Airborne Measurements of Microdust

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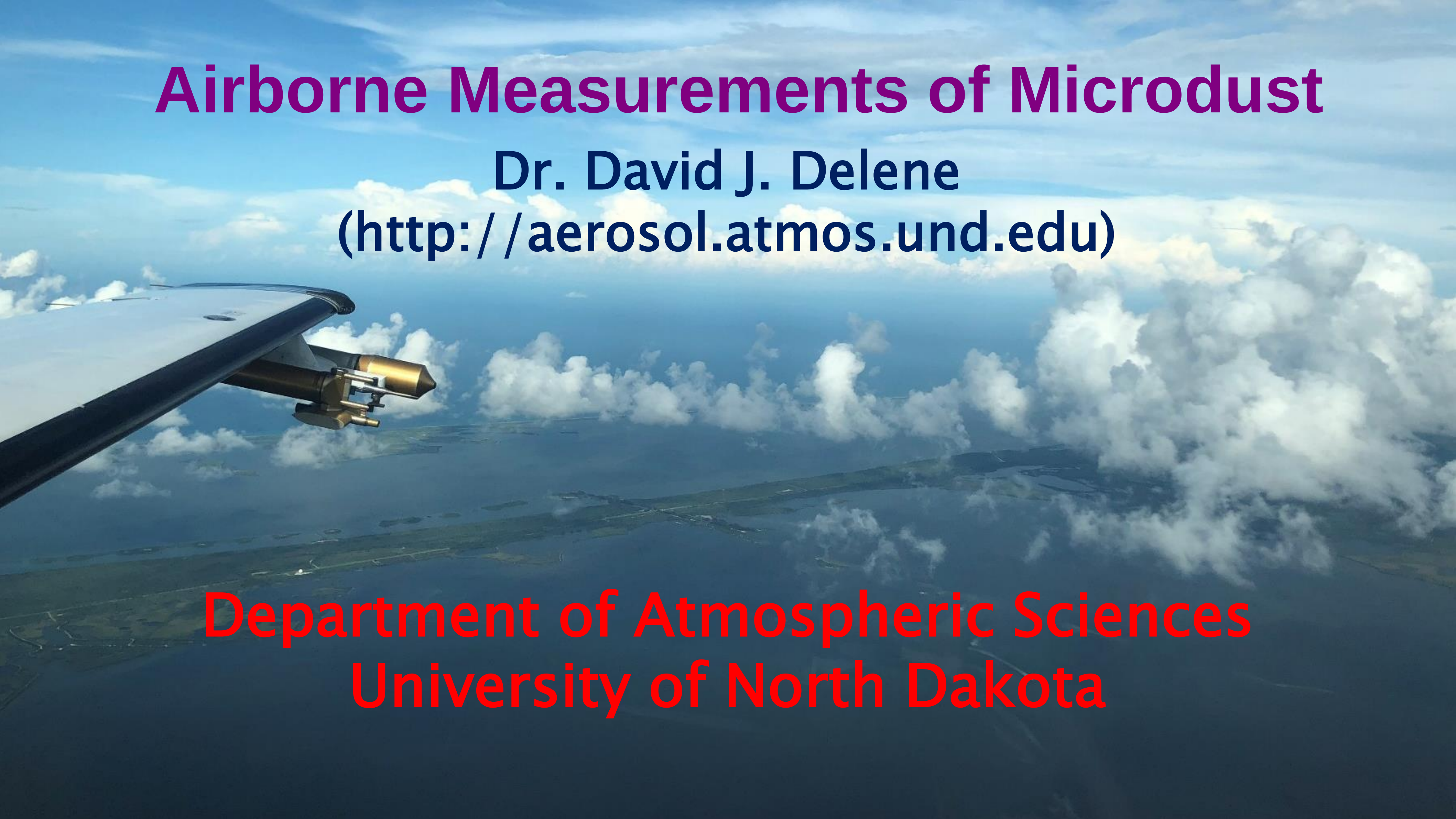

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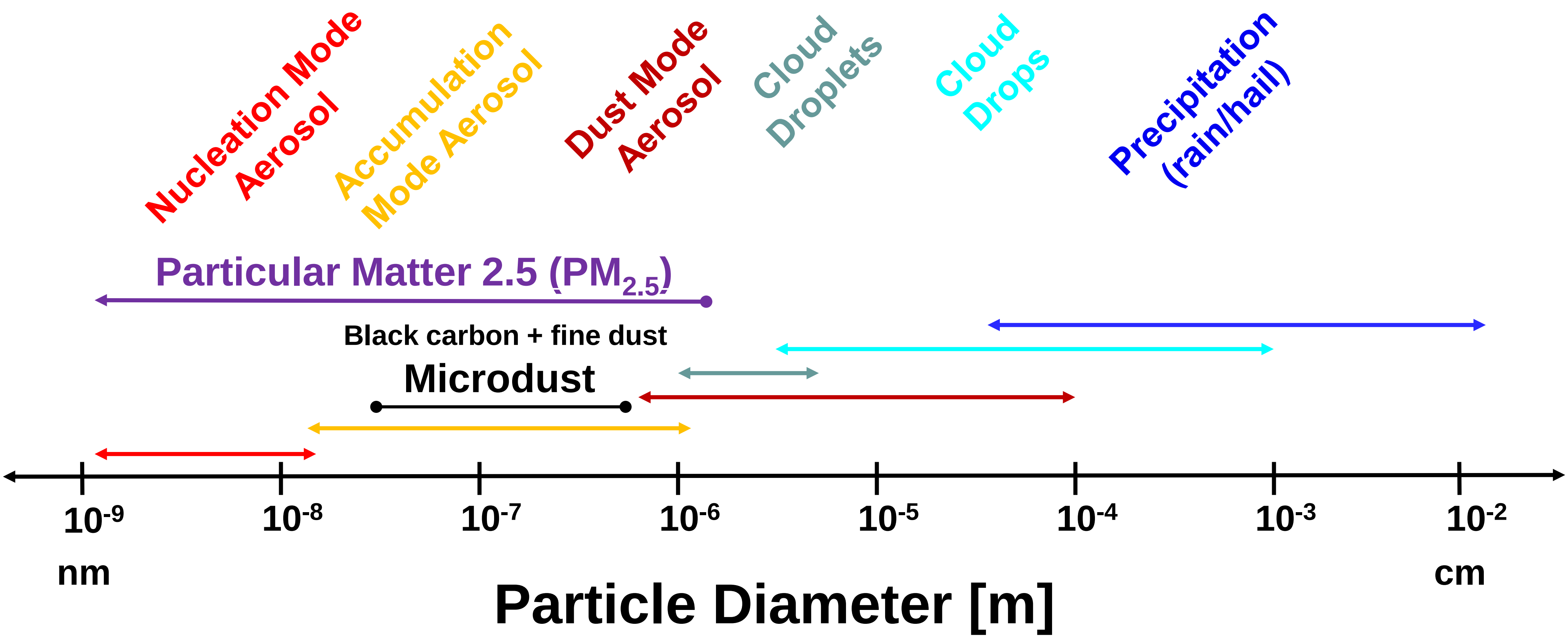
Measurements for Improved Air Quality

