3. Network Sites

NSF UV monitoring network sites currently include three locations in Antarctica (McMurdo Station, Palmer Station, and Amundsen-Scott South Pole Station), one station in Ushuaia Argentina, one site close to Barrow, Alaska, and one site at Summit, Greenland. In addition, one instrument system is installed in San Diego, California, which also serves as a training facility for site operators. An overview of site locations is given in Table 3.1. All sites are described in detail in the following, including prevailing meteorological conditions and typical column ozone values.

Table 3.1. NSF spectroradiometer installation sites.

ID #	Site	Longitude	Latitude	Elevation	Established	Normal Season
1	McMurdo, Antarctica*	166º40'E	77º50'S	183 m	March 1988	August – April
2	Palmer, Antarctica	64º03'W	64º46'S	21 m	May 1988	Year-round
3	South Pole, Antarctica	-	90º00'S	2841 m	February 1988	September - March
4	Ushuaia, Argentina**	68º19'W	54º49'S	~25 m	November 1988	Year-round
5	San Diego, California***	117º12'W	32º46'N	22 m	November 1992	Year-round
6	Barrow, Alaska****	156º41'W	71º19'N	8 m	December 1990	January – November
7	Summit, Greenland*****	38°27'W	72 34'N	3200 m	August 2004	January – November

* Located at Arrival Heights, approximately 3 km north of McMurdo
** Located at the Centro Austral de Investigaciones Cientificas (CADIC), Argentina
*** Collocated with Biospherical Instruments Inc.
**** Located at the Ukpeaġvik Iñupiat Corporation (formerly) Naval Arctic Research Laboratory (UIC/NARL)
***** Located in the "Green House"

3.1. McMurdo Station, Antarctica

McMurdo Station is located on the southern tip of Ross Island and is surrounded by the Ross Sea and the Ross Ice Shelf. The station has had a long history in Antarctic exploration. It is the largest field station in Antarctica, accommodating up to 1200 people in summer and 250 in winter. There is a large laboratory facility, the "Crary Lab," supporting a wide range of scientific projects. McMurdo Station is operated year-round but is typically only accessible between the months of October and February, with the exception of a short series of flights in early September or late August ("WinFly"). The spectroradiometer at McMurdo Station is located at Arrival Heights, a cliff-like location approximately 3 km north of McMurdo Station. The active volcano Mount Erebus, 3795 m high, is 34 km north of the instrument. We use McMurdo rather than Arrival Heights when referring to instrument location and data due to the more familiar name recognition. The instrument is mounted into in the roof of a modular building. The facility is not continuously manned, but is visited regularly every one to three days. During the reporting period, the system was operated by personnel from Raytheon Polar Services Company (RPSC). All operators have been trained by BSI staff.

Figure 3.1.1 shows the research building at Arrival Heights. The horizon, as it is seen from the collector of the SUV-100 spectroradiometer, is plotted in Figure 3.1.2. Bearings of obstructions limiting the instrument's field-of-view are further listed in Table 3.1.1. A map of Ross Island, indicating the location of the instruments is provided in Figure 3.1.3. The annual cycles of day length and noon time solar zenith angle for McMurdo are given in Figure 3.1.4 and Figure 3.1.5, respectively.

Weather at Arrival Heights is quite variable. Calm and clear conditions can be superceded within one hour by overcast skies, snow fall, and strong catabalic winds, which are typical for the Antarctic coast, particularly during winter. Recorded temperature extremes at McMurdo have been as low as –50 °C and as high as +8 °C. Annual mean temperature is –18 °C; monthly mean temperatures range from –3 °C in January to –28 °C in August. Rain is a very rare event and may not occur for years. The vicinity of the measurement site is usually covered by snow. Snow may disappear during the summer, exposing dark volcanic rock, see Figure 3.1.1.

The climatology of total column ozone at McMurdo is summarized in Table 3.1.2, Figure 3.1.6, and Figure 3.1.7. A pronounced downward trend in yearly minimum column ozone can be seen in Figure 3.1.6. Minimum values in recent years are about 100 DU lower than 20 years ago, as a consequence of the "ozone hole." Figure 3.1.7 shows the annual cycle in column ozone. Between January and August, typical ozone values fluctuate around 300 DU and drop to values below 150 DU in October.

The SUV-100 system at McMurdo has received subsequent computer and LAN upgrades along with minor enhancements over the years. Data archiving is automated. The system control computer is setup as a File Transfer Protocol (FTP) server. This allows for automatic data transfers to BSI.

Figure 3.1.1. *Arrival Heights in the hills above McMurdo Station. The SUV-100 is installed in the white building in the foreground. The collector is accessible via a stairway that is built on the outside of the facility. The ease of access facilitates maintenance, like cleaning of the collector, and calibrations with the external lamp stand. The green building to the right belongs to the New Zealand Antarctic Program. McMurdo station is located at the foot of the hill, which is marked by the spherical dome serving as a satellite uplink. In the background is Mount Discovery, separated from McMurdo Station by the "McMurdo Ice Shelf."*

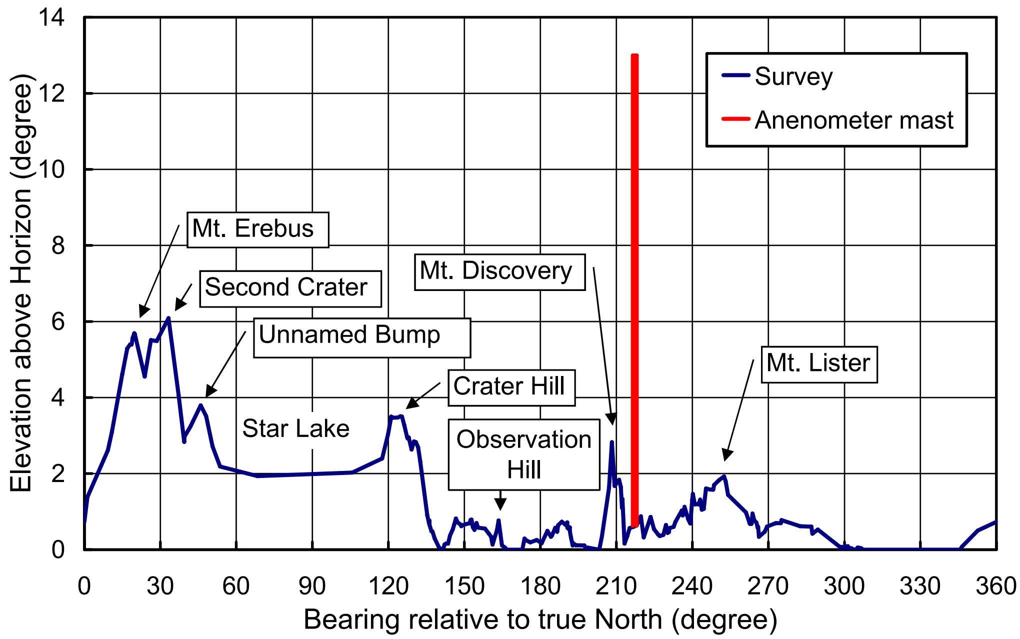

Figure 3.1.2. *Horizon seen from the collector of the SUV-100 spectroradiometer at Arrival Heights. The Survey was performed by Antarctic Support Associates in 1998.*

Table 3.1.1. Bearings of obstructions to the instrument's field-of-view at Arrival Heights.

Object Name	Bearing (degrees)	Elevation (degrees)
Observation Hill	163.5	0.8
Mt. Erebus	6-22	5.7
Second Crater	24-39	6.1
Unnamed Bump	41-52	3.8
Mt. Terror	53-55	2.9
Star Lake	57-115	2.2
Crater Hill	120-136	3.5
Mt. Discovery	207-211	2.8
Mt. Lister	246-257	1.8
Anemometer Mast	216.5 - 218	13

***Notes*:** Elevation is measured in degrees above the Arrival Heights instrument location. Instrument is at 183 meters above sea level. Bearings are referenced to True North.

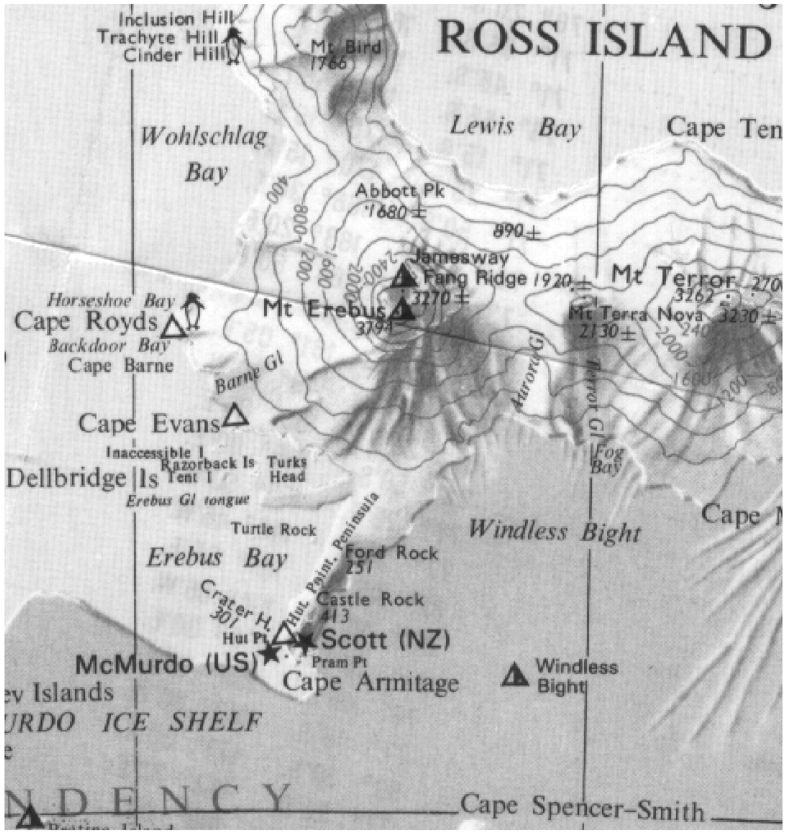

Figure 3.1.3. *Map of Ross Island. Arrival Heights is located in the lower left corner between McMurdo and Crater Hill.*

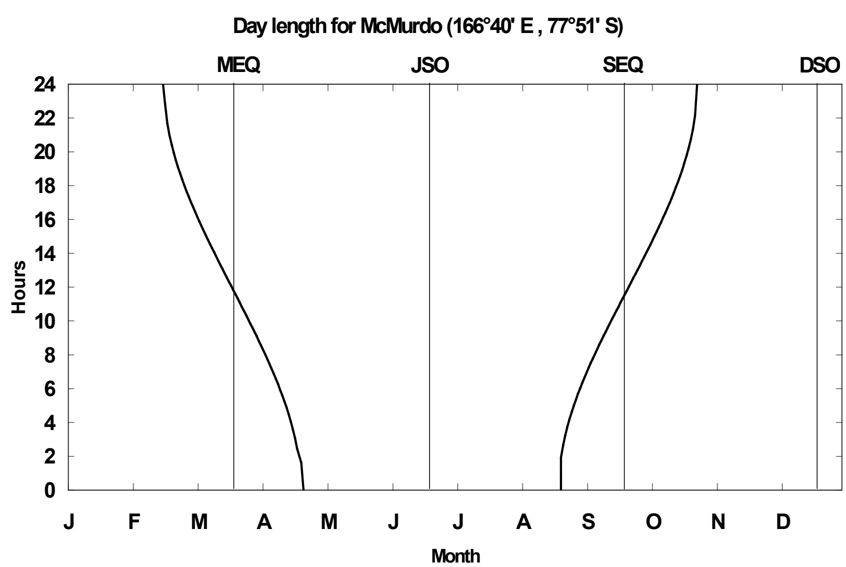

Figure 3.1.4. *Day length plot for McMurdo. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice).*

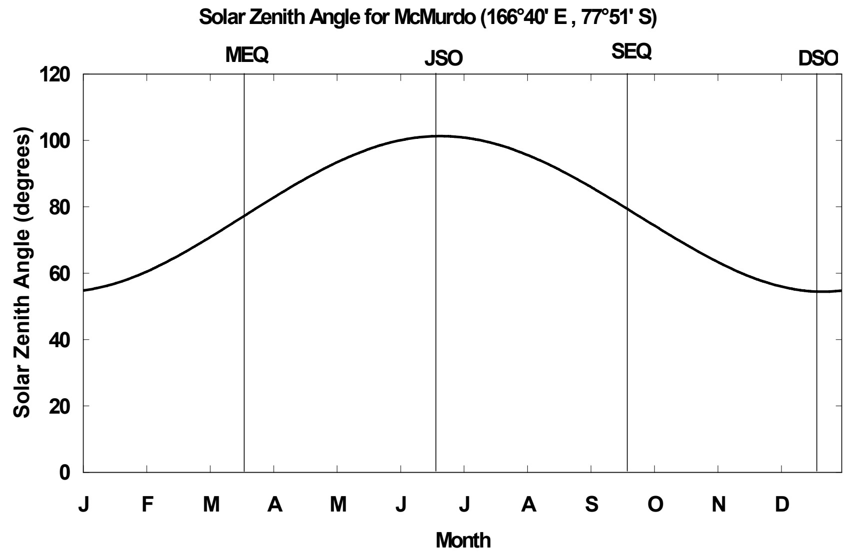

Figure 3.1.5. *Plot of noontime solar zenith angle in degrees.*

Table 3.1.2. Total ozone averages and minima for McMurdo, September 1 – December 31.

