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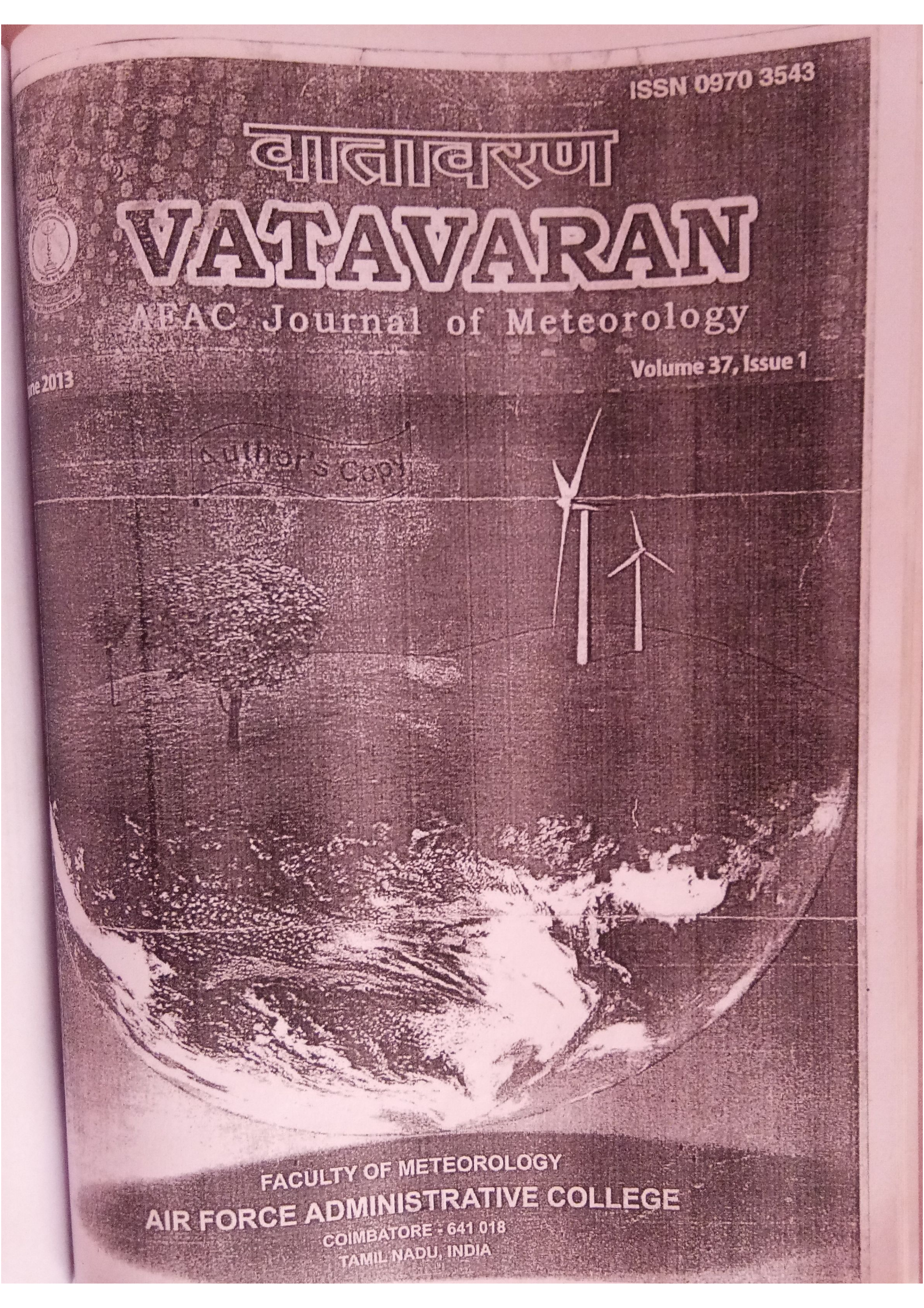

