

2、4度C暖化情境對臺灣地區空氣品質的影響

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臺灣地區空氣品質

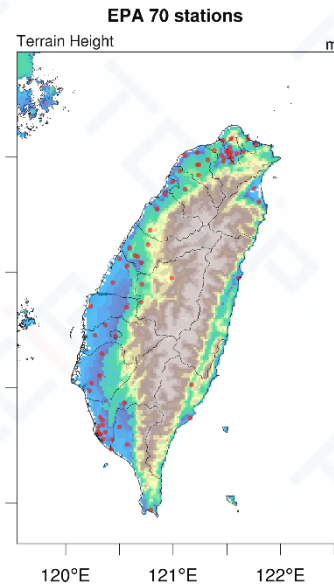
■ 9月到隔年4月，容易發生高污染；
夏季空氣品質佳

■ 對敏感族群不健康日數(AQI>100 days)：

- 北部、竹苗：春季, 10 days/mn.
- 南部：秋冬季, ≥ 20 days/mn.

2005-2021 AQI(O₃,PM_{2.5})>100 days LST

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Keelung	3.9	3.3	5.7	6.1	3.2	1.2	2.8	1.7	2.2	2.5	2.8	3.6
FugueiCape	0.5	2.0	5.4	8.8	2.6	2.2	0.2	0.2	2.4	5.0	2.8	1.2
Wanli	3.3	2.4	6.7	10.2	6.3	2.8	2.7	2.1	3.3	5.4	2.8	3.3
Tamsui	3.8	4.2	7.2	6.9	3.2	1.4	0.7	1.6	2.8	3.5	3.1	4.7
Linkou	4.7	4.3	7.3	8.9	4.8	2.0	1.9	2.7	3.9	4.5	4.1	6.0
Sanchong	8.5	7.9	12.9	11.6	7.8	5.0	5.2	4.9	4.6	6.1	6.4	8.0
Cailiao	5.5	6.2	7.2	7.8	5.0	2.2	1.7	2.7	3.2	3.5	3.4	6.0
Xizhi	3.7	4.1	7.2	6.3	4.8	2.6	3.7	2.7	2.9	2.9	3.0	4.4
Datong	3.7	4.2	6.8	5.5	2.8	2.8	2.8	2.2	2.0	4.2	4.1	4.3
Xinzhuang	6.8	7.3	10.9	11.2	7.3	3.3	3.5	3.7	4.3	4.2	4.5	6.5
Yonghe	5.9	7.5	10.4	7.5	5.0	1.9	1.9	2.8	2.5	3.3	3.7	6.2
Banqiao	6.1	7.1	9.6	9.1	6.1	2.9	3.8	4.0	4.2	3.5	4.4	7.1
Tucheng	6.0	7.1	10.1	10.3	7.5	4.4	4.6	4.5	4.8	4.3	4.7	6.8
Xindian	3.9	4.7	7.1	7.5	6.1	3.4	4.7	3.8	3.3	2.8	2.8	4.3
Yangming	1.2	1.5	4.2	7.7	5.2	1.9	0.8	1.4	2.9	2.8	1.9	1.2
Shilin	3.7	4.3	7.2	7.4	5.1	2.3	2.2	2.7	3.4	3.8	2.9	4.4
Zhongshan	6.9	7.3	11.1	9.9	6.9	4.1	4.2	4.3	4.4	4.9	5.3	7.2
Songshan	4.7	5.8	8.4	8.2	6.6	3.2	4.8	3.8	3.6	3.9	3.5	5.5
Wanhua	4.9	5.9	9.4	8.5	5.7	2.2	2.5	3.2	3.4	4.0	3.9	5.9
Guting	5.9	5.6	10.0	9.4	5.3	2.2	3.7	2.1	3.1	4.1	4.8	7.0
Dayuan	6.3	7.2	8.9	9.2	5.3	2.2	1.7	2.1	3.8	4.1	4.8	7.0
Guanyin	6.1	5.9	8.4	8.9	5.3	1.6	1.6	2.4	4.5	5.2	4.7	7.3
Taoyuan	6.2	6.6	8.8	9.3	6.2	2.5	2.6	3.8	4.2	4.1	4.6	6.8
Pingzhen	5.4	6.7	8.6	8.2	5.5	1.7	2.1	2.5	4.5	4.3	4.3	5.8
Zhongli	6.8	7.7	10.6	9.0	6.3	2.8	2.5	4.2	4.1	4.1	4.8	7.5
Longtan	4.8	5.7	8.1	8.4	5.3	1.6	2.5	2.8	5.1	3.6	4.6	5.2
Hukou	7.0	7.5	10.8	11.2	6.2	1.6	1.9	2.9	4.1	6.8	5.5	8.2
Zhudong	5.3	6.5	8.4	8.0	5.4	1.6	2.6	3.5	6.4	5.2	4.2	5.4
Hsinchu	7.8	8.4	11.2	10.0	5.3	1.8	1.4	2.8	6.2	6.3	6.1	8.8
Toufen	6.9	7.1	10.4	9.5	5.7	1.5	1.4	2.6	6.3	6.4	5.3	7.2
Miaoli	7.5	8.3	11.5	9.5	5.8	1.2	1.2	3.4	6.2	7.0	6.2	7.6
Sanyi	4.2	4.7	10.3	9.5	5.8	2.1	2.3	3.8	9.1	8.8	6.2	6.4
Fengyuan	6.0	6.4	11.4	12.3	7.7	2.2	3.4	4.6	10.2	10.1	7.3	6.5
Shalu	9.5	9.4	14.4	13.2	7.9	2.0	1.6	3.6	8.6	9.6	9.5	9.9
Xitun	9.6	10.8	15.1	13.2	8.3	2.7	2.8	4.8	11.1	12.5	10.1	10.5
Zhongming	11.1	10.7	15.5	12.9	8.5	2.5	3.2	5.3	11.2	12.3	10.3	10.5
Dali	12.2	11.3	15.8	13.9	10.1	3.5	4.3	5.9	13.8	16.1	12.8	11.9
Xianxi	9.1	9.6	14.4	12.9	7.5	1.9	1.1	3.3	7.4	8.5	8.9	9.9
Changhua	10.4	11.4	14.9	13.4	8.1	2.6	2.5	4.1	11.5	12.6	11.6	12.3
Erlin	10.8	10.7	15.4	13.4	8.1	2.6	3.1	4.7	10.8	11.8	12.6	12.6
Puli	13.9	13.4	20.4	14.9	8.2	2.9	3.8	4.9	12.0	17.8	14.2	13.0
Nantou	14.4	13.6	18.4	15.0	7.9	2.4	3.8	4.8	13.0	16.1	12.7	14.2
Zhushan	16.8	17.6	21.8	17.7	9.8	3.3	3.9	4.5	13.6	22.2	17.9	18.5
Lunbei	13.4	14.5	17.7	14.9	8.9	2.4	2.3	3.3	11.0	13.5	11.1	12.6
Maliiao	9.5	10.2	15.8	11.8	8.8	0.8	0.8	1.0	8.0	9.6	8.0	8.8
Taixi	10.9	10.2	15.8	14.6	9.4	1.9	0.8	2.5	8.6	11.2	10.0	10.0
Douliu	17.9	16.9	21.0	17.8	10.8	3.8	3.5	4.5	13.8	20.4	17.2	16.2
Xingang	13.9	15.5	19.2	15.1	8.2	2.8	1.9	3.5	12.2	16.9	13.5	14.5
Puzi	13.5	13.4	18.1	14.4	8.1	2.5	1.1	2.6	10.3	15.1	12.5	13.6
Chiayi	19.7	18.2	21.8	16.2	9.6	3.1	2.5	3.5	11.9	20.1	17.2	18.9
Xinying	16.4	16.1	17.6	14.6	7.8	2.1	1.7	2.7	10.8	18.6	15.2	16.8
Shanhua	16.6	15.5	17.6	14.1	7.2	2.2	1.5	2.3	10.8	18.4	15.9	17.5
Annan	17.0	15.4	19.4	15.2	7.9	2.2	1.1	2.3	11.5	19.4	16.1	18.6
Tainan	19.1	16.9	19.8	15.6	8.8	2.7	1.2	3.1	11.5	20.7	16.1	18.0
Meinong	17.5	14.8	17.8	12.5	7.2	2.3	1.3	1.5	9.5	18.6	17.0	17.9
Qiaotou	23.2	20.3	22.2	15.8	7.9	2.6	1.4	2.3	12.1	22.2	20.7	22.1
Nanzi	23.9	19.5	21.5	15.8	8.9	2.8	1.9	2.7	12.7	22.4	20.7	21.9
Renwu	23.4	19.5	22.6	16.5	9.4	2.8	1.7	3.5	12.1	21.1	20.2	21.9
Zuyoying	22.1	17.7	20.8	15.8	8.0	3.0	1.8	3.3	11.5	23.6	21.7	22.6
Qianjin	24.8	21.5	21.8	17.4	9.5	2.9	1.8	3.9	13.9	24.4	21.1	22.9
Fengshan	23.7	19.7	20.4	14.6	7.7	2.7	1.8	2.9	11.9	20.2	20.5	22.9
Fuxing	23.5	20.0	20.0	13.4	6.3	1.7	0.9	1.7	8.2	17.9	19.4	22.6
Qianzhen	24.3	20.1	20.5	14.7	7.3	2.2	1.2	2.9	11.5	20.5	20.3	21.7
Xiaogang	25.1	20.4	20.9	14.1	7.4	2.7	2.2	3.3	11.6	20.6	19.9	23.0
Daliao	25.2	20.8	22.1	15.4	7.9	2.7	2.5	3.1	12.8	20.8	20.8	23.8
Linyuan	22.9	18.8	21.1	16.5	8.5	2.8	1.8	3.1	11.5	22.0	22.7	23.7
Pingtung	23.6	20.1	20.7	16.5	8.5	2.9	2.5	3.8	15.9	22.5	20.9	21.8
Chaozhou	25.1	20.6	21.2	15.2	7.6	2.8	2.8	4.0	11.8	21.8	23.1	24.0
Hengchun	0.8	1.4	1.9	3.5	1.6	0.5	0.3	0.8	2.4	2.5	0.6	1.0
Yilan	2.7	2.3	3.7	3.6	2.0	0.7	0.2	0.6	1.9	1.9	1.7	2.9
Dongshan	2.4	1.5	3.1	2.5	1.1	0.6	0.3	0.2	1.5	1.6	1.4	2.5
Hualien	1.4	1.0	2.3	2.6	1.2	0.5	0.1	0.5	1.4	1.4	0.9	2.5
Guanshan	0.5	0.4	0.7	0.4	0.4	0.0	0.0	0.1	0.6	0.5	0.6	1.2
Taitung	0.5	0.3	0.6	1.0	0.5	0.1	0.0	0.2	0.7	0.8	0.6	0.9
Matsu	12.9	9.8	13.3	15.6	13.2	3.7	1.7	3.2	8.4	13.2	9.1	12.2
Kinmen	19.1	14.7	17.7	18.5	12.5	2.4	2.5	5.8	10.1	15.4	12.6	17.4
Magong	6.3	5.1	6.8	8.4	5.0	0.9	0.5	1.7	4.2	6.5	3.5	5.1



