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Tests of the closure for the CoMorph cumulus parameterization

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Overview

CoMorph [1] is a new mass-flux cumulus parameterization scheme for use the UK Met Office Unified Model (UM). It performs well in global model tests, with promising coupling to the large-scale circulation improving the development of emergent features such as the MJO. Here we focus on its closure formulation by comparing against a traditional CAPE closure with fixed closure timescale using some idealized test cases.

The CoMorph closure

- Mass flux can be initiated from any height depending on local instability (moist instability if there are pre-existing clouds)
- **No closure rescaling**: intermittency is avoided by using implicit-in-time discretization for initiating mass and detrainment
- Ensures that the convection cannot remove more buoyant instability in one timestep than is actually present in each layer

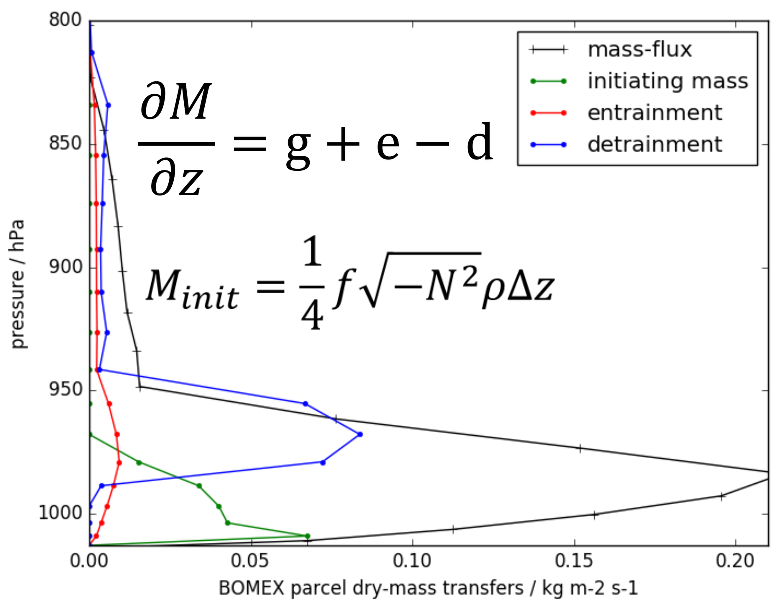


Fig. 1 Example of initiating mass flux profile for a BOMEX sounding.

Test Case 1: DGW coupling with changing forcing

RCE state coupled to a large-scale circulation derived from the damped-gravity wave (DGW) approach, <50 days. Then with additionally imposed moistening, on days 50-100, and additionally imposed destabilization, on days 100+. [2]

