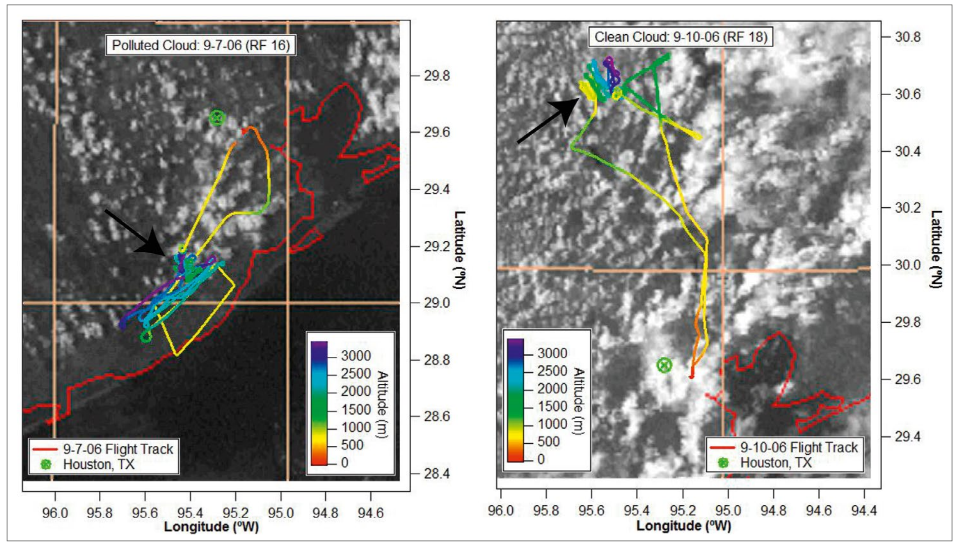
Cloud-aerosol interactions and climate change

To better understand climate change and the factors that influence it, **Dr Jennifer Small Griswold**, an atmospheric scientist from the University of Hawai'i, has been investigating the effects of atmospheric aerosols on cloud structure. The data gathered during this investigation offers insights into the relationship between cloud-aerosol interactions and climate, taking us a step closer to understanding current climate change and offering opportunities to improve our existing methods of study.

Climate change is often a controversial topic. Political stances can influence public trust in claims made by climate scientists and imperfections in the way we study climate, paired with vague data this can lead to misinterpretations, further fuelling that distrust. By improving the methods and models we use to examine climate change, not only can we better our understanding of its effects, we can also solidify trust in future research, enabling actions to be taken before it's too late.

Dr Small Griswold has been doing just that. As a specialist in cloud microphysics, Dr Small Griswold has been able to build upon previous research to fine tune it. This has allowed more accurate data to be collected and has uncovered some interesting findings on the effects of pollutant aerosols on rainfall and the reflection of solar radiation. By collecting data on cloud and aerosol properties, Dr Small Griswold and her collaborators have been able to assess the accuracy of existing models used to simulate cloud-aerosol interactions and identify their short-comings.

Aerosols are causing changes to cloud coverage and lifetime that we do not yet fully understand



Satellite images showing cloud structures with flight tracks of the CIRPAS Twin Otter during the 2006 Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS) field campaign in Houston Texas, showing an example of a polluted flight track down wind of the Houston pollution plume and a clean cloud case north of the pollution plume.

THE IMPORTANCE OF CLOUDS

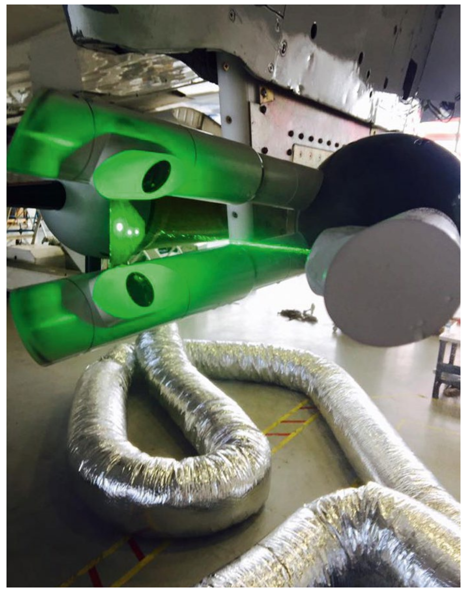
Without clouds, the Earth would be a lot hotter and a lot dryer. Understandably, this would make practices such as agriculture a lot harder to maintain. This is because clouds not only provide much needed rainfall, but they also act as a protective layer surrounding the Earth, keeping a balance between the amount of solar radiation that gets reflected back into space and the amount that reaches the Earth's surface. Too much radiation and temperatures can increase, too little and they decrease.

