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Liquid water skin structure & its influence on atmospheric electric fields

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Abstract

A stable quasi rigid water molecule structure and structure for solid and liquid water body was presented recently. A liquid water skin structure may be derived from that model with the electric coupling principles between water molecules on the air-water interface. The surface tension and latent heat for evaporation of water are simulated with high accuracy. The water surface, including water drops might "generate" negative ion/molecule (NWI, as the carrier of electron) to air with probability of $(1/11)^8$ among the water surface molecules, influencing the atmospheric electric fields. The surface structure of water droplets may lead to concentrate water molecules including NWI on bigger drops and form high negative voltage in cloud, heavy rainfall and lightning. The water quantity and electron recycling and climatic balance in atmosphere were presented in this article. The analysis results were verified by the experiments, mean vertical distribution of electricity in atmosphere and climatic world lightning frequency map data.

Keywords: Water molecule structure, water skin structure; water surface tension; latent heat of water evaporation; atmospheric electric fields; lightning;

Introduction

"**What is the structure of water?**" is one of the 125 questions listed in the Special issue of *Science* in 2005 [*1*]. A model for water molecule was developed in our recent paper [*2*]. The core of the water molecule is an isosceles triangle with ratio of squared distances: $(H\text{-}H)^2/(H\text{-}O)^2=2.5$, which would be surrounded by moving electrons and form **a principle pyramid water molecule** ("**pyramid**" model in short) **with 4 equilateral triangle planes and 6 equal-edges** of 0.48017nm, equidistant separating two pairs of "+"/"-" electric endpoints, possessing obvious dipole moment. The solid water state is the frame constructed by water molecules according to the principle of "unlike charges attract each other, like charges repel each other", and the liquid state has the same frame with "free molecules" by ratio of 1/11 to the "frame molecules" . On this basis, a series of specific properties of water might be simulated and modeled with high accuracy. Such as, why the water molecule possessing obvious dipole moment, but the electric conductivity of pure water is extremely low; why the solid state of water has the less density than that of its liquid state, and the density of water gas under high pressure and temperature can reach to 2.16 g cm^{-3}, which was detected in earth mantle [*3*]; why the snowflake with the hexagon-sexangle-six needle forms is formed, during desublimation of water in atmosphere; why water has so large specific heat capacity, thermal conductivity, etc?

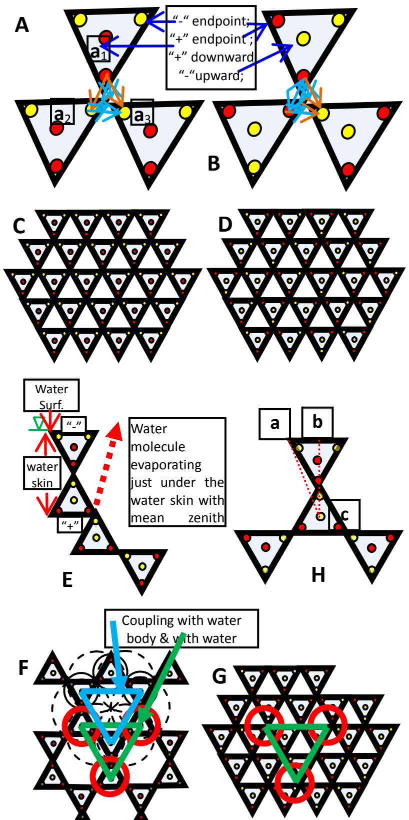


Fig. 1. Sketch of surface frame structure of liquid water

Does this model can be extended to water skin construction? Why does liquid water possess high surface tension and huge latent heat for evaporation? The electric charges are balanced in water body, but how would be the situation on the water surface? Why there are **stable electric fields near water/ ground surface and in atmosphere?** The water drops have big ratio of its surface/volume, so the water surface structure will extremely influence on the water recycling processes (evaporation/ condensation/ cloud formation/ rainfall/ **lightning**) in earth ocean-atmospheric system. How the water surface structure strongly influences on the earth environment? All these issues would be discussed in this article.

Results/discussion/materials:

1. Surface structure model of liquid water

1.1 Surface/plane model of liquid water

The water surface (may assume the plane is a horizontal, without loss of generality) should be constructed by one of the 4 planes of the pyramid water molecule with 3 endpoints as the element of the surface, the 4th endpoint of the molecules should be perpendicular to the water surface and downward (inward) with "+" electric charge (Fig.1**A**, red circle in the center), because there is no any water molecule to be coupled outside the water body. The equilateral triangle with three circles at the corners, indicating the electric charges of "-"—yellow coloured and "+"—red coloured), which might be coupled with other water molecules with opposite electricity. The "+" endpoint is coupled with other two "-" endpoints of two molecules symmetrically (Fig. 1 **A**, **C**). All the surface water molecules have a common parallel plane and the "+" electric charged downward endpoints. There are three molecules coupled at each point (node). The ratio of cavity/ water molecule is **1:1**, instead it is **2.28** in the water body [*2*]. The 2nd layer under the surface layer has the similar structure as the above layer, having a common plane net with 3-molecules nods (one with "-" electric charge and two molecules with "+" electric charge, Fig.1 **D**, **G**), but the 4th endpoints with "-" electric charge of the molecules are upward (outward) and couple with the downward endpoints with "+" electric charge of the above layer's molecules. Structure of 3rd below water surface layer has the structure of water body with hexagon frame with ratio of 1/11 "free molecules/ frame molecules" [*2*]: constructed by 6 molecules in a same plane but the 4th endpoints change their directions alternately one by one (upward/downward, Fig. 1 **F**), the "-" endpoints of which are coupled with the corresponding nodes of the 2nd layer (Fig.1 **E**, **F**, **G**). Therefore, the water skin is a **membrane constructed by a net system of two layers of water molecules** with cavity/water molecule of 1:1 and thickness of about 0.8~1nm. The water surface is segmented by lattice cell- net of water molecule/empty space with equilateral triangle of area of 0.101178nm^2≈0.1nm^2 [*2*]. The materials with cross section less than 0.1nm^2, such as oxygen and other air molecules may easily pass through water surface. So the water surface is a **“breathy”**, but not **“airtight”** membrane.

