Nucleation of Water Droplets and Ice Particles in the Earth's Atmosphere

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http://aerosols.atmos.und.edu

Atmospheric Chemistry Class

- AtSc 520 - Fall 2019 Tuesday/Thursday 9:30-10:45
  - Atmospheric Transport
  - Simple Chemical Modes
  - Geochemical Cycles
  - Atmospheric Aerosols / Cloud Processing of Aerosols
  - Ozone
  - Polar Stratosphere Clouds
  - Aqueous-Phase Chemistry / Wet Deposition / Fog

https://learn.aero.und.edu/pages.asp?PageID=202625

Collaboration and Teams

- Work together on goal to provide exceptional learning experience and student opportunities.
- Teams are required for solving today's most important problems.

CAPE 2015 Flight Crew

NASA ORACLES 2016

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.

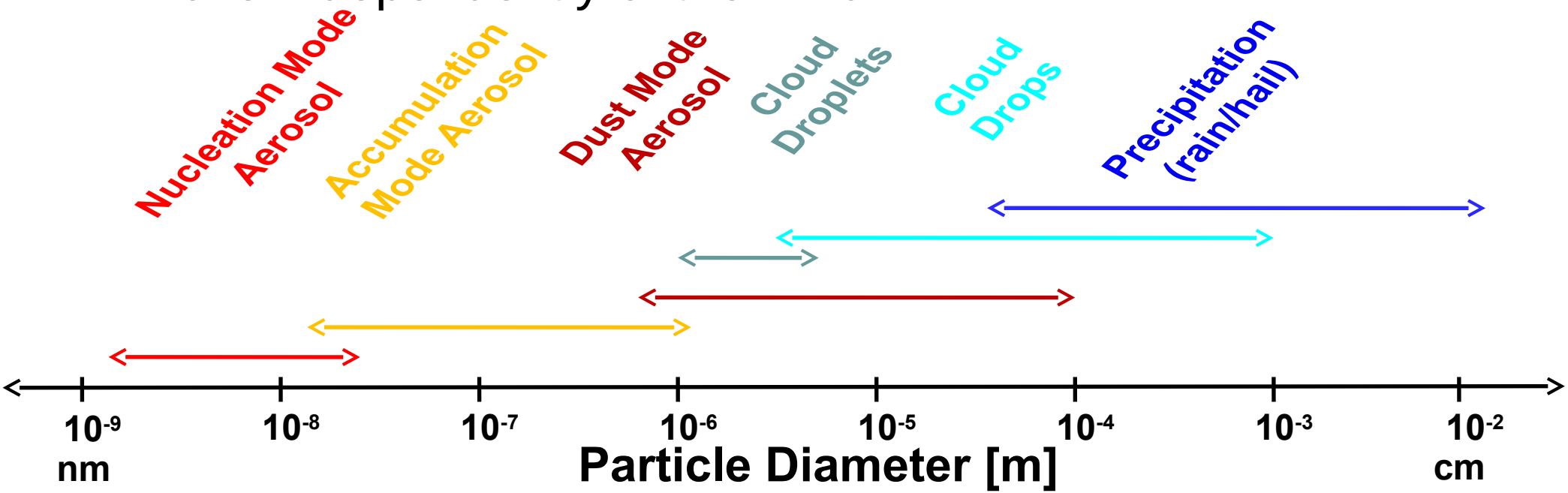
East Grand Forks: 17 July 2011

Citation Flight: 14 July 2011

Atmospheric Particles

Atmosphere contains particles of all sizes.

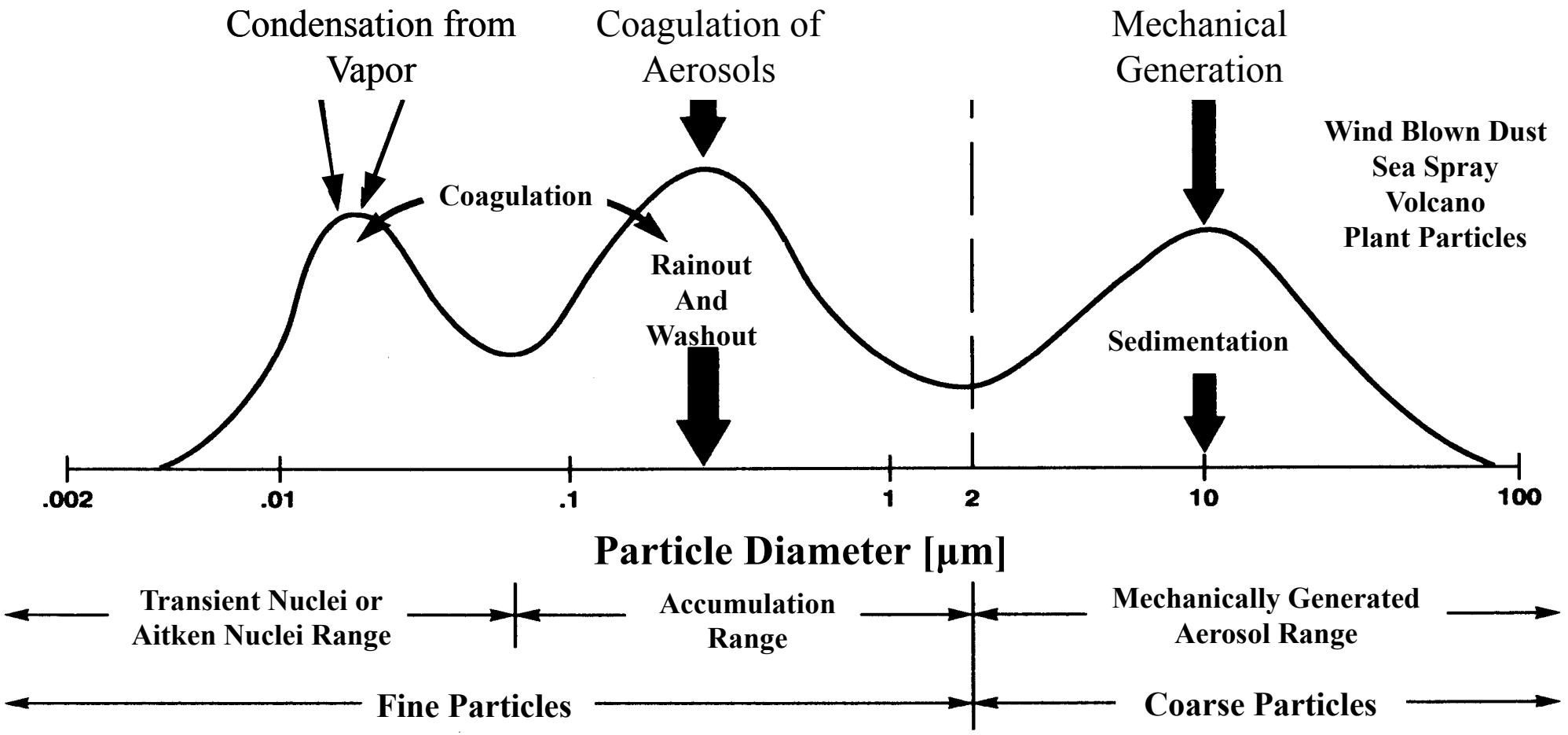
- Suspended particles (aerosols) move with the average flow of gas molecules (atmospheric wind).
- Large particles (dust/drops/rain) have sufficient inertia to move independently of the wind.



