

太空與海洋世界 — 太空部份 —

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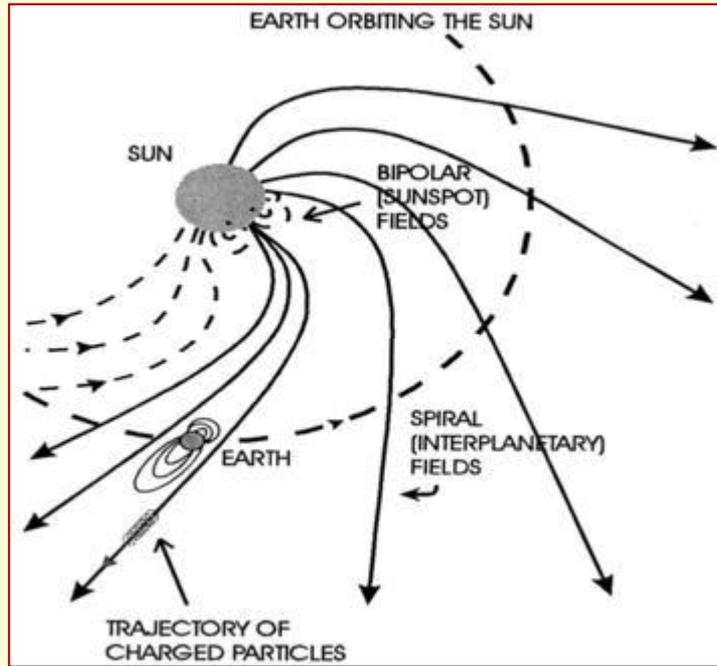
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第二週(107年5月3日)

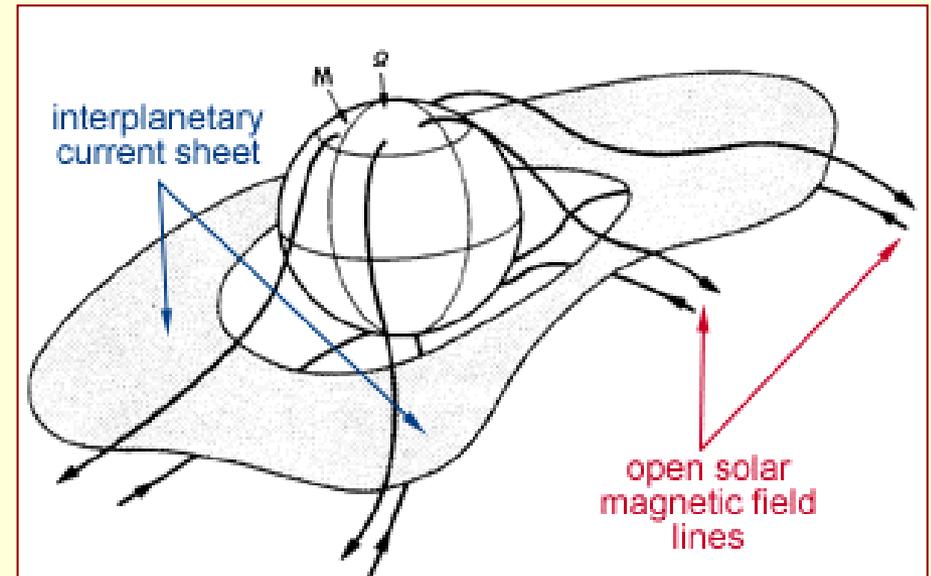
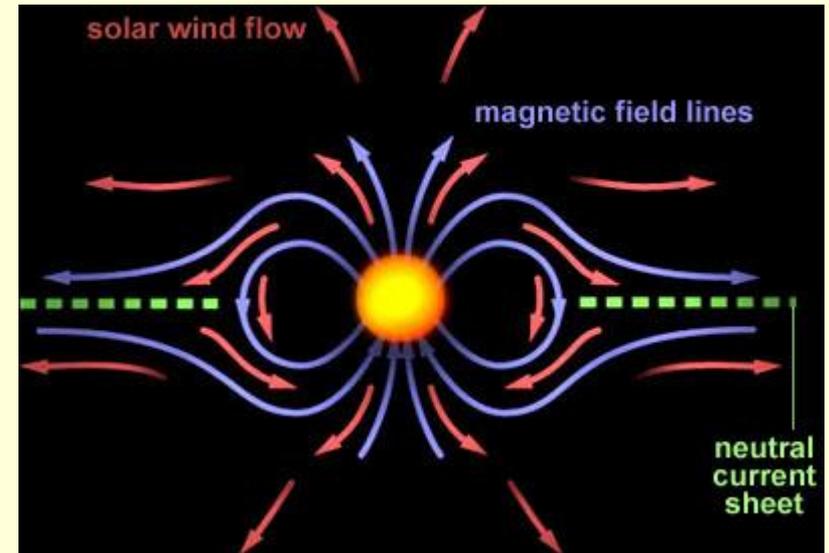
地球高層大氣與太空環境的結構

- 行星際空間介質 (Inter-Planetary Medium)
 - * 太陽風 (Solar Wind) 與 太陽磁場
- 磁層 (Magnetosphere)
 - * 極光 (Aurora)
- 電離層 (Ionosphere)
 - * 短波電波傳播 (Short Wave Propagation)
- 中層大氣 (Middle Atmosphere)
 - * 地球溫度最低處：中氣層頂 (Mesopause)

行星際空間內的太陽磁場



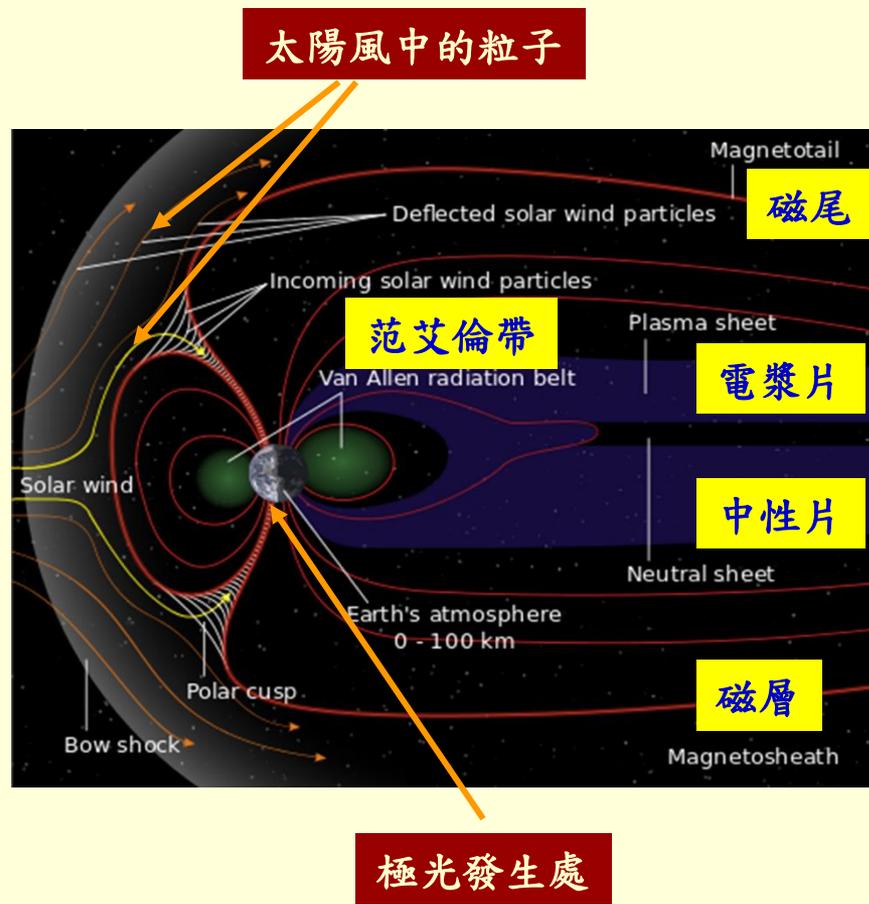
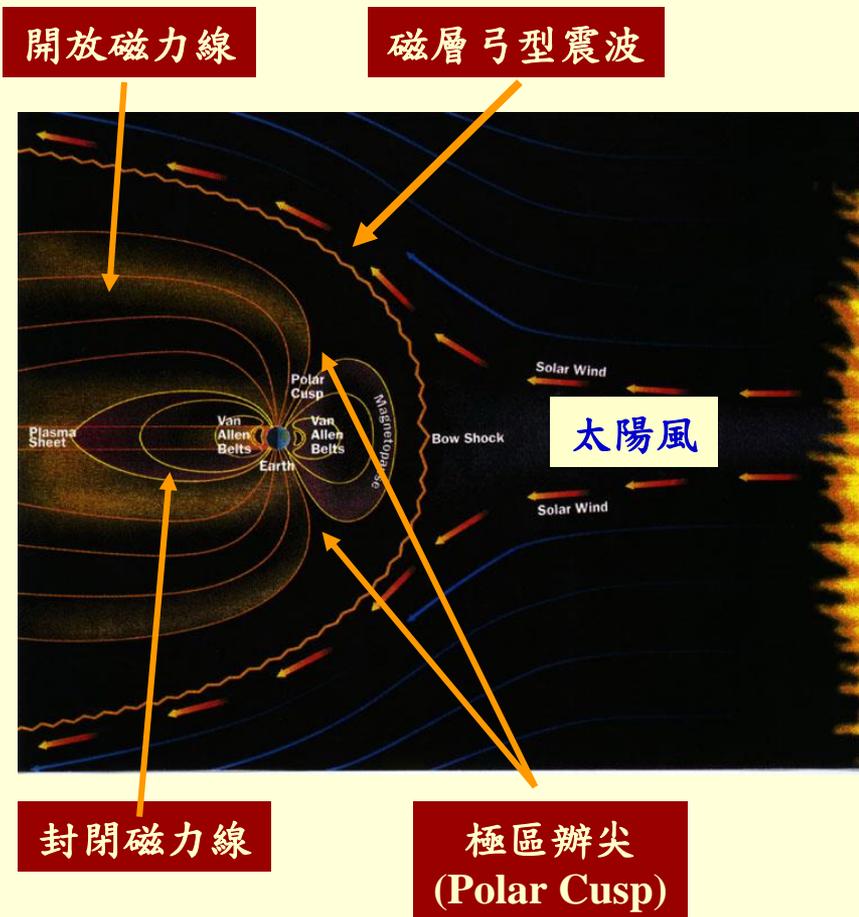
https://ryanoursun.wikispaces.com/The+Journey+Of+Solar+Wind+In+The+Solar+System+And+Earth_Ethan



<http://pluto.space.swri.edu/image/glossary/IMF.html>

太陽磁場會凍結在太陽風中，隨太陽風向外吹拂而被拉扯向外伸展，形成片狀結構，由於太陽風的不均勻性分布，導致太陽磁場片狀形狀呈現皺摺結構。當地球繞太陽公轉時，由於地球位於片狀皺褶中不同位置，地球磁層所遇到的太陽磁場方向將有可能不同，導致地球層磁層發生擾動。

地球磁層結構以及與太陽風的關係



地球磁層粒子特性

Table 1: Plasmas in the Earth's Magnetosphere

	Density N	Velocity V _e	Velocity V _p	Electron Temperature T _e	Proton Temperature T _p	Magnetic Field	Comments
Solar Wind	1 - 10 cm ⁻³	200 - 600 km/sec	200 - 600 km/sec	6x10 ⁴ to 3x10 ⁵ °K	2x10 ⁴ to 2x10 ⁵ °K	2-15 nT	<ul style="list-style-type: none"> • High Speed Streams Associated With Coronal Hole • Low Speed Streams Near Sector Boundaries
Magnetosheath	2 - 50 cm ⁻³	200 - 500 km/sec	200 - 500 km/sec	10 ⁵ to 10 ⁶ °K	5x10 ⁵ to 5x10 ⁶ °K	2-15 nT	<ul style="list-style-type: none"> • Turbulent Solar Wind Plasma and Magnetic Fields
High Latitude Boundary Layer	0.5 - 50 cm ⁻³	No Reported Measurements	100 - 300 km/sec	10 ⁵ to 10 ⁶ °K	5x10 ⁵ to 8x10 ⁶ °K	10-30 nT	<ul style="list-style-type: none"> • Entry Layer into the Magnetosphere of Magnetosheath Plasma
Plasma Sheet Boundary Layer	0.1 - 1.0 cm ⁻³	500 - 5000 km/sec	100 - 1500 km/sec	2x10 ⁶ to 10 ⁷ °K	10 ⁷ to 5x10 ⁷ °K	20-50 nT at 20 Re	<ul style="list-style-type: none"> • Region Which Maps to Auroral Zone Producing Discrete Auroral Arcs
Plasma Sheet	0.1 - 1.0 cm ⁻³	10 - 50 km/sec	10 - 1000 km/sec	2x10 ⁶ to 2x10 ⁷ °K	Always Hotter by a factor of 3 to 5 such that T _p /T _e >1	9 nT in Deep Tail	<ul style="list-style-type: none"> • Thickness of 4 to 6 Re • Forms into the Ring Current at 5-6 Re From Earth
Lobe	10 ⁻³ to 10 ⁻² cm ⁻³	No Reported Measurements	No Reported Measurements	<10 ⁶ °K	<10 ⁷ °K	Increases with Southward IMF	<ul style="list-style-type: none"> • Lowest Densities Found in the Magnetospheric Cavity