This delicate balance can be disrupted when aerosols – particles in the air resulting from events such as the burning of vegetation, industrial activities or desert dust – interact with clouds. Aerosols can have a marked effect on cloud structure, size and lifetime. These changes can in turn have an impact on rainfall and solar radiation levels reaching the Earth's surface. Whether from man-made or natural sources, these aerosols are causing changes to cloud coverage and lifetime that we do not yet fully understand but that could, undoubtedly, have a big impact on future life on Earth.

A DIFFICULT UNDERTAKING

The factors which lead to cloud formation, lifetime and rainfall are surprisingly complex, making studying them a difficult task. To take on this challenge, Dr Small Griswold examines these processes, particularly in warm cumulus clouds, using aircraft and satellites to observe cloud composition and structure.

Warm and cold clouds do not form rain in the same way. While a cold clouds ice content is important in starting rainfall, a warm cloud does not contain ice crystals so different processes must be at work. We know from some of Dr Small Griswold's previous work that entrainment – a process by which dry air is drawn into a cloud through turbulent motion – leads to the dilution of a warm clouds water content.



Top left: Dense trade wind cumulus field captured as sunset between the islands of Oah'u and the Big Island of Hawai'i in Summer 2016. Top right: Stratocumulus cloud field with a rolled and cellular structure captured on a transit from Hawai'i to California over the eastern Pacific Ocean.

Below: The Flight-Probe Dual Range Phase Doppler Interferometer mounted on the wing pylon of the NASA P-2 Orion research aircraft for the ObseRvations of Aerosols above CLouds and their intEractionS (ORACLES) field campaign. By spraying droplets the laser used for measurements can clearly be seen.

If enough of this dry air is mixed into the cloud it will dissipate, but the way in which the mixing of dry and cloudy air occurs can have differing effects on its structure. Homogenous mixing is when all the droplets involved are exposed to the same levels of saturation, while inhomogenous mixing means that drops in close proximity evaporate at a higher rate to those which are further away. Dr Small Griswold has found that homogenous mixing is most important at the tops of warm clouds, where large water droplets are found most frequently. These large water droplets initiate rainfall, so a cloud experiencing more homogenous mixing is more likely to rain than a cloud where inhomogenous mixing has occurred.

Once she established some of the factors involved in warm cloud structure and life cycle, Dr Small Griswold was able to focus on how aerosols affect them. Her subsequent work through observational flights has found that when aerosols interact with clouds, they can cause the number of small water droplets to increase. These small droplets are what give clouds their reflectance – the higher the number of small droplets, the higher the reflectance of the cloud, preventing solar radiation from reaching the Earth. Aerosol interference also leads to fewer large, rainfall initiating water droplets within the cloud as this appears to increase the level of inhomogenous mixing seen within the affected cloud. However, the data collected during these flights has not been conclusive as the changes in droplet size are often too small to be statistically significant at present and require further study.

IMPROVING ON PAST MODELS

Research of this kind can be a huge undertaking, often involving large teams of scientists, each dedicated to a different factor. Location, season and aerosol types and levels, all must be taken into account. It is also difficult to predict how a cloud has been affected by aerosols prior to being observed and how this may influence any data collected. It is this that leads to imperfections in modelling data, as the sheer number of factors involved, and the variability of these factors is not yet entirely clear. The inaccuracies in modelling data are problematic for predicting future trends and mean we could be missing out on a wealth of knowledge that could prove to be vastly important to the future of agriculture and water availability, to name but a few consequences of climate change. To improve these models, Dr Small Griswold and her collaborators have been working to compare and refine how existing models represent clouds, aerosols and how they interact.

