Unified Parameterization

-Vertical Structures and Physical Sources and Sinks

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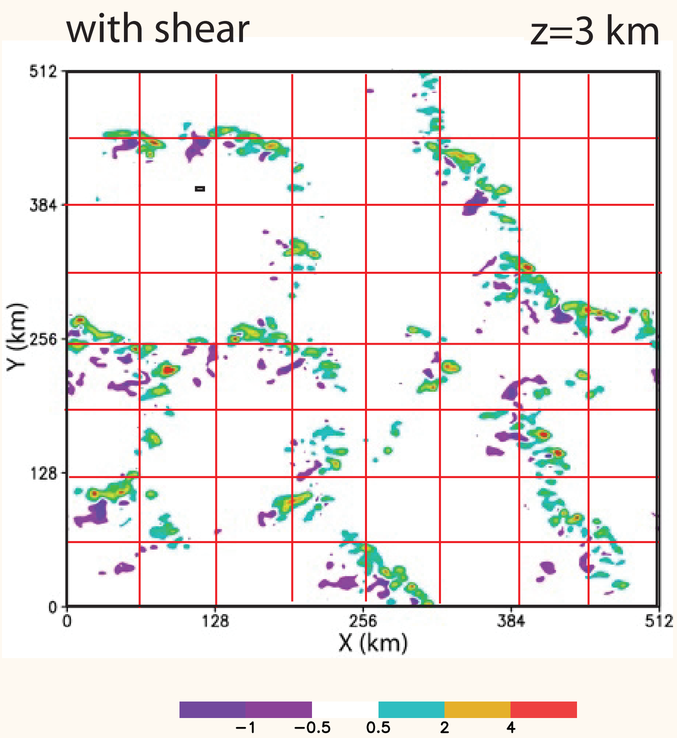
CRM SIMULATIONS USED

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

Steady forcing based on - Q1/Q2 typically observed during GATE Phase III

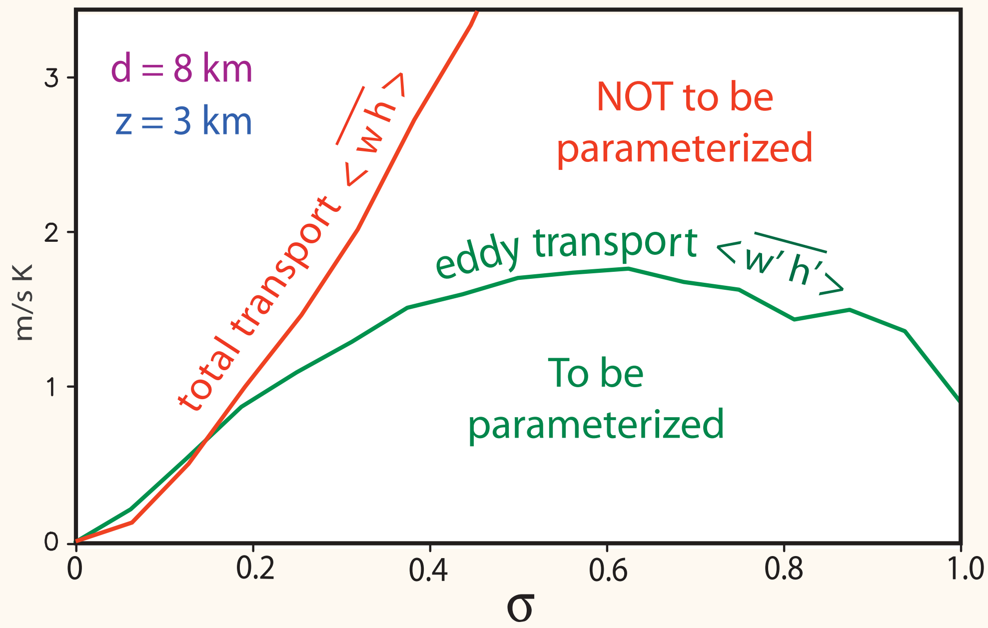
With and without background vertical shear

A snapshot of w with an example of subdomains



] d : Subdomain size representing GCM grid size

DIAGNOSED VERTICAL TRANSPORT OF MOIST STATIC ENERGY



Fractional area covered by updrafts

– a measure of cloud population in the grid cell –

h : Deviation of moist static energy from a reference state

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

$\langle\ \rangle$: Ensemble average over all cloud-containing ($\sigma > 0$) sub-domains throughout the analysis period

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

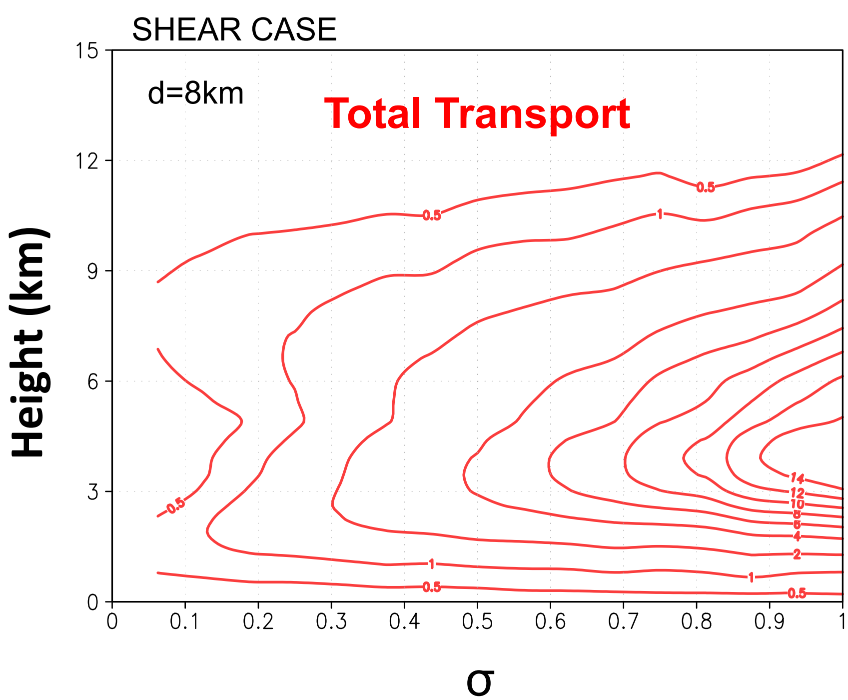
Parameterization must not overdo its job

