UNIFIED PARAMETRIZATION

– MORE DIAGNOSTICS AND INTERPRETATIONS –

A. Arakawa[1] **and C.-M. Wu**[2]

1 *University of California, Los Angeles*

2 *National Taiwan University*

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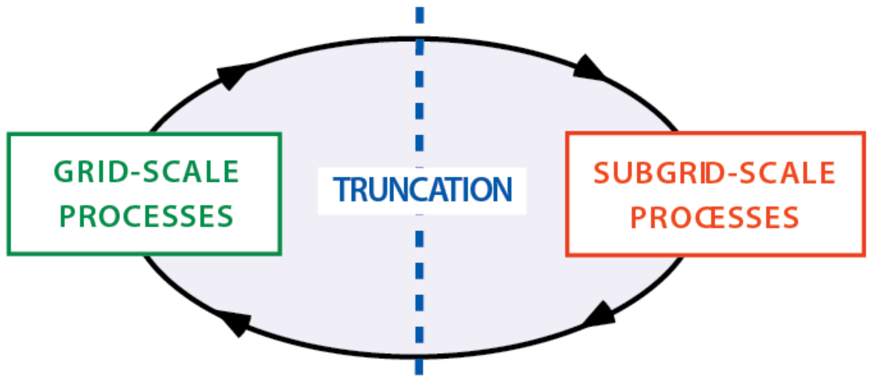
THE PARAMETERIZATION PROBLEM IN NUMERICAL MODELING

The need for parameterization arises from the *artificial* truncation of atmospheric processes.



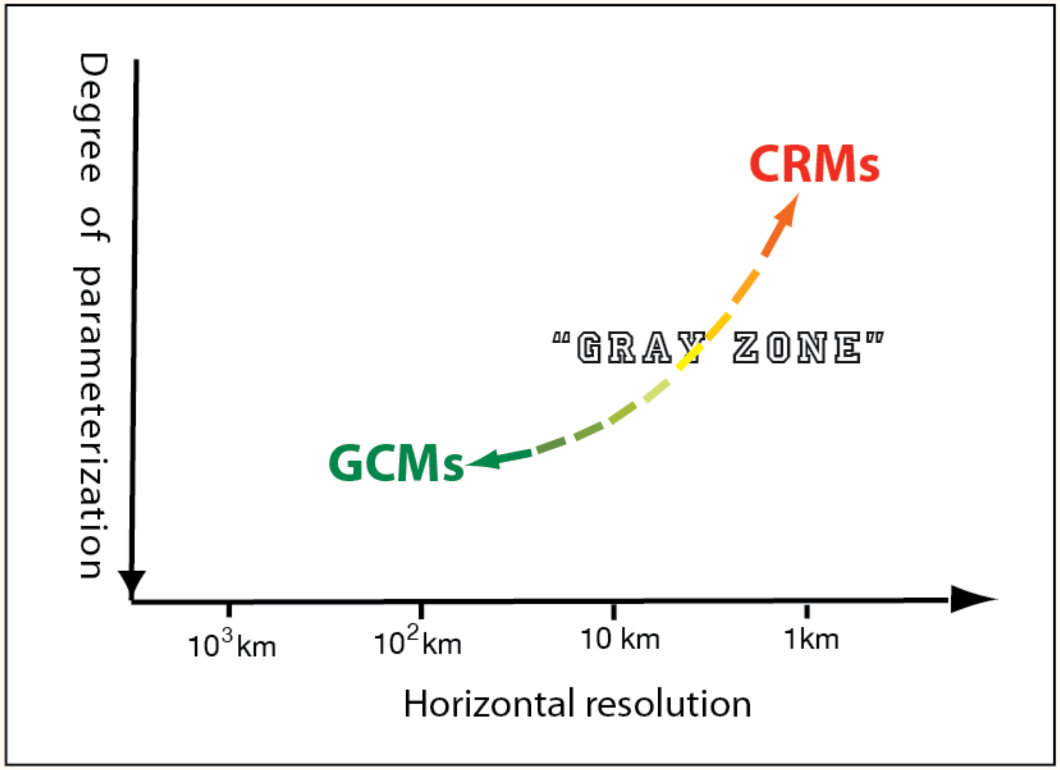
Parameterization in numerical modeling is an inherently resolution-dependent problem.

UNIFIED PARAMETERIZATION

– An attempt to break through the "GRAY ZONE" –

Deep convection *explicitly simulated*

Deep convection *highly parameterized*



JOINT USE OF PARAMETERIZATION AND EXPLICIT PREDICTION

- In mesoscale modeling, the importance of jointly using parameterization and explicit prediction of hydrometeors has been well recognized :

  e.g.,

  Full physics approach (Zhang et al. 1988)

  Hybrid approach (Molinari and Dudek 1992)

  Cascading approach (Gerard 2007)

- Approaches similar to these are now often taken even in GCMs for selected species of hydrometeors.

Resolution-dependent formulation of the subgrid dynamical response to cloud microphysics remains challenging.

