WORKING DOCUMENT

PREPARATION OF A CLIMATE DATA SET FOR THE MURRUMBIDGEE RIVER CATCHMENT FOR LAND SURFACE MODELLING EXPERIMENTS

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Working Document 03/1
February 2003

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EXECUTIVE SUMMARY

This report describes the preparation of a climate data set for ten locations in the Murrumbidgee River Basin; Balranald, Hay, Griffith, Yanco, West Wyalong, Cootamundra, Kyeamba, Adelong, Canberra and Cooma. The data will be used as forcing data for land surface modelling experiments. The locations coincide with the sites in the CRC's Murrumbidgee River Basin soil moisture monitoring program.

The climate data prepared are 30-minute time series of rainfall, air temperature, specific humidity, wind speed, wind direction, incoming shortwave radiation and incoming longwave radiation. At present, the data have been compiled for the period from January 2000 to June 2002. The data will be updated every six months.

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1. PURPOSE OF DATA PREPARATION

Meso-LAPS is one of the operational weather prediction models employed by the Bureau of Meteorology for the Australian region. The soil moisture field in the model is integrated within the land surface scheme (LSS) of Viterbo and Belijaas, 1995 (VB95). Soil moisture has a significant influence on the latent and sensible heat fluxes between the ground and the lowest layers of the atmosphere. These fluxes contribute to the temperature and humidity structure of the atmospheric boundary layer and thus ultimately influence rainfall and other meteorological forecasts.

To initialise the soil moisture field, the LSS is run off-line and is forced by observed climate data. To test the soil moisture and soil temperature predictions of the LSS and to evaluate its overall performance within the weather prediction framework, a monitoring exercise is being undertaken across the Murrumbidgee catchment. The core of the monitoring network consists of eighteen sites, with two groups of five in Kyeamba and Adelong Creeks and eight other sites associated with Bureau of Meteorology (BoM) meteorological stations across the Murrumbidgee catchment.

The purpose of this analysis is to prepare a 30-minute interval climate data set for ten locations in the Murrumbidgee catchment for carrying out land surface modelling experiments. At present, the data set covers a period of two and half years from January 2000 to June 2002 and it will then be updated every six months. The locations for which the climate data are prepared are Balranald, Hay, Griffith, Yanco, West Wyalong, Cootamundra, Kyeamba, Adelong, Canberra and Cooma. Kyeamba and Adelong creeks are catchments while the other eight locations coincide with BoM meteorological stations. The ten locations are shown in Figure 1.1

Half-hourly climate data required for the VB95 experiments are:

- Rainfall (mm) (30-minute accumulation)
- Air temperature (^{o}C) (instantaneous)
- Specific humidity (g/kg) (instantaneous)
- Wind speed (m/s) (averaged over previous 10 minutes)
- Wind direction (averaged over previous 10 minutes)
- Incoming shortwave radiation (W/m^2) (instantaneous)
- Incoming longwave radiation (W/m^2) (instantaneous)

Rainfall, air temperature, wind speed and wind direction are measured directly at the climate stations. The specific humidity, incoming shortwave and longwave radiation are computed from other climate variables such as dew point temperature, station level pressure, cloud cover and sunshine hours.

2. DATA SOURCES AND AVAILABILITY OF CLIMATE DATA

The sources of data used in this study are:

- ***Half-hourly or hourly*** Australian Weather Services (AWS) climate data obtained directly from BoM meteorological stations (rainfall, air and dew point temperatures, wind speed, wind direction and atmospheric pressure);
- ***Three-hourly climate data*** at BoM meteorological stations obtained from the National Climate Centre of Bureau of Meteorology (air and dew point temperatures, wind speed and wind direction, cloud cover and atmospheric pressure);
- ***Six minutes rainfall data*** from CRC soil moisture monitoring stations (SMS);
- ***Daily data*** obtained from the National Climate Centre of BoM (daily rainfall and sunshine hours);
- ***Half-hourly solar radiation data*** obtained from the National Climate Centre of BoM;

- ***Satellite derived daily solar radiation data***; obtained from SOLARNET CD-ROM of BoM (with databases and associated extraction programs).

The stations used in this study are shown in Figure 1.1 and are listed in Table 2.1. Availability of data at these stations is summarised in Tables 2.2-2.6.

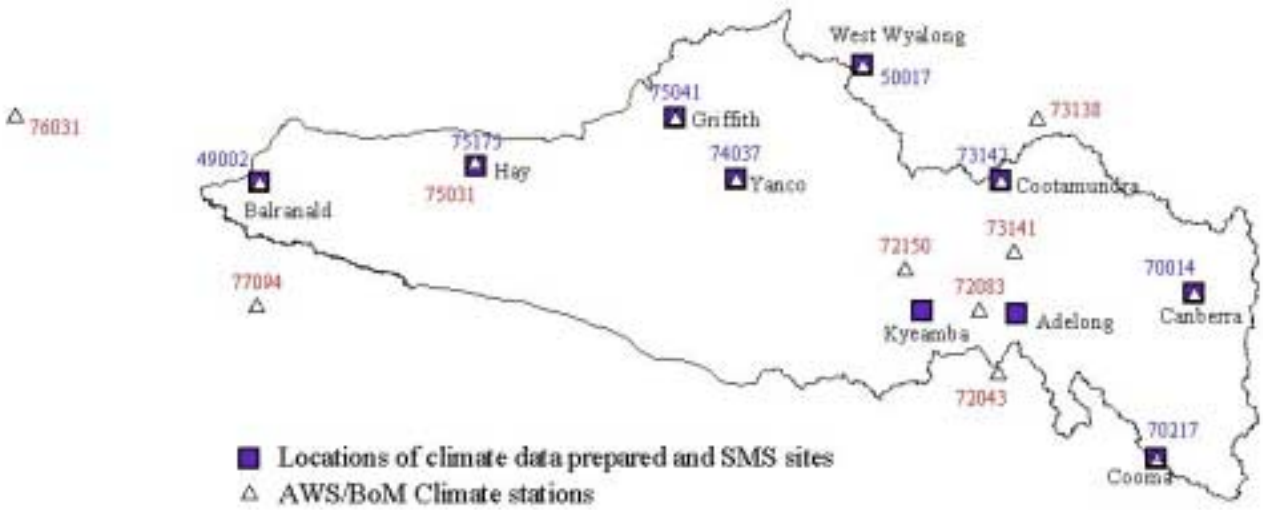

Figure 1.1: Climatological stations used in the study

Table 2.1: Climatological stations used for preparation of climate data set

Location	Station Name	Code	Longitude	Latitude	Height (m)
Balranald	Balranald RSL# *	49002	143.559	-34.641	61
	Swan Hill Aerodrome+	77094	143.540	-35.378	71
Hay	Hay CSIRO+ *	75175	144.867	-34.547	90
	Hay (Miller Street)#	75031	144.855	-34.519	93
Griffith	Griffith Airport+ *	75041	146.070	-34.249	134
Yanco	Yanco Agricultural Institute+ *	74037	146.433	-34.622	164
West Wyalong	West Wyalong Airport+ *	50017	147.196	-33.938	257
Cootamundra	Cootamundra Airport# *	73142	148.036	-34.630	335
	Young Airport#	73138	148.248	-34.249	380
'Kyeamba' (Wagga Wagga)	Wagga Wagga AMO+	72150	147.457	-35.158	212
	Kyeamba (Gentle Slope)*	-	147.559	-35.408	-
'Adelong'	Tumbarumba Post Office#	72043	148.012	-35.778	645
	Gundagai (William Street)#	73141	148.108	-35.048	250
	Adelong (Strathvale)*	-	148.132	-35.428	-
	Willows**	72083	147.90	-35.50	-
Canberra	Canberra Airport+ *	70014	149.201	-35.305	578
Cooma	Cooma Airport+ *	70217	148.973	-36.294	930
	Mildura++	76031	142.083	-34.233	-

+ AWS station (half-hourly or hourly data)
# BoM climate station (three-hourly data)
* CRC soil moisture monitoring sites (used for rainfall only)
** BoM rainfall station (used for daily rainfall only)
++ BoM station used for derivation of incoming shortwave radiation only

Table 2.2: Availability of AWS data

Station	Data frequency	Air Temp	Dew Temp	Wind speed[2]	Wind direction	Rainfall	Sea level Pressure[4]
Swan Hill (77094)	30-min	✓	✓	✓	✓	✓	✓
Hay (75175)	1-hour	✓	✓	✓	×	✓(3)	×
Griffith (75041)[1]	1-hour	✓	✓	✓	✓	✓	✓
Yanco (74037)	1-hour	✓	✓	✓	✓	✓	✓
West Wyalong (50017)	1-hour	✓	✓	✓	✓	✓	✓
Wagga Wagga (72150)	30-min	✓	✓	✓	✓	✓	✓
Canberra (70014)	30-min	✓	✓	✓	✓	✓	✓
Cooma (70217)	1-hour	✓	✓	✓	✓	✓	✓

1 : Griffith – No data from 01/01/2000 – 12/06/2000
2 : At Hay wind speed is measured at 2m height; at all other sites wind speed is measured at 10m height;
3 : Hay – No rainfall data from 01/01/2000 – 27/03/2000
4 : Mean sea level pressure is given; these data need to be converted to station level pressure for computation of specific humidity

Table 2.3: Availability of three-hourly data (THD)
(the data are provided at three-hourly intervals with 8 observations per day unless otherwise noted)

Station Name	Air temp	Dew point temp	Wind speed (7)	Wind direction	Cloud cover	Station level pressure
Balranald (49002)	✓(1)	✓(1)	✓(1)	✓(1)	✓(1)	×
Swan Hill (77094)	✓	✓	✓	✓	✓(2)	✓
Hay (75175)	✓	✓	✓	×	×	×
Hay (75031)	✓(3)	✓(3)	✓(3)	✓(3)	✓(3)	✓(3)
Griffith (75041)	✓(4)	✓(4)	✓(4)	✓(4)	×	✓(4)
Yanco (74037)	✓	✓	✓	✓	×	✓
West Wyalong (50017)	✓	✓	✓	✓	×	✓
Cootamundra (73142)	✓(5)	✓(5)	✓(5)	✓(5)	✓(5)	×
Young Airport (73138)	✓	✓	✓	✓	×	✓
Wagga Wagga (72150)	✓	✓	✓	✓	✓(6)	✓
Gundagai (73141)	✓(1)	✓(1)	✓(1)	✓(1)	✓(1)	×
Tumbarumba (72043)	✓(1)	✓(1)	✓(1)	✓(1)	✓(1)	×
Canberra (70014)	✓	✓	✓	✓	✓(5)	✓
Cooma (70217)	✓	✓	✓	✓	×	✓

(1) - Two values per day only; at 09:00 and 15:00 hrs
(2) - Number of observations per day varies from 3 to 6
(3) - Four (4) values per day; 06:00, 09:00, 15:00 and 21:00 hrs
(4) - No data available from 01/01/2000 to 15/06/2000
(5) - Four (4) values per day; 06:00, 09:00, 12:00 and 15:00 hrs
(6) - Seven (7) values per day; no record at midnight
(7) - At Hay (both sites), Tumbarumba, Gundagai and Cootamundra, wind speed is measured at about 2m height; at all other sites wind speed is measured at 10m height.

Table 2.4: Availability of daily data

Station Name	Rainfall	Sunshine hours
Mildura (76031)	×	✓
Balranald (49002)	✓	×
Swan Hill (77094)	✓	×
Hay (75175)	✓	×
Griffith (75041)	✓	×
Yanco (74037)	✓	×
West Wyalong (50017)	✓	×
Cootamundra (73142)	✓	×
Wagga Wagga (72150)	✓	✓
Gundagai (73141)	✓	×
Willows (72083)	✓	×
Tumbarumba (72043)	✓	×
Canberra (70014)	✓	✓
Cooma (70217)	✓	×

Table 2.5: Availability of six minutes rainfall data (CRC Soil Moisture Sites)

Station Name	Rainfall record starting date
Balranald (Bolton Park)	25/09/2001
Hay (UNSW Field Station)	25/09/2001
Griffith (Aerodrome)	26/09/2001
Yanco (Research Station)	26/09/2001
West Wyalong (Airfield)	13/09/2001
Cootamundra (Aerodrome)	12/09/2001
Kyeamba (Gentle Slope)	14/11/2001
Adelong (Strathvale)	21/11/2001
Canberra (Airport)	11/09/2001
Cooma (Airfield)	11/09/2001

Table 2.6: Availability of half-hourly radiation data (cumulative over preceding 30 minutes)

Station Name	Incoming shortwave radiation data
Mildura (76031)	✓
Wagga Wagga (72150)	✓

3. COMPILATION OF CLIMATE DATA FOR LAND SURFACE MODELLING EXPERIMENTS

In preparing the climate data set, half-hourly or hourly AWS data are used directly if they are available; otherwise 3-hourly data are used. If measured data are not available at the desired location, the data at the nearest station are used, with appropriate adjustments if necessary. Specific humidity and longwave radiation are calculated from other primary climate variables as they are not measured directly.

As there is little climate data, other than rainfall, at Balranald, the preparation of the climate data set (except rainfall) for Balranald is primarily based on the data at the nearest AWS station, Swan Hill. For Kyeamba, the data at the nearest AWS station, Wagga Wagga, is used directly, except for rainfall where the SMS rainfall at Kyeamba is used. For Adelong, a number of stations in the vicinity (Tumbarumba, Wagga Wagga, Willows) are used to derive a representative climate data set for the site. For other locations, adequate data at the respective sites are generally available for preparation of a reliable climate data set.

A regular data set over 30-minute interval is obtained by linearly interpolating the data values when the observations are at longer durations. For rainfall, this is done by linearly interpolating accumulations over longer periods.

3.1 Rainfall

AWS rainfall data are used up until the commencement of the Murrumbidgee soil moisture and rainfall monitoring (starting from September 2001 for most of the sites); CRC soil moisture site (SMS) rainfall data are used since then.

Missing AWS rainfall data are infilled with daily rainfall data at the same or closest station and disaggregated using the 30-minute (or hourly) pattern from the closest AWS station with data on the day; sequentially using the next closest station if there is no rainfall on the given day at the priority station. Gaps in SMS rainfall data are infilled using corresponding AWS rainfall data. Table 3.1 summarises the compilation of rainfall data for each location.

Table 3.1: Compilation of rainfall data for study locations

LOCATION	PROCEDURE OF DATA COMPILATION
Balranald	Use AWS data at Swan Hill directly; SMS data at Balranald from Sep 2001 onwards.
Hay	Use AWS data at Hay; for the missing period Jan-Mar 2000, disaggregate daily data using the hourly pattern at Yanco. SMS data from Sep 2001 onwards.
Griffith	Use AWS data at Griffith; for the missing period Jan-May 2000, use hourly data at the nearest AWS station, Yanco; SMS data from Sep 2001 onwards.
Yanco	Use AWS data at Yanco; SMS data from Sep 2001 onwards.
West Wyalong	Use AWS data at West Wyalong; SMS data from Sep 2001 onwards.
Cootamundra	Use daily rainfall data at Cootamundra; infill missing daily data using data at Young (73138); then disaggregate daily values using rainfall pattern at the nearest AWS station that has rainfall, Wagga Wagga, West Wyalong, Canberra, Yanco and Griffith in order. SMS data at Cootamundra from Sep 2001 onwards.
Kyeamba	Use AWS data at Wagga Wagga directly; SMS data at Kyeamba (Gentle Slope) from Nov 2001 onwards.
Adelong	Use daily rainfall data at Willows (72083); infill missing daily data using data at Tumbarumba (72043); then disaggregate daily values using rainfall pattern at the nearest AWS station that has rainfall, Wagga Wagga, Canberra, Cooma and Yanco in order. SMS data at Cootamundra from Nov 2001 onwards.
Canberra	Use AWS data at Canberra; SMS data from Sep 2001 onwards.
Cooma	Use AWS data at Cooma; SMS data from Sep 2001 onwards.

SMS rainfall data measurements have been carried out exactly at the locations desired for land surface modelling experiments. However, for three sites, Balranald, Kyeamba and Adelong, the locations of AWS/BoM rainfall stations differ from those of SMS sites. Hence, the assessment of

the consistency between the two sets of rainfall data is important. Figure 3.1 compares the daily rainfall from the two sources of data over the concurrent period of records.

The AWS/BoM and SMS daily rainfall at Balranald/Swan Hill, Kyeamba/Wagga Wagga and Adelong/Willows are significantly different on a number of days. This is because the AWS and SMS stations at Balranald/Swan Hill, Kyeamba/Wagga Wagga and Adelong/Willows are not at the same locations (about 20 km apart for Kyeamba and Adelong and 70 km apart for Balranald).

In general, there is a good agreement between the AWS/BoM and SMS daily rainfall at the other eight sites where the stations are at the same locations. However there are minor inconsistencies between the AWS and SMS rainfall at West Wyalong, Yanco and Cootamundra. At West Wyalong, the AWS rainfall is higher than the SMS rainfall on three rain days. At Yanco, the AWS station recorded zero rainfall on four days when the SMS station recorded significant rainfall. At Cootamundra, the BoM rainfall is slightly lower than the SMS rainfall.

3.2 Air Temperature (and Dew Point Temperature for Specific Humidity Calculations)

AWS temperature data are available for eight locations except for Cootamundra and Adelong. Gaps in the data need to be infilled as the diurnal variation of the temperature is to be preserved to sufficient accuracy. Missing data are first infilled using three-hourly data (THD) at the same location and remaining gaps are then infilled using the data at the nearest station based on a linear regression relationship between the two data sets. The comparison plots and regression relationships for air temperature between Balranald and Swan Hill, Griffith and Yanco, and Cootamundra and Young are shown in Figure 3.2. The figures show that adequate relationships exist between temperature data at each pair of locations having coefficient of determination (R^2) greater than or equal to 0.96. Furthermore, it also shows that the regression line matches the 1:1 comparison line closely for each case, suggesting that direct infilling using the data at nearby stations would not cause significant error.

If the temperature observation is infrequent (e.g., two or four observations per day), the diurnal variation is estimated by applying the temperature variation pattern at the nearest station. The gap between the observations is linearly interpolated to match the pattern of the temperature data at the nearest station. This is carried out for each gap independently. The gaps less than or equal to three hours are linearly interpolated between the two values. Table 3.2 summarises the compilation of temperature data for each location.

Inconsistencies between air and dew point temperatures occasionally occur due to the interpolation of the two data sets independently, in particular for Cootamundra and Adelong due to infrequent observations. Where the interpolated dew point temperature is greater than the air temperature, the dew point temperature is set equal to air temperature during specific humidity calculations.

