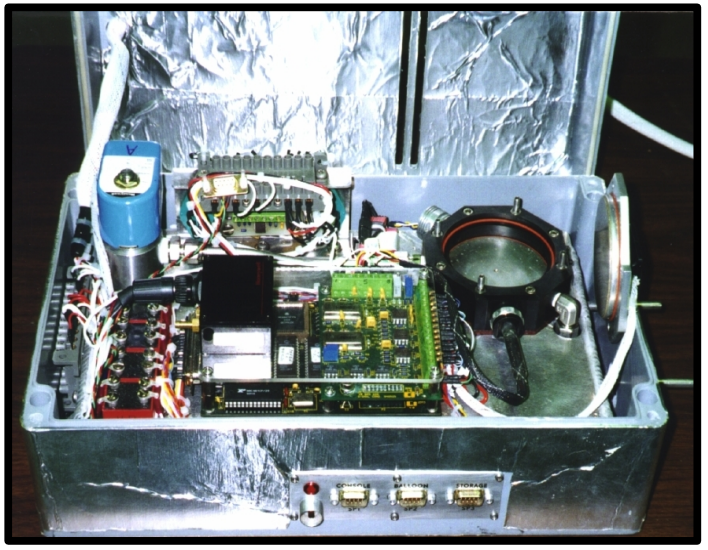
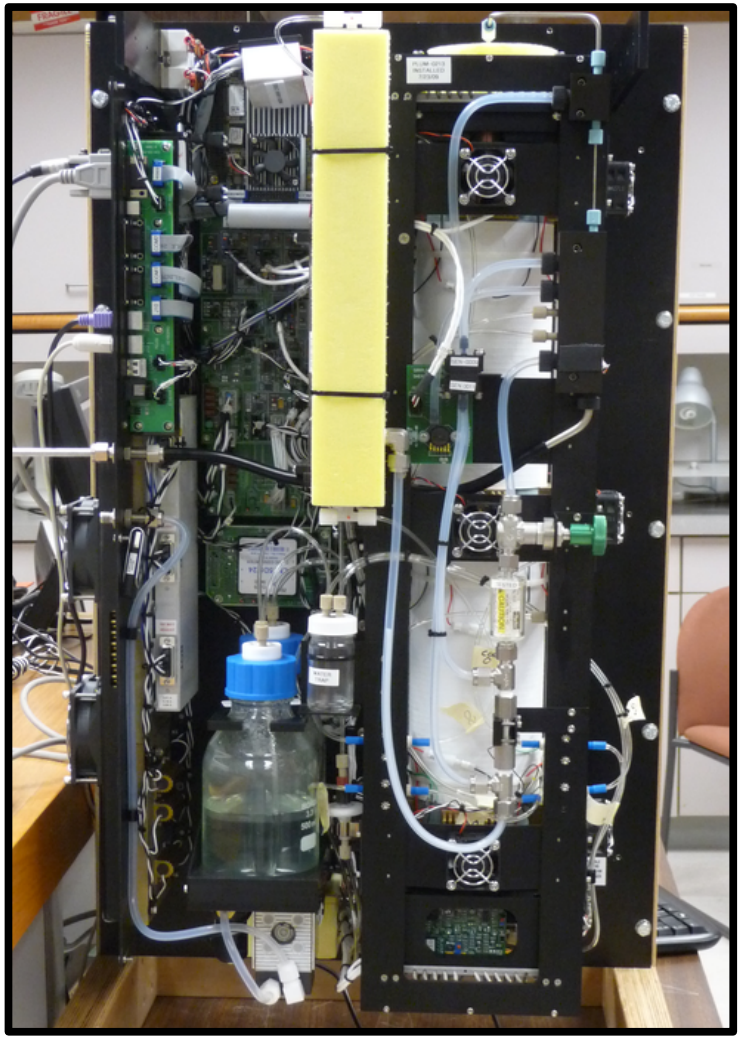
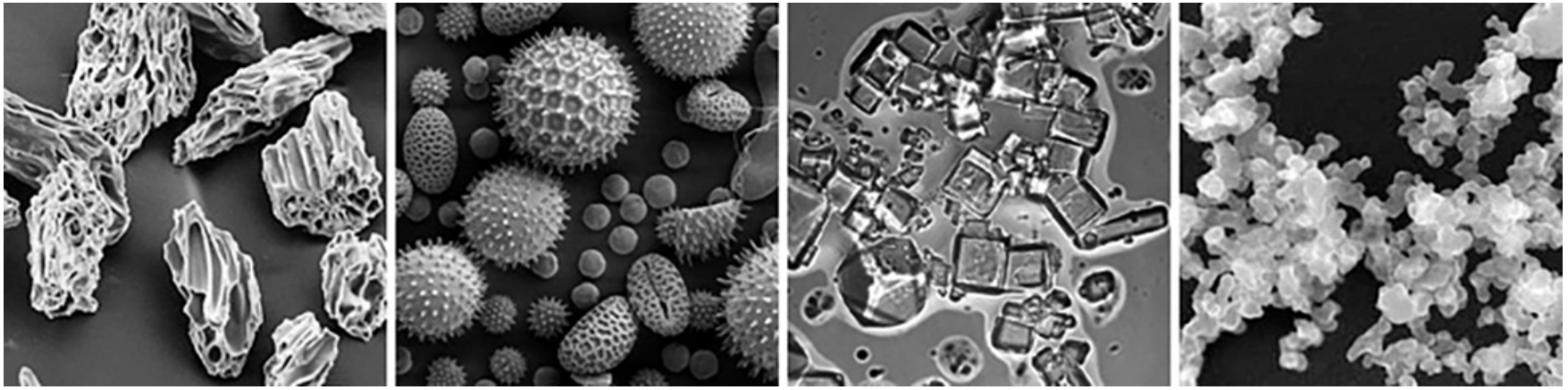
Atmospheric Aerosols and Particle Nucleation





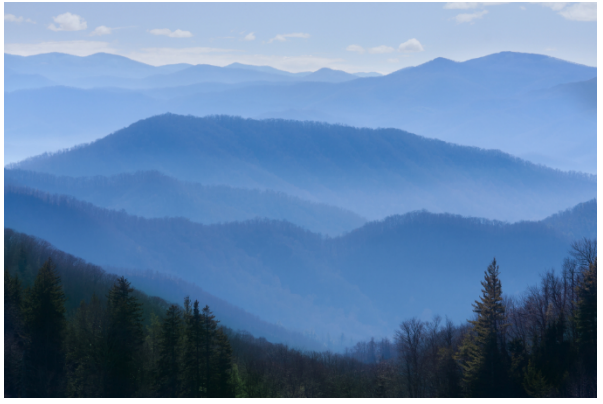
What are Aerosols?

- 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)

How do we know when present in the air?