Definitions

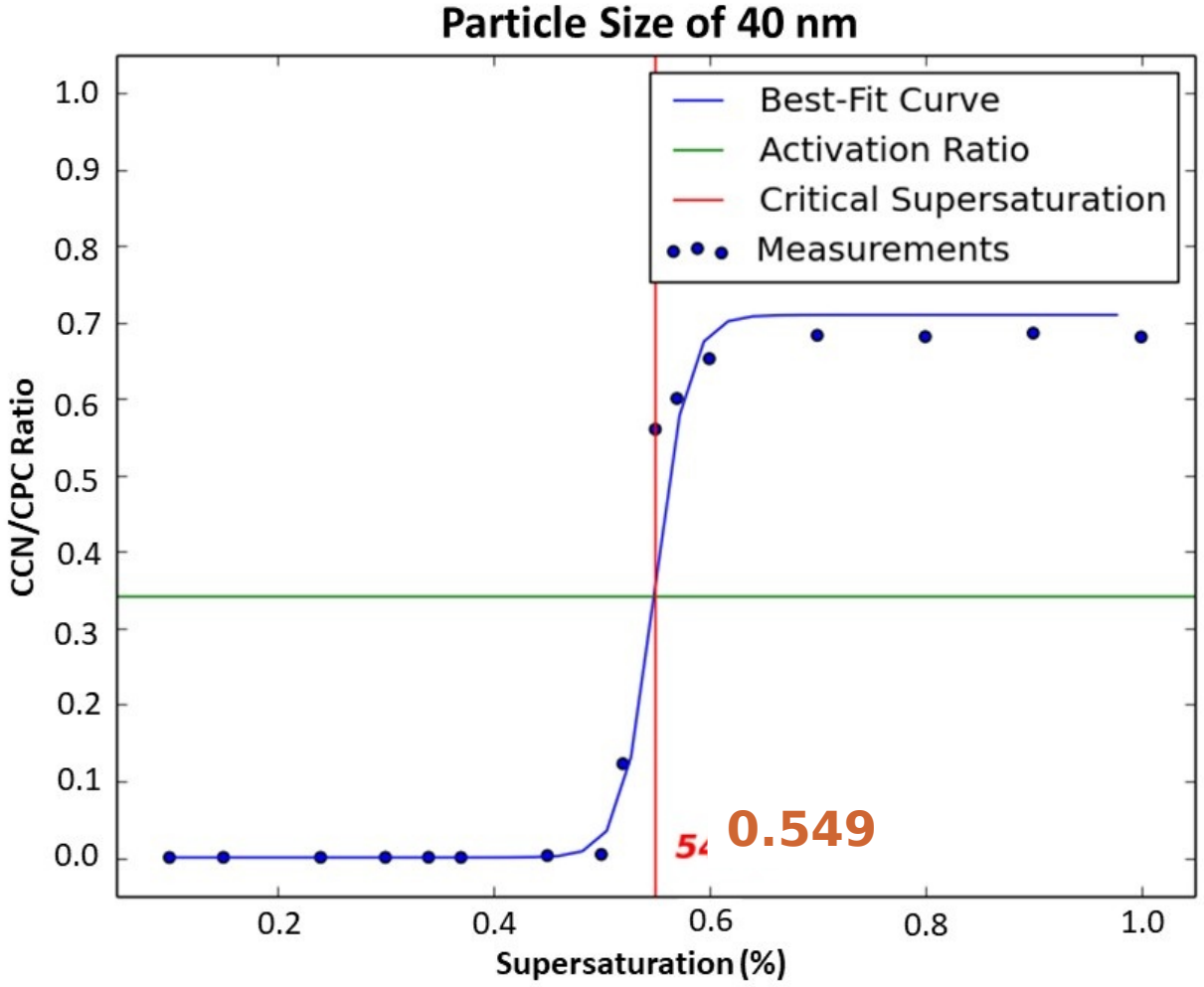
- **Aerosols**
  - Suspended material in the Earth's atmosphere that have troposphere residence times (lifetimes) of days to a few weeks.
  - Atmospheric Aerosols are sometimes referred to as “particles”.
- **Cloud Condensation Nuclei (CCN)**
  - Aerosols that produce cloud droplet in a supersaturated environment.
- **Ice Nuclei (IN)**
  - Aerosols that produce ice particles in the atmosphere.

