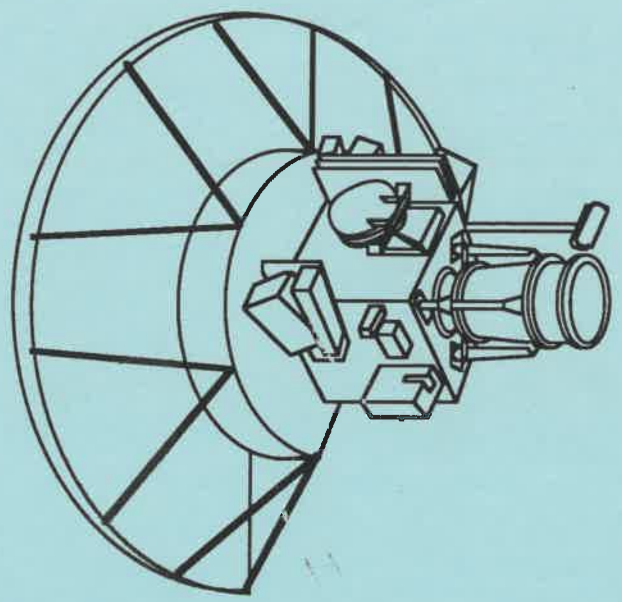
SME



Solar Mesosphere Explorer
Scientific Data & Publications
Final Report

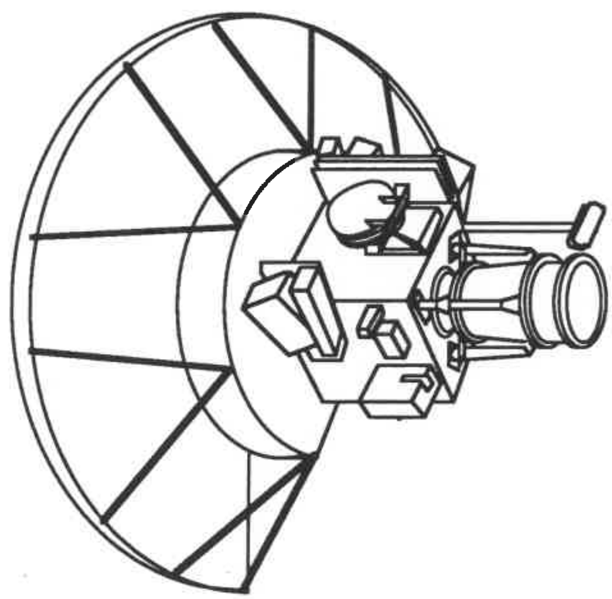
Laboratory for Atmospheric and Space Physics
University of Colorado at Boulder
Box 392
Boulder, Colorado 80309-0392

December 1989

LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO
BOULDER, COLORADO

SOLAR MESOSPHERE EXPLORER (SME) FINAL REPORT

Scientific Data & Publications



December 1989

Scientific Data Archives and Scientific Publications from the Solar Mesosphere Explorer

December 1989

The Solar Mesosphere Explorer satellite was launched on October 6, 1981, into a 3:00 am — 3:00 pm Sun-synchronous polar orbit at an altitude of 530 km. The satellite is expected to re-enter Earth's atmosphere late in 1990 due to orbit decay from atmospheric drag. The satellite was operational from October 6, 1981, until April 13, 1989. The ultraviolet, visible, and near-infrared spectrometers were used to measure the properties of the mesosphere from December 15, 1981, until December 22, 1986, a period of five years from solstice to solstice. The ultraviolet and near-infrared spectrometers measured the density of ozone in the mesosphere as a function of altitude, latitude, and time. The ultraviolet spectrometer measured the density of nitric oxide in the lower thermosphere as a function of altitude, density, and time. The visible spectrometer measured the density of nitrogen dioxide in the upper stratosphere as a function of altitude, latitude, and time. The solar ultraviolet spectrometer measured the solar ultraviolet irradiance from October 8, 1981, until April 13, 1989, a period of seven years during the declining phase of the solar cycle, through solar minimum, and during the beginning of the rising phase. The SME data have been archived in the National Space Science Data Center and in the SME database at the University of Colorado. This report describes the content of those archives and lists the scientific papers published from the SME data together with their abstracts

OZONE: ORBIT-TRACK

The SME orbit-track data consist of ozone mixing ratios measured by two instruments. The archived data cover the period from 1981 through 1986. The ozone mixing ratios in parts per million by volume from the Near-Infrared Spectrometer are given on pressure surfaces from about 50 to 90 km between 85° North and 85° South at each 5 degrees. The analysis is described by Thomas *et. al.*, 1983, 1984.[1] The ozone mixing ratios in parts per million by volume from the Ultraviolet Spectrometer are given in pressure levels from 1.0 to 0.1 mb from 85° South to 85° North in 5-degree latitude intervals (see Rusch *et. al.*, 1983, 1984[2]).

SME OZONE MIXING RATIO DATA, 1981 - 1986

FILE	NO. BLOCKS	CONTENTS
AOZORB1.DAT	6365	Airglow ozone, 12/15/81 - 12/31/82
UVOZORB1.DAT	2914	UV ozone, 12/15/81 - 12/31/82
AOZORB2.DAT	5300	Airglow ozone, 1/ 1/83 - 12/31/83
UVOZORB2.DAT	2404	UV ozone, 1/ 1/83 - 12/31/83
AOZORB3.DAT	5000	Airglow ozone, 1/ 1/84 - 12/31/84
UVOZORB3.DAT	2255	UV ozone, 1/ 1/84 - 12/31/84
AOZORB4.DAT	7075	Airglow ozone, 1/ 1/85 - 12/31/85
UVOZORB4.DAT	3254	UV ozone 1/ 1/85 - 12/31/85
AOZORB5.DAT	10235	Airglow ozone, 1/ 1/86 - 12/18/86
UVOZORB5.DAT	4654	UV ozone, 1/ 1/86 - 12/18/86

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[1]Thomas R. J., C. A. Barth, G. J. Rottman, D. W. Rusch, G. H. Mount, G. M. Lawrence, R. W. Sanders, G. E. Thomas, and L. E. Clemens, Ozone Density Distribution in the Mesosphere (50-90 km) Measured by the SME Limb-Scanning Near-Infrared Spectrometer, *Geophys. Res. Letters* **10**, 245-248, 1983.

Thomas, R. J., C. A. Barth, D. W. Rusch, and R. W. Sanders, Solar Mesosphere Explorer Near-Infrared Spectrometer: Measurements of 1.2μm Radiances and the Inference of Mesospheric Ozone, *J. Geophys. Res.* **89**, 9569-9580, 1984.

[2]Rusch, D. W., G. H. Mount, C. A. Barth, G. J. Rottman, R. J. Thomas, G. E. Thomas, R. W. Sanders, G. M. Lawrence, and R. S. Eckman, Ozone Densities in the Lower Mesosphere Measured by a Limb-Scanning Ultraviolet Spectrometer, *Geophys. Res. Letters* **10**, 241-244, 1983.

Rusch, D. W., G. H. Mount, C. A. Barth, R. J, Thomas, and M. T. Callan, Solar Mesosphere Explorer Ultraviolet Spectrometer: Measurements of Ozone in the 1.0 to 0.1 mb Region, *J. Geophys. Res.* **89**, 11677-11687, 1984.

OZONE: DAILY AND MONTHLY AVERAGE

The SME daily and monthly average data consist of ozone mixing ratios measured by two instruments. The archived data cover the period from 1981 through 1986. The ozone mixing ratios in parts per million by volume from the Near Infrared Spectrometer are given on pressure surfaces from about 50 to 90 km between 85° North and 85° South at each 5 degrees. The ozone mixing ratios in parts per million by volume from the ultraviolet spectrometer are given in pressure levels from 1.0 to 0.1 mb from 85° South to 85° North in 5-degree latitude intervals.

SME OZONE MIXING RATIO DATA, 1981-1986

FILE	NO.BLOCKS	CONTENTS
AOZAVEM.DAT	260	Near-Infrared Spectrometer: Monthy average ozone mixing ratios
UVOZAVEM.DAT	105	Ultraviolet Spectrometer: Monthly average ozone mixing ratios
AVEAOZ.DAT	7815	Near-Infrared Spectromter: Daily average ozone mixing ratios
AVEUVOZ.DAT	3210	Ultraviolet Spectrometer: Daily average ozone mixing ratios

Nitric Oxide: Orbit-Track

The SME orbit-track NO data were derived from Ultra-violet Spectrometer radiance measurements. The archived data cover the years 1982 trhough 1986. The nitric oxide densities are given on altitude surfaces from 100 to 160 km. There are two sets of NO densities, one on a grid of magnetic latitudes, and the other on geographic latitudes. Each set also includes longitudes and solar zenith angles.

SME NO DENSITY DATA, 1981 - 1986

MAGNETIC LATITUDE GRIDDED NO DENSITY

FILE	NO. BLOCKS	CONTENTS	FIRST ORBIT
NOM82A.DAT	10718	1/ 6/82 - 6/30/82	1387
NOM82B.DAT	9269	7/ 1/82 - 12/31/82	4046
NOM83A.DAT	7774	1/ 1/83 - 6/30/83	6834
NOM83B.DAT	7843	7/ 1/83 - 12/31/83	9576
NOM84A.DAT	7889	1/ 1/84 - 6/29/84	12365
NOM84B.DAT	5267	6/30/84 - 12/31/84	15110
NOM85A.DAT	3703	1/ 1/85 - 6/30/85	17915
NOM85B.DAT	3979	7/ 1/85 - 12/31/85	20659
NOM86A.DAT	4048	1/ 1/86 - 6/30/86	23451
NOM86B.DAT	2323	7/ 1/86 - 12/11/86	26211

GEOGRAPHIC LATITUDE GRIDDED NO DENSITY

FILE	NO. BLOCKS	CONTENTS	FIRST ORBIT
NOG82A.DAT	10718	1/ 6/82 - 6/30/82	1387
NOG82B.DAT	9269	7/ 1/82 - 12/31/82	4046
NOG83A.DAT	7774	1/ 1/83 - 6/30/83	6834
NOG83B.DAT	7843	7/ 1/83 - 12/31/83	9576
NOG84A.DAT	7889	1/ 1/84 - 6/29/84	12365
NOG84B.DAT	5267	6/30/84 - 12/31/84	15110
NOG85A.DAT	3703	1/ 1/85 - 6/30/85	17915
NOG85B.DAT	3979	7/ 1/85 - 12/31/85	20659
NOG86A.DAT	4048	1/ 1/86 - 6/30/86	23451
NOG86B.DAT	2323	7/ 1/86 - 12/11/86	26211

NITROGEN DIOXIDE: ORBIT-TRACK

The SME orbit-track NO_2 data were derived from Visible Spectrometer radiance measurements. The archived data cover the years 1982 through 1986. Nitrogen dioxide mixing ratios in parts per billion by volume are given on pressure surfaces from about 24 to 40 km between 120° South and 120° North at each 5 degrees.

