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Cosmic Ray Influenced Reduction of Oceanic pH During Solar Eclipse

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Abstract

On 22 July 2009 South India had a partial eclipse, and the radiation effect due to eclipse is analyzed through an indirect method of analyzing the pH value of seawater, and our first result shows a reduced effect. The experiment on the longest eclipse day of the millennium on 15 January 2010, an annular eclipse of 98% obscuration, confirms the initial result. Analysis with previous studies suggests that eclipse effect is different than night time chemistry. The first observation of reduction of pH in seawater during eclipse and its cause are reported in this paper. In the course of solar eclipse, due to the change in pressure gradient force gravity induced reduction in stratospheric Ozone concentration is formed and which allows short range radiations. We found a positive correlation between the ionospheric and stratospheric anomalies and the biosphere. The nocturnal behavioral studies of marine organisms are addressed within the frame of pH and enzyme activity and the results reveal the requirement of a reassessment in such studies in the context of pH change due to gamma ray ionization during eclipse.

Key words: **Ionosphere, Stratospheric Ozone, solar radiation, solar eclipse, biosphere, seawater**.

1. INTRODUCTION:

Celestial events always attracted much of the human interest, even from the date of Indian Vedic period, ie., 2000BC. The fast radiation change during solar eclipse is different than the change during day and night. It is expected that a huge quantity of shorter wavelength radiations are reaching the earth’s surface during solar eclipse since the disturbance of the heat balance along the supersonic travel of the trajectory of the Moon’s shadow could generate eclipse-induced gravity waves(Eastman et al., 1980; Seykora et al,. 1985; Singh et al., 1989; Hanuise et al., 1982), which results a reduction in the concentration of ozone layer in the stratosphere(Eastman et al., 1980; Chudzynski et al., 2001; Tsanis et al., 2008; Zerefos et al., 2001). The highly charged ionic layer above the stratosphere is highly sensitive to solar radiation and is important to understand about the cosmic rays inducing various radiational effects. Experimental studies, nowadays, are carried out to measure the radiation directly using high resolution equipments, as collaborative works of various research centers. Several measurements of solar radiation were carried out since 1960. Recent works (Zerefos et al., 2000; Zerefos et al., 2001) focused on the study of eclipse-induced changes in the spectral solar irradiance at the earth's surface, the effect of multiple scattering on sky brightness, and the wavelength dependence of the limb darkening effect etc,. The layer of ionic plasma, the ionosphere, plays a critical role in the effect of radiation on the material surface of the earth. An earthquake can even induce a massive charging of ionosphere with electrons. The increase in electron concentration in the ionospheric layers seems to be a measuring source for earthquake. The pair production and annihilation due to solar radiation in the ionosphere generates huge quantity of gamma rays, in addition to other particles. Detecting the radiation change is the only reliable method to probe into the different levels of atmosphere behavior to celestial events. Indirect method of detecting radiation is an age old procedure, and which cannot be excluded completely even in the present age.

The environmental effects of solar eclipse had been mainly focused on meteorological parameters(Anderson et al., 1972), photochemistry (Srivastava et al., 1982; Sharma et al., 2010), boundary layer physics (Antonia et al., 1979), total columnar ozone (Kawabata, 1961), gravity waves (Chimonas, 1970), and ionospheric parameters (Klobuchar, 1965). Compared to that of the longer wavelengths, the radiations of shorter wavelengths (350nm) are generally influenced more by the eclipse, and at large eclipse percentages (>85%), it slowly decreases as the eclipse approaches its maximum(Kazadzis et al., 2007; Kazantzidis et al., 2007). Hence expecting shorter wavelength radiations during partial eclipse could frame the work which is less studied.

Zerefos et. al.(2001) pointed out a characteristic artificial decrease of total ozone during solar eclipse, which allows more radiations to pass through. India met a total solar eclipse on 22 July 2009, which was visible over the central India, while a partial eclipse in southern part, and an annular eclipse on 15 January 2010. A large number of research output about eclipse have been published in various fields of science, such as, astronomy, atmospheric science, Earth science and Biological sciences. In order to analyses the phenomenological influence of solar radiation on the biosphere during eclipse we have conducted an indirect method of radiation detection, ie., measurement of pH of seawater. Since major part of the earth is covered with sea it is obvious to fix the analyzing sample as seawater which is highly sensitive to solar radiation and hence the measurement of any changes is more accurate. This paper discusses about the link between ionosphere and biosphere in addition to the link between stratosphere and biosphere in the context of total electron concentration and gravity waves respectively, through the findings of our experiment on seawater during solar eclipse.

2. IONOSPHERE

Cosmic rays form an important source of ionization of the Earth's atmosphere and the main source of the ionization in the troposphere and stratosphere. Most important for ionization in the troposphere-stratosphere are galactic cosmic rays (GCR) that possess high energies and produce a complicated cascade of secondary particles in the atmosphere, leading to permanent ionization of the ambient air. While the net energy brought by cosmic rays is small and the resulting ionization rate is not high, GCR can affect physical and chemical properties of the atmosphere.