Aerosol Modes



Adapted from Singh: Figure 5.4

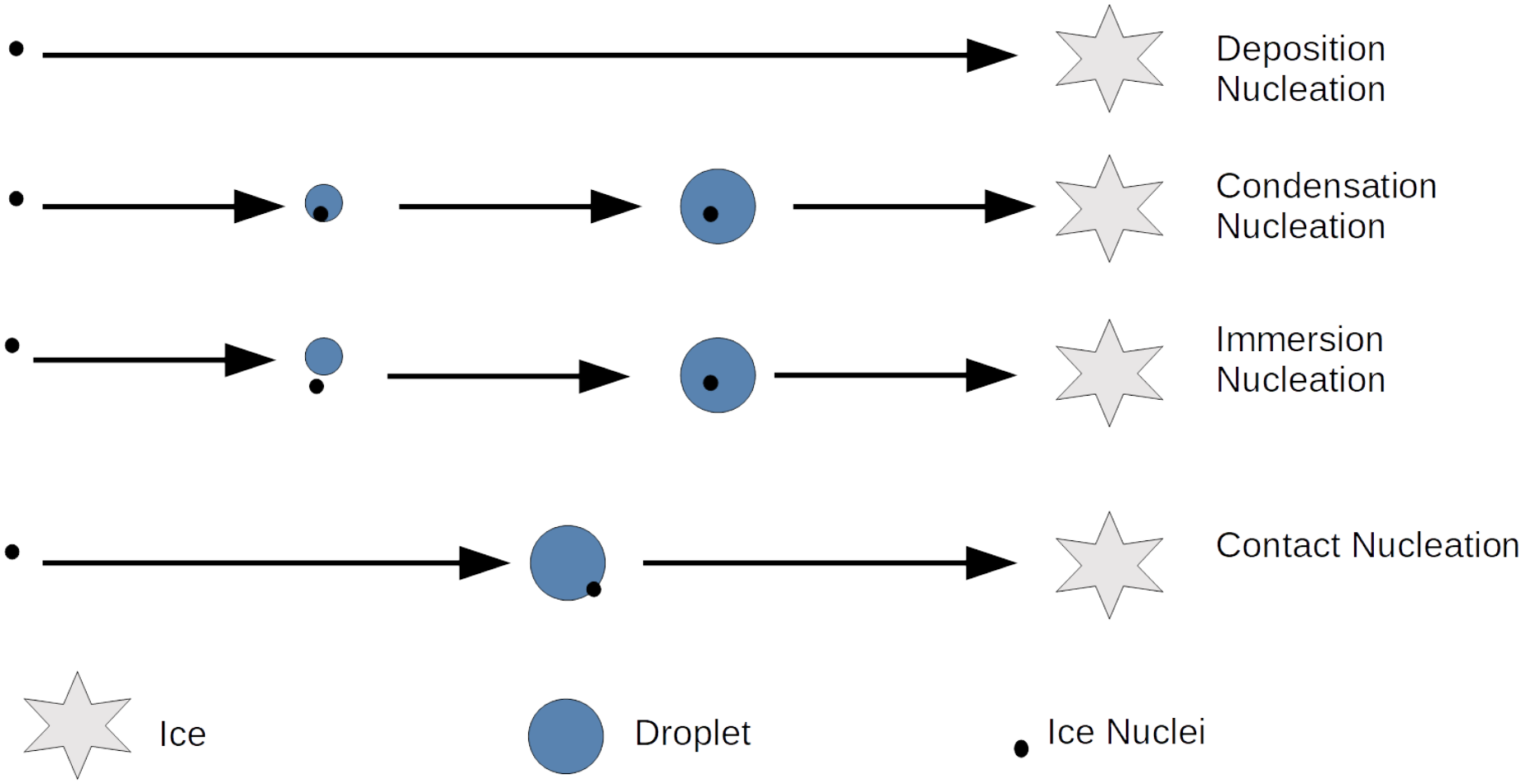
Cloud Condensation Nuclei (CCN)



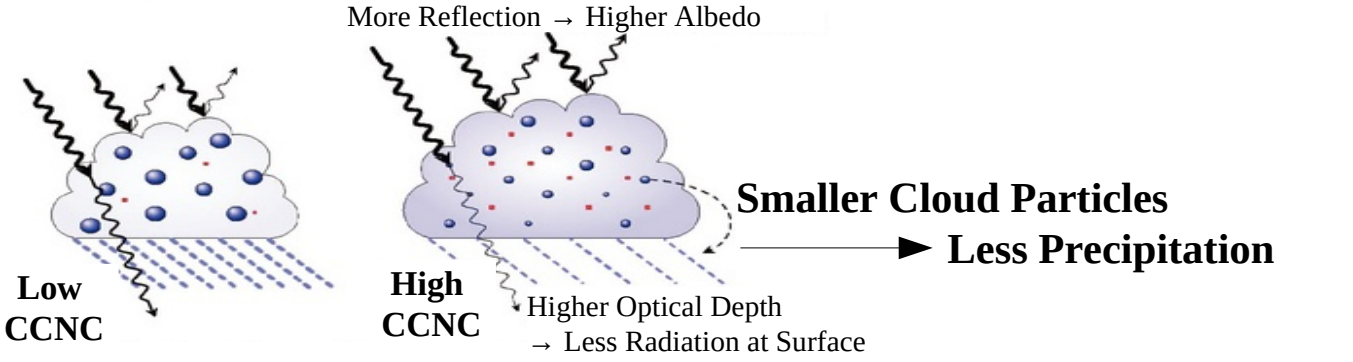
Kappa Values

Soot:	0.00
$(NH_4)_2SO_4$:	0.61
Liquid Smoke	0.81
H_2SO_4	0.91
NaCl	1.28

Ice Nucleation (IN)



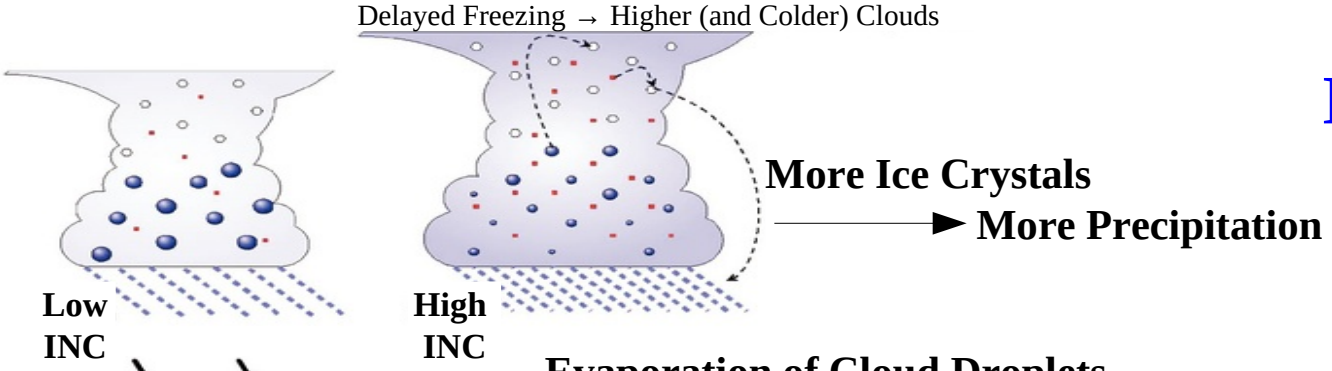
Importance of Aerosol Nucleation and Clouds