1.2 Water surface tension

Liquid water surface possesses large surface tension of 75.62 dyn cm^{-1}=0.07562 N m^{-1} at 0℃, and 58.84 dyn cm^{-1} at 100℃ [*4, 5*]. The detailed data are shown in Tab. 1:

Table 1. Variation of water surface tension with temperature [*4, 5, 6*]; 1 dyn cm^{-1}=mN m^{-1}=10^{-3} N m^{-1}

t, (℃)	-5	0	4	5	10	15	16	17	18	19	20	21	22
(dyn cm^{-1})	76.40	75.62	75.09	74.90	74.20	73.48	73.34	73.20	73.05	72.89	72.75	72.60	72.44
t, (℃)	23	24	25	30	40	50	60	70	80	90	100	110	120
(dyn cm^{-1})	72.28	72.12	71.96	71.15	69.55	67.90	66.17	64.41	62.60	60.74	58.84	56.89	54.89

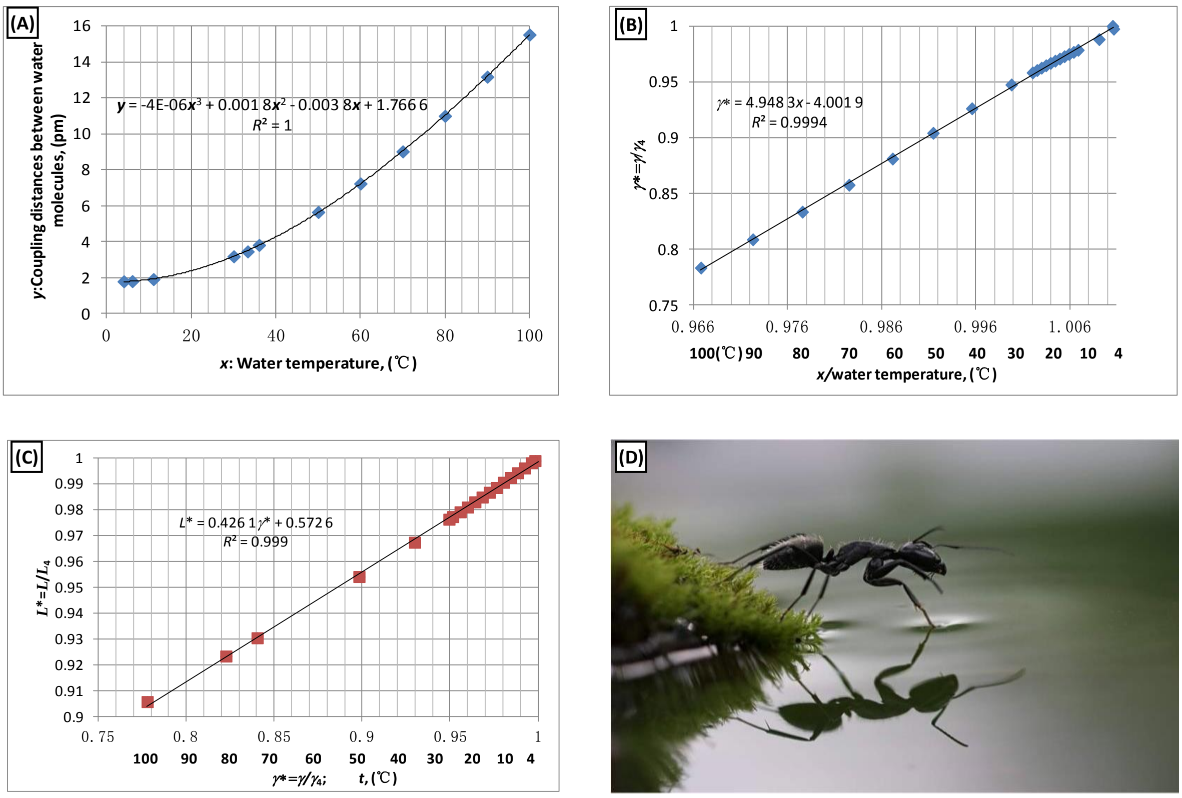


Fig. 2: (**A**) Coupling distances between water molecules *d* versus water temperature [*2*] ; (**B**) Relationship between the non-dimensional water surface tension ($\gamma^*=\gamma/\gamma_4$) and the parameter of *x'* ; (**C**) Relationship between the non-dimensional water surface tension $\gamma^*$and the parameter of *x*; (**D**) Linear correlation between latent heat $L^*=L/L_4$ for water evaporation and surface tension $\gamma^*=\gamma/\gamma_4$; (**E**) Illustrates the tough water skin.

The water surface tension is defined as the tension along the unit tangent line on the water surface. So it's related with two facts: (1) the coupling force between molecules, which is in reverse proportion to square of coupling distance (d^2) between water molecules; (2) number of molecules in d_1=1 m distance $d_1/(h_0+d)$, where h_0-height of the pyramid of water molecule. Both of them are related with temperature. The d increases with temperature [*2*]. It is shown in Fig. 2 (**A**) and can be calculated according to the following equation: d= -4E-06t^3 + 0.0018t^2 - 0.0038t + 1.7666; （R^2= 1）; unit for [d]: pm; [t]: ℃.

