Mesoscale Radiatively-Induced Anvil Spreading

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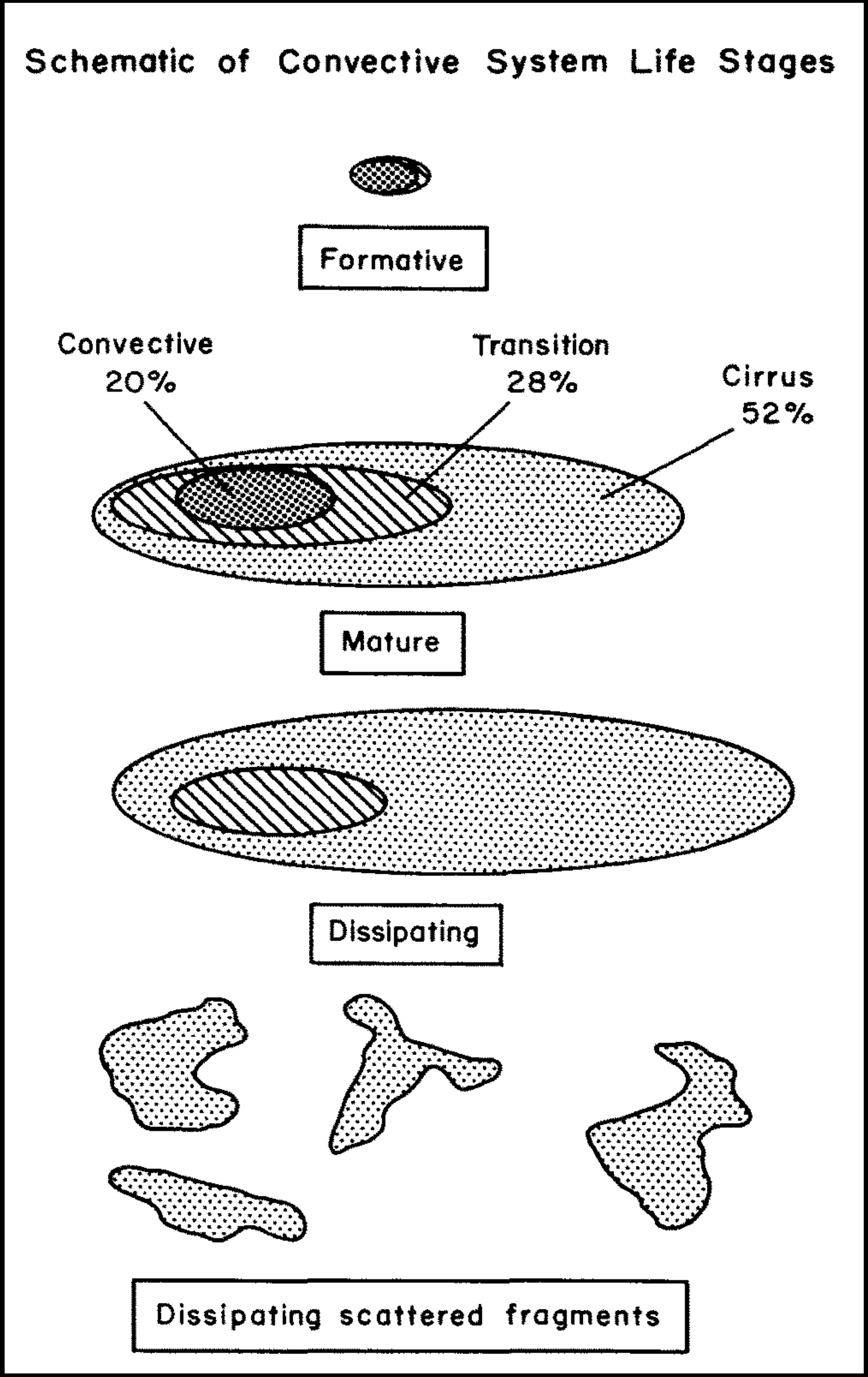
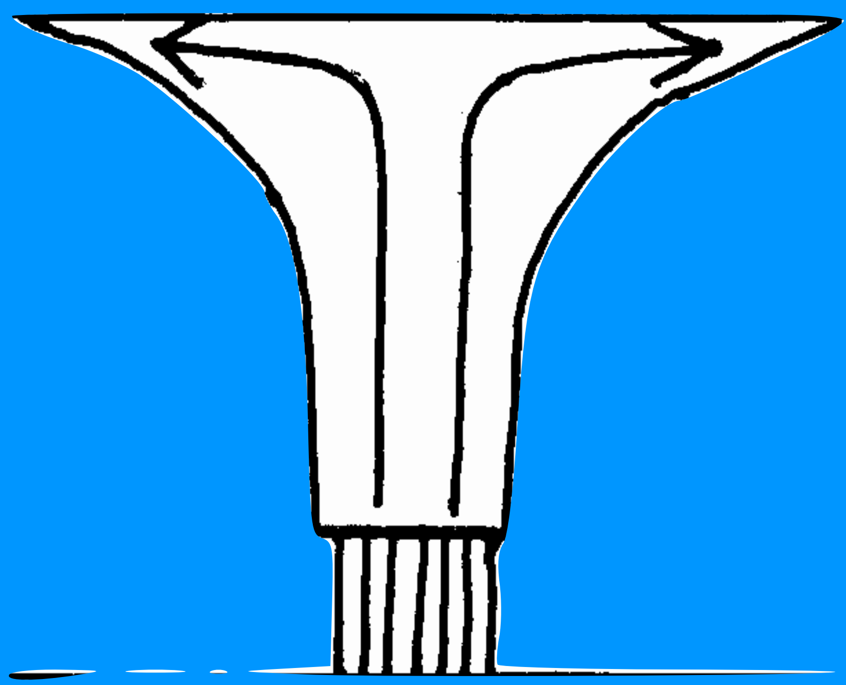
Cirrus clouds often result from the life cycle of convective cloud systems



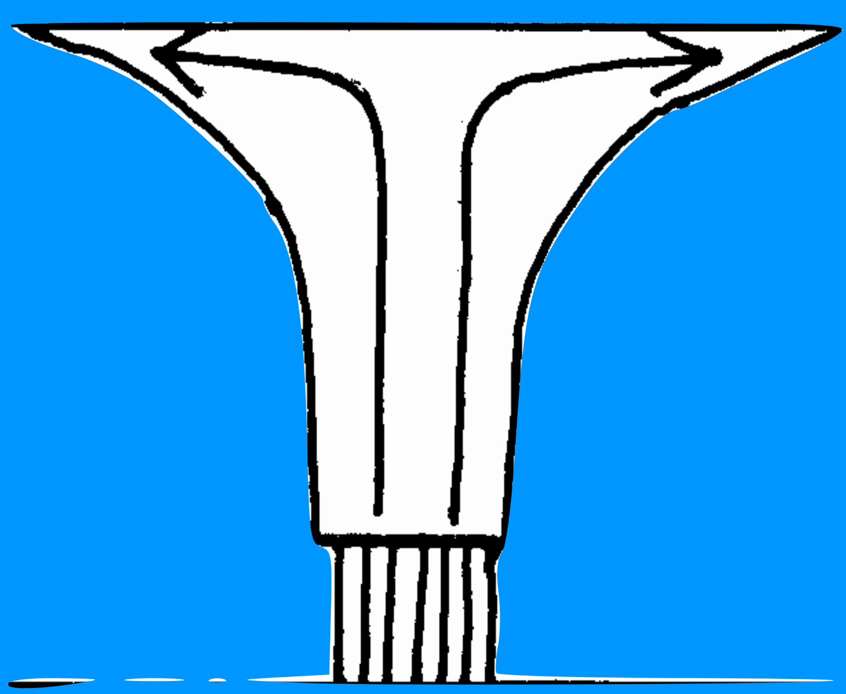
Machado and Rossow (1993)

Why do anvil clouds spread?