Cloud Albedo and Lifetime Effect

Smaller Cloud Particles → Less Precipitation

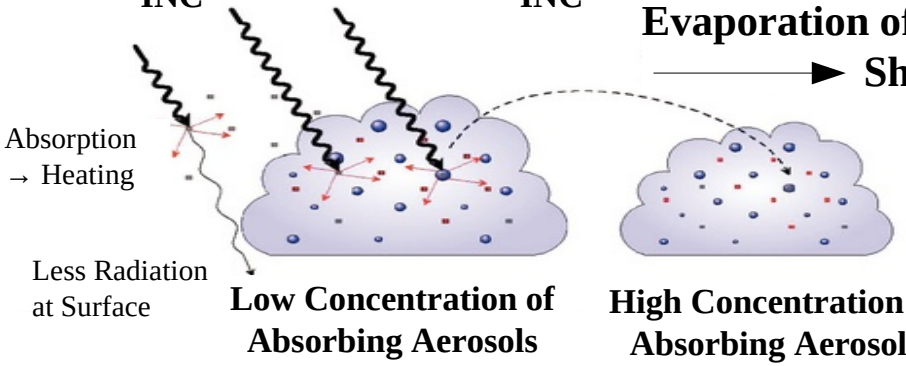
Less Precipitation



Glaciation Effect

More Ice Crystals → More Precipitation

More Precipitation



Semi-direct Effect

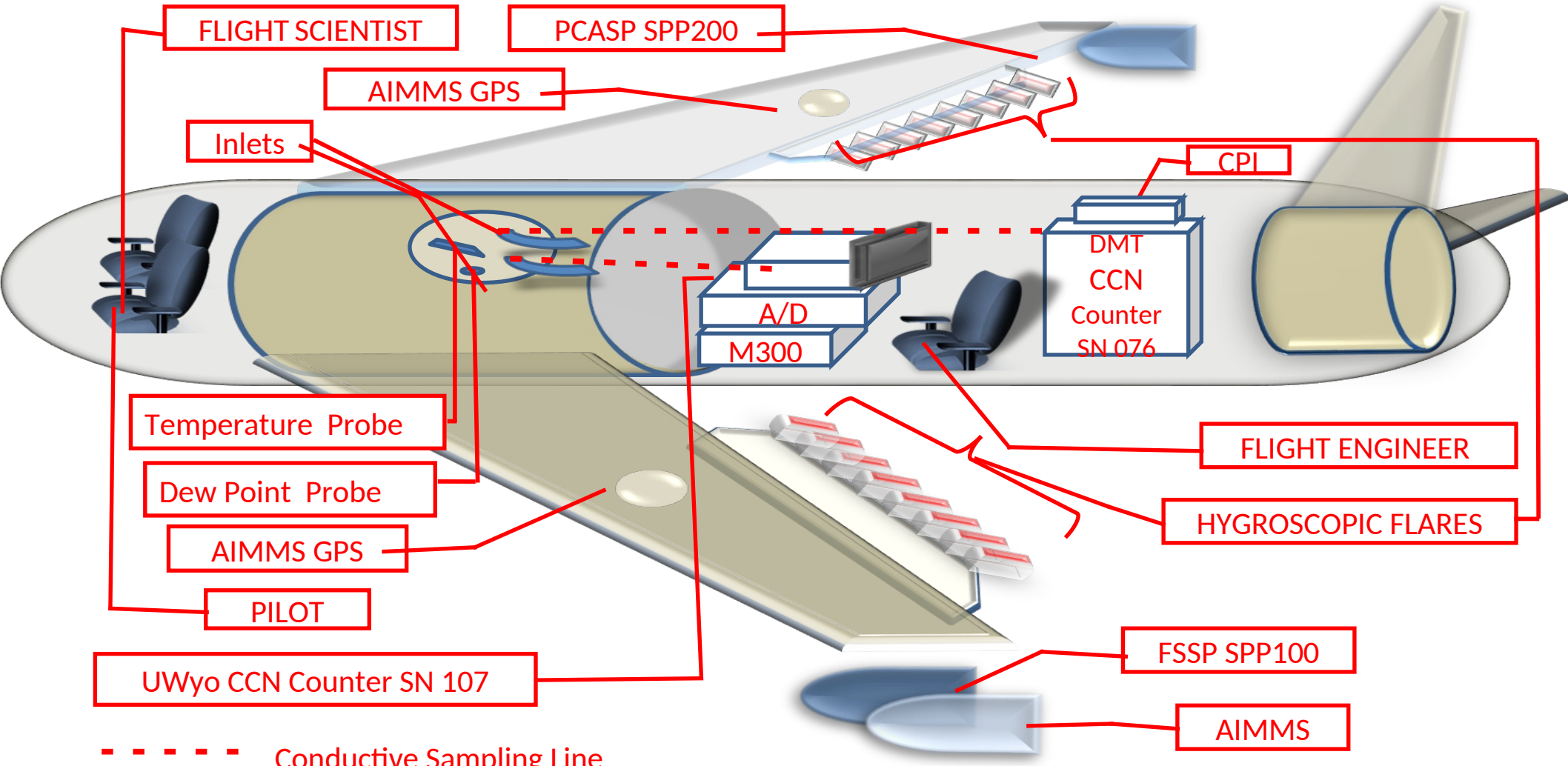
Evaporation of Cloud Droplets → Shrinking of Cloud