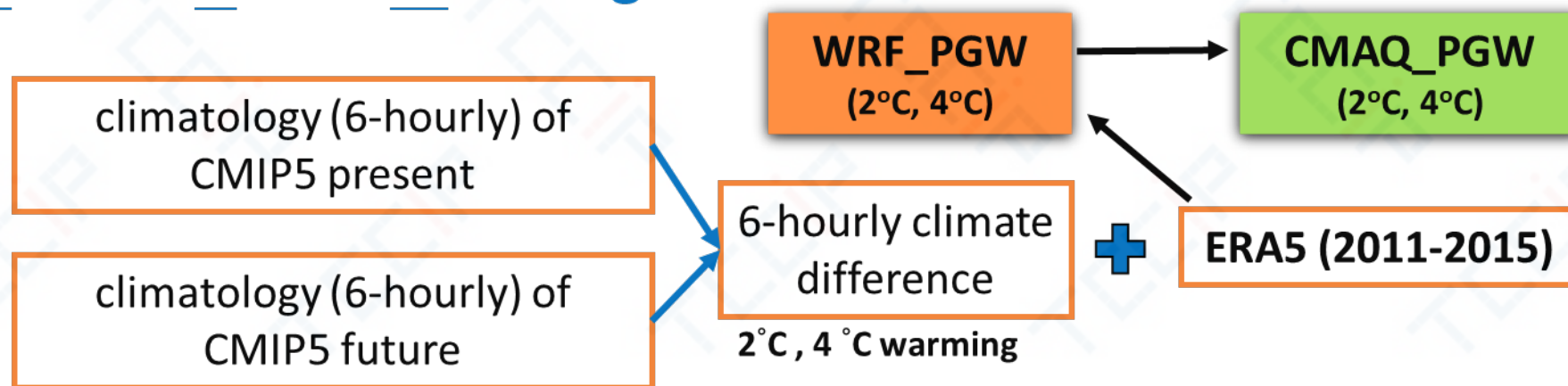
數值實驗設計

- 以中尺度模式進行3組動力降尺度，以CMIP5模式系集平均當作初始及邊界條件
- 數值實驗：2011–2015年(CTRL run)及2組暖化情境（2度、4度）

CTRL run



Pseudo Global Warming run

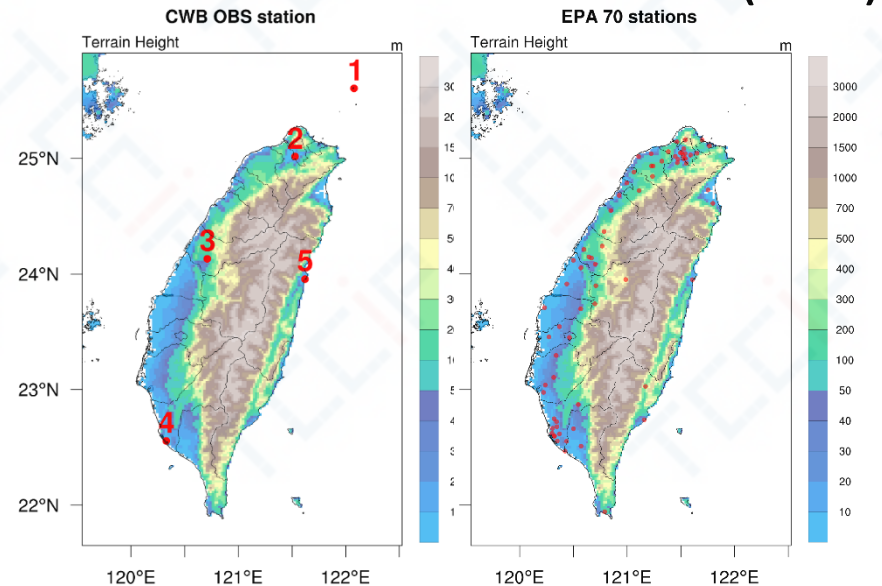


數值實驗及觀測資料

■ Horizontal resolutions : 10 km and 2 km

■ Observational datasets :

