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School on "Exploring the Atmosphere by Remote Sensing Techniques"
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"Atmospheric Observations: Synergy between Ground, Airborne & Space-Based Measurements"

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

Atmospheric Observations:
Synergy between ground, airborne and space-based measurements.

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acknowledgements:
J-C. Lambert, P. Peeters, M. Van Roozendael
IASB-BIRA.

OUTLINE

- ☑ The Earth System: a coupled, non-linear system

- ☑ The need for an integrated science strategy for Earth Observations, including the Atmosphere

- ☑ World initiatives

- ☑ Exploitation of observing synergies : examples of scientific studies

The Earth System ... *cont'd*

☑ variability

- natural
- anthropogenic
- different scales
  - in time: years (climate), months-days (chemistry, dynamics), minutes (H_2O, clouds)
  - in space: regional to global, UT/LS region

☞ **GLOBAL CHANGE**

Towards an integrated science strategy

- integration of science studies, interdisciplinary approach
- integration of observing systems, international approach
  - synergy between ground, airborne and space-based systems - multi-platform missions
  - synergy between remote sensing and in-situ measurements
- synergy with modelling activities, data assimilation
- synergy with laboratory measurements

  e.g., spectroscopy, physico-chemistry of aerosols, ...
- integration of data archives

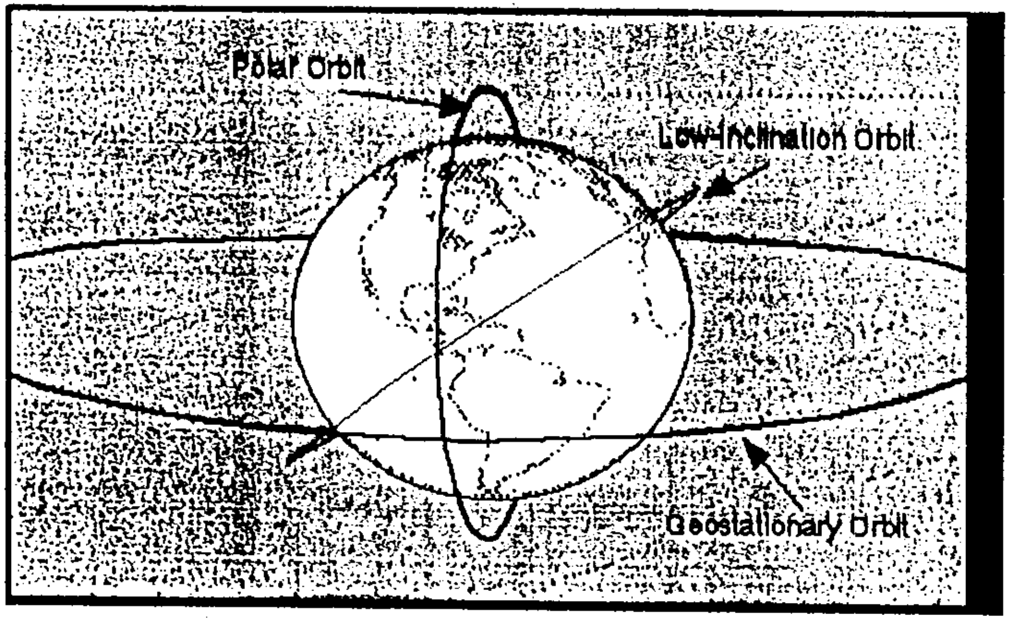
Integration of observing systems ... cont'd

Which technique for what?

- Space-based (remote sensing)
  - global scale, long-term
  - low time/space (vert/horiz) resolution, integrated quantities
  - high cost, large effort
  - low flexibility, advance planning
  - bad access to low atmosphere (clouds…), particular timing requests (cf. choice of orbit)

Integration of observing systems ... *space*

- Space-based
  - Multi-instrument, multi-platform missions
  - Different orbits needed to get the global perspective

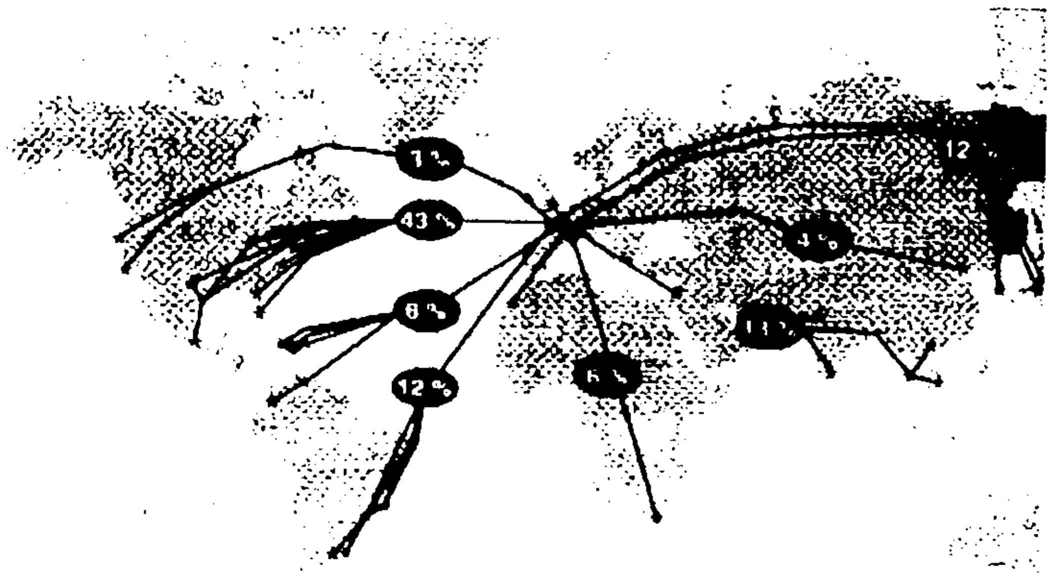


Integration of observing systems... *air*

MOZAIC (EC, 1994):