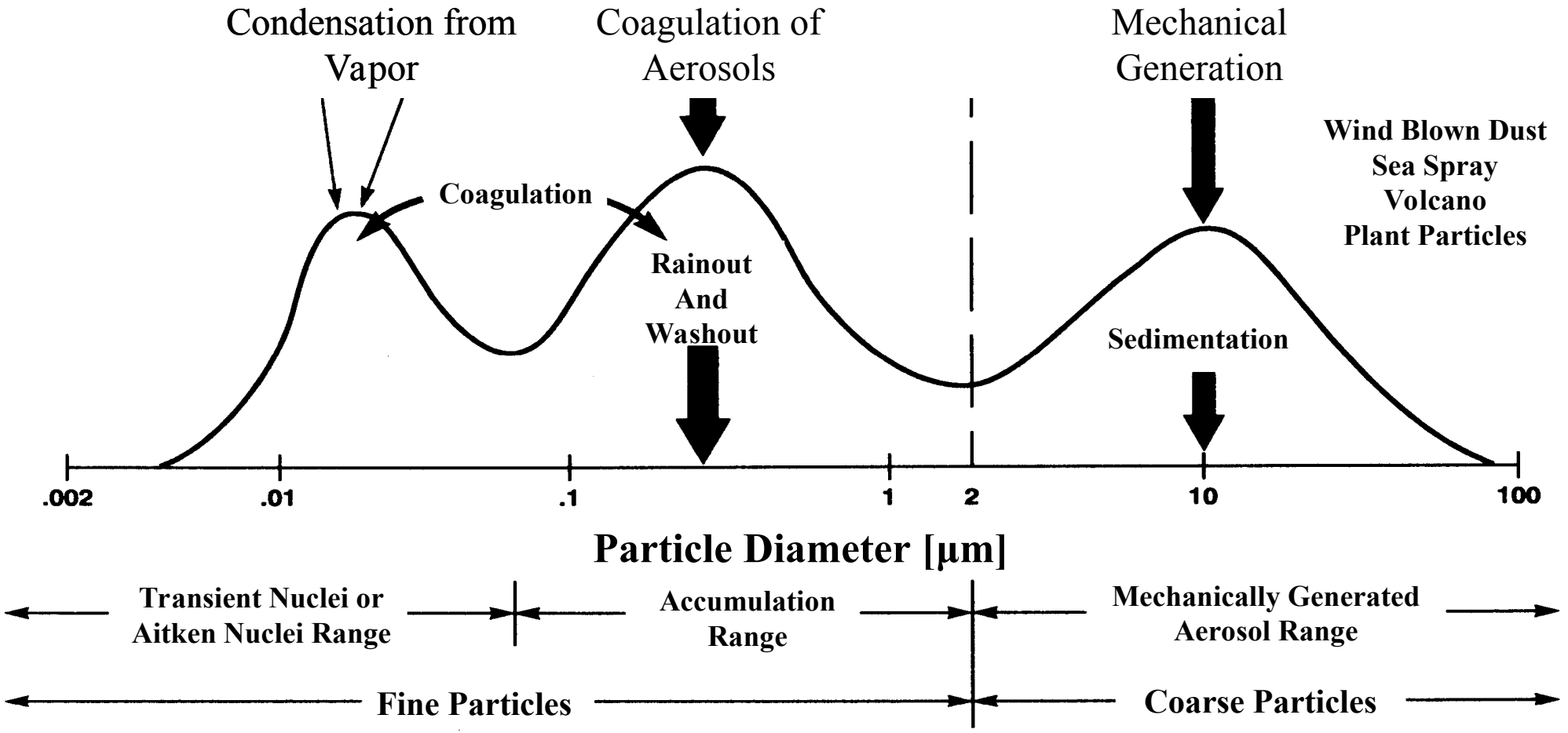
Clouds in the Atmosphere

- 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

Sizes of Particles

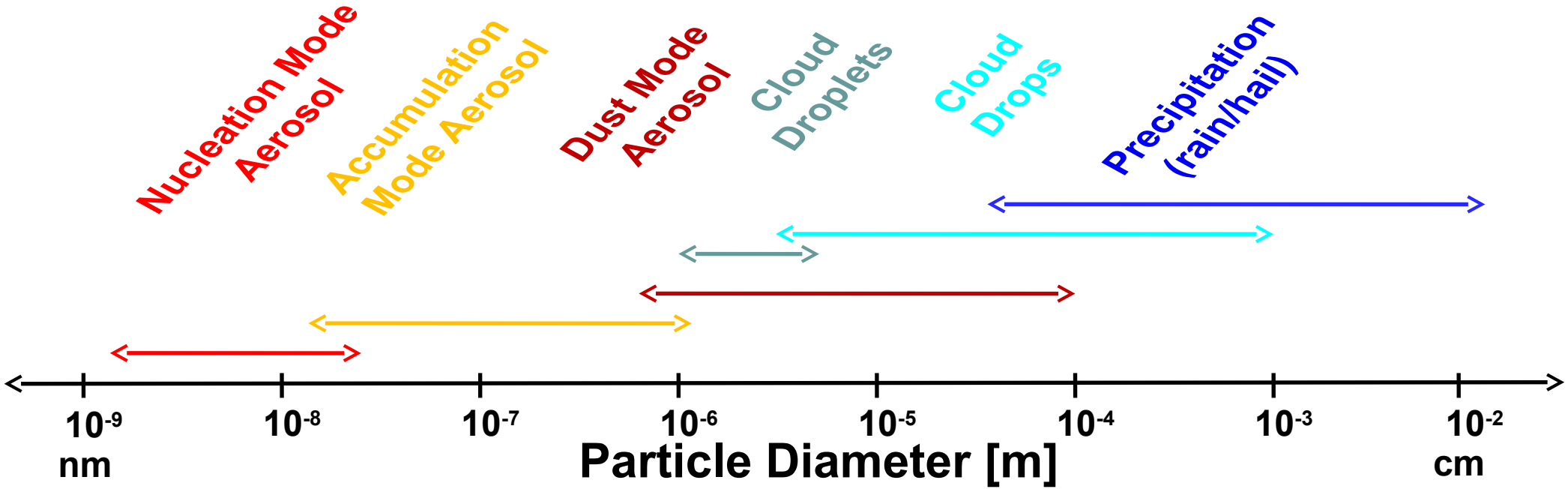


Adapted from Singh: Figure 5.4

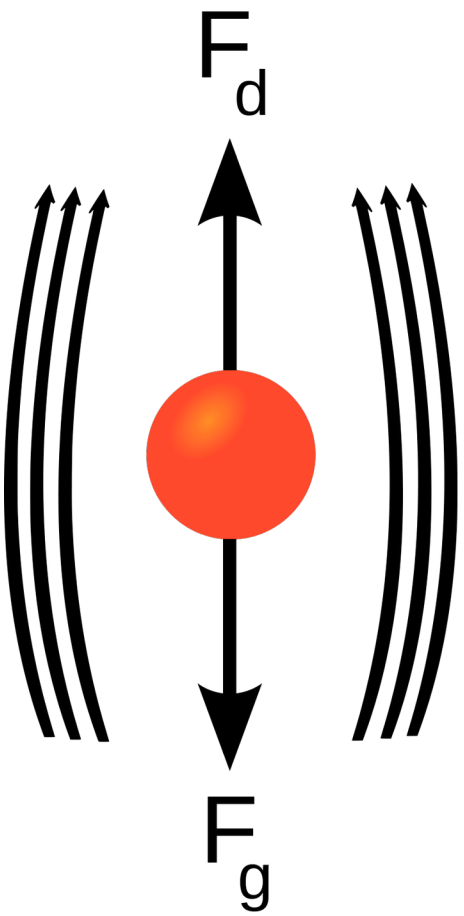
