TCCIP 臺灣氣候變遷推估與資訊平台
Taiwan Climate Change Projection and Information Platform

Projection of Taiwan Climate

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

Approaches

- **Statistical Downscaling** (all RCP model projections)

- **Projection of Key Phenomena**
  → Identification of key circulation characteristics
  → Check model performance
  → Selection of models
  → Projection of selected models: phenomenon and associated circulation changes (mechanism understanding)

- **Dynamical downscaling**
  → RCP8.5 SST changes
  → Time-slice experiments (present vs. end of century) using high-resolution AGCMs (HiRAM, MRI, CAM5)
  → a. Changes in certain phenomena (TC, frontal activity, ISO/TC, etc.)
  b. Dynamical downscaling of the whole period and extreme/mesoscale events using WRF (e.g., TCs, diurnal cycle, etc.)

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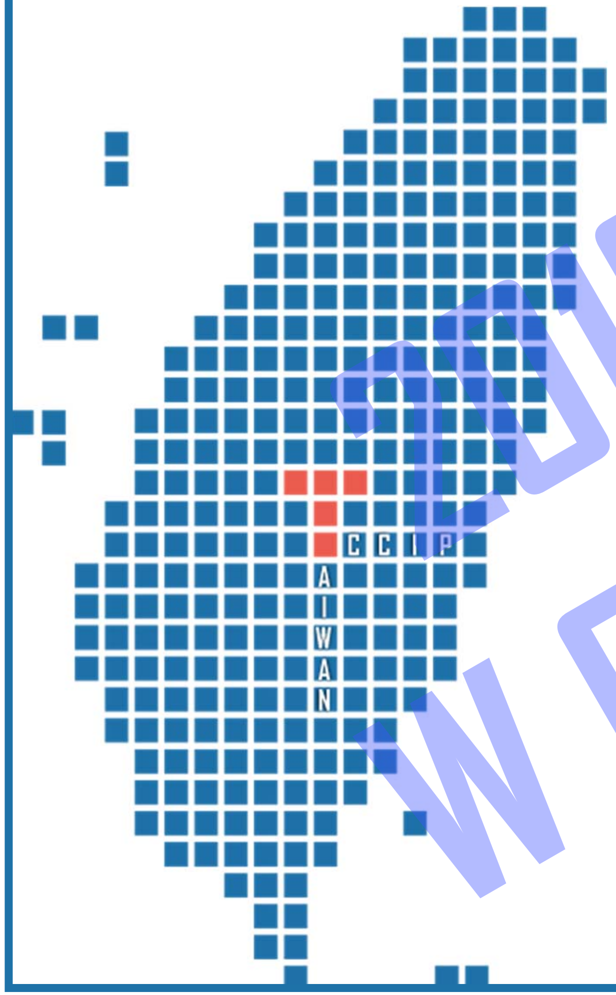
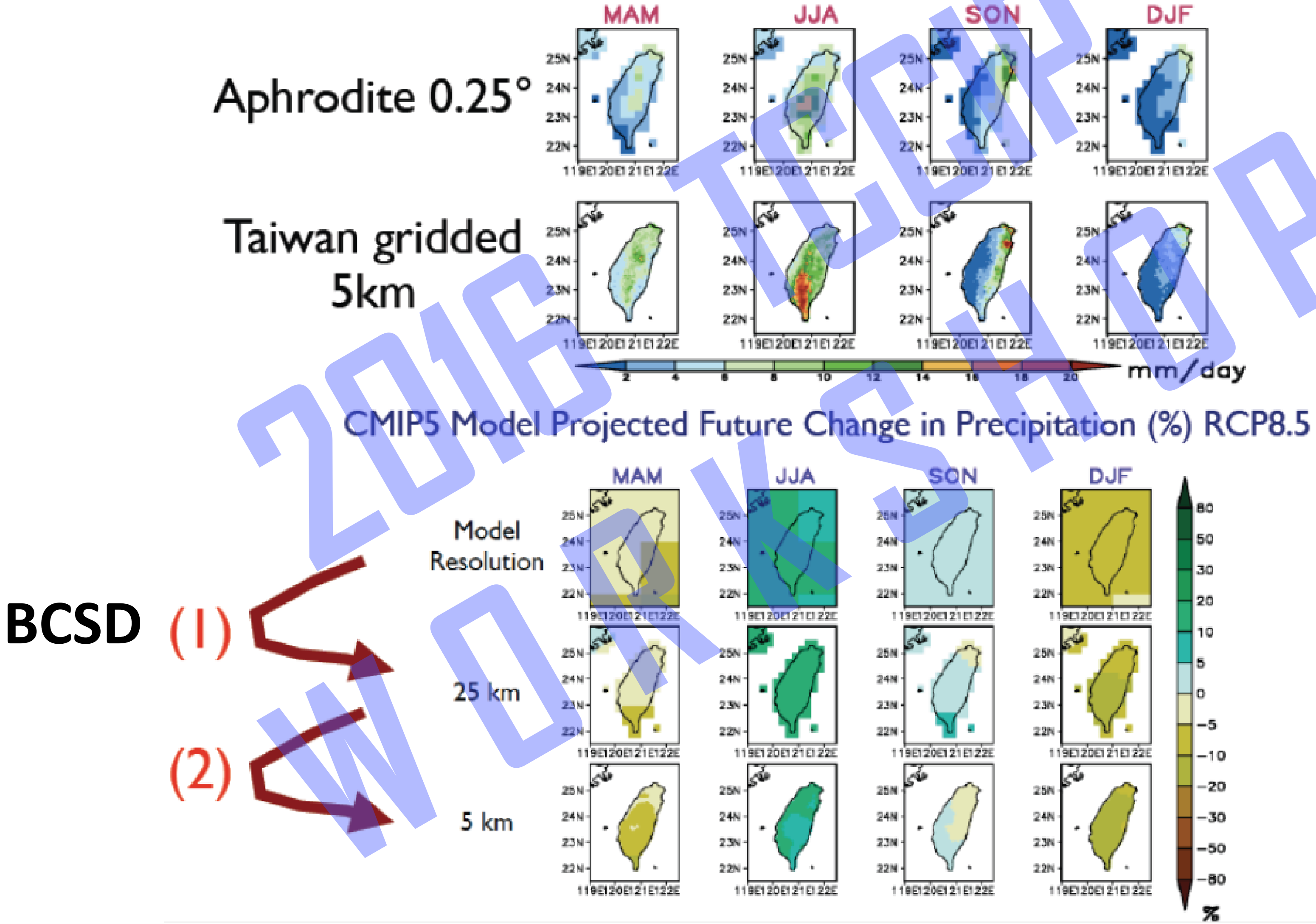


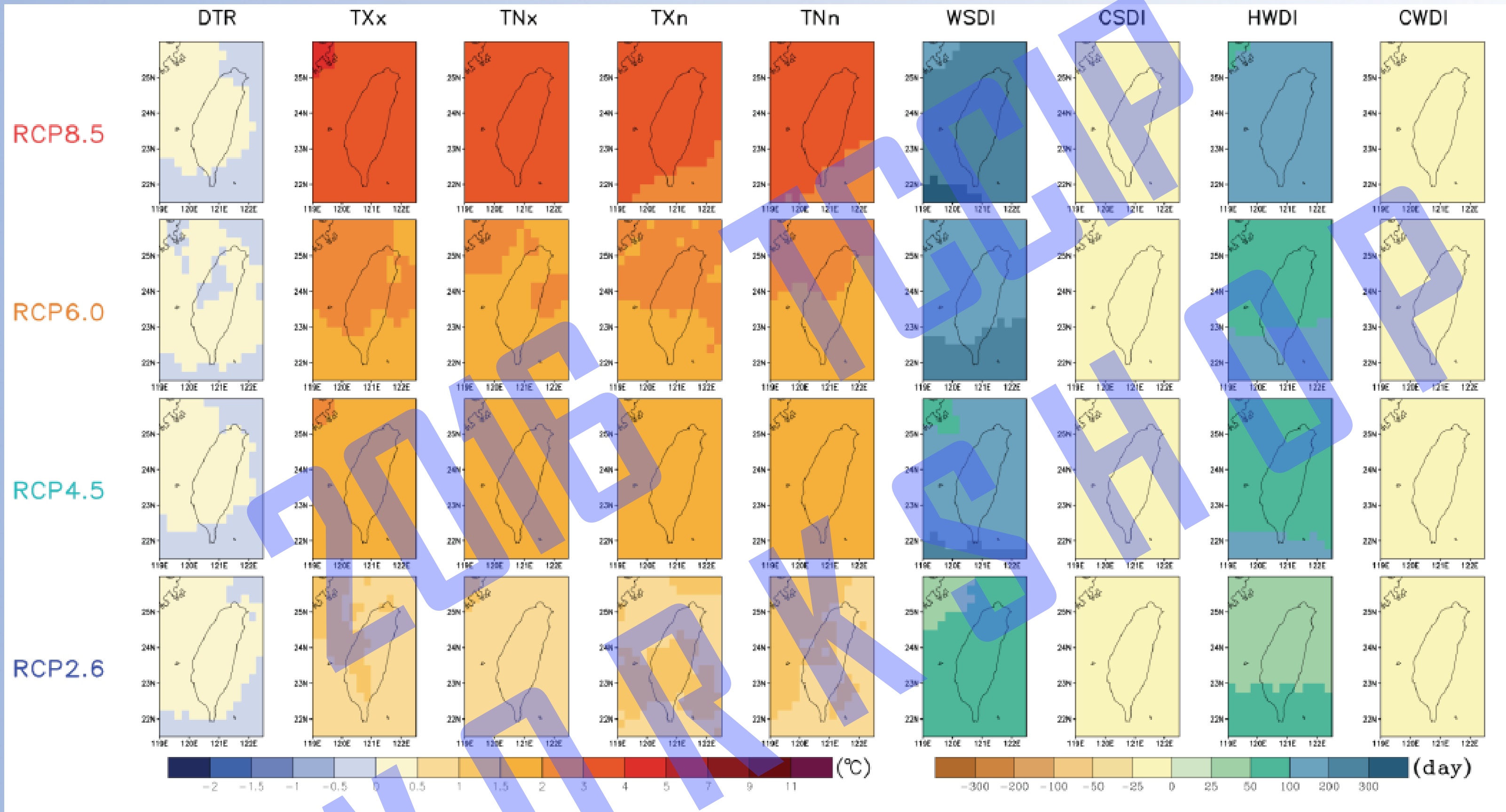
Statistical Downscaling

Downscaling Process

2-stages: (I) GCM ⇒0.25° (2) 0.25°⇒ 5 km



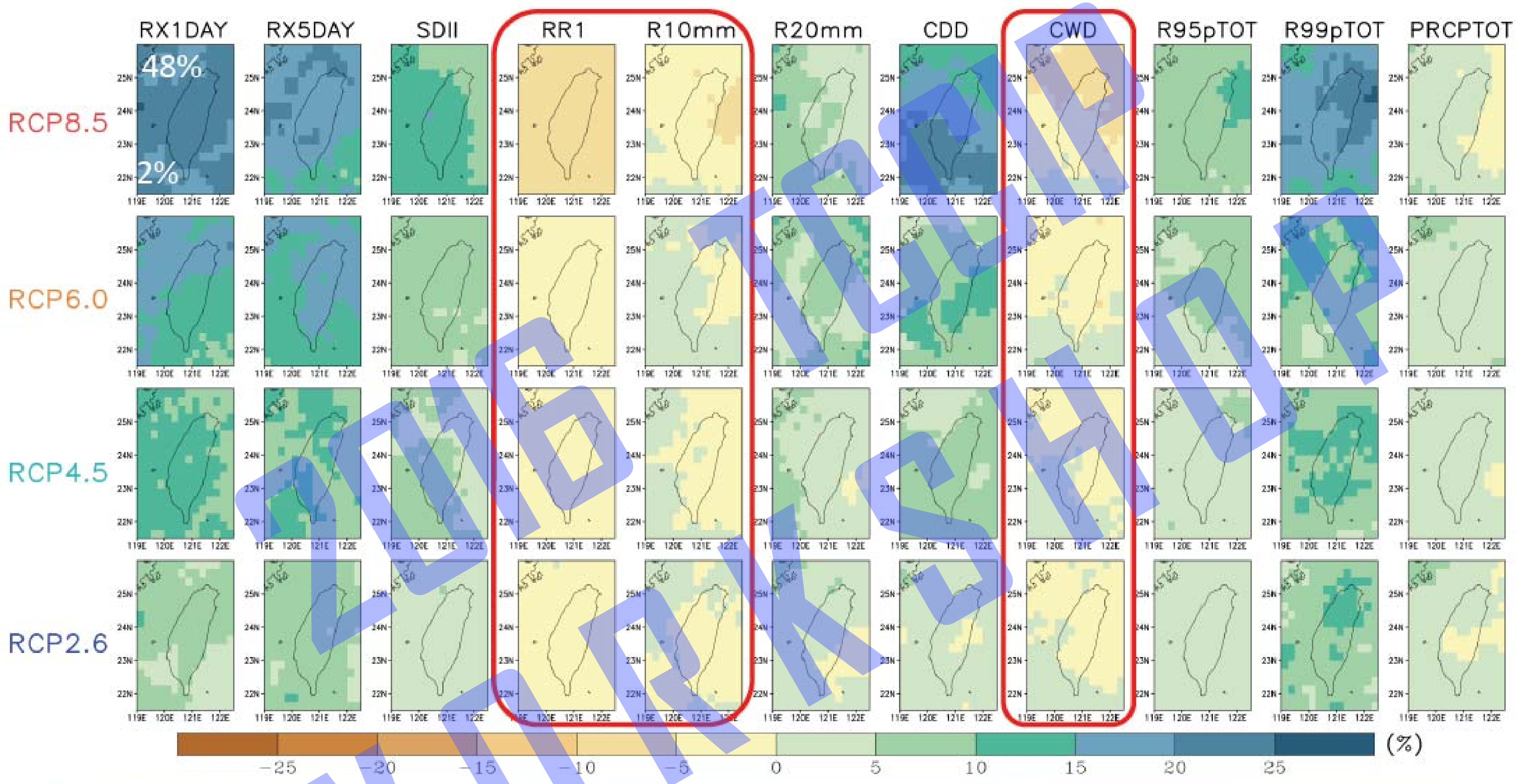
Extreme Indices(Temperature)



日夜溫差(DTR)並無明顯改變；TXx、TNx、TXn、TNn四者變化一致，空間分布也相同；由於世紀末的升溫明顯，造成WSDI與HWDI明顯上升呈現南部略高於北部

Significant warming (RCP8.5: median 2.9°C-3.2°C)

Extreme Indices(Precipitation)



- RX1DAY, RX5DAY, SDII, R95TOT, PRCTOT: increase; R20mm frequency: increases
- RR1, R10mm, CWD: decrease; CDD: increases

→ **Wet gets wetter, dry gets drier; larger wet-dry seasonal contrast; higher risk for drought**

NCDR

(41) CMIP5 CGCM +
HiRAM、CAM5、MRI

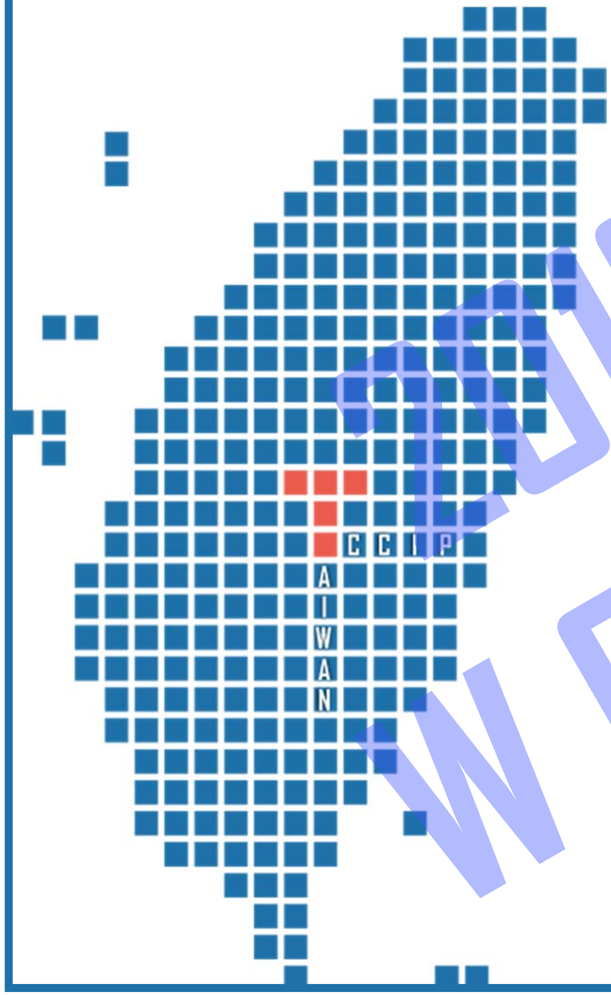
Phenomenon Metrics

- frontal activity
- spring rainfall
- Mei-yu extreme rainfall
- heat wave
- cold surge
- afternoon thunder storm activity

Model Performance Metrics

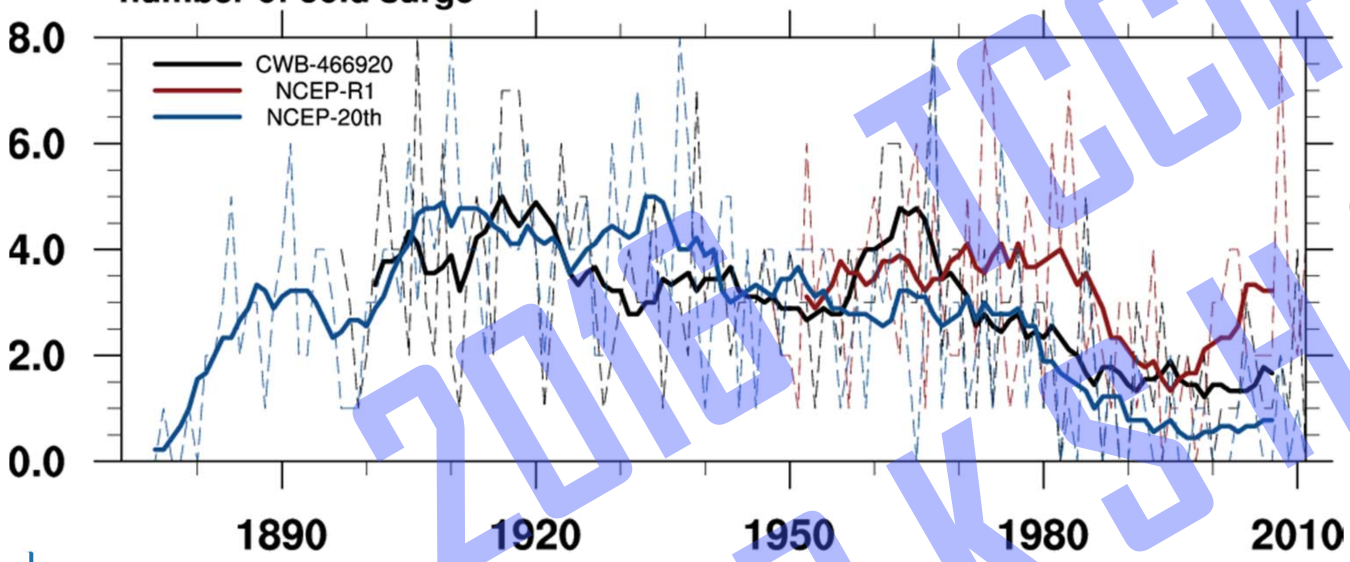
- CMIP5 CGCM and high resolution model output data analysis

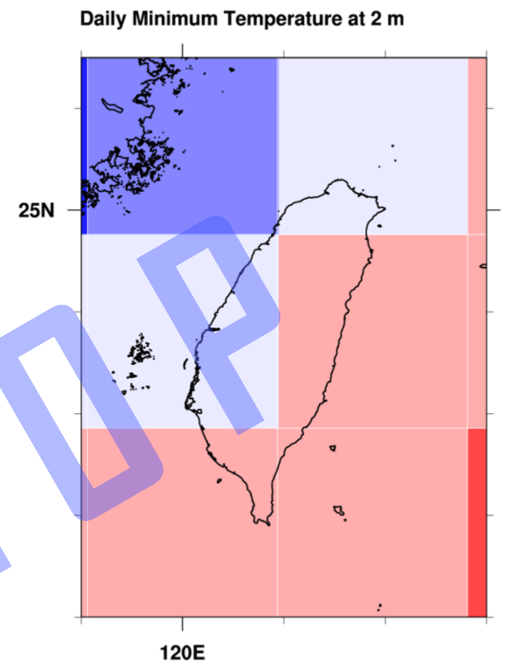
Model Projections



Cold Surge

寒潮發生次數





Data:

NCEP R1 Daily Minimum temperature at 2m

	DJF
最低溫PR10	13.9
最低溫PR20	14.9
24小時升溫PR10	2.8
48小時降溫PR10	-3.2
平均寒潮次數	3.1
平均低溫天數	9.9

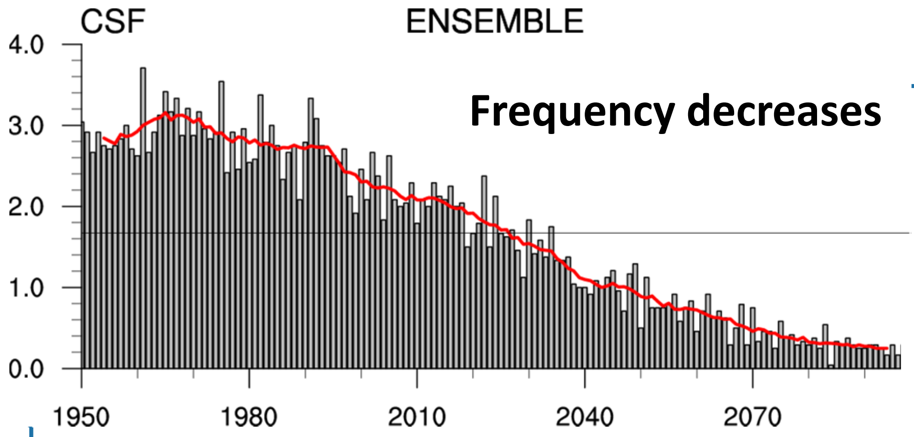
Significance of 30/50/100 years linear trend

unit: %	30year	50year	100year
NCEP-R1	4.6	83.2	NA
NCEP-20th	65.1	99.9	99.9

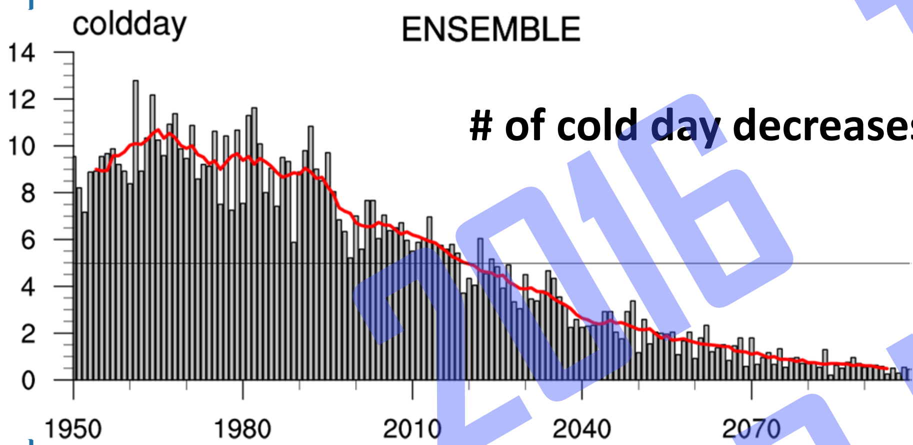
1950-2010 9yr CSF running mean

Correlation (CWB&NCEP-R1) : 0.67

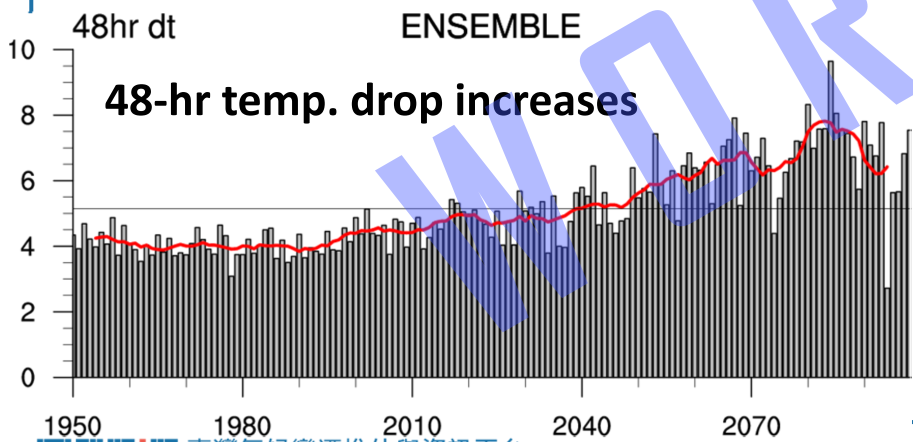
Correlation (CWB&NCEP-20th): 0.88



Frequency decreases

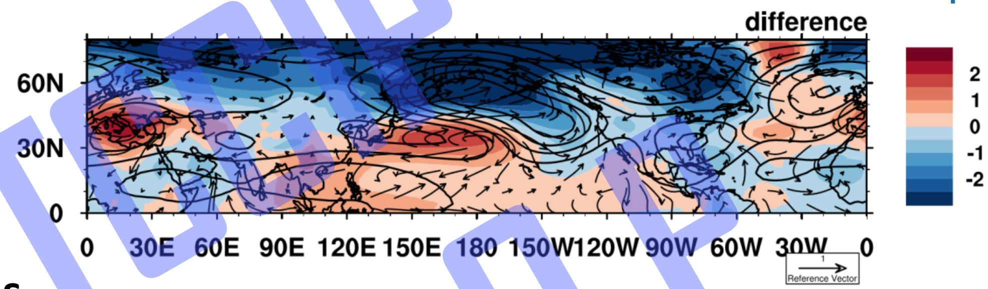


# of cold day decreases

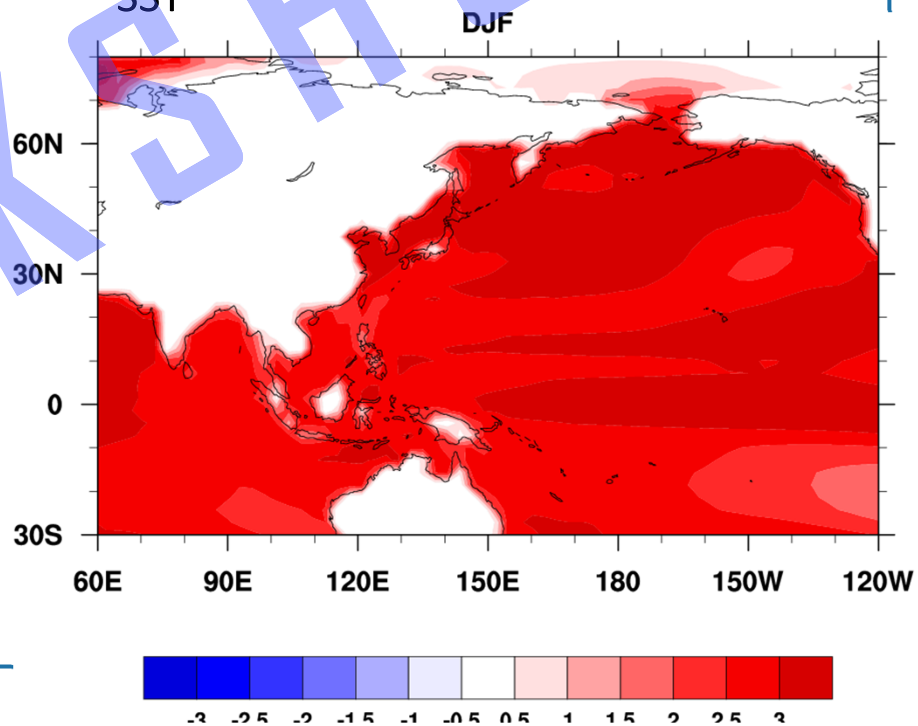


48-hr temp. drop increases

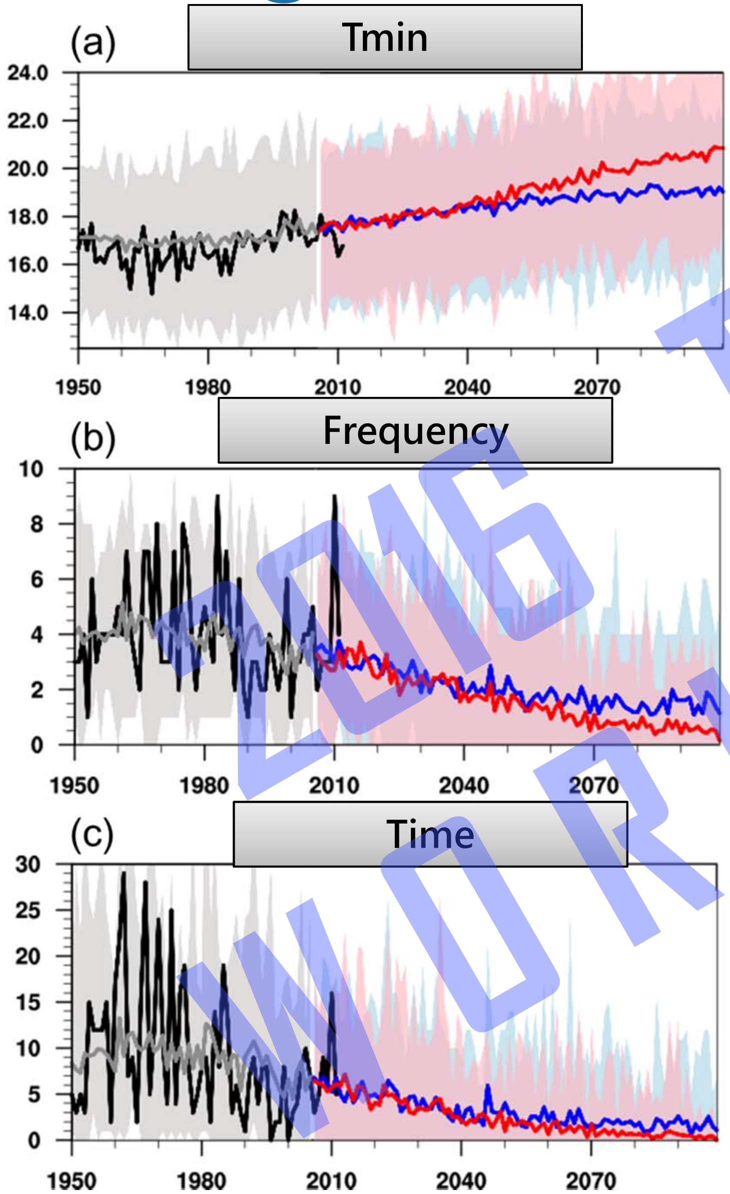
Slp (shading) , z500 (contour) , v1000 (vector)