Measurement of Ozone and Water Vapour by AIRBUS In-Service Aircraft

focus on UT/LS region



MOZAIC

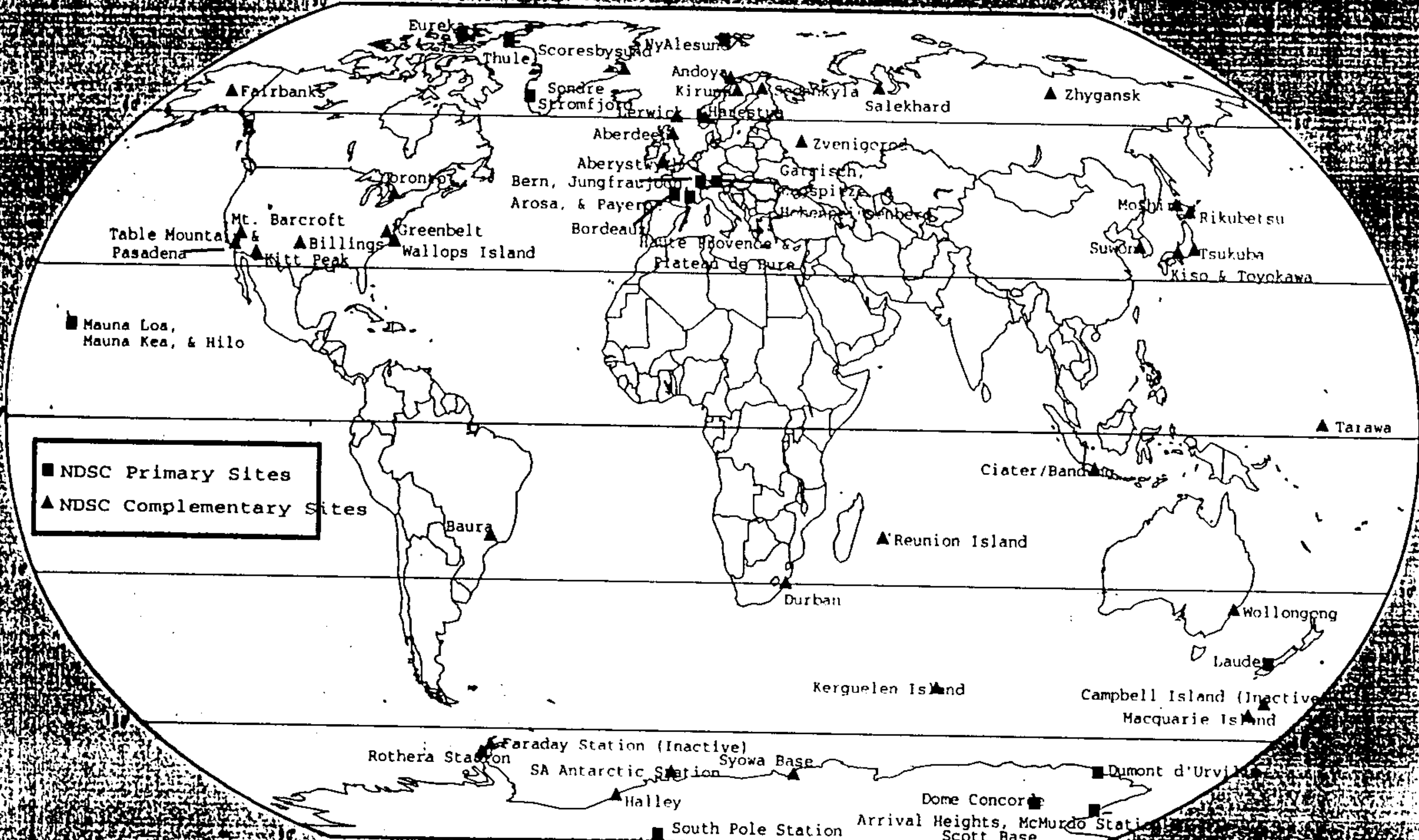
Database at METEO France

numbers = % of total number of flights (8500), per route

Integration of observing systems ... *cont'd*

- Airborne (balloon, aircraft, sonde; in-situ, remote sensing)
  - fast turn around ⇒ may address upcoming questions
  - typically for studies of diurnal variations, processes
    e.g., O_3 vs. ClO in Antarctic, tracer correlations
  - single measurements, few occasions
    - *BUT*: **MOZAIC**
- Ground-based (remote sensing, in-situ)
  - typically for long-term continuity (operational stations) at relatively low cost
  - quasi-global coverage in network operation, e.g. NDSC
  - QC/QA efforts !

NDSC Sites

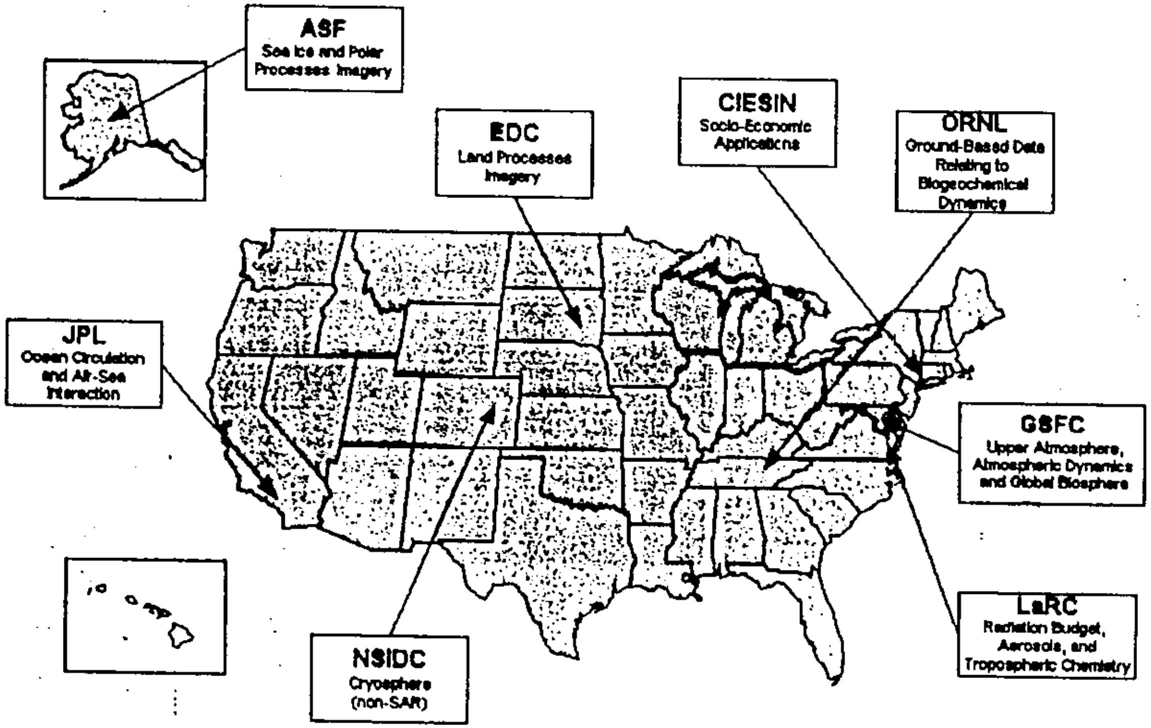


Eureka
Thule
Scoresbysund
NyAlesund
Andoya
Kiruna
Sodankyla
Salekhard
Zhygansk
Fairbanks
Sondre Stromfjord
Lerwick
Harestua
Aberdeen
Zvenigorod
Aberystwyth
Toronto
Bern, Jungfraujoch
Arosa, & Payerne
Mt. Barcroft
Table Mountain &
Pasadena
Billings
Greenbelt
Wallops Island
Kitt Peak
Bordeaux
Haute Provence &
Plateau de Bure
Moshiri
Rikubetsu
Suwon
Tsukuba
Kiso & Toyokawa
Mauna Loa,
Mauna Kea, & Hilo
Tarawa
NDSC Primary Sites
NDSC Complementary Sites
Ciater/Bandung
Baura
Reunion Island
Durban
Wollongong
Lauder
Kerguelen Island
Campbell Island (Inactive)
Macquarie Island
Faraday Station (Inactive)
Rothera Station
SA Antarctic Station
Syowa Base
Dumont d'Urville
Halley
Dome Concorde
Arrival Heights, McMurdo Station,
Scott Base
South Pole Station

integration of data archives

➢ integration of data archives

- NDSC / GAW /
- EOSDIS: distributed, open system architecture



World Initiatives

☑ IGOS - Integrated Global Observing Strategy, builds on

G3OS - Global Observing Systems

- ➢ GTOS - Global Terrestrial Observing System
- ➢ GCOS - Global Climate Observing System
  http://193.135.216.2/web/gcos/gcoshome.html
- ➢ GOOS - Global Ocean Observing System

- initiative started in 1992 (UK) -

- focus on the observing system -

☑ (I)EOS ← NASA ESE (MTPE) ← USGCRP

- focus on (US) earth science from space -

IEOS - ESE ... cont'd

http://eospso.gsfc.nasa.gov/sci_strategy/Contents.html

☑ EOS = central element

- Terra (EOS-AM), EOS-PM, EOS-AERO, EOS-ALT, EOS-CHEM…: Multi-instrument platforms, in various orbits, launched at different times.

Satellites (First Launch)	Mission Objectives
EOS-AM Series (1998) Earth Observing System Morning Crossing (Descending)	Clouds, aerosols and radiation balance; characterization of the terrestrial ecosystem; land use, soils, terrestrial energy/moisture, tropospheric chemical composition; contribution of volcanoes to climate; and ocean primary productivity (includes Canadian and Japanese instruments)
EOS-COLOR (1998) EOS Ocean Color Satellite	Ocean primary productivity
EOS-AERO Series (2000) EOS Aerosol Mission	Distribution of aerosols and greenhouse gases in the stratosphere and upper troposphere (spacecraft to be provided through international cooperation)
EOS-PM Series (2001) Earth Observing System Afternoon Crossing (Ascending)	Cloud formation, precipitation, and radiative properties; atmospheric temperature and moisture profiles; air-sea fluxes of energy and moisture; sea-ice extent; and soil moisture and snow over land (includes European instruments)
EOS-ALT Series (2002) EOS Altimetry Mission	Ocean circulation and ice-sheet mass balance (includes French instruments)
EOS-CHEM Series (2003) EOS Chemistry Mission	Atmospheric chemical composition and dynamics; chemistry-climate interactions; air-sea exchange of chemicals and energy (to include an as-yet-to-be-determined Japanese instrument)

IEOS - ESE ... *cont'd*

☑ Additional components from ongoing missions (e.g., UARS), and from collaborations with Europe (ENVISAT, METOP, ...) and Japan (ADEOS, TRMM, ADEOS-II, ...)

