Tellus (1997), 49A, 401–403
Printed in UK – all rights reserved

TELLUS
ISSN 0280–6495

LETTERS TO THE EDITOR

Comments on "The origin and evolution of low-level potential vorticity anomalies during a case of Tasman Sea cyclogenesis"

By LINDA C. HOPKINS[1,*] AND GREG J. HOLLAND[2], [1]*Centre for Dynamical Meteorology and Oceanography, Monash University, Wellington Road, Clayton, Victoria 3168, Australia;* [2]*Bureau of Meteorology Research Centre, GPO BOX 1289K, Melbourne, 3001, Australia*

(Manuscript received 1 August 1996; in final form 10 January 1997)

1. Introduction

The influence of moisture, latent heating and surface fluxes on the development of a case study of coastal cyclogenesis in Australia, has been investigated by Revell and Ridley (1995, hereafter RR). Using potential vorticity diagnostics from a high-resolution (40 km) numerical simulation, RR conclude that surface temperature gradients and surface fluxes of heat and moisture, play a secondary rôle to latent heating at the time of most rapid development of the 1–3 August, 1990, "East-Coast Cyclone".

While we agree that latent heating is an important factor in the development of this storm, we would like to comment on initialising the RAMS mesoscale model with a monthly mean sea-surface temperature (SST), instead of a high-resolution weekly SST, and the possible ramifications.

2. Remarks

2.1. *Characteristics of the East-Coast of Australia*

The east coast of Australia is characterised by a western ocean boundary current, the East-Australian Current and an extended coastal mountain range, known as the Great Divide. The warm East-Australian Current flows southward usually within 100 km of the continental shelf and terminates in the vicinity of Sydney (Harmon, 1961). Poleward of Sydney, warm core anticyclonic oceanic eddies are shed from the East-Australian Current and may be coastally trapped and/or drifting polewards. Climatological mean, land-sea surface temperature contrasts off the east coast of Australia, are much less than those seen off the east coasts of the more polar northern hemisphere continents. However, over a weekly time frame, a sharp coastal, west(cool)-east(warm) sea surface temperature gradient may exist below 30°S, due to the position of the East-Australian Current and/or the advection of warm tropical surface water around developing eddies, especially in winter (Andrews, 1979).

A climatology of east-coast cyclones between 1959–1992 by Hopkins and Holland (1997) demonstrates a preference for rapidly intensifying east-coast cyclones to occur in regions of strong zonal SST gradient. This finding is in good agreement with Sanders and Gyakum (1980), who found a similar preference for the northern hemisphere "bombs". As noted by RR, land-sea temperature

* Corresponding author

contrasts are not as marked as those of North America; however, rapidly intensifying Australian east-coast cyclones also do not appear to reach the potential intensification rates of North American "bombs". Rapidly intensifying Australian east-coast cyclogenesis, including the RR August 1990 case, have maximum intensification rates of between 0.8–1 Bergeron (Holland et al., 1987; Lynch, 1987; McInnes and Hess, 1992), compared with an average intensification rate of 1 Bergeron for northern hemisphere "bombs" during the period September 1978-August 1979 (Sanders and Gyakum, 1980).

2.2. *Coastal conditions during the August 1990 east-coast cyclone*

For the week ending 30 July 1990, the sea surface isotherm analysis, Fig. 1, obtained from Royal Australian Naval Laboratories (RANL),

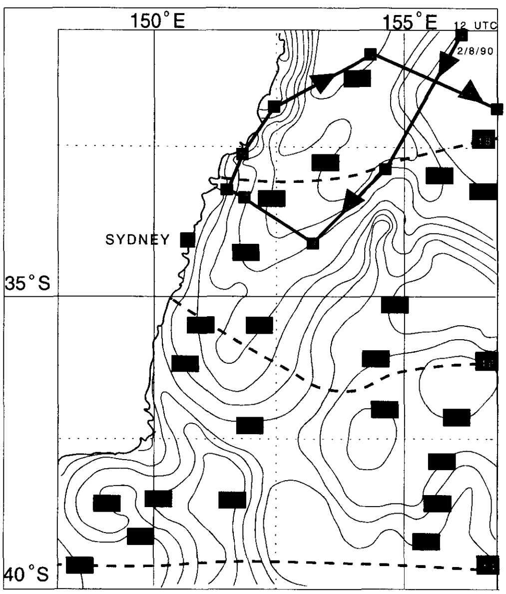

Fig. 1. Weekly RANL sea-surface isotherm analysis (solid thin line), valid 30 July 1990. Units are °C with contours every °C. August 1990 monthly mean sea-surface temperatures used by RR are indicated by thick dashed lines, with contours every 2 °C. The track of the system (thick black line), beginning 12 UTC 2nd August 1990, shows 3-hourly positions of the cyclone, analysed from MSLP charts obtained from the Sydney Regional Forecast Centre. A minimum central pressure of 986 hPa was reached at 02 UTC 3 August 1990.

demonstrates the presence of considerable zonal SST gradients over the region where intensification of the system occurred. Assuming that this SST analysis does not alter significantly during the following 3 days, station observations over land, taken at 21 UTC (7.00am LST) 2nd August 1990, suggest a 21(17)°C zonal surface temperature difference at 31(34)°S, between 149–154°E. There is a marked contrast between the structure of the RANL SST and the August 1990 monthly mean SST (thick black dashed line Fig. 1) as used by RR. Not only are the monthly mean isotherms primarily zonal and lacking in detail, they also are up to 4°C cooler than the RANL isotherms. The magnitude and gradient of sea-surface temperatures has a significant impact upon surface sensible and latent heat fluxes. The use of a monthly mean SST casts some doubt over the validity of using the derived surface trajectories, heat and moisture fluxes (RR Figs. 11, 12; Table 2) in assessing the role of surface fluxes in the development of August 1990 storm.