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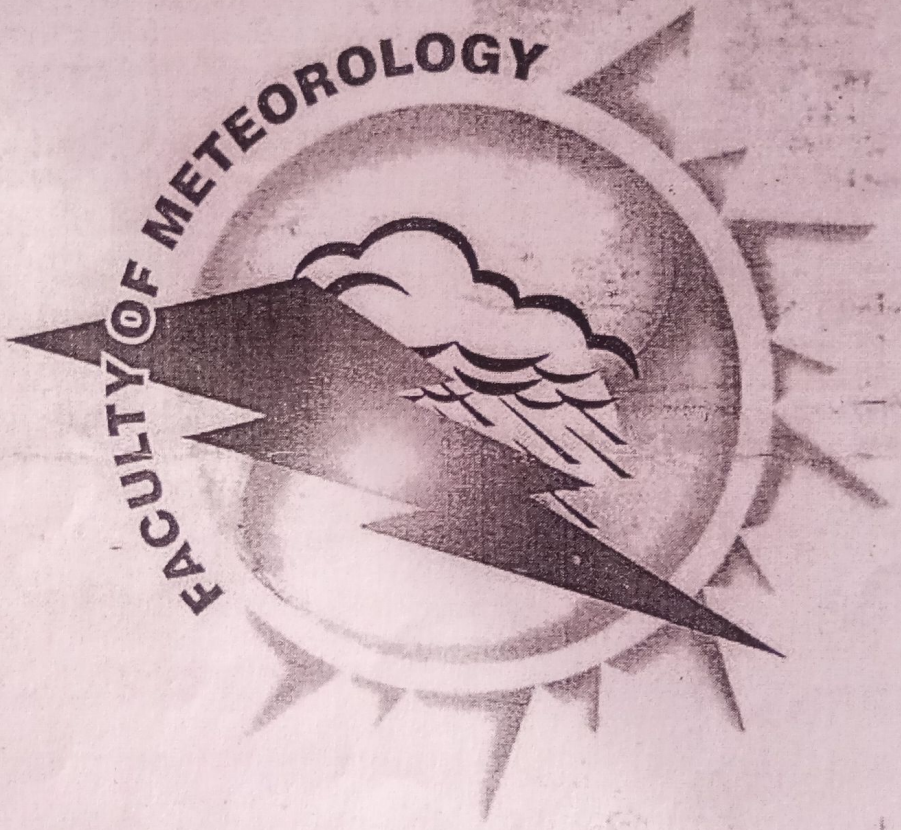

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AFAC JOURNAL OF METEOROLOGY
June 2013, Volume 37, Issue 1

From Editor's Desk...

The latest issue brings out novel ideas and new theories. The editorial board is thankful to all the contributors and requests invaluable support in the future too. With this the journal would be more user-friendly and interactive.

The time bound seasons obey nature and strictly follow their curriculum. The SW Monsoon is expected to be normal in 2013. This season poses good challenge to the forecasters with many number and types of systems. Forecasters too, do not miss this opportunity to experiment new ideas and improve the standards of forecast. Well, this magazine is a platform to share your latest experiences of using innovative and interesting techniques in the field of forecasting.

This issue has some very interesting articles and brings out the techniques well for the benefit of IAF field forecasters. First article uses different Microphysics and Cumulus parameterization schemes to catch a hailstorm. The second and fifth articles discuss traditional forecasting techniques in a heavy rainfall situation. A novel and innovative third paper brings out statistical details of Earth Quake occurrences over Car Nicobar Islands and neighbourhood. Next article explains objective techniques applied to winter rainfall. A very interesting next article is on Markov chain model for the occurrences of dry and wet days over Sulur. Next article is another interesting article on artificial rainmaking. The last article deals with Space weather.

The changes in the journal are dynamic and are based on the suggestions and requirements. The editorial board is open to all suggestions and would be willing to bring out any changes to make this journal contain more and more interesting and informative articles. I once again request you all to send the articles at the earliest. May the coming season bring you all cheers and prosperity.

