Physical mechanisms and theories governing aerosol - deep convection interactions

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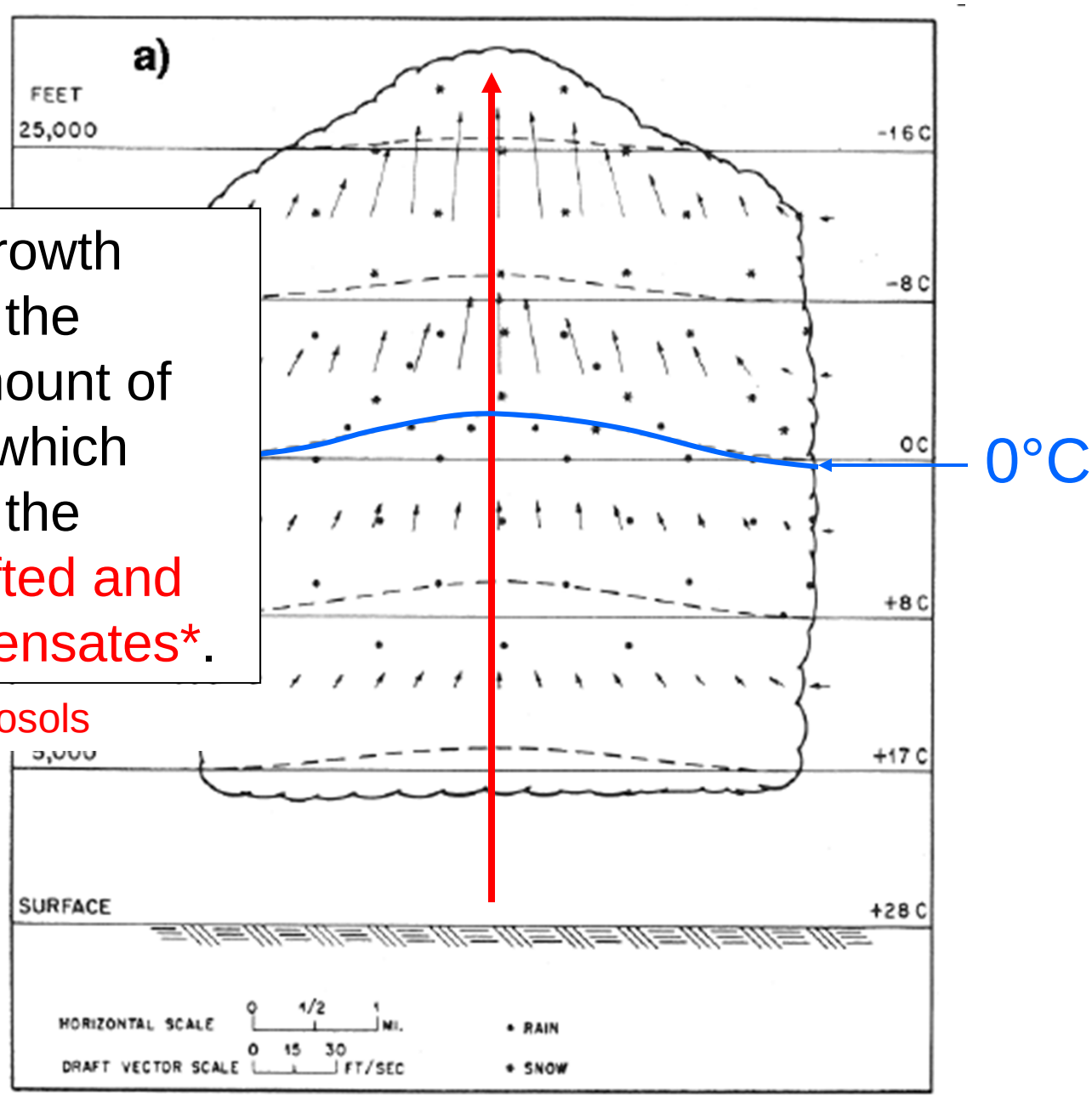
The cloud growth depends on the released amount of latent heat, which depends on the amount of lifted and frozen condensates*.

