



Changes in the annual frequency of the extreme events of Taiwan Mei-yu and preliminary results of the future projection

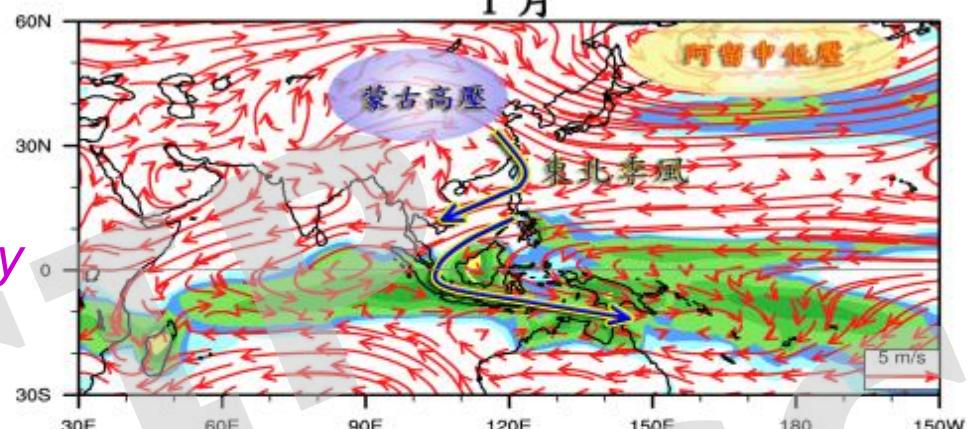
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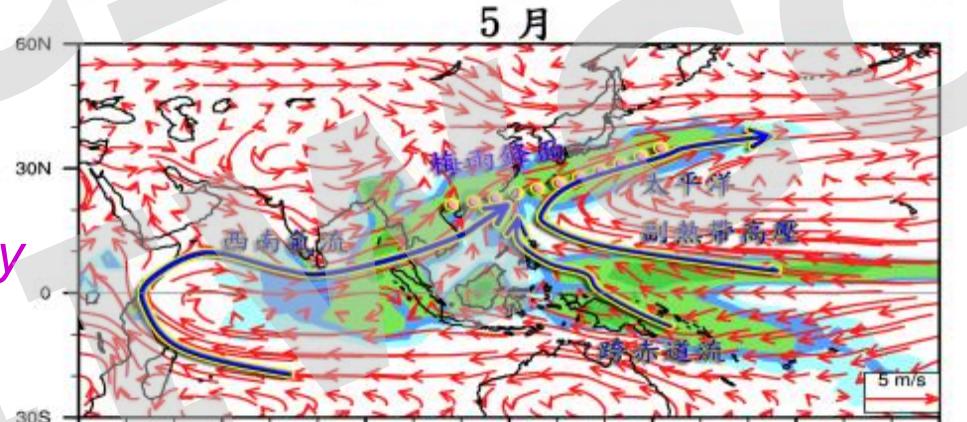
Rain & Low-level Winds

Taiwan climate & its variations are strongly influenced by Monsoons & Tropical Cyclones.

