中央氣象局八面體網格全球預報系統：全球波譜模式

劉邦彥[1] 、孫于力[2] 、 陳登舜[3] 、陳建河[2] 、莊漢明[4] 、林沛練[3]

1. 中央氣象局氣象科技研究中心
2. 中央氣象局氣象資訊中心
3. 國立中央大學大氣科學系
4. 美國國家環境預測中心

2019.05.14 天氣分析研討會

大綱

- 模式簡介
- 上線評估實驗
- 初步評估結果

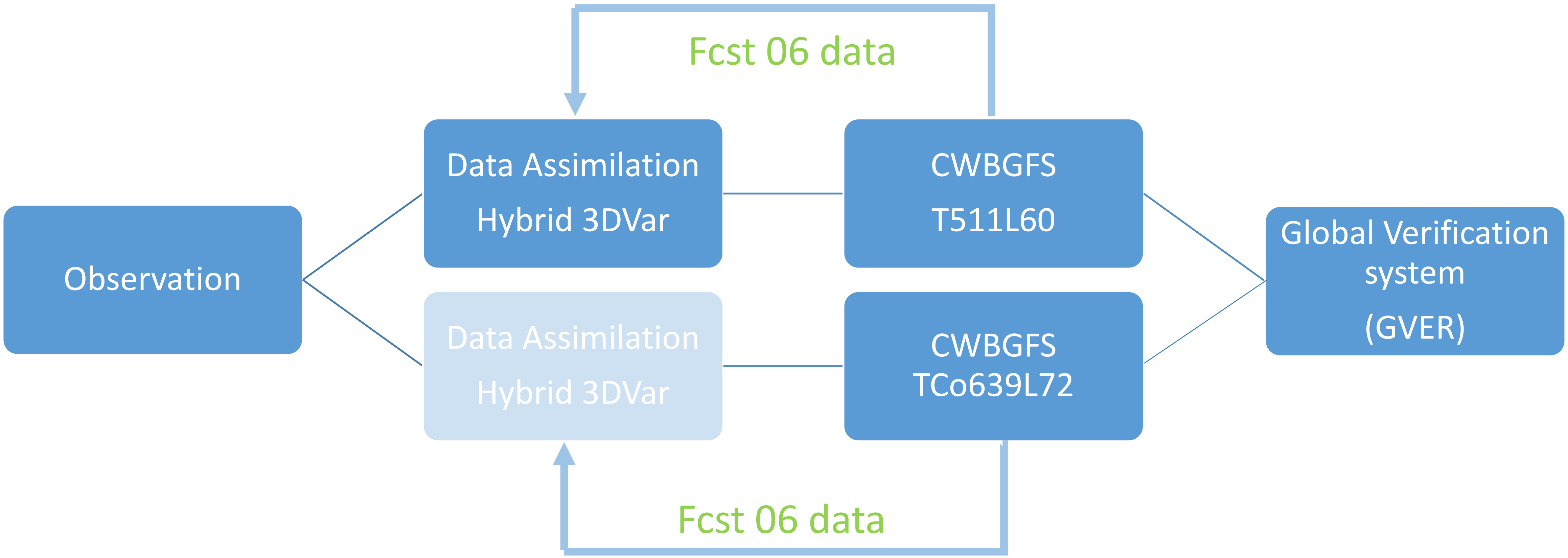
  20180901~20180930 (00Z) 共30個案
- 結論與未來工作

模式簡介

CWB GFS		
Resolution	T511L60 (1536*768*60) Horizontal grid : reduced Gaussian grid (~25KM) → **Octahedral reduced Gaussian grid (~15km)** Vertical grid: S-P hybrid 60 layers Model top: 0.1 mb **TCo639L72 (2576*1280*72)** **S-P hybrid 72 layers**	
Progonostic variables	divergence, vorticity, virtual potential temperature and Tracers	
Dy-core	Spectral method Eulerian + Semi-implicit → **Semi-Lagrangian(NDSL) + Semi-implicit** 3 time level	
Physics	**Soil model**	Noah land surface model-4 layer (Ek et al. 2003)
	Vertical turbulence	Hong and Pan (2011)
	Shallow convection	Han and Pan(2011)
	convection	NSAS(New Simplified Arakawa-Schubert scheme) (Pan and Wu 1995; Han and Pan 2011)
	precipitation	Cumulus Grid scale : Predict cloud water(pcw) and diagnose precipitation with cloud physics (Zhao and Carr 1997)
	Gravity wave drag	Palmer et al. (1986)
	Radiation	Rapid Radiative Transfer Model for GCMS (RRTM-G)
	Non-orographic gravity wave drag	Scinocca(2003)

