# REQUIREMENTS ANALYSIS AND TECHNOLOGY ASSESSMENT

# FOR THE

# NPOESS OZONE MEASUREMENT

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**NASA**

Goddard Space Flight Center
and
Langley Research Center

*Integrated Program Office*
*December 15, 1995*

# AGENDA

- Ozone Observations and Results
  - Goddard Space Flight Center
  - Langley Research Center
- Discussion of Ozone EDR's
- Measurement Assessment
- Measurement Concept for NPOESS
  - Existing Technology
  - New/Low Technology Option
- Discussion for Further Study

# OZONE OBSERVATIONS AND ANALYSIS

*NASA - Goddard Space Flight Center*

# The Goddard Ozone Processing Team

Goal: long term ozone trend analysis using data from multiple TOMS and SBUV instruments

20 years of experience with SBUV and TOMS instruments:

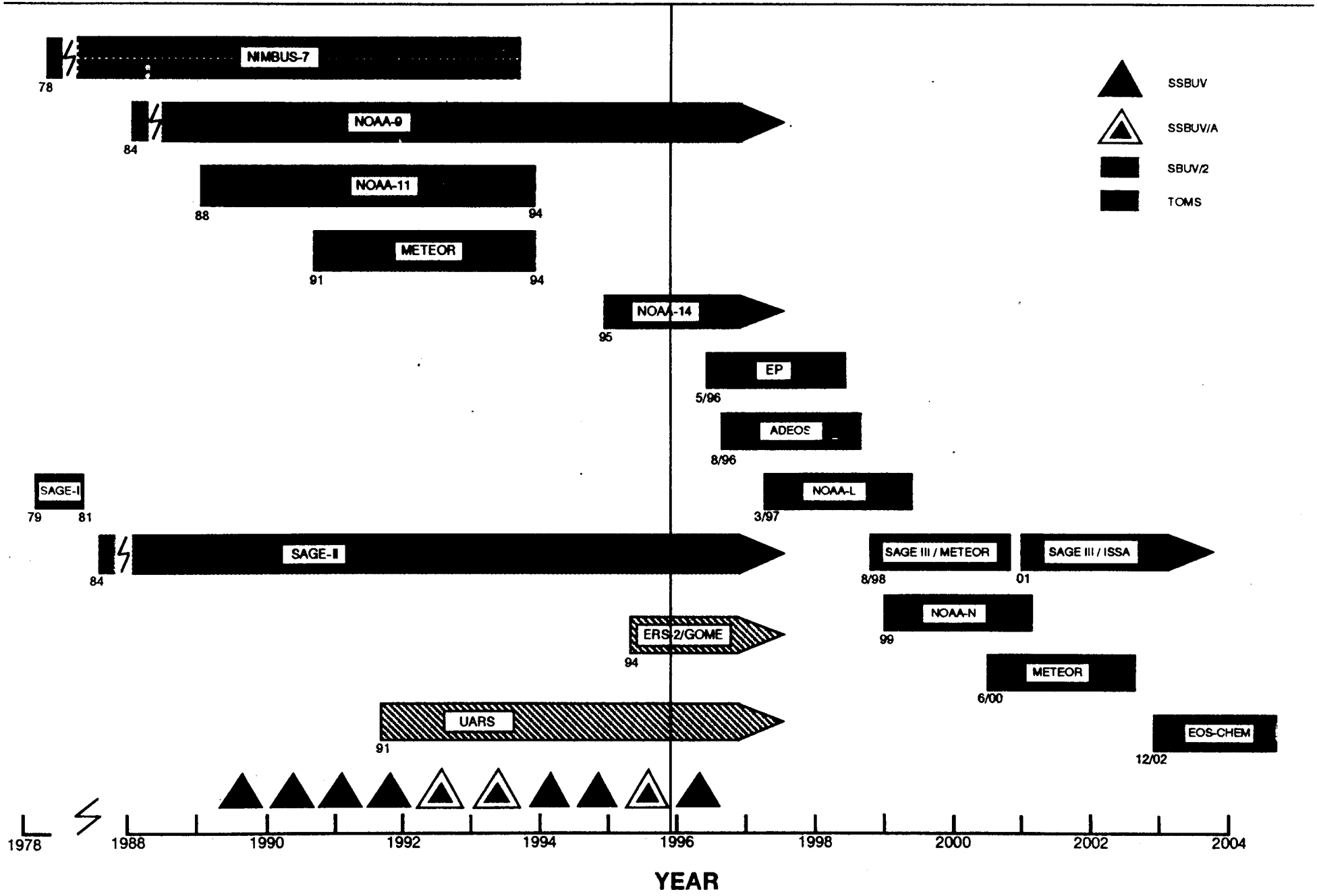
1) maintaining consistent instrument calibrations
2) ozone retrieval algorithms
3) trend analysis

| | |
|---|---|
| • Nimbus 4 BUV | April 1970 - 1975 |
| • Nimbus 7 SBUV | Nov. 1978 - June 1990 |
| Nimbus 7 TOMS | Nov 1978 - May 1993 |

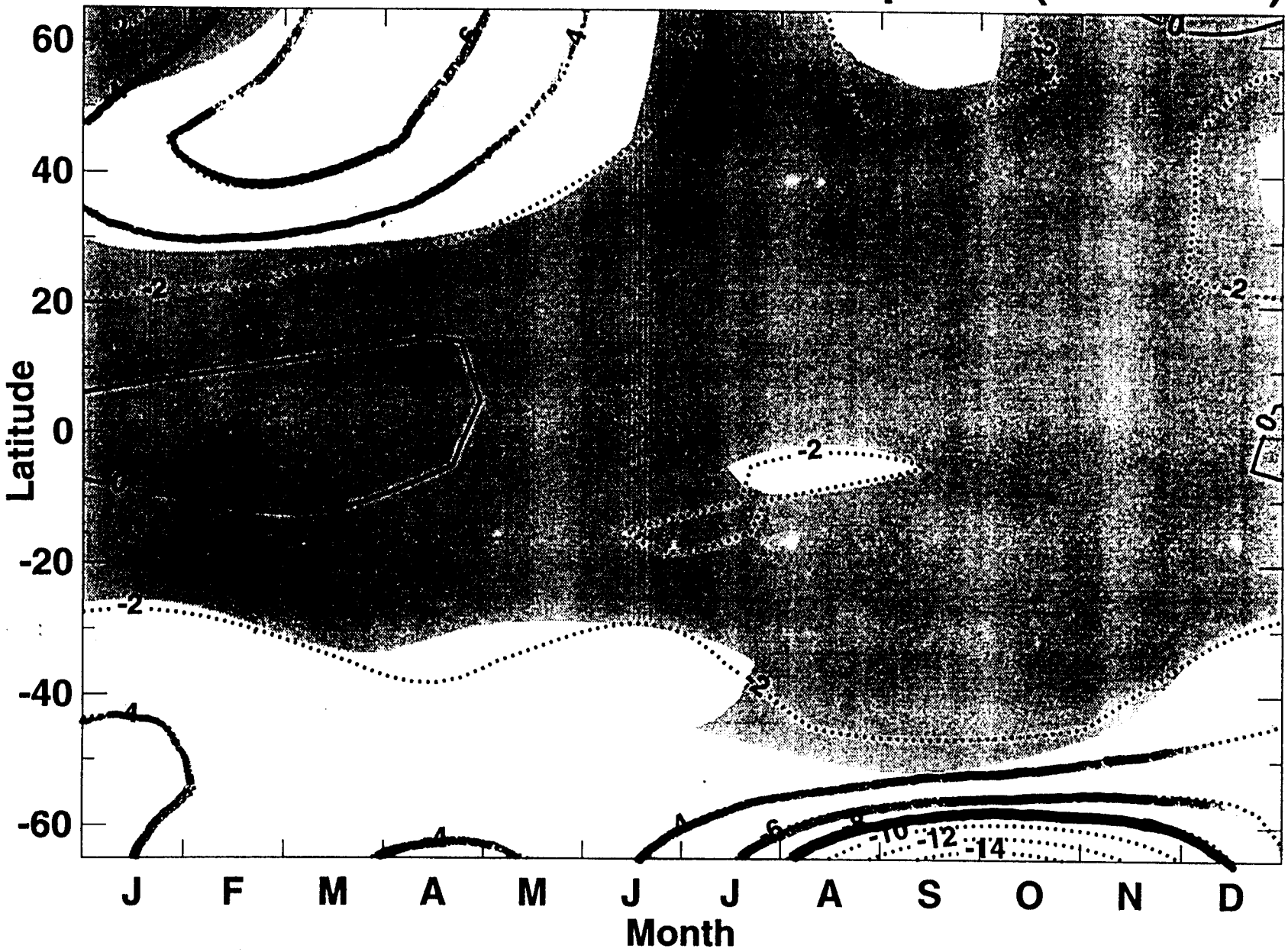
Cooperation with NOAA with responsibilities for instrument calibration and algorithm development for the SBUV/2 series

| | |
|---|---|
| • NOAA 9 SBUV/2 | March 1984 - present |
| . NOAA 11 SBUV/2 | Jan. 1989 - March 1995 |
| . NOAA 14 SBUV/2 | March 1995 - present |

