**Student questions: Pierre Herckes colloquium on "Clouds and Fogs in the Earth System"**
8/23/17

I am grateful for all your interest and your questions! Actually I am a little overwhelmed by your questions but I tried to answer all of them, although some short. Feel free to reach out to me by email.
Pierre Herckes

Question 1: You mentioned radiation fogs a few times during the talk. What is radiation fog? Thanks!
Radiation fogs are fogs that form at nighttime when the ground cools and air masses above cool and hence relative humidity increases and we see enhanced condensation on existing particles which if there is sufficient humidity will grow into droplets. So these fogs are a consequence of the absence of radiation from the sun (radiative cooling). Typically in morning hours, when the sun comes and the ground warms, the fogs dissipate.

Question 2: What is the "unclassified genus" slice in the pie chart dividing up the different microbes you found in the clouds; can you say more about it?

The DNA sequences were run against databases and unclassified means there was no match in the database. This can mean unknown or rather not in the database and this can also mean that there were errors in sequencing…

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Question 1: Are cloud droplets the same in clouds that produce rain as those that precipitate as snow?

The **short and simplistic** answer is that no.. rain tends to come out of liquid clouds while snow comes out of ice crystal clouds.. now the relaity gets complicated quickly as there can be supercooled droplets, mixed clouds etc… but as a first simple 1 line answer.. rain - liquid drop clouds and snow- ice crystal clouds.

Question 2: Do species of microbes vary based on the cloud type they are inhabiting?

We do not really know yet as insufficient studies exist. There are only results reported for Puy de Dome (France) (cf further down for references), our results from Whistler are not even published…

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Question 1: If fog is a cloud that is close to the ground, what controls the height of a cloud and causes it to form so low?

This would again require a long answer.. so I try in brief.. fogs can form because of radiative cooling (cf first question too) so cooling on the ground… another kind of fog is advection fog where fog forms when warmer humid air masses are advected over cooler ground and water starts condensing on droplets.. e.g. next to lakes or the ocean where in the wintertime humid air can get advected over land ant then cools down leading to fog… otherwise you can have clouds that just happen to "bump" into land like stratus clouds hitting a mountain… cf picture of cloud interception in the slides or the title page of my talk which actually has Mt. Rainier peeking out of a cloud field.
Link to a good page form the UK metoffice on fog…
http://www.metoffice.gov.uk/learning/fog

Question 2: Is chemical composition of clouds purely a function of what is being released into the atmosphere in a specific location or are there favorable conditions that trap particulates and gasses that could be coming from a long way away from where the cloud forms?

It is a mix of both local and transport.. as aerosol particles and gases have long lifetimes and so these travel and they can interact with clouds…

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Question 1: From your talk, I understood that the discovery of microbial communities in clouds was relatively recent. If clouds are in fact the habitat for these microbes (rather than a transport vehicle), would it be reasonable to look at clouds surrounding other planets for evidence of life?

Yes absolutely…. And it is my understanding that people do this… or are planning to do so (think fly through cloud type plume) .. of course you always have to consider the conditions locally… in some cases you are talking sulfuric acid clouds at -130deg (Venus night time)… so if life exists it will be very different than on Earth… Also keep in mind solid vs liquid clouds…

Question 2: The California Central Valley example clearly shows that anthropogenic activities strongly influence cloud chemistry. How does this change in chemistry affect other characteristics, such as thickness or volume, of the cloud? Is there a change in albedo?

There is a complex interplay between pollutants and clouds with a mix of chemistry and physics. Any quick answer will fail here.. so let me try to not fail too much: As the droplets change the atmosphere but atmospheric composition also impacts droplet formation. Examples, so chemistry can lower surface tension of droplets and so you can get droplets at lower than 100% RH or you might need higher RH depending on the chemistry, also surface films can impact growth or evaporation rates. Another aspect, the more particles or the more water soluble particles that can act as condensation nuclei (like for the shiptracks I showed) can impact droplet number concentrations and hence albedo…

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Question 1: Amongst the bacteria species shown during the presentation, there was one species which made up over half of the population. What is the reason for this species greater abundance?
I do not know… this is for the biologists to answer….

