Problems with CRU3.x and 4.x for Tmax, Tmean, Tmin and Tdew

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Abstract

As part of our quality control for ERA5 and ISIMIP3b data in coastal cells we were comparing weather station data with CRU data. We found strange dips in both Tmax, Tmean, Tmin data and Tdew data for both CRU3.x and CRU4.x for one month only in a number of places in the world. These places are likely not to be the only ones because we were only exploring issues with coastal cells.

Method: As part of our broader study of population heat stress at a grid cell level we discovered problems with the ERA5 data for coastal cells caused by averaging the ocean temperature with land temperature in a grid cell. In studies of heat exposure on populations it is the heat over land areas that matters. We were comparing the grid cell data with daily weather station data from NOAA GSOD (Global Summary of the Day) and CRU gridded data CRU TS3.x and TS4.x from CRU. We were using multi-year averages for each month either at a daily level from weather stations or at a monthly level from CRU. We were using the CRU variables TMP (mean daily temperature), TMX (maximum daily temperature), Tmin (minimum daily temperature) and Tdew which was derived by a standard formula from VAP (vapour pressure) based on Tmean and VAP. Eg Tdew = [116.9+237.3ln(VAP)]/[16.78-ln(VAP)] from Georgia Automated Environmental Monitoring Network. http://georgiaweather.net/glossary.php. In this report we use Tmax as an abbreviation for maximum monthly temperature, Tmean for the average monthly temperature, Tmin for the minimum monthly temperature and Tdew the average monthly dew point temperature. All temperatures in °C.

Results:

Part 1 Coastal Temperature Errors

Vietnam Tmean, Tmin errors:

The CRU Tmin values in March for the Vietnamese grid cell (13.75, 109.25 highlighted by the orange grid cell) are some 20C lower than for the same cell in February and April (see figure 1) while the Tmean (and Tdew) values from that same grid cell are about 8C lower than the February/April average. This effect spreads beyond the (13.75, 109.25) grid cell and Figure A1 in the appendix shows the difference between the March Tmean and the average of the February and April Tmean recorded in the nearby grid cells.

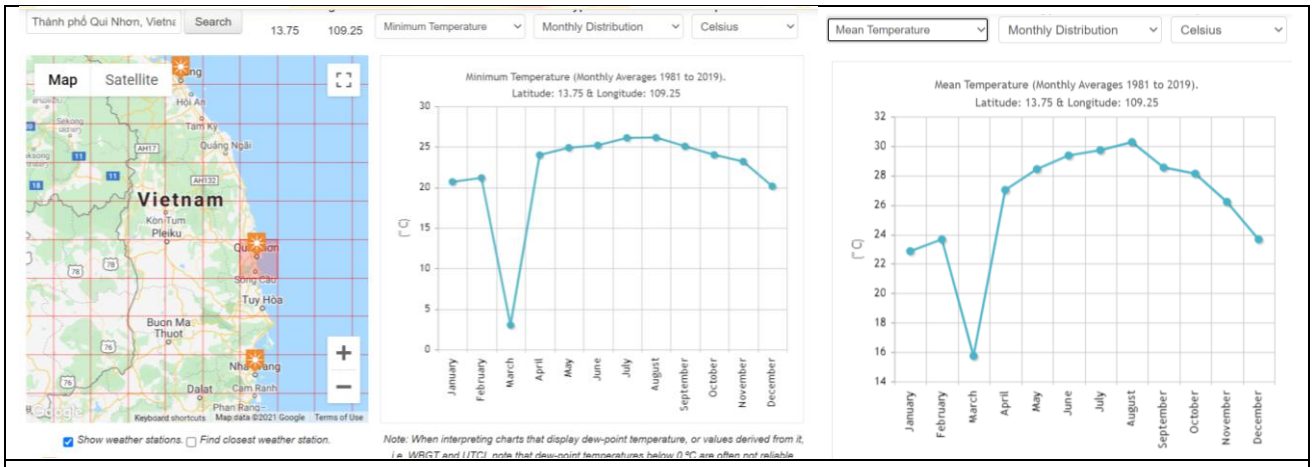


Figure 1 Climatechip output of CRU 4.04 data for cell 13.75, 109.25 showing map and monthly minimum temperature distribution and monthly mean temperature distribution averaged for years 1981 to 2019.

The weather station in the city of Qui Nhon in Vietnam (grid cell coordinates 13.73, 109.25 – shown by the central orange star in the map in figure 1) has its minimum daily temperature, as recorded in GSOD, in March 2001-2010 ranging from 20C to 22C. On the other hand the CRU TS4.04 Tmin in March 2010-2019 is some 20C lower than the weather station for March only (see figure 2). Strangely Tmax does not have the same problem.

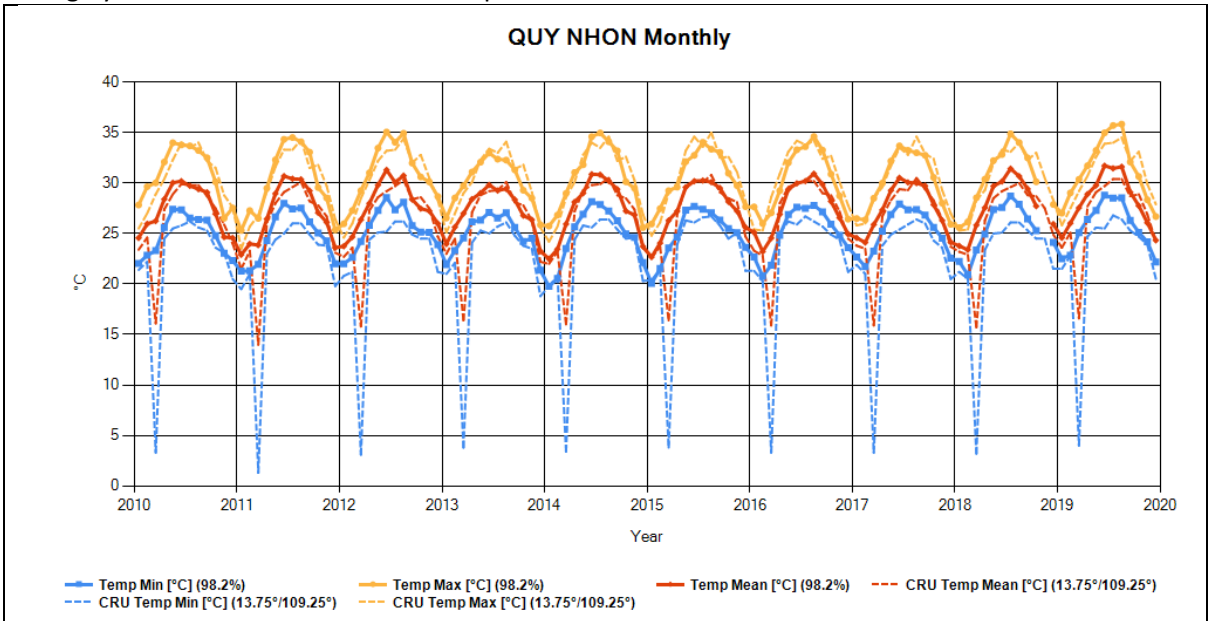


Figure 2 Grid Cell (13.75,109.25) CRU Tmin 20C less and Tmean 10C less than weather station in that grid cell for March. The graph shows the maximum monthly temperature (orange), mean monthly temperature (red) and minimum monthly temperature (blue) with the corresponding CRU temperatures as dashed lines of the same colour. HothapsSoft Output from GSOD weather station data and CRU 4.04 data.

While the main error is in the grid cell 13.75, 109.25 where the Quy Nhon weather station is located, the error is still there but gets less the further North, West and South one goes. This is shown in Figure A2 in the appendix shows the maximum, mean and minimum temperature plotted for both CRU and weather stations found in CRU grid cells. The date range is from 2010 to 2020 in order to get the most up to date data.

This dip in temperature in March to unrealistically low levels for this tropical region is apparent even as far back as we tested – to 1990 and is there for both CRU TS4.x and CRU TS3.x data sets. This March dip was not due to any Monsoon effects because these occur between September and December with March being one of the driest months. The altitude of the Quy Nhon weather station is about 6 metres and the mean altitude for this CRU grid cell is 77m above sea level so altitude is not an issue.

Iceland Tmax and Tmean errors

After we discovered this very significant error (we are about to study heat effects on working people in Vietnam) we checked other coastal cells using our combined weather station, ERA5, ISIMIP3b and CRU data and we came across another grid cell with a weather station that had the same issue for Tmax and to a lesser extent for Tmean, but no issue with Tmin or Tdew. This group of grid cells were near the Bolungavik weather station in the north-west of Iceland (see figure 3).

