Towards making Comorph scale-aware

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Introduction

CoMorph is a new convection scheme that has so far been targetting global scales. The first release was CoMorph-A, which improved coupling to dynamics, and gave better SW and LW radiative properties. Here we show work towards enabling scale-aware behaviour so that it performs well at km scales. We focus on two flavours of CoMorph:

TrailBlazer: Comorph-A tuned for better performance in planned 5km resolution quasi-operational global simulations.

CoMorph-B aims to improve on the diurnal cycle of CoMorph-A, while retaining its beneficial features (still being finalised).

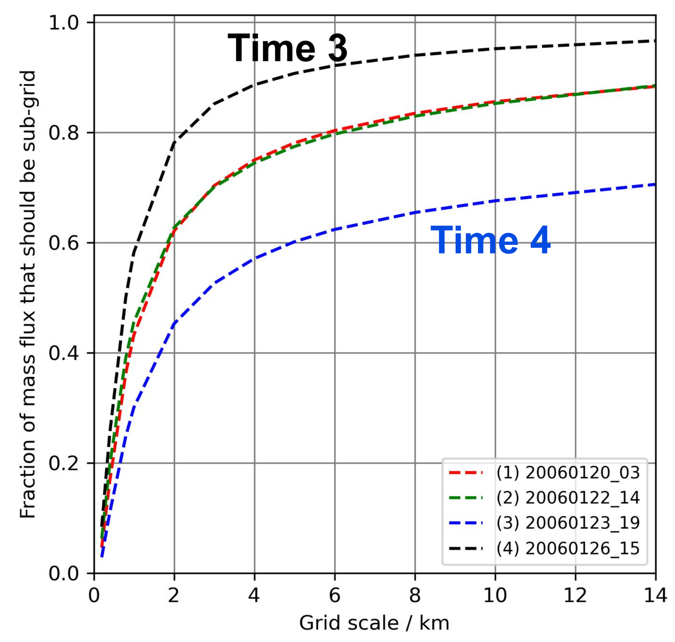
This study uses 16-day idealised UM simulations of the TWPICE case around Darwin (Australia), initialised at midnight on 18 Jan 2006 on a 200km x 200km domain.

Testing of Comorph was done at various resolutions across the convective grey zone (10km 1km).

A 100m resolution RAL3.1 simulation is treated as "truth", used for guiding Comorph scale-aware improvements.

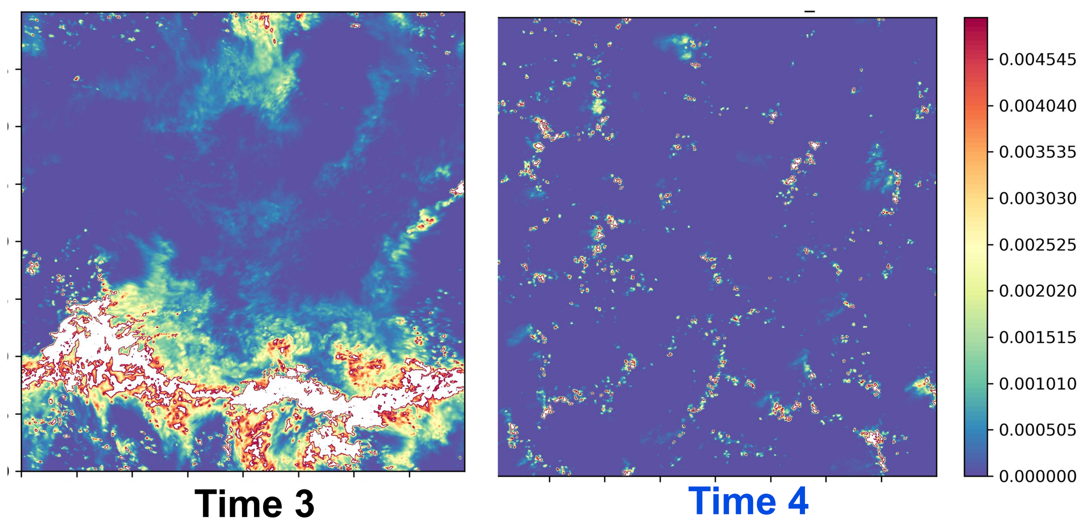
Fraction of the convective mass flux that should be sub-grid at coarse grid-spacing Δ

Estimated sub-grid W field by removing scales > Δ. Found ratio of the original updraft mass flux which is produced by this sub-grid field.



So far, we concentrated on 4 different times with different levels of large-scale convective organisation. Surface rain at the times with the least / most large-scale organisation are shown below.

Surface rain in 100m model at 2 of these times



Parcel radius precipitation ramp

Comorph entrainment dilution rate is proportional to 1/R (R = updraft radius). CoMorphA uses a single value of R → directly proportional to BL length scale L.

