

CSU Radiation Budget Pilot Study for TOGA COARE

by

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1.0 Introduction

In July 1990, the Department of Atmospheric Science at Colorado State University (CSU) received a grant from the National Oceanic and Atmospheric Administration (NOAA) to deploy Surface Radiation Budget (SRB) measurement stations in a region of the equatorial western Pacific in order to collect data for a pilot study of the radiation budget. The study was performed in support of the Tropical Oceans Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE). This report provides a summary of the activity funded by the grant over the period from October, 1990 when the first funding was received to November, 1992. The purpose of the report is to document the type of instrumentation used, its deployment and calibration history and the quality of the data collected during the period of interest.

1.1 Background of TOGA COARE

The western Pacific Ocean, from 140-180° East longitude and within 10° of the equator, has been identified as an area of interest for investigation of the atmospheric and oceanic interaction with major implications relating to climate change. The observed, nearly continuous sea surface temperature of 28 C or greater, coupled with a highly convective atmosphere and an uncertainty in net surface heat flux of about 80 watts per square meter prompted the planning committee of the TOGA experiment to initiate an intensive field experimental phase referred to as TOGA COARE. A major part of the uncertainty in the heat budget results from a lack of knowledge about the surface radiation budget.

The TOGA program is a major component of the World Climate Research Program (WCRP) which aims specifically at understanding the coupling between the tropical oceans and the global atmosphere. The goal of the program is to determine the extent to which the system is predictable on time scales of months to years and to understand the mechanisms and processes underlying its predictability. The program also aims at to establish the feasibility of modeling the coupled ocean-atmosphere system for the purpose of predicting its variations on time scales of months to years. For complete description of the goals of the TOGA program see Webster (1988).

The magnitude of the fluxes of heat, momentum and water and their spatial and temporal distributions were identified as poorly understood but crucial components of the coupled ocean-atmosphere system and the radiative exchanges at this interface constitutes a principal coupling of the ocean and atmosphere in the western Pacific. In planning for the COARE it was realized that a climatology of the surface radiation budget did not exist for the region which is referred to as the Large Scale Array (LSA) in the remainder of this report. Therefore it was recommended that a surface radiation budget pilot study be conducted.

1.2 CSU's role in the TOGA COARE SRB

CSU responded to the recognized need for a surface radiation budget pilot study and was selected to deploy instrumentation to begin a collection in the LSA. The goal of CSU's participation was twofold: first, to develop an instrumentation deployment methodology that would lead to a data set of high quality; and second, to begin a compilation of a surface radiation budget climatology for the region. The scope of activity did not extend to the development of new instrumentation since, especially for the collection of broadband solar irradiances, reliable instrumentation existed. Also, for the infrared region, only slight instrument improvements had been achieved over at least the past two decades even though a degree of uncertainty in the overall accuracy of the measurement persisted. Rather, the primary concerns focused on selection of available sites for deployment and the configuration of a robust data collection station capable of withstanding the rigors of the tropical environment. The following sections document the nature of the deployments of the SRBs and the results of the effort.

2.0 Overview of the deployment

The initial activity on the project concerned the selection of suitable deployment sites and designing the stations to be both robust and to require as little maintenance as possible. Initial considerations also extended to the development of stations which could be deployed at a remote location and which could operate unattended for long periods of time. This alternative was considered for some time but to date has not been seriously pursued. An examination of the geography of the region, especially the region west of 150° East longitude within the LSA indicated this to be a region of the globe with a paucity of suitable deployment sites. The number of possibilities is even smaller if it is required that personnel with some technical ability be available to participate. After some investigation the following sites were selected; they are the atoll of Majuro in the Republic of the Marshall Islands at 7°05' N latitude and 171°23' E longitude and the islands of Pohnepi and Chuuk in the Federated States of Micronesia at 6°58' N latitude and 158°13' E longitude and 7°27' N latitude and 151°50' E longitude respectively. Although the sites are all located in the northern third of the LSA, they provide a good sampling longitudinally and benefit from the presence of Weather Station Office (WSO) personnel who are supervised jointly by the US National Weather Service, Pacific Region headquartered in Honolulu, and by an arm of the local governments. Fig. 1 indicates the locations of the sites with respect to the LSA. Also indicated in the figure is the western extent of coverage of the GOES satellite used to transmit data back to the US in a timely fashion.

Recently, two more stations have been deployed in direct support of the COARE, one at Kavieng and one at the Bureau of Meteorology Office at Darwin, Australia; however, these deployments will be documented in a subsequent report. The following subsections detail the configuration of the stations and document the stations' deployment.

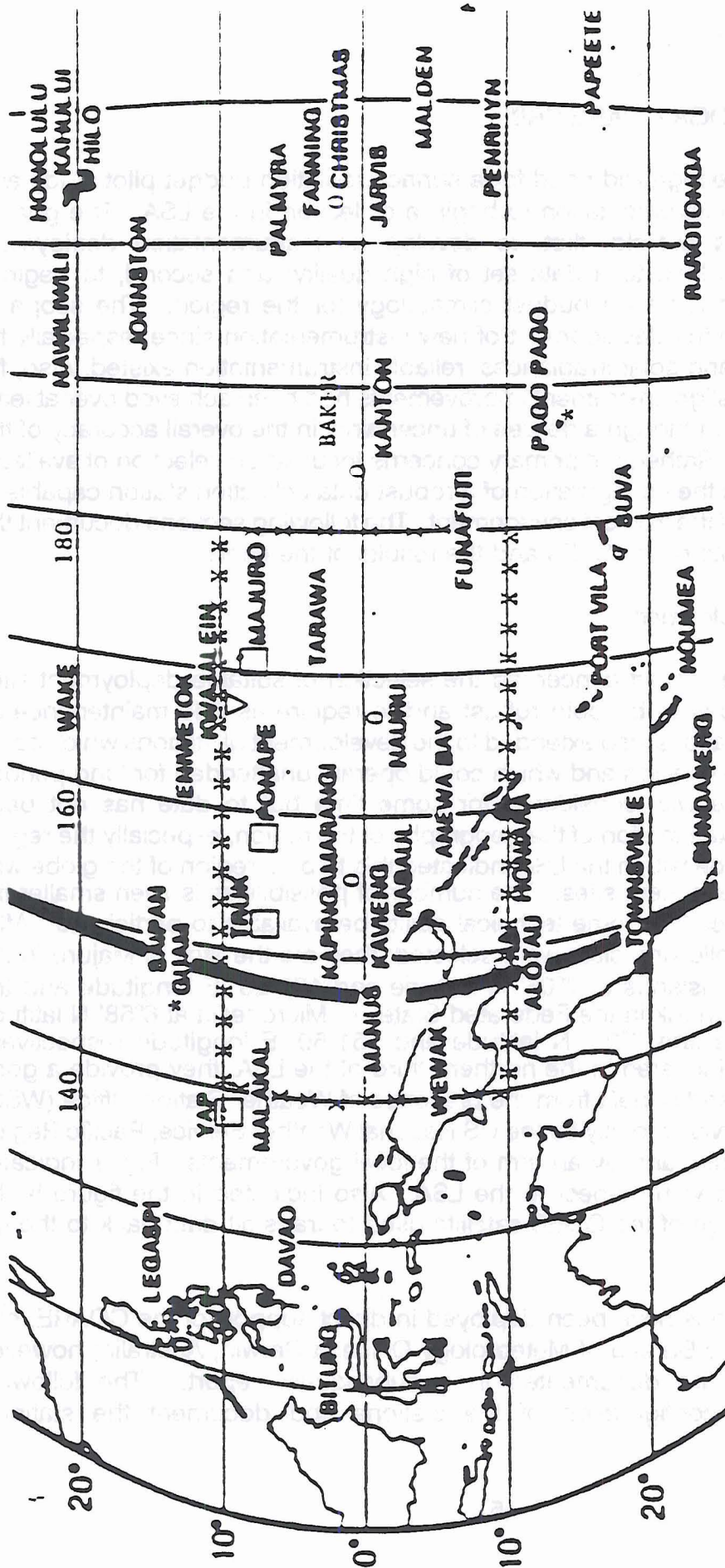


Figure 1. Locations of sites for deployment of SRB stations. The LSA is enclosed in the box bordered by X's. The heavy black line represents the western most coverage of the GOES West satellite.

2.1 Station configuration

The primary project goals consisted of deploying stations capable of providing accurate measurements of the downwelling total solar and downwelling infrared, hemispheric irradiances and to begin a compilation of climatologies of these data for the LSA. All three stations are equipped with the same instruments: an Eppley PIR pyrgeometer for measuring hemispheric infra-red irradiance, an Eppley PSP quartz dome pyranometer for measuring hemispheric solar irradiance, and a Met-one model 014 wind speed sensor and Handar air temperature sensor to support the IR measurements. The hemispheric instruments are mounted looking upward from a plate on top a sturdy station tripod constructed from 1.25" diameter aluminum pipes. A Handar 540A datalogger, mounted low on the tripod for added stability, is used to record the data from these instruments and transmit that data over the GOES satellite to National Environmental Satellite Data and Information Service (NOAA NESDIS), from where it can be retrieved. A Handar WWV radio receiver connects to the datalogger and serves to keep the station time correct to insure transmissions fall within allocated GOES transmission windows. The station is powered by a solar-charged battery within the Handar datalogger. Fig. 2 is a photo of an SRB station.

These particular radiometers were selected based on previous experience with the instruments, especially the pyrgeometers; see for example, Albrecht and Cox (1977). Although more recent designs have been introduced for the measurement of terrestrial radiation as in Foot (1986), it appears little is to be gained from the new design at least for ground based installations, and the ruggedness of the new design was unsubstantiated compared to the original Eppley design. Appendix A contains a full listing of the particular instruments deployed and their radiative and electrical characteristics.

The original plan was to utilize satellite transmission as the primary means of retrieving the data. A Memorandum of Agreement between the NOAA NESDIS and the Department of Atmospheric Science at Colorado State University was put in place for the use of two minute data transmission windows every three hours for each SRB location. Official permission to utilize the radio transmitters on site was obtained from the local governments after coordination with the Federal Communication Commission and the US Department of the Interior. Because some data transmission gaps were anticipated the Handar data units were configured with back up memory sufficient to record the data for a period of over one month and laptop computers were included in the complement of equipment at each location for the purpose of downloading the data on an as-needed basis. It was anticipated that moisture collection within the radiometers would be a likely cause of instrument degradation. In order to minimize the frequency at which the internal desiccant would require replenishment a secondary larger desiccant container was included on the platform. The backup reservoirs were filled with 0.5 liters of Drierite brand desiccant and connected by means of plastic tubing to valves inserted into the

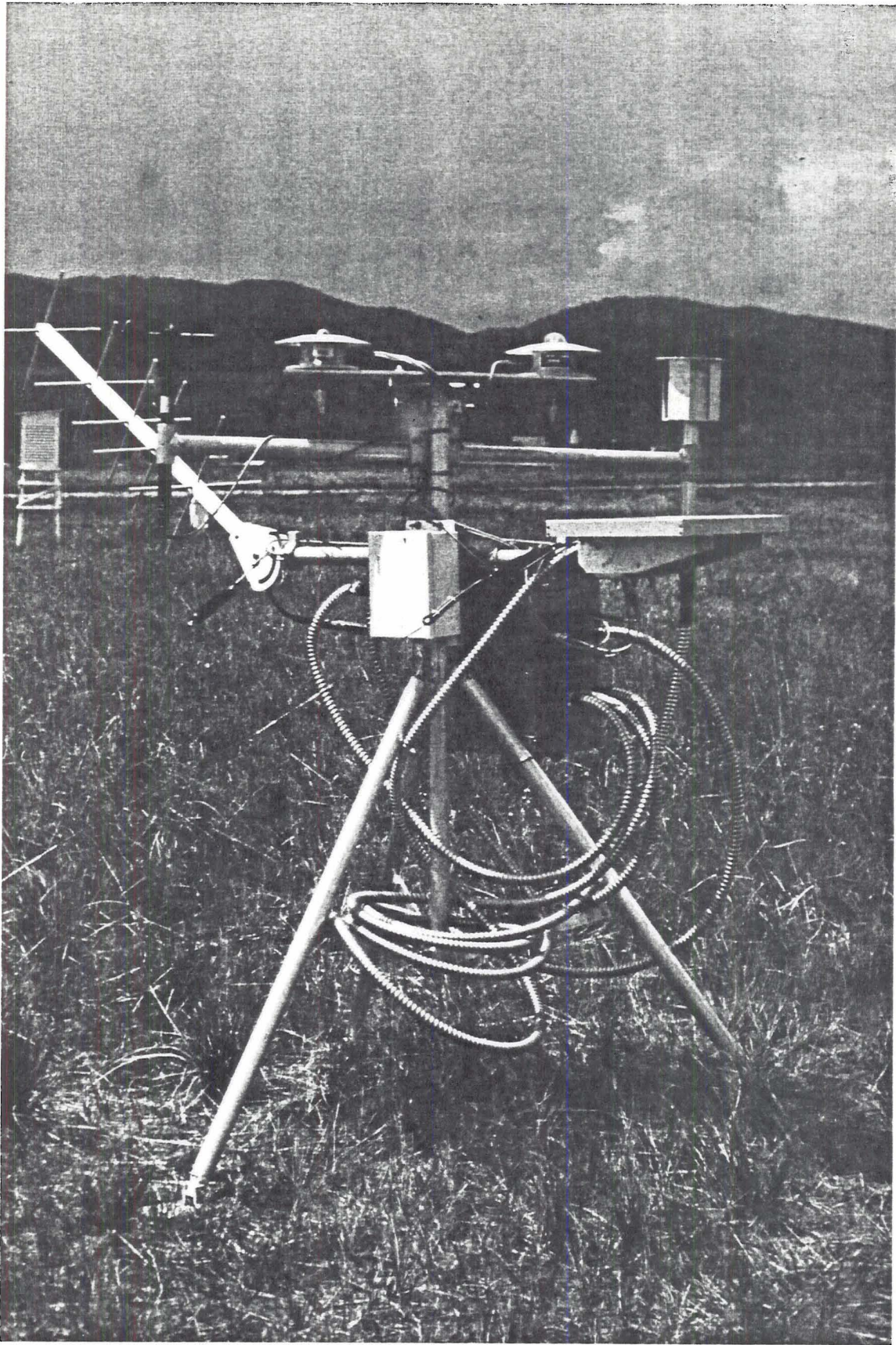


Figure 2. Photo of an SRB station during testing phase at Colorado State University.

bases of the radiometers. The effectiveness of the added system relied on small amounts of differential heating to provide a limited amount of circulation between the radiometers and the backup reservoir. The color of the internal indicating silicagel desiccant could be monitored through glass windows provided for this purpose. Apparently this system is performing well since changes of the internal desiccant are required approximately bimonthly which is much less frequently than previous tropical deployments have required.

Initially data were recorded instantaneously every three minutes and transmitted to the satellite every three hours. This rate of data collection was limited by the length of the two minute satellite transmission window (the data logger was not capable of storing information at a higher density than that used in the satellite transmission sequence). In October, 1992 during a maintenance trip a change in the collection frequency was necessitated by the installation of a UV radiometer. In order to collect the additional information the frequency was changed to one sample every five minutes. More detail on the data set is included in section 4 of this report.

2.2 Initial deployment phase

The tripods were designed and constructed at the Department of Atmospheric Science's Research Testing and Field Operations Facility and the stations configured during the winter of 1990-91. An operations and maintenance manual was written during this period and is available upon request. The radiometers were calibrated (see section 3.0) and the units field tested locally in May of 1991 and taken to the sites in June. The units were designed to be transportable such that each one could be packaged in three specially made boxes and taken as checked baggage on commercial airline flights.

The first station was installed at the Weather Station Office (WSO) of Majuro on June 10, 1991. The station was placed in a large grass field on the WSO grounds approximately 60 m from the weather station office. The WSO is located on the outskirts of the small downtown region of Majuro. The radiometers were placed at an elevation of approximately 4 meters ASL and within approximately 200 m of a lagoon. A fence was constructed around the SRB in order to protect it from the curiosity of the locals. Several hours were spent training local weather station personnel on the required maintenance data downloading procedures. Fig. 3 is a photograph of the SRB in place prior to the construction of the fence.

The second station was installed at the NOAA/WPL wind profiler site in the hills outside of town on Pohnpei on June 18, 1991. This site, at an elevation estimated at 70 m, was chosen over the WSO grounds due to the large number of tall trees in town which would have influenced the hemispheric radiation measurements. The profiler site had the required power and security--it is surrounded by a chain-link fence. A four-foot platform was constructed within the fenced area to support the station and to raise the instruments above the level of interference from the building which houses the profiler

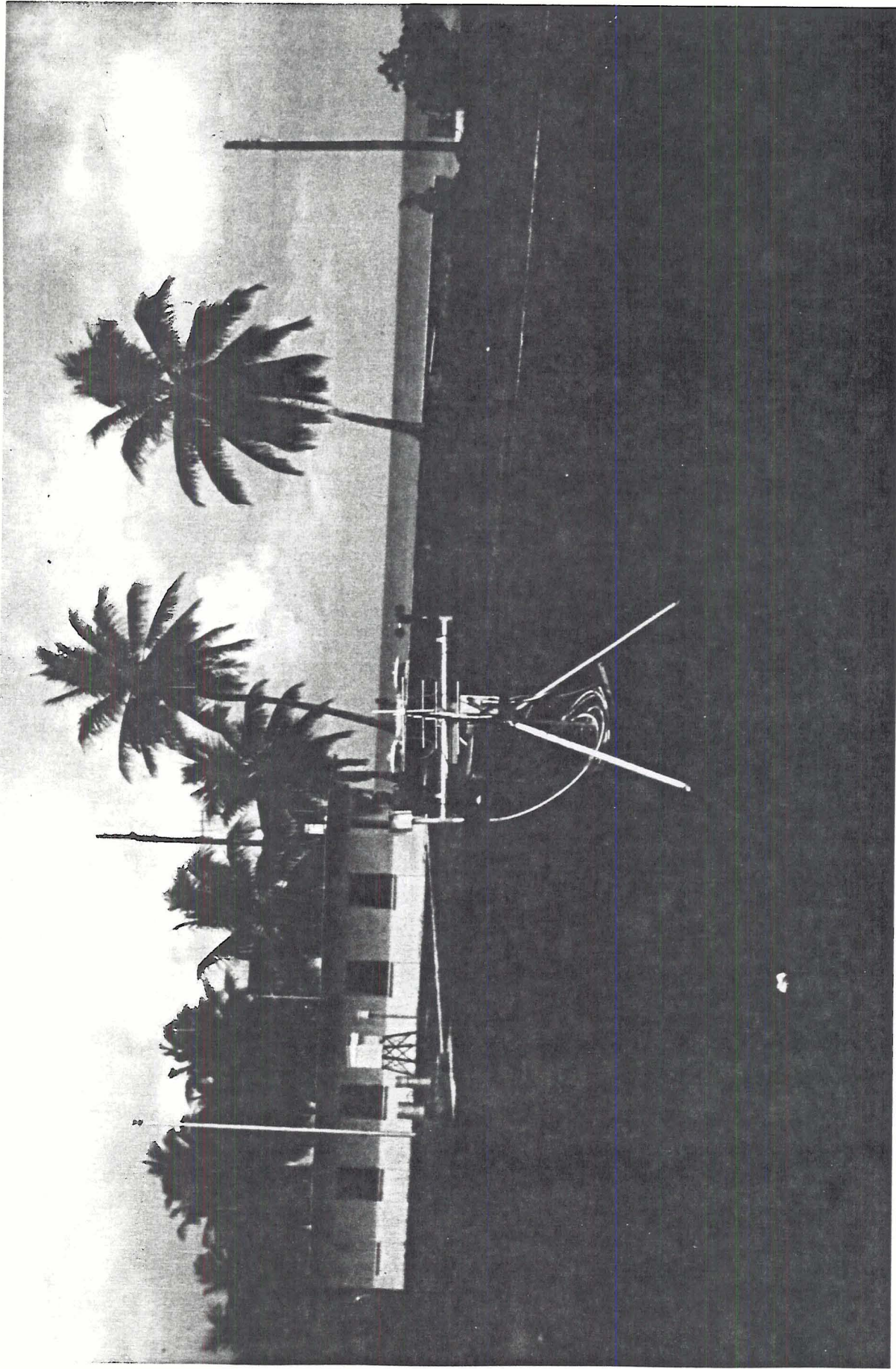


Figure 3. Photo of the SRB station at Majuro as the deployment was nearing completion.

electronics. Fig. 4 is a photograph of the installation at Pohnpei. The local personnel were trained on required maintenance and data downloading procedures.