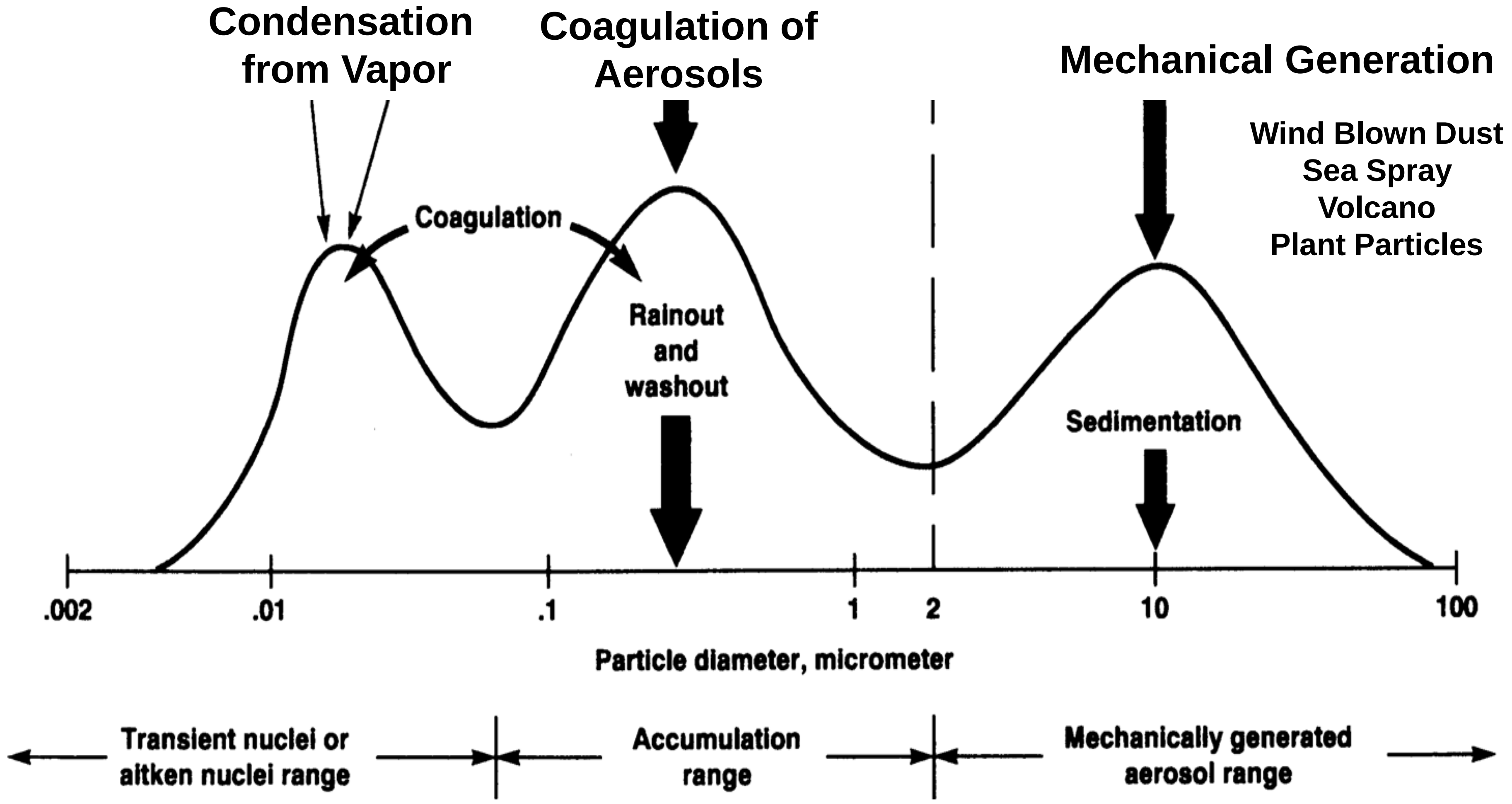
- Review our knowledge of microdust, clouds, and precipitation.
- Define the sources and sinks of microdust, including removal by clouds and precipitation.
- Airborne measurements fill caps in surface measurements and allow source and removal process to be understood.