	Instrument	Category	Measurement Objective
ENVISAT	[illegible]	[illegible]	[illegible]
	AATSR	VIS/IR Images	Sea-surface temperature and land-surface measurements for ocean dynamics and radiation interaction studies
	MWR SCARAB SCIAMACHY	Passive Atmospheric Sounding Radiation Budget Stratospheric and Tropospheric Chemistry	Corrects the radar altimeter height error caused by water vapor Global measurements of the radiation budget Total concentration and vertical distribution of atmospheric trace gas species, temperature, and aerosols in the troposphere and stratosphere
METOP	[illegible]	[illegible]	[illegible]
	ASCAT*	Active Microwave	Ocean surface wind speed and direction, and ocean circulation and dynamics
	AATSR*	VIS/IR Images	Sea-surface temperature and land-surface measurements for ocean dynamics and radiation interaction studies
	GOME*	Stratospheric Chemistry	Global ozone distributions from both solar radiation backscatter and differential optical absorption spectroscopy
	MCP	Data Relay	Direct data handling and broadcast of operational instrument data streams to ground stations
	MIMR*	Passive Microwave	Precipitation rate, cloud water, water vapor, sea-surface roughness, sea-surface temperature, ice, snow, and soil moisture
	S&R	Data Relay	Receives beacon signals, and transmits in real-time to ground stations around the world
	SCARAB* SEM	Radiation Budget Other	Global measurements of the radiation budget Monitors particles and fields to measure/predict solar events

*Proposed climatological monitoring instruments

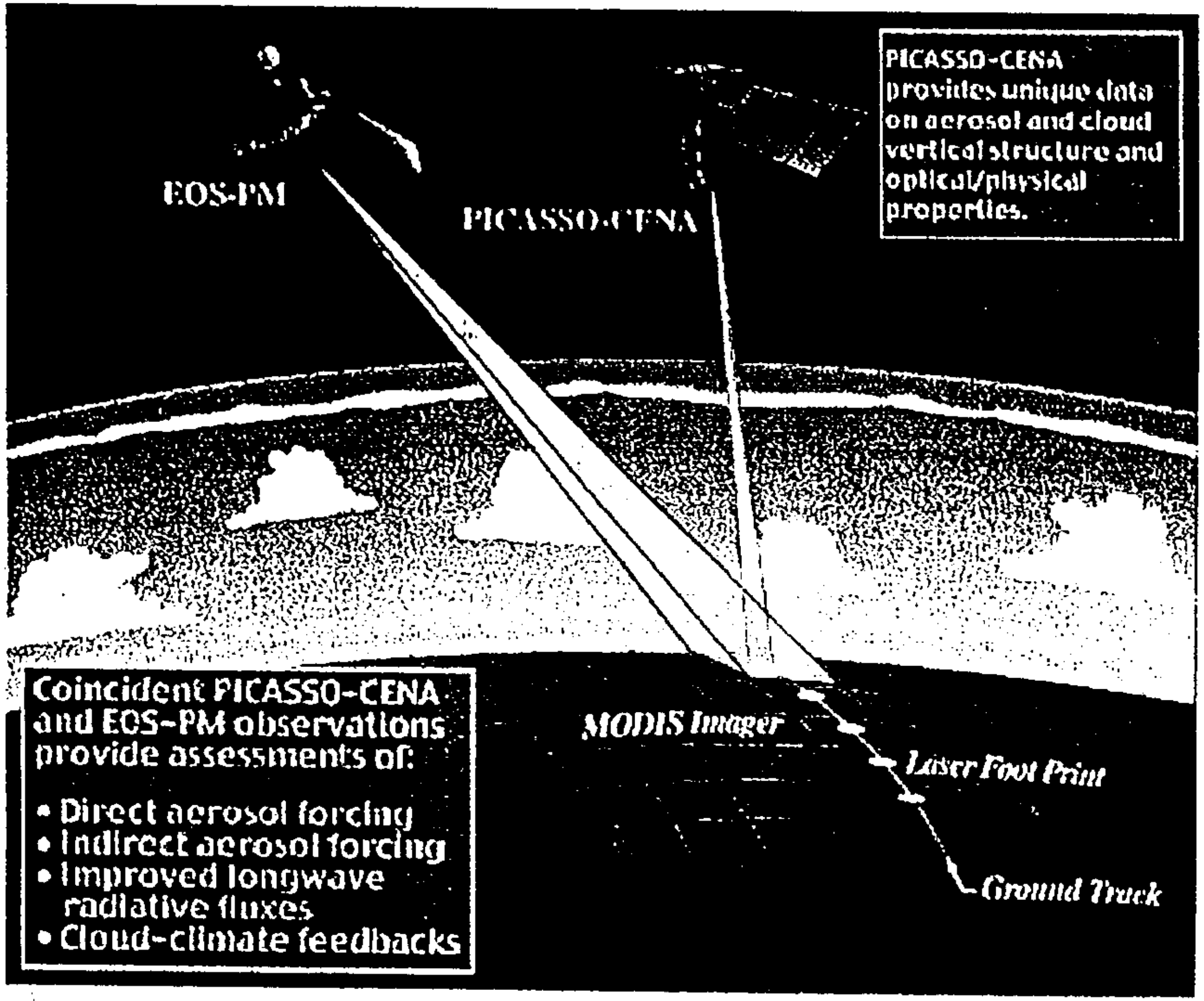
[ ] Core Instruments

	Instrument	Category	Measurement Objective
ADEOS	[illegible]	[illegible]	[illegible]
	ILAS IMG NSCAT POLDER RIS TOMS	Stratospheric Chemistry Tropospheric Chemistry Active Microwave VIS/IR Images and Radiation Budget Atmospheric Chemistry Stratospheric Chemistry	Stratospheric ozone and related species at high latitudes Carbon dioxide, methane, and other greenhouse gases Wind speed and direction over the oceans Atmospheric aerosols Atmospheric trace gases Daily global ozone observations
TRMM	CERES LIS PR TMI VIRS	Radiation Budget VIS/IR Images Active Microwave Passive Microwave VIS/IR Images	Radiation budget Distribution and variability of lightning over the Earth Three-dimensional profiles of rain rates in the tropics Precipitation measurements Variations of rainwater content with altitude
ADEOS II*	[illegible]	Passive Atmospheric Sounding [illegible] Passive Microwave VIS/IR Images	[illegible]
	IMG-2 SeaWinds	Tropospheric Chemistry Active Microwave	Carbon dioxide, methane, and other greenhouse gases Ocean surface vector winds
Candidates for HIROS 1	ADALT AVNIR+ E-LIDAR IMB PR-2 SLIES TERSE TOMUIS SAR II	Altimeter VIS/IR Images Laser Ranging and Sounding VIS/IR Images Active Microwave Stratospheric Chemistry Tropospheric Chemistry Stratospheric Chemistry Active Microwave	Geoid, ocean waves, and polar ice Upwelling radiance in multiple spectral bands Aerosol and cloud vertical profiles of water vapor, and ice sheet and sea level Ecological environment measurements with high spatial resolution Three-dimensional measurement of global rain rate Infrared emissions of stratospheric and tropospheric minor species Global monitoring of tropospheric chemistry profiles Three-dimensional mapping of stratospheric ozone distribution All-weather monitoring of land/water status