The third station was installed on the island of Moen in the Chuuk (Truk) Lagoon. This station was also installed on the grounds of the Weather Station Office, located near the south end of the airport runway. The site, at an elevation of 2 m, is enclosed by a fence, and is sufficiently distanced from tall obstructions. No fence or platform was required. The transmission of the data from Chuuk was complicated by the presence of a 700 ft high hill in the line of sight to the satellite's position. This limited the amount of data transmitted from Chuuk to about one quarter of the total amount and required the bulk of the data to be downloaded from the data logger.

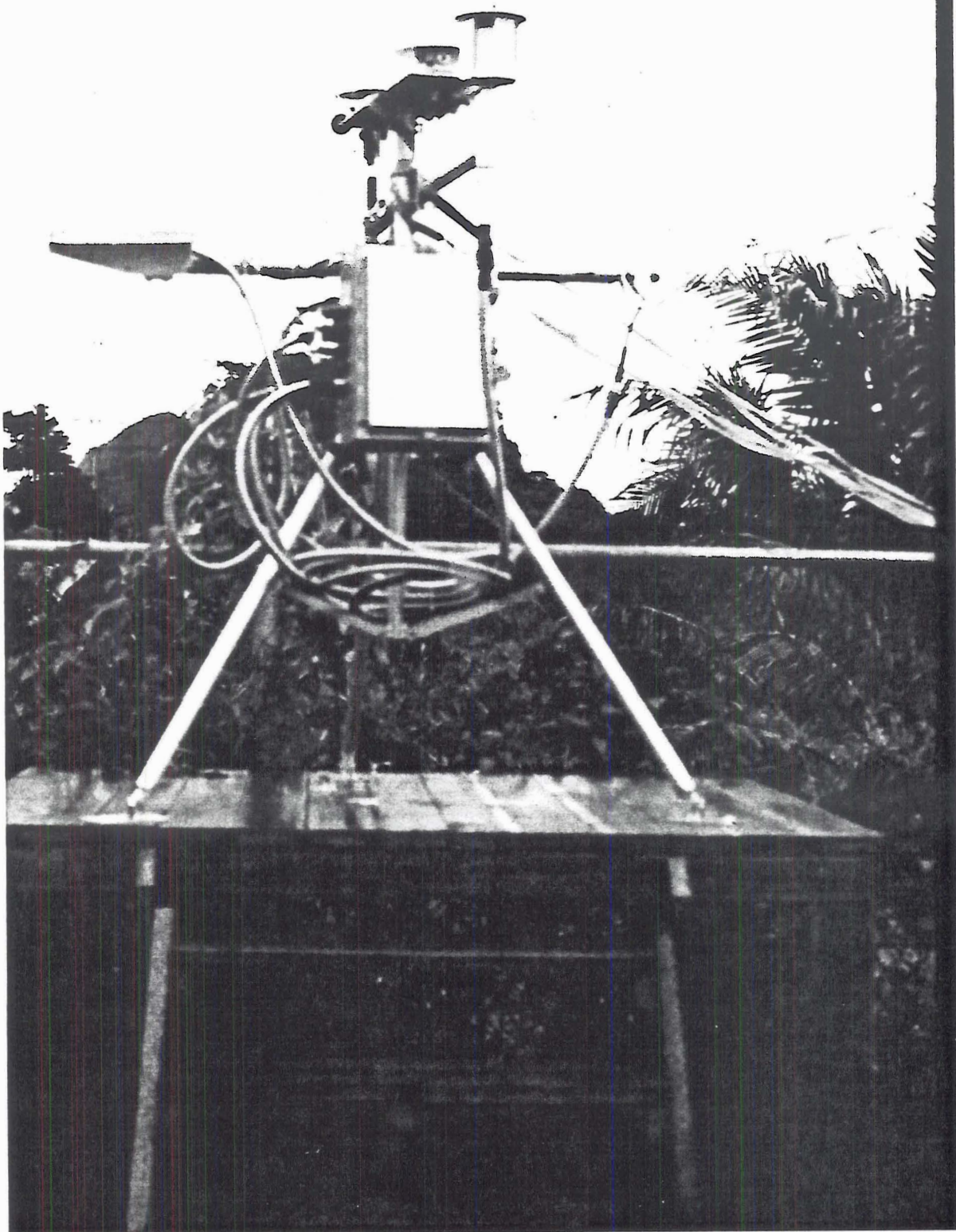


Figure 4. Photo of the SRB station at Pohnpei installed at the NOAA wind profiler site.

3.0 Calibration procedures and history

One of the most important yet difficult aspects of a remote deployment of this type is the assurance that the instruments are performing in a known manner. As mentioned above the radiometers were selected partly because they have a proven history of rugged and stable performance. However, the SRB systems include the data system and necessary cabling as well as the radiometers and the durability of the total system operating in a tropical environment had not been established. Thus, some mechanism of testing the system's performance in the field was required. The following sections describe the calibration procedures established to fulfill these requirements.

3.1 Initial calibration

The initial calibrations took place during early spring of 1990. The process included laboratory calibration of the pyrgeometers, intercalibration of pyranometers against standard instruments maintained by NOAA, calibration of data system amplifiers and intercomparison of the data from the stations in side-by-side local deployments.

The laboratory calibrations of the pyrgeometers followed the methodology presented in Albrecht and Cox (1977), whereby the incident longwave irradiance is calculated as one component in a physical model of the radiation budget of the instrument. The model takes into account the emission by the hemispherical filter dome and the thermopile sensor itself. This method of measurement requires that the temperature of the interior of the filter dome and the temperature of the brass case of the instrument, which is assumed to be at the same temperature as the thermopile, be transmitted in the data stream along with the thermopile output voltage. The calibration coefficients for the pyrgeometers are given in Appendix A.

The pyranometers were calibrated by a two stage process in which secondary standards were established by using new pyranometers in a side by side comparison with standard instruments maintained by NOAA, ERL in Boulder, Colorado. The secondary standards were subsequently used to calibrate the instruments deployed in the LSA.

Linear regression coefficients were derived from bench measurements of the amplifiers in the Handar 540A data systems. The amplifiers were found to be linear over the entire operating range to a precision beyond the requirements of the application.

Local field testing was performed in early May, 1991. The SRB stations were set up side-by-side at the Department of Atmospheric Science at Colorado State University in a configuration identical to that of their final deployment. Data were collected via the satellite system over several days and the calibrated outputs of the instruments compared. Overall the daily averages of the pyrgeometers were within 3% of the mean downwelling IR irradiance as measured by all three pyrgeometers. The intercomparison of solar irradiances indicated that the mean irradiances compared to within 2%. The

latter value is generally above what is desirable for intercomparison of daily mean solar irradiances; however, the tests were carried out under mostly cloudy conditions. The intercomparisons with the secondary standards were performed under a variety of cloud conditions with results more typical of what was expected; i.e. instantaneous rms deviations within a few percent of respective mean values were obtained.

3.2 Field calibration verification

Provision was made for spot check of the calibration values in the field. Wide mouth stainless-steel thermoses were coated with a high emissivity paint and thermistors of the same type as used in the ambient air sensor were affixed to the interior wall of the container using a high conductivity epoxy. The field procedure was thus kept as simple as possible: on site personnel merely had to place the thermos blackbody over the pyrgeometer, disconnect the ambient air temperature cable at the input to the Handar unit and replace the cable with that from the portable blackbody. The blackbody unit normally would be left in place over the pyrgeometer for a period of a few hours. The personnel were also instructed to place the cup of the thermos over the pyranometer. This procedure serves both as a signal in the data that the calibration was in progress and also indicated if any electrical or serious optical offset had been introduced. Fig. 5 is a plot of a spot check on the calibration performed in late April, 1992 for the pyrgeometer at Chuuk. Spot checks were requested from all three sites when it became obvious that the thermopile at Pohnpei had gradually drifted to negative values outside the normal measurement ranges. At that time it was also found that the pyrgeometer at Majuro disagreed by about 10% from the thermos calibration and the instrument at Chuuk agreed with the thermos blackbody to about 1% in the mean.

It was somewhat fortuitous that the weather station offices were well air conditioned. The blackbody thermoses when carried to the SRB are apparently at a sufficiently low temperature that some range in the spot check calibration data is derived as the blackbody adjusts to ambient conditions. It should be noted that the thermos blackbody devices were not designed to perform a full calibration in the field. The calibration coefficients were never modified as a result of the field checks. It is not known, for example, if the cool starting temperatures of the thermos blackbodies cause condensation within the blackbody or on the pyrgeometer dome. Rather, they were meant to provide indication of problems with the system. From these checks it was determined that the longwave data at Chuuk were acceptable, those at Majuro were questionable and the data from Pohnpei were not valid.

The problem detected with the pyrgeometer instrument at Pohnpei indicates the value of the field spot check. Initially it was speculated that the falling longwave irradiance signal was associated with the onset of an El Nino event in early 1992. Personnel at the WSOs in the region reported a drought in the region to the extent that drinking water was being brought in by ship. It was a natural conclusion that the change in the signal could be attributed to the drier atmospheric conditions and relatively clearer skies.

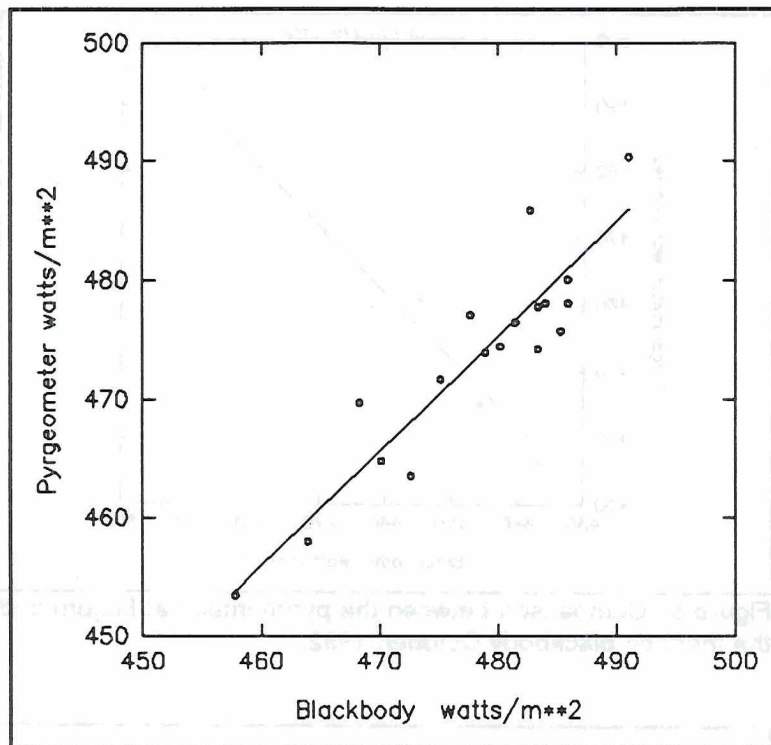


Figure 5. Comparison between the pyrgometer at Chuuk and the thermos blackbody.

However, after a continued monitoring of these data, it was apparent that the thermopile voltage had begun a slow but continual decrease beginning in October 1991, from values in the range of -0.1 to -0.2 mV to the values of -0.5 Mv or less recorded in spring of 1992.

In October 1992, CSU personnel traveled to the sites to perform repair and refurbishing of the SRBs and to install UV radiometers. Standard instruments were taken to the field for side-by-side comparisons with the field radiometers along with spare radiometers. The radiometers which had been in the field were examined and side-by-side and thermos calibrations were performed. From the information gathered on this trip it became apparent that the problem with the pyrgometer at Pohnpei was introduced by the data system.

Figs. 6 and 7 show the thermos blackbody calibrations of the pyrgometers at Majuro and Pohnpei. Although there is scatter of the instantaneous readings the mean values measured by the pyrgometers at Majuro and Pohnpei agreed with the theoretical emission from the thermos blackbodies to within 0.3% and 0.8% respectively.

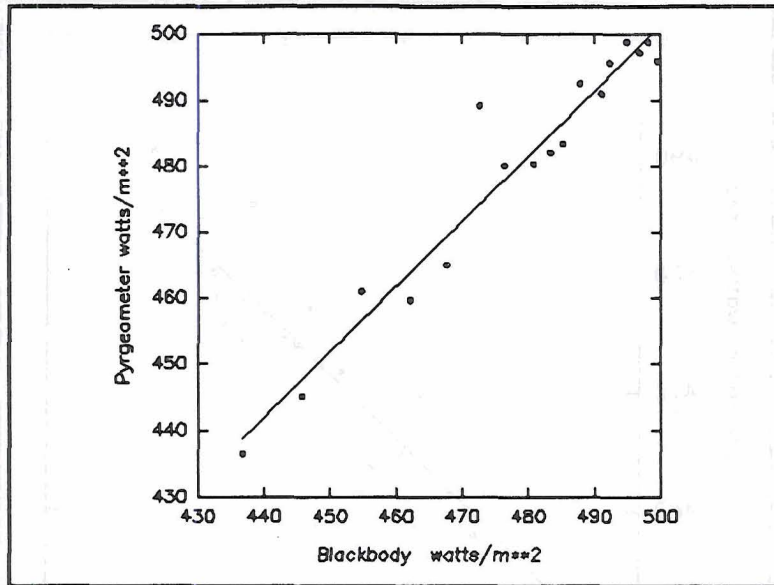


Figure 6. Comparison between the pyrometer at Majuro and the thermos blackbody October, 1992.

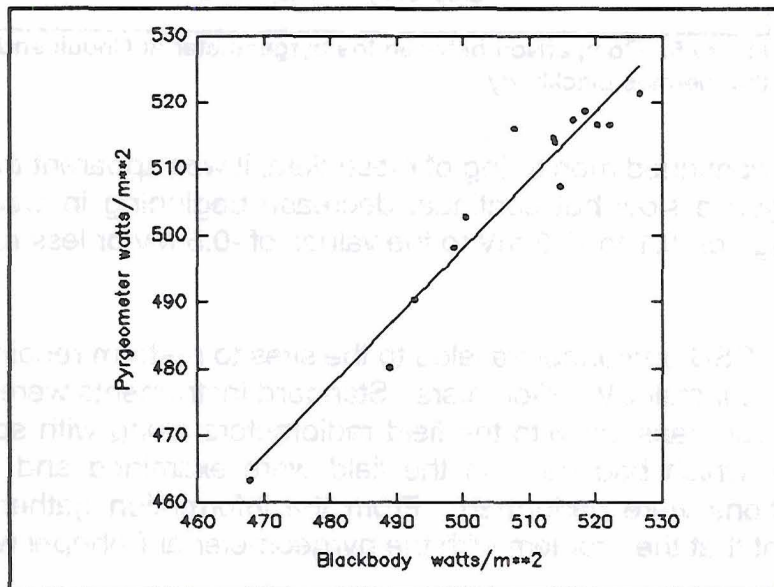


Figure 7. Comparison between the pyrometer at Pohnpei and the thermos blackbody during October, 1992.

These plots indicate excellent behavior of the pyrometers at Majuro and Pohnpei. The average irradiance values displayed in these plots are 507 and 506 watts m^{-2} respectively for the blackbody and pyrometer at Majuro and 485 and 478 watts m^{-2} respectively for the blackbody and pyrometer at Pohnpei. A thermos calibration was not performed at Chuuk due to time constraints. Instead one of the standard instruments which had been calibrated before the trip was exchanged for the original radiometer.

Side-by-side comparisons between recently calibrated instruments and the field radiometers were completed during the same site visit. Figs. 8 through 10 show the results of the comparisons.

