Experimental Atmospheric Chemistry (12.335/12.835)

Section 3, Lecture 3:

Karin Ardon-Dryer & Sarvesh Garimella

Tuesday, Nov 25, 2014

Today

- Atmospheric Particles
- Atmospheric Clouds

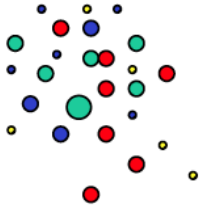
Remainder of Today

This image has been removed due to copyright restrictions.
Please see: Figure 2.15 of the book *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*. ISBN: 9780471720188.

Aerosol Abundance

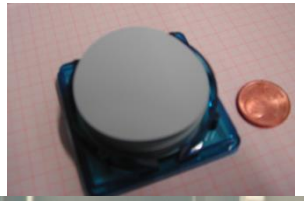
Aerosol Composition Before 1994

Traditional: Part 1



• So, what's the problem(s) here?

•Courtesy / adapted from J. Jimenez



Aerosol Mass Spectrometer

This image has been removed due to copyright restrictions.
Please see: http://cires1.colorado.edu/jimenez/amsanimation.gif.

This image has been removed due to copyright restrictions.
Please see: http://www.airmonitor.cn/upload/editorfiles/2008.12.3_13.43.7_7015.JPG.

This image has been removed due to copyright restrictions.
Please see: http://www.tropos.de/fileadmin/_processed_/csm_Aerosol_chemicalKK_20131212_c10452182e.jpg.

https://www.tropos.de/en/research/projects-infrastructures-technology/technology-at-tropos/chemical-analytics/aerosol-mass-spectrometry-techniques/

Single Particle Mass Spectrometry

PALMS

Particle Analysis by Laser Mass Spectrometry

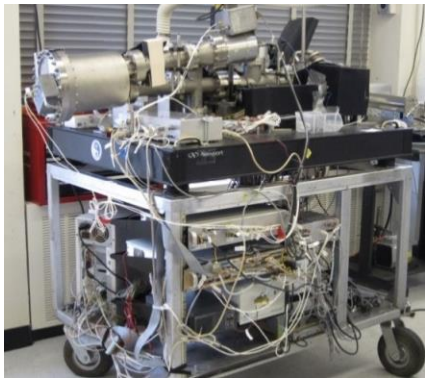
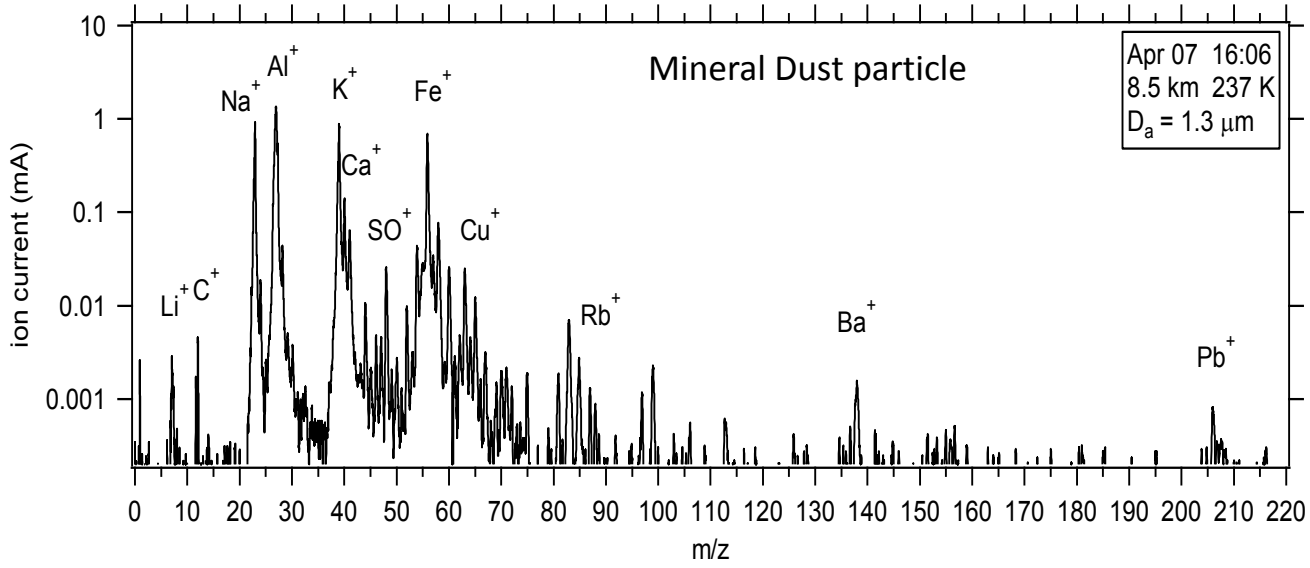
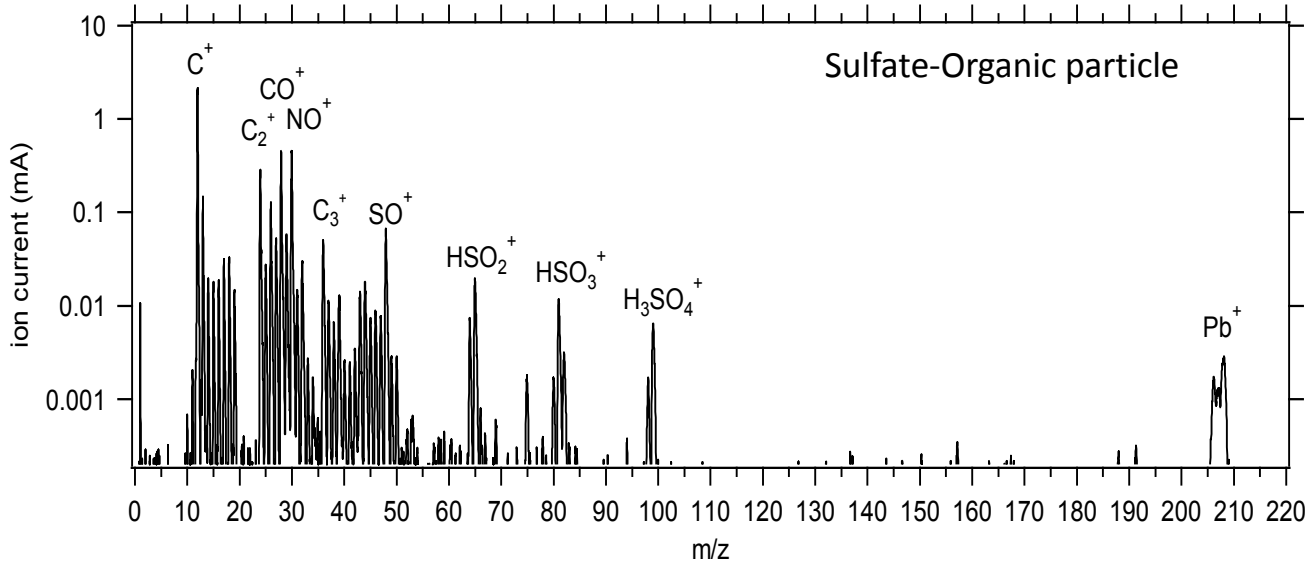


Image courtesy of Deborah Gross. Used with permission.