	TOMS									OMI, Version 8.5			TOVS		
	Nimbus 7, Version 8			Meteor 3, Version 7			Earth Probe, Version 8								
Year	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**
1988	320	205	09/09/88												
1989	257	161	10/07/89												
1990	235	143	10/09/90												
1991	278	140	10/11/91												
1992	256	148	09/26/92												
1993				278	157	9/18/93									
1994				256	126	10/3/94							255.1	128.5	10/23/94
1995													225.8	124	10/23/95
1996							244	138	10/01/96				232.6	138	10/6/96
1997							224	126	10/08/97						
1998							200	122	10/12/98						
1999							216	123	10/05/99						
2000							269	124	09/23/00						
2001							214	117	09/27/01						
2002							312	159	09/20/02						
2003							236	128	09/25/03						
2004							258	146	09/12/04						
2005							253	134	09/18/05						
2006										232	117	09/22/06			
2007										259	152	11/07/07			

Note: 1998 TOMS/Earth Probe data is not available after 12/12/98. The average was therefore calculated from the period 9/1/98 – 12/12/98.

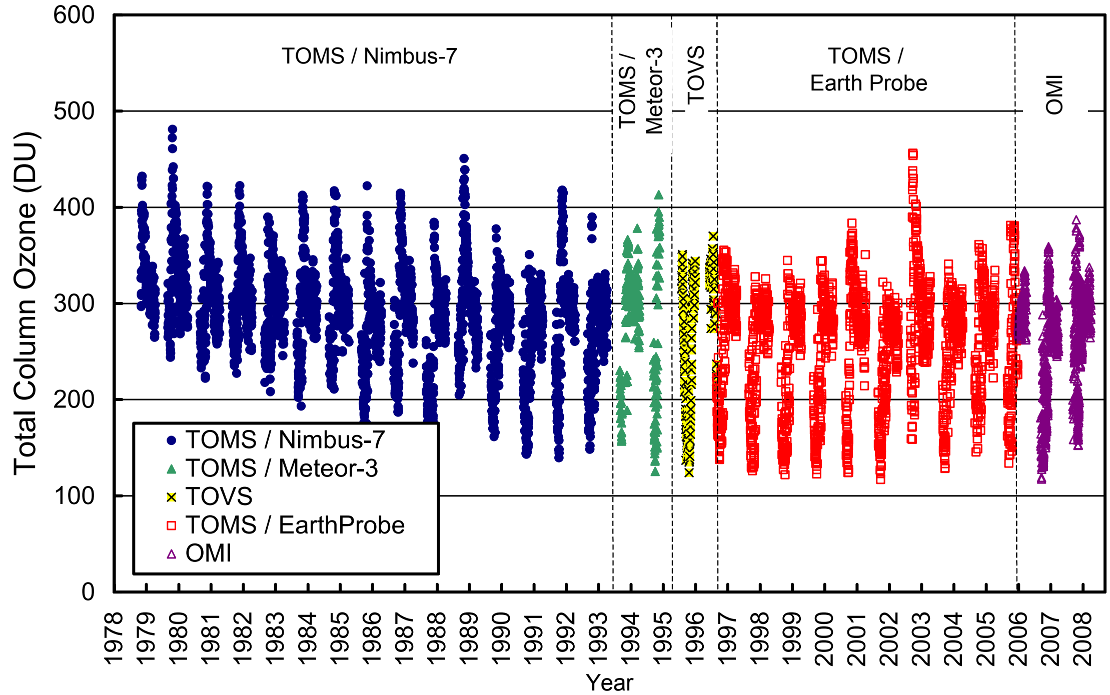

Figure 3.1.6. *Time record of total column ozone from TOMS, TOVS, and OMI data at McMurdo. The downward trend is attributed to ozone depletion. Note the difference in the minimum ozone column observed in the 1970s versus that of the 1990s and 2000s.*

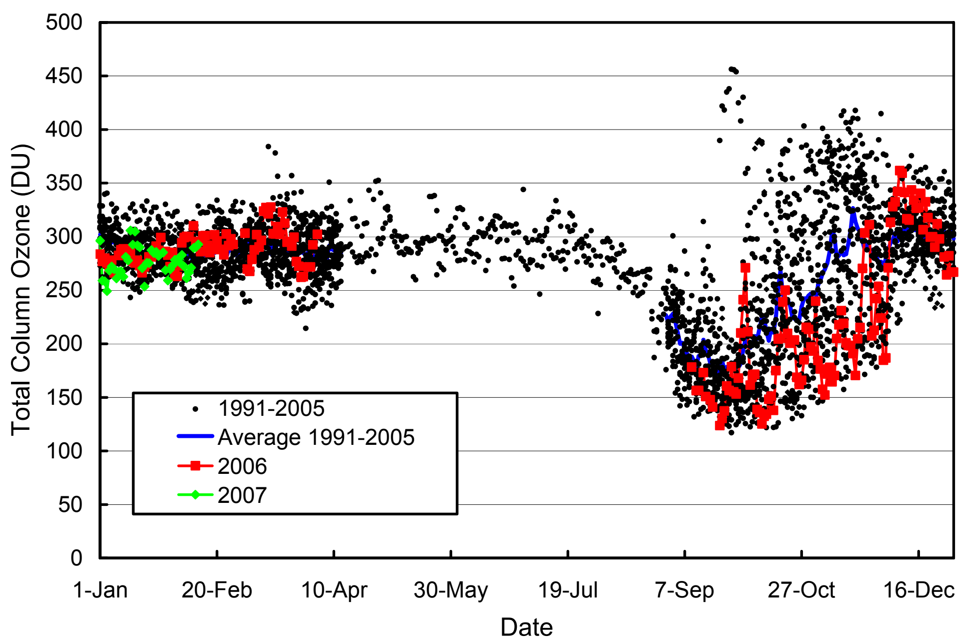

Figure 3.1.7. *Seasonal variation of total column ozone at McMurdo. OMI measurements from 2006 and 2007 are contrasted with ozone data from the years 1991-2005 recorded by TOMS /Nimbus-7(1991-1993),TOMS/ Meteor-3 (1993-1994), NOAA/TOVS (1995-1996), and TOMS/Earth Probe (1997-2005) satellites. Data between June and August are from NOAA /TOVS. The decrease in ozone values in October is clearly apparent. The data gap is due to the austral winter.*

3.2. Palmer Station, Antarctica

Palmer Station, established by the United States in 1965, is located on Anvers Island at 64°46' S, 64°03' W, slightly outside the Antarctic Circle. Palmer Station is manned year-round and has diverse flora and fauna. Various experiments, mostly relating to biological sciences, take advantage of the laboratory and field facilities. Palmer is also part of the Long Term Ecological Research (LTER) program. The population in winter is about 15-25 with a maximum of 46 in summer. Access is by icebreaker or ice-strengthened vessel. Figure 3.2.1 shows Palmer Station with the Marr Ice Piedmont in the background. The UV Spectroradiometer system at Palmer Station was originally installed in the roof of the vestibule of the Clean Air/VLF Building and was relocated to the annex of building T-5 in March 1993. This move was to facilitate improved instrument operation, serviceability, and thermal management. In May 2006, the instrument was relocated to the new "Terra Lab" building. This facility was built in 2005 to replace T-5. Figure 3.2.2. shows the installation of the SUV-100 at Terra Lab. With the exception of annual site visit periods, the system has operated continuously since 1988. The system control computer is setup as a File Transfer Protocol (FTP) server. This allows for automatic data transfers to BSI. During the reporting period, the system was operated by RPSC personnel that have been trained at BSI.

Figure 3.2.1. *Palmer Station, Antarctica (USA). The photo was taken before the construction of Terra Lab. The location of the new building is indicated by the red arrow.*

A map of the Antarctic Peninsula, indicating the location of Anvers Island is provided in Figure 3.2.3. The horizon as seen from the collector of the SUV-100 spectroradiometer at Terra Lab is plotted in Figure 3.2.4. Table 3.2.1 gives more information on the position of other objects in view of the SUV-100. The annual cycles of day length and noontime solar zenith angle for Palmer Station are given in Figure 3.2.5 and Figure 3.2.6, respectively.

Weather at Palmer Station is variable. Since the station is located at significantly lower latitude than McMurdo, it can rain in any month. Rain is common during the austral summer when temperatures typically fluctuate around 0 °C. Monthly average temperatures range from -6 °C in July and August to 2 °C in January and February. The annual mean is –2 °C. The extreme range is –31 °C to +12 °C. Clear sky days are relatively rare. The sky is often overcast and fog is not uncommon, which limits the view on the nearby glacier. During the austral summer, the immediate vicinity of the measurement is free of snow (see Figure 3.2.1). During the colder months of the year, the adjacent sea is sometimes frozen and the land is completely snow-covered, causing high albedo.

Figure 3.2.2. *Installation of SUV-100 spectroradiometer at Terra Lab. The main buildings of Palmer Station are in the background.*

Figure 3.2.3. *Map of the Antarctic Peninsula. The insert shows Anvers Island and the location of Palmer Station (Maps courtesy of U. S. Geological Survey).*

Table 3.2.1. Bearings of man-made obstructions to the instrument's field-of-view at Terra Lab.

Object Name	Bearing (degrees)	Elevation (degrees)	Horizontal distance from Collector (centimeters)
Stack CTBT	35.0	5.8	
Conical monopole antenna	36.5	4.5	
Rhombic Tower #1	67.8	11.1	
Top of Terra Lab	78.2	3.0	
Harness tie-off point	81.3	5.3	
Rhombic Tower #2	124.6	5.6	
Antenna Terra Lab	146.0	50.2	160
Rhombic Tower #3	146.5	18.0	
Anemometer Terra Lab	160.3	48.0	209
Rhombic Tower #4	169.3	4.1	
Bio Coms Tower	286.3	0.9	

Survey is from May 2006 after relocation of the instrument from the T-5 building to Terra Lab.