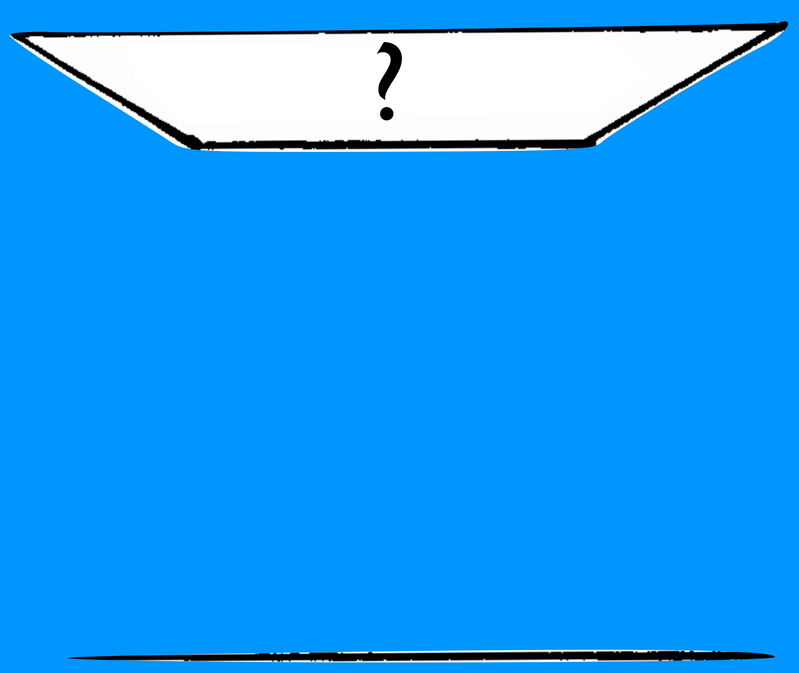
detrainment



detrainment



decay



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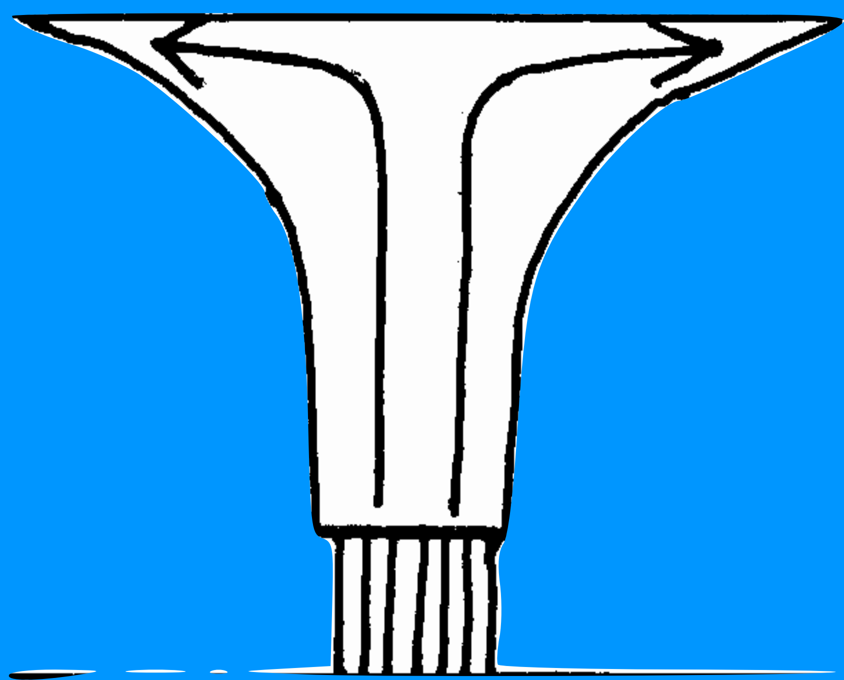
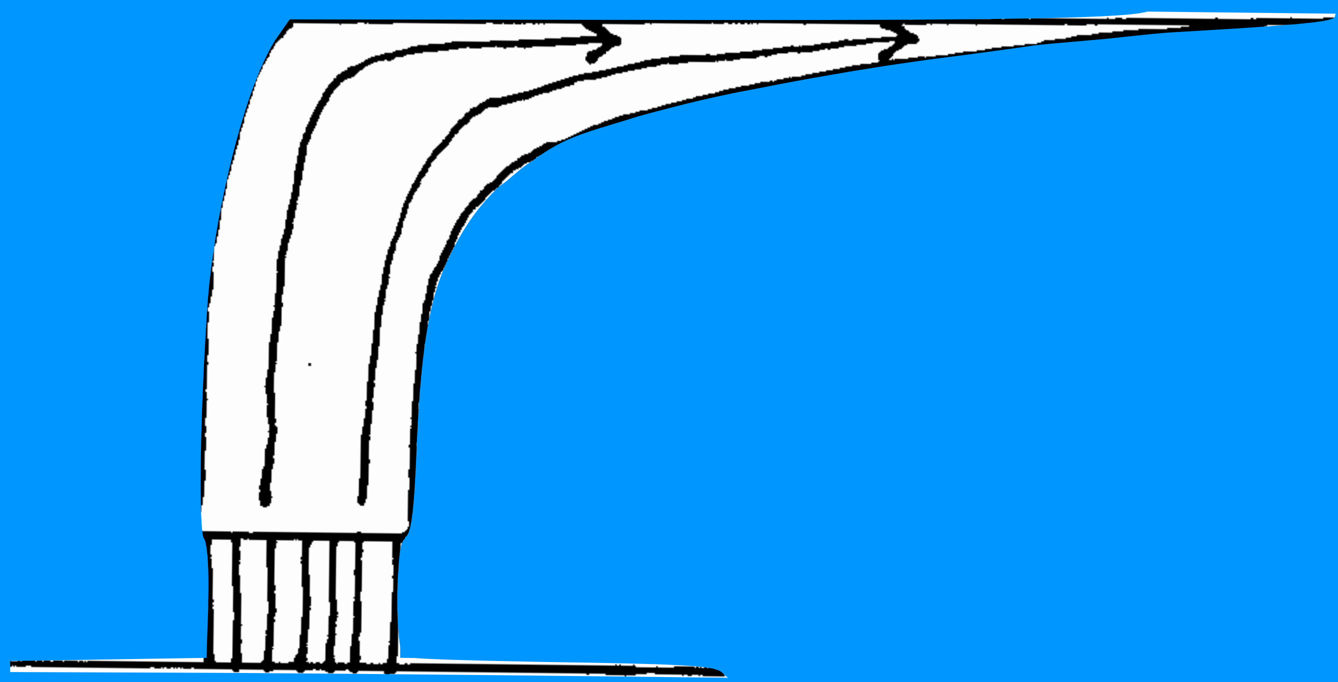
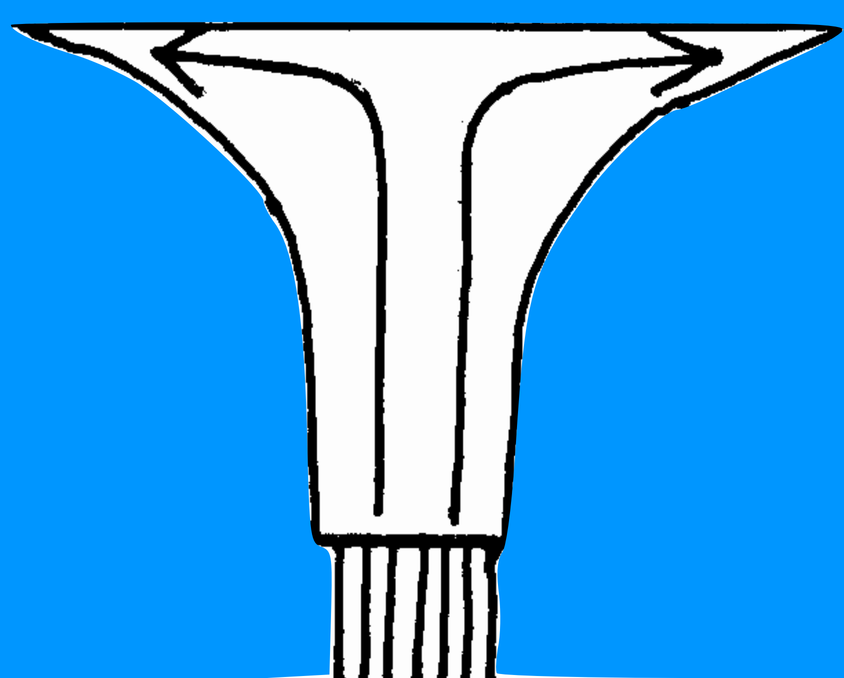