'**Parcel radius precip ramp**' is a simple representation of convective organisation when it has rained in the previous timestep. R is scaled by A, which linearly ramps from 0.45 to 2 as a function of normalized precipitation rate $\frac{p}{pmax}$

(pmax = precipitation rate leading to max updraft size in radius ramp)

Problem:

Radius-ramp increases R too rapidly at the onset of rain, more so at higher resolution as more intense local precipitation features become resolved.

So can we make pmax dependent on grid-spacing dx?

How entrainment should depend on precipitation as function of grid-spacing

Used instantaneous rain rates from 100m TWPICE simulations (every 20h).

Divided domain into 40km grid-boxes (typical of an NWP simulation). For each box, we calculated the area-averaged rainfall in concentric circles of increasing diameter away from the position of the maximum rainfall.

Plots show the ratio of this to the mean rainfall averaged over 40km diameter circle

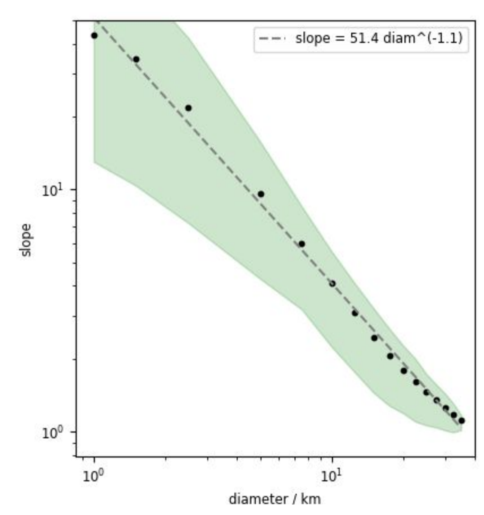
- Black dots - averages over all times and boxes.
- Green envelope - range of values

Linear relationship in log-log plot suggests an inverse relationship of pmax to dx.

So Pmax in the TrailBlazer radius ramp was made scale-aware:

$$pmax(dx) = \frac{pmax_{ref} * dxref}{MAX(dx,dy)},$$

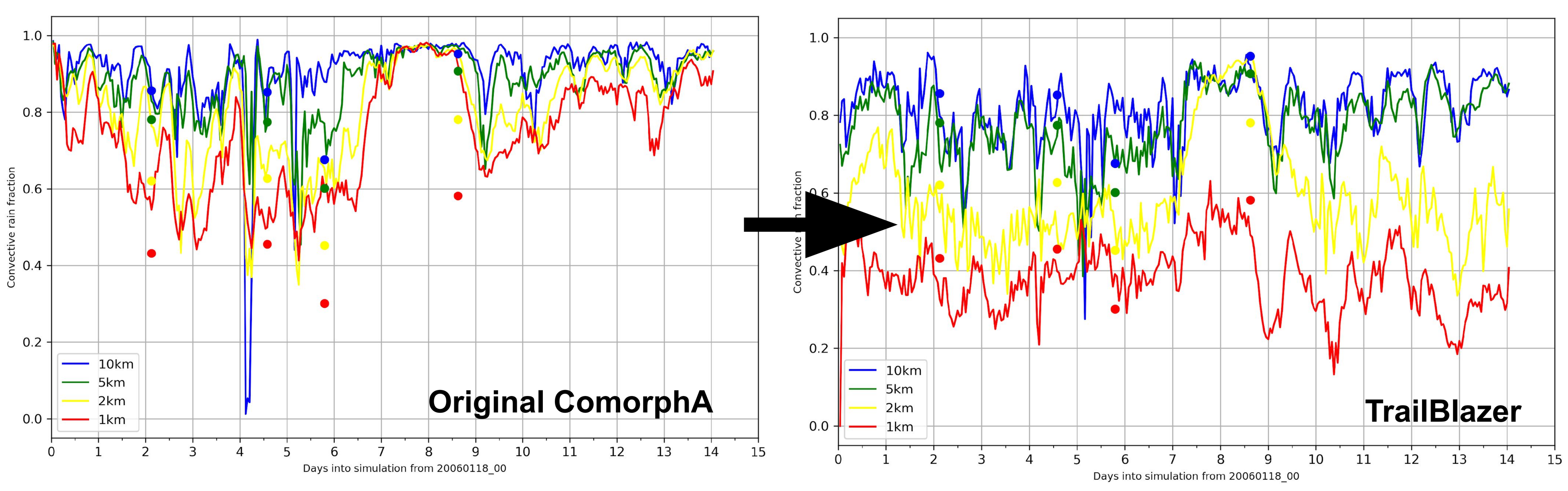
where dx_{ref} is a typical NWP grid-spacing (50km) for which pmax = $pmax_{ref}$