SST



Cold Surge (RCP4.5, RCP8.5)



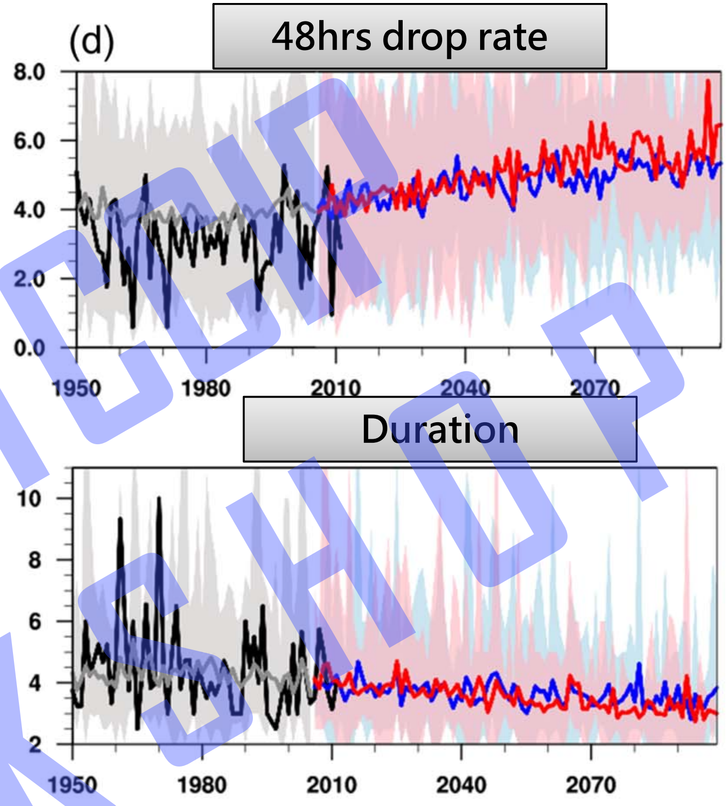
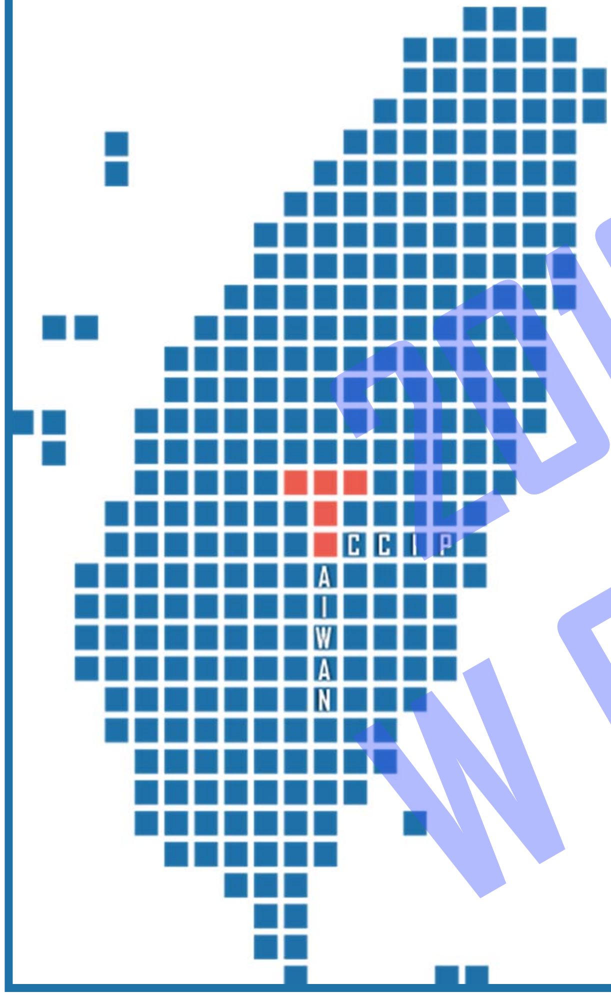
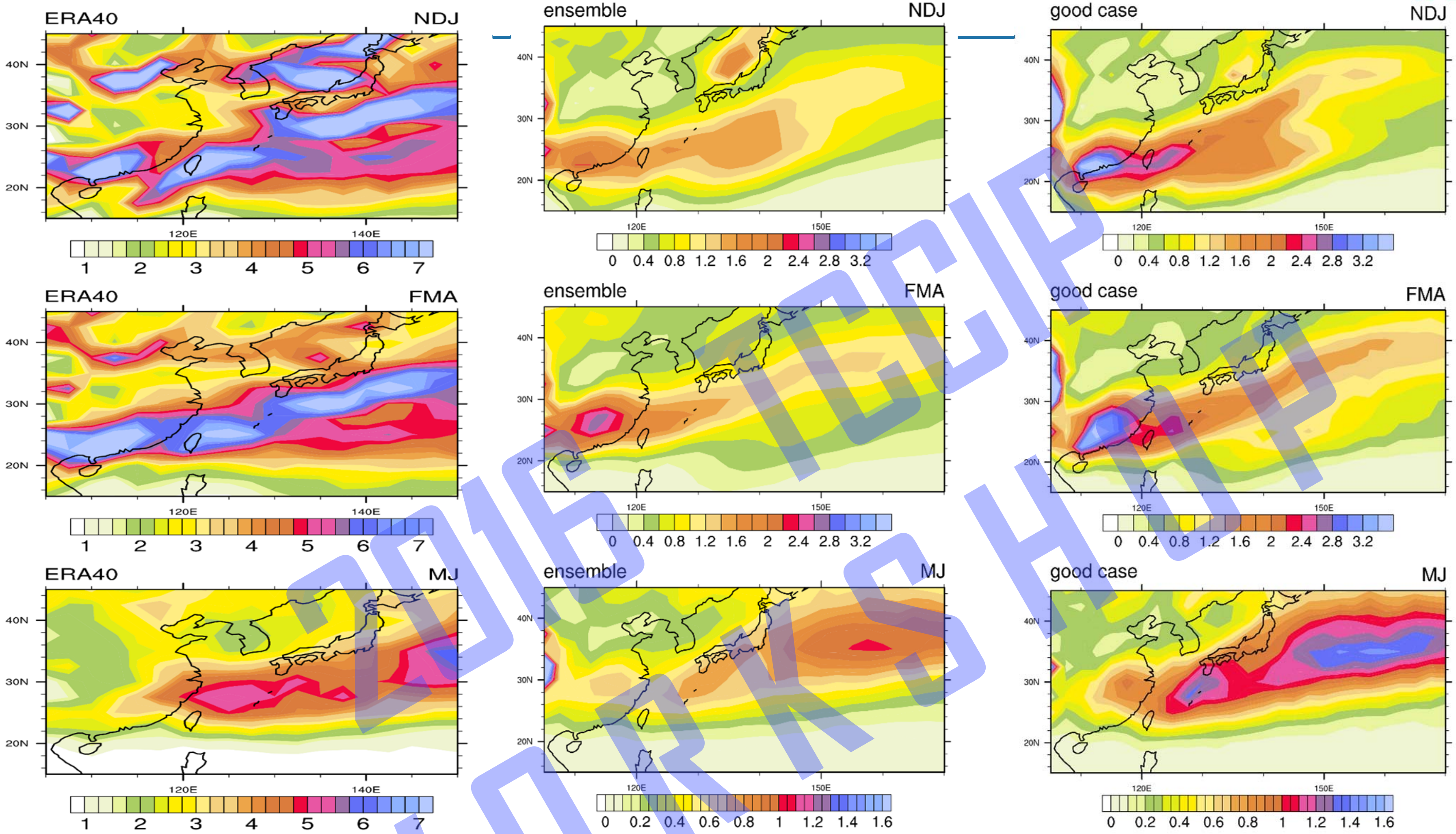


Fig.1 Time series of (a) monthly mean of daily minumum temperature, (b) cold surge frequency, (c) number of cold day (unit: day), (d) 48-hour temperate drop rate (unit: °C), and (e) duration (unit: day) over Taiwan in observation (black line) and CMIP5 historical (gray line), RCP4.5 (blue line) and RCP8.5 (red line). Shading area shows the distribution of individual models in RCP4.5 (blue) and RCP8.5 (red) scenario respectively.



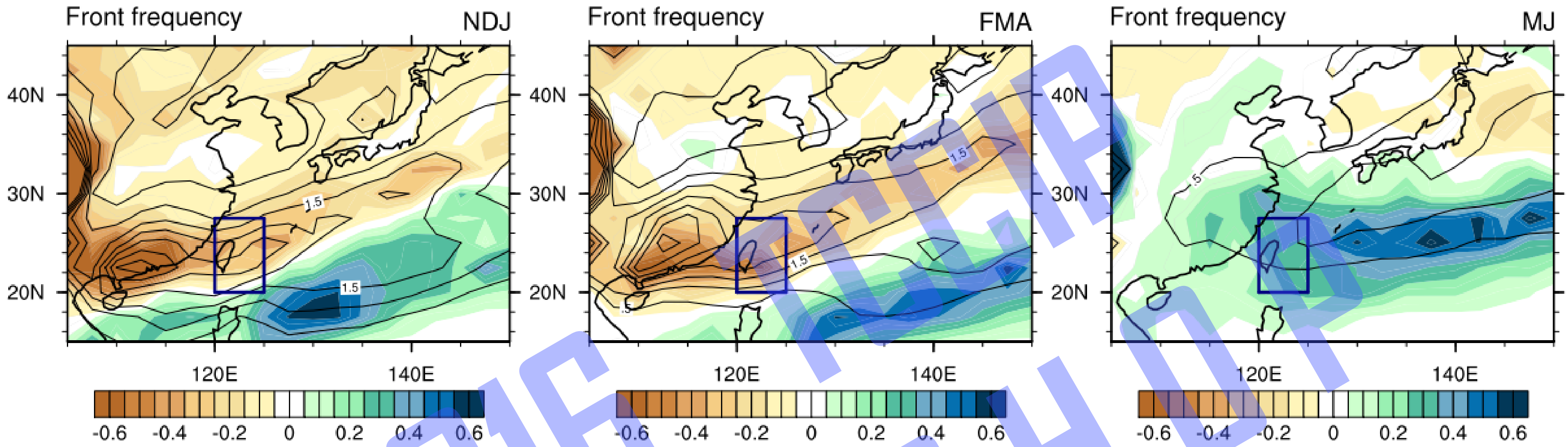
Frontal Activity

- NDJ, FMA, MJ
- auto detection scheme revised from XXXX

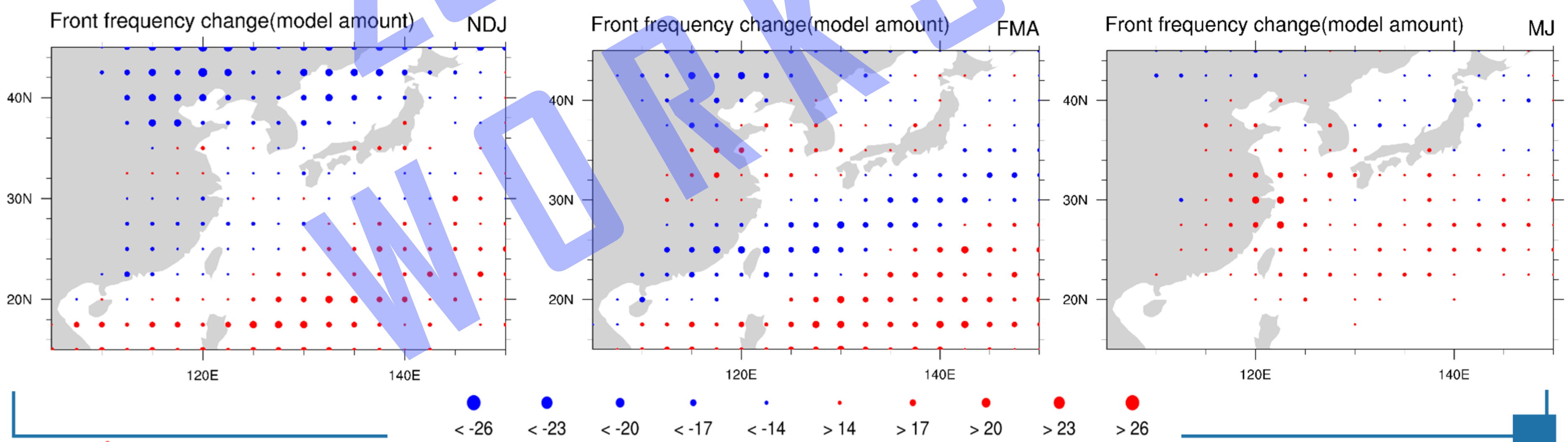


Models reasonably simulate characteristics of frontal activity.

Ensemble frequency changes



Model consensus in frequency changes



theta-w gradient(*-1) and 850mb moisture flux (historical)

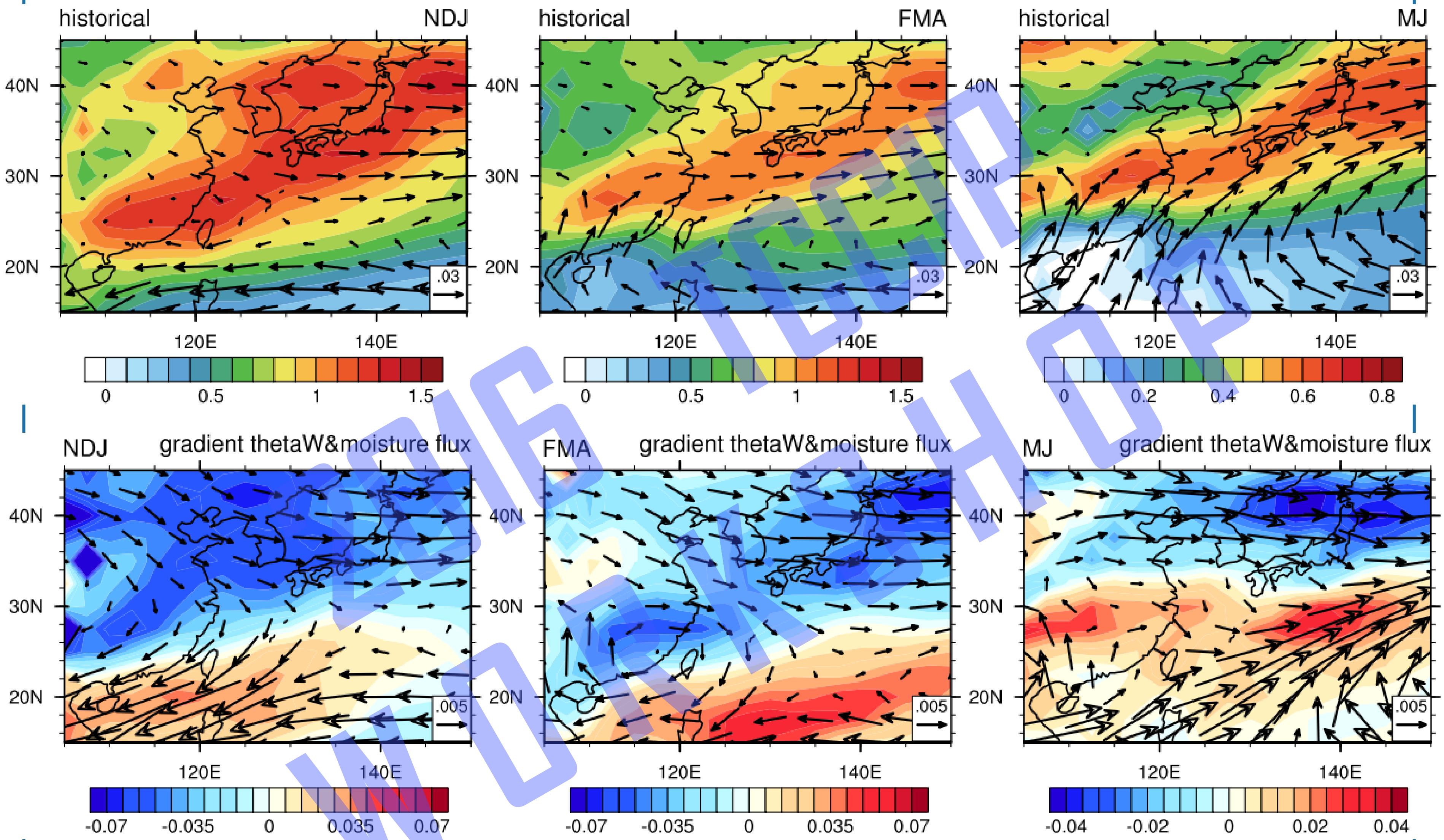


Figure 9: SLP+850mb wind, theta-w gradient(*-1) +850mb moisture flux (RCP85 minus historical)

Cross section Of T and Q 120-140E

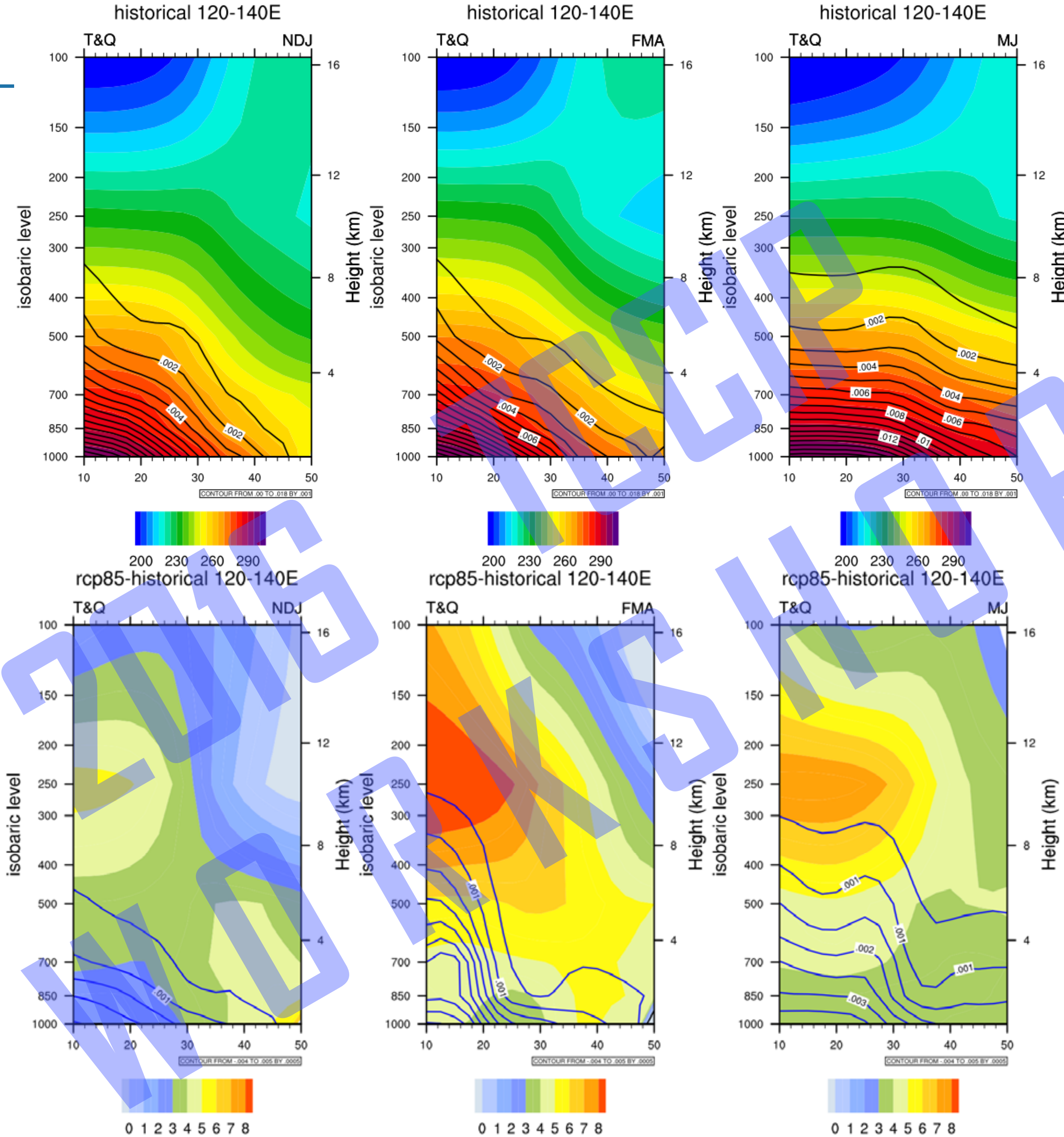


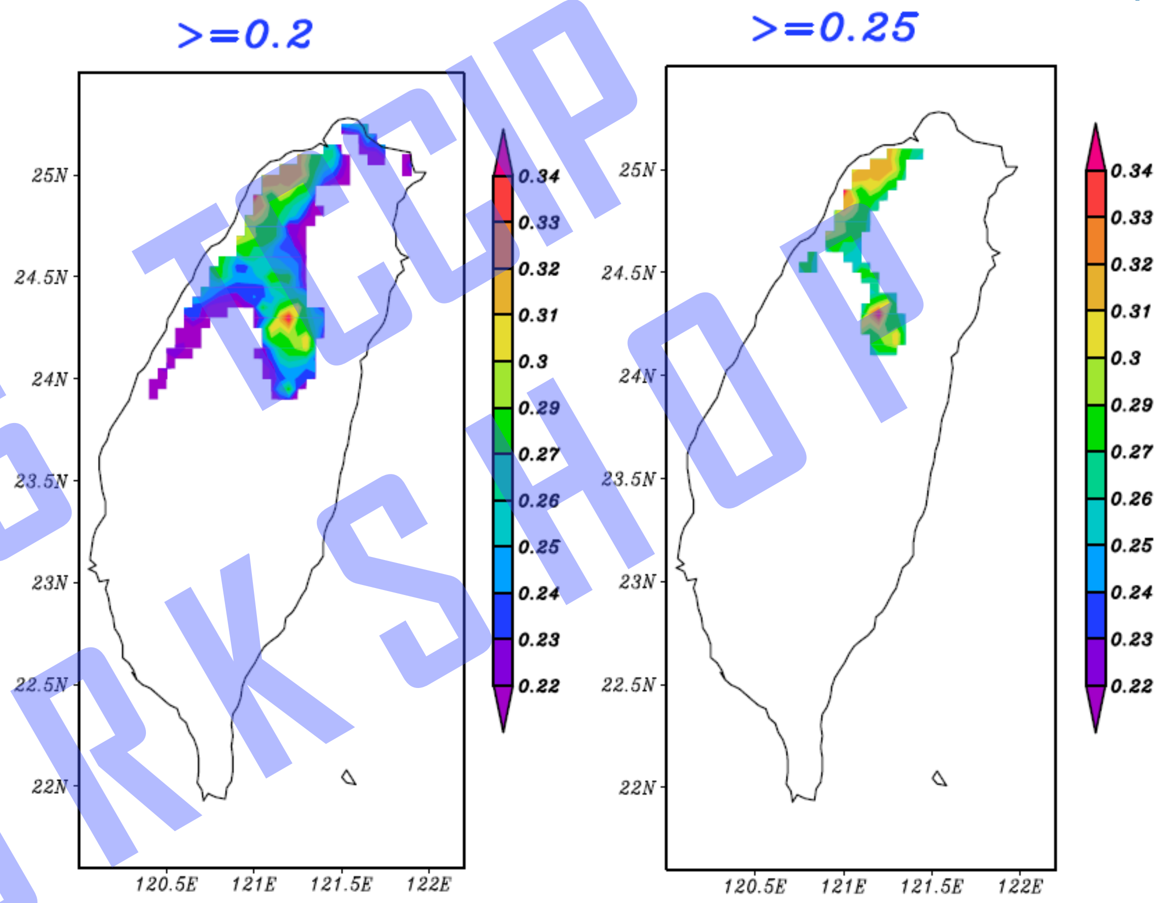
Figure 11: same as figure 10 except for temperature(shading) and specific humidity(contour, blue:+, red:-)

