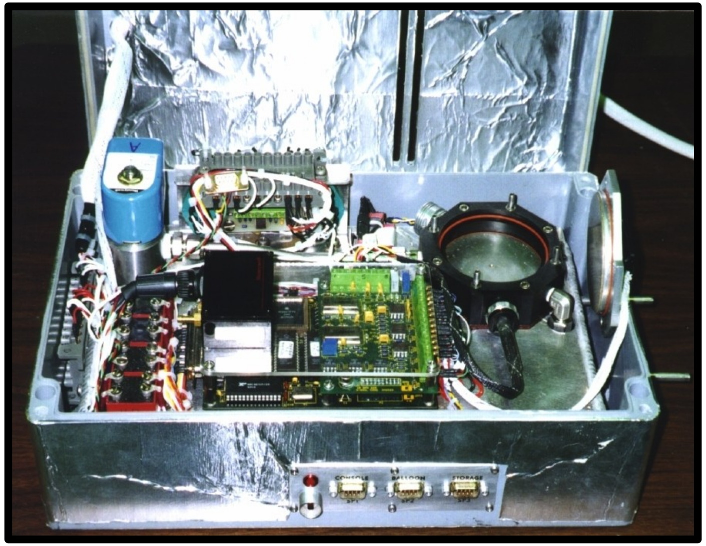
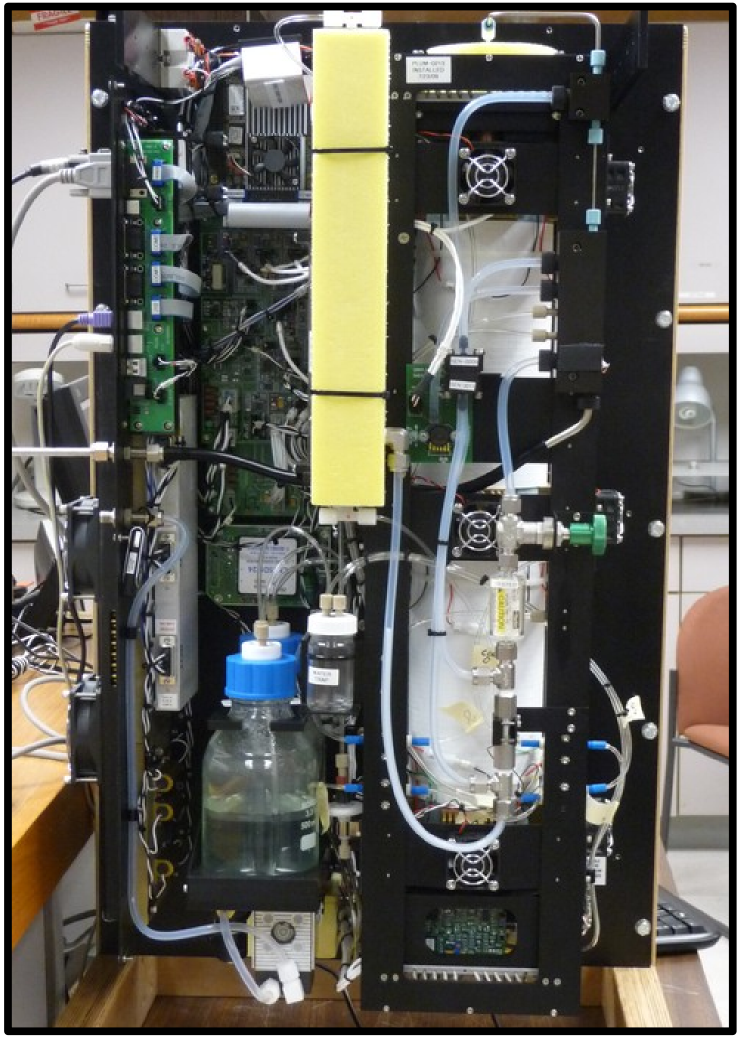
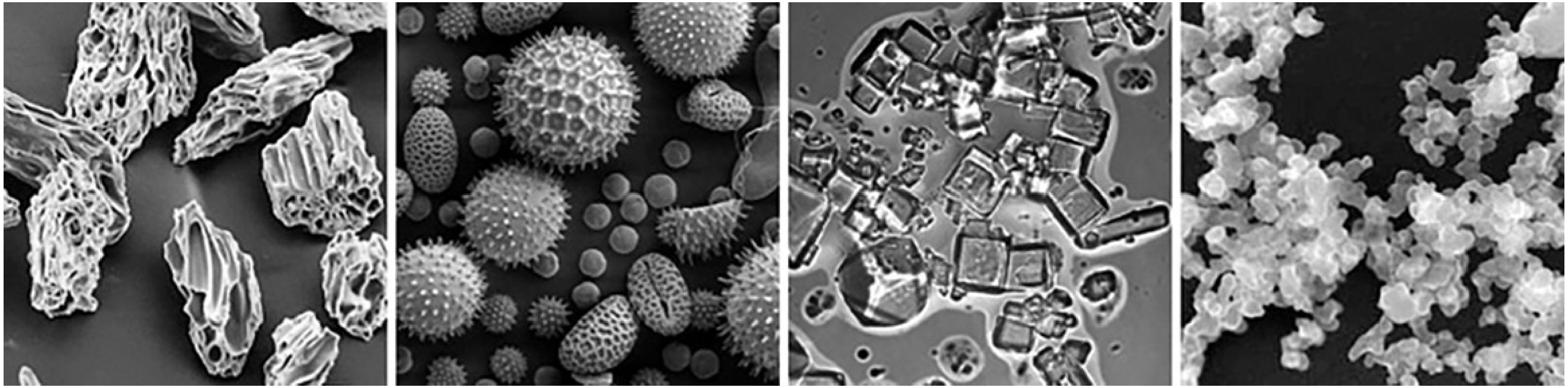
Atmospheric Aerosols and Particle Nucleation





What are Aerosols?

- Suspended particles in the air.
- May consist of liquids or solids, but not a gas.
- Suspended material in the Earth's atmosphere that have troposphere residence times (lifetimes) of days to a few weeks.
- Particles involved in the formation of water or ice are often referred to as “nuclei”.



These scanning electron microscope images (not at the same scale) show the wide variety of aerosol shapes. From left to right: volcanic ash, pollen, sea salt, and soot. Images: NASA, compiled from USGS, UMBC (Chere Petty), and Arizona State University (Peter Buseck)

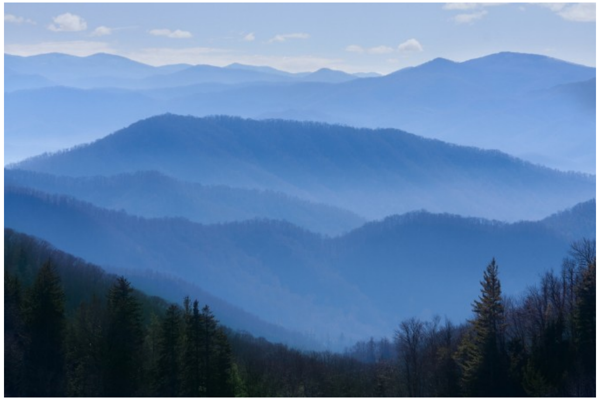
Clouds in the Atmosphere

- Clouds are made up of water droplets and/or ice crystals, much larger than typical aerosols (0.01-10 µm).
- Clouds are technically aerosols but have unique properties and are typically considered separately.

East Grand Forks: 17 July 2011

Citation Flight: 14 July 2011

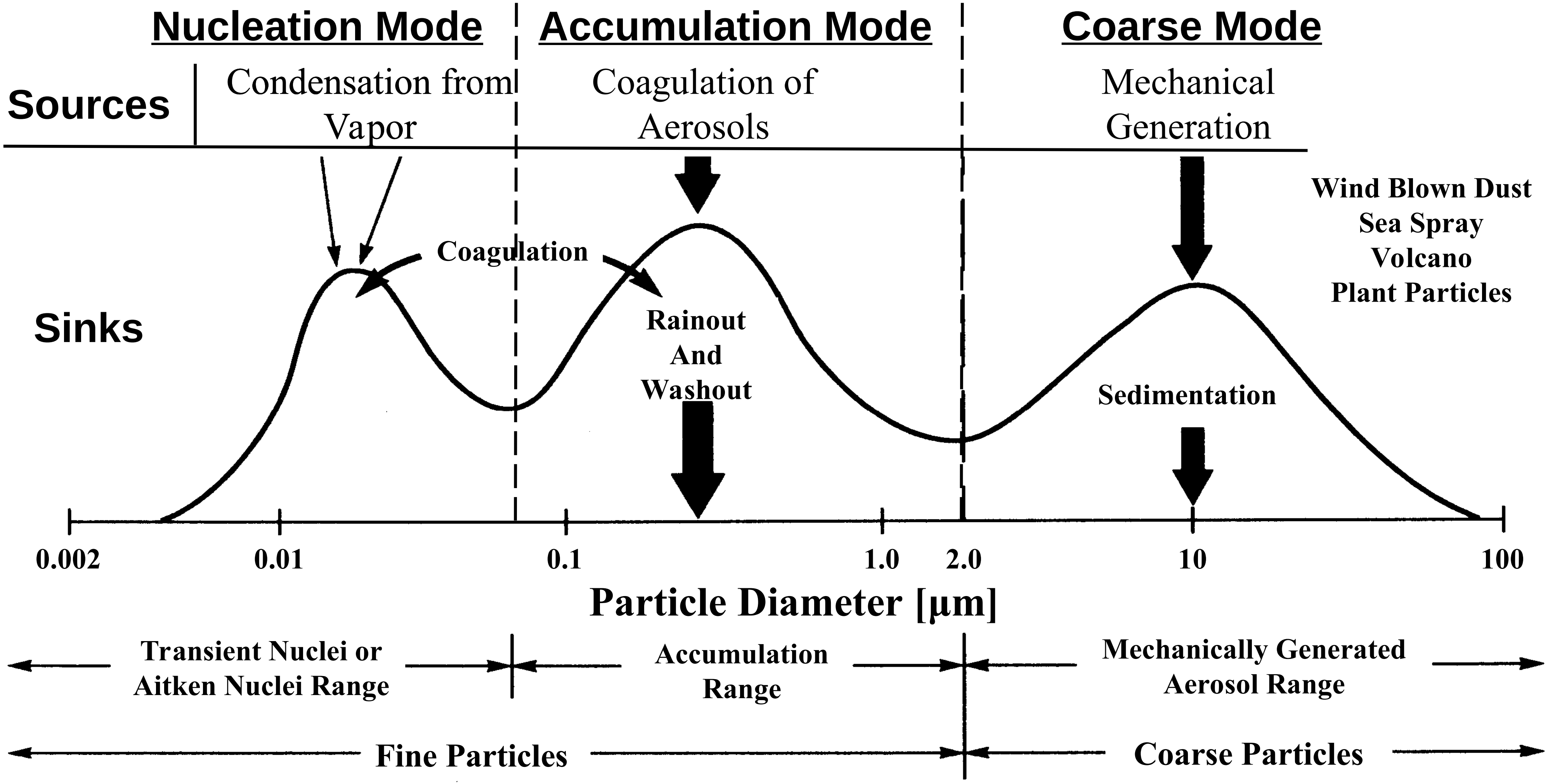
How do we know when present in the air?