The non-dimensional water surface tension $\gamma^*=\gamma/\gamma_4$ (ratio between water surface tension at certain temperature with the value at 4 ℃, subscript 4 means at t= 4℃ in interval of 0℃ ~100℃ is in linear correlation (square linear correlation coefficient R^2=0.9994) with the parameter of

$x=(1+d_4/h_0)/(1+d/h_0)+(\alpha/(d/d_4)^2)\exp(\beta(1-d/d_{100})^2)$, where α=0.00803, β=0.35 (Fig. 2 (**B**));

The second part of above equation indicates that the attraction force between the "+" "-"charges of water molecules in reverse proportion with square distances of d^2 appears obviously when d is relatively small. Fig. 2(**D**) illustrates the tough water skin (photo by: Vadim Trunov).

1.3 Huge latent heat of evaporation

Being specific constructed in both parallel and vertical to the surface directions, water skin possesses specific huge surface tension $\gamma^*=\gamma/\gamma_4$ and latent heat for evaporation $L^*=L/L_4$ (subscript 4 means at t= 4℃). They are the most among all the liquid matters [*4, 5, 7, 8*]. These two parameters are linear correlated as following equation (Fig. 2**C**.):

L^* = 0.426 1γ^* + 0.5726, R^2= 0.999.

It means the force which the water molecule should to overcome for escape from water surface is in direct proportion to water surface tension and the energy (latent heat for evaporation from water surface) equals the surface tension force multiplying displacement for escape of water molecule from water body to air.

Based on the molar mass of water of 18.01528 g mol^{-1}, Avogadro constant of 6.0221367×10^{23} [*4,5*], latent heat of evaporation at 4 ℃ of 2,490.727 J g^{-1} [*4, 7, 8*], the latent heat of evaporation per a water molecule may be calculated as 7451.035×10^{-23} J ind^{-1}. The water surface tension at 4 ℃ is 0.075089 N m^{-1}. There are $10^9/(h_0+d)$ coupling points in 1 m and 3 molecules at each coupling nodes, therefore the surface tension per one individual (ind) molecule would be 0.075089 N (N=J m^{-1})×(h_0+d)×3×10^{-9} ind^{-1}. The displacement for reach the value of latent heat for evaporation would be：

d_L=745 1.035×10^{-23} J ind^{-1} / (0.075 089 N×(h_0+d)×3×10^{-9} ind^{-1})×10^{9} nm=0.839813 nm. （1.6）

The h_0=0.392057nm, d_4=1.799197pm. Thus, the thickness of water skin with zenith angle of 15°is (2(h_0+d))/ cos 15°= 0.81550nm, which is less than d_L about 24pm and more than d_{100}=16pm—the coupling distance at 100 ℃ [*2*]. It means water molecules escape from water surface may with certain zenith angles. The water absorbs most solar energy in depth and the latent heat for evaporation is supported by energy from the lower layers. Therefore, the most possible scenes of evaporation are the free water molecules in 2nd ~3rd layers near the surface, which possess enough energy, would escape from water to air (Fig. 1 **E**).

2. Electric fields of water surface and their influences on electric fields of atmosphere

2.1 Electric fields near water surface

As it was described in §1.1 and Fig.1 (**A**, **C**), at any coupling point under the "+" electric charged endpoint there is a hydrogen atom with mean probability of strong ("+" 5/11 and "-" 2/11) electric charge, which can attract two strong "-" (probability of 6/11) [*2*] negative electric charged endpoints of other molecules ($\mathbf{a}_2$, $\mathbf{a}_3$). As the results, the water surface, including water drop's surface, would appear the characteristic of mean "-" negative charge (Fig.1). Similarly, the 2nd layer (inner surface) of liquid water skin would appear the characteristic of mean "+" positive charge (Fig. 1**E**).

2.1.1. The water surface may lose the electrons or attract "+"ions during interactions with air (gaseous elements, aerosols, etc.). The "+" electric charged "positive water ions" are easier to leave from the water frame and become "free water ions", getting into lower layers of water body.

2.1.2. For water drops the surface will be a sphere, because of the surface tension. The water spherical skin will be covered by mean "-" negative electron charged outside and will easier to lose the electrons or attract "+" ions from air during their moving in atmosphere. The "+" electric charged "positive water ions" are easier to leave from the water frame and become "free water ions" [*2*], getting into inner layers of water drops. In this case the total water drops will behave as a "+" one with a "-" negative electric charged outer surface.

