動力降尺度模式(RSM)系集校驗系統建置

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The development of CWA global model

2011
CWBGFS
T319L40

2016
CWBGFS
T511L60

CWBGEPS v1
T319L60
2017

2020
CWBGFS
$T_{Co}639L72$

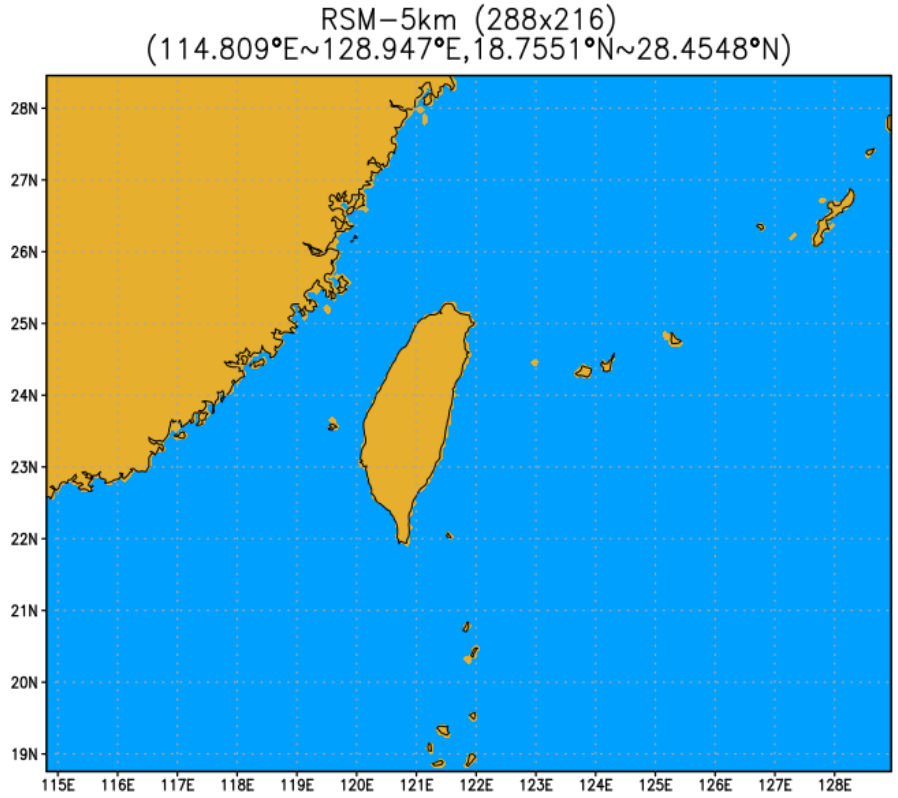
CWAGEPS v2
$T_{Co}383L72$+SIT
2023
CWBGFS-FV3
C384L64

CWAGEPS v2.1
$T_{Co}383L72$+SIT+
RSM-5km
2024

2014
CWB
5th gen. HPC

2022
CWB
6th gen. HPC

Brief Introduction of CWA GEPS V2.1



	Model configuration of TCo
Dynamical core	2-time-level, NDSL timestep=600s
Domain and coordinate	~28km (1536x768) Octahedral reduced Gaussian grid 72 sigma-P layers, model top: 0.1 hPa
Stochastic physics	SPPT with 5 scales+SKEB
Initial condition	EnKF members
Ocean model	SIT + CWACFS forecast SST
Number of members	32 ensemble members + 1 deterministic
Frequency and forecast length	Twice per day(00Z,12Z), forecast 45 days

	Model configuration of RSM
Dynamical core	3-time-level, NDSL timestep=45s
Domain and coordinate	5km (288x216) Taiwan area Mercator projection 72 sigma-P layers, model top: 0.1 hPa
Radiation	RRTM
LSM	Noah LSM
PBL	YSU
Orographic gravity wave drag	Kim and Arakawa (1995)
Cumulus	SAMF Scale-Aware Mass-Flux Deep/Shallow Convection
Microphysics	GFDL cloud microphysics V2

How do we know the performance of our model?

- **Create an ensemble verify system!**

Accuracy

Mean/Absolute Error
Root Mean Square Error
Anomaly Correlation Coefficient

Probability

Brier Skill Score
(Continuous) Ranked Probability Score

Spread and Variation

Spread
Talagrand Rank Histogram
Member Equal-Likelihood

Mean Error (ME) & Mean Absolute Error (MAE)

$$\mathrm{ME} = \frac{1}{N}\sum_{n=x}^{N} F(x) - O(x)$$

$$\mathrm{MAE} = \frac{1}{N}\sum_{n=x}^{N} |F(x) - O(x)|$$

Root Mean Square Error (RMSE)

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{n=x}^{N} \big(F(x) - O(x)\big)^2}$$

Anomaly Correlation Coefficient (ACC)

$$\mathrm{ACC} = \frac{\overline{\big(F(x) - C(x)\big) - \big(O(x) - C(x)\big)}}{\sqrt{\overline{\big(F(x) - C(x)\big)^2}\,\overline{\big(O(x) - C(x)\big)^2}}}$$

Brier Score(BS) and Skill Score (BSS)

Brier Score (BS)

針對特定門檻值進行預報機率與觀測之差值平方，得知機率預報誤差。通常以通過門檻值之觀測點$O(x) = 1.0$，未通過門檻值$O(x) = 0.0$；$F(x)$則為系集中通過門檻之之比率。BS值介於0.0(完美預報)至1.0(完美錯誤)之間。

$$\mathrm{BS} = \frac{1}{N}\sum_{n=x}^{N} \big(F(x) - O(x)\big)^2$$

BSS則為與參考BS(通常為過去氣候預報值)的比較，用以表現目前模式是否較過去預報準確。正/負值表示優/劣於參考模式。

$$\mathrm{BSS} = 1.0 - \frac{BS}{BS_c}$$

Continuous Ranked Probability Score (CRPS)

針對所有的門檻值進行預報機率與觀測之差值積分，得知機率預報誤差。

$$CRPS = \int_{-\infty}^{+\infty} \big(F(x) - O(x)\big)^2 dx$$

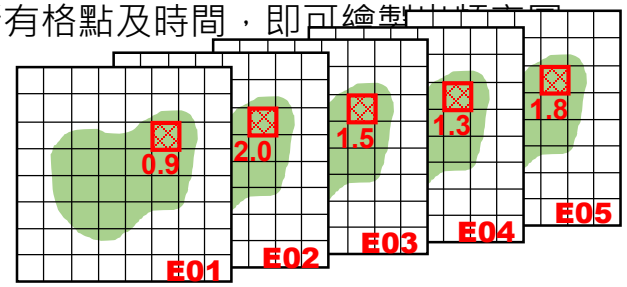
Spread

M組預報成員與總系集平均的標準差。

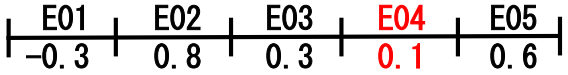
$$S = \sqrt{\frac{1}{M}\sum_{m=1}^{M}\left(F(x_m) - \overline{F(x)}\right)^2}$$

Member equal-likelihood

M組預報成員中，最接近觀測值的預報成員累加一次，統計完所有格點及時間，即可繪製出頻率圖。



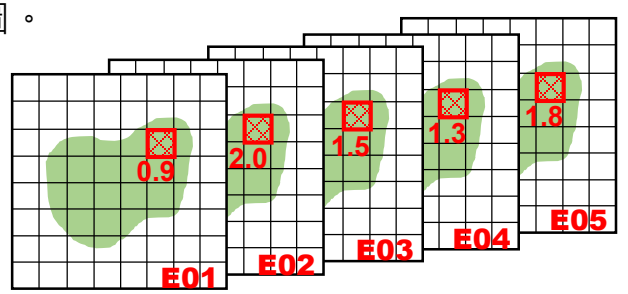
station data=1.2



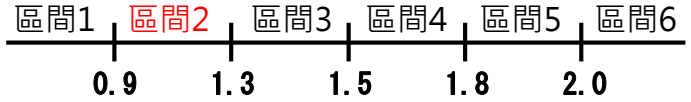
最佳的系集預報系統，為所有成員的預報命中率一致。

Talagrand Rank Histogram

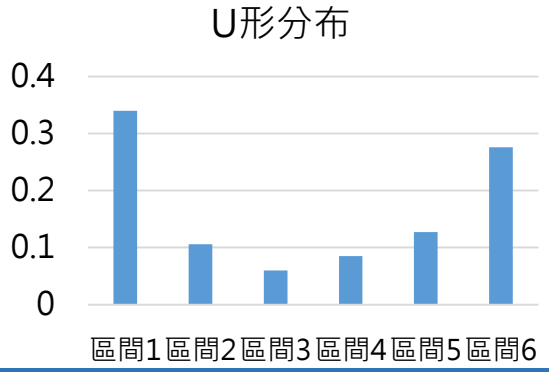
將M組預報的相同格點值按照大小排列，形成M+1個區間。將觀測值放入相對應區間中，統計完所有格點及時間，即可繪製出頻率圖。

