Liquid detrainment in convection embedded in a cold front

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DIAMET project
DIAbatic influences on Mesoscale structures in ExTratropical storms

• Consortium constituted by four UK universities (Manchester, Leeds, Reading and East Anglia) and the Met Office

• Three Work Packages
  • WP A. Structure of mesoscale anomalies and their wide-scale consequences
  • **WP B. Physical processes and their parameterisation**
  • WP C. Predictability
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- Three Work Packages
  - WP A. Structure of mesoscale anomalies and their wide-scale consequences
  - **WP B. Physical processes and their parameterisation**
    1. Improving convective parameterisation
    2. Air-sea fluxes and their influence on storm development
    3. Microphysical processes
  - WP C. Predictability
1. Lagrangian moisture budget diagnostics

- Moisture and potential temperature tracers (affected by advection)
- Budgets decomposed by parameterised processes:

\[ \Delta \theta(x,t) = \sum_{i=\text{proc}} \Delta \theta_i(x,t) \]

\[ \Delta q(x,t) = \sum_{i=\text{proc}} \Delta q_i(x,t) \]

\( \text{proc} = \{ \text{convection, boundary layer, microphysics,...} \} \)

- Current field configuration given by

\[ \theta = \theta_0 + \Delta \theta_0 + \Delta \theta \]

Initial field at t=0

Change in initial field due to advection only
2. Spectral decomposition of bulk mass flux parameterisation output

- Spectral decomposition using entrainment $\varepsilon$ as single parameter.
  1. Construction of a plume ensemble consistent with the model sounding
  2. Solve

$$\min \left| M(z^{\alpha}) - \sum_i c_i M_i(z^{\alpha}) \right|, c_i \geq 0$$

$z^{\alpha}$: $\alpha$-th height level
$M$: bulk mass flux
$M_i$: $i$-th plume mass flux
$c_i$: $i$-th coefficient
Analysis method: Motivation
Plant (2010)

Mean West Indies sounding data for “hurricane season” (Jordan 1958)

Vertical profiles of mass flux in ensemble (after Plant 2010)

N = 350 plumes
Analysis method: Motivation
Plant (2010)

Bulk parameterisation schemes ansatz (Yanai et al. 1973)

The liquid water detrained from each individual plume is given by the bulk value:

\[
l_{D_i} = l_i = l_B = \frac{\sum M_i l_i}{\sum M_i}
\]

Ensemble detrained liquid water
Bulk liquid water
(after Plant 2010)
Preliminary results

• Case from DIAMET first field campaign:
  • 30 September 2011
  • Low-pressure system centred to the south-west of Iceland
  • Long trailing active cold front
• Model:
  • Met Office Unified Model (MetUM) version 7.3
  • North-Atlantic—Europe (NAE) domain
  • Grid spacing 0.11° (~12 km)
  • 38 vertical levels (lid ~40 km)
  • (MetUM Modified) Gregory—Rowntree convection scheme
DIAMET field campaign
0600 UTC 30 September 2011

Model-derived OLR

850-hPa equivalent potential temperature

Total precipitation

Convective rain
Lagrangian budget diagnostic

Change in theta due to convection

Total change in theta
Rain

Total precipitation

[Map showing precipitation patterns with annotations A and B]

[Graph showing precipitation rate with lines labeled Total precip rate, CV rain rate, and LS rain rate]
Updraught mass flux

Total precipitation

Elevated convection
Updraught mass flux

![Diagram showing updraught mass flux and temperature layers at 0°C and -10°C](image)
T-φ-gram and plume ensemble

T-φ-gram before convection

Vertical profiles of mass flux in ensemble
**T-φ-gram and plume ensemble**

**Bulk mass flux (MetUM)**
**Spectral component plumes (thin)**
**Spectral mass flux (bold)**

**Ensemble detrained liquid water**
**Bulk liquid water**
Two tools for the analysis of convection in bulk mass flux models have been developed

1. Spectral decomposition of bulk mass flux convection
2. Lagrangian budget of energy (heating/cooling) and moisture (drying/moistening)

These tools are being applied to a realistic case involving an active cold front.

Preliminary analysis shows discrepancies between spectral and mass flux approaches
On-going work

- Quantification of the effect of discrepancies between spectral and bulk convective scheme formulations on the large-scale circulation
- Use of Lagrangian budget method to determine origin and downstream impact of moisture and energy sources/sinks from convection (and other parameterised processes)
References