Aerosols and Water

- Hygroscopic Particles
  - Readily absorbing and holding water molecules (vapor).
    - Example: Sea Salt
- Hydrophobic Particles
  - Repel water molecules.
  - Nonpolar types of materials.
    - Example: Fresh Smoke, Soot

Aerosol Modes Observed in the Atmosphere

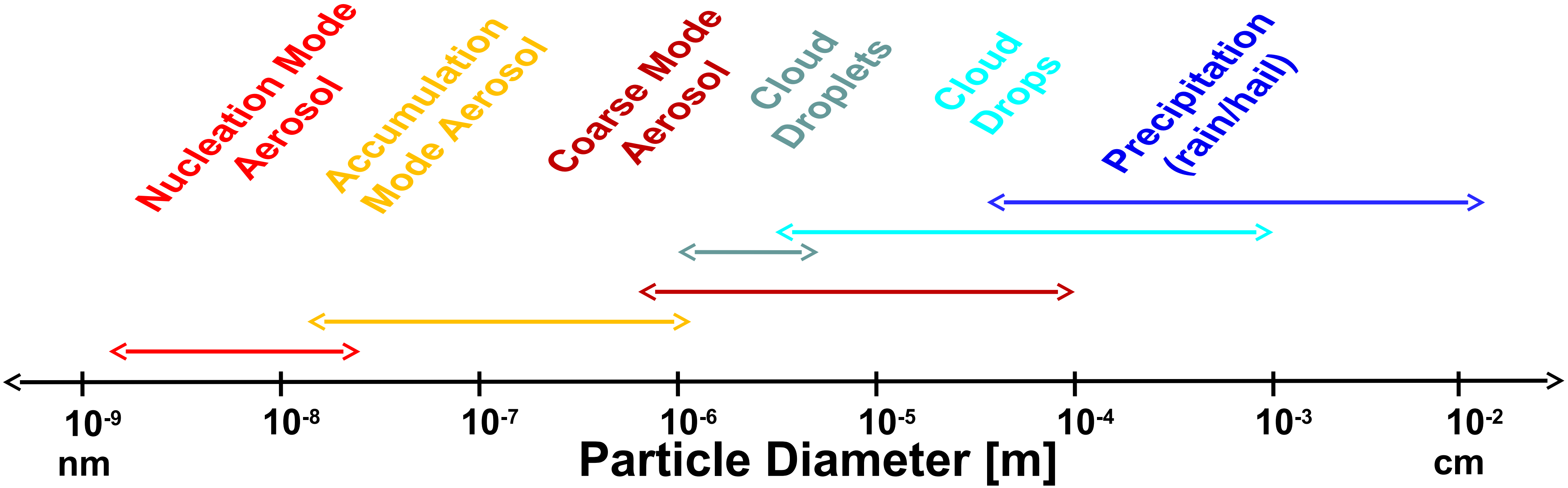


Adapted from Singh: Figure 5.4

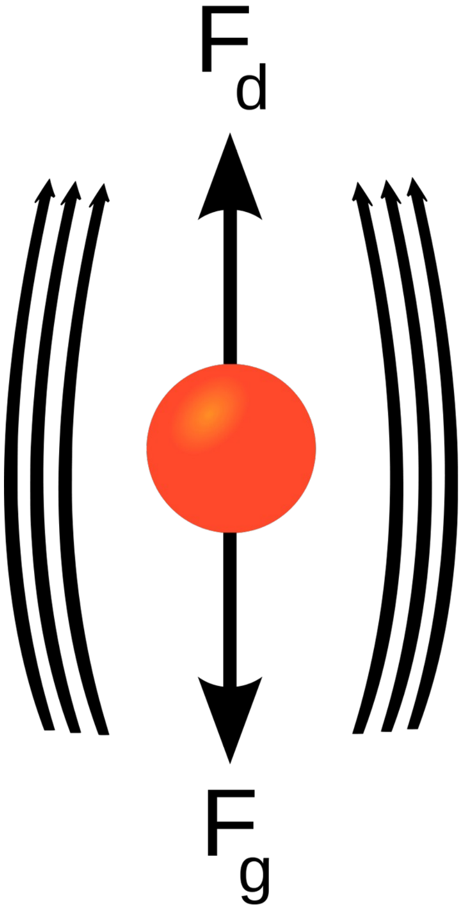
Atmospheric Particle Background

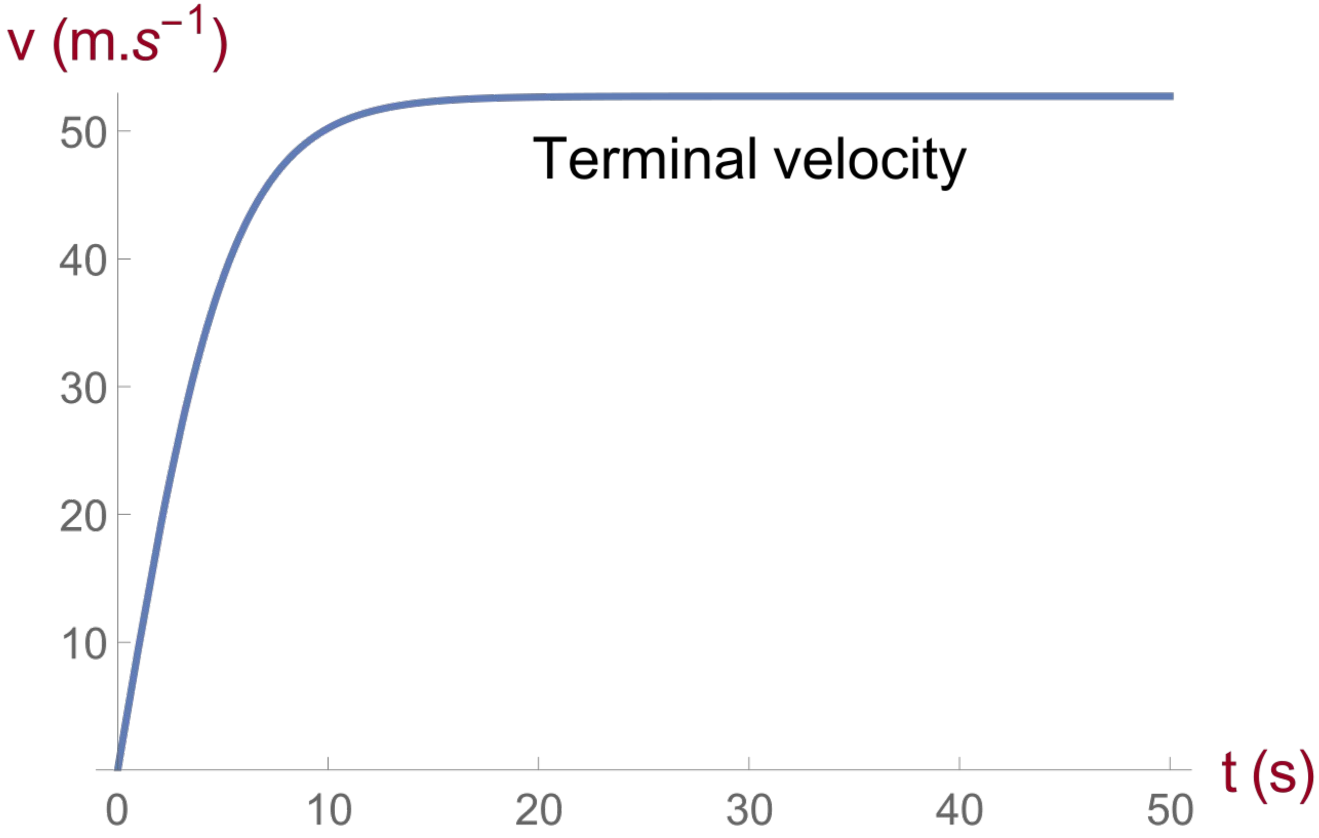
Atmosphere contains particles of all sizes.