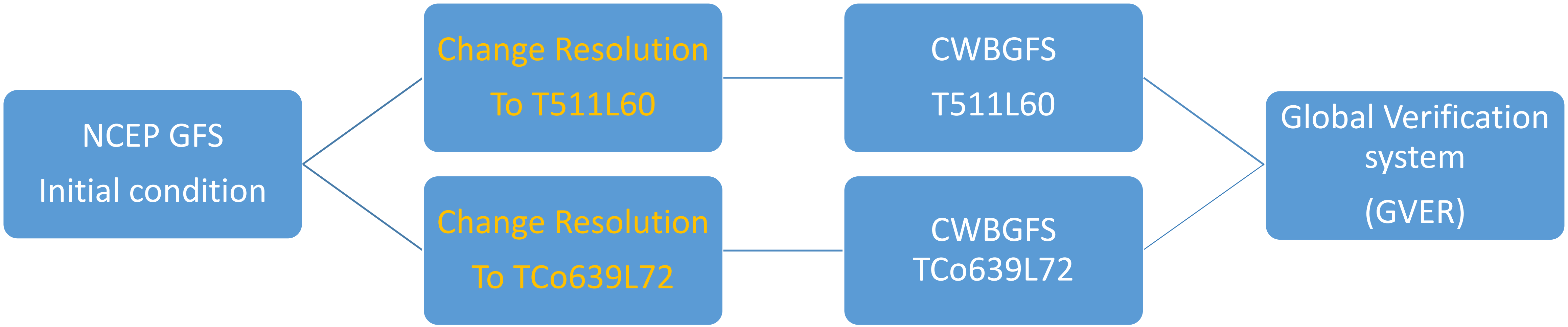
上線評估實驗

Update cycle run



上線評估實驗

Off-line run

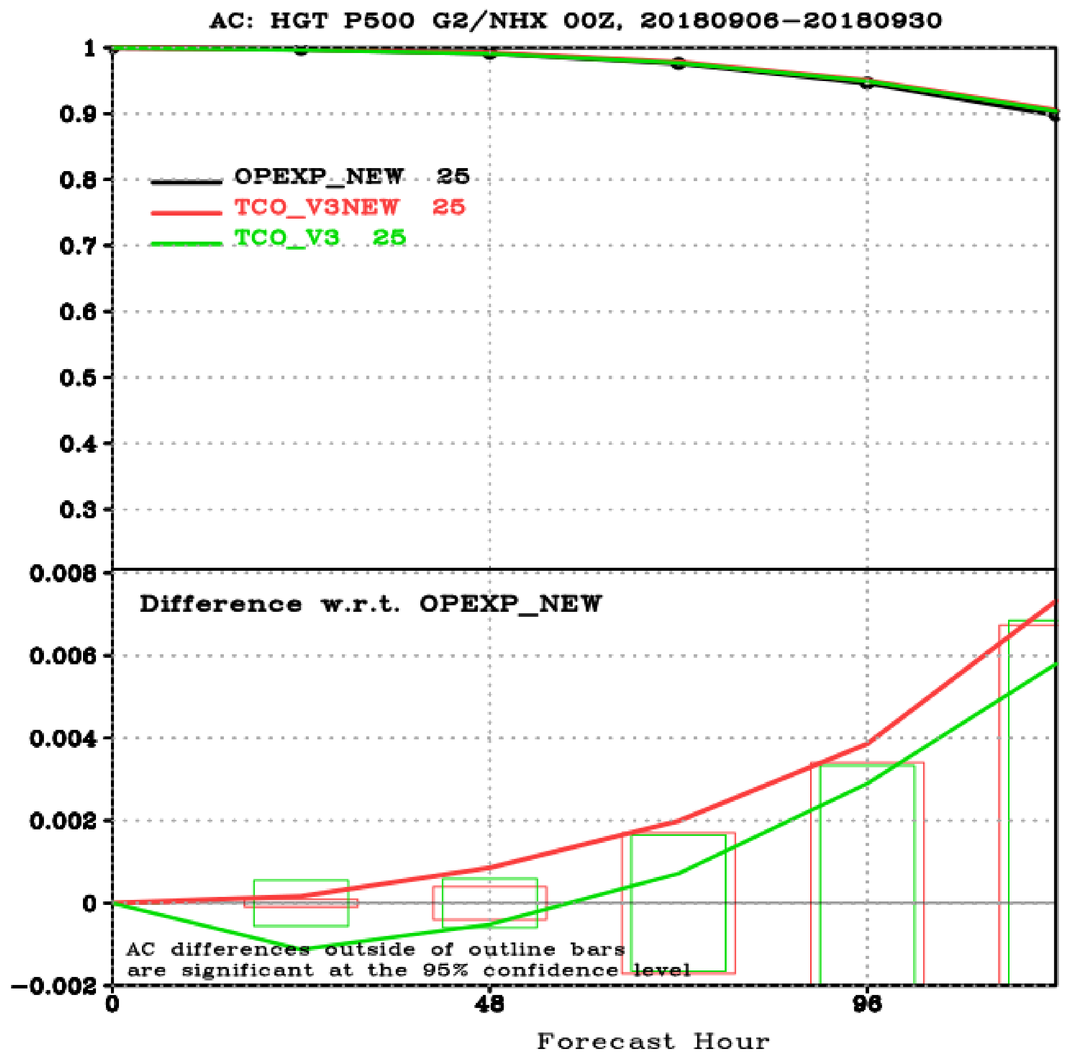


初步評估結果: 20180901~20180930(00Z)

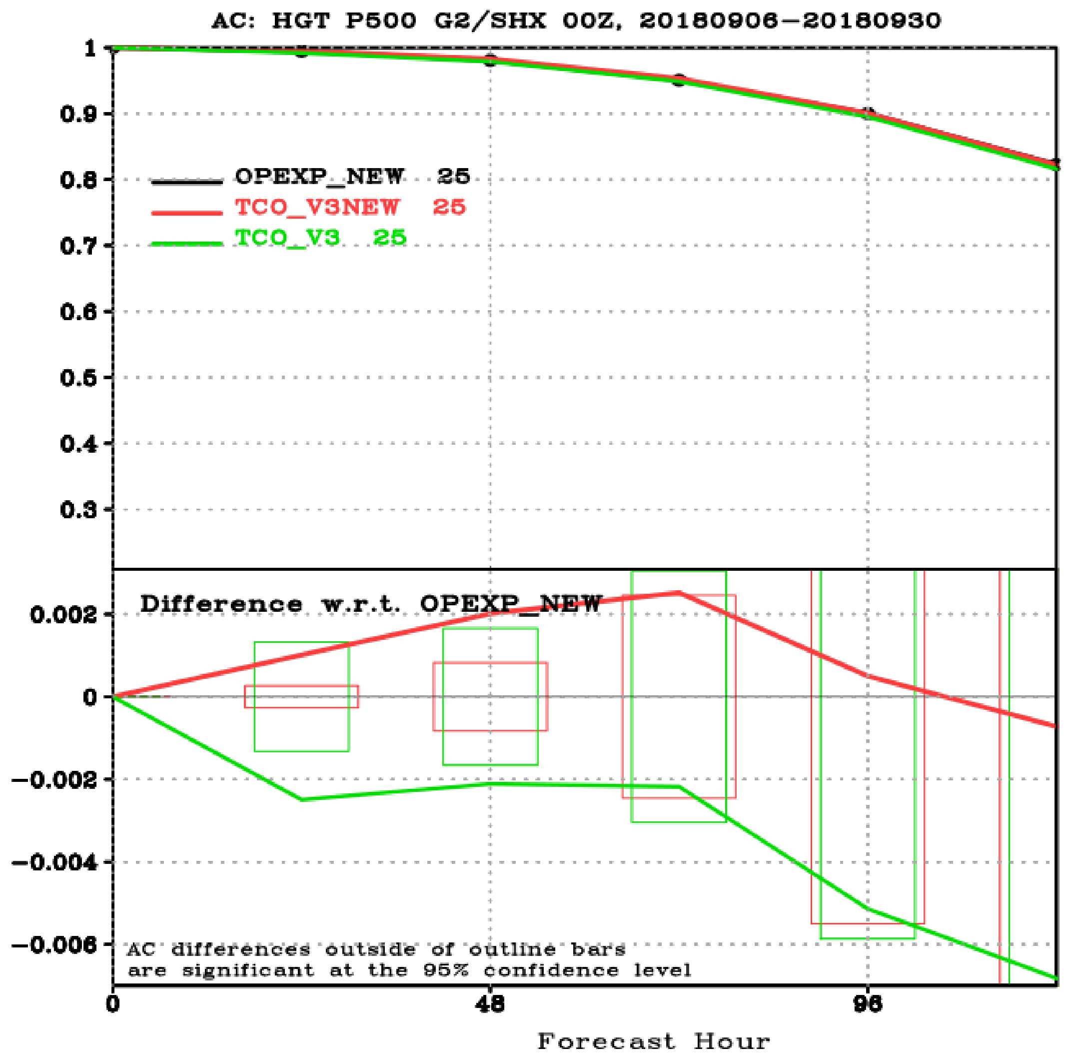
test run	CWB GFS (OPER)	CWB GFS (NDSL)
Initial Condition	20180901~20180931 (00Z)	
Model Dynamic	Eulerian	Semi-Lagrangian (NDSL)
Model Resolution (Grid Point)	T511L60 (1536*768*60) ~25km reduced Gaussian grid	T_{Co}639L72 (2576*1280*72) ~15km Octahedral reduced Gaussian grid
Initial Condition	Off-line run (from NCEP analysis data)	Off-line run (from NCEP analysis data)
Model Physics	on	
Integration Time (hours)	120	
Integration Time Step (Seconds)	90	225

