Blowing the whistle on Stevenson screens

A climate-change critique by Dr. Bill Johnston

Main points

- The instrument used to measure air temperature consists of thermometers *and* the shelter in which they are housed. Factors that affect performance of the shelter be it a Stevenson screen, metal beehive or a beer-crate, also affect temperature measurements.
- A variety of Stevenson screen types were used from when they were introduced in the 1800s until 1925 when 230-litre screens were the nominated standard. However, some screens were not replaced until after meteorological services were reorganised in June 1946 following WWII and it's a major problem that metadata for most sites is faulty or incomplete.
- Increases in temperature since the 1970s is due to the staged replacement of 230-litre screens with 60-litre ones; networked automatic weather stations (AWS) replacing thermometers after 1 November 1996 and field staff being made redundant.
- Site and instrument changes dominate Australian weather station datasets and homogenised or not, none are useful for depicting trend or changes in the climate.

Background

Large 230-litre Stevenson screens were the mainstay instrument shelter since exposure of Australian meteorological thermometers was standardised in 1925[1]. Temperatures measured under different conditions are not necessarily comparable (Figure 1). Referred to as exposure bias, differences between shelter types are detected objectively using statistical tests (or photographically using a camera!)

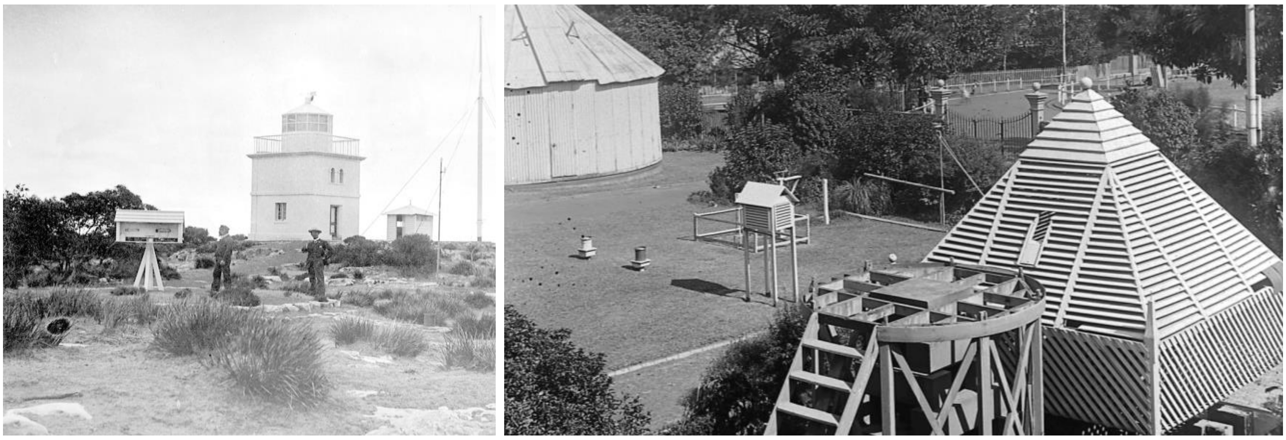

Figure 1. Temperatures measured in the open-fronted Glaisher stand at Cape Borda lightstation, Kangaroo Island SA in 1903 and the pyramid-like 'thermometer house' at Sydney Observatory before 1908 are not necessarily comparable with those measured in Stevenson screens, such as the one in the centre of the Observatory lawn. (Photographs courtesy of the State Library of South Australia (L) and the Museum of Applied Arts and sciences, Sydney (R).)

The standard 230-litre screen

The standard large screen (Figure 2) consists of a semi-gloss white-painted (or whitewashed) wooden box having double louvered sides and a ventilated double-roof and base oriented so the door faces south. Horizontally held maximum (Tmax) and minimum (Tmin) thermometers

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[1] http://www.bom.gov.au/climate/change/acorn-sat/documents/ACORN-SAT_Observation_practices_WEB.pdf p. 9.

were about 1.2 m (4-feet) above short, unwatered natural grass. The low across-grain thermal conductivity of dry wood combined with the constant albedo (reflectance) of a well-maintained screen provides thermometers with a consistent thermal environment.

Advantages of the large double-louvered wooden screen include:

- Instruments (wet and dry-bulb and maximum and minimum thermometers) are held on the same plane relative to the rear wall, which in the southern hemisphere faces north toward the sun.
- Double louvers and ventilated double roof and floor ensure extraneous radiation (direct, reflected and diffuse) can't affect measurements.
- While air is free to circulate without restriction, the enclosed volume buffers against transient eddies – convection from surfaces nearby (or passing traffic etc.) that may not be representative of the body of air being monitored.