Sudden Ionospheric disturbances(SIDs)' can be generally caused by either GRBs or Solar eclipse events. The burst of gamma-rays from GRB interacts with the upper atmosphere and lower ionosphere and ionizing atoms and molecules (GRBs are bursts of energetic gamma radiation produced by violent explosions of distant stars), in addition to natural ionization. When the Earth lies in the path of the tightly beamed burst of energy, the atmosphere is slammed with massive doses of radiations and a sudden increase in ionisation occurs due to GRBs, while the obscuration of Sun by moon causes an opposite effect and hence a decrease in critical frequency (Total Electron Content) is expected. A plasma state of the mixture of positive and negative ions, negative electrons and neutral gas in the upper layer of the atmosphere is called ionosphere.

In fact , the cosmic rays are the dominant source of ioniosation not only in the ionosphere but also in atmosphere, the hydrosphere, the lithosphere and the cryosphere of the Earth (Peter Velinov; 2006). Solar cosmic ray particles have energy of up to several hundred MeV/nucleon, rarely upto few GeV/nucleon. It composed of protons, about 10% of He, and <1% of heavier elements. It is known that the flux of particles at the earth largly increases during strong solar flares. Solar flare is a violent explosion take place in the solar carona and chromosphere.

The high energy particle from primary cosmic ray collides with an atmospheric nucleus and produces new, very energetic particles, which also collide with air nuclei. Each collision adds a huge number of particles to the cascade. The neutral pions produced in this cascade process immediately decays to a pair of high energy gamma quanta, which then produces electron-positron pairs. These electrons and positrons regenerate gamma rays via Bremsstrahlung. These secondary particles depose energy in the atmosphere resulting the ionization of the medium, ie.,cosmic ray induced ionisation.

The ionization by Solar flux increases with sunrise to a maximum at noon and decreases to a minimum with Sunset. Under such conditions concentration of charged particles significantly grows in the atmosphere and forms atmospheric plasma. Due to the composition of the neutral atmosphere together with the changing efficiency of the incoming solar radiation, the ionosphere is stratified into four distinct layers denoted by D, E, F1 and F2 with varying ionization or total electron concentration (TEC). After sunset, electrons and ions recombine rapidly in the D, E and F1 layer(Davies, 1990). The propagation of the electromagnetic wave is significantly affected by ionosphere. Depending upon the concentration of the ionospheric plasma either the wave may propagates through or reflected. In fact the lower frequency (higher wavelength) electromagnetic waves get reflected and higher frequency (shorter wave length) waves propagates through the plasma; which is confirmed through the ionosonde (or digisonde) instrument studies (Knizova & Mosna, 2011).

Ionospheric change during solar eclipse have been examined by many authors since several decades (Minnis, 1956; Minnis and Bazzard, 1958; Szendrei and McElhinny, 1956). Bamford (2001) reported that even in the partial shadow the peak electron densities of the F and E ionospheric layers decreased by 20-35%. Also reported a drop of 15% of vertical equivalent line integrated electron density at 97% partial eclipse in the path of totality. Minnis (1956) reported that during eclipse no significant change occurred in F2 Layer critical frequency but temporary appearance of an F2-1/2 layer , which indicates that the eclipse was responsible for the rearrangement of the electron distribution in the lower part of the F2 layer.

The electron concentration during the eclipse on 29 March 2006 is measured by Belikovich et al., (2007) and reported as it was approximately 4-5 times less, ie., it has gone down by 20% in the E-region and 15% in the F1 layer. They have detected wave like changes of the electron concentration, which can be produced by propagation of acoustic-gravitational waves (AGW) in the polar ionosphere. They also reported that the time shift of the response of ionosphere for the solar eclipse decreases with increasing height.

Thus the GCR create ionization in stratosphere, and troposphere and in the independent ionospheric layer at altitudes 50-80km in the D region (Velinov et al., 1974). Being a transition region between the upper atmosphere and the lower levels, the lower ionosphere, ie., the D region exhibits both solar and meteorological control, since upper atmosphere is fully solar controlled and lower level is meteorologically controlled. Buchvarora (2002) found that the GCR intensity at Earth is anti-correlated with the level of solar activity, ie., when solar activity is high the GCR intensity at Earth is low.