(VS Srinivas)
Wing Commander

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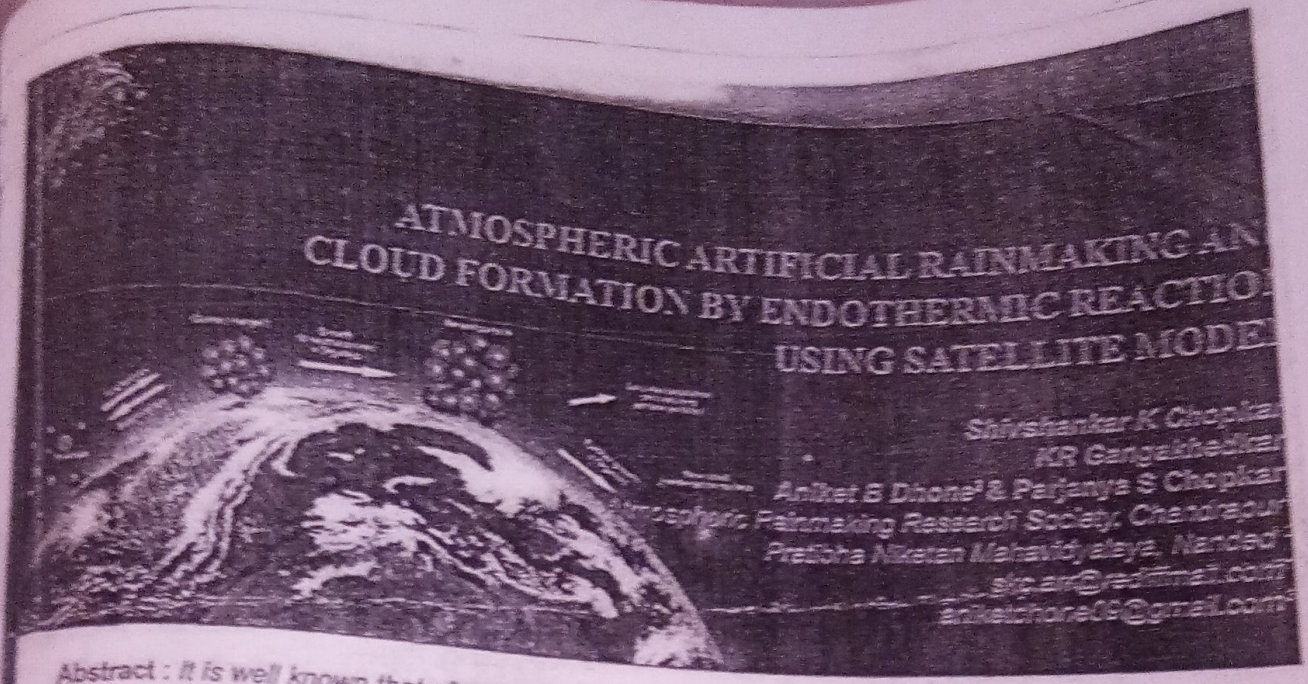

ATMOSPHERIC ARTIFICIAL RAINMAKING AN CLOUD FORMATION BY ENDOTHERMIC REACTIO USING SATELLITE MODE

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Abstract : *It is well known that after lightning, heavy rain follows due to dissociation, ionization, and natural seeding processes in the atmosphere. It is shown in this paper that, the properties of these natural phenomena can be used for making artificial rain using plasma laser pulse in the atmosphere which is confirmed in the laboratory experiments. As per the calculations 2.2 x 10^{13} gm of water drops are formed in the atmosphere by laser pulse energy of 500 mJ. In this system, plasma laser pulse creates high temperature to the tune of 3000°C. At these temperatures bonds of major species of N_2 and O_2 break up into excited N* and excited O*. These excited atoms are very unstable and immediately react to form NO and O_3. These reactions are endothermic and absorb a large amount of heat from the surrounding atmospheric clouds, where condensation takes place (condensation is the basic need for formation of water drops). Simultaneously N_2 and O_2 will be ionized to form N_2^+, O_2^+ and O_2^-. These precursor ions will undergo several reactions and will become big clustered ions. These big ions will act as seed and will lead to precipitation and rain. Low temperature created by dissociation will further help to grow bigger ions. This in turn leads to production of CCN (cloud condensation nuclei), more water drops and rainfall. These rain drops will enhance natural seeding processes. At this juncture due to the flow of air in the upper atmosphere another set of rain drops will be formed, resulting in more rainfall. Model system for artificial rainmaking is also proposed in the paper.*

