Some Considerations Concerning Effects of Artificially Injected Ions on Aerosol and Cloud Microphysical Processes

Andrew Detwiler
Institute of Atmospheric Sciences
South Dakota School of Mines & Technology
Rapid City, SD, USA

Dispersing ions in order to influence precipitation

- Some companies involved:
  - Earthwise Technologies (Texas)
  - Atlant (Australia)
  - Weathertec (Switzerland, UAE)
  - Ionogenics (Texas, California)

Abu Dhabi weather project 'creates man-made rainstorms'

A secret £7 million weather project in Abu Dhabi has resulted in dozens of man-made rainstorms, according to reports.

Children play in the street during a rain storm in Abu Dhabi Photo: ALAMY

United Arab Emirates
News » World News » Middle East »

6:54PM GMT 02 Jan 2011

Scientists employed by Sheikh Khalifa bin Zayed Al Nahyan, president of the **UAE** and leader of Abu Dhabi, successfully created more than 50 rainstorms in the state's Al Ain region last year, mostly in July and August when there is virtually no rain at all. It is believed to be the first time the system has produced rain from clear skies.

They have been using giant ionisers, shaped like giant lampshades, to generate fields of negatively charged particles, which create cloud formation.

In a company video, seen by The Sunday Times, Helmut Fluhrer, the founder of Metro Systems International, the Swiss company in charge of the project, said: "We are currently operating our innovative rainfall enhancement technology, Weathertec, in the region of Al Ain in Abu Dhabid. We started in June 2010 and have achieved a number of rainfalls."

IN NEWS

Ferrari theme park

The F1 roller-coaster

ATM machine that dispenses gold bars is unveiled

Red Bull Air Race

Derive originally from a Russian technology known as IOnization of the Local Areas (IOLA) ca. 1980's

- Set up multiple stations consisting of an array of towers, wires, and sometimes "steel wool" sorts of tufts
- Raise to a high electrical potential in order to produce corona current
- Currents ~μA's to fractions of a mA

How does it work?

How to make artificial rain?

Artificial rainfall is caused by ionized particles moving up from the ground and attracting water vapor from the ambient air to form clouds

Large ionizers produce negatively charged particles or electrons. These particles naturally attract dust particles present in the ambient air in desert and dry arid regions.

Those particles then move up and away from the ionizers as a result of the hot ground air moving and forming convection currents as a result.

As the particles reach the height around which the clouds usually form, they stabilize and the negative charge of the particles begins to attract the vaporized water molecules around resulting in the formation of mini clouds. The particles act as nuclei around which all the moisture can come together, the process is very similar to how crystals are formed. Gradually, the size of those mini clouds grows as more particles move up and attract more of the humidity

For this process to work, the ambient humidity should be at least 30%

These clouds being to rain, as the temperature starts to cool down, mostly during night times in the desert. The resulting rain will be combined with thunder and lightning, as the charged particles act as giant electrodes in the sky across which the lightning discharges

This process of artificial rainfall creation is more interesting and relevant for dry regions or deserts. For regions with more cloud formation, but little rain, the artificial rainfall approach to cause rains is to seed the clouds with chemicals (sprayed with small planes flying through the clouds) that will act as nuclei for the water drops to congeal around until they become heavy enough to start falling down in a beautiful and all artificial rainfall

Experiments in Texas

- Kauffman & Ruiz-Colombie (2009)
- Run an ionization station near Laredo, TX
- Make airborne aerosol observations along estimated plume path
- Monitor precipitation in affected region

