Aerosol Size Distributions & Optical Properties Found in the Marine Boundary Layer Over the Atlantic Ocean

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Investigation Overview

- **Purpose**
  - investigate marine aerosols
  - emphasizing submicron particles ($r < 0.05$ μm)

Part 1

- Size distribution data & growth scheme in remote tropics

Part 2

- Analysis of measured and calculated properties

1983 Lynch Cruise

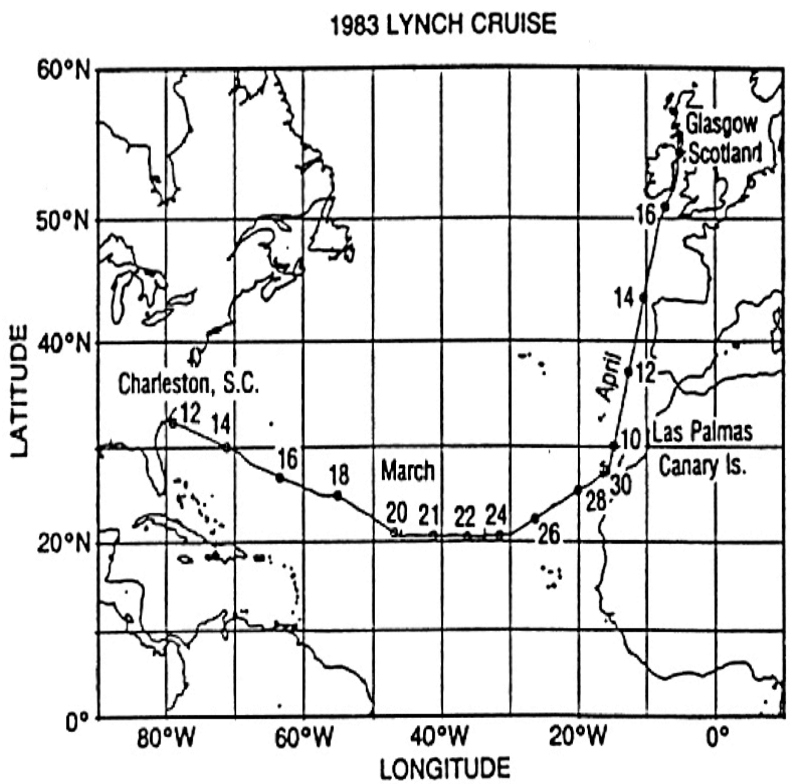


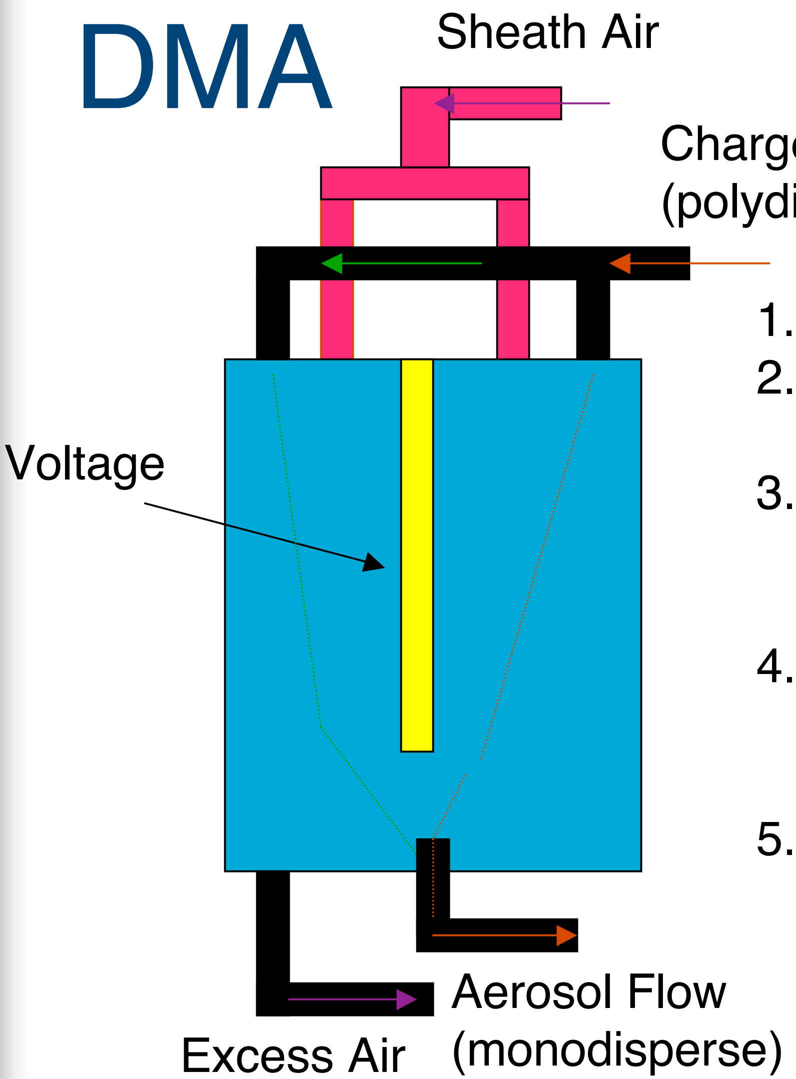
Fig. 1. Map showing the 1983 *Lynch* cruise track.

