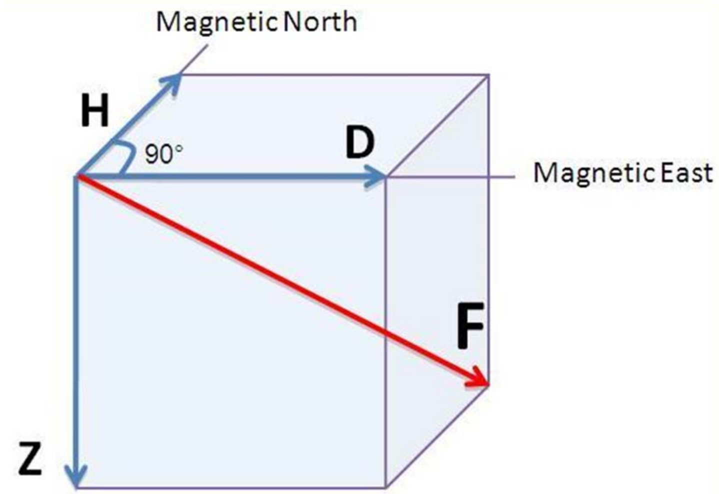
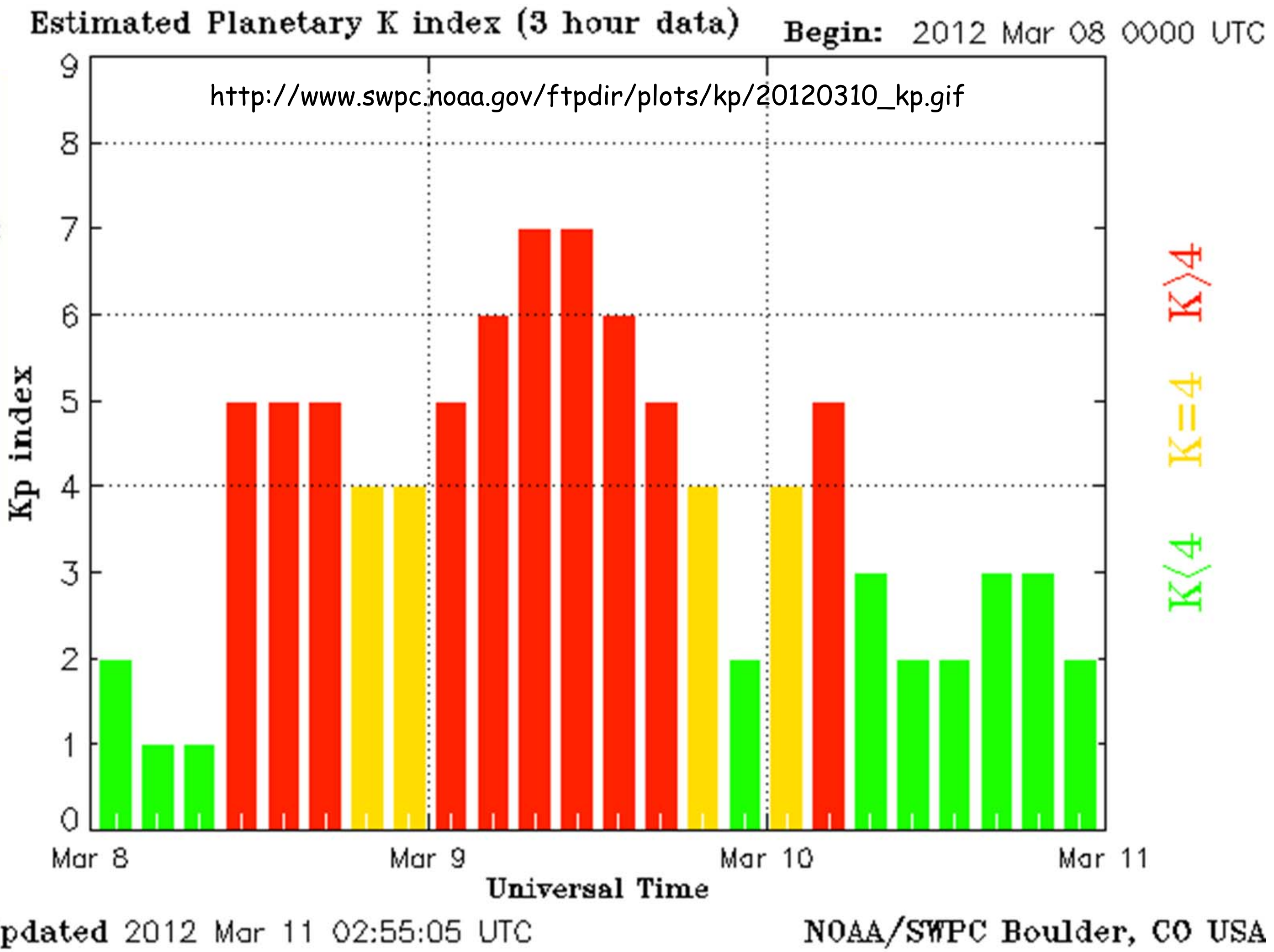
Kp Index

The Kp index is estimated from the average of the disturbance levels in the most disturbed horizontal magnetic field component (H or D) at 13 selected mid-latitude stations during three-hour period.

0o, 0+, 1-, 1o, 1+, 2-, 2o, 2+, ... , 8o, 8+, 9-, 9o



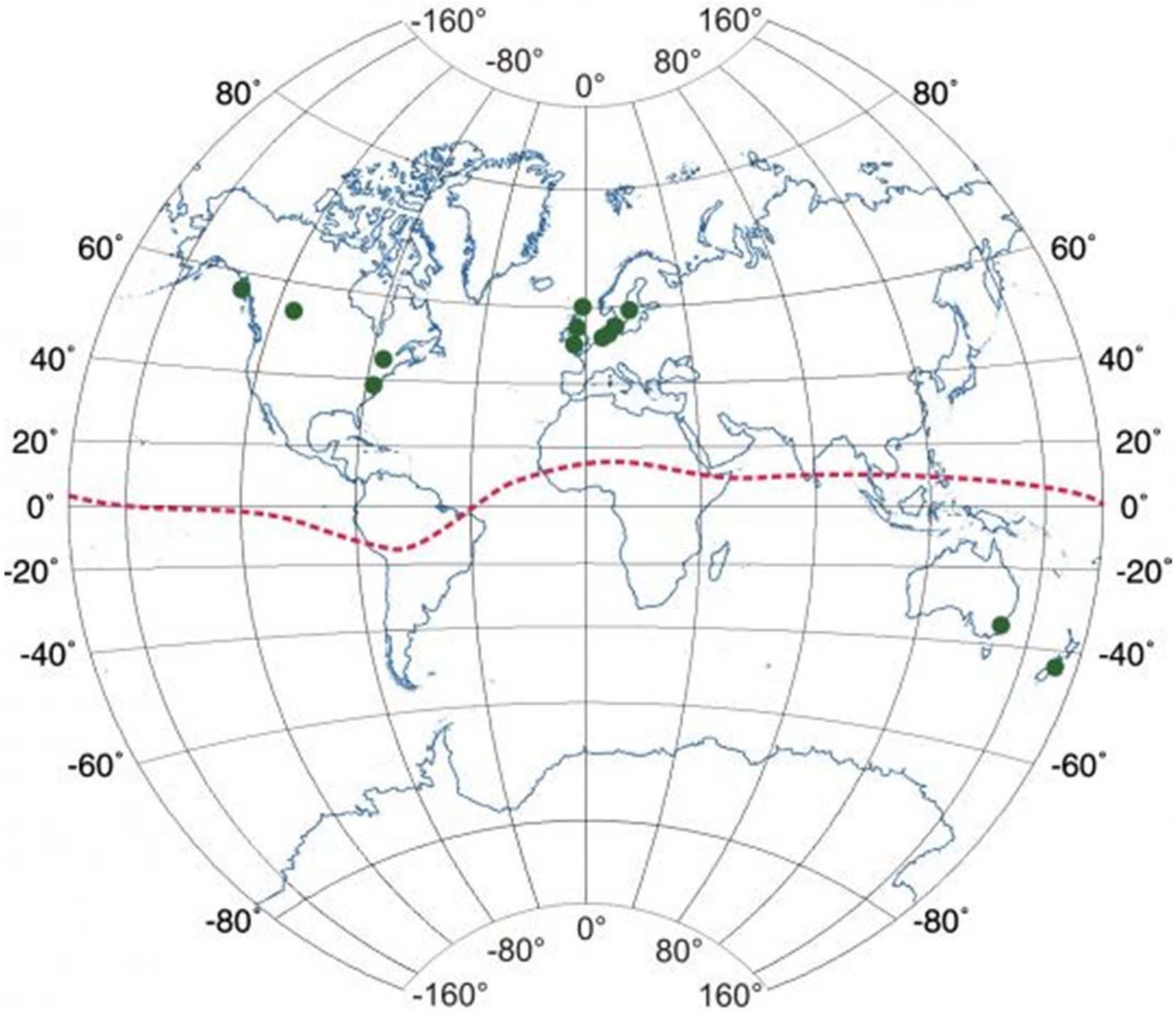
http://www.thecamino.com.ar/KPindex.htm



http://www.swpc.noaa.gov/ftpdir/plots/kp/20120310_kp.gif

http://wwwuser.gwdg.de/~rhennin/kp.html

Kp Index

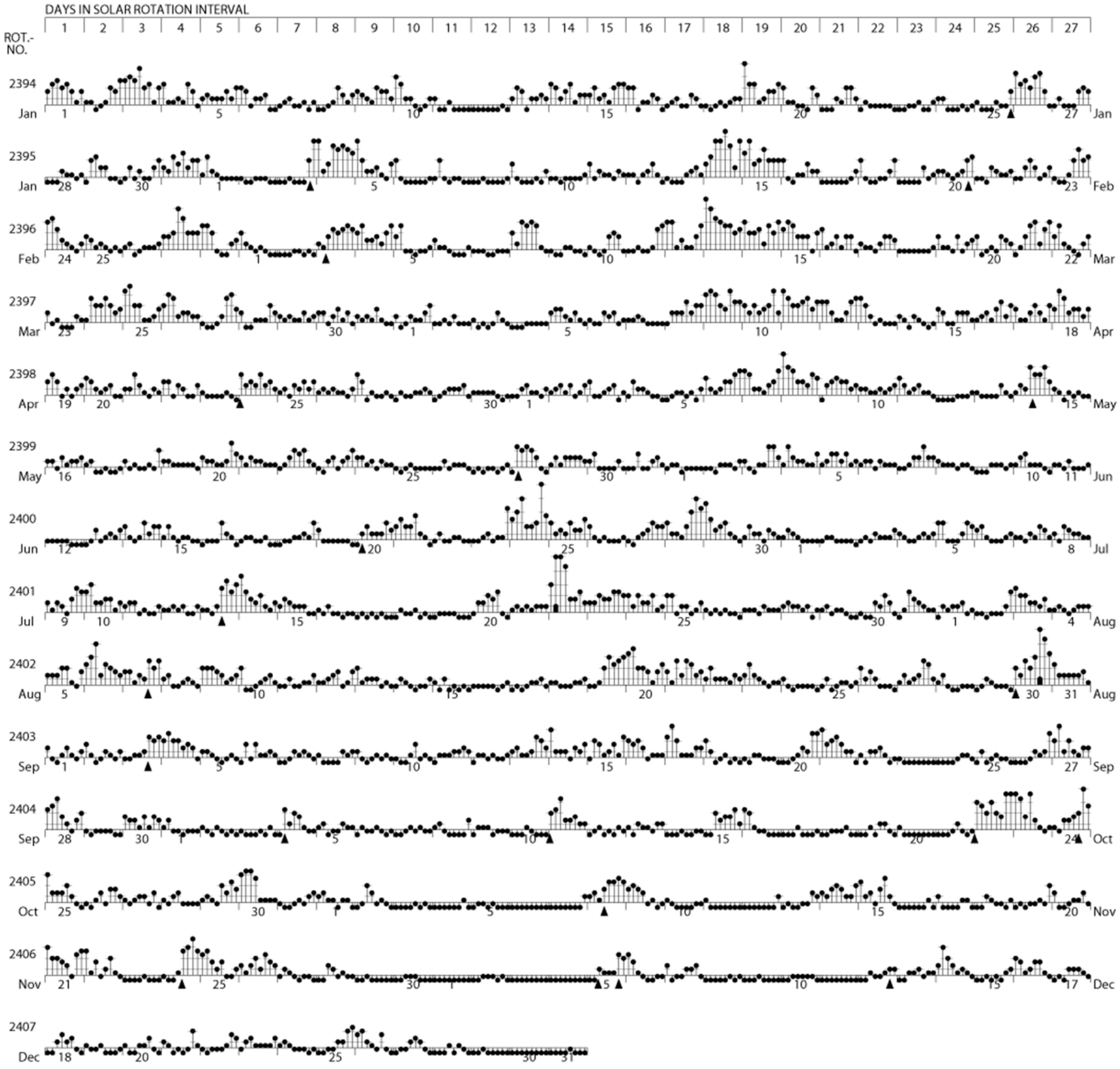


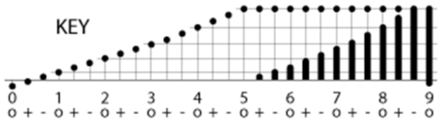
http://roma2.rm.ingv.it/userfiles/image/tematiche/IndiciGeomagnetici/Kp_obs.jpg

Kp Index

		Observatory			Geographic		Geomagnetic		K=9 (nT)
#	Code	Name	Location	Active	Lat.	Long.	Lat.*	Long.*	
1	LER	Lerwick	Scotland	1932-actual	60°08'	358°49'	62.0°	89.2°	1000
2	MEA	Meanook	Canada	1932-actual	54°37'	246°40'	61.7°	305.7°	1500
3	SIT	Sitka	Alaska (US)	1932-actual	57°03'	224°40'	60.4°	279.8°	1000
4	ESK	Eskdalemuir	Scotland	1932-actual	55°19'	356°48'	57.9°	83.9°	750
5	LOV	Lovö	Sweden	1954-2004	59°21'	17°50'	57.9°	106.5°	600
	UPS	Uppsala	Sweden	2004-actual	59°54'	17°21'	58.5°	106.4°	600
6	AGN	Agincourt	Canada	1932-1969	43°47'	280°44'	54.1°	350.5°	600
	OTT	Ottawa	Canada	1969-actual	45°24'	284°27'	55.8°	355.0°	750
7	RSV	Rude Skov	Denmark	1932-1984	55°51'	12°27'	55.5°	99.4°	600
	BFE	Brorfelde	Denmark	1984-actual	55°37'	11°40'	55.4°	98.6°	600
8	ABN	Abinger	England	1932-1957	51°11'	359°37'	53.4°	84.5°	500
	HAD	Hartland	England	1957-actual	50°58'	355°31'	54.0°	80.2°	500
9	WNG	Wingst	Germany	1938-actual	53°45'	9°04'	54.1°	95.1°	500
10	WIT	Witteveen	Netherland	1932-1988	52°49'	6°40'	53.7°	92.3°	500
	NGK	Niemegk	Germany	1988-actual	52°04'	12°41'	51.9°	97.7°	500
11	CLH	Cheltenham	USA	1932-1957	38°42'	283°12'	49.1°	353.8°	500
	FRD	Fredericksburg	USA	1957-actual	38°12'	282°38'	48.6°	353.1°	500
12	TOO	Toolangi	Australia	1972-1981	-37°32'	145°28'	-45.6°	223.0°	500
	CNB	Canberra	Australia	1981-actual	-35°18'	149°00'	-42.9°	226.8°	450
13	AML	Amberley	New Zealand	1932-1978	-43°09'	172°43'	-46.9°	254.1°	500
	EYR	Eyrewell	New Zealand	1978-actual	-43°25'	172°21'	-47.2°	253.8°	50

