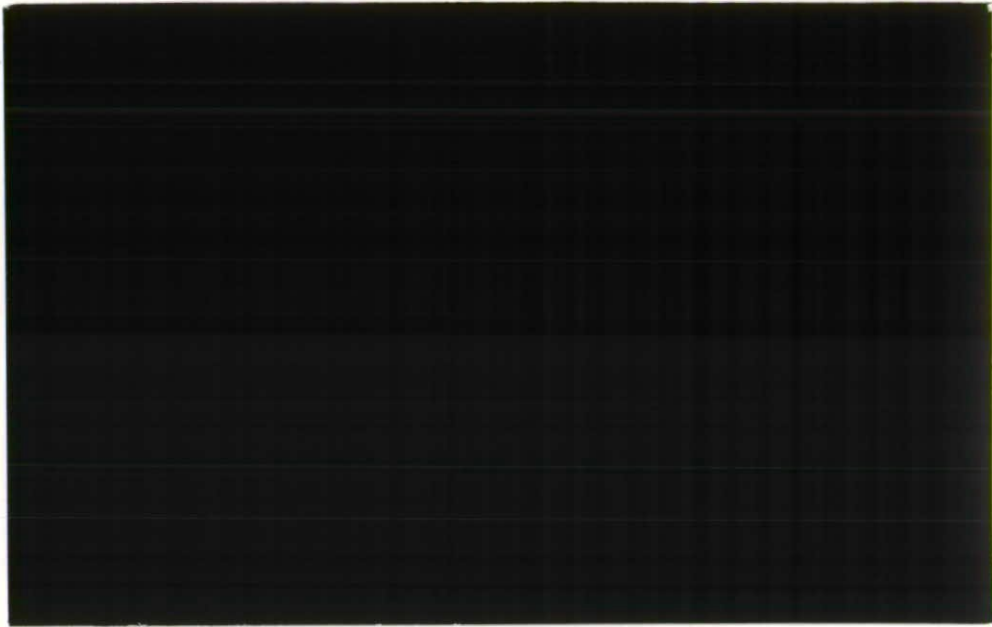




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**BASIC METEOROLOGICAL DATA
INTERCOMPARISONS BETWEEN
IH, READING AND CNRM GROUPS
IN EFEDA, JUNE 1991**

Preliminary report to the EFEDA Secretariat

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Preface

This report summarises the results of a collaborative study between the Institute of Hydrology (IH) and the University of Reading (RU) in the United Kingdom. It describes the main conclusions from a series of meetings which were held to compare the field measurements obtained during the EFEDA campaign in the summer of 1991. We are grateful to the CNRM Toulouse group for allowing their data for the vetch site to be included in the comparisons. All results are preliminary and are not to be quoted.

1. Introduction

During the EFEDA field campaign the teams working at the dry farmland sites around Tomelloso included those from the Institute of Hydrology, UK, the University of Reading, UK, and CNRM, Toulouse, France. At the vine site the IH and Reading groups worked adjacent to each other taking to some extent complementary data, while the CNRM group worked at several other vine sites in the area. Also, all three groups worked close to each other on an arable site (the vetch site). It has therefore been possible to make direct comparisons between the results obtained by the three groups.

Some preliminary intercomparisons of net radiation data are reported by Malhi and Hurk (1992), and Golden Day intercomparisons of energy flux components for all the Tomelloso groups are reported by Moene (1992). In addition detailed information is also available in the scientific papers already produced (e.g. Oliver and Sene, 1992). The results already described in these reports and papers will not be repeated but in many cases they serve to re-confirm the conclusions presented in this report.

2. Sites description

The IH and Reading experimental systems were set up in adjacent vineyard plots at the least frost-affected part of the area (Map (1)). The Airen grape vines were planted with a 2.5m spacing and grew from initial shoot appearance to a canopy cover of 20-25% of the soil surface area during the main June data collection period. The soil was of a calcareous cambisol type and near the surface was generally sandy with many stones. Local practice is to keep the soil free from weeds by ploughing at regular intervals and immediately after rainfall.

The vetch crop at the second site, Map (2), had been badly damaged by late frosts and had only reached a height of 20-30cm by the beginning of June. The crop was already in an advanced state of senescence. The soil at this site was much more compact with fewer stones.

Further information on the sites is provided in the main EFEDA reports produced by the EFEDA Secretariat.

3. Equipment

The main equipment used by the three groups has previously been described in the submissions to the programme coordinators and in the reports and papers already produced. It has been possible to intercompare most of the instrument types at one or both sites, although vine data comparisons have not been made with the CNRM results as their nearest

site was over 1 km from the shared IH and Reading site.

An outline of the main sensor types and measurements heights is given in Table (1) and a summary of meteorological conditions is given in Table (2). The data averaging period for IH and Reading was ten minutes, with the exception of the IH sensible and latent heat flux and friction velocity measurements which were hourly averages. A ten minute averaging period was also used by CNRM but the results presented here are based on half-hourly averages so some slight time shifts may be evident in some of the diurnal plots of data.

4. Intercomparison of results

4.1 BASIC METEOROLOGICAL MEASUREMENTS

(i) *Temperature*

Figures (1) and (2) show some examples of temperatures measured by the IH and Reading groups for the vine site, and for all three groups for the vetch site for one of the Golden Days. There are differences of up to about 2°C which reflect the differences in instruments and heights but the general variations through the day are very similar. Figure (3) shows a longer run comparison of air temperatures measured by IH, Reading and CNRM at the vetch site and the very good agreement is obvious.

Figure (4) shows comparisons at the vetch site between the IH and CNRM temperatures (maximum, minimum and mean) for the whole of June and again good agreement is seen.

(ii) *Humidity*

Humidity measurements were made using aspirated psychrometers (IH), dew point cells (Reading) and capacitance hygrometers (CNRM). For the vetch site, comparisons between vapour pressure were generally good as can be seen in Figure (5) which shows the ten minute data of IH and Reading and 30 minute data for CNRM for three days in early June.

Figure (6) compares the IH and Reading data for the vine site for 28 June when a gravity current passed across the area together with the IH and CNRM vetch site values. The Reading data appears to read low, especially after the passage of the front, both when compared with the IH data for the vine site, and the IH and CNRM data for the vetch site.

(iii) *Wind speed and direction*

The anemometers of the three groups varied in their model type and height but gave consistent results as shown in Figures (7) and (8) for an example Golden Day at the two sites. Similarly the whole period comparison of wind speed between IH and CNRM (Figure (9)) shows good agreement. For the wind direction data at the vine site, there appears to be an offset of about 15° between the IH and RU groups.

4.2 INCOMING SOLAR RADIATION

Figures (10), (11) and (12) show vine site measurements of incoming solar radiation made

by IH and Reading using Kipp solarimeters for a single Golden Day, for a series of three days, and daily totals for the whole June period. In addition, Figures (11) and (12) also include the CNRM solar radiation data for the vetch site for comparison. The IH values were about 4% higher than Reading and about 3% lower than CNRM. These differences are surprisingly large for such a basic measurement made with what is usually one of the most reliable instruments available.

Before the experiment, the IH Kipps were all intercalibrated at Wallingford to 2% against a sub-standard that had been checked at the UK Meteorological office. Further intercalibrations between the IH and Reading instruments will be made at Reading and may explain some of these discrepancies. Checks using models for solar radiation such as those used at IH for weather station processing and slope irradiance analyses gave results that agreed fairly well with the field data but were not of sufficient accuracy to distinguish between the IH and Reading measurements as they necessarily include various modelling assumptions which result in some uncertainty in the results.

Figure (13) shows a three day run of IH and CNRM solar radiation measured at the vetch site and Figure (14) shows the June daily totals. For the three days shown, the peak daily values agree well which suggests that the 3% difference in daily totals (noted above) may arise from different instrumental responses near dawn and dusk.

Because the surface type is irrelevant to incoming solar radiation measurements, a meaningful comparison should be possible for all groups working in the Tomelloso area. Some preliminary results are described in the first EFEDA annual report for the Golden Days and in general showed fair agreement with the IH, Reading and CNRM results. However, further comparisons should be made when the full corrected dataset becomes available.

4.3 REFLECTED SOLAR RADIATION

The IH measurements of reflected solar radiation at the vine site were made from four frames which supported downward facing Kipp solarimeters at between 2 and 3m above the ground surface. The Kipp solarimeters were set to view both representative vine covered and bare soil areas. The Reading sensors were mounted at about 4m from horizontal booms and also viewed representative areas of vines and soil. Because of the small area coverage of the vines, very little difference was noted between the variously positioned IH instruments. Only by bringing a Kipp solarimeter down very close and directly above a developed vine were significant differences found which even then resulted in an albedo reduction of only about 5% compared to the field area average value.

Figure (15) shows reflected solar radiation data for IH and Reading for an example Golden Day, and includes individual measurements for three of the IH sensors. Figures (16) and (17) show the Reading data and mean IH values for a three day period and the daily totals for the whole of June. As with the solar radiation data, the IH values are higher than the RU values, but the percentage error is larger (about 8%), most probably due to differences in albedo between the IH and RU sites. Even though the IH and RU sites were only about 300m apart, there were noticeable differences both in soil texture (less stony near the RU masts) and colour (bands of light and dark soil, particularly near the RU masts). These differences should be allowed for when comparing these results with the reflected solar measurements made by other groups working in the Tomelloso area.

Figures (18) and (19) show reflected solar radiation values for the vetch site for three days and the daily totals for June as measured by the IH and CNRM equipment. Because the

surface was reasonably uniform at this site, there should be little spatial variation between the IH sensors mounted on 2m high frames and the CNRM boom mounted sensor. However, the CNRM peak values were about 6% higher than the peak IH values and about 8% on daily totals - enough difference to have a small effect on albedo calculations.

4.4 NET RADIATION

Figures (20), (21) and (22) show measurements of net radiation made at the vine site by the IH and Reading groups for a single Golden Day (showing three individual IH sensors), a series of three days (showing the two Reading sensors), and the averaged daily and 0900-1500 totals for the whole period. It can be seen that the IH results are consistently lower by about 7% when compared to the Reading values during the day but agree well at night. Differences between individual instruments of the same make seem to be insignificant, irrespective of the position of the instrument relative to the plants and bare soil. This result confirms the conclusion from other reports (e.g. Mahli and Hurk, 1992) that the REBS net radiometers read lower than the Middleton and other instruments and are probably the ones in error. This conclusion is further borne out in Figure (23), which shows the measured values for one of the Golden Days compared with 4 component estimates of net radiation, calculated from independently measured or calculated short and long wave components. The calculated values agree remarkably well with the Middleton values by day and night.

Since, for the REBS instruments, the differences in the measurements are only found in daylight, and are therefore likely to be mostly due to shortwave calibration errors, the simplest way to correct the IH values is therefore to add a correction proportional to solar radiation. Trial calculations show that addition of 4% solar would achieve generally good agreement with the Middleton instruments, as shown in Figure (21).

For the vetch site the comparisons with the Reading results are less clearcut and, as can be seen from Figure (24), there is evidence of an offset between the results which leads to disagreement even at night. Comparisons of IH and CNRM values of net radiation again show a consistent and significant underestimation by the IH instruments which reaches as much as 10% during the day (Figure (25)). Calculations of net radiation from the four individual components for the IH and CNRM data are also shown which confirm the daytime offset of the IH net radiometer results. Figures (26) and (27) show the 0900-1500 and 24 hour totals of net radiation for the three sets of measurements for the whole of June, and a consistent difference between the IH and CNRM values is again clear throughout the period. However, the Reading values show considerable variation in relation to the other two data sets and therefore some doubt must attach to these data.

4.5 INCOMING LONG WAVE RADIATION

Measurements of incoming long wave radiation were made by the IH and CNRM groups using Eppley and Schenk pyranometers respectively. Figures (28) and (29) show examples of a run of diurnal cycles for the latter part of June and the daily totals for the whole period. There is fair agreement except near-noon for some of the hottest clear days when the IH and CNRM values can differ by up to about 3-4%. This is likely to be due to inadequate temperature compensation within the IH instrument for very high temperature and radiation loadings. Previous studies in Niger have indicated that the error from this effect can amount to about 3% of the incoming solar radiation, but the comparison of daily totals over the whole period suggests that a much smaller correction would be required to achieve good agreement between the IH and CNRM results.

Further checks on long wave balance by means of atmospheric models have been attempted but the errors involved are larger than the discrepancies described above so they have not been further developed. Further comparisons with other groups working in the Tomelloso area would be useful since spatial variations in long wave radiation over the area are likely to have been small.

4.6 SOIL HEAT FLUX

Soil heat fluxes are amongst the most difficult of the energy components to measure due to errors associated with discrepancies between the thermal properties of the plates and soil, spatial variability, depth corrections etc. At the vine site the presence of growing vines was an additional problem for correct sampling.

At the vine site the IH group used an array of nine independently monitored Thornthwaite plates buried close to the surface - three in open bare soil, plus three close to and three further from two plant stems. An averaged soil heat flux was obtained by weighting the average open soil value by 75% and the average vine values by 25% (appropriate to the eventual vine surface cover percentage). The Reading group used six Middleton plates connected in series so comparison of the values from individual sensors was not possible. All plates were installed at (nominally) 0.5cm depth.

Figure (30) shows a comparison of the IH and Reading values for a single Golden Day. The IH values are presented as averages for the 3 bare soil plates and for the two sets of plates positioned underneath the vines. The Reading values are comparable to the IH values measured 35cm from a plant stem, and are only about 60% of the IH bare soil values. Figures (31) to (34) compare the area averaged IH soil heat fluxes (all 9 plates) for a three day period and the 24 hour totals, daytime totals (0900-1500) and nighttime totals (2000-0500) for the whole period. By day, the Reading results are consistently only about 60% of the area averaged IH values, and about 80% by night. There appears to be no obvious change in these errors with plant growth. Part of these differences may arise from the different types of plate used; the Reading Middleton plates were both thicker and of larger diameter (6-7cm) than the IH Thornthwaite plates (2cm).

As a check on the IH values, the soil heat fluxes and soil temperatures measured for the vine site were examined in more detail. Figure (35) shows the averaged daytime components (0600-1900) of soil heat flux for the 6 plates positioned underneath vines plotted as a ratio of the averaged bare soil values for the whole of the data collection period. The trend with time is consistent with the increase in canopy cover observed over the period. Similar trends (not plotted) were also found for the changes in the amplitudes of 10cm soil temperatures measured around the vines and also in the reductions in measured solar radiation observed using tube solarimeters positioned beneath the vines (Oliver and Sene, 1992). These results confirm that the IH measurements of soil heat fluxes and temperatures were self consistent and gave the expected trends with increasing plant growth. Further conclusions on the accuracy of these measurements can probably only be reached by comparisons with typical values (e.g. daily maxima and totals) from other vine sites in the Tomelloso area, and with typical soil heat fluxes recorded in other experiments in semi-arid areas. Preliminary comparisons suggest that the Reading results, at about 15% of net radiation, are probably too low.

At the vetch site, soil heat flux measurements were much easier to make since the site was more uniform. Figure (36) shows the IH, Reading and CNRM data for a Golden Day and, in contrast to the vine site, very good agreement is seen. A comparison between the groups

is shown for three days in Figure (37); the IH and Reading results agree extremely well but there is a consistent trend for the CNRM values to read higher by day, especially near dawn and dusk. This may be due partly to the corrections used to convert the CNRM values, which were measured at 5cm depth, to surface values. Daily totals for the three groups over the whole period are shown in Figure (38) and show that a major increase occurred in the CNRM values relative to the other groups from about 10 June, suggesting that some modifications to the CNRM results may be desirable.

4.7 FLUX MEASUREMENTS

IH measurements of friction velocity and sensible and latent heat fluxes were made at both sites using Hydra MkII eddy correlation equipment at a height of 3.25m. Corrections were applied to the data for frequency response, long term trends, sensor size and separation, temperature dependence and the mean vertical flow generated by atmospheric buoyancy. Sigma T estimates of sensible heat flux were also calculated for a measurement height of 3.25m by iteration of the Tillman equations.

Estimates of sensible heat flux and friction velocity were also obtained by the Reading group using sigma T and profile methods. The profile derived terms were calculated using least squares fits to wind and temperature profiles measured at six levels up to 9.04m at the vine site and five levels up to 5.87m at the vetch site. Sigma T estimates were calculated for the same levels by iteration of the Tillman equations. Sensible heat flux estimates for the vetch site were also obtained by the CNRM group using a SAMER (Systeme Automatique de Mesure de l'Evapotranspiration Reelle) station. The calculations use a flux gradient relationship and are based on wind speed and temperature measurements at two levels (1m and 2.5m above the displacement height).

Sensible heat flux

Figure (39) shows the IH and Reading measurements of sensible heat flux at the vine site for an example Golden Day. The agreement between the IH eddy correlation values and the Reading sigma T values is very good. The Reading profile values show the same trend, but with large variations during the unstable middle part of the day which are strongly correlated with wind speed (not plotted). Figure (40) shows a comparison of the IH eddy correlation data and the Reading sigma T data for a longer run of 5 days, together with the daytime (0700-1900) IH sigma T estimates. The agreement is again excellent at night, but with considerable variations in peak values during the day. There is a general trend for the sigma T estimates to reach peak values about 20-40 Wm^{-2} higher than the eddy correlation values.

Daily totals, daytime totals (0900-1500) and nighttime totals (2000-0500) for the whole of June are shown in Figures (41), (42) and (43). The IH eddy correlation, IH sigma T and Reading sigma T 24 hour totals agree well, especially for the last 11-12 days of June. The Reading profile estimates also follow the same general trend but the 24 hour totals are about 20% higher than the other estimates. The differences between instruments could be due to many reasons, including instrument design (e.g. frequency response, vibration at high wind speeds, stalling speed for anemometers), wind direction and measurement height (fetch and sampling problems) and the estimation method used (i.e. inherent assumptions and approximations). Much further work needs to be done to quantify the likely errors arising from these factors. However, from the preliminary work done so far, there appears to be a trend for the difference between the sigma T and eddy correlation values to increase significantly for sensible heat fluxes above about 200-300 Wm^{-2} (Figure 44). This could possibly be an instrumental effect (perhaps related to temperature) or a consequence of the various assumptions and corrections in the sigma T and eddy correlation methods under

strongly unstable conditions. Comparisons with vine site data obtained by other groups in the Tomelloso area may also be useful in further assessments of the accuracy of these measurements, although the spatial variations between sites may themselves be comparable with the indicated measurement accuracy.

Comparisons for the vetch site show a similar level of agreement. Figure (45) shows some example results for a single Golden Day for the IH, Reading and CNRM groups. All three estimates follow the same general trend, but the Reading profile estimates again show the most variability. For this day, the peak IH values are some 30-40 Wm^2 lower than the average of the other three estimates but a comparison for other days (Figure (46)) shows that this is not a general trend. Comparisons for the whole period - Figures (47) and (48) - also show little consistent difference between the different methods, although, as at the vine site, the Reading profile estimates are consistently the lowest. Again, as at the vine site, the differences between the sigma T and eddy correlation values increase for sensible heat fluxes greater than about 200-300 Wm^2 (Figure (49)).

Friction velocity

Figures (50) and (51) show comparisons of the direct measurements of friction velocity made by IH with the profile estimates derived by Reading for a run of 5 days. The agreement is generally very good (to within 5%) particularly at the vine site, and large differences (10-20%) only occur on the windiest of the 5 days (16/6).

Latent heat flux and the overall energy budget

Direct measurements of latent heat flux were only made by the IH group, but estimates could be obtained for all three groups from the remaining terms in the energy budget. Figures (52) and (53) compare these energy budget estimates with the eddy correlation measurements on a daily total and daytime total (0900-1500) basis for the whole of June for the vine site. For the IH energy budget estimates, the recommended 4% of solar correction (see earlier) has been used to correct the net radiation results. The overall agreement between the different estimates is reasonable and is typically to within 20-30%. For the 24 hour totals, the biggest differences occur on days when the eddy correlation system gave significant negative fluxes during the night. Comparisons with a second, mobile Hydra system at the same site showed similar daytime totals but nighttime values generally much closer to zero, which suggests that the occasional high negative values at night may have been due to problems with the instrument at 3.25m (possibly related to rapid changes in humidity). Comparisons with other groups working in the Tomelloso area (Moene, 1992) also suggest that nighttime values of latent heat flux were normally close to zero.

For the vetch site, the agreement between latent heat fluxes is slightly better (Figures (54) and (55)), and again improves confidence in both the eddy correlation measurements and in the measurements of the remaining terms in the energy balance. As an aid to assessing the accuracy of the measurements, Figures (56) and (57) show these results plotted in cumulative form as mm equivalent of water. For the vine site, the cumulative difference in evaporation between the IH eddy correlation measurements and the IH and Reading energy budget estimates is less than 10mm. For the vetch site, the difference (including the CNRM energy budget estimates) is again about 10mm. To put these results in perspective, it is helpful to consider the evaporation errors which would result for each percentage point (1%) error in the main components of the energy budget. For the vine site, over the whole of June, the following results are obtained:

Solar radiation	3.3mm
Net radiation	1.3mm
Reflected solar radiation	0.8mm

Soil heat flux	0.2mm
Sensible heat flux	0.9mm

Thus, for example, the 4% of solar adjustment to the IH net radiation values is alone equivalent to a 13mm increase in the IH energy budget estimate for evaporation during the whole of June. By comparison, the 40% discrepancy at the vine site between the Reading and IH soil heat flux measurements is equivalent to an error of about 8mm in evaporation, and so has a much smaller impact on total evaporation than the much smaller percentage error (7%) in the IH net radiation measurements.

5. Initial suggestions for data modifications

In general, the comparisons show no major problems with timing or data availability between the three groups. However, the following recommendations can be made:

Humidity: The Reading values at the vine site appear to be consistently too low and substitution with the IH or CNRM results might be appropriate.

Incident and reflected solar radiation: There are some differences, especially for reflected solar, which are a little in excess of acceptable calibration errors and a definitive solar data set could perhaps be considered especially if further tests show that calibrations were not consistent. However the effects on albedo data which has most relevance for climate studies etc will not be very great.

Net radiation: These and previous results suggest the IH (REBS) sensors read low by about 7% in the day and a correction of 4% solar is suggested to be applied to the IH values. The Reading vetch site data are suspicious and could perhaps be replaced with other results.

Soil heat flux: The Reading results for the vine site seem to be low and may need to be modified or replaced. The discrepancy between the CNRM and the IH and Reading values at the vetch site is higher than expected and some modified mean data set for the soil heat fluxes may need to be considered for this site.

Sensible and latent heat fluxes: Further work and comparisons with other groups are needed to determine the relative accuracies of the different measurement techniques.

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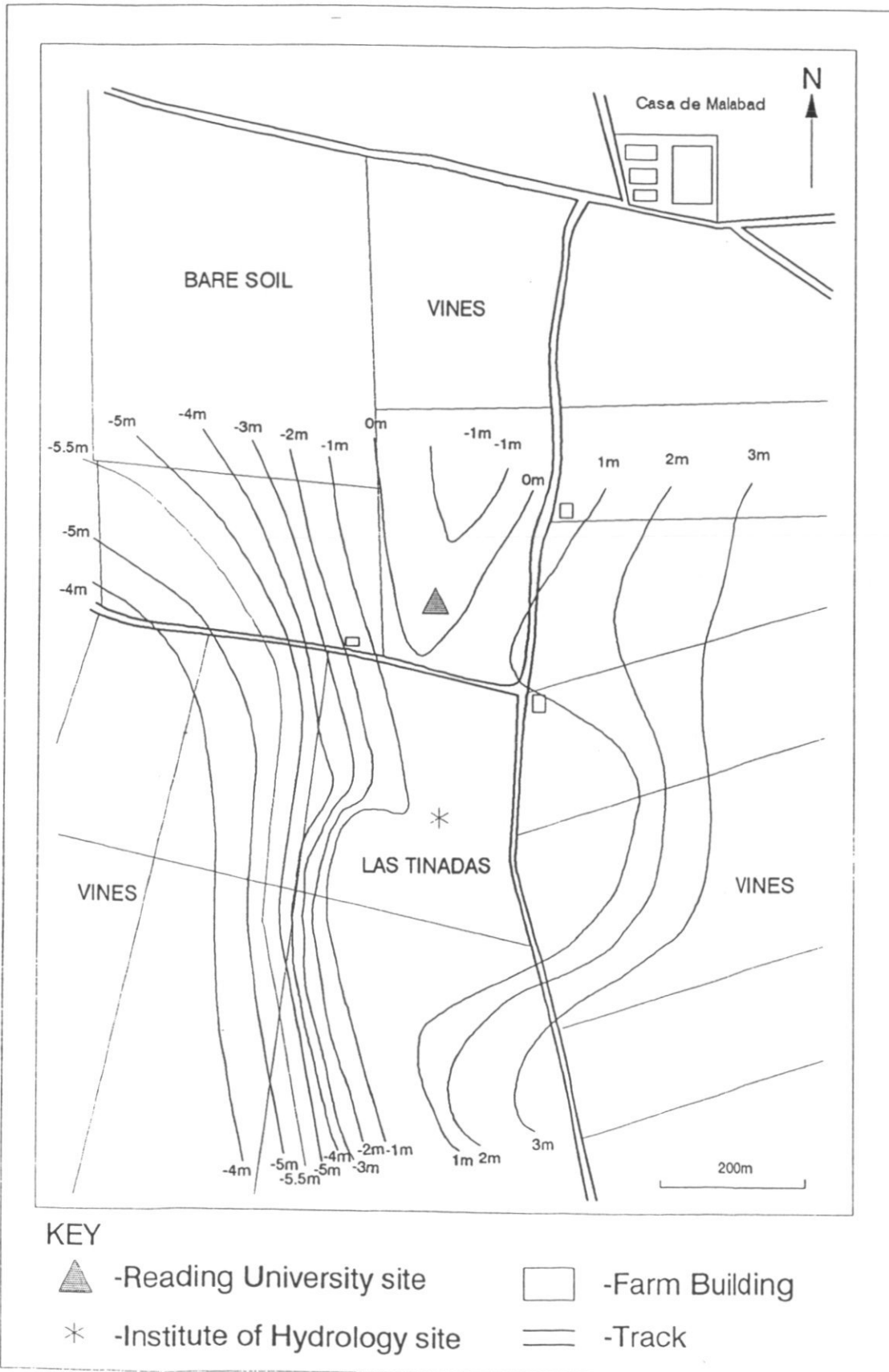
Table 1 - Key to figures, showing measurement methods for each group