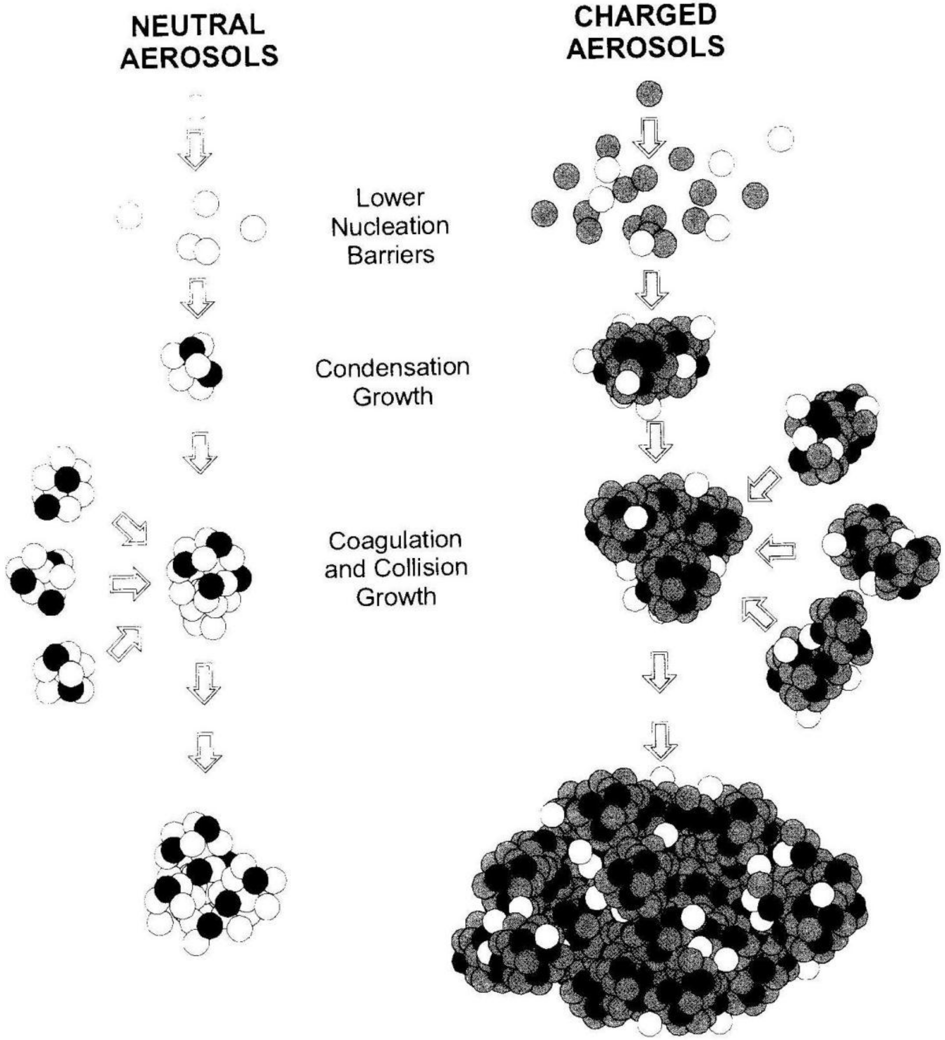


Fig. 2. Illustration of Aerosol Growth, Conceptual Model

From Kauffman & Ruiz-Columbie, 2009

Kauffman & Ruiz-Columbie, 2009:

Main hypothesis:

•Dispersing ions will lead eventually to more rapid production of CCN. Earlier increase in CCN concentration and transport into base of convective clouds will increase rate at which precipitation forms and lead to more total precipitation

Alternative hypothesis:

•Greater charge on aerosols will lead to more rapid aerosol growth by coagulation and lead to more rapid aerosol deposition, lowering aerosol particle concentration in the PBL

Experimental results inconclusive

Brian Tinsley & collaborators: *Electrofreezing*

- Modulation of cosmic ray flux modulates ionization in atmosphere
- With higher ionization rates, end up with more charge on ice nucleating aerosols (IN)
- Charged IN are more likely to contact supercooled droplets
- Higher rates of glaciation produce more precipitation
- Timescales of many hours to days
- The only observational studies have been to correlate cloudiness and precipitation with cosmic ray fluxes

