THE UNIFIED PARAMETERIZATION

– NEW DIAGNOSTIC RESULTS –

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- Introduction
- Vertical structure of eddy transports
- Physical sources and sinks
- Momentum transports
- . . . . . .

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OBJECTIVE OF THE UNIFIED PARAMETERIZATION

Unification of the model physics of GCMs and CRMs

through *generalizing* conventional cumulus parameterizaion

THE KEY PARAMETER IN THE UNIFIECATION

σ : Fractional area covered by updrafts

Conventional cumulus parameterizations regard the given grid-point values as if they represent the cloud environment.

This implicitly assumes $\sigma << 1$.

The unified parameterization eliminates this assumption from the beginning.

CRM SIMULATIONS USED

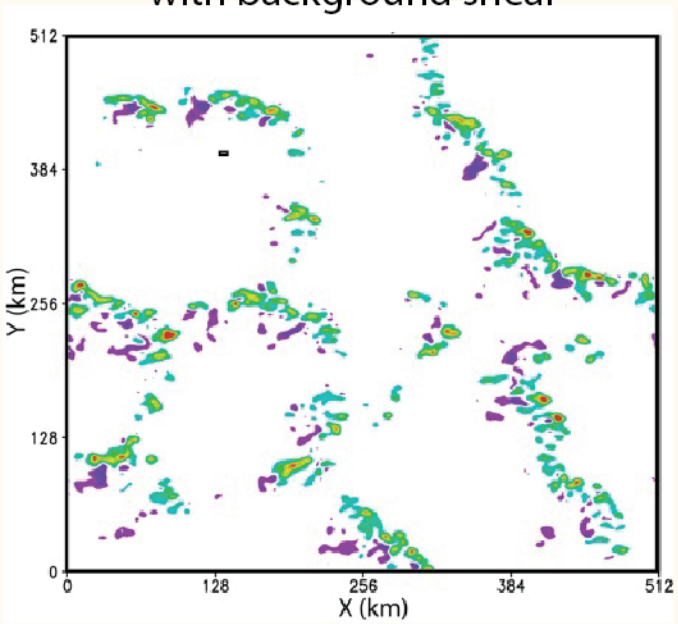
Dynamics: VVM (Jung and Arakawa 2008)

Clooud microphysics: Krueger et al. (1995)

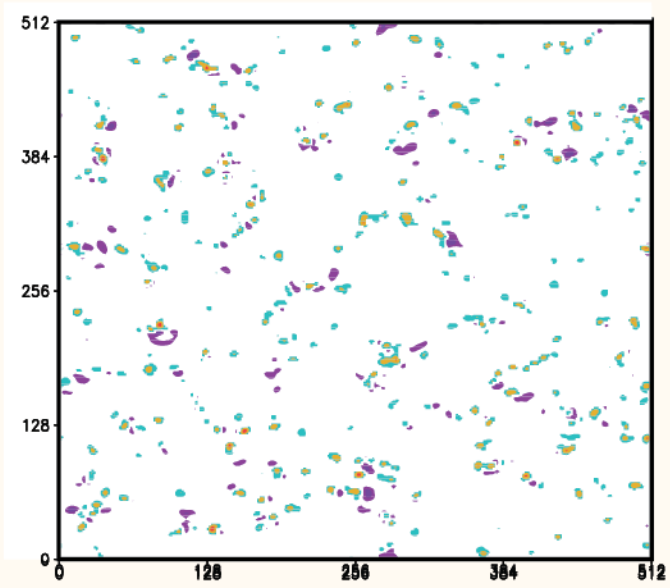
Horizontal domain size : 512 km Horizontal grid size : 2km

Snapshots of w at z=3 km

with background shear



without background shear

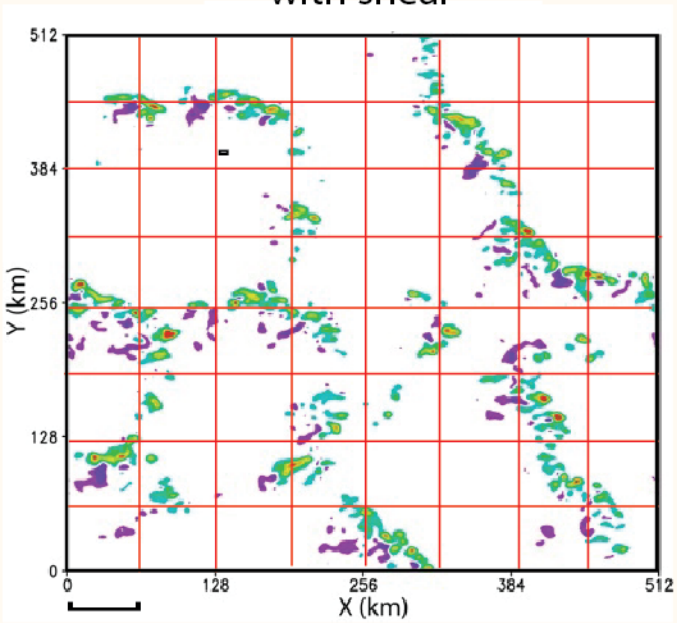


INTRODUCTION OF SUBDOMAINS

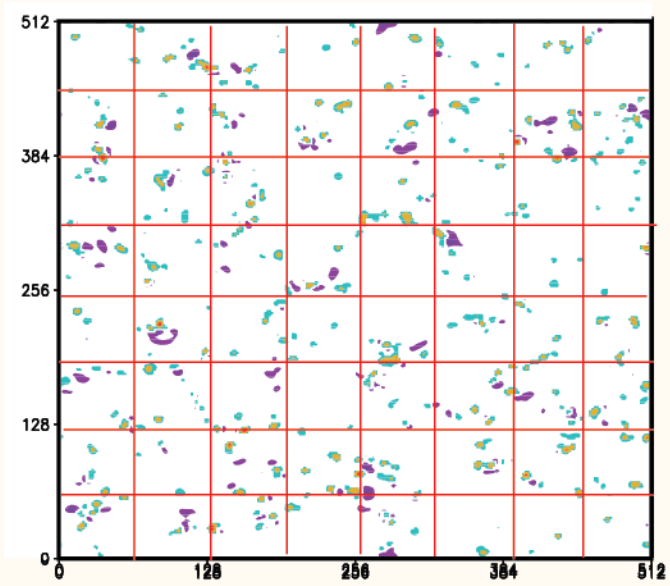
FOR DIAGNOSING RESOLUTION-DEPENDENT STATISTICS

An example

with shear



without shear



d :

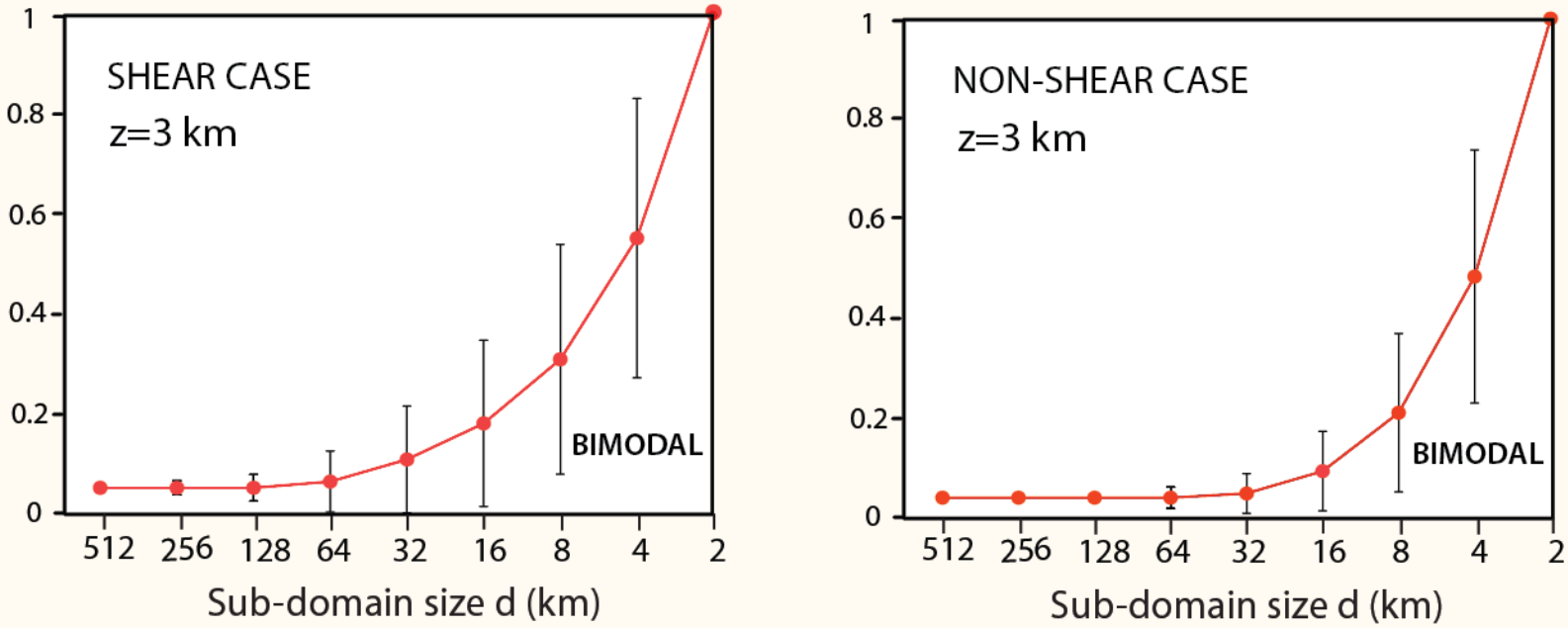
Subdomain size
(representing GCM grid size)