- Suspended particles (aerosols) move with the average flow of gas molecules (atmospheric wind).
- Large particles (dust/drops/rain) have sufficient inertia to move independently of the wind.



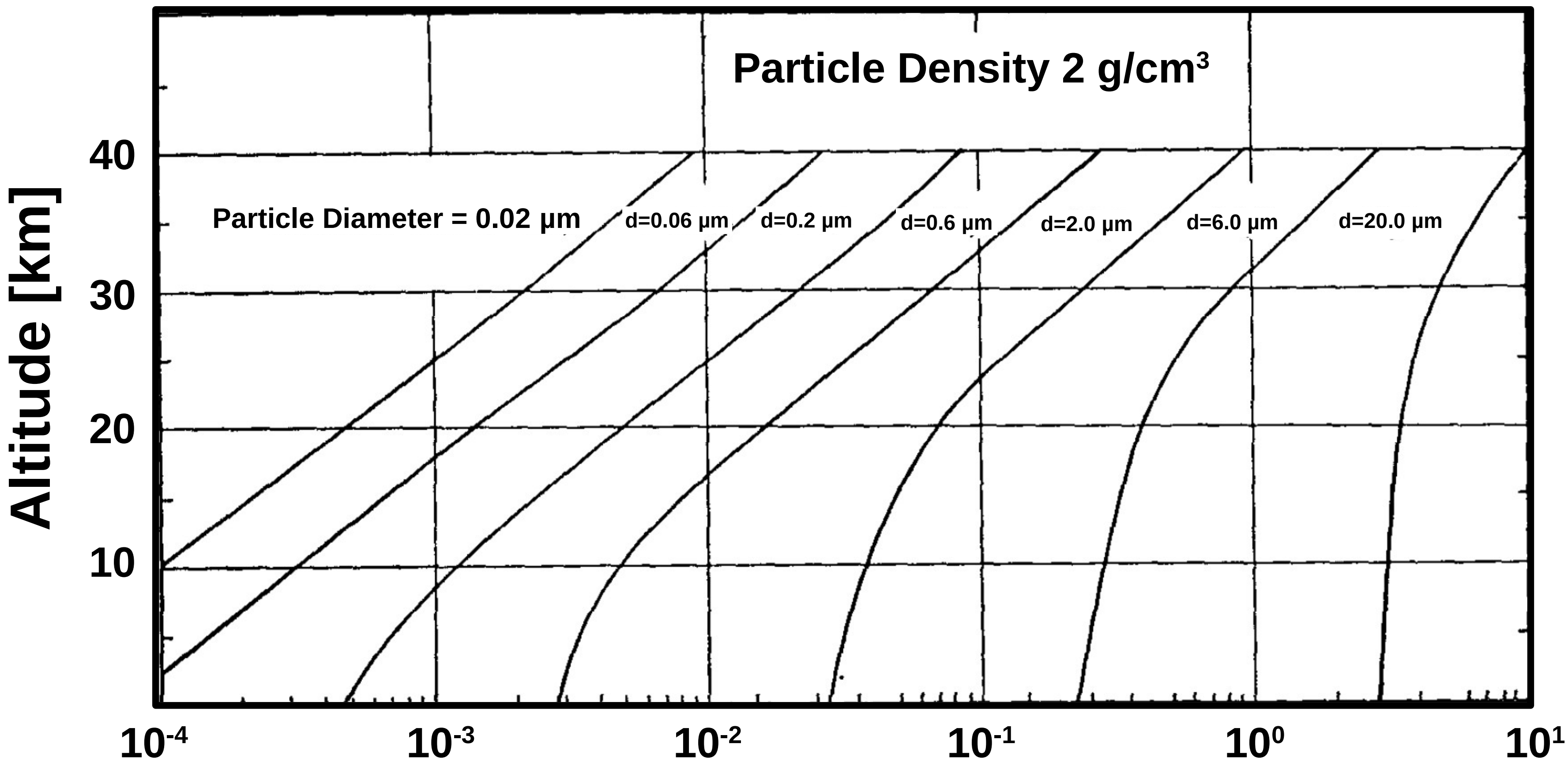
Terminal Velocity (Gravity = Drag Force)





Adapted from Wikipedia Terminal Velocity article.

Terminal Velocities of Aerosols



Adapted from Junge, Christian E., Charles W. Chagnon, and James E. Manson. "Stratospheric aerosols." Journal of Atmospheric Sciences 18, no. 1 (1961).

Instrumentation Based Aerosol Definitions

Ultrafine Aerosols (UF)

- **Aerosols larger than 3 nm diameter.**

Condensation Nuclei (CN)

- **Aerosols larger than 10 nm diameter.**

Optical Aerosols ($D_{0.3}$)

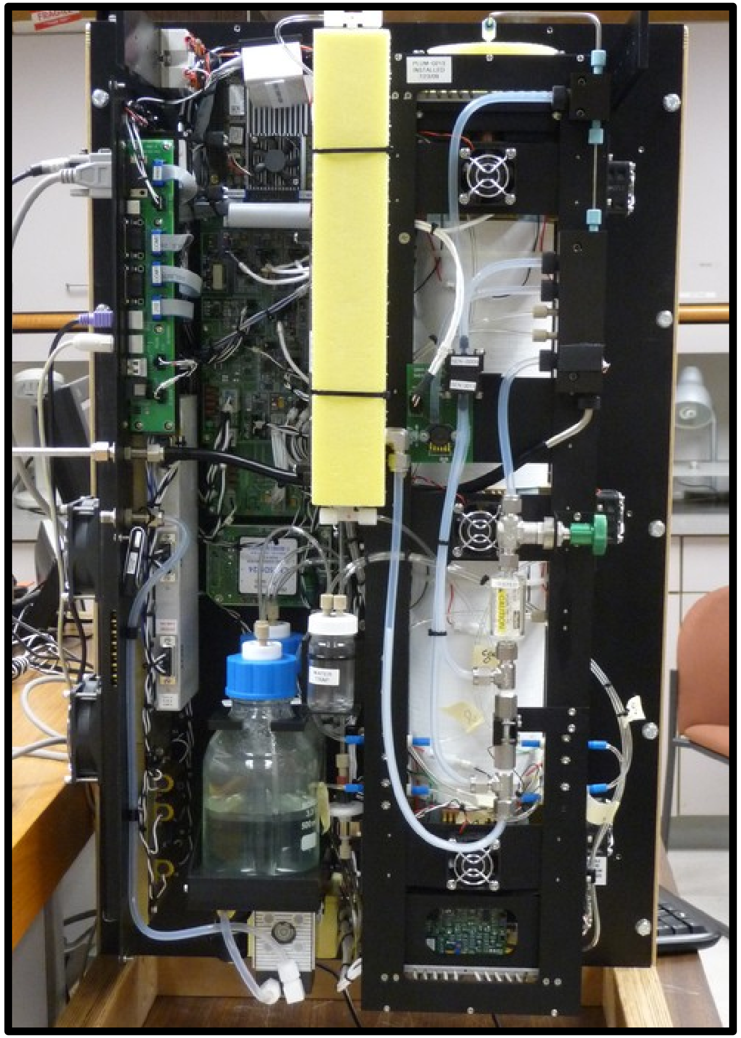
- **Aerosols larger than 0.3 µm diameter.**

Cloud Condensation Nuclei (CCN)

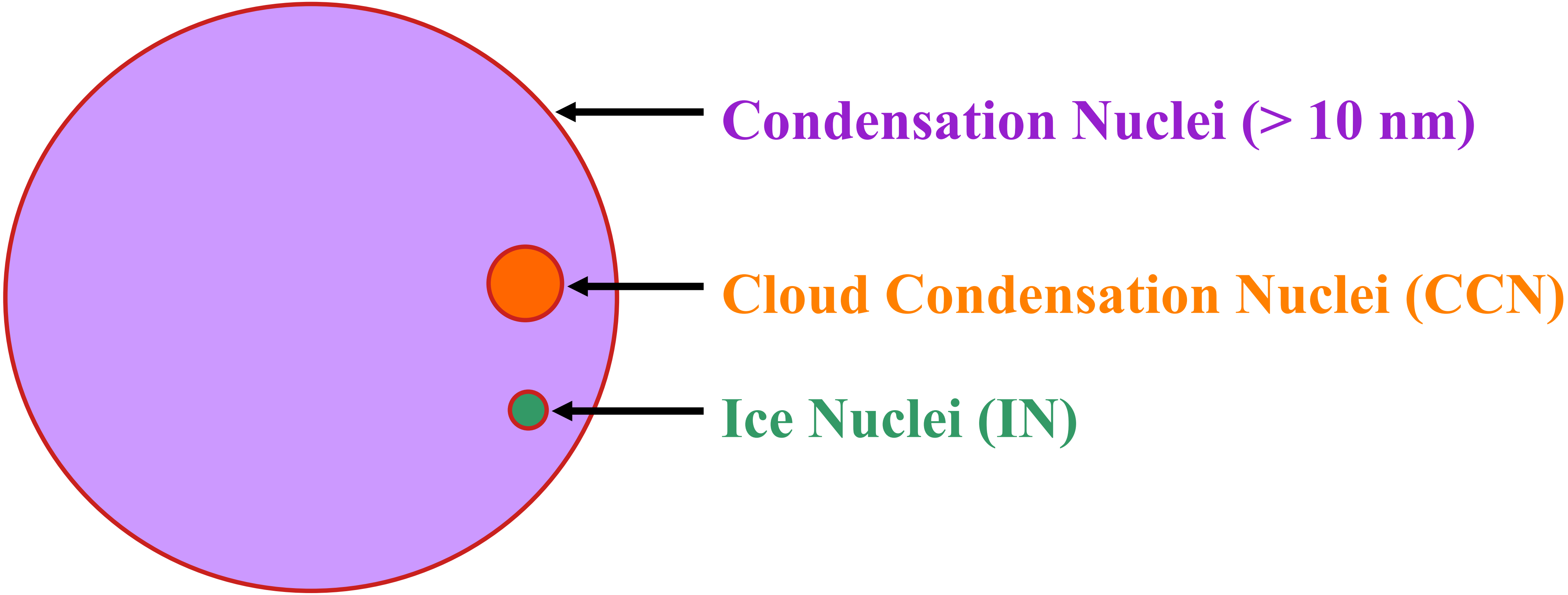
- **Nuclei on which cloud droplets form.**

