Improving ACCESS-C convection settings

Hongyan Zhu and Gary Dietachmayer

December 2015
Enquiries should be addressed to:

Hongyan Zhu

Bureau of Meteorology
GPO Box 1289, Melbourne
Victoria 3001, Australia

Contact Email: h.zhu@bom.gov.au

Copyright and Disclaimer

© 2015 Bureau of Meteorology. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of the Bureau of Meteorology.

The Bureau of Meteorology advise that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law and the Bureau of Meteorology (including each of its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.
Contents

1. Introduction .......................................................................................................... 1
2. Convection scheme in ACCESS-C ................................................................. 1
3. Results: ................................................................................................................. 2
4. Conclusion: .......................................................................................................... 6
Acknowledgements: ..................................................................................................... 6
5. Reference: ............................................................................................................ 6
List of Figures

Fig. 1  (a) The model forecast of rainfall rate (mm/day) on July-3, 2013. (b) the satellite image. ..........................................................

Fig. 2  The rainfall rate (mm/day) from (a) the large scale rainfall rates; (b) the convective rainfall rates in the control forecast.................................

Fig. 3  The model forecast of rainfall rate (mm/day) on July-3, 2013 in the sensitivity experiment, which uses the new time scale for the CAPE closure. ..........................

Fig. 4  For the sensitivity experiment: the rainfall rate (mm/day) from (a) the large scale rainfall rates; (b) the convective rainfall rates. ........................................

Fig. 5  For the sensitivity experiment with 3m/s vertical velocity threshold: the rainfall rate (mm/day) from (a) the large scale rainfall rates and (b) the convective rainfall rates. ....
1. INTRODUCTION

The Australian Community Climate and Earth System Simulator (ACCESS, Puri et al. 2010) is a fully coupled earth system model (ESM) being jointly developed by the Bureau of Meteorology and CSIRO.

ACCESS City model (ACCESS-C) uses the ACCESS atmospheric model with 4km resolution to forecast for city-based regions in Australia. In this model, the vertical velocity (W)-based CAPE closure is chosen for model stability (avoidance of grid point storms) for the forecasts in the Brisbane region where intense deep tropical convection often occurs along the coast line. In this closure, a vertical velocity threshold of 1 m/s is set. When the vertical velocity exceeds the threshold, the time scale for the CAPE closure is reduced to one third of the default value, and as a result, the parameterized convection scheme is more efficient in reducing the convective instability and the chances of a grid point storm.

Using the same W-based CAPE closure, the ACCESS-C model has failed to produce a rainband propagating over Tasmania for the 03-July-2013 forecast. The reason is that the parameterized convection has reduced the convective instability too much, and consequently the convection dies out before reaching the Tasmania west coast. In this work, we will re-visit the CAPE closure in the ACCESS-C model to find new settings, which will be more suitable for both areas, Queensland and Tasmania.

2. CONVECTION SCHEME IN ACCESS-C

The model uses a modified mass flux scheme based on Gregory and Rowntree (1990). The convective diagnosis is based on an undiluted parcel ascent from the near surface. The convective diagnosis is used to determine whether convection is possible from the boundary layer and, if so, whether the convection is deep or shallow depending on the level of the cloud top. The mid-level convection scheme operates on any instability found in a column above the top of the deep/shallow convection or above the boundary layer in columns where the surface layer is stable.

For deep convection, the cloud-base mass-flux is calculated based on the reduction to zero of Convective Available Potential Energy (CAPE) over a given timescale.
\[ M = \frac{CAPE}{\tau} \]  \hspace{1cm} (1)

By increasing / decreasing the time scale for the CAPE closure, the efficiency of convection will decrease/ increase.

\[ W \text{ based CAPE closure is the option used in ACCESS-C to try to avoid model instability (grid point storms). In this scheme, if the maximum large-scale vertical velocity in the grid-box, evaluated before convection, is larger than the threshold vertical velocity, the timescale to remove convective instability is reduced to remove the convective instability faster.} \]

The closure usually recommended for use at 4km is the grid-box area scaled CAPE closure. In Grid-box area scaled CAPE closure, the CAPE timescale used is given by

\[ \tau = \tau_{CAPE} \frac{CAPE}{CAPE_{min}} + \tau_{CAPE} \exp\left(-\frac{CAPE}{CAPE_{min}}\right) \]  \hspace{1cm} (2)

where \( CAPE_{min} \) is the minimum value of CAPE (usually set to 0.5 J/kg for 4km). \( \tau_{CAPE} \) is the reference CAPE timescale. All convective ascents with CAPE greater than the minimum value have CAPE timescales greatly increased. In this way, the time scale to release the convective instability is larger than the reference value so that the convection is mainly solved on the grid scale, and convective increments from the parameterized convection are usually small compared to the large-scale convection.

