AN OVERVIEW OF THE ASTEX DATA COLLECTED AT PORTO SANTO

by R. Levy, D. Randall and W. Schubert

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Colorado State University

DEPARTMENT OF ATMOSPHERIC SCIENCE

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ABSTRACT

The purpose of this paper is to try to "make a story" out of some of the ASTEX observations of 1 to 28 June, 1992. This paper will concentrate on observations from the rawinsonde, ceilometer, microwave radiometer, solar pyranometer, and 8 mm radar, as well as visual observations. The ceilometer, radiometer and pyranometer data have been grouped together in two-minute intervals throughout the whole month. The 203 balloon soundings were launched approximately every three hours. All forms of data have been fitted together in "time-windows" of one hour width(around the sonde launch time) in order to get a clear picture of what was going on. Most of this paper is in the form of tables and pictures.

TABLE of CONTENTS

LIST of FIGURES

1. INTRODUCTION

1.1 ASTEX

ASTEX is the acronym for the Atlantic Stratocumulus Transition Experiment which was conducted from 1 to 28 June in the region of the Azores and Madeira Islands of the north Atlantic Ocean. The primary goal of ASTEX was to gain an understanding of the processes responsible for the maintenance and dissipation of boundary layer clouds, especially the transition between stratocumulus and trade cumulus clouds. More detail can be found in the ASTEX plan (FIRE Project Office 1992) and in Schubert et al., (1992)

1.2 Porto Santo

One of the islands that was used in the experiment was Porto Santo (33.08 N, 16.33 W). This island, with an area about 50 square kilometers, is almost continually influenced by the Azores high pressure area during the summer months. The instruments were all located at 97 meters above sea level and about 200 meters south of the Northern coast in order to minimize island effects.

1.3 The Instruments

The instruments listed below were supplied by various organizations. A detailed discussion can be found in the ASTEX Operations Plan (FIRE Project Office, 1992) or Cox et al., (1993).

1.3.1 Rawinsonde

Soundings were taken approximately every three hours with an Intellisonde Rawin System. Actually, the data that were used in this paper are "level 2" data, data which had already been filtered for errors and is available via anonymous ftp on ROSSBY. This level 2 data consists of interpolated data at 10 meter increments of geopotential height. Values of height, pressure, temperature, dewpoint temperature, wind speed and wind direction were available for every 10 meters. Unfortunately, many of the soundings had missing data in the first 200-500 meters.

Visual observations were also taken during the soundings, starting about half way through the experiment. For more information about the Rawinsonde system and its data, see Schubert et al., (1992).

1.3.2 Laser Ceilometer

Ceilometer readings were taken approximately every minute throughout the month. The data are stored in /data/astexdata/ceilometer on TRUENO. The data file has recordings of date, time and ceiling height (in meters above sea level); where "-1" indicates "no ceiling."

1.3.3 Microwave Radiometer

This data set can be recovered by anonymous ftp from TRUENO. The radiometer-derived liquid water path and precipitable water path are given at two minute intervals throughout the experiment. Missing data is not listed in the data files. Much of the data for liquid water path (32%) was registered as negative, but not below -0.10 mm.

1.3.4 Solar Pyranometer

The pyranometer measured shortwave irradiance, near infrared irradiance and infrared irradiance at two minute intervals throughout the experiment. Missing data was represented by -99.99 and many values for near infrared and total solar irradiation were negative. This data set can be recovered by anonymous ftp from ROSSBY.

1.3.5 NOAA/WPL 8 mm Doppler Radar

This scanning radar measures radar cross section as a function of height and doppler shifted frequency. For the duration of ASTEX, the radar pointed straight up, providing information about the same sky region seen by the ceilometer and the radiometer. For more information see Kropfli et al., (1993).

2. THE RAW DATA

Table 1 is a portion of the complete table of data collected every two minutes throughout ASTEX. Each row lists the date and time of the observation, the cloud base level (ceilometer), the liquid water path and the precipitable water path (radiometer), and the solar total irradiation, near infrared irradiation, infrared irradiation, surface temperature and surface relative humidity (from the pyranometer).

There were two difficulties in dealing with the data. First was the fact that some of the data (3.4% of the ceilometer, pyranometer and radiometer data) was missing. This included: missing ceilometer data on 5, 17, 25 and 26 of June, and missing radiometer data on the 6th, 7th and the 22nd. In some cases the sounding data was also missing, especially for the first 100-200 meters (sometimes 500 meters or more). The "error flags" initially were all different, so they were made consistent.

The other difficulty was in the keeping of time. Each data set used a different "code" for the date and time. Time was kept for the ceilometer and pyranometer in Julian Decimal day: i.e. 160.82710, the radiometer was written as 19.8505 (stored in file that its name included June 8th), and the soundings were written in file names that included the date, hour, and minute. The equivalent date and time were 8 June, 19:50 GMT. Programs were written just to convert the time, so that all data sets used the same time-keeping system.

Originally, the liquid water path was measured in millimeters, equivalent to kilograms per square meter, while the precipitable water was measured in grams per square centimeter. The precipitable water path units were converted to millimeters.

Finally, once all the data was referred to the same time, a data set was made to include all of the data at two minute intervals throughout the whole experiment. This made it possible to figure out what was going on at a certain time on a certain day. This dataset (hereafter called the "all" data-set) was used for subsequent analyses.

DAY	HR	MN	ceiling	prec.	liq.	Solar Tot.	Near Inf.	Infrared	T (°C)	RelH.
601	12	0	0	20.4	0.01	1171.71	602.417	362.289	20.2	75.8
601	12	2	6898	20.9	0.04	1068.87	543.907	366.062	20.1	75.3
601	12	4	625	20.6	0.03	419.344	202.014	355.274	20	74.9
601	12	6	0	20.6	0.02	856.251	418.328	354.747	20.1	75.3
601	12	8	2134	20.4	0.01	841.229	413.998	346.073	19.9	74.9
601	12	10	2127	20.3	0.01	710.538	345.216	345.048	19.8	74.9
601	12	12	5313	20.6	0.01	1282.64	665.76	363.909	19.8	75.8
601	12	14	648	20.7	0.01	605.385	297.986	354.361	19.9	76.2
601	12	16	0	20.5	0.01	517.68	236.858	344.038	20	75.2
601	12	18	7172	20.3	0.01	1134.74	574.723	345.585	19.9	74.6
601	12	20	0	20.7	0.01	850.474	424.572	347.194	20.1	74.7
601	12	22	6014	20.8	0.01	522.302	250.151	337.953	20.2	74.4
601	12	24	846	20.9	0.01	1220.25	626.888	357.025	20.2	74.8
601	12	26	3186	21.3	0.02	1164.78	596.677	350.227	20.3	74.9
601	12	28	4848	21	0.01	1187.89	610.574	353.552	20.4	75.2
601	12	30	1059	20.8	0.02	1243.36	642.497	360.889	20.4	73.9
601	12	32	4444	21.5	0.03	1184.42	612.991	362.031	20.5	73.4
601	12	34	655	21.4	0.01	1260.69	655.79	370.674	20.6	73.7
601	12	36	648	22	0.06	567.252	280.765	368.223	20.5	73.4
601	12	38	1143	21.8	0.03	589.669	282.377	373.843	20.5	74.2
601	12	40	6623	22.1	0.08	592.443	284.391	372.213	20.4	73.9
601	12	42	6745	21.4	0.02	659.81	317.623	373.173	20.1	73.7
601	12	44	1852	21.8	0.09	452.161	213.293	371.318	20.1	73.9
601	12	46	1822	21.9	0.12	412.064	192.044	379.033	20	73
601	12	48	1890	22.3	0.14	389.184	179.758	377.701	19.9	74.1
601	12	50	6631	22.5	0.13	378.091	172.709	377.827	19.8	74.6
601	12	52	1883	22.4	0.15	382.713	174.723	378.029	19.8	74.7

Table 1 Part of Table of Data Collected Every Two Minutes During ASTEX.

DAY, HR, MN are the time of observation, ceiling height (m), precipitable water path (mm), liquid water path (mm), Solar Total Irradiation (W m^{-2}), Near Infrared Irradiation (W m^{-2}), Downwelling Infrared Irradiation (W m^{-2}), T(°C), and RelH (%)

2.1 Histograms and History

Histograms have been made for each of the different data types. About 25% of the liquid water measurements were between 0.00 and 0.01, and 32% were below 0.00, indicating an error in the calibration of the instrument. The histogram of precipitable water shows most observations in the 19 to 23 mm range. (FIGURE 1 and FIGURE 2). The other histograms and history can be found in Cox et al. (1993).

FIGURE 3 is a graph of time of day versus height of cloud base as registered by the ceilometer. It was hypothesized that time of day would have an effect on the likelihood of clouds and their base levels. Upper-level clouds (3250 meters and higher) were only detected between 8:00 and 16:00 GMT, with the highest concentration around 13:00 GMT, which corresponds to noon on Porto Santo. There also seems to be less likelihood of extremely low clouds (< 300 meters) between 16:00 and 20:00 GMT.

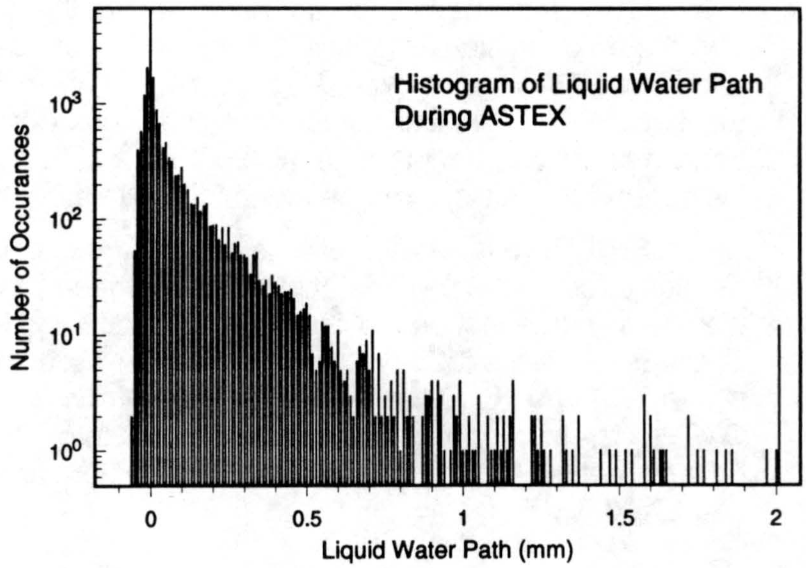


FIGURE 1 Histogram of Liquid Water Path During ASTEX

Y - axis is in log form to show numbers better. $10^0 = 1$. Blank columns are zero. The column above 2 is for all observations greater than or equal to 2.

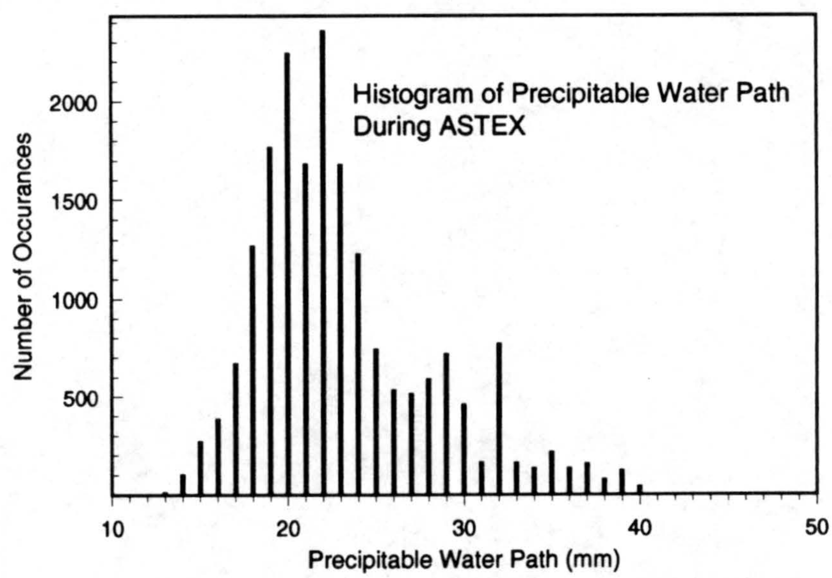


FIGURE 2 Histogram of Precipitable Water Path During ASTEX

Precipitable water path is measured by the microwave radiometer.

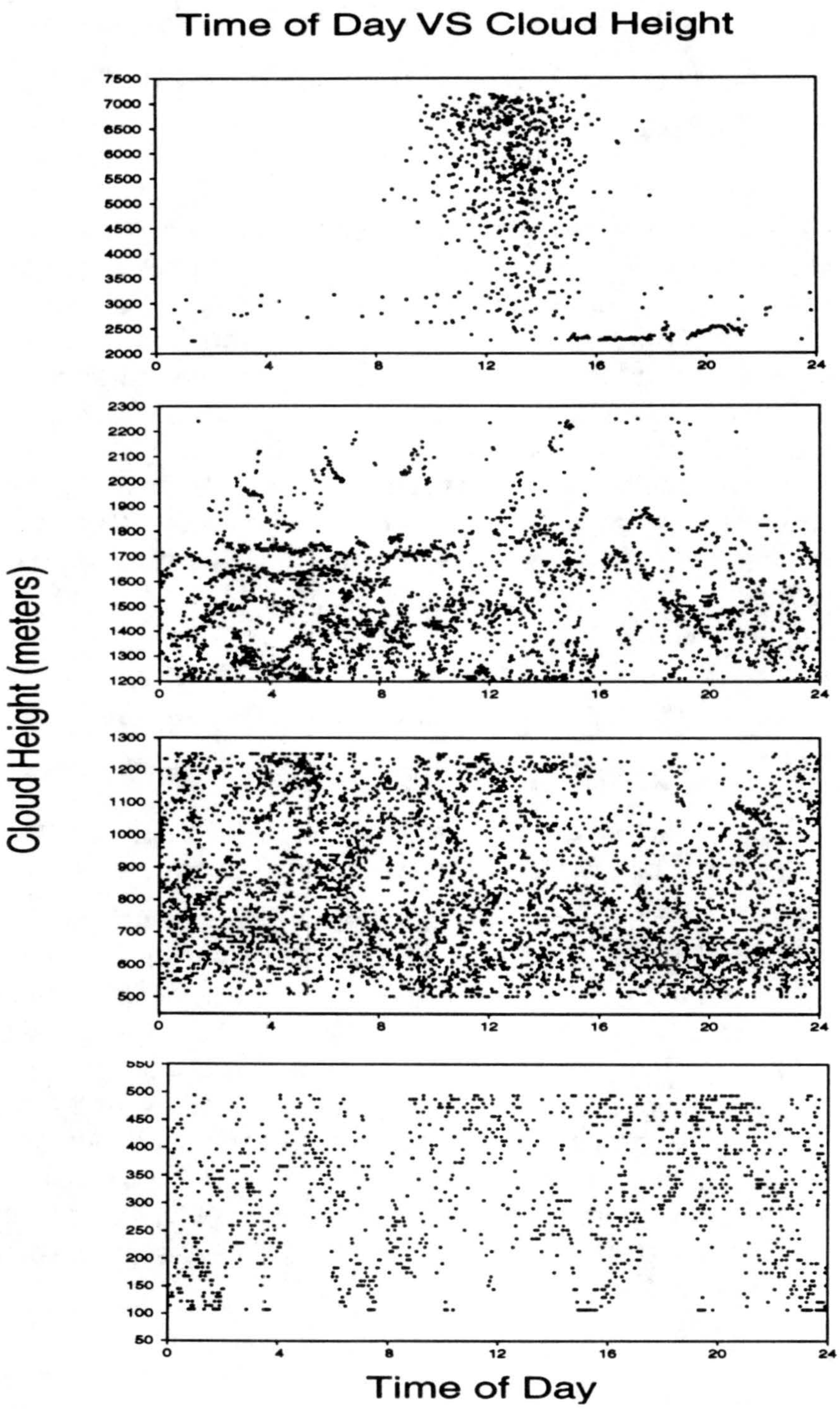


FIGURE 3 Time of Day vs. Cloud Height

The graphs have been scaled in order to better show that there are high concentration regions for clouds.

