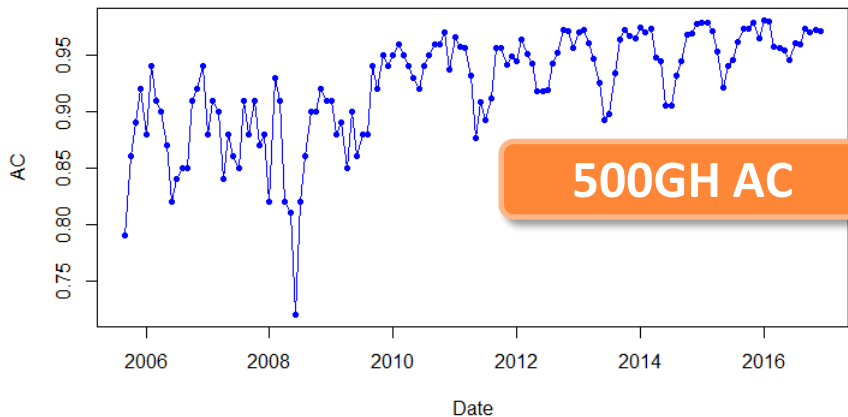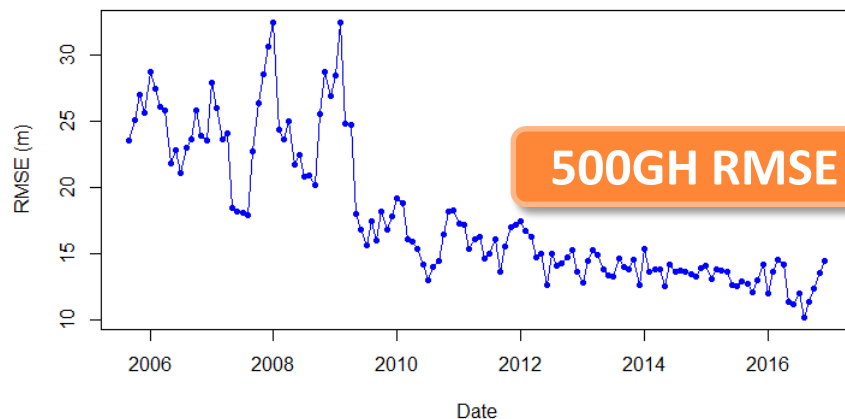# 數值預報模式綜合表現指標之研究

陳白榆　　洪景山　　馮欽賜

中央氣象局

Why we need integrated performance index ?
→ Evaluate the overall forecast skill of NWP models

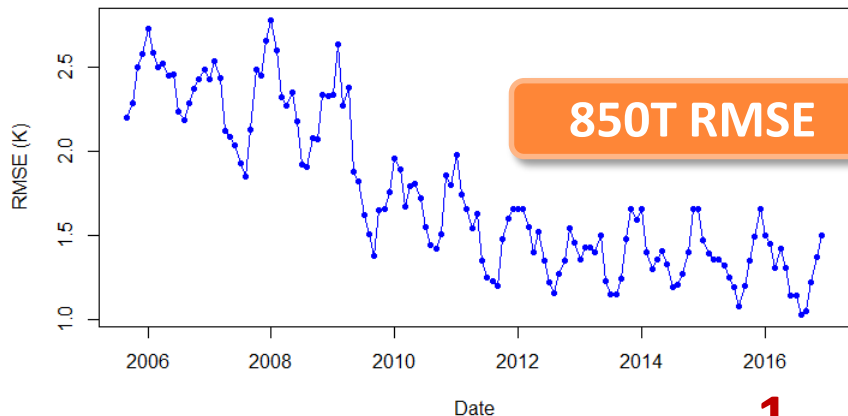CWB NWP 500 hPa HGT Day-3 Anomaly Correlation

500GH AC

CWB NWP 500 hPa HGT Day-3 RMSE

500GH RMSE

CWB NWP 850 hPa Temperature Day-3 RMSE

850T RMSE

CWB NWP 300 hPa Wind Day-3 RMSE
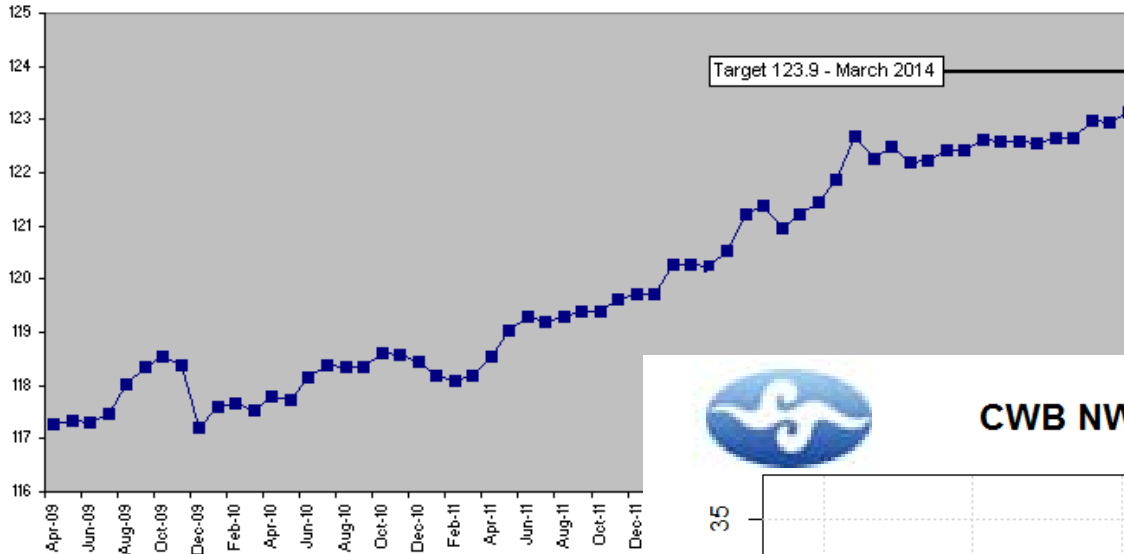
300U RMSE
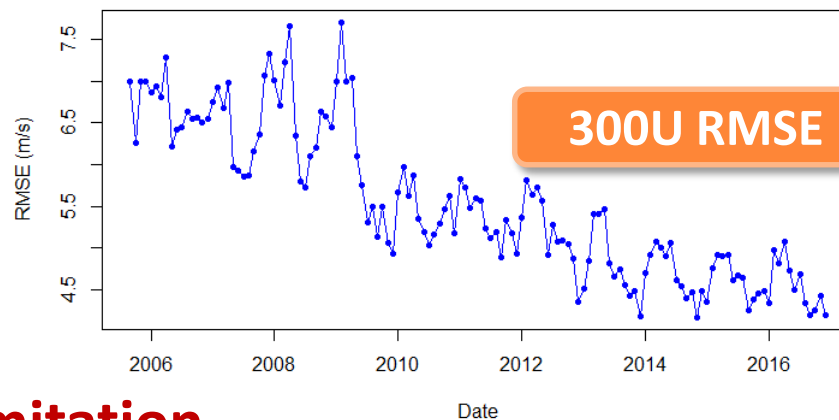
1. **Limitation**
2. **Summary ?**

