

Large-Scale Convective Sources from Two- and Three-Dimensional Cloud-System-Resolving Models

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I. Superparameterization is based on notion of embedding CSRM in GCM. Does it matter whether the CSRM is 2D or 3D?

II. This presentation will contrast 2D and 3D versions of a CSRM. Large-scale convective sources, which are the terms to be applied in superparameterization, will be examined.

Workshop on The Future of Cloud Parameterization, May 2003

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represent points at which the large-scale winds are predicted. At a CSRW grid point that is not at the intersection of the two high-resolution grids, we can do a quasi-three-dimensional calculation by interpolation between the neighboring orthogonal high-resolution grids.

From Randall et al. (2003, BAMS)

Large-Scale Convective Sources

Convective Heat Source:

$$Q_T = \sum_{i=1}^6 \frac{L_i}{c_p} \gamma_i - \frac{1}{\rho \pi} \frac{\partial}{\partial z} \overline{\rho w' \theta'}$$

Convective Moisture Source:

$$Q_Q = \sum_{i=1}^6 \frac{|L_i|}{L_i} \gamma_i + \frac{1}{\bar{\rho}} \frac{\partial}{\partial z} \overline{\rho w' q'}$$

NOTATION: ρ , density; π converts temperature to potential temperature; w , vertical velocity; θ , potential temperature; q , water vapor mixing ratio. Phase changes γ_i are condensation, evaporation, deposition, sublimation, freezing, and melting for $i = 1, 6$. Latent heats are indicated by L_i , with $L_2 = -L_1, L_4 = -L_3$, and $L_6 = -L_5$.

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WRF as a Cloud-System Resolving Model

I. NOAA/NCAR Weather Research & Forecasting (WRF) Model. Nonhydrostatic with imposed T,q advection.

II. 3D: 170 x 170 km x 20 km with 250-m vertical and 2-km horizontal resolution.

III. 2DX: 7225 2-km horizontal points by 20 km with 250-m vertical resolution.

IV. 2D: 255 2-km horizontal points by 20 km with 250-m vertical resolution.

V. Bulk Lin microphysics (cloud liquid, cloud ice, rain, snow, graupel) and interactive GFDL SW & LW radiation.

VI. ARM A , TOGA-COARE.

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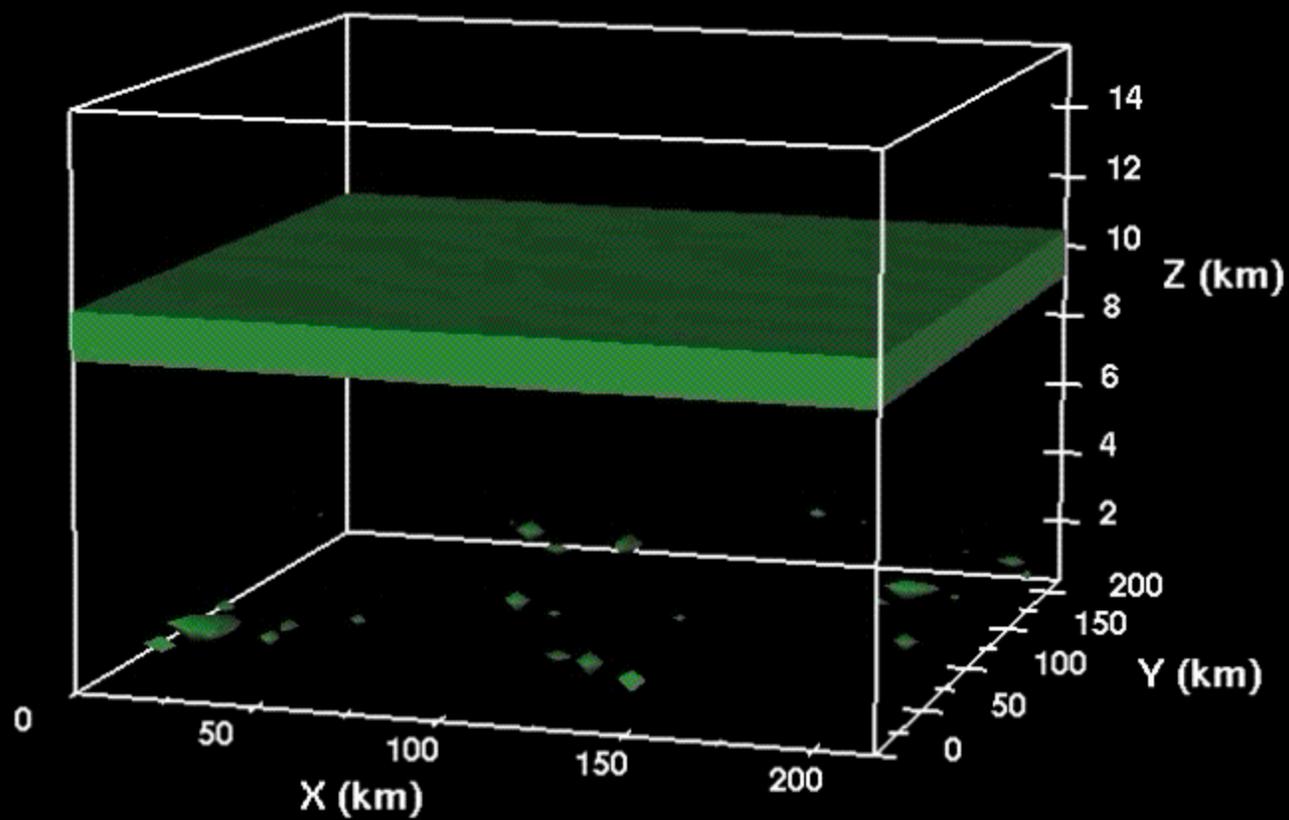
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Time = 9.00 hr