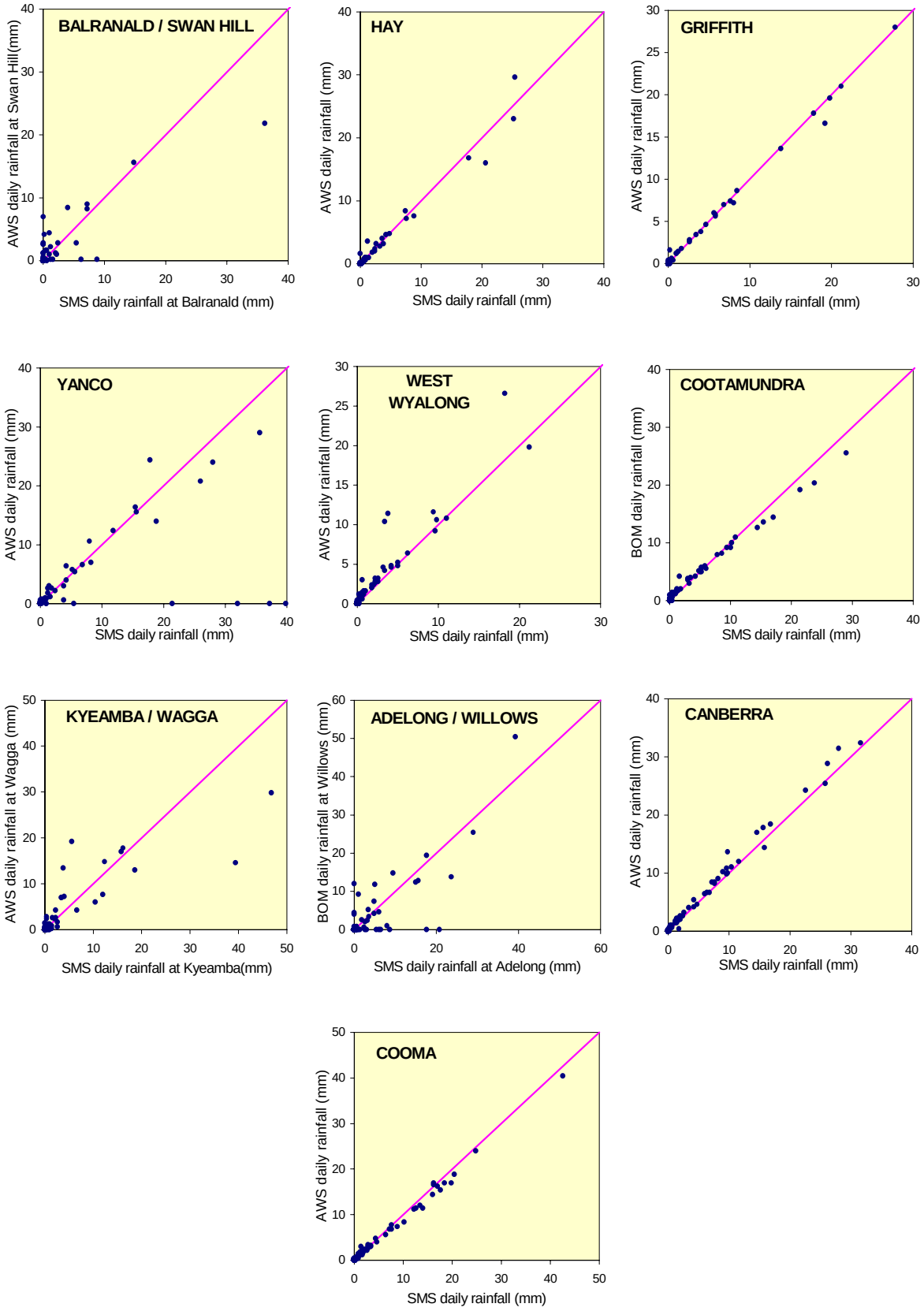

Figure 3.1: Comparison of daily rainfall measured at AWS and SMS sites (Sep 2001 - May 2002)

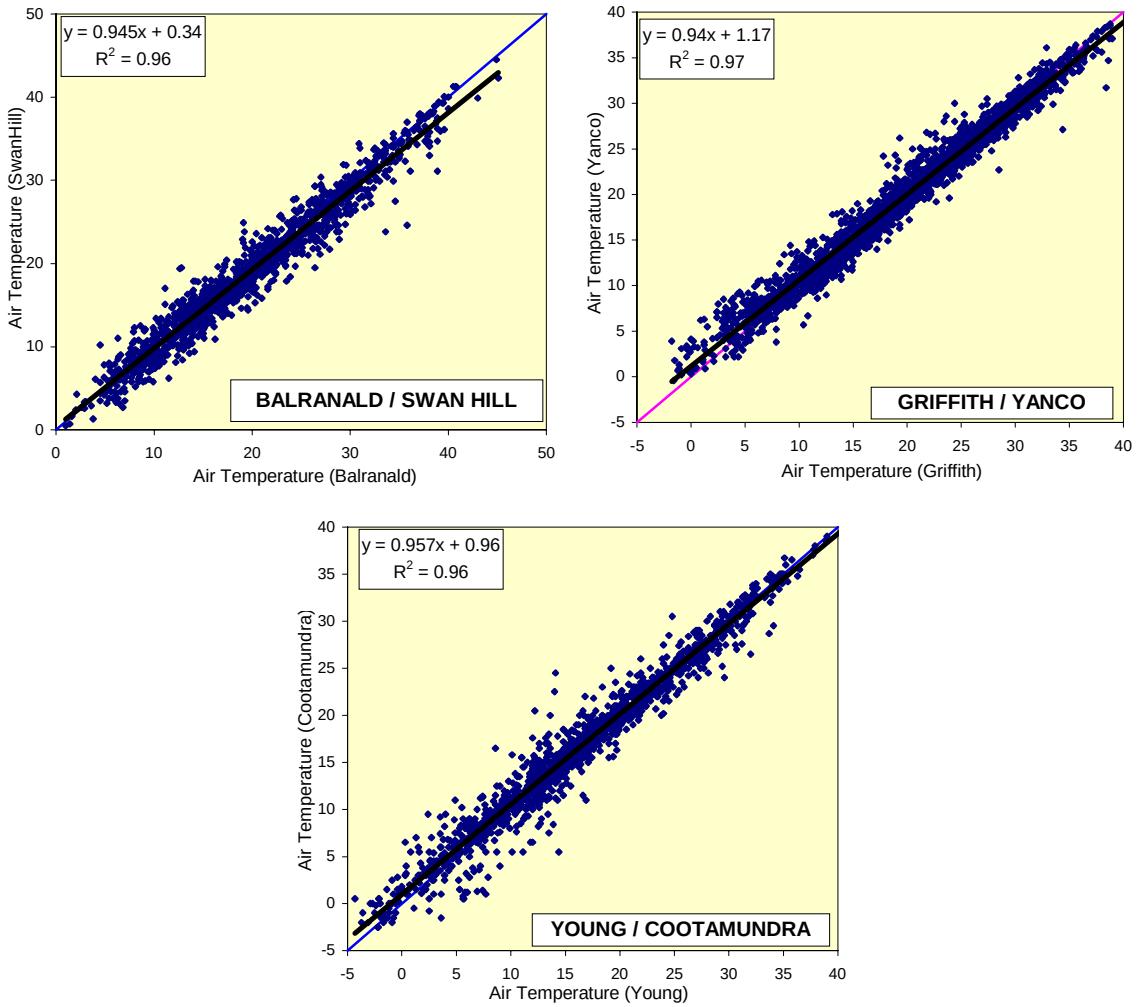

Figure 3.2: Regression relationships for air temperature

Table 3.2: Compilation of temperature data for study locations

LOCATION	PROCEDURE OF DATA COMPILATION
Balranald	Use AWS data at Swan Hill directly.
Hay	Use AWS data at Hay; infill few gaps (less than 2%) first, using three-hourly data and then using data at Yanco (74037).
Griffith	Use AWS data at Griffith; for the missing period Jan-May 2000, use hourly data at the nearest AWS station, Yanco, directly.
Yanco	Use AWS data at Yanco; infill few gaps (less than 2%) using hourly data at Griffith.
West Wyalong	Use AWS data at West Wyalong.
Cootamundra	Temperature data are available at 06:00, 09:00, 12:00 and 15:00 hours only; interpolate the 15-hour gap using data at Young (73138) station to match the pattern at this station; linearly interpolate remaining three-hourly data.
Kyeamba	Use AWS data at Wagga Wagga directly.
Adelong	Temperature data are available at 09:00 and 15:00 hours only; interpolate 6-hour and 15-hour gaps at half-hourly intervals using temperature variation pattern at Wagga Wagga.
Canberra	Use AWS data at Canberra.
Cooma	Use AWS data at Cooma.

3.3 Wind Speed and Direction

In compiling wind data, AWS data are used directly if they are available, otherwise three-hourly data (THD) are used. Gaps in the AWS data are first infilled using THD data at the same location and gaps of more than 24 hours are infilled using data at the nearest station. As the regression relationships between wind data at adjacent stations are generally poor, the infilling is carried out by directly transferring the values across the stations rather than based on regression relationships.

At AWS sites, wind direction is given as true bearing from North to the nearest 10 degree (0°-360°). For three-hourly data, wind direction is given as 16 compass point text (eg., SW, SSW, NNE etc). These figures when converted to true bearings from North are only approximate as they are read in 22.5° intervals.

Wind data at 2 m are required as the forcing data for the land surface modelling experiments. Wind data at Hay (both sites), Cootamundra and Tumbarumba are recorded at about 2 m using either wind vanes or hand held anemometers. Wind speed data at the other sites are recorded at 10 m, and these wind speed data are multiplied by 0.7 to convert them to wind speed data at 2 m.

Table 3.3 summarises the compilation of wind speed and wind direction data for each location.

Table 3.3: Compilation of wind speed and wind direction data for study locations

LOCATION	PROCEDURE OF DATA COMPILATION
Balranald	Use AWS data at Swan Hill directly. Wind speed values are multiplied by a factor of 0.7.
Hay	Use AWS data at Hay (75175); at this site, only wind speed data are available; Wind direction data, up to four measurements per day, (along with wind speed measurements) are available at the nearby station Hay (75031). However, due to inconsistencies between the two data sets, it is not reliable to use wind direction data at Hay (75031) along with wind speed data at Hay (75175). Hence, no wind direction data can be provided with adequate accuracy. No conversion is required as the wind speed measurements are at 2m height.
Griffith	Use AWS data at Griffith; for the missing period Jan-May 2000, use hourly wind speed and wind direction data at the nearest AWS station, Yanco, directly. Wind speed values are multiplied by a factor of 0.7.
Yanco	Use AWS data at Yanco; infill few gaps (less than 2%) using hourly data at Griffith. Wind speed values are multiplied by a factor of 0.7.
West Wyalong	Use AWS data at West Wyalong. Wind speed values are multiplied by a factor of 0.7.
Cootamundra	Wind data are available at 06:00, 09:00, 12:00 and 15:00 hours. Intermediate values are directly interpolated from the available readings. No conversion is required as the measurements are at 2m height.
Kyeamba	Use AWS data at Wagga Wagga directly. Wind speed values are multiplied by a factor of 0.7.
Adelong	Wind speed and wind direction data are linearly interpolated from the two readings (06:00 and 21:00) at Tumbarumba. No conversion is required.
Canberra	Use AWS data at Canberra. Wind speed values are multiplied by a factor of 0.7.
Cooma	Use AWS data at Cooma. Wind speed values are multiplied by a factor of 0.7.

3.4 Specific Humidity and Incoming Longwave Radiation

Specific humidity and incoming longwave radiation are calculated using other recorded climate variables using appropriate relationships based on physical phenomena. Dew point temperature and atmospheric pressure at station level are used to calculate specific humidity while air temperature, dew point temperature and fraction of cloud cover are used to calculate longwave radiation.

3.4.1 Atmospheric pressure at station level

Atmospheric pressure data at sea level are available for seven of the AWS sites (except at Hay) at either 30-minute or 1-hour intervals. These data are converted to station level pressure for the computation of specific humidity. The three-hourly data (THD) record pressure at station level, which can be used directly.

The study uses AWS pressure data if they are available after converting them to representative station level values, otherwise THD are used directly. Gaps in AWS pressure data are first infilled using THD at the same location if available, the remaining gaps are then infilled by transposing the pressure data at the nearest station adjusting for elevation difference between the stations.

The following equation is used to convert sea level pressure values to station level pressure values.

$$\frac{P_{Site}}{P_{Sea}} = \left[\frac{288 - 0.0065h}{288}\right]^{5.256} \qquad (1)$$

where P_{Site} = station level pressure in millibars
P_{Sea} = sea level pressure in millibars
h = station height in meters above mean sea level

With respect to Eqn (1), the sea level pressure data at the AWS sites need to be multiplied by the factors given in Table 3.4 to convert them to corresponding station level pressure data.

Table 3.4: Factors for converting sea level pressure to station level pressure

Station	Height (m)	Conversion factor
Swan Hill	71	0.9916
Griffith	134	0.9842
Yanco	164	0.9807
West Wyalong	257	0.9699
Wagga Wagga	212	0.9751
Canberra	578	0.9334
Cooma	930	0.8945

The following equation is used to adjust station pressures from one station to another.

$$\frac{P_2}{P_1} = \exp\left[\frac{-g(z_2 - z_1)}{R\overline{T}}\right] \qquad (2)$$

where $\overline{T} = \frac{(T_1 + T_2)}{2}$

where P_2 = station pressure at station 2 in millibars (the higher station so that $z_2 > z_1$)
P_1 = station pressure at station 1 in millibars
$(z_2\text{-}z_1)$ = altitude difference between stations 1 and 2 in metres

T_1 = absolute temperature at station 1
T_2 = absolute temperature at station 2
g = 9.81 m/s^2
R = 287

Table 3.5 summarises the compilation of atmospheric pressure data for each location.

Table 3.5: Compilation of atmospheric pressure at station level for study locations

LOCATION	PROCEDURE OF DATA COMPILATION
Balranald	Use AWS data at Swan Hill directly after converting them to station level values.
Hay	As there are no pressure measurements at the AWS site at Hay, use station level pressure data at the nearby station, Hay (75031). Interpolate pressure values linearly from the 3-6 measurements per day.
Griffith	Use AWS data at Griffith after converting them to station level values; for the missing period Jan-May 2000, use hourly pressure data at the nearest AWS station, Yanco, directly (calculation of specific humidity as at Yanco).
Yanco	Use AWS data at Yanco after converting them to station level values; infill few gaps (less than 2%) using data at Griffith after adjusting for elevation difference.
West Wyalong	Use AWS data at West Wyalong after converting them to station level values.
Cootamundra	As there are no pressure measurements at Cootamundra, use three-hourly station level pressure data at the nearest station, Young (73138) after adjusting for elevation difference. Interpolate pressure values linearly from three-hourly data.
Kyeamba	Use AWS data at Wagga Wagga directly after converting them to station level values.
Adelong	No pressure data are available at the nearest station Tumbarumba or at the other nearby station Gundagai. Hence, use pressure data at Wagga Wagga after adjusting for elevation difference between Wagga Wagga and Tumbarumba (433m).
Canberra	Use AWS data at Canberra after converting them to station level values.
Cooma	Use AWS data at Cooma after converting them to station level values.

3.4.2 Cloud Cover

Availability of cloud cover measurements is limited to a few stations across the Murrumbidgee catchment with number of measurements ranging from 2 to 7 per day. The measurements are usually given in eighths (oktas). Where cloud cover data is not available at the location, the data at the nearest station are used directly. Table 3.6 shows cloud cover measuring station used for each location. Values at 30-minute interval are linearly interpolated from the available data.

Table 3.6: Cloud cover measuring stations selected for study locations

Location	Cloud cover measuring station	Measurements per day
Balranald	Swan Hill (77094)	3-6
Hay	Swan Hill (77094)	3-6
Griffith	Wagga Wagga (72150)	7
Yanco	Wagga Wagga (72150)	7
West Wyalong	Cootamundra (73142)	4
Cootamundra	Cootamundra 73142)	4
Kyeamba	Wagga Wagga (72150)	7
Adelong	Wagga Wagga (72150)	7
Canberra	Canberra (70014)	4
Cooma	Canberra (70014)	4

3.4.3 Calculation of specific humidity and incoming longwave radiation

Specific humidity and incoming longwave radiation can be calculated based on physical relationships using basic observed data.

The following equations can be used to calculate specific humidity.

$$e_s = 6.11\exp\left[\frac{17.27T}{(T+237.3)}\right] \quad (3)$$

$$e = 6.11\exp\left[\frac{17.27T_{dew}}{(T_{dew}+237.3)}\right] \quad (4)$$

$$e = RH \text{ x } e_s \quad (5)$$

$$e = 6.11\exp\left[\frac{17.27T_{wet}}{(T_{wet}+237.3)}\right] - 0.67(T - T_{wet}) \quad (6)$$

$$S = \frac{622e}{(P - 0.378e)} \quad (7)$$

where e_s = vapour pressure for fully saturated condition at T (mbar)
e = vapour pressure of the air (mbar)
T = air (dry bulb) temperature (°C)
T_{dew} = dew point temperature (°C)
T_{wet} = wet bulb temperature (°C)
RH = relative humidity
P = station level pressure (mbar)
S = specific humidity (g/kg)

The following equation is used to calculate incoming longwave radiation.

$$I = \varepsilon\sigma T^4 - (1 - c'n)\varepsilon\sigma T^4(0.39 - 0.05\sqrt{e}) \quad (8)$$

where I = incoming longwave radiation (Wm^{-2})
ε = infrared emmissivity relative to a black body (use 0.96 to be consistent with VB95)
σ = Stefan-Boltzmann constant (5.674 x 10^{-8} $Wm^{-2}K^{-4}$)
T = air temperature (°K)
e = vapour pressure of the air (mbar)
n = fraction of cloud cover
c' = a value depends on latitude (0.65 is used as appropriate for 35° latitude)

Equations (4), (5) and (6) provide various options for calculating vapour pressure (*e*); it can be calculated using dew point temperature, wet bulb temperature or air temperature and relative humidity. Vapour pressures (*e*) calculated from the different types of data are compared in Figure 3.3. The plots show that there is very little difference in the values calculated from the different procedures. Dew point temperature is available at all AWS sites at 30-minute or hourly intervals, whereas wet bulb temperature and relative humidity are only available at three-hourly intervals. This study uses Eqn. (4) to calculate vapour pressure (e) using dew point temperature and then Eqn. (7) to calculate specific humidity.

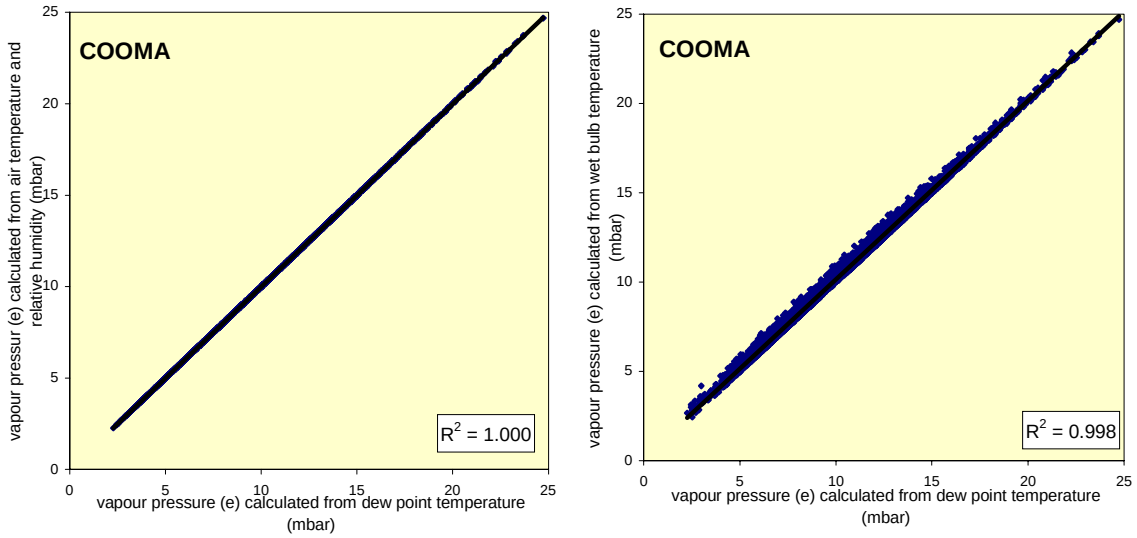

Figure 3.3: Comparison of vapour pressure (*e*) calculated from different procedures

Half-hourly data (air and dew point temperatures, station level pressure and cloud cover) are used to calculate specific humidity and incoming longwave radiation for all sites except for Adelong. For Adelong, as dew point temperature is measured only at 09:00 and 15:00 hours, specific humidity is calculated at these hours; the two values are then interpolated at half-hourly intervals using the pattern of calculated specific humidity at Wagga Wagga. Alternatively, two dew point temperature measurements can be interpolated at half-hourly intervals using the dew point temperature pattern at Wagga Wagga, and then specific humidity can be calculated at half-hourly intervals. The two sets of specific humidity data are compared in Figure 3.4. The results indicate some scatter between the two data sets. The values calculated from the first approach are used here.

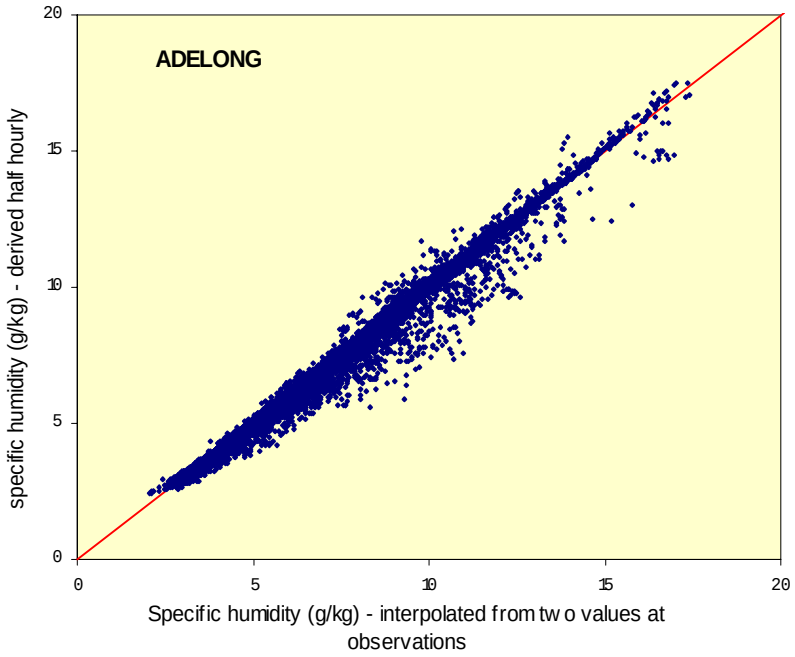

Figure 3.4: Comparison of specific humidity for Adelong from different procedures of interpolation

3.5 Incoming Shortwave Radiation

Incoming shortwave radiation data are recorded at three locations in the region; Mildura, Wagga Wagga and Canberra. Half-hourly data are available at Mildura and Wagga Wagga over the period of interest. For Canberra, only daily data are available from 1990 to 1994.

Daily incoming shortwave radiation can be estimated from sunshine hours using a suitable empirical formula such as Angstrom formula. Sunshine hours data are recorded at Mildura, Wagga Wagga and Canberra.