Fraction of surface rain produced by convection scheme

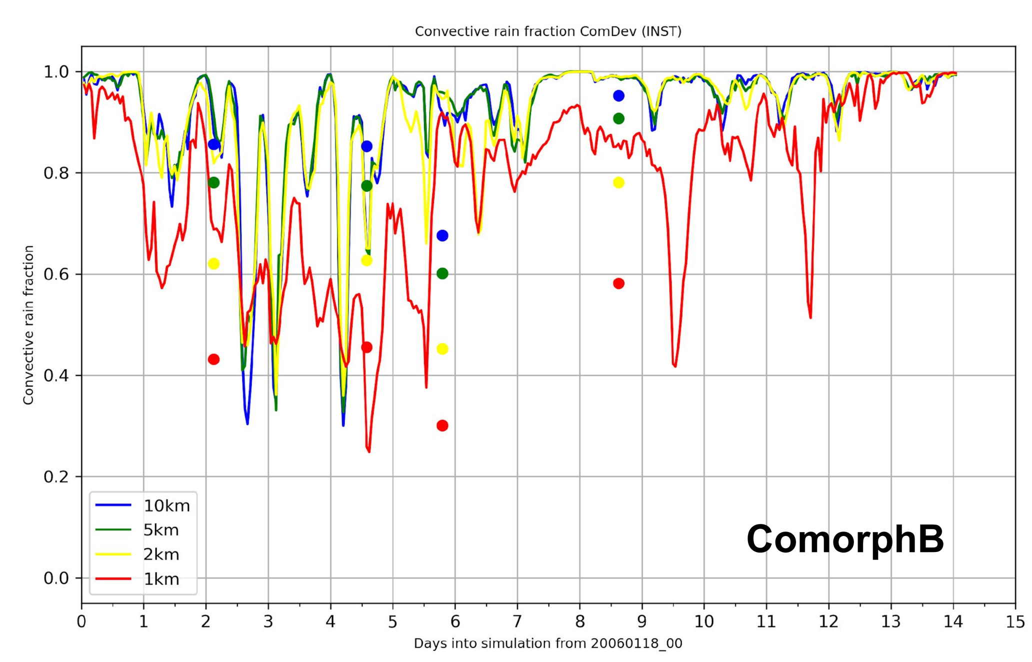
Dots are how much of the convection should be sub-grid at each resolution (colour) and time – read from top plot.

Scale aware behaviour was improved by the addition of the resolution-dependent radius ramp.



Now working on making ComorphB scale aware

We aim to turn down the initiating mass flux in a way that is guided by the 100m simulation as described below.



New method for scale analysis:

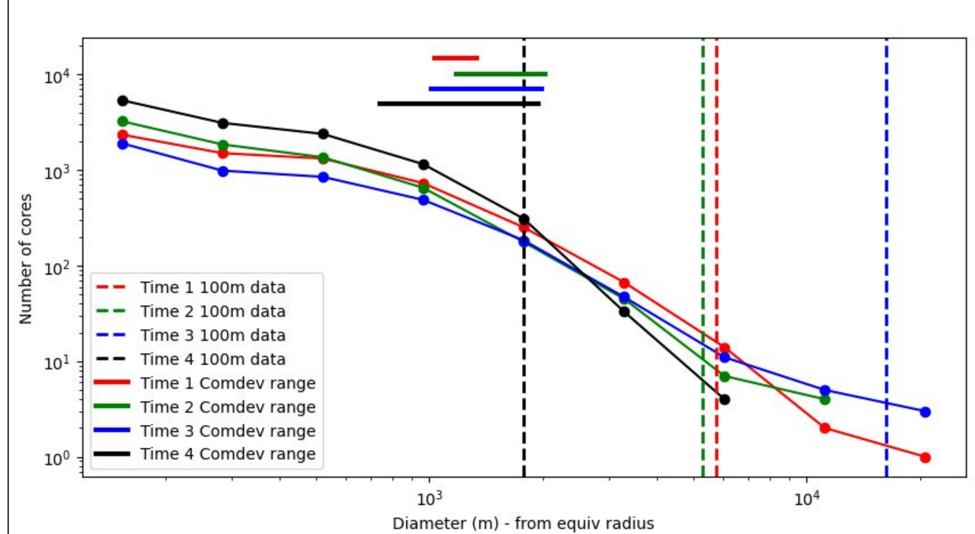
- Identify cores as W > 0.1 m/s and QL > 1e-4 kg/kg
- For each individual core calculate
  - Diameter of area-equivalent circle
  - Mass Flux (total W)

Then for the whole domain at each time, calculate:

- Lx = mass-flux-weighted-mean diameter

Core Size Distributions

The size distributions for the 4 times is shown below, along with the values of Lx (dashed vertical lines).