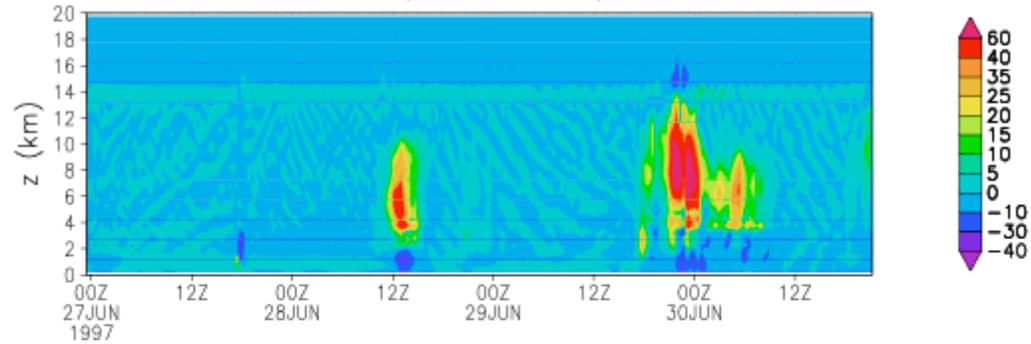
GFDL LAN Model

Isosfc: 0.25 g/kg 14 K/day -16 K/day

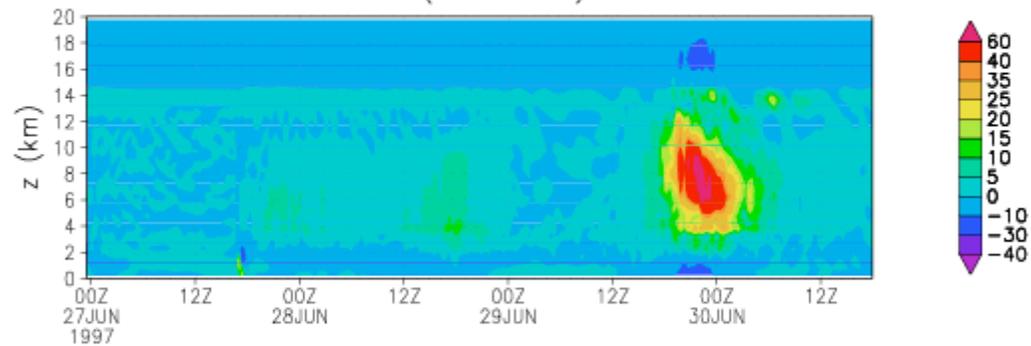


ARM A
THETA FLUX CONVERGENCE (K/day)

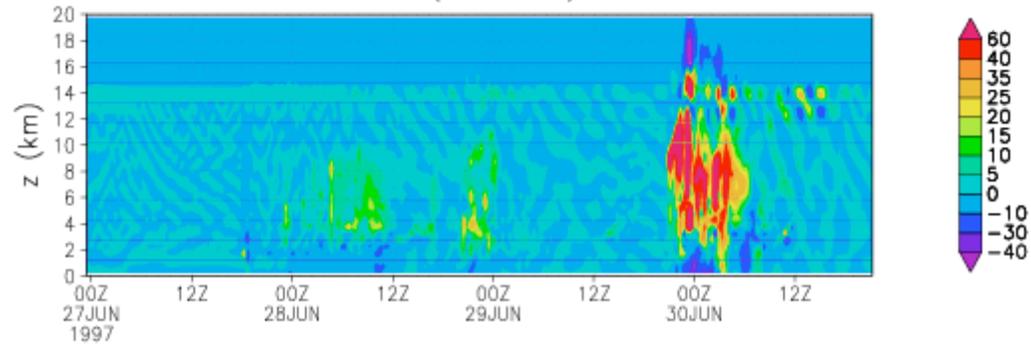
3D (85 x 85 x 40)



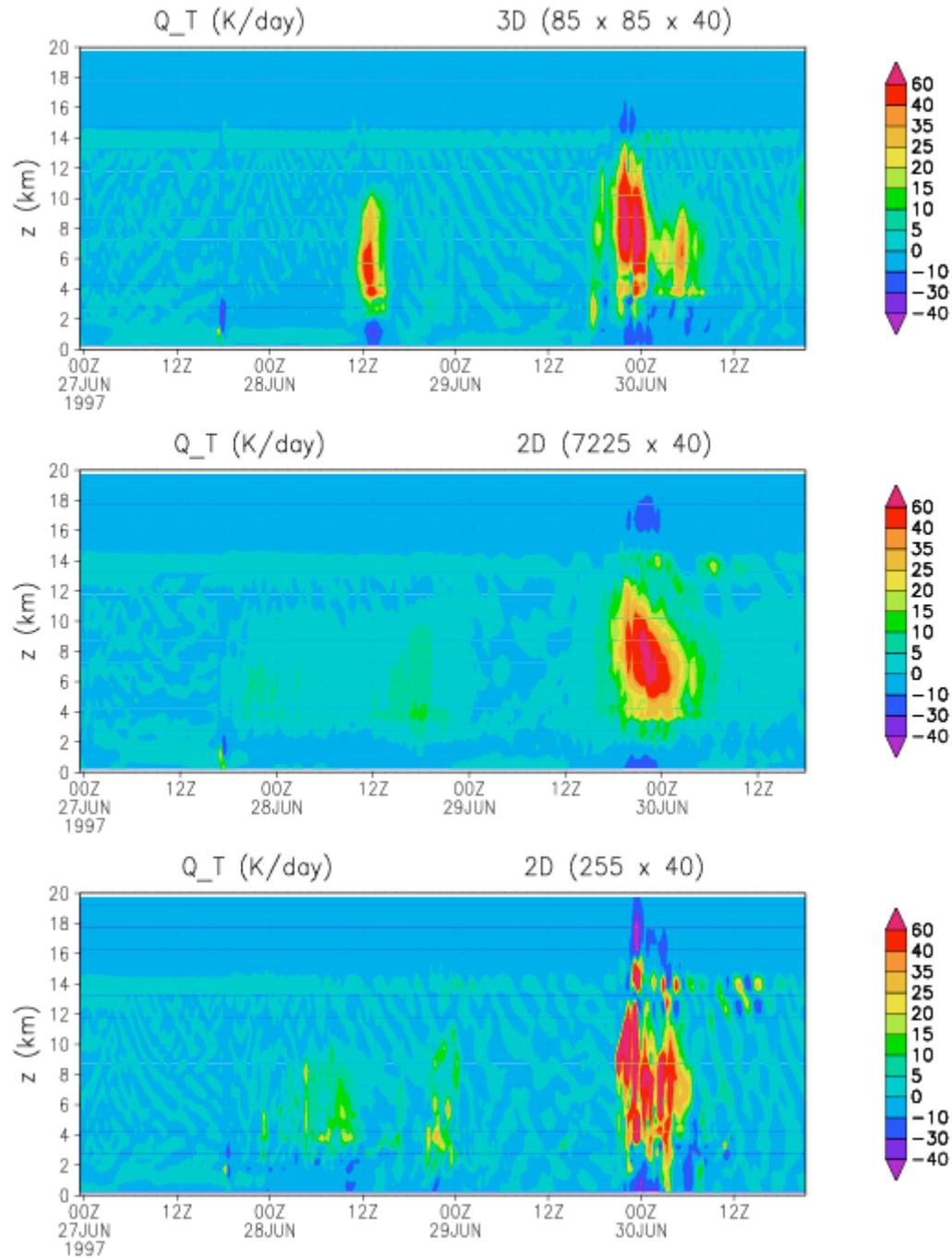
2D (7225 x 40)



