Intercomparison of *F*-Region Electron Temperatures Measured by the Satellites AEROS-B and TAIYO

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Electron temperatures measured by the AEROS retarding potential analyzer (RPA) and by the TAIYO electron temperature probe are compared when both satellites were close to each other. The selected data are in the height range 250 to 400 km. During local nighttime good agreement is obtained between the measurements of both satellites. This allows to derive temperature gradients with respect to the altitude profile and the increase at sunrise. At daytime the temperatures from TAIYO are, on the average, 10% higher than from AEROS.

1. Introduction

In the past decade a large amount of observations of electron temperatures in the ionospheric *F*-region has been obtained with satellites and from ground. This was reviewed recently by SCHUNK and NAGY (1978). During the period from February to September 1975 the AEROS-B and the TAIYO satellites simultaneously provided electron temperature measurements. While AEROS had a polar orbit with nearly constant local time, TAIYO had a low inclination orbit covering all local times. It is obvious that the analysis of a combined set of measurements does not only increase the amount of available data but allows to study phenomena where at least two simultaneous measurements are needed in order to separate spatial from time-dependent effects, which cannot be achieved with one satellite alone. Therefore a joint data basis is of great interest for many investigations.

Before significant results can be obtained from a detailed investigation of two different experiments on different satellites a careful comparison of both measurements has to be done. It has to be proved first that both instruments give correct temperatures within the expected error limits and that differences, if they are observed, are not due to experimental inaccuracies. One way to

calibrate a satellite-borne instrument is to compare its results with ground-based incoherent scatter radar observations. Good agreement was found at a few AEROS passes over several IS stations (SPENNER and RAWER, 1978). In this paper we shall compare AEROS temperatures with those from TAIYO during orbits when both satellites were close to each other. In the past unexplained discrepancies between ground-based and satellite measurements (BOOKER and SMITH, 1970; CARLSON and SAYERS, 1970) have clearly demonstrated that different measuring techniques sometimes yield large differences. Therefore it is also of experimental interest to intercompare temperatures obtained by a planar RPA (SPENNER and DUMBS, 1974) with a stepping retarding voltage and those from a radio frequency probe (OYAMA and HIRAO, 1975).

2. Observation

During the overlapping lifetime of AEROS-B and TAIYO, i.e. between February 24 and September 25, 1975 a total of 39 encounters of these satellites did occur, where time and location were the same within narrow limits and electron temperatures were measured on both spacecraft. These events are listed in Table 1 with coordinates, times and differences thereof. The maximum differences is 5° in latitude, 35° in longitude, 200 km in altitude, 1 hr in local time, and 2 hr in universal time. Close encounters suitable for direct intercomparison of electron temperatures are rare; even when the geographic coordinates coincide the height and/or the time in most cases are rather different. On the other side data comparisons at only a few crossings are like snapshots and do not give enough confidence for a further combined data analysis. The number of appropriate comparisons can be increased when we are able to scale one temperature to the height of the other satellite in a proper way.

For this purpose we use a model representation of the electron temperature (SPENNER and PLUGGE, 1978). This model describes the temperature dependence on latitude, longitude, and height and was derived from the AEROS-A measurements representing the mean temperature averaged over a period of 3 months. Assuming that the temperature height gradient does not strongly vary we add to the measured AEROS temperature the temperature difference given by the model corresponding to the height difference of both satellites.

The AEROS temperature "scaled" to the altitude of TAIYO is also indicated in Table 1. We can prove the above-mentioned assumption by determining the height gradients between measurements when one satellite is approximately above the other (within 15° longitude and half an hour time difference) and comparing them with the model gradient. The result is given in Fig. 1 for night conditions. It is obvious that the gradients given by the slopes of the

Table 1. AEROS and TAIYO at near encounters.

