COMP 5070 – Statistical Programming for Data Science

Assignment 2 - Global Warming: Fact or Fiction?

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Introduction

Global warming refers to the long-term increase in Earth's average surface temperature due to the accumulation of greenhouse gases in the atmosphere. The consequences of global warming cause disruptions to ecosystems and biodiversity. Addressing global warming is not just an environmental challenge but a vital task to ensure the well-being of future generations and the preservation of our planet's delicate balance. This is a report to analyse data containing information about the daily maximal and minimal temperatures for **Adelaide weather station 023034** at **Adelaide Airport** to study the effects of climate change, if any.

Data Collection

To study the effect of climate change in Adelaide, South Australia, we will use some competitive aspects of R. Data has been collected from the Australian Bureau of Meteorology and we will be focusing specifically on the daily temperatures from **1st January 1955** to **9th October 2023**.

Data was received as two zip files, '*IDCJAC0010_023034_1800.zip*' containing maximal daily temperatures and '*IDCJAC0011_023034_1800.zip*' containing minimum daily temperatures. The maximum daily temperature data set will be stored in *maxTempData* and the minimum daily temperature data set will be stored in *minTempData*.

	Product code	Bureau of Meteorology station number	Year	Month	Day	Maximum temperature (Degree C)	Days of accumulation of maximum temperature	Quality
1	IDCJAC0010	023034	1955	01	01	NA	NA	NA
2	IDCJAC0010	023034	1955	01	02	NA	NA	NA
3	IDCJAC0010	023034	1955	01	03	NA	NA	NA
4	IDCJAC0010	023034	1955	01	04	NA	NA	NA
5	IDCJAC0010	023034	1955	01	05	NA	NA	NA
6	IDCJAC0010	023034	1955	01	06	NA	NA	NA
7	IDCJAC0010	023034	1955	01	07	NA	NA	NA
8	IDCJAC0010	023034	1955	01	08	NA	NA	NA

Showing 1 to 8 of 25,118 entries, 8 total columns

Table 1*: maxTempData containing* maximum daily temperatures

Table 1 shows *maxTempData* has **25118 rows** and **8 columns**. The columns are as below:

1. **Product code**: Contains value 'IDCJAC0010' throughout the data set.

2. **Bureau of Meteorology station number:** Contains value '023034' to signify Adelaide Weather Station.
3. **Year:** It contains the years for which the recording was noted from 1955 to 2023.
4. **Month:** It contains the months for which the recording was noted from 1955 to 2023.
5. **Day:** It contains the days for which the recording was noted from 1955 to 2023 for each month.
6. **Maximum temperature (Degree C):** It gives the maximum temperature recorded for a particular, year, month and day in degrees Celsius.
7. **Days of accumulation of maximum temperature:** It signifies how many days contributed to the maximum temperature.
8. **Quality**

	Product code	Bureau of Meteorology station number	Year	Month	Day	Minimum temperature (Degree C)	Days of accumulation of minimum temperature	Quality
1	IDCJAC0011	023034	1955	01	01	NA	NA	NA
2	IDCJAC0011	023034	1955	01	02	NA	NA	NA
3	IDCJAC0011	023034	1955	01	03	NA	NA	NA
4	IDCJAC0011	023034	1955	01	04	NA	NA	NA
5	IDCJAC0011	023034	1955	01	05	NA	NA	NA
6	IDCJAC0011	023034	1955	01	06	NA	NA	NA
7	IDCJAC0011	023034	1955	01	07	NA	NA	NA
8	IDCJAC0011	023034	1955	01	08	NA	NA	NA

Showing 1 to 8 of 25,119 entries, 8 total columns

***Table 2**: minTempData containing* minimum daily temperatures

Table 2 shows *minTempData* has **25119 rows** and **8 columns**. The columns are as below:

1. **Product code**: Contains value 'IDCJAC0011' throughout the data set.
2. **Bureau of Meteorology station number:** Contains value '023034' to signify Adelaide Weather Station.
3. **Year:** It contains the years for which the recording was noted from 1955 to 2023.
4. **Month:** It contains the months for which the recording was noted from 1955 to 2023.
5. **Day:** It contains the days for which the recording was noted from 1955 to 2023 for each month.
6. **Minimum temperature (Degree C):** It gives the minimum temperature recorded for the particular, year, month and day in degree Celsius.
7. **Days of accumulation of minimum temperature:** It signifies how many days contributed to the minimum temperature.

8. **Quality**

Data Cleaning

Year, Month and Day in *maxTempData* and *minTempData* are gathered to form the 'Date' column and converted to Date type as can be seen in *Tables 3* and *4*.

	Product code	Bureau of Meteorology station number	Year	Month	Day	Maximum temperature (Degree C)	Days of accumulation of maximum temperature	Quality	Date
1	IDCJAC0010	023034	1955	01	01	NA	NA	NA	1955-01-01
2	IDCJAC0010	023034	1955	01	02	NA	NA	NA	1955-01-02
3	IDCJAC0010	023034	1955	01	03	NA	NA	NA	1955-01-03
4	IDCJAC0010	023034	1955	01	04	NA	NA	NA	1955-01-04
5	IDCJAC0010	023034	1955	01	05	NA	NA	NA	1955-01-05
6	IDCJAC0010	023034	1955	01	06	NA	NA	NA	1955-01-06
7	IDCJAC0010	023034	1955	01	07	NA	NA	NA	1955-01-07

***Table 3**: maxTempData with new 'Date' column*

	Product code	Bureau of Meteorology station number	Year	Month	Day	Minimum temperature (Degree C)	Days of accumulation of minimum temperature	Quality	Date
1	IDCJAC0011	023034	1955	01	01	NA	NA	NA	1955-01-01
2	IDCJAC0011	023034	1955	01	02	NA	NA	NA	1955-01-02
3	IDCJAC0011	023034	1955	01	03	NA	NA	NA	1955-01-03
4	IDCJAC0011	023034	1955	01	04	NA	NA	NA	1955-01-04
5	IDCJAC0011	023034	1955	01	05	NA	NA	NA	1955-01-05
6	IDCJAC0011	023034	1955	01	06	NA	NA	NA	1955-01-06
7	IDCJAC0011	023034	1955	01	07	NA	NA	NA	1955-01-07
8	IDCJAC0011	023034	1955	01	08	NA	NA	NA	1955-01-08

***Table 4**: minTempData with new 'Date' column*

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The 'Month' column is converted to literal names of month to improve readability and Day is converted to numeric values shown in *Tables 5* and *6*.

	Product code	Bureau of Meteorology station number	Year	Month	Day	Maximum temperature (Degree C)	Days of accumulation of maximum temperature	Quality	Date
1	IDCJAC0010	023034	1955	January	1	NA	NA	NA	1955-01-01
2	IDCJAC0010	023034	1955	January	2	NA	NA	NA	1955-01-02
3	IDCJAC0010	023034	1955	January	3	NA	NA	NA	1955-01-03
4	IDCJAC0010	023034	1955	January	4	NA	NA	NA	1955-01-04
5	IDCJAC0010	023034	1955	January	5	NA	NA	NA	1955-01-05
6	IDCJAC0010	023034	1955	January	6	NA	NA	NA	1955-01-06
7	IDCJAC0010	023034	1955	January	7	NA	NA	NA	1955-01-07
8	IDCJAC0010	023034	1955	January	8	NA	NA	NA	1955-01-08

Table 5: 'Month' and 'Date' in maxTempData converted to month names and numeric column respectively