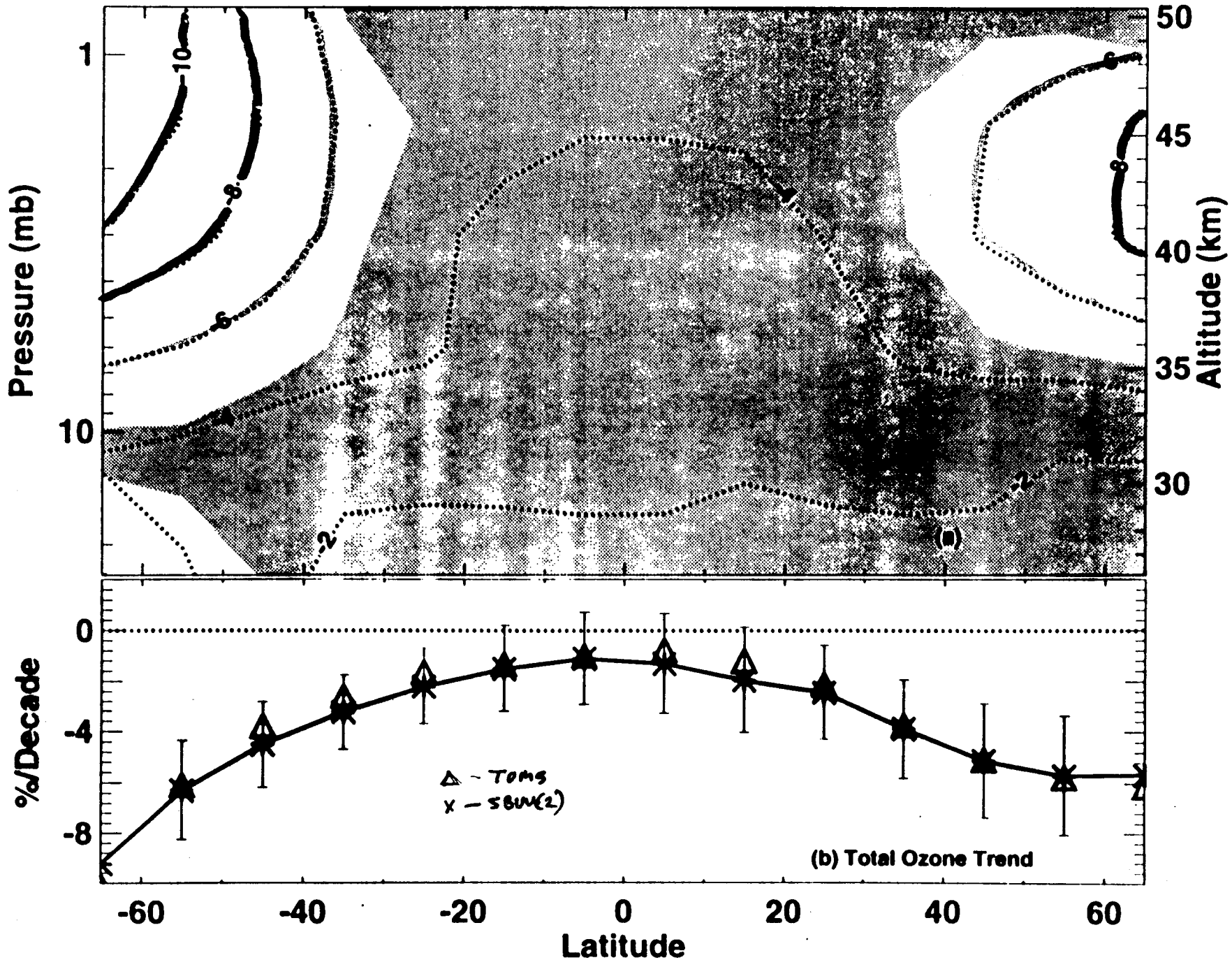
# SATELLITE OZONE MONITORING

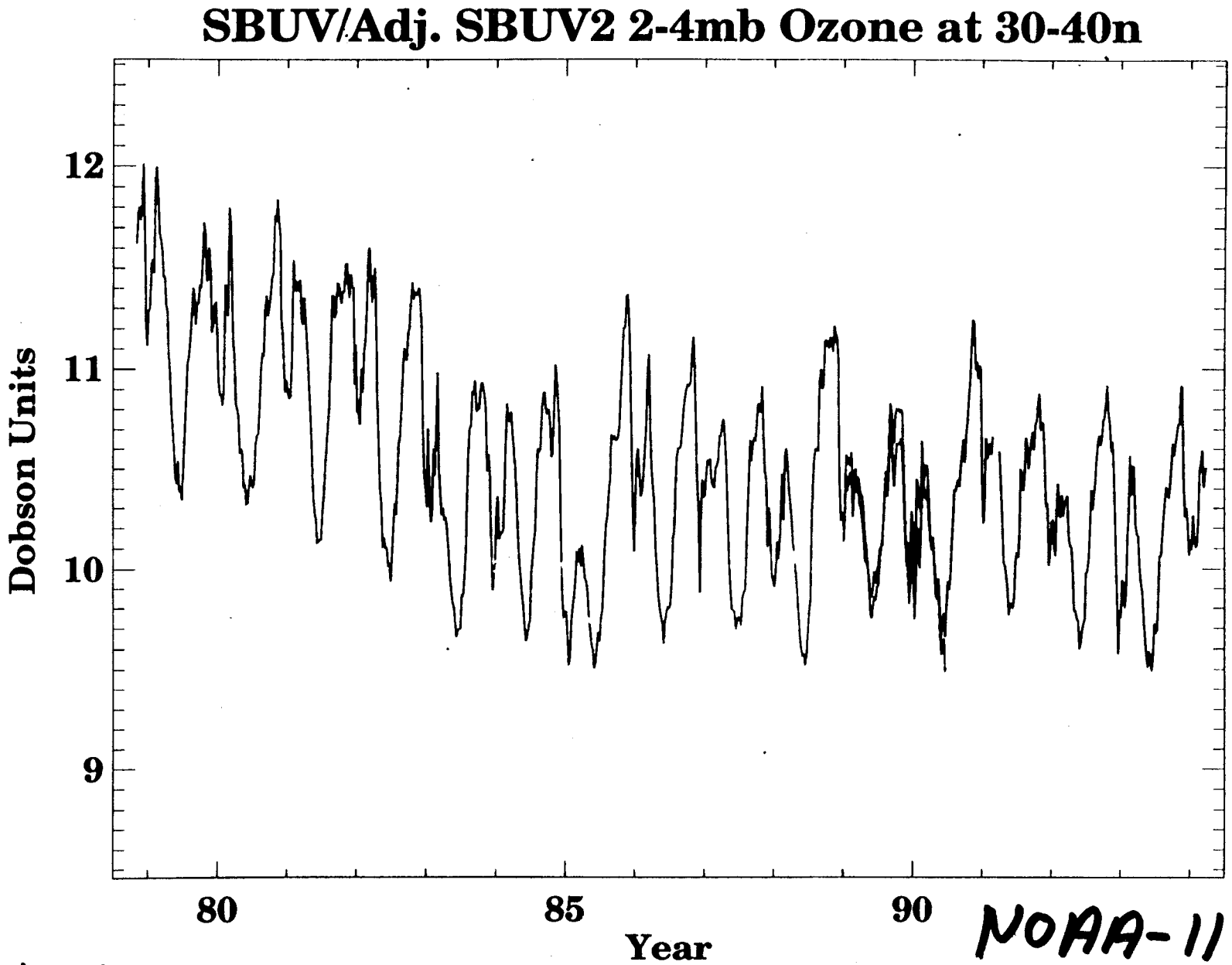


# TOMS V7 Total Ozone Trend Thru April 93 (%/Decade)



1979-1993

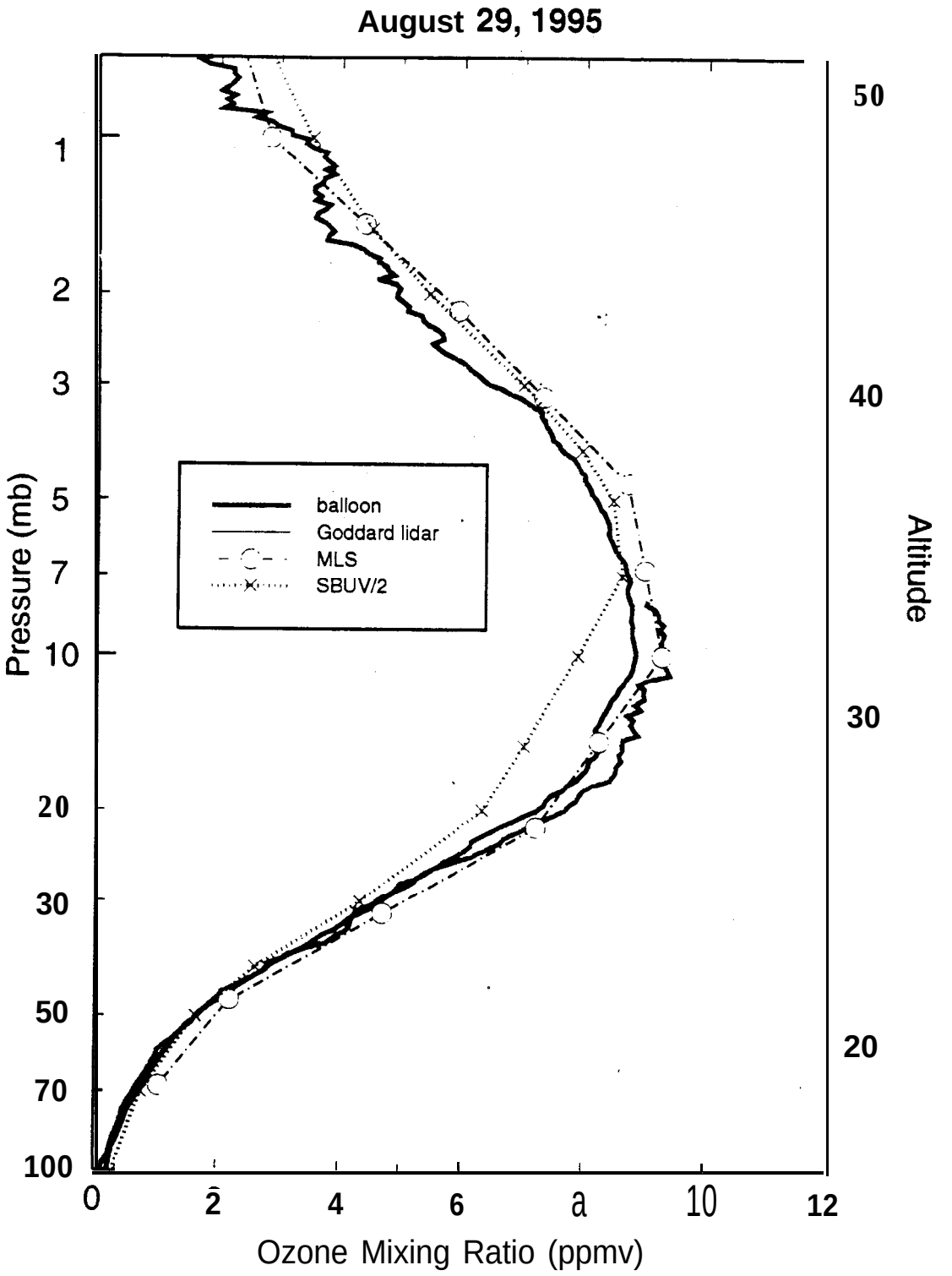

Pressure (mb)
1
10
Altitude (km)
50
45
40
35
30
-10
-8
-6
-2
(a)
%/Decade
0
-4
-8
Δ - TOMS
x - SBUV(2)
(b) Total Ozone Trend
-60
-40
-20
0
20
40
60
Latitude




Nimbus-7 1978-1990

NOAA-11 1989-1994

McPeters Dec. 14. 1995



# OZONE OBSERVATIONS AND ANALYSIS

*NASA - Langley Research Center*

# DISCUSSION OF

# OZONE

# ENVIRONMENTAL DATA RECORDS

# DOC/NOAA/NESDIS WORKSHOP ON OZONE REQUIREMENTS

August 30-31, 1995 at NESDIS

Attendees included:

DOC/NOAA: NESDIS, NWS, GFDL, ARL, OAR

Universities of: Arizona, Illinoise, Maryland, Colorado, and Texas A&M

DOD/Naval Research Laboratory

NASA: HQ, LaRC, GSFC

Draft report under review

# IORD I For Phase 0; Parameter 28.

# OZONE TOTAL COLUMN AND PROFILE AMOUNT

## Summary:

1) Critical environmental variable which responds to anthropogenic injection.
2) Total column amount is input to SeaWIFS data processing (requirement?).
3) Safety and environmental hazard and emergencies; e.g. UVB and pollution.
4) Polar ozone depletion morphology.
5) Dynamical and radiation assessments.
6) Monitor long term history and document changes.
7) Sufficient data to provide clues to depletion mechanism.