*HIRDLS, ILAS II, POLDER, and TOMS are also candidates for this mission

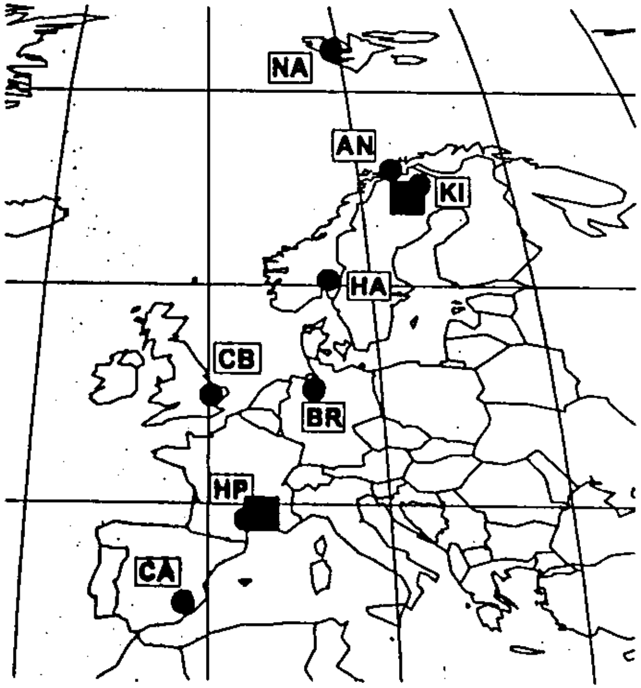
Core Instruments

IEOS - ESE ... *cont'd*



Stratospheric O_3 destruction by bromine

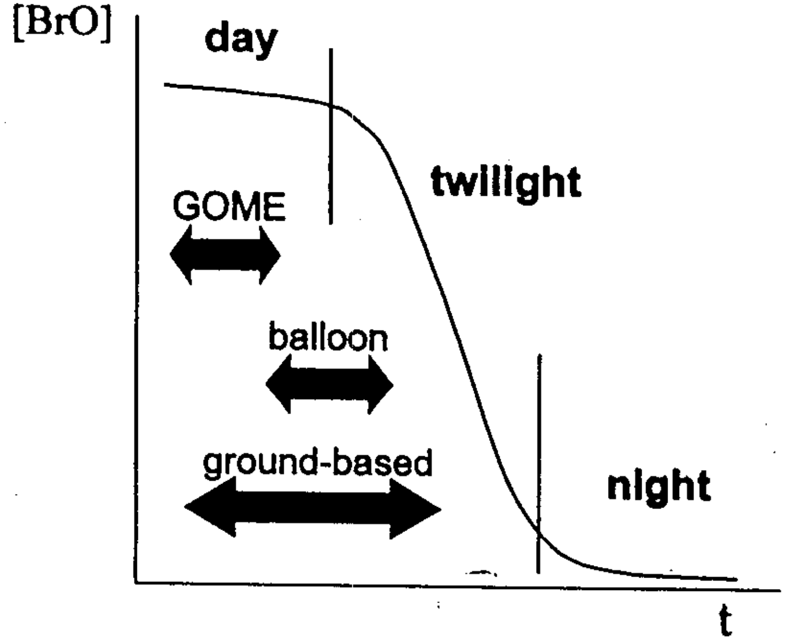
BrO observations



● Ground-based stations
■ Balloon launch sites

+ GOME

BrO diurnal cycle



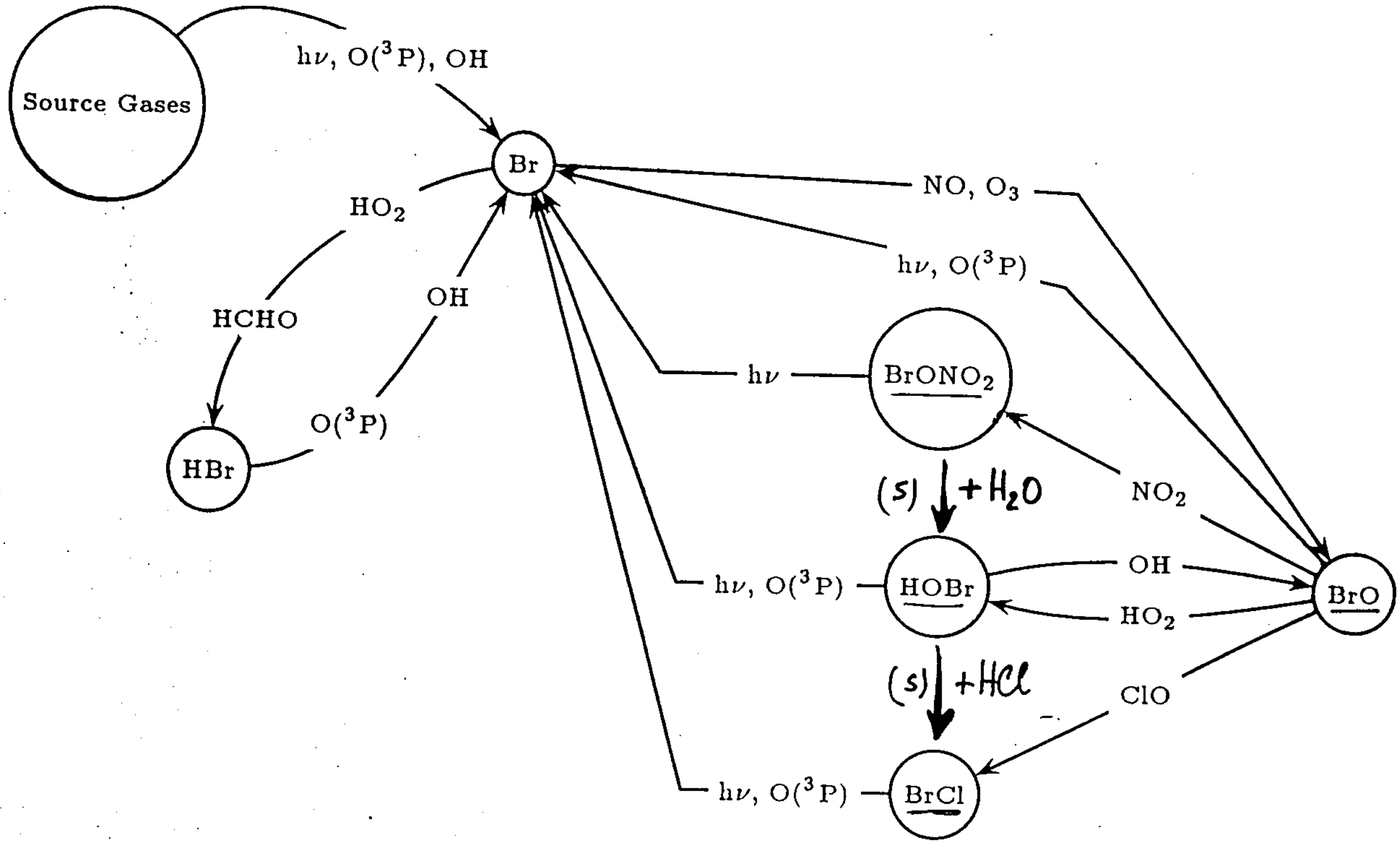
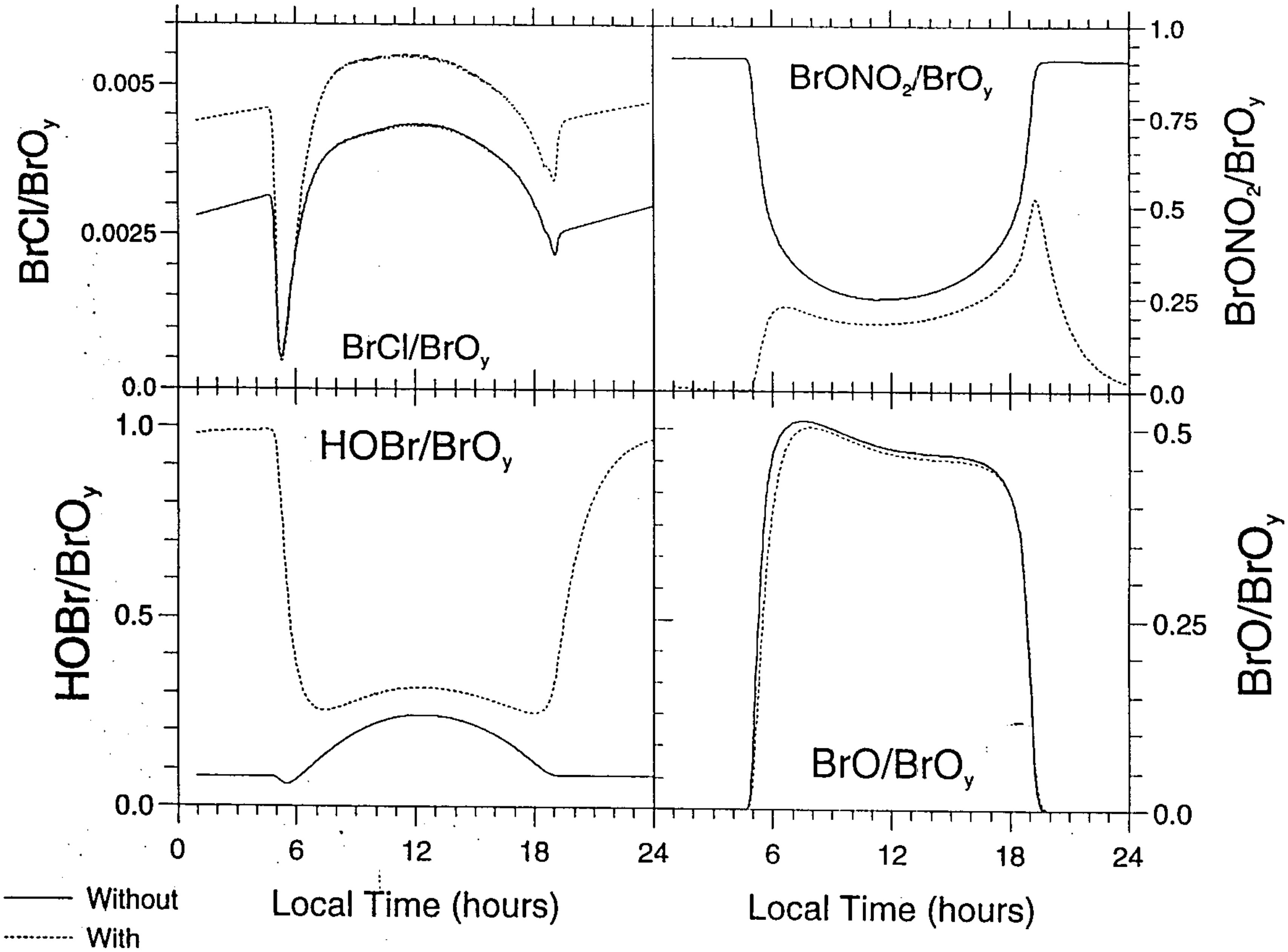


