2008 年中央研究院「年輕學者研究著作獎」得獎人簡介

<table>
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</table>

得獎著作名稱：(請以申請時之格式填入)

1. Lin, C. H.*, W. B. Wang, M. E. Hagan, C. C. Hsiao, T. J. Immel, M. L. Hsu, J. Y. Liu, L. J. Paxton, T. W. Fang, and C. H. Liu, "Plausible effect of atmospheric tides on the equatorial ionosphere observed by the FORMOSAT-3/COSMIC: Three-dimensional electron density structures", *Geophysical Research Letters*(2007), 34, L11112, doi:10.1029/2007GL029265.
2. Lin, C. H.*, C. C. Hsiao, J. Y. Liu, and C. H. Liu, "Longitudinal structure of the equatorial ionosphere: Time evolutions of the four-peaked EIA structures", *Journal of Geophysical Research* (2007), 112, A12305, doi:10.1029/2007JA012455..
3. Lin, C. H., J. Y. Liu*, T. W. Fang, P. Y. Chang, H. F. Tsai, C. H. Chen, and C. C. Hsiao, "Motions of the Equatorial Anomaly Crests Imaged by the FORMOSAT-3/COSMIC", *Geophysical Research Letters*(2007), *34*, L19101, doi:10.1029/2007GL030741.

得獎著作簡介：(2000 字左右)

低緯度與赤道地區電離層特性:臺灣正上空電離層特有現象

地球的高層大氣在 80-1000 公里高度，由於受到太陽光照射(EUV 與 X-ray)，將高層大氣中的中性氣體解離成為帶有等量離子與電子的電漿狀態區域，帶電區域的電漿(或電子)密度會影響電磁波的傳播並對地球的無線電通訊電波、人造衛星通訊與訊號造成衝擊，這個帶電區域稱為-電離層。臺灣位於靠近赤道的低緯度地區，而低緯度地區電離層的最大特徵為其電漿結構因為受到赤道電漿噴泉(Equatorial Plasma Fountain)效應的影響而形成所謂的電離層赤道異常區，赤道異常區的特徵為在赤道兩側的電漿濃度大於赤道的電漿濃度，並在低緯度地區形成電漿極大值而非在原先所預期的赤道地區產生電漿極大值，因此這一個現象稱之

為赤道異常現象，而最大電漿存在的區域則稱為電離層赤道異常區。造成赤道電漿噴泉效應的主要原因為白天電離層在赤道地區產生的東向電場與地球磁場相互作用產生一個將電漿向上抬升的電磁作用力，此一電磁作用能夠把電漿由較低的高度往上抬升，當電漿被抬升向上後，會因為電漿高密度聚集後向外擴散(diffusion)的作用力與重力同時影響之下沿地球磁場由高處向下傳輸到赤道兩旁較高緯度地區，並形成在赤道兩側的電漿堆積，此一現象宛如噴泉水池般的將水由下往上噴，因此被稱為是赤道電漿噴泉(圖一)。在電漿噴泉效應作用下，電漿會在赤道兩側堆積而赤道本身的電漿反而會因為傳輸到鄰近區域而減少。電離層赤道異常區的電漿濃度是全球最大的，而臺灣就位於該區域之下(圖二)，因此電離層擾動對臺灣的 GPS 使用者以及其他與衛星通信相關的國防、民生應用有著很大的影響。

地面天氣效應影響太空電漿分佈

在過去，研究太空電離層電漿變化與擾動主要是考慮電離層受到太陽風暴與地球磁層能量傳輸所產生的磁暴效應影響，然而美國太空總署的 IMAGE 衛星在 2002 年春季藉由觀測電離層中氧離子與電子結合所發射出的紫外線頻段電離層暉光，觀測到低緯度與赤道地區電離層主要在南美洲、非洲、東南亞、以及中太平洋四個區域有較為明亮的電離層暉光，並與大氣潮汐的四個極大區域相互疊合，推測此現象是由較強大氣潮汐所產生的電離層東向電場增強效應並造成電離層電漿噴泉效應的增強，而使得在這四個區域的赤道異常區電漿密度更為增強。此一觀測結果令太空科學家相當驚訝，因為可能影響此一電離層增強效應的大氣潮汐，主要是源自於較靠近地表的對流層頂端(Tropopause)的旺盛天氣系統所產生的強烈對流以及雨滴凝結產生的潛熱(Latent Heat)。在這四個區域中有三個區域是位於雷雨系統活躍的熱帶雨林區，包含南美洲亞馬遜流域、非洲剛果雨林以及印尼的熱帶雨林區，而位於中太平洋(往往也是熱帶氣旋開始發展的區域)的增強區域則可能源自於當地的雷雨系統，或者是經由其他三個區域所產生的潮汐因為不均勻分佈並向東飄移所產生的第四個增強區。