In general, during the solar eclipse, with the decreasing solar flux, atmospheric temperature falls in the moon shadow creating a cool spot in the atmosphere that sweeps at supersonic speed across the Earth. The sharp border between sunlit and eclipsed regions, characterized by strong gradients in temperature and ionisation flux, moves throughout the atmosphere and drives it into a non-equilibrium state. Earth atmosphere shows variable sensitivity to the changes of ionization flux. The variation in the reflection heights, decrease/increase in electron concentration at all ionospheric heights, decrease/increase in TEC, rising/falling of the layer height are in general the characteristic for the processes during sunrise/sunset in the ionosphere. It is quite important to note here that the supersonic movement of the eclipsed region represents a key difference from the regular solar terminator motion at sunrise and sunset times. These changes in the neutral atmosphere and ionosphere induced by solar eclipse, force the evolution of the ionospheric plasma toward a new equilibrium state. The return to equilibrium is likely accompanied by the eclipse induced wave motions excited in the atmosphere. Any moving discontinuity of gas parameters such as temperature, pressure etc. will generate transit-like waves. In the upper ionosphere, waves can be generated by a strong horizontal electron pressure gradient. Possible mechanisms contributing to the wave generation in the region of solar terminator are discussed in detail by Somsikov & Ganguly (1995).

Several studies show direct evidence that solar eclipses induce wave-like oscillations in the acoustic gravity wave domain (AGW). First experimental evidence of the existence of gravity waves in the ionosphere during solar eclipse was reported by Walker et al. (1991), where waves with periods of 30–33 min were observed on ionosonde sounding virtual heights.

During solar eclipse event, solar ionization flux decreases producing well-defined cool spot in the atmosphere that moves through the Earth’s atmosphere. Moving source in the atmosphere can emit both acoustic and gravity waves which can be radiated in association with supersonic motion in the atmosphere. When the source is moving within atmosphere with subsonic velocity, only gravity waves can be emitted (Kato et al., 1977).

Solar eclipse induces changes in all atmospheric regions extend from the upper atmosphere down to ground level. Despite the low magnitude of the eclipse induced effects at ground level, Jones et al. (1992) reported wave-like oscillation related to eclipse on the microbarometer pressure records. The cooling effect of the Moon’s shadow may induce the powerful meridional airflow in the atmosphere, which accelerates the ionized clouds in the Es layer (Chen et al., 2010).

Fritts and Luo (1993) suggested that perturbations generated by the eclipse induced ozone heating interruption may propagate upwards into the thermosphere–ionosphere system. Such an excited wave was detected during solar eclipse event at F1 layer heights by Liu et al. (1998) with vertical ionospheric sounding. Ivanov et al. (1998) found that during solar eclipse with maximum obscuration of about 70% the F-region electron density decreased by 6-8% compared to a control day and detected travelling ionospheric disturbances. Studies reported by Farges et al. (2001) suggest a longitudinal diversity of the disturbances with respect to prenoon and postnoon phases. Xinmiao et al. (2010) reported synchronous oscillations in the Es and F layer during the recovery phase of the solar eclipse. Oscillations in the ionosphere, similar to gravity waves, were observed by many authors during solar eclipse events (Chimonas and Hines, 1970; Cheng et al., 1992; Liu et al., 1998; Sauli et al., 2006).

Studies of the latitudinal dependence of the maximum electron density of the F2 layer indicated that the strongest response was at middle latitudes (Le et al., 2009). During the eclipse of 20 July 1963 a remarkable decrease in Es layer ionization was observed (Davis et al., 1964). Enhancement of Es layer ionization was reported by Datta (1972) which was related to the generation of internal gravity waves during eclipse.

Peter Velinov (2006) proposed a galactic-solar-terrestrial CR mechanism which describes that the ionization by cosmic ray is not only in the ionosphere but will influence the process in the biosphere also. Many authors have found impact of the solar activity variations and related to them geomagnetic activity changes on cardio-vascualr system (Oraevskii et al. 1998), circulatory system (Pikin et al. 1998), nervous system and respiratory system.

We have done an inverse problem to what cosmic ray scientists usually do; ie., how cosmic radiation influences the physics and chemistry of the atmosphere. From which we tried to understand the cosmic ray effects. Eventhough it is a complex procedure it gives good understanding about atmosphere and solar system, since the event is abrupt and repeated measurements are taken with different parametric range of eclipses (total-partial and annular maximum) using multiple equipments.

3. STRATOSPHERIC OZONE

Cosmic ray influence on stratospheric chemistry and Ozone layer is in force after great solar flare events in August 1972 (Dorman 2004). Many authors have considered that the galactic and solar CR has influence on the Earth's climate (Dorman, 2004; Swensmark, 2000; Dorman, 2009).

Solar superflare events considerably affect the ozone layer through ionization process by the charged particles reaching the atmosphere. They ionize the nitrogen and oxygen molecules in the atmosphere and form nitrogen oxides. These nitrogen oxides in turn react with ozone breaking it into Oxygen molecules and atomic Oxygen. This breakdown causes a drop of 5% of the global atmospheric ozone level. But the atmosphere maintains a neutral balance between ozone layer formation and depletion in the stratosphere. Adrion Melott, a physicist at University of Kansas in Lawrence, US said that chlorofluorocarbons and other chemicals have depleted the ozone level about 3% in recent years (Kelly Young, 2007). However the influence of solar flare in ozone depletion is greater than the latter.