2D (255 x 40)

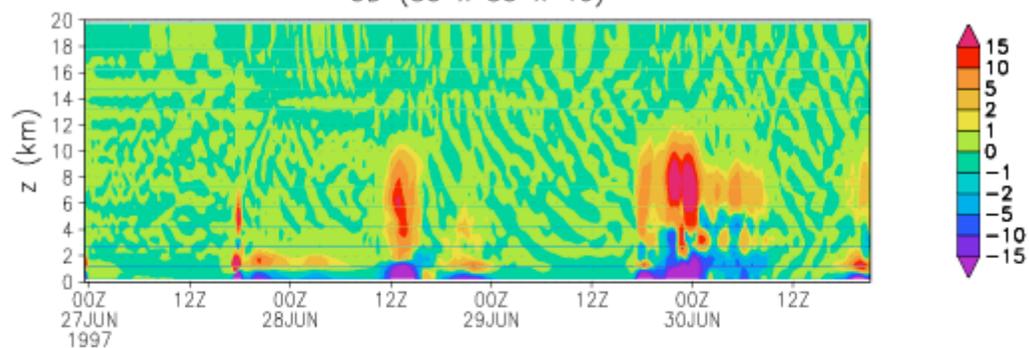


ARM A

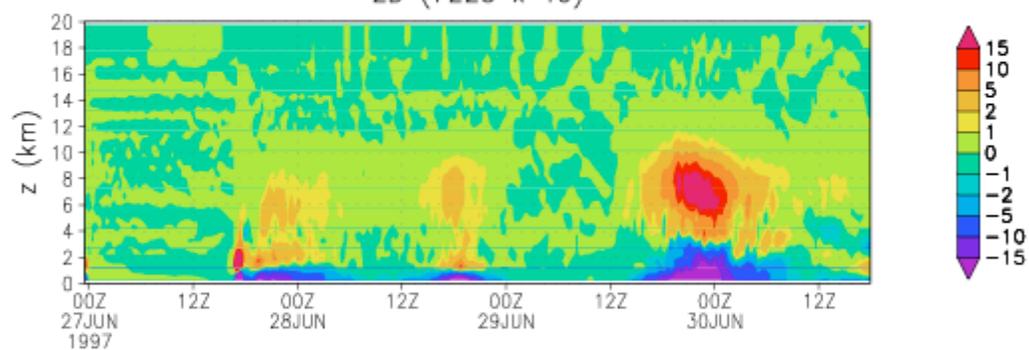


ARM A
MOISTURE FLUX CONVERGENCE (g/kg/day)

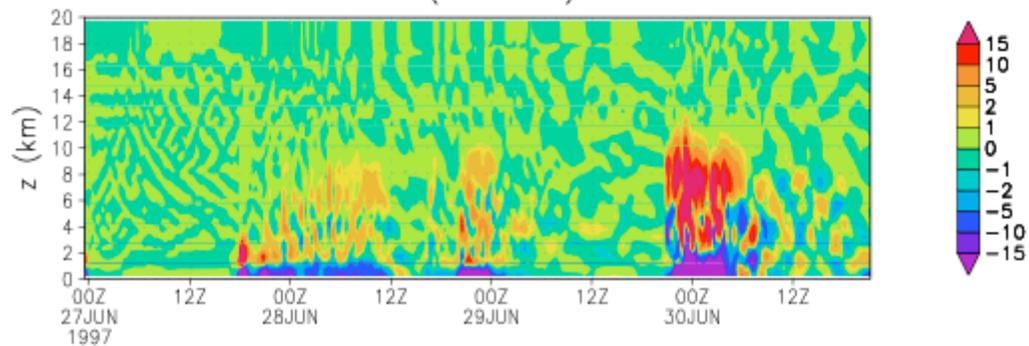
3D (85 x 85 x 40)



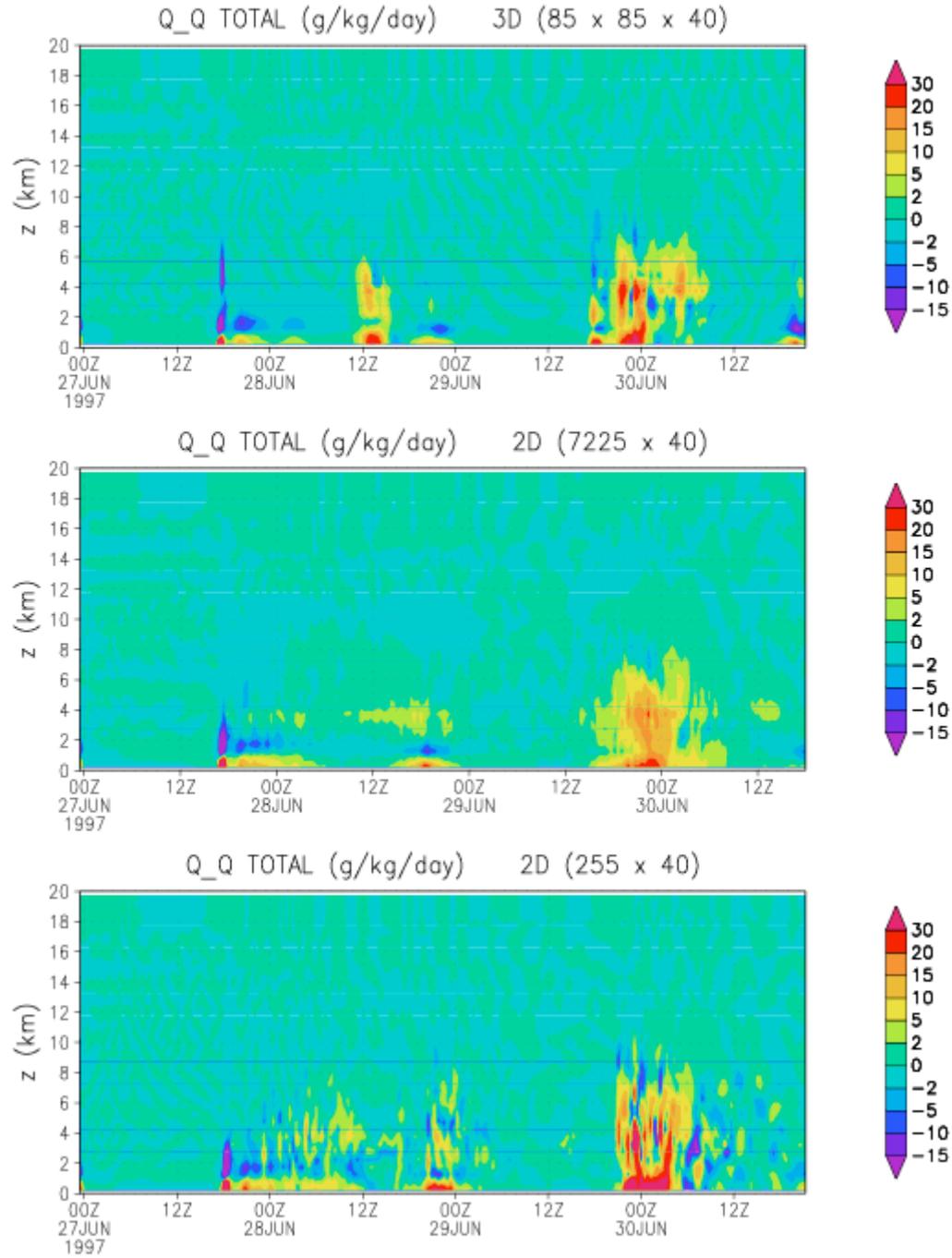
2D (7225 x 40)