- Central Weather Bureau (CWB) : hourly data
- Taiwan Climate Change Projection and Information Platform (TCCIP) : 1-km resolution, daily data
- Environmental Protection Administration (EPA) : hourly data



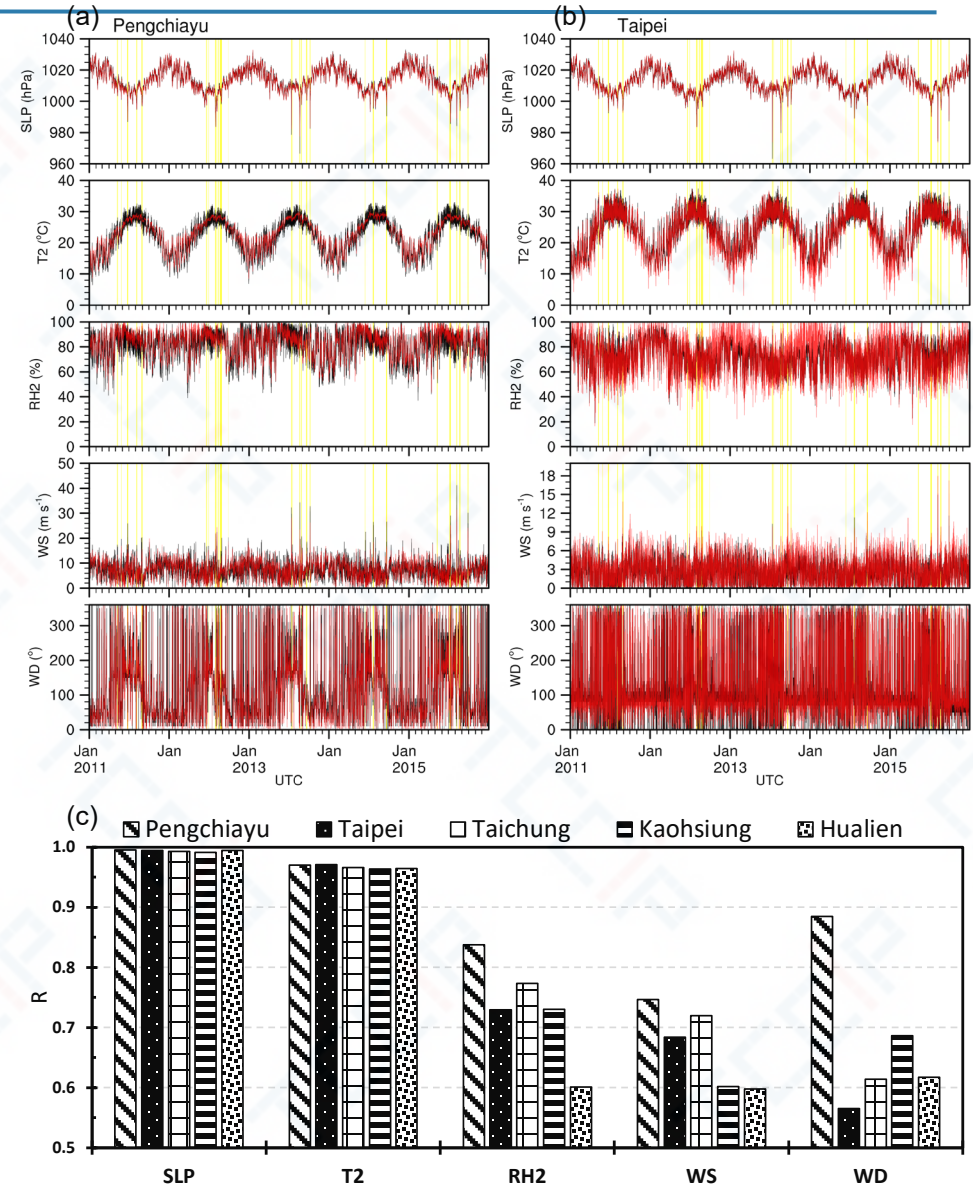
模式驗證(I) 氣象場

■ 5 CWB stations SLP and 2m-T :

$R > 0.96$, RMSE = 0.70 hPa and 1.62°C

- Pengchiayu : (background condition)
The R of 2m-RH, WS, and WD : 0.75 – 0.84.
- Urban (Taipei, Taichung, and Kaohsiung) and rural (Hualien) stations :
R of 2m-RH, WS, and WD : 0.6 – 0.8

■ Considering the good performance of the WRF model in depicting the present climate conditions during 2011–2015, we further applied the WRF model to project climate changes under different warming scenarios



