



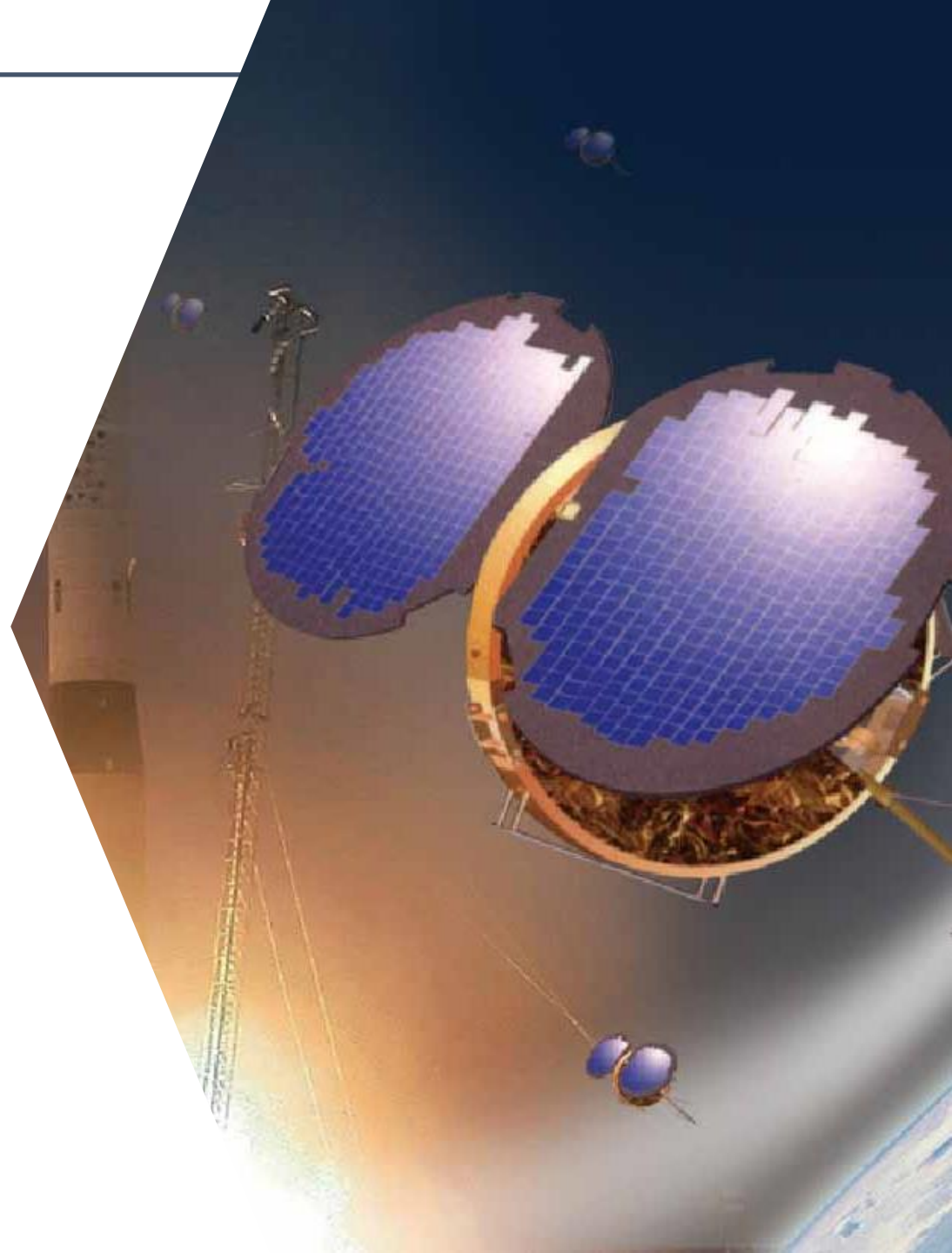
115 年天氣分析與預報研討會 利用福衛三號觀測估算電離層空間相關距離

李奕德

國家太空中心衛星操控組

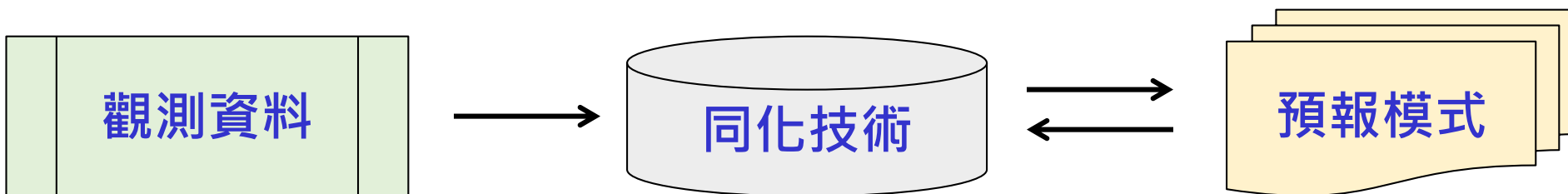
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2026/09/02



報告綱要

- 資料同化技術
- 局地化影響
- 過去分析結果
- 福衛三號分析結果
- 討論與小結



**Ground-based
Space-based**

(Ionosonde, ISR,
GPS-TEC,
GPS RO data,
other in-situ
measurements)

**Variational Method
Kalman Filter**

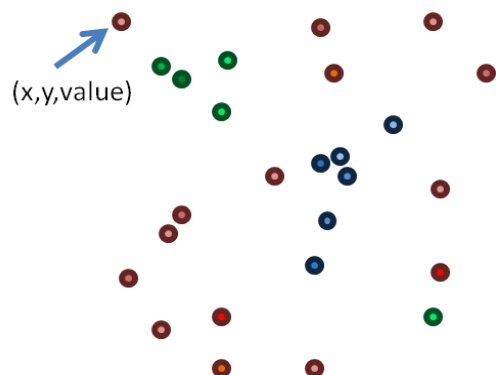
(3DVar, 4DVar, KF,
EnKF,...)

**Empirical Model
Physical Model**

(IRI, **TIE-GCM,...**)

