The impact of parametrized diabatic processes on weather forecasts

Keith Williams
Open IFS workshop, June 2019
Annual mean bias in TOA reflected SW (vs CERES-EBAF)

UM (GA7.1)  IFS (cycle 43r1)

Albedo too low

Albedo too high

Richard Forbes (ECMWF)
The impact of parametrized diabatic processes on weather forecasts:

- By impacting the dynamical evolution
- Directly on the surface weather
The impact of parametrized diabatic processes on dynamical evolution
Z500 Hovmoller Error Diagrams (July 2016)

UM

ECMWF

Adrian Semple

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Downstream impact of convection induced on Europe (Z250)
Model or DA?

DA appears perfectly capable of representing the system. But model clearly resists developing it.

Sim IR Images from separate Fcsts approaching the event

Adrian Semple
Assessing forecast tendencies

Rodwell and Palmer (2007)
Z500 RMSE rate of change ($\partial 'error'/\partial 'T+')$:
Across NAWDEX Period (15/9 to 15/10).
Z500 RMSE rate of change (\(\frac{\partial \text{error}}{\partial \text{‘T+’}}\)):
Across NAWDEX Period (15/9 to 15/10).

There are events where error grows rapidly, occurring at the same validation time (00Z 16\(^{th}\) for event A).
Events with large increase of error at a similar validation time are defined as **predictability barriers**

- Similar for IFS and UM.
- Low ensemble spread and ensemble mean not too different from deterministic.
A:Ex-TC Ian (IOP1)

Longer forecast fail to merge, important ascent and heating from LS-rain over ridge.

‘advection only dθ’ tracer on 12Z 16\textsuperscript{th} for (a,c) 00Z 15\textsuperscript{th} (b,d) 00Z 12\textsuperscript{th} forecast. (c,d) Cross section on dashed line in (a,b). X: Pos of Ian and merged cyclone. Tracer initialized at 00Z 15\textsuperscript{th}

Same as left, but for dθ\textsubscript{LS}.
E: After stalactite (IOP7)

Claudio Sanchez

dPV_{LS} tracer in different forecasts (initialized at 00Z 3rd, 2nd and 1st).

Delay in ridge building, strong negative PV filament associated to LS rain process.
SG model integrated for one hour from Met-UM (N768) 6 hourly output

AGeostrophic Advection of PV (AGAQ) shows areas where:

• Deposition of diabatic heating on the Warm Conveyor Belt (WCB) outflow region
• There are cross-tropopause and ridge building action

[Right]: AGAQ (coloured) and ageostrophic wind (vectors) for Case A (12Z 16/9/2016). (a) No diabatic sources T+24. (b) Diabatic heating only for T+24. (c) No diabatic sources T+72. (d) Diabatic heating only for T+72. Box: area of average for AGAQ and RMSE

\[ AGAQ = -v_{ag} \cdot \nabla q \]
Most of PB cases (A,B,C,D,E,F) coincide with $\langle AGAQ \rangle \uparrow$

Several of the PB (A,B,F) got lower $\langle AGAQ \rangle$ values on T+↑ than T+↓

Strong influence of diabatic processes over outflow region on model error

[Left] $\langle AGAQ(DIAB) \rangle$ (coloured) and PB (contoured)
Effect of convective entrainment on MJO

Nick Klingaman (U. Reading)

Increasing the entrainment (blue) and switching off the convective momentum transport (brown) improve the strength and propagation of the active event.

The 1.5x entrainment simulation shows the lowest RMSE against the observations (black).
Tropical wave spectra (effect of cloud and convection package)

Prince Xavier
Dynamical impact of tropical convection

High frequency noise in vertical winds above convection

Martin Willett
The impact of parametrized diabatic processes on the weather
SEEPS decomposition - winter

Europe

Observed

Dry

Light

Heavy

Forecast

1 2 3 4 5 6 7 8 9 10

Forecast day

1 2 3 4 5 6 7 8 9 10

Forecast day

1 2 3 4 5 6 7 8 9 10

Forecast day

c/o Nils Wedi (ECMWF)
European Ensemble for Renewable Energy Systems (SEEPS) decomposition - summer

Observed

Dry

Light

Heavy

Forecast

1 2 3 4 5 6 7 8 9 10
Forecast day

1 2 3 4 5 6 7 8 9 10
Forecast day

1 2 3 4 5 6 7 8 9 10
Forecast day

Europe

c/o Nils Wedi (ECMWF)
Tropics diurnal average SEEPS decomposition $S_{ij}$ trial average over all dates (20120630 to 20121210)

- Too few dry events
- Too many light events
- 200%
Convective intermittency

Instantaneous precip. rate (GA7 N320)
Adding convective memory

- High recent convective activity
  - Large convective clouds
  - Low entrainment rates
- Low recent convective activity
  - Small convective clouds
  - High entrainment rates
West Africa

Impact of prognostic entrainment on precip intensity distribution and diurnal cycle.