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What is integrated performance index (from UK & CWB regional models) ?
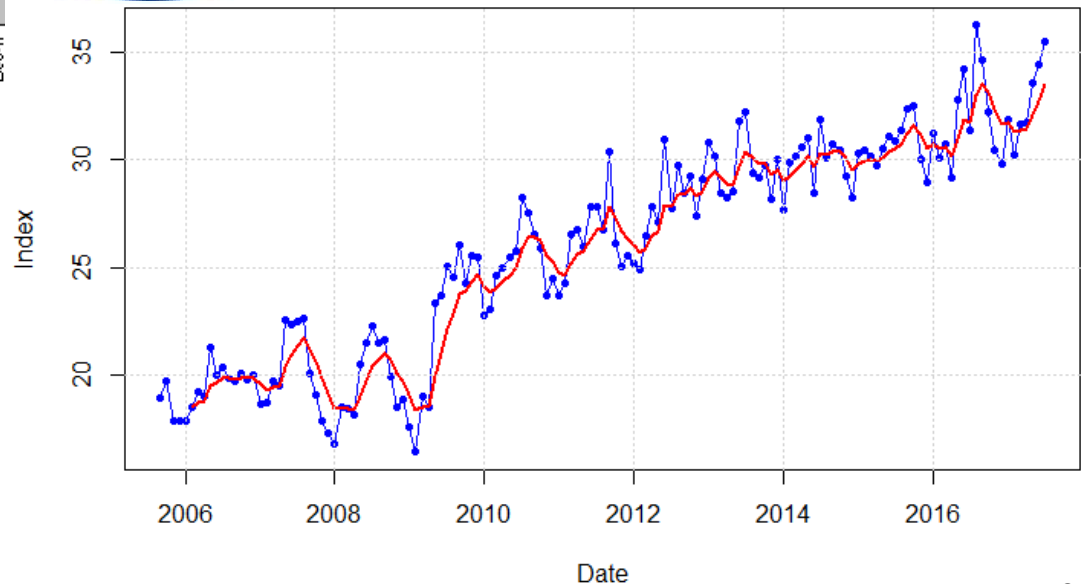

UK NWP Index

Included:
1. **Importance**
2. **Sensitivity**

Higher is better

CWB NWP Performance Index

Integrated performance index of US NRL, AFWA & NCEP

FNMOC NAVGEM Scorecard

U.S. NAVAL RESEARCH LABORATORY

(Courtesy of Melinda Peng)

Reference	Level	Region	Variable	Lead time	Level type	Metric	Weight	Score
Fixed Buoy	None	Northern Hemisphere	Wind Speed	72	surface	Mean Error	2	0
Fixed Buoy	None	Southern Hemisphere	Wind Speed	72	surface	Mean Error	2	0
Fixed Buoy	None	Tropics	Wind Speed	72	surface	Mean Error	2	0
Radiosondes	100.0	Global	Geopotential Height	72	pressure	RMS Error	1	+1
Radiosondes	250.0	Global	Air Temperature	72	pressure	RMS Error	1	0
Radiosondes	250.0	Global	Wind	72	pressure	Vector RMS Error	1	0
Radiosondes	500.0	Global	Geopotential Height	72	pressure	RMS Error	1	0
Radiosondes	850.0	Global	Air Temperature	72	pressure	RMS Error	1	0
Radiosondes	850.0	Global	Wind	72	pressure	Vector RMS Error	1	0
Self Analysis	200.0	Northern Hemisphere	Wind	72	pressure	Vector RMS Error	1	0
Self Analysis	200.0	Tropics	Wind	72	pressure	Vector RMS Error	1	0
Self Analysis	500.0	Northern Hemisphere	Geopotential Height	96	pressure	Anomaly Correlation	4	+4
Self Analysis	500.0	Southern Hemisphere	Geopotential Height	96	pressure	Anomaly Correlation	1	+1
Self Analysis	850.0	Northern Hemisphere	Wind	72	pressure	Vector RMS Error	1	0
Self Analysis	850.0	Tropics	Wind	72	pressure	Vector RMS Error	2	0
Self Analysis	1000.0	Northern Hemisphere	Geopotential Height	96	pressure	Anomaly Correlation	1	+1
Self Analysis	1000.0	Southern Hemisphere	Geopotential Height	96	pressure	Anomaly Correlation	1	+1