Figure	Parameter	Site	Institute of Hydrology	University of Reading	CNRM (Toulouse)
1	Air temperature	Vine	Campbell PRT at 1.5m	PRT at 1.8m	-
2	Air temperature	Vetch	Campbell PRT at 1.5m	PRT at 1.8m	PRT at 2.0m
3	Air temperature	Vetch	Campbell PRT at 1.5m	PRT at 0.94m	-
4	Air temperature	Vetch	Campbell PRT at 1.5m	-	PRT at 2.0m
5	Vapour pressure	Vetch	Asp psychrometer at 1.5m	Dew point cell at 0.94m	Cap. hygrometer at 2.0m
6	Vapour pressure	Vine	Asp psychrometer at 1.5m	Dew point cell at 2.7m	-
7	Wind direction	Vine	Wind vane at 2.0m	Wind vane at 7m	-
8	Wind speed	Vetch	Cup anemometer at 2.0m	Cup anemometer at 1.8m	Cup anemometer at 10m
9	Wind speed	Vetch	Cup anemometer at 3.75m	Cup anemometer at 1.8m	Cup anemometer at 10m
10	Solar radiation	Vine	Kipps and Zonen CMS (x2)	Kipps CS pyranometer (x1)	-
11	Solar radiation	Vine	Kipps and Zonen CMS (x2)	Kipps CS pyranometer (x1)	Schenk 8104 albedometer (x1)
12	Solar radiation	Vetch	Kipps and Zonen CMS (x2)	Kipps CS pyranometer (x1)	Schenk 8104 albedometer (x1)
13	Solar radiation	Vetch	Kipps and Zonen CMS (x2)	Kipps CS pyranometer (x1)	Schenk 8104 albedometer (x1)
14	Solar radiation	Vetch	Kipps and Zonen CMS (x2)	Kipps CS pyranometer (x1)	Schenk 8104 albedometer (x1)
15	Reflected solar	Vine	Kipps CMS x3 (1.7-2.7m)	Kipps CS pyranometer (4m)	-
16	Reflected solar	Vine	Kipps CMS x3 (1.7-2.7m)	Kipps CS pyranometer (4m)	-
17	Reflected solar	Vine	Kipps CMS x3 (1.7-2.7m)	Kipps CS pyranometer (4m)	-
18	Reflected solar	Vetch	Kipps CMS x2 (1.3m)	-	Schenk 8104 albedometer (3.5m)
19	Reflected solar	Vetch	Kipps CMS x2 (1.3m)	-	Schenk 8104 albedometer (3.5m)
20	Net radiation	Vine	REBS Q*5.5 x3 (1.7-2.7m)	Middleton x2 (4.0m)	-
21	Net radiation	Vine	REBS Q*5.5 x3 (1.7-2.7m)	Middleton x2 (4.0m)	-
22	Net radiation	Vine	REBS Q*5.5 x3 (1.7-2.7m)	Middleton x2 (4.0m)	-
23	Net radiation	Vine	REBS Q*5.5 x3 (1.7-2.7m)	Middleton x2 (4.0m)	-
24	Net radiation	Vetch	REBS Q*5.5 x2 (1.4m)	Swissteco x1 (1.75m)	4 component
25	Net radiation	Vetch	REBS Q*5.5 x2 (1.4m)	Swissteco x1 (1.75m)	4 component
26	Net radiation	Vetch	REBS Q*5.5 x2 (1.4m)	Swissteco x1 (1.75m)	4 component
27	Net radiation	Vetch	REBS Q*5.5 x2 (1.4m)	Swissteco x1 (1.75m)	4 component
28	Long wave (in)	Vetch	Eppley pyranometer	-	Schenk 8111/8104
29	Long wave (in)	Vetch	Eppley pyranometer	-	Schenk 8111/8104
30	Soil heat flux	Vine	Thorntwaite x9 (0.5cm)	Middleton x6 (0.5cm)	-
31	Soil heat flux	Vine	Thorntwaite x9 (0.5cm)	Middleton x6 (0.5cm)	-
32	Soil heat flux	Vine	Thorntwaite x9 (0.5cm)	Middleton x6 (0.5cm)	-
33	Soil heat flux	Vine	Thorntwaite x9 (0.5cm)	Middleton x6 (0.5cm)	-
34	Soil heat flux	Vine	Thorntwaite x9 (0.5cm)	Middleton x6 (0.5cm)	-
35	Soil heat flux	Vine	Thorntwaite x9 (0.5cm)	-	-
36	Soil heat flux	Vetch	Thorntwaite x4 (0.5cm)	Middleton x1 (0.5cm)	Thorntwaite x1 (5cm)
37	Soil heat flux	Vetch	Thorntwaite x4 (0.5cm)	Middleton x1 (0.5cm)	Thorntwaite x1 (5cm)
38	Soil heat flux	Vetch	Thorntwaite x4 (0.5cm)	Middleton x1 (0.5cm)	Thorntwaite x1 (5cm)
39	Sensible heat	Vine	Eddy correlation (3.25m)	Profile/sigma T	-
40	Sensible heat	Vine	Eddy correlation/sigma T	Sigma T at 9.04m	-
41	Sensible heat	Vine	Eddy correlation (3.25m)	Profile/sigma T	-
42	Sensible heat	Vine	Eddy correlation/sigma T	Profile/sigma T	-
43	Sensible heat	Vine	Eddy correlation (3.25m)	Profile/sigma T	-
44	Sensible heat	Vine	Eddy correlation (3.25m)	Profile/sigma T	-
45	Sensible heat	Vetch	Eddy correlation (3.25m)	Profile/sigma T	SAHER station
46	Sensible heat	Vetch	Eddy correlation/sigma T	Sigma T at 5.87m	SAHER station
47	Sensible heat	Vetch	Eddy correlation (3.25m)	Profile/sigma T	SAHER station
48	Sensible heat	Vetch	Eddy correlation/sigma T	Profile/sigma T	SAHER station
49	Sensible heat	Vetch	Eddy correlation (3.25m)	Profile/sigma T	-
50	Friction vel.	Vine	Eddy correlation (3.25m)	-	-
51	Friction vel.	Vetch	Eddy correlation (3.25m)	-	-
52	Latent heat	Vine	Eddy correlation (3.25m)	Energy budget	-
53	Latent heat	Vine	Eddy correlation (3.25m)	Energy budget	-
54	Latent heat	Vetch	Eddy correlation (3.25m)	Energy budget	Energy budget
55	Latent heat	Vetch	Eddy correlation (3.25m)	Energy budget	Energy budget
56	Latent heat	Vine	Eddy correlation (3.25m)	Energy budget	-
57	Latent heat	Vetch	Eddy correlation (3.25m)	Energy budget	Energy budget

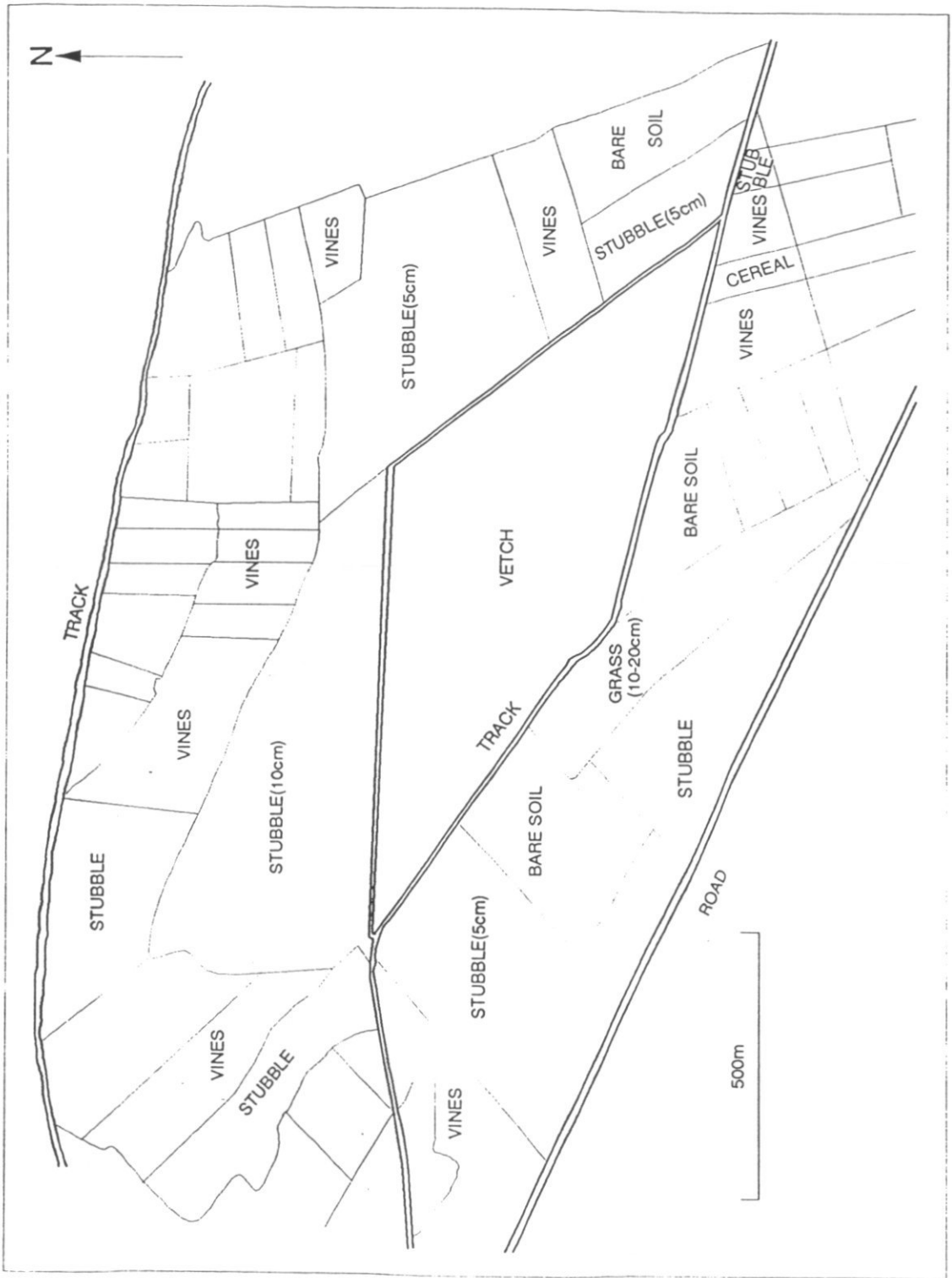
Table 2 - Summary of meteorological conditions at the vine site (1/6-30/6/91)

Date	Wind direction	Air temp. (deg.C.)	Wind speed (m/s)	Rainfall (mm)
1/6	SE-S	14.4	2.2	1
2/6	E-SE	15.6	2.2	2.5
3/6	SW-W	17.8	2.4	0.5
4/6	S-SW	20.5	4.4	0
5/6	SW-W	20.2	4.4	0
6/6	SW-W	19.7	4.9	0
7/6	SW-W	18.6	8.3	0
8/6	SW-W	18.9	2.3	0
9/6	W-NW	23.7	1.9	0
10/6	S-SW	24.6	3.3	0
11/6	NE-E	22.5	3.7	0
12/6	NE-E	25.1	2.0	0
13/6	SE-S	26.5	2.6	0
14/6	E-SE	27.2	2.6	0
15/6	SW-W	27.4	3.3	0
16/6	SW-W	26.2	4.6	0
17/6	NW-N	20.3	2.5	0
18/6	NE-E	19.5	3.0	0
19/6	W-NW	20.3	2.0	0
20/6	SW-W	24.0	2.6	0
21/6	SW-W	26.4	2.0	0
22/6	S-SW	27.0	1.9	0
23/6	W-NW	26.4	1.5	0
24/6	SE-S	28.7	2.1	0
25/6	SE-S	30.1	2.7	0
26/6	S-SW	30.5	2.5	0
27/6	SW-W	28.2	2.7	0
28/6	NE-E	24.4	3.4	0
29/6	NE-E	24.0	2.8	0
30/6	NE-E	24.3	3.6	0

General Location Map of Vine Site ($2^{\circ}53'20''\text{W}$, $39^{\circ}08'30''\text{N}$)



General Location Map of Vetch Site (2°56'55"W, 39°09'10"N)
(Crop descriptions apply to 11/07/91)



Vine site - 11/6/91

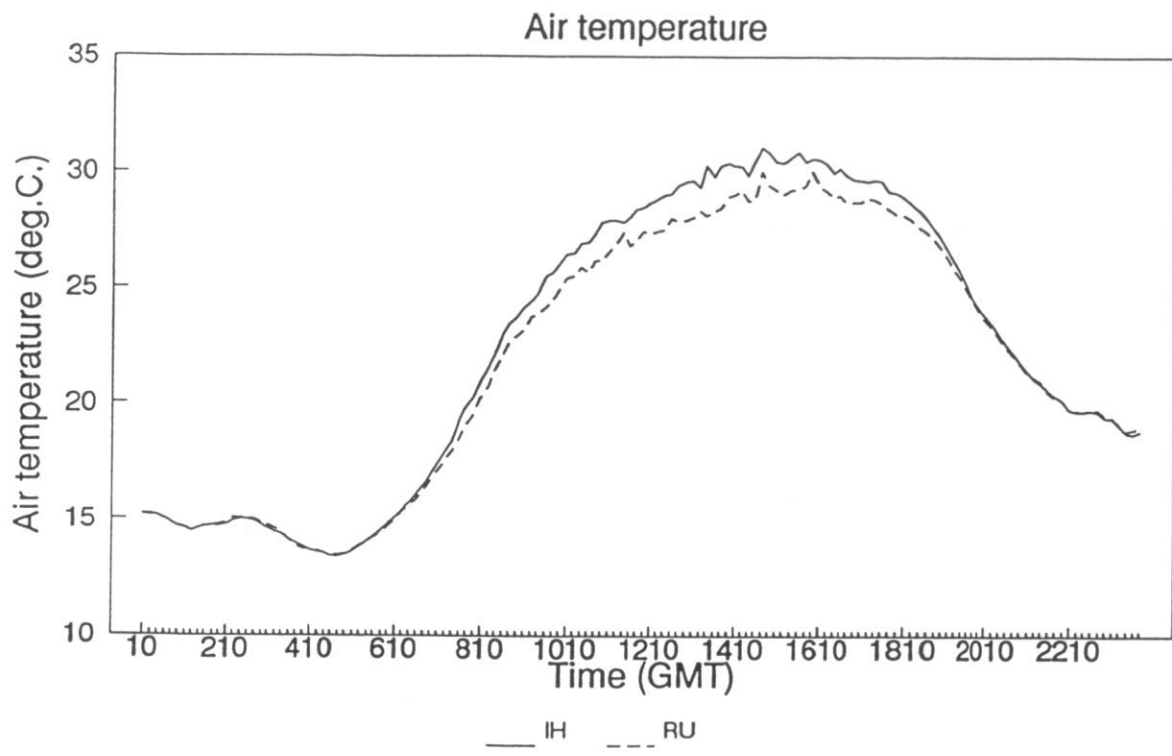


Figure 1

Vetch site - 11/6/91

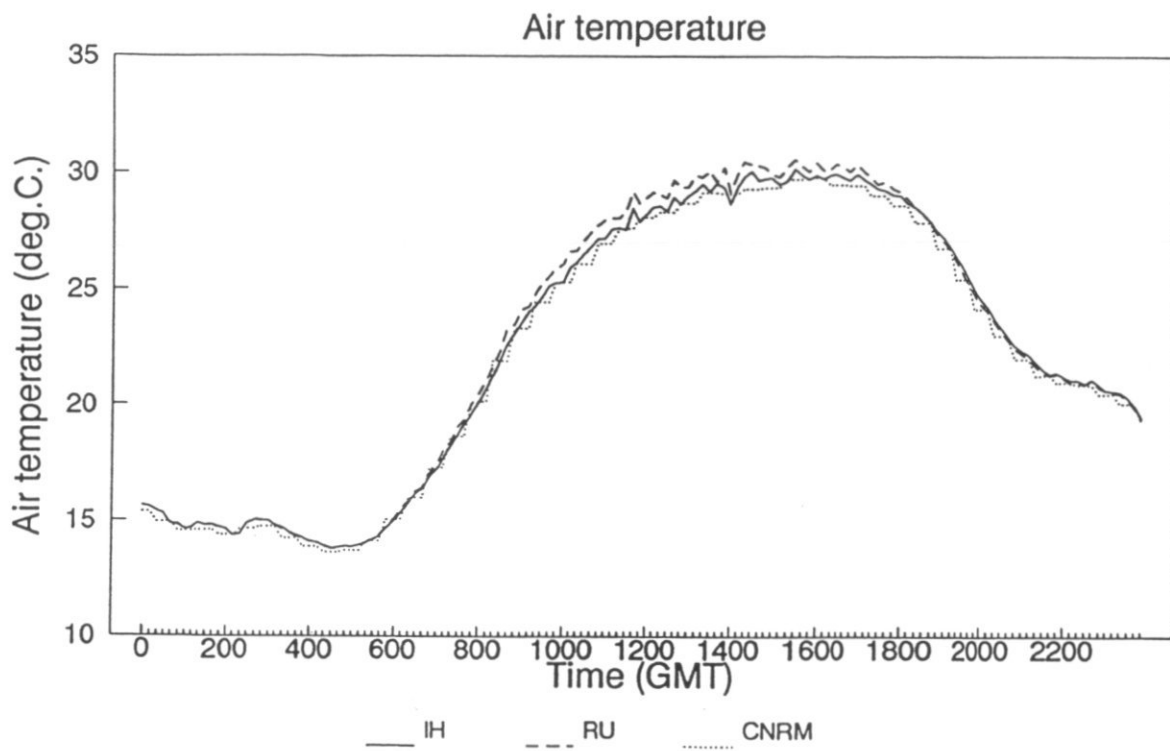


Figure 2

Vetch site 7/6-10/6/91

Air temperatures

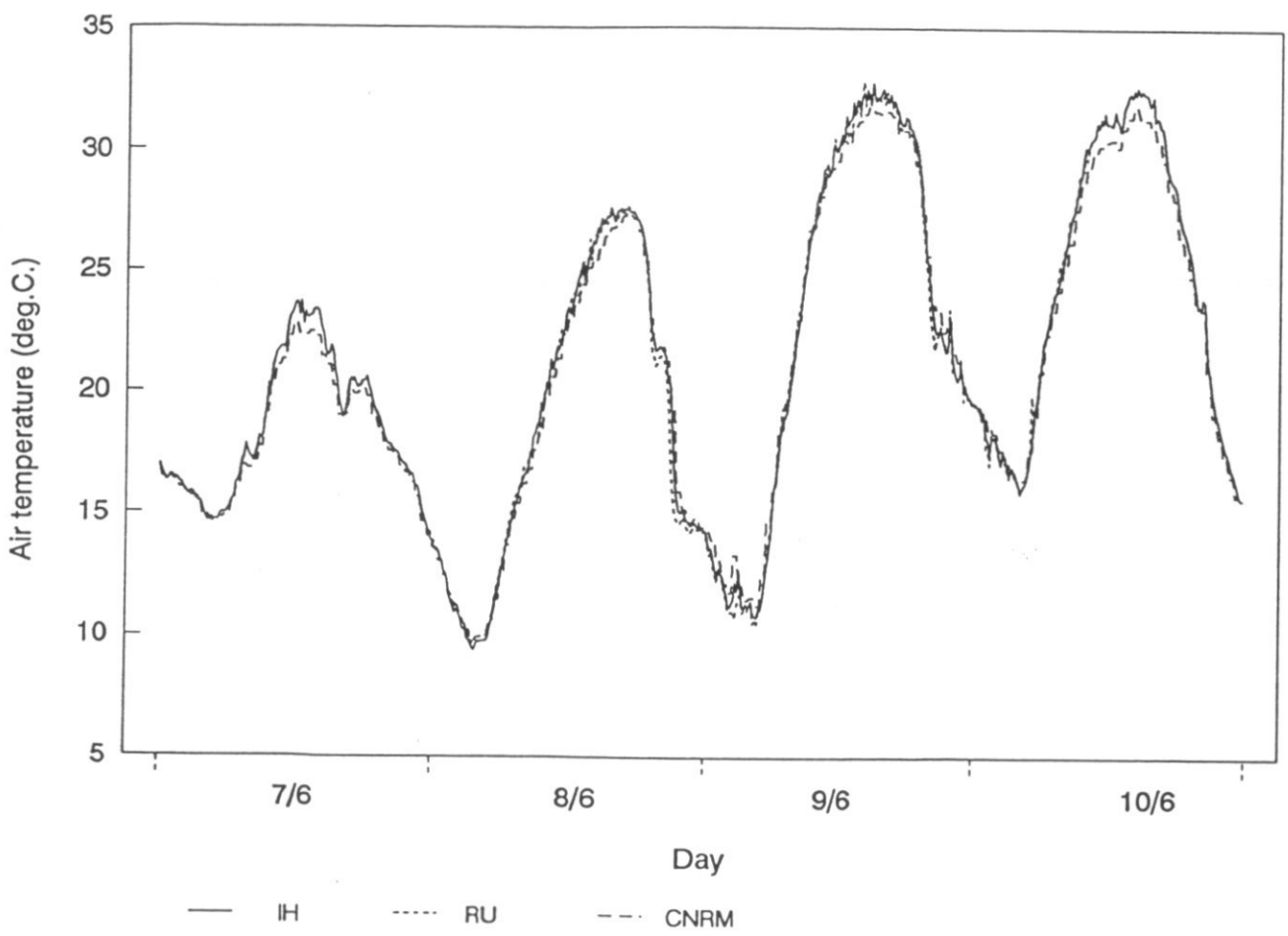


Figure 3

Vetch site - air temperatures

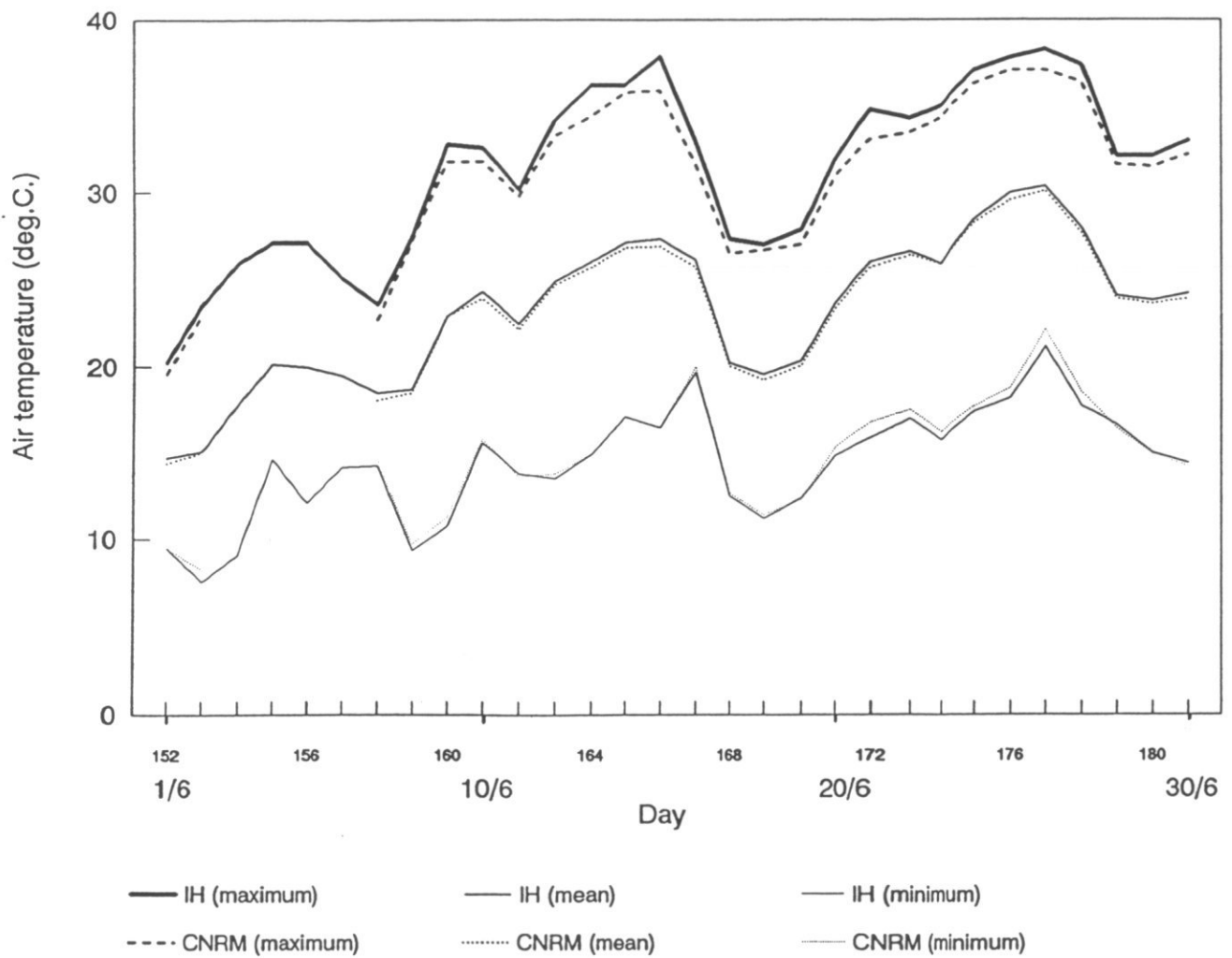


Figure 4

Vetch site - vapour pressure

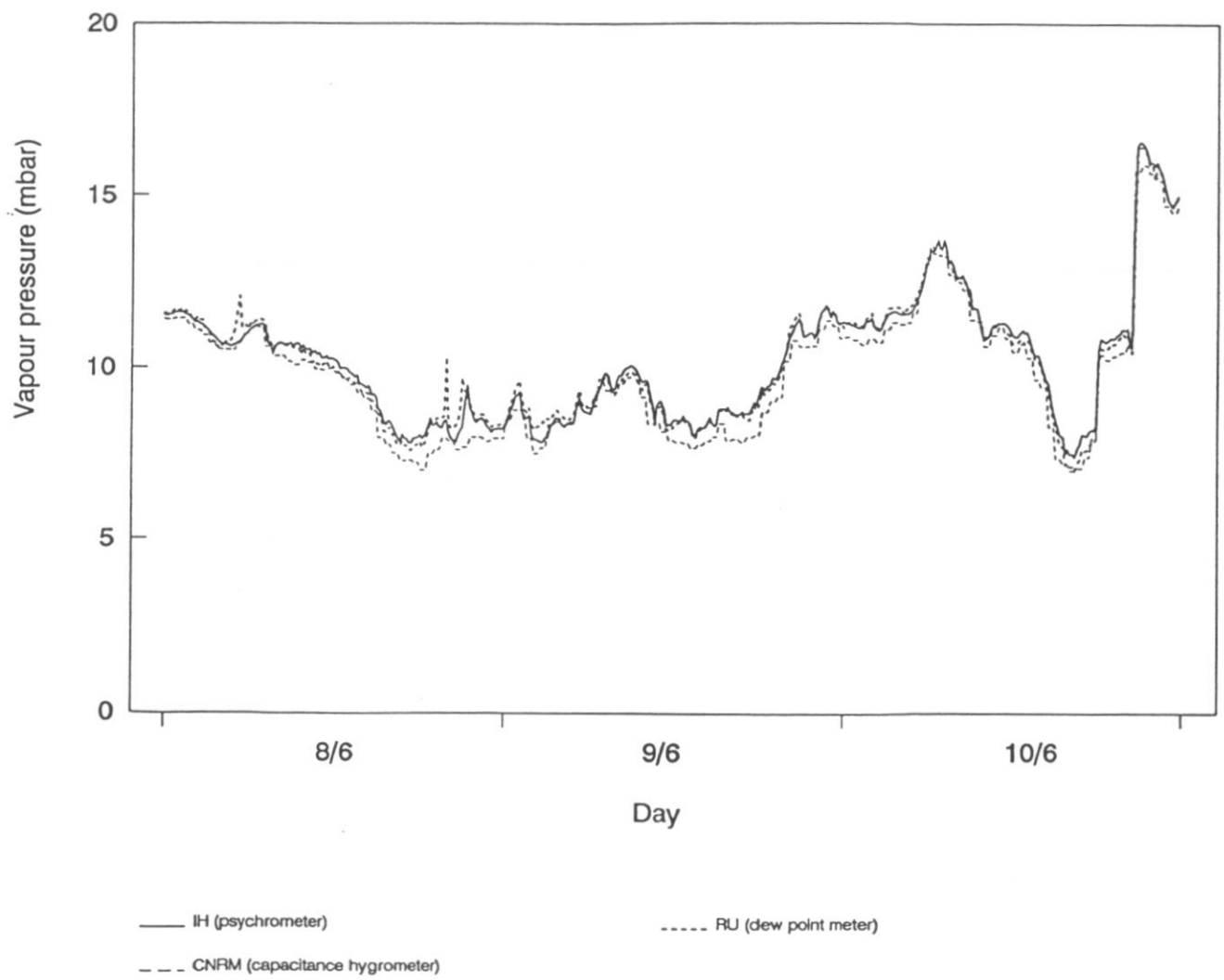
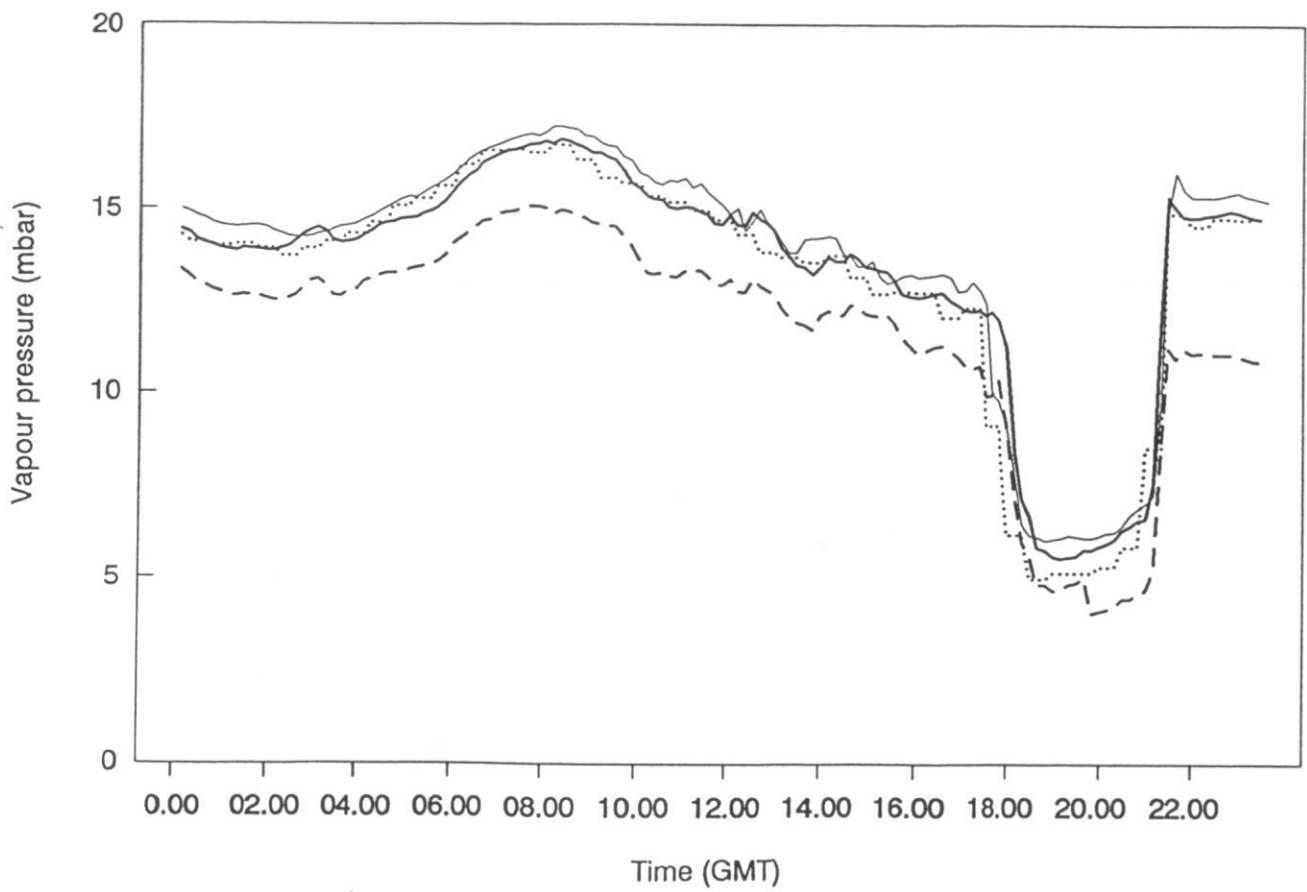