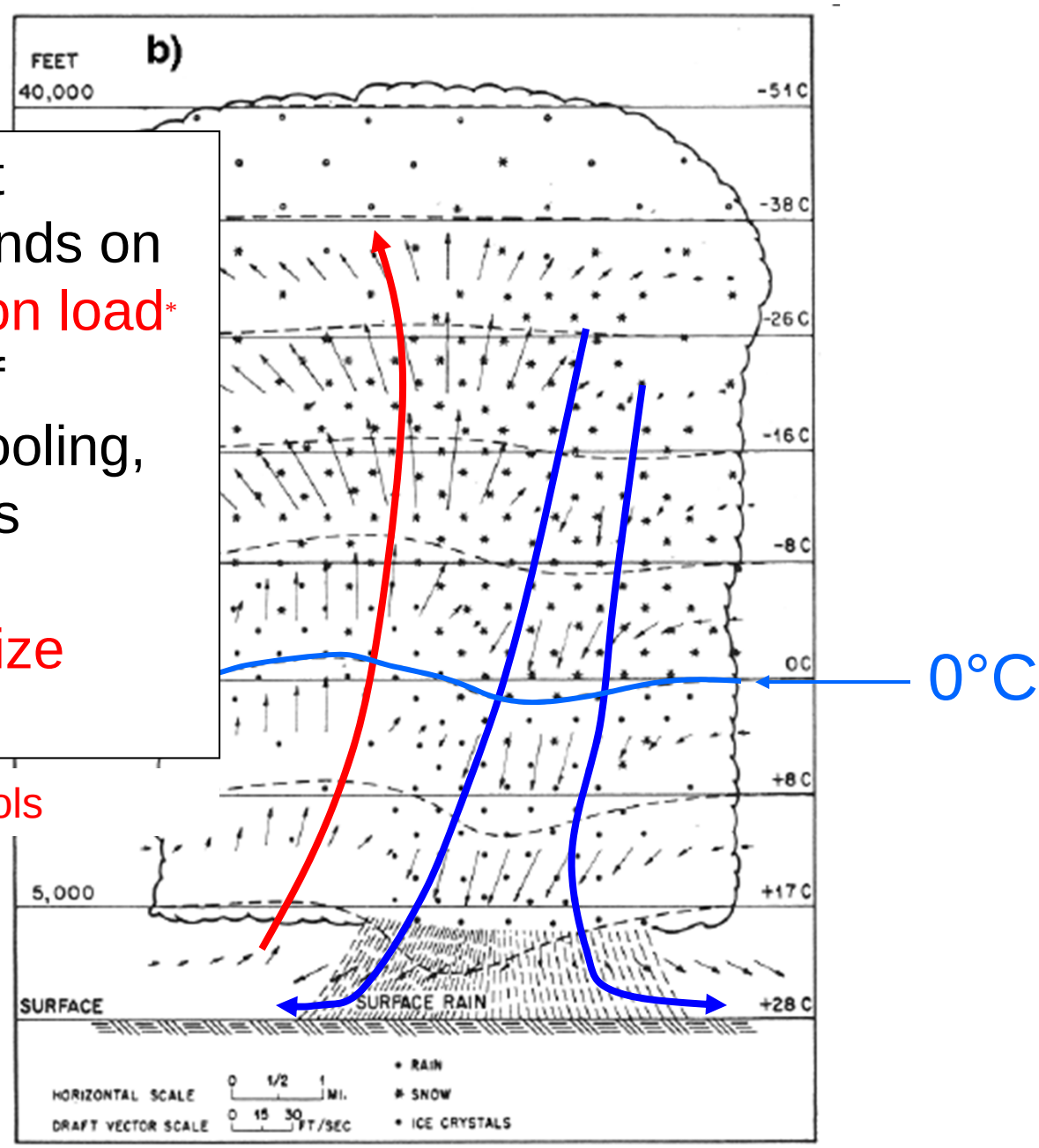
*Affected by aerosols



Schematic of a **growing** storm cell (From Byers and Braham. 1949)

The downdraft intensity depends on the precipitation load* and amount of evaporative cooling, which depends primarily on precipitation size distribution*.