One of the interesting issues is the problem of variation of Ozone content during a solar eclipse. A simple answer to this is hardly available in the literature. According to the photochemical theory during a solar eclipse there must be observed the same course of Ozone as during transition from day to night, but only during a short time interval. However most of the studies report differently. A 40% increase in Ozone density at altitude of 60km during the total solar eclipse on 29 March 2006 in Kislovodsk (43.7oN 42.7oE) is observed by Kulikov et al. (2007), using a ground-based microwave instrument. Belikovich et al., (2007) reported that the total Ozone concentration(TOC) changes in antiphase with TEC in the lower ionosphere and they have suggested that which can be explained by changes of atomic oxygen concentration during a solar eclipse. Most of the authors, who studied this issue found rather noticeable increase of the total content of Ozone during eclipses (Agashe and Rathi, 1982), Zerefos et al., :2001) which is caused by the clipse induced gravity waves, and the surface ozone level getting decreased (Zerefos et al., 2001) due to photochemical reaction in the troposphere. However the region of partial eclipse, which is not yet discussed in detail, is having a remarkable effect on the stratosphere. From the diagram (Fig.2. of Gerasopoulos et al., 2008) it is very clear that at the vertical shadow region of partial maximum in a total solar eclipse, there is a depletion region of Ozone due to gravity waves and hence an increase in concentration of Ozone at eclipse maximum. We are more particular in the depleted Ozone region since the penetration probability of cosmic and solar radiation is high due to the decreased thickness of Ozone layer. Hence, more cosmic rays of all wave lengths are expected to reach the surface of the earth, especially short range radiations. And so we have tried to analyse its impact on the hydrosphere and biosphere in general.

4. SURFACE OZONE:

The solar eclipse phenomenon affects the surface ozone concentration as well as the temperature, the relative humidity and the wind speed near the ground. Zerefos et al. (2001) observed an ozone decrease upto 2km during the 11 August 1999 solar eclipse. Kolev et al(2005) reported that the duration of the impact of eclipse on ground ozone concentration was almost two hours. As per the experimental findings of solar eclipse on 29 March 2006 at Athens (Tzanis et al., 2008) the decrease in surface ozone concentration started after beginning of the eclipse and maximized after the eclipse maximum, in response to the solar radiation, which affects the photochemical reaction (See fig. 1 & 2 of Tzanis et al., 2008), and it took several minutes after the end of the eclipse to reach its ordinary behavior. A rapid decrease in surface Ozone concentration during partial solar eclipse (22 july 2009) and annular eclipse (15 January 2010) is reported by Chung et al., (2010) and Sharma et al.(2010) respectively, which is in direct correlation with the reduction in photochemical process due to the solar radiation (Amiridis et al., 2007). In fact the surface ozone content, the atmospheric density, aerosols and cloud, control the intensity of radiations of all wavelengths.

5. DESCRIPTION OF THE SOLAR ECLIPSES

The study location, Karaikal, a district of Union Territory of Puducherry located in the latitude 10^o 55' N and longitude 79^o 52' E on the shore of Bay of Bengal, had witnessed a partial eclipse of around 55% obscuration on 22 July 2009 at 06:08 IST. On 15 January 2010, an annular solar eclipse was witnessed at the same location and the Moon's umbral shadow reached the maximum around 98% of the annular position at 13:27 IST, and the eclipse ended at 15:11 IST; which is predicted to be as the longest in the millennium and until December 23, 3043.

6. EXPERIMENT

Giving emphasis to the abrupt change of solar radiation during solar eclipse, the response of seawater in the context of pH variation is studied. This work also aims at delineating the different types of radiations reaching the earth's surface and the possible effects on seawater, marine organisms and the biological system.

Earlier studies on the ozone concentration reveal that considerable reduction in ozone concentration during partial eclipse (Eastman et al., 1980)and total eclipse (Chudzynski et al., 2001; Tsanis et al., 2008; Zerefos et al., 2001), which is the major phenomenon for the observation of more radiations of shorter wavelength on the earth. Many observational evidences on the formation and propagation of eclipse-induced gravity waves at different atmospheric heights(Seykora et al,. 1985; Singh et al., 1989; Hanuise et al., 1982; Jones, 1999; Altadil, et al., 2001) were reported. Zerefos et. al.(2007) pointed out that the eclipse-induced cooling of the ozone layer in the stratosphere is the main source of gravity waves propagating both upwards and downwards. Measurements of total column of ozone using Brever Spectrophotometers have revealed that there was a reduction of 30-40 DU total ozone on the day of eclipse, 29 March 2006, than the day before at Athens. Such a reduction in surface O_3 may be due to decreased efficiency of the photochemical O_3 formation(Sharma et al, 2010).