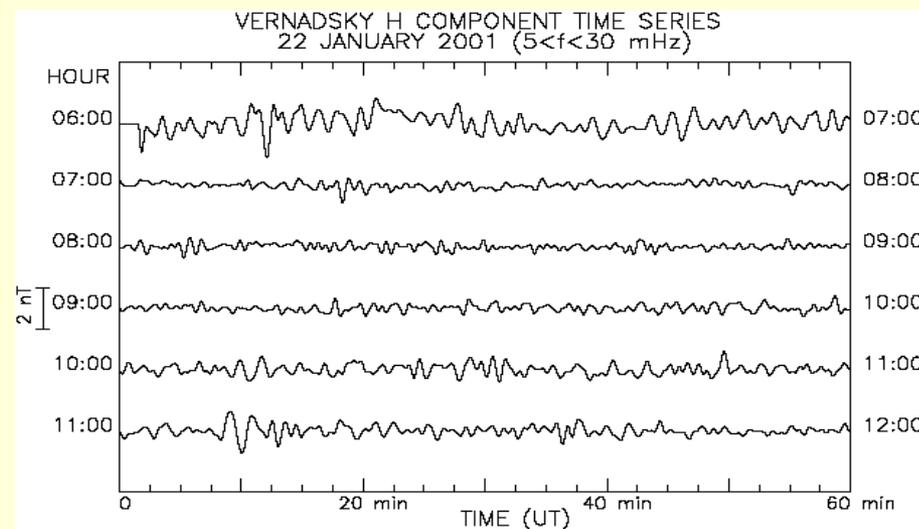
地磁微脈動

— 地球磁場的微小擾動現象 —

地磁微脈動的分類

Pc1	0.2-5 (秒)
Pc2	5-10
Pc3	10-45
Pc4	45-150
Pc5	150-600

地磁微脈動的實際擾動



註：地面地球磁場平均大小約為**0.45高斯(Gauss)**，或**45000 nT**

人腦波的分類與特性

— α 波， β 波， θ 波， δ 波—

人腦波的分類

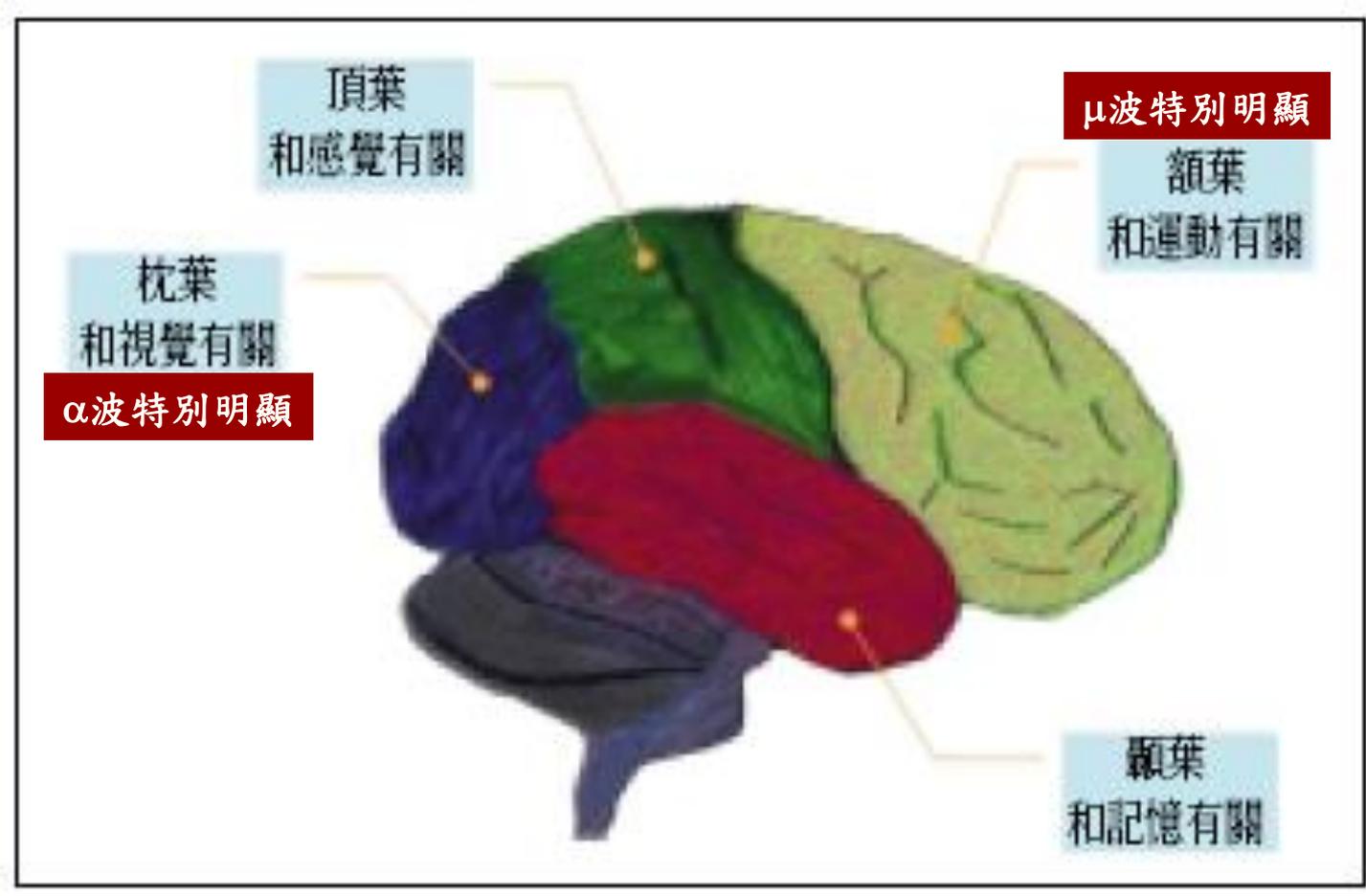
(每秒振動次數)

α 波	8-14 赫茲
β 波	大於14赫茲
θ 波	4-8赫茲
δ 波	0.4-4赫茲
μ 波	與 α 波類似， 但稍快一些

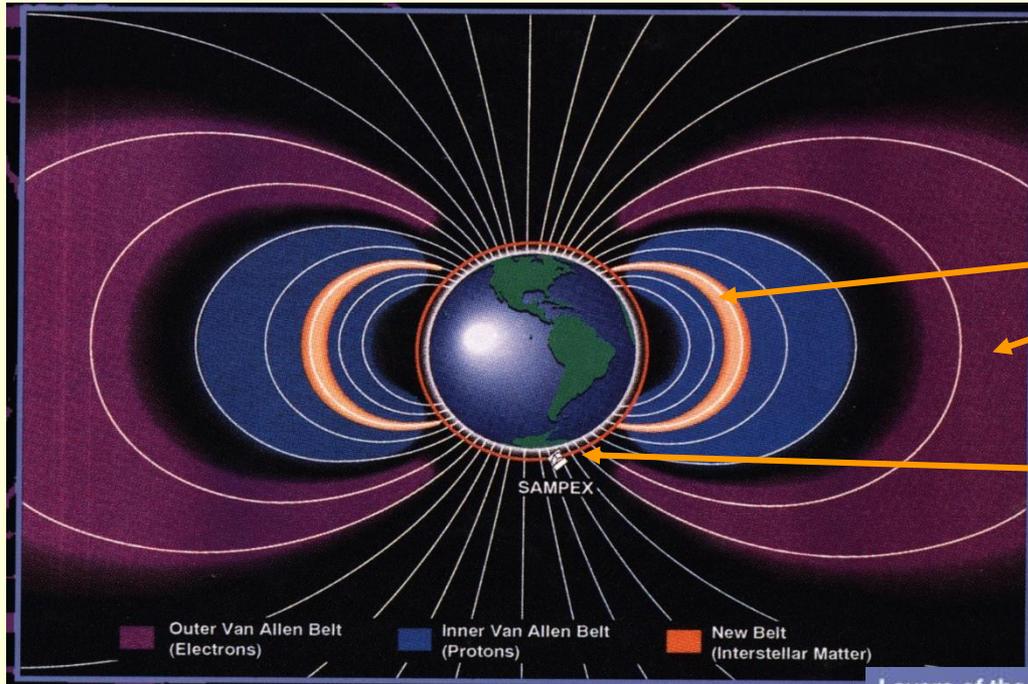
腦波特性

α 波	在清醒與放鬆的情形下 出現，適合思考與學習
β 波	出現在有壓力與緊張 狀態下
θ 波	入定時發生
δ 波	與睡眠品質有關，在熟睡 深度睡眠中出現
μ 波	進行或想像肌肉收縮(運動) 時會被壓抑(念力控制)

不同腦波出現的位置圖



近地球太空環境

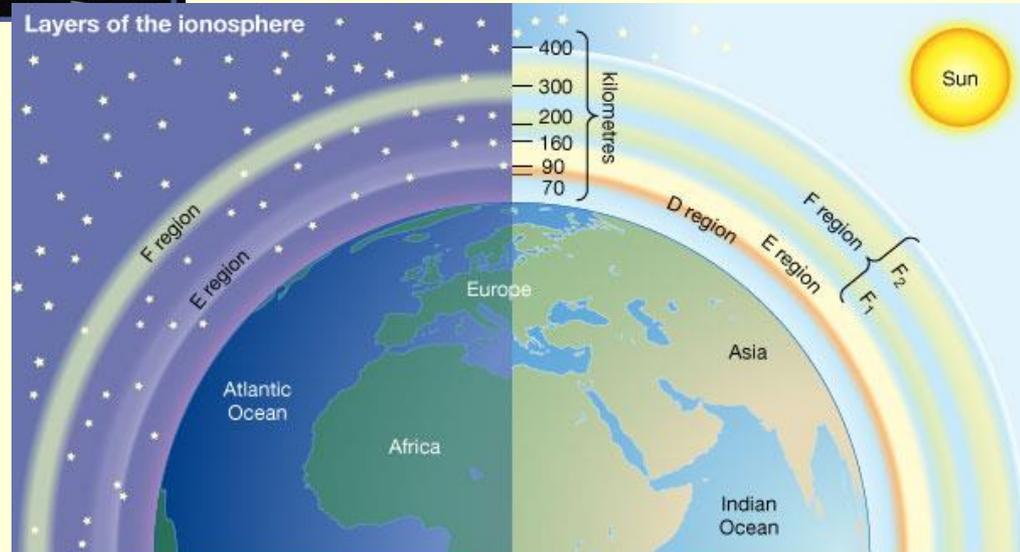


范艾倫帶

電離層

電離層 (Ionosphere) 結構

電漿層 (Plasmasphere) 結構



電離層 (Ionosphere) 的形成與定義

定義

若地球大氣中之某一部分，具有充分多的自由電子 (free electron)，且能持久的影響無線電波 (Radio Waves) 之傳播 (Propagation) 者，此氣層即稱為電離層

形成

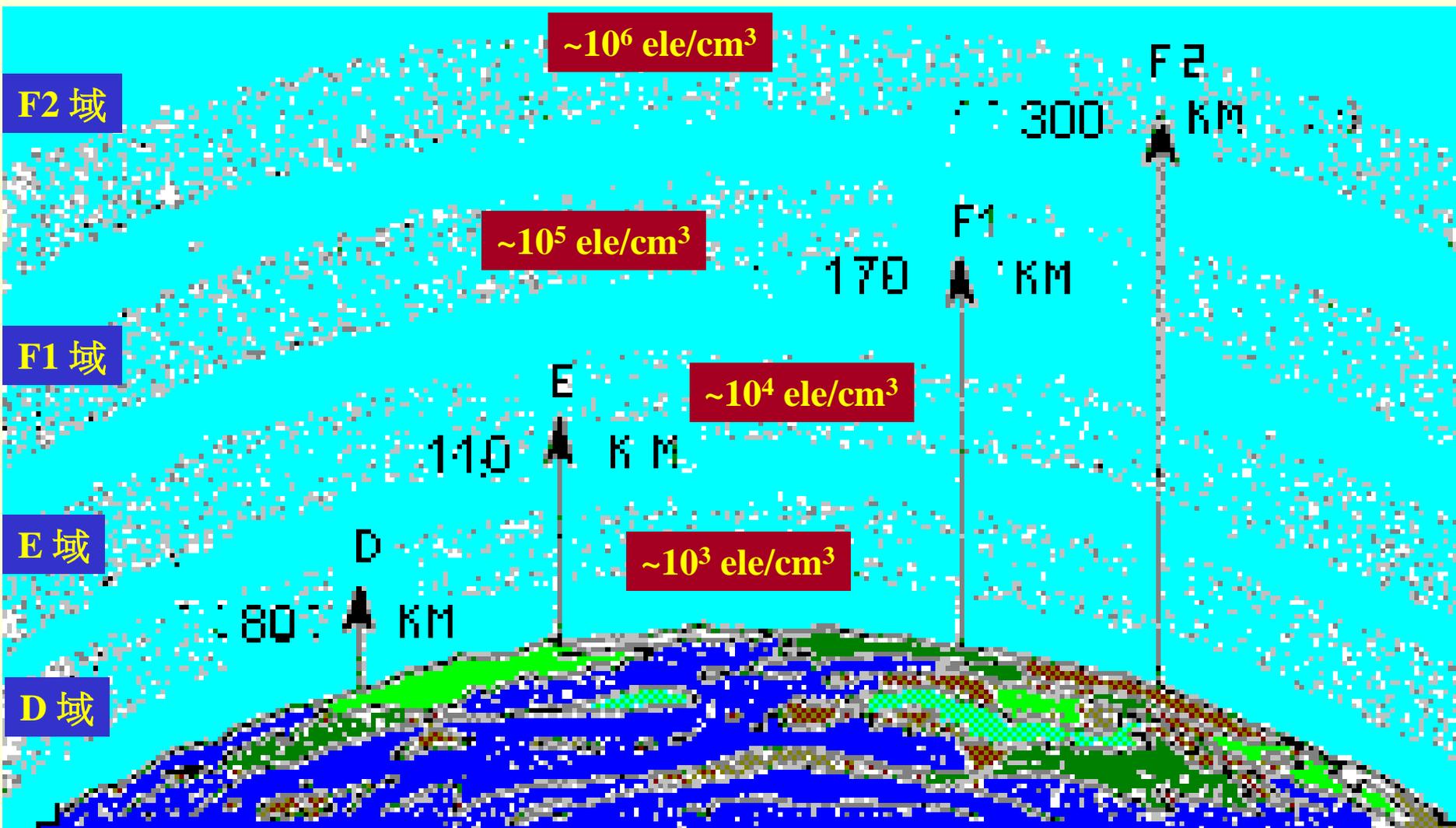
地球大氣中之氣體粒子，受到太陽輻射中的X射線與紫外線的照射，將氣體粒子最外層的電子游離出，產生自由電子以及帶正電的離子。由於地球高層大氣中的自由電子與主要的離子(即氧原子離子)的結合反應甚慢，使得自由電子可以長久存在，而形成電離層。

電離層的結構

電離層係由四個副層所組成：

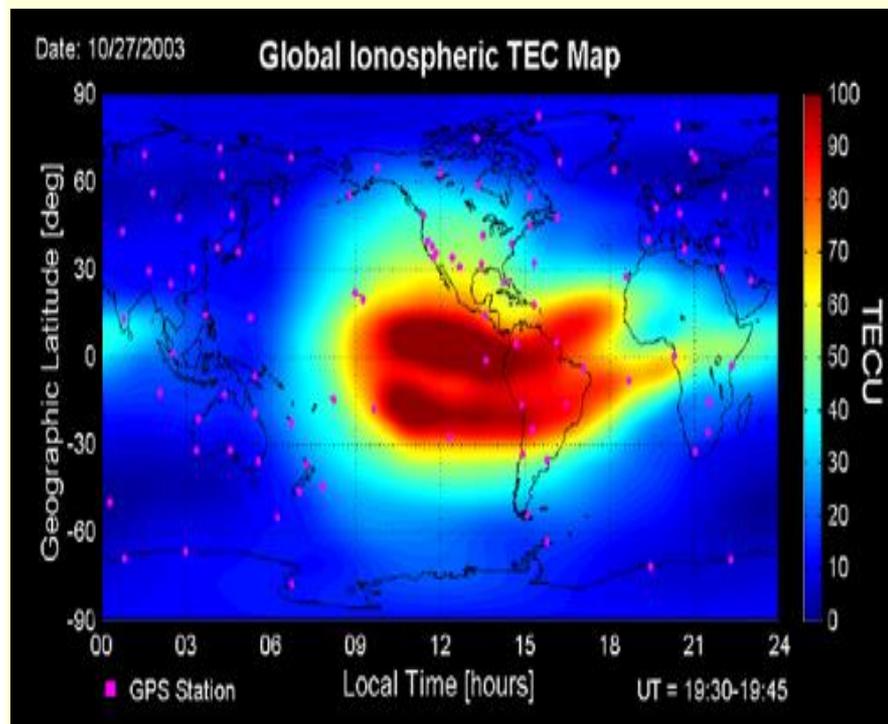
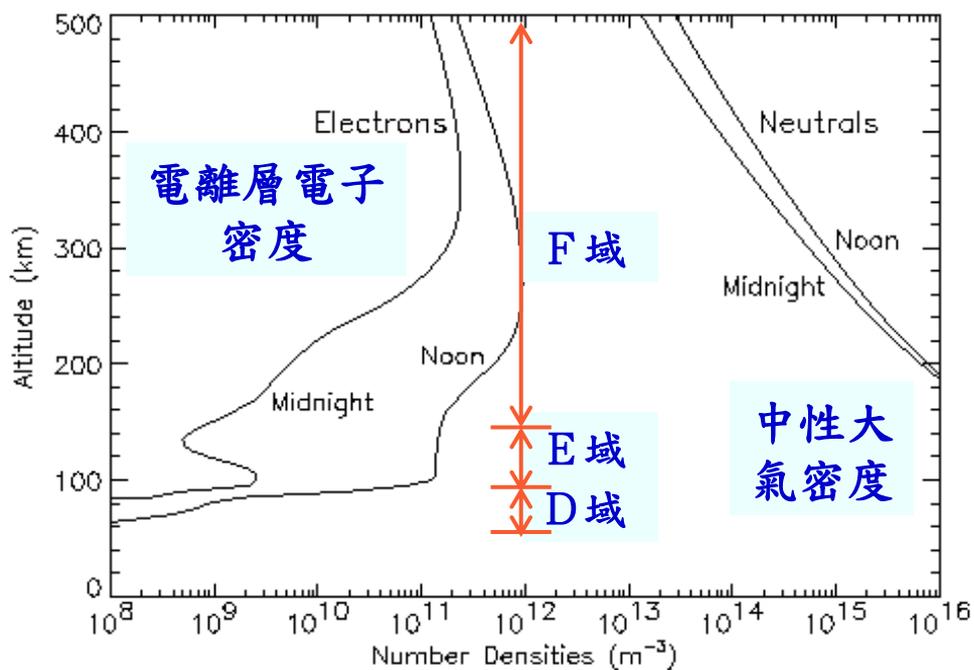
- (a) 60 ~ 90 km 為 D 層。此層僅在白天出現，但並不是每天均出現，對高頻電波具強烈之吸收作用。
- (b) 90 ~ 140 km 為 E 層。此層亦僅在白天出現，夜間消失。此層中有較強之電場存在，影響了電離層之動力。
- (c) 140 ~ 200 km 為 F1 層。事實上，此層之上邊界甚難界定。此層只在日間存在，對遠距離電波傳播助益不大。
- (d) 200 ~ 1000 km 為 F2 層，為電離層的主體，深深影響低頻(Low Frequency)與高頻(High Frequency)電波越地平(Over-The-Horizon)傳播以及人造衛星的通信。