Spring Rainfall

Spring rain distribution

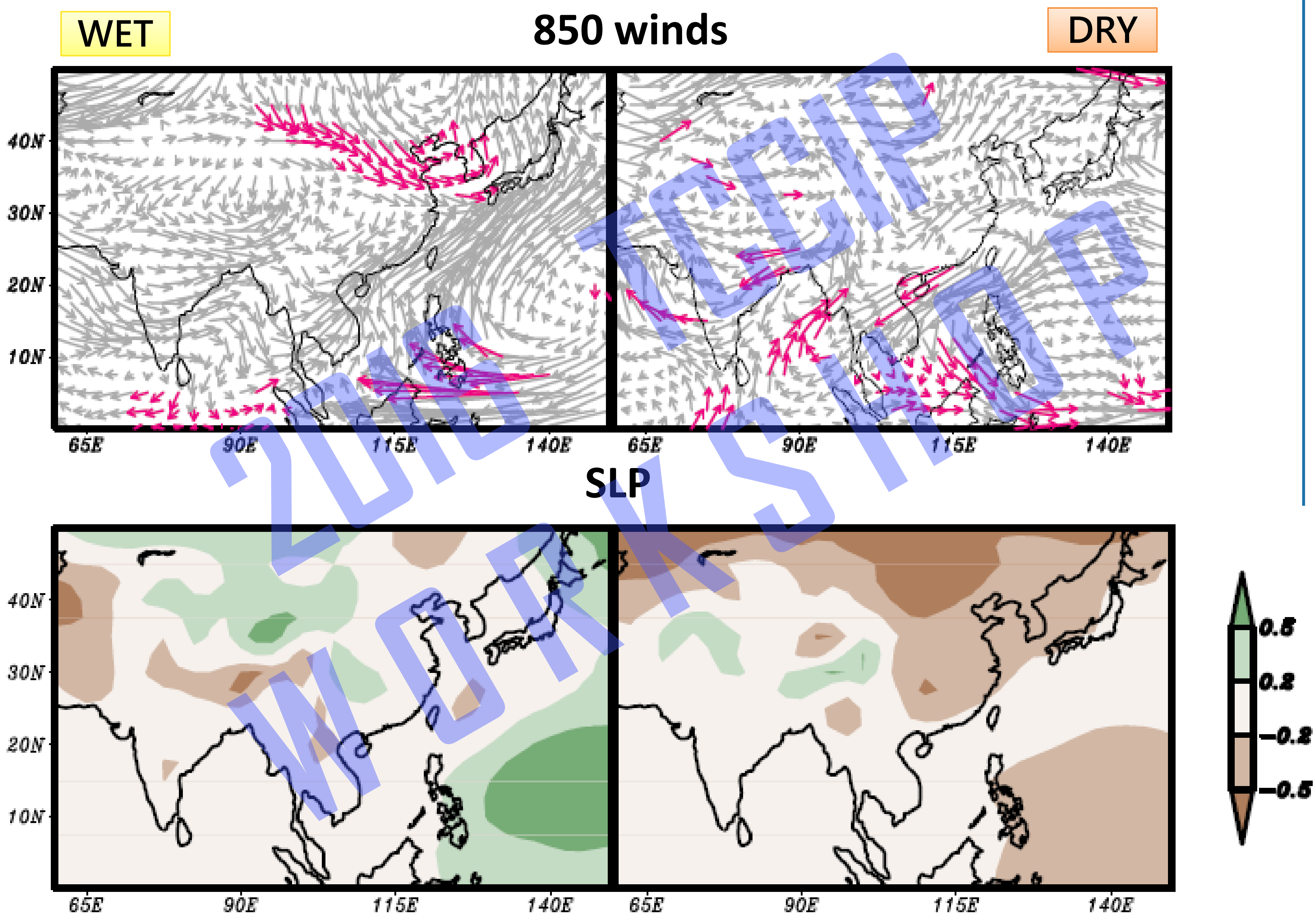
Major impacts:
Reservoir water storage

- Agriculture
- IT Industry
- Livelihood activity

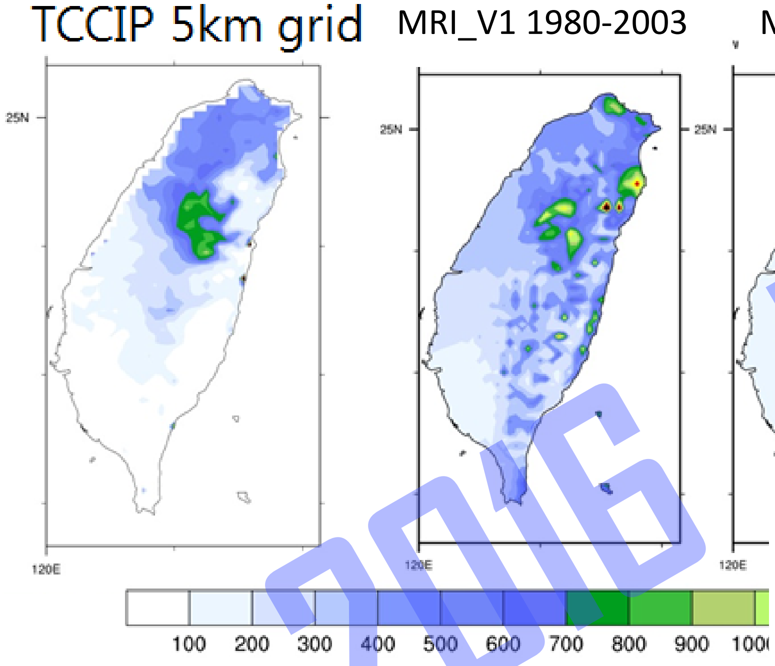


Contribution (ratio) to annual rainfall

Characteristics of large-scale circulation

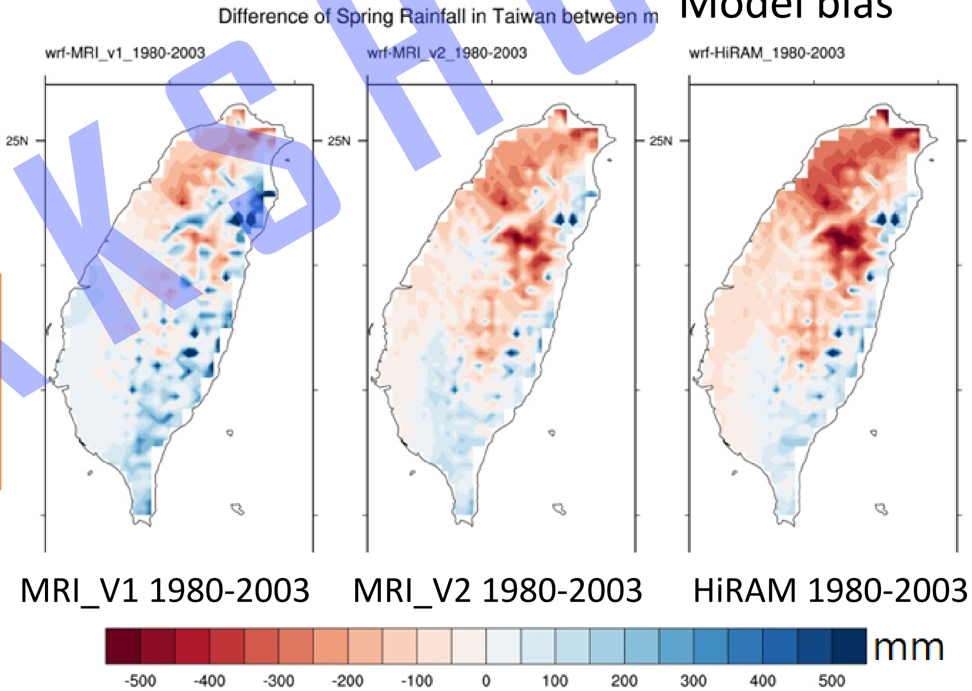


Dynamic Downscaling



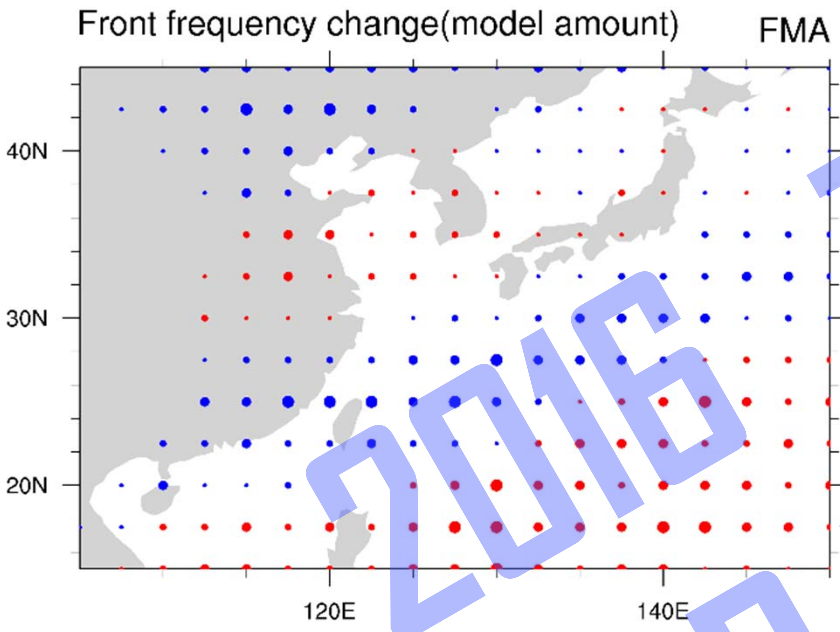
AGCM (20 km)
→WRF (5 km)

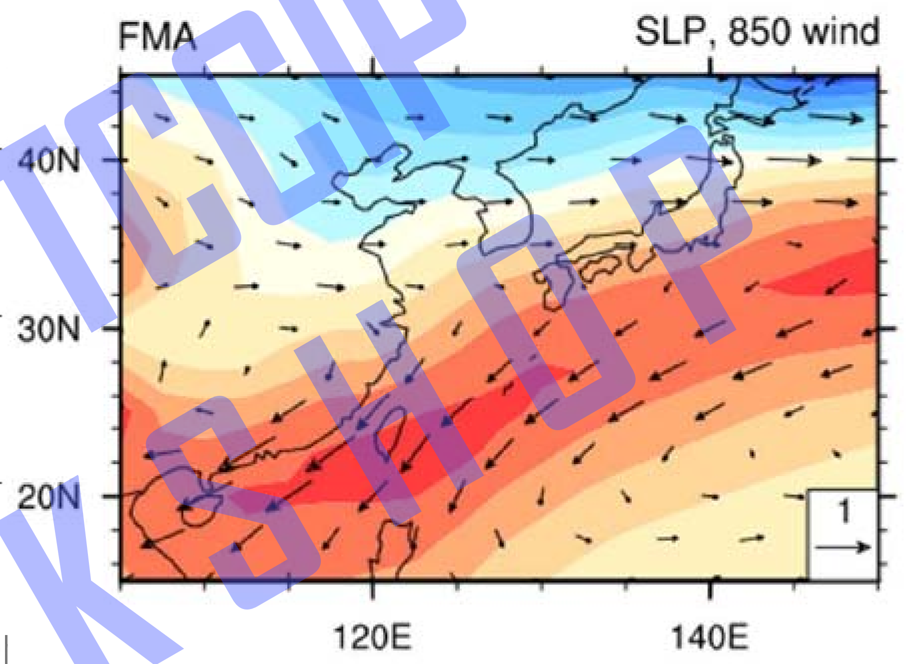
Model bias



- Models have difficulty simulating the key rainfall feature.

Future Change





Projected northeasterly anomaly and weaker frontal activity
→ Possibility of spring rain reduction in the future

-400 -350 -300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400

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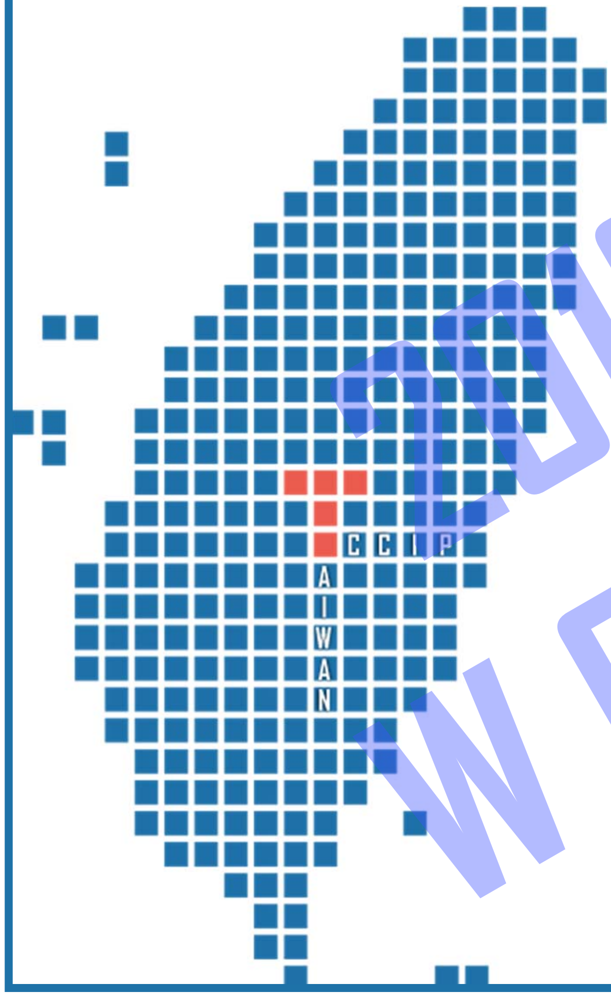
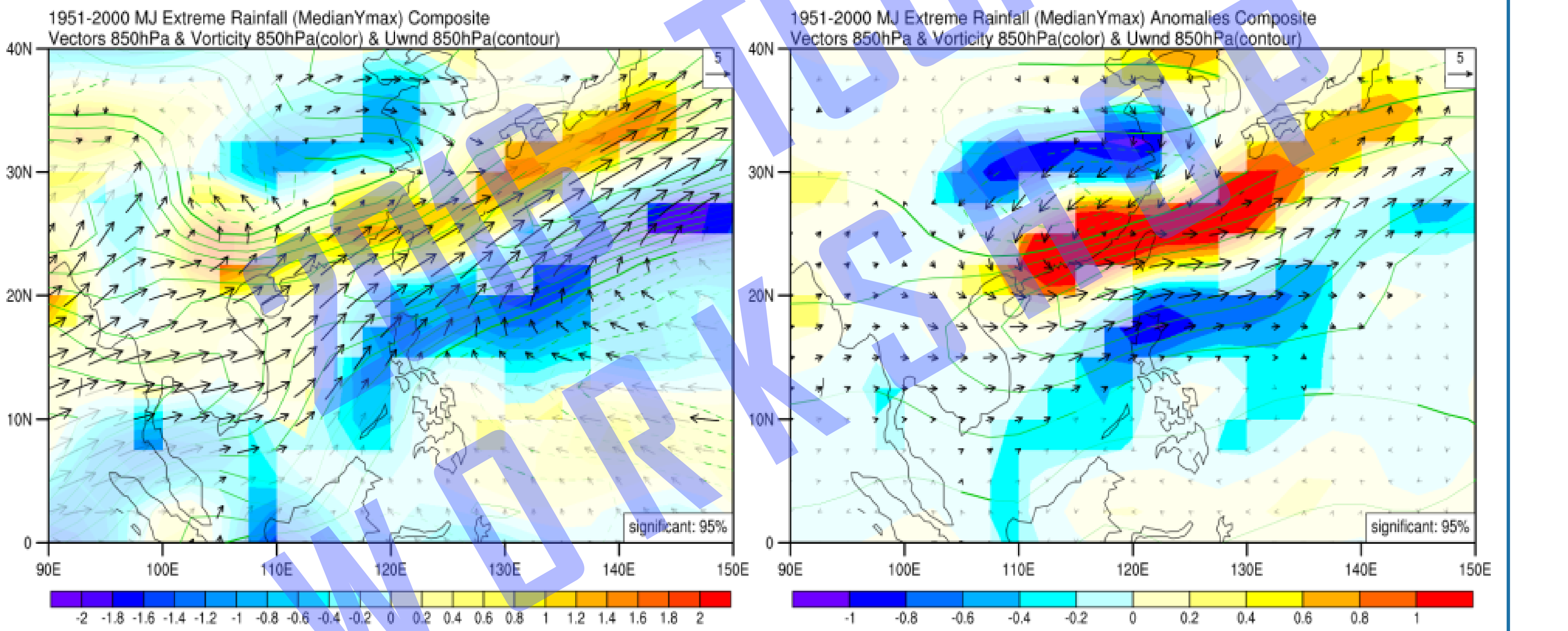


Mei-yu Extreme Rainfall

- 179 days in the 50 Mei-yu seasons are identified on which at least at one station saw the extreme event. The cases influenced by typhoons do not count.

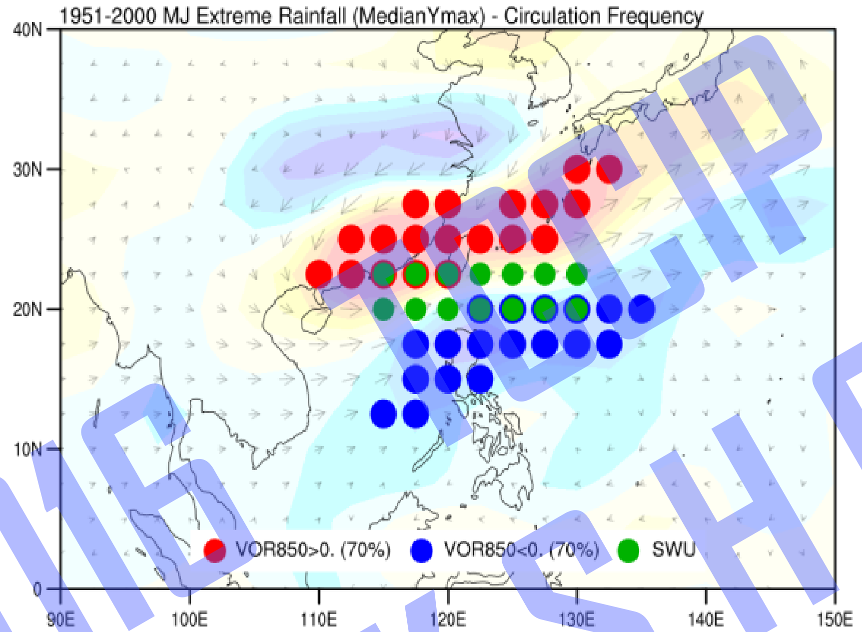
179 days total composite **179 days anomaly composite**



Blue: Negative Vor850

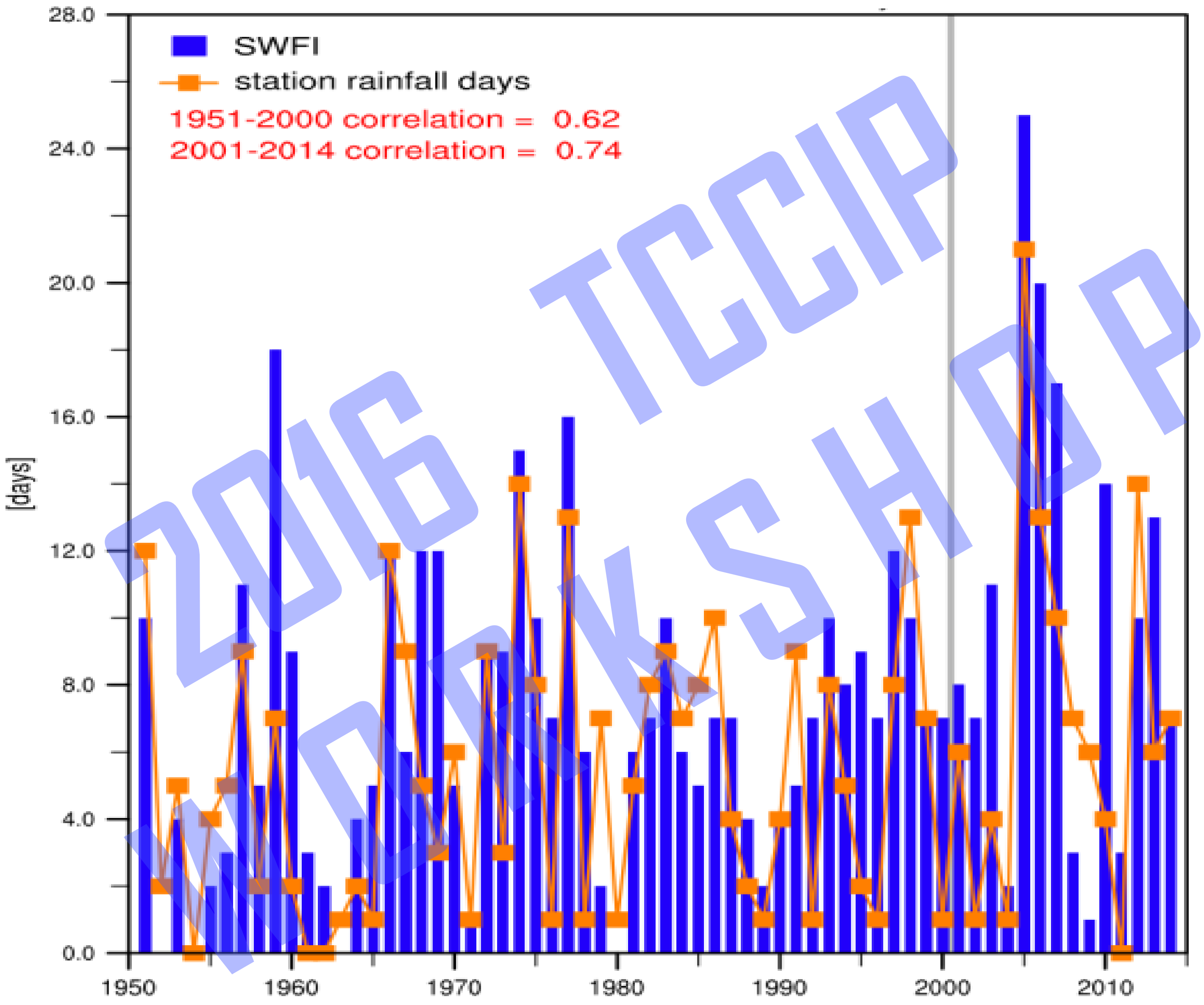
Red: Positive Vor850

The Large-scale Circulation Index: SWFI



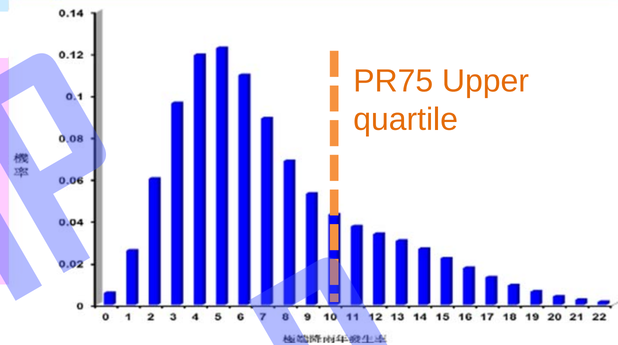
1. Select the days with favorable vorticity condition during May and June: positive vorticity over S. China and Taiwan (**red** grid) and negative vorticity over the SCS and Philippine Sea (**blue** grid)
2. Calculate the **SWU** – the mean U850 of the grids with strong vorticity gradient (**green** grid)
3. Determine **SWUc** on the multi-year climate basis: in this study - the **median** value of **SWU** in 50 years (1951-2000)
4. **SWFI** is defined **as the number of days during May and June** that satisfying the criteria of **850-hPa Vorticity** and **SWU >= SWUc**

SWFI (model analysis data) and Annual frequency of Taiwan Mei-yu Extremes (station data), Year: 1951-2014



7/10 models project future increase in occurrence of extreme rainfall at the end of century

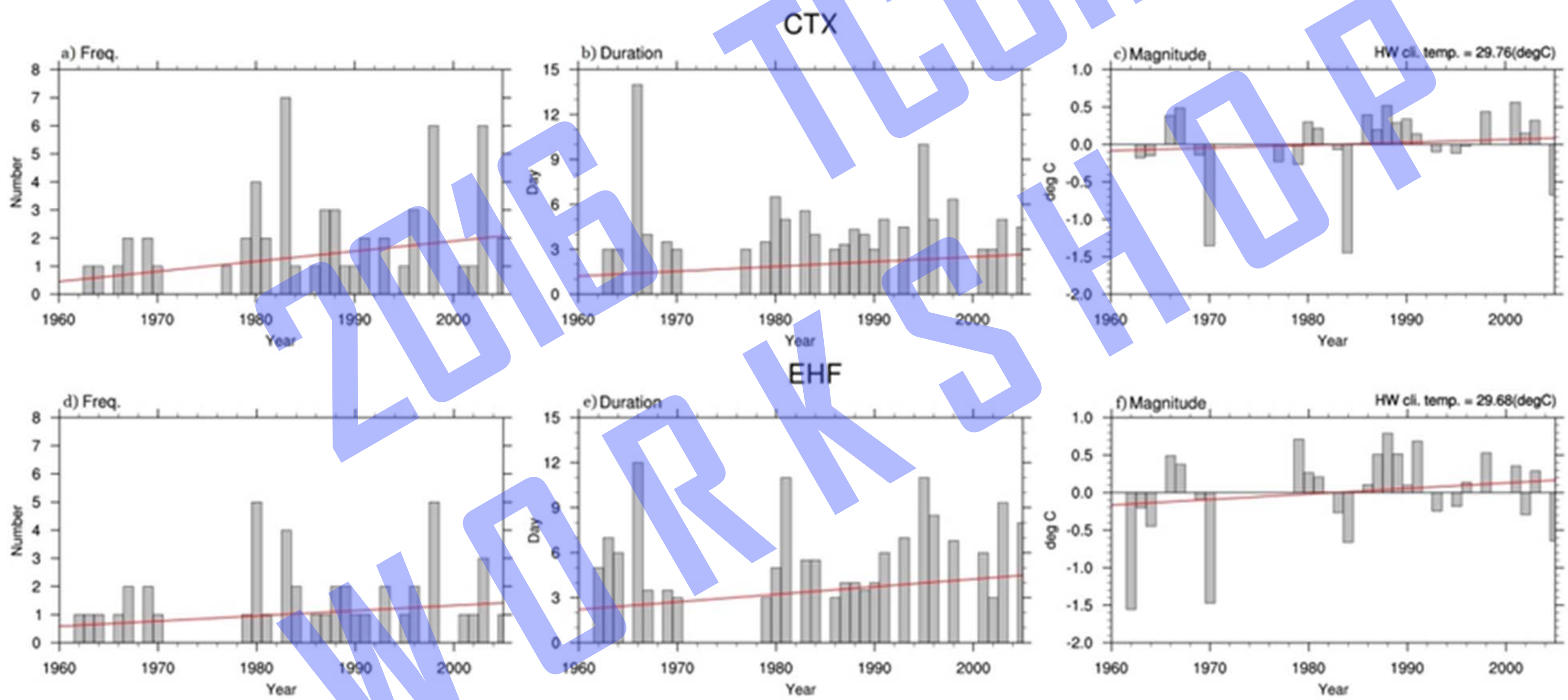
依據10個IPCC氣候模式資料推估未來臺灣梅雨季極端降雨事件頻率：以目前氣候(1986~2005)極端降雨事件累積機率第75百分位為門檻值，各模式於未來情境下三段時期高於門檻值的比例相對於25%的差異，負值表示極端事件發生率降低。



