Report on Rain Enhancement by Altant Ion Generation.

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November 11, 2022

Brief Bio of Plasma Physicist Dr. Theodore Anderson

(author of this report)

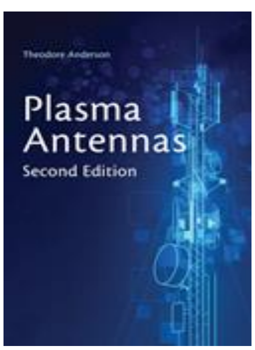
Full resume is in the appendix.

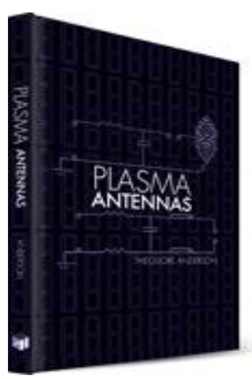
Dr. Theodore R. Anderson (sometimes referred to as Dr. Ted Anderson) is a foremost authority and pioneer on plasma antennas. Dr. Anderson has over 20 issued patents on plasma antennas, plasma frequency selective surfaces, plasma waveguides, and plasma MRI/PET. He has published several peer reviewed journal articles on plasma antennas, and has presented at many conferences with symposium papers on plasma antennas. He founded Haleakala Research and Development, Inc. in 2002 which became a company focused on the plasma antenna technology. His contact information is tedanderson@haleakala-research.com and cell phone 518-409-1010. The Haleakala R&D, Inc webiste is: www.haleakala-research.com**.** He has published in the areas of plasma antennas, plasma physics, electrodynamics, fluid dynamics, acoustics, hydroacoustics, atomic physics, foundations of quantum mechanics, nuclear engineering, and mathematical scattering theory.

Books by Dr. Theodore Anderson

The Second Edition of my book titled "Plasma Antennas".
See: https://us.artechhouse.com/Plasma-Antennas-Second-Edition-P2101.aspx

The Second Edition of my book titled "Plasma Antennas":





Plasma Antennas, Second Edition,
Theodore Anderson, Copyright:
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ISBN: 9781630817503

**My original book titled "Plasma Antennas", Theodore Anderson, ISBN: ISBN 978-1-60807-143-2
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Book chapters on plasma antennas by Dr. Theodore Anderson.

Theodore Anderson, ***Plasma Antennas,*** Open access peer-reviewed chapter, ***Selected Topics in Plasma Physics,*** Submitted: October 21st 2019Reviewed: March 2nd 2020Published: July 14th 2020, DOI:10.5772/intechopen.91944

Theodore R. Anderson, chapter 10; *Plasma Antennas, Frontiers in Antennas: Next Generation Design & Engineering*,, McGraw -Hill, Frank Gross editor. ISBN 0071637931 / 9780071637930

Bottom Line

In my opinion this technology is very positive. The experiments in cloud cambers verify the physics of the technology. Experiments in the real world and in the field is a different matter. Since there is not yet a theoretical physics model that can predict the amount of rain given a number of ions generated from the ground by an Ionization Rainfall enhancement device or some other ion generating device, lots of data is taken and it is analyzed with statistics. The efficiency can be greatly improved using atmospheric plasma antennas mounted on aircraft. There are parts of the theoretical model developed such as the numerical solutions of transient advection diffusion reaction equation, but more needs to be done.

This technology works, but with atmospheric plasma antennas mounted on aircraft can very significantly improve the amount of rainfall enhancement from about 18 % to 60 to70 %. Therefore I endorse it.

Theodore Anderson

Dr. Theodore R Anderson

Abstract

Ground-based ionization as a means of weather modification has a long history of experimental investigation including the widespread releases of ions into sub-cloud air using corona discharges generated from extensive arrays of small diameter wires connected to a high-voltage power supply, and exposed to local winds and over the years a number of field experiments have been run using technologies derived from this technique . Most recently a series of field trials of ground-based ionization rainfall enhancement technology known as Atlant have been conducted in Australia. Several mechanisms exist by which ions might influence the microphysical processes of precipitation formation at multiple stages through the process.

I. Introduction

The Atlant model is based on a mechanism by which ions generated a plausible "chain of events" mechanism by which negative ions are generated by a high-voltage corona discharge wire array These ions are hypothesised to become attached to particles in the atmosphere (especially soluble particles), which later act as cloud condensation nuclei (CCN). In turn, these particles are conveyed to the higher atmosphere by wind and the electric charges on them are transferred to cloud droplets. Finally the electrostatic forces on droplet interaction aid the coalescence of the cloud droplets, resulting in enhanced raindrop growth rate and ultimately increasing rainfall downwind from the Atlant ion emitter.

The problem is there is no physical model in mathematical terms of this "chain of effects" tied together to predict the actual amount of rainfall from initial conditions.

The Wegener–Bergeron–Findeisen process is a related process but it does not apply here. It is a process of ice crystal growth that occurs in mixed phase clouds in regions where the ambient vapor pressure falls between the saturation vapor pressure over water and the lower saturation vapor pressure over ice. Thus instead of doing modeling with simulations to confirm the validity of the Atlant method, the Atlant method is verified by trial and error guided by statistical models. As with chemical cloud seeding, field trials are seen as the best means of establishing the efficacy of Atlant with statistics.

II. Cloud Chamber R&D

The science of rainfall activation by ionization has been verified in cloud chambers Fig 1 but it has been difficult to completely verify it in real outdoor situations. The land area where it works can be shown in a cloud chamber, but it is difficult to predict the land area where it is valid in a field environment because of wind and other changing atmospheric conditions.

1. Hence rainfall activation by ionization is verified in a cloud chamber.

2. Outside the cloud chamber, it is difficult to predict the amount of rainfall from a given amount of ionization. The author of this report is confident that with more R&D, this can be achieved.

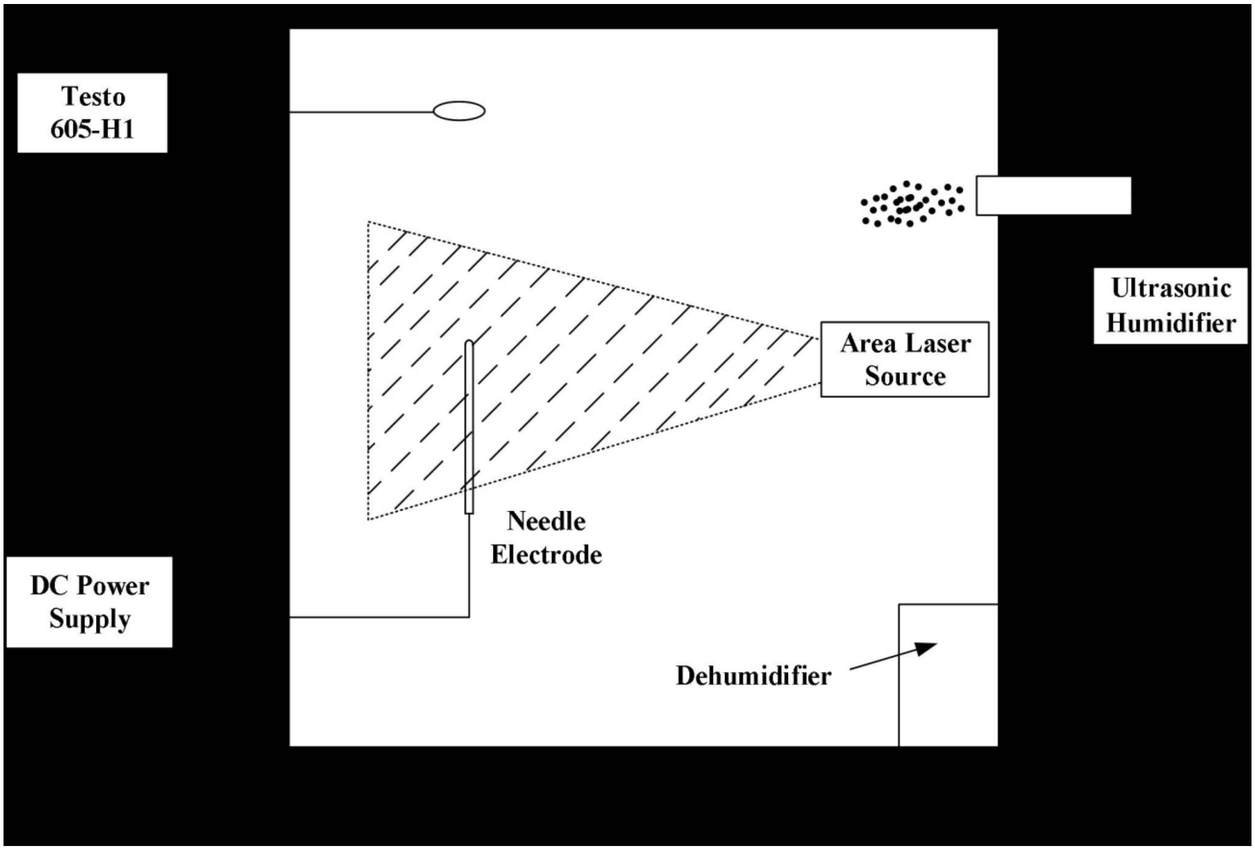
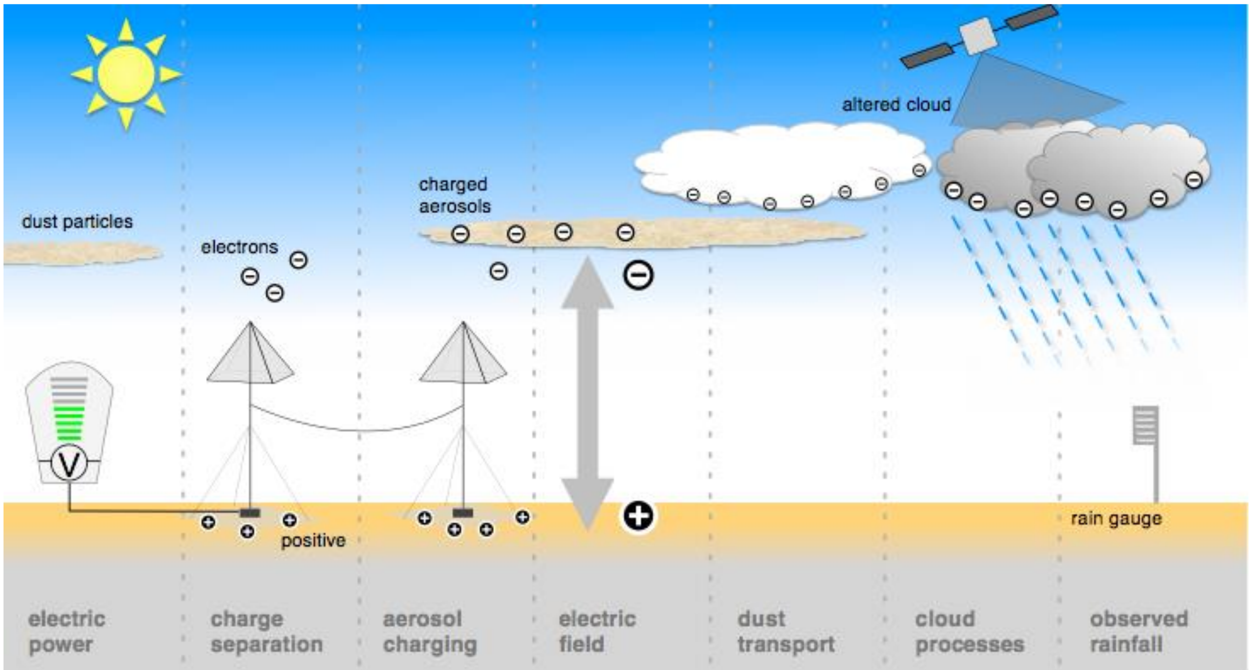


Fig 1. Schematic of the 6.75m3 cloud chamber used for the ion-enhanced 3 precipitation. Ion activated or enhanced rain has and is bring verified by experiments in cloud chambers such as this. Because of this real outdoor lack of predictability, the technology relies on trial and error techniques with statistical analysis to show the validly of rainfall activation by ionization. This statistical analysis shows that the technology works but a physical theory which predicts the amount of rainfall from an amount of ionization in various weather conditions and makes this technology more reliable and powerful. The technology is moving in the right direction and I think such a theory will be developed. To date there are bits and pieces of good theory developed, and some simulations have been done that agrees with experimental data. However, these disjointed theories need to be tied together to predict rainfall by simulations. This is not an easy task, but it can be done and should be done. In field the technology works but we do not know how well and how much. There are answers to these questions in cloud chambers which is important, but a harness needs to be put on the theoretical predictions by simulations in real field environments.