4.1.6.2.28 Ozone Total Column/Profile (DoC). Measurement of ozone concentration within a specified volume.

| Systems Capabilities | | Thresholds (Required) | Objectives (Goal) |
|---|---|---|---|
| a. Sensing Depth (km) | | | |
| 1. Total column | | O-top of atmosphere | 0- top of atmosphere |
| 2. Profile | | 10-60 | O-60 |
| b. Horizontal resolution (km) | | | |
| 1. Total column | | 60 at nadir[1] | 60 everywhere[2] |
| 2. Profile | | 250 | 250 |
| c. Vertical resolution (km) | | | |
| 1. Total coluinn | | N/A | N/A |
| 2. Profile | O-10 km | N/A | 3 |
| | 10–25 km | 3 | 1 |
| | 25–60 km | 5 | 3 |
| d Mapping (km) | | | |
| 1. Total column | | 5 | 5 |
| 2. Profile | | 25 | 25 |
| e. Range | | | |
| 1. Total column | | 0.05-0.65 atm-cm | 0.05-0.65 atm-cm |
| 2. Profile | 0–10 km | N/A | 0.01–3 ppmv or $10^{11}$–$3 \cdot 10^{12}$ cm-3 |
| | 10–60 km | 0.1-15 ppmv or $3 \cdot 10^{9}$–$10^{13}$ cm-3 | 0.1–15 ppmv or $3 \cdot 10^{9}$–$10^{13}$ cm-3 |
| f. Precision[3] | | | |
| 1. Total column | | 0.001 atm-cm | 0.00 1 atm-cm |
| 2. Profile | O-10 km | N/A | 10% |
| | 10–15 km | 10% | 3% |
| | 15–50 km | 3% | 1% |
| | 50-60 km | 10% | 3% |

[1] In combination with the refresh requirement, this requirement means that footprints must be 50 km at nadir increasing as necessary to edge of the swnth.