一般而言，受到重力的影響大氣分子密度隨高度升高而迅速遞減，因此在對流層頂(~10 公里高)產生的潮汐波動在往太空傳播時，因為大氣密度迅速的減低，該波動的振幅會迅速倍增。雖然潮汐波動振幅會隨高度倍增，但是能否由 10 公里高度向上傳播到 300 公里以上的高度並影響電離層 F 層電漿結構則仍然是不確定的，因為大氣中的波動在垂直向上傳播時也會受到渦旋氣流而將其波動振幅減弱。除了潮汐波動的直接向上傳播之外，另一個可能的機制是潮汐波動傳播到 90-120 公里較低高度的電離層 E 層，藉由影響電離層 E 層的電動效應(Electrodynamic Effect)增強赤道電漿噴泉效應造成較多的電漿堆積在這四個區域。由於 IMAGE 衛星僅能觀測夜間電離層暉光而非直接觀測電子密度，且該衛星亦無法分辨所觀測到的較明亮電離層暉光主要是來至電離層的哪一個高度範圍，因此無法進一步證實此一推論。

福爾摩沙衛星三號提供有力觀測證據

為了證實上述的物理機制，我們利用了我國於 2006 年 4 月發射的福爾摩沙衛星三號並利用該衛星所具備的全球電離層電子密度三維觀測能力，進行了類似的觀測實驗，在分析了 2006 年 9-10 月的大量無線電掩星(Radio Occultation)觀測資料後，此一特殊的電離層電漿結構被福衛三號再次觀測到，並進一步證實此潮汐效應造成的電離層電漿增強效應主要是發生在高度 300 公里以上的 F 層(圖三)，此結果證實大氣潮汐效應影響電離層是藉由大氣潮汐向上傳播到電離層底部 E 層，並產生增強極化電場並經由地球磁場傳輸到 300 公里以上的電離層 F 層造成電子濃度的大量堆積。因為福衛三號觀測結果顯示此一電漿結構在 300 公里以下並不存在，可以證實此現象並非潮汐直接傳播到 300 公里高度而是藉由影響電離層底部 90-120 公里具有較高導電性的地方，並將電場傳到 300 公里的高度對赤道噴泉效應造成影響。

然而要進一步證實此一理論模式，仍然需要更多的觀測證據，其中最重要的就是必須在白天也能夠觀測到此一電漿結構。因為電離層 E 層的電漿主要是受到太陽照射產生的光化學效應所產生，因此 E 層的電漿密度以及電動效應在白天較為增強許多，也較能將電場傳到 300 公里高的電離層 F 層，因此所提出來的物理模式必須要在白天也能夠成立才合乎電離層物理機制。我們在福衛三號白天的觀測結果中也發現了類似的現象，可作為解釋此現象的物理機制一個重要的佐證，相同的效應在白天也存在(圖四)，而且藉由三維電離層電漿觀測技術，在較強與較弱赤道異常區域的三維電漿結構觀測結果也證實了該現象與赤道電漿噴泉效應的強弱有關。此外，比較四個極大區在白天與夜晚的位置，發現這四個區域有向東飄移的趨勢，此一向東飄移特性與造成此現象的東向飄移大氣潮汐亦相吻合。

這個重要的研究結果使得科學家在未來考慮電離層擾動等太空天氣效應時將同時需要考慮到地面天氣以及熱帶雨林的效應！除此之外，特別值得一提的是，這四個電漿增強區域與福爾摩沙衛星二號高空閃電儀(ISUAL)所觀測到的高空閃電分佈位置十分的吻合!因此在這四個區域的較強電漿密度可能也提供了較大的導電性，有助於誘發高空閃電的發生率，這個新發現的電離層結構可能也提供了更進一步瞭解大氣與電離層之間的電流環流以及交互作用的新證據。

