

東亞鋒面活動及降水未來推估 (using CMIP6)

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Wang et al. (2021), *J. of Climate*, **34**, 3067–3085
<https://doi.org/10.1175/JCLI-D-19-0959.1> (CMIP5 version)



113年天氣分析與預報研討會(2024/09/03)

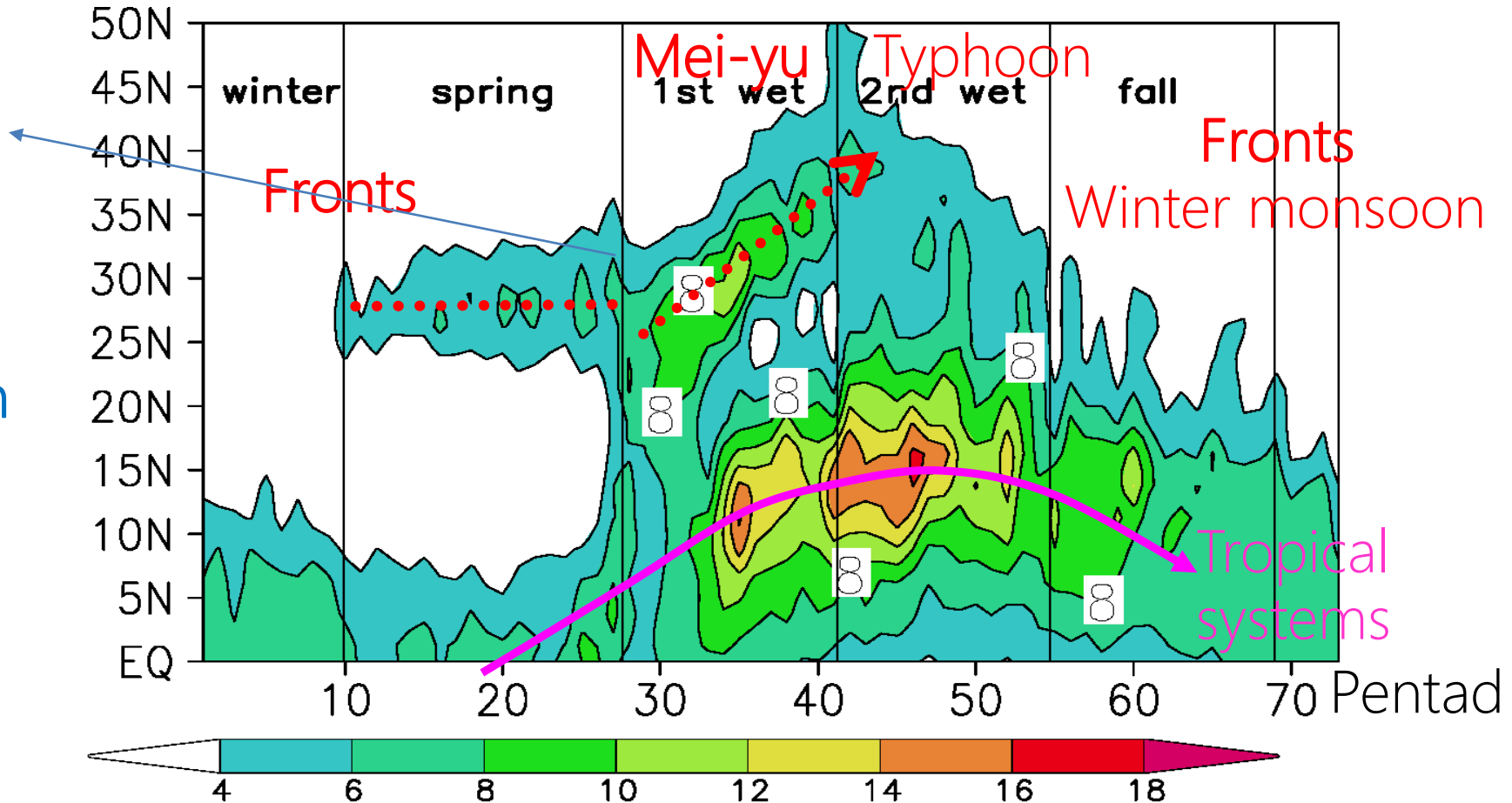
Motivation

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

Important
Water
Resource

Extreme
Precipitation
& floods

Droughts in
Spring

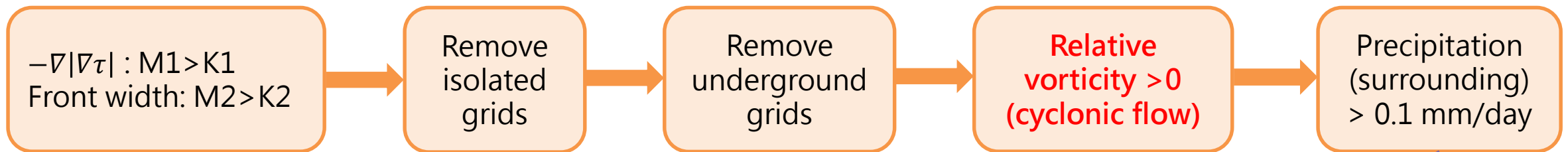


Chou et al. (2009). *J. Climate*, **22**, 2073–2094

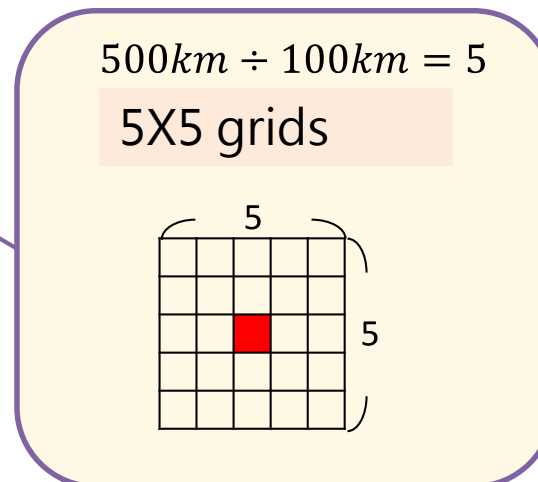
Data and Methodology

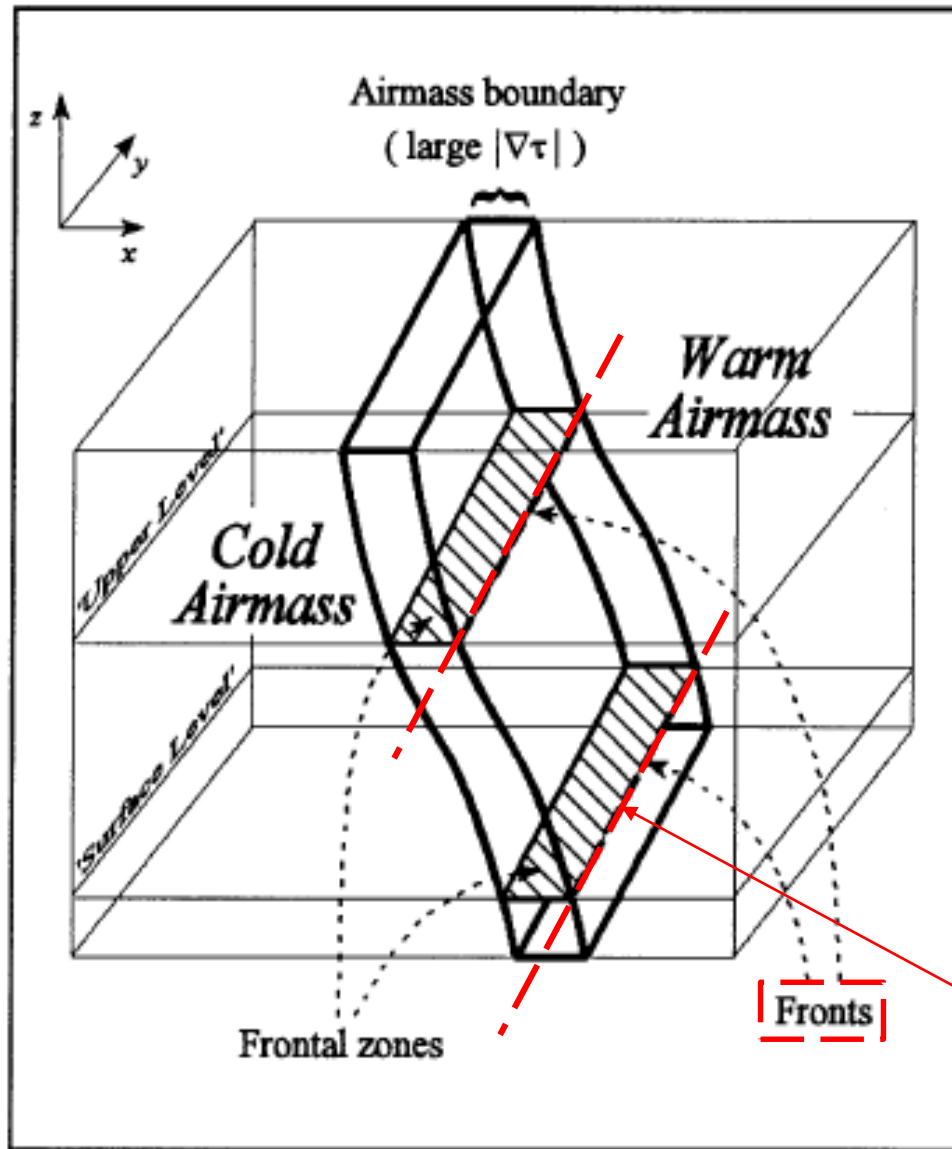
- ERA5 (1995-2014) as a reference (0.25 °)
 - CMIP6 historical (1995-2014) (8 models)
 - CMIP6 SSP5-8.5 (2081-2100) (9 models)
- } Re-grid to 1°

