Data Article

Hygrothermal climate analysis: An Australian dataset

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A R T I C L E   I N F O

Article history:
Received 13 April 2022
Revised 12 May 2022
Accepted 13 May 2022
Available online 18 May 2022

Keywords:
Hygrothermal
MRY
Moisture index
WUFI
Wind-driven rain factor
Wetting index
Drying index
Moisture reference year

A B S T R A C T

Transient hygrothermal assessments rely on the definition of external climatic conditions, usually collected in a moisture reference year (MRY) file. Currently, hygrothermal climate files for Australia are not available, leaving researchers and practitioners to either use typical meteorological years (TMY) files, generated for thermal analysis, or other propriety datasets that are not unified, standardized or shared, hence hindering reproducibility of studies and comparative analysis. This dataset provides a comprehensive suite of climatic files ready to be used in hygrothermal simulations, as well as general climate data that could serve as a basis for further analysis. The dataset can be used to create a hygrothermal map, as presented in Javed et al. (2022) or directly employed in building simulations.

This dataset contains two different types of data that can be employed for transient hygrothermal analysis: MRYs for 30 locations across Australia completed with the climatic data necessary to generate the file, and 10 consecutive years of hourly climate parameters for Brisbane, Cairns, Melbourne, Darwin, Hobart, Sydney, and Canberra cities, representing those locations where most of the population live. These two types of data provide the input for hygrothermal assessment as defined by the ASHRAE 160-2016. Raw climate
data were extracted from the Australian Bureau of Meteorology database and the NOAA's National Weather Service, National Oceanic and Atmospheric Administration database to generate a complete hourly dataset. Additionally, for the first type of data, 30 consecutive years of climate data have been analysed following the moisture index method by calculating the wetting and drying indices. The resulting yearly moisture indexes were ranked from highest to lowest and the MRY was selected as the 10th-percentile year, considered to be the most representative year for severe moisture stress on a building envelope.

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Specifications Table

| Subject                  | Engineering: civil and structural engineering |
|-------------------------|----------------------------------------------|
| Specific subject area   | Hygrothermal performance assessment and simulation: condensation, mould growth and durability assessment |
| Type of data            | Tables; Graphs; Climate file and MRY (.wac). |
| How the data were acquired | Secondary data: analysed and processed output data |
| Data format             | Analysed data. |
| Description of data collection | Hourly data of each climate parameter necessary for hygrothermal simulation (dry bulb temperature (°C), dewpoint temperature (°C), relative humidity (%), precipitation (mm), air pressure (Pa), wind speed (m/s), wind direction, (degrees from North) extracted from the database available from the Australian Bureau of Meteorology (http://www.bom.gov.au/climate/data/) NOAA's National Weather Service, National Oceanic and Atmospheric Administration (https://www.weather.gov). Moisture index, wetting index, drying index, wind-driven rain factor and moisture reference year have been calculated from the primary data. |

Data source location

Primary data location:
Australian Bureau of Meteorology (http://www.bom.gov.au/climate/data/) [2].
NOAA's National Centers for Environmental Information (https://www.weather.gov) [3].
The evaluations are performed considering the following cities (Australia): Albury, Alice Springs, Adelaide, Bendigo, Brisbane, Broome, Bunbury, Bundaberg, Cairns, Canberra, Darwin, Devonport, Dubbo, Esperance, Geraldton, Hobart, Kalgoorlie-Boulder, Mackay, Melbourne, Mount Gambier, Mount Isa, Perth, Port Hedland, Port Macquarie, Rockhampton, Sydney, Tennant Creek, Townsville, Wagga Wagga, Warrnambool.