Air Force Weather Agency
Generalized Operations (GO) Index
(by Robert J. Craig)

U.S. AIR FORCE

	6hr/12hr	18hr/24hr	30hr/36hr	42hr/48hr
400WS	4	3	2	1
250WS	4	3	2	1
850WS	4	3	2	1
700TD	8	6	4	2
400TD	8	6	4	2
400TT	4	3	2	1
400HT	4	3	2	1
SLP	8	6	4	2
SFCTT	8	6	4	2
850TD	8	6	4	2
SFCTD	8	6	4	2
SFCWS	8	6	4	2

NCEP
NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

$$SS = 1 - \frac{r_f^2}{r_p^2}$$

$$S_j = \frac{1}{\sum w_i} \left(\sum (w_i SS_i) \right)$$

$$PI = \sqrt{\left(\frac{1}{(1 - S_j)} \right)}$$

Performance Index (PI)
(by Perry Shafran)

Skill Score Weighting

|	Forecast hours:	24	48	72	96	120
Northern Hemisphere	Sea level pressure	10	8	6	4	4
	500-mb Z	6	4	2	0	0
	250-mb wind	12	0	0	0	0
Tropical	850-mb wind	5	3	3	0	0
	250-mb wind	6	0	0	0	0
Southern Hemisphere	Sea level pressure	5	4	3	2	2
	500-mb Z	3	2	1	0	0
	250-mb wind	6	0	0	0	0

Objectives

➢ Design **CWB NWP Performance Index (PI)** algorithm:

1. Based on regional model forecasts of **selected parameters** currently out to 72 hours ahead verified against analysis.

2. A **score** is calculated for **each parameter** included in the PI.

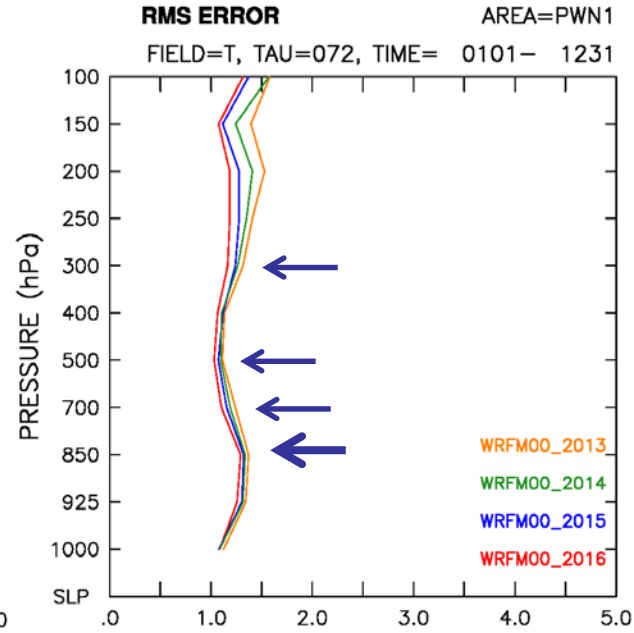3. The individual scores are then combined in a **weighted sum** to form a **single value**.

CWB WRF RMSE annual mean vertical profile

GH

T

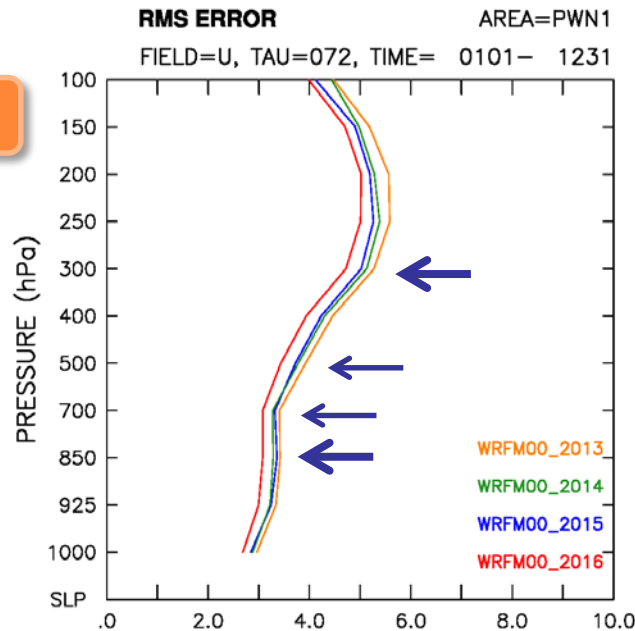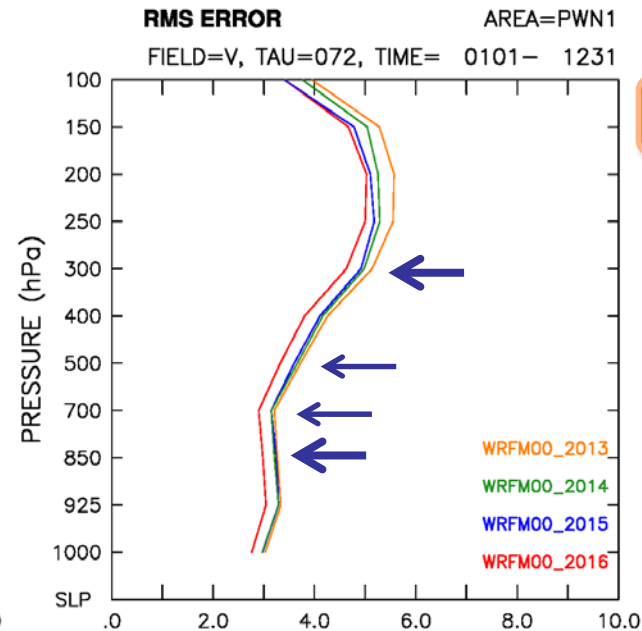**72-hr fcst**
2013-2016
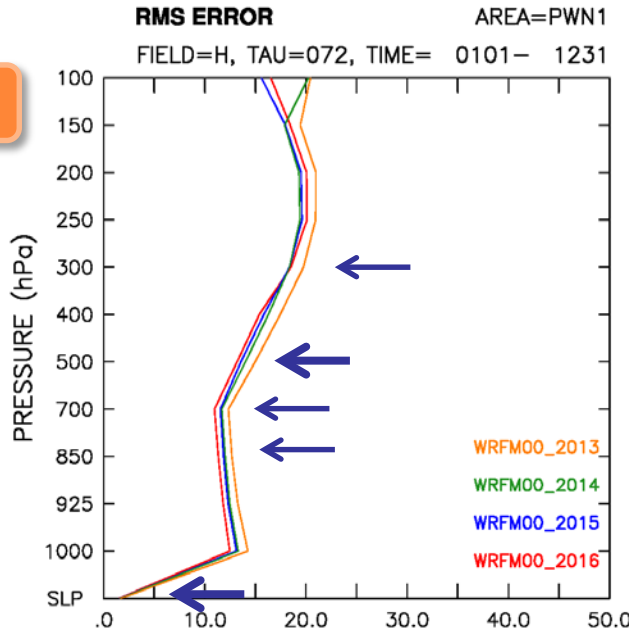
U