Classification of Particles



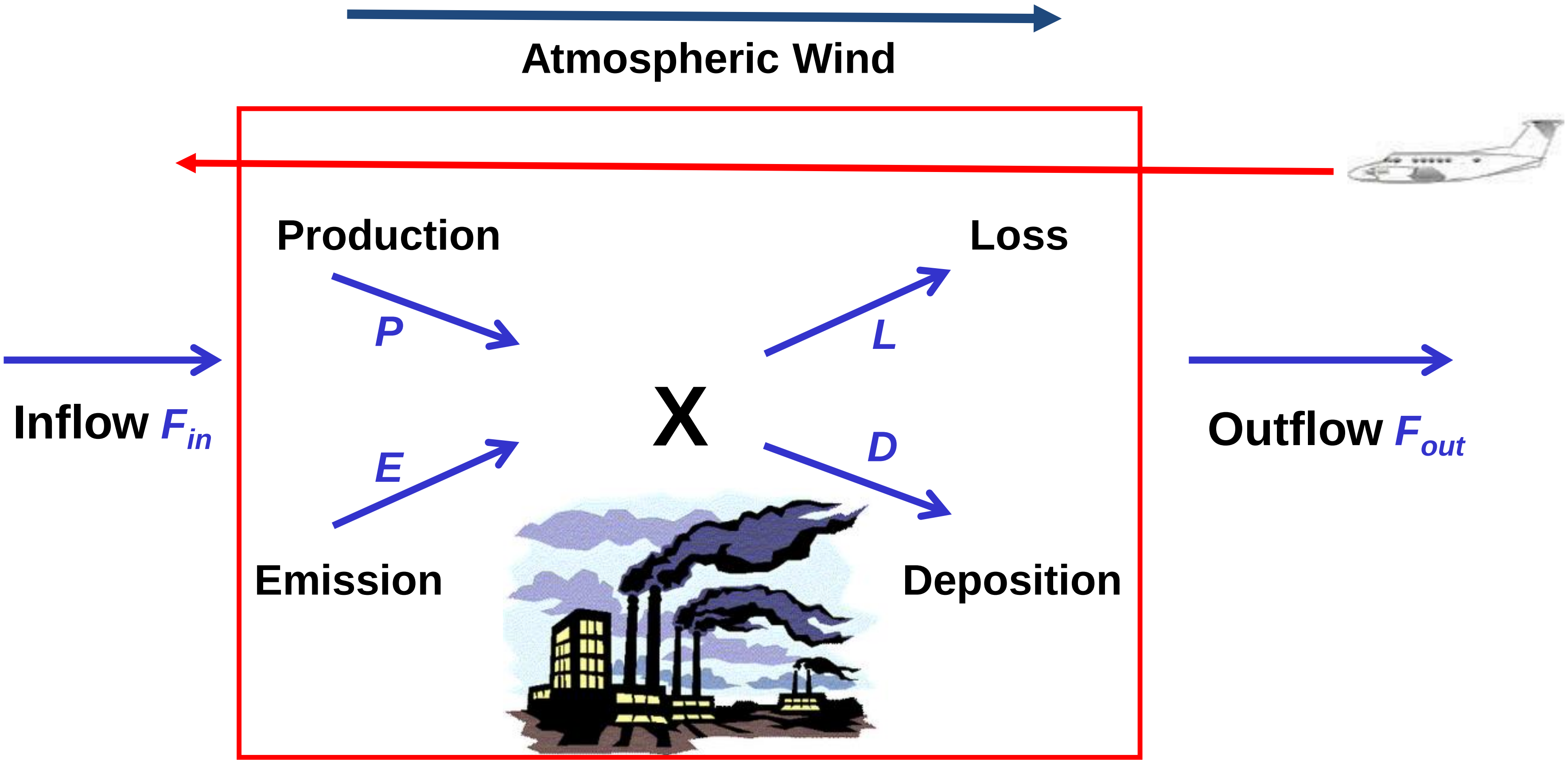
Precipitation and atmospheric mixing reduces particles ($PM_{2.5}$).