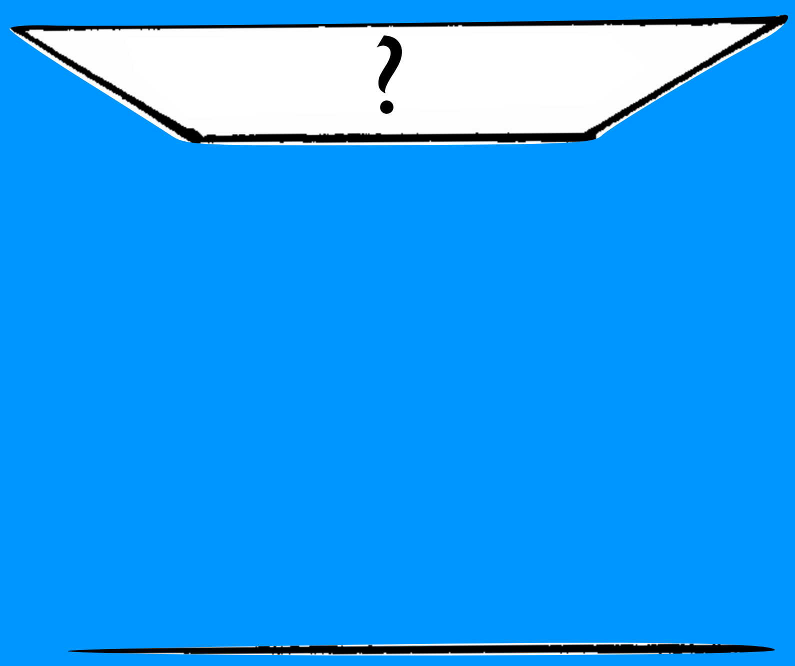
detrainment + wind shear

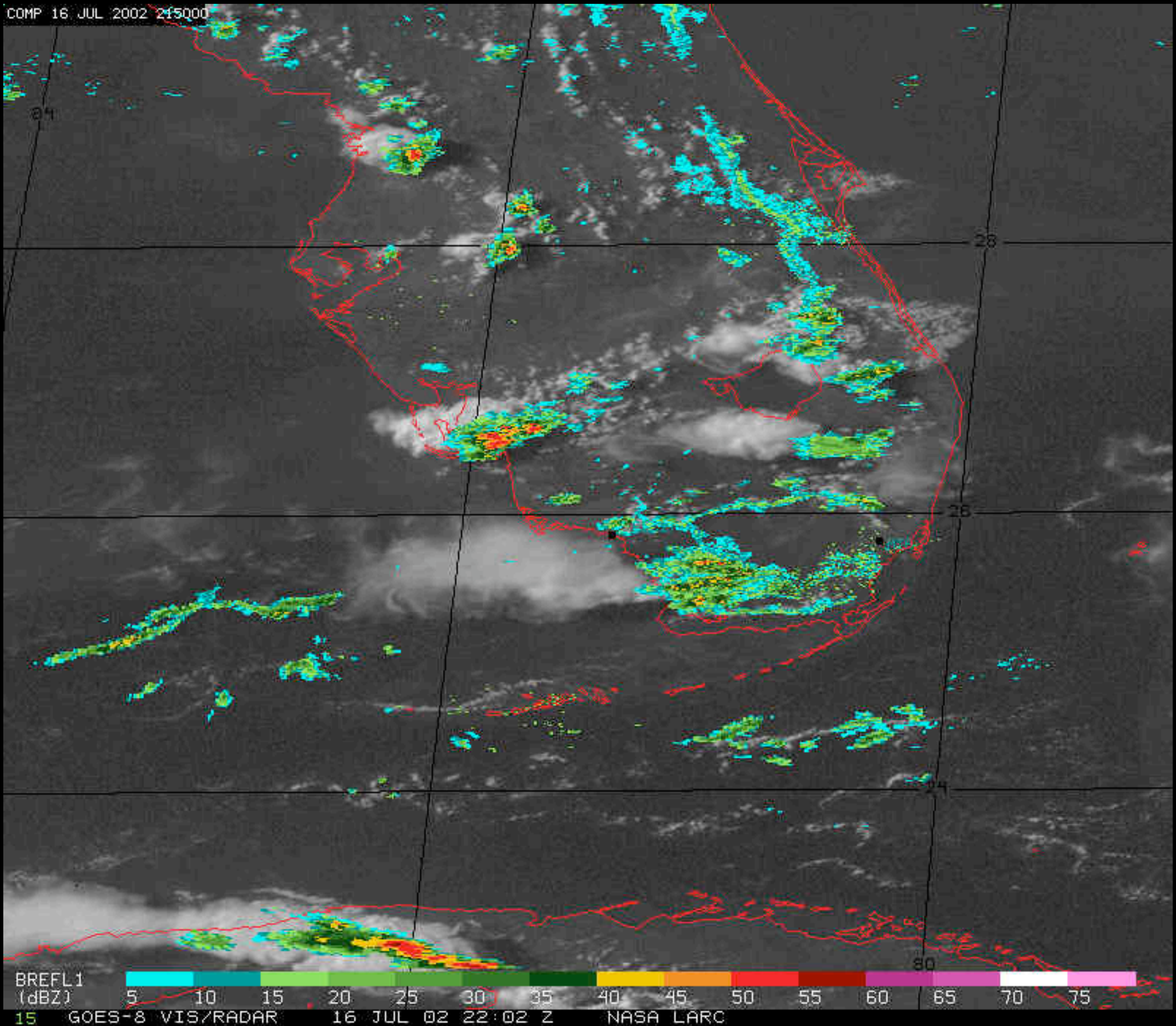


detrainment



decay

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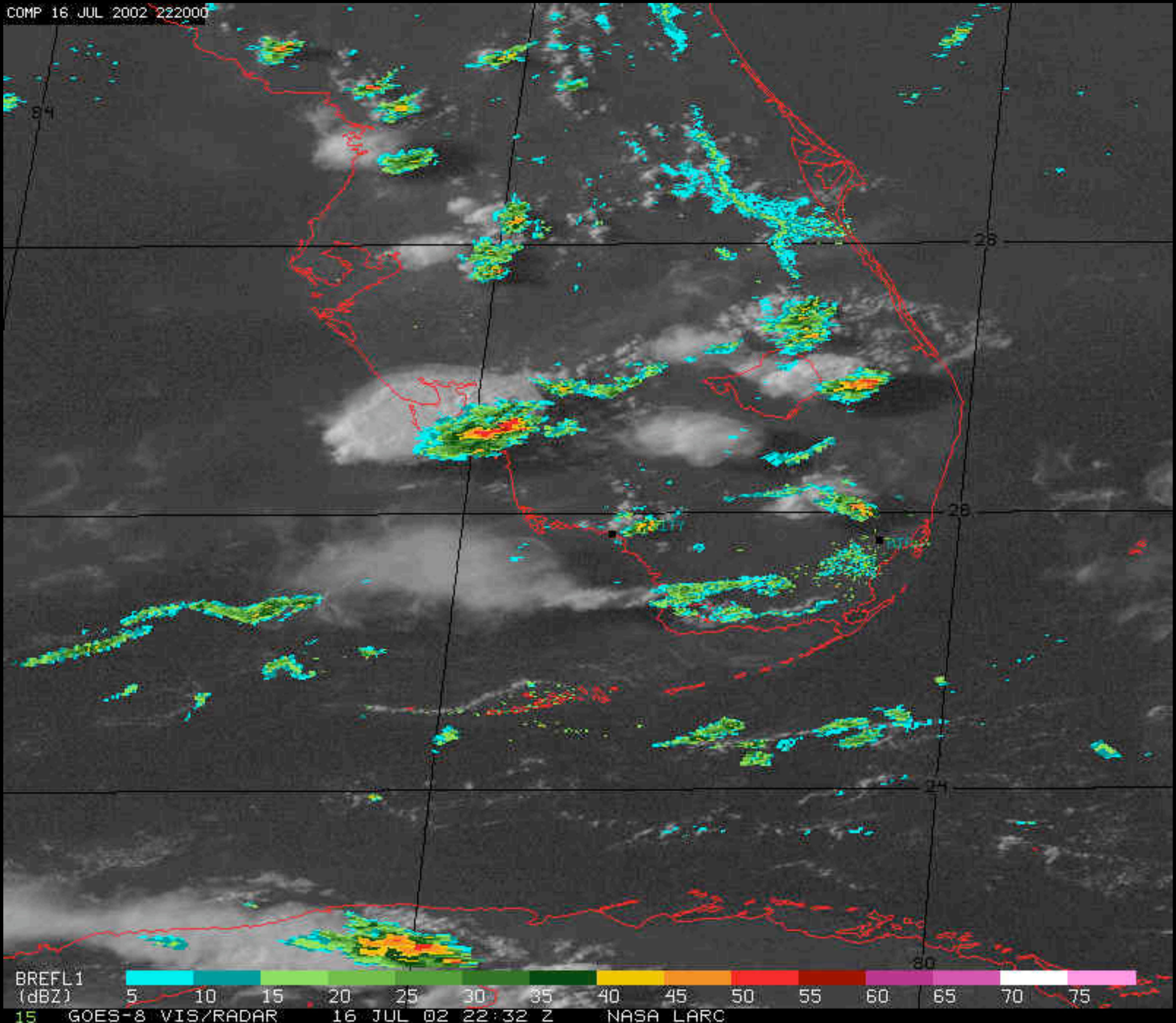
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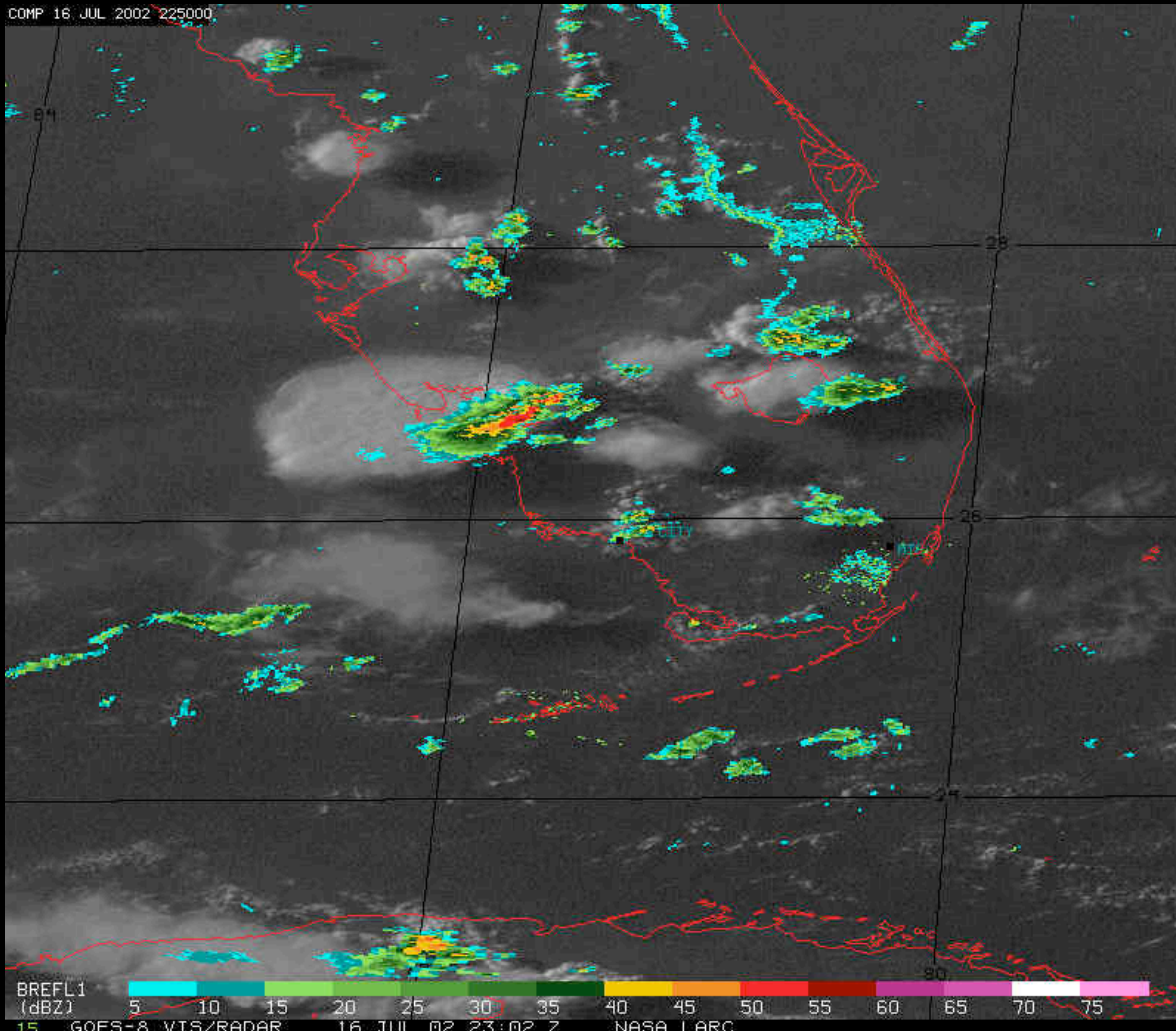