V

CWB WRF Scorecard in 2016

Reference	Variable	Lead time	Level type	Metric	Weight	Score
Self Analysis	300GH	72	Pressure	RMS error	1	1.41
Self Analysis	500GH	72	Pressure	RMS error	2	1.49
Self Analysis	700GH	72	Pressure	RMS error	1	1.48
Self Analysis	850GH	72	Pressure	RMS error	1	1.46
Self Analysis	300T	72	Pressure	RMS error	1	1.24
Self Analysis	500T	72	Pressure	RMS error	1	1.26
Self Analysis	700T	72	Pressure	RMS error	1	1.30
Self Analysis	850T	72	Pressure	RMS error	2	1.39
Self Analysis	300WIND	72	Pressure	RMS error	2	1.23
Self Analysis	500WIND	72	Pressure	RMS error	1	1.26
Self Analysis	700WIND	72	Pressure	RMS error	1	1.27
Self Analysis	850WIND	72	Pressure	RMS error	2	1.30
Self Analysis	SLP	72	MSL	RMS error	2	1.46

Total Score = 31.95

Variable	Metric	Weight	Value	Normalized (0~2)	Score
300GH	RMS error	1	17.91	0.71	1.41
500GH	RMS error	2	12.56	0.67	1.49
700GH	RMS error	1	10.95	0.67	1.48
850GH	RMS error	1	11.74	0.68	1.46
300T	RMS error	1	1.07	0.81	1.24
500T	RMS error	1	0.99	0.79	1.26
700T	RMS error	1	1.13	0.77	1.30
850T	RMS error	2	1.30	0.72	1.39
300U	RMS error	2	4.57	0.81	1.23
300V	RMS error	2	4.43	0.82	1.22
500U	RMS error	1	3.29	0.79	1.27
500V	RMS error	1	3.16	0.80	1.24
700U	RMS error	1	2.89	0.79	1.26
700V	RMS error	1	2.70	0.79	1.27
850U	RMS error	2	2.83	0.77	1.31
850V	RMS error	2	2.72	0.78	1.29
SLP	RMS error	2	1.70	0.69	1.46

Data normalization/ standardization

➢ **Min-max normalization** [0,1]:

$$X' = \frac{X - Xmin}{Xmax - Xmin}$$

➢ **Z-score normalization** (standard normal distribution [-3,+3]):

$$X' = \frac{X - Xmean}{S}$$

(If normal distribution, after z-score $Xmean = 0$; $S = 1$)