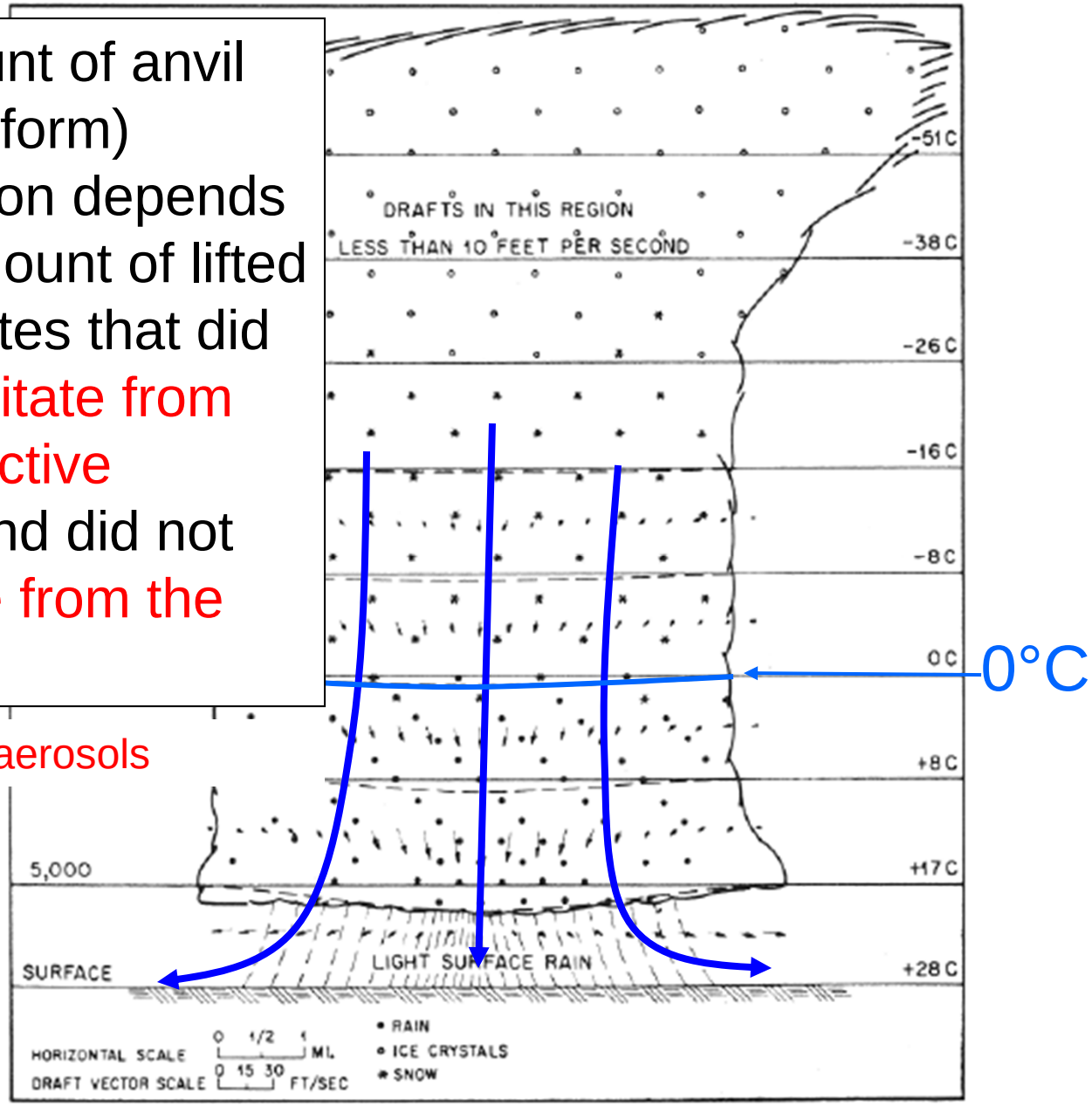
*Affected by aerosols



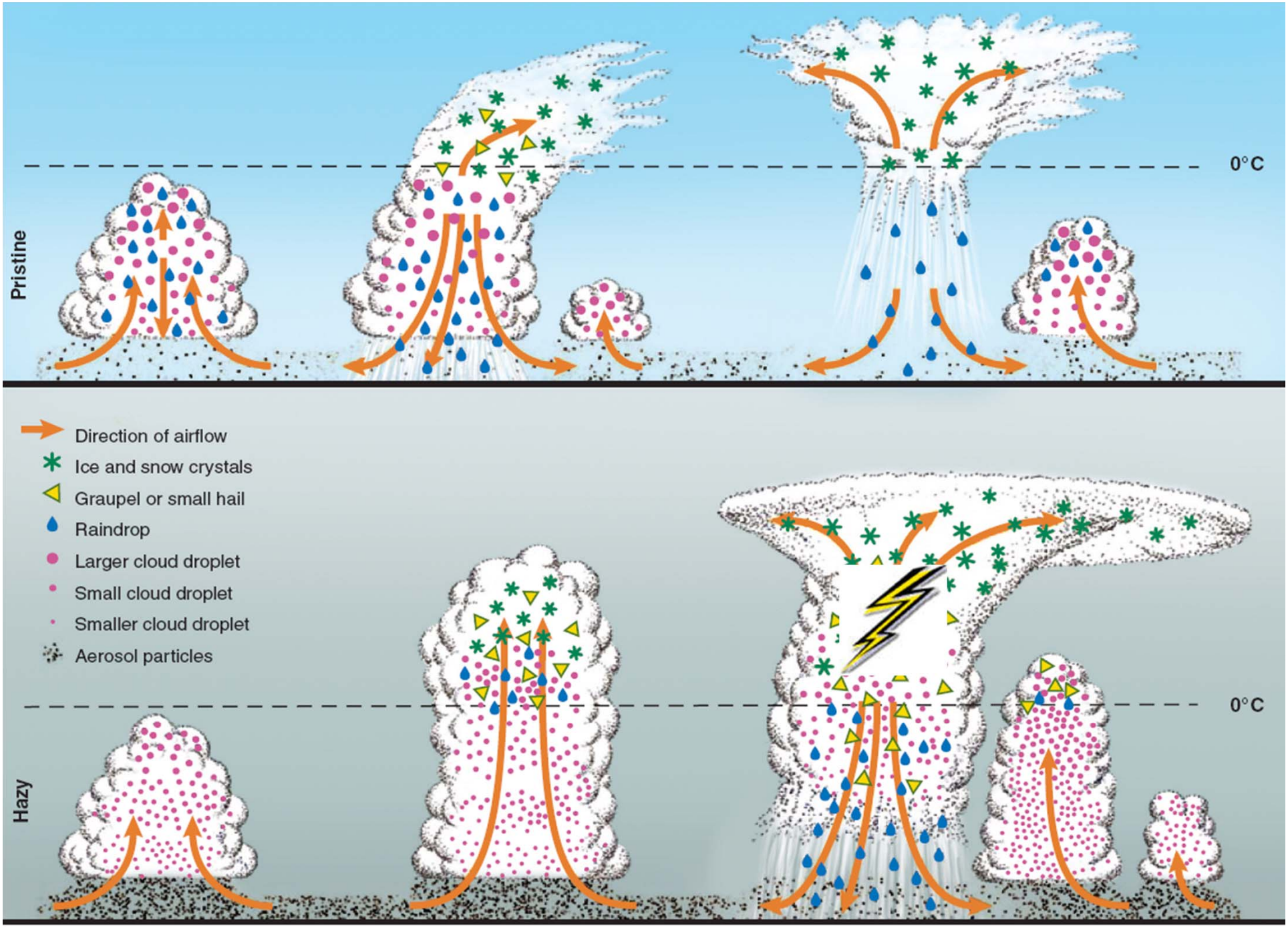
Schematic of a **mature** storm cell (From Byers and Braham. 1949)

The amount of anvil (i.e., stratiform) precipitation depends on the amount of lifted condensates that did not precipitate from the convective updraft* and did not evaporate from the anvil*.