Additionally, under high-wind conditions the rate of airflow is restricted somewhat, and instruments are kept dry and clean – Tmax and Tmin are presumed to be dry-bulb estimates while accumulated grime, dust or sea-spray affects responses to changing conditions.

Figure 2. The 1913 Stevenson screen at Hawkesbury Agricultural College, Richmond NSW (L) was a small louvered type with a copper or zinc roof. (The fenced enclosure surrounds a sunken-tank evaporimeter and gauge-rod.) Len Walker 'doing the met' at the Aeradio weather station on Groote Eylandt in 1940 (R). The consistent thermal environment provided by the well-maintained 230-litre screen minimises exposure-bias. (The conduit supplied power to a low-power lamp so observations could be made at night.) Although both are Stevenson screens, due to its metal roof and smaller dimensions the Hawkesbury screen is likely to be biased-high on warm days. (Photos courtesy of the University of Western Sydney archives (L) and the Civil Aviation History Society (CAHS) (R)).

The change to 60-litre screens

Following metrication on 1 September 1972 when all Fahrenheit thermometers were replaced with Celsius ones on the same day; in 1973 the small (60-litre) screen was specified as the standard shelter. A comparison of screen types undertaken at Broadmeadows, Melbourne (which was not an official weather station), was published by the World Meteorological Organisation in 1999[1]. However, the study was of limited scientific merit: screens were not replicated (only one of each type was included), it failed to consider if screens behave differently in different environments and thermometers were not used as the control-instrument.

[1] Warne, J 1998, 'A preliminary investigation of temperature screen design and their impacts on temperature measurements', *Instrument Test Report 649*, Bureau of Meteorology, Melbourne, Australia. https://www.wmo.int/pages/prog/www/IMOP/WebPortal-AWS/Tests/ITR649.pdf

Thus, questions remain unanswered. For instance what was the effect on data of replacing the screen at Learmonth (WA) *vs*. the one at Flinders Island airport (Tas); or, for cases where the screen size changed at the same time thermometers were replaced by rapid-sampling AWS probes like at Moomba (SA), Rabbit Flat and Mandora (WA); or, a combination of changes happened like at Sydney and Launceston airports, Bundoora and Cobar MO? While manual observations were made in parallel with AWS for years at most Bureau-operated sites (including Canberra, Alice Springs, Norfolk Island, Wagga Wagga and Port Hedland), the official Bureau policy was that comparative data were either destroyed or not databased.

Adding further confusion, Figure 5 in the *Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) Observation practices* bulletin (p. 10) shows the internal layout of the 230-litre screen at Hobart airport, but describes it as that of a 60-litre screen (Figure 3). Holding instruments on the same plane parallel with the north-facing rear wall minimises spatial bias as the screen warms and cools through the day.