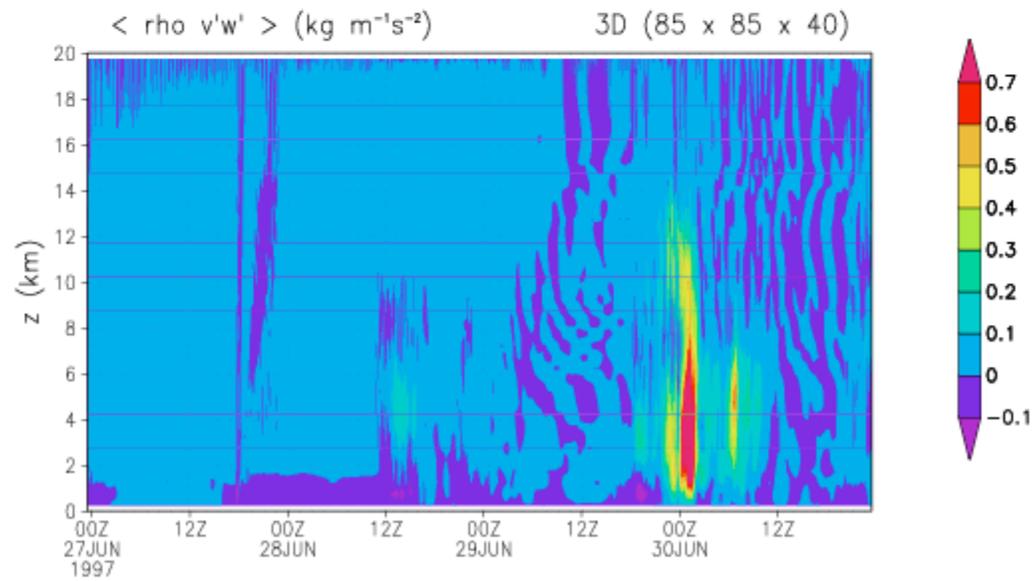
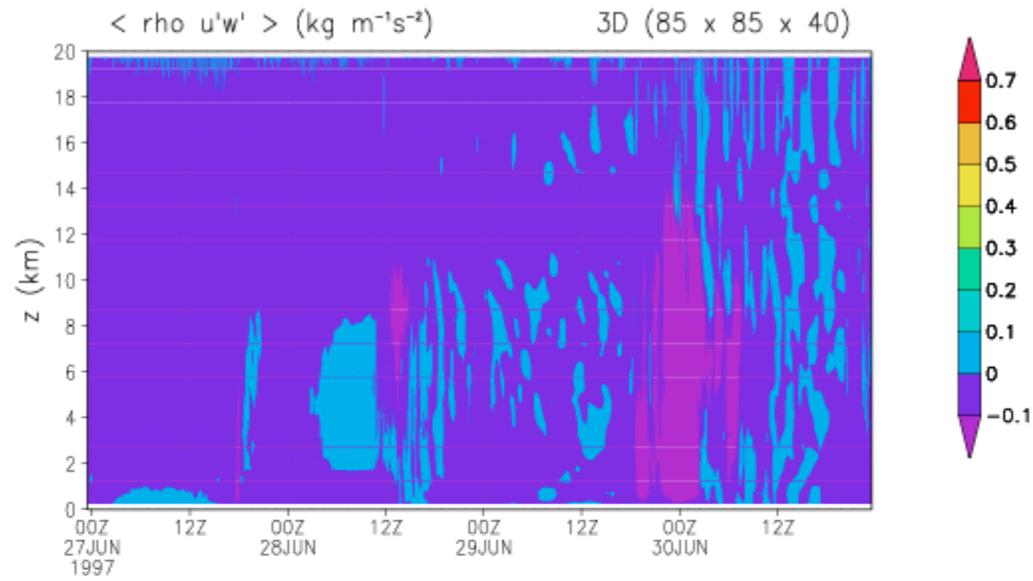
2D (255 x 40)