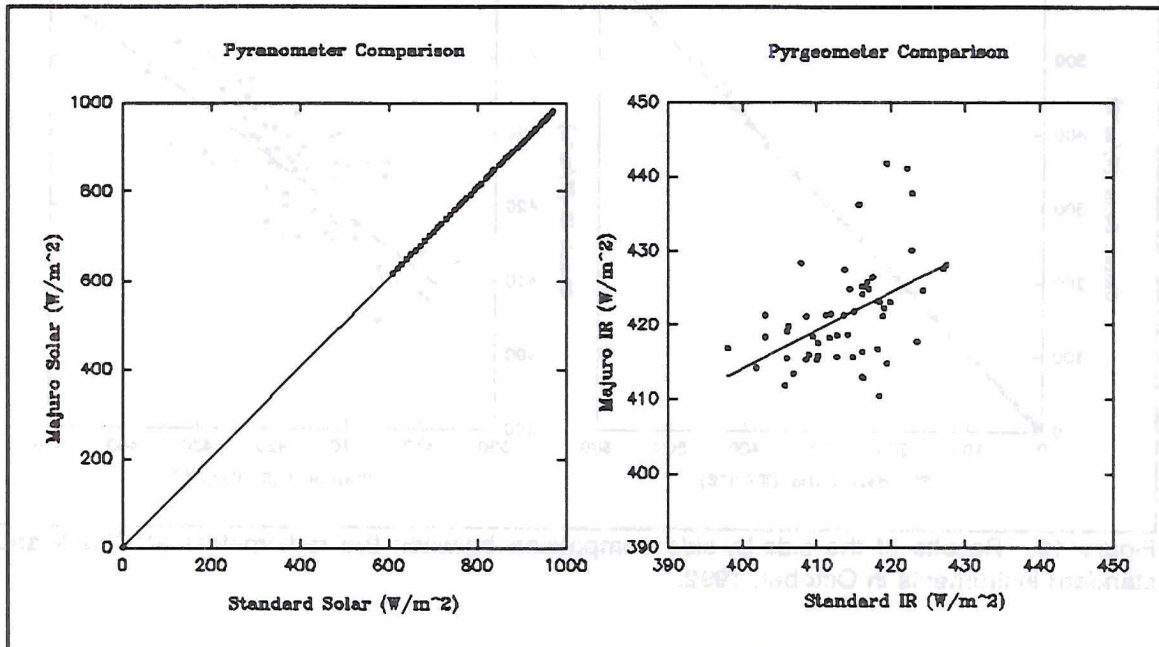


Figure 8. Results of the side-by-side comparison between the radiometers at Majuro and standard instruments in October, 1992

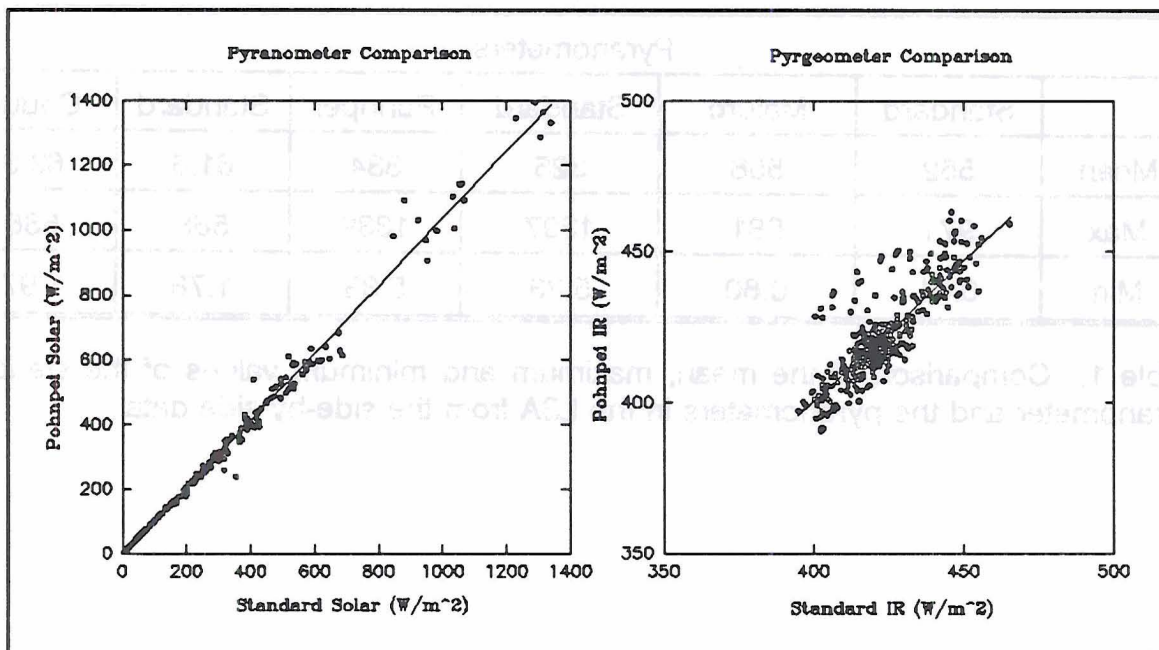


Figure 9. Results of the side-by-side comparison between the radiometers at Pohnpei and standard instruments in October, 1992

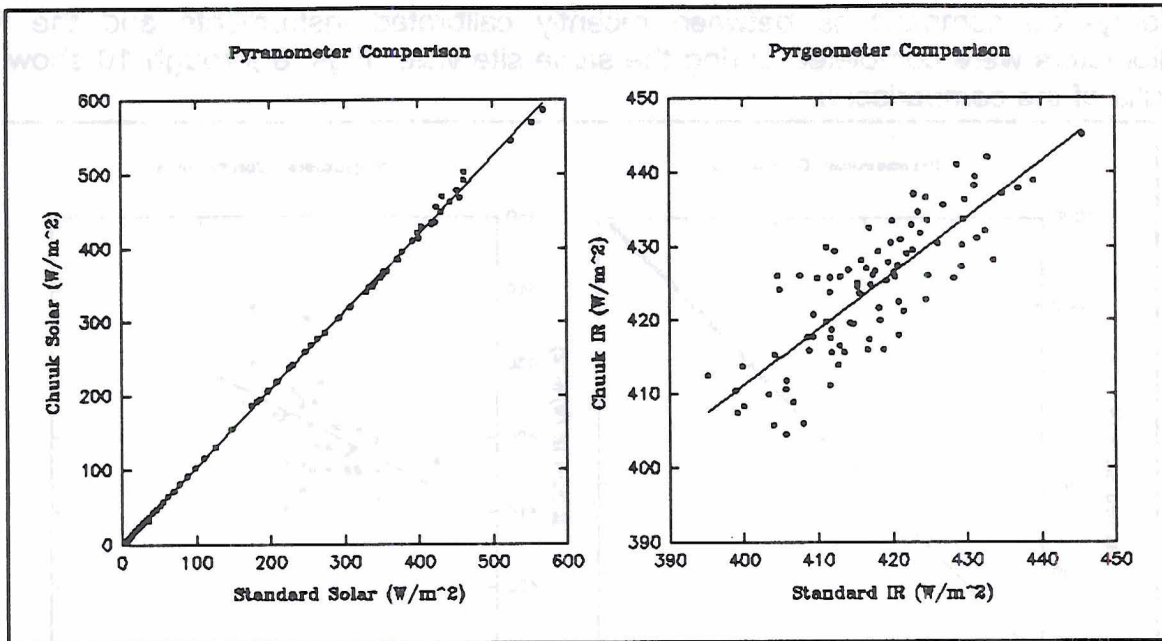


Figure 10. Results of the side-by-side comparison between the radiometers at Chuuk and standard instruments in October, 1992.

Tables 1 and 2 below show comparisons of the average, maximum and minimum values for the data in Figs 8,9 and 10.

Pyranometers						
	Standard	Majuro	Standard	Pohnpei	Standard	Chuuk
Mean	552	558	325	334	61.6	63.3
Max	971	981	1397	1339	568	586
Min	0.61	0.60	5.33	5.33	1.78	1.97

Table 1. Comparison of the mean, maximum and minimum values of the standard pyranometer and the pyranometers in the LSA from the side-by-side data.

Pyrgeometers						
	Standard	Majuro	Standard	Pohnpei	Standard	Chuuk
Mean	414	421	422	423	417	424
Max	427	442	463	465	446	445
Min	398	391	391	395	395	404

Table 2. Comparison of the mean, maximum and minimum values of the standard pyrgeometer and the pyrgeometers in the LSA from the side-by-side data.

From the plots of the thermos blackbodies it is clear that any serious malfunction of the pyrgeometer signal can be detected. Thus, we are confident that the use of thermos blackbodies by WSO personnel allows monitoring of the instrument performance of the pyrgeometers without the need of travel to the area.

The side-by-side comparisons were performed over a time period of from 4 to 8 hours. The means presented in tables 1 and 2 indicate that the data are of sufficient quality, when operating normally, to supply the community with at least daily estimates of the solar and IR irradiance values. Thus, if the incoming data stream is carefully inspected for hardware malfunction, a dataset useful for acquiring the daily mean solar and infrared downwelling hemispheric irradiances should be assimilated.

From the intercomparisons it is obvious that the IR data are relatively noisier than the corresponding solar data. Since in each location both the standard and on-site instruments were collocated, it is unlikely that the source of the variability lies in natural variation due to temporal changes in the low level cloudiness, even though it is noted that the instantaneous measurements for these data were separated by a period of four seconds. Fig. 11 below indicates that the noise in the intercomparison data is evident in two of the three terms comprising the total IR value.

The method used to derive the infrared irradiance is taken from Albrecht and Cox (1977). In terms of the calibration coefficients presented in the Appendix A the irradiance is derived as one component of the IR radiation budget of the instrument. The equation describing the assumed behavior of the instrument may be written as;

$$N = k_1 E + \sigma T_s^4 - k_2 \sigma (T_d^4 - T_s^4).$$

where E is the thermopile voltage in millivolts, σ is the Stefan Boltzmann constant, k_1 , and k_2 are the calibration coefficients T_s and T_d are the sink and dome Kelvin temperatures and N is the derived infrared irradiance in W / m^2 . The irradiance N is depicted in the upper left portion of Fig. 11, the contribution of the thermopile (the first term on the right of Eq. 1) by the lower left part of Fig. 11, the emission by the thermopile (the second

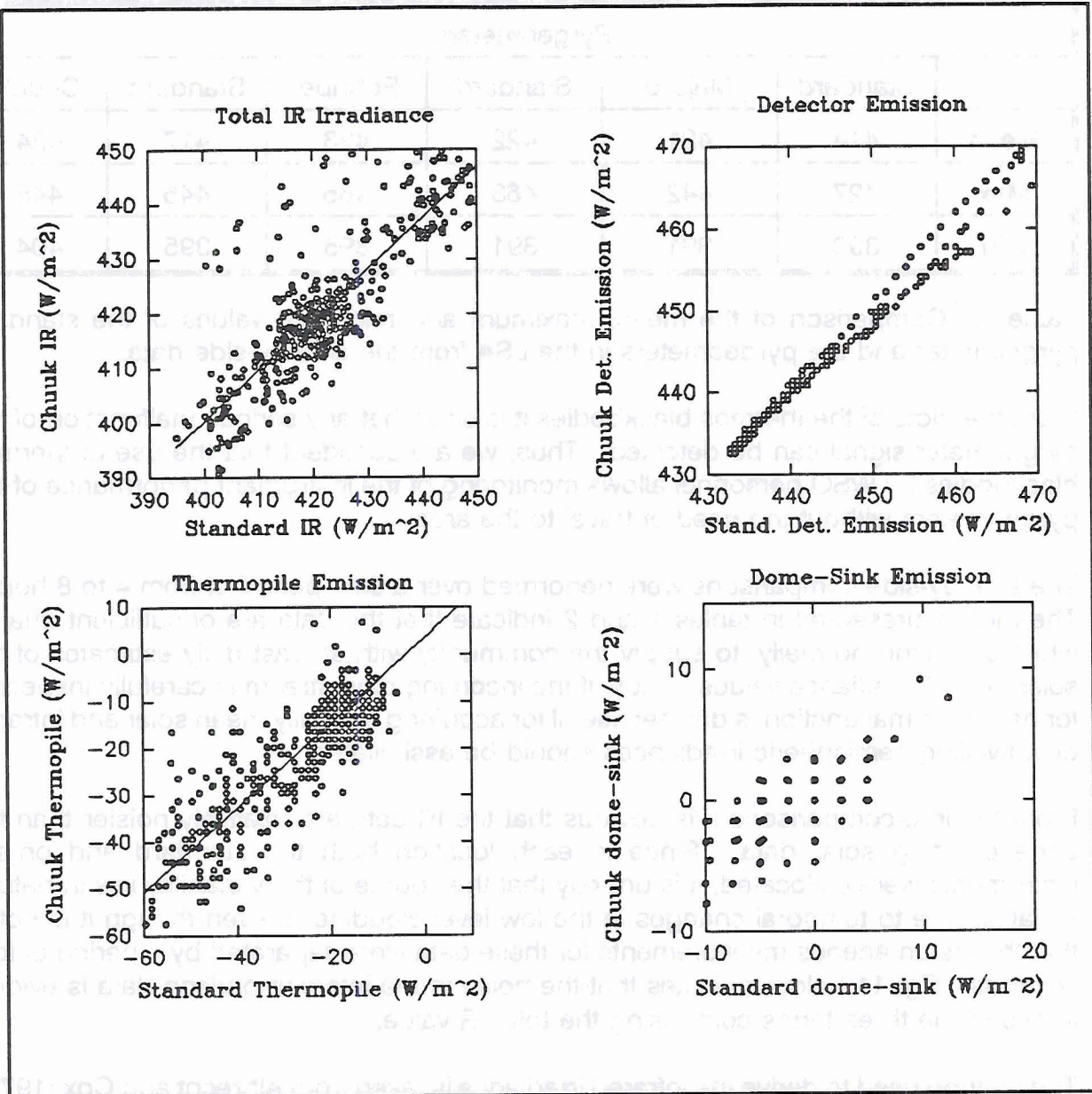


Figure 11. Intercomparison of the components of the IR irradiance from a standard pyrgeometer and the pyrgeometer at Chuuk

term on the right of Eq. 1) by the upper right part of Fig. 11 and the dome-sink emission (last term on the right of Eq. 1) by the lower right portion of Fig. 11. One may conclude that the noise in the signal (at least for this case) is comprised of a good deal of digitization noise, and also that it isn't only the low level (fraction of millivolts) thermopile output which is noisy but the dome temperature as well. Since the operating environments are thought to be relatively noise free in terms of radio frequency emission and the like, the source of the noise is assumed to be associated with the data system; however, to date it has not been feasible to conduct adequate testing of the systems to

minimize the noise level.

4.0 Description of the retrieved data

Data are retrieved from the island stations via the GOES DCP facility and from downloads from the Handar data logger onto computer diskette. The GOES data are retrieved three times per week and diskette downloads are performed once each month. The data retrieved from satellite are converted to ASCII and processed through a calibration program. The diskette data are processed separately. In either case the quantities of interest are the instantaneous, downwelling, hemispheric solar and infrared irradiance values in watts/m^2 . The original uncalibrated instrument output voltages, which were sampled once every three minutes for the time period covered by this report, are archived at the Department of Atmospheric Science at Colorado State University so that the data could be reprocessed in the unlikely event that it would become necessary. Processed data are available to the community via an "anonymous ftp" account on a CSU work station. Files containing one month of processed data have been compressed and placed on the account. "README" files are also contained on the account to provide instructions and warnings about the usage of the data. For instructions on obtaining the data the reader may contact Mr. Christopher Cornwall at the Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523; Tel 303-491-8693.

For those wishing a more cursory inspection of the data, Appendix B contains plots of the diurnal variation of the downwelling solar transmittance and infrared "emittance" averaged over monthly periods. The plots of solar transmittance have been obtained by dividing the instantaneous solar irradiance by the corresponding extraterrestrial quantity and then averaging over the hour and finally plotting the monthly average of the hourly values. A value of 1369 W/m^2 was used for the solar constant. The infrared "emittance" values were obtained by dividing the instantaneous infrared irradiance by the blackbody Stefan-Boltzmann irradiance calculated using the measured ambient temperature. These values were averaged over the hourly periods and then over the month in a manner analogous to the solar data. Fig. 12 provides an example of this type of presentation of the data and a complete set of plots is found in Appendix B.

The reader is cautioned that at the time of preparation of these plots final quality control checks had not been applied to the data. The data should be examined after reading the next section that presents known problems in the dataset.

4.1 Discussion of data quality

There were two major episodes of loss of data quantity/quality. The first of these occurred early on in the IR dataset from Pohnpei. An inspection of the plots for Pohnpei for September of 1991 and subsequent months indicates a continually decreasing IR "emittance." At the onset of the decrease it was believed to be real and to be caused

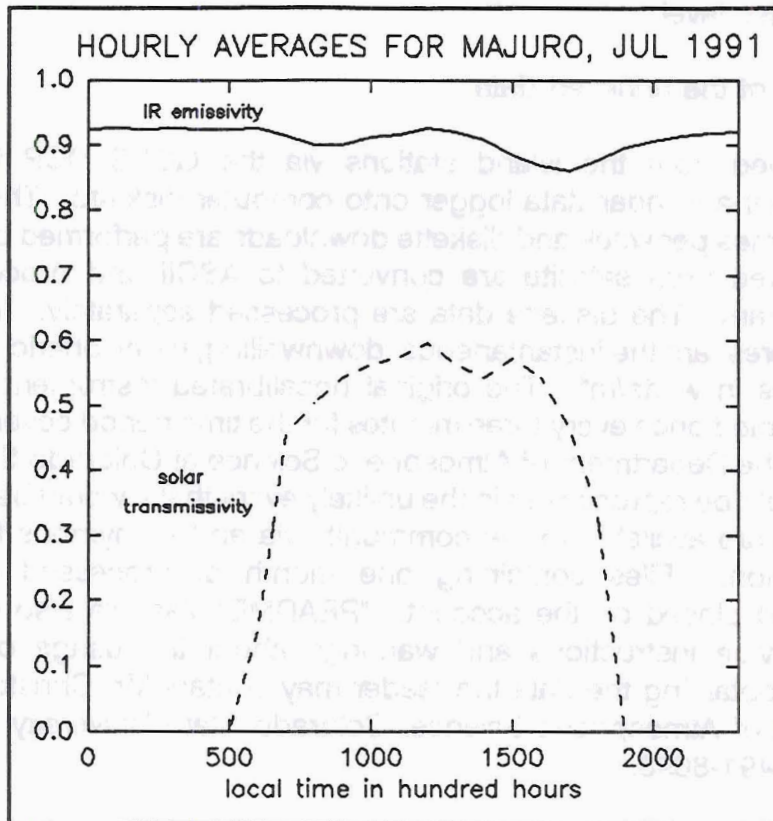


Figure 12. Hemispheric solar transmittance and infrared "emittance" (see text) from Majuro for July of 1991.

by a drier, clearer atmosphere associated with the El Nino event. This was a logical conclusion in view of telephone conversations with WSO personnel who indicated draught conditions had set upon the region to the extent that drinking water was being shipped in. Also, the signal affected was the thermophile output, which nominally ranges between -0.3 to + 0.2 millivolts. The degradation of this signal occurred at a very slow rate of about -0.1 millivolts per month. However, inspection of the plots reveals this was a continuing hardware induced problem and a reasonable guess as to its onset was sometime in October 1991. Thus all IR data after that should not be used. The problem was corrected during the site visit in October 1992.

The second major problem occurred in the solar data from Majuro. The problem was the result of water accumulation in the Handar data logger unit apparently after a change in personnel at the WSO. Apparently, the desiccant was not changed after the maintenance responsibility was transferred to new personnel. This problem manifested itself in the data after May, 1992. Although the IR data appear to be reasonable after that time some caution should be employed when using that data as well.

There were other problems with the data during the period covered by this report. Most of these "glitches" are trapped by the data processing software with the result that the data which are available on the "anonymous" ftp should be as error free as it can be without corroborating measurements. Regarding the large periods of loss of data it is noted that the remoteness of the installations made travel expensive and trips could only be made infrequently. The first maintenance trip was not undertaken until October, 1992. Also, the personnel at the sites had limited technical skills and were reluctant to attempt maintenance procedures. Finally, it is noted that the assistance of the WSO personnel was of a voluntary nature and at times their schedules did not allow immediate attention to the problems with the SRBs.

5.0 Acknowledgements

This project was funded by the National Oceanic and Atmospheric Administration under grant NA90RAH0077 and by the Office of Naval Research under Contract No. N00014-91-J-1422, P00002. We are pleased to acknowledge the cooperation of the National Weather Service Pacific Region for their assistance in coordinating operations with the local governments of The Federated States of Micronesia and The Republic of the Marshall Islands. We are indebted to the personnel at the WSOs at Majuro, Pohnpei and Chuuk for their assistance. For, most certainly, without their help nearly all of the data would be of questionable quality.

6.0 References

Albrecht, B., and S. K. Cox, 1977: Procedures for improving pyrgeometer performance. *J. Appl. Meteor.*, 16, 188-197.

Foot, J.S. 1986: A new pyrgeometer. *J. Atmos. and Ocean. Tech.*, 3, 363-370.

Webster P. J., 1988: The role of hydrological processes in ocean-atmosphere interaction. In Proc. of the U.S. TOGA Western Pacific Air-sea Interaction Workshop, R. Lukas and P. Webster, eds., USTOGA 8, U. Corp. Atmos. Res., 71-100.

APPENDIX A

A1.0 Radiometers

This Appendix contains details of the electrical and radiative characteristics of the instrumentation deployed at the SRB sites.

A1.1 Pyrgeometer

A1.11 Instrument Description

The Eppley Precision Infrared Pyrgeometer measures irradiance in the 4-100 μ m spectral region of terrestrial radiation. It uses a blackened multi-junction thermopile to create a voltage which ideally is linearly related to the net gain in radiant power. The thermopile is coated with Parsons black lacquer and emits like a black body at a temperature T. A thermistor is used to measure the sink temperature of the thermopile.

This pyrgeometer achieves its aim by isolating the desired spectral region by means of an interference filter vacuum deposited on the inside of a silicon dome.