	Product code	Bureau of Meteorology station number	Year	Month	Day	Minimum temperature (Degree C)	Days of accumulation of minimum temperature	Quality	Date
1	IDCJAC0011	023034	1955	January	1	NA	NA	NA	1955-01-01
2	IDCJAC0011	023034	1955	January	2	NA	NA	NA	1955-01-02
3	IDCJAC0011	023034	1955	January	3	NA	NA	NA	1955-01-03
4	IDCJAC0011	023034	1955	January	4	NA	NA	NA	1955-01-04
5	IDCJAC0011	023034	1955	January	5	NA	NA	NA	1955-01-05
6	IDCJAC0011	023034	1955	January	6	NA	NA	NA	1955-01-06
7	IDCJAC0011	023034	1955	January	7	NA	NA	NA	1955-01-07
8	IDCJAC0011	023034	1955	January	8	NA	NA	NA	1955-01-08
9	IDCJAC0011	023034	1955	January	9	NA	NA	NA	1955-01-09

Table 6: 'Month' and 'Date' in minTempData converted to month names and numeric column respectively

All the rows in *maxTempData* and *minTempData* which have NA values in 'Maximum temperature (Degree C)' and 'Minimum temperature (Degree C)' respectively are removed from the data frames. Now, we have **25071** rows in *maxTempData* from *Table 7* and **25065** rows in *minTempData* from *Table 8.*

	Product code	Bureau of Meteorology station number	Year	Month	Day	Maximum temperature (Degree C)	Days of accumulation of maximum temperature	Quality	Date
1	IDCJAC0010	023034	1955	2	16	24.0	NA	Y	1955-02-16
2	IDCJAC0010	023034	1955	2	17	29.9	1	Y	1955-02-17
3	IDCJAC0010	023034	1955	2	18	27.2	1	Y	1955-02-18
4	IDCJAC0010	023034	1955	2	19	22.6	1	Y	1955-02-19
5	IDCJAC0010	023034	1955	2	20	25.6	1	Y	1955-02-20
6	IDCJAC0010	023034	1955	2	21	26.6	1	Y	1955-02-21
7	IDCJAC0010	023034	1955	2	22	29.2	1	Y	1955-02-22

Showing 1 to 8 of 25,071 entries, 9 total columns

Table 7: maxTempData with no NA values in 'Maximum temperature (Degree C)'

	Product code	Bureau of Meteorology station number	Year	Month	Day	Minimum temperature (Degree C)	Days of accumulation of minimum temperature	Quality	Date
1	IDCJAC0011	023034	1955	2	16	16.1	NA	Y	1955-02-16
2	IDCJAC0011	023034	1955	2	17	17.1	1	Y	1955-02-17
3	IDCJAC0011	023034	1955	2	18	17.2	1	Y	1955-02-18
4	IDCJAC0011	023034	1955	2	19	15.1	1	Y	1955-02-19
5	IDCJAC0011	023034	1955	2	20	13.4	1	Y	1955-02-20
6	IDCJAC0011	023034	1955	2	21	11.4	1	Y	1955-02-21
7	IDCJAC0011	023034	1955	2	22	15.1	1	Y	1955-02-22

Showing 1 to 8 of 25,065 entries, 9 total columns

Table 8: minTempData with no NA values in 'Minimum temperature (Degree C)'

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Data Exploration

We can study the highest maximum and lowest minimum temperature observed in Adelaide Airport from the year 1955 to 2023.

	Year	Month	Maximum temperature (Degree C)
1	1955	12	39.1
2	1956	2	37.8
3	1957	12	39.6
4	1958	1	38.1
5	1959	1	40.9
6	1960	1	41.8
7	1961	1	39.5
8	1962	11	41.9
9	1963	2	38.4
10	1964	1	39.9
11	1965	3	38.9
12	1966	1	39.7
13	1967	2	39.6
14	1968	1	44.0
15	1969	1	41.2
16	1970	2	41.2
17	1971	2	39.8
18	1972	12	40.8
19	1973	1	40.8
20	1974	1	37.4
21	1975	12	40.8
22	1976	12	40.6
23	1977	2	39.9
24	1978	1	39.2
25	1979	1	41.9
26	1980	2	42.6
27	1981	2	42.6
28	1982	1	42.9
29	1982	1	42.9
30	1983	2	42.2
31	1984	12	37.9
32	1985	1	41.1
33	1986	3	40.8
34	1987	12	38.4
35	1988	1	39.6
36	1989	3	39.9
37	1990	1	41.4
38	1991	2	41.8
39	1992	2	39.5
40	1993	11	41.7
41	1994	1	41.0
42	1995	2	38.8
43	1996	1	42.9
44	1997	11	40.9
45	1998	12	39.8
46	1999	1	41.9
47	2000	1	40.8
48	2001	1	43.8
49	2002	12	40.4
50	2003	1	41.8
51	2003	1	41.8
52	2004	2	43.6
53	2005	12	42.4
54	2006	1	43.2
55	2007	1	40.5
56	2008	1	40.8
57	2009	1	44.0
58	2010	1	41.0
59	2011	1	41.9
60	2012	12	41.7
61	2013	1	44.1
62	2014	1	43.3
63	2015	1	42.5
64	2016	12	38.9
65	2017	2	41.7
66	2018	1	41.4
67	2019	1	45.8
68	2020	1	42.3
69	2021	1	42.0
70	2022	12	40.0
71	2023	1	40.4

Table 9: Maximum temperature for each year and corresponding month name from maxTempData

Table 9 provides valuable insights into the historical climate of Adelaide, specifically focusing on the maximum recorded temperatures over a span of almost six decades, from 1955 to 2023. It also includes information about the respective months during which these extreme temperatures occurred. The data presented allows us to draw several significant observations.

First and foremost, January emerges as the month that frequently records the highest maximum temperatures. This pattern is in line with Adelaide's typical summer climate, where January is often associated with hot and scorching weather conditions.

Notably, the data reveals that 2019 holds the record for the warmest maximum temperature across these 60+ years, reaching a scorching 45.8 degrees Celsius. This extraordinary temperature record serves as a stark reminder of the extreme heat events that can occur, especially in the context of global climate change and the potential for more frequent and intense heat waves.