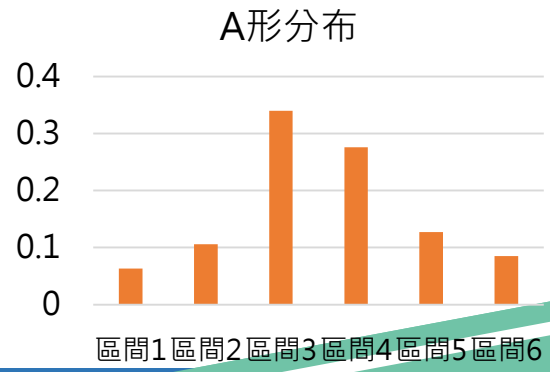


station data=1.2



圖表成U形分布時，表示觀測值多落在系集預報範圍外，系集離散度不足；成A形分布時，表示觀測值多落在系及預報中心，系集離散度過大。最佳的系集預報系統，為所有區間的預報命中率一致。





Data prepared

◆ Analysis data

- ✓ WRF(WD02) (surface and pressure levels variables) (res：3km)
- ✓ Observation gridded data(觀測網格資料) (near surface temperature, precipitation) (res：2.5km)

◆ RSM ensemble forecast data

- ✓ for 4 weeks forecast time, 20 members forecast data

◆ RSM hindcast data

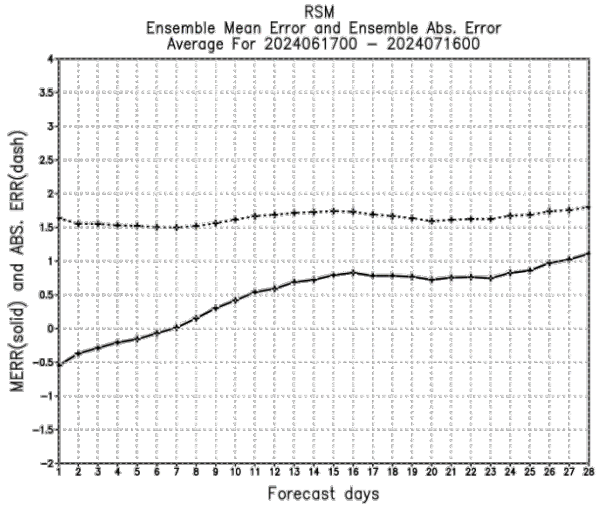
- ✓ for 4 weeks forecast time, past 20 years(2001~2020) forecast data

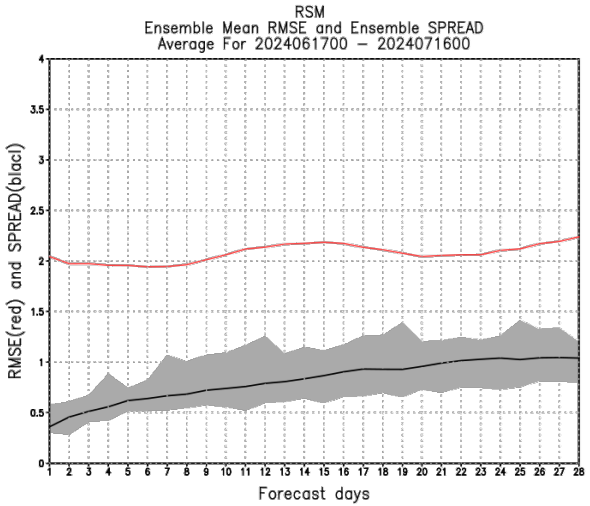
◆ Climate data

- ✓ past 20 years climate observation gridded data(氣候觀測網格資料)
- ✓ past 20 years RSM hindcast data (f000, based on TCo383 ini:CFSR)

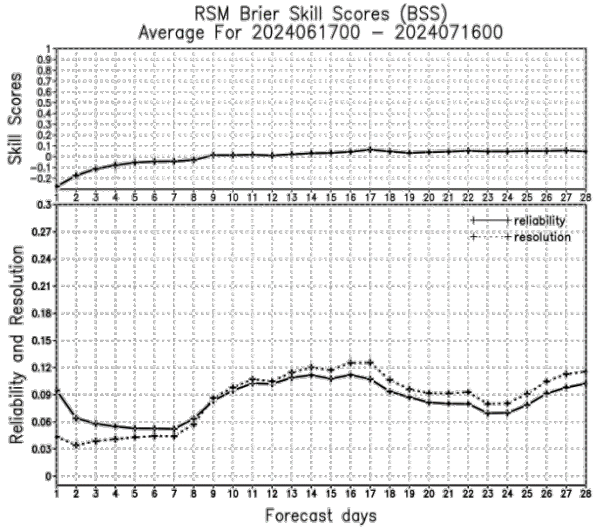
RSM-5km ensemble verifying

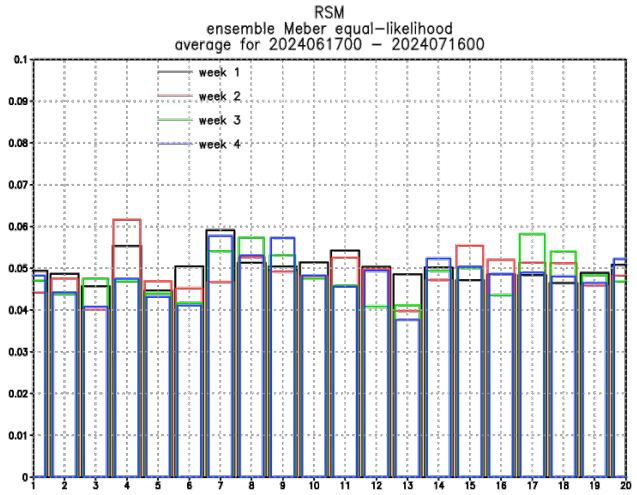
2m Temperature (valid time: 20240617~20240716)

