

東亞鋒面活動及降水未來推估 (using CMIP6)

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Wang et al. (2026), *J. of Climate*, **39**, 2721-2738 (CMIP6)

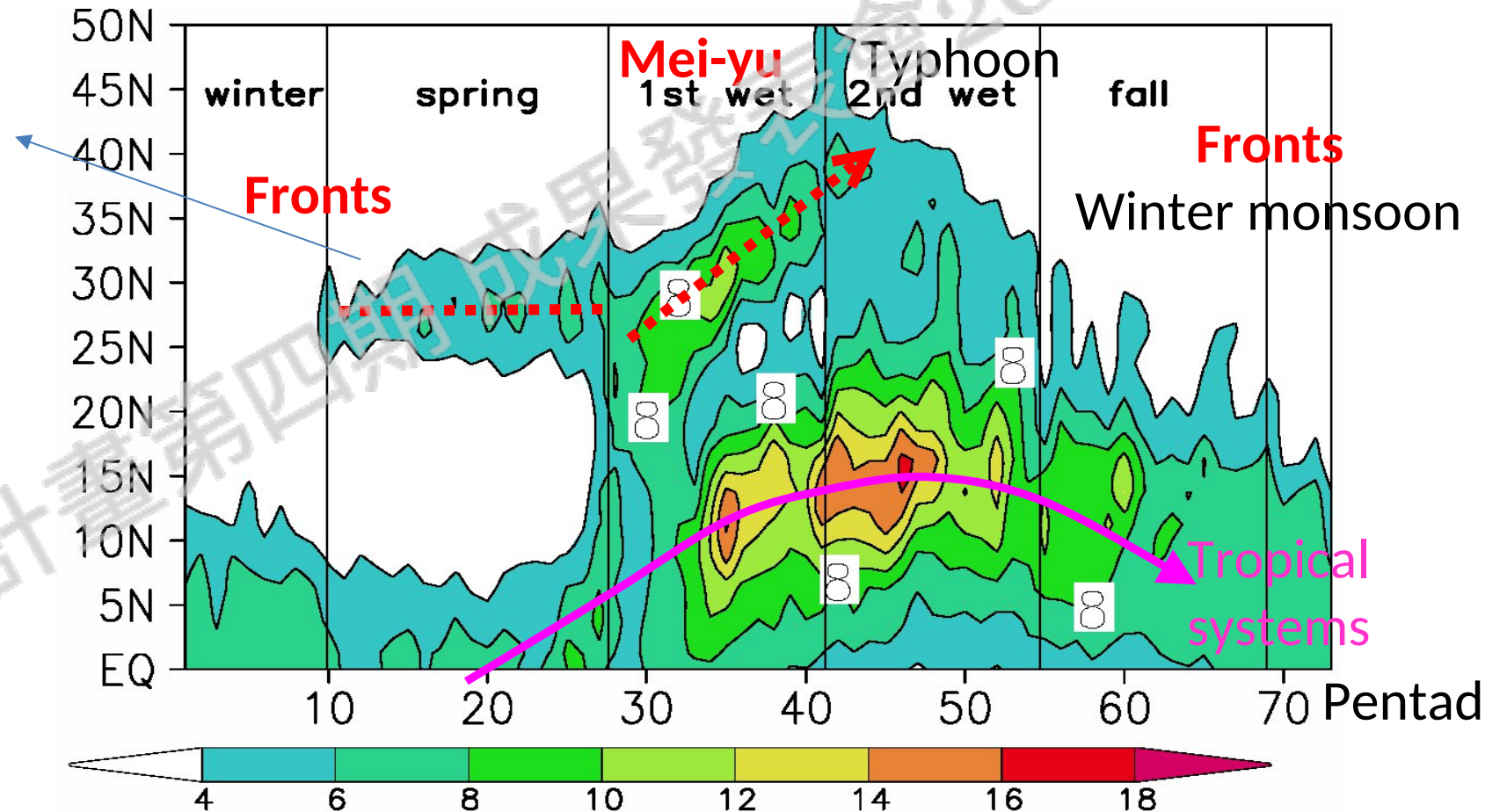
Wang et al. (2021), *J. of Climate*, **34**, 3067-3085 (CMIP5)



Motivation

Precipitation (CMAP) 115-135E (1979-2006)(mm/day)

- Significantly affected by fronts
- Frontal precipitation is important water resource
- Extreme precipitation & floods
- Droughts in Spring



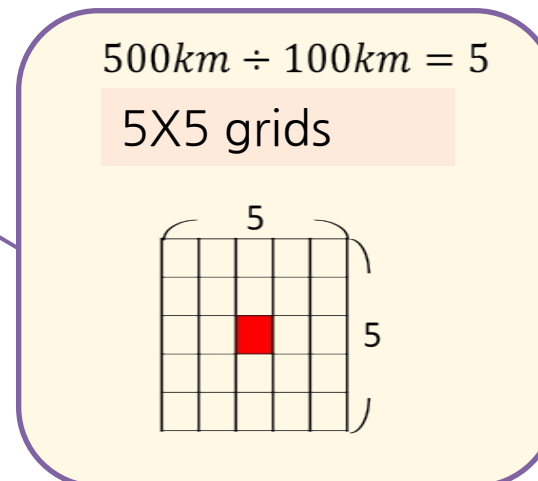
Chou et al. (2009). *J. Climate*, **22**, 2073–2094

Data and Methodology

- ERA5 (1995-2014) as a reference (0.25 °)
 - CMIP6 historical (1995-2014) (8 models)
 - CMIP6 SSP5-8.5 (2081-2100) (9 models)
 - Front detection steps (modified from Hewson, 1998)
- Re-grid to 1°

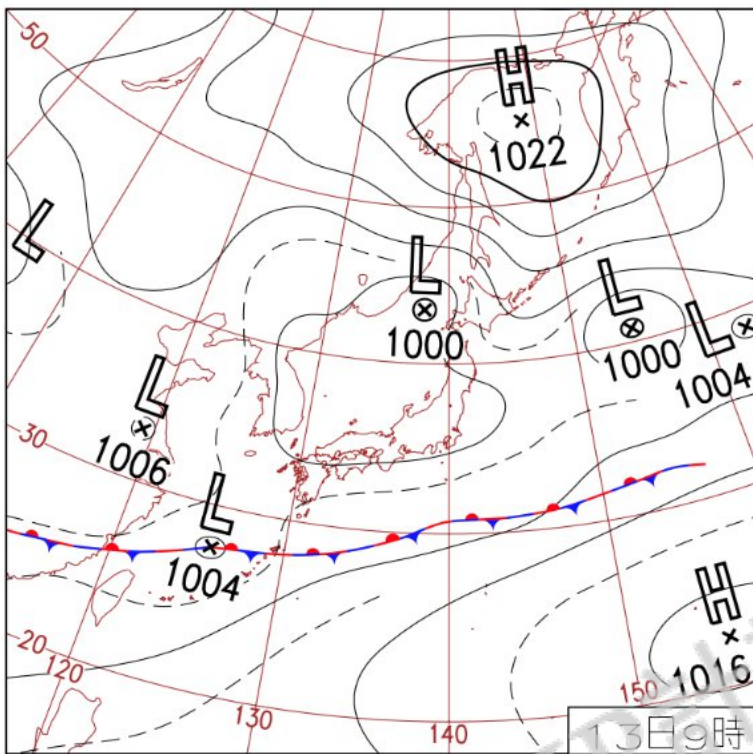


Basic idea: Use thermal gradient ($-\nabla|\nabla\tau|$) to find the warm side of frontal zone.



Mei-yu 2009.06.13

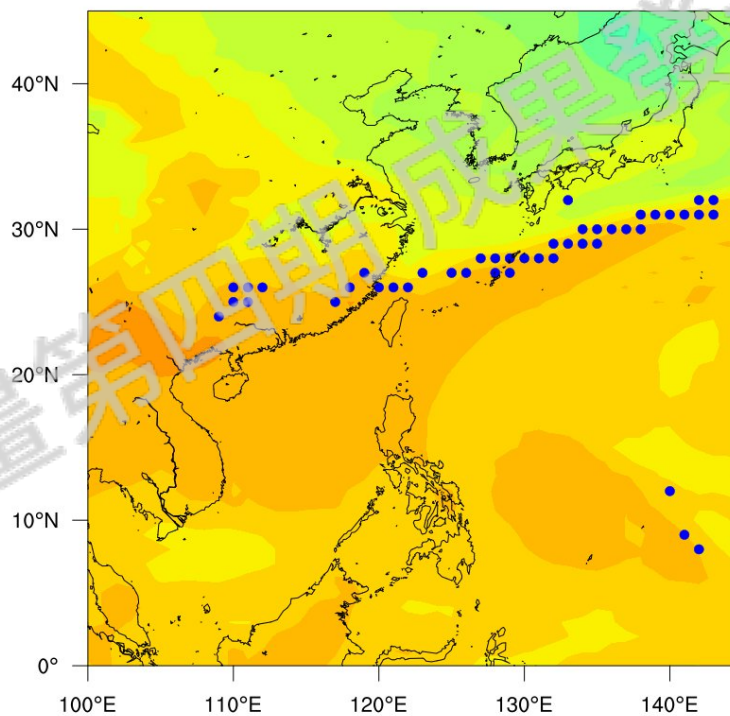
JMA weather chart 2009.06.13



ERA5 850hPa thetaW & point flvort500km

EA 2009.06.13 K1=0.08 K2=0.8 (4/25)