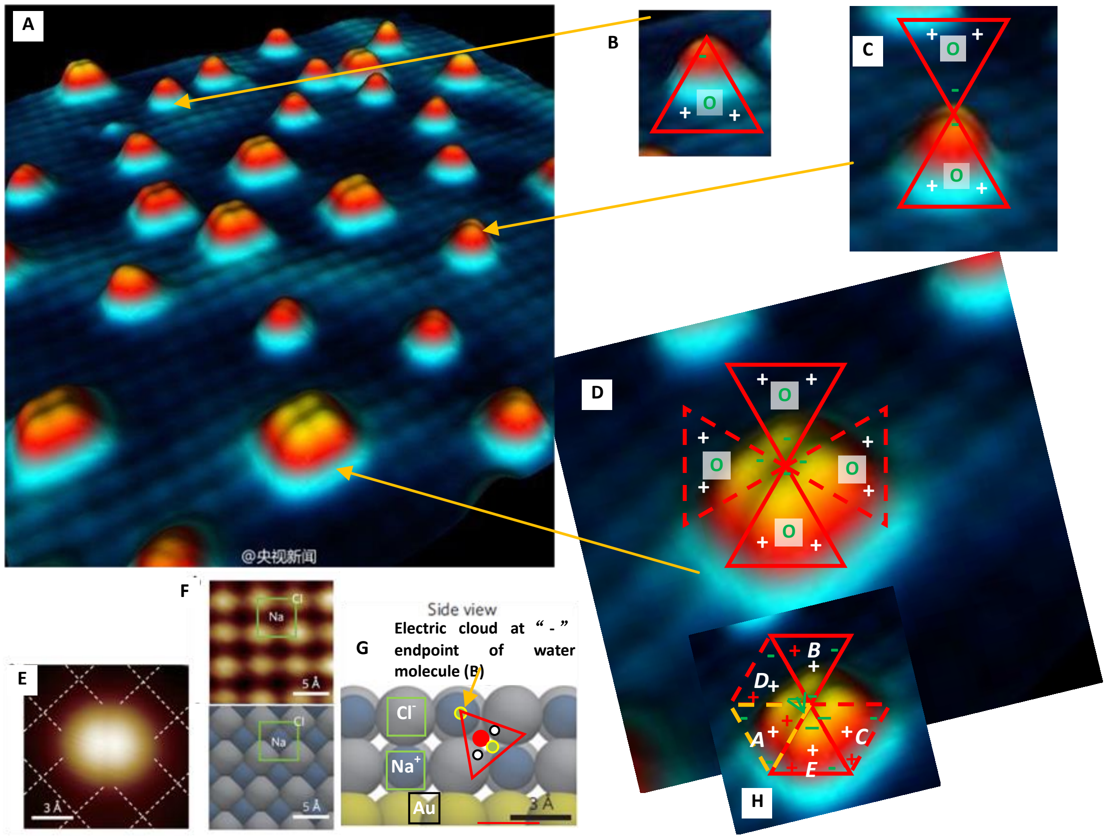


Fig. 3. Images taking by scanning tunneling microscope –STM at 5 K on the substrates of NaCl. The islands with yellow-red colour have bulges with height of about 1 Å (=0.1nm) [*9*, *10*, *11*]

2.1.3. A series of images for individual water molecules, which were coupled to the NaCl polar atomic sites of the surface under low temperature of 5 K by using tip-enhanced inelastic electro tunneling spectroscopy based on a scanning tunneling microscope (STM) have been published [*9*, *10*, *11*, Fig. 3]. All these images reflect the "-" electric charged endpoints of our presented water molecule and their orientations can be explained on the basis of the frame of Na^+-Cl^- analyzed in [*2*] and in Fig 4. The water molecules would insert into (Na^+- Cl^-) crystal chink by gravity (the O-atom is heavier than the 2H-atoms and is located under the latter and one "-" electric charged point is downward vertically in supervacuum, $\boxed{\textbf{D-}}$) and stable balance of electric charges (Fig. 3**G**), $\boxed{\textbf{C-}}$ in Fig. 4**F** with "-" electron cloud is over the Na^+ ion of **151** pm, higher than Cl- ion of **100** pm (Fig. 4, left upper corner) and may be detected by the instrument as a red/yellow circle (Fig. 3**B**). In cases of 2 or 4 molecules (maximum from 4 directions, Fig. 4) meet at this point the pictures display as Fig. 3**C**, **E**, **D**.

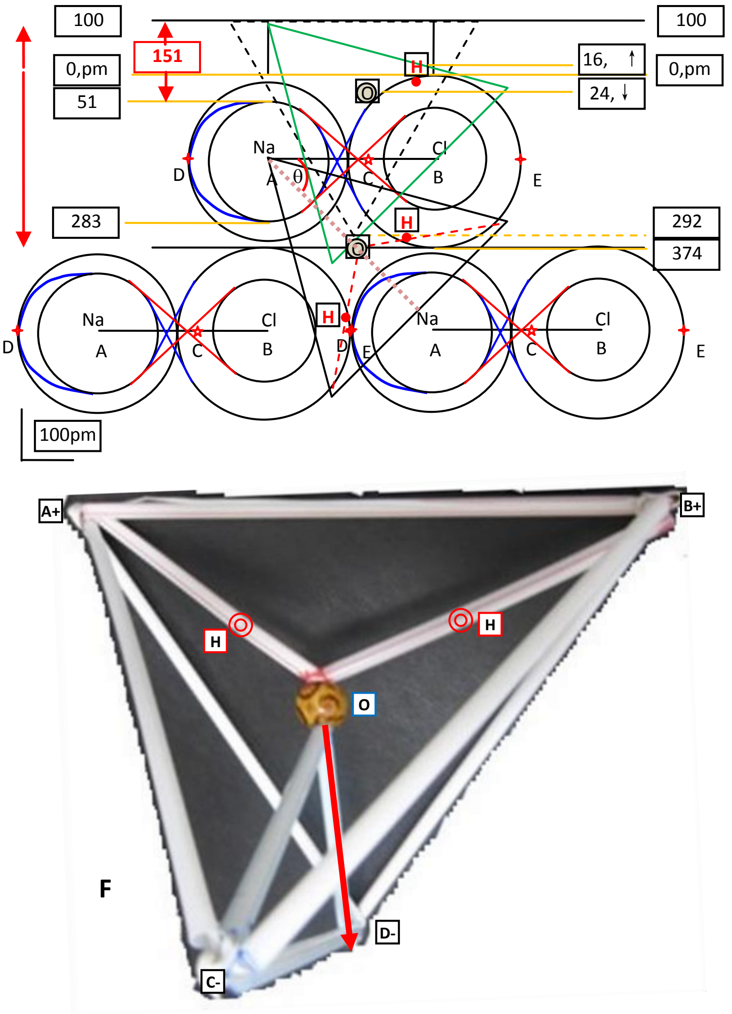


Fig. 4. The structure of NaCl crystal [2] and water molecule is infixed in the NaCl crystal with same length unit in horizontal plane section. The vertical unit is indicated in the sketch. The top of the Cl^- is the reference 0 elevation in vertical. Being paralleled with the Na^+ and/or Cl^- crystal plane (horizontal), one of the equilateral triangle planes of the water molecule has median (Na^+-Na^+) associated with the grids of Na-Cl crystal in =45°. The downward "-" electric charged endpoint of the water molecule is located lower than the bottom layer of the N^+'s sphere on 292-283=9 pm (in vertical plane).