From Khain et al., 2004

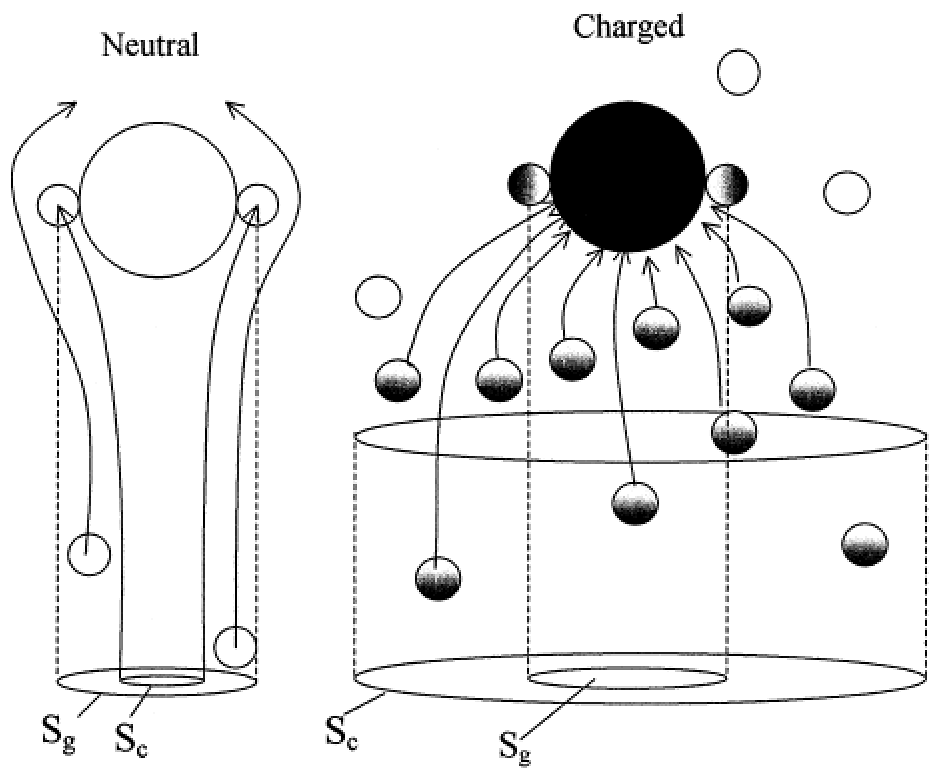


FIG. 3. Scheme of hydrodynamic droplet interaction and collisions in the cases of (left) neutral droplets and (right) charged drop collector. In the case of neutral droplet collisions, the collision cross section S_c is less than the geometrical cross section S_g (the collision efficiency $E = S_c/S_g < 1$). In the case in which the drop collector is charged, $E = S_c/S_g > 1$.

Charged cloud droplets collide and coalesce more efficiently, leading to more rapid precipitation formation

Can artificially dispersed charge influence precipitation processes?

- Khain et al. (2004)
  - Put charge directly on droplets
  - Bin representation of microphysics, with each size bin having multiple charge bins
  - Calculations simplified by assuming only 2 charge bins – no charge (most) and maximum charge (few %)
  - With these assumptions, precipitation formation was significantly accelerated

What is the electrical environment like in the absence of IOLA?

Natural & anthropogenic sources of ions in atmosphere

- Ionization near the ground due to cosmic rays, radon, etc.
  - 10^7 molecular ion pairs/m^3/sec
  - Lifetime of ions ~minutes before attached to aerosol particles in clean air, ~seconds in polluted air
- Aerosol particle population ends up with a distribution of net charges with a mean of zero

Lifetime of net charge on aerosols before neutralization by attachment of ions of opposite sign

- Minutes in “normal” atmosphere
- 10’s of minutes to hours in “clean” atmosphere or within clouds

Fair weather current

- Fair weather current of ~10^{-12} C/m^2/sec bringing + charge to ground
  - Including ions + aerosols
  - Corresponds to a net flux of 10^7 elementary charges m^{-2} sec^{-1}

Power grid transmission lines

The following statistics characterize EHV transmission lines operating at different voltages, in normal weather, carrying 1000 MW of power:

	LINE LOSSES - MW/100 MILES		
	Resistive	Corona*	Total
765 kV LINE @1000 MW LOAD:			
Original 4-conductor ("Rail") bundle	4.4	6.4	10.8 (1.1%)
Newer 4-conductor ("Dipper") bundle	3.3	3.7	7.0 (0.7%)
Current 6-conductor ("Tern") bundle	3.4	2.3	5.7 (0.6%)
Planned 6-trapezoidal cond. ("Kettle") bundle	3.1	2.3	5.4 (0.5%)
500 kV LINE @1000 MW LOAD:			
Typical 2-conductor bundle	11.0	1.6	12.6 (1.3%)
345 kV LINE @1000 MW LOAD:			
Typical 2-conductor bundle	41.9	0.6	42.5 (4.2%)

*Yearly average corona loss at sea level based on 20%/2%/78% rain/snow/fair weather conditions, respectively.