$$Normalized\ x' = \frac{x}{RMS} = \frac{x}{\sqrt{\frac{\sum x^2}{n-1}}}$$

$$Score = \frac{1}{Normalized}$$

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Kernel density estimate
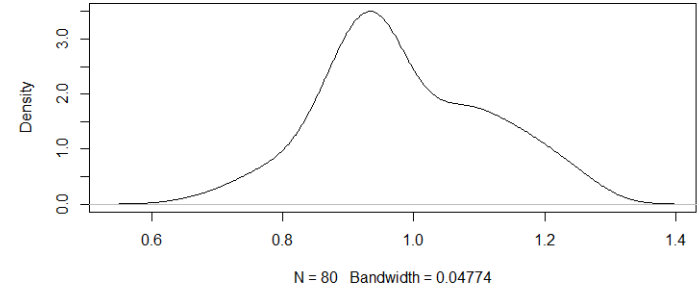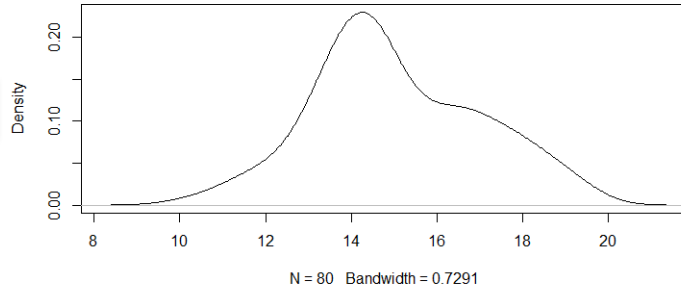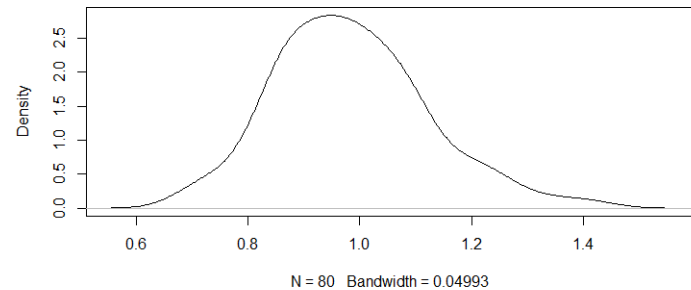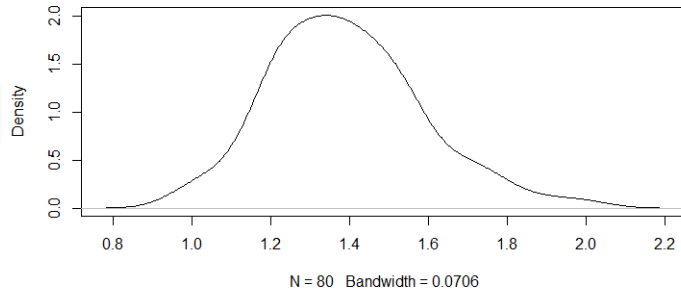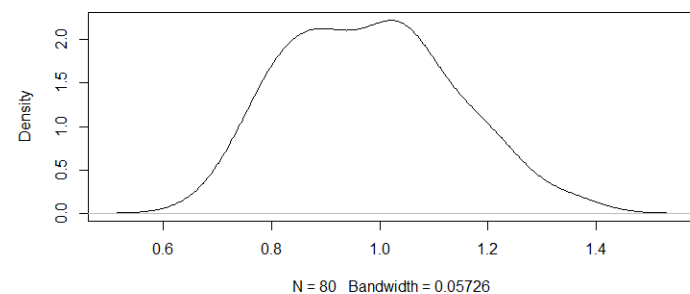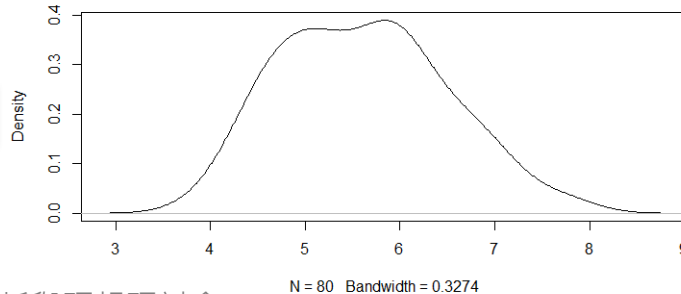
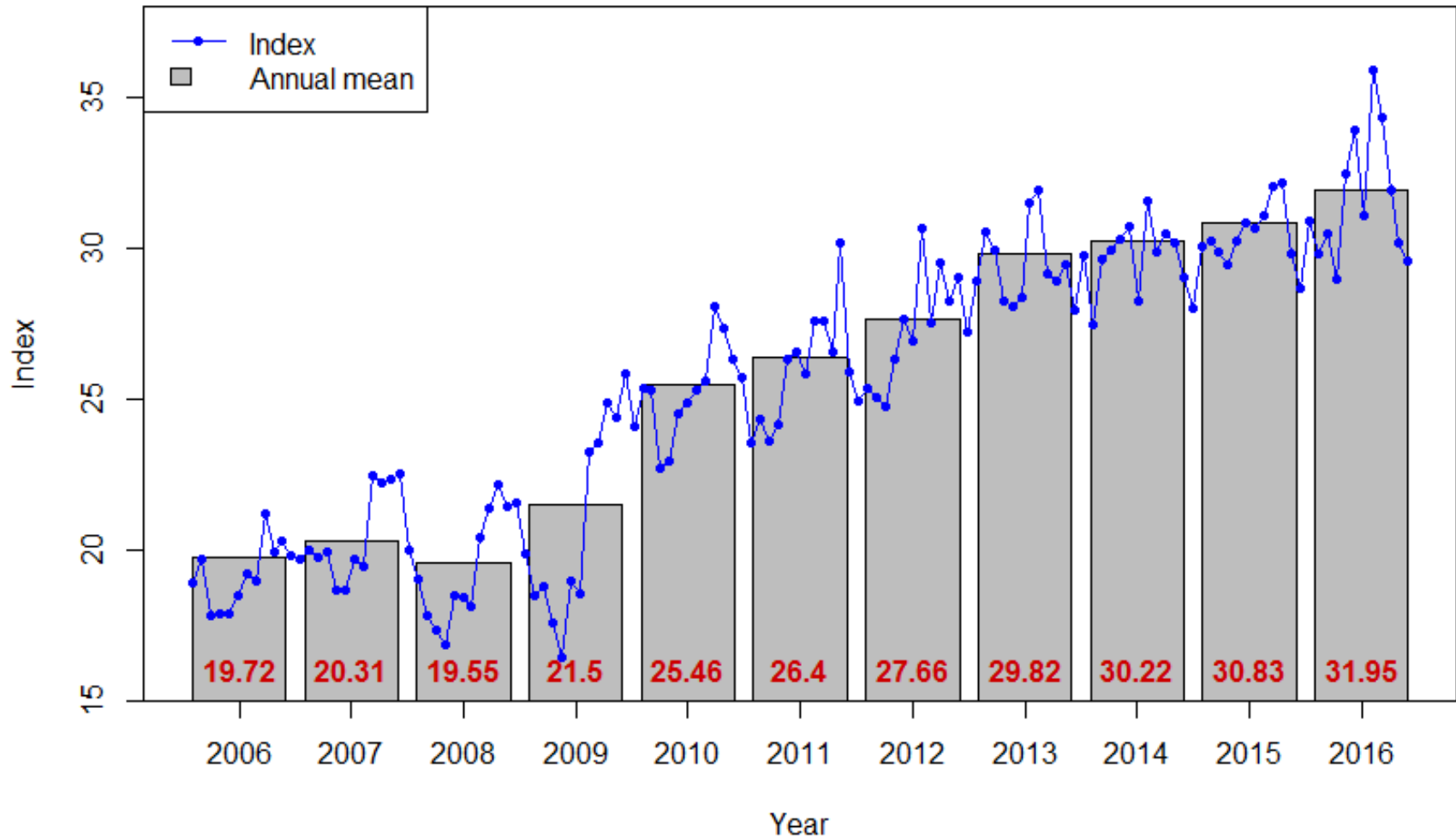# CWB NWP PI (Sep 2005 ~ Aug 2017 monthly)