No.	Date Day K_P	Exp. A=AEROS T=TAIYO	Orbit	UT	LT	Geogr.		Geomagn.		Height	T_e	T_e scaled
						Lat	Long	Lat	Long			
1	26.02.75	A	3,473	21.15	15.9	20	280	31	349	310	1,950	2,050
	57	T	34	21.42	16.4	20	280	31	349	277	2,300	
	3	DIF		-27	-0.5	0	0	0	0	33	-350	-250
2	27.02.75	A	3,490	21.40	15.9	21	273	32	341	310	2,320	2,460
	58	T	46	21.43	15.9	21	273	32	341	254	2,480	
	1+	DIF		-3	0	0	0	0	0	56	-160	-20
3	01.03.75	A	3,521	20.53	16.0	9	287	20	358	301	1,180	1,220
	60	T	70	21.51	16.8	9	284	20	353	297	1,700	
	3+	DIF		-58	-0.8	0	3	0	5	4	-520	-480
4	02.03.75	A	3,536	21.16	16.0	8	281	19	350	299	1,240	1,380
	61	T	82	21.53	16.6	8	281	19	350	280	1,550	
	3-	DIF		-37	-0.6	0	0	0	0	19	-310	-170
5	03.03.75	A	3,552	21.40	16.0	8	275	19	344	296	1,290	1,420
	62	T	94	21.54	16.3	8	275	19	344	259	1,350	
	3+	DIF		-14	-0.3	0	0	0	0	37	-60	70
6	05.03.75	A	3,583	20.53	16.2	-4	289	7	358	300	1,350	1,350
	64	T	118	22.01	16.9	-4	284	7	354	303	1,250	
	4	DIF		-68	-0.7	0	5	0	4	-3	100	100
7	09.03.75	A	3,646	20.51	16.3	-16	291	-5	1	303	1,460	1,390
	68	T	166	22.10	17.0	-16	283	-5	353	304	1,550	
	2	DIF		-79	-0.7	0	8	0	8	-1	-90	-160
8	10.03.75	A	3,662	21.13	16.3	-19	286	-8	356	303	1,350	1,340
	69	T	178	22.11	17.1	-19	284	-8	354	311	1,400	
	7	DIF		-58	-0.8	0	2	0	2	-8	-50	-60
9	11.03.75	A	3,678	21.36	16.3	-20	281	-9	351	302	1,320	1,330
	70	T	140	22.12	16.9	-20	281	-9	351	291	1,450	
	5+	DIF		-36	-0.6	0	0	0	0	11	-130	-120
10	20.03.75	A	3,821	21.50	16.5	-31	280	-20	351	293	1,270	1,160
	79	T	298	22.19	17.0	-31	280	-20	351	257	1,650	
	3+	DIF		-29	-0.5	0	0	0	0	36	-380	-490
11	21.03.75	A	3,833	17.41	16.3	-16	339	-8	47	287	1,180	1,240
	80	T	308	18.20	17.2	-31	343	-24	48	257	1,450	
	0	DIF		-39	-0.9	15	-4	16	-1	30	-270	-210
12	21.03.75	A	3,835	20.40	16.5	-30	297	-19	6	293	1,220	1,230
	80	T	309	20.16	16.0	-30	297	-19	6	278	1,500	
	3	DIF		24	0.5	0	0	0	0	15	-280	-270
13	23.03.75	A	3,867	21.23	16.5	-31	286	-20	356	292	1,180	1,180
	82	T	334	22.22	17.3	-31	284	-20	354	261	1,450	
	2	DIF		-59	-0.8	0	2	0	2	31	-270	-270

Table 1. (continued)

No.	Date	Exp. A=AEROS T=TAIYO	Orbit	UT	LT	Geogr.		Geomagn.		Height	T_e	T_e scaled
	Day K_P					Lat	Long	Lat	Long			
14	31.03.75	A	3,989	15.05	16.4	-21	20	-21	86	302	1,190	1,180
	90	T	427	16.23	17.3	-21	14	-19	80	278	1,450	
	3	DIF		-78	-0.9	0	6	-2	6	24	-260	-270
15	06.04.75	A	4,084	15.40	16.3	-1	9	1	79	329	1,200	1,250
	96	T	499	16.21	17.2	-6	14	-5	83	295	1,320	
	3-	DIF		-41	-0.9	5	-5	6	-4	34	-120	-70
16	08.04.75	A	4,116	16.20	16.3	-3	359	1	69	334	1,200	1,220
	98	T	523	16.19	17.0	-3	10	-1	79	327	1,400	
	6-	DIF		1	-0.7	0	-11	2	-10	7	-200	-180
17	09.04.75	A	4,134	19.42	16.3	-2	309	9	19	339	1,270	1,270
	99	T	536	18.17	16.7	-2	336	6	46	339	1,330	
	5-	DIF		85	-0.4	0	-27	3	-27	0	-60	-60
18	13.04.75	A	4,195	16.30	16.2	10	356	14	68	361	1,180	1,180
	103	T	583	16.14	16.8	10	8	12	80	365	1,300	
	2+	DIF		16	-0.6	0	-12	2	-12	-4	-120	-120
19	12.07.75	A	5,611	2.39	4.6	-31	29	-32	92	286	950	900
	193	T	1,661	3.23	4.2	-31	13	-29	76	426	852	
	2-	DIF		-44	0.4	0	16	-3	16	-140	98	48
20	12.07.75	A	5,613	5.39	4.6	-25	344	-18	50	287	843	690
	193	T	1,663	7.22	4.2	-31	312	-20	20	416	771	
	2	DIF		-103	0.4	6	32	2	30	-131	72	-81
21	12.07.75	A	5,615	8.41	4.6	-31	298	-20	7	286	840	770
	193	T	1,663	7.22	4.2	-31	312	-20	20	416	771	
	2	DIF		79	0.4	0	-14	0	-13	-130	69	-1
22	14.07.75	A	5,634	2.56	4.5	-31	24	-31	87	282	950	890
	195	T	1,685	3.12	4.1	-31	14	-29	77	381	895	
	3	DIF		-16	0.4	0	10	-2	10	-99	55	-5
23	14.07.75	A	5,647	8.58	4.6	-30	294	-19	3	281	931	859
	195	T	1,687	7.11	4.2	-30	316	-20	24	390	1,065	
	2+	DIF		107	0.4	0	-22	1	-21	-109	-134	-206
24	15.07.75	A	5,659	3.04	4.6	-29	23	-29	86	280	969	820
	196	T	1,697	3.08	4.6	-29	23	-29	86	425	830	
	3	DIF		-4	0	0	0	0	0	-145	139	-10
25	15.07.75	A	5,663	9.07	4.6	-30	292	-19	1	279	969	868
	196	T	1,699	7.06	4.2	-30	317	-20	25	370	799	
	3+	DIF		121	0.4	0	-25	1	-24	-91	170	69
26	16.07.75	A	5,675	3.12	4.6	-28	21	-28	85	278	931	893
	197	T	1,709	3.02	4.5	-28	21	-28	85	388	860	
	2+	DIF		10	0.1	0	0	0	0	-110	71	33

