Department of Meteorology

Environmental Controls on Convective-Scale Error Growth

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Summary

Flash flooding causes major damage in the UK and is mainly due to intense rainfall from convective events. These events can be broadly classified into two distinct regimes: convective quasi-equilibrium (CQE) and triggered (non-equilibrium) convection. These regimes could help to determine whether the implementation of fine-scale data assimilation techniques within convection-permitting models could improve the convection. To determine the convective regime a convective adjustment timescale can be used. It is shown that the convective adjustment timescale is sensitive to the calculation method; however, if a Gaussian kernel is used to average the precipitation accumulation and Convective Available Potential Energy (CAPE) a physically sensible timescale can be achieved.

Background

Convective Available Potential Energy (CAPE): The CAPE gives a measure of the energy that could be available for convective motion for a particular parcel. In this work, the CAPE has been calculated from the following equation, and the maximum taken after lifting over the first 5 pressure levels or 10 model levels in the North Atlantic European domain (NAE) and 20 model levels in the United Kingdom Variable resolution (UKV) models. Where R_d is the specific gas constant, and $T_{p/a}$ are parcel and ambient temperatures respectively.

$$CAPE = \int_{p_{LFC}}^{p_{LNB}} R_d \left(T_p - T_a\right) d\ln(p).$$

Convective Quasi-Equilibrium (CQE): In CQE the large scale production of CAPE balances its release at convective scales. The type of convection expected is scattered showers (Fig. 1b). The predictability is low in terms of location (Done et al., 2006) but high in terms of total precipitation (Keil et al., 2014).

Triggered Convection: In non-equilibrium (triggered) convection the CAPE builds up and is then released all at once. Events such as convection lines triggered by convergence (Fig. 1a) and supercells are expected to occur in this regime. The predictability for these events is high in terms of location (Done et al., 2006) but low in terms of total precipitation (Keil et al., 2014).

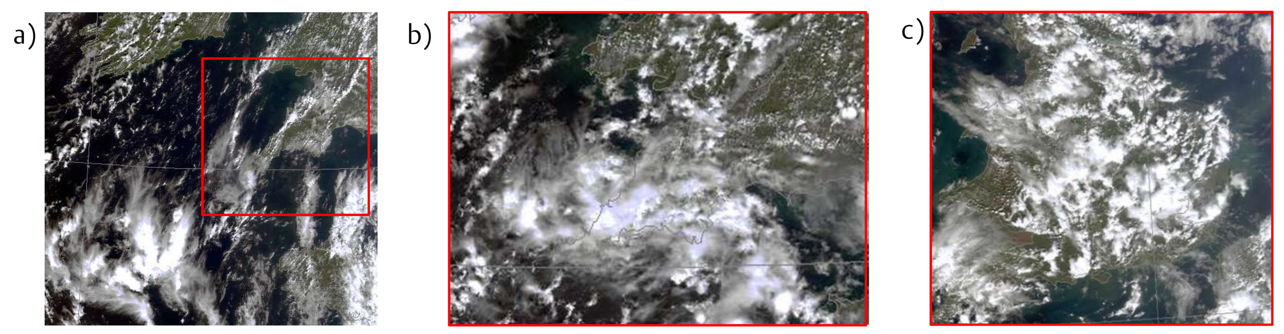

Fig. 1 a) a convergence line (non-equilibrium event) at 1348 UTC on 2 August 2013, b) a potentially marginal case at 1316 UTC on 28 July 2013 and c) scattered showers case on 20 April 2012 at 1328 UTC (Dundee Satellite Receiving Station, 2013). The red boxes on each of the plots show the domains used in Fig 2.

Convective Adjustment Timescale:

The convective adjustment timescale, τ_c, measures the ratio of the CAPE to the release of CAPE at the convective scales (Done et al., 2006):

$$\tau_c \sim \frac{CAPE}{\left|(dCAPE/dt)_{CS}\right|} = \frac{1}{2}\frac{c_p}{L_v}\frac{\rho_0 T_0}{g}\frac{CAPE}{P},$$

Where all symbols have their usual meteorological meanings and P represents the precipitation variable.

It can be used to distinguish between CQE and triggered convection using thresholds of τ_c. Non-equilibrium convection is likely to occur where $\tau_c > 12$ hrs, whereas CQE is likely to occur for $\tau_c < 3$ hrs (following Zimmer et al., 2011).