- Front detection steps (modified from Hewson, 1998)



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





Objective Front Detection Method Hewson (1998)

τ : any thermodynamic parameter

θ_w : wet-ball potential temperature

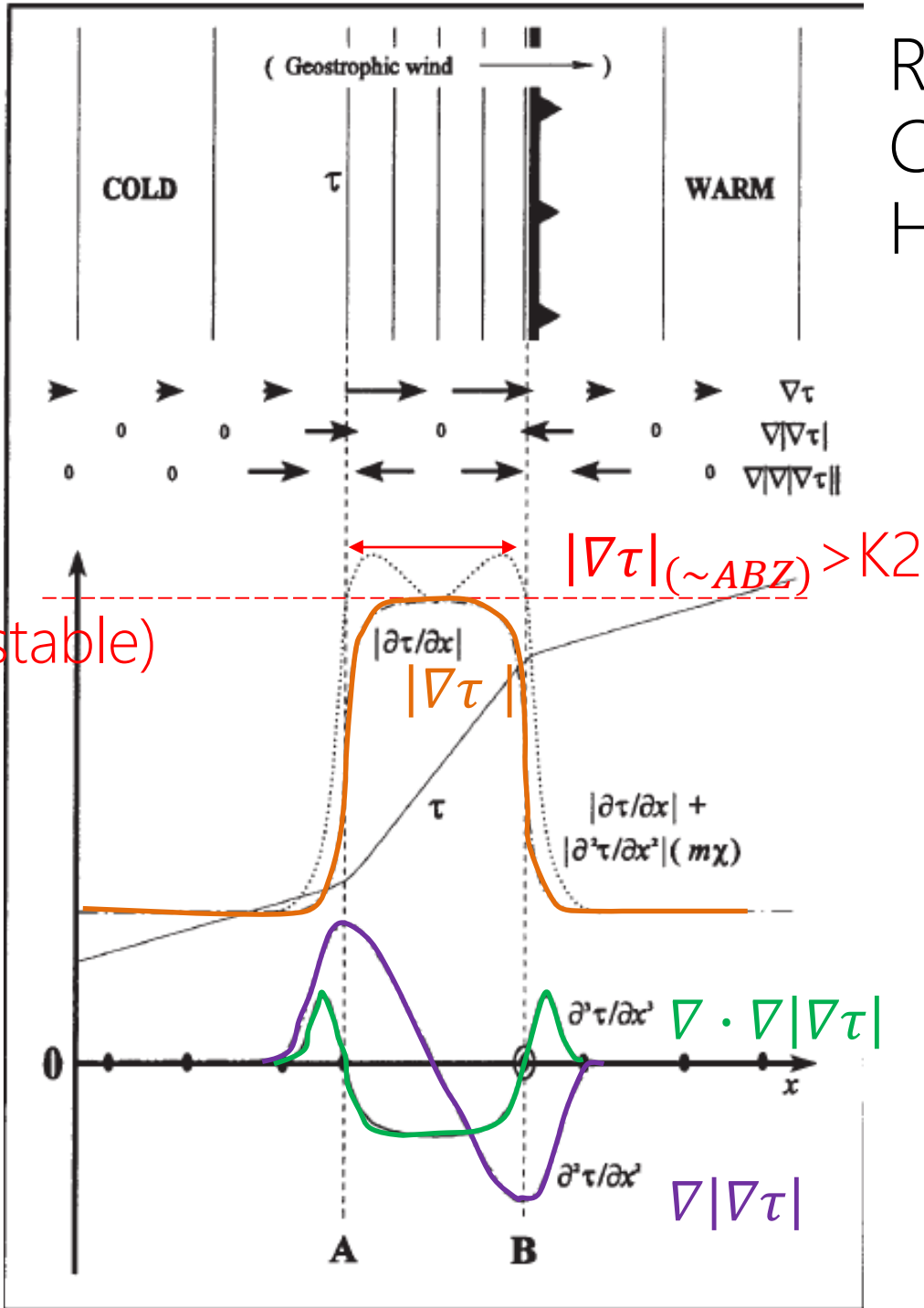
Basic idea: Use thermal gradient to find the warm side of frontal zone

Figure 1. Schematic representation of a frontal surface in three-dimensions.

Renard and Clarke (1965)
 Clarke and Renard (1966)
 Hewson (1998)

τ : any thermodynamic parameter
 θ_w : Wet-ball potential temperature (850 hPa)

$K2=0$
 (adjustable)



M2: (masking 2)

$$|\nabla\tau|_{(\sim ABZ)} = |\nabla\tau|_{(x,y)} + m\chi|\nabla|\nabla\tau||_{(x,y)}$$

where $|\nabla\tau|_{(\sim ABZ)} > K2$

L: locating variable

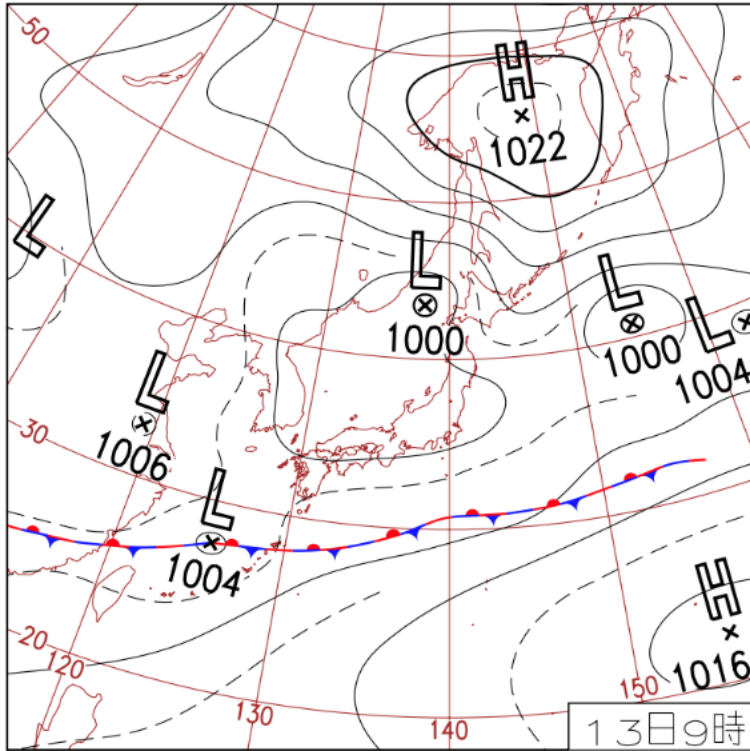
$$L = \nabla \cdot \nabla|\nabla\tau|$$

M1: (masking 1)

$TFP = -\nabla|\nabla\tau|$, where $TFP > K1$ (where $K1=0$, adjustable) (pick up the point on the warmer side of the frontal zone)

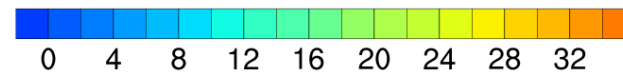
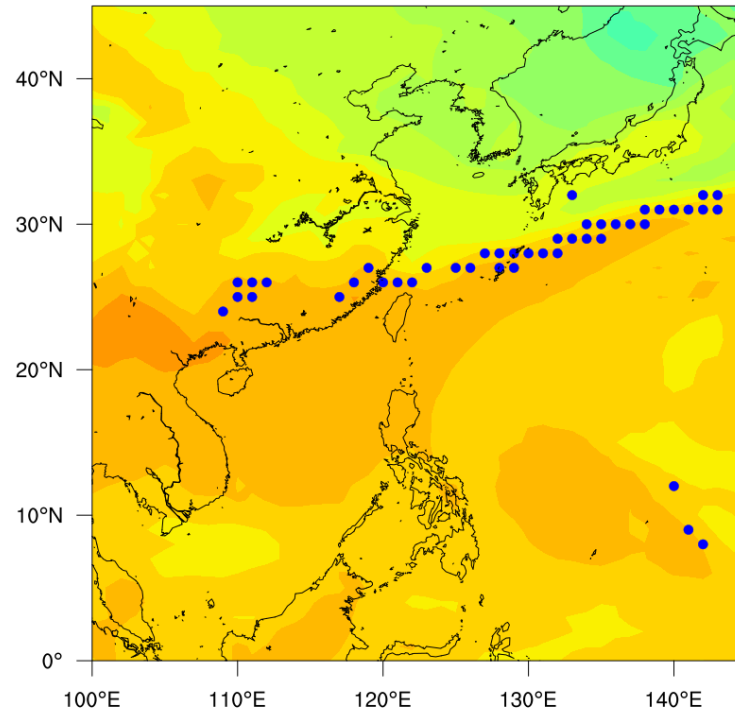
Mei-yu 2009.06.13

JMA weather chart 2009.06.13



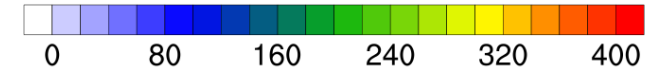
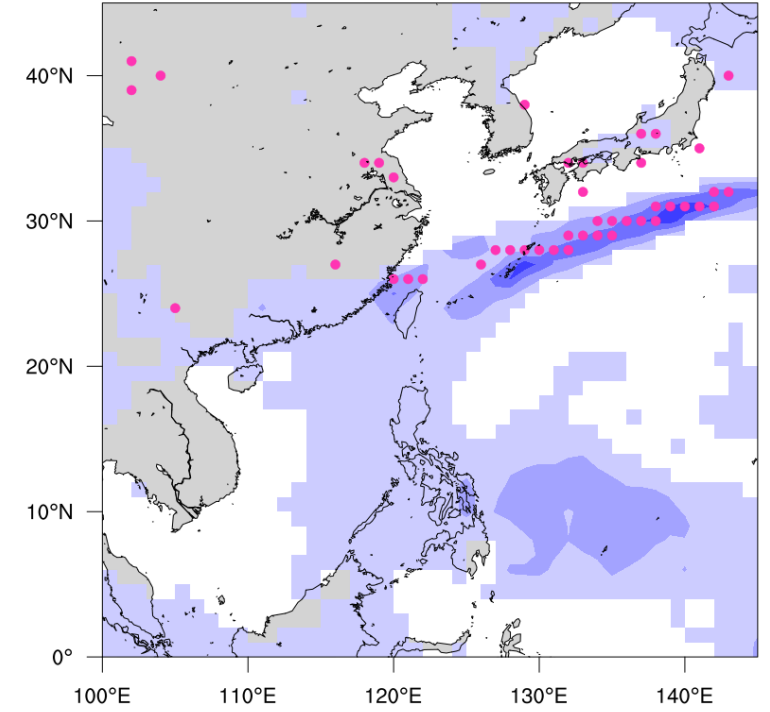
ERA5 850hPa thetaW & point flvort500km