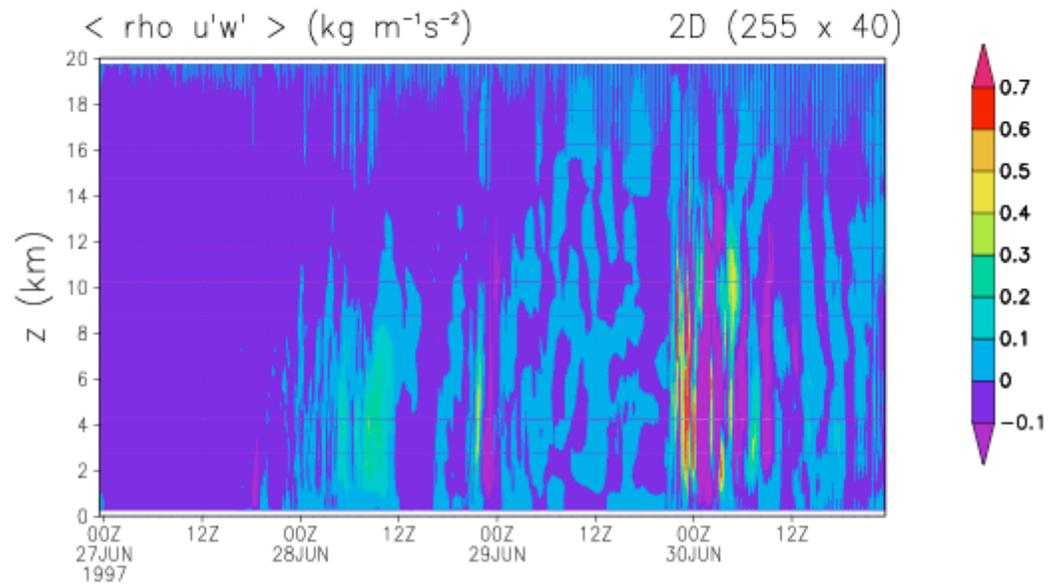
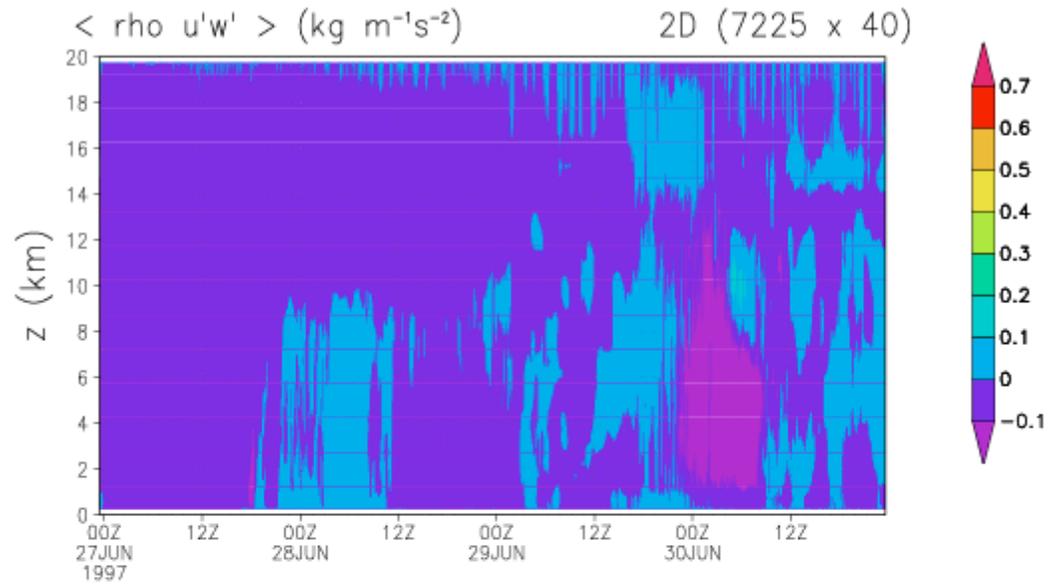


ARM A



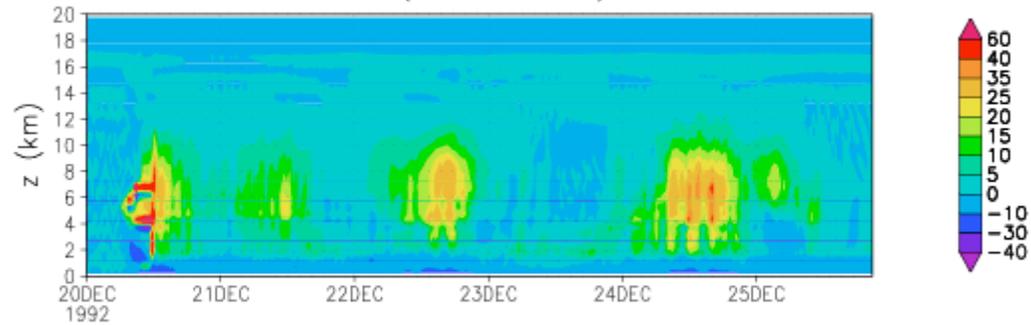
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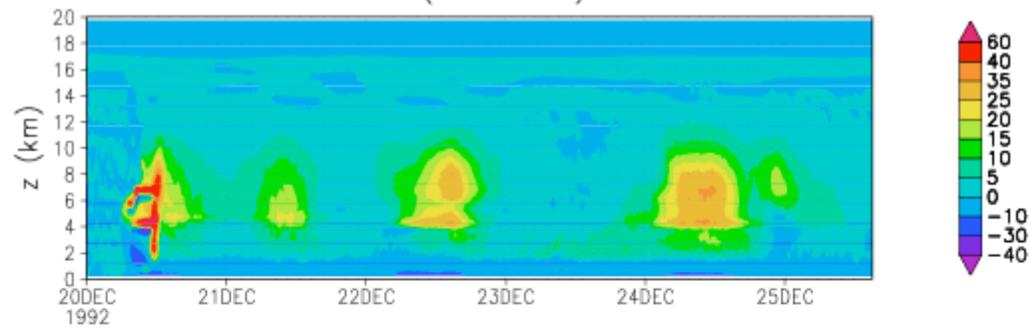


TOGA-COARE
THETA FLUX CONVERGENCE (K/day)

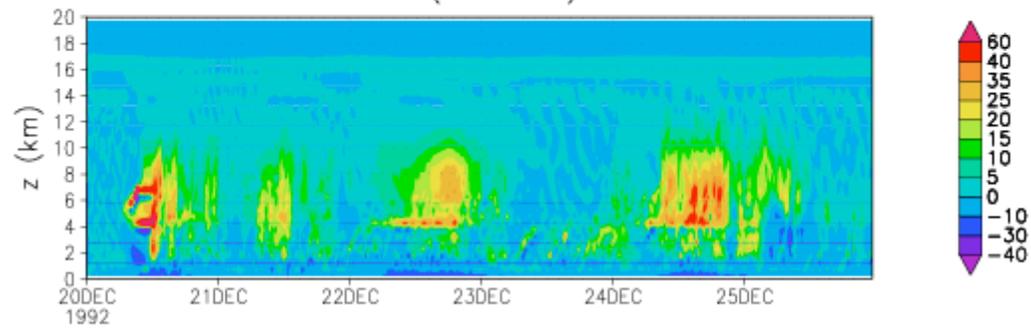
3D (85 x 85 x 40)