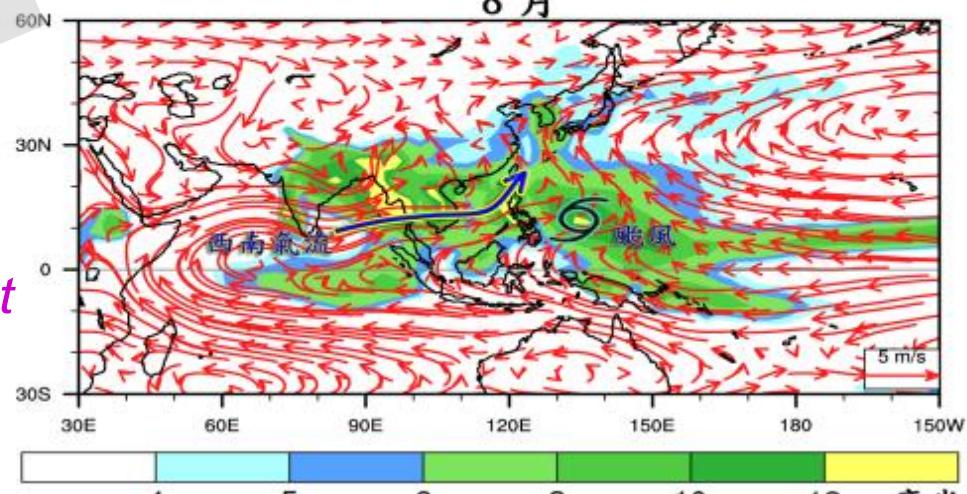
January

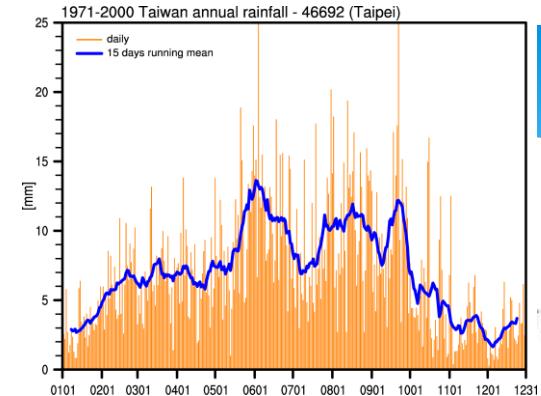


May

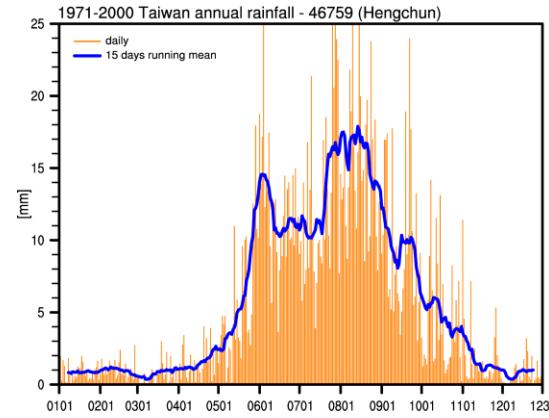
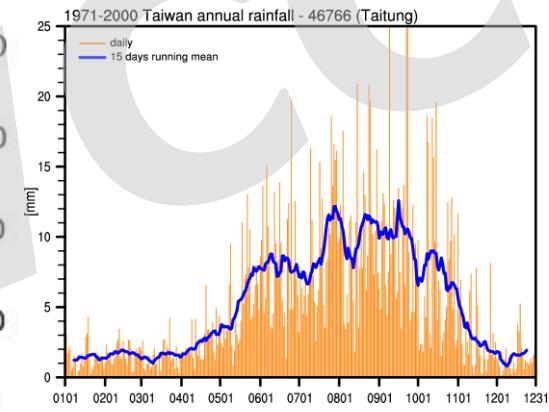