電離層電子密度垂直分布示意圖

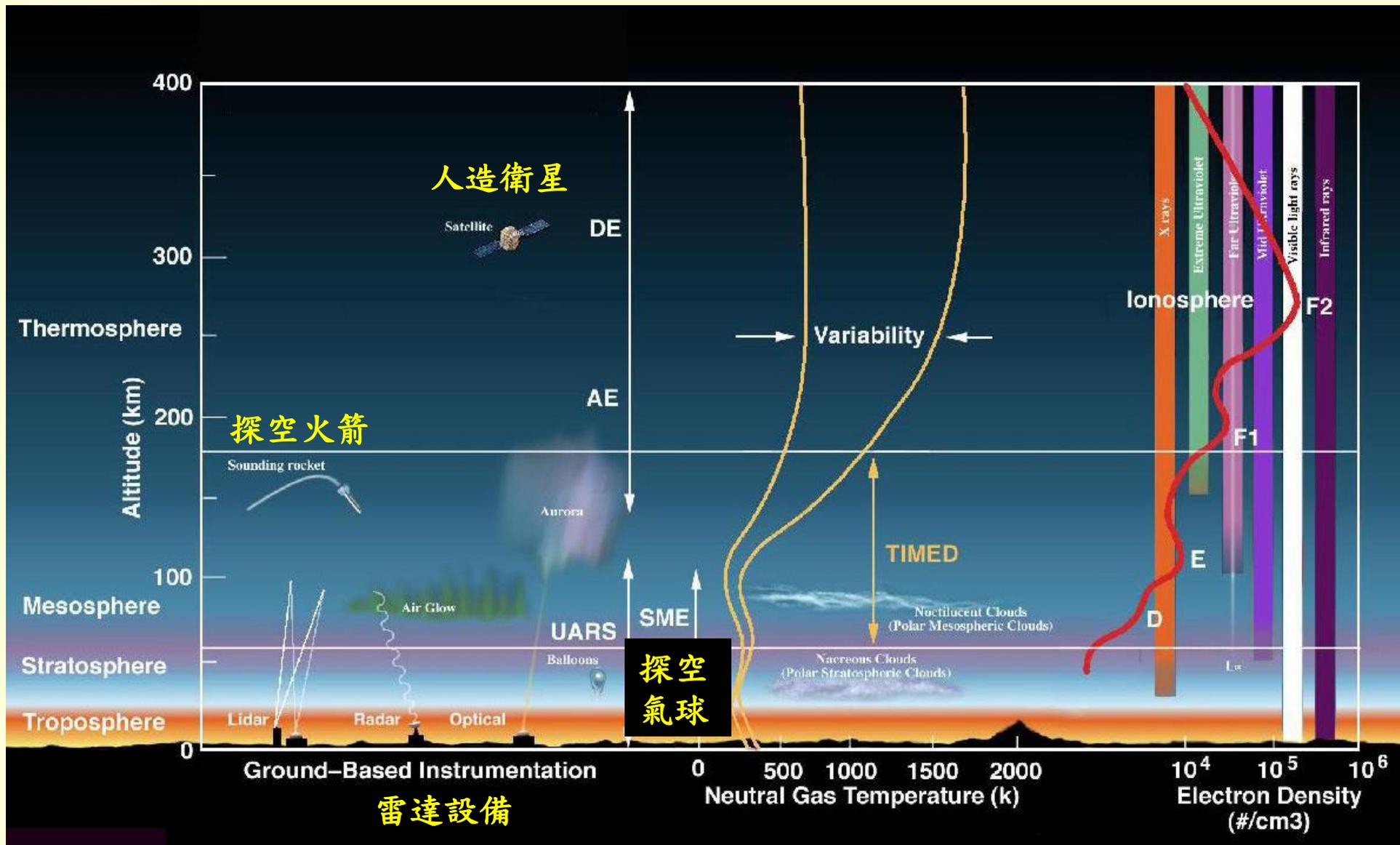


Ionosphere layers

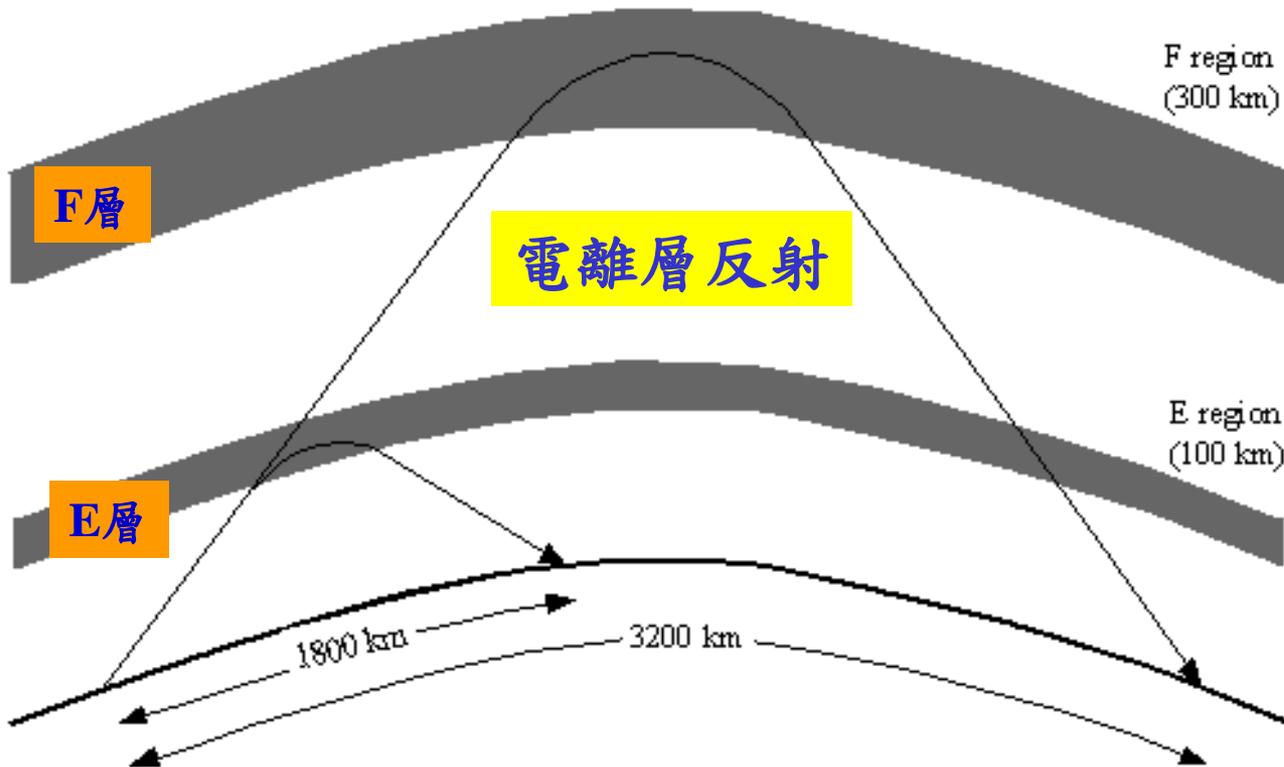
電離層電子密度的垂直與水平結構



高層大氣結構與監測



高頻電波傳播—天波(Sky Wave)模式

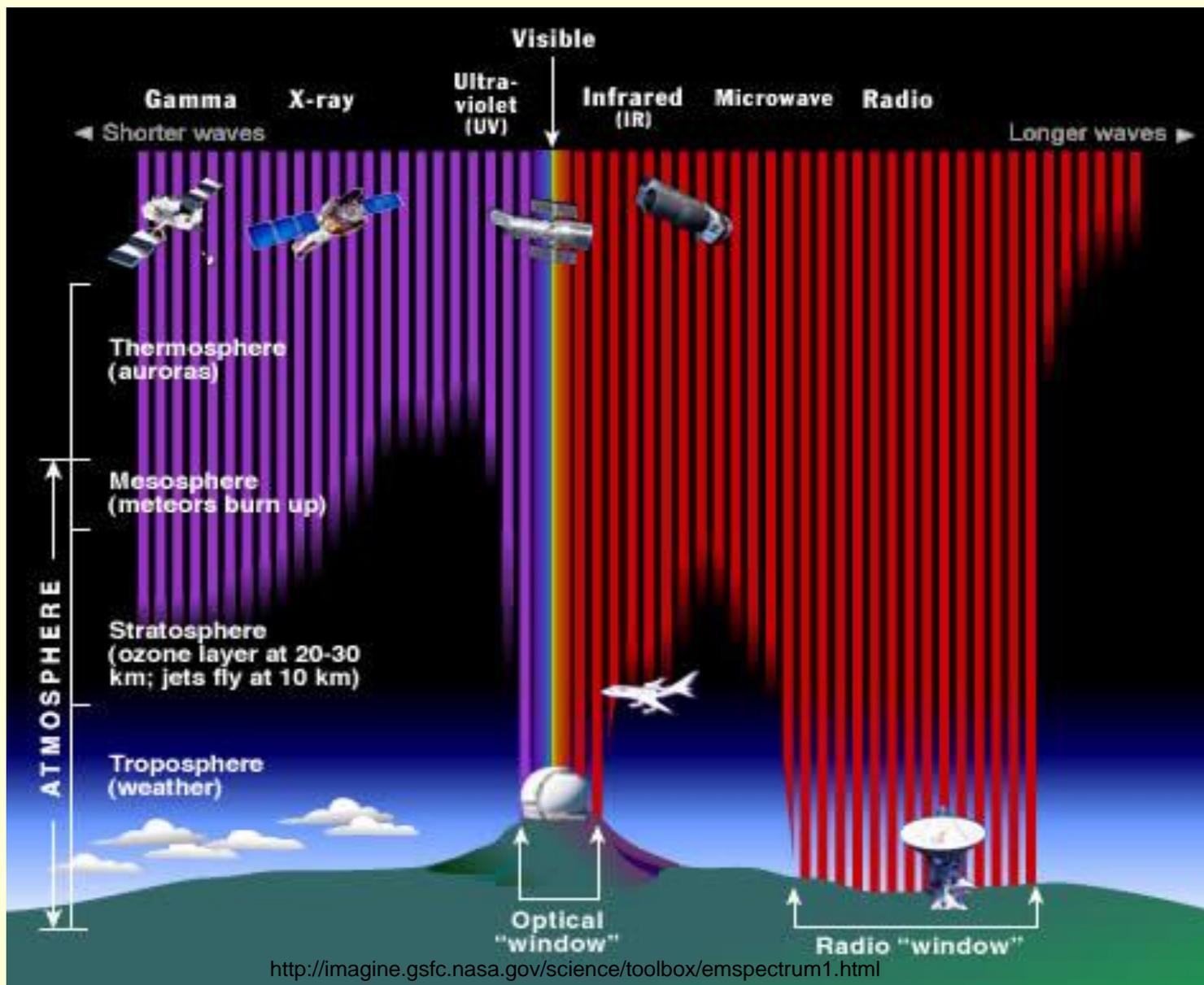


電離層反射電波頻率與電離層電子密度之關係

$$f_0 = 9\sqrt{10^{-6} n_e}$$

(f_0 in megahertz, n_e in cm^{-3})

不同波段太陽光子輻射被地球大氣吸收高度

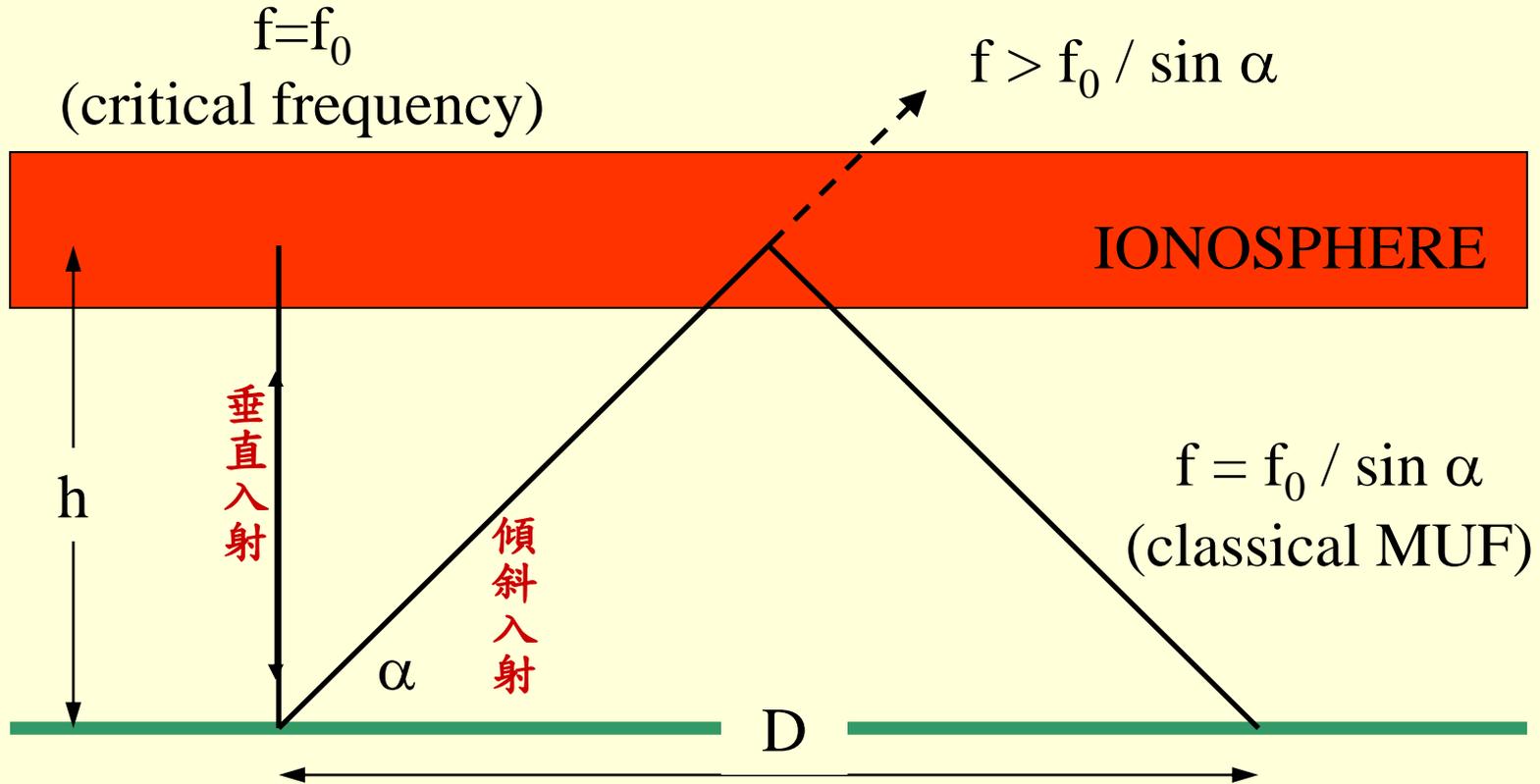


最大可用頻率 (Maximum Usable Frequency, MUF)

$$MUF = f_v \sec i_o$$

若發射短波電波頻率超過 $f_v \sec i_o$ ，則電波將會穿透電離層，而不會被反射回地面，其中 f_v 為反射點處的最大臨界頻率 (Maximum critical frequency)。因此欲進行電離層短波傳播，操作頻率必須小於或等於最大可用頻率，亦即MUF。在實際的電波傳播應用上，則通常使用最佳操作頻率FOT，來作為短波通訊之用，亦即 $FOT=0.85 \times MUF$

