Quality Assurance of Available Meteorological Data

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Abstract

This paper investigates and compares several sources of meteorological data, providing quality assurance for their inclusion into weather and climate datasets for applications to engineering and architectural modelling.

Substantial errors are identified, and their correction proposed in an overall update and extension of weather and climate data for the whole of Australia.

An evaluation of CSIRO Reference Meteorological Years

Firstly, the authors analysed a set of Reference Meteorological Years (RMY) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), set as the baseline for the organisation's work in creating "projected weather files" which are used to investigate the impact of climate change on building energy consumption and peak loads. These RMY data were transposed from the Australian Climate Data Bank (ACDB) format climate files generated by the New Zealand National Institute for Water and Atmospheric Research (NIWA) into the EnergyPlus Weather (EPW) format. ACDB format is the basis for climate information in the Nationwide House Energy Rating Scheme (NatHERS) software tools, providing data for 70 geographic climate zones across Australia.

As of August 2021, the CSIRO has made these climate data sets freely available, and they have since been established as the de facto norm for building energy modellers looking to demonstrate compliance with the National Construction Code's (NCC) requirements for energy efficiency as well as a number of other applications, particularly in the renewable energy industry. In light of the fact that the RMY data sets' quality has a big impact on the energy efficiency of Australia's future building stock, the authors reviewed the CSIRO climate data sets before the NCC 2022 was published.

When transposing a dataset from ACDB to EPW format, it is imperative to take into consideration the differences between different time conventions that apply to solar irradiation data: in the ACDB format, solar data represents the integral of solar irradiance over the hour centred on the time stamp (i.e., each hourly data point represents 30-minutes either side of the timestamp), whereas in the EPW format the irradiance is reported for the time interval leading up to the timestamp (i.e., timestamped at the end of each hourly period). Most other weather elements (Dry Bulb Temperature, Dew Point, Wind Speed etc.) are instantaneous and their transposition between formats should be relatively straightforward.

Nevertheless, the authors found that CSIRO's method introduces a time offset error such that instantaneous weather elements are incorrectly offset by 60 minutes.

For the solar elements, it appears that the CSIRO EPW approximately matches the authors' and the NIWA ACDB data (see Figure 1). However, there appears to be a time offset (albeit not the 60-minute offset seen in instantaneous elements) as well as some inconsistencies in the underlying data.

Considering the time convention differences between EPW and ACDB previously described, the authors suspect that the CSIRO EPW has simply taken the ACDB data without adjusting for the 30-minute time offset deriving from different time conventions.

