TASA 國家太空中心 Taiwan Space Agency

太空天氣對衛星操作的影響
Effects of Space Weather on Satellite Operations

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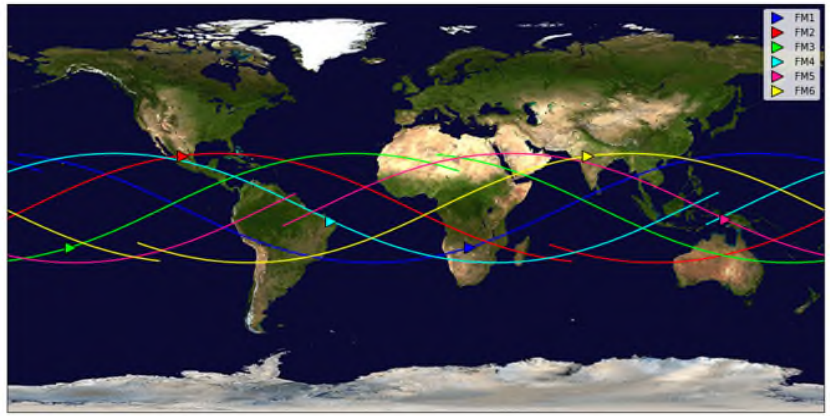
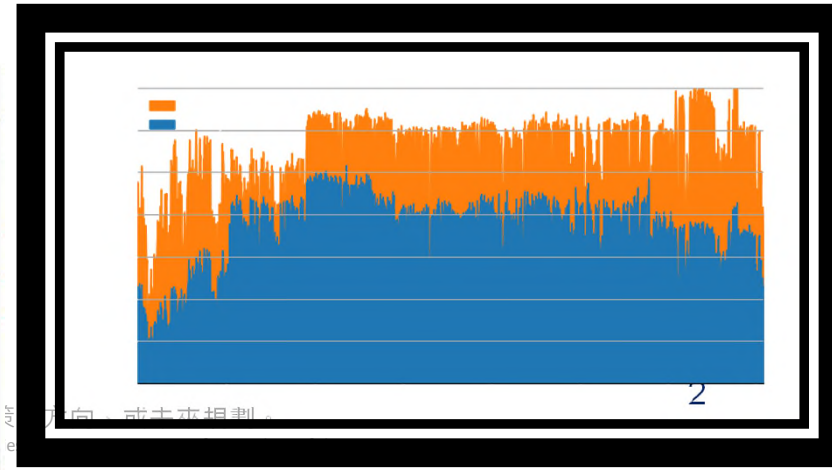
福衛七號任務簡介

TASA

- Partnership: AIT-TECRO **NOAA:** AIT Designated Rep; **TASA:** TECRO Designated Rep
- 5 years mission, launched on 6/25/2019, SpaceX Falcon Heavy (USAF STP-2 Mission)
- 6-satellite constellation in six evenly-spaced orbit planes to provide uniform equatorial coverage
- 10 ground stations for downlink support
- Each satellite has 3 instruments provided by US Space Force (USSF)
  - Tri-GNSS Radio Occultation System (TGRS) –Primary Instrument
  - Ion Velocity Meter (IVM) – Secondary Instrument
  - Radio Frequency Beacon (RFB) – Secondary Instrument
- Providing > 5,500 (**+Galileo > 6000**) daily radio occultation for weather forecasting
- Providing ~ 4,000 daily ionospheric total electron content tracks for space weather monitoring
- Providing ~ 30 min latency for ionosphere and neutral atmosphere data

Mission Constellation Orbit





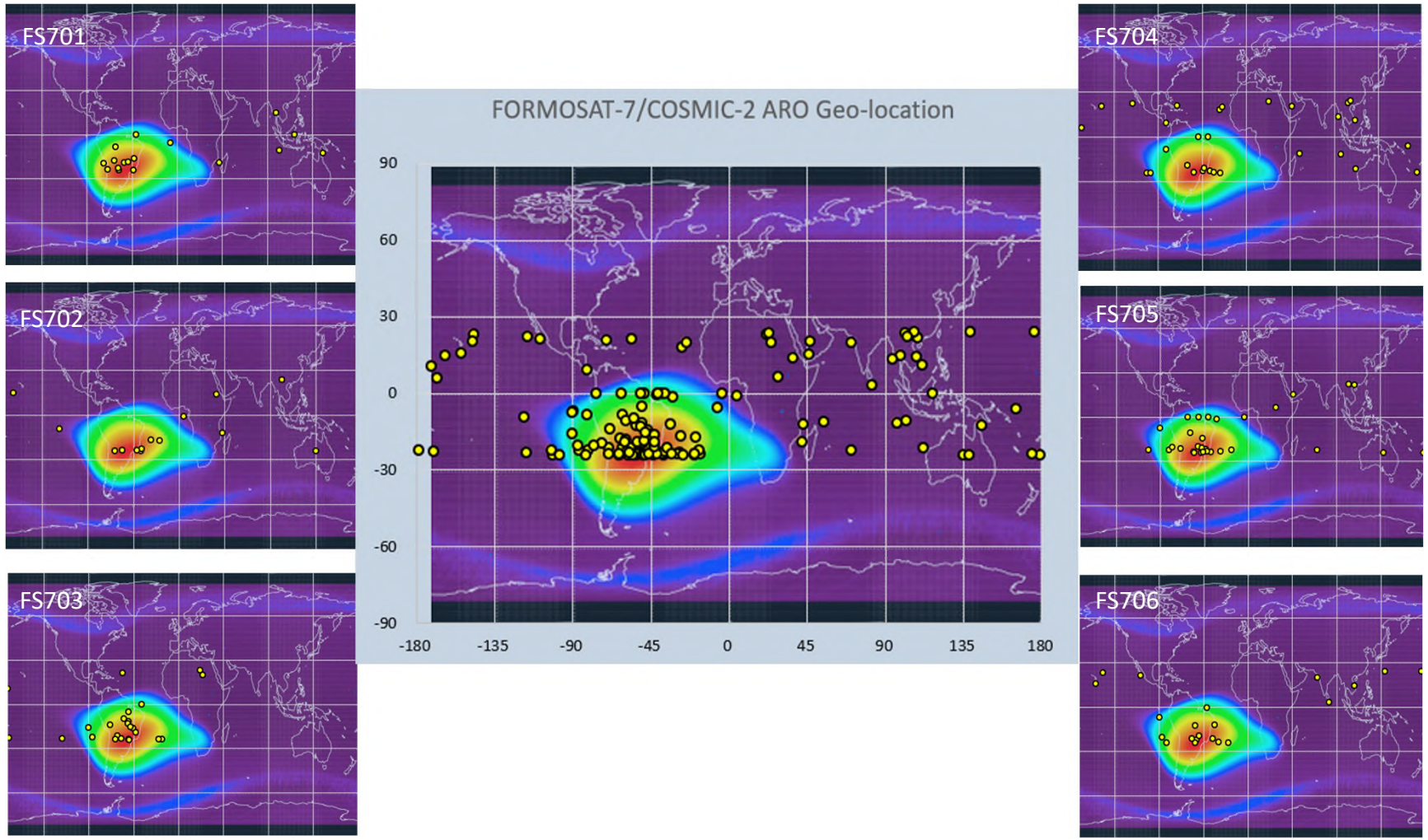
太陽活動直接對衛星的影響 (SEU)