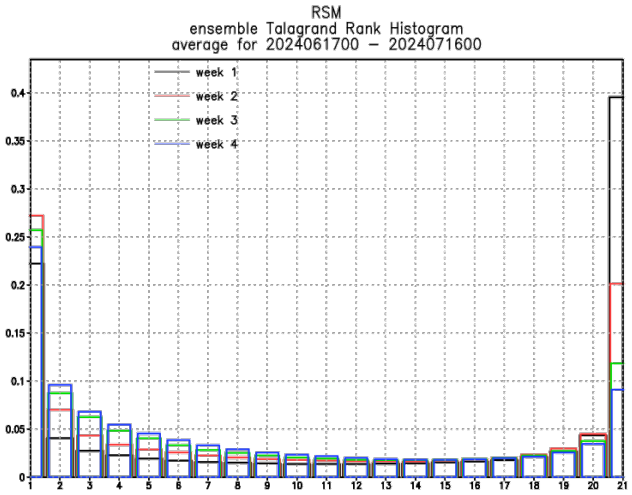




1. 系集離散度偏小
2. 模式預報在一週後後略優於過去預報
3. 每個系集的預報準確度各有消長
4. 隨預報時間拉長，系集成員有較高溫的預報傾向



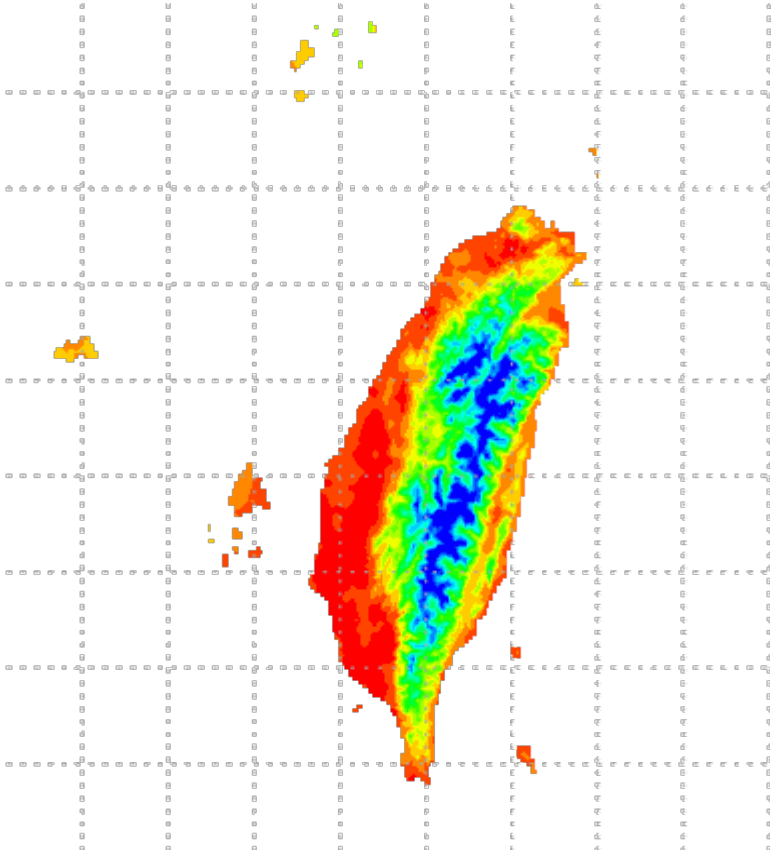




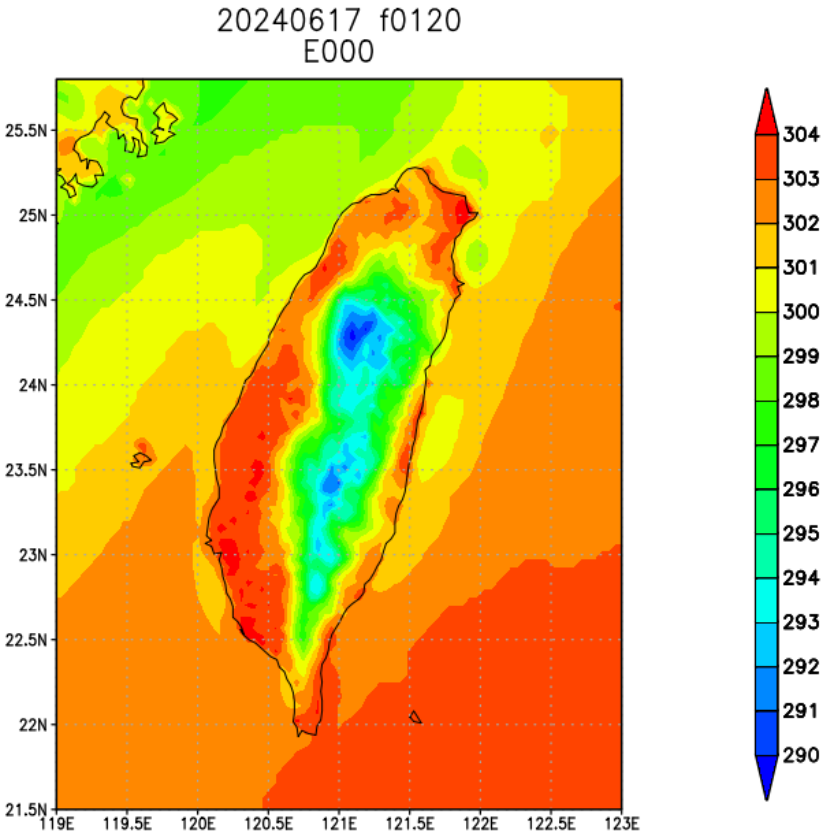
RSM-5km ensemble verifying

2m Temperature (valid time: 20240617~20240716)

Observation gridded data



Model forecast data

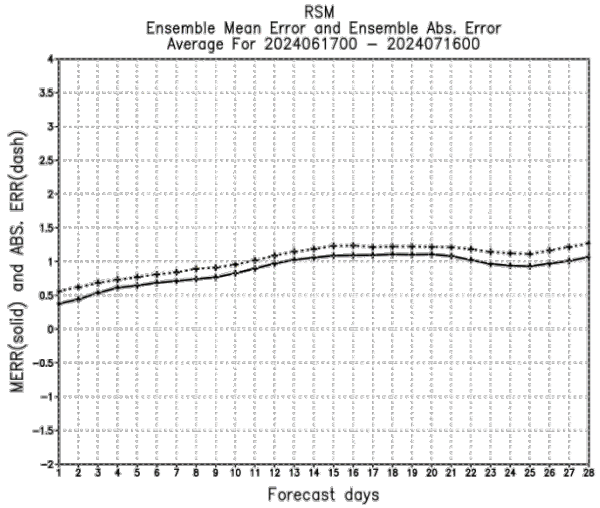


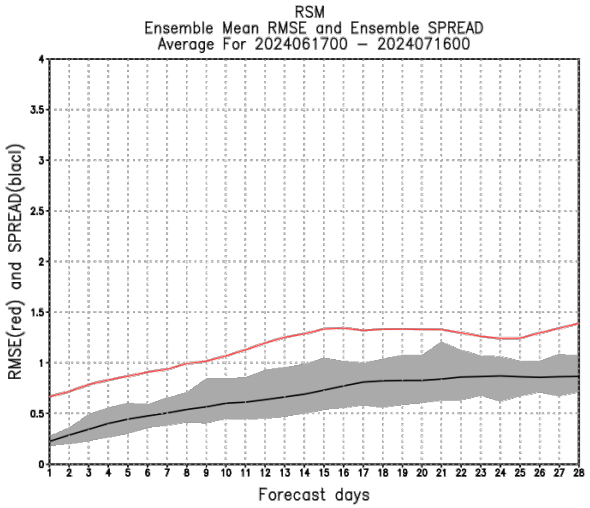
1. 因模式地形解析度關係，模式在山區的氣溫預報偏高
2. 平地部分在預報前期氣溫較低

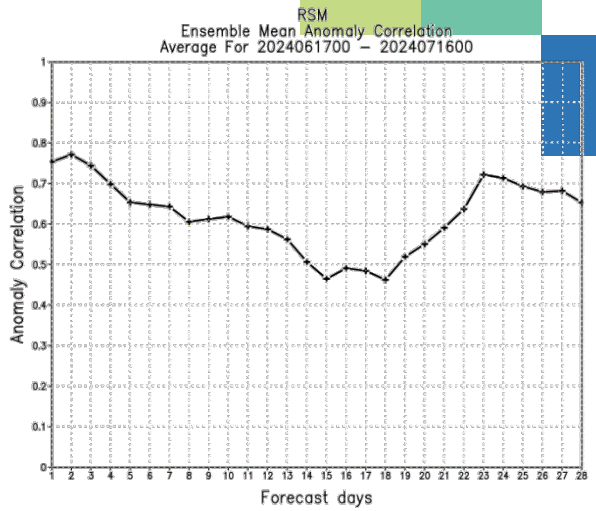
*T2m的校驗僅在陸地(不包含中國大陸範圍)

RSM-5km ensemble verifying

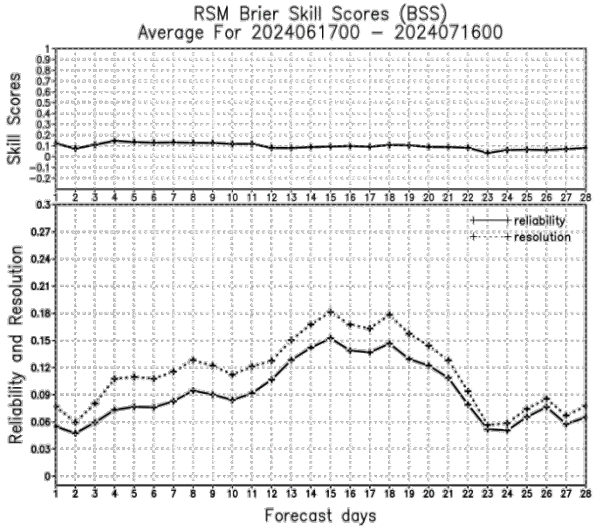
850hPa Temperature (valid time: 20240617~20240716)

