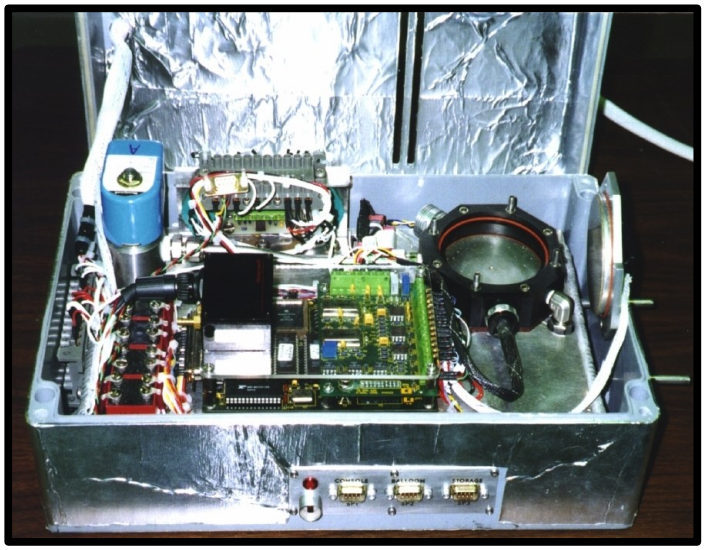
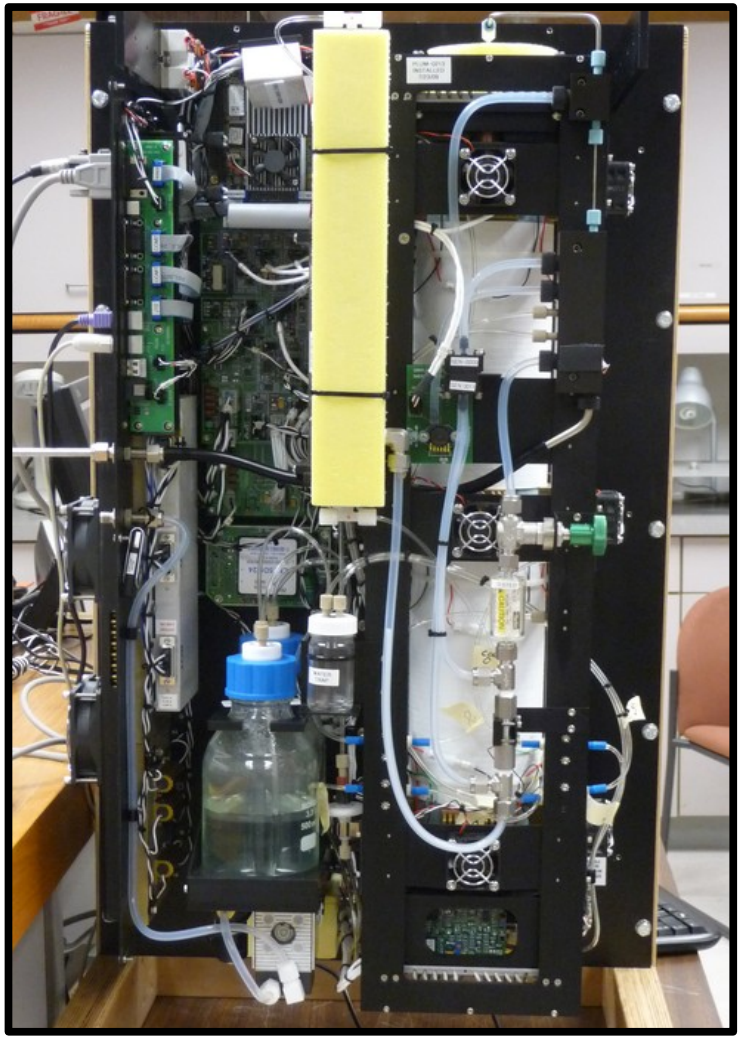
Atmospheric Aerosols and Particle Nucleation

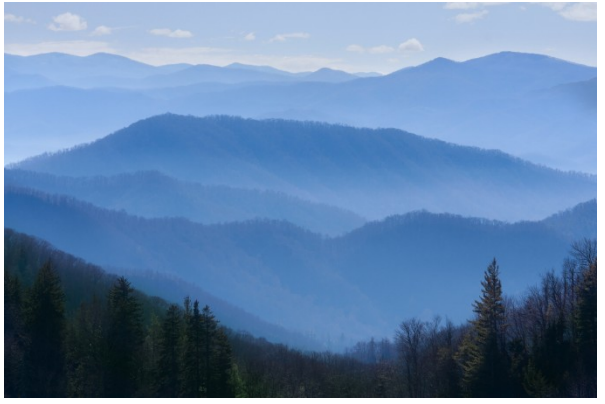




What are Aerosols?

- 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”.

How do we know when present in the air?