Courtesy of D. Gross





adapted from D. Cziczo

Influential Results

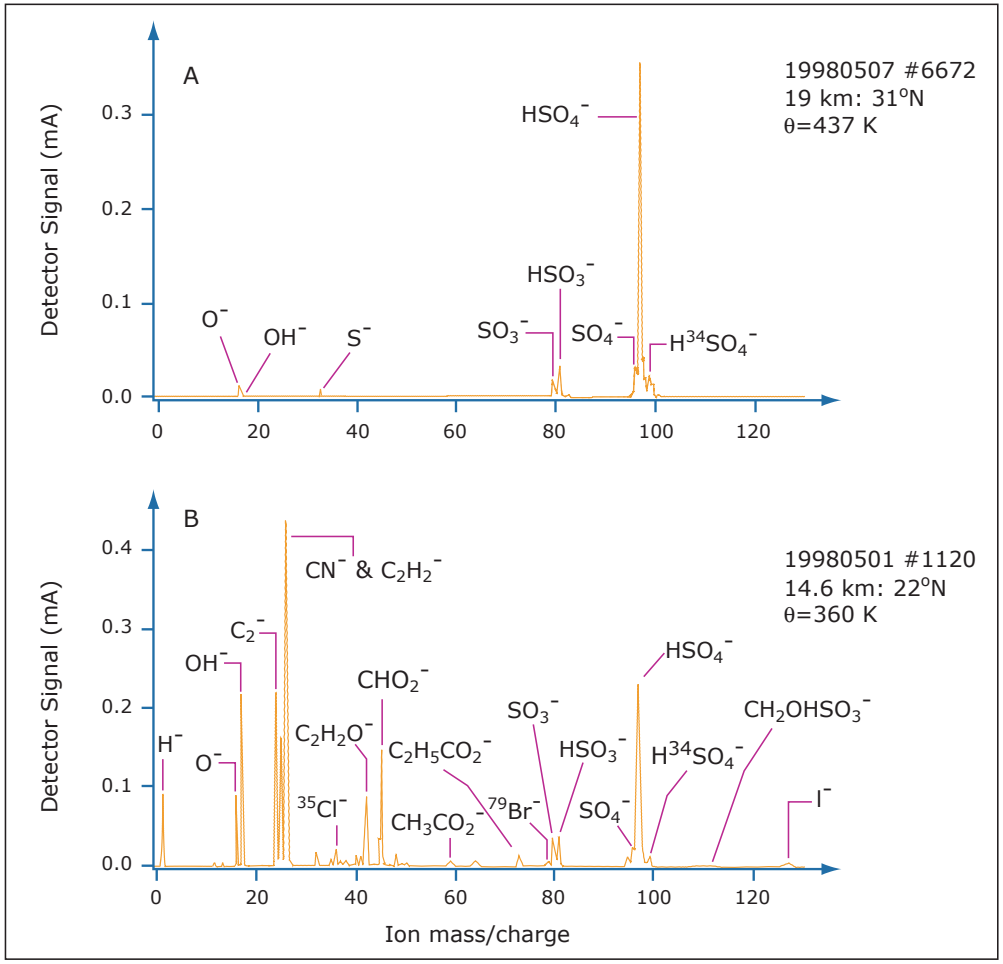


Figure by MIT OpenCourseWare.

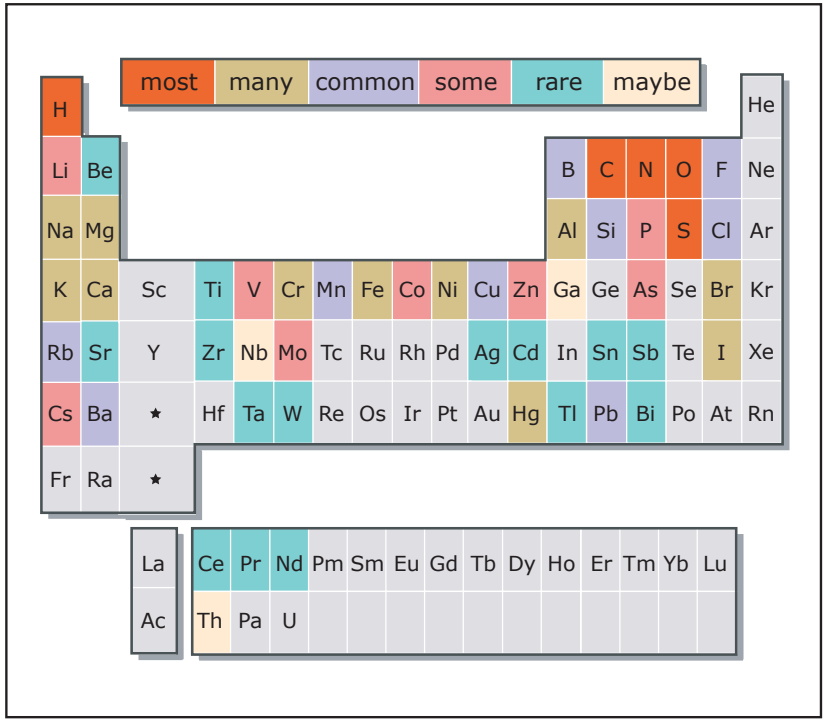


Figure by MIT OpenCourseWare.