評估測試: 500hPa geopotential height ACC

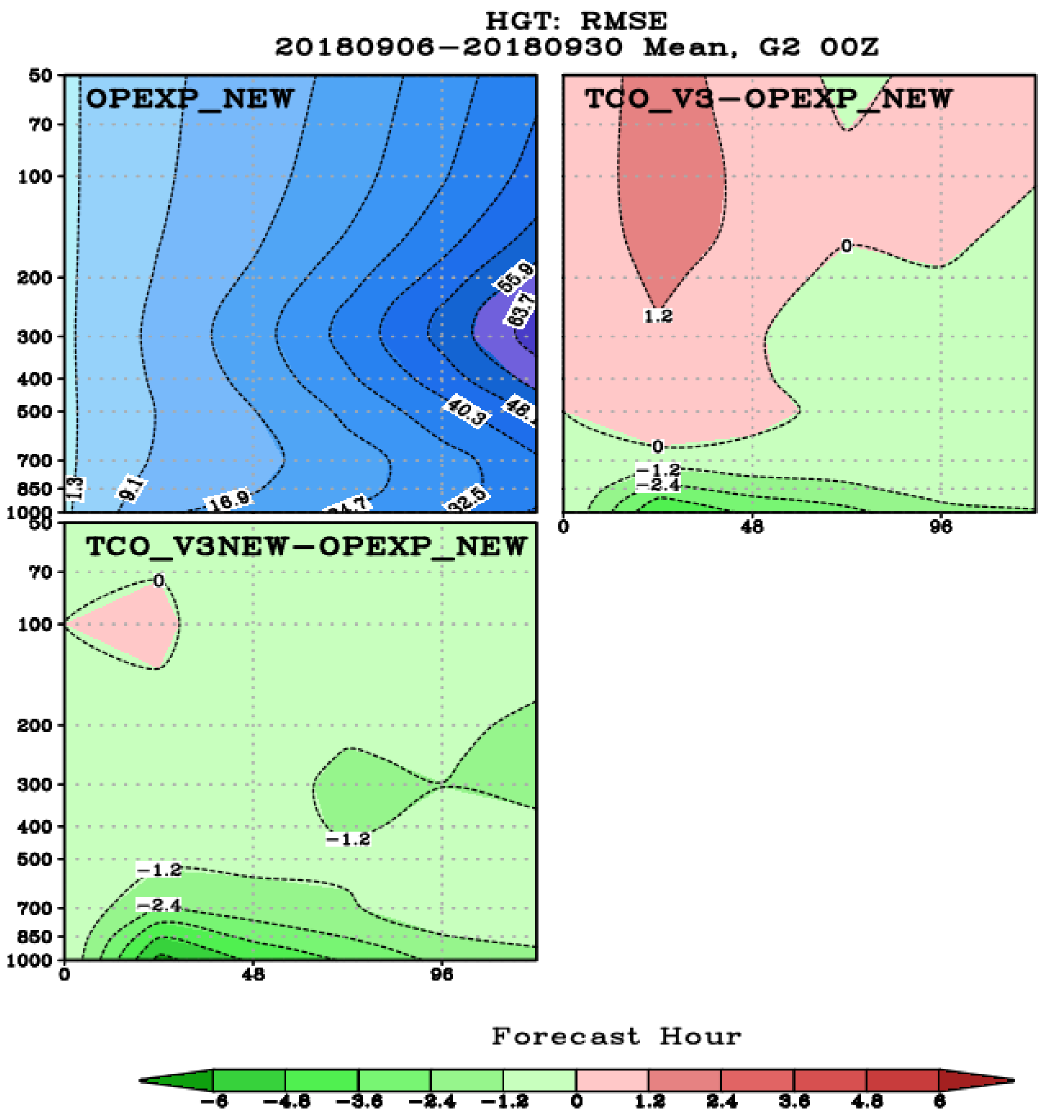
North Hemisphere



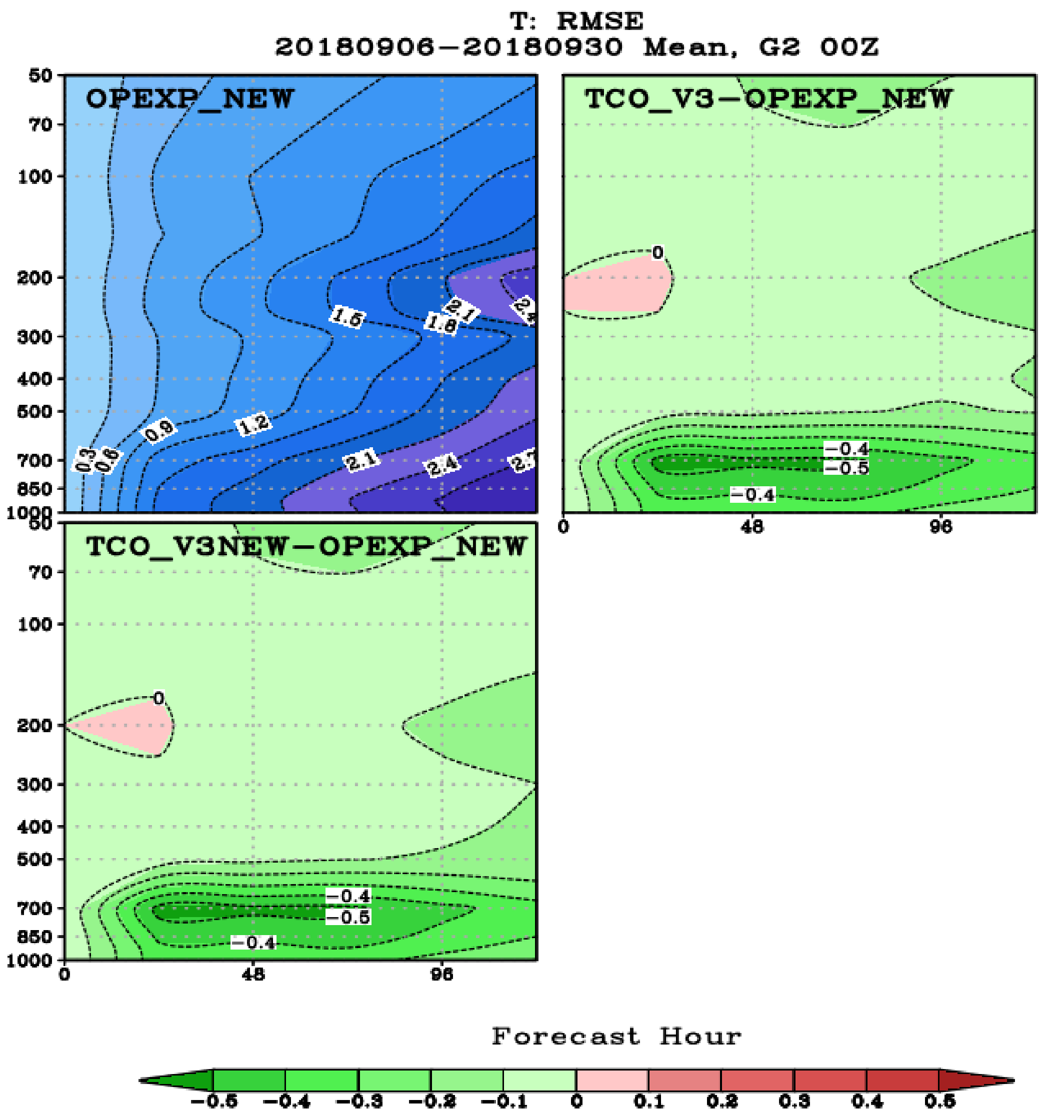
South Hemisphere



評估測試: time series of RMSE profile

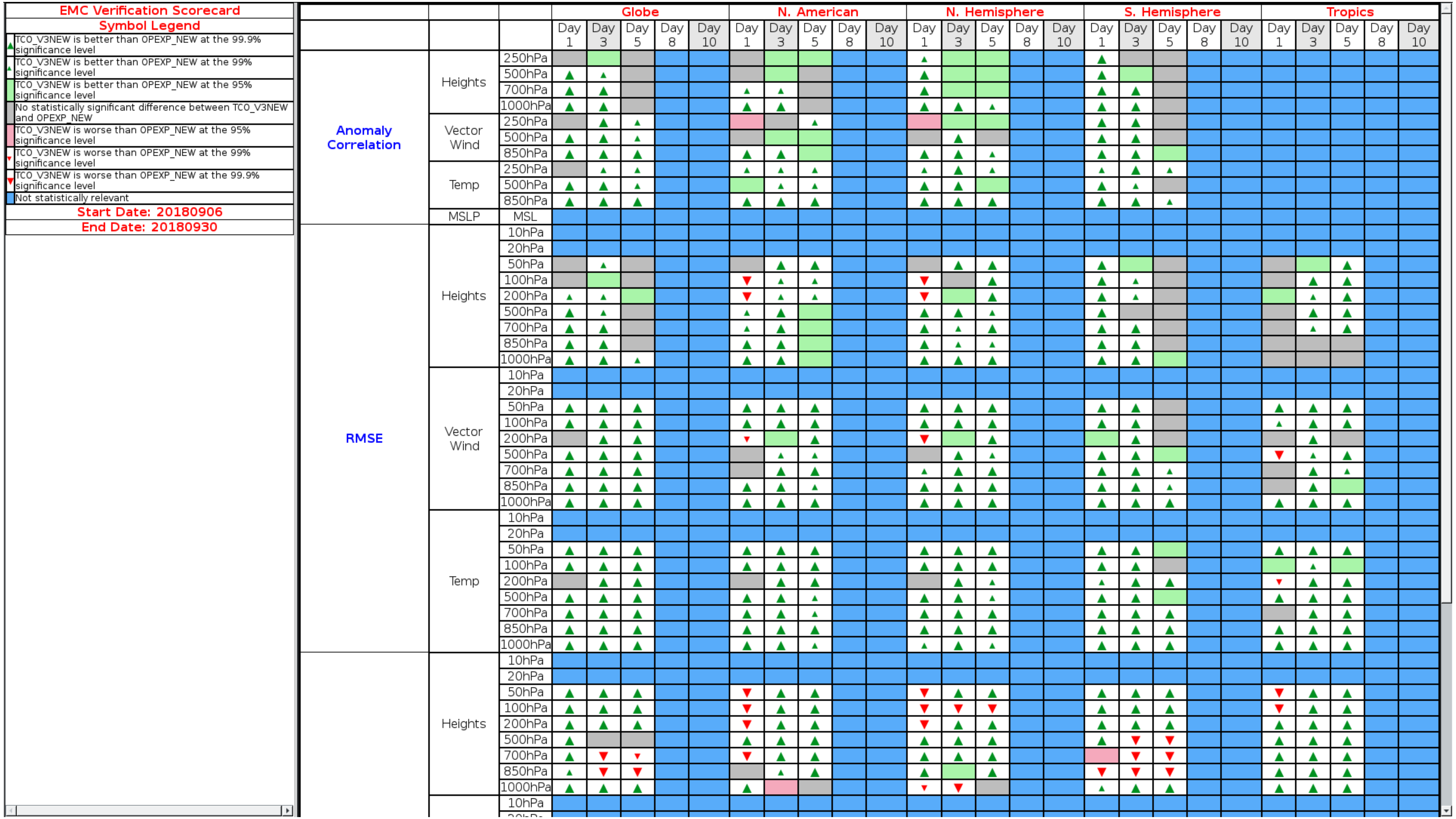


Geopotential Height



Temperature

評估測試: Score Card (TCo_V3NEW v.s. OPEXP_NEW)