Keywords : *Laser, Endothermic reactions, Cloud Condensation Nuclei, Artificial Rain.*

roduction

Rain plays an important role in world conomy by influencing the agriculture yield. ll rain is a natural phenomenon, and it es not fall as and when humans need it. esearchers are trying to create artificial for the past few decades. At present, the ding process is used to make artificial fall. The chemicals such as silver Iodide, ium chloride or sodium chloride are used uch cloud seeding experiments. Chemicals spread from an aircraft in the growing cloud ot. Nucleation starts on these chemicals, ing to precipitation. This process has been in South Africa, Thailand, Japan, Mexico, Brazil and some parts of India. This process is not reliable and failure rate is high. Besides, it is harmful to mankind because, sprayed chemicals come back to the earth along with the rain. Also these methods are quite expensive. In this paper, a non-polluting, economical and more reliable method is proposed. The plasma laser pulse is used to trigger the rainfall and this can be applied to warm clouds also.

2. Laser so far has not been employed to create artificial rain. Recently, Rohwetter et al. (2010) have shown that, self-guided ionized filaments generated by ultra-short laser pulses are able to induce water-cloud condensation in the free, sub-saturated atmosphere in the

altitude region between 45 and 75 m. In this method, a high power pulse laser creates a bunch of filaments (low resistance path) between lightning cloud and the earth.

Theory

3. Nitrogen (N_2, 78%) and oxygen (O_2, 21%) are the two major gases in the atmosphere. When a laser pulse is shot in atmosphere, depending on the energy of the pulse, it may dissociate N_2 and O_2 as follows:-

$$N \equiv N \rightarrow N_2 + h\nu \rightarrow N^* + N \quad \ldots\ldots\ldots (1)$$

$$O = O \rightarrow O_2 + h\nu \rightarrow O^* + O \quad \ldots\ldots\ldots (2)$$

3. Bond energy of N_2 = 226 kcal/mole (A. Kerr 1999-2000). Therefore energy required to break 1 molecule of N_2 = $226 \times 10^3 \times 4.184 / (6 \times 10^{23}) = 1.58 \times 10^{-18}$ Joule. Bond energy of O_2 = 96 kcal/mole (A. Kerr1999-2000). Therefore energy required to break 1 molecule of O_2 = $96 \times 10^3 \times 4.184 / (6 \times 10^{23}) = 0.67 \times 10^{-18}$ Joule. So the total energy required for breaking 1 molecule of N_2 and 1 molecule of O_2 will be 2.25×10^{-18} Joule. The laser pulse with energy 500 mJ is capable of dissociating a column of N_2 and O_2 containing about $(0.5/2.25 \times 10^{-18}) = 2.2 \times 10^{17}$ molecules (Chopkar & Chakrabarty 2010).

4. In reactions 1 and 2, two excited atoms, N^* and O^* are formed. So total numbers of excited N^* and excited O^* atoms formed by laser pulse of 500mJ in a column of N_2 and O_2 is 2.22×10^{17}. They are very unstable and react immediately to form NO and O_3 as follows:

$$N^* + O_2 + \Delta H \rightarrow NO + O \quad \ldots\ldots\ldots (3)$$
$(\Delta H = 43{,}200$ cal/mol.)

$$O^* + O_2 + M + \Delta H \rightarrow O_3 + M \quad \ldots\ldots\ldots (4)$$
$(\Delta H = 67{,}600$ cal/mol.)