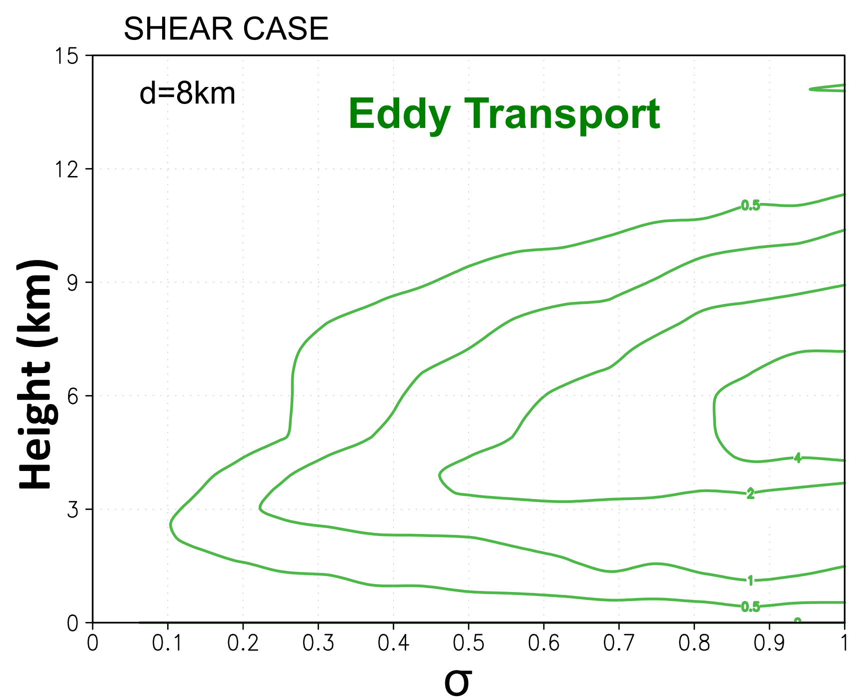
so that explicitly-simulated transport is not over-stabilized .

The σ-DEPENDENCE OF VERTICAL TRANSPORT OF MOIST STATIC ENERGY

VERTICAL STRUCTURE

Eddy transport of moist static energy is only a fraction of total transport as σ increases. Similar σ dependencies apply vertically.

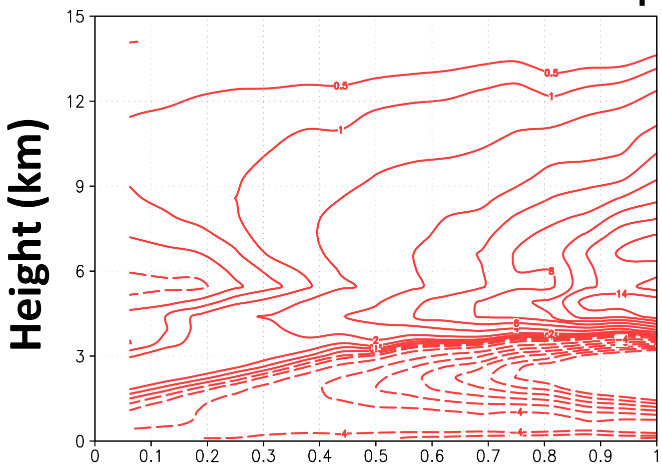




The σ-DEPENDENCE OF SOURCES OF MOIST STATIC ENERGY AND TOTAL WATER

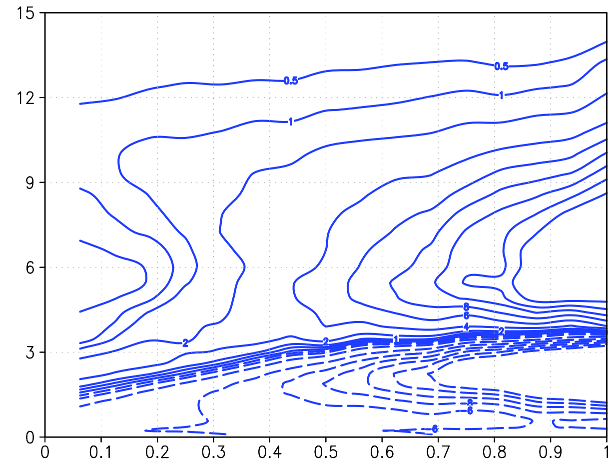
All sources increase approximately linearly with the increase of σ. The σ-dependence is important for simulating microphysical effects

Sources of h due to total transport

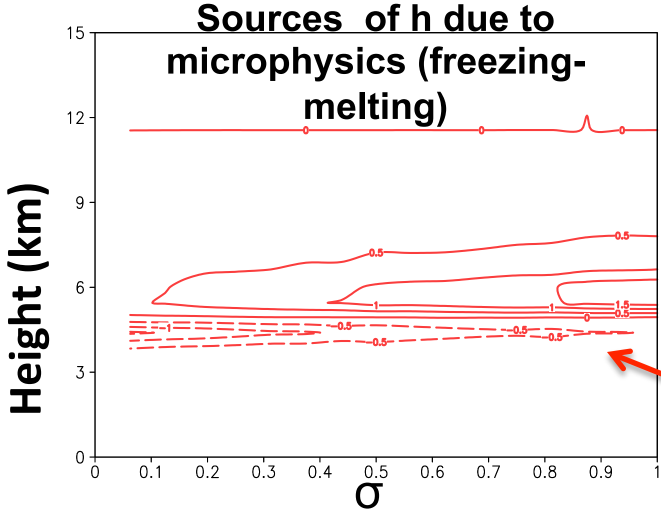


SHEAR CASE
d=8km
(K/hr)

Sources of total water due to total transport

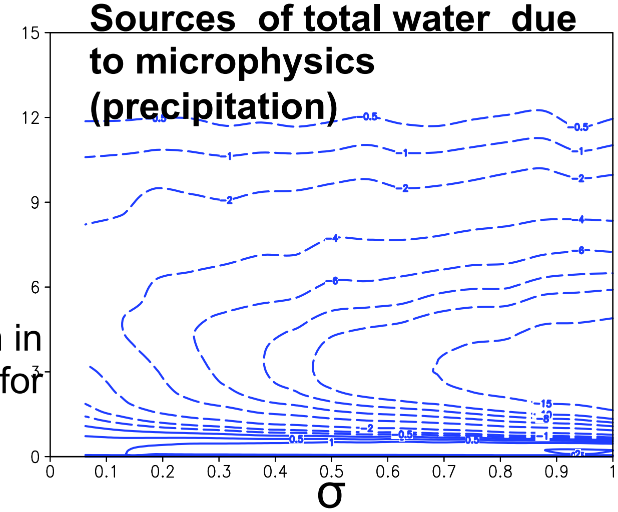


Sources of h due to microphysics (freezing-melting)



Due to less room in the environment for convective downdraft

Sources of total water due to microphysics (precipitation)