3. Data Sets that are Referred to by making a "Time-Window" Around the Sounding Launch Time

Now that we have observations collected at two minutes intervals throughout ASTEX, these can be compared with the soundings. Because the soundings are not instantaneous (at a rise rate of 5 m s^{-1}, the sonde will take 3-4 minutes per 1000 meters; 15-20 minutes to reach 5000 meters), we need to invent a "time-window" around the sounding launch. It was assumed that between the period 16 minutes before and 44 minutes afterward (every two minute observations) for a total of an hour (31 observations in an hour), the weather would not change substantially from the time that the sonde was launched. Therefore, data from the ceilometer, radiometer and pyranometer were averaged during this "time-window." Also, the radar data obtained during ASTEX can be examined during this same "time-window" for further evidence of atmospheric conditions.

3.1 Ceilometer, Radiometer, and Pyranometer Data During the "Time-Window"

Table 2 is a table which includes averages of the ceilometer, radiometer, and pyranometer data during the "time-window."

Ceilometer data: Cloud base height classifications were made based on the observation that cloud base levels seemed to be clustered around certain heights. For example, many cloud-bases were located just below 500 meters, just below 1200 meters and just below 2200 meters. It seemed natural to put the clouds into "bins" corresponding to these heights. The cloud heights in each bin were then averaged, to hopefully give some indication of different cloud layers at the same time. CLD is the number of observations (out of 31) when the ceilometer detected a cloud, while CLR is the number of times when the ceilometer did not detect a cloud. Often there is data missing, explaining why they don't total 31.

Radiometer Data: Both liquid water path and precipitable water path were averaged during the "time-window." If all the data was missing during the "time-window" then liquid water path registered 9.99 while precipitable water path registered -1. Some values for liquid water path were negative, implying a calibration error.

Pyranometer Data: Solar total (shortwave), near infrared and infrared irradiation were averaged during the "time-window." Some of the near infrared and solar total observations were negative, likely due to a slight calibration error.

DAY	HR	MN	c500	c1250	c2250	c5000	c9000	CLD	CLR	Prec.	Liq.	Inf.	SolarT
601	2	3	0	757	1922	0	0	13	18	19.3	0.02	333.4	-2.7
601	4	56	0	622	1728	0	0	30	1	21.9	0.14	371.8	-1.1
601	8	4	0	0	2050	0	0	4	0	21.3	0.05	337.4	143.6
601	10	55	0	676	0	3712	5244	6	25	19.9	0.01	335.1	865.4
601	14	0	0	692	2060	3537	6128	28	3	23.6	0.16	376.7	330.2
601	16	56	0	709	2241	2291	6334	31	0	21.6	0.05	370.8	188.3
601	23	1	0	0	1547	2271	0	13	18	22.1	0.14	332	-3.2
602	5	2	0	766	0	0	0	4	27	19.2	0.01	322.7	-2.5
602	7	58	0	636	0	0	0	17	11	19.9	0.02	341.3	252.2
602	10	57	434	933	1280	3399	5977	30	1	18.9	0.49	375.8	413.1
602	16	57	0	827	1849	0	0	23	8	19	0.01	342	426.1
602	20	8	0	876	1571	0	0	26	5	21.1	0.19	361.4	0.5
602	23	28	0	737	1728	0	0	22	9	19.8	0.03	338.5	-2.1
603	1	52	0	753	1653	0	0	28	3	19.9	0.05	360.4	-1.2
603	4	57	0	665	0	0	0	13	18	19	0.01	319.5	-2.7
603	7	57	0	0	0	0	0	0	19	18.5	0	316.4	381.4
603	11	2	0	712	0	0	0	10	21	20.2	0.01	340.1	782.3
603	16	57	0	741	1280	0	0	11	20	18.7	0.02	338.4	396.2
603	23	5	0	760	0	0	0	8	23	18	0.01	322.4	-3
604	5	0	0	928	1556	0	0	25	6	19.1	0.06	358.7	-1.3
604	7	57	0	0	1408	0	0	10	21	17.4	0	315.3	347.4
604	11	1	0	725	1490	4886	6647	23	8	21.5	0.01	351.9	842.1
604	14	1	0	958	0	0	6796	8	23	20.2	-0.01	328.2	1013.9
604	16	50	0	819	0	0	0	2	29	20.9	-0.01	319.8	555.7
604	22	51	0	755	0	0	0	15	16	21.4	0	336.1	-2.4
605	5	5	0	1183	1265	0	0	31	0	20	0	346.1	-1.6
605	7	55	0	1151	0	0	0	14	6	19.7	0	335.3	206.2
605	10	51	0	841	0	0	5983	8	23	20.4	-0.01	332.6	894.5
605	13	50	0	0	0	2828	6067	4	27	19.6	-0.01	324.6	1004.2
605	16	47	0	0	0	0	0	0	0	21.8	0.04	362.3	337.2
605	22	55	0	0	0	0	0	0	0	23.6	0	319.4	-3
606	5	2	394	604	0	0	0	31	0	26.8	0.16	386.2	-0.8
606	7	58	239	503	0	0	0	27	0	27.1	0.07	381.2	132.6
606	10	51	308	900	0	0	6489	26	5	27.4	0.52	386	395
606	13	46	0	1197	1317	0	6308	22	9	26.4	0	363.6	821.8
606	16	54	0	699	1410	0	0	26	5	26.1	0.08	371.4	156.6
606	23	3	0	556	0	3201	0	2	29	-1	9.99	316.6	-3.4
607	4	59	0	694	0	0	0	1	30	-1	9.99	304.2	-3.1
607	8	6	0	0	0	0	0	0	30	-1	9.99	305.4	433.5
607	10	56	0	0	0	0	0	0	31	15.6	0	316.3	939.3

DAY	HR	MN	c500	c1250	c2250	c5000	c9000	CLD	CLR	Prec.	Liq.	Inf.	SolarT
607	16	49	0	919	1334	0	0	9	22	19.4	0	331.8	568.9
607	22	51	0	844	0	0	0	6	25	19.8	0.01	319	-3.1
608	4	56	0	895	0	0	0	10	21	22.6	-0.01	320.8	-3
608	8	30	0	809	0	0	0	10	16	21.8	0	331.6	490.7
608	10	57	0	0	0	0	0	0	30	22.8	-0.01	326.2	937.6
608	13	59	0	1084	0	3704	6370	31	0	26	0.02	377.6	746
608	16	50	0	860	0	0	6189	14	17	27.5	0.01	349.2	523.3
608	22	48	465	673	0	0	0	20	11	22.7	0.1	350.5	-2.3
609	1	44	0	878	1265	0	0	14	17	19.9	0.01	328.6	-2.4
609	4	53	0	0	0	0	0	0	31	17.5	-0.01	300.4	-3.5
609	8	5	0	0	1499	3125	0	11	17	19.3	-0.01	325.5	362
609	11	7	0	1100	0	0	6712	5	26	20.6	-0.01	327.9	956.8
609	14	7	0	960	0	4116	6296	4	27	21.6	-0.02	321.1	976.7
609	17	3	0	990	0	0	0	8	23	20	-0.01	322.1	530.8
609	22	52	0	931	1267	0	0	28	3	23.3	0.18	361.9	-1.7
610	1	52	0	798	0	0	0	4	27	21.6	-0.01	310.9	-3.5
610	4	55	0	1069	0	0	0	30	1	22.7	0.07	361.5	-1.3
610	7	54	0	0	0	0	0	0	27	20.6	-0.01	322	344.1
610	13	3	0	640	0	4743	6066	15	16	22.1	0	349.8	635.4
610	16	55	0	595	1394	0	0	26	5	22.4	0.01	355.5	343.4
610	19	42	0	671	1401	0	0	28	3	22.1	0.01	348.1	15.9
610	22	47	0	720	1320	0	0	27	4	21.1	0.09	356.1	-2.2
611	2	1	0	624	0	0	0	8	23	19.6	0.01	325.2	-2.9
611	4	49	0	1103	0	0	0	13	18	18.7	0.01	329.1	-2.5
611	8	9	0	753	0	0	0	15	16	18.6	0.02	345.2	376.2
611	11	3	0	988	0	4832	6551	12	19	19	0.01	341.1	926.5
611	14	3	0	711	0	3746	6151	11	20	19	0.01	340.4	998.3
611	16	53	0	664	0	0	0	17	14	22.8	0.03	361	493.5
611	20	5	474	668	1288	0	0	30	1	28.6	0.11	378.9	5.7
611	22	46	167	534	0	0	0	31	0	28.3	0.3	392.2	-1.1
612	1	50	187	1199	0	0	0	29	2	27.2	0.2	390.1	-0.6
612	4	45	351	1016	0	0	0	26	5	30.7	0.06	388.2	-0.4
612	8	7	0	665	0	0	0	23	0	29	0.26	389.2	65.1
612	10	51	488	795	0	0	6314	29	2	29.6	0.13	390.5	315.4
612	13	51	284	758	0	0	6227	31	0	29.2	0.11	398.4	437
612	16	52	249	831	0	0	0	28	3	29.4	0.11	397.6	210.5
612	20	6	415	545	0	0	0	31	0	28.7	0.28	392.7	1.3
612	22	49	220	572	0	0	0	30	1	32.1	0.32	392.8	-1
613	1	53	190	0	0	0	0	23	8	35.9	0.43	391.1	-0.3
613	5	38	0	1104	1286	0	0	17	14	20.9	0.01	335.4	7.4

DAY	HR	MN	c500	c1250	c2250	c5000	c9000	CLD	CLR	Prec.	Liq.	Inf.	SolarT
613	7	50	0	1074	1258	0	0	29	0	22.2	0.11	381.4	129.6
613	10	47	412	1056	0	0	6509	31	0	21.4	0.13	384.2	529.8
613	14	1	495	645	1448	4188	6284	21	10	19.1	0.02	356.4	901.9
613	16	52	462	874	1265	0	0	30	1	17.9	0.04	374.5	333.2
613	19	58	0	861	0	0	0	30	1	15.2	0.05	368.8	5.5
613	22	59	0	962	0	0	0	31	0	16.2	0.08	375.5	-1.1
614	1	52	0	1035	0	0	0	27	4	15	0.05	355.2	-1.5
614	5	42	0	1124	1314	0	0	31	0	16.9	0.11	375.7	2.7
614	7	54	0	849	1376	0	5274	24	5	19	0.04	360.1	186.9
614	10	52	0	681	0	3933	6522	21	10	22.3	0.01	363	494
614	13	53	480	586	0	3524	5844	27	4	22.2	0	369.2	721.3
614	16	47	488	547	0	0	0	6	25	16.3	-0.01	332.8	585.6
614	20	9	495	558	0	0	0	12	19	16.6	0.01	342.3	3.6
614	23	0	0	735	0	0	0	9	22	17.3	0.01	334.8	-2.3
615	7	57	0	664	1380	2797	0	12	15	23.5	0.11	365	133.3
615	10	50	0	562	1346	3742	5762	22	9	20.5	0.02	362.6	543.2
615	16	56	0	747	0	0	0	1	30	20.5	0	332.3	512
615	19	49	434	0	0	0	0	1	30	21.7	0	326	16
615	23	32	388	1120	1604	0	0	25	6	24.4	0.1	383.1	-1.1
616	1	58	384	572	0	0	0	20	11	25	0.11	387.1	-0.9
616	4	54	411	579	0	0	0	24	7	25	0.15	375.5	-1.2
616	7	58	0	889	1608	0	5061	5	26	23.7	0	339	299.2
616	10	55	0	0	1428	4893	6429	14	17	23.3	-0.01	356.8	858.6
616	13	47	0	0	0	4272	6606	8	23	23.4	-0.02	346	811.7
616	16	56	473	840	0	0	0	6	25	24.6	-0.01	358.5	454.6
616	20	17	360	564	0	0	0	13	18	27.4	0	351.7	-0.1
616	22	52	314	903	0	0	0	29	2	29.7	0.14	390.3	-1.2
617	1	56	340	753	0	0	0	23	8	28.9	0.2	390	-1.1
617	4	52	0	951	0	0	0	30	1	26.8	0.06	387.3	-1.1
617	8	4	244	1143	0	0	0	21	9	26.6	0.11	391.8	107.8
617	10	53	0	0	0	0	0	0	0	25.9	0.1	395.8	265.7
617	13	54	0	0	0	0	0	0	0	25.9	0.08	395.7	378.3
617	16	59	335	566	0	0	0	25	6	26.5	0.17	392.7	95.4
617	19	59	468	572	0	0	0	29	2	25.1	0.03	377.4	4.2
617	22	51	0	980	0	0	0	2	29	23.6	-0.02	324	-2.8
618	1	49	0	855	0	0	0	31	0	23.5	0.01	380.1	-1.1
618	4	53	0	811	0	0	0	30	1	22.3	0.03	380.2	-1
618	7	53	0	993	0	0	0	18	0	22.1	0.01	381.4	152.6
618	10	55	0	1160	1262	0	6264	30	1	23.4	0	379.7	584.2
618	13	54	0	1214	0	0	6692	27	4	22.3	-0.02	363.4	879.2

DAY	HR	MN	c500	c1250	c2250	c5000	c9000	CLD	CLR	Prec.	Liq.	Inf.	SolarT
618	16	51	0	0	0	0	0	0	31	21.1	-0.03	326.9	546
618	20	1	0	857	0	0	0	2	29	22.9	-0.03	340.8	3.7
618	22	49	0	729	0	0	0	5	26	23.2	-0.02	346.8	-2.4
619	1	54	0	868	0	0	0	6	25	23.8	-0.01	358.8	-1.8
619	4	53	0	819	1354	0	0	25	6	23.9	0.02	369.2	-1.5
619	7	53	0	598	1412	0	0	27	1	24.4	0.01	370.9	157.2
619	10	54	0	617	0	0	6787	5	26	24.6	-0.02	340.3	853.2
619	13	57	0	709	0	4147	5817	12	19	24.5	-0.02	351.8	983.8
619	17	7	0	591	0	0	0	2	29	25	-0.02	332.5	470.9
619	20	48	0	620	1335	0	0	20	11	30.1	0.05	364.3	-1.7
619	22	53	490	549	0	0	0	13	18	29.2	-0.01	341	-2.5
620	1	57	0	545	1475	0	0	22	9	29.9	0	356.9	-1.7
620	4	54	450	993	1568	0	0	16	15	29.6	0.04	357	-1.6
620	7	41	0	579	1632	0	0	19	10	29.4	0	374.3	131.6
620	10	44	0	583	1715	4057	6469	22	9	29.5	-0.02	362.2	682.7
620	13	45	464	678	1514	3896	6076	29	2	30.5	0.03	375	706.4
620	16	46	495	561	0	0	0	9	22	29.2	-0.02	349.4	514.8
620	19	59	0	585	0	0	0	7	24	25.7	-0.01	327.3	10.2
620	22	57	0	0	1448	0	0	28	3	26.1	0.03	376.4	-1.2
621	2	3	0	808	1426	0	0	30	1	22.3	0.01	366.7	-1.3
621	4	58	0	1204	1268	0	0	30	1	18.7	0.11	377.3	-1
621	7	51	0	742	1375	0	0	27	1	21.6	0.2	380.8	57.4
621	10	48	0	1088	1377	0	5313	20	2	21	0.24	383.6	159.9
621	13	52	0	728	1601	3444	5940	21	10	18.3	0.03	362.4	810
621	16	56	0	0	0	0	0	0	31	16.2	0	319.7	545.7
621	19	45	0	910	1324	0	0	22	9	18.3	0.1	362.9	8
621	22	54	0	930	0	0	0	22	9	23.4	0.34	381.8	-1.6
622	1	54	0	918	1270	0	0	21	10	23.8	0.32	381.4	-1.3
622	4	58	0	869	1356	0	0	31	0	22.3	0.1	377.5	-1.1
622	7	39	0	1053	1321	0	0	28	0	22.5	0.14	379.8	65.9
622	10	45	0	1136	1522	2755	5816	27	4	22	0.07	382.2	368.2
622	13	44	0	0	1607	3293	6338	28	3	-1	9.99	376.7	691.4
622	16	41	0	0	1662	0	0	1	27	19	-0.01	327.9	592.8
622	20	2	0	717	1470	3125	0	30	1	19	0.02	362.3	3.4
622	22	53	0	0	1457	0	0	5	26	17.5	-0.01	313.2	-3.6
623	1	51	0	0	1452	0	0	2	29	17.1	-0.01	307.9	-4.4
623	4	52	0	838	1557	0	0	31	0	19.8	0.02	368.6	-1.4
623	7	49	0	909	1448	0	0	22	0	22.8	0.15	378.6	94.1
623	10	47	0	922	1610	4977	6432	19	12	-1	9.99	373.8	440.1
623	13	47	0	0	0	3780	6270	12	19	20.3	-0.01	348.6	824.5