Figure 5

Vine site - vapour pressure

(28/6/91)



— IH (psychrometer)

- - - RU (dew point meter)

— IH (vetch site)

..... CNRM (vetch site)

Figure 6

Vine site - wind direction
(11/6/91)

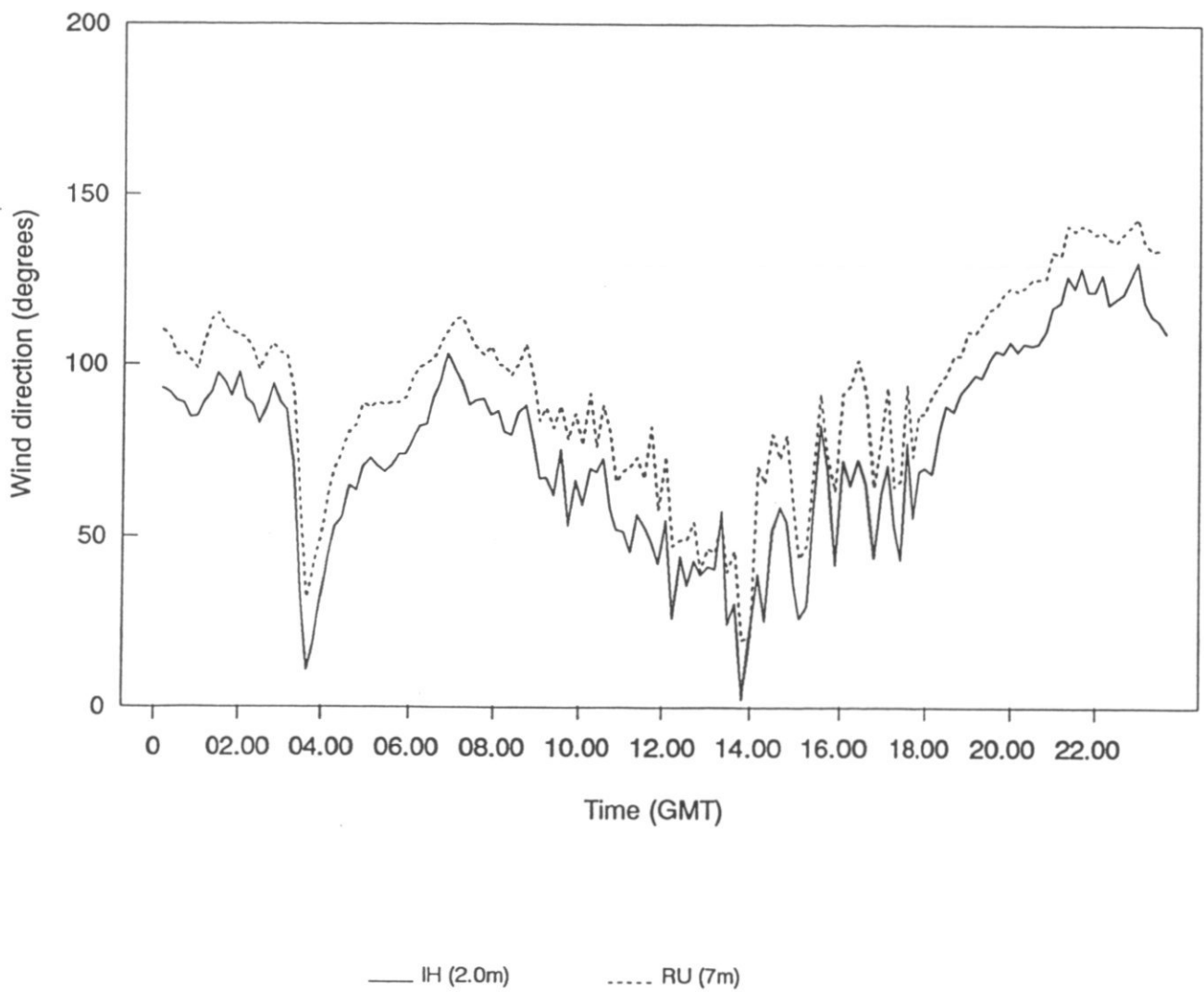


Figure 7

Vetch site - wind speed

(11/6/91)

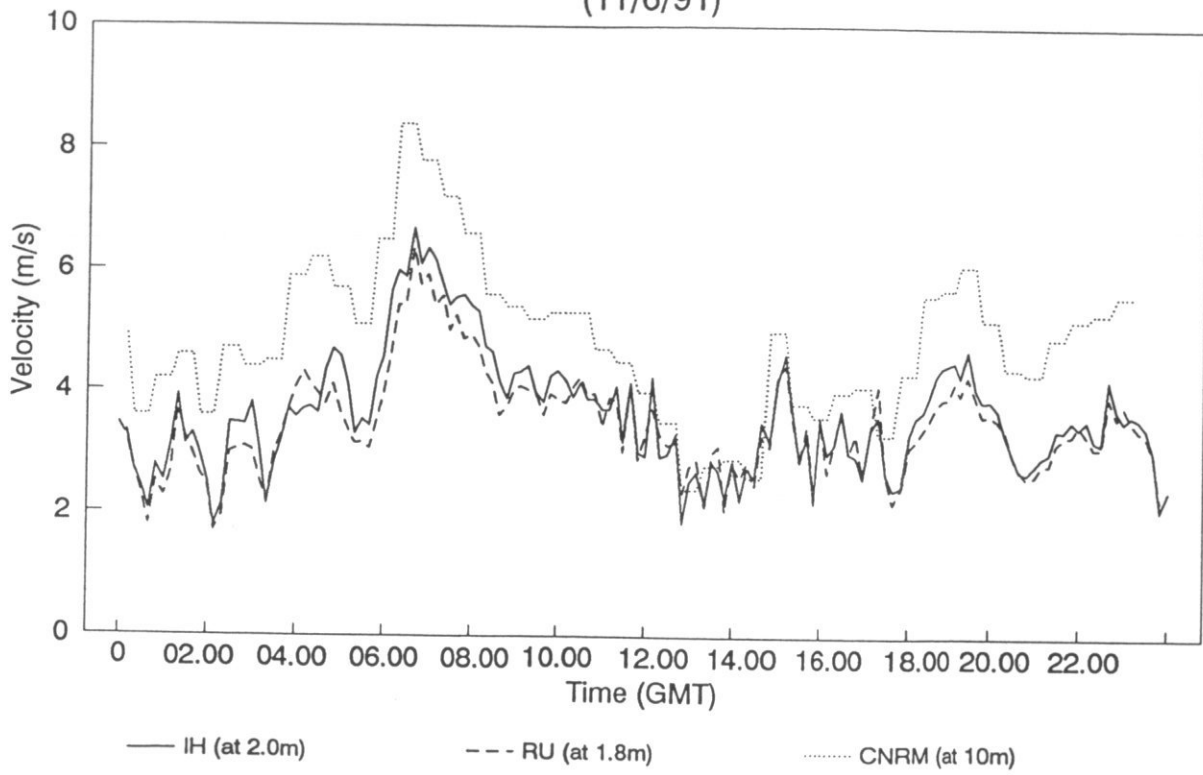


Figure 8

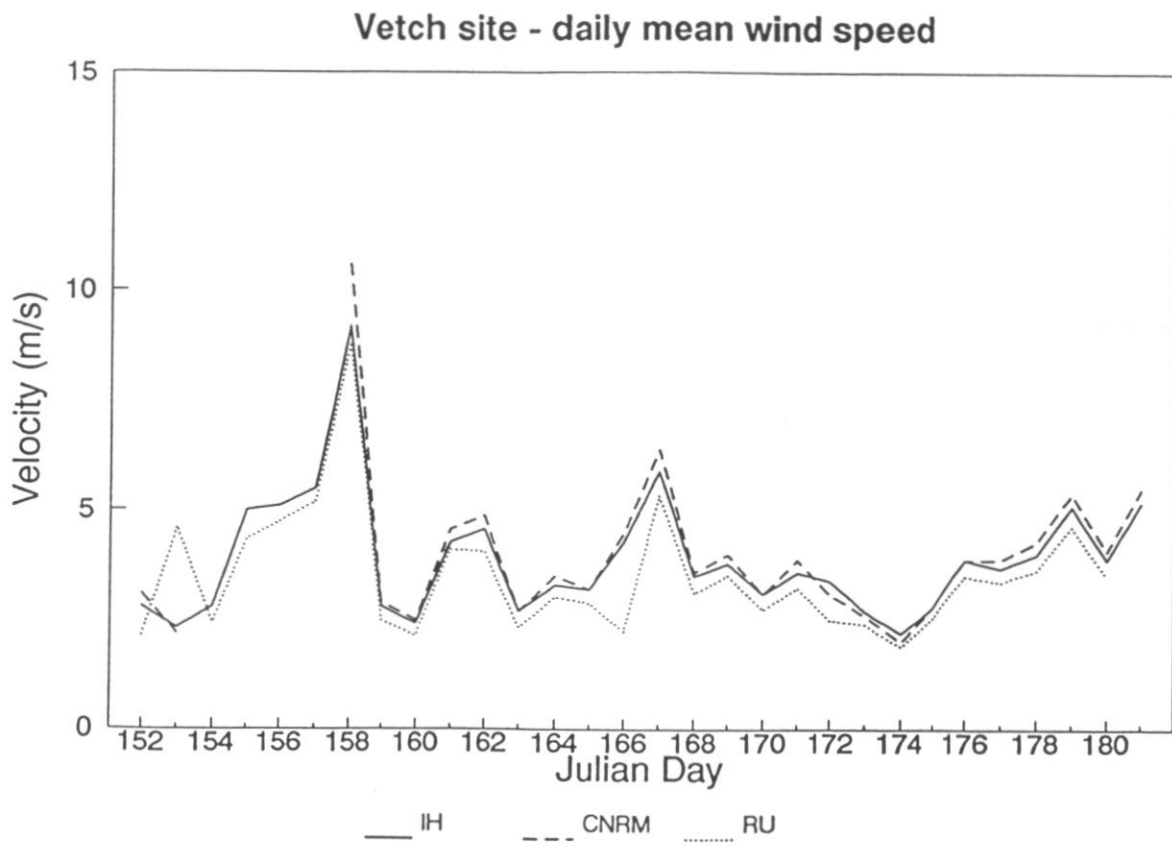


Figure 9

Vine site - incident solar radiation

(11/6/91)

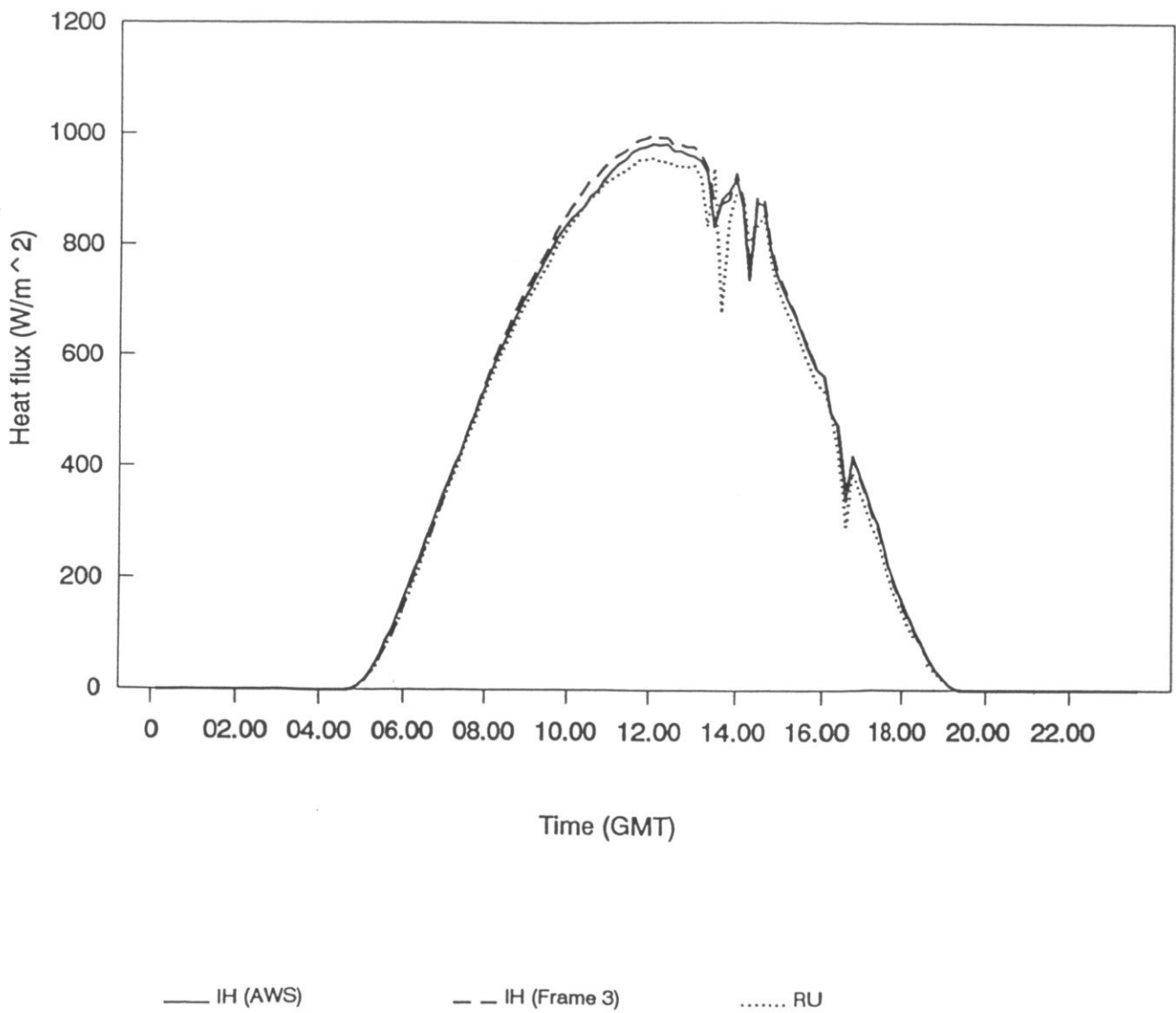


Figure 10

Vine site - solar radiation

(28/6 - 30/6/91)

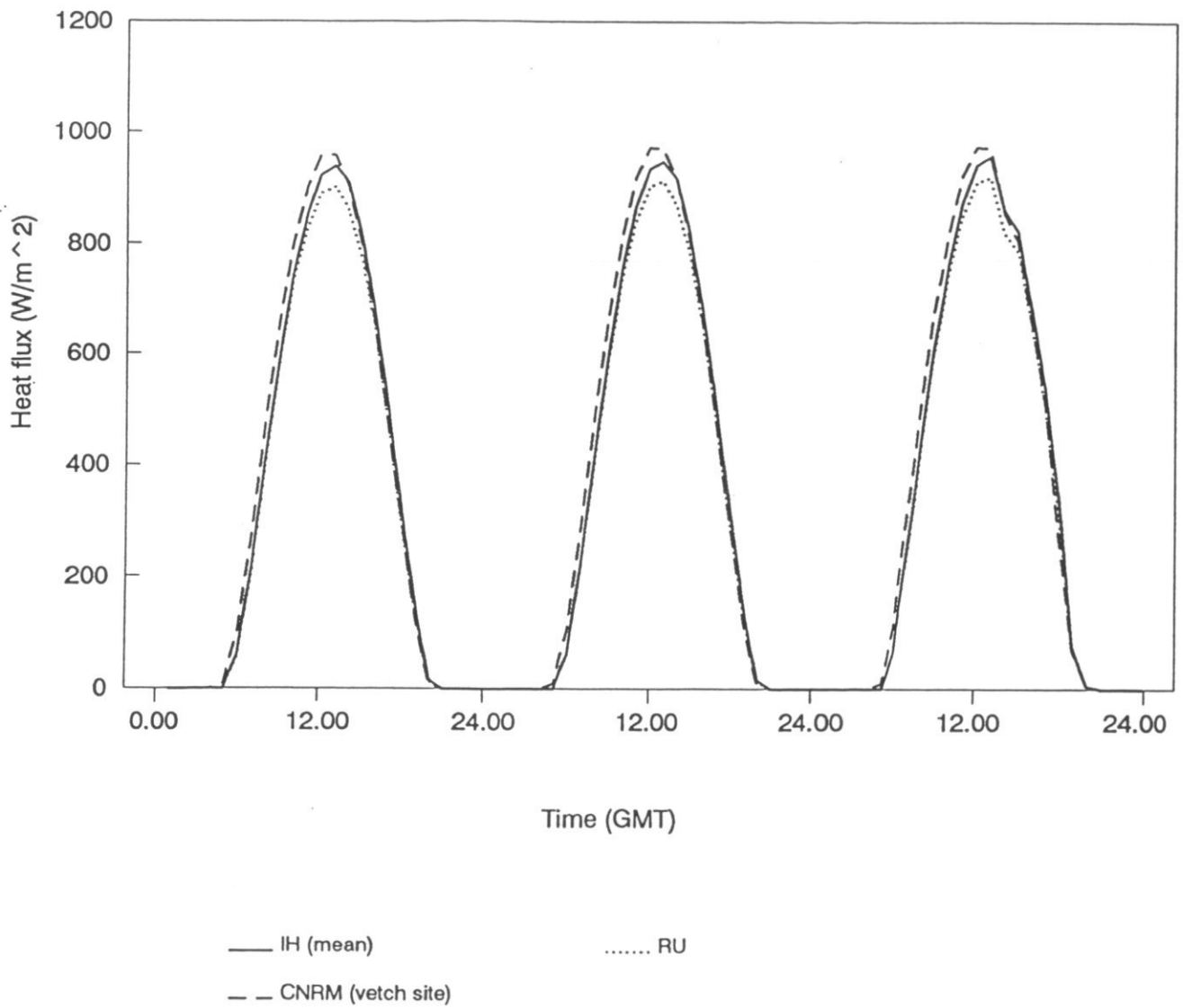


Figure 11

Vine site - daily total solar radiation
(1/6-30/6/91)

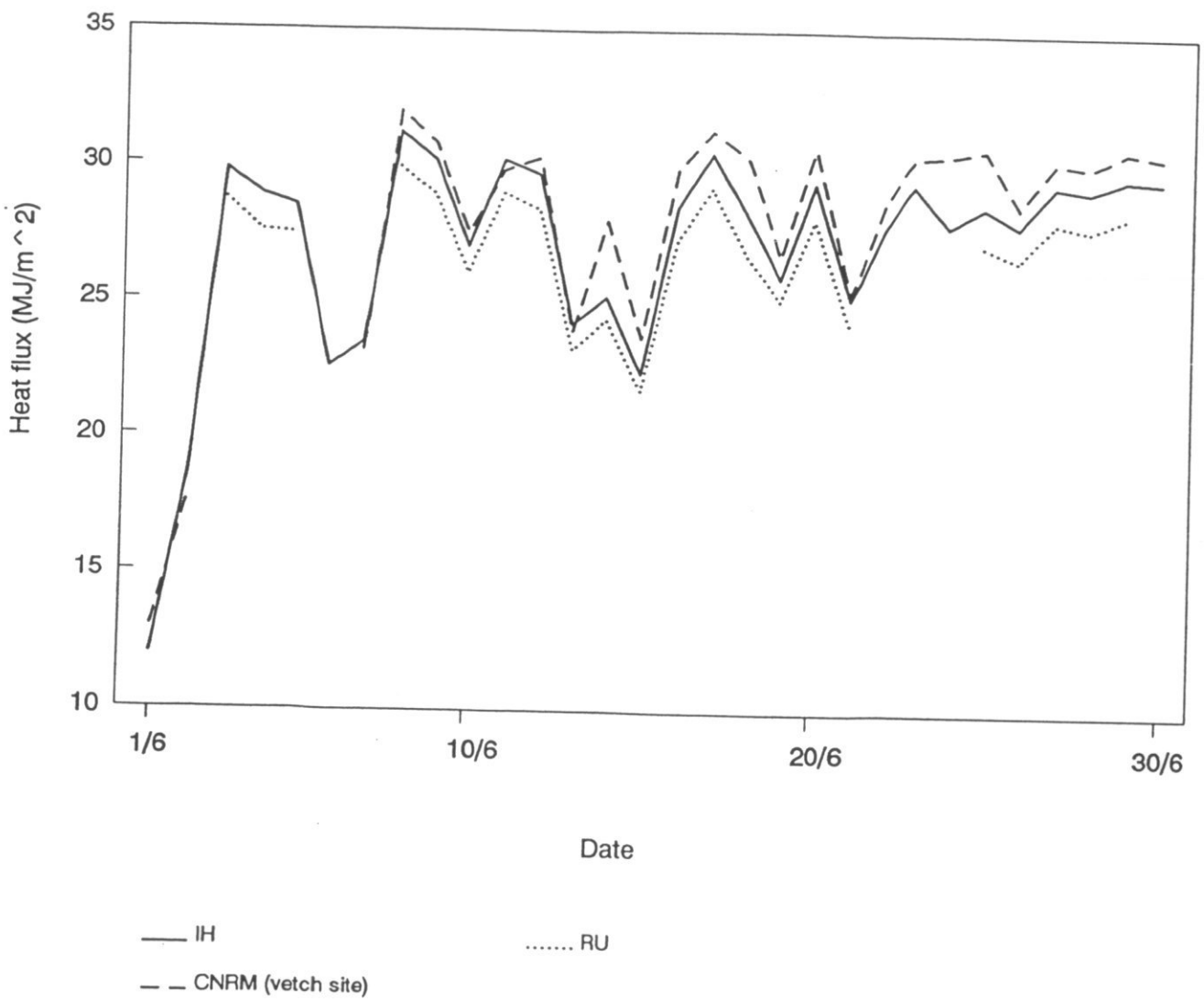


Figure 12

Vetch site - solar radiation

(28/6 - 30/6/91)

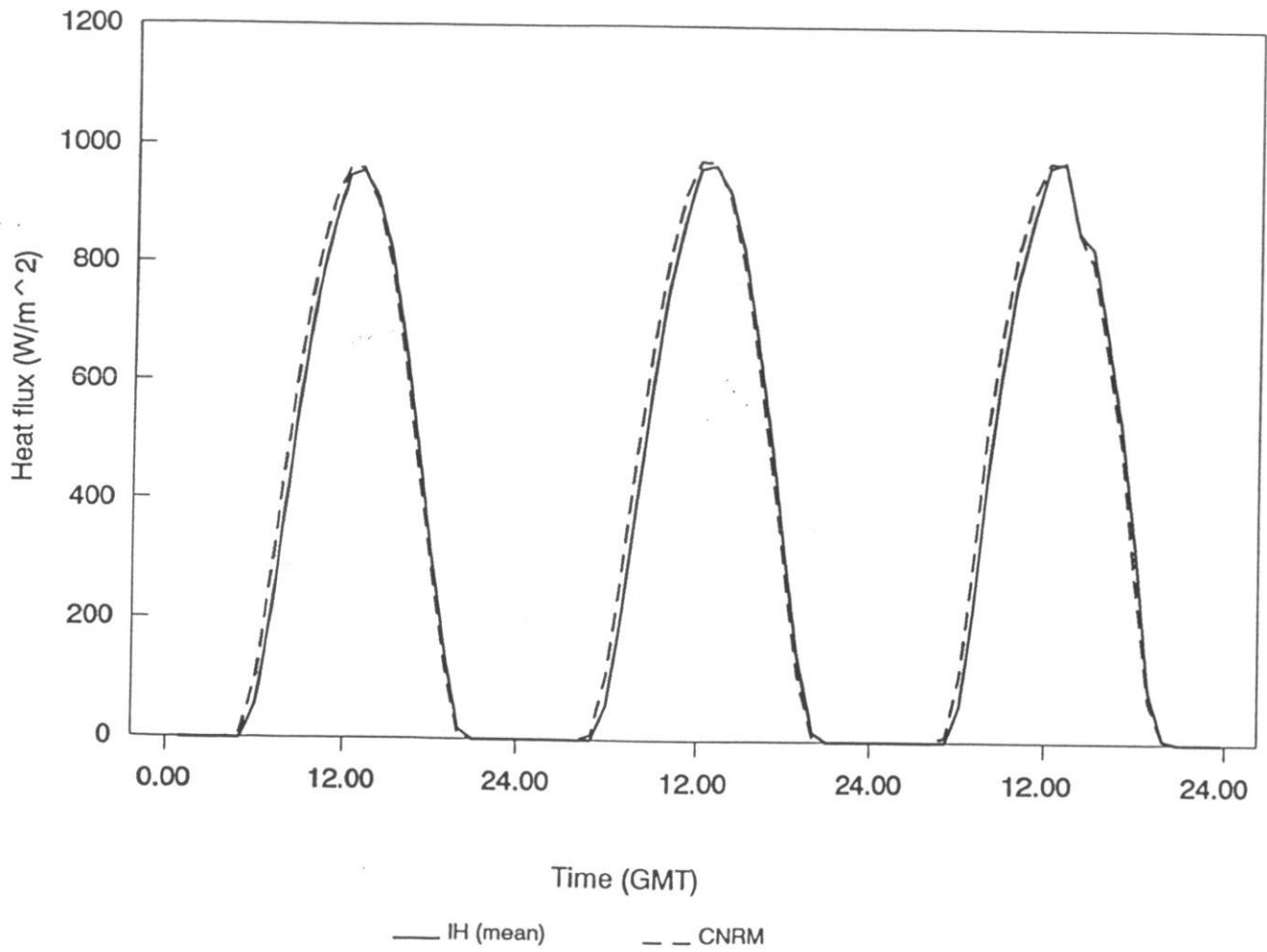


Figure 13

Vetch site - daily total solar radiation
(1/6-30/6/91)