Atmospheric Particle Background

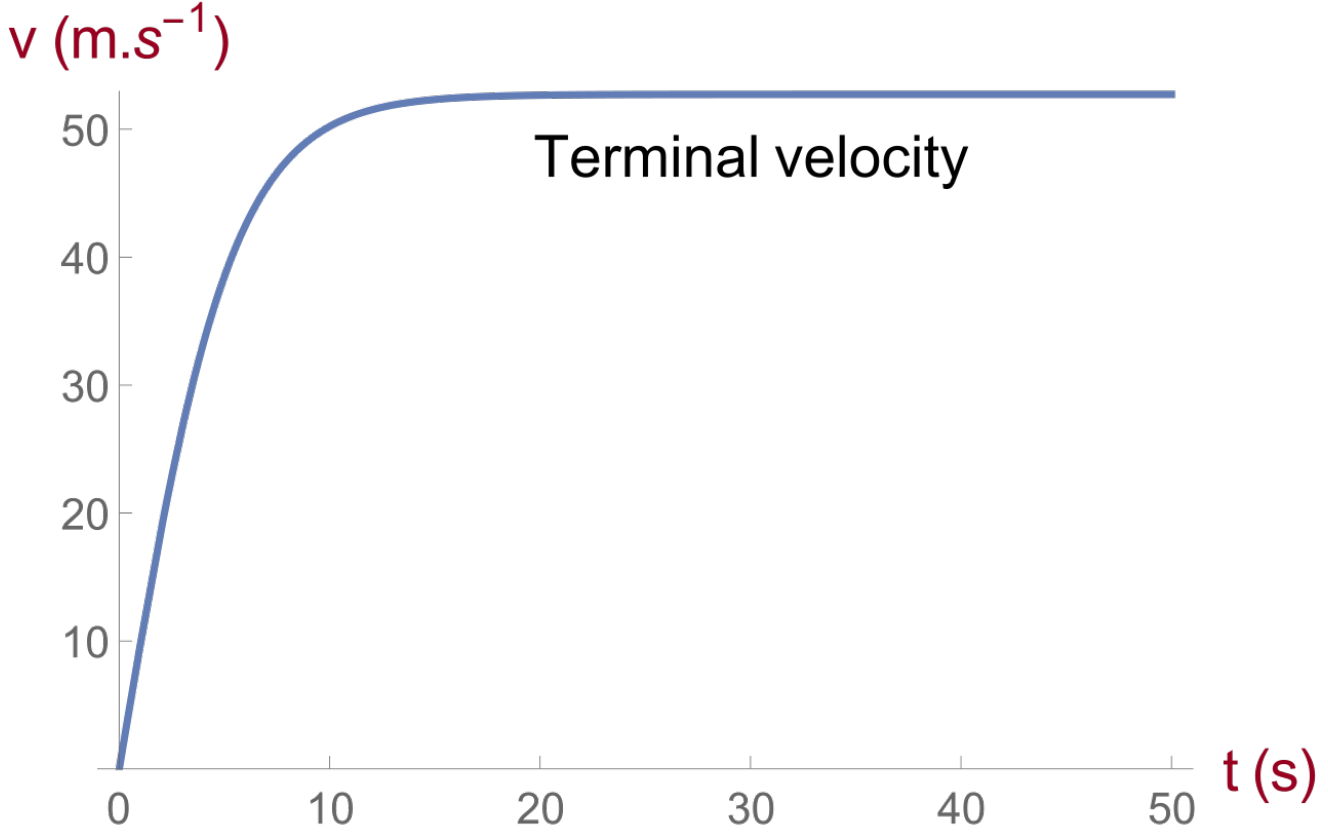
Atmosphere contains particles of all sizes.

- 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.



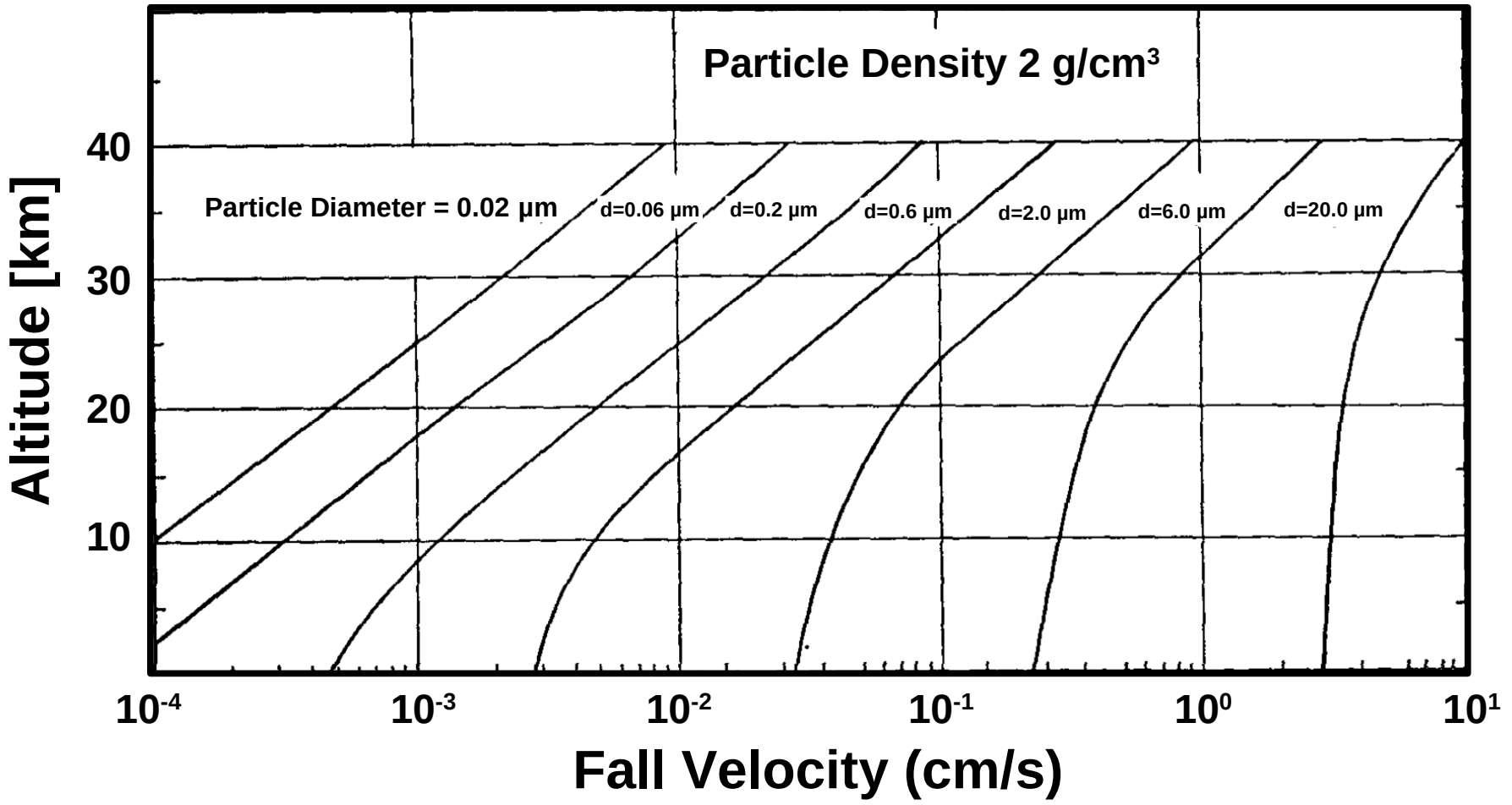
Terminal Velocity (Gravity = Drag Force)