DAY	HR	MN	c500	c1250	c2250	c5000	c9000	CLD	CLR	Prec.	Liq.	Inf.	SolarT
623	16	51	0	0	0	0	0	0	31	19.1	-0.01	324.7	553.9
623	19	56	0	0	1534	0	0	15	16	20.5	-0.01	333.1	9.6
623	22	50	0	0	1718	0	0	16	15	19.3	0.01	341	-2.6
624	1	50	0	729	1753	0	0	20	11	19.1	0.01	345.6	-2.7
624	5	4	0	747	1727	0	0	31	0	19.8	0.02	368.6	-1.5
624	7	51	0	720	1686	0	0	28	0	22.5	0.1	380.4	186.6
624	10	44	0	0	1733	0	6017	18	13	21.5	0	361.5	683.5
624	13	54	0	0	1779	4446	6275	31	0	22.5	0	383	715.1
624	16	46	0	0	1688	0	0	27	4	22.7	0	370.3	594.4
624	19	57	0	0	1829	0	0	1	30	22.1	-0.02	321.2	9.7
624	22	58	0	0	0	0	0	0	31	23.1	-0.01	315.2	-3.9
625	1	44	0	0	1615	0	0	22	9	23.2	-0.02	325.5	-2.3
625	4	58	0	0	1633	0	0	31	0	23.3	-0.01	364.4	-1.4
625	7	49	0	0	1603	0	0	6	21	23.4	-0.03	325.9	332
625	10	51	0	789	1478	0	0	31	0	24.1	0.05	373.8	294.4
625	13	51	0	776	1550	4505	6147	17	14	22.5	0.01	356.9	779.3
625	16	47	0	0	0	0	0	0	0	22.7	-0.03	352.1	649.7
625	19	44	0	0	0	0	0	0	0	24.1	-0.03	333.1	30.3
625	22	46	0	0	0	0	0	0	0	23.7	-0.02	313.9	-4.3
626	1	48	0	0	0	0	0	0	0	23.8	-0.03	308.8	-3.6
626	4	37	0	0	0	0	0	0	0	22.5	-0.03	307.5	-3.3
626	7	49	0	0	0	0	0	0	26	26.1	-0.04	326.8	328.5
626	10	55	0	0	0	0	0	0	0	31.1	-0.05	345.6	936.1
626	13	51	0	0	0	0	0	0	0	33.6	-0.05	349.4	1008.9
626	16	48	0	0	0	0	0	0	31	32.8	-0.05	341.7	568.7
626	19	51	0	0	0	0	0	0	31	32.7	-0.04	334.4	15.5
626	22	51	0	0	0	0	0	0	31	32.5	-0.03	329.8	-4.1
627	1	59	0	0	0	0	0	0	31	32.5	-0.03	328.6	-2.9
627	4	49	0	0	0	0	0	0	31	35.5	-0.04	330.2	-2.1
627	7	50	0	0	0	0	0	0	28	35.9	-0.04	341.2	343.4
627	10	49	0	624	0	0	0	11	20	37.4	-0.04	361.8	858.1
627	13	51	0	0	0	0	0	0	31	40.1	-0.04	357.3	960.9
627	16	40	0	701	0	0	0	5	25	36.5	-0.02	357.7	604
627	20	8	0	0	0	0	0	0	31	33.2	-0.01	347.4	1.9
627	22	59	0	0	0	0	0	0	31	32.8	-0.01	346.1	-2.7
628	1	48	0	0	0	0	0	0	31	32.4	-0.01	342.6	-2.5
628	4	50	0	1197	0	0	0	1	30	32.5	0	344.7	-2.3
628	7	46	0	0	1759	0	0	7	22	34.2	0	358.9	336.8
628	10	45	437	533	0	0	6902	28	3	39.3	0.01	397.7	635.7
628	13	48	291	641	0	4421	6133	29	2	39	0.03	404.3	670.8

DAY	HR	MN	c500	c1250	c2250	c5000	c9000	CLD	CLR	Prec.	Liq.	Inf.	SolarT
628	16	47	359	682	0	0	0	31	0	37.6	0.07	409.3	213
628	20	14	0	618	0	0	0	26	5	33.1	0.01	386.5	0.1
628	22	53	0	628	0	0	0	31	0	30.5	0.09	404.5	-1.3

Table 2 Ceilometer, Radiometer and Pyranometer Data Averaged Over the "time-window" of the Sounding.

The Day, Hr, and Mn are the time of the sounding launch. cheight is the average height of clouds below that level (meters).Prec. = precipitable water path (mm), Liq = liquid water path (mm), Inf = infrared irradiation (W m^{-2}), and solarT = Total Solar Irradiation (W m^{-2}). Missing radiometer data are -1 for Prec. and 9.99 for Liq.

3.2 Derived Quantities Using the Soundings

The original "level2" sounding data gives height, pressure, temperature, dewpoint, windspeed and wind direction. This was not useful as is, so a program (originally written by Paul Ciesielski of CSU) was modified to take the level two data and convert it into height, pressure, temperature, relative humidity, mixing ratio, and saturation mixing ratio. These quantities could then be used to find clouds, estimate the precipitable water path and estimate the downwelling infrared irradiation from the cloud bases. This data is found in Table 3.

Clouds: A cloud was assumed to exist anytime the relative humidity exceeded 95%. The cloud base was noted as well as its thickness. The cloud levels are the same as in TABLE 2. (<500, <1250, <2250, < 5000, > 5000) The amount of cloud in these levels was totalled. Then the total cloud amount was listed in "Totthick." For example, the sonde launched at 5:02 on June 6th detected 150 meters of cloud below 500 meters, 750 meters between 500 and 1250 meters, 930 meters between 1250 and 2250, 80 meters above 2250,giving a total of 1910 meters of cloud in the balloon's path.

Precipitable Water Path: Once the pressure, temperature, relative humidity and mixing ratios were known for 10 meter increments of the sounding, the vapor density for that 10 meter increment can be calculated. By summing over the whole height of the sounding, the precipitable water path was estimated.

Infrared Irradiation: A tag was assigned to the base of the first cloud detected by the sonde. At this level, the temperature was also registered. This is the cloud base temperature. The Stefan-Boltzman law was used to find the total downwelling irradiation from the cloud, assuming that it was a blackbody (Wallace and Hobbs, 1977).

DATE	HR	MN	<500	<1250	<2250	<5000	>5000	TotThick	Prec.	Infrared
601	2	3	0	0	310	0	0	310	21	333.3
601	4	56	0	230	660	80	0	970	20.5	382.5
601	8	4	90	160	240	0	0	490	23	387.7
601	10	55	0	0	0	0	0	0	20.9	0
601	14	0	0	200	340	230	0	770	22.4	380.9
601	16	56	0	0	40	350	0	390	20.6	322.1
601	23	1	0	0	250	240	0	490	22	349.8
602	5	2	0	80	0	0	0	80	19.1	376
602	7	58	0	90	0	0	0	90	19.6	371.1
602	10	57	0	650	170	0	0	820	21.5	378.8
602	16	57	0	0	60	0	0	60	19.7	330.6
602	20	8	0	420	630	0	0	1050	18.3	373.8
602	23	28	0	140	270	0	0	410	19.8	373.4
603	1	52	0	320	160	0	0	480	19.1	370.5
603	4	57	0	230	0	0	0	230	19.2	376.3
603	7	57	0	0	0	0	0	0	18.2	0
603	11	2	0	140	0	0	0	140	20.2	374
603	16	57	0	280	140	0	0	420	18.8	365
603	23	5	0	40	0	0	0	40	18.8	375
604	5	0	0	410	330	0	0	740	17.8	372.8
604	7	57	0	0	160	0	0	160	18.3	343.7
604	11	1	0	170	0	0	0	170	21	370.9
604	14	1	0	0	0	0	0	0	18.6	0
604	16	50	0	0	0	0	0	0	19.2	0
604	22	51	0	530	60	0	0	590	21	381.4
605	5	5	0	260	100	0	0	360	18.8	373.2
605	7	55	0	160	80	0	0	240	18.9	352.9
605	10	51	0	10	0	0	0	10	19.1	366.5
605	13	50	0	0	0	0	0	0	17.7	0
605	16	47	0	0	0	0	0	0	19.6	0
605	22	55	0	200	0	0	0	200	23.7	376.9
606	5	2	150	750	930	80	0	1910	24.6	392
606	7	58	410	710	720	0	0	1840	26.3	403
606	10	51	0	640	450	0	0	1090	25.5	383.8
606	13	46	0	230	300	0	0	530	24.3	371.7
606	16	54	60	750	520	0	0	1330	25.1	392
606	23	3	0	0	360	0	0	360	19.7	354.1
607	4	59	0	60	190	0	0	250	18.8	370.1
607	8	6	0	0	0	0	0	0	15.5	0
607	10	56	0	0	0	0	0	0	14	0

DATE	HR	MN	<500	<1250	<2250	<5000	>5000	TotThick	Prec.	Infrared
607	16	49	0	200	40	0	0	240	20.2	365.2
607	22	51	0	540	110	0	0	650	17.1	371.7
608	4	56	0	530	0	0	0	530	20.1	372.4
608	8	30	0	440	0	0	0	440	19	370.3
608	10	57	0	0	0	0	0	0	20.9	0
608	13	59	0	430	0	0	0	430	23.4	371.7
608	16	50	0	650	20	0	0	670	25.9	381.2
608	22	48	0	390	0	0	0	390	22	374.3
609	1	44	0	370	80	0	0	450	18.1	363.9
609	4	53	0	0	0	0	0	0	16.1	0
609	8	5	0	0	0	0	0	0	15.1	0
609	11	7	0	0	0	0	0	0	20.5	0
609	14	7	0	0	0	0	0	0	19.9	0
609	17	3	0	100	0	0	0	100	20	355.7
609	22	52	0	460	280	0	0	740	18.1	366.5
610	1	52	0	270	60	0	0	330	21.7	365.8
610	4	55	0	230	10	0	0	240	21.7	372.3
610	7	54	0	0	0	0	0	0	20.8	0
610	13	3	0	0	0	0	0	0	22.7	0
610	16	55	0	0	140	0	0	140	21.8	353.9
610	19	42	0	0	210	0	0	210	19.5	357.8
610	22	47	0	630	0	0	0	630	19.2	385.8
611	2	1	0	280	100	0	0	380	21.4	380.3
611	4	49	0	0	0	0	0	0	20.7	0
611	8	9	0	370	0	0	0	370	19.3	381.1
611	11	3	0	110	0	0	0	110	20.1	374.8
611	14	3	0	140	0	0	0	140	20.3	375
611	16	53	0	540	0	0	0	540	23.2	386.4
611	20	5	0	290	0	0	0	290	28.2	385.8
611	22	46	400	150	0	0	0	550	28.6	404.7
612	1	50	390	750	60	0	0	1200	24.1	408.7
612	4	45	180	630	50	0	0	860	25.2	399.4
612	8	7	0	570	0	0	0	570	22.8	383.2
612	10	51	0	230	80	0	0	310	28.3	372.8
612	13	51	290	750	70	0	0	1110	26	404.8
612	16	52	390	260	0	0	0	650	24.6	411.9
612	20	6	180	210	0	0	0	390	24.9	399.8
612	22	49	410	500	0	0	0	910	30.2	406.3
613	1	53	10	0	0	0	0	10	32.5	406.3
613	5	38	0	220	50	0	0	270	20	369.2

DATE	HR	MN	<500	<1250	<2250	<5000	>5000	TotThick	Prec.	Infrared
613	7	50	0	180	130	0	0	310	21.9	362.4
613	10	47	0	280	240	0	0	520	19.2	366.1
613	14	1	0	190	0	0	0	190	21	380.8
613	16	52	0	290	0	0	0	290	20.8	383.7
613	19	58	0	150	0	0	0	150	17.5	368.3
613	22	59	0	560	80	0	0	640	14.5	374.4
614	1	52	0	440	130	0	0	570	16	368.4
614	5	42	0	80	0	0	0	80	16	356.2
614	7	54	0	0	240	0	0	240	20.4	348.9
614	10	52	0	0	0	0	0	0	17.4	0
614	13	53	0	280	0	0	0	280	20.2	383.9
614	16	47	0	70	0	0	0	70	16.5	383.3
614	20	9	0	40	0	0	0	40	17.8	382.5
614	23	0	0	0	0	0	0	0	18.6	0
615	7	57	0	430	110	0	0	540	18.6	370.3
615	10	50	20	150	10	0	0	180	21.6	388.1
615	16	56	0	0	0	0	0	0	21.5	0
615	19	49	0	40	30	0	0	70	22.8	372.2
615	23	32	130	750	400	0	0	1280	24.1	395.9
616	1	58	230	370	0	0	0	600	21.2	399.9
616	4	54	170	470	190	0	0	830	23.5	395.5
616	7	58	0	70	0	0	0	70	19.8	346.7
616	10	55	0	0	0	0	0	0	23.8	0
616	13	47	0	0	40	0	0	40	24.1	352.3
616	16	56	0	0	0	0	0	0	23.9	0
616	20	17	210	330	0	0	0	540	26.5	399
616	22	52	230	600	0	0	0	830	23.6	401.7
617	1	56	200	470	0	0	0	670	21.9	399.9
617	4	52	0	440	10	0	0	450	22.4	379.8
617	8	4	410	750	120	0	0	1280	23.1	401.9
617	10	53	260	320	0	0	0	580	23.2	402.1
617	13	54	210	640	90	0	0	940	23.5	402.5
617	16	59	230	750	150	0	0	1130	21	398
617	19	59	120	730	0	0	0	850	20	391.4
617	22	51	0	300	0	0	0	300	22.9	372.6
618	1	49	0	330	0	0	0	330	17.7	372.1
618	4	53	0	450	0	0	0	450	19.1	374
618	7	53	0	330	50	0	0	380	21.2	364.9
618	10	55	0	650	140	0	0	790	22.5	382.7
618	13	54	0	20	90	0	0	110	22.3	353.9