致謝

此研究能獲中央研究院肯定主要是受惠於國家所提供的全世界最先進之大氣探測衛星系統-福爾摩沙衛星三號。感謝成功推動與規劃福爾摩沙衛星三號計畫的科學家：蔡清彥博士、劉兆漢院士、李羅權院士、林進雄博士、Dr. Rick Anthes、郭英華博士，以及國家科學委員會與國家太空中心工作團隊的多年付出。同時也感謝參與本研究的團隊成員：中央大學太空科學所劉正彥教授、中央氣象局蔡和芳博士、太空中心蕭俊傑博士、美國國家大氣中心(NCAR/HAO)王文

斌博士與 Dr. Maura Hagan、加州大學柏克萊分校(UC Berkeley) Dr. Thomas Immel、約翰霍普金斯大學應用物理實驗室(The Johns Hopkins Univ.-APL) Dr. Larry Paxton、與中央大學太空科學所研究生許美蘭、方慈瑋、張博雅、陳佳宏。

本研究多項成果為得獎人任職於國家太空中心期間完成，特別感謝國家太空中心的全力協助與支持。

㊍㊎㊏㊍：

我國太空計畫室於 2006 年佈署 6 顆微衛星組成的 Cosmic“星座”各載在一部接收機。用以觀測 28 顆ＧＰＳ衛星由地平線升起或落下，當兩者的連線掃過大氣層時，由信號受大氣影響程度便可得到該層大氣在當時的溫度、密度、含水量及電子密度。這樣的「星」出「星」落，每天約發生三千次之多，而每次都可以求得數千公里沿線大氣層在不同高度的平均性質。這麼豐富的資料在過去是不存在的。林建宏博士得獎之作就是利用Ｃosmic 資料來探索太空環境與地球大氣的藕合作用，他看到了低層大氣擾動先經由 10 公里高度的對流層頂傳至 100 公里的電離層Ｅ層，再傳到 400 公里高的Ｆ層。電離層的赤道異常區似乎也與低層大氣擾動有關，而台灣正位於一異常區之下，因此其工作不但有國際水準，有助於人類對大氣圈的了解，也有本土意義。此大發現根據的資料來自我國佈署的衛星星座更值得國人自豪激賞。

2008 Academia Sinica

Research Award for Junior Research Investigators

Name：Chien-Hung Lin 	Education: Ph. D. 2005, National Central University, Taiwan BS. 1999, Fu-Jen Catholic University, Taiwan Employer(s)/Job Title(s): Research Assistant Professor, 2008.01.01-present, Plasma and Space Science Center, National Cheng-Kung University. Assistant Researcher, 2006.01.16-2007.12.31, National Space Organization, NARL. Postdoctoral Researcher, 2005.08.01-2005.09.30, Institute of Space Science, National Central University. Graduate Research Assistant, 2001.09.27-2005.06.30, High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA.

Award publications：

1. Lin, C. H.*, W. B. Wang, M. E. Hagan, C. C. Hsiao, T. J. Immel, M. L. Hsu, J. Y. Liu, L. J. Paxton, T. W. Fang, and C. H. Liu, "Plausible effect of atmospheric tides on the equatorial ionosphere observed by the FORMOSAT-3/COSMIC: Three-dimensional electron density structures", Geophysical Research Letters(2007), 34, L11112, doi:10.1029/2007GL029265.

2. Lin, C. H.*, C. C. Hsiao, J. Y. Liu, and C. H. Liu, "Longitudinal structure of the equatorial ionosphere: Time evolutions of the four-peaked EIA structures", *Journal of Geophysical Research* (2007), 112, A12305, doi:10.1029/2007JA012455..

3. Lin, C. H., J. Y. Liu*, T. W. Fang, P. Y. Chang, H. F. Tsai, C. H. Chen, and C. C. Hsiao, "Motions of the Equatorial Anomaly Crests Imaged by the FORMOSAT-3/COSMIC", *Geophysical Research Letters*(2007), *34*, L19101, doi:10.1029/2007GL030741.