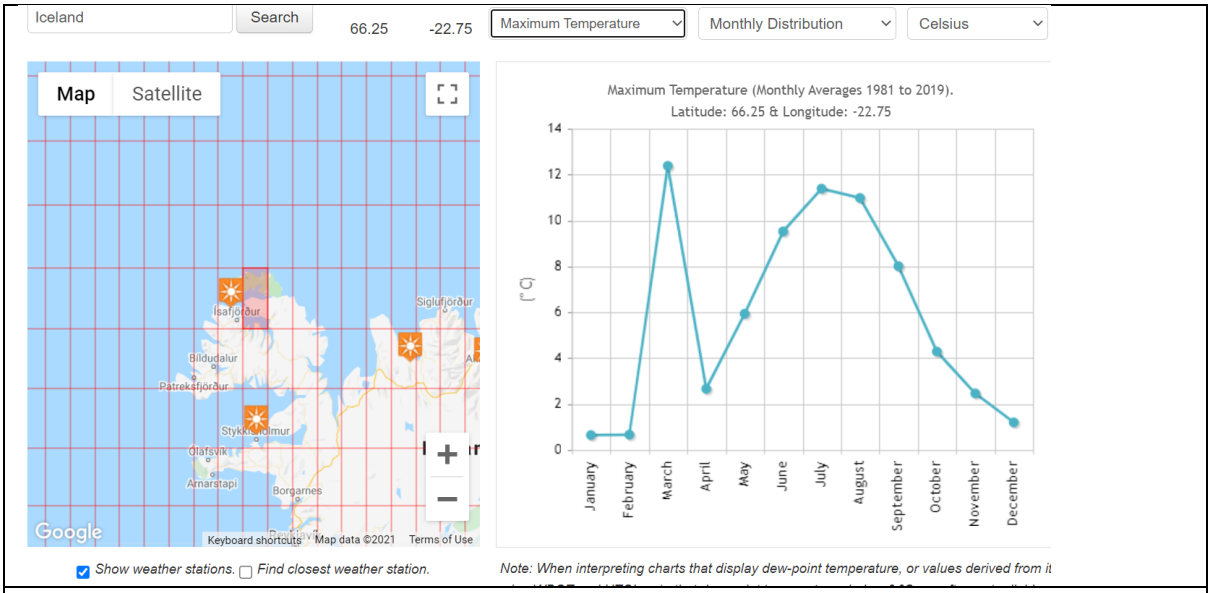


Figure 3 Climatechip output of CRU 4.04 data for the Icelandic cell 66.25, -22.75 showing map and monthly maximum temperature distribution. There was a small effect for Tmean for March, but no effect on Tmax or Tdew. Distribution averaged for years 1981 to 2019.

Part 2: errors in coastal Tdew derived from CRU VAP

A critical component of our heat stress studies involved the humidity so this also needed to be checked. Unfortunately, a similar 1 month dip was found for Tdew derived from CRU VAP in a number of locations. The Vietnam location has already been discussed above. Another location that only had a one month (August) error in Tdew was at the southern and south western tip of Taiwan centred around the weather station of Kaohsiung (in grid cell 22.75, 120.25), but also including neighbouring grid cells, especially 22.25, 120.75 but not in the coastal tip in cell 22.75, 120.75. In these cells the Tdew dropped as much as 25C just for August to an unrealistically low (for a tropical country) of 0C. See figure 4. This effect translates to the same sharp dip in our WBGT calculation.

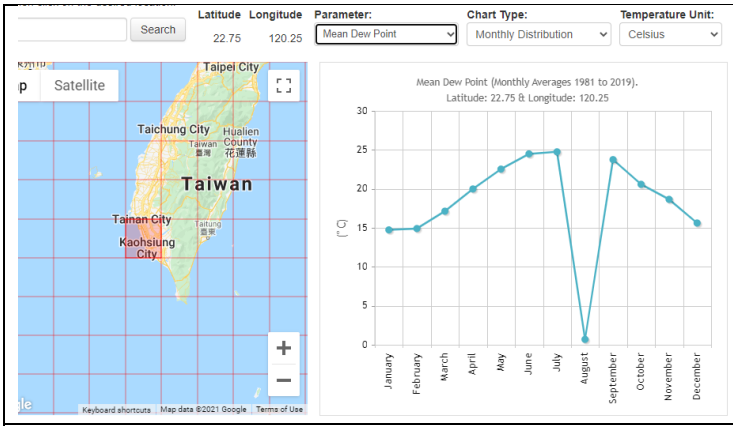
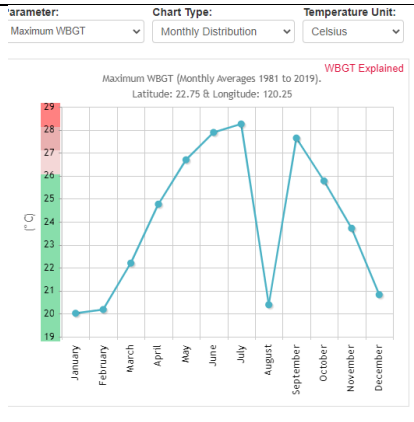


Figure 4a. Kaohsiung (Taiwan) grid cell showing the dip for Tdew in August. Data from climatechip.org.



4b. Same location showing dip in WBGTmax.

A further coastal location with the same error was found near the city of Surat in India in October. See figure 5. This effect was also present in a decreasing amount 3 grid cells north, 3 grid cells south (to just above Mumbai) 5 grid cells east (inland) and 3 grid cells west. This group of cells have a very high population)population 60.5M which would render our heat impact studies using WBGT very inaccurate for that location. Figure 5b compares the weather station data for Tdew in Surat with the CRU data for the same grid cell.

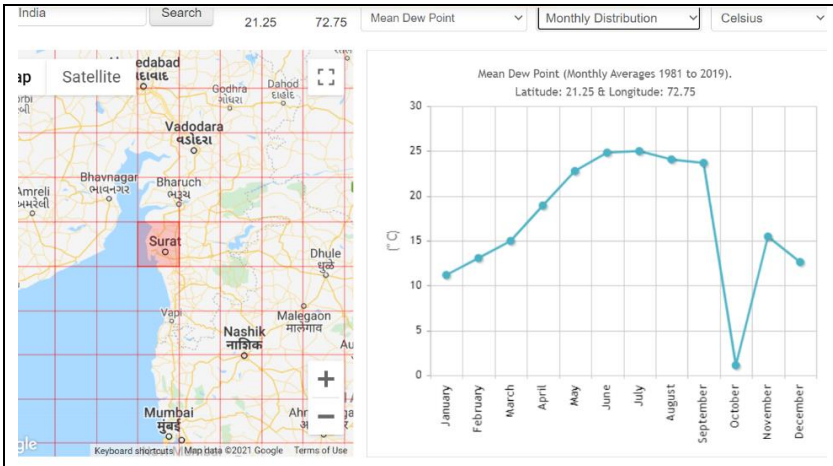


Figure 5a. Surat (India) grid cell showing the dip for Tdew in October. Data from climatechip.org.

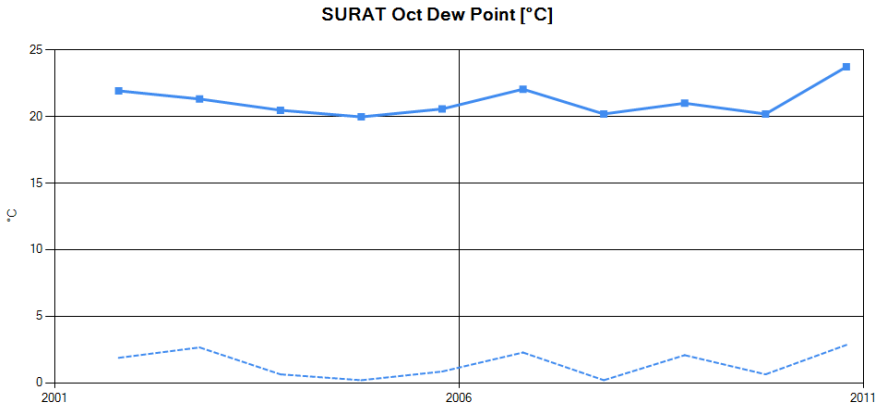


Figure 5b. Data from HothapsSoft showing both the weather station data (solid line) and the CRU data (dotted) for Surat in October for every year from 2001 to the end 2010.

Other Tdew issues.

The one month issues were easy to identify for the coastal cells we studied, but there was also another problem that became apparent. In a number of grid cells the Tdew was considerably higher than the Tmin. This is difficult to understand because as Tmin becomes lower than Tdew, the Tdew value should also be dragged lower. Examples of such locations (by no means exclusive) include grid cell

(62.25, -114.25) at the location of the Yellowknife weather station in Canada; (42.75, 89.25) at the location of the Turpan weather station in China (see figure 6). This error was not explored further because it was only identified in sparsely populated places during cold months when they experienced sub-zero temperature. Also we have recently discovered that weather station daily Tdew values are not accurate when there is rapid cooling because hourly decreasing Tmin values drag down the hourly Tdew values so that the average hourly Tdew used to derive the daily Tdew in faulty under those conditions.