Sources and Sinks of Particles



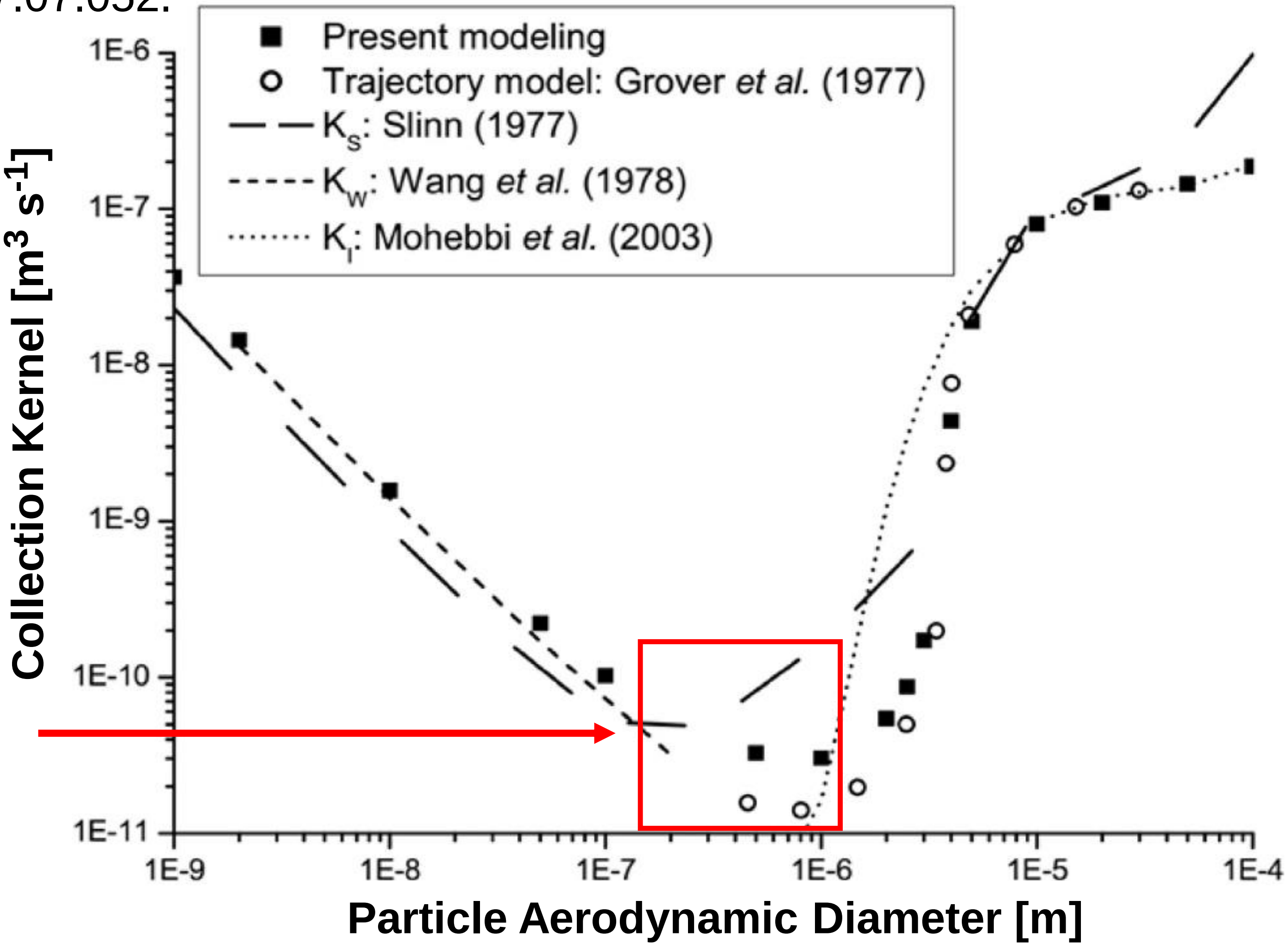
Courtesy of Singh: Figure 5.4

Airborne Measures for Microdust Source



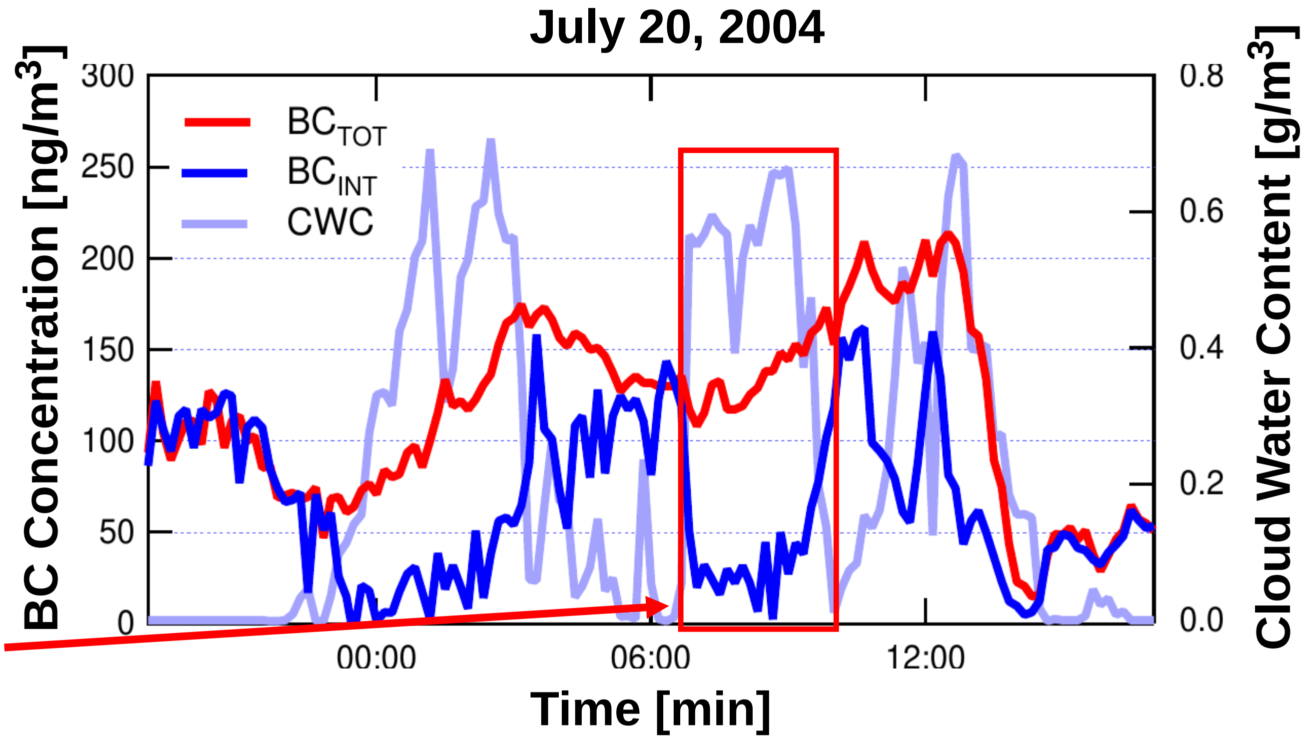
Cherrier, G., E. Belut, F. Gerardin, A. Tanière, and N. Rimbert, 2017: Aerosol particles scavenging by a droplet: Microphysical modeling in the Greenfield gap. Atmospheric Environment, 166, 519–530, doi:10.1016/j.atmosenv.2017.07.052.

- Modeling of droplet scavenging (removal) of aerosols.
- Fig. 6 – Collection kernel values at Re_d = 30 and H = 0 as a function of particle aerodynamic diameter. Here $K_w = K_B$ because of the null value of H.
- **Microdust of 0.1 to 1 µm in diameter are not removed as effectively as larger or smaller sized particles.**



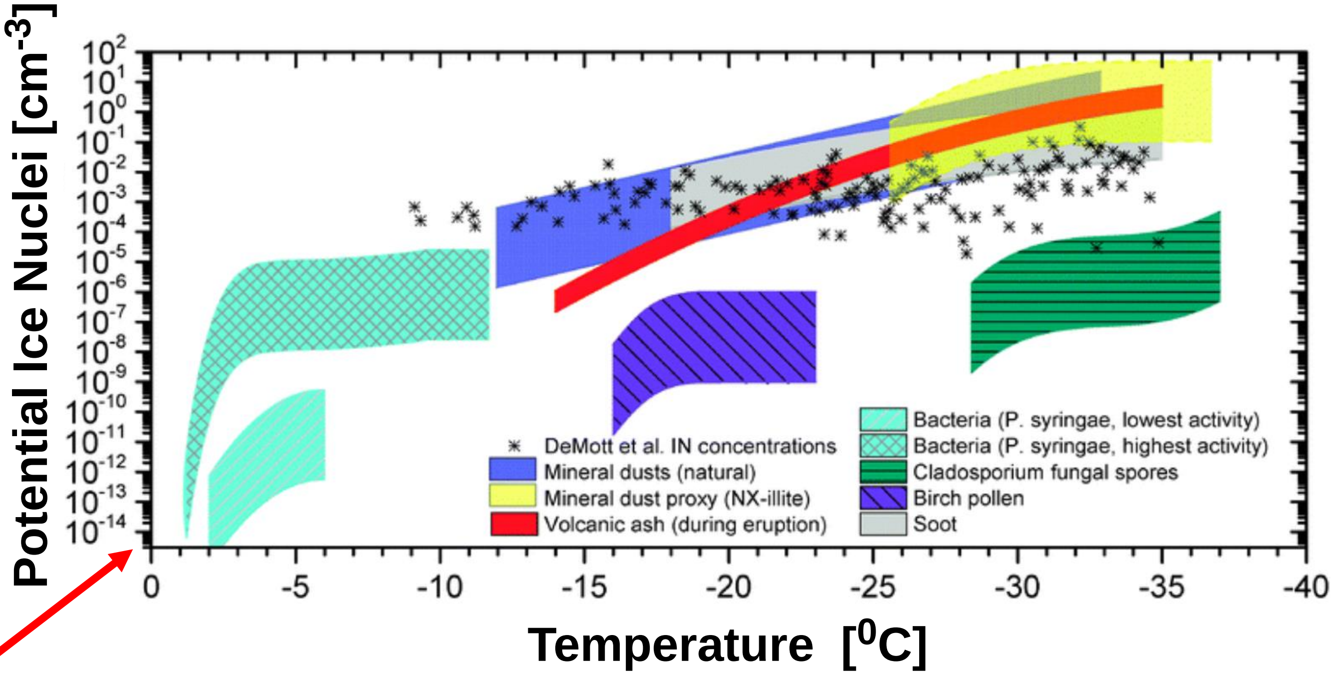
Cozic, J., B. Verheggen, S. Mertes, P. Connolly, K. Bower, A. Petzold, U. Baltensperger, and E. Weingartner, 2007: Scavenging of black carbon in mixed phase clouds at the high alpine site Jungfraujoch. Atmos. Chem. Phys., 7, 1797–1807, doi:10.5194/acp-7-1797-2007.