In terms of baroclinic instability and potential vorticity, the RANL isotherms (Fig. 1) demonstrate a localised east (warm)-west (cool) coastal temperature gradient, that will further reduce the static stability over the coastal ocean in a moist environment and hence reduce the Rossby radius of deformation $L_R \approx NH/f$, where N is a measure of the static stability of the atmosphere, f, the coriolis parameter and H is horizontal separation between upper and lower potential vorticity anomalies. This relationship by definition assumes significant coupling between the buoyancy and vertical motion fields. Further reduction of the length scale L_R, may occur due to a significant dip in the tropopause, displayed in RR Fig. 15, which effectively decreases the distance between upper and lower PV anomalies. It is not inconceivable that some form of localised baroclinicity may play a role in the development of the cyclone, with the upper level PV anomaly lying more to the north (RR Figs. 7, 16), of the localised zonal surface temperature gradient.

2.3. *The effect of real time SST's on numerical simulations of Australian east-coast cyclones*

Case studies of rapidly intensifying east-coast cyclones in July 1984 (Leslie et al., 1987) and August 1986 (Lynch, 1987) show that, even at

150 km resolution, the use of actual SST produces a significantly lower 24-h forecast central pressure of the system. Like the east-coast cyclone studied by RR, the real time SST for these case studies, display the presence of a strong zonal SST gradient in the vicinity of the intensification. The effect of this SST structure is: (i) the low-level easterly flow is curved cyclonically (Fandry and Leslie, 1984); (ii) the warm SST anomaly acts as an additional source of sensible and latent heat (Lynch, 1987). It should be noted, however, the effect of a positive sensible heat flux anomaly may aid or dampen the development of the storm, dependent upon the relative position of the anomaly to the storm (Nuss, 1989).

McInnes et al. (1992), demonstrated that introducing a warm SST anomaly upon the climatological SST fields, and thereby enhancing the land-sea surface temperature difference, resulted in deeper central pressures in 4 numerically simulated east-coast cyclones. In one case study, May 1990, the effect of enhanced SST resulted in an additional 7 hPa central pressure drop over a 24-h forecast period.

3. Conclusion

RR addresses the importance of latent heating in the rapid development of the August 1990 east-coast cyclone. Whilst we agree that latent heating is important in the development of the system, the omission of a more accurate SST in the high-resolution numerical simulation gives misleading results in terms of surface heat and moisture fluxes. Observations suggest that rapid coastal cyclogenesis is associated with warm ocean eddies and strong zonal SST gradients along the east coast of Australia. These localised gradients appear to play an important role in preconditioning the environment for the development and intensification of east-coast cyclones. Previous numerical studies of east-coast cyclones have shown significant sensitivity to real time SSTs, which are poorly resolved at coarse resolution. The addition of a real time SST to RR simulation of the August 1990 east-coast cyclone at higher resolution would be of value in gaining a more complete understanding of the life cycle of this system.

REFERENCES

Andrews, J. C. 1979. *Eddy structure and the West and East Australian Currents.* Flinders Institute for Atmospheric and Marine Sciences Research Report. The Flinders University of South Australia.

Fandry, C. B. and Leslie, L. M. 1984. A two-layer quasi-geostrophic model of summer trough formation in the Australian subtropical easterlies. *J. Atmos. Sci.* **41**, 807–818.

Harmon, B. V. 1961. The structure of the East Australian Current. Division of Fisheries and Oceanography, Technical paper no. 11. Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia.

Holland G. J., Lynch, A. H. and Leslie, L. M. 1987. Australian East-Coast Cyclones. Part I: Synoptic overview and case study. *Mon. Wea. Rev.* **115**, 3024–3036.

Hopkins, L. C. and Holland, G. J. 1997. Australian heavy-rain days and associated east-coast cyclones: 1958–1992. *J. Climate*, in press.

Leslie, L. M., Holland, G. J. and Lynch, A. H. 1987. Australian east-coast cyclones. Part II: Numerical modelling study. *Mon. Wea. Rev.* **115**, 3037–3053.

Lynch, A. H. 1987. Australian east-coast cyclones III: case study of the storm of August 1986. *Aust. Meteor. Mag.* **35**, 163–170.

McInnes, K. L. and Hess, G. D. 1992. Modifications to the Australian regional limited area model and their impact on an east coast low event. *Aust. Meteor. Mag.* **40**, 21–31.

McInnes, K. L., Leslie, L. M. and McBride, J. L. 1992. Numerical simulation of cut-off lows on the Australian east coast: Sensitivity to sea-surface temperature. *Int. J. Climatol.* **12**, 783–795.

Nuss, W. A. 1989. Air-sea interaction influences on the structure and intensification of an idealized marine cyclone. *Mon. Wea. Rev.* **117**, 351–369.

Revell, M. J. and Ridley, R. N. 1995. The origin and evolution of low-level potential vorticity anomalies during a case of Tasman Sea cyclogenesis. *Tellus* **47A**, 779–796.

Sanders, F. and Gyakum, J. R. 1980. Synoptic-dynamic climatology of the "Bomb". *Mon. Wea. Rev.* **108**, 1589–1606.