電離層臨界頻率與最大可用頻率MUF



$$f = f_0 * \text{SQRT}[(D^2/4h^2) + 1]$$

太陽活動性與電離層臨界頻率的關係

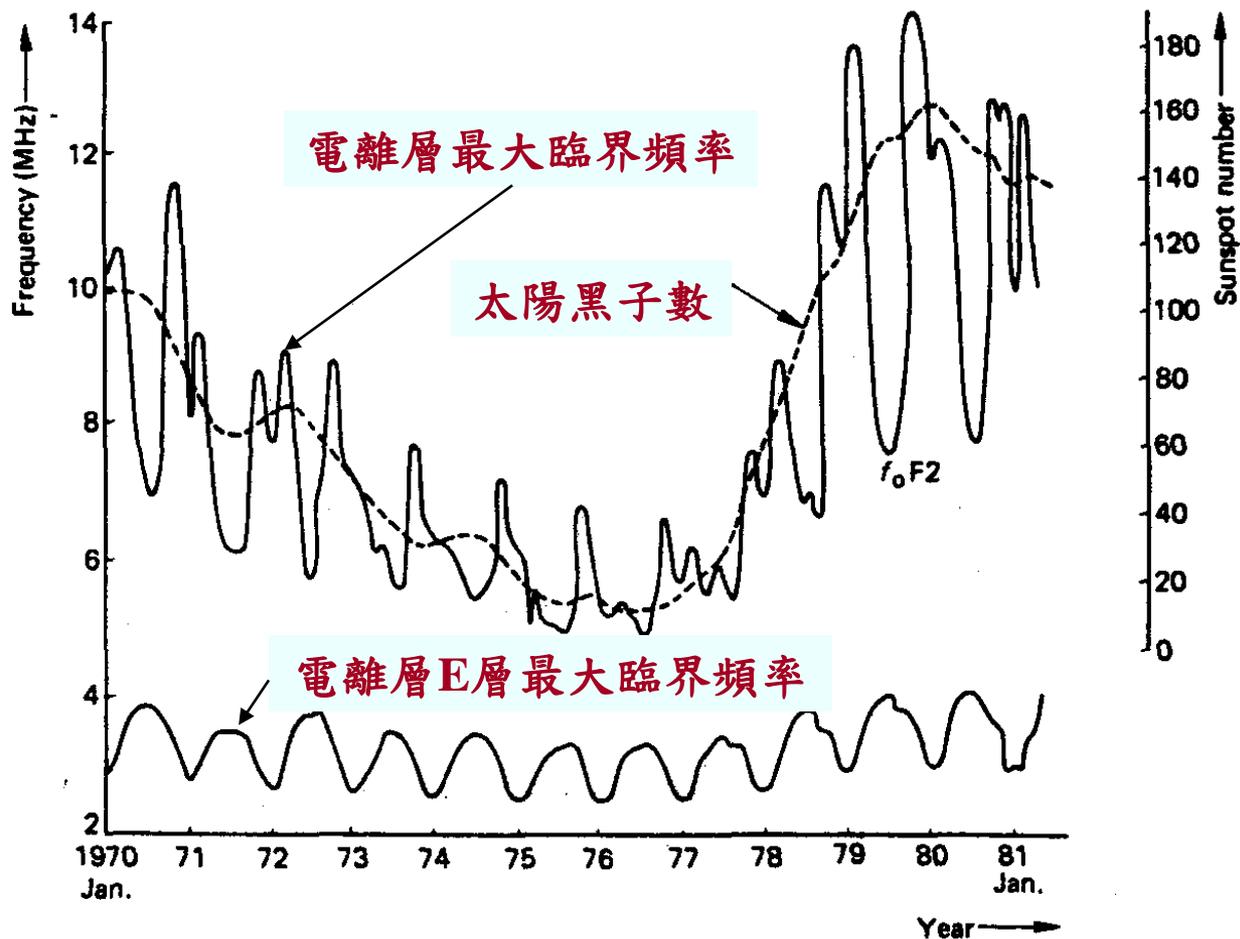
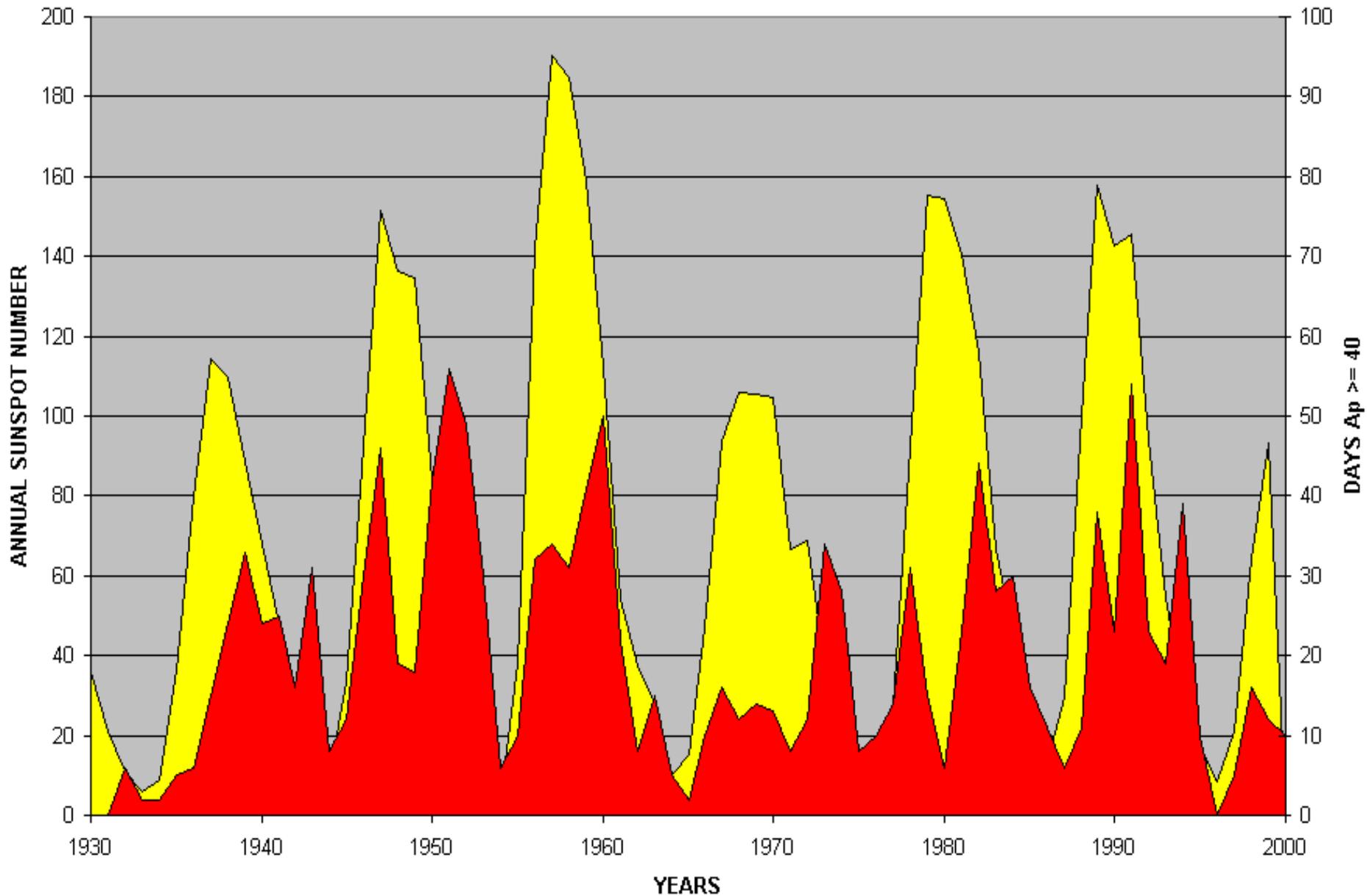
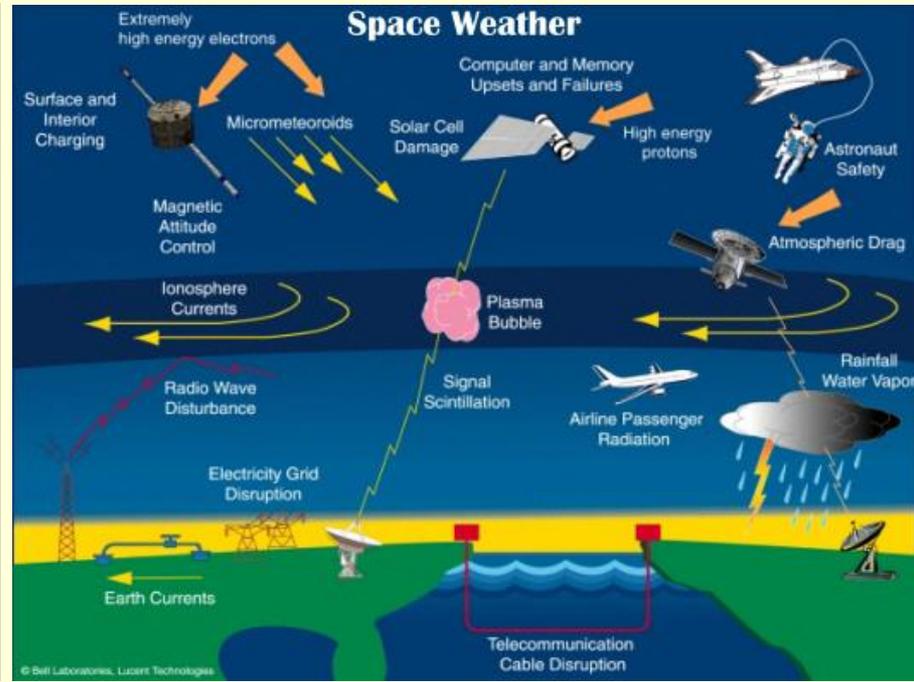
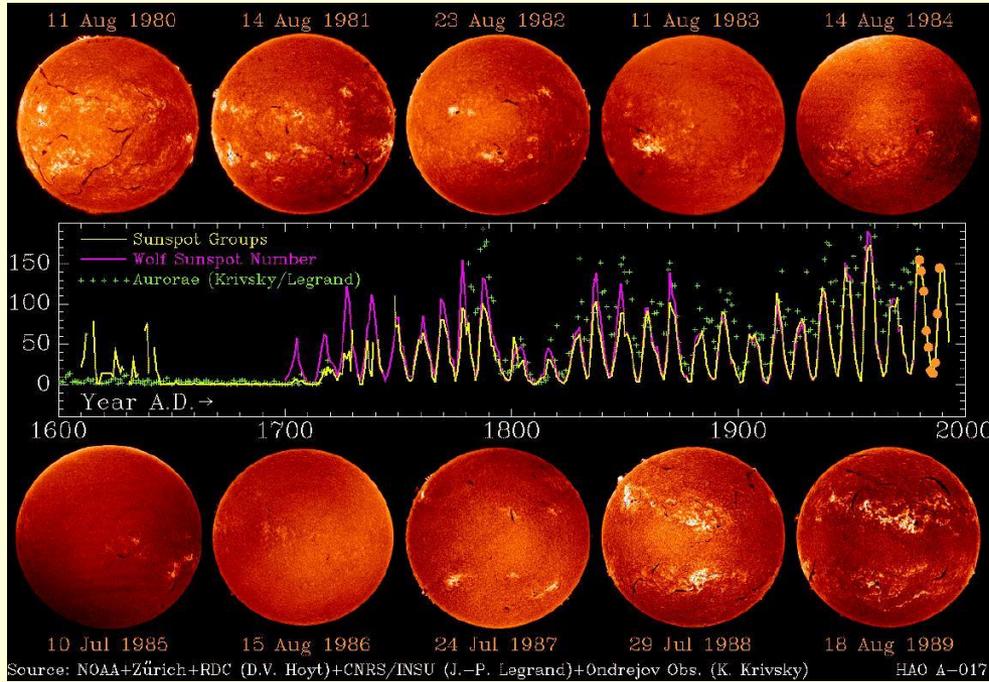


Fig. 4.11 Monthly mean of the noon critical frequencies observed at Slough 1970 with superimposed sunspot activity

太陽黑子週期與地球電離層發生擾動的關係



太空天氣(Space Weather)現象



Space Weather Impacts on Earth

Global Positioning System (GPS)
Geomagnetic storms can impact the accuracy and availability of GPS by changing the ionosphere, the electrically charged layer of the atmosphere. GPS signals must pass through this layer to ground receivers. The ionosphere is the largest source of error in GPS positioning and navigation. These ionospheric disturbances can be even more severe during geomagnetic storms, resulting in errors in excess of 100 feet, or even resulting in a loss of lock on the GPS signal entirely. These errors can have significant impacts on precision uses of GPS such as navigation, agriculture, oil drilling, surveying, and timing.

Satellite Operations
There are thousands of satellites in orbit around Earth with applications in television and radio, communications, meteorology, national defense, and research. Space weather can affect these satellites in many ways. Solar radiation storms can cause spacecraft orientation problems by ionizing with their bodies and by causing noise or damage in electronic devices. Geomagnetic storms can create a hazardous charging environment or satellite malfunctions, such as shorting out solar panels and getting stuck on the wrong orbit. Geomagnetic storms also cause heating of the atmosphere, increasing its density at regions, which can cause drag on satellites, in a worst case, space weather can cause the satellite to fall.

Space Operations
Astronauts and their equipment in space are bombarded with charged particle radiation. This radiation causes tissue or cell damage in humans. Space weather and solar radiation storms are a particular concern for activities outside the protection of Earth's atmosphere and magnetic field.

Aurora
The Aurora Borealis (Northern lights) and Aurora Australis (Southern lights) are the result of electrons colliding with Earth's upper atmosphere. The electrons are energized through geomagnetic processes in the streamer and tail regions of the magnetosphere. The accelerated electrons follow the magnetic field of Earth, closer to the polar regions where they collide with oxygen and nitrogen atoms and molecules at Earth's upper atmosphere. In their collisions, the electrons transfer their energy to the atmosphere, by exciting the atoms and molecules to higher energy states. When they relax back to lower energy states, they release their energy in the form of light. The aurora typically forms 50-200 miles above the ground. Earth's magnetic field guides the electrons such that the aurora forms two ovals approximately centered on each magnetic pole.