Question 2: To what degree are outside contaminant sources a consideration when choosing cloud sample collection sites?

It depends on what the question is you study.. we did a lot of work in the Central Valley as local organizations and policymakers wanted to know about the impact on air pollution. Other studies aim at understanding formation, chemistry and transport in more remote or pristine areas and organize studies there. It really depends on what the scientific questions are.

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Question 1: What are possible reasons for the models to underestimate particle content in clouds?

Models underestimate particle mass in the atmosphere overall, not (only) within clouds. In the atmosphere, the obvious reasons can be an underestimation of sources (not account for all sources) or an overestimation of sinks (so removal processes). Right now it looks for regional models that we (the atmospheric chemistry community) underestimate carbonaceous aerosol and given how "well" we know primary (=direct) emissions of aerosols and sinks (deposition) we seem to be missing a secondary source of particles. This means a way how gases are being transformed into particles. We think we understand well gas to particle conversion between gases and solids and so we really think the issue must be aqueous phase processes… or haze processes…

Question 2: Is it expected to have different microorganism abundances in clouds in alternate latitudes, such as closer to the Equator, where microorganisms tend to thrive? The examples mentioned during the talk (Canada and France) have a similar latitude, despite being across the ocean from one another.

Yes, there could be differences but again we have not looked in different atmospheres. This is in its infancy….

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Question 1: Why does the Central Valley in California have so many areas ranked within the top 10 air polluted cities in the U.S. if the air and fog appear to be cleaner now than in the past?

The Valley has often stagnant air because of its topography (coastal moutnains to the west and the Sierra Nevada to the east so the air does not mix well and you get frequent wintertime inversions. In the latter the air above the valley is warner than the air in the valley and keeps like a lid on the valley preventing mixing. This is also typically when the fog happen.. so the air sits stagnant in the valley for days to weeks.. and you still have substantial agricultural activities (including the waste of hundreds of thousands of cows) and 3-4 millions people living and driving cars in the valley, you have a lot of emissions that stay local….. so imagine a room where you do not open a window (or vent otherwise) and have a lot of (stinky) activities…it just accumulates over time and gets bad… same thing at larger scale….

Question 2: Could we utilize microorganisms living in water droplets within clouds to help us clean the air and/or cloud particles?

May be.. we do not know enough at this time… This I in its infancy… so we are not sure the microbes are all alive. The results I showed you is DNA sequencing.. so we know there is DNA and you can get DNA off a corpse.. also even if they are alive, we do not know what they actually do in the clouds as all the experiments where we saw them doing things are in the lab. Now is the lab representative of cloud conditions. We do not know.

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Question 1: How random (in time and sapce) are your testing (fog capture) sites? Are they primarily sites of opportunity? And if so, what methods do you employ to offset you bias?

No bias evaluation. It all depends on the scientific questions and goals. So the sites have to fit study purpose (scientific questions) and logistics (power, access, safety etc… ) Some studies were designed at vertical resolution (towers) while others looked at horizontal resolution with sites across an area to get spatial information on the ground. For airplane studies different flightpaths are chosen.

Question 2: Have you made attempts to quantify the effect size of specific policies (for example in California's Central valley), on pollution?

Quantify not really as the trends are nonlinear… but we looked at trends yes…

Herckes, P., Marcotte, A. R., Wang, Y., Collett, Jr., J. L. (2015) Fog composition in the Central Valley of California over three decades, Atmos. Res. 151, 20-30.

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Question 1: You mentioned that the researchers are discussing that clouds might be habitat or transport vehicles of micro organisms. What are the most recent discussions/ controversies regarding that view?

You can google it and find a bunch of public media discussions, I give some of the French papers in one of my answers below. I participated in an NSF workshop on it last September but nothing came out of this in terms of public papers. Many people have strong opinions but there is little science so too much speculation. We lack quality observations.

Question 2: During Q&A time, you also mentioned that it is hard to distinguish which droplet contains which micro organisms since researchers are looking at the collected samples as aggrogate, not each droplet. Could you tell me what kind of methods are being discussed now in order to take a look at each particle, both in fieldwork, experiments, and theoretical work?