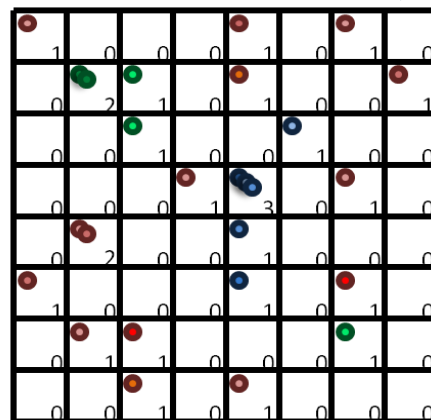
資料分布與網格

觀測



觀測資料多樣且零散

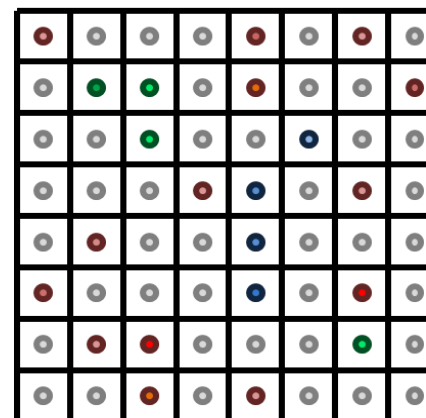
初始猜測場
first guess



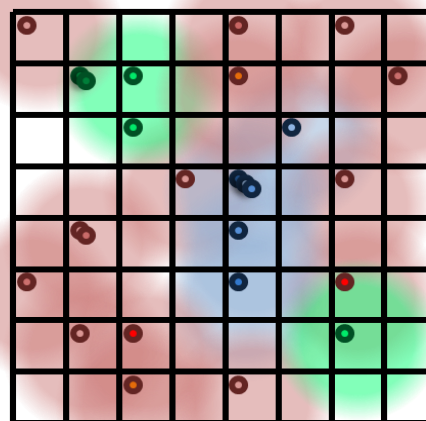
先依照背景場
網格尺寸分配

No Smoothing

僅影響到有觀測的網格

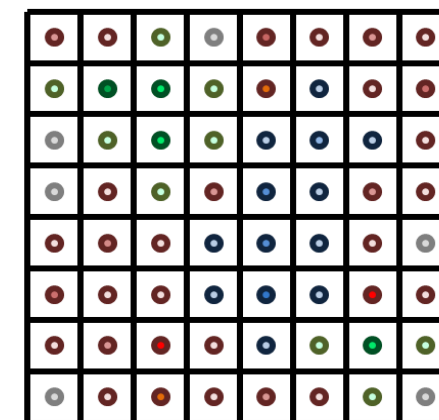


Smoothing



透過權重調整影響幅度
Impact area/Localization

分析場
Analysis



讓所有的網格都能獲得
來自觀測資料的影響

電離層資料同化系統

■ 背景模式：NCAR TIE-GCM v1.95 HRES/LRES

■ 系集成員數量：48個

- 產生方式透過擾動模式地球物理參數

■ 觀測資料：

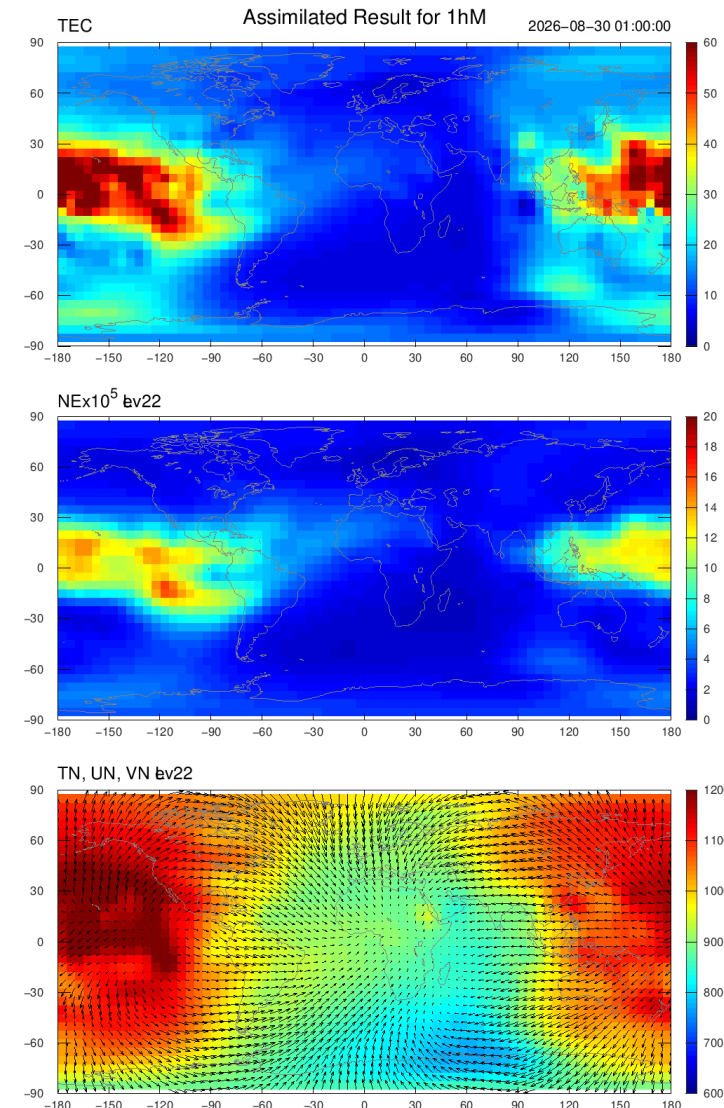
- 福衛電離層剖線、地面全電子含量

■ 同化方式：系集卡曼濾波器(EnKF)

- NCAR DART (Data Assimilation Research Testbed)

■ 局地化參數：**Gaspari-Cohn function**

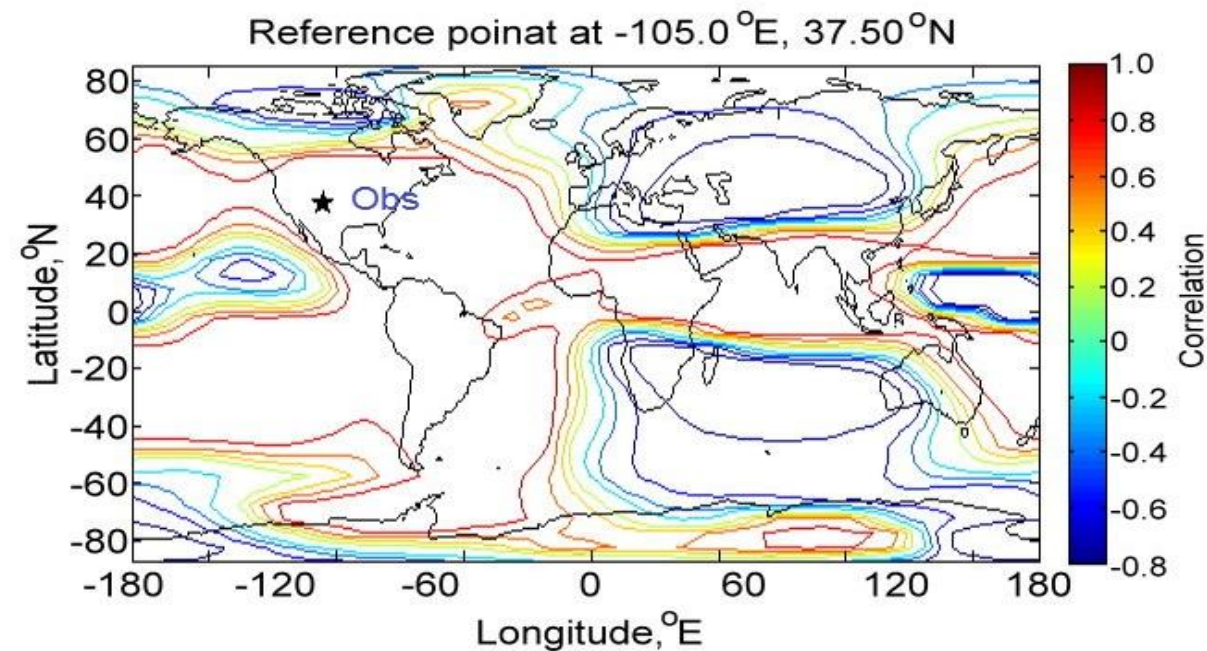
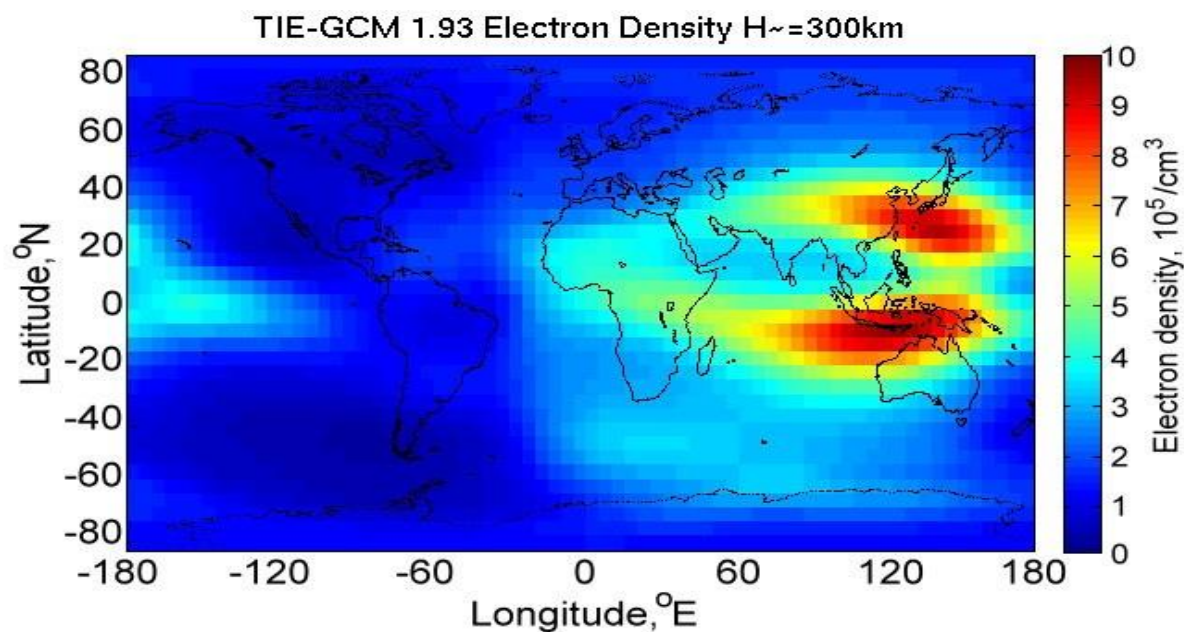
- 設定數值為0.2，半徑約20公里。