[2] This objective means constant size footprints across a swath.

[3] Precision in this context means the instantaneous repeatability due to noise. not long term-repeatability due to instrument drift.

| | | | |
|---|---|---|---|
| g. Accuracy" | | | |
| 1. Total column | | 0.0 15 a tm-cm | 0.005 atm-cm |
| 2. Profile | O-10 km | N/A | 10% |
| | 10–15 km | 20% | 10% |
| | 15–60 km | 10% | 5% |
| h. Refresh (days) | | | |
| 1. Total column | | 1 | 1 |
| 2. Profile | | 7 | 1 |
| i. Long-term calibration[5] | | | |
| 1. Total column | | 1.0% – [illegible] | 0.5% |
| 2. Profile | | 2.0% – occultation | 1.0% |

[4]Accuracy may be limited by uncertainties in our knowledge of fundamental absorption/emission cross-section. The figures given here do include the error due to uncertainties in line strengths.

[5]Long-term calibration means the long-term repeatability of a measurement.

# Explanation of EDR's

**Total ozone can only addressed with a nadir instrument**

10-60 km contains >99% of column ozone

50 km, 1 day refresh:
SeaWIFS?, 3 (UVB, tropospheric ozone), 4 (TOMS map during NH minihole), 5

Vertical Resolution:
0 -10; Not achievable. but would crucial for boundary layer events
9 -12; 15-17, 3 (SST, a/c, ops and volcanoes)
10-25; 4 (altitude range of AOH), 5, (vertical resolution consistent with temperature, region of aerosol effects, maximum effect on temperatures), 7 (impacts on narrow altitude band, balloon profile)

Initial concern for ozone depletion was in broad altitude range (40-50 km). Major ozone changes now occur in 18-22 km range

Tropospheric ozone
Major uncertainty in natural variation is obstacle in local pollution events and trends.
Critical environmental parameter.
Trends appear to be out of phase with trends in stratosphere.

**Resolution requirements can only met with Limb (or occultation) instrument**

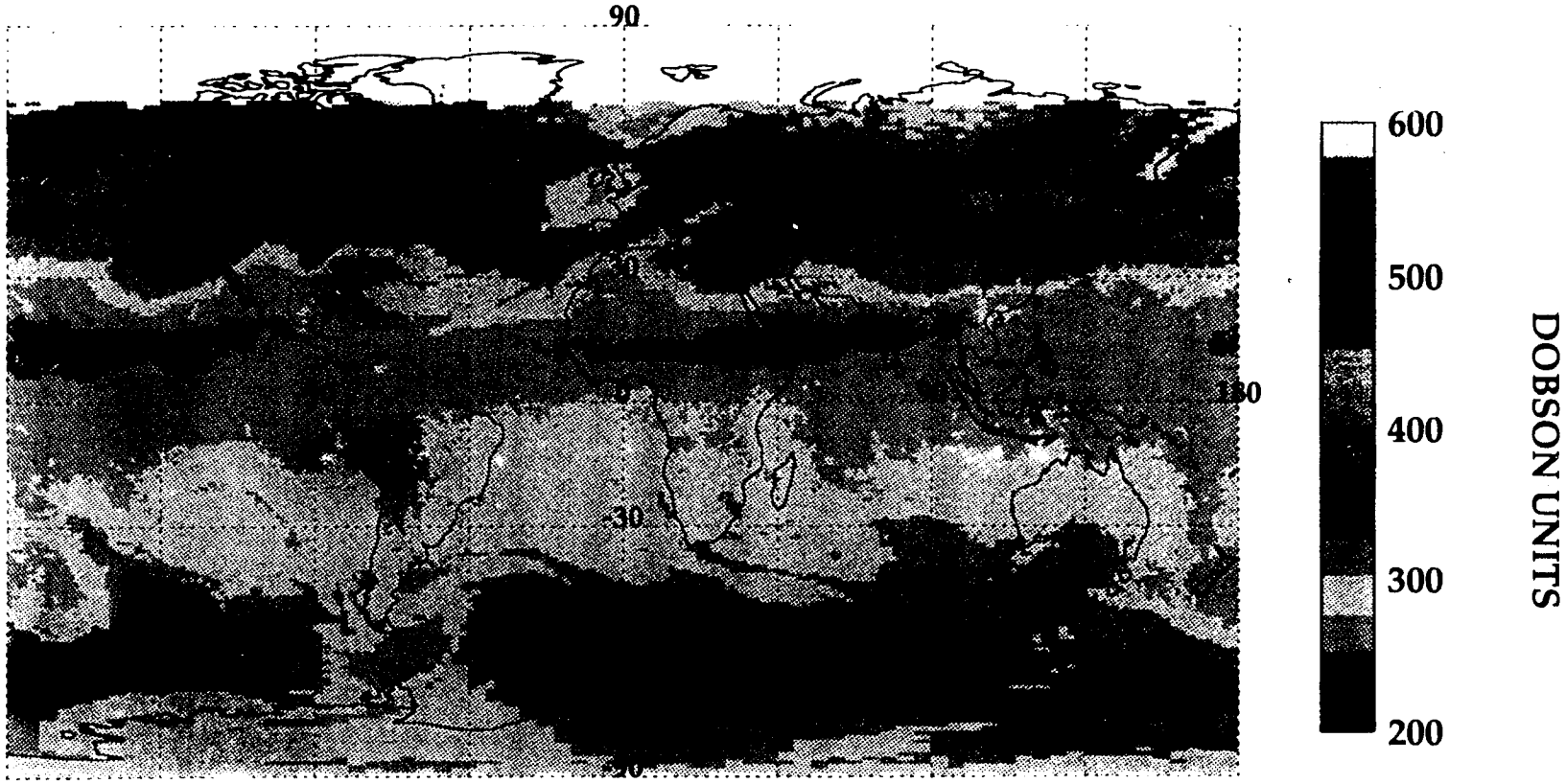
Long term calibration:

Accurate measure of stratosphere trends, with high vertical resolution in lower stratosphere, is needed to detect tropospheric trends.

Calibration requirements is about 1/3 expected trend per decade.

Trend instrument should have heritage (SBUV and TOMS) to trend observations since 1978.

