An Account of the Radiation Observations during EBEX00, 2000

July 30 - August 25, JD 214 - 244

During EBEX00, radiometers were deployed to measure both incoming and outgoing long-wave and short-wave radiation. The sky over the kilometer-scale research area could be considered to have a common input for the upward-looking radiometers whereas the several square meters of crop and soil viewed by the downward-looking radiometers at the nine separate surface sites would each have subtle differences.

The equipment deployed during the EBEX00 study involved in the radiation studies included.

Net radiometers: REBS Q7 net radiometers to measure integral radiation. These devices utilize different calibration factors for net positive and negative fluxes in an attempt to compensate for the different efficiencies for sensing short-wave and long-wave radiation.

Pyranometers: Eppley PSP and Kipp and Zonen CM21, were both utilized. Both radiometers are designed to measure the short-wave radiation within the 0.5 to 2.3 micrometers range CHECK THIS . Both radiometers purport to have a cosine response.

Pyrgeometers: Custom modified Eppley pyrgeometers were used. These radiometers had been fitted with voltage standard references and three thermisters attached to the inner surface of the domes to yield accurate dome corrections. The radiometers are designed to measure the long-wave radiation within the 3.2 to 40 micrometers range CHECK THIS and were purported to have a uniformly cosine response**.**

Surface temperature radiometers: Everest surface temperature sensor were used. The devices utilized a 0.96 emissivity factor and a 15 degree viewing angle.

Ventilators: All of the pyrgeometers and most of the pyranometers were mounted in ventilation housings. An attached 2.7 Watt DC fan drew ambient air into the housing and discharged ~ 10 lpm CHECK THIS through an annular slot surrounding the radiometer dome. Smoke tests have shown that this discharge wraps over the dome and provides a measure of protection from dust and insect deposition.

Radiometer platforms: The radiometers were mounted on platforms designed to allow them to be leveled to within one degree. These platforms were in turn mounted at the center of the 3 meter long horizontal top members of the radiation stands which stood 2.5 meters above the surface.

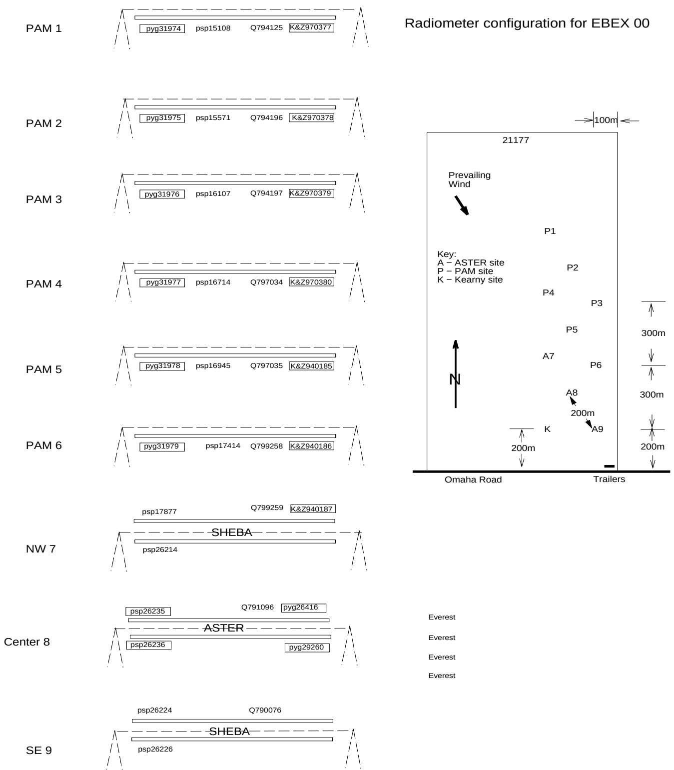
Data acquisition: Each array of radiometers was connected by ~ 2m cable to a Campbell 2200? data-logger. The data-logger analog to digital convertor sequentially multiplexed between the different sensors and used the appropriate coefficients loaded in the memory to generate a buffered digital file. The Campbell sent a serial message to the local site ADAM or EVE data system which forewarded the data by Radio Frequency Modem to the EBEX base computer.