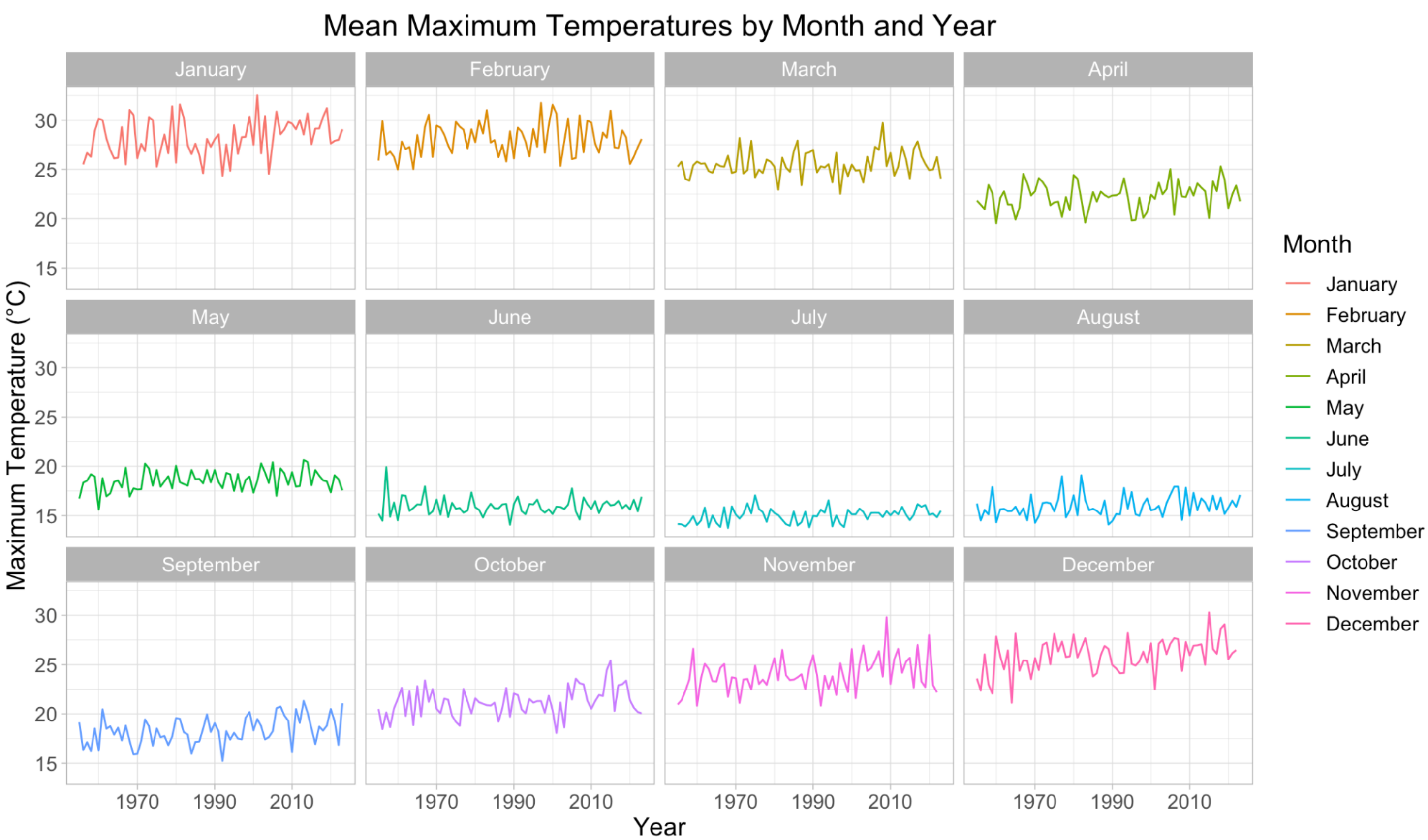

Figure 1: Mean maximum temperatures throughout the month for all months year-wise

It is clear from *Figure 1* that Adelaide temperatures vary considerably throughout the year, with clear differences between the four seasons December to February representing the summer months in Adelaide, the maximum temperature is always above 20 degrees Celsius. These months are associated with hot, dry weather. In contrast, the summer months from June to August show the lowest average temperatures, always below 20 degrees Celsius. These months are known for being cool and beautiful, with fewer extreme heat waves.

Temperatures are at a summer low in September, October and November, and an autumn peak in March, April and May. The gradual transition between summer and winter makes the weather pleasant and mild during these months.

Figure 1 also displays the annual variation of maximum temperature for the 60-year period from 1955 to 2023. Notably, temperature exhibits the greatest variability in the first four months of the year (December to March) and months the last four (September) into November). This means that different seasons, especially the transition to winter and autumn and the beginning of winter, exhibit large temperature variations in contrast to the May, June, July and August temperatures show small variations from year to year.

	Year	Month	Minimum temperature (Degree C)
1	1955	7	1.1
2	1956	6	2.2
3	1957	7	1.1
4	1958	6	-1.2
5	1959	7	-1.1
6	1960	6	0.9
7	1960	8	0.9
8	1961	7	0.1
9	1962	7	0.8
10	1963	8	1.6
11	1964	6	0.1
12	1965	7	1.1
13	1966	7	1.8
14	1967	5	-0.1
15	1968	7	-1.1
16	1969	8	0.3
17	1970	8	1.2
18	1971	6	1.4
19	1972	6	-2.2
20	1973	5	-0.3
21	1974	6	0.9
22	1975	6	0.6
23	1976	7	0.7
24	1977	7	0.5
25	1978	8	0.8
26	1979	5	1.6
27	1980	7	1.0
28	1981	8	2.7
29	1982	6	-2.6
30	1983	6	0.0
31	1984	6	1.5
32	1985	5	1.2
33	1986	7	1.5
34	1987	7	1.0
35	1988	7	1.3
36	1989	7	0.2
37	1989	7	0.2
38	1990	7	2.2
39	1991	7	2.4
40	1991	8	2.4
41	1992	8	1.7
42	1993	6	1.7
43	1994	8	1.1
44	1995	8	0.9
45	1996	6	2.6
46	1996	6	2.6
47	1997	7	0.4
48	1998	6	1.5
49	1999	8	0.7
50	2000	7	0.0
51	2001	8	2.3
52	2002	8	-0.2
53	2003	7	1.7
54	2004	5	2.2
55	2005	7	1.4
56	2006	6	-0.5
57	2007	6	-0.4
58	2008	7	-0.1
59	2009	7	1.8
60	2010	6	1.8
61	2011	7	0.1
62	2012	6	1.1
63	2013	6	2.5
64	2014	8	0.5
65	2015	7	1.4
66	2016	8	2.3
67	2017	6	1.8
68	2018	6	2.2
69	2019	6	-0.2
70	2020	6	-0.4
71	2021	8	2.0
72	2022	7	1.5
73	2023	7	2.0

Table 10: Minimum temperature for each year and corresponding month name from minTempData

Similarly, *Table 10* shows the minimum recorded temperature for each year starting from 1955 up to 2023 and the corresponding month during which it was recorded. One of the prominent trends revealed by this data is the recurring occurrence of the lowest minimum temperatures in the months of June and July. These months coincide with winter in Adelaide, and it is a common feature of temperate climates to experience colder temperatures during this time of year. This consistency suggests that winter in Adelaide can be characterized by chilly nights and potentially frosty conditions, which is a notable and expected feature of the region's climate.

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A striking highlight of this dataset is the year 1982, which stands out as the coldest in the recorded period, with a minimum temperature of -2.6 degrees Celsius. This exceptionally cold temperature record serves as a reminder of the climatic variability experienced in Adelaide.

