

Tropical cyclone *Bobby* — a notable example of the impact of local TOVS data

J.F. Le Marshall and G.A. Mills
Bureau of Meteorology Research Centre, Australia
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Introduction

At approximately 1500 UTC on 24 February 1995, tropical cyclone *Bobby* crossed the Western Australia coast near Onslow. It moved inland, passing over several mining areas, and caused significant damage to the regional economy.

The operational regional numerical forecasts after landfall predicted that the cyclone would move west of south over the coast near Shark Bay, and then further off the coast. This proved to be a significant numerical model forecast error, providing poor operational guidance in this severe weather situation. The current operational Regional Assimilation and Prognosis system (RASP), the next generation Bureau of Meteorology (BoM) Limited Area Prediction System (LAPS), which was then undergoing parallel trials, and the BoM's Tropical Analysis and Prognosis System (TAPS), each produced similar forecast errors.

As it transpired, logistic problems, including an extremely heavy load on the communications link between Perth and Melbourne, resulted in the loss of local TOVS (TIROS Operational Vertical Sounder) radiance data west of 130°E from the input stream into the operational regional forecast system on 25 February 1995. Concern at these forecast errors, generated in the absence of local sounding data over a major weather system in the operational and next generation operational models, and a knowledge that longer-term studies (e.g. 121 cases in Le Marshall et al. (1994)) had demonstrated the utility of these data, led to a reanalysis of the situation for 1200 UTC on 25 February. This used the operational analysis first guess and boundary conditions, and the operational data utilised by the National Meteorological Centre with additional local TOVS sounding

data generated from three orbits near 1200 UTC, employing the current operational retrieval scheme.

Subsequent forecasts from this reanalysis, shown below, moved the cyclone south and slightly east, keeping it ashore, and would have provided much improved forecast guidance in this important case. The clear improvement from the inclusion of these high resolution soundings, calculated from raw TOVS radiances collected by the BoM's S-band groundstation network, provides a dramatic demonstration of the importance TOVS data can assume in numerical analysis and prediction in the Australian region.

This example should be considered in conjunction with longer-term studies, which have documented the general benefit of using these TOVS data in operational Australian region forecasts (Le Marshall et al. 1993, 1994). The operational physical retrieval scheme and the regional forecast system used in this study are described briefly below, along with the forecasts with and without local TOVS data.

The operational TOVS system

For over a decade, the Australian BoM has received (by direct readout and via the GTS) and used NOAA second-generation sounding data from the TIROS-N NOAA-A series of satellites. The real-time application of these data in the Australian BoM is vital to numerical weather analysis and prediction, both in the Australian region and over the southern hemisphere. The regional polar-orbiting satellite groundstations at Melbourne, Perth, Darwin and Casey thus occupy an important position in the Bureau of Meteorology as they provide high-resolution TOVS data for the operational regional forecast system within the stringent operational cut-off times.

Corresponding author address: Dr J.F. Le Marshall, Bureau of Meteorology Research Centre, GPO Box 1289K, Melbourne, Vic. 3001, Australia.

The direct readout TOVS data, used here, were processed using the Bureau's real-time operational processing system. This employs a full physical retrieval scheme similar to that described in Le Marshall et al. (1994). The scheme uses a simultaneous solution of the Radiative Transfer Equation for temperature, moisture and skin temperature, similar to Smith et al. (1991). The TOVS data retrieval scheme is embedded in the Australian region McIDAS system (Le Marshall et al. 1987). It uses fields from the operational Global Analysis and Prognosis System to provide first guess fields of temperature and moisture at satellite orbit time. The retrieved temperatures and moistures are also automatically quality controlled by examining internal consistency and using data from the operational Global Analysis and Prognosis System. The retrieval system uses local bias and transmittance correction and also produces estimates of cloud amount and height, skin temperature and total ozone.

The local TOVS data have already been used in a series of real-time data assimilation experiments (Le Marshall et al. 1993, 1994) in the Australian region to gauge their impact on operational regional forecasts. The impacts demonstrated have been obtained against the full NMC database which includes locally generated cloud-drift winds (Le Marshall and Pescod 1991), and NESDIS low resolution TOVS data (SATEM) available at the regional cut-off time of $T + 1.5$ h for the 0000 UTC and 1200 UTC analyses. These studies have indicated an S1 skill score advantage (Teweles and Wobus 1954) of between 1 and 3 skill score points for the operational system, using local TOVS data, at most levels through the atmosphere, depending on the synoptic situation and the distribution of the TOVS data available at forecast time.

