Kurnell Storm (2015) simulations with high resolution UM

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1. Introduction

On 15th December 2015, the intense storm cell that originated around 35S on the coast, to the north of Sydney, approached Kurnell. This storm, now known as the Kurnell storm, induced local severe wind damage and flooding. The storm moved along the coastline northwards, undergoing further intensification and reached its maximum rainfall and rotating wind intensity around 23:30 UTC when it was passing Kurnell (Fig.1).

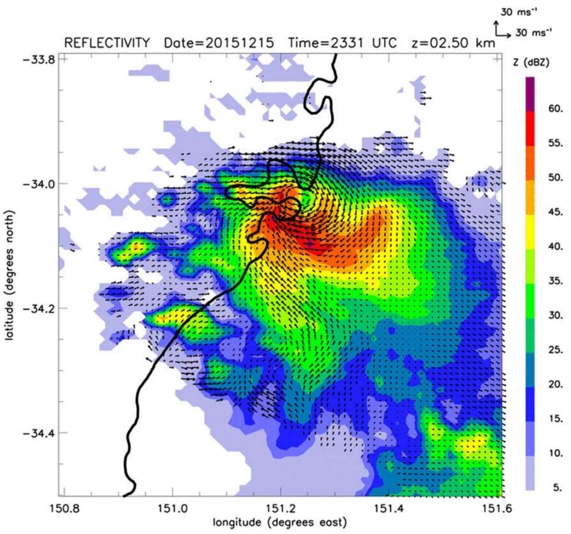


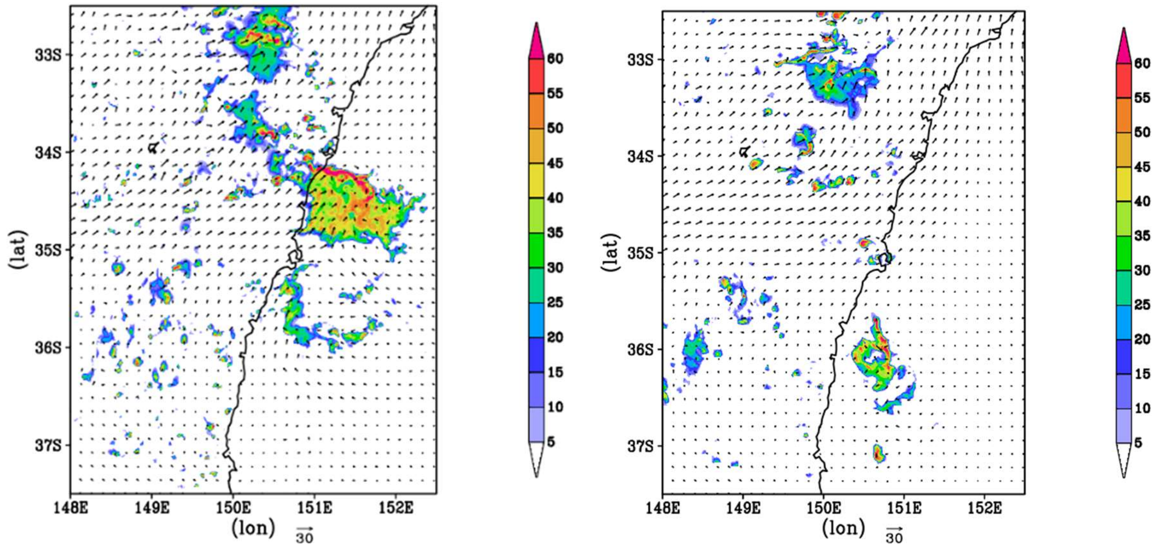
Fig.1 *Observed Radar reflectivity (colours, unit: dBZ) and horizontal winds (arrows, unit: m/s) at 2.5km at 23:31UTC 15 Dec 2015.*

2. Results

The forecasts were carried out using the Regional Atmosphere and Land (RAL) configurations of the Unified Model (UM) developed at the UK Meteorological Office (Bush et. al 2019). The model integrated for 24h with the initial conditions downscaled from the Bureau's global NWP model (ACCESS-G) with a basetime of 15 UTC on 15 December 2015. The model horizontal grid spacing was 1.5 km and there are 90 vertical levels with the highest resolution in the boundary layer. The simulations were using the physics configuration for the middle latitude (RAL2M), and the Tropics (RAL2T). The main differences between RAL2M and RAL2T configurations are the cloud scheme and the boundary layer scheme. We also compared the 1.5 km simulations with additional simulations using a higher horizontal grid spacing of 500m.