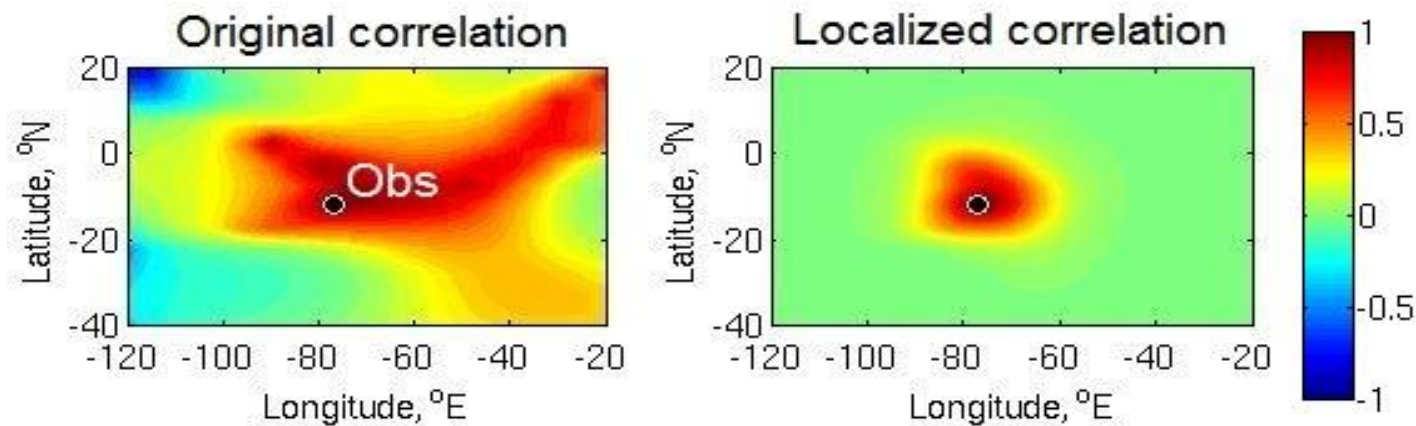
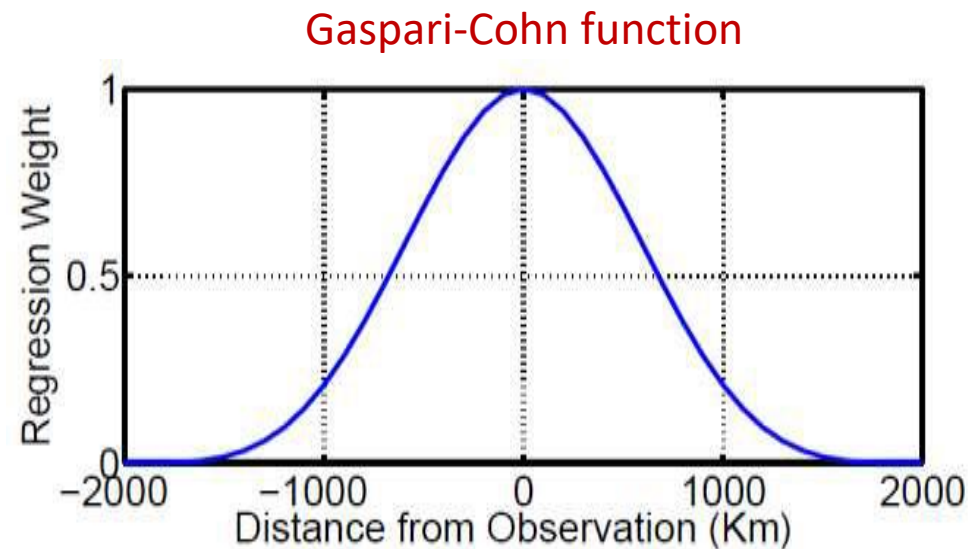
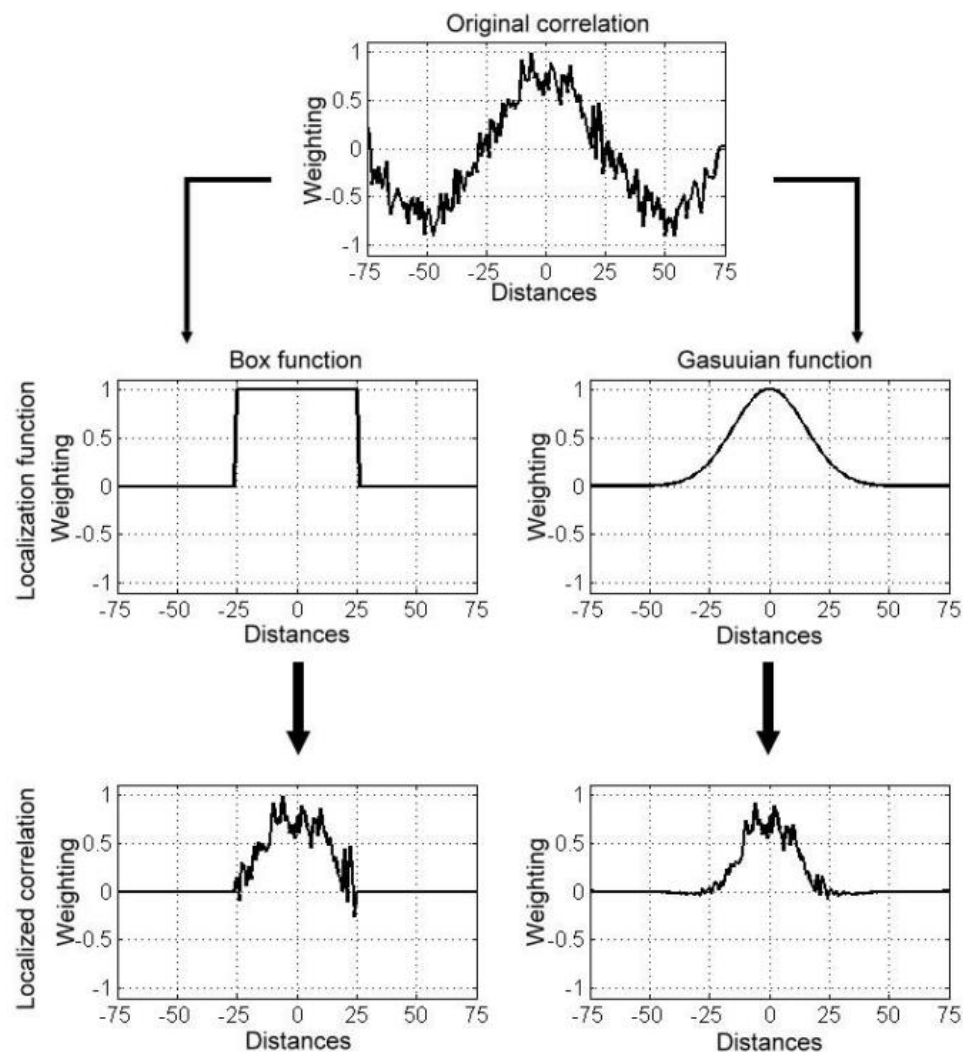
空間相關性(Correlation)