Extra-High-Voltage Transmission:		
765 kV:	2,116 Miles	
500 kV:	113 Miles	
345 kV:	5,910 Miles	
	EHV Subtotal:	8,139 Miles
High-Voltage Transmission:		
230 kV:	140 Miles	
161 kV:	282 Miles	
138 kV:	16,202 Miles	
115 kV:	66 Miles	
	HV Subtotal:	16,690 Miles
Below 100 kV:		14,230 Miles
AEP Transmission Total:		**39,059 Miles**

Source:
"American Electric Power 2008 Fact Book," 43rd EEI Financial Conference, Phoenix, AZ, November 9-12, 2008.

AEP ranks among the nation's largest generators of electricity, owning nearly 38,000 megawatts of generating capacity in the U.S. AEP also owns the nation's largest electricity transmission system, a nearly 39,000-mile network that includes more 765 kilovolt extra-high voltage transmission lines than all other U.S. transmission systems combined. AEP's transmission system directly or indirectly serves about 10 percent of the electricity demand in the Eastern Interconnection, the interconnected transmission system that covers 38 eastern and central U.S. states and eastern Canada, and approximately 11 percent of the electricity demand in ERCOT, the transmission system that covers much of Texas. AEP's utility units operate as AEP Ohio, AEP Texas, Appalachian Power (in Virginia, West Virginia), AEP Appalachian Power (in Tennessee), Indiana Michigan Power, Kentucky Power, Public Service Company of Oklahoma, and Southwestern Electric Power Company (in Arkansas, Louisiana and east Texas). AEP's headquarters are in Columbus, Ohio.

Sources of charged aerosols

- Industrial combustion plumes tend to have net negative charge
- Internal combustion exhaust from vehicles
- Wind-blown dust
- lightning

Can the background ion and aerosol environment be intentionally modified?

Evidence for transport of charge plumes through the atmosphere

…release of charge from a fine horizontal electrified wire about 14 km long and 10 m above the ground, it is possible to raise the atmospheric space charge concentration to about 10^2 elementary charges cm^{-3}, either positive or negative, over an area of about 50 km^2 .

Vonnegut et al., 1962

EFFECT OF SPACE CHARGE ON CUMULUS CLOUDS 3911

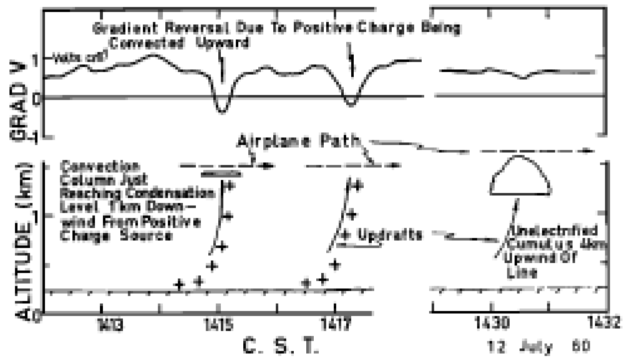


Fig. 3. Potential gradient over positively charged updrafts, one in which condensation had formed a thin cloud and one in which condensation had not yet occurred.

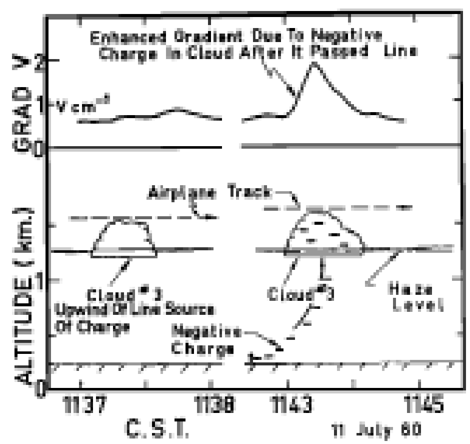


Fig. 4. Potential gradient above a cloud growing from negatively charged air.