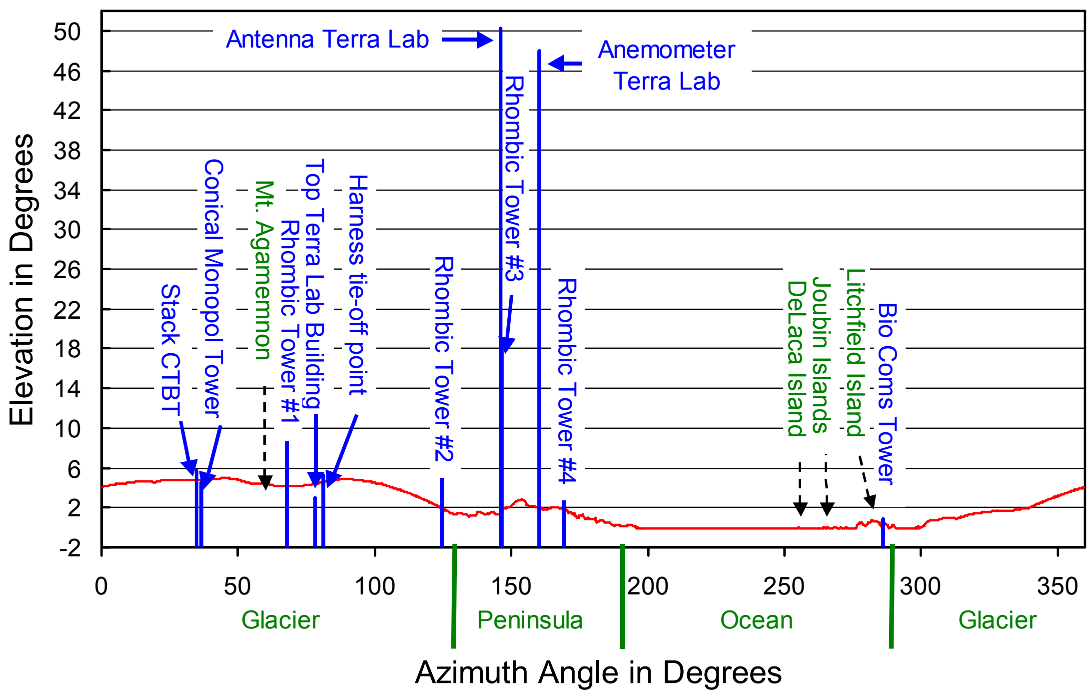

Figure 3.2.4. *Horizon as seen from the collector of the SUV-100 spectroradiometer at Terra Lab. Units are in degrees above the horizon vs. bearing relative to True North. The red line indicates the natural horizon. Vertical blue lines show the height and extension of man-made objects, which are mostly towers and antennas. Prominent mountain peaks are also labeled. The survey of the natural horizon was performed by John Booth in 1999/2000. Man-made objects were surveyed in May 2006 after relocation of the instrument from the T-5 building to Terra Lab.*

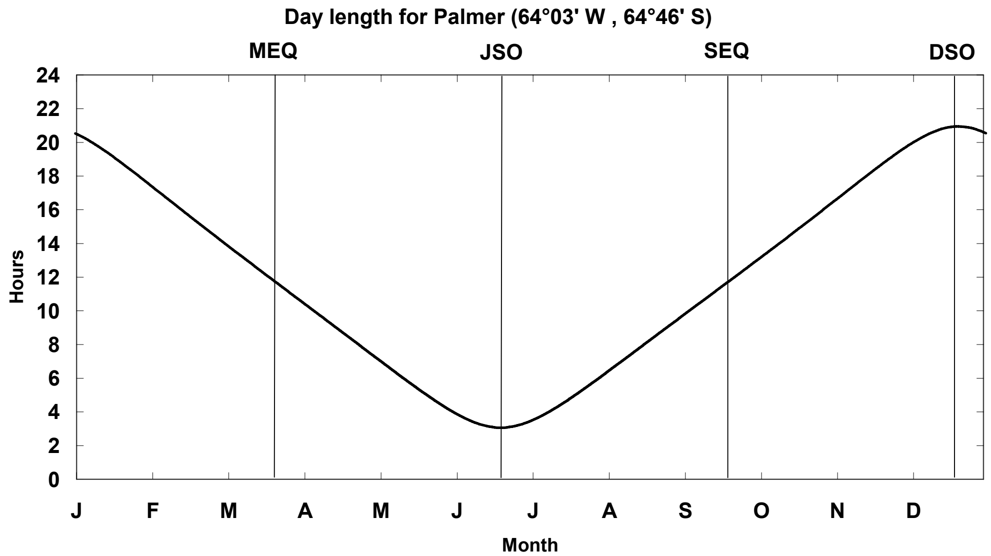

Figure 3.2.5. *Day length for Palmer Station. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice.)*

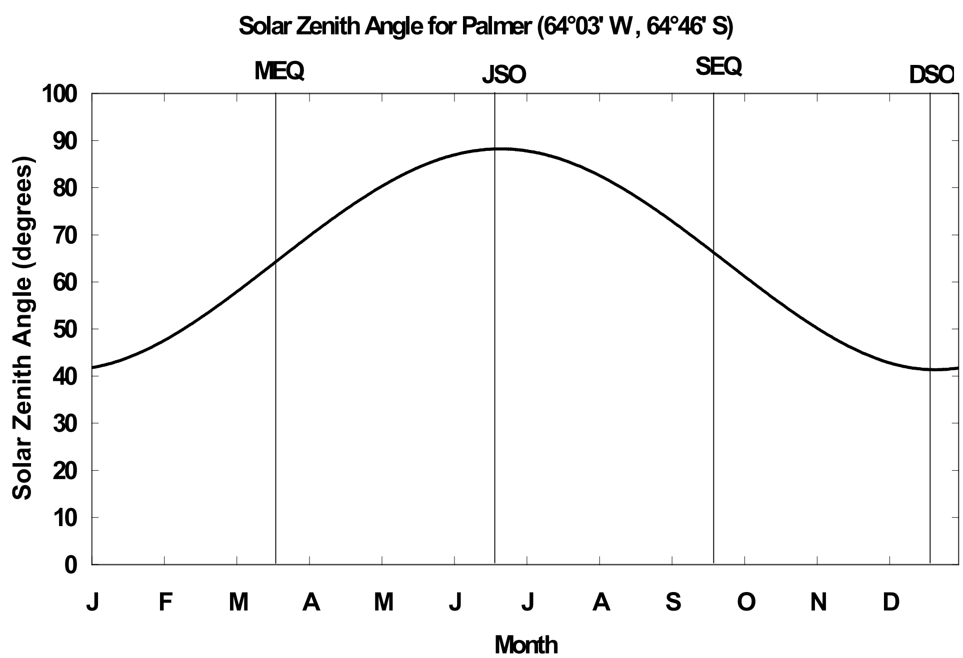

Figure 3.2.6. *Noontime solar zenith angle during the year at Palmer Station.*

Figure 3.2.7 gives an overview of total column ozone at Palmer Station. A pronounced downward trend in yearly minimum column ozone can be seen. Minimum values in recent years are about 100 DU lower than 20 years ago, as a consequence of the "ozone hole." Figure 3.2.8 shows the annual cycle in column ozone. Between January and August, ozone values are typically fluctuating around 300 DU, dropping to values of about 150 DU in October. This is similar to the pattern observed at McMurdo. In Table 3.2.2, average and minimum values for the months September – December are provided.

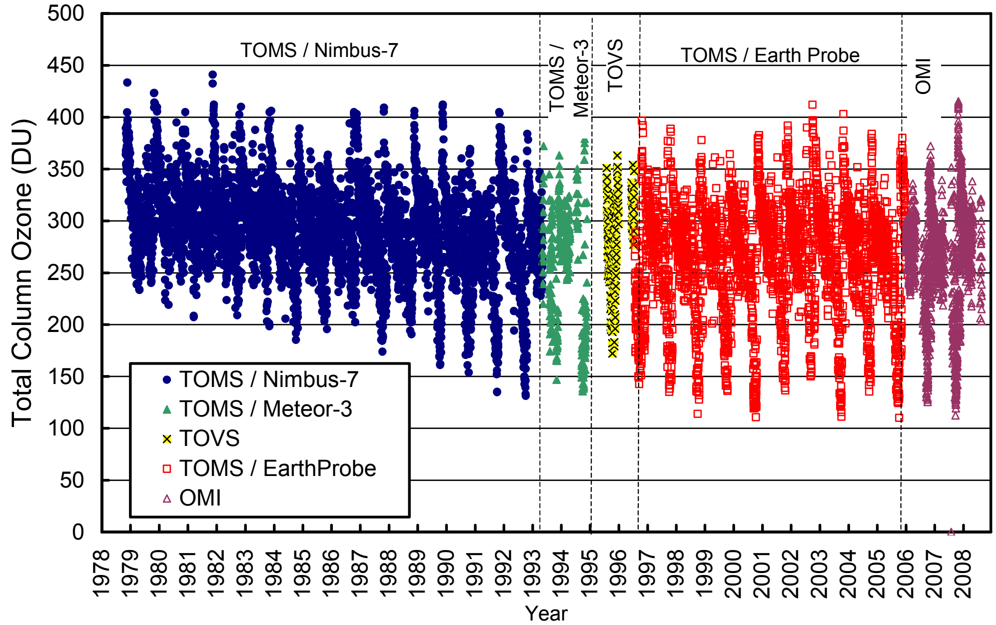

Figure 3.2.7. *Time record of total column ozone from TOMS, TOVS, and OMI data at Palmer Station. The downtrend attributed to ozone depletion can be seen clearly. Note the difference in the minimum ozone column observed in the 1970s versus that of the 1990s and 2000s.*

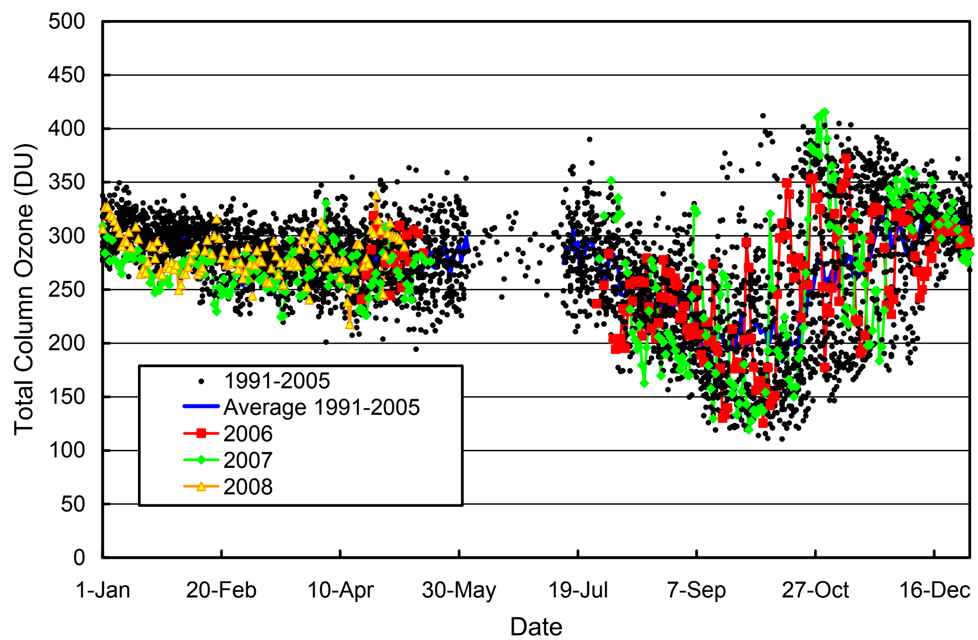

Figure 3.2.8. *Seasonal variation of total column ozone at Palmer Station. OMI measurements from 2006 - 2008 are contrasted with ozone data from the years 1991-2005 recorded by TOMS /Nimbus-7(1991-1993),TOMS/ Meteor-3 (1993-1994), NOAA/TOVS (1995-1996), and TOMS/Earth Probe (1997-2005) satellites. Data from June and July are from NOAA /TOVS.*

Table 3.2.2. Total ozone averages and minima for Palmer Station, September 1 – December 31.

	TOMS									OMI, Version 8.5			TOVS		
	Nimbus 7 Version 8			Meteor 3 Version 7			Earth Probe, Version 8								
Year	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**
1988	286	191	10/14/88												
1989	278	161	10/14/89												
1990	250	154	10/13/90												
1991	273	135	10/08/91												
1992	261	131	10/06/92												
1993				262	147	11/2/93									
1994				202	136	10/1/94							251.6	158	10/2/94
1995													261.5	172	10/14/95
1996							242	143	09/17/96				254.2	183	10/18/96
1997							251	135	10/05/97						
1998							237	114	10/01/98						
1999							243	136	10/16/99						
2000							252	111	10/11/00						
2001							263	136	10/21/01						
2002							291	150	09/09/02						
2003							255	111	10/05/03						
2004							262	135	09/22/04						
2005							250	110	10/7/05						
2006										258	125	10/05/06			
2007										260	112	09/25/07			

Note: 1998 TOMS/Earth Probe data is not available after 12/12/98. The average was therefore calculated from the period 9/1/98 – 12/12/98.