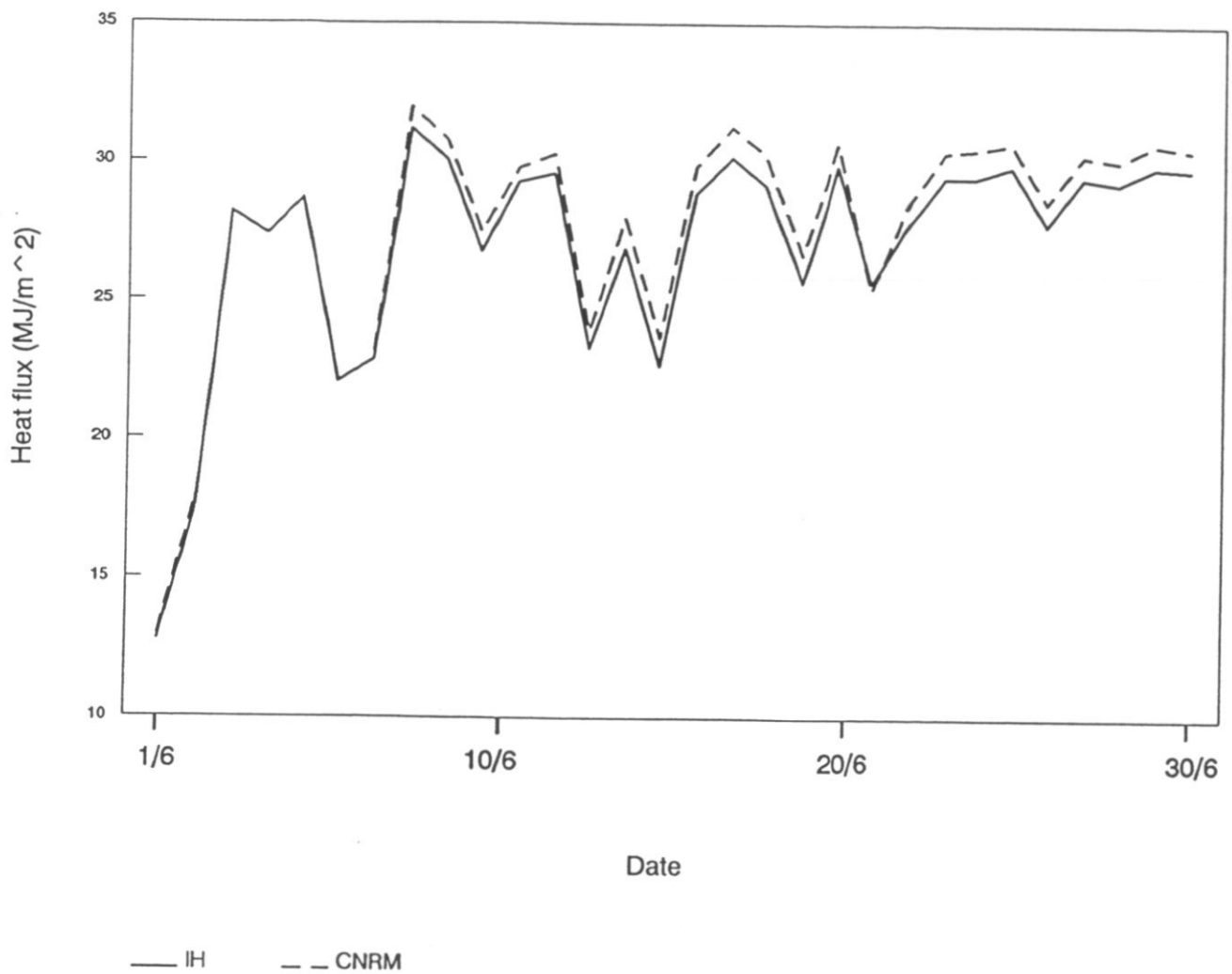


Figure 14

Vine site - reflected solar radiation

(11/6/91)

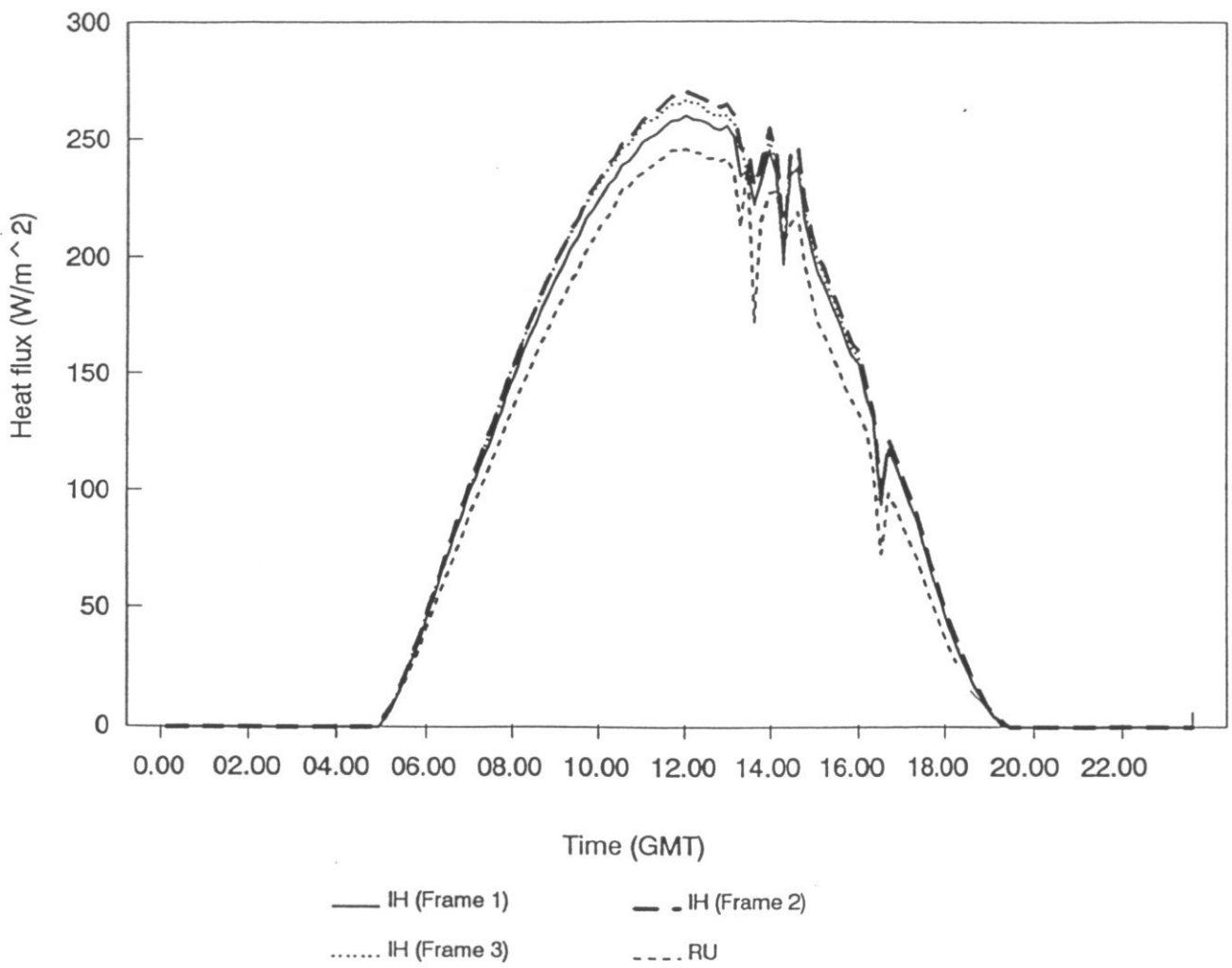


Figure 15

Vine site - reflected solar radiation

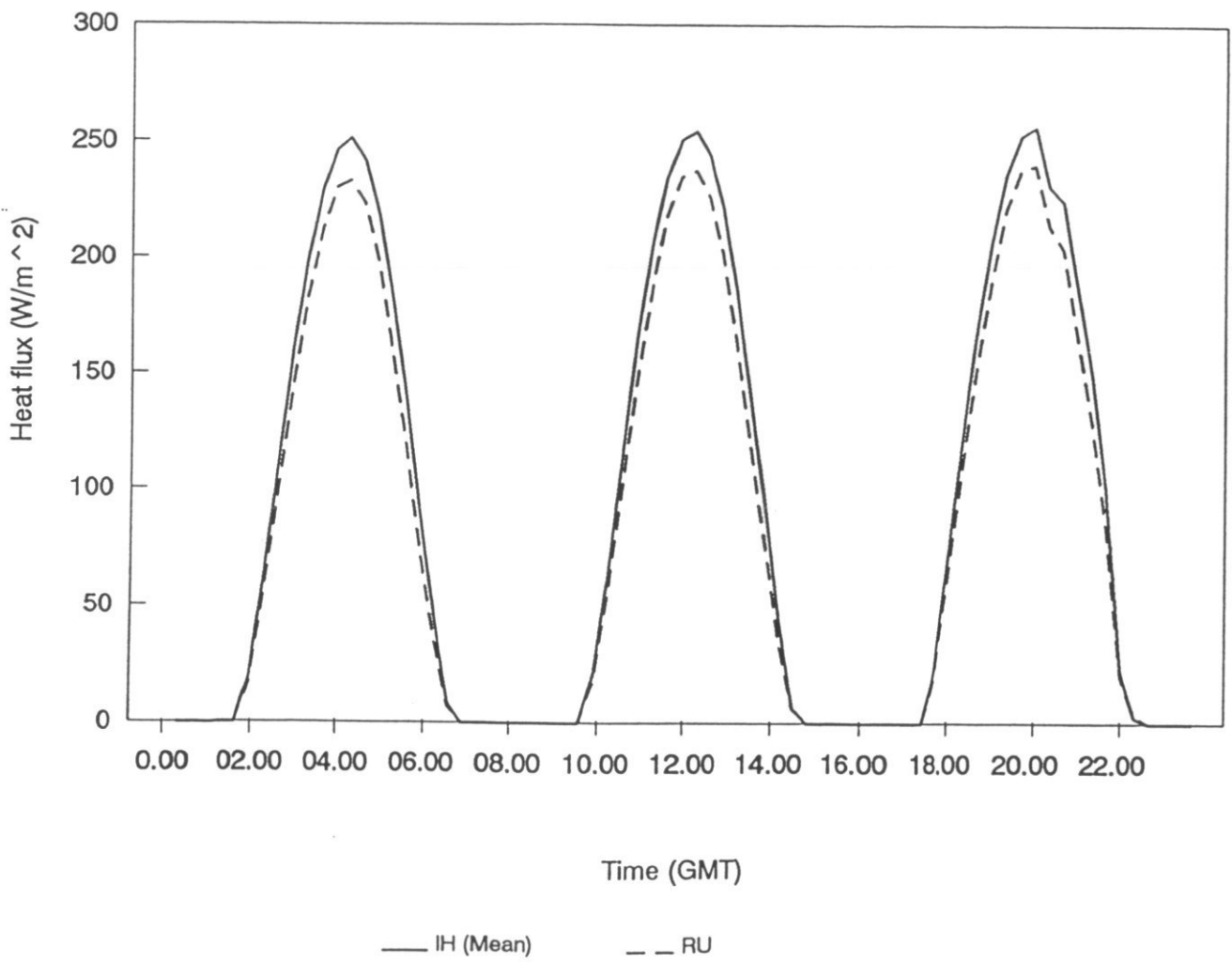


Figure 16

Vine site - reflected solar radiation

(1/6-30/6/91)

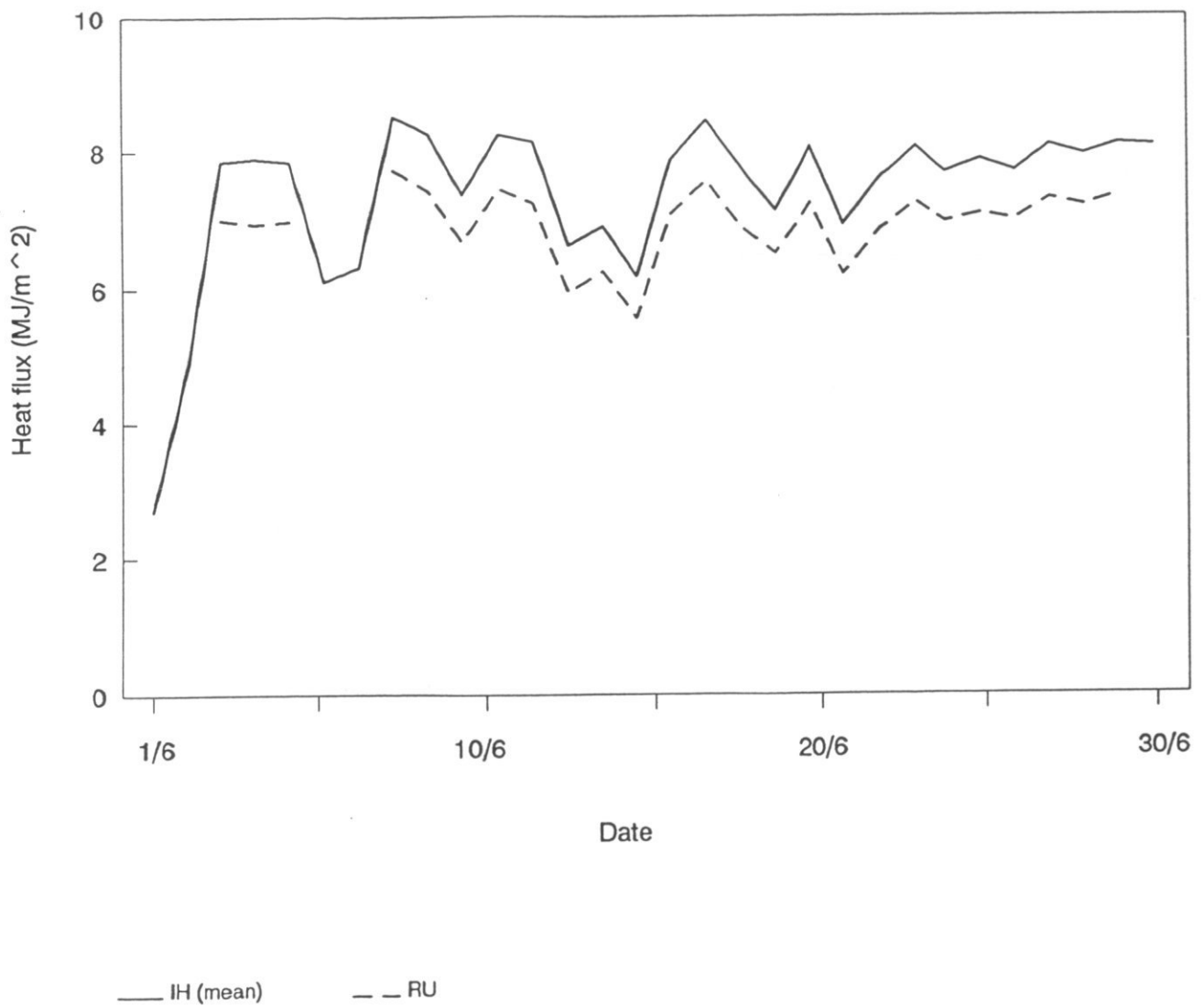


Figure 17

Vetch site - reflected solar radiation

(28/6-30/6/91)

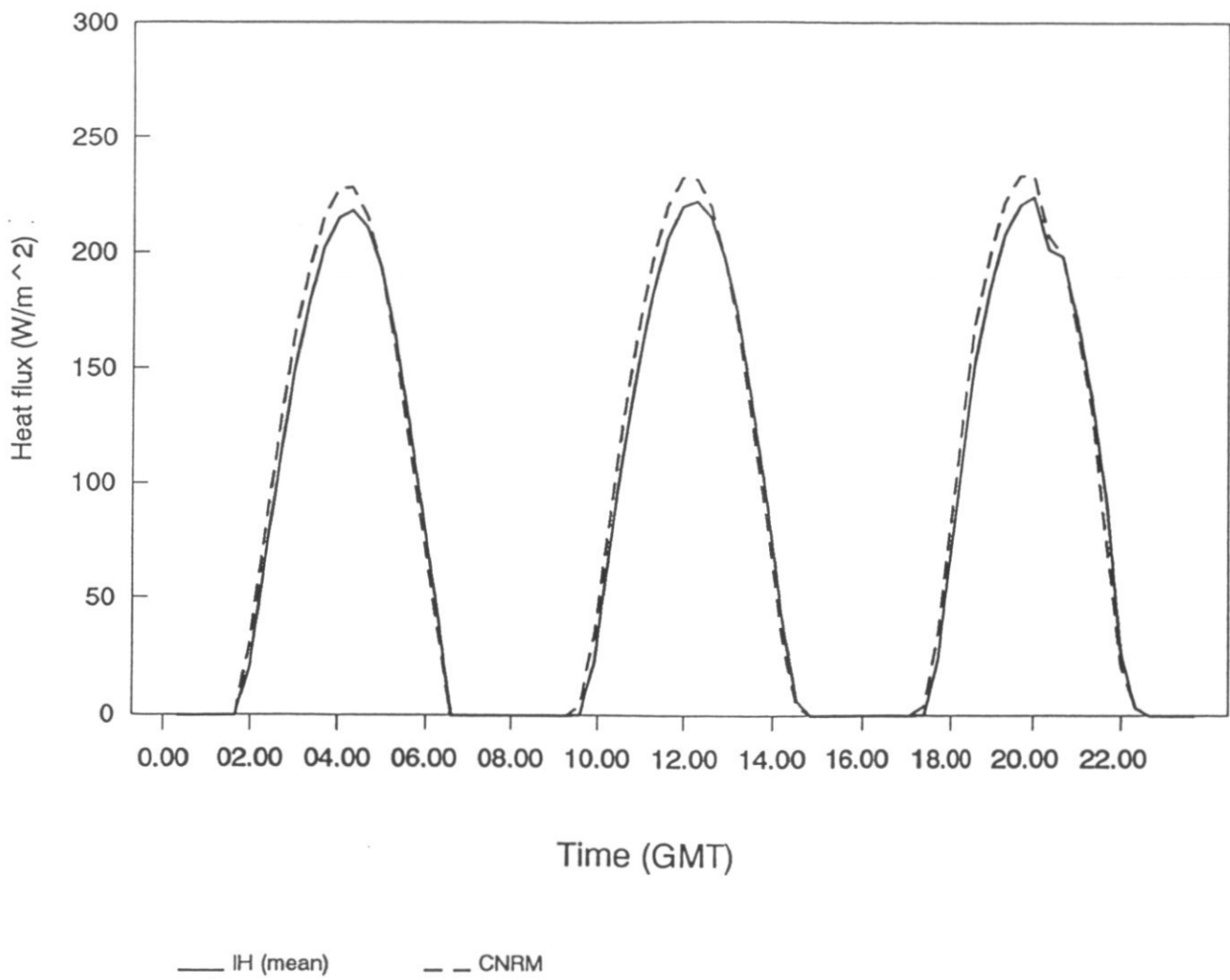


Figure 18

Vetch site - reflected solar radiation

(1/6-30/6/91)

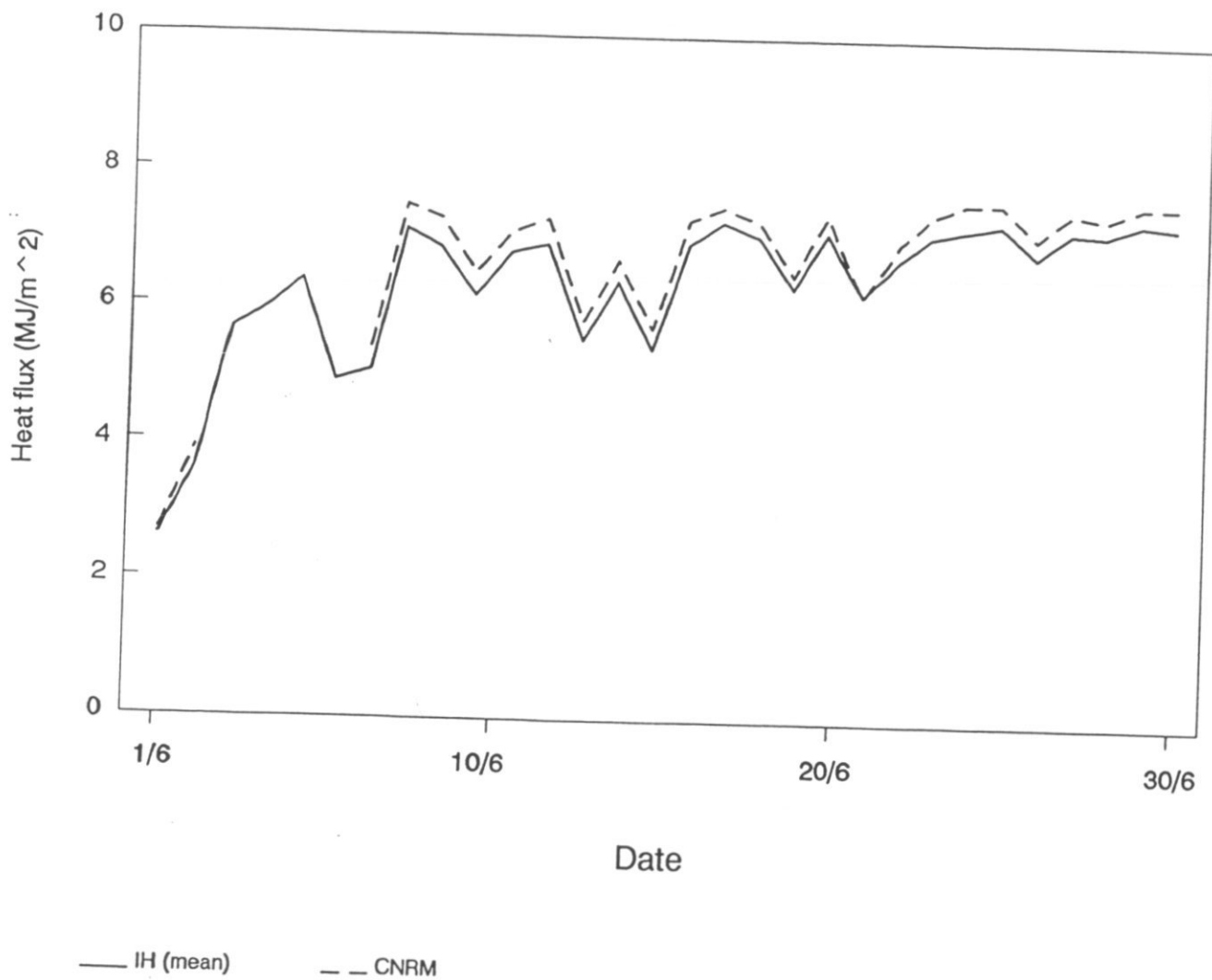
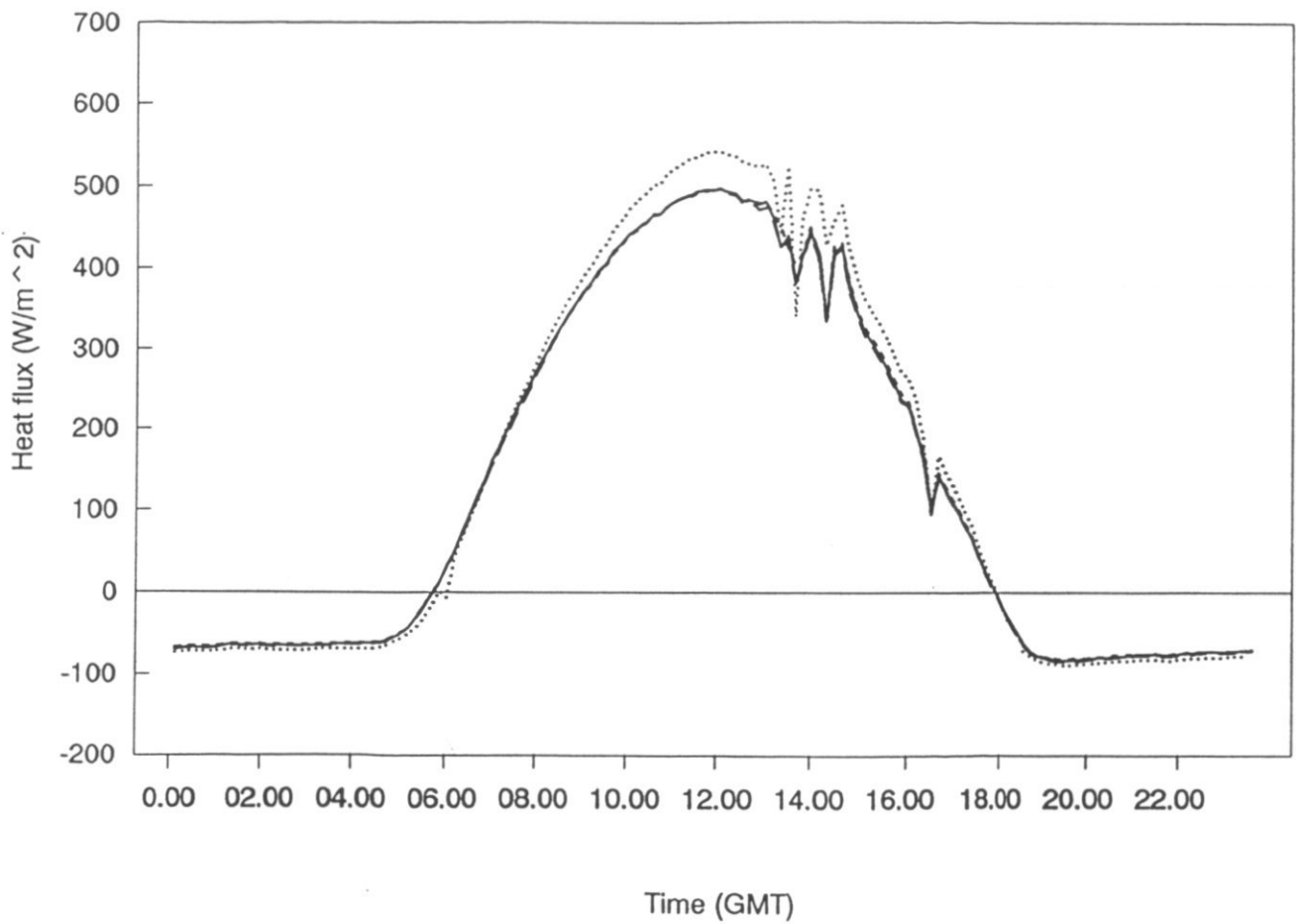


Figure 19

Vine site - net radiation

(11/6/91)



— IH (Frame 1) - - - IH (Frame 2)
- - - IH (Frame 3) RU

Figure 20

Vine site - net radiation
(28/6-30/6/91)