Ice Nuclei (IN)

- **Nuclei on which ice crystals form.**

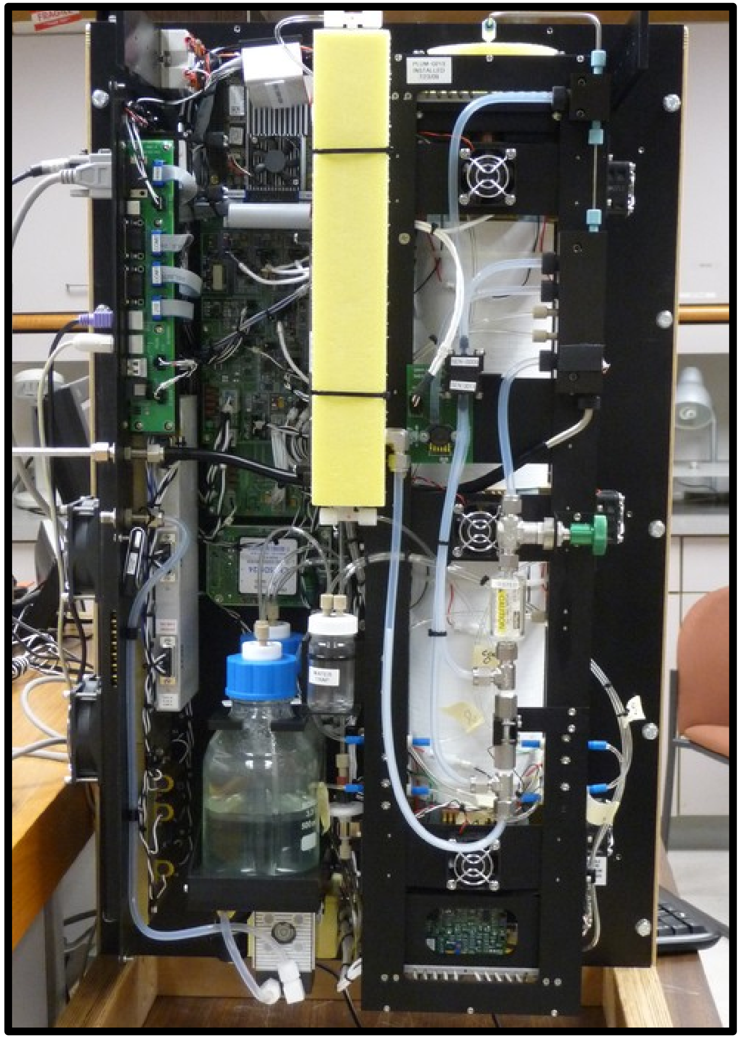


Relative Concentrations



Cloud Condensation Nuclei (CCN)

- CCN are hygroscopic substances.
- Larger aerosols are better CCN.
  - Examples:
    - Sodium Chloride (Sea Salt)
    - Ammonium Sulfate
    - Organic Materials.



Cloud Condensation Nuclei (CCN)

Location	CCN Concentration
Australian Cost	120 $\#/cm^{-3}$
North Atlantic Ocean	145-370 $\#/cm^{-3}$
High Planes, Montana	290 $\#/cm^{-3}$
Australia, Africa, USA	600 $\#/cm^{-3}$
High Planes, Montana	2000 $\#/cm^{-3}$
Buffalo, New York	3500 $\#/cm^{-3}$
Texas, USA	3000-5000 $\#/cm^{-3}$

Cloud Condensation Nuclei (CCN) concentrations at 1% Supersaturation measured at various locations.

Source: Pruppacher, H. R., and J. D. Klett, Microphysics of Clouds and Precipitation, pp. 287-289, Kluwer Acad. Norwell, Mass., 1997.

