Novel parameterisations in the boundary layer

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NCAS Boundary-Layer Workshop

1st July 2011

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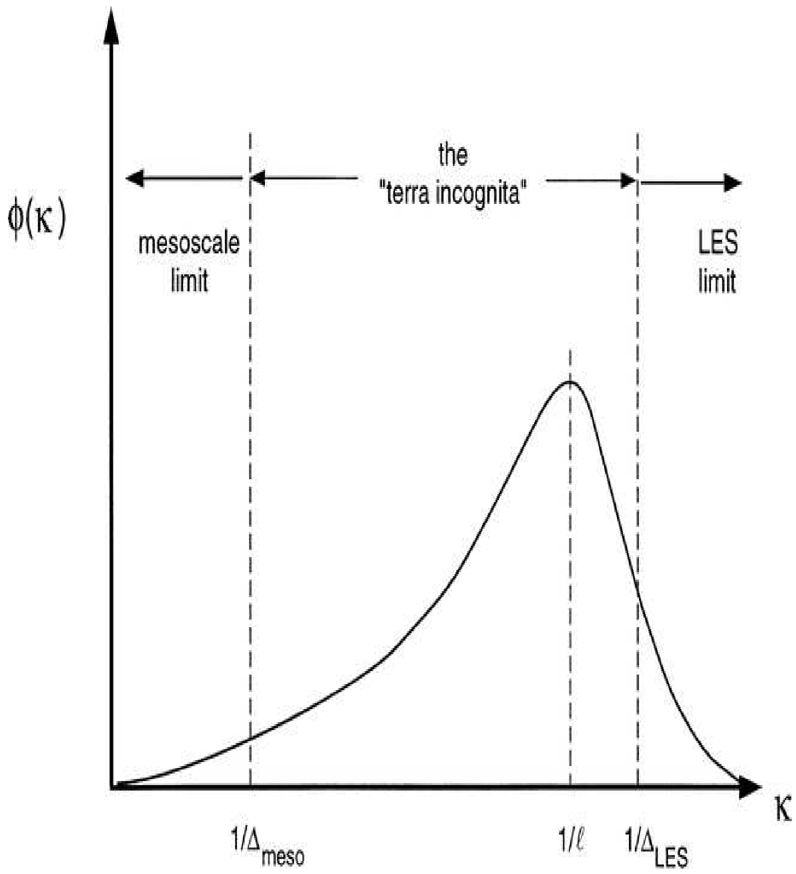
The University of Reading

Structure

- The terra incognita
- Towards the terra incognita: perspective from LES
- Towards the terra incognita: perspective from NWP
- Uncertainties associated with the boundary layer: perspectives from ensemble forecasting