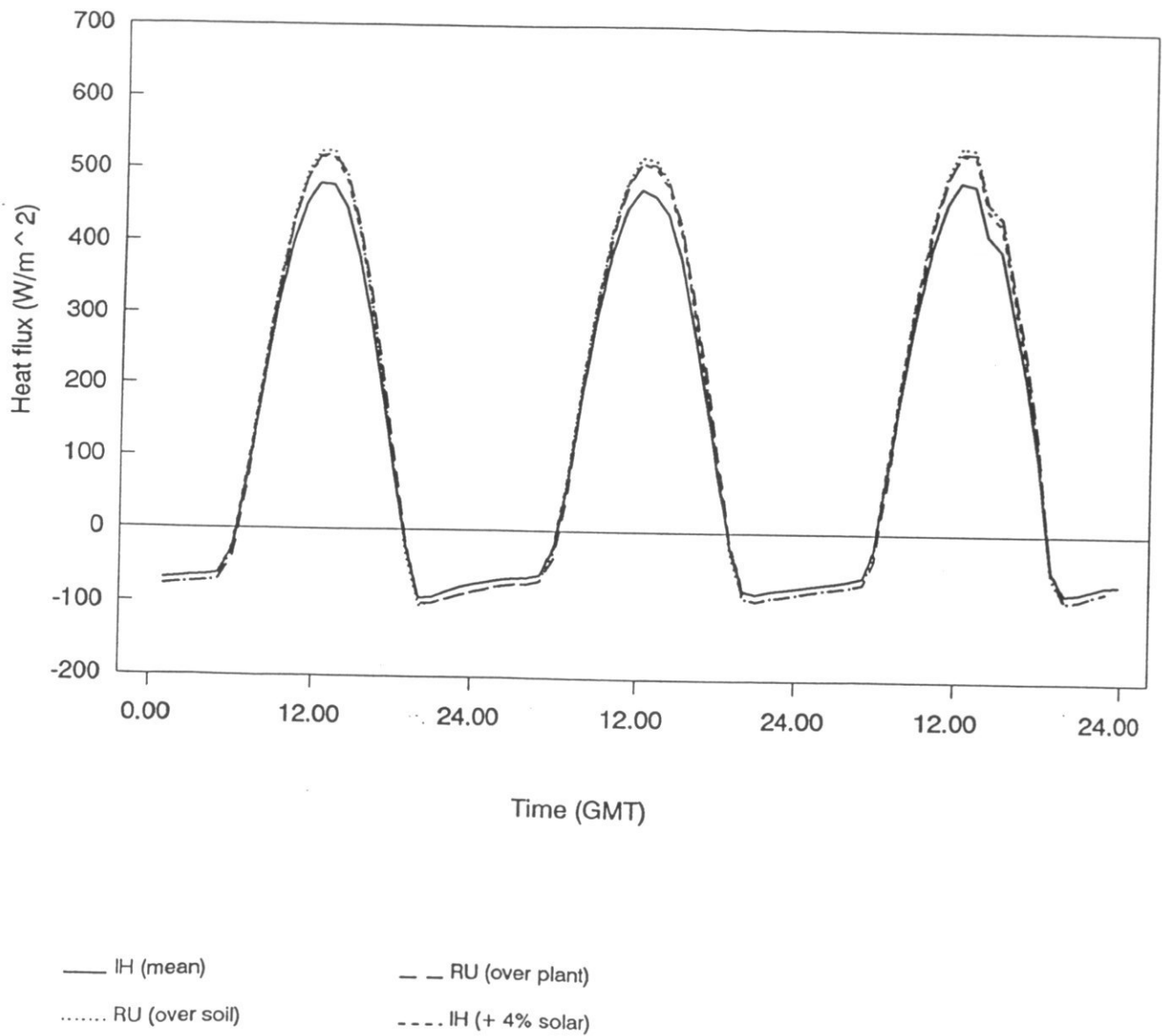


Figure 21

Vine site - net radiation
(1/6-30/6/91)

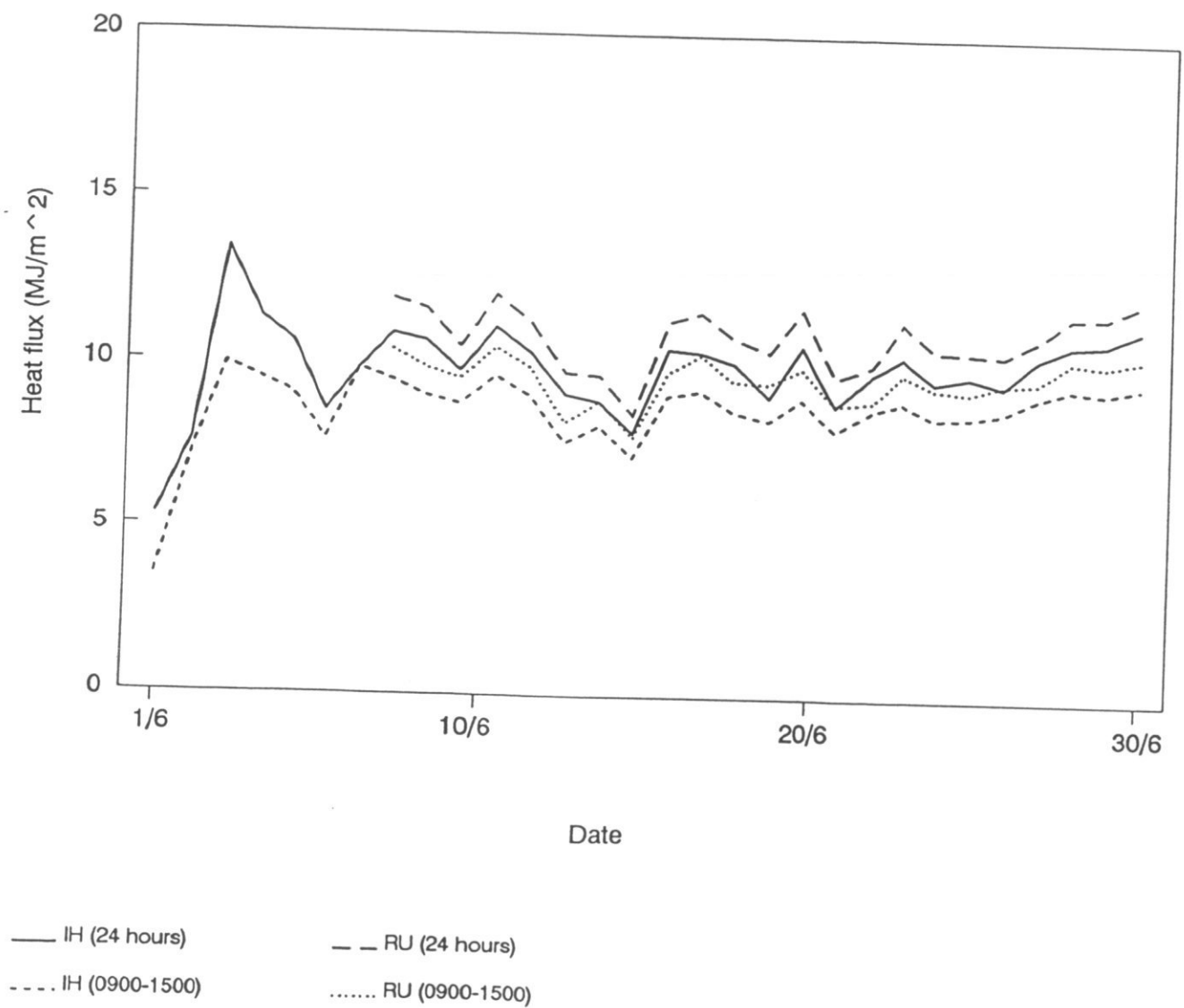


Figure 22

Vine site - net radiation
(11/6/91)

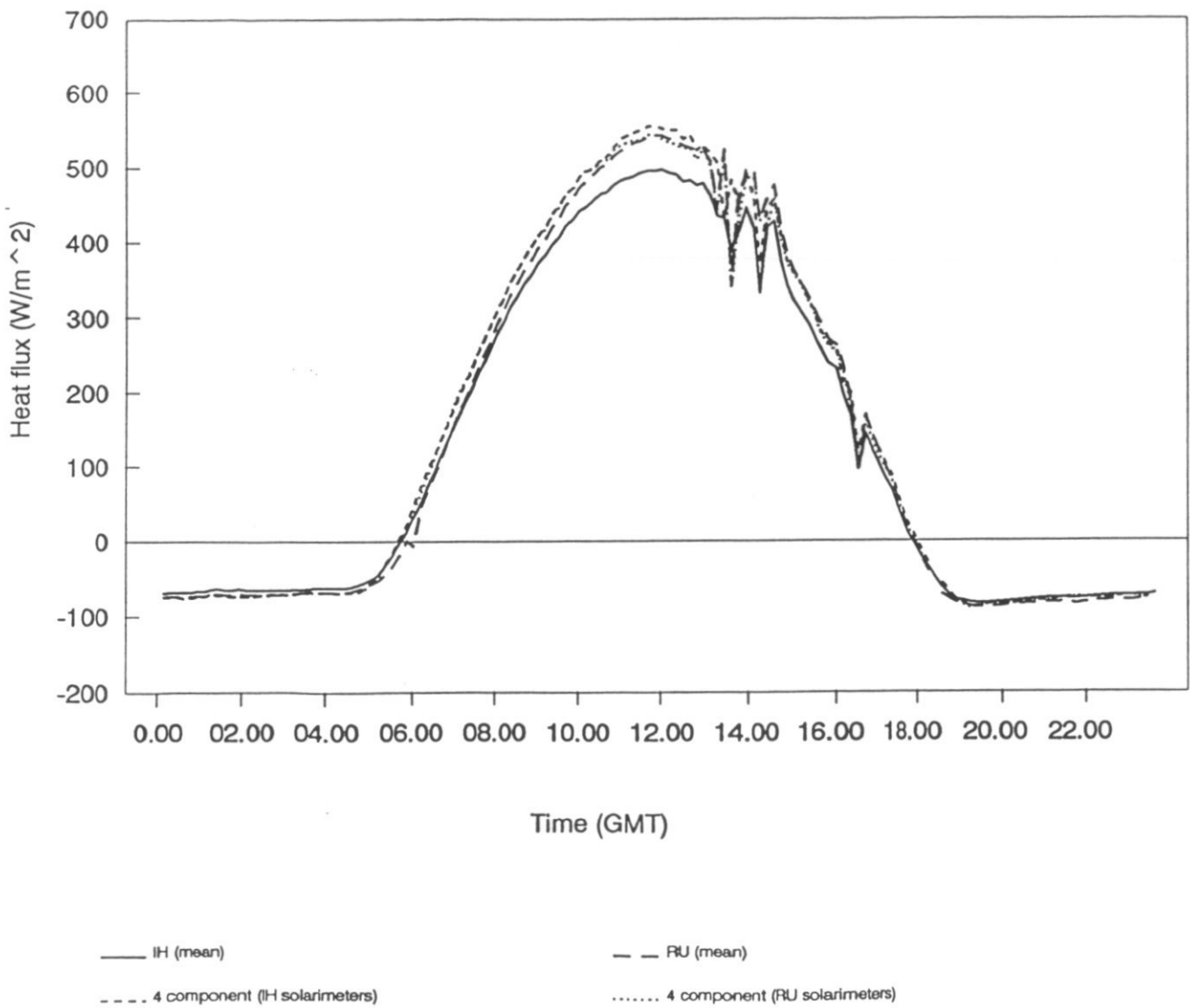


Figure 23

Vetch site - net radiation

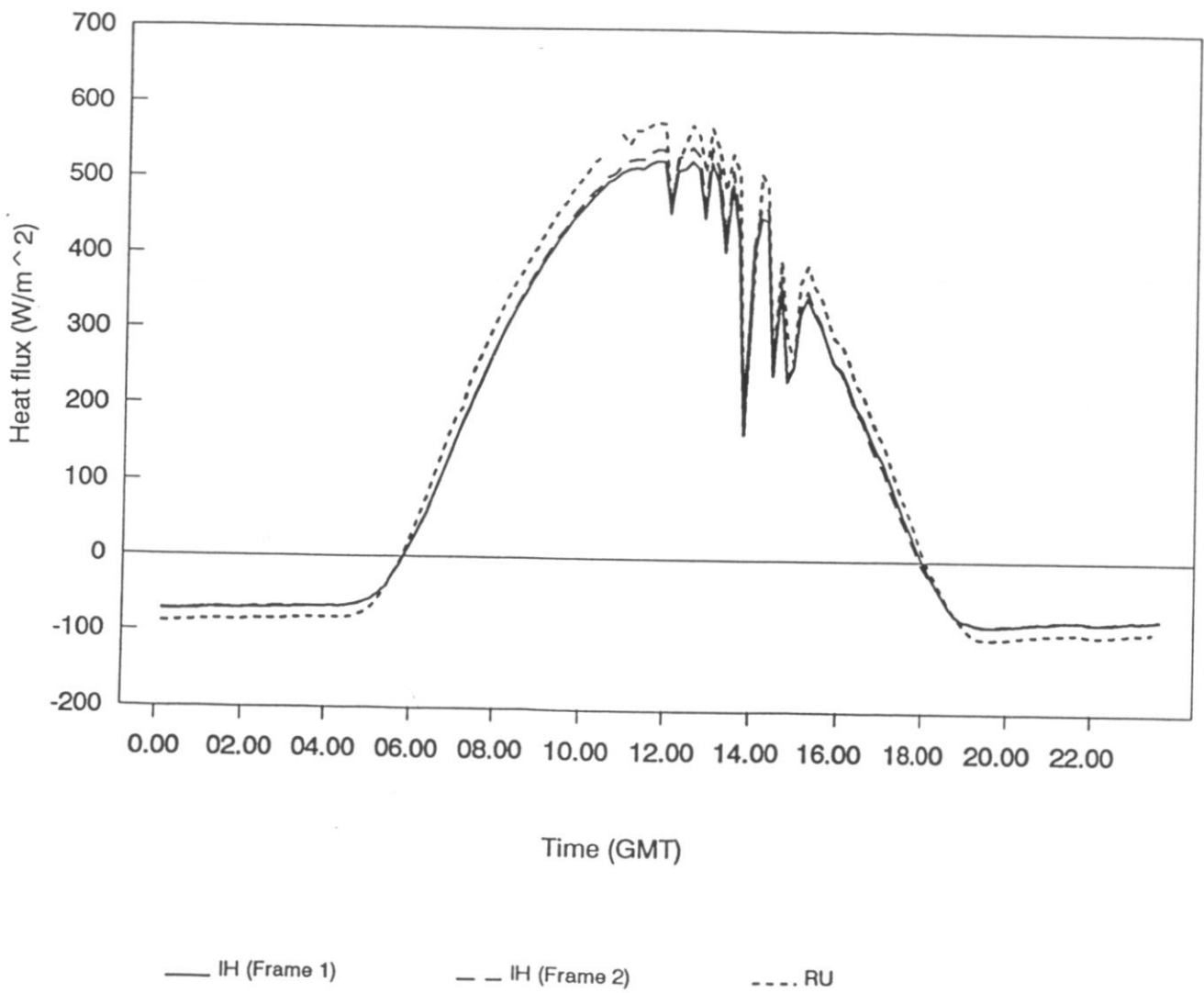


Figure 24

Vetch site - net radiation

(28/6-30/6/91)

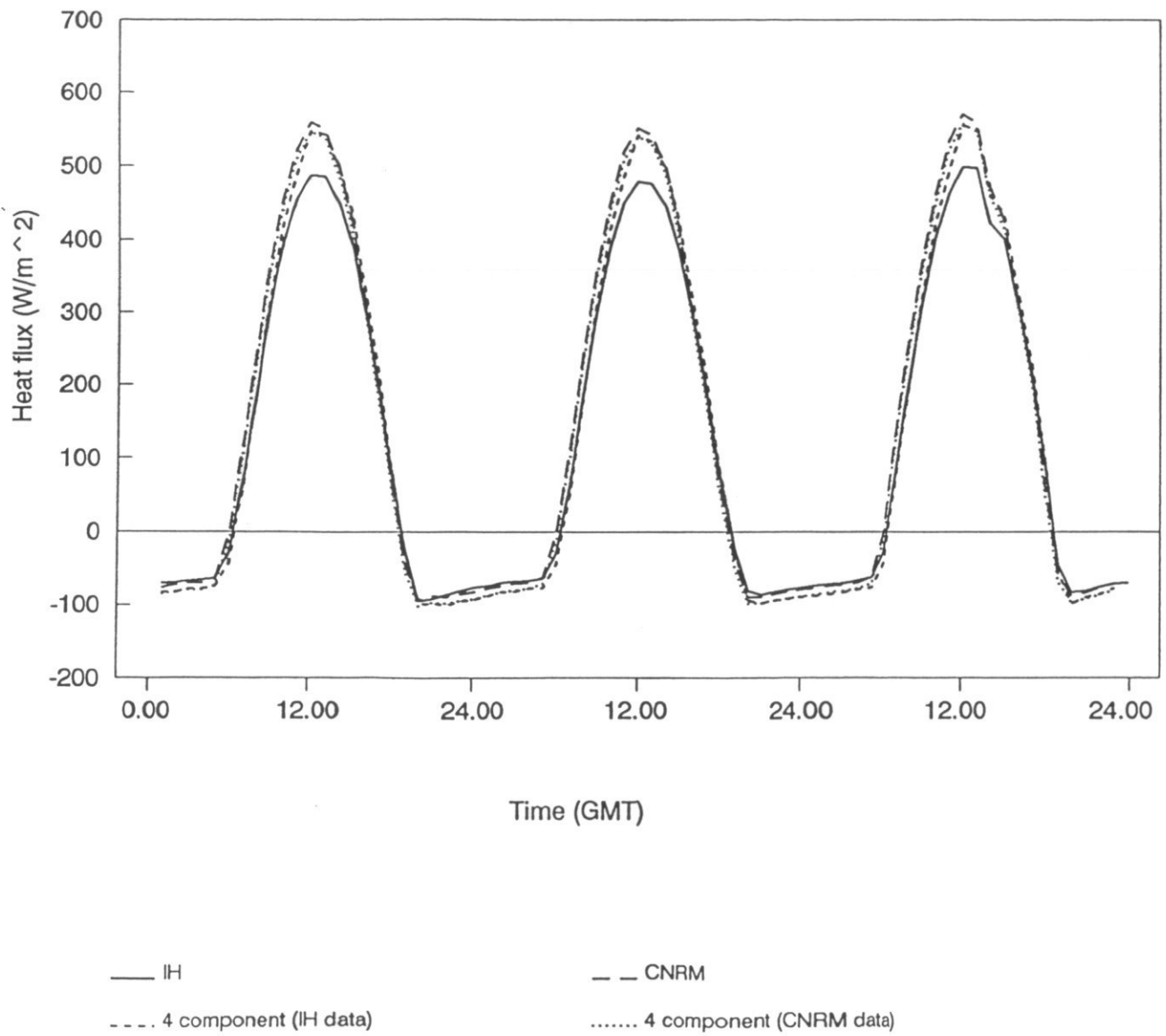


Figure 25

Vetch site - net radiation
(24 hour totals 1/6-30/6/91)

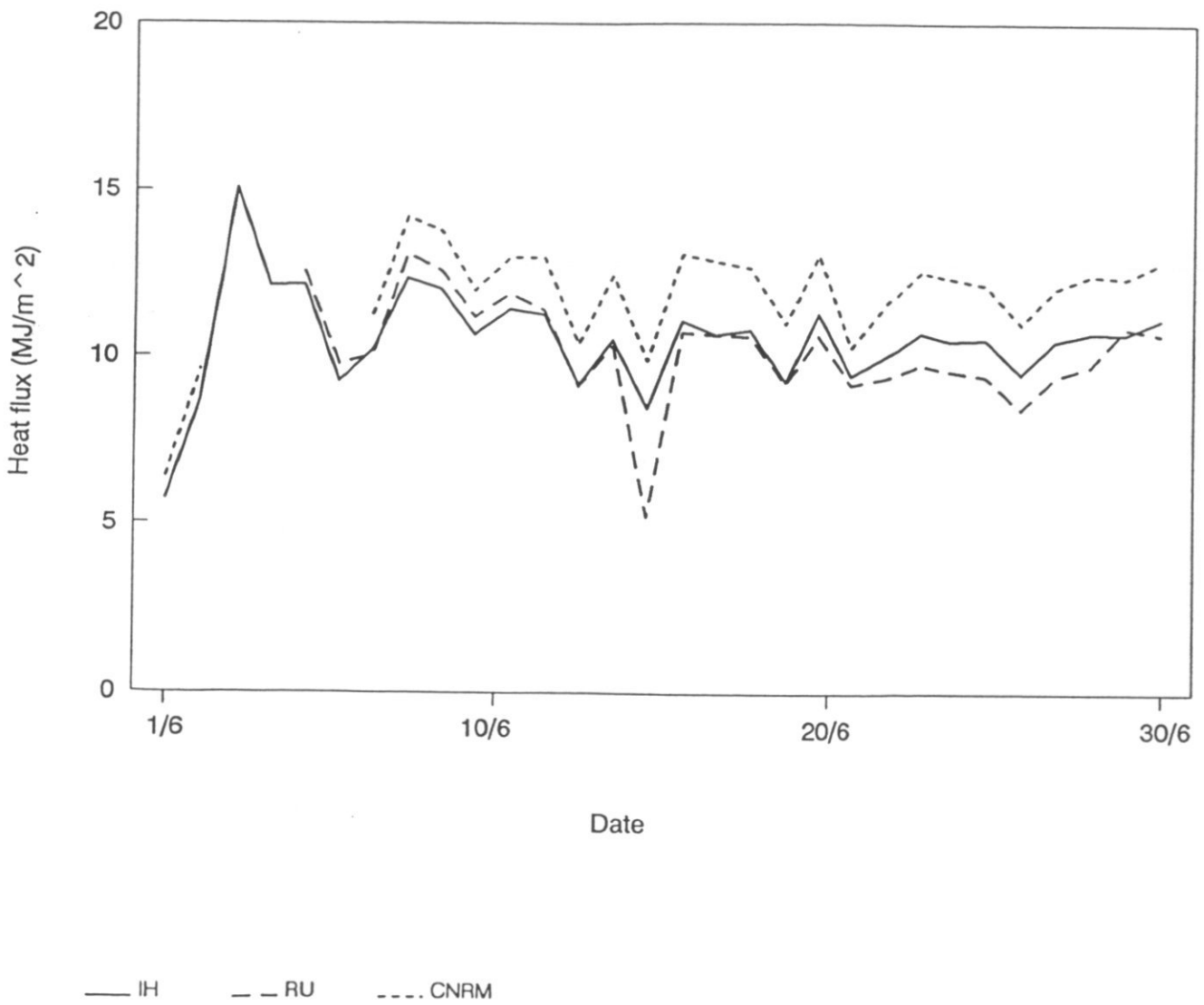


Figure 26

Vetch site - net radiation
(0900-1500 totals 1/6-30/6/91)

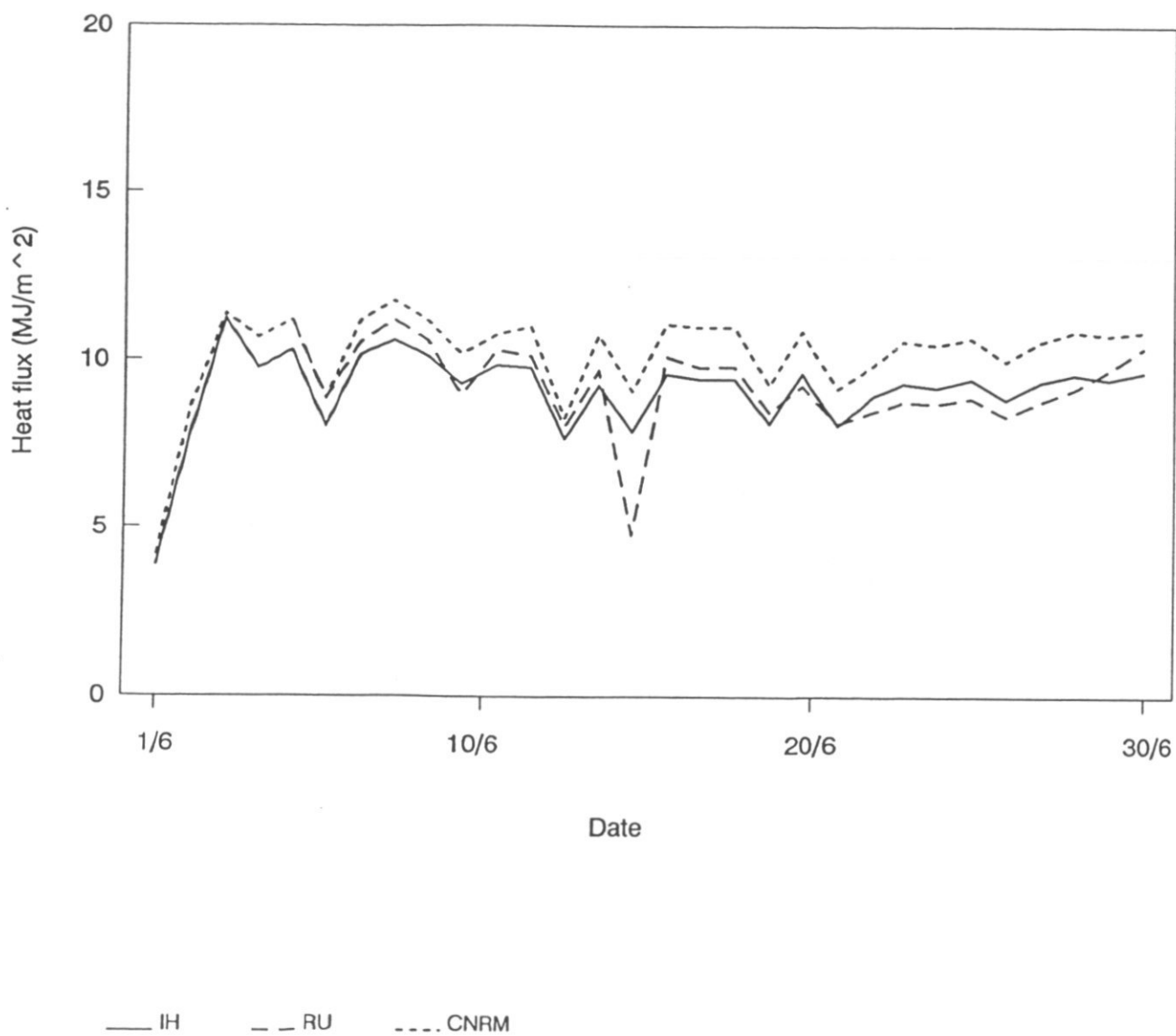


Figure 27

Vetch site - incoming long wave radiation

(21/6-30/6/91)