5. Reactions (3) and (4) occur simultaneously in the atmosphere. These endothermic reactions absorb heat energy nearly to the tune of 1.22×10^{19} k cal from surrounding atmospheric clouds. Both the reactions occur in the atmosphere and have been confirmed in the laboratory experiments (Sander et al 2003). Reaction (3) is important for the formation of NO in the thermosphere and reaction (4) is the main source of formation of O_3 in the stratosphere. Both the reactions are endothermic and absorb large amount of heat energy (43,200 cal/mol for reaction (3) and 67,600 cal/mol for reaction (4)) from the surrounding atmosphere. As a result, the atmosphere is cooled below the condensation temperature of water vapor. The water vapor particles come close due to the condensation and this leads to natural seeding. Means, this cooling will create CCN (clouds condensation nuclei) in cloud parcel and produce tiny water droplets in the atmosphere. These tiny water droplets then act as natural seed for the formation of rain drops in the atmosphere (Drake 2006). These water droplets may also shift to other places due to flow of air motions and form another set of rain drops there.

Result & Discussion

6. On several occasions it has been found that precipitation follows after lightning. Golde (1977) from a number of radar observations reported that intense precipitation is not even present in the clouds before the first discharge but it develops abruptly in the same region after discharge from which the lightning flashes originate. Battan (1981) has observed very rapid growth of precipitation particles/ice crystals caused by electrical forces following a lightning discharge. In many cases the on-set of strong electrification follows the appearance of heavy precipitation within the cloud in the form of hail stones (Wallance and Hobbs, 1977). The correlation between lightning and precipitation is as follows:-

(a) Heavy gushes of rain or hail often reach the ground within 2-3 minutes after the lightning flash.

(b) It is evidenced that lightning is the cause of the rapid intensification of the precipitation (Mason, 1975).

(c) It is further speculated that the rapid intensification of the precipitation from about 1mm/h to 50mm/h in this 2-3 min period is brought about by a greatly accelerated rate of coalescence of water drops under the influence of electrical forces by a mechanism that is obscure and has no convincing experimental or theoretical base (Mason, 1971).

7. From the above work it is clear that precipitation is formed after lightning. In an earlier theoretical study, it has been shown that the bonds of N_2 and O_2 break at temperature above 3000 K (Chopkar 1993). An experiment was done in the laboratory in which electrical spark was produced in a glass chamber to act as artificial lightning. Formation of water droplets was seen on the walls of the glass chamber (Chopkar and Chakrabarty, 2008). This experiment shows that water droplets are formed by condensation, which is due to endothermic reactions associated with artificial lightning created in the glass chamber by electrical spark. Carls and Brock (1987) did an experiment in which atmosphere was heated by a laser pulse up to 1600 to 2400 K. They observed water droplet formation in the atmosphere. Braun et al. (1995). Kasparian et al. 2003, Mejean et al., 2006, did an experiment in a fog chamber. They observed water droplet formation inside the chamber after every laser shot. They postulated that water droplets were formed by ionization process. N_2 and O_2 would be ionized (Rohwetter et al., 2010) as follows:-