- 太空中的高能輻射粒子擊中衛星上的電子晶片，導致晶片內部儲存的資料或狀態發生非永久性的、可恢復的錯誤(衛星內部的積體電路，如CPU、記憶體、FPGA、暫存器等）。

AR for Safe Mode Entrance									
FS	Early Orbit	SAA	SEU	FSW (incl. SADE)	AOCS	Data Bus	Operation	Unknown	
701	1	11	1	3			1		17
702	1	10	1		4	3		1	20
703	2	18	1		3	3			27
704	5	13		10	4		1		33
705	2	23	1	1	8	2			37
706	4	12	2		1	1		1	22
								Total:	153
								As-of-Dec. 15, 2024	

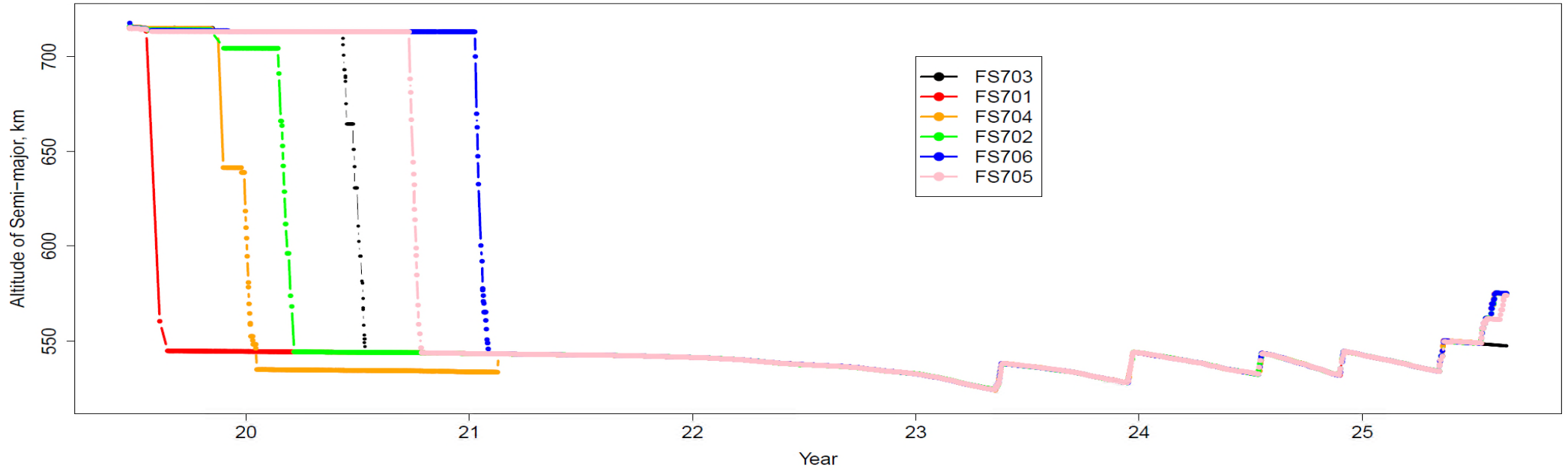
*Note: Safe Mode Entrance related to SEU & SAA at higher altitude take the majority of the root causes and when satellite was recovered back to OBC control, SC telemetry data will be missing during the anomaly resolution period.

太陽活動直接對衛星的影響 (SEU)

