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AUSTRALIAN BUREAU OF METEOROLOGY UPPER WIND AND RADAR PROFILER NETWORK

Alex Kariko*, Dean Lockett and Roger Atkinson

Bureau of Meteorology, Melbourne, Victoria, Australia

1. INTRODUCTION AND HISTORY

The Bureau of Meteorology has a long history of measuring upper winds, but the operational use of radar wind profilers has been a recent addition to its upper-wind network. Research in the field has a history stretching back several decades. This year marks the tenth anniversary of the installation of the first operational radar wind profiler at Sydney airport. To highlight the importance of continuous upper-wind observations offered by wind profilers it is useful to review the history of upper-air wind measurements.

1.1 *Pilot Balloons and Nephosocopes*

Since the formation of the Bureau in 1908, meteorological observers have gathered wind data by tracking free-flying balloons with pilot-balloon theodolites. Upper-wind observations continue to be made at six and twelve hour intervals each day, but now with more capable equipment. Before the introduction of radars, some weather stations were equipped with 'nephoscopes' that tracked the movement of cloud elements and provided rudimentary indications of upper wind velocities without the need for balloons.

2. RADARS

2.1 *The 277 and MKVII radars*

After World War II, surplus ship's and artillery radars became available and these were used for wind finding at many Australian weather stations. They tracked light-weight, metallic, corner-reflector targets. The first 277 ship's radar was installed at the Bureau's field training station in Melbourne in 1948 (Morgan 2001). Beginning in 1952, another fifteen were installed over the next ten years. Between 1956 and 1961, four Mark VII artillery radars were also incorporated into the upper-air network. The 277 radar, in weather watch mode, was also the first used to photograph a tropical cyclone in Australia, when Freddy Soutter, operator of the Townsville radar took photos of the rain bands of Tropical Cyclone *Agnes* on 6 March 1956 (Morgan 2001). Coincidentally the Townsville 277 radar was the last of its type to be retired in 1985.

2.2 *Radio theodolites*

Parallel with the installation of the ex-military radars, seven French Metox radio theodolites were placed into service between 1952 and 1961 (Morgan 2001). They saw service from the steaming ridges of the Solomon Islands to the icy wastes of Antarctica. These 'passive' radars tracked the transmissions from radiosondes carried by balloons, and though they suffered from limitations at high and low elevations, unlike optical theodolites, they could track the sonde through clouds. For a short period in the late nineties and early two thousands, the Bureau collaborated in the development of a new radio theodolite, but the project was discontinued.

2.3 *The WF series Radars*

Following the successful trial of a prototype Plessey WF 1 radar in Townsville in early 1961, the first of thirty, purpose-built, manual-tracking Plessey WF 2 radars was introduced in 1964. In April 1966 the first Plessey WF 44 was installed. This was a state-of-the-art dual role weather-watch and wind-finding radar, a robust instrument that has aged well and has undergone numerous upgrades to its electronics. These stalwarts of the radar network have now been almost entirely phased out of service. Between 1969 and 1978 the Bureau installed fifteen Plessey WF 3 radars; these were portable, automatically tracking wind-finding radars. They were installed at many remote stations where wind-finding was essential but did not justify the installation of a dual-mode radar. In 1981 the Bureau chose Enterprise Electronics Corporation WF100 radars as a direct replacement for the WF 44. This radar is of a much lighter construction and is housed in a radome to protect the dish from destructive winds.

2.4 *Other enhancements*

In the early 1980s programmable pocket calculators were developed and these were issued to radar stations to replace the pilot balloon slide rule for calculating upper winds.

As cheap processors and desk top computers developed, this allowed the entire network of automatic tracking radars to have wind processors

* *Corresponding Author:* Alex Kariko, Bureau of Meteorology, Observations and Engineering Branch, GPO Box 1289, Melbourne, Victoria, Australia, 3001;
e-mail: alex.kariko@bom.gov.au.

progressively retro-fitted. These processors released the observer from the laborious task of calculating and encoding upper winds.

The increasing civilian use of the Global Positioning System (GPS) in the late eighties saw the development of the Vaisala GPS radiosonde. These instruments provided wind data as well as pressure, temperature and humidity (PTU) as the balloon ascendes. Global positioning system radiosondes have superseded wind-finding radars at several remote stations.