Clouds in the Atmosphere

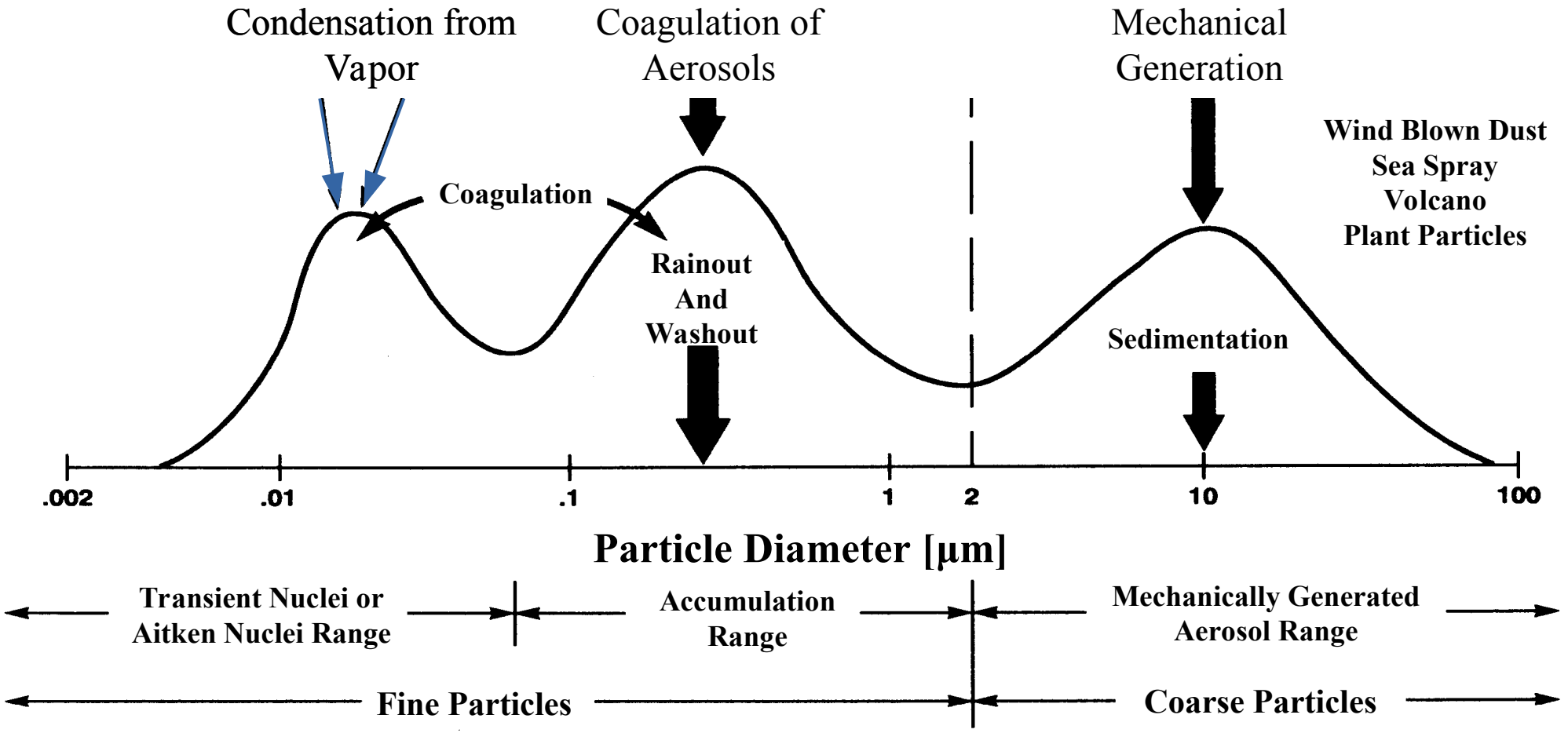
Clouds are made up of water droplets and/or ice crystals, much larger than typical aerosols (0.01-10 μm).