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 ($D_{0.3}$)

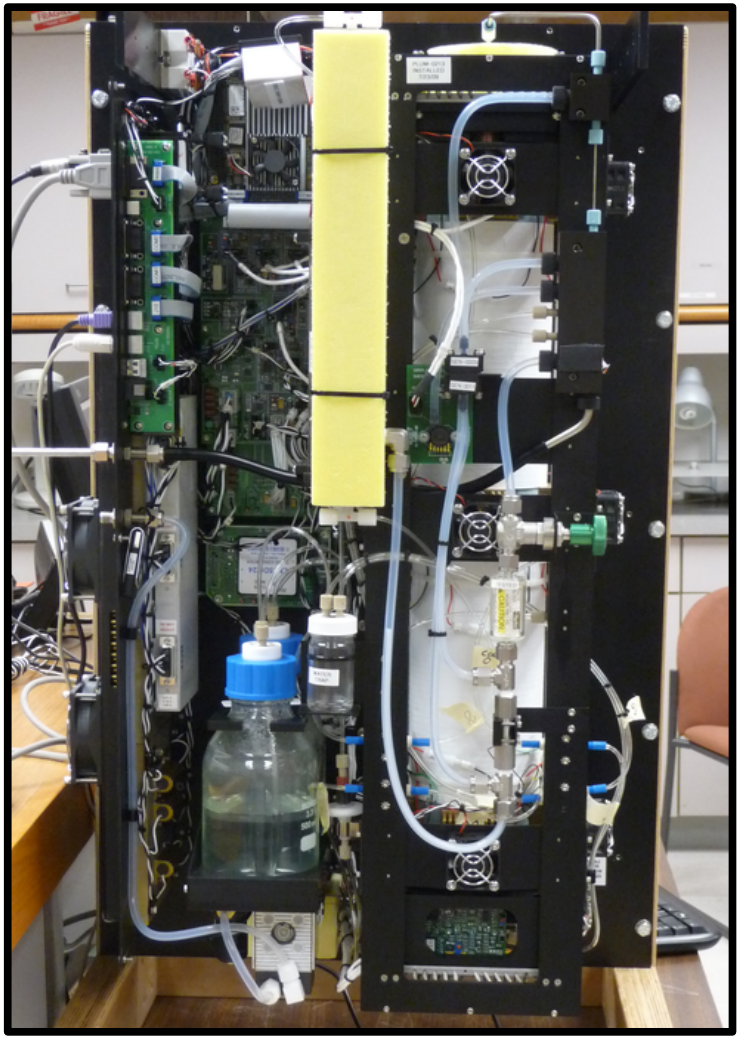
- **Aerosols larger than 0.3 µm diameter.**

Cloud Condensation Nuclei (CCN)

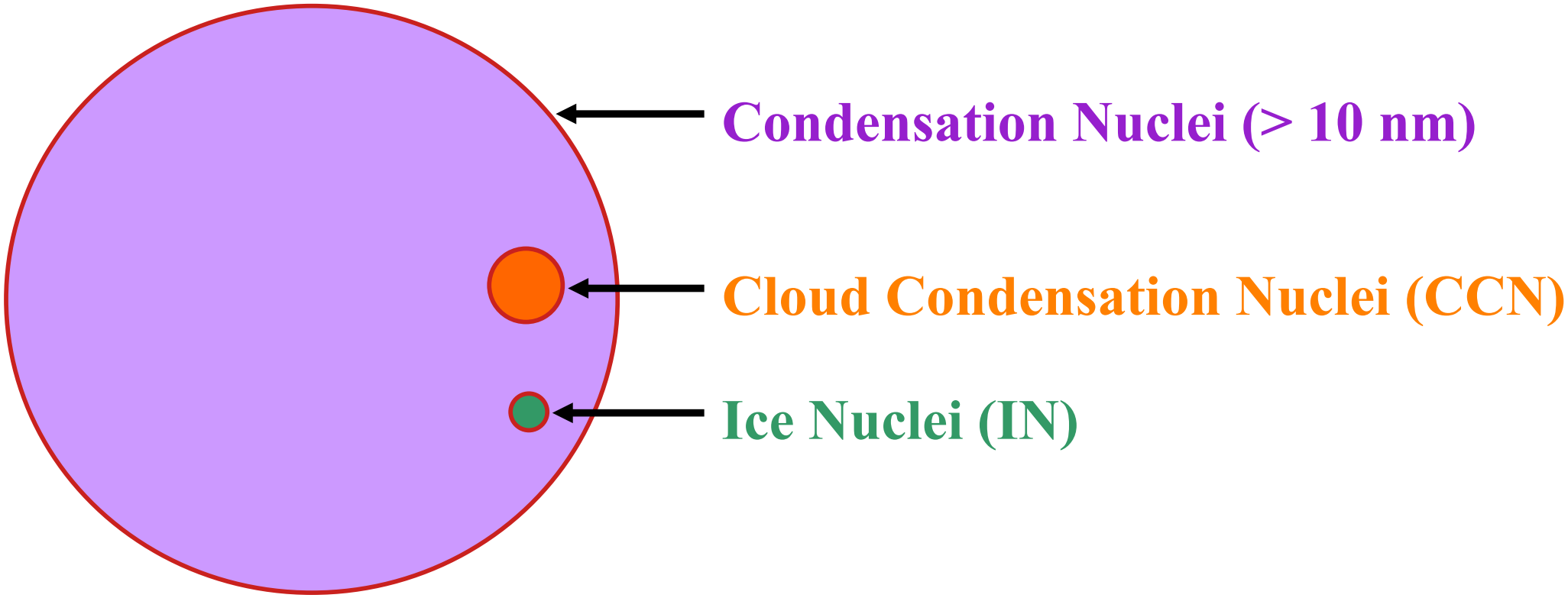
- **Nuclei on which cloud droplets form.**

Ice Nuclei (IN)

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



Relative Concentrations



Cloud Condensation Nuclei (CCN)

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.