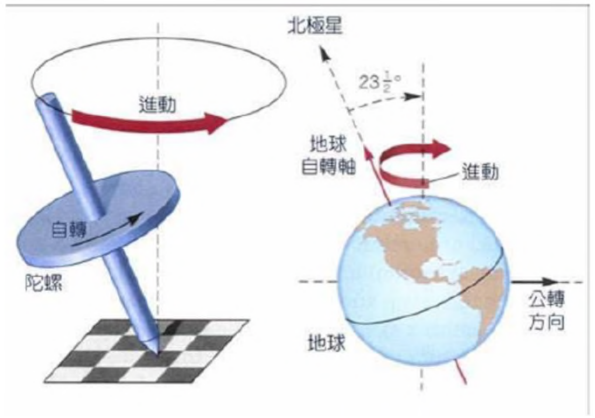


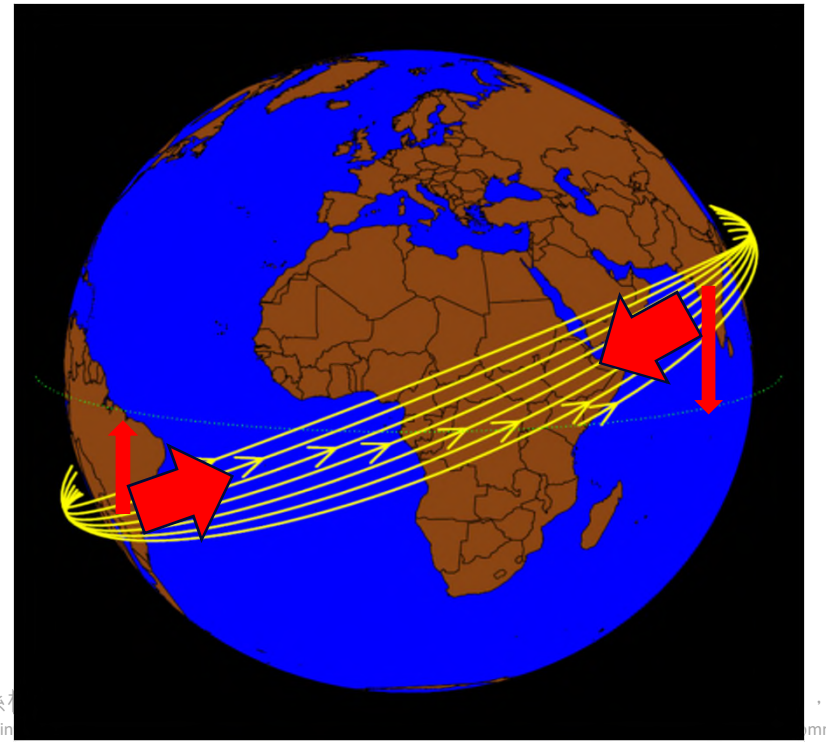
太陽活動對軌道的影響

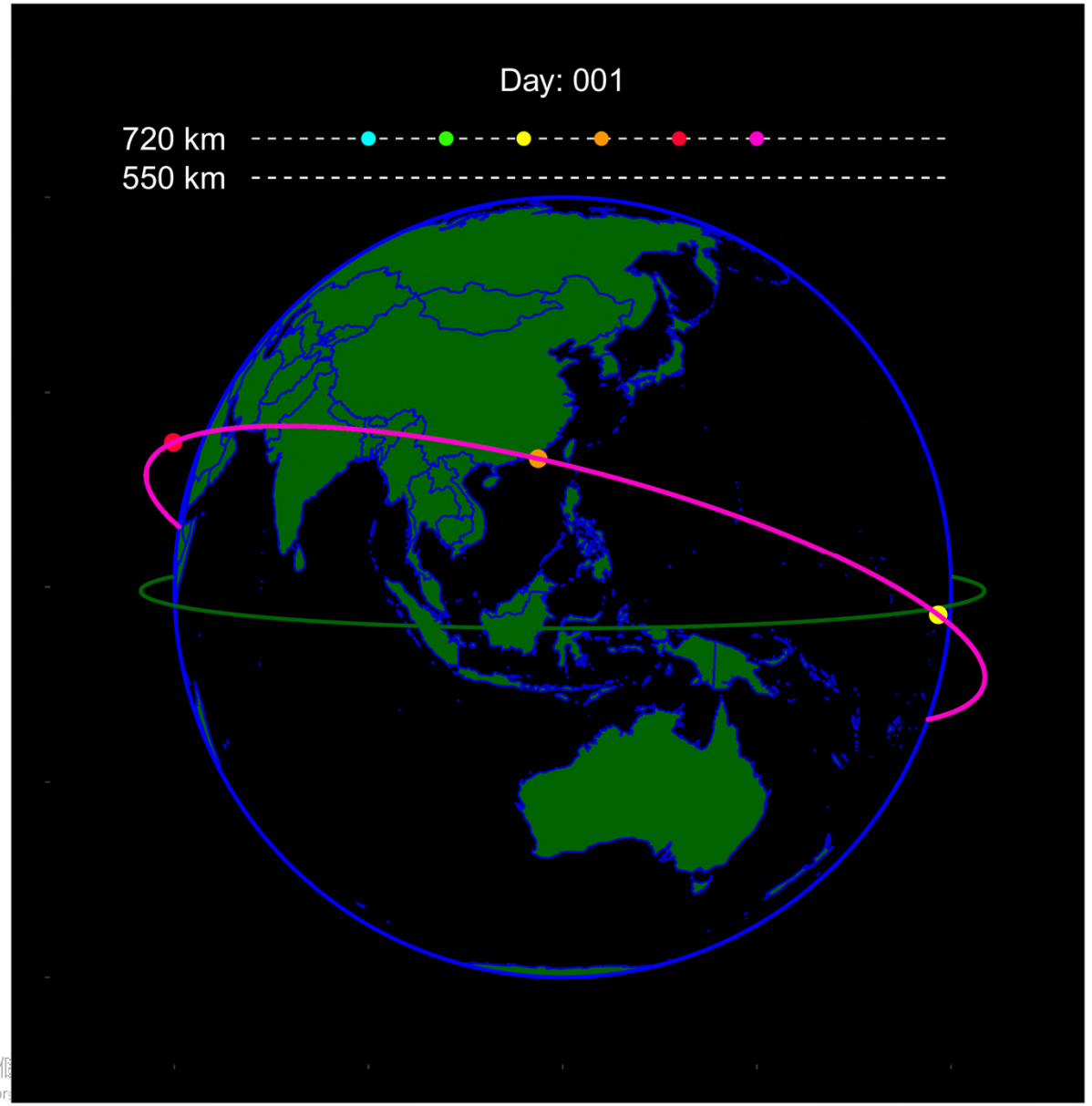
- 於太陽活動活躍期伴隨太陽輻射量增加，造成空氣膨脹，低層空氣分子往高空移動，致使衛星軌道所在高度之大氣密度增加。
- 福衛七號衛星軌道所在高度(550km)，太陽活動活躍時期的大氣密度為太陽寧靜時期的10倍左右，衛星運行的空氣阻力增加導致軌道高度下降率變快。
- 2023-2024 年太空中心已執行4次衛星高度調升，同時調整6顆衛星，每次10-15公里，共提升高度50公里(使用燃料約4公斤)。
- 2025年8月執行第5次衛星高度調整(5顆衛星)，調升至580公里。