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

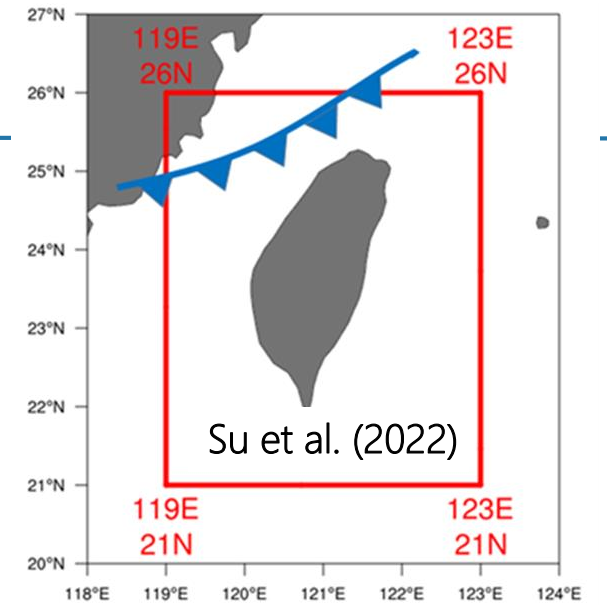


ERA5 850hPa pre & point flvortflpre500km

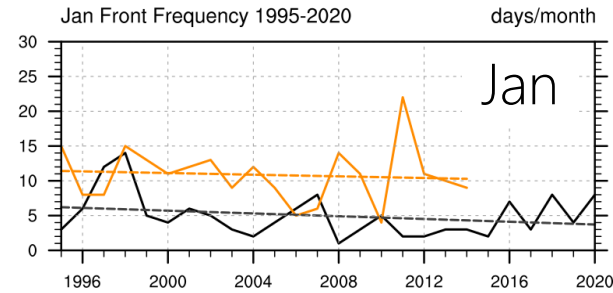
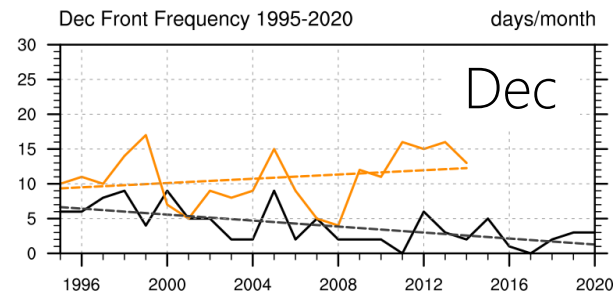
EA 2009.06.13 K1=0.25 K2=1.2 (4/25) mm/day



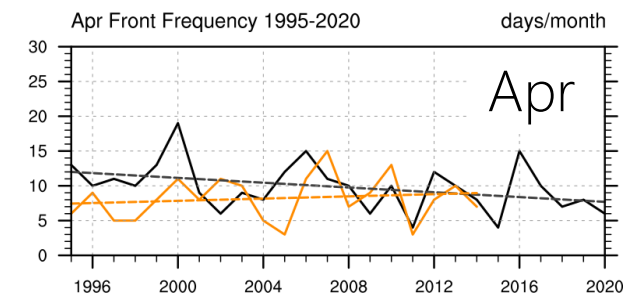
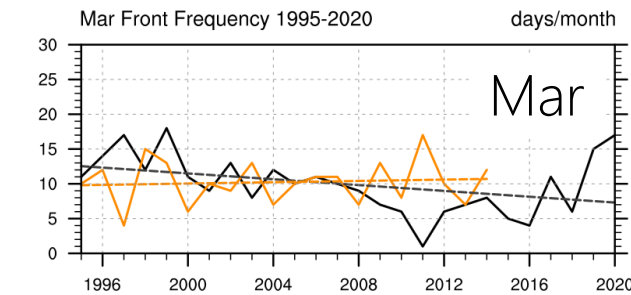
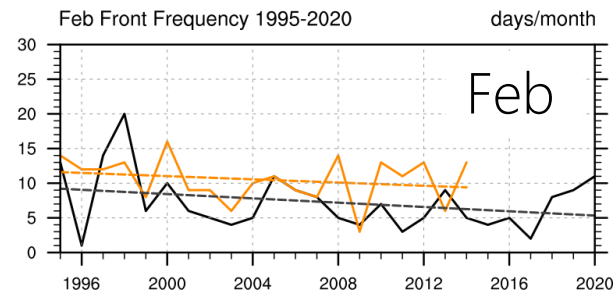
Adjust Parameters to Match Observation



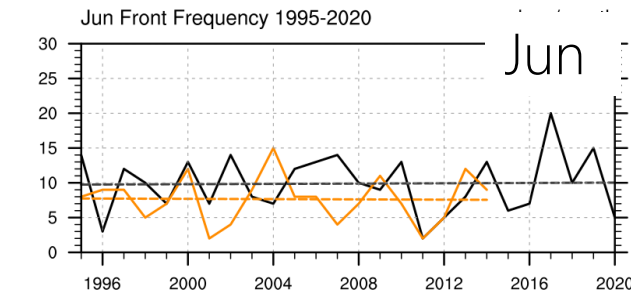
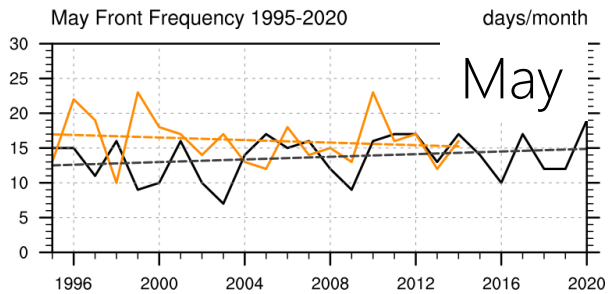
Winter
(Dec-Jan)



Spring
(Feb-Apr)



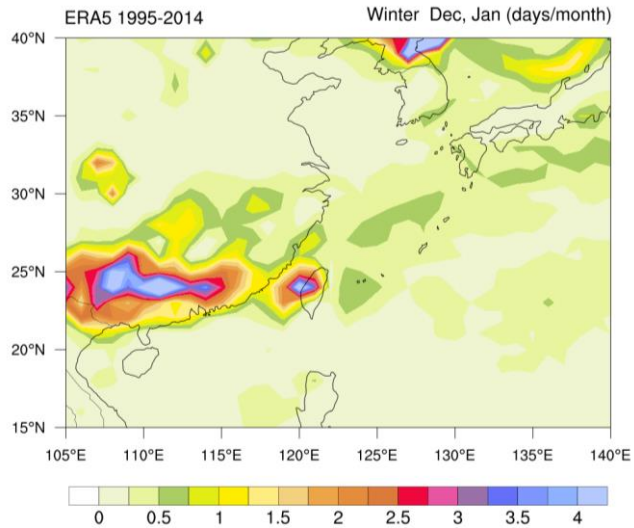
Mei-yu
(May-Jun)



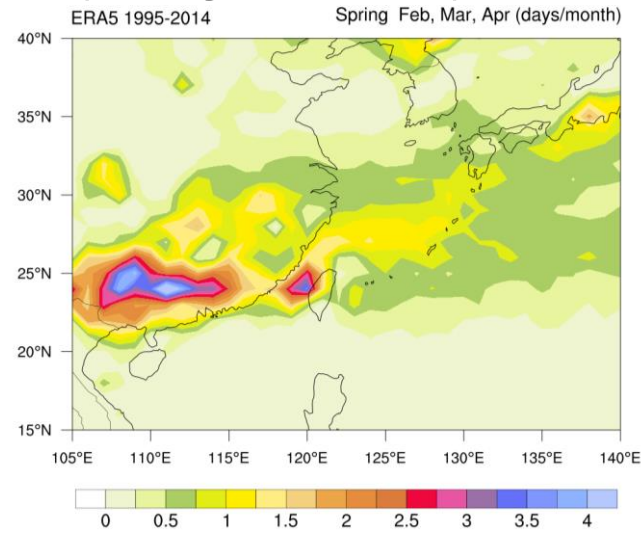
- ERA5 regline
- Su regline
- ERA5
- Su et al. (2022)

Front Frequency Climatology (days/month)

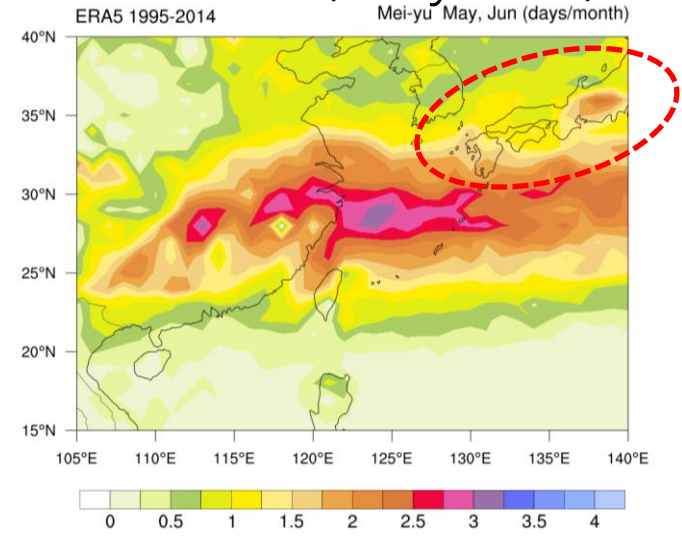
Winter (Dec-Jan)