http://www-app3.gfz-potsdam.de/kp_index/kp_sites.html

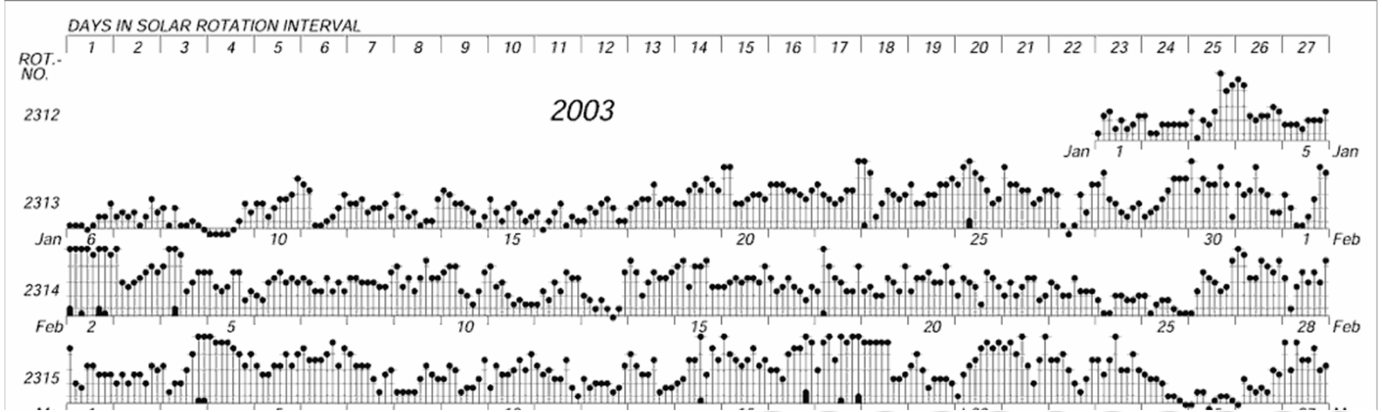


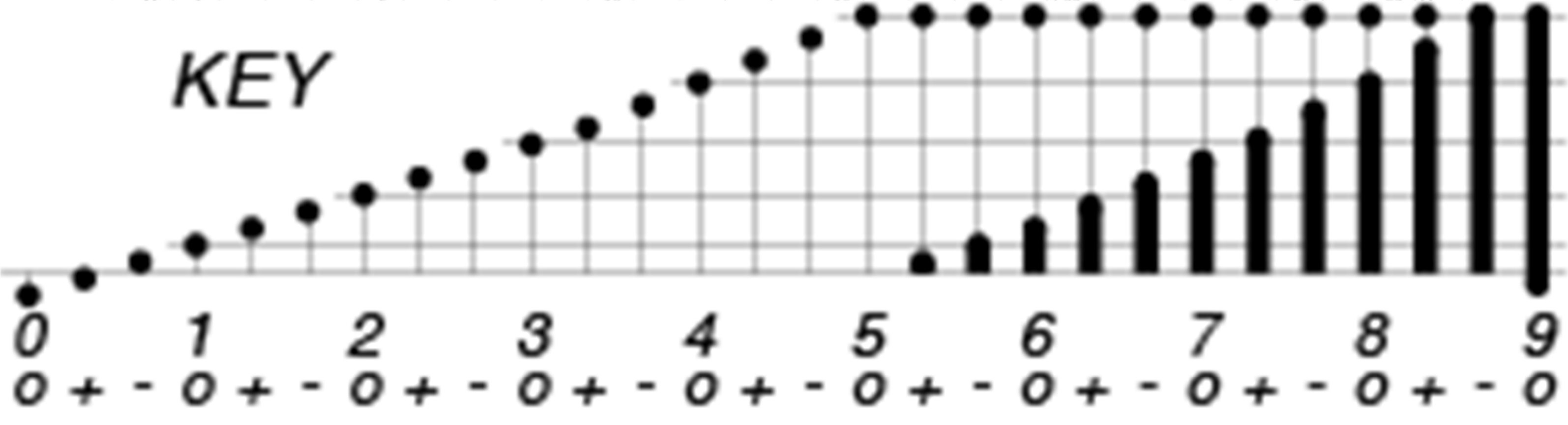


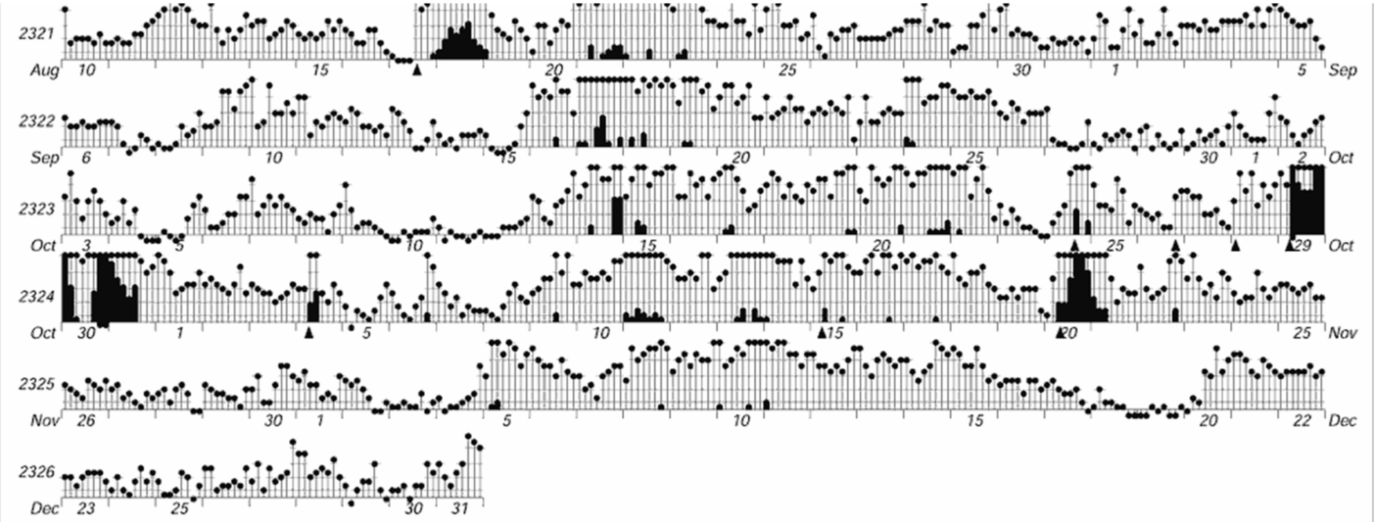
▲ = sudden commencement

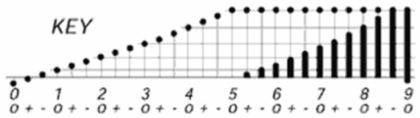
PLANETARY MAGNETIC
THREE-HOUR-RANGE INDICES

Kp 2009





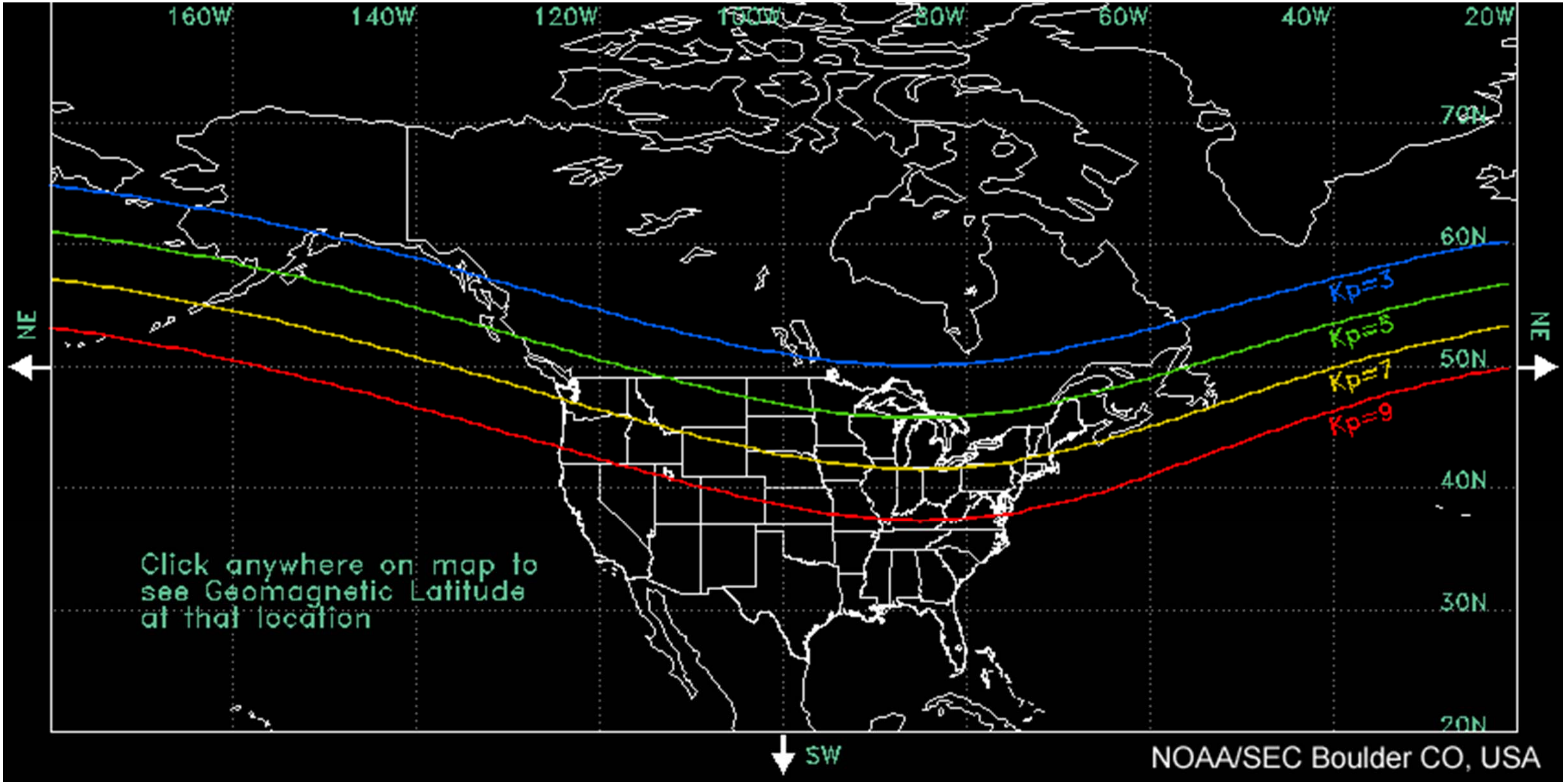




▲ = sudden commencement

PLANETARY MAGNETIC
THREE-HOUR-RANGE INDICES

Kp 2003



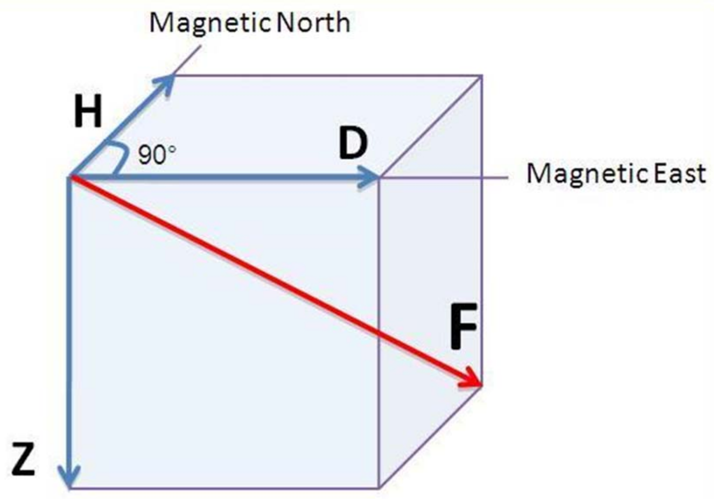
http://www.swpc.noaa.gov/Aurora/globeNW.html

AE (Auroral Electrojet) Index

The AE indices (AU, AL, AO, and AE) are derived from geomagnetic variations in the horizontal component during one-minute interval observed at selected observatories along the auroral zone in the northern hemisphere.

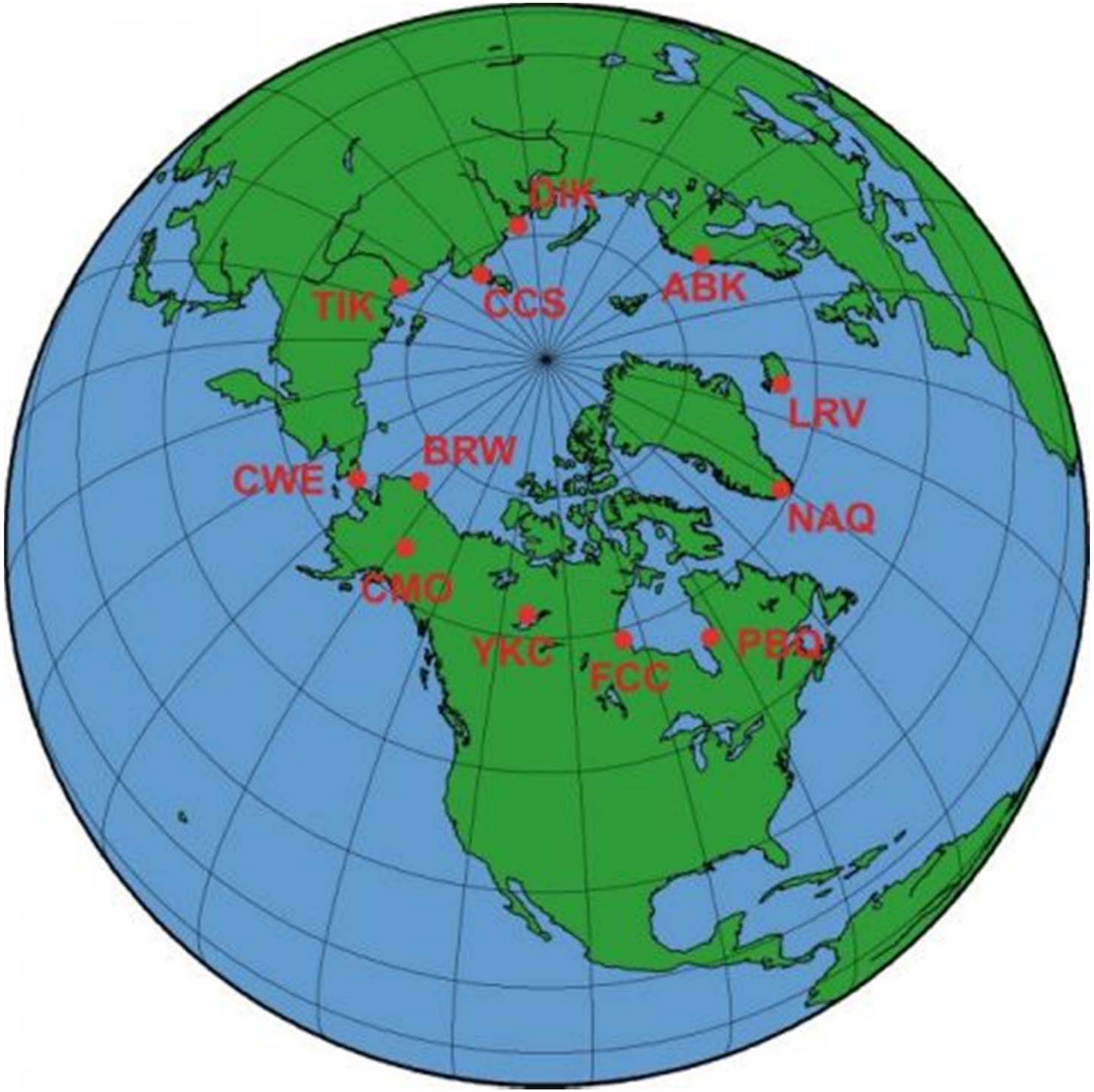
TABLE 1 - List of AE(12) Stations.

	IAGA	Geographic Coord.		Geomagnetic Coord.	
Observatory	**Code**	**Lat.(°N)**	**Long.(°E)**	**Lat.(°N)**	**Long.(°E)**
Abisko	ABK	68.36	18.82	66.04	115.08
Dixon Island	DIK	73.55	80.57	63.02	161.57
Cape Chelyuskin	CCS	77.72	104.28	66.26	176.46
Tixie Bay	TIK	71.58	129.00	60.44	191.41
Cape Wellen	CWE	66.17	190.17	61.79	237.10
Barrow	BRW	71.30	203.25	68.54	241.15
College	CMO	64.87	212.17	64.63	256.52
Yellowknife	YKC	62.40	245.60	69.00	292.80
Fort Churchill	FCC	58.80	265.90	68.70	322.77
Poste-de-la-Baleine	PBQ	55.27	282.22	66.58	347.36
Narsarsuaq (Narssarssuaq)	NAQ	61.20	314.16	71.21	36.79
Leirvogur	LRV	64.18	338.30	70.22	71.04



http://wdc.kugi.kyoto-u.ac.jp/aedir/ae2/AEObs.html

AE (Auroral Electrojet) Index



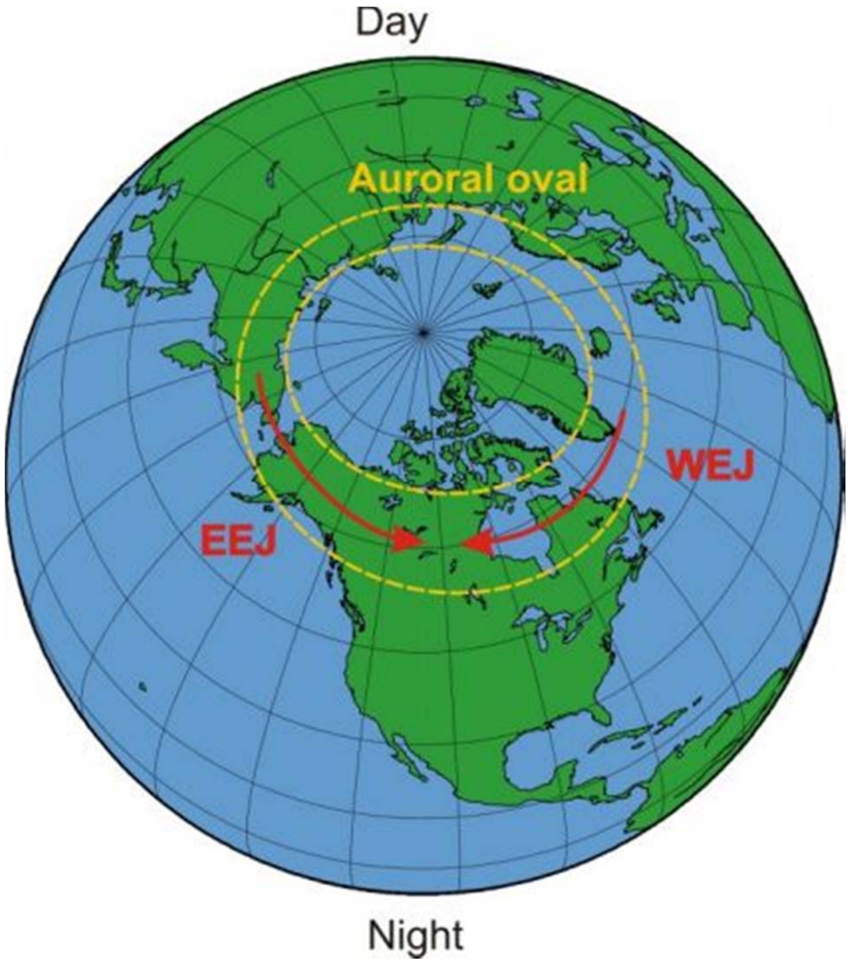
http://roma2.rm.ingv.it/en/themes/23/geomagnetic_indices/26/auroral_electroject_indices

AE Index
(Auroral Electrojet)

AU (Auroral Upper) is the uppermost envelope of the superposed H-component perturbations at auroral latitudes

AL (Auroral Lower) is the lowest envelope of the superposed H-component perturbations at auroral latitudes

AO= (AU + AL)/2; AE= AU – AL



→AU is a measure of the eastward auroral electrojet (EEJ).