The forecast model

The analysis and forecast model used here is the BoM's next generation regional model, the Limited Area Prediction System (LAPS), which has been developed by BMRC's Regional Meteorology Group. In parallel trials, it has clearly outperformed the current system and operational trials in the NMC are expected to commence shortly. The system has a resolution of 0.75° latitude/longitude and has 19 levels. Its domain is from 15°N to 65°S and 65°E to 185°E . The model uses high-order numerics and a detailed parametrisation of physical processes which include deep convection, large-scale rain, shallow convection, radiative transfer, diagnostic clouds, stability-dependent constant flux layer and iterative soil

moisture. The digital filtering technique of Lynch and Huang (1992) is used to initialise the model.

The analysis scheme is a multivariate, statistical interpolation (MVSI) (Seaman et al. 1995), formulated in sigma co-ordinates on the latitude/longitude model grid. MVSI is applied to influence the MSLP, geopotential height, thickness and wind. Prediction error statistics are used in the LAPS with mass and wind statistics adjusted for geostrophic consistency. An error growth algorithm is also implemented to increase the error assigned to the background in data-sparse areas. Divergent wind increments are analysed and gross error checking is followed by a comprehensive cross-validation. In this system, superobbing (see Mills and Seaman (1990), Seaman et al. (1995) for detail) of closely spaced observations is implemented and data are manipulated in large volumes of the order of an octant of the globe. Another important feature is that significant and mandatory level wind and moisture data are used.

The tropical cyclone *Bobby* forecasts

After tropical cyclone *Bobby* crossed the Western Australian coast near Onslow, around 1500 UTC on 24 February 1995, operational regional forecasts of the cyclone trajectory were issued by the regional forecast system, based on a 1200 UTC 25 February analysis.

As noted earlier, the local TOVS data for the 1200 UTC analysis were not available west of 130°E and hence did not influence the 24 and 36-hour operational regional forecasts. The forecasts from the RASP, LAPS and TAPS moved the cyclone south and west, across the coast and out to sea over the 36-hour forecast period, a significant forecast error. The operational RASP 24 and 36-hour forecasts can be seen in Figs 1(a) and (b). The corresponding real-time forecasts from the next generation LAPS can be seen in Figs 1(c) and (d). They show some improvement in track but still significant forecast error. The verifying analyses can be seen in Fig. 2.

These forecasts were subsequently repeated using the next generation LAPS and the NMC database (available at the operational cut-off time) plus additional local TOVS data from the BoM's satellite groundstations for three orbits near 1200 UTC on 25 February 1995. The TOVS data coverage can be seen in Fig. 3(a), along with the initial LAPS MSLP analysis in Fig. 3(b). In Fig. 3(a) part of the eastern orbit (received in the Melbourne groundstation) was used in the operational RASP forecasts, while the two orbits west

Fig. 1(a) The 24-hour MSLP forecast from the current operational RASP, valid 1200 UTC on 26 February 1995.

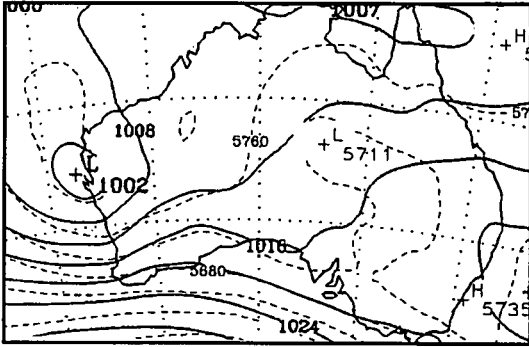


Fig. 1(d) A 36-hour MSLP forecast from the next generation LAPS, valid 0000 UTC on 27 February 1995.

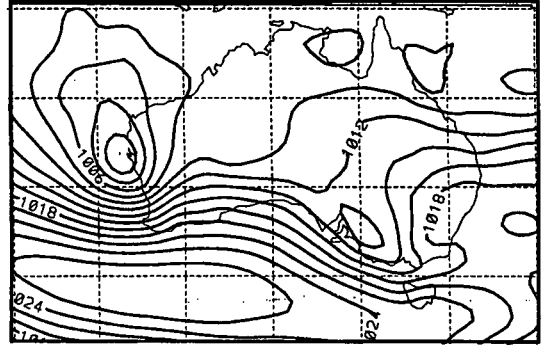


Fig. 1(b) The 36-hour MSLP forecast from the current operational RASP, valid 0000 UTC on 27 February 1995.

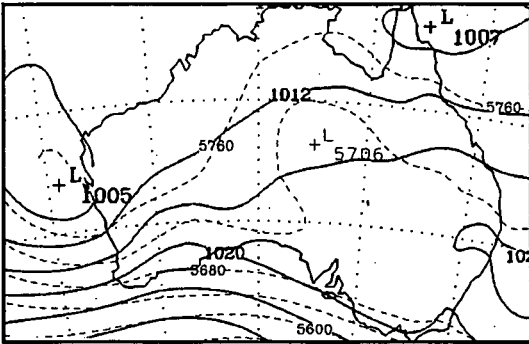


Fig. 2(a) The MSLP analysis valid 1100 UTC on 26 February 1995.