Spring (Feb-Apr)

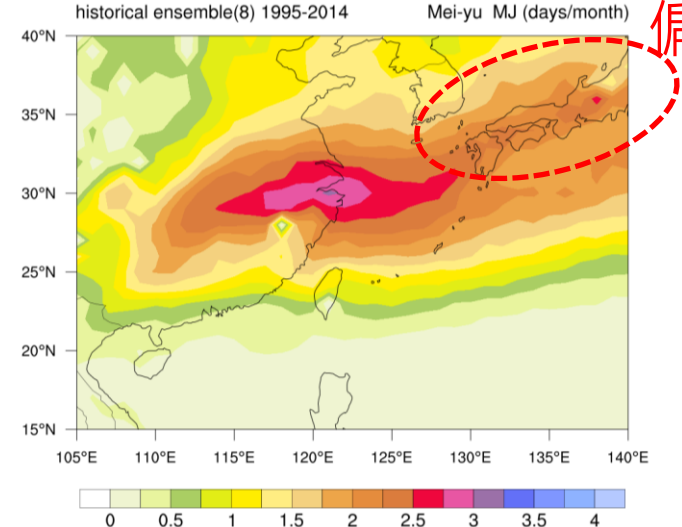
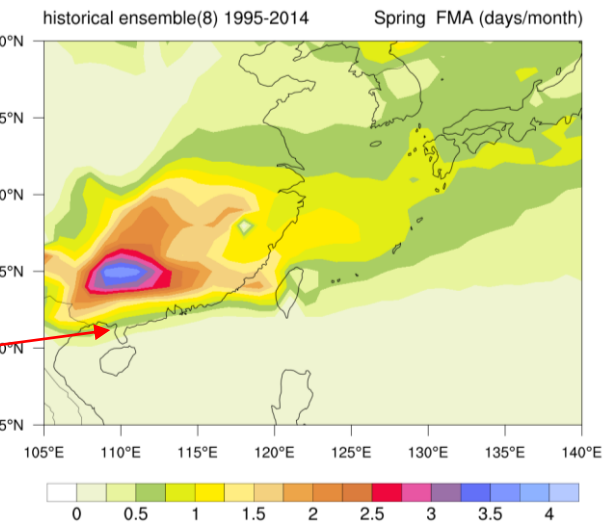
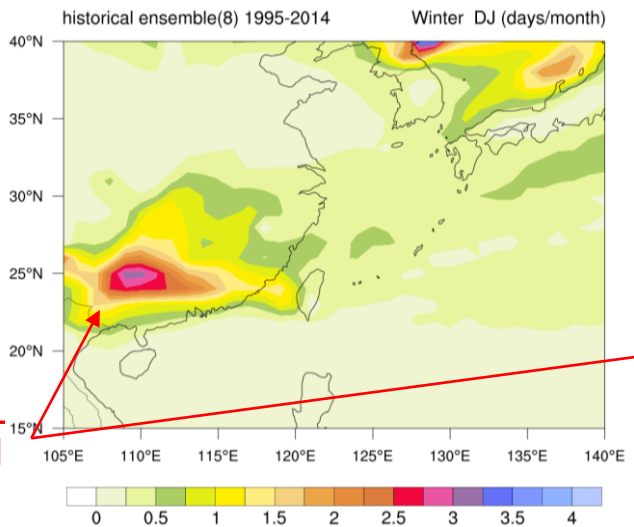


Mei-Yu (May-Jun)



ERA5

CMIP6
Ensemble
(8 models)



略為低估

偏北

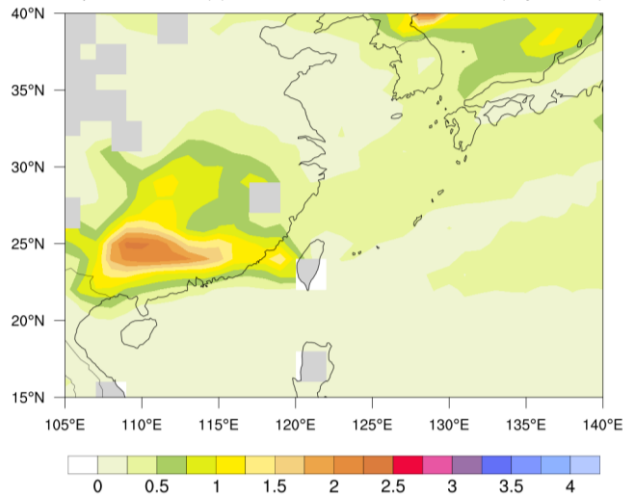


CMIP6 FUTURE PROJECTION SSP5-8.5, 2081-2100

SSP5-8.5 (2081-2100) and Changes

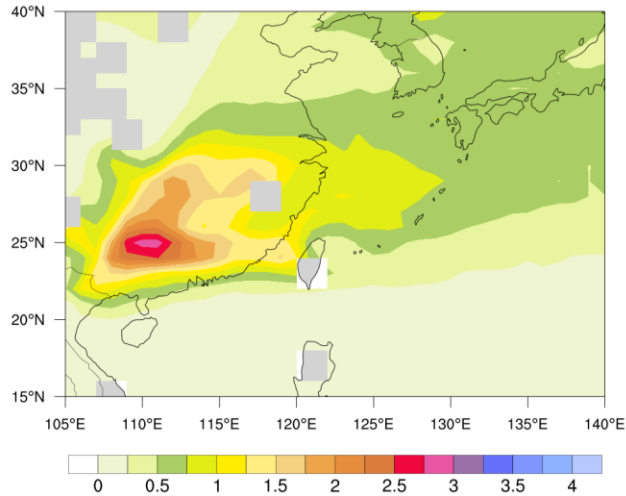
Winter (Dec-Jan)

ssp585 ensemble(9) 2081-2100 Winter DJ (days/month)



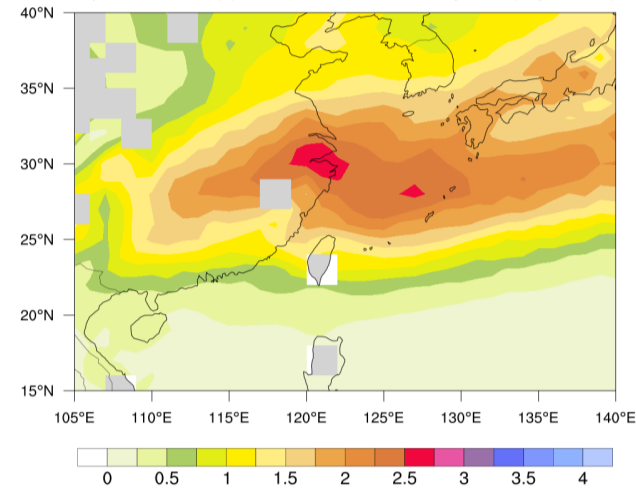
Spring (Feb-Apr)

ssp585 ensemble(9) 2081-2100 Spring FMA (days/month)

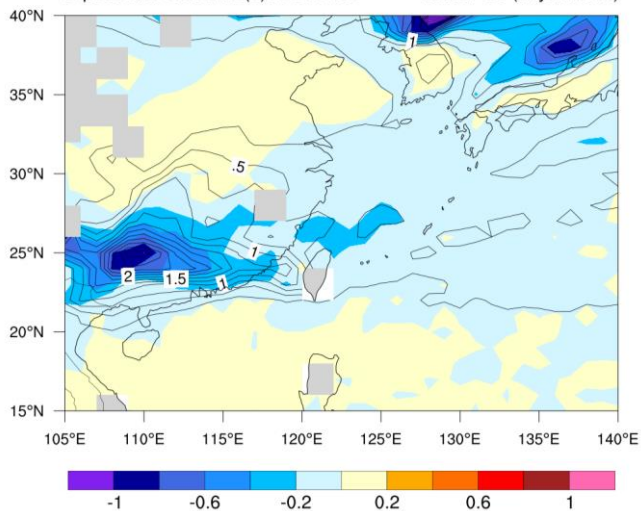


Mei-Yu (May-Jun)

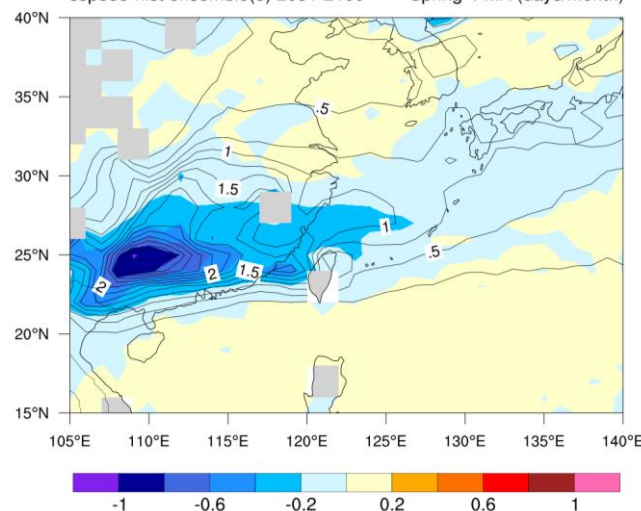
ssp585 ensemble(9) 2081-2100 Mei-yu MJ (days/month)



