Error Growth at The Convective Scale

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Outline

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1. Introduction
   - Uncertainties and ensembles
   - The problem at the convective scale
   - Snapshot of current efforts
   - Our approach
2. At The Large Scale
3. At the storm scale
4. Summary

Introduction
The FREE program

Flood Risk from Extreme Events:

- comprehensive: pluvial, fluvial and coastal flooding
- across scales: from wave modelling to NWP
- across disciplines: oceanography, hydrology, meteorology and data assimilation
- with policy and climate change in mind
- our bit: ensemble technique for storm and flood forecasting

Introduction

An Ensemble Forecasting System provides estimation of uncertainties: this benefits

- forecast user: more conscious choices
  - flood warning & alerts
  - transport related issues
  - energy company
  - ...
- research: can be used to explore reality

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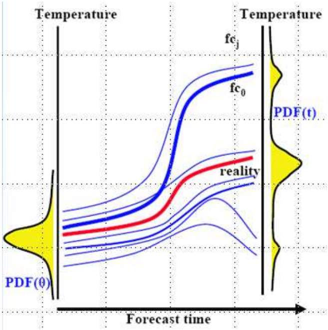

Buizza, 2001

Introduction

Ensemble Forecasting System is an ideal tool for severe convective events:

- improves risk quantification
- severe convective weather has high societal impacts
  - principal cause of flash flood
- high uncertainties

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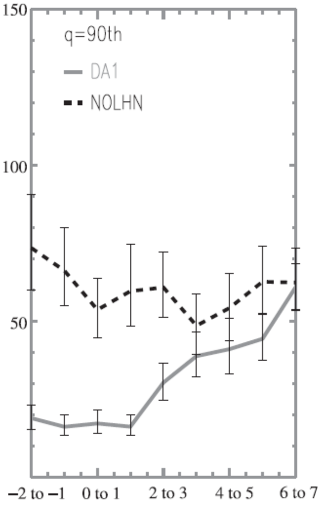


Dixon et al 2009

Introduction

Where does the uncertainty come from?

- data
- parameterisations: we do our best, but
  - some processes need more research
  - CPU, robustness
- there are fast propagation processes (gravity and acoustic waves)
- strong sensitivity to LBC
  - slightly different position/intensity/timing of synoptic system
  - g-waves can propagate error upstream ... or not
- reality: convection is often a subtle and complex problem

Introduction

The problem is a difficult one:

- geostrophic, hydrostatics and linearity assumptions all break down at the convective scale
- error double times are < 10 h (Hohenegger and Schar, 2007)
- DWD is working on a combination of LBC and parameterisations
- SLAF (Kong et al, 2007)
- and a lot more is being done (NCEO, JCMM)

Introduction

We introduce a novel technique:

perturb model state

as the perturbation progresses

We face the problem from two different perspectives:

at the large scale several storms within domain

- processes involved in *error* propagation
- general overview of model response to perturbation
- use ensemble to explore reality

at the storm scale focus on one specific flood

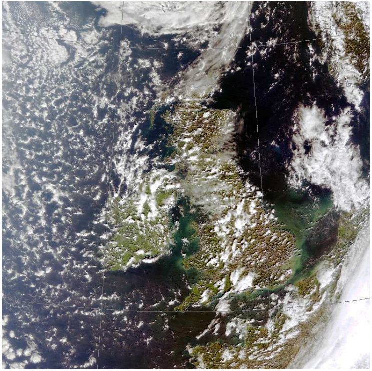
- accumulation within an area
- what needs to be changed: μphysics or perturbation?
- more practical approach

Outline

The event - CSIP IOP18

why this case?

- good large scale forecast
- tropopause fold
- interesting mesoscale features:
  - surface forcing
  - scattered convection
  - MCS within domain
  - cold pools



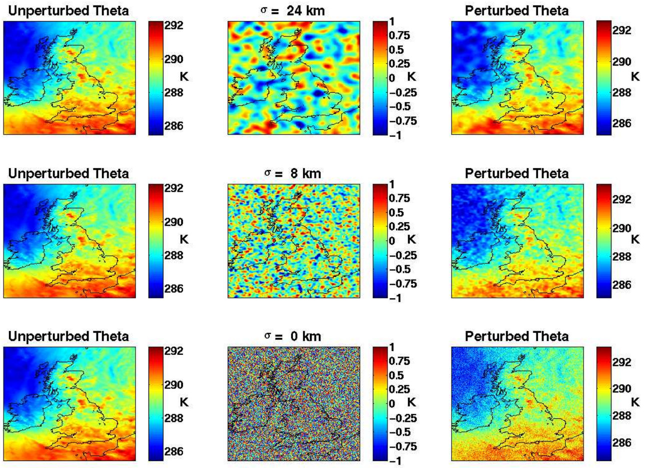
Perturbation Structure

The Perturbation

- 2D Gaussian kernel applied to random numbers
- potential temperature
- applied at fixed model level ($\sim$ 1280 m agl)
- at regular intervals (30 mins)

