The Plant-Craig stochastic Convection scheme in MOGREPS

R. J. Keane [1] R. S. Plant [2] W. J. Tennant [3]

[1]Deutscher Wetterdienst

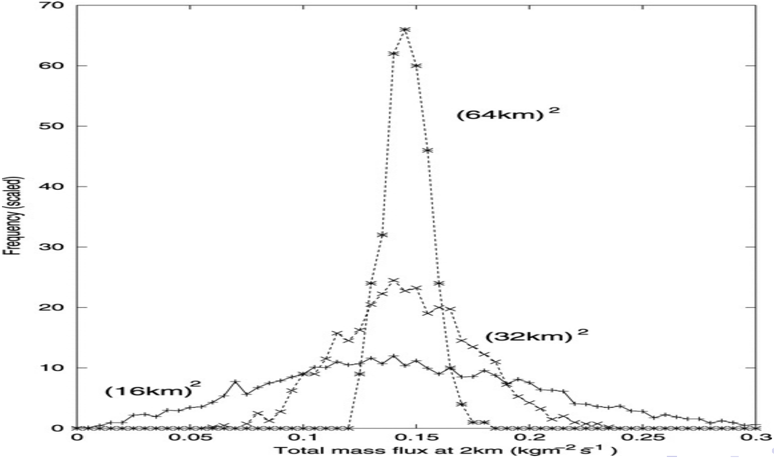
[2]University of Reading, UK

[3]UK Met Office

1. Overview
   - Motivation for using a stochastic convection scheme
   - How the scheme works
   - Overview of MOGREPS
2. General climatology and model performance
3. Detailed investigation of precipitation forecasts
   - Main results
   - Effects of removing forecasts with particularly low convective fraction
4. Conclusions

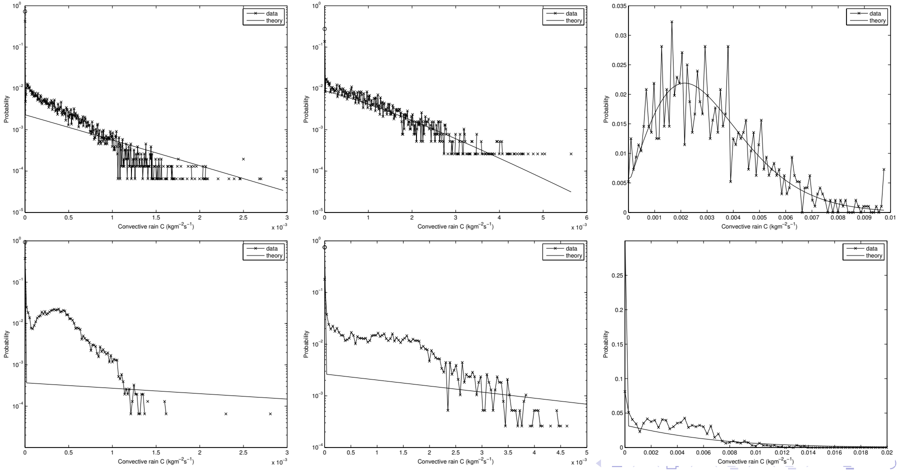
Variability of convective response to a given large-scale forcing (Convective Equilibrium Experiment)

Taken from Plant & Craig, JAS (2008): 2 km grid spacing; convective mass flux per unit area averaged over different parts of the domain, with sizes as shown.



Performance of the Plant-Craig scheme (top line) and the Gregory-Rowntree scheme (bottom line) against theory based on CRM results for a CEE.

Taken from Keane & Plant, QJRMetS (2012):



Overview of the Plant-Craig convection scheme methodology

From Craig & Cohen, JAS (2006), the distribution of mass flux per cloud m, given a mean $\langle m \rangle$, is