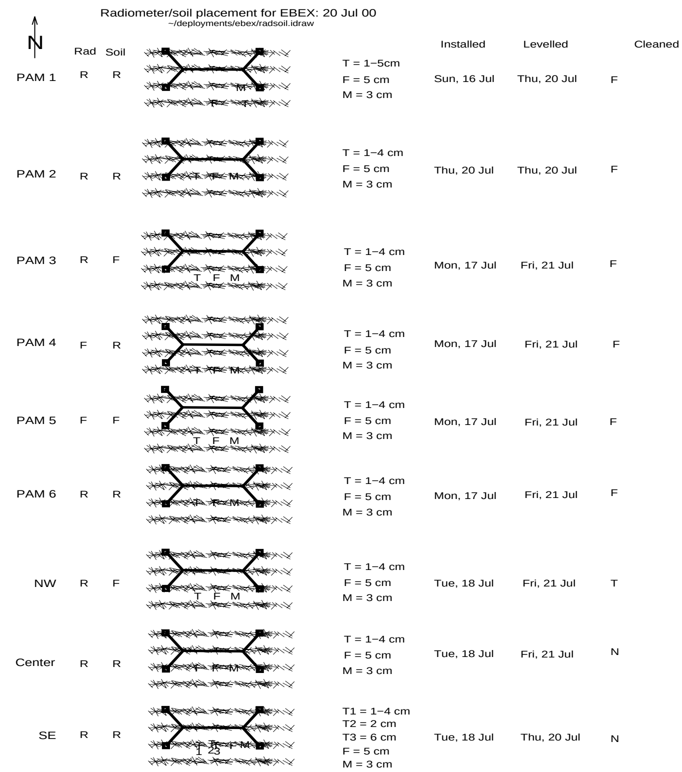
Radiometer configuration

At each of the six PAM sites, the radiometer array consisted of a REBS Q7 net radiometer, a downward-looking Eppley pyrgeometer and downward looking Eppley PSP and Kipp and Zonen CM21 pyranometers. The radiometers at these PAM sites were mounted on simple leveling platforms suspended 2.5 m above the soil surface in the center of the 3 m boom of the standard PAM darkhorses.

The three main sites were each equiped with a REBS Q7 net radiometer, and an upward-looking and a downward-looking Eppley pyranometer. The Center 8 site also had upward-looking and a downward-looking Eppley pyrgeometers, and the NW 7 site an additional Kipp and Zonen CM21 pyranometer. The radiometers at these main sites were mounted on the ASTER four component leveling platforms, 2.5 m above the soil surface in the center of the 3 m boom of the standard PAM darkhorses.

Figure 1(raddeploy.idr), shows the location of the nine sites in the cotton field and the configuration of the radiometers at each site. The rectangle about the radiometers serial number indicates that the radiometer was ventilated. The darkhorses all stood 2.5 meters above the soil surface but the crop height varied at the different sites. In addition, as there was a strong variation between row and furrow this had to be addressed in defining surface

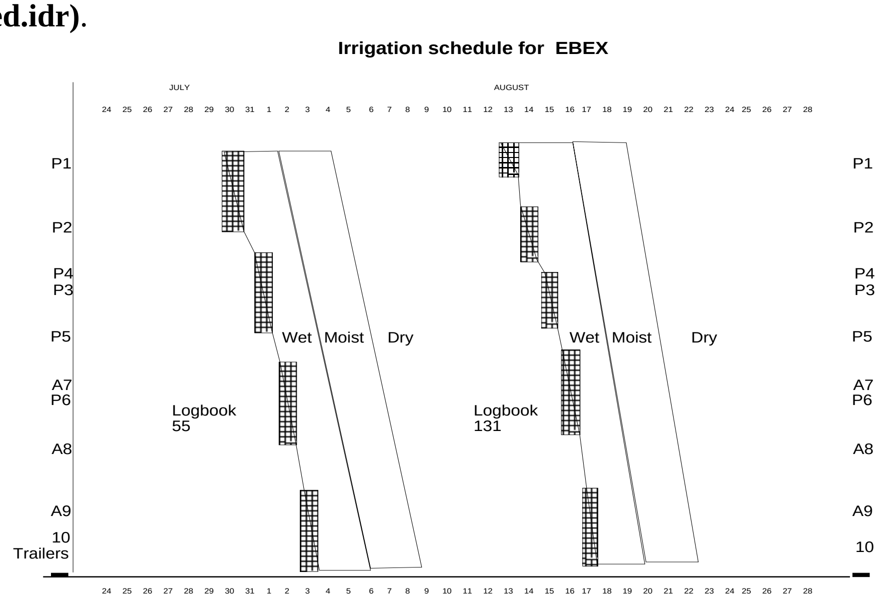




radiative properties. Seven of the radiometer arrays were positioned over the rows and two over the furrows. **Figure 2 radrep2.idr)** illustrate the placement of the radiation stands with respect to the row-furrow configuration.