TWO CRM SIMULATIONS USED IN THIS STUDY

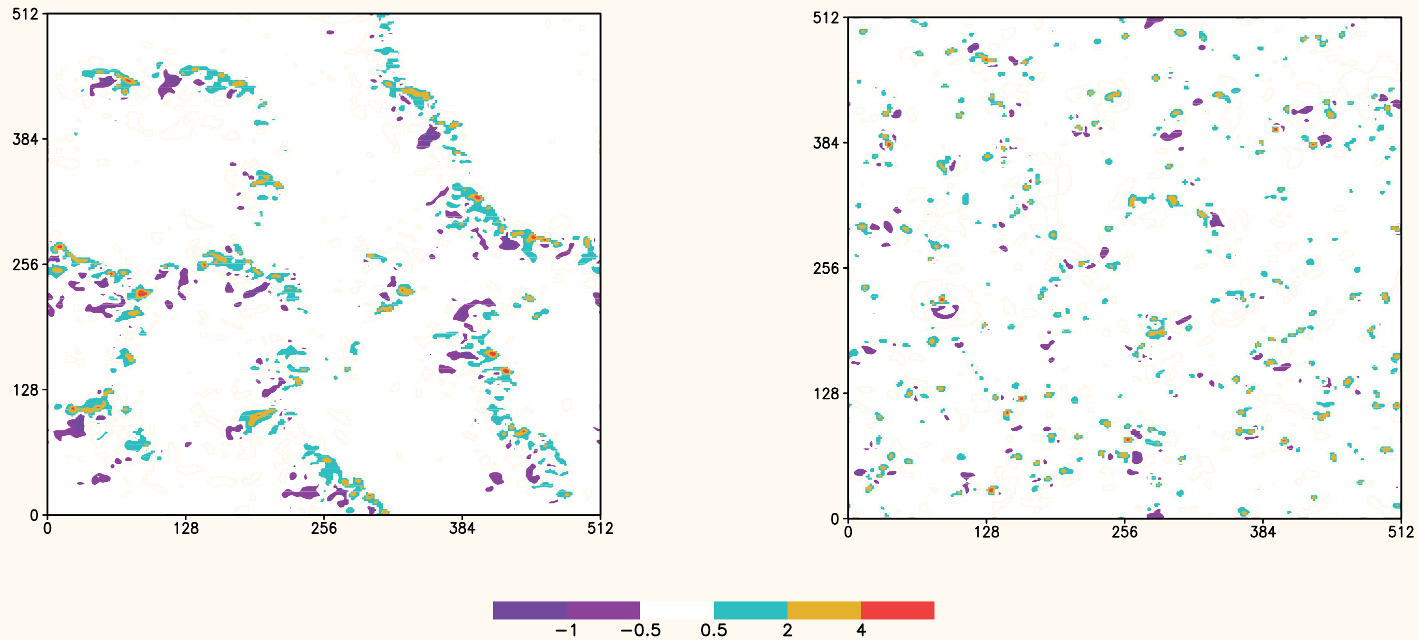
Model : The vorticity equation model of Jung and Arakawa (2008)

Horizontal domain size : 512 km   Horizontal grid size : 2km

Data used : last 2 or 12 hrs of two 24-hr simulations with 20-min intervals

Snapshots of vertical velocity w at 3 km height

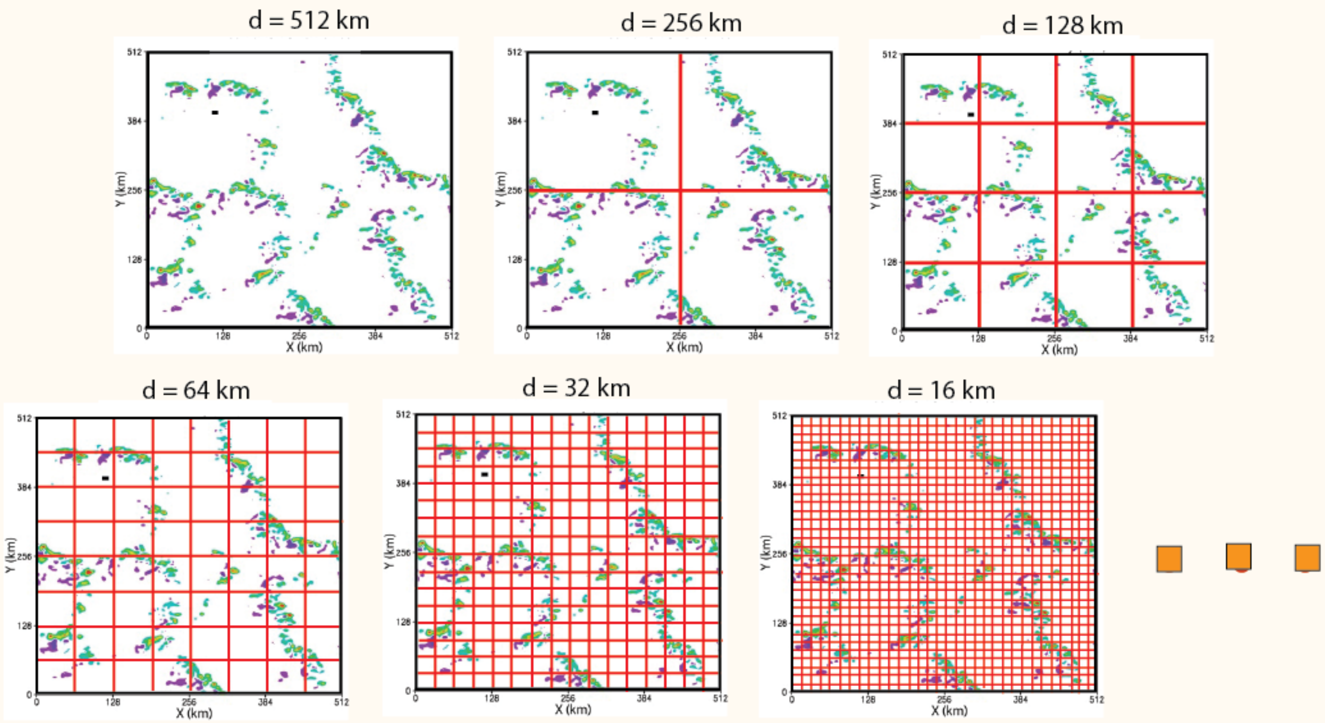
With Shear   Without Shear



ANALYSIS OF THE RESOLUTION-DEPENDENT STATISTICS OF THE CRM–SIMULATED DATA

The original domain (512 km) used for CRM simulations is divided into sub-domains of same size.