DATE	HR	MN	<500	<1250	<2250	<5000	>5000	TotThick	Prec.	Infrared
618	16	51	0	0	0	0	0	0	21.2	0
618	20	1	0	180	0	0	0	180	23.5	365.3
618	22	49	0	30	0	0	0	30	23.5	380.1
619	1	54	0	60	0	0	480	540	24.8	379.5
619	4	53	460	250	0	30	0	740	17	380.9
619	7	53	0	140	300	0	0	440	25.1	385.5
619	10	54	0	0	0	0	0	0	22.8	0
619	13	57	0	0	0	0	0	0	22.3	0
619	17	7	0	70	0	0	0	70	23.7	380.6
619	20	48	0	70	0	0	0	70	26.8	377.9
619	22	53	0	10	0	0	0	10	26.5	379.5
620	1	57	0	0	80	0	0	80	27.6	352.6
620	4	54	0	190	310	0	0	500	26.2	379.4
620	7	41	0	40	340	0	0	380	26.1	380.3
620	10	44	0	0	0	0	0	0	26.3	0
620	13	45	0	0	550	0	0	550	26	359.2
620	16	46	0	470	0	0	0	470	25.5	388.2
620	19	59	0	220	0	0	0	220	24.2	384.9
620	22	57	0	0	390	0	0	390	23.1	357.6
621	2	3	0	0	270	0	0	270	21.8	349
621	4	58	0	120	380	0	0	500	16.9	355.6
621	7	51	0	530	430	0	0	960	20.5	379.8
621	10	48	0	170	400	0	0	570	19.6	371.6
621	13	52	0	0	40	0	0	40	21.3	345.1
621	16	56	0	0	0	0	0	0	18.2	0
621	19	45	0	450	0	0	0	450	14.9	377.2
621	22	54	0	330	100	0	0	430	21	367.5
622	1	54	0	580	0	0	0	580	23.9	393.1
622	4	58	0	10	440	0	0	450	16.3	354
622	7	39	0	110	390	0	0	500	20.1	375.6
622	10	45	0	200	530	0	0	730	20	362.8
622	13	44	0	0	80	0	0	80	22.5	341.5
622	16	41	0	0	0	0	0	0	20.9	0
622	20	2	0	460	220	0	0	680	20.6	377.2
622	22	53	0	0	190	0	0	190	19.4	347.4
623	1	51	0	0	0	0	0	0	19.8	0
623	4	52	0	0	290	0	0	290	20.7	345.6
623	7	49	180	410	0	0	0	590	16.2	361.4
623	10	47	0	590	710	0	0	1300	21.3	376.5
623	13	47	0	0	0	0	0	0	19.7	0

DATE	HR	MN	<500	<1250	<2250	<5000	>5000	TotThick	Prec.	Infrared
623	16	51	0	0	110	0	0	110	21	340.9
623	19	56	0	0	250	0	0	250	20.2	349.1
623	22	50	0	0	70	0	0	70	22.2	336.9
624	1	50	0	0	0	0	0	0	21.6	0
624	5	4	0	80	300	0	0	380	21	376
624	7	51	0	560	330	0	0	890	19.7	382.8
624	10	44	0	0	230	0	0	230	21.4	338.8
624	13	54	0	0	420	0	0	420	21.4	345
624	16	46	0	0	100	0	0	100	23.9	342.7
624	19	57	0	0	130	0	0	130	23.7	339.7
624	22	58	0	0	200	0	0	200	24.8	342.3
625	1	44	0	0	230	0	0	230	23	346.7
625	4	58	0	0	250	0	0	250	22.5	343.9
625	7	49	0	0	110	0	0	110	24.7	342.1
625	10	51	0	40	250	0	0	290	24.2	369.3
625	13	51	0	120	310	0	0	430	23.7	377.1
625	16	47	0	0	0	0	0	0	24.4	0
625	19	44	0	240	0	0	0	240	24.5	385.7
625	22	46	0	80	0	0	0	80	23.7	375.6
626	1	48	20	0	0	0	0	20	23	395.8
626	4	37	0	0	0	0	0	0	22.2	0
626	7	49	0	0	0	0	0	0	23.8	0
626	10	55	0	0	0	0	0	0	28.1	0
626	13	51	0	0	0	0	0	0	30	0
626	16	48	0	0	0	0	0	0	29.8	0
626	19	51	0	70	0	0	0	70	31	386.6
626	22	51	0	150	0	0	0	150	31.1	389.1
627	1	59	0	0	0	0	0	0	31.9	0
627	4	49	0	0	0	40	0	40	34.2	358.7
627	7	50	0	0	50	0	0	50	28.3	326
627	10	49	0	0	0	0	0	0	33.9	0
627	13	51	0	10	80	0	0	90	37.2	384.9
627	16	40	0	0	0	0	0	0	27.1	0
627	20	8	0	0	20	0	0	20	33.9	380.8
627	22	59	0	30	200	0	0	230	32.7	384.3
628	1	48	30	130	60	0	0	220	30.9	414.3
628	4	50	100	200	90	0	0	390	28.9	413.1
628	7	46	30	0	360	0	0	390	30.7	416.5
628	10	45	250	190	550	0	0	990	35.3	414.8
628	13	48	210	480	20	0	0	710	38.6	419.7

DATE	HR	MN	<500	<1250	<2250	<5000	>5000	TotThick	Prec.	Infrared
628	16	47	160	750	200	0	0	1110	35	412.3
628	20	14	60	730	60	0	0	850	32	418.7
628	22	53	20	480	70	0	0	570	26.9	415.9

Table 3 Derived Quantities Using The Soundings:

This table shows the date and time of the sounding launch, the amount of clouds detected (in meters) between the height levels, the total amount of all clouds (meters), a precipitable water estimate (mm) and an estimate of infrared irradiation (W m^{-2}) assuming the lowest cloud detected was a blackbody. Infrared readings of "0" are indicated when the sonde detected no cloud.

3.3 Weather and Radar Observations

The purpose of Table 4 is to provide insight into the state of the atmosphere when the sonde was launched. The dates and times in this table are the dates and times of the sonde launches. Visual observations were not consistently taken until after the first third of the experiment (Cox et al. 1993).

The radar interpretation is a visual interpretation of the 8mm radar pictures from the duration of ASTEX. It is to note that the radar only sees what is right above it, so it gives some indication of the changing of the sky cover.

To save space, there are many abbreviations used in this table. They are as follows:

Z, Z_1, Z_2... = 300m(300m) are cloud base levels and thicknesses. If there is only layer of cloud it is written as Z. If there are two or more, there are subscripts. The first number is the cloud base level in meters above sea level, and the number in parentheses is its thickness in meters.

"Precipitation" is indicated when the radar shows high values of downward particle fall velocity (large negative values) with high reflectance.

"Updraft" is indicated when the radar shows high values of upward particle velocity (large positive values).

"Virga" is precipitation falling from cirrus clouds, never reaching the ground

Cloud << 15, Cloud < 15, Cloud ~ 15, Cloud > 15, and Cloud >>15 are an estimate of how often the radar detected clouds during the hour "time-window." Officially, the radar makes continuous observations, but this terminology was used to try and compare to Table 2 and the ceilometer's estimate of cloud occurances. Cloud << 15 means that the radar detected few clouds during the "time-window."

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
601	2:03		
601	4:56		
601	8:04		Radar off
601	10:55		Radar off
601	14:00		Z_1 = 300 m (300m); Z_2 = 2000 m (400 m), precipitation?, cloud >>15.
601	16:56		Z = 2200m (300m); virga from 8000m, cloud >15
601	23:01		Radar off
602	5:02		Z = 700m (300m), cloud >15
602	7:58		Z = 700 (200m), cloud >15
602	10:57		Z_1 = 500m (300m); Z_2 = 900m (500m), precipitation, cloud >> 15
602	16:57		Z = 1900m (100m); cloud >15
602	20:08		Precipitation 1700m?, cloud >>15
602	23:28		Z_1 = 700m (200m); Z_2 = 1600m (300m), cloud 15
603	1:52		Z_1 = 790m (300m); Z_2 = 1600m (200m), cloud > 15
603	4:57		Z = 700m (200m), cloud > 15
603	7:57		Radar off
603	11:02		Radar off
603	16:57		Radar off
603	23:05		Radar off

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
604	14:01		Z = 800m (200m), cloud <15
604	16:50		Z = 800m (100m), cloud <15
604	22:51		Radar off
605	505		Z = 1100m (200m), cloud >>15
605	7:55		Z = 1000m (200m), cloud <15 (clouds after 8:15)
605	10:51		Varying clouds below 300m (all thin), cloud <15
605	13:50		Z = 400m (300m); cloud <15?
605	16:47		Z = 1000m, precipitating after 17:00?
605	22:55		Clouds @ 500m, but mostly clear.
606	5:02	Drizzle	Z_1 = 400m (500m); Z_2 =1000m, th=200m.precipitating after 5:20, cloud >15
606	7:58		Z_1 = ground (300m), Z_2 = 600m (300m), Z_3 = 1000m (300m), possibly precipitation, cloud >15
606	10:51		Precipitating, varying cloud base, with top of clouds at 2000 m
606	13:46		Scattered clouds below 600m; Z = 1100m (200-300m), cloud >15
606	16:54	Stratocumulus, cumulus:50% Cloud cover	Both strong vertical lift and fall, thick cloud tops about 2600m, precipitation, cloud >>15
606	23:03		Mostly clear, cloud << 15
607	4:59		Mostly clear with few clouds @ 600m (100m), cloud < 15

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
607	8:06	Clear	No clouds
607	10:56	Cumulus, cirrostratus: 10%	Radar off
607	16:49	Cumulus:30%	Few clouds @ 700 m(200m), cloud < 15
607	22:51		Z = 700m (400m), cloud ≈15
608	4:56	Cumulus:30%	Scattered clouds, bases near 6500m and 1000m; most pretty thin, cloud ≈15
608	8:30	Cumulus:30%	Cloud bases near 600mafter 8:40, cloud < 15
608	10:57		Machine off
608	13:59	Thin stratocumulus	Z = 1000m (200m), cloud >>15
608	16:50	Stratocumulus, cumulus	Z = 700m (300m) before 17:00, after scattered around 400m, cloud ≈15
608	22:48	Light rain	Cloud near 500-600m (200-300m); precipitating clouds at 23:15 from 1000m (500m, cloud >15
609	1:44		Z = 500m (500), cloud >15
609	4:53		Mostly clear, cloud << 15
609	8:05		Z_1 = 900m (100m); Z_2 = 1500m (200m), cloud > 15
609	11:07		Z = 1000m (100m), cloud < 15
609	14:07		Very few clouds, cloud < 15
609	17:03		Z = 1000m (100m), cloud < 15
609	22:52	Drizzle starting	Precipitation from clouds around 1000m, cloud > 15
610	1:52		Z = 700m (thin), mostly clear, cloud < 15

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
610	4:05		Z = 1000m (500m); cloud >15
610	7:54		Z = 10,000m
610	13:03		Clouds @ 500m; virga from 10,000m, cloud ≈ 15
610	16:55		Z_1 = 600m (200m); Z_2 = 1700m (100m); Z_3 = 8500m (virga), cloud > 15
610	19:42	Scattered cumulus, cirrostratus	Z = 1400m (200m), cloud > 15
610	22:47		Z = 1300m? Most of the time machine not on!
611	2:01		Z = 500m (200m), cloud < 15
611	45:49		Z = 1000m (100m), cloud < 15
611	8:09		Z = 500m (600m), cloud < 15
611	11:03	Cumulus humilis	Mostly clear, cloud < 15
611	14:03	Cumulus humilis	Mostly clear, possibly some clouds around 800m, cloud < 15
611	16:53	Stratocumulus	Z_1 = 700m (200m); Z_2 = 9000m (virga), cloud ≈ 15
611	20:05	Cumulus, stratus, cirrus	Machine off. Probably Z = 300m (900m), cloud >> 15
611	22:46	Drizzle	Z = ground (1200m), cloud >> 15
612	1:50		Two cloud levels or all cloud from ground to about 1400m, cloud > 15
612	4:45		Two cloud levels: thickening from ground; lowering from 1000m; joining around 11:15
612	8:07	Cloudy	Two cloud levels or all cloud; up to 1500m

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
612	10:51	Cloudy	Two cloud levels; ground to 500m; 100m to 1400m, cloud > 15
612	13:51	Cloudy/rain	Two cloud levels; sometimes all cloud; ground to 1400m, cloud > 15
612	16:52	Cloudy	Lowering cloud tops, 1200m- 1000m. All cloud splitting into two layers, cloud > 15
612	20:06	Stratocumulus	Z = ground (1000m), cloud >> 15
612	22:49	Drizzle	Z = ground (1000m), possibly two layers, cloud >> 15
613	1:53	Drizzle	Cloud from ground to 1000m. Sometimes precipitation, cloudy > 15
613	5:38	Clear, Stratocumulus	Z = 1000m (200), clear ≈15
613	7:50		All cloud between ground and 1500m, cloud >> 15. On second look, drizzle coming from 1200m clouds.
613	10:47		Cloud tops around 1400m, but cloud bases between 600 & 1000m, cloud >> 15
613	14:01		Z = 400m (300m), cloud ≈15
613	16:52		Z_1 = ground (400m), Z_2 = 700m (400m), at 17:15 they connect
613	19:58	Stratocumulus	Z = 500m (500m), mixture of up and down vertical movements, cloud >> 15
613	22:59	Stratocumulus	Z = 800m (500m), some precipitation, cloud >> 15
614	1:52	Stratocumulus	No picture
614	5:42	Stratocumulus	No picture
614	7:54		Z_1 = ground (700m); Z_2 = 1200m (400m), cloud >> 15

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
614	10:52		Z = 500m (200-400m), cloud ≈15
614	13:53		Clouds at ground (800m), but varying bases, cloud > 15
614	16:47		Clouds at ground (300m), but varying bases, cloud ≈15
614	20:09	Cumulus	Z = 500m (200m), cloud ≈15
614	23:00	Cumulus humilis	Z = 400m (300m), updraft, cloud < 15
615	7:57 •	Cumulus, stratus	Z_1 = 400m (500m); Z_2 = 1200m (600m), precipitation, cloud > 15
615	10:50	Cumulus haze	Z_1 = 400m (300m); Z_2 = 1200m (200m), cloud > 15
615	16:56	Some cumulus	Radar off
615	19:49	Cumulus	Radar off
615	23:32	Stratocumulus	Radar off
616	1:58	Stratocumulus	Two cloud layers or three, ground level near 1000m (thin); 1200m (700m); 800m, cloud >> 15
616	4:54	Cumulus fractus	Multiple layers of clouds up to 1600m, cloud >> 15
616	7:58	Broken stratocumulus	Z = 1700m, (very thin), cloud < 15
616	10:55	Few ragged cumulus	Z = 7200m, cloud < 15
616	13:47	Scattered cumulus haze	Some thin clouds around 900-1000m; virga coming from around 7500m.
616	16:56	Cumulus haze	Some thin clouds around 800m; virga from near 8000m; overcast cirrus.
616	20:17	Cumulus humilis scattered	Z_1 = 300m (400m); Z_2 = 8000m, cloud > 15