The Bureau of Meteorology has a SOLARNET software package that gives satellite-derived daily solar radiation data for any location in Australia. However, the data are only available for the periods November 1990 to May 1994 and June 1997 to August 1999. Figure 3.5 compares the observed daily shortwave radiation with the satellite-derived shortwave radiation data at Wagga Wagga and Mildura.

The estimation of net incoming shortwave radiation using the Angstrom formula is described below.

Extraterrestrial radiation, R_a, is the shortwave radiation incident upon the earth's atmosphere. It is a function of the location and time of the year and is given by,

$$R_a = \frac{I_0}{\pi} d_r \left[\omega_s \sin(\psi)\sin(\delta) + \cos(\psi)\cos(\delta)\sin(\omega_s)\right] \quad (9)$$

where, R_a is extraterrestrial radiation (MJ/m^2/day)
I_0 is solar constant (118.2 MJ/m^2/day)
ψ is latitude (in radians, negative for South Hemisphere)

The inverse relative earth-sun distance, d_r, is given by

$$d_r = 1+0.033 \cos(0.0172J) \quad (10)$$

The solar declination, δ, is given by

$$\delta = 0.409 \sin(0.0172J - 1.39) \quad (11)$$

where J is Julian day (1 for 1 Jan, 365 for 31 Dec)

The sunset angle, ω_s, is given by

$$\omega_s = \arccos [-\tan(\psi) \tan(\delta)] \quad (12)$$

Daylight hours, N, is defined as:

$$N = \frac{24}{\pi}\omega_s \quad (13)$$

As it penetrates the atmosphere, R_a is scattered, reflected or absorbed by clouds, water vapour, gasses and dust. The total shortwave radiation, R_s, (direct beam plus diffuse) can be estimated using the Angstrom formula,

$$R_s = \left(a_s + b_s \frac{n}{N}\right) R_a \quad (14)$$

a_s is the fraction of extraterrestrial radiation reaching the surface on overcast days, a_s+b_s is the fraction reaching the surface on clear days and n is sunshine hours. For "average" climate, a_s and b_s are about 0.25 and 0.5 respectively, but if possible they should be calibrated for local climate conditions.

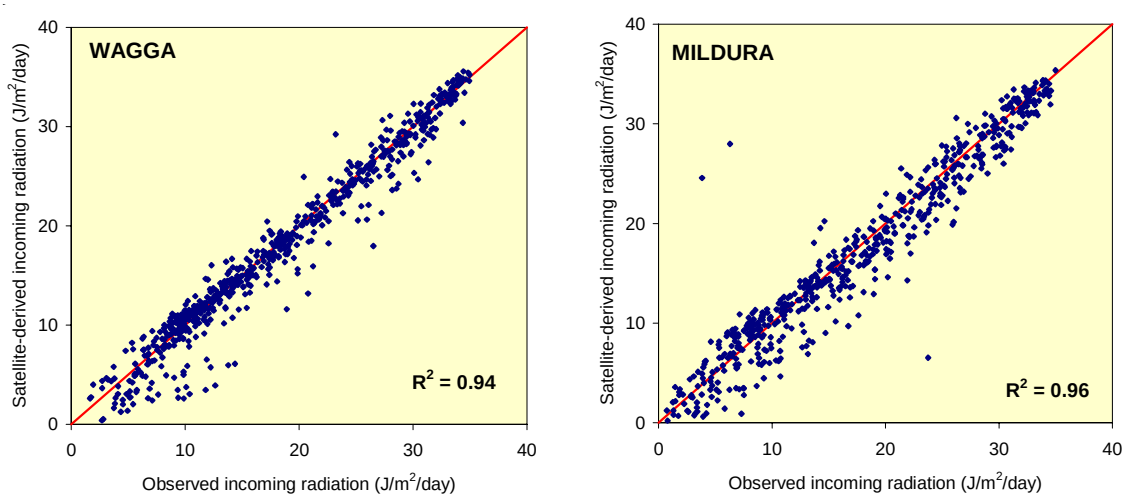

Figure 3.5: Comparison of observed and satellite-derived radiation data for Wagga Wagga and Mildura

The steps adopted to estimate net incoming shortwave radiation at the ten locations are described below.

1. The extraterrestrial radiation, R_a, for Mildura, Wagga Wagga and Canberra is calculated using Eqn. (9). The parameters a_s and b_s are calibrated to provide the best fit between the shortwave radiation estimated using Eqn. (14) and the recorded shortwave radiation at Mildura and Wagga Wagga (using data from 1990 to 2002) and SOLARNET satellite-derived shortwave radiation at Canberra (over the period when satellite-derived data are available). The optimum a_s and b_s values are given in Table 3.7.

   Table 3.7: Calibrated parameter values for Angstorm formula

	Mildura	Wagga Wagga	Canberra	Standard
a_s	0.22	0.21	0.23	0.25
b_s	0.54	0.56	0.54	0.50
R^2	0.90	0.92	0.80	-

   The high coefficient of determination (R^2) indicates that daily incoming shortwave radiation can be estimated satisfactorily from sunshine hours data. The estimated and recorded shortwave radiation data for Wagga Wagga and Mildura are compared in Figure 3.6.

2. The Angstrom formula with the calibrated parameters (a_s and b_s) is used to estimate daily incoming shortwave radiation at Mildura, Wagga Wagga and Canberra. For Canberra, this provides an estimate of daily incoming shortwave radiation for the period of interest (from January 2000). For Mildura and Wagga Wagga, the estimated values are used to infill missing data.

3. The SOLARNET satellite-derived shortwave radiation data are extracted for the other locations. The mean monthly values at Balranald and Hay are compared with the values at Mildura, the mean monthly values at Griffith, Yanco, West Wyalong, Cootamundra and Adelong are compared with the values at Wagga Wagga, and the mean monthly values at Cooma are compared with the values at Canberra to derive monthly adjustment factors for these locations. The monthly adjustment factors (see Table 3.8) are used to estimate the daily incoming shortwave radiation at these locations by scaling the recorded/estimated values at Mildura, Wagga Wagga or Canberra (from Steps 1 and 2).

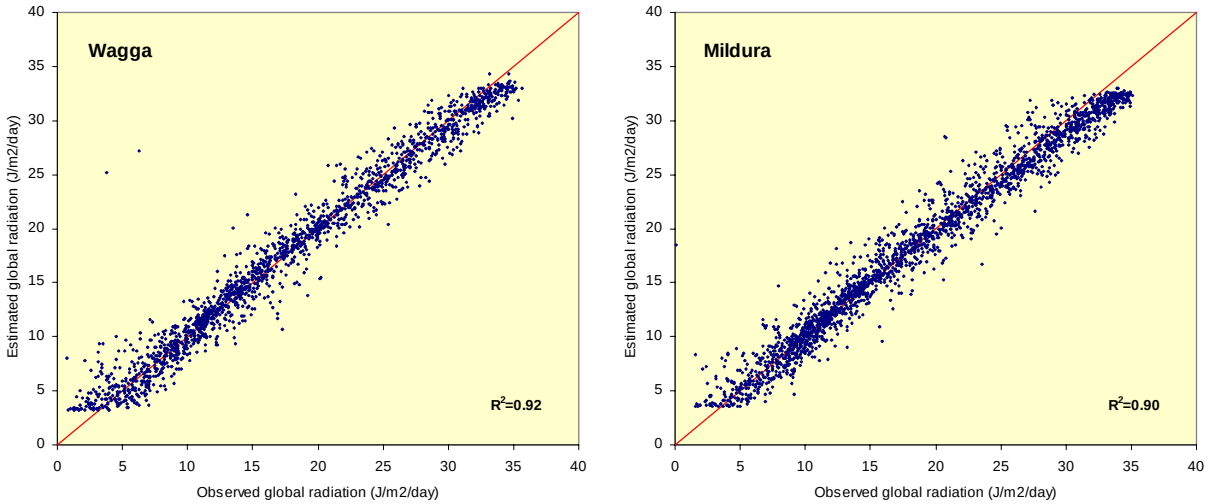

Figure 3.6 : Comparison of observed and estimated radiation data for Wagga Wagga and Mildura

4. 30-minute data are recorded at Mildura and Wagga Wagga. The few missing data are infilled by comparing the values at the two stations. Where data from the two stations are not available on the same day, the typical pattern for the time of the year is used. The daily data at the other locations are disaggregated to 30-minute data using the patterns at Mildura (for Balranald and Hay) or Wagga Wagga (for Griffith, Yanco, West Wyalong, Cootamundra, Adelong, Canberra and Cooma). Wagga Wagga values are used directly for Kyeamba.

Table 3.8: Monthly adjustment factors for daily radiation data

	Against Mildura		Against Wagga Wagga					Against Canberra
Month	Balranald	Hay	Griffith	Yanco	W. Wyalong	Cootamu.	Adelong	Cooma
Jan	1.01	1.01	1.00	1.01	1.00	0.98	0.96	0.96
Feb	0.99	1.00	1.01	1.01	1.00	1.01	0.97	0.98
Mar	1.00	1.00	1.04	1.02	1.04	1.01	0.97	1.00
Apr	0.98	1.01	1.03	1.02	1.04	1.00	0.96	0.94
May	0.99	1.01	1.07	1.03	1.07	1.03	0.95	0.95
Jun	1.01	1.03	1.17	1.11	1.16	1.00	0.92	0.94
Jul	1.00	1.02	1.14	1.08	1.15	1.02	0.95	1.00
Aug	0.98	1.00	1.10	1.06	1.13	1.04	0.93	1.02
Sep	0.99	1.01	1.10	1.06	1.12	1.03	0.93	0.99
Oct	1.00	1.00	1.03	1.04	1.04	1.01	0.96	0.98
Nov	1.01	1.03	1.01	1.02	1.03	1.01	0.97	0.95
Dec	0.99	1.00	1.01	1.02	1.01	1.00	0.97	0.96

4. REVIEW OF CLIMATE DATA PREPARED FOR MODELLING EXRERIMENTS

Several plots are shown in Appendices A and B to review the prepared data to ensure that the data are consistent. Figures A.1-A.10 show the average 24-hour variation of derived climate variables for January and July, for all locations. Figures B.1-B.10 show annual variation of the time series of climate variables (30-minute time series) for the year 2001.

APPENDIX A

Average Daily Variation of Climate Variables for January and July

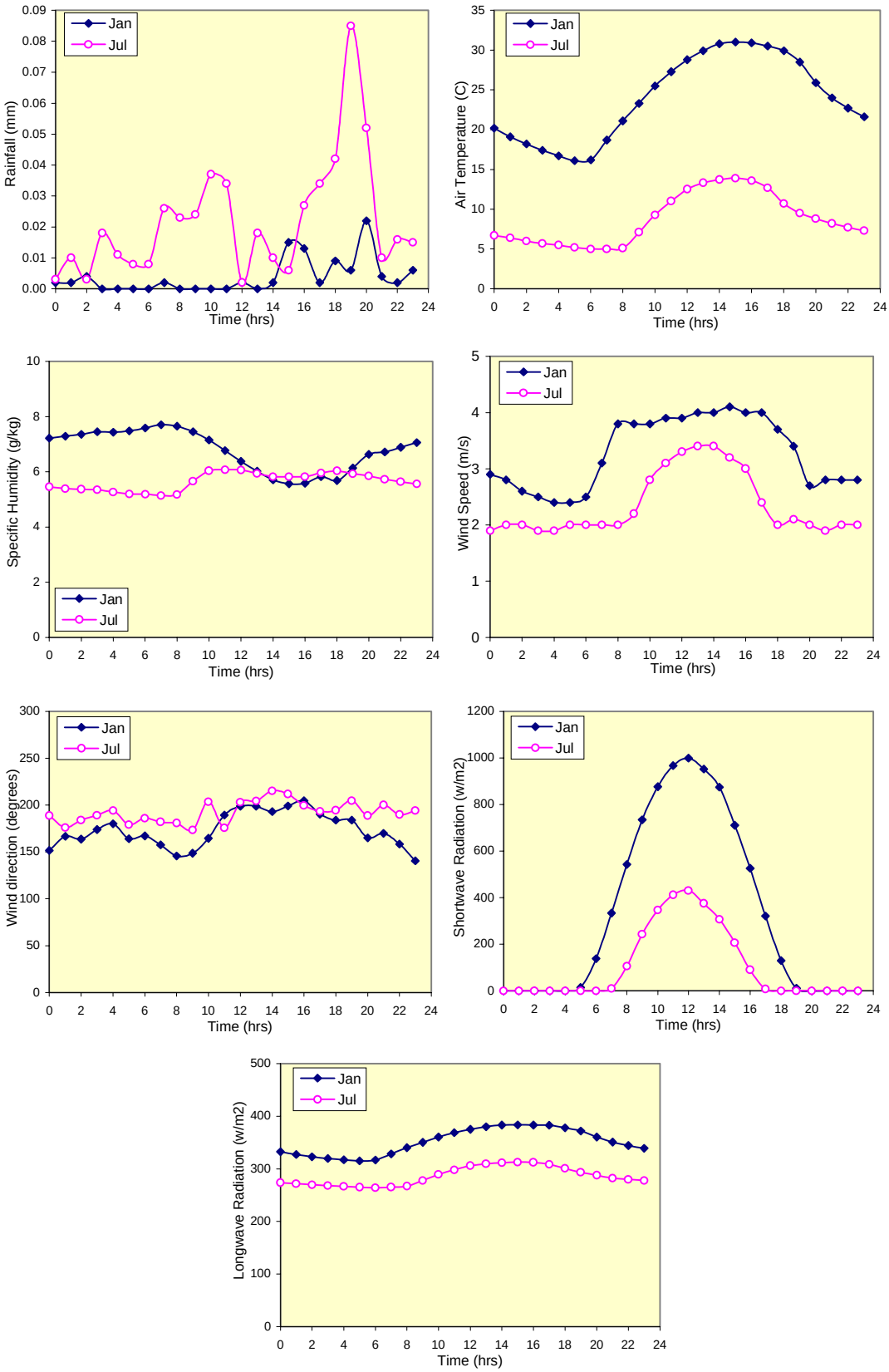

Figure A.1: Average daily variation of climate variables for Balranald for January and July

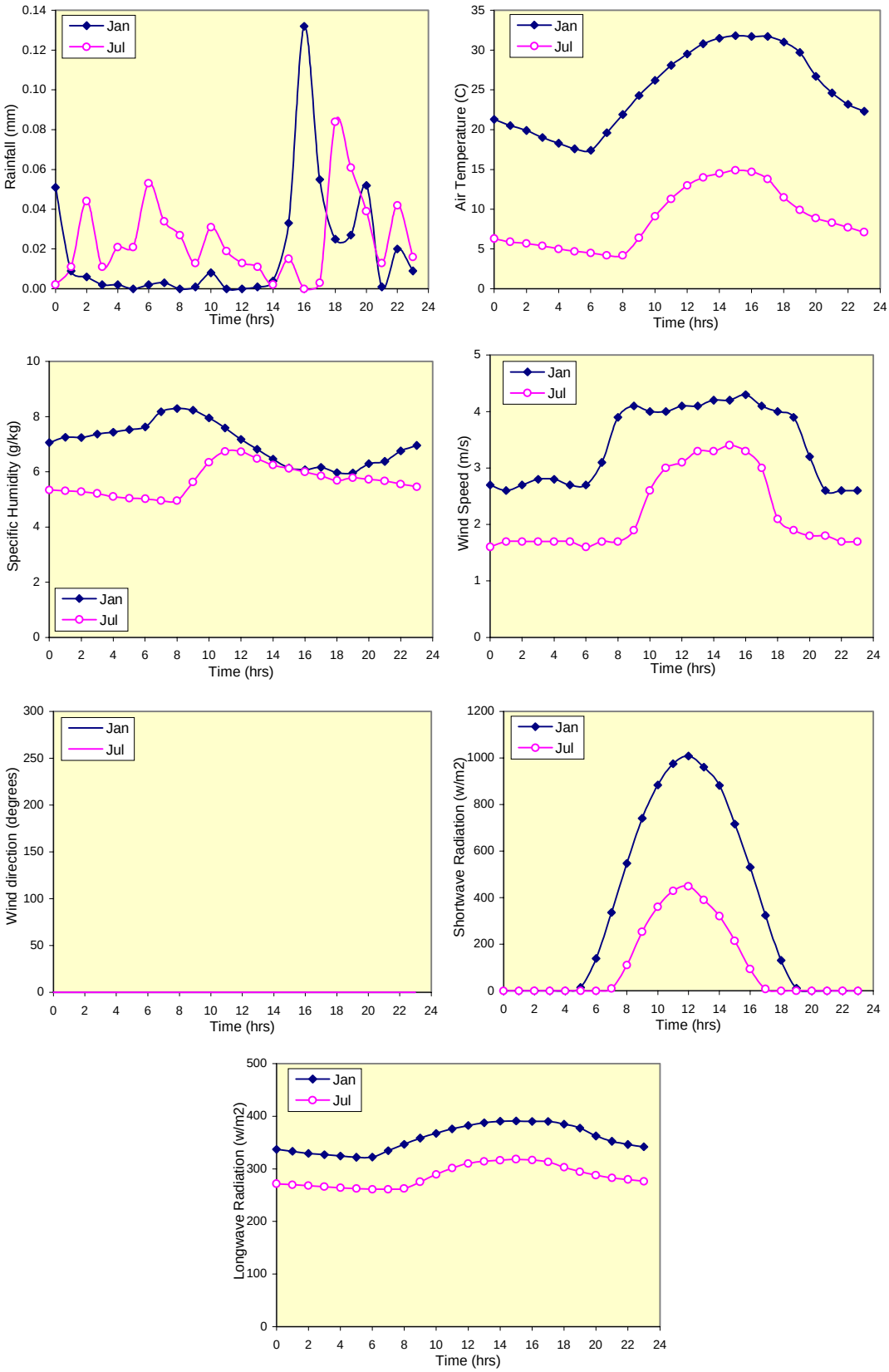

Figure A.2: Average daily variation of climate variables for Hay for January and July

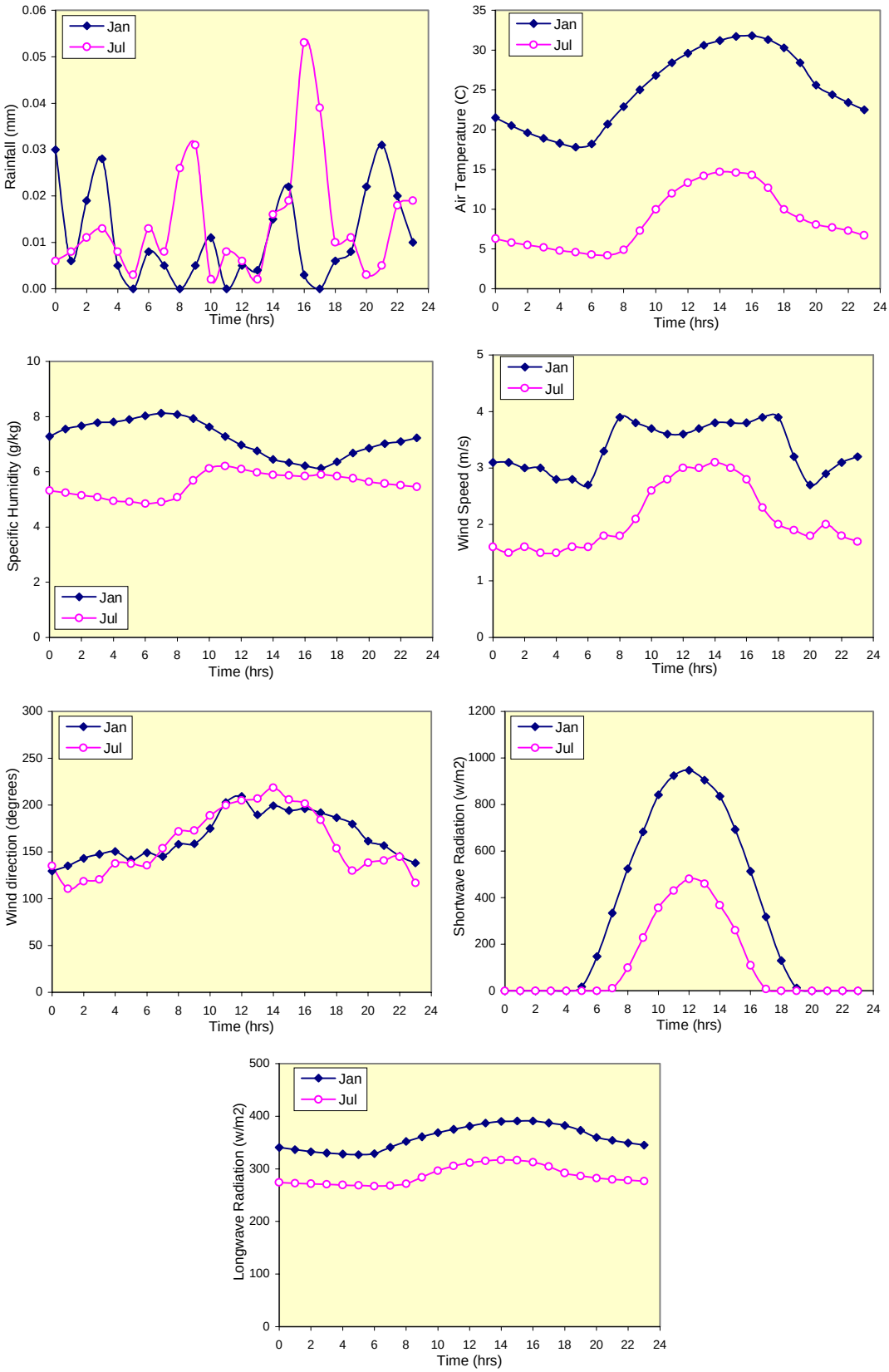

Figure A.3: Average daily variation of climate variables for Griffith for January and July