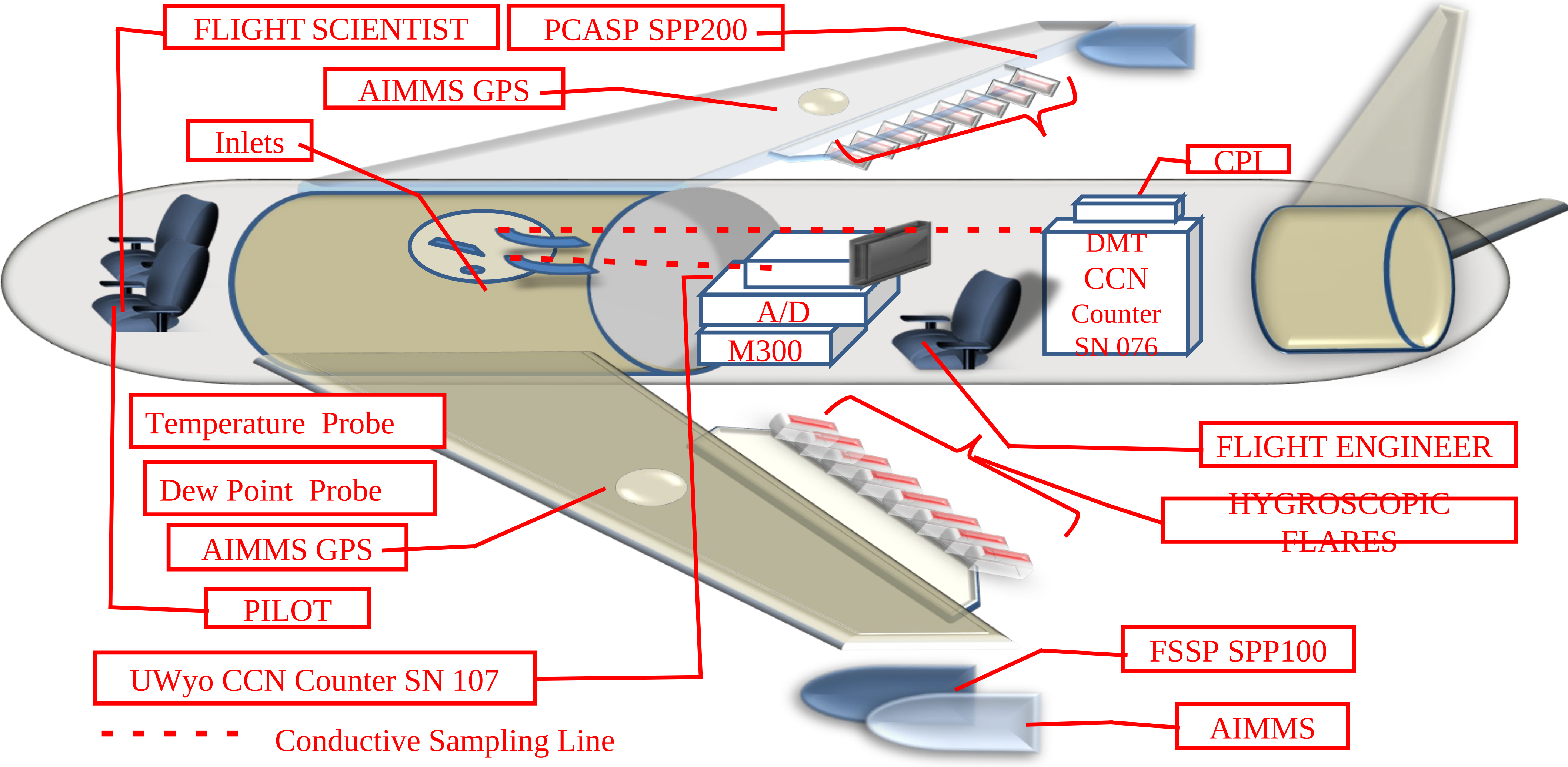
Uwyo Balloon-borne CCN Counter

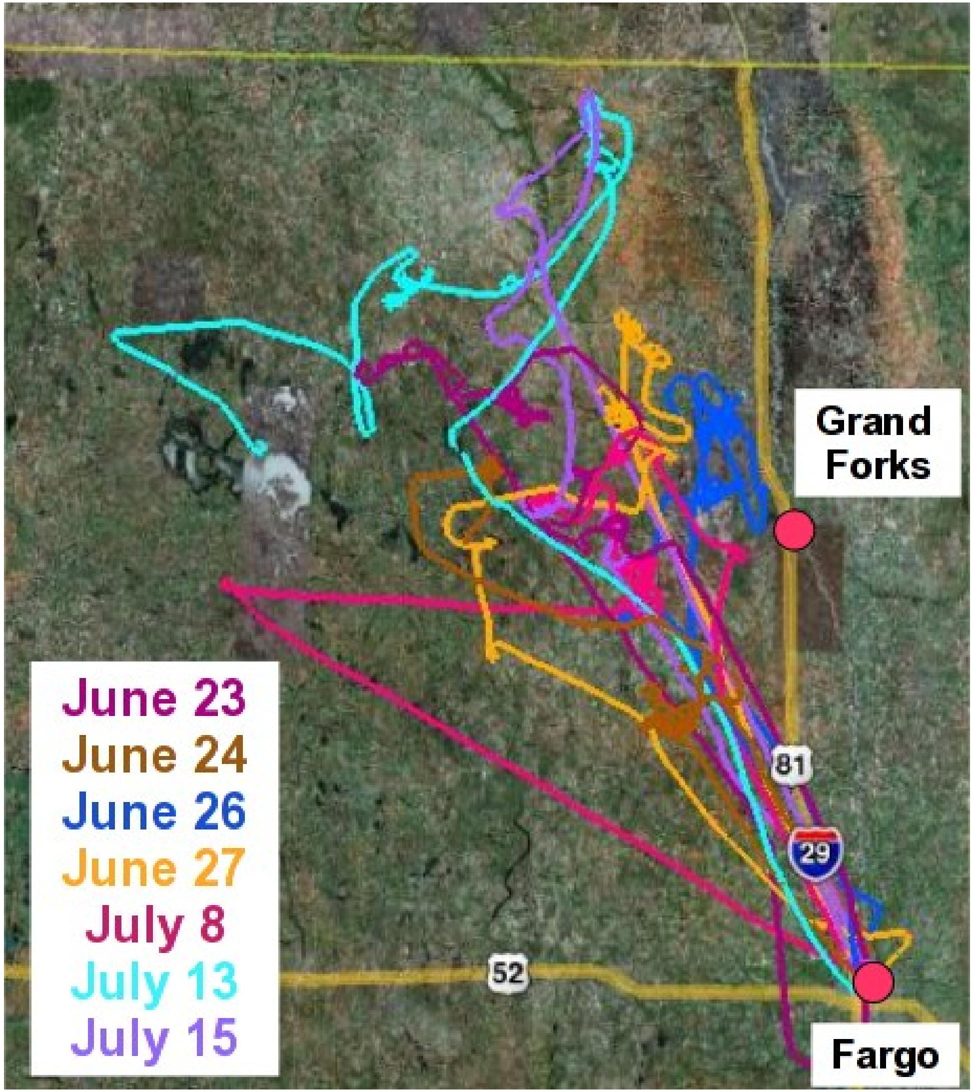
Location	Time of Year	CCN Concentration
Wyoming, USA	Winter	146 ± 20 #/cm^{-3}
Wyoming, USA	Summer	445 ± 157 #/cm^{-3}
New Zealand	Summer	964 ± 17 #/cm^{-3}
Bamako, Mali	09/08/07	367 ± 247 #/cm^{-3}

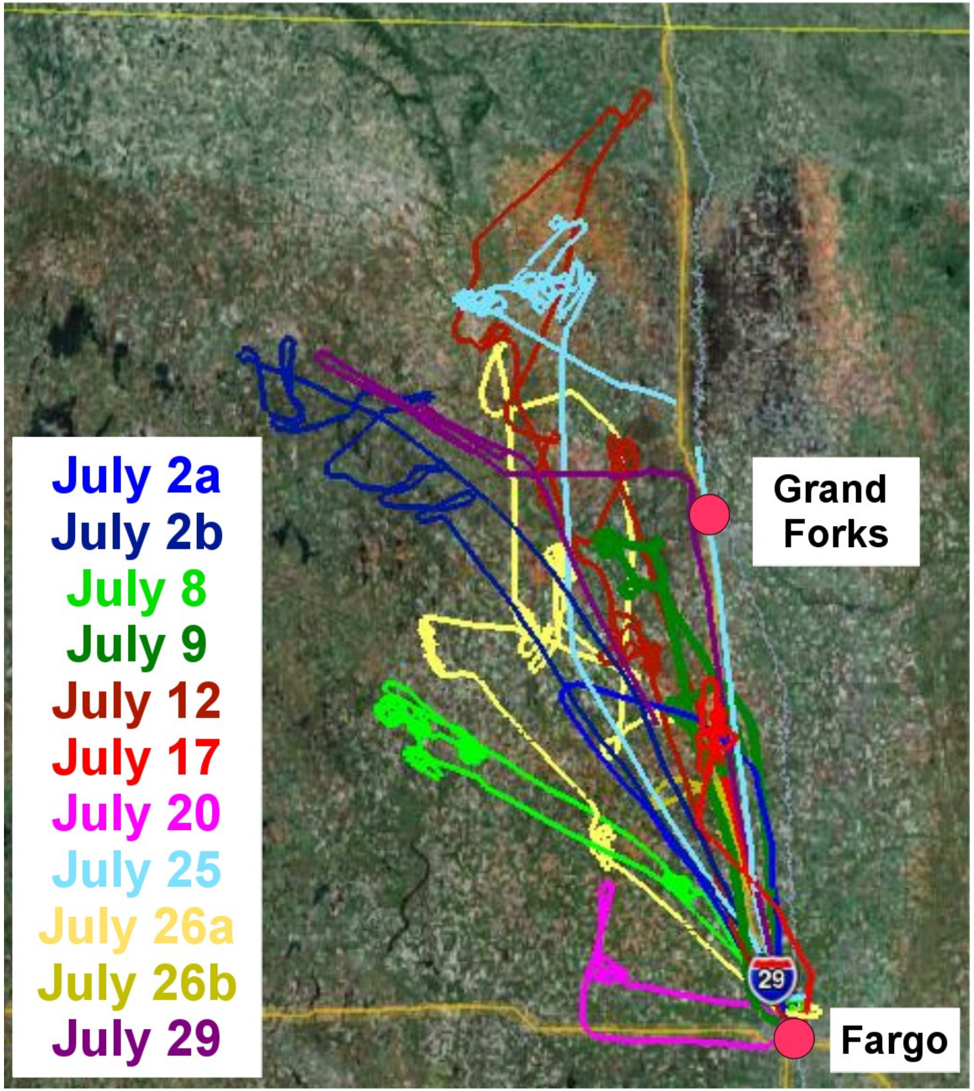
Cloud Condensation Nuclei (CCN) concentrations at 1% supersaturation measured by the University of Wyoming CCN counter in the lower troposphere at various locations.

Source: Delene, D. J. and T. Deshler, Vertical profiles of cloud condensation nuclei above Wyoming, Journal of Geophysical Research - Atmospheres , 106, 12579-12588, 2001.