- Black carbon (BC) microdust is scavenged (removed) as effectively as other microdust, which indicates that black carbon microdust is covered with soluble material.
- Fig. 2 – Temporal evolution of the total and interstitial black carbon concentrations along with the temporal evolution of the cloud water content (CWC) for a liquid cloud (i.e., no ice phase).
- **Microdust, including Black Carbon (pollution), is incorporated into cloud droplets.**



Murray, B. J., D. O'Sullivan, J. D. Atkinson, and M. E. Webb, 2012: Ice nucleation by particles immersed in supercooled cloud droplets. Chem. Soc. Rev., 41, 6519–6554, doi:10.1039/C2CS35200A.

- Mineral dust, biological species, and carbonaceous combustion produced particles immersed within supercooled water droplets nucleate the formation of ice.

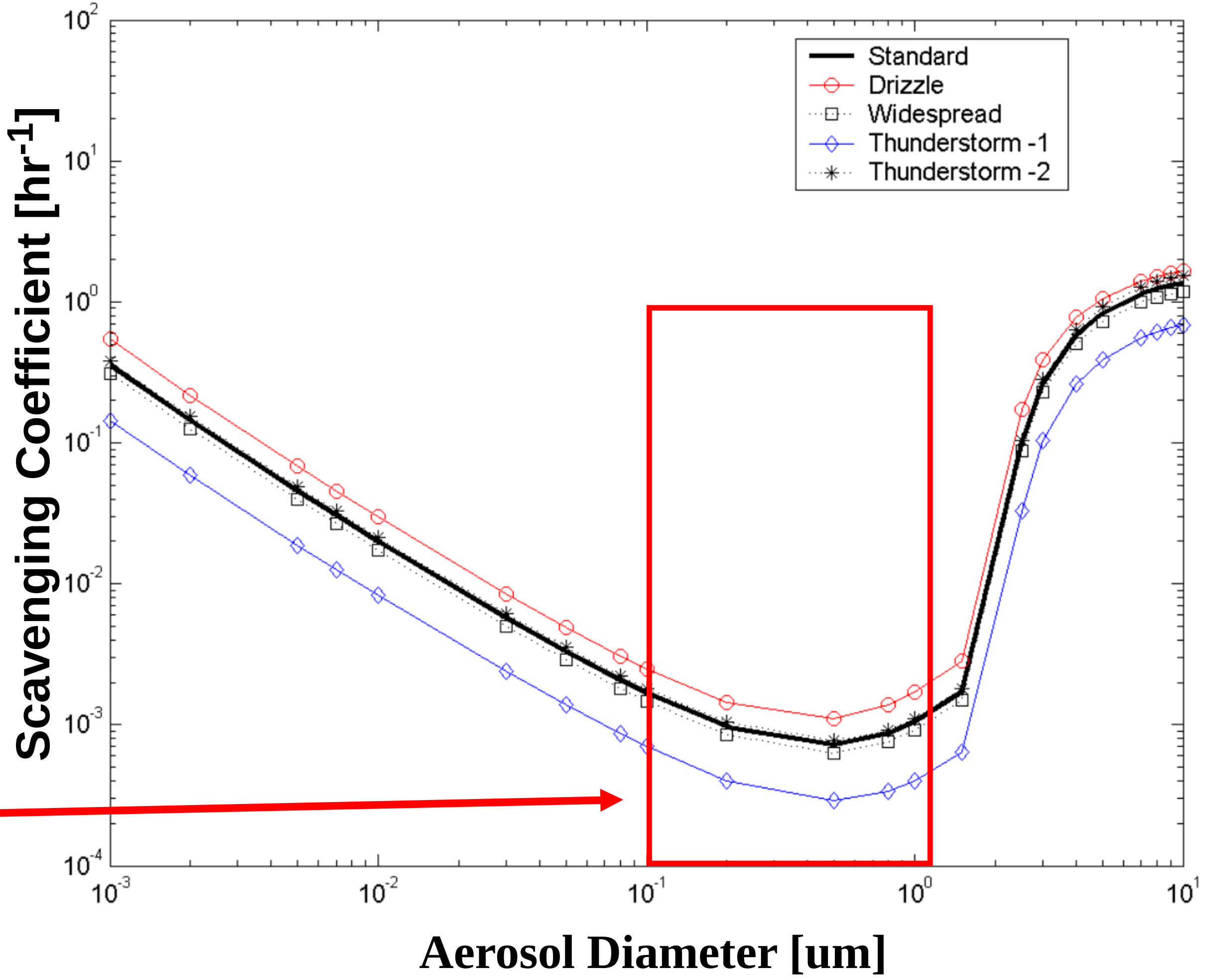


- **The atmosphere lacks microdust that nucleates ice at warm temperatures.**

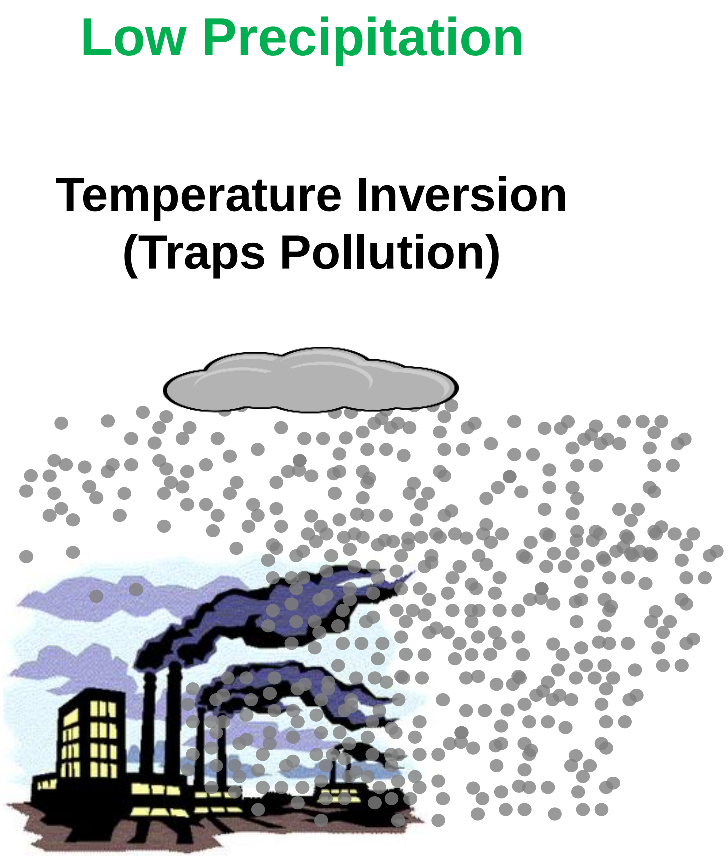
Fig. 19 – Potential immersion mode ice nuclei concentrations as a function of temperature for a range of atmospheric aerosol species. Calculations performed using concentrations of different particle sizes.