Case testing: Typhoon

implementation of scale-aware deep & shallow convection scheme in CWBGFS TCo639L72

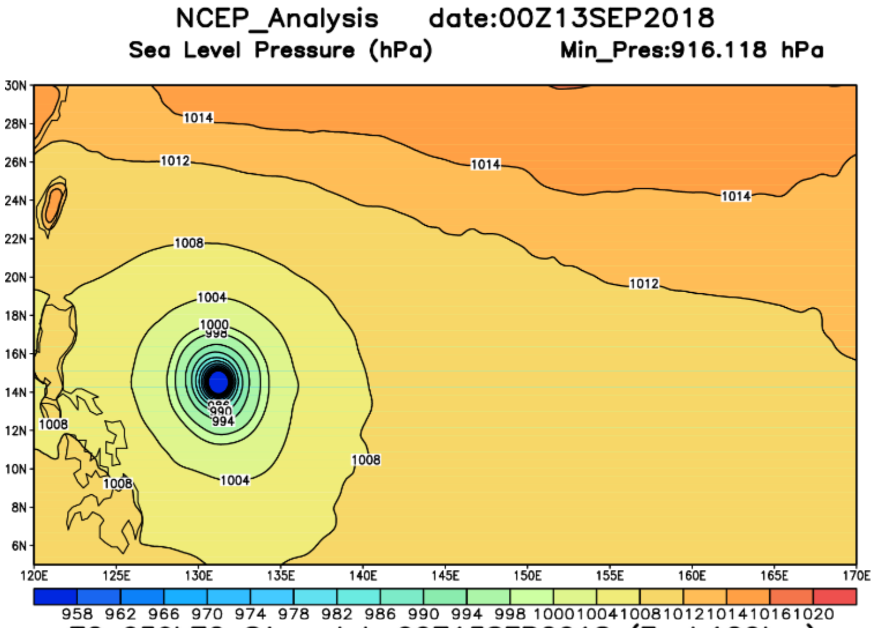
- Analysis：NCEP
- TCO_V3 : TCo639L72 (sascnv & shlcnv)
- TCO_SA : TCo639L72 (scale-aware sascnv & shlcnv)
- T511 : T511L60 (ndsl T)