SME NO_2 MIXING RATIO DATA, 1981 - 1986

FILE	NO.BLOCKS	CONTENTS
NO282.DAT	4137	2/17/82 - 12/31/82
NO283.DAT	3237	1/ 1/83 - 12/31/83
NO284.DAT	2829	1/ 1/84 - 12/31/84
NO285.DAT	3335	1/ 1/85 - 12/31/85
NO286.DAT	4683	1/ 1/86 - 12/18/86

NITROGEN DIOXIDE: MONTHLY AVERAGE

The SME monthly average NO_2 data were also derived from Visible Spectrometer radiance measurements. The archived data cover the years 1982 through 1986. The nitrogen dioxide mixing ratios in parts per billion by volume are given on pressure surfaces from about 24 to 40 km between 120° South and 120° North at each 5 degrees.

SME NO_2 MIXING RATIO DATA, 1982-1986

FILE	NO. BLOCKS	CONTENTS
SMENO2M.DAT	396	Visible Spectrometer: Monthly averages of NO_2 mixing ratios in ppbv

SOLAR ULTRAVIOLET IRRADIANCE

The Solar Ultraviolet Spectrometer made daily measurements of the solar flux from 115 nm to 302 nm with 1 nm resolution. The archived data cover the period 1 January 1982 through 30 June 1988. The SME Solar UVS daily solar irradiance data are reduced from multiple scans, in 0.25-nm steps, of the full disk solar irradiance at the SME by a spectrometer with a full-width half-maximum resolution of 0.75 nm (Rottman *et al.*, 1982[3]). That is, multiple measurements spaced at 0.25 nm are convolved with an instrument response function and integrated to a resolution of 1 nm. The absolute flux is normalized to a rocket experiment of 17 May 1982 (Mount and Rottman, 1983[4]) and is accurate to $\pm$15%.

SME SOLAR FLUX DATA, 1981-1988

FILE	NO. BLOCKS	CONTENTS
SMESOL.TXT	2373	Solar flux and quality index 1/1/82 - 6/30/88

Data for the last year of the SME mission (*i.e.*, 1 July 1988 to 13 April 1989) will be available in both the NSSDC and University of Colorado archives after 30 June 1990. This will constitute the final database of the SME solar measurements, and, in addition, it will include the 1981 data (13 October 1981 - 31 December 1981). Estimates of the precision and long-term relative accuracy of the entire solar data set are presently being determined. These parameters are essential to establishing solar-cycle variability and will be made available to the data users.

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[3]Rottman, G. J., C. A. Barth, R. J. Thomas, G. H. Mount, G. M. Lawrence, D. W. Rusch, R. W. Sanders, G. E. Thomas, and J. London: Solar Spectral Irradiance, 120 to 190 nm, October 13, 1981 -- January 3, 1982, *Geophys. Res. Letters* **9**, 587--590, 1982.

[4]Mount, G. H., and G. J. Rottman, The Solar Absolute Spectral Irradiance 1150--3173 Å : May 17, 1982, *J. Geophys. Res.* **88**, 5403--5410, 1983.

Scientific Publications from the Solar Mesosphere Explorer

December 1989

Barth, C. A., Reference Models for Thermospheric NO, *Adv. Space Res.* **10**, 103-115, 1989.

Nitric oxide has been measured with an ultraviolet spectrometer on the polar-orbiting satellite Solar Mesosphere Explorer (SME) for the period January 1982 to August 1986. The nitric oxide database contains densities at all latitudes sorted into 5°-gins and at altitudes between 100 and 140 km sorted into 3.3-km-bins. The largest densities occur at latitudes in the auroral zones where the density varies as a function of geomagnetic activity. Variations of a factor of 10 occur between times of intense activity and quiet times. At low latitudes, the nitric oxide density at 110 km varies from a mean value of 3×10^7 molecules/cm^3 in January 1982 to a mean value of 4×10^6 molecules/cm^3 during solar minimum conditions in 1986. In addition, the low-latitude nitric oxide density varies $\pm 50\%$ with a period of 27 days during times of high solar activity.

Barth, C. A., R. W. Sanders, G. E. Thomas, G. J. Rottman, D. W. Rusch, R. J. Thomas, G. H. Mount, G. M. Lawrence, J. M. Zawodny, R. A. West, and J. London, Solar Mesosphere Explorer Measurements of the El Chichon Volcanic Cloud, *Bull. Amer. Meteor. Soc.* **63**, 1314, 1982.

Instruments onboard the NASA Solar Mesosphere Explorer (SME) satellite have been measuring the formation and dispersal of the stratospheric cloud produced from the major eruption of the El Chichon volcano on 4 April 1982. SME is a polar-orbiting satellite in a sun-synchronous orbit. Its instruments view the stratosphere and mesosphere by limb-scanning along the track of the orbit. This observational technique has provided altitude-latitude maps of the atmosphere every day since the eruption.

Barth, C. A., D. W. Rusch, R. J. Thomas, G. H. Mount, G. J. Rottman, G. E. Thomas, R. W. Sanders, and G. M. Lawrence, Solar Mesosphere Explorer: Scientific Objectives and Results, *Geophys. Res. Letters* **10**, 237-240, 1983.

Instruments on the Solar Mesosphere Explorer simultaneously measure ozone density, temperature, and solar ultraviolet flux. Results from six months of observations show that ozone density in the mesosphere changes from day-to-day and with the seasons and that the principal cause of these changes is the variation in atmospheric temperature. The dependence between ozone density and temperature is inverse, with a decrease in temperature producing an increase in ozone density. This dependence is observable in the seasonal patterns and also in orbit-to-orbit observations during dramatic atmosphere changes such as stratospheric warmings.

Barth, C. A., R. W. Sanders, R. J. Thomas, G. E. Thomas, B. M. Jakosky, and R. A. West, Formation of the El Chichon Aerosol Cloud, *Geophys. Res. Letters* **10**, 993-996, 1983.

Thermal emission at 6.8 μm and particle-scattered radiation at 1.9 μm from the El Chichon aerosol cloud were measured by instruments on board the Solar Mesosphere Explorer satellite. The cloud moved westward circling the globe in twenty-one days. During its initial formation the cloud was centered at an altitude of 27 km and was confined to the altitude band between the equator and 30°N. At the 27 km level, the maximum density was reached eight to nine weeks after the eruption. Following that time, the maximum in the density gradually moved lower in altitude.

Barth, C. A., W. K. Tobiska, D. E. Siskind, and D. D. Cleary, Solar Terrestrial Coupling: Low-Latitude Thermospheric Nitric Oxide, *Geophys. Res. Letters* **15**, 92-94, 1988.

As measured by the Solar Mesosphere Explorer satellite, the density of nitric oxide at low latitudes (30°S to 30°N) and at 110 km (E-region) decreased from a mean value of 3×10^7 molecules/cm^3 in January 1982 to a mean value of 4×10^6 molecules/cm^3 in April 1985. In addition, the nitric oxide density varied $\pm$50% with a 27-day period during times of high solar activity. The variation of nitric oxide correlates with variations in the solar Lyman-alpha irradiance which is also measured by the Solar Mesosphere Explorer satellite. The Lyman-alpha irradiance is interpreted as an index of the variations in the solar EUV and soft X-ray flux. They hypothesis is proposed that the solar X-ray flux between 20 and 100 Å has a larger variation than the solar EUV flux between 100 and 1050 Å and that the solar X-rays produce photoelectrons which are the source of the nitric oxide.

Barth, C. A., W. K. Tobiska, G. J. Rottman, and O. R. White, Comparison of 10.7 cm Radio Flux with SME Solar Lyman Alpha Flux Analysis, *Geophys. Res. Letters*, in press, 1990.

Measurements of the solar Lyman alpha flux that were made over a seven-and-one-half-year period between October 8, 1981 and April 13 1986 have been compared with ground-based measurements of the solar 10.7 cm radio flux made over the same time period. There is a long-term correlation between these two measures of solar flux between October 8, 1981 and July 26, 1984 during the declining part of the solar cycle. During the period July 26, 1984 — April 11, 1987, during the solar minimum period, there is not a correlation between the two solar fluxes because the 10.7 cm radio flux reaches a minimum of 65×10^{-22} W m^{-2} Hz^{-1} and does not vary below this value while the Lyman alpha flux continues to decline and show long-term and short-term variations. During the period April 11, 1987 — November 25, 1988, during the rising part of the solar cycle, there is again a correlation between the two fluxes, although the proportionality between the two is different from the proportionality during the declining phase of the solar cycle. During the period November 25, 1988 — April 13, 1989, the last period when observations of Lyman alpha were made, a medium-term correlation exists and the proportionality of the two indices is similar to what it was during the declining phase of the solar cycle. A study of the correlation of the 10.7 cm flux with the Lyman alpha for a 999-day period during the declining phase showed that for the short-term (27-day) variation there is a correlation between the two fluxes but the proportionality between them varies from one solar rotation to the next. The conclusion is that the solar 10.7 cm radio flux is not a useful index for the solar Lyman alpha flux for the short-term, 27-day variations.

Clancy, R. T., El Chichon and "Mystery Cloud" Aerosols between 30 and 55 km: Global Observations from the SME Visible Spectrometer, *Geophys. Res. Letters* **13**, 937-940, 1986.

Visible limb radiances measured by the Solar Mesosphere Explorer (SME) are used to obtain volume scattering ratios for aerosol loading in the 30-55 km altitude range of the stratosphere. Global maps of these ratios are presented for the period January 1982 to August 1984. Significant aerosol scattering from the "mystery cloud" and El Chichon aerosol layers are found above 30 km. A timescale of approximately 2 months between the appearance of the aerosol at 30.5 km and at 37.5 km is consistent with vertical transport of aerosol or vapor by eddy diffusion above 30 km. An anticorrelation exists between aerosol scattering and stratospheric temperatures. Periods of lower stratospheric temperatures may account for the formation of aerosol between 40 and 55 km altitude.

Clancy, R. T., and D. W. Rusch, Climatology and Trends of Mesospheric (58-90 km) Temperatures Based upon 1982-1986 SME Limb Scattering Profiles, *J. Geophys. Res.* **94**, 3377-3394, 1989.