$$N_2 + h\nu \rightarrow N_2^+ + e^- \quad \ldots\ldots\ldots\ldots (5)$$

$$O_2 + h\nu \rightarrow O_2^+ + e^- \quad \ldots\ldots\ldots\ldots (6)$$

Ionizing potential of N_2 = 15.58 ev = 2.49×10^{-18} Joule and ionizing potential of O_2 = 12.2 ev = 1.95×10^{-18} Joule. Hence the energy required for ionizing 1 molecule of N_2 and 1 molecule of O_2 is (2.49×10^{-18} + 1.95×10^{-18}) = 4.44×10^{-18} Joule. If the energy of the laser pulse is 500 mJ, then this much energy is capable of ionizing a column of N_2 and O_2 containing about ($0.5/4.44\times10^{-18}$) = 10^{17} molecules or ~ 10^{17} ions and electrons. Electrons will react with O_2 to form negative ion O_2^-, which after a series of reactions will form heavy negative cluster ions. N_2^+ and O_2^+ will also undergo a series of reactions to form heavy positive cluster ions. According to Rohwetter et al. (2010), these ions act as seed to create artificial rain in the atmosphere. But, it is well understood that, energy (2.25×10^{-18}Joule) required for disassociation is less than the energy (4.44×10^{-18}Joule) required for ionization Frost D C & McDowell CA, 1956, Lide, David R., ed, 1997-1998. Yoshihara et al. (2007) have shown that the pulsed UV-laser irradiation of ambient air induces the formation of water droplets or small ice particles in the laboratory. They also observed that the atomic oxygen which is formed in this process quickly reacts with oxygen molecules to form ozone. In their experiment ozone is formed due to endothermic process by which condensation takes place and CN (condensation nuclei) is formed which produces water droplets or ice crystals.

9. Chopkar (1993) also concluded the same. Thus, in endothermic reaction given by equations (1) to (4), the heat from the atmosphere is absorbed. In white warm clouds the seeding can take place due to the endothermic reaction triggered by plasma laser pulse. The ionization, proposed by Rohwetter et al. (2010), is also accompanied with the disassociation and endothermic reaction proposed by Chopkar(1993). This dissociation and the occurrence of endothermic reactions are responsible for cooling and capable of causing CCN formation.

Model system to trigger artificial rainfall

10. To trigger actual artificial rainfall, we propose a model as shown in Figure.1. This Model system consists of three main parts :-

(a) Receiver Unit

(b) Processor Unit and

(c) Transmission Unit.

11. The communication between these units will be through satellite. The receiver unit will receive the data about the clouds like cloud temperature, humidity, height from earth surface, pressure etc. It will also receive the information about the necessity of rain in the region. The data is transferred to processor unit, where the data is processed and the technical details about the intensity, pulse duration etc. of plasma laser pulse will be calculated. The processor unit will also decide which transmission unit to be used to trigger the artificial rainfall by applying laser pulse. One can have number of transmission units in the region as per necessity. The main function of the transmission unit is to send a laser pulse in the given direction of the intensity calculated by the processor. This unit is connected to processor unit by using satellite, so more than one transmission units can be connected to one centrally located receiver and processor unit. This will cut cost of the system and will cover larger region.

12. The transmission unit can be designed as given in figure 2. The transmitter could be a terawatt femtosecond Ti: sapphire pulse laser. Its fundamental wavelength could be ~800nm. The pulse will have energy ~400mJ, duration 100fs and repetition frequency of 10-100Hz. The laser pulse has to propagate with almost high peak intensity over a distance of ~500m. This nonlinear phenomenon is caused by the subtle interplay between self-focusing induced by optical Kerr effect and the defocusing by the self-generated plasma. Further experimental work is necessary to determine accurately what should be the power and wavelength of the laser so that the bond breaking and ionization could take place at the cloud height of ~500m. A block diagram of the system to be used is shown in Fig. 1. The system is controlled by Micro Controller (remote unit), which consists of data acquisition and processing system. Th peripherals of the system include fast transie digitizer, computer controlled stepper moto (SM-1 and SM-2). The laser beam energy will b adjusted by SM-2. The system will be operat by an MV power supply. Initially the beam w be of 15cm arc and then the beam expand will vary the width of the beam to get signific amount of rain. A movable mirror will direct t beam in the larger area of the atmosphe Further experimental work is necessary to determine what should be the cross-sectio of the beam for rainfall to cover a reasonably wi er area. Artificial rain making at any place as per human need for green revolution in the wh le world can be achieved by this model systen

Conclusions

13. By dissociation reaction, artificial rain making can be done by laser energy using plasma laser pulse. Ionization at high temperatures also supports the artificial rainfall due to the proposed dissociation theory The proposed model is non-polluting economical more reliable and can be used effectively o larger area.