RESOLUTION DEPENDENCE OF ENSEMBLE-AVERAGE σ

σ: The fractional number of grid points with w>0.5 m/s in a sub-domain

< > : Average over an ensemble of cloud-containing (i.e., σ > 0) sub-domains

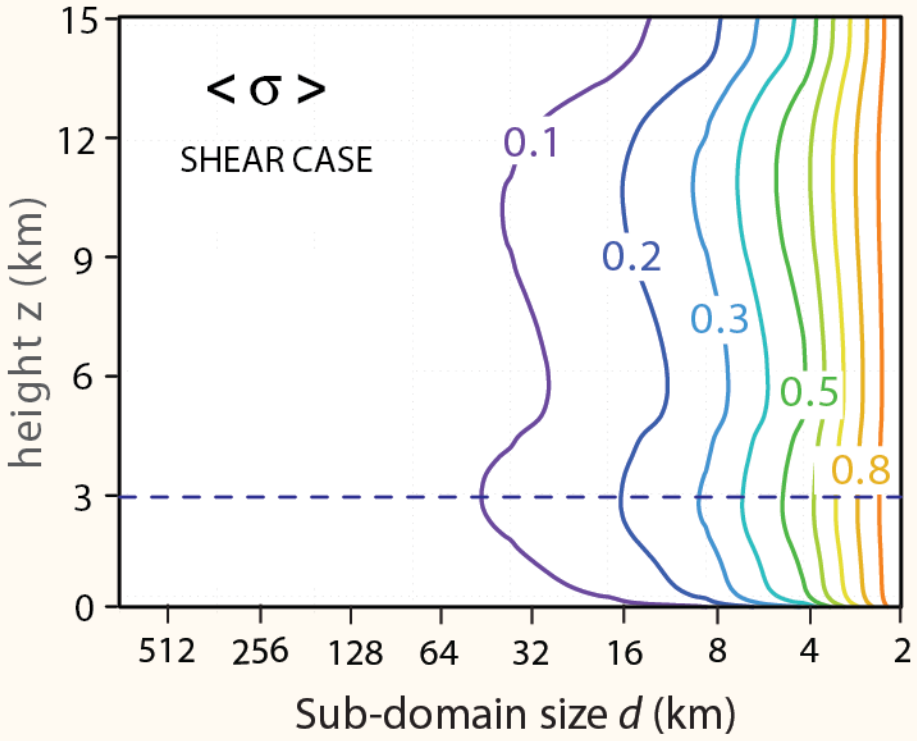
$< \sigma >$



The assumption σ<<*1 is valid only for low resolutions.*

RESOLUTION DEPENDENCE OF ENSEMBLE-AVERAGE σ

VERTICAL DISTRIBUTION



Situation is similar at all levels.

REMINDER:

THE OBJECTIVE OF CUMULUS PARAMETERIZATION

- Cumulus parameterization is supposed to represent the subgrid effects of cumulus convection, NOT its total effect .

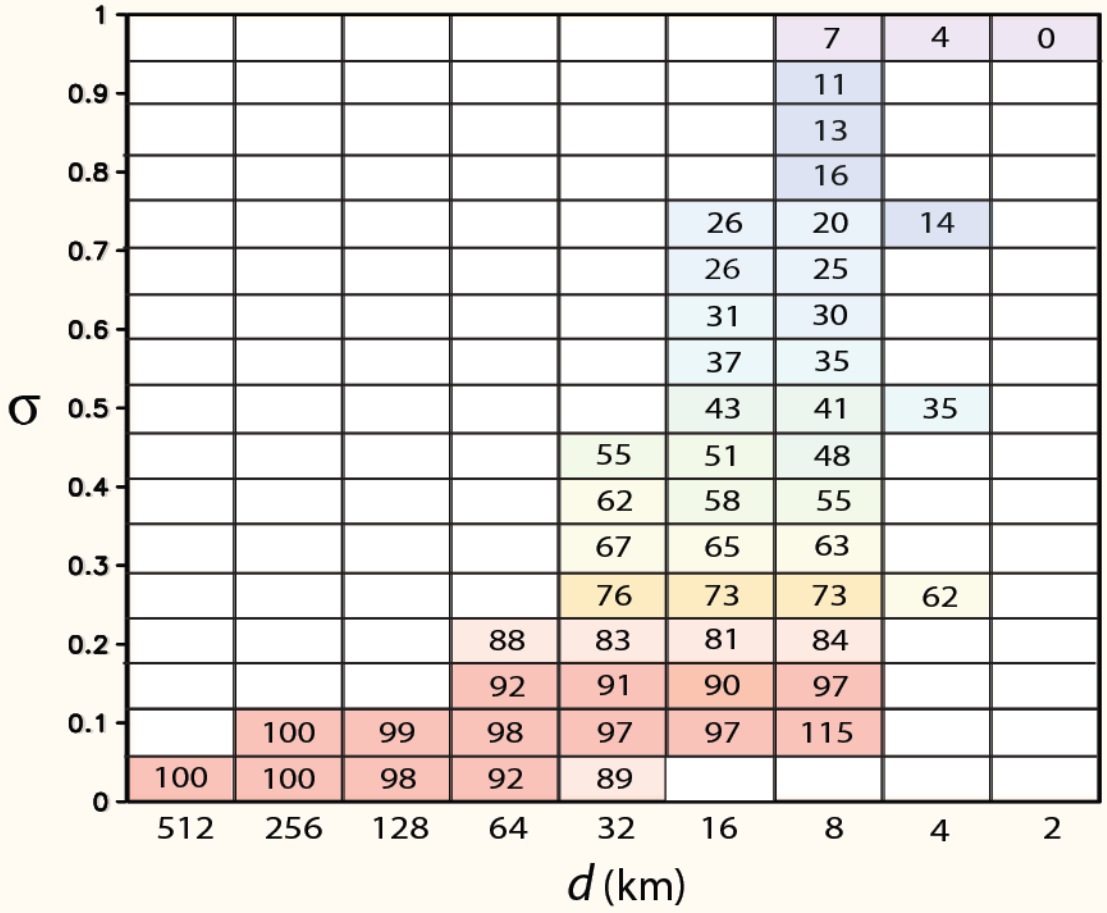
  For the vertical transport, what needs to be parameterized is the eddy transport, NOT the total transport.

- If the parameterization does more than its job, double counting or spurious stabilization of grid-scale fluctuations may occur.