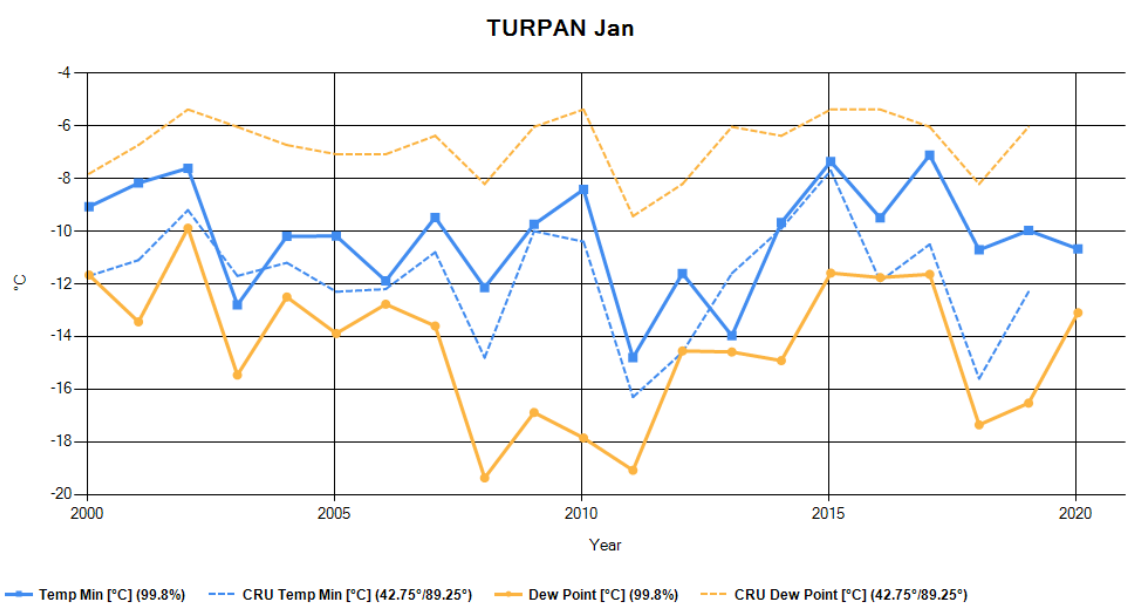


Figure 6 Turpan weather station in China and CRU data for the same grid cell. One would expect Tdew to be lower than Tmin, which is the case for the weather station (solid blue and solid yellow lines). However for the CRU TS4.04 data from the grid cell with Turpan shows the physically unrealistic Tdew (yellow dotted) ABOVE the CRU Tmin temperature (bloe dotted).

Conclusion:

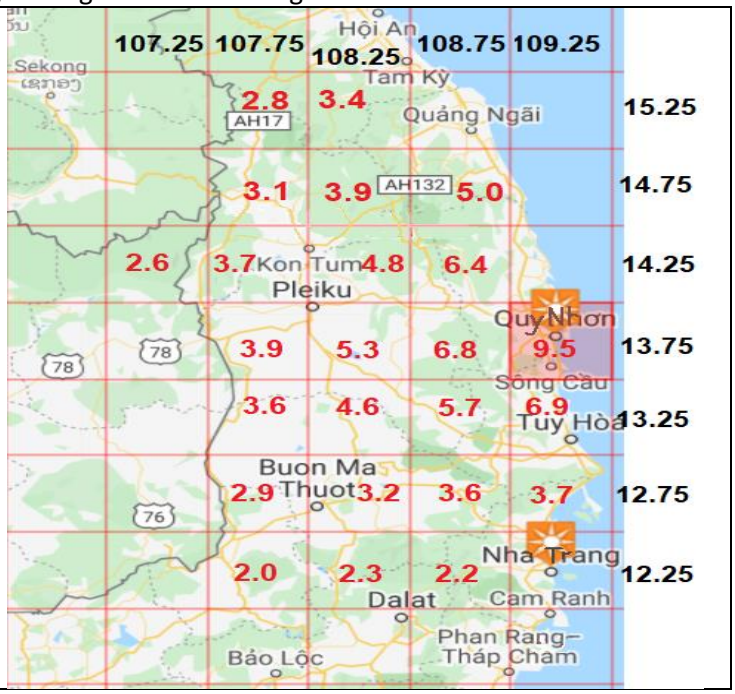
We discovered strange one month errors in the CRU data base both the TS3.x version and the TS4.x version for Tmax, Tmean, Tmin and tdew derived from CRU vapour pressure. We have only identified coastal grid cell errors and have not studied inland grid cells. Of the 5 clusters of grid cells identified all except one (in Iceland) had high populations.

Appendix 1:

0.5x0.5 grid cells in Vietnam where the March average of Tmean differed by more than 2C from the mean of the February and April monthly average are shown in figure A1.

Figure A1

The difference in °C is shown in red in those grid cells where the March value was more than 2C lower than the average of February and April. Longitude and latitude numbers for each grid cell are shown in black along the top and down the right of the figure. The weather station (at Quy Nhon) used to confirm the issue of very low Tmax values for these cells in W5E5 is shown in the pink highlighted cell (13.75, 109.25).



Appendix 2:

The sequence of graphs in figure A2 starts with Da Nang 2.5 degrees to the north of Quy Nhon and shows the monthly Tmax, Tmean and Tmin for weather stations and CRU as one goes south and west to the last graphic showing the weather station and CRU data for Ho Chi Minh City 2.75 degrees south of Quy Nhon.

Each graph shows the maximum monthly temperature (orange), mean monthly temperature (red) and minimum monthly temperature (blue) with the corresponding CRU temperatures as dashed lines of the same colour. The graphs are for all grid cells in that region that also have a weather station in the grid cell.

The x axis shows the data for each month from 2010 to 2020 for CRU and for weather station data where available (some months are missing). The month of concern is March which is 3 twelfth of the distance to the right of each year line.

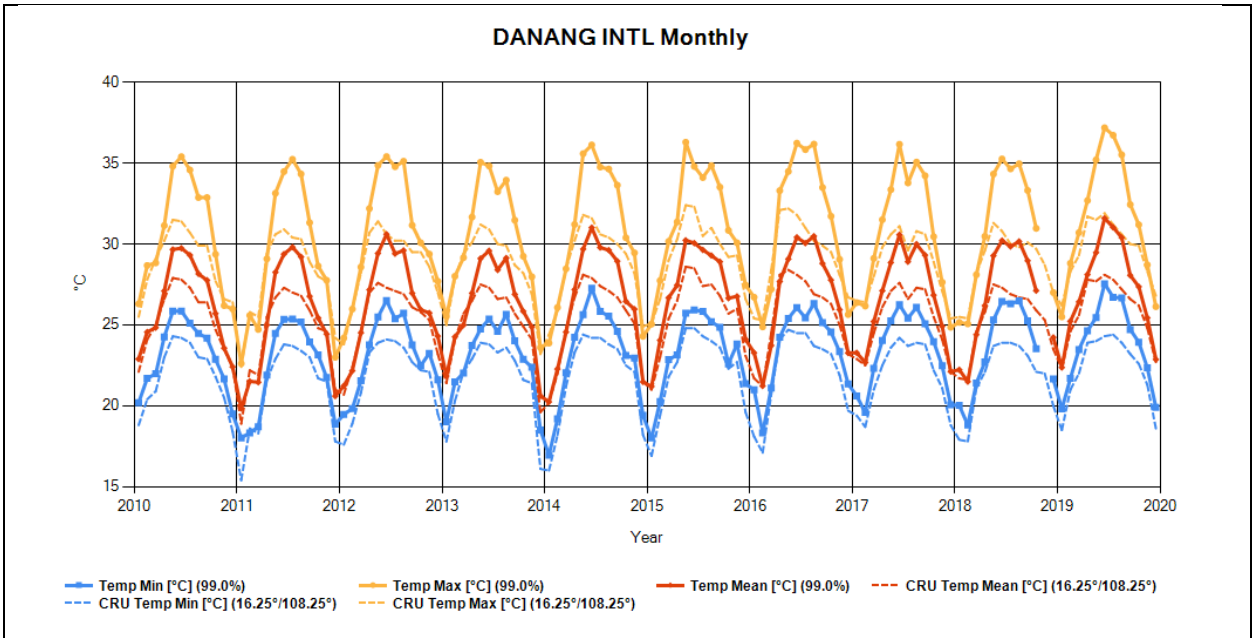


Figure A2.1 Grid Cell (16.25,108.25) CRU data compares relatively well with weather station data.