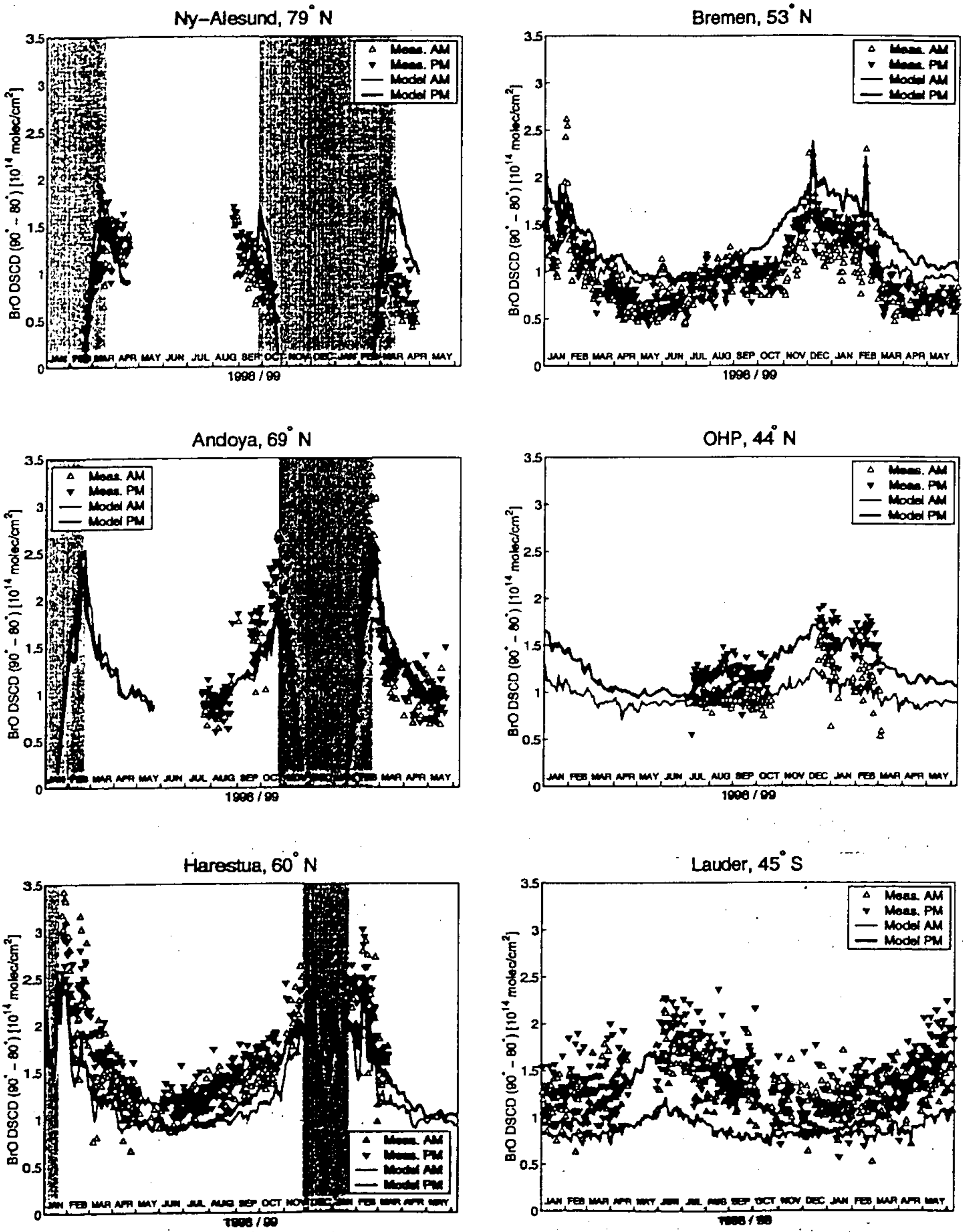
Figure 1. Schematic of atmospheric bromine photochemistry.



37.9° N, 214.5 K, 66.9 mb, 5 May, Aerosol area = 6 $\mu m^2\ cm^{-3}$.