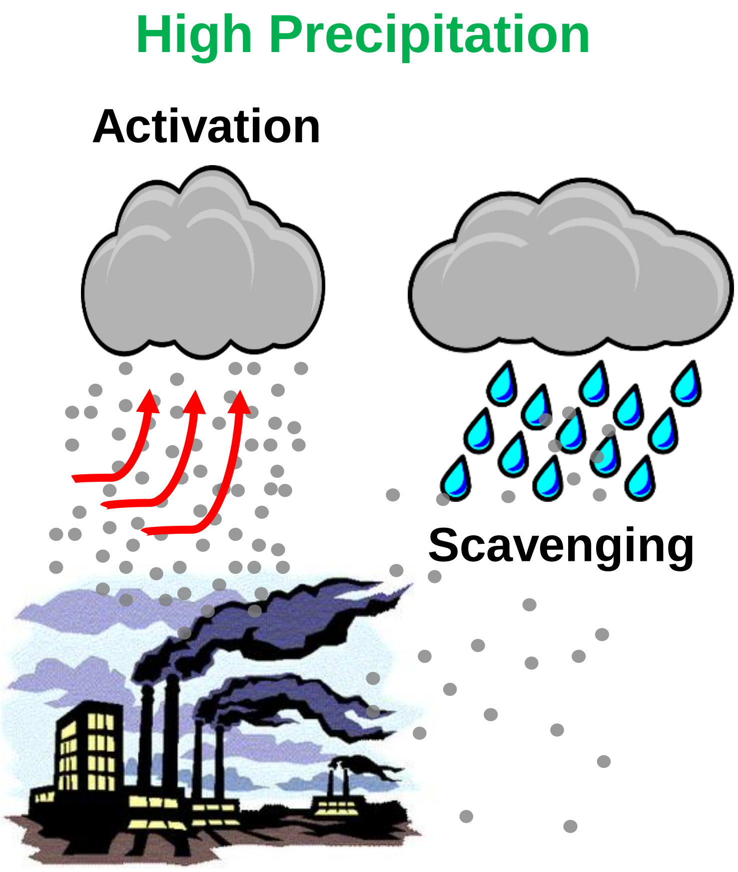
Andronache, C.: Estimated variability of below-cloud aerosol removal by rainfall for observed aerosol size distributions, Atmos. Chem. Phys., 3, 131-143, https://doi.org/10.5194/acp-3-131-2003, 2003.

- Below-cloud scavenging (removal) of microdust by rainfall increases with rainfall rate and has a significant dependence on particle size.
- Fig. 3B – Scavenging coefficient L(dp) versus aerosol diameter for the same raindrop size distributions. The plots are for rain rate of (R) of 1 mm hr^{-1}.
- **Microdust of 0.1 to 1.0 µm in diameter are not removed by rainfall as effectively as larger or smaller sized particles.**