Examples

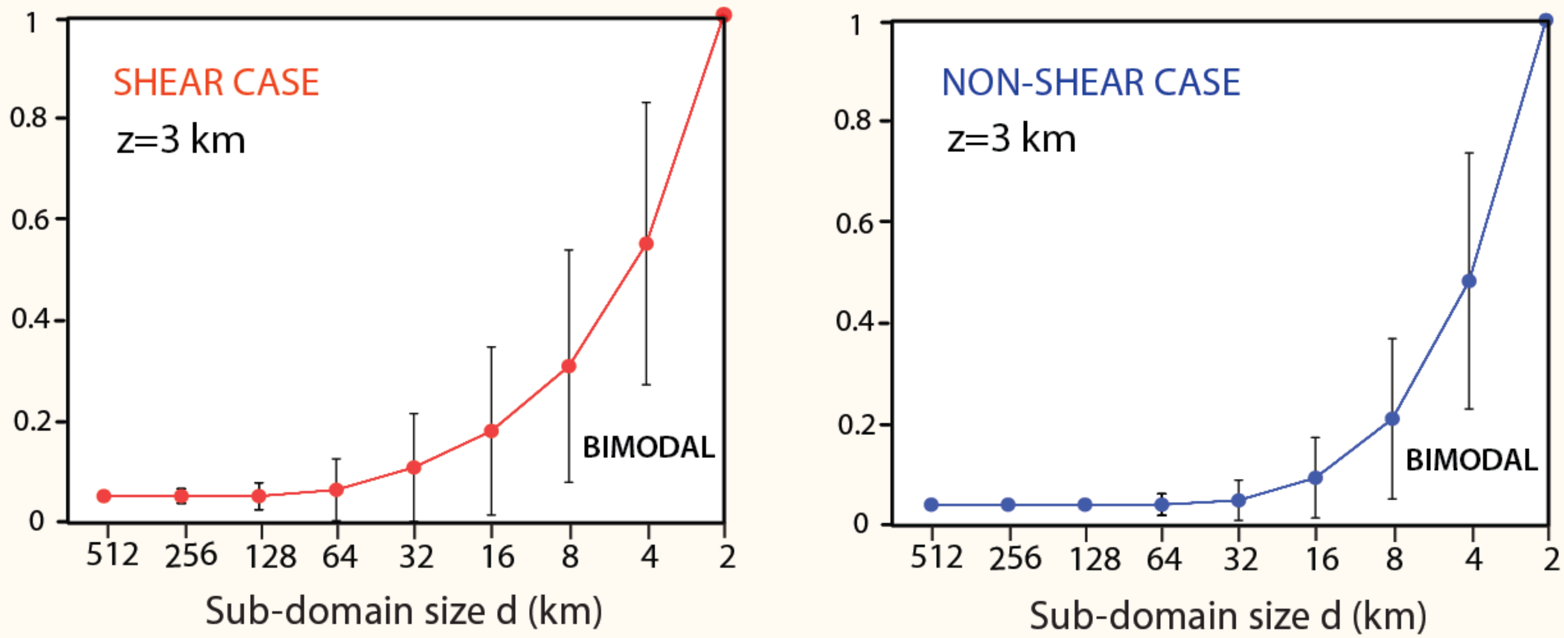


The size of subdomains is interpreted as the GCM grid size.

FRACTIONAL AREA COVERD BY CONVECTVE UPDRAFTS, σ

Measured by the fractional number of grid points in a sub-domain that satisfy w>0.5 m/s.

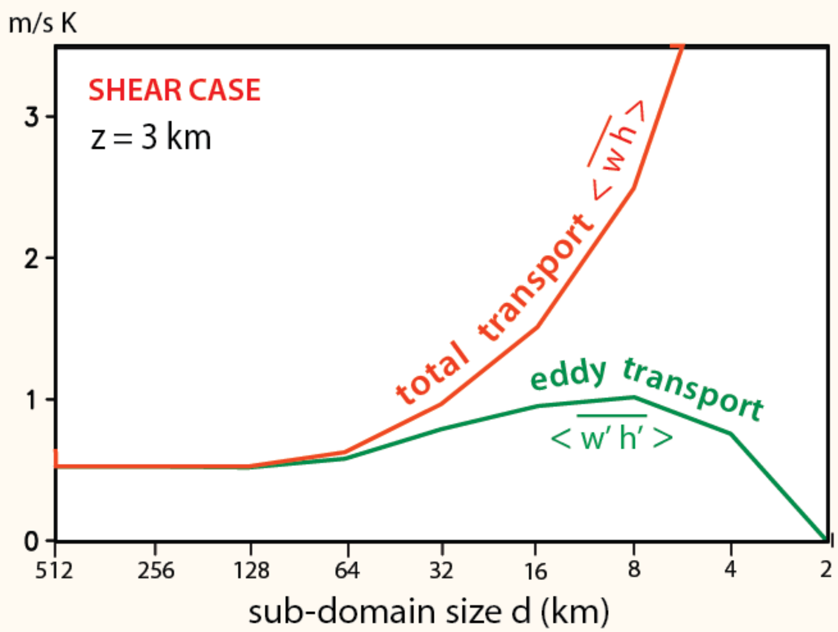
Ensemble average of σ over all sub-domains wth σ > 0



σ<<1 can be a good approximation ONLY for low resolutions.

