to have potential climatic effects (Mitchell 1989). The stratosphere is expected to warm (Ramanathan 1988), Iatsev et al. (1988) and the stratosphere is expected to cool (Braesht and Hitchman 1988). Rind et al. (1990). The mesosphere and thermosphere are also expected to cool (Roble and Dickinson 1989). Global warming in the past decade was demonstrated by Jones et al. (1988). For the 30 hPa temperatures. Labitzke et al. (1988) reported long-term trends (cooling) of about -0.03°C/ decade at 30°N, ~0.05°C at 40°N, -0.22 at 50°N and ~0.15 at 20°N. Using the 30 hPa temperatures at the North Pole for winter months (November-

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addition, we examine the changes in the height of the atmospheric sodium layer (~90 km) at Sao Jose dos Campos (23°S, 45°W), reported by Clemesha et al. (1992), pressure changes at 80 km at Kuhlungsborn (51°N, 13°E) derived from reflection heights of long radio waves (Taubenheim et al. 1990) and secular changes in noctilucent cloud occurrence as observed from northwest Europe (Gaddesen 1990). Low latitude atmospheric (50 hPa) winds (Verme and Dartt 1990), Tahiti minus Darwin barometric pressure difference (Parker 1983, updated) and global surface temperature (Jones et al. 1988) are also examined. The ozone data are an average of 58 ground-based Dobson spectrophotometers in north temperate latitudes (Angell and Kroshover 1983 and further private communication from Dr Angell). Sunspot data were obtained from Solar Geophysical Data.

3. Results

Fig. 1 (left half) shows a plot of the various parameters. For some parameters, the scatter is large and the authors seem to have preferred to fit only a straight line trend as indicated in Figs. 1 (b), (c), and (d). However, at least in one case, viz. Fig. 1 (b) for the 80 km air pressure, the authors (Taubenheim et al. 1990) hinted at an apparent quasi-cyclic shape rather than a monotonous trend. In some of the other cases, there seems to exist an indication of a QBO (Quasi-Biennial Oscillation, period 2-3 years). To minimize the same, moving averages were calculated first over two successive (yearly) values and then, for the so-smoothed series, further over three successive values. This is equivalent to applying a 1, 2, 2, 1 filter. The results are shown in the right half of Fig. 1. The following may be noted:

(1) In some cases, notably the North Pole 30 hPa winter temperature, there is probably an 11-year solar cycle effect. Sunspots are plotted in Fig. 1(a) and the vertical lines mark sunspot minima. The solar cycle effect can be maximized by calculating moving averages over 11 consecutive yearly values. The thick lines show the 11-year averages.

(2) In the North Pole 30 hPa winter temperatures (Fig. 1(b)), the 11-year averages of November and December temperatures seem to have an almost uniform downward trend from about 1960 onwards (~3°C in ~25 years). For January, there is no downturn during 1960-70. Only later, there is a downtrend of ~4°C in about 10 years. For February, March and April, trends are positive, ~1.4°C and ~5°C respectively in about 10 years, starting solar about 1970. The vertical arrows indicate the approximate beginning or change of a trend in the 11-year averages only, in a qualitative and subjective way.

(3) For the atmospheric pressure changes [Fig. 1(d)] at 80 km at 51°N, 13°E [Taubenheim et al. (1990)], the 3-year averages indicate a non-uniform trend. For 1962-69, the trend is slightly upward and thereafter, downward. However, there is a possibility of a solar cycle effect, as both 1969 and 1982 (years of sunspot maxima) show maxima. In that case, the downward trend could be considered as having started near 1965, the beginning of the data. According to Taubenheim et al. (1990), the 10% decrease in pressure from 1963 to 1985, would correspond to an average mesosphere cooling of 4°K, i.e., 1.6°K/decade. This is much smaller than the 4°C/decade cooling in the mesosphere reported by Hauchecorne et al. (1991), but for 1978 onwards only. Part of this discrepancy could be because of non-uniformity of the trend. For Taubenheim data, trend for 1970-85 may still be ~4°C cooling (in 15 years instead of 22 years).

(4) For the frequency of occurrence (number per year) of noctilucent clouds as observed from northwest Europe, Gaddesen (1990) mentioned a solar cycle effect with an amplitude of about 10 nights per year, superposed on a steady increase during 1964-82. In Fig. 1(c), there appear two minima, one at 1969 and another at 1982. Even if these are ignored, it seems that an up trend started near about 1970.