■ 利用模式系集成員計算空間相關性

- 可以是二維也可以是三維的關聯性
- 可計算不同物理參數(model state)的相關性

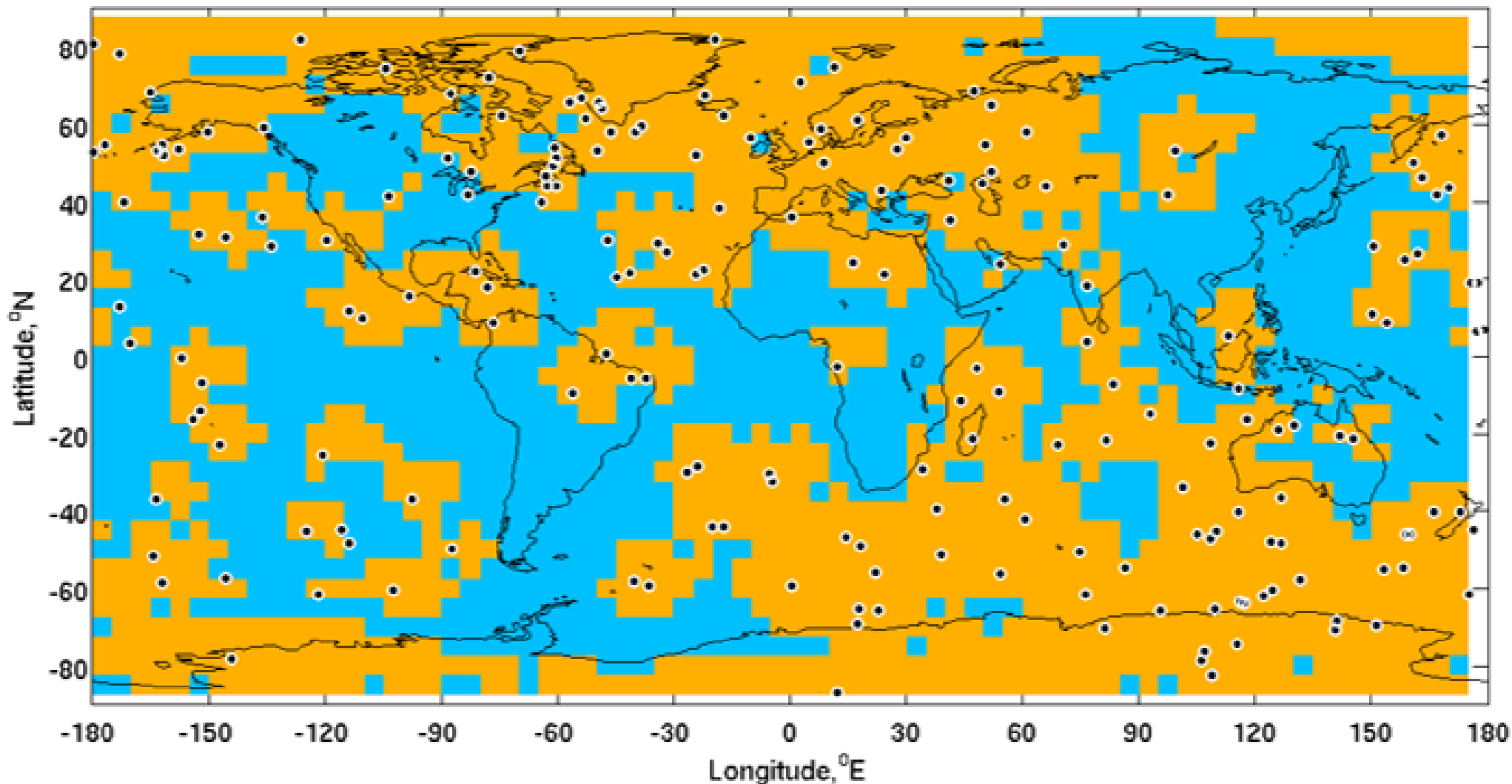


❖ 局地化參數(Localization Function)