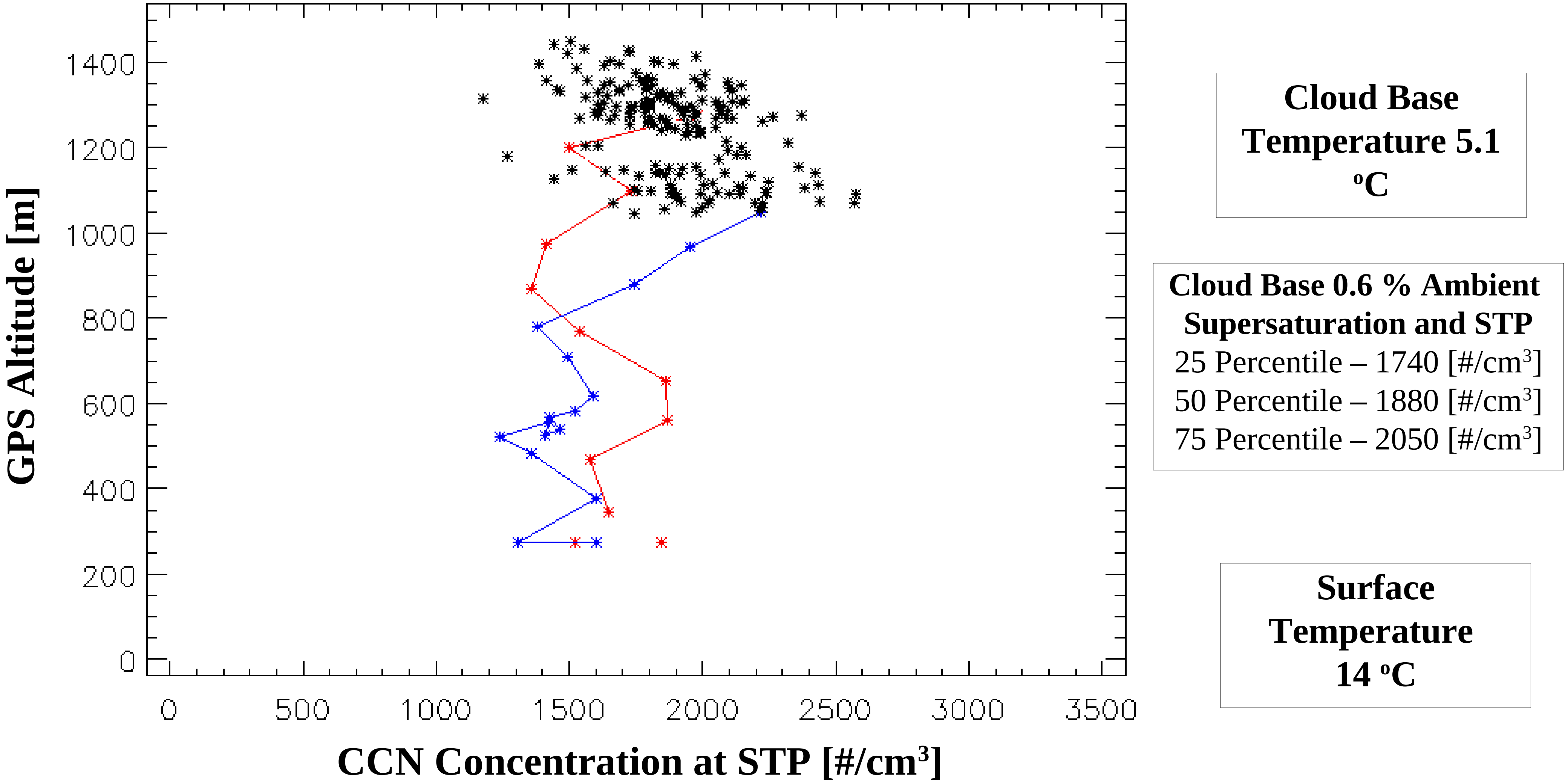
POLCAST4 Cessna340 N98585 Instruments





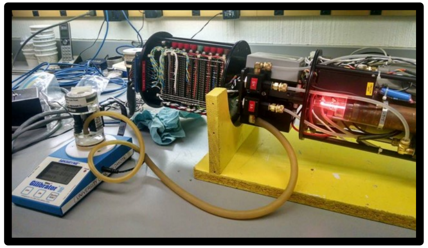


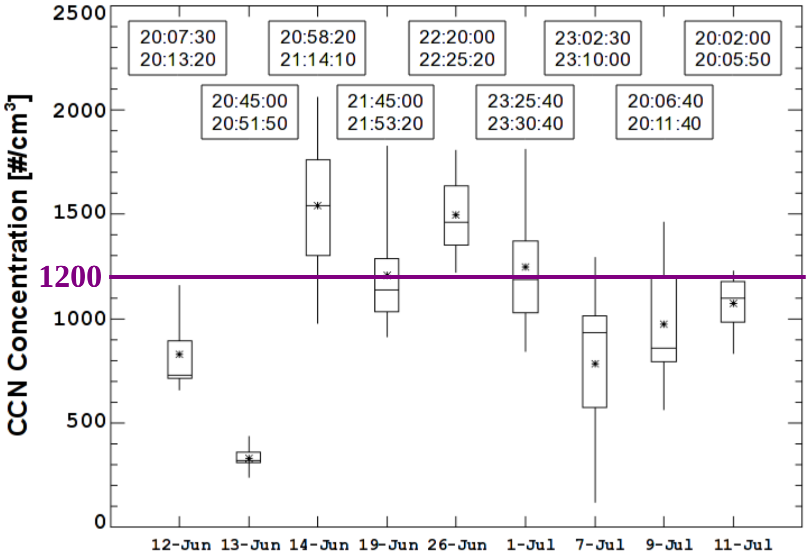
Flight paths during the 2010 POLCAST3 (left) and 2012 POLCAST 4 (right) projects.

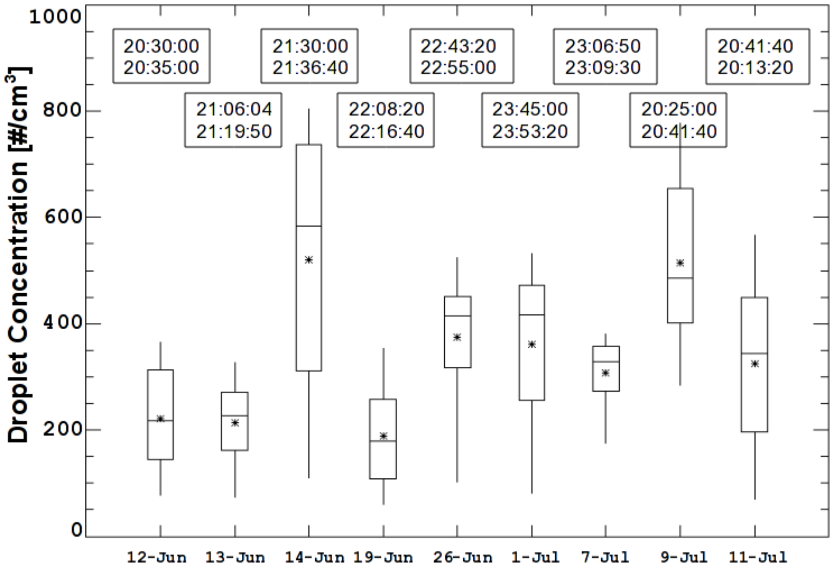


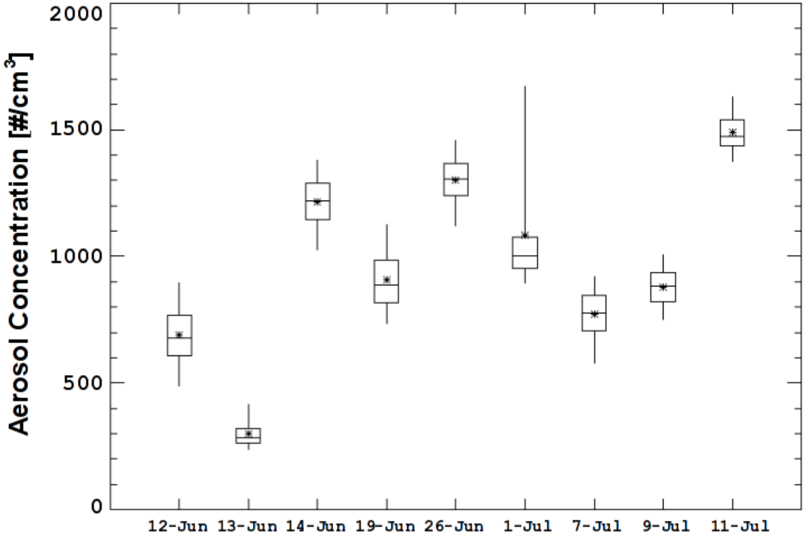
University of Wyoming cloud condensation nuclei (CCN) counter measurements (0.6 % ambient supersaturation) adjusted to standard pressure and temperature (STP) on aircraft ascent (red, 17:40:00-17:45:00 UTC), during July 8 2012 cloud base sampling (black stars, 18:04:00-19:36:10) and during descent (blue, 19:36:20-19:56:40).

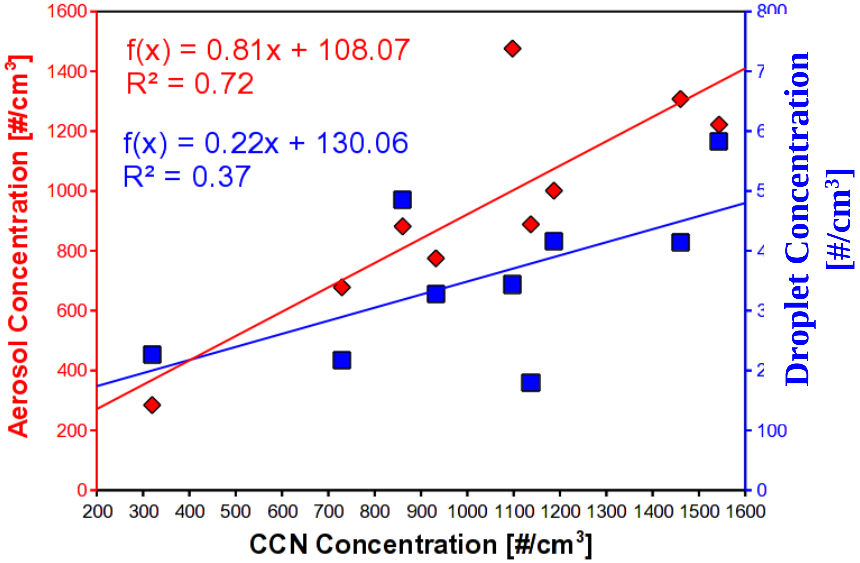

CLOUD CONDENSATION NUCLEUS COUNTER
CCNC-100B




CCN Concentration [#/cm^3]
1200
20:07:30 20:13:20
20:45:00 20:51:50
20:58:20 21:14:10
21:45:00 21:53:20
22:20:00 22:25:20
23:25:40 23:30:40
23:02:30 23:10:00
20:06:40 20:11:40
20:02:00 20:05:50
0
500
1000
1500
2000
2500
12-Jun 13-Jun 14-Jun 19-Jun 26-Jun 1-Jul 7-Jul 9-Jul 11-Jul


Droplet Concentration [#/cm^3]
20:30:00 20:35:00
21:06:04 21:19:50
21:30:00 21:36:40
22:08:20 22:16:40
22:43:20 22:55:00
23:45:00 23:53:20
23:06:50 23:09:30
20:25:00 20:41:40
20:41:40 20:13:20
0
200
400
600
800
1000
12-Jun 13-Jun 14-Jun 19-Jun 26-Jun 1-Jul 7-Jul 9-Jul 11-Jul


Aerosol Concentration [#/cm^3]
0
500
1000
1500
2000
12-Jun 13-Jun 14-Jun 19-Jun 26-Jun 1-Jul 7-Jul 9-Jul 11-Jul


f(x) = 0.81x + 108.07
R² = 0.72
f(x) = 0.22x + 130.06
R² = 0.37
Aerosol Concentration [#/cm^3]
Droplet Concentration [#/cm^3]
CCN Concentration [#/cm^3]
200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600