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

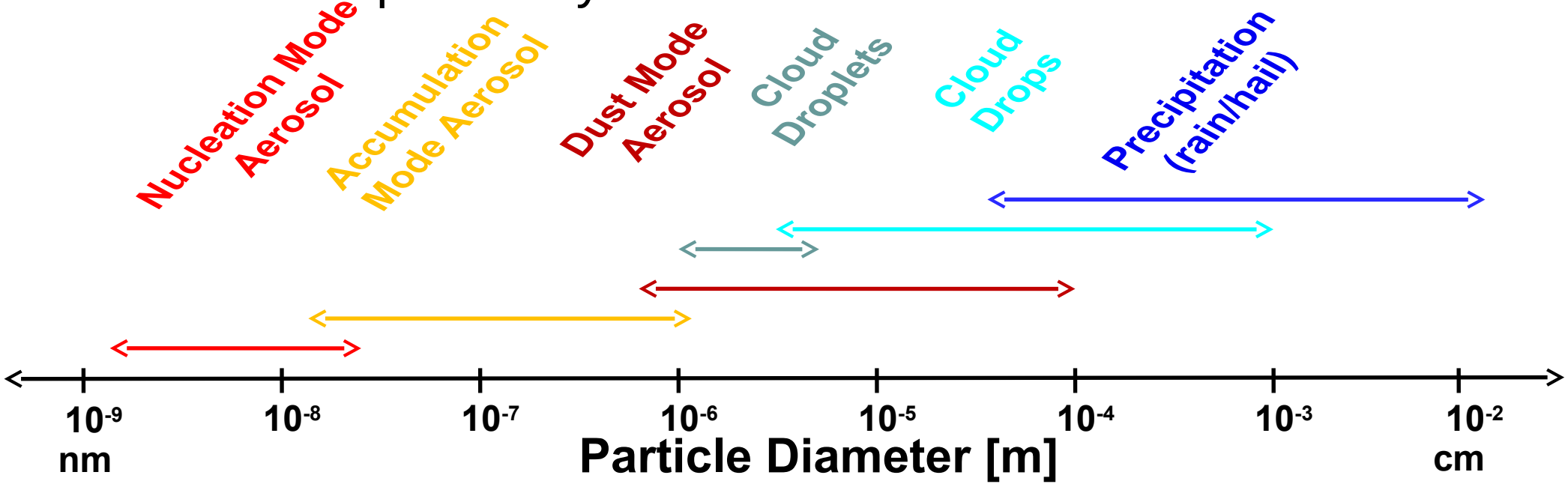


Adapted from Singh: Figure 5.4

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 Velocities of Aerosols

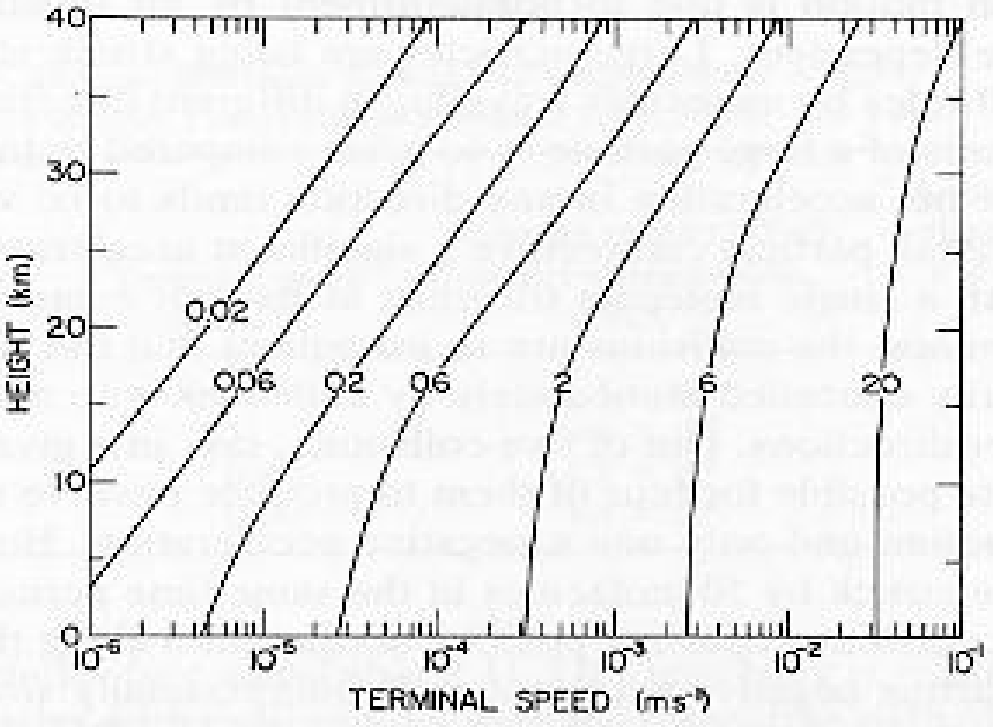


Fig. 2.3. Terminal fall speeds of spherical particles of density 2 Mg m^{-3} as a function of diameter and height in a standard atmosphere. Curves are labeled according to particle diameter in micrometers. [After C. E. Junge, C. W. Changnon, and J. E. Manson (1961). *J. Meteorol.* **18**, 81, by permission of American Meteorological Society and senior author.]

Instrumentation Based Aerosol Definitions

Ultrafine Aerosols (UF)

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

Condensation Nuclei (CN)

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

Optical Aerosols ($D_{0.3}$)

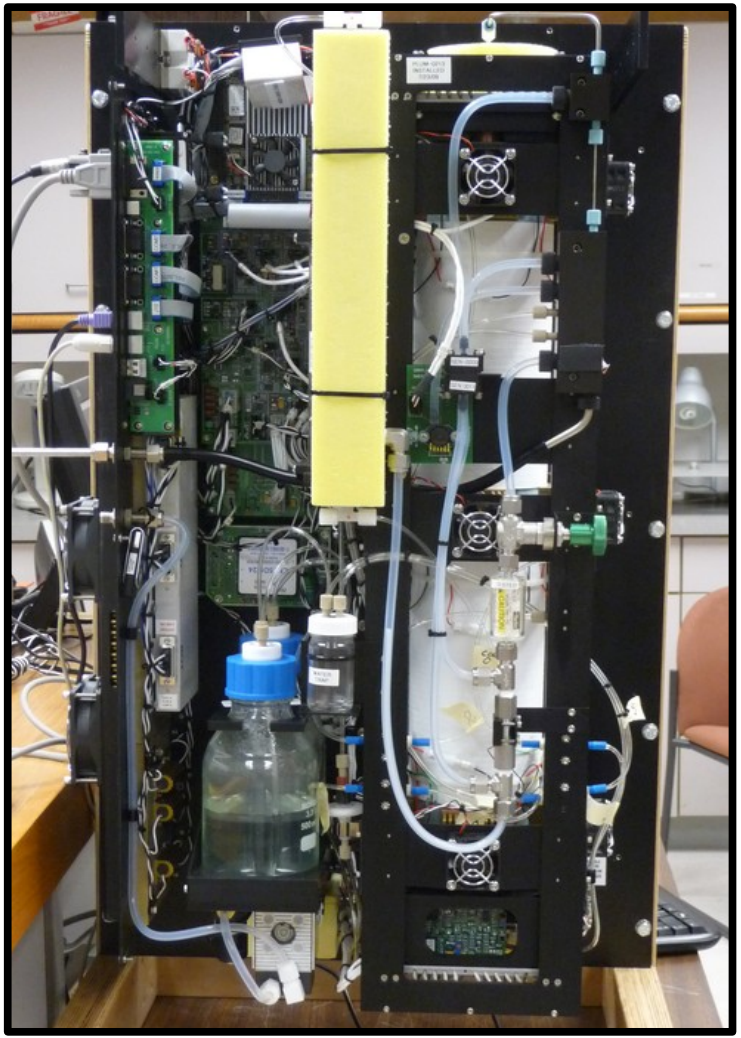
- **Aerosols larger than 0.3 µm diameter.**

Cloud Condensation Nuclei (CCN)

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

Ice Nuclei (IN)

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



CCN Measurements

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.

