TOWARDS DEVELOPMENT OF A UNIFIED PARAMETERIZATION

Key Scientists : Krueger, Randall, Jung and Arakawa

" A necessary condition for the rational solution of forecasting problems is a sufficiently accurate knowledge of the laws according to which one state of the atmosphere develops from another. " – Vilhelm Bjerknes (1904)

- Numerical modeling of the atmosphere has been and *still is* a struggle for finding such laws.
- The proposed research will put the CMMAP at the front edge of that struggle.

MOTIVATION AND GOAL

The Q3D MMF will become a useful framework for climate modeling.

This does not mean we can totally abandon the parameterization approach, which has its own scientific merit as well as the practical merit.

- As the GCM grid size is refined, the Q3D MMF converges to a global CRM while simulating details.
  - The goal of unified parameterization is to achieve the convergence while staying with a simple conceptual framework.

When developed successfully, they will be almost perfect complements for all scales down to the cloud scale.

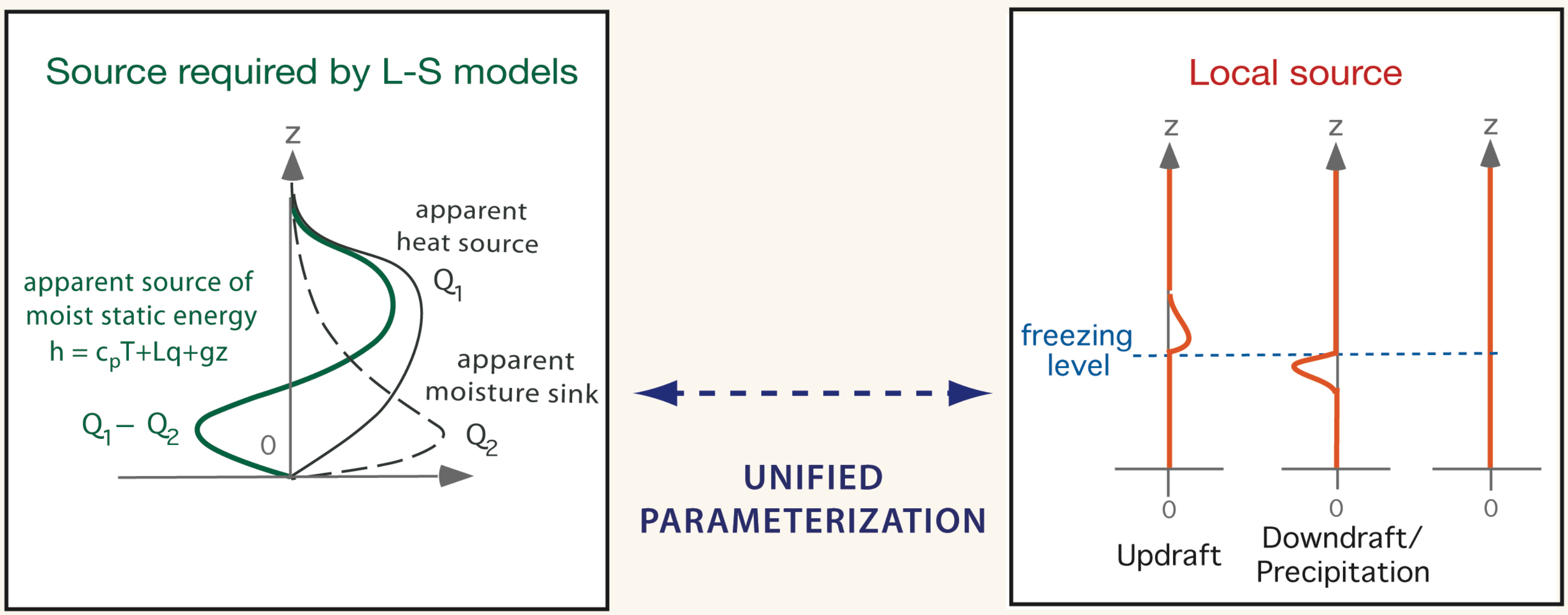
A FUNDAMENTAL PROBLEM EXISTING NOW

Currently, there are ***only two*** ways to represent deep clouds :

One ***highly parameterizes*** the cloud system (as in GCMs);