RESOLUTION DEPENDENCE OF

ENSEMBLE-AVERAGE VERTICAL TRANSPORT OF MOIST STATIC ENERGY



h : Deviation of moist static energy from a reference state

$\overline{(\ )}$: Average over all grid points in the sub-domain

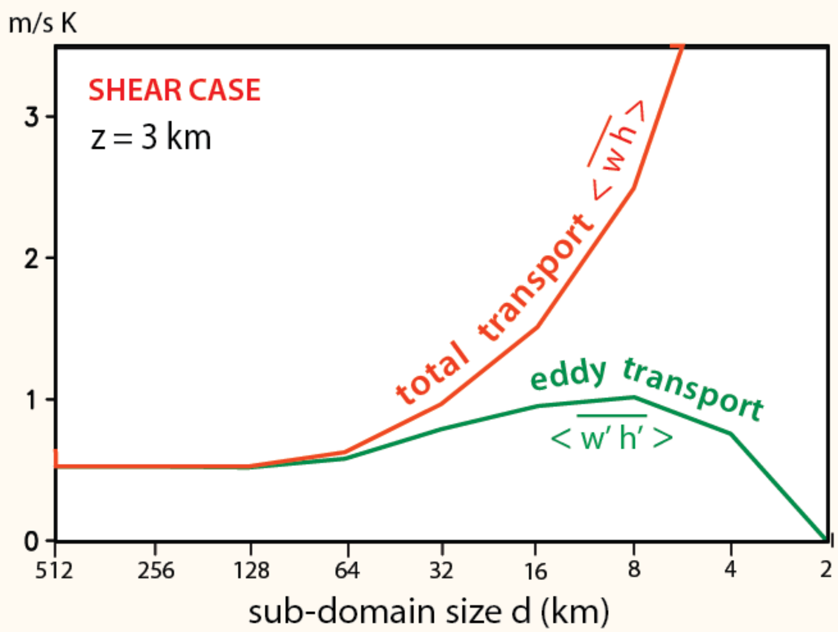
< > : Ensemble average over all sub-domains with $\sigma > 0$.

$(\ )'$: $(\ ) - \overline{(\ )}$

As the resolution increases, the total transport tends to increase while the eddy transport for small d tends to decreease.

RESOLUTION DEPENDENCE OF

ENSEMBLE-AVERAGE VERTICAL TRANSPORT OF MOIST STATIC ENERGY



h : Deviation of moist static energy from a reference state

$\overline{(\ )}$: Average over all grid points in the sub-domain

$\langle\ \rangle$: Ensemble average over all sub-domains with $\sigma > 0$.

$(\ )' : (\ ) - \overline{(\ )}$

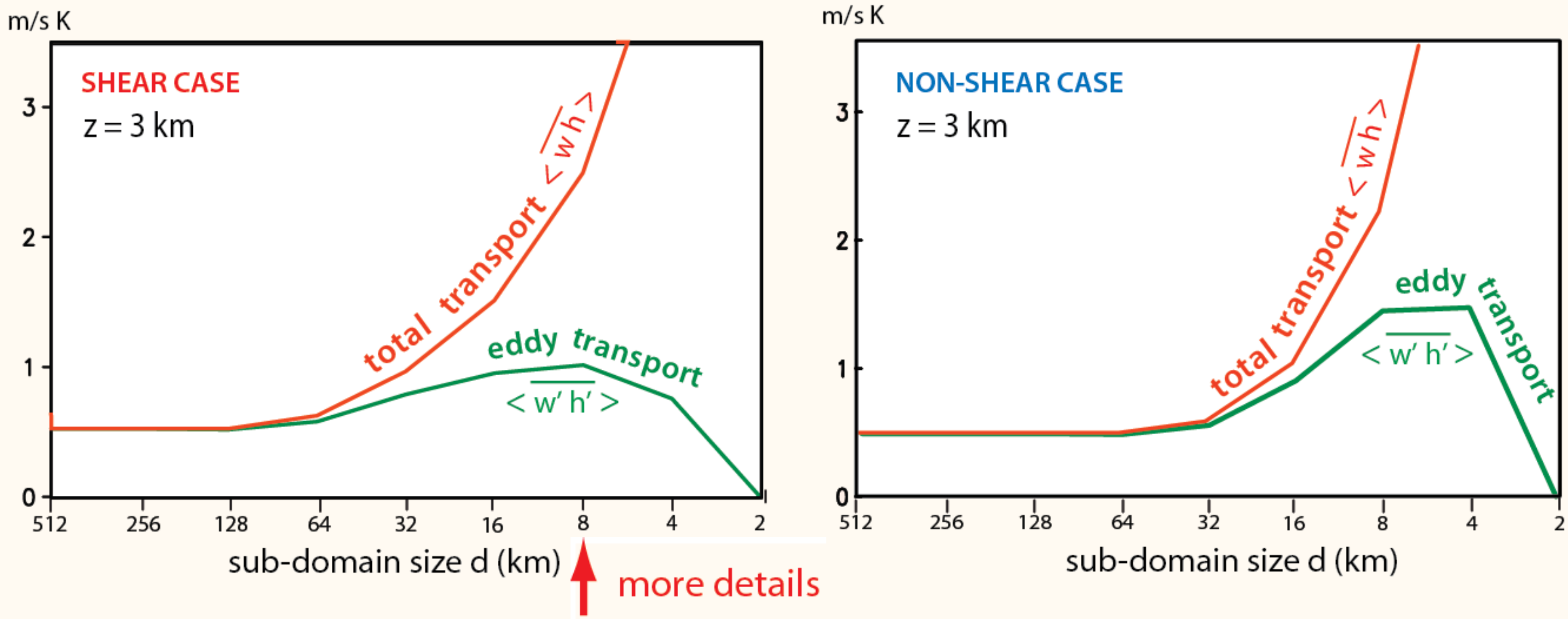
IMPORTANT !