A1.12 Specifications

Sensitivity	-	5 μ V/Watt/m ²
Impedance	-	700 ohms
Temperature Dependence	-	\pm 2% (-20° C to 40° C)
Linearity	-	\pm 1% (0 to 700 watts/m ²)
Response Time	-	2 seconds
Cosine Response	-	< 5% from normalization (Insignificant for a diffuse source)

The orientation of the instrument has no effect on performance, but the accuracy of the instrument is very dependent on calibration which requires special care due to the dome-sink temperature differences.

A1.13 Data Reduction

Using the reduction equations from Albrecht and Cox, 1976, the incident radiance, L , upon the pyrgeometer is given by the following equation.

$$L = K_1 E + \sigma \epsilon_0 T_s^4 - K_2 \sigma (T_d^4 - T_s^4)$$

- T_s - sink temperature
- T_d - dome temperature
- L - incident radiation
- E - voltage

The constants K_1 and K_2 for the stations are given below.

June '91 to October '92

Majuro:	$K_1 = -221.4$	$K_2 = 0.020$
Pohnpei:	$K_1 = -213.4$	$K_2 = 0.0042$
Chuuk:	$K_1 = -228.8$	$K_2 = 0.064$

October '92 to present

Majuro:	$K_1 = -243.36$	$K_2 = 3.40$
Pohnpei:	$K_1 = -213.4$	$K_2 = 0.0042$
Chuuk:	$K_1 = -241.78$	$K_2 = 3.96$

December '92 to present

Darwin:	$K_1 = -233.1$	$K_2 = 0.70$
Kavieng:	$K_1 = -264.6$	$K_2 = -1.15$

A1.2 Pyranometer

A1.21 Instrument Description

The Eppley Precision Spectral Pyranometer (PSP) measures shortwave radiation including the direct component of sunlight, the diffuse component, and reflection from natural surfaces.

It uses a multi-junction thermopile blackened with Parsons black lacquer and temperature compensated to give a response independent of ambient temperature.

The pyranometers used have a pair of concentric hemispheres of precision ground and polished Schott optical glass. Both hemispheres are made of WG7 clear glass transparent from .28 to 2.8 μm .

The accuracy of the PSP is typically 1%. It should be noted, calibrations could have a diurnal and annual cycle and may change with temperature.

A1.22 Specifications

Sensitivity	~	9 $\mu\text{V/watt/m}^2$
Impedance	~	650 ohms
Temperature Dependence	~	$\pm 1\%$ over ambient temperature (20°C to 40°C)
Linearity	~	$\pm .5\%$ (0 to 2800 watt/m^2)
Response Time	~	1 second
Cosine Response	~	$\pm 1\%$ from normalization (0 to 70° zenith) $\pm 3\%$ from normalization (70° to 80° zenith)

A1.23 Data Reduction

The instruments used in this experiment were compared with secondary standards to establish calibration coefficients relating the voltage output of the instruments to the irradiance. The following calibration coefficients were obtained and compared with pyranometer calibrations from NOAA CMDL:

$$H(\text{w/m}^2) = aV + b \quad \text{Slope} \quad a(\text{w m}^{-2} \text{mv}^{-1}) \quad b \text{ is negligible}$$

where V is the measured voltage output expressed in mV.

June '91 to October '92

Majuro:	117.924
Pohnpei:	103.306
Chuuk:	99.128

October '92 to present

Majuro: 118.755
Pohnpei: 100.010
Chuuk: 115.902

December '92 to present

Darwin: 100.705
Kavieng: 113.973

A2.0 Supporting Instrumentation

A2.1 Wind Speed Sensor

A2.11 Instrument Description

The Met-One 014A Wind Speed Sensor is a 3-cup anemometer which uses a magnet-activated reed switch to create a frequency output signal proportional to wind speed.

A2.12 Specifications

Threshold	-	0.45 m/s
Calibrated Range	-	0 - 45 m/s
Accuracy	-	1.5% or .11 m/s
Temperature Range	-	-50 to +70°C
Distance Constant	-	< 4.6 meters
Output Signal	-	Contact Closure, Reed Switch

A2.2 Air Temperature Sensor

A2.21 Instrument Description

On the Handar data stations (Majuro, Pohnpei and Chuuk), air temperature is measured using a Handar 432A Temperature Sensor. This is essentially a precision thermistor device, surrounded by a model 442B Solar Radiation Shield. The resistance of the thermistor is measured in a voltage-divider circuit, and the result is linearized by a table lookup routine in the datalogger.

The Campbell stations (Darwin, Kavieng) use a Campbell model 107 Temperature Probe, mounted in a model 41301 6-plate Gill Radiation Shield. The 107 also contains a precision thermistor, which is measured using a voltage-divider circuit. The result is converted to a temperature using a polynomial curve fit within the datalogger.

A2.22 Specifications

Handar 432A:

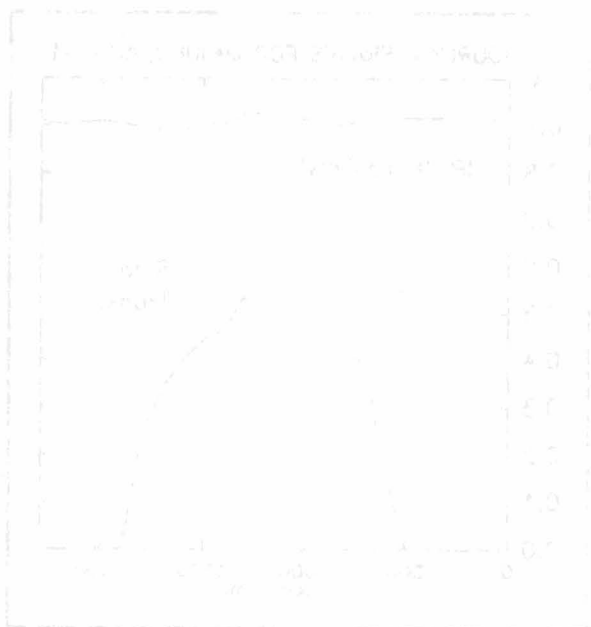
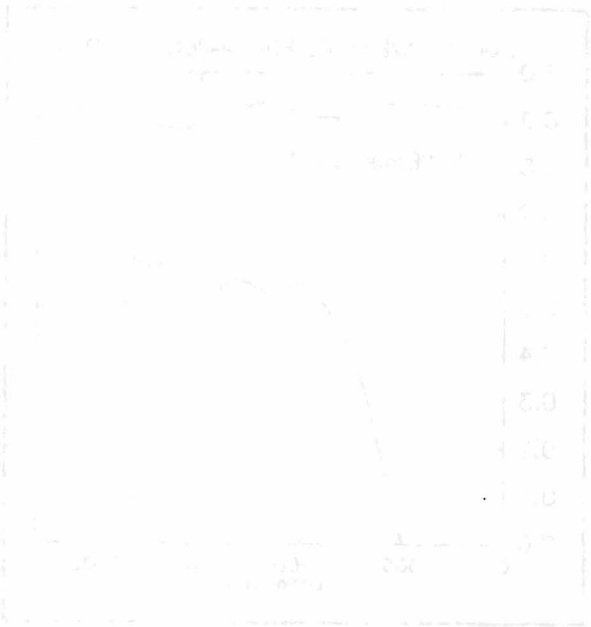
Type	-	Single Thermistor
Conversion Table Range	-	-50°C to +50°C
Accuracy	-	±0.2°C, -20° to +80°C
Input power	-	10-15VDC; 2.5mA (nom) @12.5V

Campbell 107:

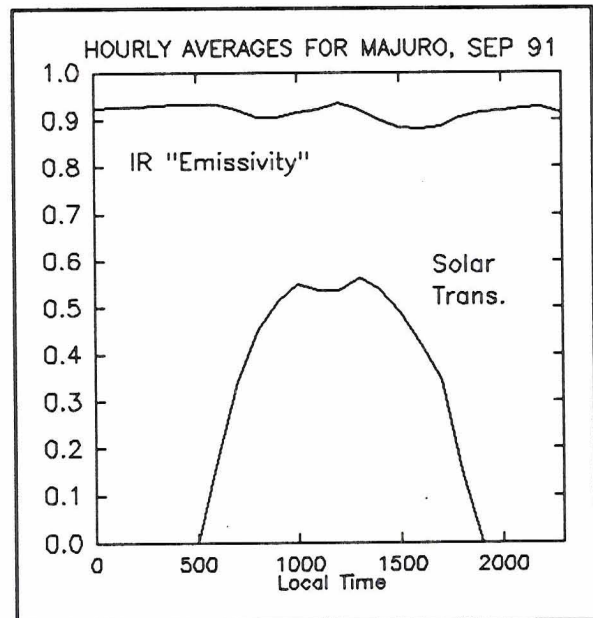
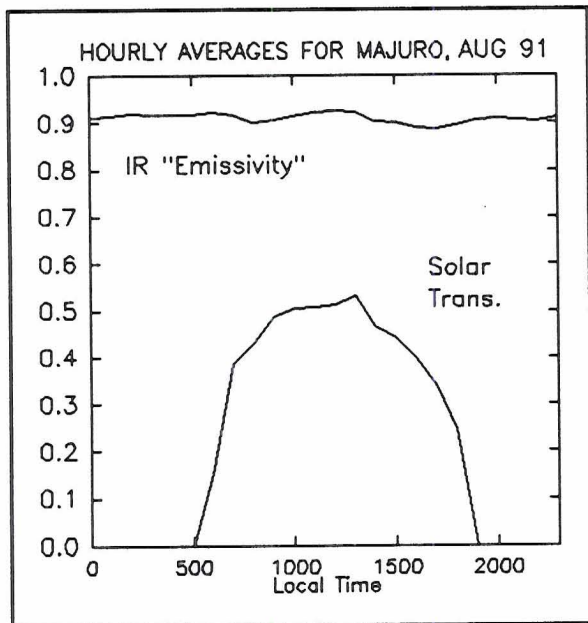
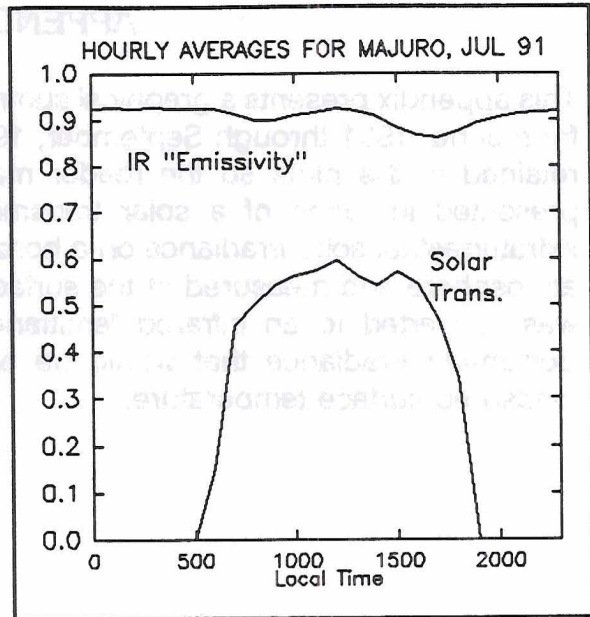
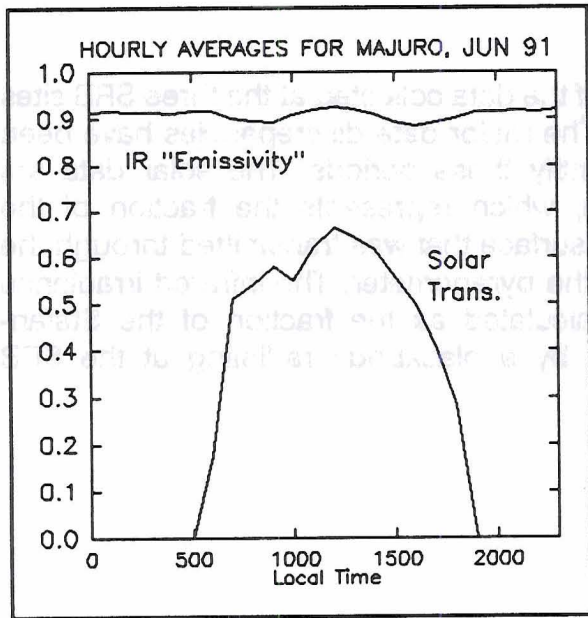
Type	-	Single Thermistor
Linearization Error	-	<0.1°C, -33 to 48°C
Overall Accuracy	-	±0.2°C, -33 to 48°C

APPENDIX B

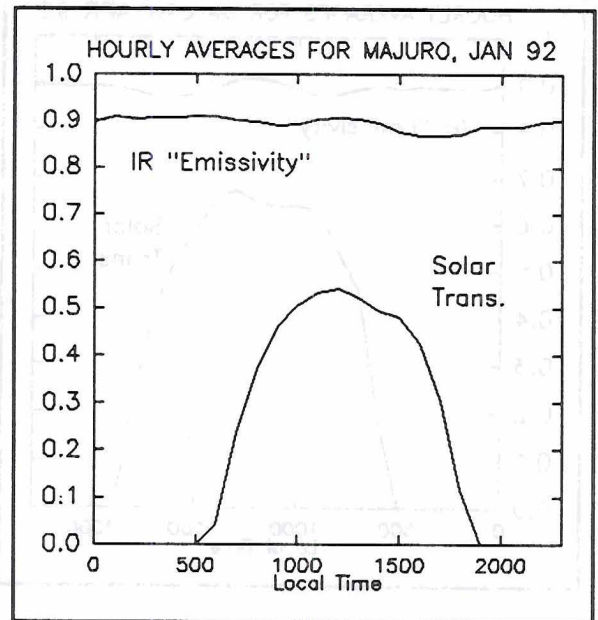
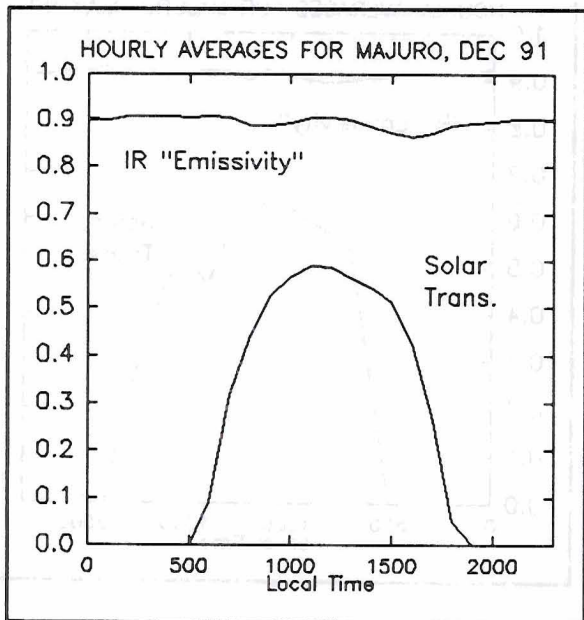
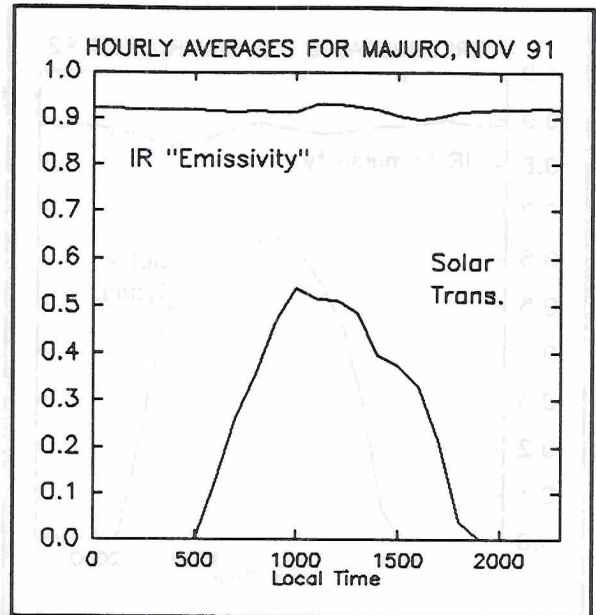
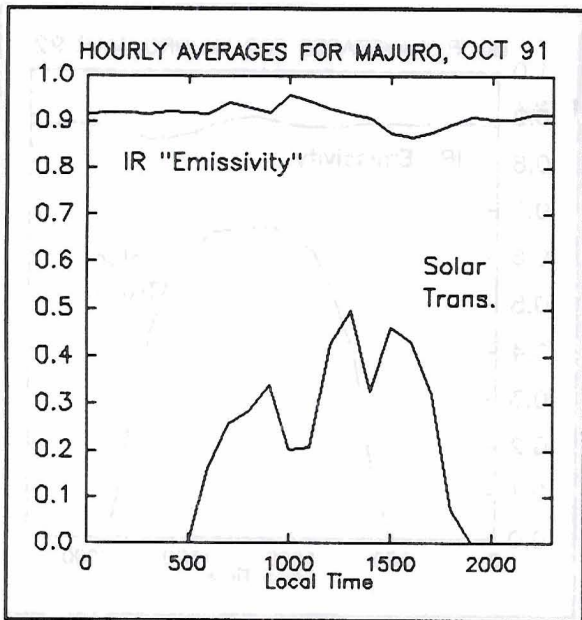
This appendix presents a graphical summary of the data collected at the three SRB sites from June, 1991 through September, 1992. The major data discrepancies have been retained in the plots so the reader may identify these periods. The solar data are presented in terms of a solar transmittance, which represents the fraction of the extraterrestrial solar irradiance on a horizontal surface that was transmitted through the atmosphere and measured at the surface by the pyranometer. The infrared irradiance was converted to an infrared "emittance", calculated as the fraction of the Stefan-Boltzmann irradiance that would be emitted by a blackbody radiating at the SRB measured surface temperature.