Droplets are highly problematic. So for field and lab studies people use aerosol mass spectrometers but they cannot really handle droplets (they are too large). So attempts around this use counterflow virtual impactors that dry the droplets so that you are left with a dry residue that van be analyzed by aerosol mass spectrometry. This is being done a lot for chemistry but not so much for biology. There have been exotic methods aiming at collecting large droplets into liquid nitrogen and then analyzing. We tried this, it is very hard to do anything with the droplets. Other techniques impacted individual droplets into a gel or another substrate to then analyze individual droplets, but mainly for chemistry.
In lab studies, some groups trapped, levitated and manipulated individual water droplets.

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Question 1: Is there variability in cloud chemistry between different altitudes (for example when you collect data on the ground versus in flight)?

Yes, the chemistry varies vertically. We did tower experiments. Also the water content actually varies a lot in a cloud with higher concentrations typically close to cloud base. Finally people did vertical profiles in clouds with planes and also saw a lot of variability.

Question 2: If clouds with some particulates have a negative relative forcing compared to the 1700s, can they be used to slow down or counteract some effects of global warming?

Yes! A lot of climate engineering approaches are based on aerosols and clouds to cool the planet by scattering light. Examples for aerosol are stratospheric radiation management (inject aprticles in the stratosphere) while other ideas are brightening marine clouds by spraying oceanwater into the atmosphere over the ocean (to enhance albed or reflectivity)

You can look here for concepts or just google it… lots out there…
https://en.wikipedia.org/wiki/Solar_radiation_management

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Question 1: For field measurements of clouds, how many samples are typically taken?

This totally depends… Planes have very limited capacities, in ground based studies we have more samplers and can sample longer etc but I have had field studies that went without a single fog or cloud event to studies that we had over dozens of events in a short period of time. Depending on the research question too we get time resolved samples or one sample per event.

Question 2: Is a cloud sample defined as per cloud, over an amount of time, or by physical sample volume?

Typically we look for a specific time interval, however in some instances we look at quantifying/studying specific chemicals we know we need a volume X for analysis so we will collect until we get that volume.

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Question 1: Even though we are in the early stages of discussing the ecology and biology of microorganisms in clouds, what future studies can be conducted to test and analyze the human impact on cloud organisms?

It could be as easy as look at pH as one parameter. Humans impact pH substantially and easily so how does pH impact viability of the microorganisms would be an obvious question.. and then also "nutrients": nitrogen species like nitrate or ammonia are "pollutants" of anthropogenic origin but also essential nutrients… so many options…

Question 2: Is it possible/feasible to introduce organisms into the atmosphere that can help eliminate toxic particles or are there too many risks associated with introducing species in an "unnatural" way?

Many issues with trying to manipulate anything in the atmosphere. People tried using (and do use) bacteria in cloud seeding (search this) so this can help induce precipitation. However any large scale applications are highly problematic for a variety of reasons cf weather modification to not talk about terrorism etc..

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Question 1: Does occult deposition erode surfaces chemically and mechanically?

Theoretically both… so you can enhance acid deposition (so chemical erosion) and through "stemflow" along the trees you can get a little bit of mechanical erosion.. but as it is little water compared to precipitation it is more a chemical issue than a hydrological (mechanical) one

Question 2: Who were the principle actors that helped enforce the mandate that lowered Ph levels in California?

There was the Clean Air Act and its enforcement by the EPA at federal level as a lot of sulfur reduction came from policies in place to address "acid rain" CA has more stringent state regulations too which are enforced through the California Air Resources Board at the state level.

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Question 1: Given that microbiome concentrations in France and at BC were strangley similar, is it possible that the same microbiomes are recycled? If not, what plausible explanation could account for this?

Yes.. and just atmospheric lifetimes. It takes a small particles about 1-2 weeks to go around the globe… so it is likely just global transport… cf plume from Fukushima observed in the US.. what goes around comes around. In same latitudes it takes 1-2 weeks of transport time.

Question 2: What factors determine a cloud's ability to carry and transport particulates? For example similar density etc.

No.. biggest thing is hygroscopicity so the ability to act as condensation nucleus for the droplet.