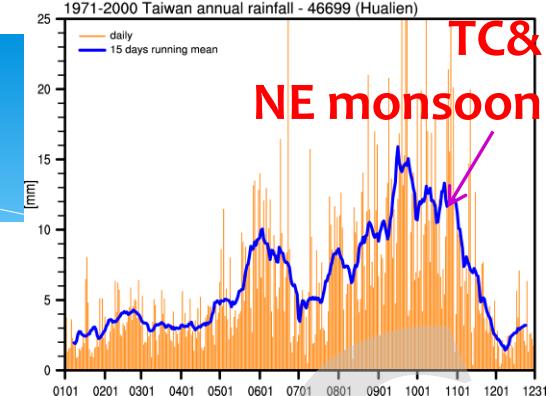
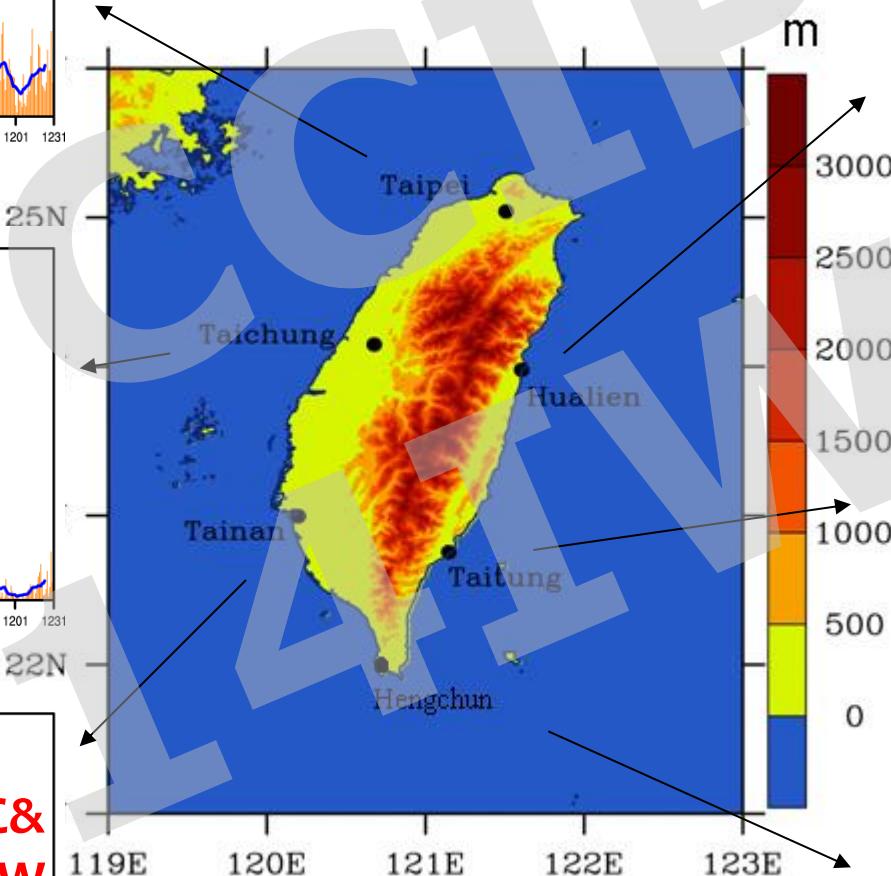
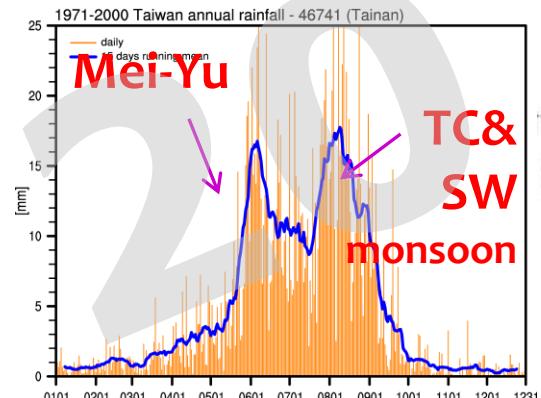
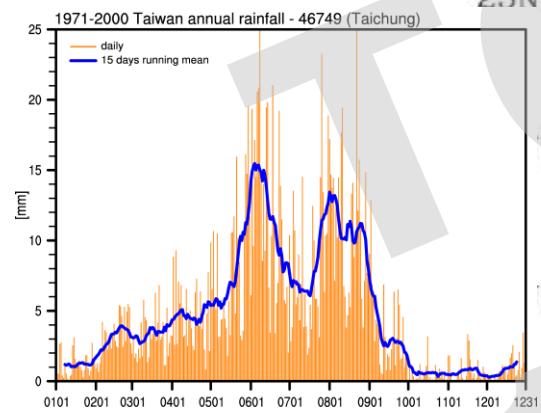