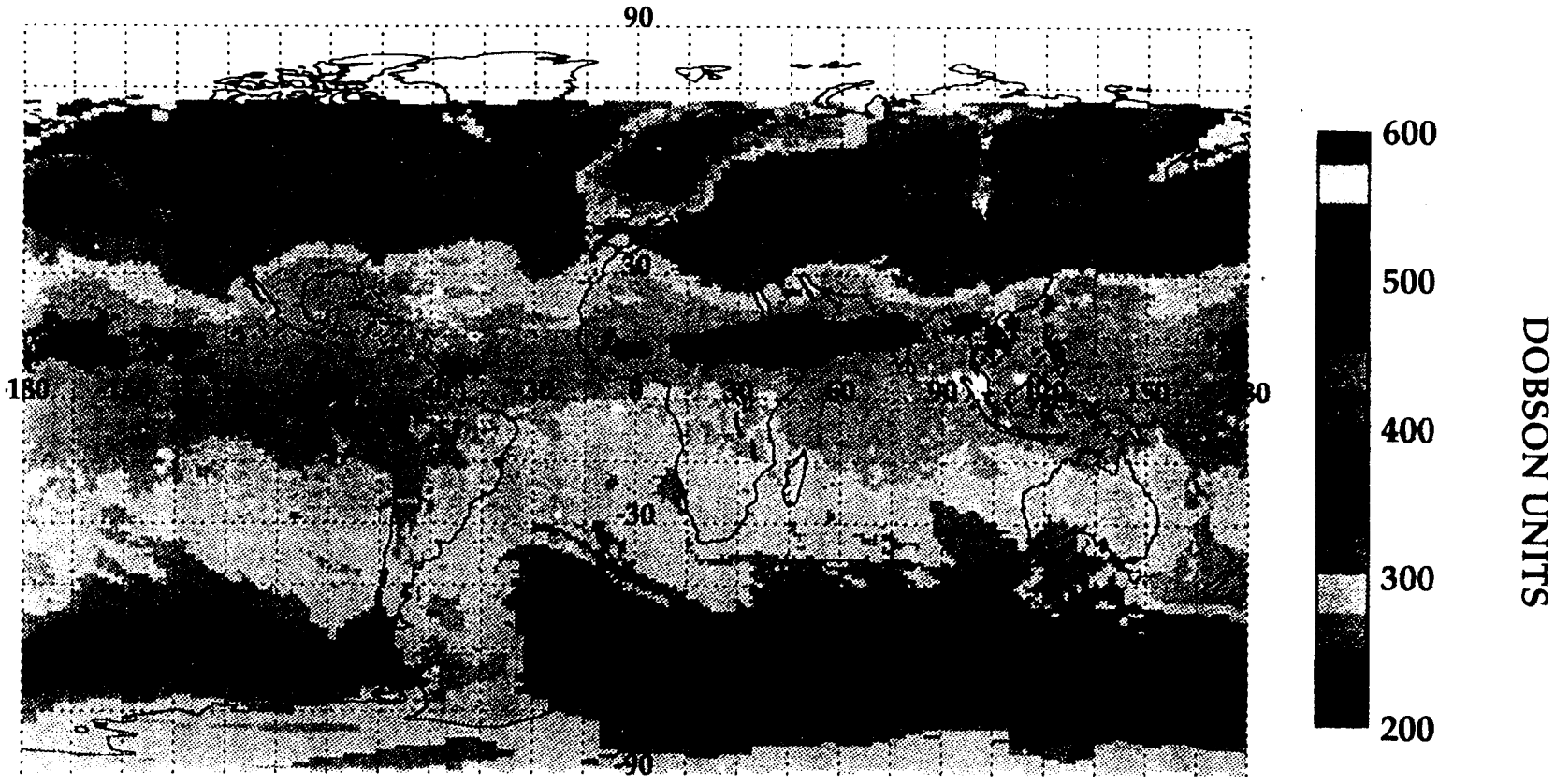
# February 4, 1990




TOTAL OZONE
NASA/GSFC

# Nimbus 7 TOMS

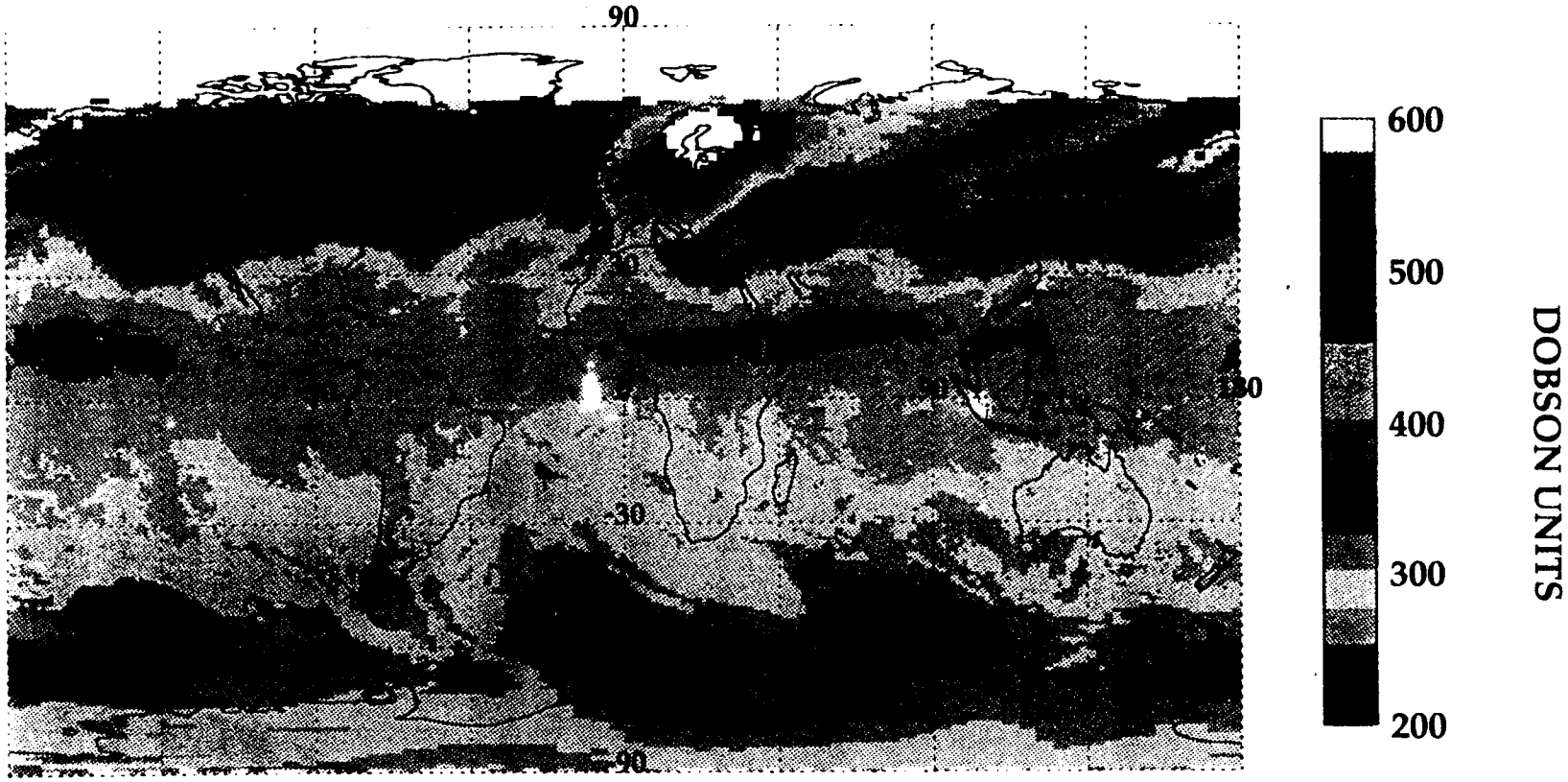
# February 5, 1990




TOTAL OZONE
NASA/GSFC

# Nimbus 7 TOMS

# February 6, 1990




TOTAL OZONE
NASA/GSFC

# Nimbus 7 TOMS

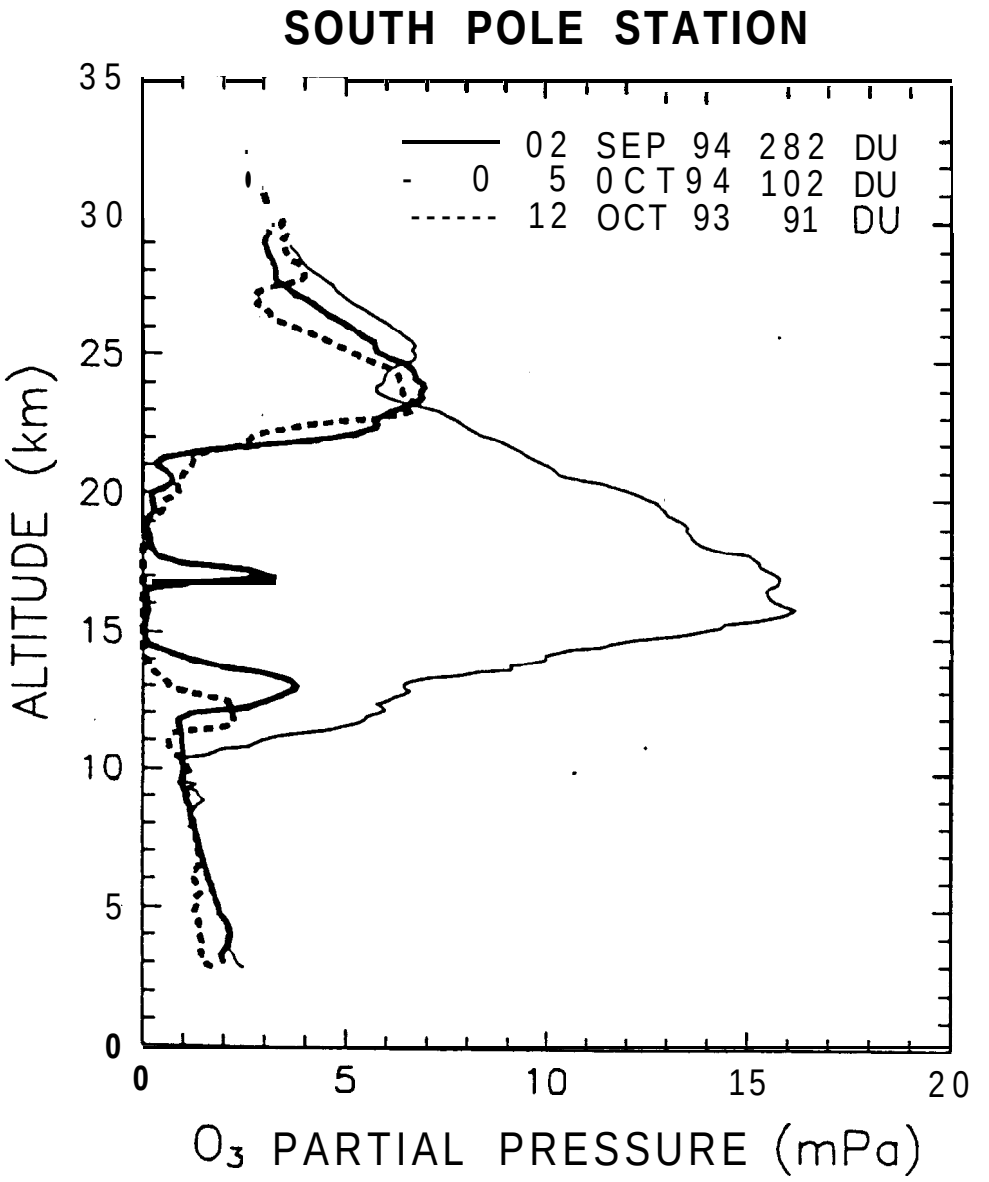



Figure 2. Comparison of the pre-depletion ozone profile in 1994 (September 2) with the profile when total ozone reached a minimum in 1993 (October 12) and 1994 (October 5) at the south pole. Differences in the 10-12 km region are related to differing tropopause heights.

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# MEASUREMENT ASSESSMENT

*P.K. Bhartia*

## Mapping of EDR requirements to Measurement Techniques

### Total Ozone Measurement Techniques

- UV backscattering **(O-3-0.4** μ). **e.g.** TOMS
  - A **TOMS-like** instrument would meet the EDR reqmts (except in polar twilight/night).
  - key issue: technology insertion
    use proven 1970s technology or insert new technology to simplify instrument and reduce long-term cost

- Thermal Emission (9.6 μ band), e.g. TOVS, AIRS
  - Fundamental scientific limitation on accuracy that cannot be solved by instrument redesign