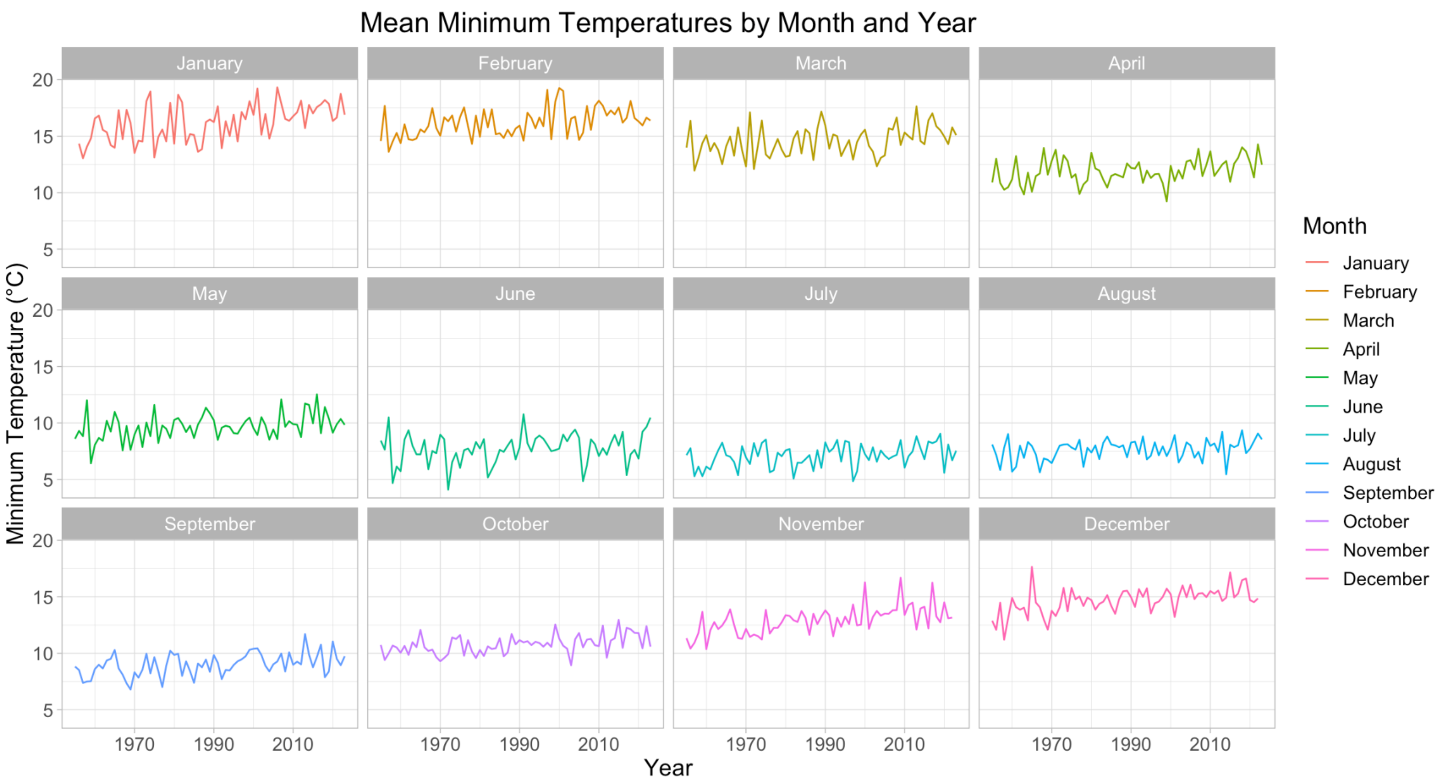

Figure 2: Mean minimum temperatures throughout the month for all months year-wise

The data presented in Figure 2, showcasing the minimum temperatures in Adelaide over the course of six decades (from 1955 to 2023), offers a comprehensive view of the city's climate and seasonal variations. One of the most evident trends is the seasonal temperature fluctuations, with minimum temperatures generally being higher during the summer months of December to February. During these months, Adelaide experiences its summer season, marked by warmer nights and milder minimum temperatures ranging between 10 to 20 degrees Celsius. Conversely, during the winter months of June to August, Adelaide encounters its colder season, with minimum temperatures often falling below 10 degrees Celsius.

The intermediate months, both in the spring (September, October, November) and autumn (March, April, May), exhibit relatively moderate minimum temperatures, maintaining a balance between the warmth of summer and the chill of winter. These months serve as transitional periods leading up to the following seasons, allowing for more comfortable and moderate nighttime temperatures.

Figure 2 also reveals an interesting aspect of Adelaide's climate—the variations in mean minimum temperatures across the years from 1955 to 2023 are relatively consistent for all months. This indicates that, over the recorded decades, Adelaide's climate has maintained a degree of stability in terms of minimum temperatures.

Data Transformation

	Year	Month	Mean	SD	Skewness	Kurtosis	Median	IQR
1	1961	January	30.00	6.21	0.01	-1.59	29.8	11.55
2	1961	July	14.50	1.06	0.16	-0.31	14.4	1.25
3	1971	January	27.60	5.53	0.68	-0.92	26.5	7.40
4	1971	July	14.70	1.64	0.58	-0.56	14.2	2.20
5	1981	January	31.58	5.21	-0.07	-0.93	32.0	7.80
6	1981	July	15.05	2.53	1.21	0.03	14.1	1.75
7	1991	January	28.55	5.99	0.51	-0.86	27.6	8.70
8	1991	July	14.93	1.81	-0.19	-0.67	14.9	2.30
9	2001	January	32.52	5.19	-0.13	-0.82	34.5	7.70
10	2001	July	15.14	1.74	0.91	-0.34	14.6	2.05
11	2011	January	29.07	4.87	1.07	0.44	27.3	5.30
12	2011	July	15.46	2.59	1.15	0.50	14.6	2.40
13	2021	January	27.90	5.28	0.80	-0.20	26.8	6.70
14	2021	July	15.20	2.20	0.14	0.59	15.1	2.45

Table 11: Comparison of maximum temperatures in January and July

From *Table 11*, we can see the mean, standard deviation, skewness, kurtosis, median and IQR for maximal temperatures of January and July for years from 1961 to 2021.

Mean: The mean is a measure of central tendency, and in this case, it represents the average maximal temperature for January and July over these decades. A high mean indicates that, on average, temperatures during these months are relatively warm, while a low mean suggests cooler temperatures. In 1961, January boasted a mean temperature of 30 degrees Celsius, while July recorded a cooler 14.5 degrees Celsius. A decade later, in 1971, the mean January temperature slightly decreased to 27.6 degrees Celsius, while July remained steady at 14.7 degrees Celsius. The year 1981 witnessed a new high, with January hitting an impressive 31.58 degrees Celsius, and July warmed to 15.05 degrees Celsius. Moving to 1991, January's mean temperature was 28.55 degrees Celsius, and July held at 14.93 degrees Celsius. By 2001, January surged again to a remarkable 32.52 degrees Celsius, while July reached 15.14 degrees Celsius. In 2011, the trend continued, with January at 29.07 degrees Celsius, and July climbed to 15.46 degrees Celsius. Most recently, in 2021, January registered a mean of 27.9 degrees Celsius, while July was at 15.2 degrees Celsius.

Standard Deviation: Standard deviation quantifies the variability or spread of data. A higher standard deviation indicates that temperature readings are scattered and more unpredictable. For January and July, it means that temperatures can fluctuate significantly. In this case, the standard deviation of 6.21, 5.53, 5.21, 5.99, 5.19, 4.87, 5.28 degrees Celsius for January and 1.06, 1.64, 2.53, 1.81, 1.74 degrees Celsius for July suggests that temperatures in January have a wider range compared to July, which is relatively more consistent.

Skewness: Skewness measures the asymmetry in a distribution. Positive skewness suggests that the distribution has a tail extending to the right (toward higher values), while negative skewness implies a tail to the left (toward lower values). Most values denote a positive skewness for January and July suggesting unusually warm days might occur in January and cold days in July.

Kurtosis: Kurtosis measures the 'tailedness' of a distribution. High kurtosis indicates heavy tails, while low kurtosis suggests light tails. Mostly negative and closer to zero values imply that extreme temperature values are less frequent and that temperature measurements tend to cluster around the mean in both months.

Median: The median is the middle value in a dataset when arranged in ascending order. It's less affected by extreme values compared to the mean. In January, a median of 26.0 degrees Celsius indicates that half of the temperatures are above this value, while half are below. For July, a median of 14.7 degrees Celsius follows the same logic. These values give you a sense of typical temperature conditions for both months.

IQR (Interquartile Range): The IQR represents the range in which the middle 50% of the data falls. It is a measure of data dispersion. An IQR of 11.55 degrees Celsius for January and1.25 degrees Celsius for July tells us that, in January 1961, the middle half of the data falls within a range of approximately 5.6 degrees Celsius, and for July 1961, it's within 3.2 degrees Celsius. It gives you an idea of the consistency of temperatures in these months.