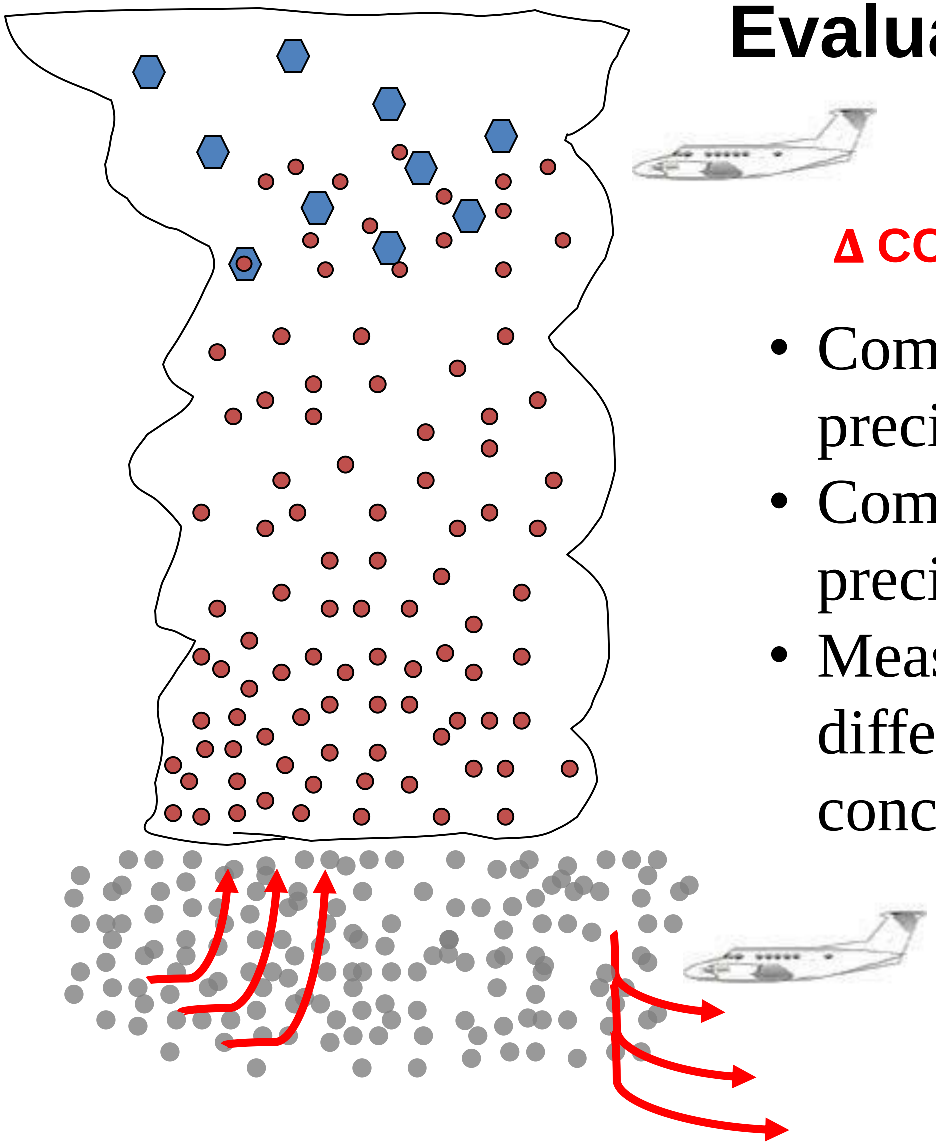


Airborne Measurements for Microduct Sink





Evaluating the Removal of Microdust

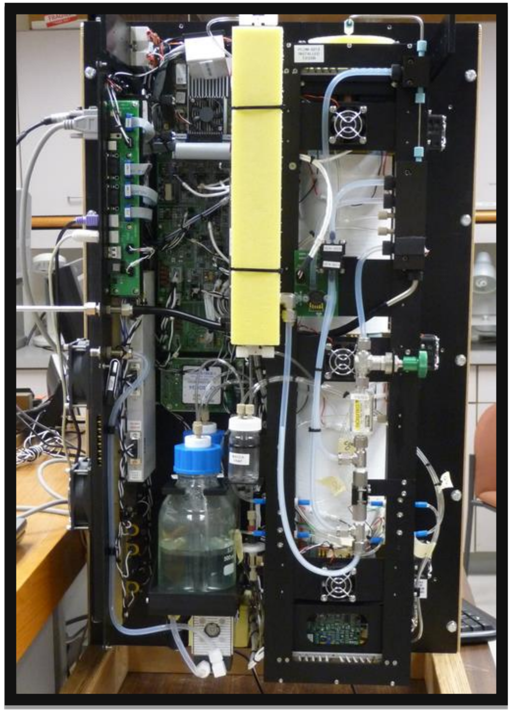


Δ CCN and/or Δ IN -> ↑ Precipitation -> ↓ Microdust

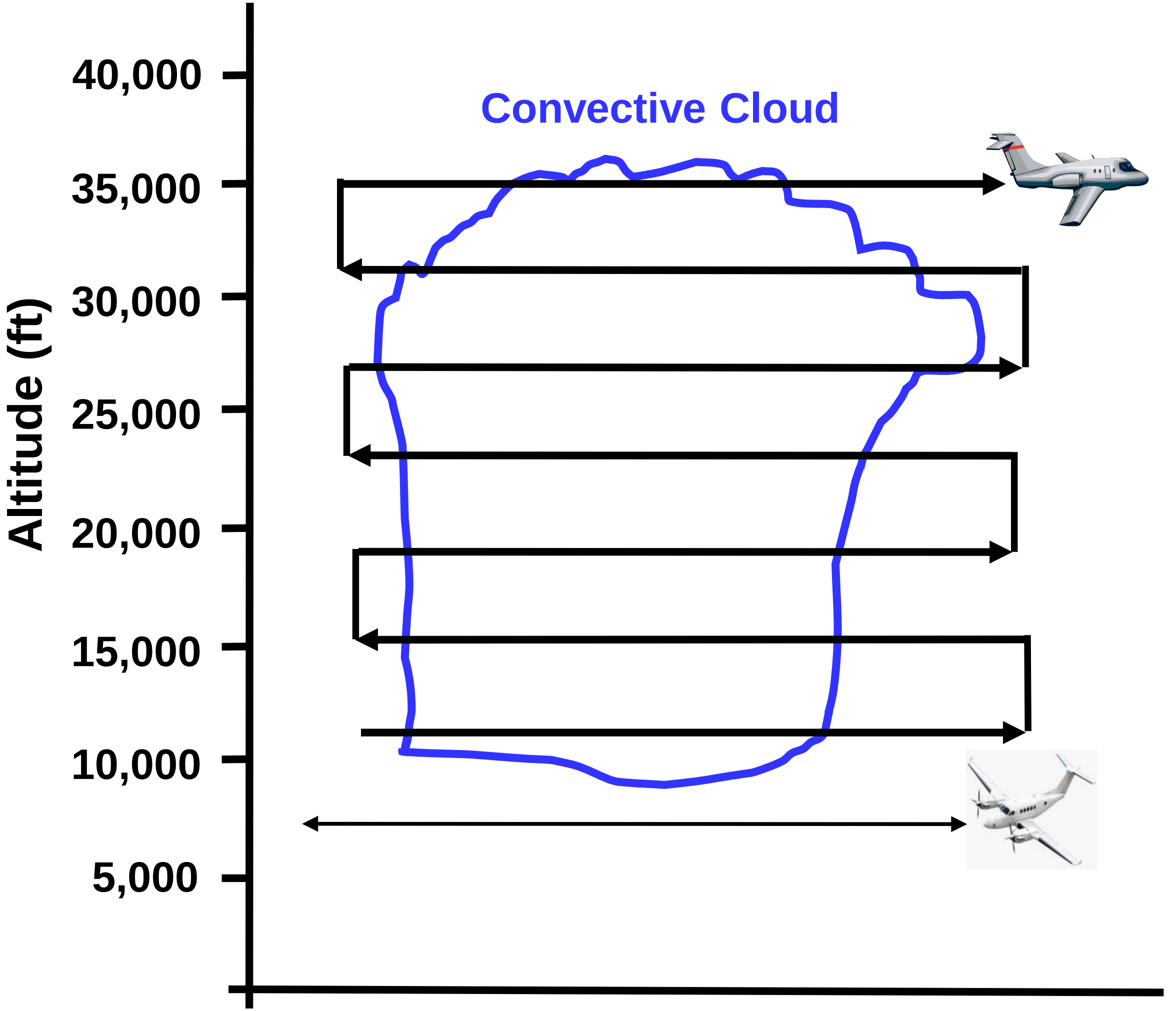
- Comparison of microdust at cloud base prior to precipitation and after precipitation.
- Compare microdust upwind and downwind of precipitating clouds.
- Measure changes in cloud properties due to difference in cloud base microdust concentrations.