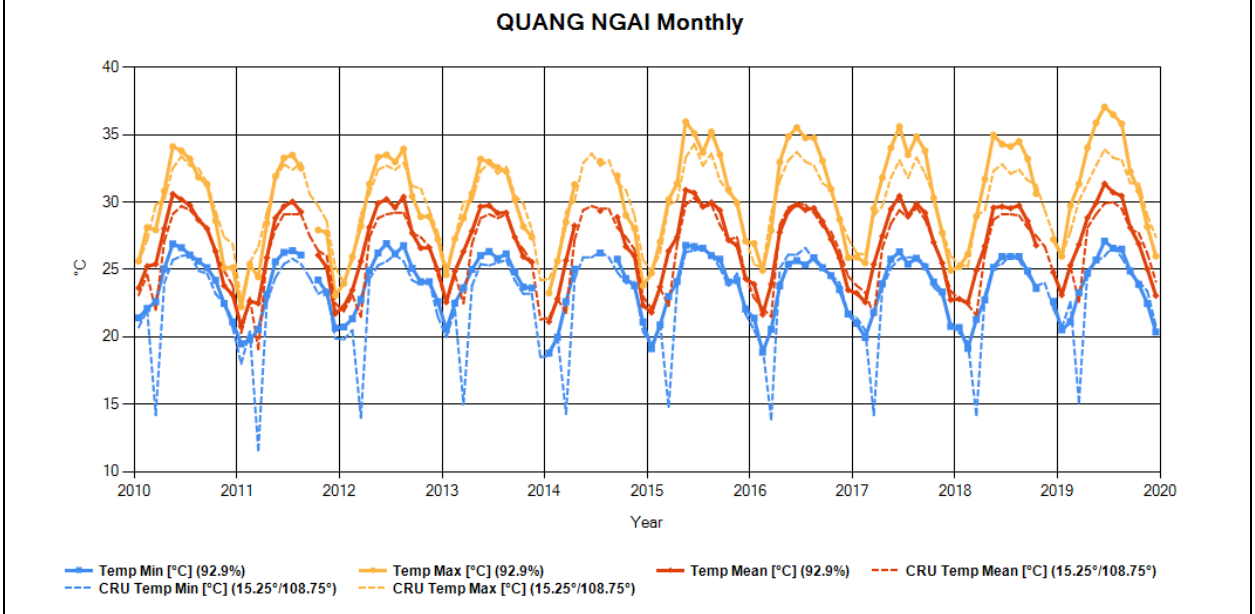


Figure A2.2 Grid Cell (15.25,108.75). CRU March Tmin is 7C less than weather station data.

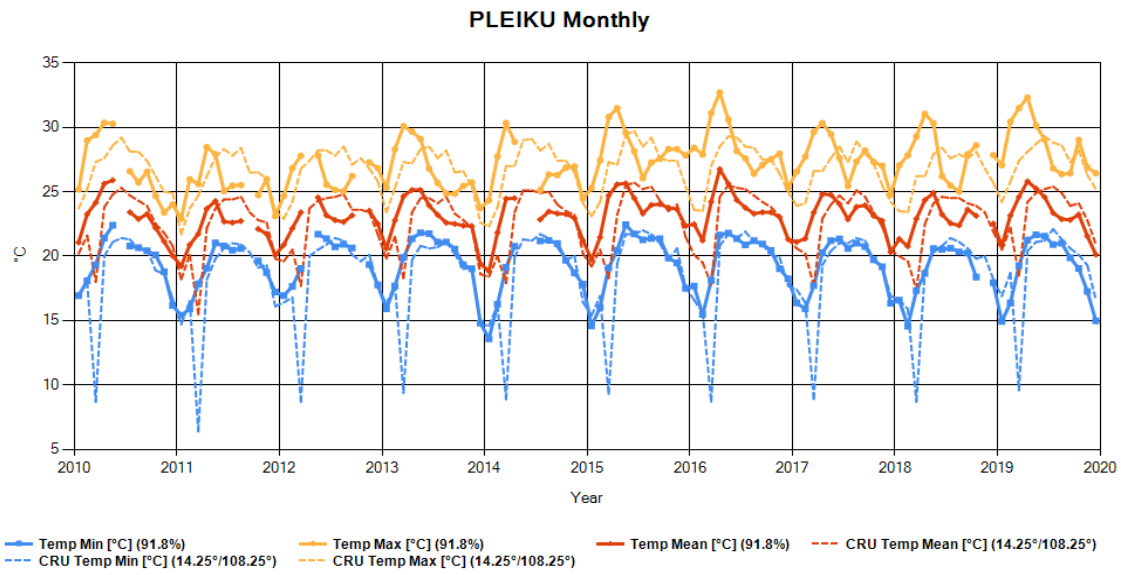


Figure A2.3 Grid Cell (13.25,108.25). CRU March Tmin 8C less; Tmean 2C less than weather station

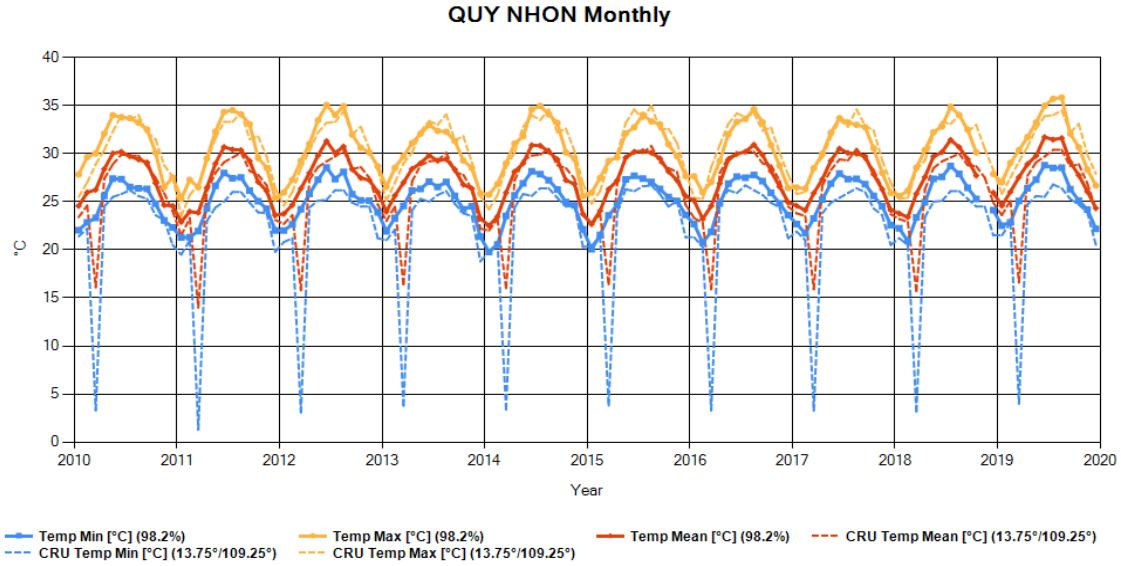


Figure A2.4 Grid Cell (13.75,109.25) CRU March Tmin 20C less; Tmean 10C less than weather station

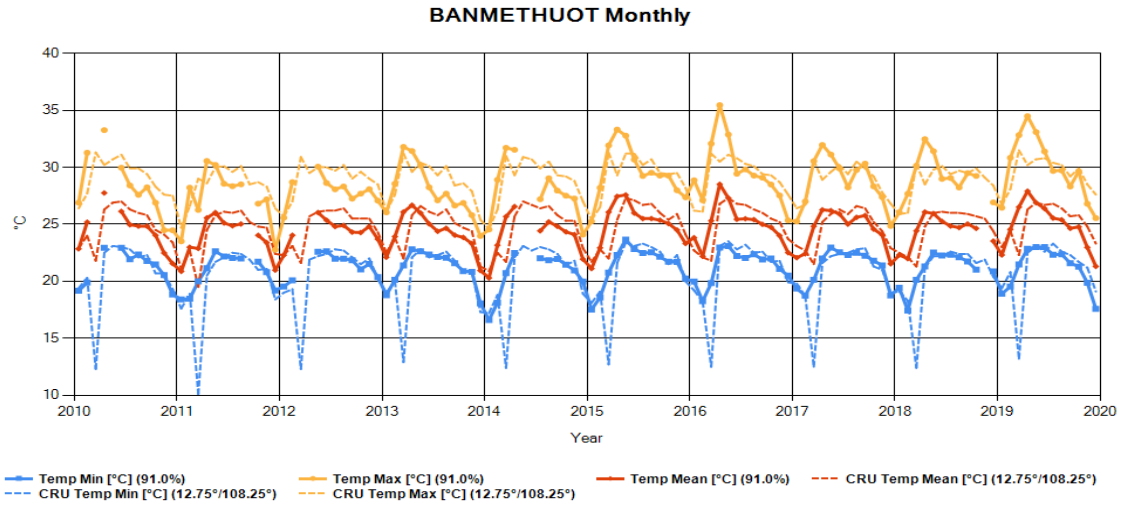


Figure A2.5 Grid Cell (12.75,108.25) CRU March Tmin 8C less; Tmean 2C less than weather station