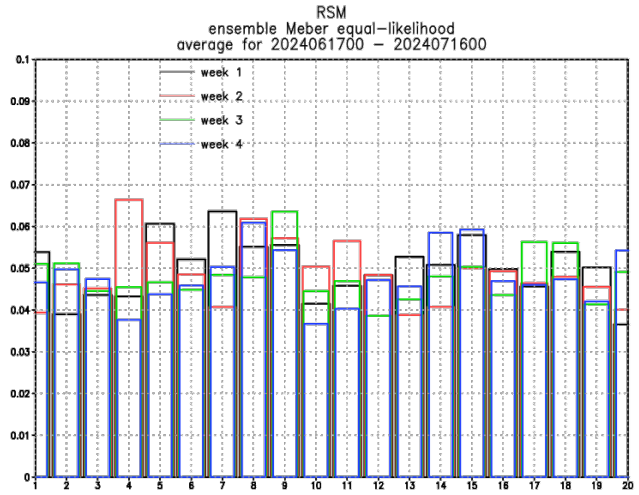


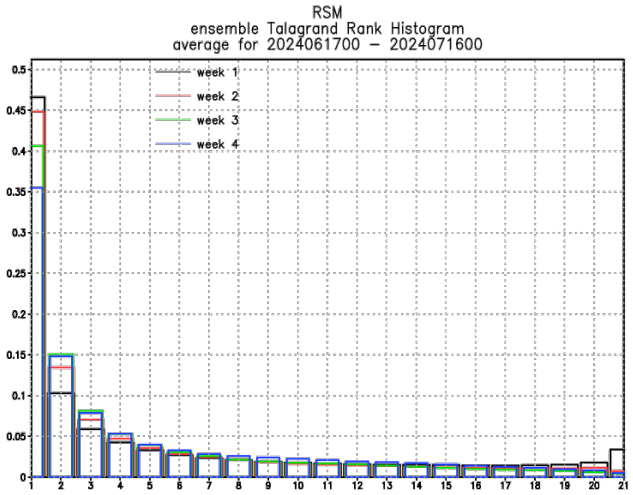




1. 系集離散度略小
2. 模式預報略優於過去預報
3. 每個系集的預報準確度各有消長
4. 系集成員持續有較高溫的預報傾向

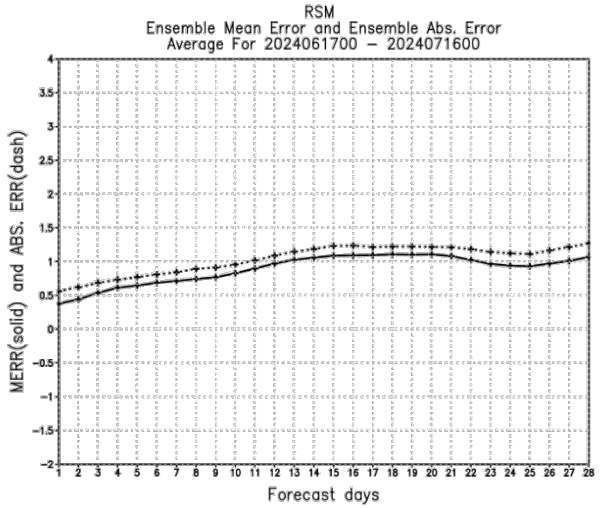


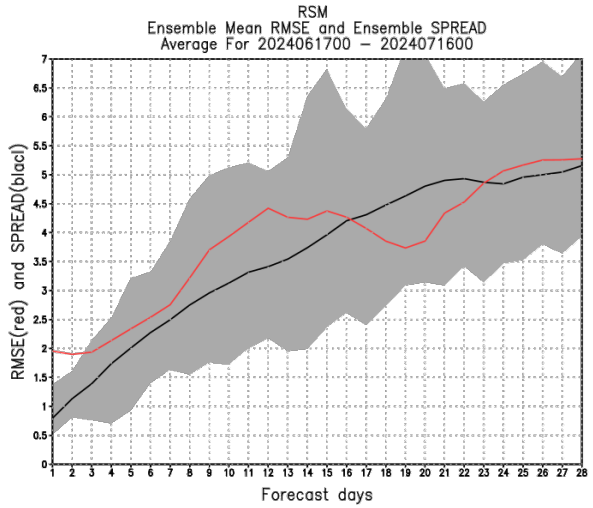


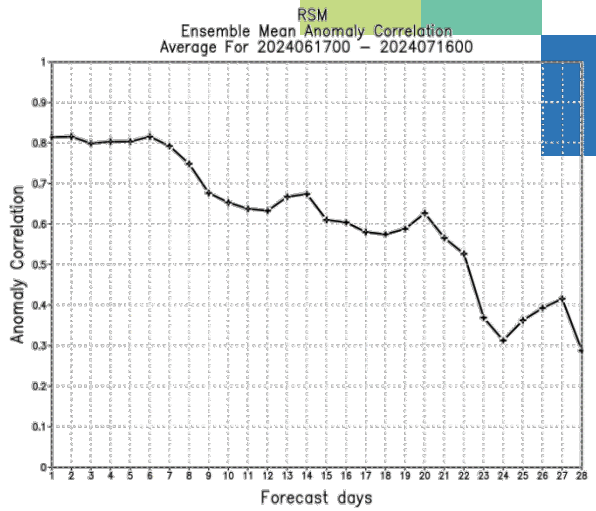


RSM-5km ensemble verifying

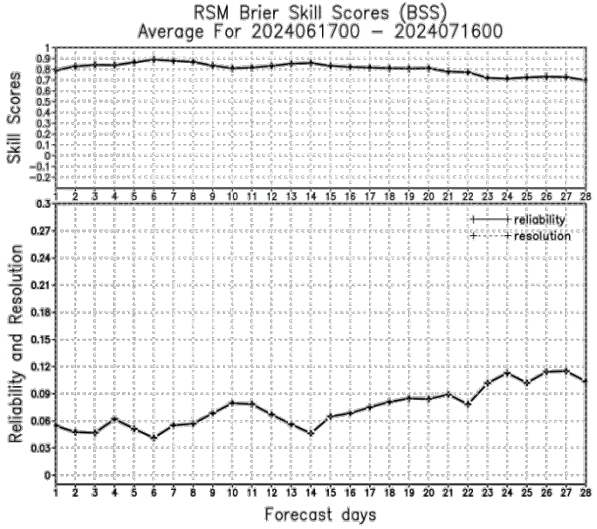
850hPa U-wind (valid time: 20240617~20240716)