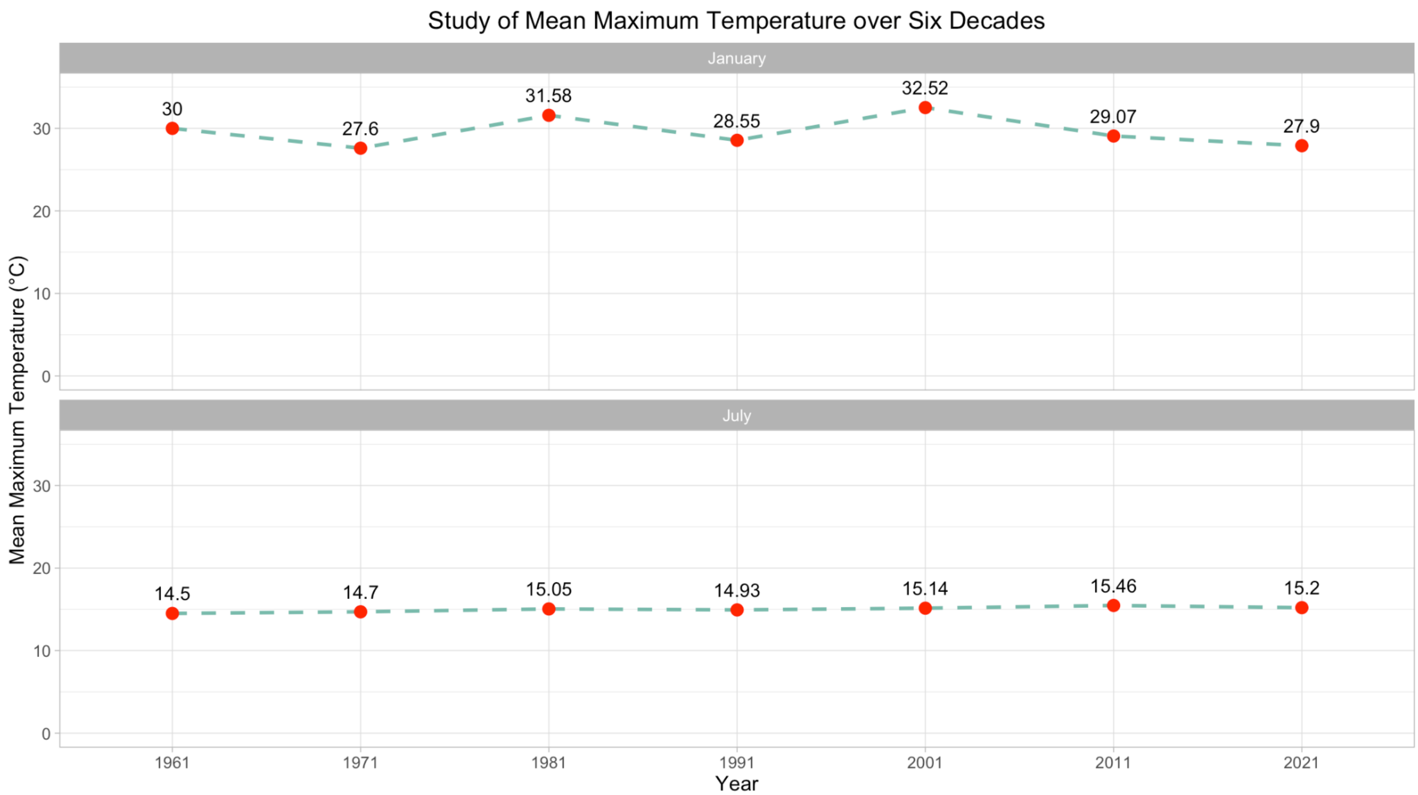

Figure 3: Study of mean maximum temperatures over six decades for January and July

To study whether the warmth of January in a specific year is directly linked to the temperature of July in that same year being warmer than the previous year, we can use a line plot to visualise the means. In 1971, while the mean maximum temperature for January dropped from 30 degrees Celsius in the previous decade to 27.6 degrees Celsius, the mean temperature for July in 1971 increased slightly by 0.2 degrees Celsius.

But in the following decade, the mean temperature for January increases by 3 degrees Celsius while in July of the same year, the temperature rises by less than a degree. This trend can be seen in the following decades. While the mean maximal temperatures for January of every decade see a rise and fall, the mean maximum temperature of July stays relatively constant. The line plot in *Figure 3* indicates that January tends to be warmer than July each year, but it doesn't provide a direct year-over-year comparison for July temperatures.

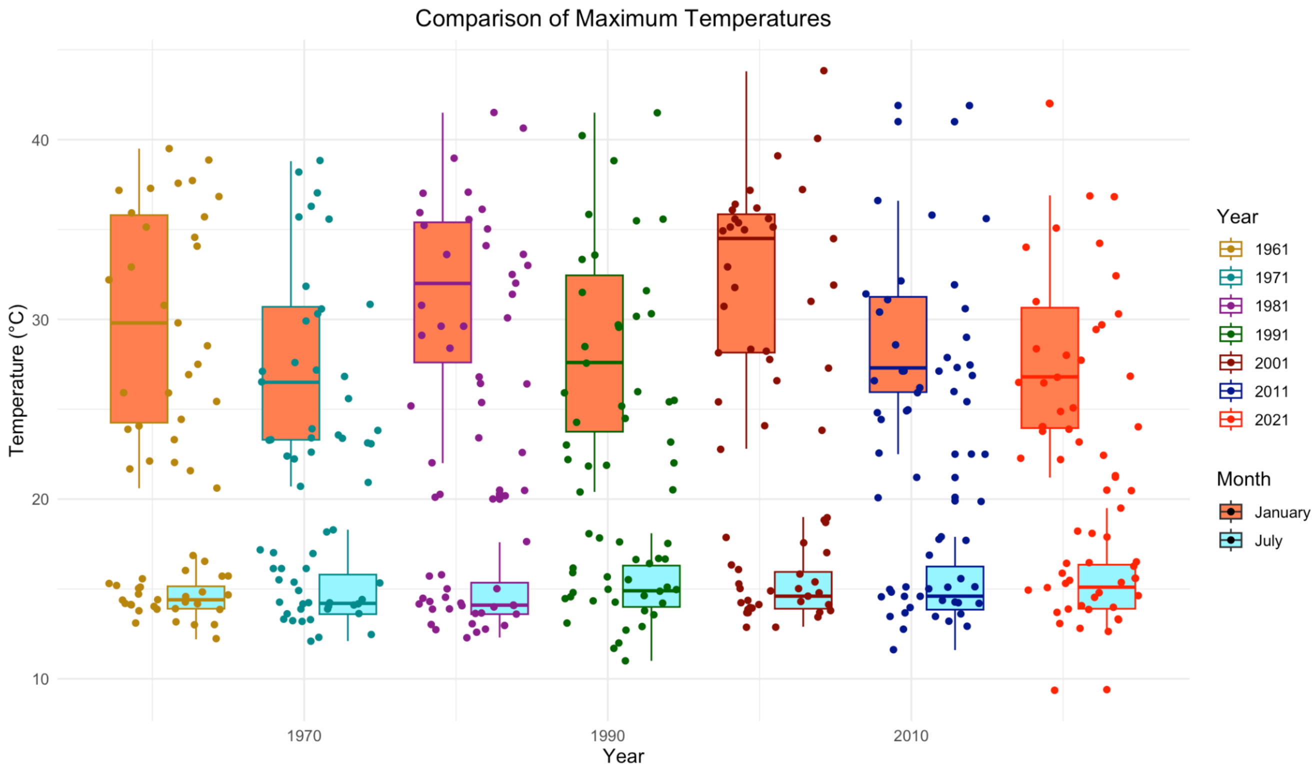

Figure 4: Comparison of median maximum temperatures over six decades for January and July

Similarly, the medians of maximum temperatures of January and July can be seen in *Figure 4*. The medians are either right-skewed or left-skewed depending on where the maximum proportion of data lies as visualised by points. The medians show a better representation of the maximal temperature values for both months since means are pulled towards sides with extreme temperature values. January of 1980 and 2000 had a median temperature value of above 30 degrees Celsius which indicates that January was quite a warm month in these two years are opposed to other years. The decade of 1990 to 2000 had the warmest July as the median temperature was close to 15 degrees Celsius.

Now, we can try to combine the data sets and study the daily range between maximal and minimal temperature.