THE COLORS OF THE AURORA
Deep and from high altitude atomic nitrogen
Generally yellow from lower altitude atomic oxygen
Magenta from high altitude molecular nitrogen in sunlight

Aviation
Aurora of low HFQ frequency (40-100 MHz) communication to other aircraft with ground controllers is minimal. Areas such as over the ocean or over the poles. Solar flares can "black out" the use of HF on the display of Earth and radar collision warnings can "black out" use of IFF near the poles, impacting the aircraft's ability to fly in areas with aurora. Impacts to GPS systems can also significantly affect aviation operations.

Power Grids
Geomagnetic storms result in electric currents in the magnetosphere and ionosphere in the area shaped by Earth's magnetic field as compressed and distorted. The distorted conditions create additional currents in the conductors on the ground such as overhead transmission lines and power lines. In the worst extreme cases, these currents can cause voltage instability or damage to power system components, potentially resulting in temporary service interruptions, or even a widespread power outage.

NOAA Education www.education.noaa.gov
NOAA Space Weather Prediction Center www.spaceweather.gov

<http://SunSpotWatch.com> ~ <https://www.facebook.com/spacexw.hfradio>
Twitter: @hfradiospacexw ~ @NW7US

Space Weather

Sunspots
Sunspots are magnetically induced areas of relatively cooler and less turbulent solar activity. They are caused by intense magnetic activity that inhibits convection, resulting in darker areas on the solar surface. Sunspots are often associated with solar flares and coronal mass ejections.

Coronal Mass Ejections (CMEs)
A coronal mass ejection (CME) is a large-scale release of plasma and magnetic field from the Sun's corona. CMEs are often associated with solar flares and can cause geomagnetic storms when they reach Earth.

Solar Wind
The solar wind is a constant outflow of electrons and protons from the Sun, shaped primarily by the Sun's magnetic field. The background solar wind flows at approximately one million miles per hour.

Sun's Magnetic Field
Strong and ever-changing magnetic fields above the level of the Sun and underlie magnetic storms. Disturbances in the field can cause geomagnetic storms and aurora.

Solar Radiation Storms
Charged particles, including electrons and protons, can be accelerated by coronal mass ejections and solar flares. These particles bounce and drift through the solar wind and its magnetic field towards Earth. The primary source of geomagnetic storms is solar wind. The primary source of geomagnetic storms is solar wind. The primary source of geomagnetic storms is solar wind.

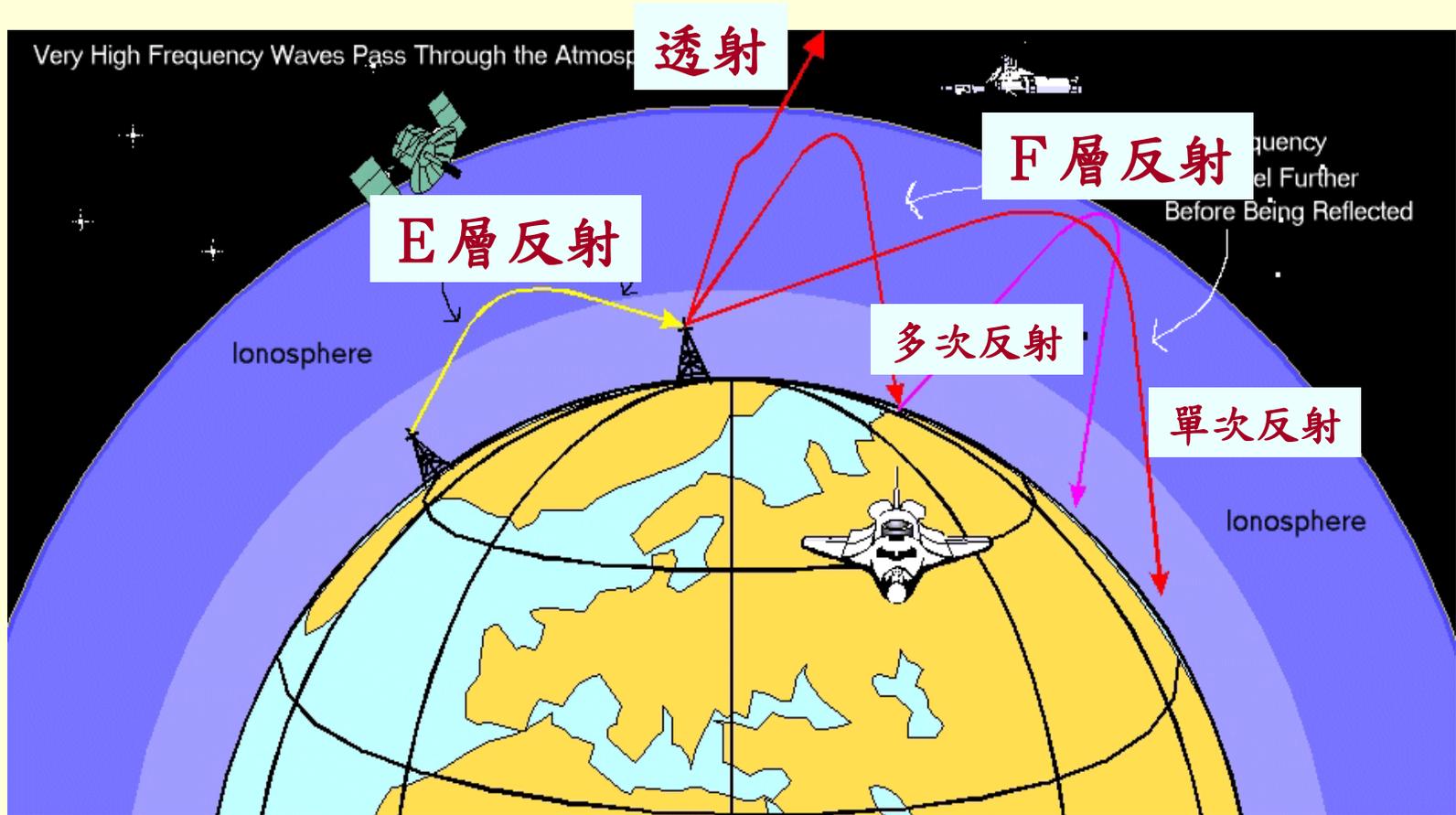
Geomagnetic Storms
A geomagnetic storm is a temporary disturbance of Earth's magnetic field typically associated with an enhancement in the solar wind. These storms are created when the solar wind and its magnetic field interact with Earth's magnetic field. The primary source of geomagnetic storms is solar wind. The primary source of geomagnetic storms is solar wind.

Solar Flares
Reconnection of the magnetic field on the surface of the Sun releases huge quantities of energy and results in solar flares. These flares can cause geomagnetic storms when they reach Earth.

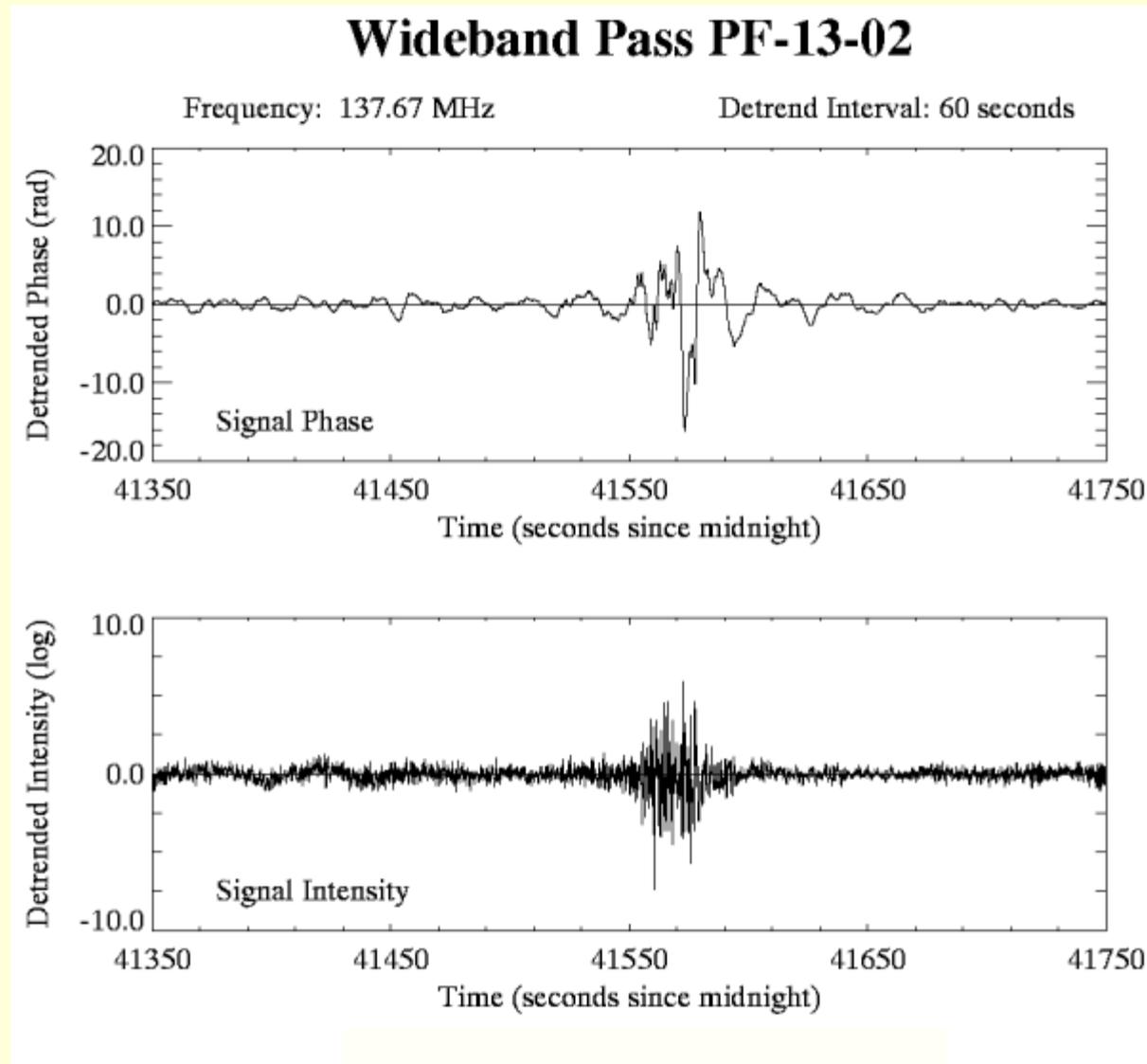
Earth's Magnetic Field
Earth's magnetic field is largely the result of a hot, liquid, outer core of molten iron. The magnetic field is constantly compressed on the day side and stretched on the night side by the solar wind.

NOAA Space Weather Prediction Center ~ www.spaceweather.gov

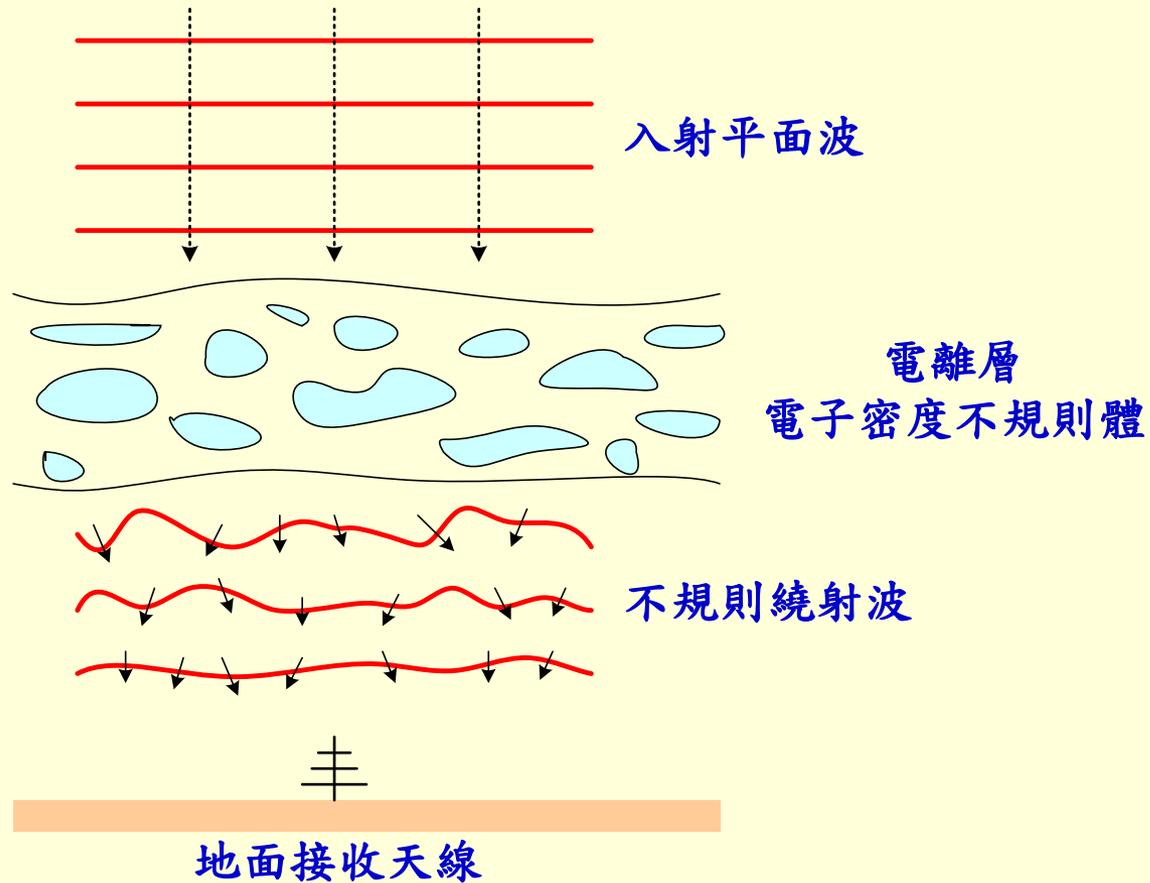
電離層高頻(HF)電波傳播方式



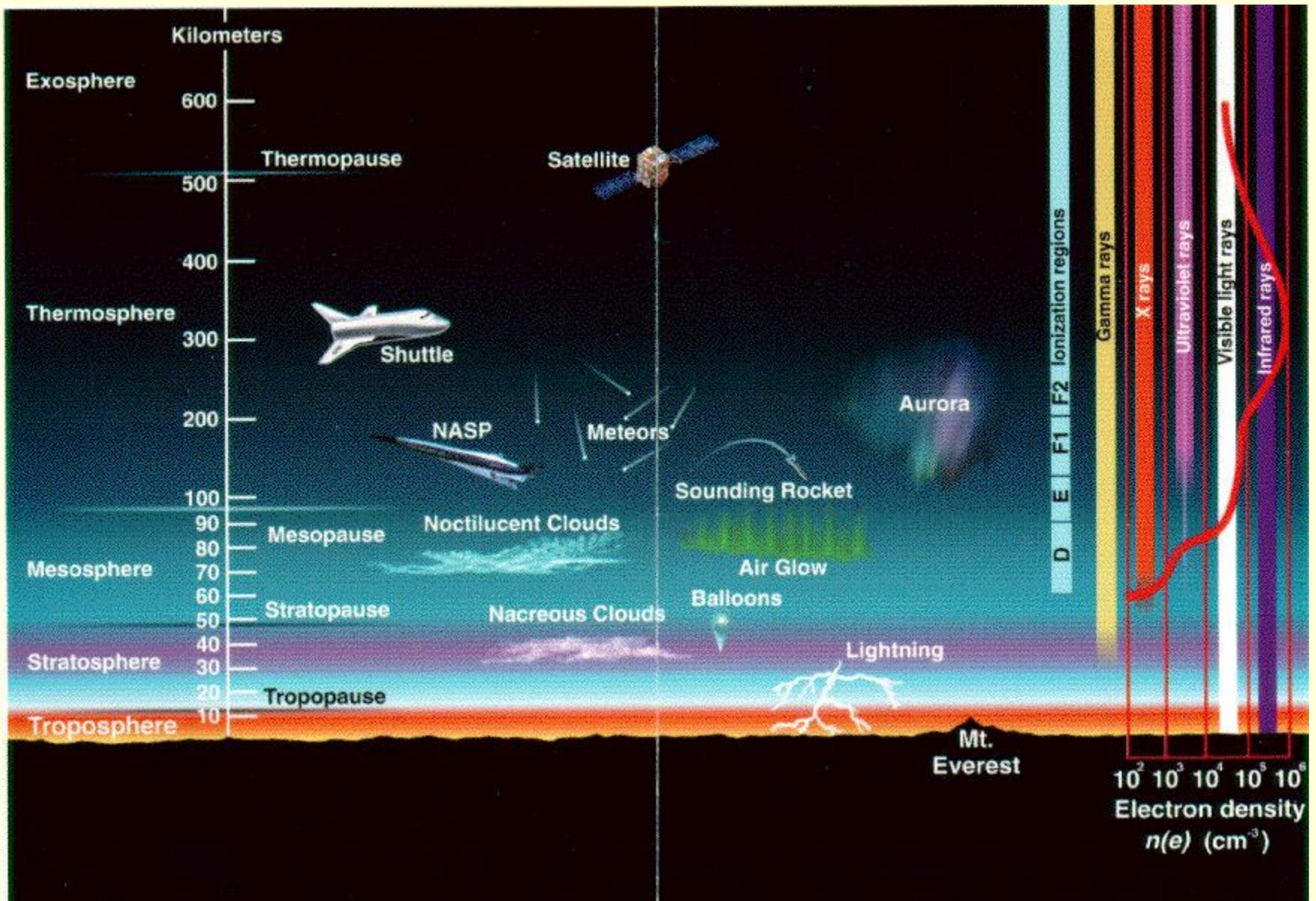
人造衛星訊號的電離層閃爍現象



電離層閃爍現象發生原因 (電子密度不規則體存在所致)