The terra incognita



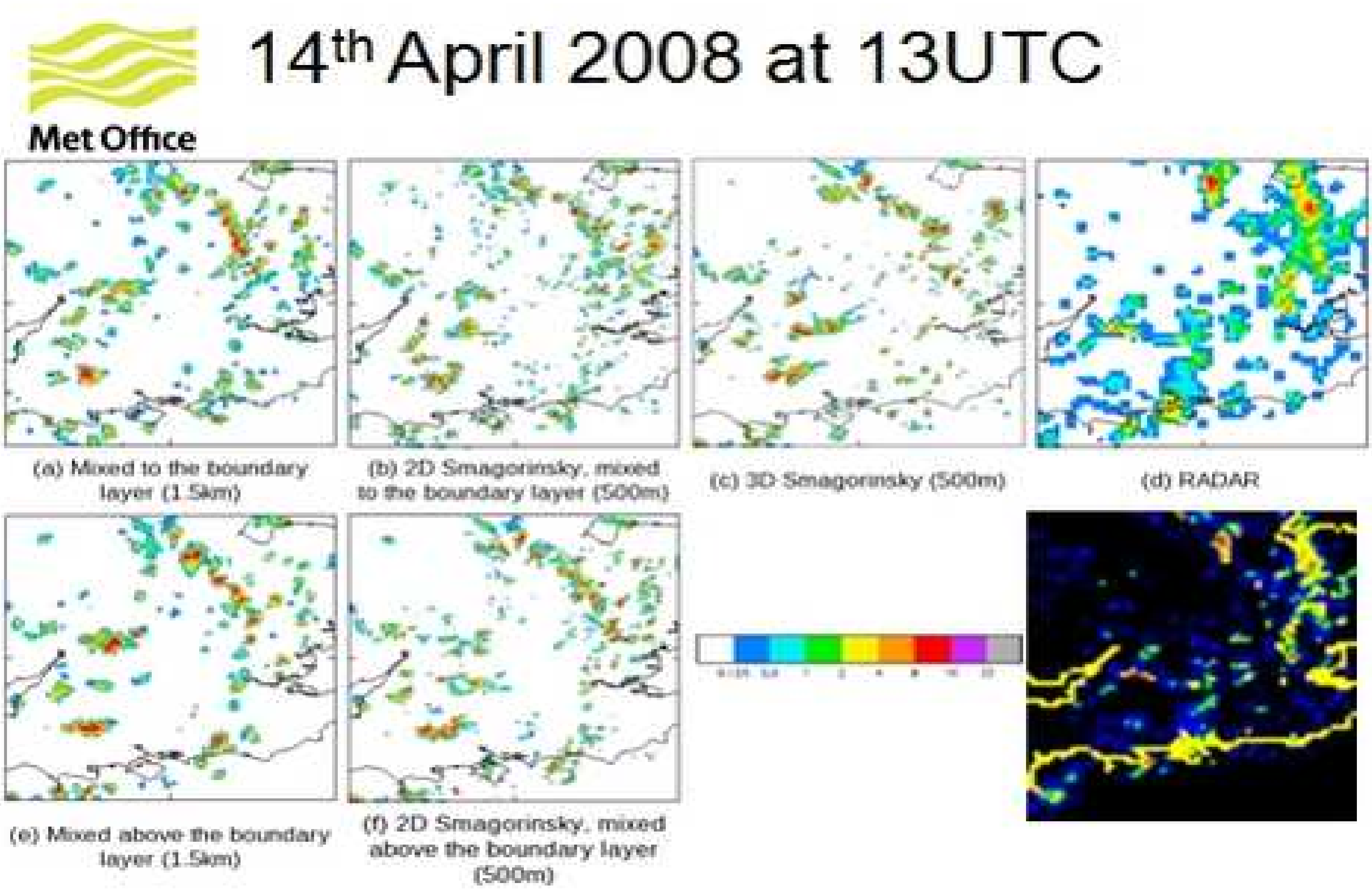
- l is integral lengthscale of the turbulence
- Δ is model filter scale
- LES if $\Delta \ll l$
- Mesoscale modelling if $l \ll \Delta$ and turbulence is sub-filter
- Terra incognita where $l \sim \Delta$

Wyngaard 2004

The terra incognita

- If $l \sim \Delta$ then a spatially-averaged field on the scale Δ looks turbulent but an ensemble-averaged field on that scale is not
- Which eddies are resolved/unresolved/partially-resolved will be sensitive to details of the filter and solutions may become qualitatively sensitive to numerics

  Piotrowski et al 2009
- Question: what do we want our high-resolution models to produce?
  - a more detailed picture of the ensemble-mean flow?
  - a particular, possible realization of the actual flow?