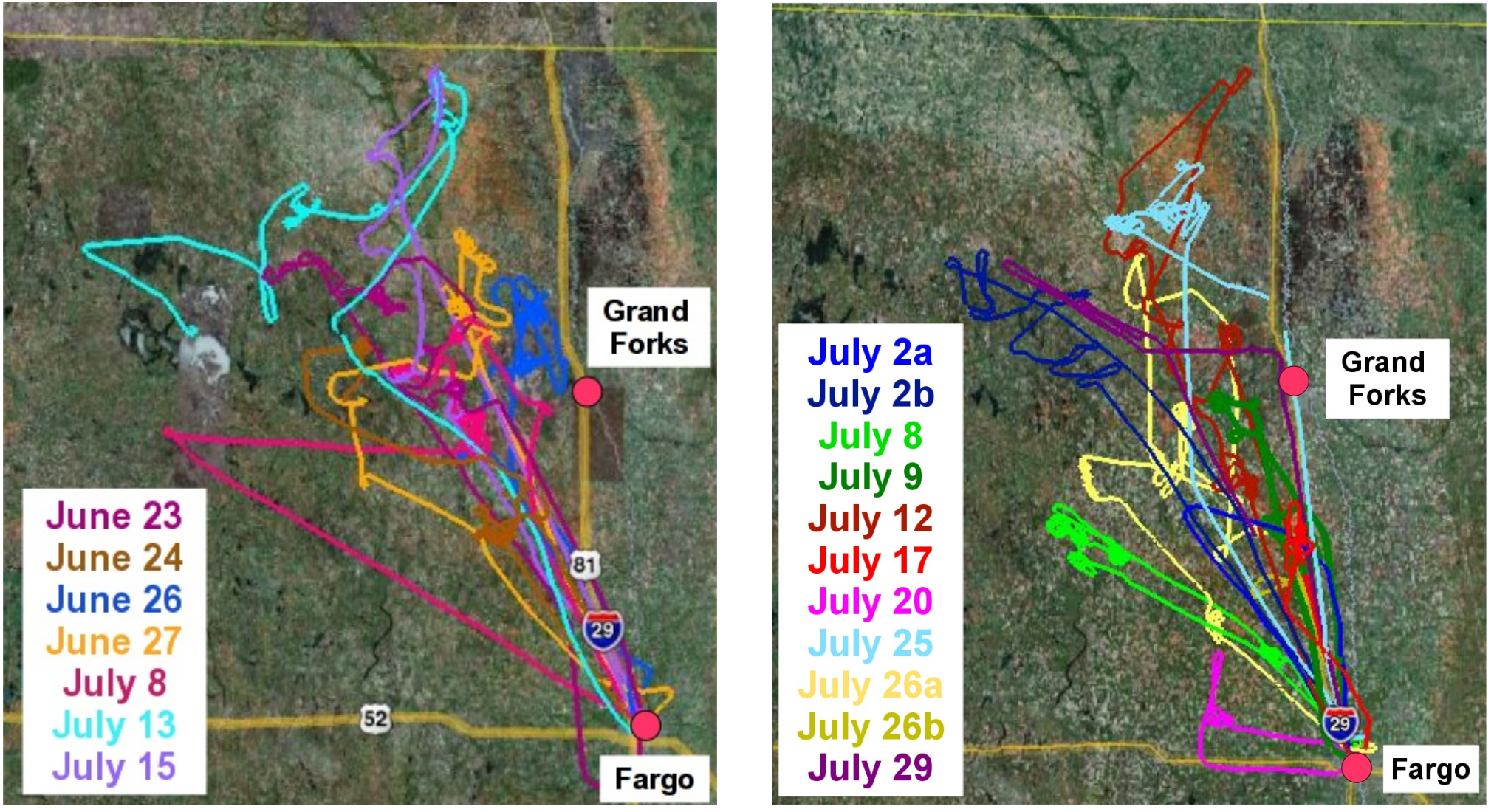
Less Precipitation

CCNC – Cloud Condensation Nuclei Concentration
INC – Ice Nuclei Concentration

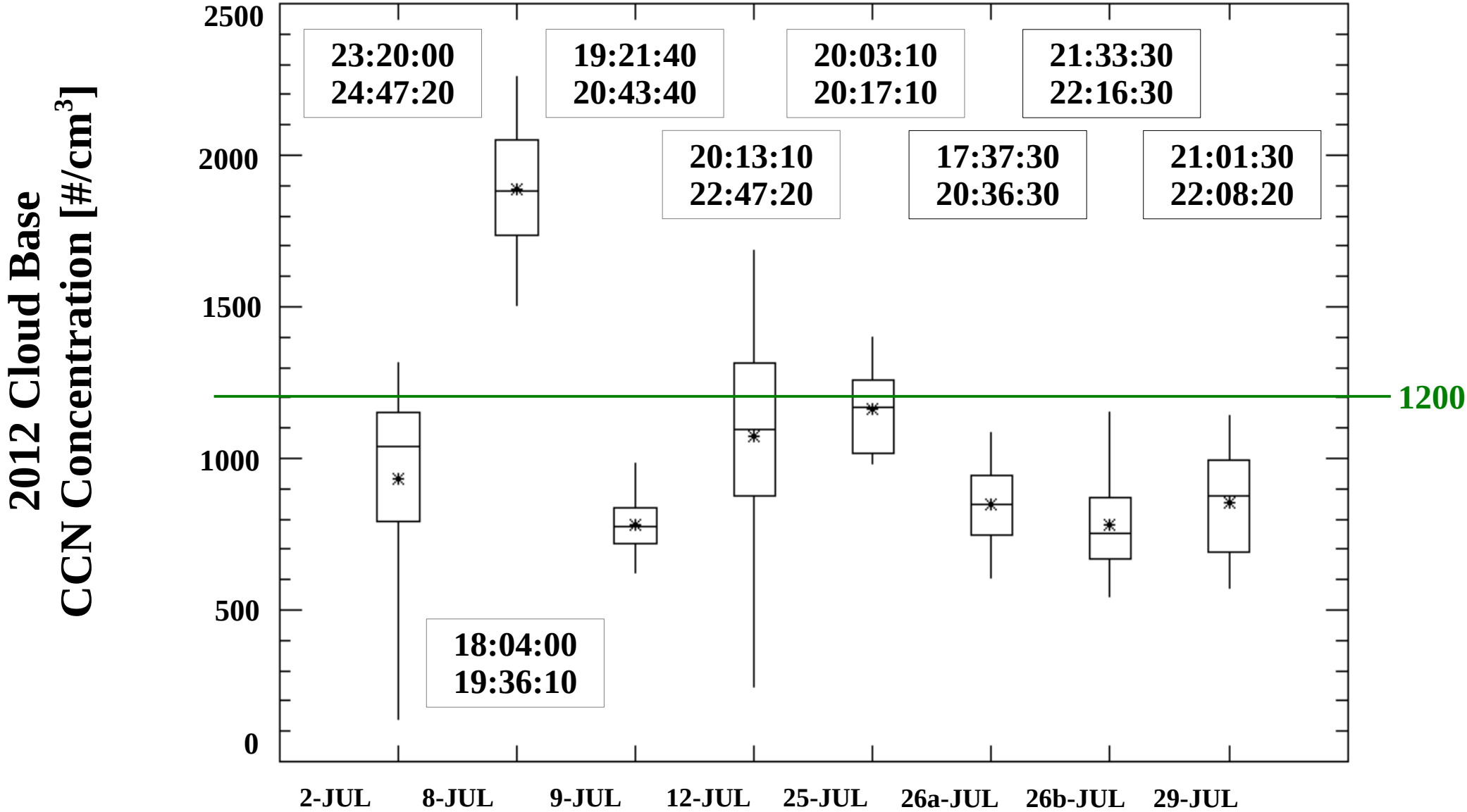
IPCC Fourth Assessment Report: Climate Change 2007: Working Group 1: The Physical Science Basis, Figure 7.20

