Synoptic Meteorology

[MAPH P312]

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Seminar Room
Dept. of Maths. Physics, UCD, Belfield.

Part 6

Cloud Microphysics

These lectures follow closely the text of *Wallace & Hobbs*.

Introduction

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Scientific investigations of these processes is the domain of *cloud microphysics*.

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We are concerned with the formation of *water droplets* from the condensation of water vapour.

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This work may be written as $A\sigma$, where σ is the work required to create a unit area of vapour-liquid interface (called the *surface energy* of the liquid).

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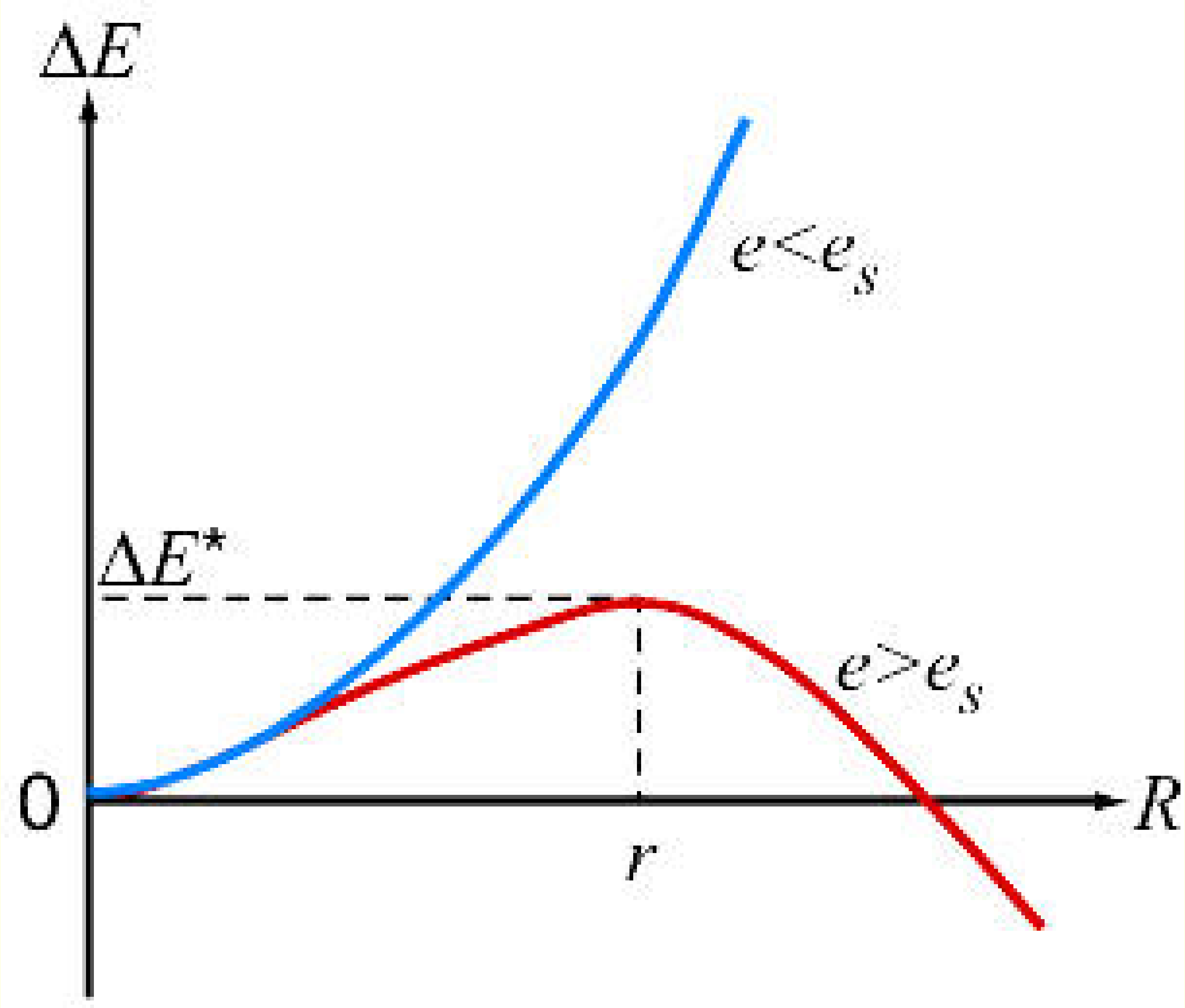
Under subsaturated conditions, $e < e_s$ and $\ln(e/e_s)$ is negative. Thus, ΔE is always positive and increases with R.



Increase ΔE in the energy of a system due to the formation of a water droplet of radius R from water vapour with pressure e.