Parameterization is a formulation of the eddy transport,

NOT that of the total transport.

RESOLUTION DEPENDENCE OF

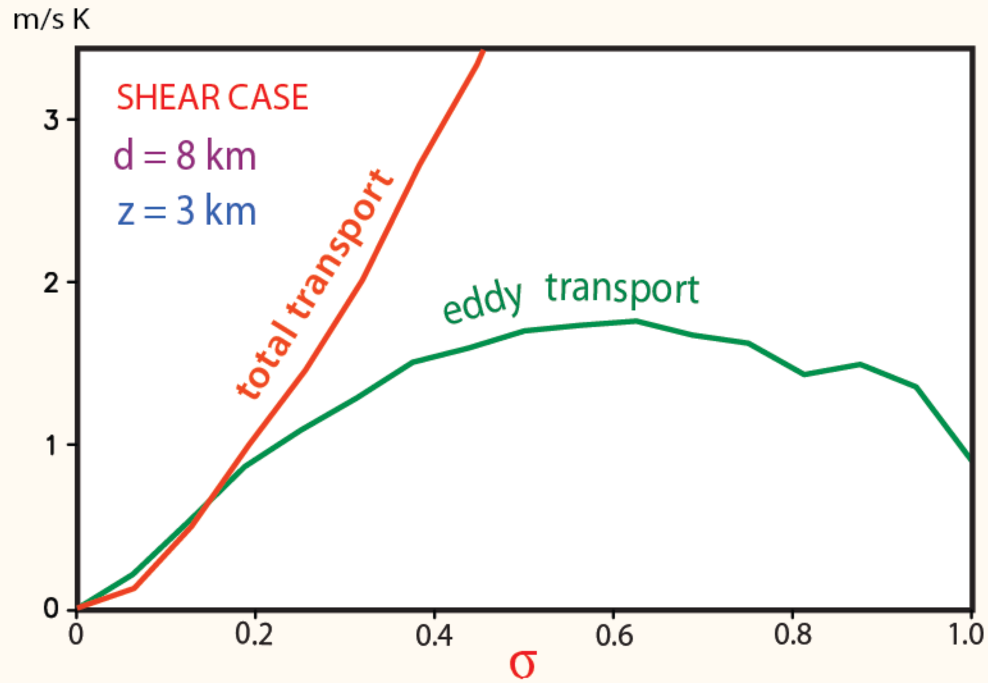
ENSEMBLE-AVERAGE VERTICAL TRANSPORT OF MOIST STATIC ENERGY



There is no qualitative differene between the shear and non-shear cases.

THE σ–DEPENDENCE OF

ENSEMBLE-AVERAGE VERTICAL TRANSPORT OF MOIST STATIC ENERGY



Even with the same resolution,

the relative importance of eddy transport strongly depends on σ.

VERTICAL EDDY TRANSPORT

BY HOMOGENEOUS CLOUDS/ENVIRONMENT

Most conventional parameterizations assume that clouds and the environment are horizontally homogeneous.

Continue to use this assumption to start with.

For a thermodynamic variable ψ, we can derive

$$\overline{w'\psi'} = \sigma(1-\sigma)\Delta w\,\Delta\psi$$

$\Delta(\ )$: cloud-environment difference

If $\Delta w\,\Delta\psi$ is independent of σ,

the σ-dependence of $\overline{w'\psi'}$ is through $\sigma(1-\sigma)$.