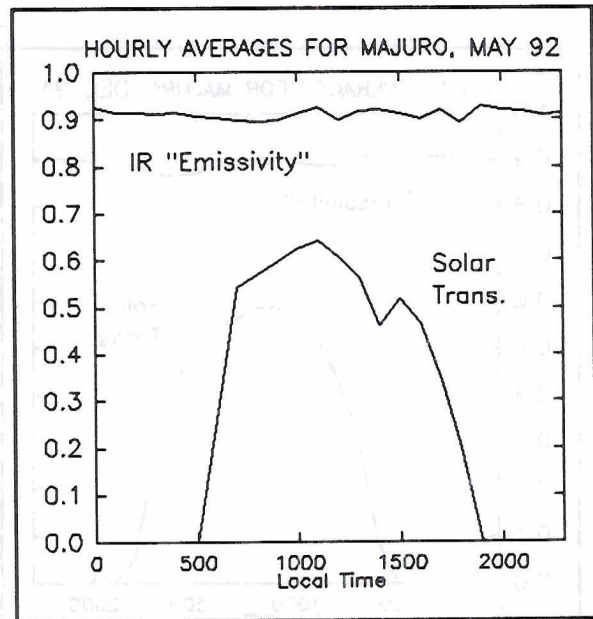
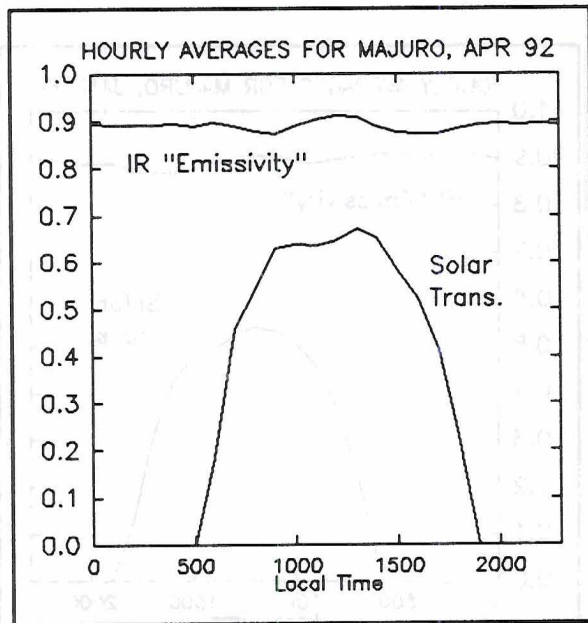
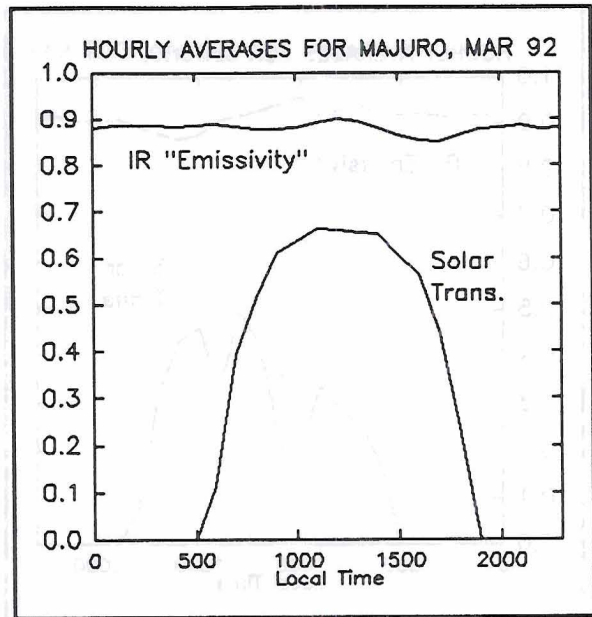
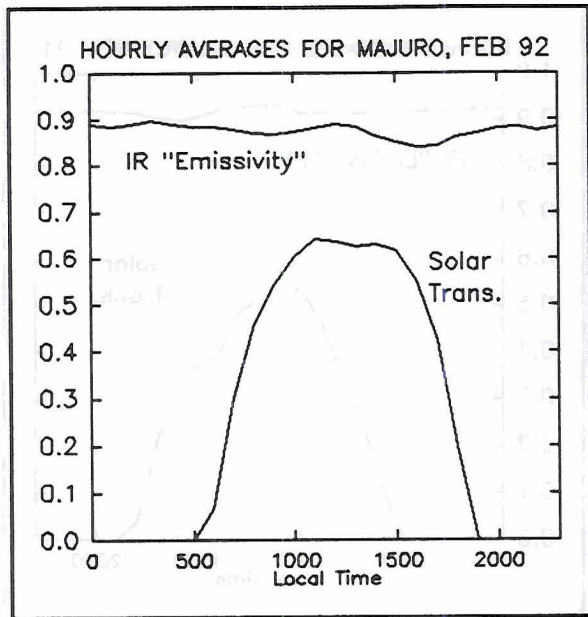
Figures B-1 through B-4 show the solar transmittance and infrared emittance data for the three SRB sites from June 1991 through September 1992.



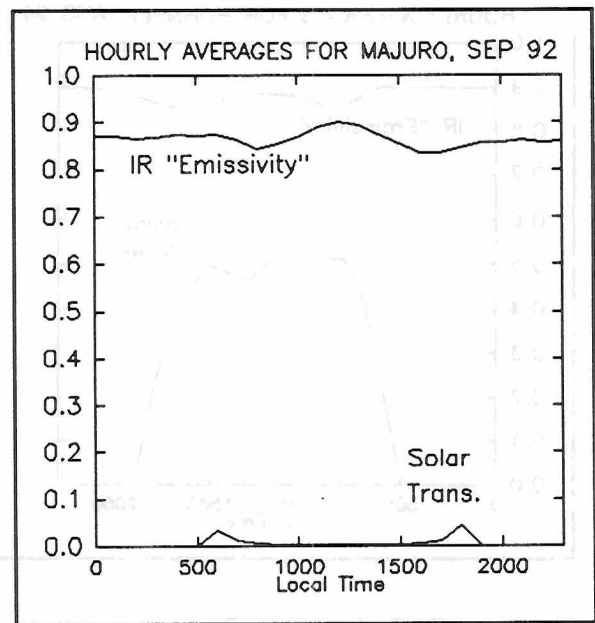
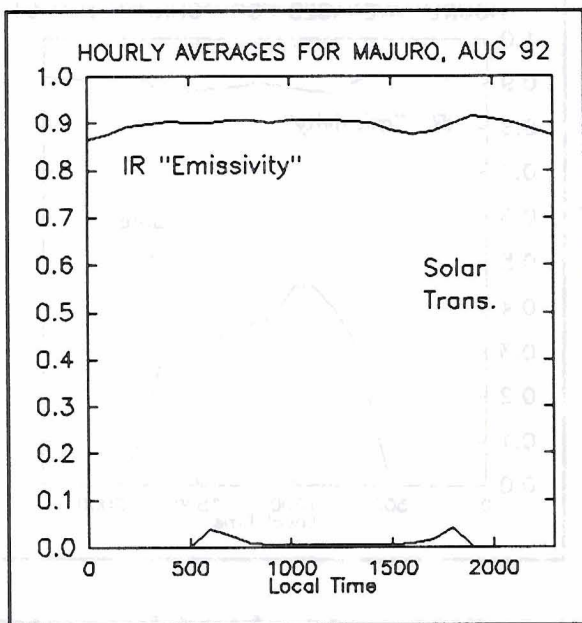
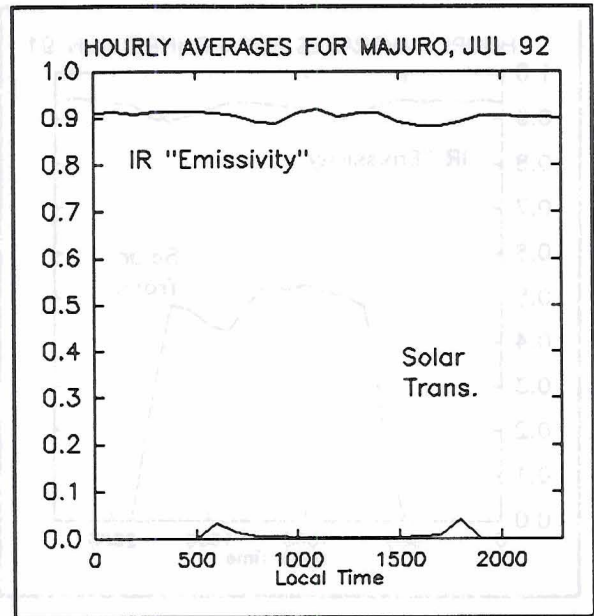
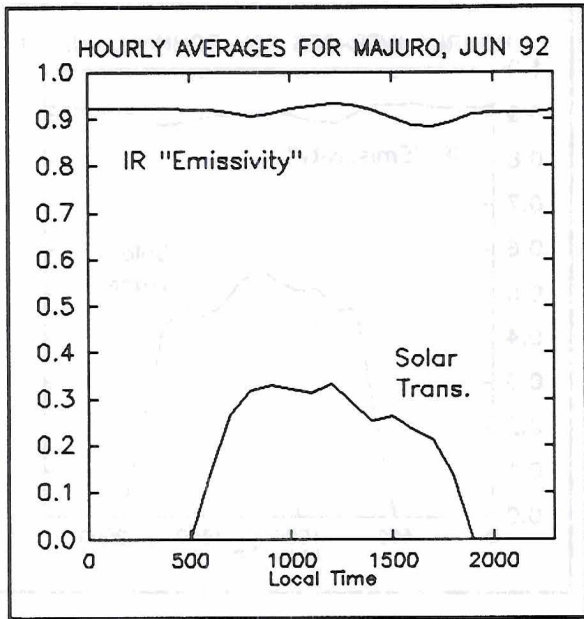
Figures B1 through B4 show the solar transmittances and infrared "emittances" measured at Majuro during the period June - September, 1991.



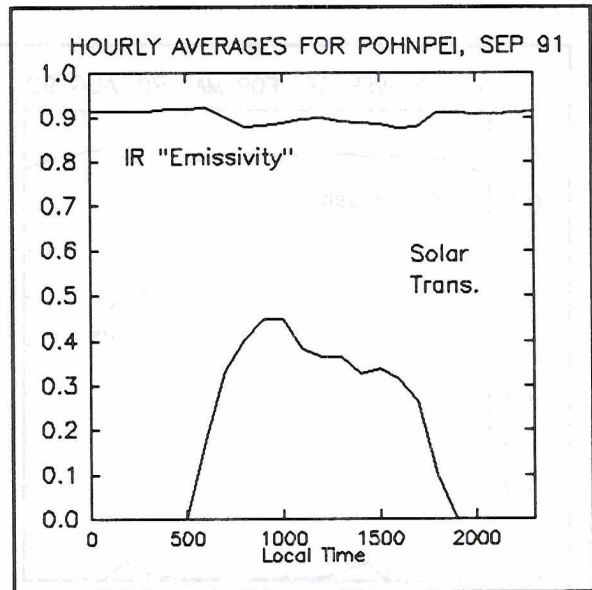
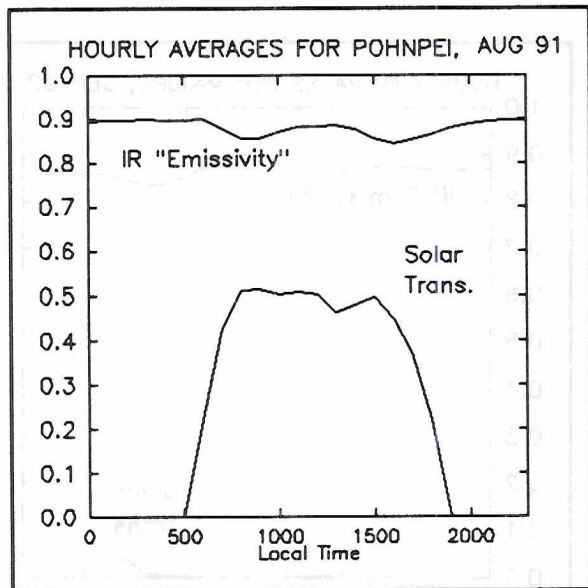
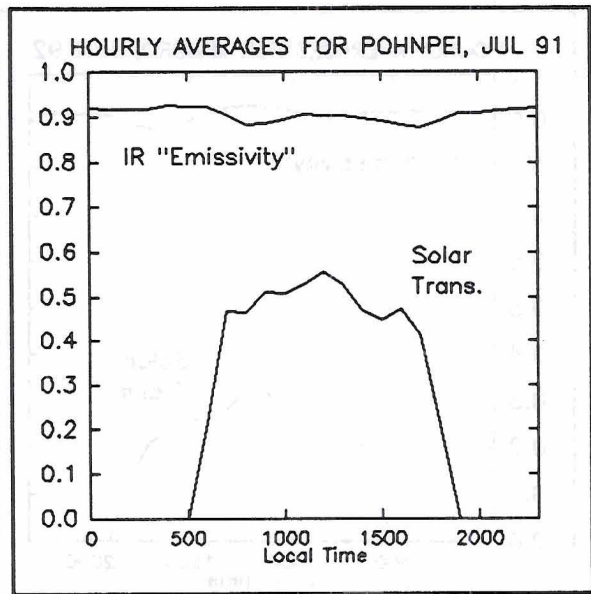
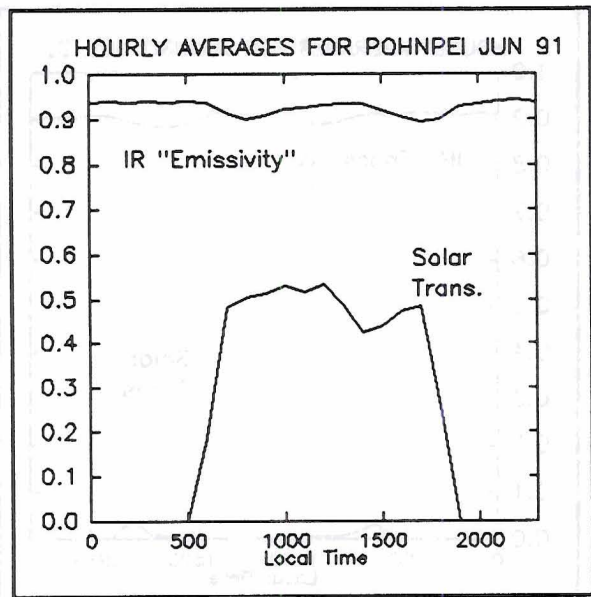
Figures B5 through B8 show the solar transmittances and infrared "emittances" measured at Majuro during the period October, 1991 - January, 1992.



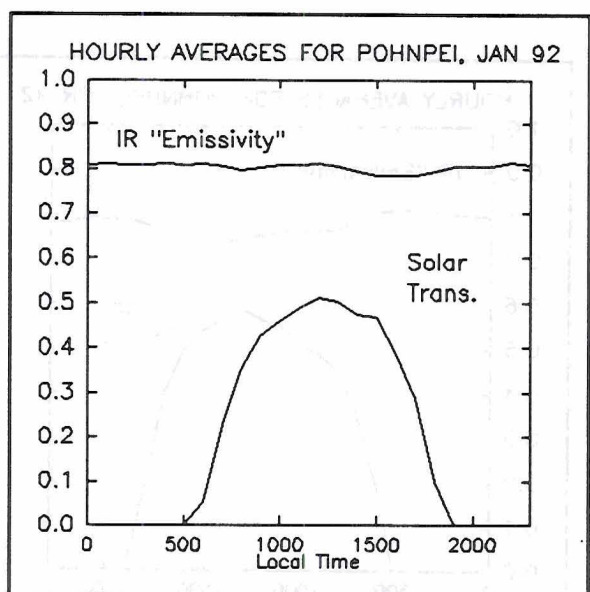
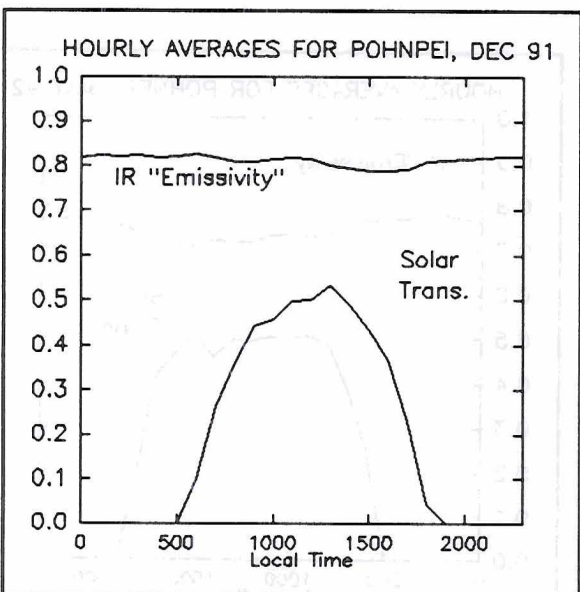
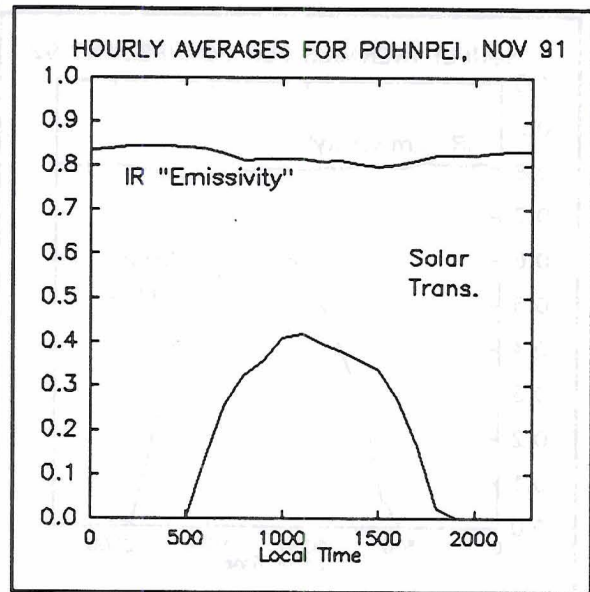
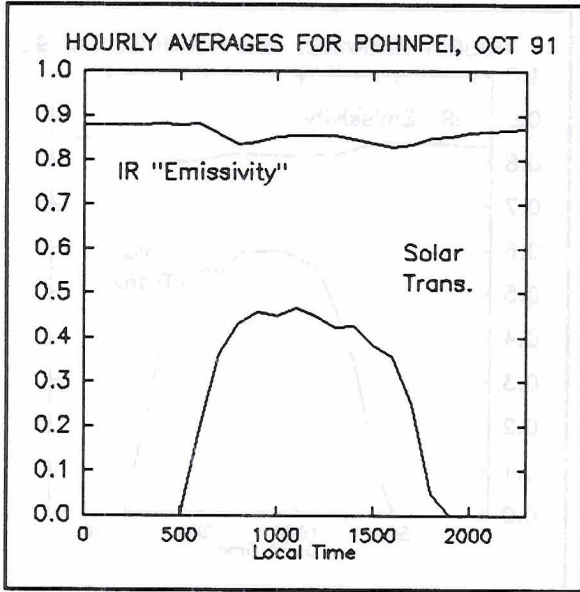
Figures B9 through B12 show the solar transmittances and infrared "emittances" measured at Majuro during the period February - May, 1992.