III. Physical Processes to Enhance Rain.

To date in my estimation, Australia is the leader of rainfall activation by ionization. German and Chinese groups are making excellent contributions. Fig 2 is a schematic of the physical processes but it is simplistic.



Fig, 2 Steps by which the technology generates charged particles, affects the atmosphere, and aims to alter rainfall processes. This diagram gives a very rough schematic representation of a process with complex physics.

In the various documents and research papers I have read, the explanation of the physics has some serious holes in it. You can have a theory to predict rainfall by simulation if these holes are not resolved. I will the explain the physics here in a step by step process.

1. Corona discharge of ions from Ablaut or similar technology. A special high-voltage system produces a large amount of negative ions, by means of a corona discharge process, that form a negative electric space charge in the air mass above the Atlant system.
2. Ions are carried upward by air currents and attach themselves to aerosols. The ions either attach themselves to an aerosol, thus charging the aerosol, or else grow by condensation and join into charged particles called ion clusters. Under the influence of the negative electric field of the earth and positive electric field of the ionosphere, this volume of electric charge is lifted up to
higher and cooler layers of the atmosphere.

3. The vertical effect of the enhanced electric current initiates an updraft that transfers more warm and humid air masses to levels in the atmosphere where condensation of water vapor takes place. Hydration occurs and charged droplets are formed, along with the release of latent heat of condensation. This initiates a dynamic convection process, which creates a positive feedback loop using energy available from the surrounding atmosphere in the form of heat of condensation. This process is enhanced by a number of circumstances like atmospheric convective flows, turbulences or thermals.
4. Negative ions on aerosols induce positive charge on the nearest size of the raindrops with negative charge on the opposite side. When contact is made the negative charge of the aerosol neutralize the positively charges side of the raindrop. This leaves the raindrop with a negative change.
5. The negatively charged raindrops collide with other raindrops and induce positive charge on the side nearest the raindrop. The Coulomb force between the raindrops cause the raindrops to collide with a force great than the surface tension of both raindrops causing them to coalesce. In this way raindrops coalesce and keep coalescing until they are heavy enough to cause rain.
6. The convection process is concluded by the formation of cumulonimbus clouds and the precipitation process. Cumulonimbus clouds can be distributed in a horizontal direction to a significant distance from the Atlant system by means of natural atmospheric transfer (wind).

IV. Basics of the Atlant Model.

Ground-based ionization as a means of weather modification has a long history of experimental investigation including the widespread releases of ions into sub-cloud air using corona discharges generated from extensive arrays of small diameter wires connected to a high-voltage power supply, and exposed to local winds and over the years a number of field experiments have been run using technologies derived from this technique . Most recently a series of field trials of ground-based ionization rainfall enhancement technology known as Atlant have been conducted in Australia

Several mechanisms exist by which ions might influence the microphysical processes of precipitation formation at multiple stages through the process .

<u>The Atlant model is based on a mechanism by which ions generated a plausible “chain of events” mechanism by which negative ions are generated by a high-voltage corona discharge wire array.</u>

These ions are hypothesized to become attached to particles in the atmosphere (especially soluble particles), which later act as cloud condensation nuclei (CCN). In turn, these particles are conveyed to the higher atmosphere by wind and the electric charges on them are transferred to cloud droplets. Finally the electrostatic forces on droplet interaction aid the coalescence of the cloud droplets, resulting in enhanced raindrop growth rate and ultimately increasing rainfall downwind from the Atlant ion emitter.

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Thus instead of doing modeling with simulations to confirm the validity of the Atlant method, the Atlant method is verified by trial and error guided by statistical models. As with chemical cloud seeding, field trials are seen as the best means of establishing the efficacy of Atlant with statistics.

A number of trials have now been conducted in Australia. The trials in South Australia were conducted under the oversight of an independent scientific review panel. In addition, a benefit cost analysis was carried out as a part of the 2009 South Australian trial. Consequently, the 2009 trial is the focus of the case study presented here.
Three trials were conducted in South Australia in the Mount Lofty Ranges outside the capital city of Adelaide, from 2008 to 2010. The trials were conducted over winter and spring, when the region receives most of its annual rainfall. Rainfall and other meteorological observations were all obtained from the Australian Bureau of Meteorology and are a part of the public record. Efforts were made to improve the experimental design and methods of statistical analysis in each successive trial. 2008 and 2009 was to change from a single site operating on a randomized schedule to a randomized cross-over design with two sites in 2009. The major statistical improvement was in the way in which the spatiotemporal correlation in gauge-level rainfall observations was accounted for in the analysis. The theory underpinning this development was completed over 2009 to 2011.

V. Statistical Models.

The statistical methods developed for the 2010 trial were applied to the 2009 and 2010 trial data. The estimated enhancement effect from the 2009 trial was 10.5 per cent with an estimated standard error of 5.3 per cent, significant at the 95 per cent confidence level based on a standard t-test. The estimated enhancement effect from the 2010 trial was 10.0 per cent with an estimated standard error of 6.4 per cent, significant at the 90 per cent confidence.

VI. Demonstration of Atlant Technology

The Atlant technology is utilizing a ground-based ionization system to influence the atmospheric conditions in the vicinity of the installation. The processes lead to the generation of an “ion wind”, which creates an updraft of low level, higher humidity air masses to the mid-level atmosphere where condensation lead to further enhanced convective airflows and the formation of clouds. These combined effects are believed to generate under suitable conditions large convective cumulus clouds (similar to thunderstorms), which can then initiate or increase precipitation in an area around the Atlant installation. The technology has been developed over many years primarily in Russia where numerous projects have been conducted mostly on a contractual basis. Most recently tests have also been conducted in Switzerland, Germany and the United Arab Emirates. While there is extensive documentation of these events, the technology has not been fully scientifically documented.

1. Australian Research

As stated earlier, Australia is in the lead for Atlant rain enhancement technology.

1.1. The University of Queensland Research and Development.

The University of Queensland of the test of the Atlant rain enhancement technology conducted in SE Queensland during the period between 15 May to 30 June 2007. The target area was defined as the catchment area of the Wivenhoe, Somerset and North Pine dams, which are the main water supplies for the wider Brisbane area. The catchment area has been experiencing extreme drought conditions for over 6 years. The rainfall deficit in the catchment has been the worst on record and the combined dam levels were around 18% of capacity at the time of the test period.
Due to the short duration of the test and the difficulty in achieving scientifically conclusive results in meteorological studies, most of the observations reported are based on the professional assessment of the evaluation team using best available data and evaluation methods. The following key observations could be made during
To demonstrate and evaluate the potential of the Atlant technology in Australia, a demonstration test was conducted in southeast Queensland from 15 May to 30 June 2007 by the Australian Rain Corporation, which has the Australian licence to the Atlant technology owned by the Swiss company Meteo Systems AG. The University of Queensland was contracted to evaluate the demonstration test.

Fig 3. Atlant System during demonstration in Queensland May/June 2007

Due to the short duration of the test and the difficulty in achieving scientifically conclusive results in meteorological studies, most of the observations reported are based on the professional assessment of the evaluation team using best available data and evaluation methods. The following key observations could be made during this test:
Significant rainfall was measured in the catchment area within two weeks of the start of the Atlant operations on 15 May. This first rainfall event was not part of a widespread rain pattern in South-East Queensland and was unusual in that the easterly sourced rainfall passed and was even enhanced over the coastal ranges north of Brisbane and into the catchment area. There was unseasonably heavy and widespread rainfall in Queensland during June, restricting the ability to evaluate the direct impact of the Atlant system. However, direct rainfall measurements over the whole test period showed that the average rainfall in the catchment area was 28% (31 mm) higher than in the wider Southeast Queensland area outside the catchment. This is the highest positive difference observed over the same seasonal period in the last 50 years and contrasts the long-term average, which shows that the catchment area has typically around 12% less rainfall than the stations outside the catchment. Over the last 10 years (1997-2006) this difference was even much more pronounced (-25% or -20mm).
A number of unusual meteorological patterns were observed whereby rainfall seemed to be enhanced in the vicinity of the Atlant system. These patterns included unusual intensification of rainfall areas after crossing the coastal ranges near the Atlant station and prolonged "anchoring" of intense rainfall areas downwind of the Atlant station. These observations are consistent with the expected influence of the processes believed to be initiated by the Atlant system.

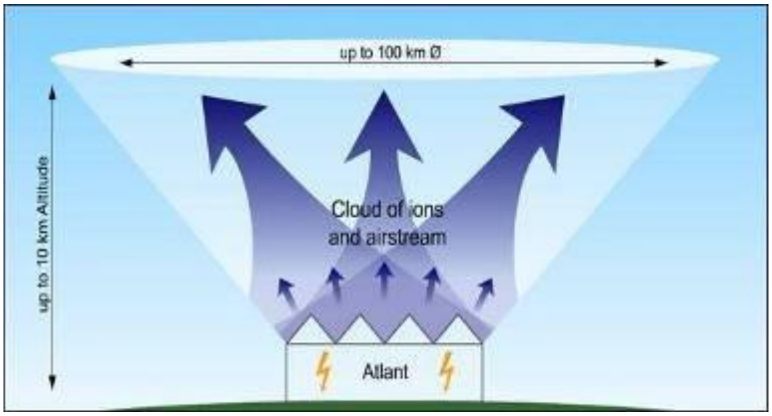

Fig 4 Method of Atlant ionization process

The observations of this test, together with the existing information from previous tests, provide substantial evidence to indicate that the Atlant technology has an influence on the local regional precipitation pattern. To make a conclusive assessment of the influence of the system, more detailed and scientifically validated evidence needs to be collected from a longer-term demonstration of the technology.

In southeast Queensland coastal stream showers in south-easterly airflow are typically confined to the coastal plain and seldom travel far inland to cause rainfall west of the D'Aguilar Range. As a result, the Wivenhoe Dam under these conditions remains in a region of rain shadow..
In the Fig 5 below, the cross-section of southeast Queensland showing coastal stream showers in south-easterly airflow**.**
The potential enhancement of convective precipitation by the Atlant over the D'Aguilar Range is shown in the figures below. This situation would occur during weather patterns that produce warm and humid east to north-easterly airflow onto the southeast Queensland coast. In this situation positioning of the Atlant on a ridge above the coastal plain also ensures that dynamic lifting of the moist onshore airflowby the topography enhances the influence of the Atlant.