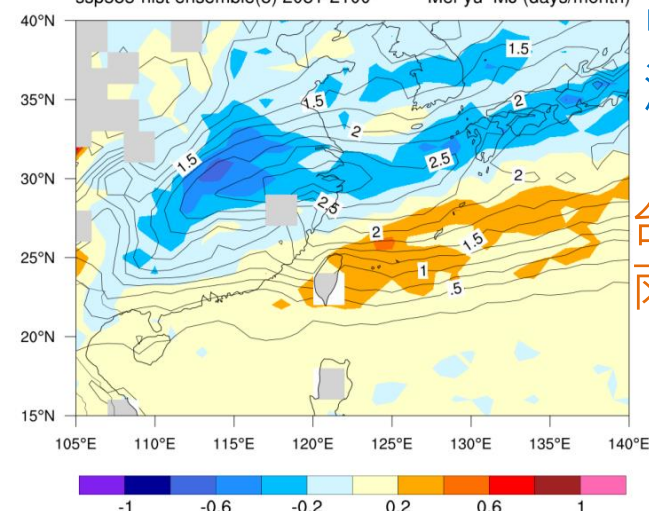
ssp585-hist ensemble(8) 2081-2100 Winter DJ (days/month)



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

鋒面頻
率減少

Model Consensus in Font Frequency Change

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

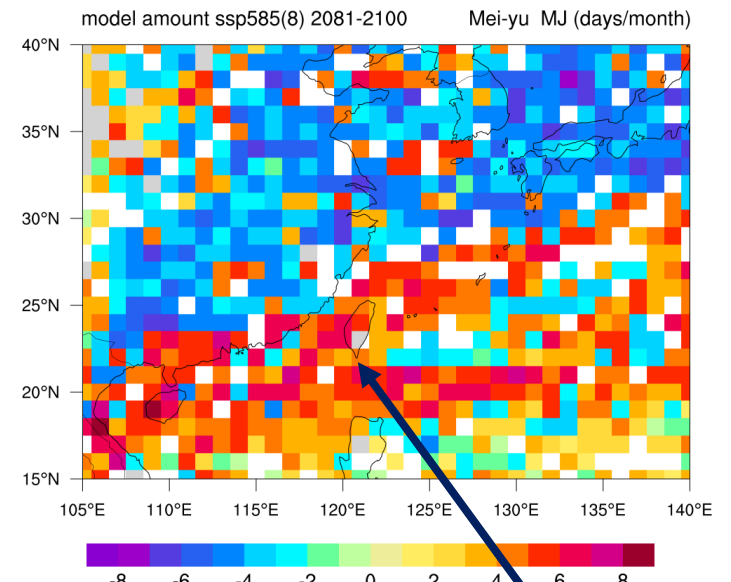
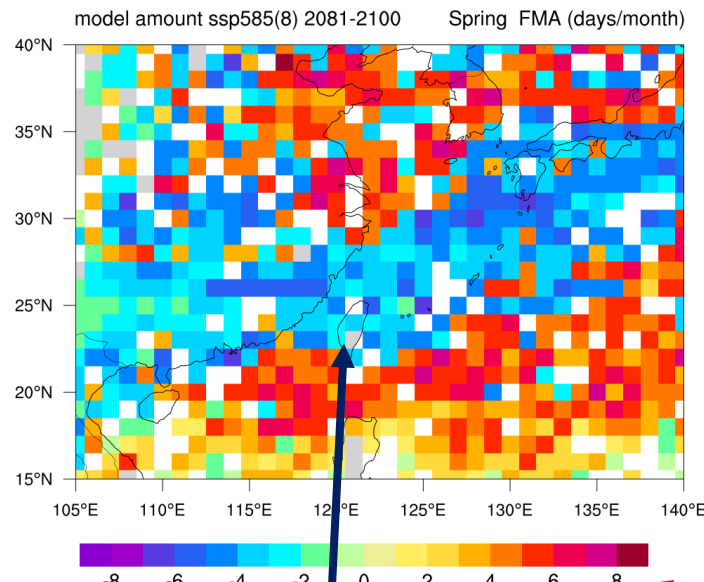
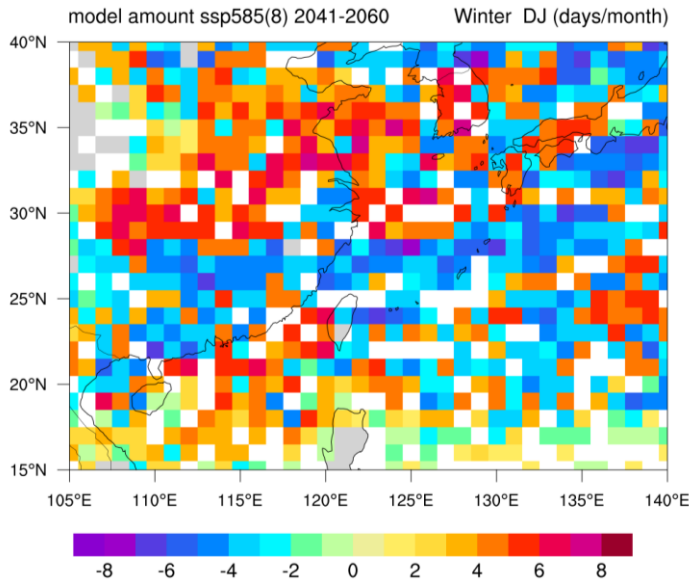
Total: 8 models
Only models that pass
90% significance are counted

Grey: underground
White: no trend

Winter

Spring

Mei-yu



of models of decreasing frequency

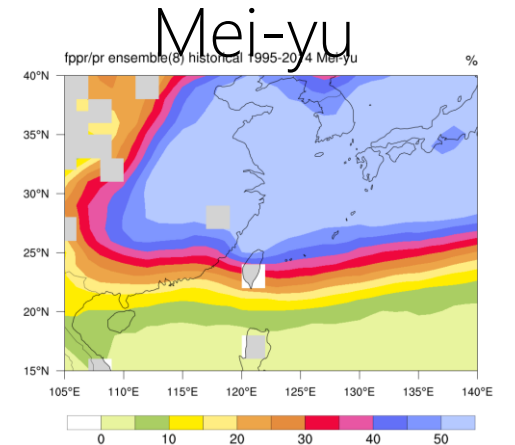
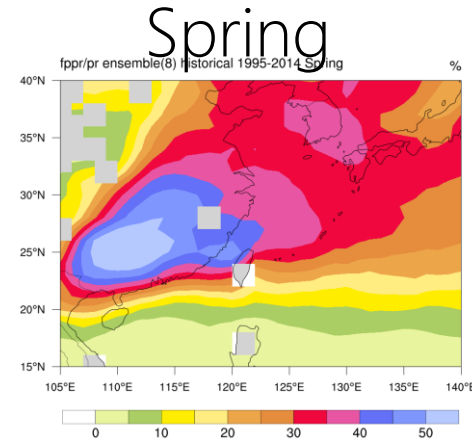
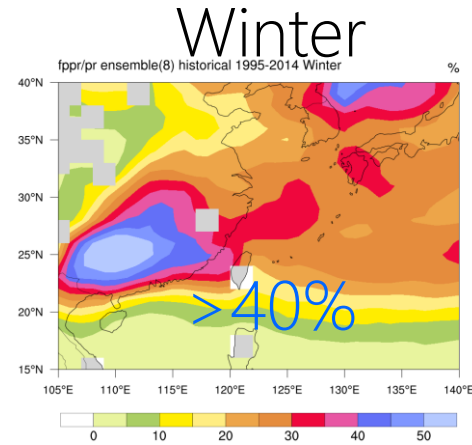
可能減少

of models of increasing frequency

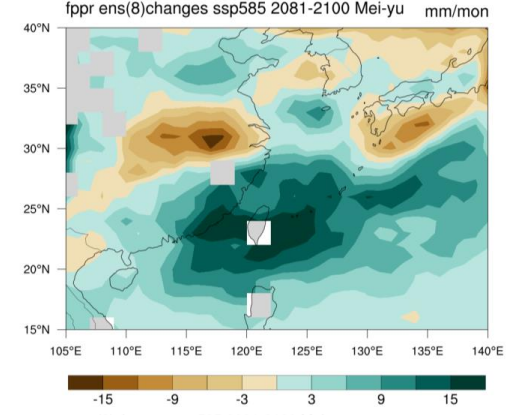
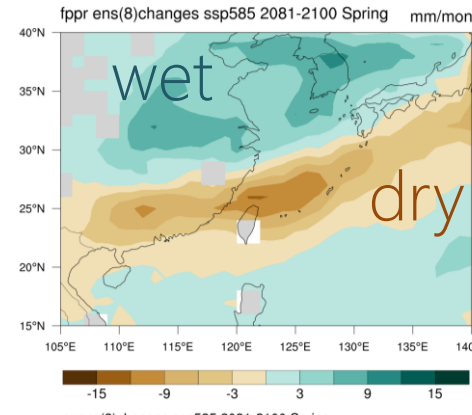
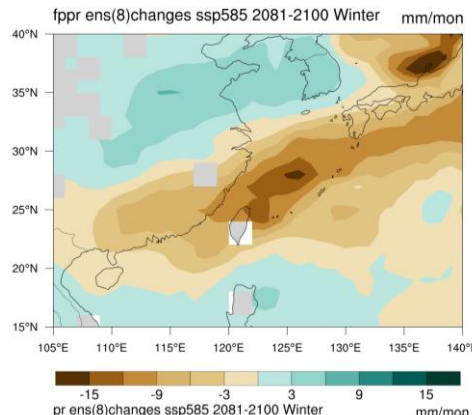
台灣中南部趨勢增加