Summary of the Award publications（around 2000 words）：

The Character of the Low- and Equatorial Ionosphere: A unique phenomenon lies right above Taiwan:

The ionosphere is a layer of charged ionized particles approximately 80 - 1000 km above the Earth's surface and has been defined as "the part of the Earth's upper atmosphere where ions and electrons are present in quantities sufficient to affect the propagation of radio waves." The ionosphere is formed by the absorption of the solar EUV/UV radiations in the Earth's upper atmosphere, which produces appreciable photoionization leading to a partially atmospheric region. Taiwan locates under the low-latitude ionosphere close to the magnetic equatorial region. The low-latitude ionosphere is unique in that the magnetic field is nearly horizontal, so that zonal electric fields, produced by the neutral wind dynamo during magnetically quiet times, can transport the plasma vertically through the electro-magnetic drift. This quiet-time vertical drift is upward during the daytime, causing plasma to drift to higher altitudes from where it diffuses down along magnetic fields, due to the pressure gradient and gravity, to higher latitudes creating two plasma crests on either side of the magnetic equator. Since the plasma is transported from the magnetic equator to higher latitudes, a density trough is formed centered on the magnetic equator with two density crests around 15^o-20^o to the northern and the southern hemispheres. This unique latitudinal distribution of the plasma/ionization density is called the equatorial ionization anomaly (EIA) or the equatorial anomaly for short, and the effect of transporting the plasma from the magnetic equator to higher latitudes is referred as the equatorial plasma fountain (Fig. 1). As Taiwan locates underneath the region of maximum plasma density (Fig. 2), ionosphere variations affect the GPS navigation user and other applications of the communication in both national defensive and civil objectives.

Space Weather Affected by the Meteorological Weather

The ionospheric space weather was known to be disturbed significantly by solar magnetic storms. Recent airglow observations show longitudinal structure of four enhanced equatorial plasma regions located at South America, Africa, Southeast Asia, and Central Pacific. This four-peaked longitudinal structure was seen by using far-ultraviolet (FUV) 135.6 nm emission observation on board the NASA IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) satellite during equinox-to-early summer of 2002. The most surprising result of the study is the coincidence of these structures between the locations of four nonmigrating tidal maxima and the ionospheric nightglow brightness observed by the IMAGE satellite at far-ultraviolet (FUV) 135.6 nm emission line. The observations strongly suggest that the equatorial ionosphere is coupled with a nonmigrating tide which is excited in the troposphere, possibly produced by the latent heat release in tropical cloud formation or deep tropical convection. They proposed a possible mechanism that the diurnal eastward wavenumber three (DE3) nonmigrating tide, excited from the lower atmosphere, propagates upward to the lower ionosphere and subsequently affects the

E region dynamo electric field and the strength of the equatorial plasma fountain may be the possible explanation. Three of the four regions are located in the tropical rainforest areas; they are the Amazon rainforest of the South America, Congo basin of the Africa, and Indonesia rainforest. The fourth enhanced region, the Central Pacific (often to be the region where the tropical hurricane formed), may be formed due to uneven distribution of the other three regions or due to some localize rainstorms.

