united nations educational, scientific and cultural organization

international atomic energy agency

the
abdus salam
international centre for theoretical physics

School on "Exploring the Atmosphere by Remote Sensing Techniques"
18 October - 5 November 1999

1151-18

"Ozone Networks"

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Brussels
Belgium

Please note: These are preliminary notes intended for internal distribution only.

Ozone Networks

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ICTP course "School on Exploring the Atmosphere with Remote Sensing Techniques"

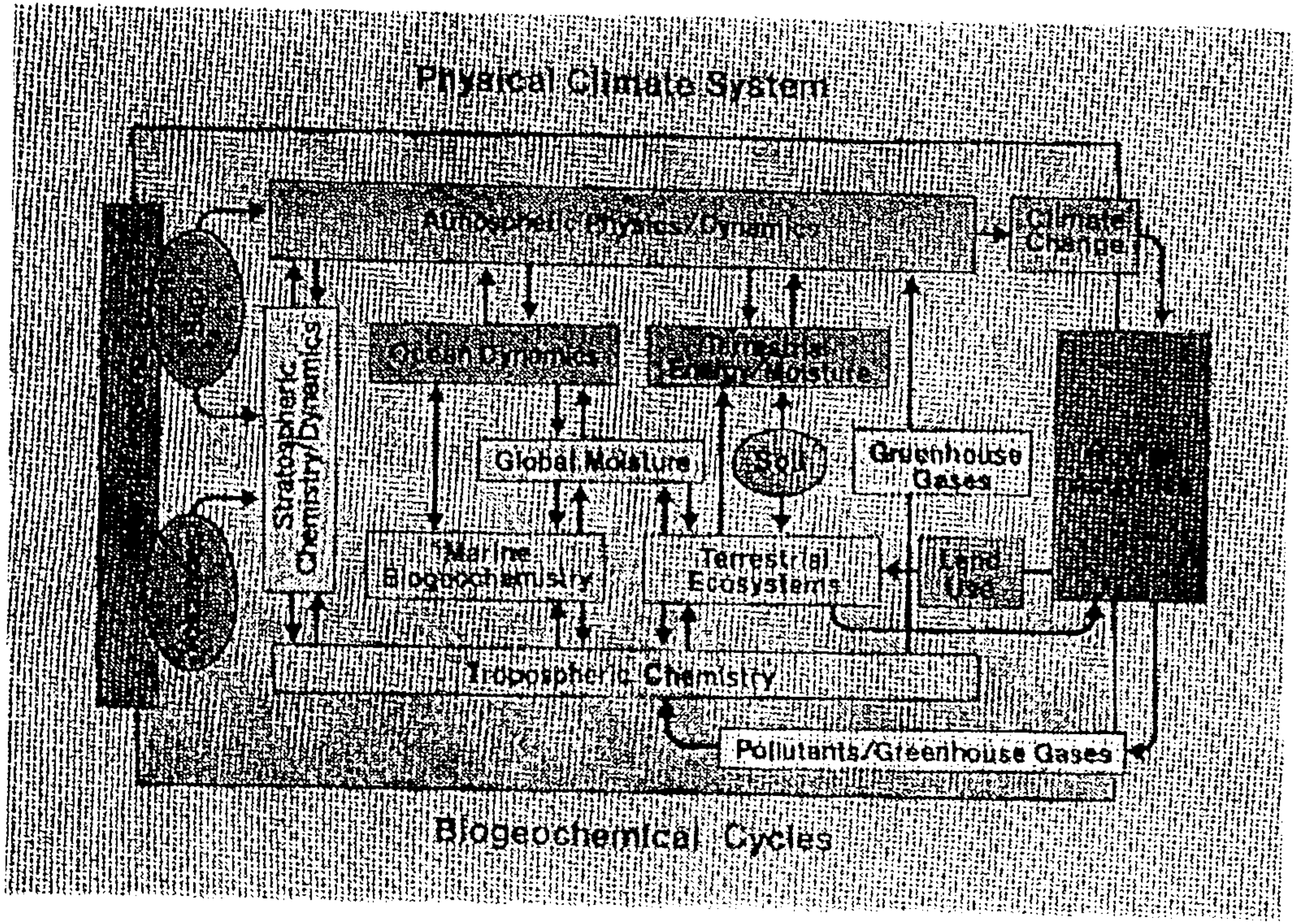
October 18 - November 5, 1999, Trieste, Italy

Observation Networks: The Challenge

- ❑ **Earth System**

  - ✓Complexity
  - ✓Couplings
  - ✓Non-linearity (e.g. O_3 hole)

➔Necessity of network observations to assess global environmental issues on a world-wide scale



Global modelling studies within the IGBP will connect models of the biogeochemical system, the physical climate system, and human impacts, to develop our predictive understanding of the behaviour of the Earth system as a whole

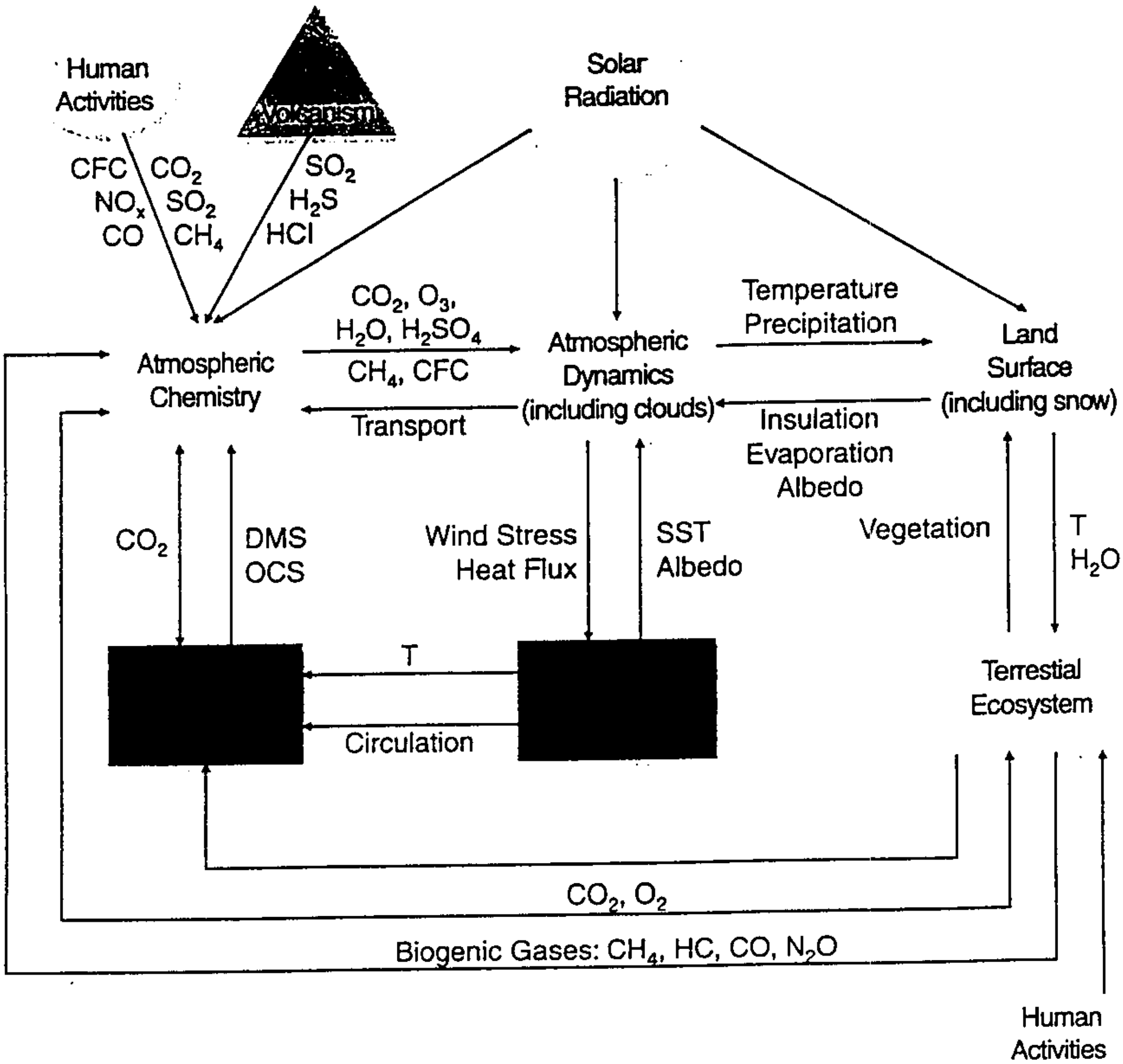
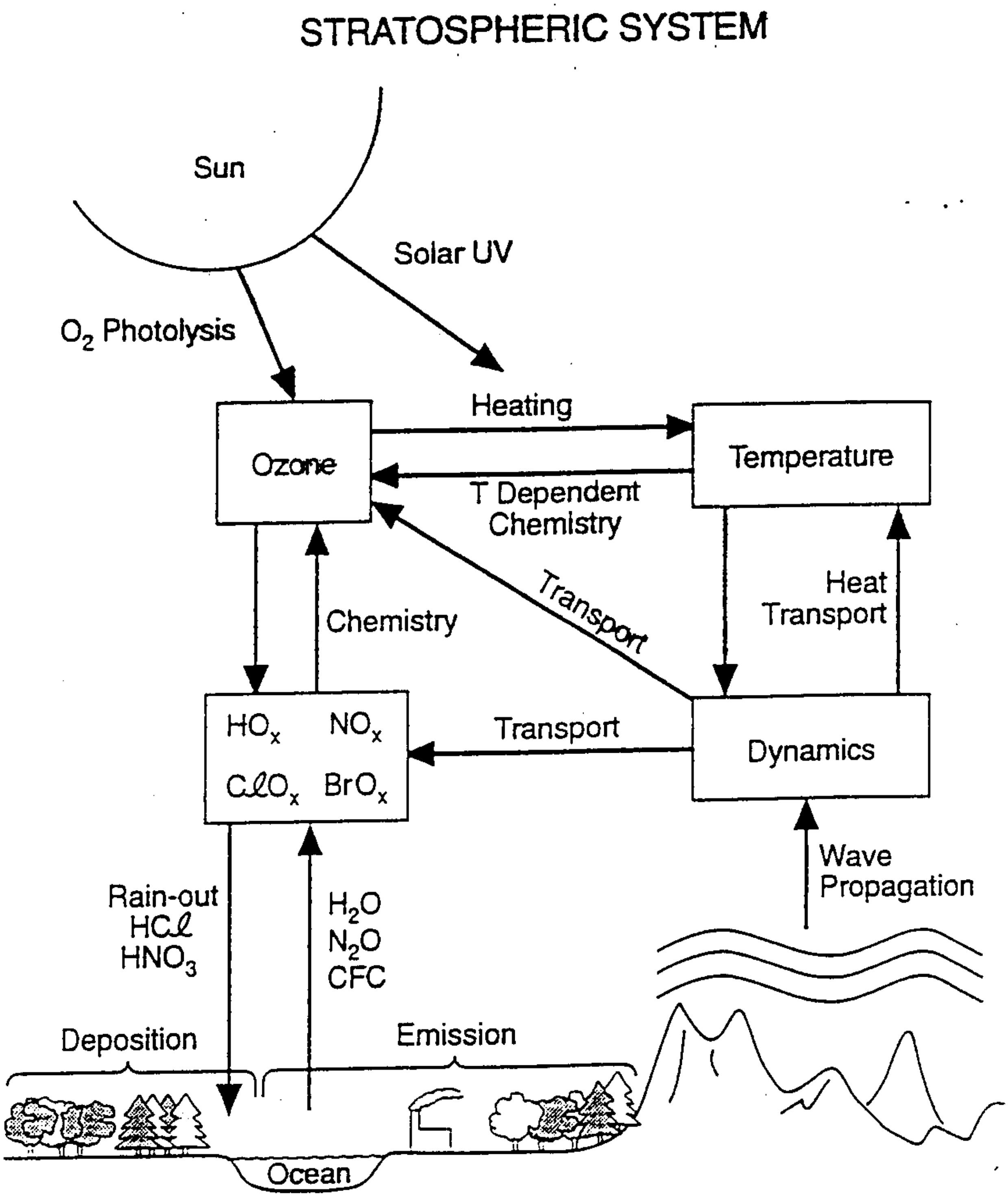
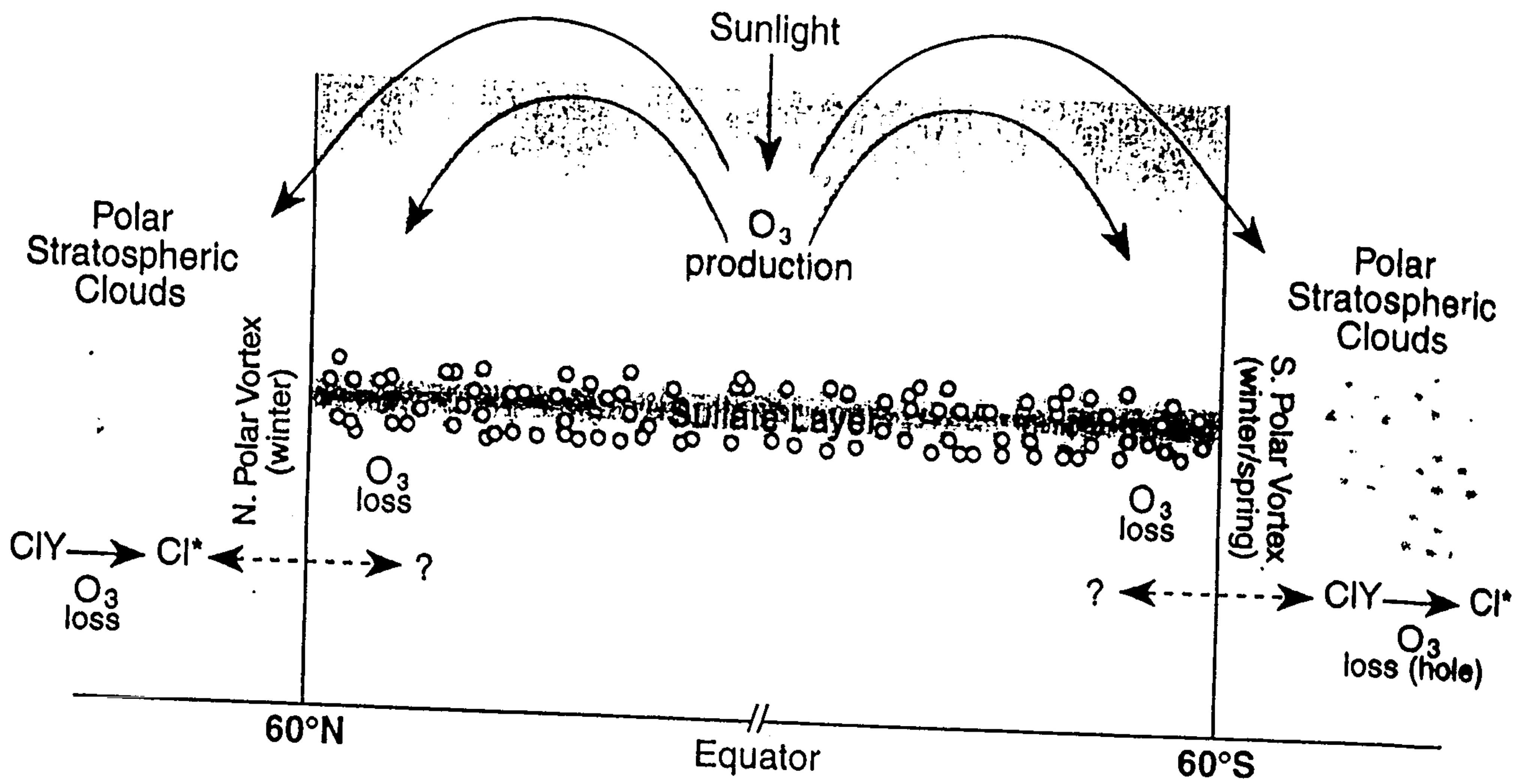


Figure 2.1 Schematic of the various components of the coupled Earth System



ıre 1. Schematic representation of coupled chemical, radiative, and dynamic middle atmosphere.


Sunlight
O_3 production
Polar Stratospheric Clouds
N. Polar Vortex (winter)
Sulfate Layer
O_3 loss
ClY → Cl*
O_3 loss
?
60°N
Equator
60°S
O_3 loss
S. Polar Vortex (winter/spring)
Polar Stratospheric Clouds
?
ClY → Cl*
O_3 loss (hole)

Observation Networks: The Challenge

✓ **Global Climatology**

✓ **Global Changes**

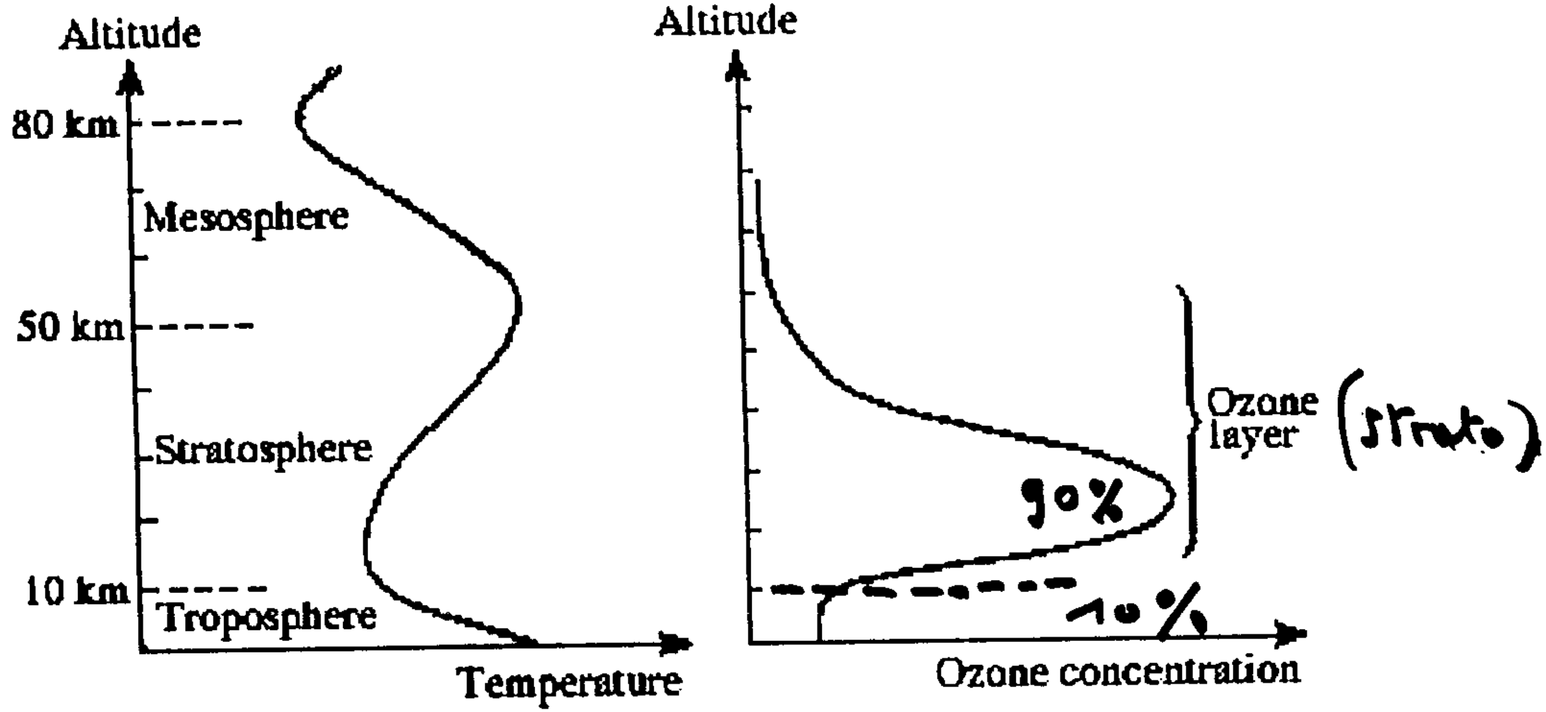
- Stratospheric ozone
- Tropospheric ozone
- Source gases, e.g, greenhouse gases

<u>Impact</u>:

- Changes in the radiative balance of the Earth - Atmosphere energy system
- Health effects