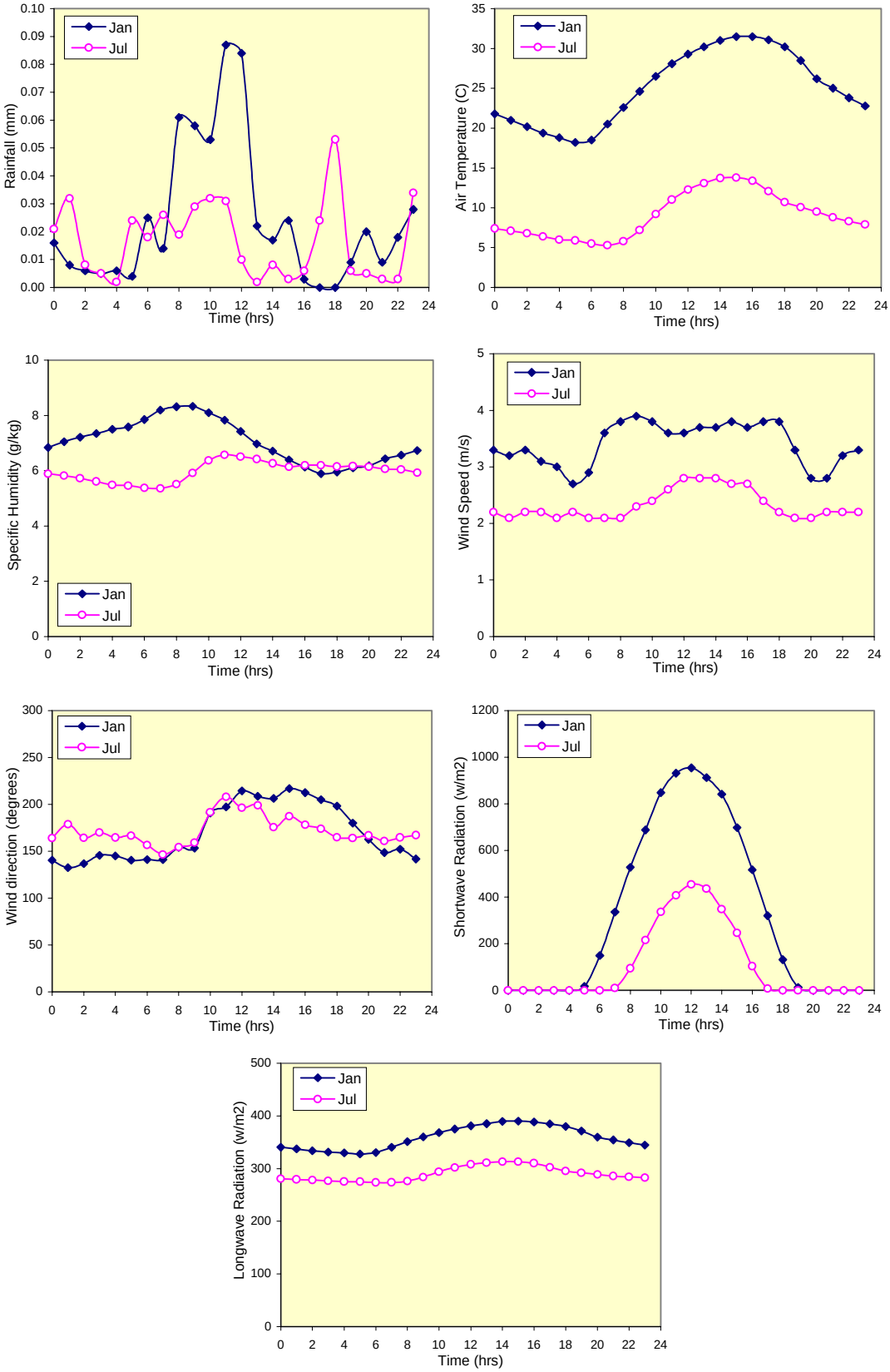

Figure A.4: Average daily variation of climate variables for Yanco for January and July

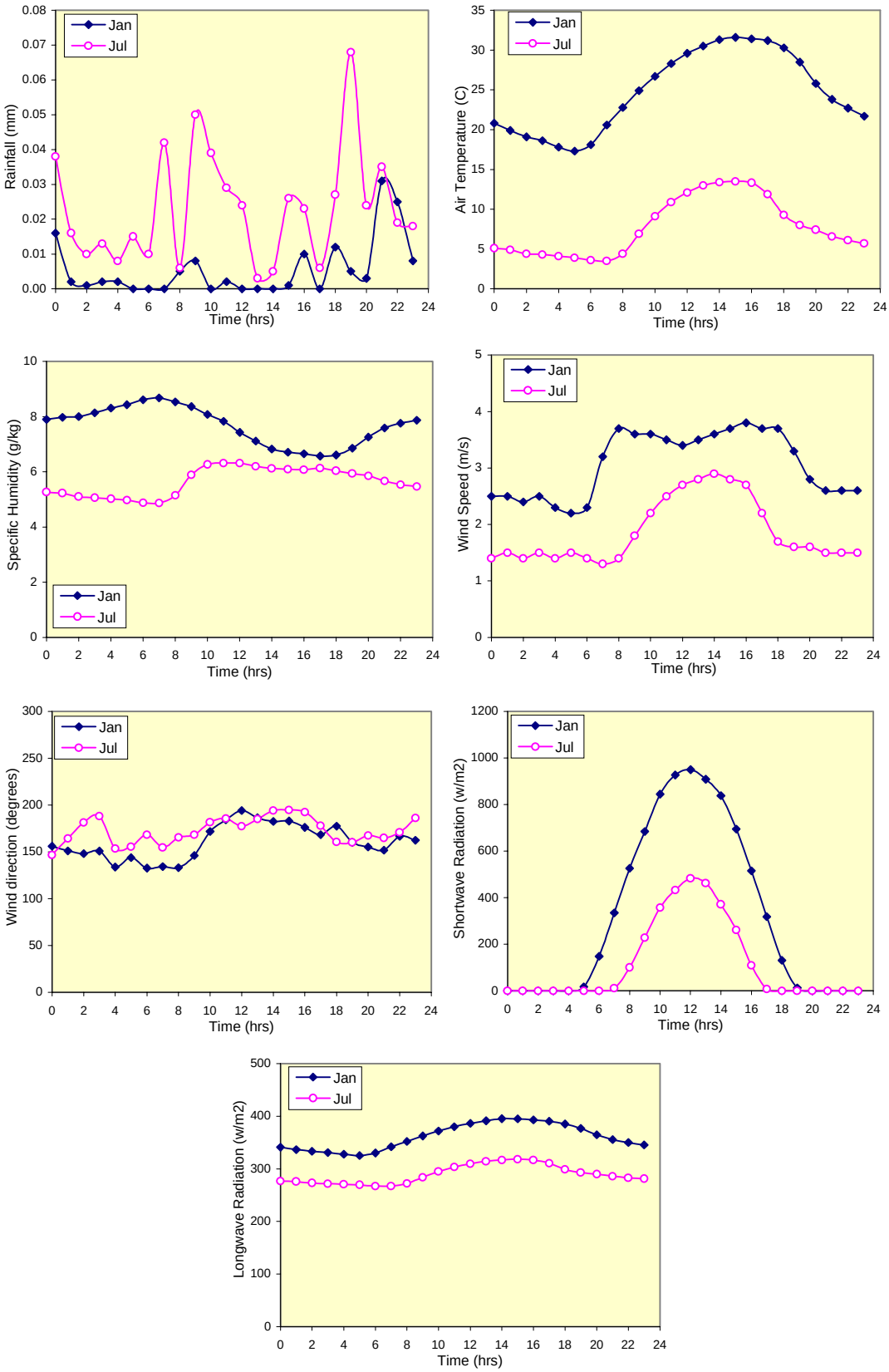

Figure A.5: Average daily variation of climate variables for West Wyalong for January and July

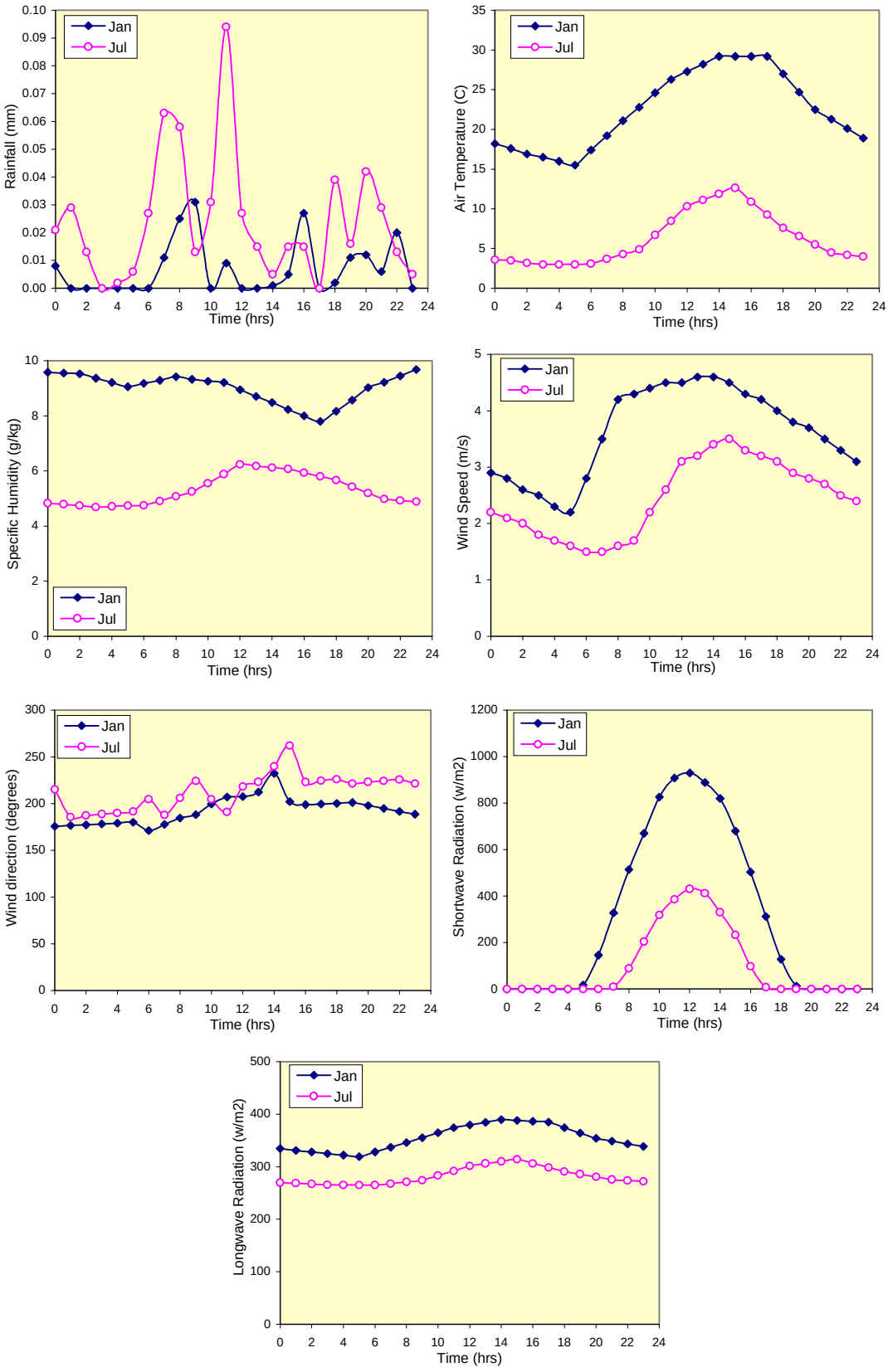

Figure A.6: Average daily variation of climate variables for Cootamundra for January and July

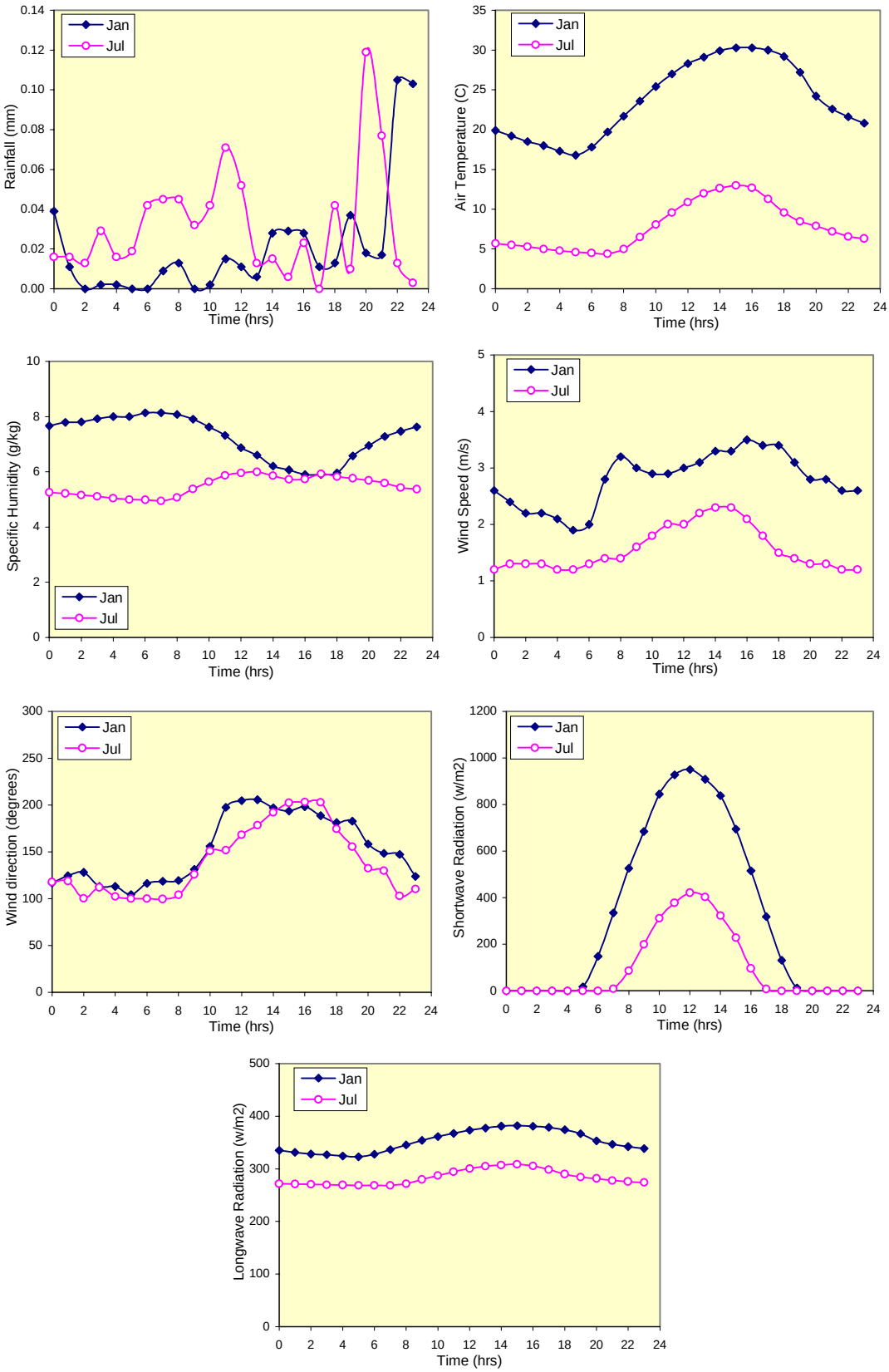

Figure A.7: Average daily variation of climate variables for Kyeamba for January and July

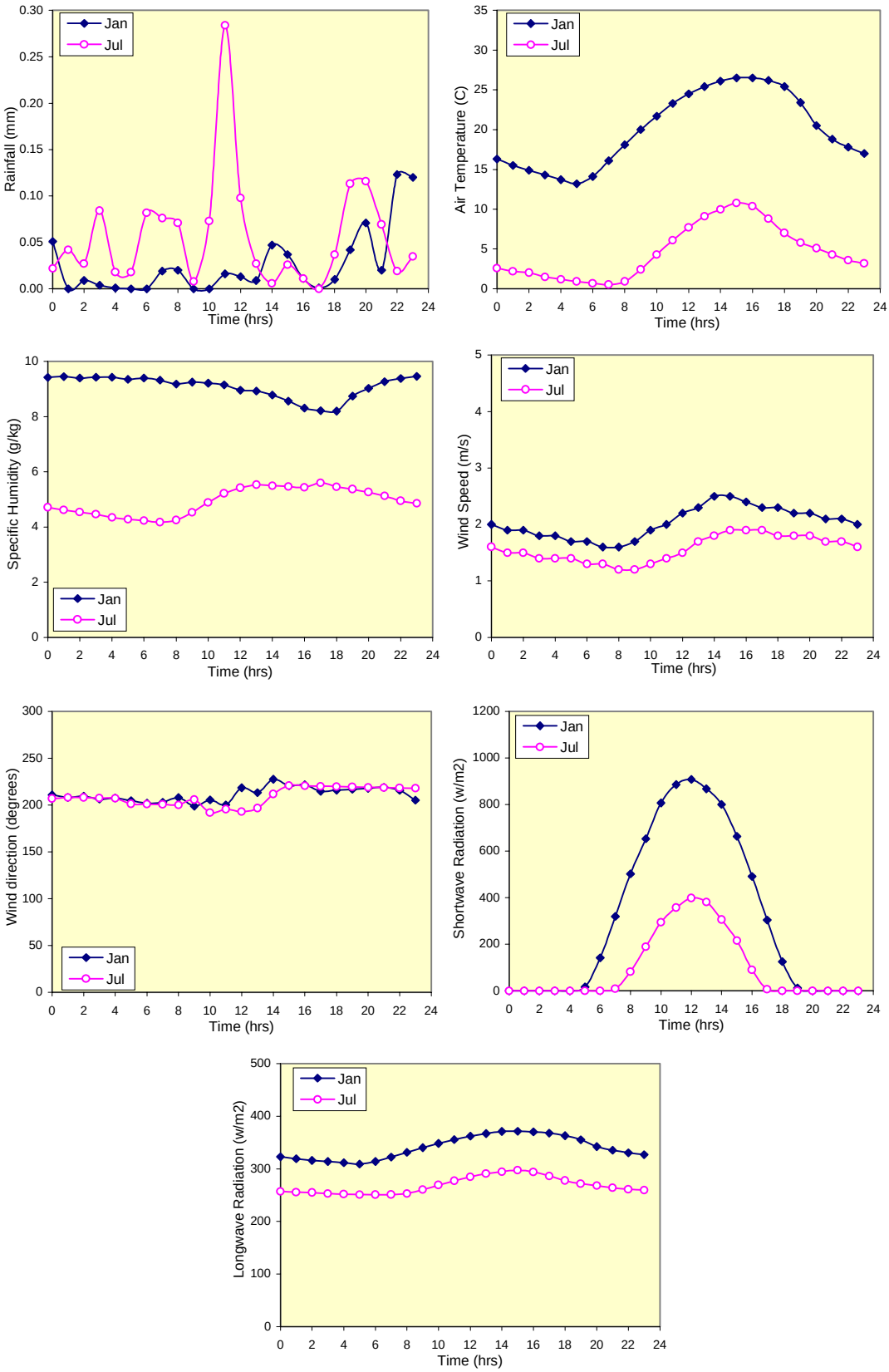

Figure A.8: Average daily variation of climate variables for Adelong for January and July