3.3. Amundsen-Scott South Pole Station, Antarctica

The South Pole system is installed at the top of the Atmospheric Research Observatory (ARO; Figure 3.3.1) at Amundsen-Scott South Pole Station, located at the geographical South Pole. This system operates in one of the harshest environments on the planet, with average temperatures of -49 °C. During the polar night, temperatures drop below -70 °C and rise rarely above -20 °C during the austral summer. Clouds are usually thin and clear sky days are frequent. This advantageous location provides conditions that are virtually free of daily changes in solar zenith angle, at substantial elevation (approx. 2841 m), in the cleanest known natural atmospheric environment on Earth. The South Pole is normally accessible only by airplane between November and February.

Prior to 1991, the instrument was located on top of the former Clean Air Facility (CAF). From January 1991 to January 1997, the instrument was built into an enclosure of the CAF allowing access from within the laboratory. In January 1997 the system was relocated from the CAF to ARO into a specially built "penthouse" room at the ARO.

Figure 3.3.1. *Top of the SUV-100 spectroradiometer installed into the roof the Atmospheric Research Observatory (ARO). In the background, the dome of the Amundsen-Scott South Pole Station and the building of the new station, which is currently under construction, can be seen. The pictures was taken in January 2002.*

The ARO is visited regularly by RPSC personnel. The system control computer is setup as a File Transfer Protocol (FTP) server. This allows for data to be directly transferred by BSI staff from the system control computer, limited only by satellite windows. Objects in the collector's field-of-view of the SUV-100 installation at the South Pole are listed in Table 3.3.1. The annual cycles of noontime solar zenith angle is shown in Figure 3.3.2.

Table 3.3.2 gives average and minimum values of total column ozone, observed in the months September – December. The change in column ozone during the last 20 years is indicated in Figure 3.3.3. Minimum ozone values in October of recent years are about 150 DU lower than in the 1970s. In the 1990s and

2000s, values below 100 DU have been observed, caused by the ozone hole. The severe loss of ozone in the stratosphere can also clearly be seen in Figure 3.3.4, where the annual cycle of column ozone at South Pole is depicted. Between August and October, column ozone values decrease from 300 DU down to values near 100 DU.

Table 3.3.1 Objects in the collector's field-of-view at the South Pole.

Object	Bearing	Elevation
Open frame radio tower	334.00° - 335.30°	7.83°
Galvanized steel wrapped exhaust stack	87.61° - 89.60°	15.26°
Galvanized steel wrapped exhaust stack	91.56° - 93.56°	17.21°
Open frame radio tower	181.89°	1.94°
Open frame radio tower with "T" shape construction at top, having a horizontal angular width of 2.25°	198.31° - 199.60°	1.39°

Notes: Sightings were made in January 1998 by ASA Surveying staff. Bearings are relative to Grid North.

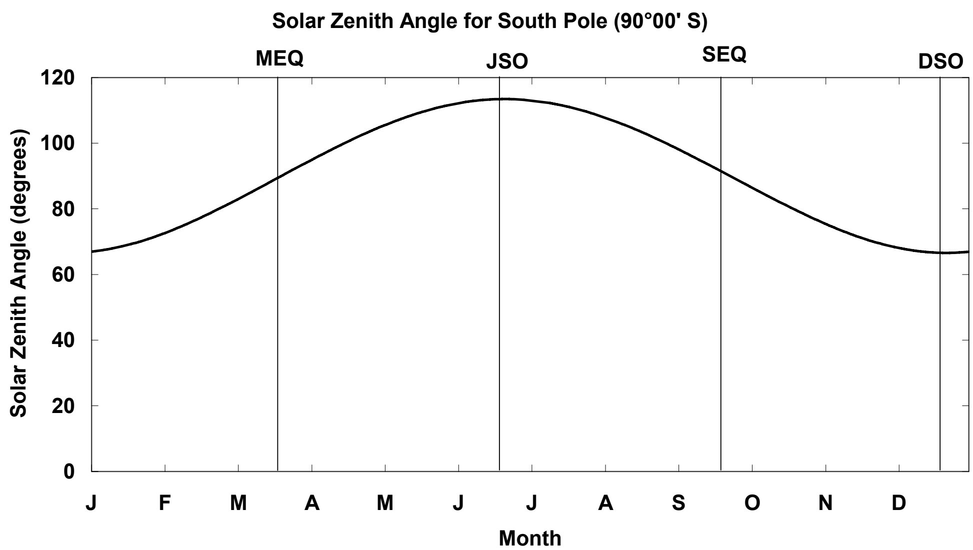

Figure 3.3.2. *Plot of noontime solar zenith angle at South Pole. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice).*

Table 3.3.2 Total ozone averages and minima for South Pole, September 27 – December 31.

	TOMS									OMI, Version 8.5			TOVS		
	Nimbus 7, Version 8			Meteor 3, Version 7			Earth Probe, Version 8								
Year	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date
1988	294	177	10/10/88												
1989	226	131	10/08/89												
1990	194	122	10/10/90												
1991	245	106	10/05/91												
1992	204	119	10/12/92												
1993				205.4	89	10/8/93, 10/12/93									
1994				206.34	108	10/2/94							231.9	93	10/23/94
1995													185.3	102	10/18/95
1996							202	107	10/05/96				178.3	105	10/25/96
1997							197	110	10/07/97						
1998							151	92	10/14/98						
1999							177	105	10/12/99						
2000							243	102	10/06/00						
2001							181	111	10/06/01						
2002							280	134	10/20/02						
2003							204	106	10/09/03						
2004							224	113	10/05/04						
2005							214	114	10/06/05						
2006										190	84	10/09/06			
2007										195	116	10/09/07			

Note: Earth Probe data from the years 1996, 1997, and 1998 is only available for the period 1-Oct –to 31-Dec.

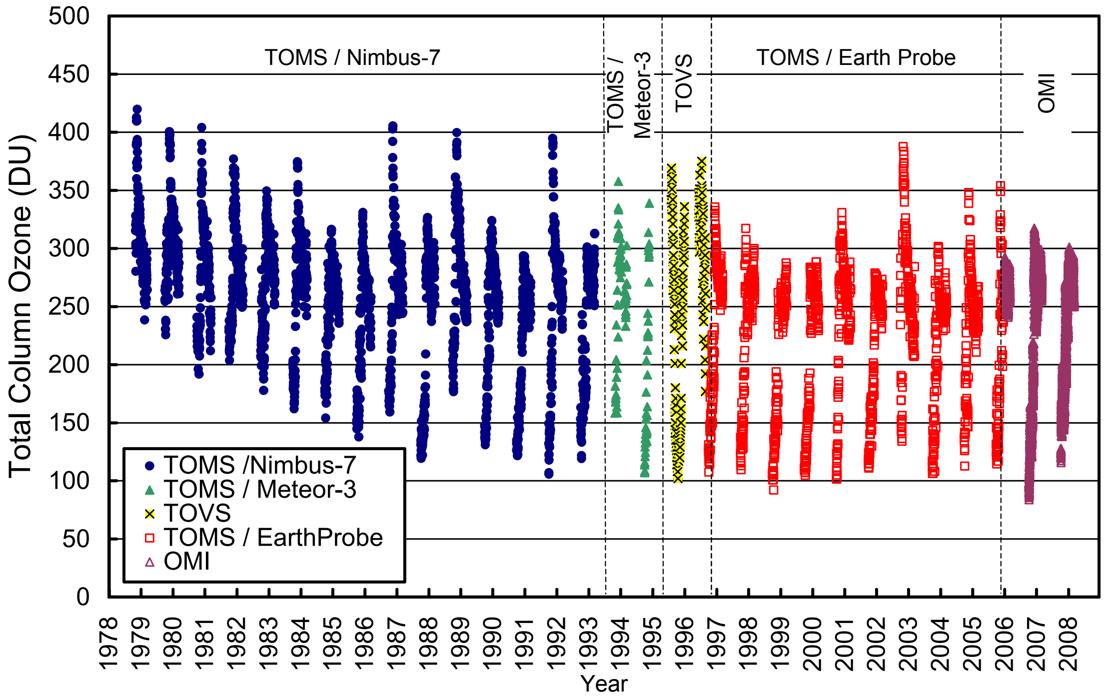

Figure 3.3.3. *Time record of total column ozone from TOMS,TOVS, and OMI data at South Pole. The downtrend attributed to ozone depletion can be seen clearly. Note the difference in the minimum ozone column observed in the 1970s versus that of the 1990s and 2000s.*

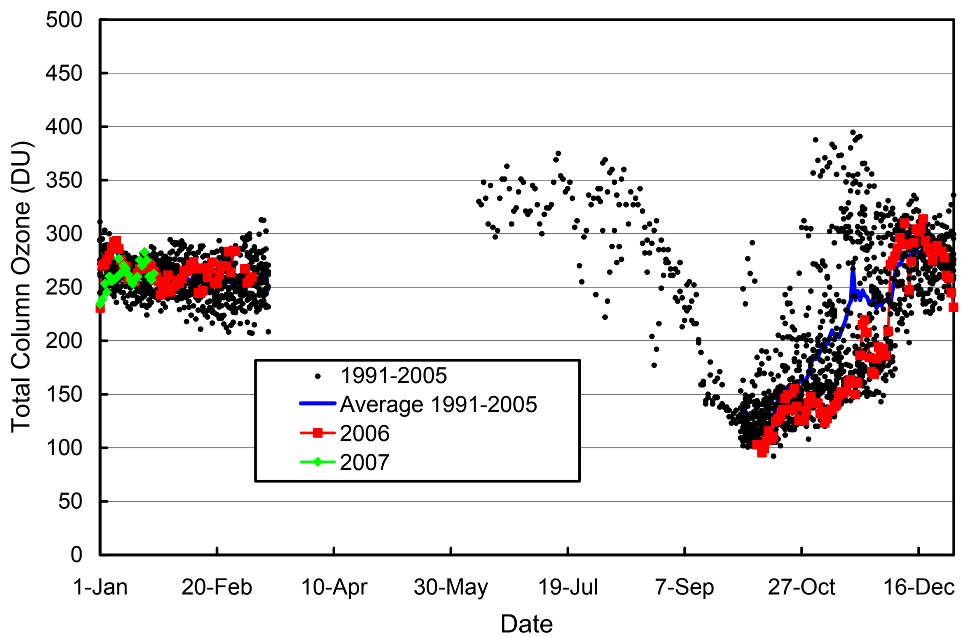

Figure 3.3.4. *Seasonal variation of total column ozone at South Pole. OMI measurements from 2006 and 2007 are contrasted with ozone data from the years 1991-2005 recorded by TOMS /Nimbus-7(1991-1993), TOMS/ Meteor-3 (1993-1994), NOAA/TOVS (1995-1996), and TOMS/Earth Probe (1997-2005) satellites. Data between March and mid-September are from NOAA /TOVS. The decrease in ozone values between July and September is clearly apparent. The data gap is due to the austral winter.*

3.4. Ushuaia, Argentina

The Ushuaia installation is near the southern port city of Ushuaia, Argentina, at the Centro Austral de Investigaciones Científicas (CADIC) facility. CADIC is a regional research center of the National Research Council of Argentina (CONICET). A Global Atmospheric Watch (GAW) Station is also located at Ushuaia. The installation (Figure 3.4.1) is located in the foothills of the Andes and is subject to frequent clouds, rain, and snow. The SUV-100 instrument is installed in the roof of the main CADIC building. The system control computer is connected via modem to a local Internet service provider. Data is usually transferred to BSI on a daily basis by the operator on-site.