- 3 amplitudes: 1, 0.1 and 0.01 K
- 3 std: 24, 8 and 0 km

Perturbation Structure



Experiments

Single Perturbations:

- IC
- 0700 UTC
- 0830 UTC
- 1000 UTC

- 2 amplitudes: 0.01 and 1 K
- 1 scale length: 24 km

Sequential Perturbations:

9 combinations of

- 1, 0.1 and 1 K
- 24, 8 and 0 km

Experiments

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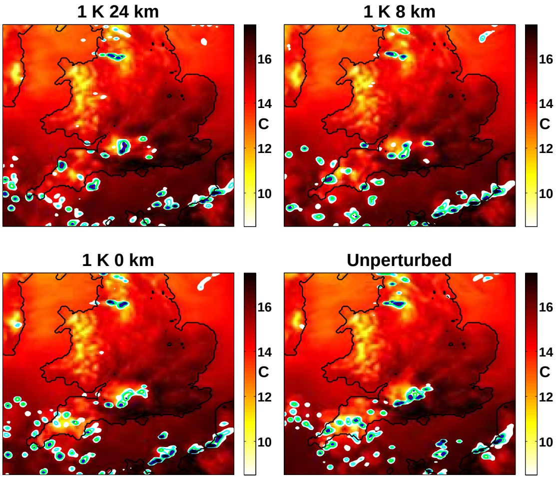
Model of choice: UM

- 4 km grid spacing
- modified convection
- PBL scheme has 7 types

Experiments



2m Temperature and Rain Rates, on August 25th at 1000 UTC

Direct Effects

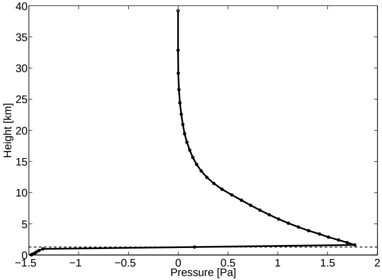
compare:

- perturbed run values 1 time-step after the perturbation
- unperturbed run at the same time

- CAPE: $\pm$ few Jkg^{-1}, rarely in discontinuous ways
- BL types change: 1 K $\sim$ 5%, 0.01 K 0.05%

Direct Effects

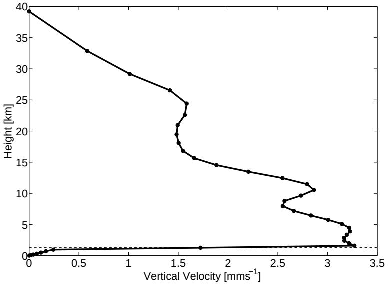
pressure bias over positive points



consistent with a Lamb wave, in a linearised atmosphere

Direct Effects

w bias over positive points



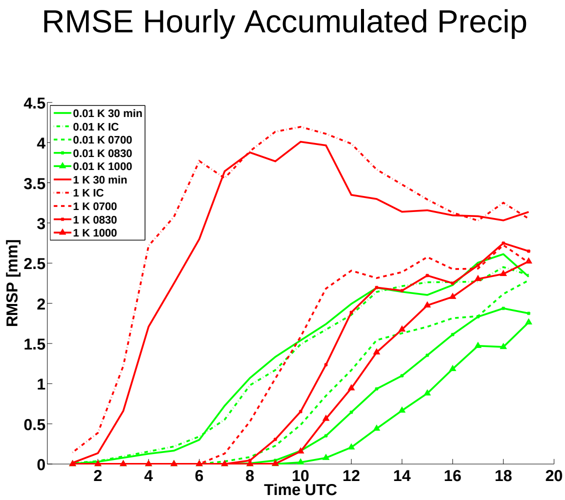
- *not* consistent with a Lamb wave
- scales linearly with amplitude
- max w 38% > unperturbed w
- spreads very fast