- Sailed from Charleston, SC to the Canary Islands, and onto Scotland
- 3/11 – 4/17, 1983

Instrumentation

- **Aerosol Size Distributions**
  - *Differential Mobility Analyzer (DMA)* (0.006-0.5 μm radius)
  - *Calspan Impactor* (0.5-50 μm particle radius)
- **Total Aerosol Concentrations**
  - *Gardner Counter*
- **Continental Air Mass Detection**
  - *Radon Monitor* (Radon 222)
- **Optical Depth**
  - *Sun Photometer*
- **Aerosol Light Scattering**
  - *Integrating Nephelometer & Visiometer*

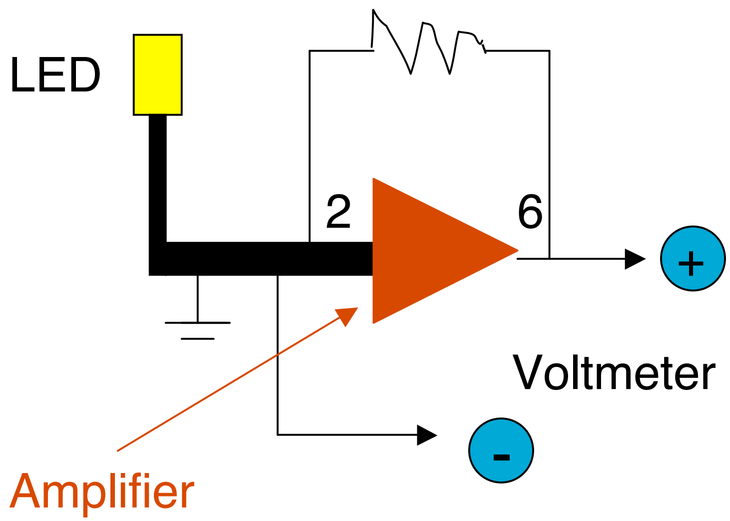
DMA



1. Apply **electric charge** to particles
2. Particles **migrate** (mobility = size & charg into clean sheath air flow under electric fie
3. A narrow range of particle mobilities are **separated** from the aerosol by withdrawir a portion of the sheath air flow
4. Varying the electric field provides a range of particle mobilities, and the concentratio in each range can be measured
5. Convert to a size distribution by using the distribution of charges produced by th charger and the known relation between mobility and size.

http://www.cac.yorku.ca/people/mozurke/Analyzer.htm (accessed 1/22/04)

Sun Photometer



• Measure intensity of sunlight arriving directly from the sun

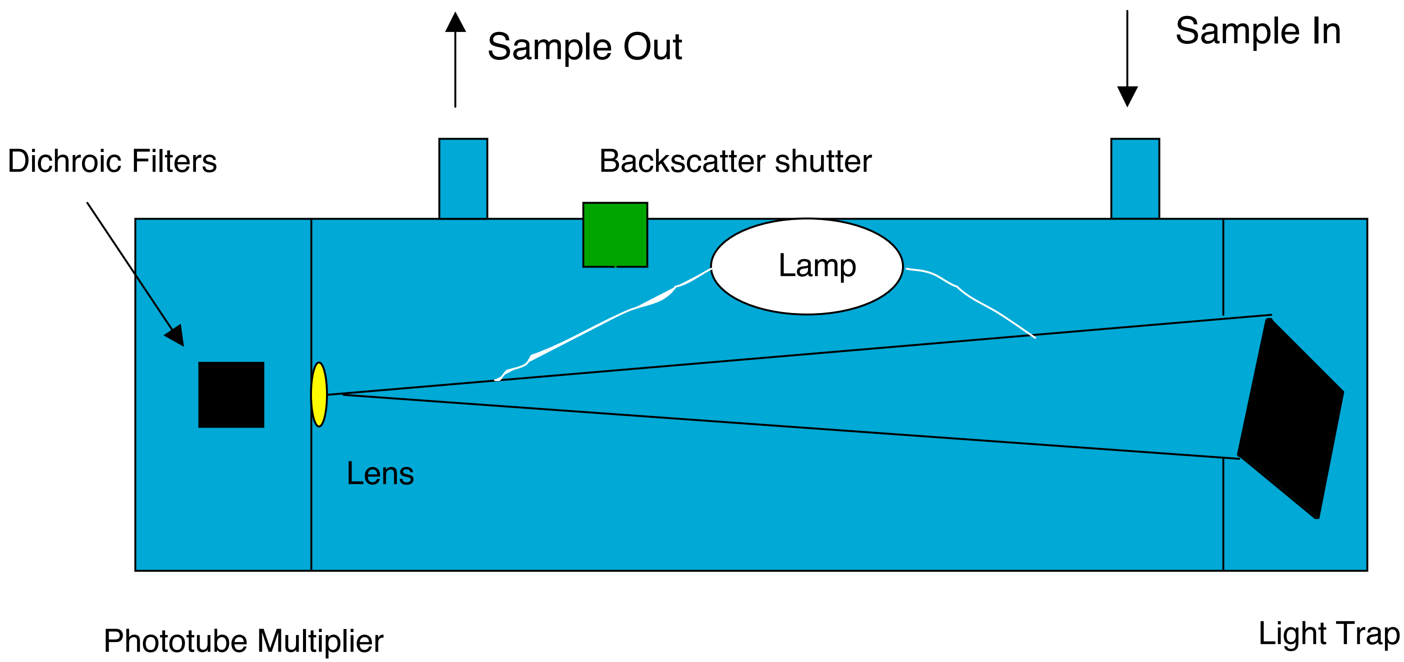
• Ideal instrument for measuring haze

1. Sunlight causes the LED detector to generate an **electrical current**
2. LED current **transformed** to a voltage and boosted by the **amplifier**
3. The voltage is measured with a digital voltmeter

http://www.concord.org/haze/spworks.html (accessed 1/22/04)

Nephelometer

$b_{ext} = b_{scat} + b_{abs} = \ln(I/I_0)/x$
x = length of light path
I = intensity of light after distance
I_0 = initial intensity of light
b_{scat} and b_{abs} are the scattering and absorption coefficients