(5) For the yearly mean sodium layer centroid height for 1900-2000 h.t. observed above Sao Jose dos Campos (23°S, 45°W) by Clemesha et al. (1992), Fig. 1(d) shows a probable non-uniform trend, viz. a slight uptrend during 1972-78 and a large downturn thereafter.

(6) For average total ozone for North temperate latitudes shown in Fig. 1(e) (Angell and Kroshover 1983, Kane 1988, updated),


Vertical lines mark sunspot minima. Vertical arrows indicate possible changes (or commencement of) trends. Thick lines represent 11-year moving averages.
LONG-TERM TRENDS IN ATMOSPHERIC PARAMETERS

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4. For the frequency of occurrence (nights per year) of noctilucent clouds as observed from northwest Europe, Gadsden (1990) mentioned a solar cycle effect with an amplitude of about 10 nights per year, superposed on a steady increase during 1964-82. In Fig. 1(c), there appear two minima, one at 1969 and another at 1982. Even if these are ignored, it seems that an uptrend started near about 1970.

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6. For average total ozone for North temperate latitudes shown in Fig. 1(c) (Angell and Korshover, 1983, Kane 1988, updated),
there is an upturn for 1960-70 and a downturn thereafter. There is a small solar cycle effect. But the 11-year averages also show a slight uptrend up to about 1970, followed by a downturn.

(7) The 50 hPa low latitude wind velocities (Venne and Davitt 1977) have a very strong QBO (Fig. 10b, half). Positive values represent westerlies and negative values represent easterlies. The trends in westerlies and easterlies (peak values) were considered separately. In Fig. 10b, right half, the 11-year averages of the westerlies show increasing values from 1960 to 1980. The easterlies remained almost constant.

(8) For the Tahiti minus Darwin barometric pressure (Parker 1983, updated) (Fig. 1g) shows an uptrend during 1955-75 and a downturn thereafter. No solar cycle effect is discernible.

(9) For the global surface temperature (Land + Marine, Jones et al., 1988 and private communication, Fig. 1h) shows a slight downturn during 1957-75 and an upturn thereafter.

(10) Altim et al. (1991) have reported temperature decreases (~3°K per decade) in the lower mesosphere (55 km and 0.4 hPa) at Haute Provence (44° N, 6° E), using ground-based lidar and satellite techniques. However, these data refer to only 10 years (1980-90). For these years, results in our Fig. 1 show clear trends. For the same location and for 60-70 km altitude, Hauchecorne et al. (1991) reported a cooling of about ~4°K per decade but only since 1978 onwards. However, it is difficult to say whether this is a part of a secular trend or a component of decadal-scale variability.

4. Conclusions and discussion

It would, thus, seem that long-term trends in atmospheric parameters in the last 2-3 decades have not always been uniform. For some parameters, trends started in early sixties. But for some others, there were ups (downs) trends up to about 1970-75 and reverse trends thereafter, with magnitudes larger in the last few years. Thus, some extra factors seem to have come into play during 1970-75. Generally, apart from a solar cycle effect, which rather small in most of the cases, the changes are attributed to changes in greenhouse gas concentrations. The most important greenhouse gas is water vapour. It is highly variable in space and time, but to a first approximation, the relative humidity of the troposphere has remained constant (Mitchell 1989), and hence, could not have contributed to the long-term trends. Carbon Dioxide (CO2) is an almost monomeric ice which formed from 1588 onwards when the first regular measurements started (Kelling et al., 1989). For Methane (CH4), amounts seem to have increased by about 1% per year (Blake and Rowland 1988). However, regular measurements seem to be available only for the last 10-15 years. The same seems to be true for Nitrous oxide (N2O) (W eiss 1981) as also for chlorofluoromethanes (CFCl-11 and CFCl-12) (Bodhaine 1989). The CFC's have increased and are increasing very rapidly in the last few years but the observations date only back to about 1978 (Cunnold et al. 1986). Could it be that their role became significant only since about 1975? Or could it be that the various greenhouse gases have a threshold concentration, only above which significant changes in temperature and ozone occurred? Or were these thresholds reached only after 1970? This needs further exploration.