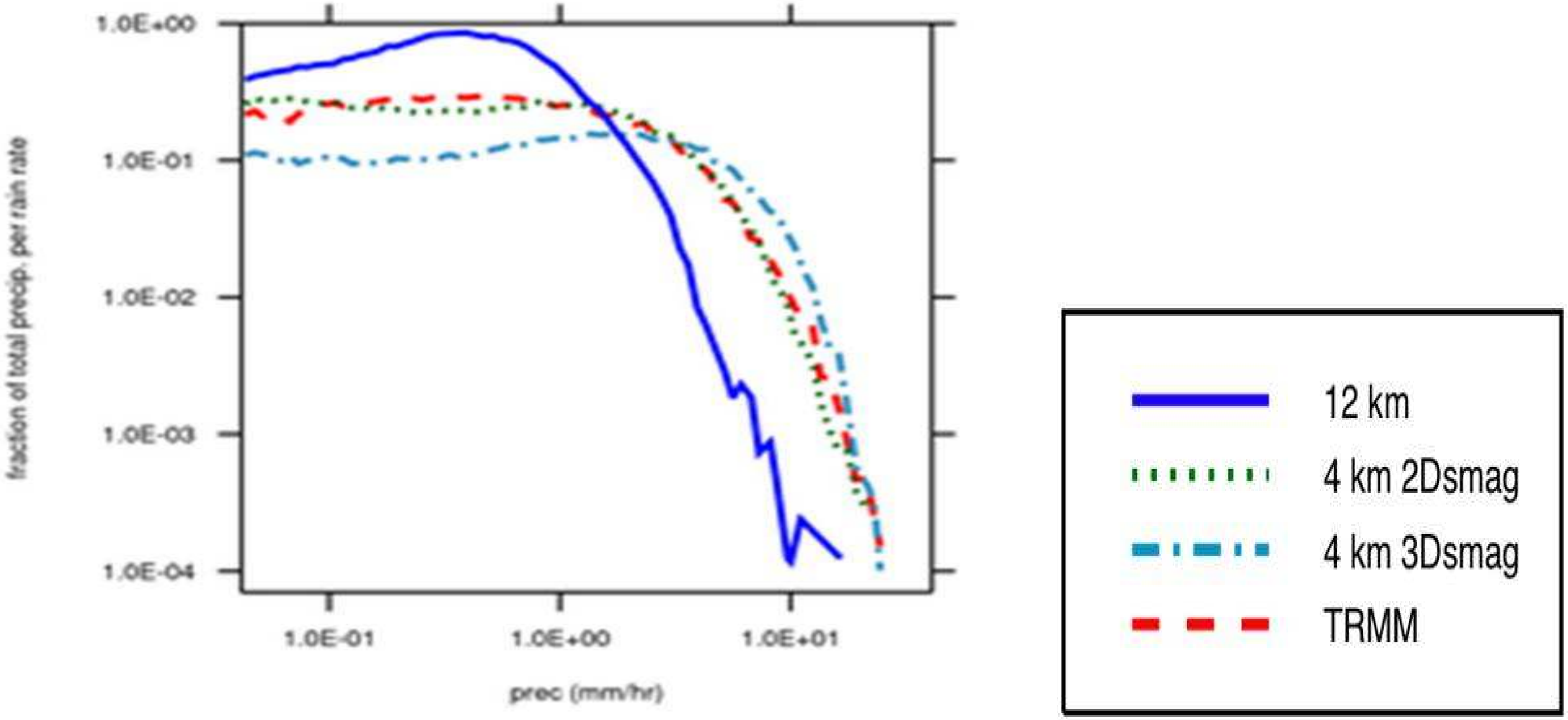

14th April 2008 at 13UTC
Met Office
(a) Mixed to the boundary layer (1.5km)
(b) 2D Smagorinsky, mixed to the boundary layer (500m)
(c) 3D Smagorinsky (500m)
(d) RADAR
(e) Mixed above the boundary layer (1.5km)
(f) 2D Smagorinsky, mixed above the boundary layer (500m)

(Carter 2011)

Cascade experience

- 4km large-domain tropical convection
- Have experimented with:
  - 1D vertical mixing from default UM boundary-layer scheme
  - As above + Smagorinsky in the horizontal
  - Smagorinsky for both vertical and horizontal
- 3D Smagorinsky is most realistic
- Choice of scheme affects large-scale organization, total rainfall in the domain, and moisture content of lower troposphere

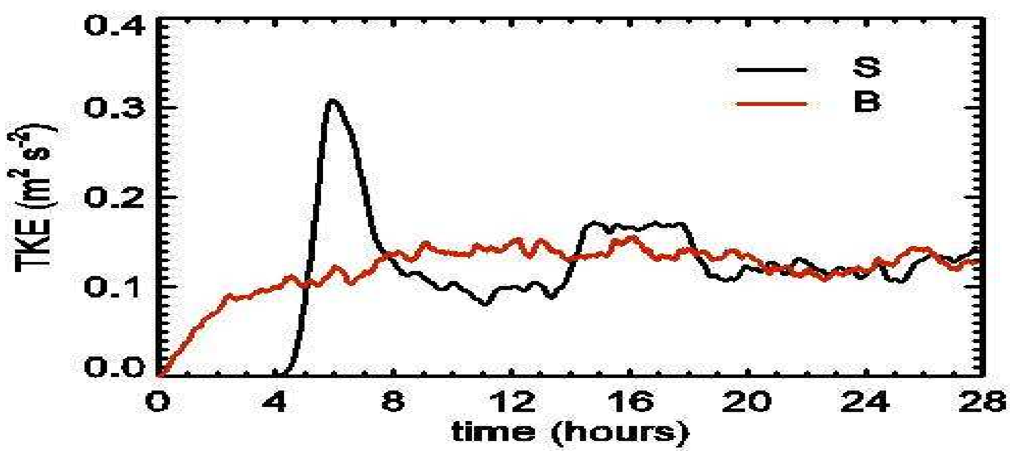
Cascade: rainfall pdf



(Holloway 2011)

