Parameterization in the grey zone: what should it recognize?

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Understanding and Representing Atmospheric Convection Across Scales
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1. What is the grey zone?

2. Explicit convection done poorly

3. Traditional parameterization done poorly

4. Explicit and parameterized convection both active

Outline

1. What is the grey zone?
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4. Explicit and parameterized convection both active

Quotation I

Should cumulus parameteriztaion be used for models with a grid size of 1-20km?
Should we work with a totally explicit scheme?
Or should we work with a hybrid approach?

All quotes from the same source which will be revealed later

Model Grid Lengths

Grid length (km)	# models
up to 2	2
2–2.5	14
2.5–3	6
3–4	5
4–5	3
5–6	5
6–7	12
7–8	3
8–9	2
9–10	5
10+	16

- Current operational NWP in Europe
- The grey zone is where we already are

From audit of operational models of EUMETNET members, `http://srnwp.met.hu/C_SRNWP_project/Eumetnet_List.html`

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(Don't worry, the Croatians have a model with 2km, but UKV at 1.5km is still the lowest)

Meaning of grey zone

- Historically: range of scales where a parameterization of deep convection needs adaptation because some of the large scale parameterisation hypotheses do not hold any more
- More recently: range of scales where a parameterisation of deep convection may or may not be necessary

(Geleyn and Mironov, 2012, COST Action Discussion Document)

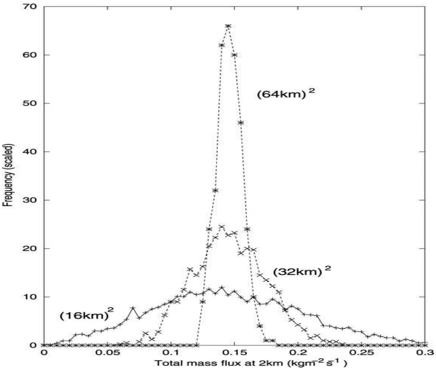
Encompassing both of these descriptions...

The grey zone is the range where we first of all need to talk about the model's filter (averaging operation)

Averaging

- Parameterizations usually formulated in terms of ensemble mean (grid-scale state given, and answer is ensemble mean flux divergence consistent with that state)
- In grey zone, ensemble mean $\neq$ space-time mean
- Key question: what do we want the grey-zone model to produce?
  - a more detailed picture of the ensemble-mean flow? (This is totally legitimate...)
  - or a particular, possible realization of the actual flow? (...but this is what most people seem to have in mind)
- The difference is that the first answer gives smooth fields whereas the second answer looks realistic

Variability



- CRM with fixed forcing
- pdf of mass flux averaged over various areas
- Convection on grid scales < 20km unpredictable, but randomly sampled from a pdf dictated by the large scale
- Leads to stochastic version of conventional parameterization

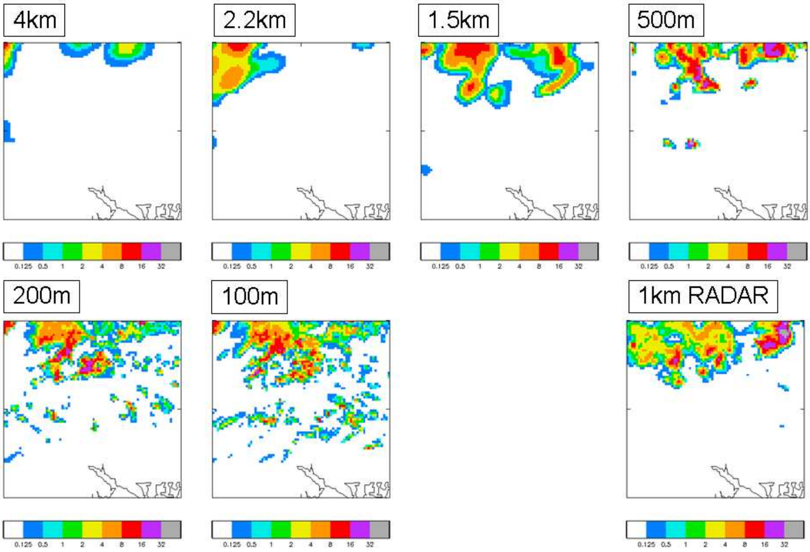
(Plant and Craig 2008 for deep; Sakradzija et al 2012 for shallow?)