EDDY TRANSPORT vs. TOTAL TRANSPORT

FOR MOIST STATIC ENERGY

$<\overline{w'h'}>/<\overline{wh}>$ (%) SHEAR CASE z=3 km



h : Deviation of moist static energy from a reference state

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

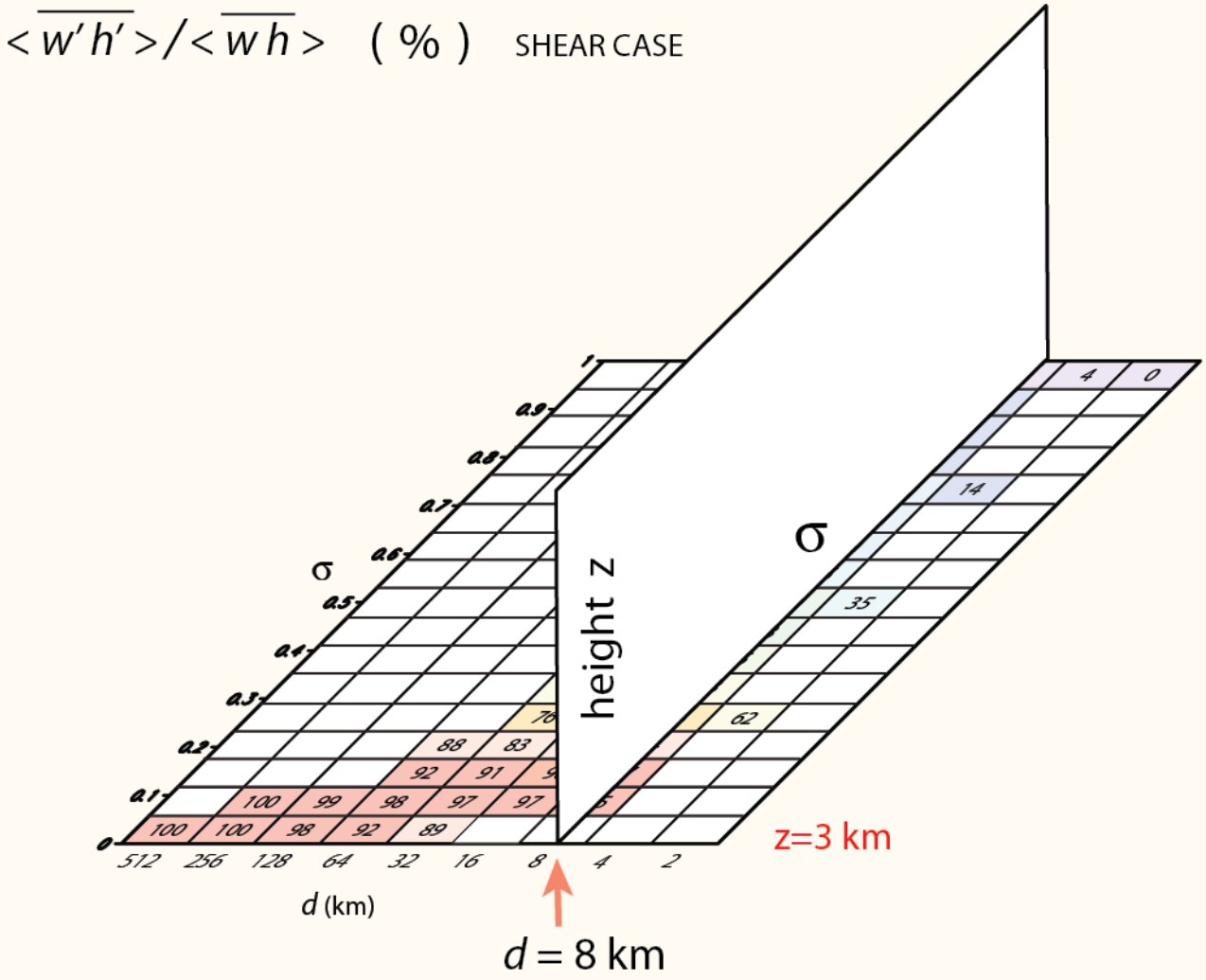
$(\ )' : (\ ) - \overline{(\ )}$

$< > :$ Ensemble average over updraft-containing ($\sigma > 0$) subdomains

The ratio depends on σ rather than d.

EDDY TRANSPORT vs. TOTAL TRANSPORT

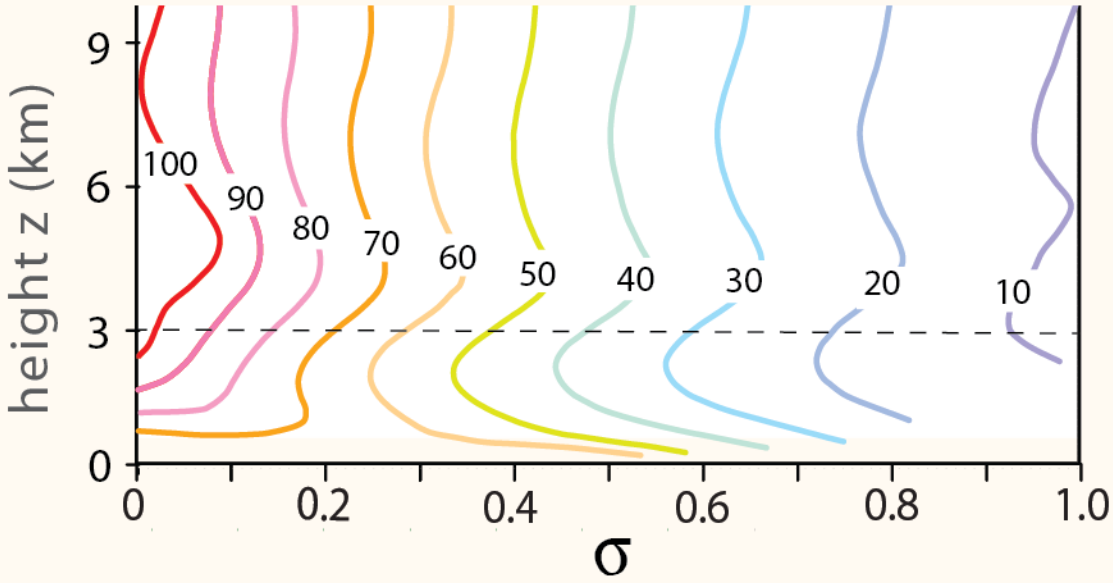
FOR MOIST STATIC ENERGY



EDDY TRANSPORT vs. TOTAL TRANSPORT

FOR MOIST STATIC ENERGY

$< \overline{w'h'} > / < \overline{wh} >$ (%) SHEAR CASE d = 8 km

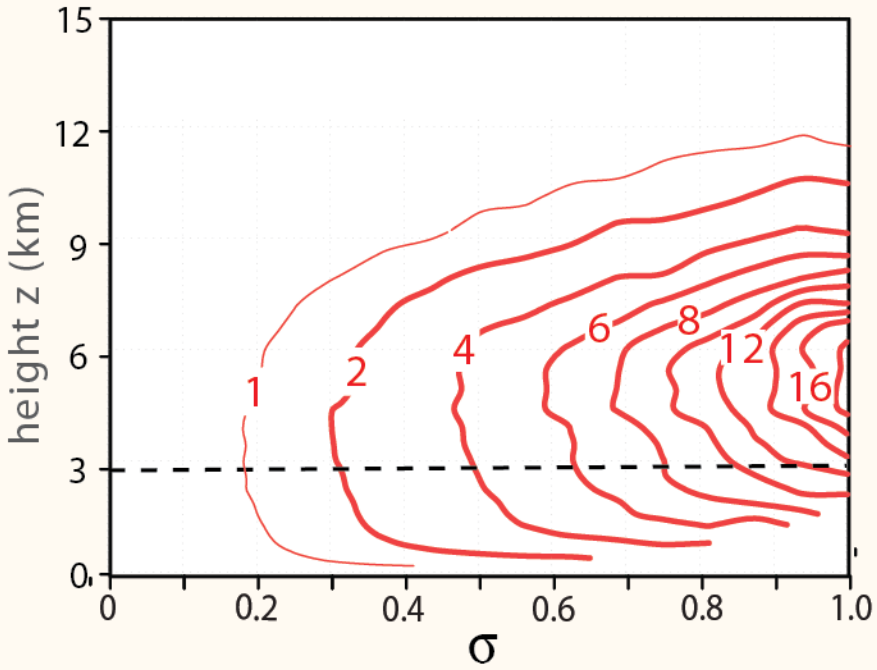


The σ-dependence is similar at all levels.