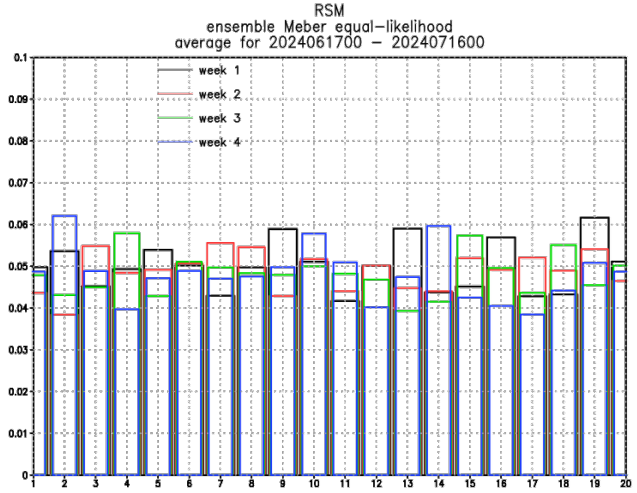


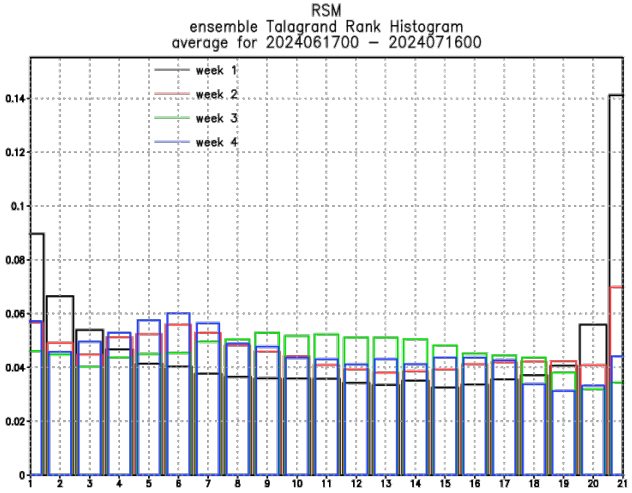




1. RMSE於第三週下降
2. 模式預報優於過去預報
3. 每個系集的預報準確度各有消長
4. 除了第一週外，系集成員的離散表現較溫度場優異

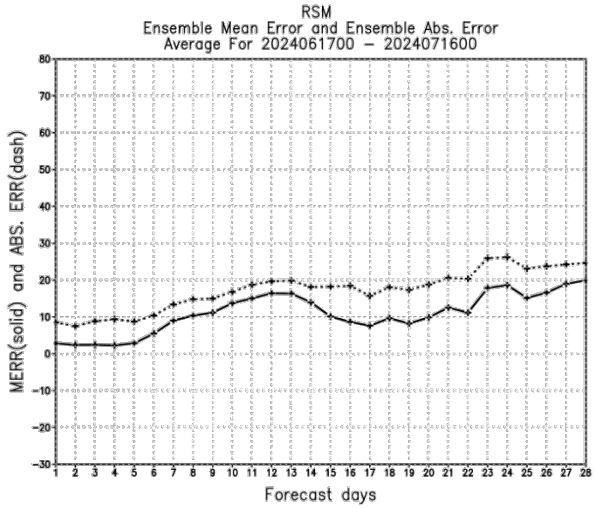


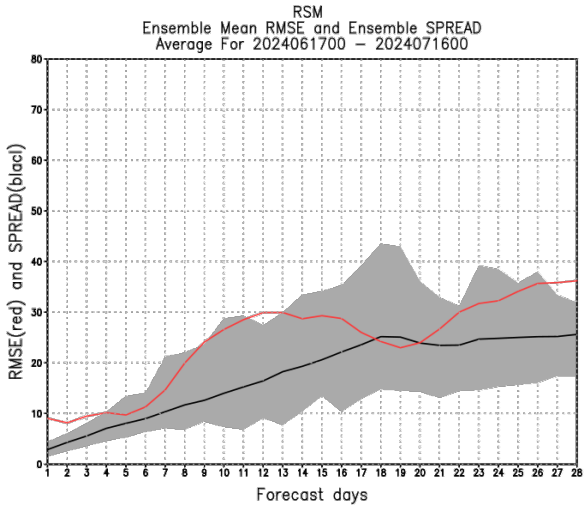


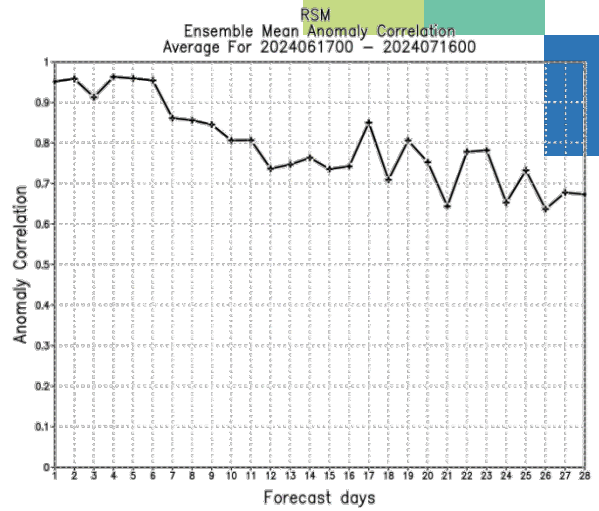


RSM-5km ensemble verifying

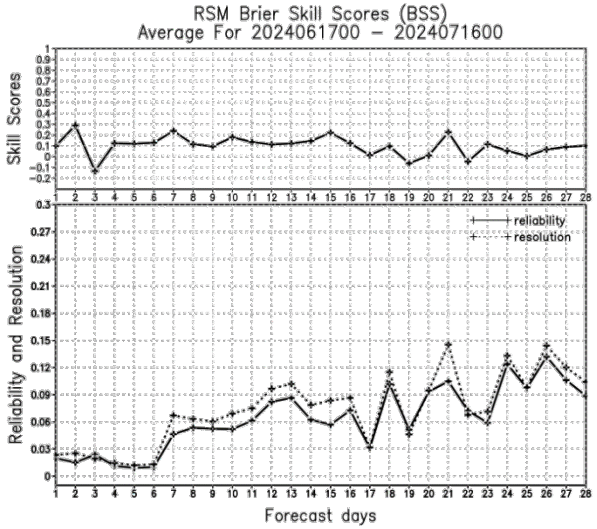
500hPa Z (valid time: 20240617~20240716)

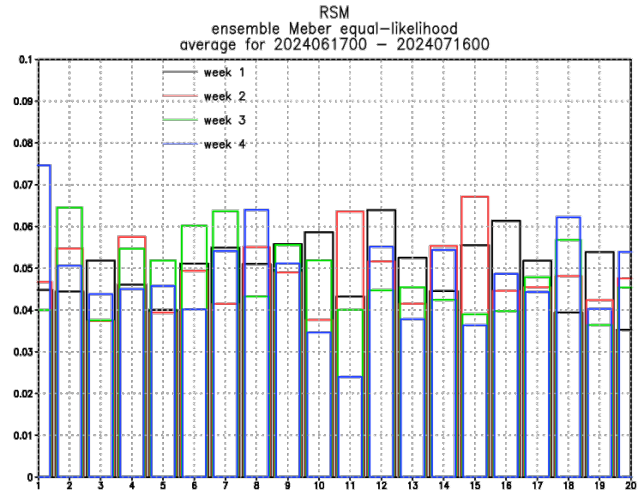


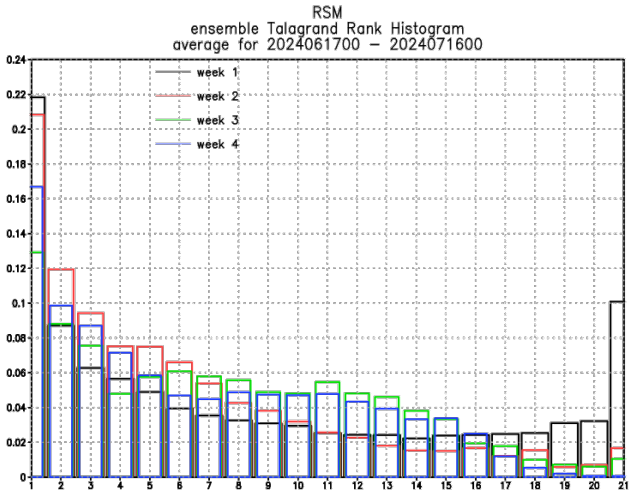




1. RMSE於第三週下降
2. 模式預報略優於過去預報
3. 每個系集的預報準確度各有消長，第11個成員於第四週預報準確率明顯降低
4. 系集成員持續有較高的重力位高度預報傾向

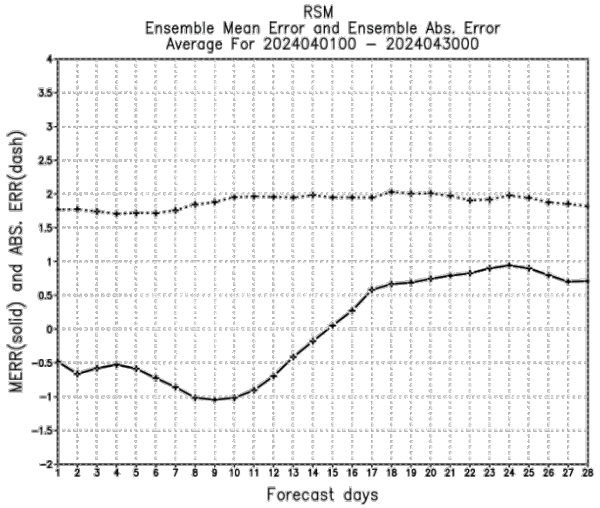


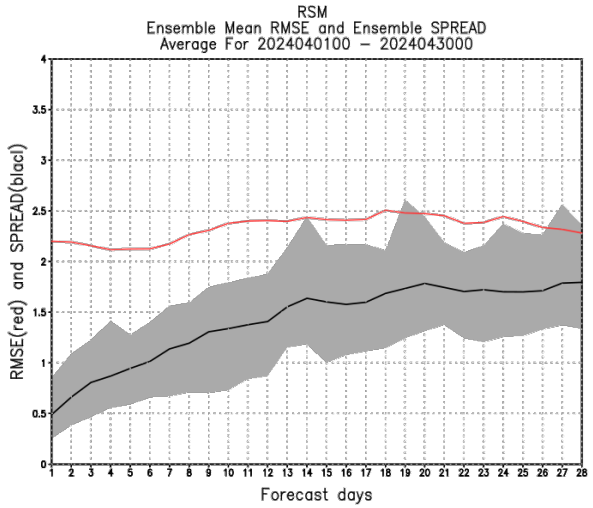




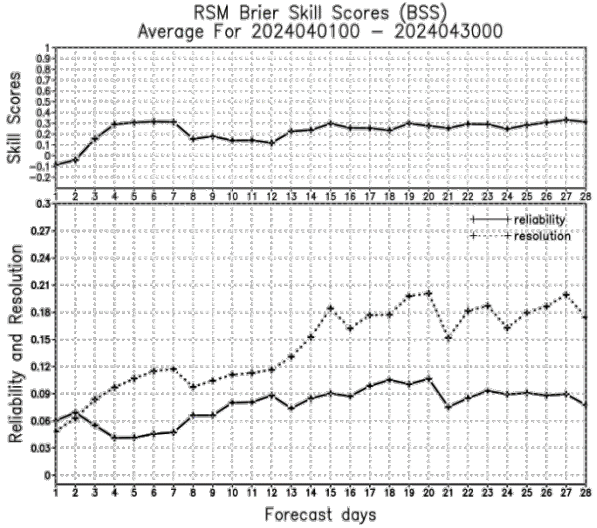
RSM-5km ensemble verifying

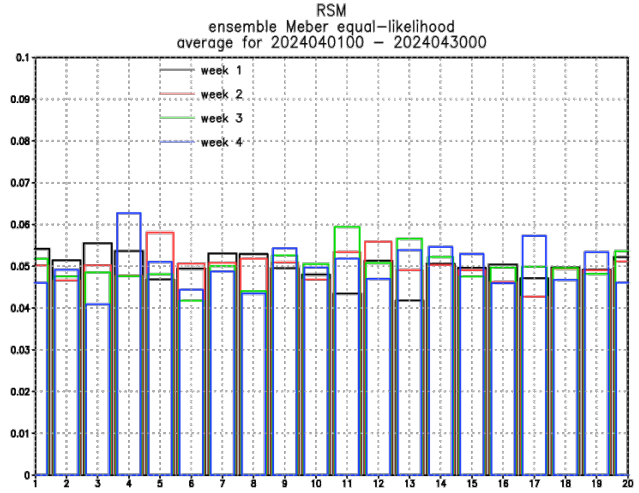
2m Temperature (valid time: 20240401~20240430)