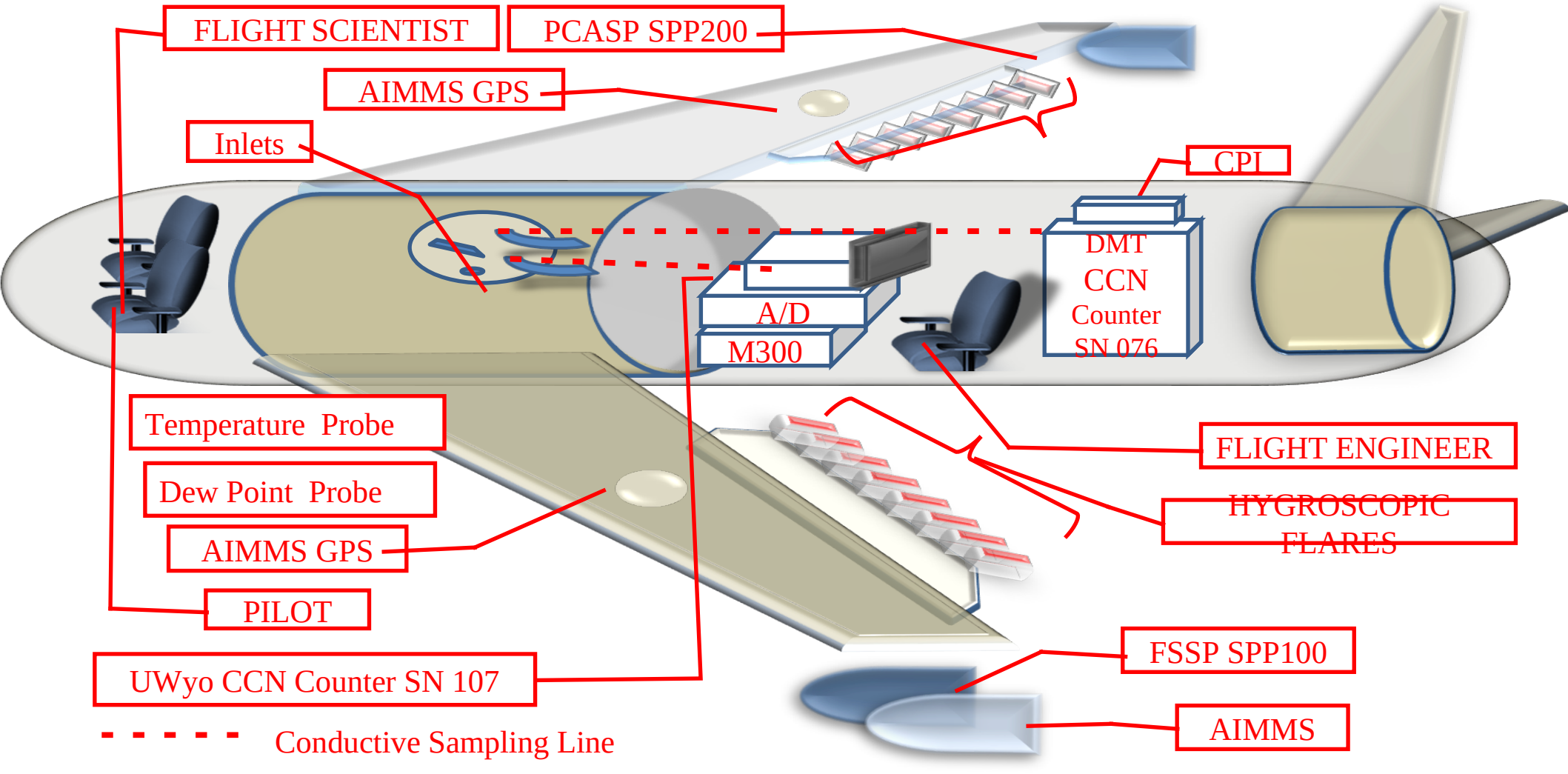
Uwyo Balloon-borne CCN Counter

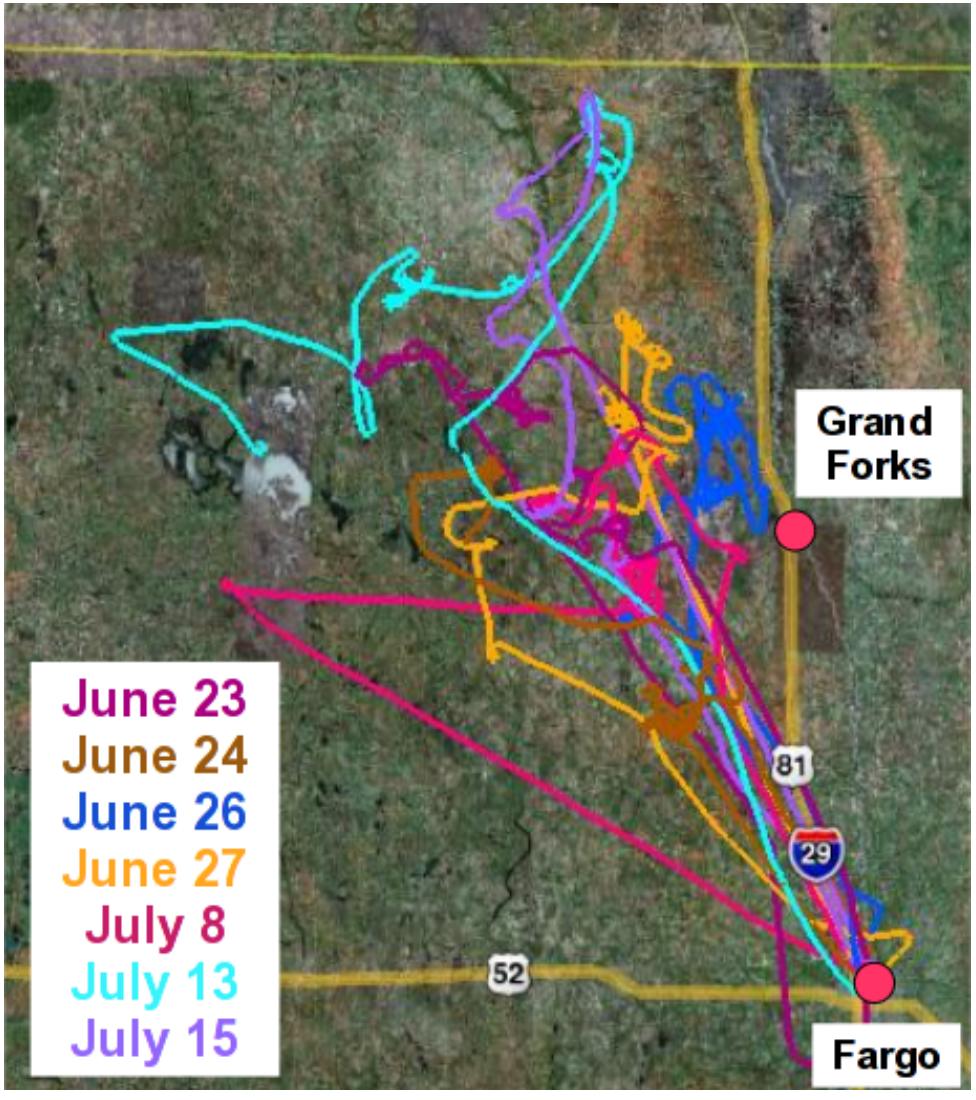
Location	Time of Year	CCN Concentration
Wyoming, USA	Winter	146 ± 20 #/cm^{-3}
Wyoming, USA	Summer	445 ± 157 #/cm^{-3}
New Zealand	Summer	964 ± 17 #/cm^{-3}
Bamako, Mali	09/08/07	367 ± 247 #/cm^{-3}