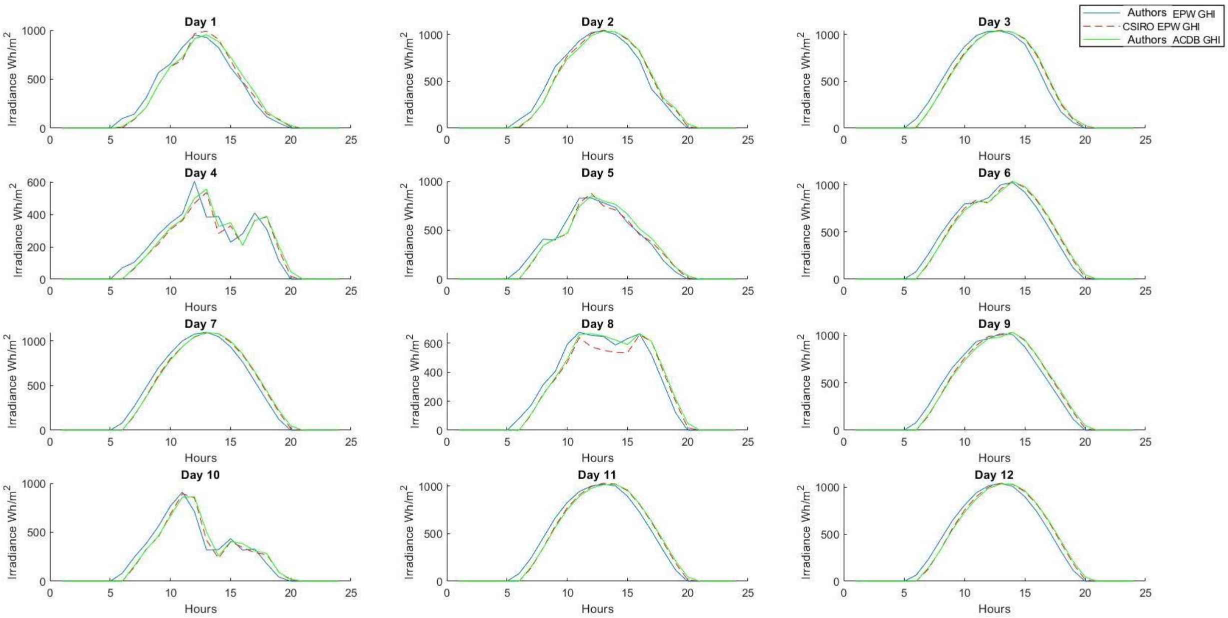

Figure 1: Comparison between Global Horizontal Irradiation (GHI) in the Canberra climate between the CSIRO EPW and the authors datasets – January 2005.

More importantly for buildings, the differences in total solar radiation over longer periods can be significant. Utilising our full 28-year historical weather record, we produced what we called a Selected Meteorological Year (SMY) dataset with source-months selected to replicate the NIWA/CSIRO RMY (1990- 2015) in EPW format by concatenating the same calendar months for Brisbane, Canberra, and Melbourne. This allowed us to simulate with EnergyPlus™ an archetype 10-storey office building which complies with the proposed energy efficiency requirements of the National Construction Code (NCC) of Australia 2019. This model was used to estimate the cooling and heating energy demand utilising the CSIRO RMYs and our SMY for each city. The results for Canberra are shown in Figure 2 and Figure 3 below, where it is possible to appreciate how these timing offsets are introducing non-trivial errors both for heating and cooling consumptions, and heating and cooling peak loads (not showed in the charts).

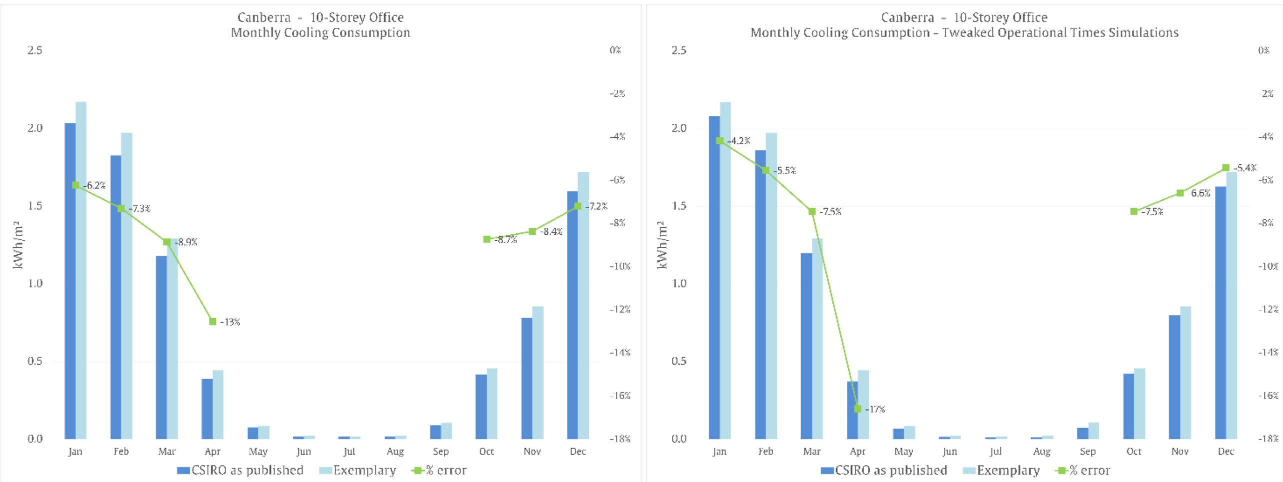

Figure 2: Simulation results and workaround: authors SMY cf CSIRO RMY in the Canberra Climate for a DTS NCC2019 10-storey office building – effect on cooling consumption