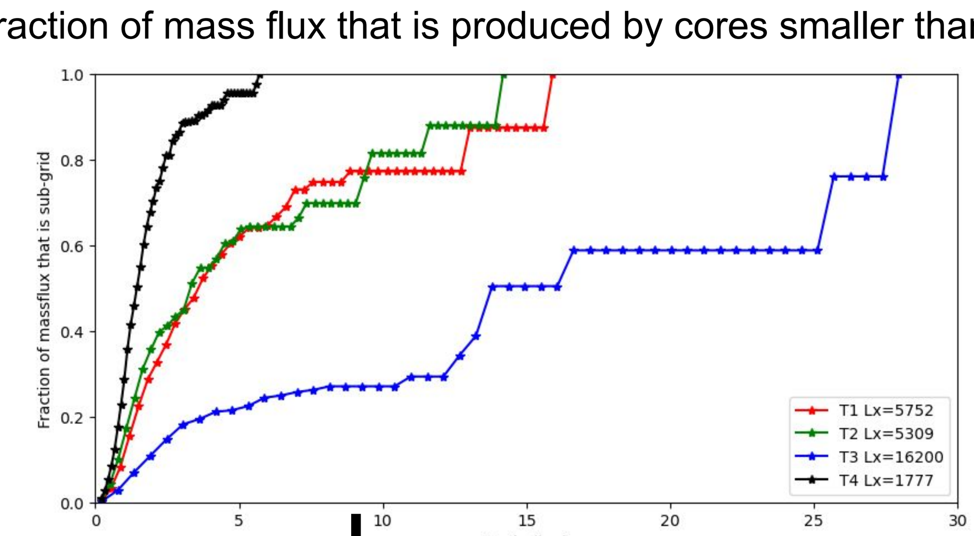


These are compared against the domain-averaged values predicted by ComorphB. The thick horizontal lines represent the range of values from the different resolution Comorph simulations (10,5,2,1km).

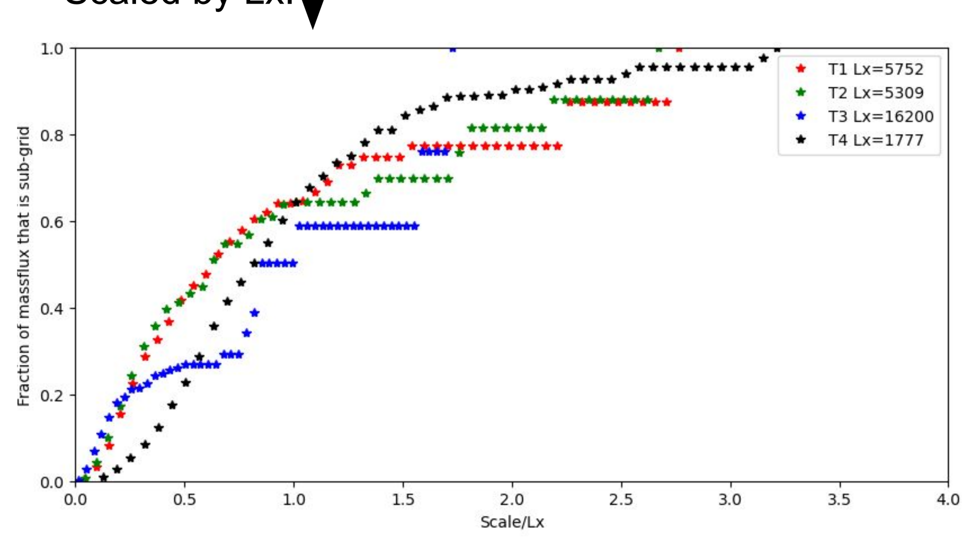
Work us ongoing to evaluate the discrepancies and improve the Comorph predicted values.

Proportion of mass flux that SHOULD be sub-grid

Fraction of mass flux that is produced by cores smaller than Δ



Scaled by Lx.



This preliminary scaling with Lx suggests the possibility of a single functional form. Working on the ComorphB code to insert this as a first step to turning it down at high resolution.

Conclusions

Analysed performance of different flavours of Comorph at horizontal resolutions across the convective grey-zone. Guided by analysis of 100m resolution "truth" simulations.

ComorphA TrailBlazer

- **I**nitially tuned specifically for use at 5km horizontal resolution.
- A scale-aware tuning has been added to the parcel radius precipitation ramp.
- This improved its performance at other resolutions and made it more scale-aware.

ComorphB (ComDev) – still in development

- Currently not particularly scale-aware.
- Plots of the fraction of mass flux that should be sub-grid fall onto common curve when the grid-length is scaled by the mass-flux-weighted mean updraft size Lx. Now working on ComorphB code to turn down the initial mass flux using a single function of (dx/Lx)
- Mass-flux-weighted mean updraft sizes predicted by ComorphB are currently not perfect. Work is ongoing evaluate these in a systematic manner.
- Additional work will focus on how to scale down the initial θv and RH perturbations used for updraft initial conditions.

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