14. Schematic flow chart showing methodolo to create artificial rain in the atmosphere is follows:-

High-energy plasma laser pulse creates hi temperature in a fraction of a second

↓

At this high temperature bonds of N_2 and O break (dissociate) to form at least one excit N^* and one excited O^*

↓

$$N \equiv N \rightarrow N^* + N$$
$$= O \rightarrow O^* + O$$

↓

Excited N^* and O^* are very unstable and immediately react to form NO and O_3

↓

$$N^* + O_2 \rightarrow NO + O$$
$$O^* + O_2 + M \rightarrow O_3 + M$$

↓

These two reactions are endothermic and absorb a large amount of heat from the surrounding atmosphere

↓

This lowers the temperature of the surrounding atmosphere and condensation nuclei (CCN) is formed in the cloud

↓

These condensation nuclei act as seed and start rain

↓

Simultaneously with the breaking of their bonds, N_2 and O_2 will also be ionized

↓

$$N_2 + h\nu \rightarrow N_2^+ + e$$
$$O_2 + h\nu \rightarrow O_2^+ + e$$

Free electrons 'e' thus produced will get attached to O_2 and form negative ion O_2^- ↓ N_2^+, O_2^+ and O_2^- ions are quickly transformed into heavy clustered ions

↓

These heavy ions in cooled atmosphere act as CCN for formation of rain droplets.

cknowledgement

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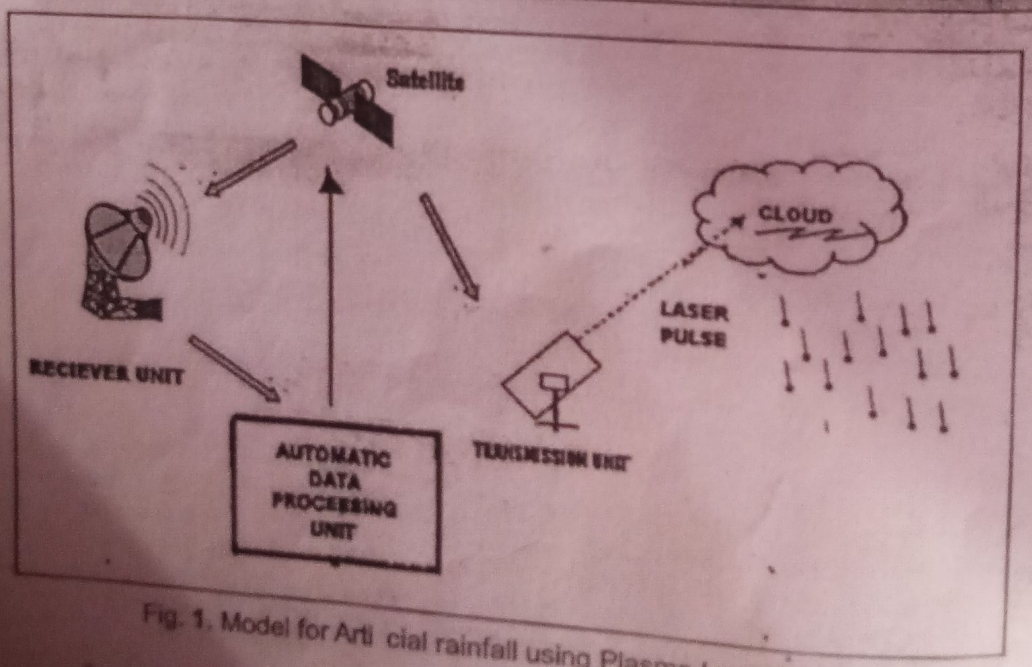