Perspective from LES

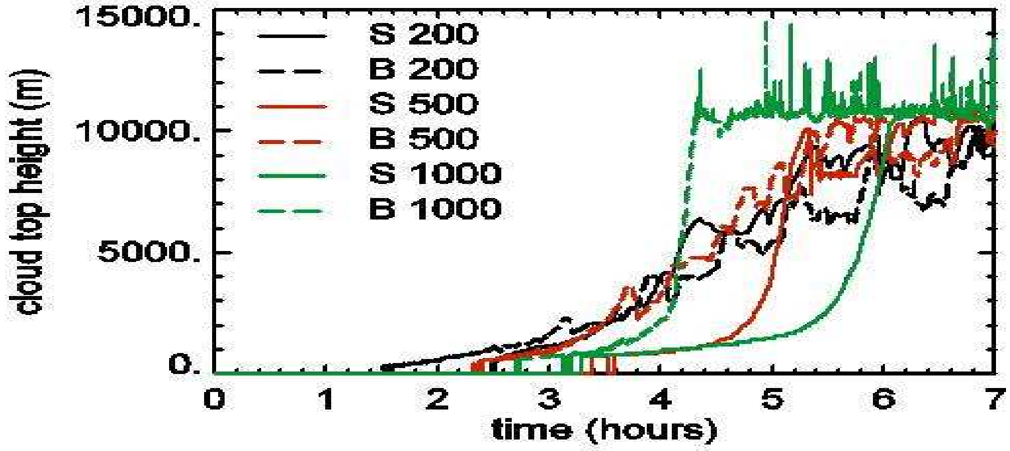
- Stochastic backscatter useful very near surface where $\Delta \ll l$ breaks down
- eg, improves profiles of dimensionless wind shear near surface
- Reduces transient response times and spurious initial overshoots



Dry, neutral boundary layer, Weinbrecht 2006

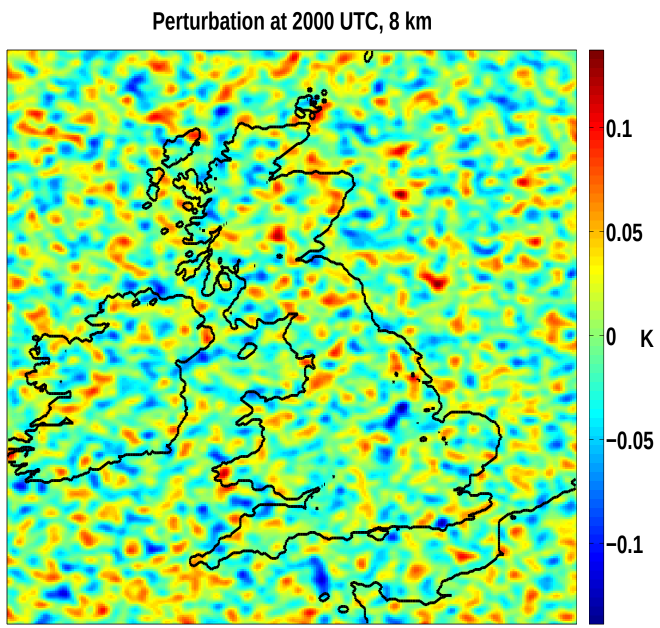
Helpful, but only so far...