Vonnegut et al., 1962

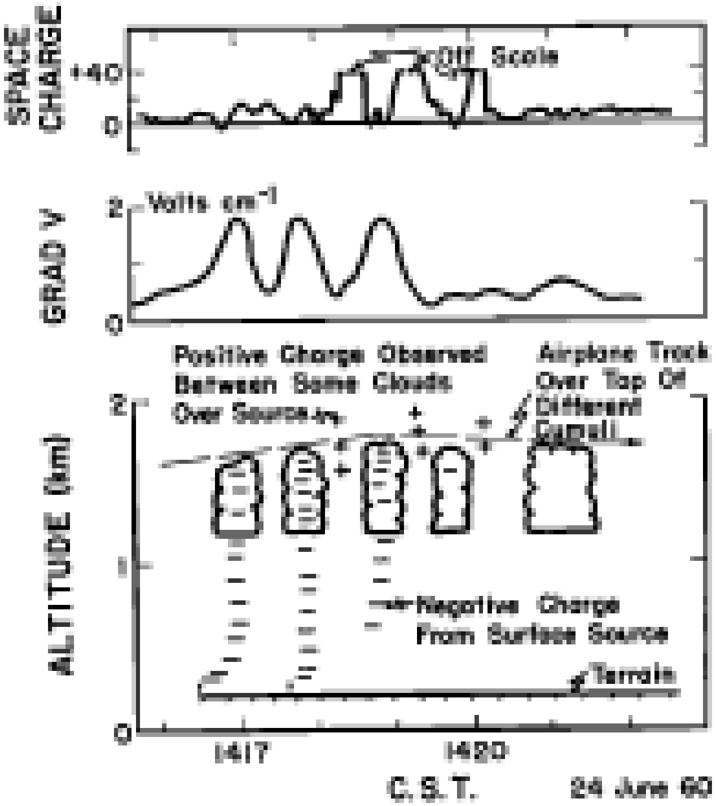


Fig. 10. Region of positive space charge observed above clouds growing from negatively charged air.

Vonnegut et al., 1962

Abnormal Polarity of Thunderclouds Grown from Negatively Charged Air

C. B. Moore, B. Vonnegut, T. D. Rolan, J. W. Cobb,
D. N. Holden, R. T. Hignight, S. M. McWilliams,
G. W. Cadwell

Experiments were carried out in New Mexico to determine whether the electrification processes that lead to the formation of lightning in clouds are influenced by the polarity of the charges in the air from which the clouds grow. The normal, positive space charge in the sub-cloud air was reversed by negative charge released from an electrified wire, suspended across a 2-kilometer-wide canyon. On more than four occasions when the clouds over the wire grew and became electrified, they were of abnormal polarity with dominant positive charges instead of the usual negative charges in the lower part of the cloud. The formation of these abnormally electrified clouds suggests both that the electrification process in thunderclouds can be initiated and that its polarity may be determined by the small charges that are present in the atmosphere.