	Product code	Bureau of Meteorology station number	Year	Month	Day	Maximum temperature (Degree C)	Days of accumulation of maximum temperature	Quality	Date	Minimum temperature (Degree C)	Days of accumulation of minimum temperature	Daily Range
1	IDCJAC0010	023034	1955	February	16	24.0	NA	Y	1955-02-16	16.1	NA	7.9
2	IDCJAC0010	023034	1955	February	17	29.9	1	Y	1955-02-17	17.1	1	12.8
3	IDCJAC0010	023034	1955	February	18	27.2	1	Y	1955-02-18	17.2	1	10.0
4	IDCJAC0010	023034	1955	February	19	22.6	1	Y	1955-02-19	15.1	1	7.5
5	IDCJAC0010	023034	1955	February	20	25.6	1	Y	1955-02-20	13.4	1	12.2
6	IDCJAC0010	023034	1955	February	21	26.6	1	Y	1955-02-21	11.4	1	15.2
7	IDCJAC0010	023034	1955	February	22	29.2	1	Y	1955-02-22	15.1	1	14.1
8	IDCJAC0010	023034	1955	February	23	24.9	1	Y	1955-02-23	15.4	1	9.5

Showing 1 to 8 of 25,071 entries, 12 total columns

Table 12: Combined dataset containing maximum and minimum temperatures and daily range between them

Table 12 gives the combination of maximum and minimum temperatures for every day from 1955 to 2023. The 'Daily Range' column is computed to find the difference between the maximum and minimal daily temperature. It helps in understanding the seasonal variations and climate patterns in a specific region. A wider temperature range might indicate significant variations between day and night, which is common in arid or continental climates. Meteorologists use daily temperature ranges to make weather predictions. A narrower range suggests more stable weather conditions, while a wider range can indicate the potential for more dynamic weather patterns.

In *Figure 7*, we can visualise how the daily temperature changes for each month during a span of six decades by comparing seven years.

Winter months (June, July, and August) consistently exhibit the lowest daily temperature ranges. The small temperature range signifies that these months experience cooler and more stable conditions. Both daytime and nighttime temperatures during this period are relatively close, indicating that the days and nights are cool.

In 1961, a notable characteristic is the large portion of daily temperature ranges hovering around 15 degrees Celsius. This suggests that, in 1961, the temperature differences between daytime and nighttime were fairly consistent across all months. The climate was relatively stable throughout the year.

A decade later, in 1971, the daily temperature range began to increase. It started crossing the 20-degree Celsius mark, especially during the summer months of October, December, January, and February. This indicates more significant fluctuations between daytime and nighttime temperatures during these months. The weather conditions during these months became more variable.

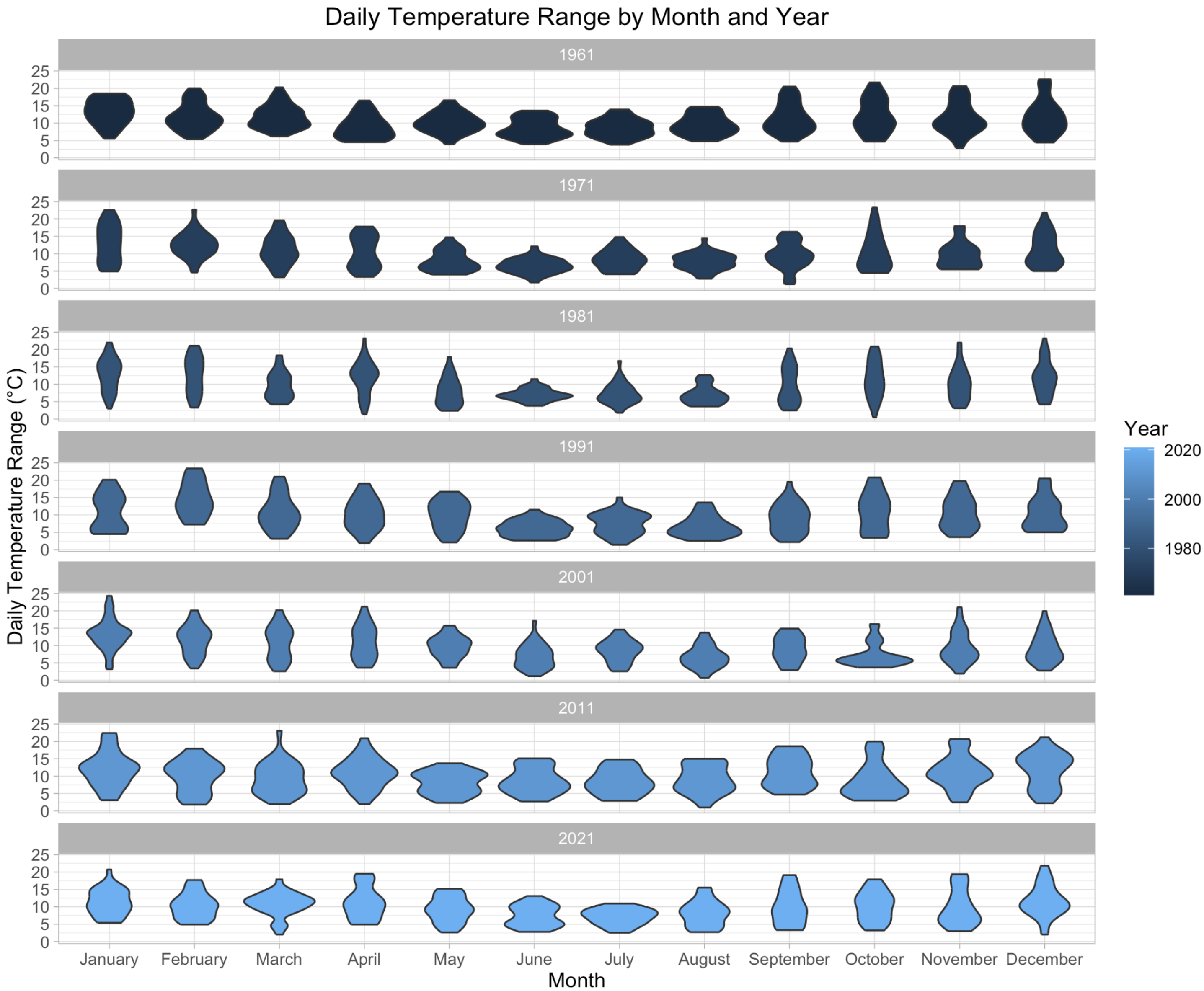

Figure 5: Comparing the daily spread of temperature for 7 years month-wise

By 1981, the daily temperature range increased yet again, but the trend wasn't uniform across all months. Most months experienced higher temperature ranges, suggesting greater variability in temperature fluctuations. However, May, June, and July continued to have stable conditions with less variation between day and night. Notably, April and October witnessed a few days with almost no temperature difference between daytime and nighttime, indicating extremely stable weather.

In 1991, there was a shift in the trend. The extreme differences in daily temperatures began to decrease, and the majority of differences stayed within a range of up to 15 degrees Celsius. This suggests a move towards more consistent temperatures between day and night across various months.

2001 saw reduced temperature ranges, except for January, which experienced unexpected fluctuations in temperature. On some days, the temperature difference reached up to 25 degrees Celsius, implying unpredictable and variable weather conditions during the month. The rest of the months had more stable temperature patterns.

In 2011, the majority of the differences in daily temperature ranges were less than 15 degrees Celsius, and some were even less than 5 degrees Celsius. This suggests that the weather remained consistent throughout the day, with minimal fluctuations between daytime and nighttime temperatures. The climate during this year was characterized by its stability.

In 2021, all the months had a daily temperature range of less than 20 degrees Celsius, except for a few days in December. This indicates that most of the months had relatively stable weather conditions with consistent temperature patterns. December experienced some fluctuations, which may have been due to specific weather events.

From these daily temperature ranges, it's important to identify and analyze extreme temperature events, such as heatwaves (>= 35 degrees Celsius) or cold spells in Adelaide, and assess their frequency and intensity over the years.