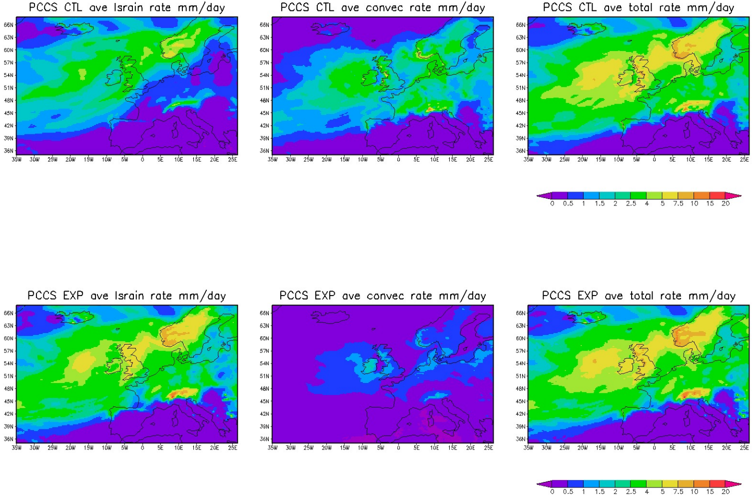
$$p(m)\mathrm{d}m = \frac{1}{\langle m \rangle}\mathrm{e}^{-m/\langle m \rangle}\mathrm{d}m \tag{1}$$

- The Kain-Fritsch trigger function is used, applied to the upper tail of this distribution, to determine whether or not to initiate convection.
- The large-scale state is obtained by averaging grid-scale flow variables in space (nearby grid boxes).
- The mean total mass flux $\langle M \rangle$ is obtained from a CAPE closure and used to scale the distribution above.
- This distribution is separated into discrete bins, and plumes are drawn at random to obtain the cumulus properties in the grid box.
- Tendencies of grid-scale variables are computed from the cumulus properties using the Kain-Fritsch plume function.

Met Office (Global and) Regional Ensemble Prediction System

- The setup described here is what was used in this study.
- 24 members, 24 km grid length.
- Domain over Europe and the North Atlantic.
- 2 forecasts per day, 10–31 July 2009 (34 forecasts in total); 54 hour lead time.
- MOGREPS forecasts with the Plant-Craig scheme ("EXP") are verified in comparison with the Gregory-Rowntree scheme ("CTL").
- The forecasts are evaluated over the whole domain using the standard MOGREPS verification package, for general surface variables.
- Rainfall over the UK is investigated in more detail using NIMROD data.