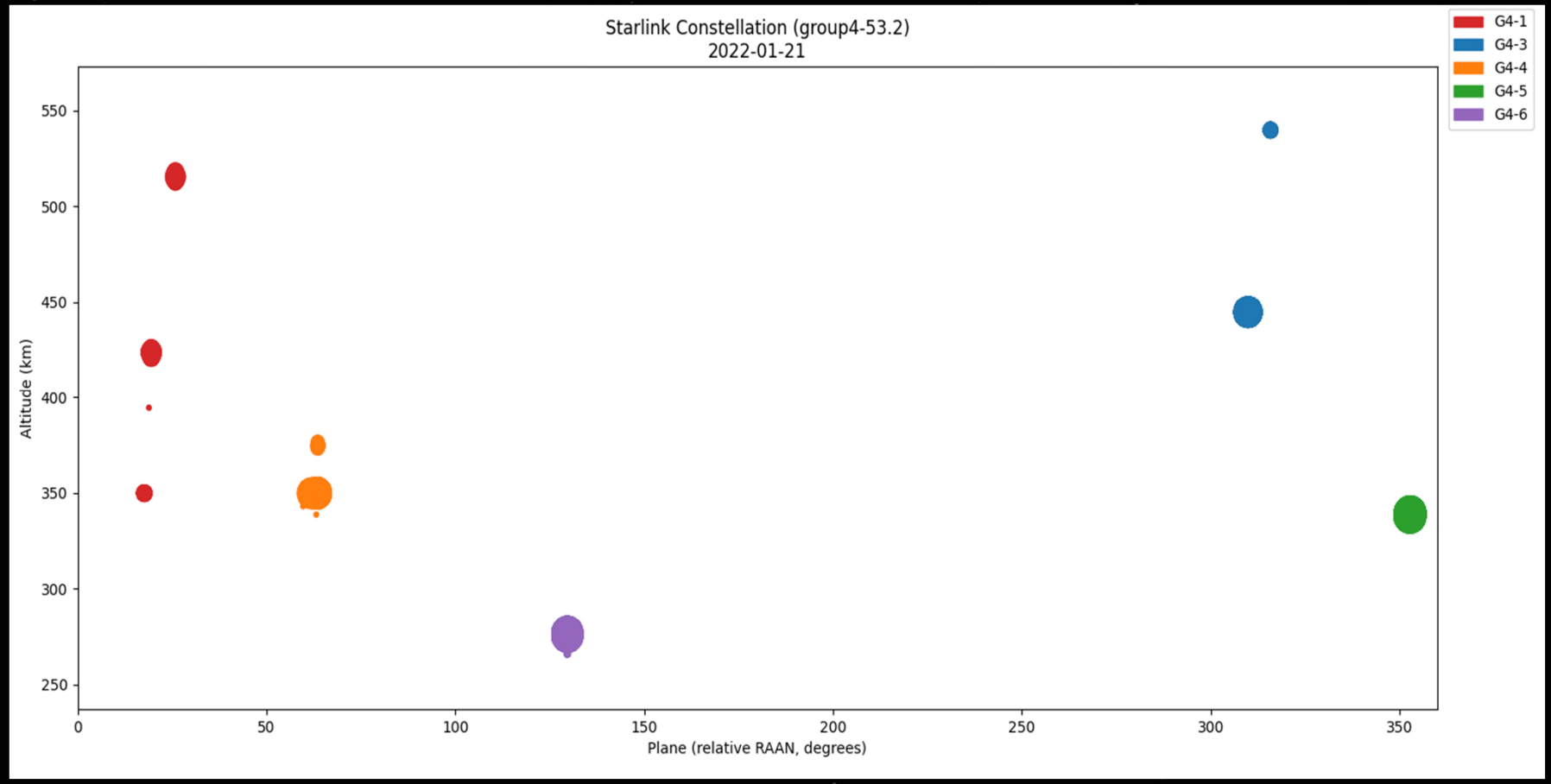
福衛七號星系佈署



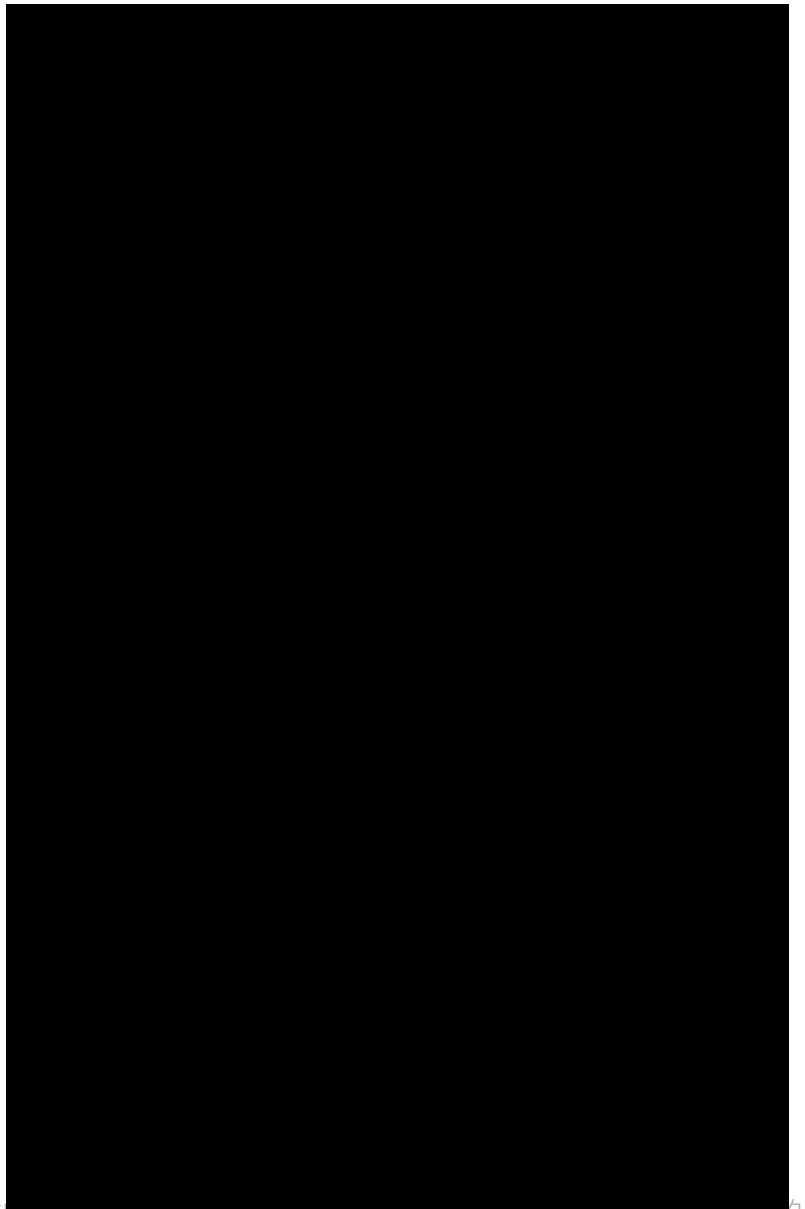




STARLINK 衛星軌道佈署與太空天氣的影響

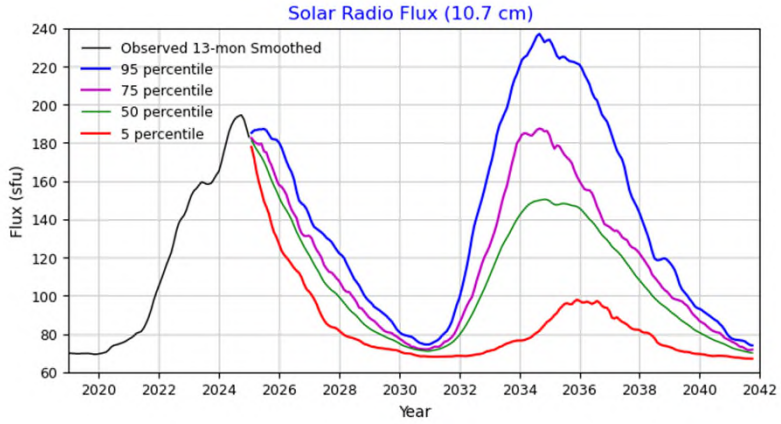


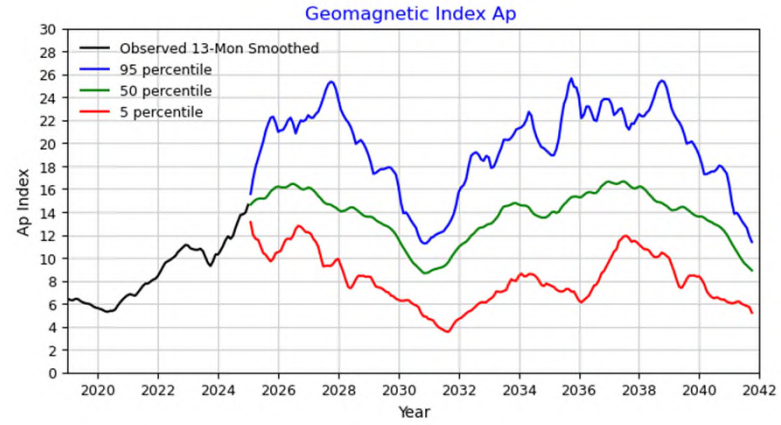
太空天氣預報的重要性



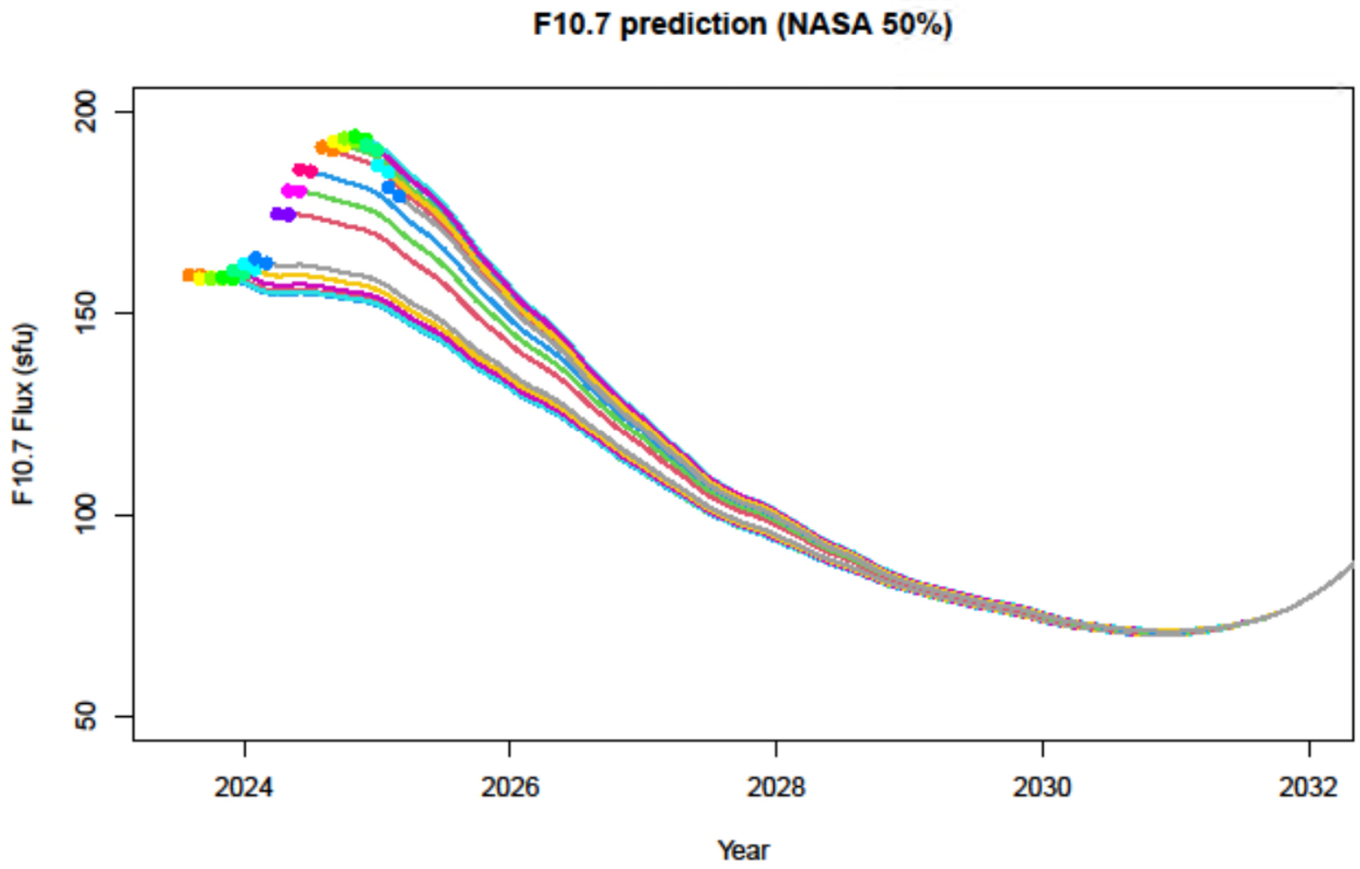
太空天氣預報的布準確性

F10.7 & AP index predicted by NASA