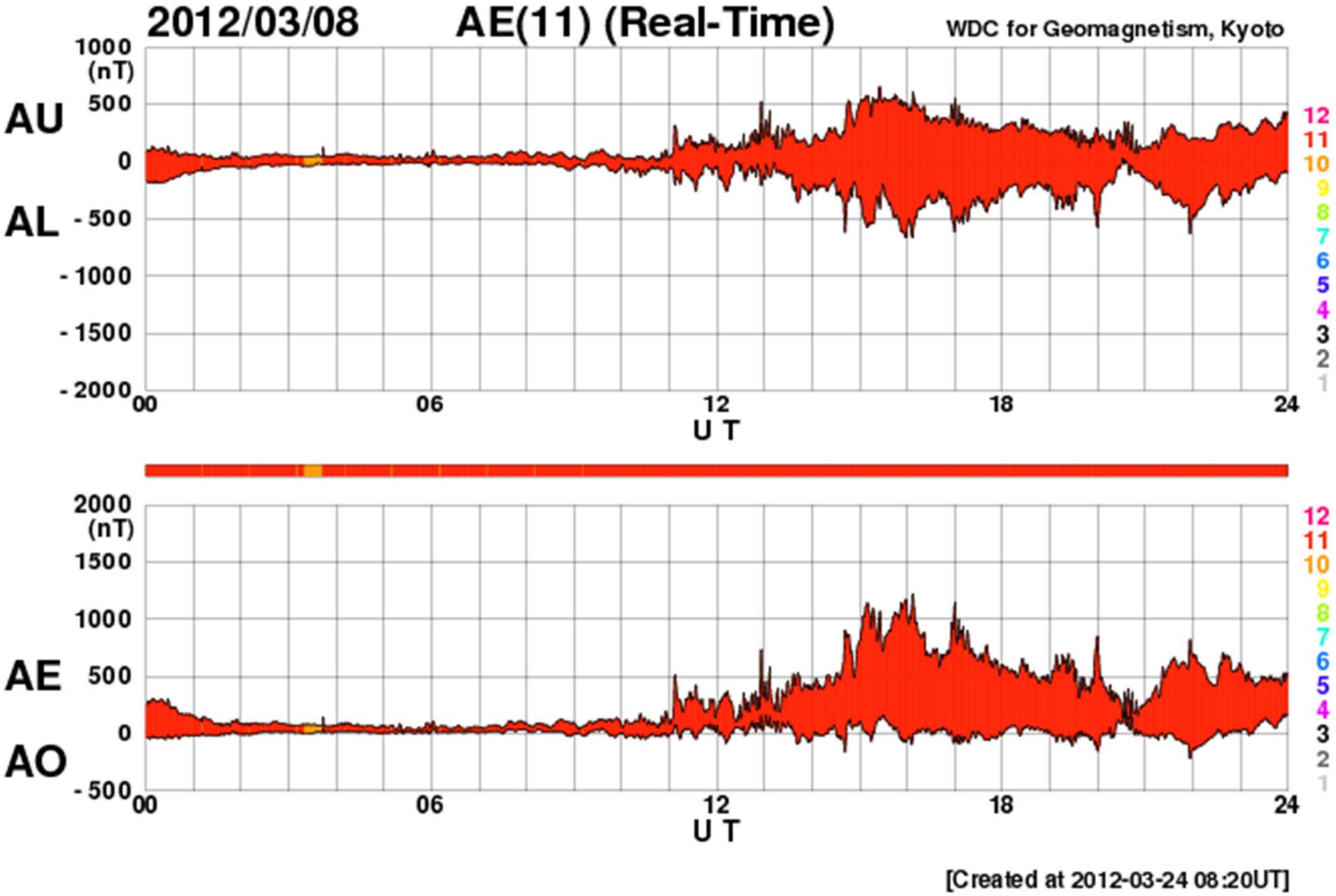
→AL is a measure of the westward auroral electroject (WEJ).

→AO is a measure of the equivalent zonal current.

→AE is the integrated effect of different current systems and not necessarily quantify specific physical processes occurring in the magnetosphere-ionosphere coupling system.

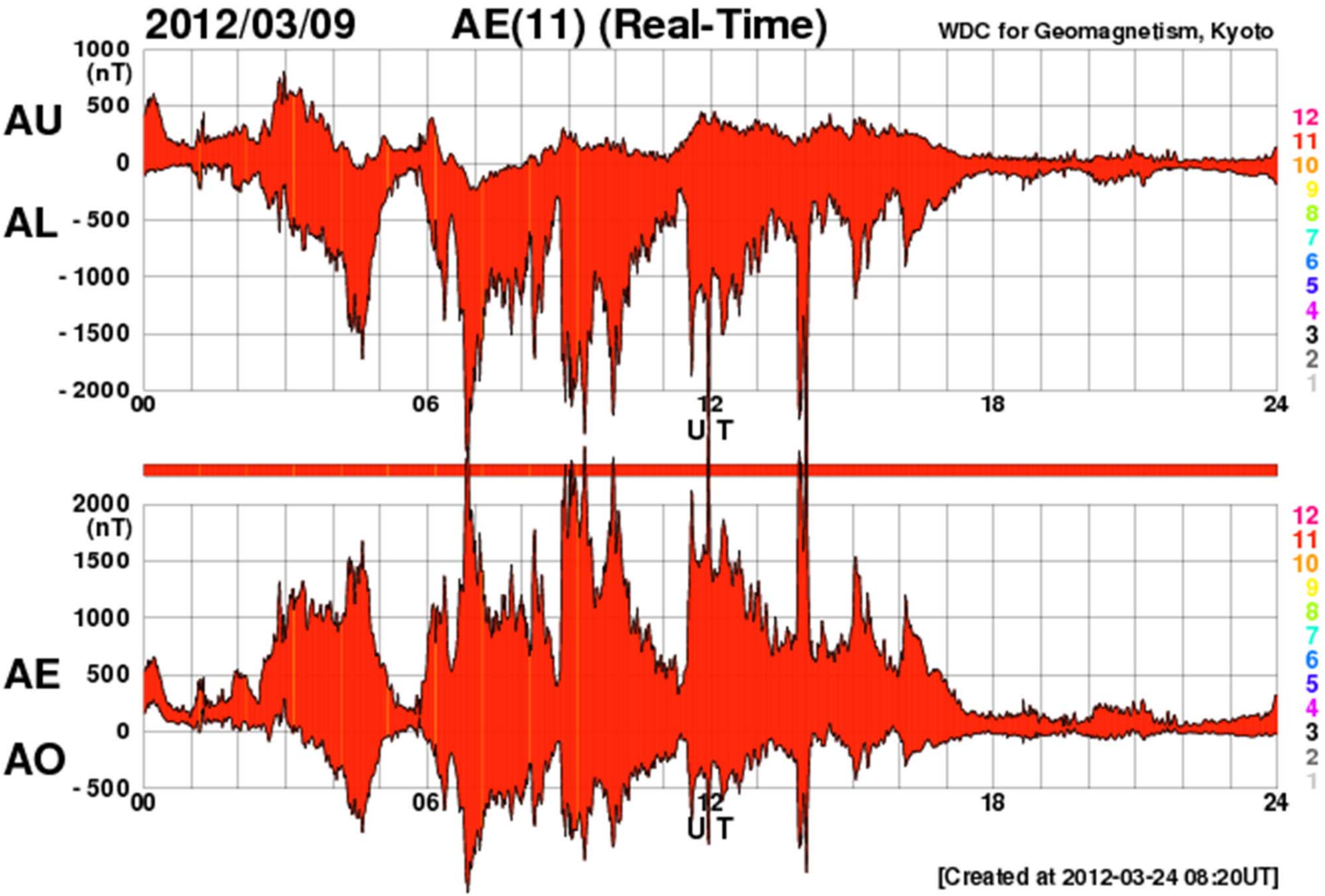
http://roma2.rm.ingv.it/en/themes/23/geomagnetic_indices/26/auroral_electroject_indices

AE (Auroral Electrojet) Index



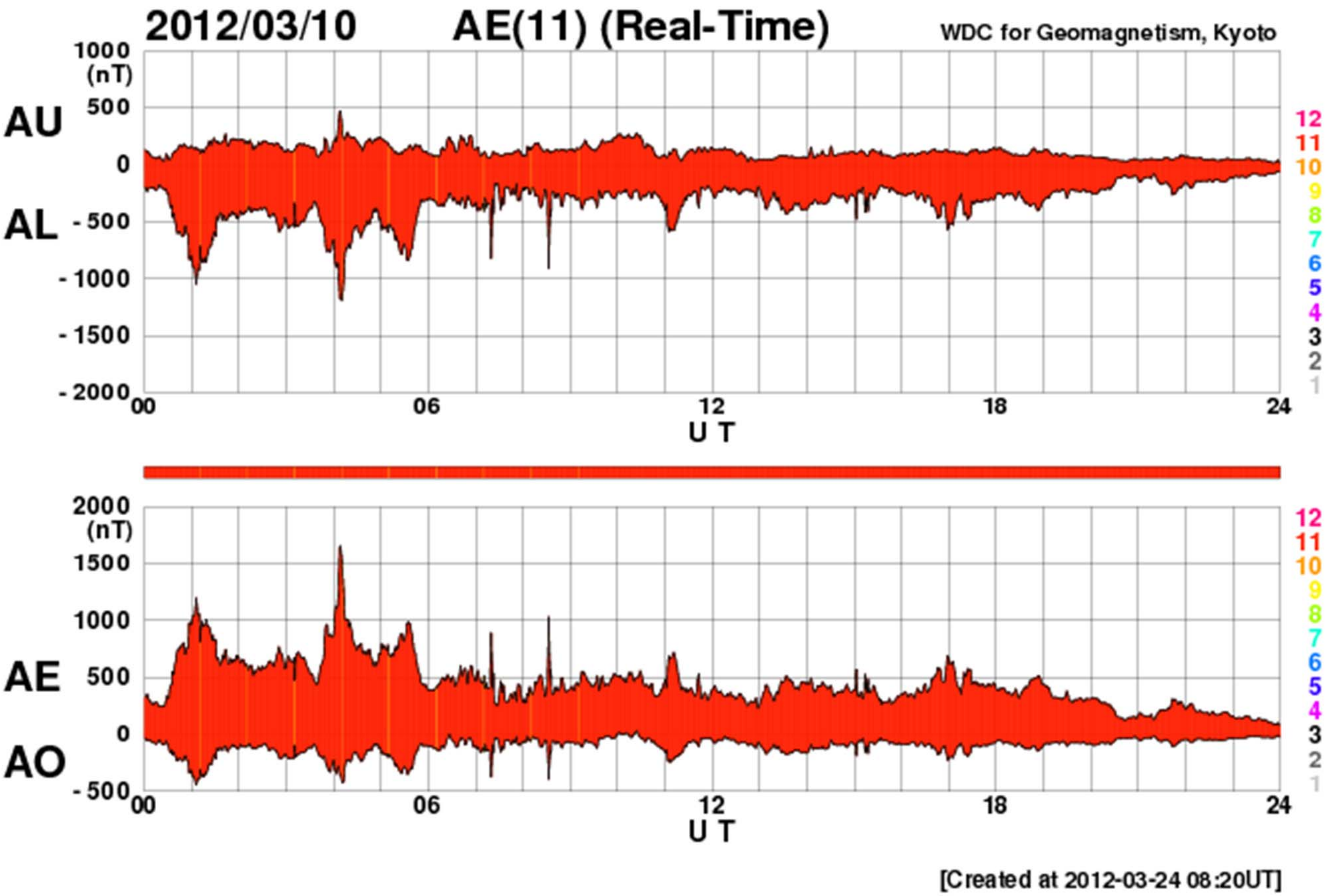
http://wdc.kugi.kyoto-u.ac.jp/aedir/index.html

AE (Auroral Electrojet) Index



http://wdc.kugi.kyoto-u.ac.jp/aedir/index.html

AE (Auroral Electrojet) Index



http://wdc.kugi.kyoto-u.ac.jp/aedir/index.html

磁暴(magnetic storm)

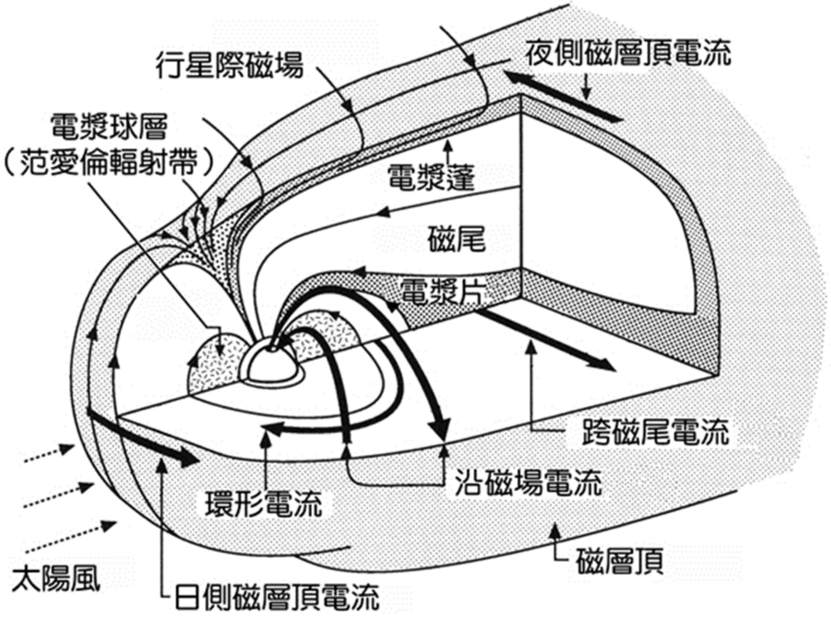
→持續時間約3天至一個多星期

→影響地表中低緯度區域

→過程:

initial phase:

日側磁層頂內移，日側磁層頂電流強度增強，中低緯地表磁場增強



main phase:

電漿球層頂內移，范愛倫輻射帶的高能粒子數目增多，環形電流強度增強，中低緯地表磁場減弱

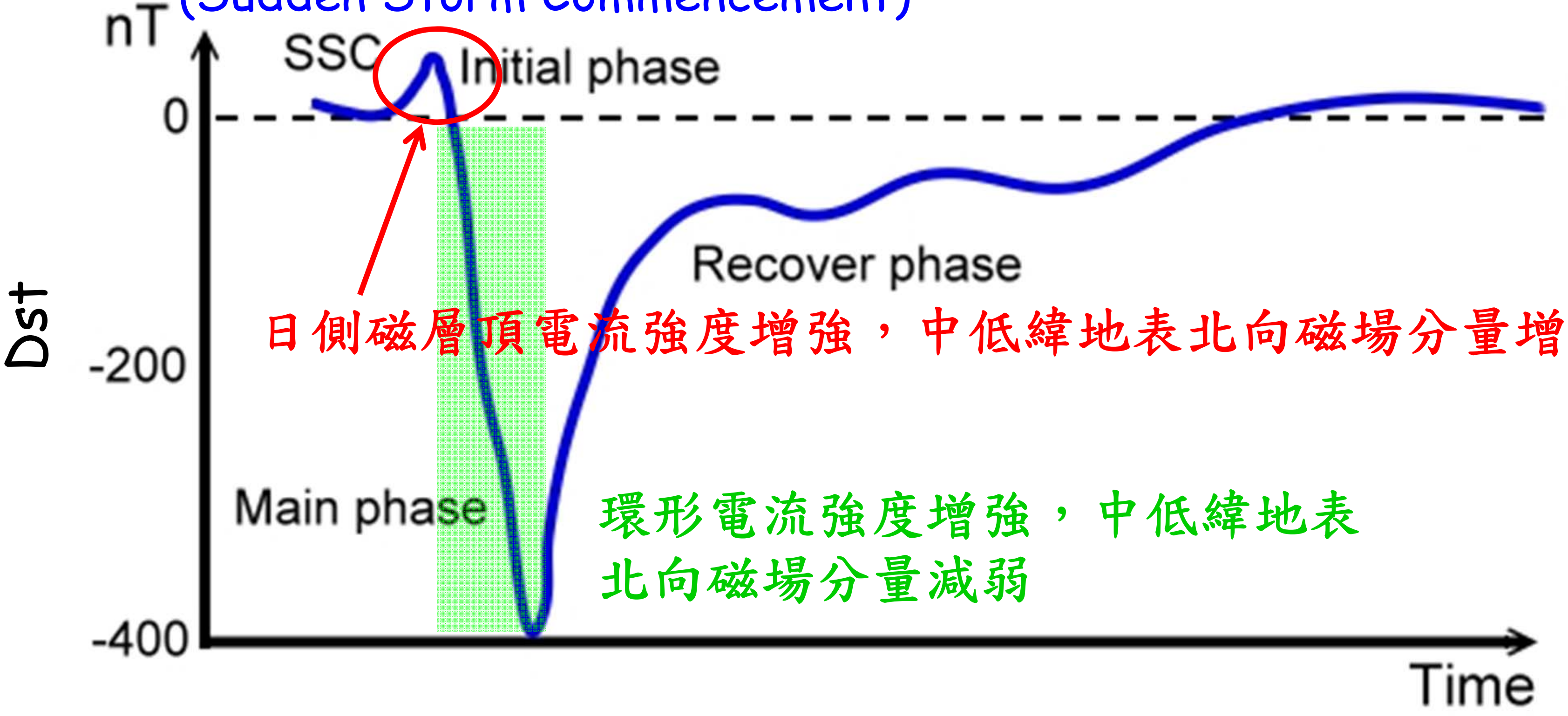
recovery phase:

磁層頂與電漿球層頂還原到安靜期的位置

http://www.ss.ncu.edu.tw/~lyu/lecture_files/

Dst (Disturbance Storm Time) Index

Super storms	Dst < -200 nT
Intense storms	-200 nT < Dst < -100 nT
Moderate storms	-100 nT < Dst < -50 nT
Weak storms	-50 nT < Dst < -30 nT



(Sudden Storm Commencement)

日側磁層頂電流強度增強，中低緯地表北向磁場分量增強

環形電流強度增強，中低緯地表
北向磁場分量減弱

http://roma2.rm.ingv.it/en/themes/23/geomagnetic_indices/27/dst_index

磁副暴(magnetic substorm)