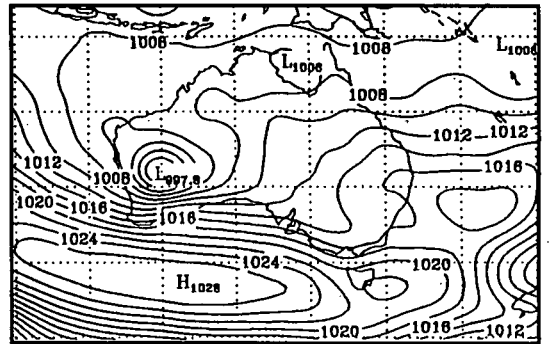


Fig. 1(c) A 24-hour MSLP forecast from the next generation LAPS, valid 1100 UTC on 26 February 1995.

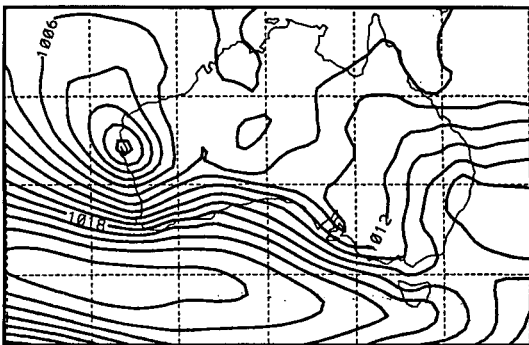


Fig. 2(b) The MSLP analysis valid 0000 UTC on 27 February 1995.

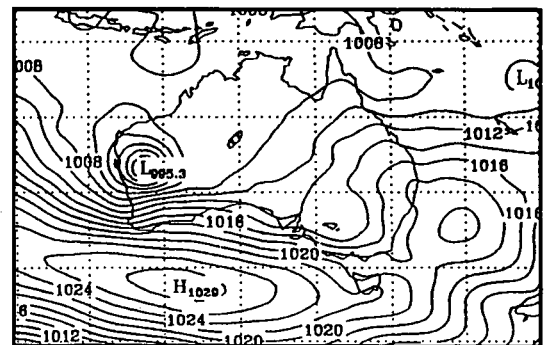


Fig. 3(a) The coverage of local TOVS data, used in the analysis at 1200 UTC on 25 February 1995, shown over the GMS infrared image for that time.

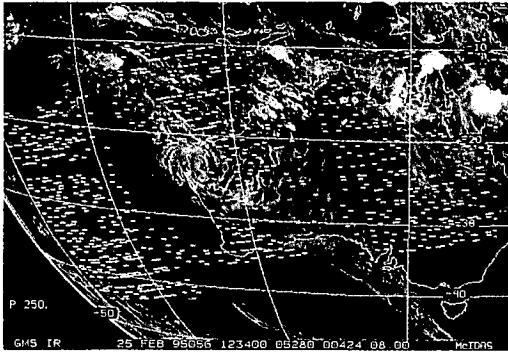


Fig. 3(b) The MSLP analysis from LAPS (with TOVS) for 1100 UTC on 25 February 1995.

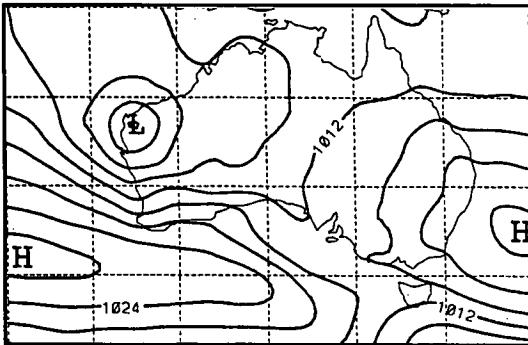


Fig. 4(a) The 300 hPa LAPS geopotential height analysis for 1100 UTC on 25 February 1995, using the operational data.