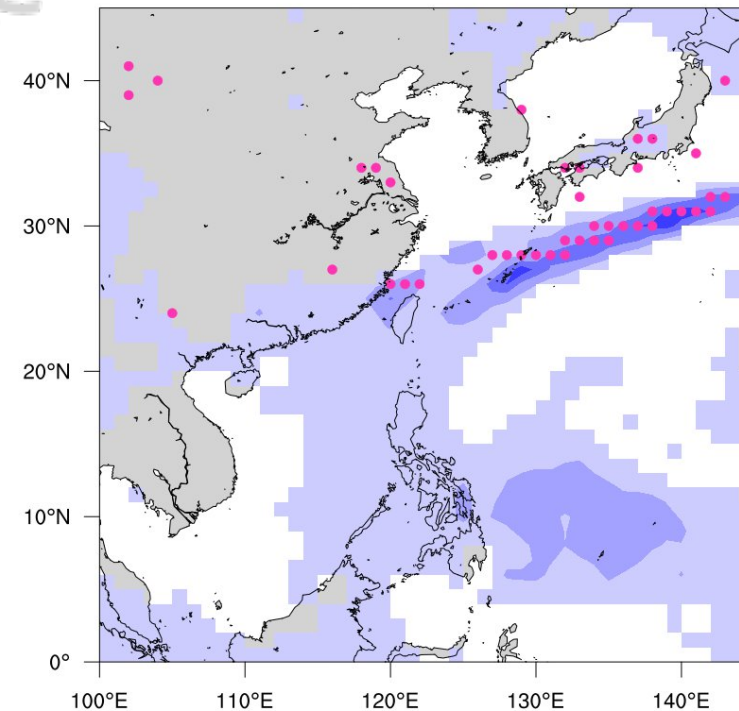
C°



ERA5 850hPa pre & point flvortflpre500km

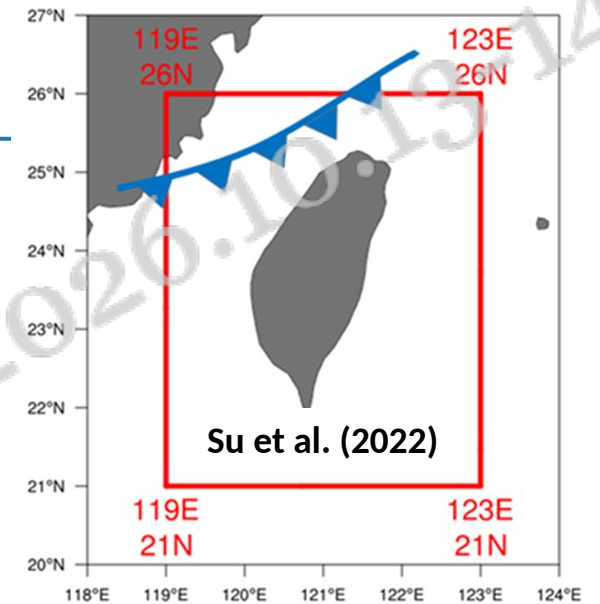
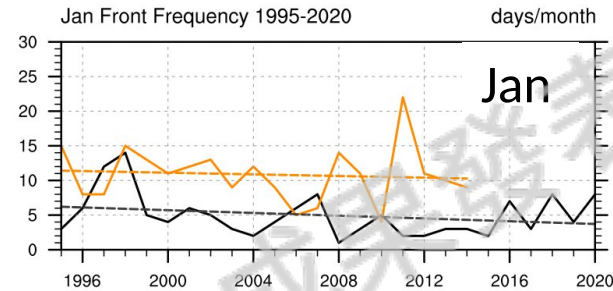
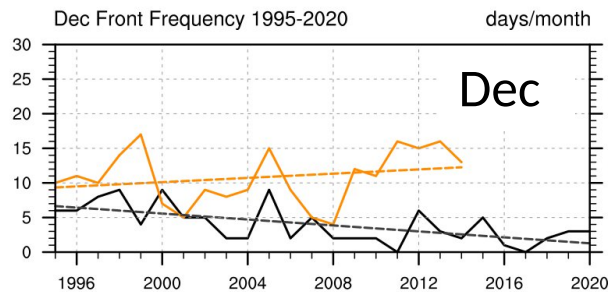
EA 2009.06.13 K1=0.25 K2=1.2 (4/25)

mm/day

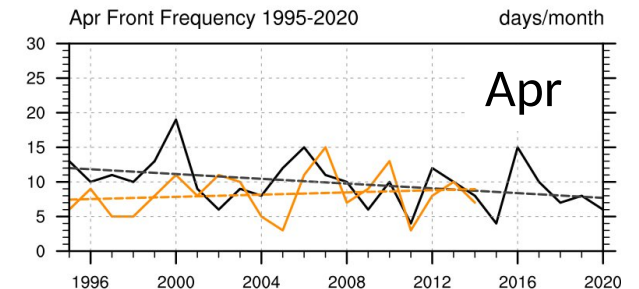
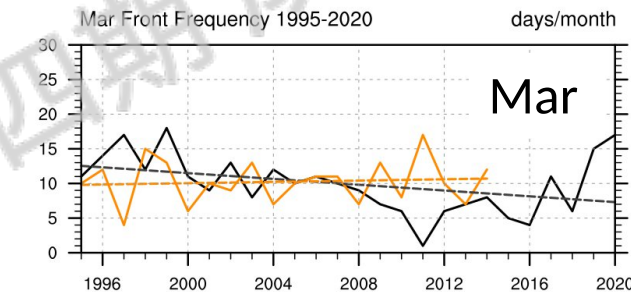
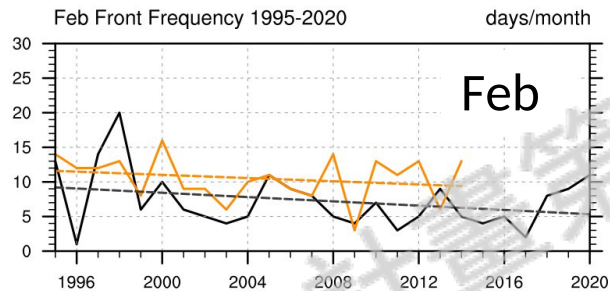


Adjust Parameters to Match Observation

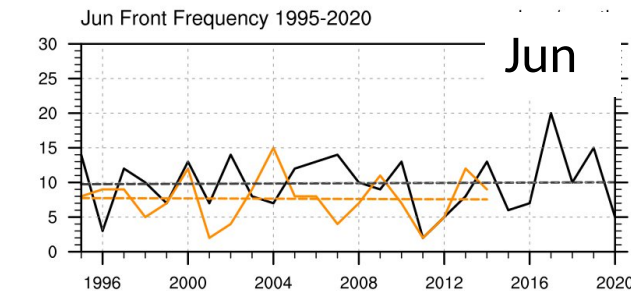
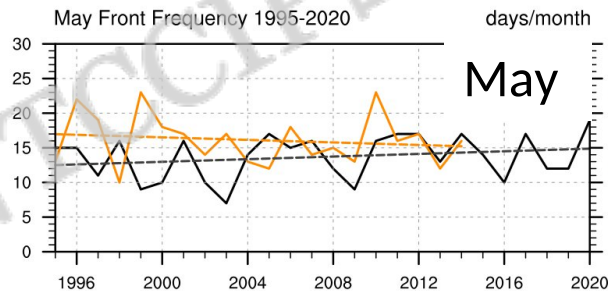
Winter
(Dec-Jan)



Spring
(Feb-Apr)



Mei-yu
(May-Jun)

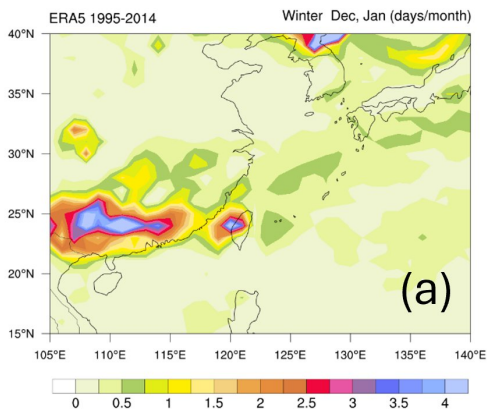


- ERA5 regline
- Su regline
- ERA5
- Su et al. (2022)

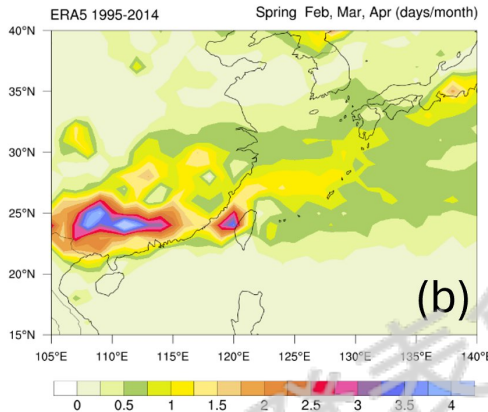
Front frequency

ERA5

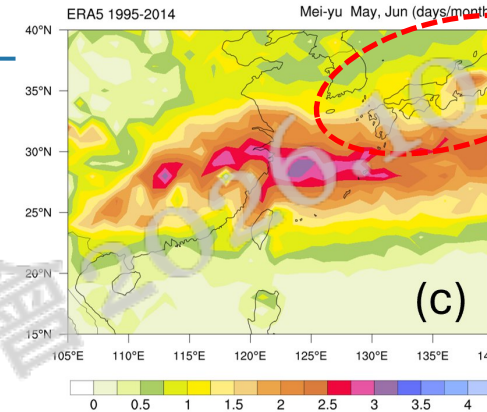
Winter (Dec-Jan)