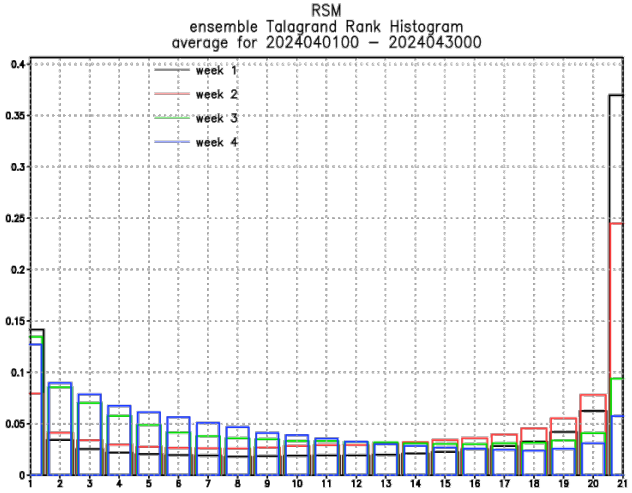




1. 系集離散度偏小
2. 模式預報在一週後後略優於過去預報
3. 每個系集的預報準確度各有消長
4. 隨預報時間拉長，系集成員有較高溫的預報傾向

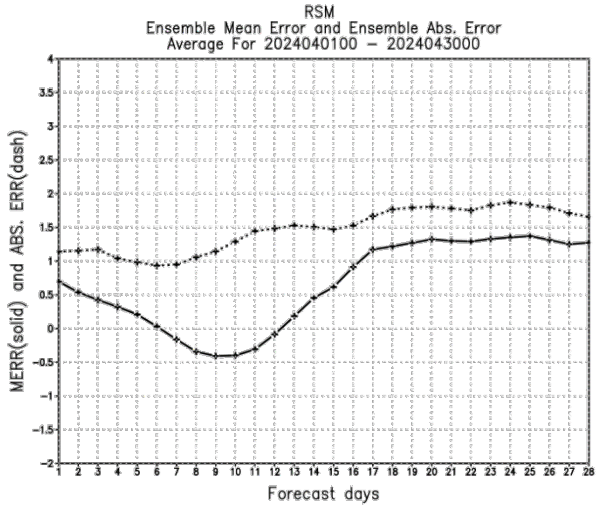


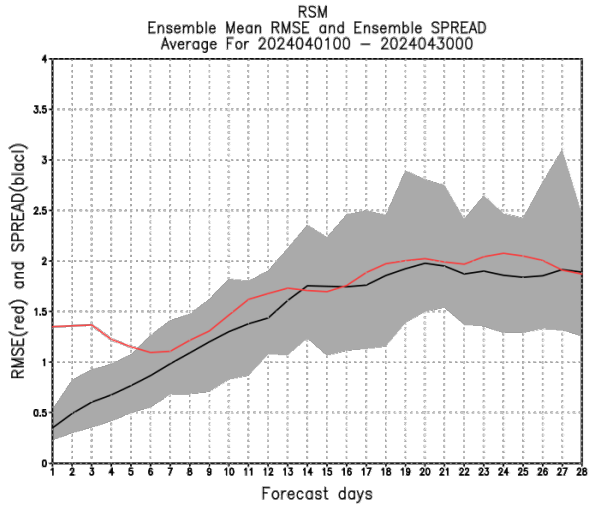


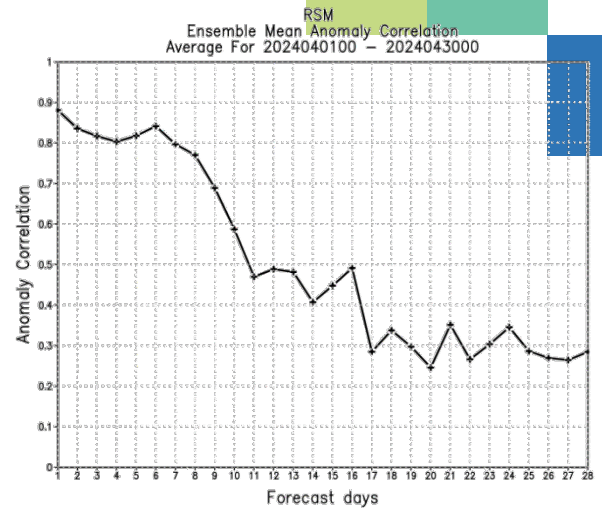


RSM-5km ensemble verifying

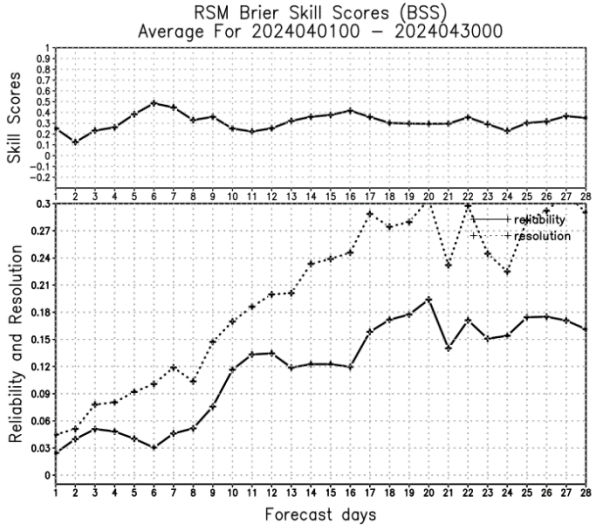
850hPa Temperature (valid time: 20240401~20240430)