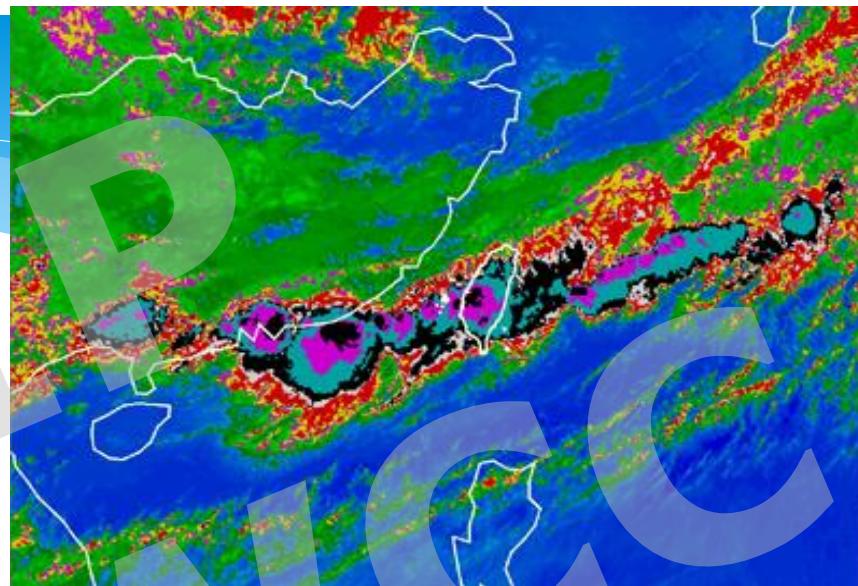
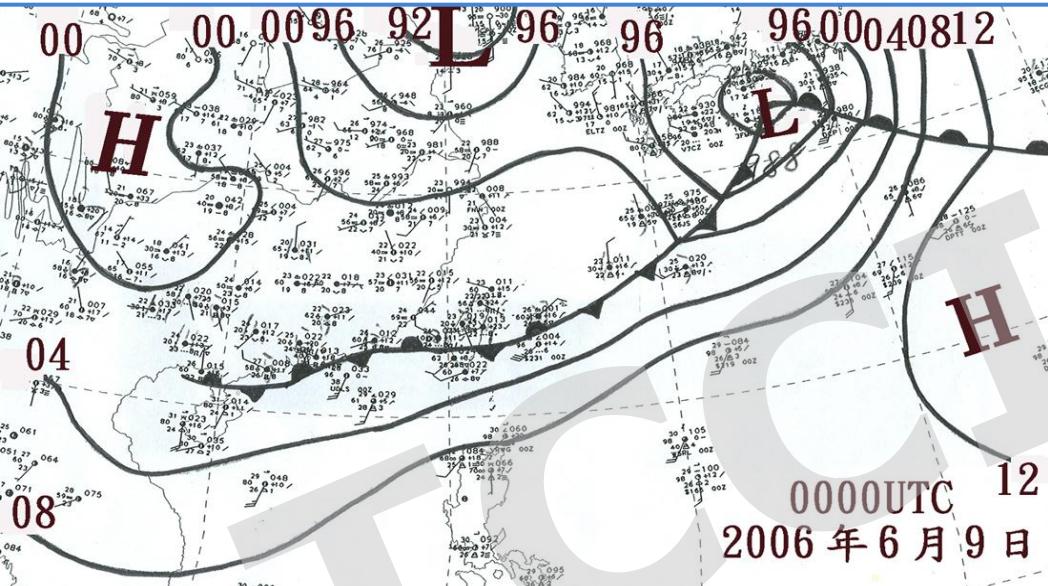
August