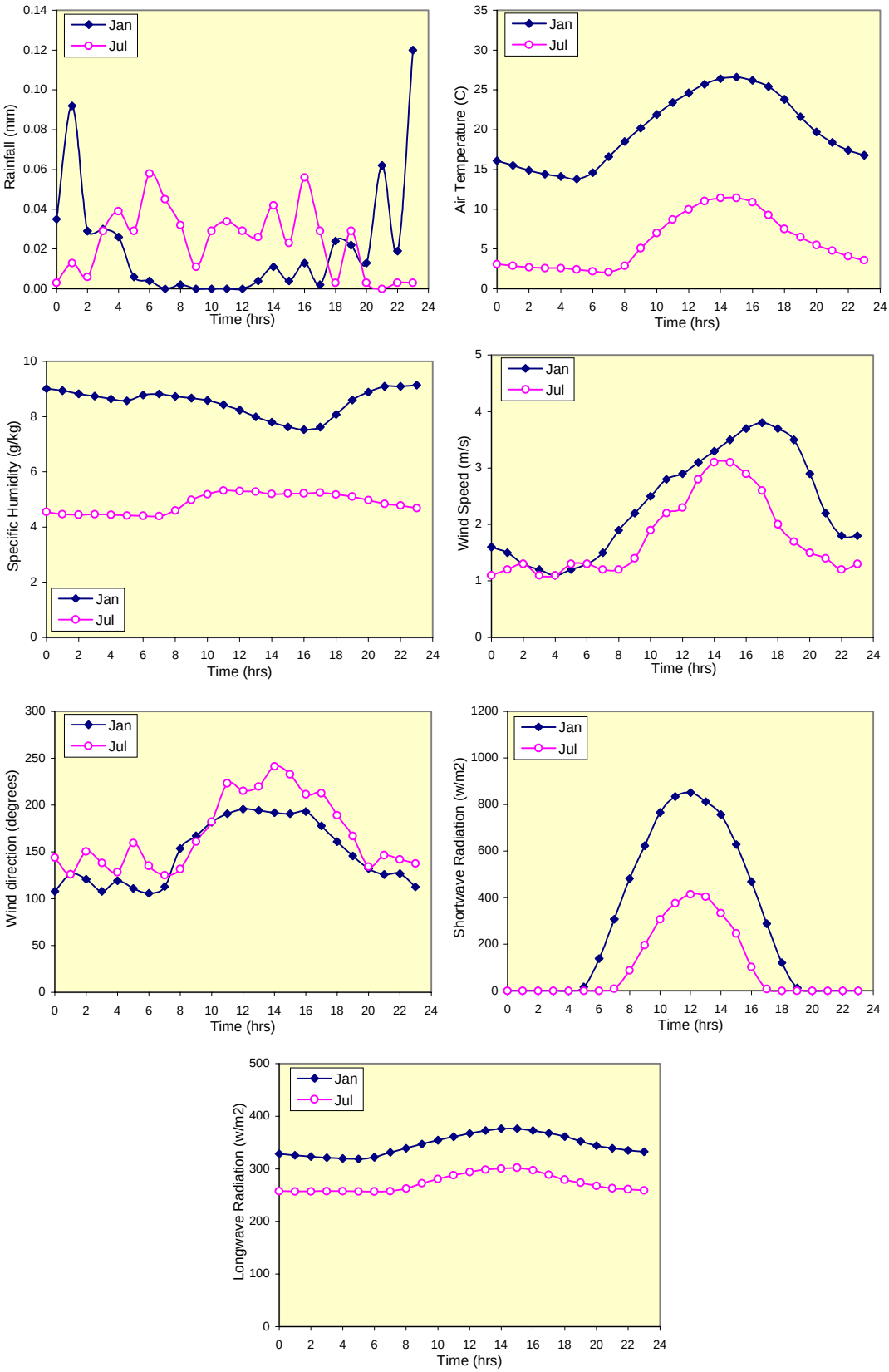

Figure A.9: Average daily variation of climate variables for Canberra for January and July

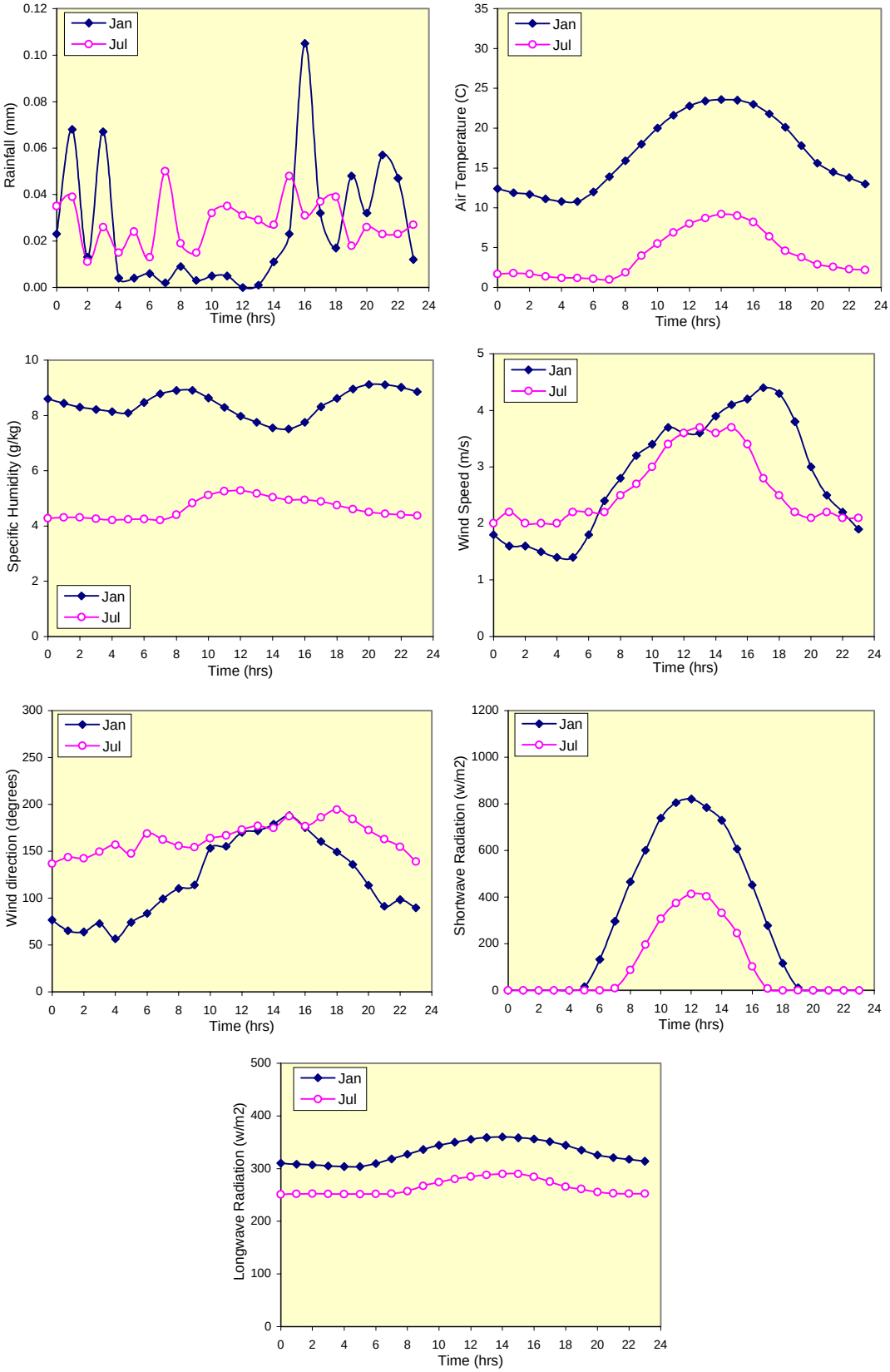

Figure A.10: Average daily variation of climate variables for Cooma for January and July

APPENDIX B

Annual Variation of Climate Variables for Year 2001

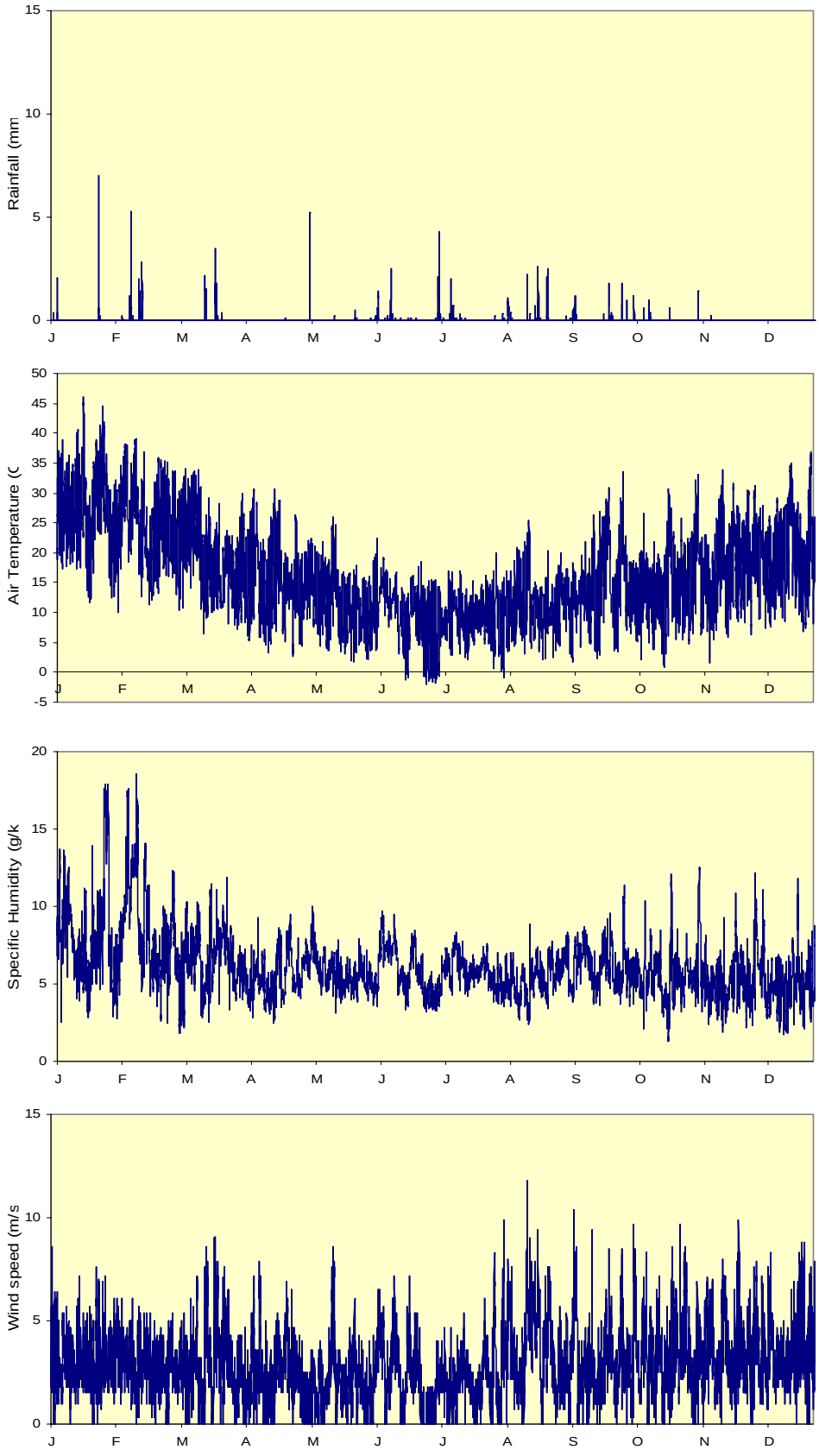

Figure B.1: Annual variation of climate variables for Balranald for year 2001

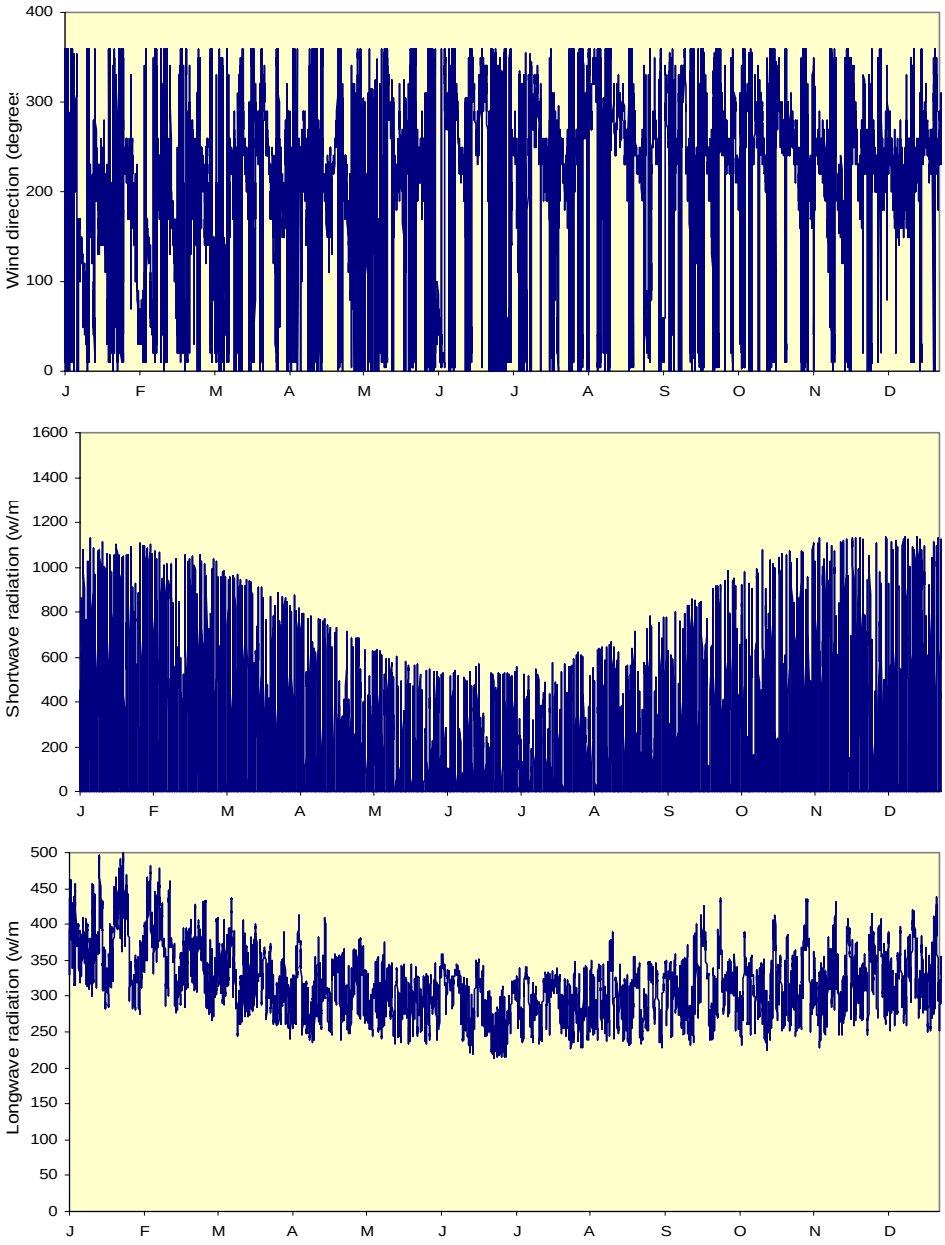

Figure B.1: Annual variation of climate variables for Balranald for year 2001 (continued)

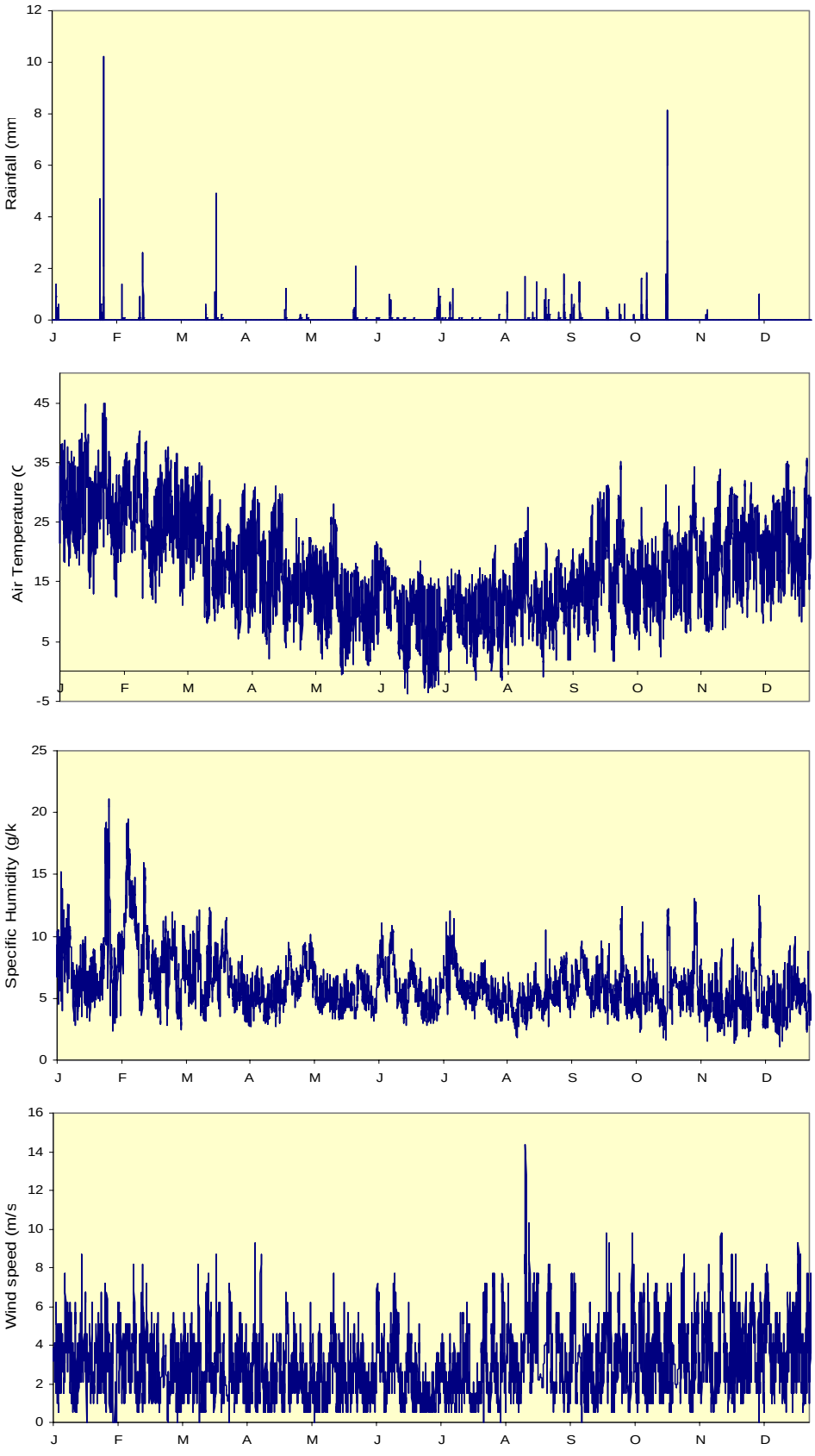

Figure B.2: Annual variation of climate variables for Hay for year 2001

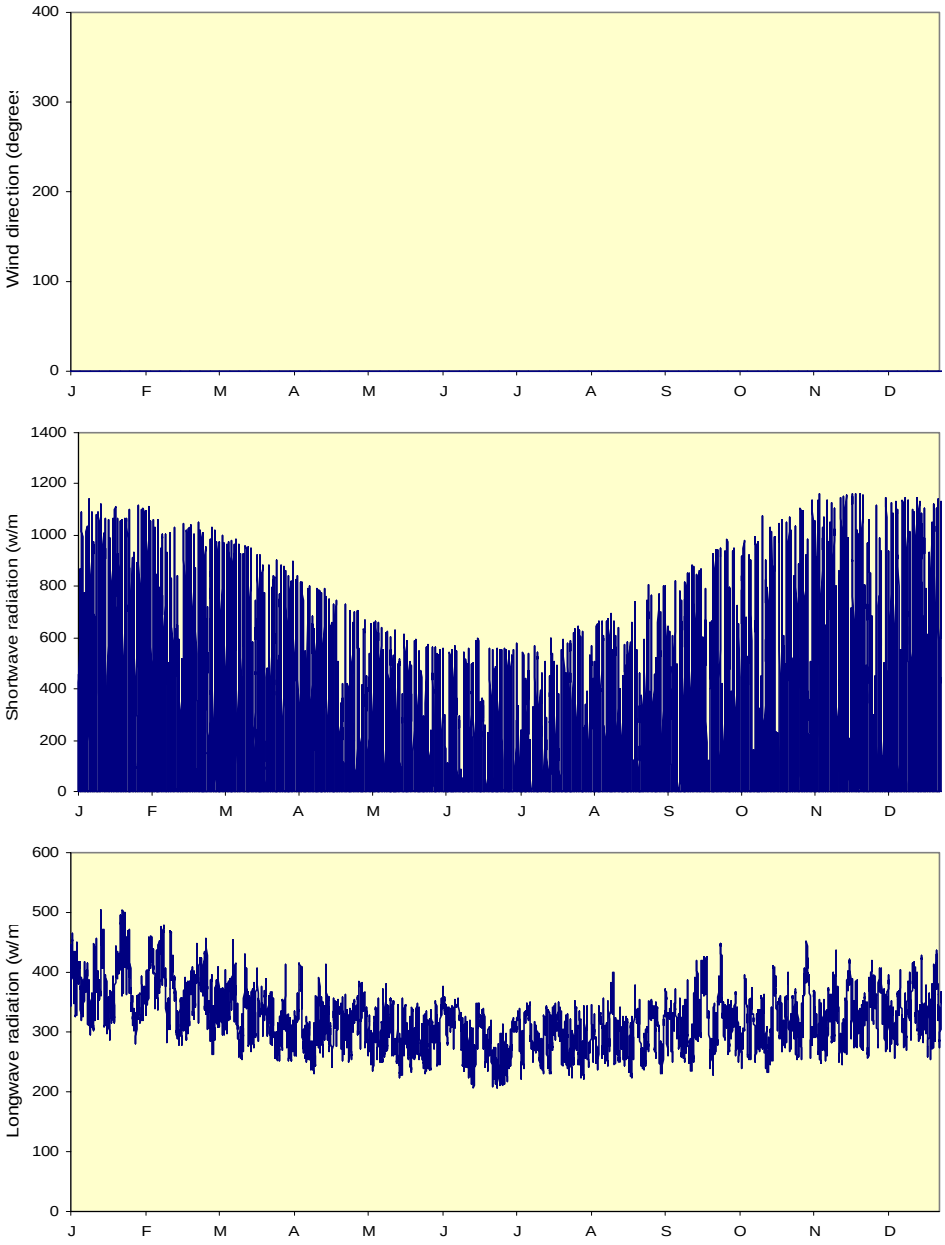

Figure B.2: Annual variation of climate variables for Hay for year 2001 (continued)