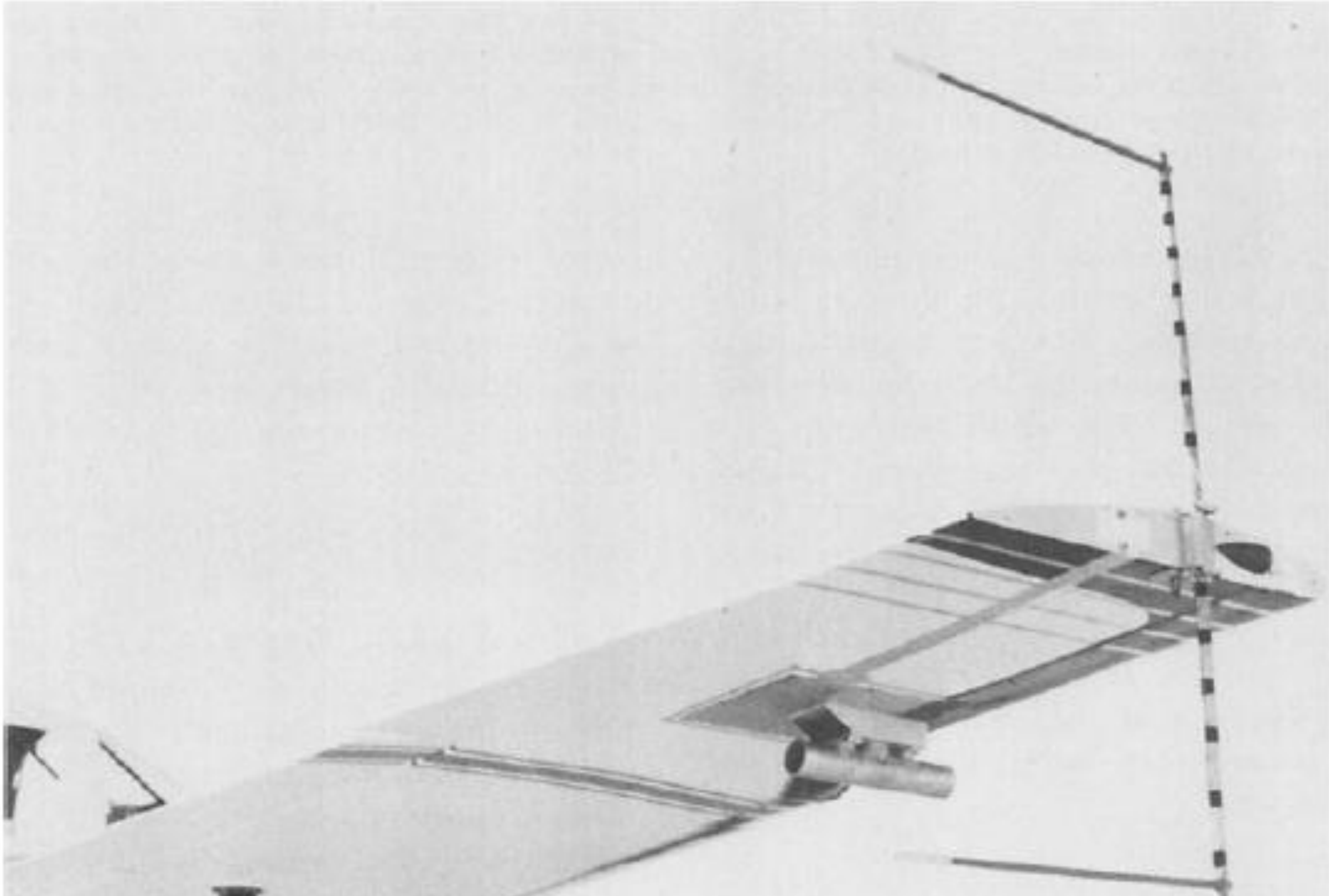
Moore et al., 1986

Markson et al., 1979: airborne observations:

- Pollution plumes have low conductivity
- Pollution plumes typically have net negative charge whether or not electrostatic precipitators are turned on
  - Combustion itself produces ions?
  - Triboelectric charging due to collisions between particles and stack walls?
  - Effect of fair weather field producing a positive charge on stack walls?

A question that arises is whether all aerosol plumes are electrified and hence suitable for atmospheric electrical detection. All our experience indicates that such plumes have invariably been negatively charged, while Boeck (personal communication, 1974) and Moore *et al.* (1962) also reported negative plumes. The source of the charge is probably triboelectric (frictional) charging as the particles go up the stack. In addition, there will be charging by Cottrell electrostatic precipitators, which also introduce negative charge into the plume. Boeck (personal communication, 1974) has detected plumes from stacks without Cottrell precipitators, and the plume we report on here was detected remotely with the electric field instrumentation although no electrostatic precipitator was in the stack. A third mechanism by which such plumes would be negatively charged has been pointed out by Clark (personal communication, 1977) who made extensive measurements (unpublished) of the sort described here for the Naval Research Laboratory in the 1950s. He believes the predominant reason for the usual net negative charge on effluent from vertical stacks is the relatively large downward electric field at the mouth of the stack produced by the "vertical needle" augmentation of the earth's fair-weather electric field. Because of this, some positive charge would be attracted to, and collected by, the stack, leaving net negative charge in the air nearby that would be accelerated away from the stack and collected on the effluent particles.