- Initial time : 20180908 00Z
- Integration : 120 hours

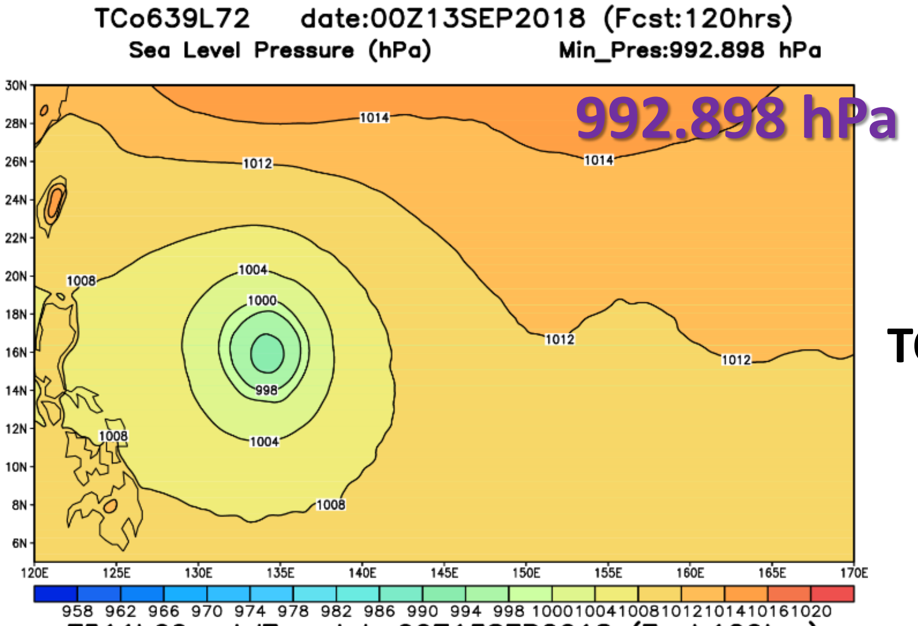
評估測試: Typhoon

Tau=120

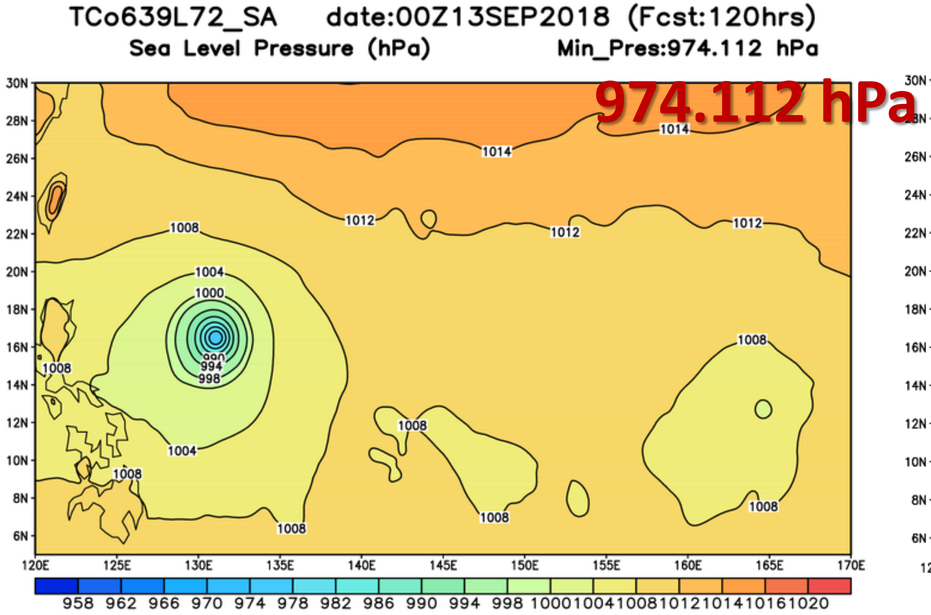
NEMSIO



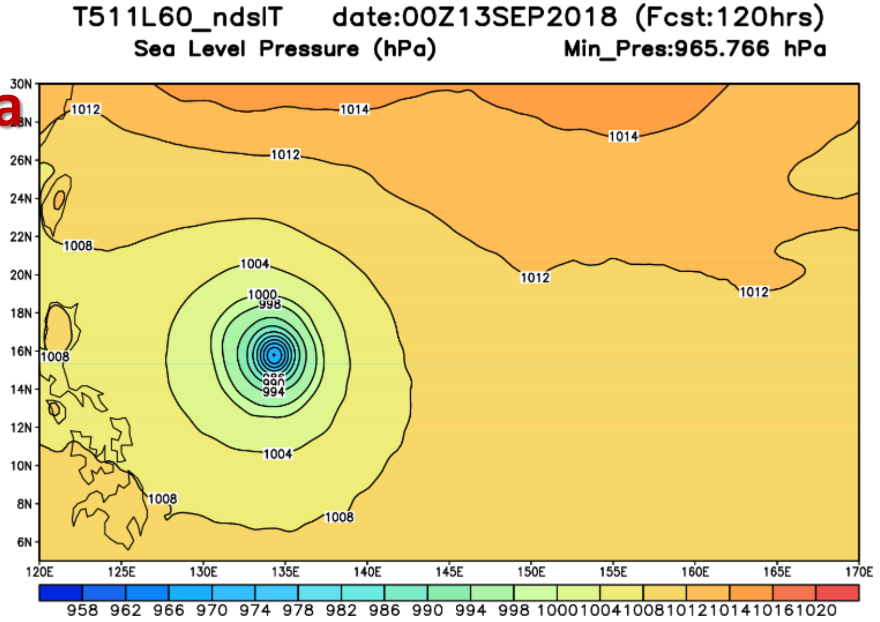
TCO_V3



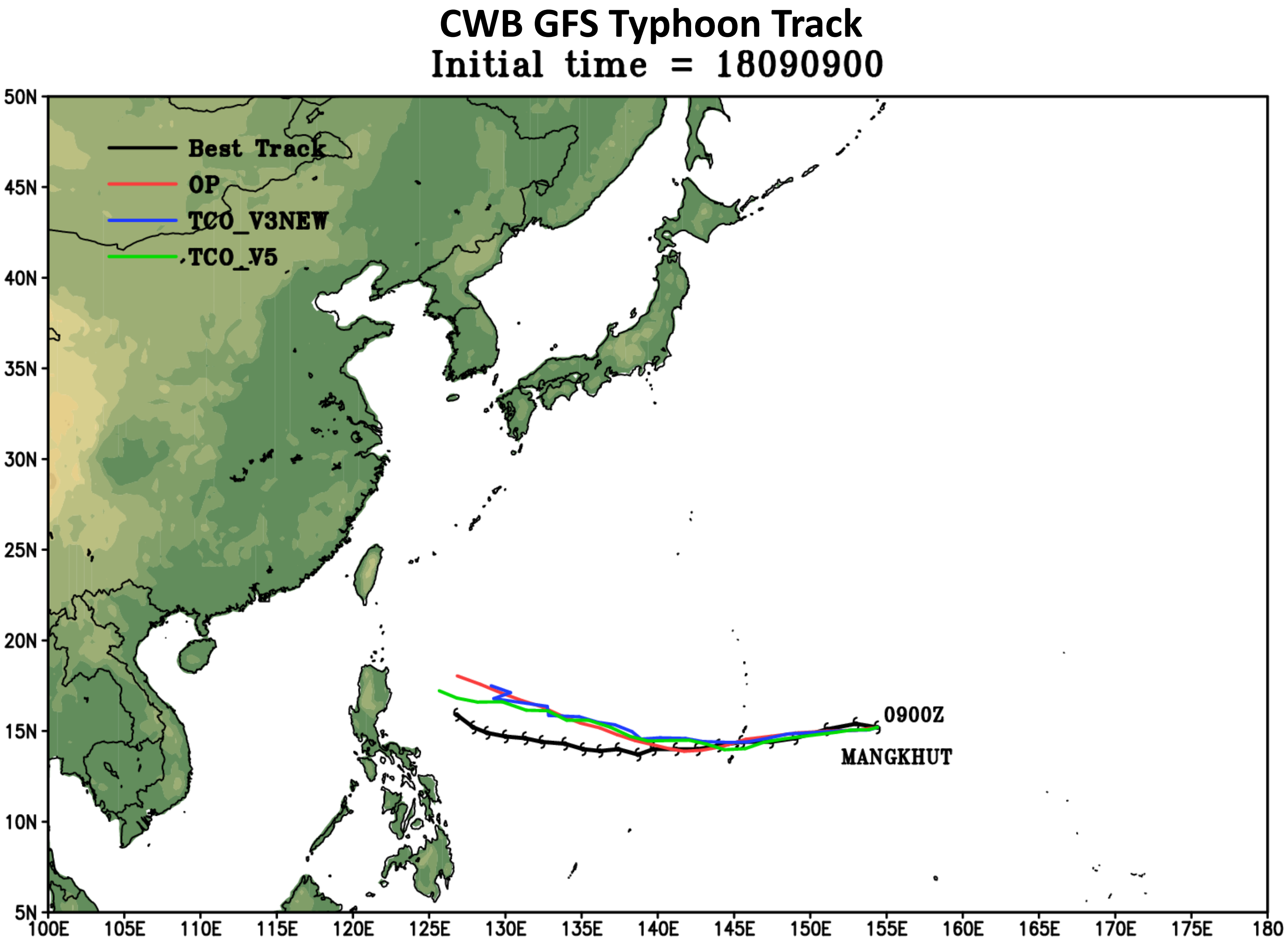
TCO_SA



T511

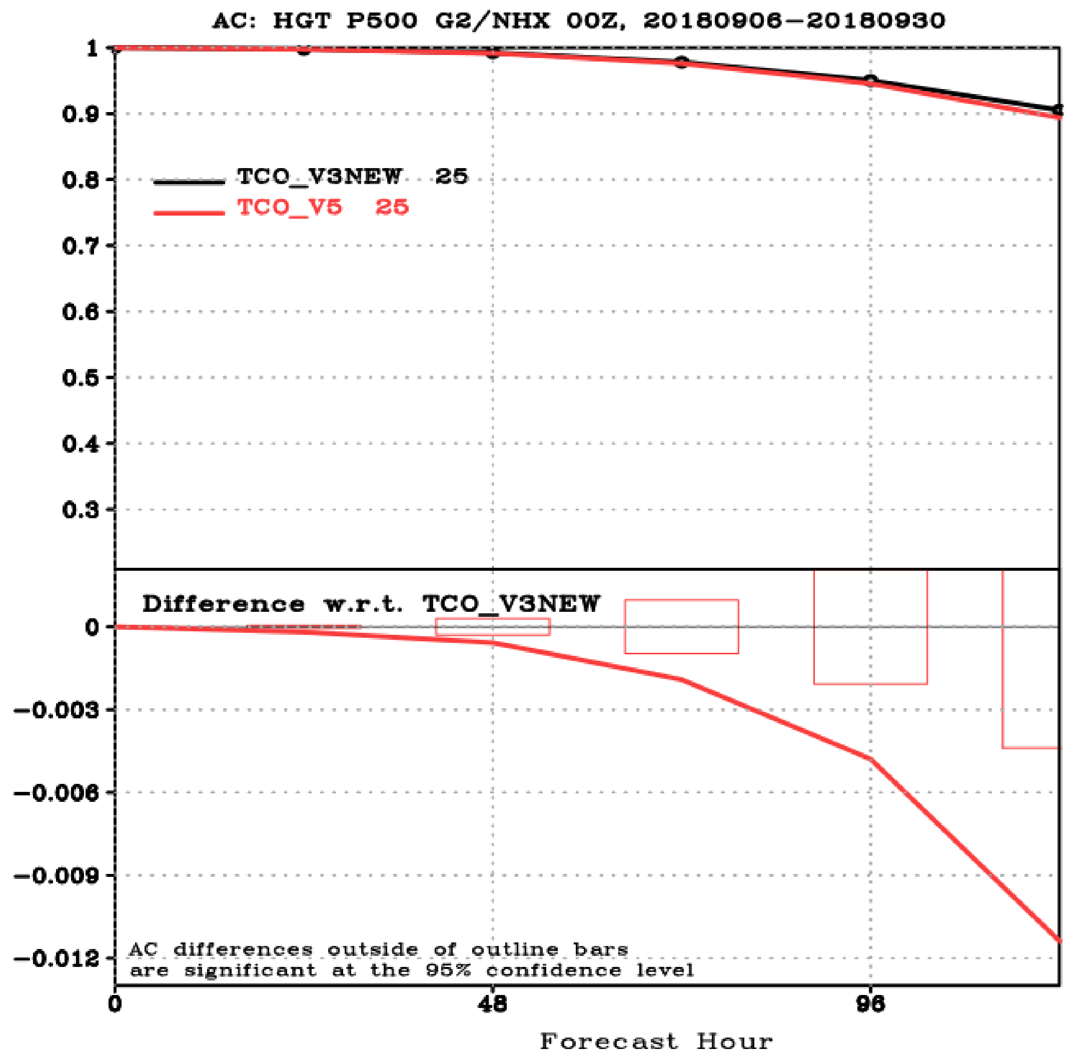


評估測試: Typhoon

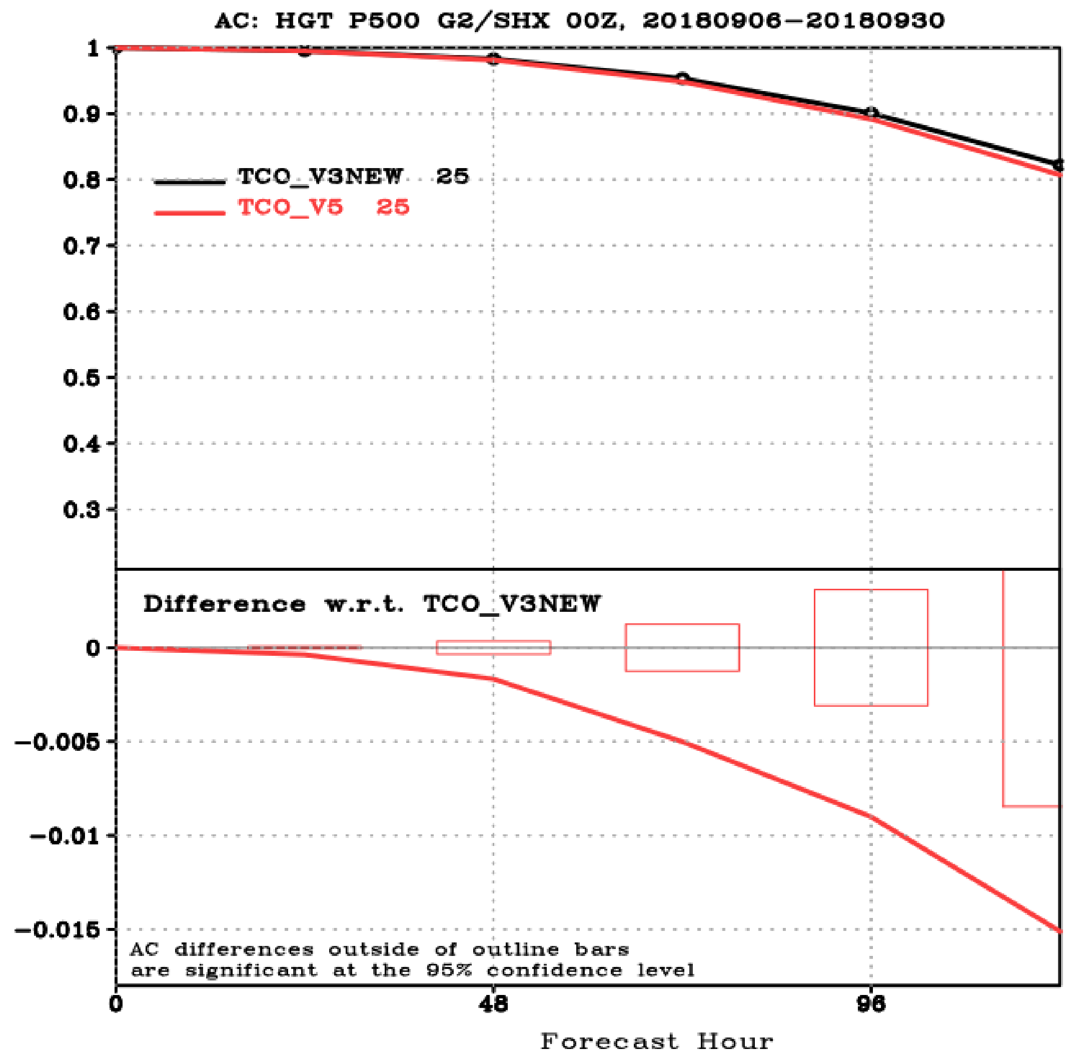


評估測試: 500hPa geopotential height ACC (TCo_V5 v.s. TCo_V3NEW)

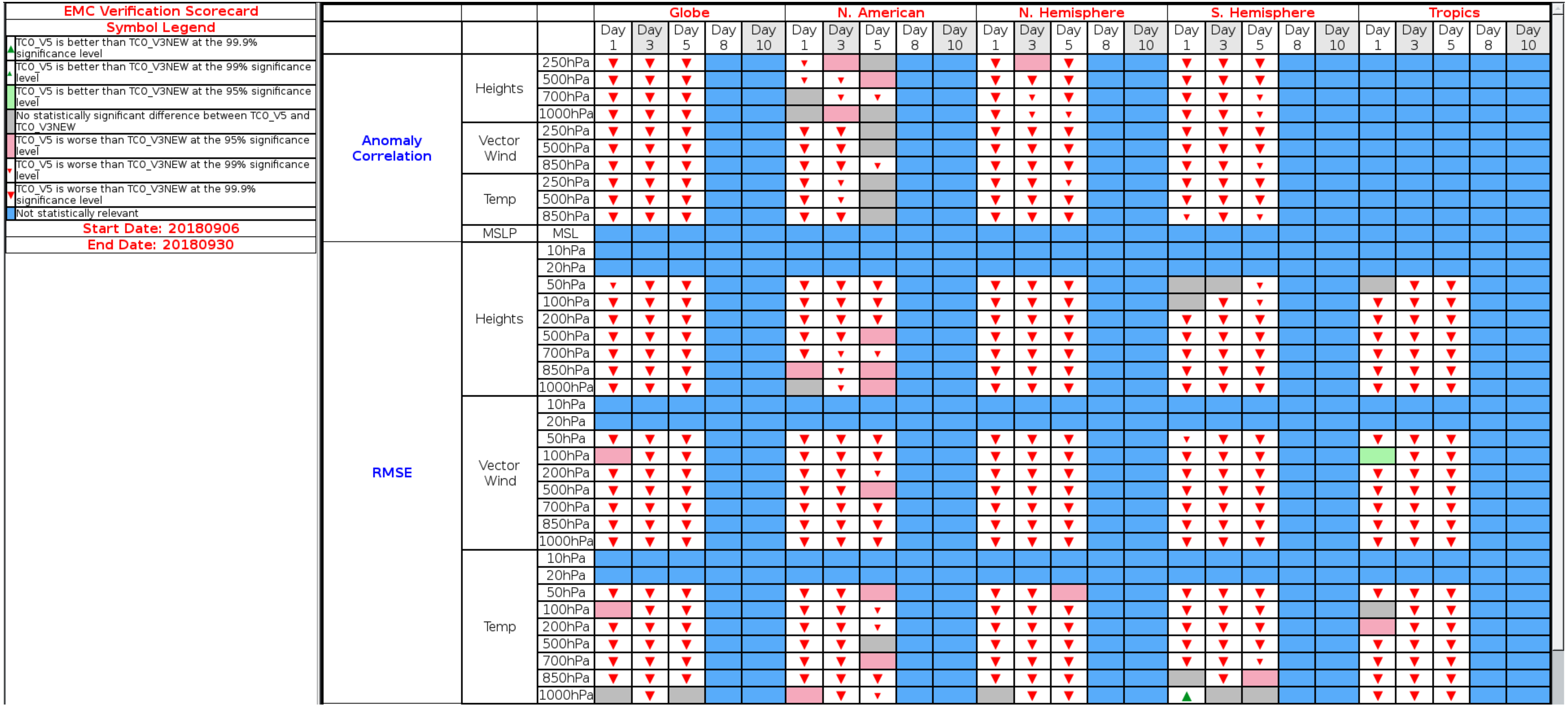
North Hemisphere



South Hemisphere



評估測試: Score Card (TCo_V5 v.s. TCo_V3NEW)



Summary & Future work

Summary

1. TCo639L72 offline run測試評估：
   - 無論在重力位高度、溫度以及風場的整體表現，皆比T511L60之表現好
   - 颱風的強度預報上，有明顯偏弱的情況發生

2. 物理參數化更新：
   - 更新深淺對流之參數化，颱風強度之預報有略為改善，但仍與T511L60有段差距
   - 改善了颱風強度預報，但是綜觀尺度之表現反而較不理想

Future work

- 持續改進動力上之運算效能（減少記憶體使用量、優化運算過程、2-time level之發展....）
- 持續更新物理參數化之部分
- 進一步評估模式預於東亞地區天氣預報的掌握程度
- 建置資料同化系統 ，完整上線評估

The End

Introduction

	CWB GFS	CWB GEPS	CWB 2-tier CFS	CWB 1-tier CFS
Resolution	T511L60 (1536*768*60) ~25km	T319L60 (960*480*60) ~40km	T119L40 (360*180*40) ~110km	
Grid type	Reduced Gaussian grid	Reduced Gaussian grid	Regular Gaussian grid	
Vertical grid	S-P hybrid 60 layers	S-P hybrid 60 layers	Sigma 40 layers	
Model top	0.1 mb	0.1 mb	1 mb	
Prognostic variables	Divergence Vorticity Surface Pressure Virtual Potential Temperature Tracers			
Dy-core	Spectral method Eulerian + Semi-implicit → Semi-Lagrangian + Semi-implicit 3 time level			