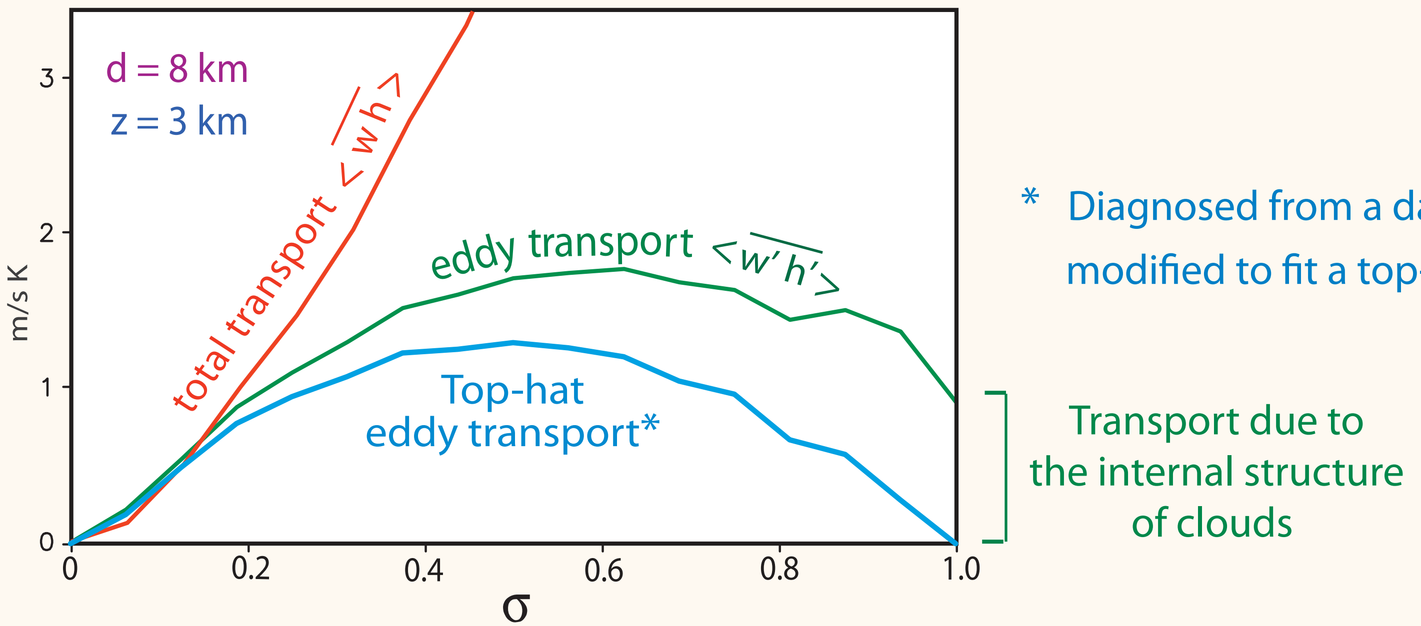


FIRST STEP TOWARD UNIFIED PARAMETERIZATION

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

— "top-hat profile" —

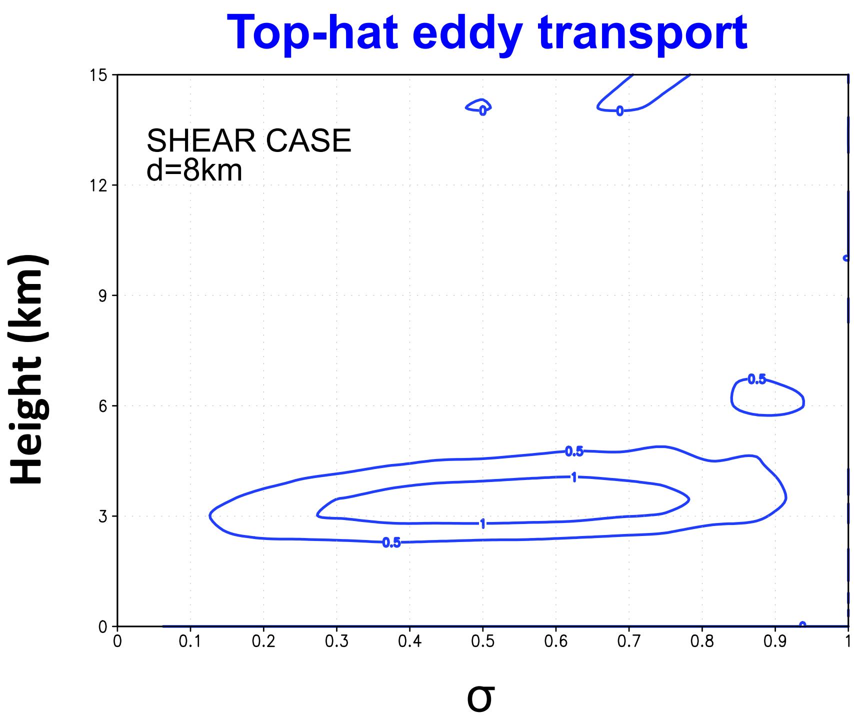
Continue to use this assumption to start.



* Diagnosed from a dataset modified to fit a top-hat profile

VERTICAL STRUCTURE OF TOP-HAT EDDY TRANSPORT

Vertical structure also show strong σ dependence.



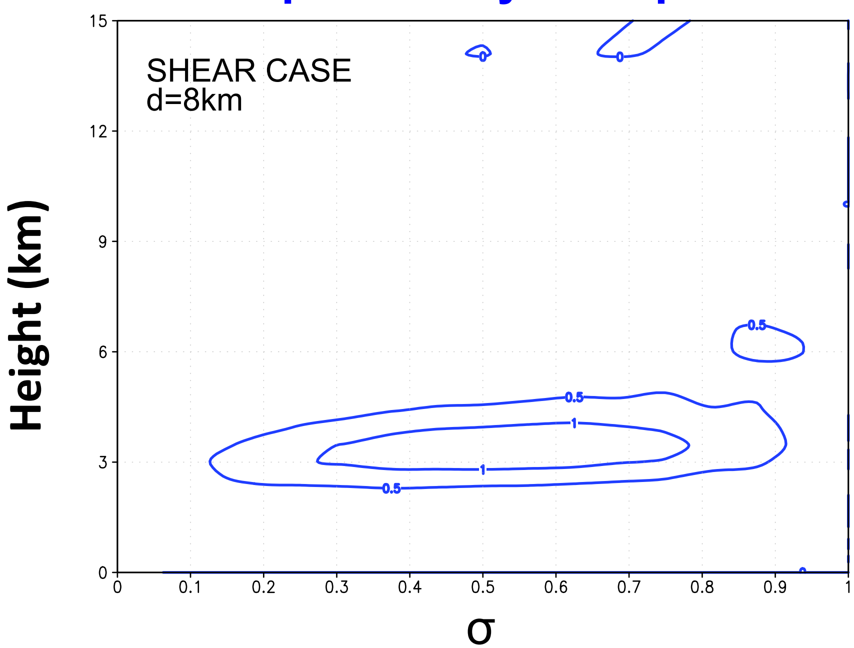
VERTICAL STRUCTURE OF TOP-HAT EDDY TRANSPORT

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

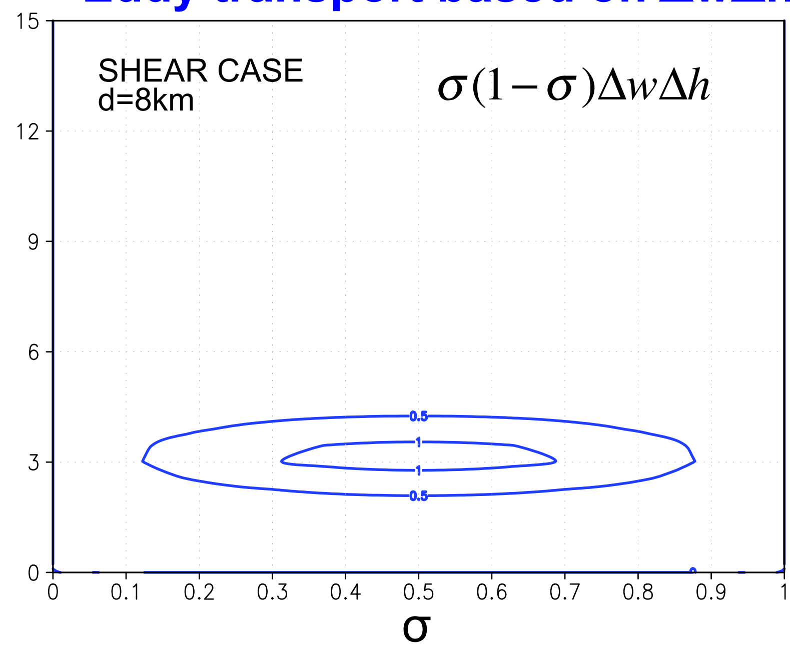
If $\Delta w \Delta\psi$ is in fact independent of σ,
the eddy transport depends on σ through $\sigma(1-\sigma)$.