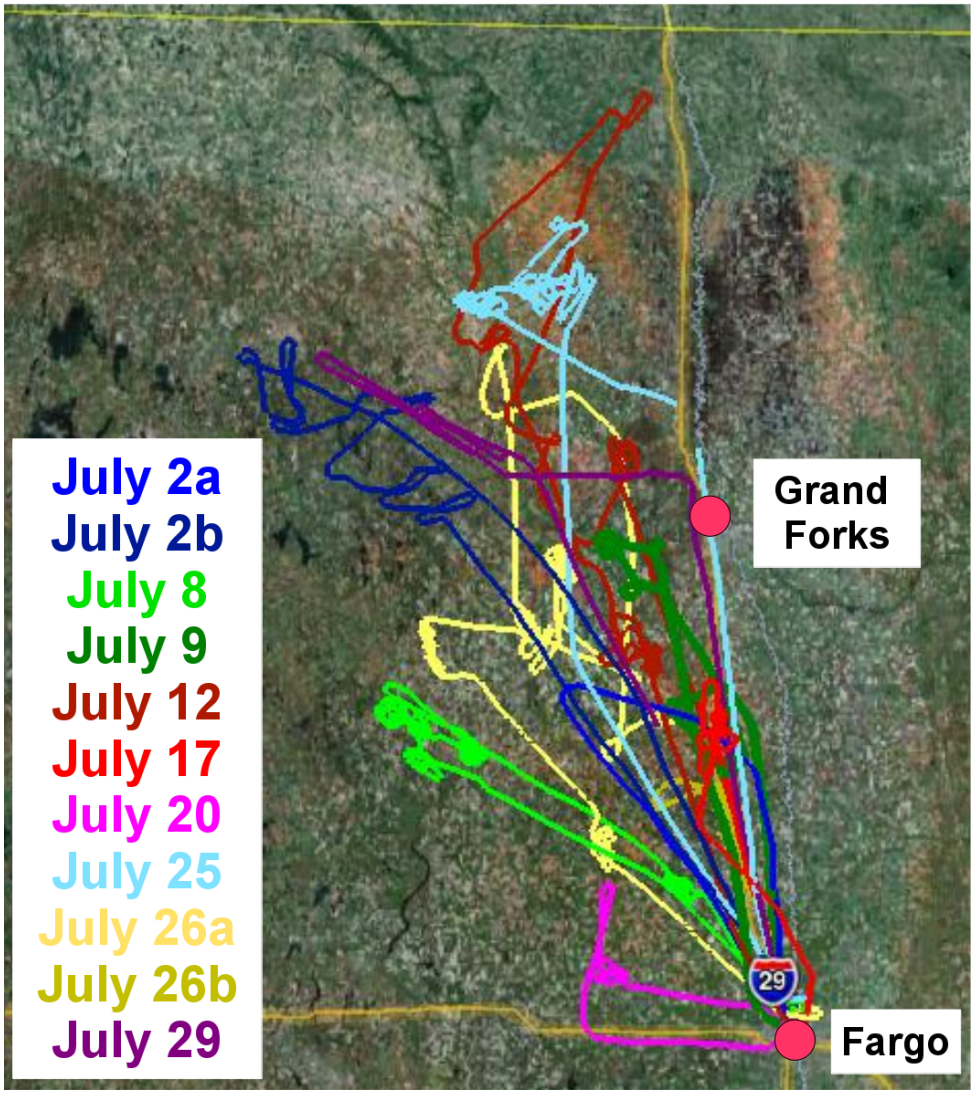
Cloud Condensation Nuclei (CCN) concentrations at 1% supersaturation measured by the University of Wyoming CCN counter in the lower troposphere at various locations.