During the partial solar eclipse of Oct. 1995, we have detected huge gamma counts at the eclipse maximum by gamma ray spectrometric experiments with NaI(Tl) scintillator. Zhaobing et al.[(2009) observed that irradiation of drinking water using gamma rays reduces its pH value. In this regard, the seawater from Bay of Bengal, the eastern coast of India, with a pH of 8.1, equivalent to average oceanic pH, is subjected to find the influence of solar radiation on the pH value under the exposed condition, since major part of the earth is covered by sea. pH is a measure of the acidity or alkalinity of a substance and is one of the stable measurements in seawater. Ocean water has an excellent buffering system with the interaction of carbon dioxide and water so that it is generally always at a pH of 7.5 to 8.5. In this context, a three stage experiment is conducted:

a. Sample at exposed condition during solar eclipse,
b. normal days
c. Sample at non-exposed condition, to identify the influence of solar radiation on sea water during eclipse.

Simultaneously, the changes in the meteorological parameters are also recorded for better understanding of other influencing parameters. Since the said location had a partial eclipse on July 22, 2009, we were able to detect the abrupt change of solar radiation and its effect on seawater. The change in pH value is recorded accurately with a calibrated pH meter containing a glass electrode with temperature compensation controls, from 05:30 hrs to 07:30 hrs (IST) continuously on the day of eclipse and a few days prior to and after the eclipse but on 15 January 2010, it was recorded well before the beginning of the eclipse, at 30 sec. resolution. The percentage of solar disk covered by the moon's umbral shadow was calculated using a high resolution telescope with curved grid lines. The meteorological factors like air temperature and the light intensity using lux meter are recorded continuously during the eclipse period. The wind speed and wind direction are recorded using anemometer and wind wane respectively, of Cyclone Detection Radar Station, Karaikal.

7. RESULTS AND DISCUSSION

The experiments performed during the past two eclipses at the said location, Karaikal in India offered an interesting result of significant decrease in pH of seawater on the day of eclipse than normal days.

On the day of total solar eclipse, 22 July 2009, the observed value of pH reveals a considerable reduction of 20% of the difference between the normal and seawater, which is plotted in Fig.1. This observed change in pH value raised the curiosity and interest of continuous assessment of this study and hence the experiment is repeated on the day of annular eclipse, 15 January 2010.

The pH value is recorded well before the beginning of the eclipse. Even an hour before the eclipse event the pH value seems decreased from normal day value and reached its maximum reduction when the moon's umbral shadow on the solar disc was 45% and when the eclipse percentage was maximum, the decrease in pH value is minimum.

A second minimum is recorded when the solar disc was released around 40% during the end of the eclipse event. Hence, it was understood that the effect of solar eclipse on radiation exists even well before the beginning of the eclipse and the drastic decrease of pH value observed during partial maximum prolonged even after the end of the eclipse. During the complete process of eclipse a raise in pH value between the two minimum [Fig.2.(iii)] is observed and hence we have divided the full process is divided, for the first time, into four stages namely, normal to first minimum (N_{1M}), first minimum to central maximum ($1M_{CM}$), Central Maximum to second minimum (CM_{2M}) and second minimum to normal ($2M_N$). The pH at eclipse maximum did not reach the normal level of pH since the obscuration during the annular eclipse is not 100%, so there must be a portion of sunlit always.

7.1. IONOSPHERIC EFFECT

The shift in pH value is compared with the corresponding change in ionosphere and stratosphere. The effect on ionosphere due to a same type of eclipse, ie., annular eclipse, has to be compared with the present finding and hence the profilogram record given in (Petra and Zbysek 2011; page 315) recorded during an annular eclipse on 3 Oct. 2005 is considered. This Profilogram (height-time-plasma frequency development) measured by DPS 4, gives a clear picture about the plasma frequency at all heights. To our interest we need to analyse the plasma frequency with respect to the percentage of obscuration and the time of the eclipse event. At the partial maximum the plasma frequency is high during the two phases of the event but at eclipse maximum it is less, ie., at the maximum obscuration there is a strong decrease in electron concentration which corresponds to the radiation flux; ie., the ionization process decreases to maximum. The occurrence of depletion of 0.1% to 64% of TEC is observed at six selected ionosonde stations located in Japan and China during the annular eclipse on 15 January 2010 (Fig. 4 of Momani & SUlaiman, (2011) for illustration) But the plasma frequency at partial maximum is little higher than normal time, which is the key difference of eclipse effect and normal day/night effect. While comparing this increase of plasma frequency at partial maximum (Fig.1.(i)), with the pH curve of seawater (Fig.1.(iii)), one can easily arrive at a conclusion that the ionosphere has an important role in the decrease in pH during partial maximum of the eclipse. (The first part (i) of Fig.1, is reproduced from Petra and Zbysek,(2011). This finding also provides information regarding the source of radiation which reduces the pH value. A significant report is arrived when this effect is compared with the stratospheric effect to eclipse.

