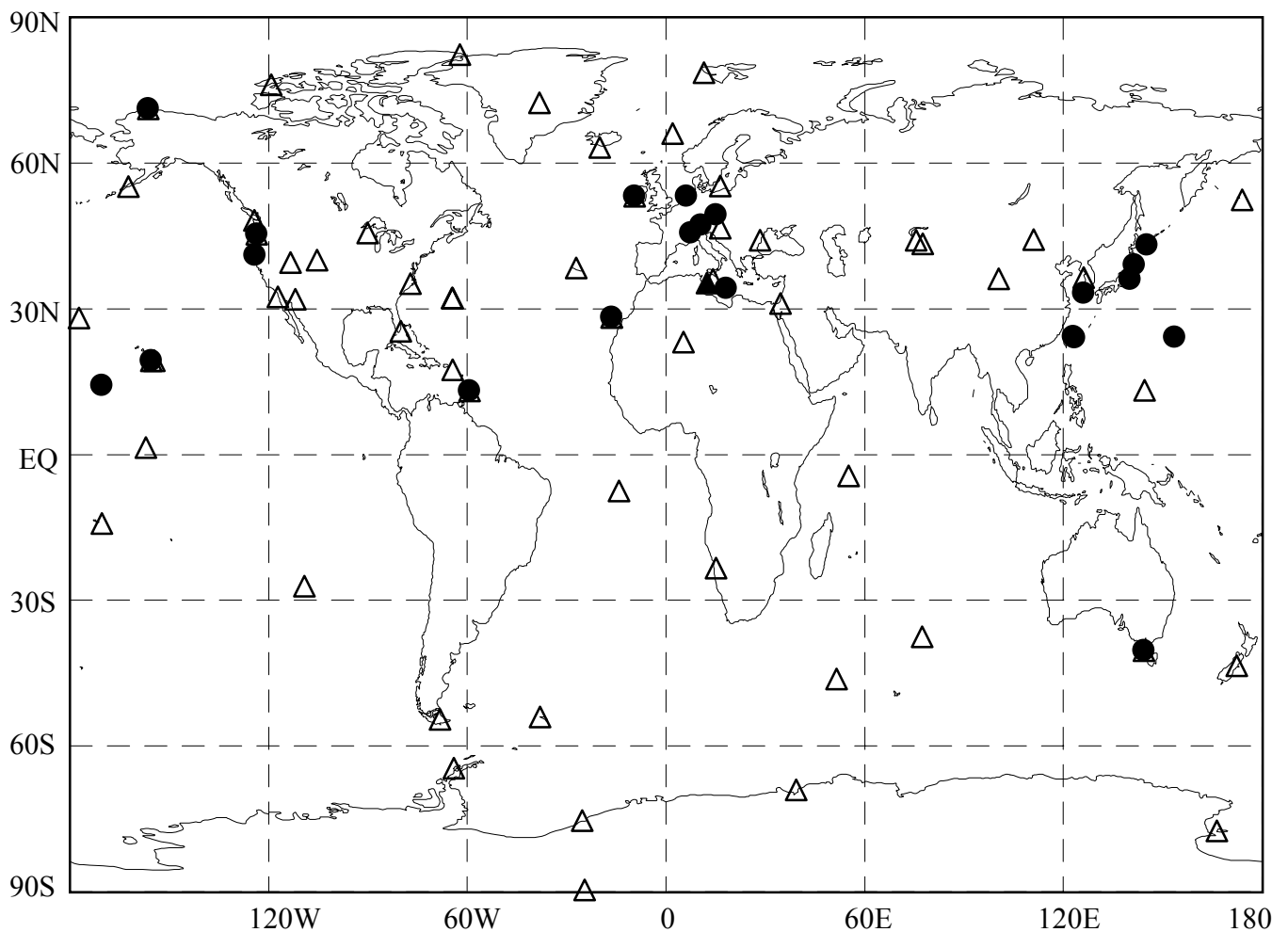


4. Methane (CH₄)

● : *IN SITU* STATION

▲ : FLASK STATION

△ : NOAA/CMDL AIR SAMPLING NETWORK STATION



4. Methane (CH₄)

Methane (CH₄) is the second most significant greenhouse gas in terms of its contribution to global warming. From 1000 to 1800 A.D., the concentration of CH₄ was about 700 ppb and varied within 40 ppb in synchronization with climatic variations (Etherridge *et al.*, 1998). The global average was estimated at 1730 ppb in 1997 (WMO, 1999a). The increase in the atmospheric CH₄ concentration over industrial and agricultural periods has brought about positive radiative forcing that amounts to about 30% of that for CO₂ (IPCC, 2001).

Atmospheric CH₄ is emitted mainly from anaerobic processes and fossil fuel exploitation, and removed by reaction with hydroxyl radicals (OH). Sources of CH₄ are both natural and anthropogenic, including natural wetlands, oceans, landfills, rice paddies, enteric fermentation, gas drilling and biomass burning. CH₄ sinks involve reaction with OH in the troposphere, reaction with chlorine atoms and oxygen atoms in an excited state of O(¹D) in the stratosphere and soils. However, uncertainties concerning the sources and sinks of CH₄ must be further reduced to improve estimates in the atmospheric CH₄ budget. Carbon isotope studies should provide constraints for the budget.

At the beginning of this chapter, operational observation sites on the ground that submitted CH₄ concentration data to the WDCGG are shown on a map. For an explanation of the symbols in the map, please refer to the corresponding map for CO₂.

4.1 Analysis for global, hemispheric and zonal mean concentrations

Global, hemispheric and zonal mean concentrations were provided based on data from 79 stations (points) that can be considered to provide background data.