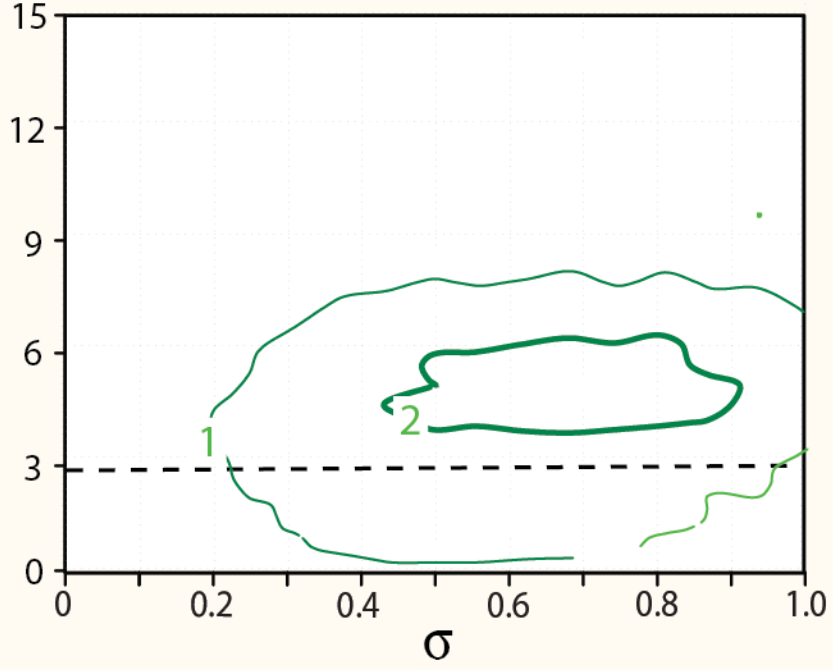
σ–DEPENDENCE OF THE VERTICAL TRANSPORT OF *h*

SHEAR CASE d = 8 km $\rho^* = \rho / \rho_{z=3\ km}$

Total transport $\rho^* < \overline{w\,h} >$



Eddy transport $\rho^* < \overline{w'\,h'} >$



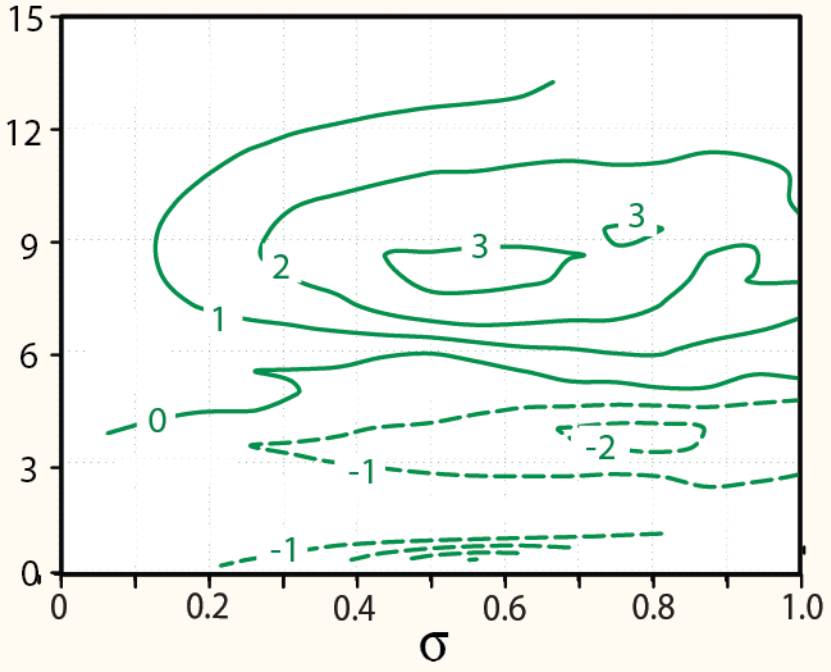
The relative importance of the eddy transport strongly depends on σ.

CONVERGENCE OF

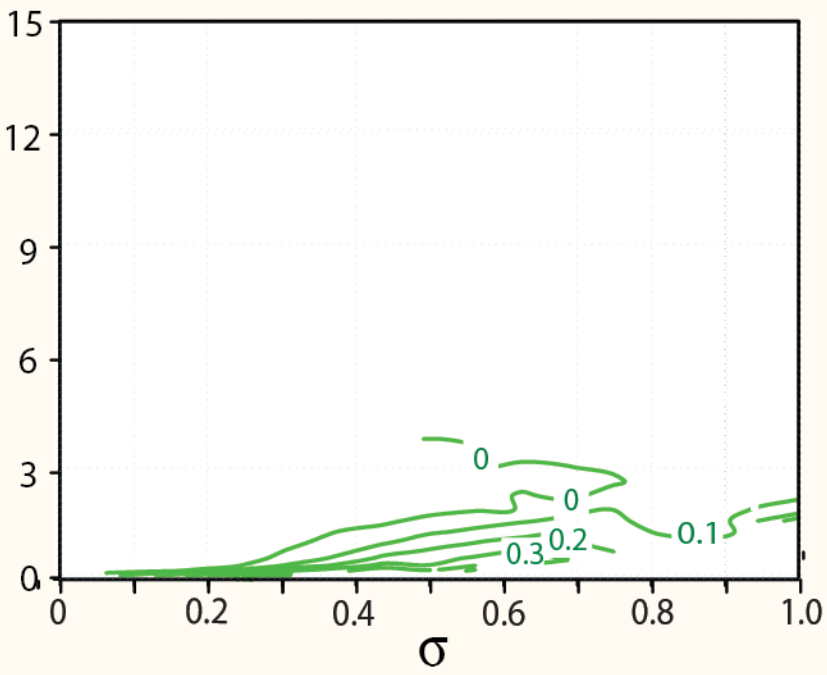
VERTICAL AND HORIZONTAL EDDY TRANSPORTS OF *h*

SHEAR CASE d = 8 km

Vertical K/hr



Horizontal 10^{-3} K./s



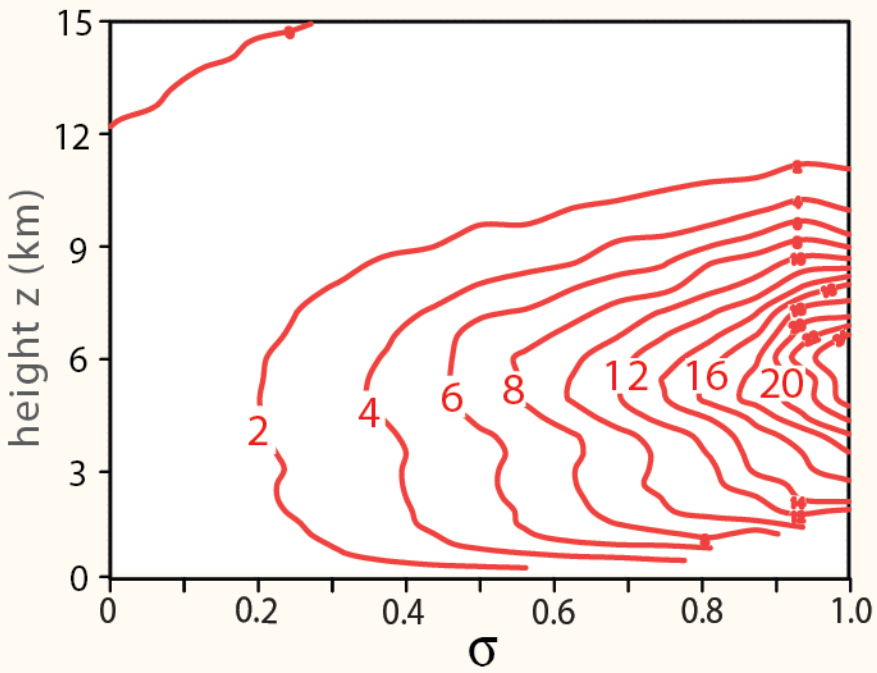
Horizontal convergence is negligible compared to vertical convergence at most levels.