Global observations of ultraviolet limb radiances from the Solar Mesosphere Explorer (SME) have been analyzed to obtain atmospheric temperature profiles over the altitude range 58–90 km. The temperature analysis is based upon vertical profiles of Rayleigh scattering, which are derived from the SME ultraviolet limb radiances. Comparisons are provided with lidar and Stratosphere and Mesosphere Sounder (SAMS) temperature observations at 65 km altitude, and with previous temperature climatologies of the mesosphere. SME monthly average temperature profiles are presented for 10° latitude intervals between 70°S and 70°N latitudes, over the January 1982 to September 1986 time period. The altitude resolution (~4 km), latitudinal coverage (with 5° resolution), 5-year term, and mesopause coverage of these temperature observations allow new insight into the average mesospheric temperature structure and unique observations of mesospheric temperature trends corresponding to the 1982–1986 solar maximum to solar minimum cycle. The SME temperature observations define large (10–30 K) semiannual oscillations of equatorial mesopause temperatures; mid-latitude temperature inversions in the winter mesosphere accompanied by steep mesospheric temperature gradients at low latitudes, and -1.5 to +1 K/year trends, which suggest an intensification of these latitude-dependent temperature gradients over the 1982-1986 period. The SME temperature trends are ~4 times smaller than those reported by Mohanakumar (*Planet.*

Space Sci. **33**, 795-805,1985), Groves (*Planet. Space Sci.* **34**, 1037-1041,1986), and Chanin *et al.* (*J. Geophys. Res.* **90**, 10,933-10,941, 1987) for solar cycle variations of temperatures in the altitude region 65–70 km.

Clancy, R. T., and D. W. Rusch, "Solar Mesosphere Explorer: Temperature Climatology of the Mesosphere as Compared to the CIRA Model," in *COSPAR International Reference Atmosphere* (M. Roemer, ed.), Holland: Pergamon Press, in press, 1989.

Global observations of ultraviolet limb radiances from the Solar Mesosphere Explorer (SME) have been analyzed to obtain atmospheric temperature profiles over the 58-90 km altitude range. The temperature retrievals are based upon analysis of vertical profiles of Rayleigh scattering, which are derived from the SME ultraviolet limb radiances. A complete description of the SME analytical procedures, including error analysis and comparisons to a wider range of mesospheric temperature data sets, may be found in Clancy and Rusch (1989). This current document provides a detailed comparison of SME temperatures to the new CIRA model temperatures over the 60-90 km altitude region.

Clancy, R. T., and D. W. Rusch, "The Relationship between 1982—1986 Trends in Upper Stratospheric Ozone and Temperatures," in *Atmospheric Ozone* (D. Bojkov, ed.), Boston, Mass.: D. Reidel, in press, 1989.

Trends for upper stratospheric temperatures and ozone are calculated from the NMC and SBUV data sets, respectively, over the 1982-1986 period. Latitudinal and longitudinal variations in ozone and temperature trends are found to be anticorrelated. The observed temperature-ozone trends relationship appears consistent with ozone sensitivity to temperature dependent kinetic rate coefficients for ozone formation and destruction. The absolute SBUV ozone trends include a constant 4%/yr decrease at 1.0 mbar, most of which may be due to a calibration drift in the SBUV experiment. The absolute NMC temperature trends indicate ~0.5K/yr global decreases in upper stratospheric temperatures over the 1982-1986 period. Such temperature trends would force ~0.5%/yr global increases in upper stratospheric ozone over the same period, based upon the derived relationship between ozone and temperature trend anticorrelations.

Clancy, R. T. , D. W. Rusch, R. J. Thomas, M. Allen and R. S. Eckman, Model Ozone Photochemistry on the Basis of Solar Mesosphere Explorer Mesospheric Observations, *J. Geophys. Res.* **92**, 3067-3080, 1987.

Morning and afternoon mesospheric ozone profiles (50-90 km) measured by the Solar Mesosphere Explorer (SME) satellite are analyzed with one-dimensional photochemical models. The observed ozone abundances are 40% and 100% greater than the model ozone abundances at 50 and 80 km, respectively, assuming standard chemistry and rate coefficients. A Monte Carlo analysis for model ozone abundances that includes uncertainties in kinetic rate coefficients indicates that the model-data disagreement exceeds 2 standard deviations. The majority of the dis-

agreement must be due to errors in the rate of odd-hydrogen catalytic distribution of ozone, unless the rate coefficient for $O+O_2+M \rightarrow O_3+M$ is significantly (>50%) in error. Diurnal model calculations are compared with SME observations of ozone profiles at ~0400 and 1400 LT for high northern summer latitudes. Analysis of the ratios of these early morning and midafternoon ozone profiles provides the additional constraint that larger odd-oxygen production rates are required if lower odd-hydrogen activity is invoked to increase model O_3 abundances. The increase in odd-oxygen production must be solar zenith angle independent in the mesosphere, ruling out significant changes in the Schumann-Runge band O_2 opacities from Allen and Frederick (*J. Atmos. Sci.* **39**, 2066-2075, 1982). However, an increase in three-body formation of O_3 is also consistent with the observed morning/afternoon ratios. Any of the above changes are consistent with an improvement in model ozone comparison with stratospheric observations. Finally, we find evidence for diurnal variations in mesospheric ozone above 80 km altitude, which are likely related to diurnal variations in vertical transport.

Dickinson, P. H. G., G. Witt, A. Zuber, D. Murtagh, K. U. Grossman, H. B. Brockelmann, P. Schwabbauer, K. D. Baker, J. C. Ulwick, and R. J. Thomas, Measurements of Odd Oxygen in the Polar Vortex on 10 February 1984 during MAP/WINE, *J. Atmos. Terr. Phys.***49**, 843-854, 1987.

Donnelly, R. F., D. F. Heath, J. L. Lean, and G. J. Rottman, Differences in the Temporal Variations of Solar UV Flux, 10.7-cm Solar Radio Flux, Sunspot Number, and Ca-K Plage Data Caused by Solar Rotation and Active Region Evolution, *J. Geophys. Res.* **88**, 9883-9888, 1983.

Two types of temporal variations in the solar UV spectral irradiance, caused by solar rotation and active region evolution, are presented and discussed. These particular UV variations differ markedly from the concurrent variations in the 10.7-cm radio flux and sunspot number. The temporal variations of the modeled UV flux based on Ca-K plage data are similar to the observed UV flux. The first type of dissimilar temporal behavior occurs when concentrations of solar active regions evolve at solar longitudes nearly 180° apart. Both the UV observations and modeled UV fluxes based on Ca-K plage data then show strong 13-day periodicity, while the 10.7-cm solar radio flux and sunspot number exhibit quite dissimilar temporal variations. This type of dissimilarity is related to the modeled UV flux, having a dependence on the solar central meridian distance that is narrower than that for the 10.7-cm radio flux or for sunspot numbers. A second case of marked dissimilarity occurs when major new solar active regions arise and dominate the full-disk fluxes for several rotations. The strongest peaks in 10.7 cm and sunspot numbers tend to occur on their first rotation, for example,during major dips in the total solar irradiance, while the Ca -K plages and UV enhancements peak on the next rotation and then decay more slowly on subsequent rotations. This type of dissimilarity is related to major active regions having a more rapid growth, peak, and decay of sunspots, their strong magnetic fields and related coronal radio emission at centimeter wavelengths than for the Ca-K plages and their related UV enhancements.

Eckman, R. S., The Response of Ozone to Short-Term Variations in the Solar Ultraviolet Irradiance. 1. Theoretical Model, *J. Geophys. Res.* **91**, 6695-6704, 1986.

The response of atmospheric ozone and temperature to variations in the solar ultraviolet irradiance over time scales corresponding to the solar rotation period is examined using a one-dimensional, time-dependent radiative-photochemical model of the upper stratosphere and lower mesosphere. The model uses temporally varying measurements of the solar irradiance in the 120- to 300-nm range made by the Solar Mesosphere Explorer satellite. Calculations of the amplitude and phase of the ozone response due to solar UV oscillations made by the model show that the effects of the coupling of radiation and photochemistry in the region near the stratopause may not be neglected. At 0.85 mbar the computed 27-day 0.6 K temperature variation decreases the amplitude of the corresponding ozone response over the solar rotation period by 25%. The occurrence of small phase leads (up to 1.5 days) in the response of ozone with respect to the solar UV variations may also be explained in light of the radiative-photochemical coupling.

Eckman, R. S., The Response of Ozone to Short-term Variations in the Solar Ultraviolet Irradiance. 2. Observations and Interpretations, *J. Geophys. Res.* **91**, 6705-6721, 1986..

An analysis of the response of middle atmospheric ozone to short-term variations in the solar ultraviolet irradiance is presented. Measurements of ozone from the Solar Mesosphere Explorer (SME) ultraviolet spectrometer (UVS) are compared to calculations of a one-dimensional, radiative-photochemical model of the upper stratosphere and lower mesosphere. SME UVS measurements in the 0.1- to 1-mbar range suggest that tropical ozone responds to solar rotational variations when analyzed using both frequency and time domain techniques. Three periods during 1982 and 1983 were selected for the analysis. The solar irradiance during each period exhibited different spectral characteristics. A significant 27-day variation in the solar irradiance at 205 nm was measured during mid-1982, with an amplitude of 2.5%. Observations of ozone near the stratopause during this period showed a corresponding variation, with a 1.3% amplitude. Analysis of ozone variations at extratropical latitudes revealed different periodicities that were not correlated with solar variations. The amplitude of the measured response is, in all cases, systematically larger than theoretical calculations but is nonetheless in agreement when uncertainties in the analysis are considered. However, the observed phase lag of ozone with respect to the solar UV variations is generally not in accord with model predictions.

Fesen, C. G., J-C. Gerard, and D. W. Rusch, Rapid Deactivation of $N(^2D)$ by O; Impact on Thermospheric and Mesospheric Odd Nitrogen., *J. Geophys. Res.* **94**, 5419-5426, 1989.

One- and two-dimensional models of thermospheric odd nitrogen are used to explore the consequences of the recently-measured fast quenching of $N(^2D)$ by O. A large rate coefficient for this reaction profoundly affects the odd nitrogen chemistry by removing $N(^2D)$ as a source of NO and increasing the concentration of

$N(^4S)$, which destroys NO. The model calculations show that, as the quenching rate increases, the NO and $N(^2D)$ densities decrease, while $N(^4S)$ densities increase. Comparisons with Atmosphere Explorer and Solar Mesosphere Explorer satellite observations are made. Use of the fast quenching rate in the models causes the NO peak altitude, typically observed near 110 km, to rise to 140 km. The $N(^2D)$ densities become 20 times smaller than those observed, while the modelled NO ($N(^4S)$) densities are roughly two to three times too small (large). Additional measurements of the $N(^2D)$ + O quenching rate are clearly warranted. If the quenching rate is indeed very rapid, the chemistry of thermospheric odd nitrogen must be completely re-examined. (odd nitrogen, quenching, modelling.)

Gérard, J-C, C. G. Fesen, and D. W. Rusch, Solar cycle variation of chemospheric nitric oxide at solstice, *J. Geophys. Res.*, in press, 1989.