- Detects scattering properties by measuring light scattered by the aerosol and subtracting light scattered by the g
the walls of the instrument and the background noise in the detector
- Light that passes through the lens is separated by dichroic filters into wavelengths
- The reflected light passes through a filter into a photomultiplier tube
- Nephelometer measures extinction, caused by scattering and absorption of light, over a distance

http://www.cmdl.noaa.gov/aero/net/instrumentation/neph_desc.html (accessed 1/22/04)

4 Case Studies

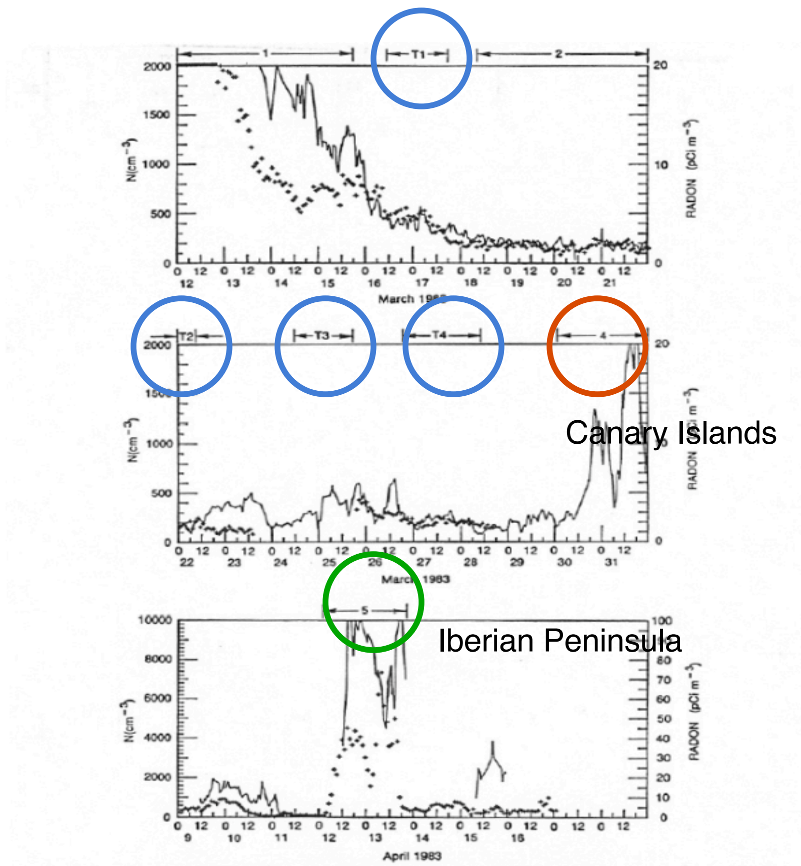


Fig. 6. Chronological history of total aerosol (solid curve) and radon concentrations (crosses) throughout the cruise. The numbered time periods refer to case studies discussed in section 3.

- T1 and T3
  - Meteorological disturbance brought air of African origin
- T2 and T4
  - Precipitation scavenging removed particles

Transition in Particle Sizes

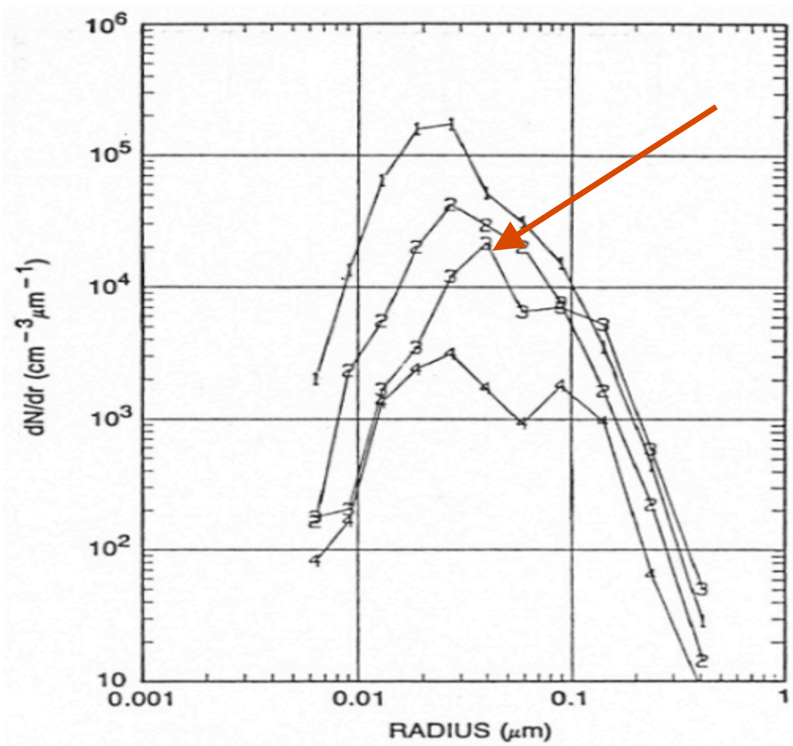


Fig. 7. Transition in the size distribution from continental to marine. The location at which the size distributions were taken are shown in Figure 9. Curve 4 is the size distribution for air with a long history over the Atlantic.

<u>Curve 1 (3/12/83):</u>

- Total aerosol 5460 cm^{-3}
- Radon 25pCim^{-3}
- Overcast sky w/stratocumulus

<u>Curve 2:</u>

- Total aerosol 1920 cm^{-3}
- Radon 7pCim^{-3}
- Clear sky w/10% cumulus

<u>Curve 3:</u>

- Total aerosol 1325 cm^{-3}
- Radon 7-8pCim^{-3}
- Overcast 80-100% w/80-100% altocumulus & stratocumulus
- Hump associated w/nonppt cloud effect on particle size distribution (cause for double-peaked distributions?)