Murphy et al. Science 1998

Free Tropospheric

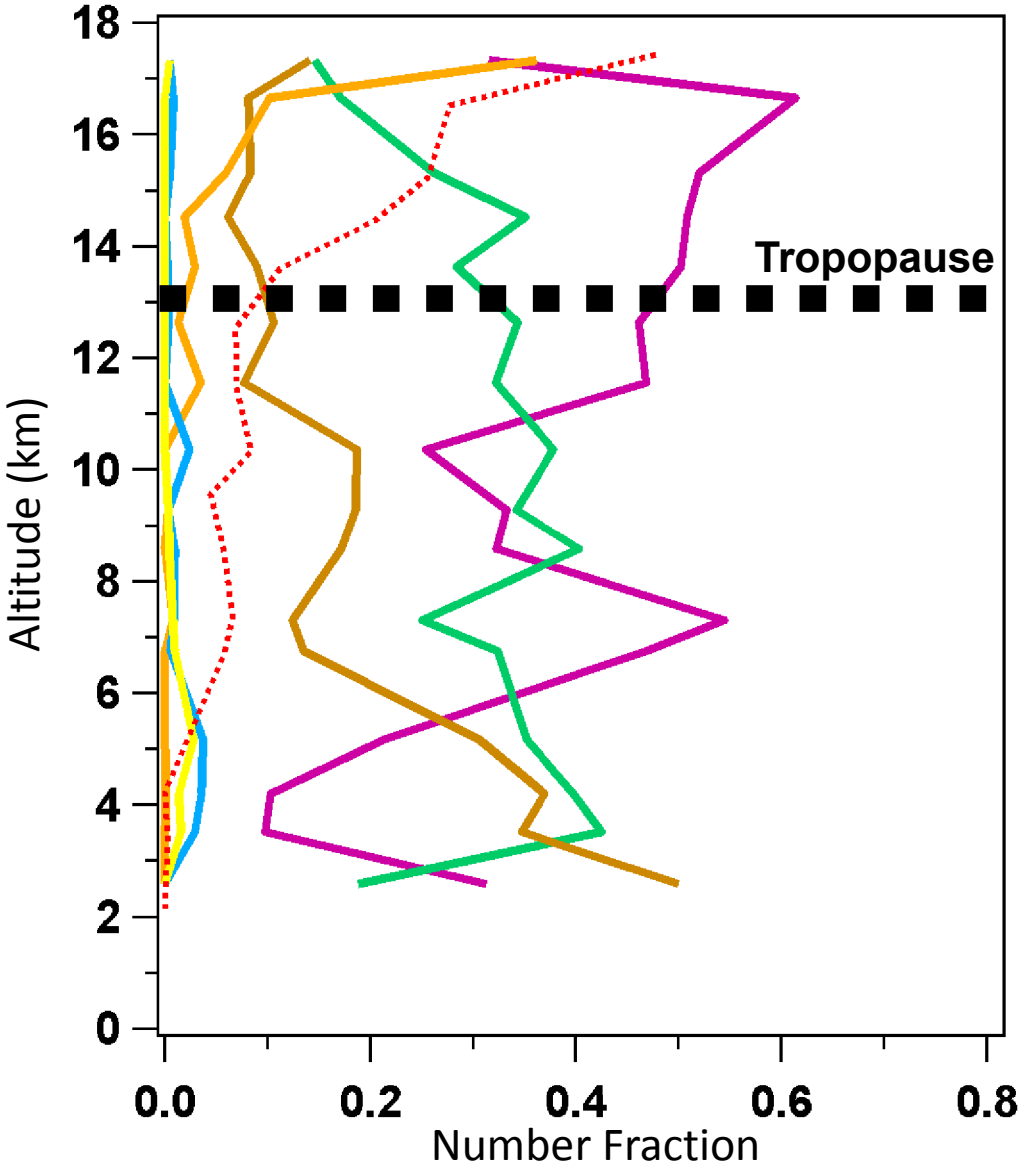


Image courtesy of Karl Froyd. Used with permission.

- **Biomass Burning**
- **Sulfate-Organic mixtures** dominate in UTLS
- **Mineral Dust**: 10-30%
- Little **Sea Salt** in UT
- **Meteoric** particles in stratosphere
- **Acidic sulfate** mainly in stratosphere

K. Froyd, unpublished

This image has been removed due to copyright restrictions.
Please see Figure 6 on page: https://cloud1.arc.nasa.gov/intex-na/publications/articles/2006JD007340.pdf.

Murphy et al. JGR 2006

Influential Results

This image has been removed due to copyright restrictions.
Please see: http://eloquentscience.com/wp-content/uploads/2013/03/img_global.jpg.

Zhang et al. GRL2007

What Forms Clouds?

This image has been removed due to copyright restrictions.
Please see: Figure 17.6 of the book *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*. ISBN: 9780471720188.

This image has been removed due to copyright restrictions.
Please see: Figure 2.15 of the book *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*. ISBN: 9780471720188.

Seinfeld and Pandis, 2006

Cloud Formation Basics

This image has been removed due to copyright restrictions.
Please see: http://www.harding.edu/lmurray/113_files/html/d2_earth%20revised/img037.jpg.

http://jennyse7en.blogspot.com/

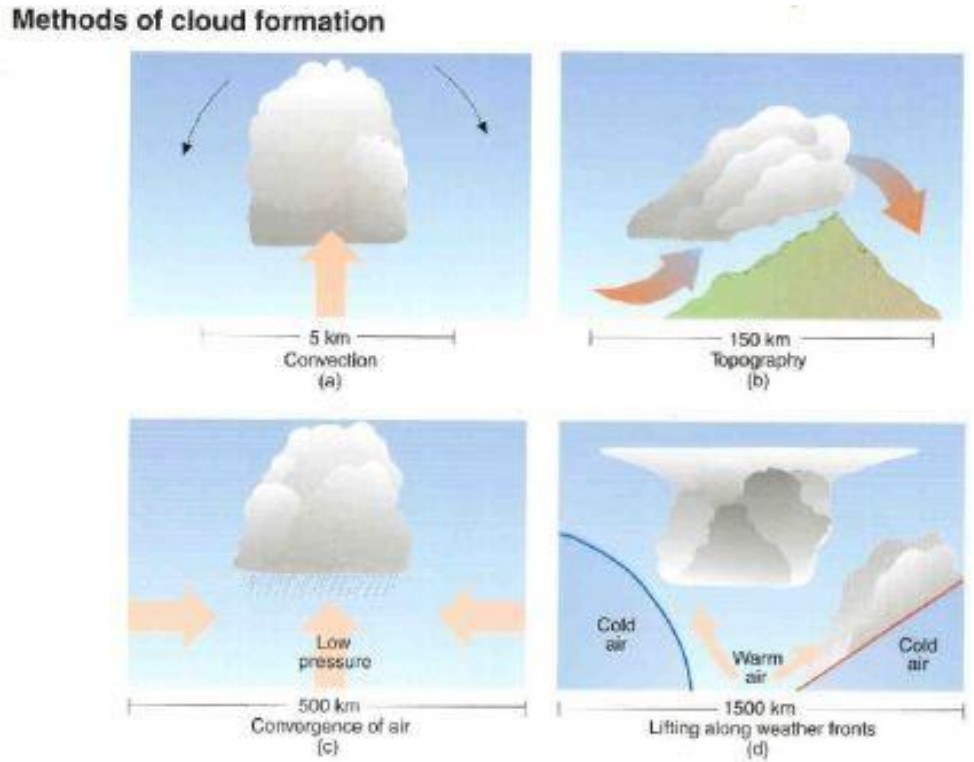
"The Atmosphere", Lutgens and Tarbuck, 10th Edition Reference Texts on Reserve in EPSc Library: "Understanding Our Atmospheric Environment", Neiburger et al. "Meteorology Today", Ahrens http://epsc.wustl.edu/courses/epsc105a/, W. H. Smith

Cloud Development

Clouds form as air **rises, expands and cools**

Most clouds form by:

a. Surface heating and free convection
b. Lifting of air over topography
c. Widespread air lifting due to surface convergence
d. Lifting along weather fronts