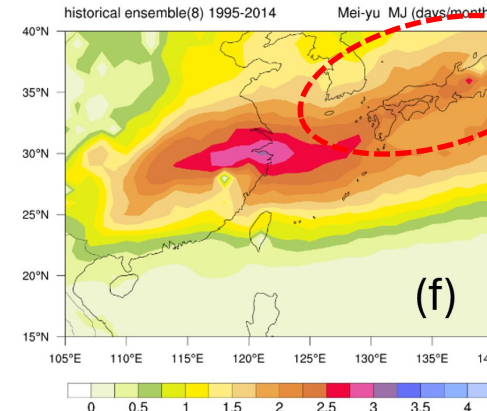
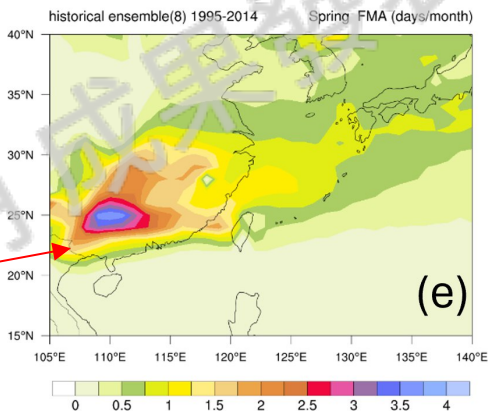
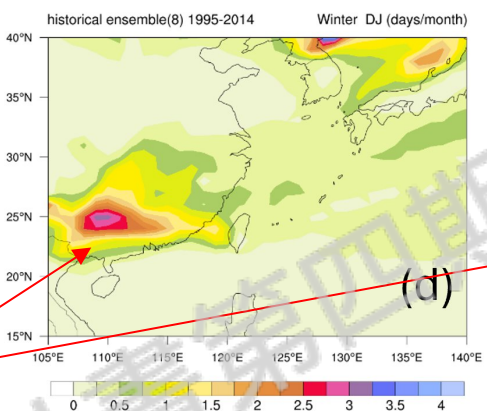
Spring (Feb-Apr)



Mei-Yu (May-Jun)

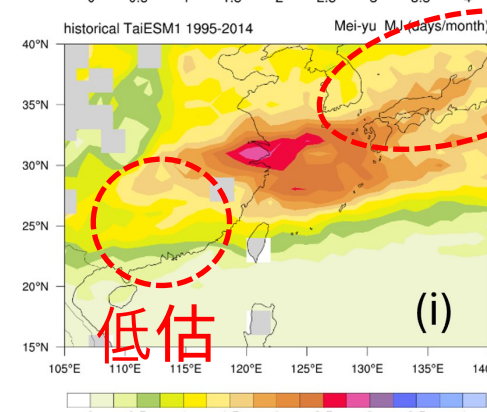
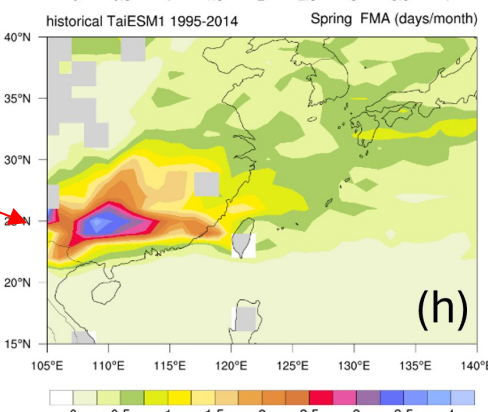
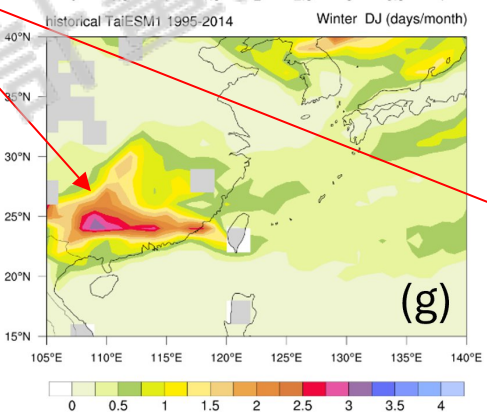


CMIP6
Ensemble
(8 models)



低估

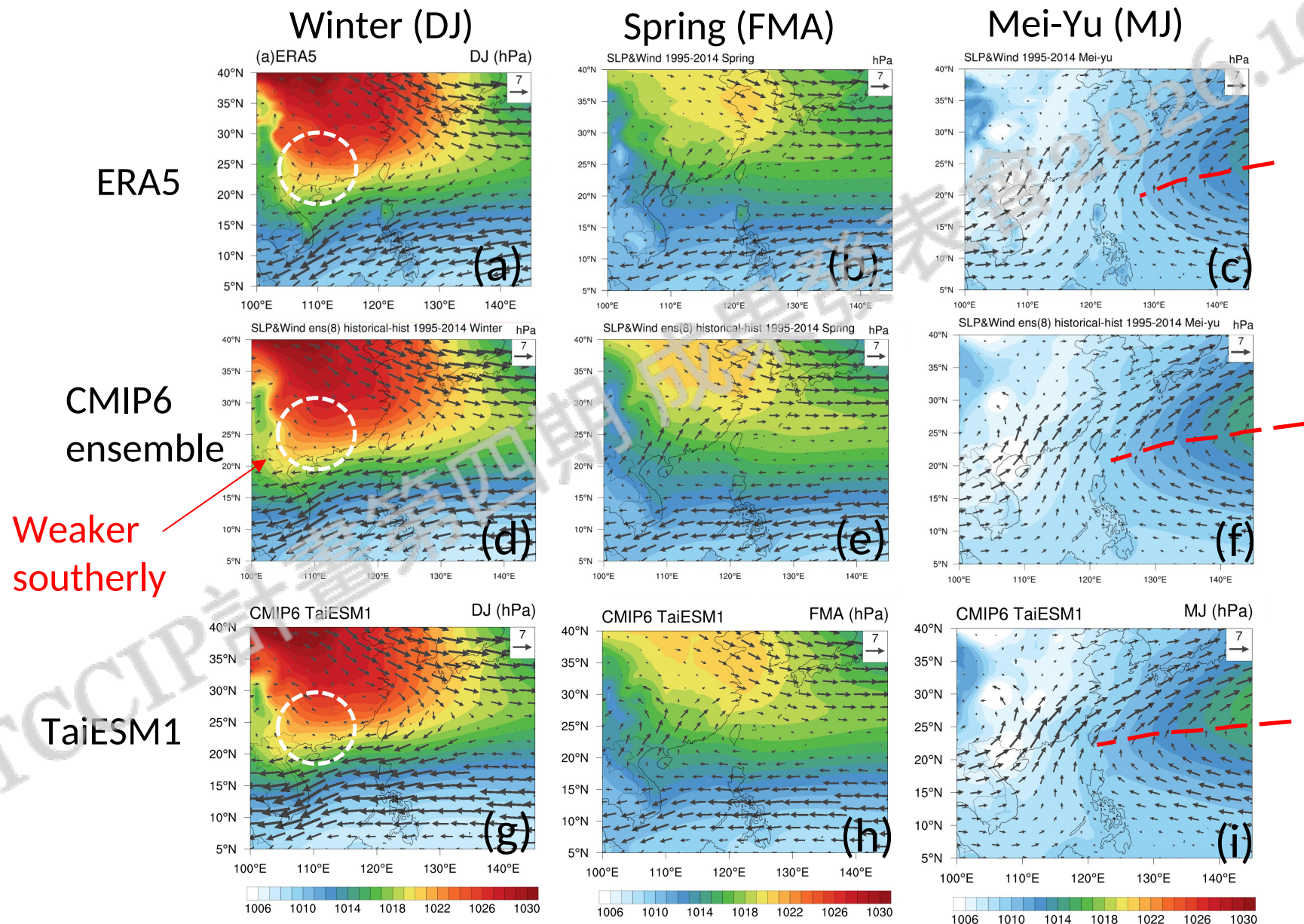
TaiESM
1



偏北

低估

MSLP and 850 hPa Wind (Historical)

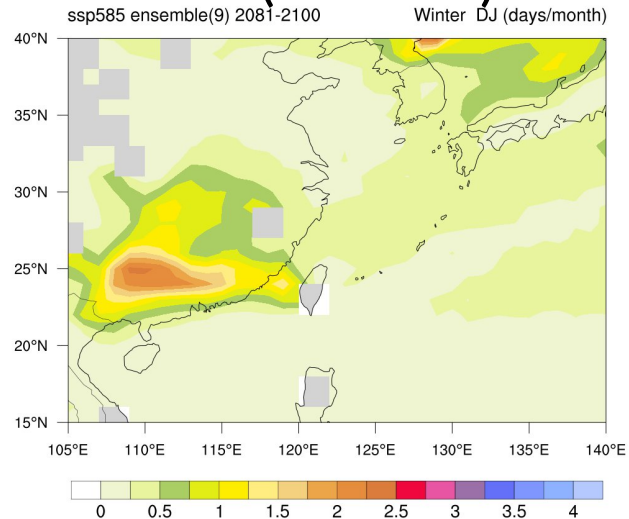




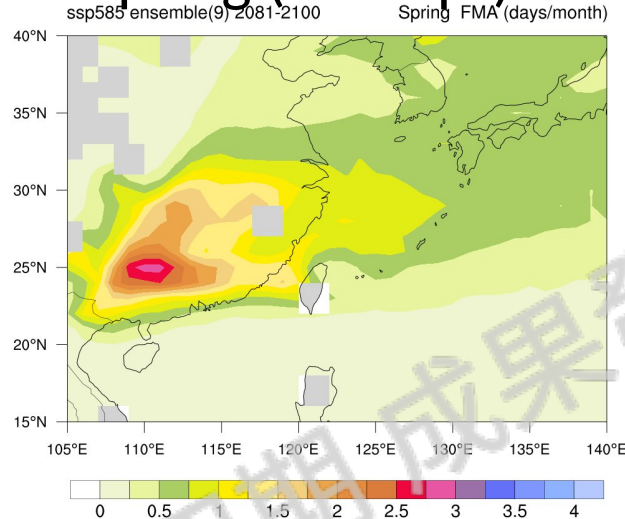
CMIP6 FUTURE PROJECTION SSP5-8.5, 2081-2100