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Question 1: It was shown through experiment that the cloud samples had distinct variations (dark brown to light yellow), indicating pollution and/or contamination. How would the colors compare if the samples were collected above a busy city as opposed to a rural area where there is not much pollution from human activity? What if the samples were collected above the middle of the ocean?

If you look at the fog collector in the slides, you see also clear water on the bottles. This is more normal so it looks like “clean” water. In urban areas it typically looks a tiny bit yellowish and/or specs of black in it (soot). Over the ocean it is typically completely clear and no color.. Then in heavy pollution plumes like impact by forest fires or impact by domestic fireplace burning (like in the extreme pic on the slides) you end up seeing more yellowish or the very extreme black fog. Black just has a huge amount of “soot” material in it…

Question 2: Again through sample collecting, microorganisms were found to be living in the clouds. What effect do they have on life on Earth? Are they harmful or beneficial or neither?

We do not know.. we are at the beginning. Further down I give some references for the work by the French. There are some more speculative “fiction” pieces out there about the potential interplay of bacteria clouds and Earth, you will see some of that if you google “Gaia, bacteria and clouds”. But we have left evidence based science in many of these pieces…

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Question 1: When you were talking about Clouds and Climate, about how much soot goes into the clouds; the graph showed that there was a difference between urban/city areas and remote areas. Can you explain more about why there was such a difference between the two areas and why the error bars were larger for the remote areas?

Sorry for the confusion, these were not error bars but they represented the range of observations ( min and max vlaue). So it is just very variable the observations.
Reasons on why more soot gets scavenged as it ages and gets transported to more remote sites are multiple. There are chemcial reaosns as soot can oxidize and hence gets more water soluble or hydroscopic and more easily scavenged. Also fresh soot is tiny in size (few to 10s of nm) and hence does nto tend to act as condensation nucleus as it is too small. Through aging though soot can associate with larger particles that act as condensation nuclei and hence more easily and efficiently be incorporated in cloud droplets.

Question 2: Has much progress happened on looking into haze droplets for where there is more particulate material in the atmosphere than the models predicted?

People still work on this…papers are coming out and larger field studies are conducted.
Here is an older but good overview.. newer ones certainly cite this…:
Ervens, B et al, Secondary organic aerosol formation in cloud droplets and aqueous particles (aqSOA): a review of laboratory, field and model studies. Atmos. Chem. Phys, 11 , 11069-11102, 2011

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Question 1: When it comes to air pollution, people always seem to focus on the big greenhouse gases such as CO2. Do you think that other particulates that aren't necessarily greenhouse gases but can still impact the composition of clouds deserve as big of a spotlight in terms of regulation?

Yes they (particles) are regulated already and actually $CO_2$ only very recently got considered an air pollutant by EPA and it is actually not "regulated" check out the National Air Quality standards etc…
https://www.epa.gov/criteria-air-pollutants/naaqs-table

Question 2: You mentioned that ships can cause brighter clouds with less water to form due to the particles they put out. However, I think, you said that their impact is not that large in the whole picture. Do you see this becoming more of an issue as time progresses or are there larger things to worry about when it comes to cloud composition?

For ships it is not that big of a deal… but overall the fact that particles have this interaction with clouds is a big deal. Any kind of particles do this. There are reports that for instance large areas in India have the same number of cloudy days but less rain.. so there could be already a substantial effect of particular air pollution on hydrologic cycle. The big problem (cf error bar on that IPCC slide/figure) is that we do not know enough o see the full impact. With brightening of clouds come impacts of lifetimes and impacts on precipitation. Cf also another answer further down.

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Question 1: Are there ways that we could potentially use clouds to help reduce the effects of global warming and pollution?

Possibly if we understand them (cf also my climate engineering answer and link above)…. So there are ideas of "making clouds" to help cool so geoengineering ideas.. which include making clouds or brightening clouds over the ocean. We are still only in the infancy in terms of understanding the processes and mostly in terms of evaluating unintended consequences…
Cf also ASU and SESE's Planetworks.

Question 2: What causes the water droplets to condense on the nets that are used to capture clouds?