CWB NWP Performance Index

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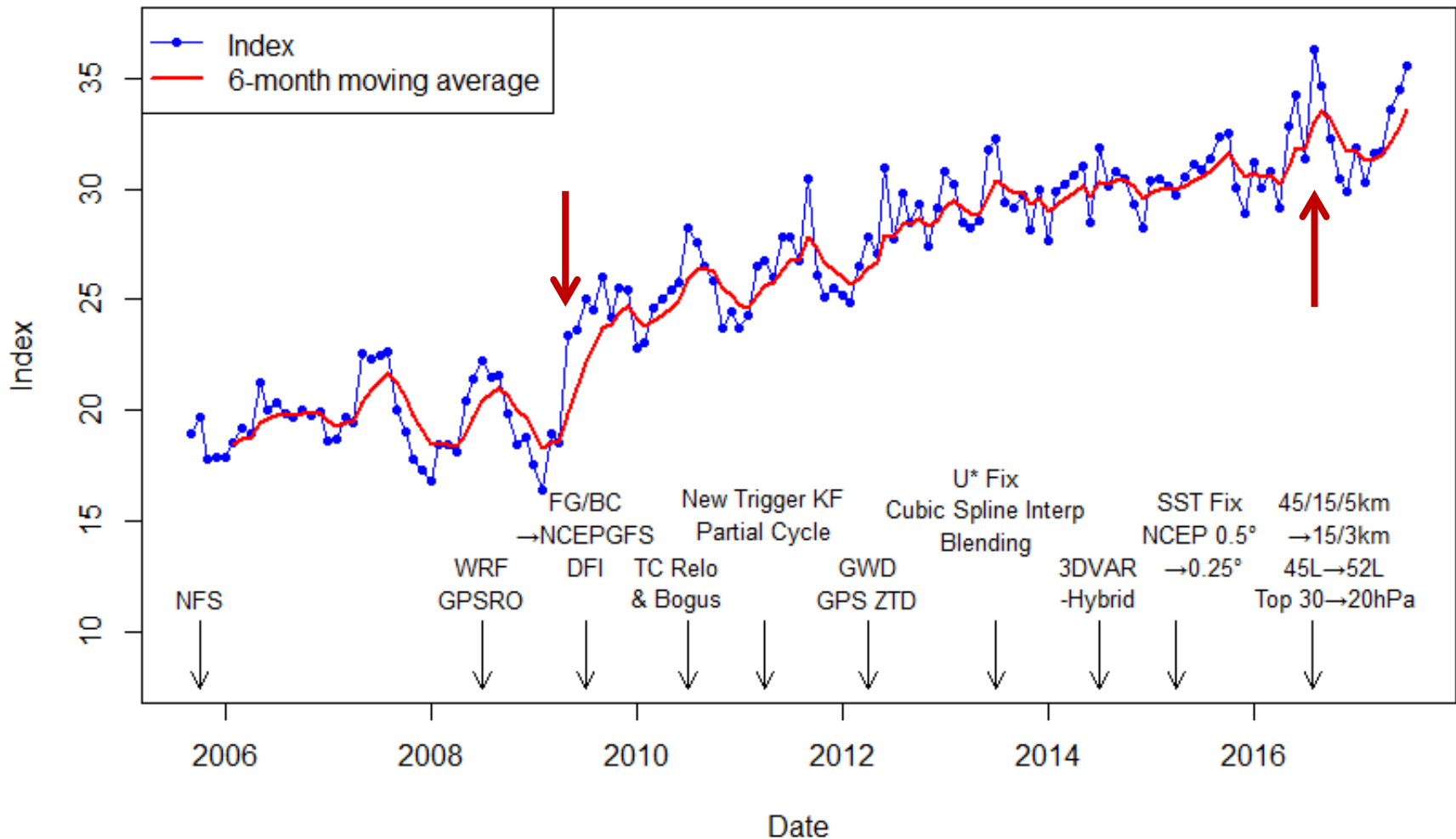
Jun 2010 ~ Mar 2017 mean monthly (72-hr fcst)