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

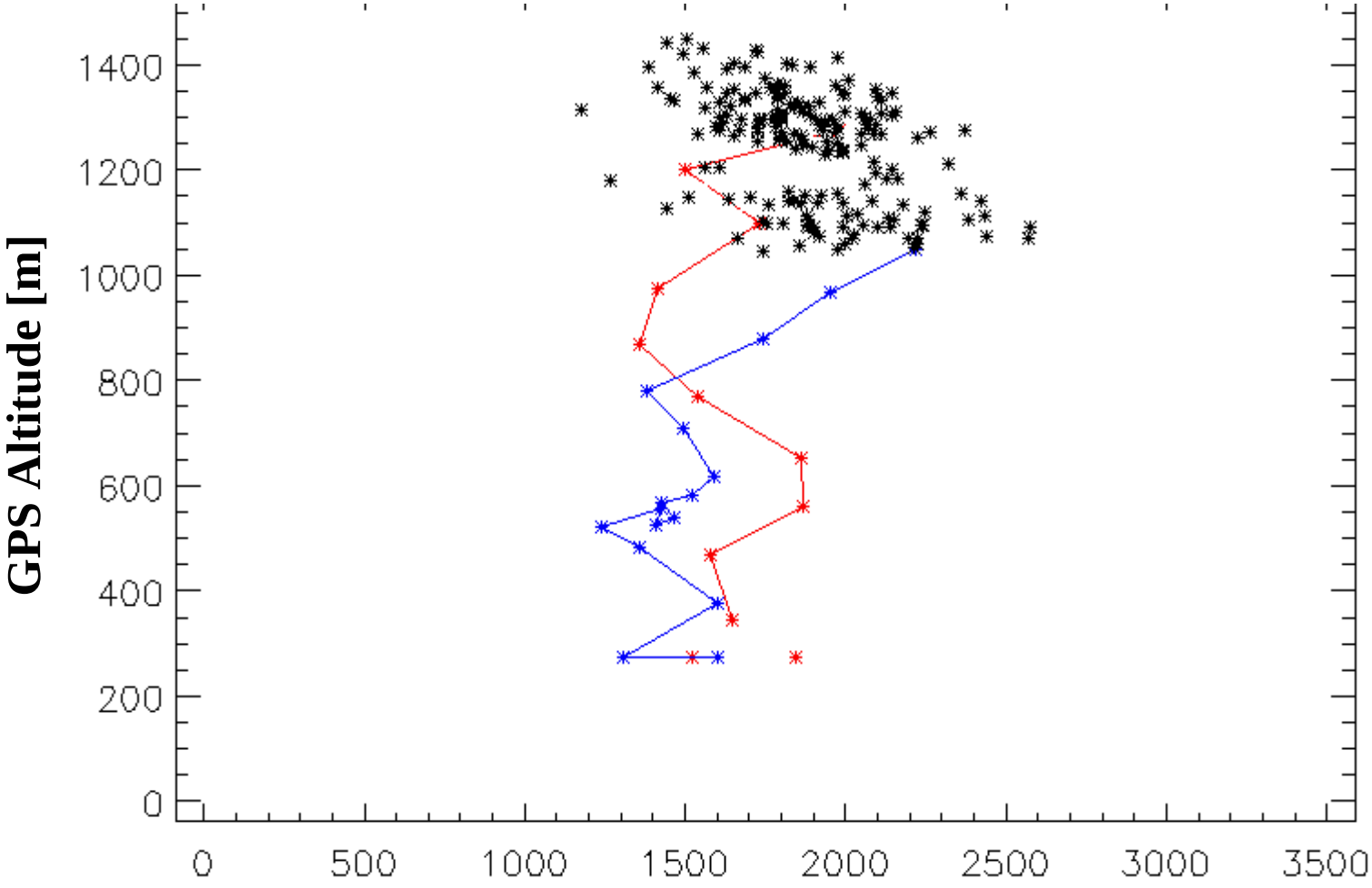
POLCAST4 Cessna340 N98585 Instruments







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



Cloud Base Temperature 5.1 ºC

Cloud Base 0.6 % Ambient Supersaturation and STP

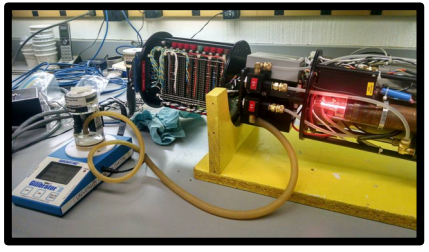
25 Percentile – 1740 [#/cm^3]

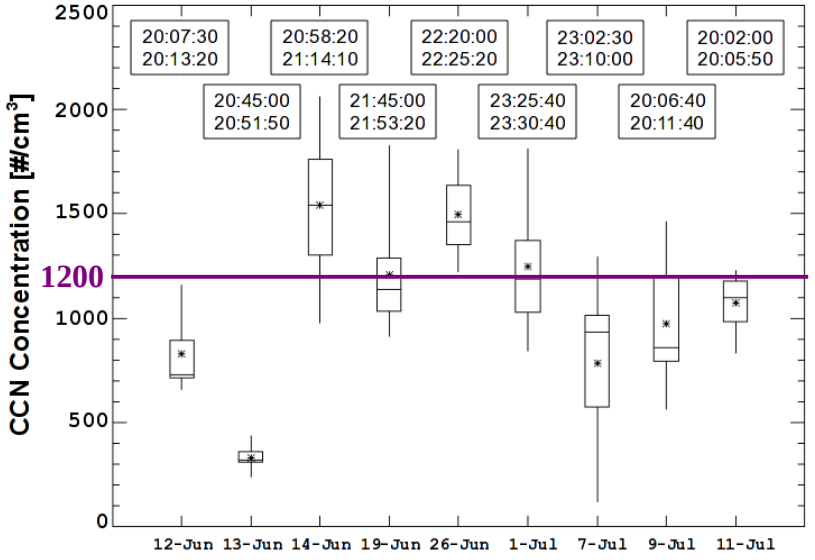
50 Percentile – 1880 [#/cm^3]

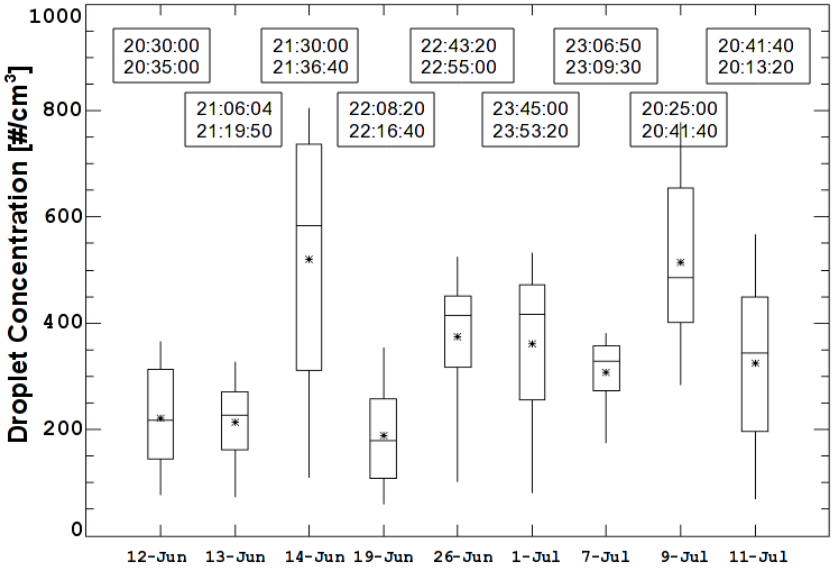
75 Percentile – 2050 [#/cm^3]