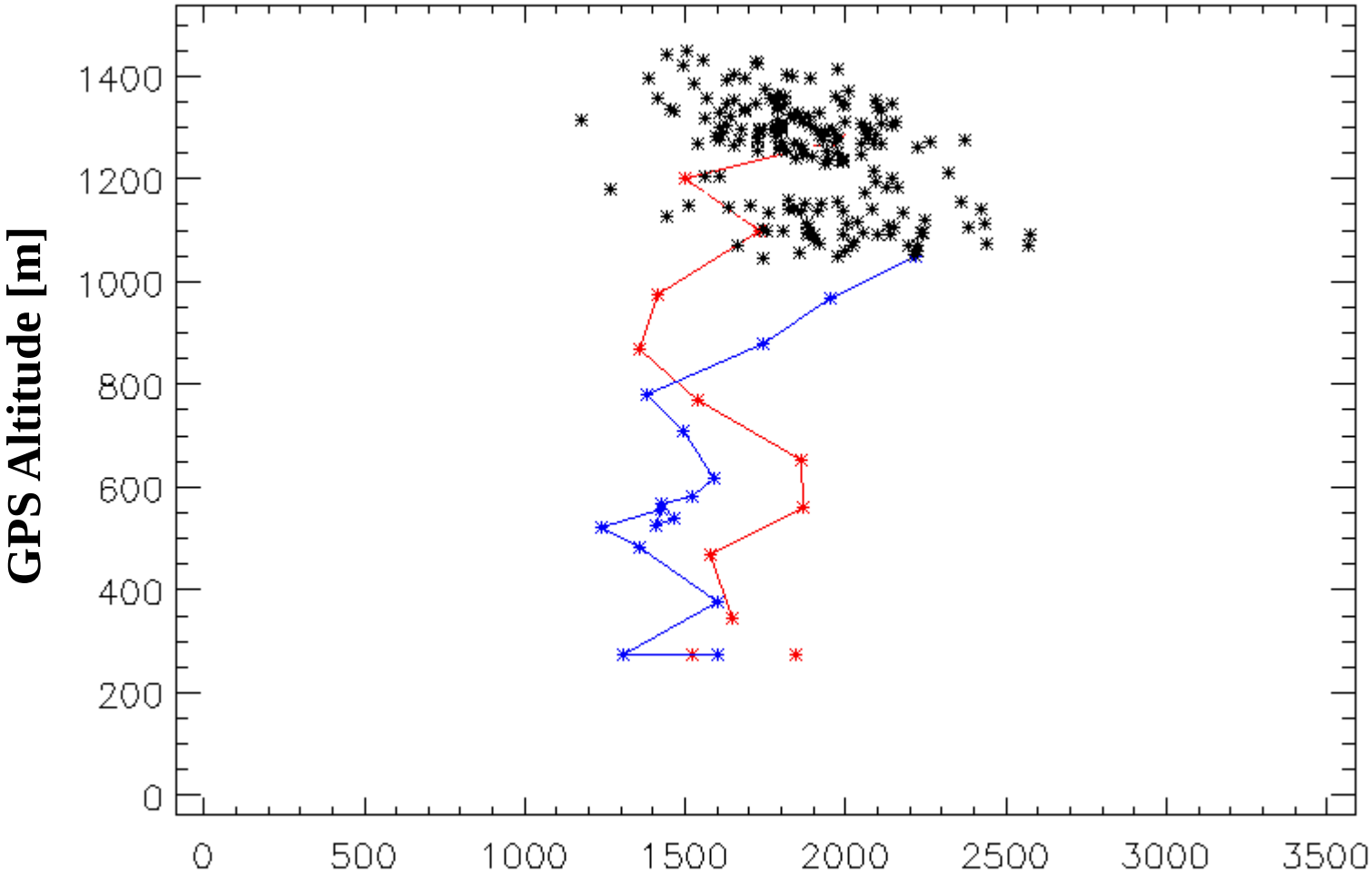
POLCAST4 CESSNA340 N98585 INSTRUMENT CONFIGURATION





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


2012 Cloud Base
CCN Concentration [#/cm3]
2500
2000
1500
1000
500
0
1200
23:20:00
24:47:20
19:21:40
20:43:40
20:03:10
20:17:10
21:33:30
22:16:30
20:13:10
22:47:20
17:37:30
20:36:30
21:01:30
22:08:20
18:04:00
19:36:10
2-JUL
8-JUL
9-JUL
12-JUL
25-JUL
26a-JUL
26b-JUL
29-JUL



Cloud Base Temperature 5.1 ºC

Cloud Base 0.6 % Ambient Supersaturation and STP

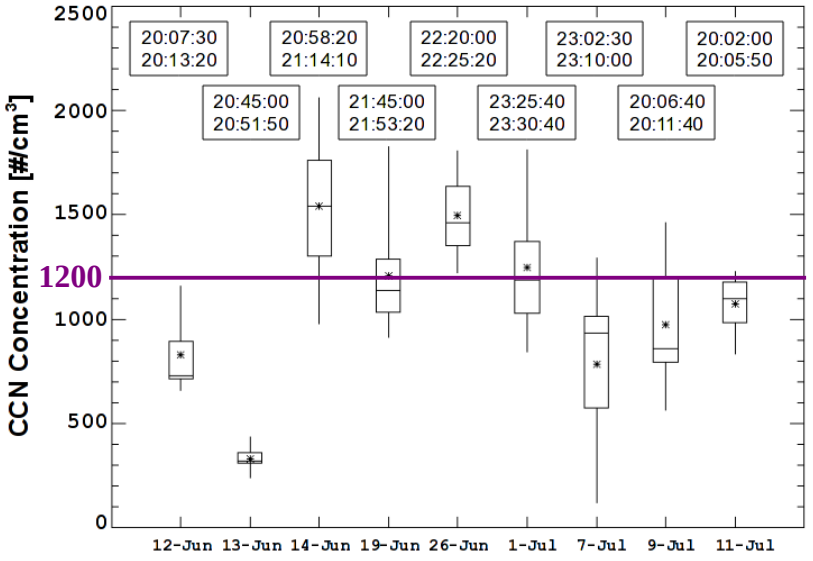
25 Percentile – 1740 [#/cm^3]