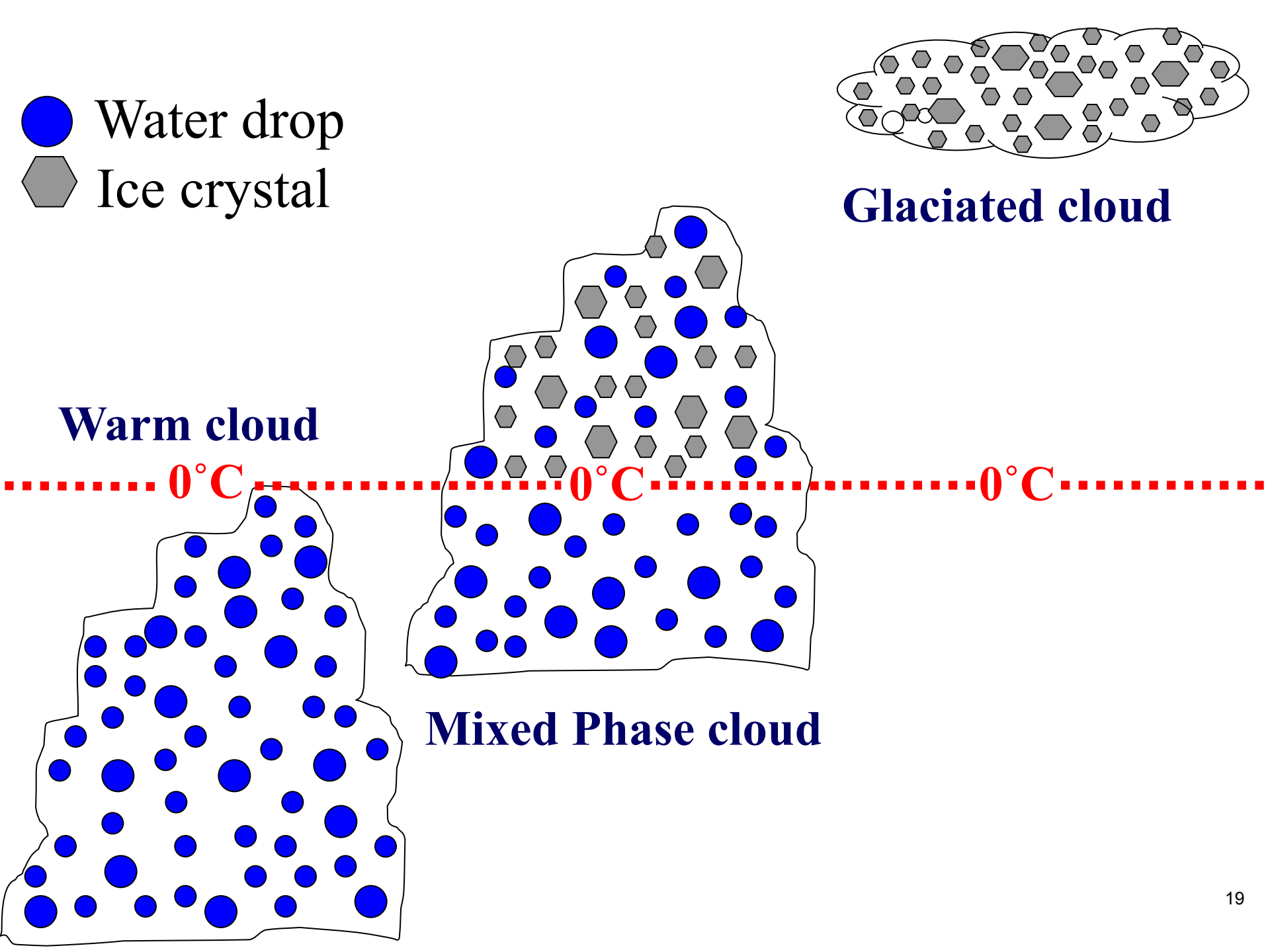
http://www.sir-ray.com/cloudformation2.jpg

A Few Words About *ALL* Clouds

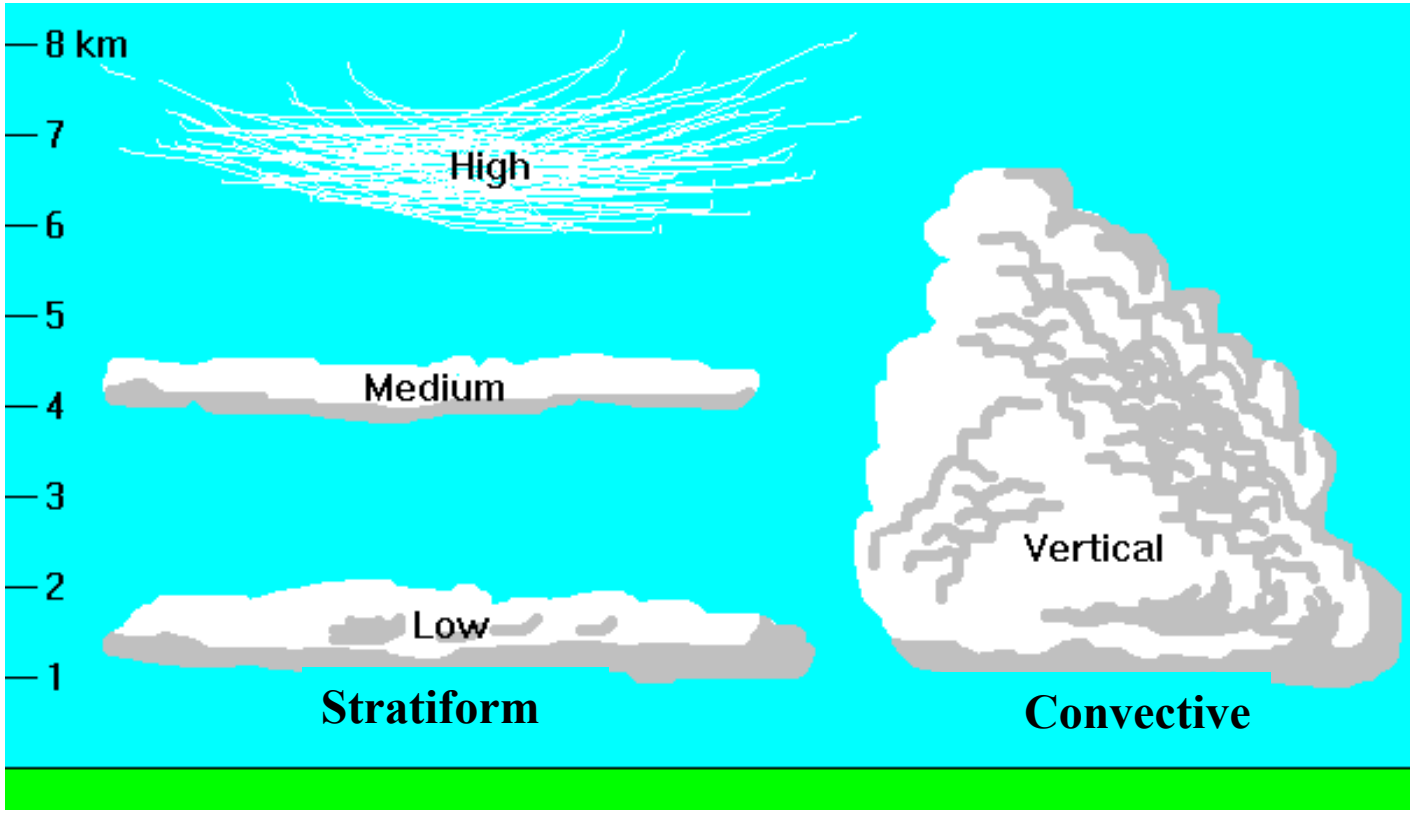
This image has been removed due to copyright restrictions.
Please see the image on page: http://scied.ucar.edu/webweather/clouds/cloud-types.