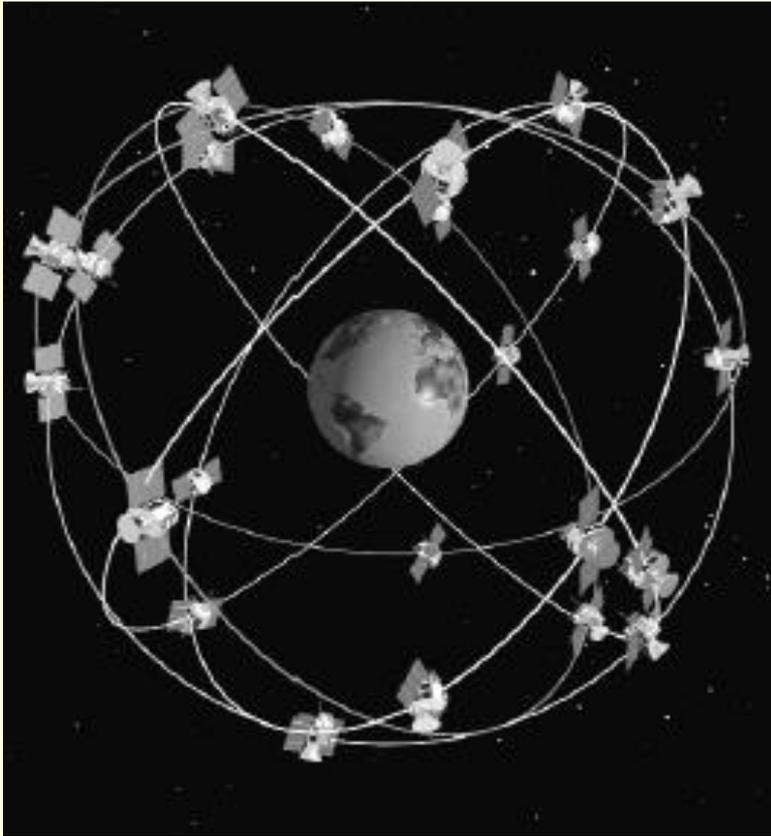


人類在大氣中的活動範圍

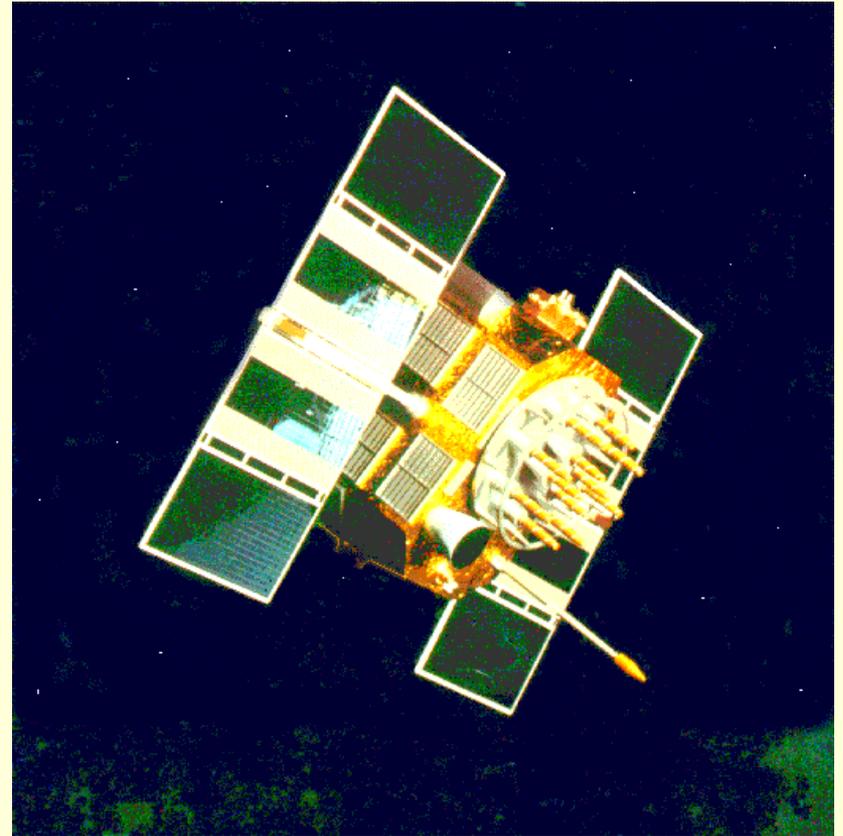


電離層與GPS定位

GPS人造衛星網



GPS人造衛星

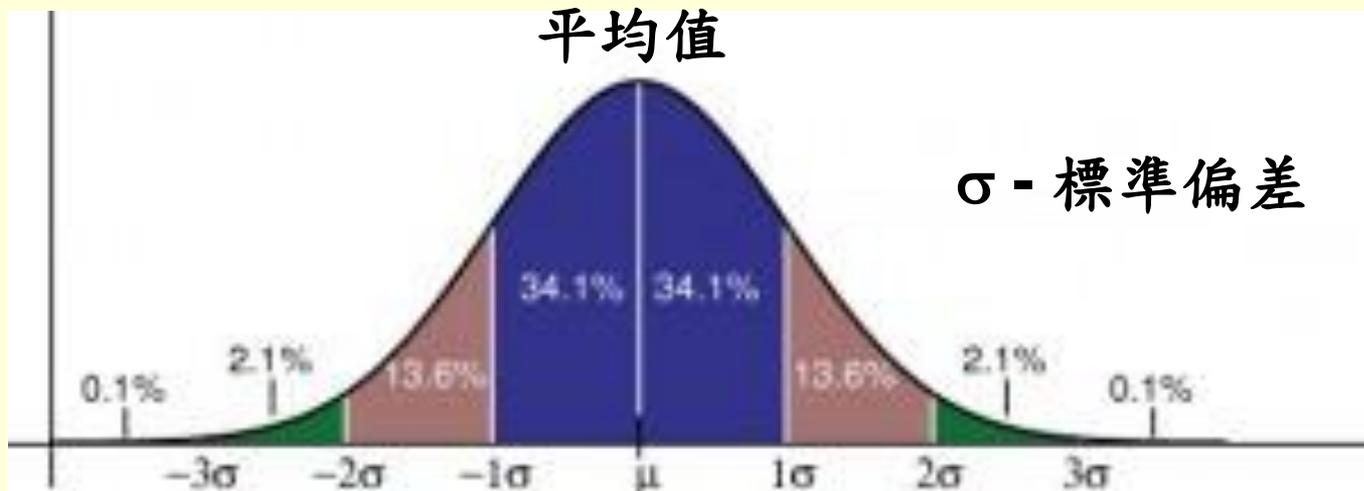


每一個GPS人造衛星具備有2具銻原子鐘和2具銣原子鐘，其時間精確度(precision)或不確定度分別為 10^{-13} 與 10^{-12} ，亦即分別要30萬年與3萬年的時間，才會有一秒鐘的不確定度(一年約有 3.15×10^7 秒)

精確度(Precision)與準確度(Accuracy)的概念



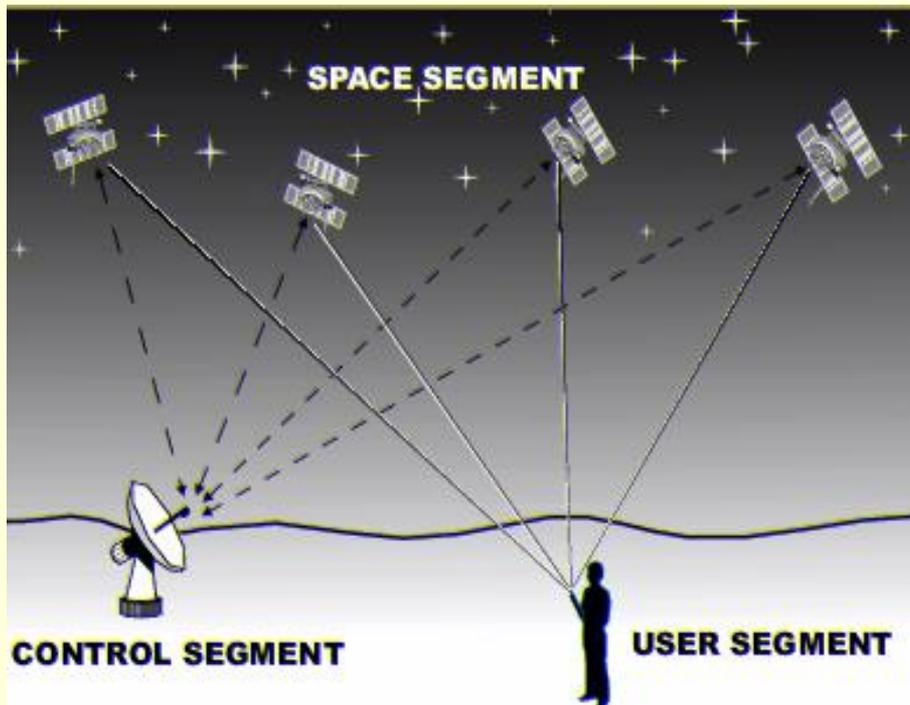
<http://highscope.ch.ntu.edu.tw/wordpress/wp-content/uploads/2011/04/%E7%B2%BE1.jpg>



<http://www.statisticshowto.com/probability-and-statistics/normal-distributions/>

GPS衛星定位系統的組成

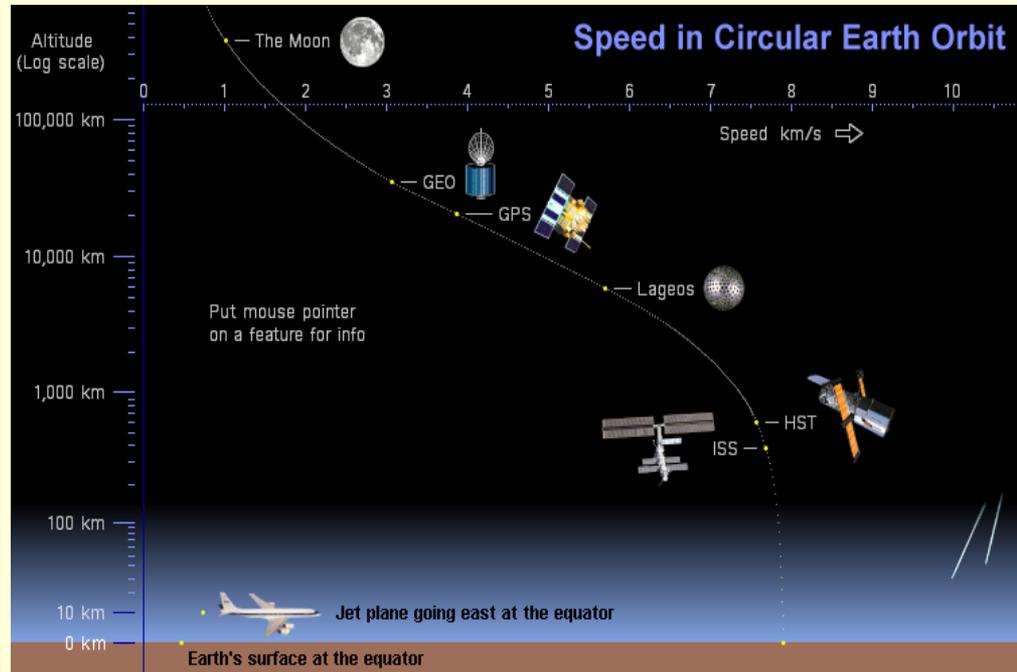
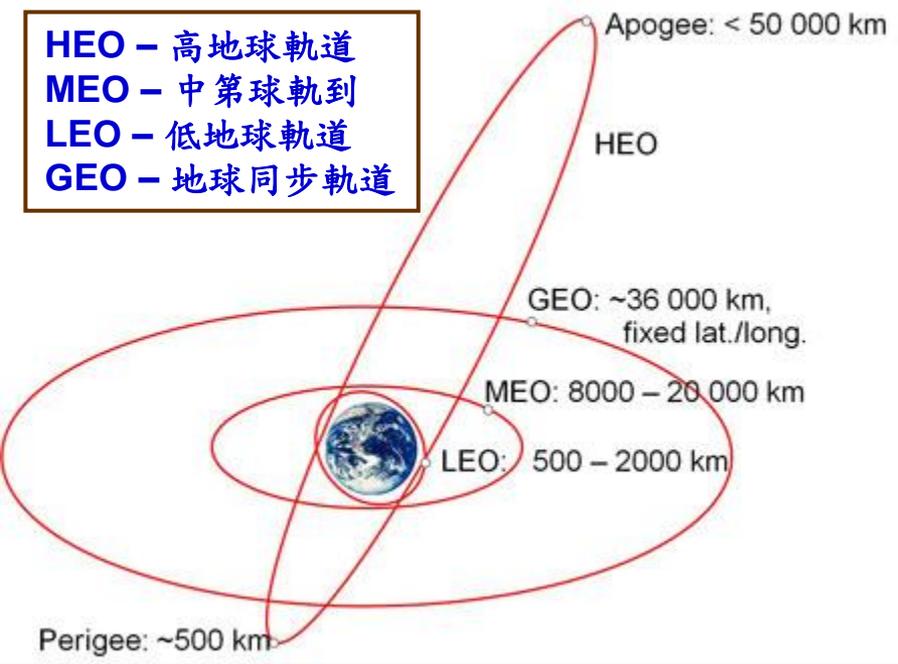
(至少要能接收到四顆GPS衛星以上才可以進行定位)



由於自由電子的存在，將導致GPS訊號通過電離層時，電波傳播速度變慢，造成人造衛星訊號傳播的遲延，因而使得GPS定位產生誤差。目前已針對此問題有了解決之道。亦即使用雙頻GPS訊號進行電離層遲延校正。

人造衛星軌道與太空垃圾

- HEO - 高地球軌道
- MEO - 中地球軌道
- LEO - 低地球軌道
- GEO - 地球同步軌道



自1957年10月起，人類共發射超過4800火箭，佈放超過6000枚人造衛星在軌道中。目前在太空中共有約29000個大於10公分的人造物體繞地球運行，其中17000個被相關單位監測中，而其中的7%屬於功能正常的運作中的衛星，約5000個為喪失功能的衛星，剩下約7000個物體，為衛星在軌道中裂解後的殘骸，不同軌道中

太空碎片(垃圾)Space Debris

WASTE IN SPACE

Currently, a thick band of working space junk—composed primarily of broken satellite pieces and discarded rocket boosters—circles the Earth. Two or three times a day, a satellite circling our planet narrowly misses a fragment of the orbital debris. This phenomenon has jeopardized not only current space travelers, but future missions as well.