σ–DEPENDENCE OF THE VERTICAL TRANSPORT

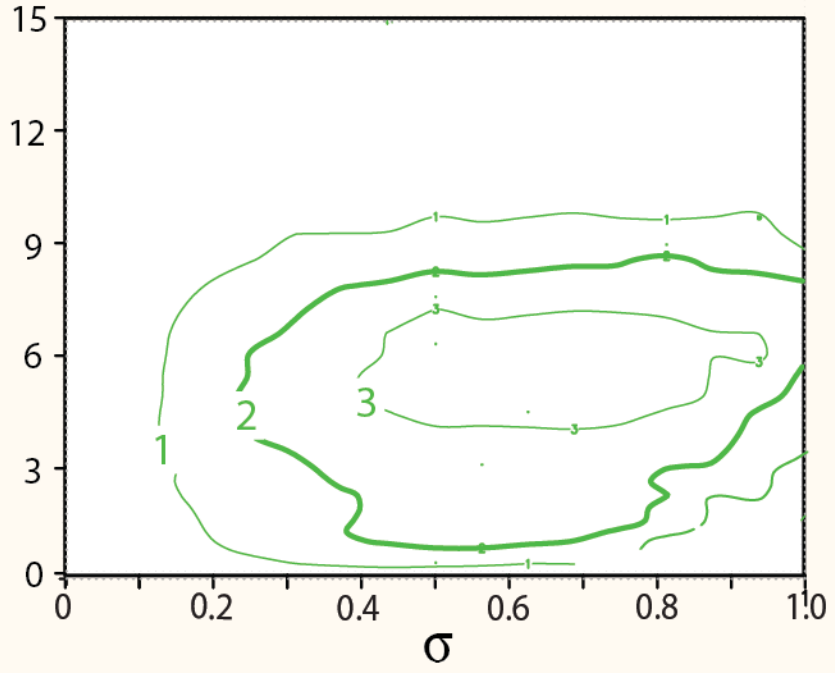
OF TOTAL (AIRBORNE) WATER

SHEAR CASE d = 8 km $\rho^* = \rho / \rho_{z=3\ km}$

Total transport $\rho^* \overline{w\,(q+l)}$



Eddy transport $\rho^* \overline{w'\,(q+l)'}$

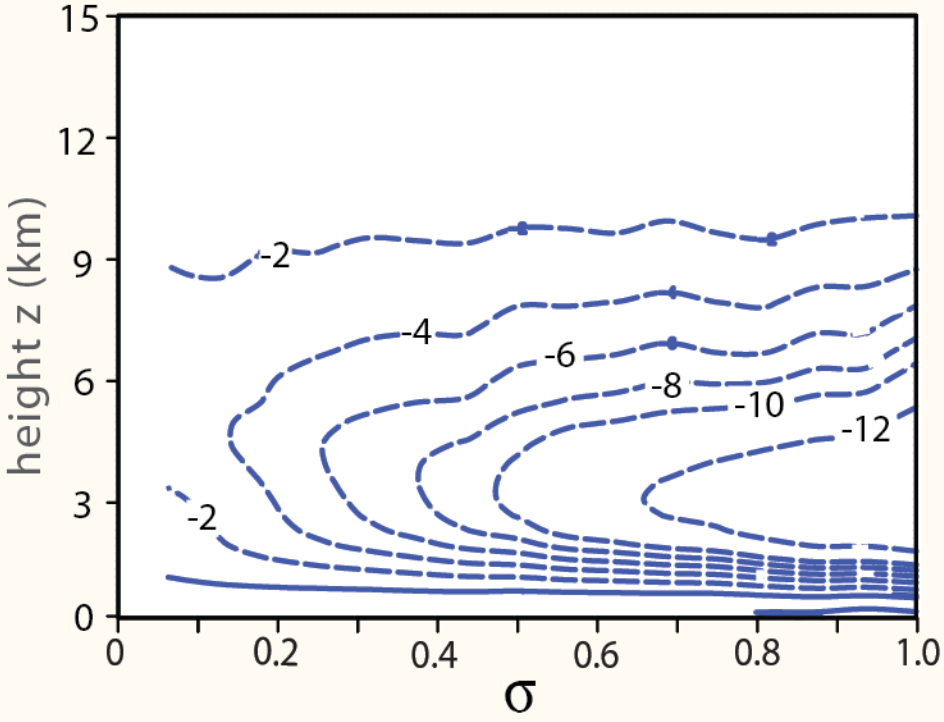


Similar to the moist static energy transports

THE SOURCE/SINK OF TOTAL (AIRBORNE) WATER

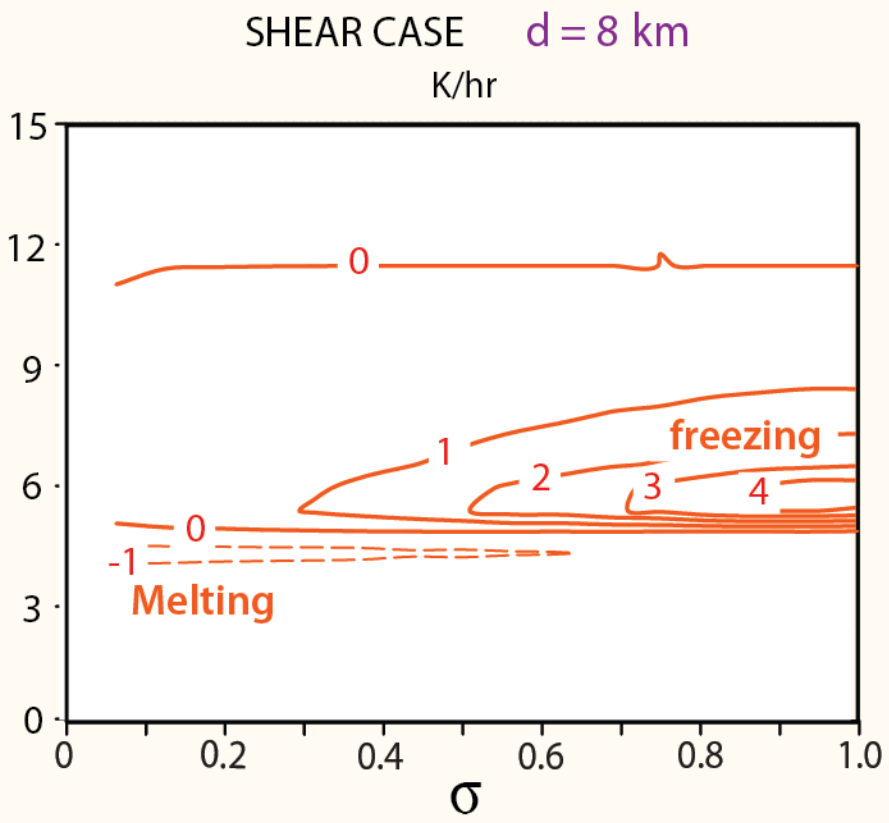
DUE TO CONVERSION FROM/TO PRECIPITATION

SHEAR CASE d = 8 km



Roughly proportional to σ.

THE SOURCE/SINK OF MOIST STATIC ENERGY



Freezing : roughly proportional to σ

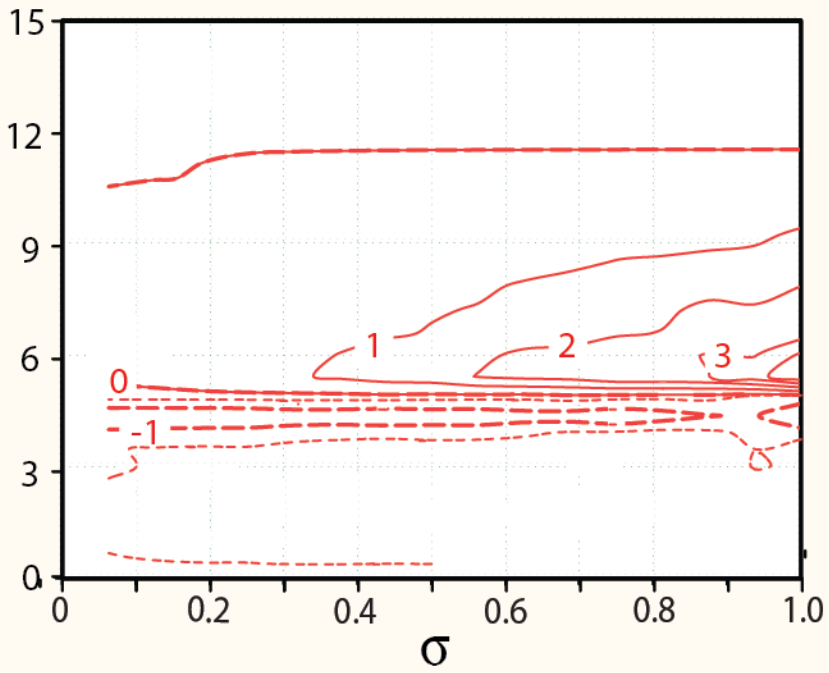
Melting : roughly proportional to $1-\sigma$