SSP5-8.5 (2081-2100) and Changes

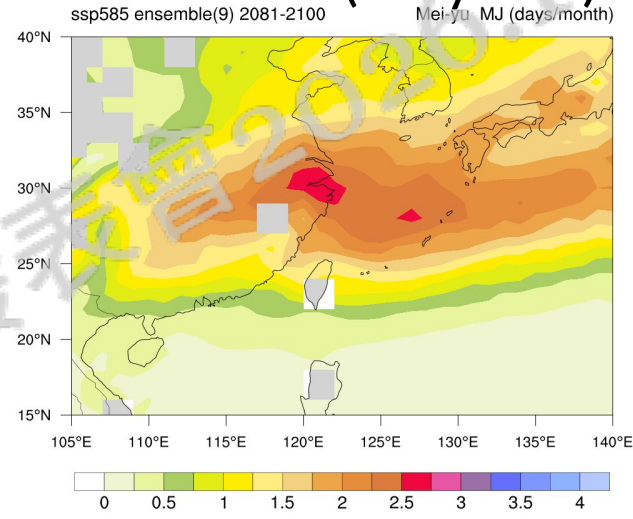
Winter (Dec-Jan)



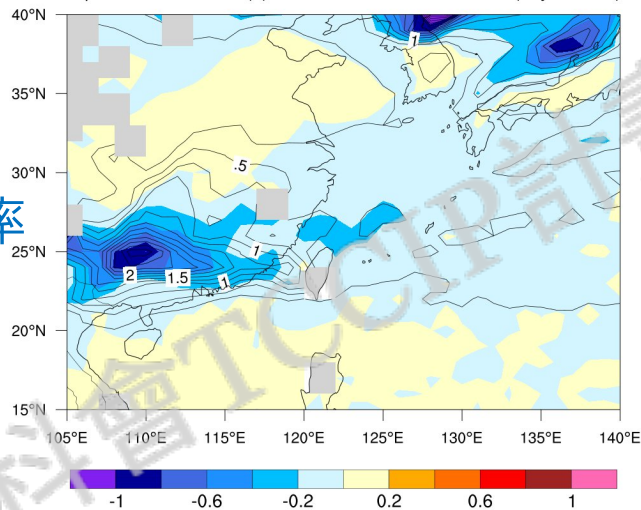
Spring (Feb-Apr)



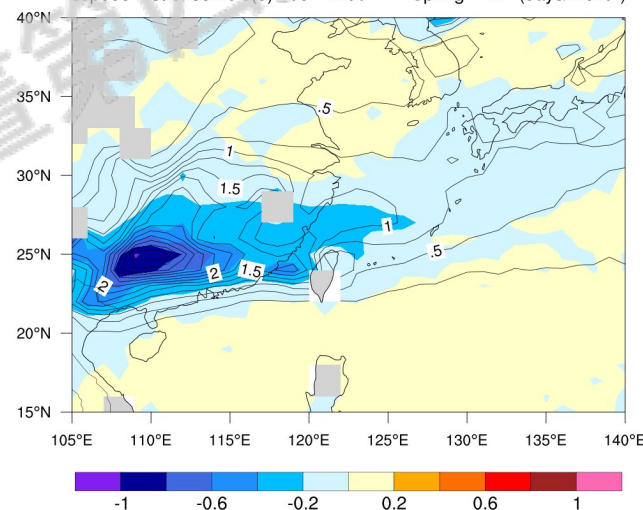
Mei-Yu (May-Jun)



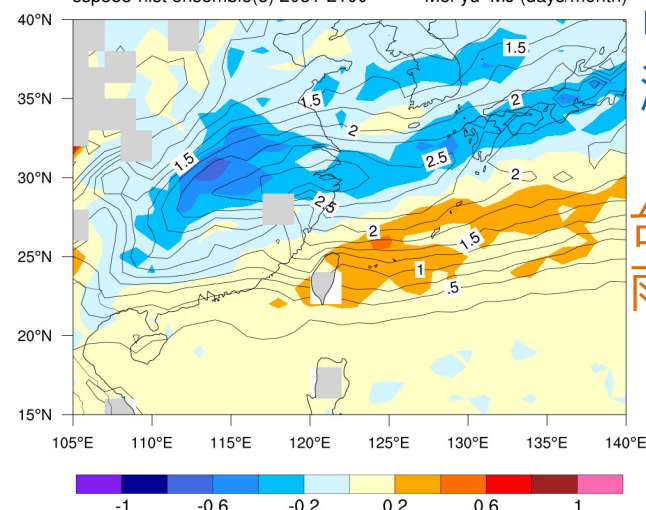
ssp585-hist ensemble(8) 2081-2100 Winter DJ (days/month)



ssp585-hist ensemble(8) 2081-2100 Spring FMA (days/month)



ssp585-hist ensemble(8) 2081-2100 Mei-yu MJ (days/month)



中國、韓、日
減少

台灣、琉球梅
雨鋒面增加

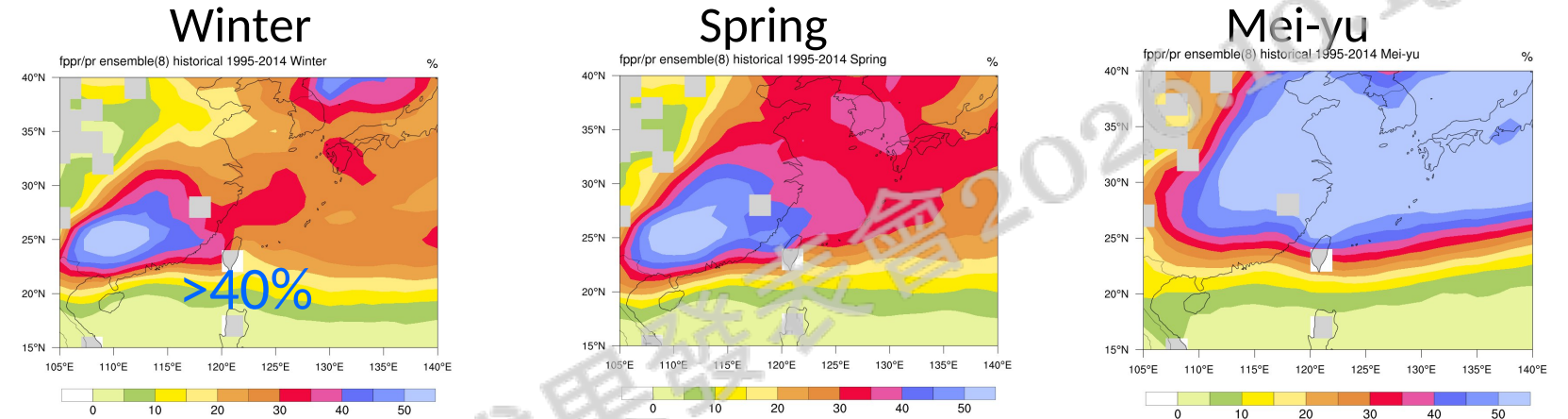
decrease

increase

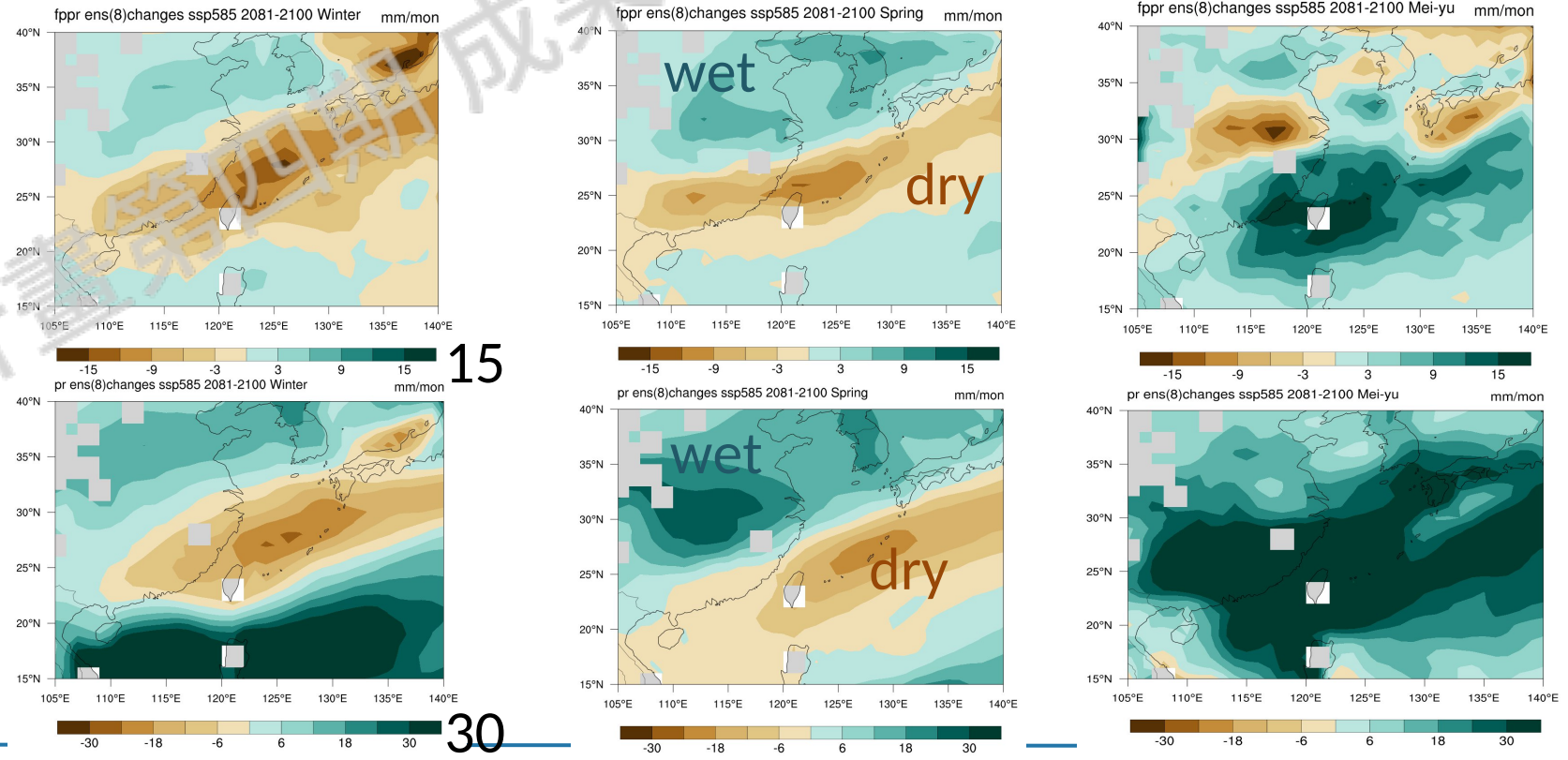
Contour: historical

Changes in Frontal Precipitation

Historical Ratio of
Frontal Precipitation (%)