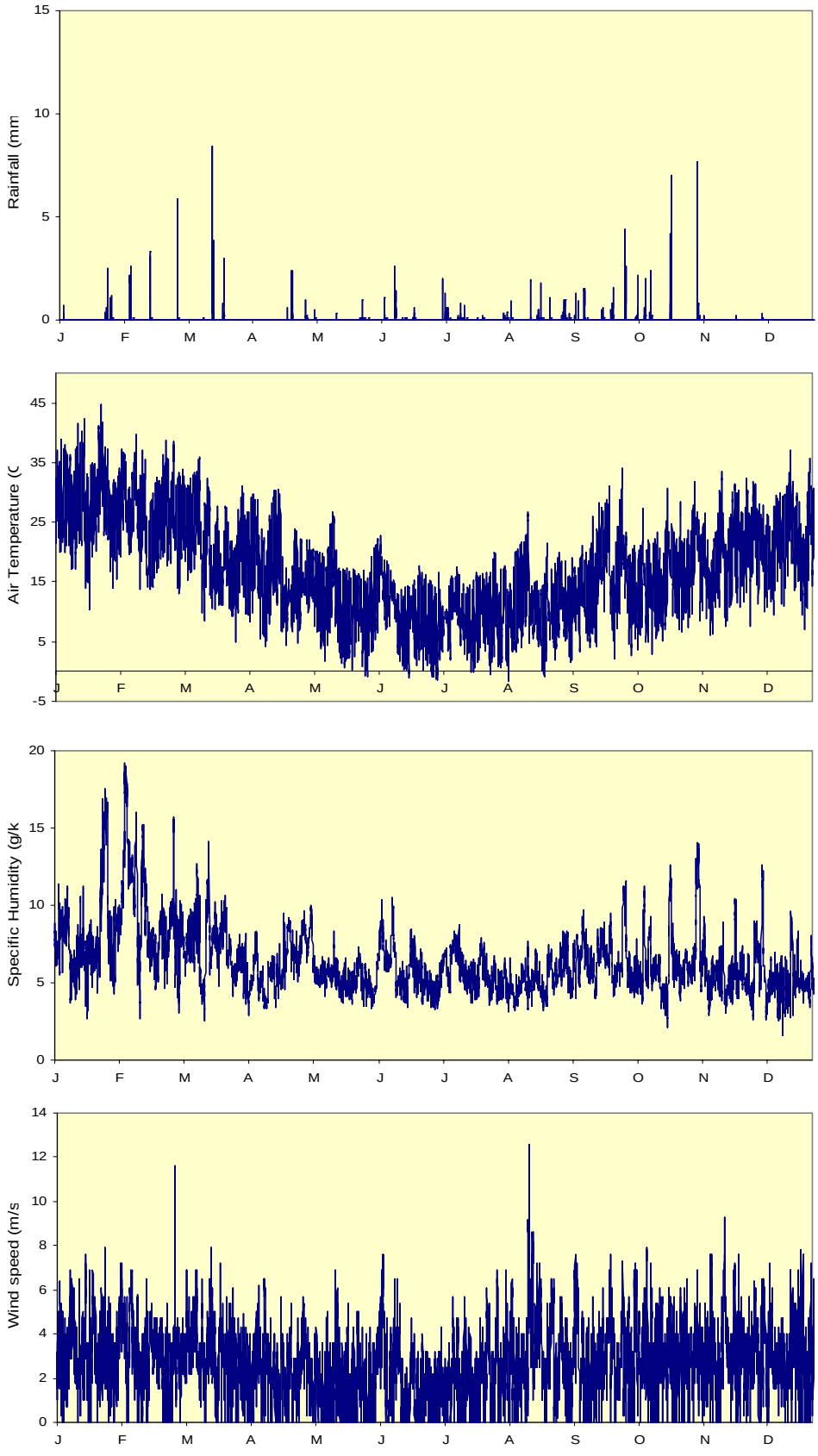

Figure B.3: Annual variation of climate variables for Griffith for year 2001

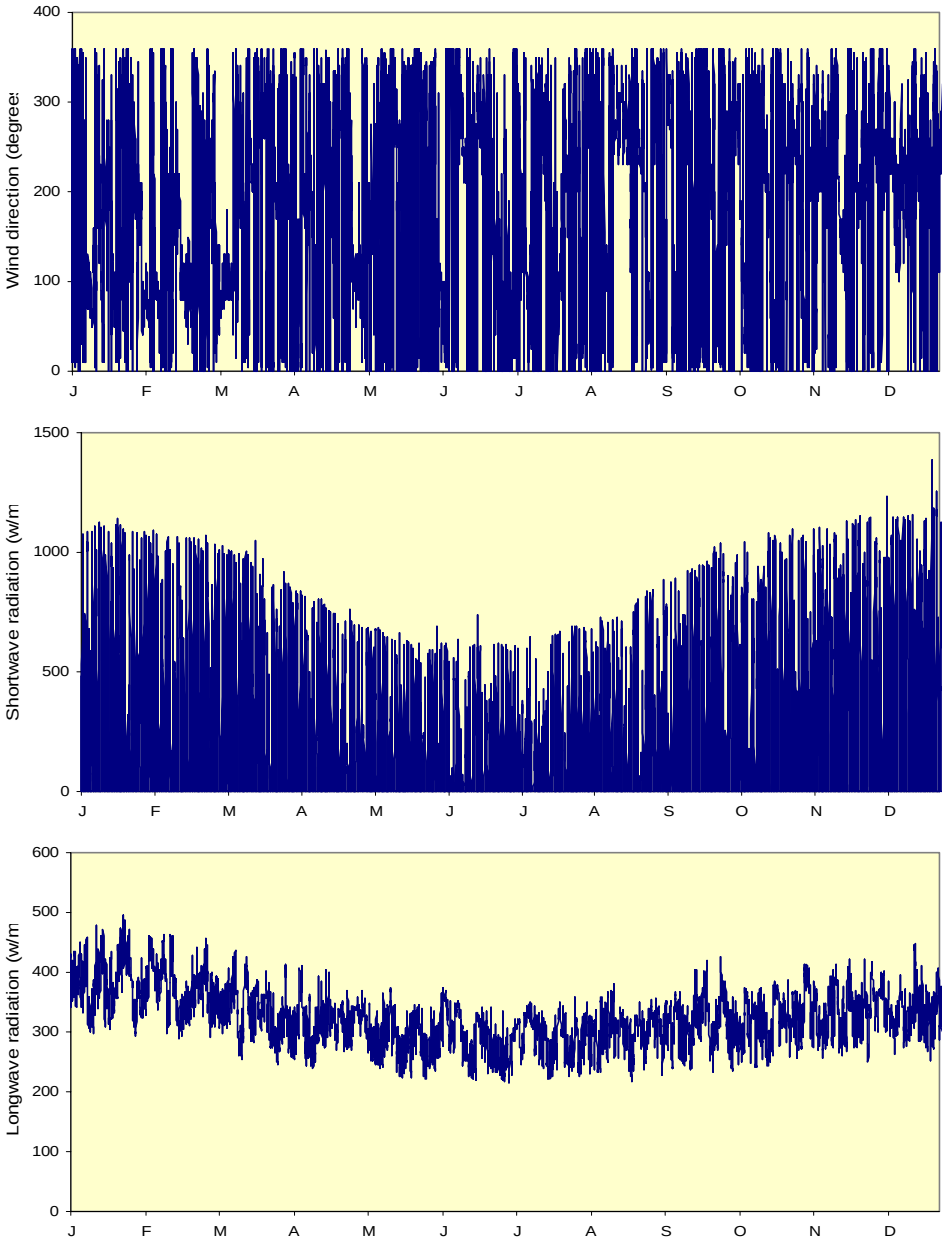

Figure B.3: Annual variation of climate variables for Griffith for year 2001 (continued)

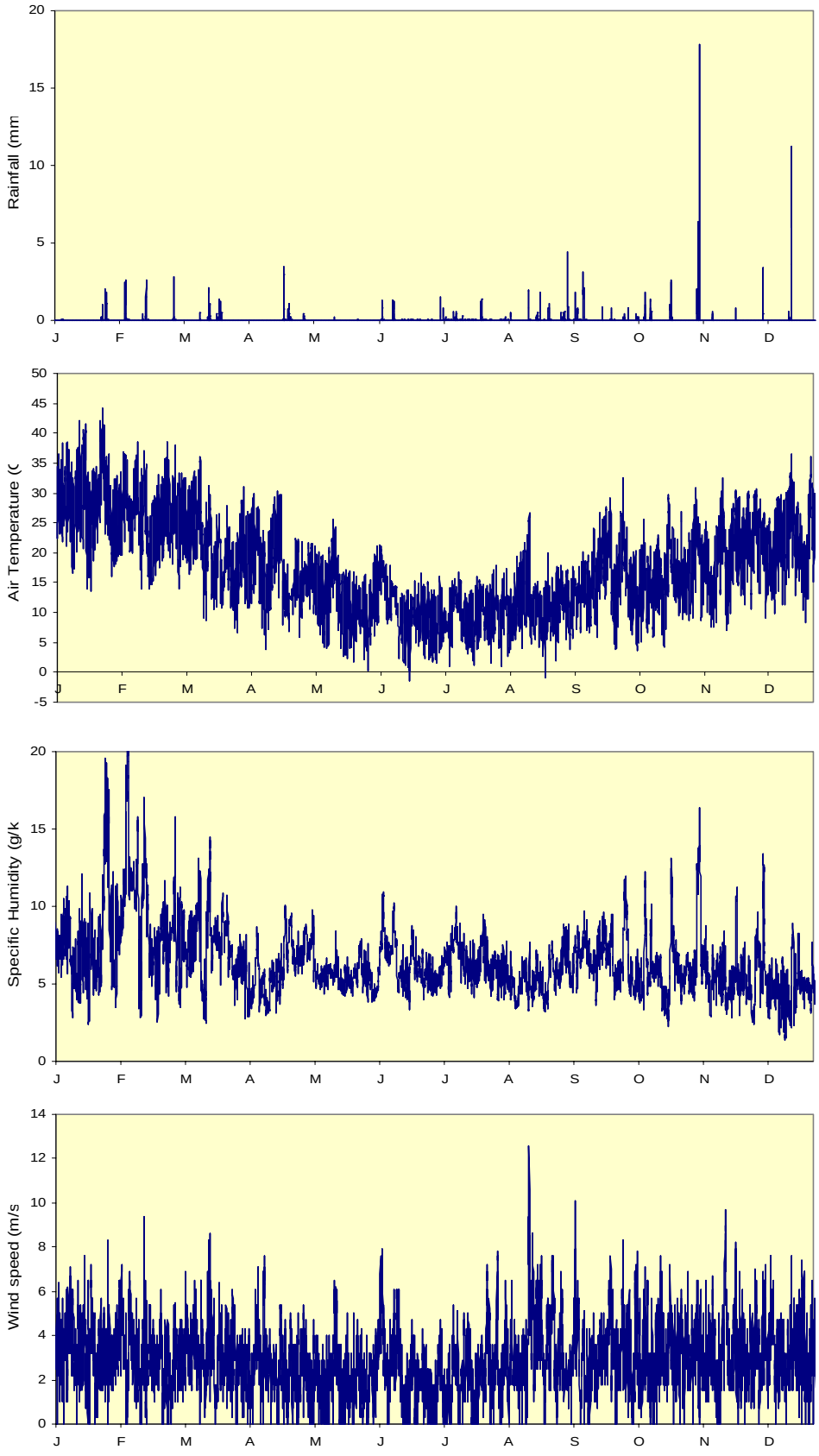

Figure B.4: Annual variation of climate variables for Yanco for year 2001

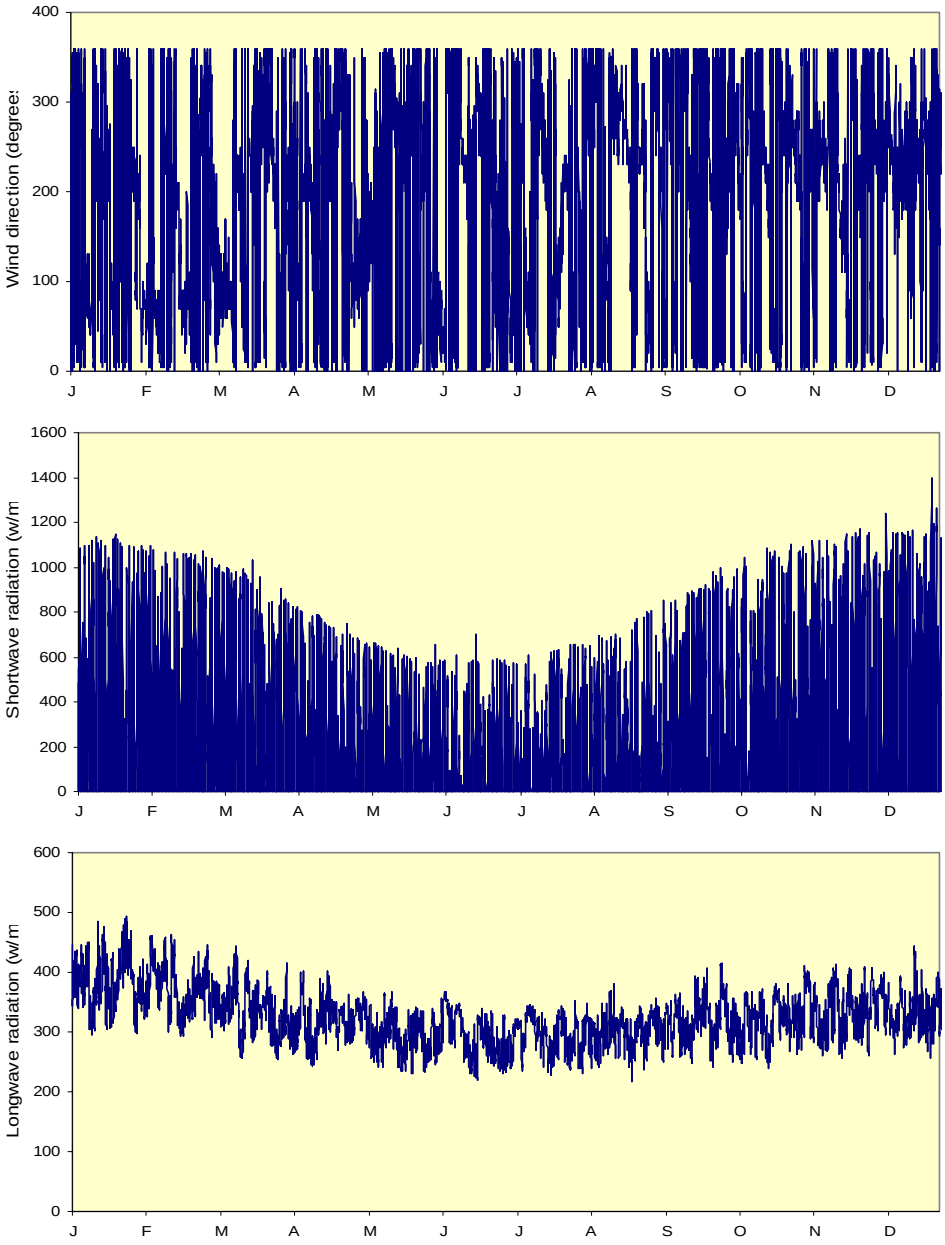

Figure B.4: Annual variation of climate variables for Yanco for year 2001 (continued)