Data accessibility

Repository name: 4TU.ResearchData
Data identification number: https://doi.org/10.4121/19730950.v1
Direct URL to data: https://data.4tu.nl/articles/dataset/Data_underlying_the_publication_An_Australian_climate-based_characterization_of_hygrothermal_risks_for_buildings_/19730950/1

Related research article
H. Javed, A. Brambilla, M. Strang, An Australian climate-based characterization of hygrothermal risks for buildings, Energy Build, 265 (2022) 112,086 https://doi.org/10.1016/j.enbuild.2022.112086

Value of the Data

• The data provide a shared and common source for hygrothermal simulations in Australia, allowing for comparison and benchmarking of different studies.
• The refined climate clustering and the analysed data can be used for studies aimed at assessing the hygrothermal performance of materials, systems, components or buildings.
• The methodology used for developing the MRYs and representing the moisture load severity can support researchers in developing specific and refined hygrothermal clustering for other countries.
• The data can be used to validate, compare or provide a deviation from the average in experimental campaigns aimed at collecting actual climate data.
• The data can be used as inputs for transient hygrothermal assessments and can be compared to international studies on hygrothermal clustering and mapping.

1. Data Description

The dataset includes different types of files, provided as supplementary data. Appendix 1 contains the compiled climate data for 30 consecutive years for each location and a summary of the climate input used for the calculation of the MRY. Appendix 2 contains the climate file that can be used directly in building simulation software, provided in editable format (.wac, the file can be open in any spreadsheet software or as a text file). These files are included as MRY for all locations and, additionally, as 10 consecutive years climate files for Brisbane, Cairns, Melbourne, Darwin, Hobart, Sydney, and Canberra. The ASHRAE 160 [4] for hygrothermal assessments describes two types of files that can be used for transient simulations, and hereby supplemented:

• MRY (moisture reference year), being a calculated representative year for moisture loading and represents the 10th percentile most critical year of a 30 years range.
• And a climate file continuing 10 consecutive years of actual monitored climate data.

1.1. Appendix 1

Files with a name of a city contain hourly climate data from 1991 to 2020 for that city. Table 1 shows the analysed cities and their original climate zone, as classified by the Australian Building Code Board ABCB [5]. The name indicates the original climate zone and the city: X_City_Climatedata.

Each year is provided as a separate sheet, where columns report the hourly values for the year of the following parameters, starting from the first column on the left:

• Months: cardinal number indicating the months of the year (1=January to 12=December).
• Days: day of the month, from 1 to 31, depending on the month. This parameter resets every month.
• Hours: hour of the day, from 1 to 24. This parameter resets every day.
• Dry bulb temperature in °C.
• Relative humidity in %.
• Wind speed in m/s.
• Wind direction in degree.

| Zone | Classification | City |
|------|----------------|------|
| 1    | High humidity summer, warm winter | Broome, Cairns, Darwin, Port Hedland, Townsville |
| 2    | Warm humid summer, mild winter   | Brisbane, Bundaberg, Mackay, Rockhampton |
| 3    | Hot dry summer, warm winter      | Alice Springs, Mount Isa, Tennant Creek |
| 4    | Hot dry summer, cool winter      | Albury, Dubbo, Kalgoorlie-Boulder, Wagga Wagga |
| 5    | Warm temperate                   | Adelaide, Bunbury, Esperance, Geraldton, Perth, Port Macquarie, Sydney |
| 6    | Mild temperate                   | Bendigo, Melbourne, Mount Gambier, Warrnambool |
| 7    | Cool temperate                   | Canberra, Devonport, Hobart |
Fig. 1. Example of moisture index equipotential graph included in the dataset. Representative image, reproduced with permission from [1] (Folder: MoistureIndex_classification_graphs).

- Air pressure in hPa.
- Direct normal radiation in W/m².
- Diffuse horizontal radiation in W/m².
- Cloud index in Oktas.
- Precipitation in [mm].

On the right of the columns containing climate parameters, each sheet indicates the year, the city, the latitude (lat), longitude (lon), and elevation (elev).