(ΔwΔh is calculated from d=8km cloudy sub-domain average)

Top-hat eddy transport



Eddy transport based on ΔwΔh

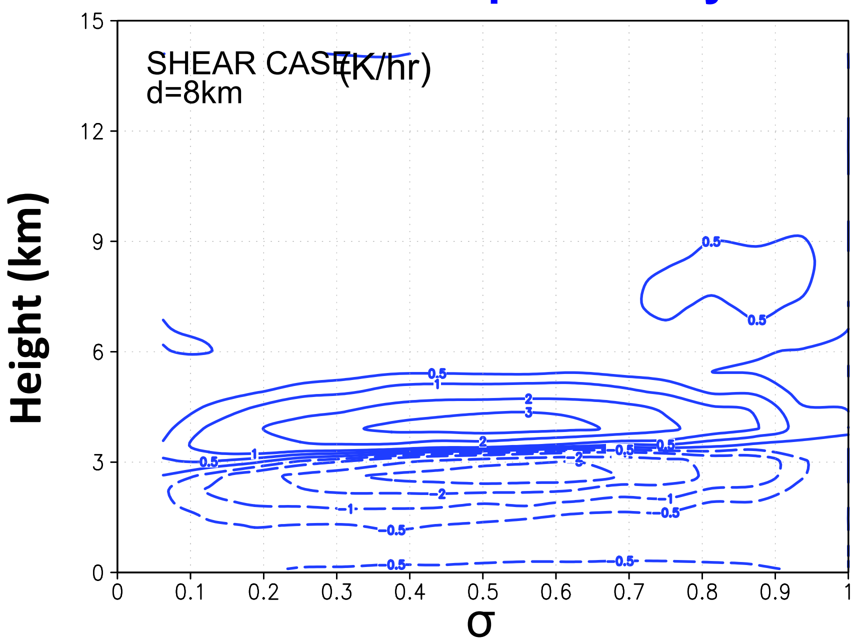


VERTICAL STRUCTURE OF TOP-HAT EDDY TRANSPORT

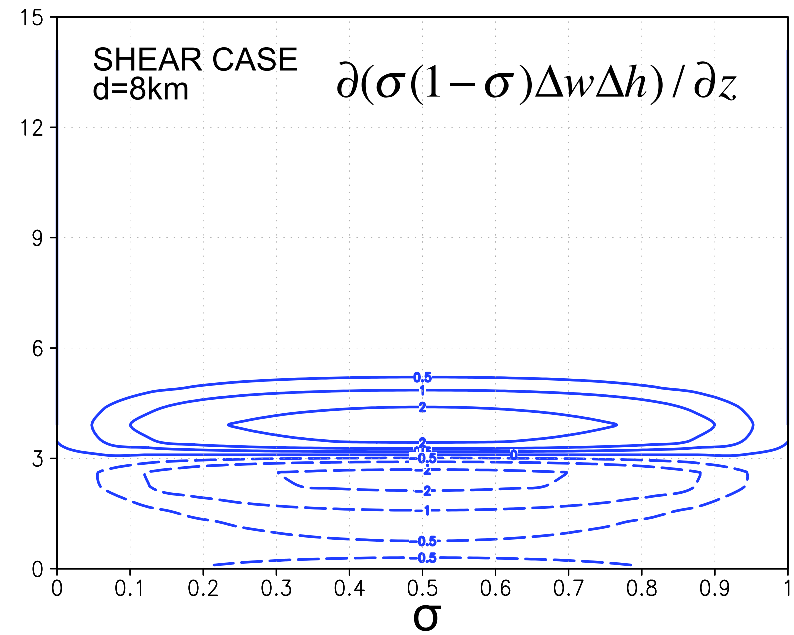
Sources of top-hat eddy transport depends on σ through σ(1-σ) at all levels.

(ΔwΔh is calculated from d=8km cloudy sub-domain average)