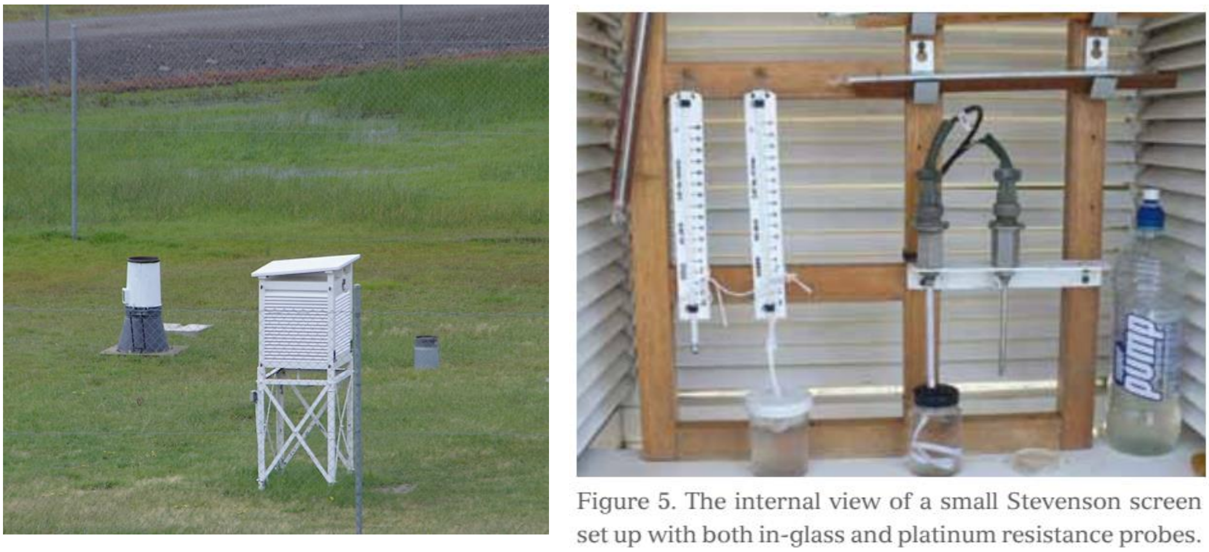

Figure 3. Placement of instruments in the 230-litre Stevenson screen at Hobart airport (L., photographed in October 2016) on the same plane relative to the north-facing rear wall (right) minimised spatial bias. The Tmax thermometer is out of sight.

Confounded somewhat with poor documentation and the inability to access the Bureau's metadata database (SitesDB) on-line, the problem of instrument bias is real and on going. At some sites, while the screen stayed the same, changes in data coincided with AWS becoming primary instruments; at others, they were due to changing to a small screen; while at others, a combination of factors were involved – the site moved at the same time the screen changed or an AWS was installed or it became the primary instrument; or developments occurred nearby that caused temperature to step-up. For instance, there is no mention in available metadata that the pre-1957 screen at Mildura airport was non-standard and that surrounds were watered; or that when the site at Townsville moved to a 2-metre high mound and was automated in December 1994, AWS-probes were positioned 2 cm closer to the north-facing rear of the screen than the thermometers they ultimately replaced (Figure 4).

Homogenisation

Homogenisation aims to compensate for the effect of site and instrument changes on data. However, documentation used to apportion data-changes to either site-changes or the climate is mostly unreliable or misleading. For instance, opening of the Cahill Expressway in 1958, which surrounds the Sydney Observatory site, was ignored to imply the climate warmed when it didn't. Also, pretending the effect was due to the climate, moving from the roof of the met-section building at Laverton RAAF to a new met-office in about 1958 was also ignored. Data for Kent Town Adelaide warmed when a parking area was sealed south of the site before February 2003 and the large air-conditioned indoor sports complex opened nearby in 2012. Also, reducing transpiration by the grass they replaced, new wind-profiler arrays installed at Canberra, Launceston, Longreach, Ceduna, Coffs Harbour, Tennant Creek and other airports caused warm days to be warmer even though they weren't. Reinforced by homogenisation and exacerbated by averaging across unadjusted datasets, recent rapid rates of warming is due to relocating screens to warmer exposures, replacing thermometers with AWS-probes, the staged replacement of 230-litre screens with 60-litre ones, slack maintenance and changes to local heat balances caused by new buildings, roads and wind-profiler arrays.

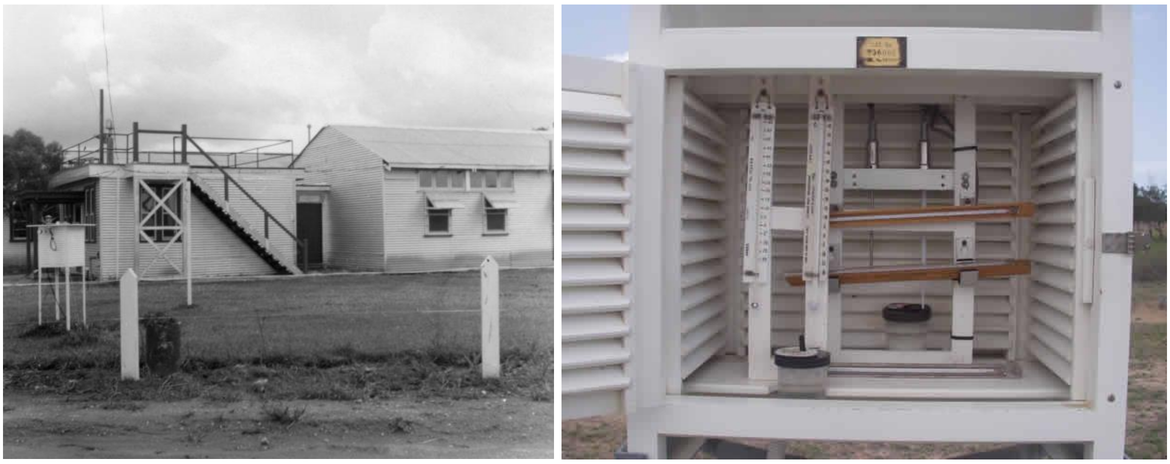

Figure 4. The effect of replacing the non-standard WWII-era screen at the former Aeradio met-office at Mildura airport (L) probably in 1957 was apparently adjusted out of the data. AWS-probes at Townsville airport are about 2 cm closer to the north-facing wall of the screen, which results in upper-range bias on warm days. (1954 photo (L) courtesy of CAHS; Bureau of Meteorology photo (R).)