Korean Specific Measurements Required

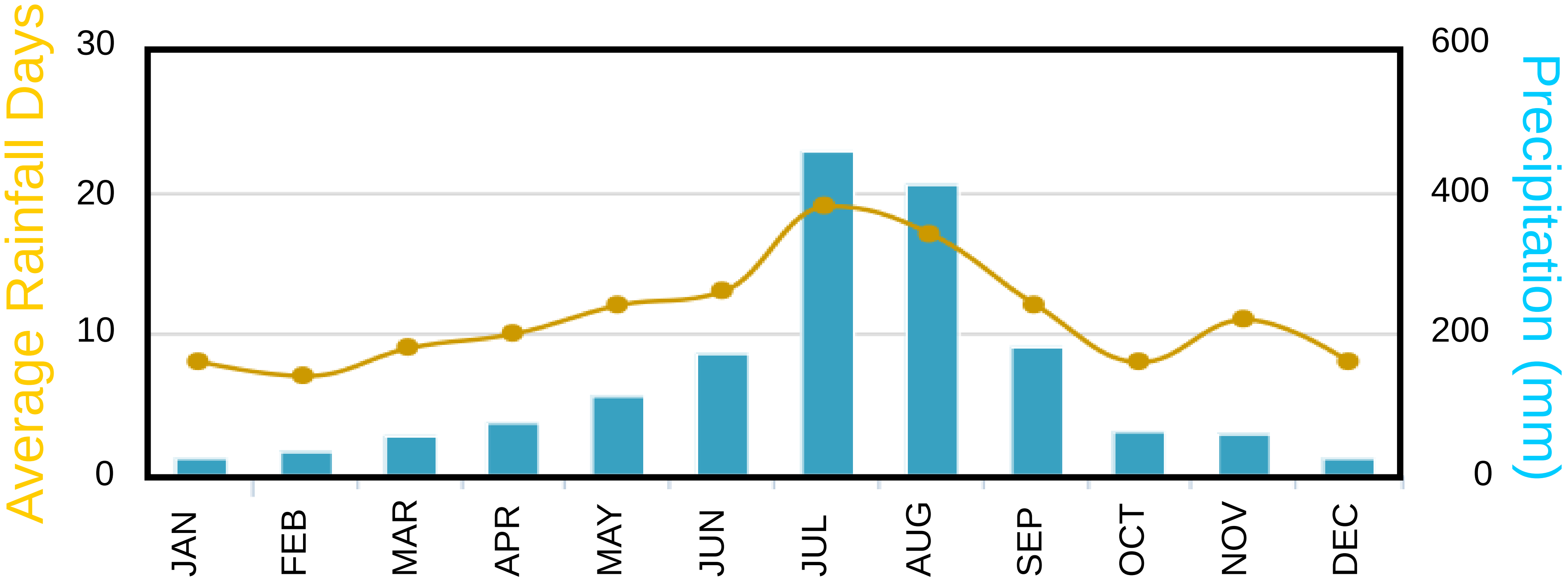
- The concentration of aerosols (cloud condensation nuclei and microdust) related to clouds and precipitation development on the Korean Peninsula.
- Microdust impact on the ability of clouds to produce large drops and ice particles.
- Microdust impact on the temperature of ice formation in clouds.
- What are the commonalities and differences between urban and rural clouds?



Aircraft Observations



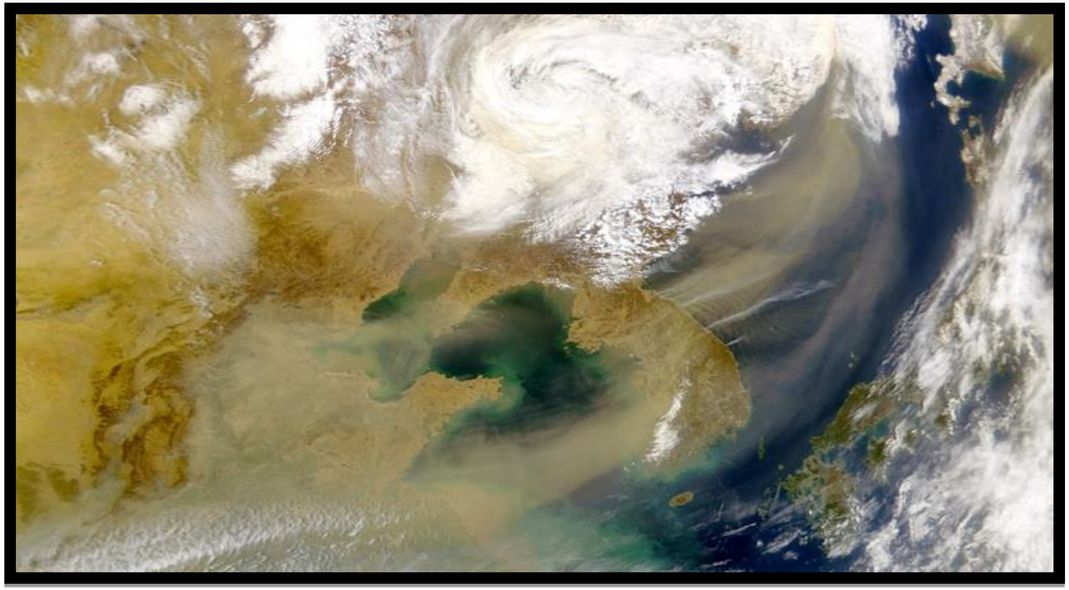
Seoul Average Rainfall (mm)



Late Spring (May/June) and Early Fall (Sep/Oct) Important Time Periods for Field Measurements.

Summary and Conclusions

- Measurements are key to understanding changes in the amount of Microdust.
- Measurement are necessary for determining sources.
- Precipitation and air mixing reduces microdust (sink).



References – Airborne Measurements

Andronache, C.: Estimated variability of below-cloud aerosol removal by rainfall for observed aerosol size distributions, Atmos. Chem. Phys., 3, 131-143, https://doi.org/10.5194/acp-3-131-2003, 2003.

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Delene, D., Hibert, K. Poellot, M., and Brackin N., The North Dakota Citation Research Aircraft Measurement Platform, SAE Technical Paper 2019-01-1990, 2019, doi: 10.4271/2019-01-1990.

George A. Kantor, David Wettergreen, James P. Ostrowski and Sanjiv Singh Conference Paper, Proceedings of the SPIE Conference on Sensor Fusion and Decentralized Control in Robotic Systems IV, Vol. 4571, pp. 76-83, October, 2001

Murray, B. J., D. O’Sullivan, J. D. Atkinson, and M. E. Webb, 2012: Ice nucleation by particles immersed in supercooled cloud droplets. Chem. Soc. Rev., 41, 6519–6554, doi:10.1039/C2CS35200A.