

chemically-related species down to the planetary boundary layer, using *in situ* and remote sensing instruments; intercomparison of different sensors, including co-ordinated correlative measurements for satellite instrumentation; three-dimensional fields of key atmospheric trace constituents, solar spectral flux and meteorological parameters;

- (iv) Instrument development, including satellite and non-satellite sensors for atmospheric trace constituents, solar flux and meteorological parameters;

**(b) Research into healthy biological and photodegradation effects**

- (i) The relationship between human exposure to visible and ultra-violet solar radiation and (a) the development of both non-melanoma and melanoma skin cancer and (b) the effects on the immunological system;
- (ii) Effects of UV-B radiation, including the wavelength dependence, upon (a) agricultural crops, forests and other terrestrial ecosystems and (b) the aquatic food web and fisheries, as well as possible inhibition of oxygen production by marine phytoplankton;
- (iii) The mechanisms by which UV-B radiation acts on biological materials, species and ecosystems, including the relationship between dose, dose rate, and response; photorepair, adaptation, and protection;
- (iv) Studies of biological action spectra and the spectral response using polychromatic radiation in order to include possible interactions of the various wavelength regions;
- (v) The influence of UV-B radiation on: the sensitivities and activities of biological species important to the biospheric balance; primary processes such as photosynthesis and biosynthesis;
- (vi) The influence of UV-B radiation on the photodegradation of pollutants, agricultural chemicals and other materials;

**(c) Research on effects on climate**

- (i) Theoretical and observational studies of the radiative effects of ozone and other trace species and the impact on climate parameters, such as land and ocean surface temperatures, precipitation patterns, the exchange between the troposphere and stratosphere;
- (ii) The investigation of the effects of such climate impacts on various aspects of human activity;

**(d) Systematic observations on:**

- (i) The status of the ozone layer (i. e. the spatial and temporal variability of the total column content and vertical distribution) by making the Global Ozone Observing System, based on the integration of satellite and ground-based systems, fully operational;
- (ii) The tropospheric and stratospheric concentrations of source gases for the HO<sub>x</sub>, NO<sub>x</sub>, ClO<sub>x</sub> and carbon families;
- (iii) The temperature from the ground to the mesosphere, utilizing both ground-based and satellite systems;
- (iv) Wavelength-resolved solar flux reaching, and thermal radiation leaving, the Earth's atmosphere, utilizing satellite measurements;
- (v) Wavelength-resolved solar flux reaching the Earth's surface in the ultra-violet range having biological effects (UV-B); ~

- (vi) Aerosol properties and distribution from the ground to the mesosphere, utilizing ground-based, airborne and satellite systems;
- (vii) Climatically important variables by the maintenance of programmes of high-quality meteorological surface measurements;
- (viii) Trace species, temperatures, solar flux and aerosols utilizing improved methods for analysing global data.

3. The Parties to the Convention shall co-operate, taking into account the particular needs of the developing countries, in promoting the, appropriate scientific and technical training required to participate in the research and systematic observations outlined in this annex. Particular emphasis should be given to the intercalibration of observational instrumentation and methods with a view to generating comparable or standardized scientific data sets.

4. The following chemical substances of natural and anthropogenic origin, not listed in order of priority, are thought to have the potential to modify the chemical and physical properties of the ozone layer.

**(a) Carbon substances**

**(i) Carbon monoxide (CO)**

Carbon monoxide has significant natural and anthropogenic sources, and is thought to play a major direct role in tropospheric photochemistry, and an indirect role in stratospheric photochemistry.

**(ii) Carbon dioxide (CO<sub>2</sub>)**

Carbon dioxide has significant natural and anthropogenic sources, and affects stratospheric ozone by influencing the thermal structure of the atmosphere.

**(iii) Methane (CH<sub>4</sub>)**

Methane has both natural and anthropogenic sources, and affects both tropospheric and stratospheric ozone.

**(iv) Non-methane hydrocarbon species**

Non-methane hydrocarbon species, which consist of a large number of chemical substances, have both natural and anthropogenic sources, and play a direct role in tropospheric photochemistry and an indirect role in stratospheric photochemistry.

**(b) Nitrogen substances**

**(i) Nitrous oxide (N<sub>2</sub>O)**

The dominant sources of N<sub>2</sub>O are natural, but anthropogenic contributions are becoming increasingly important. Nitrous oxide is the primary source of stratospheric NO<sub>x</sub>, which play a vital role in controlling the abundance of stratospheric ozone.

**(ii) Nitrogen oxides (NO<sub>x</sub>)**

Ground-level sources of NO<sub>x</sub> play a major direct role only in tropospheric photochemical processes and an indirect role in stratosphere photochemistry, whereas injection of NO<sub>x</sub> close to the tropopause may lead directly to a change in upper tropospheric and stratospheric ozone.

**(c) Chlorine substances**

**(i) Fully halogenated alkanes, e. g. CCl<sub>4</sub>, CFC1<sub>3</sub> (CFC-11), CF<sub>2</sub>Cl<sub>2</sub> (CFC-12), C<sub>2</sub>F<sub>3</sub>Cl<sub>3</sub> (CFC-113), C<sub>2</sub>F<sub>4</sub>Cl<sub>2</sub> (CFC-114)**

Fully halogenated alkanes are anthropogenic and act as a source of ClO<sub>x</sub>, which plays a vital role in ozone photochemistry, especially in the 30—50 km altitude region.

**(ii) Partially halogenated alkanes, e. g. CH<sub>3</sub>Cl, CHF<sub>2</sub>Cl (CFC-22), CH<sub>3</sub>CCl<sub>3</sub>, CHFCl<sub>2</sub> (CFC-21)**

The sources of CH<sub>3</sub>Cl are natural, whereas the other partially-halogenated alkanes mentioned above are