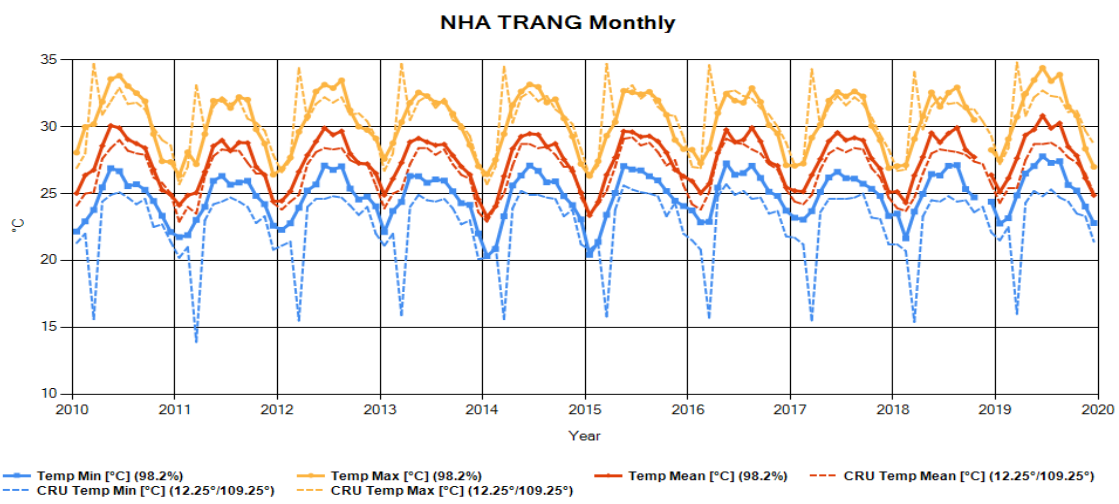


Figure A2.6 Grid Cell (12.25,109.25) CRU March Tmin 8C less; Tmax 4C higher than weather station

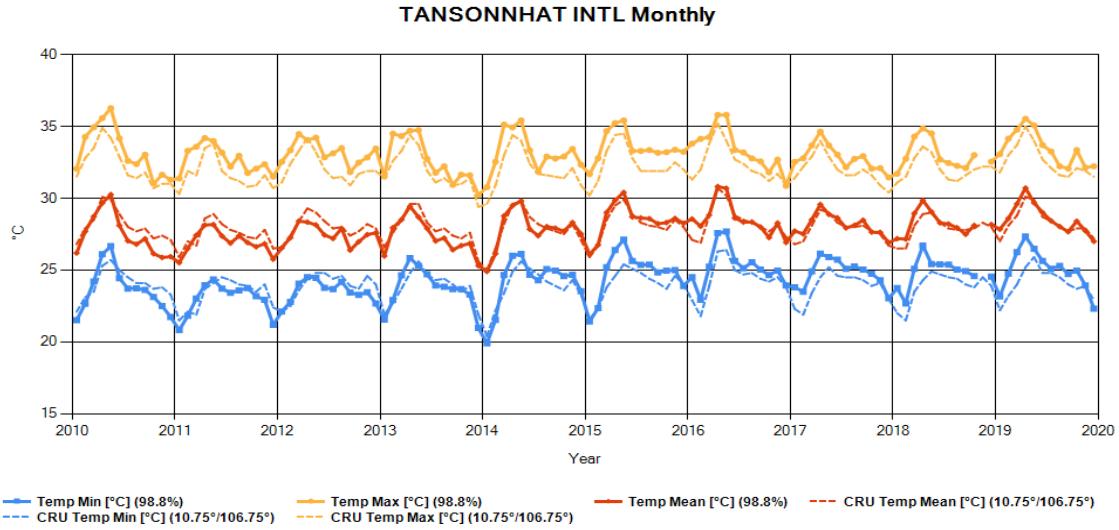


Figure A2.7 Ho Chi Minh City Grid Cell (10.75,106.75). All CRU temperatures agree well with weather station

Appendix 3

A computer script was used to scan all CRU temperature data searching for locations where Tmax, Tmean, Tmin and Tdew differed siginificantly in one month from neighbouring months. This identified only one further potential problem with Tmax and Tmean in March in the middle and north of Greenland, but this could due to the continous cooling during the sunless winter and then the rapid warming when the sun again strikes that continent.

However we did find issues with Tdew in a number of locations which are listed below with the most obvious issues listed first. The data is shown by our Climatechip graphics although the original data was interrogated directly from the database that drives Climatechip. The CRU version in this case was 4.04, but as mentioned earlier, similar issues were present in CRU.3x data.

Tdew "errors"

A reminder the Tdew in CRU was calculated from vapour pressure using standard formula so that comparisons could be made with weather station data. The formula we used was Tdew = [116.9+237.3ln(VAP)]/[16.78-ln(VAP)] (see methods section). Of course, it is possible that there is an error in the conversion, but this is unlikely because we compared a specific month with the Tdew of

both neighbouring months. In all cases where weather stations were available in the CRU cell, the Tdew of weather stations matched our calculated Tdew from CRU vapour pressure.

Figure A3.1a shows a grid cell near the city of Nagpur in the centre of India and its associated weather station (figure A3.1b). The Tdew dip in June is apparent in CRU but not in the weather station data.

Another Tdew dip is found in grid cell (26.25, -106.25) in April in the northern-central region of Mexico. See figure A3.2. Unfortunately there is no reliable weather station nearby.

A less apparent March dip in Tdew occurs on Banks Island (**71.75, -122.25)** to at the northern polar regions of Canada. See figure A3.3. There is a similar Tdew profile for most of Banks Island. Again no reliable weather station data is available on the island.

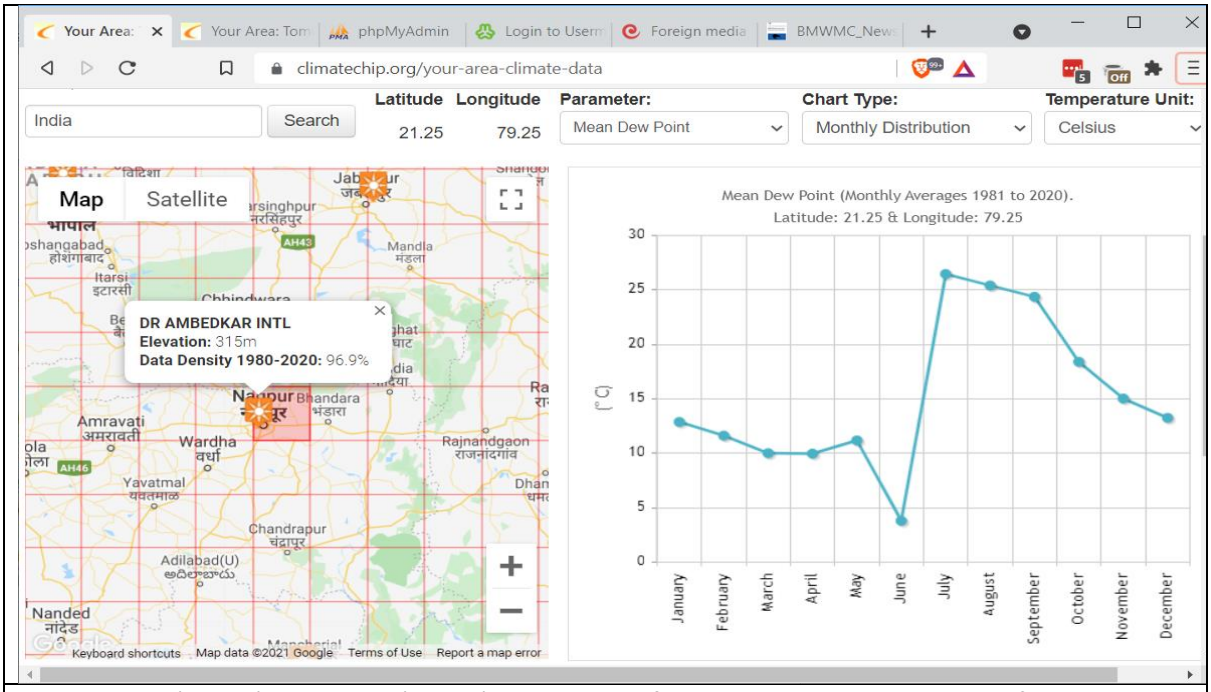
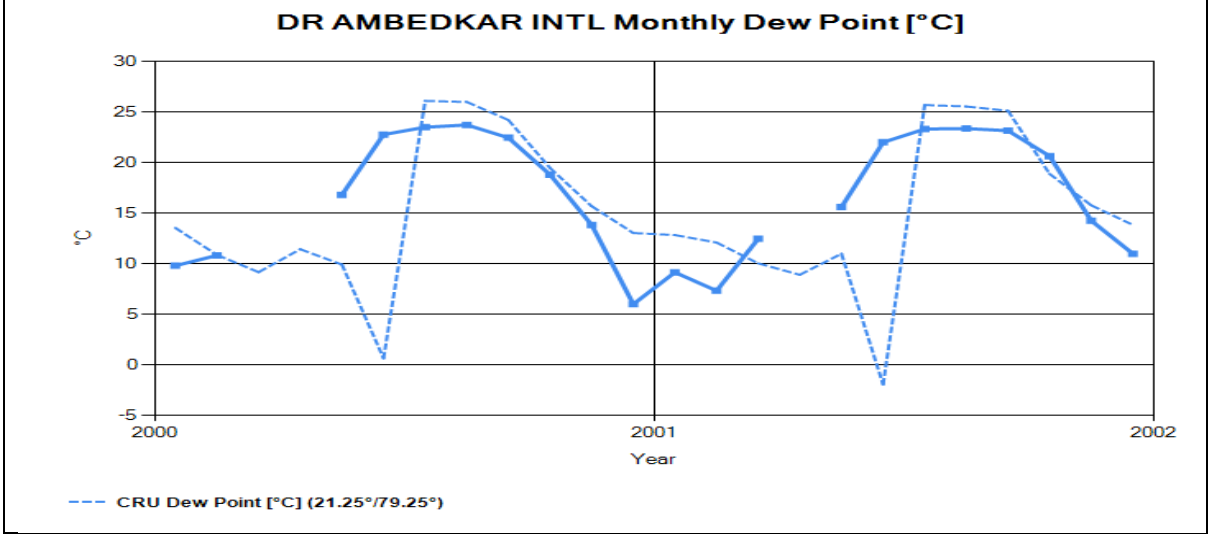