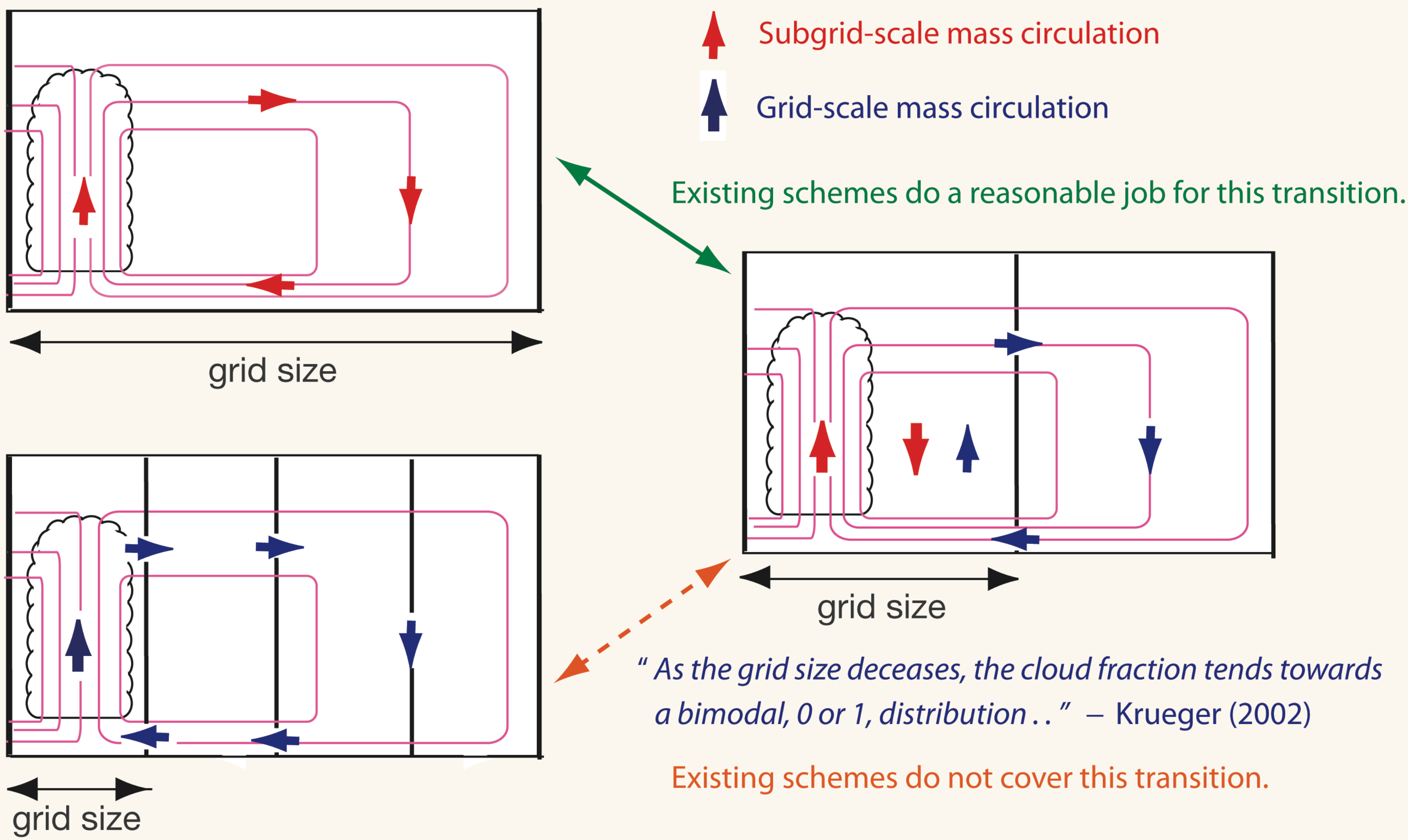
The other ***explicitly simulates*** individual clouds (as in CRMs).

MOIST STATIC ENERGY SOURCE DUE TO DEEP CONVECTION



Any statistical average of the three profiles in the right panel does NOT give the profile in the left panel.

ILLUSTRATION OF GRID-SCALE AND SUBGRID-SCALE MASS CIRCULATION



One of the first steps towards the unification will be

REFORMULATION OF AS (1974) OR ANY OTHER EXISTNG SCHEME

Elimination of the assumption $\sigma \ll 1$

σ : fractional area covered by *all* clouds in a grid box

Diagnose σ from $M_c = \sigma \rho w_c$

M_c : cumulus mass flux

w_c : cumulus vertical velocity

If $\sigma > 1$, reduce M_c in such a way that $\sigma = 1$.

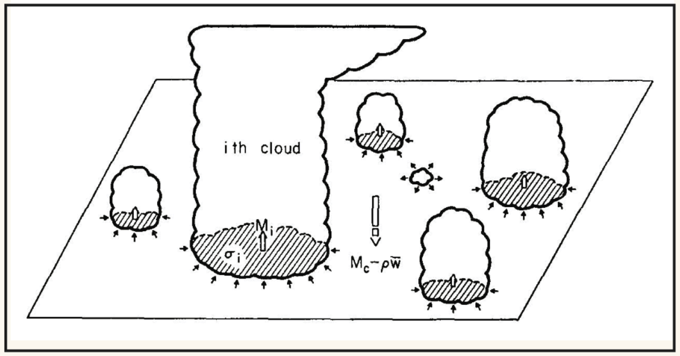
Reformulate the vertical eddy transport due to clouds in such a way that it vanishes as $\sigma \to 1$.