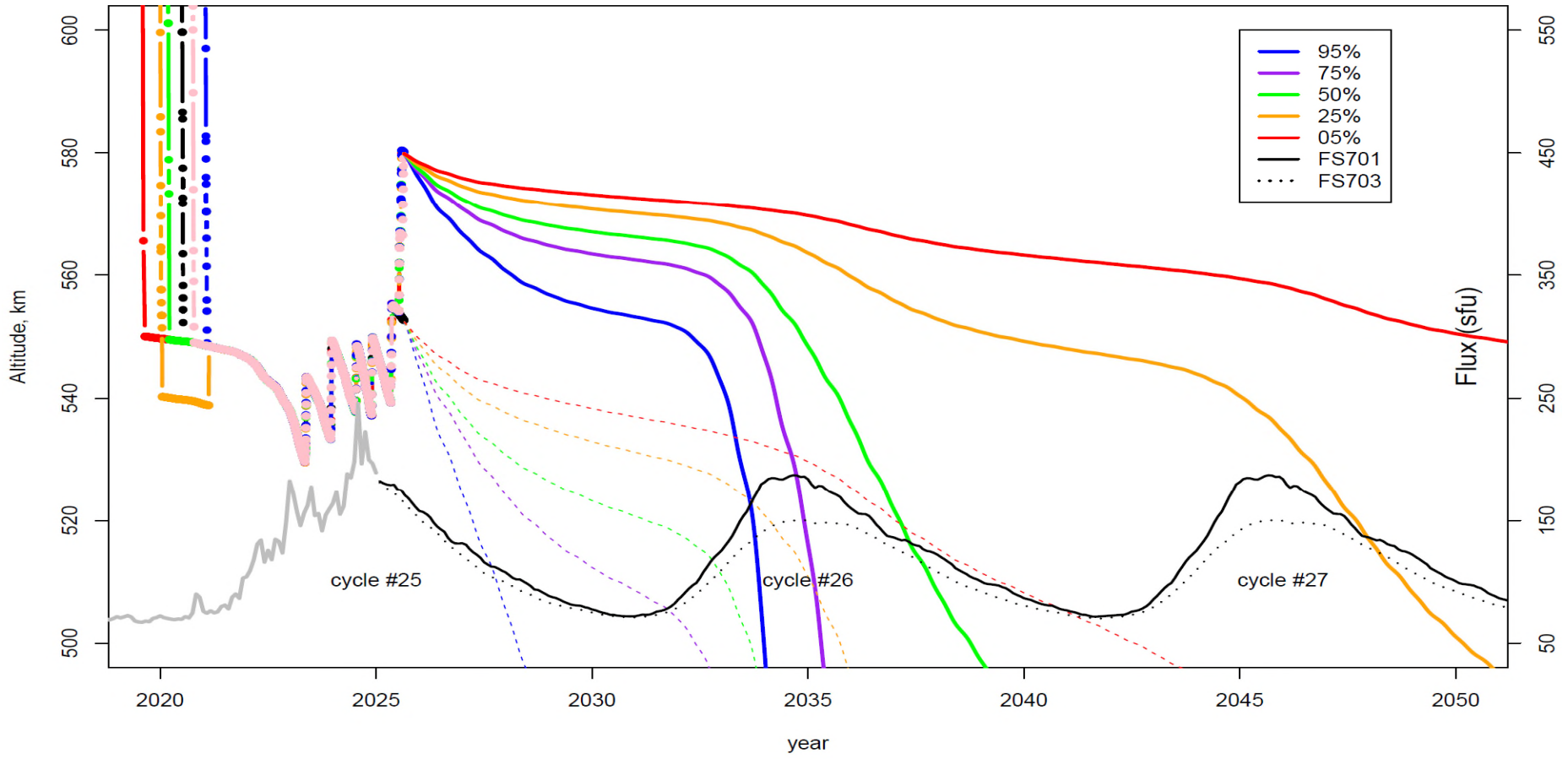
長時間太空天氣預測仍有相當大的不確定性



太空天氣對衛星任務設計，衛星在軌時間的影響

福衛七號在軌時間模擬

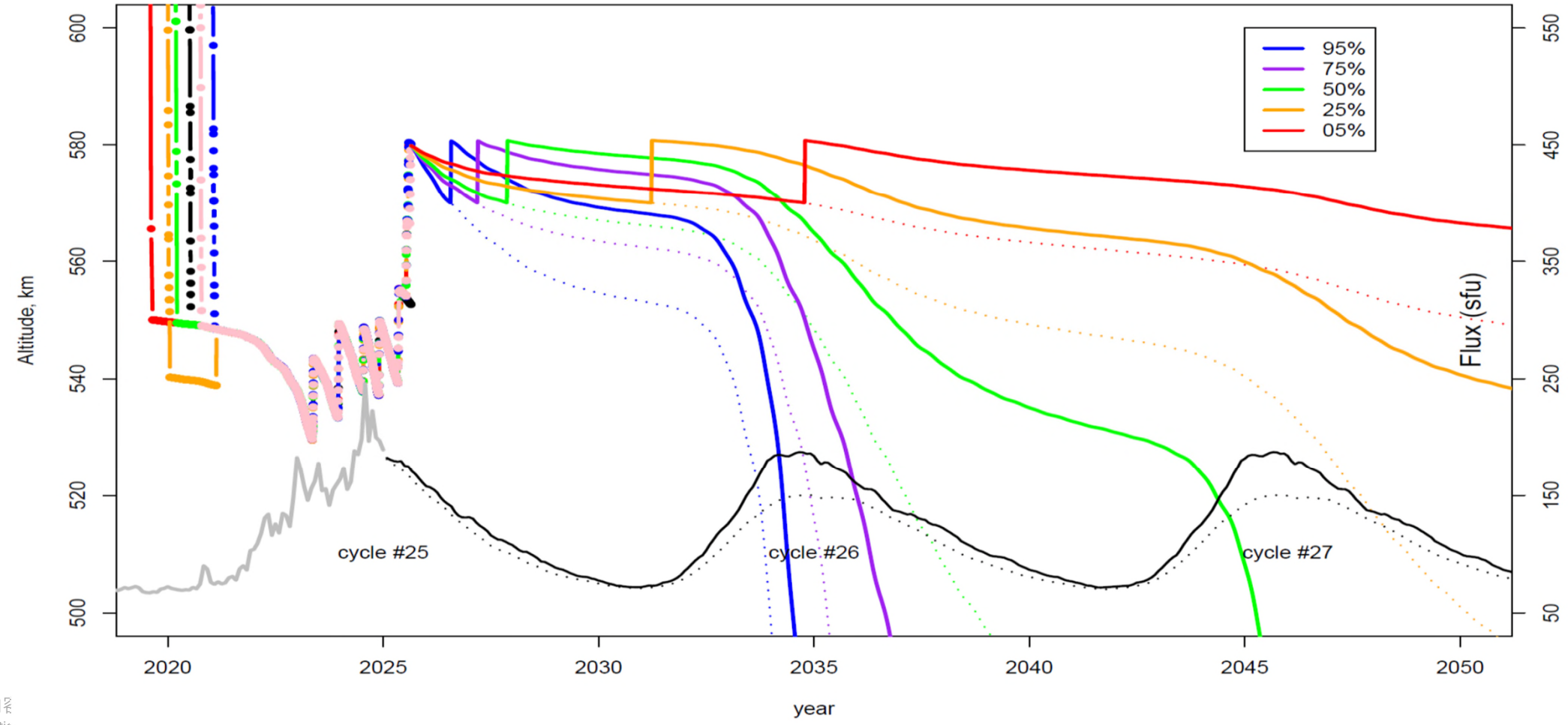
- 太陽活動周期為影響衛星在軌時間的重要因素



太空天氣對衛星任務設計，衛星在軌時間的影響

福衛七號在軌時間模擬

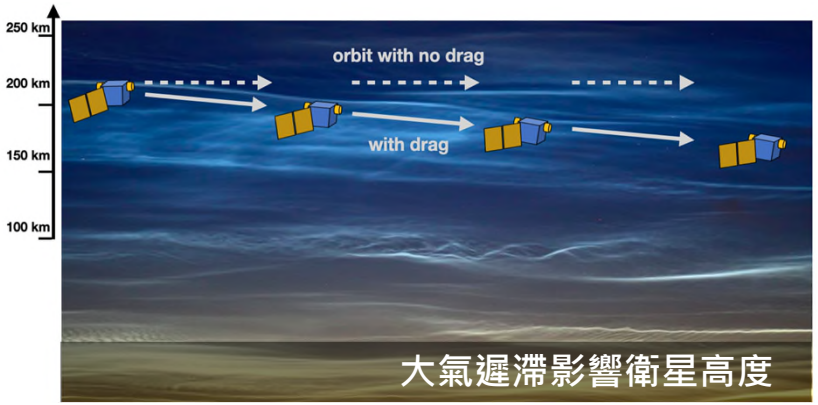
- 進行一次衛星軌道調整，可延長1~10年衛星在軌壽命

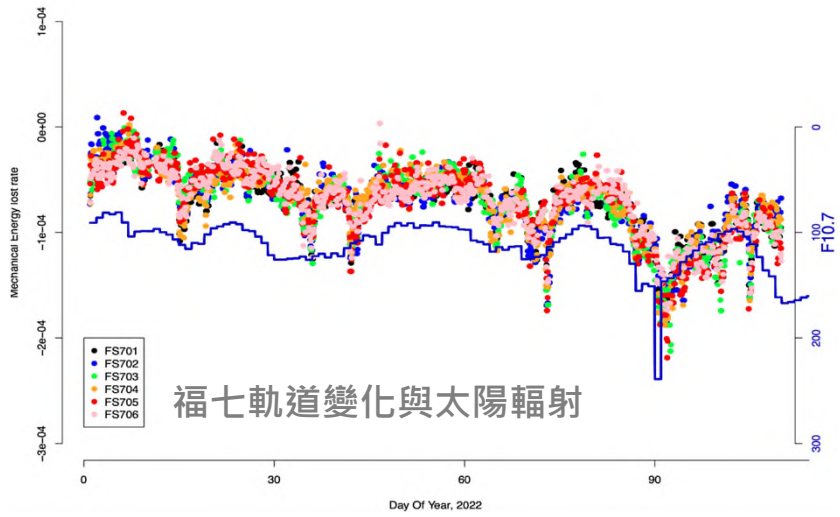