Changes in Frontal Precipitation

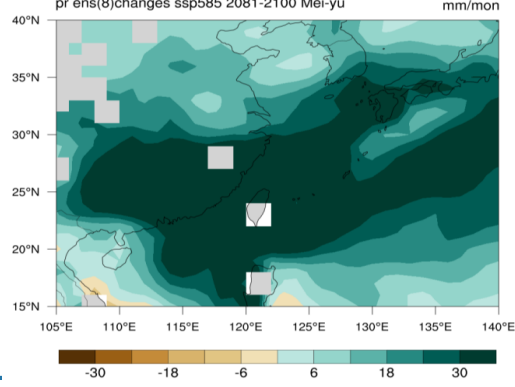
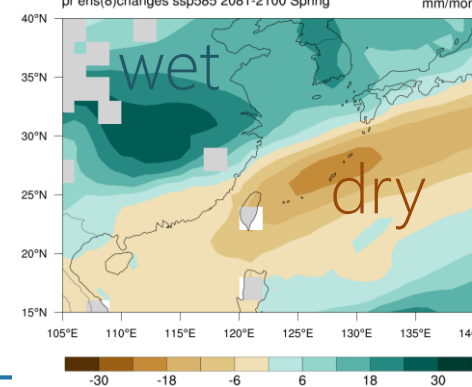
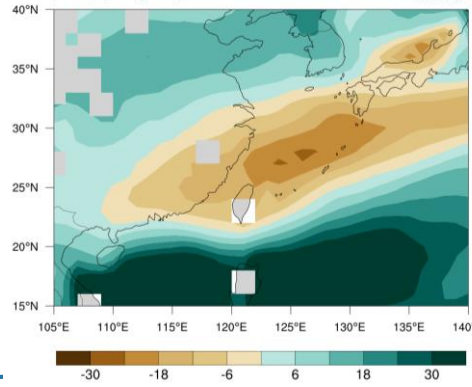
Historical Ratio of Frontal Precipitation (%)



Frontal Precipitation change (SSP5-8.5, 2081-2100)



Total precipitation change





PHYSICAL MECHANISMS

LARGE-SCALE ENVIRONMENT CHANGES IN SSP5-8.5

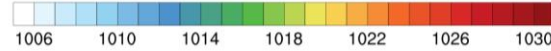
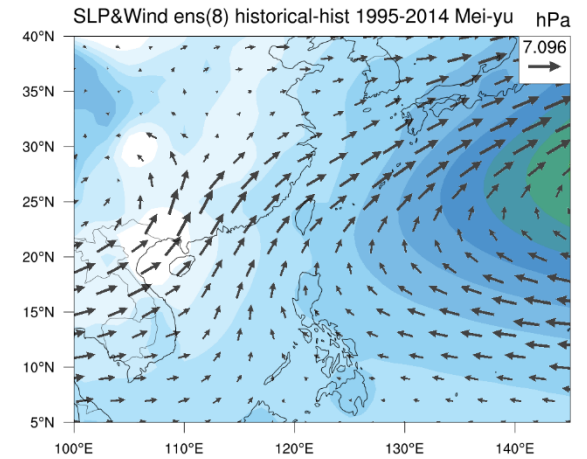
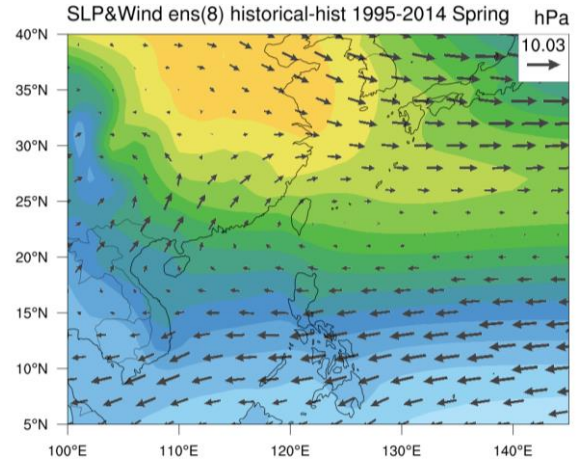
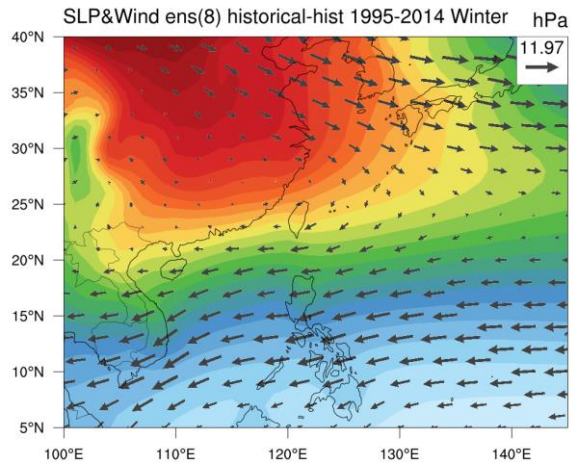
MSLP (shading) and 850 hPa Wind (vector)

Winter

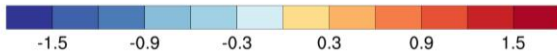
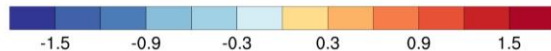
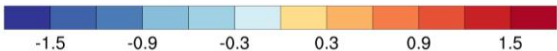
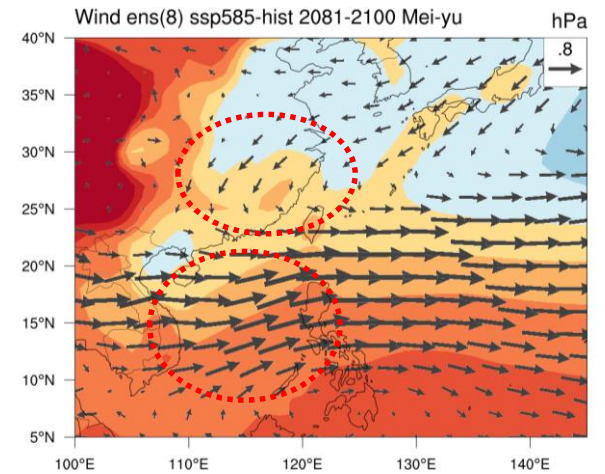
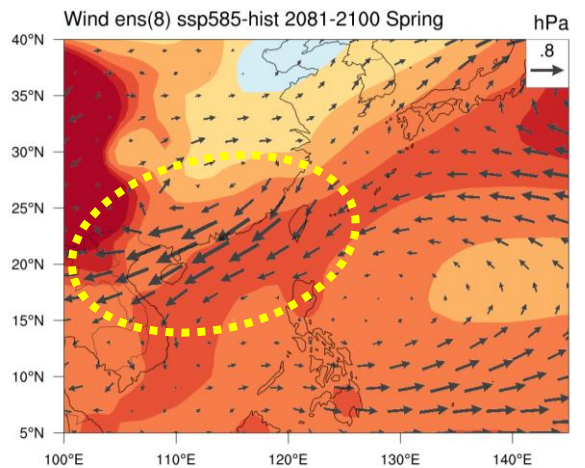
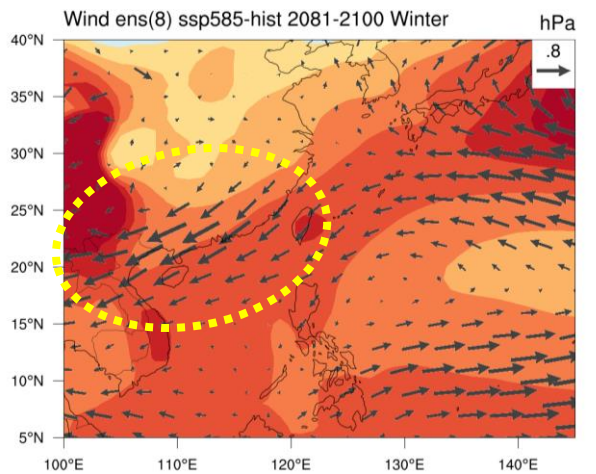
Spring

Mei-Yu

Historical



Changes



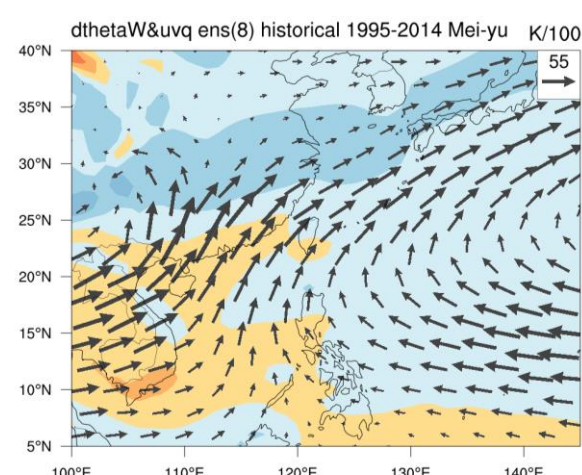
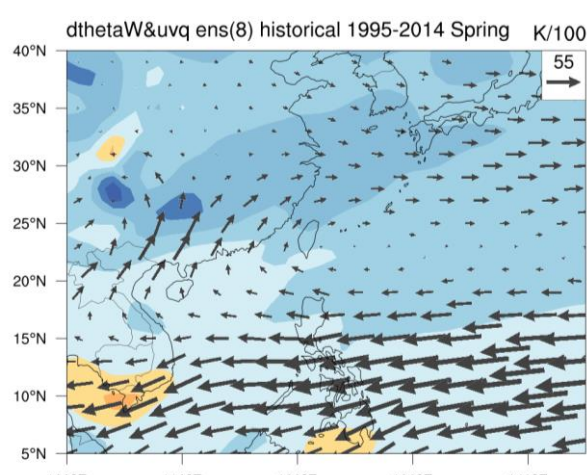
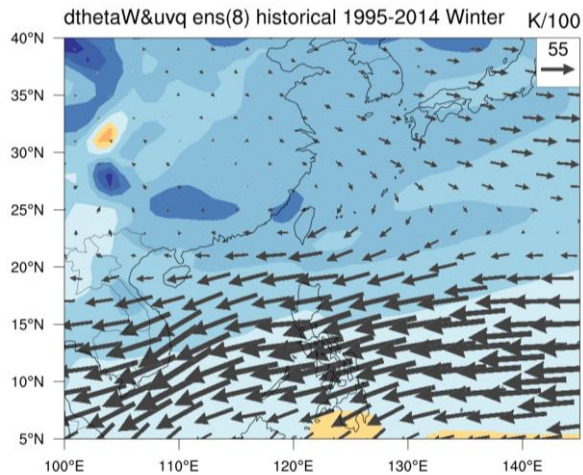
$\nabla\theta_w$ (shading) and 850 hPa Moisture Flux (vector)