Observations
- Control
- Prog.
- Entrainment

Impact on precip intensity distribution and diurnal cycle.
Case study test of PS38 physics
14UTC 27th Aug 2015, T+11

Stochastic BL perturbations in PS38 initiates showers more readily

PS36

PS38
Comparison against satellite data over the tropics
Comparison against satellite data over the tropics

ISCCP

CALIPSO

CloudSat

Too little medium brightness cloud
Comparison against satellite data over the tropics

ISCCP

Too little medium brightness cloud

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Excessive cirrus and too low (important for aviation)

CloudSat
Comparison against satellite data over the tropics

ISCCP

Too little medium brightness cloud

CALIPSO

Excessive cirrus and too low (important for aviation)

CloudSat

Excess hydrometeor at low levels
Comparison against satellite data over the tropics

**ISCCP**

- Too little medium brightness cloud

**CALIPSO**

- Excessive cirrus and too low (important for aviation)

**CloudSat**

- Excess “drizzle” (<0.005mm/hr) (important for products)
Comparison against satellite data over the tropics

ISCCP

CALIPSO

CloudSat
Comparison against satellite data over the tropics

- ISCCP
- CALIPSO
- CloudSat

6A convection
Reduced cirrus spreading rate
Comparison against satellite data over the tropics

ISCCP

CALIPSO

CloudSat

6A convection

Reduced cirrus spreading rate

Warm rain microphys
• Biggest gap between user expectation and forecast skill.

• Current skill is poor and uncertainty is large
  • Spatial distribution subject to both large scale and local influences

• Physically complicated
  • Result of feedbacks and imbalances between many small scale processes (turbulence, microphysics, radiation, land surface)
LANFEX
Local And Non-local Fog EXperiment

- 18 month campaign to examine development and evolution of (primarily) radiation fogs (Autumn 2014-Spring 2016).
  - Deploying long-term networks of instruments (flux towers, surface sites, dopler lidar, etc)
  - IOPs with sondes, tethered balloon
- High resolution modelling run in parallel
- Two sites: Shropshire hills and Met Office Cardington
  - Contrasting hilly and flat(-ish)
Fog onset much improved by more realistic fog microphysics

- “New taper” applies observed cloud droplet number (50 cm\(^{-3}\)) below 150m
  - Smaller drop number implies optically thinner for a given condensed water content
- Surface temperature and vertical profile now much improved, although still not perfect (higher vertical resolution?)
Impacts of cloud-aerosol interaction

Improved continental temperature biases
(T+120 errors July/August 2012)

Mean N512 GA3.1 f/c

Mean f/c difference N768 GA6.1 – N512 GA3.1

Mean N512 GA3.1 error

Mean N512 GA3.1 error

Aerosol indirect effect from HadGEM-based climatologies improves N. American low-cloud/T biases

Malcolm Brooks
Excessive drizzle & microphysics

• Issues with mixed phase microphysics
  • Main culprit was too efficient riming of supercooled water onto ice
  • Including the crystal shape in the cross-sectional area, rather than assuming circular, reduces efficiency – now operational

Model operational in Feb 2015

Including revised riming

Paul Field
Crystal shape-dependent riming in the climate model

- Despite significant effort over many years on the “Southern Ocean problem”, too efficient riming had not been thought of until it fortuitously ruined UKV!

[Images of maps showing differences in SW TOA for different scenarios]
Summary

- Parametrized diabatic processes affect weather forecasts:
  - By impacting the dynamical evolution
  - Directly on the surface weather
- Getting both aspects right is important.
- Detailed diagnostic techniques such as PV tracers and satellite simulators help with understanding which processes are contributing.
- Sometimes the solution to one error can help with something (seemingly) completely different.