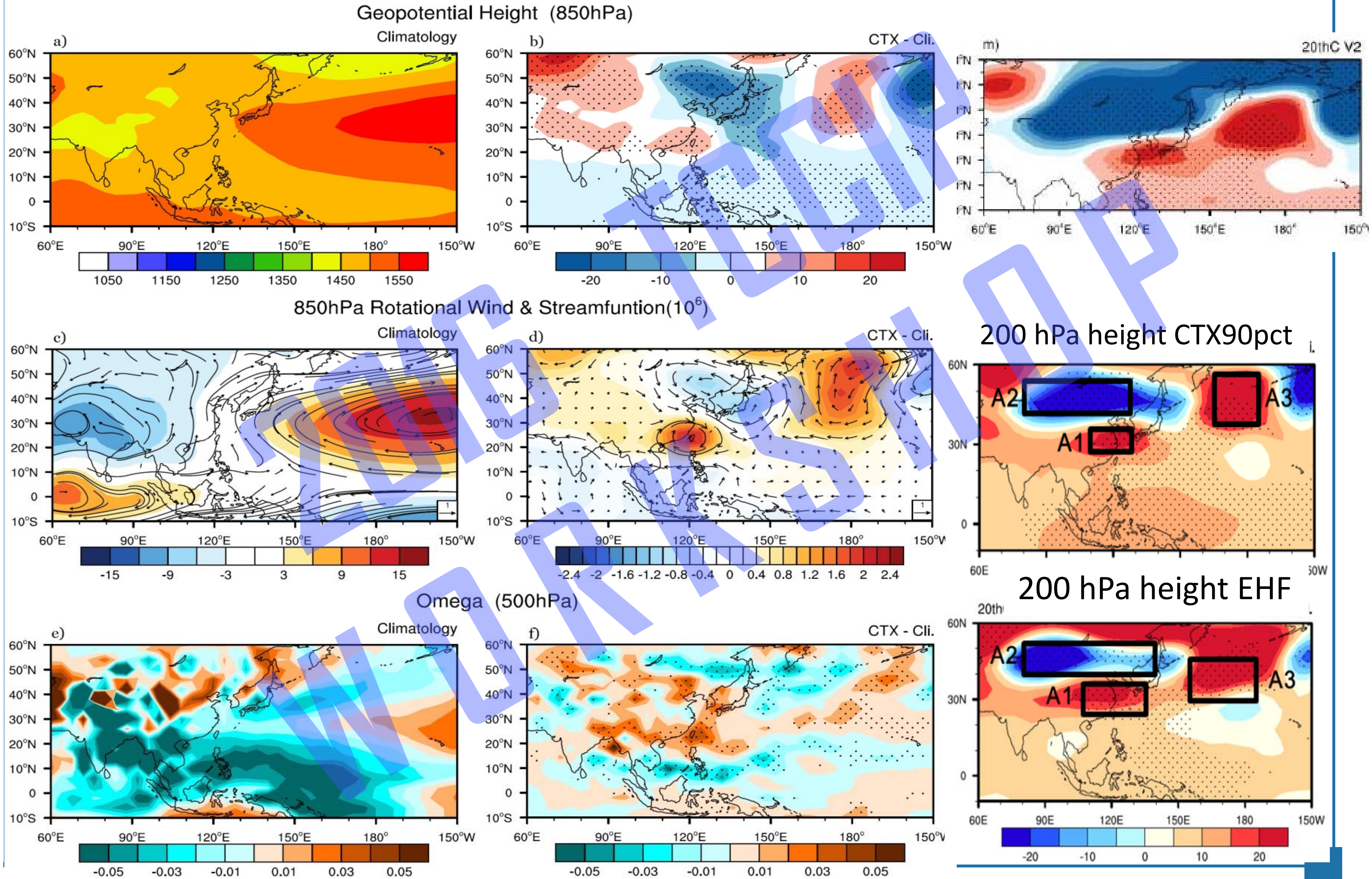
RCP8.5(%)	ACCESS_10	BNU_ESM	CMCC_CM	CNRM_CM5	HadGEM2_CC
Early	-19	-2	+3	-6	-2
Mid	-10	-6	+4	-11	+4
End	-3	-11	+3	+1	+2
RCP8.5(%)	IPSL_CM5A_MR	MIROC5	MPI_ESM_MR	MRI_CGCM3	NorESM1_M
Early	-6	+15	+18	-17	+4
Mid	-13	+15	-6	-10	-4
End	-16	+1	+16	+12	+15
RCP4.5(%)	ACCESS_10	BNU_ESM	CMCC_CM	CNRM_CM5	HadGEM2_CC
Early	-10	+4	+6	-9	+2
Mid	-6	+14	+3	-3	-5
End	-8	-16	+2	+7	+21
RCP4.5(%)	IPSL_CM5A_MR	MIROC5	MPI_ESM_MR	MRI_CGCM3	NorESM1_M
Early	-8	+8	+10	-13	-1
Mid	-6	+20	+13	-6	-3
End	-9	+11	+11	+7	+8

Heat Wave

Observed Heat Wave Trend
Frequency, Duration, and Magnitude
(based on CTX and EHF, observed Taiwan temperature)



Circulation



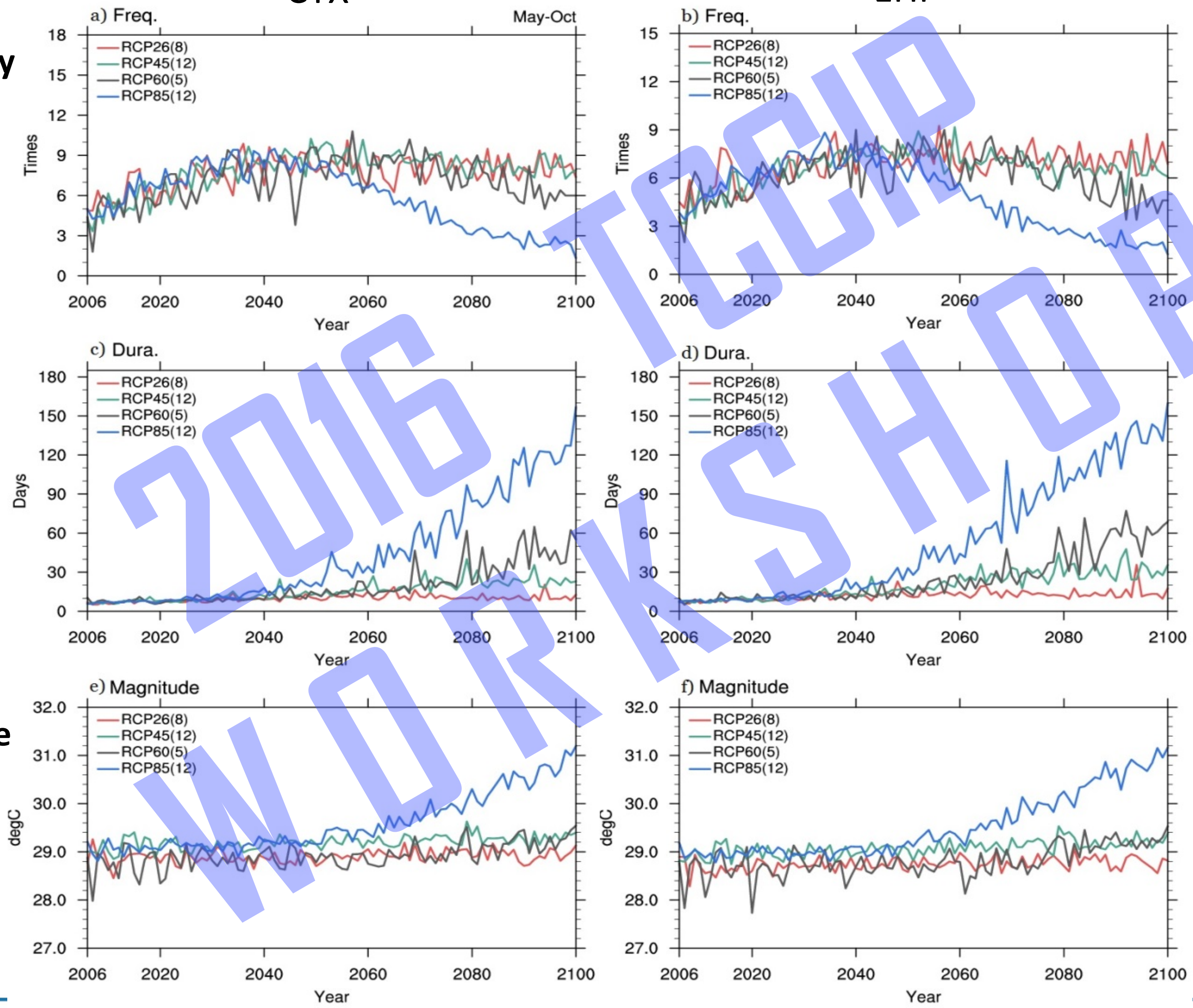
Changes in Heat Wave

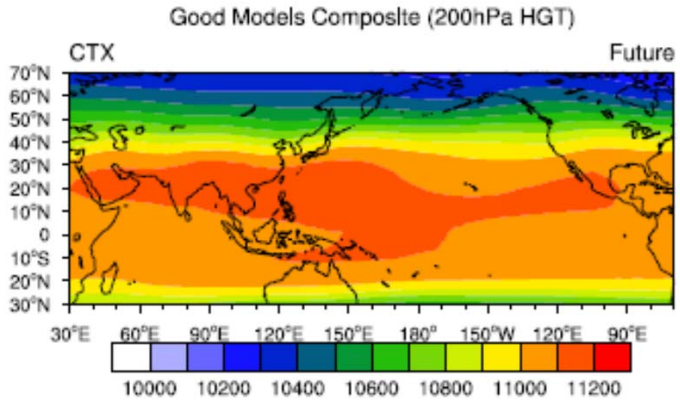
CTX | EHF

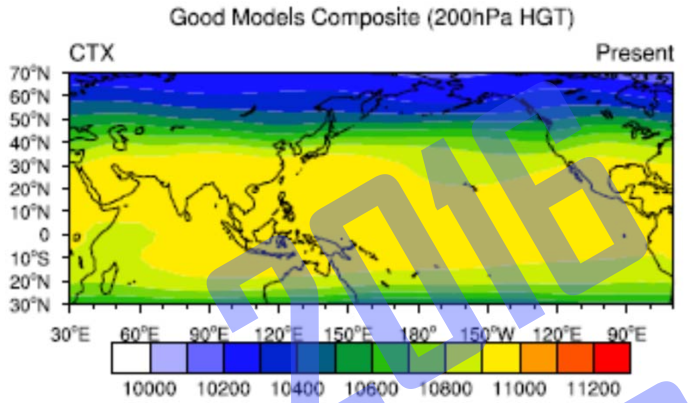
Frequency

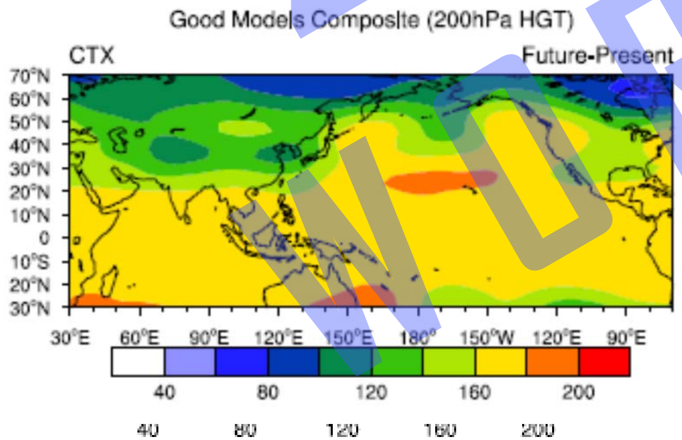
Duration

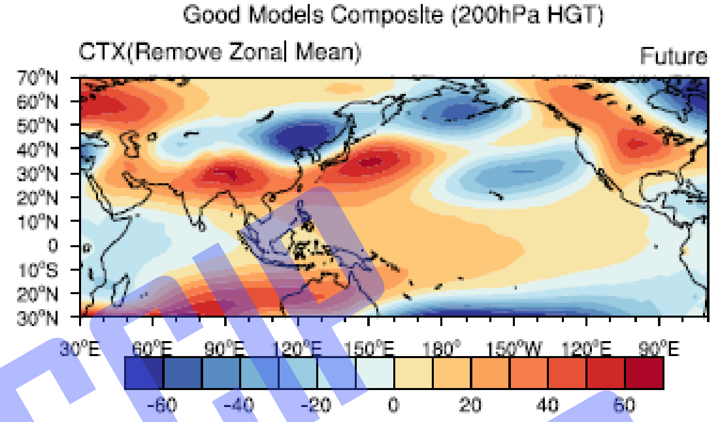
Magnitude

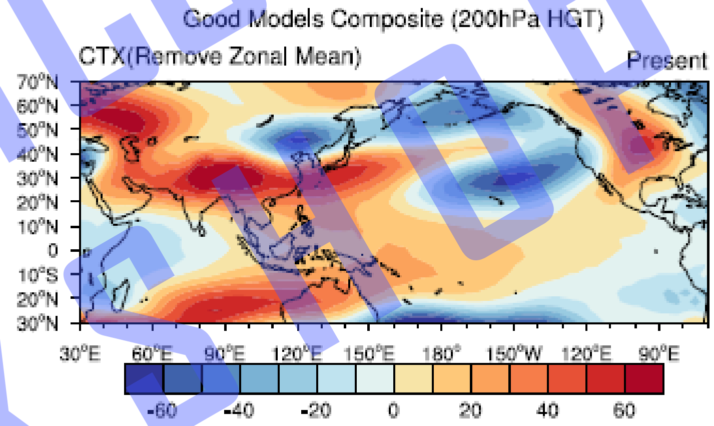


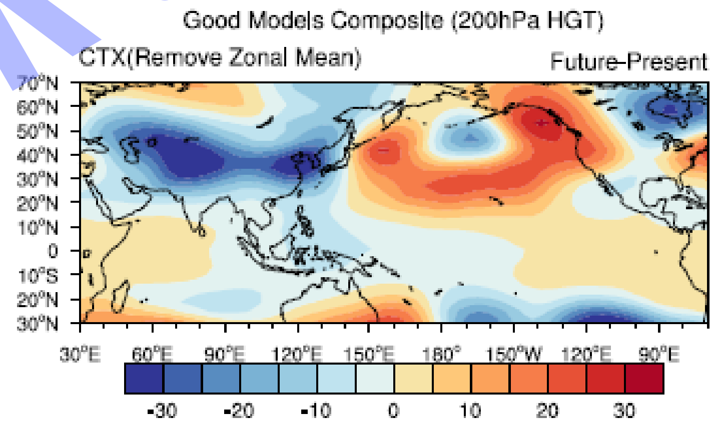

Good Models Composite (200hPa HGT)
CTX
Future
10000 10200 10400 10600 10800 11000 11200


Good Models Composite (200hPa HGT)
CTX
Present
10000 10200 10400 10600 10800 11000 11200


Good Models Composite (200hPa HGT)
CTX
Future-Present
40 80 120 160 200
40 80 120 160 200


Good Models Composite (200hPa HGT)
CTX(Remove Zonal Mean)
Future
-60 -40 -20 0 20 40 60


Good Models Composite (200hPa HGT)
CTX(Remove Zonal Mean)
Present
-60 -40 -20 0 20 40 60

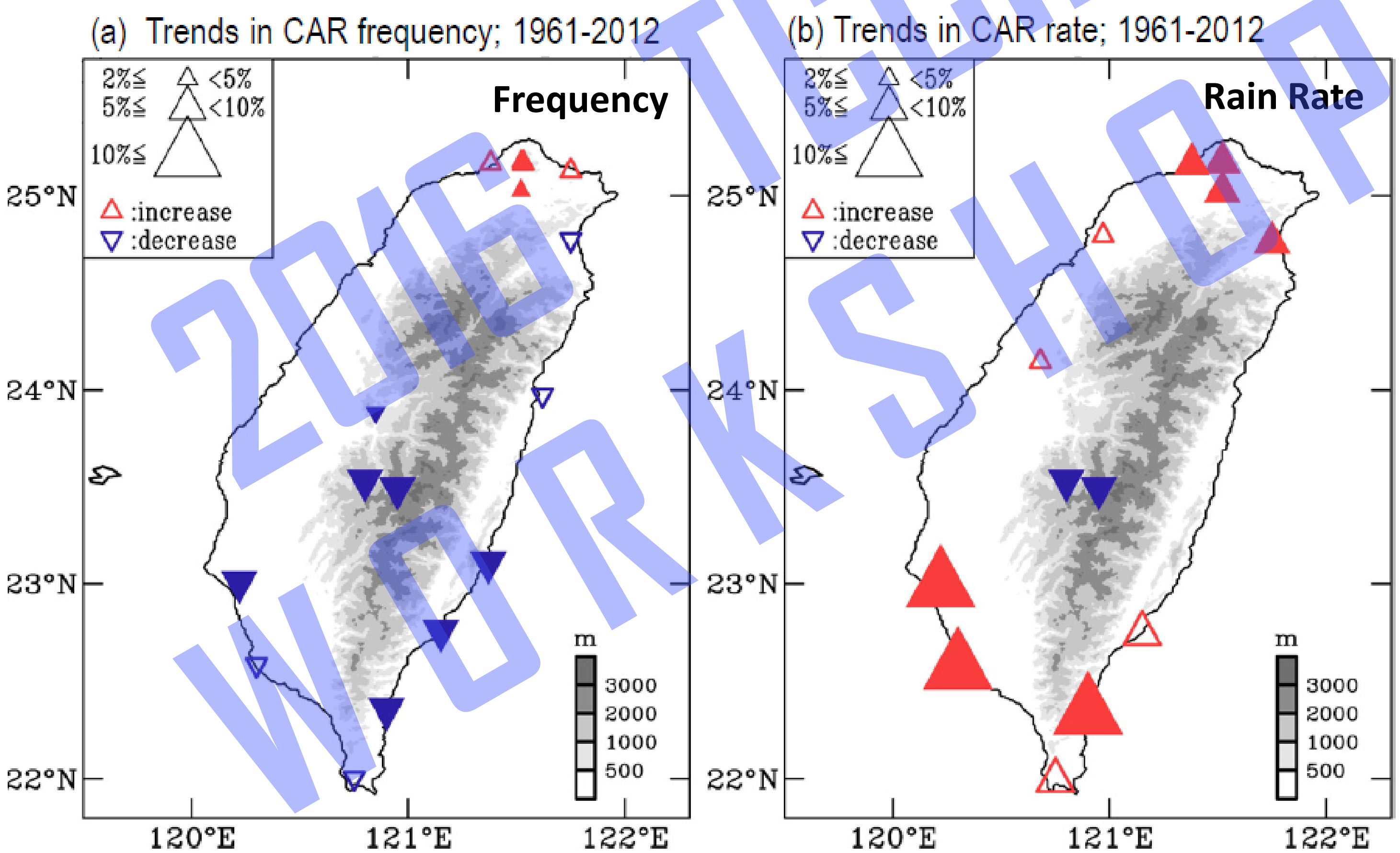

Good Models Composite (200hPa HGT)
CTX(Remove Zonal Mean)
Future-Present
-30 -20 -10 0 10 20 30

Afternoon Thunder Storm Activity

Convective Afternoon Rainfall (CAR)

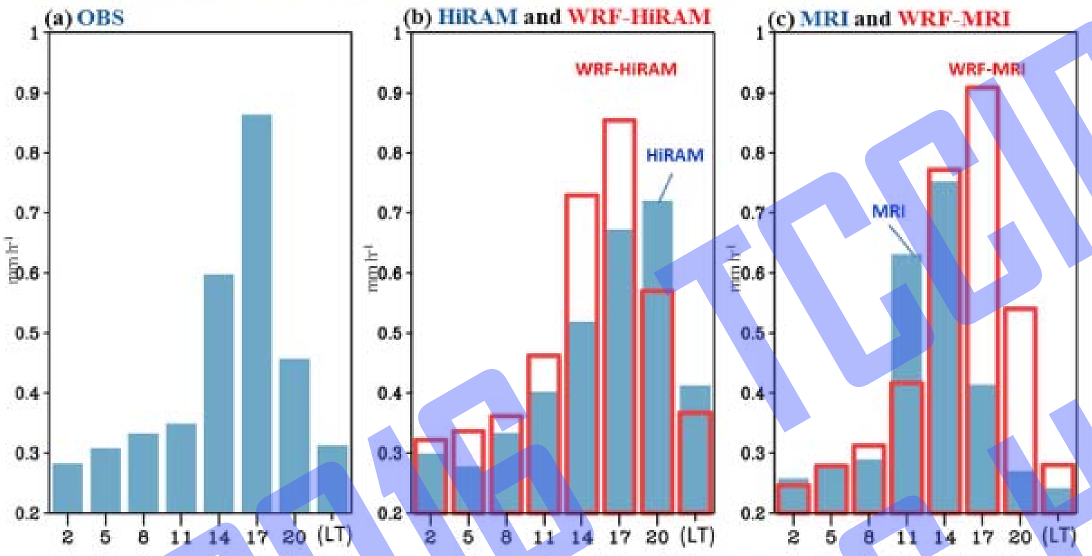
Observation

Significant regional contrast in observed trend (see Huang et al., JGR, 2015, for mechanism)

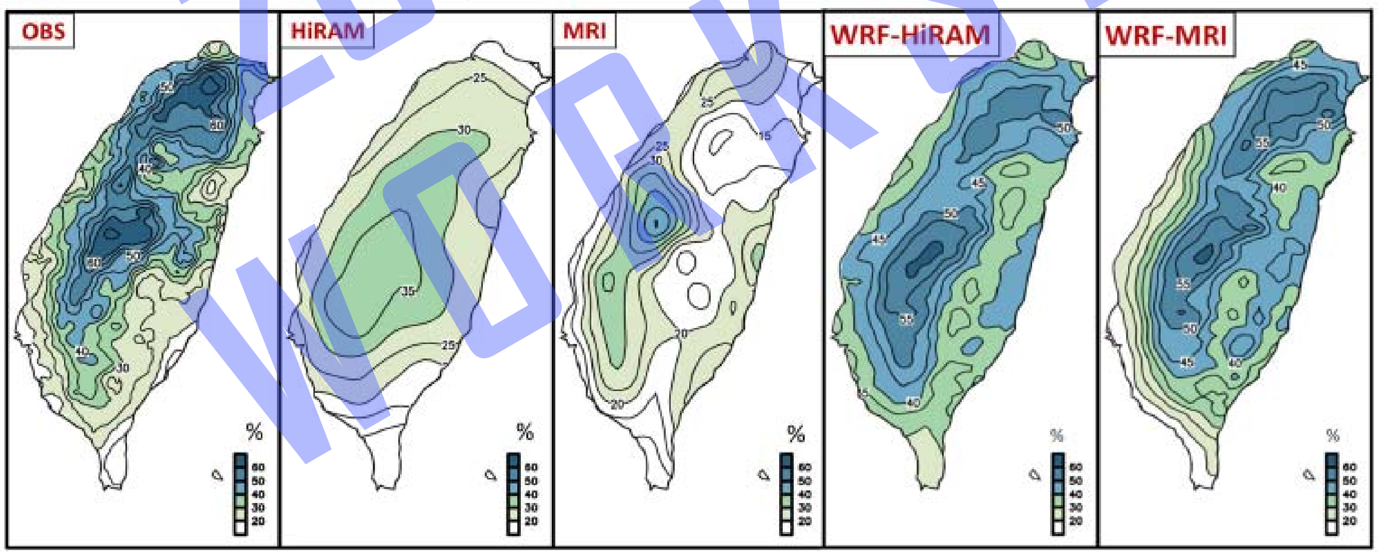


Present Climate (Validation)

Temporal evolution of climatological 3 hourly rain rate



Contribution of CAR to total summer rainfall



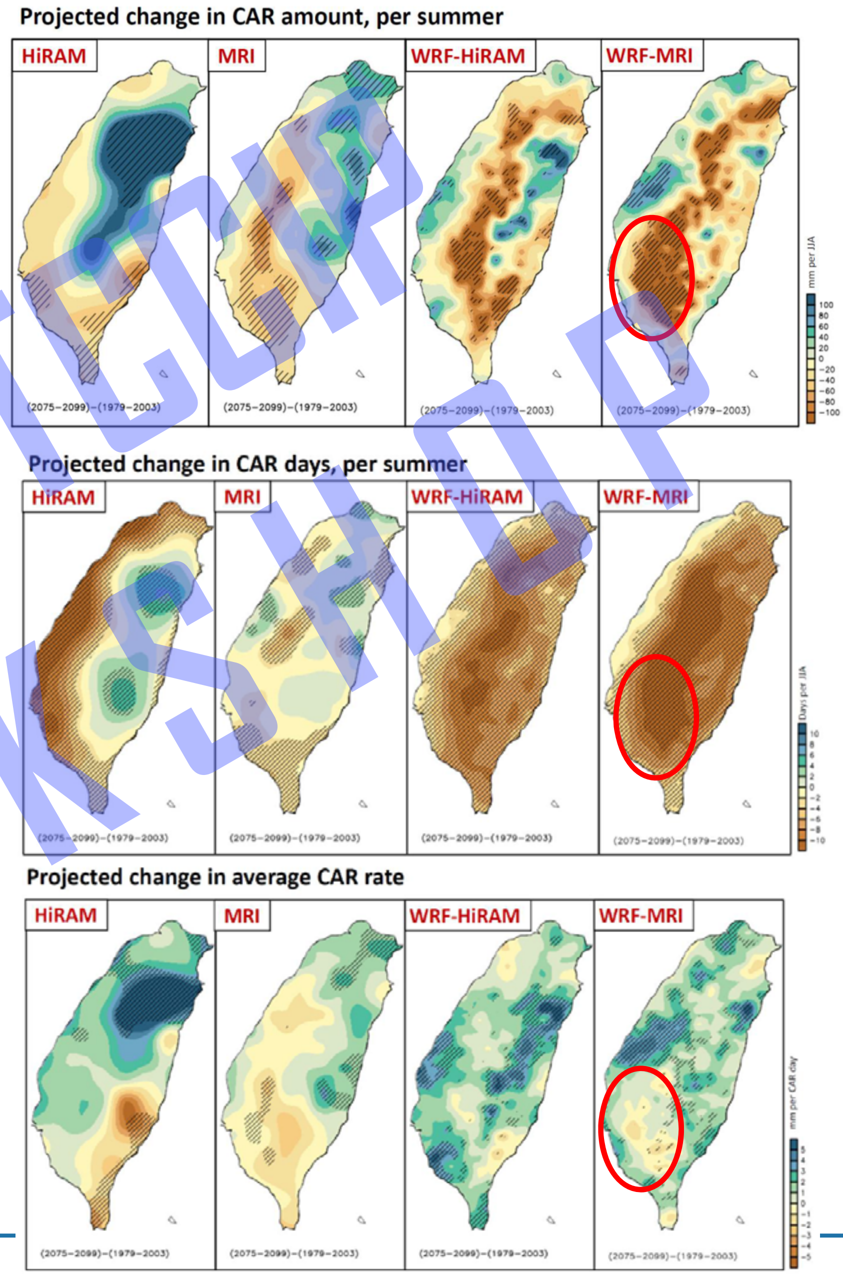
Dynamic downscaling corrects the biases of simulated evolution and distribution of CAR activity by AGCM.