Grossman, K.U., H.G. Brockelmann, D. Offermann, P. Schwabbauer, R. Gyger, K. Kunzi, G.K. Hartmann, C.A. Barth, R. Thomas, A.F. Chijov, S.P. Perov, V.A. Yushkov, F. Glede and K.H. Grasnik, Middle Atmosphere Abundances of Water Vapor and Ozone During MAP/WINE, *J. Atmos. Terr. Phys.* **49**, 827-842, 1987.

Howell, C. D., D. V. Michelangeli, M. Allen, Y. L. Yung, R. J. Thomas, SME Observations of $O_2(^1\Delta g)$ Nightglow: An assessment of the Chemical Production Mechanisms, *Planet. Space Sci.*, in press, 1989.

Jensen, E. J., and G. E. Thomas, A Growth-Sedimentation Model of Polar Mesospheric Clouds: Comparison with SME Measurements, *J. Geophys. Res.* **93**, 2461-2473, 1988.

A numerical model for the brightness of polar mesospheric clouds (PMC) is described, and is compared with measurements from the Solar Mesosphere Explorer (SME) satellite. These clouds occur during the summer months at polar latitudes where temperatures are known to fall below 140 K. We calculate the optical properties of a cloud by simulating the growth and sedimentation of ice particles at the cold supersaturated mesopause. Time-dependent trajectories of ice particles are calculated from their origin at the temperature minimum region to their demise at the cloud base through evaporation. We consider the effects of the removal of atmospheric water vapor by the growing particles and its restoration by ice evaporation at the cloud base. The "freeze-drying" effect is crucial in limiting the maximum size of the particles and therefore the maximum brightness of the cloud. Assuming spherical particles, Mie-scattering calculations of the directional albedo of a cloud are performed using a range of possible values for the atmospheric variables (water vapor mixing ratio, temperature, upward wind speed, atmospheric pressure, and eddy diffusion coefficient). We find that for a nominal atmospheric case the model predicts a moderately weak cloud at 265 nm, the wavelength of the SME measurements. An extreme model (cold and moist with high vertical wind and eddy transport) is needed to account for the brightest cloud observed. We estimate an upper limit for the water vapor to be of the order of 5 parts per million by volume. Higher values would imply the existence of clouds which exceed in brightness every cloud observed by the satellite over the time

period 1981-1986. SME observations of greater cloud height in the northern hemisphere, despite their greater brightness, possibly imply an excess (by a factor of 2) of northern hemisphere water vapor. This holds if the other atmospheric variables (and cloud particle numbers) are the same in both north and south. Dependence of model cloud brightness on atmospheric pressure ($\sim P^{4.4}$), water vapor mixing ration ($\sim w^{2.8}$), thickness of the cloud saturation region ($\sim d^4$) and advective wind speed ($\sim v$) are determined. These scalings are shown to result from a calculated proportionality of the cloud brightness of R^6 (R is the maximum particle radius), and from simple considerations of ice layer growth, particle sedimentation, and the mass budget of water. Mie scattering calculations for a wavelength of 550 nm show that SME and OGO-6 data on PMC brightnesses are consistent.

Jensen, E. J., G. E. Thomas, and B. B. Balsley, On the Statistical Correlation between Polar Mesospheric Cloud Occurrence and Enhanced Mesospheric Radar Echoes, *Geophys. Res. Letters* **15**, 315-318, 1988.

Using data from the Poker Flat MST radar and the Solar Mesosphere Explorer Satellite (SME), we demonstrate the existence of a statistically significant correlation between the occurrence of Polar Mesospheric Clouds (PMC) and enhanced VHF radar echoes near the high-latitude summer mesopause. We propose three physical conditions which could explain the coexistence of strong summertime echoes and PMC. First, both the enhanced echoes and the PMC are most likely to occur in the presence of very low mesopause temperatures and associated steep temperature gradients. Second, the presence of PMC ice particles could induce a strong gradient in the electron density profile, which would produce enhancements in the radar echo strength. Third, it is likely that heavy water cluster ions, indicative of PMC particle nucleation, can alter the ambipolar diffusion coefficient, thus allowing the electron density fluctuations to extend down to much smaller vertical scales. Under these conditions, the turbulent power at the 3 meter scale required for the occurrence of the MST radar echoes could be greatly enhanced. Finally, we discuss the possibility of using MST radars as instruments for PMC detection.

Jensen, E. J., G. E. Thomas, and O. B. Toon, On the Diurnal Variation of Noctilucent Clouds, *J. Geophys. Res*, in press., 1989.

LeTexier, H., S. Solomon, and R. R. Garcia, Seasonal Variability of the OH Meinel Bands, *Planet. Space Sci.* **35**, 911-939, 1987.

LeTexier, H., S. Solomon, R. J. Thomas, and R. R. Garcia, OH*(7-5) Meinel Band Dayglow and Nightglow Measured by the SME Limb Scanning Near Infrared Spectrometer: Comparison of the Observed Seasonal Variability with Two-dimensional Model Simulation, *Annal. Geophys.*, **7**, 365-374, 1989.

London, J., and G. J. Rottman, The Contribution of Solar UV Irradiance Variations to Variations of the Solar Constant, in *IRS '88: Current Problems in Atmospheric Radiation*, (J. Lenoble and J. S. Geleyn, eds.), A. Deepak Pub. Co., 1989.

The total solar irradiance in the wavelength interval 250-330 nm is about 13.25 Wm^{-2}, which represents almost 1% of the solar constant as measured by the Nimbus 7-ERB instrument. In that spectral interval the normalized solar irradiance observed by the Solar Mesosphere Explorer (SME) decreased during the period Jan 1982 to May 1986 (solar minimum) by about 1.3%. The decrease of the SME observed near UV irradiance contributed over 35% to the observed solar constant change for that period, a value that is certainly significant in considering possible atmospheric responses to solar variability. The implications of the observed solar irradiance variation will be discussed.

London, J., G. G. Bjarnason, and G. J. Rottman, Eighteen Months of Ultraviolet Irradiance Observations from the Solar Mesosphere Explorer, *Geophys. Res. Letters* **11**, 54-56, 1984.

Daily solar irradiance measurements in the spectral interval 120-305 nm have been made since 6 October 1981 with an instrument on the Solar Mesosphere Explorer. The instrument operates with a spectral resolution of about 0.75 nm. Analysis of the observed data for the period 6 December 1981 to 3 June 1983 (20 solar rotations) shows that during this period there was an apparent decrease in irradiance at all wavelengths observed (-19.7% $\pm$ 9.7% at Lyman alpha) but the decrease was not significantly different from zero at wavelengths longer than 210 nm. The cross correlations between daily values of the solar irradiance and 10.7 cm flux varied from 0.7 (Lyman alpha) to 0.5 (210-215 nm) and ~0 (290-295 nm). Calculations of the % range (*i.e.*, highest to lowest value) of the irradiance within each solar rotation showed that for Lyman alpha the range varied between 6% and 30% over the 20 solar rotations studied. At longer wavelengths the % range was smaller — about 7% at 180 nm and about 2% beyond 240 nm. The percent range values indicate representative variations useful as input data for model calculations of stratosphere/mesosphere responses to short period solar variability.

Mount, G. H., and G. J. Rottman, The Solar Absolute Spectral Irradiance at 1216 Å and 1800-3173 Å: January 12, 1983, *J. Geophys. Res.* **88**, 6807, 1983.

Mount, G. H., and G. J. Rottman, The Solar Absolute Spectral Irradiance 1150-3173 Å: May 17, 1982, J. Geophys. Res. **88**, 5403-5410, 1983.

The full-disk solar spectral irradiance in the spectral range 1150-3173 Å was obtained from a rocket observation above White Sands Missile Range, New Mexico, on May 17, 1982, halfway in time between solar maximum and solar minimum. Comparison with measurements made during solar maximum in 1980 indicate a large decrease in the absolute solar irradiance at wavelengths below 1900 Å to approximately solar minimum values. No change above 1900 Å from solar maximum to this flight was observed to within the errors of the measurements. We find irradiance values lower than the Broadfoot results in the 2100-

2500 Å spectral range, but we find excellent agreement with Broadfoot between 2500 and 3173 Å. The absolute calibration of the instruments for this flight was accomplished at the National Bureau of Standards Synchrotron Radiation Facility which significantly improves calibration of solar measurements made in this spectral range.

Mount, G. H., and G. J. Rottman, The Solar Absolute Spectral Irradiance 1180-3000 Å: July 25, 1983, *J. Geophys. Res.* **90,** 13,031-13,036, 1985..

Mount, G. H., D. W. Rusch, J. M. Zawodny, J. F. Noxon, C. A. Barth, G. J. Rottman, R. J. Thomas, G. E. Thomas, R. W. Sanders, and G. M. Lawrence, Measurements of NO_2 in the Earth's Stratosphere Using a Limb Scanning Visible Light Spectrometer, *Geophys. Res. Letters* **10**, 265-268, 1983.

NO_2 densities determined from the limb scanning visible light spectrometer on board the Solar Mesosphere Explorer spacecraft are reported for winter 1981/82 in the altitude region 28-40 km. The observational technique utilizes the photoabsorption by NO_2 of Rayleigh scattered sunlight in the 440 nm spectral region. The NO_2 density varies from pole to pole and shows large variations at high northern latitudes during the winter months which are related to both the temperature and flow of air near 30 km.

Mount, G. H., D. W. Rusch, J. F. Noxon, J. M. Zawodny, and C. A. Barth, Measurements of Stratospheric NO_2 from the Solar Mesosphere Explorer Satellite. I. An Overview of the Results, *J. Geophys. Res.* **89**, 1327-1340, 1984.

The visible light spectrometer on board the Solar Mesosphere Explorer spacecraft measures stratospheric NO2 in the 20-40 km altitude region and provides accurate daytime NO_2 density profiles with nearly complete latitudinal coverage over an extended period of time. The instrument and data analysis are discussed in detail, and NO_2 results for winter/spring 1982 are presented and compared to current theoretical models. Agreement with other measurements is good, and comparison with NO_x models indicates that although the overall agreement is acceptable, improvements in the models are required before good agreement is reached at all latitudes. The data indicate that NO_2 has a strong memory of the physical conditions present in the stratosphere over a time period of several days.

Naudet, J.-P., and G. E. Thomas, Aerosol Optical Depth and Planetary Albedo in the Visible from the Solar Mesosphere Explorer, *J. Geophys. Res.* **92**. 8373-8381, 1987.