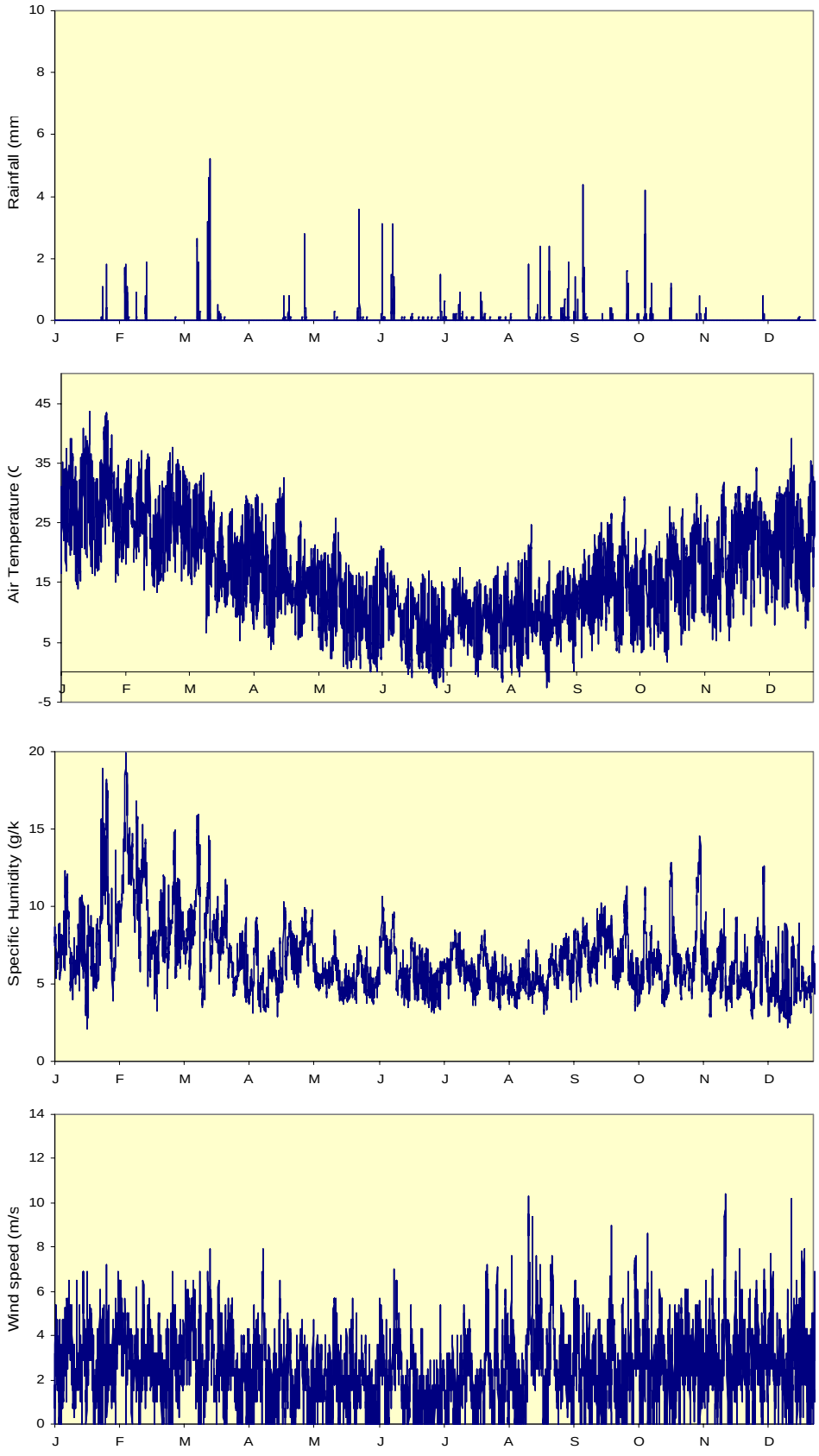

Figure B.5: Annual variation of climate variables for West Wyalong for year 2001

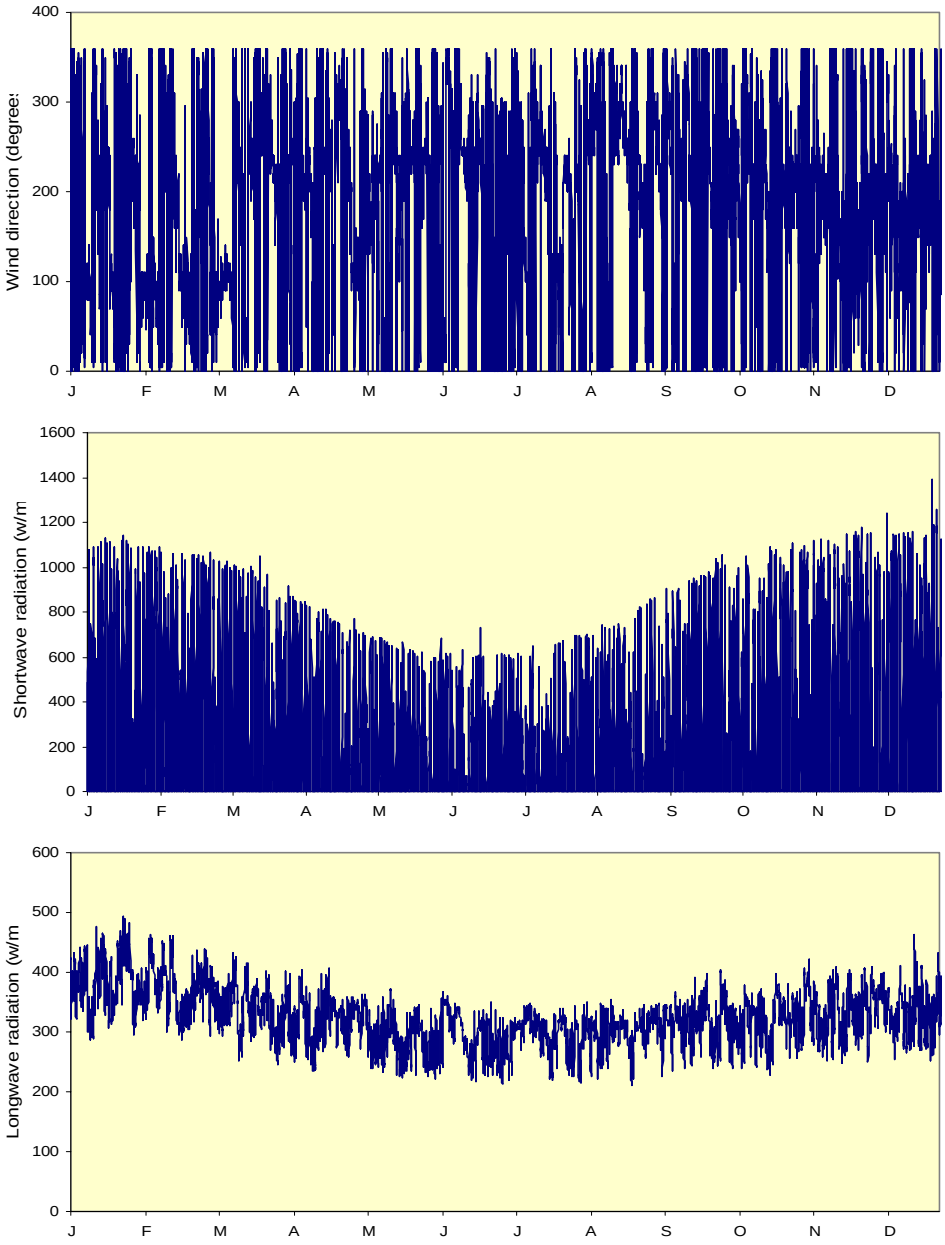

Figure B.5: Annual variation of climate variables for West Wyalong for year 2001 (continued)

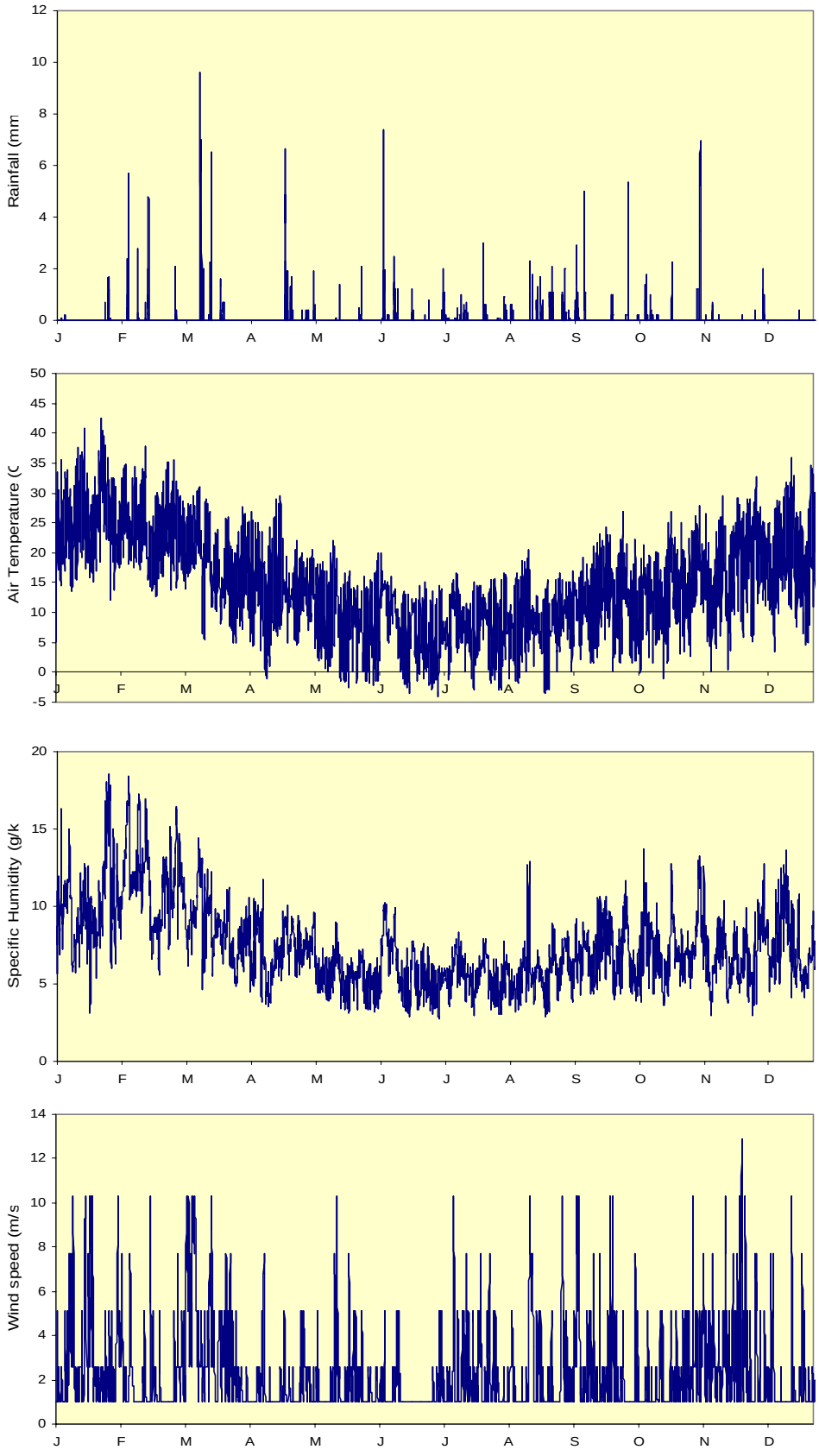

Figure B.6: Annual variation of climate variables for Cootamundra for year 2001

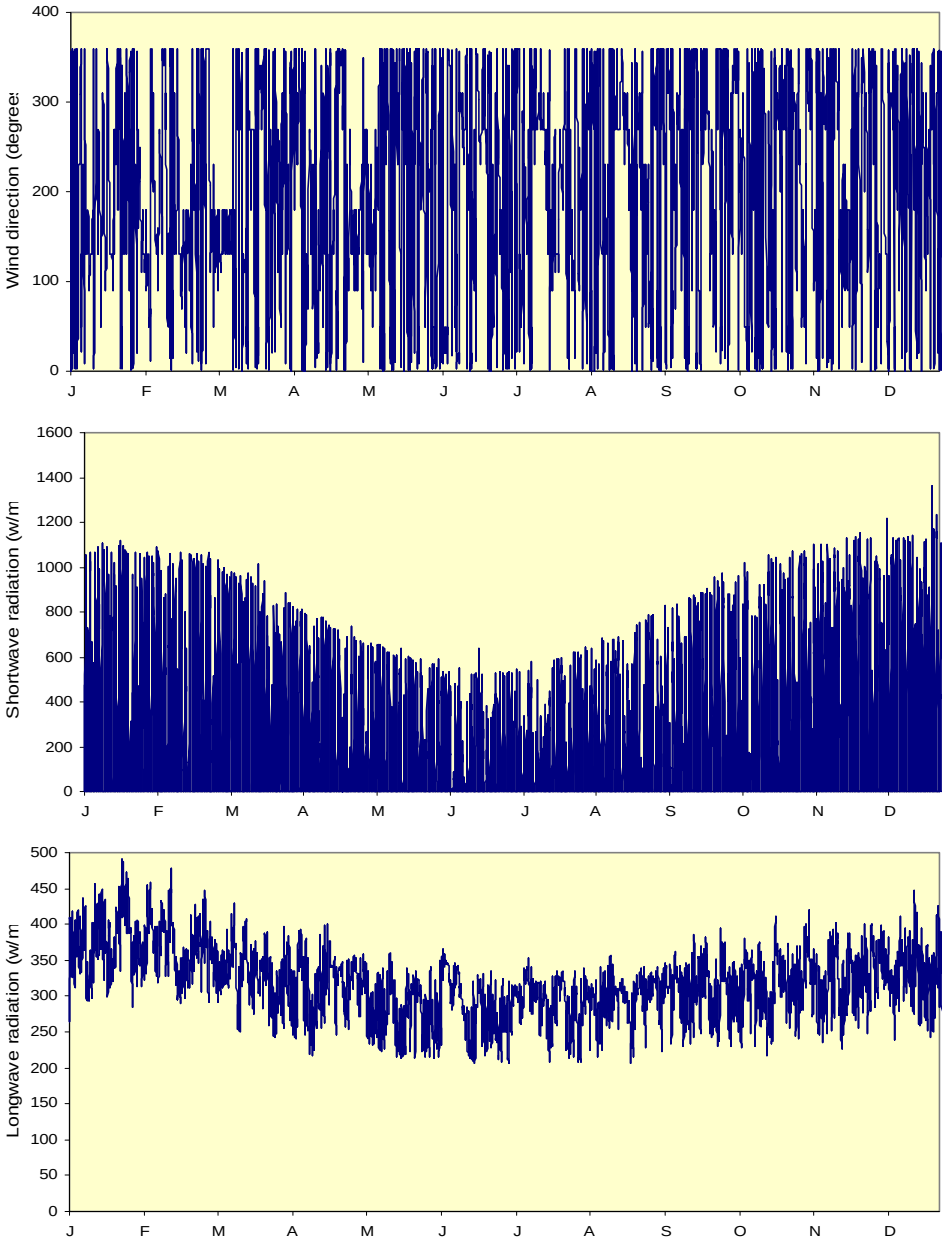

Figure B.6: Annual variation of climate variables for Cootamundra for year 2001 (continued)

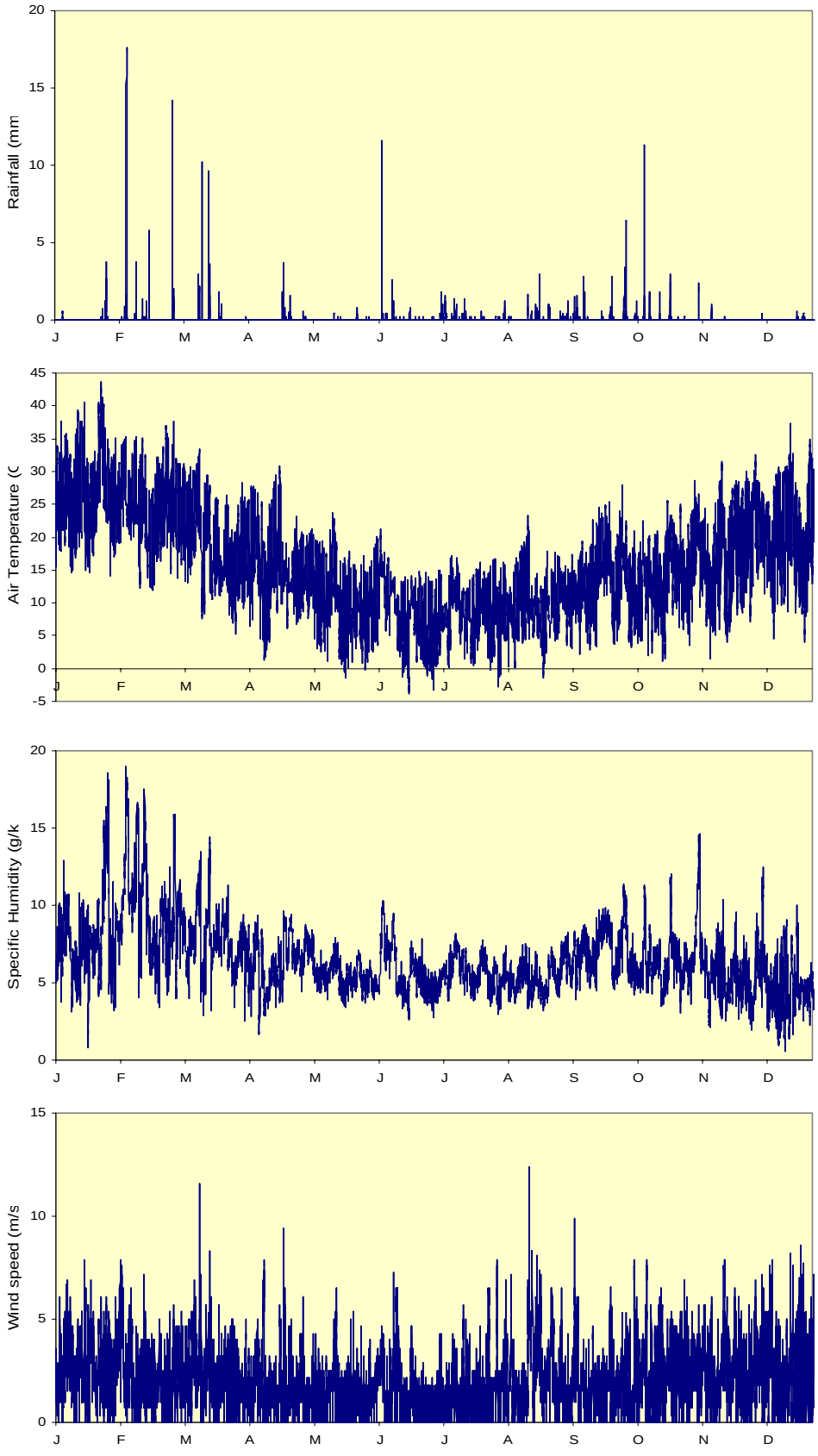

Figure B.7: Annual variation of climate variables for Kyeamba for year 2001

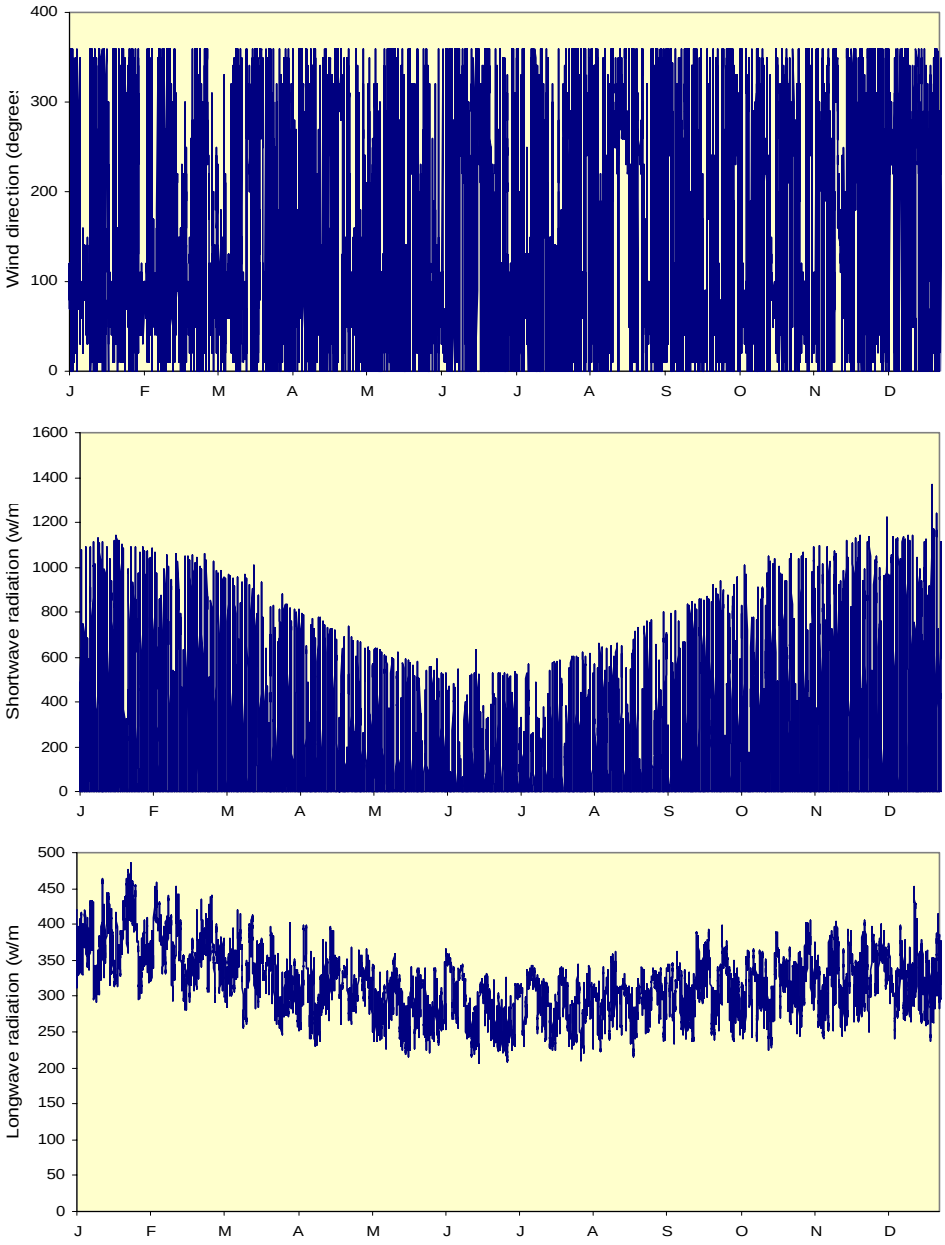

Figure B.7: Annual variation of climate variables for Kyeamba for year 2001 (continued)