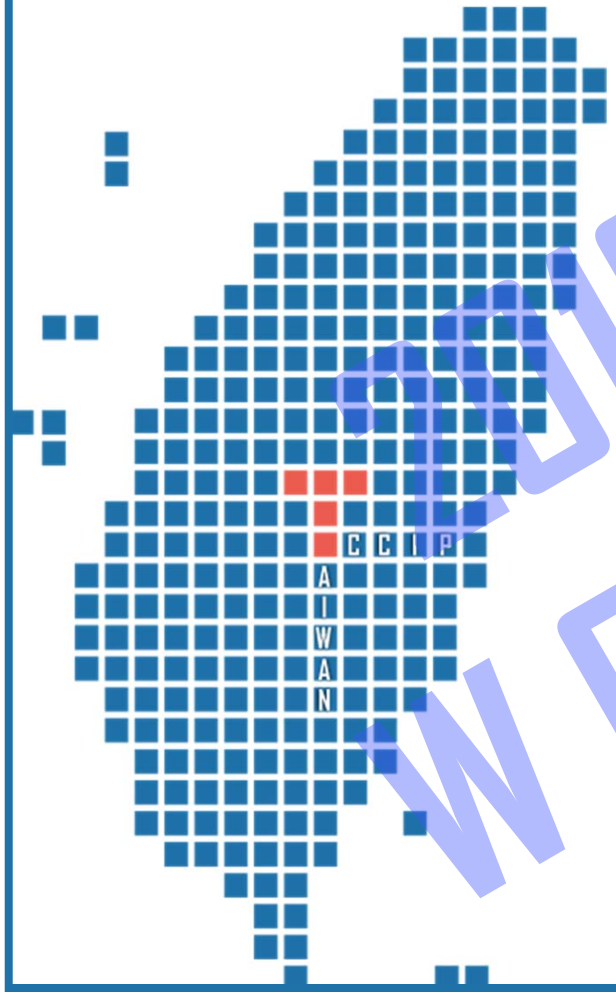
Future Projection(1)

- Downscaling produces more consistent projection between models

- Projection (SW Taiwan):
  - total CAR rainfall and frequency: reduced;
  - no consistent results for rainfall strength

- Reduced low-level convergence and enhanced stability





Thank you for your attention

MJO與台灣地區冬春季(NDJFMA)降雨機制探討

Journal

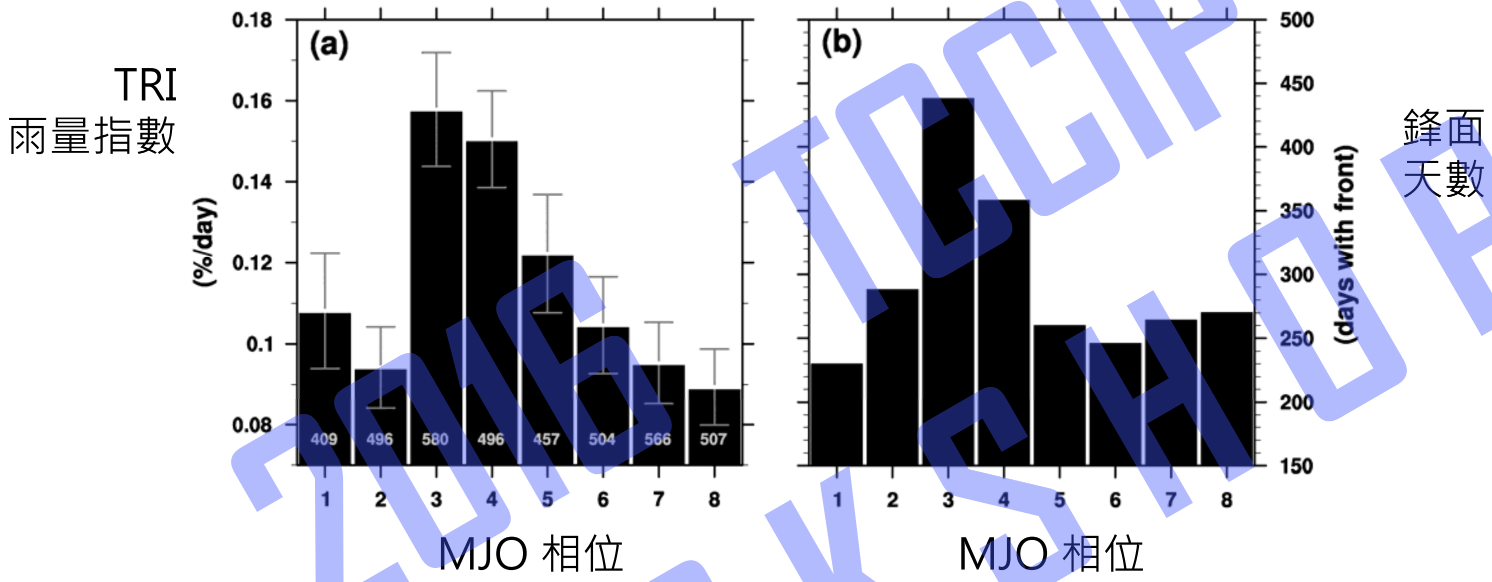
Hung C.-W., H.-J. Lin, H.-H. Hsu, 2014: Madden–Julian Oscillation and the Winter Rainfalls in Taiwan, J. Climate.

Conference

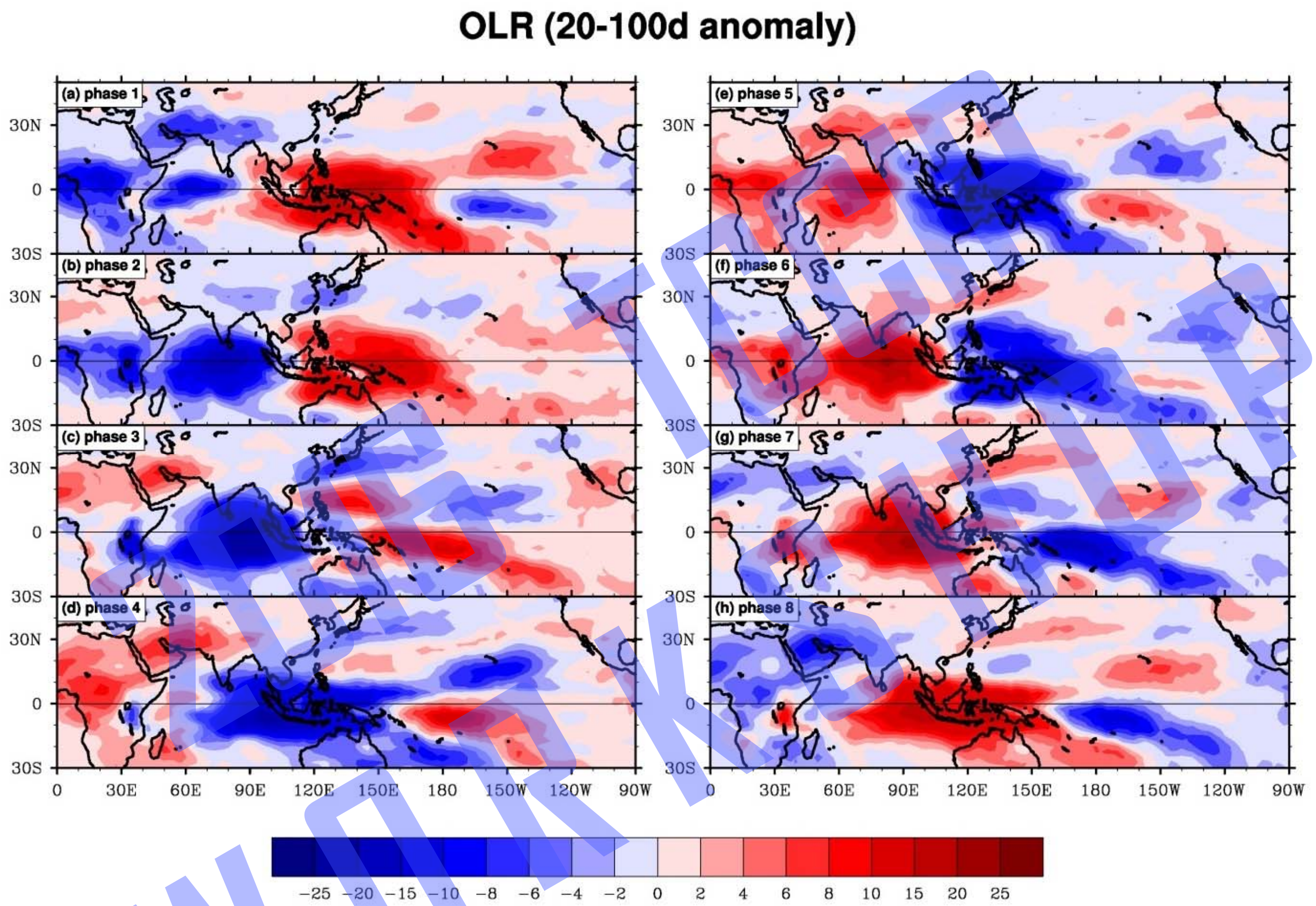
Hung C.-W., H.-J. Lin, H.-H. Hsu, 2014: Madden–Julian Oscillation and the Winter Rainfalls in Taiwan. AOGS 11th Annual Meeting (AOGS2014), 2014.7.28-8.1, Sapporo, Japan.

Hung, C.-w., and H.-J. Lin, 2013: Impacts of the Madden-Julian Oscillation on the East Asian Winter Monsoon Rainfalls Observed in Taiwan. 2013 International Geographical Union (IGU) Kyoto Regional Conference, 2013.8.4-9, Kyoto, Japan.

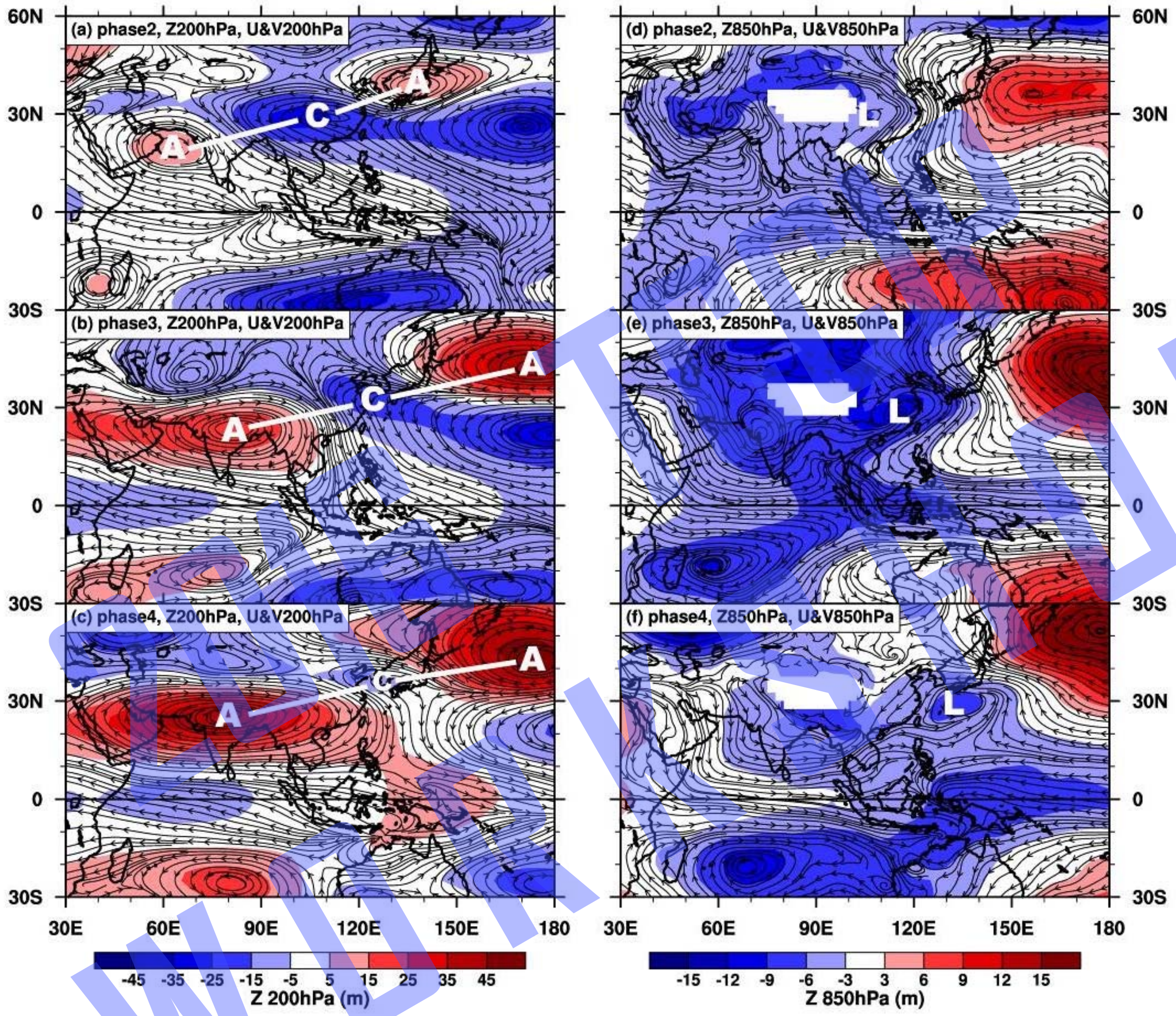
林和駿、洪致文，2013：季內尺度MJO對臺灣冬半季降水的影響。102年天氣分析與預報研討會，2014.5.13-15，中壢。



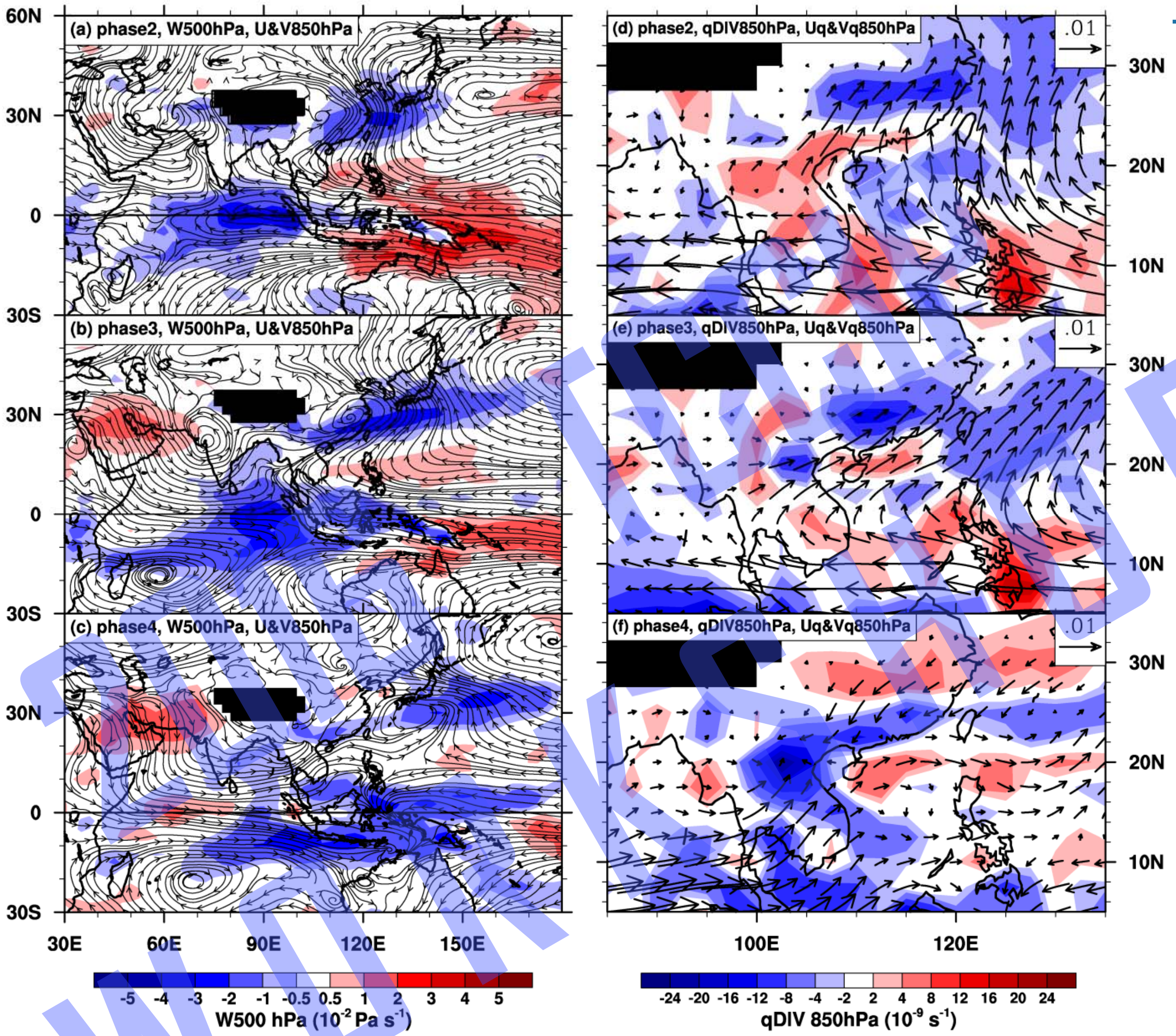
（a）1974-2009年MJO相位1-8的TRI指數平均值，長條圖下方的數字代表該相位的個案數目。（b）1974-2009各個MJO相位台灣附近（118-124E, 20-28N）有鋒面之天數。



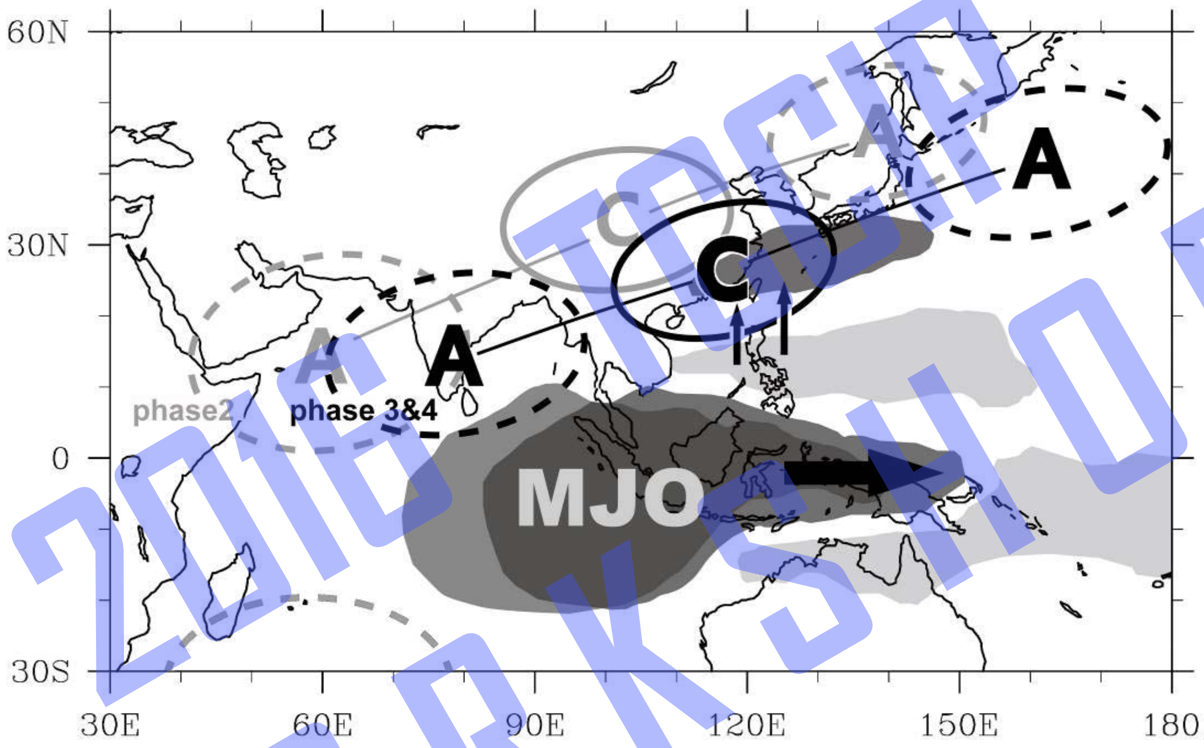
經過20-100天濾波處理的OLR距平圖，a至h分別為MJO相位1-8。



（a）MJO phase 2合成圖（20-100天濾波)距平場，200hPa重力位高度（紅藍色塊，單位：m）及200hPa氣流線，圖中”A”與”C”分別代表反氣旋及氣旋，白色直線連結的為同一個波列。（b）、（c）與（a）相似，但分別為MJO相位3及4。（d）、（e）及（f）相似於（a）、（b）及（c），但為850hPa，圖中的“L”代表低壓。



（a）MJO phase 2合成圖（20-100天濾波）距平場，500hPa垂直速度（紅藍色塊）及850hPa流線場。（b）及（c）與（a）相似，但是相位3及4。（d）、（e）及（f）分別與（a）、（b）及（c）相似，但是850hPa的水氣傳送場*uq***i**及*vq***j**（*q*是比溼），及水氣輻散場（紅藍色塊，單位10^{-9} s^{-1}）。



MJO影響台灣冬半季降雨的兩種機制概念圖。深灰色跟淺灰色分別代表上升及下沉區，” A” 跟” C” 分別代表反氣旋及氣旋，” MJO” 表示MJO對流中心。大箭頭表示MJO的移動方向，小箭頭表示往台灣附近的南來水汽供應，相位2及相位3&4波列的位置分別用灰色及黑色表示。

Definition

- **Occurrence of cold surge：**

The percentile rank of daily minimum temperature is lower than 10th percentile or the rank of 48-hour temperature drop is higher than 90th percentile.

- **End of cold surge:**

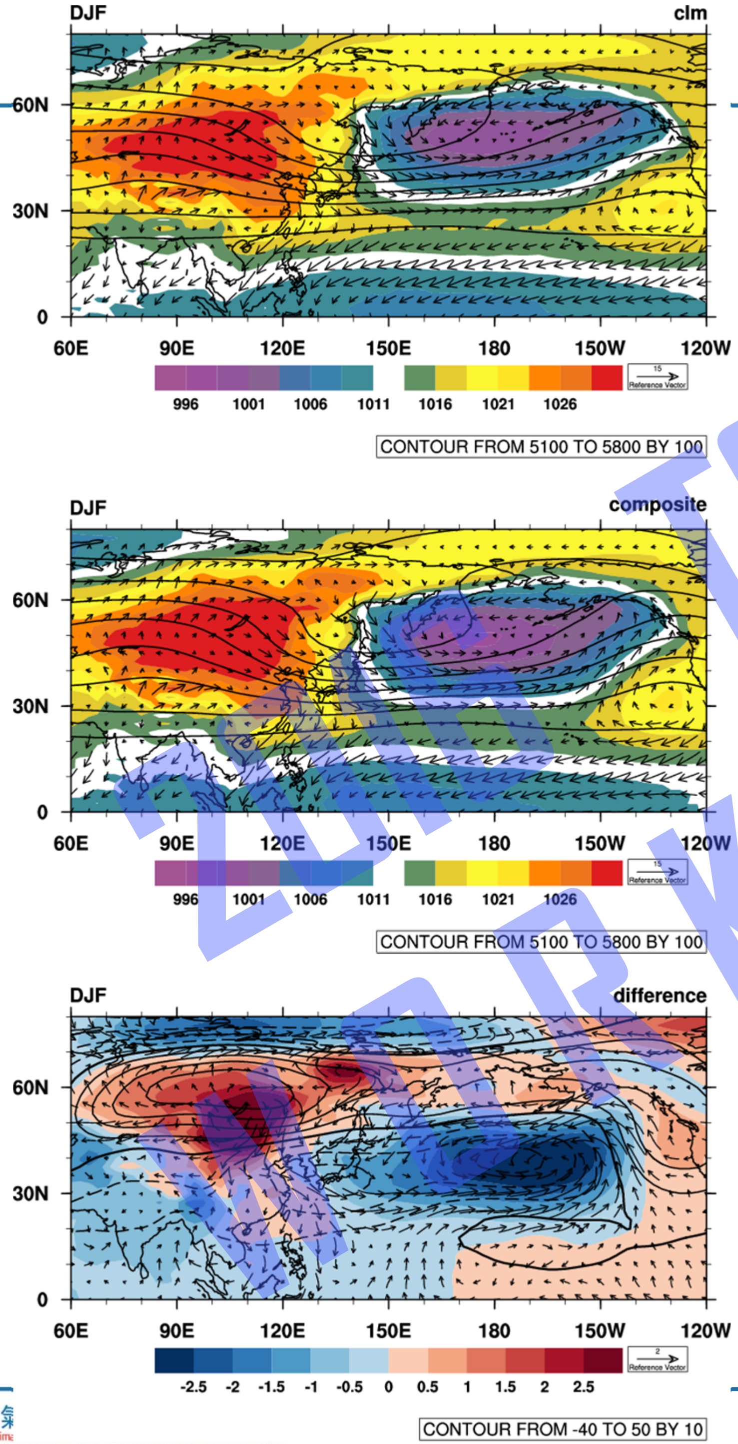
The percentile rank of daily minimum temperature is higher than 20th percentile or the rank of 24-hour temperature rise is higher than 90th percentile.

- **Cold day:**

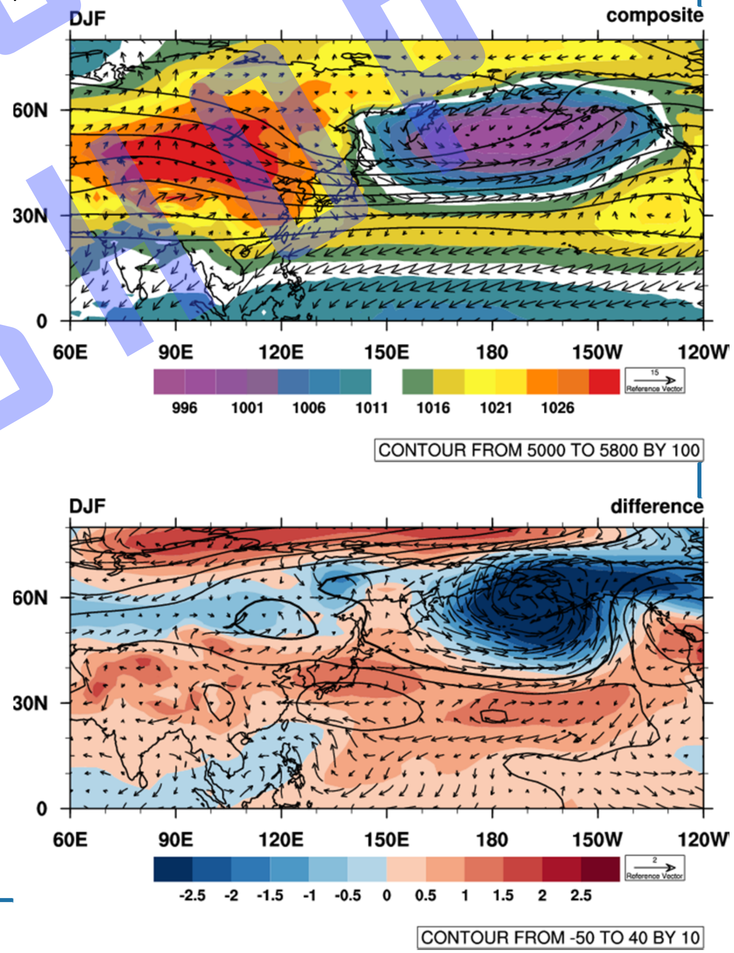
The day of daily minimum temperature below 10th percentile.