Winter

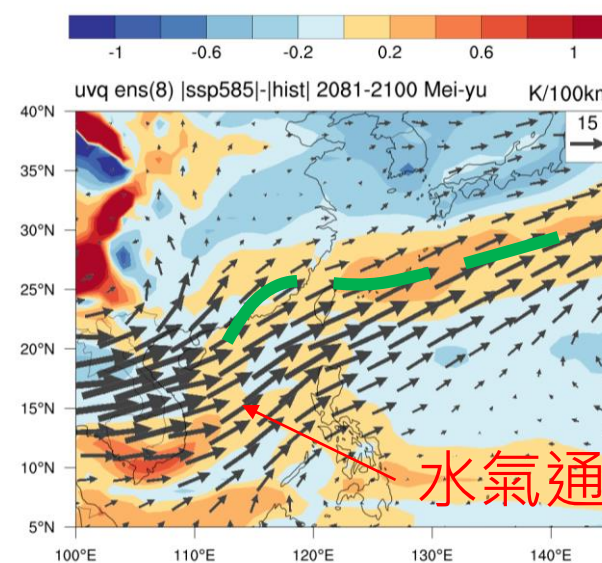
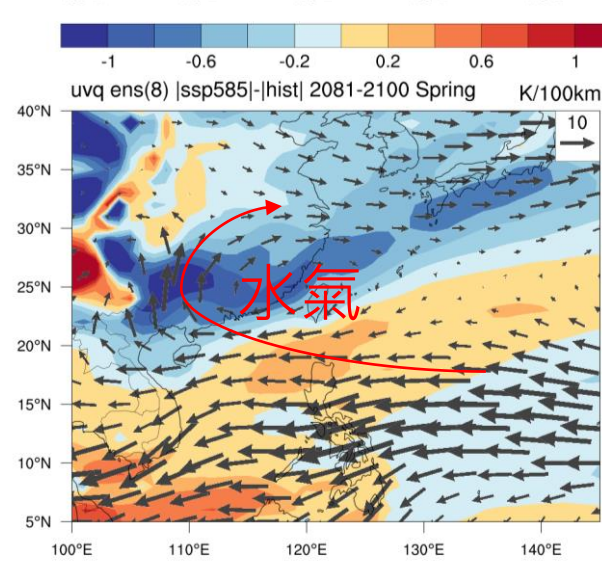
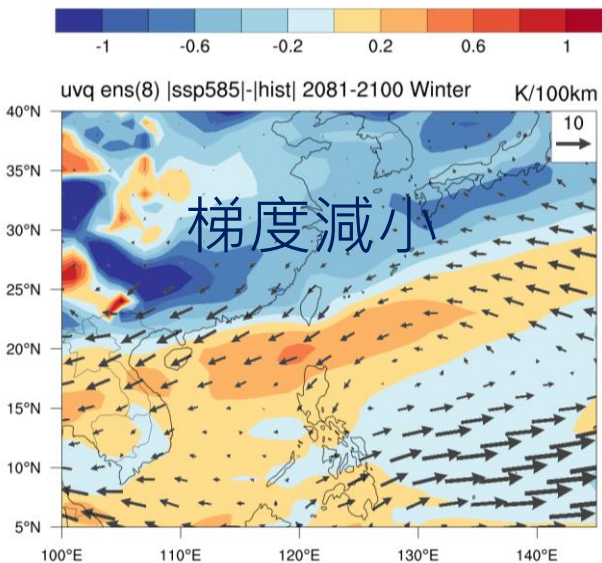
Spring

Mei-Yu

Historical



Changes



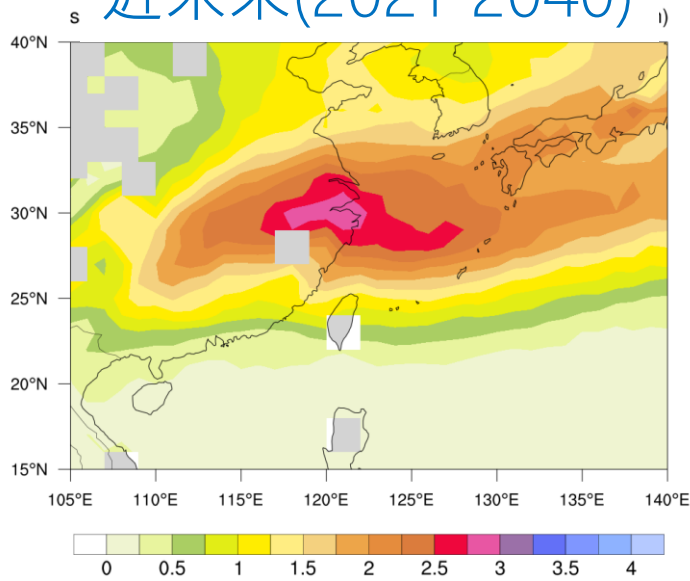


MEI-YU SEASON

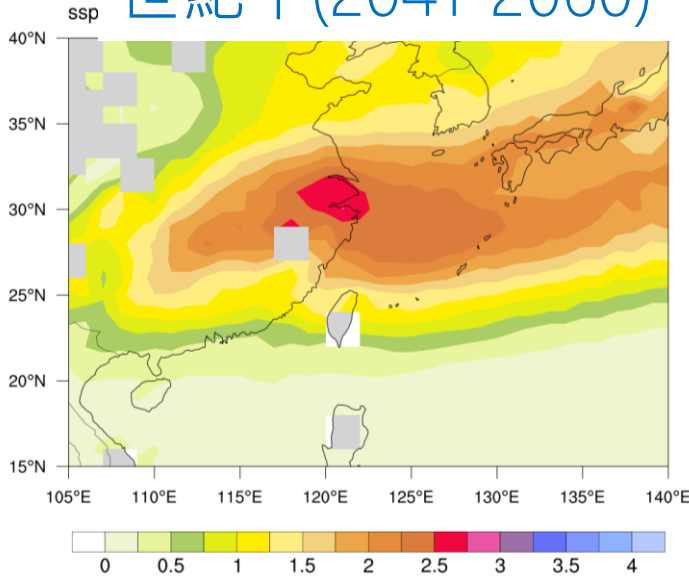
DIFFERENT TREND IN SSP5-8.5

Mei-Yu season, SSP585 climatology & change

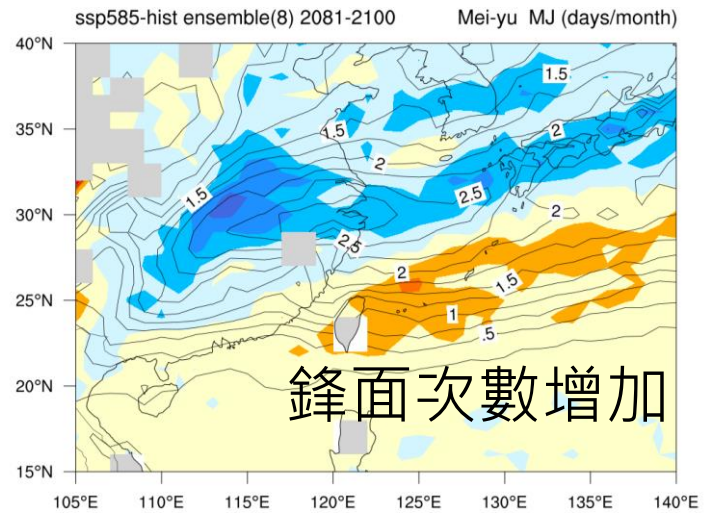
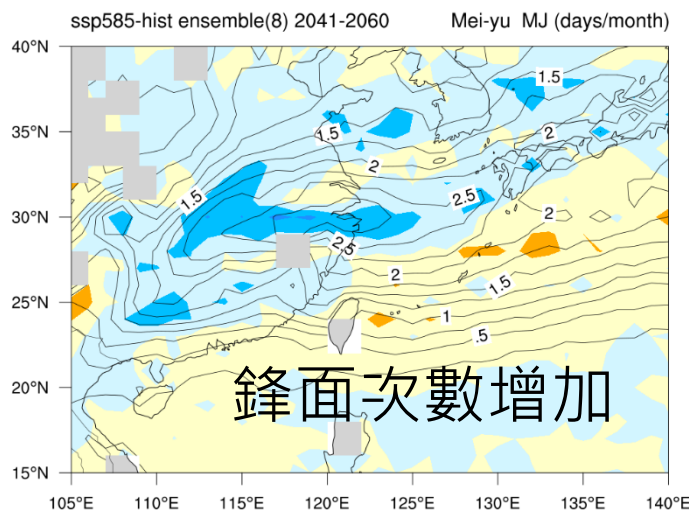
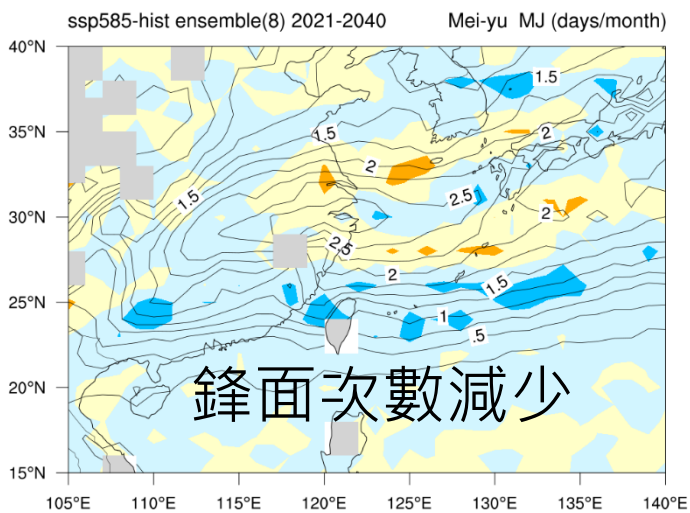
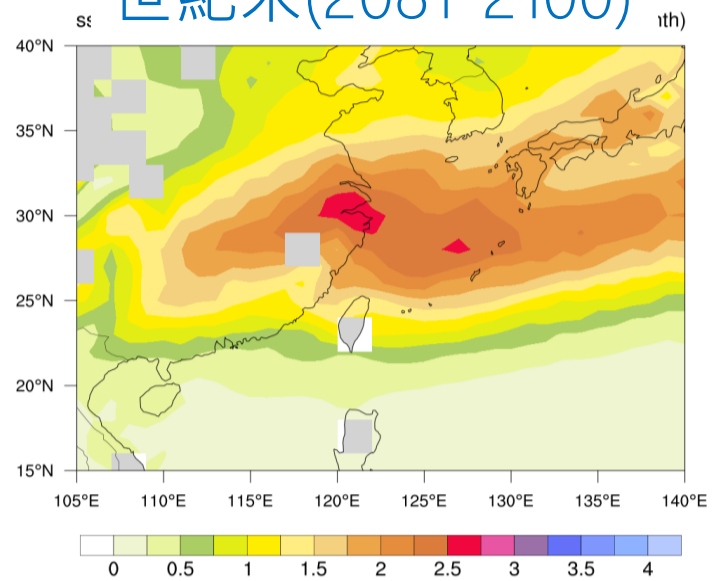
近未來(2021-2040)