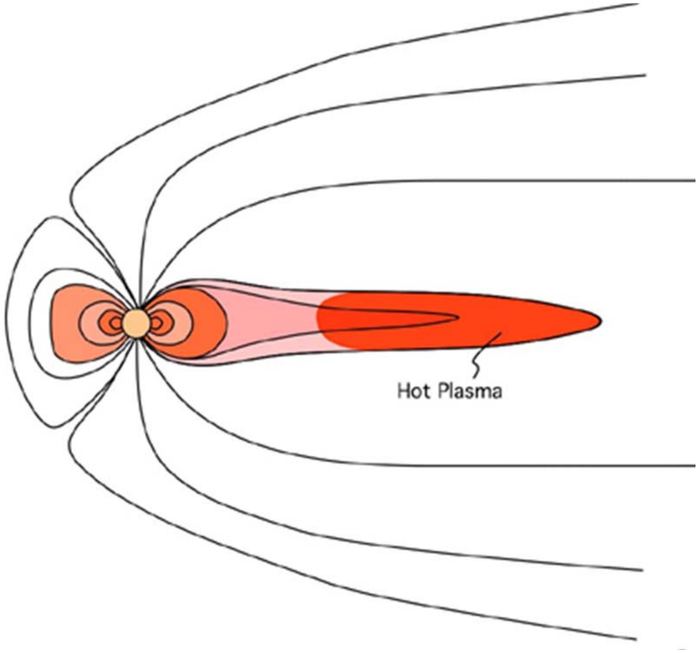
→持續時間約3小時

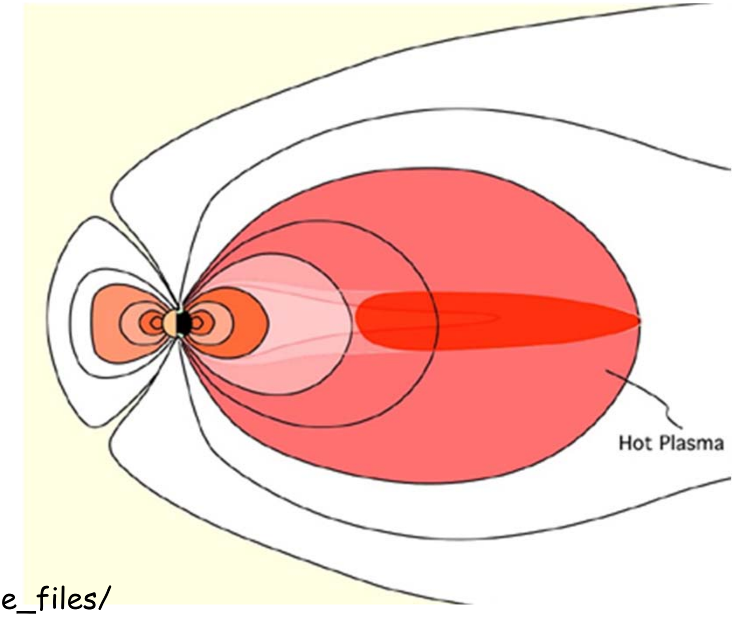
→影響地表高緯度區域

→過程:

grow phase:
磁尾電漿片變薄，連原來接近磁偶極場區域的磁場也被拉長成磁尾的形狀，跨磁尾電流逐漸增強

expansion phase:磁尾電漿片變厚，磁場變成比較像磁偶極場的結構。



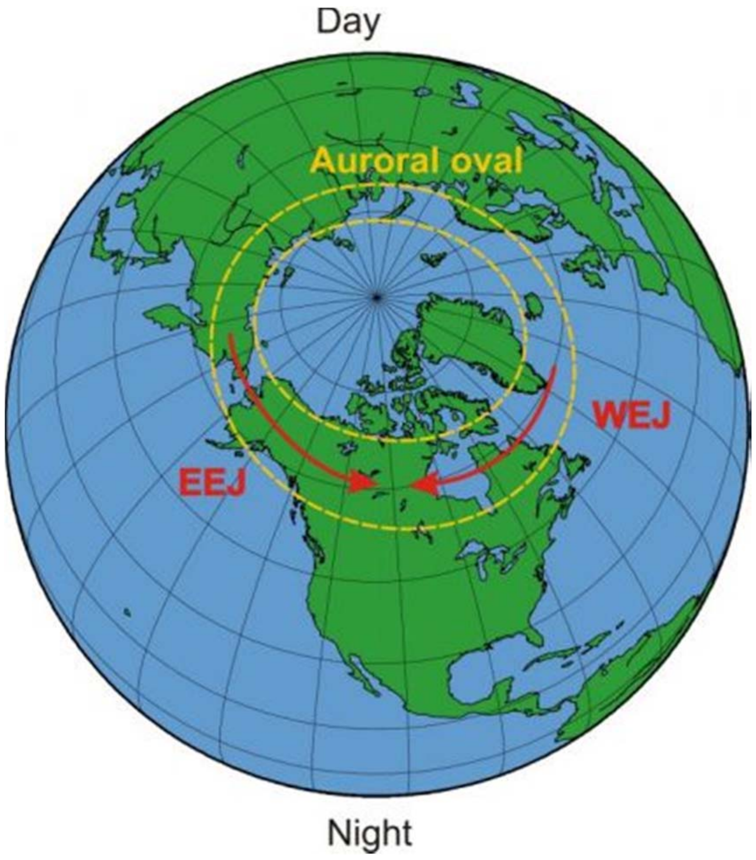


http://www.ss.ncu.edu.tw/~lyu/lecture_files/

磁副暴(magnetic substorm)

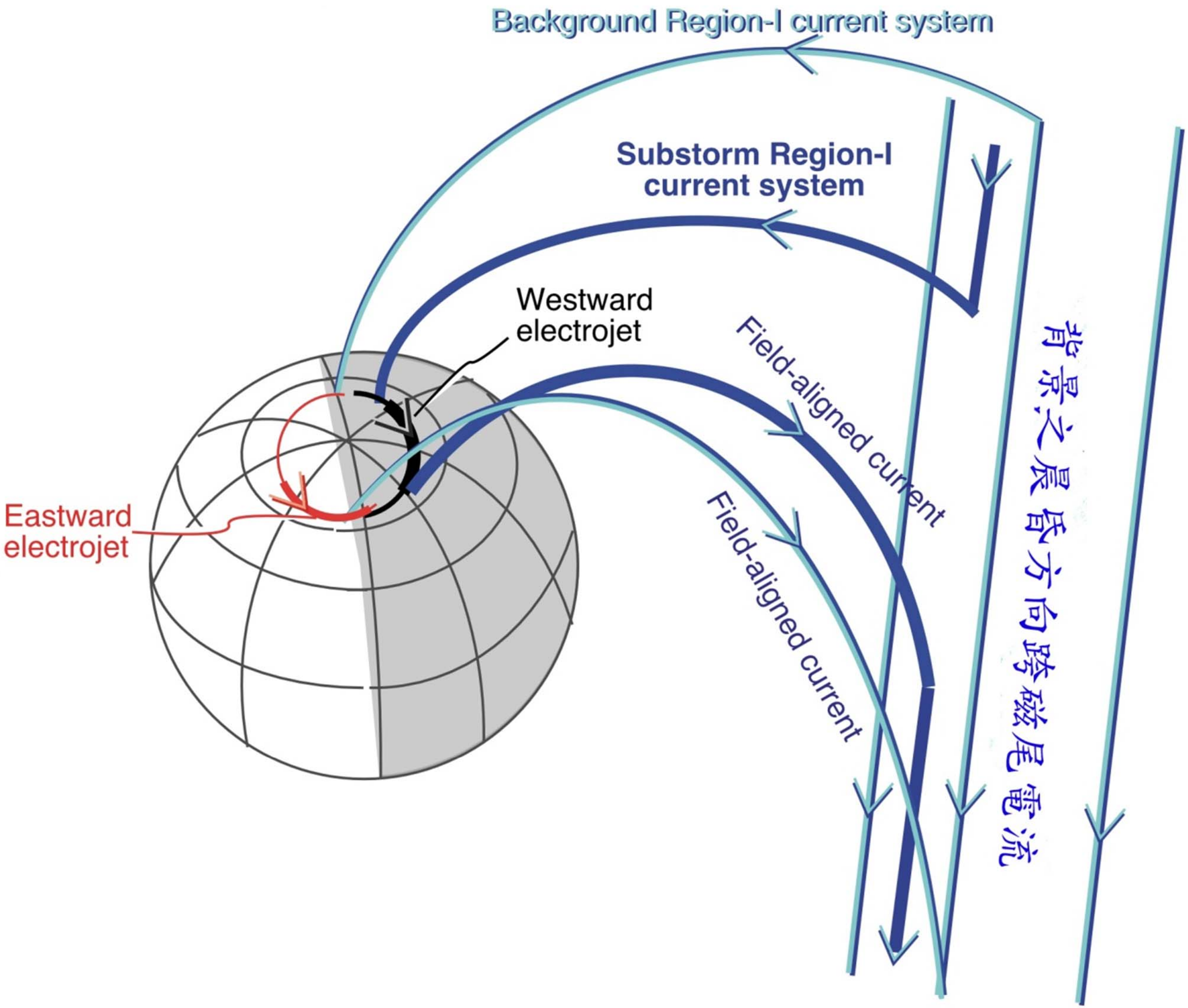
expansion phase:原來應該經由磁尾電漿片由晨到昏的電流被迫改道，先沿磁場線流入晨側電離層，再經由西向電噴流以及東向電噴流由黃昏側流出電離層，再沿磁場線流入黃昏側磁尾。