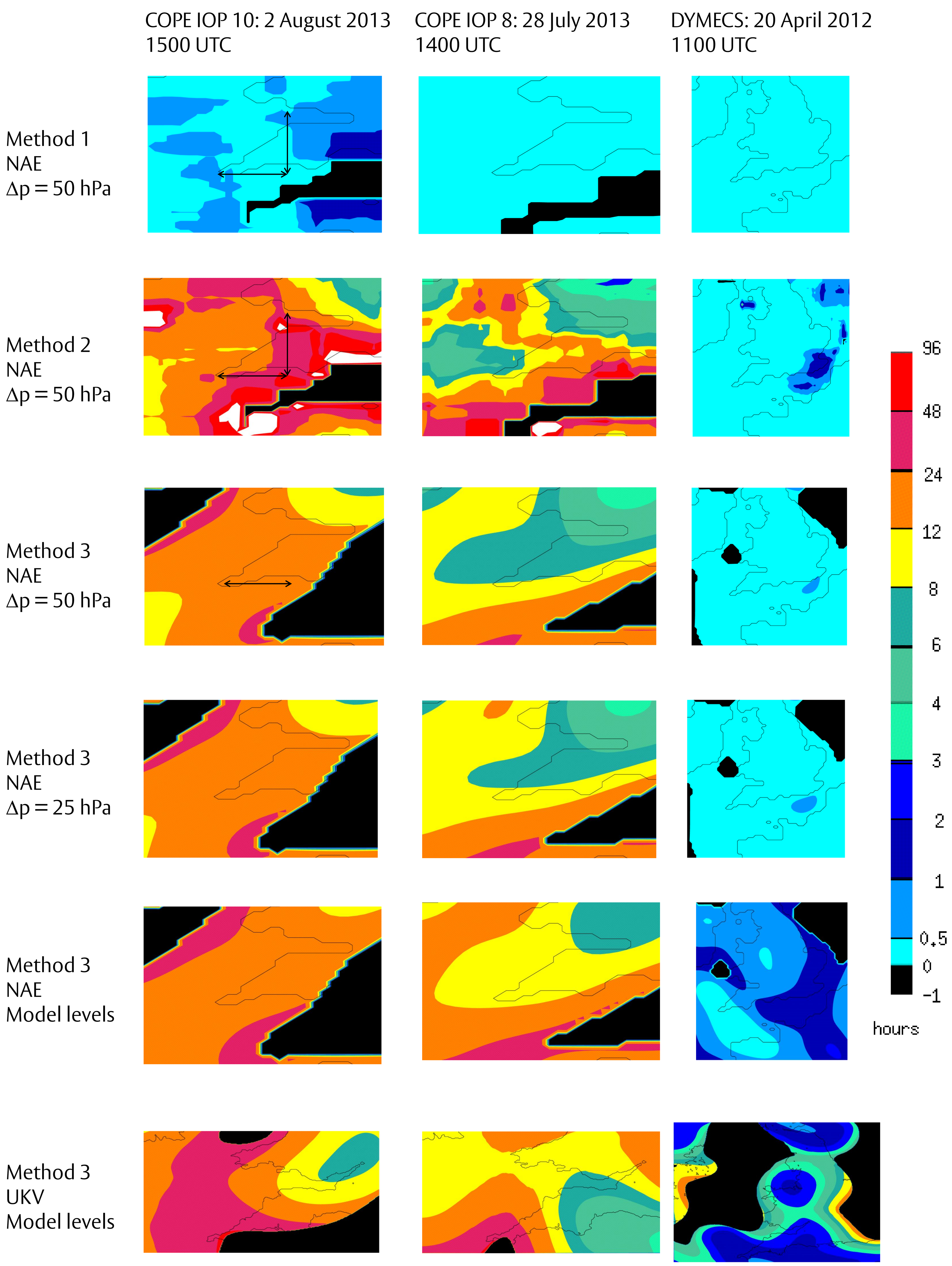

Figure 2: The convective adjustment timescale calculated using the methods above for all cases on a log colour scale, and from data on pressure levels with discretizations of 50- and 25- hPa, from model level data from the NAE and from model level data from the UKV. The arrows represent the distances of the averaging domain (Method 1 and 2) and the distance of 2 standard deviations of the Gaussian kernel (Method 3).

Project Aims

1. Explore the different definitions of and frequency of regime placement from a convective timescale (Done et al., 2006).
2. Explore convective-scale error growth for ensembles to assess the use of convective-scale data assimilation.
3. Assess hypothesis: 'A predicted convective timescale (and as such different convective regimes) can distinguish qualitatively-different convective-scale error growth.'

Work on the first aim is presented here.

Methods for Aim 1

1. Calculate grid-point τ_c, then average over points where τ_c is not infinite (following Molini et al., 2011).
2. Calculate a spatial average of CAPE and precipitation, then calculate τ_c (following Done et al., 2006).
3. Use a Gaussian kernel to average CAPE and precipitation, then calculate τ_c (based on Keil and Craig, 2011, etc.).

For these methods an area of 132 x 132 km^2 has been used for the averaging and a half-width of 60 km has been used for the Gaussian kernel (Fig. 2).

The data is from the NAE domain of the MetUM (Met Office Unified Model), interpolated onto pressure levels and model levels. The last row (Fig. 2) uses data from the UKV domain.

The Sensitivity of the Convective Adjustment Timescale

Using case studies from the Convective Precipitation Experiment (COPE) and Dynamical and Microphysical Evolution of Convective Storms (DYMECS) projects the timescale has been calculated using the methods described above (Fig. 2). The events show that the timescale does distinguish between different dynamical cases; however care needs to be taken when drawing comparisons with previously published results. However this could be dependent upon whether the timescale was calculated on a model using a convective scheme.

Discussion and Future Work

Although the timescale is sensitive to its calculation, it still gives useful results. The COPE IOP 10 case is a triggered event, IOP 8 is triggered with a large marginal region and the DYMECS case is in CQE. The method that gives the most representative results is method 3, calculated on model levels at UKV resolution.

Future Work:

- Calculate the timescale for at lest one summer over Cornwall.
- Use ensembles to determine the predictability of the events and look at the convective-scale error growth.

References

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