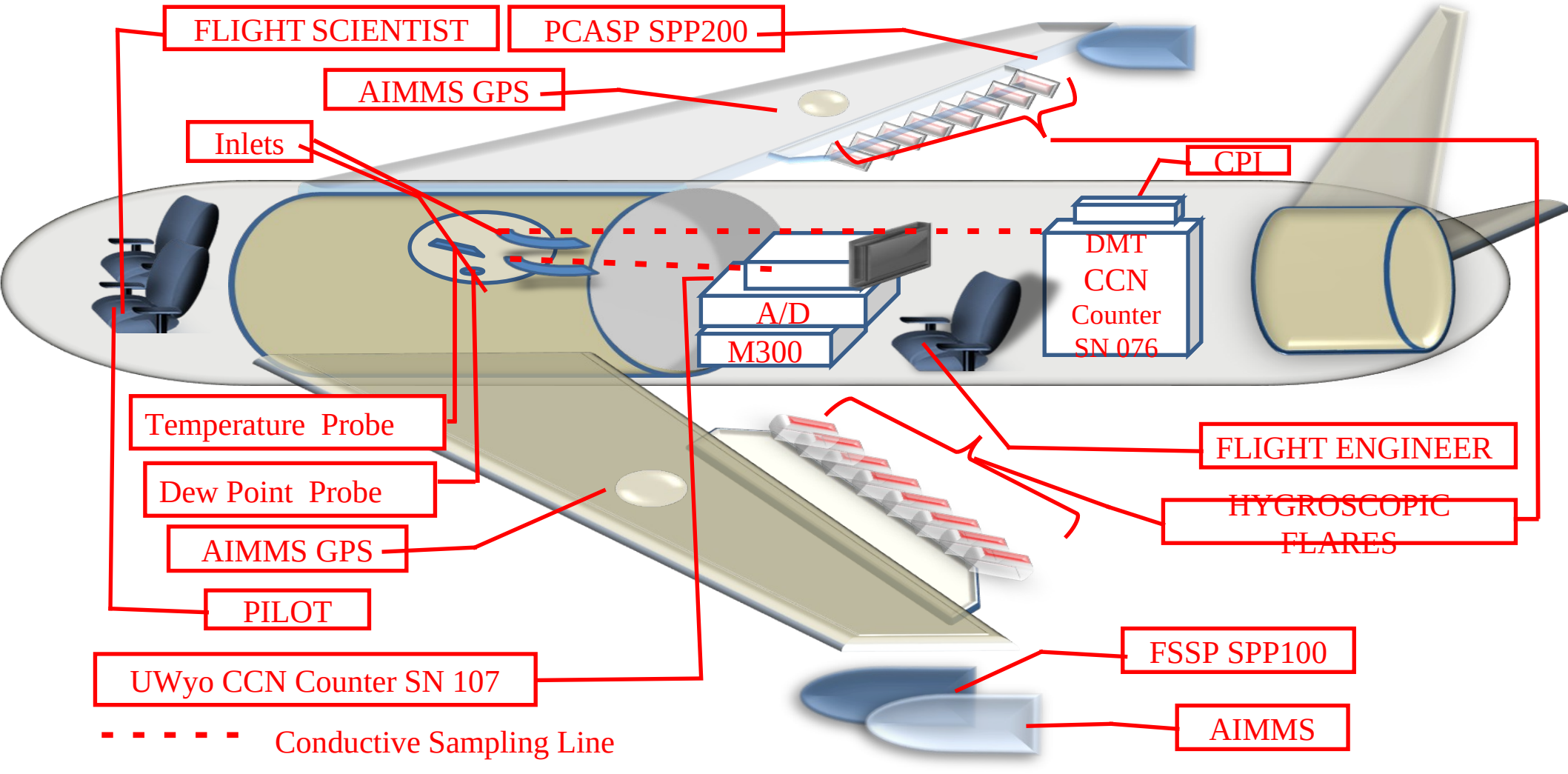
Uwyo CCN Counter Measurements

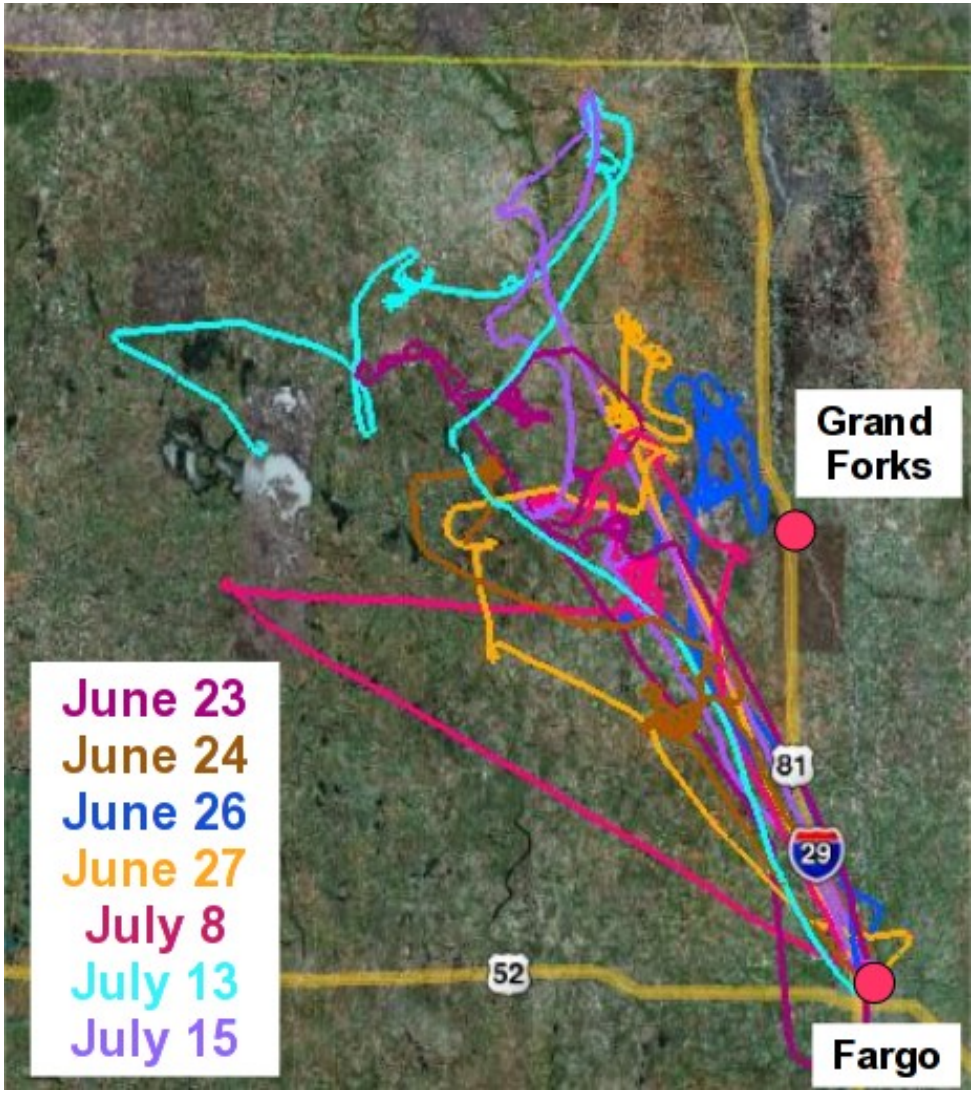
Location	Time of Year	CCN Concentration
Wyoming, USA	Winter	146 ± 20 #/cm^{-3}
Wyoming, USA	Summer	445 ± 157 #/cm^{-3}
New Zealand	Summer	964 ± 17 #/cm^{-3}