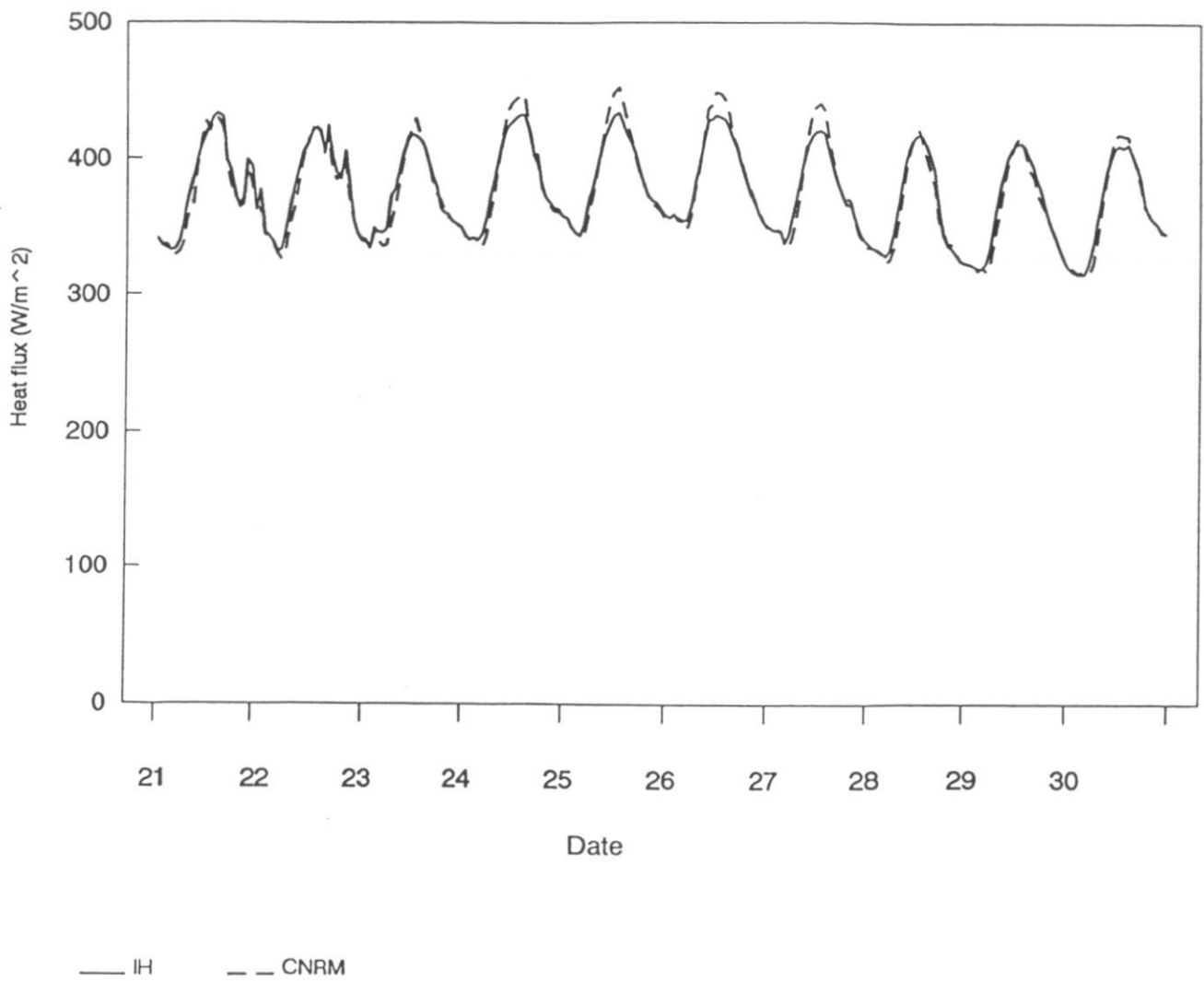


Figure 28

Vetch site - incoming long wave radiation

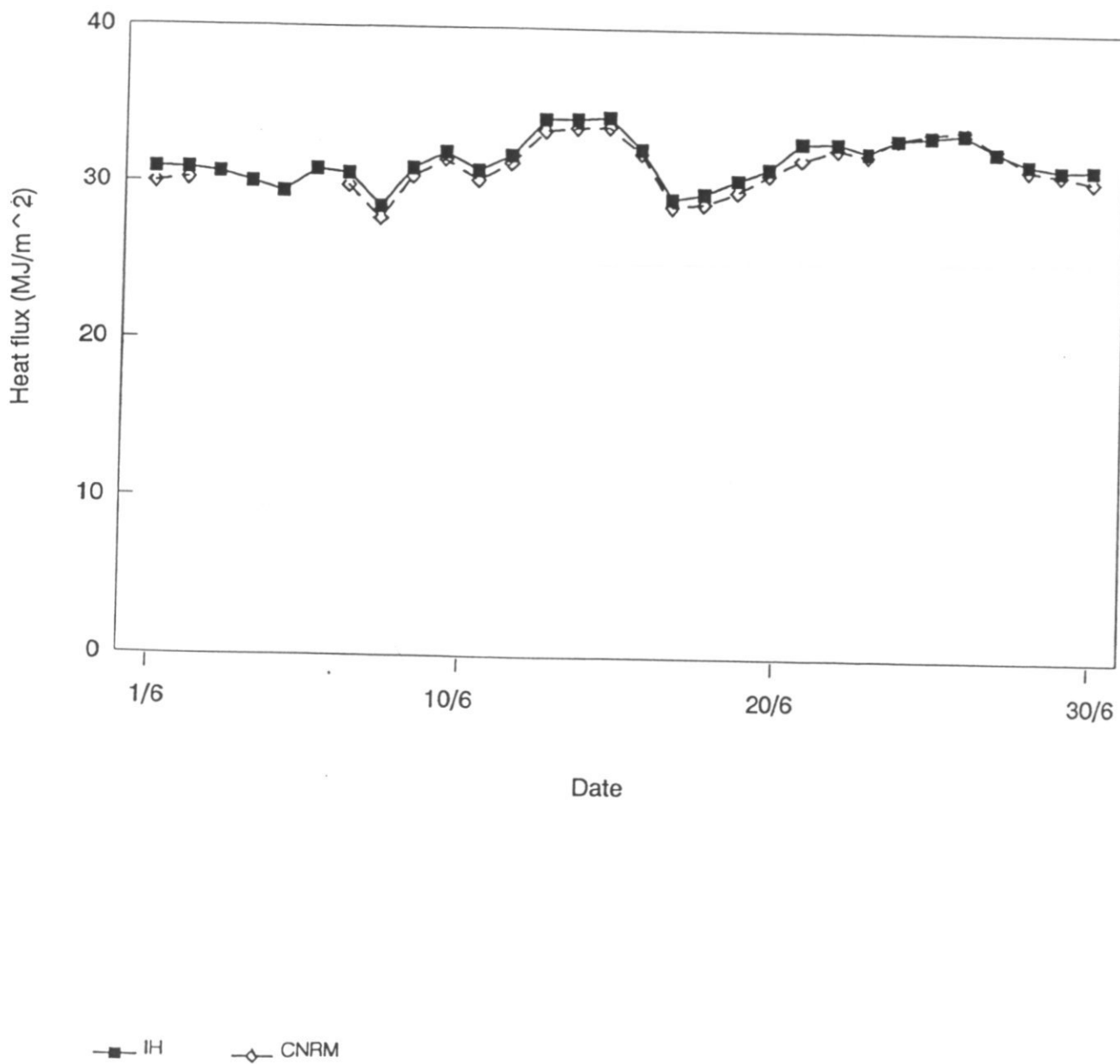


Figure 29

Vine site - soil heat flux

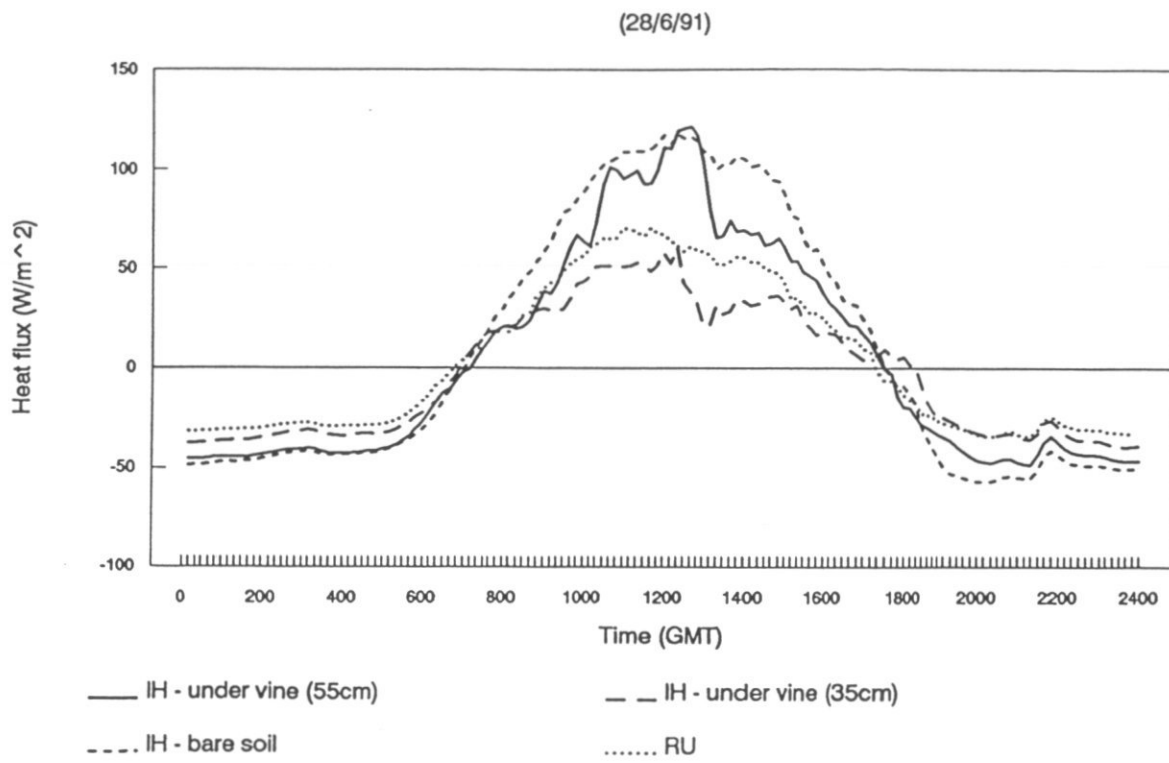


Figure 30

Vine site - soil heat flux

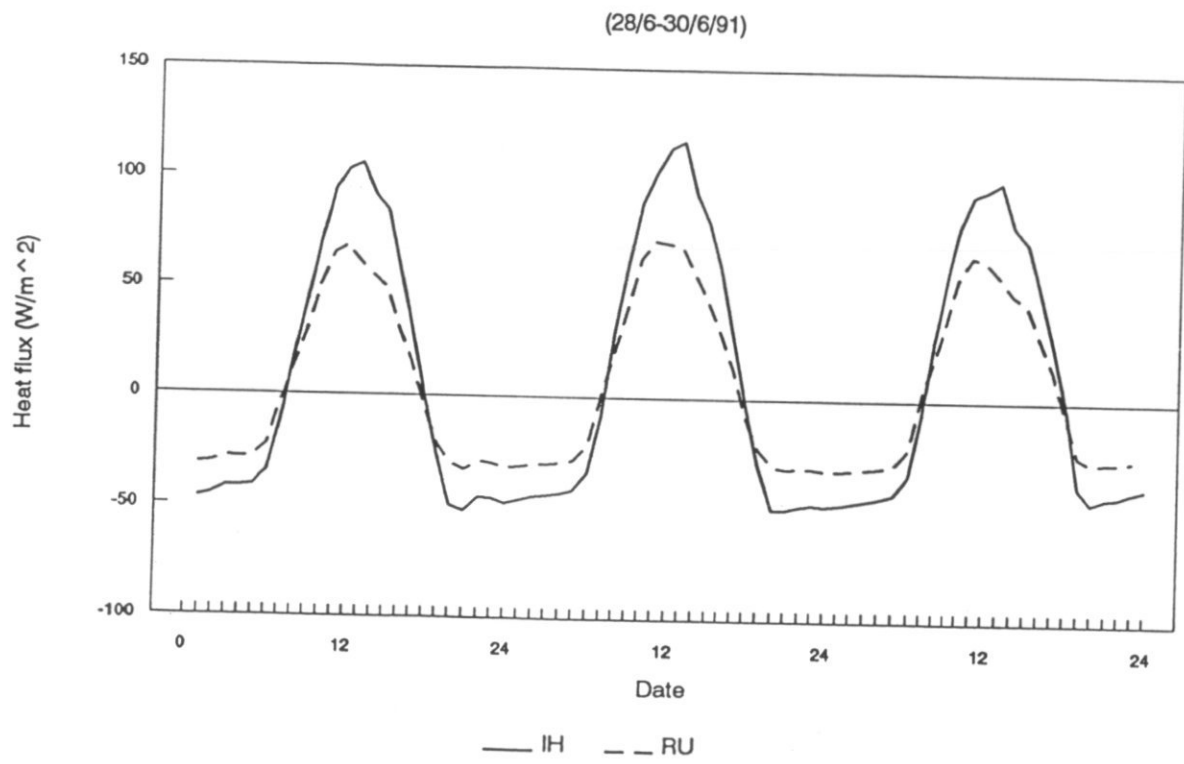


Figure 31

Vine site - soil heat flux

(24 hour totals, 1/6-30/6/91)

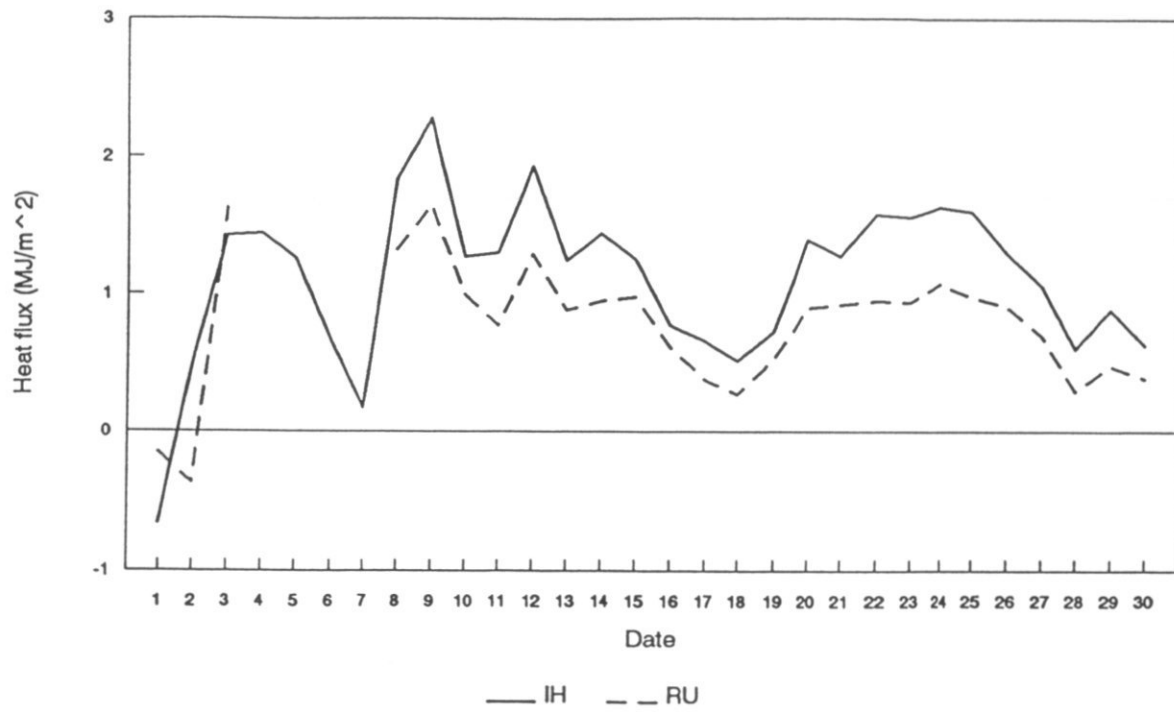


Figure 32

Vine site - soil heat flux

(0900-1500 totals, 1/6-30/6/91)

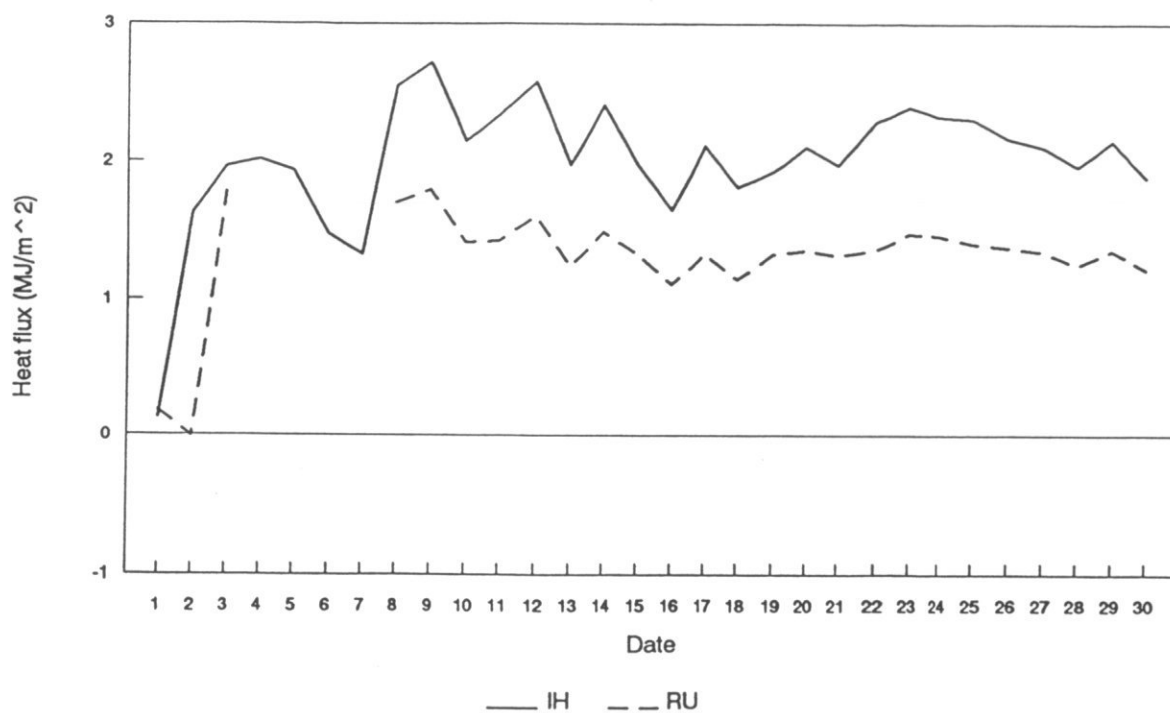


Figure 33

Vine site - soil heat flux

(Nighttime totals, 1/6-30/6/91)

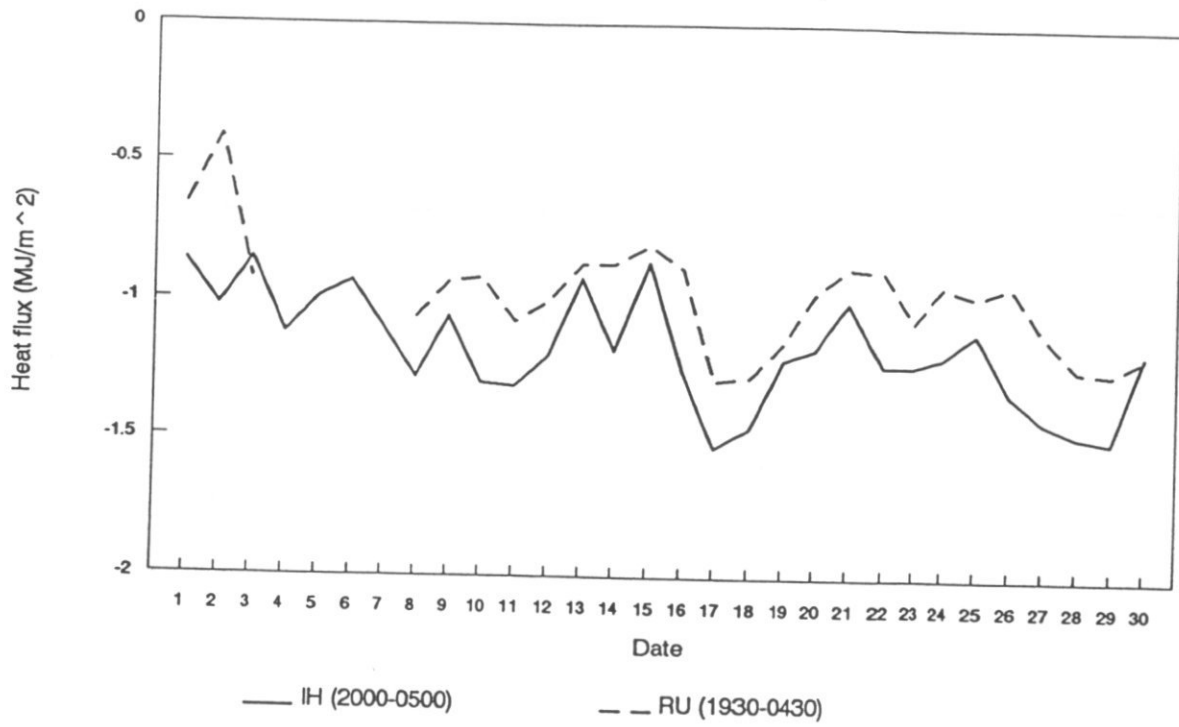


Figure 34

Vine site - soil heat flux

(0600-1900 totals, 1/6-30/6/91)

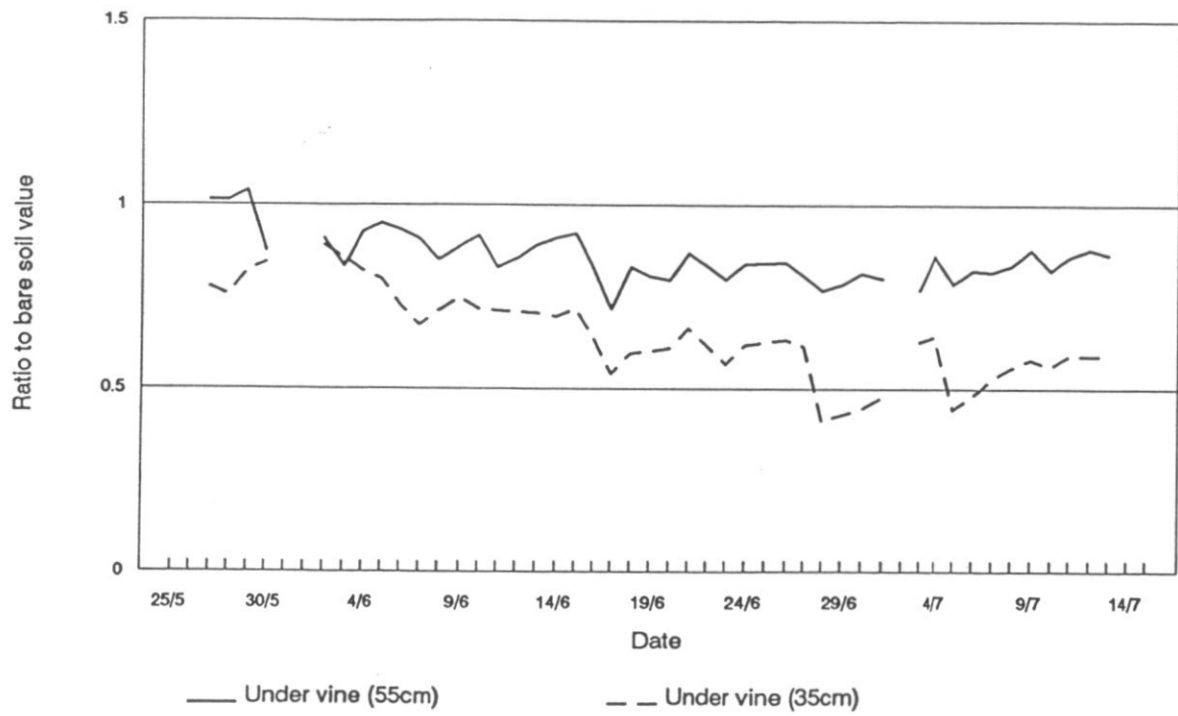


Figure 35

Vetch site - soil heat flux

(11/6/91)

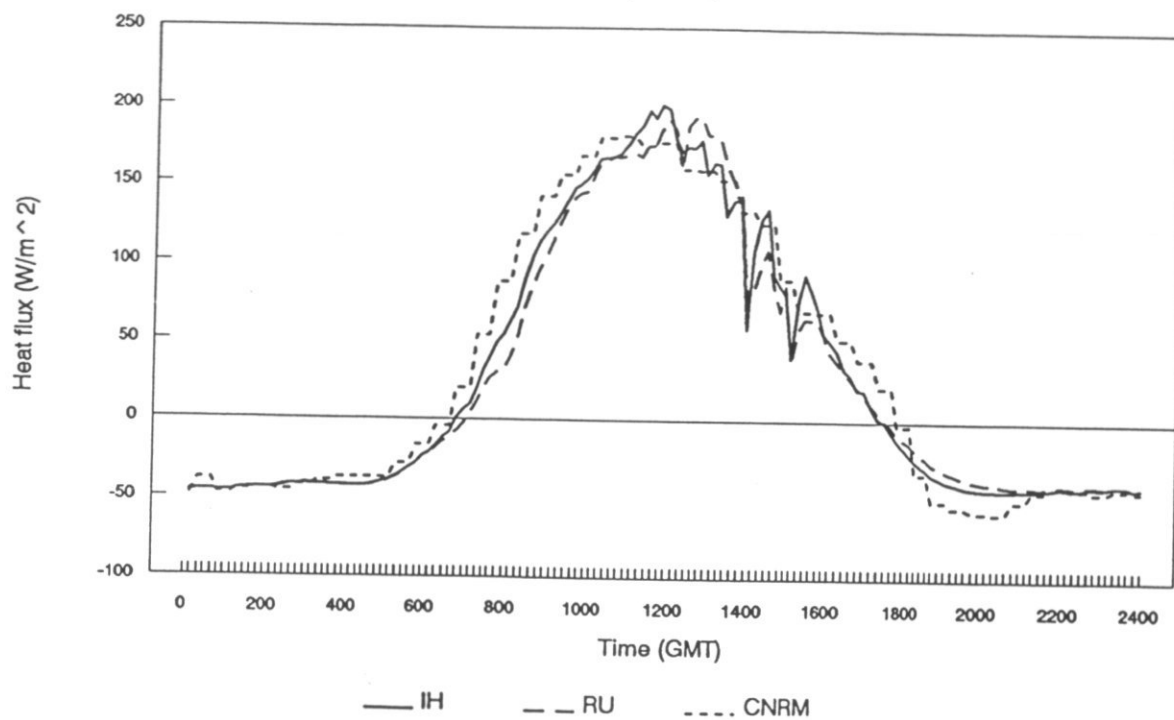


Figure 36

Vetch site - soil heat flux

(28/6-30/6/91)

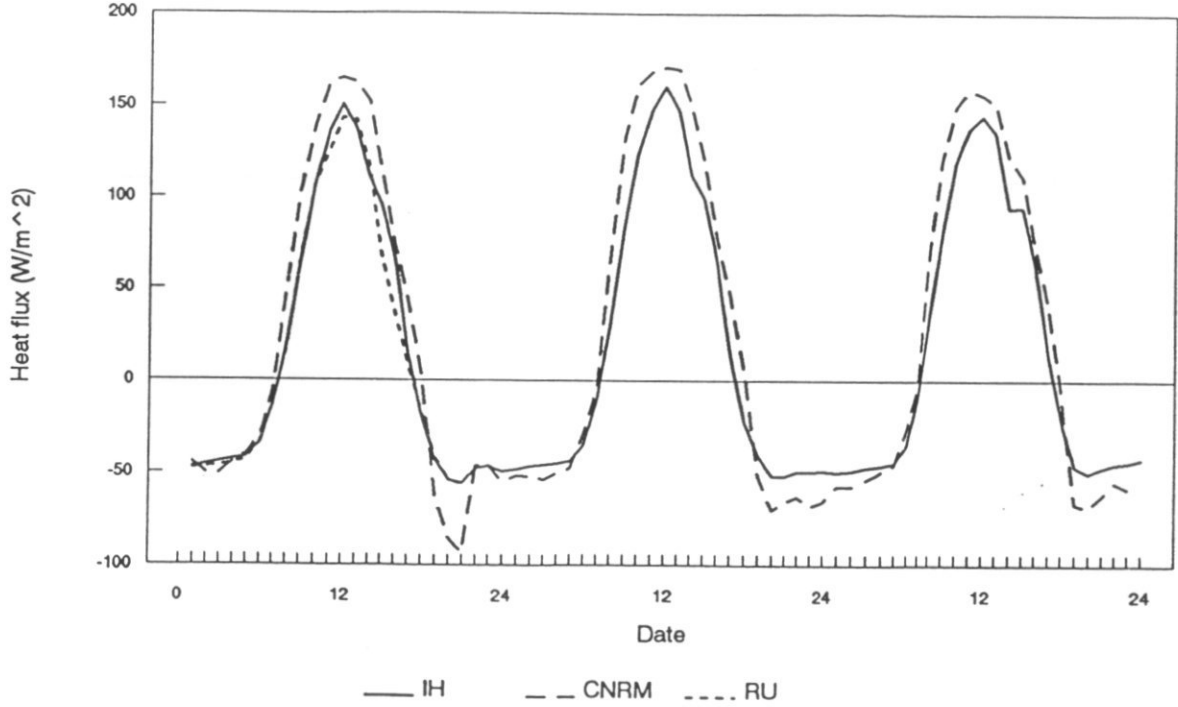


Figure 37

Vetch site - soil heat flux

(24 hour totals, 1/6-30/6/91)