Frontal Precipitation change
(SSP5-8.5, 2081-2100)
Contribute to half of the total
change



Total precipitation
change

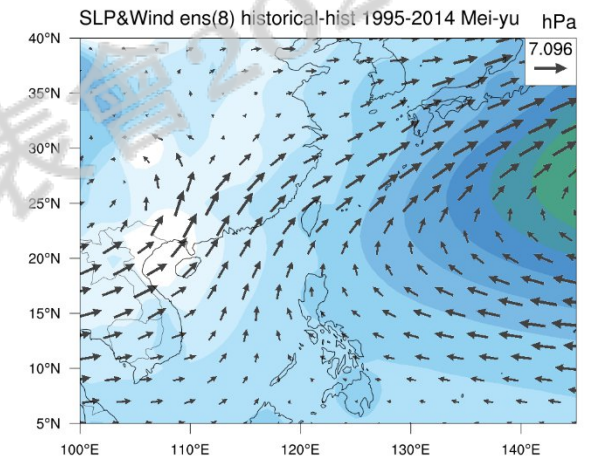
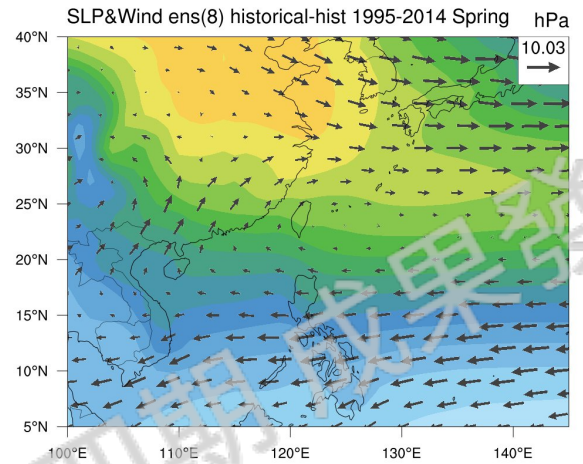
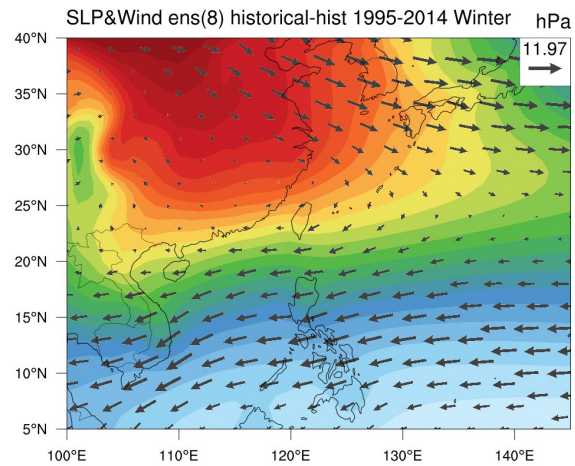
MSLP (shading) and 850 hPa Wind (vector)

Winter

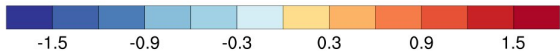
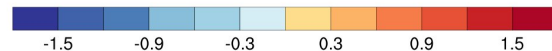
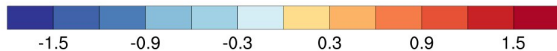
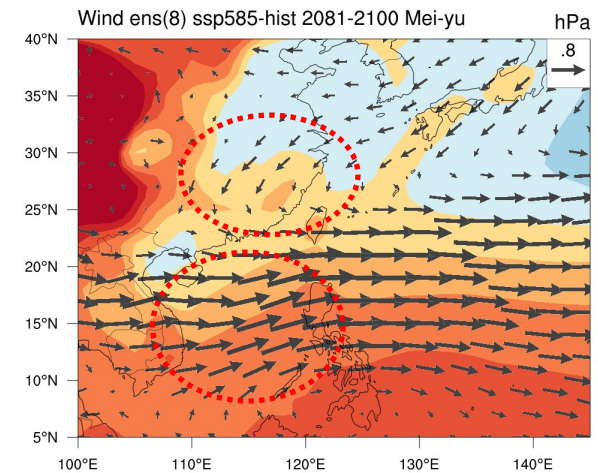
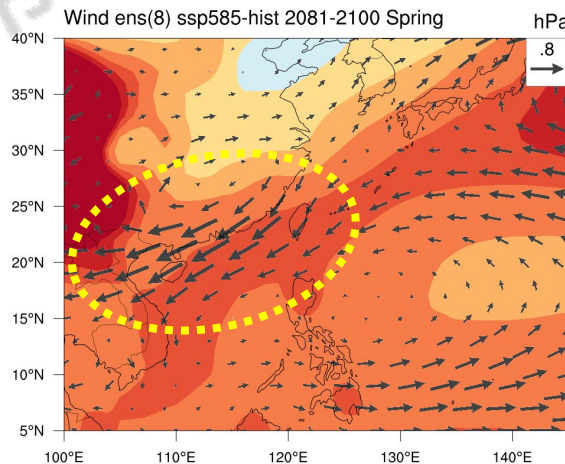
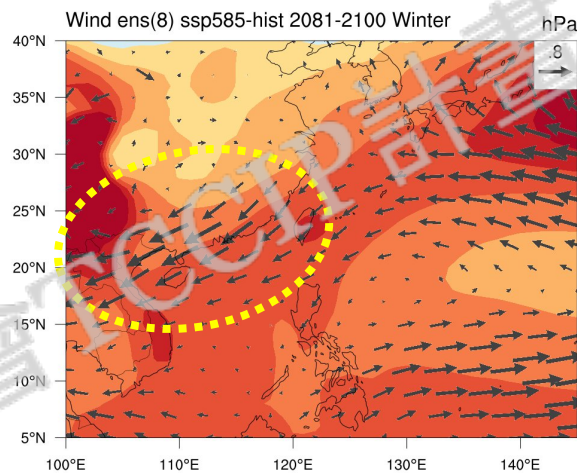
Spring

Mei-Yu

Historical

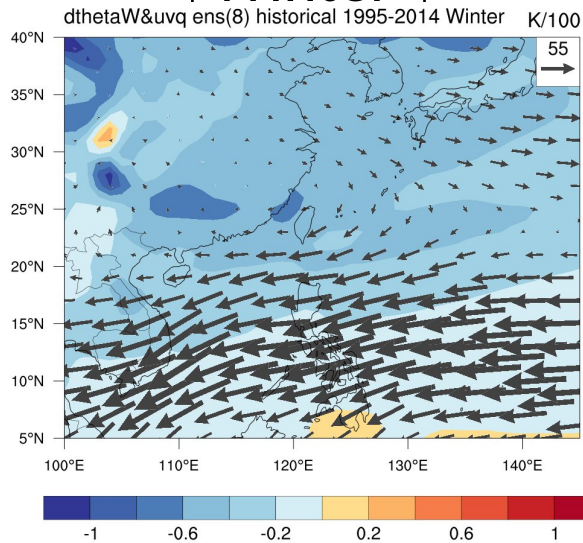


Future
Changes

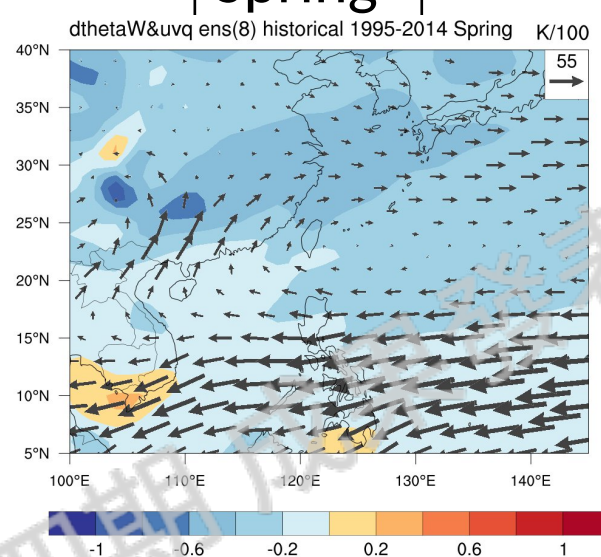


$\nabla_y \theta_w$ (shading) and 850 hPa Moisture Flux (vector)

