Transformational Research - Aerosol-Cloud Expert Rain System (TRACERS)

## Principal Investigator Information

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Modeling all processes involved in the chain of events that result in rain is difficult due to the complex interactions that occur on many different spatial and temporal scales. Atmospheric components experience small scale changes due to turbulence while embedded in an environment characterized by an overall steady thermodynamic state. Due to this complexity, there is currently no formulation that can predict rain formation given measured properties. The rain formation processes are not understood well enough to allow the development of sufficiently accurate models. Processes linking below cloud-base properties to measurements of the cloud’s droplet distribution is only possible in an averaged sense. Therefore, it is impossible to directly quantify how changes introduced by cloud seeding methods affect cloud microphysical properties. Without quantitative relationships, it is impossible to model the effects that different techniques have on precipitation amounts.

Our proposed project aims to be transformational by using advancements in Machine Learning to relate measured atmospheric properties to resulting cloud properties. The project will treat the complex processes involved in water vapor condensation to form a cloud as a black box and simply relate measured atmospheric properties to measured cloud properties. Utilization of such a black box approach does not enable understanding of the underlying processes; however, it does allow artificially produced changes, such as changes produced by seeding clouds, to be modeled so that accurate rain production can be determined. Standard deep learning methods, such as Convolutional Neural Network, will be applied to a labeled data set of measurements below and above cloud base. Obtaining a large, labeled data set is the project’s core work, which uses an innovative measurement methodology. The element indium is used to create a tracer flare that allows for distinguishing seeded cloud parcels from non-seeded, naturally occurring cloud parcels. A counter-flow virtual impactor is used to evaporate droplets in cloud parcels to enable measurements of particles involved in the nucleation process. An Aerosol Mass Spectrometer system monitors the particle chemical composition in real-time for the element indium. Detection of indium is a direct indication that the cloud parcel is affected by seeding since indium is not a detectable component of atmospheric aerosols. Cloud droplet size distribution measurements concurrent with indium detection provide observations of seeded parcels, while periods without indium detection provide observations of non-seeded parcels. Concurrent time series measurements of below cloud base properties and cloud properties thus provide a labeled data set. The rapid variation of properties in space and time provide a large data set that can be used by standard deep learning methods to accurately predict cloud properties. Incorporating the developed cloud parameterization into existing weather forecasting models would result in accurate determination of precipitation changes due to different weather modification techniques. The proposed expert rain system utilizes atmospheric observations to determine rain production similar to how Machine Learning methods have been shown to accurately predict planet orbits without using the underlying physical law but instead only using past planet locations.