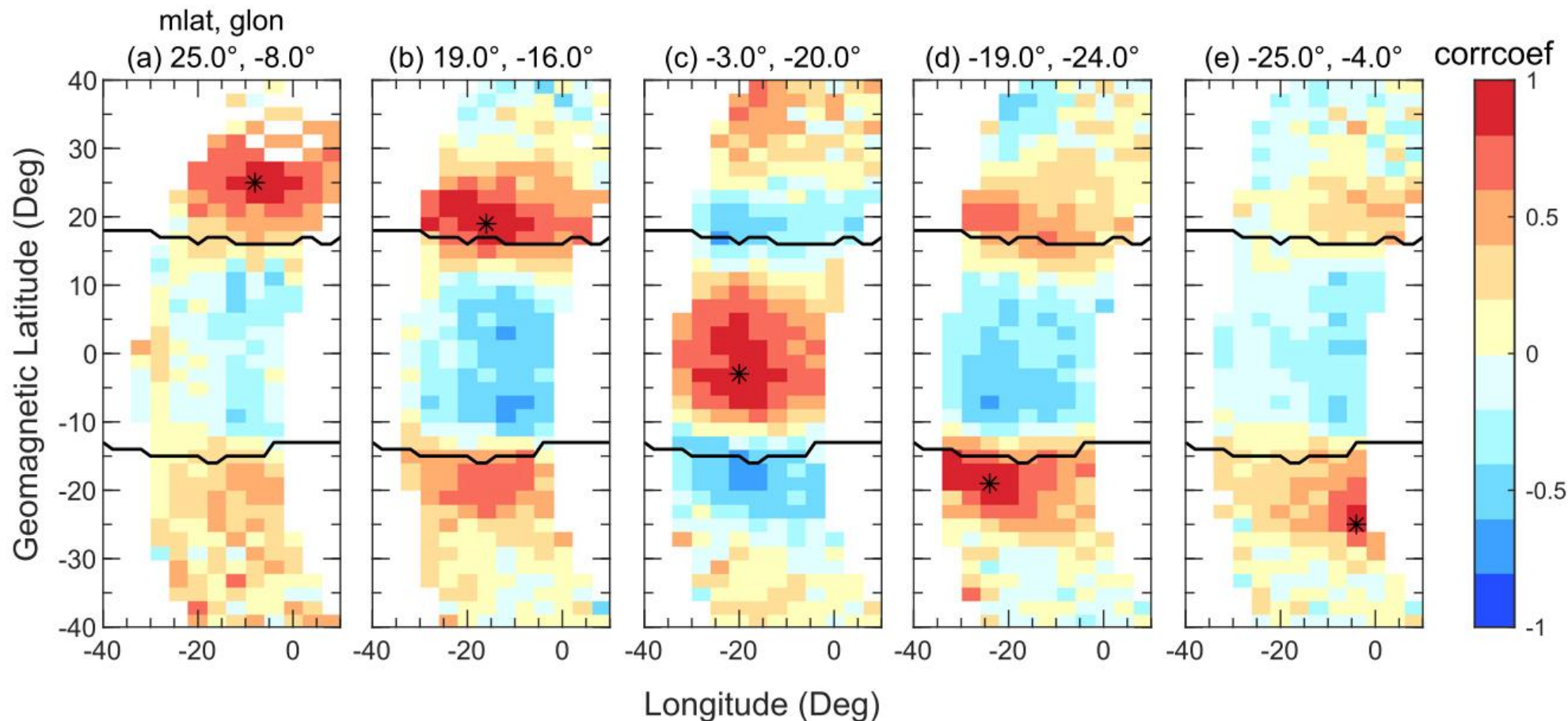
全域同值應用結果



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從觀測推估電離層濃度相關距離

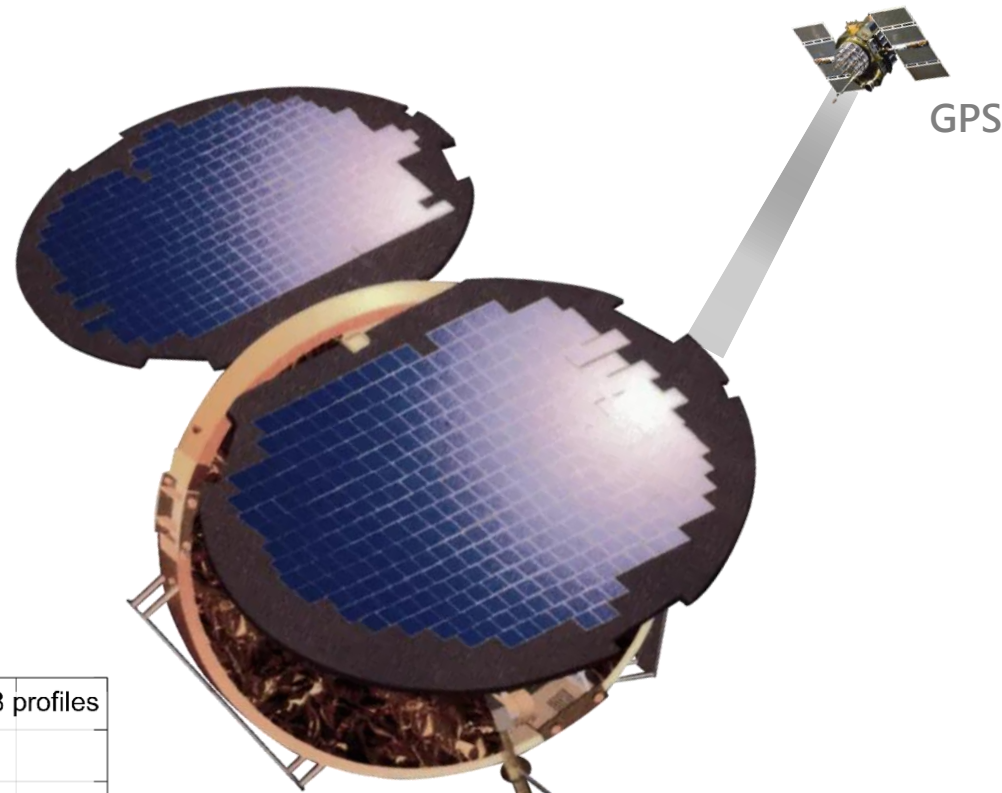
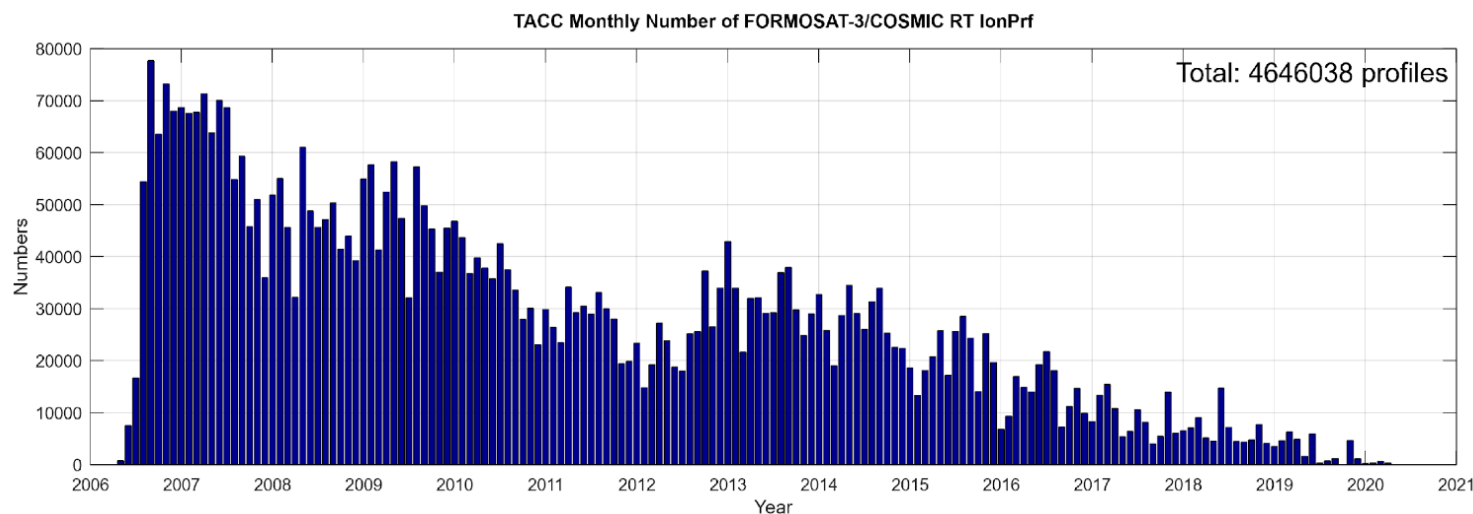


By using the NASA/GOLD observations, the average value of the zonal correlation distance is approximately 8.55° and 3.56° for the meridional direction at low geomagnetic latitudes (magnetic latitudes <30°).

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利用福三觀測進行全球分析

- ◆ 軌道高度：700~800公里
- ◆ 軌道傾角：72度
- ◆ 觀測數量：日均2,500筆
- ◆ 資料延遲：約90分鐘
- ◆ 發射日期：2006年4月15日
- ◆ 功成身退：2020年(完整涵蓋太陽活動週期)