Forgetting where the original Stevenson screens were located and the conditions under which observations were made is also commonplace (Figure 5). For instance, photographs show Aeradio sites at Mildura, Onslow and Port Hedland airports and the yard at the Marble Bar and Bourke post offices were shaded or watered, and that original Aeradio sites at Canberra, Norfolk Island, Amberley, Sydney airport, Charleville, Meekatharra, Rockhampton, Launceston, Darwin, Townsville, Halls Creek, Cairns, Oodnadatta and elsewhere were not where metadata claim they were. Such looseness with important details is unacceptable.

Figure 5. The original instrument enclosure (centre, in front of the trees) and surrounds in the vicinity of the Aeradio office at Onslow WA, photographed in 1964 (L) were watered, probably to control dust. Observations were suspended after cyclone Trixie demolished the place in 1975 until 1997 when an AWS was installed at an unwatered site beside the runway. That site moved further away in 2002. While the climate was unchanged since observations commenced in 1939, data were warmed artificially by site moves and instrument changes. At Charleville (Qld) (right), metadata ignored that the original Aeradio site was near the WWII operations centre on the northern side of the aerodrome near the town racecourse. The effect of moving to the new met-office in 1956 was adjusted out of the data using rainfall as a co-variable. (Photographs courtesy of Dawn McAullay (L) and CAHS.)

Compounding the metadata problem, telephone exchanges replaced gardens and lawns in post office yards in the 1940s and 50s; microwave towers in the 1970s and 80s; buildings were built nearby, roads were sealed, carparks ... and on it goes. No sites have stayed the same and claims by the Bureau, CSIRO, the Climate Council, Australian Academy of Science and orchestras of professors that changes in data since the 1950s reflect the climate are not true.

Making weather warmer

More recent strategies employed to warm the climate include gravel-mulching sites like at Woomera; grading around the AWS at Bourke; ignoring that data for sites like Penrith Lakes, Cunderdin, Cranbourne Botanic Gardens and Badgery's Creek (and others like Giles and Halls Creek) are warmed by cultivation, new playgrounds, roads and buildings; spraying-out the grass at Mt Isa, Learmonth, Richmond RAAF, Longreach, Bridgetown (WA); moving small Stevenson screens into dusty situations at Oodnadatta, St George, Tibooburra, Moomba or beside dusty tracks like at Mardie, Mandora, Maree and Marble Bar; into the scrub like at Cape Bruny, into the sea like at Low Head; beside up-draft zones at Cape Leeuwin, Nobbys Head and Cape Otway and beside water and sewerage treatment works like at Logan (Qld), Burnie (Round Hill) and Ti Tree Bend (Launceston). Saving on maintenance so equipment is only cleaned of accumulated grime once per year or less and not regularly mowing the grass warms the data but not the climate.

To top it off, the latest scheme is installing PVC Stevenson screens in the hottest places they can find in the far north-west of NSW east of the Strzelecki Desert at Smithville, Wanaaring (Borrona Downs), Wanaaring (Delta), Noona AWS, Nyngan (Girilambone (Okeh)), Walgett (Brewon AWS) and Mulurulu AWS. While during summer 2018 the Bureau claimed multiple records were broken at many of those sites, most had only been running for six-months!

PVC screens have not been evaluated as fit for purpose. Their closely-spaced louvers would warm up quickly and their matt-black interiors would radiate a high proportion of that heat onto the instruments than would be the case for white-painted wooden screens (Figure 6).

Figure 6. In the middle of no-where and surrounded by a stony gibber-plain, the 60-litre PVC screen at Wanaaring (Delta) is biased-high. Matt-black internal louvers radiate heat into the screen increasing the likelihood of temperature extremes especially on windless warm days. (Photos by the Author.)

Conclusions

- The Bureau has lost its way. Australia's average temperature has been warmed by the staged replacement of standard 230-litre Stevenson screens with 60-litre ones, which accelerated over recent decades; making automatic weather stations (AWS) primary instruments from September 1996; introduction of PVC screens, closing offices, sacking staff and reducing maintenance to one or fewer site-visits per year.
- Due to compounded changes and biased homogenisation methods no Australian weather station datasets are useful for depicting trend or changes in the climate.