Bamako, Mali	09/08/07	367 ± 247 #/cm^{-3}

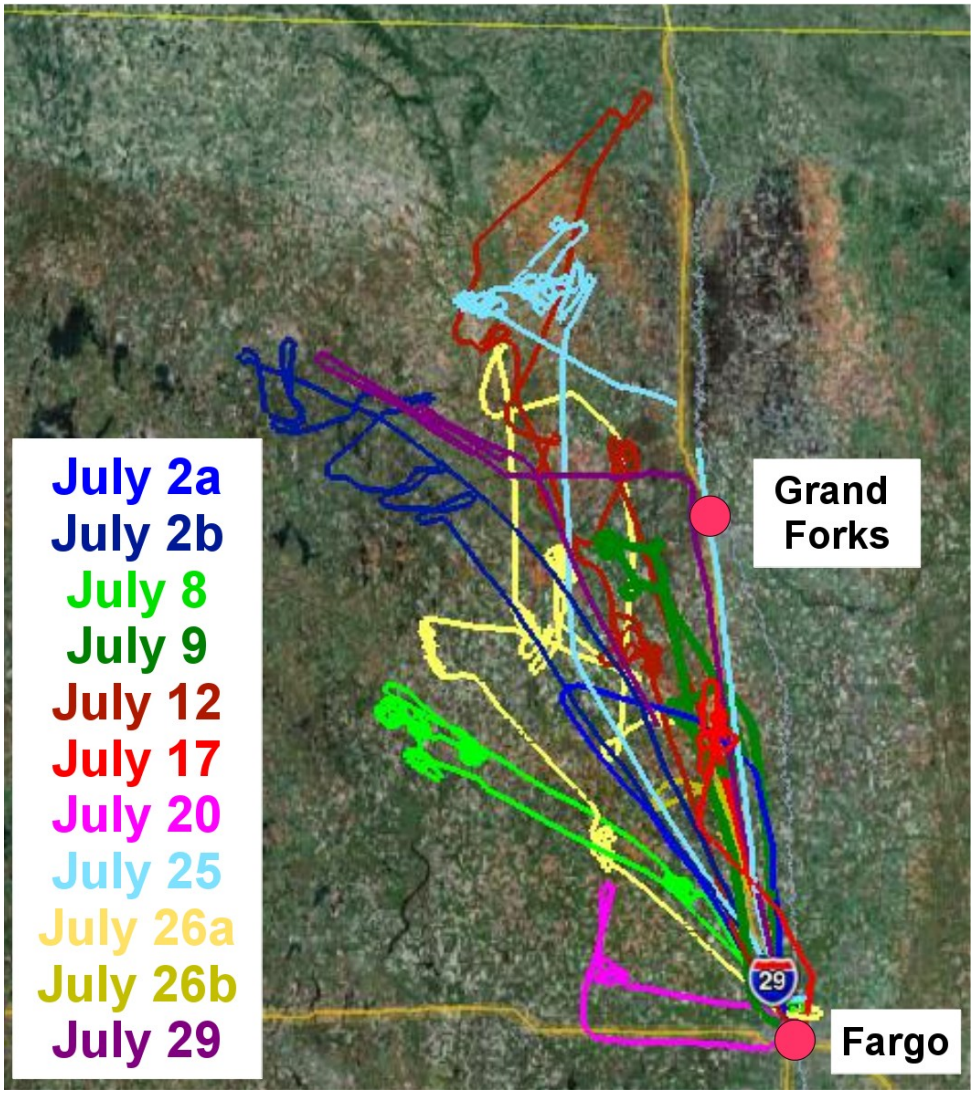
Cloud Condensation Nuclei (CCN) concentrations at 1% supersaturation measured by the University of Wyoming CCN counter in the lower troposphere at various locations.