The file named MoistureIndex_30 cities_Australia contains the annual values of calculated indices for each city. The different sheets refer to the different cities and are named accordingly. Data are ordered in columns as follows:

- Column A: year of reference for the calculation of the indices, from 1991 to 2020.
- Columns B–J: data relative to the WDR index, where the first columns B to I contain the value calculated for orientation (in order N, NE, E, SE, S, SE, W, NW), and column J reports the worst orientation for WDR.
- Column K and L: data referred to the calculated wetting index, based on the worst WDR orientation for that year. Column K indicates the maximum wetting index, calculated as the max value among the different orientations, and column L is the normalized value relative to wetting indices of all locations.
- Columns M - O: values referred to the drying index, where column M reports the drying index based on vapour differentials, and column N indicates the normalized values based on all locations’ drying indices. Column O lists the value of “1 – normalized drying index” which is used as an input for the graphs in Fig. 1.
- Column P: annual moisture index for 30 years from 1991 to 2020 based on the normalized value of the worst annual WDR orientation for that year.
- Column Q: ranking value of the years. All years are ranked from highest to lowest based on the MI, this column reports the nominal number of the ranking.

Fig. 1 displays an example of moisture index equipotential graph, used to visualize the annual MI. The graph reports the drying index on the y-axis and the wetting-index on the x-axis, whilst the MI is the distance of a point from the two axis [6]. Both the wetting and drying index are normalized between 0 and 1, thus, an MI of 1 corresponds to the maximum moisture loading risk, whereas a value of 0 to a no-risk situation. Therefore, the selected MRY is categorized into classification groups of critical, high risk, and moderate potential for moisture loading.

The resulting moisture indices are visualized and shared in the folder: MoistureIndex_classification_graphs.zip, which includes individual equipotential graph image files for each
Fig. 2. Example of Wind driven rain graph included in the database. Representative image reproduced with permission from [1] (folder WDR_Roses).

location in PDF format, named as X_City_MI_graph.pdf. The graphs show each year as black dots, with the selected MRY highlighted as a white dot. The placement of the MRY dot in relation to the risk groups defines the moisture loading potential of that location.

Fig. 2 shows an example of a WDR graph, which reports the WDR value for orientation. The graph shows the magnitude of driven rain for 8 orientations for three instances: Mean WDR for all 30 years, the worst year of wetting, and the selected MRY for the city of Mackay. The graphs are developed from the annual sum of WDR, calculated individually for the 8 orientations for 30 years and represent the most susceptible orientations for wind-driven rain impacts at a location. A compilation of the graphs can be found in the zip file: WDR_Roses.zip, which includes PDF format image files (X_City_WDR.pdf) for all 30 cities.

1.2. Appendix 2

This supplementary file contains the moisture reference year for each of the 30 locations and the 10-year climate file for Brisbane, Cairns, Melbourne, Darwin, Hobart, Sydney, and Canberra. These files are given as .wac extensions, which is the format used by the transient simulation software WUFI, the most diffused hygrothermal assessment tool. However, the file can be opened in any text or spreadsheet reader. The header of the file is the same for both the MRY and the 10-year climate file, reporting the climate parameters:

- Air temperature [°C].
- Relative humidity [%].
- Wind speed [m/s].
- Wind direction [°].
- Air pressure at station height [hPa].
- Direct horizontal solar radiation [W/m²].
- Diffuse horizontal solar radiation [W/m²].
• Cloud index [Oktas].
• Rain to the normal [L/m²h].
• Global horizontal solar radiation [W/m²].

After this section, the file contains a row reporting the parameters on hourly value. The MRY has 8760 rows (hourly values) as it reports one year of moisture representative hourly data, while the 10-year climate files have 87,600 rows, corresponding to hourly values of 10 consecutive years.