SOURCE/SINK OF TEMPERATURE AND GRAUPEL

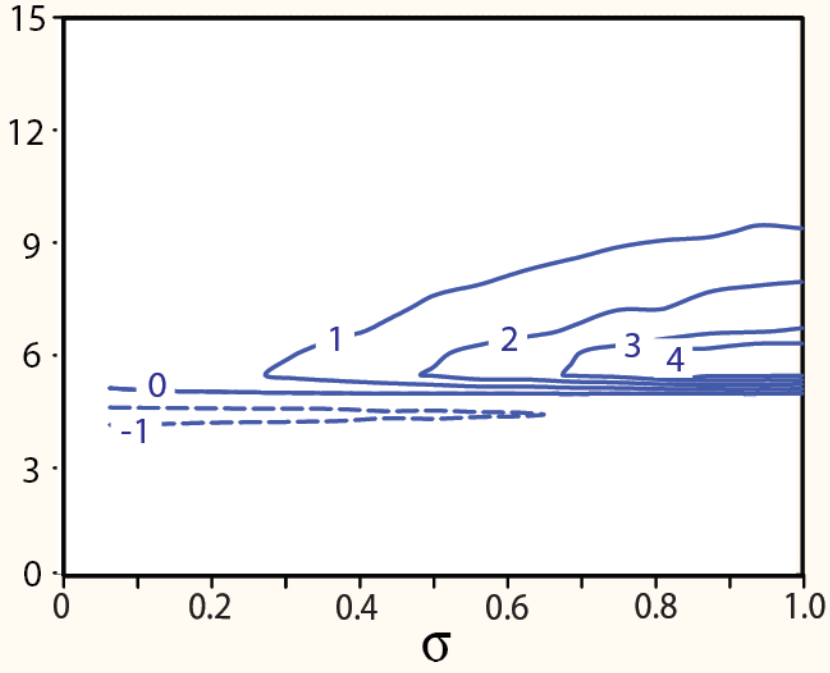
SHEAR CASE d = 8 km K/hr

Temperature

(not including heat of condensation)



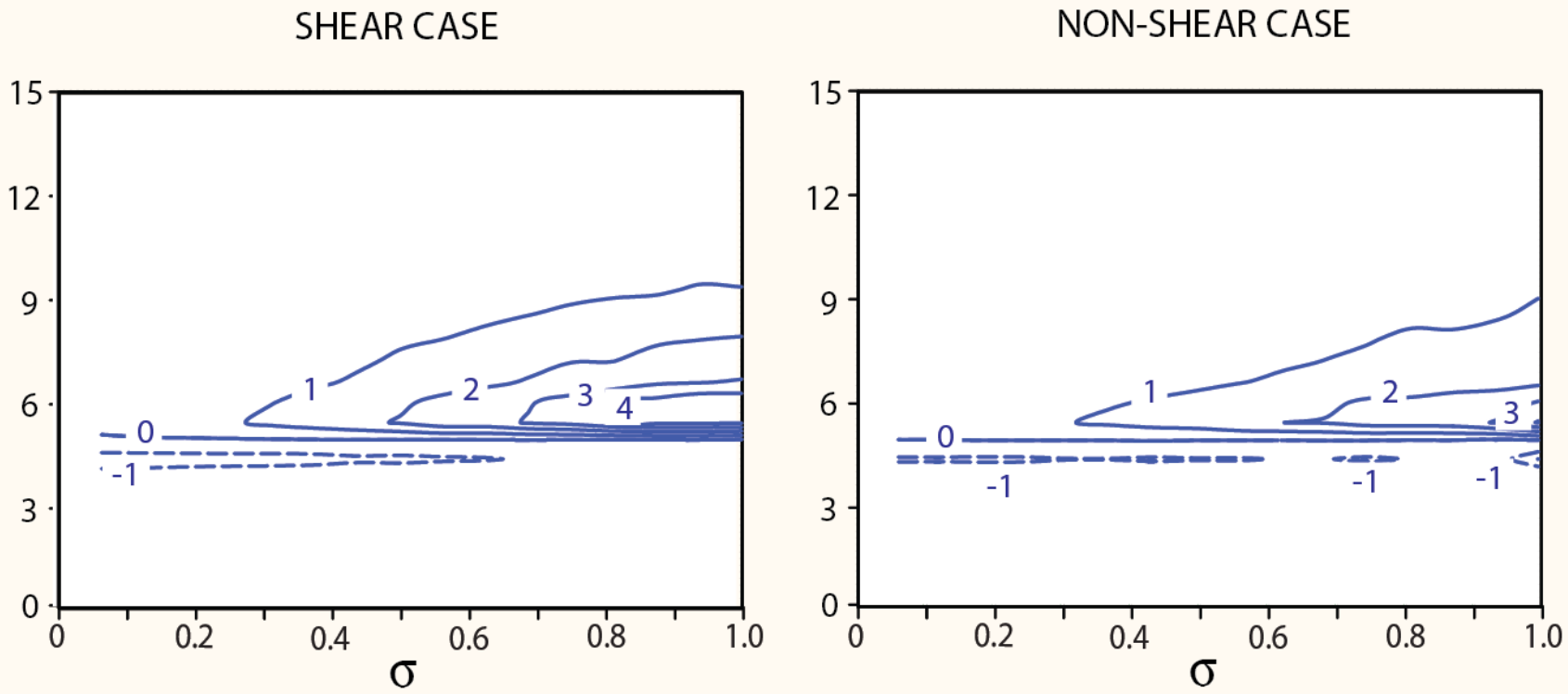
Graupel



Confirms the freezing/melting effects.