模式驗證(II) 空氣品質

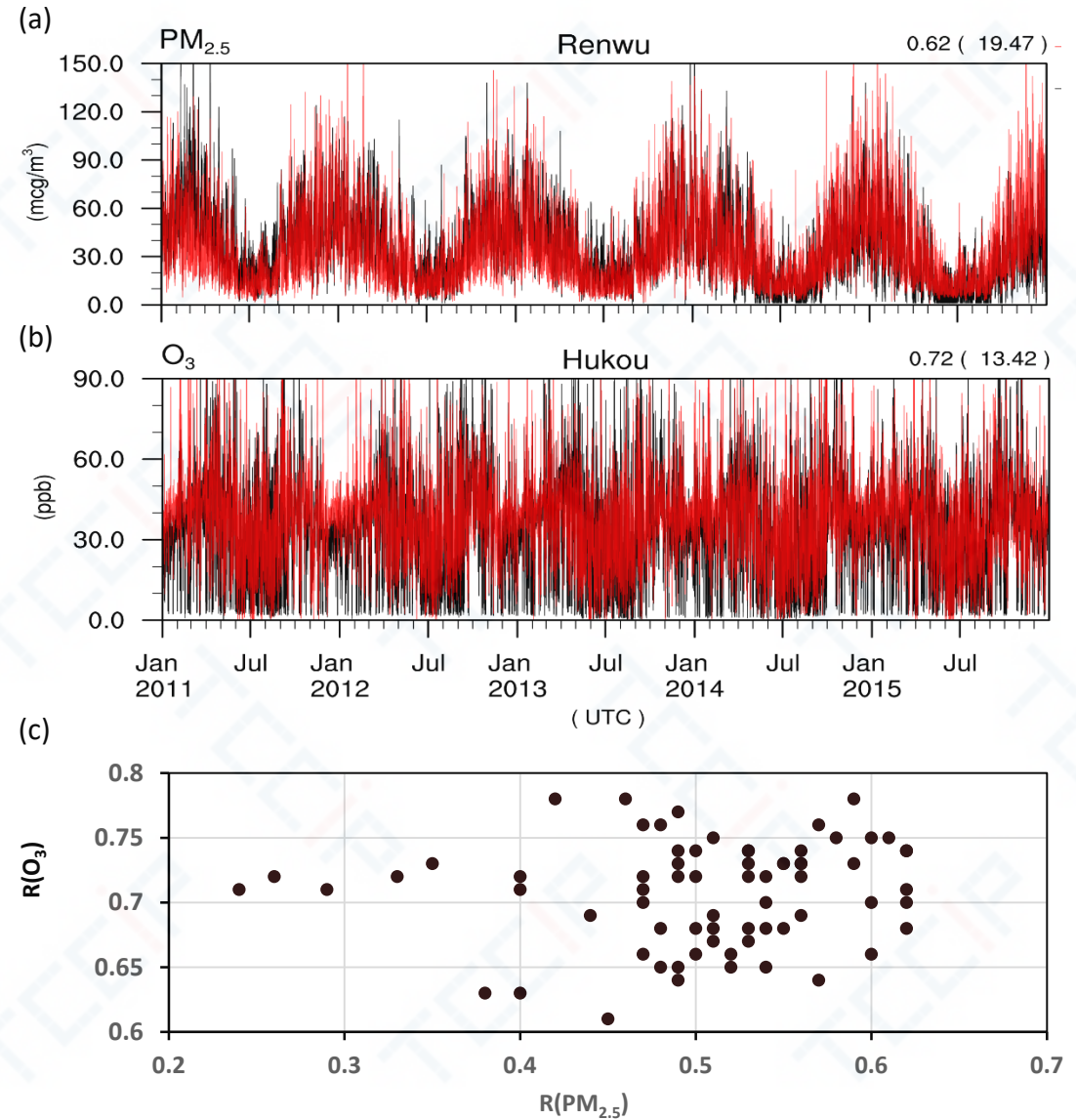
■ EPA stations

—PM_{2.5} : Sep – Apr

$R_{PM2.5}$ 0.24 ~ 0.62 (0.50)

—O₃ Mar – Apr , Sep – Oct

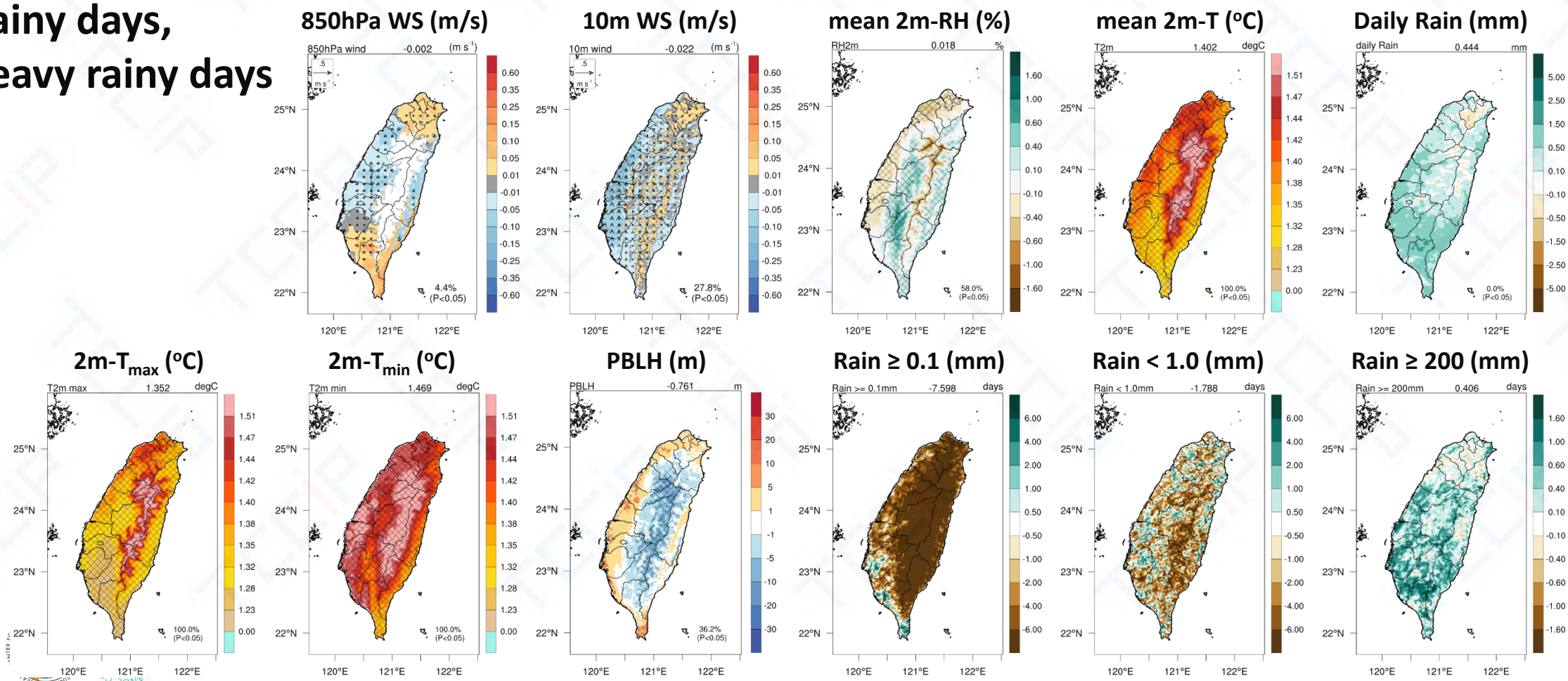
R_{O_3} : 0.61 ~ 0.78 (0.71)