2. Experimental Design, Materials and Methods

2.1. Data Extraction and Preparation for the 10-Year Actual Meteorological Years (Appendix 1)

The data used for this study are retrieved from the National Centres for Environmental Information (NCEI) database and supplemented by the Bureau of Meteorology archive. In particular, the latter is used for values of hourly dry bulb temperature, dew point temperature, precipitation, wind direction, wind speed, atmospheric pressure, and cloud index. The data were then cleaned and processed, for use in WUFI. This was done by interpolating missing values, removing duplicates and using the Zhang Huang solar model [12] to approximate the diffuse, direct, and global horizontal solar irradiation.

It must be noted that data concerning rainfall was given in 6 h intervals, which may introduce a source of uncertainty [13]. However this interval is found to be commonly used in climate databases, despite it has been estimated that even hourly rainfall data may not be sufficiently granular to increase the accuracy of the data for wind-driven rain calculations [14]. The 6 h precipitation values were then cleaned and distributed across the 6 h measurement period.

Raw data was retrieved as distributed data by linear interpolation, performed using a script in Grasshopper. The relevant climatic parameters were then separated into individual files, each one representing one city, and arranged at hourly timestep.

Each city is characterized by a 10-year range, chosen based on the raw data availability: the representative range was defined as the most recent 10 consecutive years of data with less than 5% of annual rainfall data missing from the archives.

- The Melbourne year range was 2005:2014.
- The Brisbane, Cairns, Darwin, Sydney, Canberra, and Hobart year ranges were 2011:2020.

3. Data Extraction and Preparation for the Moisture Reference Years (Appendices 1 and 2)

The dataset comprises different analysed and processed data for the 29 selected locations. The primary data were extracted from the satellite data processed by National Oceanic and Atmospheric Administration (NOAA) [3], provided in an hourly format, and supplemented, whenever a value was missing, with data from the Australian Bureau of Meteorology (BOM) [2], available in the sub-hourly and daily time format.

Data generally presented in sub-hourly values have been averaged to generate hourly values, while steradian values for wind direction were divided into the two vectorial components.

The data were used to generate the moisture reference year (MRY) for each city, defined as the 10th-percentile year considered to be the most representative year for severe moisture stress on a building envelope. The 30 MRYs were generated using the moisture index method, further explained below.
4. Calculation of the Moisture Index

The moisture index MI is a yearly parameter that compares the wetting and drying potential of a climate to indicate the moisture load that the climate holds and the magnitude of moisture risk for the building envelope that is associated with the climate [7].

The MI links the envelope’s susceptibility to wetting and the evaporation potential offered by the climate, calculates as [7]:

\[ MI = \sqrt{WI_n^2 + (1 - DI_n)^2} \]

Where \( WI_n \) is the normalized wetting index, while \( DI_n \) is the normalized drying index. The normalization is calculated by including the relevant index (wetting or drying) from all locations, giving values between 0 and 1 inclusive, for both WI and DI.

4.1. Calculation of the Wetting Index

The wetting index [8] is a yearly value defined as the sum of hourly wind-driven rain factors WDR calculated for each orientation (North, South, West, East, North-West, North-East, South-East, and South-West):

\[ WI = \sum WDR_{\text{orientation}} \]

Where the yearly WDR is the sum of the hourly rain deposition factor \( R_{\text{WDR}} \) for the determined orientation \( x \):

\[ WDR_x = \sum_{h=1}^{8760} R_{\text{WDR},x} \]

The rain deposition factor \( R_{\text{WDR},x} \) (kg/m²h) measures the wind-driven rain striking a vertical surface of a given orientation \( x \). This factor has been calculated following the ASHRAE 160 [4] definition:

\[ R_{\text{WDR},x} = F_E \times F_D \times 0.2 \times R_h \times V_{10} \times \cos \theta \]

where:
- \( R_h \), the rainfall intensity on a horizontal surface (mm/h), and \( V_{10} \), the hourly average wind speed at 10m height (m/s), were taken from the raw climate data.
- The angle \( \theta \) describes the angle formed by the incoming wind vector perpendicular to the wall surface. The steradian values for wind direction in the dataset were split into 8 orientations: North, South, East, West, North-East, North-West, South-East, and South-West.
- The constant 0.2 is an empirical value derived from Lacy’s constant for the driving rain factor [9].
- \( F_E \) and \( F_D \), respectively representing the rain exposure factor and the rain deposition factor, are further explained below.