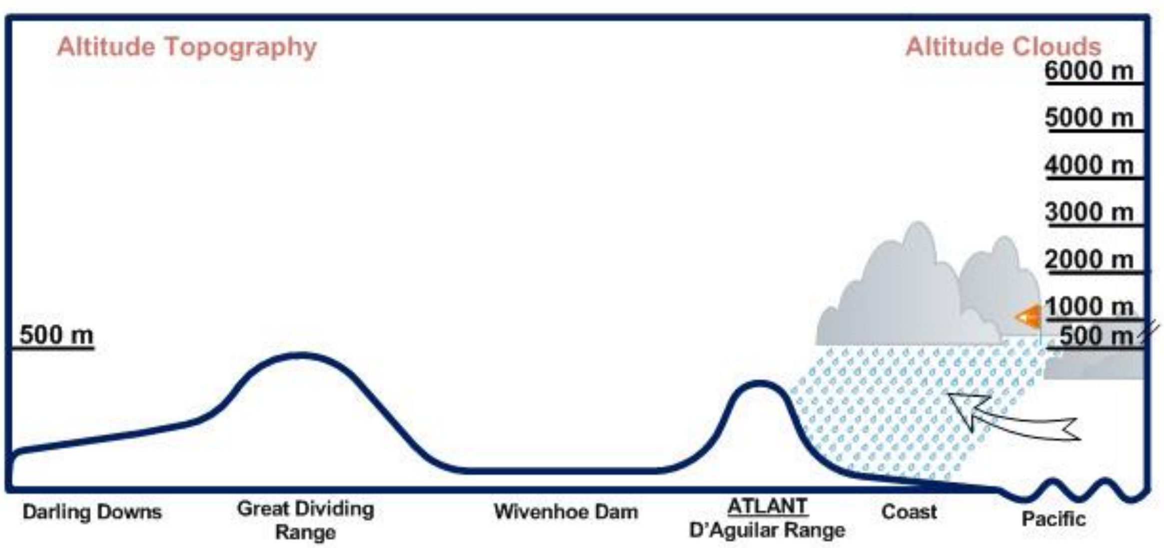

Fig 5, A cross-section of southeast Queensland showing coastal stream showers in south-easterly airflow.

The Atlant potentially influences rainfall intensity during widespread precipitation events associated with stratus cloud Fig 6. In these situations, rainfall enhancement is considered likely to occur both upwind and downwind of the D'Aguilar range during light to moderate winds. At higher wind speeds, the area of rainfall enhancement would be shifted downwind of the Atlant.

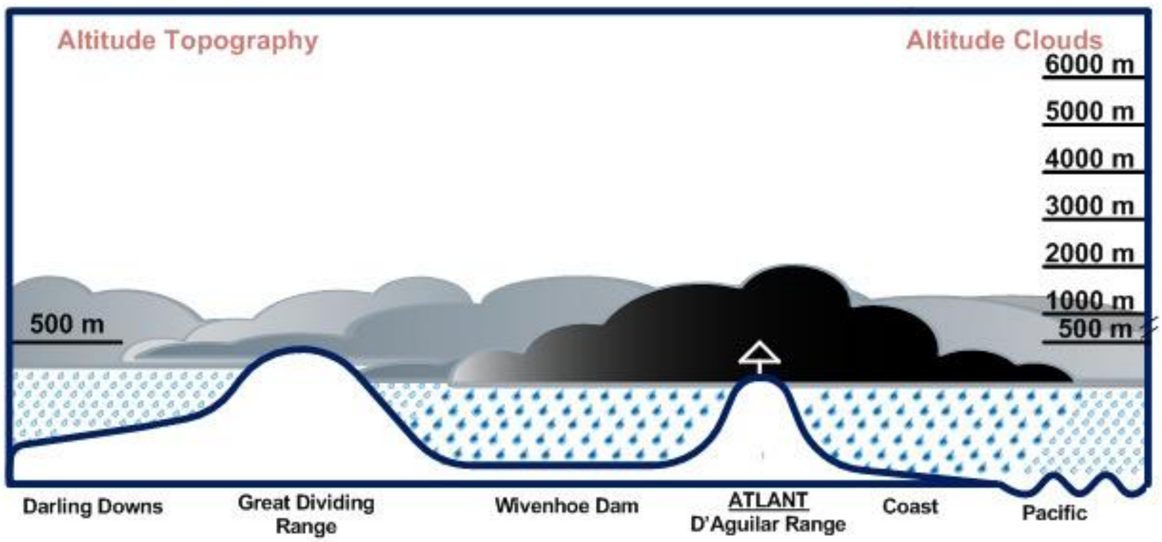

Fig 6 Schematic representation of how the Atlant is believed to affect rainfall intensity during widespread precipitation events associated with stratus cloud over southeast Queensland.

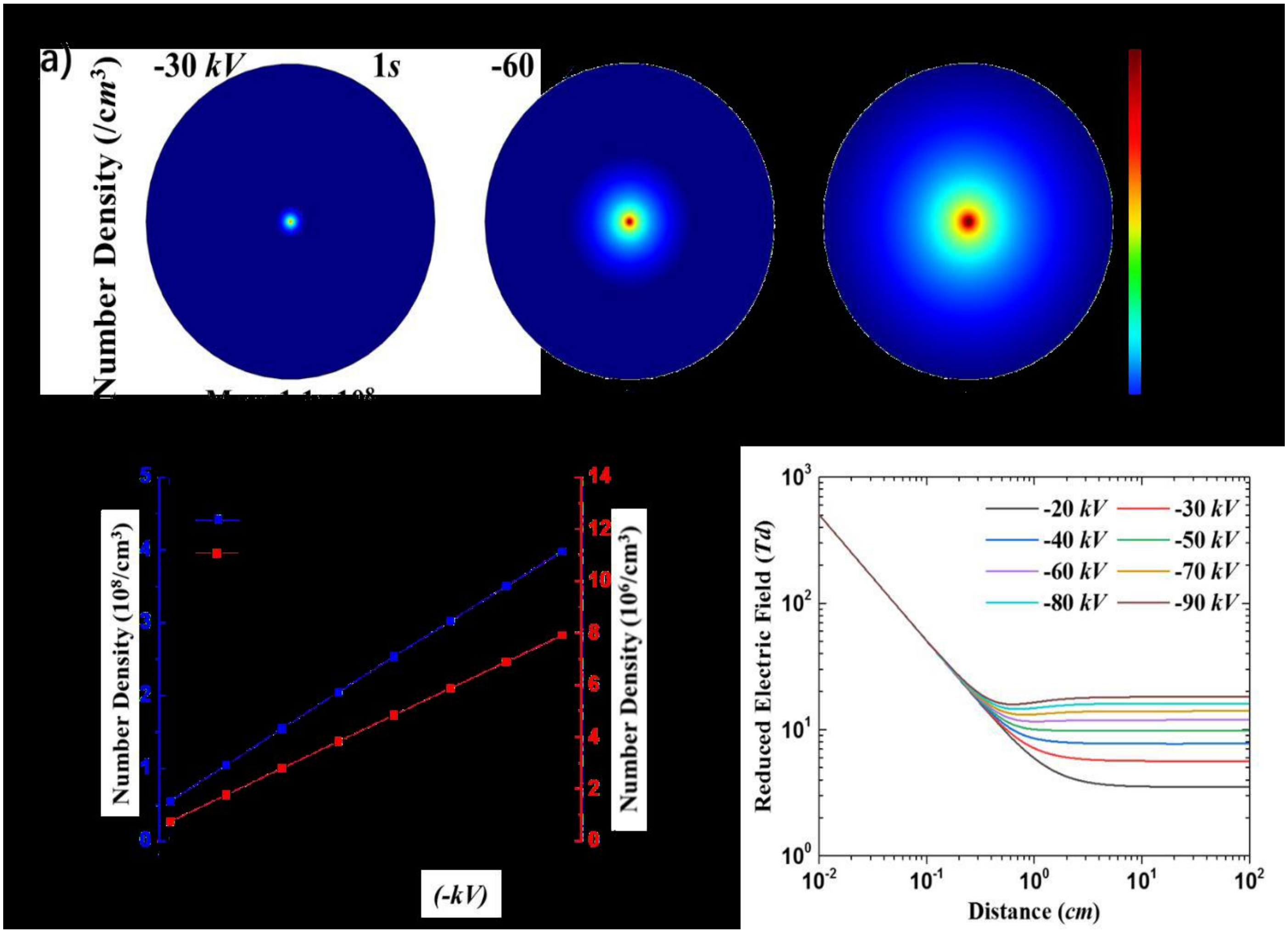

Fig 7. The increasing applied voltage enhances the ion output capacity 3 of the corona discharge source. (a) The distribution of ions generated by single corona discharge point (simulation). The center is the corona discharge point. The radius of the big blue circle is 1 m. (b) The ion density at 1 cm from the center as a function of applied voltage. (c) The electric field from the center as a function of applied voltage.

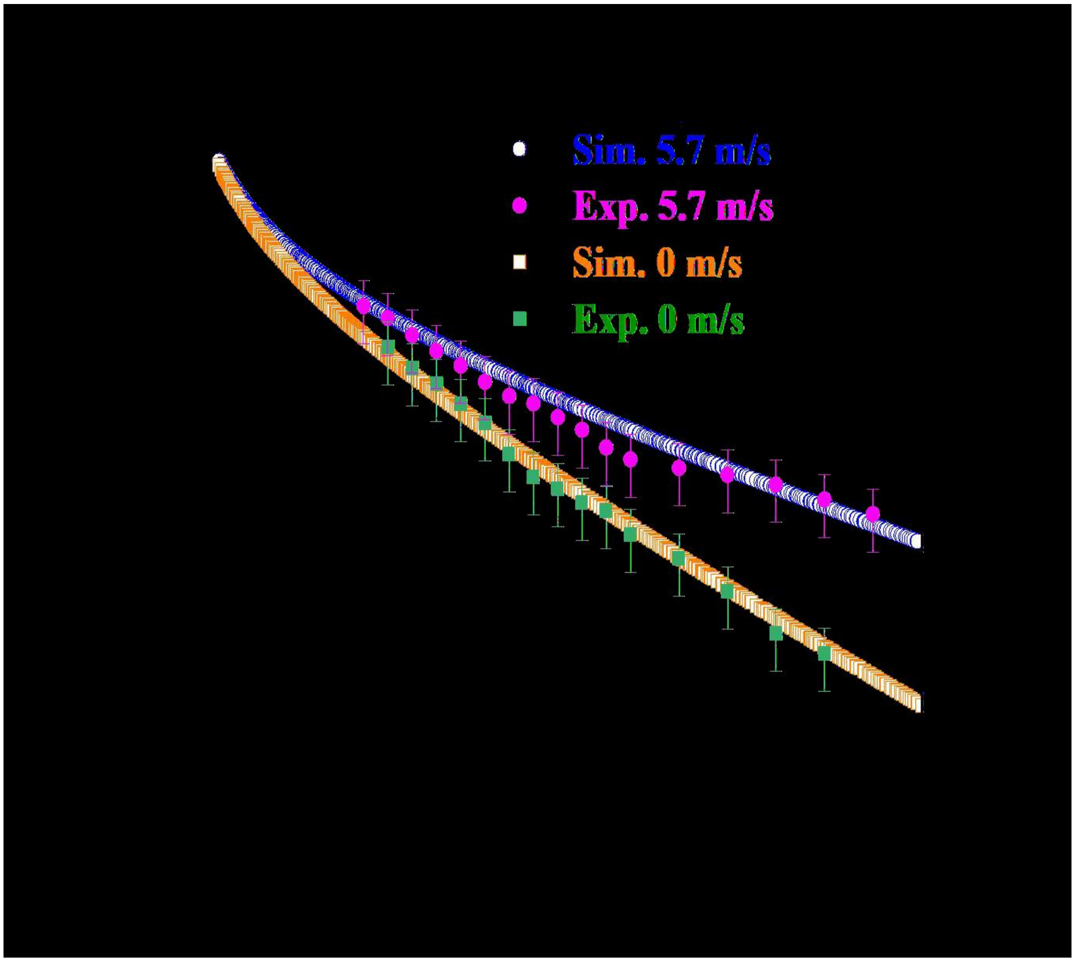

Fig. 8. The effect of wind on the distribution of ions generated by a single 3 corona discharge point (indoor tests). Wind speed at 0 m/s and 5.7 m/s. The applied voltage on the wire electrode was -40 kV. The experiment measurement data is plotted with error bar. The simulation data is plotted by hollow symbols.