Classification of Clouds

- **Temperatures**
- **By their shape and heights**
- **Other Cloud Types:**
  - Contrail clouds
  - Ship track
  - Mammatus clouds
  - Orographic clouds


Water drop
Ice crystal
Glaciated cloud
Warm cloud
0°C
0°C
0°C
Mixed Phase cloud

Clouds Classification



Stratiform

- High-Level Clouds
- Mid-Level Clouds
- Low-Level Clouds

Convective

Clouds with Vertical Development

Other Cloud Types

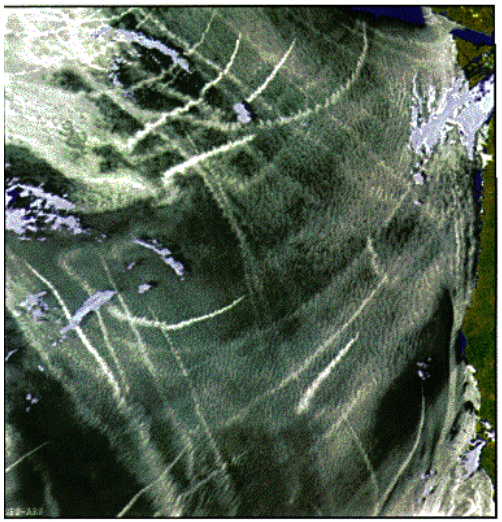


Figure 1: Ship tracks off the coast of Washington

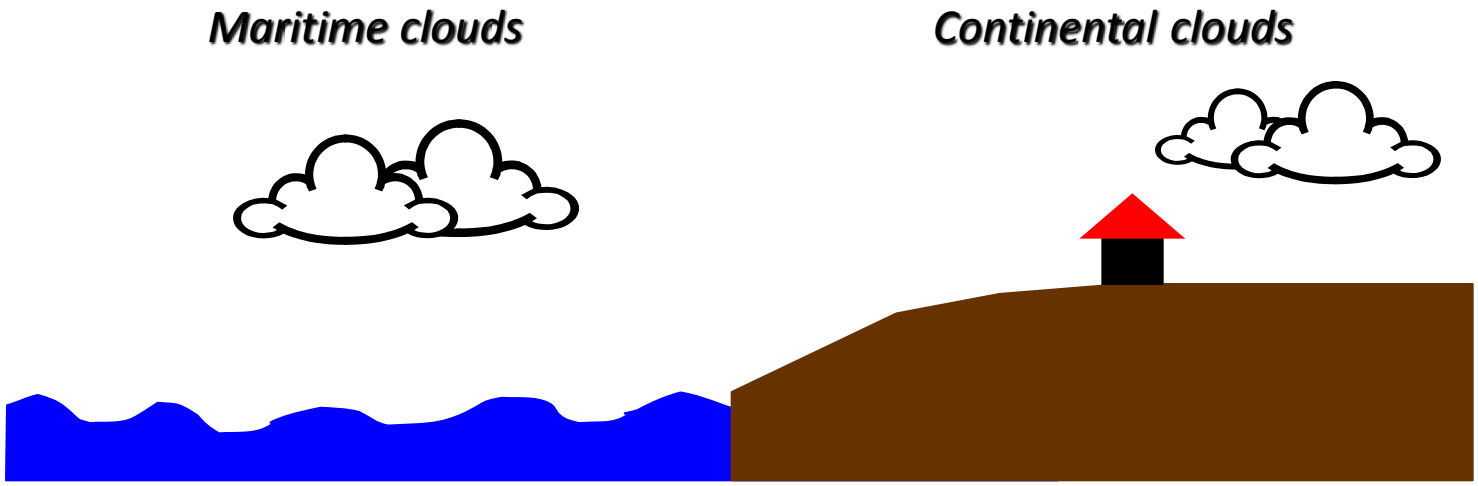
Image courtesy of NASA.

Image courtesy of NASA.
http://commons.wikimedia.org/wiki/File:Sfc.contrail.1.26.01.JPG.

This image has been removed due to copyright restrictions. Please see the image on page: http://www.rainbowskill.com/wp-content/uploads/2009/07/a132.jpg.

This image has been removed due to copyright restrictions. Please see the image on page: https://s-media-cache-ak0.pinimg.com/736x/76/e3/63/76e363ed61675f5de64f68a1608197ad.jpg.

- Clouds with high concentrations of cloud drops are referred to as **continental** clouds. These are more often found over land.
- Clouds with low concentrations of cloud drops are called **maritime** clouds and they are often found in clean regions and over water.