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

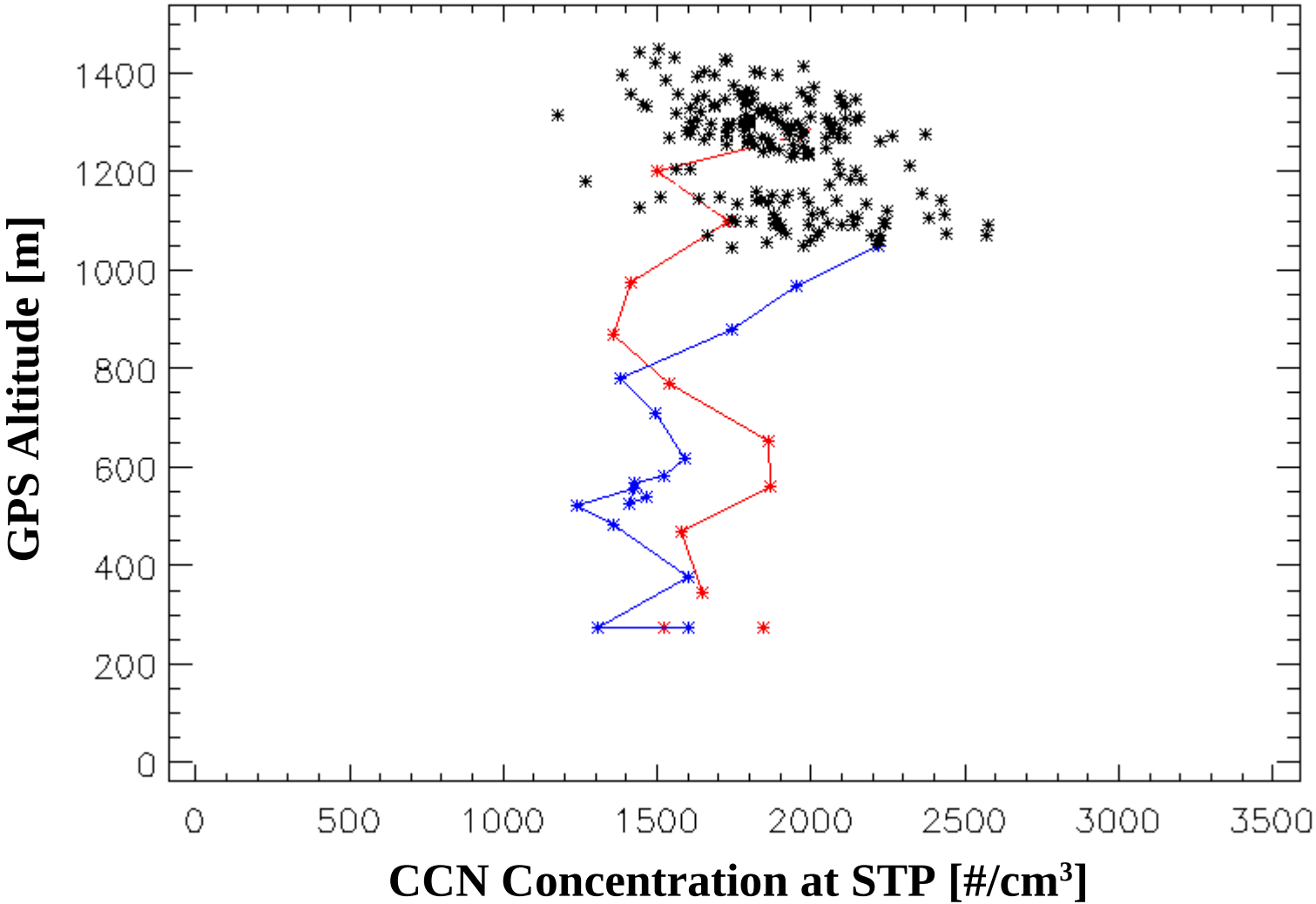
POLCAST4 Cessna340 N98585 Instruments







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



Cloud Base Temperature 5.1 °C

Cloud Base 0.6 % Ambient Supersaturation and STP

25 Percentile – 1740 [#/cm³]

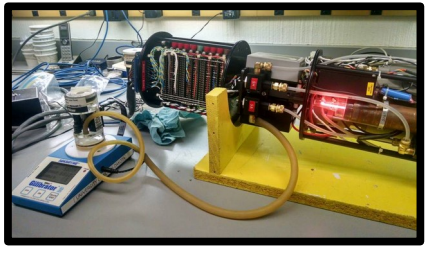
50 Percentile – 1880 [#/cm³]