<u>Curve 4 (3/18/83):</u>

- Total aerosol 243 cm^{-3}
- Radon 2pCi m^{-3}
- Overcast 85%

Double-Peaked Characteristic

- 3/18 and 3/19 size distributions exhibited double-peak char.
- Distributions did change but the double-peaked characteristic always recovered
- In the remote (tropical) marine Atlantic the size distribution is sustained by an unknown mechanism
- **Idea was**: *Separation of interstitial and CCN from aerosol cycling thru nonppt clouds*

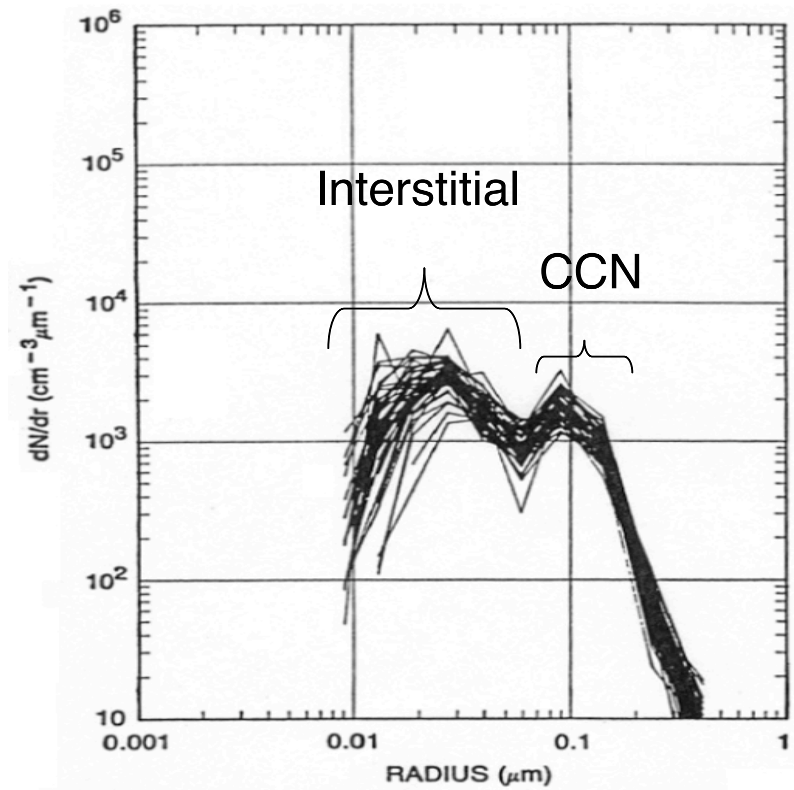


Fig. 10. Composite of 49 size distributions taken during a 35-hour period on March 18 and 19, typical of conditions when there was no continental influence.

Case T1

PPT Changes Size Distribution

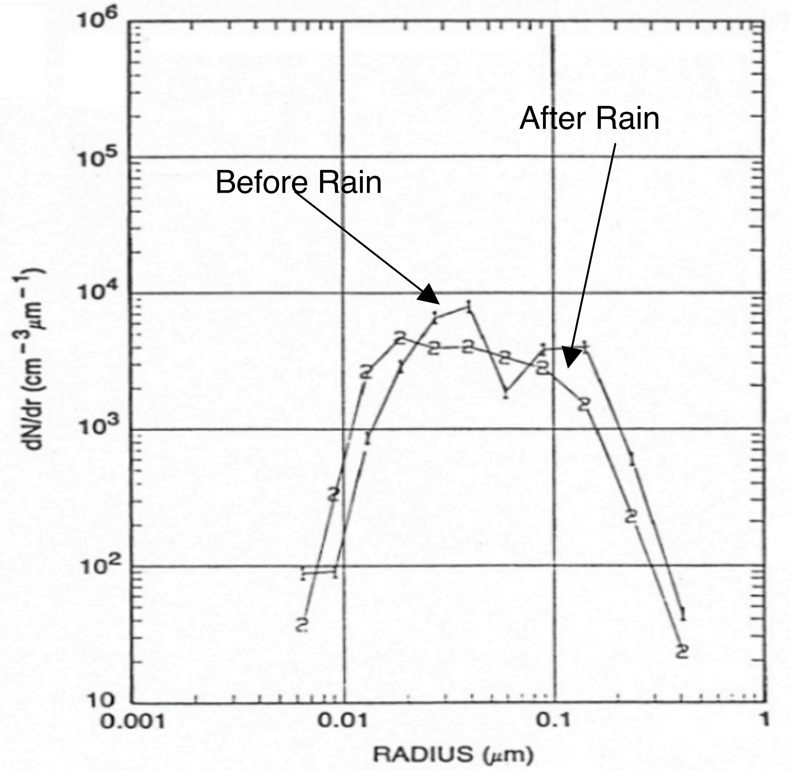


Fig. 11. Change in the size distribution during transit through weak front on March 16. Curves 1 and 2 are the average size distributions taken before and after passage of the front.

- Supports idea that aerosol cycling thru nonppt clouds causes the double-peak characteristic
- Air mass was of Saharan origin, which resulted in a transition in particle size distribution
- Even though extensive cloud cover, this was an exception to the double peak observation assoc w/nonppt cloud presence