THE SOURCE/SINK OF GRAUPEL

d = 8 km K/hr

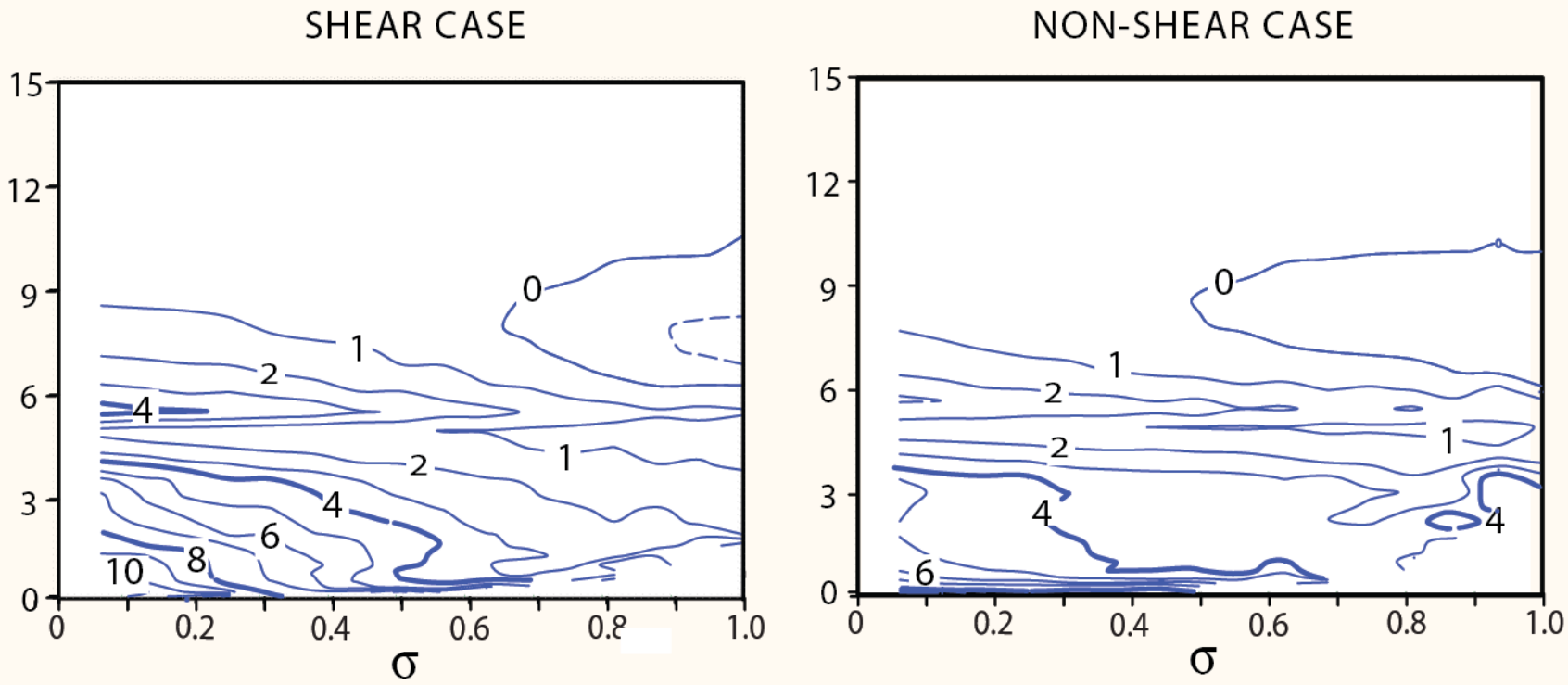


The σ-dependence of melting is not clear for the non-shear case.

SOURCE OF WATER VAPOR

DUE TO EVAPORATION/SUBLIMATION FROM PRECIPITATION

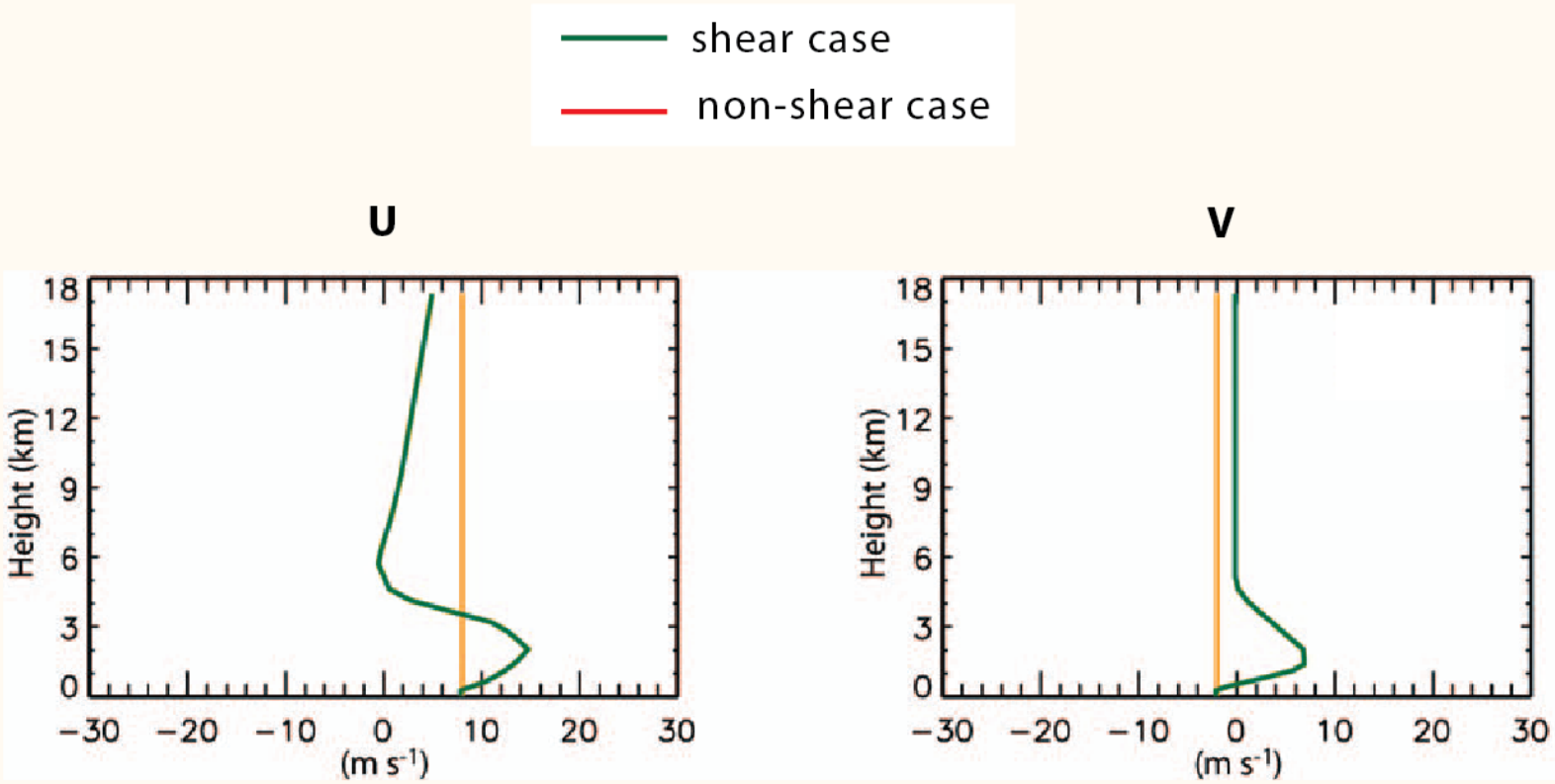
K/hr d = 8 km



More evaporation with shear (except subcloud layer).