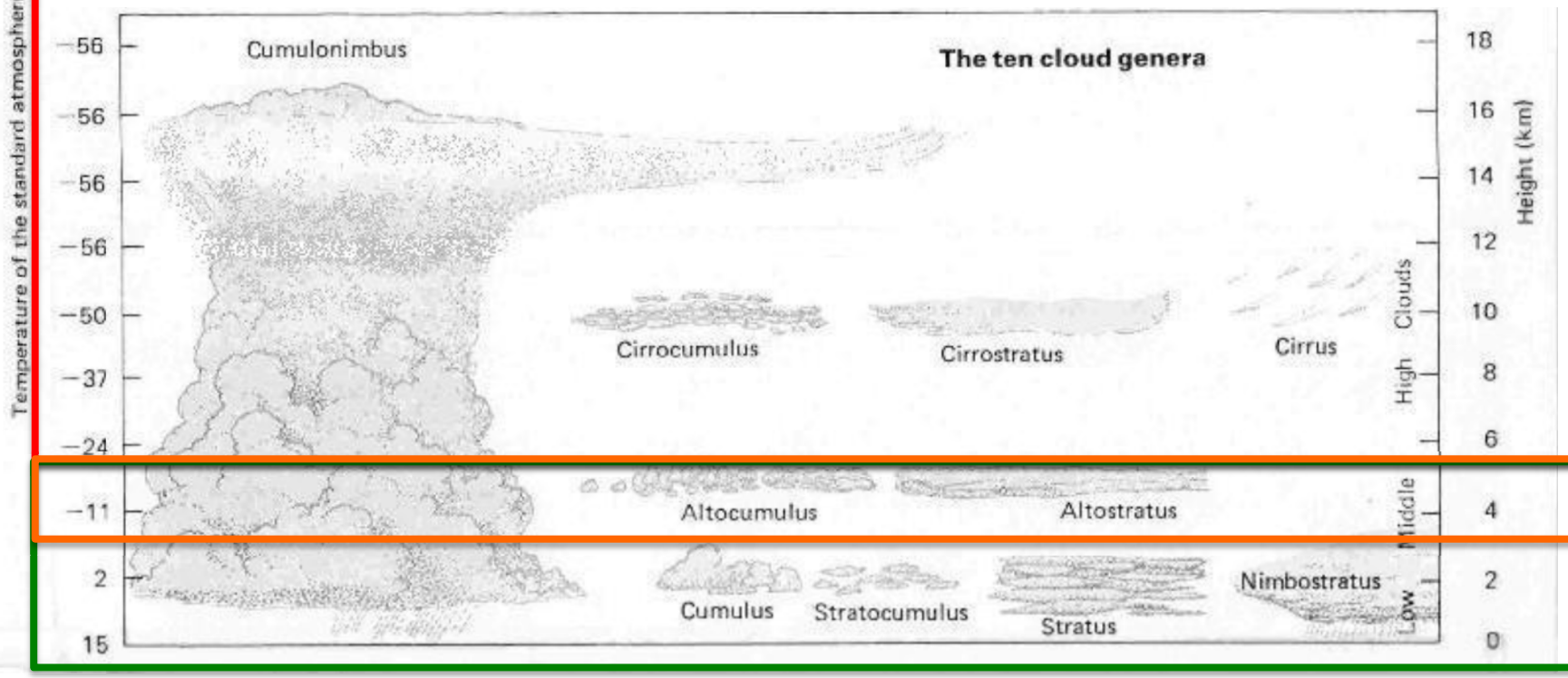


Clouds

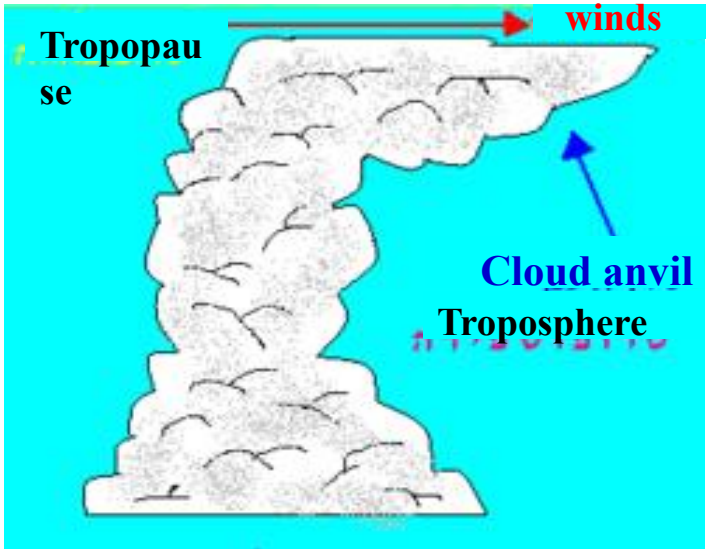
Cold or Ice

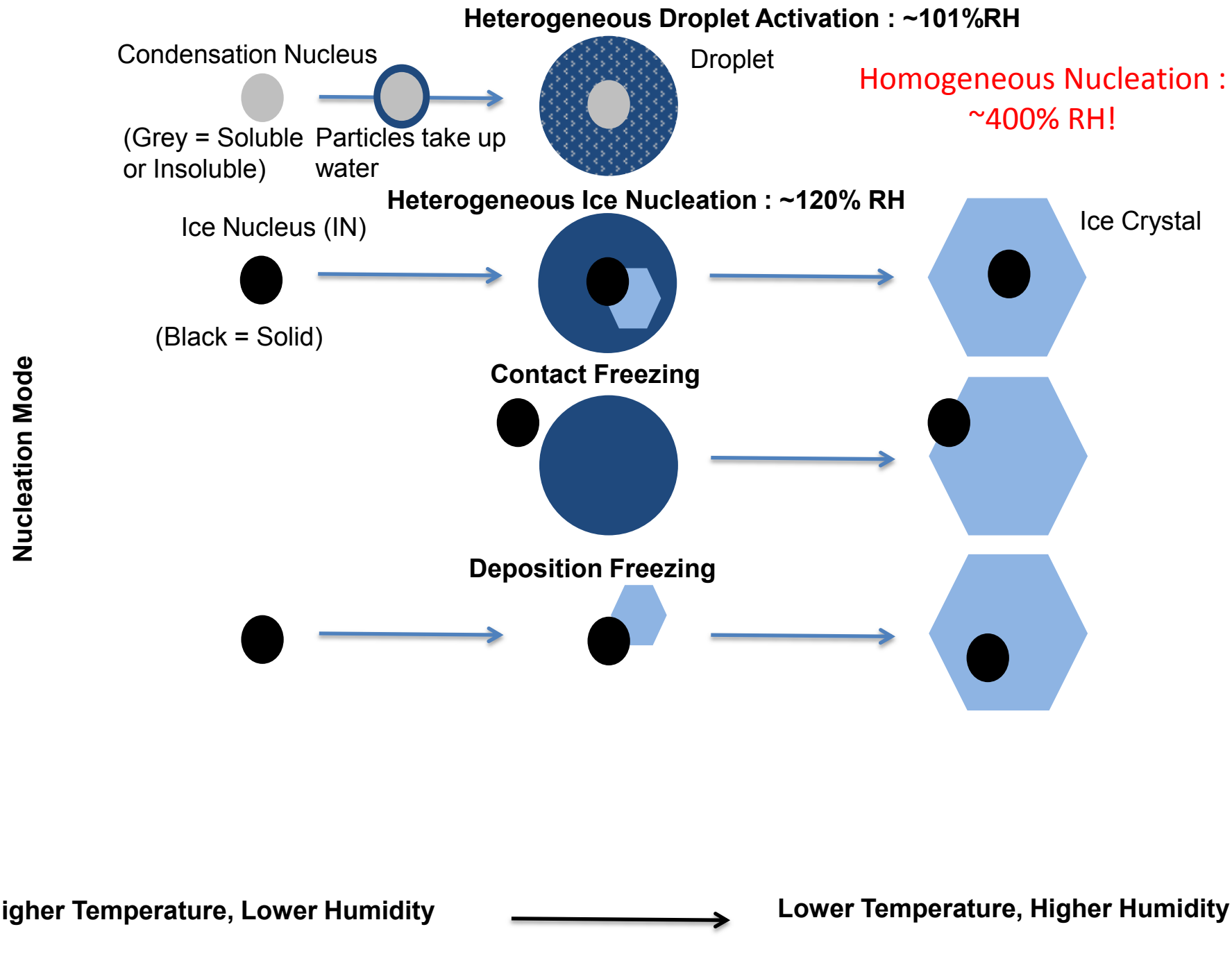
M-P

Warm



This image has been removed due to copyright restrictions.
Please see the image on page:
http://teachertech.rice.edu/Participants/louviere/Images/profile.gif.




Heterogeneous Droplet Activation : ~101%RH
Condensation Nucleus
Droplet
Homogeneous Nucleation :
~400% RH!
(Grey = Soluble or Insoluble)
Particles take up water
Heterogeneous Ice Nucleation : ~120% RH
Ice Nucleus (IN)
Ice Crystal
(Black = Solid)
Contact Freezing
Deposition Freezing
Nucleation Mode
Higher Temperature, Lower Humidity
Lower Temperature, Higher Humidity

