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"Cumulus Parameterization"

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Please note: These are preliminary notes intended for internal distribution only.

Cumulus Parameterization

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1. Scales of meteorological phenomena and numerical model resolution

Meteorological phenomena
synoptic scale
meso-scale, α(200-2000km), β(20-200km), γ (2-20km)
micro-scale, α(200m-2km), β(20m-200m), γ(<20m)

Scales in the synoptic and meso-scale primitive equation models
- Synoptic and meso-scales are resolvable with very high resolution.
- Scale representation in numerical models with inadequate resolution
  scales well represented in models
  scales inaccurately represented
  scales that are not represented
- Micro scales are unresolvable regardless of model resolution.
  convective element - latent heat release, cloud, precipitation
  turbulence - diffusion, surface flux
  unhomogeneity - surface conditions

2. Parameterization in the time integration of numerical models

Model fields, often referred to as the large scale fields, provide environmental conditions for occurrence, maintenance or intensification/decay of unresolvable phenomena.
Effects of unresolvable phenomena, which are parameterized in terms of large scale quantities, in turn, affect model fields.

Accuracy of parameterized effects depends on accuracy of model fields and accuracy of a parameterization scheme used.

3. Cumulus parameterization

large scale fields obtained from numerical models
T(z), r(z), u(z), v(z), p at the surface, the surface conditions, and quantities derived from these quantities (radiation, surface heat flux, etc.)

Views on the cumulus convection

View A: Moist convection occurs in the conditionally unstable atmosphere when the condition of the moisture field becomes favorable for convection.
As a result of convection, the profiles of the temperature and moisture are relaxed toward target profiles. [convective adjustment scheme]

Key words:
favorable: threshold relative humidity; buoyancy of a lifted parcel; or buoyancy of a hypothesized cloud.
relaxed: instantly or with a damping time.
target profile: prescribed profiles of temperature and moisture; profiles determined from the prescribed temperature lapse rate and relative humidity, using the energy budget constraint; or a neutral state for a hypothetical cloud.

View B: Cumulus convection results from a quick response of the atmosphere to the large-scale forcing when the latter works to produce the cause of convection.
By counteracting against the large scale forcing, i.e., the cumulus stabilization against the large-scale destabilization, the convection brings the cause of convection into statistical quasi-equilibrium. The convection effects depend on the composition of the convective mass flux, which is controlled by the above condition of quasi-equilibrium, and the behavior of each convective element. [convective mass flux closure scheme]

Key words:
cause of convection: production of the kinetic energy of the clouds, called the cloud work function; or the convective available potential energy.
large scale forcing: effects due to the horizontal and vertical motions of the large scale flow, the heating due to radiation, and effects due to surface heat flux.
statistical quasi-equilibrium: near cancellation of two opposing effects, i.e., very little time change in the cause of convection.
composition of the convective mass flux: cloud elements grouped by entrainment rate or mass flux; or subcloud scale updrafts grouped by mass fluxes. Composition of mass fluxes is determined so that a state of balance is maintained between the large scale forcing and the stabilizing effects due to convection.
behavior of a convective element: depends on microphysical processes in the element and the interaction of the element with the environment as well as with other elements.

View C: Cumulus convection is a manifestation of the large scale moisture convergence.
The hypothesized convection causes the warming and moistening of the air column. [large scale moisture convergence scheme]

Key words:
large scale convergence: boundary layer only or a deeper layer.
hypothesized convection: determines the height of convection and the convection effects at different levels in the air column. For example, warming and moistening may depend on the temperature and moisture profiles of the model and, possibly, on the large-scale dynamical conditions as well.

4. Topics related to the cumulus parameterization

convective element

entrainment

Impact on a large scale disturbance
- CISK (conditional instability of the second kind)
- WISHE (wind-induced surface heat exchange; evaporation-wind feedback)

5. Performance of a parameterization scheme

validity check
- diagnostic
- semi-prognostic
- prognostic
- comparison with cloud model
  - non-disturbed conditions, disturbed conditions, diurnal changes, climate

performance dependency on the model resolution
- optimum resolution
- performance at very high resolution

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