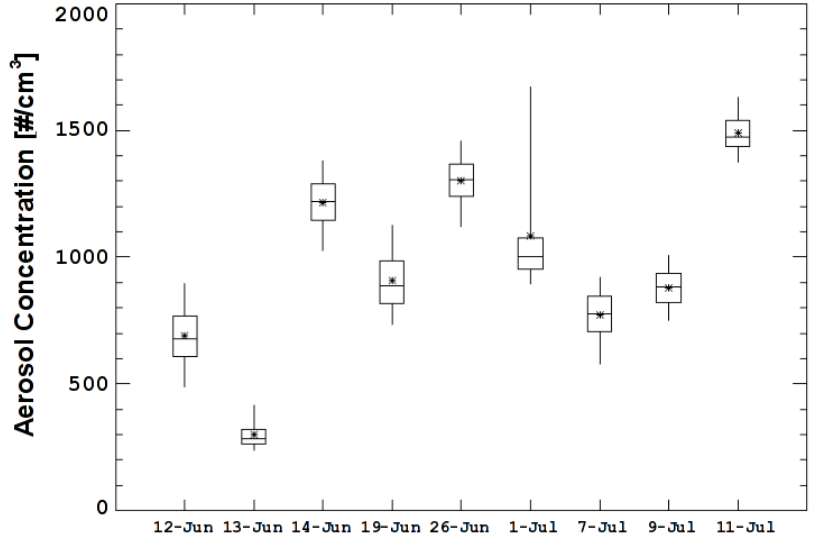
Surface Temperature 14 ºC

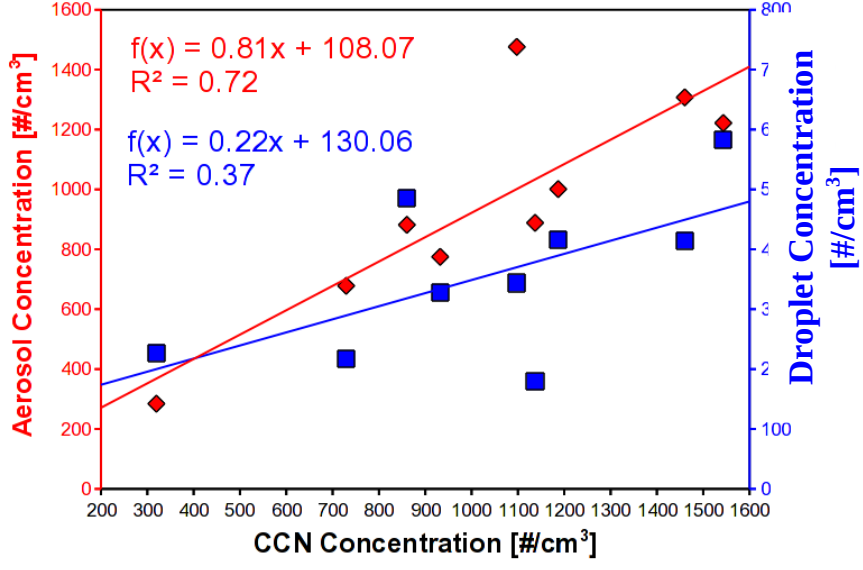
University of Wyoming cloud condensation nuclei (CCN) counter measurements (0.6 % ambient supersaturation) adjusted to standard pressure and temperature (STP) on aircraft ascent (red, 17:40:00-17:45:00 UTC), during July 8 2012 cloud base sampling (black stars, 18:04:00-19:36:10) and during descent (blue,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




CCN Concentration [#/cm3]
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
1200
12-Jun 13-Jun 14-Jun 19-Jun 26-Jun 1-Jul 7-Jul 9-Jul 11-Jul


Droplet Concentration [#/cm3]
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
12-Jun 13-Jun 14-Jun 19-Jun 26-Jun 1-Jul 7-Jul 9-Jul 11-Jul


Aerosol Concentration [#/cm3]
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 [#/cm3]
Droplet Concentration [#/cm3]
CCN Concentration [#/cm3]

Conclusions

Cloud Condensation Nuclei are a very important but difficult measurement.

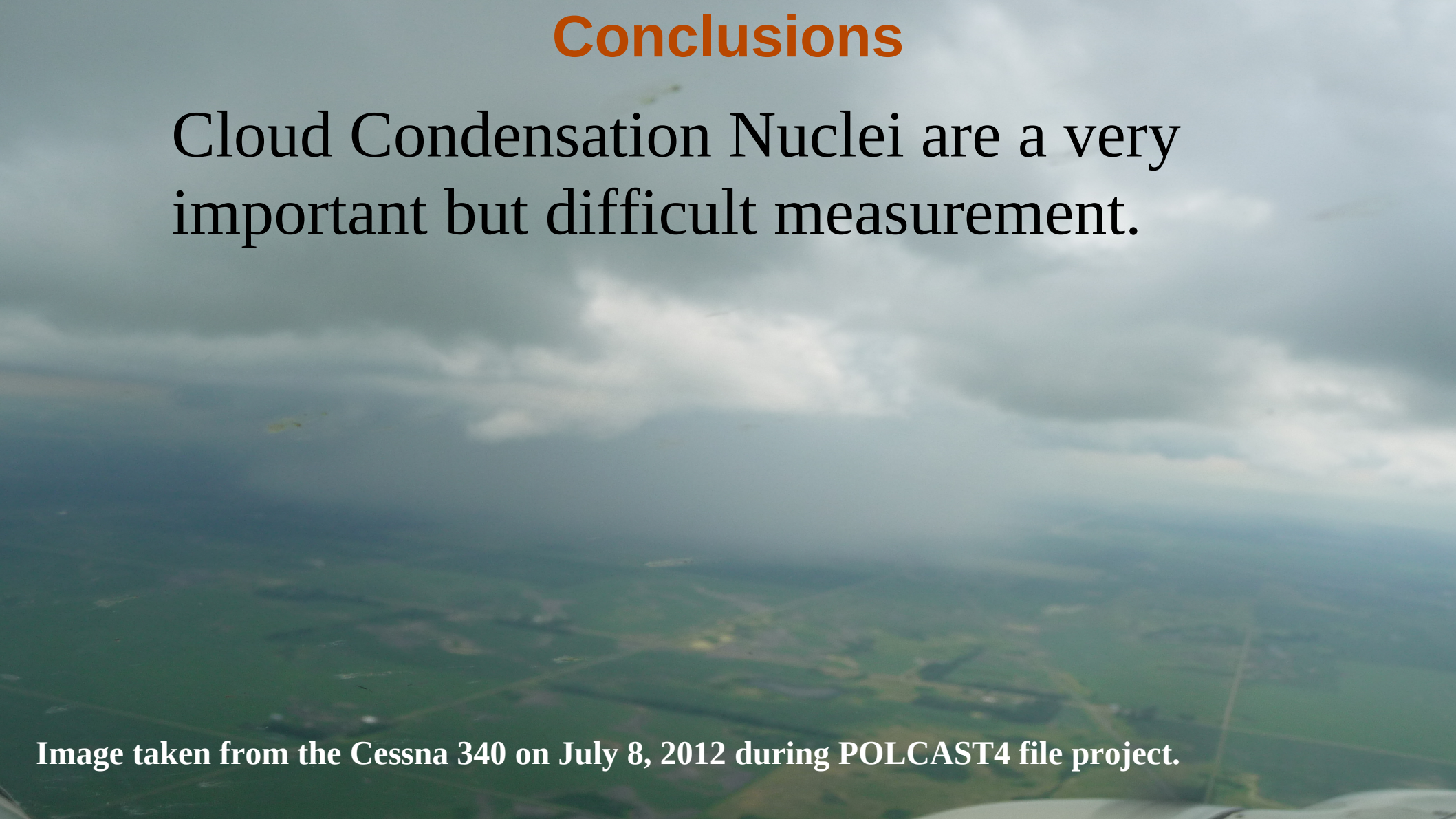


Image taken from the Cessna 340 on July 8, 2012 during POLCAST4 file project.