Table 1. (continued)

No.	Date	Exp. A=AÉROS T=TAIYO	Orbit	UT	LT	Geogr.		Geomagn.		Height	T_e	T_e scaled
	Day K_P					Lat	Long	Lat	Long			
27	17.07.75	A	5,691	3.21	4.6	−28	19	−27	83	277	940	900
	198	T	1,721	2.55	4.2	−28	19	−27	83	348	888	
	2+	DIF		26	0.4	0	0	0	0	−71	52	12
28	22.07.75	A	5,772	5.27	4.7	−14	349	−8	57	268	1,092	1,039
	203	T	1,782	4.28	4.8	−14	5	−11	73	364	786	
	1	DIF		59	−0.1	0	−16	3	−16	−96	306	253
29	22.07.75	A	5,772	5.27	4.7	−14	349	−8	58	268	1,092	1,040
	203	T	1,783	6.27	4.8	−14	335	−6	43	366	739	
	1	DIF		−60	−0.1	0	14	−2	15	−98	353	301
30	23.07.75	A	5,778	5.35	4.7	−16	347	−10	55	266	969	950
	204	T	1,795	6.19	4.2	−16	328	−7	36	294	896	
	3	DIF		−44	0.5	0	19	−3	19	−28	73	54
31	24.07.75	A	5,802	2.40	4.8	−12	32	−14	99	266	1,073	1,034
	205	T	1,805	2.15	4.4	−12	32	−14	99	312	840	
	3−	DIF		25	0.4	0	0	0	0	−46	233	194
32	25.07.75	A	5,818	2.48	4.8	−12	30	−14	97	264	1,073	1,055
	206	T	1,817	2.08	4.1	−12	30	−14	97	281	824	
	3−	DIF		40	0.7	0	0	0	0	−17	249	231
33	26.07.75	A	5,834	2.54	4.8	−9	29	−10	97	263	931	910
	207	T	1,829	2.02	4.1	−9	31	−11	99	275	869	
	4	DIF		52	0.7	0	−2	1	−2	−12	62	41
34	29.07.75	A	5,884	6.11	4.9	4	341	11	52	261	1,252	1,235
	210	T	1,867	5.45	4.5	4	341	11	52	305	730	
	6	DIF		26	0.4	0	0	0	0	−44	522	505
35	15.08.75	A	6,162	16.27	5.4	31	194	29	257	245	2,365	2,302
	227	T	2,078	15.51	4.8	31	194	29	257	252	1,600	
	3+	DIF		36	0.6	0	0	0	0	−7	765	702
36	17.08.75	A	6,194	16.32	5.4	31	193	29	256	247	2,110	2,082
	229	T	2,102	15.36	4.5	31	193	29	256	256	1,144	
	2+	DIF		56	0.9	0	0	0	0	−9	966	938
37	18.08.75	A	6,210	16.33	5.4	30	193	28	257	247	2,004	1,948
	230	T	2,114	15.28	4.3	30	193	28	257	266	770	
	3	DIF		65	1.1	0	0	0	0	−19	1,234	1,178
38	16.09.75	A	6,672	10.01	5.1	−31	286	−20	356	248	850	844
	259	T	2,461	9.46	6.5	−31	311	−20	19	283	2,300	
	1	DIF		15	−1.4	0	−25	0	−23	−35	−1,450	−1,456
39	19.09.75	A	6,717	6.12	5.1	−24	344	−17	50	223	1,140	1,132
	262	T	2,495	5.21	6.5	−29	17	−28	82	305	2,001	
	1	DIF		51	−1.4	5	−33	11	−32	−82	−861	−869