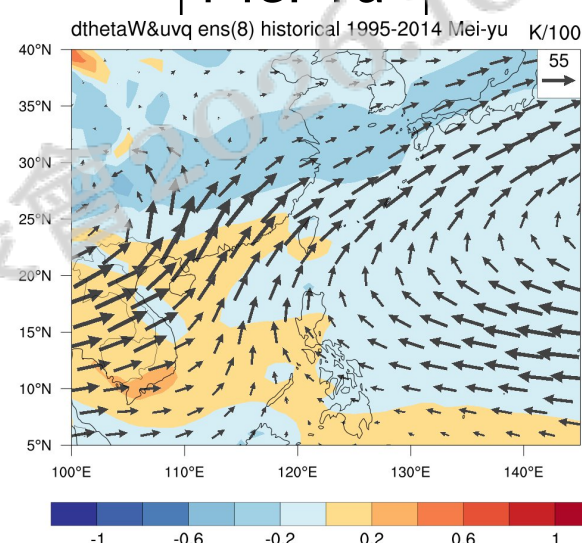
Winter



Spring



Mei-Yu

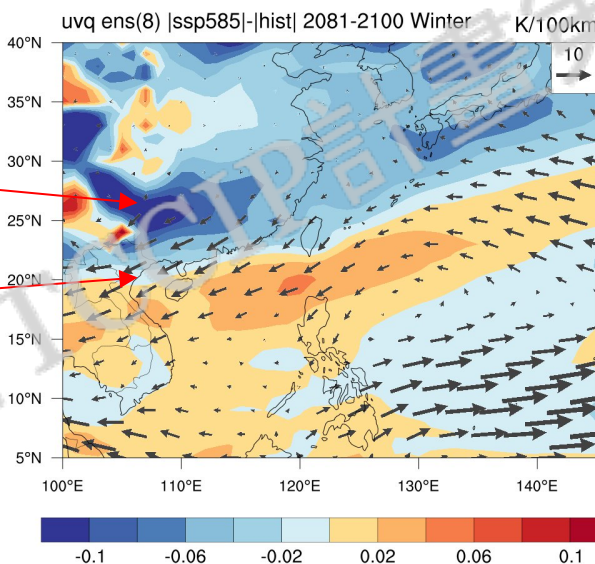


Historical

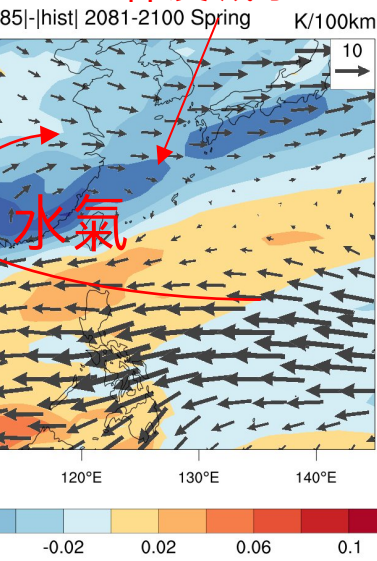
Changes

梯度减小

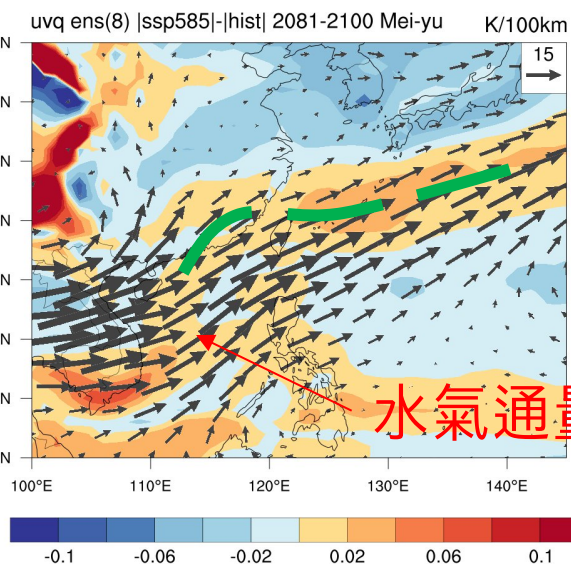
缺少水氣



梯度减小



水氣



梯度增加

水氣通量增加

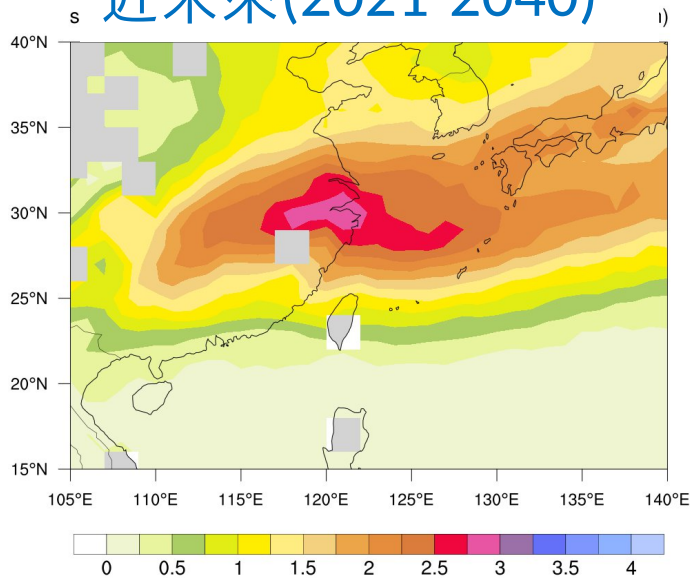


MEI-YU SEASON

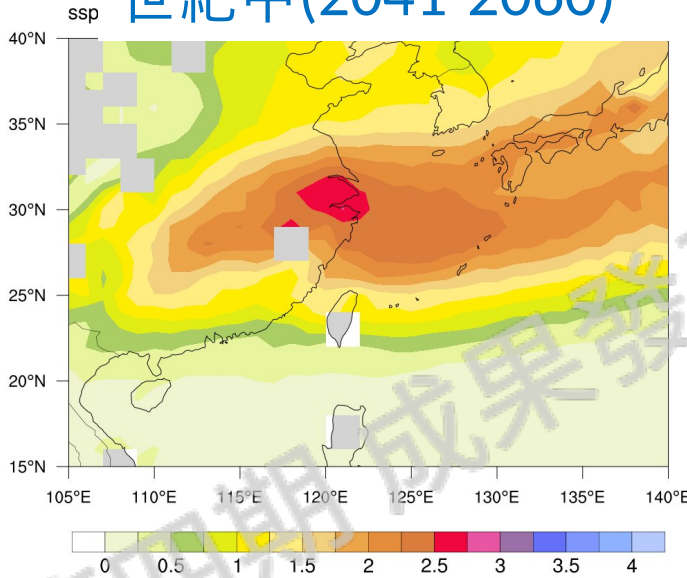
DIFFERENT TREND IN SSP5-8.5

Mei-Yu season, SSP585 climatology & change

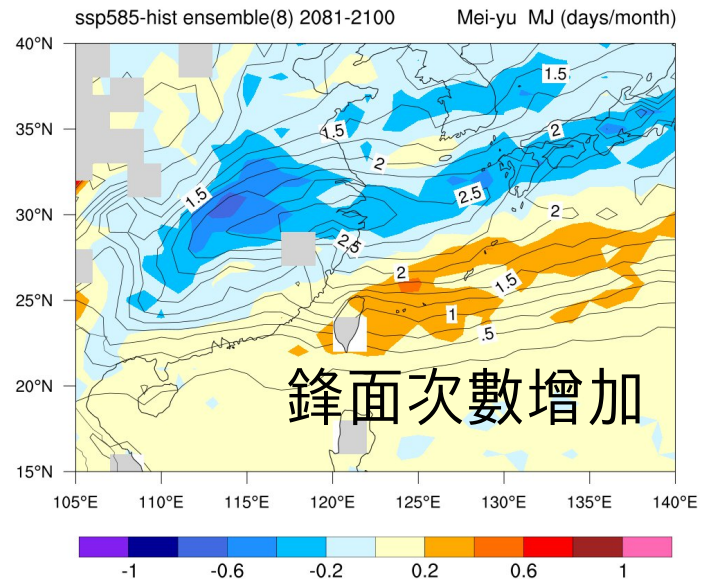
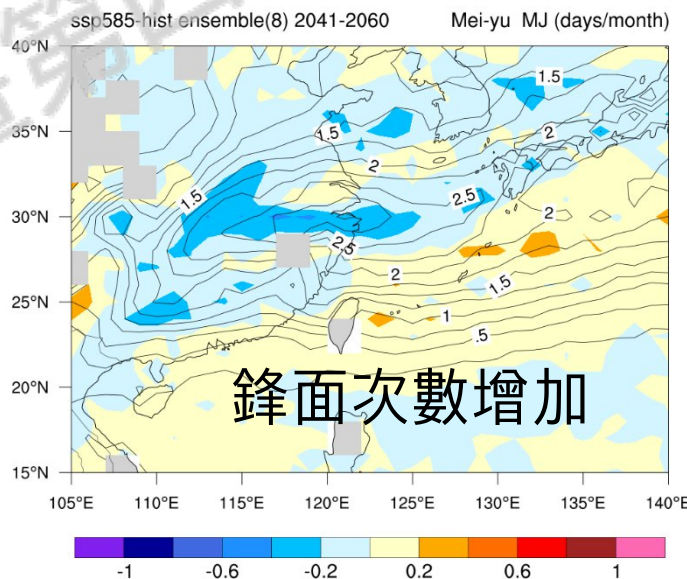
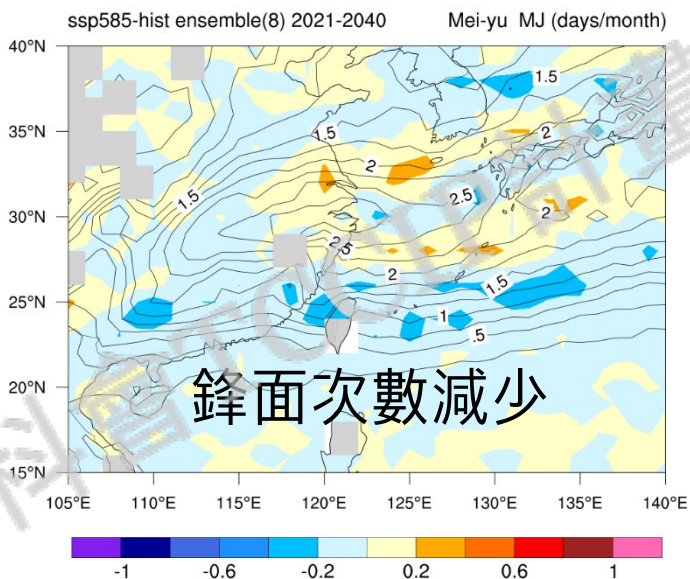
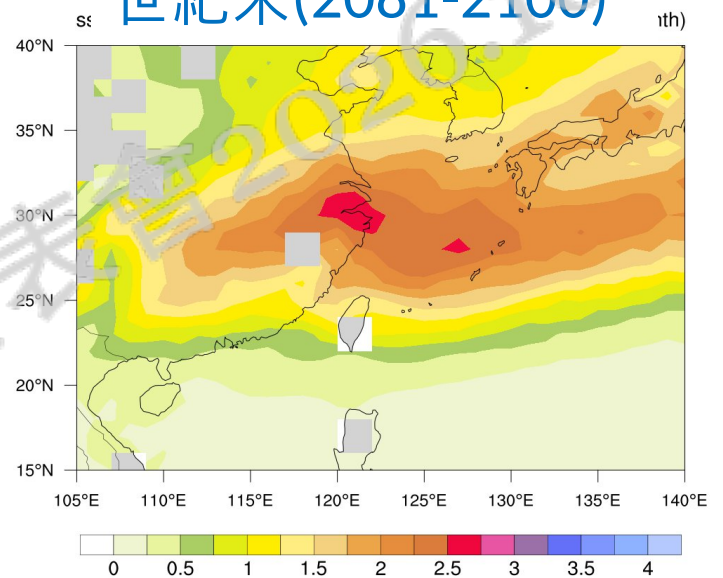
近未來(2021-2040)