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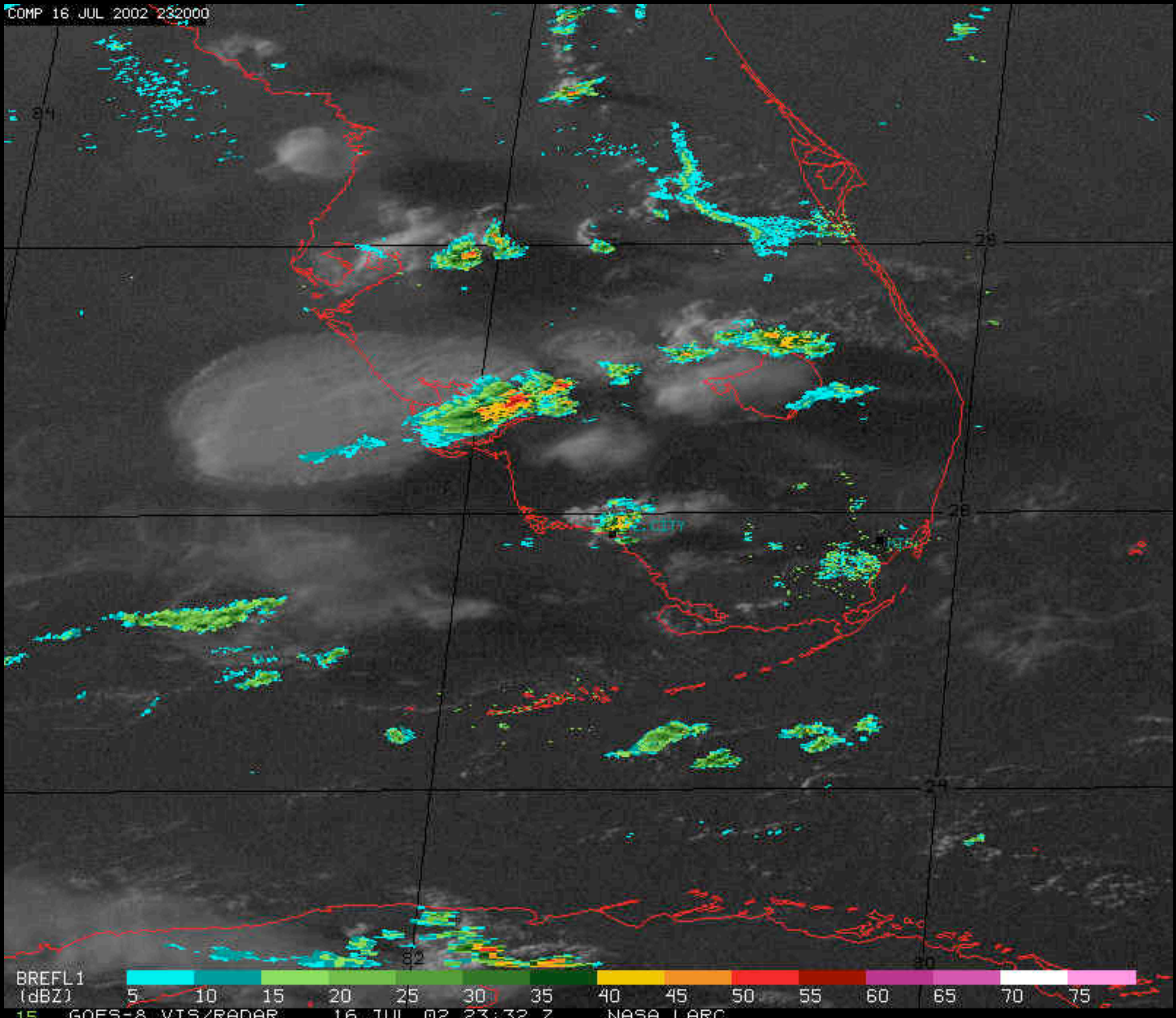
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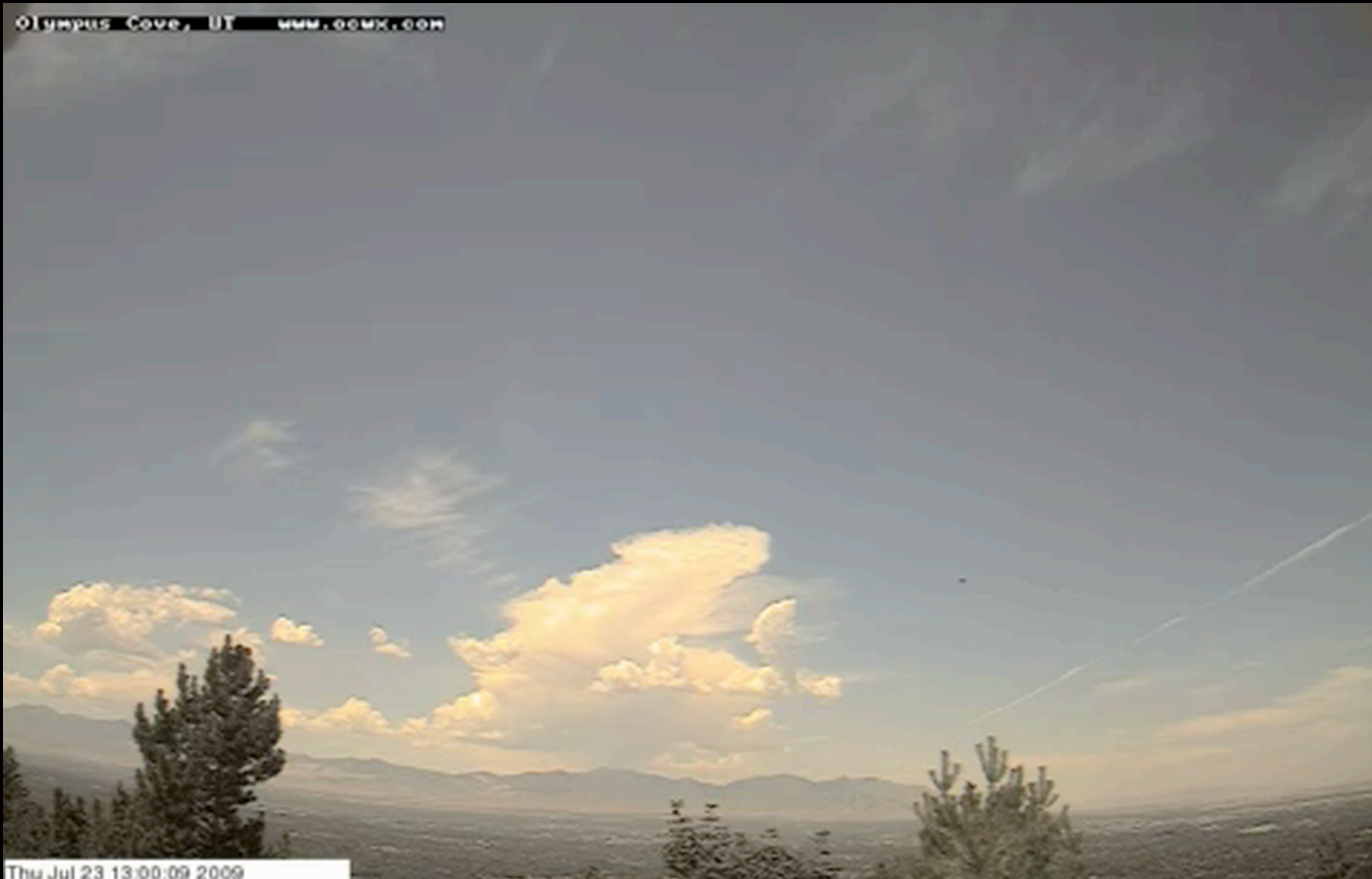
Olympus Cove, UT www.ocwx.com
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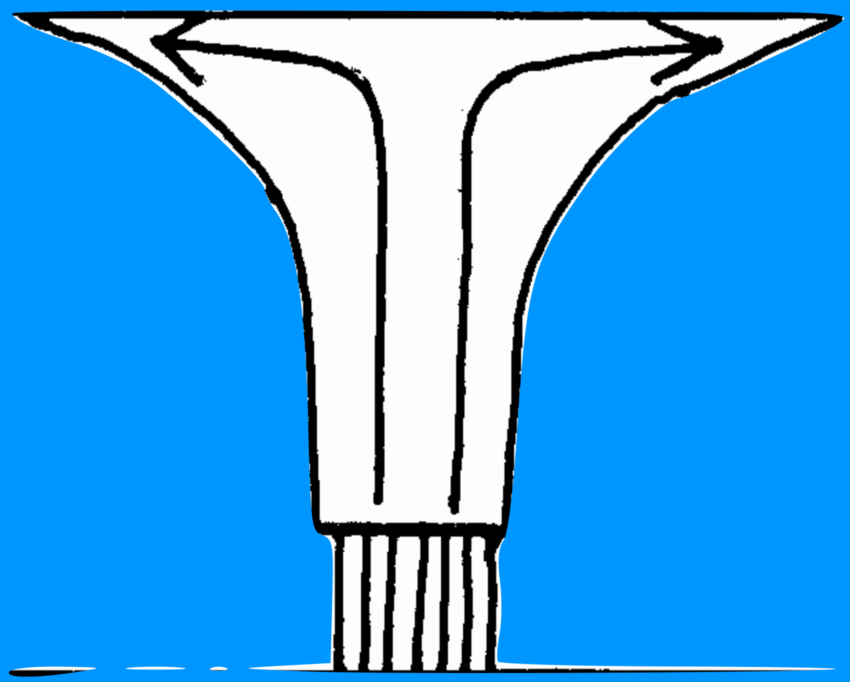
Wed Sep 17 13:00:18 2008