They do not condense. Condensation implies that the water is in the gas phase or clouds are already "condensed" in that they are made up by liquid droplets. And the droplets impact by inertia on the nets. So the wind pushes them in the nets.

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Question 1: Dr. Herckes research team focuses on fog and cloud formation sample collections. In order to show us the different types of water droplets formation he showed us two bottle containing water droplets samples collected from two different sites. One of the bottles was from China, which had a dark colored solution that looked like a coffee color, and the other was from the mountaintop, which had a much appealing clear watercolor. So my first question is
Are the mountaintops in danger of receiving fog, cloud formation, and rain droplets as the one seen from China? And if they are, what would be the effect of China's water being pored over the mountaintops relating plants, and animals, how many years will it take to see some side effects from these polluted fogs, and clouds over the mountaintops?

Simplified response to be short: yes mountain sites will have these issues and China has well documented issues with acid rain. The black fog was an extreme mainly due to a lot of soot, so it is not the "normal" but acid deposition and acid rain as well as heavy metal deposition are a big areas of concern in China and throughout Asia

Question 2: The greenhouse effect is a serious problem for the entire Earth so are there any plans on doing research on marine, or river fogs, and clouds life? And if so, what would be one of the major problems that these contaminated fogs, and clouds could bring onto oceanic life?

I do not quite get the question which seems very general, so hopefully many of these other questions/answers here address this?

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Question 1: How does the urban heating problem affect clouds and fog in our area?

Not sure I capture the question. I think you mean urban heat island may be? In Phoenix this does not impact fogs as we do not get really fogs in the Phoenix area, it is just too dry so it is at best an exceptional event. As for clouds, the urban heat island translates mostly into higher nighttime minima temperatures close to the ground. So it likely does not have a big impact on the higher atmosphere and clouds… but this is a guess as I do not know, how high vertically the heat island effect reaches but I would be surprised if it reaches high enough to impact clouds…

Question 2: Are the carcinogens found mostly in a certain environment (i.e. caused by a certain geological/urban influence)?

It depends on which carcinogens. The PAH are mainly associated with combustion products so are more common in an urban area. The nitrosamines which form in fog were actually highest in more rural agricultural areas where the precursor chemicals are more abundant.

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Question 1: As rain and moisture patterns change due to climate change, it is accurate to think of these changes in terms of changes in particle formation, distribution, and transport?

Yes but all is linked. I think I answered a similar question at the talk… if you change the particles, you change albedo, you change clouds which in turn can change rainfall pattern and humidity on the ground which can change the emission of particle s(windblown dust.. so there are many feedback mechanisms possible and it is quite complex.. also impacts on chemistry and gas to particle conversions if humidity and or temperature changes. A lot remains to be learned!

Question 2: Does the heat island effect create a strong enough signal to attribute differences in cloud formation and behavior?

I do not know. For clouds I do not think that the heat island effect reaches high enough to impact clouds. For fogs, yes the heat island effect seems to impact fog frequency and density in places like Fresno or Bakersfield in the central Valley of California.

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Question 1: I happen to be a big lightning enthusiast. What kind of precautions, if any, do you need to take when you are atop the mountains waiting for clouds? Do you assume clouds with more lightning will have much different measurements than clouds with no lightning?

On mountain sites, like in the Flagstaff area, we are often collocated with other installations (often cell towers) as they have power and access roads. So as they are substantially higher than our equipment we are safe. Often the sites are automated on mountaintops and so no person is there when there could be lightening. We arrange to go up for maintenance when there is no lightening especially when people need to hike part of the way. Also all our equipment is always grounded etc. so standard electrical safety is in place. In 20 years, I never had a lightning issue even with electronics.. We had snow issues and had wildlife (e.g.bear) issues though… or simple stupid human vandalism….

Question 2: Overall, you mentioned there is a reduction in clouds or low fogs around the California area. Have you noticed an upward trend in cloud formation in any other regions? Is the reduction in cloud formation global?

I do not know about a global decrease but I never heard about an increase but this could just be that I am not aware of or people did not look at. In the air pollution community fog decreases have been observed in the Central Valley of California, In France (Strasbourg area) and in coastal Southern California (June gloom times)

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Question 1: Approximately what weight percentage of the clouds leave by precipitation and what percentage leaves via occult deposition?