Climatology of the MOGREPS runs



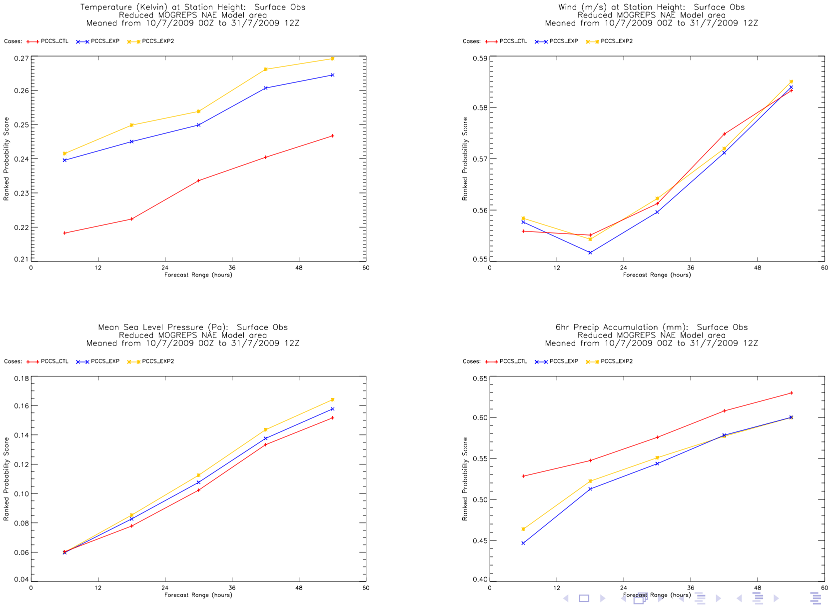
Mathematical definitions

$$BS = \langle (f - o)^2 \rangle = Rel - Res + Unc$$

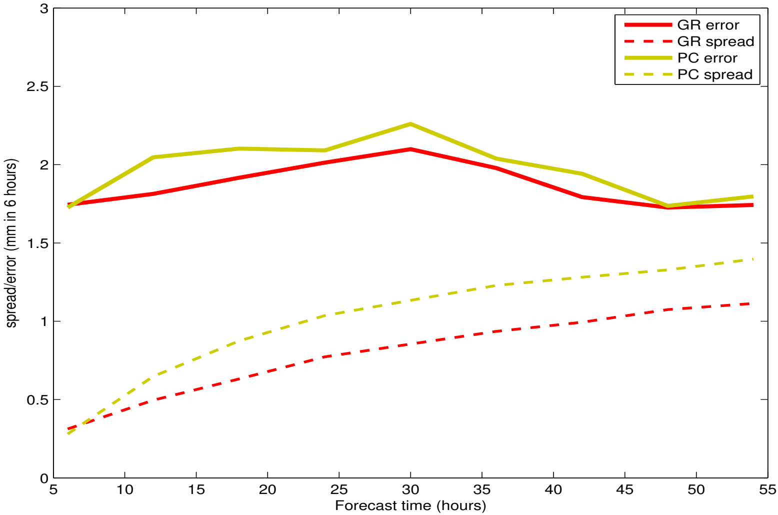
$$\begin{aligned} BSS &= 1 - \frac{BS}{BS_{ref}} \\ &= 1 - \frac{Rel - Res + Unc}{Unc} \\ &= \frac{Res - Rel}{Unc} \end{aligned}$$

$$RPS = \sum_{thres} \langle (f_{thres} - o_{thres})^2 \rangle$$

Rank probability scores for general surface variables



Model spread and error

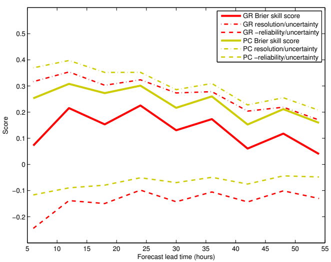


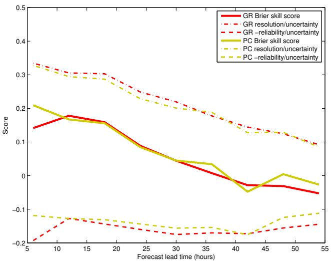
Brier Skill Scores

Threshold: 0.3 mm

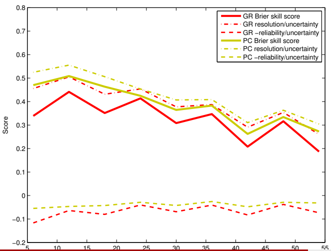
Threshold: 3.0 mm

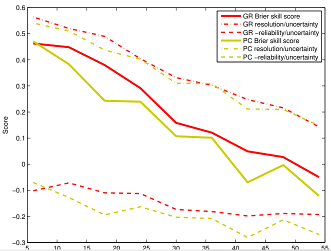
24 km





120 km





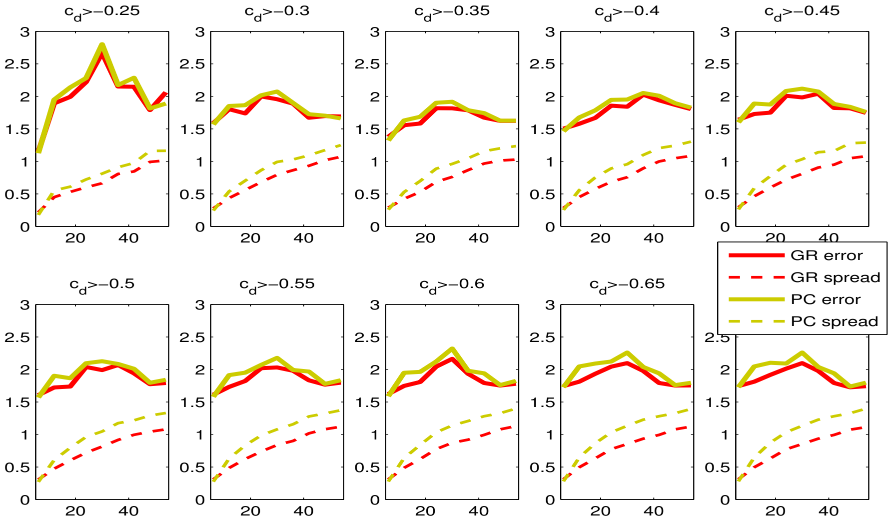
Removing forecasts where the Plant-Craig convective fraction is particularly low