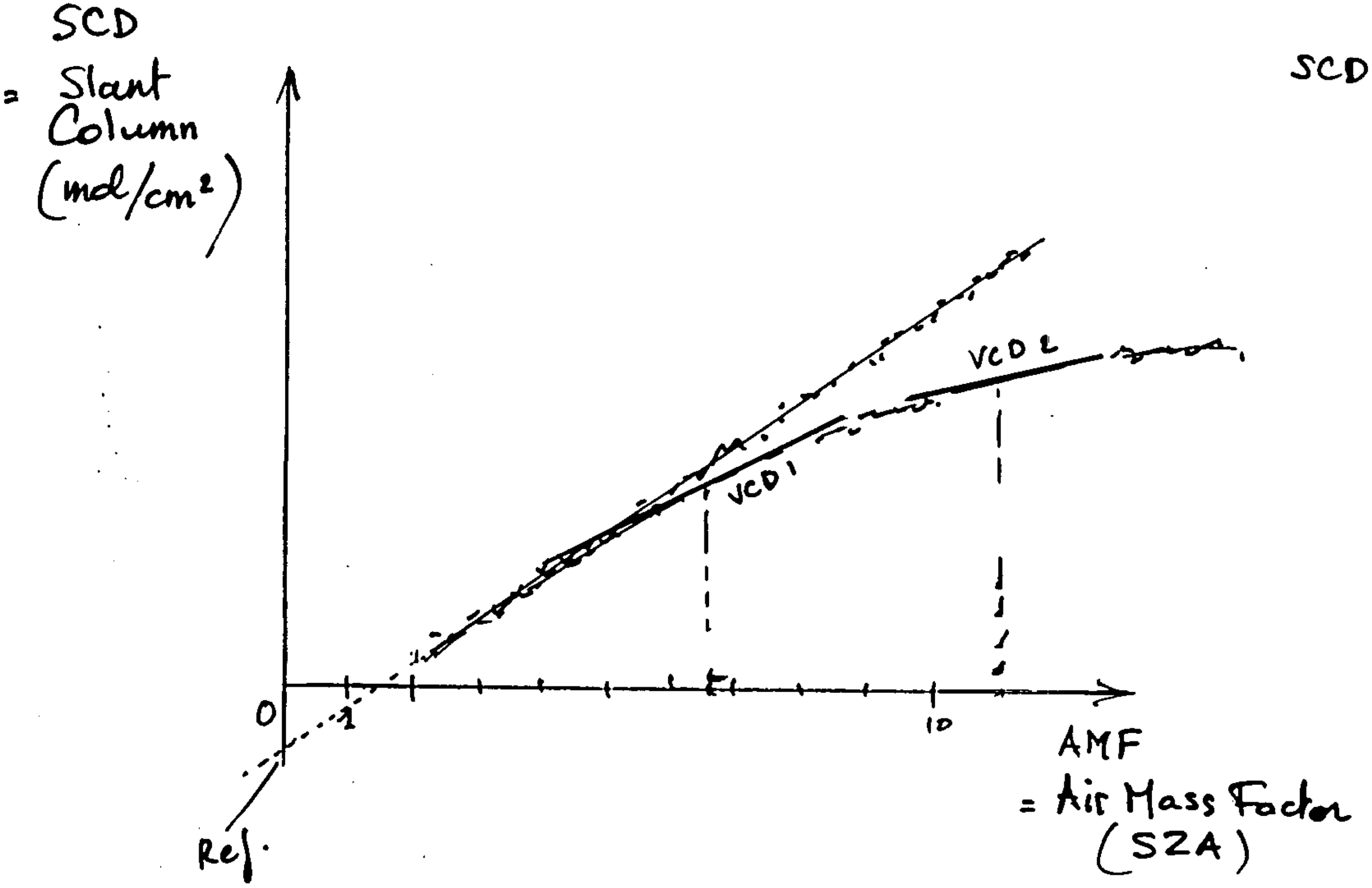
Ground-based BrO vs. SLIMCAT

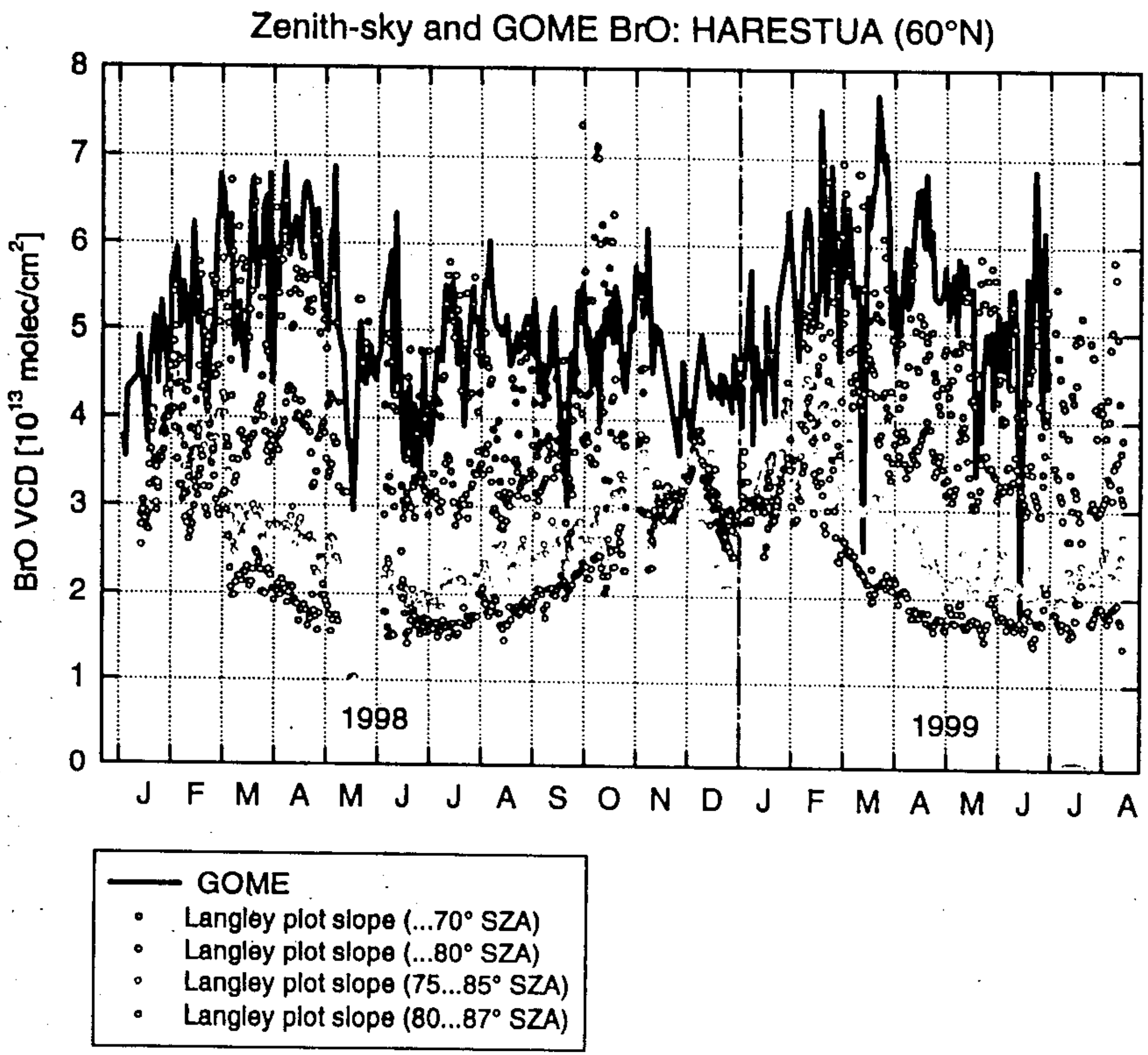
High Latitudes | Mid-latitudes



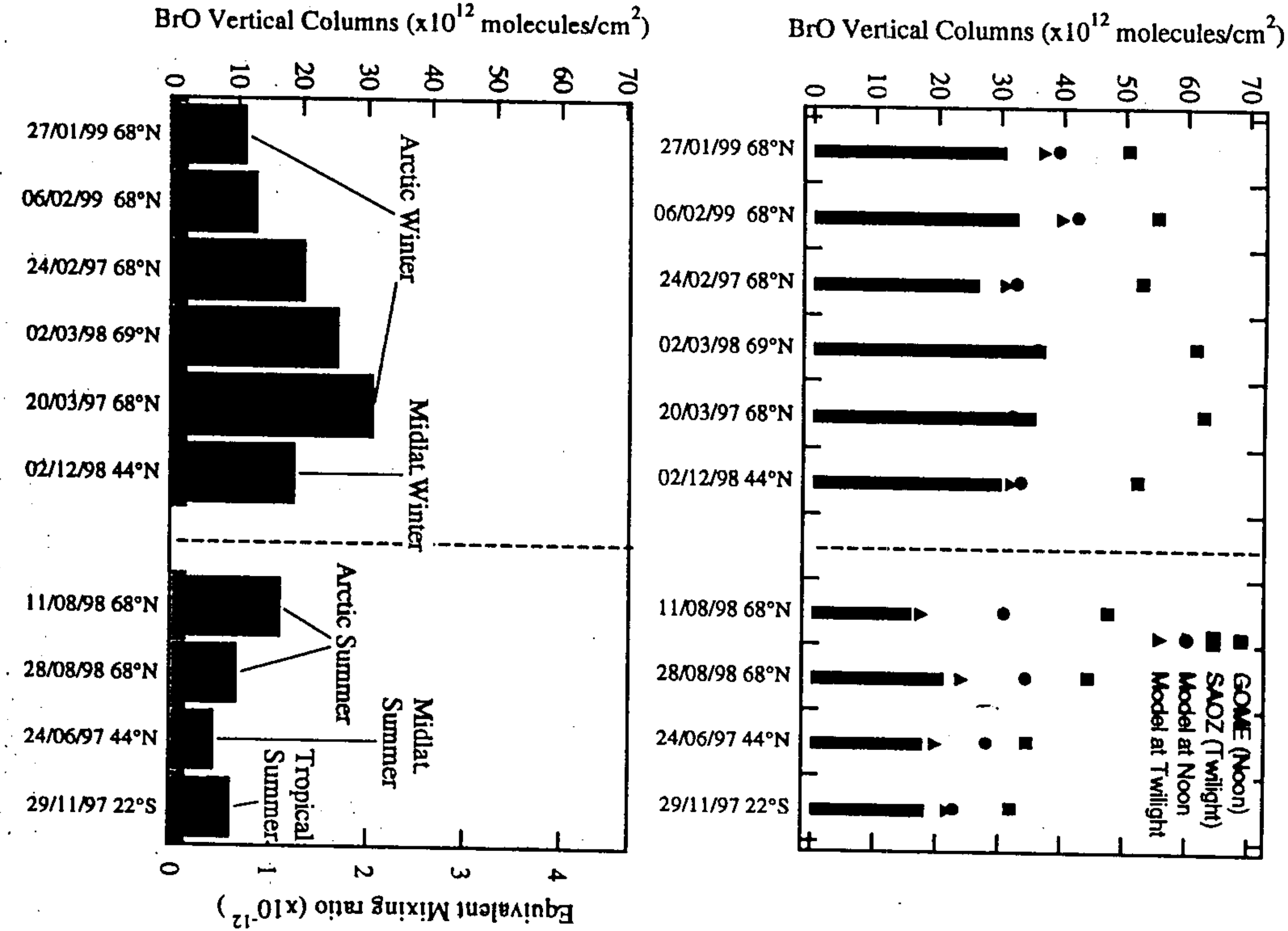
B.-M. Sinnhuber, Leeds

$SCD = VCD \times AMF - Ref$





Zenith-sky and GOME BrO: HARESTUA (60°N)
BrO VCD [10^13 molec/cm^2]
8
7
6
5
4
3
2
1
0
1998
1999
J F M A M J J A S O N D J F M A M J J A
GOME
Langley plot slope (...70° SZA)
Langley plot slope (...80° SZA)
Langley plot slope (75...85° SZA)
Langley plot slope (80...87° SZA)