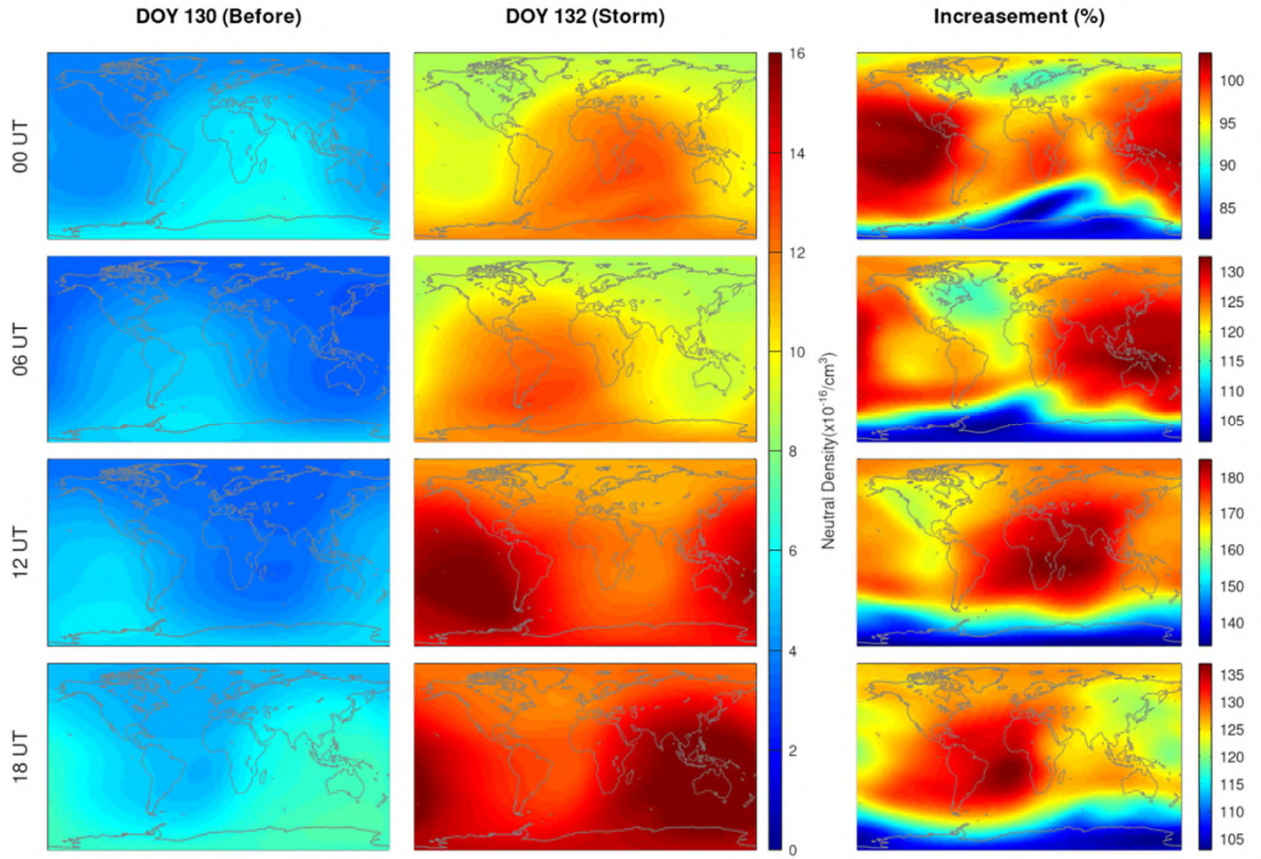
持續強化高層大氣數值預報

從電離層數值預報產品，強化熱氣層中性大氣密度預報產品

- 透過衛星精確軌道資訊反演中氣大氣密度，成為熱氣層資料同化所需觀測資料。
- 預報大氣密度計算衛星飛行所受大氣阻力(air drag)，輔助軌道預測及操控。







圖：數值模擬之2024年母親節磁暴發生前後500公里高大氣密度變化

CWA/SWOO提供

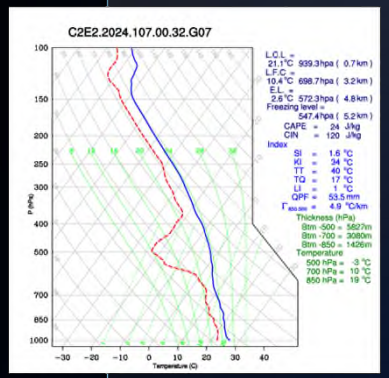
Integration and Application of Multi-Time and Multi-Source Data :