高緯地區日側電離層東向電噴流增強，造成高緯地區日側地表磁場增強(AU指數變化)。高緯地區夜側電離層西向電噴流增強，造成高緯地區夜側地表磁場減弱(AL指數變化)。



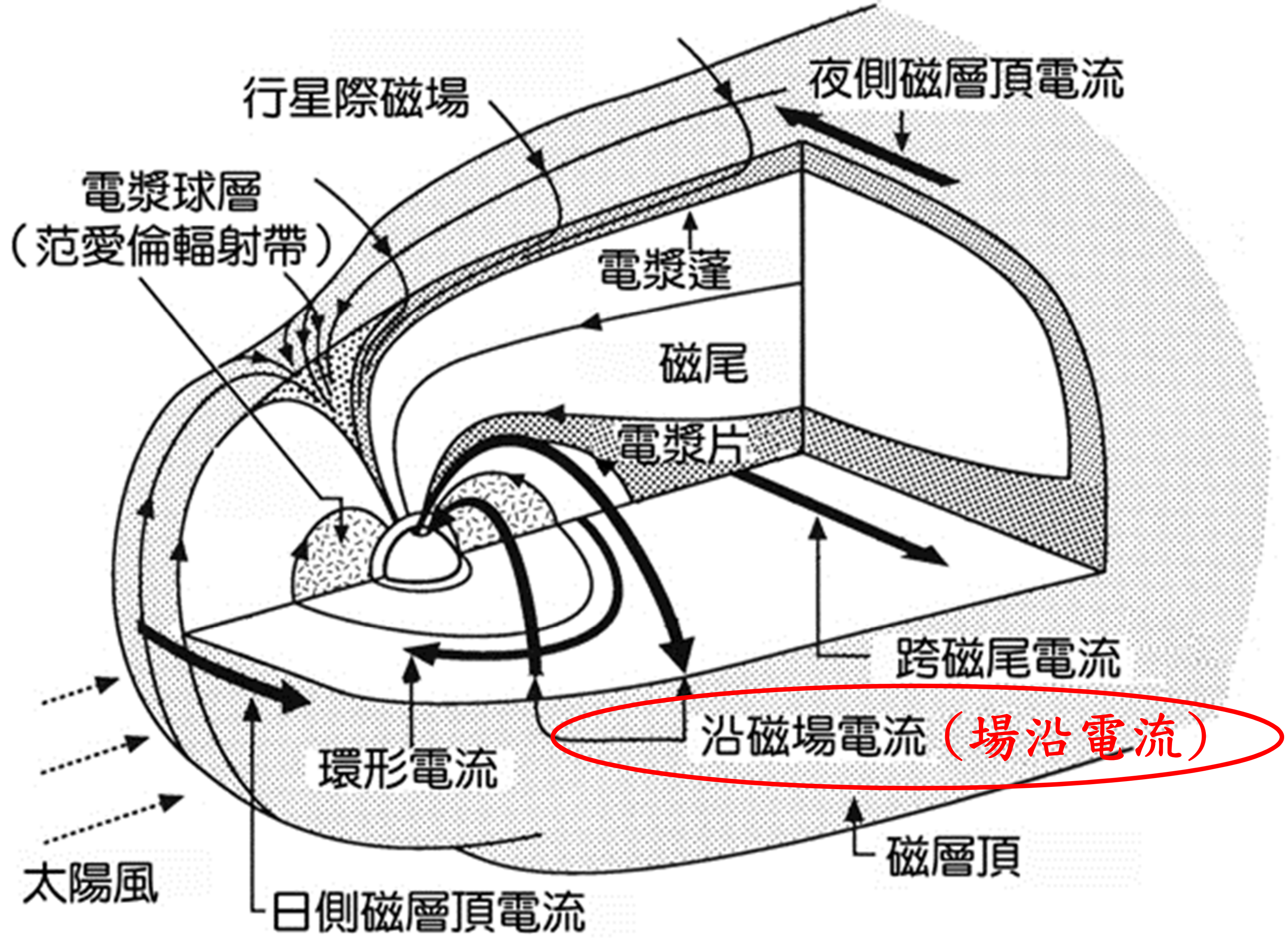
recovery phase:磁層還原為成長期以前的模樣

http://www.ss.ncu.edu.tw/~lyu/lecture_files/

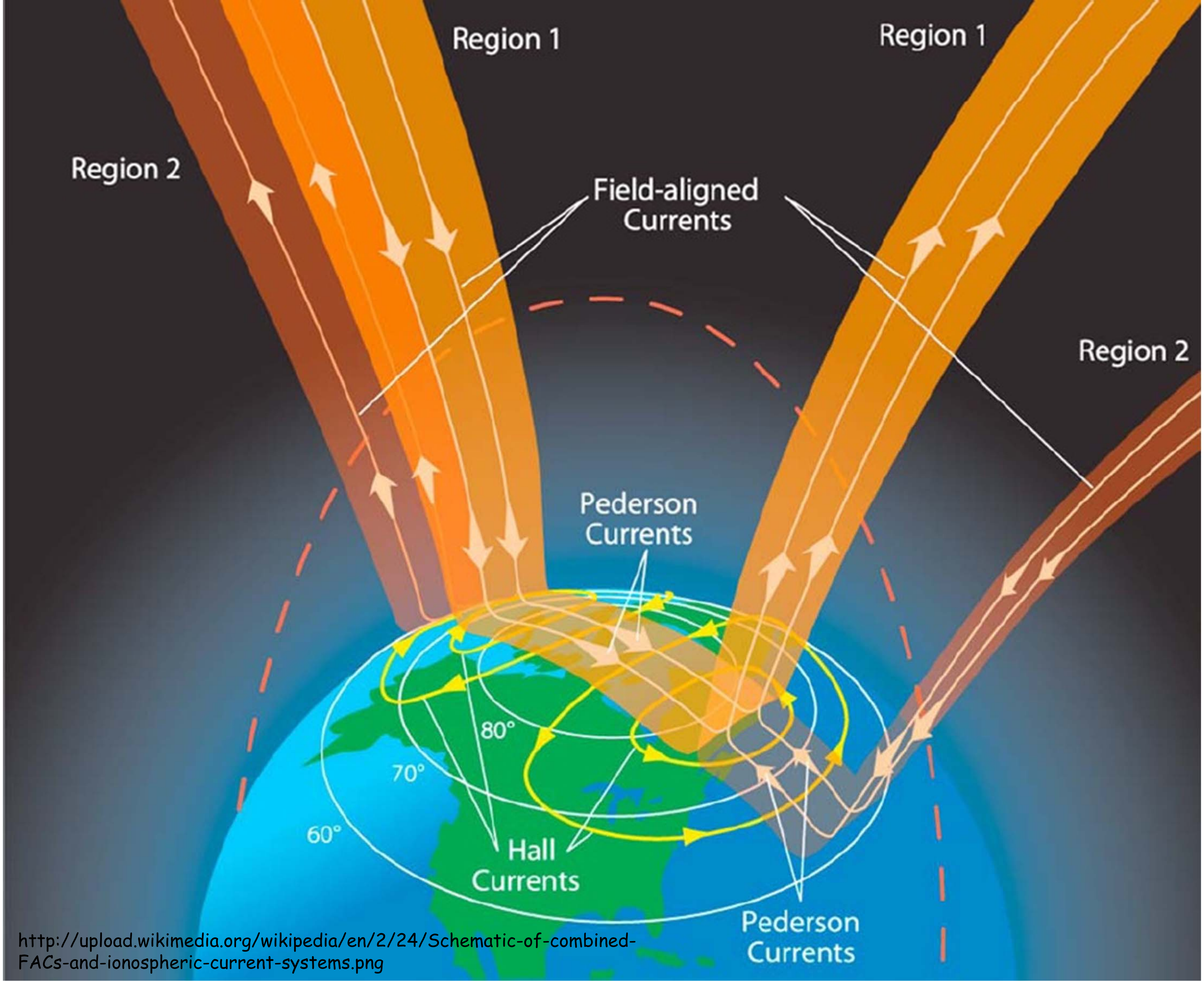


http://www.ss.ncu.edu.tw/~lyu/lecture_files/

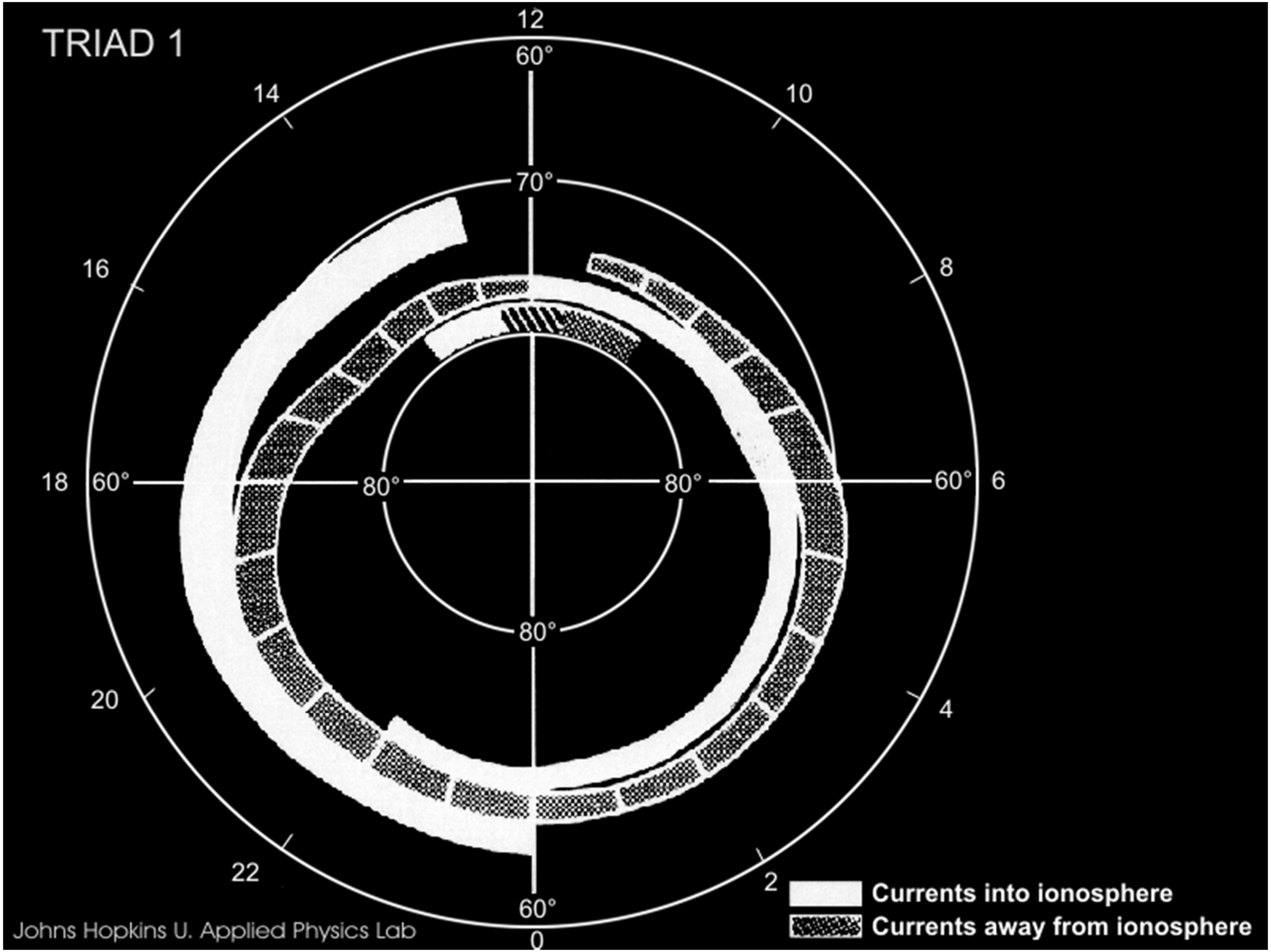
地球磁層電流系統



http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html

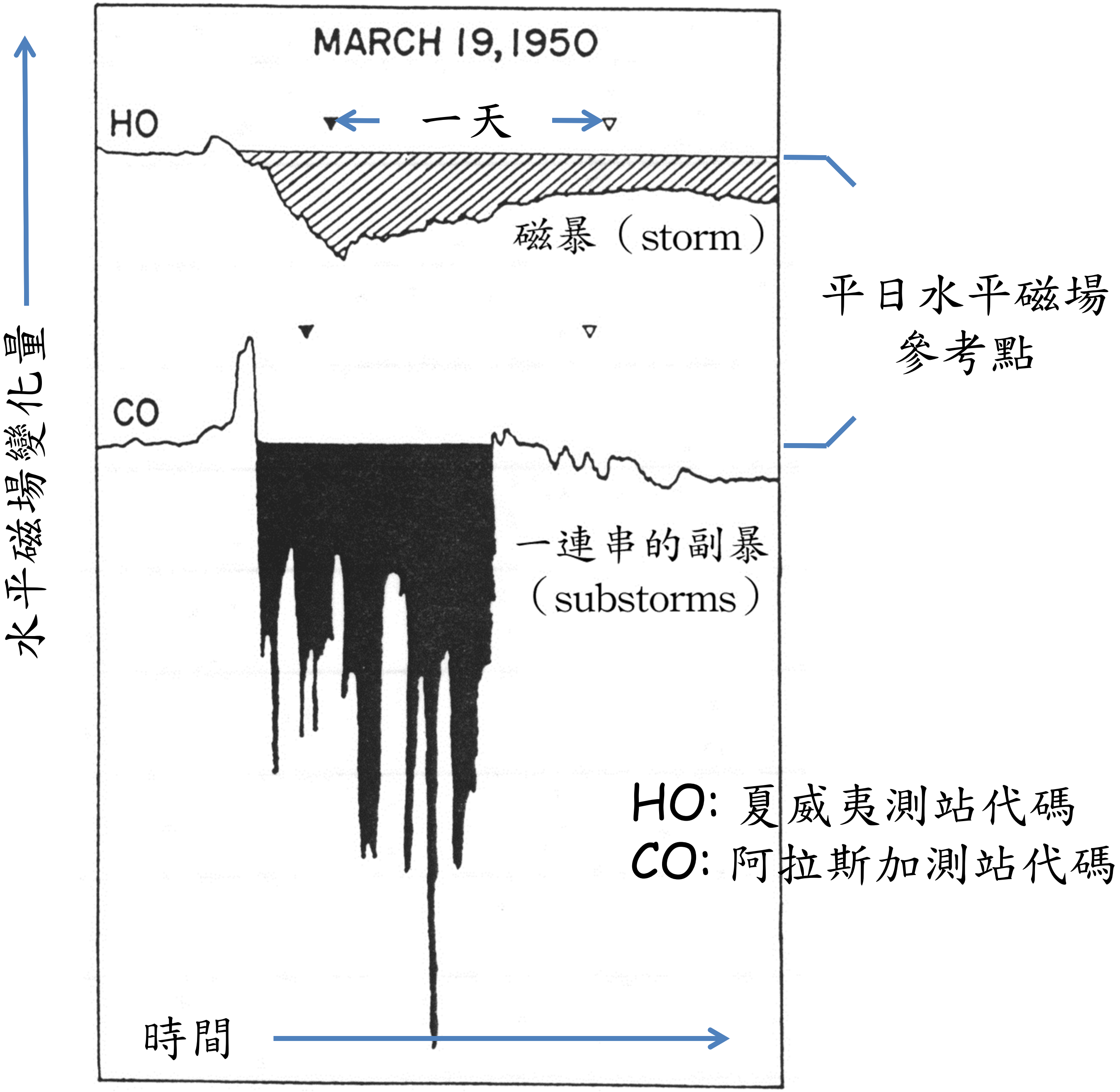


http://upload.wikimedia.org/wikipedia/en/2/24/Schematic-of-combined-FACs-and-ionospheric-current-systems.png



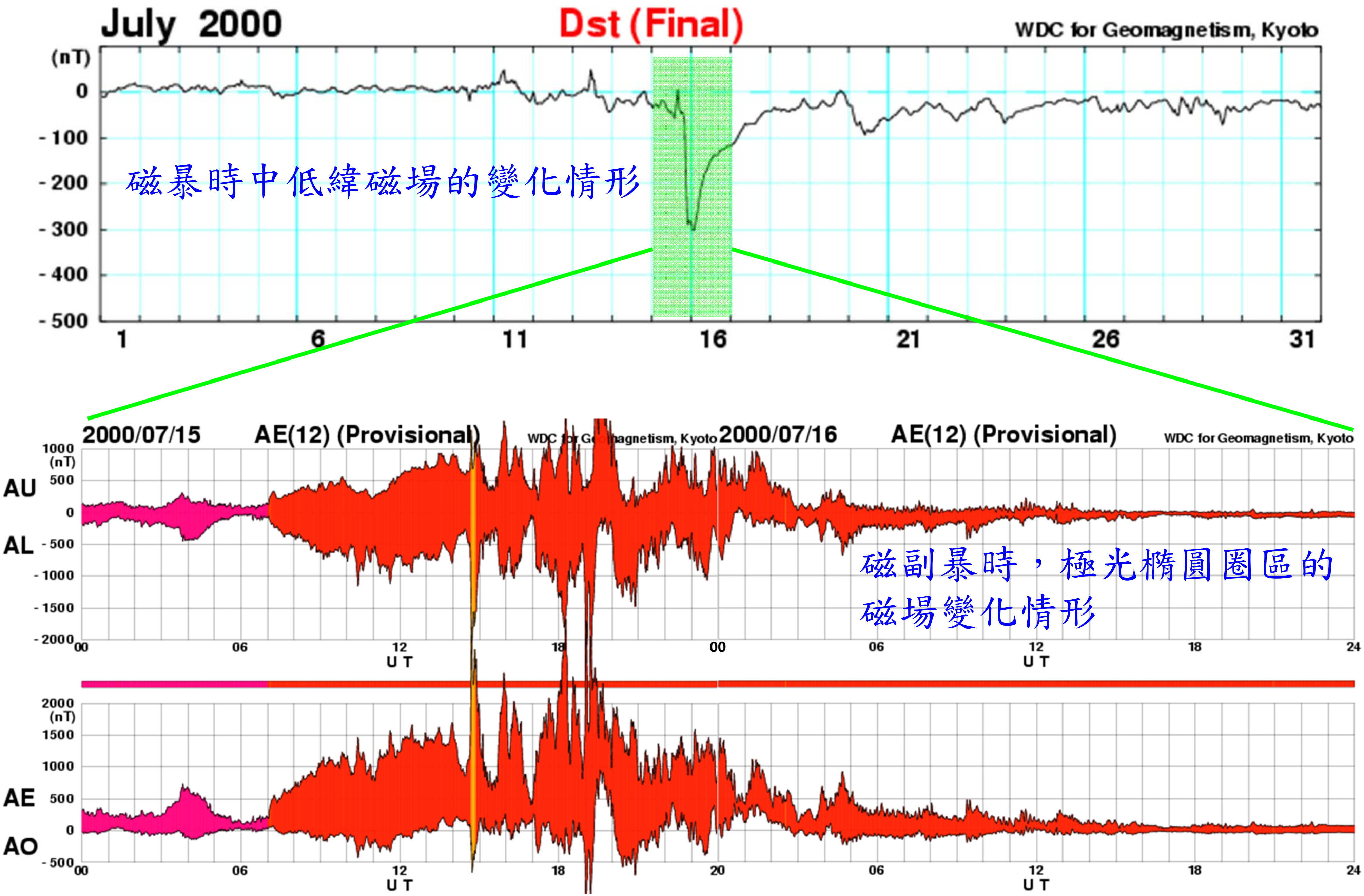
http://www.aldebaran.cz/actions/2002_aurora/various/triad.gif

磁暴與磁副暴



HO: 夏威夷測站代碼
CO: 阿拉斯加測站代碼

http://www.ss.ncu.edu.tw/~lyu/lecture_files/

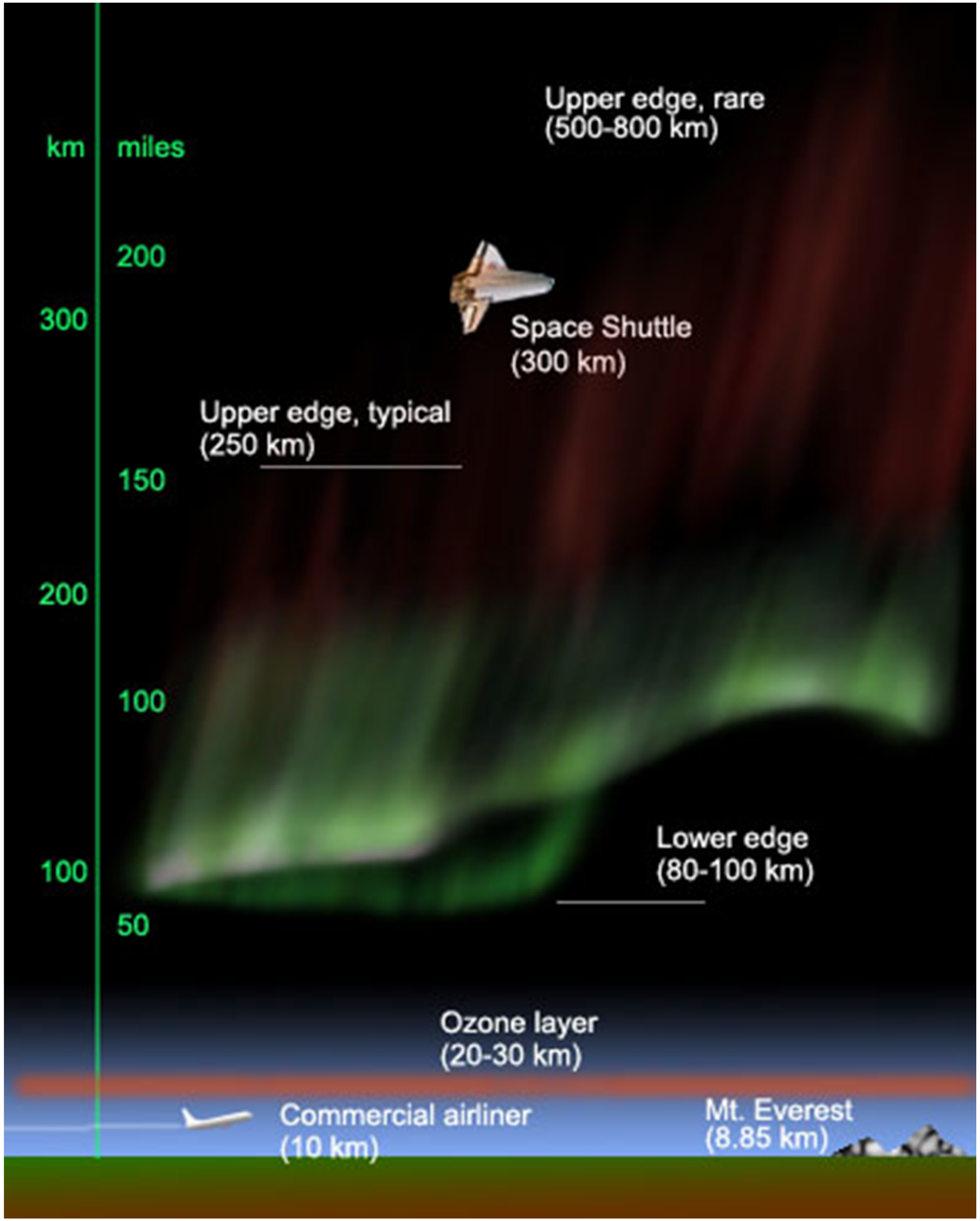


磁暴時中低緯磁場的變化情形

磁副暴時，極光橢圓圈區的磁場變化情形

http://wdc.kugi.kyoto-u.ac.jp/aedir/index.html

http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html


km
miles
Upper edge, rare
(500-800 km)
200
300
Space Shuttle
(300 km)
Upper edge, typical
(250 km)
150
200
100
Lower edge
(80-100 km)
100
50
Ozone layer
(20-30 km)
Commercial airliner
(10 km)
Mt. Everest
(8.85 km)

觀賞極光的時機與地點

→大部分極光出現在高緯度地區的極光橢圓圈(auroral oval)裡，所以高緯地區(例如:阿拉斯加、加拿大、芬蘭、挪威、冰島、瑞典)極光橢圓圈內的晴朗天空夜晚最適合看極光。

→就季節來說，在北半球看極光的最佳時間為8月底至隔年4月底，期間夜晚的長度較長，看到的機率一定比夏季時分高，尤以9月的秋分和3月的春分前後一個月左右的時間是值得推薦的絕佳觀賞時間。

→一天之中，極光最佳觀賞時間通常是午夜前後1、2個小時之內，以及清晨3、4點鐘左右。

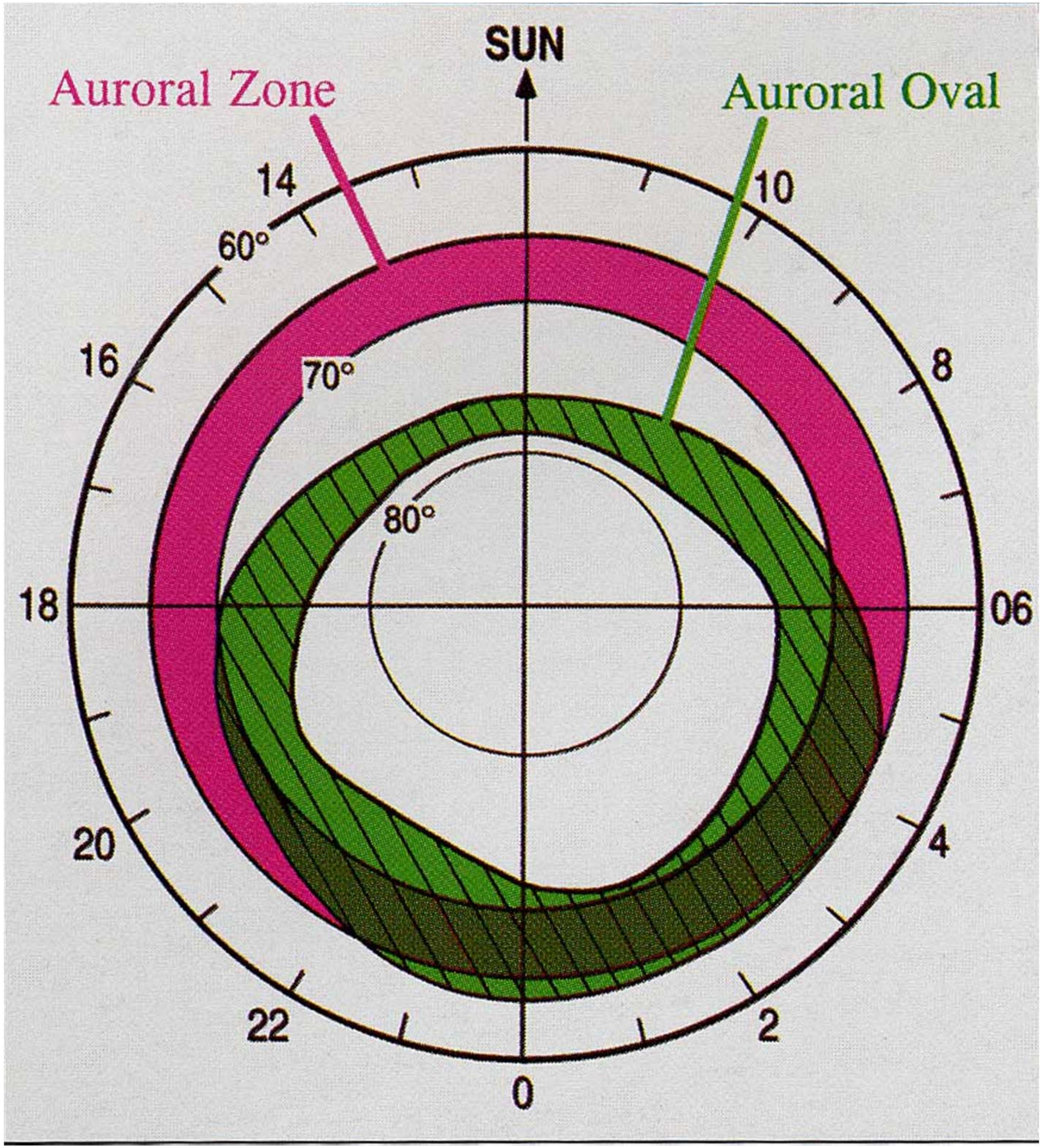
→以阿拉斯加為例，位於中部內陸的費爾班克斯出現多雲甚至下雨的日子，會比南方較靠近海洋的安克拉治少，而且費爾班克斯一年平均有243天的夜晚可能看到極光，而位於南邊相距7、8小時車程遠的安克拉治，一年平均只有1百天。

http://hchaurora.myweb.hinet.net/light.htm

Auroral Zone is a circular region around the magnetic north and south poles between 65 and 75 degrees latitude. However, the Aurora is actually distributed about an oval-shaped band that rotates about the auroral zone. This band is called Auroral Oval.