Figure 3.4.1. *SUV-100 spectroradiometer installed in the roof of the CADIC facility in Ushuaia.*

A map showing the vicinity of Ushuaia is provided in Figure 3.4.2. Table 3.4.1 gives information on the position of obstructions in the collector's field-of-view. The annual cycles of day length and noontime solar zenith angle at Ushuaia are given in Figure 3.4.3 and Figure 3.4.4, respectively.

Table 3.4.2 gives average and minimum values of total column ozone, observed at Ushuaia in the months September – December. Figure 3.4.5 shows total column ozone measurements from the last 20 years. The downward trend in column ozone is much less pronounced that at the Antarctic sites because Ushuaia lies usually outside the region of the ozone hole. However, when the Antarctic vortex becomes unstable in November and December, ozone-depleted air masses can move towards Ushuaia and low ozone levels can then be observed. Figure 3.4.6 shows the annual cycle of column ozone at Ushuaia. Usually ozone levels in October and November are about 350 DU. When the outskirts of the ozone hole pass Ushuaia, total column ozone has dropped as low as 150 DU.

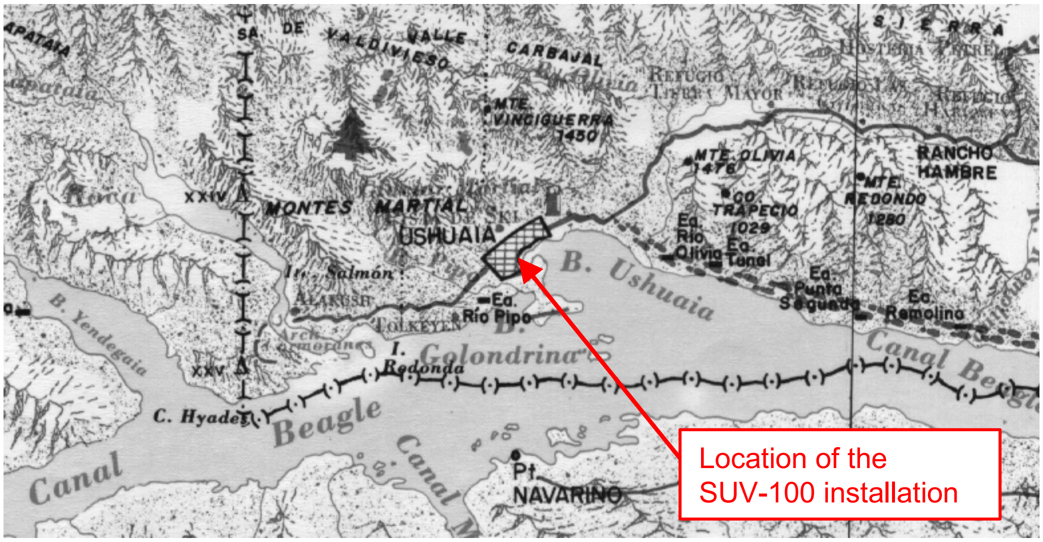

Figure 3.4.2. *Map of Ushuaia and vicinity.*

Table 3.4.1. Obstructions in the collector's field-of-view at Ushuaia.

Object Name	Range (degrees)	Elevation (degrees)
Mountains	8° - 33°	6.5°
Mountains, buildings	33° - 120°	4°
Mountains, across channel	120° - 206°	2.5°
Distant mountains	206° - 240°	4°
Mt. Susana	240° - 253°	4°
Distant mountains	253° - 286°	4°
Mountains	286° - 298°	10°
CADIC water tower	298° - 302°	17°
Mountains	302° - 8°	10°

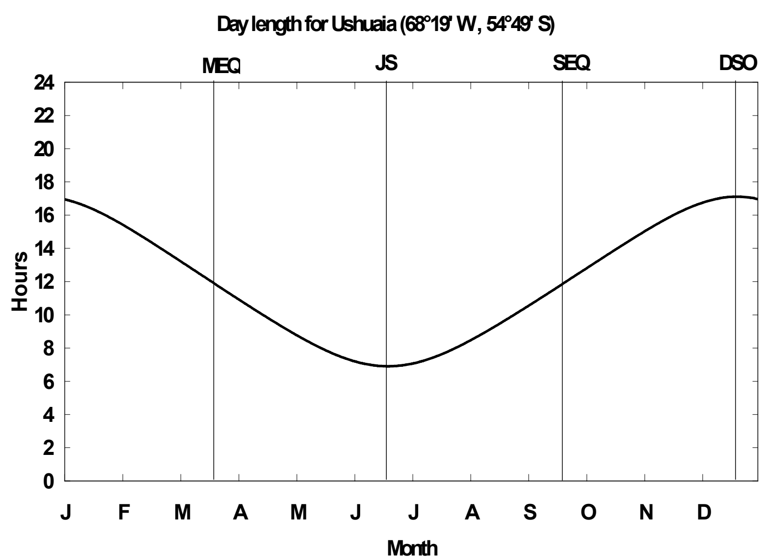

Figure 3.4.3. *Day length for Ushuaia. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice).*

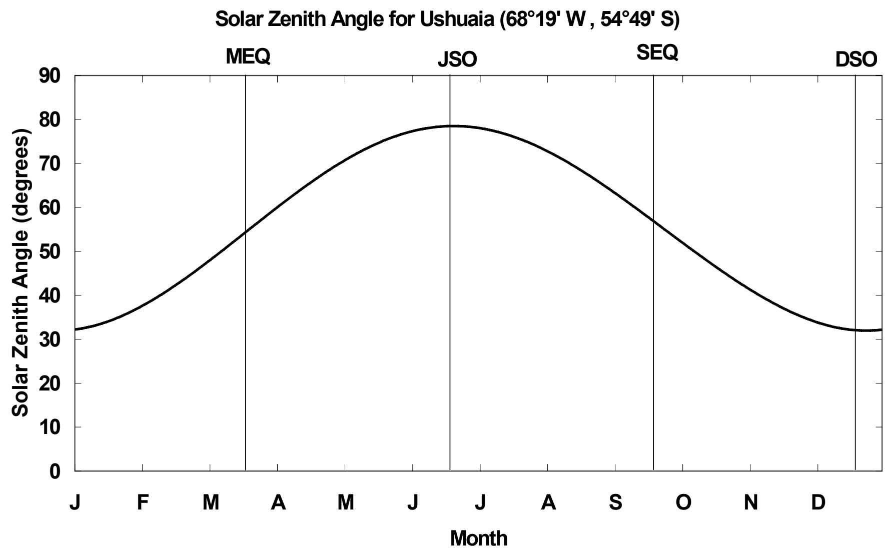

Figure 3.4.4. *Noontime solar zenith angle during the year at Ushuaia.*

Table 3.4.2. Total ozone averages and minima for Ushuaia, September 1 – December 31.

	TOMS									OMI, Version 8.5			TOVS		
	Nimbus 7, Version 8			Meteor 3, Version 7			Earth Probe, Version 8								
Year	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**
1988	319	228	10/21/88												
1989	319	220	10/16/89												
1990	303	198	10/13/90												
1991	310	192	10/23/91												
1992	306	152	10/05/92												
1993				308	212	11/12/93									
1994				283	154	10/17/94							303.5	172	10/17/94
1995													308.9	220	10/14/95
1996							312	198	09/17/96				313.9	201	9/17/96
1997							301	187	10/14/97						
1998							308	178	09/30/98						
1999							307	203	11/21/99						
2000							298	139	10/12/00						
2001							313	212	10/21/01						
2002							317	188	09/09/02						
2003							303	136	10/06/03						
2004							296	171	09/21/04						
2005							302	161	10/08/05						
2006										310	193	10/05/06			
2007										310	169	09/24/07			

Note: 1998 TOMS/Earth Probe data is not available after 12/12/98. The average was therefore calculated from the period 9/1/98 – 12/12/98.

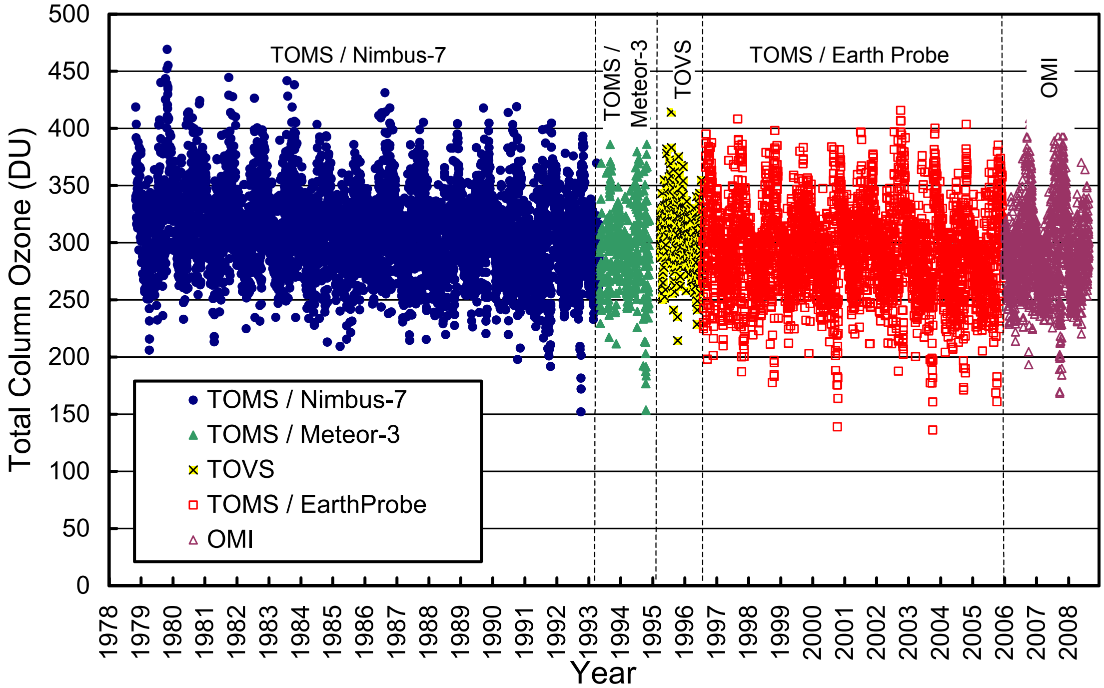

Figure 3.4.5. *Time record of total column ozone from TOMS and TOVS data at Ushuaia. Note the difference in the minimum ozone column observed in the 1970s versus that of the 1990s and 2000s.*

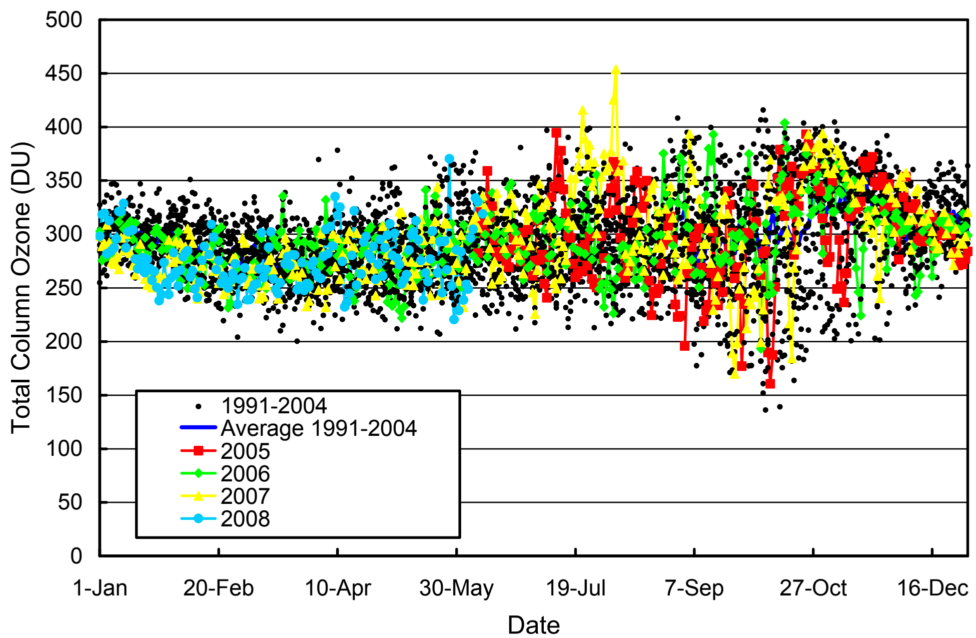

Figure 3.4.6. *Seasonal variation of total column ozone at Ushuaia. OMI and TOMS/Earth Probe measurements between 2005 – 2008 are contrasted with ozone data from the years 1991-2004 recorded by TOMS /Nimbus-7(1991-1993),TOMS/ Meteor-3 (1993-1994), NOAA/TOVS (1995-1996), and TOMS/Earth Probe (1997-2004) satellites.*

3.5. San Diego, California, USA

The spectroradiometer system at San Diego (Figure 3.5.1) is located in the roof of Biospherical Instruments Inc., approximately five kilometers from the Pacific Ocean. It was installed in October 1992. In addition to collecting data for the NSF UV network, this SUV is used for testing of software and hardware, evaluating long-term engineering changes, and training of site operators. System operation is more frequently interrupted by these activities than at other network sites.