The Solar Mesosphere Explorer (SME) satellite has observed the visible sunlight scattered at the earth's limb since early 1982. By using a radiative transfer model including multiple scattering and albedo effects, observations at 20°N latitude have been interpreted in terms of aerosol optical depth. The ratio of aerosol extinction to Rayleigh extinction at 421.8 nm shows a large increase after the eruption of El Chichon. A maximum ratio of 5 at 36 km and larger than 11 at 30 km occurs in the summer of 1982 followed by a decrease through 1983 and 1984. Aspects of

the aerosol time evolution appear to be consistent with other observations and model predictions. Quantitative differences exist between inferred SME and lidar extinction coefficients, possibly due to the different wavelengths of the measurements and to the different scattering phase functions used in the two analyses. It is also shows that visible limb radiances provide information on the planetary albedo, which shows an increase from the equator to the poles with a maximum in the winter hemisphere and a minimum in the summer hemisphere.

Naudet, J. P., D. W. Rusch, R. J. Thomas, R. T. Clancy, C. A. Barth, J. Wedding, J. M. Zawodny, P. Fabian, and M. Helten, Stratospheric NO_2 from the Solar Mesosphere Explorer during MAP/GLOBUS 1983, *Planet. Space Sci.* **35**, 631-635, 1987.

Nitrogen dioxide in the altitude range 24-40 km has been observed by the Solar Mesosphere Explorer Satellite during the MAP/GLOBUS campaign in September 1983. Results are presented and compared to other observations. NO_2 from the Solar Mesosphere Explorer appears to be in good agreement with daytime *in situ* balloon measurements in the mid-stratosphere.

Naudet, J.-P., R. J. Thomas, H. K. Roscoe, and J. M. Russell III, About a Possible Reference Model for Stratospheric NO_2 , *Adv. Space Sci.* **7**, 919-923, 1987.

Naudet, J.-P., R. J. Thomas, D. W. Rusch, and R. T. Clancy, Distribution of Stratospheric NO_2 at 10 mbar: SME Global Morphology and Comparison to LIMS Observations, *J. Geophys. Res.* **92**, 9863-9867, 1987.

The Solar Mesosphere Explorer Satellite (SME) has measured stratospheric NO_2 since January 1982 using a visible light spectrometer. The presence of large amounts of aerosol injected into the stratosphere by El Chichon on April 4, 1982, temporarily prevented NO_2 data analysis. At the end of 1983 the volcanic aerosol content of the atmosphere, although present, had decreased sufficiently to again allow reliable NO_2 measurements. Monthly average results at 10 mbar are presented for a full year of SME observations, from October 1983 to September 1984. The observed morphology of NO_2 is discussed. Interesting features include large amounts of NO_2 in the summer hemisphere, with more in the south than in the north. A low usually exists in the tropics. A comparison to Nimbus 7 Limb Infrared Spectrometer of the Stratosphere (LIMS) observations shows similar features.

Offermann, D., H. Rippel, P. Aimedieu, W. A. Matthews, G. Mégie, E. Arijs, J. Ingels, D. Nevejans, W. Attmannspacher, J. M. Cisneros, A. W. Dawkins, D. Demuer, P. Fabian, F. Karcher, G. Froment, U. Langematz, R. Reiter, K. W. Rothe, U. Schmidt, and R. J. Thomas, Disturbance of Stratospheric Trace Gas Mixing Ratios During the MAP/GLOBUS 1983 Campaign, *Planet. Space Sci.* **35**, 1987.

Olivero, J. J., and G. E. Thomas, Climatology of Polar Mesospheric Clouds, *J. Atmos. Sci.* **43**, 1263-1274, 1986.

The ultraviolet spectrometer on board the Solar Mesosphere Explorer Satellite has measured solar radiation scattered from a diffuse and patchy layer of material near the summer polar mesopause. We call this scattering layer polar mesospheric clouds (PMC) and present here a first climatology of this phenomenon covering three years (six summer seasons). We address these general questions: How bright are PMC and how frequently to they occur in space and time? Are there year-to-year or hemisphere-to-hemisphere differences in PMC seasons? We find that the brightest PMC are found right where they occur most frequently — above 70°-75° in latitude and in a season of 60 to 80 days duration centered about the peak which occurs about 20 days after the summer solstice. This holds true for both hemispheres. We find variability on time scales from day-to-day to year-to-year; averaging over large time and space scales does, however, reveal a basic underlying symmetry. A major finding is that for three years (six seasons) considered, the Northern Hemisphere clouds are inherently brighter than the Southern Hemisphere ones.

Olivero, J. J., and G. E. Thomas, Clouds of the Polar Middle Atmosphere, *Physica. Scripta.* **T18**, 276-280, 1987.

Clouds have been observed at great heights in the polar regions for a century or more. Recently this series of ground-based observations has been greatly extended by limb viewing satellite systems. A major result has been the discoveries of more pronounced, more pervasive cloud phenomena extending all the way across the poles themselves. This review focuses on the results of more than three years of observations and analysis of polar mesospheric (or noctilucent) clouds by the Solar Mesosphere Explorer satellite and team. We present an undated climatology of cloud radiances and occurrence frequencies using a conservative background removal process. We also review a quite recent study of cloud heights and show how relatively little variation occurs on all time scales investigated, except perhaps for differences between the hemispheres themselves.

Petzoldt, K., R. Lenschow, A. Hauchecorne, G. A. Kokin, W. Meyer, A. O'Neill, F. Schmidlin, and R. J. Thomas, Large Scale Structure of the Stratosphere and the Lower Mesosphere (20 to 60 km) Over the Northern Hemisphere During the MAP/WINE Campaign, *J. Atmos. Terr. Phys.* **49**, 621-637, 1987.

Rosenlof, K. H., and R. J. Thomas, Five-Day Mesospheric Waves Observed in SME Ozone, *J. Geophys. Res.*, **94**, in press, 1989.

Rottman, G. J., 27-day Variations Observed in Solar Ultraviolet (120-300 nm) Irradiance, *Planet. Space Sci.* **31**, 1001-1007, 1983.

A Fourier transform analysis of 256 days of SME solar irradiance data (115-303 nm) provides an estimate of the root mean square 27-day solar variation. The magnitude of this 27-day variation exceeds $\pm 10\%$ at 120 nm and decreases with increasing wavelength to less than 1% above 260 nm. Qualitative aspects of the analysis include a striking decrease in the per cent variation across the aluminium absorption edge near 208 nm.

Rottman, G. J., Solar Ultraviolet Irradiance 1982 and 1983 in *Atmospheric Ozone* (ed. C. S. Zerefos), D. Reidel Pub. Co., 1985.

The Solar Mesosphere Explorer (SME) has been in operation since October 6th 1981. In addition to making measurements of ozone and other trace constituents of the earth's atmosphere the observatory includes a small spectrometer to make daily measurements of the solar ultraviolet irradiance in the spectral range 115 to 305 nm. The solar spectra are obtained with 0.75 nm spectral resolution. Examination of the data show a strong signature of the 27-day solar rotation displaying a time varying modulation of incoming solar radiation exceeding ±15% near Lyman alpha, decreasing to a few percent at 200 nm, and less than 1 percent near 300 nm. Long term rends in the data, due both to changes in the instrument and to true long term solar variations, are removed in order to obtain quantitative measure of the intermediate term variations with time periods of a few days to weeks.

Rottman, G. J., Results from Space Measurements of Solar UV and EUV Flux, in *Solar Radiative Output Variation* (P. Foukal, ed), Cambridge Press, 1988

The last major review of observations of solar irradiance in the entire spectral range of 10 to 300 nm was a compilation of papers in *The Solar Output an Its Variation* (White, Colorado Assoc. Press, 1977). During the past eleven years a large amount of effort has been devoted to improved observations, especially in the wavelength interval above Lyman alpha. Recent satellite, sounding rocket, and Shuttle observations show vastly improved absolute and relative accuracy and may significantly change the previous estimates of solar cycle variability. Unfortunately in the EUV, 10 to 120 nm, the same effort has not been forthcoming. Only a single satellite experiment, AE-E, operated for a portion of solar cycle 21 and only two sounding rocket experiments were conducted.

Rottman, G. J., Observations of Solar UV and EUV Variability, *Adv. Space Res.* **8**, (7)53-(7)66, 1988.

Solar radiation at wavelengths below 300 nm is almost completely absorbed by the earth's middle and upper atmosphere. Small variations in the solar UV and EUV flux may produce concomitant atmospheric changes. during the past 11 years, major improvements in satellite observations, especially at wavelengths longward of Lyman alpha (121.6 nm), have significantly improved our understanding of short and intermediate term solar variability. Recent Solar Mesosphere Explorer (SME) and NIMBUS-7 SBUV data sets have also improved our understanding of solar cycle variability, significantly reducing previous estimates. Details of this longer period solar variability will require improved precision in the future UV observations. At wavelengths below 120 nm only a single satellite experiment, AE-E, operated during a portion of solar cycle 21. At these short wavelengths additional measurements over large portions of the solar cycle will be required to provide a definitive estimate of EUV solar variability.

Rottman, G. J., and J. London, Solar UV Irradiance Observations and Evidence for Solar Cycle Variations, *IRS '84: Current Problems in Atmospheric Radiation*, p. 320, (ed. G. Fiocco), A. Deepak Pub. Co., 1984.

The Solar Mesosphere Explorer was launched into a polar orbit on October 6th, 1981. Four limb scanning instruments make measurements of Mesospheric Ozone and other minor atmospheric constituents, for example H_2O and NO_2. The prime objective of the SME is to study the distribution of ozone and, in particular, to study the changes in ozone due to natural effect. Since a major influence on ozone is solar ultraviolet radiation, a spectrometer was included in the observatory to make daily measurements of the incoming solar radiation. This small spectrometer covers the spectral interval 115 to 305 nm with 0.75 nm spectral resolution. The daily solar spectral have high relative accuracy and provide reliable information on intermediate term solar variations. These variations have time scales of several dys and are related to the formation and disruption of active areas on the solar disk. The relatively high contrast of these active centers produces an ultraviolet signal that is strongly modulated by the 27-day rotation period of the Sun. Short term variations of the solar output are related to ;disruptive or flare type events and exhibit time scales of minutes to hours. Since the SME measurements are obtained throughout a calendar day and are combined to give a mean daily value, these short term phenomena may produce a few anomalous daily values at some wavelengths which have been ignored in the present data analyses.

Rottman, G. J., C. A. Barth, R. J. Thomas, G. H. Mount, G. M. Lawrence, D. W. Rusch, R. W. Sanders, G. E. Thomas, and J. London, Solar Spectral Irradiance, 120 to 190 nm, October 13, 1981 — January 3, 1982, *Geophys. Res. Letters* **9**, 587-590, 1982.

Beginning on October 13, 1981 a two channel spectrometer aboard the Solar Mesosphere Explorer has been obtaining daily measurements of full disc solar irradiance. These observations cover the spectral interval 120 to 305 nm with ~0.75 nm spectral resolution. The relative accuracy of the measurements from day to day over the first three solar rotations is approximately 1%. In this report we present analyses of Lyman alpha, the integrated Schumann-Runge continuum (130-175 nm), and the integrated Schumann-Runge bands (175-190 nm). All three show a clear variability related primarily to the 27-day solar rotation period. Correlations of these three values of solar irradiance to ground-based indices of solar activity, 10.7 cm flux and sunspot number, are presented.