Fig. 1. Electron temperatures measured at orbit crossings by AEROS-B and TAIYO at different altitudes. Dashed lines connect data when both satellites are in near vertical position. For comparison, a model temperature is given by the solid line. Numbers refer to the case number in Table 1.

dashed lines do not strongly vary. The model temperature for 20° geomagnetic latitude and 200° longitude is given by the solid line. The observed temperature gradients are between -0.44 and -0.65 K/km for low latitudes and night-time conditions. The temperature gradient of the model is in fair agreement with the gradients resulting from the combined satellite observations, which already implies that the temperatures from both instruments are consistent.

3. Data Comparison

A significant comparison of data can be done when the measurements are taken not far from each other. The measurements selected for comparison are restricted to the same latitude within 20° longitudinal and 0.5 hr local time difference. Furthermore, local time must not be later than 0445 LT for night conditions in order to avoid the strong gradients occurring near sunrise. The available data are shown in Fig. 2. Assuming that each experiment has an accuracy of 10% the data points should be inside the two dashed 10% boundaries. The data, indeed, coincide much better than 10% which can be considered as an excellent agreement of different experiments.

It was not possible to handle the daytime data in the same way. The measured TAIYO temperature shows some scatter which was not observed on

AEROS. In order to obtain comparable data it was necessary to first smooth the TAIYO temperatures, and such averaged values are listed in Table 1 for daytime conditions. Furthermore, only in three cases are the data points less than 0.5 hr apart in local time. Therefore we increased our time limit to 1.0 hr. We are also aware that the temperature profiles in the region of the South

Fig. 2. Comparison of altitude-corrected temperatures at nighttime, and 10% error boundaries.

Fig. 3. Comparison of altitude-corrected temperatures during daytime. TAIYO temperatures on the average are 10% higher than those from AEROS, and are more spread.

Atlantic anomaly have a complex structure which may not too well be represented by the model of SPENNER and PLUGGE (1978). Most of the daytime encounters are located in the region where systematic temperature enhancements were observed (HIRAO and OYAMA, 1976).

Resulting from these difficulties one would expect more scatter in the temperature differences at daytime. As shown in Fig. 3 the TAIYO temperatures are also 10% higher than those from AEROS, on the average. This effect is not understood yet. An improved temperature model giving more realistic gradients in the South Atlantic region may help to solve this question. However, it is also possible that our comparison has revealed a systematic discrepancy between the two data sets which has to be taken into account at future studies combining measurements from both satellites.

4. Temperature Rise at Dawn

Analysing the nighttime temperatures we find no significant influence of the local time before 0445 LT. But as soon as the solar zenith angle approaches 90° the temperature steeply increases from about 850 to 2,000 K. This temperature increase measured with the two satellites is shown in Fig. 4 and justifies that we excluded values from later than 0445 LT for our data comparison in Figs. 1 and 2.

The temperature gradient is nearly constant over a period of one hour with approximately 17 K/min for the height range below 300 km and about 30° latitude. This result is in agreement with incoherent scatter radar observations

Fig. 4. Temperature increase at sunrise, from simultaneous measurements by AEROS and TAIYO at different local times.

at Arecibo, where strong temperature gradients have been measured at sunrise (DOUPNIK and NISBET, 1968).

5. Conclusion

Good agreement was obtained during nighttime between the electron temperatures measured on both satellites by instruments using quite different experimental techniques. The result together with earlier comparisons between AEROS and incoherent scatter radar observations confirms that both satellites yield correct electron temperatures and that the spread of data is usually less than 10%. The AEROS model temperature coincides also with the available TAIYO data. The good agreement allows to use the nighttime temperatures of both satellites for coordinated investigations.

The daytime temperatures are on the average approximately 10% higher from TAIYO than from AEROS. Analysis of this effect is complicated by the fact that most observations suitable for direct comparison are in the geomagnetically anomalous region in the South Atlantic.

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