Figure 3.5.1. *SUV-100 mounted through the roof of a specially constructed room at Biospherical Instruments in San Diego, California. This rooftop facility is used for calibration and intercomparison of UV and visible radiometers.*

The city of San Diego is situated on San Diego Bay in the southwestern-most corner of California (32°46’N, 117°12’W). The Pacific Ocean tempers prevailing winds and weather, creating an environment different from other locations along this latitude. Temperatures typically range from 16 to 27 °C throughout the year. Temperatures of freezing or below almost never occur, while hot (32 °C or higher) weather is more frequent. Considerable fog occurs on the coast (where the instrument is located), particularly during spring and early summer. The following figures illustrate the day length and typical zenith angles during noon for San Diego, California. Typical cloud cover data are summarized in Table 3.5.1.

Table 3.5.1. Typical cloud-cover data for San Diego.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Sky Cover	3.9	5.9	7.0	5.7	8.1	4.7	5.1	3.4	3.0	5.0	3.7	4.5
% Possible Sunshine	83	68	54	77	40	62	64	82	84	68	90	71
Number of Clear Days	18	8	6	9	3	15	11	17	21	12	17	13
Number of Cloudy Days	10	12	19	11	22	7	7	3	4	10	8	10
Number of Part/Cloudy Days	3	9	6	10	6	8	13	11	5	9	5	8

Note: Data supplied by the National Weather Service.

The annual cycles of day length and noontime solar zenith angle at San Diego are given in Figure 3.5.2 and Figure 3.5.3, respectively.

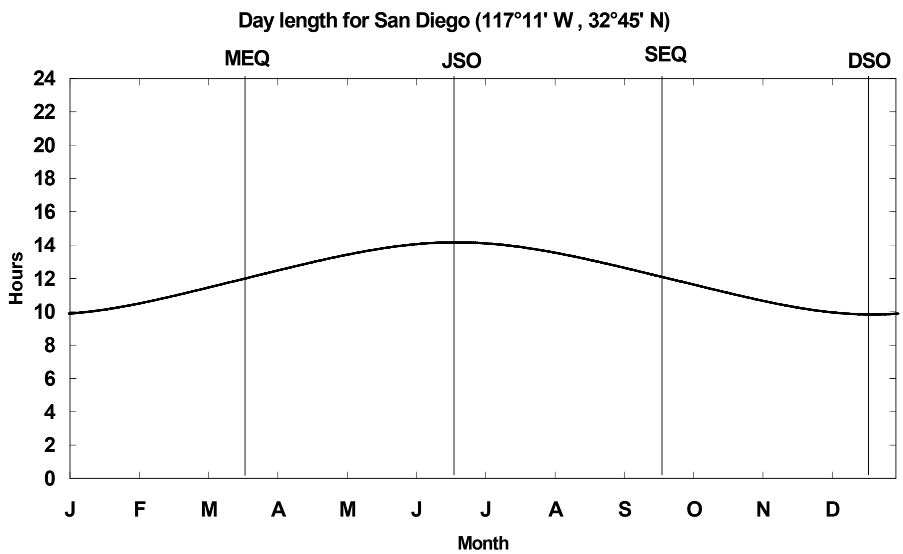

Figure 3.5.2. *Day length for San Diego. (MEQ=March equinox, JSO=June solstice, SEQ=September equinox, DSO=December solstice)*

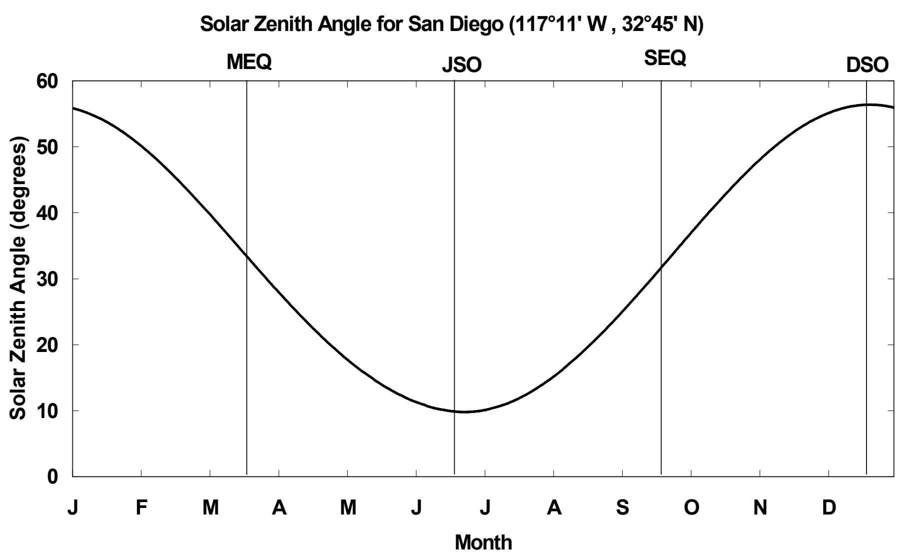

Figure 3.5.3 *Noontime solar zenith angle during the year at San Diego.*

Table 3.5.2 gives average and minimum values of total column ozone, observed at San Diego. For some years, the TOMS and TOVS datasets are not available for all months. Figure 3.5.4 shows a time series of total column measurements during the last 20 years. There is no obvious trend in ozone. Also the seasonal variation of ozone is small (Figure 3.5.5), with slightly more scatter in spring.

Table 3.5.2. Total ozone averages and minima for San Diego, January 1 – December 31.

Year	TOMS												TOVS		
	Nimbus 7, Version 8			Meteor 3, Version 7			Earth Probe, Version 8			OMI, Version 8.5					
	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date
1988	297	220	01/26/88												
1989	301	243	11/22/89												
1990	305	244	11/30/90												
1991	311	237	12/04/91	286.6	243	12/4/91									
1992	297	220	12/25/92	298.1	224	12/25/92									
1993				286.8	235	11/20/93									
1994				305.1	218	11/24/94							293.8	227	3/20/94
1995													291.1	239	12/12/95
1996							276	218	11/24/96				299.3	257	2/19/96
1997							289	242	01/30/97						
1998							302	239	11/27/98						
1999							294	231	11/30/99						
2000							292	235	12/21/00						
2001							296	234	10/30/01						
2002							291	225	01/02/02						
2003							293	226	11/18/03						
2004							290	221	12/11/04						
2005							291	225	11/30/05						
2006										295	232	02/05/06			
2007										297	239	12/04/07			

Note: Shaded areas represent partial year data.

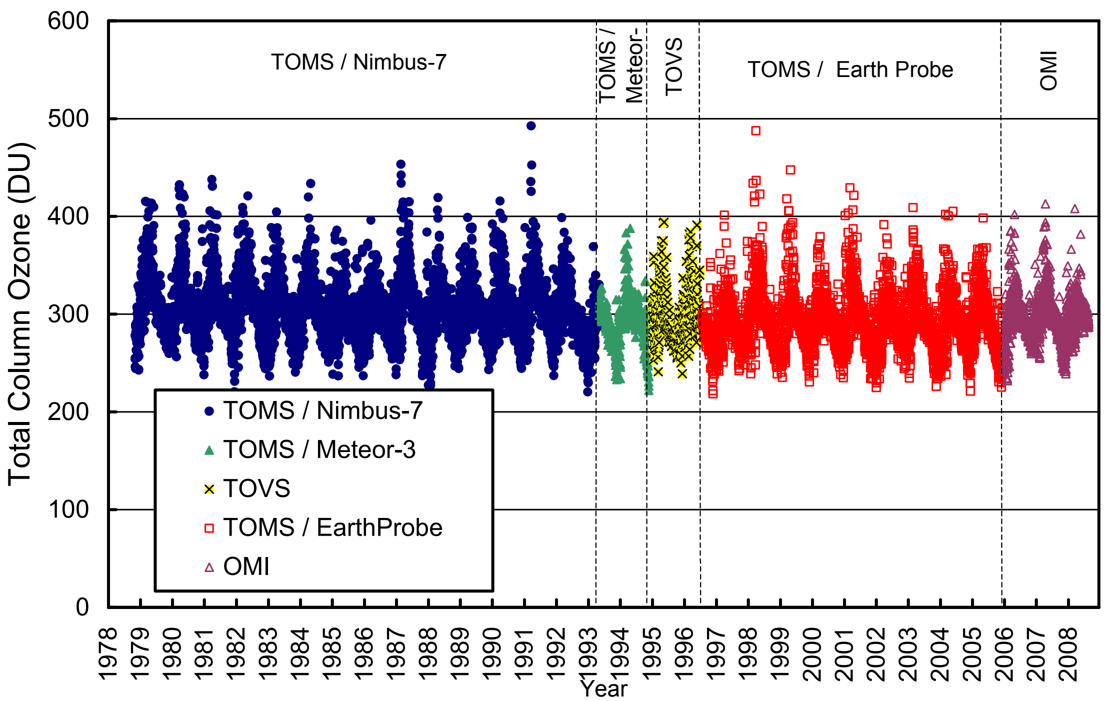

Figure 3.5.4. *Time record of total column ozone at San Diego.*

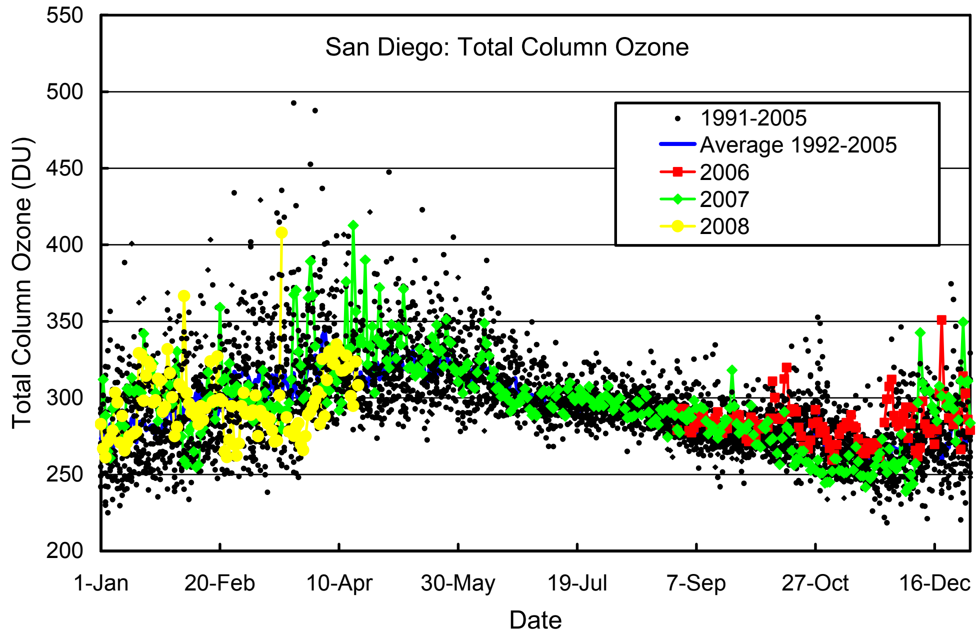

Figure 3.5.5. *Seasonal variation of total column ozone at San Diego. OMI measurements from 2006 - 2008 are contrasted with ozone data from the years 1991-2003 recorded by TOMS /Nimbus-7(1991-1993),TOMS/ Meteor-3 (1993-1994), NOAA/TOVS (1995-1996), and TOMS/Earth Probe (1997-2005) satellites.*

3.6. Barrow, Alaska, USA

The Barrow installation is located on Alaska's North Slope at the edge of the Arctic Ocean close to the village of Barrow. The instrument is located in the Ukpeaġvik Iñupiat Corporation (UIC) facility, see Figure 3.6.1. Barrow is also a research site of NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL) and the Department of Energy's Atmospheric Radiation Measurement (ARM) program. Up to March 2006, routine calibrations and instrument maintenance were conducted by personnel from the nearby NOAA/CMDL facility. From April 2006 onward, ARM personnel took over operations. Data is automatically being downloaded from the system control computer via the Internet.