Details need to be figured out.

THERE ARE MORE THINGS TO STRUGGLE WITH

"Consider a horizontal area - large enough to contain an ensemble of cumulus clouds but small enough to cover a fraction of a large-scale disturbance."

– Arakawa & Schubert (1974) –



In reality, grid box is

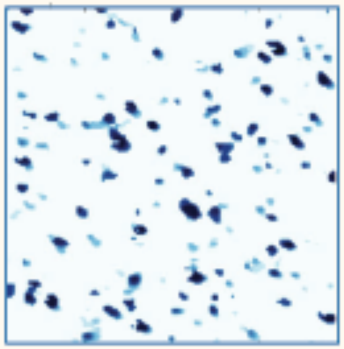
NOT large enough

⇒ Should include a stochastic component

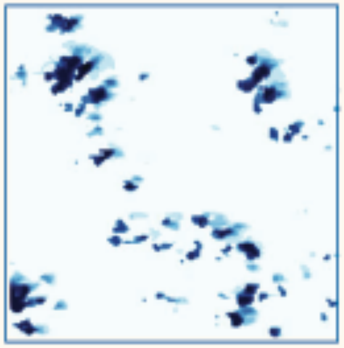
NOT small enough

⇒ Should not assume horizontally uniform cloud environment

Both require a knowledge of cloud organization. (it is needed for momentum transport anyway)



where in-between ?



Probably we should introduce
a prognostic variable
for the degree of cloud organization
as in Mapes 2009.

(e.g., prediction of kinetic energy,
as in Pan & Randall 1998, but
horizontal and vertical components separately.)

ANALYSIS 0F SIMULATED DATA TO GUIDE UNIFIED PARAMETERIZATION

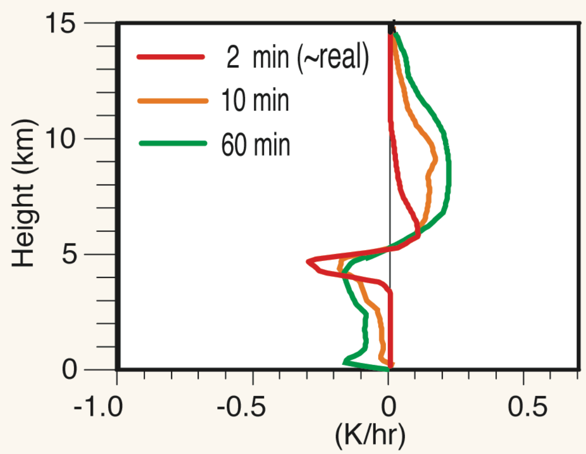
- Developing unified parameterization is very challenging, requiring multiple approaches, including data analysis.
- The required data must be very comprehensive, covering the almost continuous space-time spectrum of many coupled variables.
- There is a little hope that observations can meet these requirements, but data simulated by CRMs and LES (Large Eddy Smulation) can.

Analysis of 2D CRM results by Jung and Arakawa (2004)

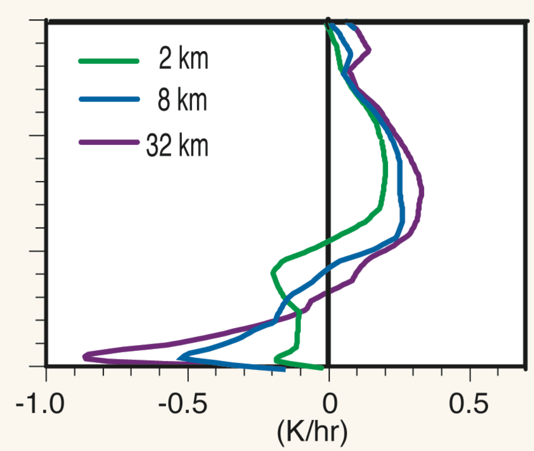
Basically budget analyses applied to various sizes of time/spacee intervals with and without cloud microphysics .

"*Required* Cloud-Microphysical Source" of Moist Static Energy

Physics time interval dependence with 2 km horizontal resolution



Horizontal resolution dependence with 60 min physics time interval



Approach I : Guide unification of the GCM physics and the CRM physics through an analysis of CRM data following the method used by Jung and Arakawa (2004), Budget analysis should include that of momentum, vorticity and kinetic energy.

Approach II : Guide unification of the CRM physics and the LES physics through an analysis of LES data for a relatively small domain.

Approach III : Obtain a broad coherent view of the multi-scale transitions from the GCM physics all the way to the LES physics through an analysis of LES data for a large domain.

> *" The problem is of huge dimensions. Its solution can only be the result of a long development. . . . I am convinced that it is not too soon to consider this problem as the objective of our researches."* – Vilhelm Bjerknes (1914)