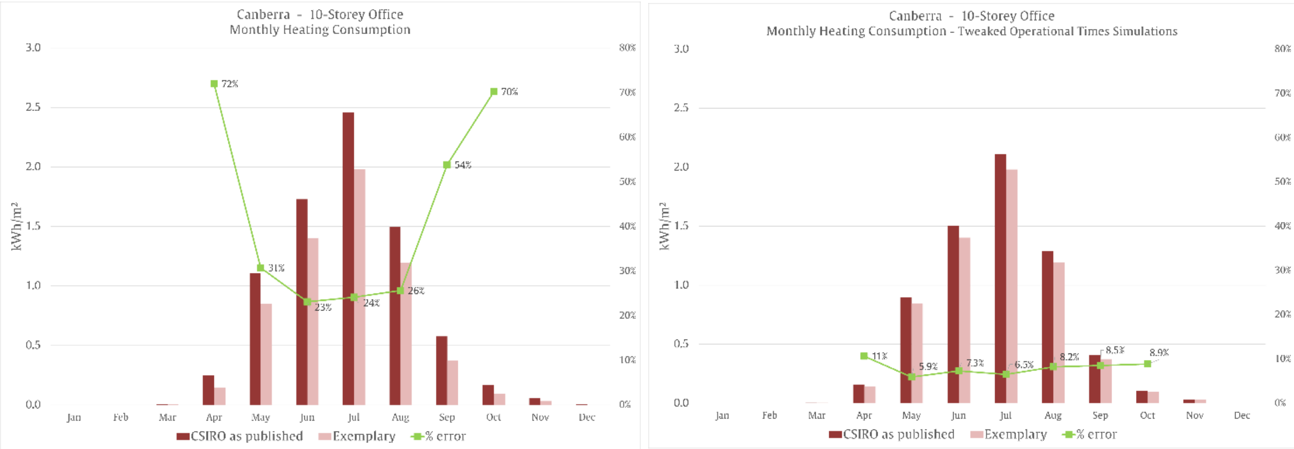

Figure 3: Simulation results and workaround: authors SMY cf CSIRO RMY in the Canberra Climate for a DTS NCC2019 10-storey office building – effect on heating consumption

In all our simulations, the effect of the offset errors was obvious: utilising CSIRO RMYs, the monthly cooling requirements were lower and the monthly heating requirements were higher compared to Exemplary SMYs.

Our attempted workaround for circumventing the CSIRO timestamp errors involved re-running the simulations while changing the operational times of the archetypical buildings. That is, we shifted the simulations' operational times by one hour to align with the CSIRO's erroneous timestamps for the non-solar weather elements. The results from these simulations, together with the ones we previously carried out, allowed us to isolate the impact of this error and estimate the effectiveness of this workaround.

As expected, the tweaked operational times resulted in an increase in cooling requirements while heating demand decreased – closer to the results using the correctly-timestamped data. In the results presented in Figure 2 and Figure 3, the author's results are always taken from standard simulations.

Finally, to assure the quality of our analysis, considering that even after the workaround there are still some discrepancies in the results, we also ran simulations with a third weather file which was using CSIRO RMYs as a base, with GHI, DNI, and DIF substituted with the ones from Exemplary's SMYs. As expected, in the results from these simulations utilising standard operational times, the effect of the offset errors of the other weather elements was still present, thus, although with lower % errors compared to CSIRO as published, the monthly cooling requirements were lower and the monthly heating requirements were higher compared to Exemplary SMYs. However, when simulating these weather files with tweaked operational times, the results were almost identical to the simulations with standard operational times utilising Exemplary SMYs, thus confirming that the discrepancy in the results is caused by the 30-minute time offset in the CSIRO solar data.

BOM cf Solcast solar irradiation data

Following the improvements to our Real Time Year (RTY) weather data services (APSRC, 2022) we have analysed the difference between the Australian Bureau of Meteorology (BOM) and Solcast gridded satellite-estimated data, with the BOM's coincident ground based measurements of Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), and Diffuse Horizontal Irradiance (DIF), to perform quality assurance analysis and determine how the differences in these datasets could possibly reflect on building energy simulations.

As the BOM's ground based measurements were available to us in half-hourly format, we extracted data with the same time granularity from Solcast's global solar database, and used the half-hourly GHI, DNI and DIF that we produced from the hourly integrated BOM's gridded satellite-estimated data. The results for Melbourne in 2017 and 2018 are shown in Figure 3, where:

- *SC_GHI* refers to Solcast half-hourly gridded satellite-estimated data.
- *BOM_GHI* refers to our half-hourly dataset produced from the hourly integrated BOM's gridded satellite-estimated data.
- *BOM_GHI_terrestrial* refers to BOM's half-hourly ground based measurements.