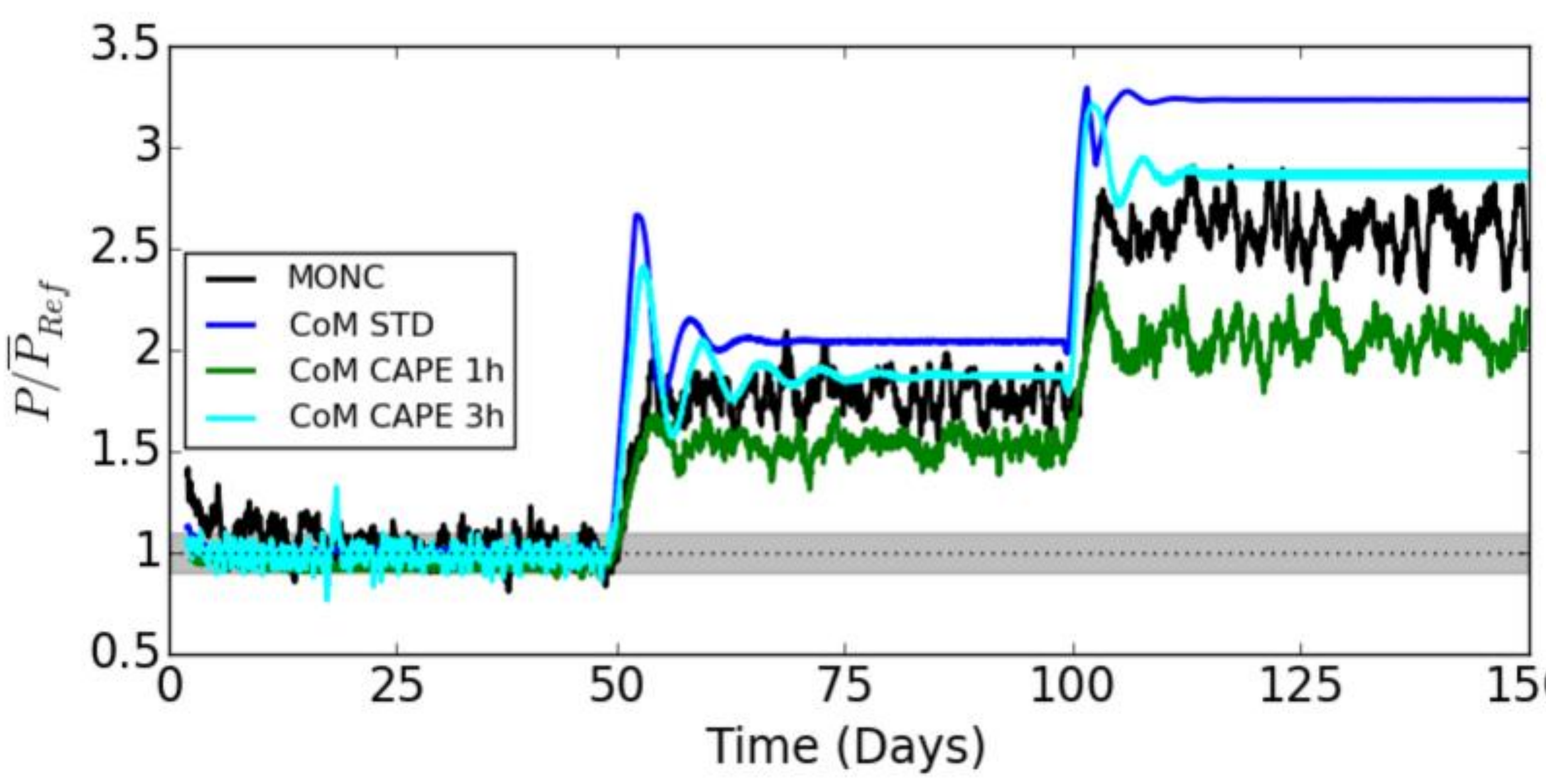
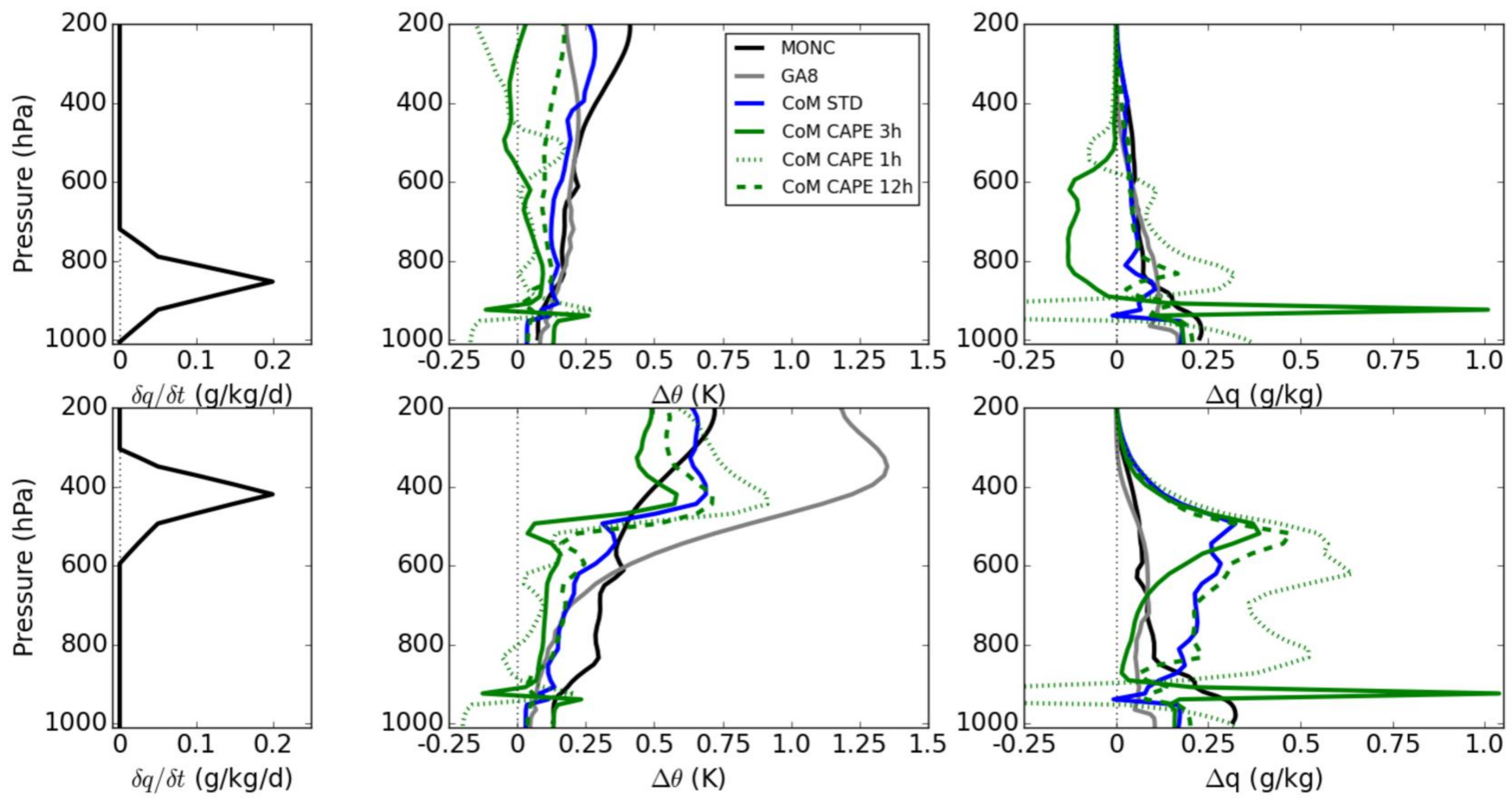