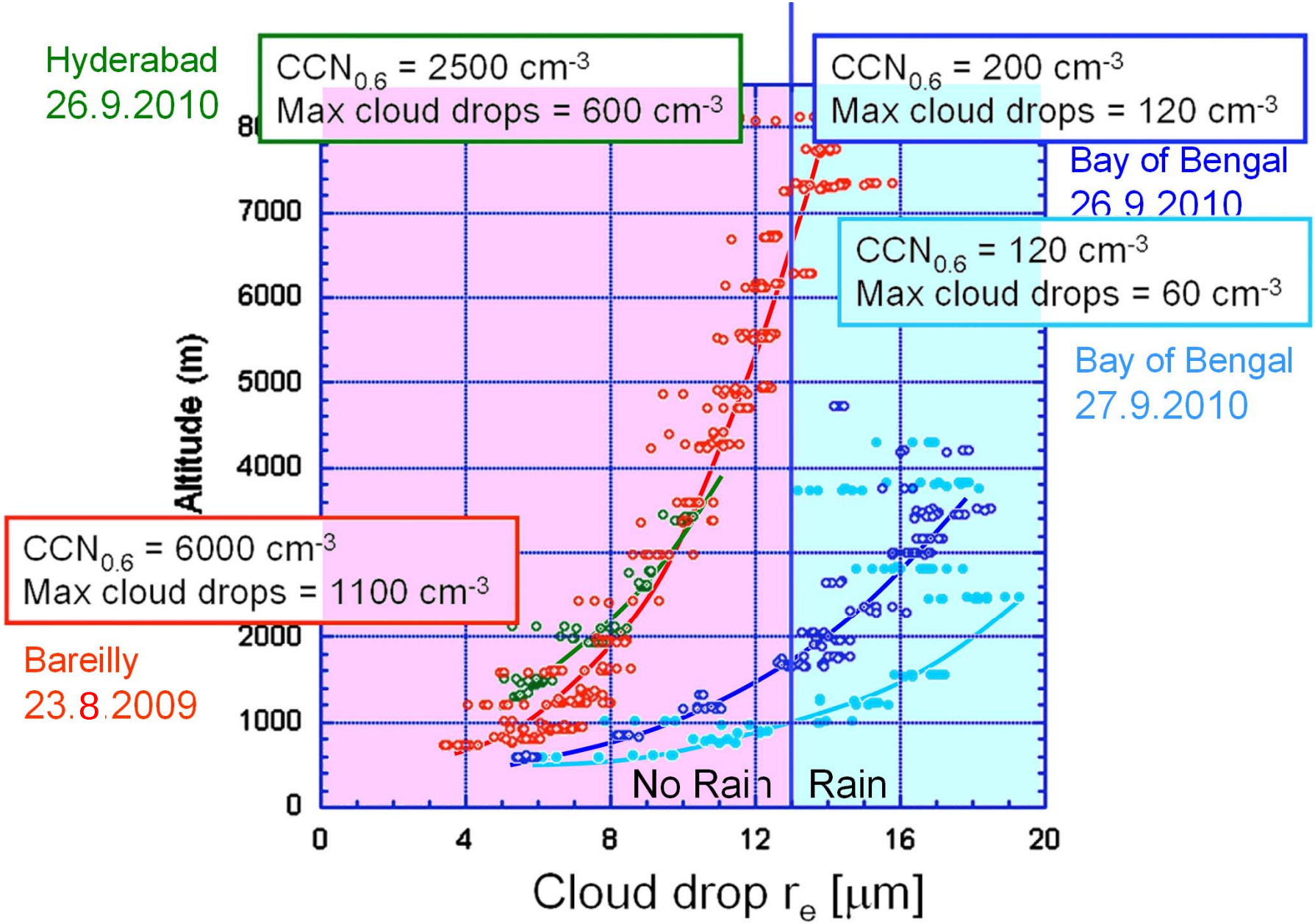
*Affected by aerosols



A **dissipating** storm cell (From Byers and Braham. 1949)



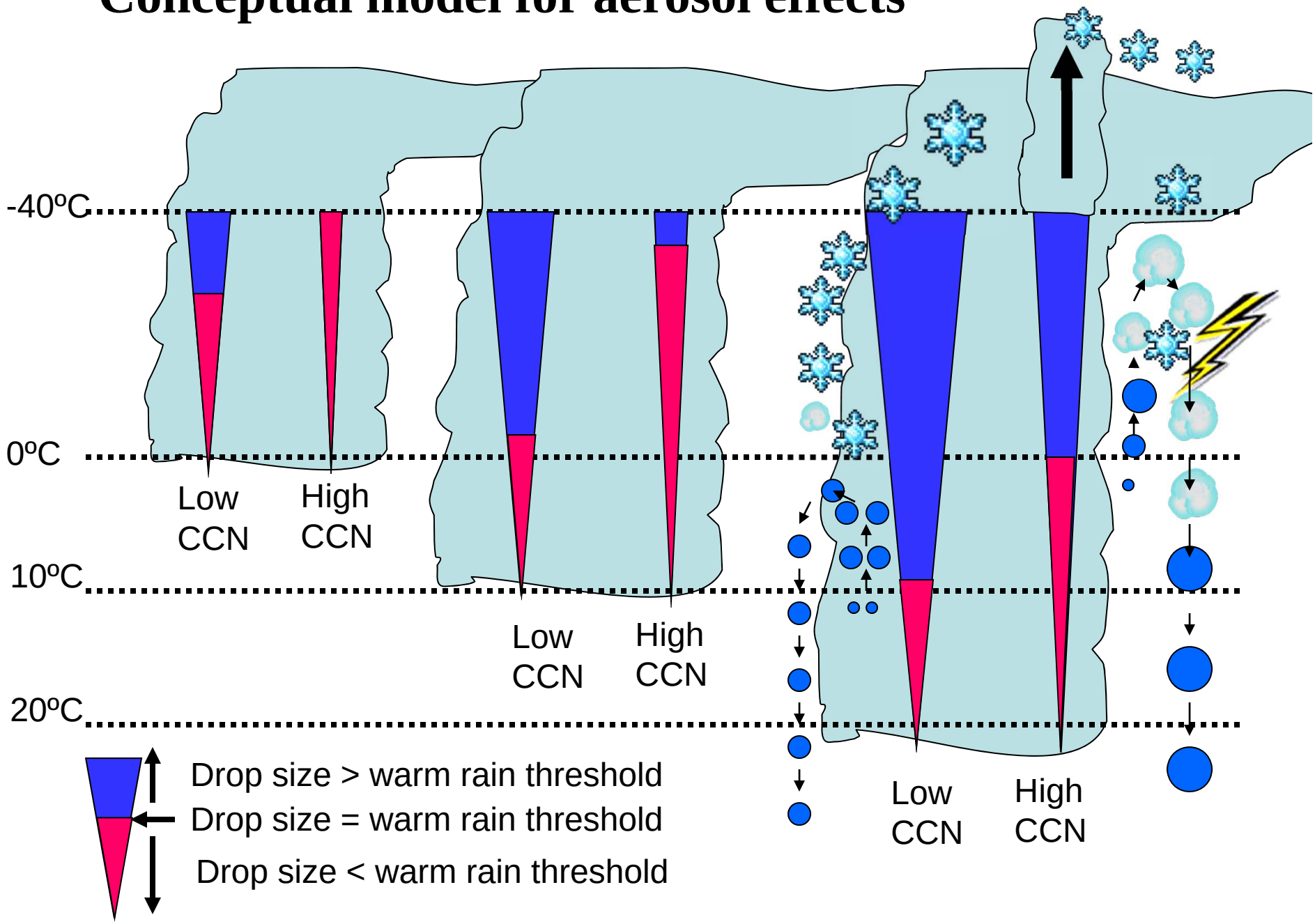
Growing Mature Hail Dissipating



The relation between r_e and depth cloud depth above its base (D) is uniquely related to CCN.

Rosenfeld and Woodley, CAIPEEX-2 Final report to IITM.