Figure 4.1 shows the monthly mean concentrations and their deseasonalized long-term trend from 1984 to 2000 for the globe and both hemispheres. A long-term increase and seasonal variation are seen as for CO₂. Amplitudes of the seasonal cycle are larger in the Northern Hemisphere than in the Southern Hemisphere. The annual mean concentration for the globe is 1784 ppb in 2000. Figure 4.2 shows the growth rates for the same areas as in Figure 4.1. Growth rates are generally lower in the 1990s than in the 1980s. Average global growth rates are 8 ppb/year in the whole period (1984-2000), 11 ppb/year in 1984-1990 and 6 ppb/year in 1991-2000. The decreased growth rates in the 1990s suggest that global CH₄ concentrations are approaching a steady state where removal of CH₄ is balanced with emission from CH₄ sources (Dlugokencky *et al.*, 1998 and Etherridge *et al.*, 1998). During this period, global growth rates were at a maximum in the summer of 1984 at 14 ppb/year and at a minimum in the autumn of 1992 at 1 ppb/year. Growth rates for both hemispheres showed a sudden decrease in 1992. However, they were high again in 1998. In the 1990s, global CH₄ growth rates varied to correspond remarkably with global mean temperatures. Global mean temperature anomalies from the 1961-1990 averages were large at around 0.5°C in 1990, 1991, 1994, 1995 and 1997, and about 0.8°C in 1998, which was the largest (JMA, 1999). However, in 1992, 1993 and 1996, they were small but positive between 0.1 and 0.2°C. Global CH₄ growth rates were generally high in

1991, 1994 and 1998, while low in 1992, 1996 and 1999/2000. Reliability of the increasing feature in the latter half of 2000 may be inferior, because a guess value is used in this trend analysis near the end of the analysis period as explained in 2.1.3.

Figure 4.3 shows the monthly mean concentrations and their deseasonalized long-term trend from 1984 to 2000 for each of the 30-degree latitudinal zones. Deseasonalized long-term trend curves have the distinct feature of high concentration in northern high- and mid-latitudes and low concentration in southern latitudes, with a larger gradient in the Northern Hemisphere than the Southern Hemisphere. According to the measurements of CH₄ concentrations in Antarctic and Greenland ice cores, inter-polar differences varied between 24 and 58 ppb from 1000 to 1800 A.D. (Etheridge *et al.*, 1998). At present, the difference between the northern and southern high latitudes is about 150 ppb. This increase is presumably due to increased emissions in the Northern Hemisphere, which are mainly from anthropogenic sources.

Figure 4.4 shows the analytical results of the deseasonalized long-term trend and growth rates. Growth rates clearly decreased from the 1980s to 1990s for all of the latitudinal zones. Large interannual variations overlay this trend. Growth rates were large in 1991 and small in 1992 and 1993 in general, and in 1992, the values were negative in northern high latitudes. The large increase in 1991 may have been caused by decreased OH radicals due to weakened UV radiation, an impact of the eruption of Mt. Pinatubo in 1991 (Dlugokencky *et al.*, 1996). The decrease in 1992 was probably caused by a decrease in fossil fuel production (Dlugokencky *et al.*, 1994) and biomass burning (Lowe *et al.*, 1997) along with an increase in OH radical concentration due to stratospheric ozone depletion after the eruption of Mt. Pinatubo in 1991 (Bekki *et al.*, 1994). Growth rates were large in 1998 for all of the latitudinal zones. A study of the relationship between CH₄ concentrations in ice cores and global temperature anomalies (Etheridge *et al.*, 1998) suggests that a large growth rate for the CH₄ concentration may follow an exceptionally high global mean temperature as in 1998, which is associated with the anomalously strong El Niño event of 1997/1998.

Figure 4.5 draws average seasonal cycles for each of the 30-degree latitudinal zones. Seasonal cycles are brought about mainly by reaction with OH, a major CH₄ sink in the atmosphere. The strength and timing of the emission from CH₄ sources such as wetland and biomass burning along with the transportation of CH₄ also affects the seasonal cycle. Amplitudes of the seasonal cycle are large in the Northern Hemisphere. Unlike CO₂, amplitudes are large in the Southern Hemisphere except for low latitudes because OH radicals are distributed in both hemispheres, which brings about a similar seasonal variation. CH₄ concentrations are at a maximum in January or February in the Northern Hemisphere and in September in the Southern Hemisphere, except in low latitudes. They are at a minimum in July in the Northern Hemisphere and in February or March in the Southern Hemisphere, except in low latitudes. The timing of the maximum and minimum concentrations of CH₄ is consistent with seasonal variation in OH concentration through photochemical reactions. Southern low latitudes have a distinct semi-annual component overlaying the annual component of the seasonal cycle. The secondary maximum occurs in boreal winter due to the large-scale

transportation of CH₄ from the Northern Hemisphere. This phenomenon is seen at stations located in the western Indian Ocean, e.g. Mahe Island, Seychelles and the western and central equatorial Pacific, e.g. Cape Matatula, Samoa. However, it is not seen at Ascension Island in the equatorial Atlantic, where CH₄ is transported on a large scale from the Southern Hemisphere in boreal winter.

4.2 Analysis for individual stations

Time-series analysis was also applied for stations representing global or regional situations: Barrow (Alaska, U.S.A.), Mauna Loa (Hawaii, U.S.A.), Cape Grim (Tasmania, Australia), the South Pole (Antarctica), Mace Head (Ireland) and Minamitorishima (Japan). Figure 4.6 shows the time series of monthly mean concentrations, deseasonalized long-term trends, growth rates for each year and average seasonal cycles for each station.

Barrow, Mauna Loa, Cape Grim and the South Pole experienced a decline in the growth rate from the 1980s to 1990s. In 1998, large positive growth rates were seen in all of these stations except Minamitorishima.

A clear seasonal cycle can be seen at all of the stations.