Figure 3.6.1. *Roof installation of the SUV-100 spectroradiometer in Barrow with snow-covered tundra in the background.*

Cloud cover in Barrow is highly variable and significant changes in surface albedo occur due to both the springtime snowmelt and changes in sea ice coverage. Barrow also experiences significant changes in incident irradiance due to Arctic storms. Cloudy conditions are more frequent in fall than in spring. The seasonal difference in cloud cover and surface albedo leads to a strong spring/fall asymmetry of irradiance measurements in the UVA and visible. This asymmetry is less pronounced in UV-B radiation because the seasonal cycle in ozone partly compensates for cloud and albedo effects. For details, see Bernhard et al. (2007).

The annual cycles of day length and noontime solar zenith angle at Barrow are given in Figure 3.6.2 and Figure 3.6.3, respectively.

Table 3.6.1 gives average and minimum values of total column ozone, observed at Barrow in the months of February through June; times series of ozone values during the last 20 years are shown in Figure 3.6.4. The downward trend of column ozone in Barrow is much less pronounced than at the Antarctic sites. Figure 3.6.5 shows the annual cycle of total column ozone. Ozone values are usually about 100 DU lower in fall than in spring. In recent years, ozone depletion has also been observed in the Arctic and episodes of lower column ozone values can now be observed also in the boreal spring.

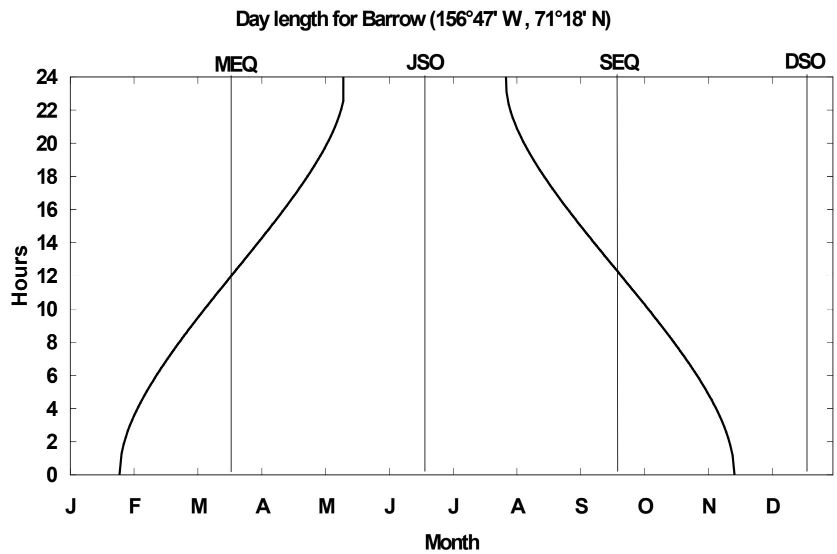

Figure 3.6.2. *Day length for Barrow. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice).*

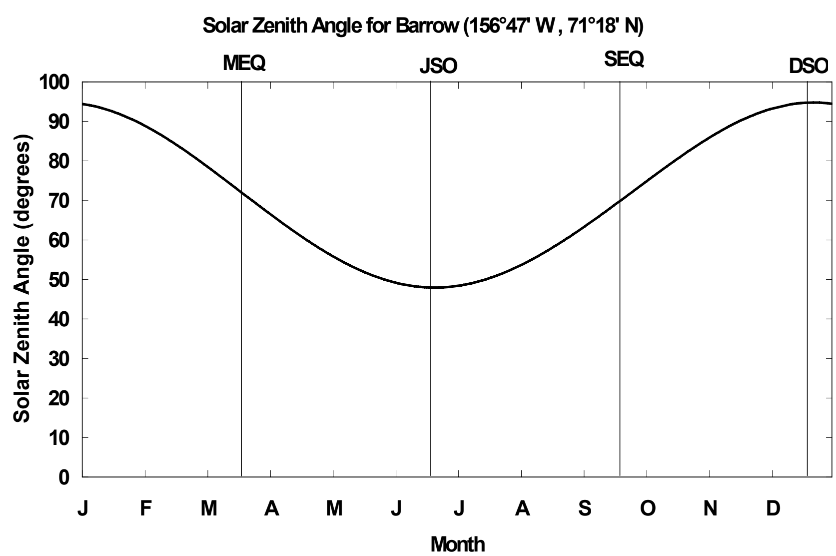

Figure 3.6.3. *Noontime solar zenith angle for Barrow.*

Table 3.6.1. Total ozone averages and minima for Barrow, February 1 – June 30.

	TOMS									OMI, Version 8.5			TOVS		
	Nimbus 7			Meteor 3			Earth Probe								
Year	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date	Avg	Min	Date
1988	413	312	06/11/88												
1989	394	263	06/29/89												
1990	391	290	04/07/90												
1991	407	303	06/29/91												
1992	391	294	06/29/92	390.5	274	6/30/92									
1993	370	304	03/14/93	365.1	304	6/30/93									
1994				414.0	338	2/17/94							403.1	319	3/27/94, 3/28/94
1995													366.7	289	3/6/95
1996													384.9	286	3/2/96
1997							377	282	06/24/97						
1998							420	331	06/28/98						
1999							407	307	06/22/99						
2000							385	309	06/23/00						
2001							413	302	06/29/01						
2002							381	281	05/21/02						
2003							408	307	06/13/03						
2004							387	282	06/21/04						
2005							389	291	04/28/05						
2006										296	275	06/19/06			
2007										404	299	06/05/07			

Note: 1994 TOVS data is only partially available; actual data starts month later on 3/1/96. TOMS/Earth Probe data is not available before February 11. The average was therefore calculated over a shorter period.

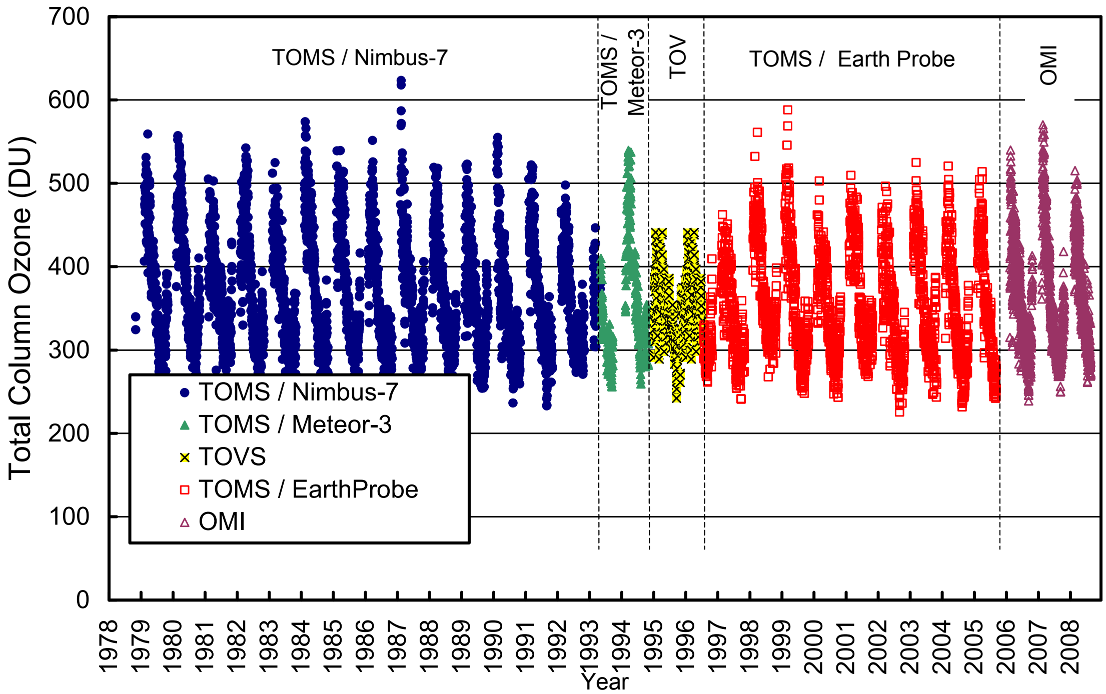

Figure 3.6.4. *Time record of total column ozone from TOMS,TOVS, and OMI data at Barrow.*

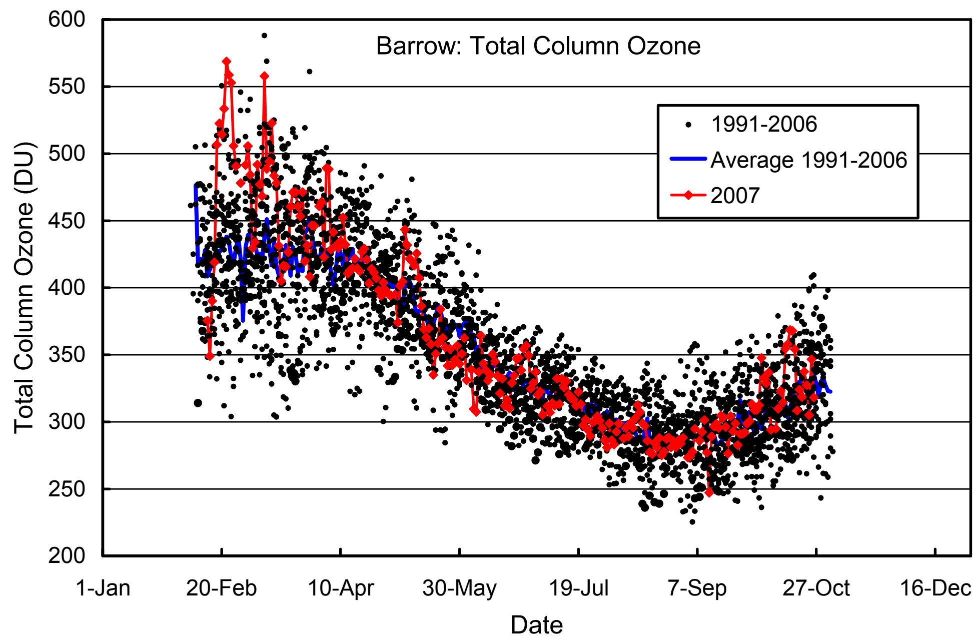

Figure 3.6.5. *Seasonal variation of total column ozone at Barrow. OMI measurements from 2007 and are contrasted with ozone data from the years 1991-2006 recorded by TOMS /Nimbus-7(1991-1993),TOMS/ Meteor-3 (1993-1994), NOAA/TOVS (1995-1996), and TOMS/Earth Probe (1997-2005) satellites and OMI (2006) satellites.*

3.7. Summit, Greenland

The Summit site is at the Greenland Environmental Observatory at Summit (GEO - Summit Camp), located at the high-point of Greenland's ice cap. The station is at 3200 m above sea level, which is the highest elevation north of the Arctic circle. High altitude, cold temperatures, and low atmospheric water vapor content provide unique opportunities for a variety of atmospheric measurements. Conditions are similar to those at the South Pole, although wind speed and precipitation are greater, and haze is more frequent.