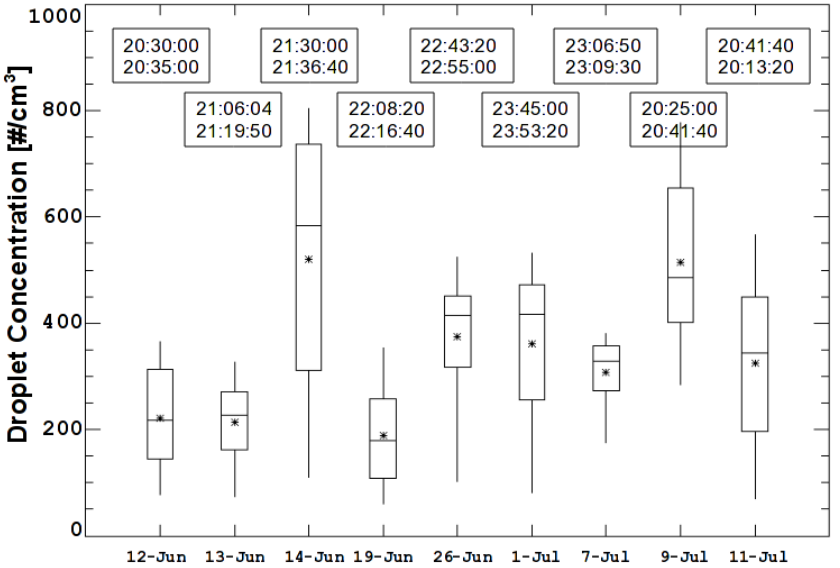
50 Percentile – 1880 [#/cm^3]

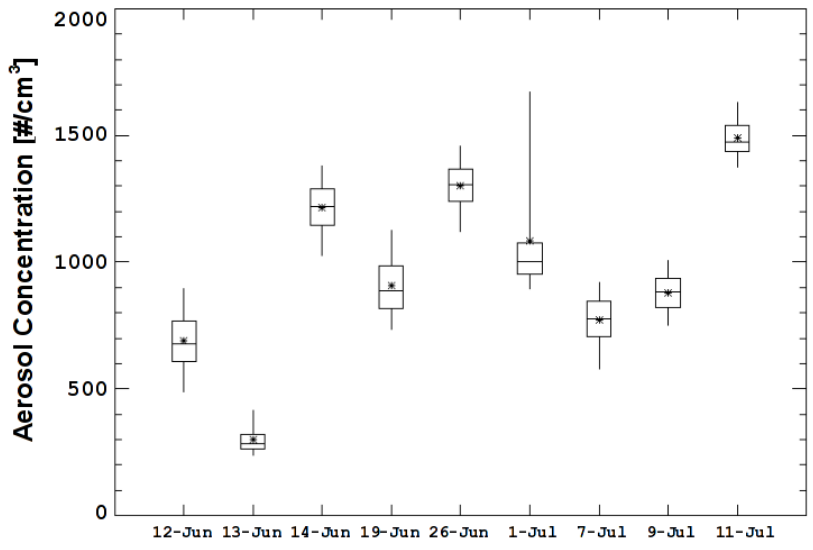
75 Percentile – 2050 [#/cm^3]

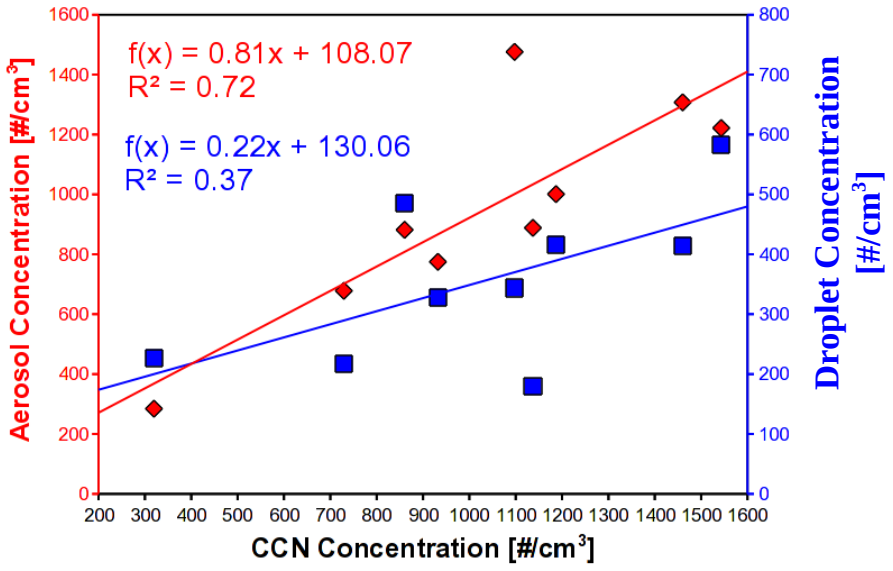
Surface Temperature 14 ºC

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).