<u>Causes</u>: Human Activity

The ozone problem



Stratospheric O_3 : shields the biosphere from harmful UV

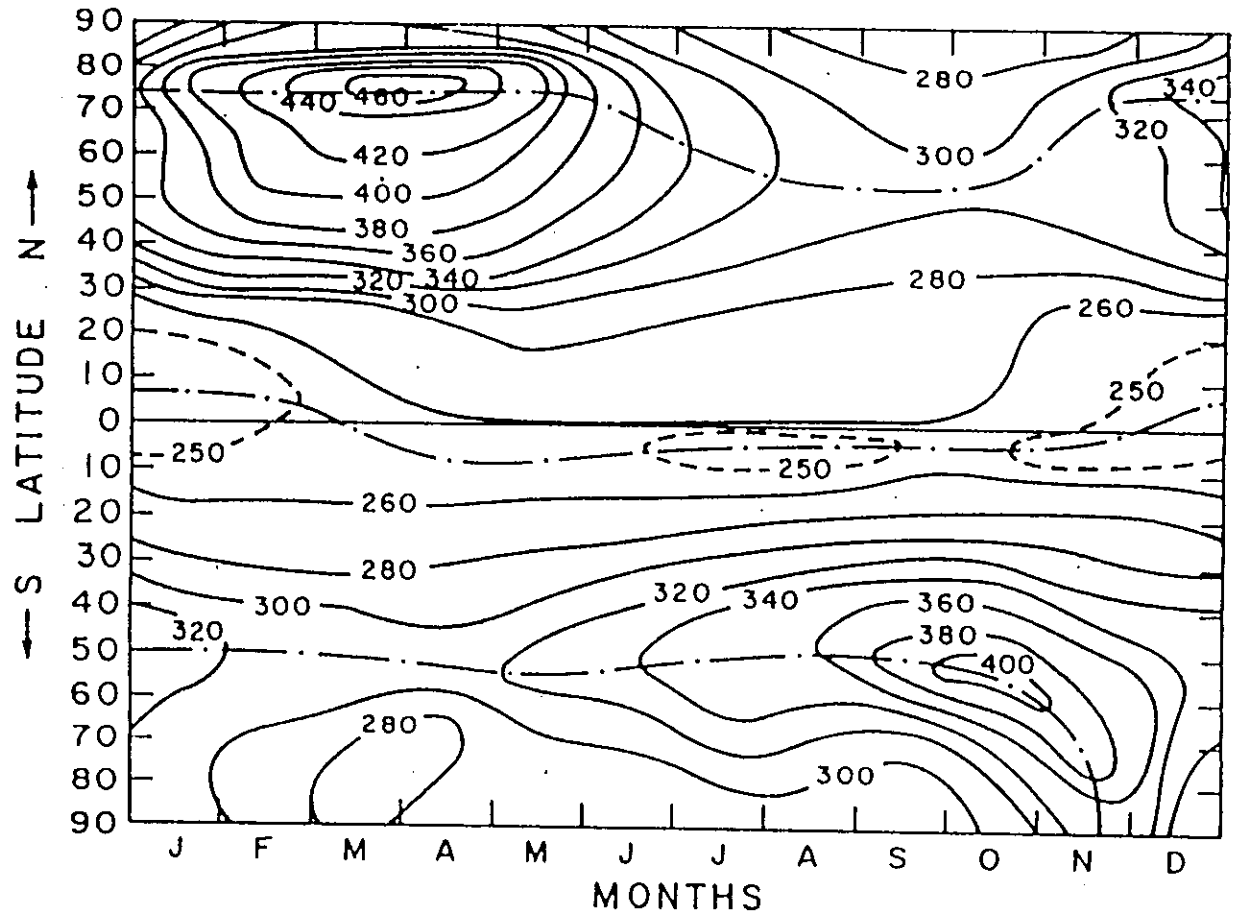


Figure 3. Seasonal variation of zonal averages of total ozone from the Dobson network for the period 1958-1977 (London, 1980). The dashed and dashed-dot lines indicate axes of minimum and maximum columns, respectively (figure from London, 1980).

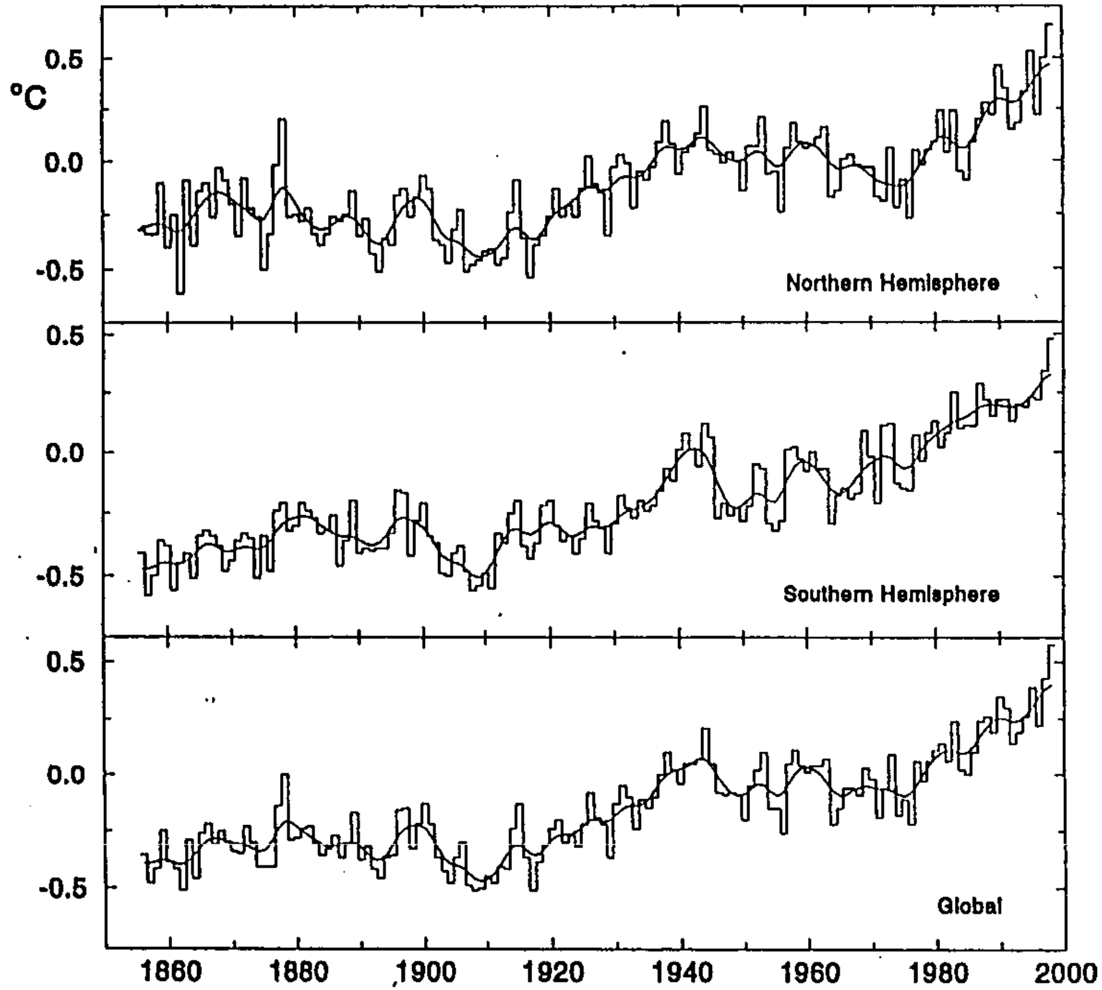
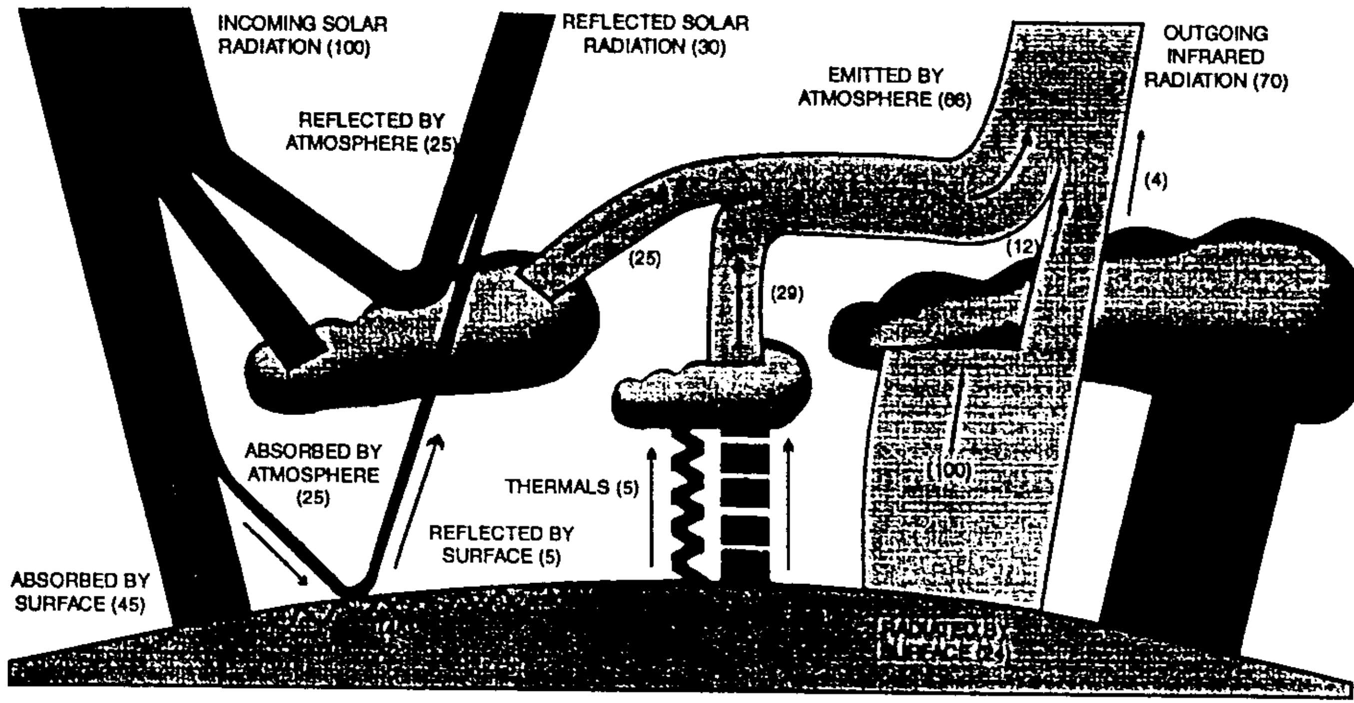


Figure 2. Hemispheric and global temperature averages on the annual timescale (1856–1998), relative to 1961–1990.

The Earth radiative budget

The Earth 's radiative budget: balance between the outgoing infrared radiation and the total solar input



Observation Networks: Why ?

✓ **Historical**

⇨ Meteorology

✓ **Scientific**

⇨ New development

- Instruments have evolved from ground based spectrometers to balloons, aircraft, rockets, and satellites
- Developments in instrumentation enable measurements to expand from the atmosphere above an isolated ground station to daily global coverage

⇨ International Geophysical Year (IGY)

The International Geophysical Year (IGY)

July 1957- December 1958

... to observe geophysical phenomena and to secure data from all parts of the world; to conduct this effort on a co-ordinated basis by fields, and in space and time, so that results could be collated in a meaningful manner

International Geophysical Year

- ✓ July 1957- December 1958
- ✓ scientific programme defined beginning 1953
- ✓ Prs. Nicolet and Chapman are both members of the executive council

The International Geophysical Year

July 1957- December 1958

- **The largest and most important international scientific effort to that date:**
  - ✓ Proposed by the International Council of Scientific Unions (ICSU) in 1952
  - ✓ Modelled on the International Polar Years of 1882-1883 and 1932-1933
  - ✓ Series of co-ordinated observations of various geophysical phenomena
  - ✓ IGY activities literally spanned the globe from the North to the South Poles
  - ✓ 67 countries had become involved

The International Geophysical Year

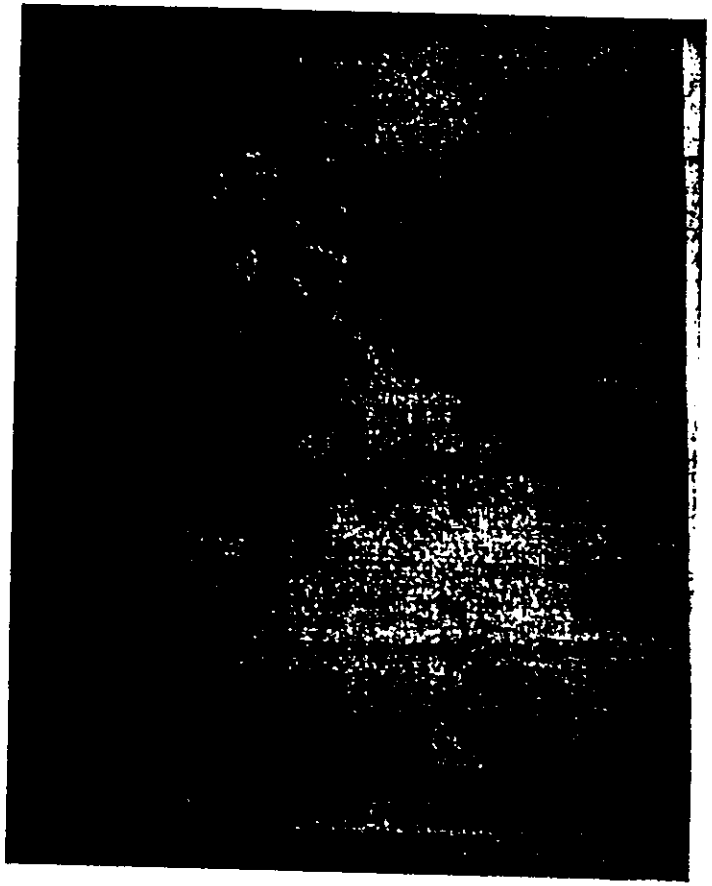
- **Open the upper atmosphere to detailed exploration**
  - ✓Cosmic ray recorders
  - ✓Spectroscopes
  - ✓Radiosonde balloons
- **Greatest breakthrough: Launching science into space**
  - ✓Rocket; Artificial satellites into Earth's orbit

Discoveries in the fields of cosmic ray research, climatology, oceanography, the nature of the Earth's atmosphere and magnetic field.

❑ Dobson Spectrophotometer

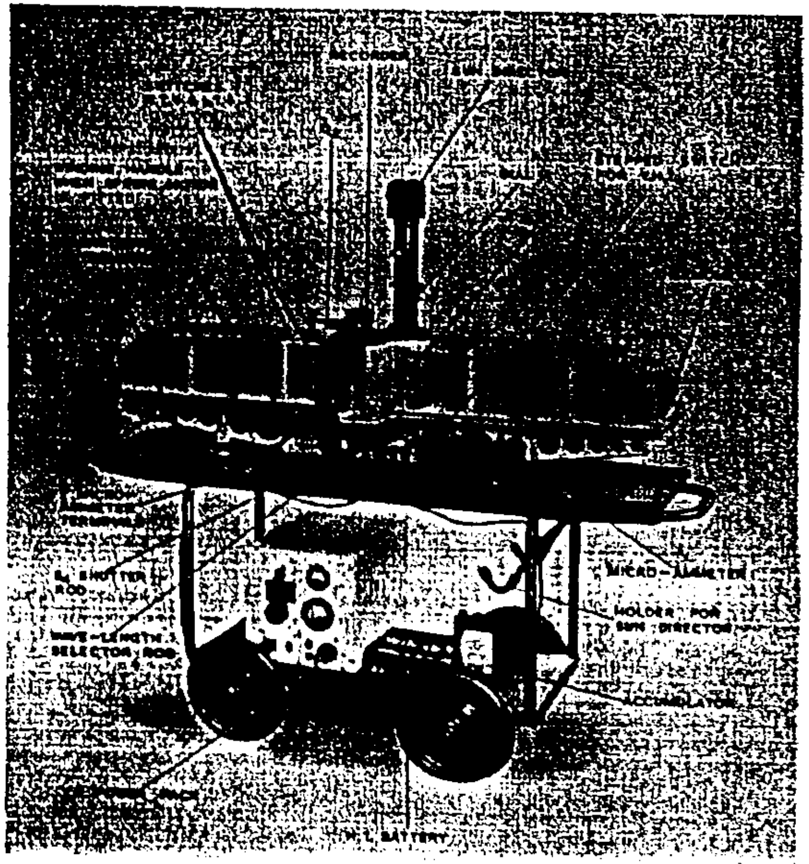
- ✓ Developed in the 1920s
- ✓ Earliest instrument used to measure ozone (total ozone and vertical profile)
- ✓ Standard instrument in the Global Ozone Observing System
- ✓ Measurements through a comparison of solar energy at two wavelengths in the ozone's absorption band
- ✓ Performs on a routine basis at a large number of locations (approximately 100) around the world

Pr. Dobson statement about the low values of October 1956 and 1957

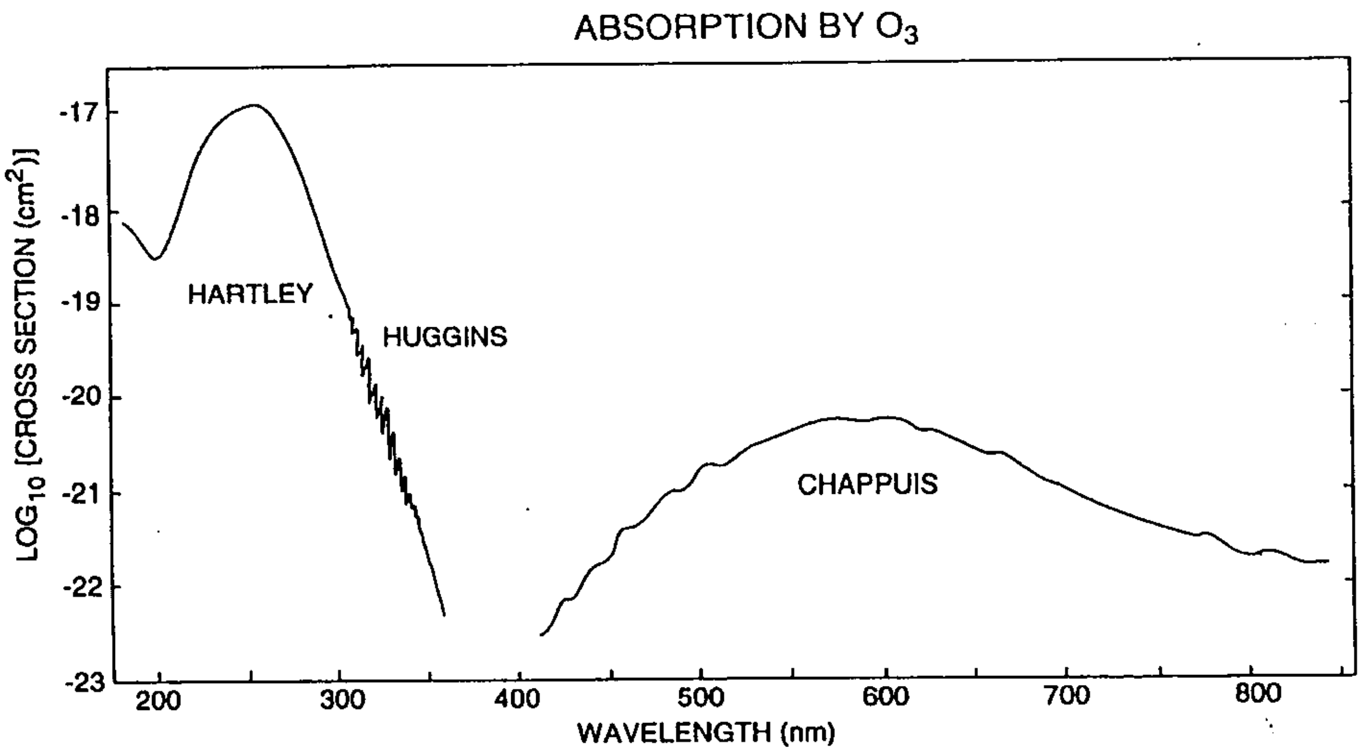


- ✓ *"It was clear that the winter vortex over the South Pole was maintained late into the spring and that this kept the ozone values low"*
- ✓ The first instruments had been installed in Halley Bay and Faraday

The Dobson instrument at Base Roi Baudouin



- ✓ Dobson instrument n° 51 belonging to World Meteorological Organisation and operated by the KNMI team (Wisse and Meerburg)
- ✓ Instrument n° 51 had been already deployed during the IGY on Argentine Island by the British Antarctic survey