Figure A3.1a (above) and A3.1b (below). This data is from the grid cell 21.25, 79.25 from around the city of Nagpur near the centre of India. The Tdew dip in June is apparent in the above image from Climatechip (1981-2020 monthly average data). It is also shown in the image below from HothapsSoft where the weather station in that grid cell is compared with CRU data (dotted line) for two specific years (2000-2001). June is at the midpoint of each year.



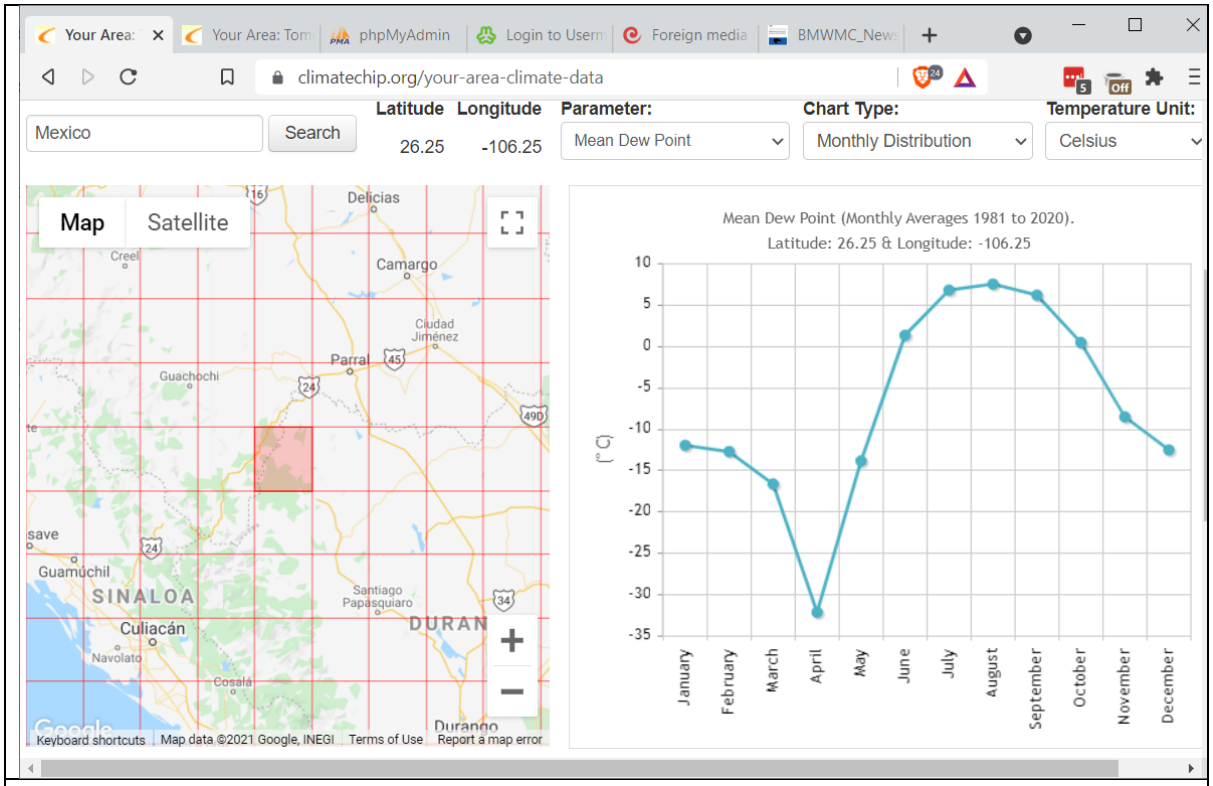


Figure A3.2 Climatecip output from CRU4.04 (1981-2020 monthly average) data for grid cell 21.25, 79.25 in central north of Mexico.

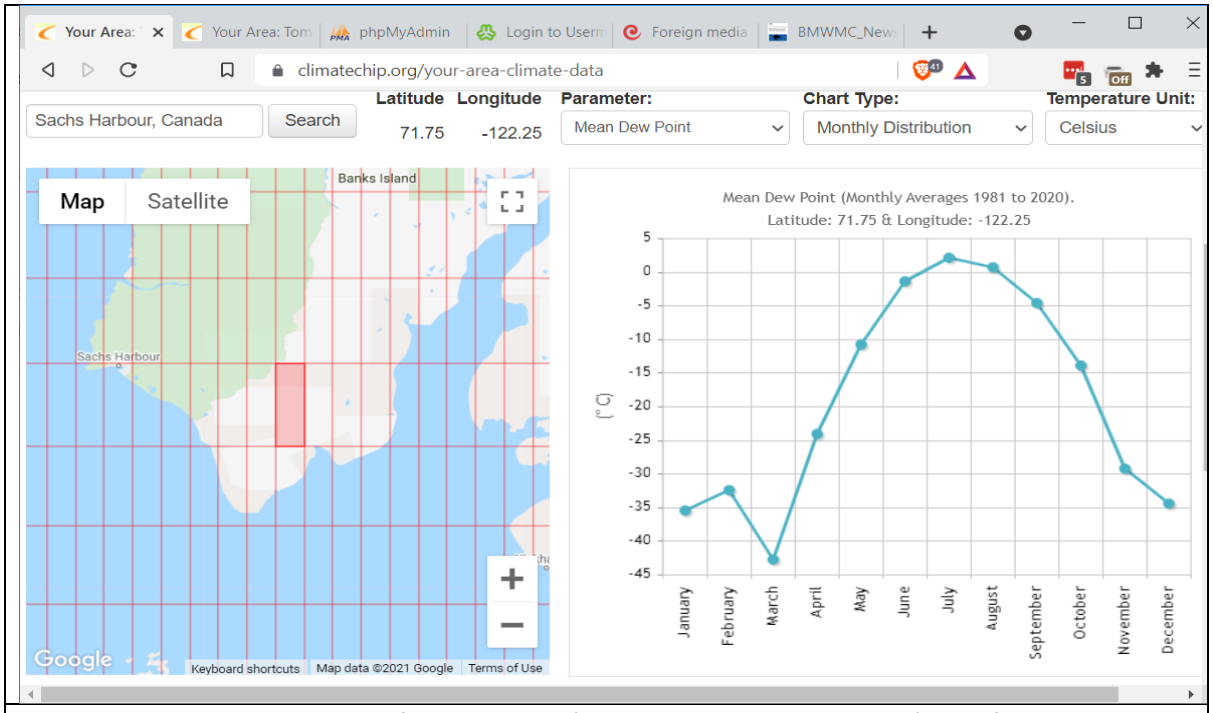


Figure A3.3 Climatechip output from CRU4.04 (1981-2020 monthly average) data for grid cell 71.75, -122.25 on Banks Island at Sachs Harbour in the North East of Canada.

The remainder of the Tdew issues we discovered (figures A3.4 to A3.8) are not as clear-cut as the above data, and many occur in mountainous regions, but they are listed for completeness. Many have similar dips in nearby cells but not in cells a little further away.