The water surface, including water drop's surface, would appear the characteristic of "-" negative charge, as follows:

2.2.1. Water drop attracted by "+" positively charged grass bar, rubbed with silk (Fig. 5 **A**);

2.2.2. Tap waters are effected by "+" charged triboelectric grass bar, rubbed with silk (Fig. 5 **B**, **C**, **D**) and "-" charged rubber stick, rubbed with fur (fig. 5 **E**);

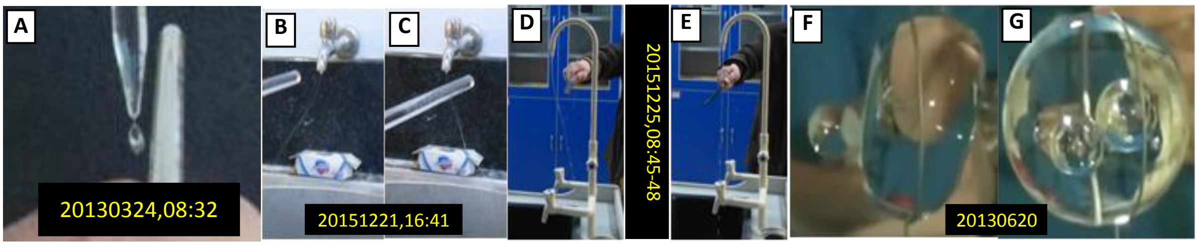


Fig. 5. Examples indicating the electric characteristics of water surface

2.2.3. Experiments in Chinese satellite "Tiangong-1" on 20th June 2013 [*13*]: (1) water drops are touching and slipping each other, appearing both liquid surfaces are electric charged by same (negative) electricity (Fig. 5 **F**); (2) The air bubble cells in the water ball are touching and slipping each other and with the internal skin of the water ball (Fig. 5 **G**). All these indicate that the air-water interface as a membrane, has one face (face 1) outward to air with "-" electric charge and other inward to liquid water face (face 2) with "+" electric charge. The perpendicular to face endpoints of these two faces are oppositely charged and attracted each other, strongly electric coupled, as indicated by the model in §1.1 (Fig. 1 **E**).

3. Influences of electric field of water surface on atmospheric environment

3.1. Characteristics of atmospheric electric field

3.1.1. Characteristics of electric field near water/ground surface and the probability of generation of negative water ion/molecule (NWI)

The fact that there are electric fields in the atmosphere was well known since the middle decades of the 18th century. The nature of the thunder and lightning is the electricity process in atmosphere. Near the earth surface exists an electric field with mean intensity of 120 V m^{-1} (on land), 130 V m^{-1} (on water) [*14*, *15*, *16*] in sunshine days. The ground is "-" charged, and the atmosphere is "+" charged. **Where is the stable electricity come from?**

According to the structure model of water surface, the water surface plane appears mean "-" negative electric charge. But all the electrons are bounded in water molecules. Is there possibility for generating "-" electric charged water ion/molecule from water surface to air?

As a normal state there is an area of 6 equilateral triangles at one coupling point with three water molecules, coupling at this net node (Fig. 1 **A**). One of the "+" electric charged endpoint of the molecule ***A*** (fig. 3**H**, for symbolical explanation, white "+" signs in triangle center mean the downward "+" electric charged endpoints of water molecules) is downward and coupled with the "-" electric charged endpoint of the 2nd layer of the water surface membrane. The second upper "+" electric charged endpoint of molecule ***A*** is coupled with two "-" electric endpoints of other water molecules (Fig. 3 **H**: ***B***,***C***). This is the normal state of construction of the water surface. In case, when there are other 2 "free water molecules" (Fig. 3 **H**: ***D***,***E***), which are inside the frame of water structure (not located on the frame) [*2*] at this coupling points (it means there are 4 "-" electric charged endpoints of 4 water molecules coupled with "+" electric charged endpoint of molecule ***A***), the probability of all the 4 molecules (Fig. 3 **H**: ***B***,***C***,***D***,***E***) have "double electrons" at this coupling point is $(1/11)^4$ (see [*2*]). In addition, when there is no electron moving in the distance between the H nucleus and the "+" electric charged endpoint of molecule ***A*** in Fig. 3 **H** at this moment, the probability would be $(1/11)^{(2\times4)}$, because there are two probabilities: whether or not the electron is moving in the distance between the H nucleus and the "+" electric charged endpoint. At this moment, the $2\times4=8$ electrons (4 double "-" electric charged endpoints of 4 coupling molecules) would be strongly attracted by the H nucleus, the distance between H^+ and 8 electrons would be shorter, and one of the closest to H nucleus electron under the repelling forces by other electrons, including the other electron of its own molecule, and attracting force by H nucleus would flight with acceleration to molecule ***A*** and could not return to its original molecule but pass through the boundary between the molecules and get into molecule ***A*** (indicated by a green arrow from molecule ***D*** to ***A***, Fig. 3 **H**). The molecule ***A*** will become a "**negative water ion**" (**NWI-water molecule with extra electron**). It will repel with the "-" electric charged endpoint of the 2nd layer of the water surface membrane and "generate/evaporate" from water surface to air easily with relatively less latent heat energy. The molecule ***A*** will become a free "negative water ion--**NWI**" (as the carrier of electron) in air near water surface. Therefore the probability of generation of "-" negative water ion is $(1/11)^8$ among the water surface molecules. There will be $10^{18}/(6\times0.101178)\times(1/11)^8=7.68\times10^9$ NWI m^{-2} near water surface. Here the area of the equilateral triangle of the water pyramid is $0.101178nm^2$, the coupling distance between the water molecules is 2.7341pm [*2*].

According to above estimation of 7.68×10^9 electrons m^{-2} near sea water surface and take attention on the differences between the water surface and land/vegetative cover, we may estimate the mean density of 7×10^5 electrons cm^{-2} for the total Earth surface. So the total volume of -5.7×10^5 C, and a mean current of 1800 electrons cm^{-2} s^{-1} , or about 1500 A might be estimated for the whole Earth surface [*14*]. Therefore NWI provide the electrons from water/ground to air-atmosphere, similar the normal liquid water molecules provide the water volume to the atmosphere by evaporation.

Observed data show the mean electric intensity of gradient d*v*/d*h* decrease with elevation in atmosphere. Namely, it is 130 V m^{-1} near ground to 5 V m^{-1} at elevation of 9 km; the number of elemental electrons in the column of 0-9 km with cross section area of 1 cm^2 is 7×10^5, which equals the density of NWI near surface water (Tab. 2) [*14*]. This is a balance of electricity in atmosphere, similar to the balance of water quantity (evaporation/evaportranspiration-precipitation-water content in atmospheric column).

Table 2. Variation of vertical gradient of voltage and volume of elemental electronics in atmosphere [*14*]

Height, (km)	0	0.5	1.5	3	6	9
d*v*/d*h*,(V m^{-1})	130	50	30	20	10	5
Column height (km) with cross section of 1 (cm^2)	0-0.5	0.5-1.5	1.5-3	3-6	6-9	0-9
Content of electrons,(10^5)	4.45	1.11	0.56	0.55	0.28	6.95

Variation of gradient of voltage *v* with height *h* may be described by equation (3.1) (Tab. 2) [*14*]:

$$dv/dh = 90\exp(-3.5h)+40\exp(-0.23h) \tag{3.1}$$

From Eq. 3.1 the voltage at elevation of 9 km relative to the ground is 180,000 V. The fact of existing a great deal of “+” electric ions in the top of troposphere may be related with **volcanic eruptions**. The gases, ash, and fragments (glass, quartz, etc.) may carry “+” electric charge during volcanic eruptions by rubbing with the solid lava and metal elements [*17-20*]. The facts that lightning (Fig. 6 **A**) associates frequently with volcanic eruptions indicate the existing of strong electric effects during volcanic processes. The heavy materials will precipitate down to ground with different speeds afterward (Fig. 6 **E**). The very small particles with the “+” positive charged ions will be retained in the atmosphere at different elevations for a long time, parts of them will combine with the “-” ions and form the neutral elements in atmosphere.

Fig. 6. **A**: lightning during volcanic eruption; **B**, **D**: lightning during heavy rainstorm; **C**: the sketch of the air flow lines and electricity distribution in heavy rainstorm cloud; **E**: fragments

of glass and quartz precipitated from volcanic eruption gas, ash, etc; **F**: conceptual climatic electric charge balance (green colour, Eq. 3.2) in the column of troposphere from 0-9 km with cross section area of 1 cm^2; and **G**: water quantity conceptual climatic balance (red colour, Eq. 3.3) in the column of troposphere from 0-9 km with cross section area of 1 cm^2. The climatic balances are as follows:

$E_1=E_2+E_3$ (lightning +rainfall with electricity)$+V_-$; $-V_-=V_+$; $-E_2=V_+$ (3.2)

Evaporation=Precipitation (3.3)

The annual mean precipitation on the Earth is 990 mm a^{-1}=2.712 mm d^{-1} [*21*] (it should be the same of mean evaporation in climatic meaning, Fig. 6 **G**), or 1.05×10^{17} water molecules $cm^{-2}\,s^{-1}$, which is 1.7×10^{14} times more than the releasing negative water ion-molecule of 1800 ind $cm^{-2}\,s^{-1}$, or the NWI are occupied only $\mathbf{6\times10^{-15}}$ of the evaporated water molecule (Fig. 6 **F**). The mean volume of water in the atmospheric column with cross section of 1 cm^2 is 25.3 mm, which is equal to the volume of mean evaporation during 25.3/2.712=9.3 d (Fig. 6 **G**). Similarly, mean number of electrons in the atmospheric column with cross section of 1 cm^2 is 7×10^5, which is the number of mean releasing electrons (negative water ion-molecules) from water surface during 6.48 min (=7×10^5/1800/60, Fig. 6 **F**). The stable state of net negative ions (electrons) in atmospheric column of 0-9 km is supported by water surface, and the positive ions in the atmosphere, especially in the upper troposphere, is mainly supported by volcanic eruptions.

3.1.2. Influences of electric field of water drops on atmospheric environments

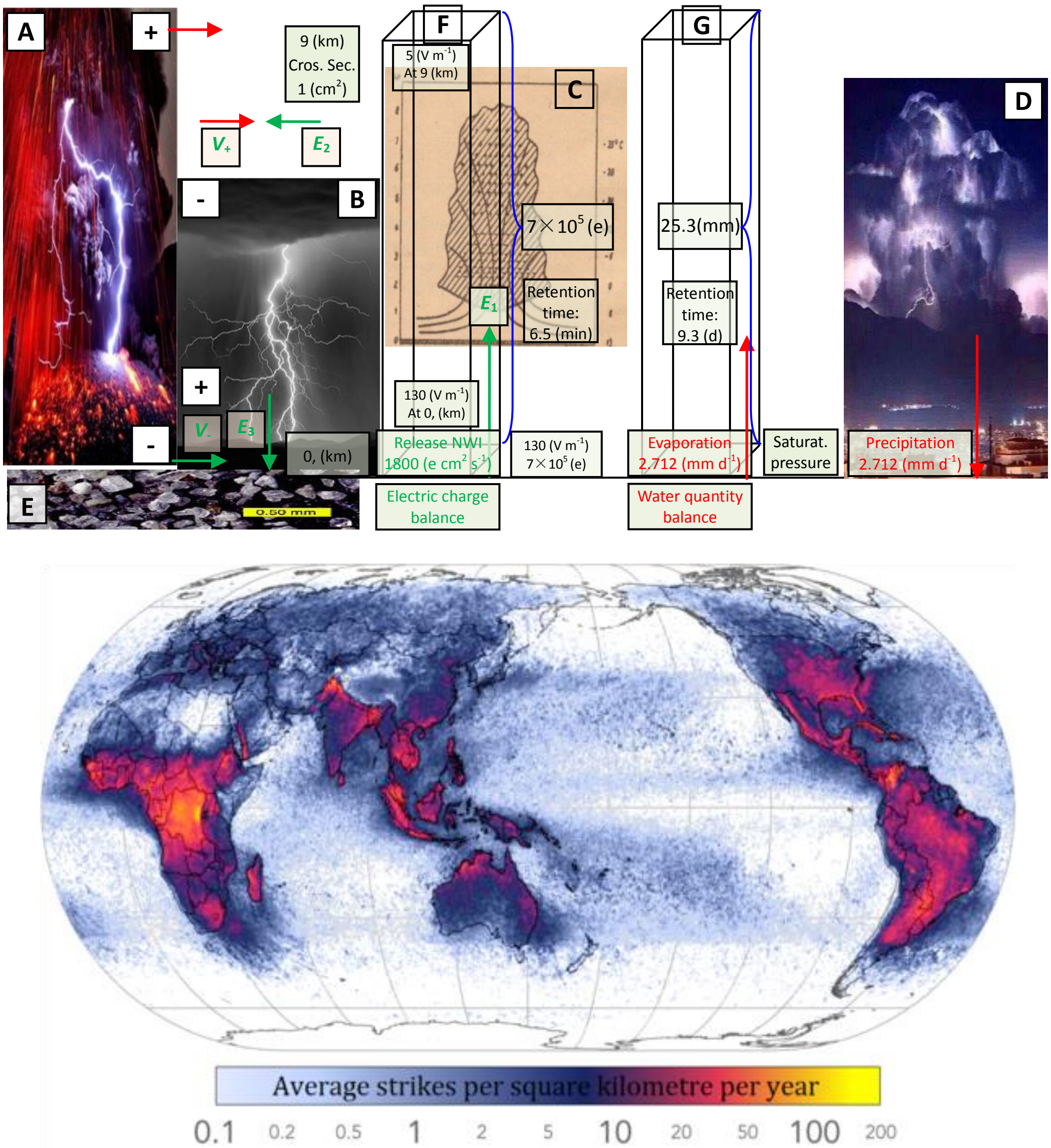
3.1.2.1. **Minimum scale of water drop** and influence of radius of water drops on saturated vapor pressure

The minimum radius for a water drop: **ac**=(**bc**^{2}+**ab**^{2})$^{1/2}$= 0.635251 nm [*2*] (Fig. 1 **H**), volume of that sphere is 1.07380 nm^3, in which can involve 41 water molecules according to the ratio of space/molecule of 1:1 as the construction of a skin of water surface (the volume of a water molecule is 0.013047 nm^3 [*2*]). The area of the surface of the minimum water drop is 5.071081 nm^2. The area of the equilateral triangle of the molecule at 4 ℃ is 0.100211 nm^2. Therefore the possible construction of a minimum water drop would be 1 (in centre) + 24 (on the outer surface) + 16 (inner molecules for connection) =41 water molecules. The saturated pressure E_r for condensation is related with the radius r of water drop (Eq. 3.4) [*14*],

$$\mathrm{Ln}(E_r/E_\infty)=C_r/r;\quad C_r=2\sigma/(\rho_w R_w T); \tag{3.4}$$

Table 3. Relationship of coefficient Cr and temperature in Eq. 3.1 [14]

t, (℃)	-20	-10	0	10	20
C_r, (nm)	1.1	1.1	1.2	1.2	1.3



world map showing frequency of lightning strikes, in flashes per km ²per year (equal-area projection), from combined 1995–2003 data from the Optical Transient Detector and 1998–2003 data from the Lightning Imaging Sensor

Fig. 6. Sketch of water quantity and electricity climatic balance and world lightning frequency distribution map.

The minimum radius for estimating over saturation of condensation is **bc**=1.5×h_0=0.588135nm in Fig. 1 **H**. According to Eq. 3.4 and Tab. 3, it should be E_r/ E_∞=769 % (10 ℃)~ 838 % (25 ℃), which are very close to the observed data 800 % [*14*].

In the cloud we have the water droplets with different radius. The droplets with smaller radius will be easier evaporated and the droplets with larger radius will be easier condensed under the same content of water vapor. The water vapor will be very quickly concentrated on the larger and larger water drops， including NWI with probability of 6×10^{-15} (§3.1.1) among the total evaporated/condensed water molecules. These processes occur usually in heavy rainstorms. The smaller water drops will have mean positive electric charge (with negative charged outer surface) and more surface coefficient of viscosity relatively with surrounding air, and easier move upward together with upward air masses, continually lost their “-” electric charge and becoming more “+” electric charged for each whole drop on their moving way. The electric current density of 10^{-15} (A cm^{-2}) (for smaller drops) and 10^{-12} (A cm^{-2}) (for bigger drops) were detected in rainfall cloud [*14*], indicating the transfer of electrons (and 1.7×10^{14} times more water molecules) from smaller water drops to larger drops. The large water drops with negative electric charge are easier moving downward. Therefore, the negative electric charge will be concentrated in the lower part of the cloud and positive electric charge will be concentrated in the upper part of the cloud of heavy rainstorm, where the overcooled droplets would possibly evaporate then freeze into snowflakes [*2*], (Fig. 6 **C**).