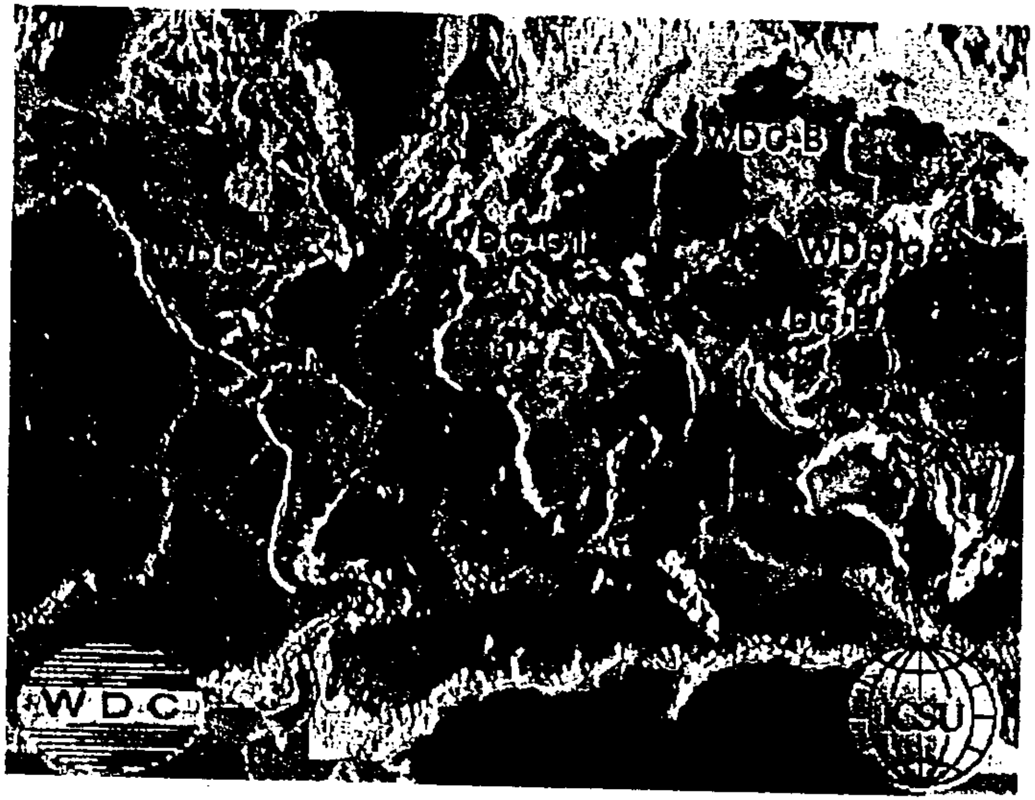
AD 305.5/325.4 nm

317.6/339.8 nm

Figure: Ozone absorption cross section

World Data Center system

http://www.ngdc.noaa.gov/wdc/wdcmain.html



WDC Guide

WDC-A USA

WDC-B Russia

WDC-C1 Europe

WDC-C2 Japan & India

WDC-D China

WDC Home Pages

ICSU

To serve the IGY and develop data management plans for each IGY scientific discipline. WDC system was made permanent and used for post-IGY data

❑ Dobson Spectrophotometer

✓ The discovery of the Ozone hole

☺ Dobson Spectrophotometer

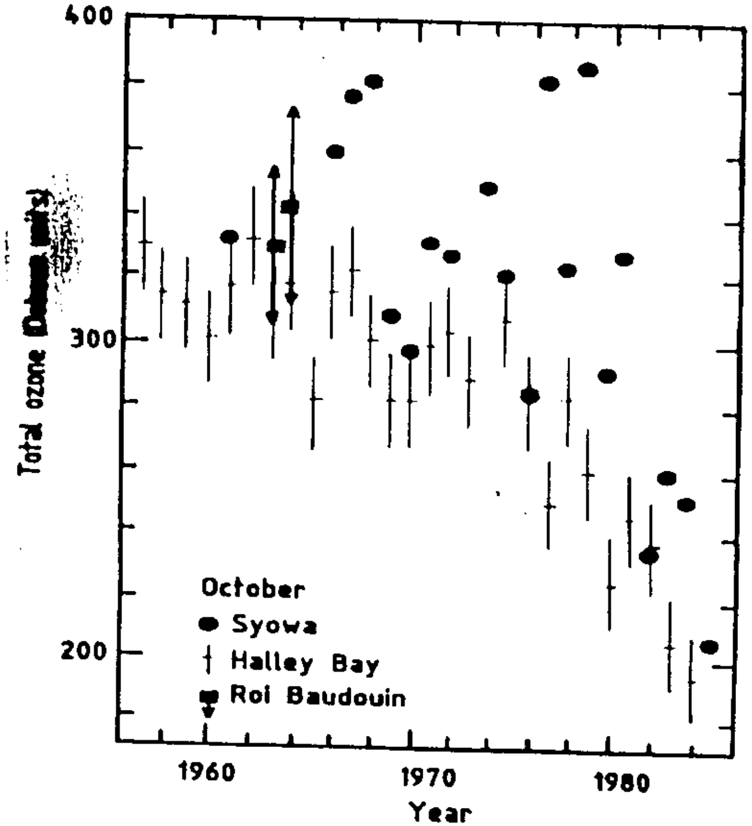
☹ Satellites

1925: 1 Dobson instrument (Arosa, Switzerland)

➡ 1930-1940: 3 to 5

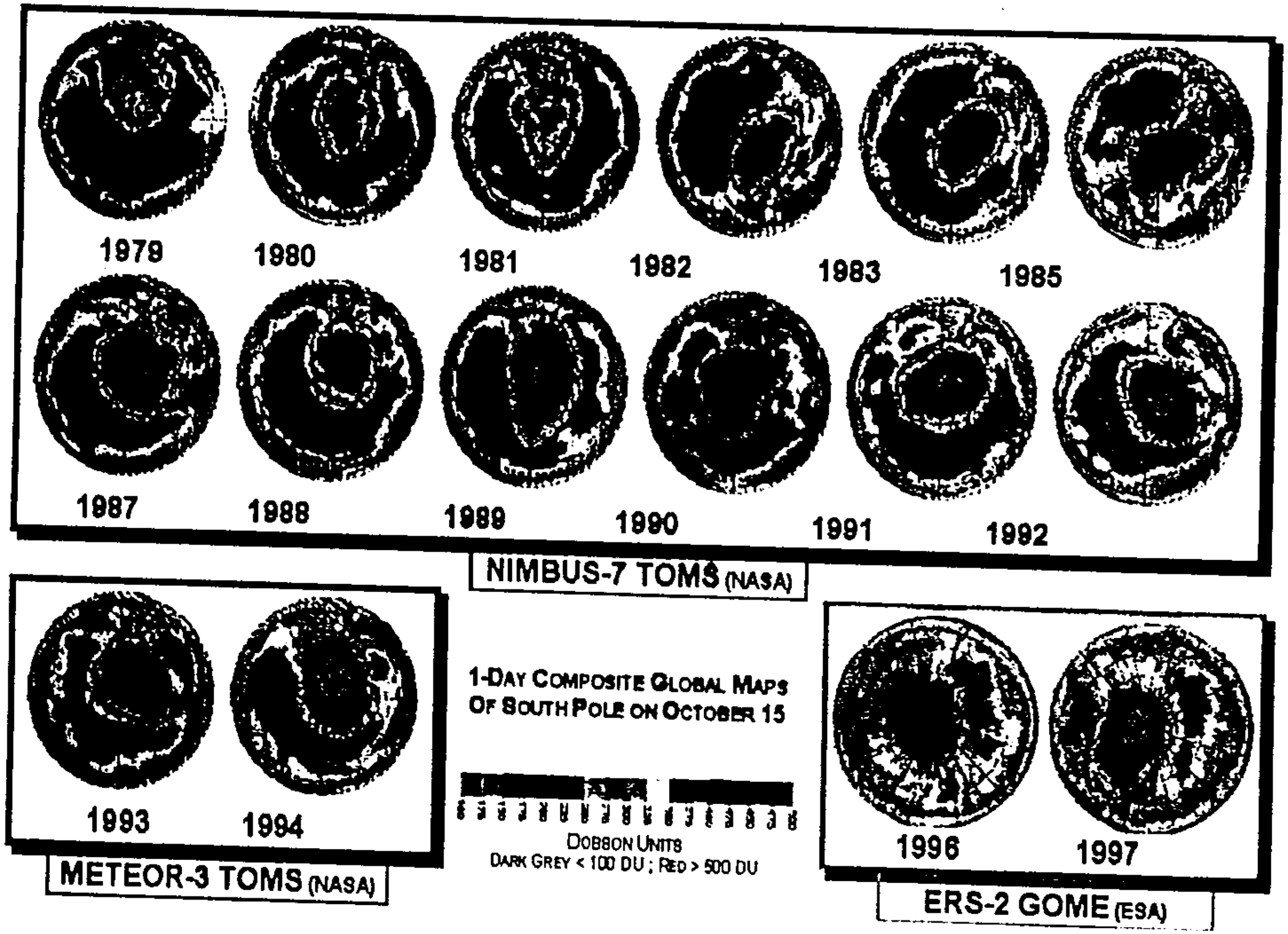
➡ 1958 (IGY): 40 !

Comparison with Halley Bay and Syowa



- ✓ Only two values for the October mean
- ✓ Higher dispersion than Halley Bay
- ✓ Probably lower dispersion than Syowa
- ✓ no evidence of low values in 1964 and 1965

Evolution of the ozone hole by satellite means



P. C. SIMON, ICTP Course, Trieste, October 26, 1999

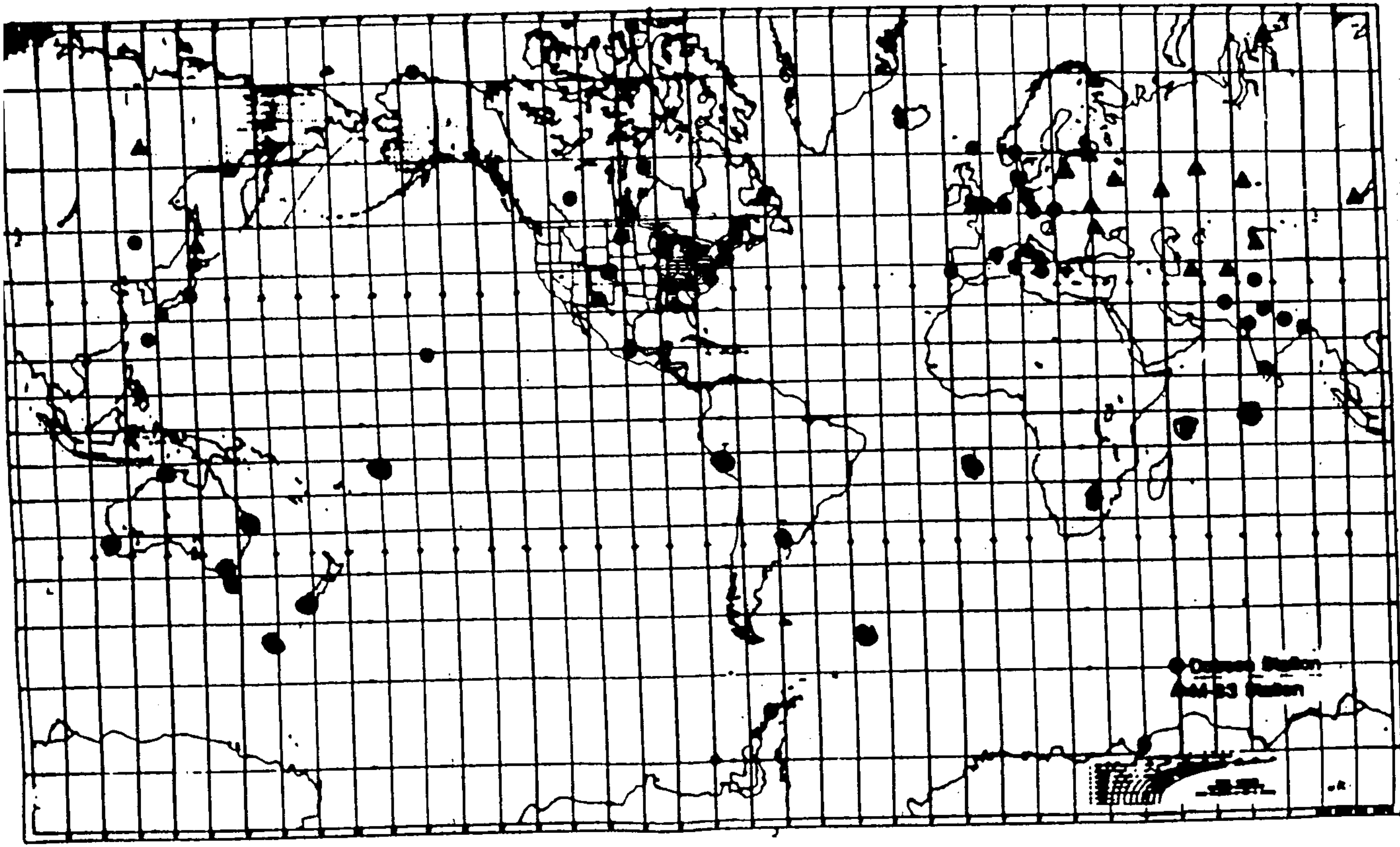
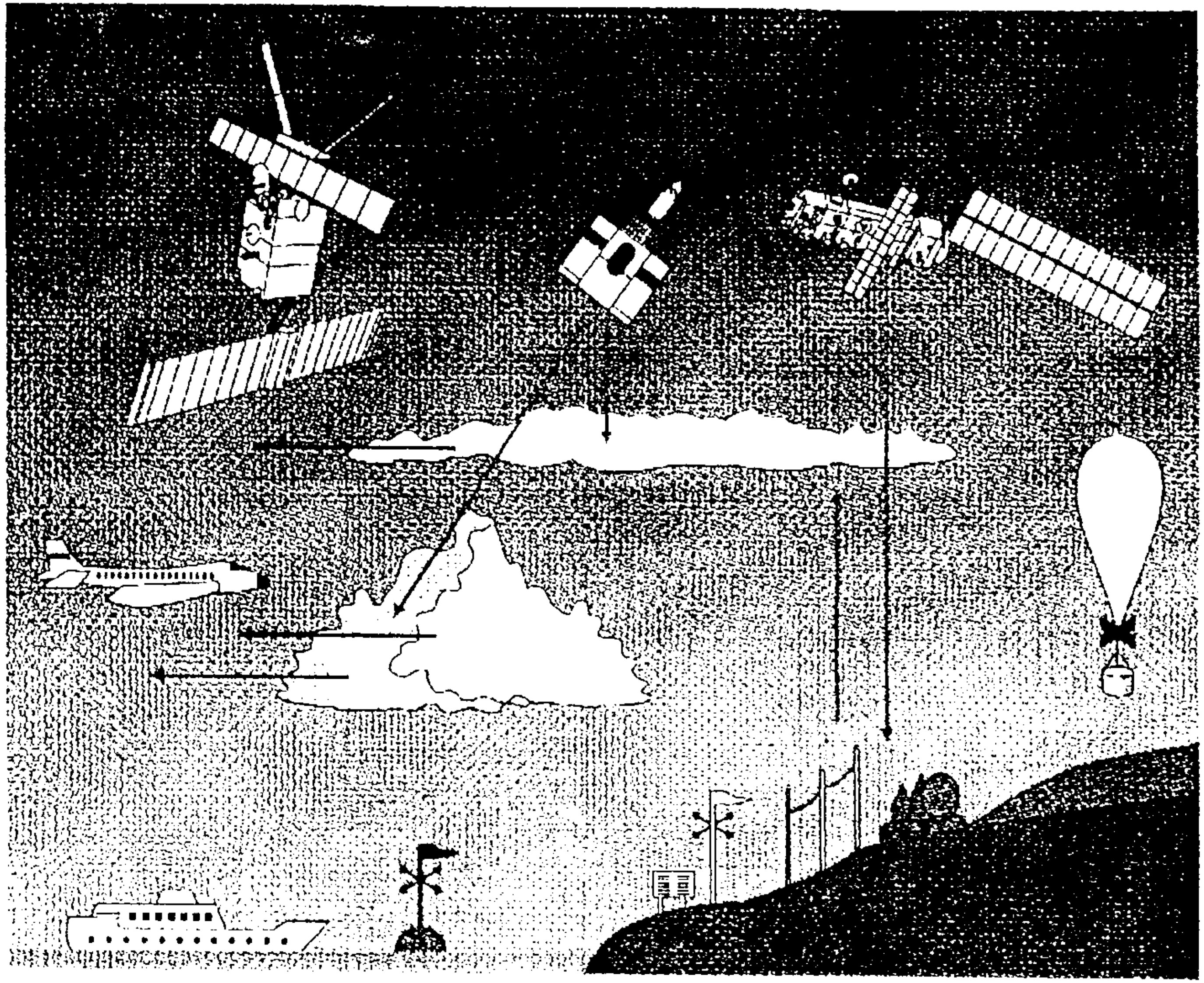


Figure 2.1-2. Location of Dobson (●) and M-83 (▲) stations.

The Network Approach: Recent efforts

- ❑ **Efforts to set up observational networks for continuous observations from the ground of main atmospheric variables**
  - ✓ More coherent picture of the atmospheric phenomena in understanding and predicting atmospheric changes
  - ✓ Improvement, better characterisation and homogenisation of a variety of instrumental techniques and data analysis methods
  - ✓ Validated data sets for satellite validation and improvement of multidimensional chemical and dynamical models



Some elements of an integrated global data collection system

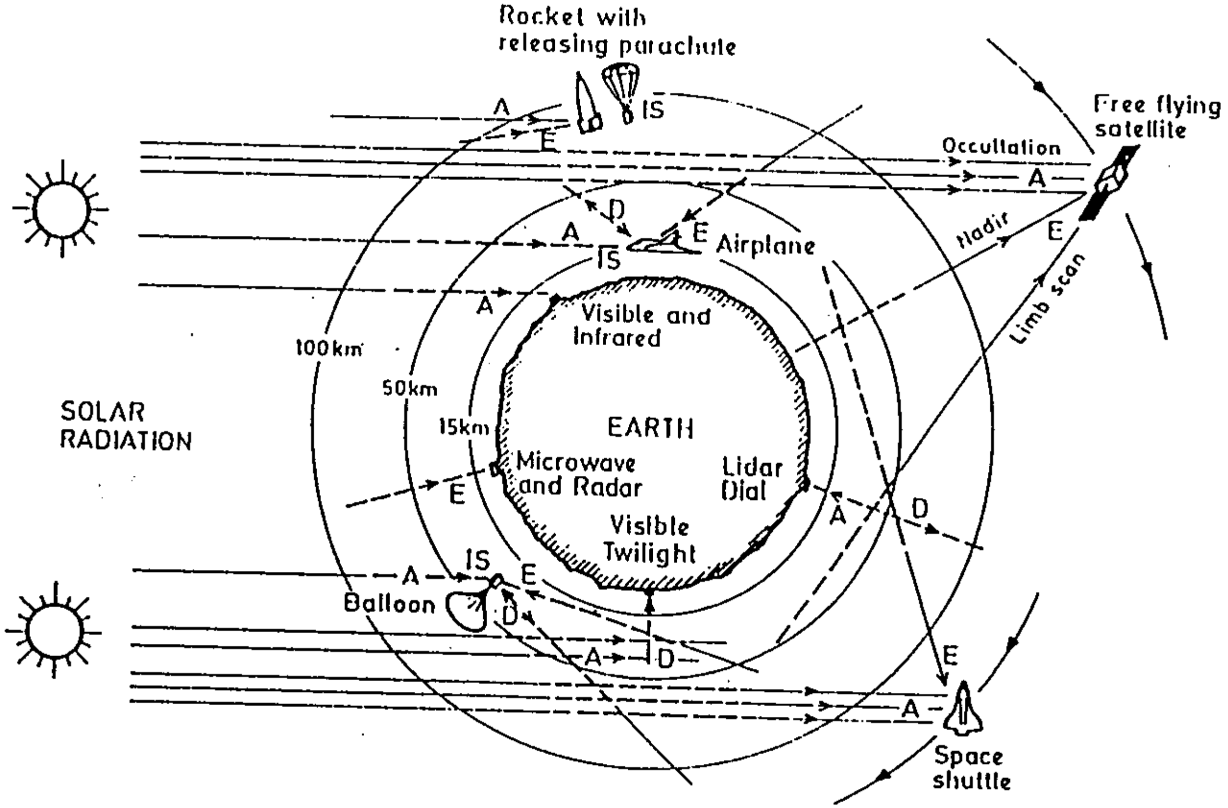


Figure 2. Illustration of the different methods and platforms that can be used to investigate stratospheric composition. In-situ measurements are denoted by "IS", while "A", "D", and "E" indicate techniques that use absorption, diffusion (scattering), and emission of radiation (from Schmidt and Zander, 1996).