Case T2

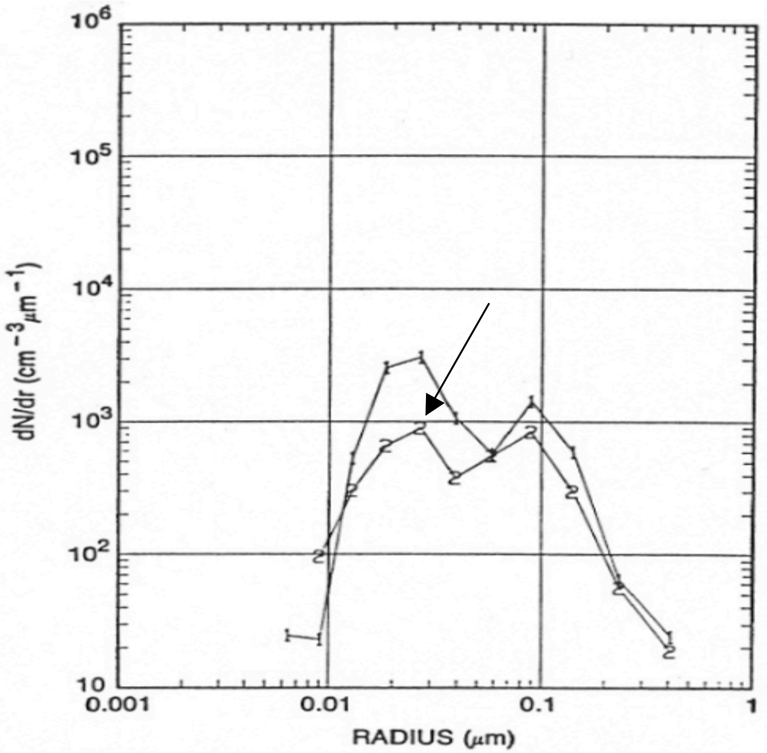


Fig. 12. Decrease in size distribution due to precipitation scavenging in local thunderstorms on March 22. Curves 1 and 2 are the size distributions taken before and after passing through a region of heavy local precipitation.

- Ship passed thru high thunderstorm activity
- Heavy ppt around and north of the ship
- After some rain the size distribution of curve 2 was observed
- Interpret low concentration in 2nd size distribution to be result of ppt scavenging in local t-storms

Case T3

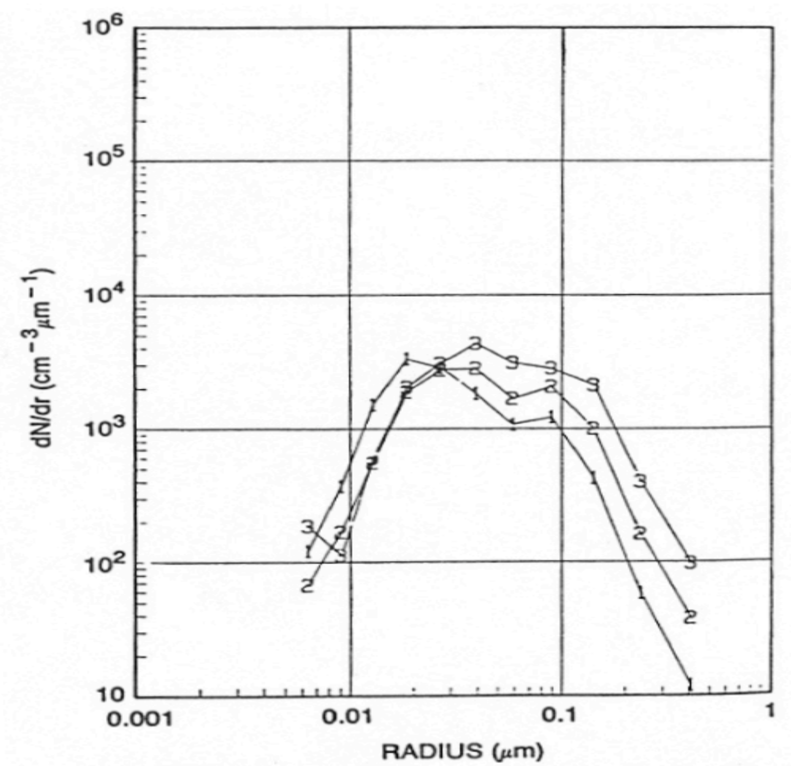


Fig. 13. Change in the size distribution as the ship encountered a weak trough containing air of African origin on March 24 and 25. Curve 1 was the distribution before entering the disturbed region. and curves 2 and 3 are the size distributions taken within the trough.

- Air trajectory indicated the air had been over Africa 7 days earlier
- Cu & Cb w/showers in vicinity of ship and change in size distribution of submicron particles
- Inc in wind speed, **no sea spray** and continentally derived elements in lg particles indicated **increase in [lg particles] due to air mass change and not locally generated sea-salt particles**
- 2nd exception to double peak observation in presence of nonppt clouds