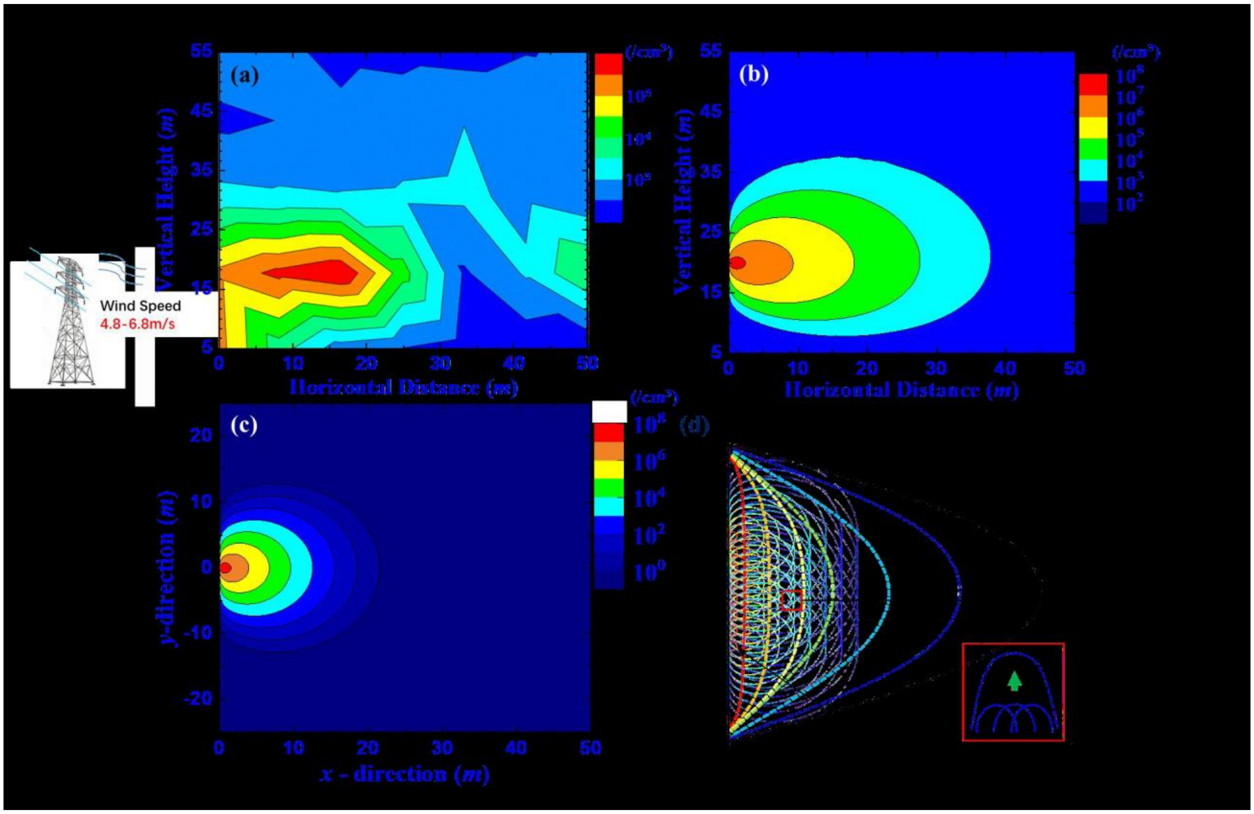

Fig 9. The coverage area of the large corona discharge system is the combination 2 of the coverage areas of the very large number of corona discharge points. (a) The ion density distribution in vertical direction and downwind direction (experimental measurement, applied voltage -90 kV). (b) The ion density distribution in vertical direction and downwind direction (simulation, z axis (vertical direction), x axis (horizontal direction)). (c) The ion density distribution of single corona discharge point (-90 kV) in horizontal direction (x-y axis). (d) The combination of ions generated by multi corona discharge points resulted in high negative ion density in the open air. The dashed color clines from red color to black color suggests the ion density decreases as the distance from the wire electrode increases. The inserted picture indicates the combination of ions generated by three corona discharge sources increases the coverage of ions substantially.

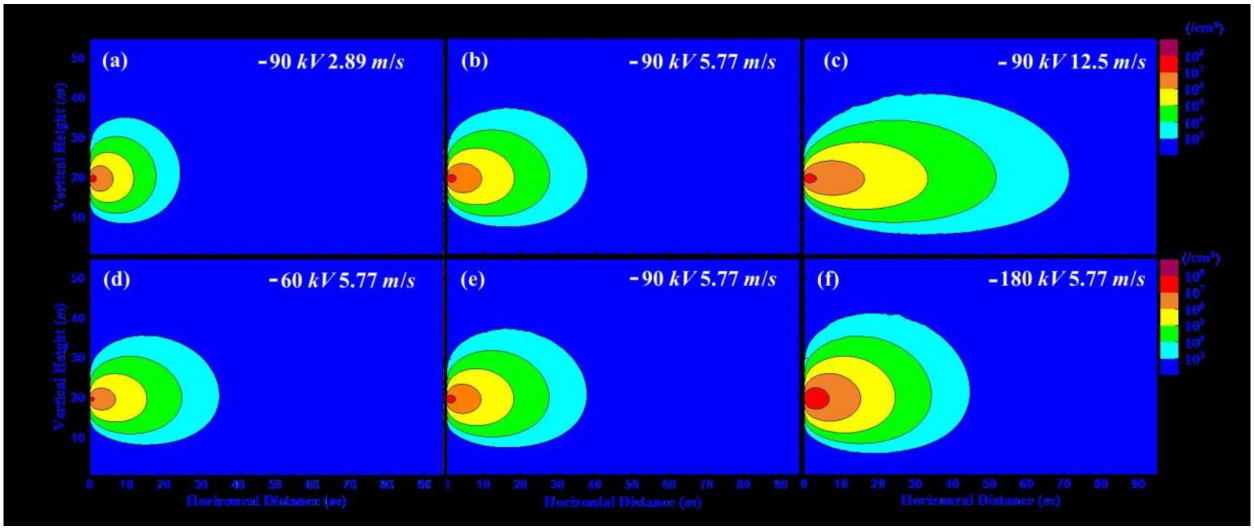

Fig. 10. The increasing applied voltage and wind speed can enlarge the coverage area of the ion source. The effect of wind on the ion distribution in the field (numerical results). (a) -90kV, 2.89m/s (wind speed), (b)-90kV, 5.77m/s, (c)-90 kV, 12.5 m/s. The effect of wind on the ion distribution in the field (numerical results). (d) -60 kV. (e) -90 kV. (f) -180 kV.

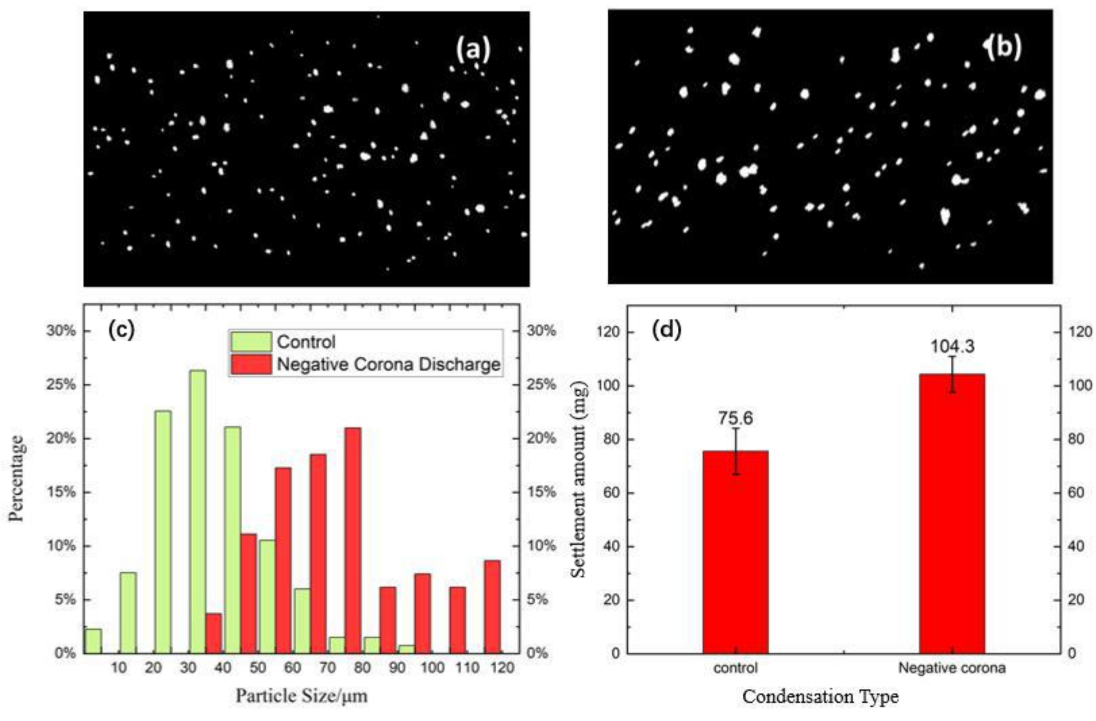

Fig 11, The ions generated by corona discharge source enhance the condensation 3 of aerosols. The photo of aerosols in the light path of a laser for the case of (a) control group, (b) the enhanced

VII. Initial Theoretical Modeling for Predicting Rain Amounts from the Number of Ions Created by Corona Effects.

1. Comparison of ion transport solutions using the transient advection diffusion reaction equation and experimental results. See Figs 7-11.

The transient advection diffusion reaction equation which is:

$$\frac{\partial c}{\partial t} = \nabla \cdot (D \nabla c) - \nabla \cdot (\mathbf{v} c) + R$$

Was solved numerically with experimental results and the results are givem in the plots below.

This is good news for the validity of the Atlant rain enhancement technique. However what is needed is a physical theory that predicts the amount of rainfall over a given area from the amount of ionization from an Atlant device.

2. Balance equations of ion concentrations.

The 2D numerical model is used to the study the distribution of ions within 1 m from the wire electrode. The model used in this study extends the existing models (to model the relevant phenomena at the relevant scales. The model solves the Poisson's equation and the transport equations for neutral and charged species as a function of time. The number density of each species is obtained by solving the continuity equation. The electric field is obtained by solving the Poisson's equation. The electron energy is calculated by the electron energy conservation equation. The transient advection diffusion reaction equation (equation is used to study the effect of wind on the transport of ions. where c is the crosswind-integrated concentration of ions.The concentration of air ions changes in time due to different formation and loss processes according to the simplified balance equations:

(1) dn/dt = q −βeff(Ztot)n−αn^2

(2) dn/dt = q −(Coag)S·n−αn^2

New air ions are formed via air molecule ionization which is q in the equations. (the first terms on right hand side). At the same time they are lost by the coagulation with the pre-existing aerosol with a total concentration of Ztot (the second term in Eq. (1). In Eq. (2), coagulation is described by the coagulation sink coefficient CoagS, which is obtained by integrating over the particle size distribution. In addition ions are lost via ion-ion recombination (the third terms on right). The coefficient α is the ion-ion recombination coefficient, and βeff is the efficient ion-aerosol attachment coefficient.

Equations (1) and (2) are sufficient for first order calculations. However, more detailed analysis requires considerations of:

(A) additional sinks, growth, deposition due to electric fields, and dry deposition.

(B) local sources (corona discharger, traffic), and

(C) errors caused by assuming equal concentrations of small positive and negative ions and symmetrical charging of aerosol particles.

Based on the balance Eqs. (1) and (2), we can calculate the maximum limit for small ion concentration if we assume a steady state situation (dn/dt = 0) and exclude the effect of background aerosol, thus ending up to the equation $q = \alpha n^2$

The coefficient α is about 1.6×10^{-6} cm^3/s

under typical atmospheric conditions. With these assumptions, ion production rates q = 2, 10 and 100 (cm^−3)s^-1 lead to concentrations of positive and negative small ions of 1100, 2500 and 7900 cm^-3.