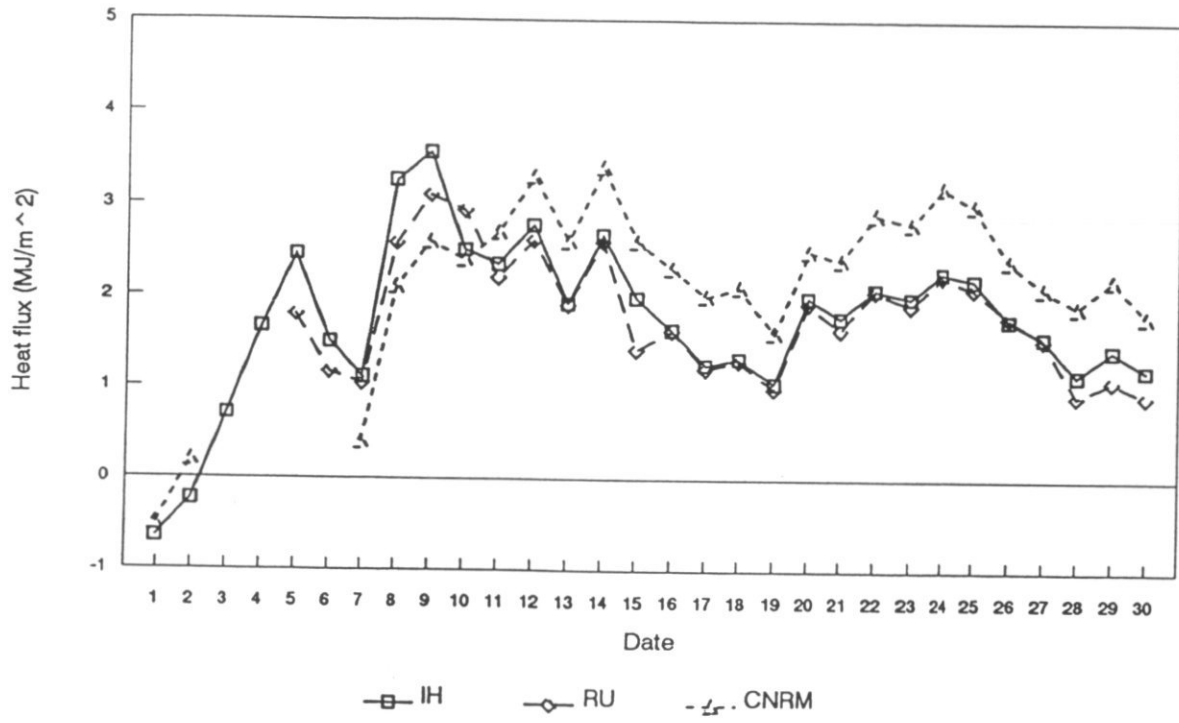


Figure 38

Vine site - sensible heat flux

(11/6/91)

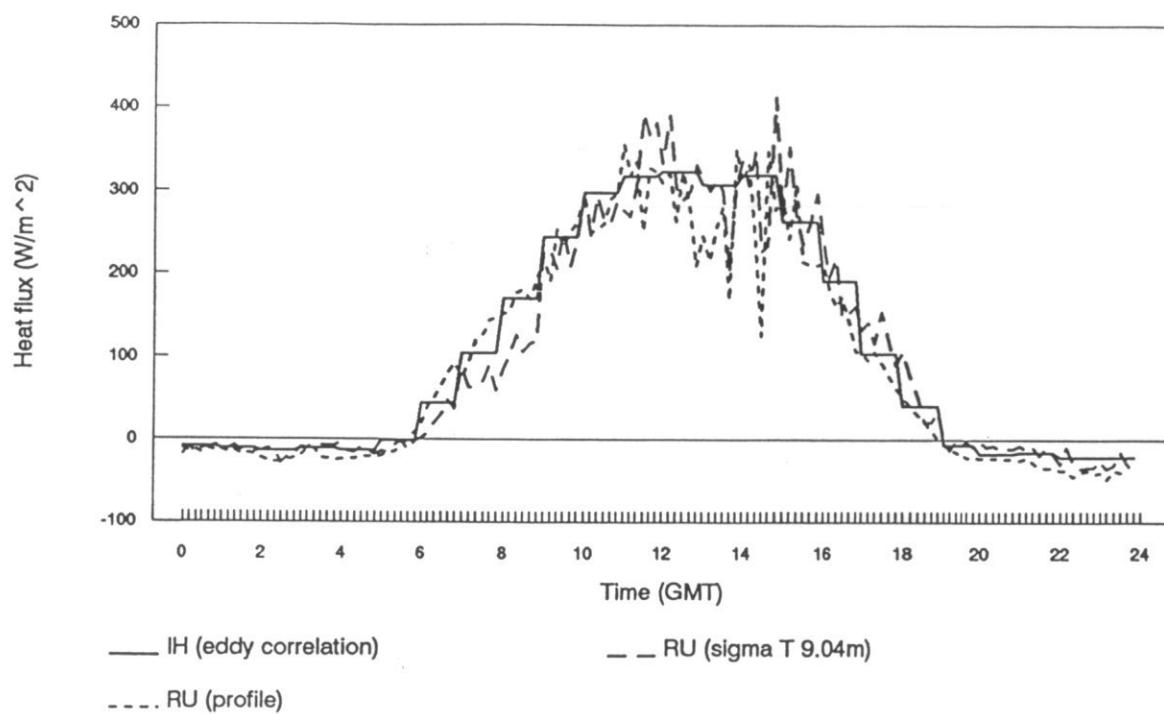


Figure 39

Vine site - sensible heat flux

(16/6-20/6/91)

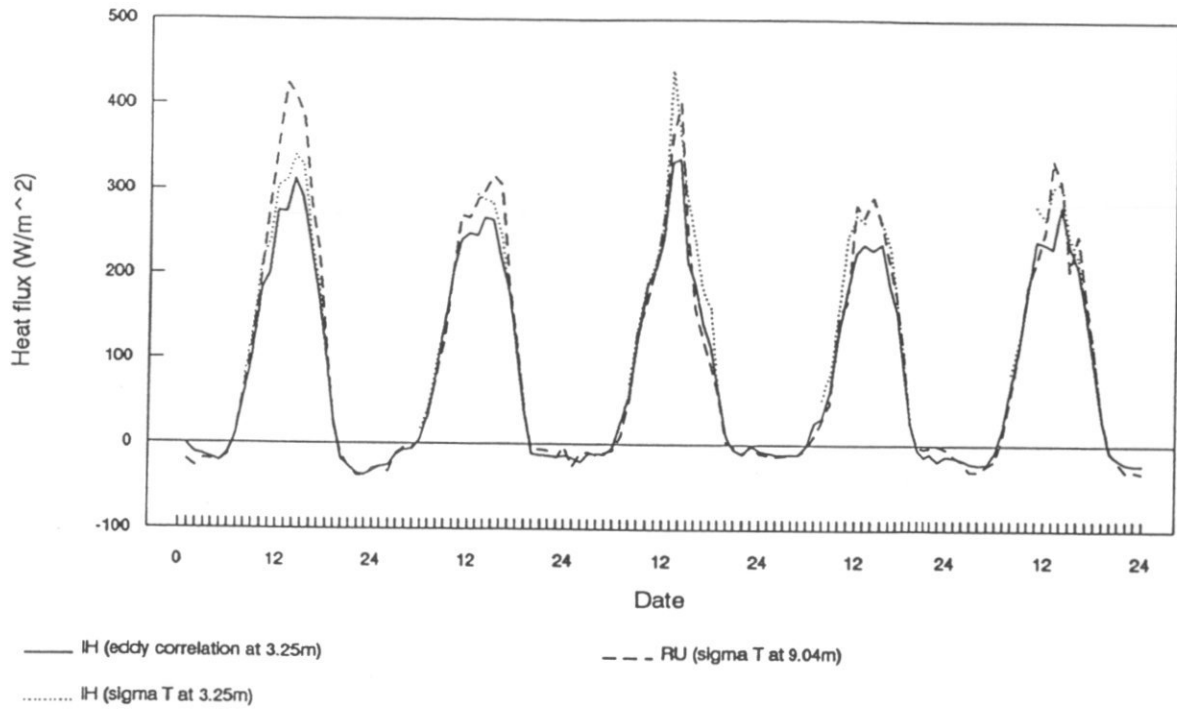


Figure 40

Vine site - sensible heat flux

(24 hour totals, 1/6-30/6/91)

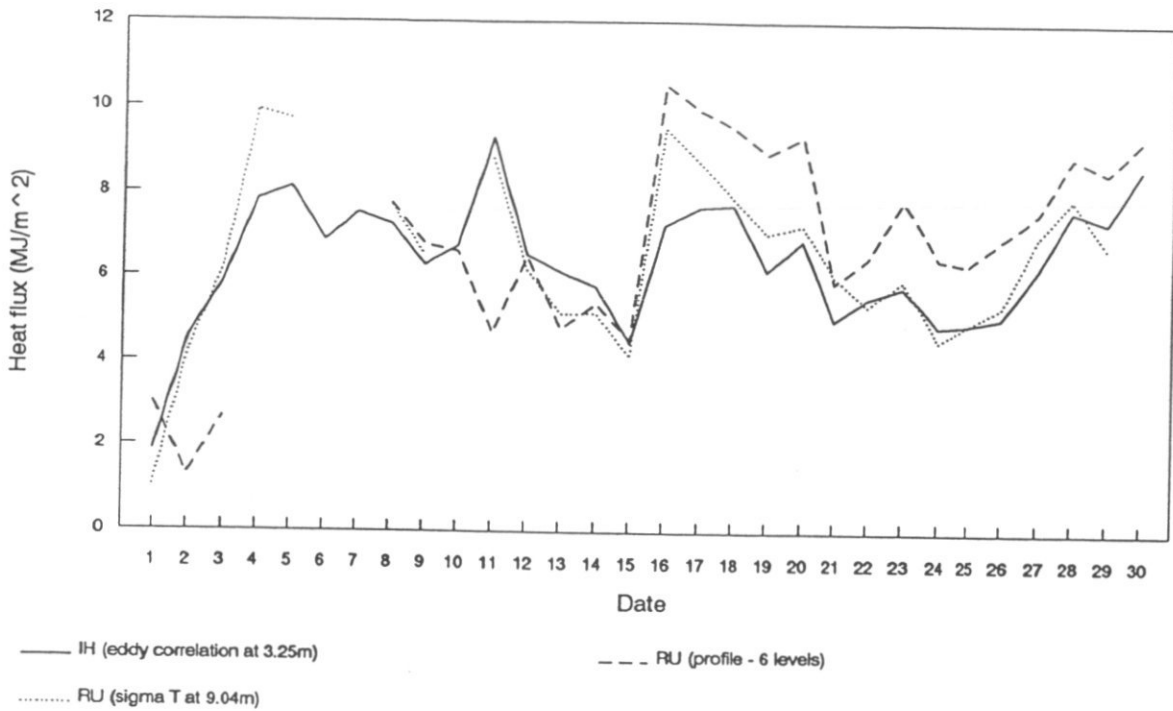


Figure 41

Vine site - sensible heat flux

(0900-1500 totals, 1/6-30/6/91)

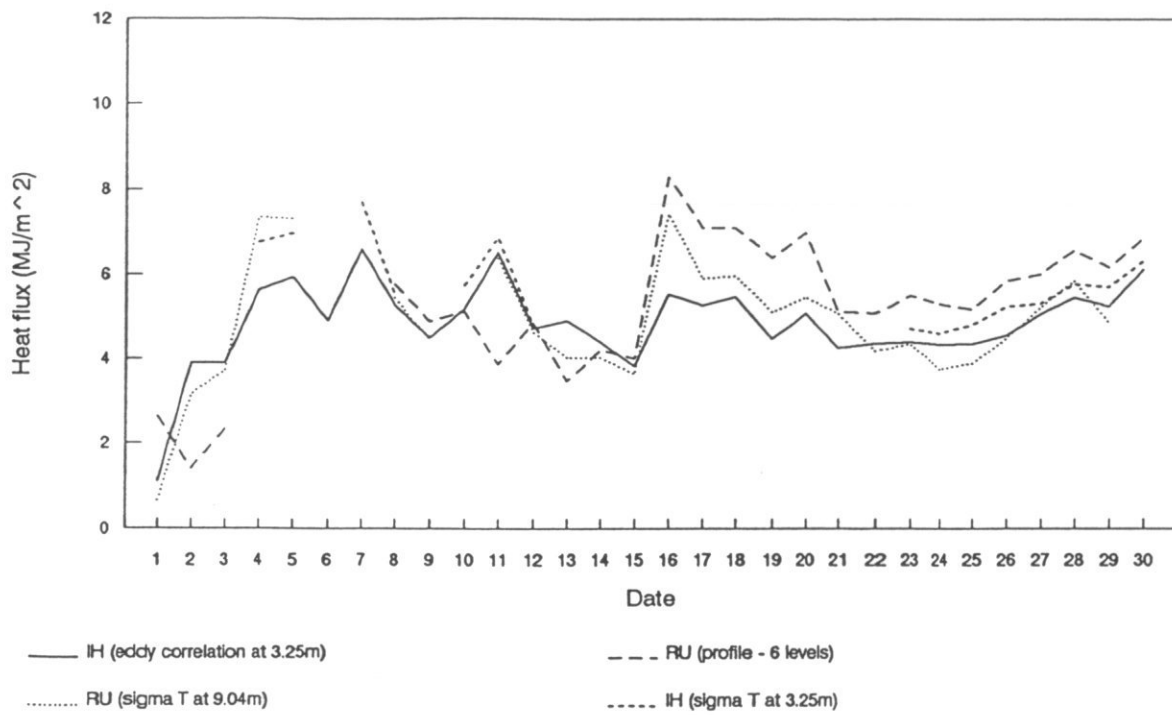


Figure 42

Vine site - sensible heat flux

(Nighttime totals, 1/6-30/6/91)

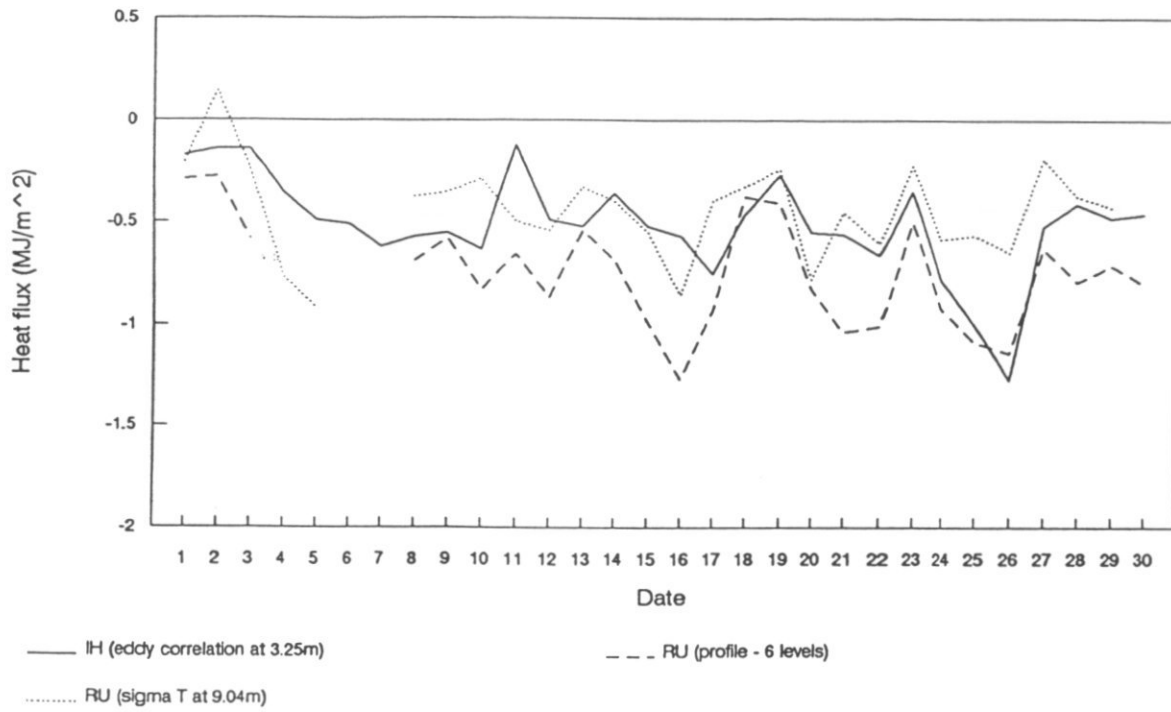


Figure 43

Vine site - sensible heat flux

Positive hourly average values 1/6-30/6/91

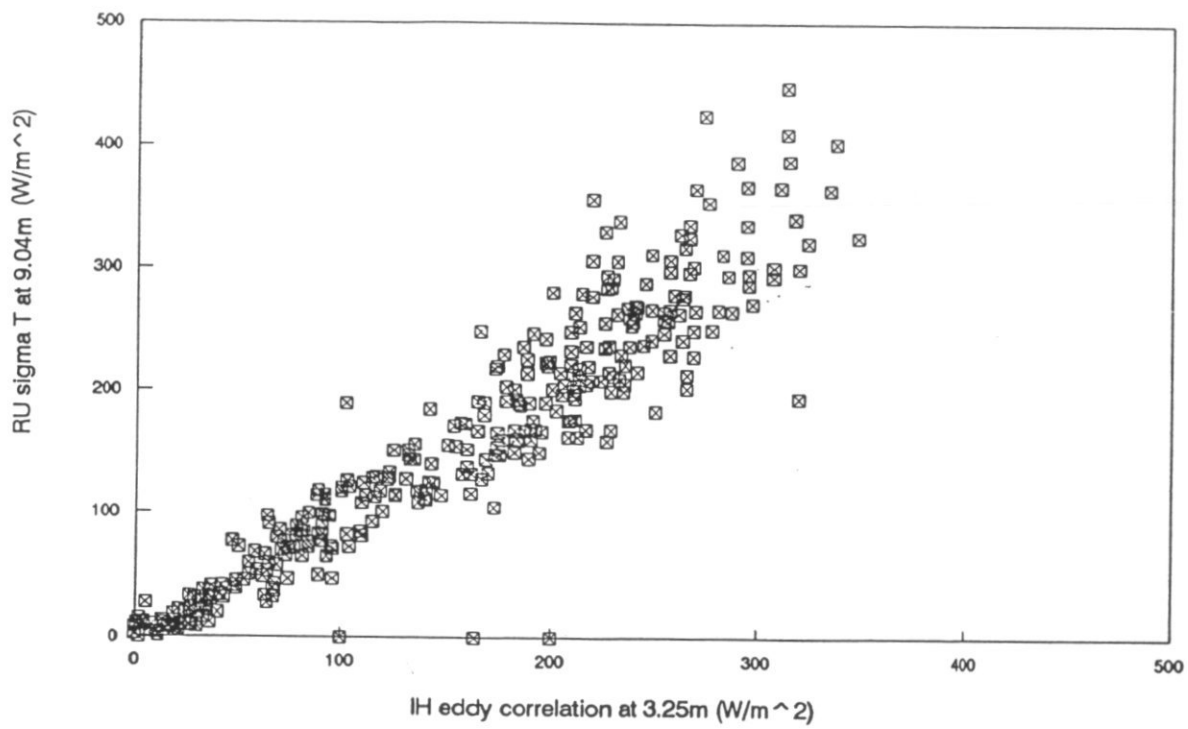


Figure 44

Vetch site - sensible heat flux

(11/6/91)

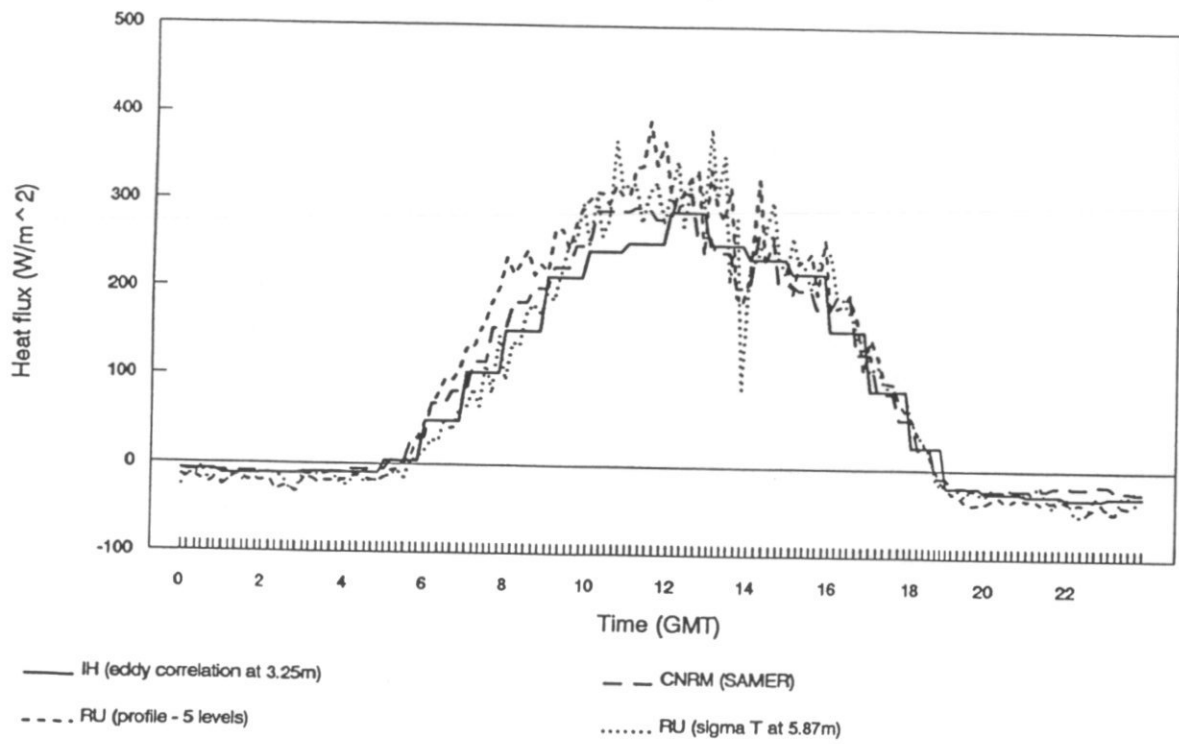
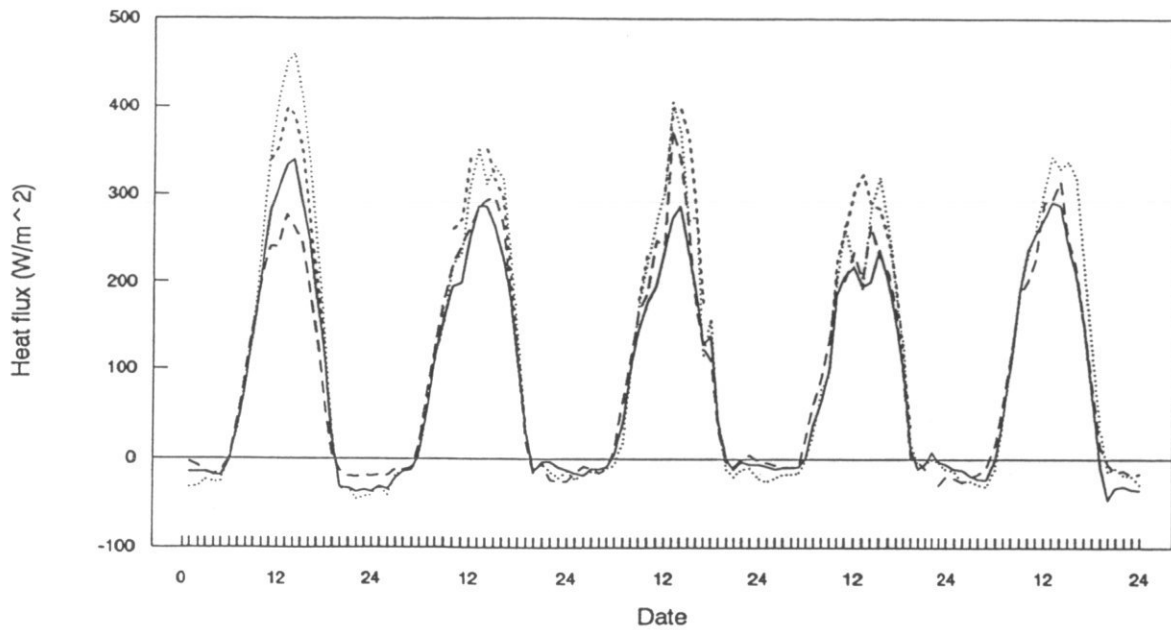


Figure 45

Vetch site - sensible heat flux

(16/6-20/6/91)



— IH (eddy correlation at 3.25m)

- - - CNRM (SAMER)

..... RU (sigma T at 5.87m)

- . - . IH (sigma T at 3.25m)

Figure 46

Vetch site - sensible heat flux

(24 hour totals, 1/6-30/6/91)

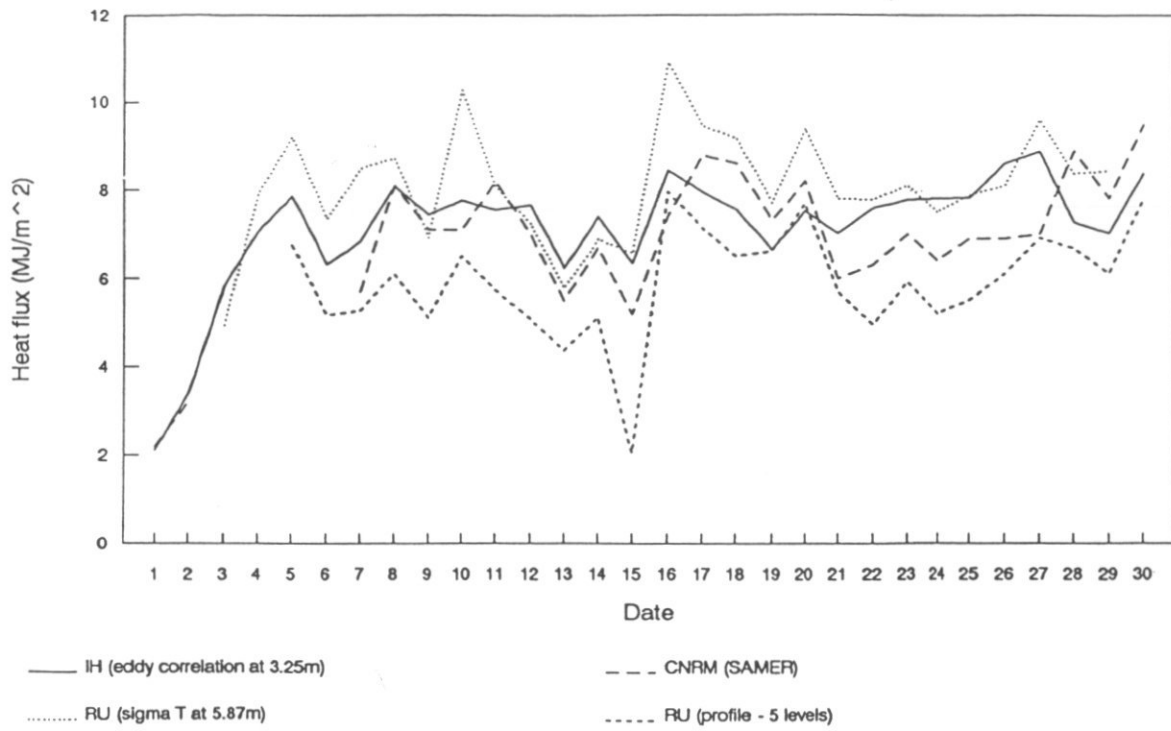


Figure 47

Vetch site - sensible heat flux

(0900-1500 totals, 1/6-30/6/91)