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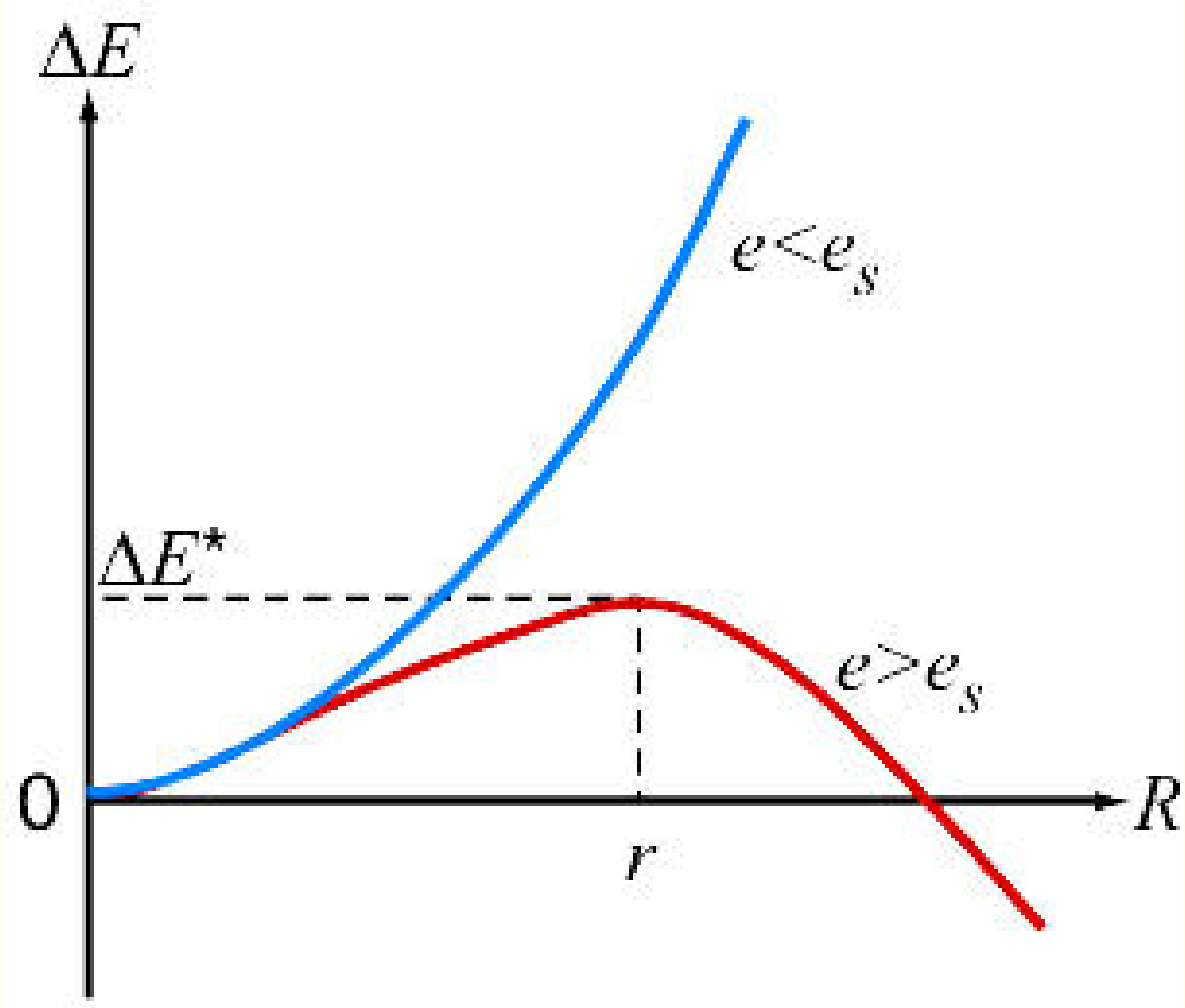
The variation of ΔE with R for $e > e_s$ is also shown in the Figure (red curve), where it can be seen that ΔE initially increases with increasing R, reaches a maximum value at $R = r$, and then decreases with increasing R.



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Hence, from the above equation for ΔE, we get

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This is referred to as *Kelvin's Equation*, after Lord Kelvin who first derived it.