Case T4

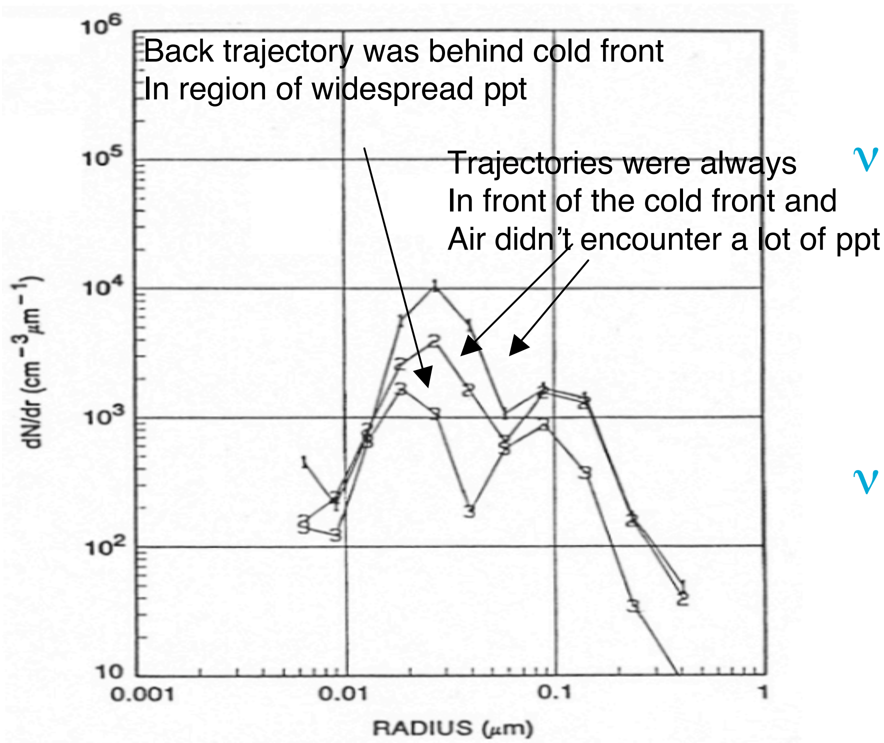


Fig. 15. Curves 1 and 2 are size distributions taken in air which had passed in front of a cold front and had encountered no (recent) precipitation, whereas the size distribution represented by curve 3 was taken in air which had passed through the cold front and encountered heavy precipitation 3 days prior to the measurement.

- Curve 1 & 2: air came from N.Atlantic passing near Iberian Peninsula 4 days prior to arriving at ship
- 2 days after curve 1 and 2, significant change in submicron size distribution (Curve 3)
- Local conditions were similar but back trajectory of the air for the 3 periods was very different

Approach to Canary Islands

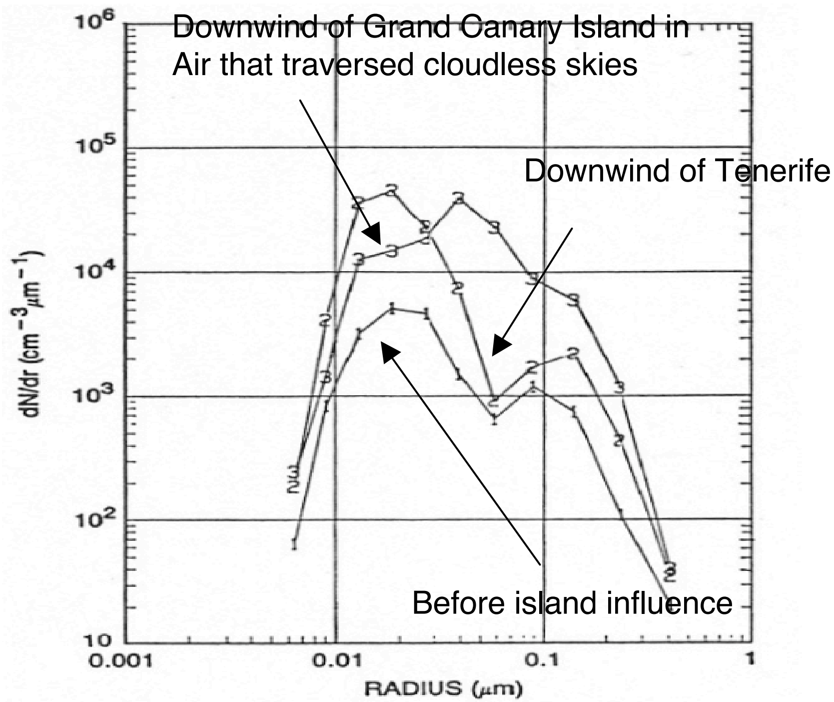


Fig. 19. Curve 1 is the size distribution before the ship was downwind of the islands. Curve 2 was taken downwind of Tenerife during heavy overcast conditions. Curve 3 was taken downwind of Grand Canary Island under clear conditions. The locations at which the three size distributions were taken are shown by the numbers along the ship's track in Figure 17.

- Downwind of Grand Canary, the double peaked feature disappeared
- Downwind of Tenerife air was more polluted than in remote tropical Atlantic and peak occurred at larger radius