Measurement of Ozone

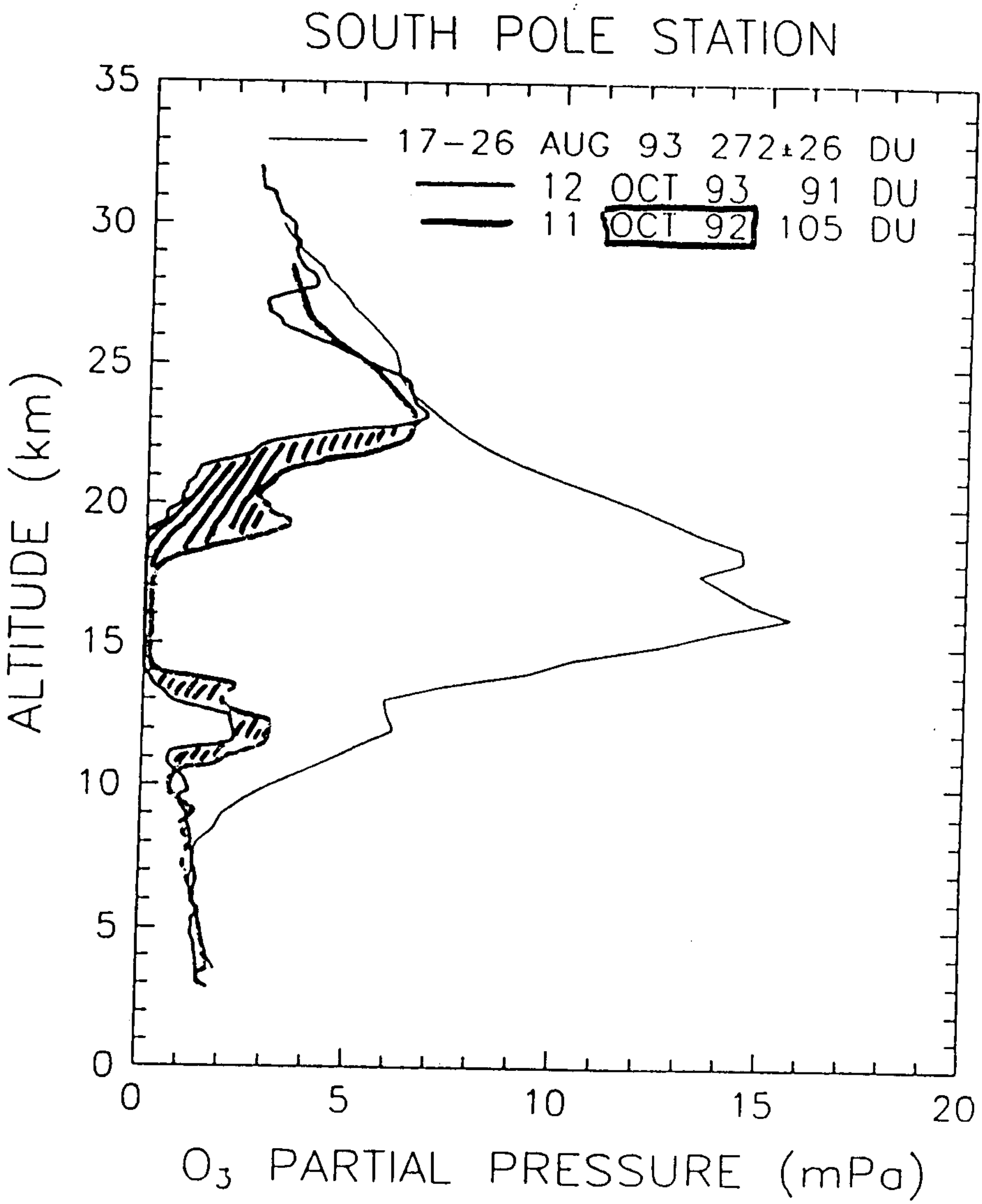
❑ **Remote sensing**

- ✓ Dobson spectrophotometers (R)
- ✓ Brewer spectrophotometers (R)
- ✓ M-83 and M-124 spectrophotometers (R)
- ✓ LIDAR (Light Detection and Ranging) and DIAL (Differential Absorption LIDAR) instruments (R)
- ✓ UV and visible photometers and spectrometers (R, IS)
- ✓ Optical rocket sondes (R)
- ✓ Optical satellites instruments (R)
- ✓ Laser heterodyne spectrometers (R)
- ✓ IR and far-IR grating and Fourier transform spectrometers (R)
- ✓ Microwave instruments (R)

Measurement of Ozone

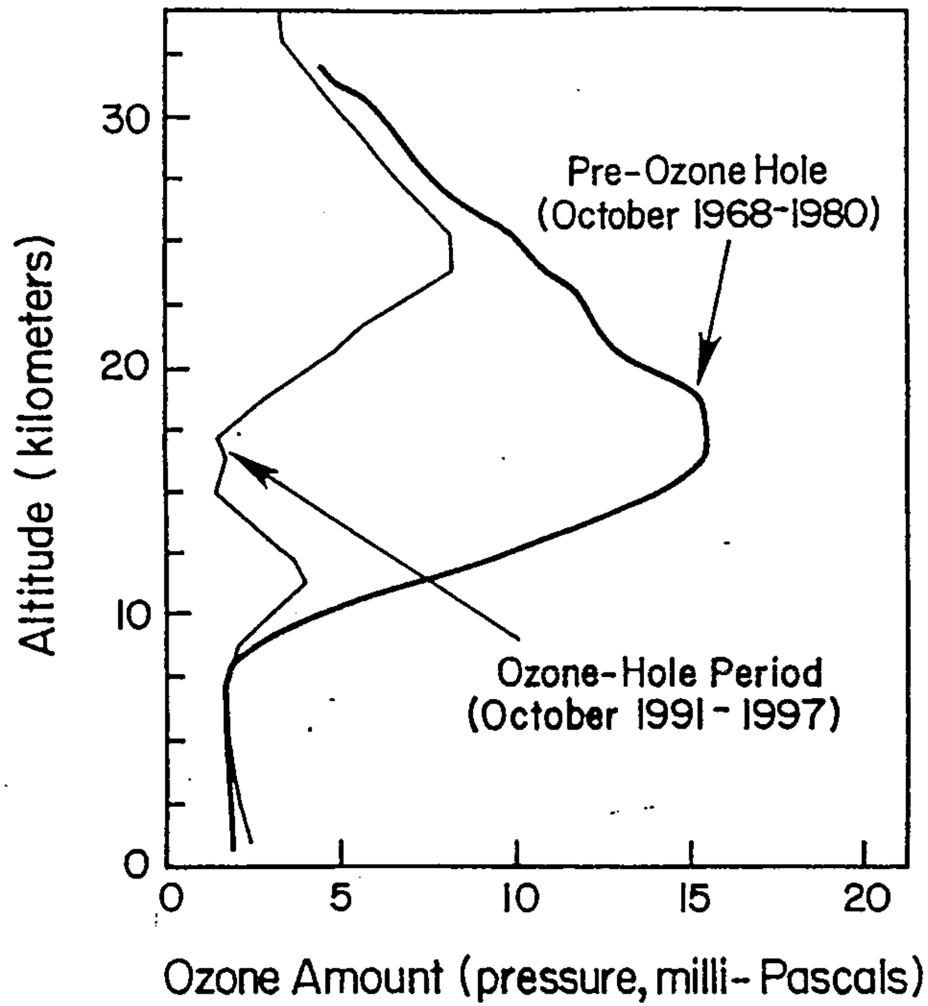
❑ **In-situ methods**

- ✓ Chemiluminescence sondes (IR)
- ✓ Electrochemical sondes (Brewer-Mast, EEC) (IS)
- ✓ Mass spectrometers (IS)



SOUTH POLE STATION
17-26 AUG 93 272±26 DU
12 OCT 93 91 DU
11 OCT 92 105 DU
ALTITUDE (km)
O3 PARTIAL PRESSURE (mPa)
0
5
10
15
20
25
30
35
0
5
10
15
20

Springtime Depletion of the Ozone Layer over Syowa, Antarctica



Network for the Detection of Stratospheric Change (NDSC)

NDSC

THE NETWORK FOR THE DETECTION OF STRATOSPHERIC CHANGE (1)

- Set of high-quality remote-sounding research stations
- Objective : observing and understanding physical and chemical state of stratosphere
- Endorsed by national and international scientific agencies (a.o. IOC, UNEP, WMO)
- Targets : ozone and key ozone-related chemical compounds and parameters
- Instruments :
  - ◊ lidar (vertical profiles of O_3, temperature, aerosol optical depth)
  - ◊ microwave radiometer (vertical profiles of O_3, H_2O, ClO)
  - ◊ ultraviolet/visible spectrometer (column abundance of O_3, NO_2, OClO, BrO)
  - ◊ Fourier Transform Infrared spectrometer (column abundances of a broad range of species including O_3, HCl, NO, NO_2, $CLONO_2$, and HNO_3)

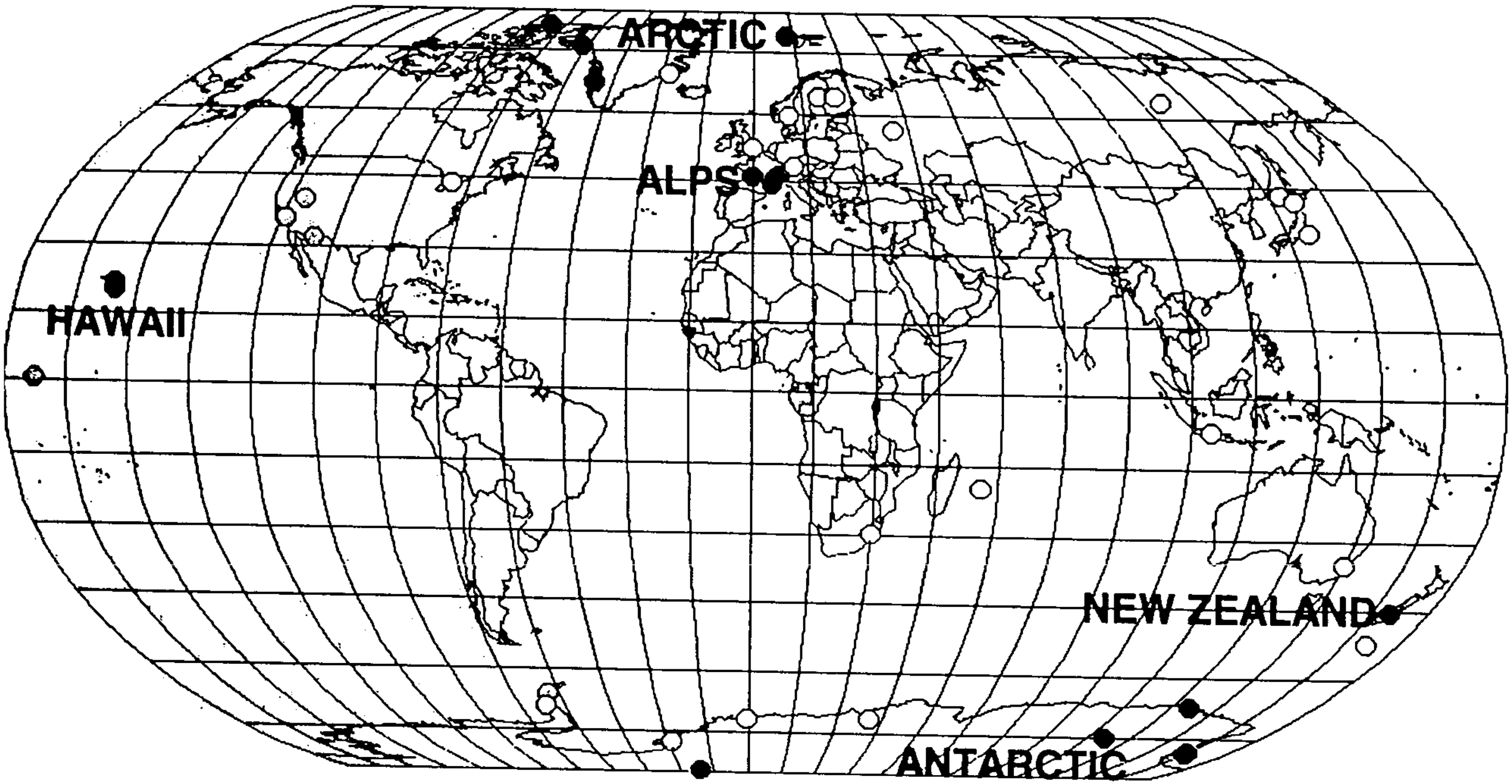
NDSC

THE NETWORK FOR THE DETECTION OF STRATOSPHERIC CHANGE (2)

- Complementarity with other existing monitoring activities and field campaigns
- Goals :
  - To make the <u>observations</u> through which changes in the physical and chemical state of the stratosphere can be determined and understood.
  - To make the earliest, possible <u>identification</u> of changes in the ozone layer and to discern the cause of the changes.
  - To provide an independent <u>calibration and validation</u> of space-borne sensors of the atmosphere.
  - To obtain the data that can be used to <u>test and improve</u> multi-dimensional stratospheric chemical and dynamical models.

NDSC

The Network for the Detection of Stratospheric Change (NDSC)



OZONE COLUMN AMOUNT VALIDATION (1)

Brewer and Dobson spectrophotometers

- Direct Sun measurement
  - ⇒ good temporal coincidence
  - ⇒ less accurate beyond 70° SZA
  - ⇒ no year-round measurement at polar circle
  - ⇒ only ‘clear’ sky conditions
- Zenith-sky measurements : less accurate
- μ-dependence
- T-dependence

OZONE COLUMN AMOUNT VALIDATION (2)

FTIR spectrometer

- Direct Sun measurement
  - ⇒ good temporal coincidence
  - ⇒ less accurate beyond 70° SZA
  - ⇒ no year-round measurement at polar circle
  - ⇒ only 'clear' sky conditions
- Simultaneously : many other species (NO_2, HCl, …)
- T-dependence
- Dependence on VMR profiles

ZONE COLUMN AMOUNT VALIDATION (3)

V-visible DOAS spectrometer

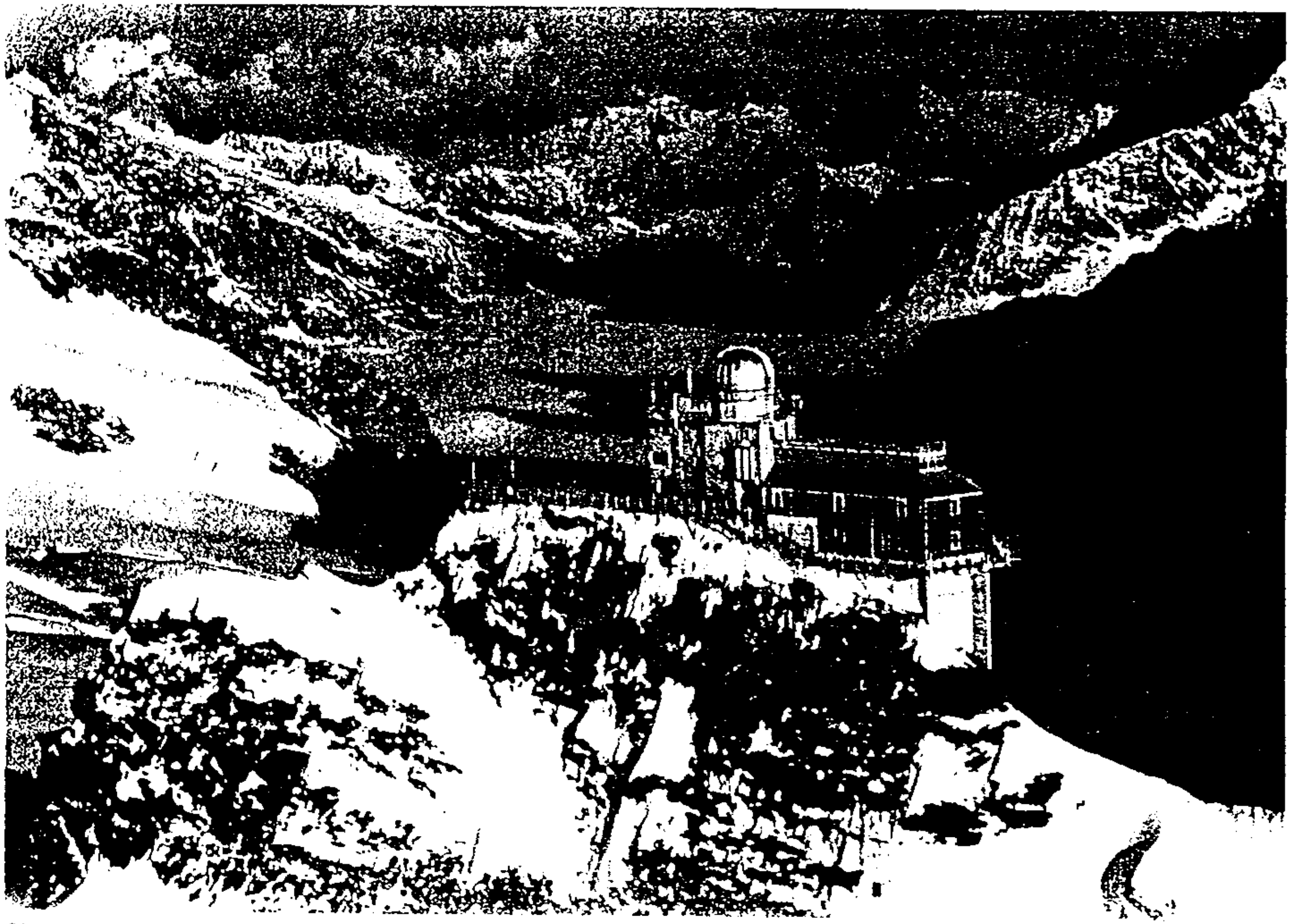
- Twilight measurements
  - ⇒ year-round monitoring up to polar circle
  - ⇒ nearly no weather limitation
  - ⇒ accurate validation even at large SZA
  - ⇒ good temporal coincidence at large SZA
- Extension of the probed air mass
  - ⇒ spatial coincidence at large SZA
- Pole-to-pole automated network
  - ⇒ entire range of SZA and of latitude within a short time
- Simultaneously : total NO_2
- Ozone retrieval in the visible Chappuis bands (T-insensitive)
- No calibration drift
- Seasonal dependence on ozone profile and scattering geometry

OTHER PRODUCTS

- Pressure and temperature profiles : ozonesonde, lidar
- ClO and H_2O profiles : microwave radiometer
- HCl, HF, HNO_3, NO, N_2O, $ClONO_2$, CH_4, CO, etc. : FTIR
- BrO, OClO : UV-visible DOAS
- Aerosols :lidar, backscattersonde

THE NDSC PRIMARY STATION AT THE JUNGFRAUJOCH

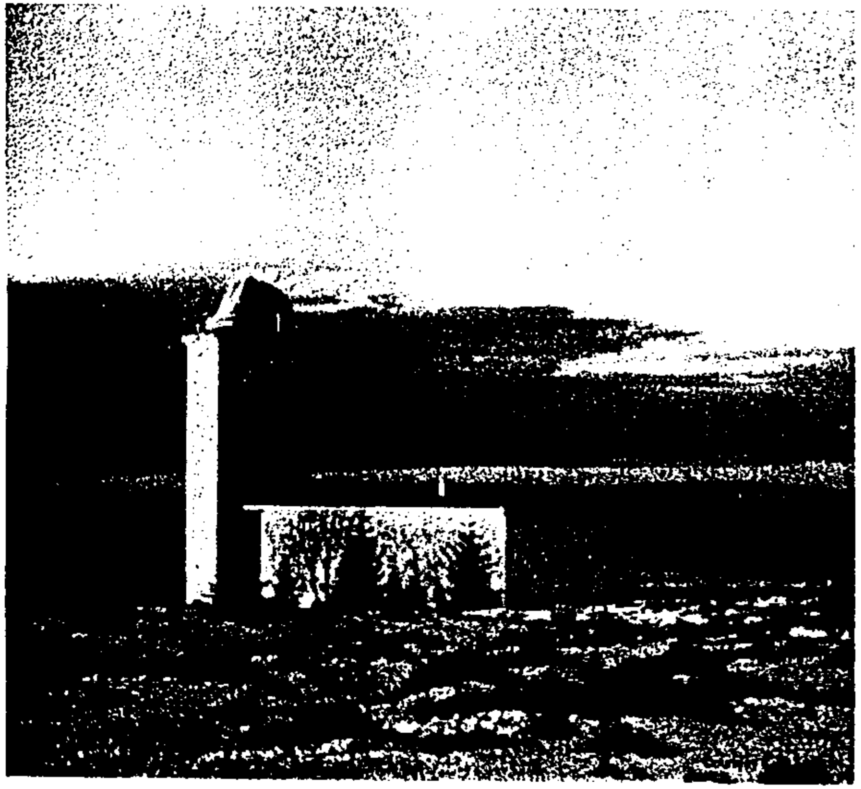
(SWITZERLAND, 46.55°N, 7.98°E)



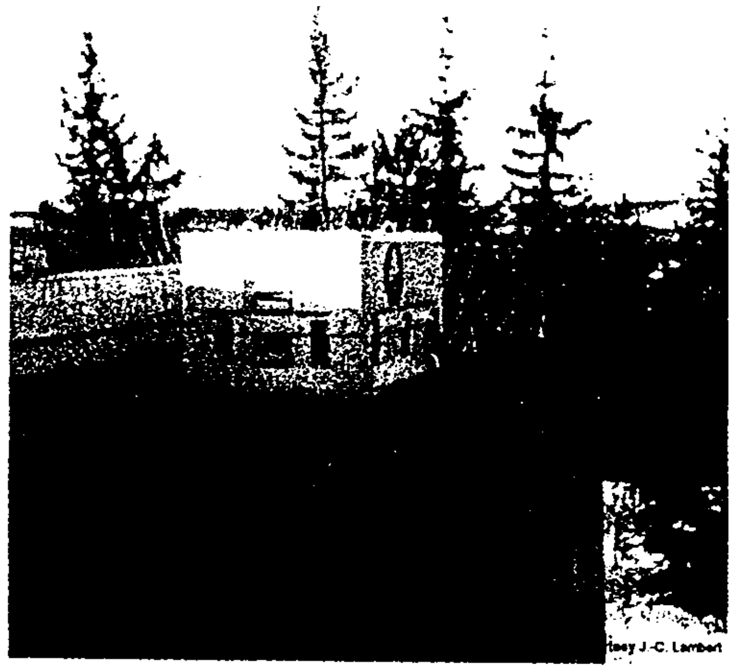
The Sphinx Observatory, International Scientific Station at the Jungfraujoch (ISSJ, Switzerland). The site contributes to the Alpine primary station of the Network for the Detection of Stratospheric Change (NDSC).