Irrigation

The 1600 m by 800 m cotton field supporting the EBEX00 program was exceptionally level, having been subjected to the agricultural process of “ground planing”. This process, common in the Central Valley, is undertaken using heavy machinery to precision-grade the fields, to ensure a slight and uniform slope which allows for the practice of flood irrigation. On an approximately periodic schedule of ~ two weeks, water in the feeder canal running the length of the western edge of the field was siphoned into a limited set of the east-west furrows, along which it flowed to debouch into the drainage canal running the length of the eastern edge of the field. Each day approximately 100 furrows were flooded allowing the irrigation front to move ~ 100 m along the length of the field. The furrows took ~ one day to fill, remained more or less mud for another three days, and then gradually dried over the remainder of the two weeks. The irrigation schedule during the EBEX00 deployment is illustrated in **Figure 3(irrigsched.idr)**.



Radiometer cleaning

A majority of the radiometers, deployed during EBEX00, were subjected to continuous ventilation to hasten evaporation of dew in the early morning and to reduce the deposition of dust on the domes. Fortunately, the EBEX00 site did not appear to be as susceptible to the formation of dew, as we had feared.CHECK THIS Although the presence of irrigation water did lead to fairly high levels of relative humidity, in the late nighttime hours, the radiative losses did not bring the upper surfaces of the equipment to below dew-point. However, the presence of traffic along the dirt road running along the western side of the field produced sufficient dust that it became a problem for the radiometers. In general the dust from the traffic along the dirt road together with the effect of agricultural aerial spraying was more apparent on the up-looking radiometers than on the down-looking radiometers.

The dome cleaning procedure during EBEX was not as systematic as could have been wished. A summary of dome cleaning undertaken during EBEX00 was derived from Logbook observations. These are summarized in Table 1. Note that cleaning could have occured at other times and not specifically noted

Table 1: Radiometer cleaning

Date/Time	Lgbook	PAM1	PAM2	PAM3	PAM4	PAM5	PAM6	NW7	Cntr8	SE9
25Jul17:30GMT	16									X
30Jul16:00GMT	38									X
01Aug18:40GMT	39									X
06Aug0000GMT	139							X		
06Aug2000GMT	139									X
06Aug2300GMT	139								X	
07Aug2100GMT	139					X				
07Aug2200GMT	139			X						
08Aug2300GMT	139	X								
09Aug0000GMT	139		X							
09Aug0000GMT	139				X					
14Aug17:15PDT	100			X						
16Aug11:32PDT	116							x		
21Aug, PDT's	123	10:40	11:10	08:45	11:35	12:05	09:15	13:10	13:30	13:50

Radiometer problems due to wiring etc

Throughout any deployment problems occured with field equipment. Typically, these problem are most significant at the beginning of the research period, reflecting set-up difficulties, and deminish throughout the remainder of the deployment. These difficuties include both sensor and data stream issues. Table 2 indicates specific instances of difficulties which occured at the different stations during EBEX00.

Table 2:

Date/Time	Lgbk	PAM1	PAM2	PAM3	PAM4	PAM5	PAM6	NW7	Cntr8	SE9
28Jul18:10PDT	25	X								
31Jul13:33PDT	34			X						
31Jul13:40PDT	35				X					
05Aug18:19PDT	56							X		
06Aug19:00PDT	61								X	
07Aug15:20PDT	64								X	
07Aug16:48PDT	66								X	
08Aug11:21PDT	67							X		
11Aug09:30PDT	76						X			
11Aug10:25PDT	77						X			
25Aug	136	X	X	X	X	X	X			

Calibration

Prior to the EBEX00 deployment all the radiometers were recalibrated. For the pyranometers, the ....LIFT THE ACCOUNT FROM THE CASES99 REPORT. For the pyrgeometers, the .... LIFT THE ACCOUNT FROM THE CASES99 REPORT. A new procedure was instigated for the EBEX00 deployment to ensure an error-free transposition of coefficients from the calibration database through to the loading of the coefficients in the Campbell data-loggers. Inspection of the coefficients indicated that the correct coefficients were used throughout the deployment. The procedure of checking coefficients is described in the file (delany/deployments/ebex00/coefftab.fm) and involved checking the coefficients throughout the sequence:

- cal lab data
- coefficients listed in LabView coefficient Campbell loading files

The procedure was followed and no errors were detected in coefficient assignments throughout the transfer process.