Sources due to top-hat eddy transport

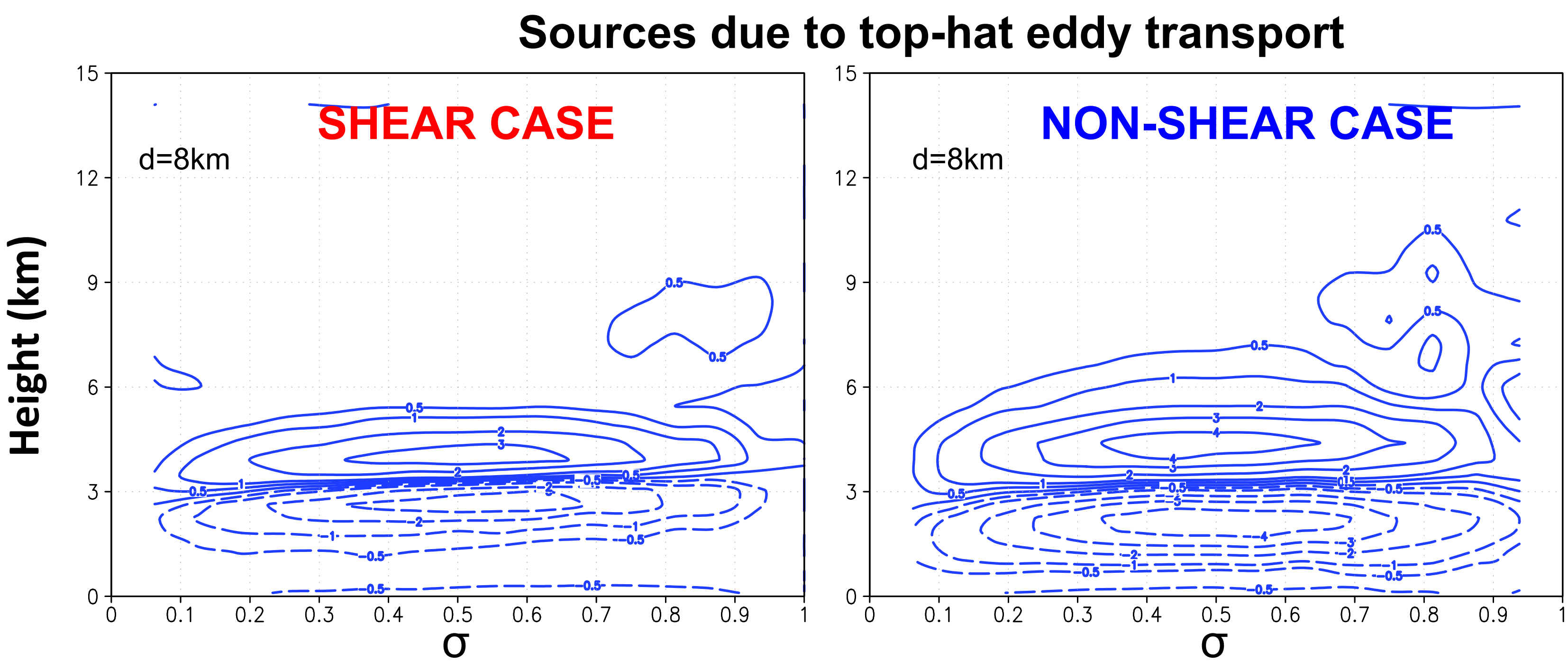


Sources based on ΔwΔh



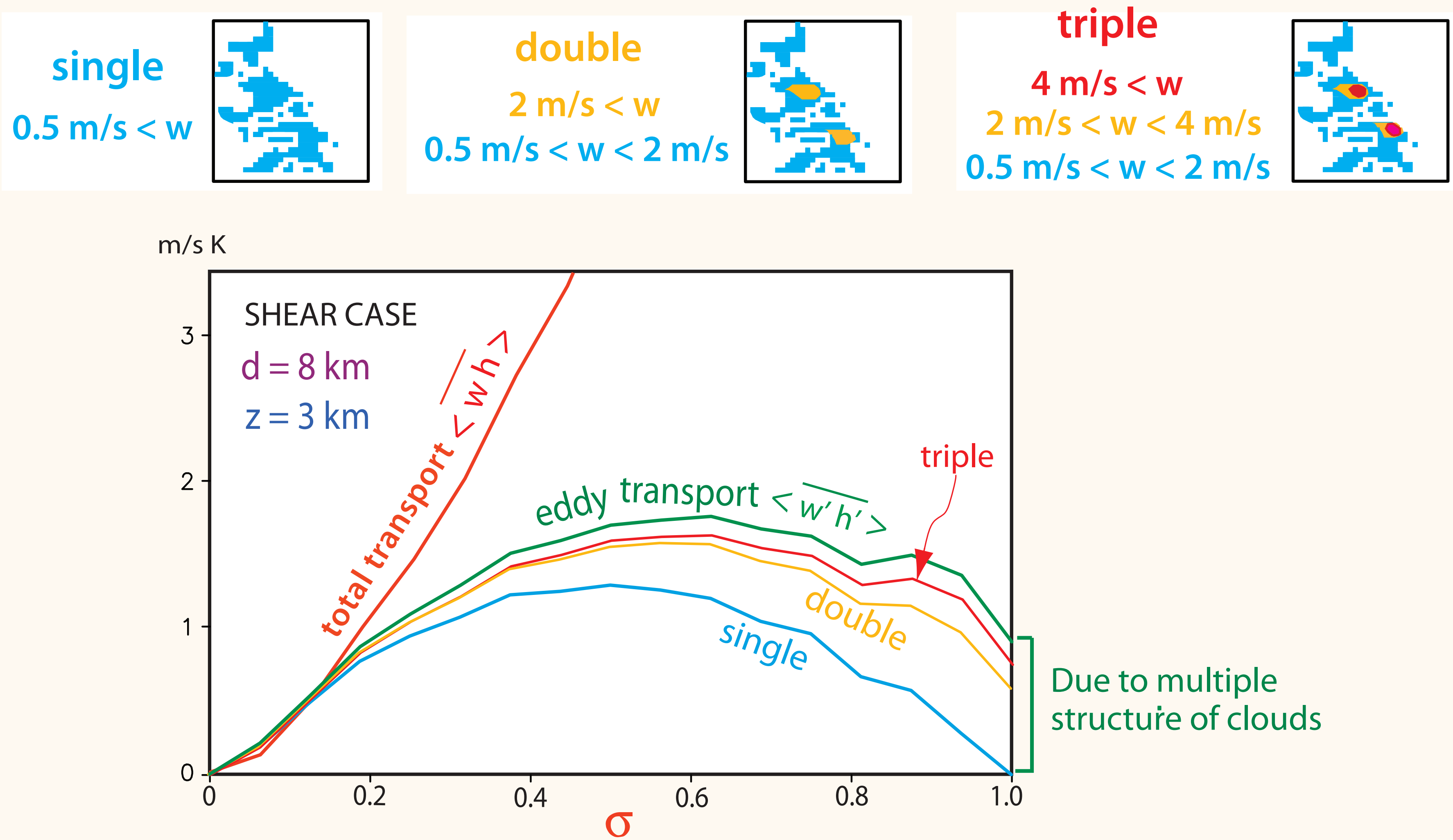
VERTICAL STRUCTURE OF TOP-HAT EDDY TRANSPORT

Similar structure for shear and non-shear case but the latter tends to have stronger eddy transport.