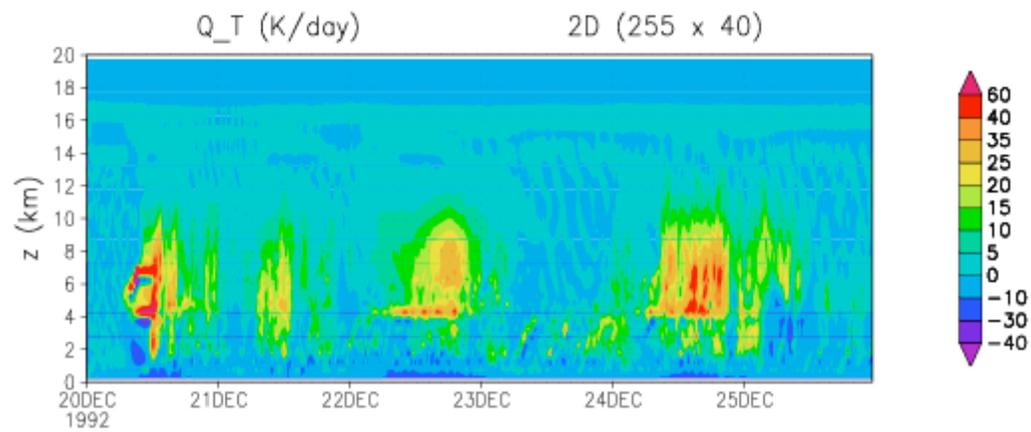
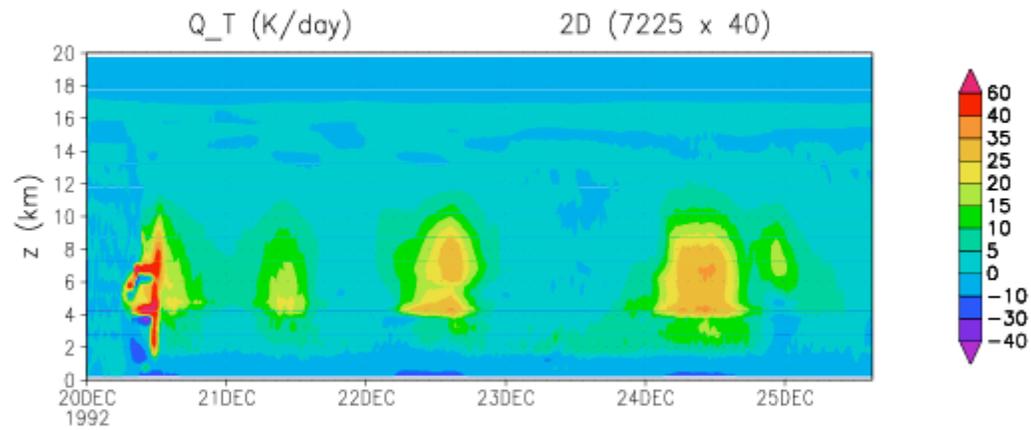
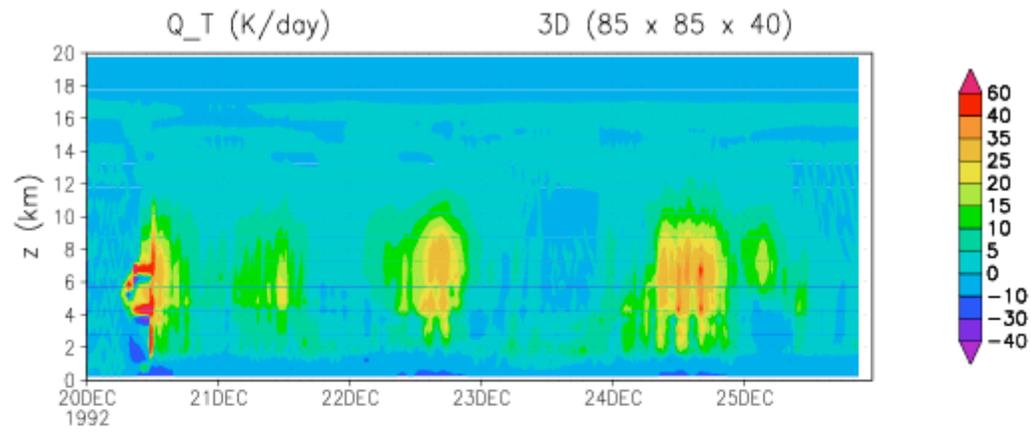
2D (7225 x 40)



2D (255 x 40)

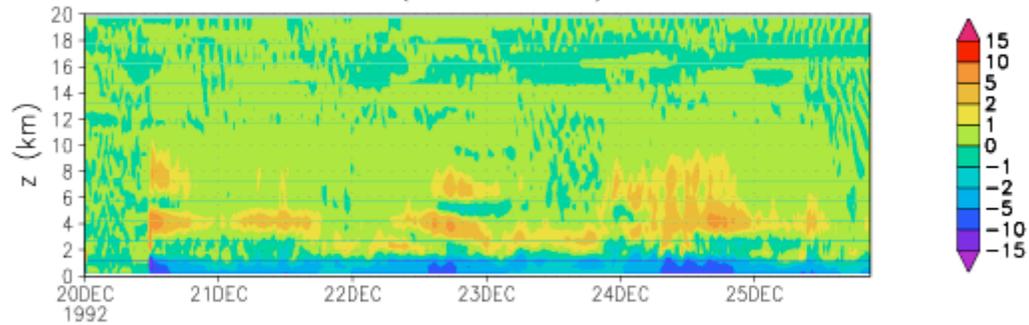


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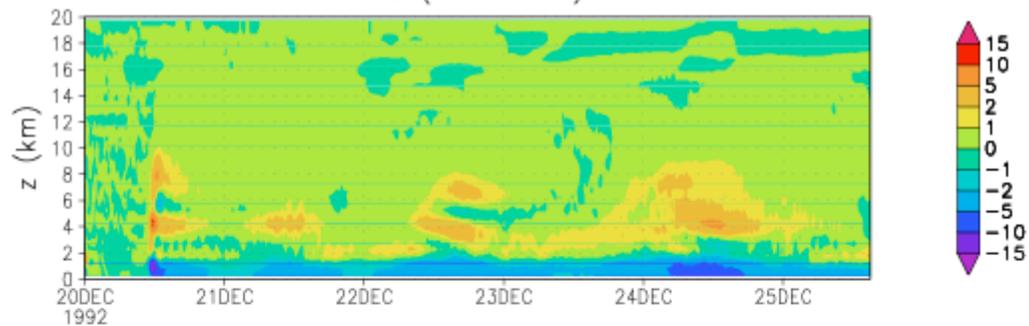


TOGA-COARE
MOISTURE FLUX CONVERGENCE (g/kg/day)

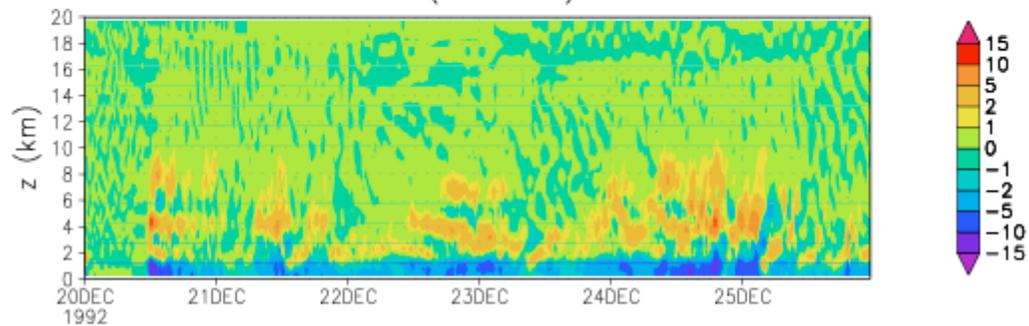
3D (85 x 85 x 40)