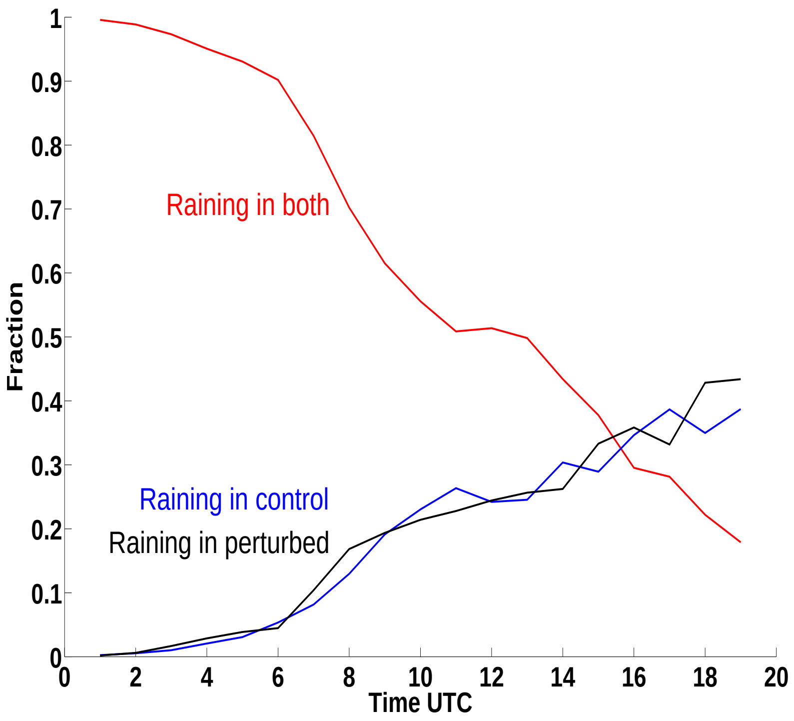
- Improves development of shallow moist convection leading to earlier onset and reduced overshoots
- Makes a medium resolution (500m) simulation looks more like a high-resolution one (200m)
- But can't rescue a coarse-resolution (1km) simulation



Perspective from NWP I

- Small boundary layer fluctuations (~ 0.1K) important for convective initiation
- Can easily shift the locations of precipitating cells e.g. Leoncini et al (2010)

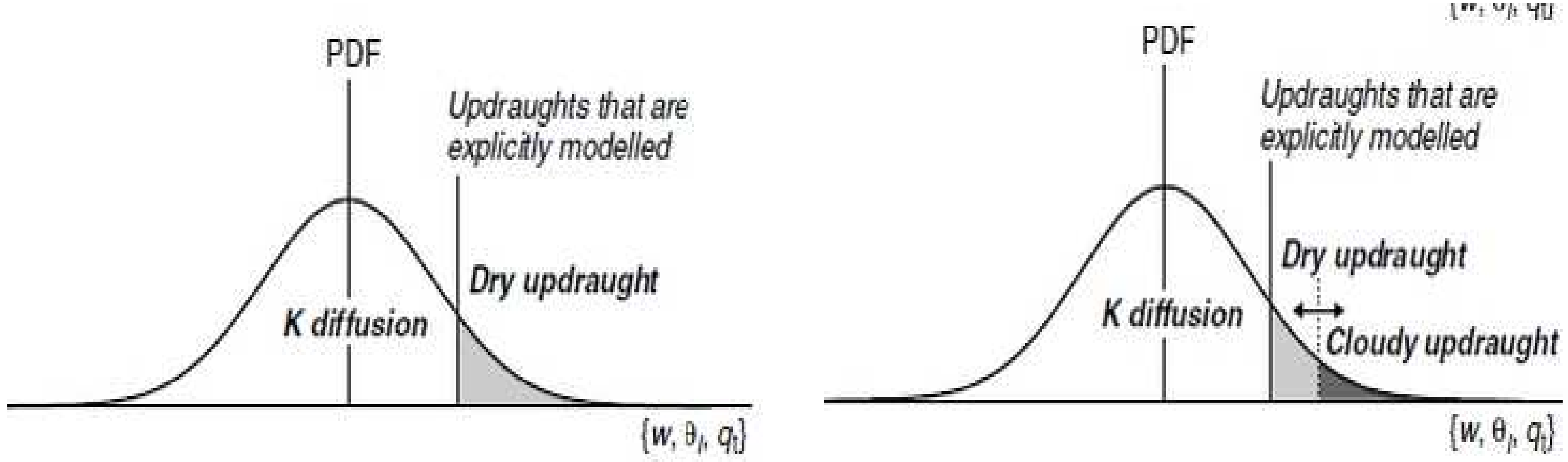




Perspective from NWP II

Eddy-diffusivity mass-flux treatment,

$$\overline{w'\phi'} = -K d\phi/dz + \sum_i M_i(\phi_i - \overline{\phi})$$



- Stochastic sampling of pdf in moist updraught part improves EDMF treatment of shallow convection (Suselj and Teixeira 2011)
- Entrainment into these shallow plumes is event-like (Romps and Kuang 2010)