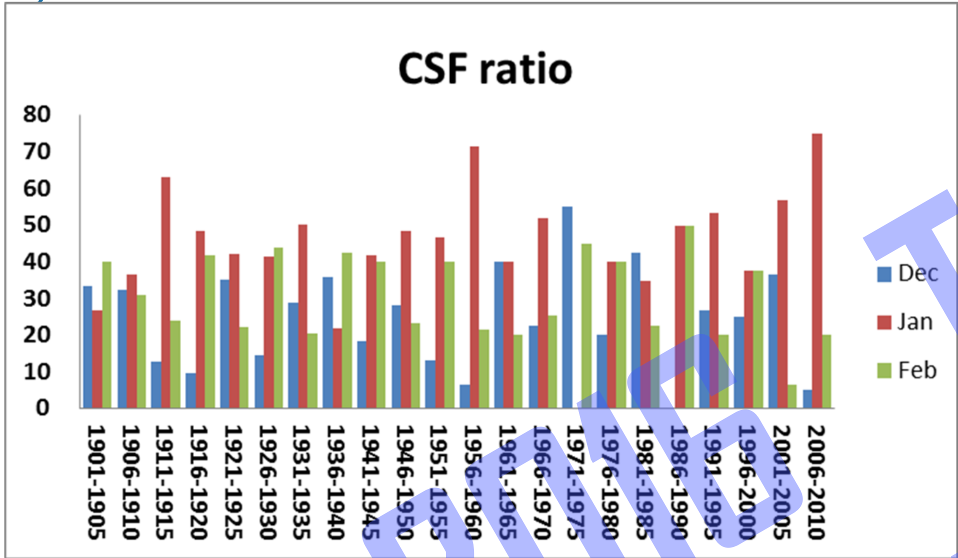
(Lu and Lee, 2009)

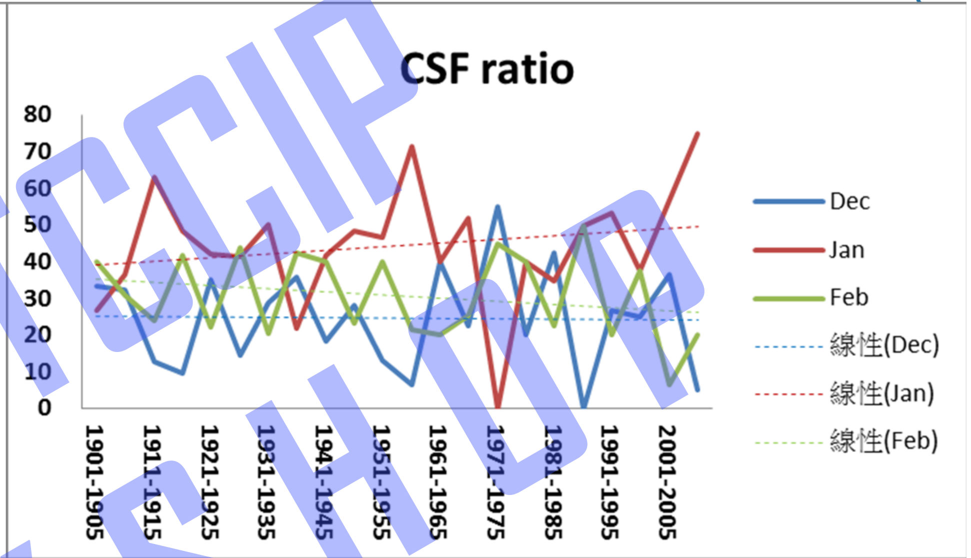
寒潮偏多年:
1961,1962,1963,1966,1967,1985
(1950-2011年 寒潮頻率大於1個標準差的年份)



寒潮偏少年:
1982,1987,1989,1990,2000,2011
(1950-2011年 寒潮頻率大於1個標準差的年份)





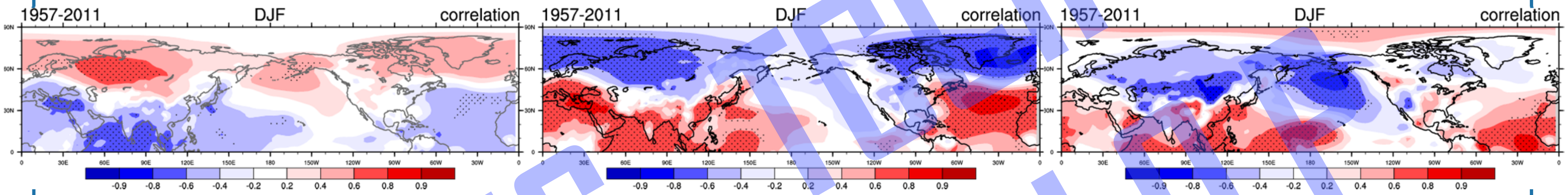


1901-2010 Taipei

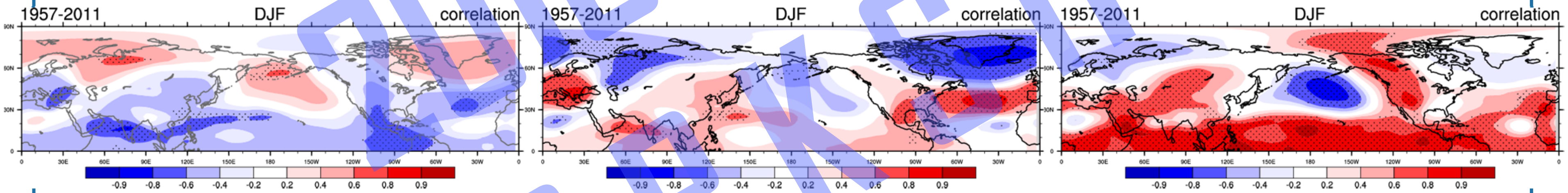
466920	Dec	Jan	Feb	DJF
freq	79	141	94	14
day	155	433	300	888

Correlation of CSF & | Correlation of NAO index & | Correlation of PDO index &

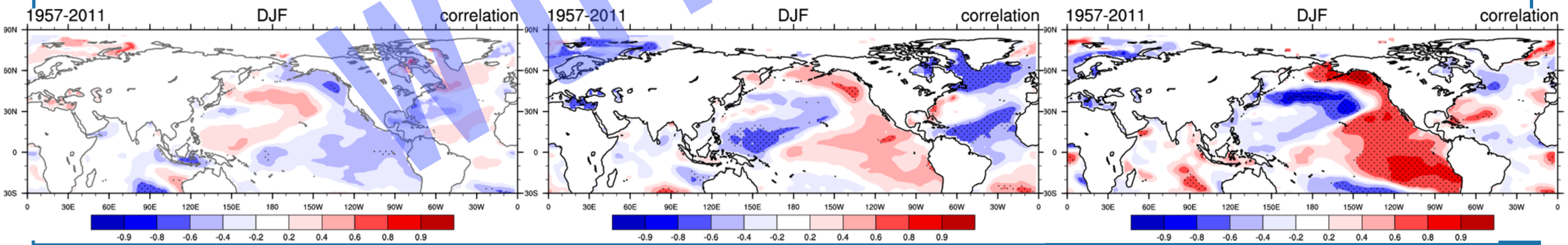
sea level pressure

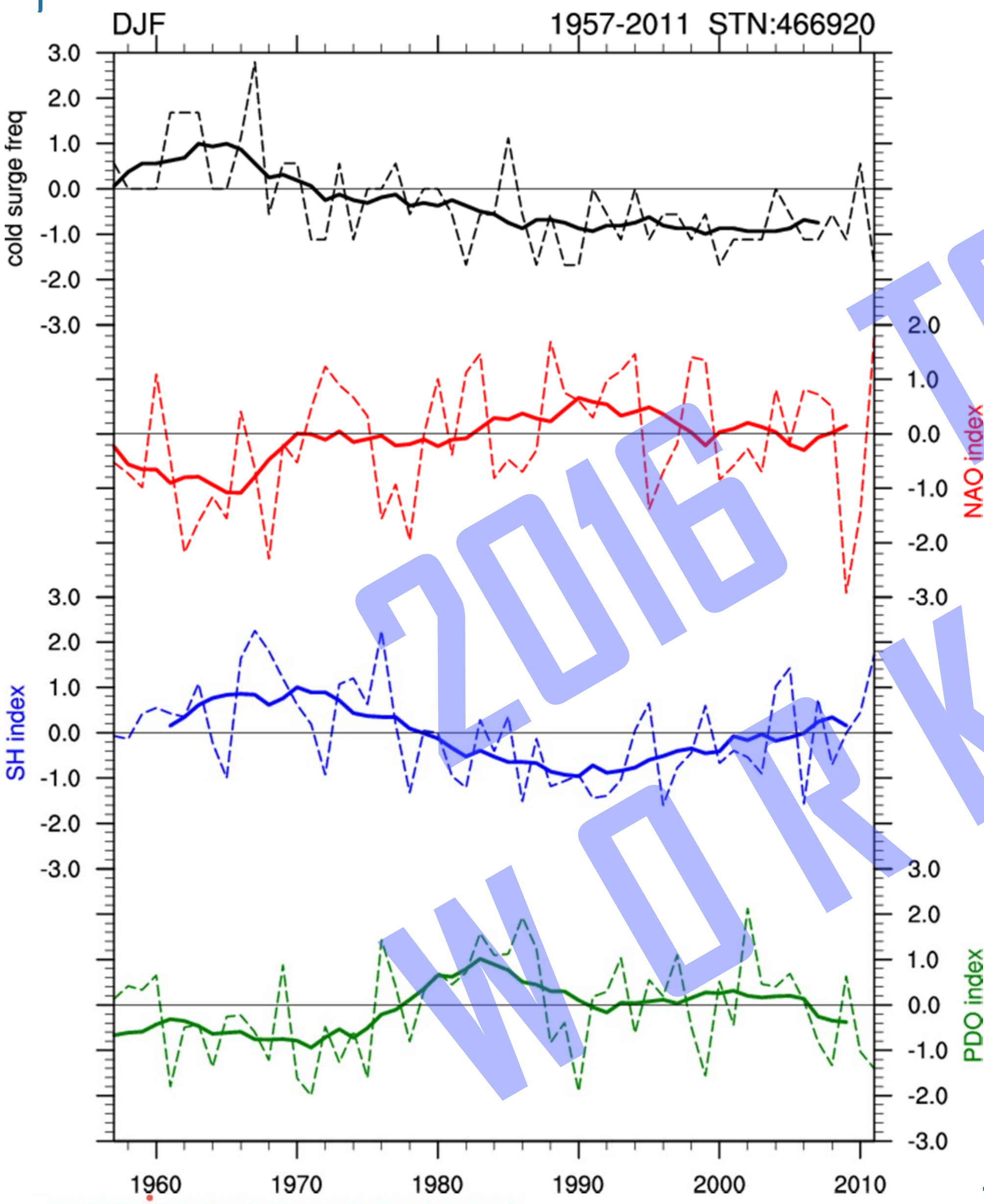


500hPa geopotential height



sea surface temperature





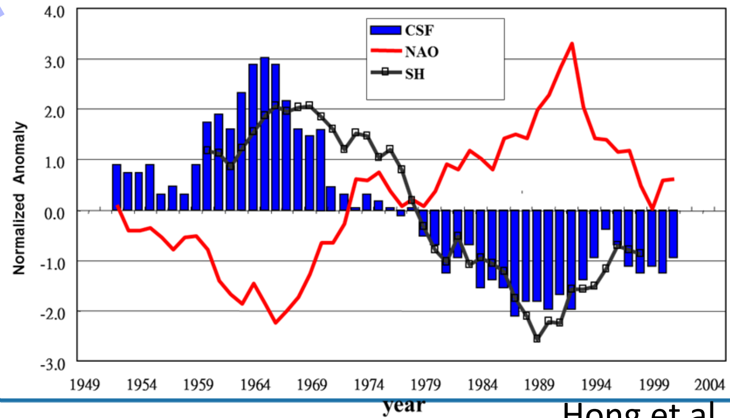
	寒潮頻率	
	年際	年代際
NAO	-0.30	-0.85
AO	-0.28	-0.80
SH	0.45	0.77
Nino3.4	-0.14	-0.27
PDO	-0.13	-0.63

	年際	年代際
NAO	-0.30	-0.85
SH	0.45	0.77
PDO	-0.13	-0.63

Cr(SH,CSF)=0.89

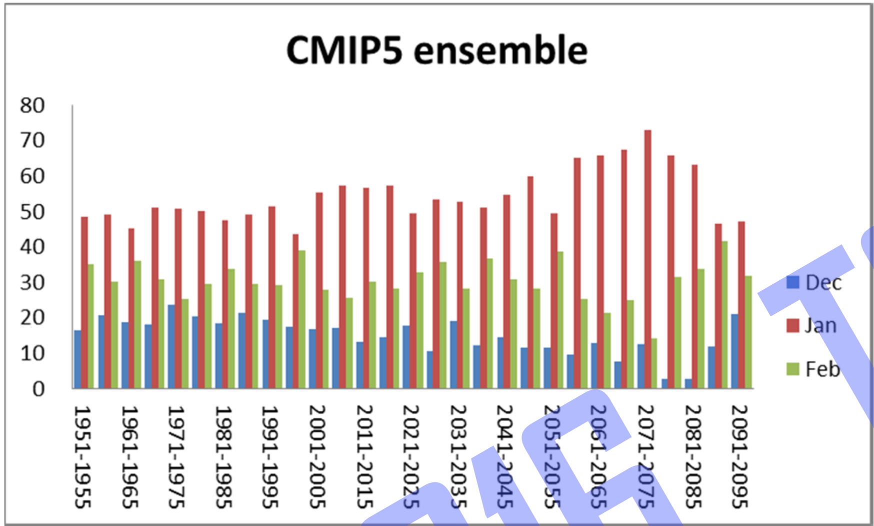
Cr(NAO,CSF)=-0.86

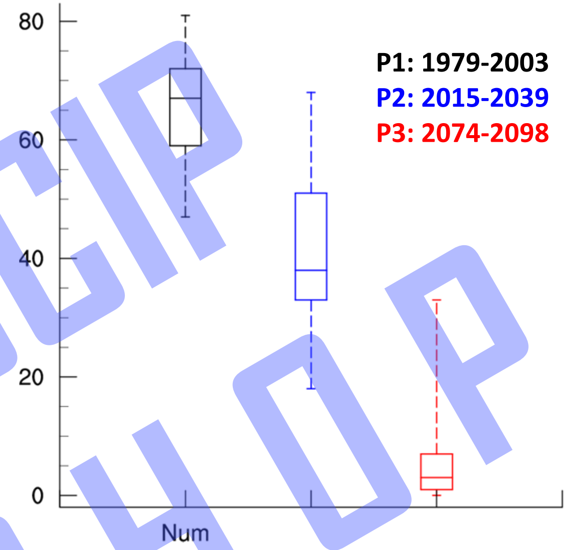
Cr(NAO,SH)=-0.73



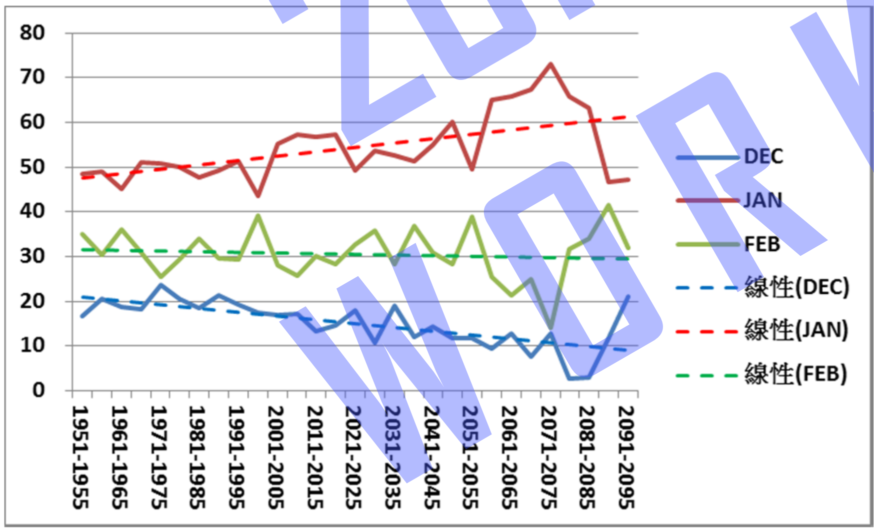
Hong et al . (2008)

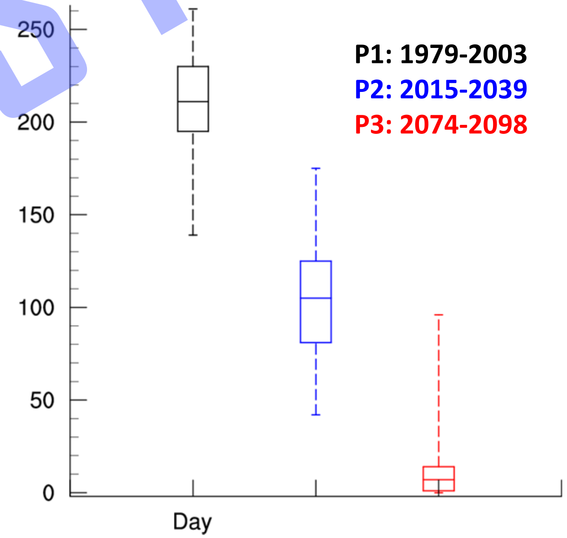
Frequency



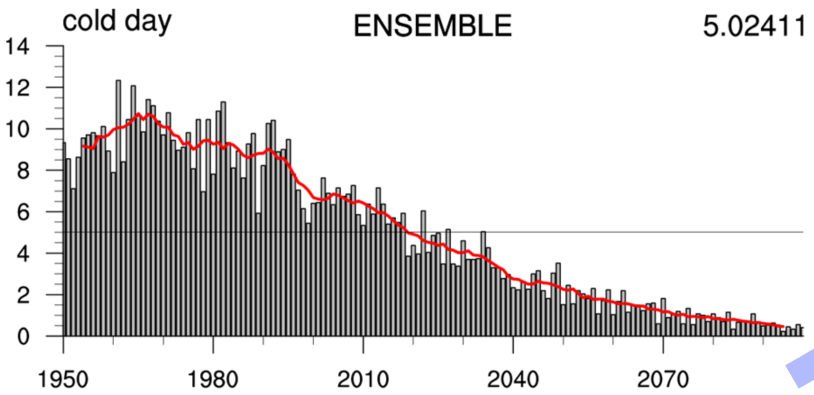


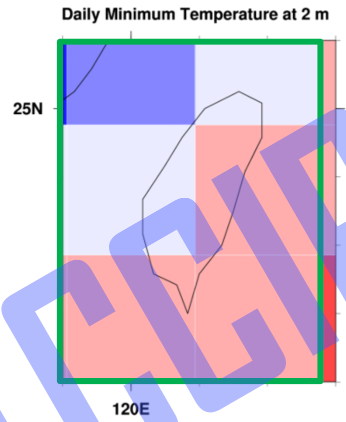
Duration





寒潮分析



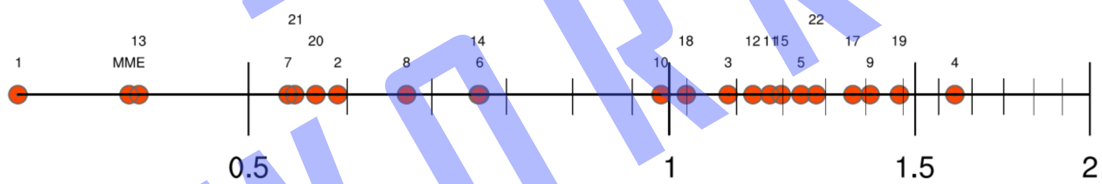


Data:
NCEP R1 Daily
Minimum
temperature at 2m

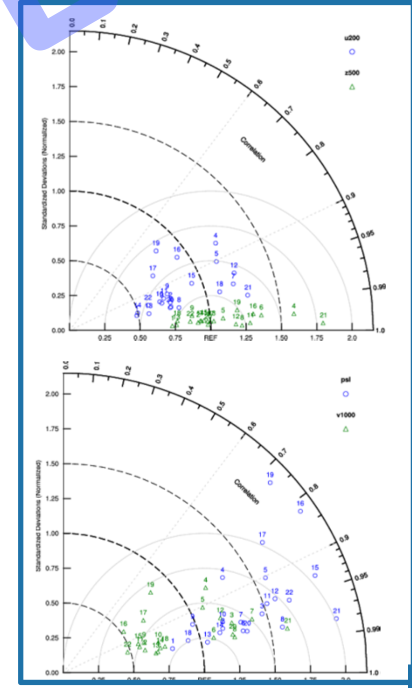
	DJF
最低溫PR10	13.9
最低溫PR20	14.9
24小時升溫PR10	2.8
48小時降溫PR10	-3.2
平均寒潮次數	3.1
平均低溫天數	9.9

- 使用盧與李(2009)的寒潮定義挑選出的冬季(DJF)寒潮個數與低溫日數，在全台平地及高山測站都顯示明顯減少的趨勢。

Performance Index



- 27個CMIP5模式(Historical , RCP85)中的寒潮個數及低溫日數在未來均有明顯的減少趨勢 。



海平面氣壓、1000hPa經向風分量、200hPa緯向風分量、500hPa高度場

Summary (Cold Surge)

- 5個百年測站資料分析結果顯示，近50年、100年的寒潮頻率以及低溫日數均有顯著的減少趨勢，進一步分析台北站冬季逐月寒潮次數發現，1月份寒潮發生頻率增加，12月及2月份則呈減少的趨勢，其中以2月份減少較明顯。

- 台北站寒潮頻率長期變化與西伯利亞高壓強度 **(Suda, 1959 ; 王, 1978 ; Ding and Krishnamuti, 1987)**、NAO指數 **(Wu and Wang, 2002 ; Chang et al., 2006 ;吳與洪, 2008)**、熱帶太平洋海溫(**許與陳, 1991 ;** Zhang et al., 1997 ; Wang et al., 2000)有較好的相關性存在

- 22個CMIP5模式資料分析結果顯示，劇烈暖化情境下(**RCP8.5**)，未來寒潮事件以及低溫日數均為顯著的減少，模式中未來環流場改變同樣不利於寒潮發生(西伯利亞高壓、東亞主槽減弱、海溫呈現ENSO Like pattern)。

SLP&850 hPa wind

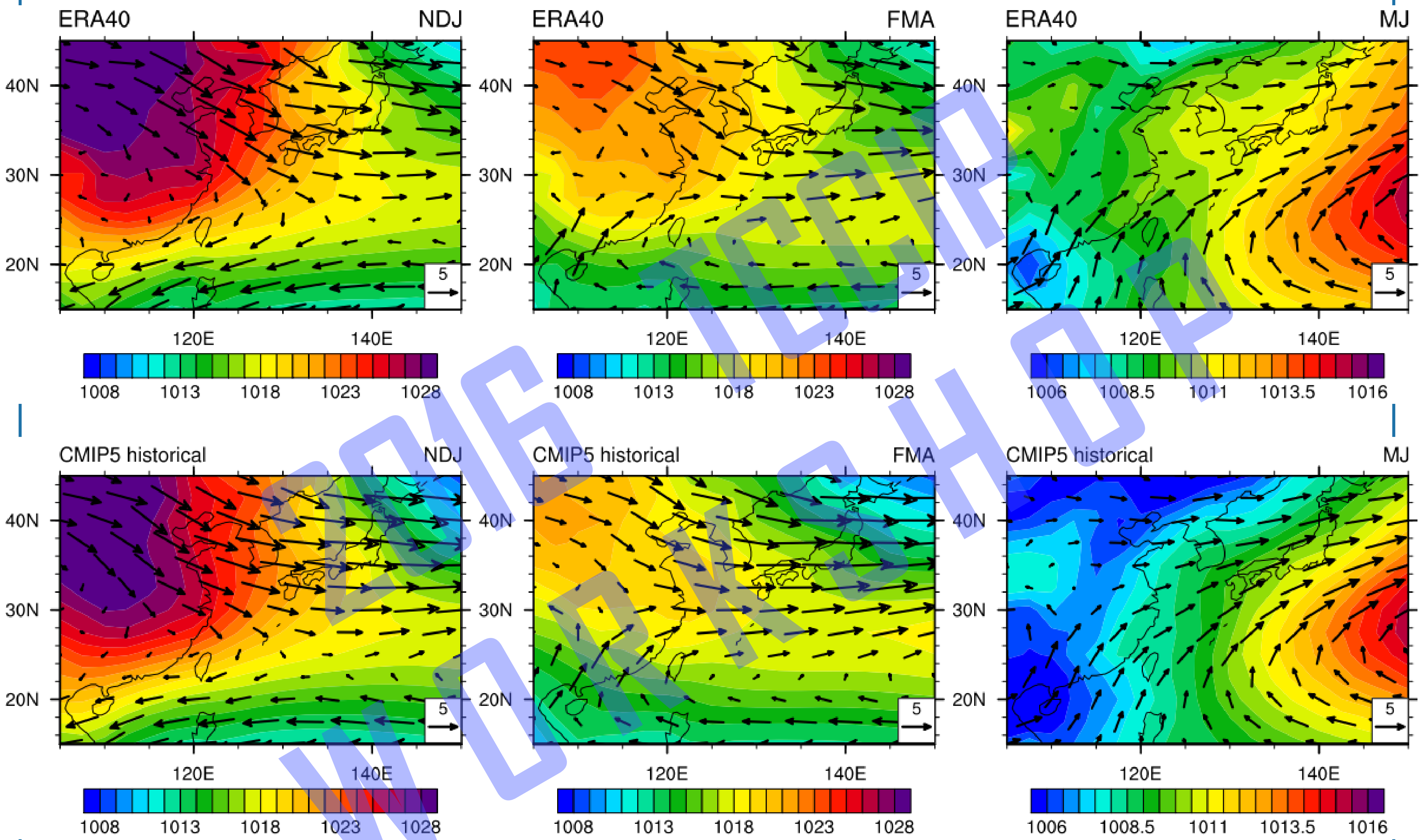


Figure 6: SLP+850md wind (observation and historical)

Theta-w &850 hPa moisture flux

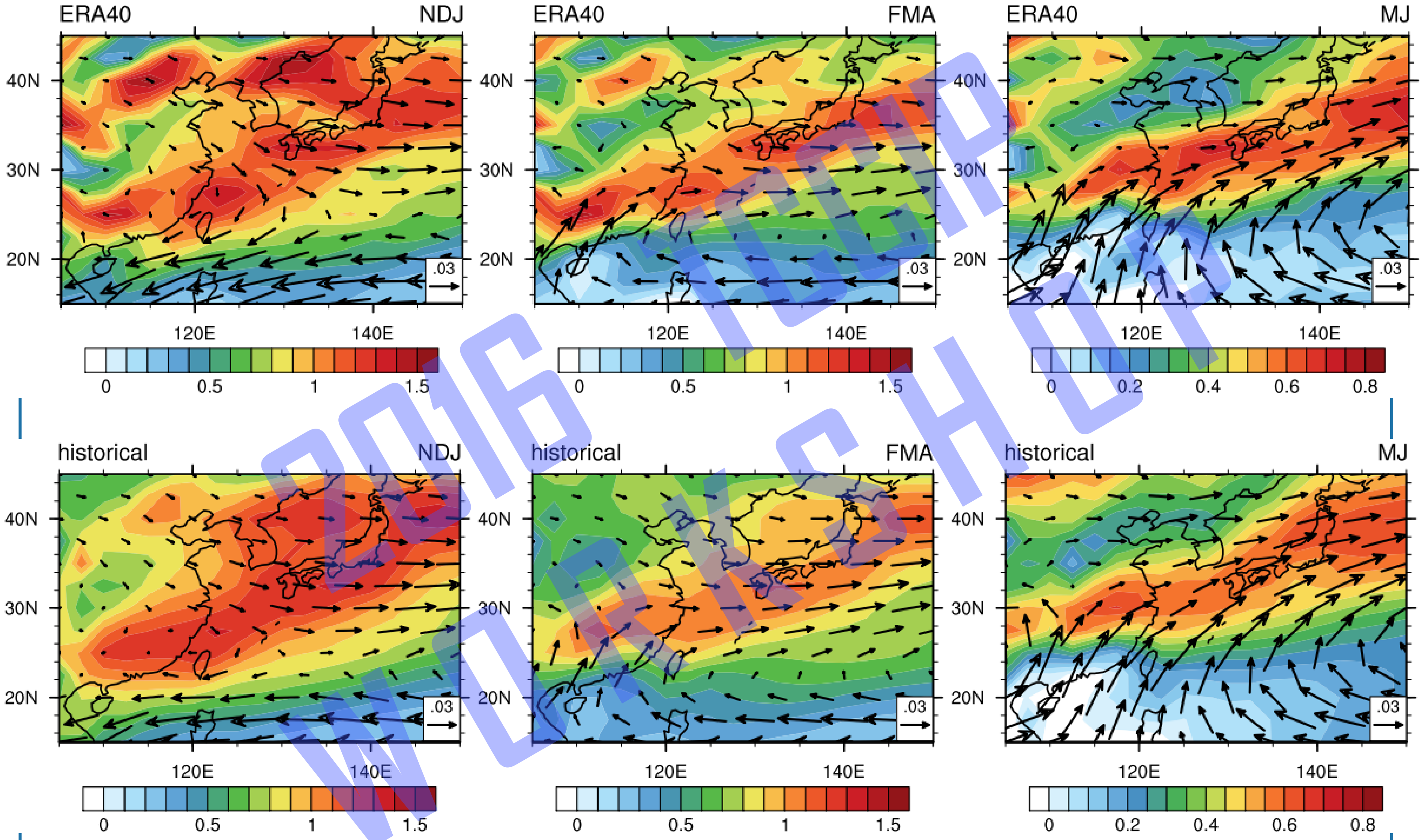


Figure 8: theta-w gradient(*-1) and 850mb moisture flux (obs.+historical)