Air Advecting off Iberian Peninsula

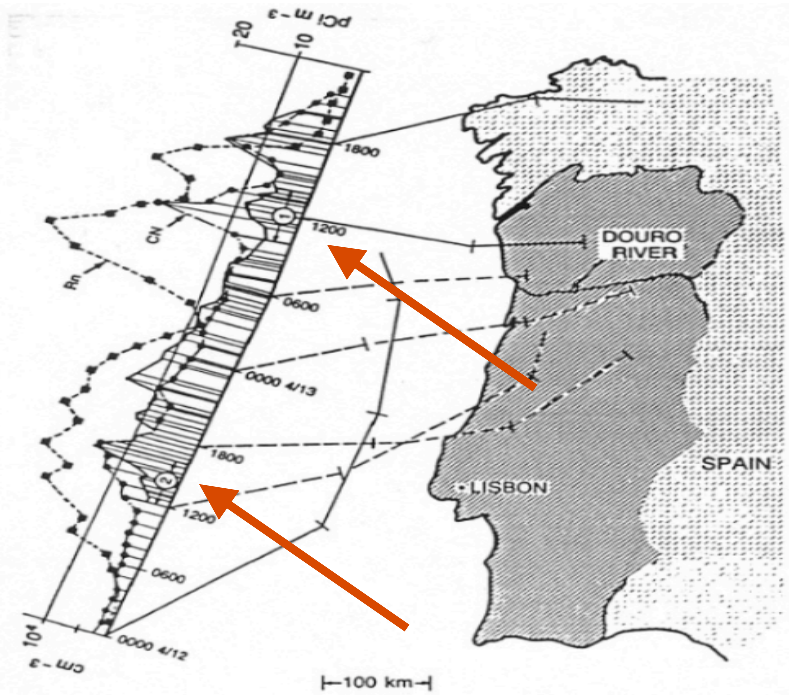
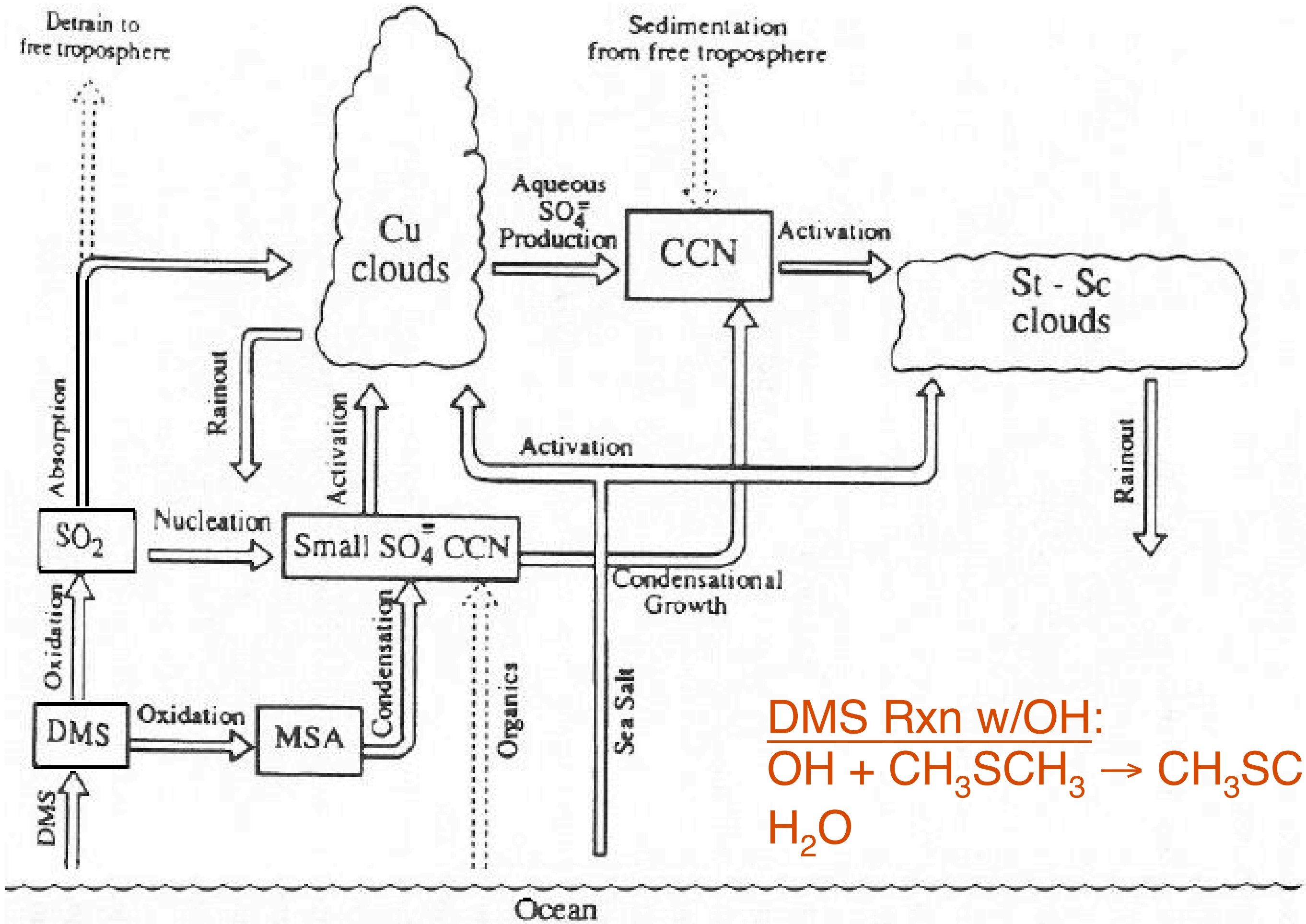


Fig. 20. Back trajectories for air encountered off the Iberian Peninsula where the tic marks indicate 6-hour intervals. Radon concentration (squares), CN concentrations (circles), and integrated aerosol concentrations (solid curve) measured along the track of the ship are plotted. (Scales are linear.) Time periods indicated by 1 and 2 refer to periods when the size distributions in Figures 22 and 23 were taken.