Outline

Explicit convection: no parameterization

- Fully resolving deep convection with LES needs < 100m
- At order a few km, the smallest features seen will be sensitive to details of the filter and solutions may be qualitatively sensitive to numerics and applied diffusion

Example of explicit convection, UM for 07/08/11



Explicit convection: no parameterization

- Fully resolving deep convection with LES needs < 100m
- At order a few km, the smallest features seen will be sensitive to details of the filter and solutions may be qualitatively sensitive to numerics and applied diffusion
- Performance typically very case dependent
- If quasi-equilibrium holds, convective activity is constrained on large-scale however modelled
- A parameterization is safer in avoiding grid point storms and unrealistic build up of CAPE
- Equilibrium can often be violated in NWP (Zimmer et al 2011)
- Squall lines and propagating systems generally handled poorly by a parameterization but better by explicit convection even at coarse resolution

Quotation II

- convective parameterization may be necessary even at grid lengths approaching cloud scale
- traditional convective parameterization theory seems to break down but the need for convective parameterization does not

Outline

Assumptions that break down...

- Everything is local to the grid box
  - grid-box state no longer a good approximation of the "large-scale" state
  - may need some communication with neighbouring grid points
  - horizontal fluxes may become important
- Assume a closure for the mass flux at cloud base
  - equilibrium closures likely to break down as Δx decreases
  - prognostic closure (or some other memory component) may be necessary
- Neglect cloud lifecycle
  - plumes in a parameterization are averaged over lifecycle
  - plume lives for single timestep and instantaneously reaches cloud top
  - may cause problems/mismatch if explicit dynamics also captures convection

Assumptions that break down...

- Sub-grid fluxes well approximated by mass flux formula
  - mass flux has issues anyway, but they become increasingly apparent
  - e.g. $\sigma \ll 1$ may not always hold
- Formulation of microphysics
  - is usually very simple in a mass flux scheme
  - arguably this is by construction since

$$M = \sum_{\text{plumes,i}} \rho \sigma_i w_i$$

  - may cause problems/mismatch if explicit dynamics also captures convection
- Indeed most of our traditional parameterization assumptions break

Quotation III

The structure of cumulus parameterization needs to change

1. from diagnostic to prognostic
2. from single column to multiple-column for the purpose of considering the horizontal-nonlocal effects
3. from deterministic to nondeterministic

Outline

Regimes within grey zone

- Large boxes: traditional param, averages equal
- Largeish boxes: space-time average starts to depart from ens average for eep convection
- Middle of grey zone
- Smallish boxes: space-time average starts to depart from ens average for shallow convection
- Small boxes: well-resolved explicit convection

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If averages similar but not identical, a suitable parameterization is stochastic sampling from a pdf characterised by an ensemble state that can be estimated from an average over grid boxes
This predicts heteogeneity but is faithful to large-scale ensemble-mean statistics

Issues if both active

- treatment of microphysics
  - is downdraught resolved? detrainment of cloud and hydrometeors to it and to the resolved scale
  - departures of spatial average from ensemble mean may activate the resolved-scale scheme for condensation: issues of consistency, double counting?
  - idea of summing condensation sources before feeding them to microphysics (e.g. Gerard and Geleyn 2005)
- the partitioning between resolved and parameterized parts
  - in a genuine convective equilibrium situation, the total convective activity on the large-scale is dictated by this large-scale constraint
  - we can still impose this!
  - aim at large-scale total (resolved plus param) convective fluxes that are resolution independent
  - need scalings for fluxes carried above and below the model's filter scale and/or online diagnoses of what the resolved fluxes are ⇒ "scale-aware" closure
  - but closure must be non-local

Coupling to dynamics and turbulence

- triggering of deep convection is sensitive to horizontal variability
  - typically triggering too late and too vigorously in grey zone models with explicit convection (diurnal cycle is classic example)
  - out of equilibrium situations need careful coupling of convection and boundary layer schemes
  - variability may be introduced explicitly with small perturbations to the model's flow (promotes explicit and param convection)
  - or used to modify trigger of parameterized convection
  - diagnosis of heterogeneity from boundary-layer schemes reasonably straightforward
  - shallow convection scheme may also need to treat scalar variances
  - how much heterogeneity does dynamics permit?
  - can consideration of boundary layer fluctuations replace a traditional closure? (does that behave well in an equilbrium situation?)

Quotation IV

the fundamental question is how should the physical processes associated with convection be partitioned between parameterized and explicitly resolved components of a mesoscale model?

Source of Quoted Text

Kuo et al, Summary of a Mini Workshop on Cumulus Parameterization for Mesoscale Models, BAMS (1997).
Workshop was at NCAR, September 1995.

Remarks

- to say what is supposed to happen in a model as resolution increases, we have to say something about the assumed averaging operation
- NWP is already well into the grey zone
- we have a lot more experience now, but the basic issues are not obscure
  - they are well known and have been for 15 years +

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- to say what is supposed to happen in a model as resolution increases, we have to say something about the assumed averaging operation
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- we have a lot more experience now, but the basic issues are not obscure
  - they are well known and have been for 15 years +
- Personal view:
  - while the issues may be difficult, genuine progress can and is being made
  - but we still need to bite the bullet on some of these issues, especially relating to partitioning and non-columnar aspects