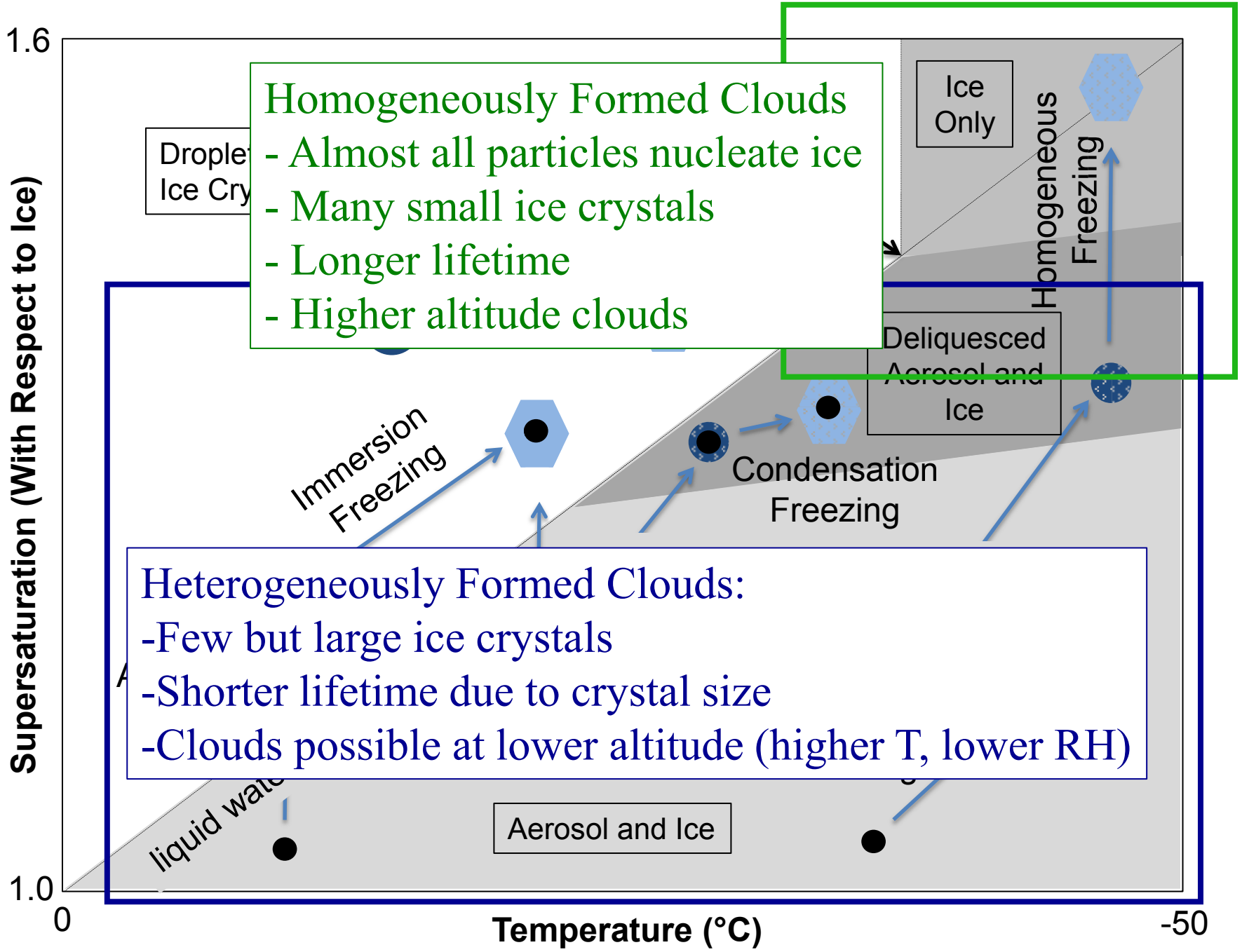

Homogeneously Formed Clouds
- Almost all particles nucleate ice
- Many small ice crystals
- Longer lifetime
- Higher altitude clouds
Heterogeneously Formed Clouds:
-Few but large ice crystals
-Shorter lifetime due to crystal size
-Clouds possible at lower altitude (higher T, lower RH)
Ice Only
Homogeneous Freezing
Deliquesced Aerosol and Ice
Immersion Freezing
Condensation Freezing
Aerosol and Ice
liquid wate
Supersaturation (With Respect to Ice)
1.6
1.0
0
-50
Temperature (°C)

Figure 3.

Cloud Measurement

Cloud Droplet Probe (CDP-2)

This image has been removed due to copyright restrictions.
Please see the "Cloud Droplet Probe" image on page:
http://dev.dropletmeasurement.com/products/airborne.

This image has been removed due to copyright restrictions.
Please see the "Cloud Imaging Probe" image on page:
http://dev.dropletmeasurement.com/products/airborne.

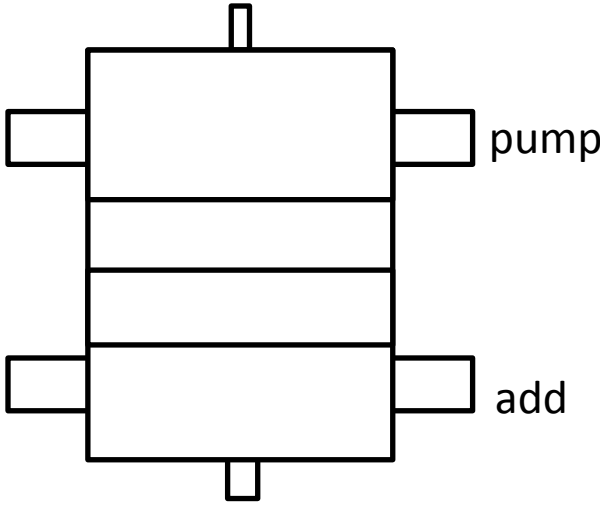
Cloud Imaging Probe (CIP)

This image has been removed due to copyright restrictions.
Please see the "Ultra-High Sensitivity Aerosol Spectrometer" image on page: http://dev.dropletmeasurement.com/products/airborne.

Passive Cavity Aerosol Spectrometer Probe (PCASP-100X)

This image has been removed due to copyright restrictions.
Please see the "Passive Cavity Aerosol" image on page: http://dev.dropletmeasurement.com/products/airborne.

PCVI - Pumped Counter flow Virtual Impactor



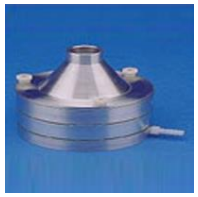
This image has been removed due to copyright restrictions.
Please see Figure 3 on page:
http://www.tandfonline.com/doi/pdf/10.1080/02786826.2010.539291.

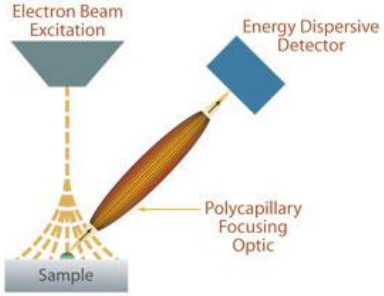
Fluid flow velocity characteristics during passage through the PCVI

This image has been removed due to copyright restrictions.
Please see Figure 4 on page:
http://www.tandfonline.com/doi/pdf/10.1080/02786826.2010.539291.

Single particle size and composition (0.2 – 3 mm)

Offline – SEM + EDS

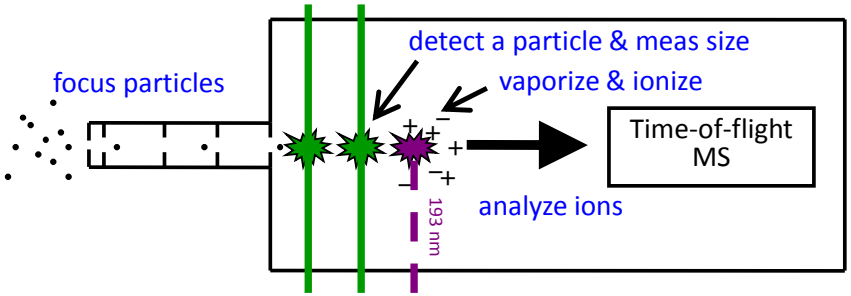




Size, morphology, and composition

This image has been removed due to copyright restrictions.
Please see Figure 1 on page: http://www.sciencemag.org/content/340/6138/1320.full.