Model calculations give estimates of expected changes in the troposphere, stratosphere, mesosphere and thermosphere. Thus, when greenhouse gases increase, the tropospheric temperature is expected to increase (Kiehl et al. 1988, Hansen et al. 1988), while the stratospheric temperatures are expected to decrease (Brasseur and Hitchman, 1988, Rind et al. 1980) and the mesosphere and thermosphere are also expected to cool (Roble and Dickinson 1989). For other parameters, viz. noctilucent clouds and sodium layer heights, the trends should be due to variations in temperature. For ozone, the downwelling is attributed to destruction by CFC compounds. What we are emphasizing in this paper is that, while comparing these with experimental observations, the changes of trends in 1970-75 presented in this paper should be taken into consideration.

A possible contribution due to meteorological changes should also be considered. In a recent communication, Komhyr et al. (1991) pointed out that the June-August sea surface temperature over the eastern tropical Pacific (6°N-6°S, 150°-90°W) were anomalously warm around 0.46°C during 1967-87 compared with 1962-75. Also, QBO easterly winds in the equatorial Pacific stratosphere were generally stronger after 1975 than before 1975. Since the global ozone increased from 1960 to about 1970-75 and decreased thereafter up to-date (Fig. 1e), this author suggested a possible linkage between long-term SST changes in the tropics and global ozone variations. The mechanisms they proposed were "modulation, by variations in convective activity associated with changes in SST, of the interaction between equatorial QBO winds and extratropical planetary waves that disperse ozone from the tropical stratospheric ozone source region to other parts of the globe; SST modulation of Hadley cell circulation; and SST changes in the equatorial Pacific and elsewhere in the tropics that, through teleconnections, affect planetary activity at higher latitudes." They also pointed out that the water vapour mixing ratios in the stratosphere at 150 kPa were different both before and after 1975 (e.g. Mastenbrook and Olafson 1983).

Negretti and Miller (1987) and Newman and Randel (1988) reported a large decrease in lower stratospheric planetary wave activity in the Southern Hemisphere after 1979. Trenberth (1990) reported an increase in the intensity of the Aleutian low in the Northern Hemisphere during November-March from 1977-87, an enhanced displacement of the low and reduced sea level pressures in the central and north Pacific and attributed these to atmospheric and underlying SST changes (El Nino). Komhyr et al. (1991) have hypothesized the increasing geostrophic wind flow intensity east and west of the Baffin island low.

Recently, Gutzler (1992) reported temperature indices for the tropical western pacific (~7°N, 135°E). For these, the 3-year averages showed a rising trend from 1974 to 1979-80 and a decrease thereafter. Even so these changes before and after 1975 may have a possible meteorological origin, due to underlying SST changes. The SST changes may be related to the changes in greenhouse gas levels. In their global climatic model experiments, Hansen et al. (1988) show that the warming due to increase of greenhouse gases may appear first in low-latitude oceans.

The present results are only roughly indicative of a possible transition during 1970-75 in large parts of the atmosphere. Significant temperature changes in the eastern tropical Pacific (6°N-6°S, 150°-90°W) were anomalously warm around 0.67°C during 1967-87 compared with 1962-75. Also, QBO easterly winds in the equatorial Pacific stratosphere were shown an extra increase (superposed on a general rising trend) during 1973-74. The CFC-11 compounds also showed an extra increase during 1977-78. Thus, the transition of temperature trends in 1970-75 could be attributed to similar transitions in greenhouse gases.

References


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(7) The 50 hPa low latitude wind velocities (Vonne and Darro 1990) have a very strong correlation with QBO (Fig. 1a). Left half. Positive values represent westerlies and negative values represent easterlies. The trends in westerlies and easterlies (peak values) were considered separately. In Fig. 1(b), right half, the 11-year averages of the westerlies show increasing values from 1960 to 1980. The easterlies remained almost constant.

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The most important greenhouse gas is water vapour. It is highly variable in space and time, but at a first approximation, the relative humidity of the troposphere has remained constant (Mitchell 1989), and hence, could not have contributed to the long-term trends. Carbon Dioxide (CO2) has increased almost monotonically from 1958 onwards when the first regular measurements started (Keeling et al. 1989). For Methane (CH4), amounts seem to have increased by about 2-3% per year (Blake and Rowland 1988). However, regular measurements seem to be available only for the last 10-15 years. The same seems to be true for Nitrous oxide (N2O) (Weiss 1981) as also for chloroform (CFCl3 and CFC-12) (Bodehaine 1989). The CFCs have increased and are increasing very rapidly in the last few years but the observations date back only to about 1975 (Cunnold et al. 1986). Could it be that their role became significant only since about 1975? Or, could it be that the various greenhouse gases have a threshold concentration, only above which significant changes occur, and that these thresholds were reached only after 1975? This needs further exploration.