Fig. 2 Precipitation timeseries, normalized to RCE value. CoMorph in single-column mode. MONC is a large-eddy code used at $\Delta x = 1$km.

CoMorph is more sensitive to the additional forcing than MONC. Can get similar results from CAPE closure with ~3h timescale. A longer CAPE timescale (not shown) gives excessive precipitation after >100 days.

Test Case 2: Response to perturbation forcing

RCE state with additional vertically-localised forcings, as in [3].



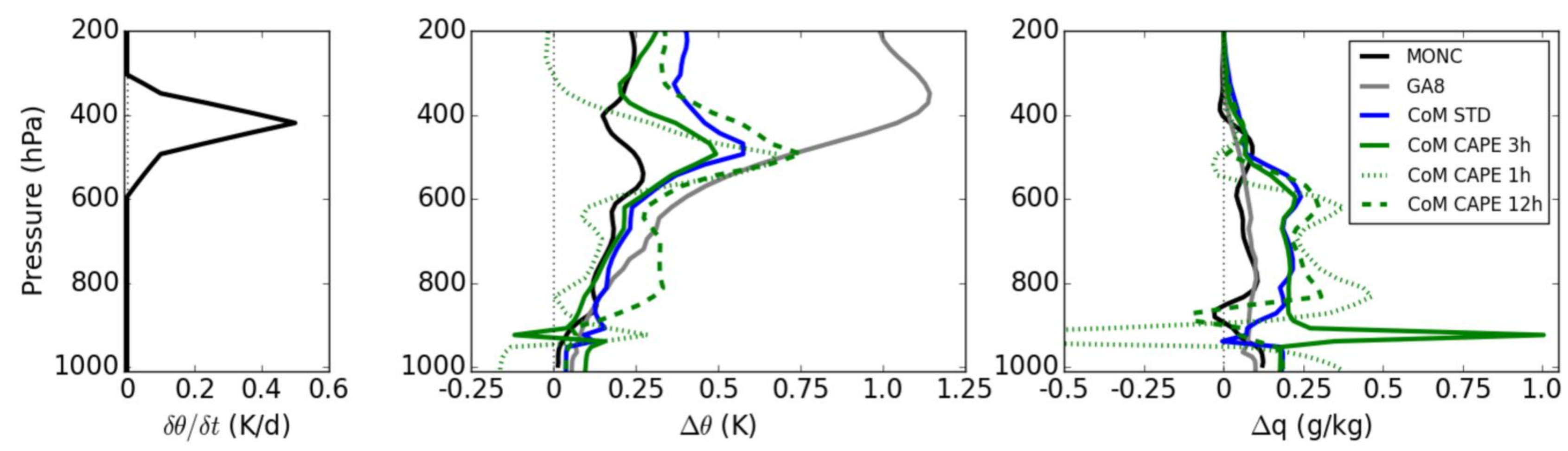


Fig. 3 Change to RCE state induced by additional forcing (left column). CoMorph in single-column mode. GA8 is the previous convection scheme. MONC is used at $\Delta x = 1$km.

Previous UM scheme, GA8, is too top heavy. CAPE closure produces large changes near cloud base. CoMorph is most similar to CAPE closure if using a long timescale (12h for a moistening perturbation, 3h for heating).

Test Case 3: Memory in an idealized diurnal cycle

An idealized diurnal cycle with rapid onset of deep convection, as in [4].