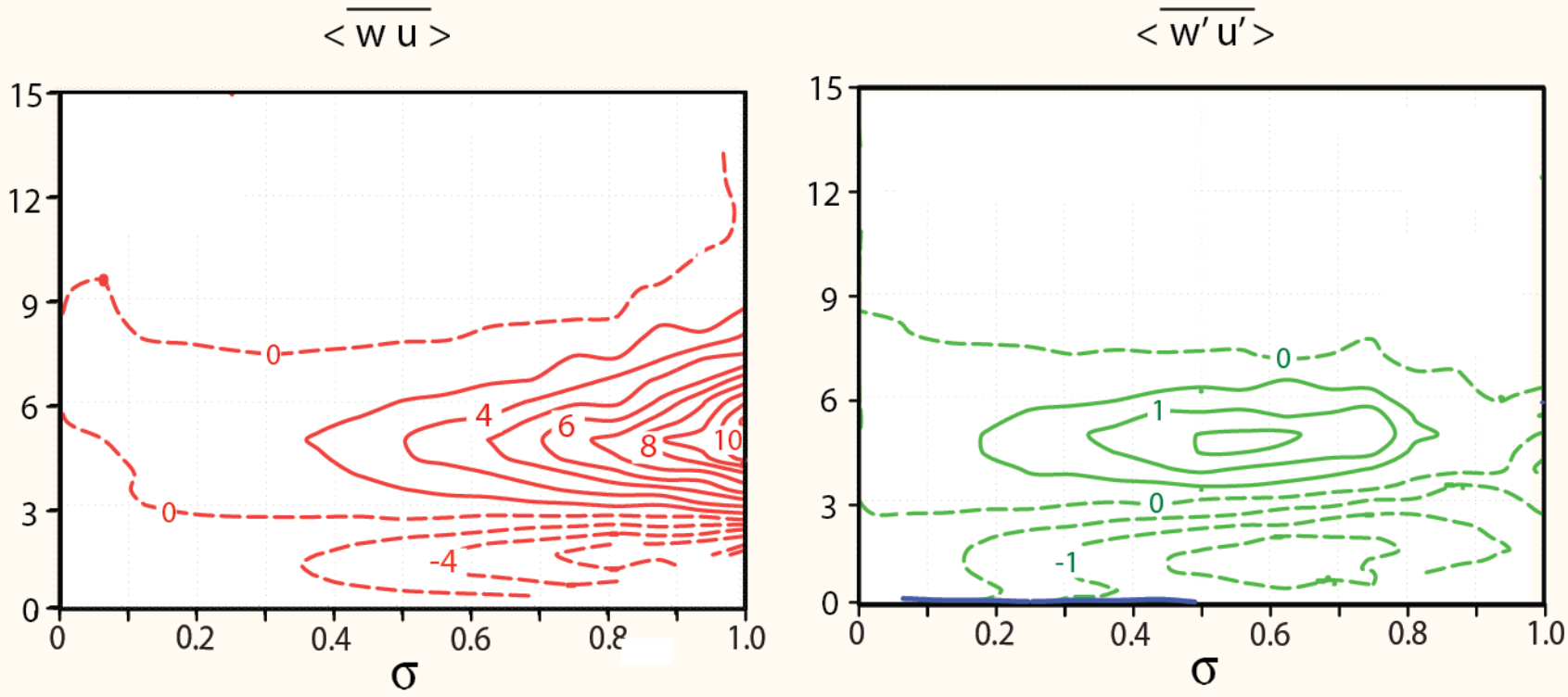
BACKGROUND WIND PROFILES

PRESCRIBED FOR THE SHEAR AND NON-SHEAR CASES



σ–DEPENDENCE OF THE MOMENTUM TRANSPOT

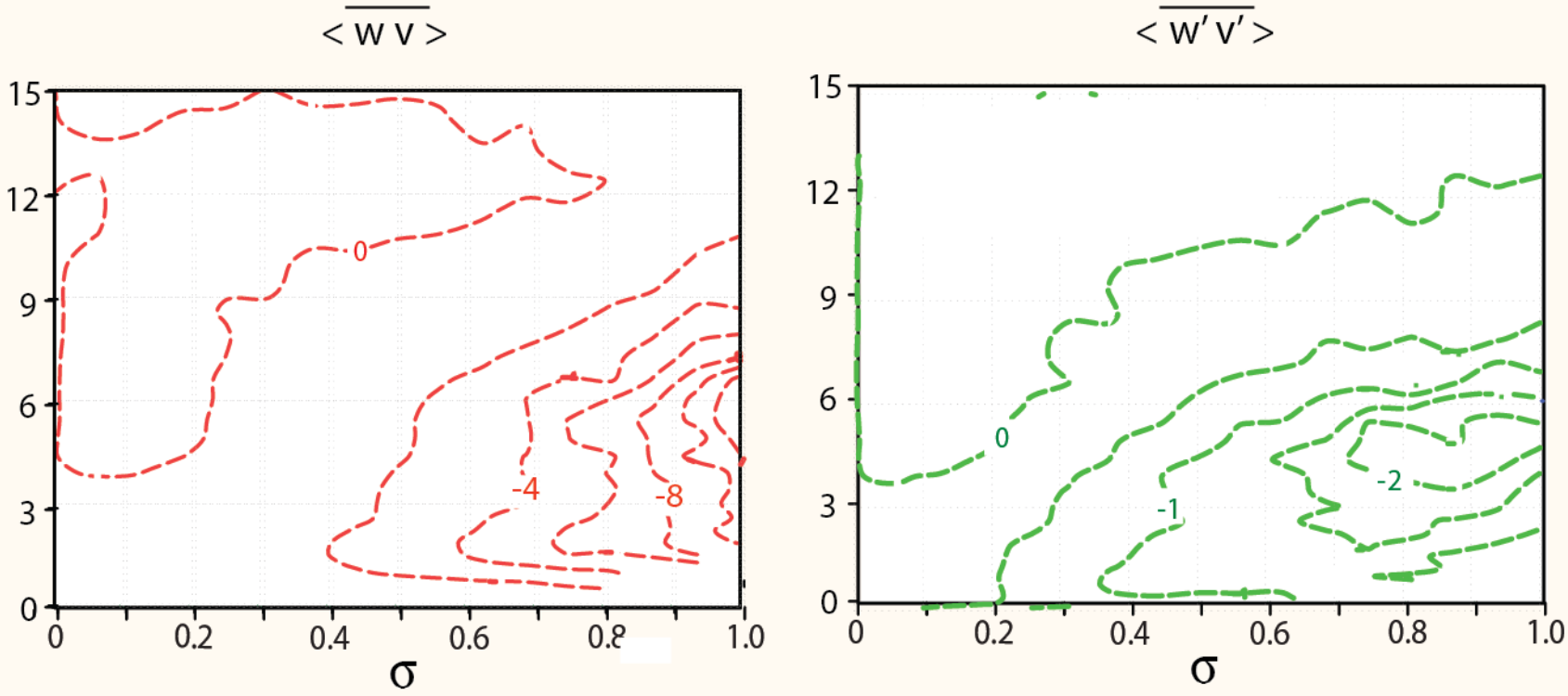
SHEAR CASE m^2/s^2 d = 8 km



Eddy transport is rather small though not negligible.

σ–DEPENDENCE OF THE MOMENTUM TRANSPOT

SHEAR CASE m^2/s^2 d = 8 km



Eddy transport is rather small though not negligible.

SUMMARY

- The fractional area covered by updrafts, σ, is the key parameter in the unified parameterization.
- At all levels, $\sigma << 1$ can be a good approximation only for low resolutions.
- At all levels, the ratio of the eddy to total transports depend on σ rather than resolution.
- Regardless of the resolution, the total transport is mostly due to eddy transport when σ is small and due to the grid-scale transport when σ is large.
- Most cloud-microphysical sources are roughly proportional to σ. Exceptions are melting of graupel and evaporation from rain.
- The eddy transport of momentum is small though not negligible.

THE EFFECT OF MULTIPLE STRUCTURE OF UPDRAFTS

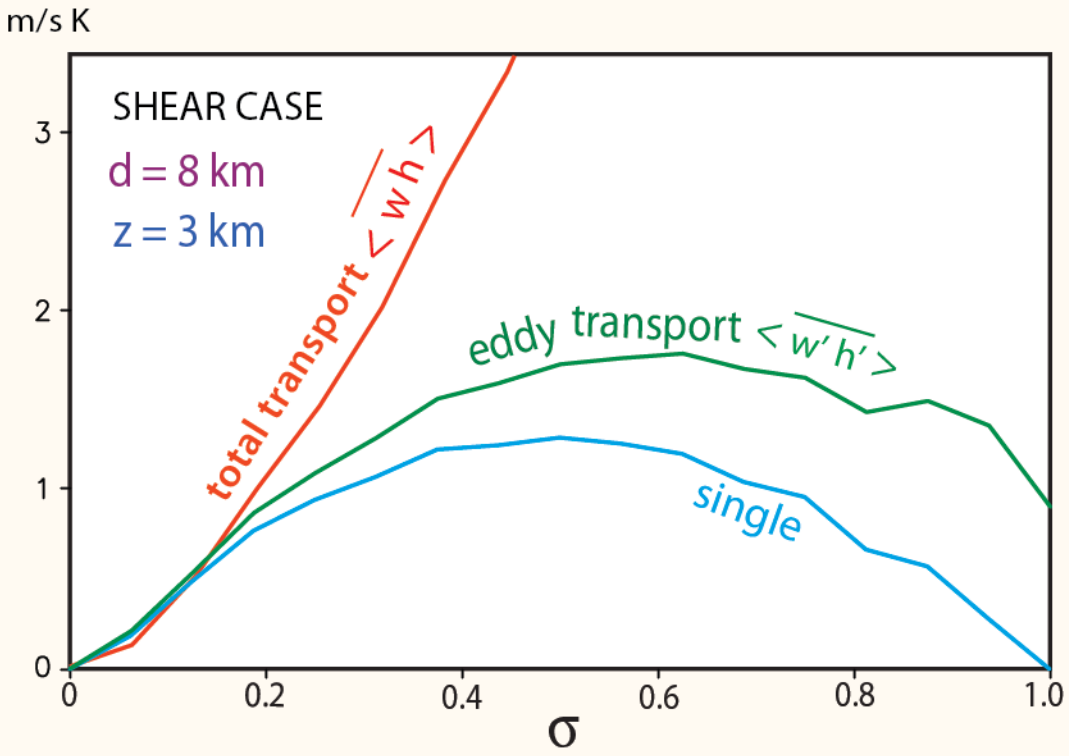
single

0.5 m/s < w

For each sub-domain:

Replace w and h of all grid points that satisfy this condition with their averages

Do the same for the other grid poirts



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