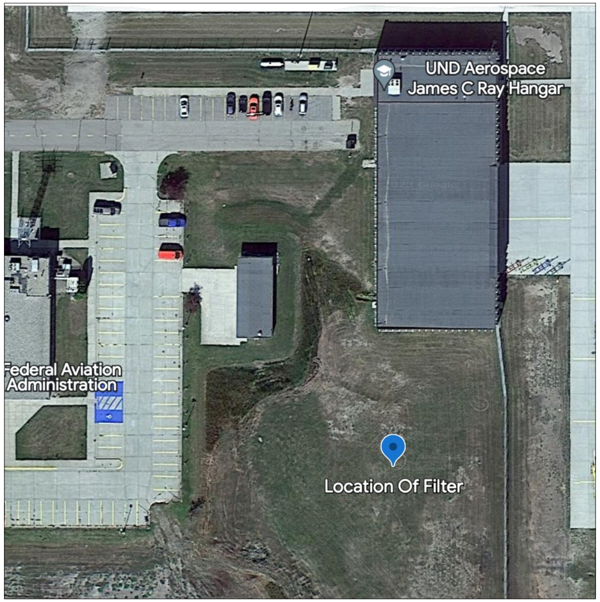
Lead Aerosols from Aviation Fuel

Tetra-ethyl-Lead (TEL) **Lead Oxide** **Ethylene Dibromide** **Lead (II) Bromide**

- As LL100 fuel burns, TEL naturally degrades to lead oxide which increases the octane rating.
- Deposits are formed due to lead oxides high melting point; these deposits are electrically conductive and is corrosive.
- To prevent deposits forming, ethylene dibromide is used to react with lead oxide to form lead bromide which is a gas at lower temperature to ensure that lead will be fully exhausted.

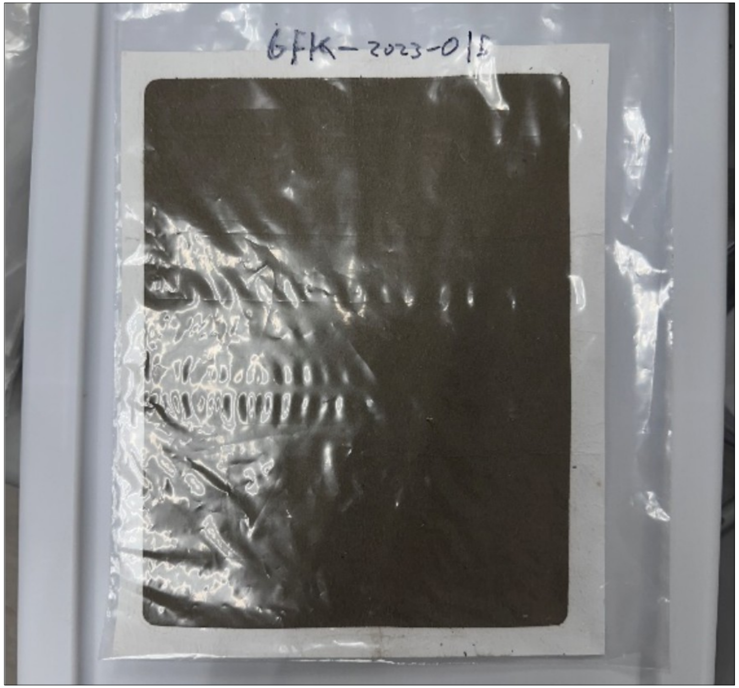
Lead Aerosols Transport

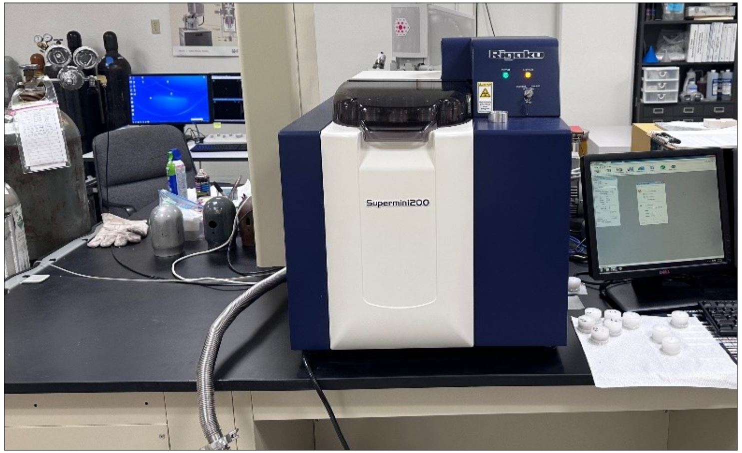
- Exhausted gas cools to the solid phase in the atmosphere where the lead exists/evolves into different leaded compounds and ions.
- Leaded compounds travel long distances in the air before going into the soil and possibly groundwater.
- Exposure to lead causes disruption of tightly regulated processes due to lead stronger a binding affinity compared to other metal ions (Ca^{2+}, Mg, Zn, Fe, et…), which are known to be involved within biological systems.



Lead Aerosols Sampling

- UND Aerospace general aviation airport was chosen for the location of high-volume sampler. Daily and weekly samples were collected.
- 8” x 10” glass fiber filter daily and weekly samples were collected. Glass fiber samples were pre and post weighed. X-Ray Fluorescence (XRF) was used to analyze the elemental composition of each filter sample.