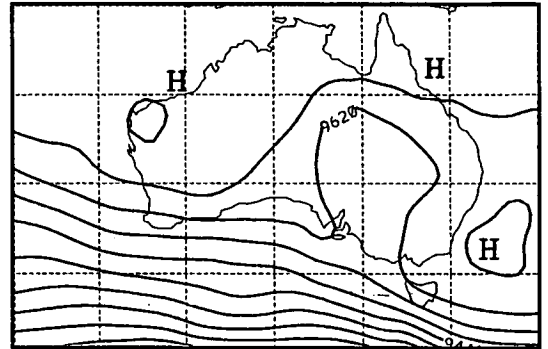
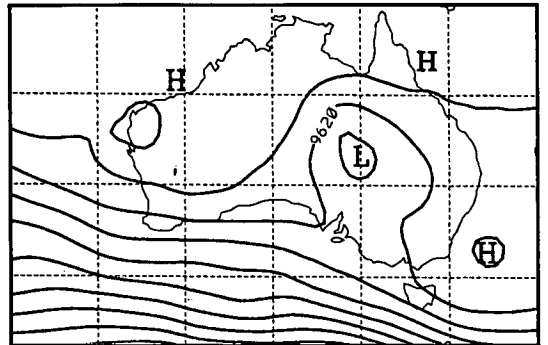


Fig. 4(b) The 300 hPa LAPS geopotential height analysis for 1100 UTC on 25 February 1995, using the operational data plus local TOVS.



of 130° (received in Perth) were added to the operational database for the test LAPS forecasts.

Figure 4(a) shows the 300 hPa (LAPS) geopotential height analysis produced using the operational database, while Fig. 4(b) shows the LAPS 300 hPa geopotential height analysis produced using the operational database plus additional local TOVS data. The chief differences between these analyses were the slightly lower heights SW of the cyclone centre in the TOVS analysis, with this lowering of heights being seen through the mid-troposphere. Some difference in the downstream trough/ridge system was also evident. The variations between analyses have resulted in quite distinct variations in the forecasts. Figures 1(c) and (d) show the resulting 24 and 36-hour MSLP forecasts for the operational database, while Figs. 5(a) and (b) show the resulting 24 and

36-hour MSLP forecasts using the enhanced database. Figures 2(a) and (b) show the verifying surface pressure analyses over Australia at 1200 UTC on 26 February 1995 and at 0000 UTC on 27 February 1995.

It can be seen that the addition of local TOVS data has had a significant impact on the forecast track of tropical cyclone *Bobby*. In the case where local TOVS data were only available over eastern Australia, the cyclone has moved to the south and west and out to sea. In the case with extra local TOVS data, the cyclone moved south and slightly east, remaining inland. The implications of the differences in this operational guidance could be significant. The return of a tropical cyclone over the ocean can often result in significant differences in subsequent intensity and trajectory forecasts.

Fig. 5(a) A 24-hour MSLP forecast from the next generation LAPS with local TOVS, valid 1100 UTC on 26 February 1995.

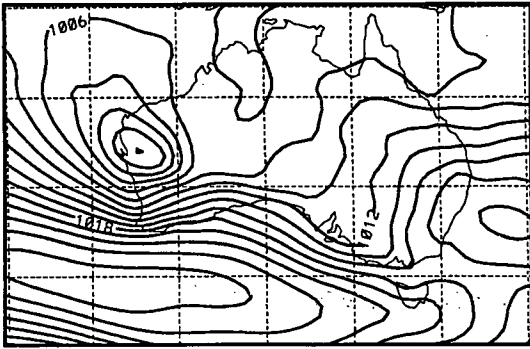
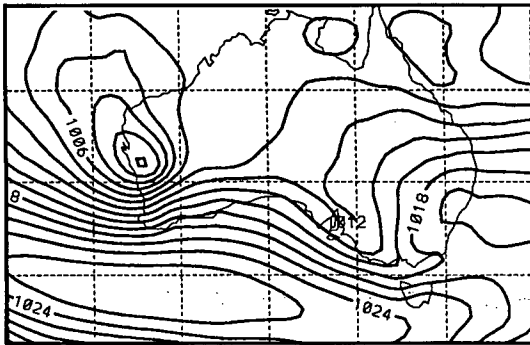


Fig. 5(b) A 36-hour MSLP forecast from the next generation LAPS with local TOVS, valid 0000 UTC on 27 February 1995.



Conclusions

Ample evidence exists, from the early cases of the use of Nimbus 6 data in 1976 (Kelly et al. 1978) to the more recent use of NOAA-11 and 12 data (Le Marshall et al. 1994), to indicate the consistent and positive impact of satellite sounding data on numerical weather prediction in the Australian region.

This case provides a significant and strong indication that even one or two orbits of TOVS data can be important in the forecasting of a significant weather event. It is consistent with the general improvement expected with a good coverage of TOVS data in the Australian region. Notably, it

points out the vital contributions that the use of these data can make to particular regional forecasts. In addition, because of the short data collection time for the operational regional forecast system, the case also indicates the value of the data being collected by the Bureau's satellite groundstation network.

Further work involving the assimilation of high spatial and temporal resolution cloud-drift winds (whose spatial and temporal resolution is such that the current six-hour cycling may not effectively extract all of their information content) and the examination of an ensemble forecast approach is underway, to complement this study.

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