BrO Vertical Columns (x10^12 molecules/cm^2)
0 10 20 30 40 50 60 70
27/01/99 68°N
06/02/99 68°N
24/02/97 68°N
02/03/98 69°N
20/03/97 68°N
02/12/98 44°N
11/08/98 68°N
28/08/98 68°N
24/06/97 44°N
29/11/97 22°S
Arctic Winter
Midlat. Winter
Arctic Summer
Midlat. Summer
Tropical Summer
0 1 2 3 4
Equivalent Mixing ratio (x10^-12)
BrO Vertical Columns (x10^12 molecules/cm^2)
0 10 20 30 40 50 60 70
27/01/99 68°N
06/02/99 68°N
24/02/97 68°N
02/03/98 69°N
20/03/97 68°N
02/12/98 44°N
11/08/98 68°N
28/08/98 68°N
24/06/97 44°N
29/11/97 22°S
GOME (Noon)
SAOZ (Twilight)
Model at Noon
Model at Twilight

Validation of space-based measurements /
improvement of retrieval algorithms

IASB BIRA

NDSC

GOME AND TOMS TOTAL OZONE VALIDATION WITH NDSC OBSERVATIONS

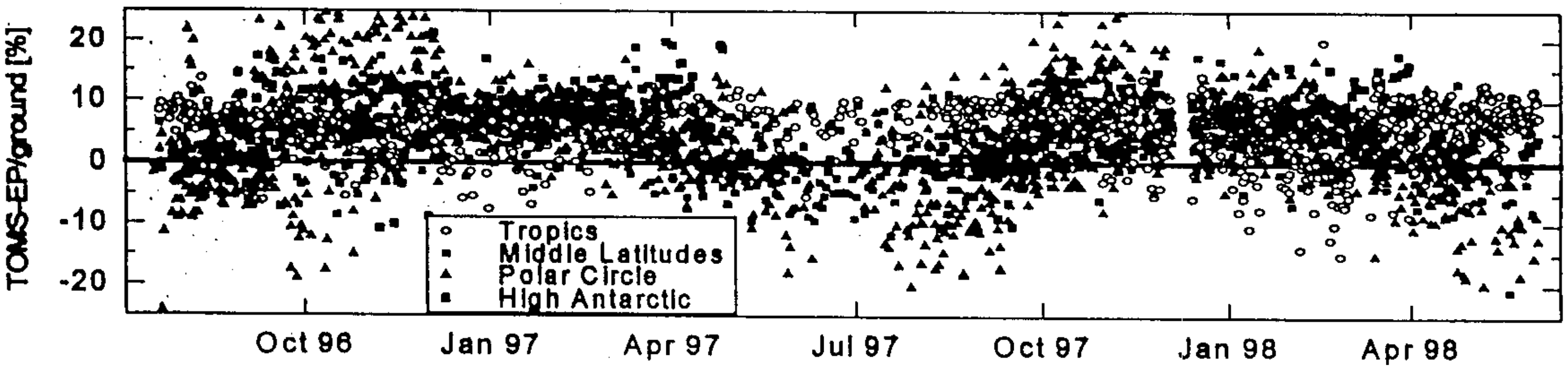


Fig. 3. Percent relative difference between the TOMS-EP and ground-based total ozone in the southern hemisphere.

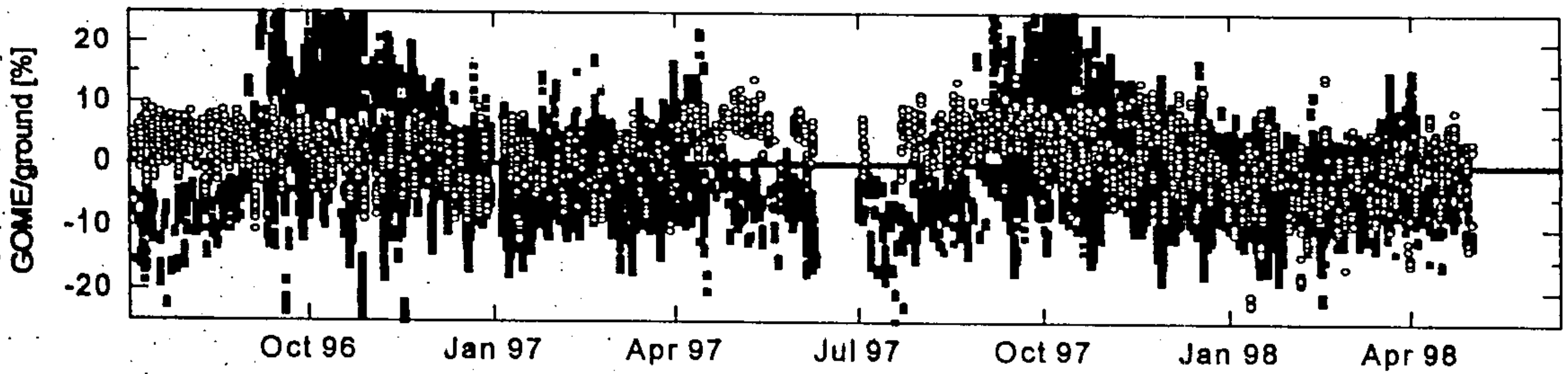


Fig. 4. Percent relative difference between the ERS-2 GOME and ground-based total ozone in the southern hemisphere.