THE NDSC COMPLEMENTARY STATION AT HARESTUA

(NORWAY, 60.13°N, 10.45°E)



The cupola of the *Solobservatoriet*, housing the FTIR spectrometer operated by the Swedish Environmental Research Institute (IVL)



The ultraviolet and visible zenith-sky spectrometers operated by the Belgian Institute for Space Aeronomy (BIRA-IASB)

THE NDSC PRIMARY STATION AT DUMONT D'URVILLE

(ANTARCTICA, 66°S, 140°E)

The Antarctic Station of Dumont d'Urville (Terre Adélie). The site contributes to the Antarctic primary station of the Network for the Detection of Stratospheric Change (NDSC).

LATITUDE DEPENDENCE OF TOTAL NO_2 (1996)

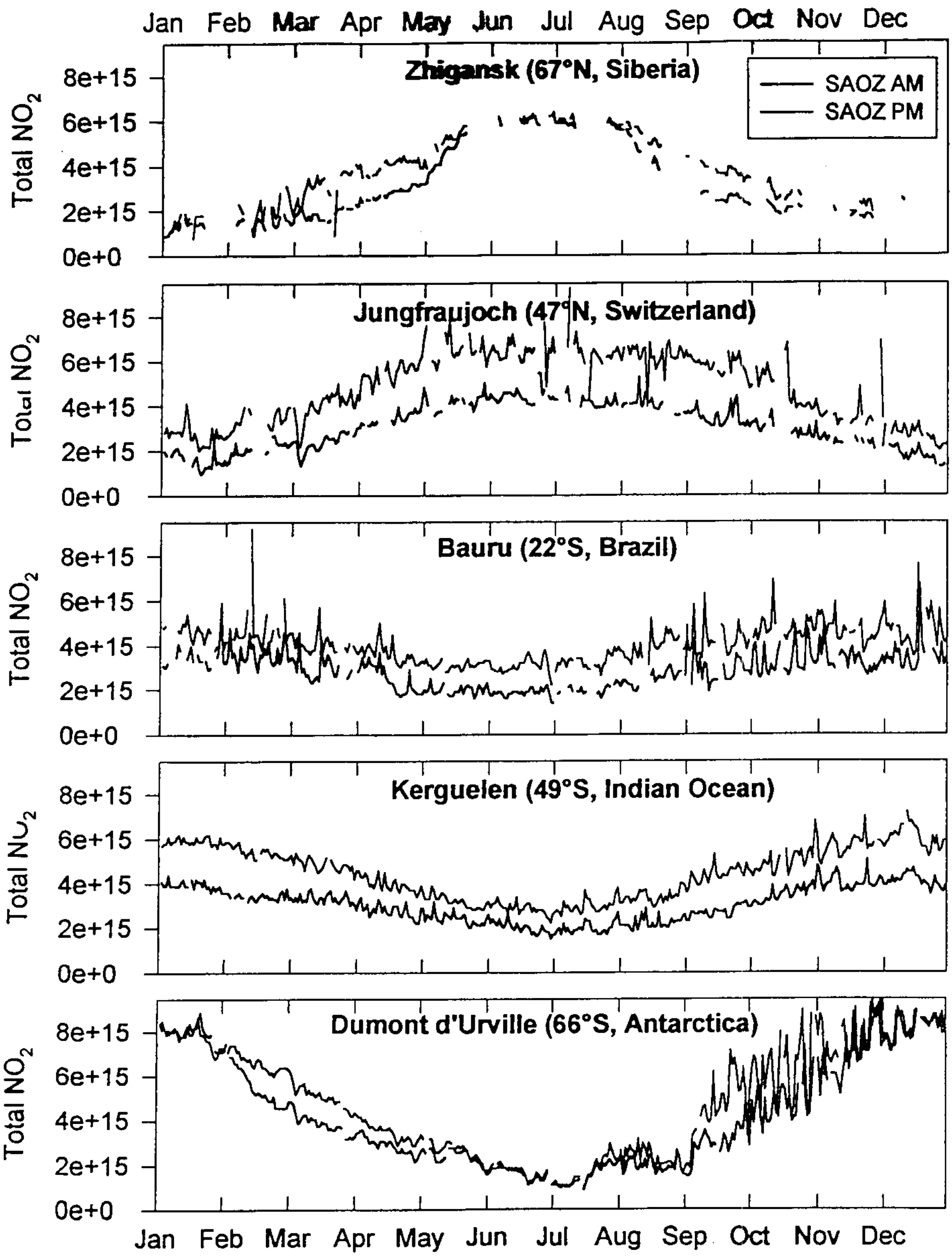


Table 1

Family	*Members*	*Source Gases*
HO_y	H, OH, HO_2, H_2O_2	CH_4, H_2O, H_2
NO_y	NO, NO_2, NO_3, N_2O_5, HONO, HNO_3, HO_2NO_2, PAN, $ClONO_2$, $BrONO_2$, aerosol nitrate	N_2O
Cl_y	Cl, Cl_2, ClO, Cl_2O_2, OClO, HOCl, HCl, BrCl, $ClONO_2$	CH_3Cl, CFCs, HCFCs, and other halocarbons

Table 2: Primary Techniques for NDSC Stations

Species[a]	*Technique*	*Observed Quantity*	*Alt. Range*
Ozone (O_3)	LIDAR	Vertical Profile	0-45 km[b]
Temperature	LIDAR	Vertical Profile	30-80 km
Aerosol	LIDAR	Vertical Profile[c]	0-30 km
Ozone (O_3)	Microwave	Vertical Profile	20-70 km
Water Vapor (H_2O)	Microwave	Vertical Profile	20-80 km
ClO	Microwave	Vertical Profile	25-45 km[d]
N_2O	Microwave and FTIR	Vertical Profile	20-50 km
O_3, NO_2, OClO, BrO	UV/VIS Spectroscopy	Column Abundance	
O_3, HCl, NO, NO_2, $ClONO_2$, CH_4, HNO_3	FTIR Spectroscopy	Column Abundance	

[a] or physical parameter
[b] 0-20 km for YAG, 15-45 km for Excimer-Lidar
[c] of aerosol optical density
[d] altitude range depending on latitude

Table 3: Primary Stations of NDSC and Operational Measurements

Station Name	*Species (Technique)*	*Composite Sites*	*Location*
Arctic Station	O_3 (LIDAR)	Ny-Ålesund	78.5°N, 11.9°E
	aerosol (LIDAR)	Thule	76.0°N, 69.0°W
		Eureka	80.0°N, 86.4°W
		Sondre Stromfjord	68.7°N, 52.7°W
Alpine Station	O_3, T (LIDAR)	Observatoire de Haute Provence	43.9°N, 5.7°E
	aerosol (LIDAR)	Plateau de Bure	44.4°N, 5.6°E
		Jungfraujoch	47.0°N, 8.0°E
		Observatoire de Bordeaux	44.4°N, 1.0°W
Mauna Loa	O_3, T (LIDAR)	Mauna Loa	19.5°N, 155.4°W
	ClO (MW)	Mauna Kea	19.5°N, 155.4°W
	CH_4, N_2O, HNO_3		
	$ClONO_2$, HCl (FTIR)		
Lauder	O_3, T (LIDAR)		45.0°S, 169.7°E
	H_2O, O_3 (MW)		
Antarctic Station	NO_2, O_3 (UV-VIS)	Dome Concorde (future site)	74.5°S, 124.0°E
	aerosol (LIDAR)	Arrival Heights	78.0°S, 166.0°E
		Dumont D'Urville	67.0°S, 140.0°E

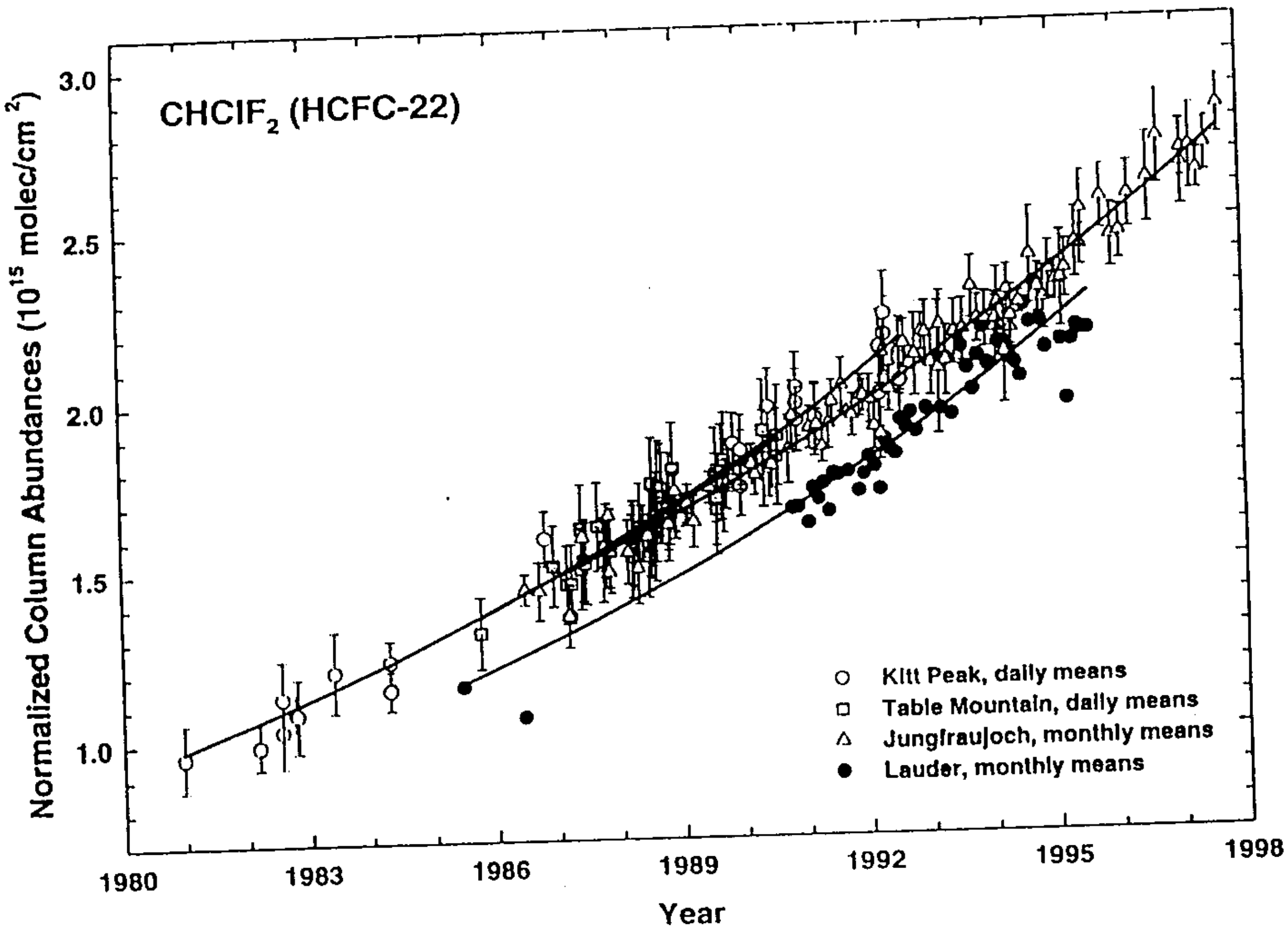


Figure 2-3. Trends (depicted by solid lines) in the normalized vertical column abundances of HCFC-22 monitored remotely at NH and SH sites, including Kitt Peak (31.9°N; open circles), Table Mountain (34.4°N; shaded squares), Jungfraujoch (46.5°N; open triangles), and Lauder (45.0°S; filled circles). The observed columns from the first three sites have been pressure-corrected (with respect to Lauder) to account for altitude differences among the various sites. Data include extensions of published work by Zander *et al.* (1994a), Irion *et al.* (1994), and Sherlock *et al.* (1997).

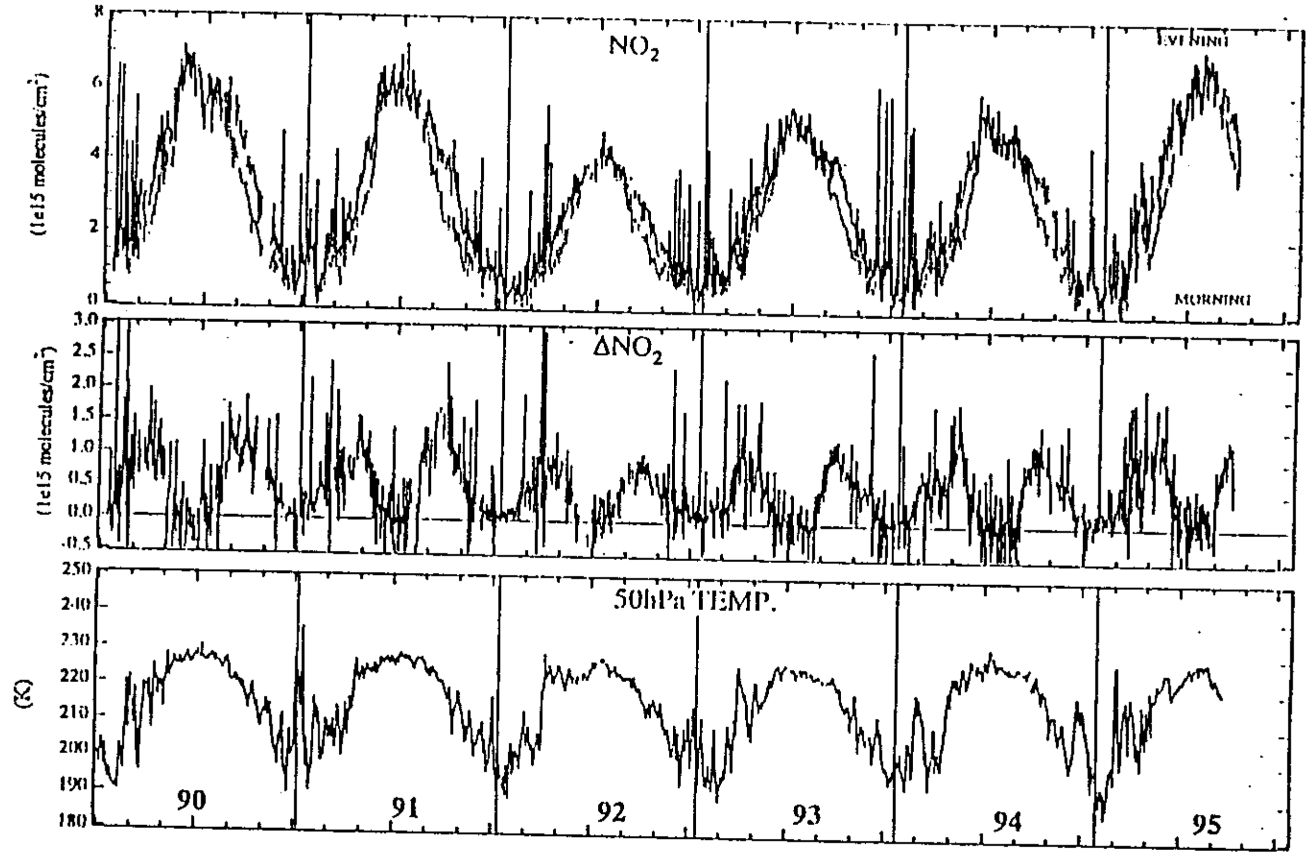


Figure 6. Upper panel: Six year time series of the seasonal variation of NO_2 vertical columns measured twice a day, at sunrise (dotted line) and at sunset (solid line) on the Arctic circle at Sodankyla in Finland. Middle panel: difference between sunset and sunrise columns. Lower panel: temperature as measured from daily radio-soundings from the same station (from Goutail *et al.*, 1994; figure courtesy of F. Goutail).