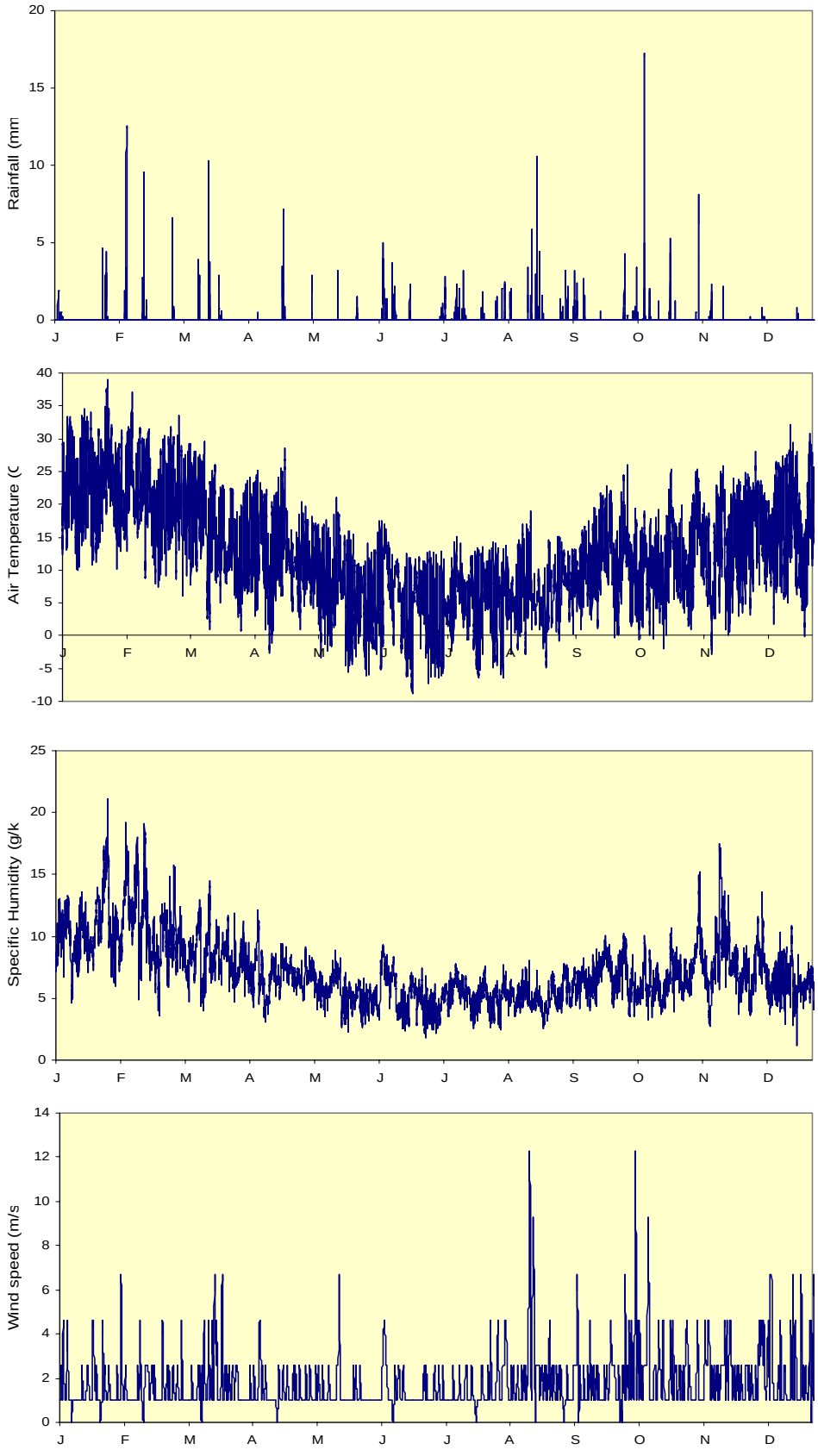

Figure B.8: Annual variation of climate variables for Adelong for year 2001

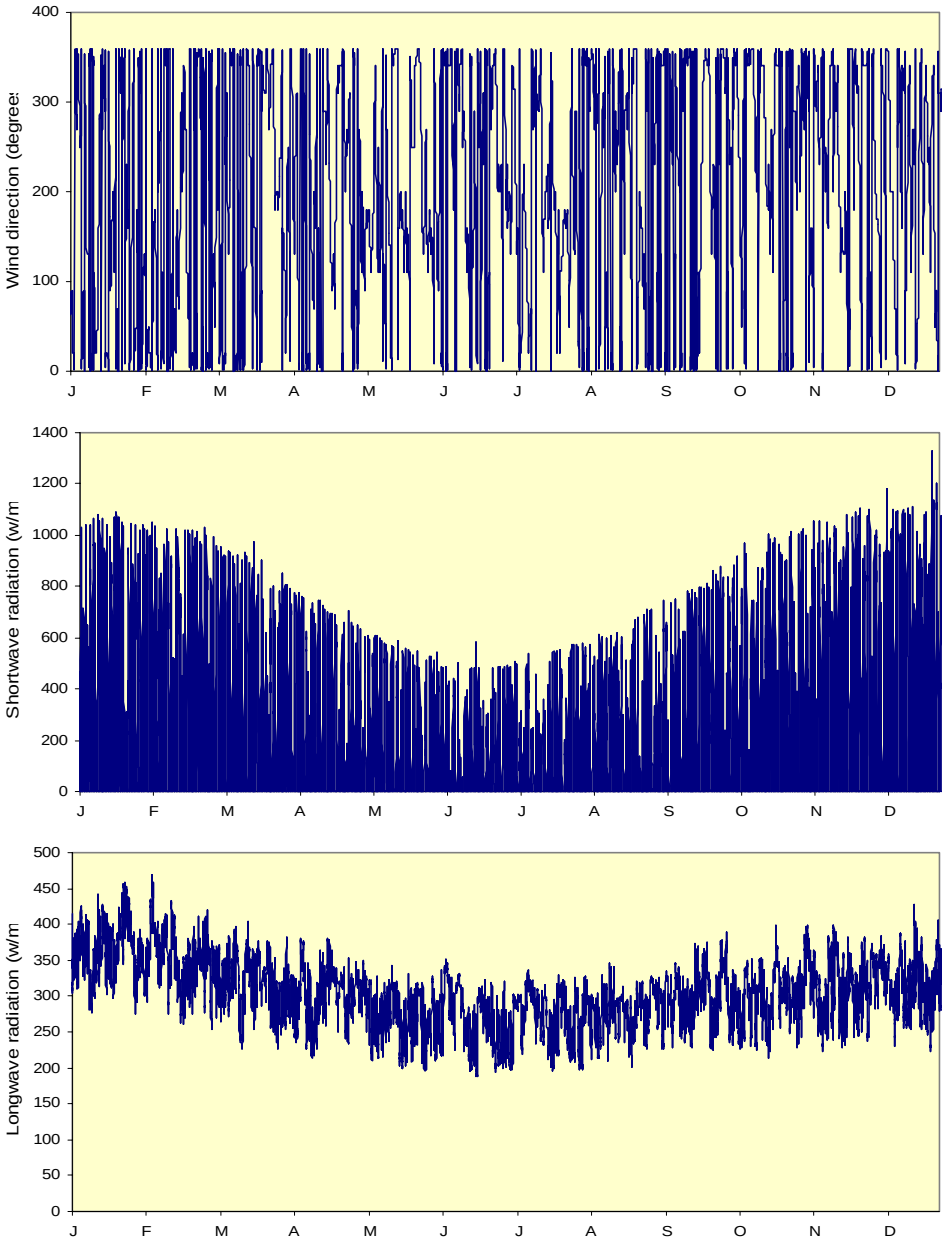

Figure B.8: Annual variation of climate variables for Adelong for year 2001 (continued)

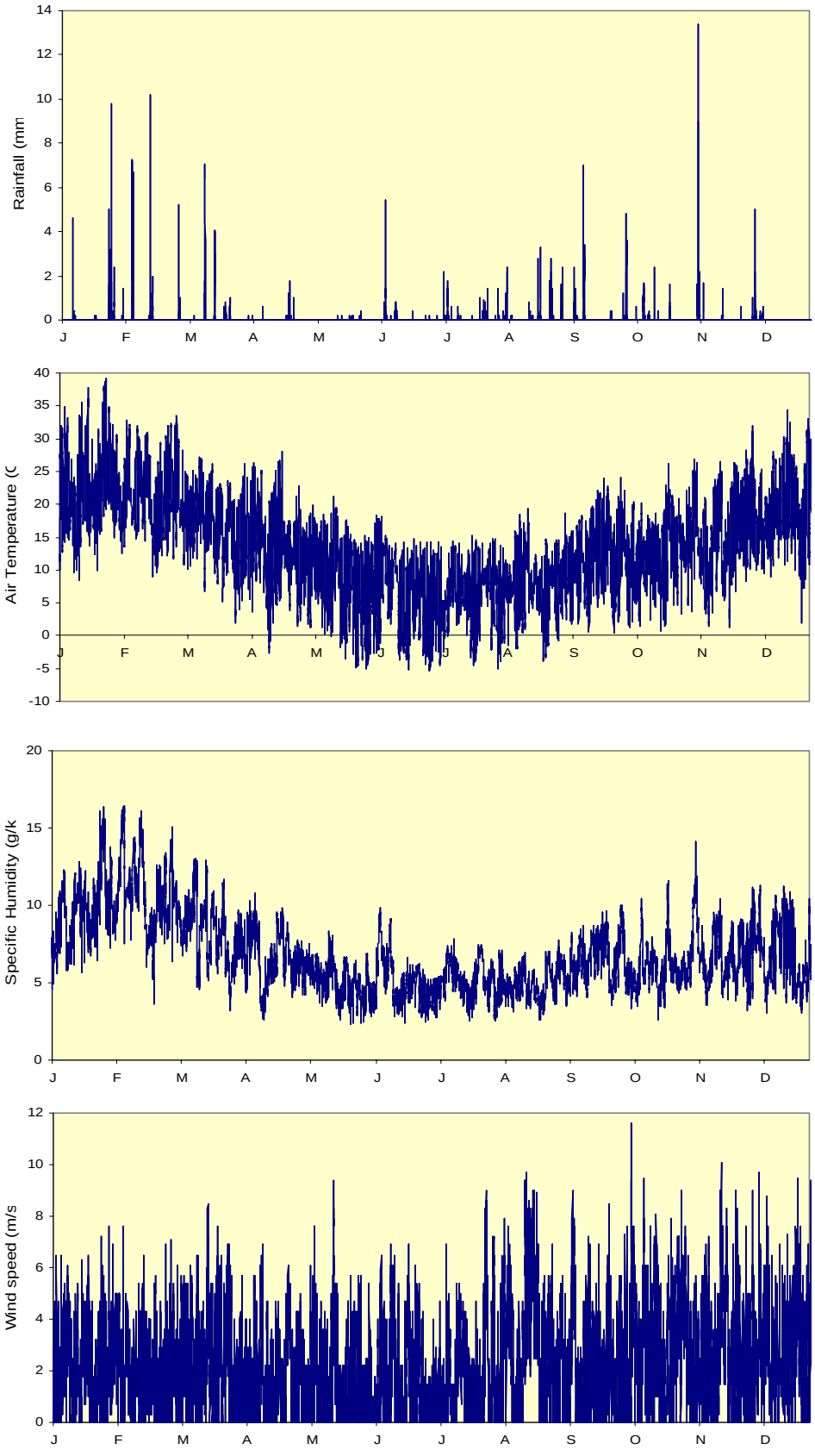

Figure B.9: Annual variation of climate variables for Canberra for year 2001

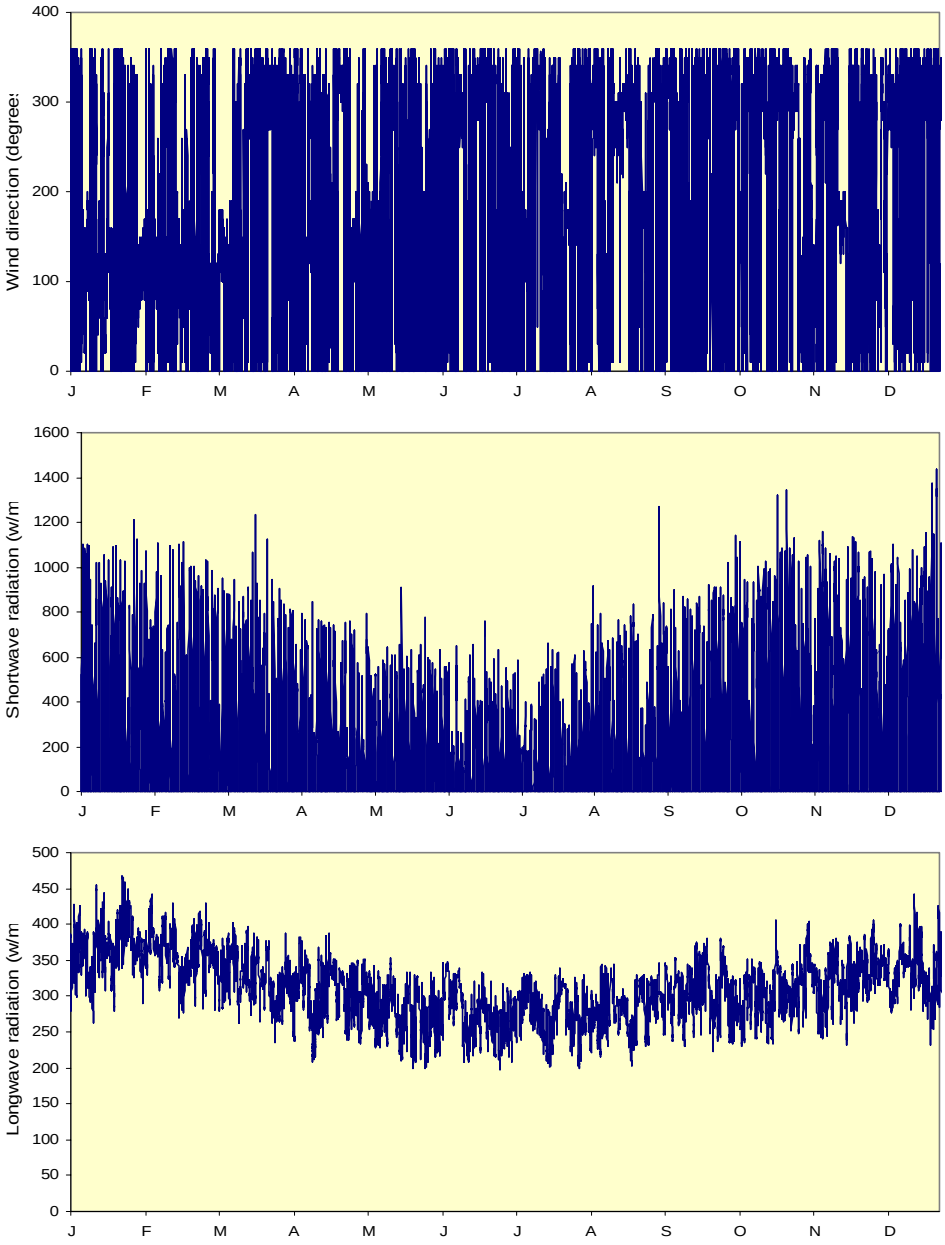

Figure B.9: Annual variation of climate variables for Canberra for year 2001 (continued)

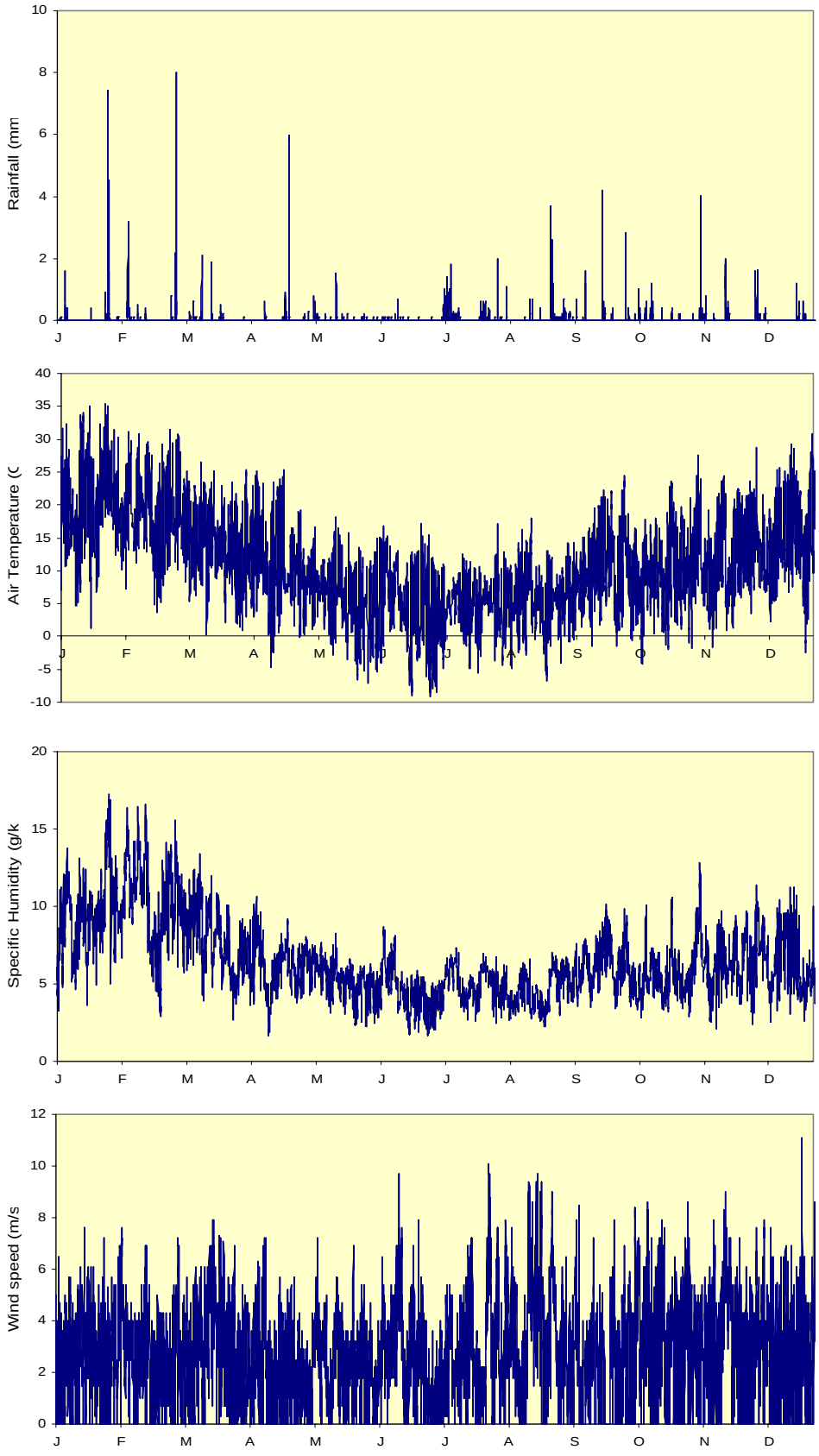

Figure B.10: Annual variation of climate variables for Cooma for year 2001

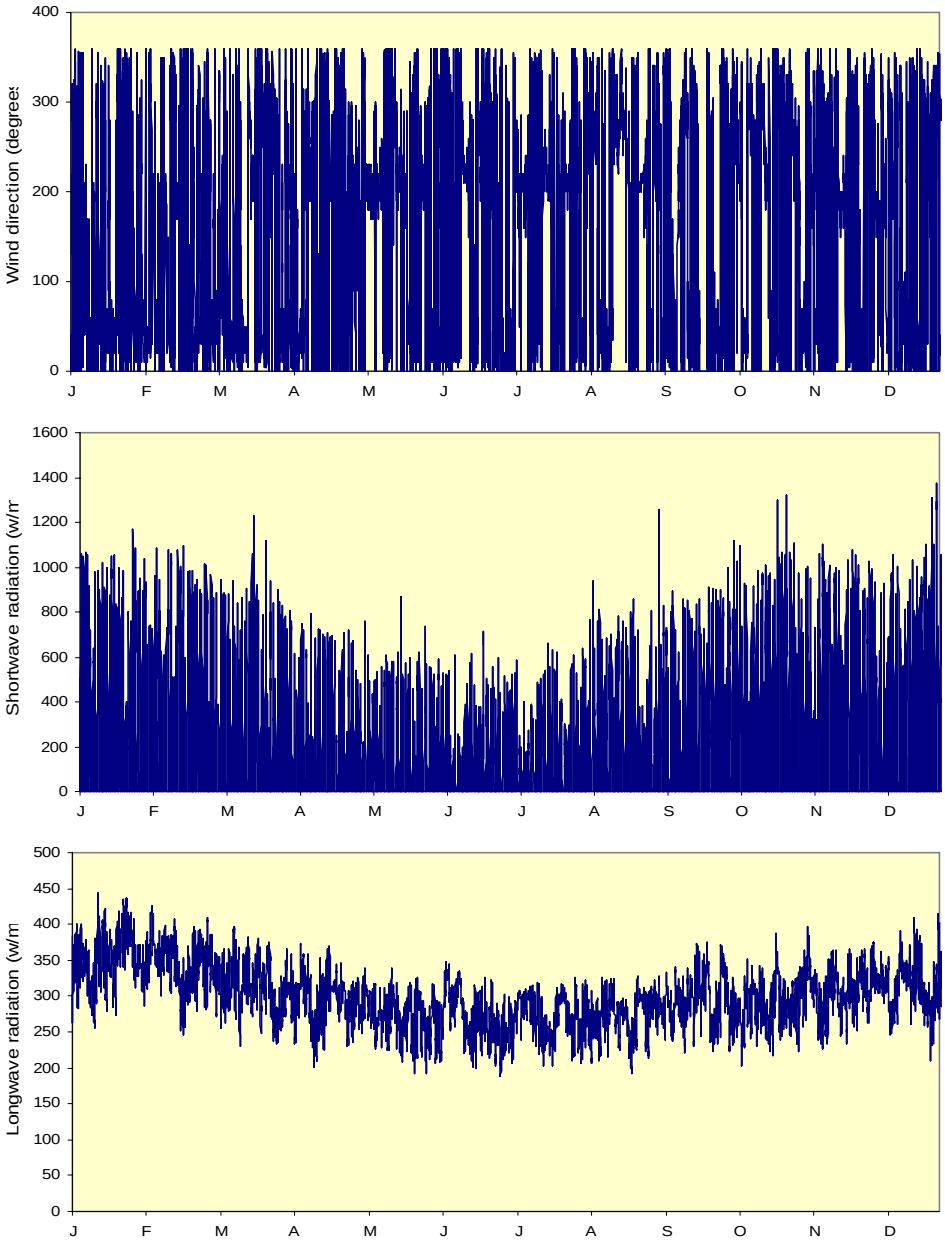

Figure B.10: Annual variation of climate variables for Cooma for year 2001 (continued)

The Cooperative Research Centre for Catchment Hydrology
is a cooperative venture formed under
the Commonwealth CRC Program between:

- Brisbane City Council
- Bureau of Meteorology
- CSIRO Land and Water
- Department of Land and Water Conservation, NSW
- Department of Sustainability and Environment, Vic
- Goulburn-Murray Water
- Griffith University
- Melbourne Water
- Monash University
- Murray-Darling Basin Commission
- Natural Resources and Mines, Qld
- Southern Rural Water
- The University of Melbourne
- Wimmera Mallee Water

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