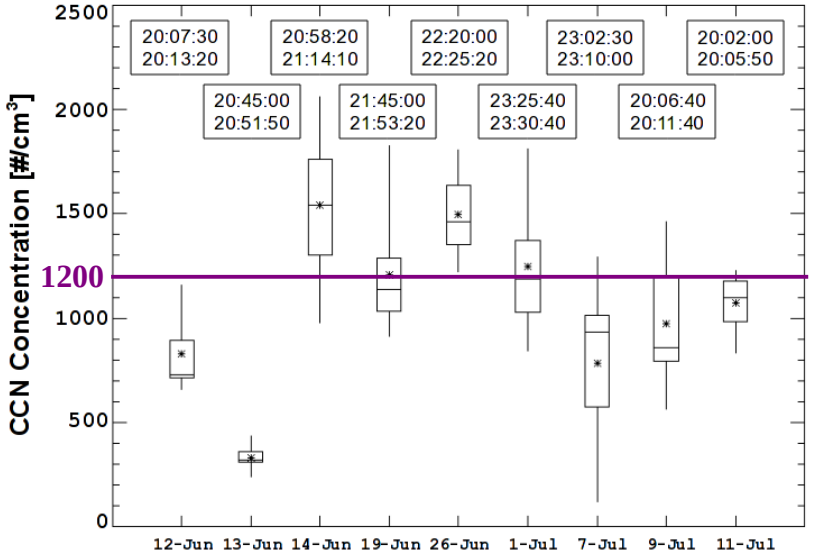
75 Percentile – 2050 [#/cm³]

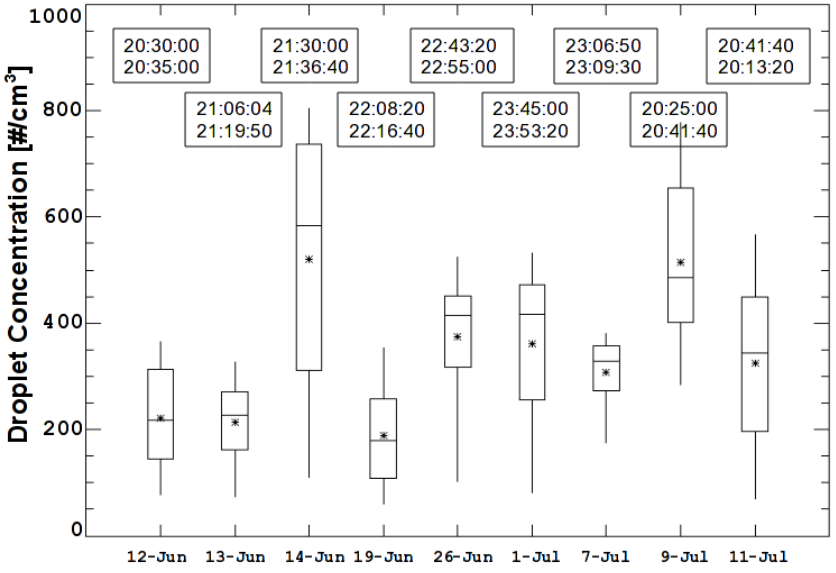
Surface Temperature 14 °C

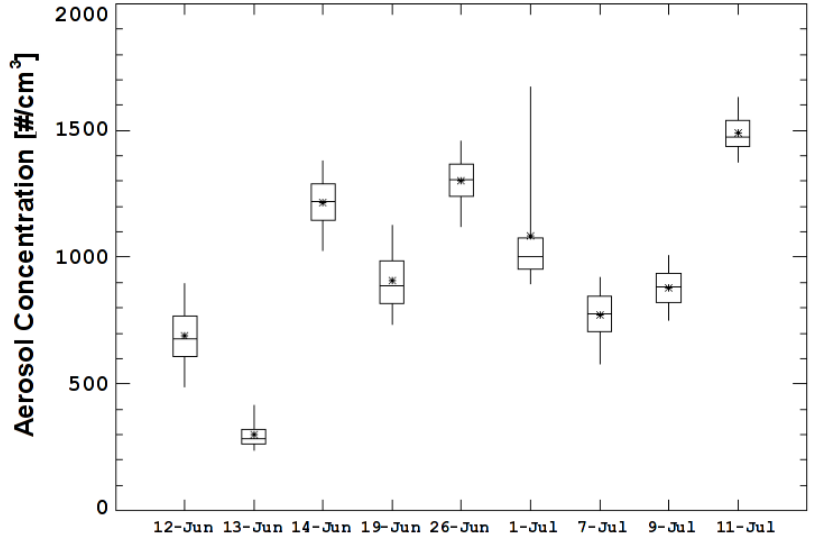
University of Wyoming cloud condensation nuclei (CCN) counter measurements (0.6 % ambient supersaturation) adjusted to standard pressure and temperature (STP) on aircraft ascent (red, 17:40:00-17:45:00 UTC), during July 8 2012 cloud base sampling (black stars, 18:04:00-19:36:10) and during descent (blue,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