To avoid grid-point storms when using the default setting for CAPE closure in the 4km ACCESS-C model, the grid-box area based CAPE closure is modified to include a vertical velocity threshold for the CAPE releasing time scale, in which if the vertical velocity is larger than the threshold in the case of strong local convection, the time scale will be reduced to rapidly release the local convective instability. In the rest situations, the time scale of CAPE closure is large to limit the role of parameterised convection.

3. RESULTS:

The problematic case forecast for the Tasmania region was on July-3, 2013. Fig.1a shows the forecast from the ACCESS-C model and Fig.1b is the satellite image of the same time. The image shows that the rainband has propagated through the West coast of Tasmania to the inland...
region. In contrast the ACCESS-C forecast the rainband was mainly located to the west of the coast line and there was no rainfall being propagated into the inland region in the composite radar image.

Figure 2 a and b are the forecast rainfall rates from the large scale rainfall and convective rainfall, respectively for the same forecast time. The rainfall rate from the ACCESS-C model indicates the forecasted rainfall in ACCESS-C model is mainly from convective parameterized rainfall and the large scale rainfall rates are almost negligible. In this forecast, using the W-based convection scheme, the parameterized convection is playing a dominant role in releasing the convective instability, so the convective instability has been reduced before the large scale rain is triggered prior to reaching the west coast.

Fig. 2 The rainfall rate (mm/day) from (a) the large scale rainfall rates; (b) the convective rainfall rates in the control forecast.
Following the discussion in Section 2, we have performed a sensitivity experiment, in which we adopt the default setting of CAPE closure time scale, which is the grid-box area dependent CAPE closure, in the convection scheme. This scheme has been modified to include the W-velocity threshold to reduce the grid point storm when intense local convection exists. With this setting, the CAPE time scale is large to limit the role of parameterization convection scheme for the higher resolution model simulation unless there is intense local convection at the grid point. In the presence of intense local convection, if the vertical velocity is larger than the threshold of 1m/s, the time scale of the CAPE closure is reduced to allow the parameterized convection dominate the moist process.

The result of the sensitivity experiment is shown Fig. 3. Different from the control experiment, the rainfall band is able to cross the west coast of Tasmania and rains develop over the western part of the inland. In this simulation, the distribution of rainfall is more comparable to those suggested from the radar observation.

![The model forecast of rainfall rate (mm/day) on July-3, 2013 in the sensitivity experiment, which uses the new time scale for the CAPE closure.](image)

Fig. 3  The model forecast of rainfall rate (mm/day) on July-3, 2013 in the sensitivity experiment, which uses the new time scale for the CAPE closure.

Similar to Fig. 2, Figure 4 a and b are the plots for the rainfall rates of the large scale precipitation and convective precipitation in the sensitivity experiment. With the new CAPE closure, the large scale rainfall rates have been largely increased compared to the control experiment, and the inland precipitation is mainly from the large scale process. Another improvement of the new experiment is that the convective rainfall along the west and south domain edge has disappeared in Fig. 3 and Fig.4.
To test the sensitivity of convective precipitation to the vertical velocity threshold, we also conducted the experiment with 3m/s vertical velocity threshold.

Increasing vertical velocity to 3m/s, the W-based CAPE closure is hardly switched on, and as a result, the grid-area based CAPE closure is dominating for the most grid points. The convective precipitation in Fig. 5b shows that the rainfall produced by convective parametrization scheme become ignorable comparing to those produced by the large scale precipitation rate (Fig. 5a). These sensitivity further prove that using the grid-area based convection CAPE closure
including the vertical velocity threshold does have a control on the intensity of the convection in the case of the stronger local convection.

4. CONCLUSION:

Using W-based CAPE closure caused a reduction of rainfall forecasts in the Tasmania region due to the fact that the parameterized convection was taking a leading role in reducing the convective instability, and as a result there was no grid-scale convection over the land. W-based CAPE closure is designed to avoid grid point storms in regions of intense convection. To find a common setting which is suitable for both rainfall forecast of the Tropics and the middle latitudes, we choose to use the grid-box dependent CAPE closure, in which the W-based convection setting is only limited to the regions with local intense convection.

With the new CAPE closure setting, the role of the large scale moisture process has been largely increased and the rainfall band is able to propagate inland to the west part of the Tasmania Island.

The new closure can also inhibit the development of grid point storms during intense convection events in the Tropics. For the simulation with vertical velocity bigger than the threshold, the CAPE time scale will be largely reduced to remove the convective instability, and the intensity of convection. This study recommends that the modified grid-box dependent CAPE closure, which includes the vertical velocity threshold, is suitable for the 4km resolution ACCESS-C model.

ACKNOWLEDGEMENTS:

We thank Dr. Lawrie Rikus, Dr. Noel Davidson and Dr. Chris Tingwell for the constructive comments on the earlier version of this work. We thank Wenming Lu for IT support on this matter.

5. REFERENCE:

