On the cause of El Nino and La Nina and the proposed strategies for counter measures

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Abstract

For centuries, the presence of El Nino and La Nina have imposed much influence on the global climate, particularly in the equatorial Pacific regions where such phenomena have been perceived as the culprit of abnormal temperature variations and subsequent economic impacts. Nonetheless, up to this day, little research effort, stemming from pure physics standpoint, has been devoted to the cause and effect of such globally collective phenomena. This study attempts to fill the theoretical gap, in the hope that, based on its find-out, pragmatic ways to confront and suppress such unfavorable climatic behaviors will gradually emerge and eventually realized in the near future.

From ancient records, it is now known that El Nino and La Nina existed millennium ago (irrespective of their roles on mankind back then) and had since been tacitly treated as a kind of natural uprising. Possibly due to this attitude, nowadays' El Nino and La Nina researches almost always focus on observations and measurements of temperature variations and changes in distribution, including oscillation amplitudes and periods, in ocean, troposphere, and stratosphere, etc. Seldom has key physics behind those phenomena been inquired and explored in depth.

The authors believe that the E x B drift of both the positive and negative ions of Earth's ionosphere, rendered by the combined action of Earth's electric and magnetic fields, has been the main cause, which subsequently counter-balances the neutral atmospheric wind (originated by Earth's spin) via friction and drag. To this end, solar activity plays a key role through significantly affecting the altitude of earth's ionosphere and consequently the strength of the down-pointing electric field which ultimately determines the magnitude of the E x B drift. At the end of this study, possible strategies for counter measures are brought up, which stem their base on attempts to manipulate key physical ionospheric parameters in a favorable way.

Keywords: El Nino, La Nina, ionosphere, E x B drift, solar activity, rain cloud, trade wind

Introduction

Under normal conditions, the global wind-and-water circulation is seen at the ocean surface as easterly trade winds (due mostly to the west-to-east spinning of Earth itself) that move water and air warmed by the sun toward the west of the brim of Pacific Ocean (See, Fig. 1). This also creates ocean upwelling off the coasts of Peru and Ecuador and brings nutrient-rich cold water to the surface, increasing fishing stocks there. On the other hand, the western side of the equatorial Pacific is characterized by warm, wet, low-pressure weather as the collected moisture is dumped there in the form of typhoons and thunderstorms (See, Fig. 1).

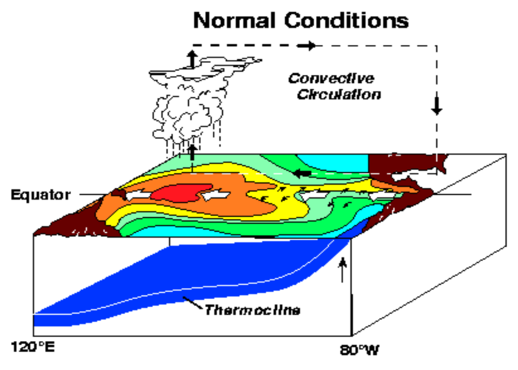

Fig. 1. Normal Pacific pattern: Equatorial winds gather warm water pool toward the west. Cold water upwells along South American coast [1]

El Nino is associated with a band of warm ocean water temperatures that periodically develops off the Pacific coast of South America. Originally, *El niño* is Spanish for "the boy", and the term El Nino refers to the Christ child, Jesus, because periodic warming in the Pacific near South America is usually noticed around Christmas [1]. More precisely, El Nino is defined by prolonged warming in the Pacific Ocean sea surface temperatures there when compared with the average value. The widely accepted standard is a warming of at least 0.5 °C (0.9 °F) averaged over the east-central tropical Pacific Ocean. Typically, this anomaly happens at irregular intervals of two to seven years, and lasts nine months to two years [1]. With an average period length of five years, this warm oceanic phase accompanies high air surface pressure in the western Pacific, instead of low pressure under normal conditions. Its signs of occurrence are summarized as: 1) Rise in surface pressure over the Indian Ocean, Indonesia, and Australia, 2) Fall in air pressure over Tahiti and the rest of the central and eastern Pacific Ocean, 3) Trade winds in the south Pacific weaken or head east, 4) Warm air rises near Peru, causing rain in the northern Peruvian deserts (See, Figs. 2 and 3) [1].

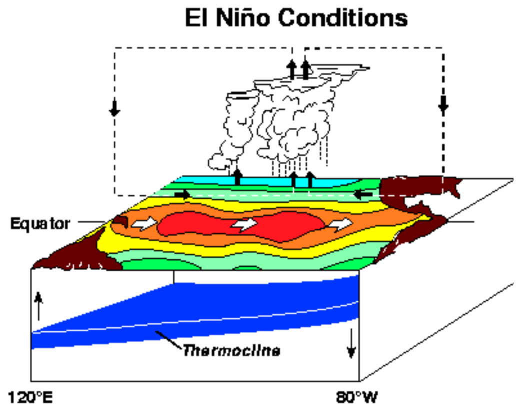

Fig. 2. El Nino conditions: Warm water pool approaches the South American coast. The absence of cold upwelling increases warming [1]

Mechanisms that cause El Nino remain obscure up to this day. Developing countries dependent upon agriculture and fishing, particularly those bordering the Pacific Ocean, are the most affected. Namely, El Nino's warm rush of nutrient-poor water heated by its eastward passage in the Equatorial Current, replaces the cold, nutrient-rich surface water of the so-called Humboldt Current (or, Peru Current) flowing north along the west coast of South America from the southern tip of Chile to northern Peru with a width span of about 1,000 kilometers offshore [1]. The so-called "Humboldt Current Large Marine Ecosystem (LME)" is one of the major upwelling systems of the world, supporting an extraordinary abundance of marine life. When El Nino conditions last for many months, extensive ocean warming and the reduction in easterly trade winds limits upwelling of cold nutrient-rich deep water, and its economic impact to local fishing for an international market can be much serious [1].

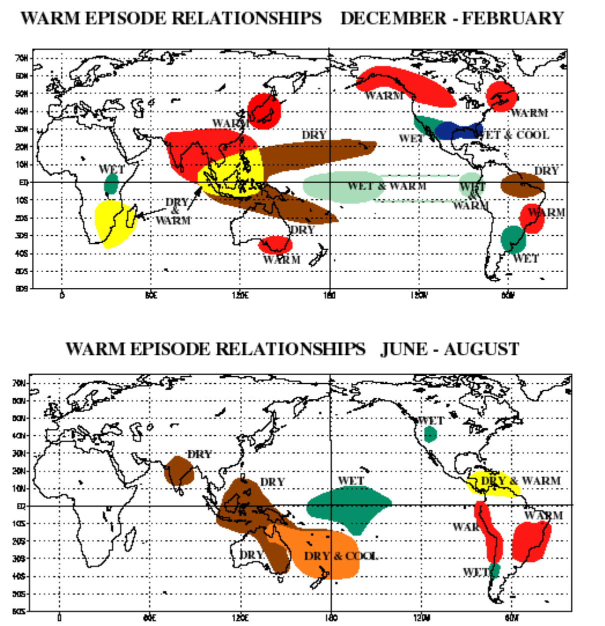

Fig. 3. Regional impacts of warm El Nino episodes [1]

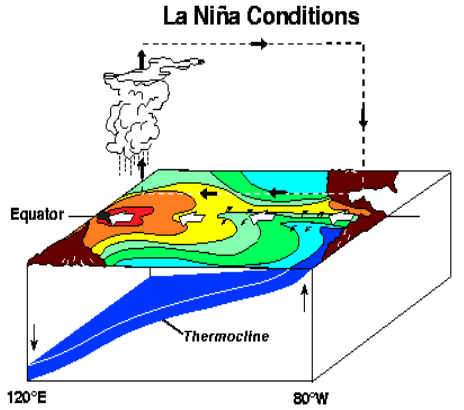

Fig. 4. La Nina conditions: Warm water is farther west than usual

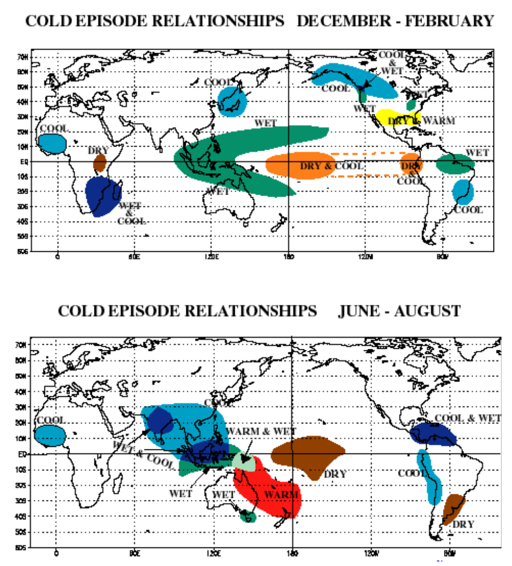

Fig. 5. Regional impacts of La Nina [1]

Similarly, La Nina is a coupled ocean-atmosphere phenomenon but as the counterpart of El Nino (See, Fig. 4). The name *La Niña* originates from Spanish, meaning "the girl", analogous to El Nino meaning "the boy". La Nina often, though not always, follows an El Nino. During a period of La Nina, the sea surface temperature across the equatorial Eastern Central Pacific Ocean will be lower than normal by 3–5 °C (See, Fig. 5) [1].

As indicated by oceanographic archeology studies, both El Nino and La Nina had at least presided over the earth stadium before the Mid-Pliocene Age when mankind has not appeared [2][3]. Fig. 6 shows the similarity of the sea surface temperature patterns of El Nino in both pre-industrial era and the Mid-Pliocene Age [3].

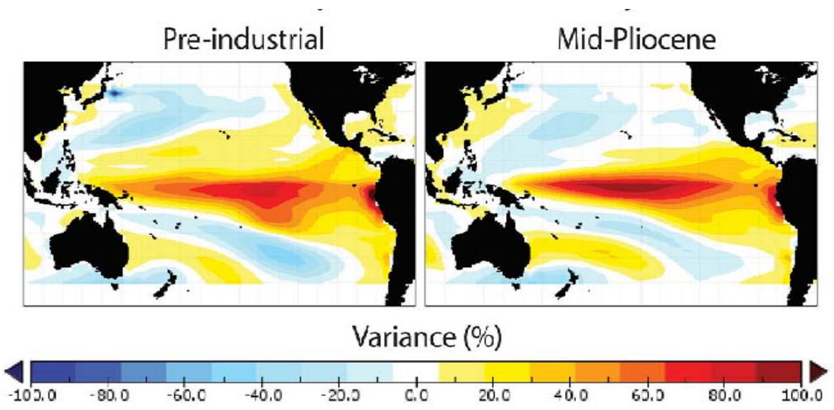

Fig. 6. Patterns of sea surface temperature at the times of pre-industrial era and in Mid-Pliocene Epoch, respectively

Proposed cause of El Nino and La Nina: E x B drift of plasma particles

The author proposes that the E x B drift rendered by the presence of Earth's electric field (near the bottom of ionosphere) and geomagnetic field, is the main cause of El Nino and La Nina. The reasons are elaborated as follows.

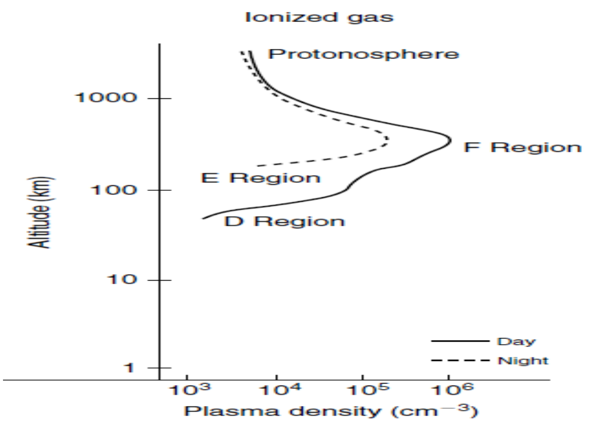

Fig. 7. A typical plasma density distribution of ionosphere along the altitude

Sun is known to be a key player in the occurrence of El Nino and La Nina. Solar activity refers to the dynamic variation of Sun's total emission of radiations. It is now known that there has been an approximately 11-year period for such solar dynamic activity (or, sunspot period) [4]. Sun's radiation forms earth's ionosphere and hence the solar activity dominates the eventual ionization pattern of ionosphere along the altitude [5] (See, Fig. 7).

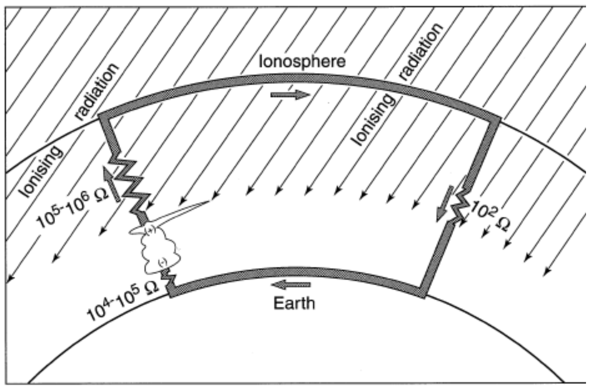

Fig. 8. A simplified equivalent circuit model of the ionosphere-ground capacitor

Though being overly simplified, Earth's ionosphere and ground essentially form a leaky spherical shell capacitor, with thunderstorms performing like a battery offering leaked electromotive force for the current flow of this gigantic eco-electric circuit (See, Fig. 8) [6]. In-between the two capacitor "plates", the atmospheric properties are highly susceptible to the ambient temperature, which in turn is much dependent on the way thunderstorms discharge and radiate. Within the earth's atmosphere, snow crystals may encounter supercooled water droplets. These water droplets, which have a diameter of about 10 μm, can exist in the liquid state at temperatures as low as −40 °C, far below the normal freezing point. Contact between a snow crystal and these supercooled water droplets results in freezing of the liquid droplets onto the surface of the crystal. This process of crystal growth is known as the accretion. Crystals that exhibit frozen droplets on their surfaces are referred to as being rimed. When this process continues so that the shape of the original snow crystal is no longer identifiable, the resulting crystal is referred to as the "graupel".

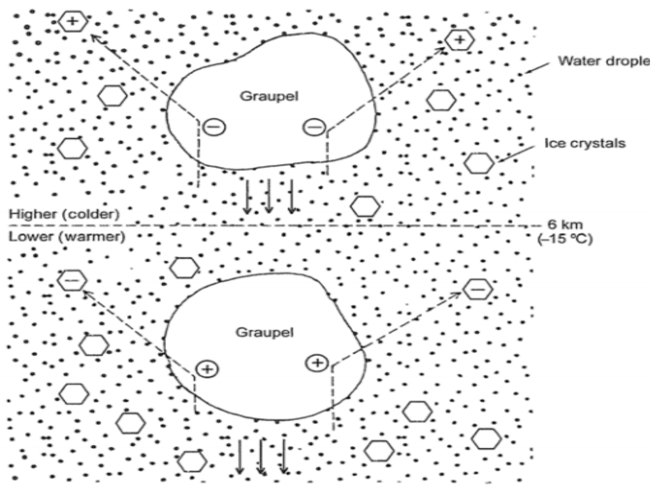

Fig. 9. The cause of down-pointing electric field

When a floating ice crystal collides with a descending graupel, the kind of electric charges it carries along and leaves behind on the falling graupel would depend on the so-called "reverse temperature" T_R [7]. To be precise, when the ambient temperature T is greater than this reverse temperature T_R, the floating ice crystal will carry negative charge and leave positive charge to the colliding, falling graupel. On the contrary, when the ambient temperature is lower than the reverse temperature, the opposite is true [7]. Fig. 9 illustrates the situation along the altitude. That is, at higher altitude, $T < T_R$, floating ice crystals carry positive charges and dropping graupels carry negative charges; and at lower altitude, $T > T_R$, ice crystals are negatively charged and dropping graupels positively charged. Since positive and negative charges of those falling graupels neutralize among themselves eventually, the atmospheric electric field is supported by floating ice crystals, and thus mostly pointing from top to down.

It is proposed that in the presence of Earth's down-pointing electric field (E) and south-to-north geomagnetic field (B) (parallel to ground), the resultant eastward E x B drift (right-hand rule) of both positive and negative charged particles at the ionospheric bottom drags along the neutral atmospheric molecules below, through collisional frictions, which in turn imposes counter-balancing force to the west-bound neutral wind (due to Earth's eastward spin). Temporal variation of the magnitude of the above down-pointing E filed, owing to solar activities and eco-electric circuit adjustments, among others, then leads to cycled patterns of El Nino and La Nina climates, as will be more quantitatively addressed below.

The plasma equation used for the momentum balance near 90 km altitude (i.e., E region) is:

$$\rho_j \frac{d\vec{v}_j}{dt} = -\nabla p_j + \rho_j \vec{g} + n_j q_j(\vec{E} + \vec{v}_j \times \vec{B}) - \rho_j \nu_{jn}(\vec{v}_j - \vec{v}_n) \quad (1)$$

where j refers to different ion species or electron, ρ_j, p_j, n_j, q_j, v_j stand for mass density, pressure, number density, charge state, velocity of j-species plasma particles, respectively, and v_n, ν_{jn} represent neutral particle velocity and collision frequency between a j-species particle and a neutral particle, and g is Earth's gravitational acceleration (= 9.8 m/s^2). The $\vec{E} + \vec{v}_j \times \vec{B}$ term on the RHS describes the unidirectional E x B drift of both positive and negative charged particles. After neglecting irrelevant and insignificant terms, and using data near 90 km altitude (E region) [7] [9], it is found that with $E \approx 5 \times 10^{-3}\, V/m$ (pointing down) and $B \approx 0.35 \times 10^{-4} T$ (horizontal, from south to north) the E x B drift (eastward horizontal) speed (= E/B) becomes 140 m/s if ions are represented by the dominant atomic oxygen ion there (i.e., O^+), matching the neutral particle speed $v_{n||} \approx 25$ m/s (east-west horizontal), order-of-magnitude-wise. Namely, a drag between the drifted positive-and-negative ions and neutral particles can readily be materialized. Such E x B drift-caused influence on neutral atmosphere is thus expected to range from around 90 km altitude and all the way down to Earth's ground via neutral-neutral collisional friction and subsequently render the all familiar El Nino and La Nina phenomena experienced on the ground/sea level.

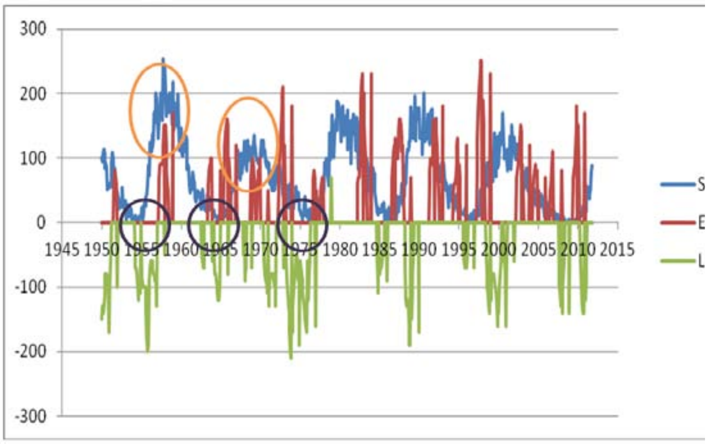

Fig. 10. Periods of sunspots, El Nino, and La Nina from 1950 to 2012

Proposed scenarios of occurrence of El Nino and La Nina

Fig. 10 illustrates the evolution of El Nino/La Nina activity strengths and sunspot numbers (SSN) from the year 1950 to 2012 [4]. It can be seen that solar maxima (i.e., SSN at peaks) and solar minima (i.e., SSN at ebbs) were highly related to the occurrence of El Nino's and La Nina's (circled in Fig. 10), though not always in phase and in some cases even nearly out of phase. Further, El Nino's and La Nina's almost always took turns in manifesting their respective dominance in time.

Normal condition

It is expected that under normal condition (i.e., without El Nino or La Nina), the west-bound neutral wind (largely originated from Earth's spin) is only partly compromised by the eastward E x B drift-caused neutral air movement. That is, a net wind is blowing westward, traditionally still called the trade wind. Across the Pacific Ocean, the trade wind moves storms to the west bank (Australia) where rain-dropped negative charges are accumulated gradually. Note that rains normally carry negative charges to the ground as can be straightforwardly verified by recording of measurements. On the other hand, due to the above same mechanism, the right bank (Peru) is gradually losing the negative charges. All these consequences have paved the way for the subsequent advent of El Nino, as to be elaborated below.

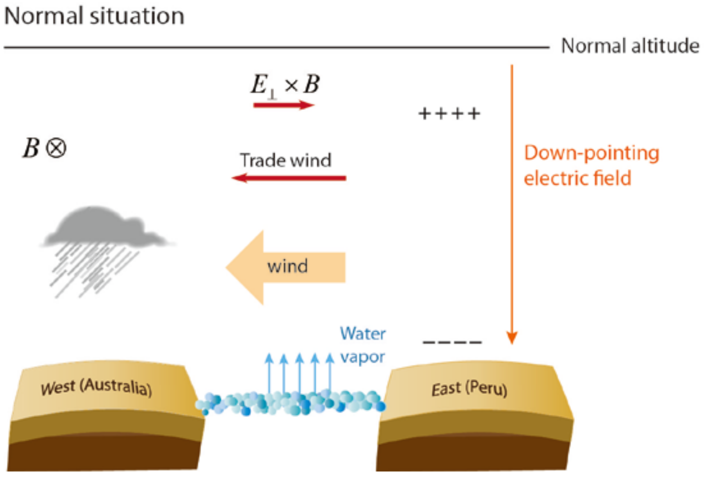

Fig. 11. Proposed normal condition

El Nino

The aforementioned negative charge accumulation on the Pacific west bank apparently will enhance the down-pointing electric field there and thus strengthen the E x B drift-caused eastward air movement. This is particularly evident during solar maxima since the moving down of equatorial ionospheric plasma further increases the electric field. In some cases, the E x B drift-caused eastward air movement would even overturn the west-bound neutral wind. As a result, most water-carrying clouds at the equator will be moved to the east bank (Peru), leading to wet weathers there, and all west bank (Australia and Southeastern nations) is left in much dry condition, characteristic of the El Nino phenomena experienced there (See, Fig. 12).

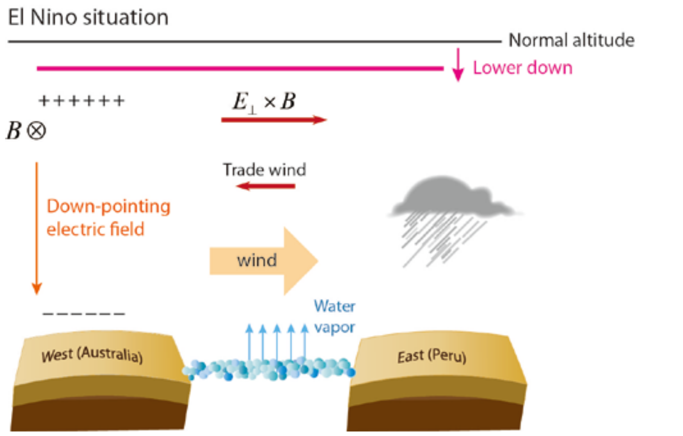

Fig. 12. Proposed El Nino scenario

La Nina

The previous El Nino essentially transports ground negative charges from the west bank to the east bank. This weakens the countering E x B drift effect against the westward neutral wind across the Pacific Ocean. Consequently, the trade wind becomes stronger than ever and water-carrying clouds are now blown over to the west side, causing hot and humid weathers there, while leaving the east coast dry (See, Fig. 13). These La Nina phenomena could be further exaggerated when encountering solar minima periods in which the ionospheric plasma recessed to further up in altitude and Earth's down-pointing electric field, and the resultant E x B drift, are thus much more decreased.