Data inspection

In order to provide a first alert of suspect radiation data, an internal comparison of the values of the different classes of radiation data can be made. This process involves inspecting the traces of all the radiometers for reasonable and continuous data.

Incoming short-wave radiation: There were four up-looking short-wave radiometers:

- Station 7 unventilated Eppley PSP -> Rsw.in 7
- Station 7 ventilated Kipp & Zonen -> Rsw.in.kz 7
- Station 8 ventilated Eppley PSP -> Rsw.in 8
- Station 9 unventilated Eppley PSP -> Rsw.in 9

As the four radiometers viewed the identical sky they should have yielded a single value of Rsw.in. Inspection of the traces for the four were made to decide how best to generate this single trace of Rsw.in

The effect of cleaning had noticeable effects on

- Rsw.in.kz 7 on 16 Aug of ~ 50 Wm-2
- Rsw.in 8 on 21 Aug of ~ 80 Wm-2

other cleaning events did not make much difference in radiometer response.
The other two up-looking short-wave radiometer yielded more consistent traces.
with Rsw.in 7 ~ 1.04 X Rsw.in 9.
I propose to use for the single value of incoming short-wave radiation:

Rsw.in.mean <- (Rsw.in 7 + Rsw.in 9)/2 for the period 6 Aug - 23 Aug when both these radiometers had good output, and

Rsw.in.mean <- (Rsw.in 9 X (Rsw.in.mean/Rsw.in 9) for the period before 6 Aug when only Rsw.in 9 had good output

Outgoing short-wave radiation: There were fifteen down-looking short-wave radiometers:

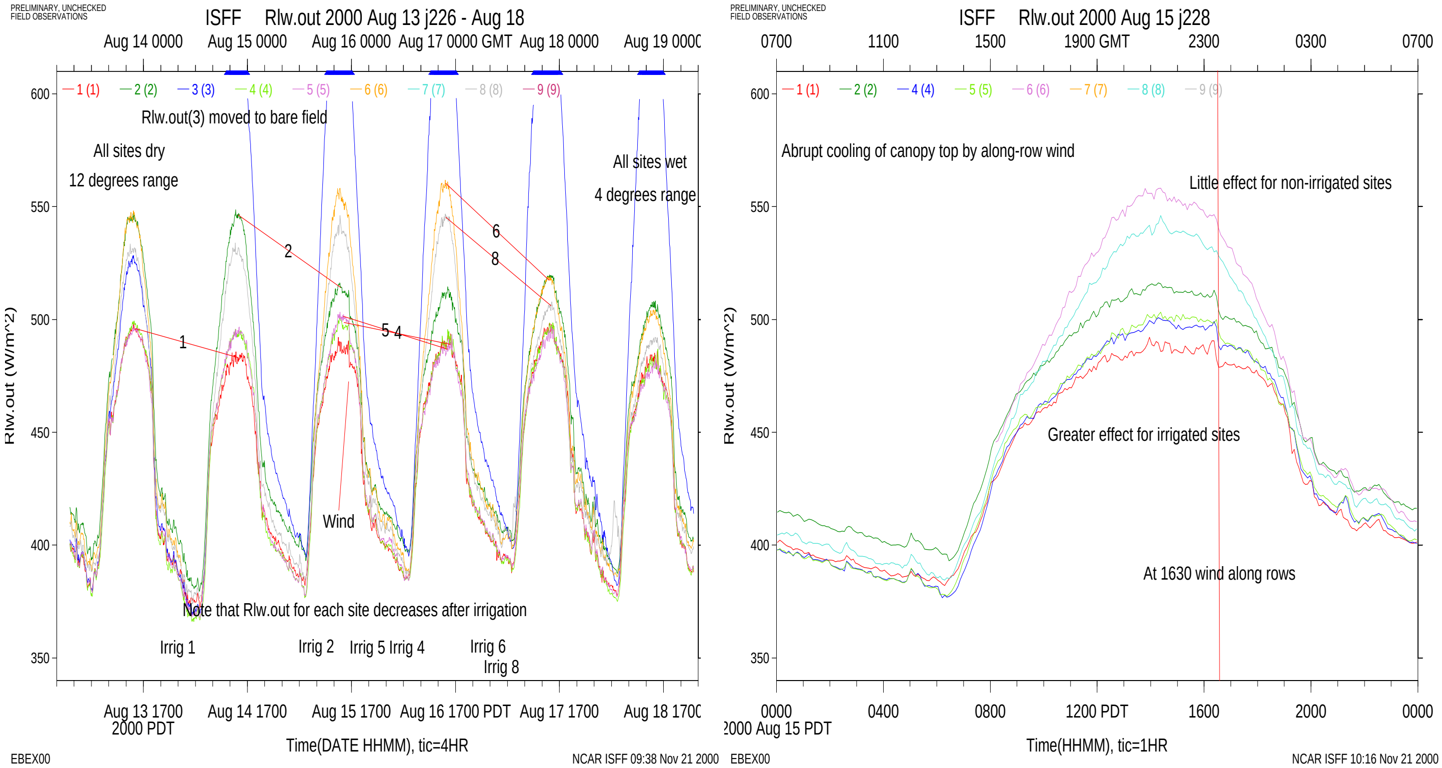
- Station 1-6 unventilated Eppley PSP -> Rsw.out 1-6
- Station 1-6 ventilated Kipp & Zonen -> Rsw.out.kz 1-6
- Station 7 unventilated Eppley PSP -> Rsw.out 7
- Station 8 ventilated Eppley PSP -> Rsw.out 8
- Station 9 unventilated Eppley PSP -> Rsw.out 9