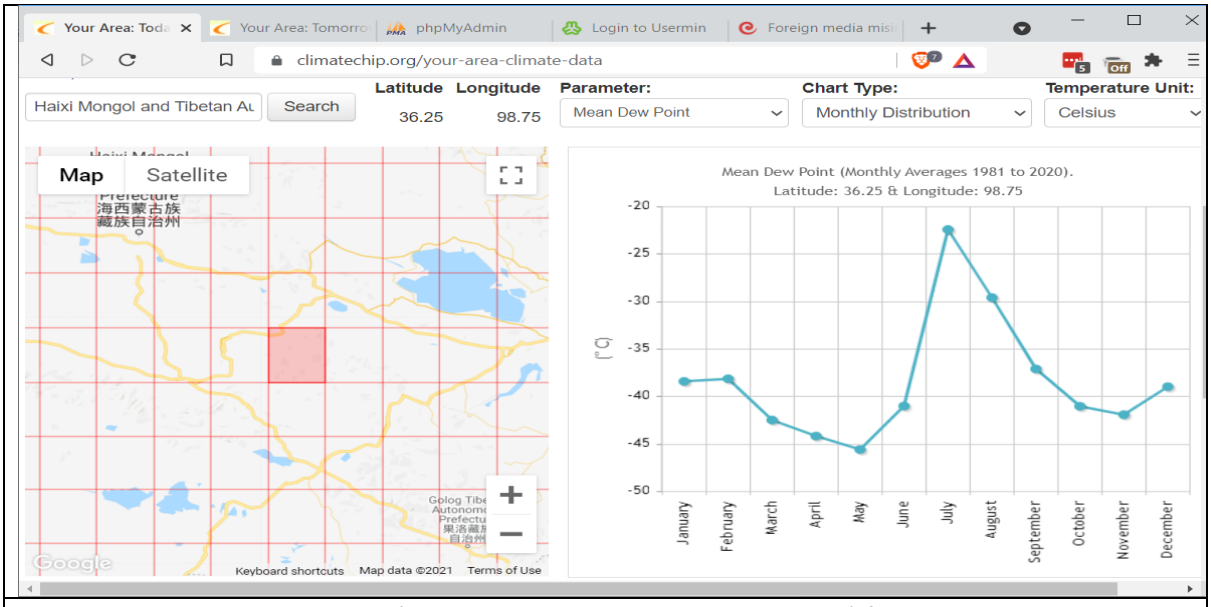


Figure A3.4 Climatechip output (CRU4.04 1981-2020 monthly average) for grid cell 36.25, 98.75

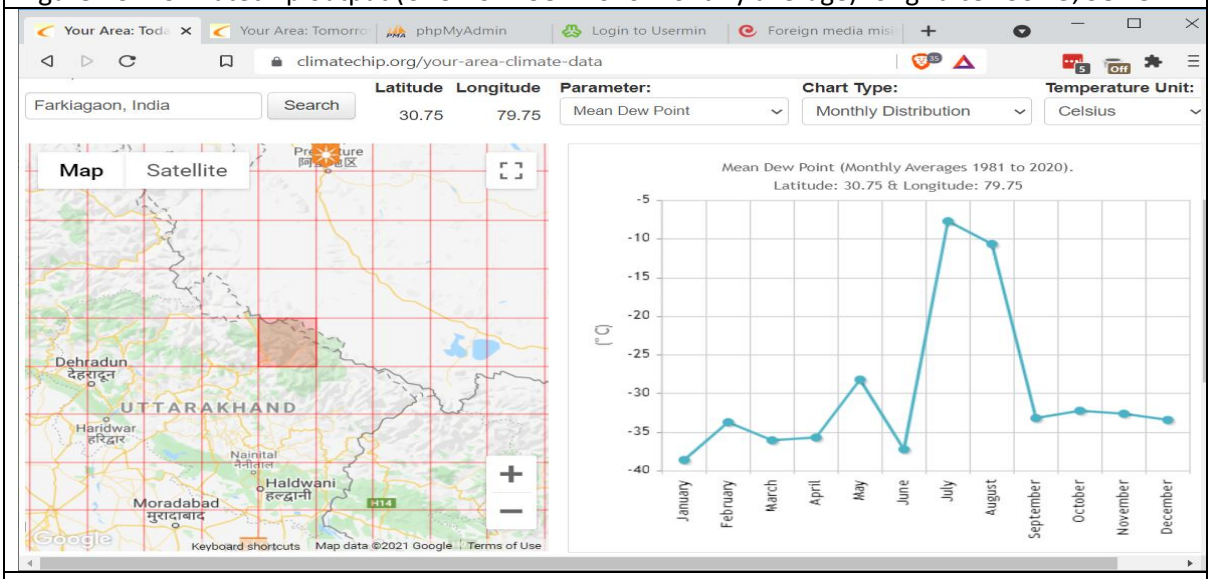


Figure A3.5 Climatechip output (CRU4.04 1981-2020 monthly average) for grid cell 30.75, 79.75

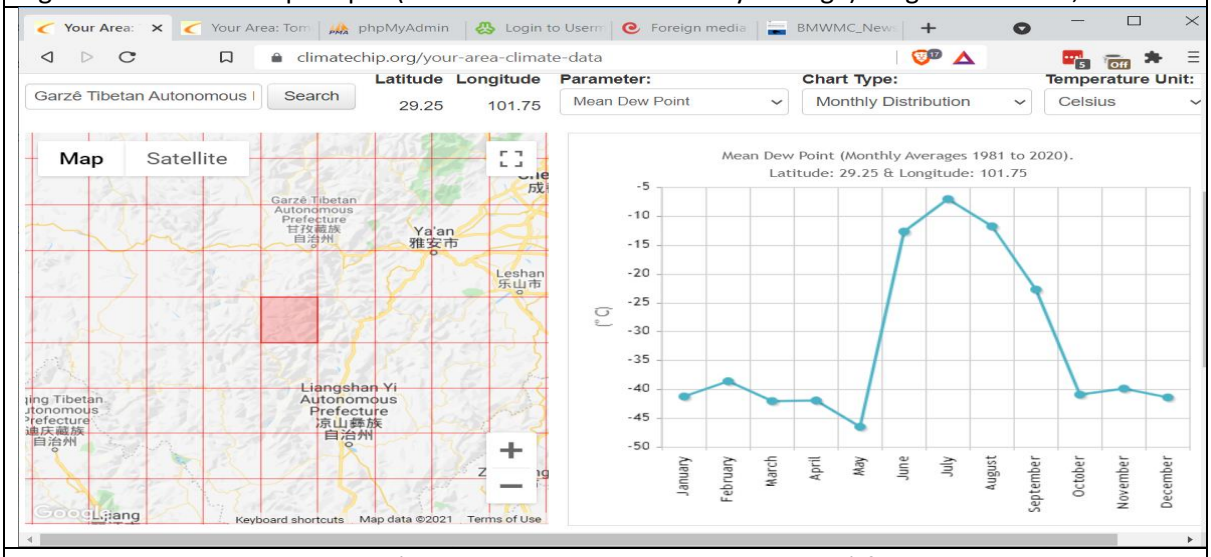


Figure A3.6 Climatechip output (CRU4.04 1981-2020 monthly average) for grid cell 29.25, 101.75