“Aurora Borealis”:the aurora in the northern auroral oval

“Aurora Australis” : the aurora in the southern auroral oval

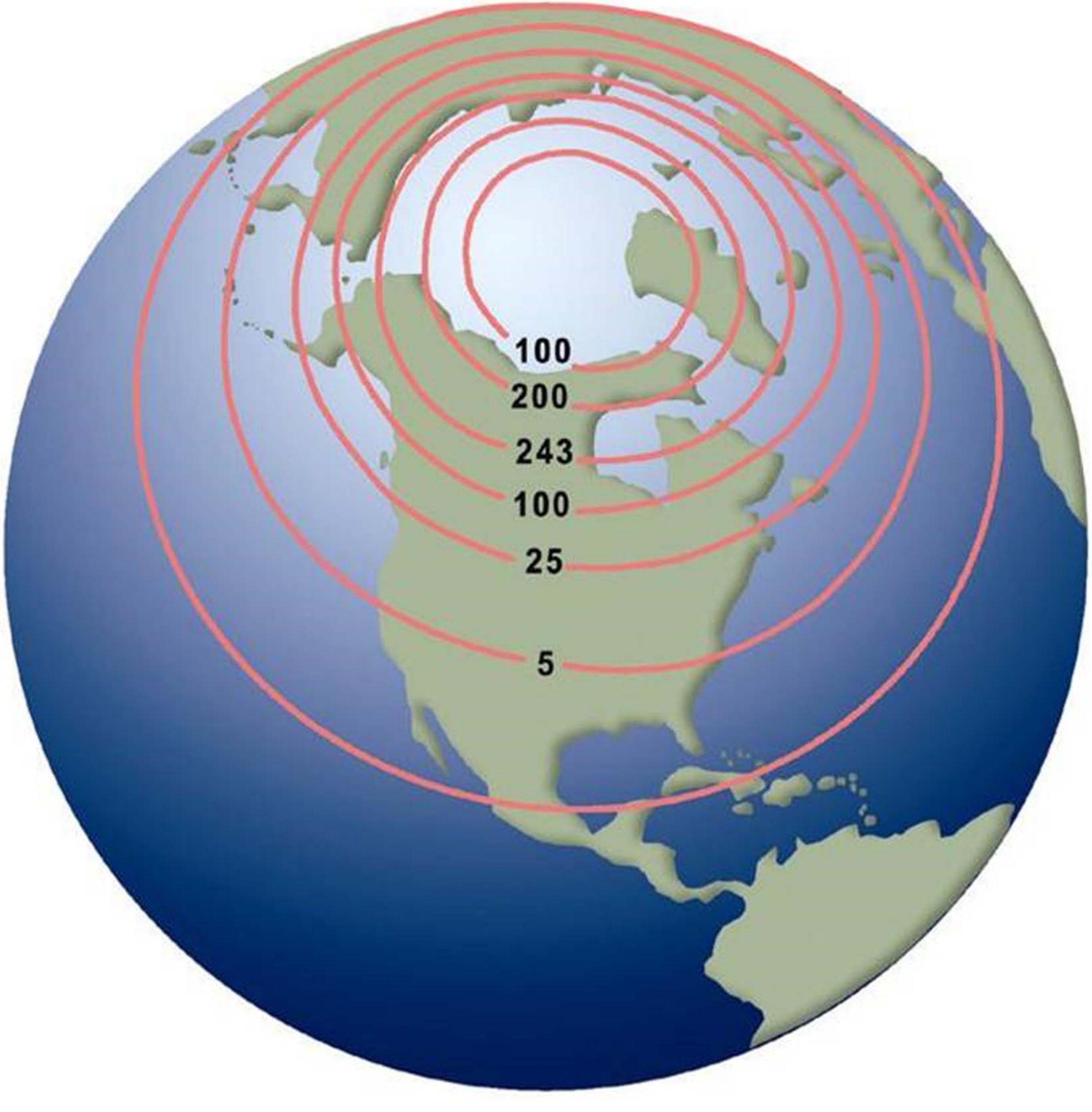


http://ffden-2.phys.uaf.edu/103_fall2003.web.dir/Raidmae_Hersey_Perry/liz's%20pages/AuroralZone.jpg
http://ffden-2.phys.uaf.edu/103_fall2003.web.dir/Raidmae_Hersey_Perry/liz's%20pages/Auroral%20Geographics.html

Auroral Zone (極光帶)

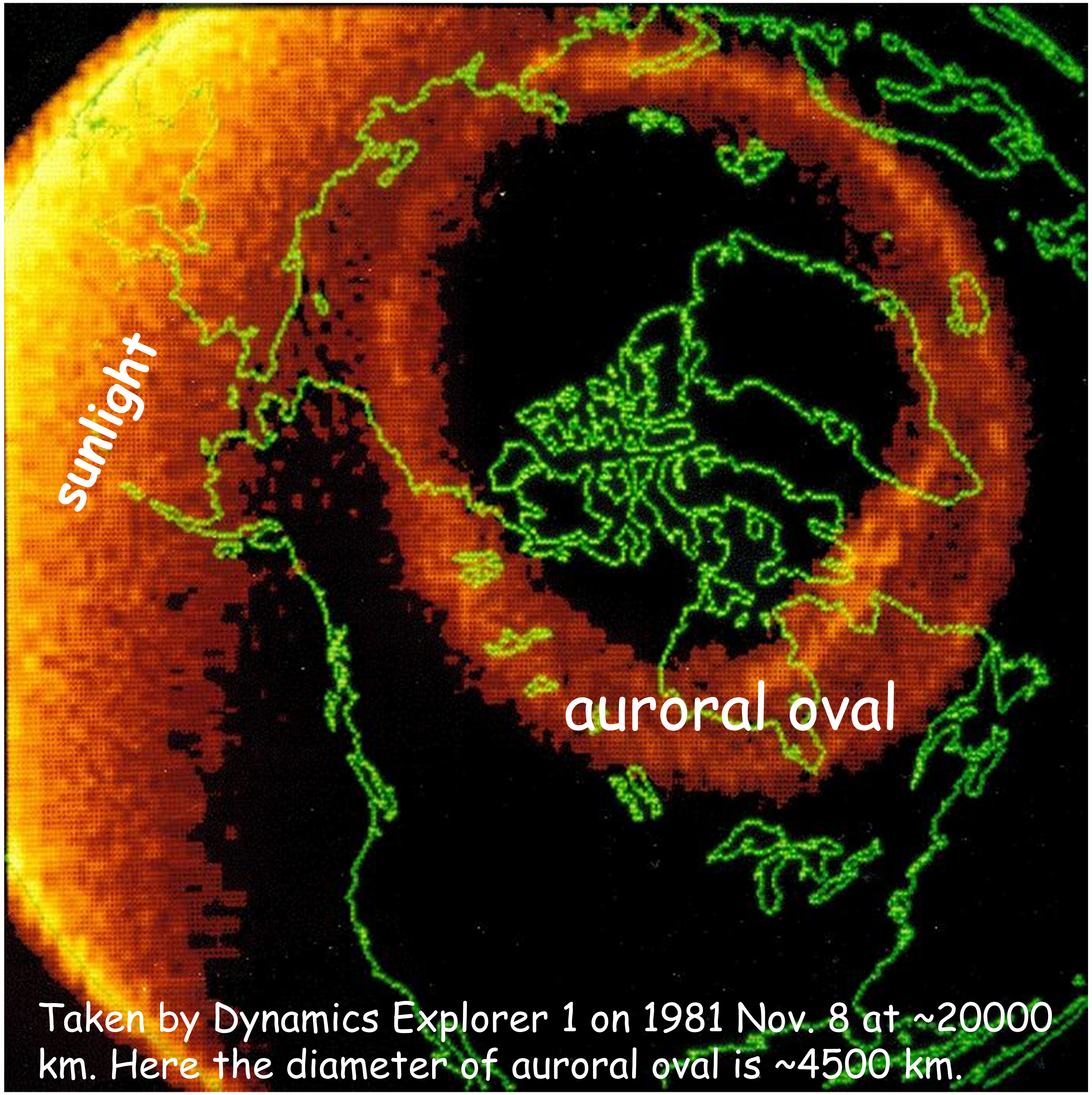
---統計上最常出現極光的區域

http://2.bp.blogspot.com/_UvE_kQ48A0I/TOBif0Q0epI/AAAAAAAAADQ/2r9qcwdu_V0/s1600/IMG_1513.JPG



http://www.jumbotour.com.tw/img/itinerary/179.jpg

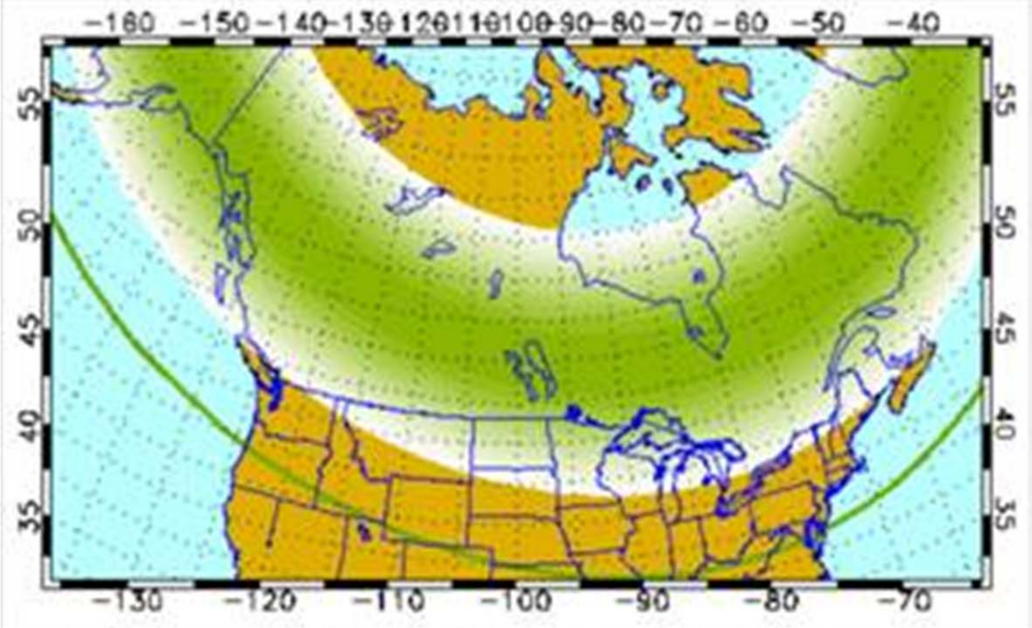
Auroral Oval (極光橢圓圈)



Taken by Dynamics Explorer 1 on 1981 Nov. 8 at ~20000 km. Here the diameter of auroral oval is ~4500 km.

http://www.mssl.ucl.ac.uk/www_plasma/visitors/dynamic_explorer.jpg

Kp = 6



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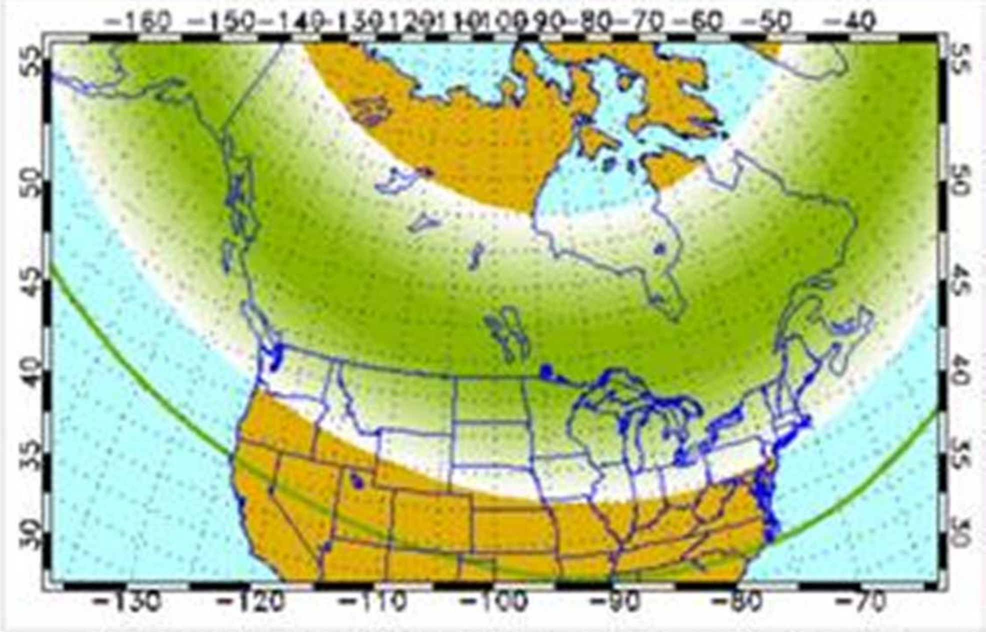