Why do anvil clouds spread?

detrainment



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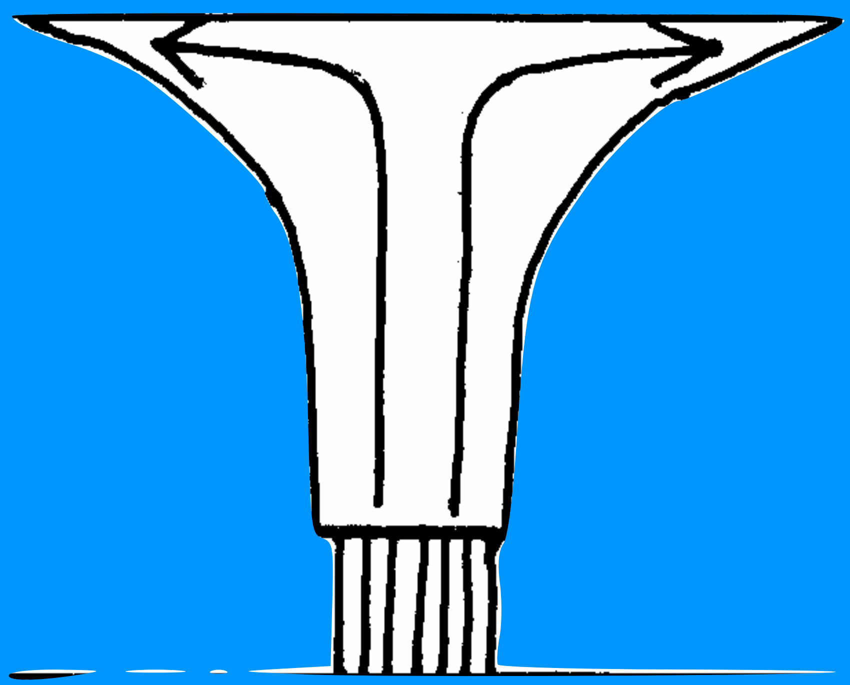
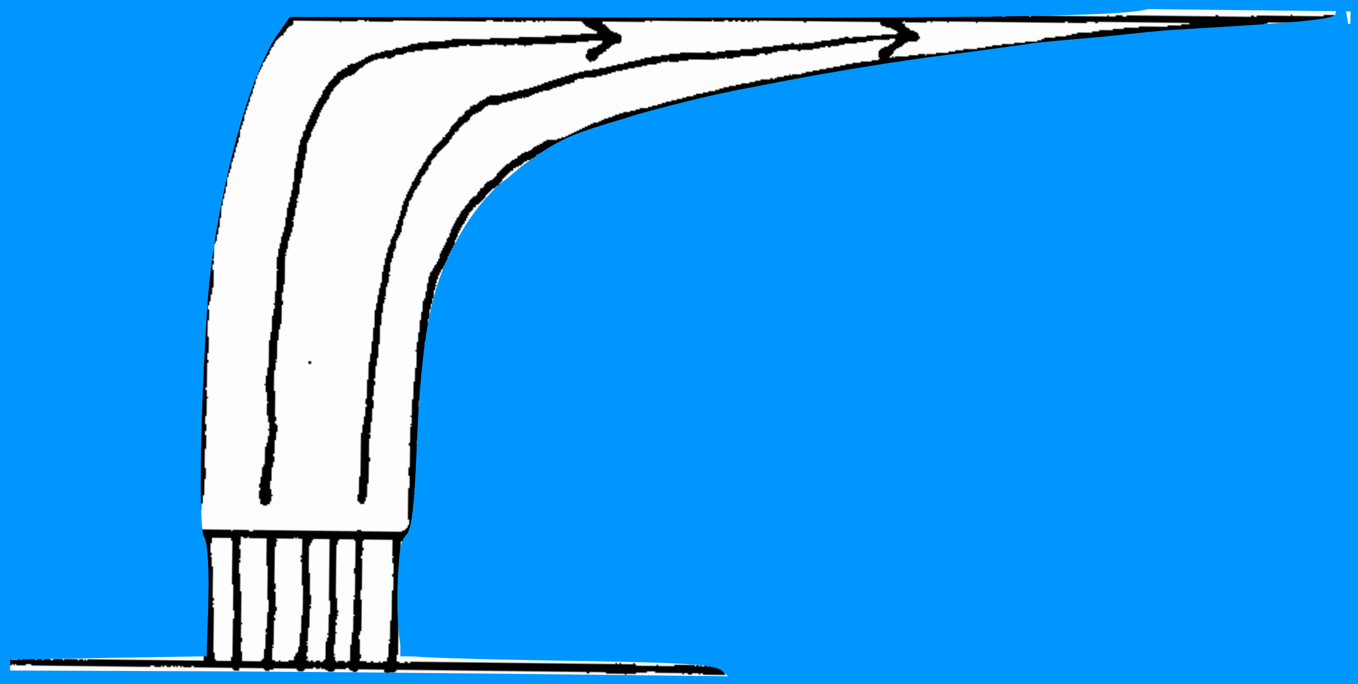