500GH AC Monthly Mean

Higher is better

500GH AC

500GH Monthly Mean

Higher is worse

500GH RMSE

SLP Monthly Mean

Higher is worse

SLP RMSE

Index Monthly Mean

Higher is better

PI

106年天氣分析與預報研討會
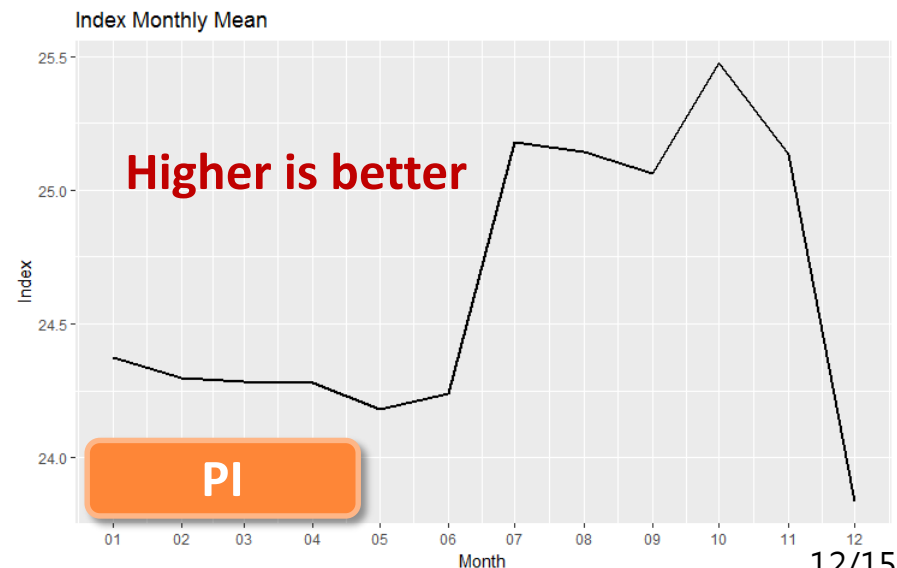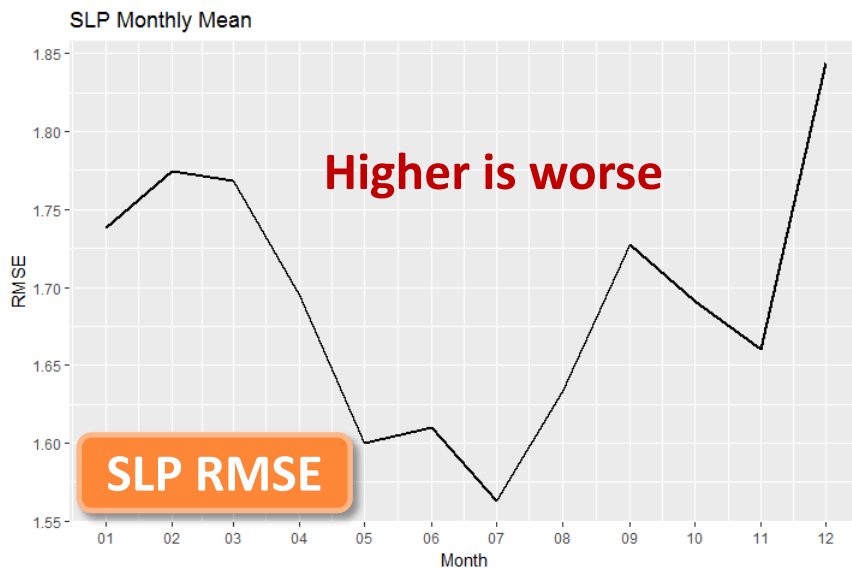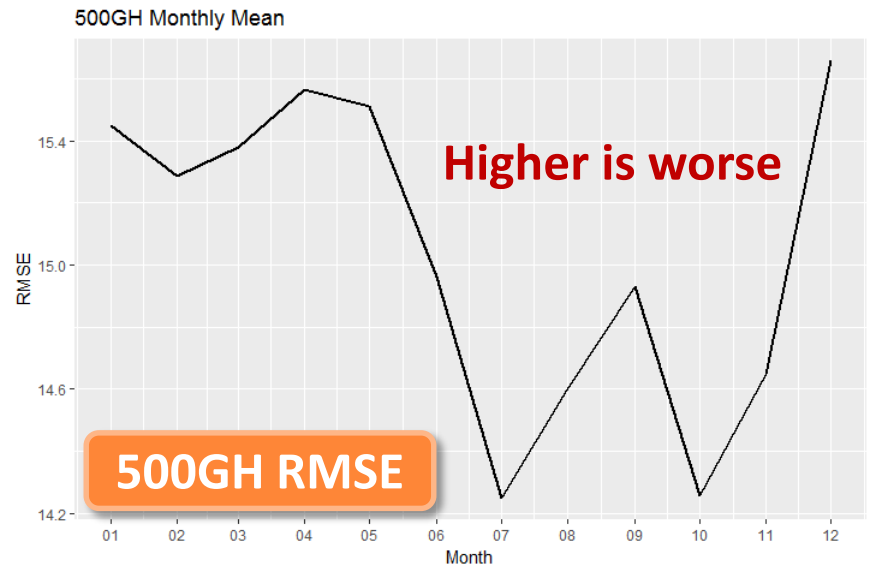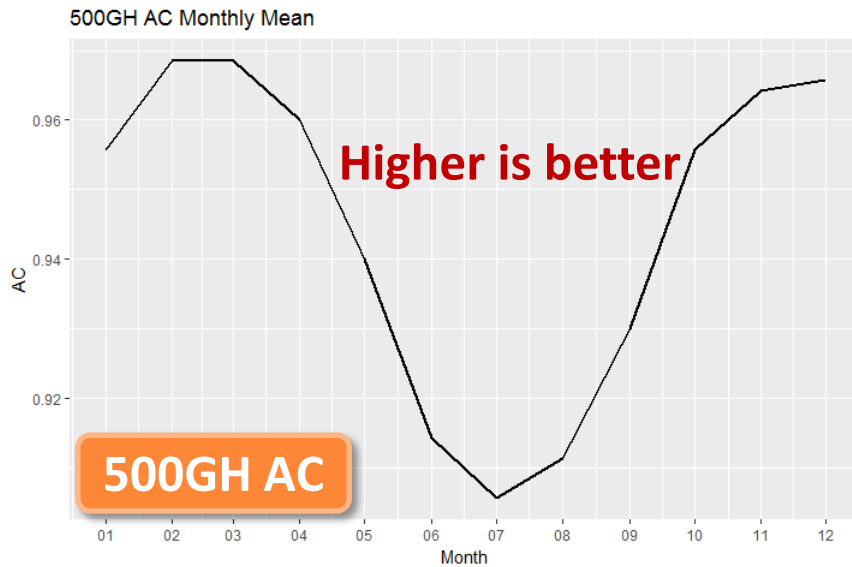
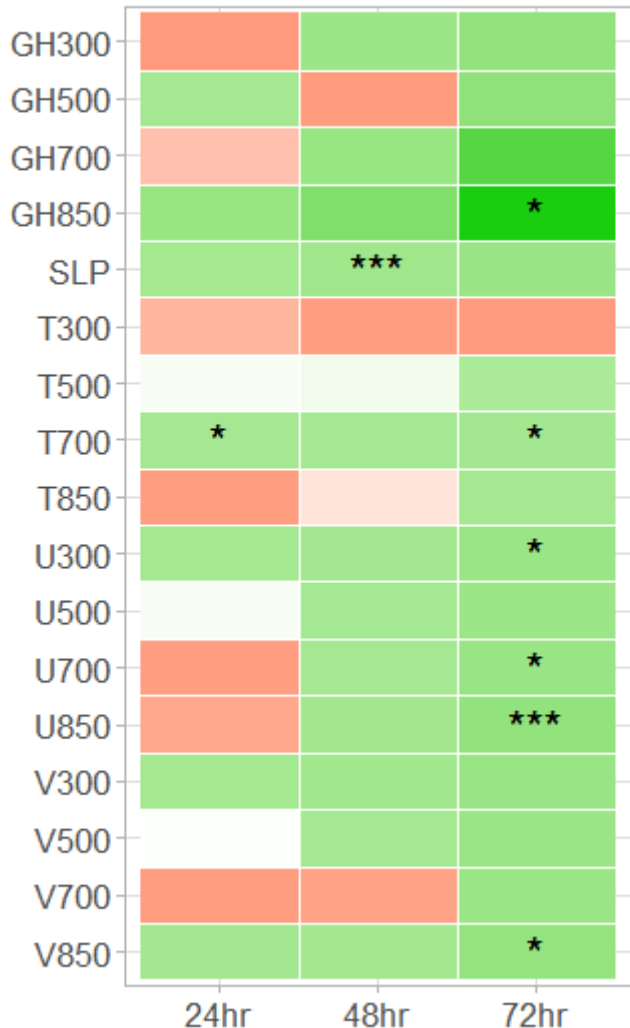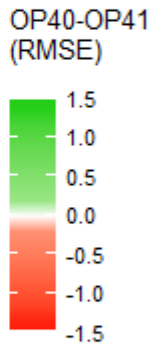# CWB NWP PI with annual mean bar