Lambert et al., Adv. Space res., 1999

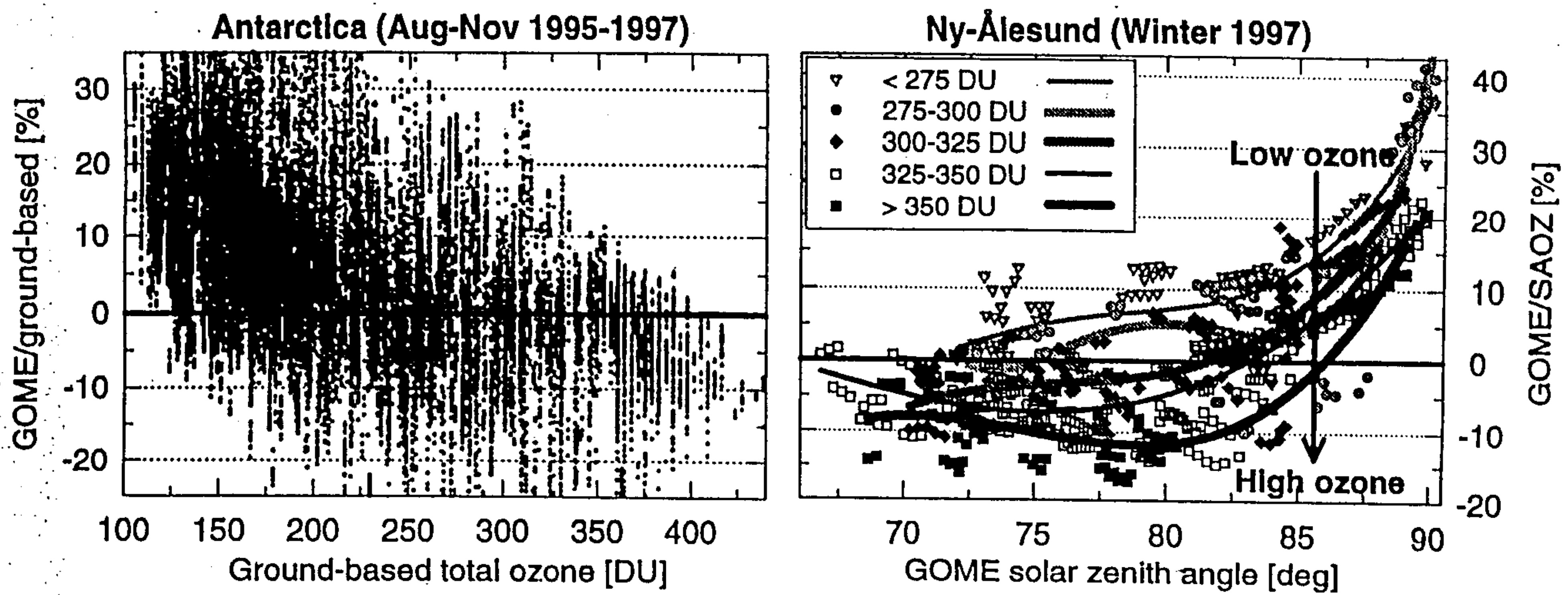
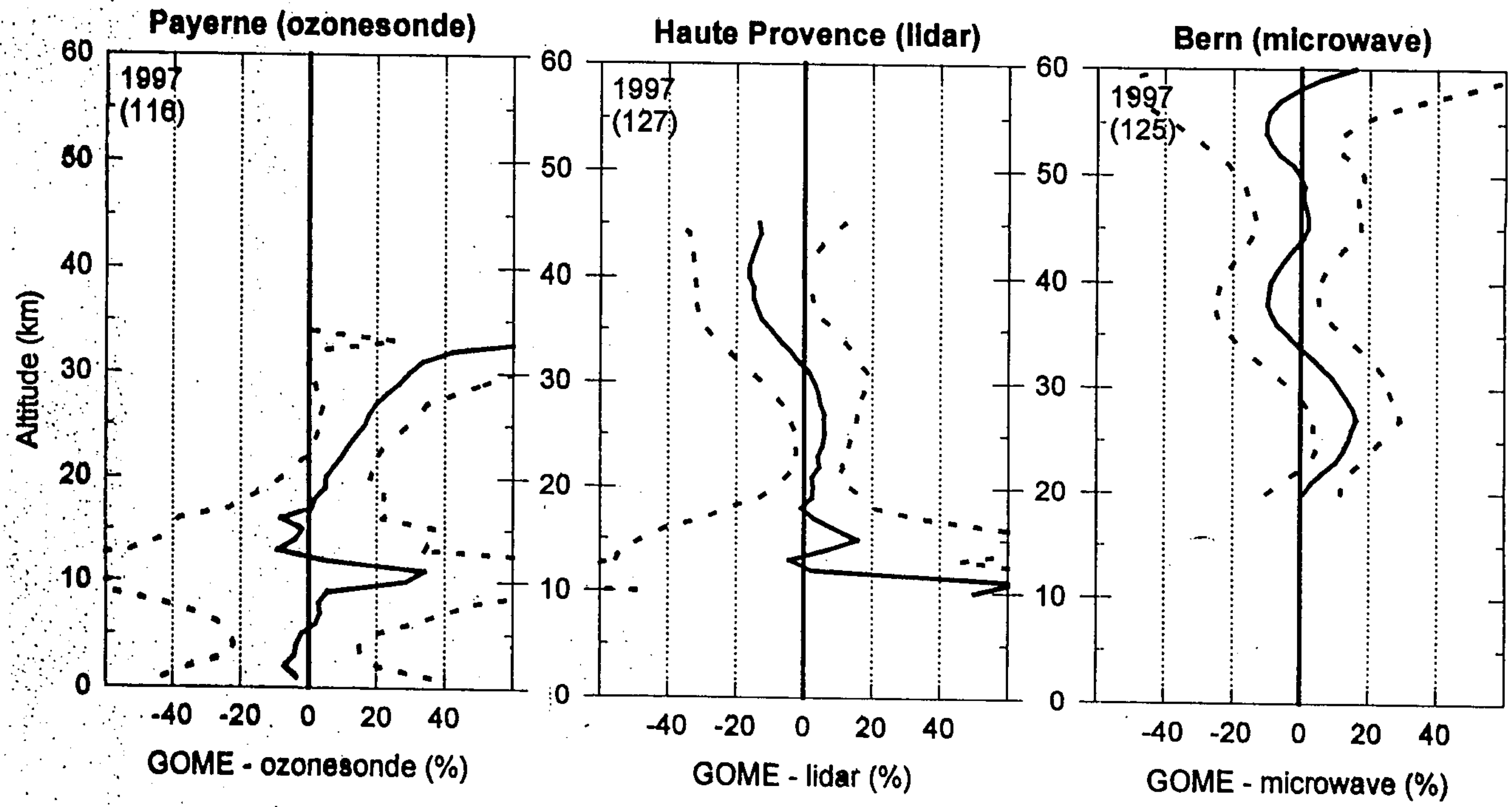
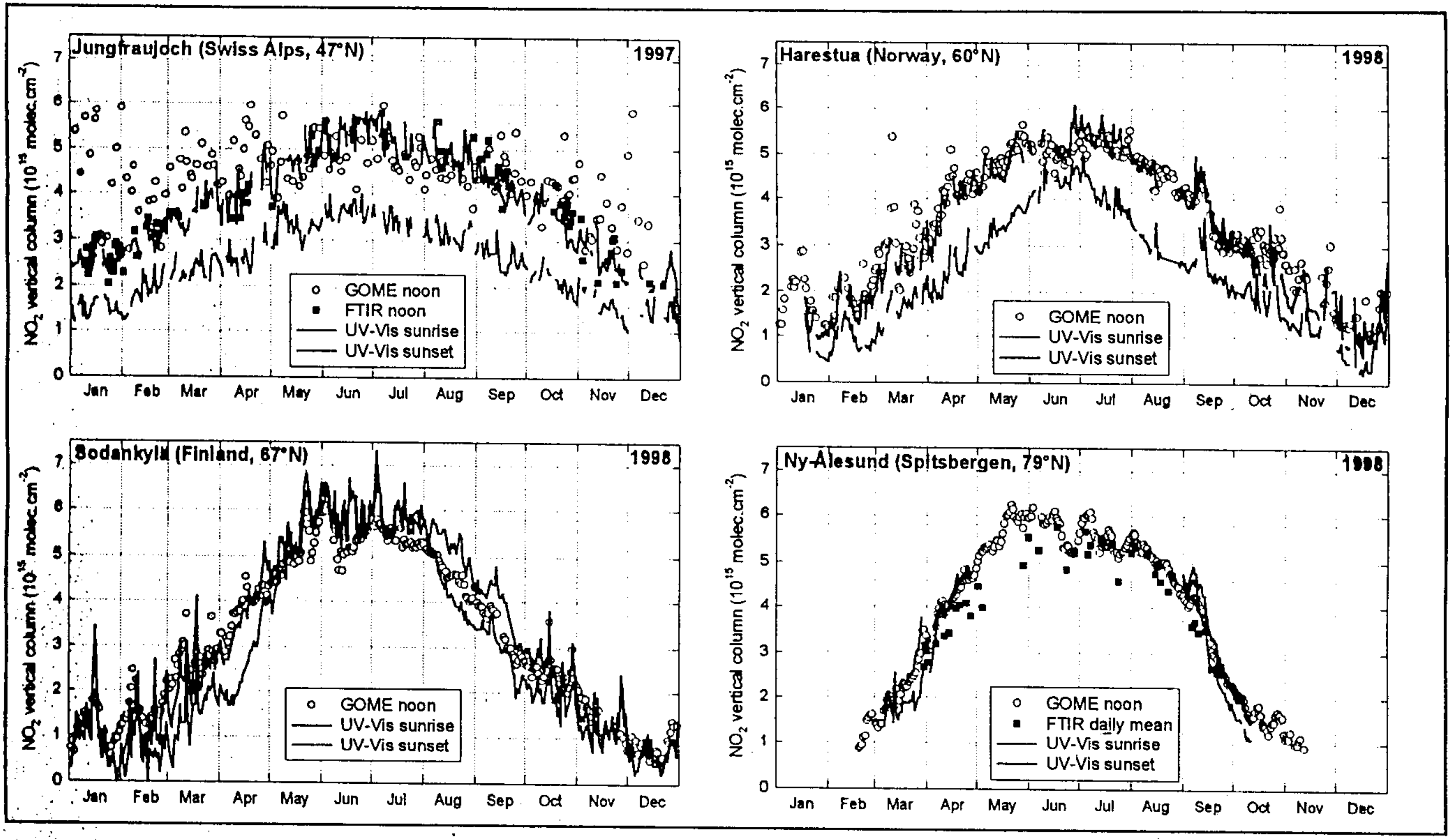


Fig. 6. Difference of sensitivity to total ozone of GOME compared to ground-based sensors at high latitudes. Left panel: column dependence of the relative difference with the five SAOZ and Dobson data records in Antarctica, during springtime ozone depletion. Right panel: column-resolved SZA dependence at Ny-Ålesund during Arctic winter 1997, with polynomial fits.

VALIDATION OF GOME OZONE PROFILE
AT THE NDSC/ALPINE STATION





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)