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
616	22:52	Occasional drizzle	Z = 1000m (200m), precipitation? until 23:10, cloud >> 15
617	1:56	Overcast, Drizzle	Z = 900m (300m), precipitation, cloud >> 15
617	4:52	Overcast	Z = 800m (400m), cloud >> 15
617	8:04	Drizzle	Z = 1000m (400m), precipitation, cloud >> 15
617	10:53	Overcast	Z = 600m (500m), cloud >> 15
617	13:54	Overcast	Z_1 = ground to 400m; Z_2= 500m (700m), cloud >> 15
617	16:59	Overcast St.	Continuous cloud and/or precipitation from ground to 1300m, cloud >> 15
617	19:59	Partly cloudy	Multiple cloud bases: near ground, 600m, 1300m: all < 200m thick, cloud >> 15
617	22:51	Mostly clear	Mostly clear, clear >> 15
618	1:49	Cloudy	Z = 800m (400m), cloud > 15
618	4:53	Cloudy	Z_1= 800m (400m), Z_2= 7800m (virga); Z_3= 8200m (virga), cloud > 15
618	7:53	Stratus	Z_1= 1000m (200m); Z_2 = 7000m (virga),
618	10:55	Stratus	Scattered below 800m; thin cloud deck at 1300m; virga from 8000m, cloud > 15
618	13:57	Cloudy	Z = 1500m (200m), virga from 9000m, cloud > 15
618	16:51	Cloudy	Nearly clear, cloud < 15
618	20:01	Mostly clear	Z = 700m (thin), Virga from 9000m, cloud <15
618	22:49	Cloudy	Serious virga 9000m

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
619	1:54	Thin clouds	Virga 10,000m, mostly clear below 5000m
619	4:53	Cloudy	Virga from 6000m, Z_1 = 800m(200m) & Z_2 = 1300m (200m), cloud > 15
619	7:53	Overcast 1500m, 900m	Z = 600m (thin), Z_2 = 1400m (200m), Z_3 = , cloud > 15
619	10:54	Scattered 1500m	Z_1 = 600m, Z_2 = 5000m, cloud > 15
619	13:57	50%	Scattered thin clouds around 500m, cloud > 15
619	17:07	10%	Mostly clear, cloud < 15
619	20:48		Precipitation, but doesn't reach ground from 1500m, lower clouds about 500m, cloud > 15
619	22:53		Z = 500m (100m), cloud ≈ 15
620	1:57		Z_1 = 600m, Z_2 = 1300m (400m), cloud > 15
620	4:54		Z_1= 900m (thin), Z_2 = 8000m (virga)
620	7:41		Z_1= 1700m (200m); Z_2= 7000m (virga), cloud > 15
620	10:44	Cirrus, cumulus	Z_1= 500m (thin); Z_2 = 1700m(thin); Z - 5000, cloud >15
620	13:45	Broken stratus	Z_1 = scattered clouds around 400m; Z_2 = cloud top 1700m, but lowering cloud to 1000m, cloud > 15
620	16:46	Cirrus, cumulus	Z = 400m (300m), cloud < 15
620	19:59	5% Cumulus haze	Z = 500m (100m), cloud ≈ 15
620	22:57		Z = 100m (500m), cloud >> 15
621	2:03		Z = 1400m (200m), cloud > 15

Table 4 **Weather and Radar Observations**

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
621	4:58	Stratus 1300-1500m	Z = 1000m (500m), cloud > 15
621	7:51	Stratus drizzle @ 8:23	Z_1= ground (800m); Z_2 = 1000m (700m), cloud > 15
621	10:48	Stratus	Precipitation/cloud mixture from ground to 1900m, cloud > 15
621	13:52	Cumulus broken; stratus	Definite clouds thinning at 1500m, lower clouds of all different bases between 300-500m
621	16:56	Cumulus	Scattered clouds below 1500m, all very thin
621	19:45	Broken cumulus	Z = 600m (800m), precipitation cloud mixture, cloud > 15
621	22:54	Drizzle	Machine off
621	1:54	Overcast/drizzle	Z = 1000m (500-700m), precipitation after 1:45, cloud > 15
622	4:58		Z = 1000m (600m), cloud > 15
622	7:39	Stratus above cumulus	Precipitation? (light) from clouds around 1000m, cloud tops at 1600m, cloud > 15
622	10:45	Stratus above cumulus	Precipitation ending?, Z = 1500m (300m); scattered clouds below 800m, cloud > 15
622	13:44	Thin stratocumulus	Z = 1600m (100m), cloud > 15
622	16:41	Thin stratocumulus	Radar off
622	20:02	Cumulus, stratus	Radar off
622	22:53		Z= 1400m(thin), cloud < 15
623	1:51		Machine off, probably Z = 1300m (100m), cloud > 15

Table 4 **Weather and Radar Observations**

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
623	4:52		Machine off, probably Z = 1300m (300m), cloud > 15
623	7:49	Stratus above cumulus	Radar off
623	10:47	Stratus above cumulus, rain	Machine off, precipitation from 2000m, cloud > 15
623	13:47	Broken stratocumulus	Virga from 2000m
623	16:51	Cirrus, cumulus	Cloud < 15, except for a few cirrus at 8500m.
623	19:56	Cumulus	Z = 1400m (200m), cloud > 15
623	22:50		Radar off
624	1:50	Scattered cumulus	Z_1 = 700m (100m - scattered); broken clouds @ 1600m (100m), cloud > 15
624	5:04	Thin stratus	Z = 1600m (200m), cloud > 15
624	7:51	Cloud base at 857 m	Cloud tops rising from 1800 to 1900m, precipitation after 8:00, cloud > 15
624	10:44	Stratus above cumulus	Z = 1500m (300m); scattered after 11:00
624	13:54	Stratus above cumulus	Z = 1600m (300m), cloud > 15
624	16:46	Stratus @800m, above cumulus	Z = 500m (400m- scattered); Z_2 = 1400m (200m), cloud > 15
624	19:57	Cumulus: 5%	Clouds at varying below 800m, cloud < 15
624	22:58	Clear	A few clouds below 800m, cloud < 15
625	1:44	Clear	Z = 1500m (100m), cloud > 15
625	4:58	Thin stratus	Z = 1500m (200m), cloud > 15
625	7:49		Z_1 = 1700m (thin); Z_2 = 10,000m (virga), cloud > 15

Table 4 Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
625	13:51		Clouds from ground to 600m, scattered clouds at 1500m (200m), cloud > 15
625	16:47		Clouds from ground to 800m, cloud > 15
625	19:44	Mostly clear	Scattered clouds below 800m, cloud < 15
625	22:46	Clear	Nearly clear, scattered below 500m, cloud << 15
626	1:48	Clear/fog?	A couple of scattered clouds around 500m, mostly clear, cloud << 15
626	4:37	Clear/fog?	Clear, cloud << 15
626	7:49	Clear	Scattered thin clouds around 700m, cirrus at 9000m
626	10:55		Broken clouds @ 800m, possibly some precipitation, cloud > 15
626	13:51		Radar off
626	16:48		Scattered clouds around 500-800m, very thin, cloud < 15
626	19:51	Nearly clear	Scattered clouds around 500-800m, very thin, cloud < 15
626	22:51	Clear	Mostly clear, cloud << 15
627	1:59		Mostly clear, cloud << 15
627	4:49	10% Clear	Mostly clear, thin clouds @ 600m, cloud < 15
627	7:50		Radar off
627	10:49		Radar off
627	13:51	Cirrus, mostly clear	Virga falling from near 10,000m
627	16:40		Clouds under 500m, extending to surface, strong updraft, cloud >> 15

Table 4   Weather and Radar Observations

Sounding Launch Date	Time	Visual Observation	Radar Interpretation
627	20:08	Clear, stratus on horizon	Strong updraft from surface to 500m, cloud > >15
627	22:59	Clear	Radar off
628	1:48	Clear	Scattered clouds at all levels below 1500m, cloud < 15
628	4:50	Clear	Nearly clear, cloud << 15
628	7:46		Scattered clouds at all levels up to 2000m, but mostly clear, cloud < 15
628	10:45	Scattered cumulus	Clouds from ground to 9000m, cloud > 15
628	13:48	Scattered cumulus	Radar off
628	16:47	Cloudy	Radar off
628	20:14	Broken stratus	Z = 500m (100m), cloud >> 15
628	22:53	Cloudy	Z = 400m (400m), cloud >> 15

4. Comparisons

4.1 Comparisons Using Data Every Two Minutes

These graphs were made using only the data from the ceilometer, pyranometer and radiometer (the "all" data set). The sounding data was not used here.

4.1.1 Liquid Water vs. Infrared Irradiation

See FIGURE 4: Liquid water path has been compared to infrared irradiation for different cloud heights as registered by the ceilometer. The breakdown of cloud heights is as follows: Cloud at less than 500 meters, between 500 and 1250 meters, between 1250 and 2250 meters, 2250 and 5000 meters and greater than 5000 meters. These intervals were picked because they reflected very-low, low, low-middle, middle and high clouds. Often the ceilometer detected clouds at different levels during the "time-window." This breakdown was an attempt to show this. The figure, itself, is made up of six graphs - each one for a different cloud height. The last graph is for "clear" sky, or when the ceilometer detected no cloud.

4.1.2 Precipitable Water vs. Infrared Irradiation

See FIGURE 5: Precipitable water path has been compared to infrared irradiation in much the same way as in 4.1.1, where the results have been put into "bins" by cloud height. Interestingly, one can draw a line for each of the graphs, going through regions of highest concentrations. All the slopes are the same, about 3 W $m^{-2}$of infrared irradiation per 4 mm of precipitable water. The difference between the graphs is where the left side of the concentration starts - highest for the low clouds and lowest for clear sky. However, there are many points in each graph that don't correspond to highest concentration.

4.1.3 Liquid Water Path vs. Height of Cloud Base

See FIGURE 6: Liquid water path has been compared to the height of the cloud base as registered by the ceilometer. The height of cloud base is in logarithmic form, in order to show that higher liquid water path indicates lower cloud base.

4.1.4 Precipitable Water Path vs. Height of Cloud Base

See FIGURE 7: This comparison was done just like that in 4.1.3. Generally, the higher the precipitable water, the lower the cloud base.

4.1.5 Solar Irradiation calculated at Top of Atmosphere vs. Maximum Solar Irradiation Observed on Ground During ASTEX

See FIGURE 8: The declination of the sun does not change very much between 1 June and 28 June, so it was assumed that it remained constant at 23.45 degrees. One could calculate the solar insolation at the top of the atmosphere. To find the maximum solar irradiation observed on the ground, a program looked through all the two-minute observation data to find the highest value at a particular time of day (expected when the sky was clear.) The solar constant was assumed to be 1367 W m^{-2}, while the eccentricity of earth's orbit was.0167, putting the June solar constant at 97% of 1367 W m^{-2} or 1326 W m^{-2} (Peixoto & Oort, 1992). In some cases, the maximum solar irradiation observed was higher than the maximum calculated. Most of these cases were right around sunrise or sunset, however a few were also around noon. Possibly, the noon cases were periods when the sky was mostly clear except for a few highly reflective (cumulus?) clouds, actually adding to the solar irradiation.

4.1.6 Liquid Water Path vs. "Missing" Solar Irradiation as a Function of Time of Day

See FIGURE 9: The solar insolation has been calculated at the top of the atmosphere for every two minutes during the day. The actual solar irradiation detected by the pyranometer is also known for every two minutes during ASTEX. The difference between the two was called "missing" because it is solar Irradiation lost due to absorption and scattering by the atmosphere and its clouds. Liquid water path is compared to this "Missing" solar irradiation at different times of day, because a cloud can presumably have a larger role in solar irradiation loss around noon as opposed to dawn or twilight.

4.1.7 Liquid Water Path vs. Percentage of Solar Insolation Reaching the Ground

See FIGURE 10: This graph uses the same data as in the one above, however instead the observed solar irradiation is a percentage of calculated solar insolation at the top of the atmosphere. There is definite correlation between the two: low values of liquid water path almost exclusively correspond to high percentages of solar insolation reaching the ground and vice versa.

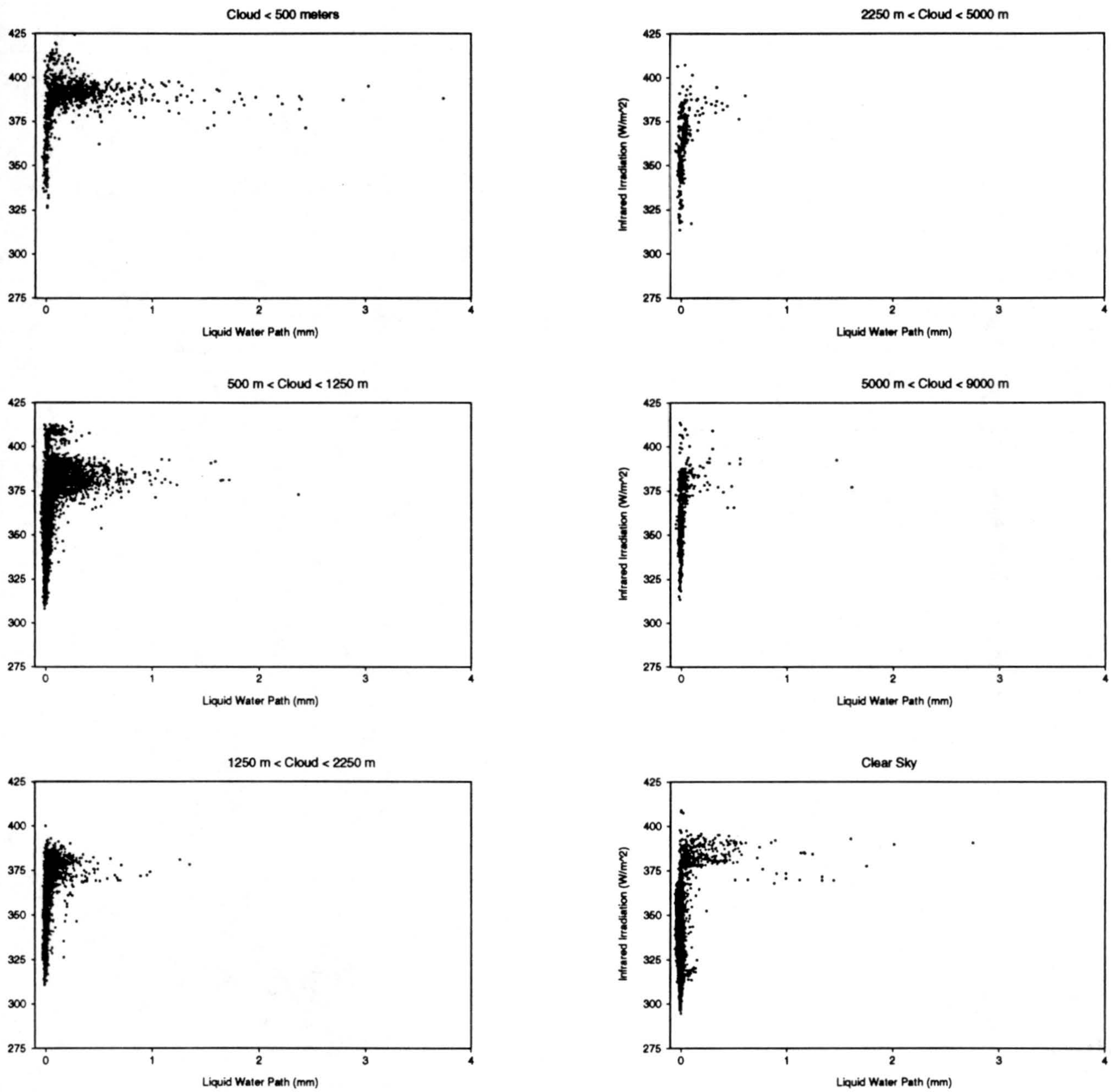


FIGURE 4 Liquid Water Path vs. Infrared Irradiation For Different Cloud Heights
Cloud heights were measured by the ceilometer.