Comparing the models has been meticulous work, with seasonal and regional effects on the factors involved being accounted for in each. By comparing the historical accuracy of the models to monthly satellite data they have been able to identify which variables the models over or under estimate. They conclude that the models seem to poorly account for seasonal differences and varying aerosol levels but that improvements to these parameters will increase the accuracy of models over time. With more accurate data we will be better able to predict trends in climate change, and, hopefully, solidify trust in climate science.

We could be missing out on a wealth of knowledge that could prove to be vastly important

Q&A

What sparked your interest in cloud microphysics?

As a child, I lived on the beach and would watch storms and clouds. This initially sparked my interest in the study of meteorology. When I was older, I found an undergraduate program to learn about weather and climate. After completing my BS in meteorology, I realised that I wanted to know more about how and why clouds work to produce the different types of precipitation we see at the surface. I then researched for a graduate program that would let me learn all there is to know about clouds!

Where do you hope to take this research next?

We will continue to investigate aerosol impacts on clouds by looking at different cloud and aerosol types using both observations from aircraft and from space using satellites. The biggest questions in the cloud physics community relate to how aerosols modify cloud properties and processes by changing how they interact with solar radiation and when and if they produce precipitation. It essential to continue to work on these questions since they are the biggest uncertainty in how we model global climate.

Are some regions more affected by cloud-aerosol interactions than others?

Different regions are populated by aerosol and clouds of varying types. For aerosols, some are absorbing and some are reflecting, some serve as great cloud condensation nuclei and some don't, these variations mean the cloud impacts vary. The complexity increases when you consider how cloud types are distributed by region. For example, regions like South America are dominated by smoke and others like Northern Africa are dominated by dust. Industrial regions or major cities are a complex mixture of aerosol. The equator for example, has deep cold clouds like thunderstorms and while regions like coastal California have stratocumulus decks that drizzle. If aerosols and clouds are present, interactions can be determined by the aerosol mixture and cloud types present.

Have you ever faced political problems when conducting this research?

We have faced issues when trying to fly research aircraft out of foreign nations. Sometimes, different parts of foreign governments (such as tourism, transportation or military) are hesitant to let 100 or so American scientists come to work in their country. There is often fear related to how we study the clouds, they may not believe that we're flying science instruments and that we might be trying to do some type of surveillance. We've been delayed when starting a field project and we've been denied entry and even had to find an alternate location. The political issues we have experienced had nothing to do with the topic of our research, but because we were representing an American agency and using aircraft.

Once you have improved the accuracy of the simulation models, how can they be used to further our understanding of cloud-aerosol interactions?

Once we can provide the modelling community with accurate parameterisations of microphysical properties of clouds with and without aerosol, (including for different types of clouds and aerosol), then they can produce more accurate simulations of global weather patterns. For example, if a certain aerosol species causes a certain cloud type to precipitate more frequently, and if the model does this correctly, it will be able to predict changes in precipitation. Improvements to models are then used to help guide governments and environmental agencies when planning for changes to weather patterns and climate.

Aerosols modify cloud properties and processes by changing how they interact with solar radiation and sometimes produce precipitation

Detail

RESEARCH OBJECTIVES

To gain a better understanding of climate change and the factors that influence it, Dr Jennifer Small Griswold's research focuses on cloud microphysics, aerosol-cloud-climate interactions, aircraft observations of clouds, and satellite remote sensing of clouds and aerosol.

FUNDING

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COLLABORATORS

- JPL collaborators - Jonathan H. Jiang and Hui Su
- UCSC collaborators - Patrick Y. Chuang
- CIRPAS collaborators - Haflidi Jonsson
- ORACLES Science Team

BIO

Dr Small Griswold is a faculty member in the Atmospheric Sciences Department at the University of Hawai'i focusing on cloud microphysics, aerosol-cloud-climate interactions and, aircraft observations of clouds. To study clouds she uses a Dual-Range Flight Probe phase Doppler interferometer for local, mainland and international field projects studying cloud microphysics and precipitation processes.

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