7.2. METEOROLOGICAL PARAMETERS

The influence of solar eclipses on cloudiness, i.e., ‘eclipse clouds’(Hanna, 2000), has been observed just before the beginning of the eclipse and remains dissipated up to the maximum eclipse period. This cloud structure prevailed during the eclipse occasionally obscuring the solar disk, but the solar disk was visible through lighter clouds during eclipse maximum. The eclipse ended at 07:18 IST with a high light intensity of 22550 Lux at the sharp border between sunlit and eclipsed region. During the annular eclipse on 15 January 2010, the sky was clear throughout the event, and hence, the eclipse maximum from 13:24 to 13:29, gave a dark effect or decrease in light intensity. Kolev et al.(2005) observed a continuous decrease in wind speed without any significant change in direction during the solar eclipse of 11 August 1999. Founda et. al.(2007) also reported a similar effect of observations during the solar eclipse on 29 March 2006.

As far as the meteorological parameters are considered the solar eclipse has maximum impact in the region of totality, i.e., the study location, Karaikal is witnessed a decrease in surface temperature of 6^oC at eclipse maximum and the wind direction is changed to 20^o towards south (from 250^o to 230^o SW), and no change in wind speed is observed since seawater influences more on meteorological parameters. This shift in wind direction may be mainly due to the change in pressure gradient force during eclipse. The cold point tropopause temperature (CPT) variations on the eclipse day was studied by Subrahmanyam at al.,(2011) and which shows a sharp decrease at the time of maximum obscuration. During the annular maximum a decrease in light intensity of 10,000 Lux is observed. The effect of eclipse at its partial maximum on the meteorological parameters like Global Horizontal irradiance, Temperature, Relative Humidity during the eclipse on 29 March 2006 at Athens (ref. fig.1. of Economou et al., 2008) shows a diurnal effect.

7.3. STRATOSPHERIC EFFECT

The change in stratosphere, particularly, the O_3 concentration(Fig.1(i)) during the eclipse event is compared with the recorded pH value of seawater(Fig.1(ii)) are in good agreement with each other. (The second part (ii) of Fig.1 is reproduced from Gerasopoulos et al, (2008). The O_3 concentration is decreased or a depletion region is formed at the partial maximum $\approx$ 45% of eclipse) due to gravity induced waves(Eastman et al., 1980; Seykora et al,. 1985; Singh et al., 1989; Hanuise et al., 1982; Chudzynski et al., 2001; Tsanis et al., 2008; Zerefos et al., 2001), and at the eclipse maximum the O_3 layer becomes wider/thicker than the normal level [Fig.1.(i)] in the shadow region. Hence the penetration of short range cosmic rays are reduced to a maximum level (Kazadzis et al., 2007; Kazantzidis et al., 2007) and the reduction in pH value is minimum during the eclipse maximum. At the partial maximum i.e., around 45% of the eclipse both at the beginning and end of the event, the reduction in pH is maximum due to the formation of depletion region in the O_3 layer. Such depletion region formation in the O_3 layer allows more short range cosmic radiations to reach the surface of the earth and hence causes a maximum reduction in pH value of seawater.

It is found that the sea water started regaining its original state after an hour of the eclipse event. This may be due to the fact that the influence of decrease of shorter wavelength radiations as the eclipse approaches its maximum compared to longer wavelengths. This is in correlation with Tsanis et al.(2008) that the solar radiation started to increase after the eclipse totality, while the surface ozone concentration started to increase about one hour later and returned to its ordinary behaviour several minutes after the end of the eclipse.

From the Fig.1. it is very clear that the higher plasma frequency of the profilogram is in vertical line with the depletion regions of Ozone layer in the Stratosphere and which also corresponds to the dip in pH curve, which provide a link between ionosphere-stratosphere and biosphere. Such an effect in pH is now interrelated with the ionization effect of radiation emerging from ionosphere and passing through the Ozone layer in the stratosphere.

Search for the scientific reason of decreasing pH value perceived the influence of ionising radiations reaching the surface of the earth during eclipse. A recent study report that Gamma ray irradiation on drinking water reduces its pH Zhaobing et al.,(2009). Also during the partial solar eclipse of 24 Oct. 1995, we have detected huge gamma counts at the eclipse maximum by gamma ray spectrometric experiments with NaI(Tl) scintillator. Since our measurements show drastic decrease in pH value of seawater during both the total eclipse event (partial at study location) on 22 July 2009 and the annular solar eclipse on 15 January 2010, when exposed to solar radiation and in view of the report of Zhaobing et al., (2009), this decrease is due to the shorter wavelength radiations reaching the surface of the earth. By comparing our earlier detection and measurements with the report of Zhaobing et al., (2009), it is obvious that among the short range waves, gamma rays influences the pH value of seawater. These gamma rays are reaching the earth's atmosphere due to the gravity wave induced reduction in ozone concentration, as explained before. Since the role of surface Ozone on sea is comparatively less other than photochemistry, it is not considered in this paper for discussion. The source of gamma rays may either be solar radiation or the ionosphere where a huge number of gamma particles are formed in the process of pair production and annihilation. These gamma particles reach the surface of the Earth easily through the depletion region of stratospheric Ozone layer due to its high penetrating power in the atmosphere.