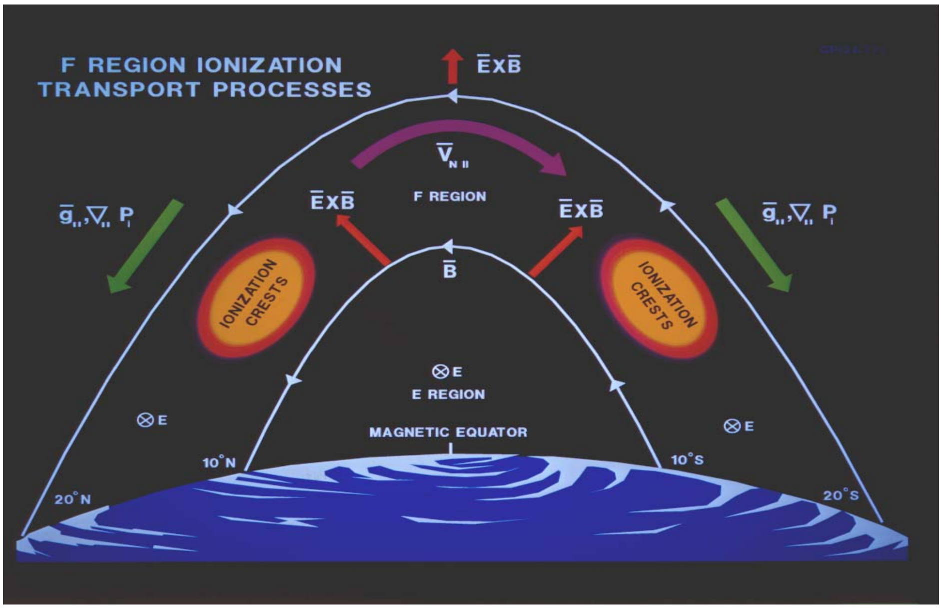
The atmospheric waves have amplitude growth with increasing altitude, since the atmospheric density decrease exponentially with increasing altitude. Atmospheric waves produced by latent heat release at the tropopause can propagate to higher altitude with increasing amplitude. However, it is uncertain if the wave can propagate all the way up to the ionospheric F-layer, since there are mechanisms for wave to dissipate, such as chemical and eddy diffusions. In addition to direct upward propagation of the waves to disturb the ionospheric electron density, another possible mechanism is the modification of the ionospheric E-region dynamo at 90-120 km altitude. The modified dynamo process results in modification of the zonal electric field that later affects the strength of the equatorial plasma fountain and the equatorial ionization anomaly. The IMAGE airglow observation provides only the night time ionospheric observation at altitude where the emission is most significant, at around F-peak altitude. Therefore, it is difficult to identify which mechanism is more important.

Strong Observation Evidence provided by the FORMOSAT-3/COSMIC

The FORMOSAT-3/COSMIC (F3/C) constellation is, therefore, the ideal suite of instruments to monitor vertical electron density of the wavenumber-four longitudinal structures and to further understanding of the possible coupling process between the equatorial ionosphere and the nonmigrating tides of tropospheric origin, or other possible mechanisms. The constellation was launched at April 2006 with its major payload, the Radio Occultation eXperiment (GOX), on board providing more than 2000 vertical ionospheric electron density observations daily. After analysis of the radio occultation observations during September-October 2006, the wavenumber-four longitudinal structure of the equatorial ionosphere is seen by the FORMOSAT-3/COSMIC. The structure is clearly seen only above 300 km altitude indicating that the feature is the F-region phenomenon (Fig. 3). This evidence suggests that it is more likely the atmospheric tides modify the E-region dynamo and the strength of the equatorial plasma fountain instead of direct upward propagation of the wave. Although the altitudinal observations have provided some evidence to support the hypothesis of modulating the E-region dynamo by atmospheric tides, those observations, however, are only limited to the nighttime period when the

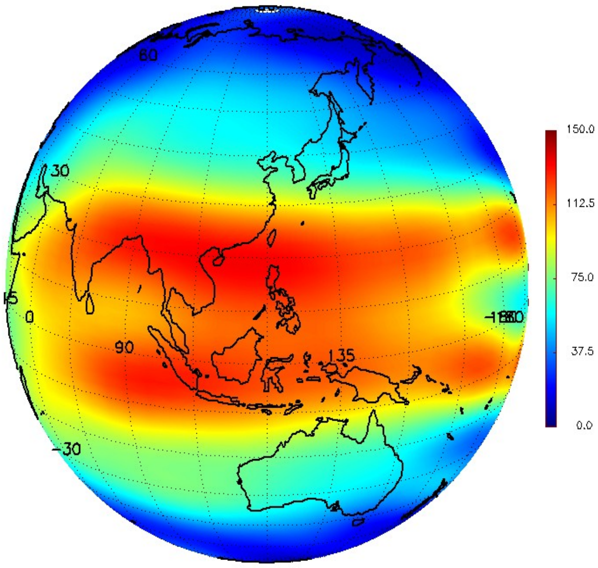
E-region has almost disappeared. Thus, it is extremely important to demonstrate that the four-peaked longitudinal structure appeared during daytime when the E-region exists with strong interactions with F-region, in order to support the hypothesis made by previous studies. Figure 4 shows the first daytime observation of the wavenumber-four structure by FORMOSAT-3/COSMIC. The existence of the structure during daytime, again, confirms the hypothesis. Meanwhile, our results also indicate the eastward propagation of the four enhanced regions, which consistent with the property of the diurnal eastward wave number three (DE3) atmospheric tide.