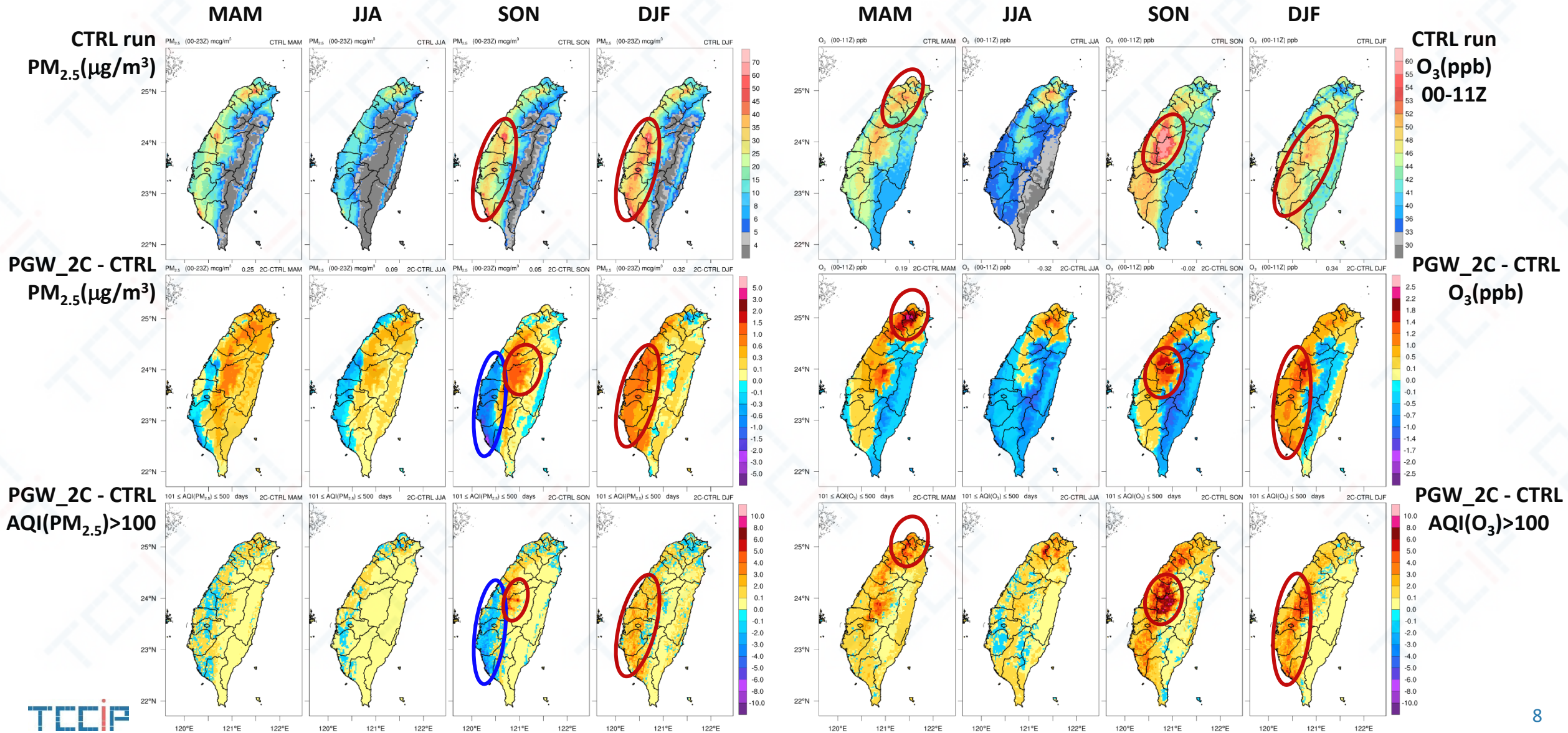
氣象場變化

- 10m wind: decreased in western coastal areas.
- T2m max, min, mean: increased especially over the mountain areas.
- Precipitation: fewer rainy days, more heavy rainy days

(2C暖化情境)

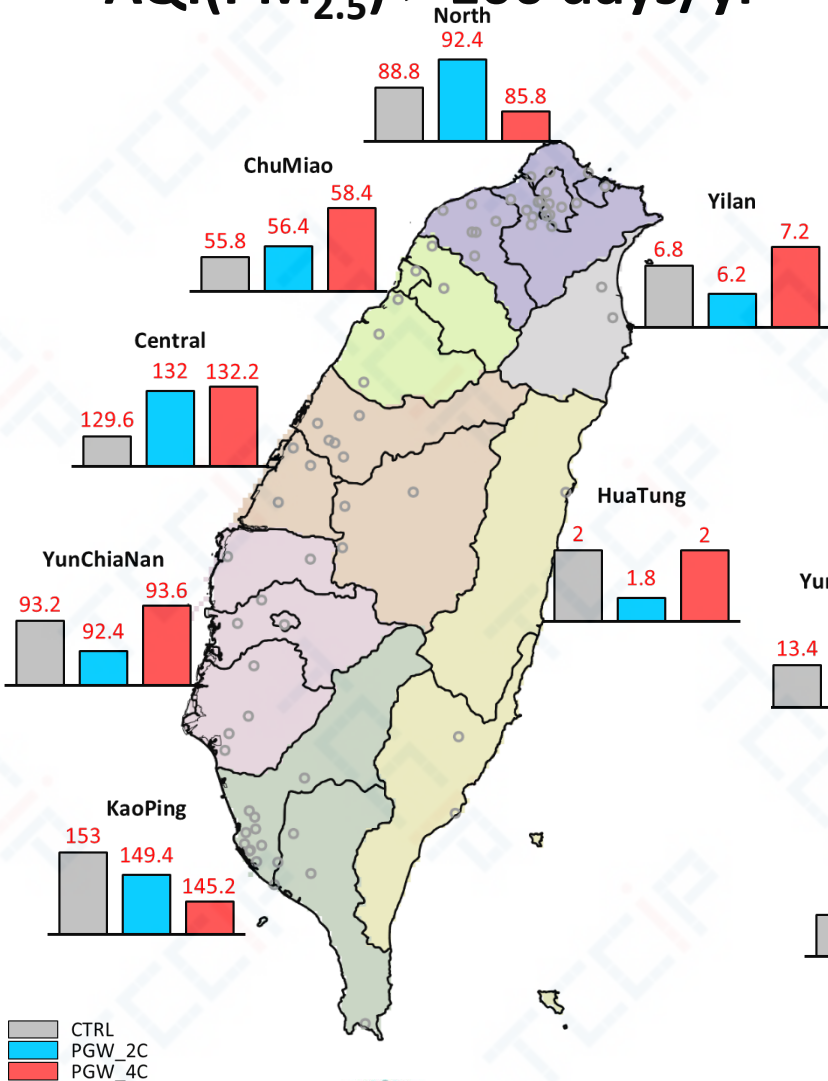


PM_{2.5} & O₃ 變化

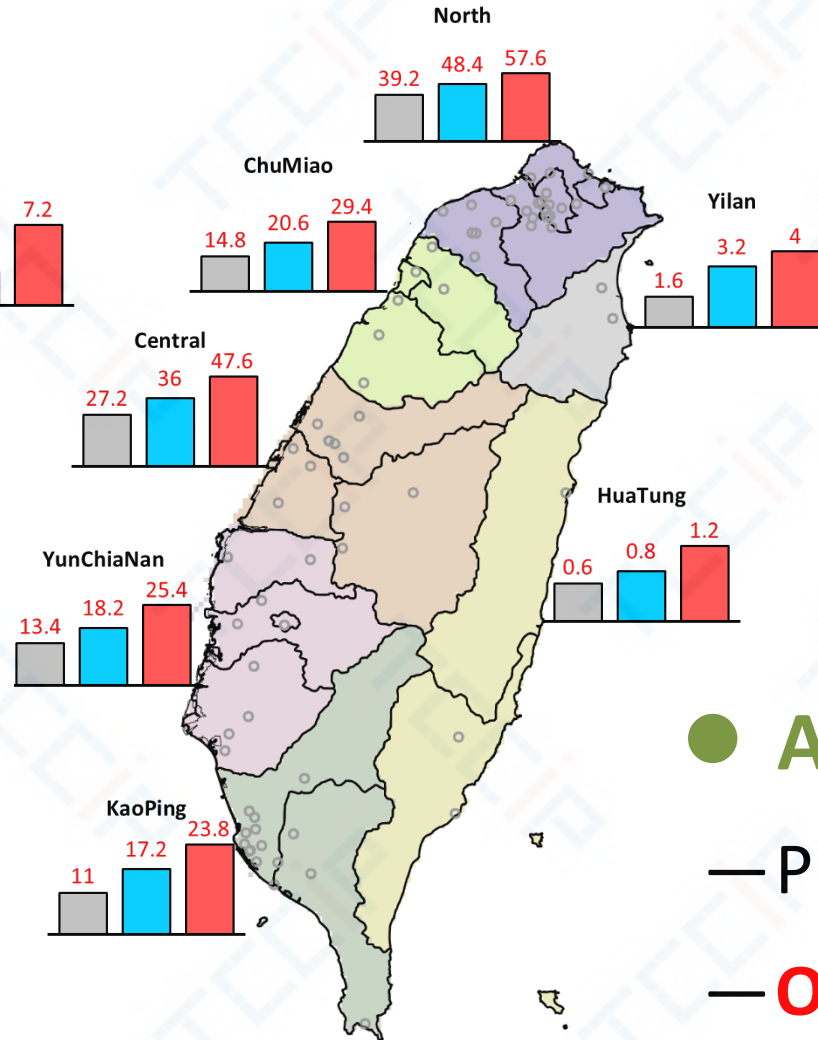


PM_{2.5} & O₃ 變化

AQI(PM_{2.5}) > 100 days/yr



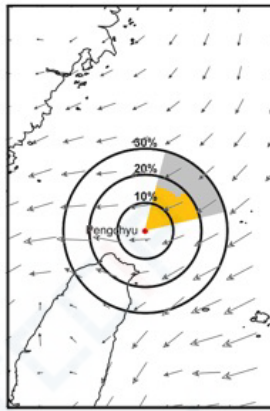
AQI(O₃) > 100 days/yr



- AQI > 100 days/yr :
- PM_{2.5}(2C,4C) : +0.3%, -0.9%
- O₃(2C,4C) : +33%, +75%

CTRL
PGW_2C
PGW_4C

東北季風事件變化



NE CTRL_PJY WD(15-75°), WS(≥ 4m/s)