ENSEMBLE-AVERAGE VERTICAL EDDY TRANSPORT

— THE EFFECT OF MULTIPLE STRUCTURE OF CLOUDS —

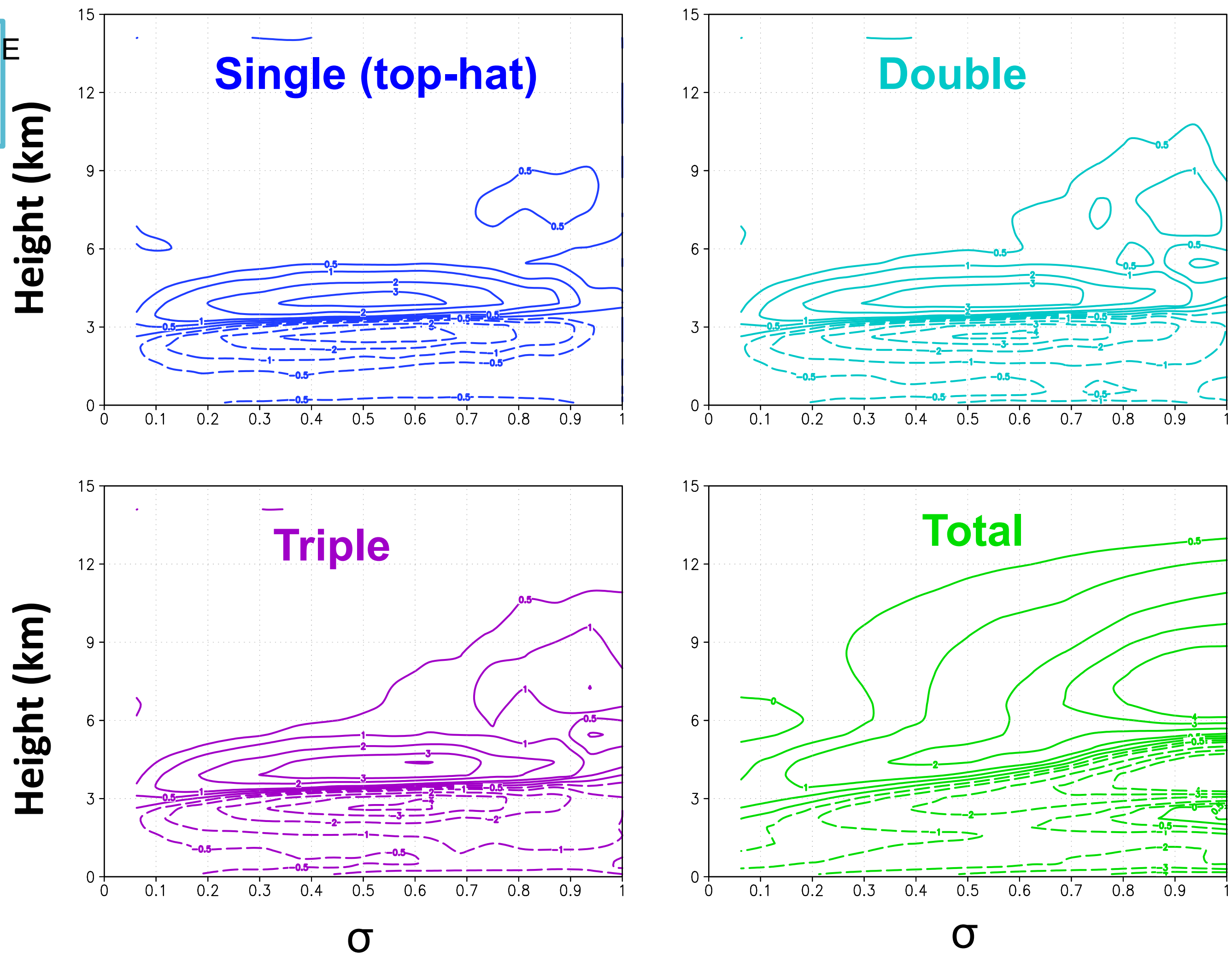


THE EFFECT OF MULTIPLE CLOUD STRUCURE/CLOUD TYPE

SOURCES OF MOIST STATIC ENERGY DUE TO EDDY TRANSPORT

Multiple cloud structure/type better capture the complicated vertical structure when σ is large.

SHEAR CASE
d=8km
(K/hr)



Current work on topography in parallel VVM

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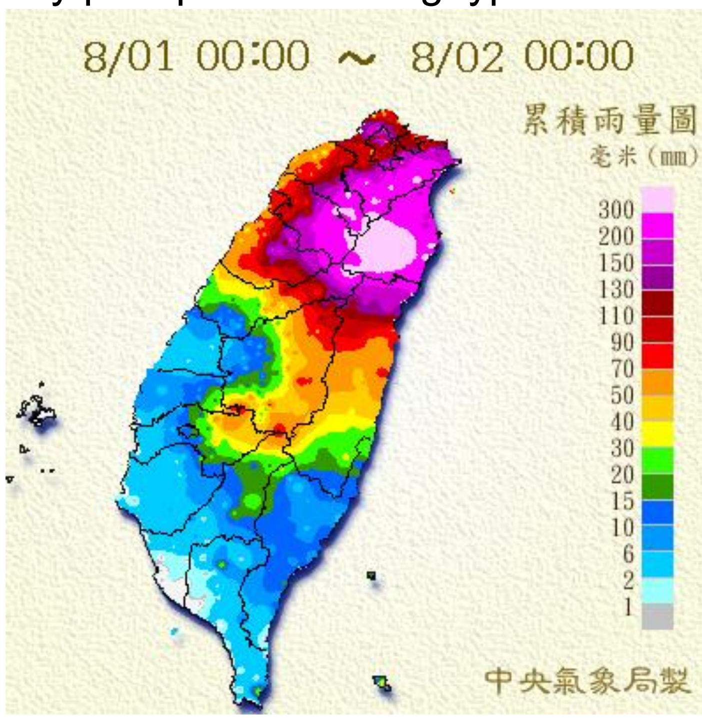
National Taiwan University

CURRENT WORK ON TOPOGRAPHY IN PARALLEL VVM

High-resolution simulation of flow over complex topography is necessary in understanding atmospheric processes in Taiwan.

Daily precipitation during typhoon SAOLA



400 km

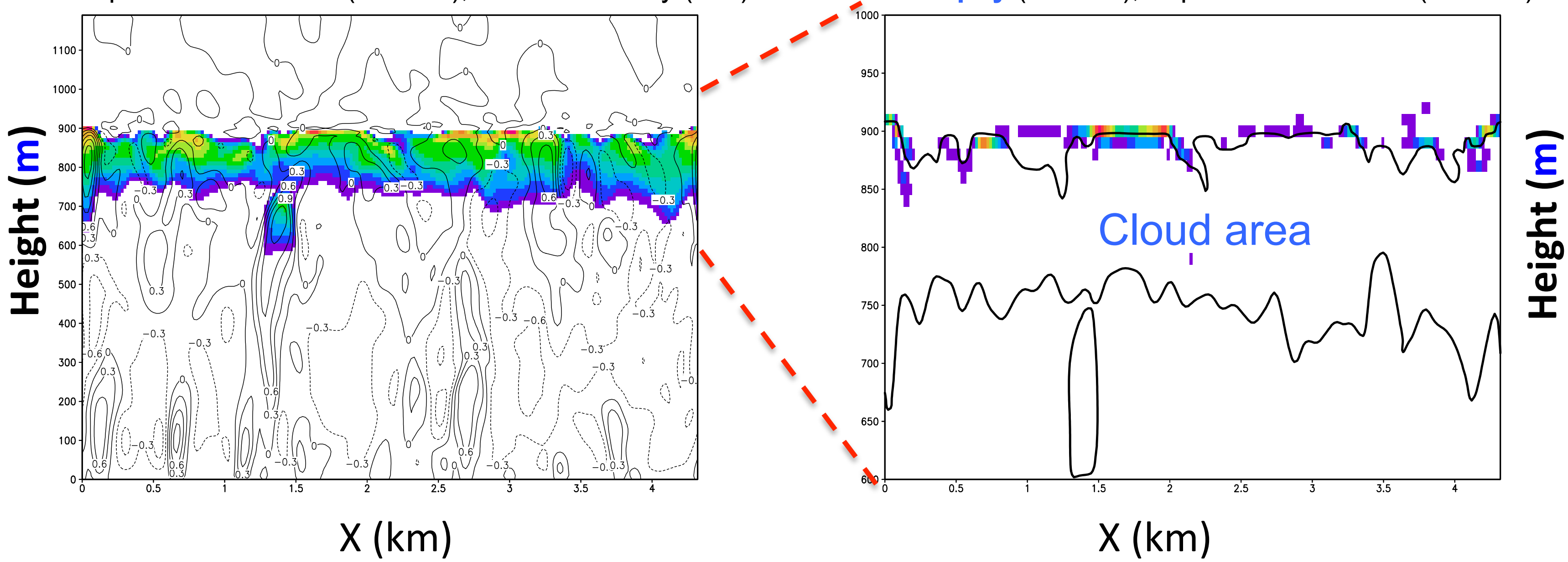
150 km

HIGH RESOLUTION SIMULATION IN PARALLEL VVM

Stratocumulus(DYCOMS case)

Δx=Δy=2Δz=20m, 6 hr simulation

Liquid water content (shaded), vertical velocity (m/s) | **Enstrophy** (shaded), Liquid water content (contour)