SIMULATED VERTICAL EDDY TRANSPORT

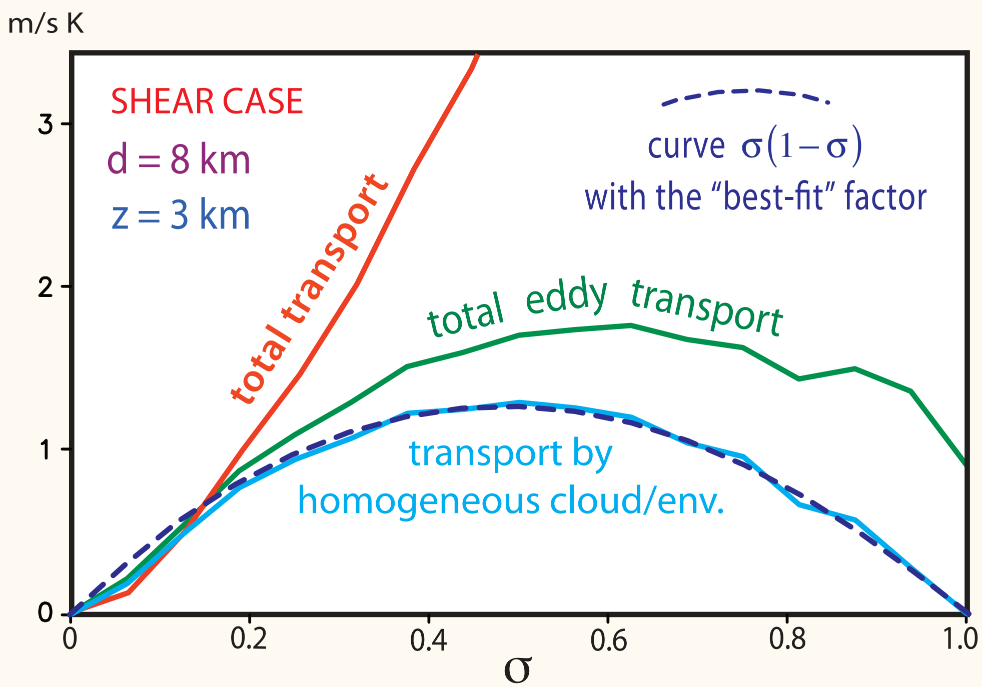
BY HOMOGENEOUS CLOUDS/ENVIRONMENT

For each sub-domain,

replace all w_c with $\overline{w_c}$,

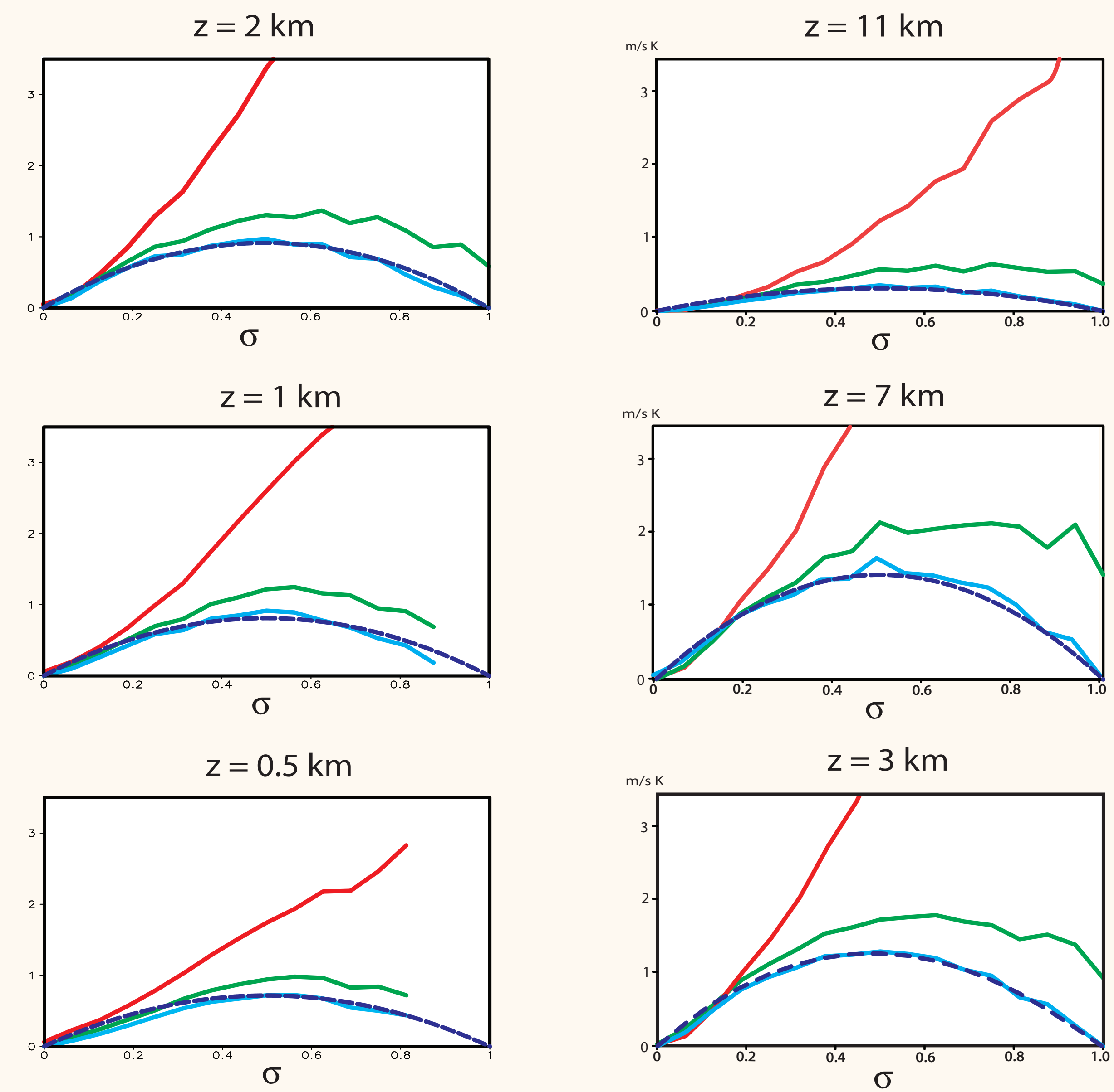
replace all h_c with $\overline{h_c}$,

the same for the environment.