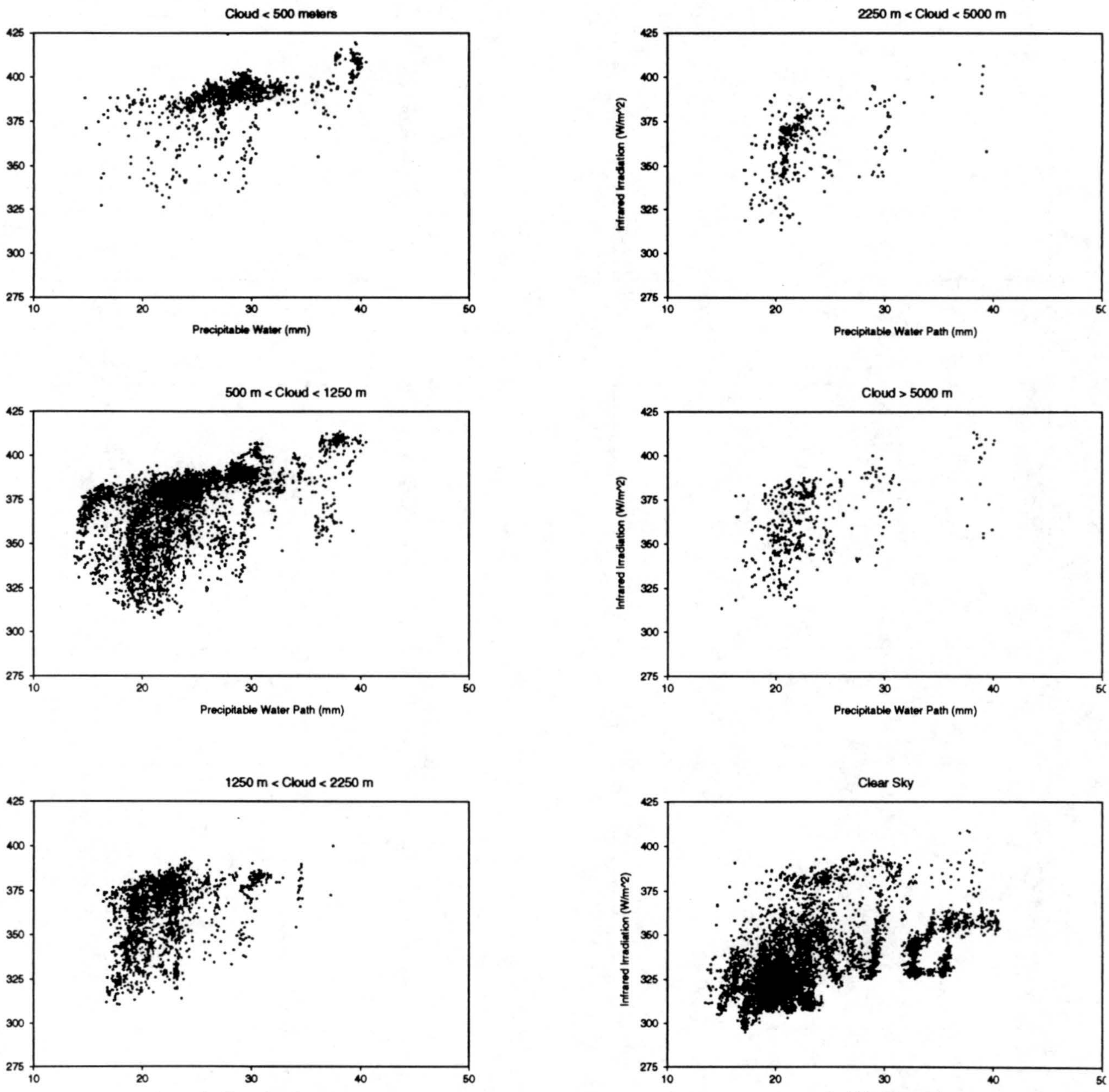


FIGURE 5 Precipitable Water Path vs. Infrared Irradiation for Different Cloud Heights

Cloud heights were measured by the ceilometer

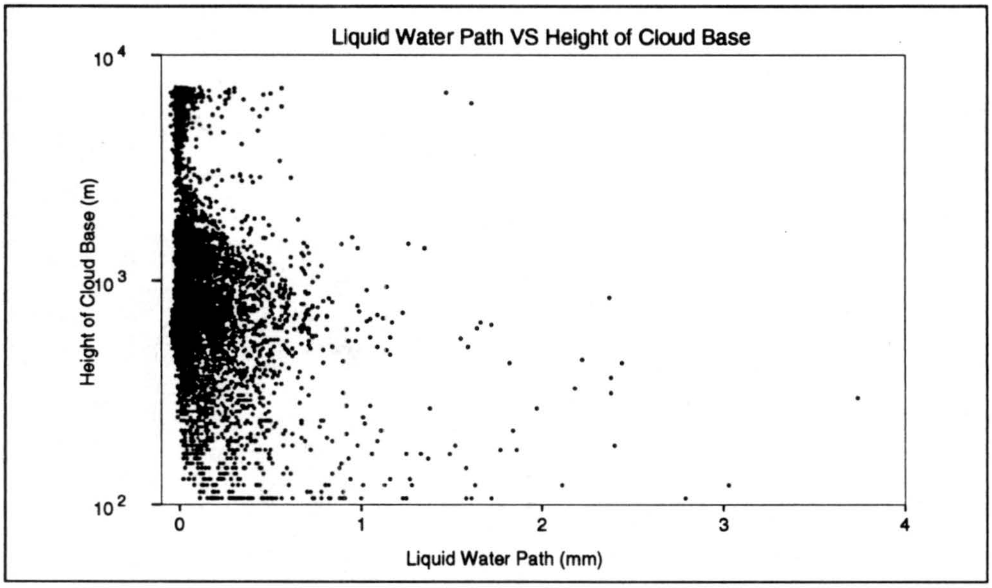


FIGURE 6 Liquid Water Path vs. Height of Ceilometer Cloud Base Height

Generally, the higher the liquid water path, the lower the cloud base.

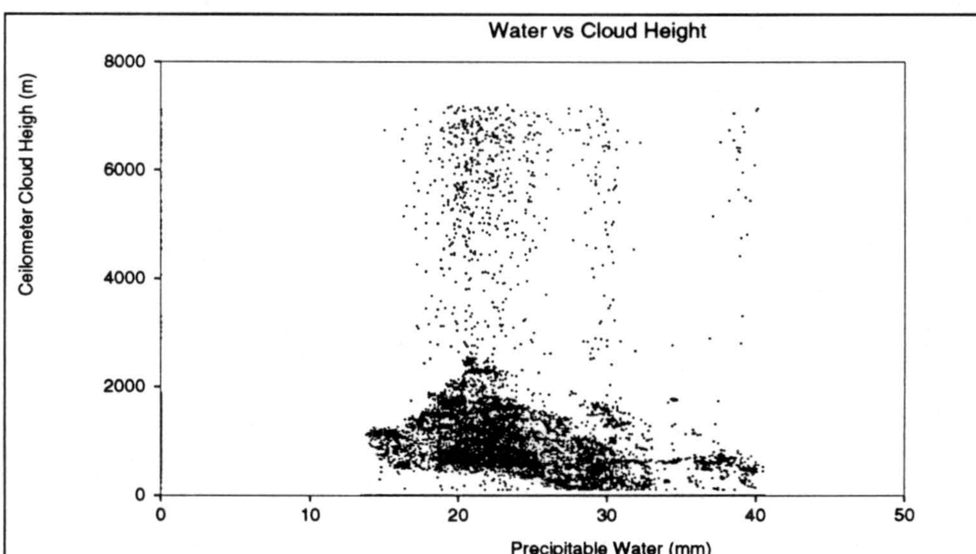


FIGURE 7 Precipitable Water Path vs. Ceilometer Cloud Base Height

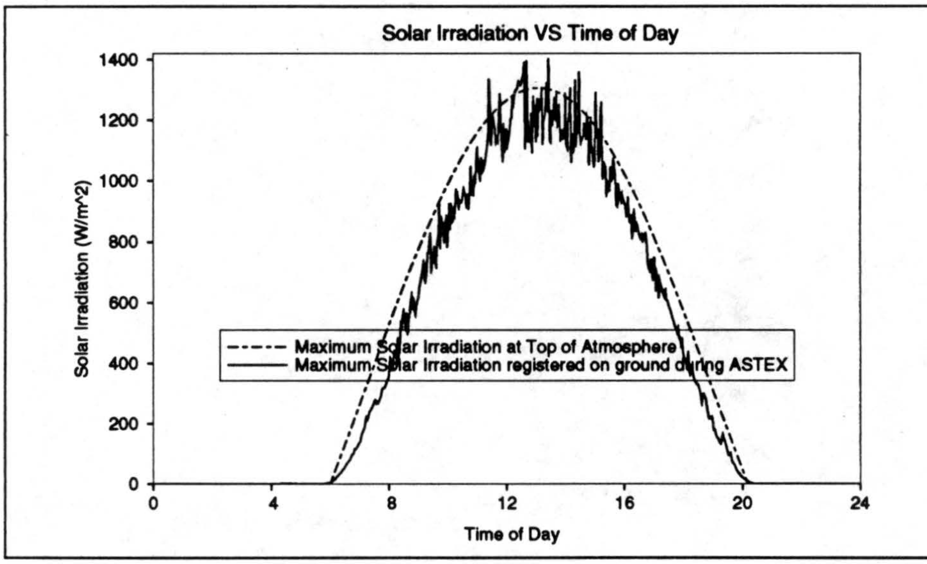


FIGURE 8 Solar Irradiation vs. Time of Day

Occasionally, the solar irradiation detected on the ground was higher than the solar constant.

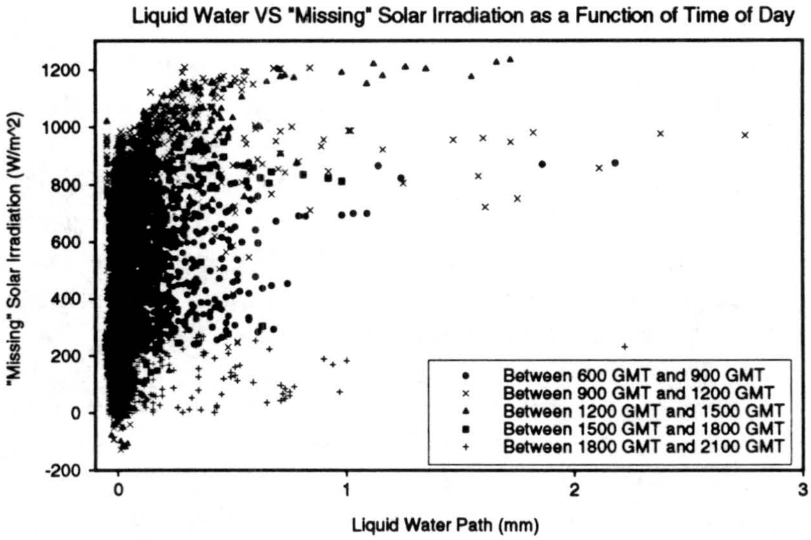


FIGURE 9 Liquid Water Path vs. "Missing" Solar Irradiation as a Function of Time of Day

Occasionally, the "Missing" solar irradiation was negative, these were cases when the pyranometer gave readings HIGHER than the calculated solar insolation at the top of the atmosphere.

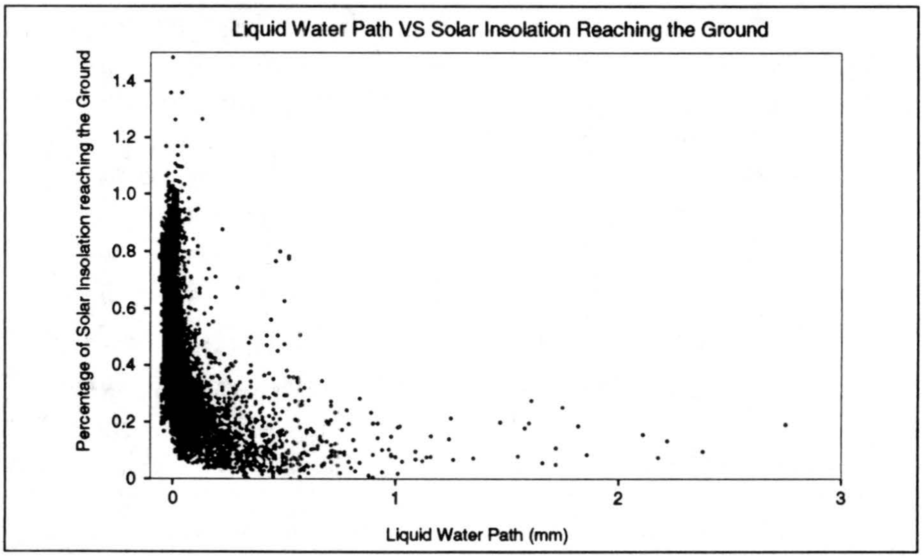


FIGURE 10 Liquid Water Path vs. Percent of Solar Insolation Reaching the Ground

The Percent is the observed solar irradiation divided by the calculated solar insolation at the top of the atmosphere. Ratios larger than one are when the pyranometer gave readings higher than the calculation, the highest values closest to sunrise and sunset. 1.0 equals 100%.

4.2 Comparisons Using the "Time-Window"

Since the "time-window" around the sounding was an hour long (16 minutes before and 44 minutes after), there were 31 observations taken every two minutes during the hour.

4.2.1 Liquid Water vs. Infrared Irradiation

See FIGURE 11: This comparison between liquid water path and infrared irradiation was made as a function of the sky cover. A qualifier was made whether it was mostly clear or mostly cloudy during the hour. If the ceilometer registered clouds more than half the time (16/31 observations), then the sky was considered mostly cloudy; if the ceilometer registered clear more than half, then the sky was considered mostly clear. In a few cases, the ceilometer did not give any results during the time-window. When this happened, the point was not graphed. For the most part, there is good visual correlation as a function of clouds: Mostly clear skies will accompany low liquid water and low infrared while the opposite is true for mostly cloudy skies.

4.2.2 Precipitable Water vs. Infrared Irradiation

See FIGURE 12: This comparison was made in the same way as 4.2.1. There is a strong correlation between precipitable water and infrared irradiation, especially when given the extra variable of sky cover. When the sky is mostly clear, infrared irradiation rises at about 1.25 W m^{-2} for every millimeter of liquid water path, while a sky of mostly cloudy produces a 1.75 W m^{-2} rise in infrared irradiation for each millimeter of precipitable water path.

4.2.3 Total Cloud Thickness vs. Percentage of Solar Insolation Reaching the Ground

See FIGURE 13: Total cloud thickness was derived from each sounding. The percentage of solar insolation reaching the ground is the ratio of observed average solar irradiation at the ground during the time window to the calculated solar insolation at the top of the atmosphere at the sonde launch. There is definitely a correlation, but not as strong as might be expected.

4.2.4 Liquid Water Path vs. Percentage of Solar Insolation Reaching the Ground

See FIGURE 14: This graph was made in much the same way as in 4.2.3. There is a pretty strong correlation between the two variables.

4.2.5 Liquid Water Path vs. Total Thickness of Clouds in the Path

See FIGURE 15: The average liquid water path throughout the "time-window" is compared with the total thickness of clouds detected by the rawinsonde. There is definitely some correlation, approximately 500 meters of cloud for every tenth millimeter of liquid water. However, as the liquid water path increases, the points spread out off the average line.

4.2.6 Number of Cloud Observations vs. Average Infrared Irradiation

See FIGURE 16: During the "time-window" a tally was kept of the number of times the ceilometer detected a cloud. This figure shows a pretty good one-to-one correlation between the two. When the infrared irradiation was low (300-325 W m^{-2}), the ceilometer detected few clouds. The infrared rises about 2.3 W m^{-2} for every "cloud" detected by the ceilometer.