  - not suitable for long-term trends, may be used for mapping
  - may provide polar twilight/night coverage when combined with primary ozone instruments

- Reflection/scattering in visible (0.6 μ band) , e.g. GOME
  - precision and accuracy not known
  - an ESA instrument (GOME) currently flying on ERS-2 to prove this technique
  - potential addition to the UV instrument to improve accuracy in polar twilight

## Mapping of EDR requirements to Measurement Techniques

## Ozone Profiling Techniques

. W Backscattering (0.25-0.35 μ). e.g. SBW
- cannot meet the vertical resolution requirement
  - 4 times worse in 10-25 krn region
  - 1-2 times worse in 25-60 km region
- cannot meet the accuracy requirement in 10-25 km region

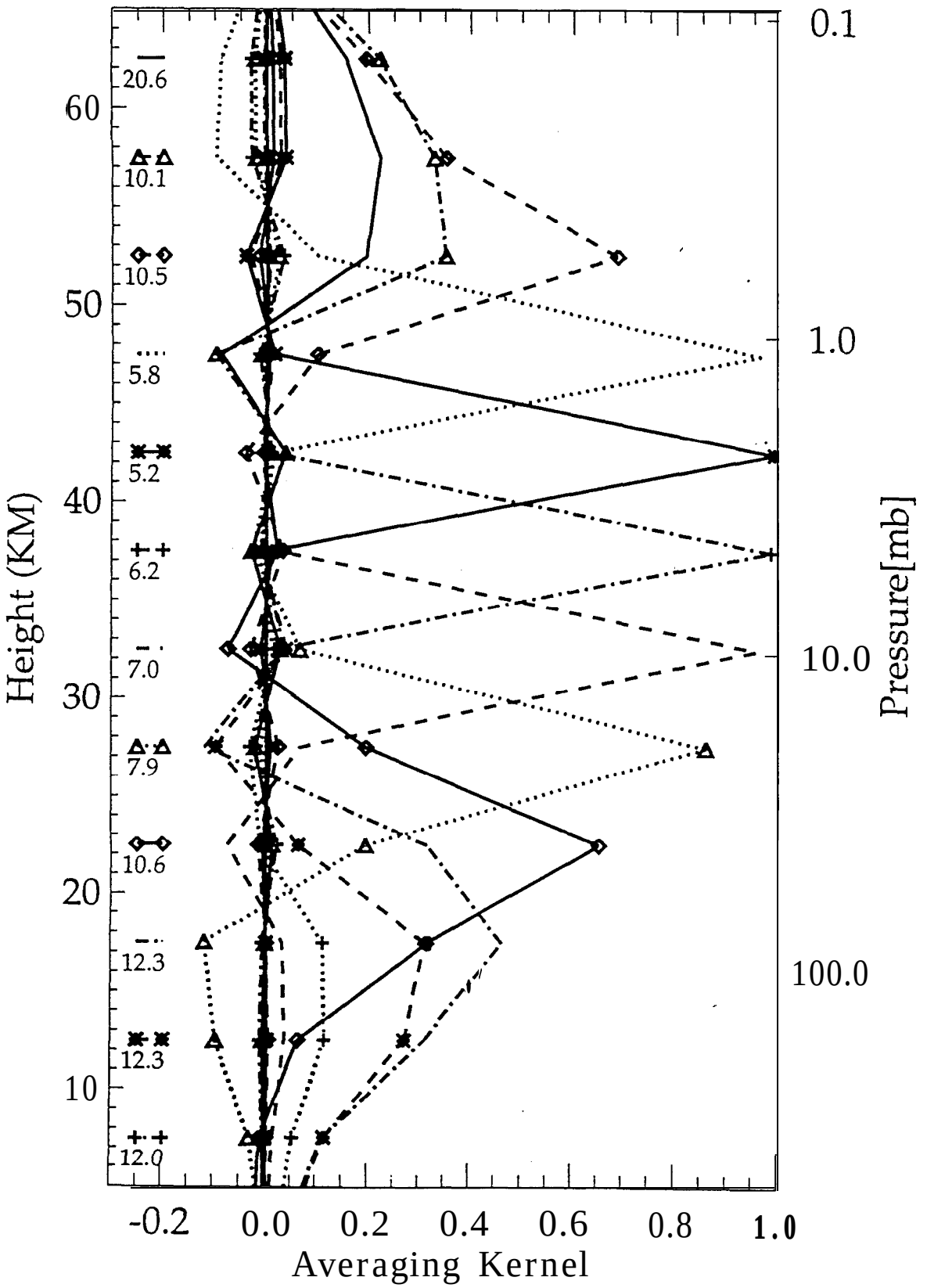
- Limb Thermal Emission (200 GHz or 640 GHz bands) , e.g. MLS, MAS
  - meets vertical resolution in 25-60 km region
  - 200 GHz instrument doesn't meet reqmt. in 10-25 km region (2-3 times worse),
  - 200 GHz cannot meet accuracy requirement in 10-25 km region
  - 640 GHz will do better, but improvement is TBD

- Limb Thermal Emission (9.6 μ bands). e.g. ISAMS, HIRDLS
  - probably can meet EDR requirements
  - requires active cooler
  - profiling below 20 km not proven