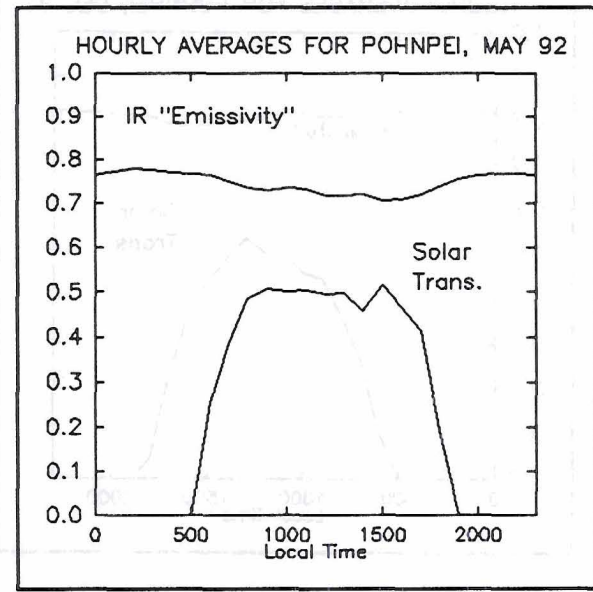
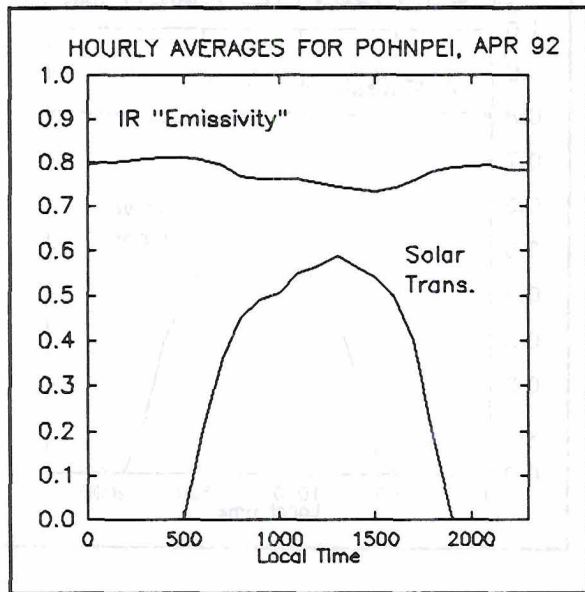
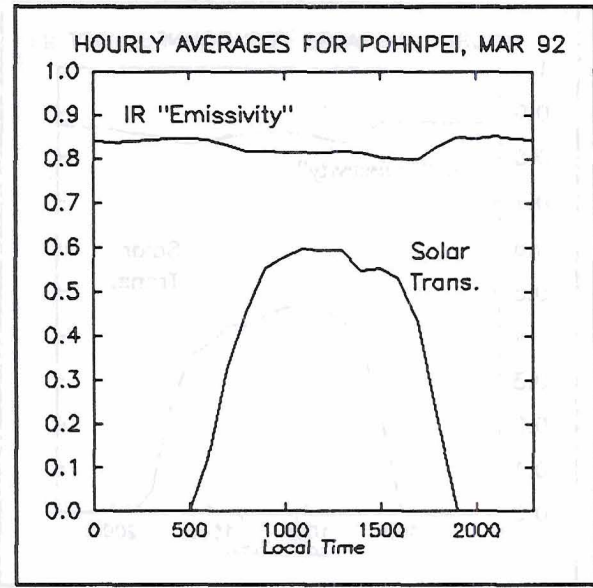
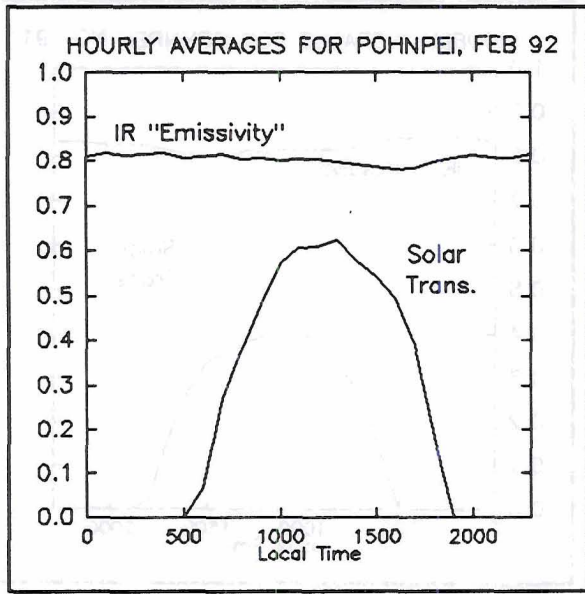
Figures B13 through B16 show the solar transmittances and infrared "emittances" measured at Majuro during the period June - September, 1992.



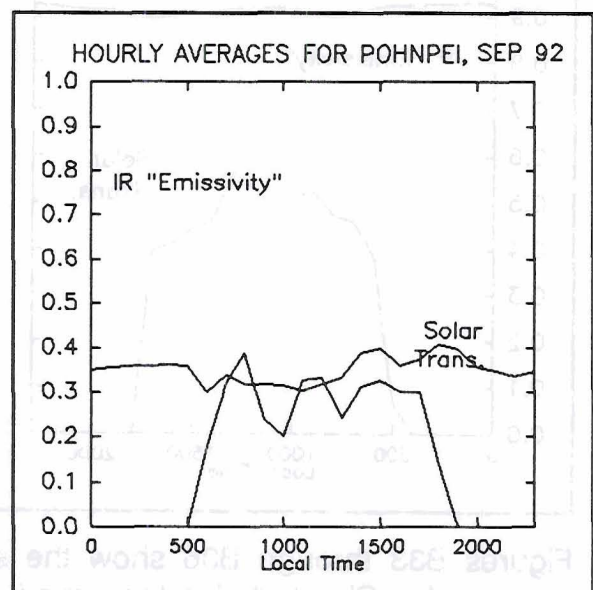
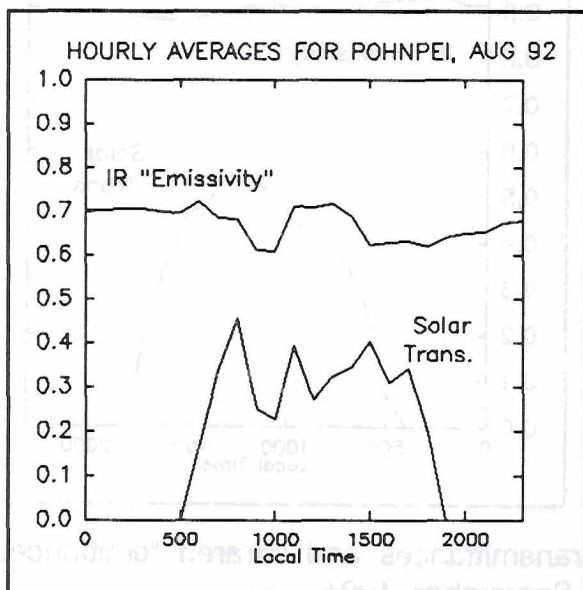
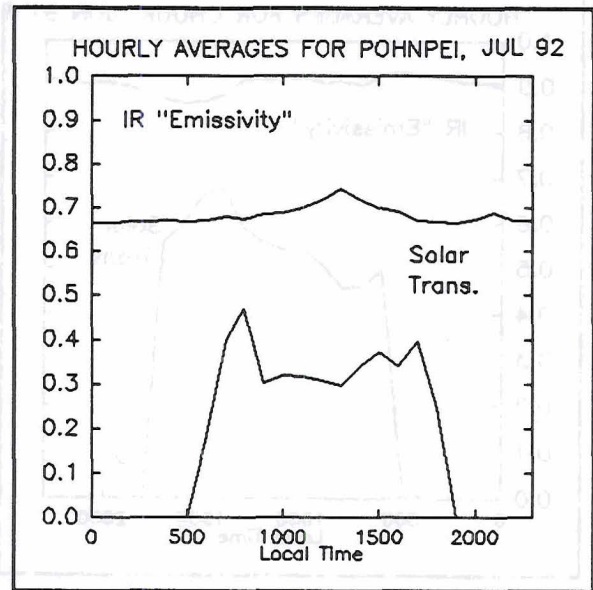
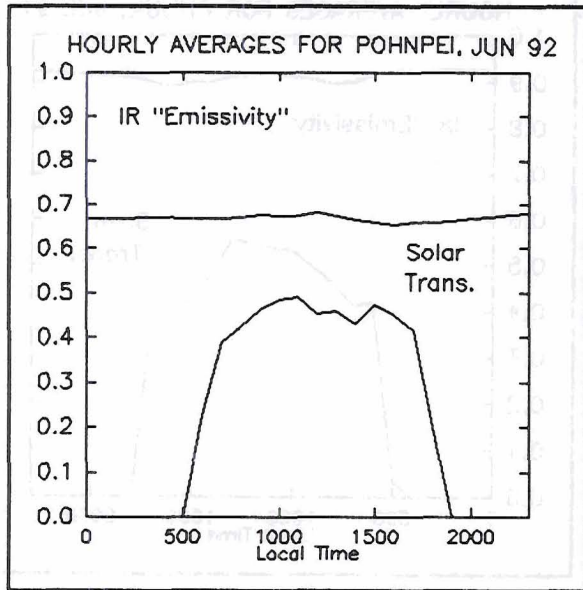
Figures B17 through B20 show the solar transmittances and infrared "emittances" measured at Pohnpei during the period June - September, 1991.



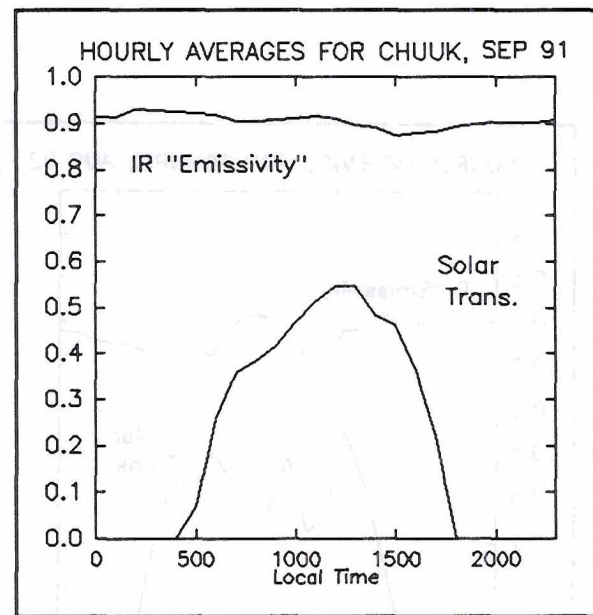
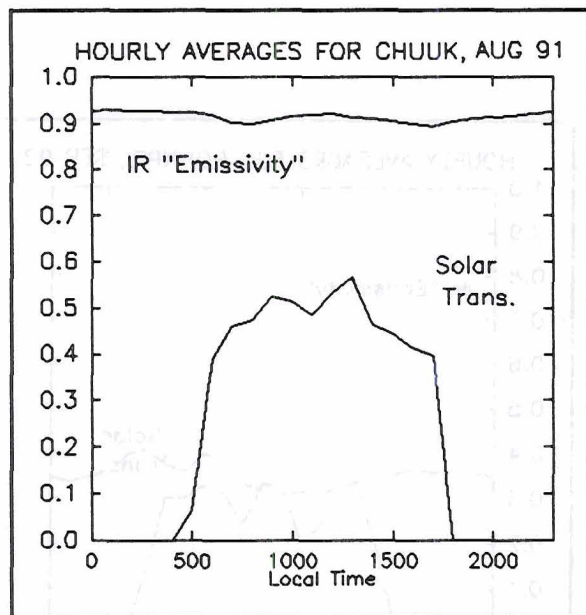
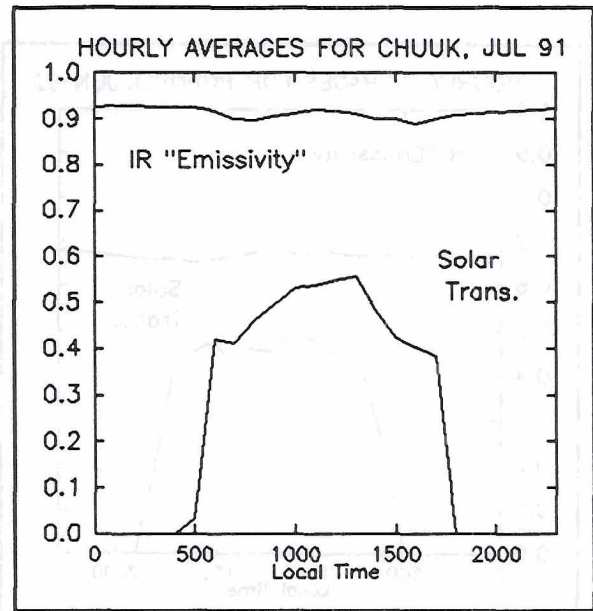
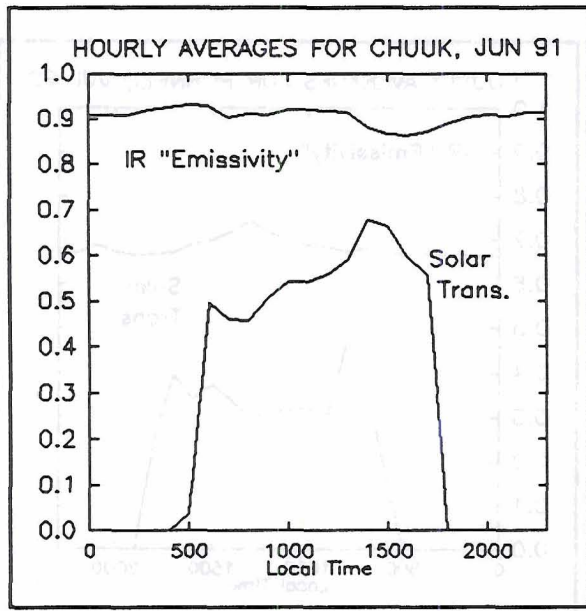
Figures B21 through B24 show the solar transmittances and infrared "emittances" measured at Pohnpei during the period October, 1991 - January, 1992.



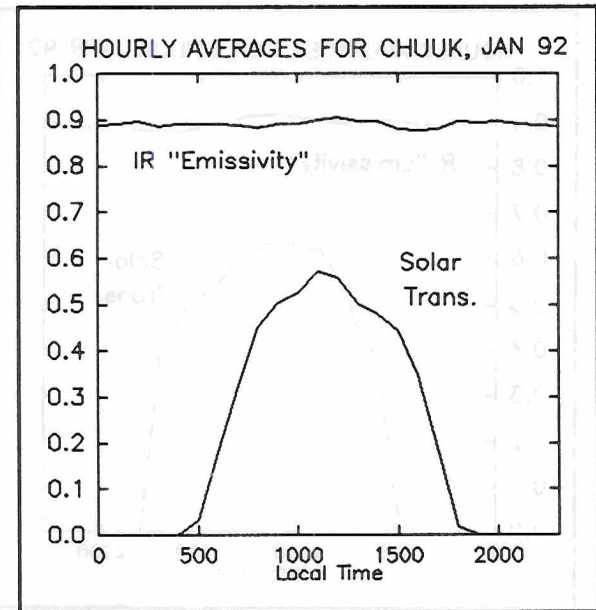
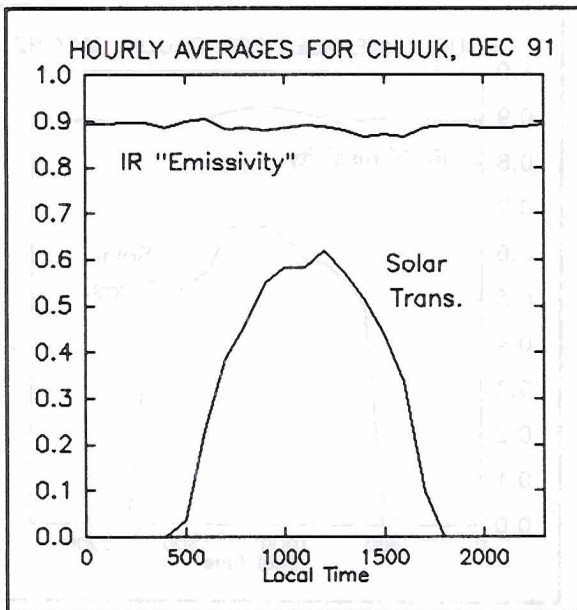
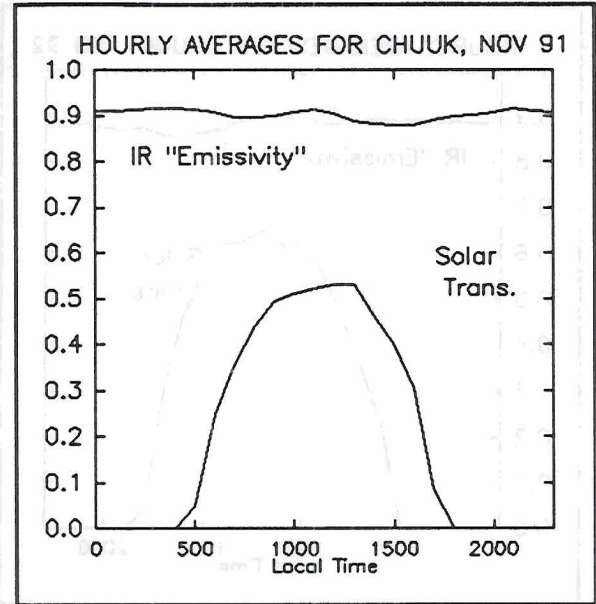
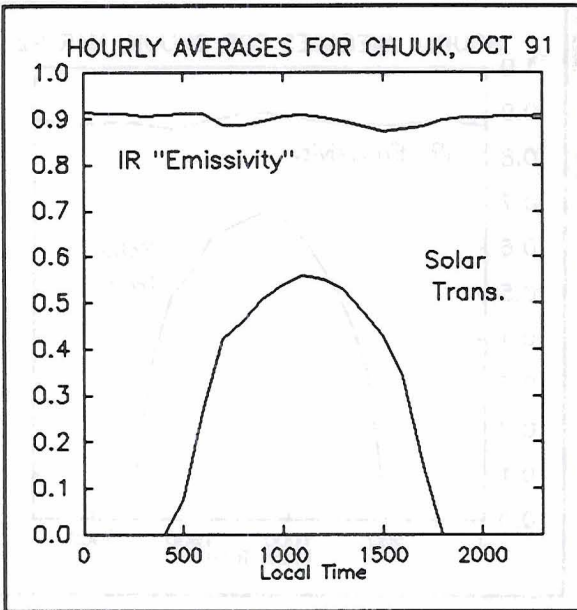
Figures B25 through B28 show the solar transmittances and infrared "emittances" measured at Pohnpei during the period February - May, 1992.



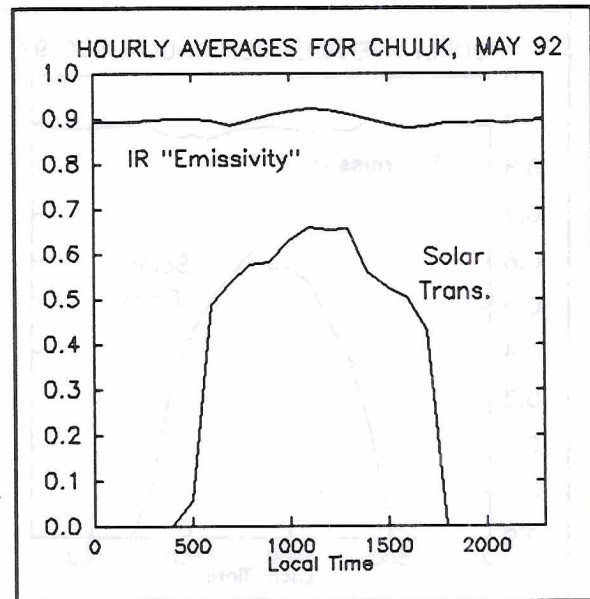
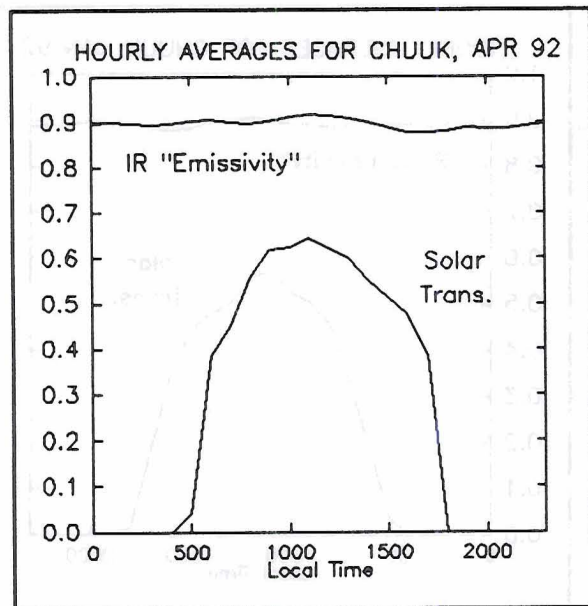
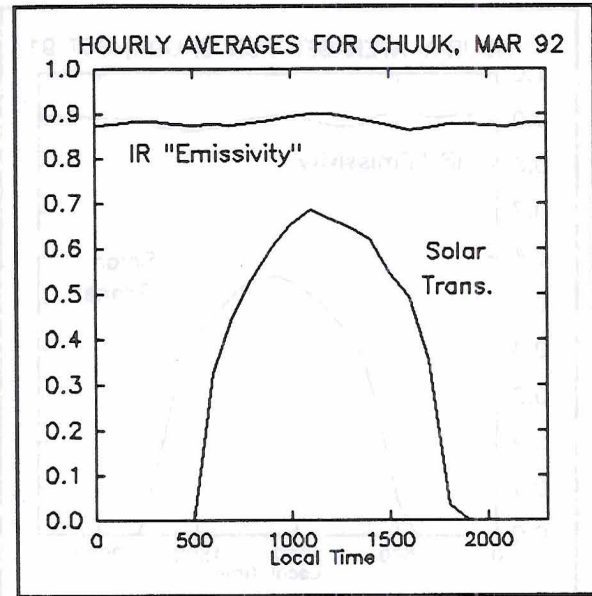
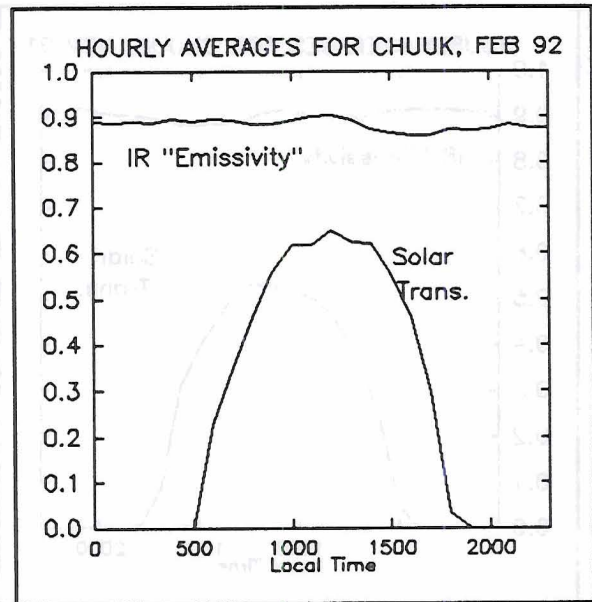
Figures B29 through B32 show the solar transmittances and infrared "emittances" measured at Pohnpei during the period June - September, 1992.