detrainment + wind shear



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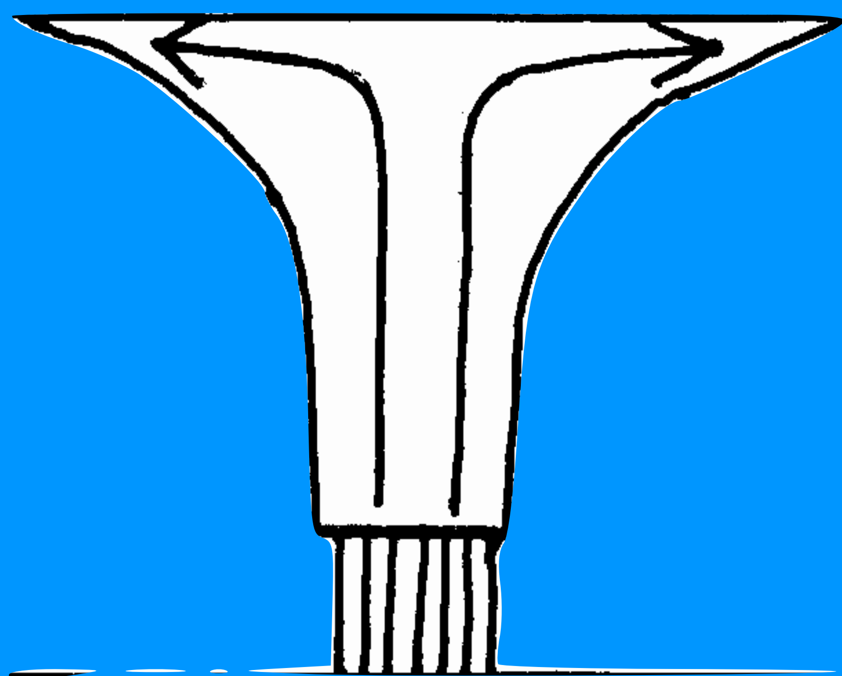
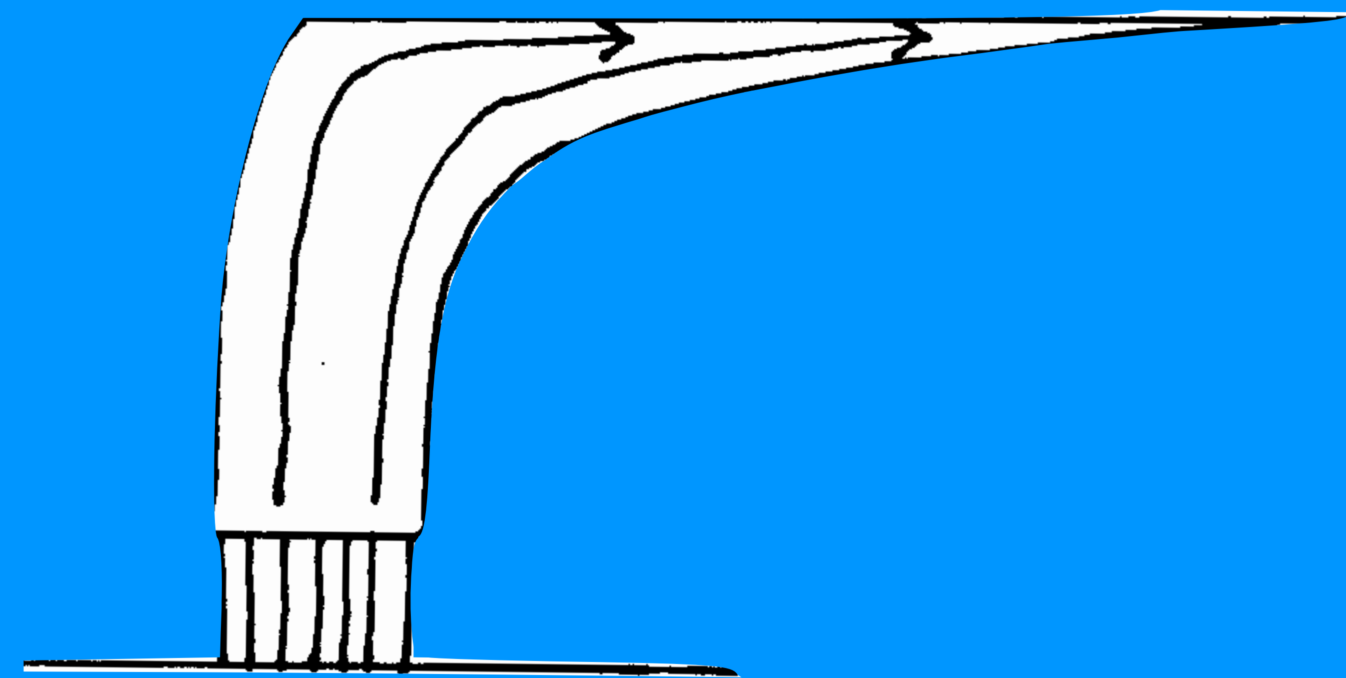
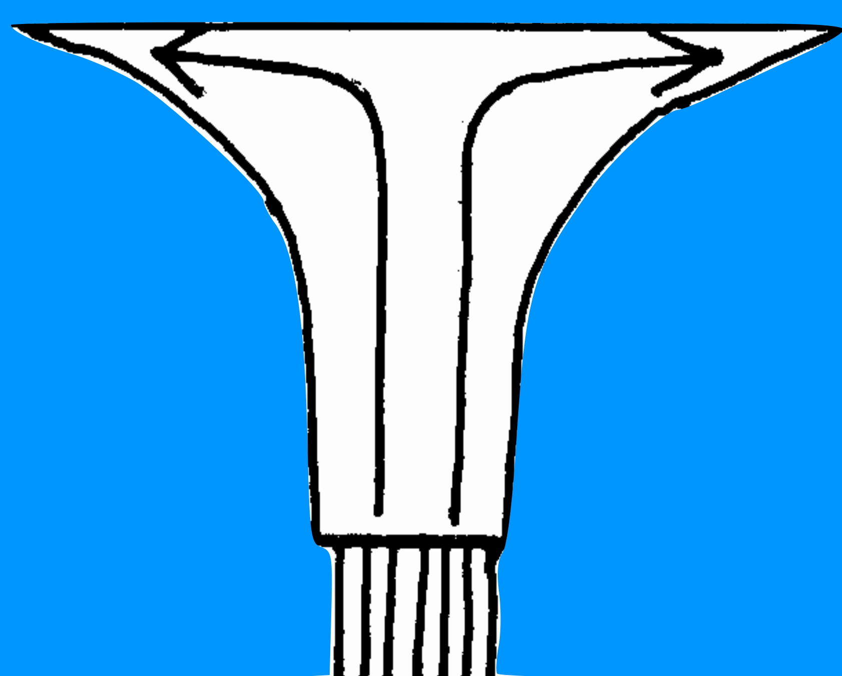