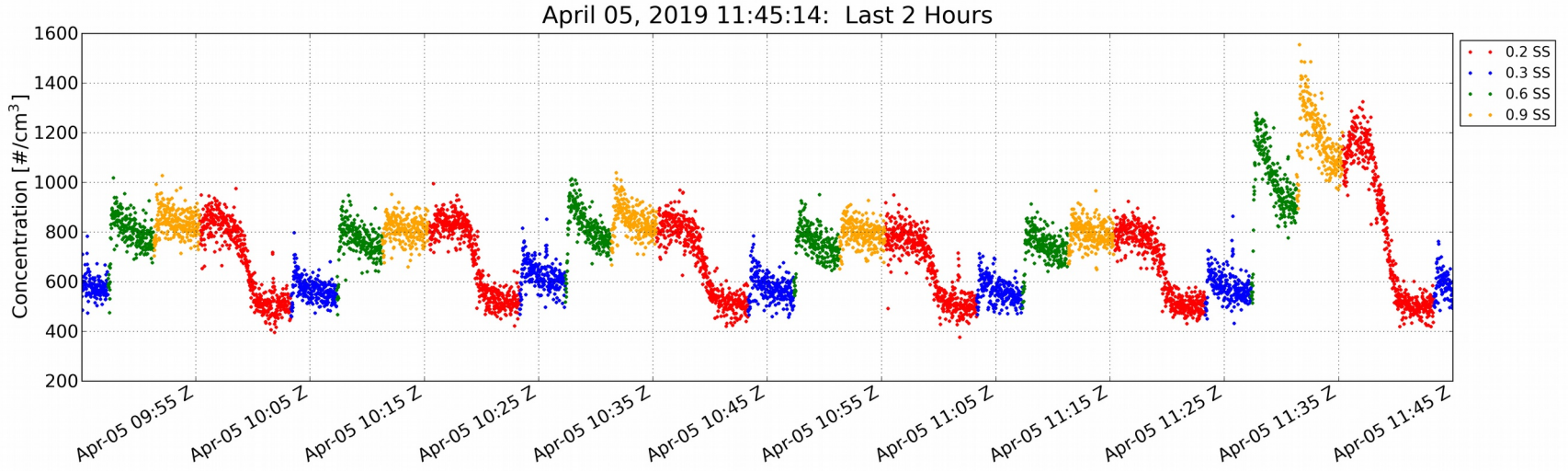

20:07:30
20:13:20
20:58:20
21:14:10
22:20:00
22:25:20
23:02:30
23:10:00
20:02:00
20:05:50
20:45:00
20:51:50
21:45:00
21:53:20
23:25:40
23:30:40
20:06:40
20:11:40
1200
CCN Concentration [#/cm3]
2500
2000
1500
1000
500
0
12-Jun
13-Jun
14-Jun
19-Jun
26-Jun
1-Jul
7-Jul
9-Jul
11-Jul

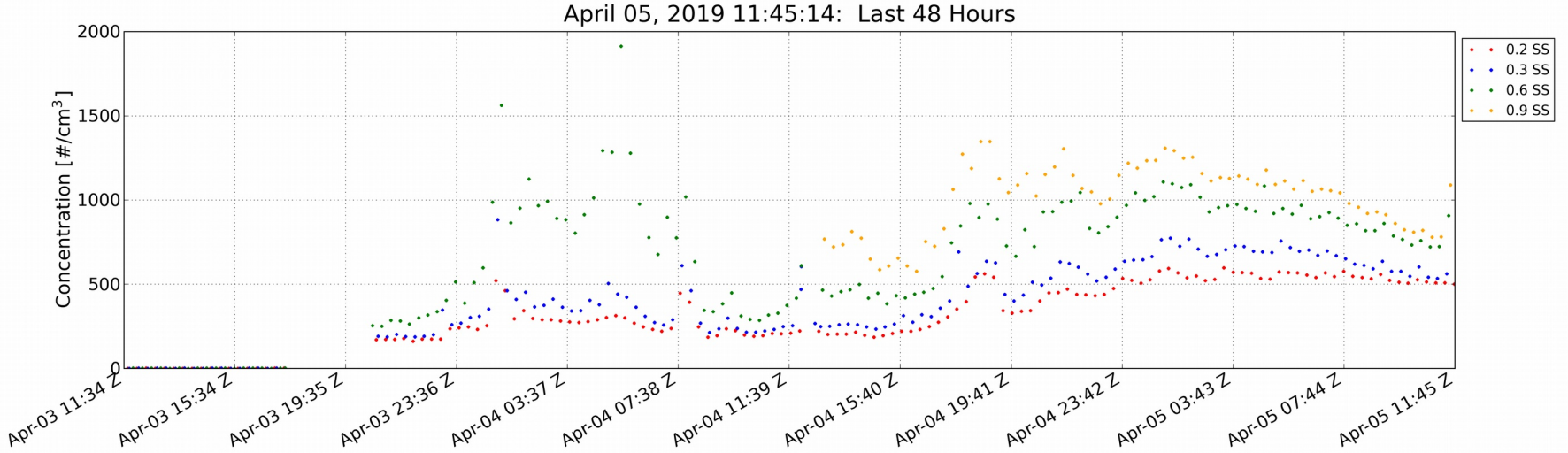

20:30:00
20:35:00
21:30:00
21:36:40
22:43:20
22:55:00
23:06:50
23:09:30
20:41:40
20:13:20
21:06:04
21:19:50
22:08:20
22:16:40
23:45:00
23:53:20
20:25:00
20:41:40
Droplet Concentration [#/cm3]
1000
800
600
400
200
0
12-Jun
13-Jun
14-Jun
19-Jun
26-Jun
1-Jul
7-Jul
9-Jul
11-Jul


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]
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
CCN Concentration [#/cm3]

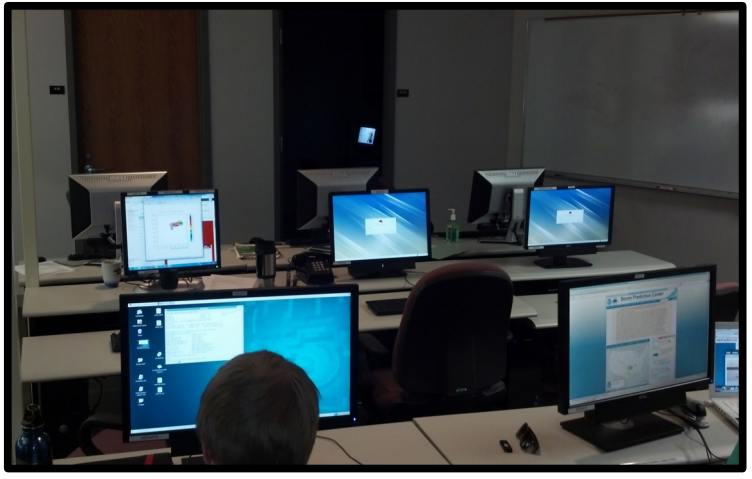
Current CCNC: http://aerosol.atmos.und.edu/





Conclusions

- Measurements are expensive.
  - Requires Robust Software
  - Need Quality Controlled and Quality Assured Data from Advanced Instruments.
  - Range of Sampling Locations
- Measurements have large impacts on advancing scientific understanding.
  - Only measurements tell you what concentration really are at a location.



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If your in the Fog
Ask Questions

Hopefully things are a little clearer.

Thanks for listing.

Conversion of Gases to Particles