Rusch, D. W., and R. T. Clancy, Minor Constituent in the Upper Stratosphere and Mesosphere, *Rev. Geophys.* **25**, 479-486, 1987.

This brief review of advances in our understanding of the physical processes important in the upper stratosphere and mesosphere is intended to highlight specific issues and to focus on areas in which further research is needed.

Rusch, D. W., and R. T. Clancy, A Comparison of Ozone Trends from SME and SBUV Satellite Observations and Model Calculations, *Geophys. Res. Letters* **15**, 776-779, 1988.

Trends in the ozone mixing ratio near the stratopause are presented for global observations by the Ultraviolet Spectrometer (UVS) instrument on the Solar Mesosphere Explorer (SME) and the Solar Backscatter Ultraviolet Instrument (SBUV) on NIMBUS-7. The June, September, and January data are separately analyzed for trends as a function of latitude over the 1982-1986 period. The SME UVS data indicate trends in the range -0.5 ± 1.3%/yr in ozone for the summer hemisphere at 1.0 mbar for January, June, and for all latitudes in September. The SBUV data show decreases of 2-5%/yr for all three months. Model calculations of ozone trends at 1.0 mb, including 5%/yr Cl_X increases, measured solar flux decreases over the 1982-1986 time period, and measured temperatures, reproduce the SME trends. The solar flux and Cl_X trends contribute equally to the measured changes at 1.0 mb. The SBUV and UVS data exhibit remarkably similar seasonal and latitudinal variations in ozone trends over the five years. The detailed variations of ozone trends from both data sets are reproduced by photochemical model calculations which include latitude-dependent NMC temperature trends over the 1982-1986 period.

Rusch, D. W., and R. T. Clancy, Trends in Atmospheric Ozone: Conflicts between Models and SBUV Data, *J. Geophys. Res.* **93**, 8431-8437, 1988.

Model calculations of ozone trends in the 1982-1986 time period show that interannual stratospheric temperature variations over that period dominate over changes in minor constituents, including Cl_x, in producing trends in ozone. Estimates for upper limits to changes in solar flux over the declining part of the solar cycle and estimates for maximum increases in Cl_x, lead to similar model decreases in upper stratospheric ozone, although the calculated trends from each are less than 1%/yr. Model calculations suggest that long-term increases in Cl_x, may produce decreases in the relative amplitude of the annual variation of ozone near 1.0 mbar that are nearly twice the secular decreases in ozone. However, trends in temperature over the period 1982-1986 lead to predicted decreases in the seasonal amplitude of ozone up to 10%/yr, based upon National Meteorological Center (NMC) observations of upper stratospheric temperatures. The secular and seasonal ozone trends derived from SBUV data for the 1982-1986 time period exhibit poor agreement with model predictions. SBUV data indicate secular tends in ozone which are negative and lager, in an absolute sense, than the largest model trends by a factor of 2 or more, indicating problems with the SBUV data or the model ozone chemistry. SBUV data also exhibit significantly smaller changes in the amplitude of the annual variation of ozone than the models which include NMC temperatures. At least part of this disagreement may be related to temperature-correlated variations in photochemistry which are not included in the model, such as changes in water vapor or other minor constituent densities. Future efforts to determine ozone trends from satellite measurements should include monitoring of ozone, temperature, and possibly water vapor in the atmospheric pressure region from 10 to 0.1 mb.

Rusch, D. W., and R. S. Eckman, Implications of the Comparison of Ozone Abundances Measured by the Solar Mesosphere Explorer to Model Calculations, *J. Geophys. Res.* **90**, 12991-12998, 1985.

Two years of ozone measurements from the Solar Mesosphere Explorer satellite are compared to the results of a model of lower mesospheric photochemistry. The measured ozone mixing ratios are larger than those predicted by the model by as much as a factor of two at pressures near 0.1 mbar and 1.3 at 1.0 mbar using currently accepted reaction rate coefficients. The model is brought into good agreement with the measurements over a wide range of latitudes and solar zenith angles only if the efficiency of the odd hydrogen catalytic cycle which destroys odd oxygen is decreased by 30-50%.

Rusch, D. W., G. H. Mount, C. A. Barth, G. J. Rottman, R. J. Thomas, G. E. Thomas, R. W. Sanders, G. M. Lawrence, and R. S. Eckman, Ozone Densities in the Lower Mesosphere Measured by a Limb-Scanning Ultraviolet Spectrometer, *Geophys. Res. Letters* **10**, 241-244, 1983.

The ozone content of the earth's atmosphere between 1 mb and 0.08 mb has been measured as a function of latitude and season by an ultraviolet spectrometer on the Solar Mesosphere Explorer spacecraft. The ozone mixing ratio is found to be highly variable in time and space during the winter of 1982 with maxima occurring in the winter hemisphere during January and February at all pressure levels. The latitude gradients near spring equinox are relatively small. A relative maximum occurs at latitudes between 15 and 30°S in January and February.

Rusch, D. W., G. H. Mount, J. M. Zawodny, C. A. Barth, G. J. Rottman, R. J. Thomas, G. E. Thomas, R. W. Sanders, and G. M. Lawrence, Temperature Measurements in the Earth's Stratosphere Using a Limb Scanning Visible Light Spectrometer, *Geophys. Res. Letters* **10**, 261-264, 1983.

The temperature of the earth's atmosphere between 40 and 50 km is inferred from measurements of Rayleigh scattered sunlight by a visible-light spectrometer on the Solar Mesosphere Explorer spacecraft. The RMS deviation of the satellite measurements from conventional rocket measurements is 5°K above 45 km and 2-3°K below 45 km. The satellite data are compared to model temperatures for March 1982.

Rusch, D. W., G. H. Mount, C. A. Barth, R. J, Thomas, and M. T. Callan, Solar Mesosphere Explorer Ultraviolet Spectrometer: Measurements of Ozone in the 1.0 to 0.1 mb Region, *J. Geophys. Res.* **89**, 11677-11687, 1984.

The ozone density of the earth's mesosphere in the 1.0-0.1 mbar (48 to 70 km) region has been measured at sunlit latitudes for the period from December 1981 until the present by an ultraviolet spectrometer on the Solar Mesosphere Explorer satellite. Results for 1982 are reported. The ozone mixing ratios are found to be highly variable in time and place, with maxima occurring in the winter hemispheres. The results show complex time variations at all pressure levels, with annual and semiannual variations apparent at most pressures and latitudes. A relative maximum occurs in July at the equator.

Rusch, D. W., M. P. McCormick, R. T. Clancy, and J. M.Zawodny, A Comparison of SME and SAGE II Ozone Densities near the Stratospause, *J. Geophys. Res.*, in press, 1989.

Ozone measurements made by the Ultraviolet Spectrometer on the Solar Mesosphere Explorer and those from the Stratosphere Aerosol and Gas Experiment II are compared at 1.0 mbar for the time period from October, 1984, to December, 1986. A model of the diurnal variation of ozone is used to correct for the difference in local times of the two measurements. The two instruments agree to within 5% at all latitudes considered in the comparison. Further, no significant divergence is found between the data sets for the time period of overlap. The results support the accuracy and precision of each instrument and the accuracy of ozone trends derived over the 1982–1986 period from Solar Mesosphere Explorer data.

Russell III, J. M., S. Solomon, M. P. McCormick, A. J. Miller, J. J. Barnett, R. L. Jones, and D. W. Rusch, "Middle Atmosphere Revealed by Satellite Observations," in *Middle Atmosphere Program Handbook,* **22,** 1986.

Siskind, D. E., C. A. Barth, and R. G. Roble, The Response of Thermospheric Nitric Oxide on an Auroral Storm, 1, Low and Middle Latitudes, *J. Geophys. Res.* **94,** 16,885-16,898, 1989.

The Solar Mesosphere Explorer (SME) satellite observed thermospheric nitric oxide (NO) during the period September 17-20, 1984, using the resonance fluorescence technique. Altitude profiles from 100 to about 130 km were obtained for 1500 LT along two orbital tracks: one over the United States and one over Europe. An auroral storm occurred on September 19. A comparison of data from September 20 with data from September 18 revealed a factor of 3 increase in NO at mid-latitudes over the United States. Little NO enhancement was seen over Europe or at equatorial latitudes. A larger increase was seen for the higher altitudes (>120 km). The SME observations are compared with the calculations of a one-dimensional photochemical model of the lower thermosphere. The National Center for Atmospheric Research (NCAR) thermospheric general circulation model (TGCM) is used to calculate the response of the background neutral atmosphere to auroral forcings such as Joule and particle heating. The output of the TGCM is used as input to the photochemical model. Calculations of the mid-latitude NO response show that temperature increases which result from Joule and compressional heating can explain the observed NO enhancements. A larger response is initially seen for altitudes greater than 120 km. After several days, downward diffusion leads to NO increases at lower altitudes. Equatorial NO shows little response because the combined effects of temperature enhancements and atomic oxygen enhancements largely cancel. The best absolute fit of the model to the data is for an $N(^2D) + O$ quenching rate of 5×10^{-13} cm^3 s^{-1}, although uncertainties in the neutral composition preclude an exact specification of the quenching rate. The success of the model in reproducing the observed NO altitude and latitude variations argues against the importance of horizontal transport of E region NO.

Siskind, D E., C. A. Barth, D. S. Evans, and R. G. Roble, The Response of Thermospheric Nitric Oxide on an Auroral Storm, 2, Auroral Latitudes, *J. Geophys. Res.* **94,** 16,899-16911, 1989.

An analysis of the response of lower thermospheric nitric oxide (NO) at auroral latitudes to the auroral storm of September 19, 1984, is presented. A comparison of data from the Solar Mesosphere Explorer (SME) taken one day after the storm (September 20) with data obtained one day before the storm (September 18) revealed a factor of 3 increase in NO. In order to model this response, particle data from the NOAA 6 and 7 satellites are used to assess the time history of the auroral energy input along each SME orbital track. The deduced fluxes and characteristic energies are used as input to a time dependent one-dimensional photochemical model. In addition, the NCAR thermospheric general circulation model (TGCM) is used to calculate the response of the background neutral atmosphere to auroral forcings such as Joule land particle heating. It was found that particle precipitation accounted for 90% of the increase in the peak NO density, although Joule heating was more important at the higher altitudes (>140 km). The results of the model calculations predict an NO enhancement; however, the amplitude of the response as well as the absolute magnitude of the calculated NO density greatly exceed the observations. Two possibilities are proposed to explain this discrepancy. The first is that the yield of $N(^2D)$ from electron impact on N_2 may only be 50%, rather than the 60-75% previously assumed. The second is that vertical winds of the order of 1-5 m s^{-1} may be generated in an E ration auroral arc. It is shown that such winds could be important in damping out the NO response to increased particle precipitation.