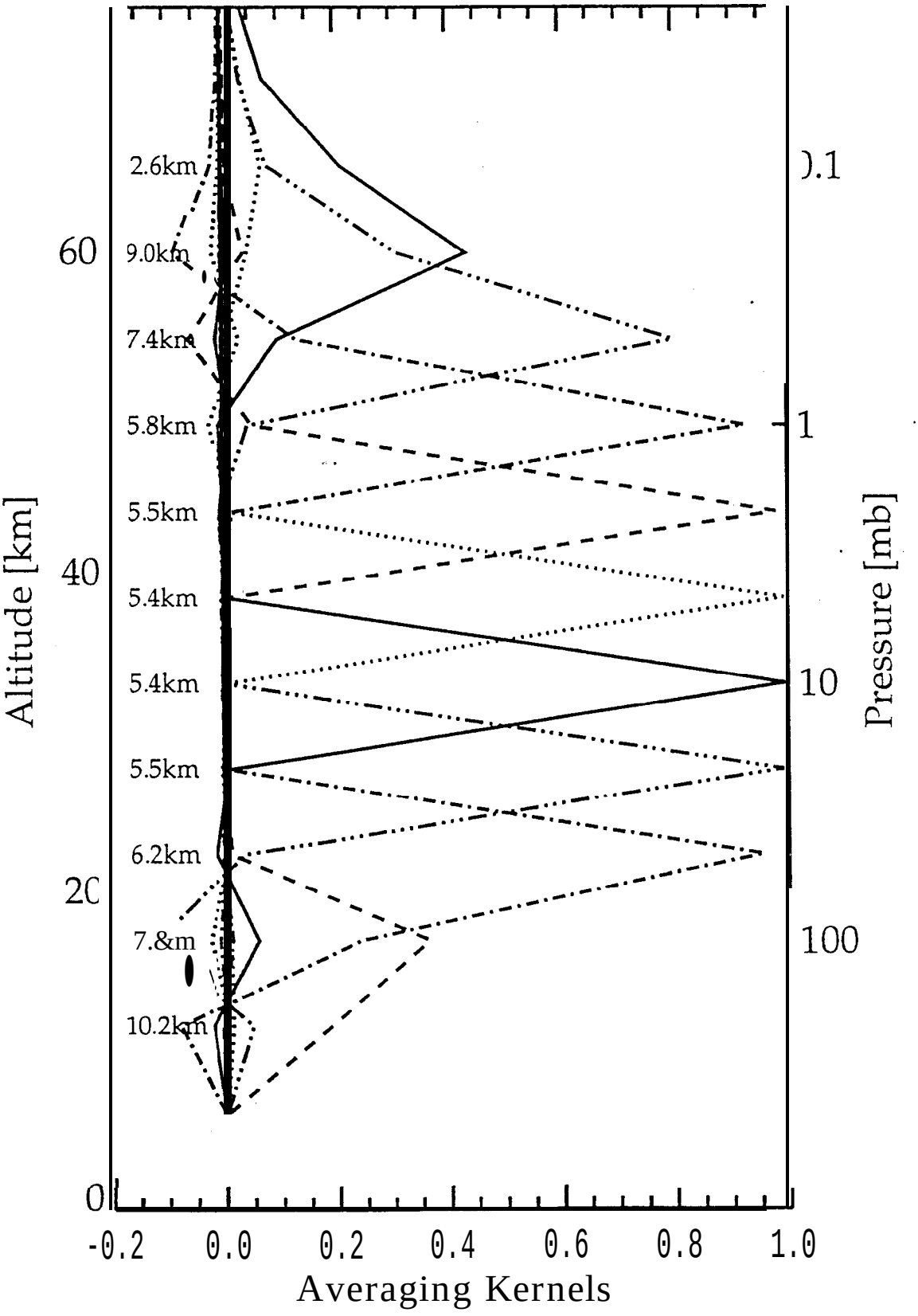
- Solar Occultation (0.3 -1.0 μ). e.g. SAGE, POEM
  - meets accuracy and resolution requirements, but not the coverage
  - requires non-polar orbits to improve coverage

- Limb scattering (0.3- 1.0 μ), e.g. UVISI, SCIAMATCHY
  - will meet vertical resolution and coverage requirement
  - accuracy requirement TBD
  - no flight experience