The solutions to (1) and (2) and more sophisticated versions of them with (A), (B), and (C). Must be connected to the corona discharge equations.

condensation group by ions. The photo was taken 5 min after the experiment started. (c)The particle size distribution of aerosols in the cloud chamber for the control group and negative corona discharge group (calculated according to (a) and (b)). (d) The ions generated by corona discharge source enhance settlement of moisture. The settlement of moisture of control, negative corona discharge groups on the acceptor 10 min after the experiment started.

3. The transient advection diffusion reaction equation.

We need to solve for c.

$$\frac{\partial c}{\partial t} = \nabla \cdot (D \nabla c) - \nabla \cdot (\mathbf{v} c) + R$$

c is the variable of interest (species concentration for mass transfer, temperature for heat transfer), In this case is the crosswind-integrated concentration of ions.

D is the diffusivity (also called diffusion coefficient), such as mass diffusivity for particle motion or thermal diffusivity for heat transport,

v is the velocity field that the quantity is moving with. It is a function of time and space. For example, in advection, c might be the concentration of salt in a river, and then v would be the velocity of the water flow as a function of time and location. Another example, c might be the concentration of small bubbles in a calm lake, and then v would be the velocity of bubbles rising towards the surface by buoyancy (see below) depending on time and location of the bubble. For multiphase flows and flows in porous media, v is the (hypothetical) superficial velocity.

R describes sources or sinks of the quantity c. For example, for a chemical species, $R > 0$ means that a chemical reaction is creating more of the species, and $R < 0$ means that a chemical reaction is destroying the species. For heat transport, $R > 0$ might occur if thermal energy is being generated by friction.

∇ represents gradient and $\nabla \cdot$ represents divergence. In this equation, ∇c represents concentration gradient.

4. Understanding the terms involved of the transient advection diffusion reaction equation.

The right-hand side of the equation is the sum of three contributions.

The first, $\nabla \cdot (D\nabla c)$, describes diffusion. Imagine that c is the concentration of a chemical. When concentration is low somewhere compared to the surrounding areas (e.g. a local minimum of concentration), the substance will diffuse in from the surroundings, so the concentration will increase. Conversely, if concentration is high compared to the surroundings (e.g. a local maximum of concentration), then the substance will diffuse out and the concentration will decrease. The net diffusion is proportional to the Laplacian (or second derivative) of concentration if the diffusivity D is a constant.

The second contribution, $-\nabla \cdot (vc)$, describes convection (or advection). Imagine standing on the bank of a river, measuring the water's salinity (amount of salt) each second. Upstream, somebody dumps a bucket of salt into the river. A while later, you would see the salinity suddenly rise, then fall, as the zone of salty water passes by. Thus, the concentration at a given location can change because of the flow.

The final contribution, R, describes the creation or destruction of the quantity. For example, if c is the concentration of a molecule, then R describes how the molecule can be created or destroyed by chemical reactions. R may be a function of c and of other parameters. Often there are several quantities, each with its own convection–diffusion equation, where the destruction of one quantity entails the creation of another. For example, when methane burns, it involves not only the destruction of methane and oxygen but also the creation of carbon dioxide and water vapor. Therefore, while each of these chemicals has its own convection–diffusion equation, they are coupled together and must be solved as a system of simultaneous differential equations.

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5. Derivation of transient advection diffusion reaction equation.

The convection–diffusion equation can be derived in a straightforward way[4] from the continuity equation, which states that the rate of change for a scalar quantity in a differential control volume is given by flow and diffusion into and out of that part of the system along with any generation or consumption inside the

$$\frac{\partial c}{\partial t} + \nabla \cdot \mathbf{j} = R,$$

where j is the total flux and R is a net volumetric source for c. There are two sources of flux in this situation. First, diffusive flux arises due to diffusion. This is typically approximated by Fick's first law:

$$\mathbf{j}_{\text{diff}} = -D\nabla c$$

i.e., the flux of the diffusing material (relative to the bulk motion) in any part of the system is proportional to the local concentration gradient. Second, when there is overall convection or flow, there is an associated flux called advective flux:

$$\mathbf{j}_{\text{adv}} = \mathbf{v}c$$

The total flux (in a stationary coordinate system) is given by the sum of these two:

$$\mathbf{j} = \mathbf{j}_{\text{diff}} + \mathbf{j}_{\text{adv}} = -D\nabla c + \mathbf{v}c.$$

Plugging into the continuity equation:

$$\frac{\partial c}{\partial t} + \nabla \cdot (-D\nabla c + \mathbf{v}c) = R.$$

6. Numerical solution of the transient advection diffusion reaction equation.

The convection–diffusion equation can only rarely be solved with a pen and paper. More often, computers are used to numerically approximate the solution to the equation, typically using the finite element method. For more details and algorithms see: Numerical solution of the convection–diffusion equation.

Vlll. The Collision and Coalescence Processes.

Unlike the Bergeron Process, where precipitation forms under supercooled conditions, the Collision and Coalescence Process typically occurs within relatively warm clouds with tops

warmer than -15C. As you can tell by the name of this process, the collision of falling and rising droplets is what allows them to grow large enough to fall to the ground as precipitation.
This process usually does not involve ice crystals, but there are circumstances that we will learn about where ice crysals can collide and become larger (coalesce) as well.
First, lets take a look at some important factors in the growth of a droplet through this process:

1) There must be a high liquid water content within the cloud.
2) There must be sufficiently strong and consistent updrafts within the cloud.
3) A large range of cloud droplet sizes is very helpful.
4) The cloud must be thick enough so that the cloud droplets have enough time to gather surrounding smaller droplets.
5) The electric charge of the droplets and the electric field in the cloud and its effects are still being studied.

The liquid water content of the cloud is important for an obvious reason. Without sufficient liquid water to form droplets, there will be no liquid precipitation!
Within the warm cloud there is an updraft of air caused by air coming together or converging at a point beneath the cloud. After the air converges, it is forced upward. This process is what initially helps to build the cloud and now that it has formed, it continues and carries smaller cloud droplets up into the cloud while larger droplets stay suspended within the cloud or even fall downward slowly. As you might guess, with billions upon billions of cloud droplets hanging out in the cloud, some of them are bound to bump into each other! This is where the term, "collision" comes into play!

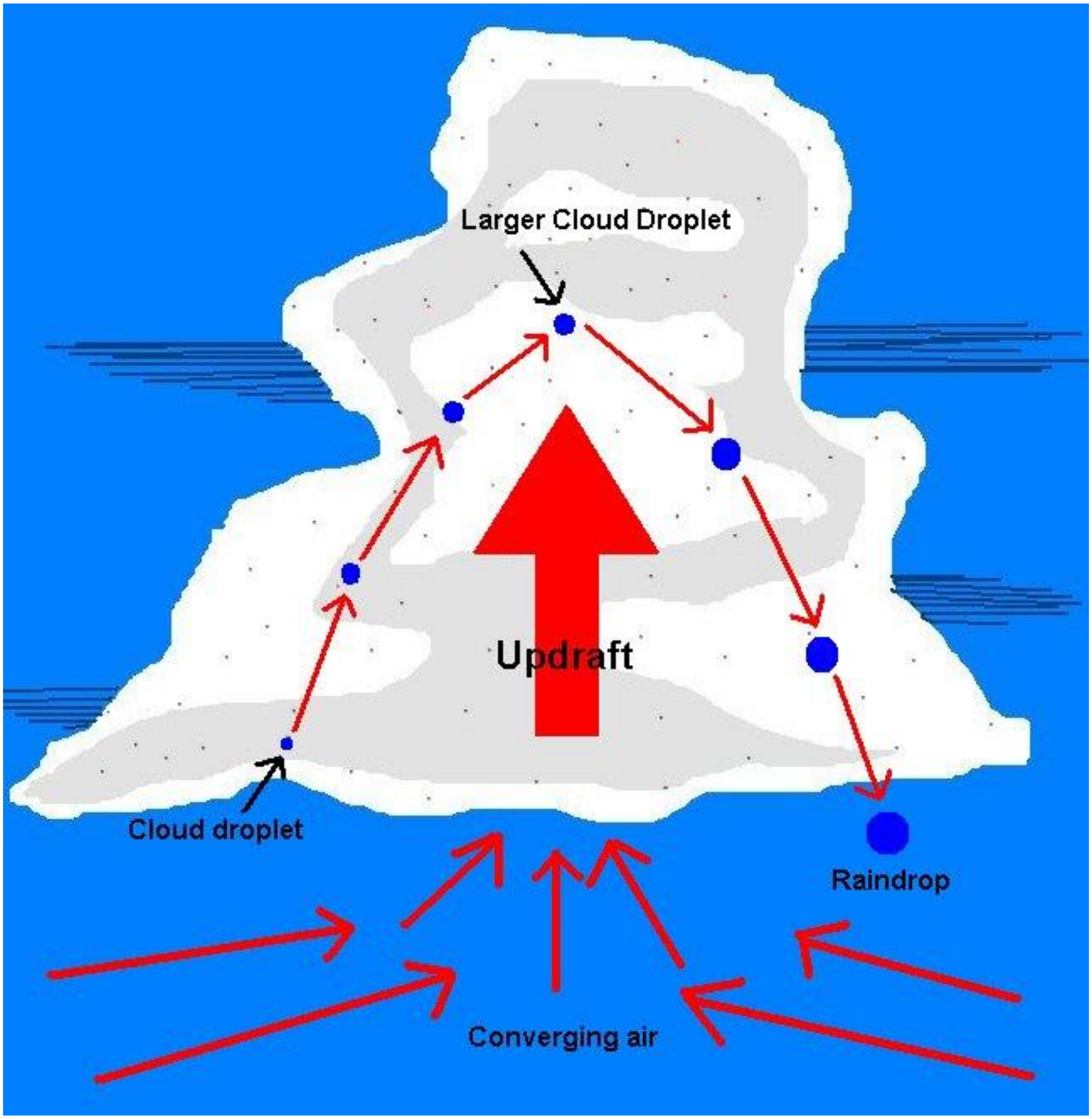


Fig 12, As the cloud droplets experience millions of collisions, they sometimes join together (or coalesce) and form larger cloud droplets. The larger cloud droplets then fall faster (because they have a higher terminal velocity, click here to learn more) and collide with smaller droplets in their path. Studies done in laboratories have shown that not all collisions result in coalescence, that is to say, that some of the drops break apart after colliding. The studies have shown that "coalescense appears to be enhanced if colliding droplets have opposite (and, hence attractive) electrical charges... especially in thunderstorm precipitation coalescence where strongly charged droplets exist in a strong electrical field" Ahrens 1994.