Conceptual model for aerosol effects



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- Expand cloud anvils and cirrus

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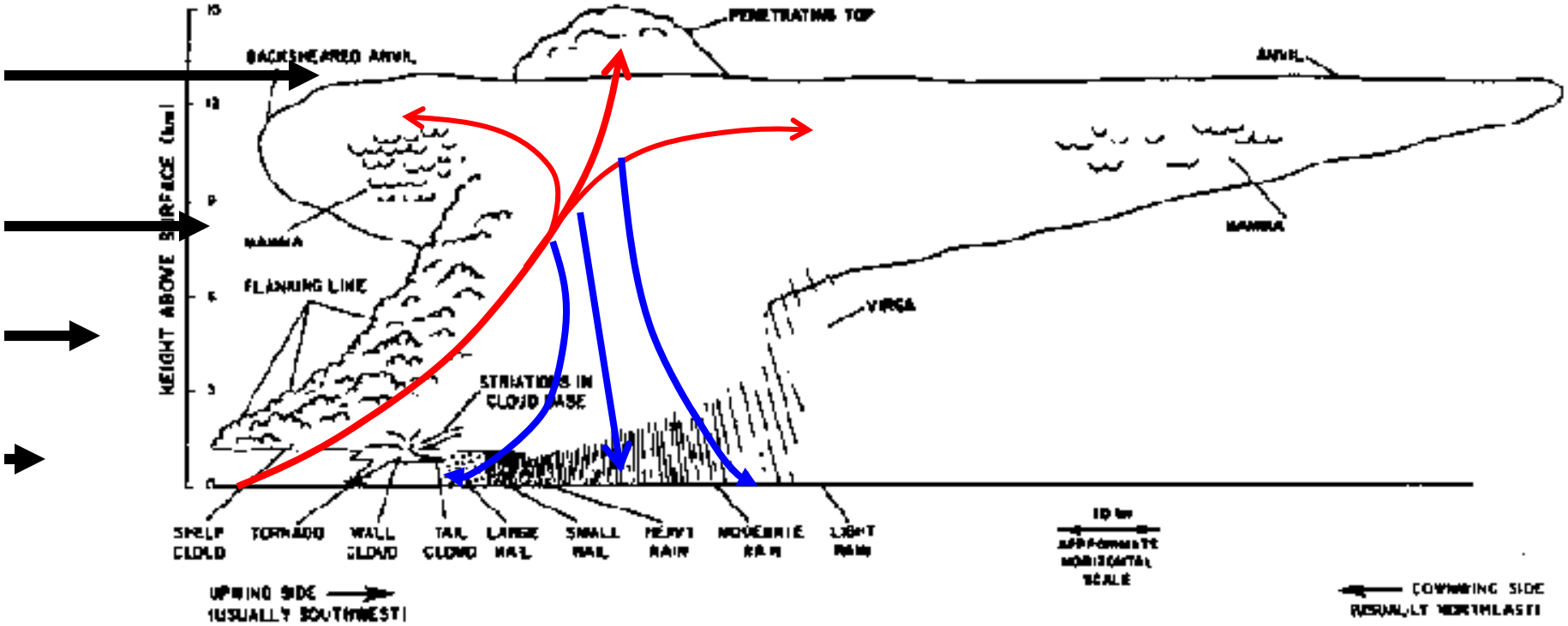
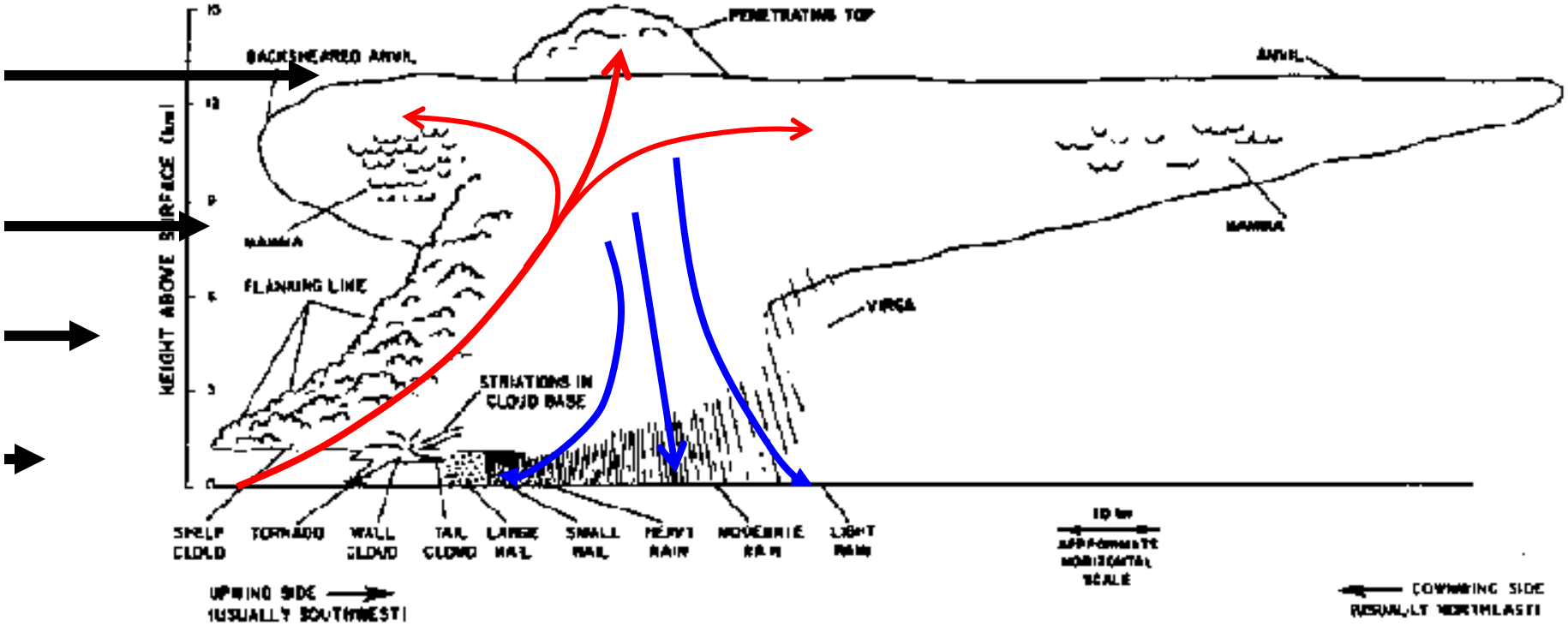
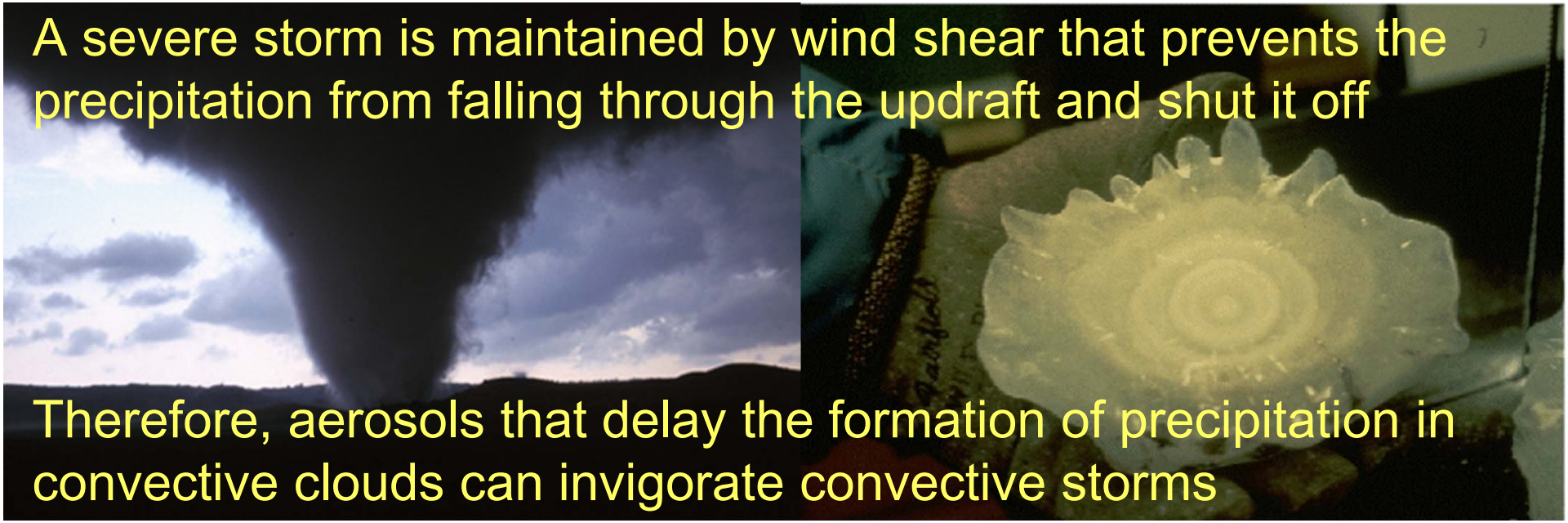
Wind Shear