WHAT IS SPACE DEBRIS?

Sometimes, human-made materials in orbit caused by something from space booster stages to satellite collisions and explosions.

73%

of tracked debris resides in low-Earth orbit (LEO), 1,200 miles above our planet's surface.

HOW MUCH SPACE JUNK IS UP THERE?

The amount of space debris larger than four inches in diameter in Earth's orbit being tracked by the U.S. Space Surveillance Network.

More than **21,000** objects

500,000 objects

Estimated amount larger than one centimeter in diameter—the size of a marble.

There are another tens of millions of even tinier bits of junk that measure smaller than a centimeter.

WHY IT'S A SERIOUS PROBLEM

Tracking of such high velocities, the particles of space junk present a considerable threat to satellites for any nation. And with more satellites being placed in orbit, the potential of collisions between satellites and large ground-based infrastructures is great.

FASTER THAN THE SPEED OF SOUND

The speed of sound travels at approximately **768 mph** on a normal day.

In order to remain in orbit, the fragments in space have to travel along at least 20 times that speed, and can go up to almost

18,000 mph.

TOO CLOSE FOR COMFORT

About 1,000 times a day, satellites and debris pass less than 5 miles from each other. Considering how expensive space is, this distance is closing.

COLLISIONS & EXPLOSIONS INCREASE DEBRIS

SHUTTLE AND SATELLITE COLLISION

In 2007, China intentionally destroyed one of their weather satellites in space, and the event led to a

900-piece cloud of debris.

THE IRIDIUM 33-COSMOS 2251 IMPACT

February 10, 2009

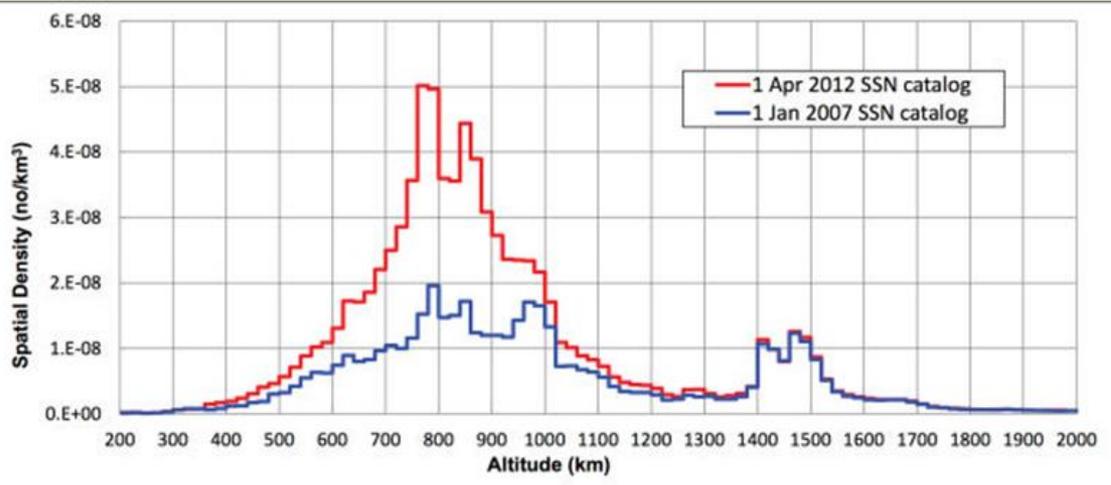
The 15,000 mph collision of the private Iridium 33 satellite and Cosmos 2251, a Russian military spacecraft, left a trail of approximately 2,000 pieces of low-Earth orbit debris.

more than **60%**

Together, these two events combined, increased the amount of debris circling Earth orbit by



太空碎片 (Space Debris) 或太空垃圾 (Space Junk)



The spatial density distribution of the cataloged objects on 1 April 2012 (red histogram). The population below 1000 km altitude is more than doubled since the beginning of 2007 (blue histogram). Fragments generated from the anti-satellite test (at 850 km altitude) conducted by China in 2007 and the collision between Iridium 33 and Cosmos 2251 (at 790 km altitude) in 2009 were responsible for the majority of the increase.



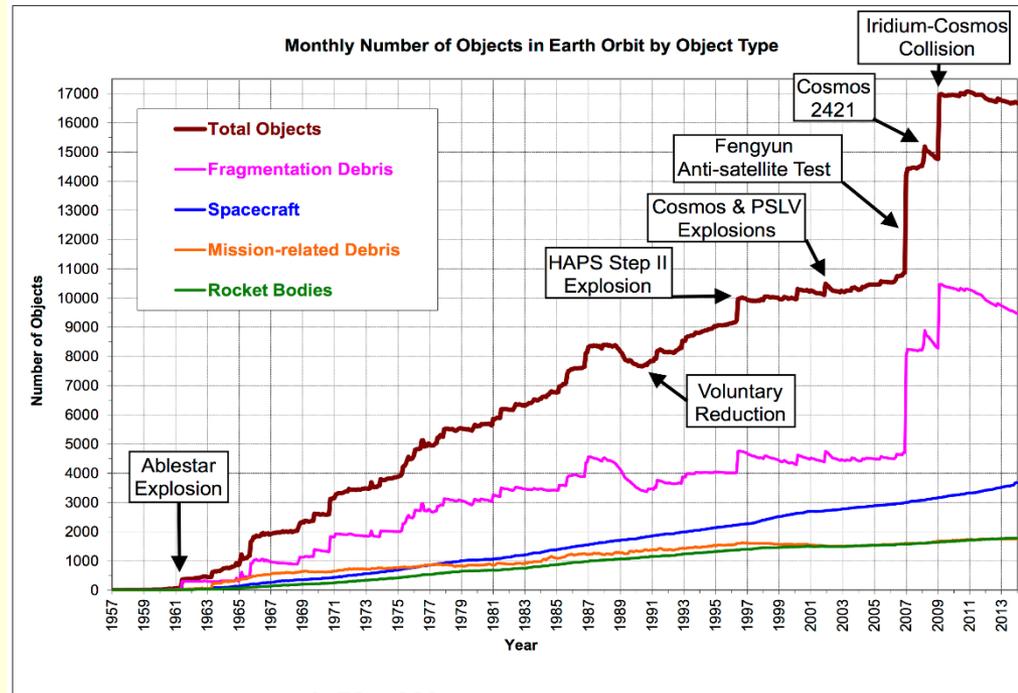
STS088-724-67

Common Name	Year of Breakup	Altitude of Breakup	Cataloged Debris*	Debris in Orbit*	Cause of Breakup
Fengyun-1C	2007	850 km	2841	2756	Intentional Collision
Cosmos 2251	2009	790 km	1267	1215	Accidental Collision
STEP 2 Rocket Body	1996	625 km	713	63	Accidental Explosion
Iridium 33	2009	790 km	521	498	Accidental Collision
Cosmos 2421	2008	410 km	509	18	Unknown
SPOT 1 Rocket Body	1986	805 km	492	33	Accidental Explosion
OV 2-1 / LCS 2 Rocket Body	1965	740 km	473	36	Accidental Explosion
Nimbus 4 Rocket Body	1970	1075 km	374	248	Accidental Explosion
TES Rocket Body	2001	670 km	370	116	Accidental Explosion
CBERS 1 Rocket Body	2000	740 km	343	189	Accidental Explosion
Total: 7903			Total: 5172		

* As of May 2010

太空碎片的產生，或因人造衛星被飛彈故意擊毀，或因流星或隕石撞擊，或因火箭在太空中爆炸，或因衛星間彼此相撞，或受其他太空碎片撞擊所致。太空碎片也會因太空中大氣阻力作用，降低運行軌道高度，最後進入大氣層燃毀消逝。

各種形狀的太空碎片(垃圾)Space Debris(續)



太空碎片 (Space Debris) 或太空垃圾 (Space Junk)