Each of these radiometers viewed different surfaces although the paired Eppley and Kipp and Zonen radiometers at the six station, stn1 - stn6 could be assumed to have had a very nearly identical view.
The ratio of Rsw.out/Rsw.out.kz for stations 1-6 were:
(1) 1.076, (2) 1.08, (3) 0.975, (4) 1.07, (5) 1.065, (6) 1.04, or (1-6) 1.05
The value taken for each of the up-welling short-wave radiation should be the mean of the Eppley and the Kipp 1and Zonen Radiometers.
The value for the other three stations should be the value of the single radiometer at that site.
Of the 15 Rsw.outaces examined to define which was the most continuous, 3, 4, and 5 had fairly good with Rsw.out 4 as the most credible radiometer.
Incoming long-wave radiation: There was only one up-looking long-wave radiometer: R.lw.in ,8. This sensor was ventilated and the trace of this pyrgeometer was inspected and appears to be credible.CHECK THIS
Outgoing long-wave radiation: There were seven down-looking long-wave ventilated radiometers, one at every station except NW7 and SE9. Although it was expected that there would be variations in the out-going long-wave radiation, corresponding to the different effective surface emissivities of the crop/soil LOOK FOR DIFFERENT Tdome AND Tcase VALUES FOR SEVERAL PYRGS
Net radiation: Each of the nine sites was instrumented with an equivalent net radiometer. CHECK THE COMPARISON.

Influence of irrigation on the outgoing radiation

At first inspection the time traces of the seven down-looking long-wave radiometers: Rlw.out(1:6,8) appear to be suspiciously variable, at times exhibiting a noon-time maximum variability of up to 75 Wm-2, the equivalent of 12 degrees C. This seems unreasonable if it is assumed that each of the long-wave radiometers views equivalent patches of cotton foliage.
However, the sites were not equivalent. Each of the cotton sites exhibited a difference in the extent of canopy closure, and the less complete the canopy closure, the more bare soil could be viewed by the radiometer. An additional factor to be considered is the state of the soil at each site, with the mprogress of the irrigation sequence a major factor.
Figure 3, "irrigsched.idr" shows the progression of irrigation during EBEX00. Two waves of irigation propagated across the study region, the first 30 Jul - 3 Aug, and the second 11 Aug - 17 Aug. Figure 4, "irrig.ps" illustrates the influence of the propagation upon the outgoing long-wave emission. Note that on 13 Aug, when all sites were dry, there was a mid-day temperature range of 12 degrees, whereas by 18 Aug, when all the sites were wet, the mid-day temperature range had decreased to only 4 degrees. As the soil at each site became wetted, the effective mid-day temperature decreased. The decrease was most pronounced at sites 2, 6 and 8, those sites which apparently were the most soil was exposed. This exposure is apparent in the higher apparent temperatures

on 13 Aug. The decrease was less pronounced at sites 1, 4 and 5. Radiometer 3 up-welling long-wave radiation was well within the normal range of surface long-wave emission until 14 August, when it was moved to the bare-soil location. Thereafter it reported considerably higher values, with a noon-time difference of ~100 Wm-2 greater than the other emissions. This difference, corresponding to ~ 18 degrees C is quite reasonable.



Influence of change of wind direction on the outgoing radiation

The apparent anomoly at 1630, 15 Aug, discernable as a rapid drop of several degrees wind direction shift blowing along the rows bringing up cooler moist air to cool the canopy more effect for irrigated sites

Figure 5, “windcool.ps”