Summit is currently the only network site where a SUV-150B spectroradiometer (see Chapter 2) is deployed (Figure 3.7.1). The instrument was installed in August 2004 into the "Green House," which also serves as berthing facility. High snow accumulation during the winter of 2004/2005 required releveling of the building. The instrument had to be temporarily removed for this activity and no data are therefore available for the period 5/18/05 - 7/31/05. Routine calibrations and instrument maintenance are conducted by personnel from VECO Polar Resources. Data are downloaded daily from the system control computer by BSI staff via the Internet.

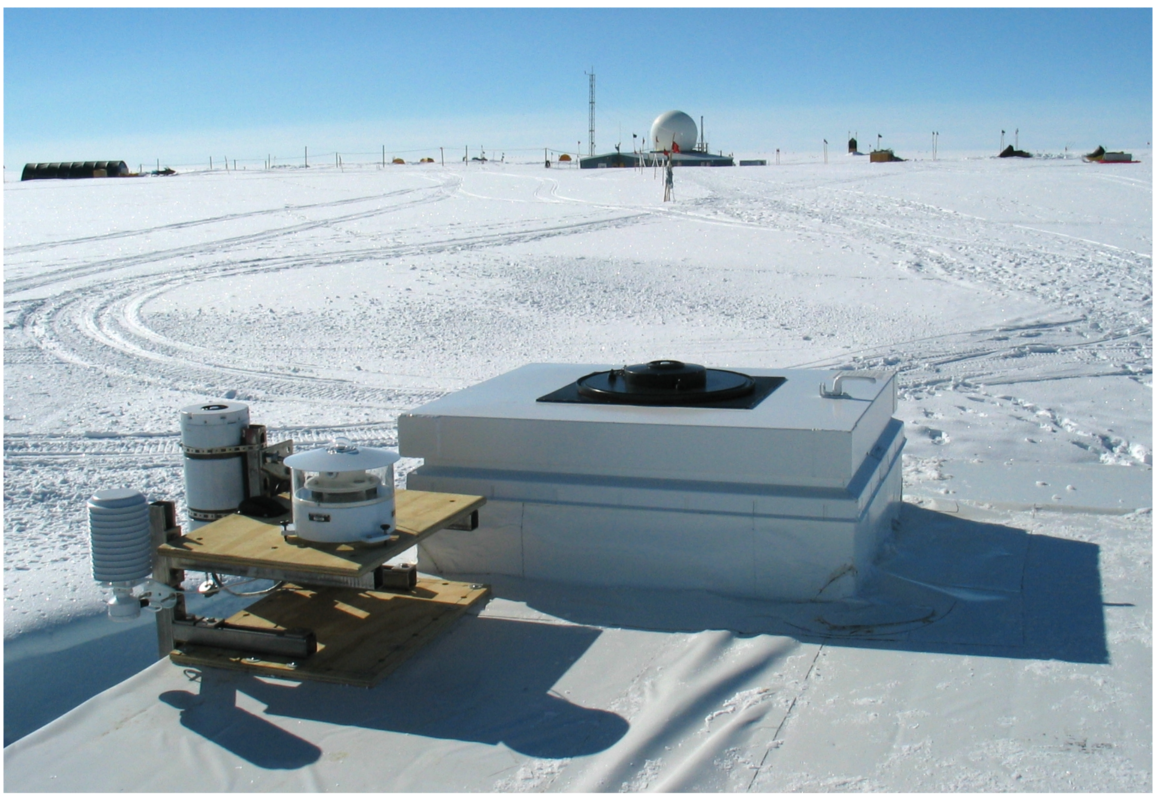

Figure 3.7.1. *Roof installation of the SUV-150B spectroradiometer and ancillary sensors on top of the "Green House" at Summit. GUV-511 and PSP radiometers are mounted to the shelf on the left. The entrance optics of the SUV-150B is in the center of the roof hatch.*

The annual cycles of day length and noontime solar zenith angle at Summit are given in Figures 3.7.2 and 3.7.3., respectively.

Table 3.7.1 gives average and minimum values of total column ozone at Summit in March, observed by TOMS / Earth Probe and OMI. Figure 3.7.4. shows times series of total ozone measured during the last 10 years. Figure 3.7.5 shows the annual cycle of total column ozone. Ozone values typically range between 250 DU in fall and 500 DU in spring. There is a large year-to-year variability in spring (February

- April) caused by annual variations in photochemical ozone destructions. Ozone values in February 2005 were abnormally small.

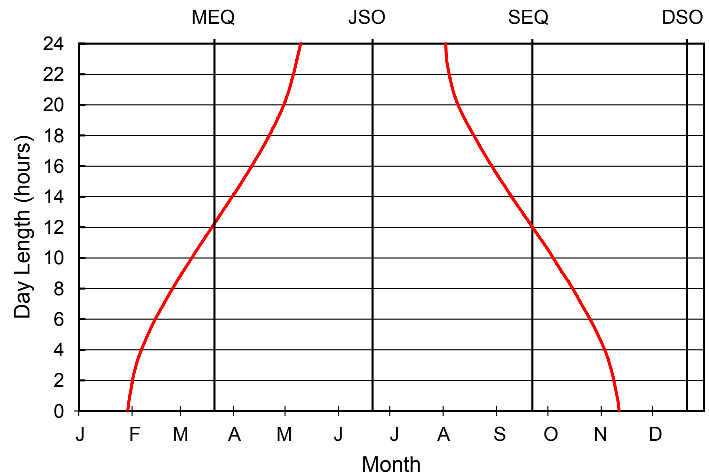

Figure 3.7.2. *Day length for Summit. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice).*

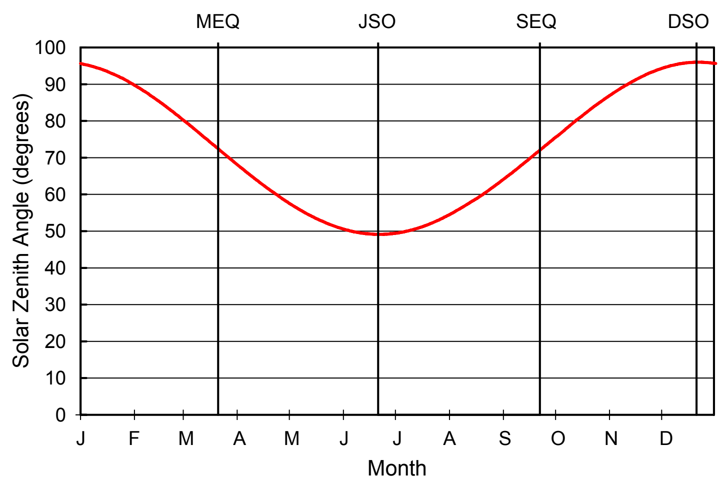

Figure 3.7.3. *Noontime solar zenith angle for Summit.*

Table 3.7.1. Total ozone averages and minima for Summit, March 1 – March 31.

	TOMS Earth Probe			OMI		
Year	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**
1997	317	267	03/27/97			
1998	391	290	03/13/98			
1999	467	270	03/31/99			
2000	387	306	02/29/00			
2001	438	360	03/01/01			
2002	418	320	03/18/02			
2003	384	295	03/06/03			
2004	400	328	03/10/04			
2005	337	247	03/06/05			
2006				396	265	03/18/06
2007				365	263	03/20/07

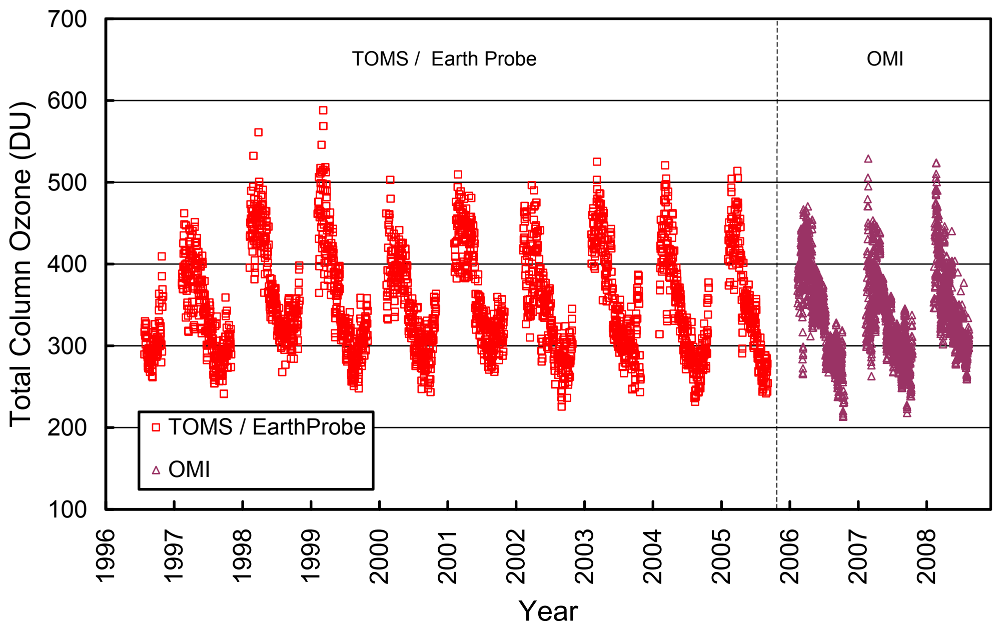

Figure 3.7.4. *Time record of total column ozone from TOMS and OMI at Summit.*

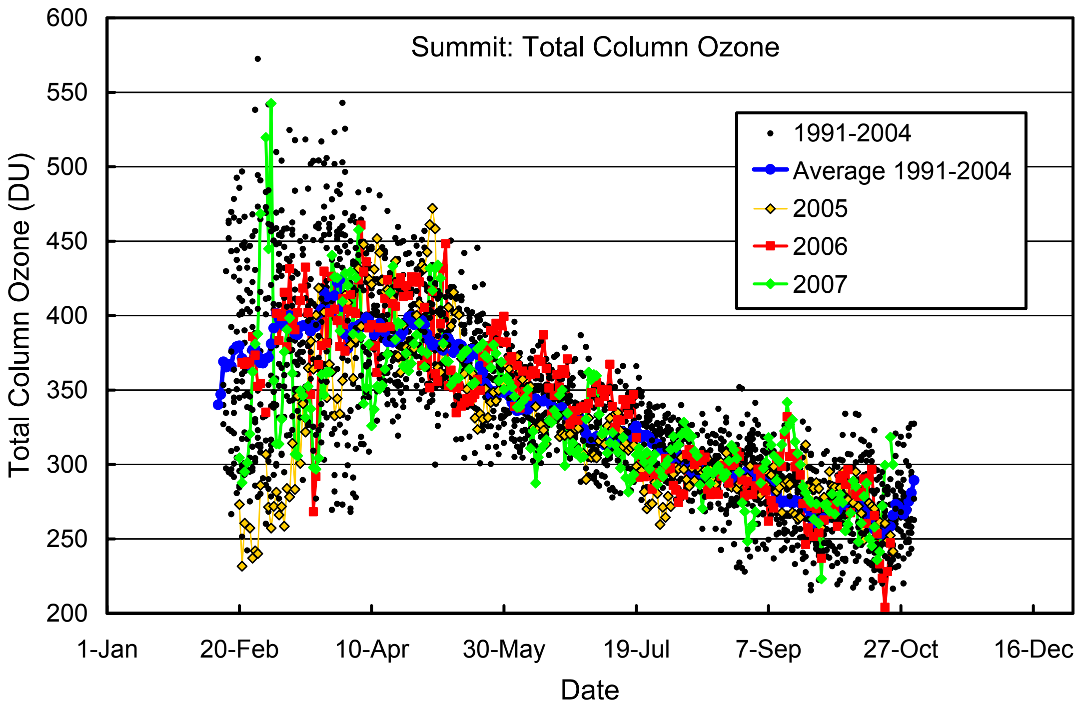

Figure 3.7.5. *Seasonal variation of total column ozone at Summit. OMI and TOMS/Earth Probe measurements from 2005 – 2007 are contrasted with ozone data from the years 1996-2004 recorded by TOMS/Earth Probe. Note that total ozone column in the spring of 2005 was abnormally low.*