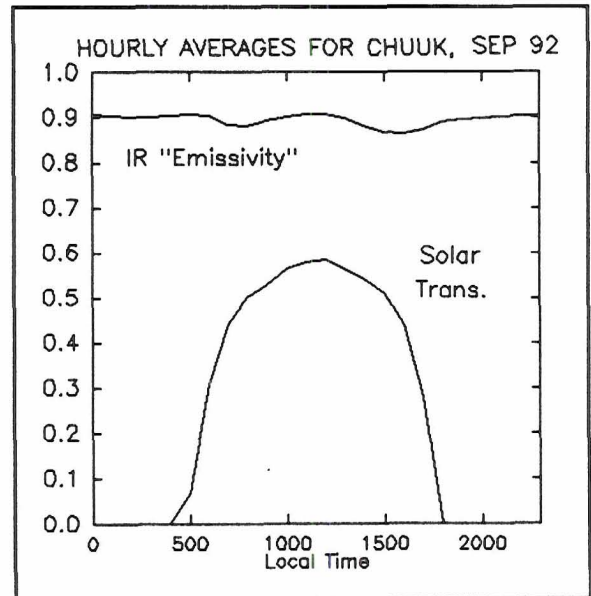
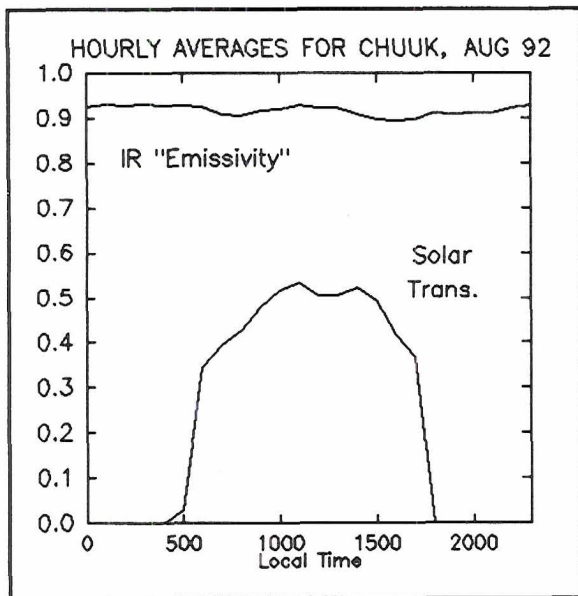
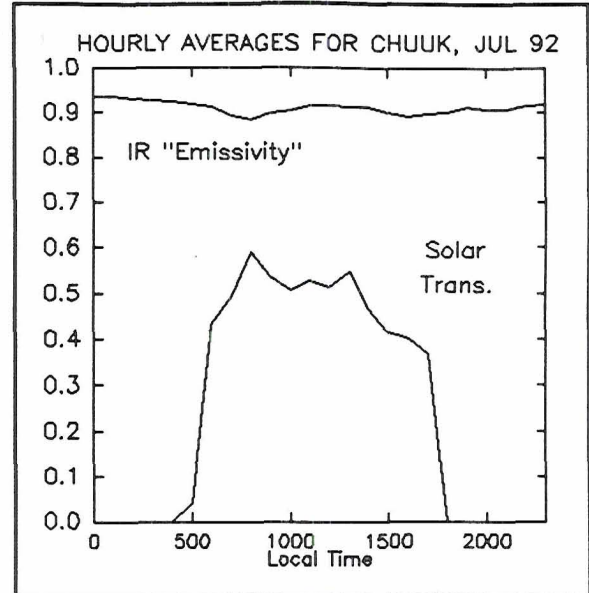
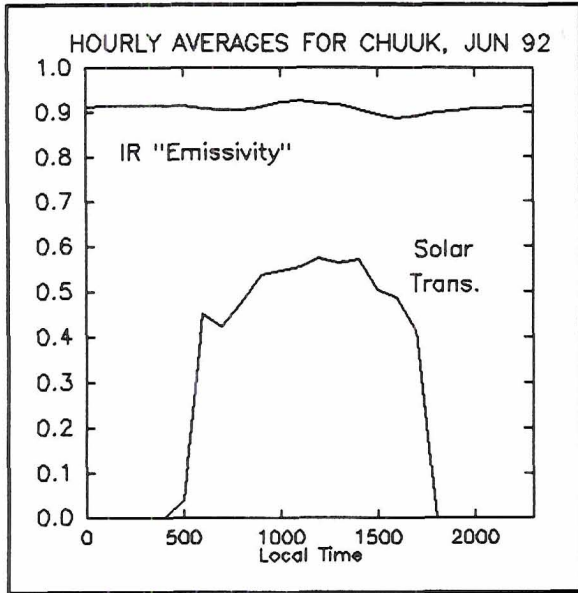
Figures B33 through B36 show the solar transmittances and infrared "emittances" measured at Chuuk during the period June - September, 1991.



Figures B37 through B40 show the solar transmittances and infrared "emittances" measured at Chuuk during the period October, 1991 - January, 1992.



Figures B41 through B44 show the solar transmittances and infrared "emittances" measured at Chuuk during the period February - May, 1992.



Figures B45 through B48 show the solar transmittances and infrared "emittances" measured at Chuuk during the period June - September, 1992.

APPENDIX C

Maintenance Manual for the TOGA COARE Surface Radiation Station

by

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November 1992

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1.0 Introduction

The surface radiation budget station which has been deployed at your site is one component of the Tropical Oceans Global Atmosphere (TOGA) Coupled Oceanic Atmospheric Research Experiment (COARE). The purpose of the project, which is funded by NOAA, is to carefully measure the amount of solar and infrared radiation reaching the earth's surface in a region which has been identified as probably the most convectively active of any on the planet. Estimates of the surface heat budget in this part of the world are somewhat questionable, and measurement of the radiative exchange is one part of a more accurate assessment of this budget.

This station has been designed to provide accurate data and operate in a reliable fashion with minimal maintenance. Some minor daily attention will be required to insure the quality of the data, and routine (bi-monthly) calibration checks will be needed as well. Just as with any electronic system, totally trouble free service can not be guaranteed; thus, this manual is being provided as a simple guide to the basic components of the system. Its purpose is to familiarize the reader with the system to the extent that simple maintenance might be possible by National Weather Service personnel if the situation warrants and only according to direction from the Department of Atmospheric Science at Colorado State University.

This manual is organized on a priority basis; i.e., the most needed information is discussed first and information least likely to be needed is included later. We hope this manual will be easy to follow and that personnel at the sites will refer to it and follow its guidance in order to assure the success of the project.

2.0 Basic description of the station

The data of interest provided by the station are the solar hemispheric downwelling radiation, the ultraviolet hemispheric downwelling radiation, and the infrared hemispheric downwelling radiation from the atmosphere. The first measurement is provided by an Eppley pyranometer (clear dome instrument), the second by an Eppley UV Radiometer, and the last measurement is provided by an Eppley pyrgeometer (silver dome instrument). These instruments are mounted on a horizontal plate at the top of the tripod system. Fig. 1 shows the location of the pyranometer and pyrgeometer on the system. The UV radiometers are not shown in Fig. 1, but are located between the pyranometer and the pyrgeometer. All other instrumentation deployed on the system is designed to aid in interpretation of the primary data streams. The other instrumentation included with the system includes: an anemometer, an ambient air temperature sensor, a Handar model 540 data collection system which includes a GOES satellite transmitting station and a Handar WWV receiver which merely assures proper operation of the internal clock of the data collection system. The small antenna is part of the GOES transmitting station and the copper length of wire is a receiving antenna for the WWV (clock) receiver. The entire system is mounted on a sturdy tripod support. A Toshiba 1000 SE laptop computer has also been supplied which serves as a communication device to the 540 data collection system. Its purpose is to allow simple reprogramming of the station, should that become necessary, and to provide a means of data retrieval if transmittal of the data via the GOES satellite fails. Each of these devices will be discussed in the following paragraphs.

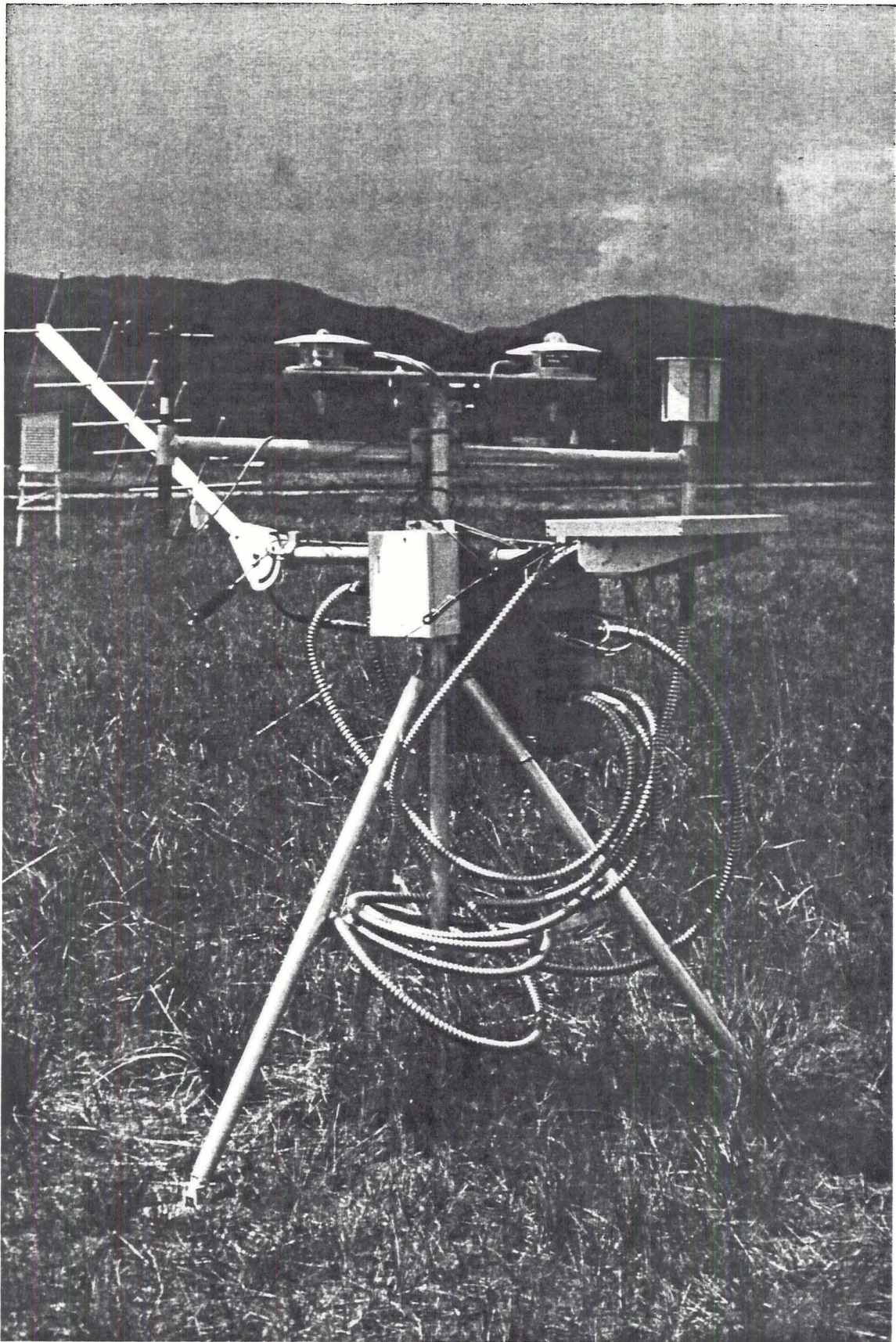


Figure 1. Photo of an SRB station during testing phase at Colorado State University.

2.1 Eppley radiometers.

The Eppley pyranometer measures the amount of hemispheric solar radiation, which includes the visible portion of the solar spectrum. The Eppley pyrgeometer measures the amount of hemispheric downwelling infrared radiation in the 2.8 - 40.0 micrometer region of the spectrum. The Eppley UV radiometer measures the amount of downwelling ultraviolet radiation. These instruments are rugged and will provide reliable data provided a simple maintenance routine is followed. Below all three instruments will be referred to as radiometers.

There are three basic maintenance procedures which need to be carried out in order to assure good data. First, on a daily basis, the filter domes (clear or silver) of the instruments must be cleaned. This can be accomplished by wiping the dome with a clean lint free cloth. A supply of lint free pads has been included with the station. The dome must be wiped daily. The best time to do this is after a precipitation event, since a wet dome also invalidates the data.

Second, approximately once a week, the level of the instruments should be checked. Each radiometer is equipped with a small bubble level mounted on the base plate of the instrument. The bubble must be within the small circle in the center of the level. The level may be adjusted by means of three black-knobbed bolts on each radiometer. Normally this will be necessary only after a severe wind storm, but a small adjustment may be necessary after time due to slight settling of the tripod system.

Third, the condition of the desiccant must be monitored. Each radiometer is equipped with a small desiccant container which mounts into the cylindrical side of the instruments. The desiccant within the containers may be inspected by viewing it through the clear glass windows. The desiccant should appear bluish in color. If it is pink or white it should be replaced. A container of silica gel crystals and extra empty desiccant containers are supplied for this purpose. If it becomes necessary to replace the internal desiccant, the extra container should be filled with silica gel indoors then carried to the station. Each extra container has an "O" ring seal around the inside of the knurled knob housing. This "O" ring should be coated with a small amount of the moisture displacement (Dow-Corning sealant/lubricant) compound which is supplied in a small tube. Remove the "O" ring using a small screwdriver included with the tool kit and coat the "O" ring with the lubricant then replace it on the container. Fill the container as much as possible with fresh silica gel desiccant and replace the lid to the silica gel bottle. While protecting the container as much as possible carry it to the station. Unscrew the depleted desiccant container from the radiometer making sure to remove the "O" ring with it and replace immediately with the refilled container and newly coated "O" ring. It is important that the amount of time the instrument is exposed without a desiccant container installed be kept to a minimum since exposure to moist tropical air will cause a more rapid depletion of the new desiccant once it is installed. After replacing the desiccant, the level of the instruments must be checked. Discard the contents of the container and store until another replacement of desiccant is required.

The useable lifetime of the desiccant is uncertain in the tropical environment. In an attempt to prolong the life of the desiccant within the radiometers, an external container, mounted on the radiometer base plate has been installed. The appearance of the drierite desiccant which it contains is light blue when active and pinkish when depleted. This container connects to the two radiometers via flexible plastic tubing and through two brass valves. The purpose of the larger supply of desiccant is to provide extra moisture removal from the radiometers. It is hoped that maintaining the larger desiccant supply will reduce or even eliminate the need to replace the silica gel within the instruments. A supply of drierite desiccant is also provided in a large jar. To replace the depleted drierite, first the supply of air into the radiometers through the tubing must be eliminated. Close both valves by turning the knobs in a clockwise direction. It is important to close the valves

before removing the tubing. The tubing may then be slipped off of the desiccant container and it can be unmounted from the radiometer plate by loosening the metal hose clamp. It also must be taken indoors to be refilled. The desiccant is replaced by removing the metal cap and spring and filter pad assembly, replacing the drierite and replacing the filter pad, spring and lid. The container can then be returned to the station and remounted in the metal hose clamps. The plastic tubing must be firmly reattached and only then should the brass valves be reopened. After replacing the external desiccant, the level of both radiometers should be checked.

2.2 The Handar 540-A data collection system.

The Handar 540-A data collection system is housed in the large stainless steel box which is supported on the mid portion of the tripod. The data system functions as a collection unit and also contains a GOES satellite transmitter which is the primary means of data recovery. It is not anticipated that NWS personnel will need to be concerned about the technical details of the system; however, in some cases, reprogramming the system, resetting the clock or retrieving the data from the system may become necessary. If any of these circumstances arise CSU will contact the representative at your location. These procedures are covered in a later section since they all involve use of the laptop computer system. The system was selected based on an outstanding record of reliability. Thus, hopefully, National Weather Service personnel should have few occasions to interact with data system. The only maintenance we originally requested was a visual inspection of the system's exterior, in particular the connector panel should be checked periodically for corrosion around the cable connectors. If it appears that corrosion is becoming a problem, the connectors should be cleaned as thoroughly as possible and recoated using the tube of moisture displacement compound included with the station. We ask that NWS personnel contact the Department of Atmospheric Science at Colorado State University regarding the problem; (phone numbers and an address may be found on the cover page of this document) if corrosion appears to be a serious problem.

Since deploying the stations, we have learned that the Handar boxes need more attention than was originally expected. This includes checking the internal desiccant bags within the stainless steel box every month, and replacing those bags if necessary. Also, each time the box is opened, a fresh layer of sealant/lubricant should be applied to the seal of the door. With this small amount of extra attention, we should be able to avoid further data problems due to water collecting inside the Handar data collection box.