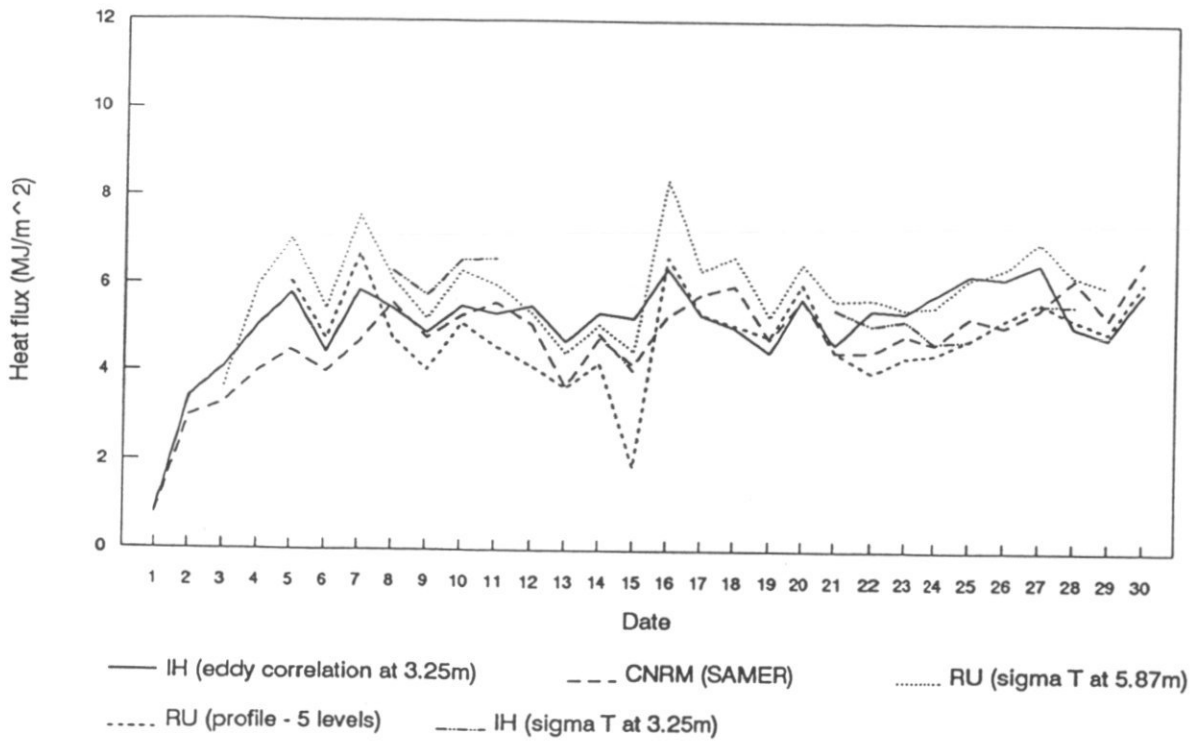


Figure 48

Vetch site - sensible heat flux

Positive hourly average values 1/6-30/6/91

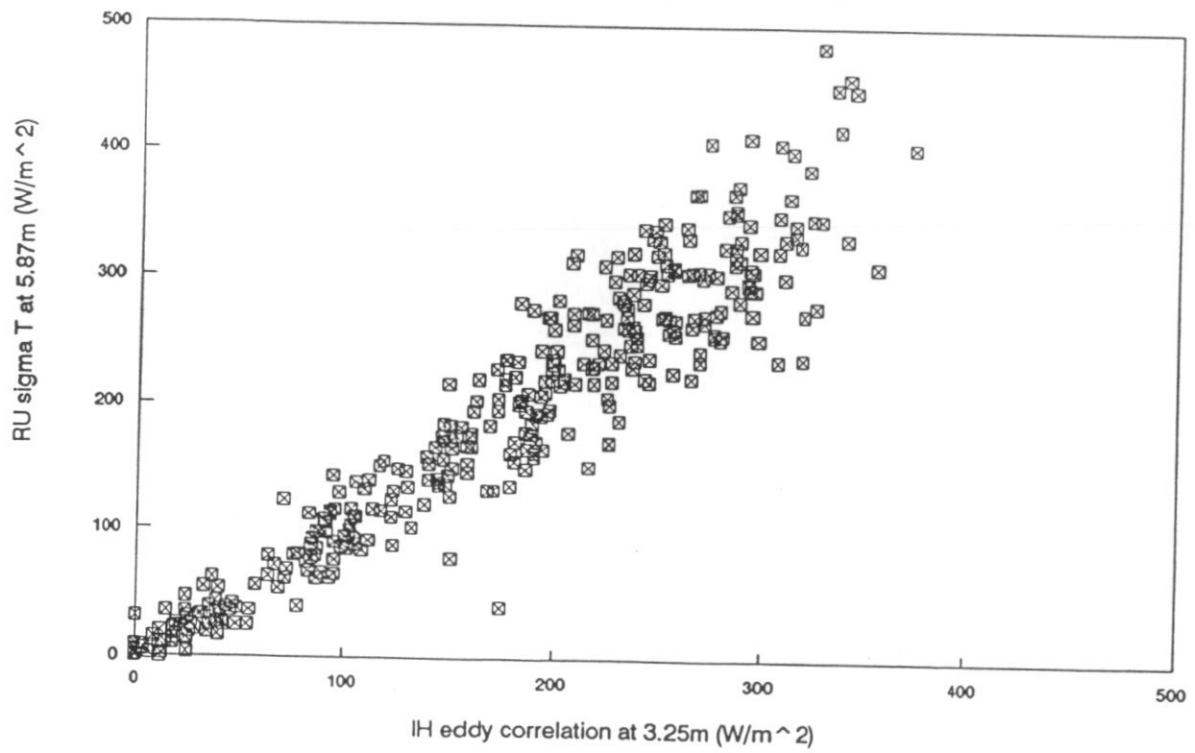


Figure 49

Vine site - friction velocity

(16/6-20/6/91)

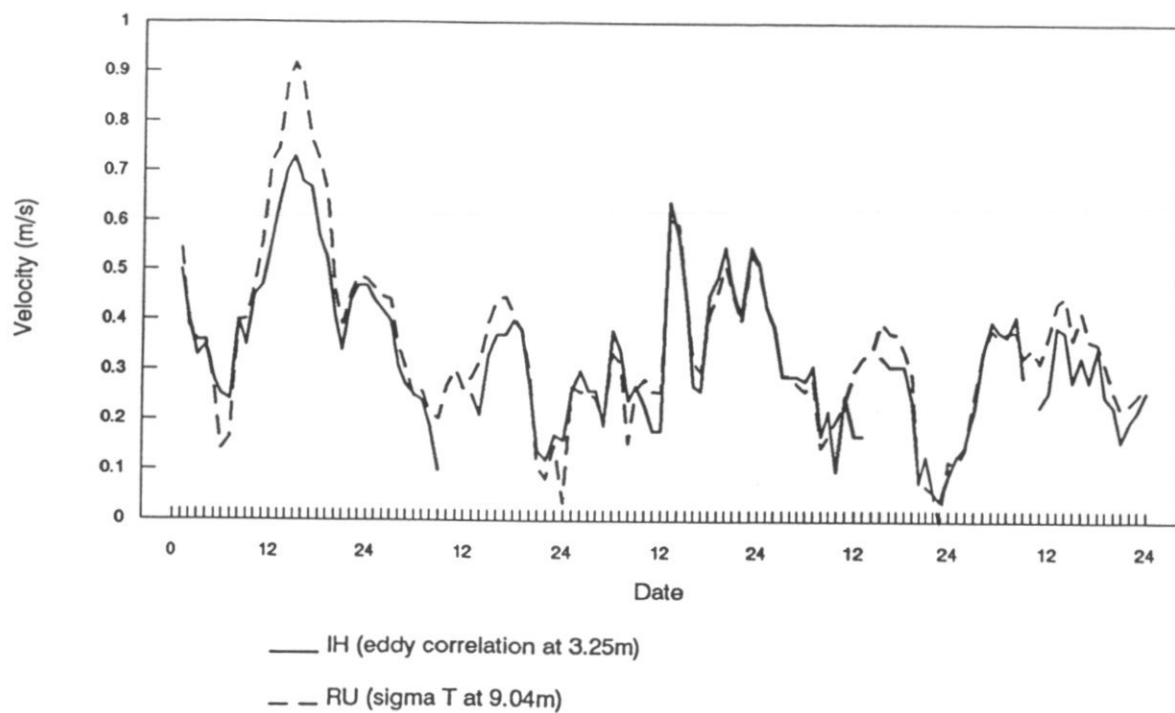


Figure 50

Vetch site - friction velocity

(16/6-20/6/91)

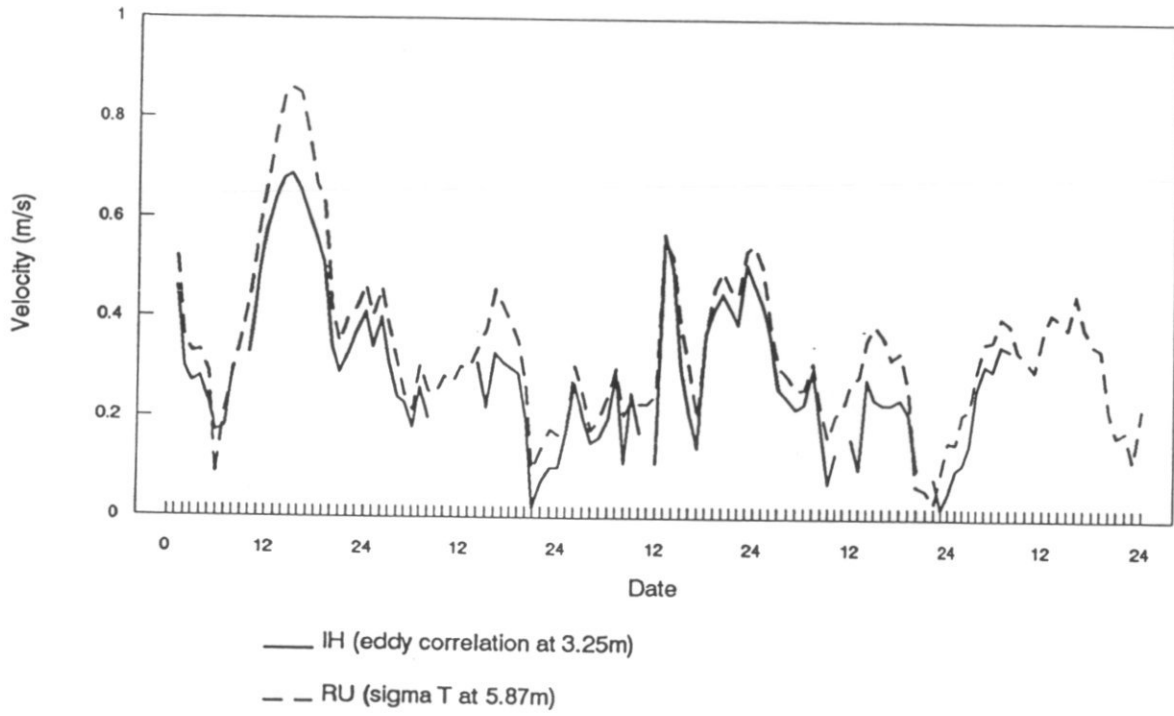


Figure 51

Vine site - latent heat flux

(24 hour totals, 1/6-30/6/91)

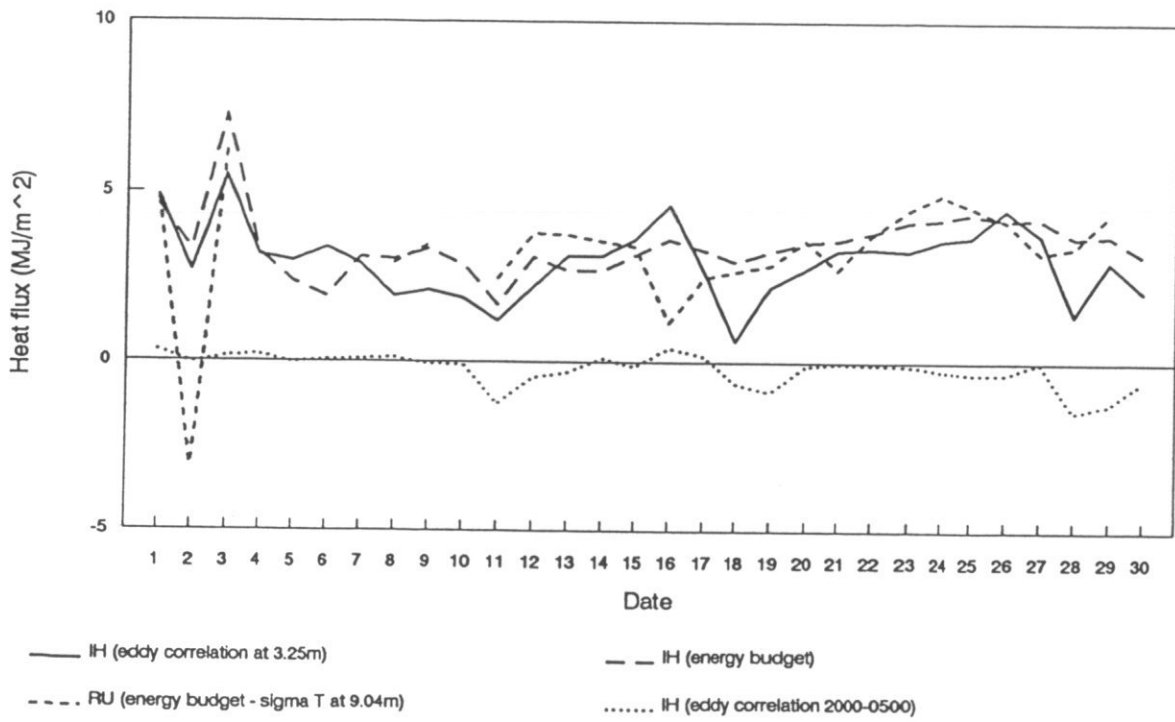


Figure 52

Vine site - latent heat flux

(0900-1500 totals, 1/6-30/6/91)

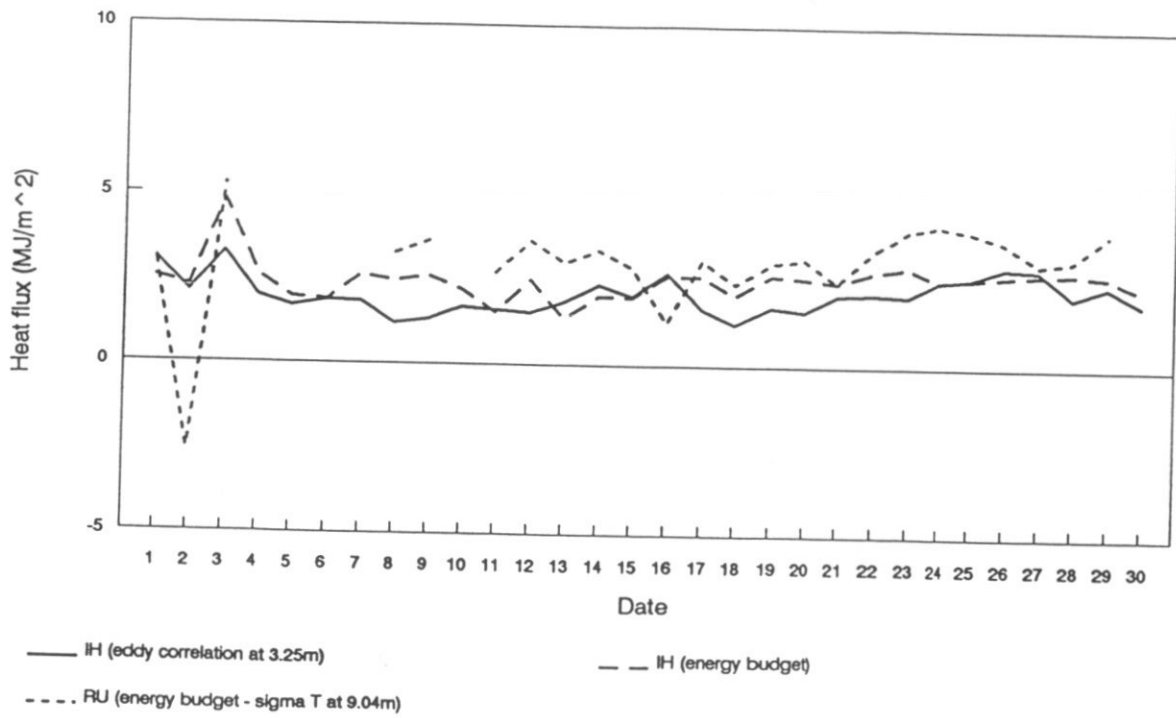


Figure 53

Vetch site - latent heat flux

(24 hour totals, 1/6-30/6/91)

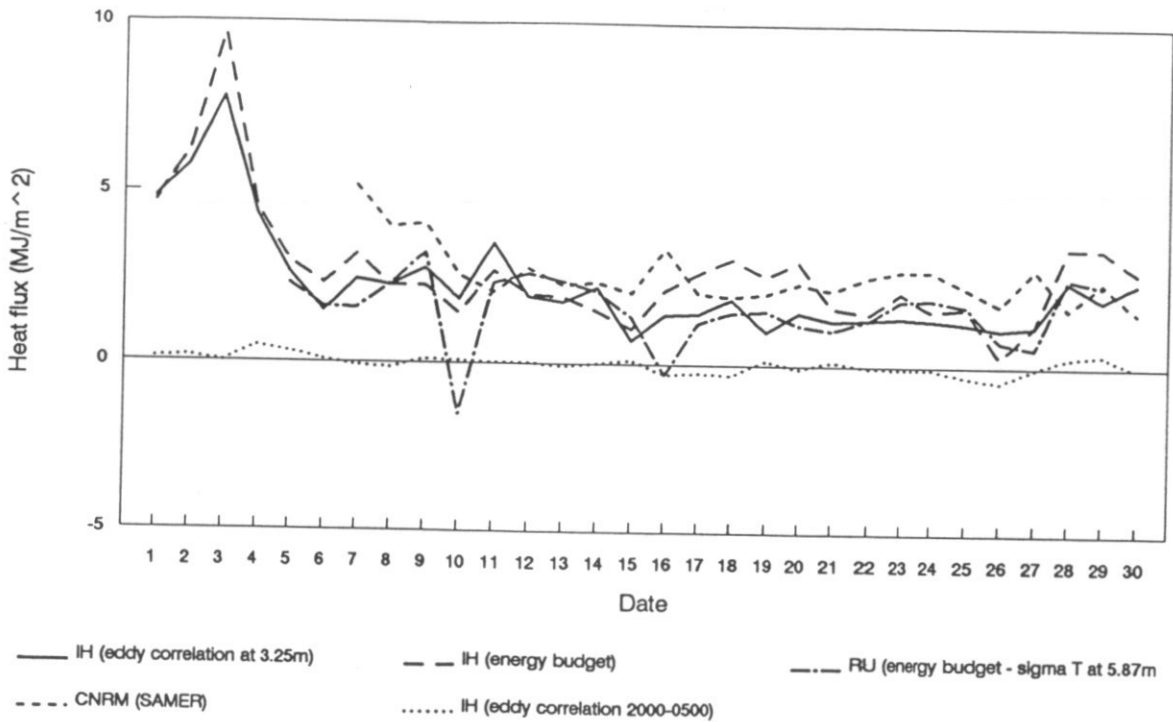


Figure 54

Vetch site - latent heat flux

(0900-1500 totals, 1/6-30/6/91)

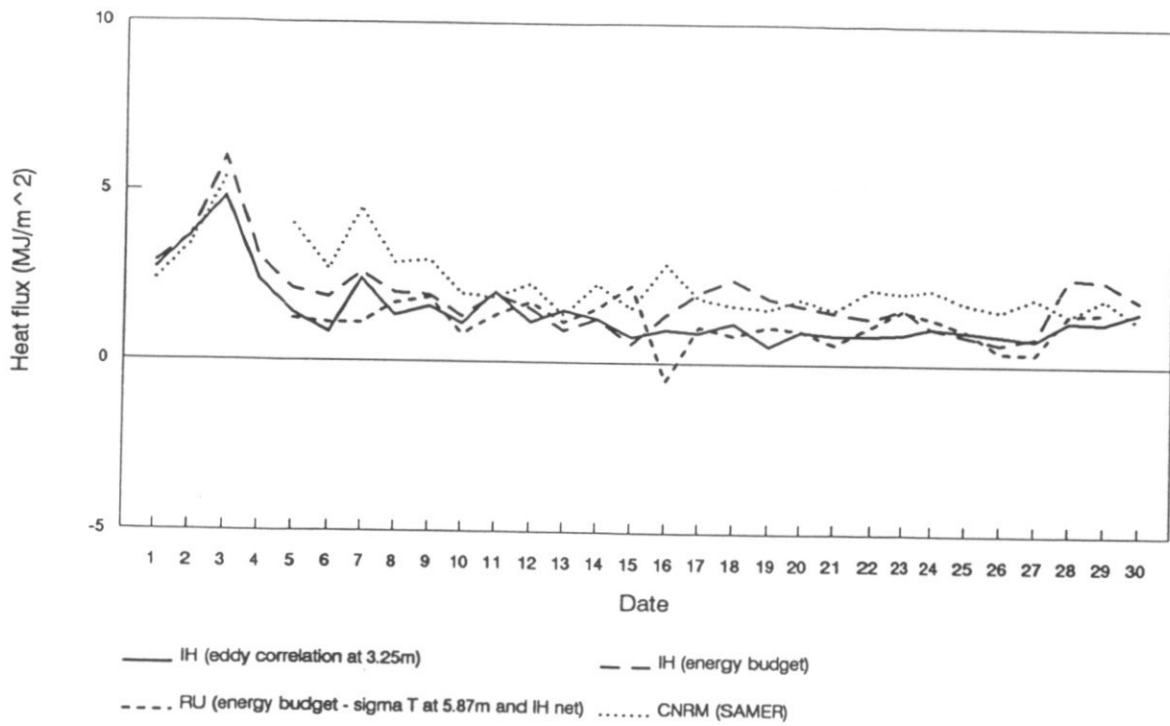


Figure 55

Vine site - cumulative evaporation

(based on 24 hour latent heat totals, 1/6-30/6/91)

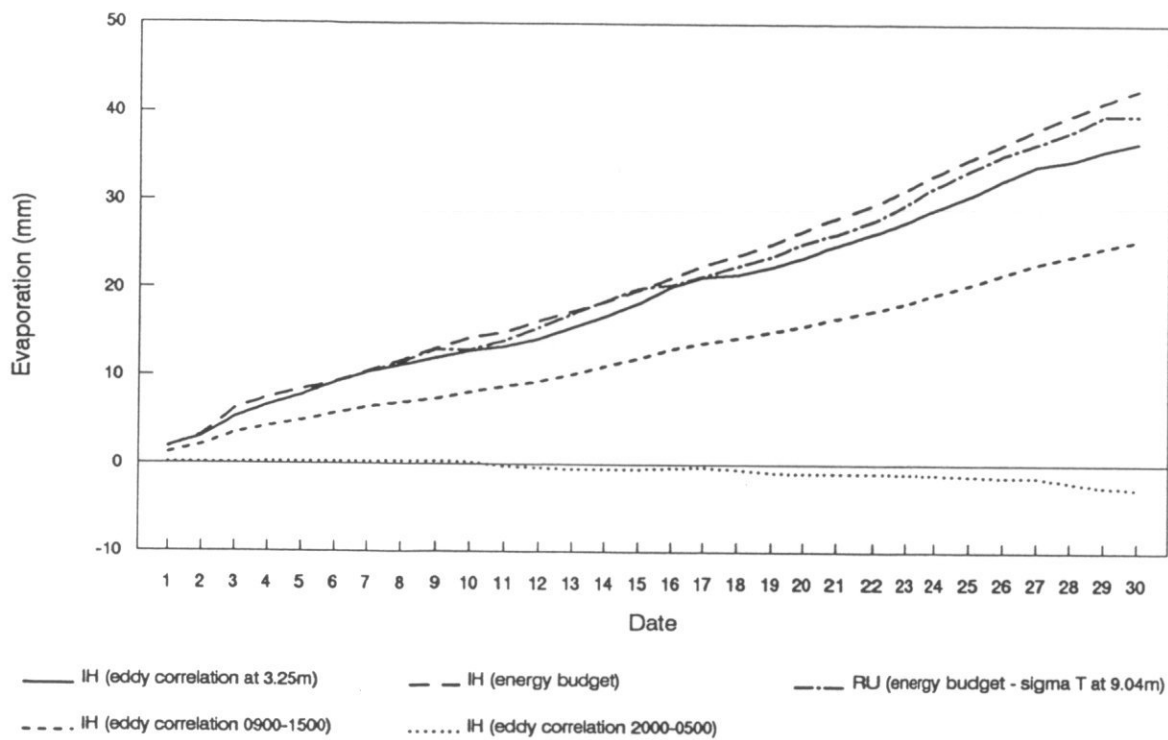
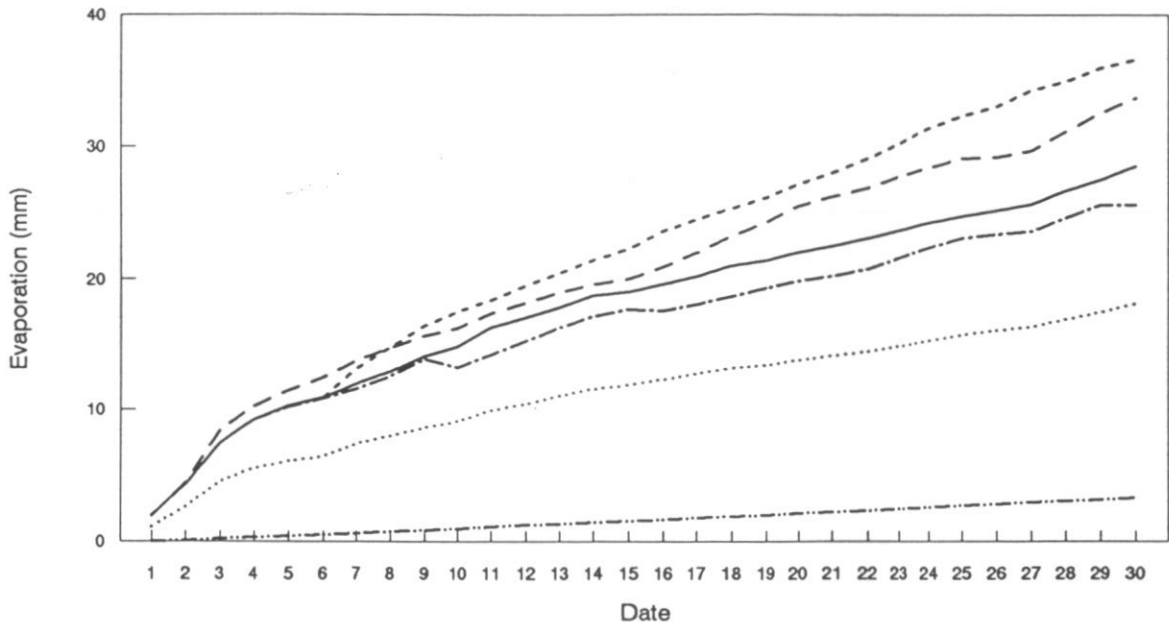


Figure 56

Vetch site - cumulative evaporation

(based on 24 hour latent heat totals, 1/6-30/6/91)



— IH (eddy correlation at 3.25m) - - - IH (energy budget) - - - RU (energy budget - sigma T at 5.87m)
 - - - CNRM (SAMER) IH (eddy correlation 0900-1500) - - - 1% of solar

Figure 57