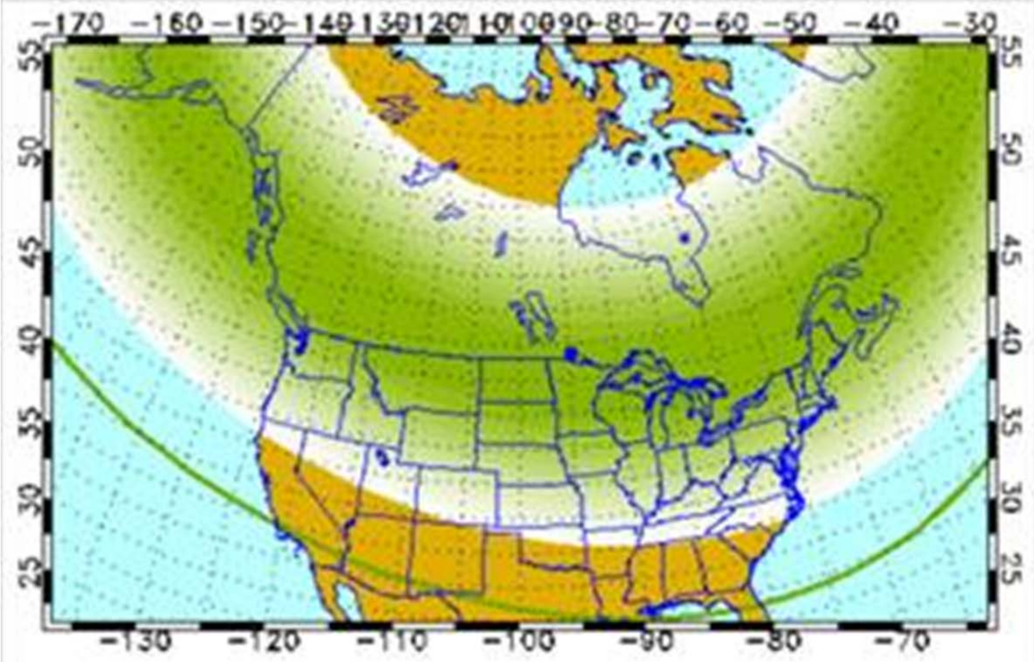

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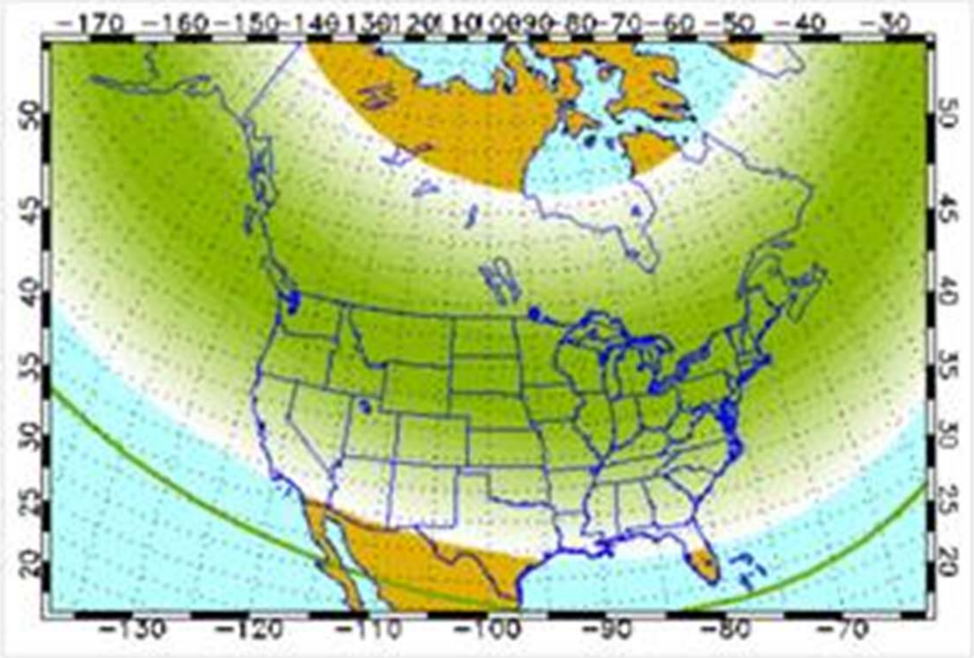
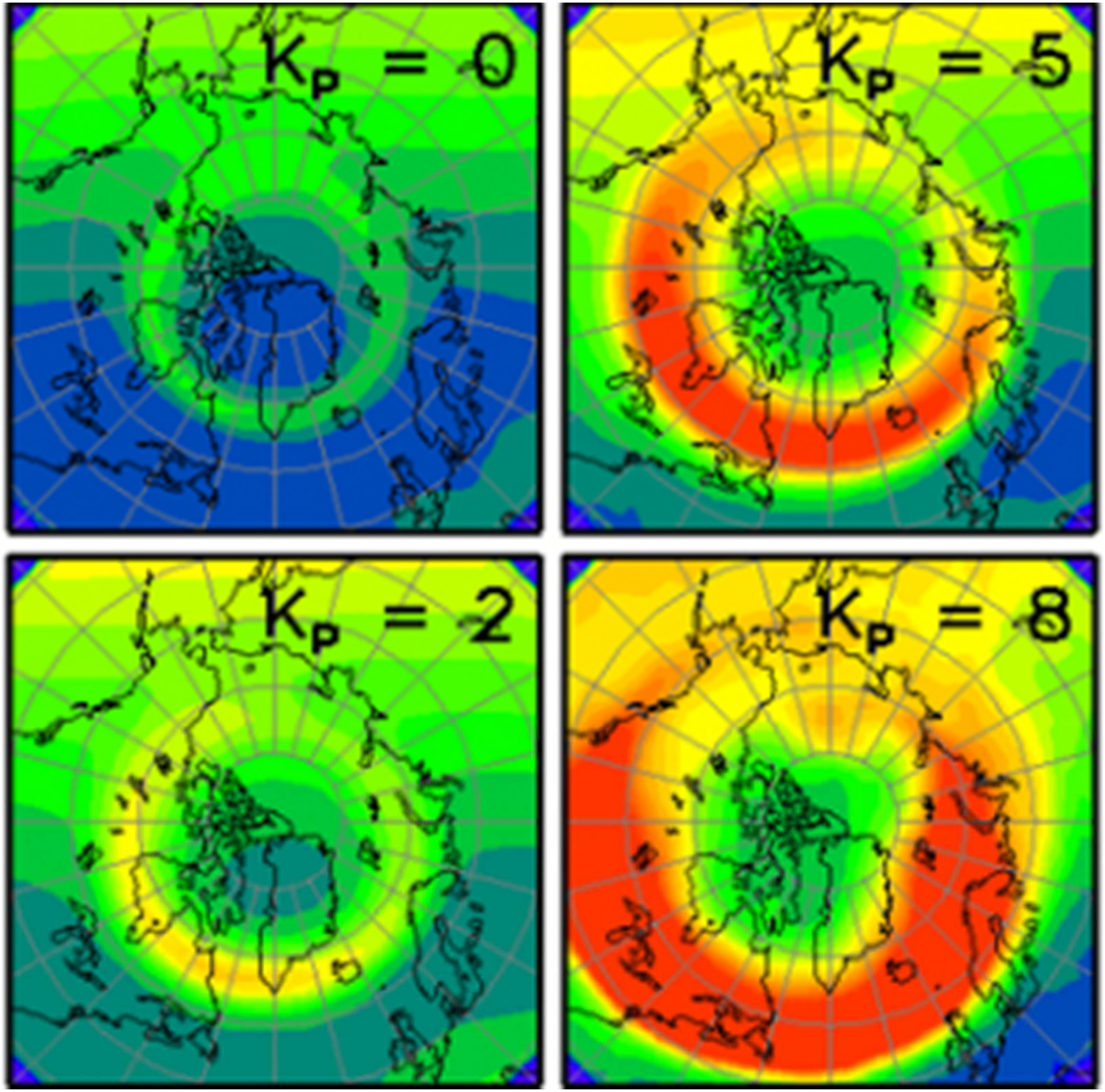


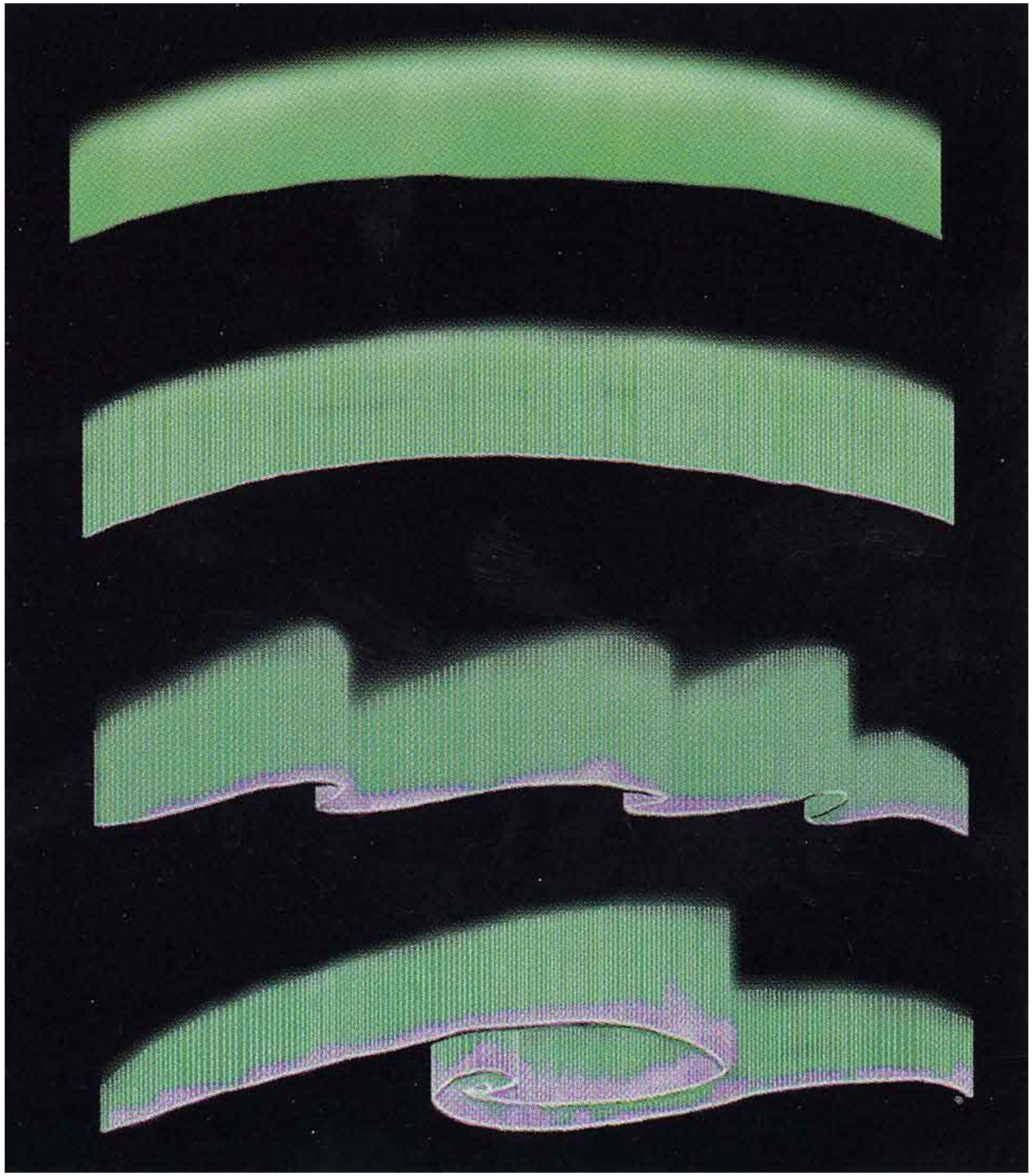
Kp = 9

http://rossellet.com/k5_9.jpg



http://www.sunearthplan.net/media/tn_5193_oval_KP_home.png

極光



高緯度地區比較容易看到明亮的極光弧(極光弧又叫做分立極光(discrete aurora))。

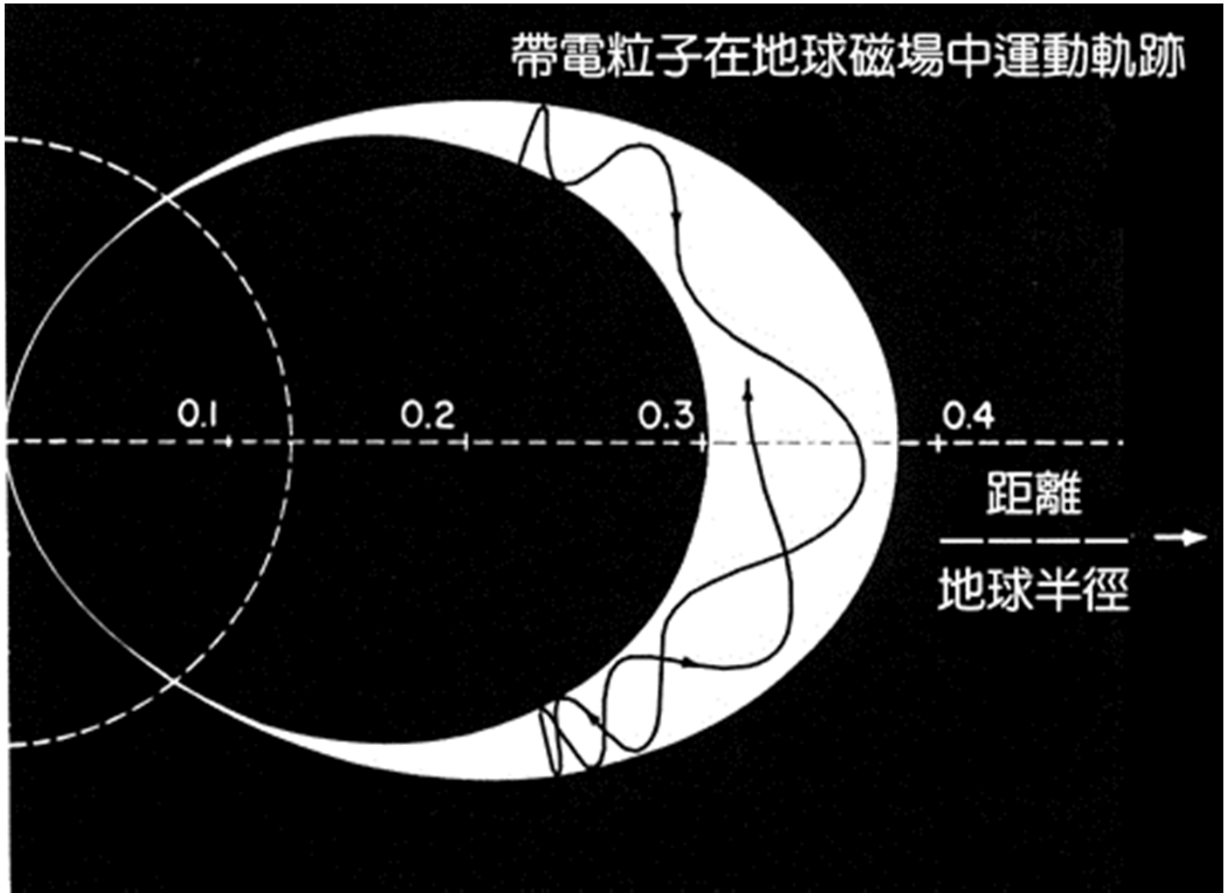
中緯度地區比較常看到朦朧的擴散極光(diffuse aurora)。

磁副暴時會出現像舞龍一般壯觀的極光弧，分布的範圍涵蓋中緯與高緯度地區。

http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html
http://ffden-2.phys.uaf.edu/103_fall2003.web.dir/Raidmae_Hersey_Perry/liz's%20pages/auroralactivity.jpg

造成擴散極光的原因

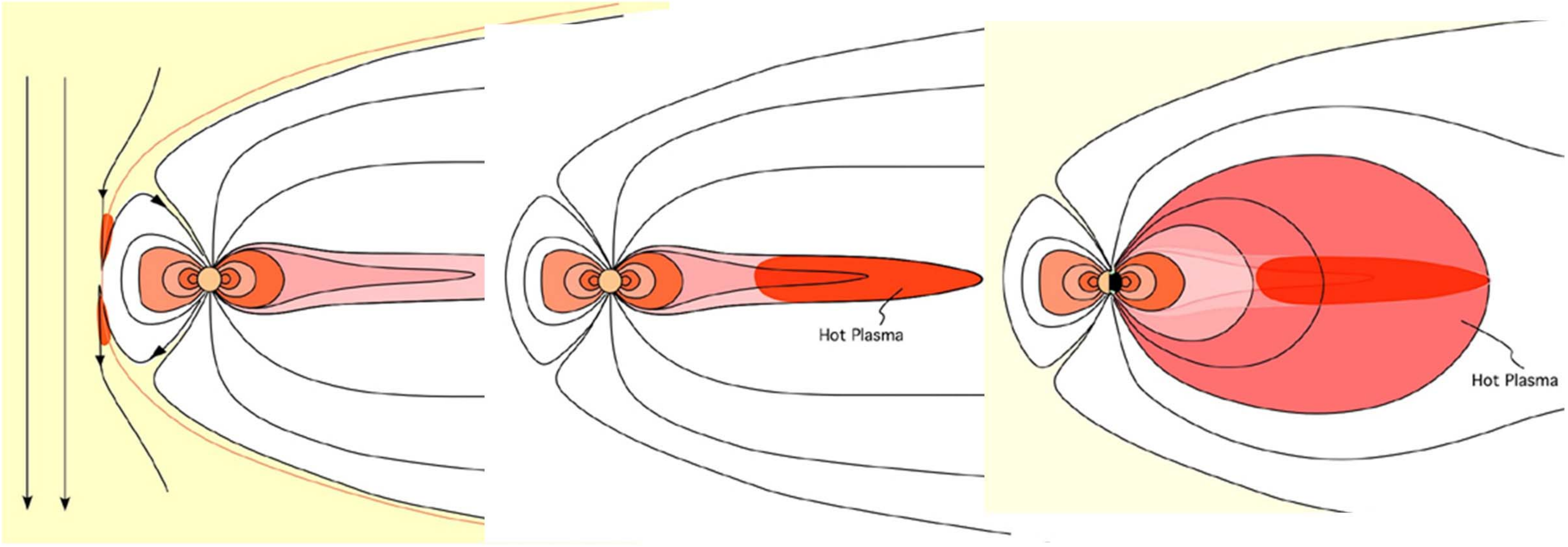
地球的磁偶極場可以抓住電漿，故有磁瓶之稱。但是磁瓶中的電漿會產生電磁場波動，使得原來在內磁層中沿磁場線來回運動的高能電子，被擾動的電磁場散射後無法繼續來回運動，少量的高能電漿得以漏出磁瓶落入中緯區的夜空造成擴散極光。



http://www.ss.ncu.edu.tw/~SpaceEdu/database/IntroSpace_notes_exam/new_Aurora_Fig/Fig1b_bounce.jpg

造成分立極光的原因

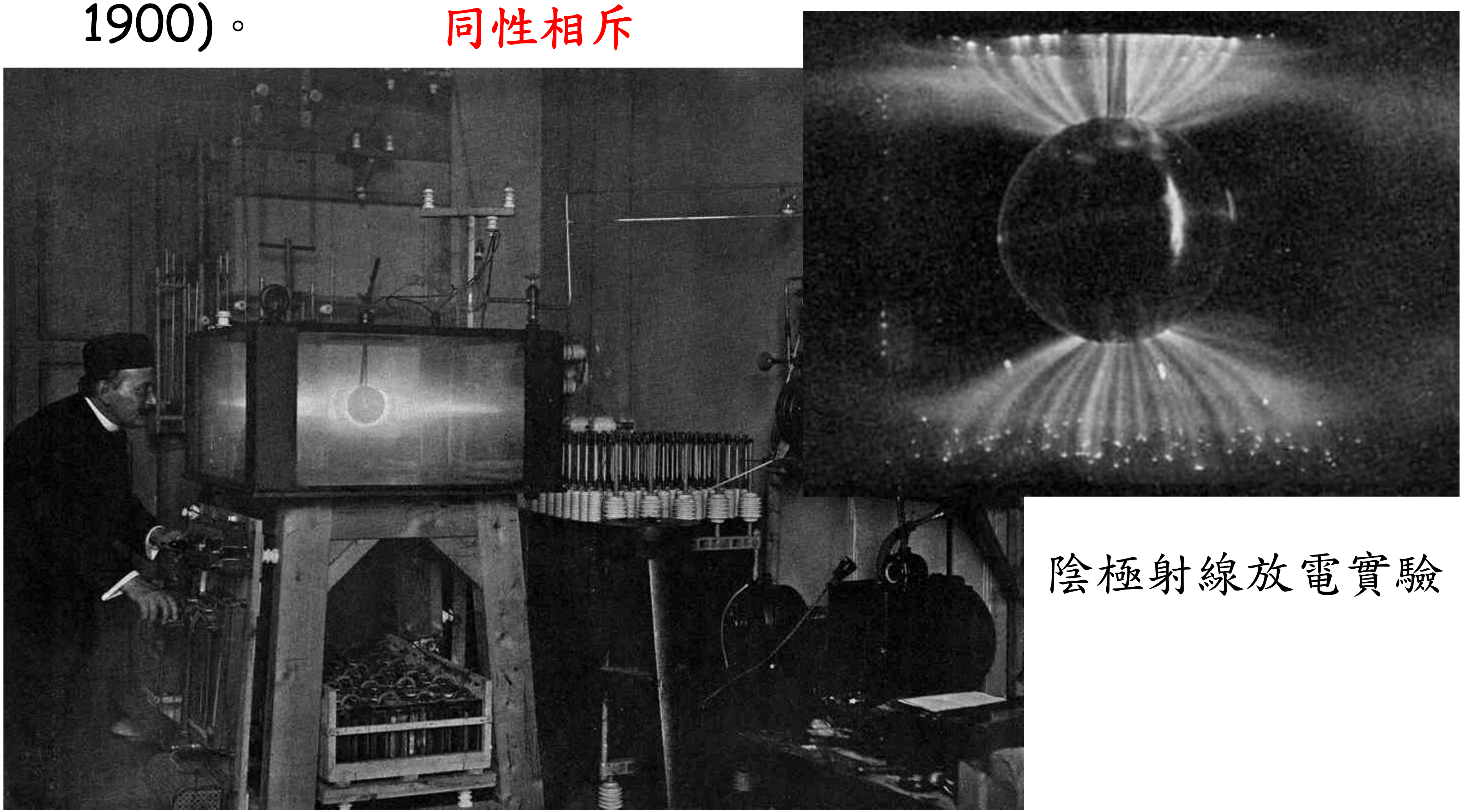
當行星際磁場與地球磁場反向時，在日側磁層頂可能會發生磁力線重聯，使得來自太陽風的能量經由磁層頂進入磁層，這些電漿先被儲存在地球磁尾，等累積到一定程度後，或當磁副暴時磁尾的磁場發生變形時，電漿片中的熱電漿會被擠出來，沿著磁場線灌入高緯電離層的極光橢圓圈內，造成絢麗極光。



http://www.ss.ncu.edu.tw/~SpaceEdu/database/IntroSpace_notes_exam/new_Aurora_Fig/Reconnection.jpg
http://www.ss.ncu.edu.tw/~SpaceEdu/database/IntroSpace_notes_exam/new_Aurora_Fig/discrete_aurora.jpg