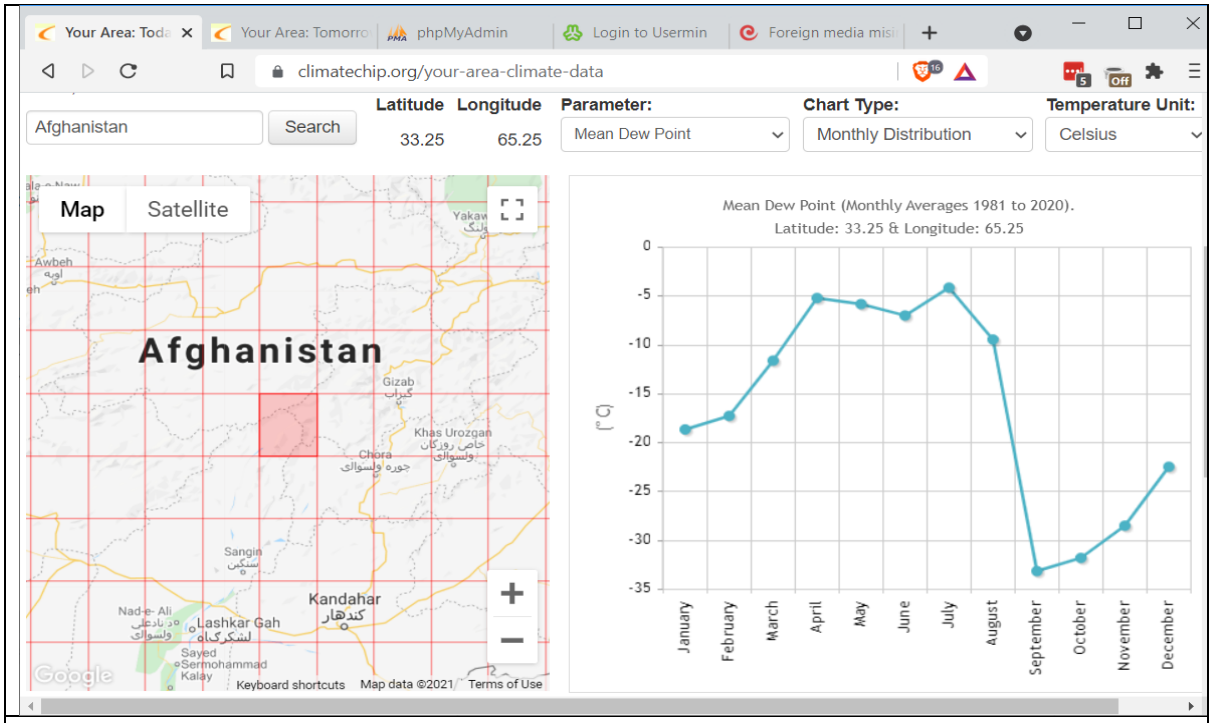


Figure A3.7 The September jump in Tdew in cell 33.25, 65.25 in Afghanistan is apparent in neighbouring cells but not as extreme.

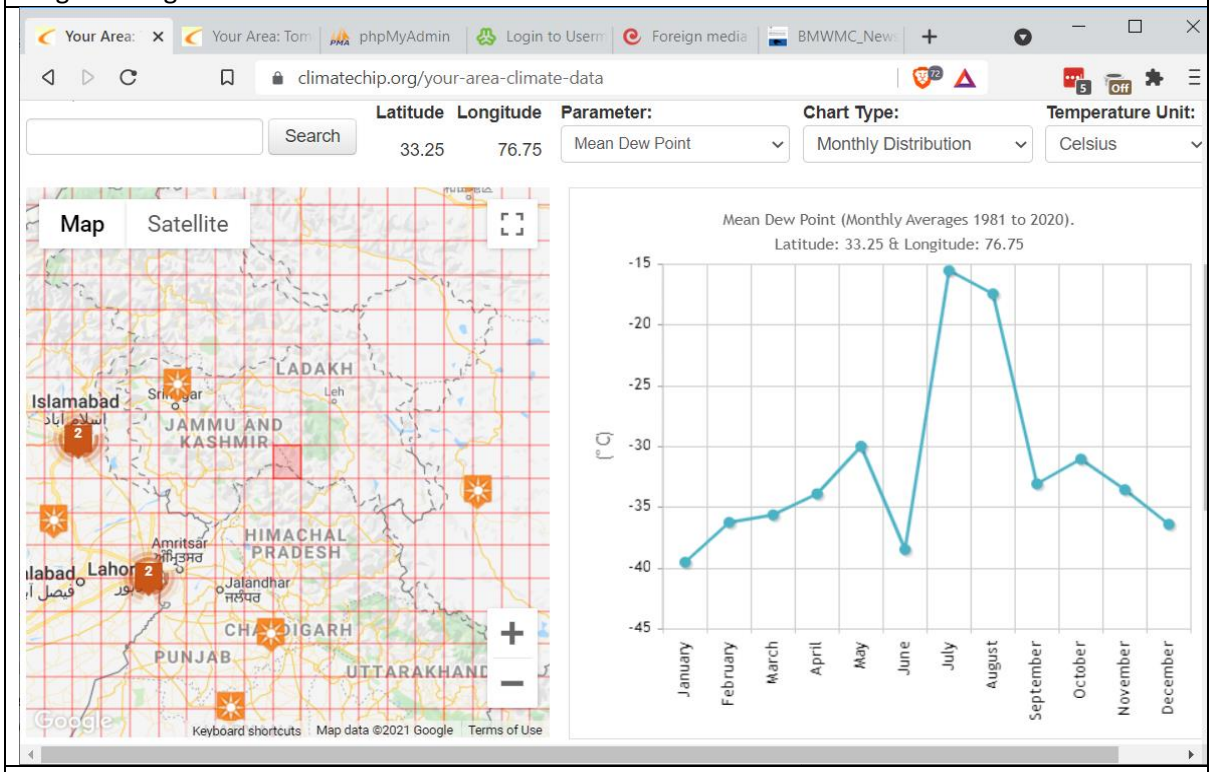


Figure A3.8 The June dip in Tdew in cell 33.25, 76.75 in Kashmir is not apparent in the west neighbouring cell.

There is a set of errors in Tdew where Tdew is less than Tmin. This is physically impossible because as Tmin reaches Tdew a dew or frost precipitates out keeping Tdew at or below Tmin. We did not search for these, but only came across them by chance so there could be many more. Here are some examples:

Table A3.1 Grid cells where Tdew is less than Tmin for some months of the year. The weather stations in that grid cell do not have that error.				
Lat	Long	Country	Weather Station	Comment
42.75	89.25	China	TURPAN	Winter months have Tdew > Tmin by 5C
62.25	-114.25	Canada	YELLOWKNIFE	CRU cannot be correct because Tmin, Tmean and Tmax are all less than Tdew by up to 15C in January
26.25	36.25	Saudi Arabia	WEJH	Possibly a CRU error Tmin(WS) = Tmin(CRU) = Tdew(WS) but Tdew(CRU) 10C less for most months.

One other error was found in our search (see table A3.2), but it did not follow any pattern and would not have been discovered with our computer program search. This is an issue with Tmax and Tmin on the other side of Taiwan where we found the Tdew error (see figure 4a in the main text). It appears that the Tmin of the weather station has become the Tmax of CRU – see Figure A3.9.

Table A3.2 CRU Tmax and Tmin for cell 22.75, 121.25 in Taiwan compared with the NOAA GSOD weather station in the city of Taidong (or Taitung) and with local weather station data. See also figure 3.9		
Tmax	Coolest month (January)	Hottest month (July)
CRU	16C	25C
NOAA Weather Station	22C	32C
weather-and-climate.com	23C	31C
Tmin	Coolest month	Hottest month
CRU	8C	18C
NOAA Weather station	17C	27C
besttimetovisit.com.ph weather-and-climate.com	17C	26C

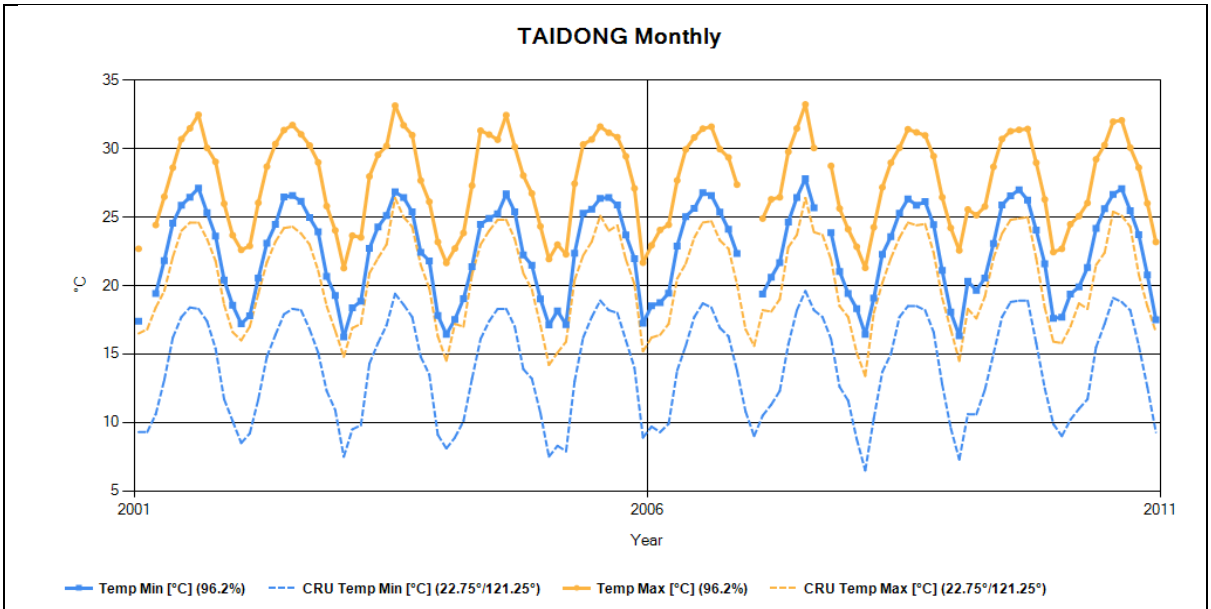


Figure A3.9 Taidong Grid Cell (22.75,112.25). CRU Tmax (dotted orange line) seems to be equivalent to weather station Tmin (solid blue line).