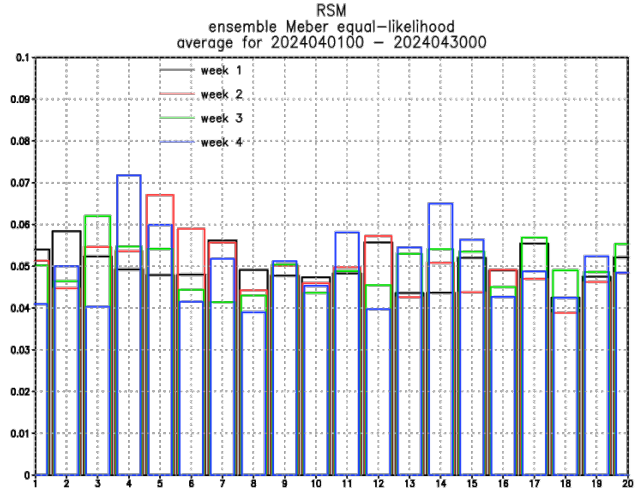


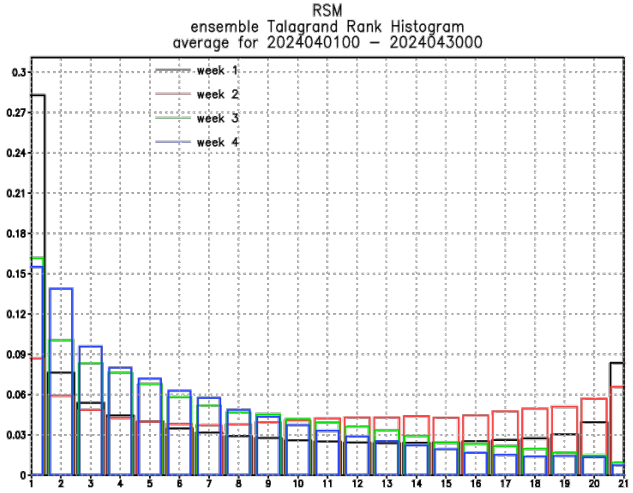




1. 系集離散度表現亮眼
2. 模式預報略優於過去預報
3. 每個系集的預報準確度各有消長
4. 隨預報時間拉長，系集成員有偏低溫至偏高溫的預報傾向

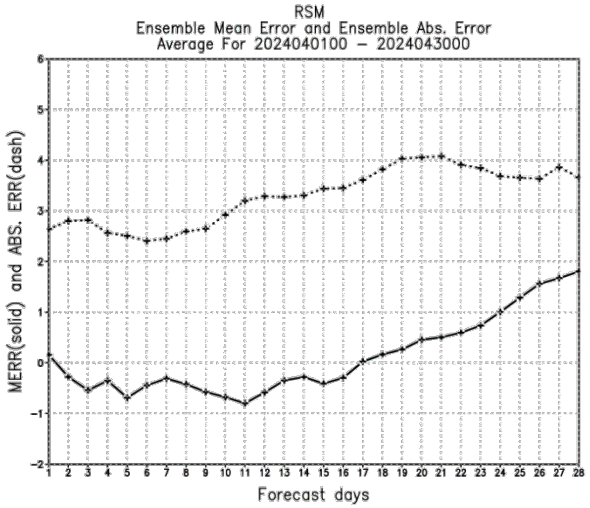


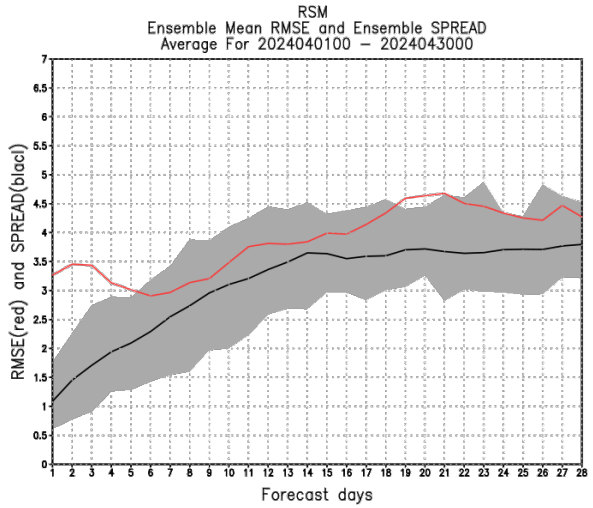


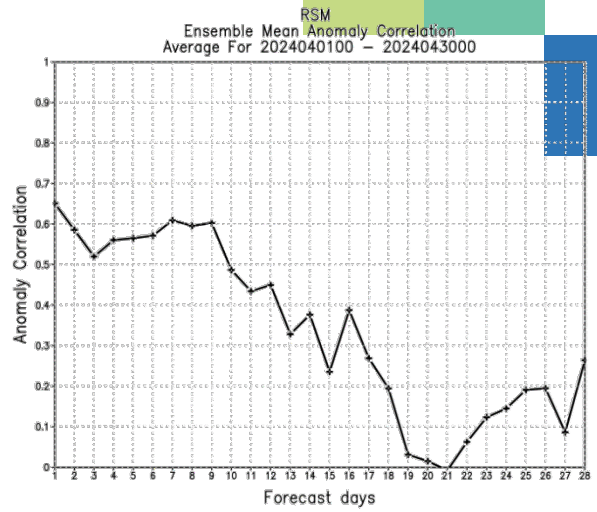


RSM-5km ensemble verifying

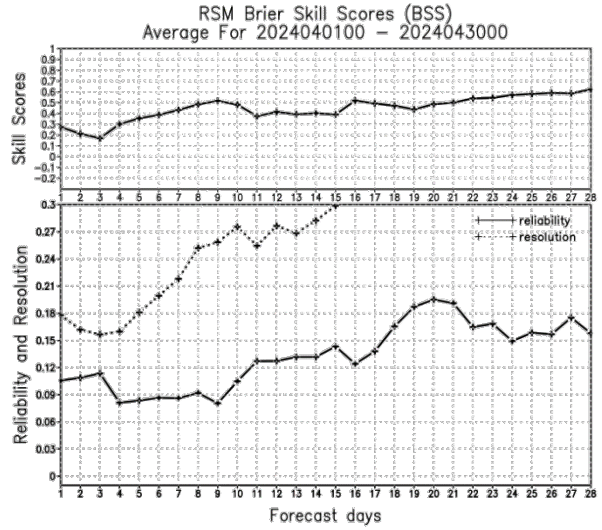
850hPa U-wind (valid time: 20240401~20240430)

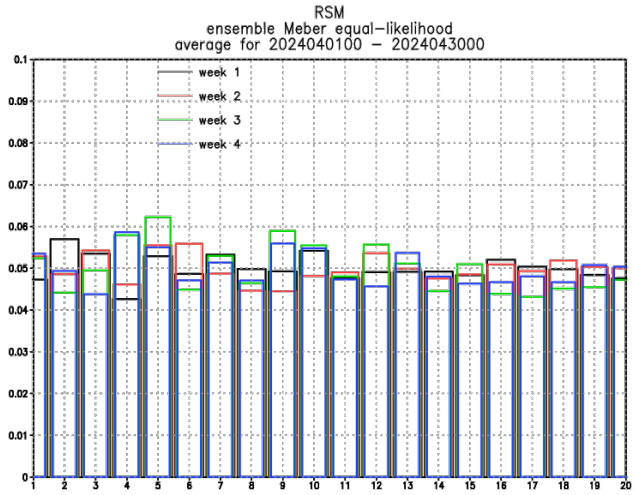


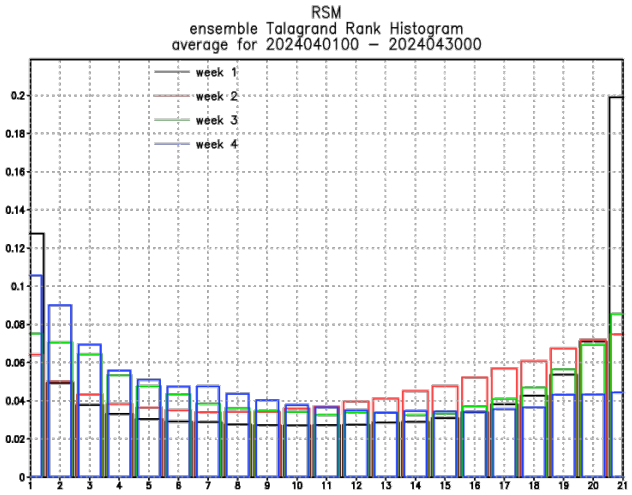




1. 模式預報優於過去預報
2. 每個系集的預報準確度各有消長
3. 系集隨預報時間拉長，風速預報有偏低到偏高傾向

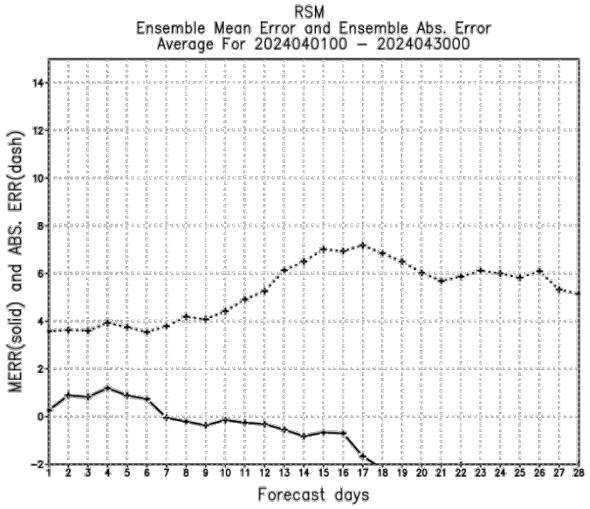


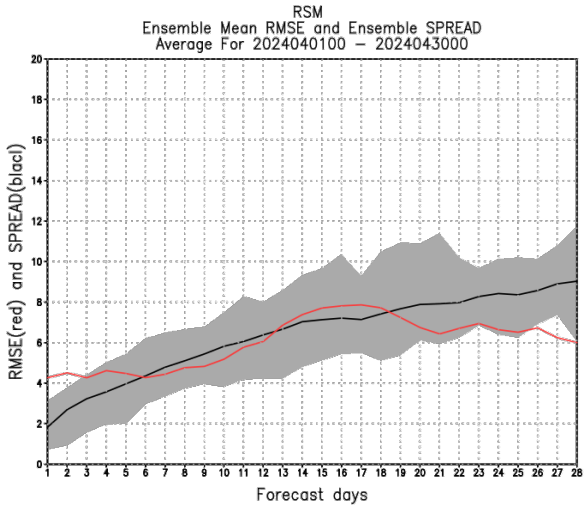


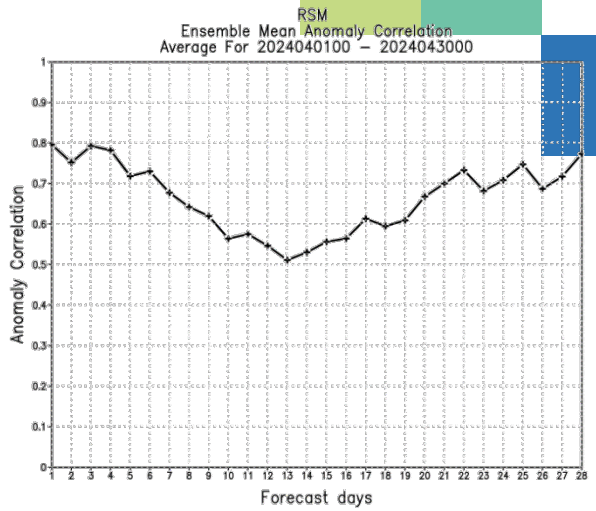


RSM-5km ensemble verifying

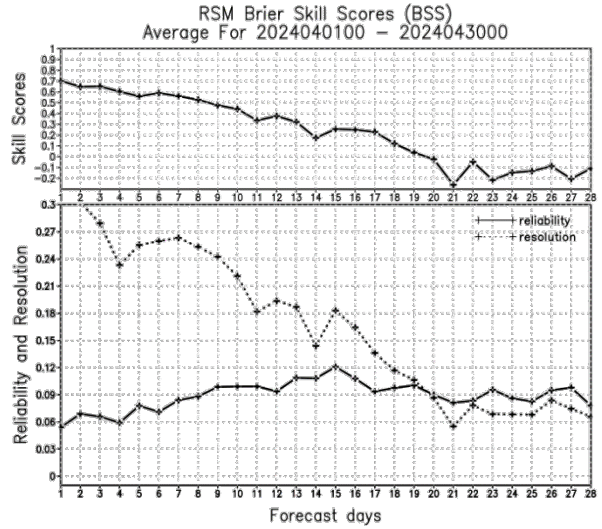
250hPa U-wind (valid time: 20240401~20240430)