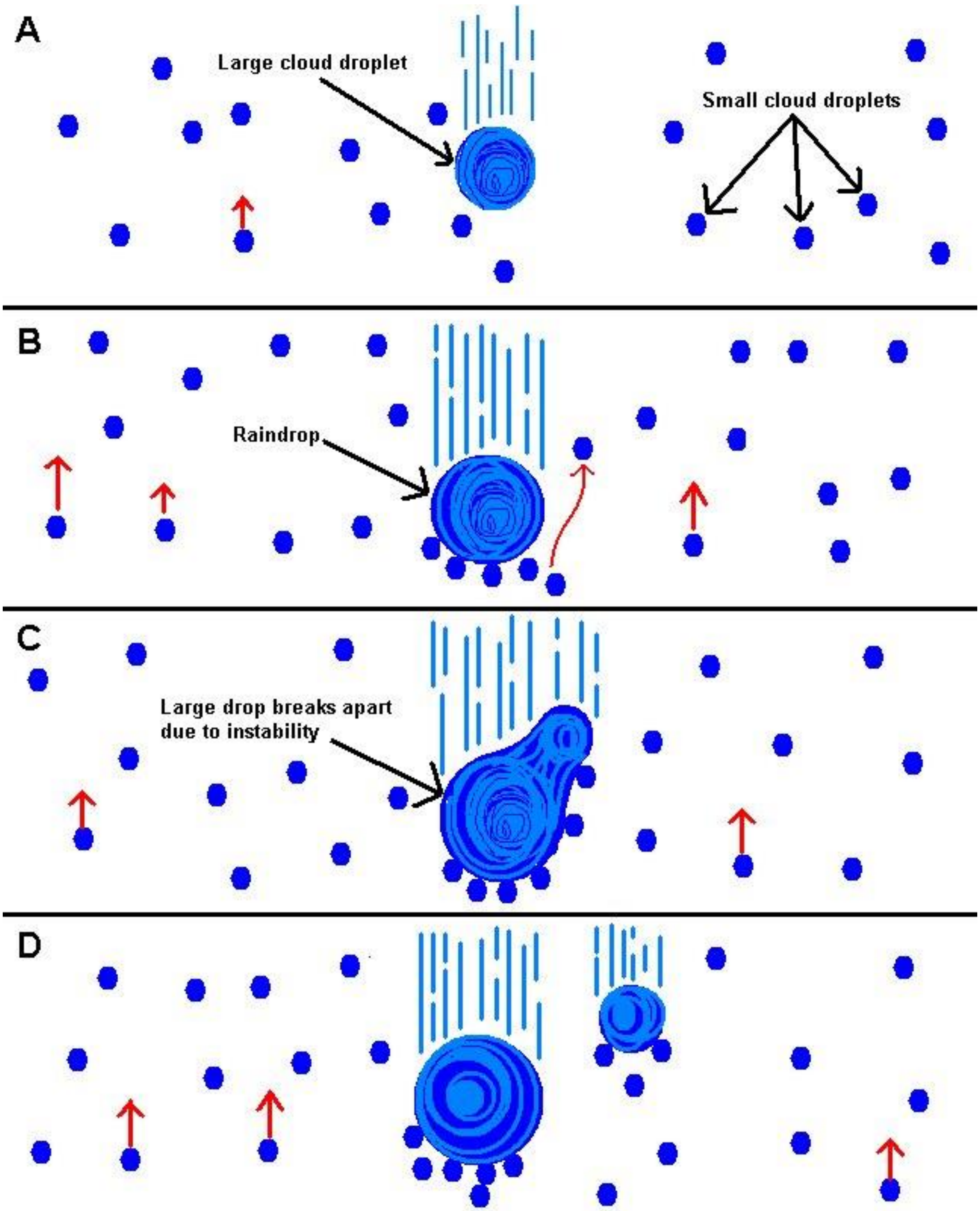


Fig 13. The diagram above shows a droplet as it grows larger by collision/coalescence and eventually becomes too large to remain in one piece. Smaller cloud droplets are shown with

some upward vertical velocities (red arrows) to indicate that they may be caught in an updraft within the cloud.
Part B of the above diagram shows a cloud droplet that initially moves toward the drop as if it were going to barely collide, but then it moves away taking a quick right hand turn/
This droplet is getting caught up in streamlines that form around a falling larger drop. These streamlines are where air has been "plowed" away by the bottom of the drop so that it turns away from the drop, carrying smaller droplets out away and keeping them from colliding, and thus coalescing with the larger drop. Picture a snow plow (if you have ever seen one!) and how the snow piles up along the front of the plow and is pushed off to the side into the snowbank, it is a similar process!
The diagram below shows a streamline in more detail:

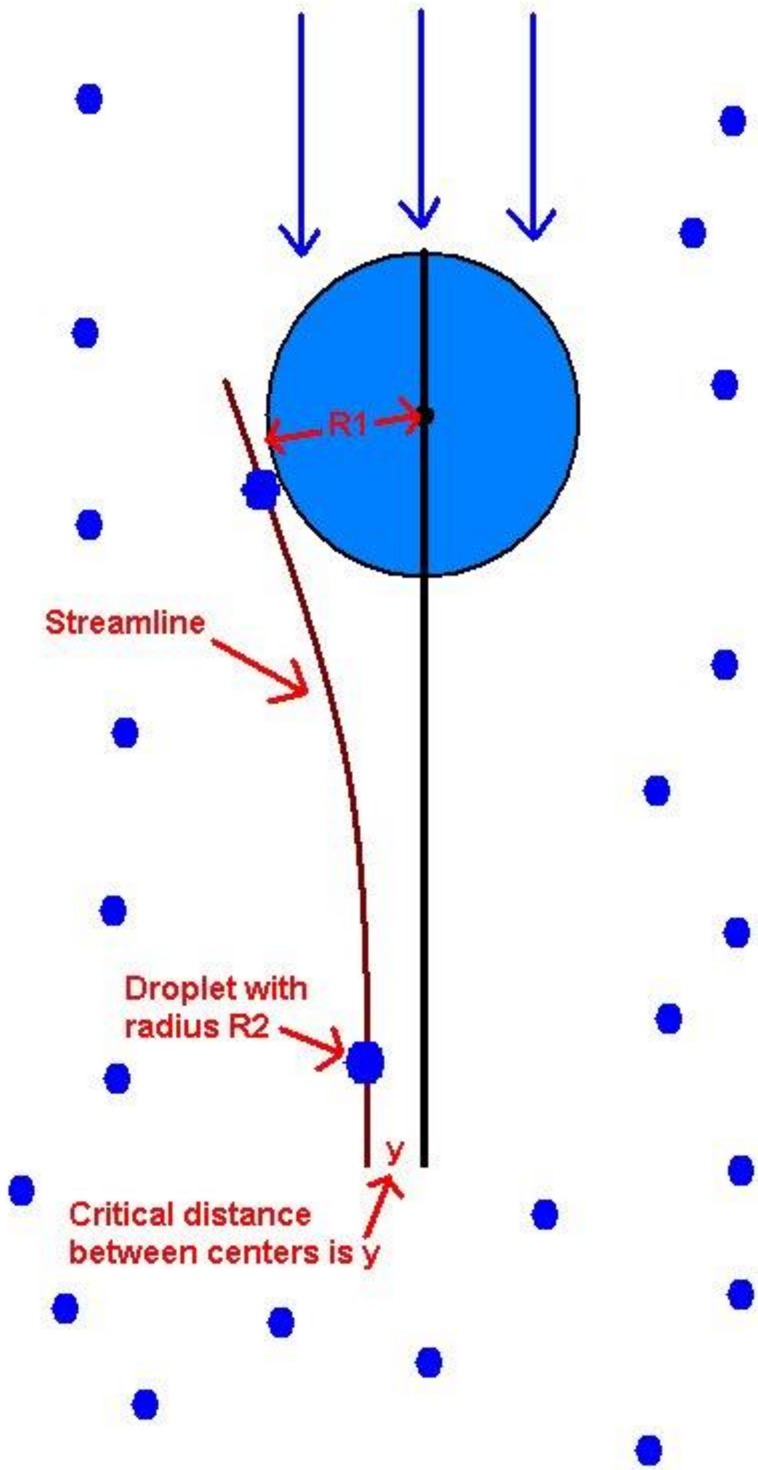


Fig 14. The above diagram shows "y", the critical distance between the centers of the droplet with radius R2 and the collector drop with radius R1. This critical distance is the farthest distance that the centers can be from one another so that the droplet can still make

contact with the collector drop. If a droplet is beyond this distance it will not collide with the collector drop and thus, will have no chance of coalescing and aiding in the collector drop's growth into a bonified precipitation droplet!
There is an equation that is used to determine the chances that a droplet will collide with a collector drop. This equation gives us the collision efficiency (E) and looks like this:

$$E = \frac{y^2}{(R1 + R2)^2}$$

The collector drop has a hard time growing because of this streamline effect. If droplets are too small, the "y" distance is much smaller and they will most likely be caught up in the streamline of air around the drop. Also, on the other hand, if the droplet is close in size to the collector drop, then their terminal velocities (fall speeds) will be close to the same and they will fall side by side to that they do not collide.
Now we have talked about how a droplet collides with a collector drop, but even if it collides, who is to say that it will "stick" to the collector drop and coalesce?
Perhaps you have seen water droplets bounce when they collide with another water surface? Such as when raindrops hit a lake surface and splash back upward so that the water droplet is not instantly absorbed or "coalesced" into the lake?
There is a coefficient that looks at the fraction of collisions that result in coalescence and it is called the coalescence efficiency. The coalescence efficiency is obtained by doing laboratory experiments in which the experimental measurements are compared to the theory.
Once you have both the Collision and the Coalescence efficiencies, you can multiply them together to get the Collection Efficiency of a drop. This is very important because it will tell you exactly how well a droplet will be able to grow into a precipitation drop.
It is also possible for a snow crystal to form initially by the Bergeron Process and then coalesce with other ice crystals to become larger. This is usually evident during a warm, wet snow event when you see snow flakes the size of half dollars (2-3 inches!) or larger. When the snow flakes become warmer, some of their surfaces may melt just enough to allow the re-freezing (Aggregation) of another flake to their outer surface. Flakes can also become large enough that they too are broken apart by the drag force of the air hitting it from below. Once the flake has has been broken up into smaller crystals, the smaller crystals are free to begin the Bergeron process or aggregate with other crystals all over again!

X. Conclusions

1. Large-scale corona plasma discharge system.

To summarize, in one test a large-scale corona plasma discharge system was installed to analyze the production and the coverage area of negative ions that are capable to induce precipitation of atmospheric aerosols in downwind direction. The nitrogen species dominated the optical emission spectra of the negative corona discharges. The corona discharge was found to perform as a stable ion source with the density of ~ 108/cm3. The coverage area of the ions was dramatically improved by using over 300,000 corona discharge points, which also reduced the common destructive interference leading to the decay of ion concentrations in the open air, thereby dramatically increasing the outward ion transport capacity of the large-scale corona plasma discharge installation. As a result, the large ion coverage area (30 m×23 m×90 m) has been achieved experimentally and validated by the numerical calculations. The faster wind speed was a more efficient way to increase the ion coverage area. The cloud chamber experiment confirms that the charged aerosols generated by ions can accelerate the settlement of moisture by 38%. These results indicate that the large scale corona discharge installation indeed can increase the ion density within a certain region. Furthermore, the ion-induced charged aerosols may realistically trigger water precipitation or, alternatively, fog elimination. Since the latter effects were studied using our large-scale cloud chamber laboratory system, systematic field studies under real-world conditions are warranted to optimize the complex processes involved in ion-induced precipitation of atmospheric aerosols under prevailing weather conditions.

2. Queensland Conclusions.

On the basis of the observations and measurements made during the test period in southeast Queensland, the following conclusions can be made: During the test period there were several strong rain events, whereby the Atlant operation seems to have at least enhanced the rainfall amounts as observed in rain radar images and rainfall measurements in the area.
T***he statistical evaluation of the rainfall amounts and local distribution shows both a higher total rainfall intensity in the vicinity of the Atlant system, as well as a significantly higher rainfall amounts in the catchment area compared to the surrounding stations relative to long-term historic values***.
The total amount of rainfall registered during the 47 day test period was estimated to be around 990 GL over the dam catchment area. Although only limited run-off was generated in this instance due to the severe drought conditions in the area prior to the test, this rainfall amount is equivalent to several years water supply from Wivenhoe, demonstrating the large potential benefits of enhancing rainfall (or harvesting atmospheric humidity) as part of the overall water supply strategy.
The major limitation of this trial is the short duration of the operating period and the fact that it coincided with a very unusual weather situation over most of northern and eastern Australia in June. For these reasons, the findings obtained in this trial are primarily based on the professional

assessment of the evaluation team using all available data and observations, but should not be seen as conclusive scientific evidence. Nevertheless, the overall findings are considered to be highly promising and encouraging. While the unseasonably heavy general rainfall in Queensland in June made it difficult to isolate the extent of Atlant's impact, the data and meteorological observations were consistent with the expected influence that this technology is believed to have on rainfall generation or enhancement. There was no evidence in the test period that the Atlant system did not generate or enhance rainfall events.