7.4. BIOLOGICAL EFFECTS

The low energy gamma rays ($\approx$1.24 MeV) reaching the surface of the earth are not passing through matter (Tsypin et al., 1956), as such these will not penetrate deep into the sea instead are absorbed by the upper layer of the seawater and the particles get excited. Due to the close association of pH value with salinity, this reduction in pH value of seawater in the surface layer during solar eclipse causes a critical change in the behaviour of marine organisms that they move to deeper region during this period. After few hours of the eclipse event these organisms come to their normal behaviour since the seawater regains its original pH value after few hours of the end of the eclipse.

The comparative plot of stratospheric change and pH change (plotted in Fig.2), suitably explain the concept of our finding. During this period an erratic movement and critical change in the behaviour of marine organisms is observed that they move to deeper region of the sea. Studies concerning behavioural changes of animals, such as fishes (Pandey et al., 1982; Jennings et al., 1998), birds (Elliott et al., 1974), rodents (Advani, 1981), and chimbanzees (Branch et al., 1986) responded rapidly during total solar eclipse. The studies on fresh water fishes during the 1980 solar eclipse in India(Pandey et al., 1982) reported that all species studied almost stopped gulping air, became sluggish, and sheltered to the bottom, and such changes during solar eclipse were related with the activities appropriate for sunset. As per the report of Sharma et al.(2010) the change in meteorological parameters and the photochemical ozone formation during eclipse are more or less similar to the behaviour of night time chemistry and Wu et al.(2011) also reported a same effect. As a conclusion of our study, the darkness effect due to eclipse is not similar to the night time darkness, instead short range radiations are reaching the surface of the earth, particularly gamma rays, in addition to the normal cosmic radiations. The consequences of gamma rays in the pH of seawater are observed well before the start of the eclipse and it prolonged even after few hours of the end of the eclipse. It is known that, pH can affect the ionization of the amino acid side chain which in turn change the secondary, tertiary and quaternary structure of the protein molecule. This will alter the active site and consequently its action. The change in pH of the medium or environment (McDermid et al., 1988; Tripathi et al., 1988) leads to alteration in the shape of the enzyme since each and every enzyme is characterized by an optimum pH, at which the specific enzyme functions most actively. Such structural change in enzyme has an effect on ionic binding which is necessary to drive chemical reaction. In biological systems an unexpected change in pH can have a major effect downstream. Hence, as per our findings, the usual nocturnal behavioural studies may be reviewed in the context of radiation and pH change during eclipse.

8. CONCLUSION

During solar eclipse, photoelectrons in the eclipsed region are reduced largely at totality. Due to a large depression of inflow of photoelectron flux coming from the eclipse region causes a great drop in electron temperature in the ionosphere. The profilogram showing a large decrease in plasma frequency at eclipse totality on 3 October 2005 also shows an increased frequency during partial maximum. A reduction in ozone concentration in the stratosphere is formed because of gravity waves due to the change in pressure gradient force. This ozone depression allows more ionizing radiation in addition to non-ionizing rays in the short period of eclipse. These rays have a wide range of effects on humans and aquatic and terrestrial ecosystems. However the role of ionizing radiation, such as gamma rays, during this process is less studied. Here, we report that, the gamma rays are reaching the earth's surface during eclipse which reduced the pH value of seawater when exposed to solar radiation. It is to be noted here that this observation is during eclipse partial maximum in both the event of total and annular eclipses, in a coastal area, where the seawater influences the effect of eclipse, especially on meteorological parameters. Our results are the first one reported about the influence of gamma rays during solar eclipse in the pH of seawater. The role of gamma rays during eclipse on the biological system is also discussed and hence a revision of usual nocturnal studies during eclipse is urged. The results discussed in this paper will probe a gateway to a new approach of the behavioural studies of marine organisms and other biological systems during eclipse and may add an additional parameter in the geophysical studies of polar region.