Our results showed that the RAL2M model simulation (Fig.2a) was the better simulation in terms of storm track and storm timing. The simulation with RAL2M was able to simulate the rotating winds associated with the storm, which supplied the moisture to further promote the storm's development. The simulated storm reached its maximum rainfall intensity around Kurnell at 01 UTC, 16 Dec 2015, about one hour later than observed. The RAL2T simulations (Fig.2b) failed to produce the convective system along the coast. There was convection initiated at 36.2S close to the coast, but the convection dissipated quickly without further intensification. There were some patches of inland convection developing associated with a trough of low pressure as shown in the weather chart (not shown), which was consistent with the RAL2M experiment.

To understand which differences in model physics between RAL2T and RAL2M caused the different behaviour of convection shown in Fig.2, we carried out two additional RAL2M sensitivity experiments, in which the cloud scheme or the boundary layer scheme were taken from the RAL2T configuration, respectively. Using the boundary layer scheme of RAL2T, the model failed to produce an intensifying storm along the coastline, just like the RAL2T model simulation. This was mainly due to the enhanced mixing in RAL2T that can make it harder to develop the convection. Furthermore, in the RAL2M boundary layer scheme, temperature and moisture perturbations based on surface buoyance flux are included, which helped convection develop over the warm ocean. The RAL2M physics configuration uses a diagnostic cloud scheme, while the RAL2T physics package has a prognostic cloud scheme. Results showed that there was no substantial difference with the initial RAL2M simulation using the prognostic cloud scheme of RAL2T, indicating that the different cloud schemes between RAL2M and RAL2T didn't play an important role in the differences shown in Fig.2. In conclusion, these two experiments clearly demonstrated that the different behaviour observed in Fig.2 can be attributed predominantly to the different boundary layer schemes of the RAL2M and RAL2T configurations.



(a) (b)

Fig.2 *Same as Fig1, but for the model simulations with 1.5km horizontal resolution (a) using the RAL2M physics package; and (b) using the RAL2T physics package (at 01 UTC, 16 Dec 2015).*

We also conducted an experiment with the RAL2M configuration using a finer horizontal grid length of 500 m instead of 1500m (Fig.3). In this experiment, the simulated storm, in its mature stage, has developed a much stronger cyclonic rotation compared to Fig. 2a with higher wind speeds and higher radar reflectivities (about 12dBZ increase for the maximum), in better agreement with radar observations shown in Fig. 1. In this experiment, the storm reached its mature stage one hour later than that in the 1.5 km RAL2RAL2M simulation presumably due to the slower moving speed for the more intense storm.

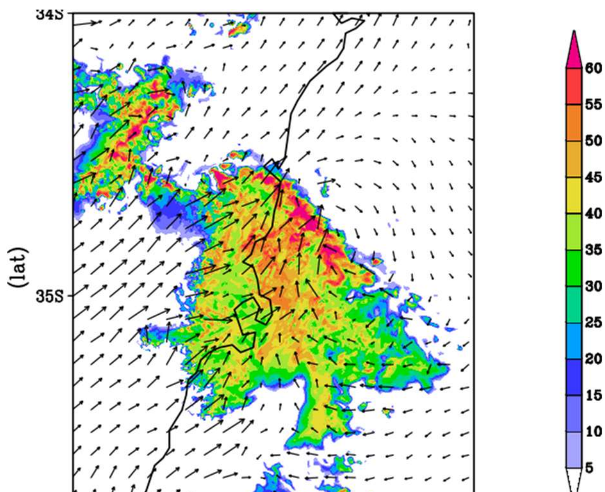


Fig.3*, Same as Fig.1, but for the model experiment using RAL2M physics with 500m horizontal resolution (at 02UTC 16 Dec 2015).*

3. Conclusion

In this study, using the high-resolution UM, we simulated the severe thunderstorm that occurred over the Kurnell peninsula near Sydney on the 15th December 2015. The results show that the model simulation using the middle latitude physics configuration was able to simulate the structure and location of the convective system developing along the coast. In this simulation, the storm also developed rotating winds as observed, which supplied the moisture to further promote the storm's development. In contrast, the simulation with the Tropical configuration failed to simulate the developing convective storm along the coast mainly due to the different boundary layer scheme. Model simulations with 500m resolution further improved the rotating structure of cloud bands but had a tendency to over-estimate the frequency of occurrence of intense rainfall within the storm (not shown).

4. References

Bush, M., and co-authors, 2019: The first Met Office Unified Model/JULES Regional Atmosphere and Land configuration, RAL1, Geosci. Model Dev. Discuss. https://doi.org/10.5194/gmd-2019-130