3. AUSTRALIAN WIND PROFILER NETWORK

3.1 *Research Profilers*

In the late 1980s and early 1990s the Bureau of Meteorology Research Centre (BMRC) began experiments with the National Oceanic and Atmospheric Administration (NOAA). They installed 920 MHz profilers at Darwin in the Northern Territory (NT) and at Northwest Cape in Western Australia (WA). Another profiler was deployed south of Perth Western Australia with collaboration with the WA Environment Protection Agency (EPA) and the State Emergency Service.

3.2 *Operational Profilers*

The need for a wind profiler network was growing, due to the aviation industry requesting continuous wind observations above airports to better manage aircraft traffic and the selection of Sydney, New South Wales to host the 2000 Olympics. In 1996 BMRC and the Bureau's Special Services Unit explored the feasibility of observing winds with radar wind profilers from 100 m to 3000 m continuously over the day, with resultant winds averaged over 15, 30 and 60 minute intervals with a vertical resolution of 100 m. These observations were to be made with 920 MHz systems.

3.21 Mt Gambier, South Australia

Planning for this profiler began around 1994 as a project between the Bureau, Adelaide University and the Australian Research Council who provided funding. This prototype profiler was installed in 1997, operating at 44.75 MHz with peak power of 36 KW. It consists of three sets of nine Yagi antennas within a 20 m square enclosure. It scans the atmosphere continuously providing wind data averaged over 15, 30 and 60 minute intervals at a vertical resolution of 100 m. It was originally intended to operate in both phased array and Doppler mode, but the latter mode was not implemented.

3.22 Sydney Airport, New South Wales

This profiler was installed in 1999, operating at 55 MHz with peak power of 7.5 KW, and three sets of nine Yagi antennas. The profiler operates in phased array mode and provides wind data at similar intervals and vertical resolutions as the Mt Gambier profiler. It is the oldest operational profiler in the network.

3.23 Shane's Park, New South Wales

This profiler was installed in 2000, operating at 1280 MHz. It is owned and operated by the NSW EPA and maintained on their behalf by the Bureau.

3.24 Launceston Airport, Tasmania

This profiler was installed in June 2004, operating at 55 MHz and peak power of 7.5 KW with three sets of nine Yagi antennas. The profiler operates in phased array mode and provides data at the same intervals and vertical resolution as the Mt Gambier profiler. This profiler underwent extensive intercomparisons with the stations WF 3 radar, GPS sondes, wind and PTU soundings from Melbourne and Hobart, and analysis output from the Bureau's meso-scale limited area prediction system (meso-LAPS). This work allowed extensive characterisation of the profiler's performance and insights into the critical effects of surface level side-lobes. It also showed the usefulness of meso-LAPS analysis data as a reference for the profiler's performance.

3.25 Canberra Airport, Australian Capital Territory

This profiler was installed in July 2005, operating at 55 MHz, with peak power of 7.5 KW and three sets of nine Yagi antennas. The WF 3 radar at Canberra was aging rapidly; it was decided to replace this radar with GPS sondes until the profiler came on line. This resulted in one set of comparison flights between the WF 3 and the GPS sondes and then later a second set between the GPS sondes and the profiler. The comparisons corroborated knowledge obtained from the Launceston comparison project.

3.26 Woomera, South Australia

In 2006 the Bureau acquired the large tropospheric profiler formerly owned by the Japanese Aerospace Exploration Agency. This profiler operates at 55 MHz and a peak power of 100 KW, the antenna array consists of 144 Yagi antennas arranged in a 12x12 square that is subdivided into four smaller arrays of 6x6 antennas. The profiler operates in Doppler mode only. It is undergoing refurbishment and servicing before being used for research and development work. It has recently come on-line as a research tool for the Bureau's observations program.

3.3 *Biases*

Analysis of the data from the operational spaced array profilers suggests a consistent low bias of between ten and twenty per cent.

4. THE FUTURE

Profilers are an attractive method of upper wind measurement. They can operate unattended for

long periods and provide near continuous data. Once installed, the continuing running costs tend to less than for wind-finding radars or GPS sonde installations. The radar and sonde installations all require frequent operator presence at the station. All these factors point to the increasing use of radar wind profilers in the Australian region.

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