	Year	Count
1	1955	3
2	1956	3
3	1957	8
4	1958	5
5	1959	8
6	1960	18
7	1961	18
8	1962	12
9	1963	7
10	1964	5
11	1965	14
12	1966	13
13	1967	12
14	1968	24
15	1969	15
16	1970	15
17	1971	13
18	1972	11
19	1973	16
20	1974	8
21	1975	13
22	1976	11
23	1977	16
24	1978	9
25	1979	16
26	1980	16
27	1981	19
28	1982	21
29	1983	22
30	1984	9
31	1985	9
32	1986	11
33	1987	12
34	1988	13
35	1989	19
36	1990	14
37	1991	13
38	1992	6
39	1993	12
40	1994	11
41	1995	13
42	1996	7
43	1997	17
44	1998	12
45	1999	12
46	2000	19
47	2001	25
48	2002	16
49	2003	17
50	2004	14
51	2005	14
52	2006	17
53	2007	20
54	2008	21
55	2009	29
56	2010	13
57	2011	9
58	2012	15
59	2013	15
60	2014	19
61	2015	26
62	2016	10
63	2017	19
64	2018	19
65	2019	26
66	2020	11
67	2021	10
68	2022	7
69	2023	12

Table 13: Count of days where temperature crossed 35 degrees Celsius every year

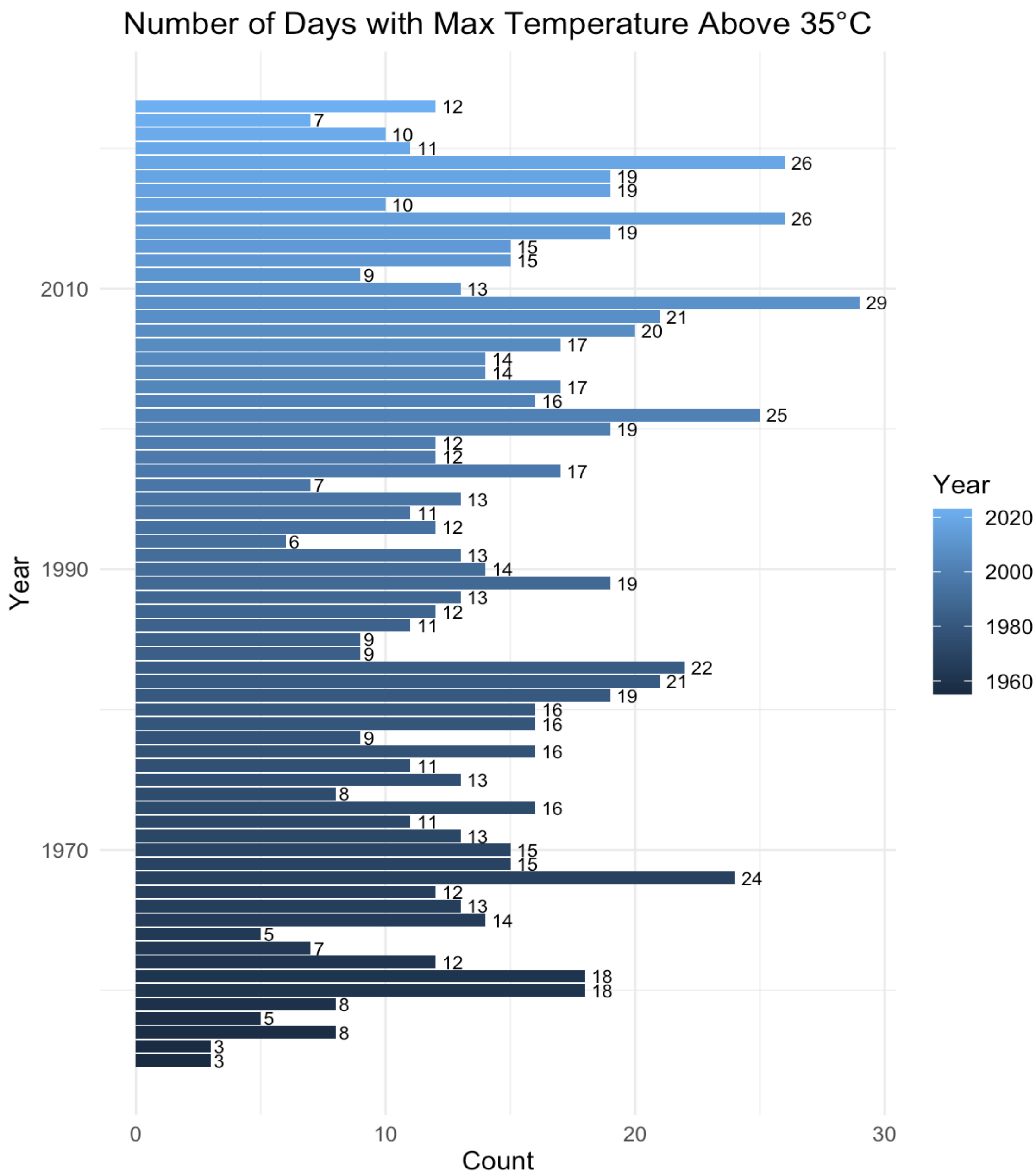

Figure 6: Bar plot to show the count of days crossing the threshold causing heatwaves

From *Table 13*, the main point that stands out is that heatwaves were not uncommon starting from the 1960s, indicating that Adelaide has been experiencing periods of exceptionally high temperatures for several decades. since the 1970s. But the proportion of days crossing the threshold has definitely increased over the past two decades.

Figure 6 shows an interesting observation that 1968 marked a significant point in the data. For the first time, the count of heatwave days reached 24, effectively doubling from the previous year. This could be seen as the emergence of an era with a notable number of heatwave days. 15 years later, in 1983, Adelaide experienced 22 days declared as having heatwaves. This suggests that such events had become relatively more frequent compared to earlier years. The 1980s witnessed an increase in the occurrence of heatwaves.

Almost two decades later, in 2001, a record-high of 25 days was categorized as dangerous due to heatwaves. This marked a concerning increase in the prevalence of heatwave conditions in the region. The 2000s appear to have been a period of heightened heatwave activity. In 2009, the region experienced a significant surge in heatwave days, with a record-breaking count of 29. This was a notable shift in the climate, indicating more frequent and severe heatwave events. The trend continued, with 26 heatwave days in 2015 and 26 in 2019. While these numbers were slightly lower than the peak of 29 in 2009, they remained considerably higher than earlier decades.

Similarly, it's important to identify and analyze extreme cold spells (below 4 degrees Celsius) in Adelaide and assess their frequency and intensity over the years.

	Year	Count
1	1955	7
2	1956	2
3	1957	7
4	1958	18
5	1959	20
6	1960	17
7	1961	8
8	1962	4
9	1963	8
10	1964	8
11	1965	7
12	1966	5
13	1967	20
14	1968	13
15	1969	6
16	1970	9
17	1971	5
18	1972	22
19	1973	13
20	1974	11
21	1975	9
22	1976	14
23	1977	11
24	1978	8
25	1979	8
26	1980	2
27	1981	2
28	1982	20
29	1983	11
30	1984	7
31	1985	8
32	1986	7
33	1987	11
34	1988	6
35	1989	13
36	1990	4
37	1991	3
38	1992	6
39	1993	6
40	1994	7
41	1995	4
42	1996	6
43	1997	16
44	1998	5
45	1999	6
46	2000	5
47	2001	1
48	2002	11
49	2003	7
50	2004	2
51	2005	6
52	2006	14
53	2007	14
54	2008	10
55	2009	4
56	2010	12
57	2011	8
58	2012	7
59	2013	2
60	2014	10
61	2015	9
62	2016	2
63	2017	6
64	2018	8
65	2019	9
66	2020	19
67	2021	2
68	2022	3
69	2023	5

Table 14: Count of days where the temperature dropped below 4 degrees Celsius every year

From *Table 14*, the data suggests that, while cold spells were relatively common during the late 1950s and early 1960, they became less frequent starting from the late 1960s. The 1970s saw occasional instances of more extensive cold spells, but after the 1980s, the region generally experienced milder winters with fewer days of cold spells. The return of a relatively higher number of cold spell days in 2020 might be linked to specific climate conditions or variations.