SNE CTRL_PJY WD(15-75°), WS(≥ 7m/s)

2011	28	21	18	10	11	9	23	14	22	156
2012	23	17	15	4	12	9	21	14	16	131
2013	19	15	13	8	3	13	22	18	22	133
2014	15	11	11	9	2	4	18	21	20	111
2015	20	18	16	11	8	13	20	14	22	142
	Jan	Feb	Mar	Apr	May	Sep	Oct	Nov	Dec	all

2011	28	16	15	4	5	6	17	13	21	125
2012	23	17	15	2	7	6	16	10	14	110
2013	17	15	8	5	1	8	16	14	17	101
2014	13	9	8	3	1	0	13	13	19	79
2015	19	13	14	7	2	4	14	11	20	104
	Jan	Feb	Mar	Apr	May	Sep	Oct	Nov	Dec	all

(a) PGW2C_re-CTRL_PJY WD(15-75°), WS(≥ 4m/s)

(b) PGW2C_re-CTRL_PJY WD(15-75°), WS(≥ 7m/s)

2011	0	0	1	-1	-1	0	0	0	1	0
2012	0	0	0	0	-1	0	0	0	1	0
2013	0	-1	0	-1	0	-2	-1	0	0	-5
2014	0	-1	0	-1	0	-2	0	0	1	-3
2015	0	0	0	0	0	-2	-2	0	0	-4

2011	-2	0	0	0	0	-1	0	0	1	-2
2012	0	0	0	0	0	-1	0	2	0	1
2013	2	-1	0	-1	-1	-1	-1	0	0	-3
2014	0	0	0	0	0	0	-2	1	1	0
2015	-1	1	-1	-1	-1	-2	-1	0	0	-6

大氣擴散情況

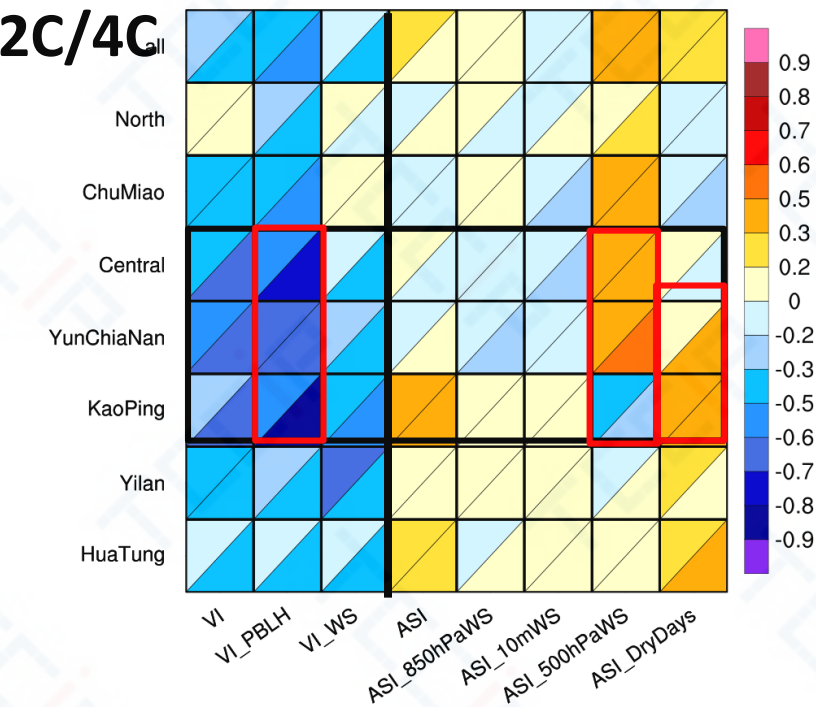
- **Air Stagnation Index (ASI)** ↑ AQI > 100 days ↑
 - Daily-mean near-surface (10-m) wind speeds < 4.0 m s⁻¹
 - Daily-mean 850 hPa wind speeds < 5 m s⁻¹
 - Daily-mean precipitation accumulation is <1 mm (i.e., a dry day)

- **Ventilation index (VI)** ↑ AQI > 100 days ↓

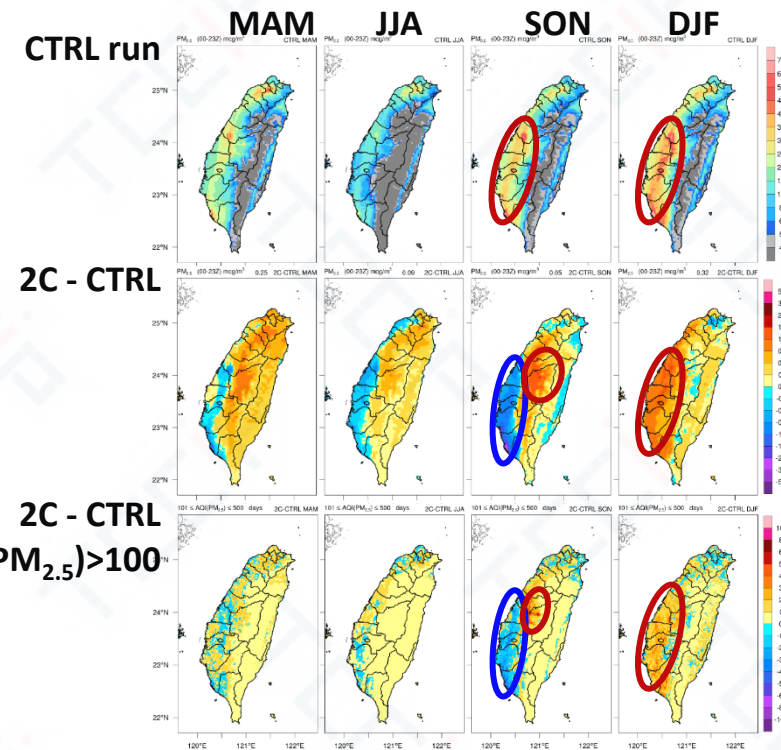
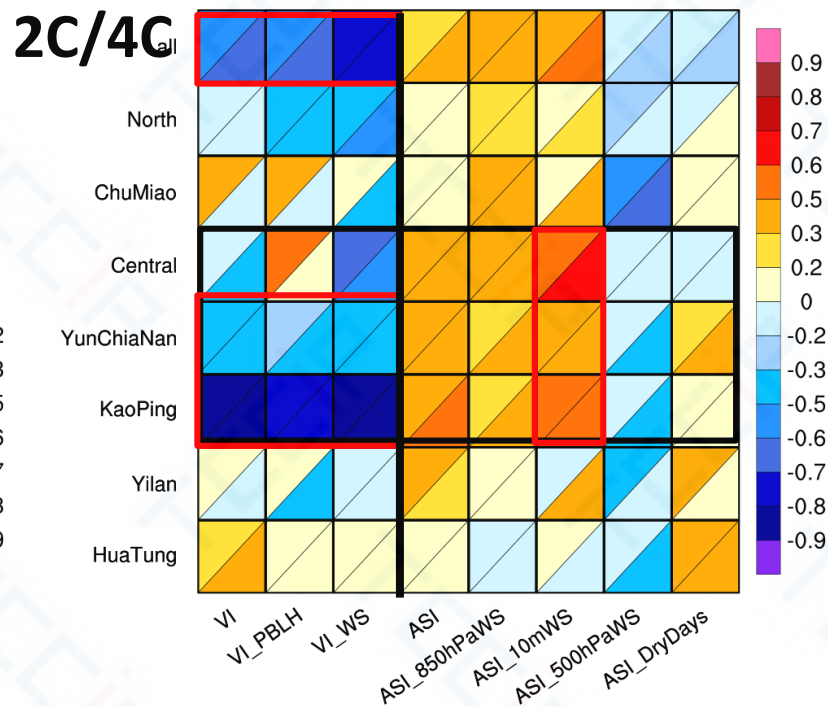
$$VI = PBLH \times WS_mean_{PBLH} \quad (HGT < 500m)$$