Satellite measurements

❑ Their integration in observing systems is imperative

✓ **The only way of achieving a truly global and homogeneous coverage of the atmosphere**

✓ **<u>But</u> ....**

Geo~~physical~~ graphical resolution tends to be low for atmospheric observations

Not all chemical species of interest can be measured

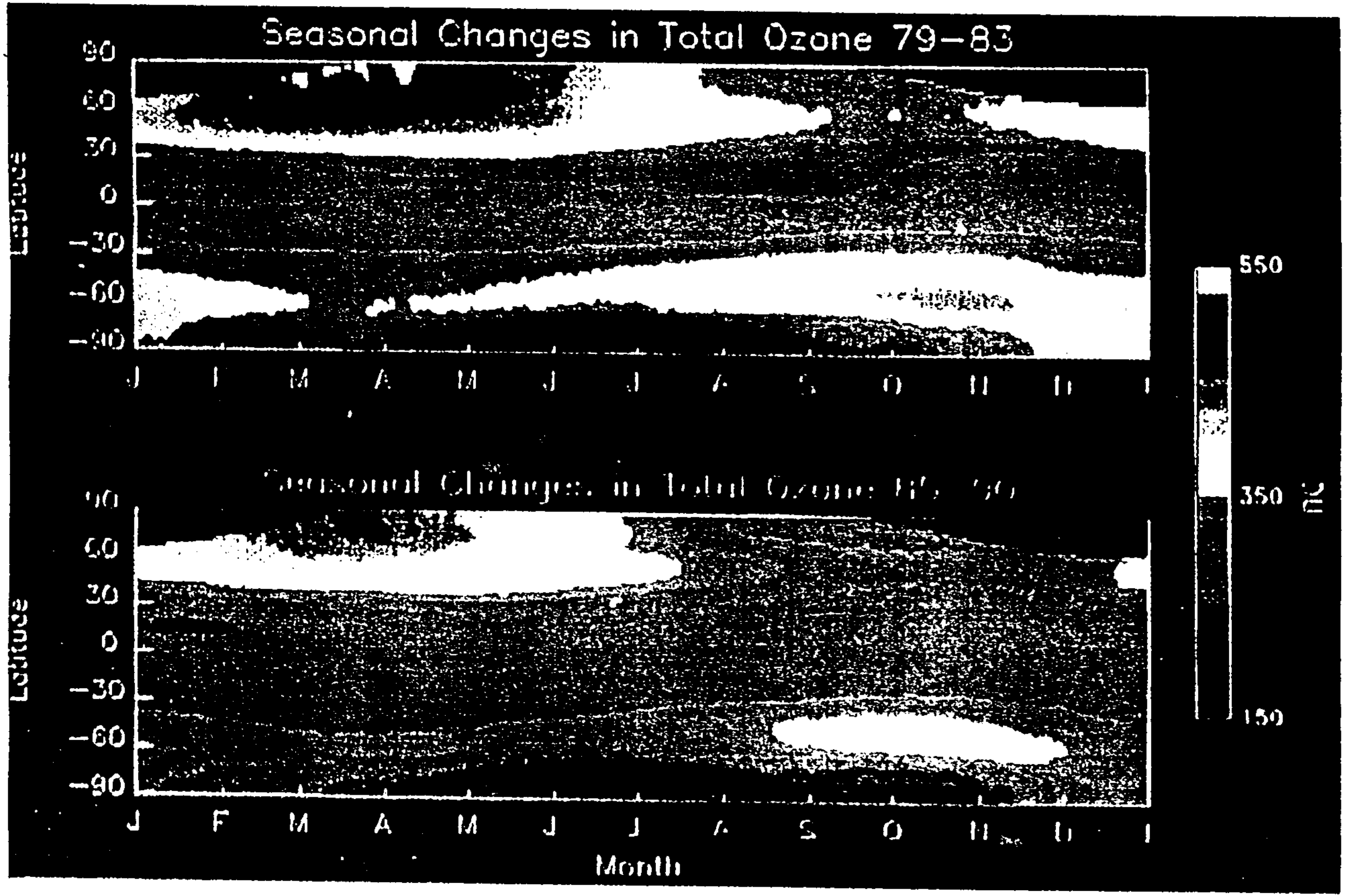
⇨ Global stations: ideal ground truthing network to make the most effective use of satellite information

Satellite measurements

❑ Ozone

✓ TOMS (total Ozone Mapping Spectrometer)
- Nimbus 7 (1978 - 1993) global coverage every day
- Meteor 3 (1993) global coverage every day
- Earth Probe (since 1996) global coverage every 3 days

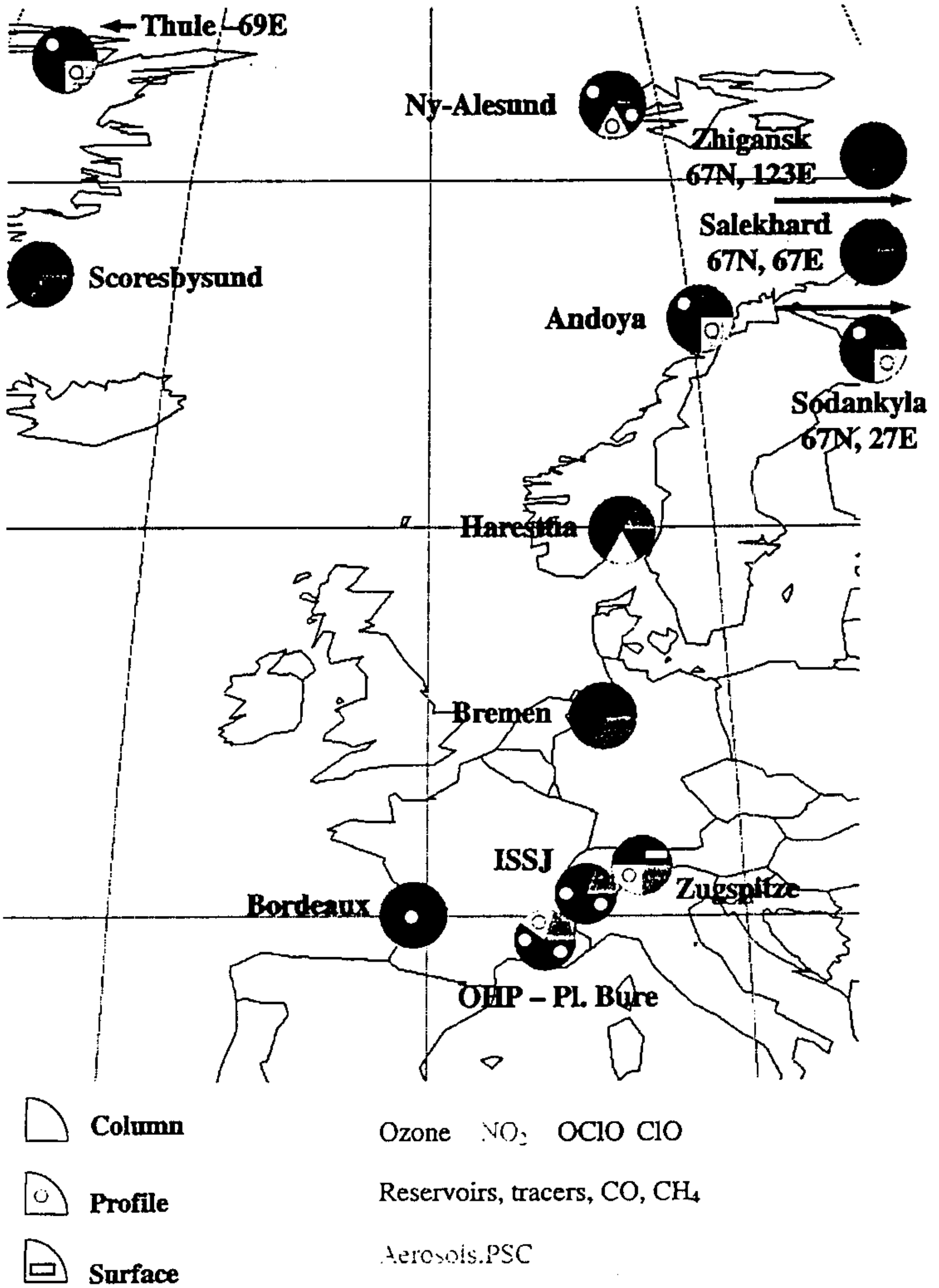
✓ GOME/ERS-2 (Global Ozone Monitoring Experiment)
- Since 1995
- Global coverage every 3 days


Seasonal Changes in Total Ozone 79-83
Latitude
90
60
30
0
-30
-60
-90
J F M A M J J A S O N D J
Latitude
-30
-60
-90
Month
550
350
150
DU

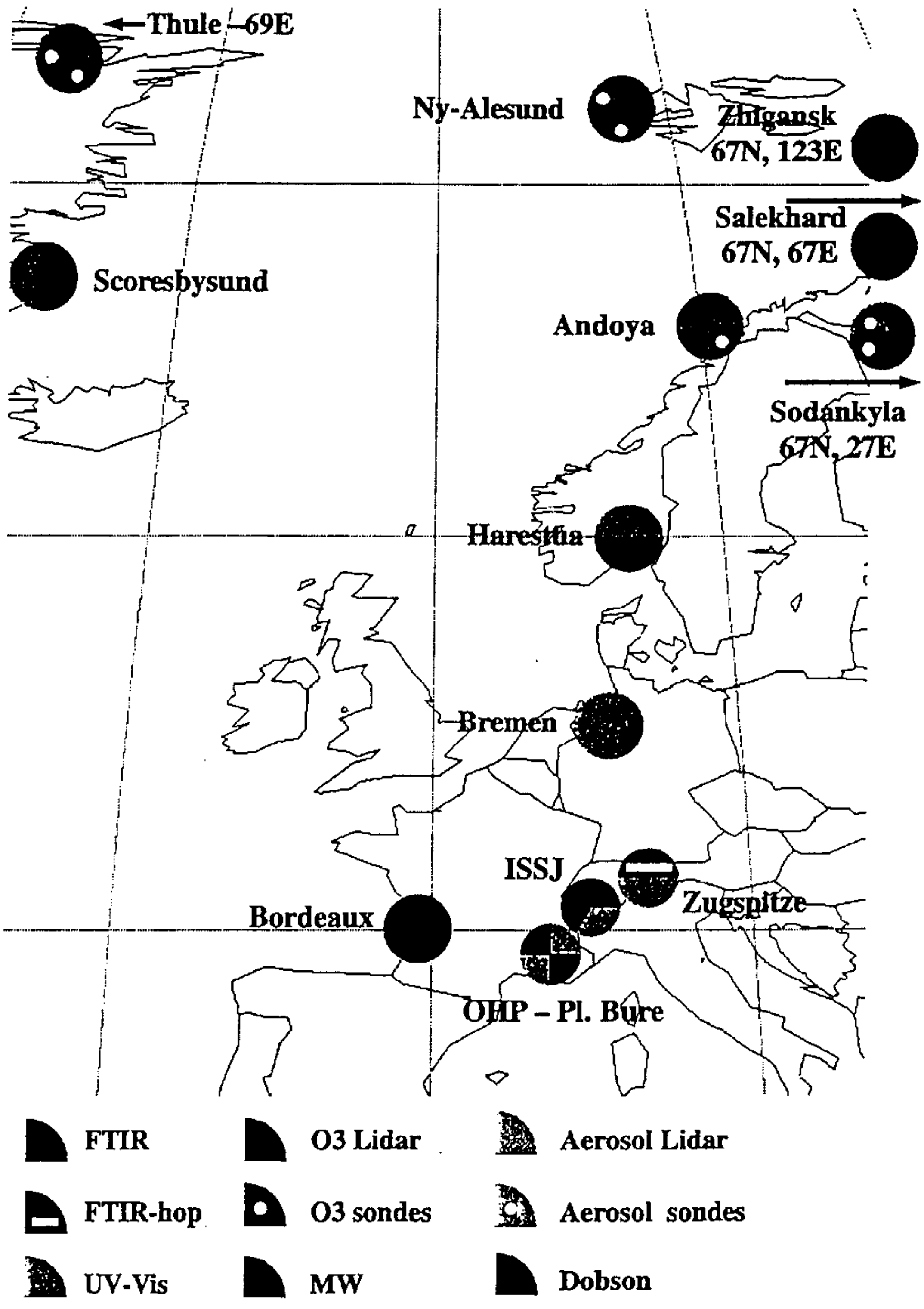
CEOS (Committee on Earth Observation Satellites)

- ❑ **CEOS has embraced the concept of an Integrated Global Observing Strategy (IGOS)**

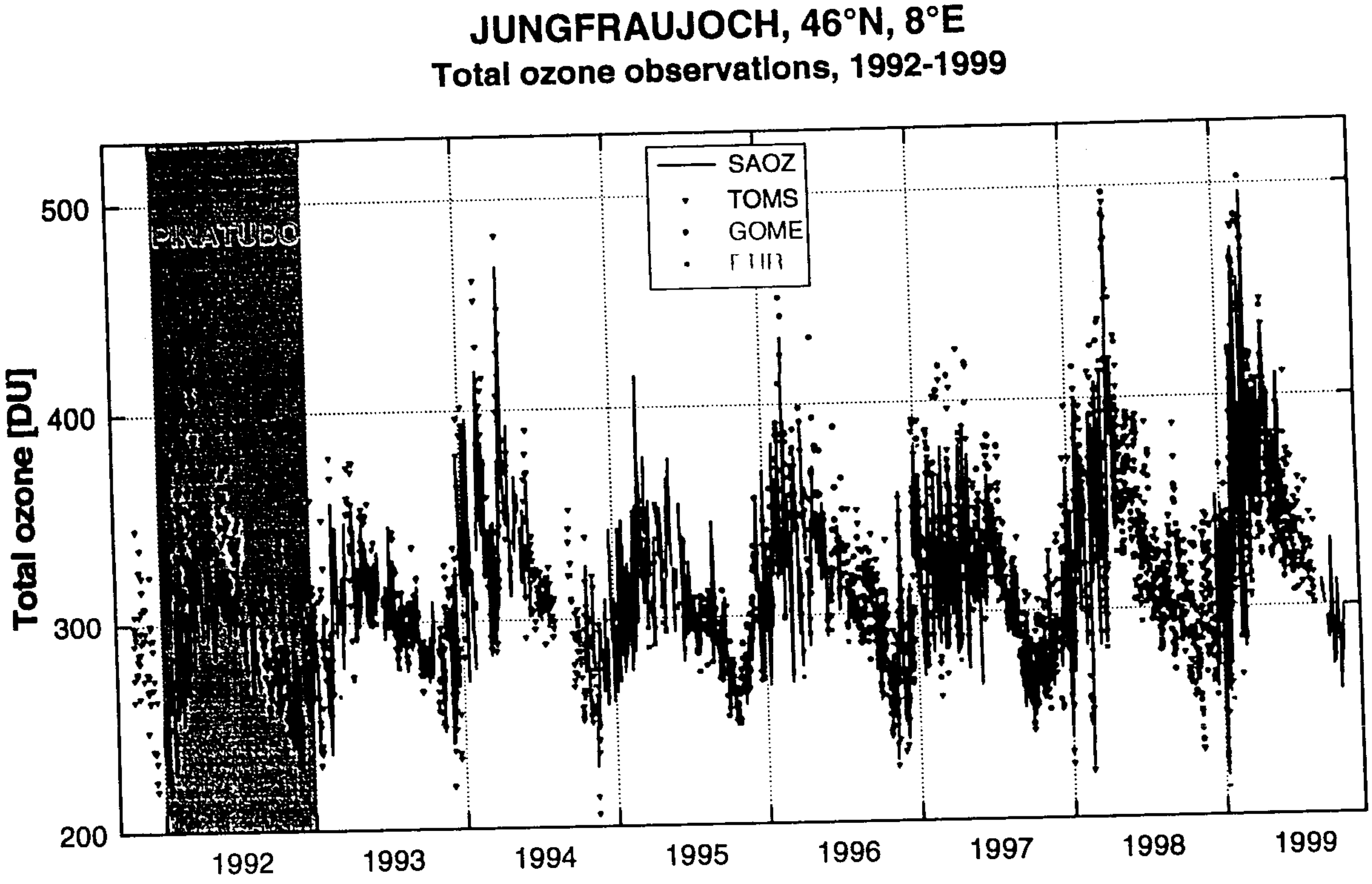
  - ✓ Unite the major satellite and ground-based systems for global environmental observations of the atmosphere, oceans and land
  - ✓ Provides a forum for co-ordinating the activities of space agencies and informing users on future missions
  - ✓ Facilitates data access and exchange, stimulates better archiving, harmonisation, quality assurance and calibration/validation of data

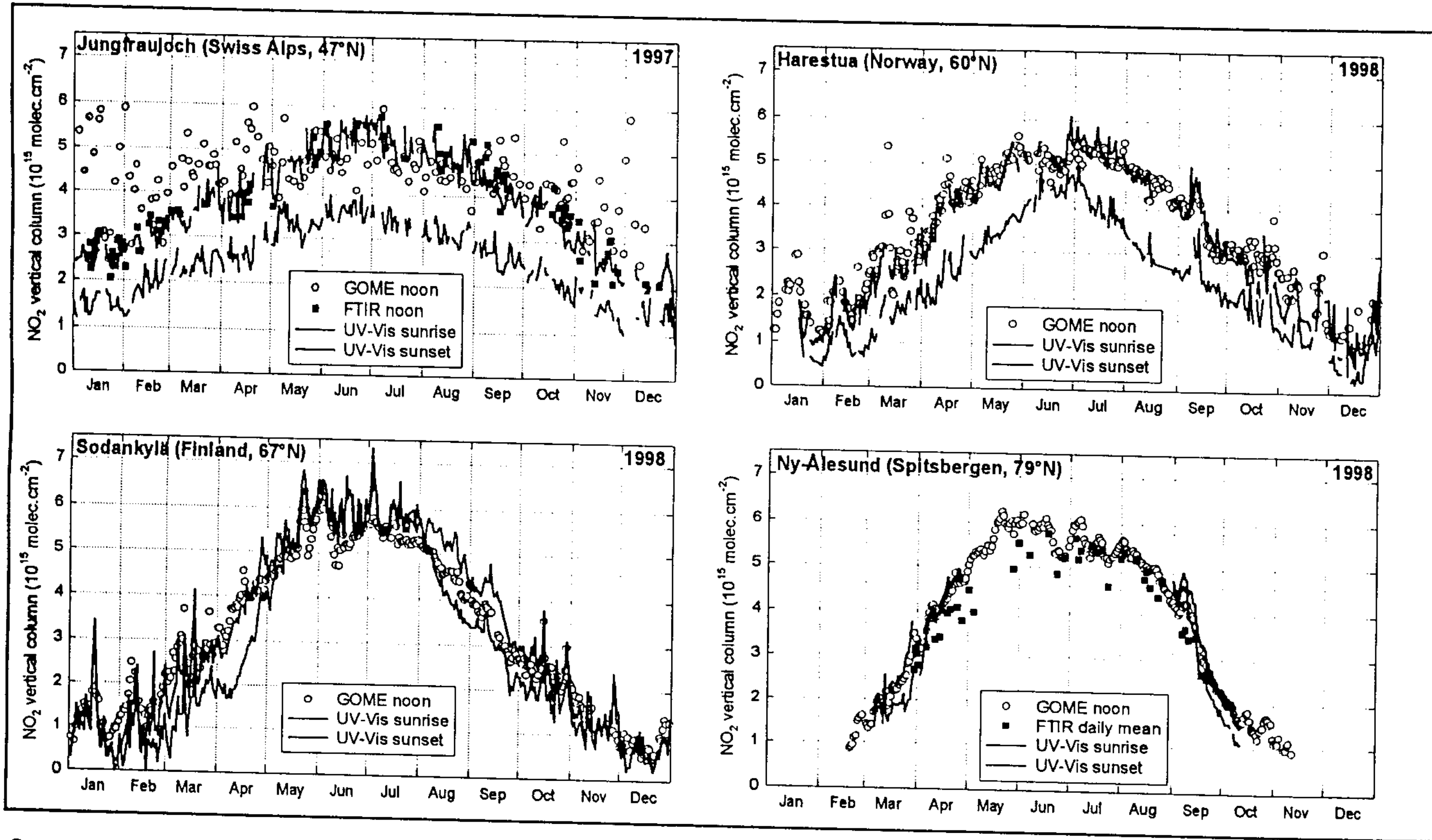


European support to NDSC (COSE co-ordinated by M. De Mazière), instruments involved.



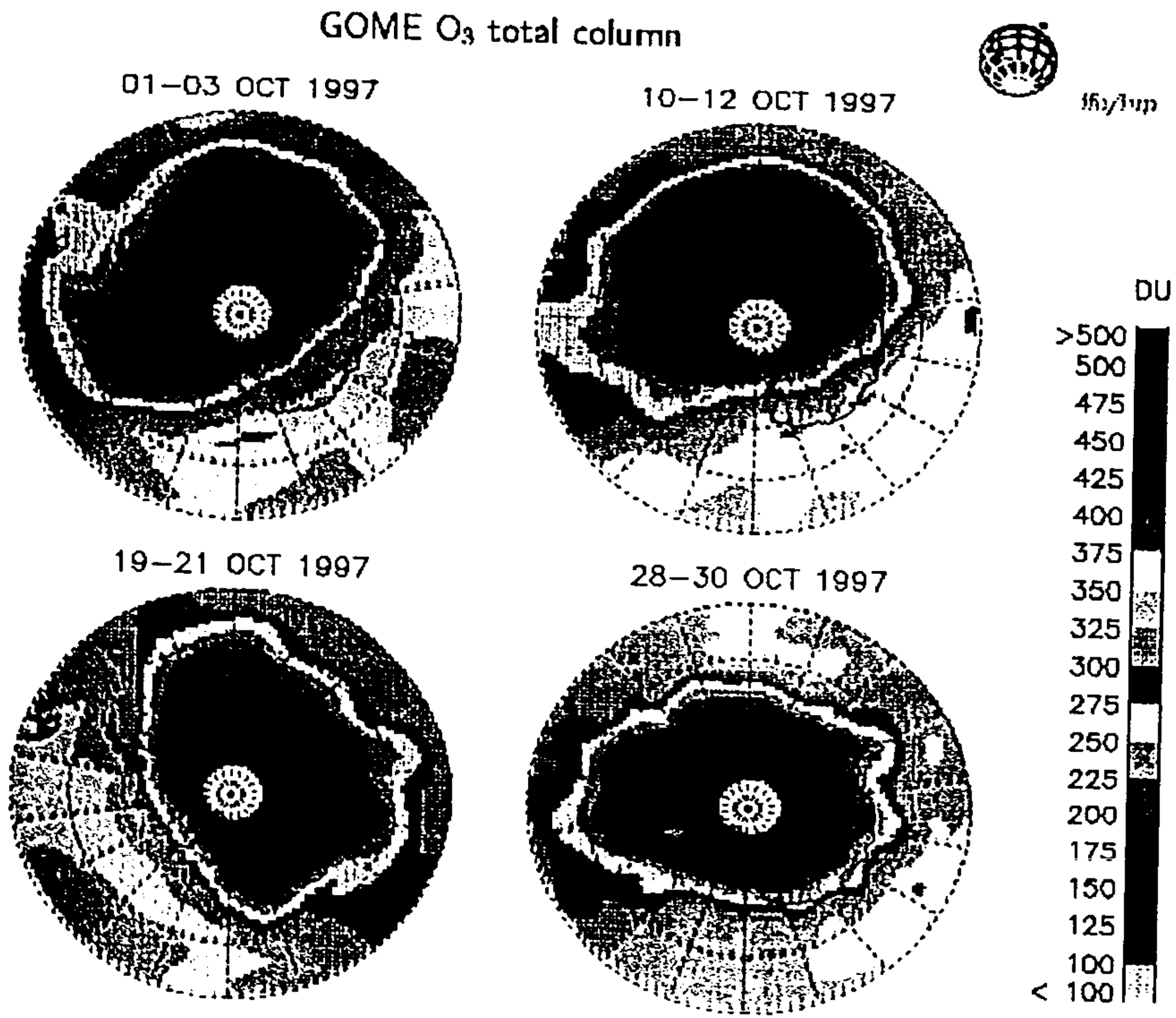
European support to NDSC (COSE co-ordinated by M. Demazière), archived data products.