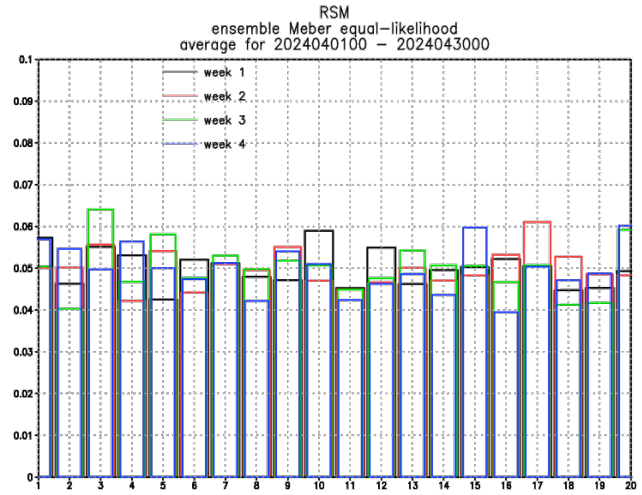


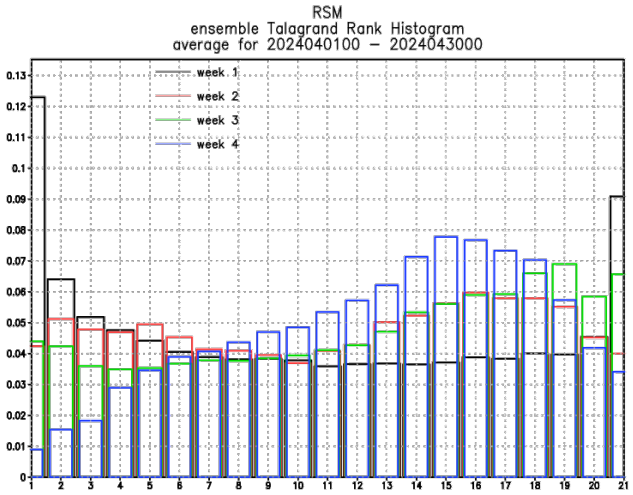




1. 模式預報至第三週優於過去預報
2. 每個系集的預報準確度各有消長
3. 系集隨預報時間拉長，風速預報有逐漸減弱的傾向

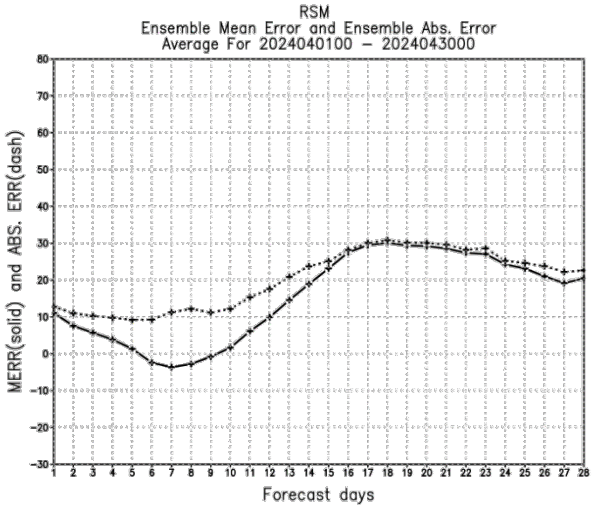


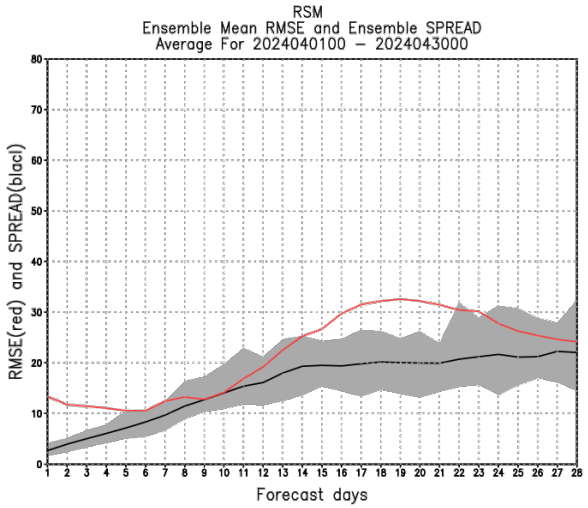


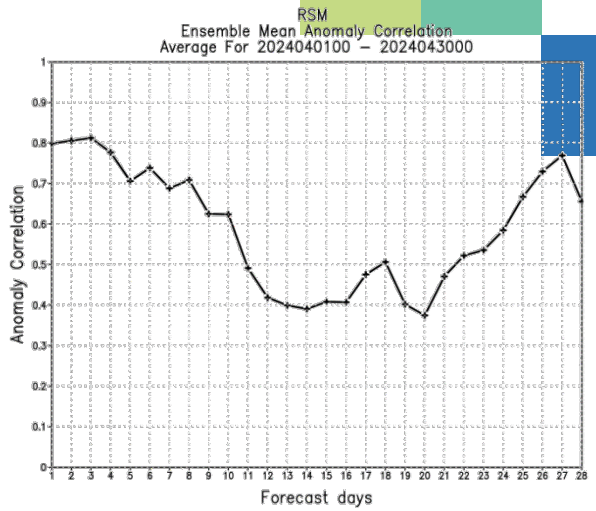


RSM-5km ensemble verifying

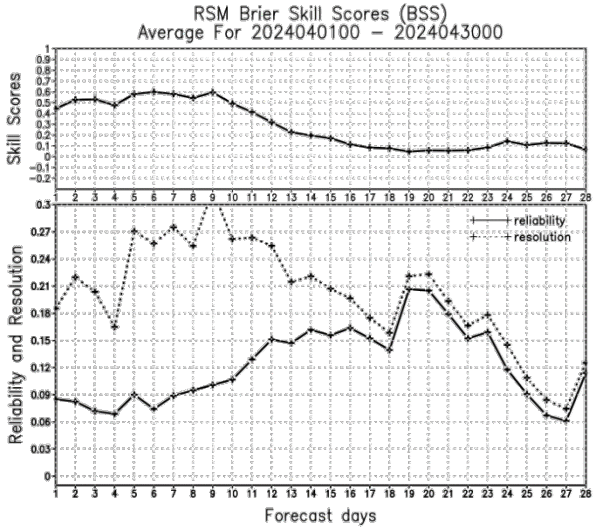
500hPa Z (valid time: 20240401~20240430)

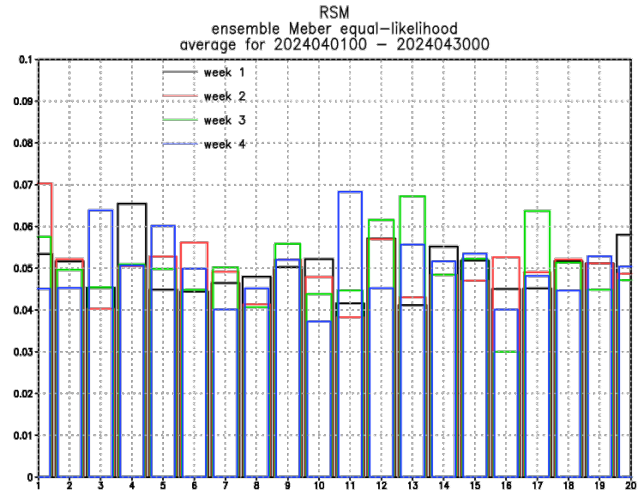


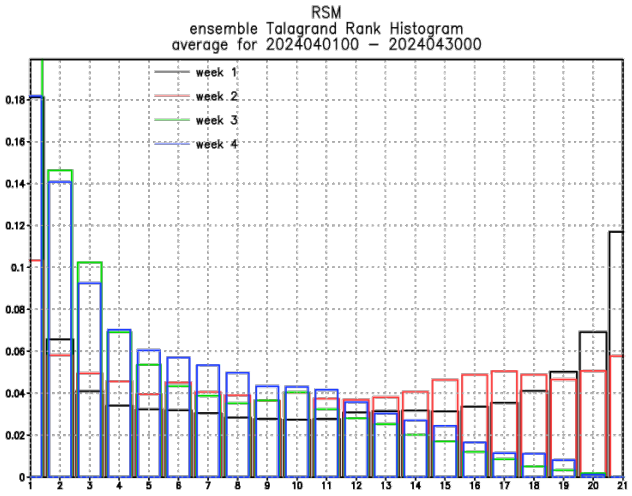




1. RMSE於第三週至高峰
2. 模式前期預報明顯優於過去預報
3. 每個系集的預報準確度各有消長，第11個成員於第四週預報準確率明顯降低
4. 隨預報時間拉長，系集成員有較高的重力位高度預報傾向







Conclusion and on going work

- 根據目前的校驗變數來看，除了低層氣溫預報均有逐漸偏暖的趨勢外，不同季節的變數預報趨勢不同。
- 系集離散度來說，RSM模式的T2m預報系集離散度較為不足，實際觀測值多落於系集預報最大最小值以外。其原因為有可能受到山區地形影響。
- 各系集成員的預報準確度並無特定成員獨佔，預報表現較過去20年系集平均預報好。

- RSM模式為使用全球模式的預報場作為base filed進行降尺度預報。因此可以檢驗全球模式與RSM相同區域的預報資訊誤差，方能看出RSM是否在數週的預報上能有有修正全球模式誤差的能力。
- 納入RSM過去20年hindcast初始預報資料(f000)，並製作每日氣候累積分布函數(daily climatology CDF)，產製CRPS, reliability diagram, ROC diagram等機率型校驗。
- 增加地面降水與其他層場校驗。