過去的極光理論

→極光是由太陽風的電子撞擊地球所形成(Kristian Birkeland, 1900)。 同性相斥



陰極射線放電實驗

http://upload.wikimedia.org/wikipedia/commons/a/a0/Birkeland-terrella.jpg
http://4.bp.blogspot.com/_KzR8on8Tdmw/RxOQohMeAuI/AAAAAAAACC4/8uHUr_UuFao/BirkelandTerellaInOut.jpg

柏克蘭在挪威北部建立地磁觀測網，觀測極光下方的地球磁場擾動情形，並證實強烈極光處的電流會沿著磁場線向上流動。他也發現沿著極光弧水平方向流動的電流強度估計可達100萬安培。

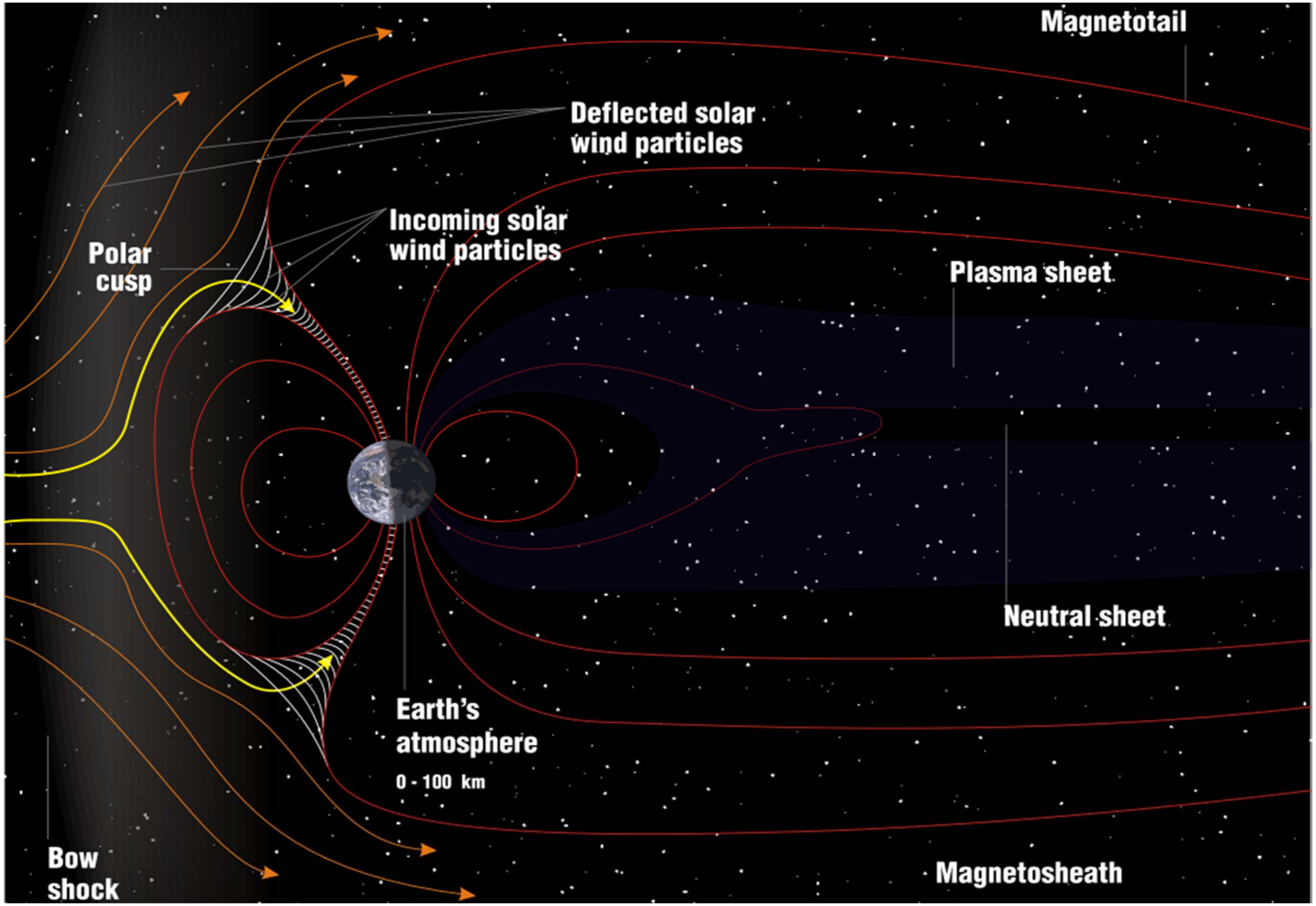
柏克蘭成功在1907年設計出一個令當時科學界大為震驚的放電實驗。柏克蘭將一個具有磁性的球體放入一個低氣體密度的真空腔中，進行陰極射線放電實驗。也就是外加一個強電壓，讓電子由陰極打向陽極，並撞擊低密度的氣體使之發光。柏克蘭的實驗，能在磁極四周製造出一個近似圓圈狀的發光區，成功解釋極光帶(auroral zone)的分布情形。然而，柏克蘭的實驗卻無法說明自然界是如何產生像陰極射線管這樣強的電壓，也無法說明造成極光電子束的來源。

柏克蘭的極光實驗所呈現的圓圈狀放電區，曾造成科學界對極光空間分布的長期誤解，直到五十多年後，才由Akasofu博士靠著許多次飛機巡迴、配合地面觀測網持續觀測後，終於證實極光主要分布在夜半球，日側極光的強度則相對較弱。二十多年後，人造衛星的觀測也證實了Akasofu博士當年的觀測結果是正確的。

http://www.ss.ncu.edu.tw/~lyu/lecture_files_en/Lyu_Aurora/Ref_Papers_AuroraSubstorm/AURORA50Y.pdf

→極光是由輻射帶中的帶電荷粒子溢出所造成(James Van Allen, 1962)。 輻射帶內為高能粒子

→極光是由太陽風的粒子順著地球磁力線直接到達大氣層頂端所造成。 只適用於**polar cusp**

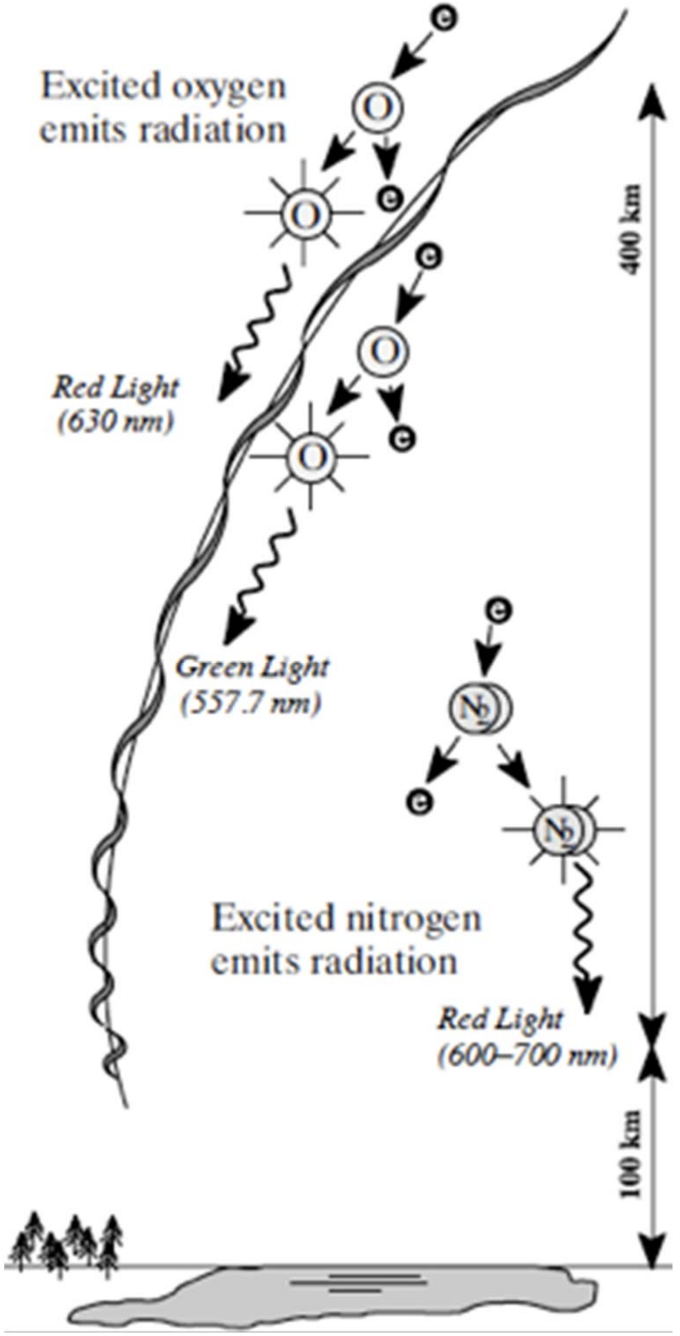


http://zh.wikipedia.org/wiki/%E6%9E%81%E5%85%89

極光的形成原因

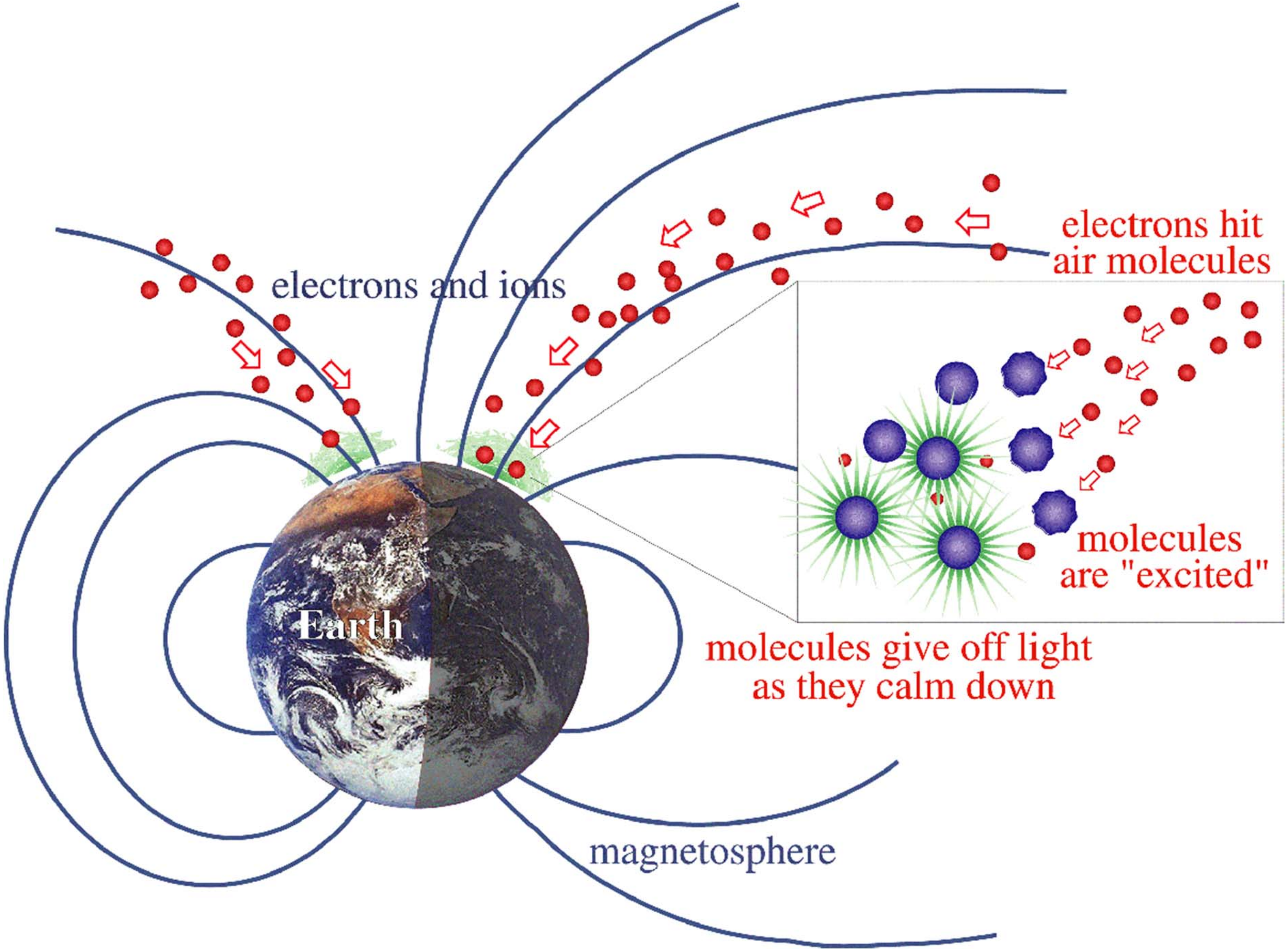
極光產生過程與霓虹燈管的發光原理相似。霓虹燈管內，兩極的電壓差將電子加速，撞擊管內稀薄氣體而發光，發光的顏色則視內部的氣體種類而定。

當從太陽表面吹出的太陽風到達地球時，來自太陽風的電漿若有機會沿著地球磁場的磁力線進入極區與大氣中的氣體碰撞，就會產生極光。當地球高層大氣的氣體分子或原子受來自太陽的高速電子碰撞後，會被激發至較高的能態(通常必須是一個高能階的準穩定態)，若氣體夠稀薄，在該準穩定態生命期結束前，該氣體粒子都尚未與另一個氣體粒子碰撞，則該氣體粒子就會自動跳回基礎態或較低能階的準穩定態，並放出一定波長的光，這就是極光。



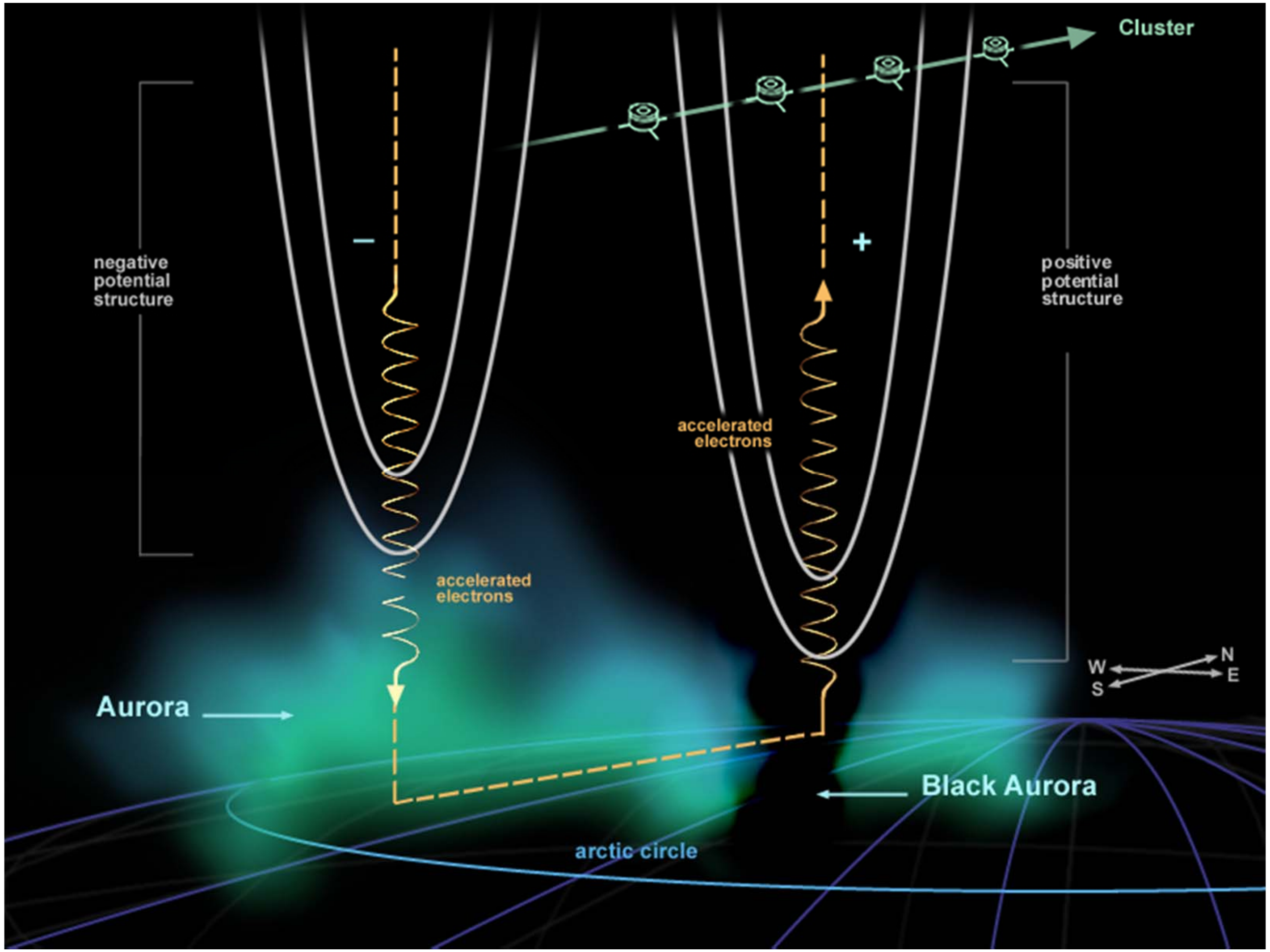
http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html

造成極光的高能電子來源，一部分來自太陽，一部分來自地球大氣。它們原本是與帶正電的離子一起行動，一直到地球高緯電離層的上空，才開始被一個沿著磁場、方向向上的電場加速。



http://0.tqn.com/d/weather/1/0/q/-/-/-/What_causes_aurora.gif http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html

除了高能電子外，由高空沉降的質子也會造成極光，但通常質子極光的光度比電子極光黯淡，且空間分布較模糊。質子極光與電子極光可以同時發生，但空間分布略微錯開。因為電子是被向上的電場加速打入大氣，而質子則被向下的電場加速打入大氣，向上與向下的電場通常呈現波動形式，呈現交錯分布的狀況。



http://www.ss.ncu.edu.tw/~lyu/lecture_files_en/Lyu_Aurora/Ref_Papers_AuroraSubstorm/AURORA50Y.pdf
http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=31048&farchive_objecttypeid=18,19,22&farchive_objectid=30912&fareaid_2=8