3.2. Thunder and lightning

Under the region with large negative charges in cloud may induce a positive charged area at certain landscape ground surface. The thunder and lightning might occur under suitable conditions (the negative electricity may partly released by heavy rainfall with electricity without lightning; the frequency of lightning would be more on land/ forest and less on water in the same climatic conditions). Occasionally the strong gradients of voltage of **43-130 kV m^{-1}** on water surface and **10-20 kV m^{-1}** on land (less at 4 times then on water, which means the probability of lightning on land is much more than that on water) were observed at the strike points of lightning [*22*]. The lightning transmits the negative electric charges from air to ground, the negative water ions-molecules are generating/ evaporating from water surface/ ground to air, completing the recycling of electric charges in earth water/ ground-atmosphere system (Eq. 3.2, Fig. 6), similar to the water quantity recycling in the earth water/ground-atmosphere system (Eq. 3.3, Fig. 6). The world map (Fig. 6**H**) shows the frequency of lightning strikes is very low over snow/ice (NWI "evaporate" only on **liquid** water surface) areas and higher in lands of equator and southern hemisphere with upwelling dynamic condition zones of large water/land ratios.

3.3. Influences of vulcanian eruption and waterfalls on atmospheric electricity

The studies on triboelectric series showed, that the fragments of glass and quartz in violent volcanic eruptions have "+" positive electric charges [*18-20*]. These fragments may capture electrons from the surroundings during their precipitation down from the top of troposphere to the ground, and generate "+" positive ions in air. The high clouds and/or upper parts of the clouds are usually rich in "+" electric charges (Fig. 6 **C**). The interactions in atmospheric processes between the "+" positive ions and the "-" negative ions, originally caused by released NWI from water surface lead to form the main characteristics of electric fields in atmosphere (Tab. 2).

The dry dust/aerosols mainly have "+" positive ion characters and the "**-**" negative ions are rich in the environments of waterfalls, valley with streams/forest area, lakeshore/seashore, etc. These regions are rich in evaporation sources and water droplets with negative water ions/molecules and "-" electric charges in air are benefit for human health.

Summary: Water surface structure determines its tension and latent heat of evaporation, generates negative water ion into air and forms lightning.

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REFERENCES AND NOTES

[1] D. Kennedy, C. Norman. *Science*, 125th Anniversary, Special Issue **309**, pp. 75 (2005).

[2] Peimin Pu, Jiangping Pu, Zhenbin Zhu. *J. Meteorological Sciences* **36** (5), 567-580 (2016). http://www.jms1980.com/ch/reader/create_pdf.aspx?file_no=20160501&flag=1&journal

_id=qxkx&year_id=2016；

[3] Zhenbin Zhan, Zhengdong Chen, Leansheng Liu, *et al*. *Theory and application of oceanography—oceanographic chemistry of Chinese coastal waters*. (China Ocean Press, Beijing), 504pp (1999).

[4] Tokyo Astronomical Observatory, Ed. *Science Year Book*. (60th Edition, Tokyo) 1007pp (1987).

[5] Properties of water, From Wikipedia, the free encyclopedia, https://en.wikipedia.org/wiki/Properties_of_water. (2016).

[6] Elizabeth Pennisi. *Science* **343**. 6176 pp (2014).

[7] Latent heat, From Wikipedia, the free encyclopedia, https://en.wikipedia.org/wiki/Latent_heat. (2016).

[8] Ball Philip. *Nature* **452**: 291–292. (2008).

[9] J. Guo *et al*. http://phy.pku.edu.cn/~yjiang/home.html. (2016)

[10] Peking University. http://www.nanowerk.com/nanotechnology-news/newsid=33927.php. (2014)

[11] J. Guo, X. Z. Meng, J. Chen, J. Peng, *et al*. *Nature materials* **13**, 184-189. (2014).

[12] From Wikipedia. *Ionic radius*. The free encyclopedia. https://en.wikipedia.org/wiki/Ionic_radius. (2016).

[13] Teaching from Tiangong 1_Simplified_20130620, mp4. (2013). http://www.wuliedu.net/read-htm-tid-2173.html;24:30-34:38.

[14] P. N. Tverskoi. Ed. *Course of meteorology*. (Hydromet Press, Leningrad, USSR). (1951).

[15] Beike shougou. *Atmospheric electric field*: http://baike.sogou.com/v68506913.htm?fromTitle=%E5%A4%A7%E6%B0%94%E7%94%B5%E5%9C%BA. (2016).

[16] Elert, Glenn Ed. http://hypertextbook.com/facts/1998/TreshaEdwards.shtml. (2005).

[17] From Wikipedia. *Volcanic ash*. https://en.wikipedia.org/wiki/Volcanic_ash. (2016).

[18] From Wikipedia. *Triboelectric effect*. https://en.wikipedia.org/wiki/Triboelectric_effect. (2016).

[19] Karen Aplin, Isobel Houghton, Keri Nicoll, Michael Humphries1, Alex Tong. *Proc. ESA Annual Meeting on Electrostatics*. 1-6. (2014).

[20] AlphaLab Inc. *Tribo-electric-series*. http://www.trifield.com/content/tribo-electric-series/. (2016).

[21] From Wikipedia. *Water distribution on Earth*;

https://en.wikipedia.org/wiki/Water_distribution_on_Earth. (2016).
[22] R. B. Toland, B. Vonnegut. *Journal of Geophysical Research* **82** (3), Version of Record online: (2012), *J. Geophysical Research*, Jan. 20, (1977).
[23] Lightning, From Wikipedia, the free encyclopedia, https://en.wikipedia.org/wiki/Lightning; This page was last modified on 10 December at 07:41 (2016),