JUNGFRAUJOCH, 46°N, 8°E
Total ozone observations, 1992-1999
SAOZ
TOMS
GOME
PINATUBO
Total ozone [DU]
500
400
300
200
1992
1993
1994
1995
1996
1997
1998
1999



Seasonal and latitudinal variation of total NO_2 as derived from ERS-2 GOME satellite measurements and as observed with ground-based UV-visible and FTIR spectrometers. The synergistic use of different observation techniques and platforms at various locations allows to discriminate measurement artifacts from real geophysical features. E.g., most of outlying satellite data – observed especially over the Alps where ground-based UV-visible data have been filtered out – are indicative of enhanced tropospheric NO_2 to which the GOME measurement is highly sensitive.

Data courtesy: AWI, BIRA-IASB, CNRS/FMI, IFE/DLR/ESA, NILU, and ULG (From COSE Brochure)

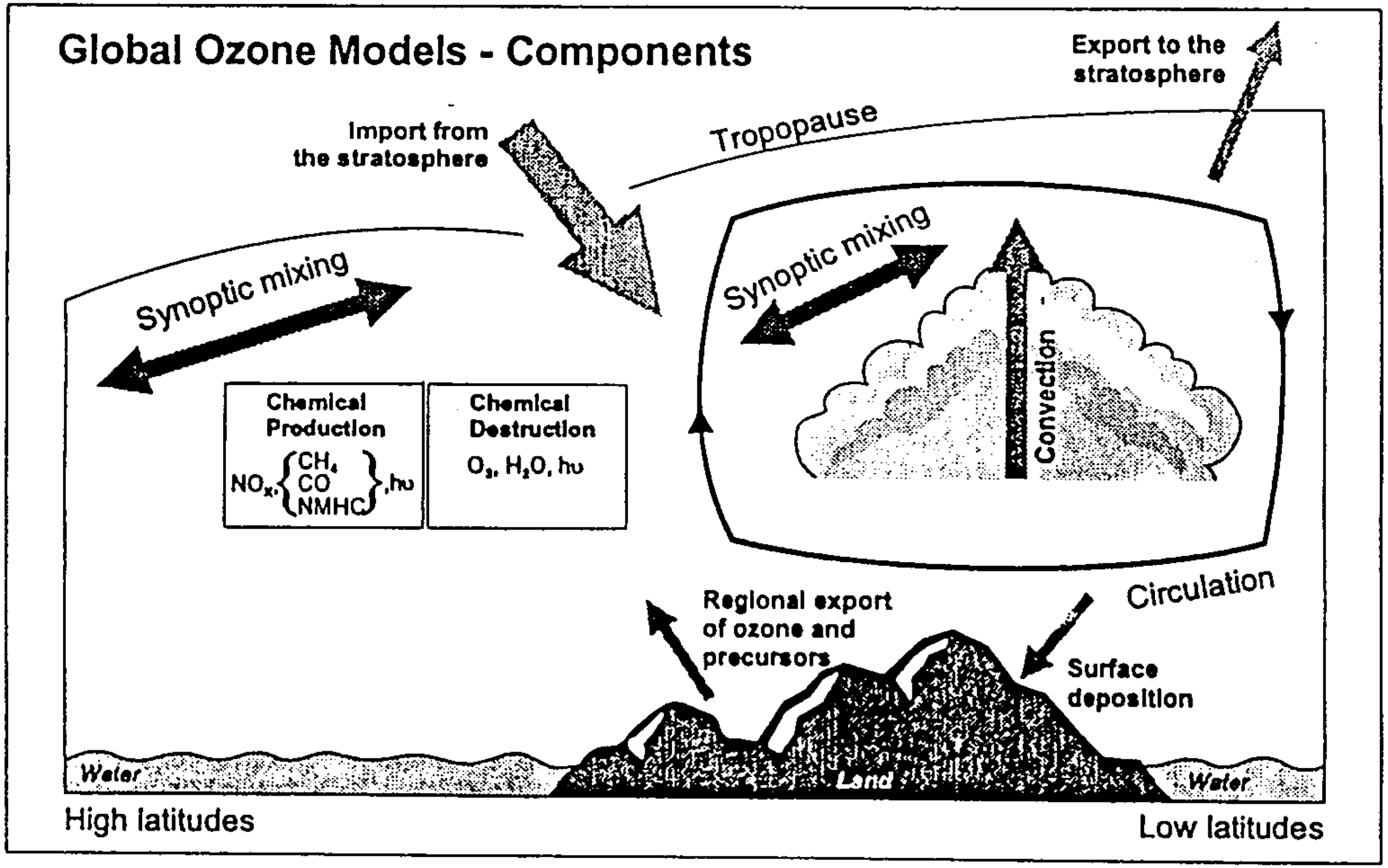

GOME O_3 total column
01–03 OCT 1997
10–12 OCT 1997
19–21 OCT 1997
28–30 OCT 1997
DU
>500
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
< 100

Tropospheric Chemistry

Global tropospheric chemistry is a component of the Earth System

It interacts with

• the ocean	(emissions, deposition)
• the climate	(meteorol., radiative forcing)
• the biosphere	(emissions, deposition, etc.)
• the stratosphere	(radiation, strat/trop exchange)
• and us	(emissions, toxicity, etc.)



Processes governing the global tropospheric ozone budget. The major components are import of ozone from the stratosphere, chemical production and loss, deposition at the ground and ozone production on the smaller urban and regional scales.

Which species are we interested in ?

CLIMATE	
(besides CO_2, H_2O, CFCs, chemically inert in the troposphere)	
O_3 (ozone)	warming effect
CH_4 (methane)	warming effect
HCFCs, HFCs	warming effect
submicronic aerosols	cooling effect

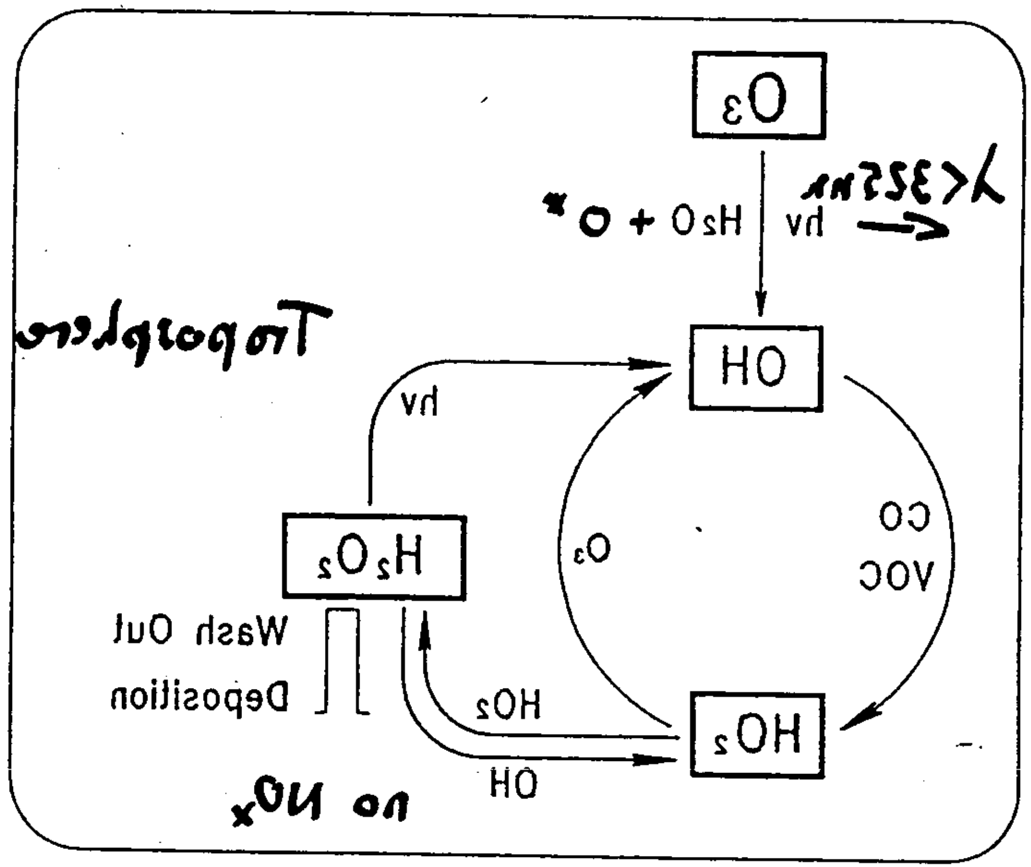
IMPACT ON BIOSPHERE	
(besides CO_2, H_2O chemically inert in the troposphere)	
O_3 (ozone)	oxidant, harmful
aerosols	harmful
acids (HNO_3, H_2SO_4)	acid rain, harmful
nitrogen species	plant nutrient
peroxides	oxidants, harmful
etc.	

<u>ALL</u> THESE SPECIES ARE (PARTLY) ANTHROPOGENIC

OXIDISING CAPACITY OF THE TROPOSPHERE

oxidising capacity of the stratosphere

$O(^1D)$



net = destruction of O_3

TROPOSPHERIC OZONE PRODUCTION
(DURING THE OXIDATION OF CO)

$\mu_{CO} = 50\text{-}200 \times 10^{-9}$

$\tau_{CO} \approx 4$ Months

$$\frac{(NO)}{(O_3)} > \frac{1}{4000}$$

$$\begin{aligned}
CO + OH &\rightarrow H + CO_2 \\
H + O_2 + M &\rightarrow HO_2 + M \\
HO_2 + NO &\rightarrow OH + NO_2 \\
NO_2 + U.V. &\rightarrow NO + O \\
O + O_2 + M &\rightarrow O_3 + M \\
\hline
CO + 2O_2 &\rightarrow CO_2 + O_3
\end{aligned}$$

$$\frac{(NO)}{(O_3)} < \frac{1}{4000}$$

$$\begin{aligned}
CO + OH &\rightarrow H + CO_2 \\
H + O_2 + M &\rightarrow HO_2 + M \\
HO_2 + O_3 &\rightarrow OH + 2O_2 \\
\hline
CO + O_3 &\rightarrow CO_2 + O_2
\end{aligned}$$

$\mu_{NO} > 10^{-11}$ IN THE LOWER ATMOSPHERE $\Rightarrow$ OZONE PRODUCTION

Figure 3. The simplest photochemical smog reaction leading to ozone formation. Ozone is created when the concentration of NO is greater than about 10^{-11}.

How do human activities influence these gases ?

- Direct emissions to the atmosphere (e.g. by fossil fuel use, biomass burning, fertilizer use) :

  $NO_x(=NO+NO_2)$, CO, CH_4, non-methane hydrocarbons, SO_2, aerosols, etc.

- Chemical transformations of these species lead to the production of secondary pollutants. E.g. ozone can be formed by:

$$NO + HO_2 \rightarrow NO_2 + OH$$
$$OH + CO \rightarrow H + CO_2$$
$$H + O_2 + M \rightarrow HO_2 + M$$
$$NO_2 + h\nu \rightarrow NO + O$$
$$O + O_2 + M \rightarrow O_3 + M$$

$$\text{Net: } CO + 2\,O_2 + h\nu \rightarrow CO_2 + O_3$$

NO_x, CO and the hydrocarbons are therefore called the "ozone precursors"

- The anthropogenic emissions can also modify the oxidizing capacity of the atmosphere (i.e. its ability to "cleanse itself" of many pollutants), via the hydroxyl radical OH

OH primary production :

$$O_3 + h\nu \rightarrow O_2 + O(^1D)$$
$$O(^1D) + H_2O \rightarrow 2\ OH$$

OH sinks (conversion to HO_2) :

$$OH + CO \rightarrow HO_2 + CO_2$$
$$OH + CH4 \rightarrow \ldots$$
$$OH + NMHC \rightarrow \ldots$$

OH secondary production :

$$HO_2 + NO \rightarrow OH + NO_2$$
$$HO_2 + O_3 \rightarrow OH + 2\ O_2$$

Model calculations (confirmed to some extent by observations) indicate that, since preindustrial times,

- Tropospheric ozone increased significantly, by more than a factor of 2 over industrialized areas

- Methane and presumably also CO, NOx and SOx have more than doubled

- The global oxidizing capacity of the atmosphere hasn't changed much

Anthropogenic emissions of ozone precursors are expected to double (or more) in the next century. Largest changes in the developing countries.

- Need for new chemical measurements

  - long-term measurements (surface networks, ozonesondes)

  - campaign measurements (aircraft) : cf. NASA missions (NOy and HOx species, CO, O3, radiation, ...)

  - satellites? Maybe promising, but retrieval is difficult due to clouds interferences and the high variability of the troposphere (the vertical profiles are not known a priori)

- Need for establishing climatologies

- Understanding ozone production in the upper troposphere/tropopause region

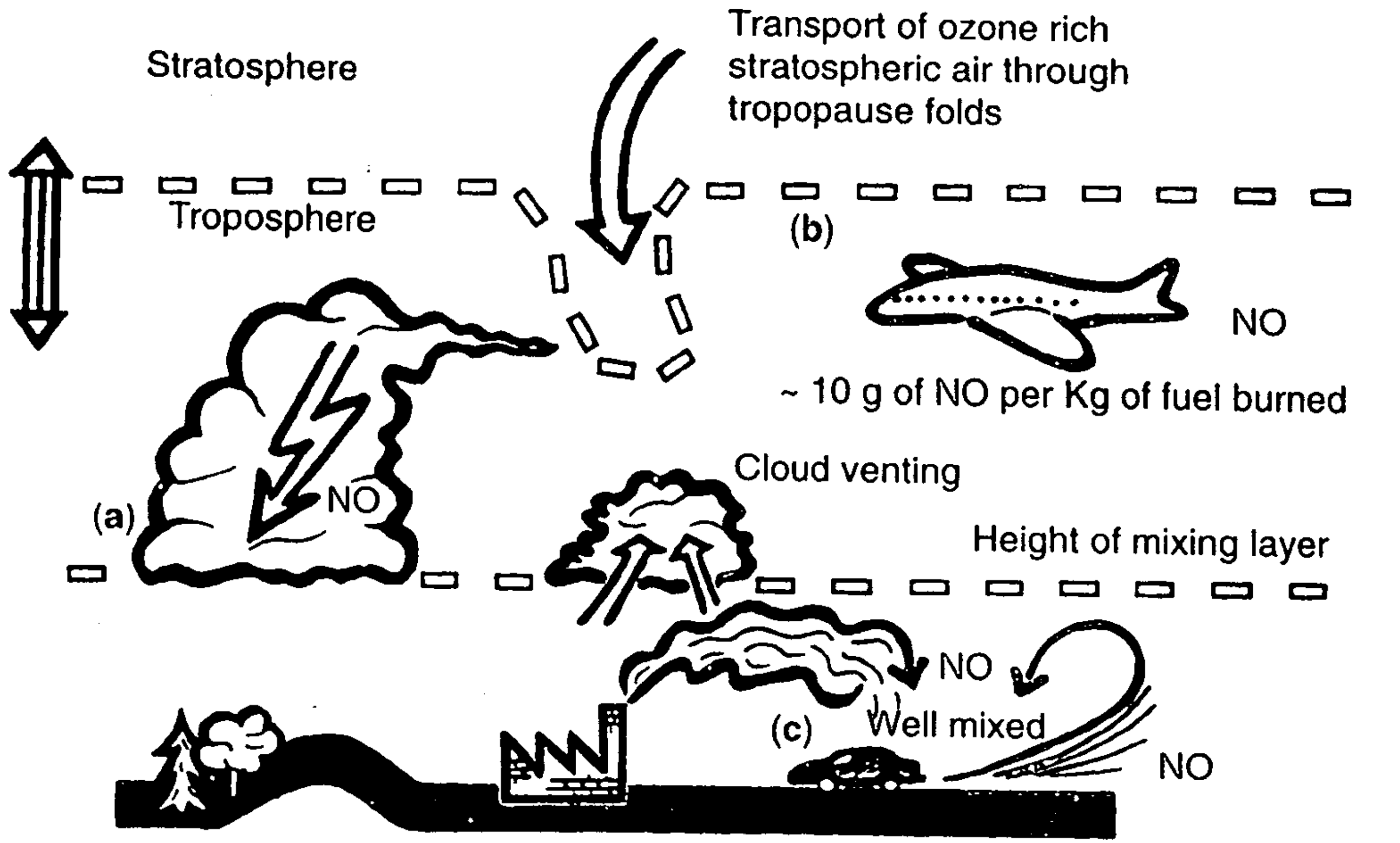
  - this is where the aircraft fly
  - this is where NO_x have the highest ozone production potential
  - this is where ozone has the highest climatic impact (for the surface)

  - cf. recent NASA, EC, IPCC reports on aircraft

  - need to quantify strat/trop exchanges, role of convection, lightning

  - ozone production potential depends on HOx levels

  - hence the importance of possible exotic HOx sources in the upper troposphere (acetone, convection of peroxides and aldehydes)



Three sources of NO_x that may influence *in situ* ozone production within the 8-12 km range

Impacts of stratospheric O3 changes on the chemical composition of the troposphere