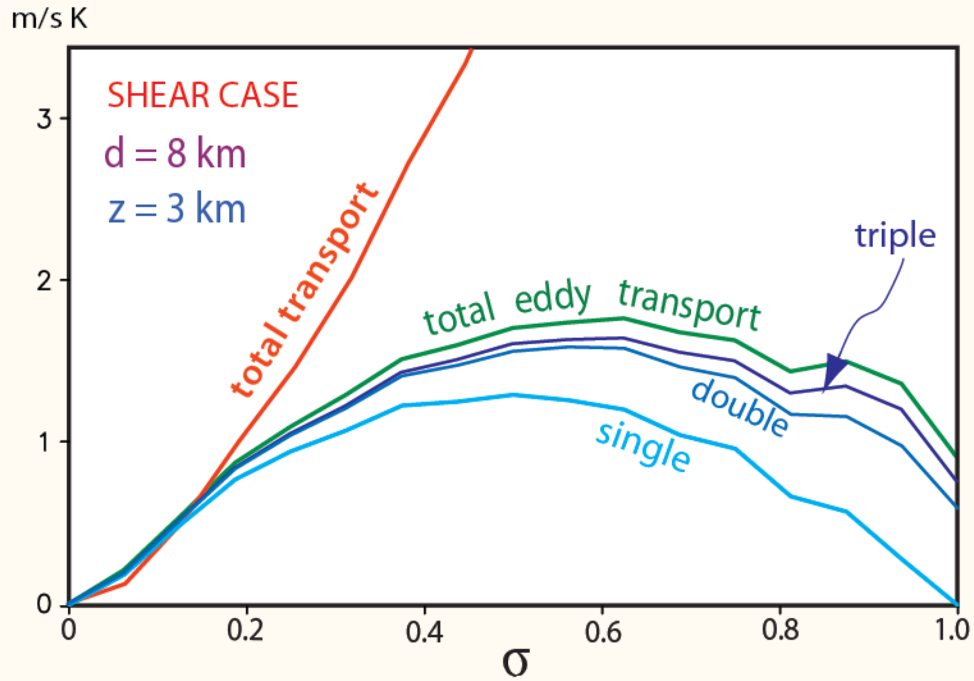


The dependence on σ through $\sigma(1-\sigma)$ is well supported.

COMPARISONS OF EDDY TRANSPORT OF h AT DIFFERENT LEVELS



THE EFFECT OF MULTIPLE CLOUD-STRUCTURE / CLOUD-TYPE



single

0.5 m/s < w

double

0.5 m/s < w < 2 m/s

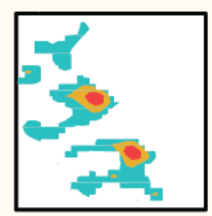
2 m/s < w

triple

0.5 m/s < w < 2 m/s

2 m/s < w < 4 m/s

4 m/s < w



CLOSURE ASSUMPTION

CONVENTIONAL ADJUSTMENT SCHEMES

Determine cloud properties w_c^* and h_c^* assuming that grid-point values represent the environment (i.e., $\sigma << 1$)

Estimate the transport $\left(\overline{wh}\right)_{adj}$ required for the adjustment to a neutral state.

↓

Assume that the eddy transport estimated with $\sigma << 1$ is totally responsible for the adjustment.

To be consistent,

$$\sigma = \frac{\left(\overline{wh}\right)_{adj}}{\left(w_c^* - \overline{w}\right)\left(h_c^* - \overline{h}\right)}$$

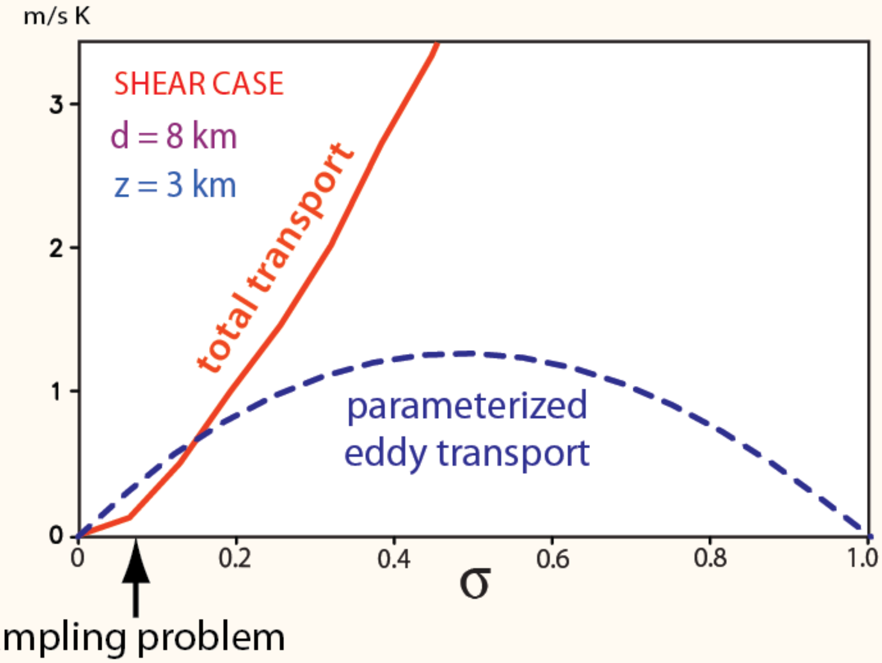
Not used, but self-contradictory because $\sigma << 1$ does not hold for large $\left(\overline{wh}\right)_{adj}$.