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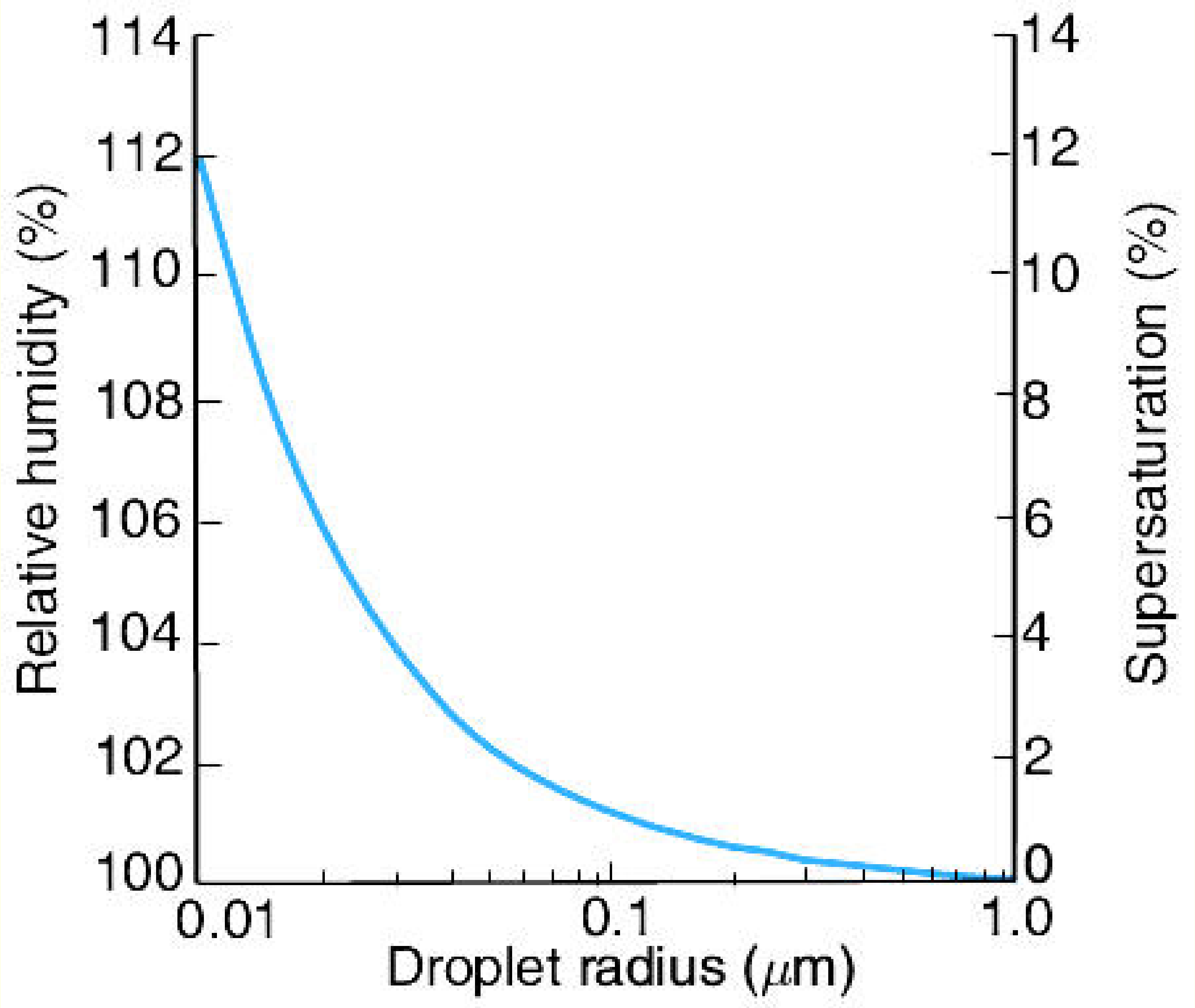
The variation of the equilibrium relative humidity with droplet radius is shown in the Figure that follows.



The relative humidity and supersaturation at which pure water droplets are in (unstable) equilibrium at 5°C.

A pure water droplet of radius $0.01\,\mu$m requires a relative humidity of 112% (i.e., a supersaturation of 12%) to be in (unstable) equilibrium with its environment.

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Consequently, droplets do not form in natural clouds by homogeneous nucleation of pure water.

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Moreover, droplets can form and grow on these particles at much lower supersaturations than those required for homogeneous nucleation.

For example, if sufficient water condenses onto a completely wettable particle $0.3\,\mu$m in radius to form a thin film of water over the surface of the particle, we see from the Figure that the water film will be in (unstable) equilibrium with air that has a supersaturation of 0.4%.

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Some of the particles in air are soluble in water. Consequently, they dissolve, wholly or in part, when water condenses onto them, so that a solution (rather than a pure water) droplet is formed.

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For example, to serve as a CCN at 1% supersaturation, completely wettable but water insoluble particles need to be at least $\sim 0.1\,\mu$m in radius, whereas soluble particles can serve as CCN at 1% supersaturation even if they are as small as $\sim 0.01\,\mu$m in radius.