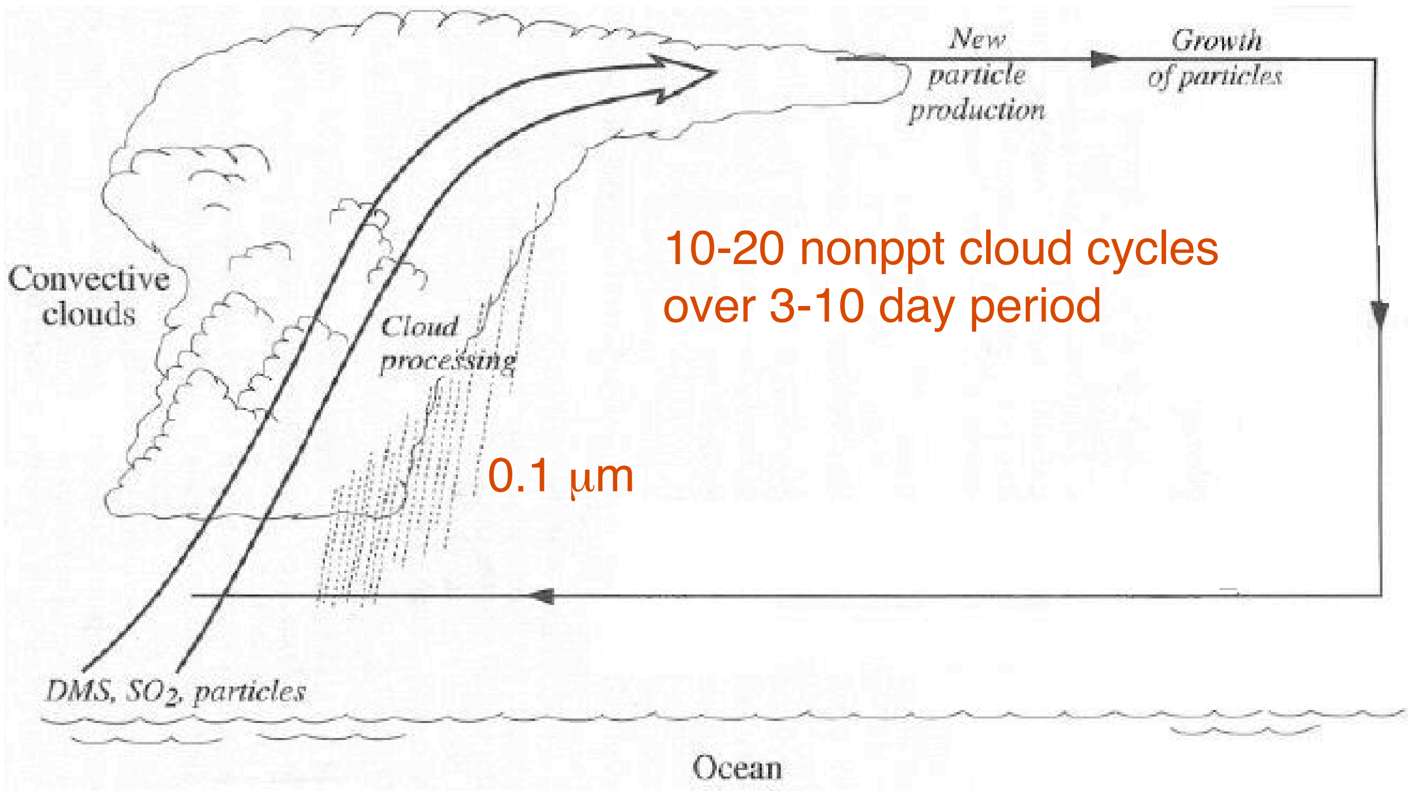
- Midday at 1 and 2, increase in small particles
- Small particle increase associated w/homogeneous nucleation and growth of new particles from gas phase rxn pdcts
- Photochemically induced since occur in air which spent the morning daylight hours over water prior to arriving at the ship

Gas-phase rxn products of marine origin provide source for small particles in MBL



DMS Rxn w/OH:
$OH + CH_3SCH_3 \rightarrow CH_3SCH_2 + H_2O$

Proposed life cycle of small marine particles in remote tropics



Rate of 10-100 cm^{-3} d^{-1},
Growing to ~0.04 μm

Nonppt Cloud Hypothesis

- <u>Supporting evidence</u>:
  - Particles under both peaks are too volatile to be sea-salt
  - Double-peaks associated with air passing thru regions of boundary layer clouds
  - Minimum occurs at 0.04-0.07 μm radius range, agrees w/cloud super-saturation
  - Particle number under 0.09 μm peak is in 50-130 cm^{-3} range, correlates with [cloud droplet] in clouds
  - Convertible gas source from sea surface able to sustain size distribution

Proposed Mechanism Time Scale

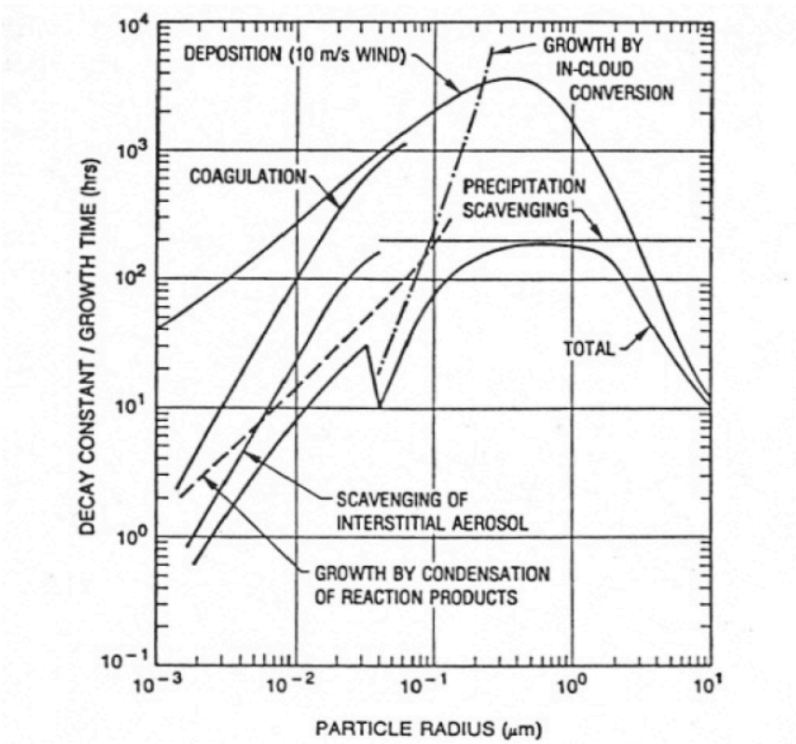


Fig. 24. Decay constants and/or growth times for various aerosol removal mechanisms. The heavy curve is the cumulative removal time.

- Assumes time for dry aerosol to inc radius by 50% is constant
- Assumes cloud droplets have 7 μm & [200 cm^{-3}]
- Assumes aerosol spends 5% time in cloud
- Assumes the size distribution observed in remote tropical Atlantic

Conclusions

A. [Small particle] decays as air masses move off continents

B. Separation of interstitial and CCN from aerosol cycling thru nonppt clouds

C. “Background aerosol” in remote tropical marine boundary layer (MBL) maintained by in-situ formation of new particulate matter from gas phase

D. Gas-phase rxn products of marine origin provide source for small particles in MBL