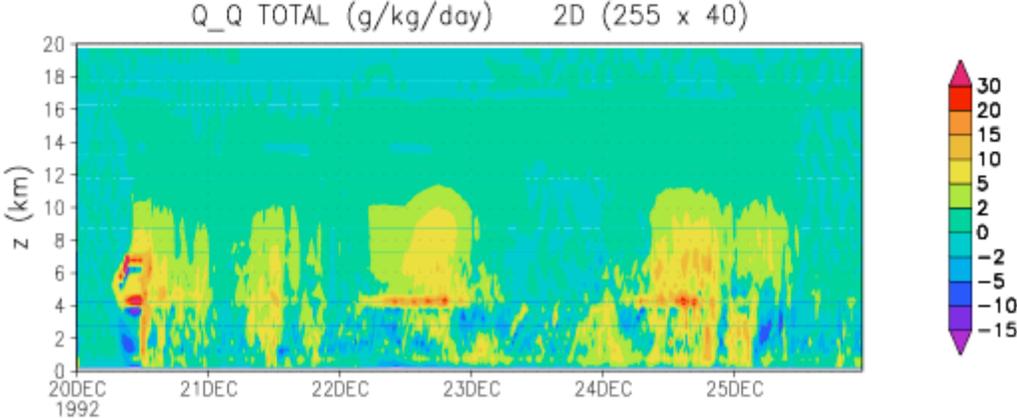
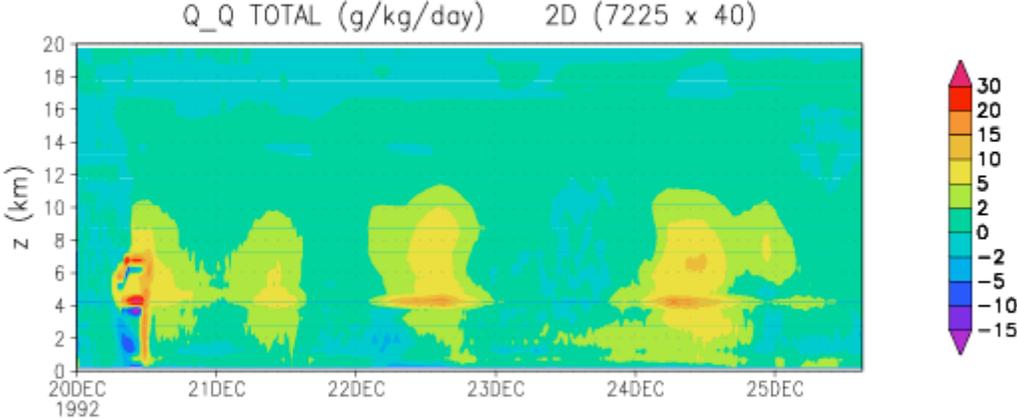
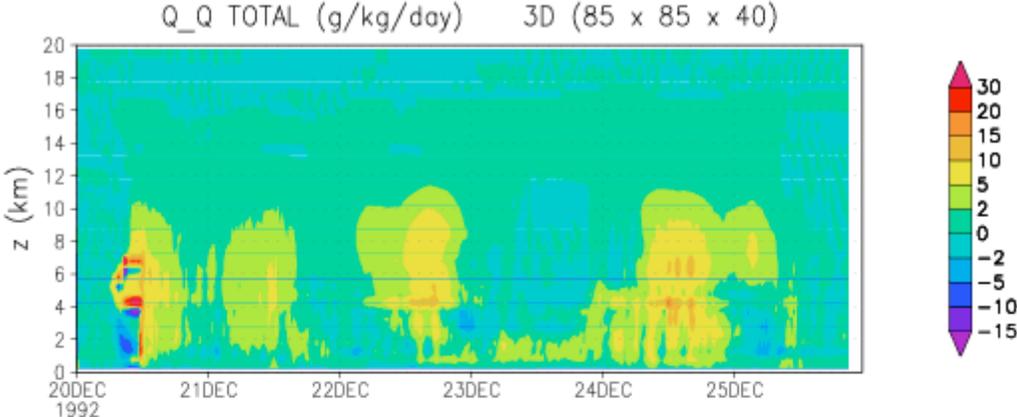
2D (7225 x 40)