9. SUMMARY

a. The first report of eclipse induced pH reduction in seawater is presented in this paper. For the first time the experiments performed during the total(partial) and annular solar eclipses of 2009 and 2010 show a concrete effect of radiation on seawater, since the pH value fluctuates(reduces) during the event.
b. Cause for this effect is investigated and which is due to gamma rays reaching the surface of the earth during eclipse.
c. Formation of ozone depletion region due to eclipse induced gravity waves allows more cosmic rays to pass through.
d. Ozone depletion strengthens the surface winds in the polar region resulting greater flow of cold air in the region.
e. Since a reduction in surface ozone allows more radiations and the impact of solar radiation on the material surface of the earth is comparatively high during eclipse.
f. To explore the cause in detail we have analysed the findings of many authors about ionospheric changes and correlated the role of various atmospheric layers to the eclipse, then an ionosphere-stratosphere-biosphere correlation study is conducted and is presented here.
g. This discovery of cosmic (gamma) ray influenced pH reduction in seawater raises questions on the biological studies and geophysical studies such as correlating the eclipse effect on marine organisms and other biological systems to the night time chemistry and the polar region studies respectively.

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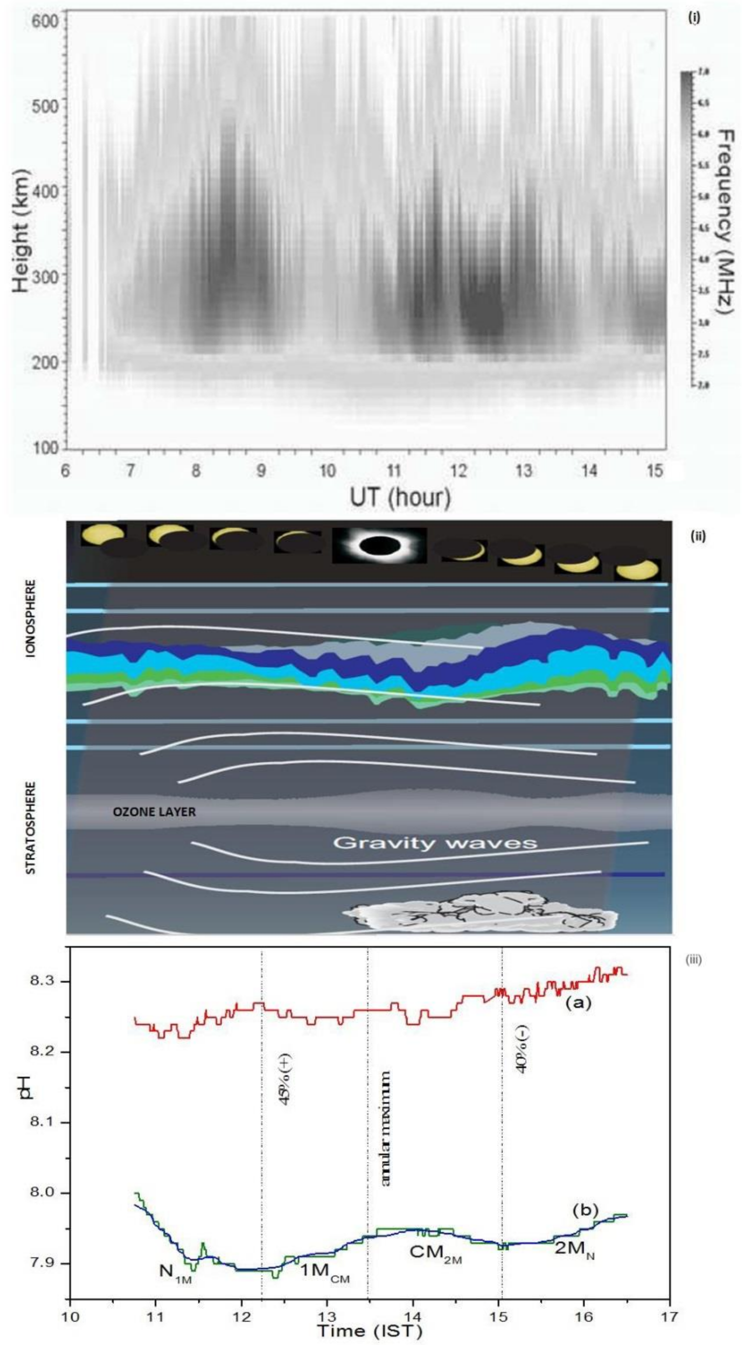

Fig.1.: pH variation of seawater with respect to ionospheric and stratospheric change (i) Plasma frequency variation of the annular eclipse on 3 Oct. 2005 (reproduced from Petra and Zbysek ,2011) (ii) Stratospheric change during solar eclipse (reproduced from Gerasopoulos et al., 2008); (iii) Variation in pH of seawater during (a) normal day and (b) annular solar eclipse under exposed condition on 15 January 2010. The reduction in pH value during eclipse is around 40% of the difference between the ordinary water and seawater (dashed line shows the % of eclipse; (+)symbol for approaching eclipse maximum and (-)symbol for towards the end of process. (hrs refers IST).