Direct Effects

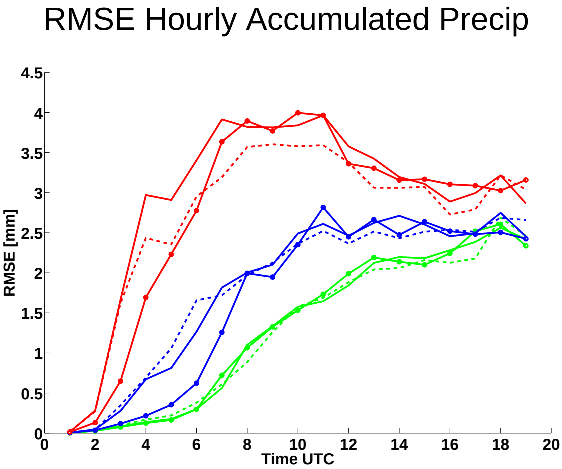
RMSE Hourly Accumulated Precip

$$\textbf{RMSE} = \sqrt{\frac{1}{N_i N_j} \sum_{ij} (x_{ij} - y_{ij})^2}$$

Direct Effects

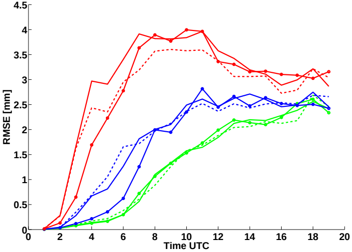


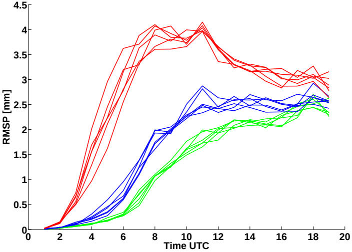
Indirect Effects



Indirect Effects

RMSE Hourly Accumulated Precip

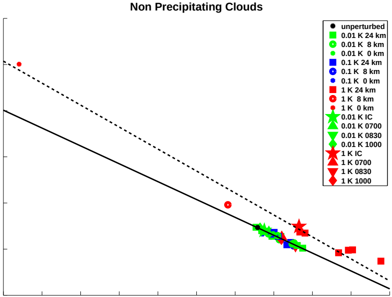




Indirect Effects

Non cirrus

TWP > 0.05 kgm^{-2}

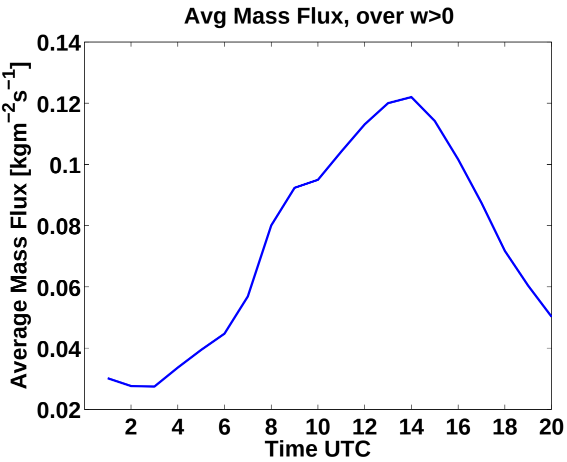


Direct cloud distribution changes:

- 0700-0.01 number of non-cirrus up 5.6
- everything else: < 1%
- mean size even less

Discussion

sensitivity to time of the day:



Conclusions

- processes involved: CAPE, BL types, acoustic waves
  - θ and cloud condensate
- CAPE can affect development
- BL changes have more potential
- acoustic waves unlikely to trigger new storms, but can propagate error quickly
- amplitude first factor in determining RMSE
- sensitivity to time of the day

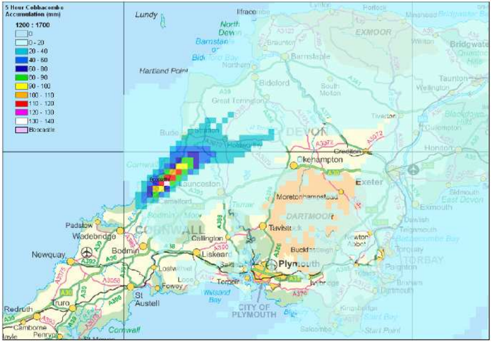
Outline

Aims

- Verify ensemble technique is useful
- Use model error scales to analyse precipitation accumulations
- Compare growth due to perturbation v warm μphysics changes