CLOSURE ASSUMPTION

UNIFIED PARAMETERIZATION (SINGLE CLOUD TYPE)

- When σ is larger, $w_c - \overline{w}$ and $h_c - \overline{h}$ are smaller.
- Then the magnitude of the eddy transport is limited.

→ **Relaxed adjustment**



We choose

$$\sigma = \frac{\left(\overline{wh}\right)_{adj}}{\left(\overline{wh}\right)_{adj} + \left(w_c^* - \overline{w}\right)\left(h_c^* - \overline{h}\right)}$$

This σ automatically satisfies $0 \le \sigma \le 1$ including $\sigma \to 1$ as $\left(\overline{wh}\right)_{adj} \to \infty$.

SPECTRAL REPRESENTATION OF CLOUDS

Suppose that we use w at cloud base to classify cloud types (as in Chikira 2010).

We can drive

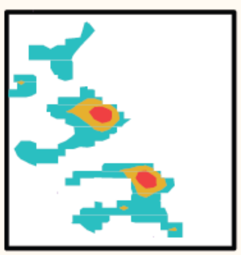
$$\overline{w'\psi'} = \sum_i (\Delta w_i \Delta \psi_i)\, \sigma_i - \sum_i \Delta w_i\, \sigma_i \sum_i \Delta \psi_i\, \sigma_i$$

A generalization of $\overline{w'\psi'} = \sigma(1-\sigma)\Delta w\, \Delta\psi$

Δ : cloud-env. difference

i : cloud type

We have to consider possible overlap of clouds.



internal structure

is more likely than

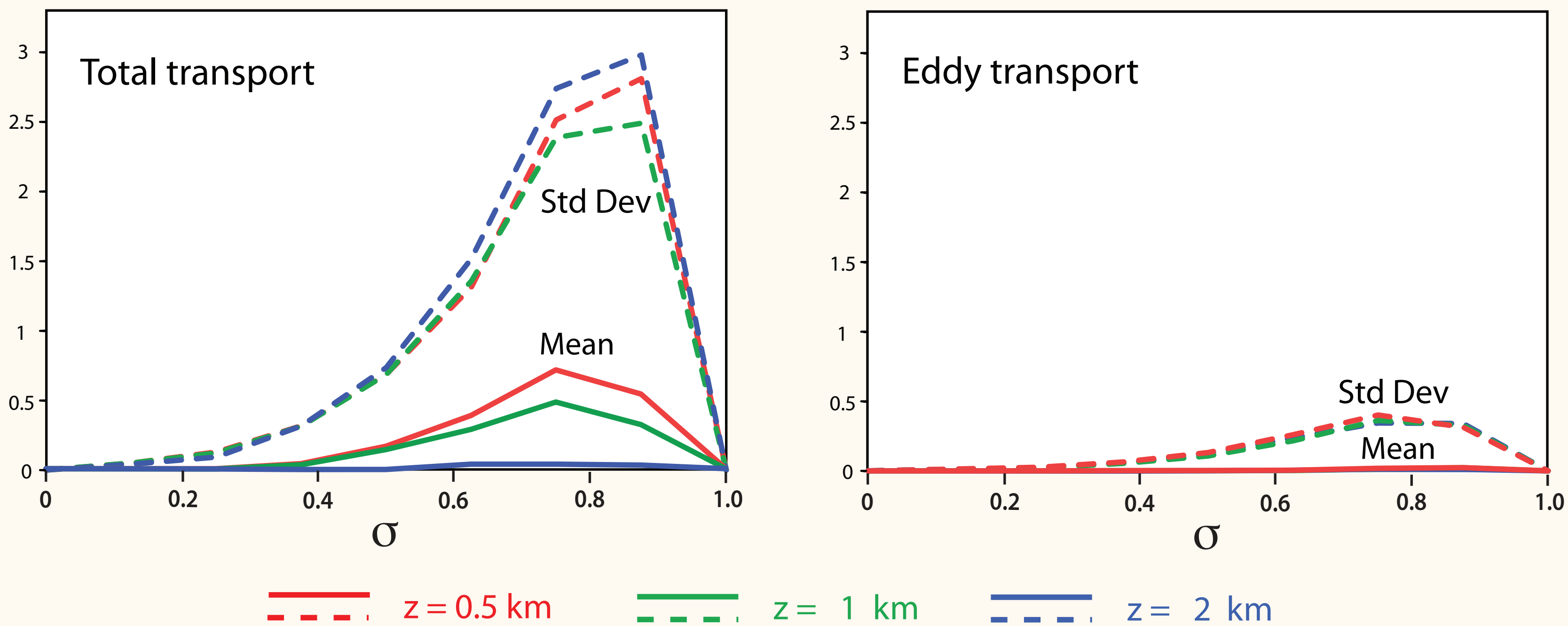
different cloud types

The problem of cloud organization

A challenge !

DIVERGENCE OF THE HORIZONTAL TRANSPORT OF h

Shear case d= 8 km



Divrgence of the eddy transport is much smaller than
that of the total transport in both means and standard deviations.

SUMMARY AND CONCLUSIONS

The unified parameterization (UP) *generalizes* conventional parameterization including the transition to explicit simulation of cloud processes.

UP eliminates the assumption of $\sigma << 1$, distinguishing the cloud environment from the grid-cell mean.

Eddy transport in UP decreases as $\sigma \rightarrow 1$ and, therefore, the adjustment to a neutral state is relaxed for large σ.

UP determines σ for each realization.

Outstanding problems in conventional parameterization (e.g., determination of cloud properties, cloud spectrum, cloud organization, . . .) remain important in UP.