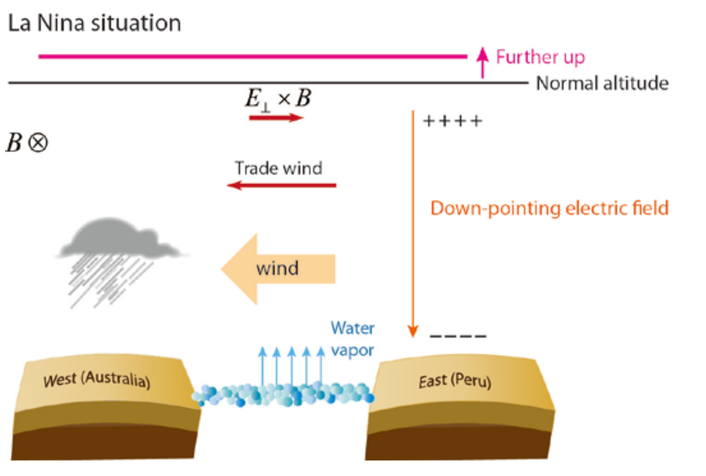

Fig. 13. Proposed La Nina scenario

Proposed strategies for counter measures

From the perspective of E x B drift-induced origin of occurrence of both the El Nino and La Nina phenomena, possible strategies for counter measures immediately come into mind. They are: 1) tinkering with the plasma-neutral collision frequency, 2) altitude control of ionosphere, 3) increase of temperature of the top atmospheric cloud to reverse the polarity of Earth's down-pointing electric field.

Tinkering with the plasma-neutral collision frequency

Since the ion-neutral collision frequency is proportional to the square-root of ion temperature, it can be enhanced by infrared (IR) radiation heating or IR resonance absorption at the equatorial E region bottom. A countering action against the west-bound La Nina can thus be arranged in principle through creating stronger eastward E x B drift-caused dragging on the neutral air.

Altitude control of ionosphere at the equator

If an extra stronger magnetic field can be artificially implemented, e.g., by satellites, in addition to the relatively feeble Earth's magnetic field (~ 0.35 G), at an altitude higher than the bottom of the ionospheric E region above the Pacific Ocean, then energetic ions from the sun can be trapped by these guarding B field lines and effectively lift the ionosphere further up in altitude. Such an approach can lead to the reduction of Earth's down-pointing E field and subsequently the strength of the El Nino behavior.

Polarity change of the Earth's down-pointing E field

The polarity of floating ice crystals at high altitude can be reversed if ambient temperature (T) can be made higher than the critical temperature (T_R) through utilizing the aforementioned graupel formation mechanism (See, Fig. 9). Namely, this might be accomplished by irradiating top atmospheric clouds at around 6-12 km altitude with IR heating waves, best at resonant heat absorption wavelengths, over the equatorial Pacific regions. If this approach is proven feasible, both El Nino and La Nina can be greatly suppressed and tamed straightforwardly.

Summary and conclusions

It is proposed that the coupling action between Earth's down-pointing electric field and the south-to-north magnetic field has been the main cause of the undesirable El Nino and La Nina phenomena, in which the E x B-drifted charged particles drag along the neutral wind to render abnormal sea level temperatures in the equatorial Pacific regions. Since man-made electric charges are always balanced in numbers of positive and negative polarities, creating charges of a particular sign on the ground level in order to manipulate the down-pointing electric field is unlikely feasible. Hence, stratagem for taming these natural uprisings is provided in this study for further more quantitative discussions. It is hoped, however, that suppressing El Nino and La Nina via these means will not stagnate nature's way of relaxing local accumulations of charges of a particular polarity, but only to let it happen all on the ground level without involving the ionosphere.

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