The event - Boscastle flood of August 16^{th} 2004

- very intense over 130 mm in 5 hours
- very localised, typical scale < skillful ones
- interesting mesoscale meteorology
  - near shore convergence line
  - moving convective elements
  - which precipitate over the same small catchment



Methodology

- UM, 1 km grid spacing
- Perturbation Strategy:
  - use 0.1 K and 8 km
  - 8 realisations (ie members)
- Accumulation is the quantity of interest:
  - model reaches acceptable skills between 40 and 70 kilometres
  - flooded river catchment is really tiny (20 km^2)
  - accumulations on a circle centred over Boscastle with diameters of 20, 40 and 60 km
- vary a few warm μphysics parameters
- std deviation of ensembles as measure of spread

Methodology

Autoconversion & the UM:

- large cloud droplets collect smaller ones
- if they are larger then a threshold they become rain (drizzle)
- 2 schemes for computing threshold
- each has 2 values of aerosol concentration: over sea & over land

Scheme	Land	Sea
3B	$6.0 \times 10^8 m^{-3}$	$1.5 \times 10^8 m^{-3}$
3C	$3.0 \times 10^8 m^{-3}$	$1.0 \times 10^8 m^{-3}$

Methodology

4 experiments:

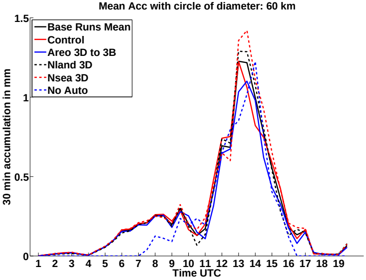
- revert 3D to 3B (areo 3D to 3B)
- 3D land aerosol everywhere (3D land)
- 3D sea aerosol everywhere (3D sea)
- no autoconversion (no auto)

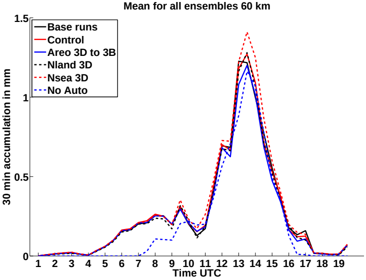
each base run, standard run included is the control run of its own ensemble

6 ensembles:

- base runs
- control
- 4 μphysics

Results


Mean Acc with circle of diameter: 60 km
Base Runs Mean
Control
Areo 3D to 3B
Nland 3D
Nsea 3D
No Auto
30 min accumulation in mm
Time UTC


Mean for all ensembles 60 km
Base runs
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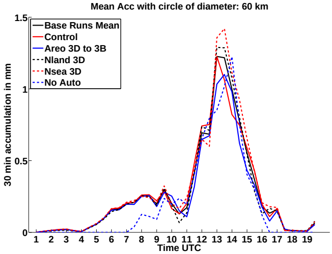
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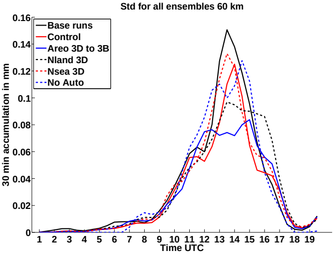
Std for all ensembles 60 km
Base runs
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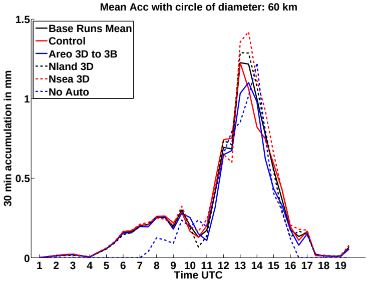
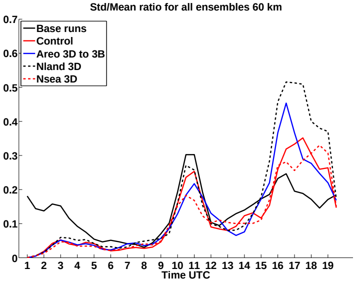
Preliminary Results





Conclusions & Future Work

- results consistent for 60 and 40 km, a bit less for 20 km
- spread generated by perturbation similar to changed μphysics
- accumulations of the same order as well
- perturbation before and at convection start is crucial for differentiation

- changed ice and sfc roughness
- how are these changes achieved?

Summary

- fundamental processes are: CAPE, BL type changes and acoustic waves
- scattered convection regime: error growth driven by amplitude and time of the day
- flood storm: ensemble generates variability comparable to μphysics
- perturbation technique useful, particularly tn capture the sensitivity to the time of the day