GNSS-RO/R Application

TASA Weather Satellites

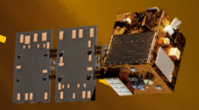
Global Navigation Satellite System,(GNSS)

Atmospheric profiles (CWA)

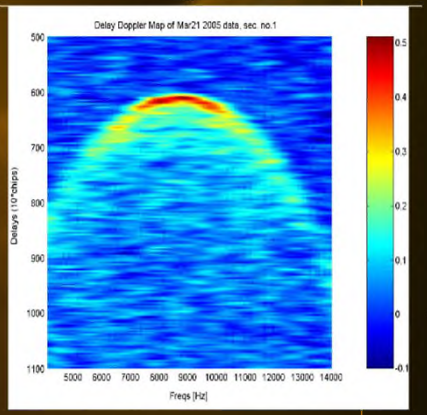


Radio occultation (RO)
FORMOSAT-7

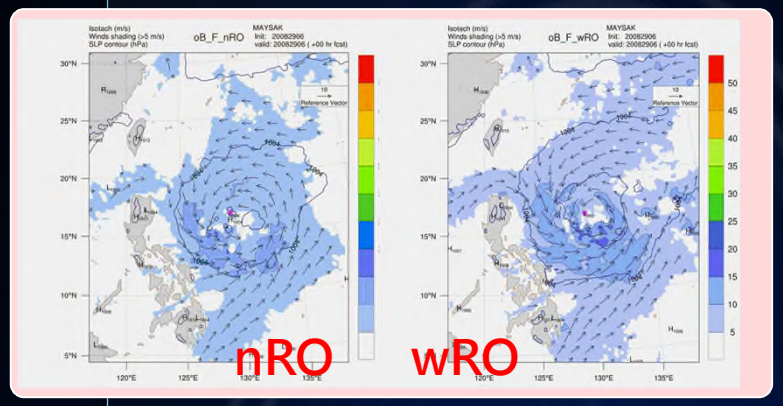
Signal reflected by ocean (R)
TRITON