- In order to investigate the possible effects of tuning on the forecast, forecasts where the Plant-Craig scheme yields a particularly low convective rainfall fraction are removed, and the remaining forecasts are reevaluated.
- For large-scale (gridscale) rainfall g and convective (subgrid) rainfall s, the convective fraction difference c_d is defined as:

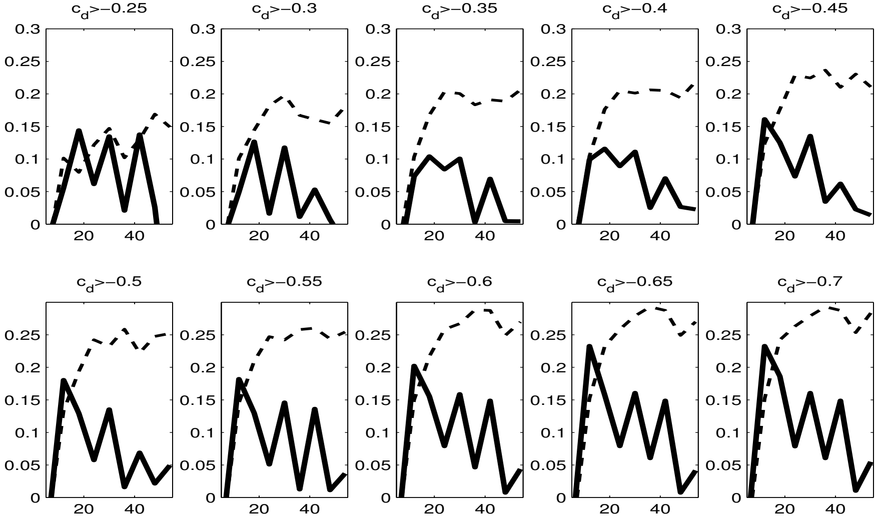
$$c_d = \frac{s^{PC}}{s^{PC} + g^{PC}} - \frac{s^{GR}}{s^{GR} + g^{GR}}$$

- Forecasts (i.e. of the 34) where this is below a threshold, are removed from both models and the spread and error are recalculated. This is repeated for different thresholds.

Variation of spread and error with convective fraction minimum threshold



Differences between spread (dashed lines) and error (full lines) between the two models

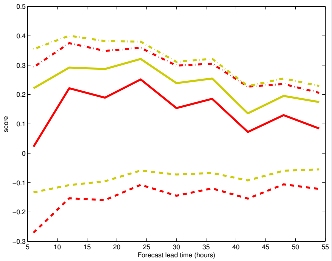


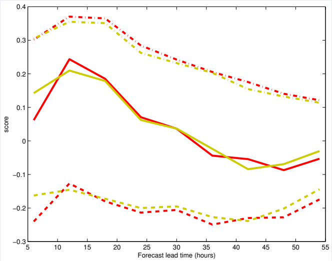
Brier Skill Scores with $c_d < -0.4$ removed

Threshold: 0.3 mm

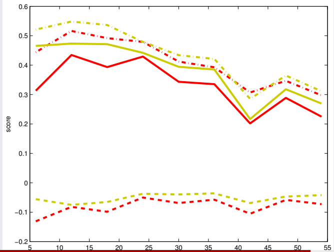
Threshold: 3.0 mm

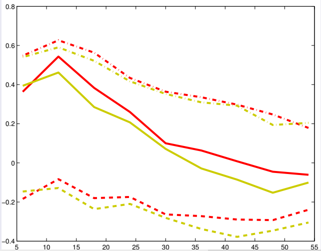
24 km





120 km





Conclusions

- The Plant-Craig scheme, as currently implemented, yields larger spread, but also larger ensemble mean errors.
- The scores are slightly degraded for general surface variables, but the improvement in rainfall scores is significantly larger.
- The probabilistic rainfall forecasts are significantly better for lower thresholds and similar for higher thresholds.
- There is some evidence that further tuning of the Plant-Craig scheme could reduce the slight degradation in the deterministic forecast, while retaining the improvement in the probabilistic forecast.
- This study represents a proof-of-concept of how stochastic convection parametrizations can improve probabilistic precipitation prediction, with grid lengths of the order of low tens of kilometres.
- This provides support for the use of stochastic convection parametrizations in global ensemble forecasts.