The important finding of the longitudinal structure at the equatorial ionosphere produced by atmospheric tides of tropospheric origins suggests that the meteorological weather can also modify the space weather. It is worthwhile to note that the four enhanced regions of greater ionospheric plasma concentration coincide well with the distribution of the space lightning, such as sprite and elves, observed by the ISUAL instrument on board the FORMOSAT-2. The four plasma enhanced regions may provide stronger conductivities favorable for space lightning to be induced. The relationship between the global atmospheric circuit and the ionosphere can be further studied based on these observations.



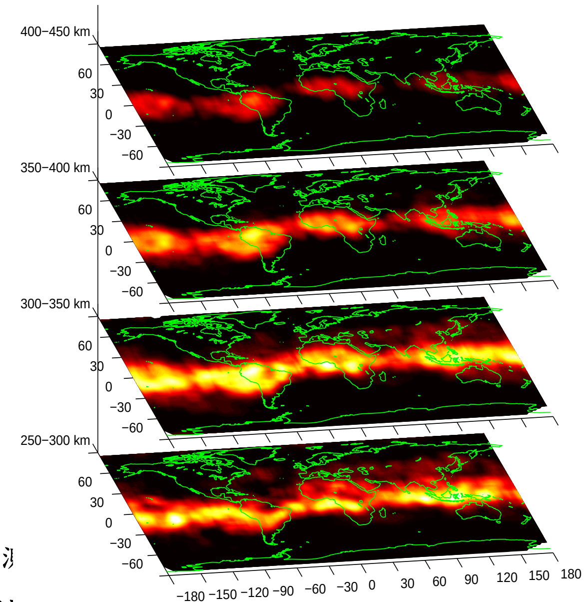
圖一、電離層赤道噴泉效應以及赤道異常現象示意圖 (圖引用自 NOAA-SWPC 的 David N. Anderson 博士)。

Figure 1. Cartoon illustration of the ionospheric equatorial plasma fountain (figure courtesy of David N. Anderson of the NOAA-SWPC).



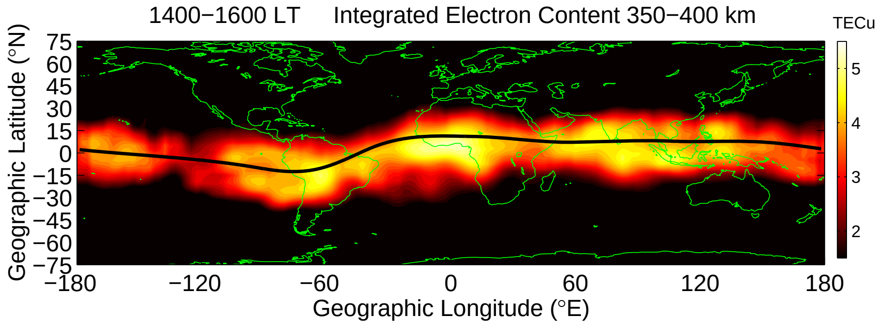
圖二、利用全 都普勒位移量所推導出的電離 的電離層赤道異常區域內。

Figure 2. Ionospheric total electron content (TEC) map derived from observations of the Doppler shifts of the GPS signals.　The TEC map indicates that Taiwan situates right under the equatorial ionization anomaly (EIA) region.



圖三、福衛三號觀 漿受大氣潮汐影響所產生的經度方向四個極大區域結構在 300 公里高度以上才逐漸明顯呈現，顯示該現象主要為電離層 F 層效應。

Figure 3. Three-dimensional observation of the longitudinal structure of the equatorial ionosphere by FORMOSAT-3/COSMIC.　The four-peaked structure produced by atmospheric nonmigrating tide occurs above 300 km altitude indicating that it is mainly the F-region phenomenon.



圖四、福衛三號首次觀測到四個赤道地區電離層增強效應於白天發生。

Figure 4. First daytime observation of the four-peaked equatorial ionization anomaly by FORMOSAT-3/COSMIC.