detrainment + wind shear



detrainment



MRAS

mesoscale radiatively-induced anvil spreading

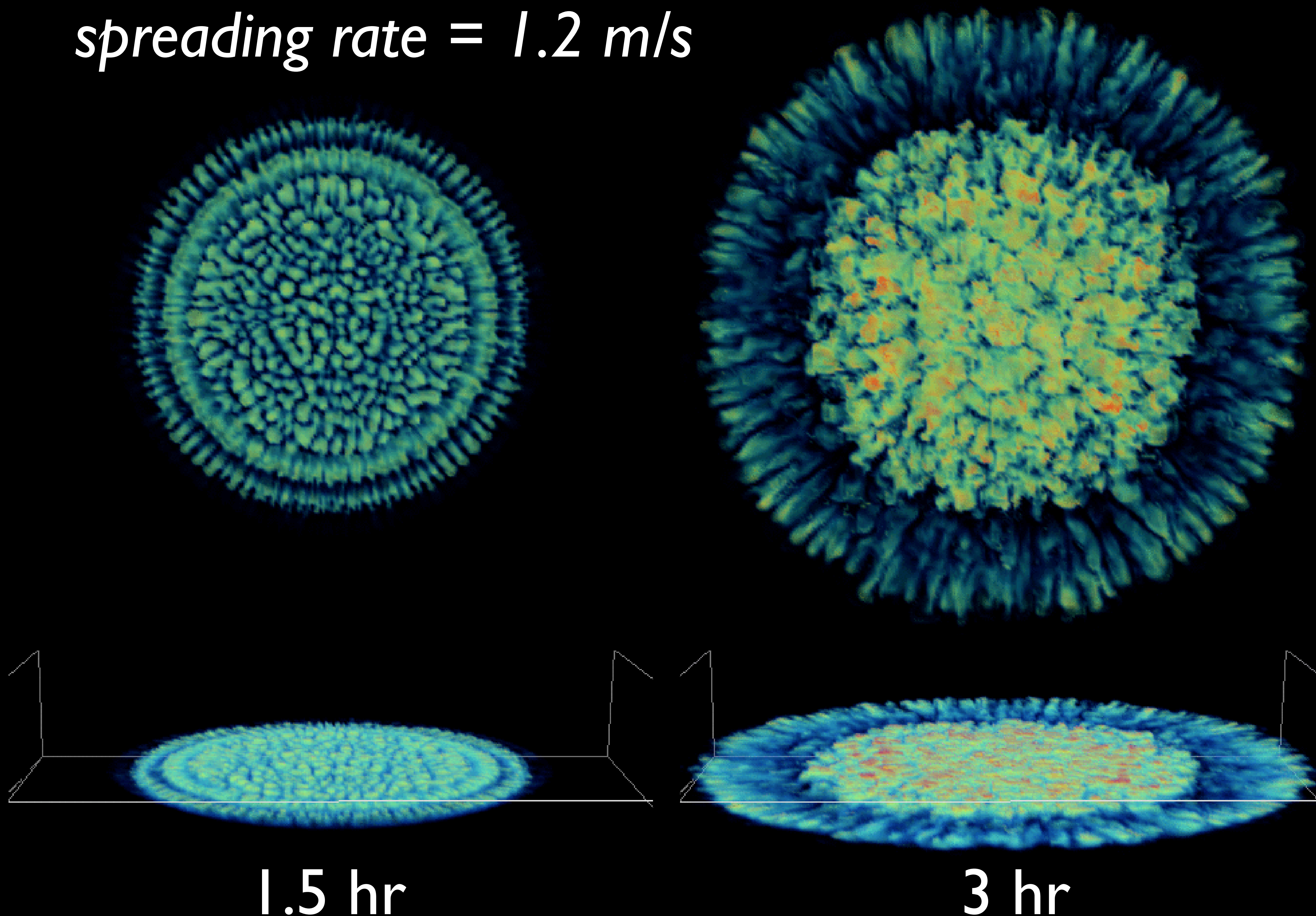
Cloud-Resolving Simulations

1. Anvil clouds were artificially generated by injecting ice crystals into a layer.

2. Anvil clouds were realistically generated by the life cycle of convective cloud systems.

Evolution of injected ice clouds due to interactive radiative heating

spreading rate = 1.2 m/s



Conclusions from injected anvil simulations

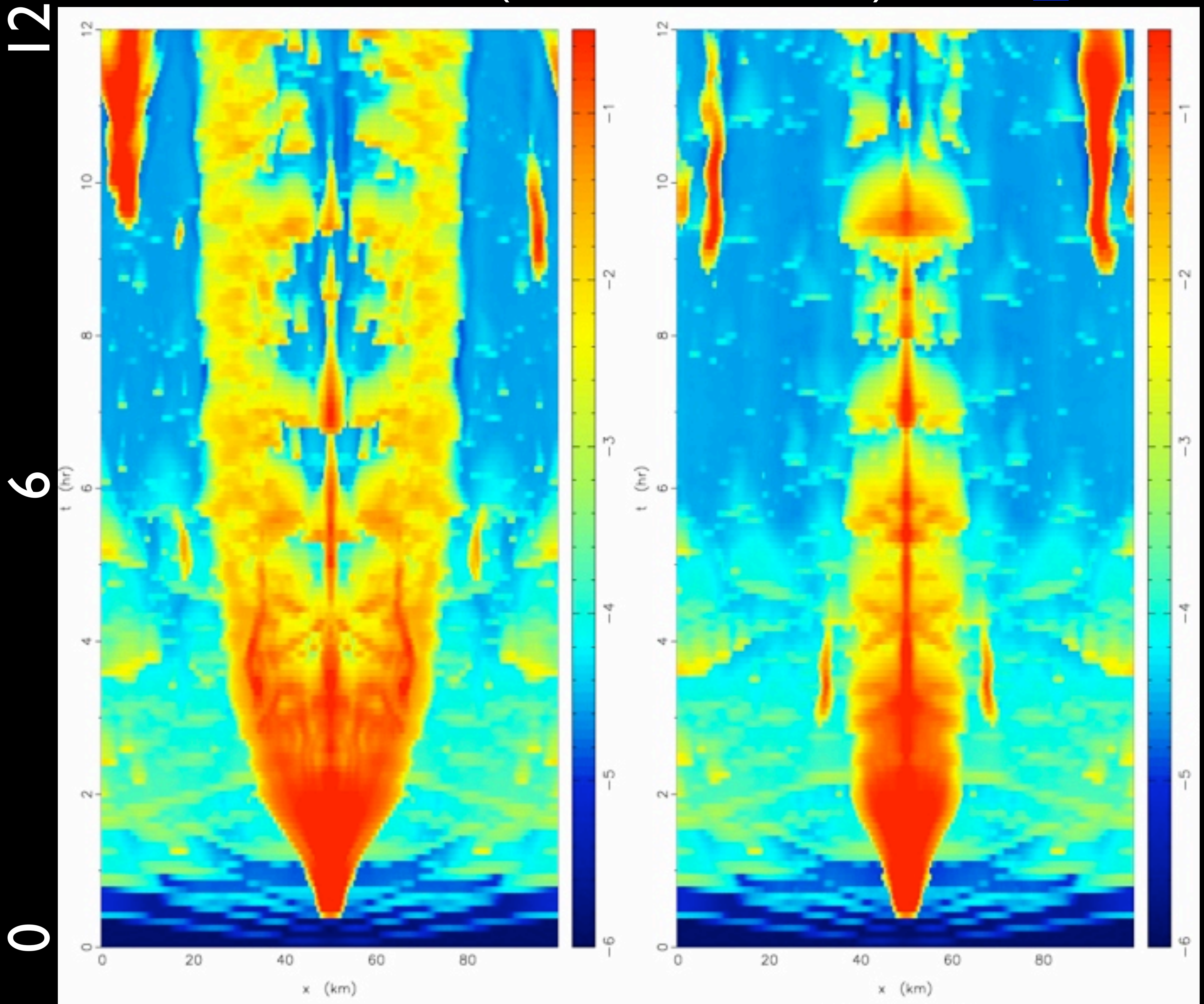
- There is no spreading without radiative heating.
- Mesoscale motions perform the spreading, not cloud-scale motions or turbulence.
- Solar radiation does not reduce the spreading.
- Spatial gradients of radiative heating at the cloud edges drive the mesoscale spreading.

Life-Cycle Simulations

- Support the conclusions reached from the injected anvil simulations.
- 12 h simulations were performed using the 2D Univ of Utah CRM.
- A single convective cell was initiated.
- Domain: 100 km by 18 km.
- Grid sizes: 500 m horizontal, 100 to 900 m vertical

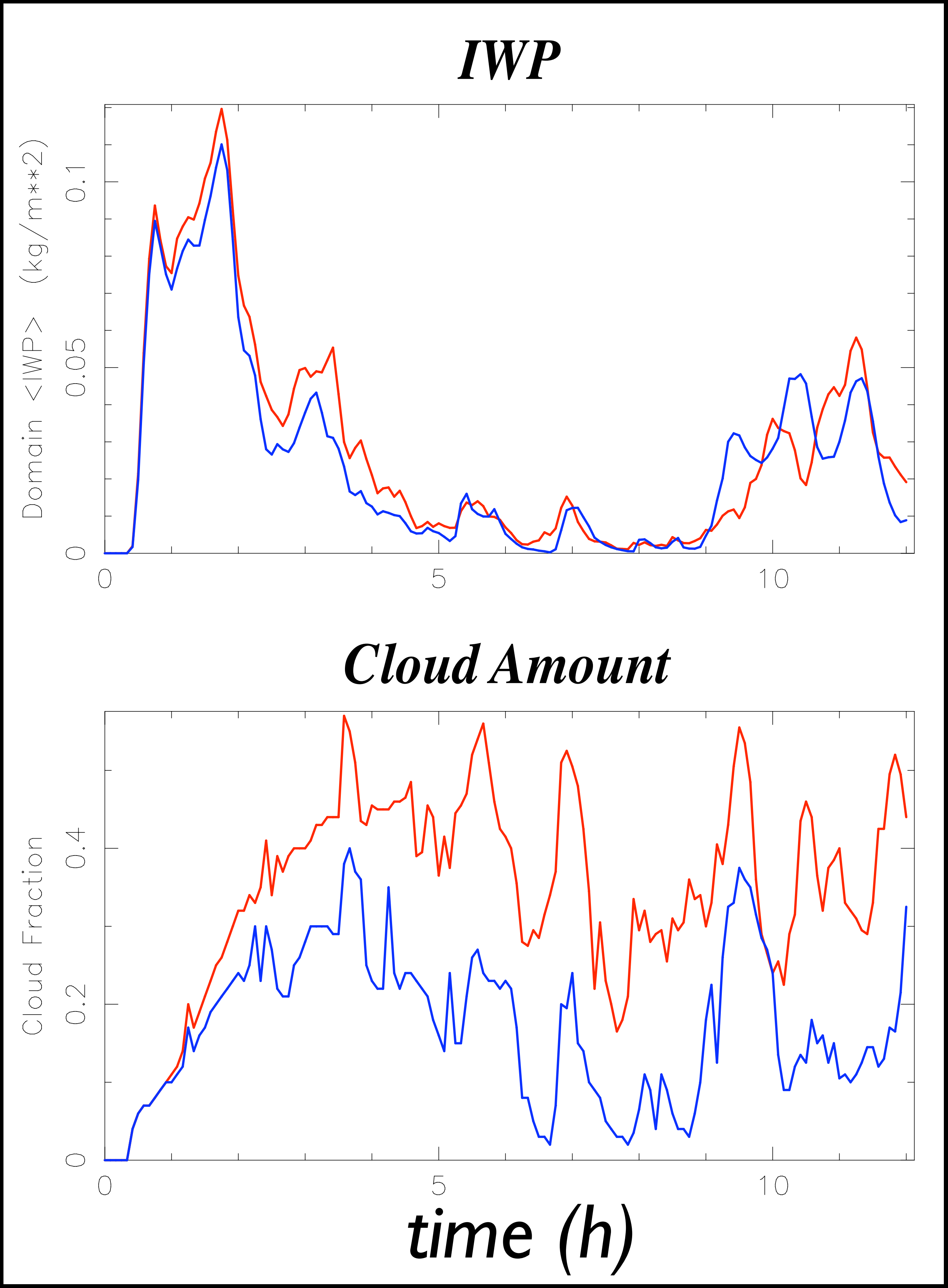
- Simulated Cb reached its maximum height of 12.5 km by 1 hr, when anvil was 10 km wide.
- For next 3 hr, the anvil spread at 1 m/s until it was 50 km across.
- To remove the effects of MRAS, we performed a simulation (NO_RAD) without radiative heating.
- In NO_RAD, the anvil stopped spreading after 2 hr, and spread to only 25 km across.

RAD IWP (Ice Water Path) NO_RAD



IWP is produced by convection.

Cloud amount is increased by MRAS.