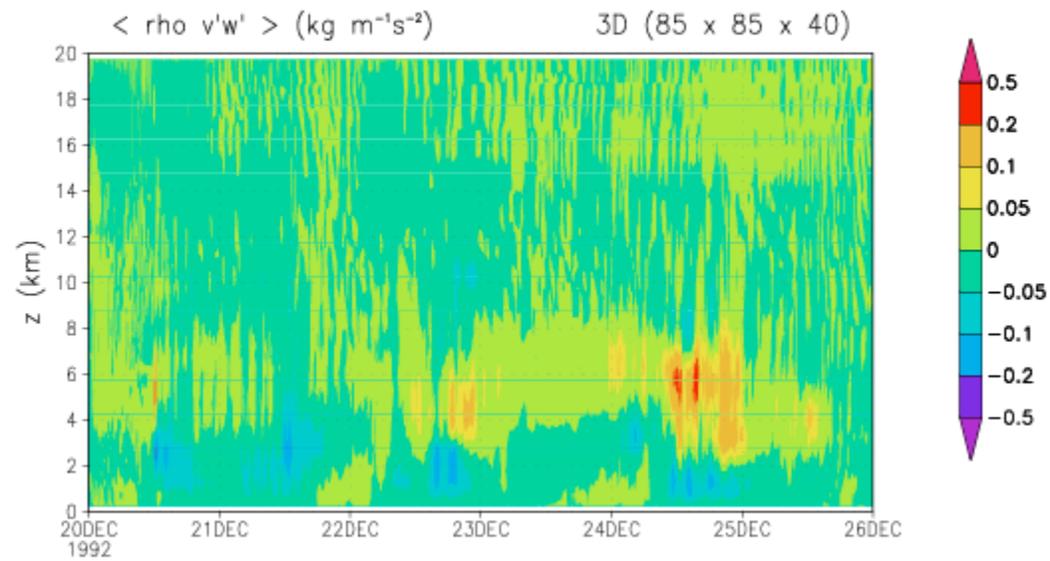
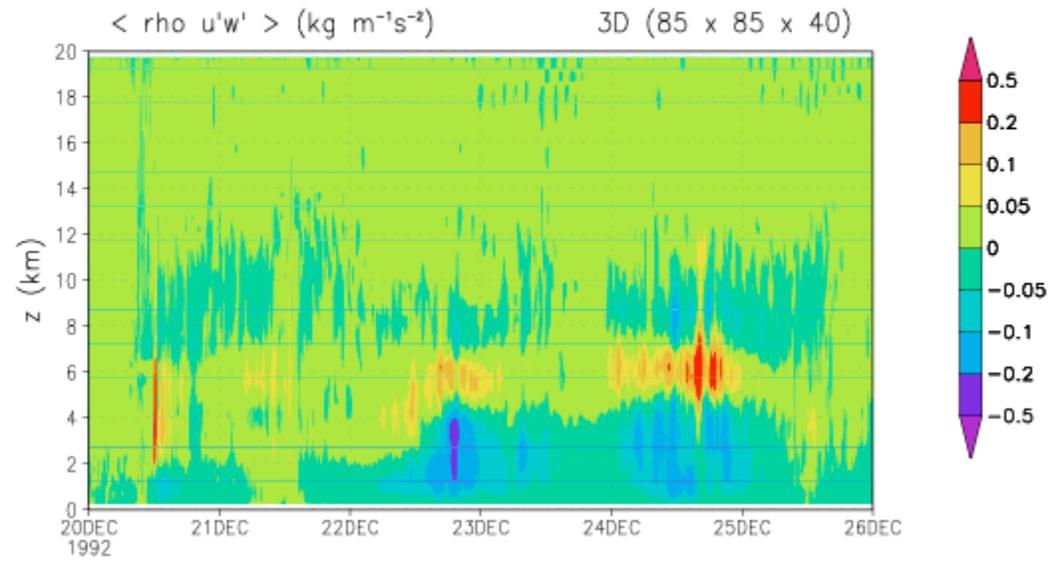
2D (255 x 40)



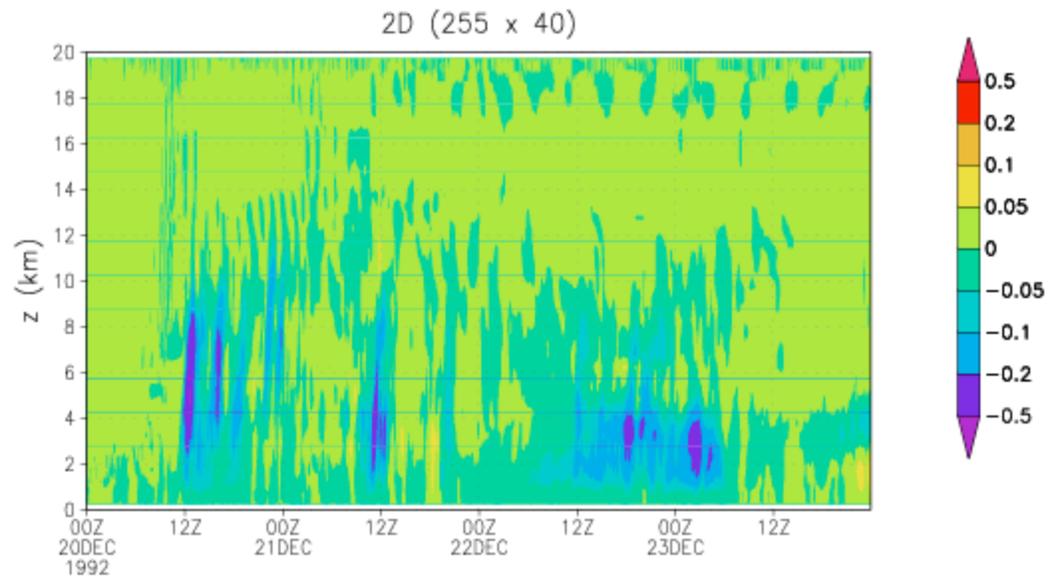
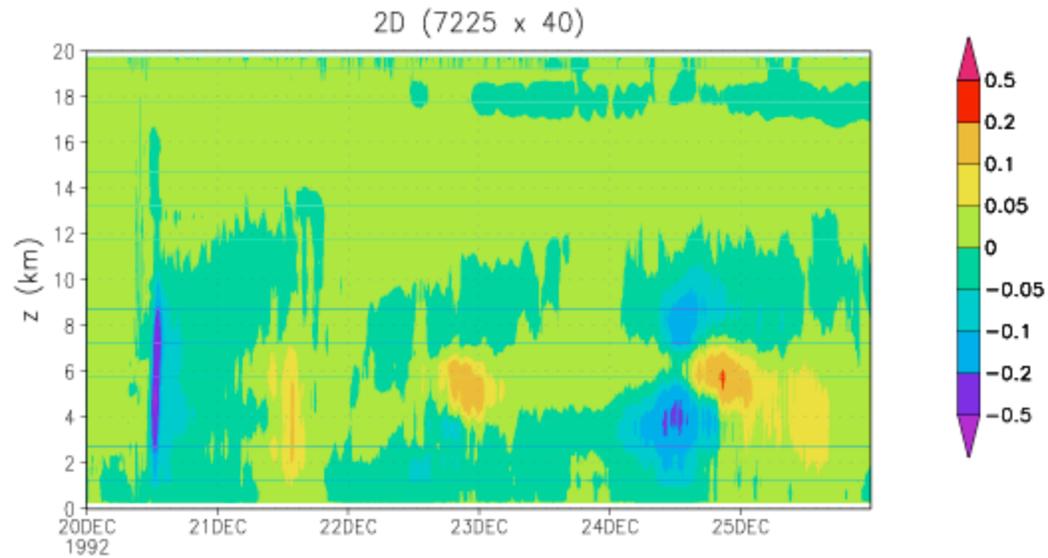
TOGA-COARE



TOGA-COARE



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 $\langle \rho u'w' \rangle$ ($\text{kg m}^{-1}\text{s}^{-2}$)



Summary

I. 3D and small 2D integrations show more structure in large-scale convective sources than large 2D integrations.

II. Large 2D integrations may average over many realizations and be smoother. Small 2D may have structure due to noise. 3D may evolve structures with intense fluxes of heat and moisture.

III. Momentum fluxes can differ greatly in 3D vs. 2D.

IV. The 3D and small 2D have qualitative similarities for heat and moisture sources, although differences in event timing and structure can occur.