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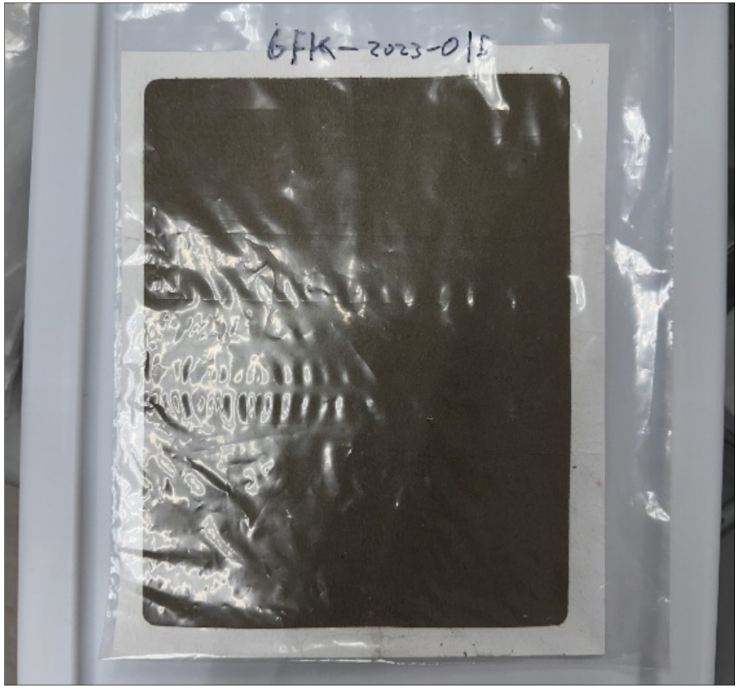
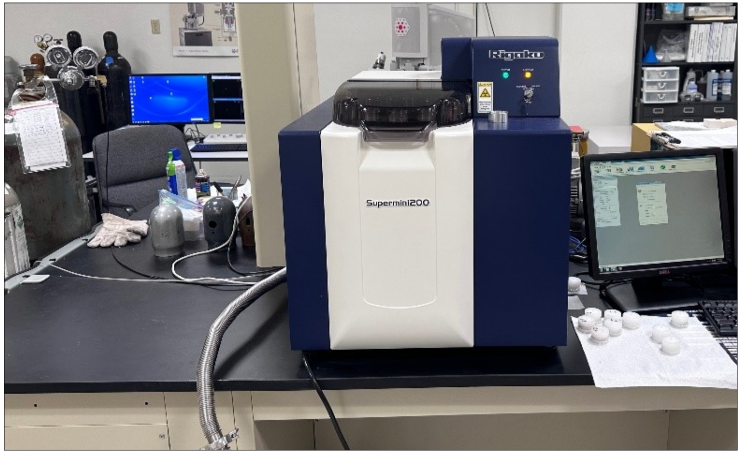
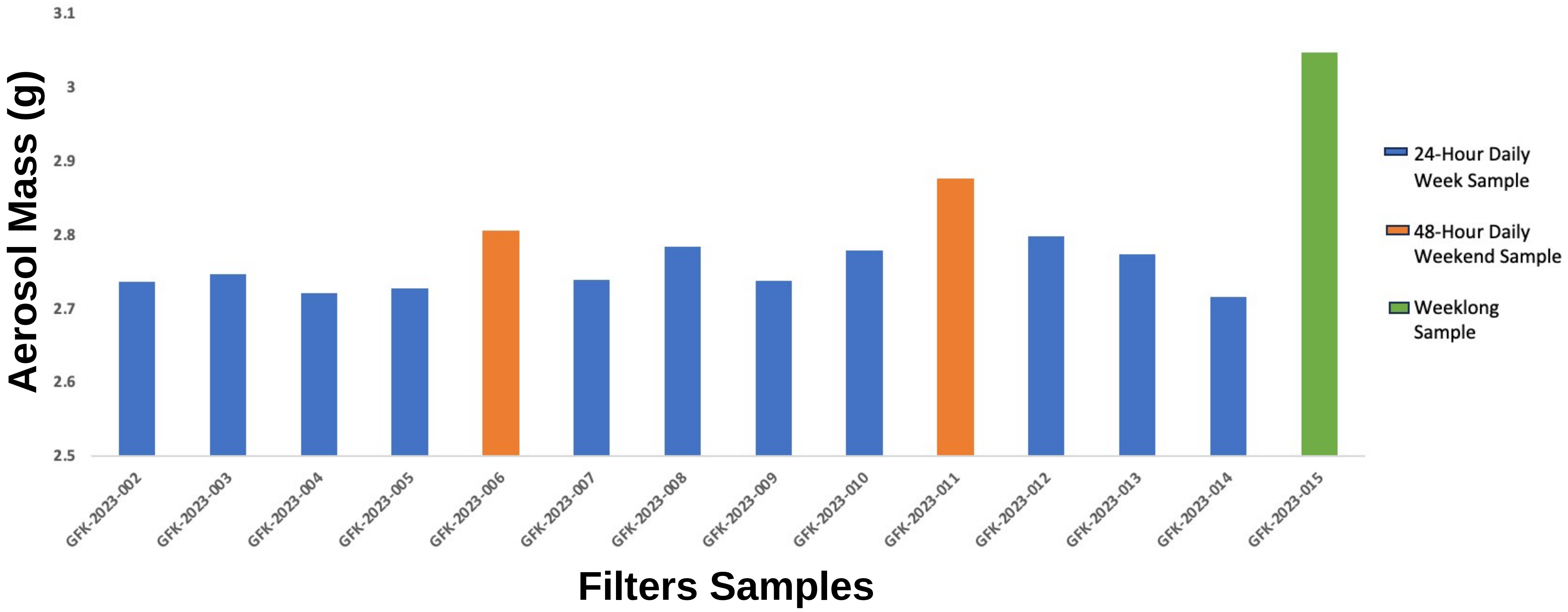
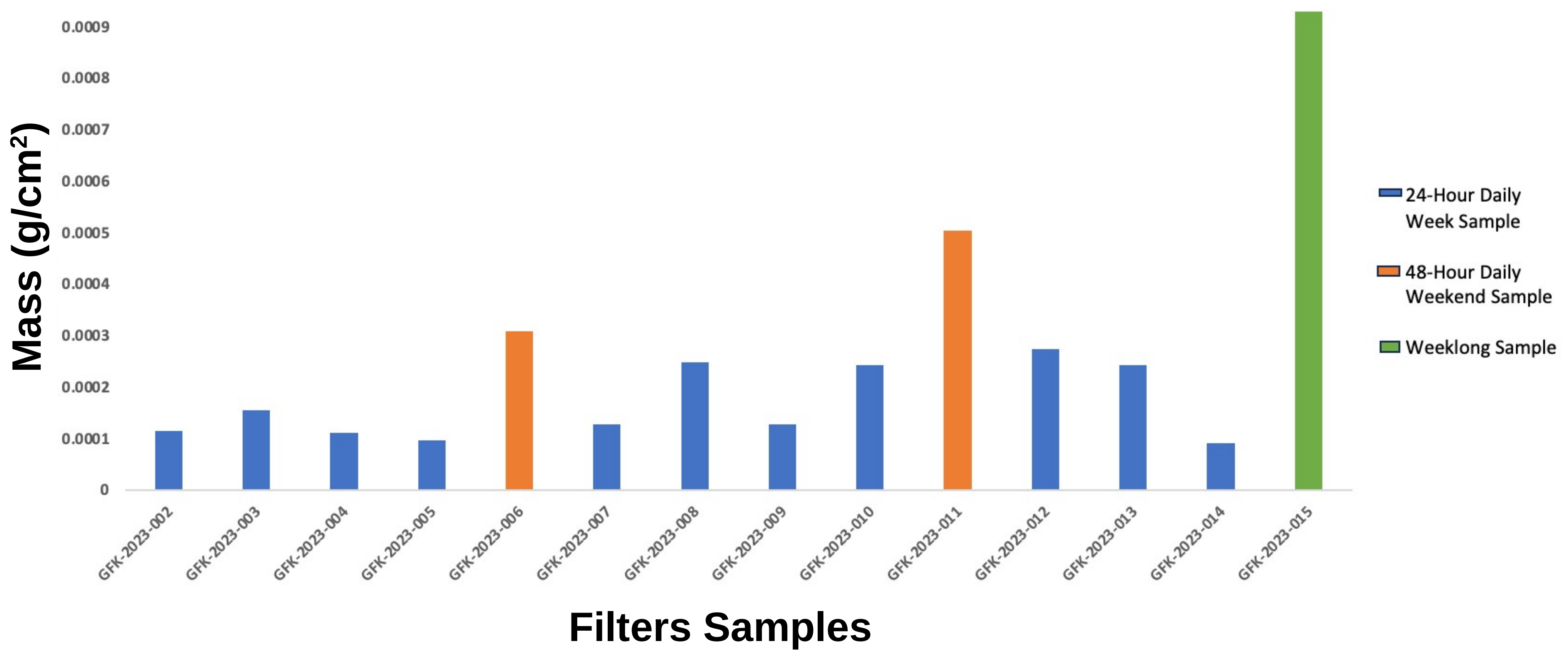




Collected Aerosol Mass on Particle Filter



Aerosol Mass on Particle Filter



Lead Aerosols GFK Conclusions

- Detected lead on daily samples, but detection issues.
- Based off results and discussion with XRF manufacture. Lead sulfide experiment was performed to determine if XRF was effective in detecting lead. Test was successful.
- Based off low concentrations of lead in daily airport samples and lead sulfide experiment. Decided to start running week-long samples beginning on the transition period (June 23rd).

Conclusions

Cloud Condensation Nuclei are a very important but difficult measurement.

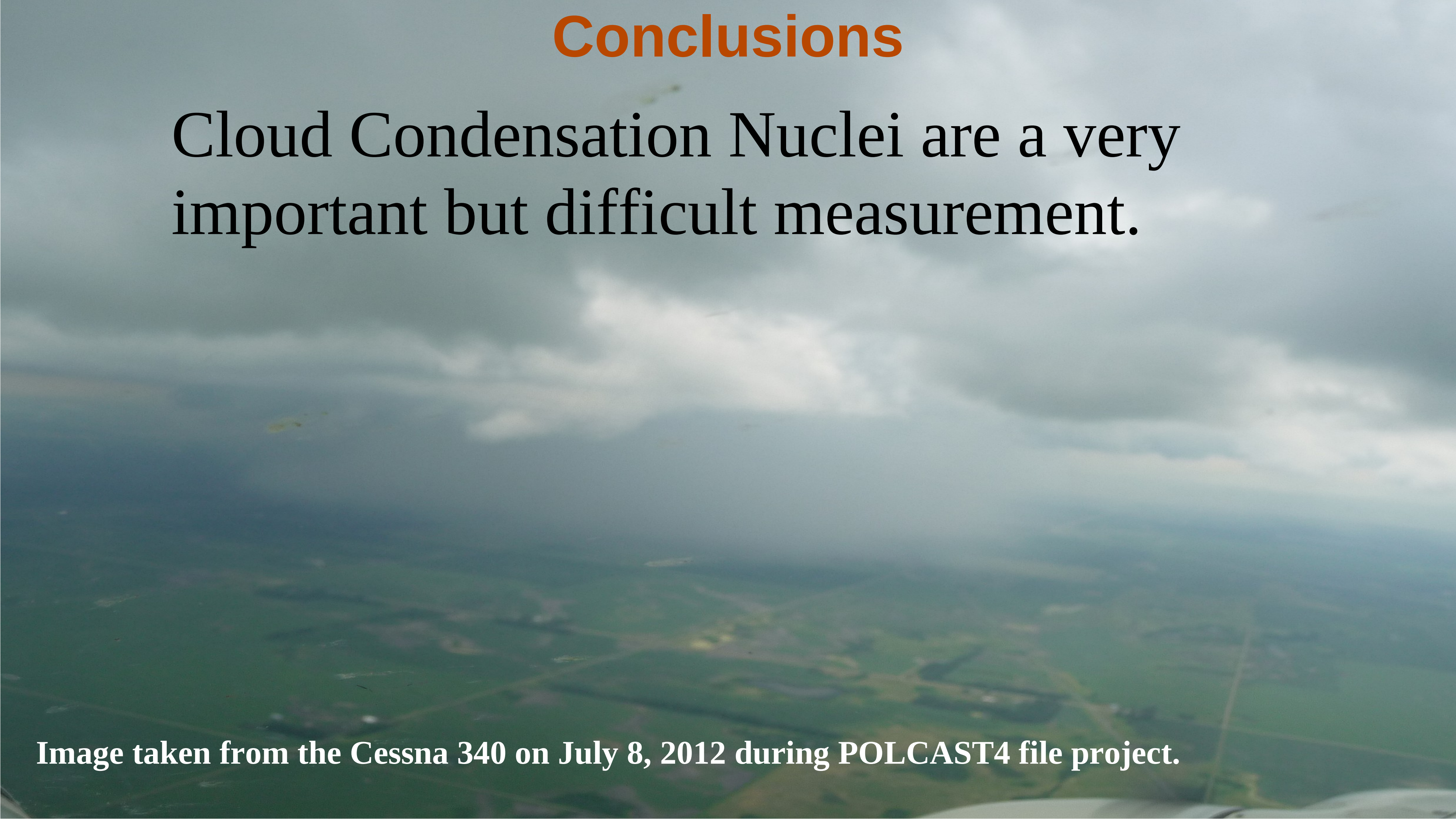


Image taken from the Cessna 340 on July 8, 2012 during POLCAST4 file project.