The general view of expert scientists exposed to the technology during the test period that it the underlying principles of the technology appear to be sound and the claimed impact possible together with a general agreement that more detailed observation of electrical and other atmospheric parameters around the Atlant operations is needed. There is an urgent need for long-term, scientific evaluation of the technology, including novel methods of measuring atmospheric and meteorological processes. It is strongly recommended to conduct a carefully structured and scientifically assessed demonstration project of the Atlant technology across different climatic and orographic areas over at least a full 12-month seasonal cycle in Australia.

The minimum duration of an Australia-wide project should be 18 months (12 months operation,6 months set-up and evaluation) to allow observations of the expected effects over at least one full seasonal cycle. At least three and ideally five independent Atlant systems should be established and assessed in different climatic and geographical locations in Australia. The operating periods (months) of each system should be randomly selected and the scientific assessment should be undertaken without knowledge of the operating status (blind test). In at least one location two identical (as far as possible) test and control areas should be established that allow the parallel assessment of the technology during the same time period.

The scientific evaluation should be based on direct measurements of rainfall on the ground, but also from detailed scientific studies of the atmospheric conditions during the different operating periods of the Atlant system. The scientific evaluation should include interdisciplinary representation from the fields of water management, meteorology, climatology, atmospheric physics and aerosol science.

3. Future numerical work.

A theoretical physics model for raindrop coalescence over the analysis in section Vll. There also needs to be a theoretical physics model for the number of ions produced from the number of corona discharge points and applied voltage in the Atlant corona discharge device. There is theoretical physics ion transport and the equation has to be solved numerically. In this case the ion transport equation is the transient advection diffusion reaction equation. This is similar to the Maxwell Boltzmann equations in neutron transport in nuclear reactors and electron and ion transport in plasmas.

3.1 Bottom line future work.

There needs to be a theoretical physics model in which the number of ions are produced are predicted from a corona discharge device with a number of corona discharge points and applied voltage plus weather input and the output the amount of rain and surface area covered.

This technology works, but with atmospheric plasma antennas mounted on aircraft can very significantly improve the amount of rainfall enhancement from about 18 % to 60 to70 %.

APPENDIX

Full resume of Dr. Theodore Anderson

Resume of Dr. Theodore (Ted) R. Anderson

Security Clearance (possibly not current) DOD and DOE
Citizenship United States
O***ffice address: 7 Martin Road, Brookfield, MA 01506-1762***

Phones: office and cell: 518-409-1010 Fax: 508 867 3918
e-mail: tedanderson@haleakala-research.com; websites: www.haleakala-research.com

Highest degree **PhD in physics** from New York University in 1986.
To verify and/or buy my PhD thesis go to: http://disexpress.umi.com/dxweb and type in: **TURBULENT WALL PRESSURE FLUCTUATIONS IN TERMS OF SPECTRAL DENSITIES CALCULATED FROM DISCRETE AND CONTINUOUS ORR-SOMMERFELD EIGENFUNCTIONS (ECKHAUS, TOLLMIEN-SCHLICTING)**
by *Anderson, Theodore Robert*, **New York University**, 1986, 173 pages; You can also type in: UMI Publication Number 8706713

CURRENT STATUS.

I am founder, Chief Executive Officer, principal investigator, and Chief Technology Officer of *Haleakala Research and Development Inc.(* www.ionizedgasantennas.com) 2002-present. I have won 9 phase 1 SBIR (Small Business Innovative Research) contracts and 2 phase 2 SBIR contracts with the US Air Force, US Army, US Navy, and US Marine Corp. This amounted to over 2 million dollars in R&D funds. Scientific American published an article on my technology and company in the February 2008 issue on page 22. The Air Force wrote a success story on my company and technology which appeared on the Air Force website. See my website for all the details: www.ionizedgasantennas.com.

I AM CURRENTLY WORKING ON A FAR-UVC TECHNOLOGY TO KILL COVID-19 AND OTHER VIRUSES WITHOUT HARMING HUMANS. I TREAT THE FAR-UVC DEVICE AS A PLASMA ANTENNA IN THE FAR-UVC SPECTRUM.

RECENT PATENTS:

Magnetic Resonance Imaging and Positron Emission Tomography Work.

Theodore Anderson, *MRI Device with Plasma Conductor*

: Appl. No.: **15/531645**
Filed: **June 15, 2016**
PCT Filed: **June 15, 2016**
PCT NO: **PCT/US2016/037568**

Allowed is US June 2019; filed internationally.

Theodore Anderson, *International Patent: Plasma elements for MRI/PET*
International Application Number PCT/US2016/037568, filed June 15, 2016; <https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2016205326>.

16 out of 21 claims allowed at international patent office in Geneva, Switzerland.

Theodore Anderson, *US Patent: Plasma elements for MRI/PET*

US Application Number 15/183,323,filed, June 15, 2016,

To see published application on the Internet, go to the PTO web site at <http://appft1.uspto.gov/netahtml/PTO/srchnum.html> and enter the Publication Number 2016/0370442 without the slash.

RECENT PUBLICATIONS

Anderson, Theodore, "Antenna Beam Focusing and Steering with Refraction Through a Plasma", EuCAP 2019, presentation and conference symposium. March 2019.

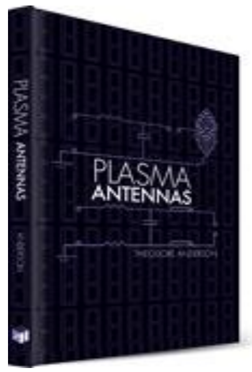
**Anderson, Theodore, "Magnetic Imaging Resolution and Positron Emission Tomography Using Plasma Antennas",
EuCAP 2019, presentation and conference symposium. March 2019.**

Books

The Second Edition of my book titled "Plasma Antennas".
See: https://us.artechhouse.com/Plasma-Antennas-Second-Edition-P2101.aspx

The Second Edition of my book titled "Plasma Antennas":

Plasma Antennas, Second Edition,
Theodore Anderson, Copyright: 2020 Artech House,
ISBN: 9781630817503



My original book titled "Plasma Antennas",
Theodore Anderson, ISBN: ISBN 978-1-60807-143-2
Copyright 2011, Artech House

Book chapters on plasma antennas by Theodore Anderson.

Theodore Anderson, ***Plasma Antennas,*** Open access peer-reviewed chapter, ***Selected Topics in Plasma Physics,*** Submitted: October 21st 2019Reviewed: March 2nd 2020Published: July 14th 2020, DOI:10.5772/intechopen.91944

Theodore R. Anderson, chapter 10; *Plasma Antennas*, *Frontiers in Antennas: Next Generation Design & Engineering*,, McGraw -Hill, Frank Gross editor. ISBN 0071637931 / 9780071637930

Popular Mechanics Article On Haleakala R&D, Inc or Dr. Ted Anderson plasma antennas:

Hambling, D.; *Scientists Control Plasma for Practical Applications*; Popular Mechanics; July 2010; page 18; http://www.popularmechanics.com/technology/engineering/news/scientists-control-plasma-for-practical-applications

Anderson, T., *An Overview of Experimental and Numerical Results on Plasma Antenna Arrays,* EuCAP Conference Proceedings, April 2015.

Anderson, T., *Numerical Investigation into the Performance of Two Reconfigurable Gaseous Plasma Antennas,* EuCAP Conference Proceedings, April 2014.

Anderson, T., *Plasma Antennas Co-site and Parasitic Antenna Interference Reduction Using Plasma Antennas,* AMTA Conference Proceedings, October 2013

Anderson, T., *Plasma Antennas: Theory, Measurements, and Prototypes*, AMTA Conference Proceedings, October 2013

Anderson, T., IEEE APS/URSI 2014 Paper #1547: *Theory, Measurements, and Prototypes of Plasma Antennas,* Conference Proceedings, July 2014.

Anderson, T., IEEE APS/URSI 2014 Paper #1928: *Plasma Frequency Selective Surfaces*, Conference Proceedings, July 2014.

Anderson, T., IEEE APS/URSI 2014 Paper #1538*: Plasma Antenna VSWR and Co-Site and Parasitic Interference Reduction or Elimination*, Conference Proceedings, July 2014.

Anderson, T., *Smart Plasma Antennas,* AMTA Conference Proceedings, October 2014, See: http://amta2014.org/

Anderson, T., *Plasma Antennas: Plasma Satellite and Reflector Antennas*, AMTA Conference Proceedings, October 2014. See: http://amta2014.org/

Anderson, T., *Plasma Antennas: Plasma Frequency Selective Surfaces for Antenna Radomes,*, AMTA Conference Proceedings, October 2014. See: http://amta2014.org/

Presented on plasma antennas at the Antenna Systems Conference in 2008, 2009, 2010, 2011, 2012, 2013, and will present in November 2014. See: http://www.antennasonline.com/conferences/program/conference-sessions/

Relatively Recent Conferences with presentations and booths

1. 2019 IEEE APS/URSI Conference, Atlanta, Georgia July 7 to July 12, 2019.

Booth with prototypes:

I will have booth displaying prototypes for my company Haleakala R&D of my plasma antenna technology at the 2019 IEEE APS Conference in Atlanta July 7 to July 12. See the link and scroll down to Booth 32
https://www.2019apsursi.org/Exhibitors.asp

2. 5 G Antenna Systems Conference September 26, 2019.

Presentation and publication:

Anderson, Theodore; *Antenna Beam Focusing & Steering with Refraction Through a Plasma with Corresponding Circuitry for the Advancement of 5G*
https://antennasonline.com/conference-schedule/

3. IEEE International Symposium on Phased Array Systems and Technology, Waltham, Massachusetts October 15-18, 2019.

Presentations and publications:

Anderson, Theodore; ***New Smart Plasma Antenna with Radiation Patterns and VSWR Measurements***

Anderson, Theodore ***Antenna Beam Focusing and Steering with Refraction Through a Plasma with Corresponding Circuitry***

GOVERNMENT AND INDUSTRIAL EXPERIENCE

I received my PhD in physics from New York University in 1986. I taught at the University of Connecticut for 12 years and Rensselaer Polytechnic institute for 16 years. I worked on antennas at Naval undersea Warfare Center for 12 years, and I taught antennas and EMI at RPI for several years. I have done extensive antenna testing with network analyzers and Diamond Engineering equipment in various anechoic chambers. I have published more work and have more patents on the plasma antenna than anyone.

Haleakala Research and Development Inc. founder, CEO and president. 2002 to present

Exponent, Inc; Army Land Warrior Technical Supervisor and Coordinator. Exponent press release:

"Exponent, Inc. (Nasdaq: EXPO), is pleased to announce the addition of **Dr. Theodore R. Anderson,** Senior Systems Engineer, to Exponent's Technology Development Practice. Dr. Anderson's focus will be on Exponent's Land Warrior project with the U.S. Army. Dr. Anderson has a strong technical background and a lengthy record of creativity in the areas of electronics design and analysis, particularly in antenna systems, which are critical to the successful development of a Land Warrior system. ***He will supervise the design, analysis, and testing of the electronic components of the Land Warrior system, and its future variants."*** **2000-20002**

Knolls Atomic Power Laboratory May, 1999-December 2000

- worked with the University of Michigan on finite element electromagnetic codes to solve frequency selective surface filtering. in the infrared spectrum.
- I used the electromagnetics code called FSDA_PRISM

Naval Undersea Warfare Center—New London, CT / Newport, RI 1988 – 1999
Electromagnetic compatibility, digital signal processing, antenna research and design. Fluid dynamics, flow noise, acoustics, and hydroacoustics.

- Used ANSOFT, NEC, and various finite difference time domain codes, and project management for submarine electromagnetics
- I program managed this work
- Began to pioneer plasma antenna technology**.**
- Pioneered flow noise and hydroacoustices work for towed arrays and SONAR domes. (see publications section).

Electric Boat, General Dynamics, Groton, CT. 1983 -1988

Worked in CFD, flow noise, hydrocaoustics, and acoustics.