4.2.7 Average Infrared Irradiation vs. Percentage of Solar Insolation Reaching the Ground

See FIGURE 17: There is a fair correlation between these two variables. When the Infrared is low, the percentage of solar insolation is high, and vice versa. An attempt was made to see if sky cover was another variable. It was expected to see the cloudier "time-windows" to be more on the right side of the graph. This is true, but not nearly as strongly as was expected.

4.2.8 Comparison Between Sounding and Radiometer Estimates of Precipitable Water Path

See FIGURE 18: The precipitable water path derived by the sounding is compared with the average precipitable water path given by the radiometer during the time window. Most cases have the readings different by not more than 20%, with the radiometer usually giving a higher reading, especially at higher levels of precipitable water. The two points that seemingly are in large error are due to greater than 500 meters of missing sounding data.

4.2.9 Comparison Between Sounding and Pyranometer Estimates of Infrared Irradiation

See FIGURE 19: The blackbody irradiation derived from the cloud-base temperature is compared with the average Infrared Irradiation given by the pyranometer during the "time-window." While most comparisons are not that close to the perfect fit line, at least all are in the ballpark. Most average pyranometer readings are lower than the blackbody cloud base readings, probably because infrared that would be detected by the pyranometer was absorbed by lower atmosphere that doesn't come close to behaving as a black body.

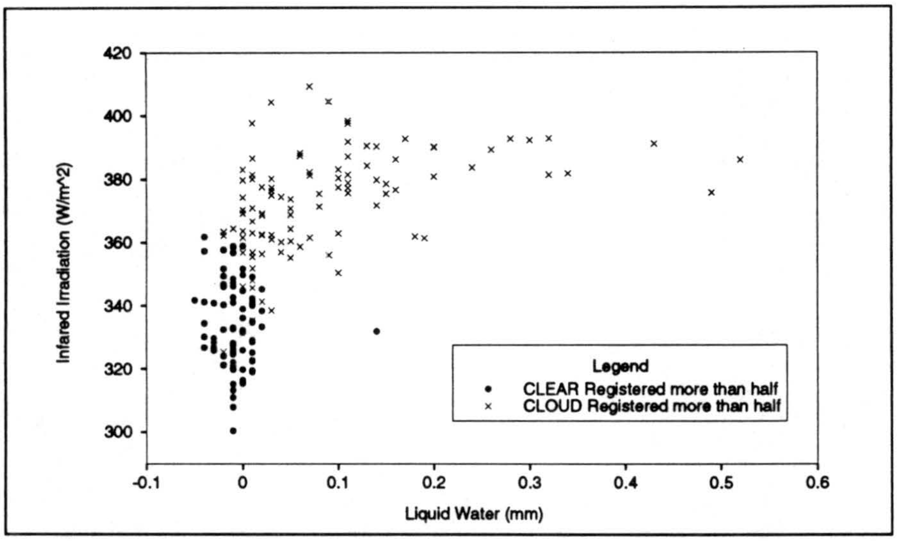


FIGURE 11 Liquid Water Path vs. Infrared Irradiation as a Function of Sky Cover

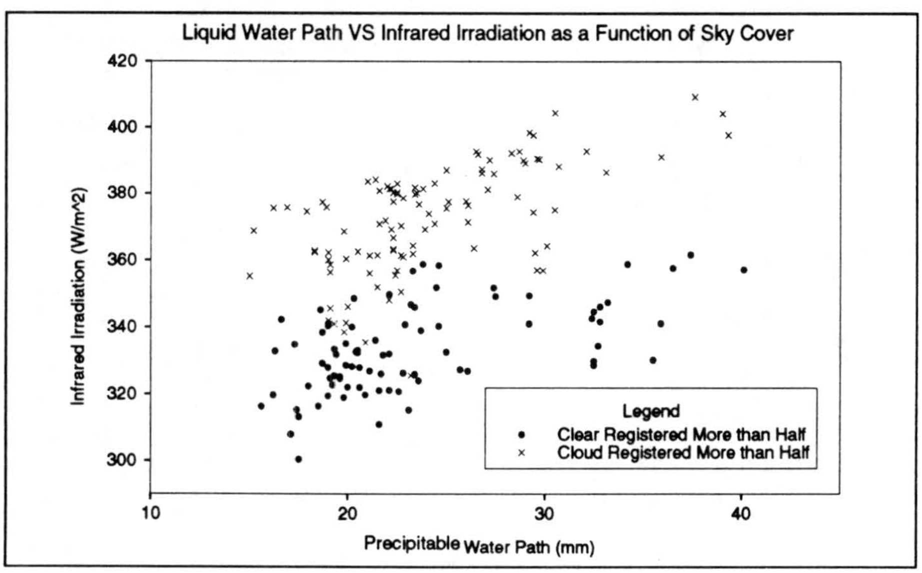


FIGURE 12 Precipitable Water Path vs. Infrared Irradiation as a Function of Sky Cover

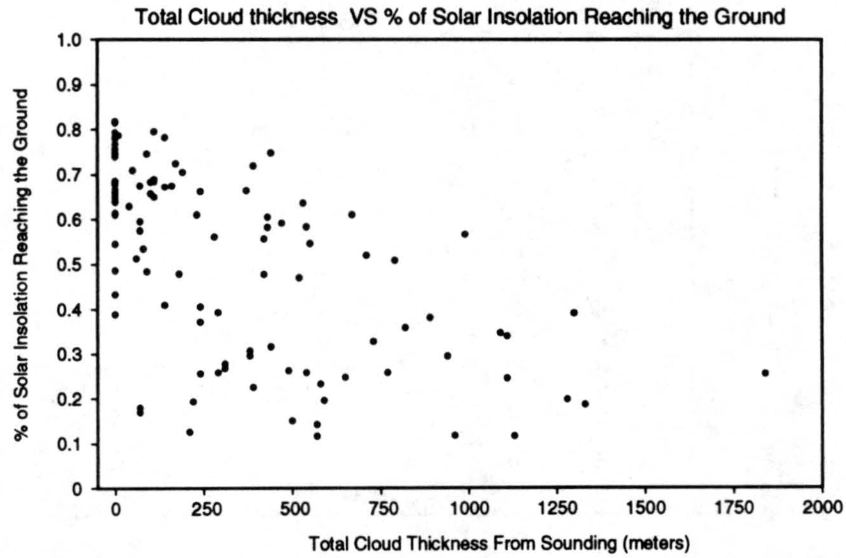


FIGURE 13 Total Cloud Thickness vs.% of Solar Insolation Reaching the Ground

Cloud thickness was measured by the sounding

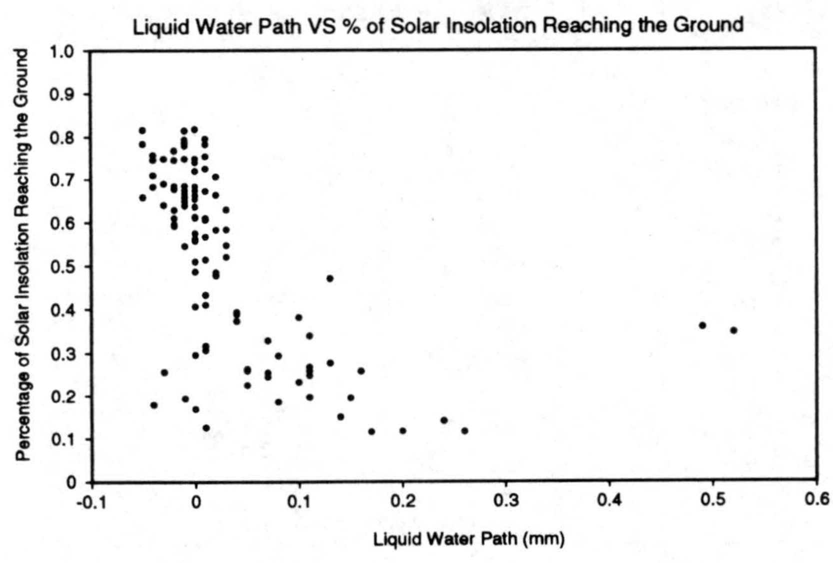


FIGURE 14 Liquid Water Path vs. Percent of Solar Insolation Reaching the Ground

Negative values for liquid water path are due to radiometer calibration.

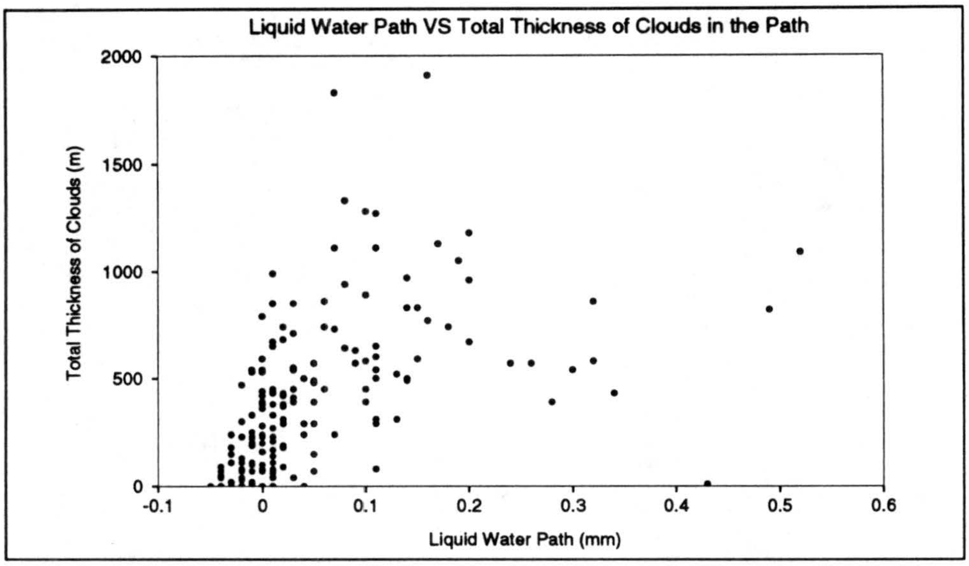


FIGURE 15 Liquid Water Path vs. Total thickness of Clouds in the Path

(The path is the sonde's path.) The two dots on the right both have missing sounding data, making the cloud thickness low.

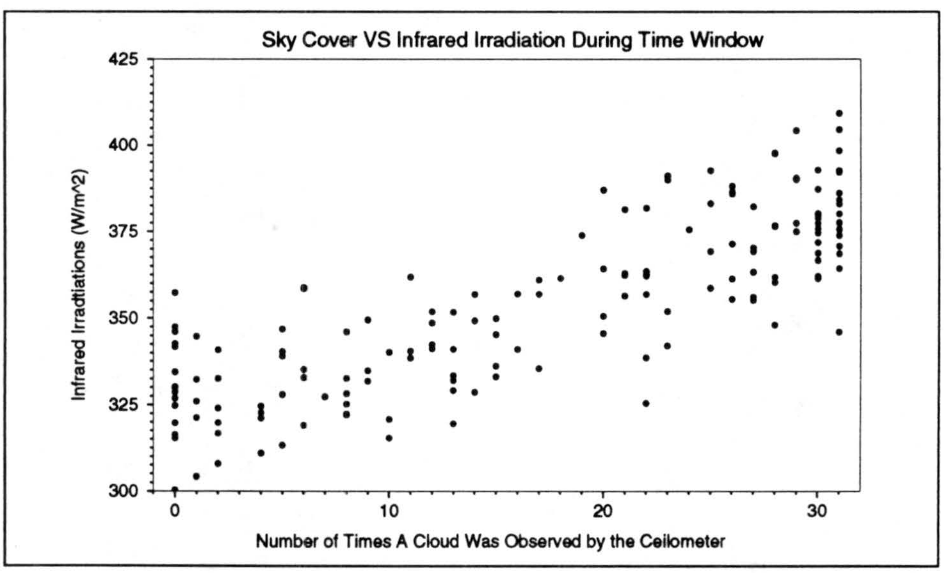


FIGURE 16 Number of "Cloud" Observations vs. Average Infrared Irradiation

There are 31 total observations during the "time-window.

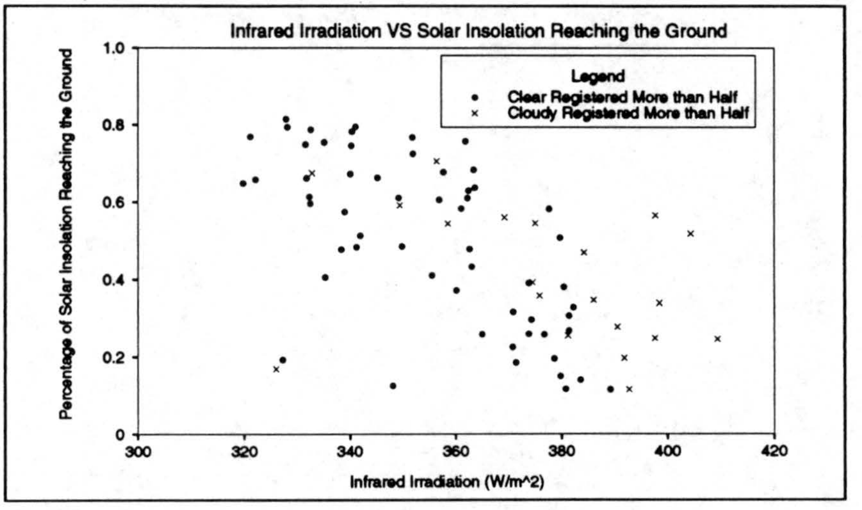


FIGURE 17 Infrared Irradiation vs. Percentage of Solar Insolation Reaching the Ground

The mostly cloudy sky had values closer to the top of the chart than the mostly clear.