A severe storm is maintained by wind shear that prevents the precipitation from falling through the updraft and shut it off

Wind Shear


PENETRATING TOP
BACKSHEARED ANVIL
ANVIL
HEIGHT ABOVE SURFACE (km)
MAMMA
FLANKING LINE
VIRGA
STRIATIONS IN CLOUD BASE
SHELF CLOUD
TORNADO
WALL CLOUD
TAIL CLOUD
LARGE HAIL
SMALL HAIL
HEAVY RAIN
MODERATE RAIN
LIGHT RAIN
UPWIND SIDE (USUALLY SOUTHWEST)
DOWNWIND SIDE (USUALLY NORTHEAST)


A severe storm is maintained by wind shear that prevents the precipitation from falling through the updraft and shut it off
Therefore, aerosols that delay the formation of precipitation in convective clouds can invigorate convective storms

References

- Causes larger hydrometeors and hail

Andreae, M. O., D. Rosenfeld, P. Artaxo, A. A. Costa, G. P. Frank, K. M. Longo, and M. A. F. Silva-Dias, 2004: Smoking rain clouds over the Amazon. *Science*, **303**, 1337-1342.

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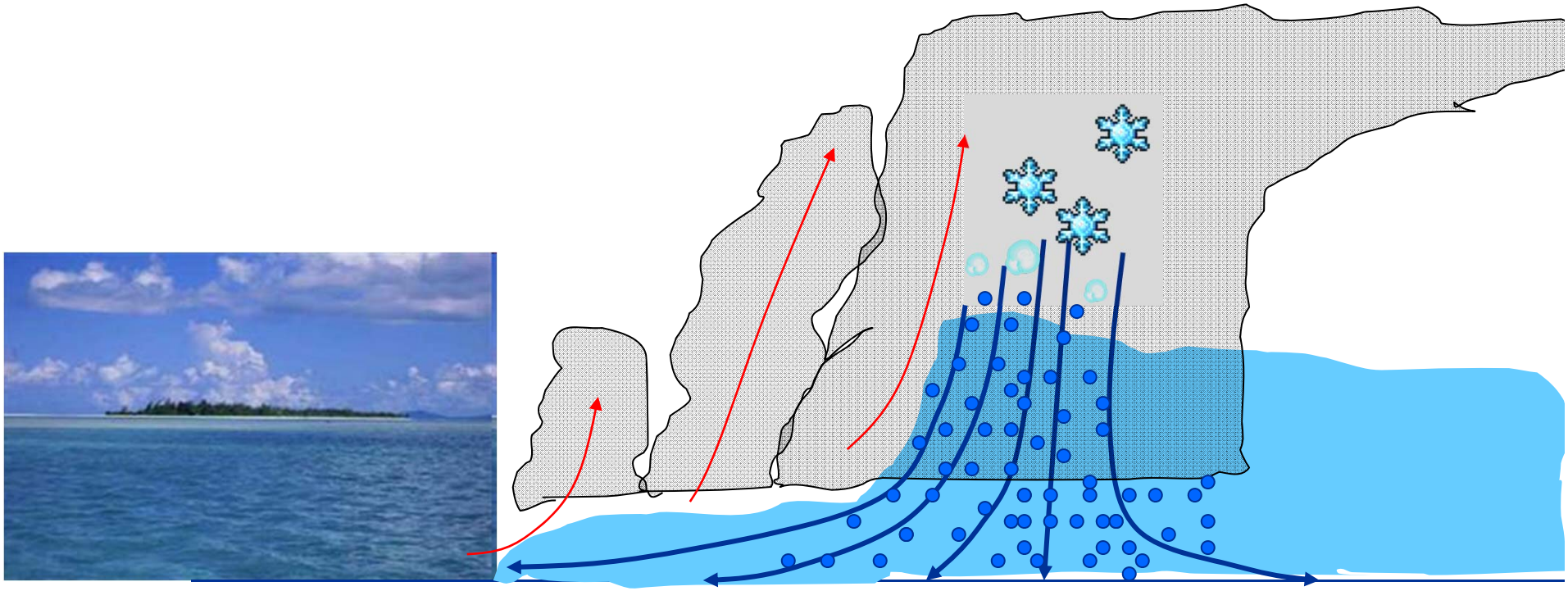
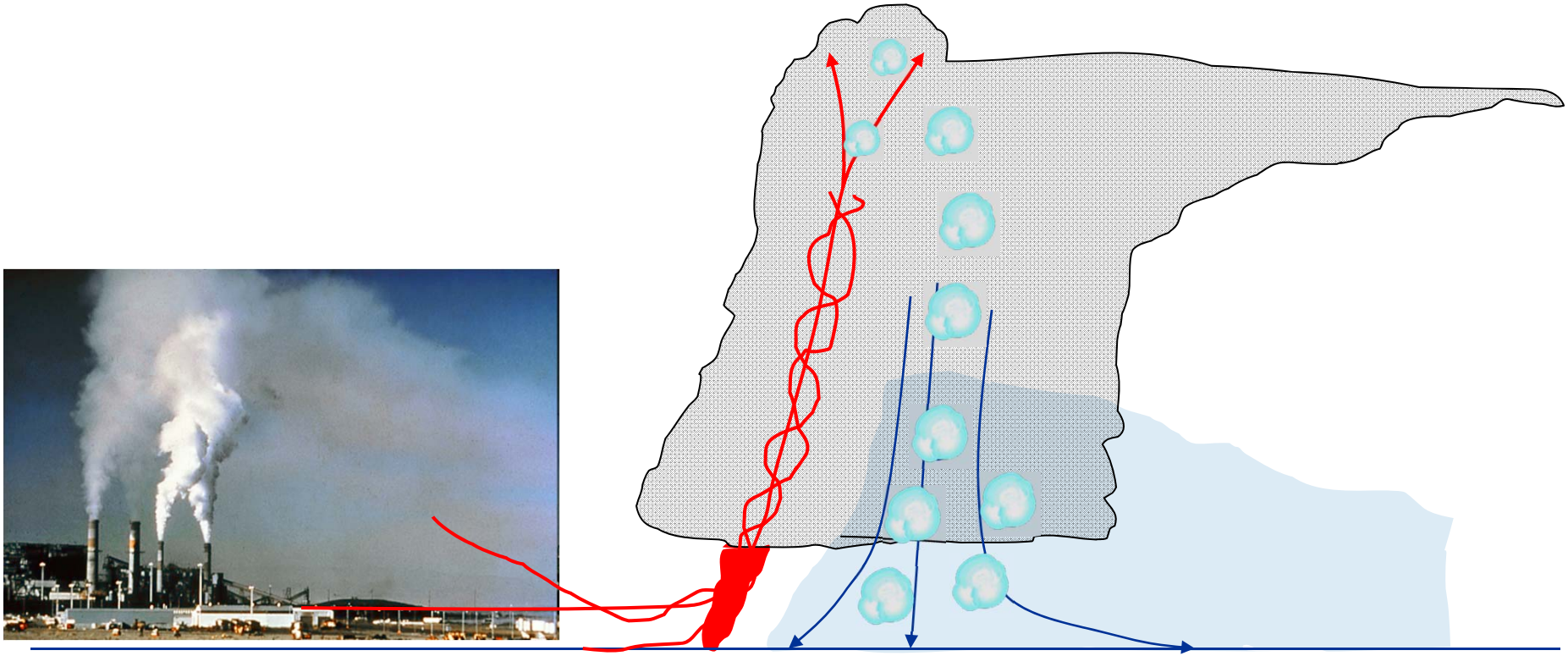
Not Polluted.
Small Hail that melts to rain with more surface area that evaporates more strongly and causes more cooling. This causes stronger downdrafts that spread on the surface and undercut the updraft and outruns the storm, thereby disrupting the organization of the tornado.



Polluted.
Large Hail and rain drops.
Less evaporation and weaker cooling.
Weaker downdrafts.



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Effects of aerosols on microstructure and intensity of tropical cyclones