I do not know.. and honestly there would be too much "it depends"…. Like at what time do you look at this.. because if the bigger the droplets get (the higher mass) the more likely they are to precipitate….

Question 2: Aqueous chemistry reactions between particles and water were discussed, but is anyone looking into the significance of the contribution that microorganisms would add to the chemistry of a droplet (assuming that the organisms are alive)? I'm curious how their metabolic processes would change the outcome of a single droplet.

Yes people (and we but unpublished) looked at that in lab studies. However a question is how representative this is as it is on bulk solutions not assemblies of droplet

Example:
Vaïtilingom, M., Deguillaume, L., Vinatier, V., Sancelme, M., Amato, P., Chaumerliac, N., & Delort, A. M. (2013). Potential impact of microbial activity on the oxidant capacity and organic carbon budget in clouds. *Proceedings of the National Academy of Sciences*, *110*(2), 559-564.

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Question 1: How effective are the giant fog/cloud harvesting nets that were illustrated in the presentation?

Not sure what you call effective? .How much water you get and at what cost and what quality depends on the size of the nets, the location, the technology (kind of nets). If you google fog harvesting you will find quite a few projects including those form fogquest. There were some MIT ones and some groups did a great job getting publicity for their work. I would now know numbers which will completely depend on site.

Question 2: You mentioned during the talk that clouds may sometimes "clean" plants by deposition. Where clouds/fog settle close to bodies of water (in places similar to San Francisco) do they have the same effect?

Not clean plants but clean the atmosphere. Yes they will remove materials. Also in San Francisco or any urban area and in the process yes fogs will deposit pollutants into water bodies like the Bay… but then again rain does the same, so does dry deposition (although overall lower flux). Still in a place like San Francisco wet (rain deposition) is substantial and yes it washes the "stuff" from the atmosphere into the ocean.

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Question 1: It was mentioned that California's central valley is highly polluted and also produces substantial agricultural yields, what kind of work is being done to filter out pollutants?

Not sure I understand your question well. The atmosphere is too large to try and filter out pollutants but what is being done is that there are substantial efforts to define policies and enforce them to reduce emissions of pollutants into the air. This is all done on a state level by the California Air Resources Board and then locally by the San Joaquin Valleywide Air Pollution Control District

So there are rules for burning (agricultural, fireplace,..), stringent vehicle emission standards, agricultural practices etc…

http://www.valleyair.org/Home.htm
https://www.arb.ca.gov/homepage.htm

Question 2: How representative of the total rain clouds of an area are cloud sampling techniques that collect from the lowest clouds possible due to few clouds being present (e.g., Flagstaff, AZ)?

Clouds are different from rain.. very different. As for larger areas, it depends.. if the sources of the pollutants are diffuse (many small sources rather than one big one) then there is reasonable mixing and you get good representativeness. If you have a huge point source e.g.a coal fired powerplant, then it will be critical where you sample relative to this…

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Question 1: Why has there been a dramatic decrease in fog in Bakersfield since the 1980s? Is this a positive or negative occcurance?

We do not know.. we and others have seen this decrease. It could be any or a combination of: urban heat island effect, regional change in irrigation patterns linked to drying of the atmosphere or an effect of regional climate change as part of larger changes..
Our paper focused on chemistry..:

Herckes, P., Marcotte, A. R., Wang, Y., Collett, Jr., J. L. (2015) Fog composition in the Central Valley of California over three decades, Atmos. Res. 151, 20-30.

Then similar paper from meteorologists…
Baldocchi, D., and E. Waller (2014), Winter fog is decreasing in the fruit growing region of the Central Valley of California, Geophys. Res. Lett., 41, 3251–3256, doi:10.1002/2014GL060018.

Question 2: Is it possible for scientists to use clouds and their abilities to cleanse the air of impurities in a controlled way to solve pollution problems and to prevent the clouds from causing more pollution?

It could be… I have seen in conferences attempts at tailor made fog for industrial gas "cleaning" but it is more complicated to make the fog and then to dissipate or precipitate it as just simply build washtowers…

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Question 1: Does the dry particle that acts as the nucleus fall with the liquid droplet?
Yes IF the droplet precipitates but only about 15% of droplets do precipitate the others evaporate again and so it goes back to a "dry" particle.. that might be different based on any aqueous phase chemistry that has happened.