福爾摩沙衛星三號
FORMOSAT-3/COSMIC
2006 - 2020

■ 取用Level 1b ionPrf資料內的Global Data資訊

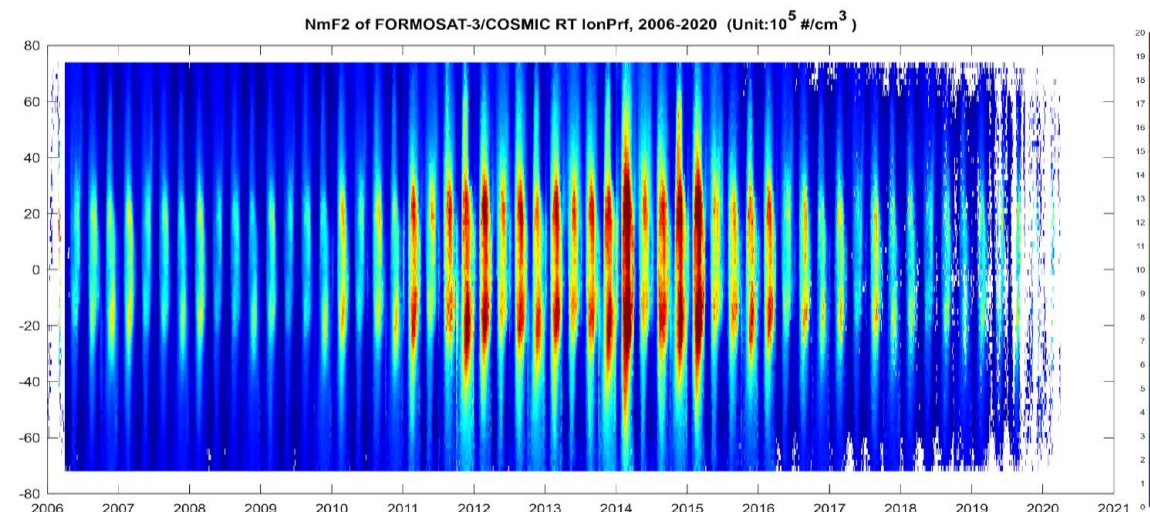
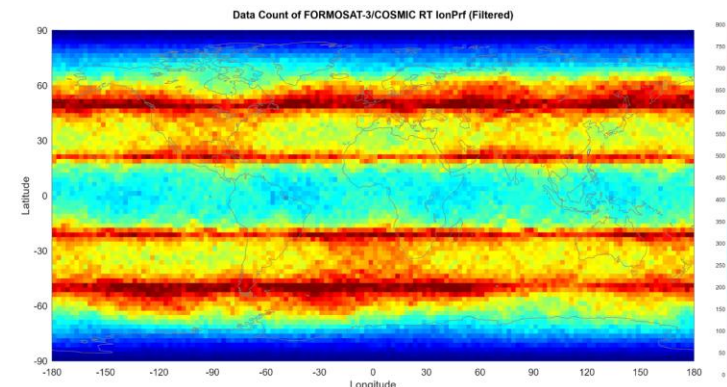
- 匯出最大電子濃度、經度、緯度、高度、時間等資訊
- 針對出現高度進行QC，限制高度範圍在150-600公里之間。
- 座標資訊轉換成地磁緯度(ML)和地磁當地時(MLT)
- 設定緯度解析度2度，時間解析度0.5小時(7.5度)進行資料網格化
- 每一年再簡化至M,J,S,D四個季節的矩陣

■ 分析方法

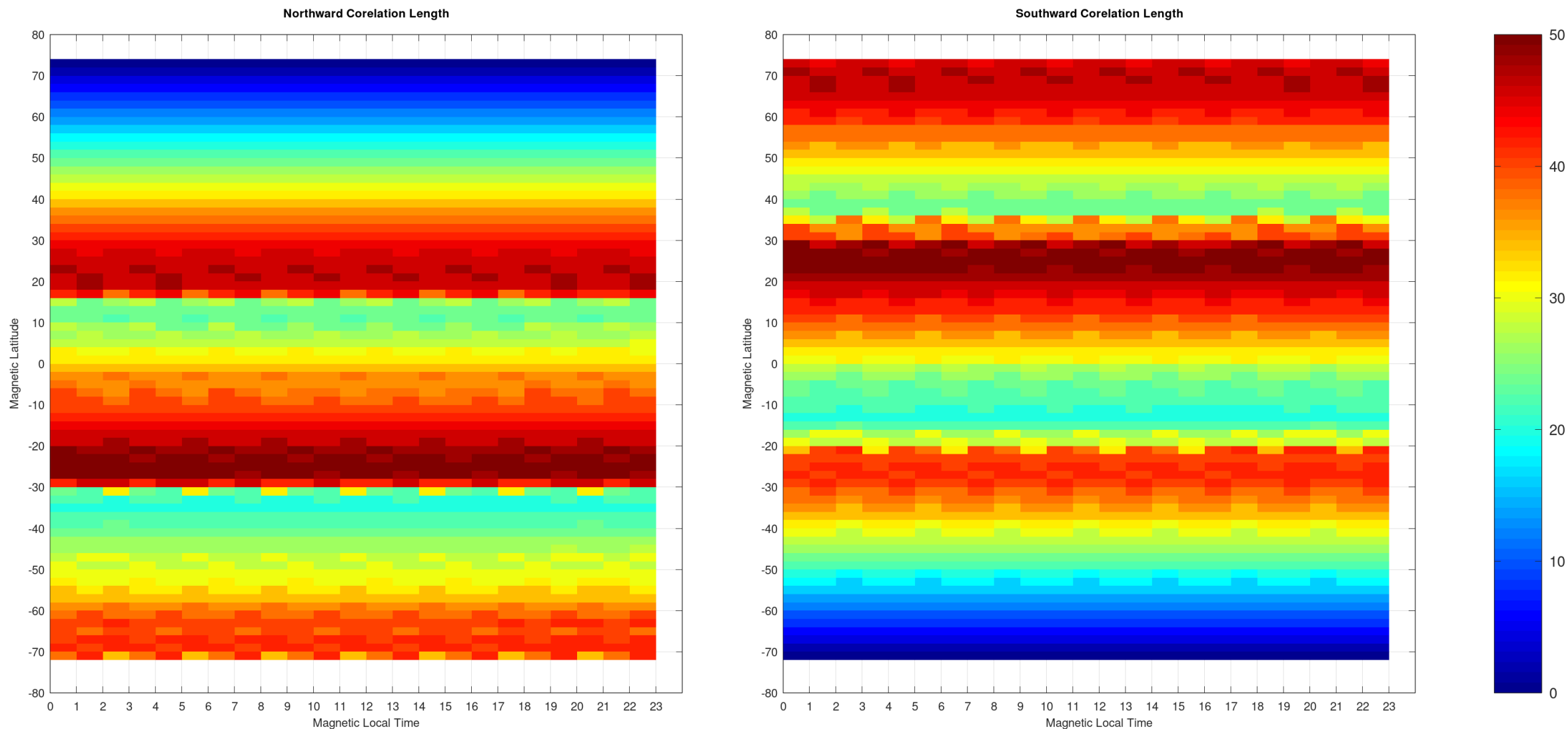
- 以14年x4季的資料，逐時計算網格緯向關聯性
- 隨緯度網格計算時間軸方向來替換經向的關聯性
- 取相關係數下降至0.95的距離

■ 資料來源：國科會大氣科學研究與應用資料庫(ASRAD)