The rain deposition factor \( F_D \) and the rain exposure factor \( F_E \) were calculated following the ASHRAE 160 standard [4]. The former refers to the possibility for the rain to hit and deposit on a wall, and it has been assumed as the worst-case scenario, meaning an unshaded wall subject to rain runoff, hence \( F_D = 1 \). The latter is construction-related, meaning that it is specified for the building that should be assessed for hygrothermal risks. It relates to the height of the building and the surrounding topography, and it indicates how much the building is exposed to wind drive rain. As the moisture index is a value characterizing a climate and used for preliminary hygrothermal considerations that can be construction-independent, assumptions were made to derive the \( F_E \). In particular, the building height was assumed to be below 10 m, as the Australian building stock is mainly formed by low-rise buildings [10]. Once assumed the building height, \( F_E \)
can be determined by selecting the category of exposure, which was determined based on the wind severity categorization of each city indicated by the Australian Building Code [9], which divides Australia into cyclonic wind zones. $F_E$ of cities classified as non-cyclonic (either category A or B) was assumed as ‘medium severity’ (value $F_E = 1$), while cities classified as cyclonic (category C or D) as ‘severe’ (value $F_E = 1.4$).

Table 2 reports the different cities and their respective $F_D$ and $F_E$ values.

### Table 2
Rain deposition factor and rain exposure factor for the cities included in the database.

| City                                    | Rain deposition factor $F_D$ | Rain exposure factor $F_E$ |
|----------------------------------------|-----------------------------|---------------------------|
| Adelaide, Albury, Alice Springs, Bendigo, Brisbane, Bunbury, Canberra, Devonport, Dubbo, Esperance, Geraldton, Hobart, Kalgoorlie-Boulder, Melbourne, Mount Gambier, Mount Isa, Perth, Port Macquarie, Sydney, Tennant Creek, Wagga Wagga, Warrnambool Broome, Bundaberg, Cairns, Darwin, Mackay, Port Hedland, Rockhampton, Townsville | 1                           | 1                          | 1.4                        |

4.2. Calculation of the Drying Index

Contrarily to the wetting index, the drying index DI does not require any assumptions regarding walls, construction materials or context, but it rather depends on climate parameters only. DI measures the potential of evaporation of a climate, expressed as the difference between the humidity ratio at saturation and humidity ratio of ambient temperature [11]. The hourly difference was calculated as:

$$\Delta w = w_{sat} (1 - \mu)$$

where $\Delta w$ is the hourly differential (kg water/kg air); $w_{sat}$ is the humidity ratio at saturation; and $\mu$ is the degree of saturation, calculated as:

$$\mu = \frac{w_{ambient}}{w_{sat}}$$

Secondly, the annual DI was calculated as the sum of the hourly difference:

$$DI = \sum_{h=1}^{8760} \Delta w$$

where $h = 8760$ is the number of hours in a year.

5. Selection of the Moisture Reference Year MRY

The moisture reference year is defined as the 10th-percentile year, considered to be the most representative year for severe moisture stress on a building envelope. The selection was based on the ranking of the yearly MI.

For each location, the MI value for 30 years is ranked from highest to lowest, with the 3rd ranking year being the MRY.

Ethics Statements

None.
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data underlying the publication: ‘An Australian climate-based characterization of hygrothermal risks for buildings’ (Original data) (4.TU Research data).

CRediT Author Statement

**Arianna Brambilla:** Conceptualization, Writing – original draft, Resources, Supervision; **Haniya Javed:** Methodology, Data curation, Formal analysis, Visualization, Writing – review & editing; **Marcus Strang:** Methodology, Data curation, Formal analysis, Visualization, Writing – review & editing.

Acknowledgments

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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