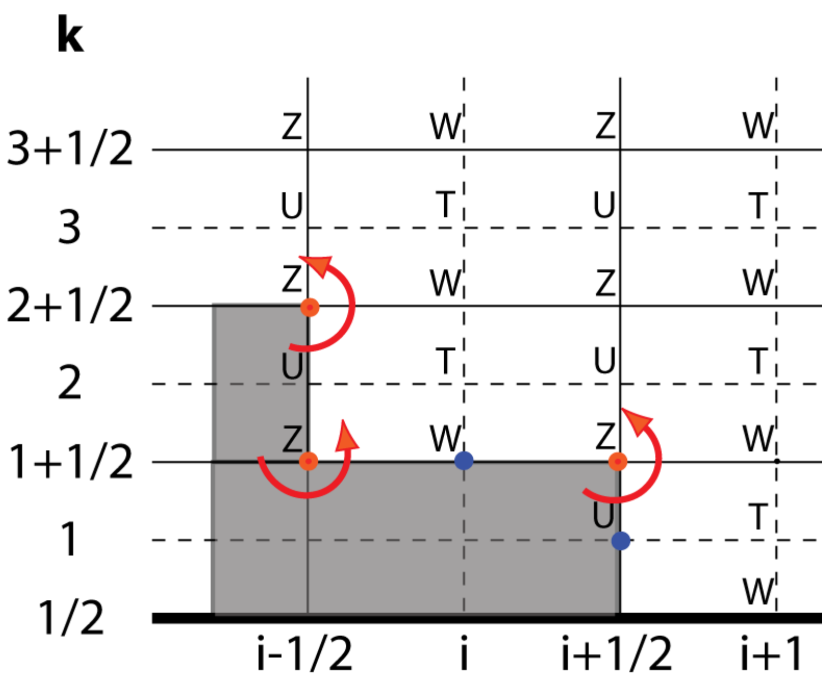


pVVM is capable of simulating fine structure of stratocumulus.

Determining the vorticity at the corners of the topography

•The strength of the vorticity at the corners is determined through vorticity definition.

$$\eta_b = \frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \qquad u_b = w_b = 0$$



$$(\eta_b)_{i,1+1/2} =$$

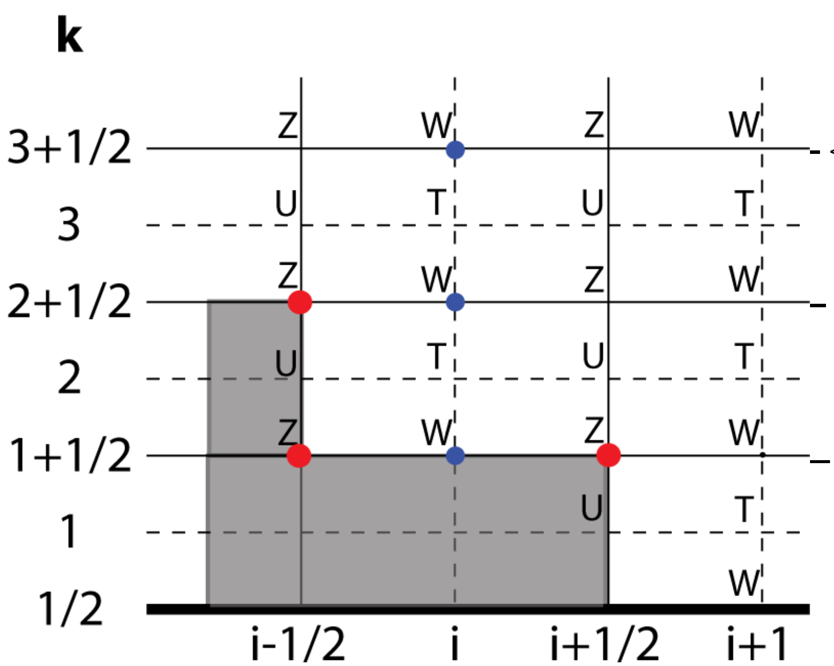
$$\frac{u_{i,2} - (u_b)_{i,1}}{\Delta z} - \frac{w_{i+1/2,1+1/2} - (w_b)_{i-1/2,1+1/2}}{\Delta x}$$

$$(u_b)_{i,1} = (w_b)_{i-1/2,1+1/2} = 0$$

Solving the relaxed w-equation in VVM

•Solving the relaxed w-equation with the addition of vorticies at the corners

$$\mu\frac{\partial w}{\partial t}+\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)w+\frac{\partial}{\partial z}\left[\frac{1}{\rho_0}(\frac{\partial}{\partial z}\rho_0 w)\right]=-\frac{\partial\eta}{\partial x}+\frac{\partial\xi}{\partial y}$$



First term of RHS=

$$-\left\{\frac{\eta_{i+1/2,k+1/2}-\eta_{i-1/2,k+1/2}}{\Delta x}\right\}$$

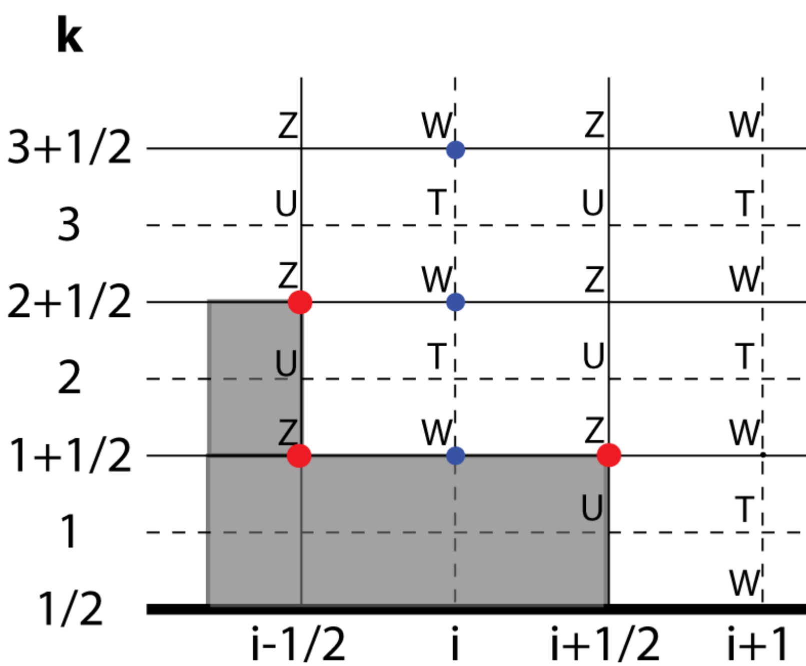
$$-\left\{\frac{\eta_{i+1/2,2+1/2}-(\eta_b)_{i-1/2,2+1/2}}{\Delta x}\right\}$$

$$-\left\{\frac{(\eta_b)_{i+1/2,1+1/2}-(\eta_b)_{i-1/2,1+1/2}}{\Delta x}\right\}$$

Solving the elliptic w-equation in Parallel VVM

- Solving the relaxed w-equation with the addition of vorticies at the corners

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)w+\frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\left(\frac{\partial}{\partial z}\rho_0 w\right)\right]=-\frac{\partial \eta}{\partial x}+\frac{\partial \xi}{\partial y}$$