- https://asrad.pccu.edu.tw/dbar/digital_data/6-福衛三號-電離層特徵資料f3-c-ro/



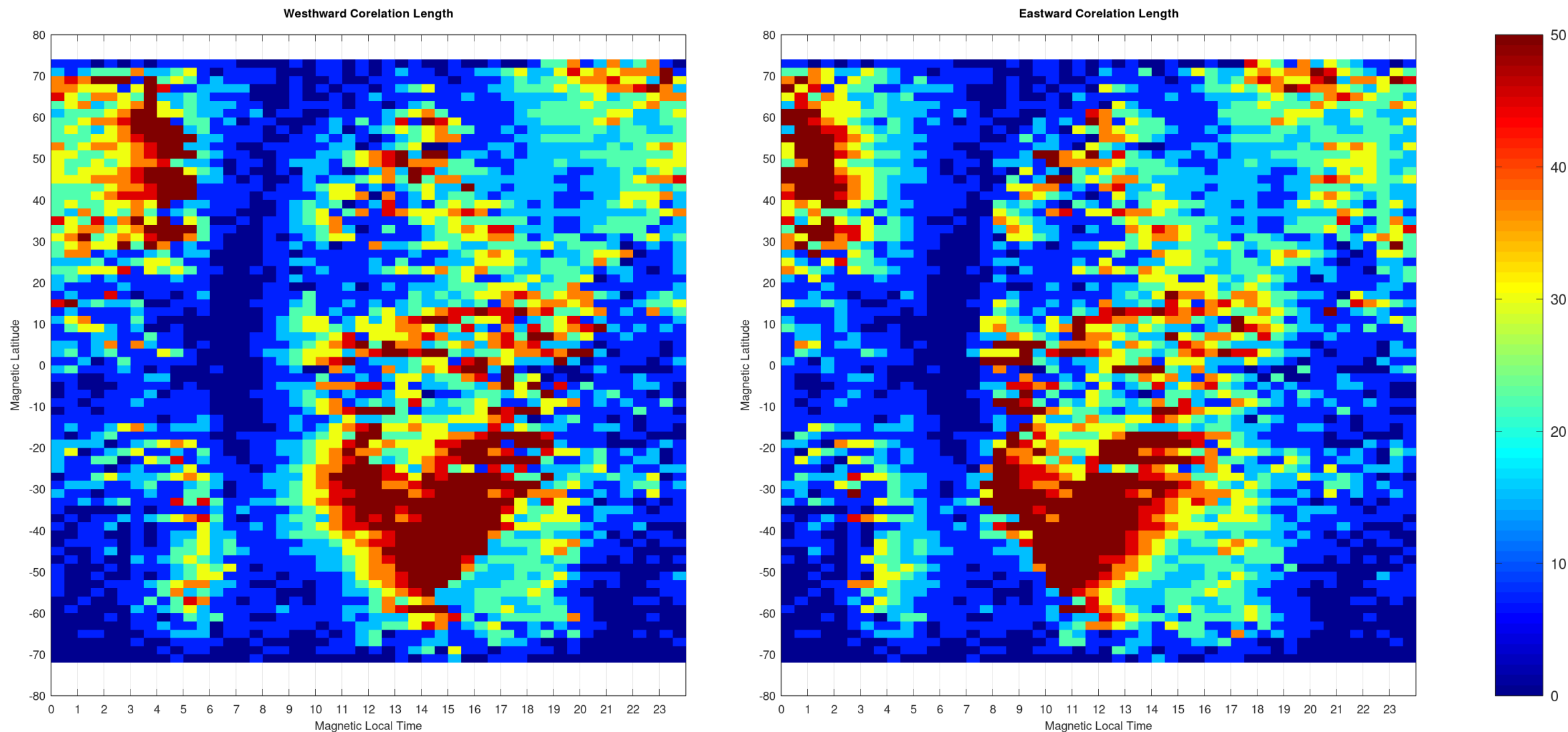
分析結果-沿緯度方向(Meridional)



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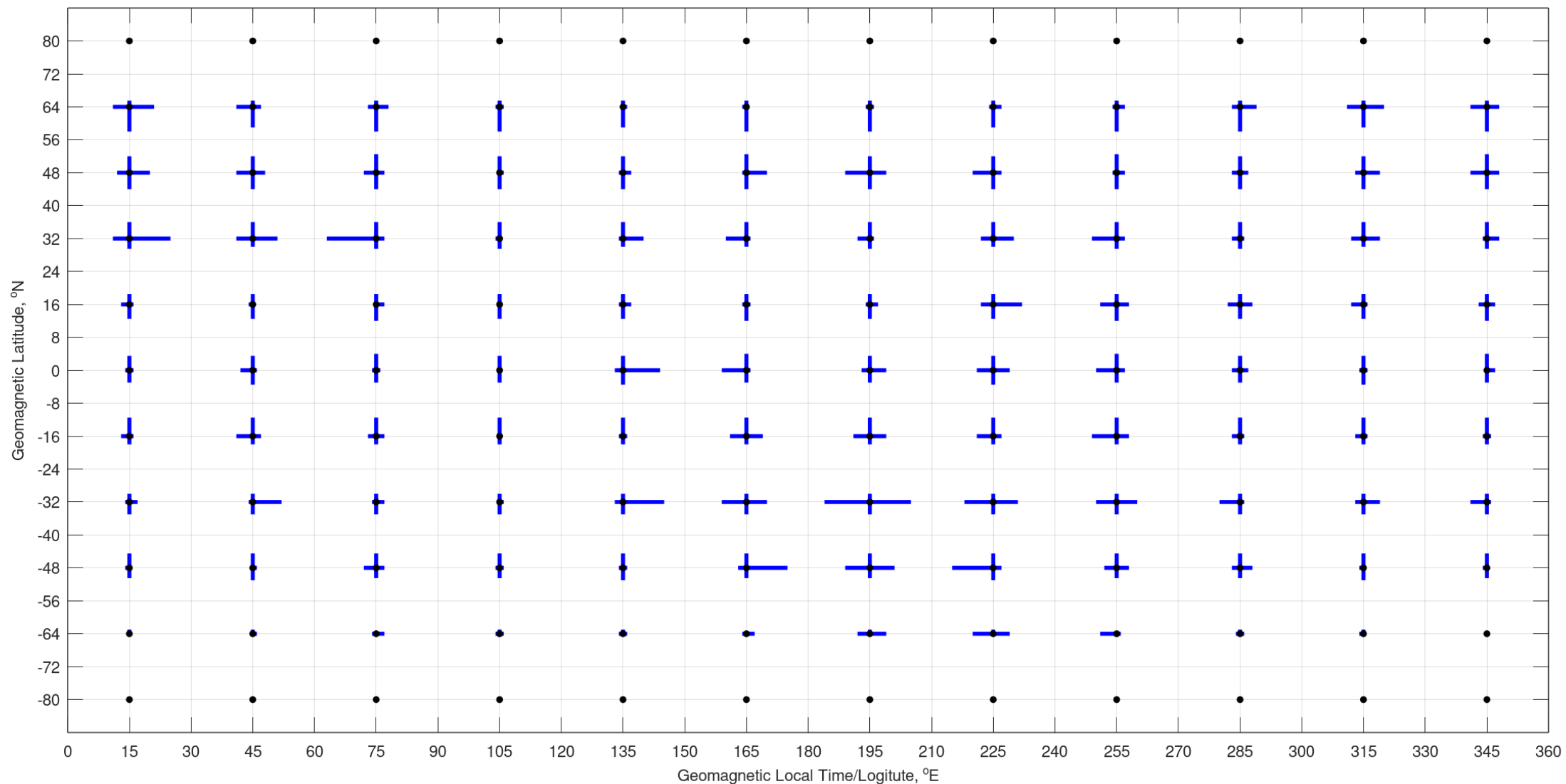
分析結果-沿經度方向(Zonal)