NDSL : Non-iteration Dimensional-split Semi-Lagrangian

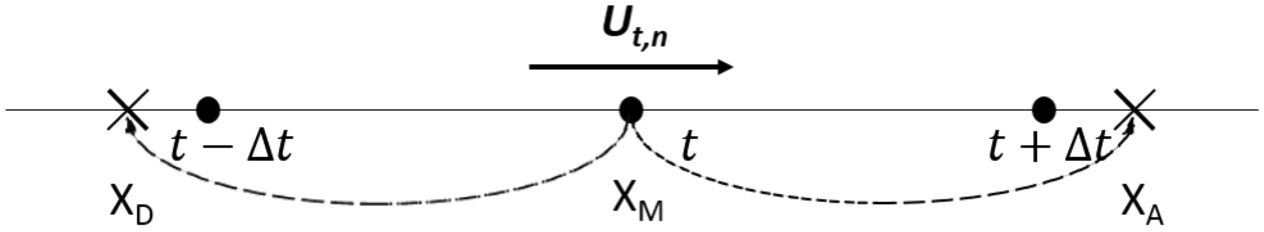
1. Evaluating Lagrangian advection separately.
   (X → Y → Z) or (Y → X → Z)

2. Doing interpolation and remapping on 1-D with no guessing and no iteration.

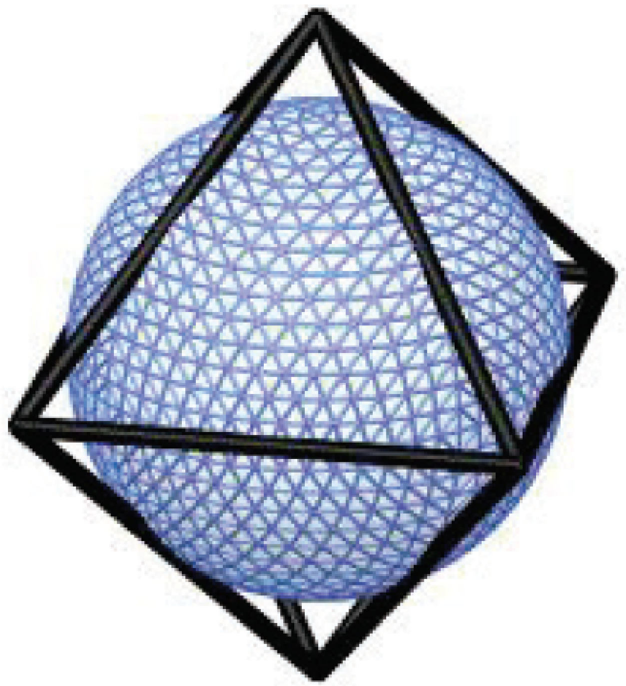
3. No need halo grids in MPI.

4. Mass conserving and positive-definite.

-- Juang 2007 & Juang 2008



Octahedral reduced Gaussian grid



Conception of Octahedral Gaussian reduced grid
（Malardel et al. 2016）

1. Setting of grid point
   - start with 20 points at the Gaussian latitude closest to the pole
   - Increase 4 points per Gaussian latitude toward the equator(16+4i)
   - 16+4N points at the Gaussain latitude nearest the equator (N=my/2, my is the grid length of longitude)

2. Using Cubic grid not Linear grid
   - prevent aliasing when doing spectral transform
   - more stable results
   - more efficiency

Governing equations: final form

$$\frac{\partial \theta}{\partial t} = -m^2 U \frac{\partial \theta}{\partial \lambda} - V \frac{\partial \theta}{\partial \mu} - \left[\dot{\eta}\frac{\partial p}{\partial \pi}\right]\frac{\partial \theta}{\partial p} + Q_\theta$$

$$\frac{\partial q}{\partial t} = -m^2 U \frac{\partial q}{\partial \lambda} - V \frac{\partial q}{\partial \mu} - \left[\dot{\eta}\frac{\partial p}{\partial \pi}\right]\frac{\partial q}{\partial p} + Q_q$$

Calculated all tracers on grid point space, no spectral transform.

1. Values always positive
2. Saving more time

$$\frac{\partial \pi}{\partial t} = \sum_{i=1}^{K} \Delta B_i \left(m^2 U \frac{\partial \pi}{\partial \lambda} + V \frac{\partial \pi}{\partial \mu}\right)_i + \sum_{i=1}^{K} (\Delta A + \Delta B p_s)_i \left(m^2 \frac{\partial U}{\partial \lambda} + \frac{\partial V}{\partial \mu}\right)_i$$

For continuity equation, Eulerian form provided much stable result than estimating the horizontal advection term by NDSL.

$$G = m^2 U \frac{\partial V}{\partial \lambda} + V \frac{\partial V}{\partial \mu} + \left[\dot{\eta}\frac{\partial p}{\partial \pi}\right]\left[\frac{\partial V}{\partial p}\right] + \frac{\cos^2\varphi}{a^2}\frac{\partial \Phi}{\partial \mu} + \frac{C_p}{a^2}\theta\left[\frac{\partial P}{\partial \pi}\right]\left[\frac{\partial \pi}{\partial \mu}\right]\cos^2\varphi + fU + \frac{(U^2+V^2)\sin\varphi}{\cos^2\varphi} - Q_v\frac{\cos\varphi}{a}$$

$$H = -m^2 U \frac{\partial U}{\partial \lambda} - V \frac{\partial U}{\partial \mu} - \left[\dot{\eta}\frac{\partial p}{\partial \pi}\right]\left[\frac{\partial U}{\partial p}\right] - \frac{\partial \Phi}{a^2 \partial \lambda} - \frac{C_p}{a^2}\theta\left[\frac{\partial P}{\partial \pi}\right]\left[\frac{\partial \pi}{\partial \lambda}\right] + fV + Q_u\frac{\cos\varphi}{a}$$

$$\alpha(g,h) = \frac{1}{\cos^2\varphi}\frac{\partial g}{\partial \lambda} + \frac{\partial h}{\partial \mu}$$

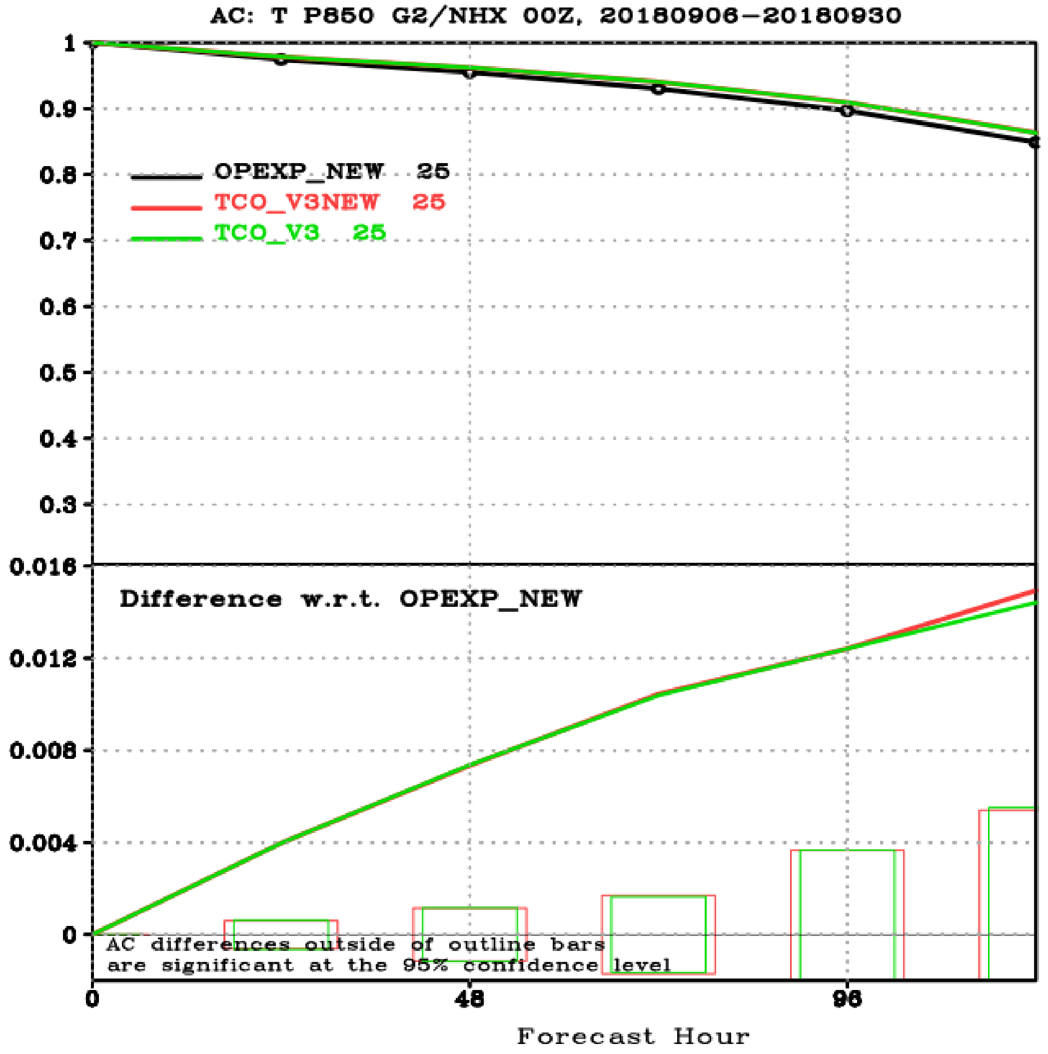
$$\frac{\partial \zeta}{\partial t} = -\alpha(G,H)$$