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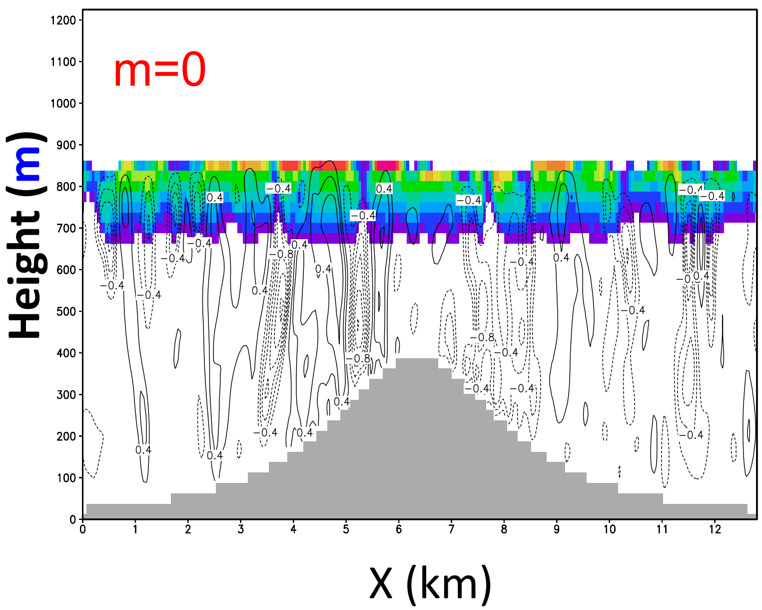
$$-\left\{\frac{(\eta_b)_{i+1/2,1+1/2}-(\eta_b)_{i-1/2,1+1/2}}{\Delta x}\right\}$$

STRATOCUMULUS OVER SMOOTH TOPOGRAPHY IN PARALLEL VVM

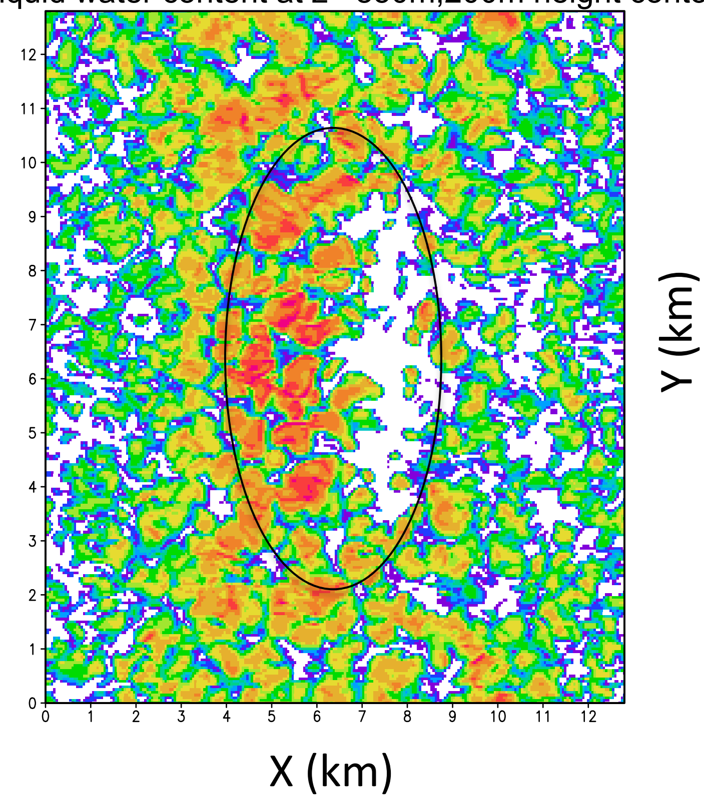
Stratocumulus with elliptic shaped mountain, no surface fluxes

$\Delta x=\Delta y=2\Delta z=50m$, 6 hr simulation

Liquid water content, vertical velocity (m/s)



Liquid water content at z= 850m,200m height contour



m: an index for the roughness of the topography

STRATOCUMULUS OVER RUGGED TOPOGRAPHY IN PARALLEL VVM

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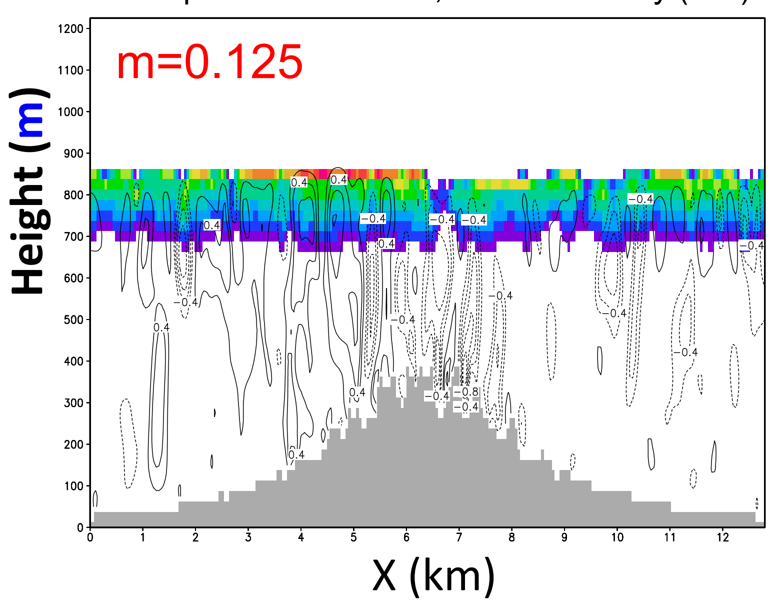

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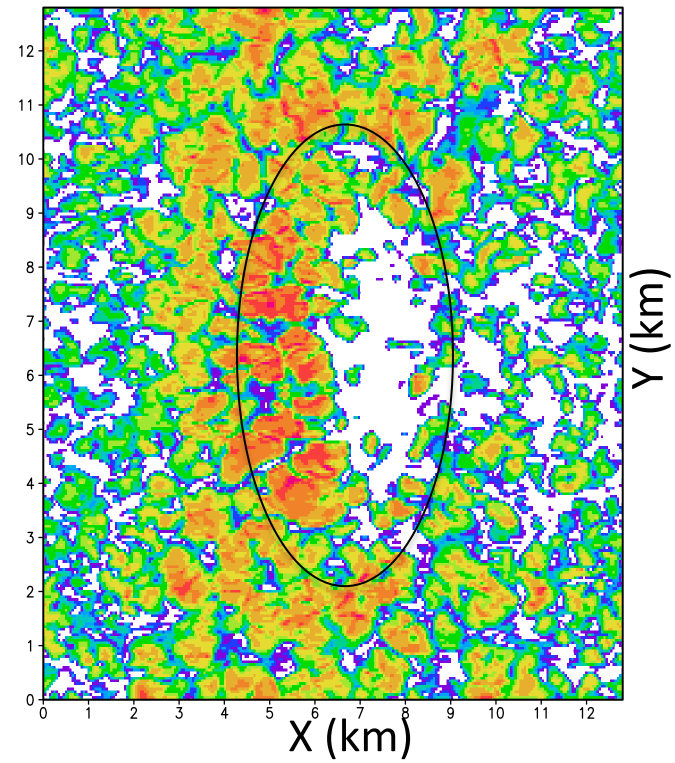

Topography is implemented in the pVVM successfully under high-resolution stratocumulus simulation.

FUTURE WORK

The topography is implemented in pVVM with only barrier effects. Future work will focus on implementation of turbulence, radiation, and land-surface processes near the bottom topography.

Cloud Forest