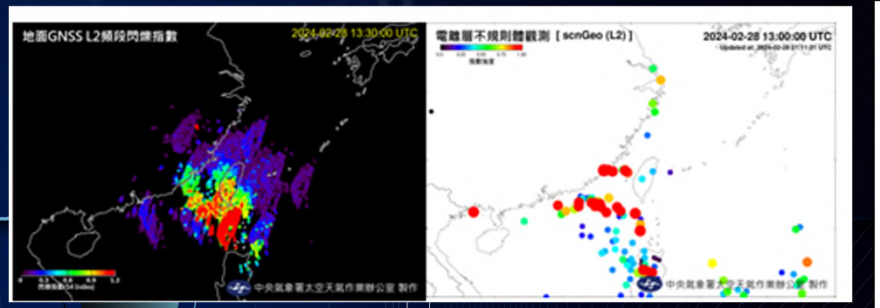
- **Ocean Wind**
- **Solid moisture**
- **Sea level**



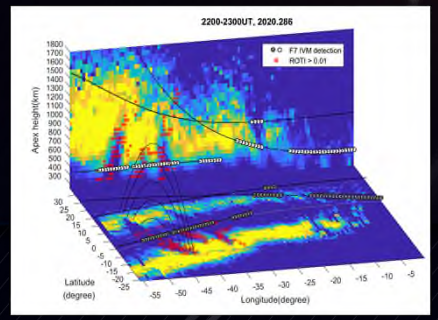
Improve Typhoon prediction (CWA)



Space Weather monitor by Ground GNSS and FS-7/C-2 (SWOO)



Space Weather monitor (Charles, NCKU)



GNSS Radio Frequency Interference (RFI) monitor (SWOO/CWA)