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地域獨立性局地化建議

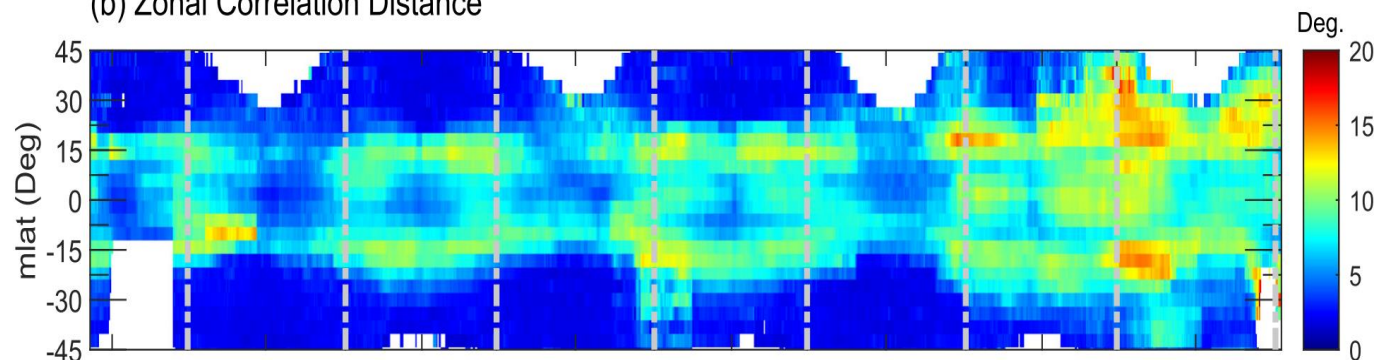


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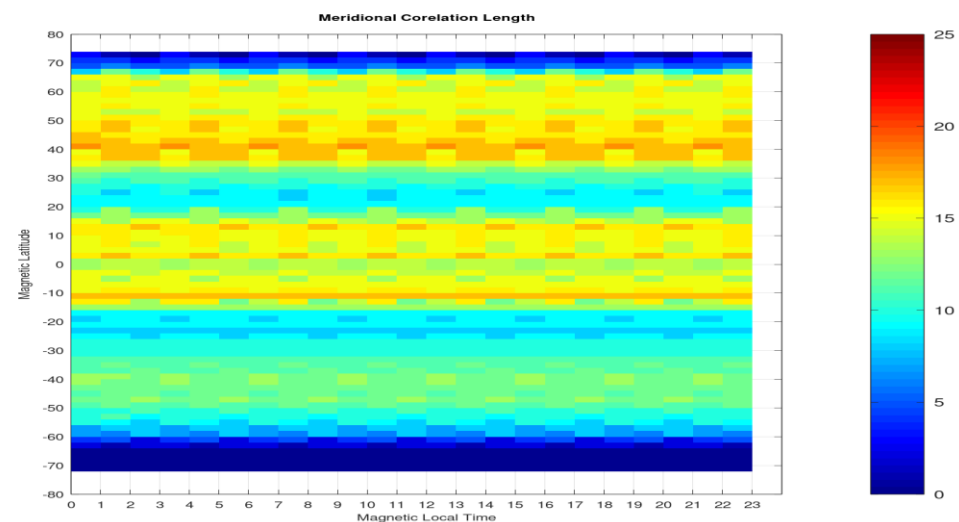
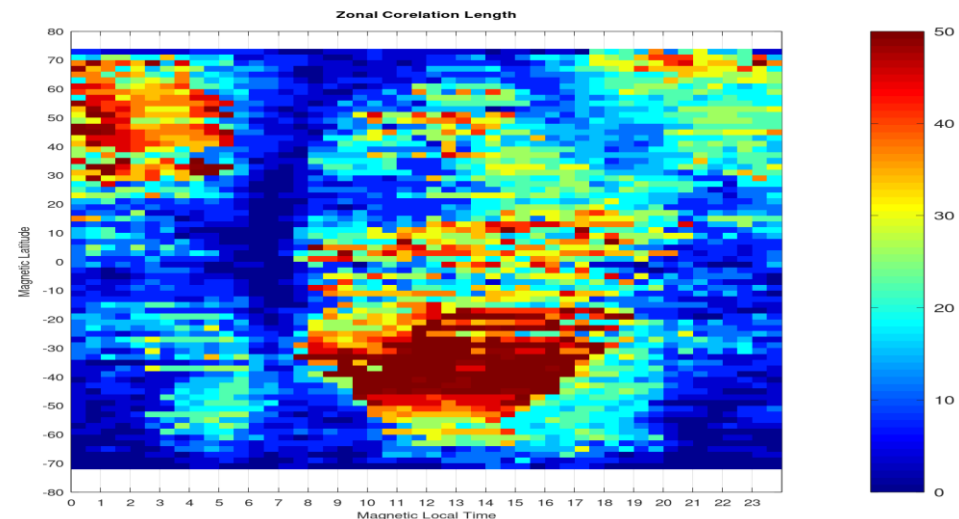
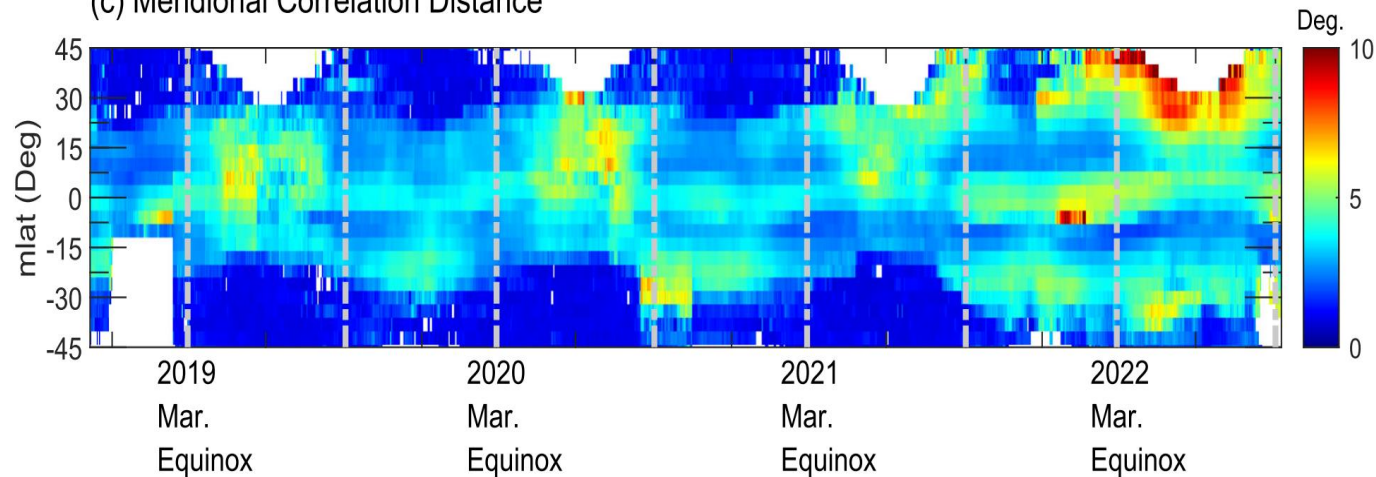


對比NASS/GOLD的分析結果

(b) Zonal Correlation Distance



(c) Meridional Correlation Distance



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- 透過資料同化技術有助透過觀測資料來修正模式的初始場，並提升預報產品的表現。而觀測資料對於初始場的修正量，除了透過觀測誤差來描述之外，也會根據局地化參數來限制觀測資料所能影響的水平與垂直範圍大小。
- 電離層資料同化系統發展初期，採用**Gaspari-Cohn**函數將每個觀測觀測的影響範圍侷限在半徑約**20度**的範圍內，可避免過度修正又可獲得良好的同化結果。
- 從以往各種觀測資料分析，電離層在沿緯度方向(**Zonal**)的相關距離應大於沿經度方向(**Meridional**)且會隨著緯度有所不同。因此，應嘗試於資料同化系統中導入地域獨立性局地化參數(**local localization**)並分析對資料同化系統的影響。
- 為能有全球分析結果，本次嘗試利用福衛三號所有觀測資料進行分析，在設定相關係數閾值為**0.95**下得出全球電離層空間相關距離，緯向較徑向和磁當地時有較高的關聯性。
- 結果僅為初步分析尚待進一步詮釋，且相關係數閾值也能在做調整後，再將所得之局地化參數配合電離層資料同化系統，驗證是否可改善預報表現及效益。

感謝聆聽
敬請指教