Markson et al. 1979



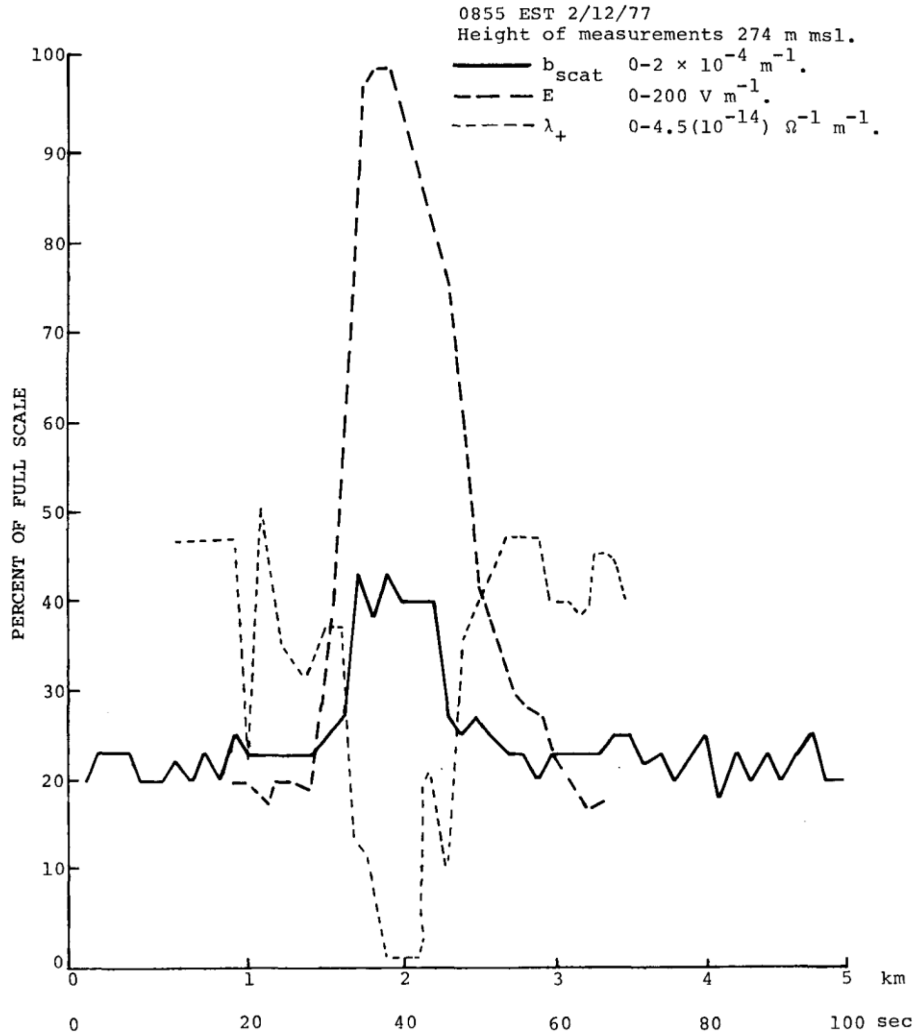


FIG. 11. *Horizontal traverse through plume at 40 km downwind showing correlation between aerosol and atmospheric electrical measurements. Data from a formation flight of the Cessna 206 and Bellanca aircraft.*

Markson et al., 1979

Summary

- Several groups worldwide are promoting cloud modification using IOLA
- Artificially-produced ions enter an environment with many other sources of ions
- Several at least semi-plausible mechanisms exist by which ions might influence precipitation processes

Summary (cont'd)

- "chain of events" mechanisms have yet to be verified observationally
- Numerical modelling of relevant processes is in its infancy