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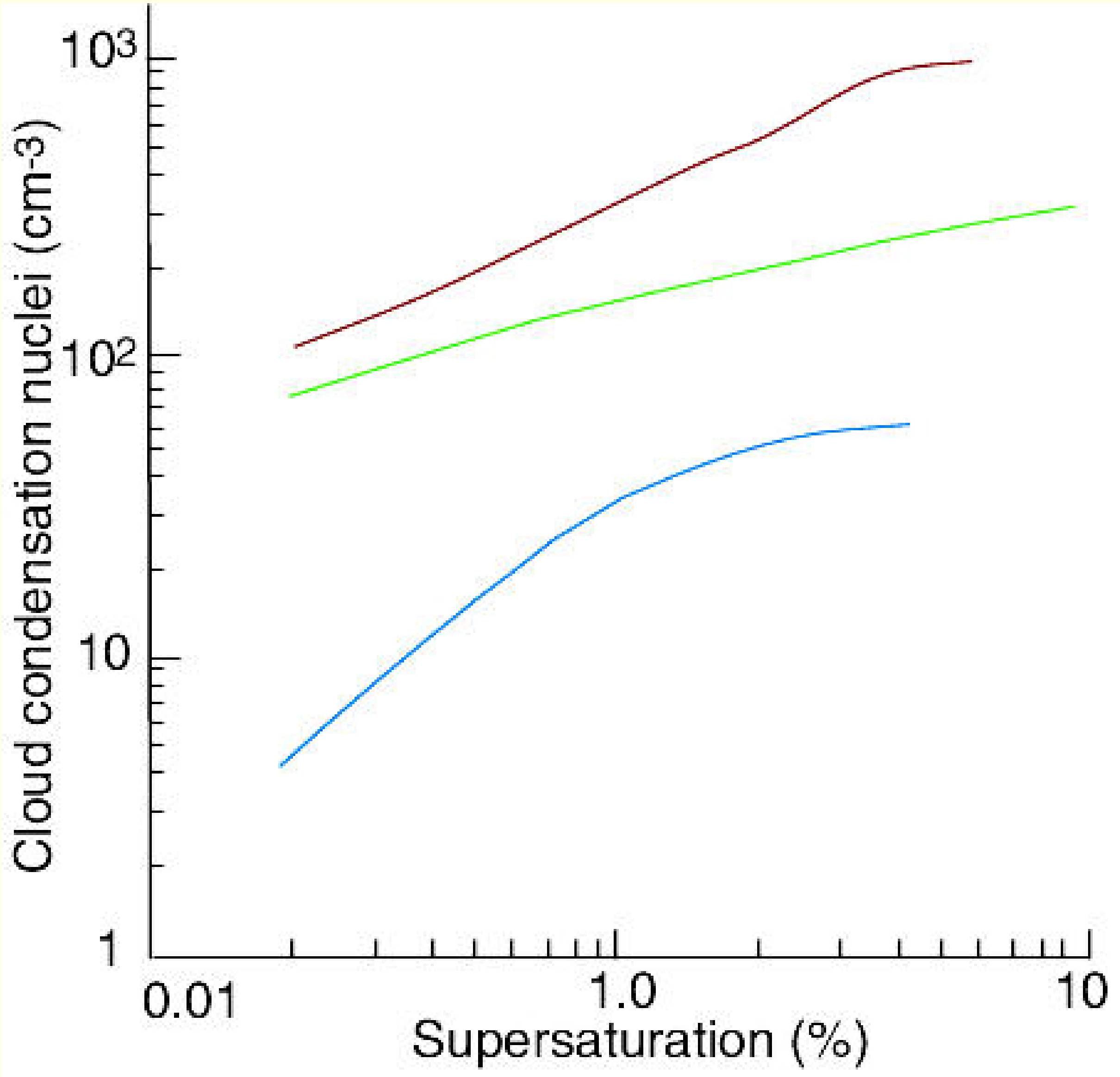
The concentration of CCN in the continental air mass over the Azores, is about 300 cm^{-3} at 1% supersaturation, while in the marine air mass over Florida it is about 100 cm^{-3}, and in clean Arctic air it is only about 30 cm^{-3}.
(Figure follows)



CCN spectra in the boundary layer from measurements near the Azores in a polluted continental air mass (brown), in Florida in a marine air mass (green), and in clean Arctic air (blue).

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Ground-based measurements indicate that there is a diurnal variation in CCN concentrations, with a minimum at about 6 a.m. and a maximum at about 6 p.m.

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Although sea-salt particles enter the air over the oceans, they do not appear to be a dominant source of CCN, even over the oceans.

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Many CCN consist of *sulfates*. Over the oceans, organic sulfur from the ocean (in the form of the gases dimethylsulfide (DMS) and methane sulfonic acid (MSA)) provide a source of CCN, with the DMS and MSA being converted to sulfate in the atmosphere.