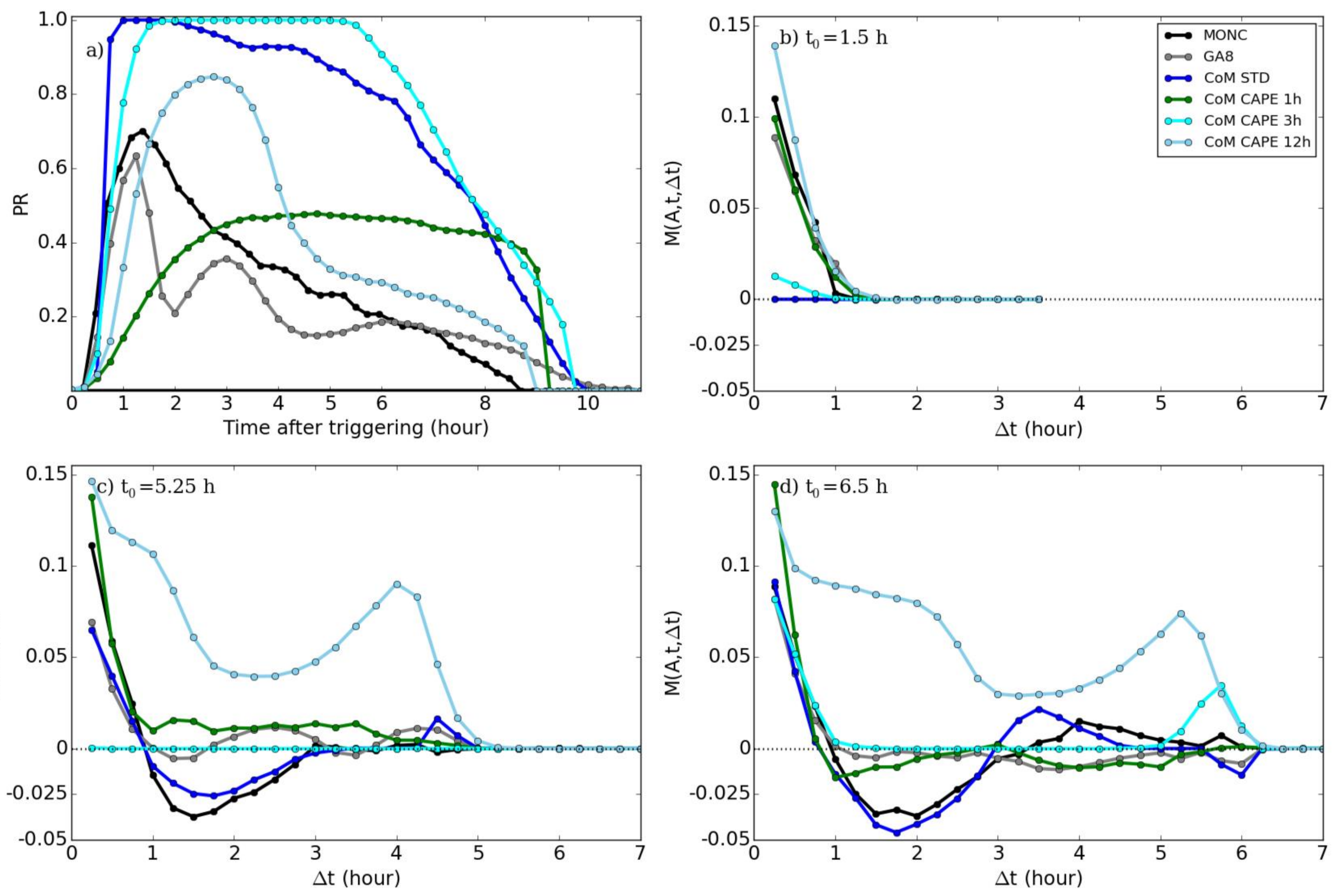


Fig. 4 Memory functions for times after onset = probability of rain at both times t_0 and $t_0 - \Delta t$, referenced to probability of random occurrence. UM with Δx=10km and MONC with Δx=200m.

CoMorph initially rains everywhere in the domain, but later develops finite duration of rain events, followed by local suppression, in good agreement with MONC. The current UM scheme, or CoMorph with a CAPE closure fails to capture the suppression phase. A long CAPE timescale (12h) can give far too much memory.

Conclusions

- CoMorph considers *initiation of convective mass-flux level-by-level*
- It has a *smooth evolution* without timestep level noise
- It does not perform a closure rescaling but we can add one to replicate the behaviour of a traditional CAPE closure
- In a range of idealised tests, the CoMorph closure often behaves similarly to a CAPE closure with a relatively long timescale. Such timescales would not be practical for use in traditional schemes without the smooth evolution
- The corresponding timescale would have to be highly case dependent to replicate CoMorph, and the long timescales implied would be problematic for other cases

References

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This work has been funded by the ParaCon programme, with use of Monsoon2 for high-performance computing.

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