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A possible contribution due to meteorological changes should also be considered. In a recent communication, Komyer et al. (1991) pointed out that the June-August sea surface temperatures in the eastern equatorial Pacific (6°-6°S, 150°-90°W) were anomalously warmer by 0.67°C during 1976-87 compared with 1962-75. Also, QBO easterly winds in the equatorial Pacific stratosphere were generally stronger after 1975 than before 1975. Since the global ozone increased from 1960 to about 1970-75 and decreased thereafter up to-date (Fig. 1e), the authors attributed a possible linkage between long-term SST changes in the tropics and global ozone variations. The mechanisms they proposed are "modulation, by variations in convective activity associated with changes in SST. of the interaction between equatorial QBO winds and extratropical planetary waves that disperse ozone from the tropical stratospheric ozone source region to other parts of the globe; SST modulation of Hadley cell circulation; and SST changes in the equatorial Pacific and elsewhere in the tropics that, through teleconnections, affect planetary activity at higher latitudes." They also pointed out that the water vapour mixing ratios in the stratosphere at 80 hPa were different before and after 1975 (e.g. Mastenbroek and Oltmans 1983).
Analysis of total ozone, potential vorticity and tropopause pressure over southeast Asia during winter

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Abstract. This study shows the analysis of total ozone and potential vorticity and also tropopause pressure during winter period (December, January and February) over the area 20°-50°N, 90°-140°E (southeast Asia). This is done for three different latitude bands 20°-30°N, 30°-40°N and 40°-50°N Due to maximum latitudinal gradient of ozone in the lower latitudinal band, high correlation is found with potential vorticity and also with tropopause level.

Key words — Total ozone, Isentropic potential vorticity, Tropopause.

1. Introduction

The ozone mixing ratio and Estell’s potential vorticity (IPV) are both quasi-conservative tracers in the lower stratosphere (Lorey et al. 1985, Clough et al. 1985, Reiter 1972, Hartmann 1977, Danielsen 1988, Danielsen et al. 1987) and also increase with decreasing pressure up to 10 hPa. Thus, the transport of IPV is to be similar to that of ozone in the lower stratosphere. Herring (1966) showed that IPV is positively correlated with ozone mixing ratio over the longitude extent of North America, and in the stratosphere, the features in the profile of IPV and ozone mixing ratio were shown to be similar on the large scale by Danielsen (1968).

Later studies have confirmed that a strong positive correlation exists between IPV and ozone mixing ratio at all scales in the lower stratosphere. The evidence was discussed by Danielsen (1985). The changes in the mixing ratio of ozone on isentropic surfaces are wholly contained in the stratosphere and advection of the tropopause along isentropic surfaces linking stratosphere and troposphere. This is equivalent to changing the depth of the stratosphere thus, clearly altering the total amount of ozone in a vertical column. By looking at the correlation between the total ozone and IPV on an isentropic (0) surface it is possible to discern how much of the variability in total ozone is contributed by variation in ozone mixing ratio on that surface. It is also possible to study the contribution to the variability in total ozone coming from changes near the tropopause by correlating total ozone directly with tropopause pressure.

In this article correlations between TOMS total ozone and IPV are calculated statistically at three different latitude bands (20°-30°N, 30°-40°N and 40°-50°N) in the region 90°-160°E, 20°-50°N and compared with the correlation with tropopause pressure.

2. Materials used

Daily gridded total ozone data have been supplied from the TOMS instrument on the Nimbus-7 satellite for the period from December 1982 to February 1993 in the region 90°-160°E and 20°-50°N. Wind speeds have been obtained from gridded analysis fields supplied by the European Centre for Medium Range Weather Forecasts (ECMWF). Reading Values of tropopause level pressure have been taken from the radiosonde tropopause reports after quality control to remove spurious values.

3. Method of analysis

Statistical method has been used in this article. For each radiosonde station, the tropopause pressure and IPV values on various isentropic (0) surfaces have been obtained for 0000 UTC on the first 20 days of each month. For each day total ozone has