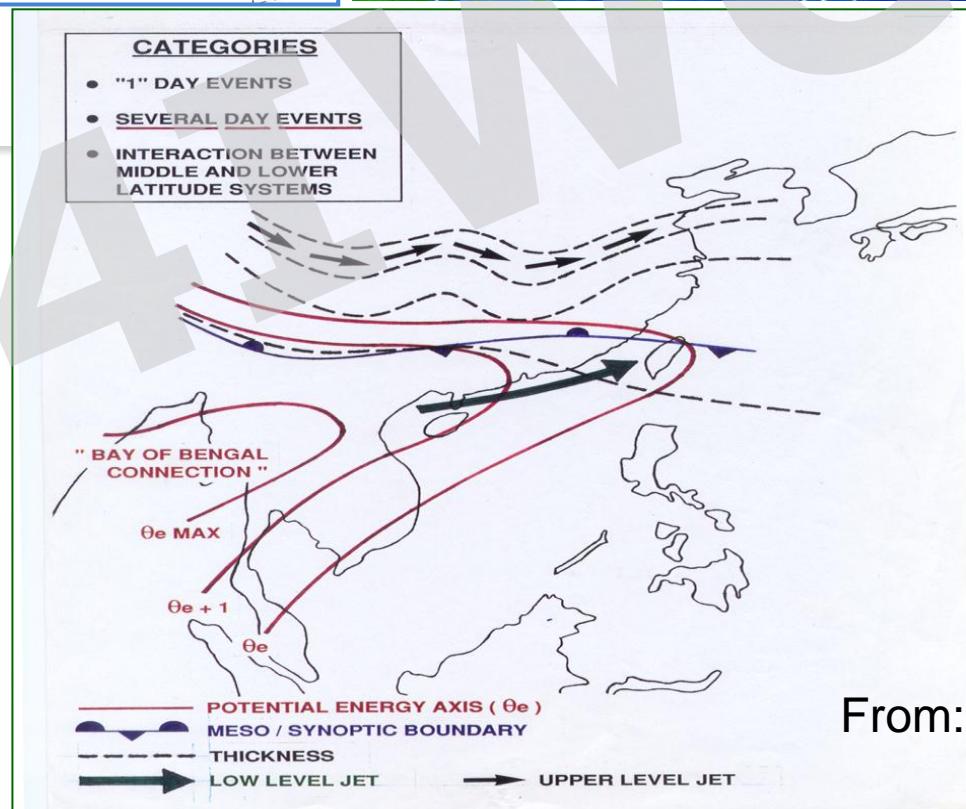


Taiwan rainfall climatology - daily (orange) & pentad (blue)

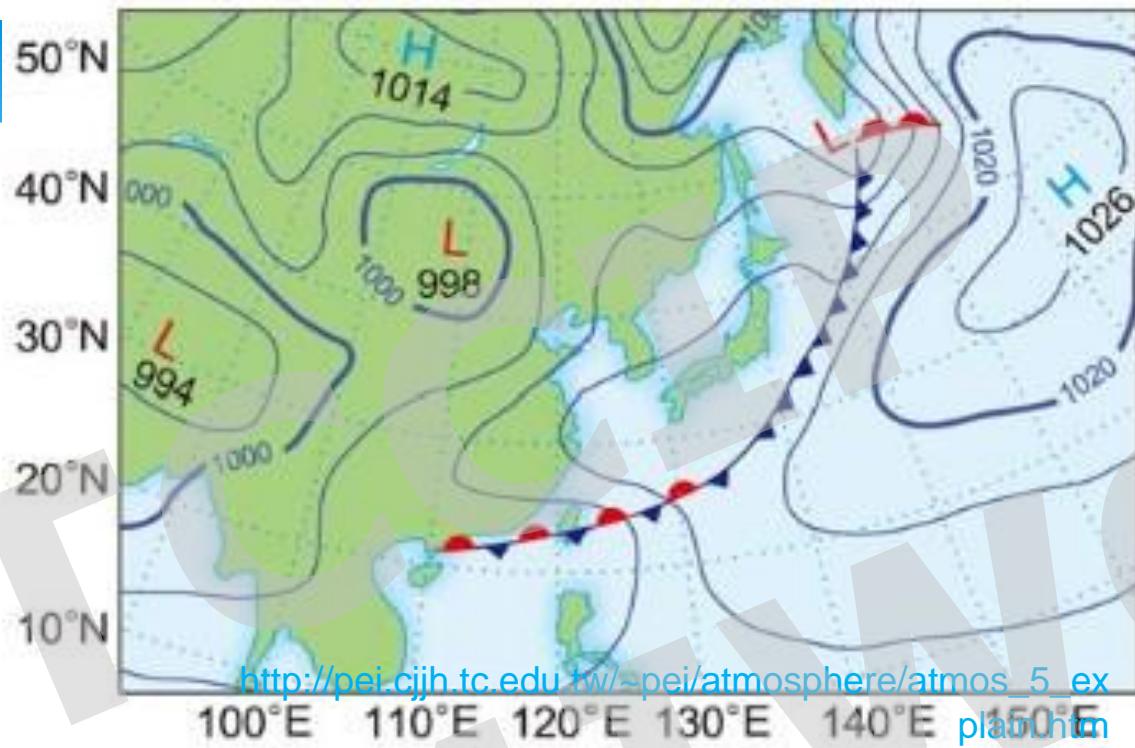




May-June
Taiwan Mei-Yu Season
Initiation Phase of the East
Asian Summer Monsoon



From: S.S. Chi
紀水上



民國89年6月14日8時地面天氣簡圖，典型梅雨季節的天氣圖，臺灣正受滯留鋒面的影響。



豪大雨攬局！馬總統取消520就職五周年記者會與參訪行程



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2013年5月19日 19:32

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政治中心／台北報導

高雄市山區今(19)日因大雨持續，桃源區復興里第三鄰已經先行撤村，預防性撤離30人。由於這波大雨雨勢被氣象局視為今年梅雨季最強鋒面，包括嘉義、台中、高雄、南投多處，均降下驚人雨量。晚間最新訊息顯示，為因應全台驚人雨勢，中央災害應變中心官網緊急成立519豪雨專區外，總統馬英九也決定取消明天520的就職五周年行程。