PM_{2.5} 變化

秋季 2C4C diffPM2.5 with diffWRF pattern correlation SON
left(2C_re) right(4C_re)



冬季 2C4C diffPM2.5 with diffWRF pattern correlation DJF
left(2C_re) right(4C_re)



■ PM_{2.5} (HGT < 500m)

- Autumn : PBLH, low-level wind speed, precipitation (Dry day)
- Winter : PBLH, low-level wind speed

O₃ 變化

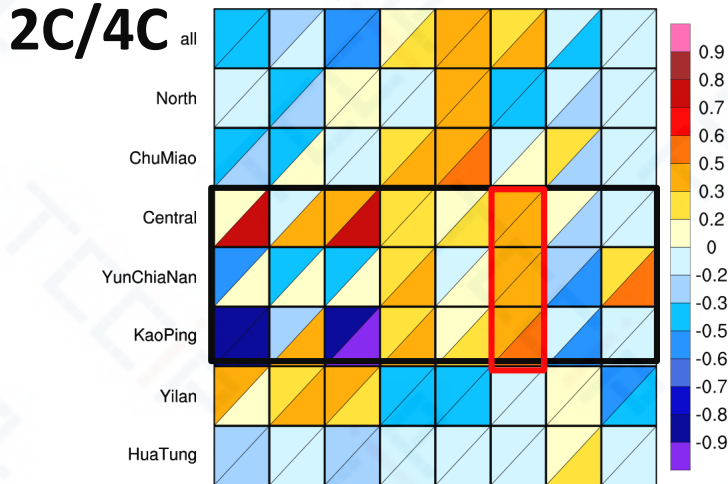
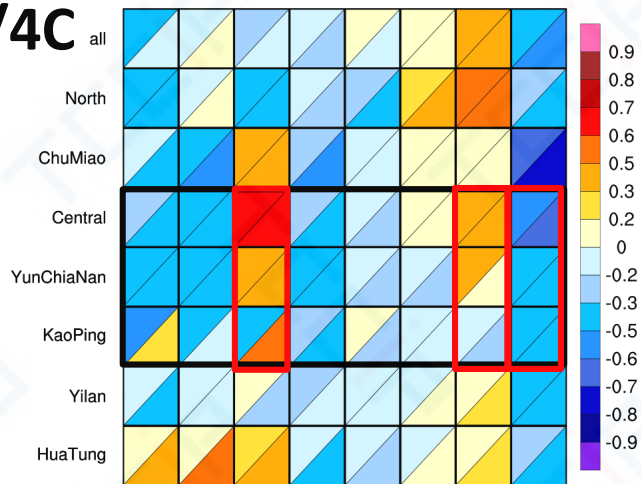
秋季

冬季

2C/4C

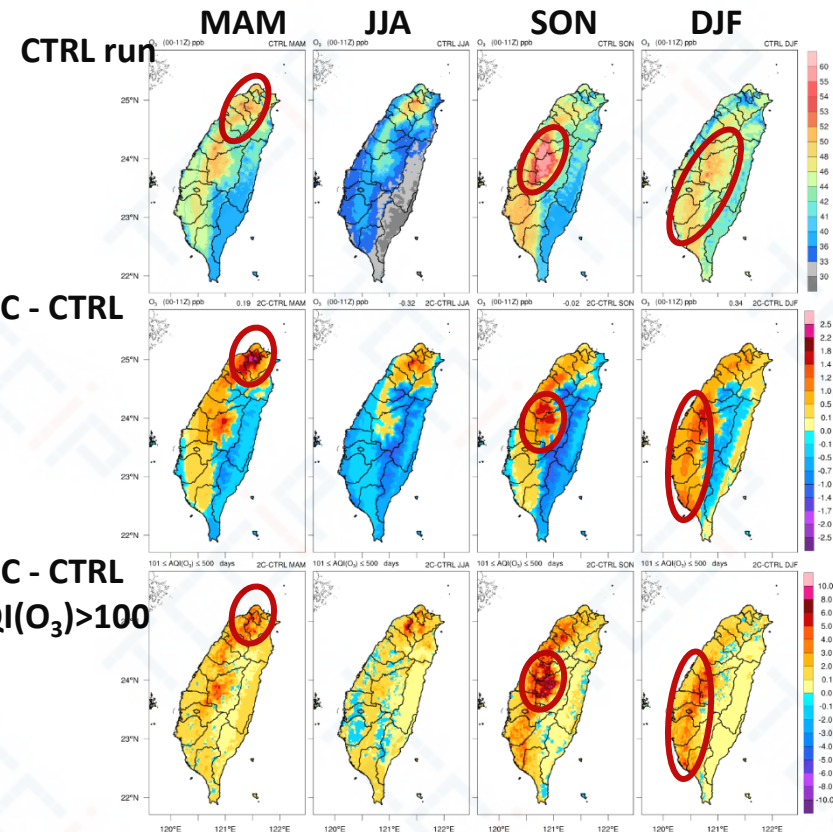
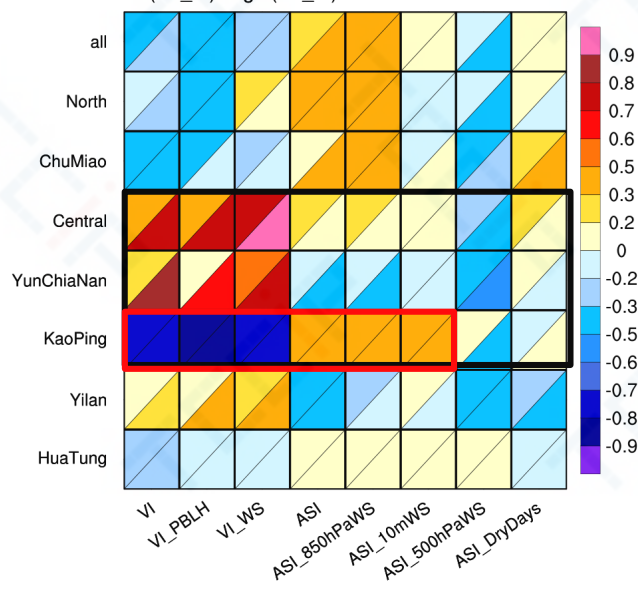
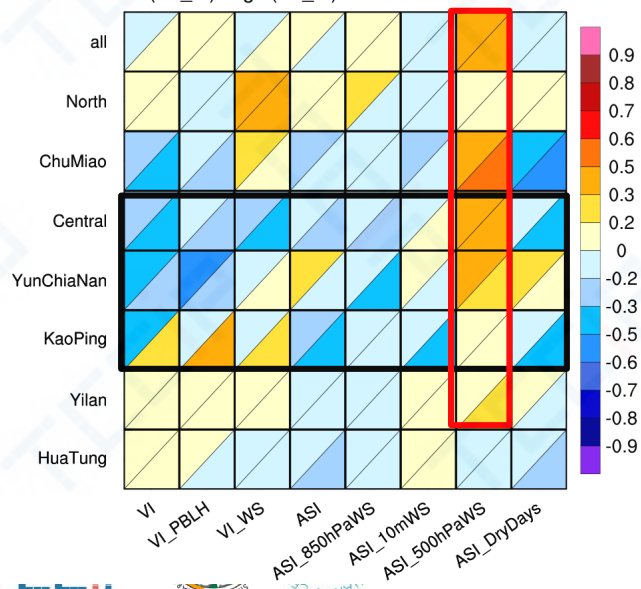
2C4C diffO3day with diffWRF pattern correlation SON
left(2C_re) right(4C_re)