A Comparison Between Radiometer and Sounding Estimates of Precipitable Water

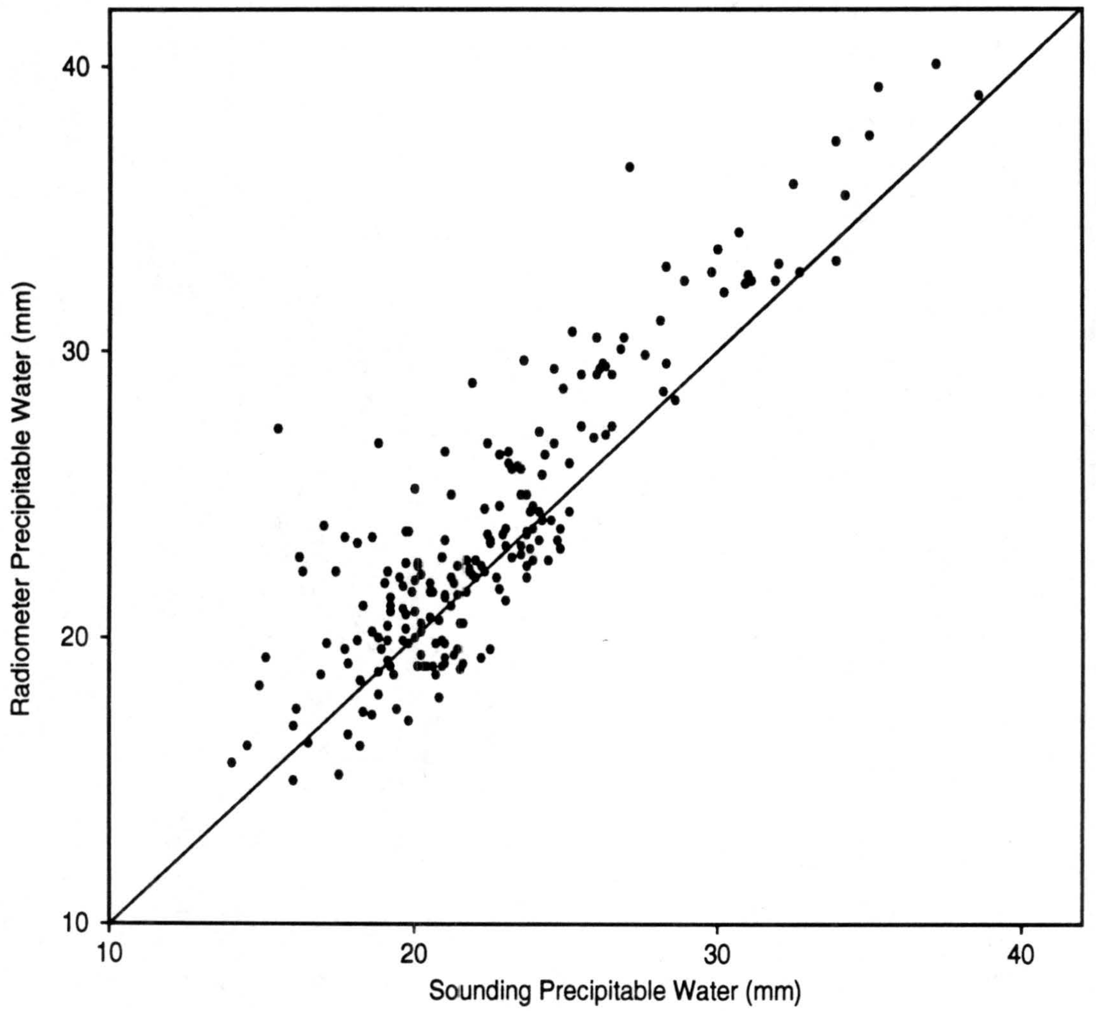


FIGURE 18 Radiometer and Sounding Estimates of Precipitable Water

The two points that are very much off the line are due to a lot of missing sounding data.

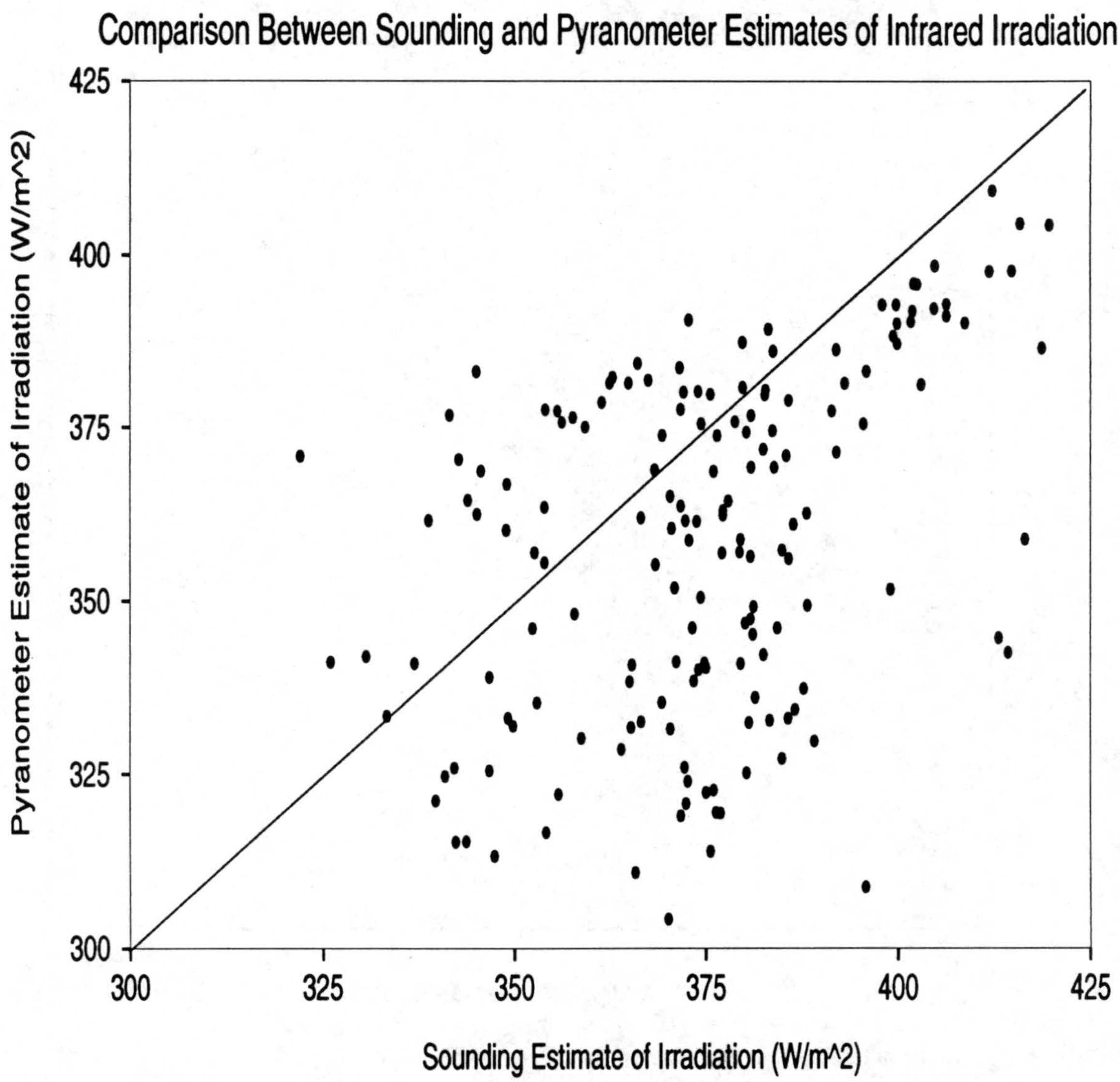
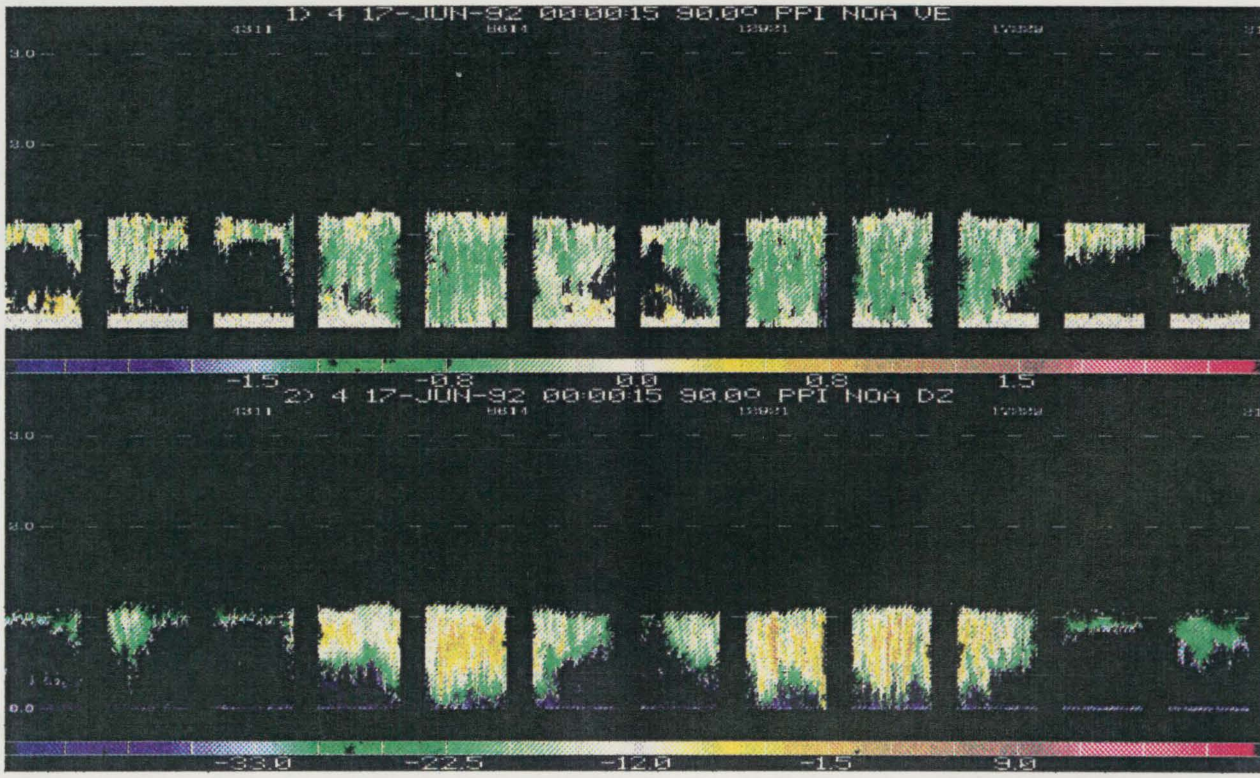
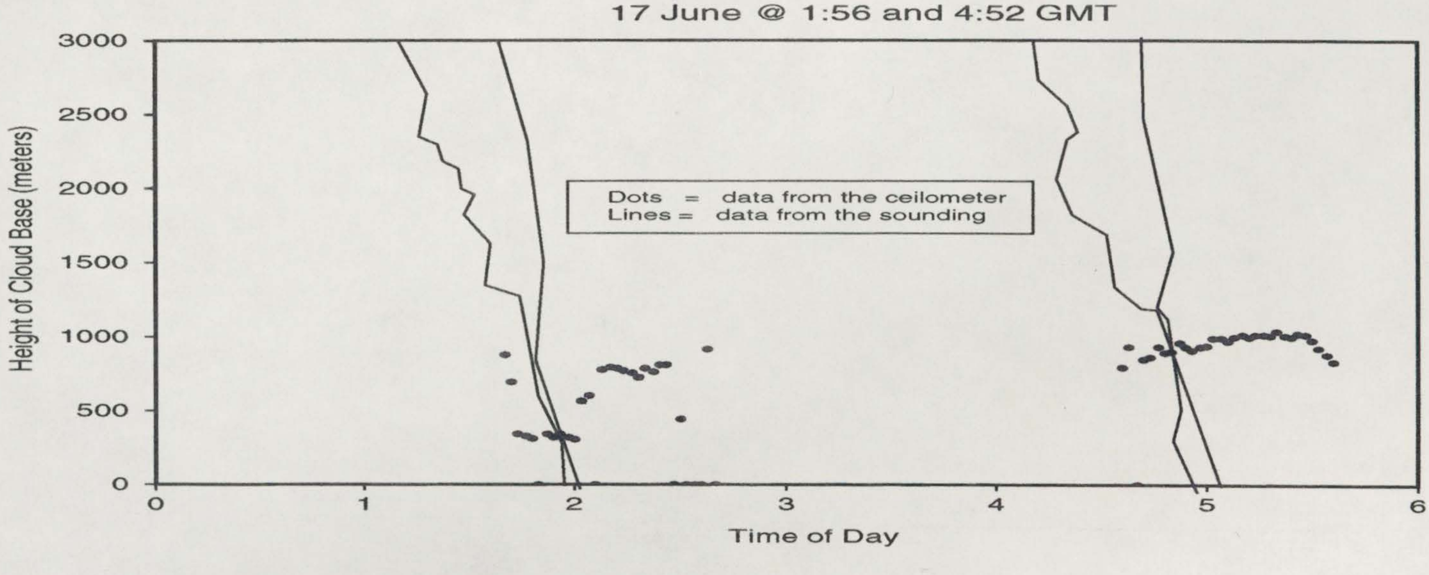


FIGURE 19 Sounding and Pyranometer Estimates of Infrared Irradiation
The line is perfect fit.

5. A picture comparison

The picture comparison is an attempt to combine all the data together for certain dates and times. Included is a ceilometer plot, with the sounding drawn on top of it, and a radar picture from the same time period. Also, the corresponding segments from Table 2 and Table 4 are also included.





DAY .HR.MN....c500.....c1250.....c2250.....c5000.....c9000..CLD. CLR....Prec....Liq.....Infrared..SolarT

DAY	HR	MN	c500	c1250	c2250	c5000	c9000	CLD	CLR	Prec	Liq	Infrared	SolarT
617	1	56	340	753	0	0	0	23	8	28.9	0.2	390	-1.1
617	4	52	0	951	0	0	0	30	1	26.8	0.06	387.3	-1.1

617	1:56	Overcast, Drizzle	Z = 900m (300m), precipitation, cloud >> 15
617	4:52	Overcast	Z = 800m (400m), cloud >> 15

The above radar picture, and combination sounding/ceilometer pictures are both of 17 June from 0:00 GMT to 6:00 GMT. In the case of the sounding/ ceilometer picture, the sounding has been superimposed on top of the ceilometer at the time of the sonde launch.

Both sonde launchs have very positive agreement between the radar and the sounding/ceilometer. The cloud bases are nearly at the same height for all three. When the radar indicates the possiblity of precipitation, (sonde launch 1:56) the liquid water path is high, the infrared irradiation is high and the ceilometer detects varying cloud bases, as if it was detecting precipitation as well as the cloud.

The other sonde launch (4:52 GMT) detects a solid cloud with a base near 900 meters. There is no precipitation detected by the radar, and very consistent cloud base height detected by the ceilometer. Therefore, the sky was overcast, but dry throughout the "time-window."

6. Summary and Conclusions

In this paper, data from the ASTEX rawinsondes, ceilometer, radiometer, pyranometer and 8mm radar has been analyzed. This has involved using data from the ceilometer, radiometer and pyranometer at two minute intervals and then making a "time-window" around the sounding launch times to include all types of observations.

Some conclusions can be made about the methods used. The two minute interval approach gave lots of data, (up to 20,160 observations for each instrument), and this was nice to get very thick "best fit" curves. "Liquid water path vs. percent of solar insolation reaching the ground "(FIGURE 10) was especially revealing. The sounding "time-window" was successful in that it was a method to get the sounding and the radar involved as well as the two-minute data. The scatter plot comparing the estimates of precipitable water between the radiometer and sounding was very close to a perfect fit. (FIGURE 18). The scatter plot comparing infrared irradiation (FIGURE 19) was also good, although not as nice as the precipitable water.

We have not yet figured out how to numerically compare the estimates of the cloud base by the ceilometer, sounding and 8mm radar. However, on inspection, in most cases the three agree pretty well. Often the data did not match when one or more the instruments wasn't recording for a time. When the radar picture shows precipitation the liquid water average over the time window is high (> 0.10 mm).)

An important observation to make is that while the cloud base levels are close to agreement at lower levels, there is little agreement at higher levels. The sonde did not detect 95% humidity (a cloud) higher than 2080 meters. The ceilometer did not detect clouds higher than about 7000 meters, but most of these 7000 meter clouds were registered as closer to 9000-10,000 meters by the radar. However, since ASTEX was mainly concerned with low level clouds (below 2000 meters), this may not matter very much.

Liquid water, infrared irradiation and percent of solar irradiation were correlated much as would be expected. High liquid water, high infrared irradiation and low percent of solar irradiation were related with cloudy skies, while low liquid water, low infrared and high percent of solar irradiation were indicative of clearer skies. Usually, the lower the cloud base, the more "cloudy" the other data seemed. During the "time-window" the same sort of results were found. The difference was that because all values were averaged, many of the deviant data was filtered out, allowing for better correlations. Two good examples were in FIGS. 11 and 12. Almost all of the high infrared values were correlated with cloudy skies over the time window, while low infrared values meant clearer skies (FIGURE 16). Precipitable water path seems to give very little indication of sky cover

7. ACKNOWLEDGMENTS

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