$$\frac{\partial D}{\partial t} = \alpha(H,-G)$$

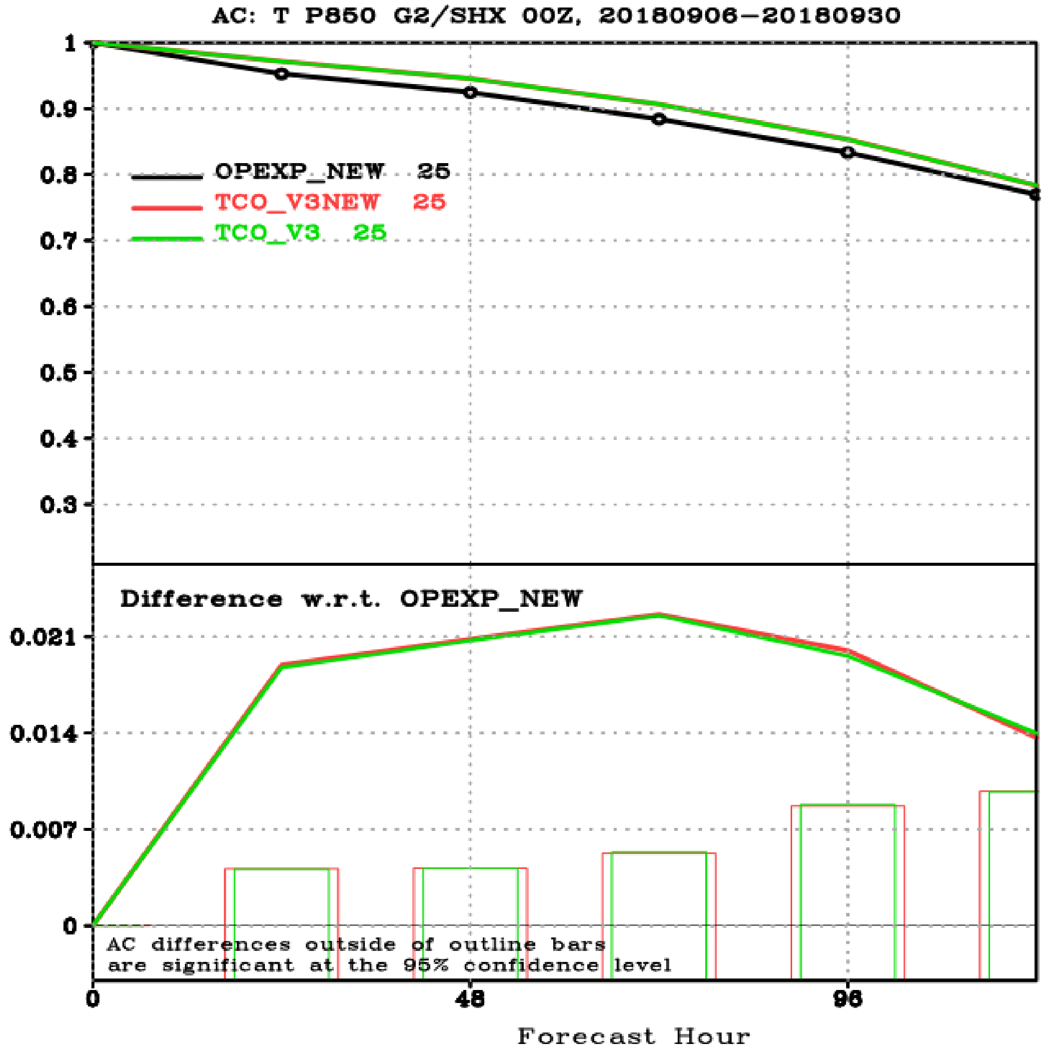
Estimating all the advection terms(red box) by NDSL

評估測試: 850hPa temperature ACC

North Hemisphere

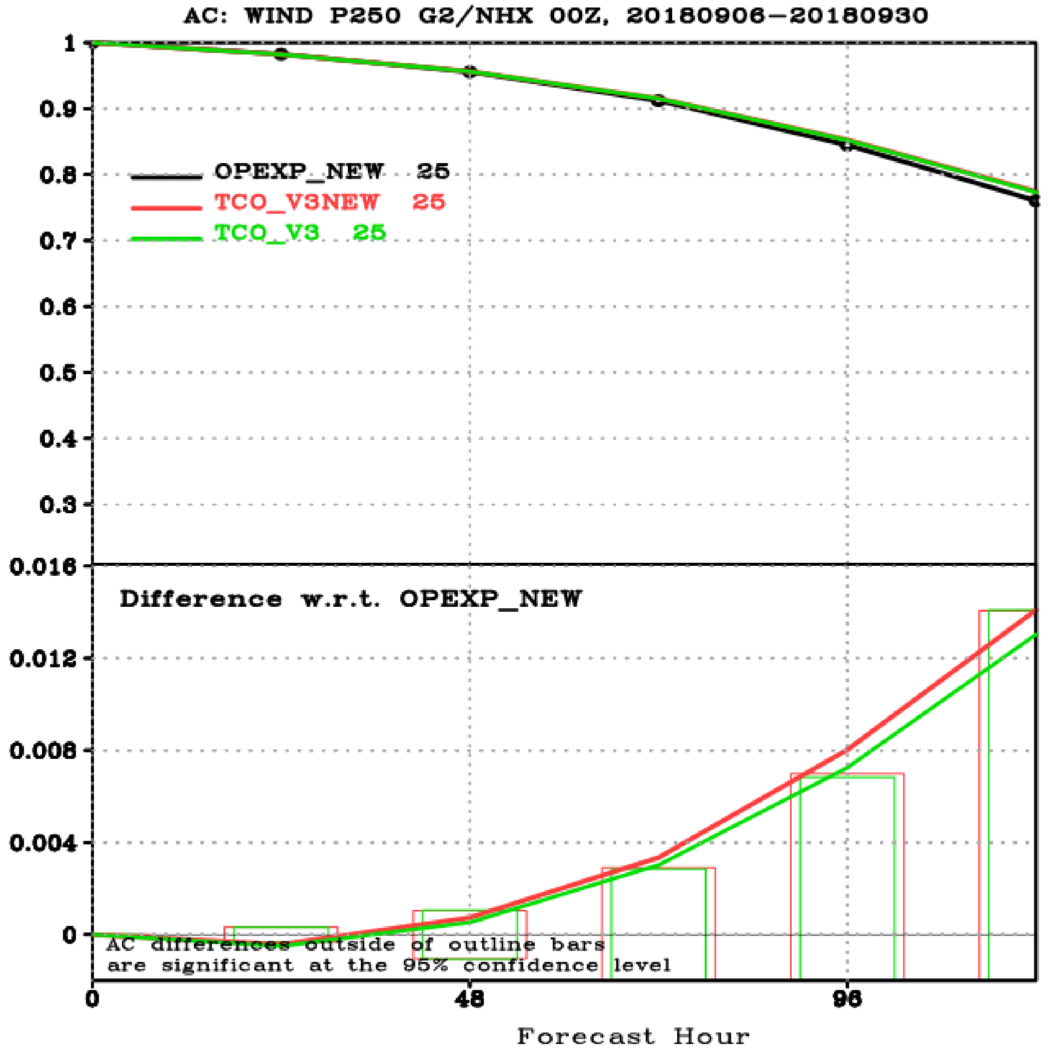


South Hemisphere



評估測試: 250hPa wind ACC

North Hemisphere



South Hemisphere