2C4C diffO3day with diffWRF pattern correlation DJF
left(2C_re) right(4C_re)



2C4C diffO3night with diffWRF pattern correlation SON
left(2C_re) right(4C_re)

2C4C diffO3night with diffWRF pattern correlation DJF
left(2C_re) right(4C_re)

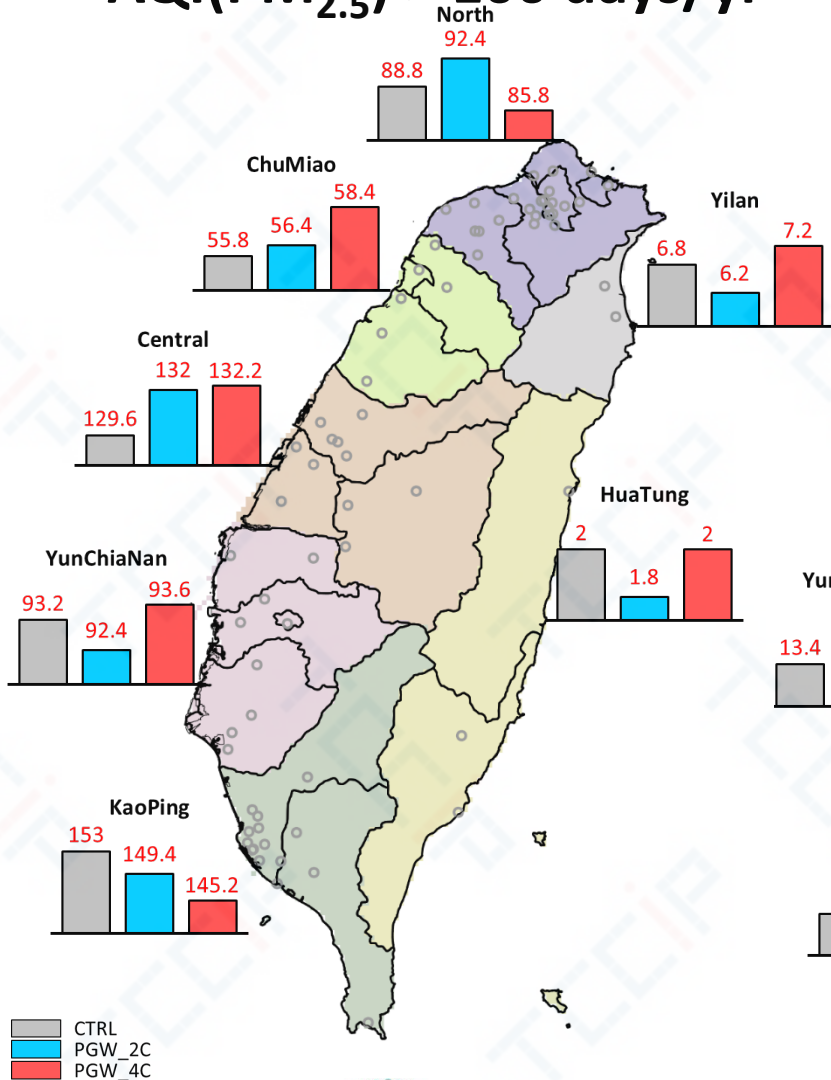


■ O₃ (HGT < 500m)

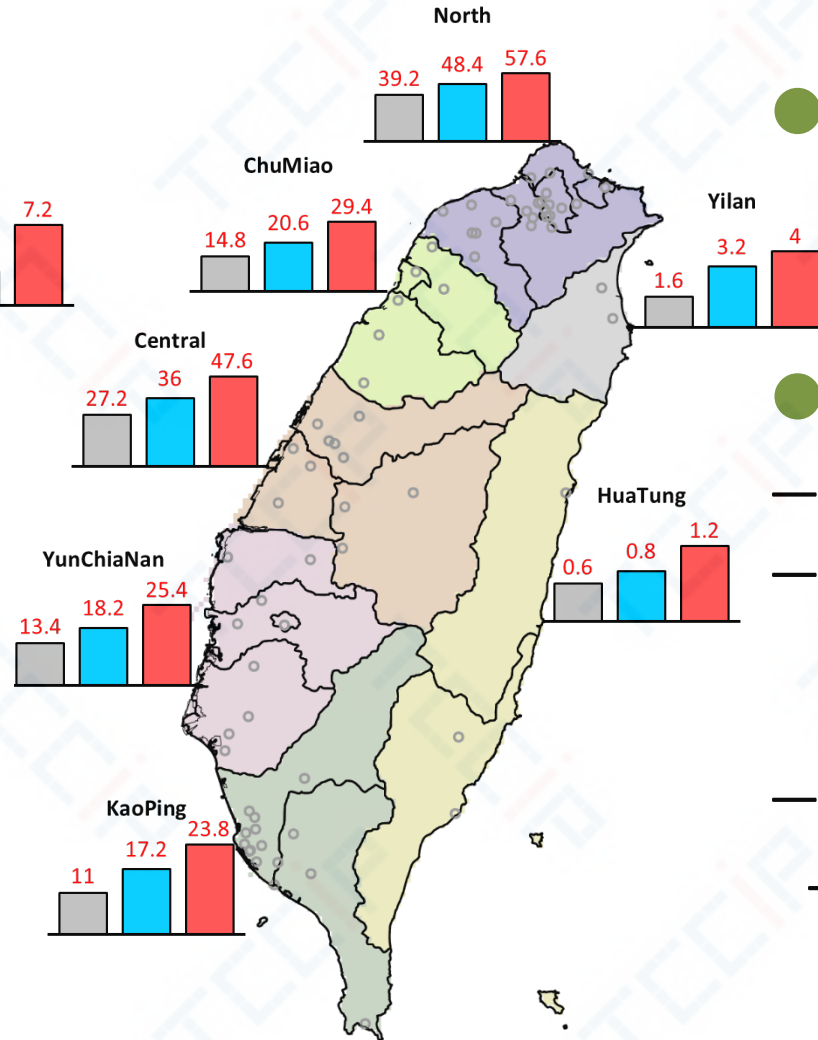
- Autumn : mid-level wind speed,
- Winter : low-level wind speed

小結

AQI(PM_{2.5}) > 100 days/yr



AQI(O₃) > 100 days/yr



● AQI > 100 days/yr :

- PM_{2.5}(2C,4C) : +0.26%, -0.9%
- O₃(2C,4C) : +33%, +75%

● More polluted days

— Less NE events

— PM_{2.5}

PBLH, precipitation (Dry day), low-level wind speed

— O₃

— Low- and mid-level wind speed, precipitation (Dry day)

CTRL
PGW_2C
PGW_4C

謝謝聆聽