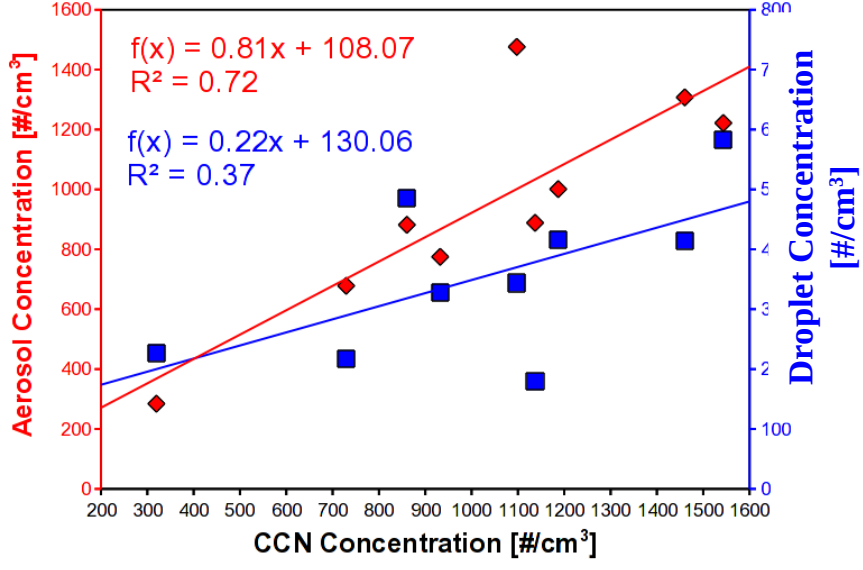

CLOUD CONDENSATION NUCLEUS COUNTER
CCNC-100B




CCN Concentration [#/cm3]
2500
2000
1500
1200
1000
500
0
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
12-Jun
13-Jun
14-Jun
19-Jun
26-Jun
1-Jul
7-Jul
9-Jul
11-Jul


Droplet Concentration [#/cm3]
1000
800
600
400
200
0
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]
2000
1500
1000
500
0
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]
1600
1400
1200
1000
800
600
400
200
0
800
700
600
500
400
300
200
100
0
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

Conclusions

Cloud Condensation Nuclei are a very important but difficult measurement.

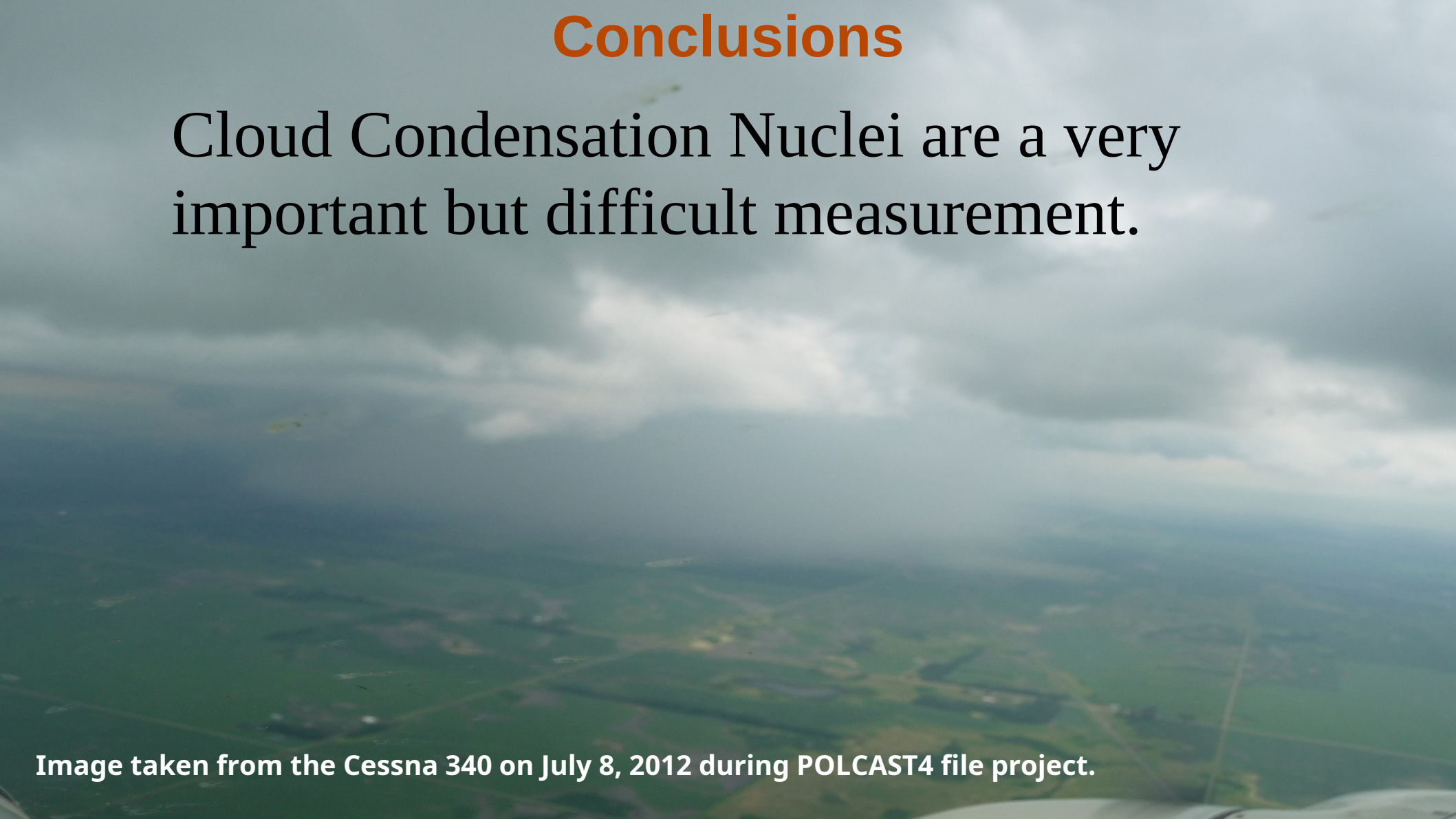


Image taken from the Cessna 340 on July 8, 2012 during POLCAST4 file project.