Solomon, S., G. C. Reid, D. W. Rusch, and R. J. Thomas, Mesospheric Ozone Depletion during the Solar Proton Event of July 13, 1982. Part II. Comparison between Theory and Measurements, *Geophys: Res. Letters* **10**, 257-260, 1983.

The solar proton event of July 13, 1982 was the largest to date in the current solar cycle. Proton fluxes observed by the NOAA-6 satellite have been used to calculate ionization rates during the event, which have been found to be almost as large as those of the August 1972 event near 70 km, but much smaller at lower altitudes. This ionization leads to the production of odd hydrogen radicals (H+OH+HO_2) which catalytically destroy odd oxygen in the mesosphere and stratosphere. A one-dimensional time-dependent model has been used to calculate the percentage change in ozone resulting from this event. The calculated ozone depletion is compared to that observed by the Solar Mesosphere Explorer (SME) satellite.

Solomon, S., D. W. Rusch, R. J. Thomas, and R. S. Eckman, Comparison of Mesospheric Ozone Abundances Measured by the Solar Mesosphere Explorer and Model Calculations, *Geophys. Res. Letters* **10**, 249-252, 1983.

Ozone observations in the mesosphere obtained by the near infrared and ultraviolet spectrometers onboard the Solar Mesosphere Explorer (SME) satellite are compared to two-dimensional model calculations for the month of January. In general, the model calculated abundances are somewhat smaller than those measured, but exhibit similar trends with respect to altitude and latitude. The possible causes of discrepancies include the mesospheric H_2O content and photochemical reaction rates, particularly the rate of O_2 photolysis.

Solomon, S., G. H. Mount, and J. M. Zawodny, Measurements of Stratospheric NO_2 from the Solar Mesosphere Explorer Satellite. 2. General Morphology of Observed NO_2 and derived N_2O_5, *J. Geophys. Res.* **89**, 7317-7321, 1984.

Observations of NO_2 densities from 28 to 40 km as measured by the Solar Mesosphere Explorer (SME) satellite are compared to model calculations for the month of January. Low densities are obtained in the topics and in high latitude winter, with much larger values in the summer middle and high latitude regions in both the observations and the model. The reasons for areas of agreement and disagreement between the model and the observations are explored. The observed NO_2 distribution is also used to infer the N_2O_5 distribution based on presently accepted chemistry and suggests that very large amounts of N_2O_5 are present in high latitude winter.

Thomas, G. E., Solar Mesosphere Explorer Measurements of Polar Mesospheric Clouds (Noctilucent Clouds), *J. Atmos. & Terr. Phys.*, **46**, 819-824, 1984.

The Ultraviolet Spectrometer experiment on board the Solar Mesosphere Explorer satellite has measured scattering of sunlight from the polar mesospheric cloud layer in the 0.2-0.3 μm spectral range. The layer is manifested in the limb-scanning measurements as large increases in radiances at heights near 80 km, at latitudes 60-90°N and 60-90°S and during the summer season. They are similar to noctilucent clouds with respect to their height, geometrical thickness (less than 3.5 km) and morphology. However, as shown by Donahue *et al.* (*J. Atmos. Sci.* **29** 1205,1972), they are much brighter and occupy the entire polar 'cap' read, a region largely inaccessible to ground-based observation. The measurements have revealed a forward-scattering asymmetry, which increases with layer brightness. This behaviour shows that the brighter clouds are composed of particles with radii according to Mie theory up to 0.07 μm, at least for the limited set of data studied so far. The variation of layer brightness with asymmetry factor is consistent with the layer being limited by the available water content of the atmosphere. The calculated water content of the particles, assuming them to consists of pure water ice, is about 100 $\mu g\ m^{-2}$, provided the particle distribution is monodisperse. This corresponds to the total amount of atmospheric water vapor residing in a vertical column above 80 km for a water vapor mixing ratio of 1.2 ppmv. This is consistent with the amount of water vapor believed to exist at mesopause heights (a few ppmv). The large amounts of ice reported by Donahue *et al.* (1972) are too large by a factor of 10. Their corrected values are consistent with the present analysis. A brief description is given concerning additional research topic which are being pursued using the extensive SME data base, which now consists of five complete summer seasons from 1981 to the present.

Thomas, G. E., Trace Constituents in the Mesosphere, *Physica Scripta* **T18**, 281-288, 1987.

Recent observations of selected trace constituents in the mesosphere are reviewed. The review is divided into discussions of some long-lived constituents (CO, NO and H_20), and short-lived constituents (OH and O_3) that are important for understanding the transport in the lower thermosphere and in the mesosphere. CO and NO are produced in the lower thermosphere and lost in the lower mesosphere and stratosphere. There is now observational evidence that downward transport into the winter polar region, and subsequent "spillage" into the winter mid-latitude regions are important for CO and NO. In comparison with CO and NO the distribution of H_2O is "upside down" in the sense that it is generated in the lower atmosphere and flows upward to its sink. The same transport mechanism may operate for H_2O, but in the opposite sense of moving dry air downward in winter, and moist air upward in summer. The short-lived OH radical is important for understanding the HO_x—O_x mechanism in the middle atmosphere. Unfortunately, there is an almost complete lack of data for its distribution above 50 km. Ozone and water vapor are out-of-phase in their seasonal behavior in the upper mesosphere; the variations in both species provide important clues for understanding the causes of eddy mixing in the mesosphere. The seasonal climatology of mesospheric ozone is now well documented as a results of five years of SME satellite observations.

Thomas, G. E., and C. P. McKay, On the Mean Particle Size and Water Content of Polar Mesospheric Clouds, Planet. Space Sci., **33**, 1209-1224, 1985.

The ultraviolet spectrometer on board the Solar Mesosphere Explorer (SME) satellite has been measuring the scattering of ultraviolet sunlight from optically thin cloud layers in the upper boundary of the mesosphere (85 km) since the launch of the spacecraft in October 1981. These layers are present only at high latitudes during the summer season. During Summer 1983 an observing sequence was undertaken to measure the cloud radiance at two different scattering angles — one in the forward hemisphere at 50°, the other in the backward hemisphere at 130°. The data show a pronounced tendency for the brighter clouds to exhibit greater forward-scattering behavior, indicating that particle size may be the most important factor in determining the cloud brightness. We conclude that if the particles are monodisperse water ice aggregates, their radii do not exceed 70 nm. Estimates are provided for the water content and column particle number of the clouds, depending upon the unknown shape of the particle size distribution. Characterizing the distribution by two parameters, the spherical equivalent particle radius and the width of the distribution, the bulk cloud properties are shown to be dependent upon the limb radiance and width parameter. For narrow widths the water ice content is less than that expected for the water vapor content at mesopause heights of a few parts per million. This confirms our earlier analysis using a smaller data set and assuming the cloud particles are monodisperse. However if the size dispersion is broad, the implied water ice exceeds the static atmospheric water supply. The calculated column number for the brightest clouds exceeds our estimates for the total supply of condensation nuclei. The alternative is that the brighter clouds are limited to a fairly narrow range of particle sizes from 40 to 60 nm. This conclusion is supported by theoretical time dependent calculations by Turco *et al.* (*Planet. Space Sci.* **30**, 1147, 1982).

Thomas, G. E., and J. J. Olivero, The Heights of Polar Mesospheric Clouds, *Geophys. Res. Letters* **13**, 1403-1406, 1986.

Data from the Solar Mesosphere Explorer satellite of polar mesospheric clouds have been used in determining the variation of cloud height from 1981 to 1985. Applying various corrections to the apparent tangent heights measured at the atmospheric limb, we find no significant variation of height within an individual cloud season (-10 days to +50 days relative to summer solstice) either with latitude or local time. Furthermore, no significant year-to-year variation is found over the 4-year time span. We find significantly higher (2 km) PMC cloud heights in the north than in the south. The average value of 85.0 ± 1.5 km for the northern PMC is in good agreement with measurements from the OGO-6 satellite, rocket-borne photometers and ground-based triangulation of noctilucent clouds.

Thomas, G. E., and J. J. Olivero, Climatology of Polar Mesospheric Clouds: Part II, *J. of Geophys. Res.*, in press, 1989.

Thomas, G. E., C. A. Barth, E. R. Hansen, C. W. Hord, G. M. Lawrence, G. H. Mount, G. J. Rottman, D. W. Rusch, A. I. Stewart, R. J. Thomas, J. London, P.L. Bailey, P. J. Crutzen, R. E. Dickinson, J. C. Gille, S. C. Liu, J. F. Noxon, and C. B. Farmer, Scientific Objectives of the Solar Mesosphere Explorer Mission, *PAGEOPH* **118**, 591-615, 1980.

The 1981-82 Solar Mesosphere Explorer (SME) mission is described. The SME experiment will provide a comprehensive study of mesospheric ozone and the processes which form and destroy it. Five instruments will be carried on the spinning spacecraft to measure the ozone density and its altitude distribution from 30 to 80 km, monitor the incoming solar ultraviolet radiation, and measure other atmospheric constituents which affect ozone. The polar-orbiting spacecraft will be placed into a 3 PM—3 AM Sun-synchronous orbit. The atmospheric measurements will scan the Earth's limb and measure: (1) the mesospheric and stratospheric ozone density distribution by inversion of Rayleigh-scattered ultraviolet limb radiance, and the thermal emission from ozone at 9.6 μm; (2) the water vapor density distribution by inversion of thermal emission at 6.3 μm; (3) the ozone photolysis rate by inversion of the $O_2(^1\Delta_g)$ 1.27 μm limb radiance; (4) the temperature profile by a combination of narrow-band and wide-band measurements of the 15 μm thermal emission by CO_2; and (5) the NO_2 density distribution by inversion of Rayleigh-scatttered limb radiance at 0.439 μm. The solar ultraviolet monitor will measure both the 0.2-0.31 μm spectral region and the Lyman-alpha (0.1216 μm) contribution to the solar irradiance. This combination of measurements will provide a rigorous test of the photochemical equilibrium theory of the mesospheric oxygen-hydrogen system, will determine what changes occur in the ozone distribution as a result of changes in the incoming solar radiation, and will detect changes that may occur as a result of meteorological disturbances.

Thomas, G. E., B. M. Jakosky, R. A. West, and R. W. Sanders, Satellite Limb-Scanning Thermal Infrared Observations of the El Chichon Stratospheric Aerosol: First Results, *Geophys. Res. Letters* **10**, 997-1000, 1983.