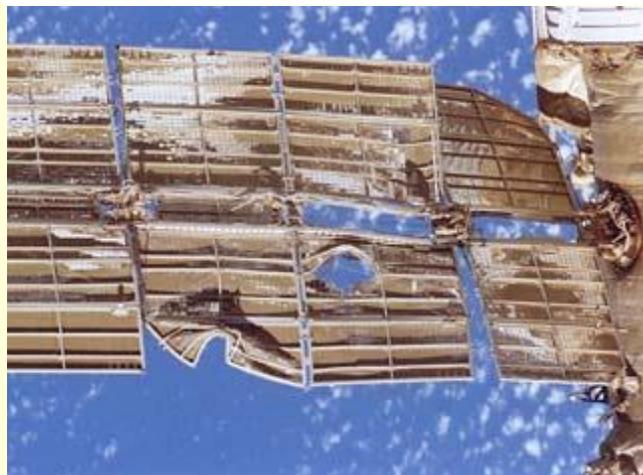
1963



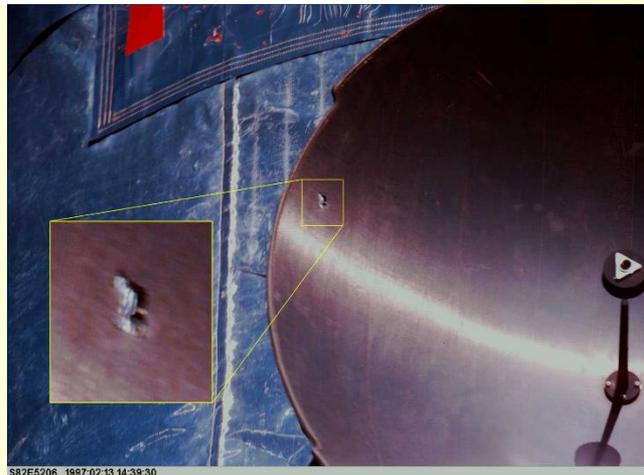
2013



18公分鋁球以時速6.8km/s速度
撞擊鋼板所產生的撞擊坑



蘇聯太空站Mir Space Station
在1997年9月被未知的太空碎
片撞擊後情形

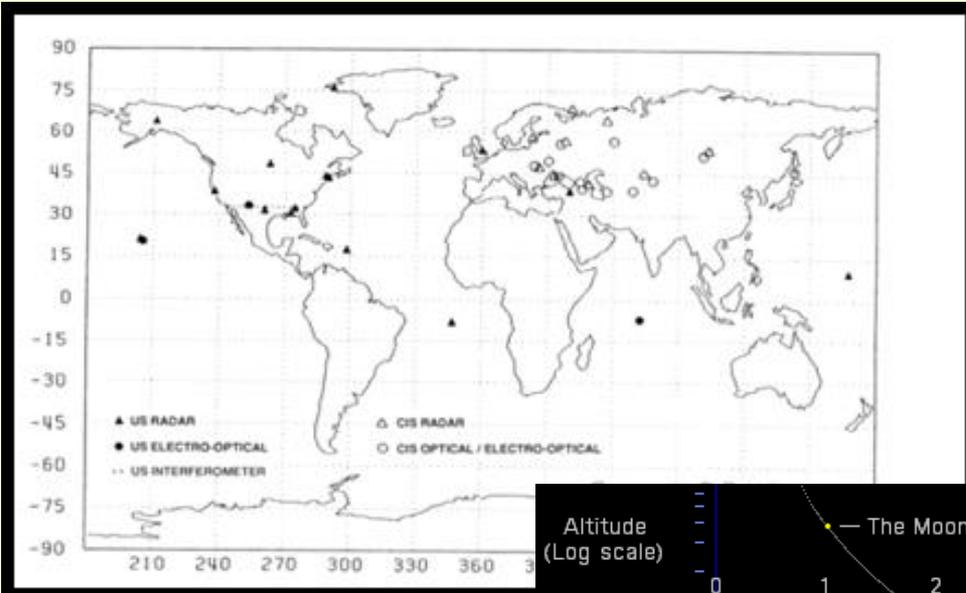


美國哈柏太空望遠鏡天線在
1997年2月被小於1公分的太
空碎片撞擊後情形

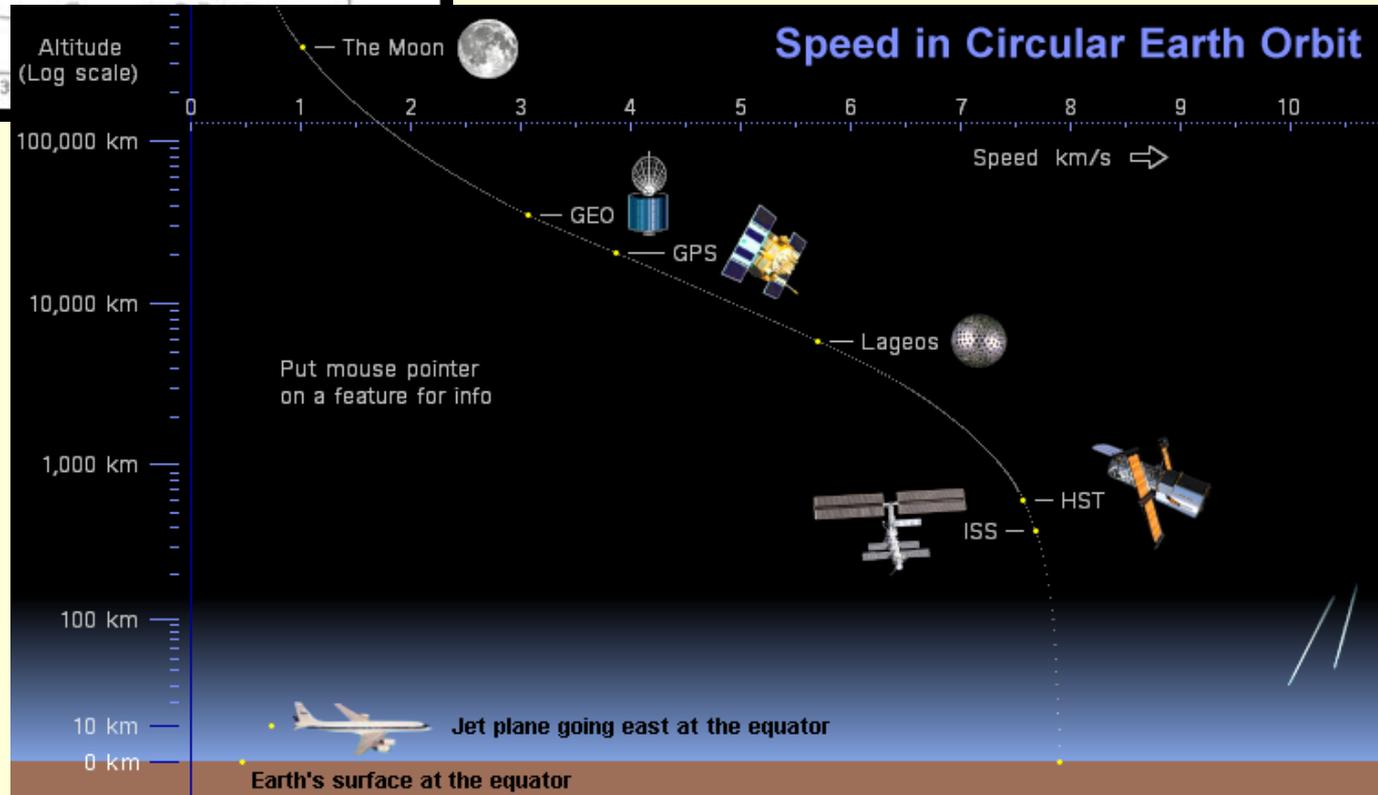


國際太空站(ISS)在2011年
11月與太空碎片，太空碎
片經常被渲染為UFO。

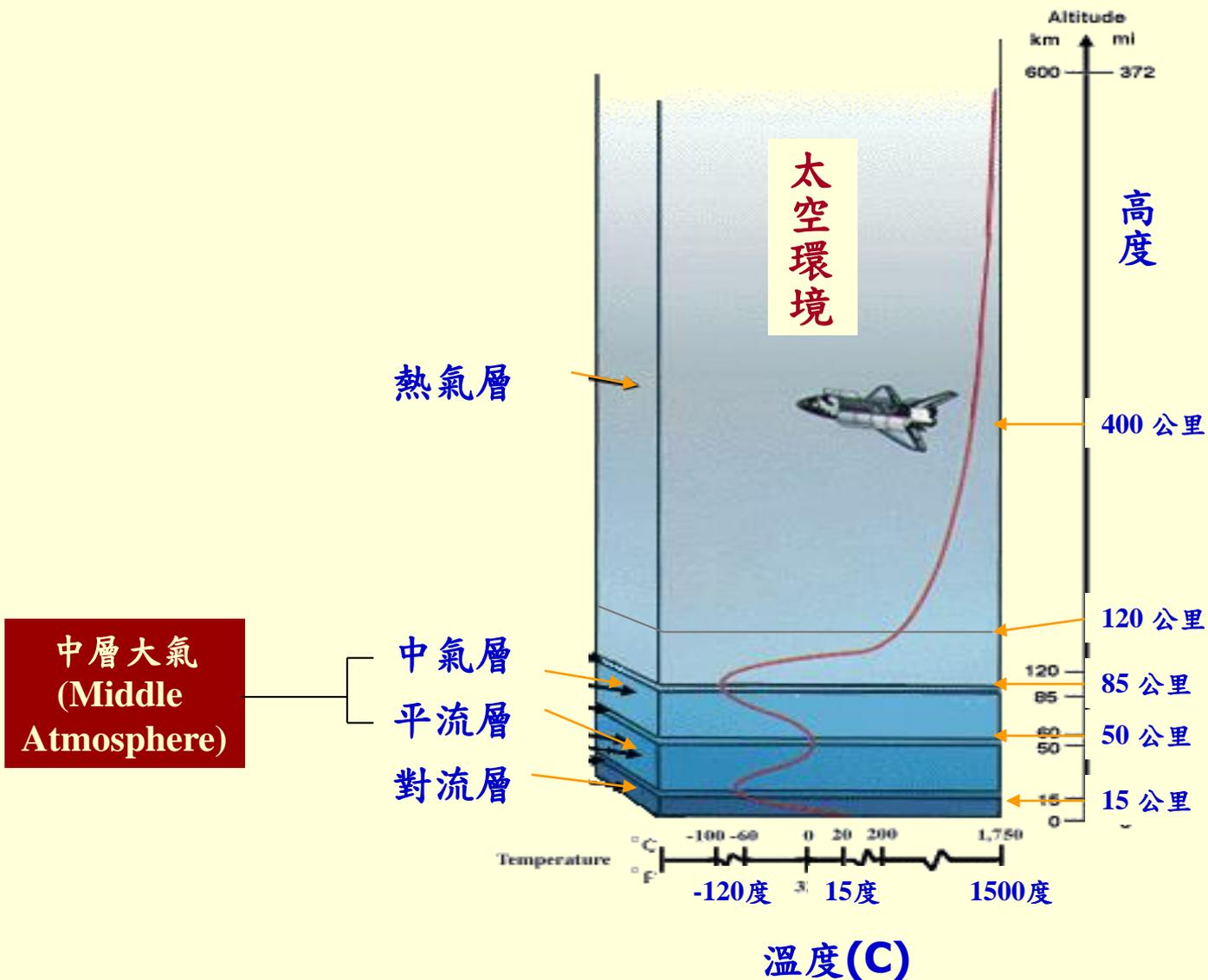
太空垃圾的監控



http://ccar.colorado.edu/asen5050/projects/projects_2010/bicket/

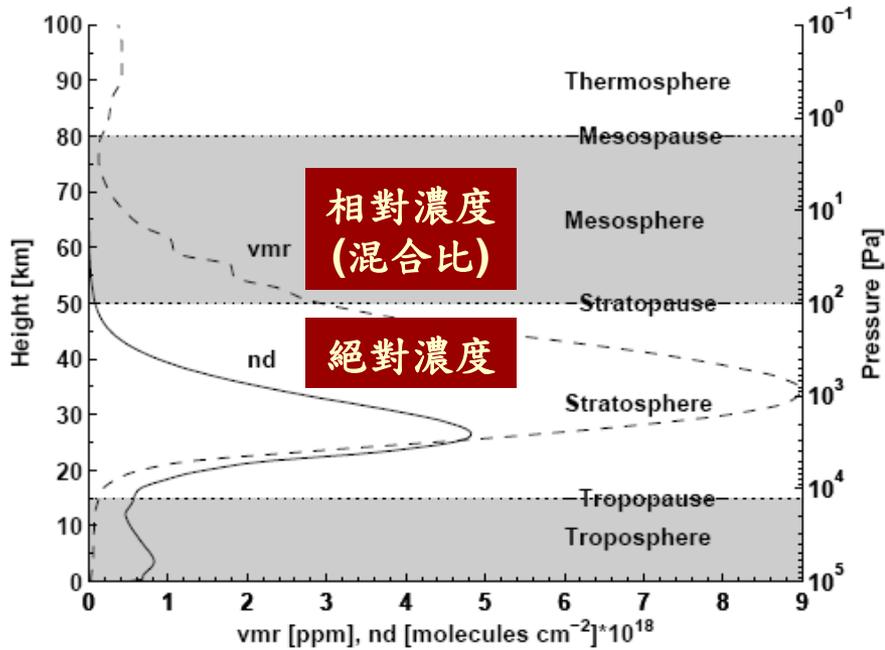


中層大氣的位置與特性

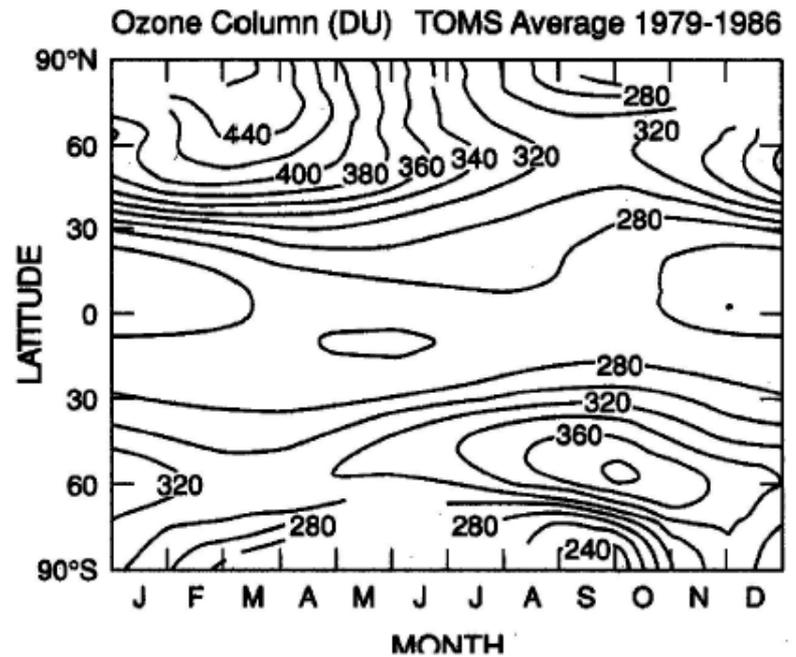


臭氧濃度在中層大氣中的分布

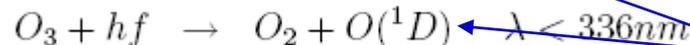
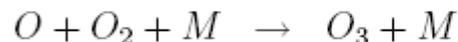
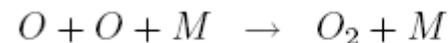
垂直分布



緯度—時間分布



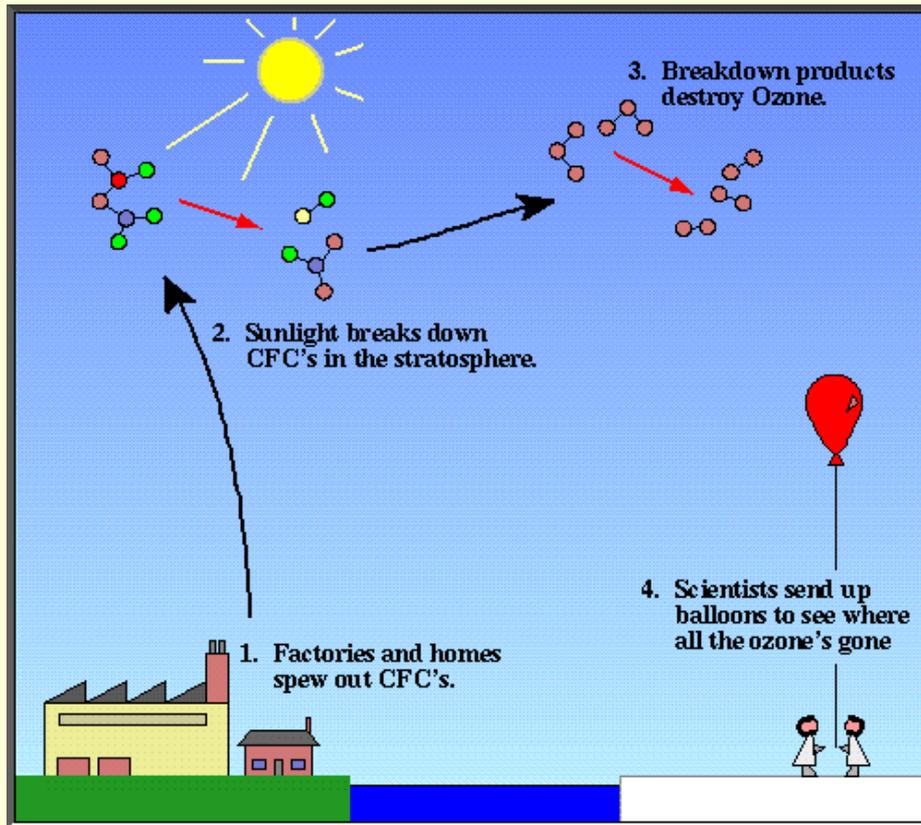
臭氧的化學反應式



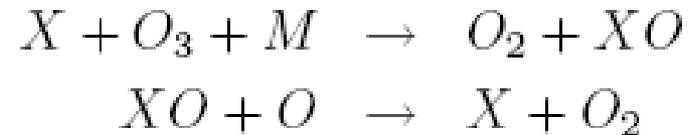
控制臭氧產生化學反應式

控制臭氧消失化學反應式

極區臭氧洞(Ozone Hole)的形成 (人類釋放大量氟氯碳化物的結果)

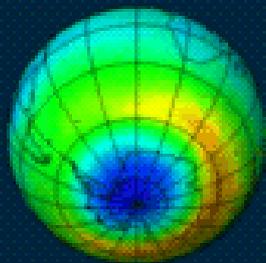


臭氧耗竭的反應式

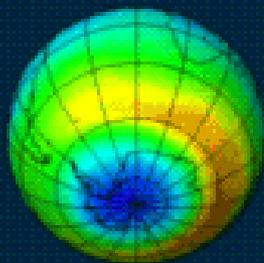


其中X為溴(Br)，氯(Cl)，NO與HO中的任何一種，而M為大氣中第三者氣體分子

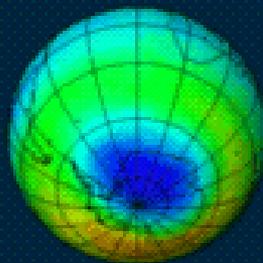
南極上空臭氧破洞變化圖



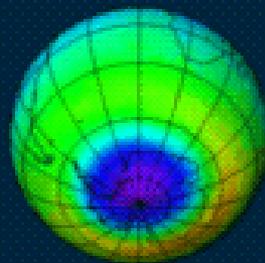
Oct 1980



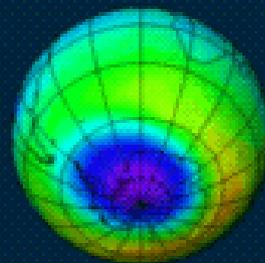
Oct 1981



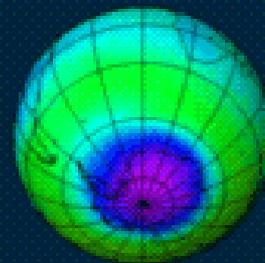
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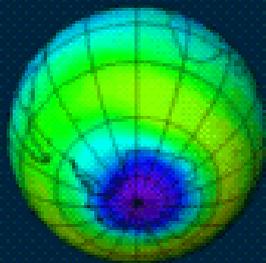
Oct 1983



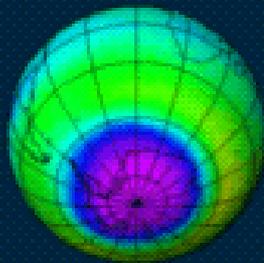
Oct 1984



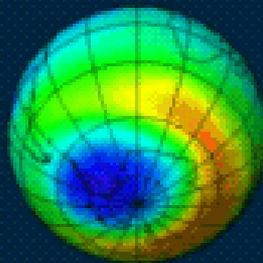
Oct 1985



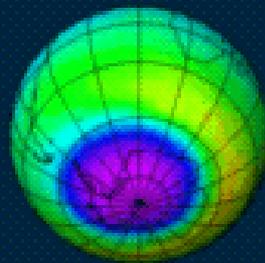
Oct 1986



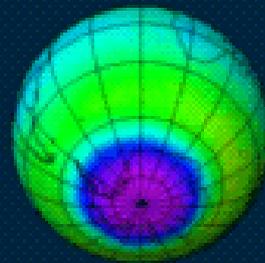
Oct 1987



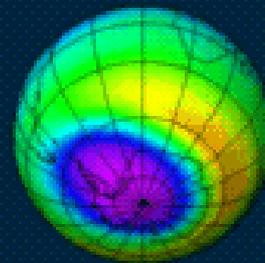
Oct 1988



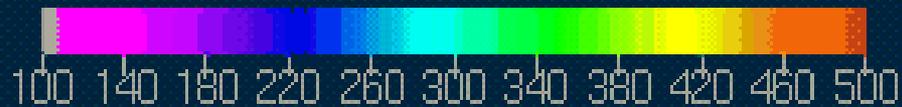
Oct 1989



Oct 1990



Oct 1991



習題一

請想一想，若沒有地球磁場，會對地球造成什麼影響(包括地球環境，生態，動物，與人類等等)？

習題二

大氣懸浮微粒中直徑小於PM2.5的粒子，會對人類帶來嚴重的疾病，屬於第一級致癌物。請問PM2.5的含意是什麼，PM2.5粒子進入人體後造成人體疾病的機制為何？

習題三

請指出下述科學報導中錯誤部分。

“科學家證實，仙后座A在收縮過程中，核心會生成放射性同位素鈦44，而鈦44會向外輻射出大量的高能量X射線，將核心外層氣體以每秒50萬公里的速度吹散，形成一般認知中的超新星爆炸。NuSTAR（核光譜望遠鏡陣列）則拍下人類史上第一組輻射圖像。”
(台灣醒報—民國103年2月21日)