Gibbs and Hill Inc., NY, NY 1980-1983
Worked on and designed commercial nuclear power plants.

TEACHING AND UNIVERSITY POSITIONS.

Rensselaer Polytechnic Institute — Troy, NY.

- I taught radar, antennas, and electromagnetic compatibility in the ECSE Dept. 1999-2015
- I taught at the Rensselaer Polytechnic Institute, Hartford, CT Branch. 1986- 1999.

I taught mechanical and electrical engineering. I taught several antenna and EMC courses, several fluid dynamics courses including CFD.

- **I taught in the RPI Navy Nuclear Program. I taught fusion, reactor physics, Monte Carlo Techniques, shielding, and radioactive waste. 1999-2015.**

Plug Power. I taught in house course at Plug Power in Electromagnetic Compatabilty. 2003.

University of Tennessee, ECE Dept. Research professor. September 2003 to present time.

Union College—Schenectady, NY 1999 – 2001

I taught mathematical methods for engineers and systems engineering

University of Connecticut Mechanical engineering, Ocean Engineering, and EE Departments—Avery Point, CT 1983 – 1995

Taught physical acoustics, underwater sound with signal processing, special topics in acoustics, acoustical oceanography, and mathematical methods for engineers, hydroacoustics, fluid dynamics and astronomy

University of Bridgeport—Bridgeport, CT 1990 – 1999

- I taught mechanical, aeronautical, and management engineering
- I taught project management, quality control, quantitative methods, heat transfer, gas turbines, turbomachinery

Uniphase Telecommunications Products—Bloomfield, CT 1997

- I taught opto-electronics (on-site)

University of New Haven—New Haven, CT 1983 – 1988

- I taught electrical and mechanical engineering

Hunter College—NYC, NY 1980 – 1983

- I taught general physics and astronomy

Cooper Union School of Engineering—New York, NY. 1980

- I taught electronic circuits

OPTICS BACKGROUND.

1. **I modeled the t-matrix for electron-atom scattering in a laser field.**

2. **I taught optoelectronics at RPI, Hartford, CT. I used texts:**
   a. **Principles of Quantum Electronics by Dietrich Marcuse (Jul 1980)**
   b. **Optical Electronics in Modern Communications (Oxford Series in Electrical and Computer Engineering) by Amnon Yariv (Mar 13, 1997).**
   c. **Quantum Electronics by Amnon Yariv (Jan 17, 1989)**
3. **I taught fiber optics at RPI, Hartford, CT. I used texts:**
   a. **Theory of Dielectric Optical Waveguides (Quantum electronics--principles and applications) by Dietrich Marcuse (Apr 10, 1974).**
   b. **Light Transmission Optics (Van Nostrand Reinhold electrical/computer science and engineering series)** by Dietrich Marcuse (Aug 1982)**.**
   c. **Principles of Optical Fiber Measurements by Dietrich Marcuse (Jul 28, 1981).**
   d. **Fiber-Optic Communication Systems (Wiley Series in Microwave and Optical Engineering) by Govind P. Agrawal (Oct 19, 2010)**

4. **I taught courses on lasers at RPI, Hartford, CT.**
   a. **Laser Fundamentals by William T. Silfvast (Jan 12, 2004)**
   b. **Laser Physics by Murray Sargent III, Marlan O. Scully and Willis E. Jr." Lamb (Jan 22, 1978)**

EDUCATION

PhD, Physics, New York University, New York, NY
(electrodynamics, opto-electronics, atomic physics and fluid dynamics) 1986

MS, Applied Science, New York University 1983

MS, Physics, New York University 1979

Studied engineering at Columbia University, New York City, 1979-1981

Studied Mathematical Physics at the Department de Physique Theorique, Universite de Geneve, Geneva, Switzerland.

PATENTS BY DR. TED ANDERSON

ISSUED PATENTS (Several of my patents have appeared in the Antennas and Propagation Magazine.)

1	6,710,746	Antenna having reconfigurable length
2	6,700,544	Near-field plasma reader
3	6,674,970	Plasma antenna with two-fluid ionization current
4	6,657,594	Plasma antenna system and method

5 6,650,297 Laser driven plasma antenna utilizing laser modified maxwellian relaxation
6 6,624,719 Reconfigurable electromagnetic waveguide
7 6,512,496 Expandible antenna
8 6,369,763 Reconfigurable plasma antenna
9 6,169,520 Plasma antenna with currents generated by opposed photon beams
10 6,118,407 Horizontal plasma antenna using plasma drift currents
11 6,087,993 Plasma antenna with electro-optical modulator
12 6,087,992 Acoustically driven plasma antenna
13 6,046,705 Standing wave plasma antenna with plasma reflector
14 5,963,169 Multiple tube plasma antenna
15. 6,876,330 Reconfigurable antennas
16. 6,870,517 Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas
17. 6,842,146 Plasma filter antenna system
18. 7,342,549. Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas.
19. 6,922,173. Reconfigurable scanner and RFID system using the scanner
20. 6,700,544. Near-field plasma reader
21. 6,870,517. Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas
22.. 7,292,191. Tunable plasma frequency devices
23. 7,453,403. Tunable plasma frequency devices.
24. 8,077,094 Plasma device with low thermal noise

Recently Issued patents.

1.Reconfigurable scanner and RFID. Patent number RE43,699.

2. Plasma Devices for Steering and Focusing Antenna Beams; U.S. Patent Issue Number: 8,384,602
.

Issued plasma waveguide patents.

1. 6,812,895 Reconfigurable electromagnetic plasma waveguide used as a phase shifter and a horn antenna
2. 6,624,719 Reconfigurable electromagnetic waveguide

Non-plasma physics patents.

1. Method And Apparatus For Detecting Misaligned Railroad Tracks, filed 4/11/01, serial number 09/832,087
2. Passive Magnetic Field Sensor Using The Barkhausen Effect To Measure Velocity (Angular Or Linear) Of A Moving Body-filed 4/11/00 serial number 09/548387
3. Portable And Lightweight Ramp Structure, issued 3/4/03, US Patent number 6526614

Take note: I presented my smart plasma antenna at the “Booz Allen Hamilton Technology Petting Zoo” in 2007. See: https://www.pressreader.com/usa/the-washington-post/20071224/282415574952689
My point of contact “Booz Allen Technology Petting Zoo” at Booz Allen Hamilton in Mclean, VA was William Barnett.

PUBLICATIONS (Partial List)

1. Anderson, T., Perturbation Model for EMC Sources in the Near Field and Shielded by a Ferromagnetic Material, August, 1997. IEEE EMC Society, Catalog Number 97CH36113. Presented at the International Symposium on Electromagnetic Compatibility, August 1997, Austin, TX.
2. Anderson, T., Iterative Model for EMC Sources in the Near Field and Shielded by Composite Materials, August 1997. IEEE EMC Society, Catalog Number 97CH36113. Presented at the International Symposium on Electromagnetic Compatibility, August 1997, Austin, TX.
3. Anderson, T., and Choo V., The Development of a Large Three-Axis Magnetic Field Susceptibility Test (L-TAMFEST), August 1997. IEEE EMC Society, Catalog Number 97CH36113. Presented at the International Symposium on Electromagnetic Compatibility, August 1997, Austin, TX.
4. Anderson, T., Model for Near Field Electromagnetic Shielding by Cylindrical Shells of Composite Materials, NUWC-NPT Technical Report 10,634, 16 October 1996.
5. Anderson, T., Models for the Near Field Interaction of a Magnetic Field Interaction of a Magnetic Field from Point Sources Representing Transformers and Power Supplies and a Ferromagnetic Cylindrical Shell. IEEE EMC Society. Presented at the Santa Clara Convention Center, August 21, 1996.
6. Anderson, T., The Use of Vector Fields to Model the Physical Blockage from Power Supply, Cable, and Transformer Sources. NUWC-NPT Technical Report 11,091, 18 March 1996.
7. Anderson, T., Turbulent Wall Pressure and Wall Shear Fluctuations Calculated from the Orr-Sommerfeld Equation with Nonlinear Forcing Terms. American Institute of Physics, “Chaotic, Fractal, Nonlinear Signal Processing,” AIP Press, Proceedings Number 375, ISBN Number 1-56396-443-0. Presented at the Third Technical Conference on Nonlinear Dynamics (Chaos) and Full Spectrum Processing, July 1995.
8. Anderson, T., Model for Washover of a Buoyant Cylindrical Antenna Towed in Calm and Various Sea States, NUWC-NPT Technical Report 10,753, 23 September 1994.
9. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure Fluctuations, NUWC-NPT Technical Report 10,135, 11 June 1993.
10. Anderson, T., Properties of Continuous Orr-Sommerfeld Waves in a Turbulent Boundary Layer, Bulletin of the American Physical Society, Volume 36, No. 10, November 1991.
11. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure and Wall Shear Fluctuations, Bulletin of the American Physical Society, Volume 35, No. 10, November 1990.
12. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure and Wall Shear Fluctuations, International Union of Theoretical and Applied Mechanics, “Structure of Turbulence and Drag Reduction,” A. Gyr (editor), Springer-Verlag ISBN 3-540-50204-1 and ISBN 0-387-50204-1, July 1989.
13. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure Fluctuations, American Society of Mechanical Engineers, Volume 6, “Acoustical Phenomena and Interaction in Shear Flows over Compliant and Vibrating Surfaces,” 1988.
14. Anderson, T., Time Domain Modeling and Experimental Verification of the Barkhausen Effect used as a Magnetic Field Sensor. Published and presented at the IEEE EMC Society Meeting, August 1998.

15. Anderson, T., and Javor, E., The Design and Modeling of a Large Helmholtz Coil for Low Frequency Magnetic Field Susceptibility Testing. Published and presented at the IEEE EMC Society Meeting, August 1998.
16. Anderson, T., and Derewainy, C., Electrostatics Discharge Sensitive (ESDS) Equipment Susceptibility to Welding Generated Electromagnetic Fields. Published and presented at the IEEE EMC Society Meeting, August 1998.
17. Anderson, T., Development of a Large Three-Axis DC Magnetic Field Susceptibility Test System, ITEM, the International Journal of EMC, 1998.
18. Anderson, T., ELF Plasma Antenna, NUWC Technical Report Number 10,892, May 1998.
19. Anderson, T., Theory, Design, and Submarine Applications of a Plasma Antenna, NUWC Technical Report Number 10,832, May 1998.
20. Anderson, T., Optimal Design of Helmhotz Coils using Variational Principles. Published and presented at the IEEE EMC Society Meeting, August 1999.
21. Anderson, T., Control of Electromagnetic Interference from Arc and Electron Beam Welding by Controlling the Physical Parameters in Arc or Electron Beam: Theoretical Model, 2000 IEEE Symposium Record, Volume 2, pages 695-698, ISBN 0-7803-5677-2
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Plasma Antennas, Second Edition

Theodore Anderson

Copyright: 2020
Pages: 350
ISBN: 9781630817503

The Second Edition of my book titled "Plasma Antennas".
See: https://us.artechhouse.com/Plasma-Antennas-Second-Edition-P2101.aspx

Theodore R. Anderson , *Plasma Antennas*, Artech House, ISBN 978-1-60807-143-2; 2011.
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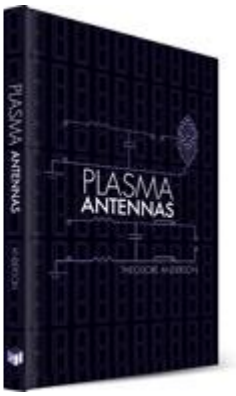

Plasma Antennas

Theodore Anderson, Haleakala Research and Development, Inc.
ISBN 978-1-60807-143-2
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Book Chapter
Frontiers in Antennas: Next Generation Design & Engineering, chapter 10; Plasma Antennas, Theodore R. Anderson, McGraw -Hill, Frank Gross editor. ISBN 0071637931 / 9780071637930

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