Online - PALMS

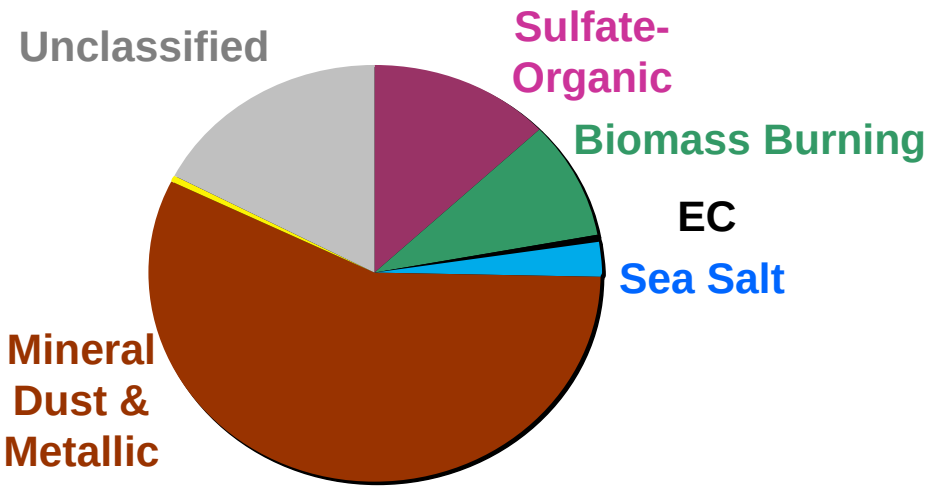


Size and composition

Cziczo et al. 2013

This images has been removed due to copyright restrictions.
Please see Figure 2 on page: http://www.sciencemag.org/content/340/6138/1320.full.

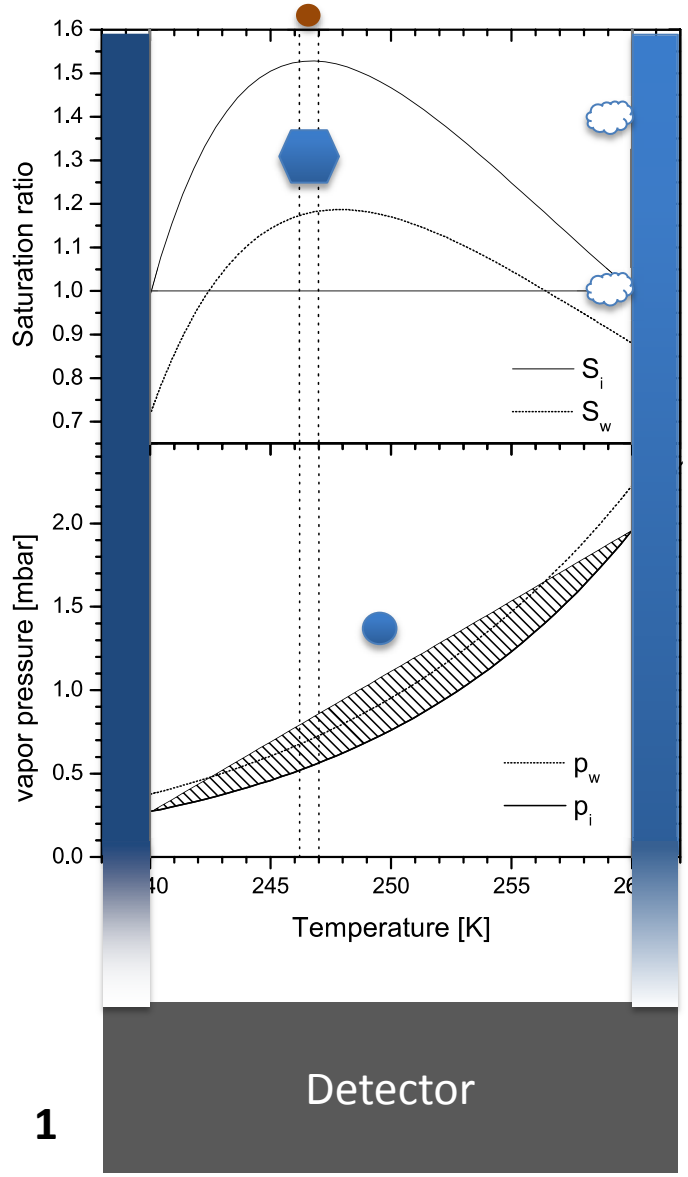
Cziczo et al. 2013



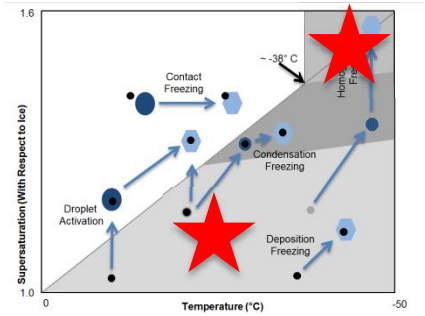
This image has been removed due to copyright restrictions.
Please see Figure 1 on page:
http://www.sciencemag.org/content/340/6138/1320.full.

Cziczo et al. 2013

Making Clouds in the lab



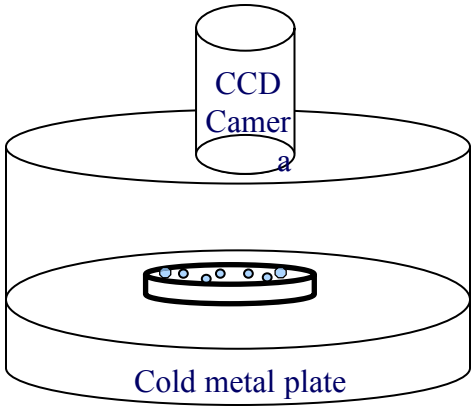
Spectrometer for Ice Nuclei (SPIN)
Commercially available from DMT, Boulder, CO
Based on Zurich Ice Nucleation Chamber (Stetzer. Lohmann)



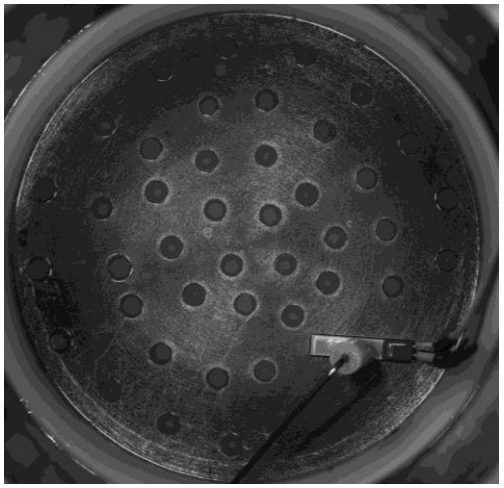
- Parallel plates
- Ice on walls
  - Ice saturation
- Linear temp and vapor gradient
- Nonlinear saturation ratio
  - Clausius-Clayperon Relation

This image has been removed due to copyright restrictions. Please see: http://www.dropletmeasurement.com/sites/default/files/pictures/Products/SPIN/SPIN_2.gif.

Drop freezing technique



130 drops
(1µl; 0.8mm diameter)



12.335 / 12.835 Experimental Atmospheric Chemistry

Fall 2014