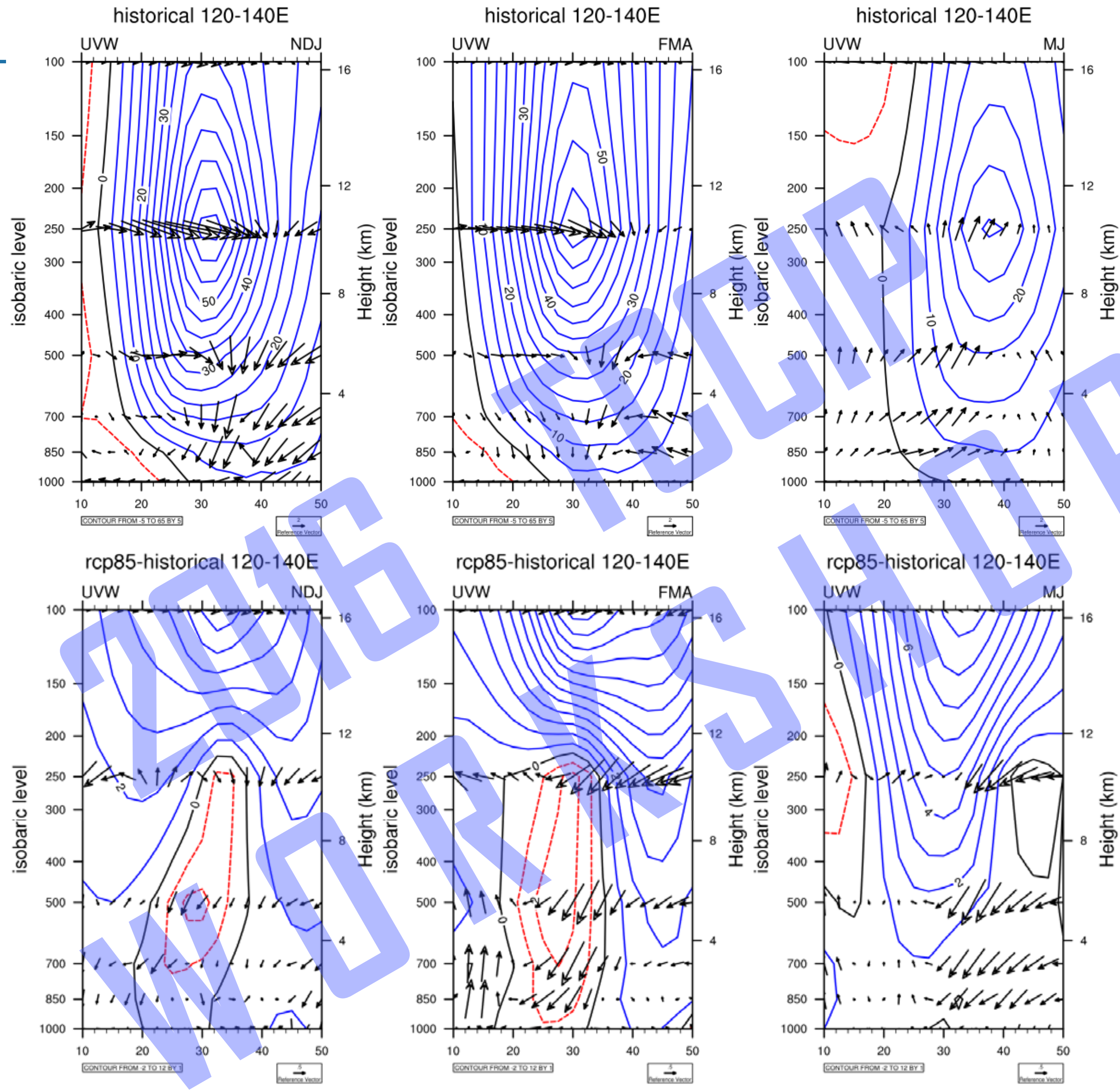
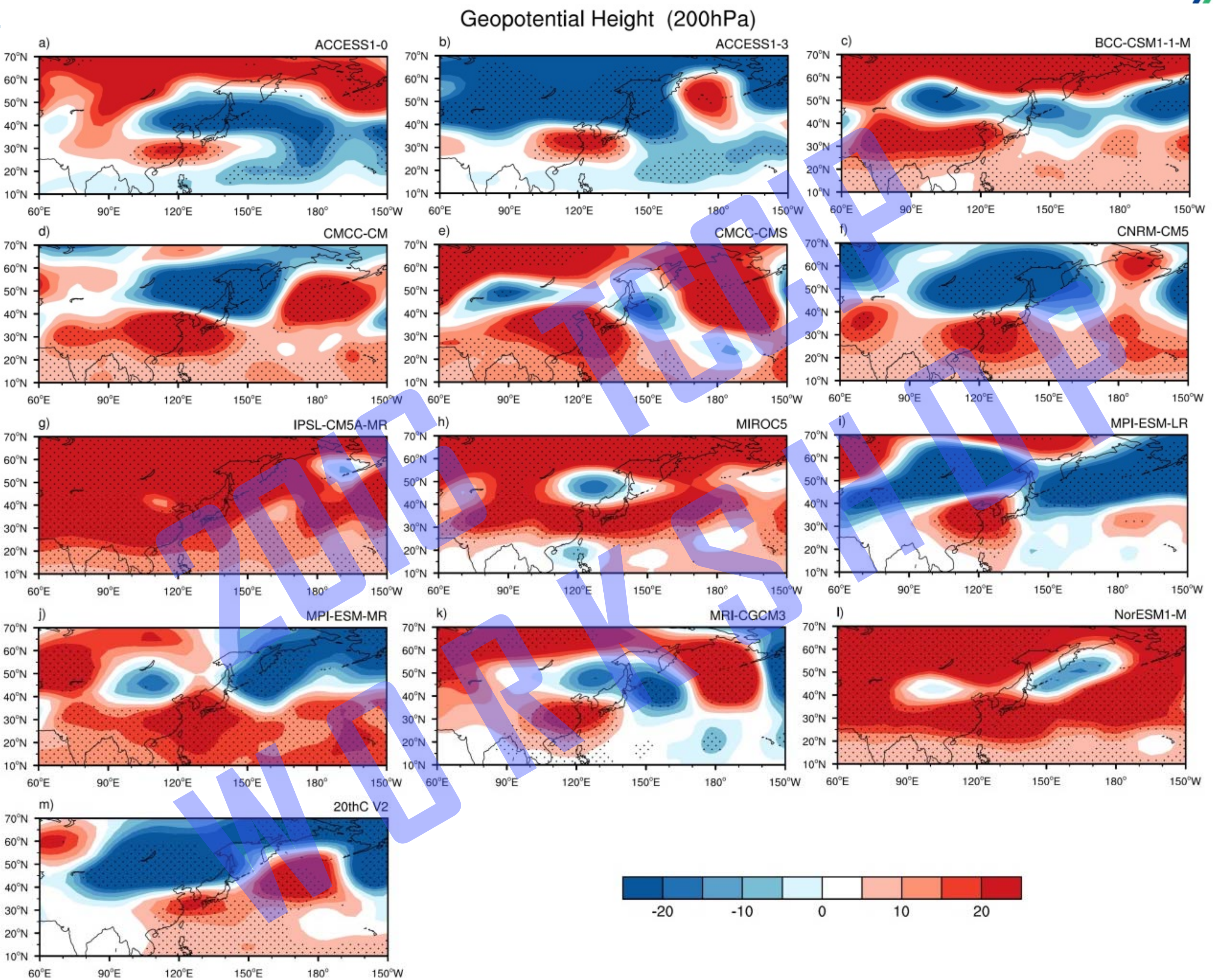
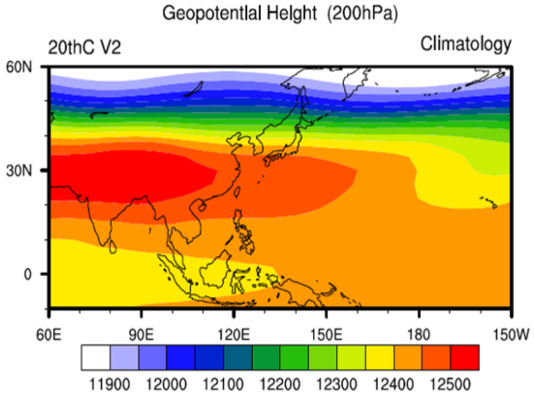


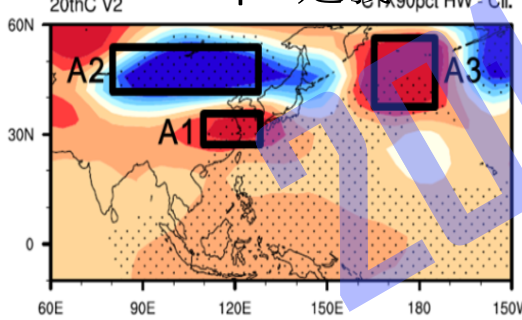
Figure 10: 10N-50N cross section averaged over 120E-140E, U (contour, blue:+, red:-), V and omega, historical + (RCP85 minus historical)


Geopotential Height (200hPa)
a) ACCESS1-0
b) ACCESS1-3
c) BCC-CSM1-1-M
d) CMCC-CM
e) CMCC-CMS
f) CNRM-CM5
g) IPSL-CM5A-MR
h) MIROC5
i) MPI-ESM-LR
j) MPI-ESM-MR
k) MRI-CGCM3
l) NorESM1-M
m) 20thC V2
70°N
60°N
50°N
40°N
30°N
20°N
10°N
60°E
90°E
120°E
150°E
180°
150°W
-20
-10
0
10
20

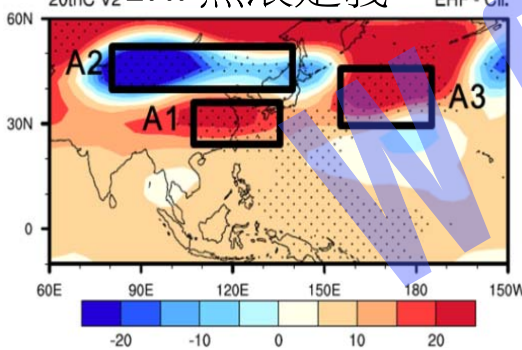
熱浪分析



CTX90pct定義



EHF熱浪定義

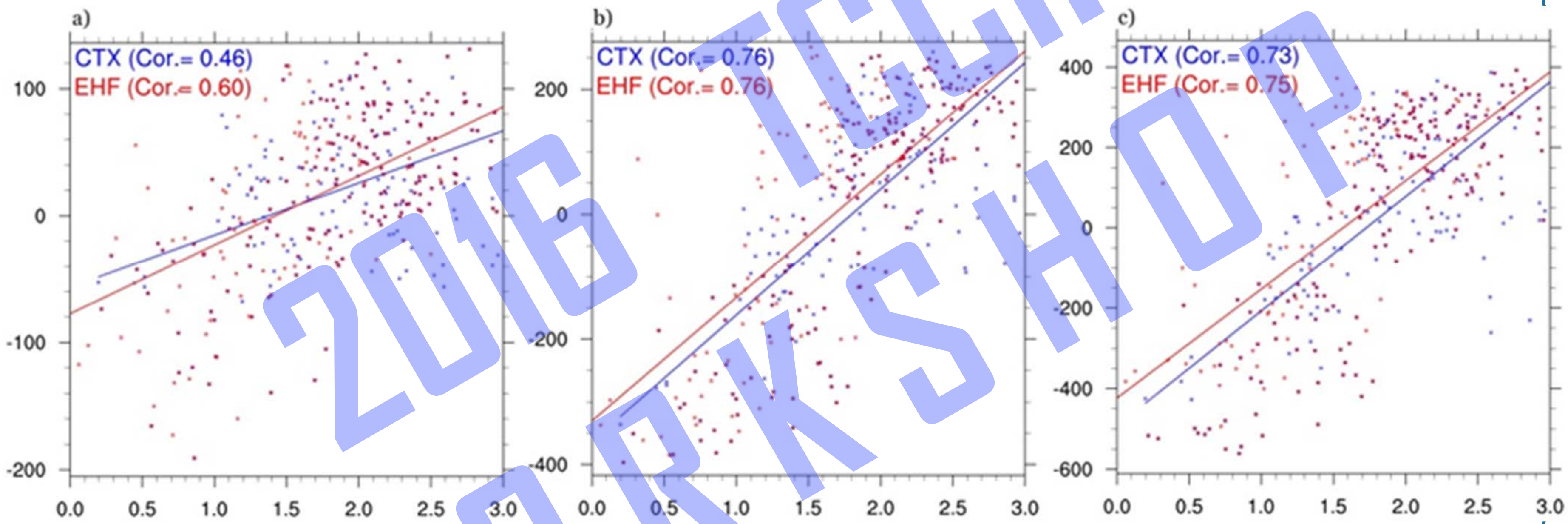


時間	天候現象	影響	氣象因子
			H200(CTX90pct定義) Perkins and Alexander (2013)
5~10月	熱浪	農作物生長、能源使用與公共衛生	(25-55N,80-130E)200hPa重力位高度距平與臺灣熱浪發生時高相關性 (方與簡，2011；王等。2006；鄧等，2009；楊與李，2005)
			H200(EHF定義) Neirn et al. (2009)
			(20-50N,80-140E)200hPa重力位高度距平與臺灣熱浪發生時高相關性

Index = A1 – A2

CTX 熱浪定義下的模式表現排序	
ACCESS1-3	0.2961397
MPI-ESM-LR	0.3169441
CNRM-CM5	0.4514
MPI-ESM-MR	0.4839657
BCC-CSM1-1-M	0.7835721
CMCC-CM	0.8631877
MRI-CGCM3	0.8931292
CMCC-CMS	0.9200718
ACCESS1-0	0.9277846
MIROC5	1.427398
NorESM1-M	1.98586
IPSL-CM5A-MR	2.650547

EHF 熱浪定義下的模式表現排序	
MPI-ESM-LR	0.2235486
CMCC-CMS	0.5117876
ACCESS1-3	0.5189768
BCC-CSM1-1-M	0.5199136
CMCC-CM	0.7290627
MPI-ESM-MR	0.7852129
NorESM1-M	0.8410165
ACCESS1-0	1.174605
IPSL-CM5A-MR	1.253578
CNRM-CM5	1.46455
MRI-CGCM3	1.969574
MIROC5	2.008175



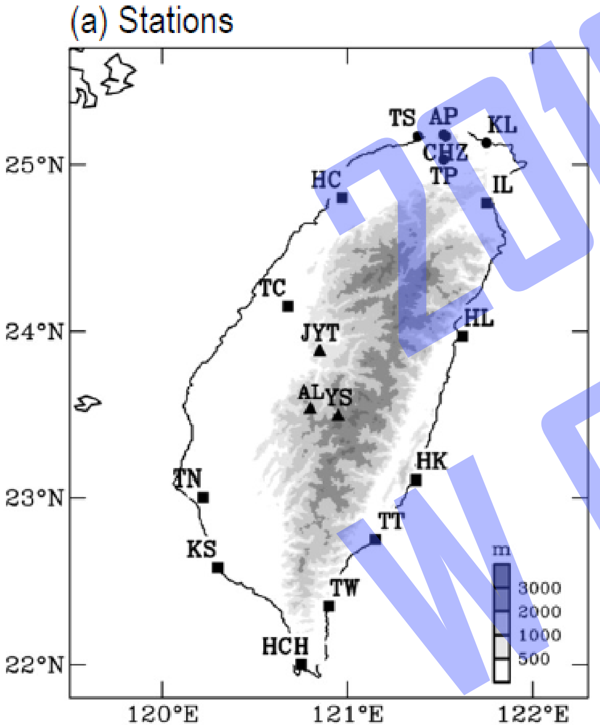
a)
CTX (Cor.= 0.46)
EHF (Cor.= 0.60)
b)
CTX (Cor.= 0.76)
EHF (Cor.= 0.76)
c)
CTX (Cor.= 0.73)
EHF (Cor.= 0.75)

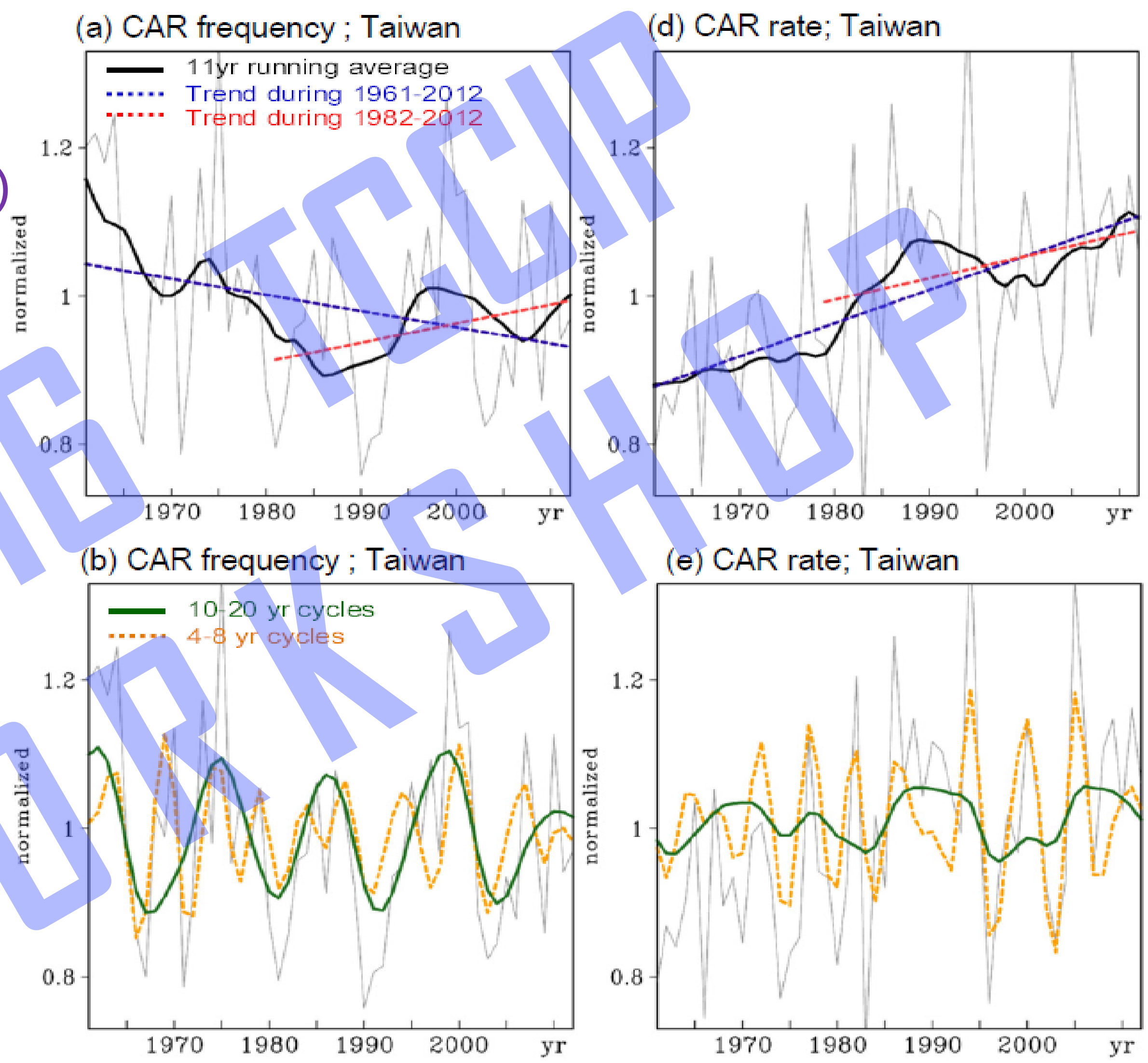
	Area1		Area1+2		Area1+2+3	
	CTX	**EHF**	**CTX**	**EHF**	**CTX**	**EHF**
20C V2	0.46	0.61	0.76	0.74	0.73	0.73
ACCESS1.0	0.60	0.21	0.40	0.47	0.33	0.60
ACCESS1.3	0.64	*0.08*	0.54	0.49	0.57	0.40
BCC-CSM1-1-M	0.54	0.17	0.47	0.49	0.52	0.44
CMCC-CM	0.65	0.62	0.67	0.67	0.68	0.67
CMCC-CMS	0.41	0.55	0.50	0.68	0.53	0.64
CNRM-CM5	0.34	0.50	0.68	0.66	0.63	
IPSL-CM5A-MR	0.25	0.61		0.66		0.65
MIROC5	0.30	0.24	0.15	0.13	0.20	0.15
MPI-ESM-LR	0.46	0.53	0.62	0.63		0.60
MPI-ESM-MR	0.49	0.49	0.44	0.63		
MRI-CGCM3	0.60	0.60	0.71	0.77	0.77	0.71
NorESM1-M	0.28	0.31	0.19	0.24		

Table3 Correlations between temperature over Taiwan and the A1, A1+A2, and A1+A2+A3 geopotential height anomaly indices for the observation and 12 CMIP5 models. All correlation passed the 90% significant confidence except ACCESS1.3 (EHF) in Area1.

Observation (1)

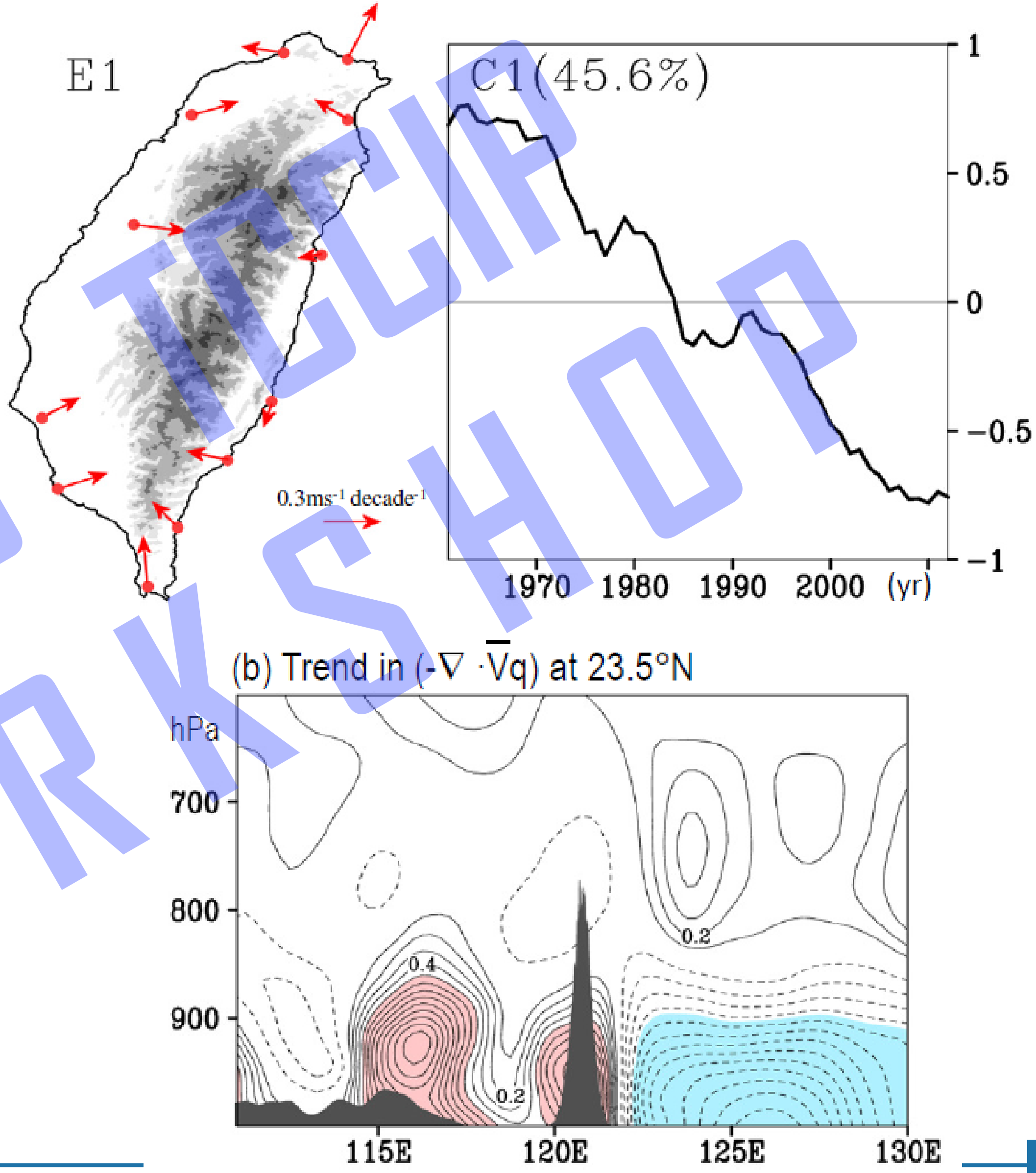
利用測站資料，我們的研究發現1960~2012夏季午後對流(Convective Afternoon Rainfall; CAR)存在多重時間尺度變化





Observation(3)

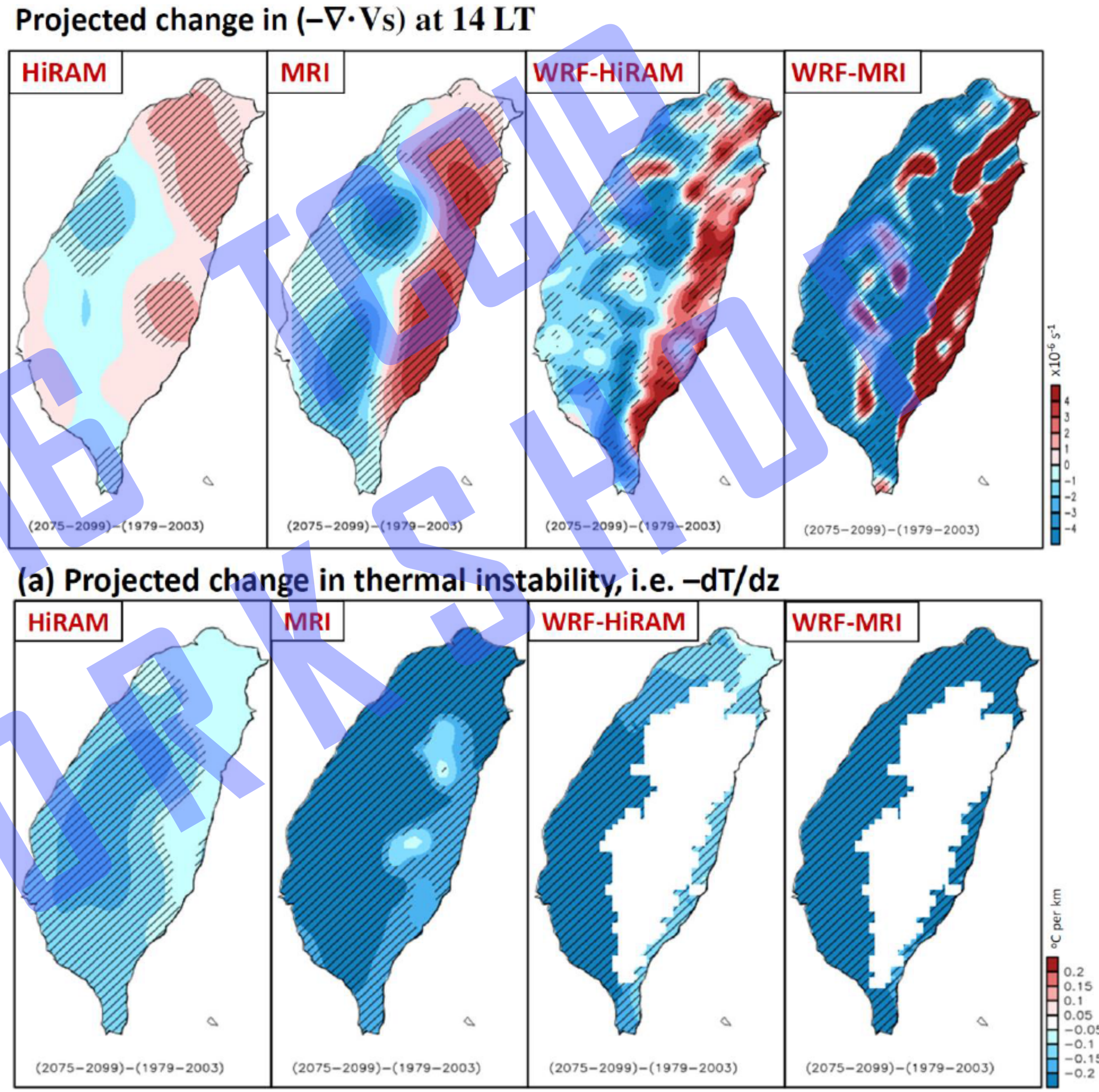
- 午後降雨**頻率**之區域性差異與區域動力(如輻散場)和熱力(如穩定度)條件的變化有關
- 午後降雨**強度**之區域性差異與水氣的趨勢變化有關