Decrease in the total ozone column over the last 2 decades

↓

Increase of the UV-B fluxes to the troposphere

↓

Increase photodissociation of chemical species

↓

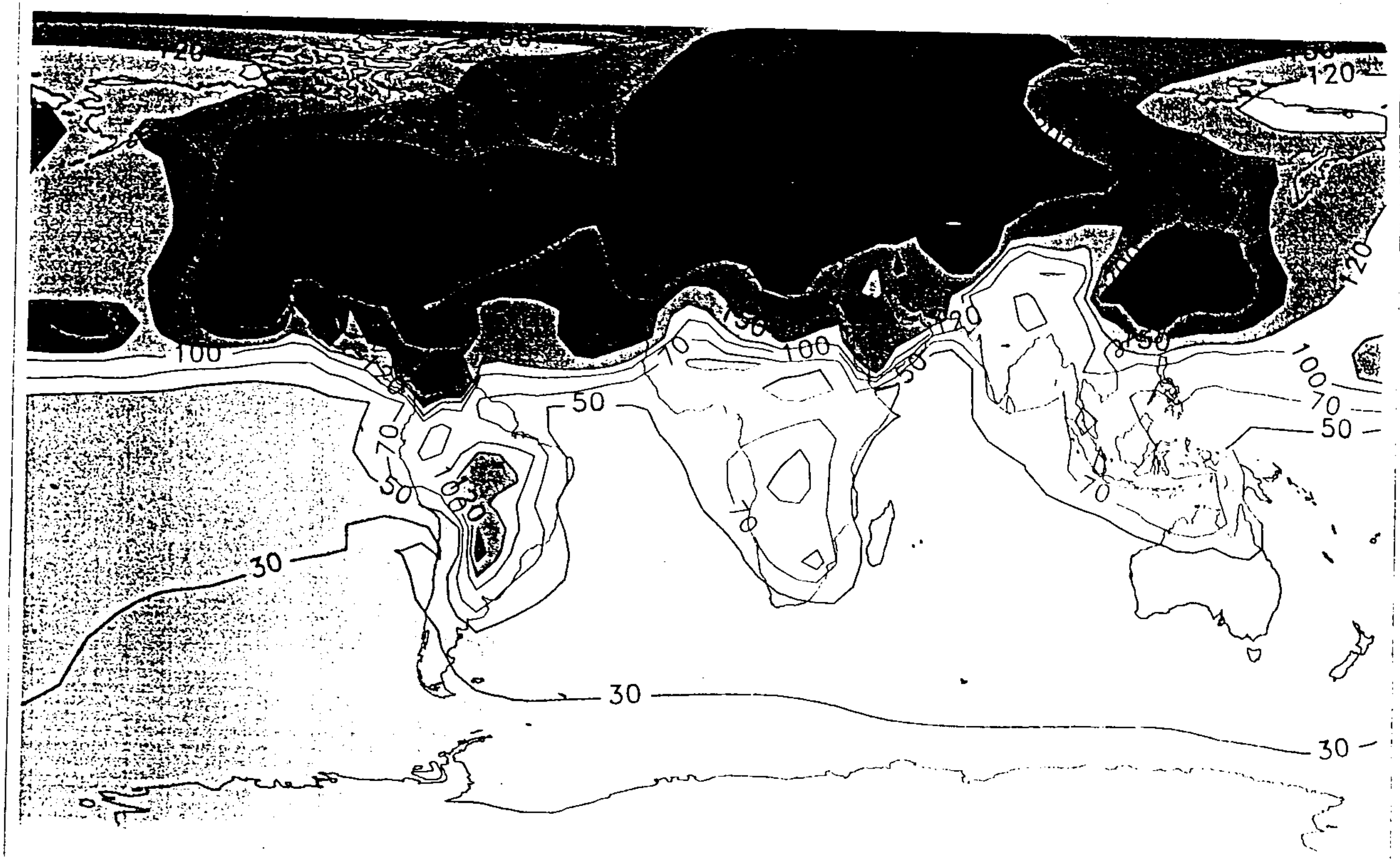
Increase in the tropospheric concentration of OH radical

↓

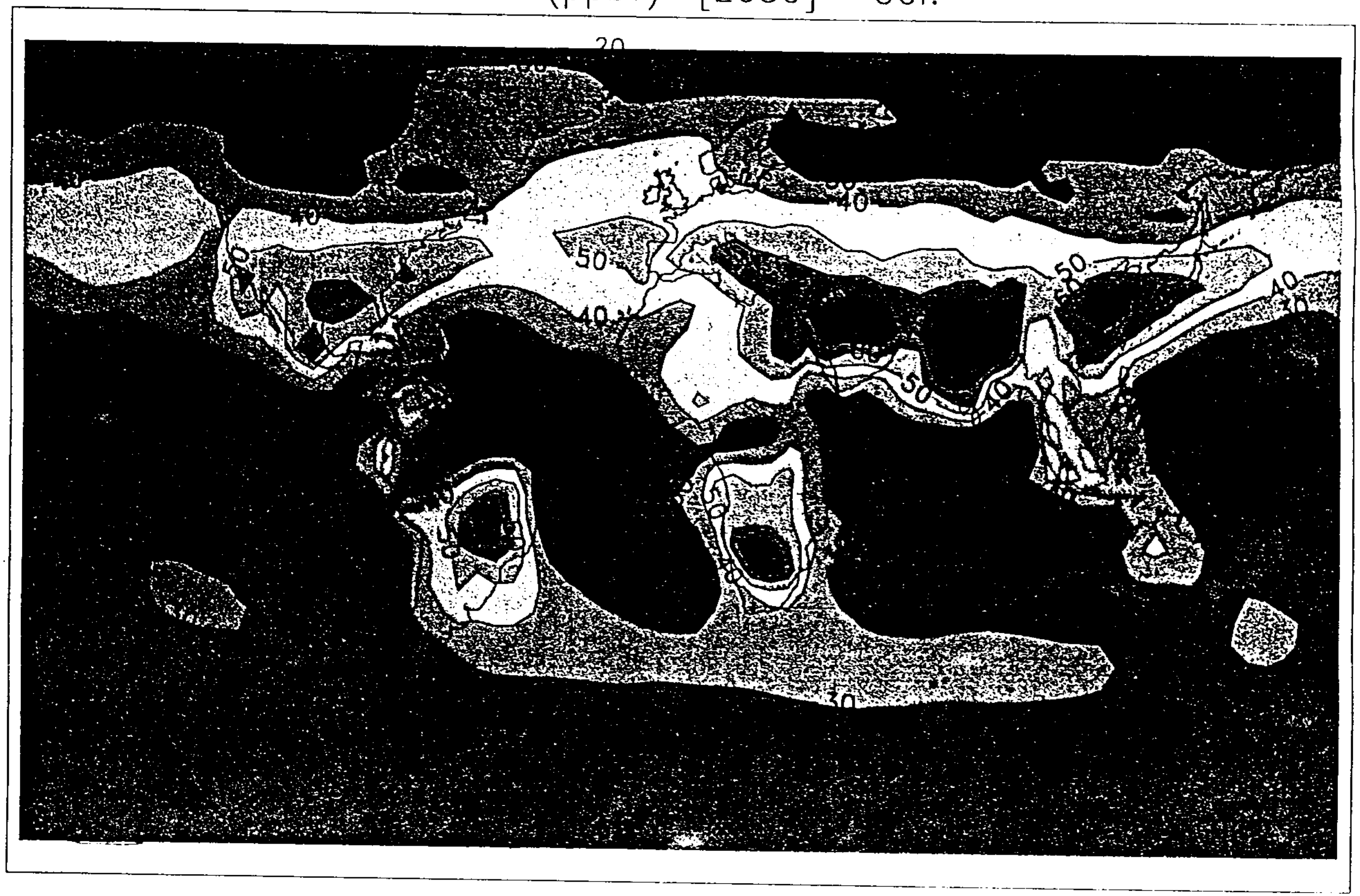
Perturbation in tropospheric distributions and lifetimes of chemical species

(CO, O3, ~~Cl~~ CH4, H2O2, HCFCs, HFCs)

Surface ozone increase ([present] [pre-industrial])



Ozone (ppbv) [2050] Oct.



WMO-GAW Global Atmospheric Watch of the World Meteorological Organization

- ✓ Implemented in 1989
- ✓ Recognized as the basic monitoring system for atmospheric chemistry and physics
- ✓ Coordinated network of observing stations and related facilities

= monitor the long term evolution of the atmospheric composition on global and regional scales in order to assess this contribution to climate change and environmental issues

WMO-GAW Global Atmospheric Watch

- ✓ **Global stations**

  22 observations in remote areas of the globe. Full programme of measurements relating to climate and global change

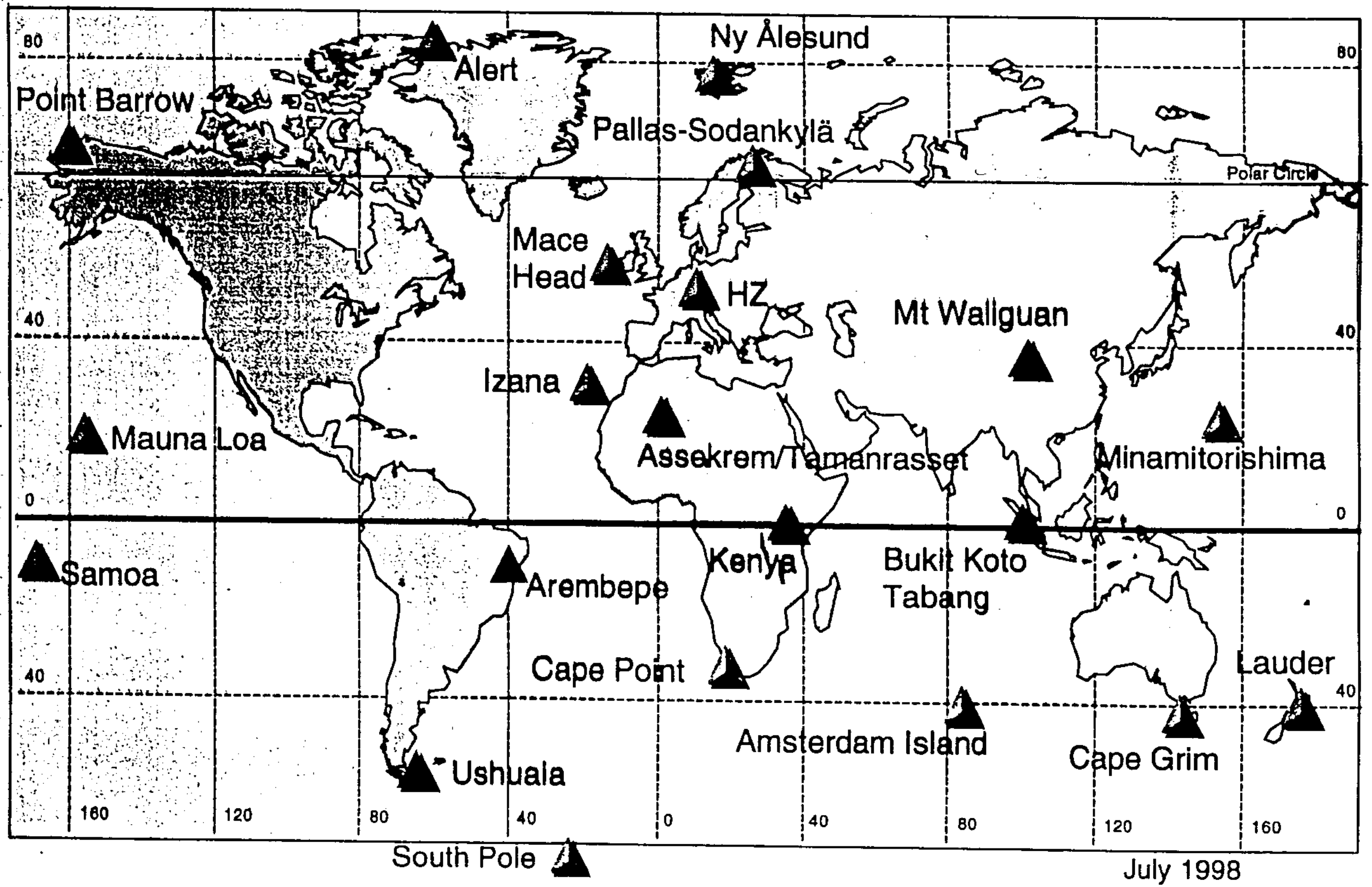
- ✓ **Regional stations**

  Over 300 with flexible programmes to meet regional and national needs

- ✓ **About 80 member countries are participating**

World Meteorological Organization

Global Atmosphere Watch



July 1998

GAW strategic plan (1997 - 2000)

- ✓ **To acquire and distribute data of high and known quality**
  - consistent / uniform quality control procedures
  - global data exchange capabilities
- ✓ **To strengthen GAW leadership**
- ✓ **To build up GAW's central facilities and expand the support base**
- ✓ **To improve and expand the measurement network**
  - stabilising operations at present stations
  - adding stations in targeted regions with sparse or no coverage

GAW strategic plan (1997 - 2000), cont.

✓ **To expand the user base for GAW data**

- data products more readily and easily available
- support modelling, scientific assessments

✓ **To evolve GAW into a three-dimensional global observation network**

- surface-based, aircraft, satellite and other remote sensing observations
- quasi-real-time monitoring capability

Clearly defined responsibilities-SAGs

- ✓ UV/radiation
- ✓ Aerosols/optical depth
- ✓ Ozone
- ✓ Precipitation chemistry and deposition
- ✓ Greenhouse and radiative chemical species

GAW related facilities

- ✓ Data collection, assesments
- ✓ QA/QC, including instrument calibration and intercomparison

  "It is better to have no data than data without unknown quality"
- ✓ WMO World Data Centres

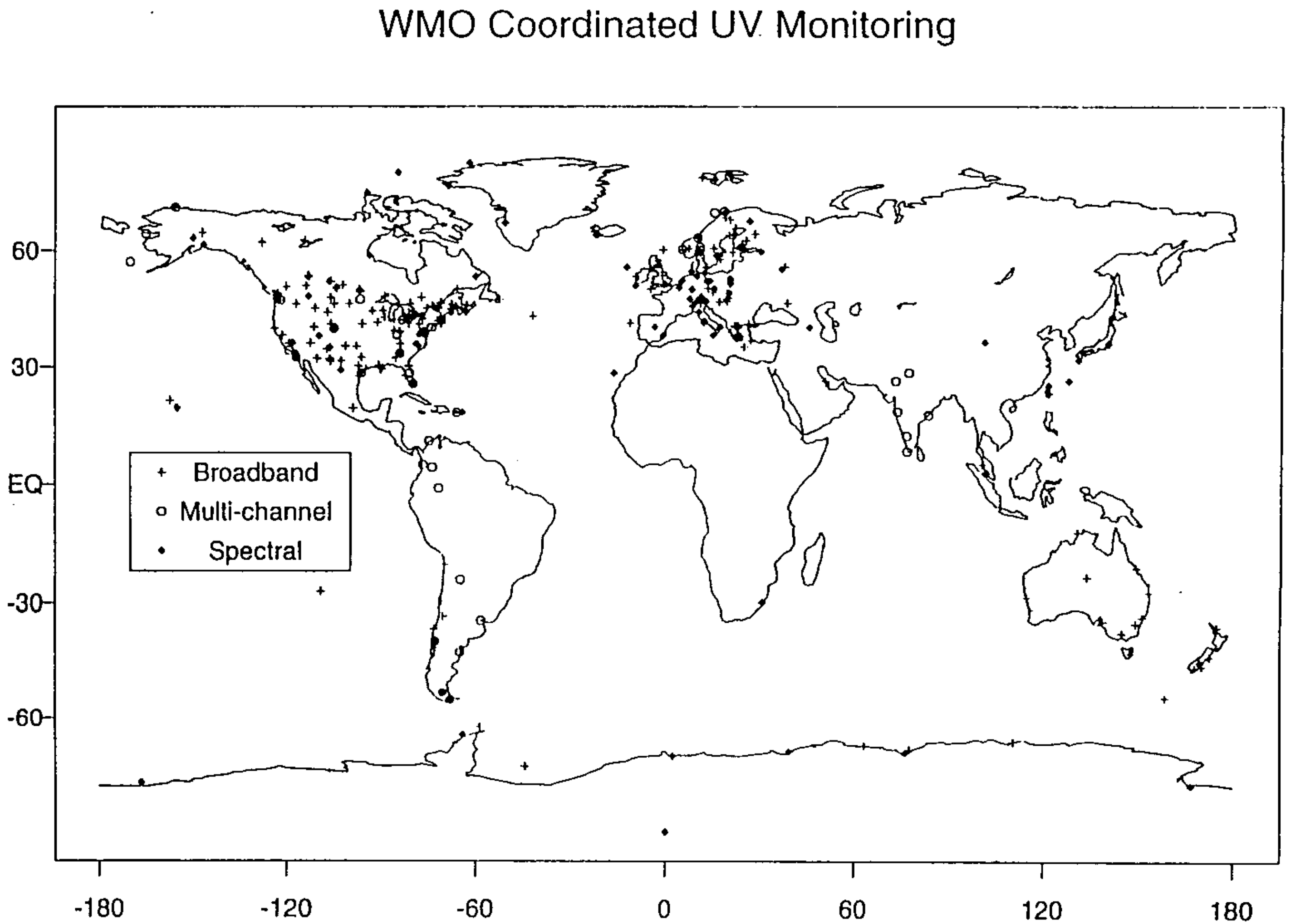


Figure 9-1. Map showing the global distribution of surface-based instruments monitoring UV radiation. (Updated from Weatherhead and Webb, 1997.)

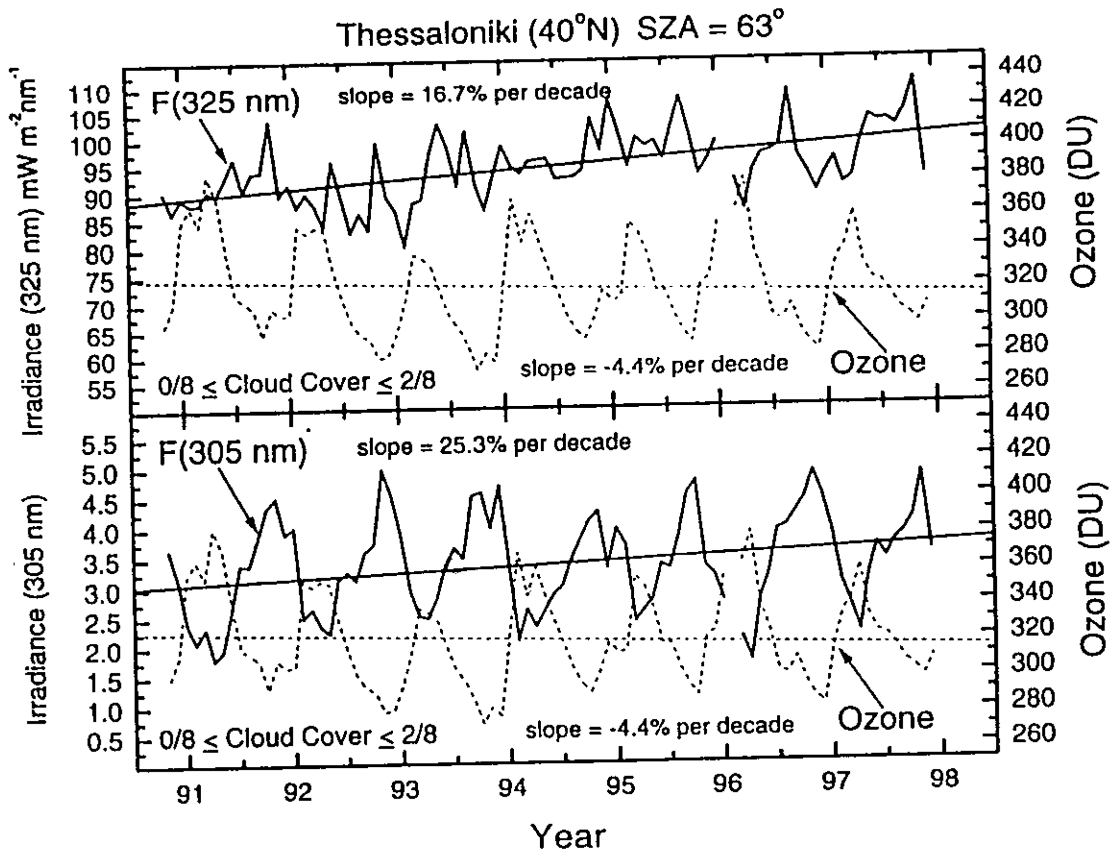


Figure 9-9. Time series of monthly mean values of solar UV irradiance (solid lines) at 325 nm (top panel) and at 305 nm (bottom panel) measured at 63° SZA under clear-sky conditions, and total ozone (dashed lines), at Thessaloniki, Greece (40°N), during the period from November 1990 to December 1997. Cloud fraction numbers can range from 0/8 (entirely clear skies) to 8/8 (entirely overcast). Straight lines represent linear regressions on the monthly mean data from November 1990 to November 1997. (Updated from Zerefos *et al.*, 1997.)

❑ Other specialised programmes using network data

- ✓ WCRP'S Baseline Surface Radiation Network (BSRN)
- ✓ SCO3P (Southern Cone Ozone Project)

  Improves the measurements of ozone (surface and total) and UV-B in 5 South American countries (Argentina, Brazil, Chile, Paraguay and Uruguay)
- ✓ EMEP (European Monitoring and Evaluation Programme)
- ✓ The North American Networks, integrated monitoring programmes of the UNEP (United Nations Environment Programme)
- ✓ GCOS (Global Climate Observing System)
- ✓ WHO (World Health Organisation) urban networks
- ✓ IGAC (International Global Atmospheric Chemistry Programme)
- ✓ SPARC (Stratospheric Processes And their Role in Climate)

❑ **In addition to GAW other long term programmes for measuring atmospheric composition on a global scale are currently being developed by:**

✔ NDSC (Network for the Detection of Stratospheric Change)
Highly sophisticated measurements related to stratospheric change
Provides complementary information on vertical distributions of atmospheric gases

Europe provides support to the NDSC through long-term observations and related scientific activities at a large number of stations