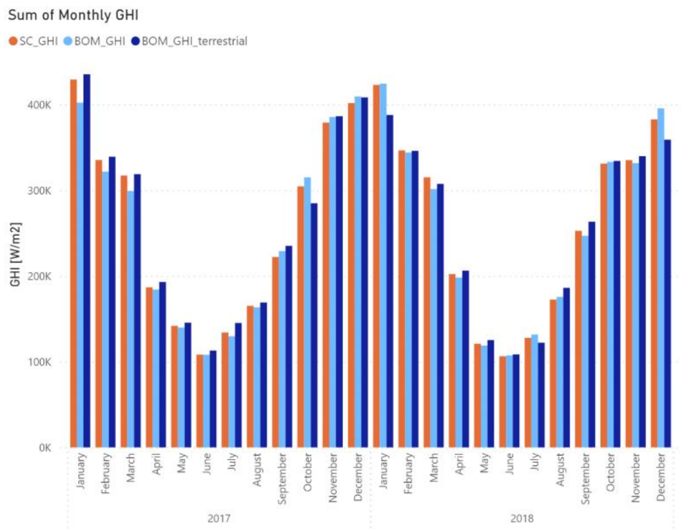

Figure 4. Comparison of Sum of Monthly GHI in Melbourne Airport.

Our quality assurance was based on the higher reliability of the terrestrial observations, compared to satellite-estimated values. Thus, we looked closer into the following the percentage differences of the two satellite-estimated datasets, as well as the percentage differences of the satellite-estimated data from the ground-based observations – the results are shown in Figure 4, utilising the same notation previously described.

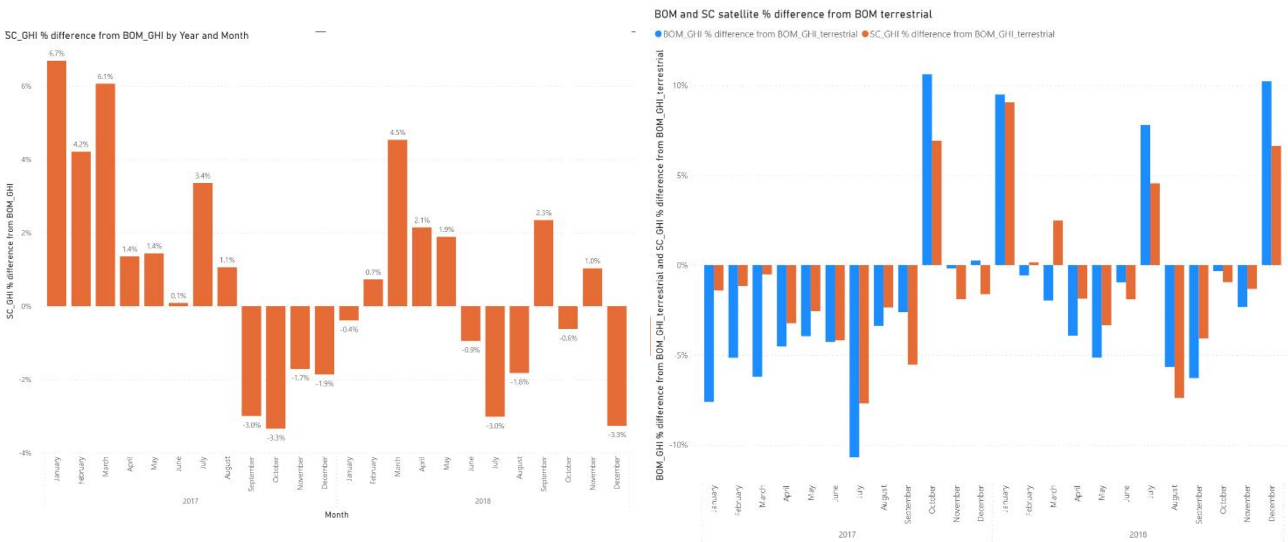

Figure 5. Percentage difference between different datasets – a) Solcast satellite-estimated GHI % difference from BOM satellite-estimated GHI; b) Solcast and BOM satellite-estimated GHI % difference from BOM ground-based observations.

Interestingly, while the percentage difference between BOM and Solcast satellite-estimated data is very low (e.g., less than 4.5% except for January and March 2017), when comparing both Solcast and BOM satellite-estimated data to BOM ground-based observations, it appears that the quality of Solcast's data is higher (Figure 4b).

To understand how these differences can affect building energy consumptions and solar PV system simulations, we are aiming to create different RTYs utilising the various sources of solar irradiation, and simulating a number of building archetypes with EnergyPlus^{TM} to estimate the building heating and cooling consumption, as well as performing Solar PV simulations with System Advisor Model (SAM) to investigate into how the system output varies utilising each dataset.

References

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https://niwa.co.nz/about/our-company

https://solcast.com