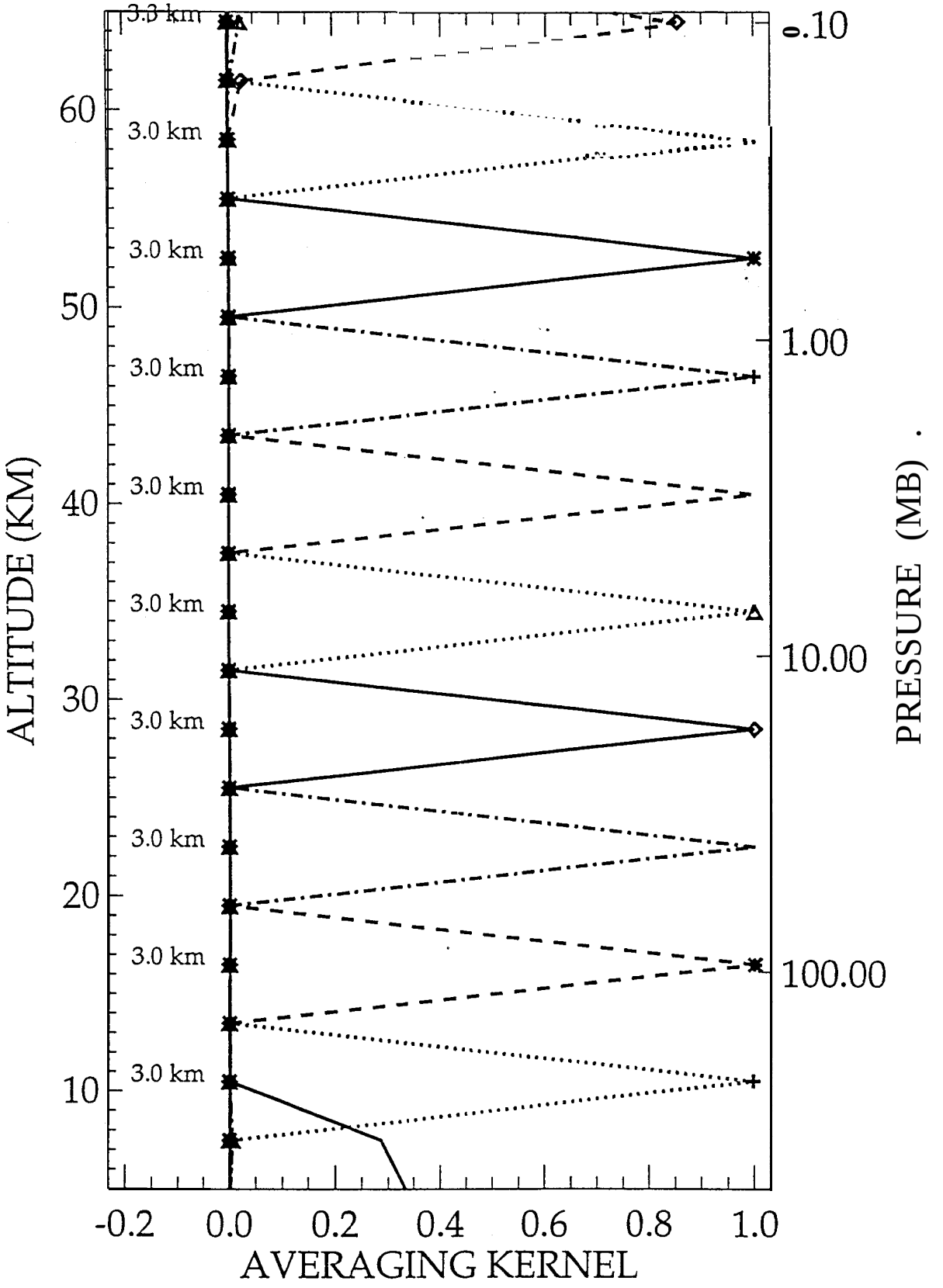
# SBUV Resolution



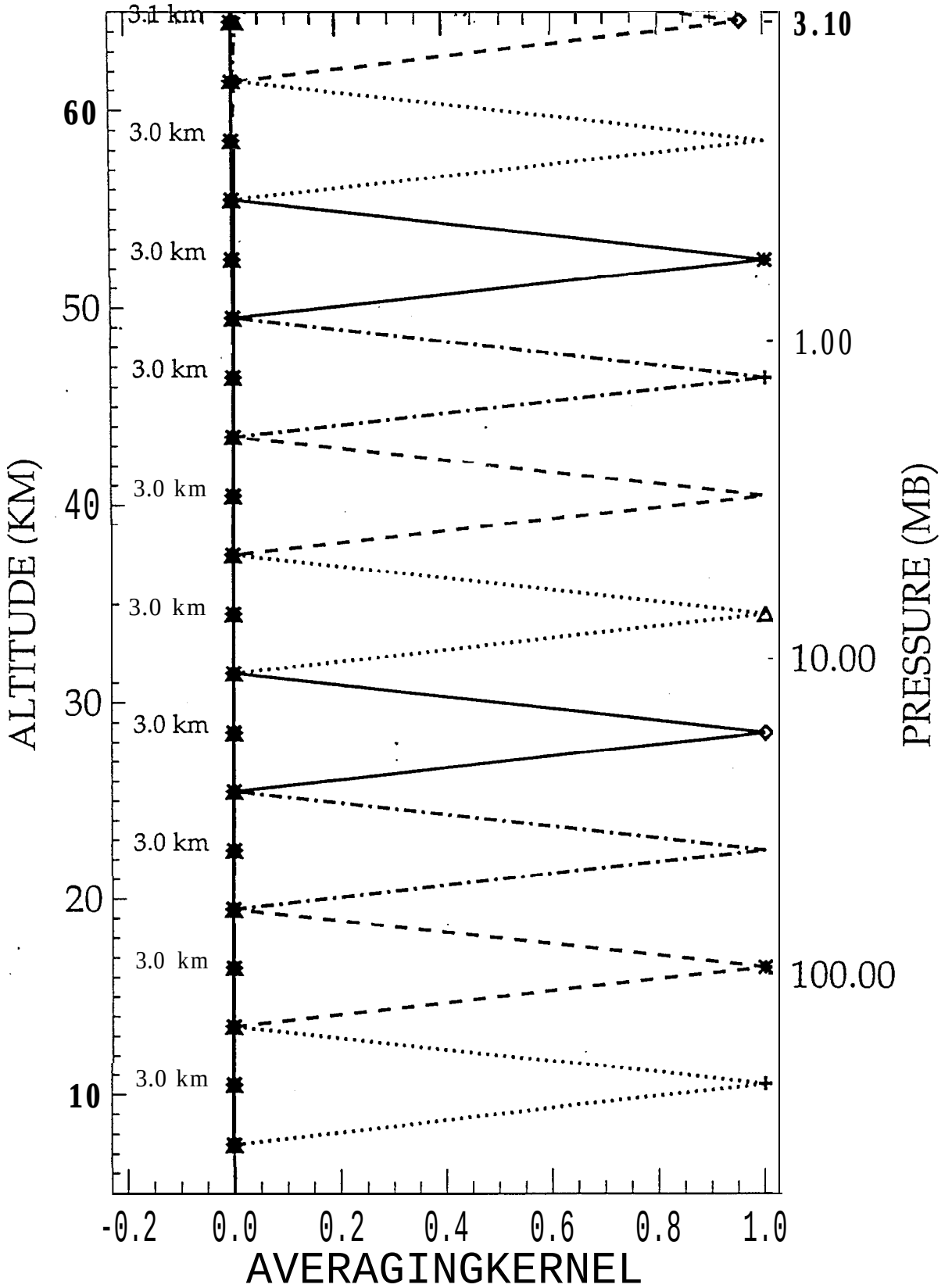
# MLS Resolution



# LIMB SCATTERING RESOLUTION



# OCCULTATION RESOLUTION



# DISCUSSION FOR FURTHER STUDY

- Optimize nadir backscatter, limb scattering, and occultation

  Radiative transfer studies - TOMS self calibration
  - aerosols and other trace gases from limb scatter
  Occultation to limb scattering cross calibration
  Heritage with ozone data set

- Existing Technology

  SAGE enhancement to incorporate limb scattering
  Revisit TOMS (update with new technology to increase performance, reduce cost, weight, mass, & power requirements)

- New Technology Option

  Sage technology
  Spectrometer on a chip
  Integrated solid state detectors

- NPOESS Phase B Studies

  Participate in requirements development
  Review studies and results

# Advanced TOMS - Low cost option

Pushbroom in wavelength and space

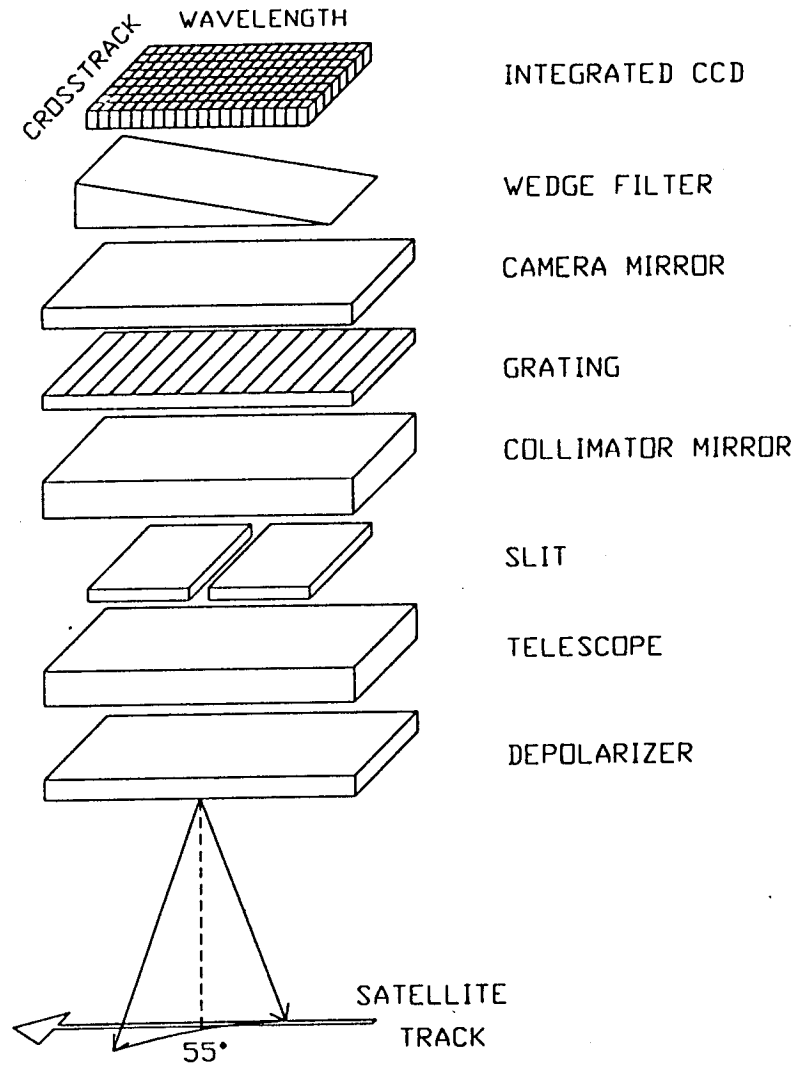
No mechanisms

Wavelength range; 300-400 nm (hyperspectral)

Two cameras; each camera;

- Field of Regard 55°x3°x3.5° (1500x43x50 km)
- Integration time 3-6 seconds
- Minimum S/N is 100 (3x better than TOMS)
- 1k x1k CCD (cooling may not be required)

Telescope focuses Earth on slit

Grating provides initial dispersion (<1.0 nm resolution)

Wedge filter (5-10 nm resolution) eliminates stray light