The procedure for checking the state of the desiccant in the data system box is outlined below. There is a humidity indicator mounted atop the battery compartment inside the data system box which indicates whether the desiccant is still effective. The door to the data system may be opened by loosening (but not removing) the four bolts which hold the metal latches against the door. After the bolts are sufficiently loosened the latches can be moved away from the data system freeing the door to open. A quick glance of the humidity indicator will reveal if the desiccant needs to be recharged. This is indicated if the color of the circle is lighter than that of the rectangular swatch on its left. If the desiccant does need replacement, it is located behind the foam pad next to the right wall of the data system, or possibly on the bottom of the data system box, in three separate packages. Extra desiccant packages have been provided and we have attempted to package them so they will retain their drying ability. Before changing the desiccant packages a thin coating of the moisture displacement compound should be applied to the rubber gasket which seals the door against the data system box. Once this is done the three desiccant bags may be replaced and the door quickly closed, the clamps moved back in place and the four bolts tightened. Although we have attempted to package the replacement desiccant to maintain its drying capacity, it is unlikely that this condition will be maintained for an extended period of time. Instructions for recharging the desiccants may be found on the individual packages (basically they must be heated in an oven at 250 F for at least 12 hours). If this is not possible at your location, exchange desiccant packages will be shipped to your site on a periodic basis depending on the experience gained in the field. We are suggesting the condition of the desiccant be checked on a monthly basis.

2.3 The WWVH Radio Receiver

The WWVH radio receiver is housed in the small white box located behind the Handar data unit and includes the copper wire antenna which makes the form of a "V" sloping up from the ground. The purpose of the receiver is to ensure correct timing of the clock in the Handar unit. Basically, the unit monitors the 5, 10 and 15 kHz frequencies once daily at a preset time and attempts to acquire the WWVH timing signal. If it is acquired, the Handar 540A's internal clock is reset. Once deployed, if power is not interrupted, the unit should function in a completely automatic mode. If power to the data system is interrupted it will be necessary to reset the Handar 540a clock. Special software is provided to perform this task and this procedure is described in a subsequent section. The primary maintenance procedure is to maintain the desiccant in the receiver unit. The condition of the desiccant is indicated on a card located within the receiver unit. Two bolts hold latches which secure the lid of the receiver. To open the lid the bolts must be loosened (but not removed) and the latches lifted off of the rim of the lid. Open the lid and inspect the desiccant indicating card. If the color of the circular indicator is as dark or darker than that of the rectangular swatch, the desiccant is still active. If not the two plastic wire ties which hold the desiccant to the lid must be cut with wire cutters and the desiccant removed from the pouch. Additional desiccant packets have been included with the station. These are identical to those for the 540A data system. The new packet should be rolled and inserted in the cloth pouch which can then be reattached to the lid using additional plastic wire ties. The lid must then be resecured by repositioning and tightening the two metal clamps. It is not known how often this procedure should be carried out in the tropical environment. We are initially suggesting a monthly inspection of the condition of the desiccant and future experience will dictate the frequency of the process.

2.4 Support tripod and cabling

The support tripod is made of sturdy aluminum. We anticipate this support will provide years of service; however, it should be inspected periodically to ensure that all hardware is still secure. This can be accomplished routinely on visits to the station to wipe the domes of the radiometers. If any of the nuts work loose they should be tightened with the tools supplied with the station. Also, the WWVH receiver's antenna should be free of any vegetation in order to assure optimum performance in updating the Handar 540A's internal clock.

3.0 The Toshiba 1000SE laptop computer

A Toshiba laptop computer has been supplied as an integral part of the system. The computer has various functions which include: programming upload and download to the Handar 540A data system, resetting the WWVH time of the data system's internal clock and data retrieval from the 540A data system. Each of these procedures will be described, but first it is necessary to become somewhat familiar with the computer and its software.

3.1 Features of the Toshiba 1000SE laptop computer.

The Toshiba 1000SE laptop computer is an MS DOS based battery operated portable. It is supplied with 1Mbyte of RAM, a 1.44Mbyte 3.5 inch floppy drive and sufficient ROM to store the operating system and certain utility programs. The upper 560 Kbytes of RAM are used as a RAM disk and the contents of this non removable disk are maintained by the battery system. The contents of the RAM disk will be lost if the backup battery (see below) becomes discharged. The configuration of the computer (including the allocation of the upper 360Kbytes for the RAM disk) and the Handar software are stored on the RAM disk. Thus if the main and backup battery become discharged the RAM disk must be repartitioned and the Handar operating software reinstalled. The RAM disk is designated as disk D:. The DOS (disk operating system) is stored in read only memory (ROM), which is designated as drive C:, and will not be lost if the batteries become

discharged. However, it is not possible to write information to the C: disk. The floppy is used to transfer program and data information to and from the computer. The keyboard of the computer is protected by a clear plastic cover and various keys on the keyboard have been marked for special function control when used with the programming software. These special decals on the keys must be ignored except when using the programming software. When delivered the laptop was initialized in such a way that the support software for the Handar 540A data system is loaded and ready to execute after power up. However, depending on the state of the battery power supply, it may be necessary to reinitialize the computer, reset the real time clock and reload the software which supports the data system. To avoid these procedures we recommend that the computer be stored with the AC power supply connected and continually supplying power to the computer. The AC adaptor plugs into the computer via a jack on the left side of the computer, toward the back.

There are three batteries within the laptop computer. First, the main removable battery pack, which has a shelf life of about 7 days if the computer is not in use or about 2 hours if the computer is on. Second, a backup battery which is recharged from the main removable battery. This battery maintains the memory in the computer (including the RAM disk) for a short time even if the main battery is discharged, but it is not possible to operate the computer from the backup battery alone. Finally, there is a small battery which maintains the real time clock, but it will become discharged in a short time if the main battery is totally depleted. With this information in mind we now proceed to describe the possible power-up conditions.

3.2 Power up conditions for the Toshiba 1000SE

As mentioned above, the Handar software is stored on the RAM disk and will be maintained in memory as long as the backup battery is still charged. The power switch to the laptop is located on the midway back on the left side of the computer. No disk will be needed to boot the computer since the DOS is stored in non-volatile ROM. To turn the unit on depress the switch and hold in for about 2 seconds then release. The unit is turned off in a similar manner. After a memory check the unit should display the message:

```
HANDAR 545C PROGRAMMING/DATA COLLECTION SET
```

```
D:\>
```

If this is the case, the Handar software is in memory and it is possible to use the unit for the desired task, program upload, modification or data download. These topics are addressed below. This section is concerned only with proper power up and initialization of the laptop. Even though the computer powers up as just described, the main battery may nevertheless be nearly discharged. This condition is indicated by a blinking red light (only if the AC adaptor is not plugged in). The AC charger should be plugged in and the unit may be operated in this mode. If it is desired to take the unit to the field it should be turned off and charged for about 4 hours before doing so.

If the batteries have been discharged, the unit may not respond at all, in which case it is necessary to charge the unit with the adaptor for at least ten minutes before proceeding. At this point, the unit may have a normal start up described above if the main battery was very low. However, if the backup battery has completely discharged all memory will have been lost. After a 10 minute charging period, the unit should boot upon power up and the system will display the message.

```
WARNING: DATA IN HARD RAM WAS LOST  
YOU MUST FORMAT HARD DISK BEFORE USE  
PRESS ANY KEY TO CONTINUE.  
WAIT.
```

Press the [ENTER] key or any other character key, and the unit will boot as above, with a different message

at the end.

MEMORY TEST nnn KB

Toshiba Personal Computer MS-DOS Version 3.30S

Bad or missing /CONFIG.SYS

It is now (day of week) (month) (day of month), (year)

C:>

With the adaptor plugged in it is possible to proceed with initialization of the system and this must be done before the unit can interact with the Handar 540A data system.

To proceed, place the TOGA System disk into the floppy drive located at the right rear of the unit and enter the following:

a:

press <Enter>, then type

setcnfg

and press <Enter>

You will be presented with a list of instructions on how to reconfigure the system. You may page through these instructions (they are a bit confusing) by pressing the enter key twice. A table will appear listing the various setup options which may be changed. This table is shown below with the parameters set to their proper values.

SYSTEM SETUP	
Set The RAM Config.sys File	= No
Config.sys File	= RAM
Boot Priority	= Normal
Hard Ram Size	= 384KB
Built-in Expanded Memory Port Address	= 258H
Option Expanded Memory Port Address	= 208H
Resume Mode	= Boot
External FDD/PRT	= Printer
Display Mode	= Normal
Display Auto Off	= 03 Min.
Primary Display Type	= Color[80*25]
Built-in TS-232C Port Assign.	= COM1
Built-in Modem	= Disable
Built-in Modem Power	= OFF
Battery Alarm	= Enable
System Speaker	= Enable
Parallel Printer Port	= Output Port
Instruction	
← & → KEYS-Select Values. ↓ & ↑ KEYS-Move Options. F5-Sets Defaults	
EXIT: Enter - Accepts Changes. Esc - Disregards Changes.	

The values in the table may be changed by using the left and right arrow keys, which toggle through the allowable choices. Most of the entries will be correct, but carefully check that each corresponds to the setting in the table, especially check the first entry to see that it is set to "No" and the second entry and be sure it is set to RAM not ROM. Once the values in the table are correct press

<Enter>

You will be prompted with the question at the bottom of the screen

Are you sure? [Yes / No]

Yes will be highlighted in reverse video.

Press <Enter> and you will be presented with some more instructions. Press any key to continue. You will be asked if you wish to continue. Press <Enter> again and you will be given still another WARNING that all data on the D: disk will be lost and prompted with:

Proceed with Format (Y/N)?

Press <Y>

then press

<ENTER>

and the system will proceed to reformat the D: disk, which is the RAM disk and will install the hardware necessary to interact with the data system. Although you will be prompted to remove the disk and reboot the computer, before doing so you must copy the config.sys file from disk a: to disk d:. Since you are now on disk d: merely enter

copy a:config.sys

<Enter>

After copy the computer displays

1 File(s) copied

Now you can remove the floppy disk from the computer. You should do so by pressing the small button just below the disk drive slot. Then you may reboot the system by pressing Ctrl, Alt and Del all at the same time, or alternately by simply turning the computer off and then back on. The computer should now respond with the proper prompt

(Day Date Time) HANDAR 545C PROGRAMMING/DATA COLLECTION SET

D:\>

If the day, date and time are correct it is OK to proceed. The day, date and time must be set to within three seconds of the correct GMT. If they are in error they may be corrected as follows:

Type the command "date" and the computer will prompt with

Current date is (Day, Date)
Enter new GMT date(mm-dd-yy)

Enter the new number of the (GMT) month-day-year each in a two digit format duplicating the format on the screen and press

<Enter>

The day and date should now be correct but you must still correct the time. Type "time" from the keyboard and the computer will respond with

Current time is: hh:mm:ss.ss
Enter new time:

Enter the new time (GMT) according to the format above using 00 for the last two digits and press

<Enter>

The system should respond with the proper time and Handar prompt. The computer is now ready to perform program upload or download, data retrieval or to be stored away until later needed. However, it is recommended that the computer be stored with the charger installed, otherwise the above reinitialization procedure will need to be repeated if the batteries become discharged.

3.3 Loading a program from the Toshiba 1000SE computer into the Handar 540A data collection platform

If for any reason the power to the Handar 540A data collection platform is interrupted, it will be necessary to reload the operating program into the data collection unit. This could happen if the battery within the unit becomes completely discharged. Also, static electricity could cause the program to be lost. In either case it will be necessary to reload the program into the data unit. In order to load a program from the computer into the data system the Handar software must be installed on the RAM disk (disk D:). This will be the case if upon powerup the computer displays the Handar prompt as discussed above. If this is not the case, it will be necessary to reinitialize the system as described in section 3.2. After the computer is properly initialized the data system operating program may be installed. This program is stored in two places on the computer system. First, it is stored in the RAM disk (disk D:) under the file name TOGARAD.PRG. If the batteries in the computer have never become discharged this file should remain on disk D:. If it was necessary to reinitialize the computer the program will have been lost from the RAM disk. In that case, after recharging and reinitialization, the program can be copied from a diskette into the RAM disk as follows: It is recommended that the file copy procedure described below be performed indoors.

After the computer is turned on and the (Day Date Time) Handar 545C PROGRAMMING/DATA COLLECTION SET message is displayed, insert the disk marked PROGRAM into the disk drive near the back on the right hand side of the computer. Then type:

d:

press <Enter>

The computer will now be addressing the d: disk and will display

D:\>

then type

copy a:\togarad.prg

and press <Enter>

The computer will respond with

1 File(s) copied

D:\>

The program will be copied from the disk drive into the RAM disk. It is also important to be sure the time and date in the computer's internal clock are correct. The day, date and time must be correct to within three seconds of the correct GMT. If the day, date, time block is in error follow the procedure outlined above for resetting them. Remove the diskette from the drive by pressing the button below the disk drive and store the disk in its box. The computer may then be carried into the field to load the program into the data system.

The computer must be connected to the data system using the cable marked "RS232". The cable is connected to the computer by lowering the small latched door located on the left hand side of the back of the unit as viewed from the rear. Plug the cable into the smaller of the two connectors. The computer must be OFF when the RS-232 cable is connected to the HANDAR data unit. The cable plugs into the data system's port which is marked "PROGRAM I/O". It will first be necessary to disconnect the cable already connected to this port. Temporarily hang the disconnected cable on the tripod system so it does not become soiled or wet on the ground. After connecting the "RS232" cable turn the computer on by depressing the switch about midway back on the left side of the unit for a couple of seconds and then release it. The unit should respond with the prompt:

Day Date Time HANDAR 545C PROGRAMMING/DATA COLLECTION SET

D:\>

Before actually entering the HANDAR software program, it is worthwhile to note that the responses to the prompts must be made exactly as shown. In addition, many of the keyboard entries will take on new functions that are indicated by the decals which have been affixed to the keys. This is particularly noticeable if you type an entry incorrectly and try to correct it by using the backspace or delete keys. Using these keys will usually generate an error message. The proper way to reenter data is to use the "CLEAR" function which is activated by pressing the "X" key. However, if you inadvertently press the delete or backspace in an attempt to make a correction, you can usually return to the same instruction by pressing the ENTER key after the error message. If you find yourself at a point in the program other than where you should be, you can use the SCROLL UP function (the "U" key) or the SCROLL DOWN function (the "V" key) to move through the prompts to the proper position.

Type

545c

and press

<Enter>

The unit will display a menu page, with a Welcome Banner followed by:

**P HANDAR 540A DCP - REV 4.Q
SYSTEM PROG REQUIRED - PRESS ID**

Press the key marked "ID" which is the letter I on the keyboard
The computer will respond

P ID 00000000

For Chuuk type 2110327C
and press

<Enter>

The computer will respond with

P ID 2110327C

Then press the F1 function key on the top row of the keyboard

<F1>

The unit responds with

LOAD PS PROG → DCP: PRESS ENTER

Press <Enter> and you will be prompted for a file name
Type the file name as

D:\TOGARAD.PRG

and press

<Enter>

The computer will display

P LOADING PROGRAM ***

and a flashing message will be displayed in the lower portion of the menu screen indicating the program filename which is being loaded. After the program load is complete the unit will display

P DONE_

At this point the program is loaded.

Now all that is necessary is to place the data system in the "RUN" mode. Simply press "RUN" which is the <Y> key and the unit will display

R RUN/MONITOR MODE

At this point the unit is fully programmed and the session may be exited by entering the F10 key on the upper row of the keyboard

<F10>

The unit will return to the HANDAR prompt and then display

D:\>

At this point the computer may be turned off by depressing the on/off switch on the left side of the unit for a few seconds. Then, disconnect the "RS232" cable and reconnect the WWV radio cable which was originally connected to the PROGRAM/IO port. Store the computer and cable (the computer should be connected to the charger).

3.4 Downloading data from the HANDAR 540A

The primary means of data transfer from the data collection site to Colorado State University (where it will be processed) is the GOES satellite Data Collection Platform. In the event that technical problems arise using this service it will be necessary to download the data onto floppy disks using the Toshiba T-1000 SE laptop computer. Even if the power to the Handar 540 data station is interrupted the data stored in the 540's RAM will be preserved by means of lithium battery backup. The Handar 540 has been equipped with 256 Kbyte of RAM for this purpose and will easily store up to 3 weeks worth of data based on the current sampling rate. Thus, even if satellite communications are interrupted for that period of time, a continuous data record is still possible.

In order to perform this function the computer must contain in its memory the Handar communications software. This software is normally found on the RAM disk, disk D:. The software will be found on the D: disk if the computer has a normal power up or if reinitialization of the unit has been performed as described in section 3.2. In either case the computer will be ready to perform data download only if the following prompt appears on the screen:

HANDAR 545C PROGRAMMING/DATA COLLECTION SET

D:\>

If this is the case the computer may be carried to the station with the RS232 cable. The cable attaches to the computer via a port located behind the small plastic door on the left hand side of the back of the computer as viewed from the rear. The RS232 cable connects to the HANDAR 540 data collection station via the "PROGRAM I/O" port. This port also accepts the WWV radio receiver information. Disconnect the cable currently connected to the "PROGRAM I/O" port and hang the cable so it does not become soiled or wet. Connect the RS-232 cable to the port and turn on the computer.

At the D:\> prompt type:

DPP

then press <Enter>

The software will present a menu of functions and prompt for your choice with:

ENTER SELECTION

Type

<F1>

The computer will log onto the 540 data collection platform and a RUN-mode log-on message will appear as:

R HANDAR 540A-1 DCP - REV - 4.Q

Insert a floppy disk into the drive on the back right hand side of the computer. (Note all floppy disks supplied with the computer have already been formatted.)

Type:

- (the "minus" key)

Then press <Enter>

The following messages will appear on the screen

R SAVING DATA ***
Enter data file name: 2110327C.BDT

The file name presented is a default file name which must be changed. This is necessary because merely using the filename above will cause the data to be written to the D: disk under the default file name and there is not enough space on the D: disk to contain this information.

Instead type:

A:2110327C.BDT

<Enter>

Several messages will begin to appear on the screen giving information on the progress of the data transfer. When the process is finished the following message will appear:

Transfer Complete - press any key to return to main menu

Pressing any key will cause the main menu to be presented. In order to exit the program enter <F10> at the prompt. Remove the floppy and write the date of the download process on the label. Turn the computer off. Disconnect the RS-232 cable and reconnect the WWV radio cable to the PROGRAM/IO port. Store the computer with the AC adaptor plugged in. The floppy should be mailed as soon as possible using one of the preaddressed padded envelopes provided with the station equipment.

3.5 Radiometer Calibration

In order to assure the quality of the dataset it will be necessary to perform calibration checks on approximately a bimonthly schedule. This procedure is simple and will take only a few man-minutes to perform. Included with the station is a stainless steel thermos which has been coated with a special emissive paint on the inner surface. A thermistor has been attached to the inner surface to measure the temperature of the interior surface of the thermos. The thermos cap will serve to block the incoming solar radiation in order to perform

an optical zero check on the pyranometer.

You will be contacted by personnel from the Dept. of Atmospheric Science as to the requested timing of each calibration. In order to perform the calibration place the thermos opening over the silver dome of the pyrgeometer. Center the rim of the thermos using the three small screws that secure the white radiation shield as a guide for centering. Disconnect the cable connected to the AIR TEMPERATURE/RELHUMIDITY port on the Handar 540 data collection system being careful not to let the connector become soiled or wet. Connect the cable from the thermos to this port. Place the thermos cup over the pyranometer's clear dome centering it as much as possible; see Fig 2. The thermos and cup should be left in place for a period of approximately 1 hour. At the end of that time remove both the thermos and the cup, disconnect the thermos cable from the data system and reconnect the air temperature sensor cable to the port. Store the thermos calibration unit with the station equipment for later use. The calibration data will be sent as part of the normal data stream. No other action is necessary on your part.