BL uncertainties: ECMWF

- ECMWF stochastic physics from perturbed tendencies:

$$\frac{D\chi}{Dt} = (1 + \varepsilon\mu)P$$

where P is parameterization tendency, ε is noise and $\mu(z)$ reduces perturbation amplitudes in stratosphere and BL

- $\mu = 0$ below 300m, and reaches 1 at 1300m
- perturbations to boundary layer tendencies helpful for probabalistic skill scores but can cause numerical instabilities
- balance between model dynamics and turbulent momentum transport near the surface is established very quickly and cannot hold r steady for 6h

Palmer et al 2009

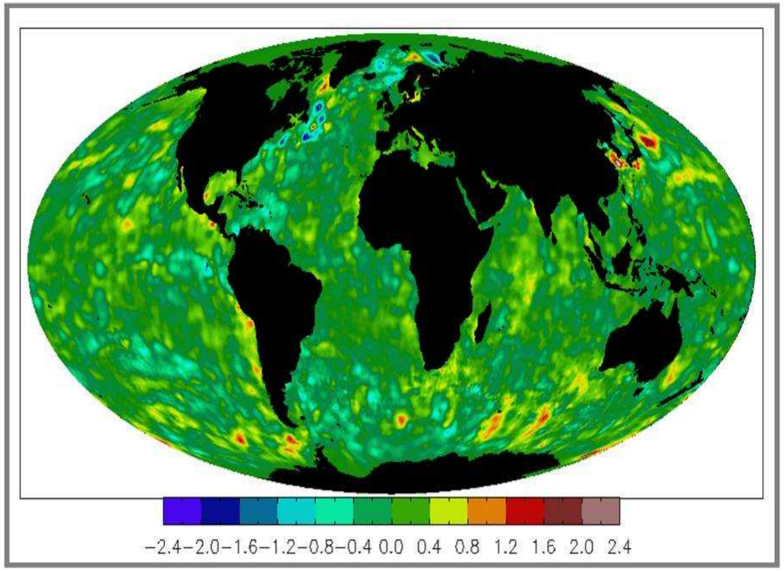
Random parameters scheme

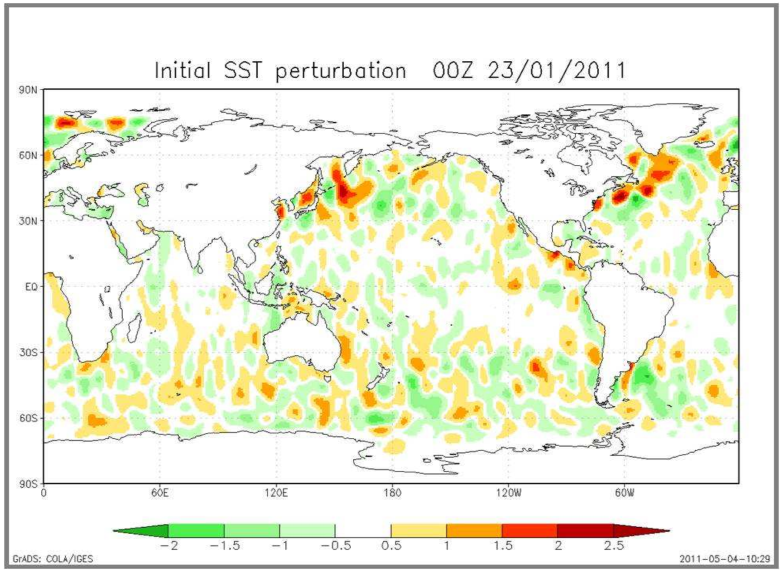
- Met Office stochastic physics from perturbed parameter choices
- Includes variations to:
  - Charnock coefficient
  - Neutral mixing length
  - Stability functions in stable boundary layer
- Scheme as a whole improves spread-skill relationship in MOGREPS
- But not clear to what extent this comes from the boundary layer parameters

Uncertainty in surface characteristics

- MOGREPS under-dispersive for near-surafce variables like 2m T and 10m wind
- SST and soil-moisture perturbations increase spread with no impact on skill

  (Tennant and S. Beare 2011)





Summary

- Spatial-average $\neq$ ensemble-average for $l \sim \Delta$
- Which one do we actually want?
- If spatial average wanted, will contain stochastic fluctuations
- These are an intrinsic aspect of the dynamics
- Uncertainties due to unresolved terrain features, unknown surface properties, unknown parameters
- Can also be treated with stochastic approach but are separate issues