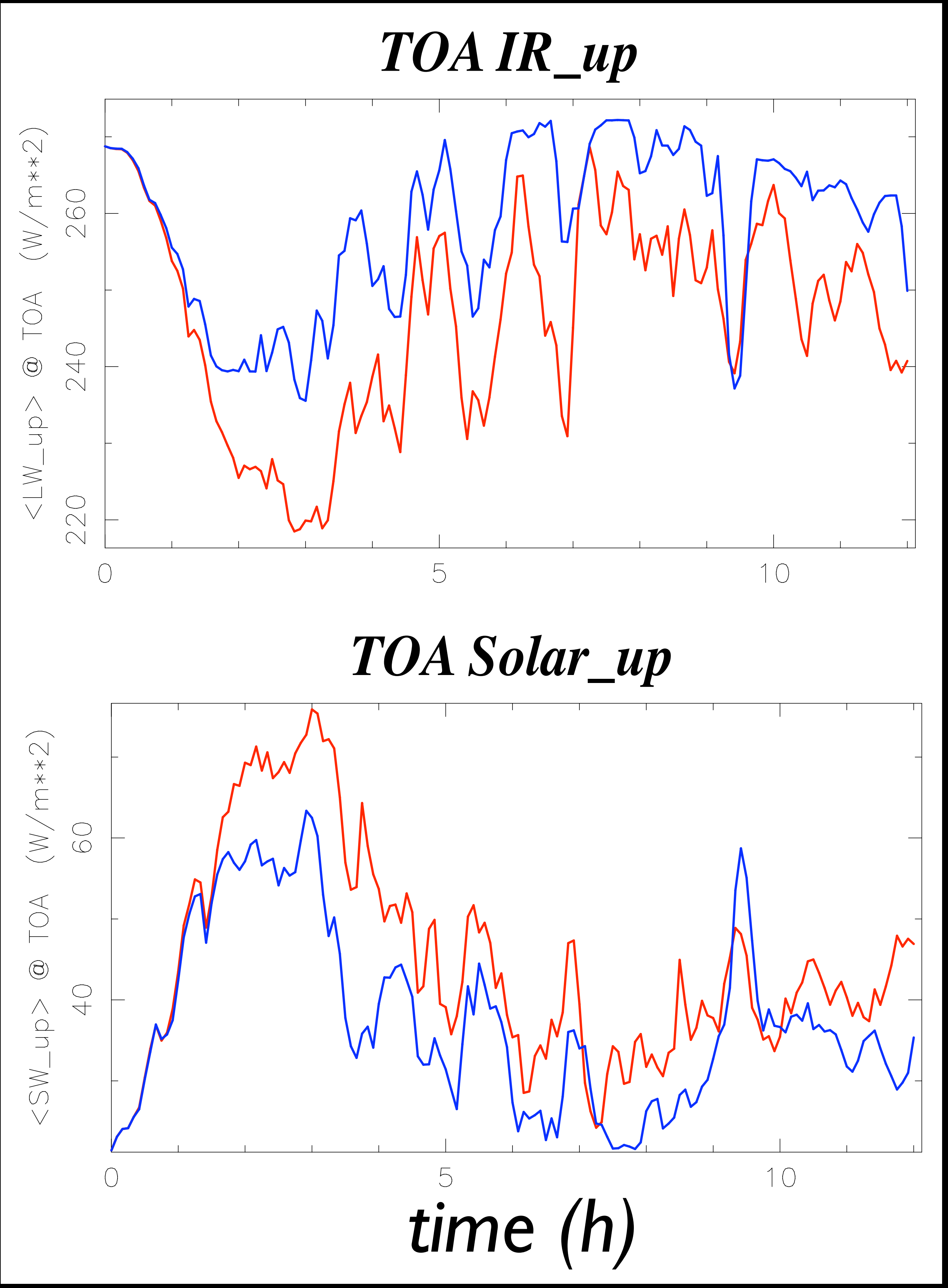


RAD

NO_RAD

Outgoing LW radiation is decreased by MRAS.

Reflected solar radiation is increased by MRAS.



RAD

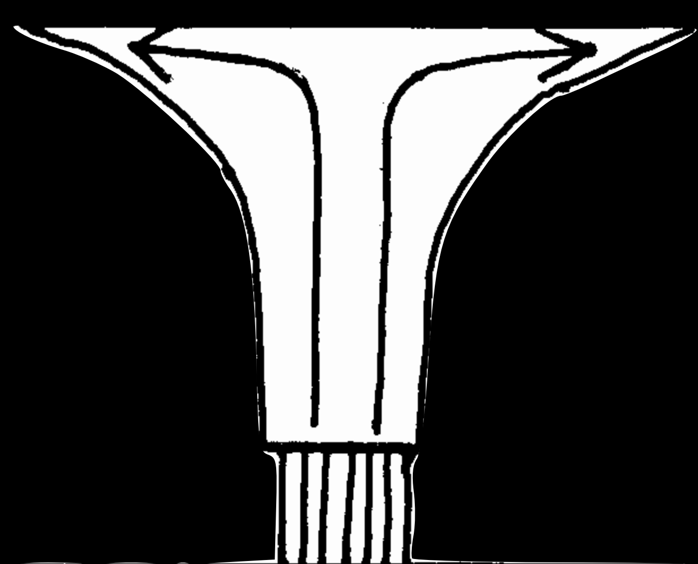
NO_RAD

Conclusions

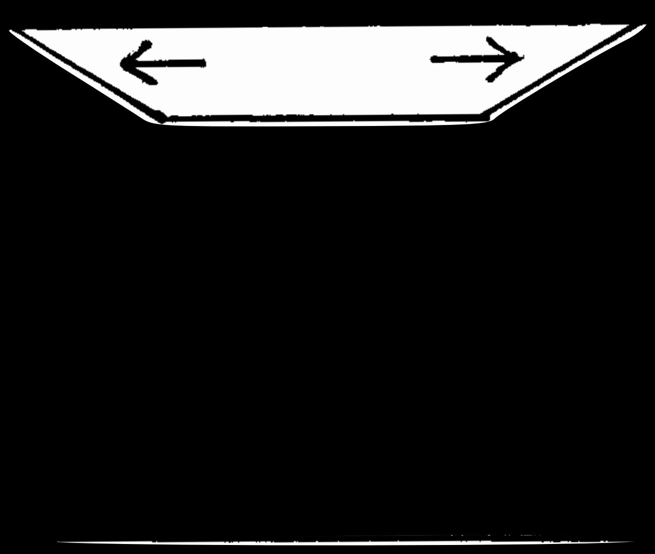
- A mesoscale circulation that spreads the anvil cloud horizontally at about 1 m/s is generated within the anvil by horizontal gradients of radiative heating at the cloud edges.

- This spreading mechanism has not been previously reported.

detrainment



MRAS



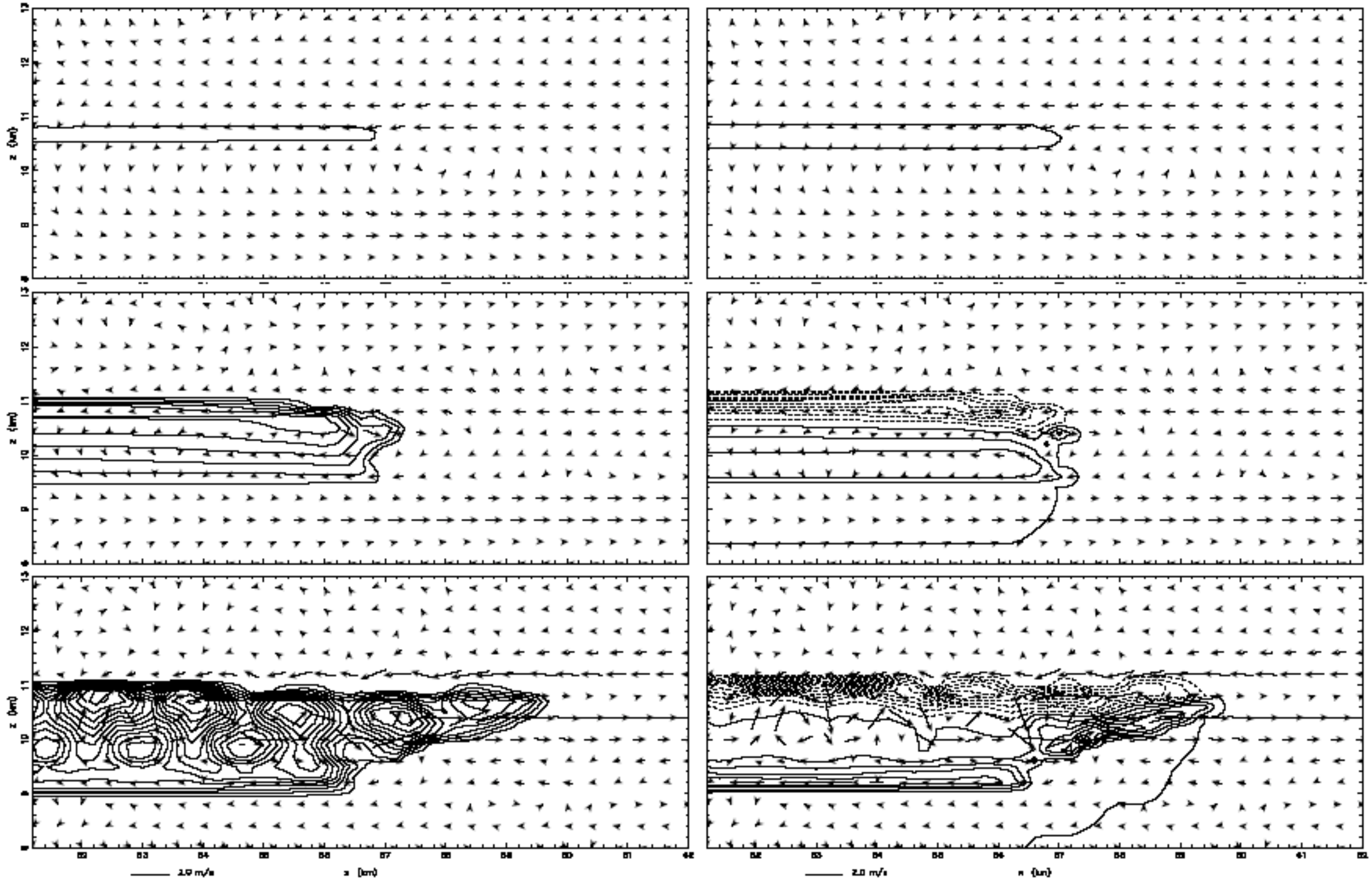


Figure 1: Cross sections of cloud ice (left) and radiative heating (right) for baseline simulation j21. The top line is from $t = 1500$ s, the middle at $t = 3300$ s, and the bottom at $t = 5700$ s. Contour intervals of q_i are 2×10^{-5}, and those of QR are 10 K d^{-1}. Plots display a subset of the computational domain from $x = 51.2$–62 km, and $z = 8$–13 km. The center of the injection is at the left edge of the plots, while the right edge of the injection region is at $x = 57.6$ km.