Question 2: What is the yield for fog catching tools used in Chile and Guatemala for purposes of irrigation and consumption?

I do not know… but passive collectors in general depend on cloud liquid water content (so how "dense" the clouds are = how much water they carry) and then wind speed. The higher the wind speed the more efficient you impact droplets by inertia and the more air volume you pass through by time step BUT if the wind speed is too high it can "blow off" the collected droplets and so you can have losses..
There are studies who looked at this. A lot of the pioneering work was done by Robert Schemenauer a scientist now retired form Environment Canada who has I think founded the fogquest.org website (good resource)

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Question 1: How do microbes get in the clouds? Are they mainly transported by wind, or are they somehow picked up as clouds pass over a mountain?

Likely either way. They are small enough to sit on or be condensation nuclei, even ice nuclei and then they can just be “scavenged by “bumping into” cloud droplets…

Question 2: Is there a particular elevation where clouds mostly form and what is their maximum elevation?

No.. you can have fogs so ground level and then all kinds of altitudes. The higher up the temperatures get lower so you see ice clouds forming and you see far less droplets or ice crystals as there are less particles, less condensation nuclei.. also higher arts of the atmosphere can be drier… But lower atmosphere.. clouds can be at any altitude… all depends on the environment (particle s(condensation nuclei) humidity and temperature…

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Question 1: My research is in modeling the atmosphere's of terrestrial exoplanets with a focus on habitability and biosignatures. The last portion of your talk dealt with microorganisms existing in cloud droplets. This particularly intrigued me since, in the search for extraterrestrial life, we must expand our thinking to incorporate habitats vastly different from our home world. I realize that this was not the main focus of your research but was hoping that you could point me in the direction of some research possibly done by the French group you mentioned in regards to the microorganisms detected in these droplets. A question I would have for you stemming off of this topic would be: Do you believe that it is possible for there to be a global cloud-based microbiome?

Yes I believe there is a ppssibility for a global microbiome. And people already saw similarities looking at microorgansims in the air (particle snto clouds) throughout the US…
So some references:
For the US and ice nuclei looks for papers by Robert M. Bowers

For the French group and Puy de dome: (a selection)
Amato, Pierre, Muriel Joly, Ludovic Besaury, Anne Oudart, Najwa Taib, Anne I. Moné, Laurent Deguillaume, Anne-Marie Delort, and Didier Debroas. "Active microorganisms thrive among extremely diverse communities in cloud water." *PloS one* 12, no. 8 (2017): e0182869.

Vaïtilingom, M., Deguillaume, L., Vinatier, V., Sancelme, M., Amato, P., Chaumerliac, N., & Delort, A. M. (2013). Potential impact of microbial activity on the oxidant capacity and organic carbon budget in clouds. *Proceedings of the National Academy of Sciences*, *110*(2), 559-564.

Vaïtilingom, M., Attard, E., Gaiani, N., Sancelme, M., Deguillaume, L., Flossmann, A. I., ... & Delort, A. M. (2012). Long-term features of cloud microbiology at the puy de Dôme (France). *Atmospheric environment*, *56*, 88-10

Question 2: My second question is in regards to your comment on planetary albedo increasing due to a greater number of pollutants making clouds brighter (I believe I heard that correctly). If this is the case, over what period of time are you seeing this albedo increase and what sort of increase in the overall albedo is being measured? Is this a neglible amount, or is Earth becoming increasingly more reflective to solar radiation on a global scale?

This cannot be answered quickly here.. yes it is getting brighter but on a global scale there are other considerations too. So the brighter clouds might have shorter lifetimes.. so while the albedo increases, over a longer period part of the increase can be negated by the decrease in lifetime. So there are many many cloud effects also on precipitation that we do not understand well (hence that big error bar on the IPCC figure I showed).
One (older) paper on this is here:
http://www.homepages.ed.ac.uk/shs/Climatechange/Stevens%20Feingold%20cloud%20life.pdf