世紀中(2041-2060)



世紀末(2081-2100)



Mei-yu Frontal Precipitation Change

近未來(2021-2040)

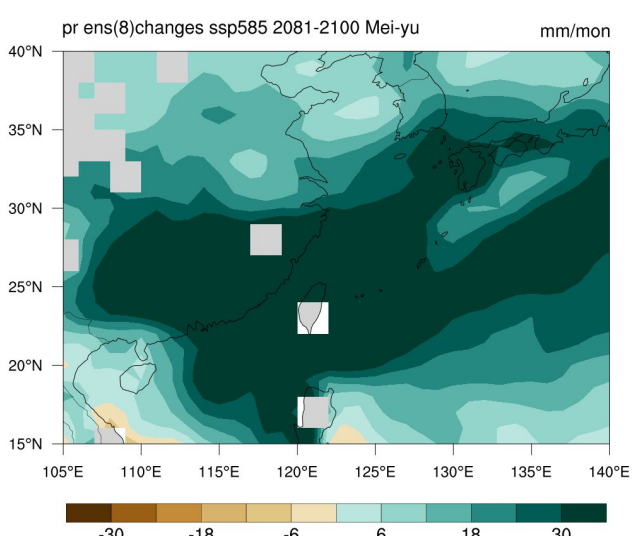
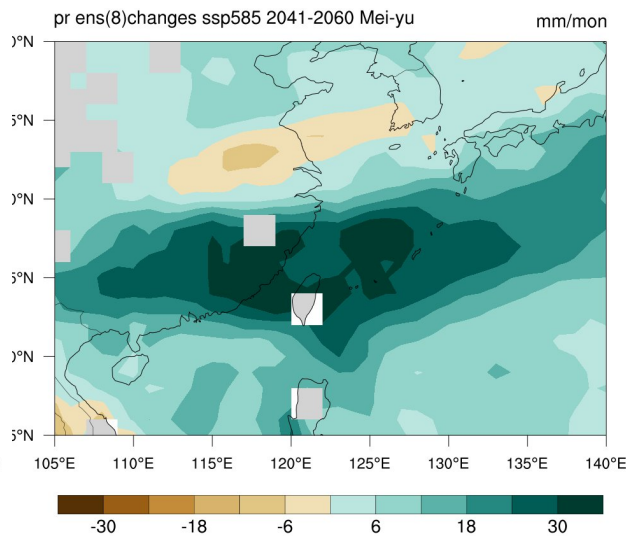
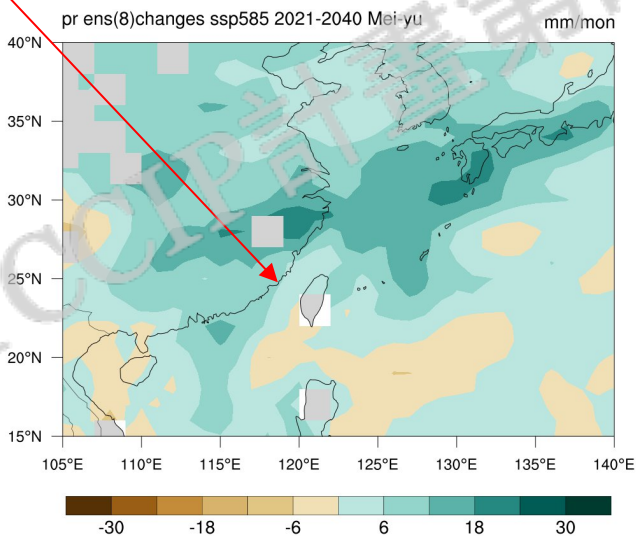
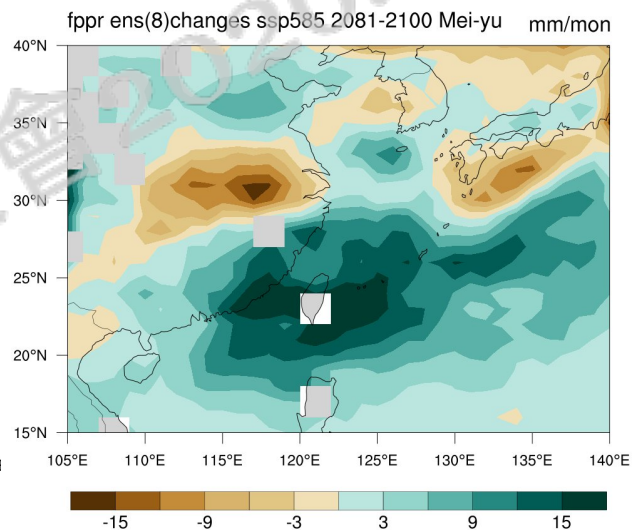
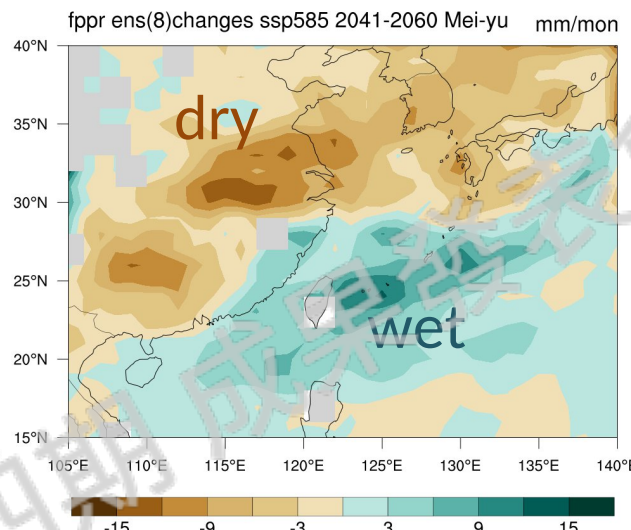
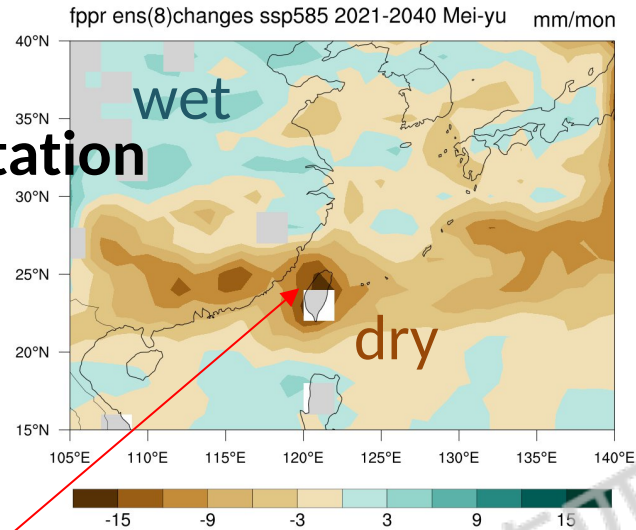
世紀中(2041-2060)

世紀末(2081-2100)

Frontal Precipitation
change
(SSP5-8.5)

降雨型態
明顯改變

Total
precipitation
change



Summary

- CMIP6 鋒面偵測較CMIP5佳，梅雨季(5,6月)加入低層氣旋式風切後，已能偵測梅雨季鋒面
- Historical vs. ERA5
 - 氣候熱力梯度及水氣通量在華南被低估，因此鋒面頻率偏低
 - TaiESM1在華南地區梅雨季的鋒面頻率明顯低估
 - 日本附近鋒面模擬偏北，與日本南方海面上的熱力梯度偏低有關
- 未來推估(SSP5-8.5, end of 21st century)
 - 春季、冬季：鋒面頻率及鋒面降雨，在原本氣候值較高的區域皆減少，鋒面降雨減少貢獻了約一半的降雨變化
 - 梅雨季：台灣、琉球鋒面增加（鋒面降雨、總降雨皆增加）；中國、韓、日減少（鋒面降雨減少，但總降雨增加）
梅雨季降雨強度或形態改變
 - 鋒面頻率的變化可對應到氣候熱力梯度及水氣通量的變化
- 梅雨季在近未來(2021-2040)就可看到降雨型態改變，總降雨量整體來說皆增加，但鋒面降雨各地變化不同
 - 台灣在近未來鋒面降雨減少，世紀中(2041-2060)開始增加
 - 華南在近未來、世紀中都減少，世紀末增加
 - 華中近未來增加，世紀中、末減少
- 針對台灣地區的鋒面頻率，模式發散程度在世紀末明顯增加，尤其有部分模式推估出極端低的鋒面頻率
- 暖化後，台灣地區由於鋒面頻率及降雨減少，由前一年冬季延續到春季的乾季可能加長

謝謝聆聽
敬請指教

TCCiP 臺灣氣候變遷推估資訊與調適知識平台
Taiwan Climate Change Projection Information and Adaptation Knowledge Platform