The Infrared Radiometer experiment on the Solar Mesosphere Explorer satellite has been continuously measuring the 6.8-μm thermal emission from the stratospheric aerosol from the El Chichon volcano since the time of eruption in early April 1982. Inversion results fro the zonally-averaged infrared extinction coefficient in height, latitude, and time show that the aerosol increased in mass to a maximum of 8 Tg(8×10^{12} gm) about 15 weeks after the April 4 eruption. It descended in height with an average speed consistent with the gravitational settling time of particles with a diameter of about 1.4 μm.

Thomas, G. E., D. W. Rusch, R. J. Thomas, and R. T. Clancy, "Long-Term Changes in the Stratosphere Due to the 1982 Eruption of El Chichon," in *The Middle Atmosphere Program Handbook*, in press, 1989.

Thomas, R. J., Seasonal Ozone Variations in the Upper Mesosphere, *J. Geophys. Res.* **95**, in press, 1990.

The global daytime ozone was measured by the Solar Mesosphere Explorer satellite (SME) for five years. The measurements extend through the mesosphere, covering from 50 km to over 90 km. The ozone in the upper mesosphere varies annually by up to a factor of 3. The observed seasonal variations may be summarized in several different ways. From year to year there is a great deal of repeatability of these variations. This repeatability occurs in most of the upper mesosphere outside the tropics. Near 0.01 mbar (80 km) the mid- and high latitude mixing ratio peaks each year in mid April.

A secondary maximum in the altitude profile of ozone density usually occurs near 85 km. Changes in this structure are directly related to the April maximum and other seasonal changes seen at 0.01 mbar. The changing seasonal structure produces a 'bump' at the ozone mixing ratio minimum that is largest just after spring equinox. This perturbation to the mixing ratio profile seems to move upward during the first half of the year.

The seasonal changes of ozone were analyzed in terms of annual and semiannual structure. The variations generally have both an annual and semiannual component depending on altitude and latitude. The phases of the variations change quickly with both altitude and latitude. The semiannual component peaks in April, over most of the upper mesosphere .

Thomas, R. J., Atomic Hydrogen and Atomic Oxygen Density in the Mesopause Region: Global and Seasonal Variations Deduced from SME Near-infrared Emissions, *J. Geophys. Res.* **95**, in press, 1990.

Atomic oxygen and atomic hydrogen have been inferred from the hydroxyl airglow measurements on Solar Mesosphere Explorer spacecraft (SME) between 0.01 and 0.0013 mbar (80-93 km). These constitute the first measurements of the seasonal and latitudinal variations of these atomic species, in the mesopause region. At night atomic oxygen is directly proportional to the Meinel band emission of OH. During the day the emission is proportional to the product of ozone and hydrogen. Since daytime ozone is inferred from the $O_2(^1\Delta_g)$ emission, daytime hydrogen can be inferred. Daytime atomic oxygen is then inferred from the measured hydrogen and ozone. At levels where both methods are valid (at 0.0032-0.0013 mbar or 88-93 km) the day and night atomic oxygen display the same seasonal behavior. Very large annual and semiannual changes are found in the atomic hydrogen density between 80 and 93 km. At 40° N the summer-to-spring ratio of atomic hydrogen exceeds a factor of 4 at 0.01 mbar (80 km). Between 80 and 90 km the odd oxygen family is found to be almost entirely atomic oxygen. Its behavior is characterized by annual variations at 40° north and south, and semiannual changes at the equator; in both cases the changes are a doubling from minimum to maximum. At least part of the mid-latitude semiannual variation in ozone is found to be due to the product of two annually varying functions. The atomic oxygen is annual and maximizes in the winter while the ozone-oxygen partitioning, controlled mostly by temperature, maximizes in the summer due to temperature changes.

Thomas R. J., C. A. Barth, G. J. Rottman, D. W. Rusch, G. H. Mount, G. M. Lawrence, R. W. Sanders, G. E. Thomas, and L. E. Clemens, Mesospheric Ozone Depletion during the Solar Proton Event of July 13, 1982. Part I. Measurement, *Geophys. Res. Letters* **10**, 253-255, 1983.

The near infrared spectrometer and the ultraviolet spectrometer on the Solar Mesosphere Explorer (SME) observed the ozone density as a function of latitude and altitude during the solar proton event of July 18, 1981. Airglow at 1.27 μm was observed at the earth's limb. The altitude profiles of the emission were inverted providing ozone densities. The ozone densities observed showed a clear decrease during the event. The maximum depletion seen was 70%. The decrease was observed in the northern high latitudes at mesospheric altitudes. The decrease was very short lived, lasting less than a day.

Thomas R. J., C. A. Barth, G. J. Rottman, D. W. Rusch, G. H. Mount, G. M. Lawrence, R. W. Sanders, G. E. Thomas, and L. E. Clemens, Ozone Density Distribution in the Mesosphere (50-90 km) Measured by the SME Limb-Scanning Near-Infrared Spectrometer, *Geophys. Res. Letters* **10**, 245-248, 1983.

The ozone densities between 50 and 90 km are deduced from 1.27 μm airglow measured on the Solar Mesosphere Explorer satellite. The derived densities agree well with those made simultaneously from SME by the ultraviolet spectrometer. The data set extends from pole to pole at about 3 pm, for most sunlit latitudes. At low altitudes, in the mesosphere, there are larger variations in ozone density in the winter latitudes than in the summer. Above the mesopause the day-to-day variation in ozone density is a factor of 2 at most latitudes and times.

Thomas, R. J., C. A. Barth, D. W. Rusch, and R. W. Sanders, Solar Mesosphere Explorer Near-Infrared Spectrometer: Measurements of 1.2μm Radiances and the Inference of Mesospheric Ozone, *J. Geophys. Res.* **89**, 9569-9580, 1984.

Ozone in the mesosphere is determined from observations made by the near-infrared spectrometer experiment on the Solar Mesosphere Explorer satellite (SME) between 50 and 90 km over most latitudes at 3:00 PM local time. The spectrometer measures emission from $O_2(^1\Delta_g)$ at 1.27 μm that is primarily due to the photodissociation of ozone. The instrument consists of a parabolic telescope that limits the field of view to less than 0.1°, an Ebert-Fastie spectrometer, and a passively cooled lead sulfide detector system. The limb radiances, measured as the spacecraft spins, are inverted, producing volume emission rate profiles from which ozone densities are inferred. The vertical resolution is better than 3.5 km. The calculation of ozone accounts for quenching and atmospheric transmission of both solar radiation and 1.27-μm radiation. We have established the existence of a secondary maximum of ozone density near 80 km. An error analysis shows that the effects of random errors in the data and in the analysis on the final ozone profile are less than 10% between 50 and 82 km.

Thomas, R. J., C. A. Barth, and S. Solomon, Seasonal Variations of Ozone in the Upper Mesosphere and Gravity Waves, *Geophys. Res. Letters* **11**, 673-676, 1984.

Ozone densities in the upper mesosphere have been measured as a function of time and latitude over a two-year period (1982-1983) by the Solar Mesosphere Explorer (SME) satellite. Large seasonal changes occur, particularly near 80 km where ozone densities at the equinoxes are about 2-3 times those observed at the solstices. The structure of the ozone secondary maximum also fluctuates substantially during the year, with extremes near equinox and solstice. Further, the variations are highly repeatable from year to year and from hemisphere to hemisphere. We propose that the seasonal variability in ozone is produced by the variation of gravity-wave-induced transport in the mesosphere which, in turn, results from the seasonal modulation of the propagation and breaking of small-scale gravity waves.

Thomas, R. J., K. H. Rosenlof, R. T. Clancy, and J. M. Zawodny, Stratospheric NO_2 over Antarctica as Measured by the Solar Mesosphere Explorer during Austral Spring, 1986, *J. Geophys. Res.* **93**, 12,561-12,568, 1988.

The visible spectrometer on the Solar Mesosphere Explorer measured stratospheric NO_2 in the 24- to 40-km region. In September and October 1986 the spatial density of the measurements was increased over Antarctica in order to examine the NO_2 change during the period of the "ozone hole." These measurements are compared with the 1985 austral spring observations, with northern polar spring measurements for both years, and with model results. A polar low in NO_2 is seen between 10 and 24 mbar. The geographic extent of the low decreases as hours of sunlight increase, in marked contrast to the behavior of the total ozone column during the same period. The latitude and time dependence of the NO_2 is similar for both years, and during the same season, in the northern hemisphere. Comparison of measurements and model imply that much of the odd nitrogen is converted to HNO_3 during the polar night. Observed vertical profiles and comparison to measurements from the ground indicate that the bulk of the NO_2 column lies above 24 km. The observed behavior does not appear to be anomalous when compared to simple model calculations, indicating no obvious connection between the polar stratospheric NO_x above 24 km and the development of the ozone hole below 24 km.

Tobiska, W. K., R. D. Culp, and C. A. Barth, Predicted Solar Cycle 22 10.7 cm Flux and Satellite Orbit Decay, *J. Astron. Sci.* **35** (4), 419-433, 1987.

This study develops an empirical model of the 10.7 cm solar flux ($F_{10.7}$) through solar cycle twenty-two as it relates to the problem of a low-Earth orbiting satellite and its orbit decay. A comparison between the predicted orbit decay using the model and the first thirty-seven months of actual altitude of the Solar Mesosphere Explorer (SME) satellite is conducted. The predicted orbit semimajor axis is solved as a function of atmospheric density using a modified Jacchia 1971 atmospheric model (J71). J71 densities vary based on the empirically modeled $F_{10.7}$ of solar cycle twenty-two. The derivation of the orbit radius, r, related to atmospheric mass density, ρ, is outlined, as are the simplifications made in this study for atmospheric density modeling. The $F_{10.7}$ model for solar cycle twenty-two is then detailed with a comparison of one other model. Finally, the results of the predicted SME orbit decay are evaluated against the actual orbit decay.

Zawodny, J. M., Short-Term Variability of Nitrogen Dioxide in the Winter Stratosphere, *J. Geophys. Res.* **91**, 5439-5450, 1986.

Zawodny, J. M., and D. W. Rusch, Seasonal Behavior of NO_2 in the Winter Stratosphere: Infrared NO_x, *J. Geophys. Res.* **91**, 5451-5454, 1986.

The long-term seasonal trend in NO_2 density near 10 mbar, as measured by the Solar Mesosphere Explorer (SME), is compared to photochemical model predictions of the trend throughout the first 3 months of 1982. The general increase in the observed NO_2 is found to be caused by a shift in the partitioning of odd nitrogen in favor of NO_2. The model is also used to infer the odd nitrogen (NO_x: NO + NO_2 + NO_3 + 2 × N_2O_5) mixing ratio, which is seen to decrease rapidly throughout the period. This rapid decrease is found to be caused in part by improper modeling of the photodissociation rate of NO_2. Indirect measurements of the photodissociation rate of NO_2 from SME show the rate to change with solar zenith angle at angles greater than 70°. Only when this dependence is taken into account do the variations in the odd nitrogen mixing ratio become consistent with theory.