世紀中(2041-2060)



世紀末(2081-2100)



Mei-yu Frontal Precipitation Change

近未來(2021-2040)

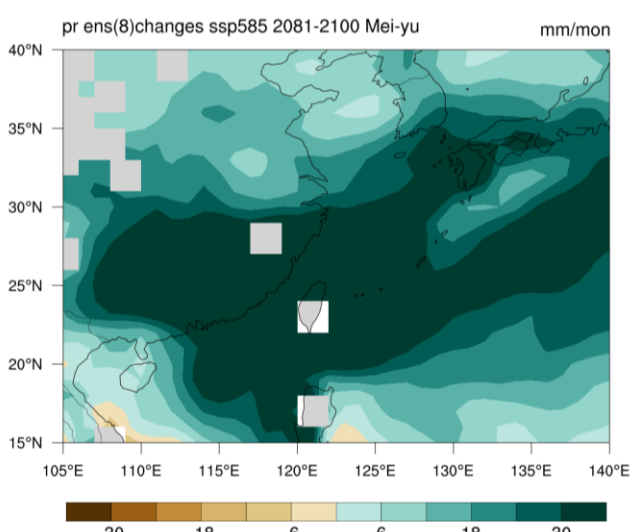
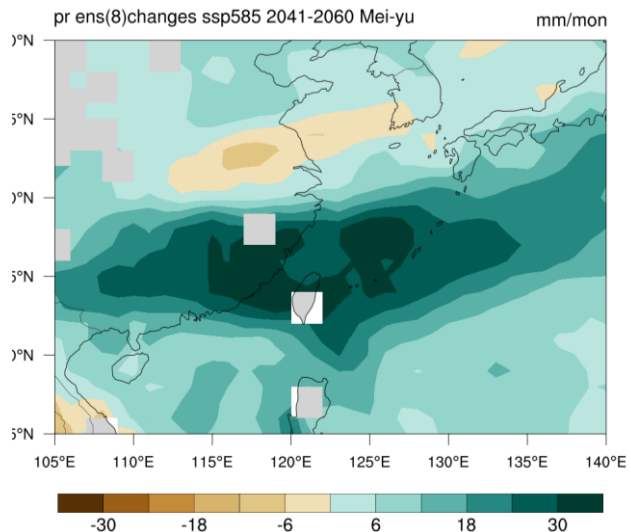
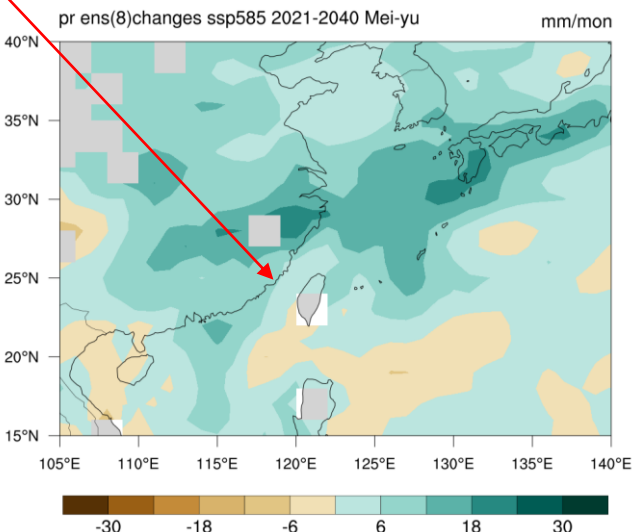
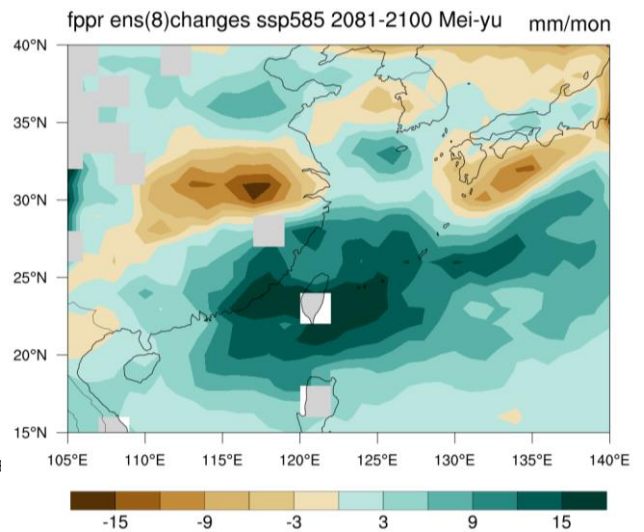
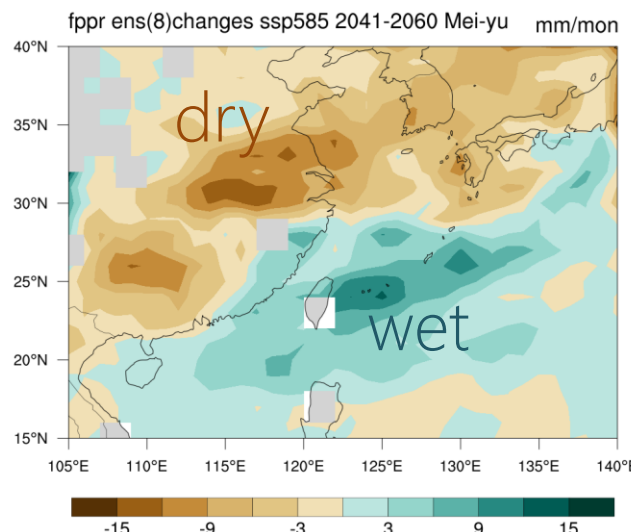
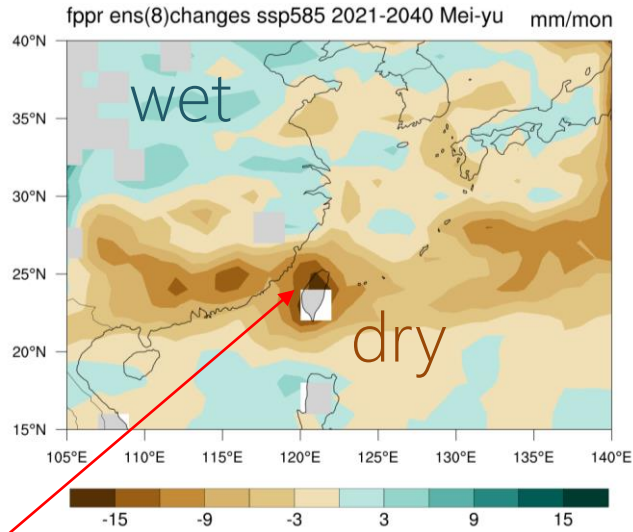
世紀中(2041-2060)

世紀末(2081-2100)

Frontal
Precipitation
change
(SSP5-8.5)

降雨型態
明顯改變

Total
precipitation
change



Summary

- Fronts/frontal precipitation decrease in climatological maxima (CMIP6), can be explained by weaker background thermal gradient.
- More Mei-Yu fronts/frontal precipitation in Taiwan, Ryukyu islands, and South China in the end of 21st Century (increased thermal gradient and more moisture supply). Opposite change in the north.
- Frontal precipitation change can explain more than half of the total precipitation change in Winter and Spring.
- Model consensus (8 models) shows high agreement in frequency change in Mei-Yu season.
- In Mei-Yu season, wet season gets wetter. However, fronts / frontal precipitation decrease 2021-40 (less fronts, less frontal prec.), increase after 2041-2060. Precipitation pattern may change.
- Longer dry season (winter/spring) for Taiwan. More extreme precipitation (Mei-yu).