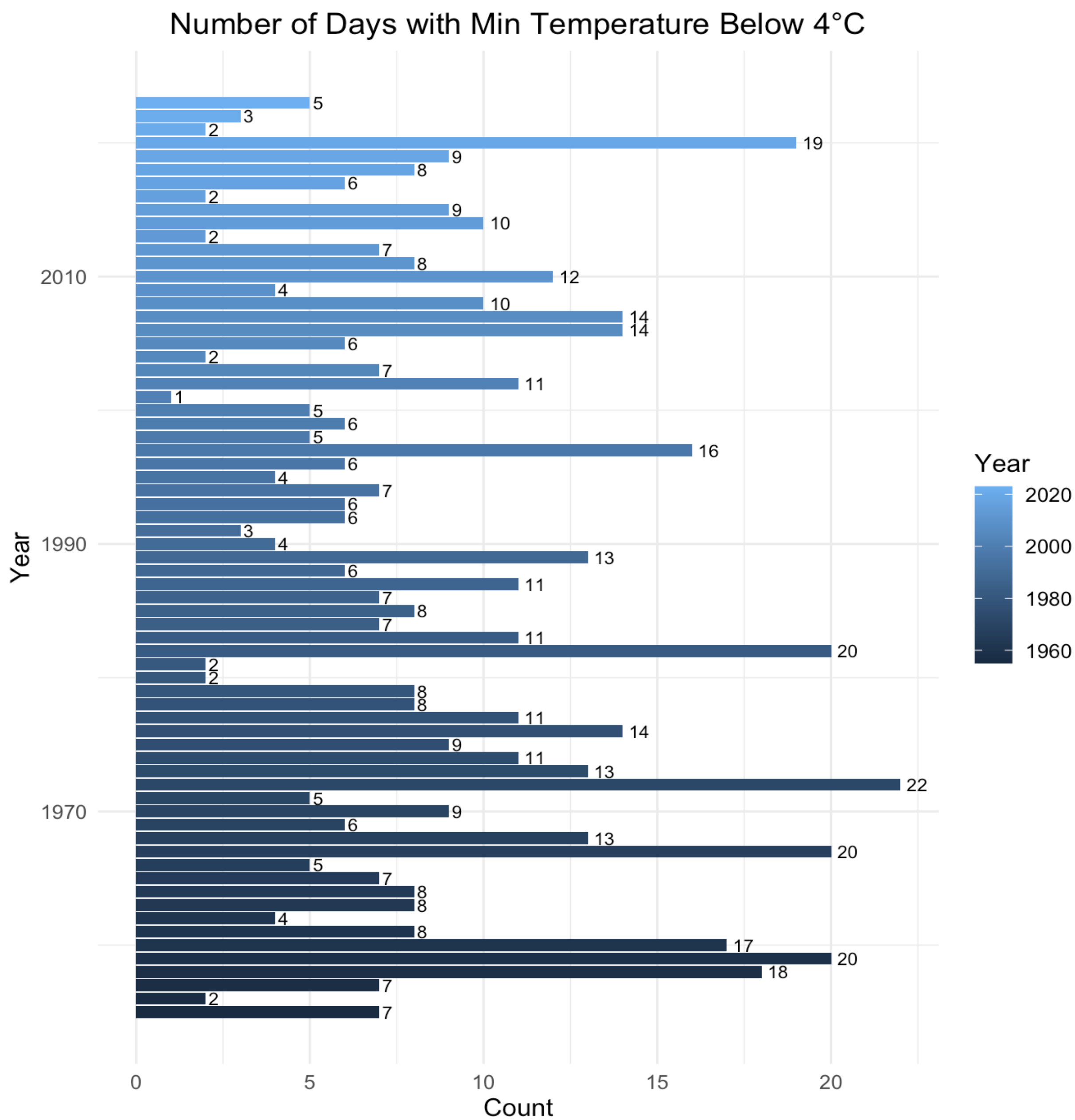

Figure 7: Bar plot to show the count of days dropping below the threshold causing cold spells

From *Figure 7*, we can observe that during the late 1950s and early 1960, a relatively high number of cold spell days were observed, with a total of 55 days of cold spells recorded. This two-year period indicates that cold spells were not uncommon during this time.

A shift in the data is noted in 1967 when there were 20 days of cold spells. This marked a notable reduction compared to the earlier years. In 1972, there was another instance of a relatively high number of cold spell days, with 22 days recorded. A significant shift occurred in the following decades. Starting from the 1980s, the data indicates that the region experienced fewer cold spell days. In the 1980s, there were 20 days of cold spells, but there were no further instances of extensive cold spells for the next three decades.

A noteworthy observation is that after several decades without extensive cold spells, the year 2020 had 19 days of cold spells. This indicates a relatively cooler period in the region after a prolonged absence of significant cold spell events.

The increase in heatwave days and the decrease in cold spell days in Adelaide are consistent with the broader global trend of climate change and warming temperatures. The data indicates a warming trend in the region, with more frequent and intense heatwaves and fewer occurrences of extreme cold spells. These climate trends have significant implications for local ecosystems, as species adapted to specific temperature ranges may face challenges in adapting to changing conditions. Increased heatwaves can stress ecosystems, affect wildlife, and impact vegetation. The rising frequency of heat waves poses substantial health risks to residents, especially vulnerable populations. Public health authorities need to prepare for more frequent and prolonged heatwave events, with measures to protect people from heat-related illnesses.

Conclusion

The analysis of daily temperature data from Adelaide, South Australia, spanning from 1955 to 2023 reveals valuable insights into the region's climate trends and their implications for climate change.

Over the 68-year period, the data shows a notable warming trend in Adelaide, reflected in both maximum and minimum temperatures. Maximum temperatures, especially during January, have increased over the years. The data highlights that January consistently records the highest maximum temperatures, with the hottest year being 2019, which reached 45.8 degrees Celsius. This trend aligns with global climate change patterns, emphasizing the need to address rising temperatures.

Adelaide experiences distinct seasonal variations. Summer months, from December to February, are characterized by high maximum temperatures, typically above 20 degrees Celsius. In contrast, winter months, from June to August, have lower maximum temperatures, usually below 20 degrees Celsius. The transitional months, spring (September, October, November) and autumn (March, April, May), exhibit moderate temperatures, making the weather pleasant and mild during these periods.

Minimum temperatures also exhibit seasonal variations, with warmer nights during the summer months and colder nights in winter. The data highlights a consistent occurrence of the lowest minimum temperatures in June and July, corresponding to Adelaide's winter months.

The data analysis indicates that Adelaide's climate has maintained a degree of stability in terms of minimum temperatures over the recorded decades, with relatively consistent variations for all months. This suggests that, despite the warming trend, Adelaide has not experienced significant variations in minimum temperatures.

The daily temperature range data shows variations between day and night temperatures. Summer months have smaller ranges, signifying stable and warm conditions. Winter months exhibit larger temperature ranges, indicating cooler nights. Notably, the analysis reveals that the variability in temperature ranges is highest in the transition months between seasons.

The data highlights the occurrence of heatwaves in Adelaide, with notable increases in the number of heatwave days, especially over the past two decades. This trend is consistent with the global rise in extreme heat events and emphasizes the need for adaptive measures and strategies to mitigate the effects of heat waves on public health and infrastructure.

Cold spells were relatively common in the late 1950s and early 1960s, but they became less frequent from the late 1960s onward. The data indicates a shift towards milder winters with fewer days of cold spells. The resurgence of more cold spell days in 2020 suggests specific climate conditions or variations contributing to colder winters.

In conclusion, the analysis of Adelaide's temperature data provides compelling evidence of climate change and its impact on the region. Rising temperatures, increased heatwave occurrences, and shifting temperature patterns are consistent with global climate change trends. These findings underscore the urgency of addressing climate change, implementing adaptive strategies, and taking measures to safeguard public health, ecosystems, and infrastructure. Understanding these climate trends is essential for informed decision-making and climate resilience in Adelaide and other regions facing similar challenges.