Fig. 1. Model for Arti cial rainfall using Plasma Laser Pulse

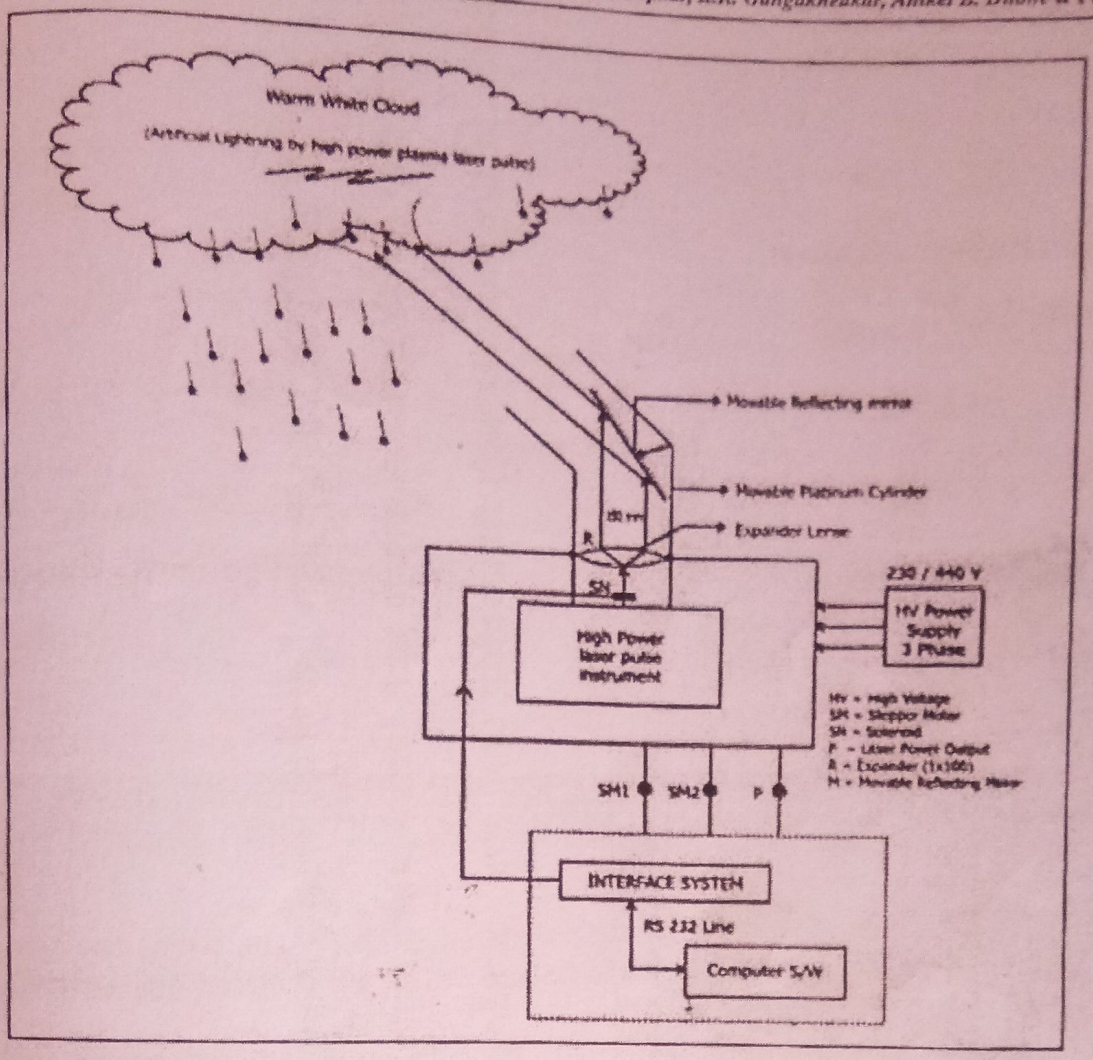

Fig.2 - Proposed Model of transmitter for emission of plasma laser pulse.

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CERTIFICATE

This is to certify that Shivshankar K Chopkar has been appreciated in recognition of having contributed an article titled Atmospheric artificial rainmaking and cloud formation by endothermic reaction using satellite model in the June 2013 . issue of Meteorological Journal 'VATAVARAN'.

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Annexure: As stated