CWB NWP Performance Index

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CWB NWP Scorecard for WRF OP4.1

CWB WRF Scorecard Aug 2015
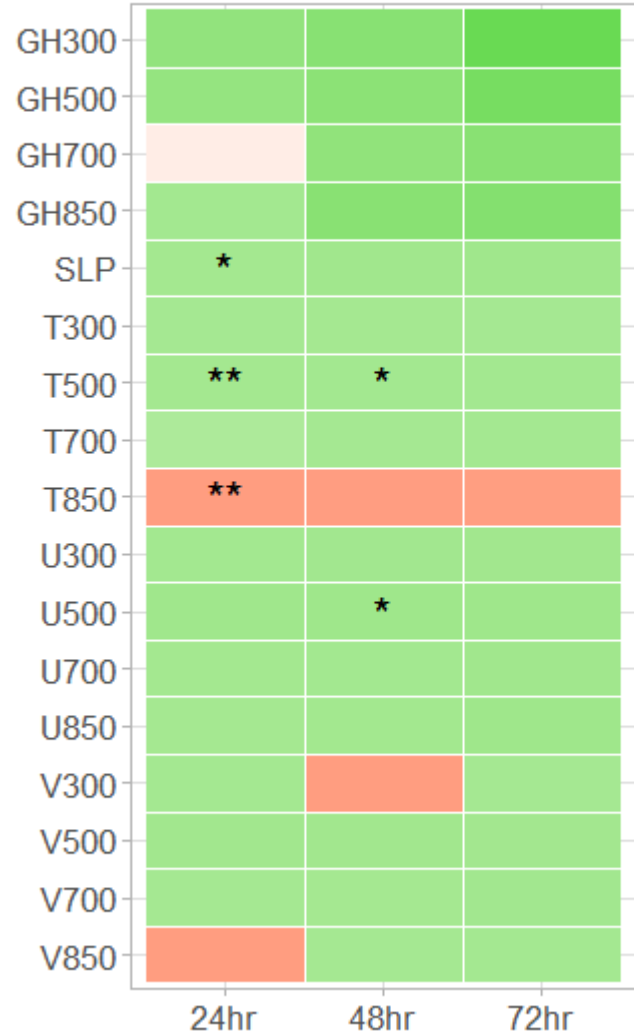OP41 SCORE = 24.95
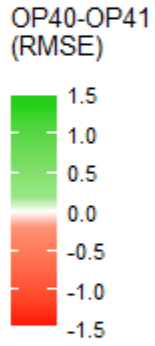OP40 SCORE = 24.42

AUG 2015

CWB WRF Scorecard Dec 2015
OP41 SCORE = 25.31
OP40 SCORE = 25

DEC 2015

* 95%, ** 99%, *** 99.9% Significance Level

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Summary and Future work

➢ **CWB NWP Performance Index (PI)** enables us to track, year-on-year, the **improvements** of our model forecasts.

➢ **Scorecard** provides a quick visual overview over the performance of the **experiment scores** compared to **control**.

➢ Current PI upper-air fields verified by comparison with **radiosondes**, expanding for **surface parameters**, e.g. 2m temperature, 10m wind & typhoon track…, and including other forecast lead time: 12, 24, 48 hours.

Thank You ☺