Huang et al. (JGR, in press)

Future Projection(2)

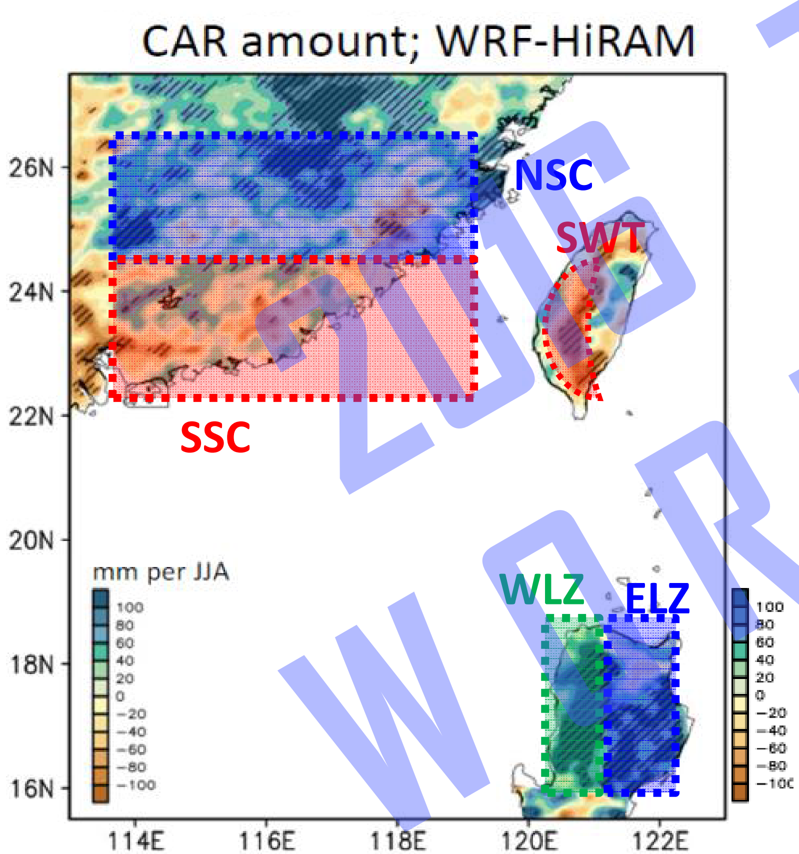
其中頻率變少和 convergence 減弱與熱力穩定度增強有關。



Huang et al. (submit to TAO)

Future Projection(3)

以WRF-HiRAM進行未來CAR之推估：
華南南部地區與臺灣西南部推估結果相似，其它區域則與台灣推估結果不同。

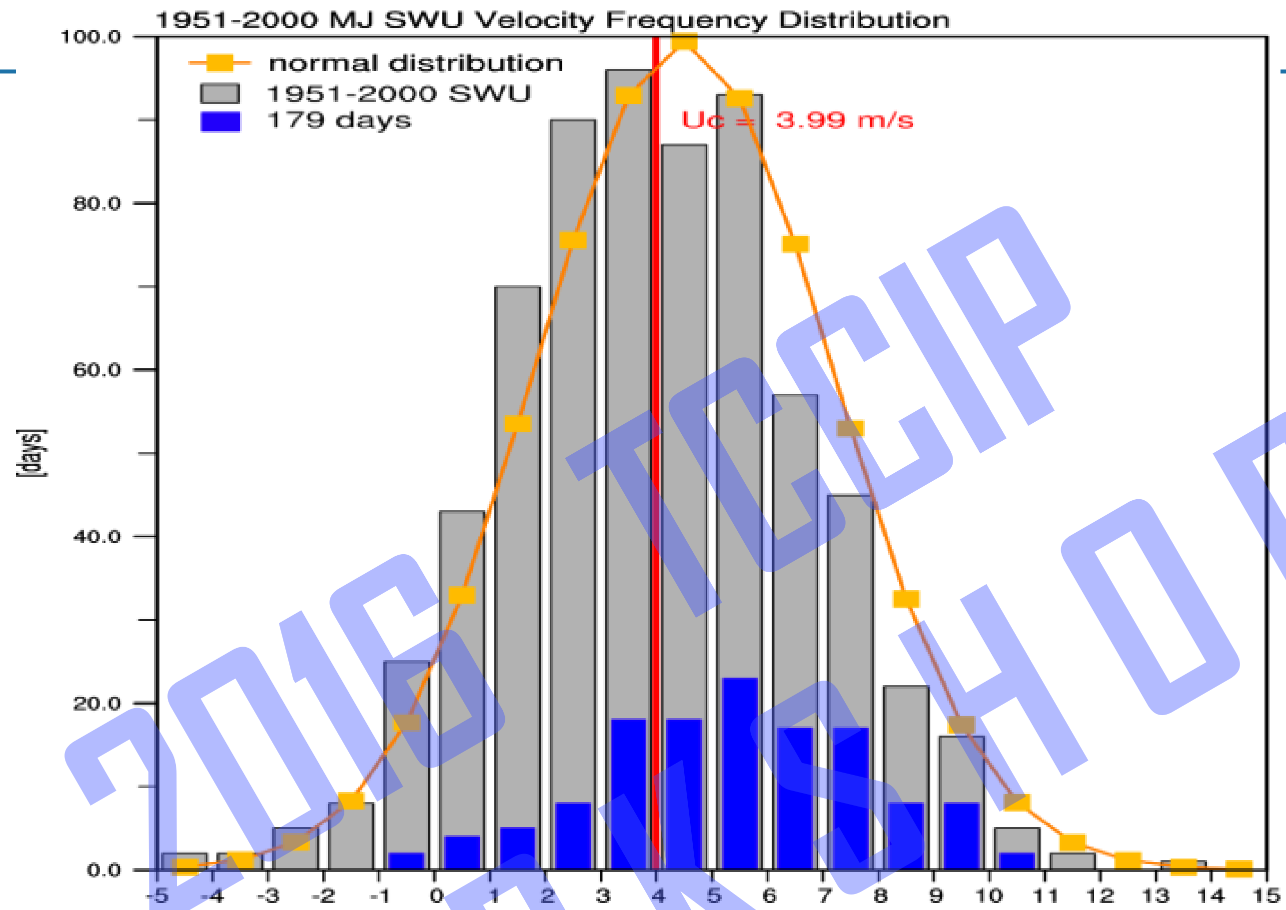


- SWT、SSC (CAR rainfall↓)
  Frequency↓
  (convergence↓，instability↓)
- NSC、ELZ (CAR rainfall↑)
  Intensity↑
  (humidity↑)
- WLZ (CAR rainfall↑)
  Frequency↑ Intensity↑
  (convergence↑，humidity↑)

Huang et al. (submit to TAO)

Issues and Phenomenon Metrics

Filed	Impact	Various	Possible Linkage
Agriculture	Tmin(Feb)<10°C, rice raising seedling	Cold Surge	Sea Level Pressure、SST、200hPa Wind
	Tmax(May)>35°C reduce rice 1st production	Extreme High Temperature	Subtropical High
	Rice lodging(Pr >130[mm])	Extreme Rainfall	Extreme rainfall in Mei-yu and Typhoon
Drought	Water resource management	Seasonal Rainfall	Numbers of front、Low level circulation、ENSO、PDO
Public Health	Dengue fever	Monthly Temperature	Monthly Temperature Variance
	Cardiovascular disease	Extreme High Temperature	200hPa Geopotential High
	Infectious disease in flood area(hepatitis A enterovirus、dysenteria)	Extreme Rainfall	Typhoon Numbers、Subtropical High、850hPa vorticity
Disaster	Disaster on slopeland	48 hrs Extreme Rainfall	Typhoon Numbers、Subtropical High、850hPa vorticity



Gray Histogram: the U850 value when the 850-hPa vorticity satisfies the positive over Taiwan and negative over the Philippines condition.

Blue Histogram: the U850 value on the 179 days of the extreme cases and the 850-hPa vorticity satisfies the positive over Taiwan and negative over the Philippines condition.

SWUc: the U850 criterion of the southwesterly winds is chosen as the **median** of the "gray histogram", which is **4 m/s**. Among the 179 days of the extreme cases, 52% of the cases can pass the criterion of SWU >= SWUc.

Obs.

PR: GPCP
U&V: NCEP-R1

MRI 60KM

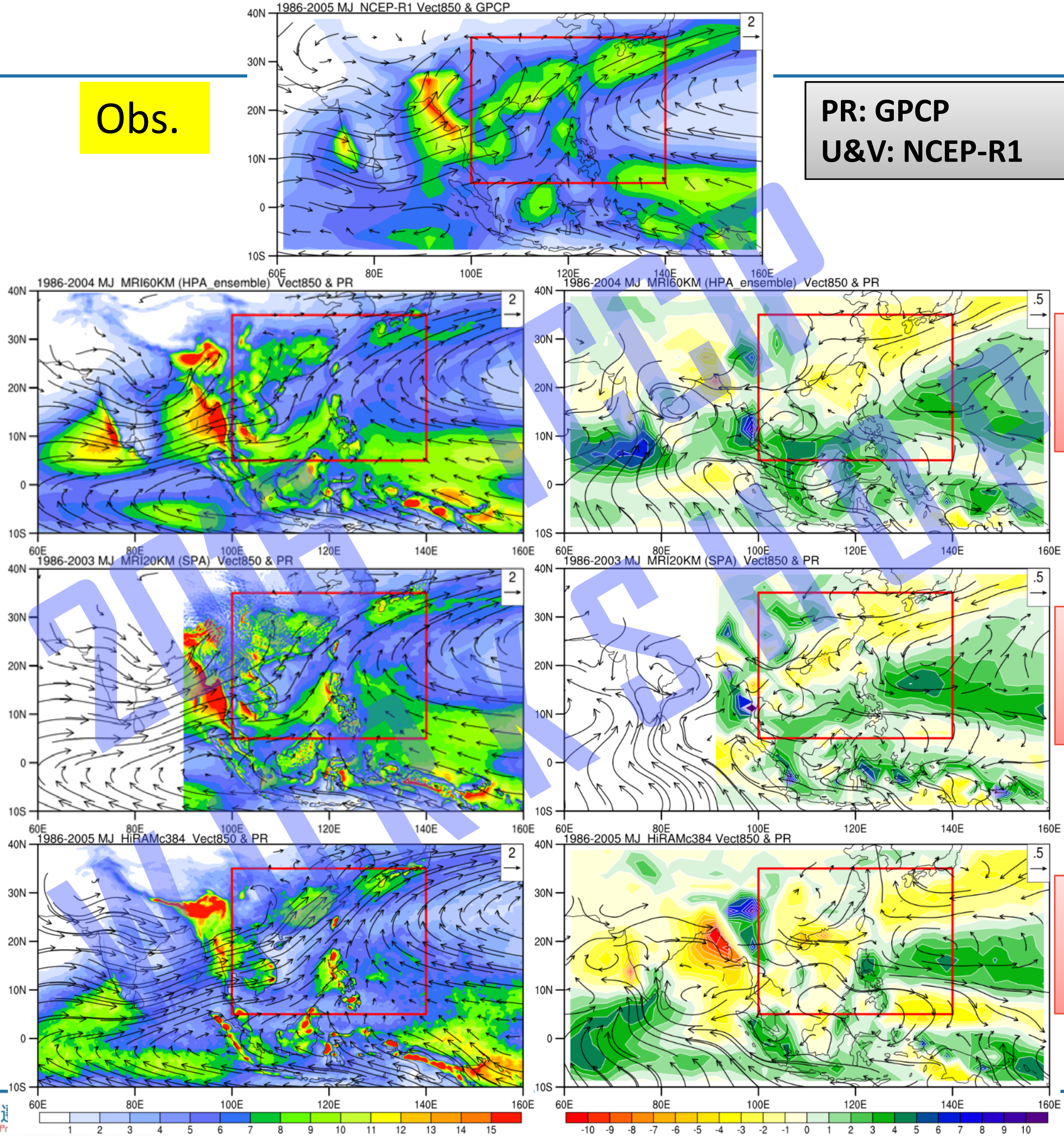
PR=0.49
U850=0.92
V850=0.80

MRI 20KM

PR=0.45
U850=0.94
V850=0.84

HiRAM

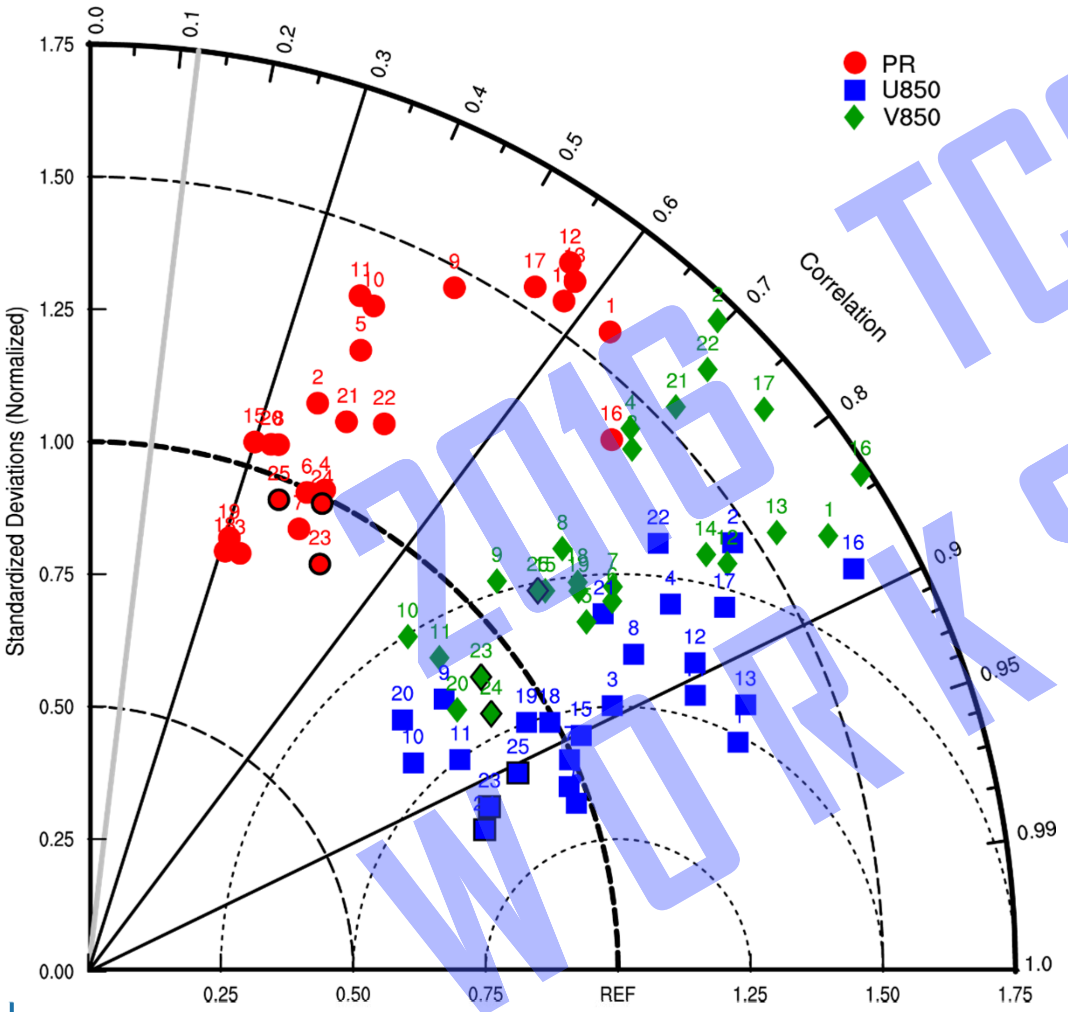
PR=0.37
U850=0.91
V850=0.76



模式挑選-梅雨季氣候特徵

- 台灣附近區域(100E-140E, 5N-35N)梅雨季雨量的氣候空間分佈特徵

Skill Score S
(Taylor, 2001)



NO	Model	PR	U850	V850
1	ACCESS1.0	0.67	0.91	0.74
2	BNU-ESM	0.67	0.80	0.64
3	CESM1 (CAM5)	0.65	0.94	0.76
4	CESM1 (WACCM)	0.72	0.86	0.75
5	CMCC-CM	0.66	0.97	0.89
6	CNRM-CM5	0.71	0.97	0.88
7	CNRM-CM5-2	0.71	0.96	0.87
8	GFDL-CM2.1	0.67	0.90	0.84
9	GISS-E2-H-CC	0.64	0.87	0.86
10	GISS-E2-R	0.63	0.83	0.83
11	GISS-E2-R-CC	0.62	0.89	0.86
12	HadGEM2-AO	0.62	0.89	0.81
13	HadGEM2-CC	0.64	0.89	0.77
14	HadGEM2-ES	0.65	0.91	0.82
15	IPSL-CM5A-MR	0.65	0.95	0.87
16	MIROC4h	0.76	0.75	0.69
17	MIROC5	0.64	0.84	0.69
18	MPI-ESM-MR	0.63	0.94	0.87
19	MPI-ESM-P	0.64	0.93	0.87
20	MRI-CGCM3	0.66	0.83	0.89
21	NorESM1-M	0.70	0.89	0.72
22	NorESM1-ME	0.72	0.82	0.68
23	MRI60KM	0.74	0.92	0.89
24	MRI20KM	0.72	0.92	0.91
25	HiRAM	0.69	0.94	0.87

$$S = \frac{4(1+R)}{\left(\sigma + \frac{1}{\sigma}\right)^2 (1+R_0)}$$

R：the pattern correlation between observation and simulation
σ：simulated spatial standard deviation divided by that of observation
R_0：an achievable maximum correlation (here set as 1)

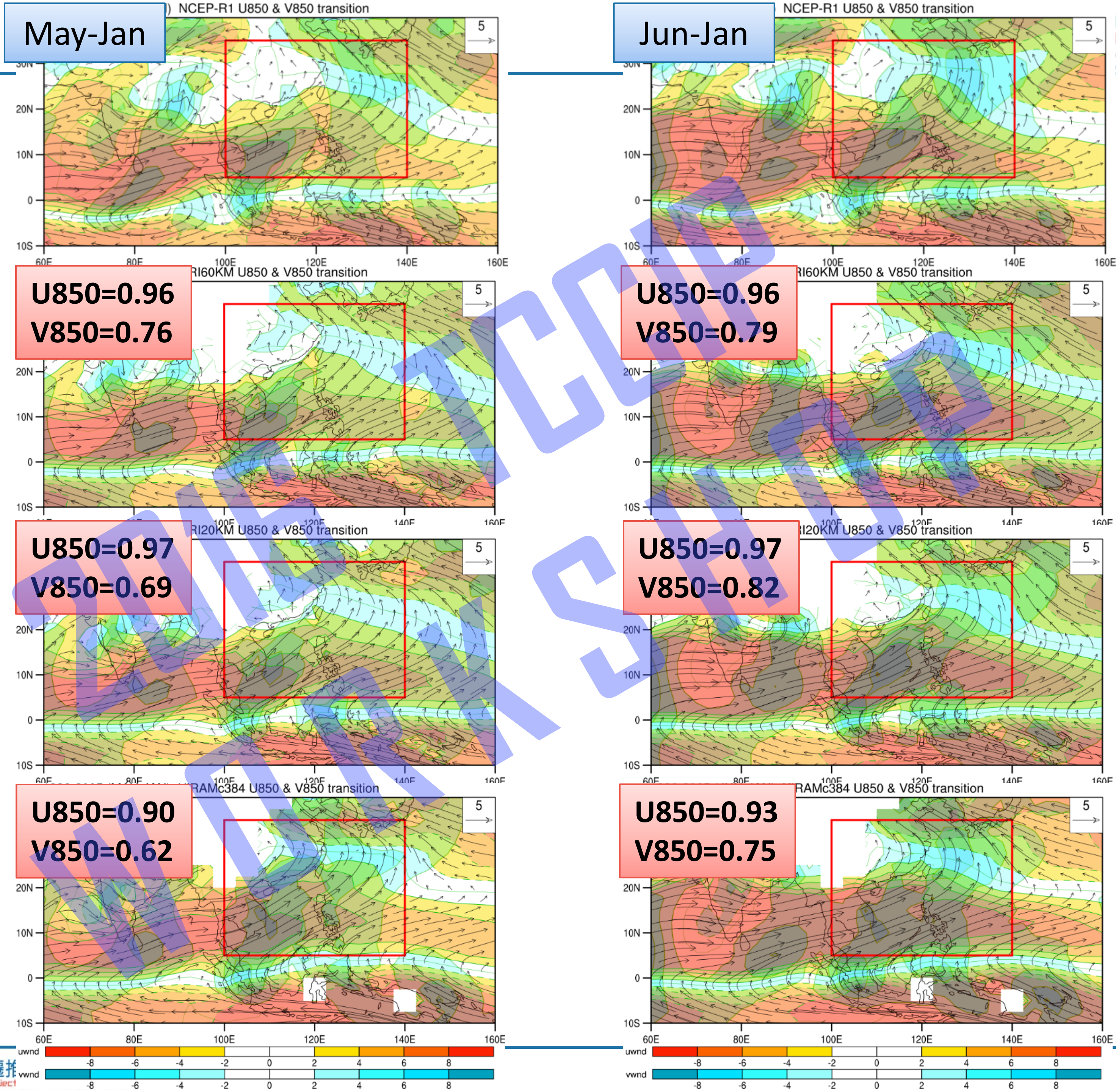
Obs.

U&V: NCEP-R1

MRI 60KM

MRI 20KM

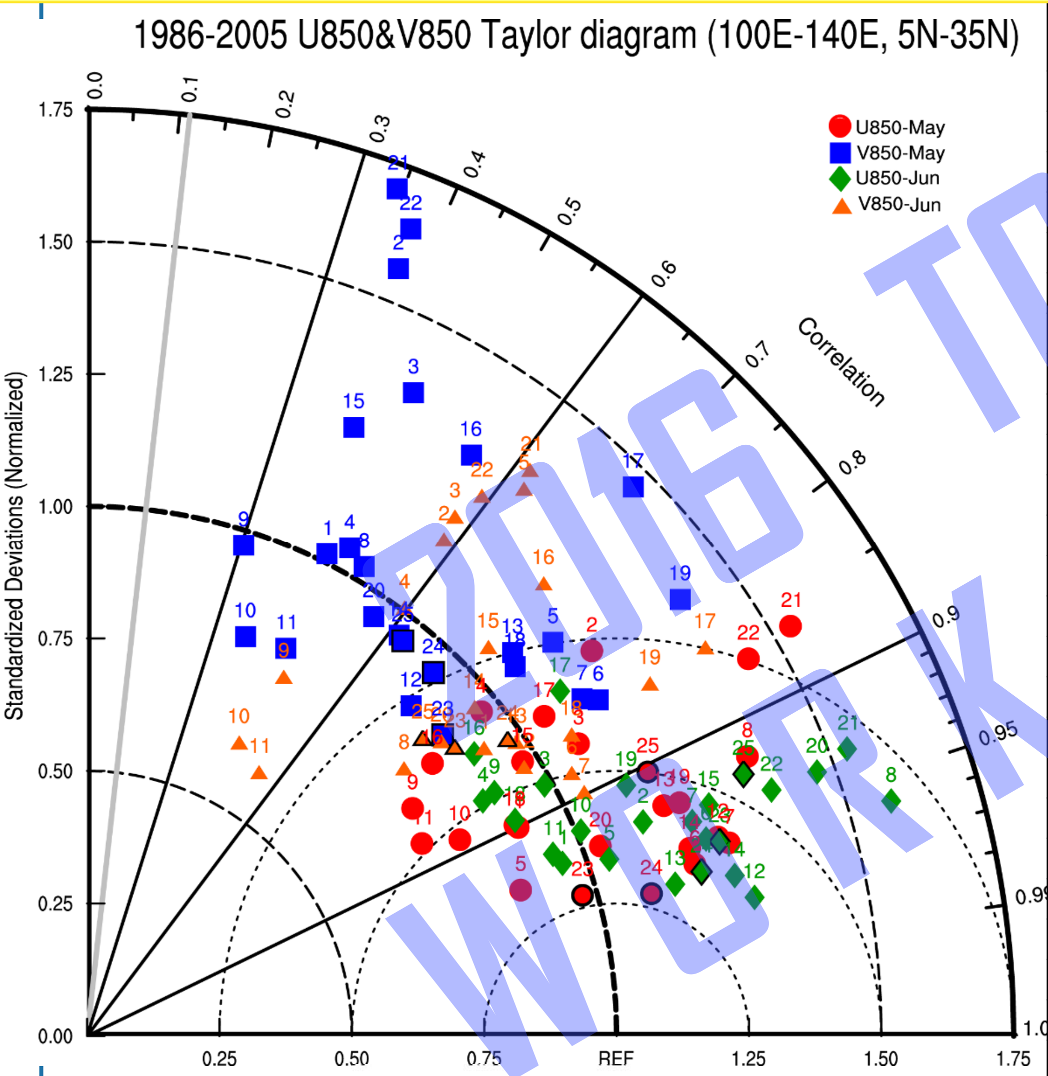
HiRAM



Circulation

·台灣附近區域(100E-140E,5N-35N)梅雨季850hPa風場季節變化的氣候空間分佈特徵

Skill Score S (Taylor, 2001)



NO	Model	U850		V850	
		MAY	JUN	MAY	JUN
1	ACCESS1.0	0.94	0.97	0.72	0.90
2	BNU-ESM	0.87	0.95	0.57	0.78
3	CESM1 (CAM5)	0.92	0.94	0.66	0.76
4	CESM1 (WACCM)	0.89	0.91	0.74	0.80
5	CMCC-CM	0.95	0.97	0.86	0.75
6	CNRM-CM5	0.95	0.94	0.90	0.94
7	CNRM-CM5-2	0.93	0.94	0.90	0.95
8	GFDL-CM2.1	0.88	0.80	0.75	0.83
9	GISS-E2-H-CC	0.84	0.92	0.65	0.69
10	GISS-E2-R	0.89	0.96	0.66	0.59
11	GISS-E2-R-CC	0.85	0.96	0.70	0.60
12	HadGEM2-AO	0.93	0.93	0.83	0.92
13	HadGEM2-CC	0.94	0.97	0.87	0.91
14	HadGEM2-ES	0.95	0.93	0.81	0.88
15	IPSL-CM5A-MR	0.92	0.92	0.67	0.86
16	MIROC4h	0.86	0.90	0.72	0.82
17	MIROC5	0.91	0.90	0.74	0.83
18	MPI-ESM-MR	0.94	0.94	0.88	0.92
19	MPI-ESM-P	0.93	0.94	0.81	0.88
20	MRI-CGCM3	0.97	0.84	0.78	0.87
21	NorESM1-M	0.78	0.81	0.51	0.74
22	NorESM1-ME	0.82	0.88	0.54	0.75
23	MRI60KM	0.98	0.93	0.87	0.88
24	MRI20KM	0.98	0.95	0.84	0.91
25	HiRAM	0.93	0.89	0.81	0.85

$$S = \frac{4(1+R)}{\left(\sigma + \frac{1}{\sigma}\right)^2 (1+R_0)}$$

R：the pattern correlation between observation and simulation

σ：simulated spatial standard deviation divided by that of observation

R_0：an achievable maximum correlation (here set as 1)

Circulation Change

- 觀測顯示，全臺春雨以中北部地區為主，模式低估。
- 分析海平面氣壓、U200、U850、V850、Q850等環流場差異。
- 三組推估資料皆顯示，未來臺灣東部春雨將減少。與太平洋高壓增強或低層南風分量變化有關。