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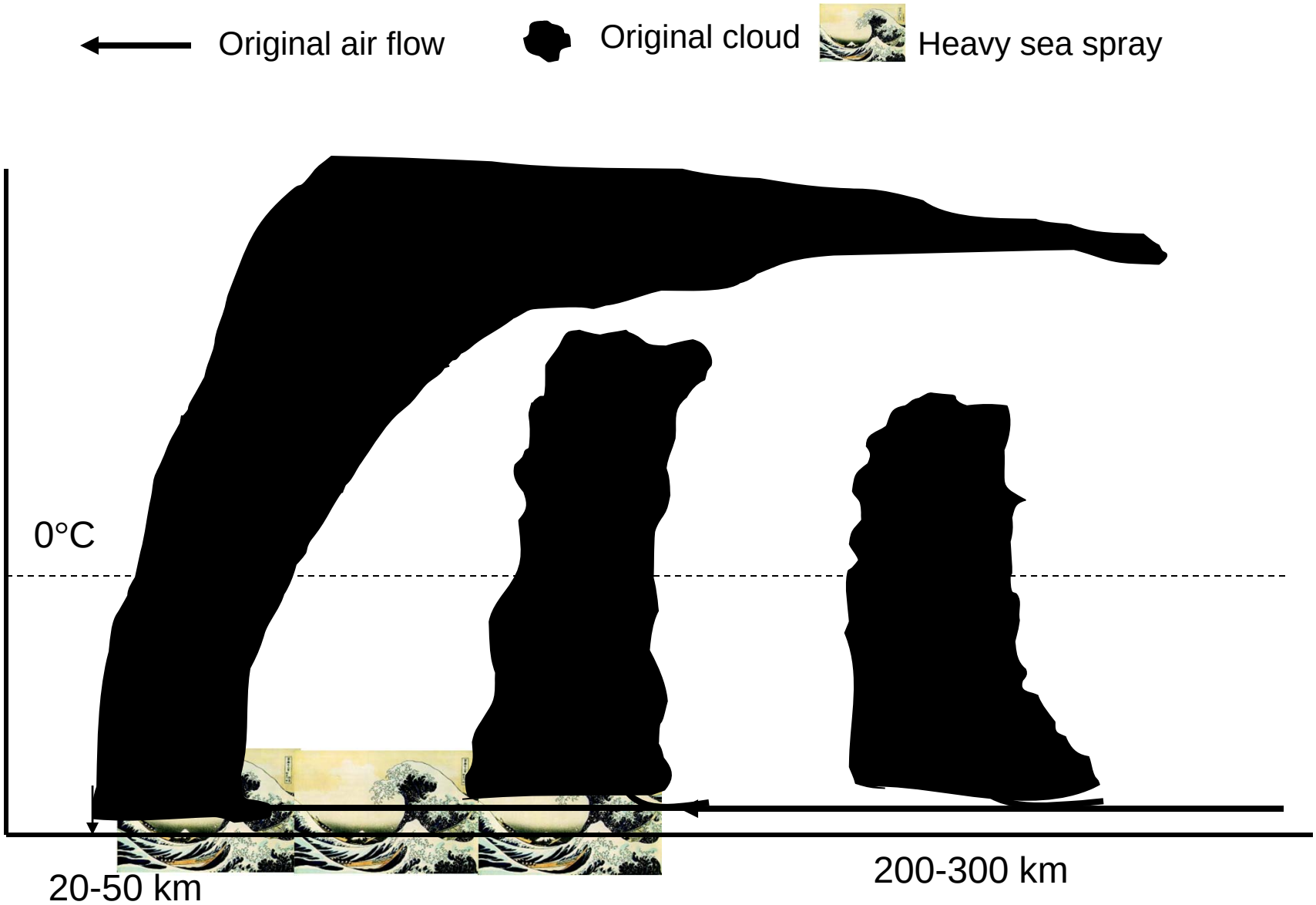
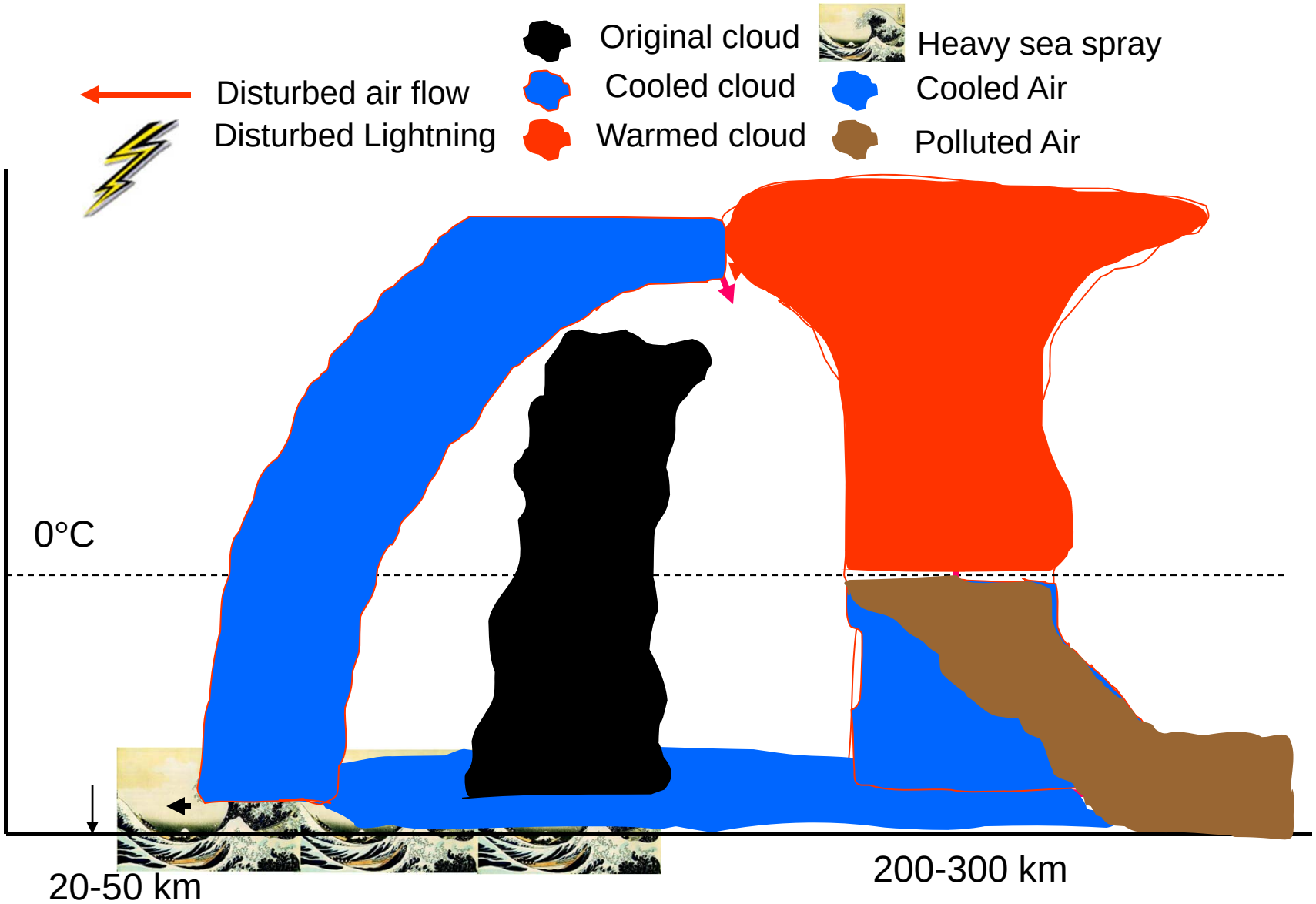

Original air flow
Original cloud
Heavy sea spray
0°C
20-50 km
200-300 km


Original cloud
Heavy sea spray
Disturbed air flow
Cooled cloud
Cooled Air
Disturbed Lightning
Warmed cloud
Polluted Air
0°C
20-50 km
200-300 km

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Summary

Aerosols, by creating larger numbers of smaller cloud drops in deep convection:

- Convert warm rain to mixed phase
- Enhance cloud electrification
- Expand cloud anvils and cirrus
- Invigorate warm base convective clouds
- Causes larger hydrometeors and hail
- Enhance risk for tornadoes
- Weaken tropical cyclones