NSTC 國家科學及技術委員會
National Science and Technology Council

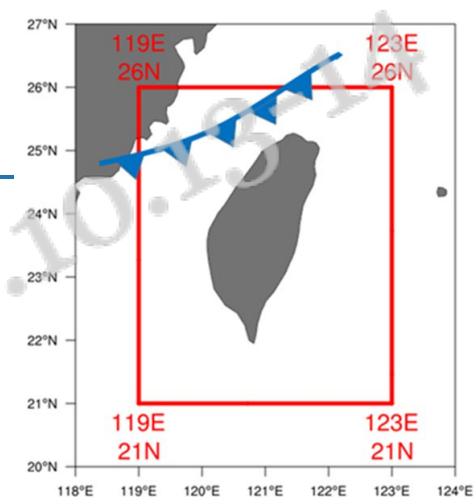
NCDR 國家災害防救科技中心
National Science and Technology Center
for Disaster Reduction

SSP585 台灣附近各季節鋒面頻率

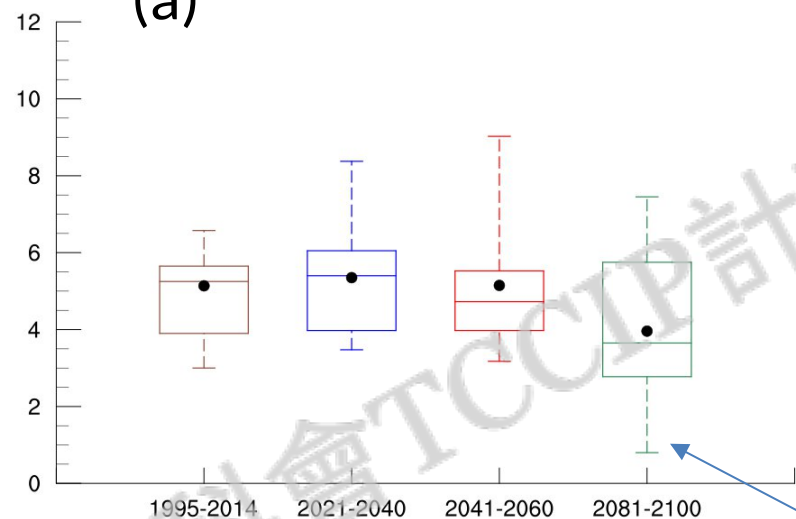
➤ 統計範圍 $21^{\circ}\sim 26^{\circ}\text{N}$, $119^{\circ}\sim 123^{\circ}\text{E}$

Unit: days/month

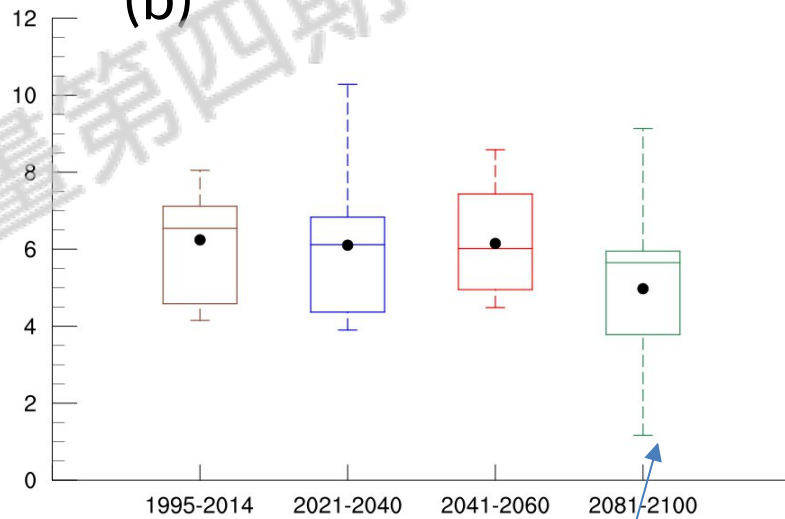
盒鬚圖分別為最小值、第一四分位數(25%)、中位數、第三四分位數(75%)、最大值
黑色點為平均值



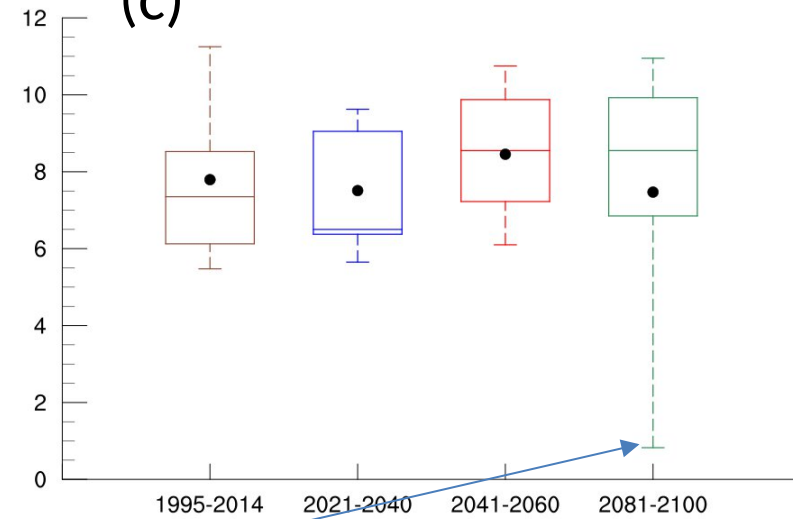
(a) Winter ssp585



(b) Spring ssp585



(c) Mei-yu ssp585



世紀末有部分模式推估鋒面頻率明顯下降

Model Consensus in Font Frequency Change

SSP5-8.5(2081-2100)
minus
Historical(1995-2014)

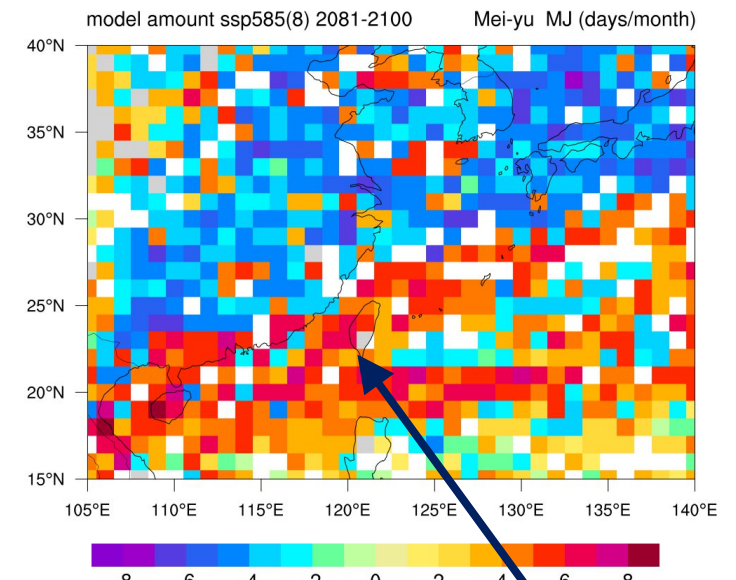
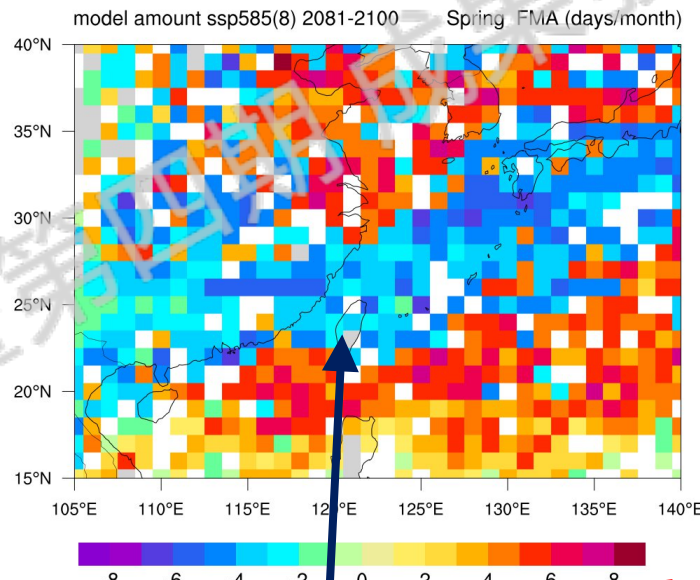
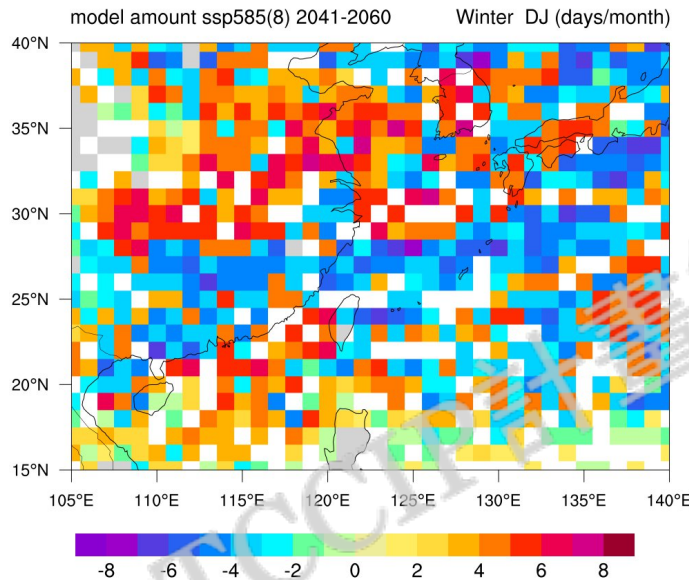
Total: **8 models**
Only models that pass
90% significance are counted

Grey: underground
White: no trend

Winter

Spring

Mei-yu



of models of
decreasing frequency

可能減少

of models of increasing
frequency

台灣中南部
趨勢增加