總統與特教小畫家作畫 總統馬英九（後中）17日出席總統府「台北市立瑩橋國小特教班繪畫展」開幕典禮，與4名小畫家一起以手掌沾顏料作畫。中央社記者孫仲達攝 102年5月17日

18日鋒面接近，19日至22日受到滯留鋒面影響，各地易有局部性大雨或豪雨發生的機率，依中央氣象局資料顯示，16日華南雨區移入，17、18日鋒面接近，19日至22日受到滯留鋒面影響，各地易有局部性大雨或豪雨發生的機率，為防豪雨成災，水利署長楊偉親赴各地河川局關心防汛動向情形。並要求旗下各河川局切注意降雨及河水水位變化，加強低窪及易致災地區

Q: How will the Mei-yu season extreme rainfall frequency change in a warmer climate ?

We need to know -

1. The relationship between Taiwan's extreme rainfall frequency and large-scale climate

- * Taiwan station data (1951-2012) → extreme rainfall frequency
- * Global analysis data → Large-scale circulation index

2. The future projections of the influential large-scale climate

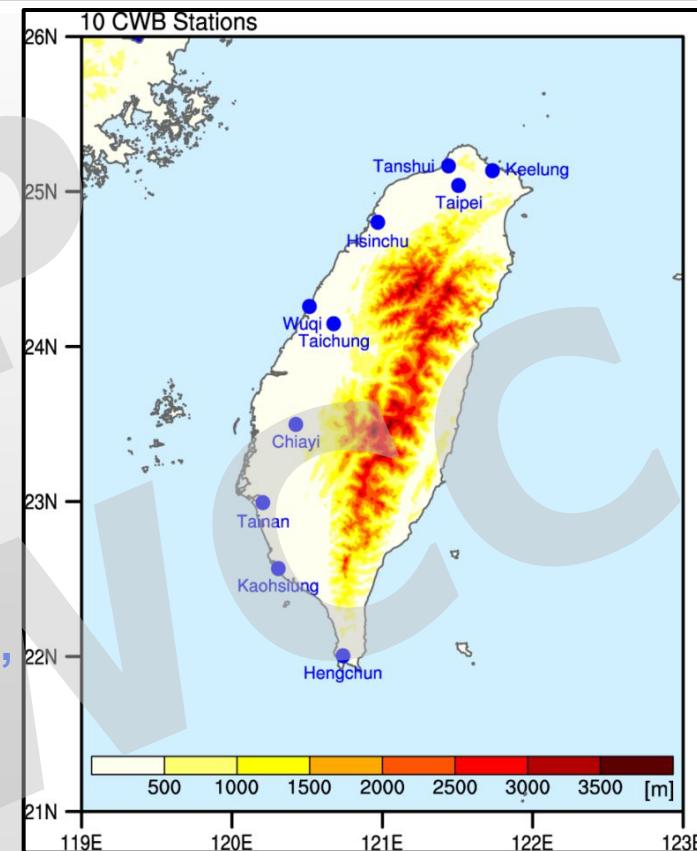
- * Use the large-scale circulation index derived from the climate change model output (CMIP3, CMIP5) to infer the possibilities of future changes

Data

➤ CWB Weather Stations

10 (west) stations
hourly precipitation 1951-2000

Tanshui(46690), Keelung(46694), Taipei(46692),
Hsinchu(46757), Wuqi(46777), Taichung(46749),
Chiayi(46748), Tainan(46741), Kaohsiung(46744),
Hengchun(46759)



➤ Large-scale Analysis Data

NCEP/NCAR-R1

U & V 850hPa (2.5° X 2.5°)

➤ Extreme Events - Only the data greater than 5mm/hr is used for analyzing the statistics of the extreme events.

DEFINITION - extreme rainfall events

- Rainfall Event - an event is characterized by its duration (D) and amount (R)
- Extreme Rainfall Event – a rainfall event is identified as “extreme” by 4 steps:
 - (1) Box plots

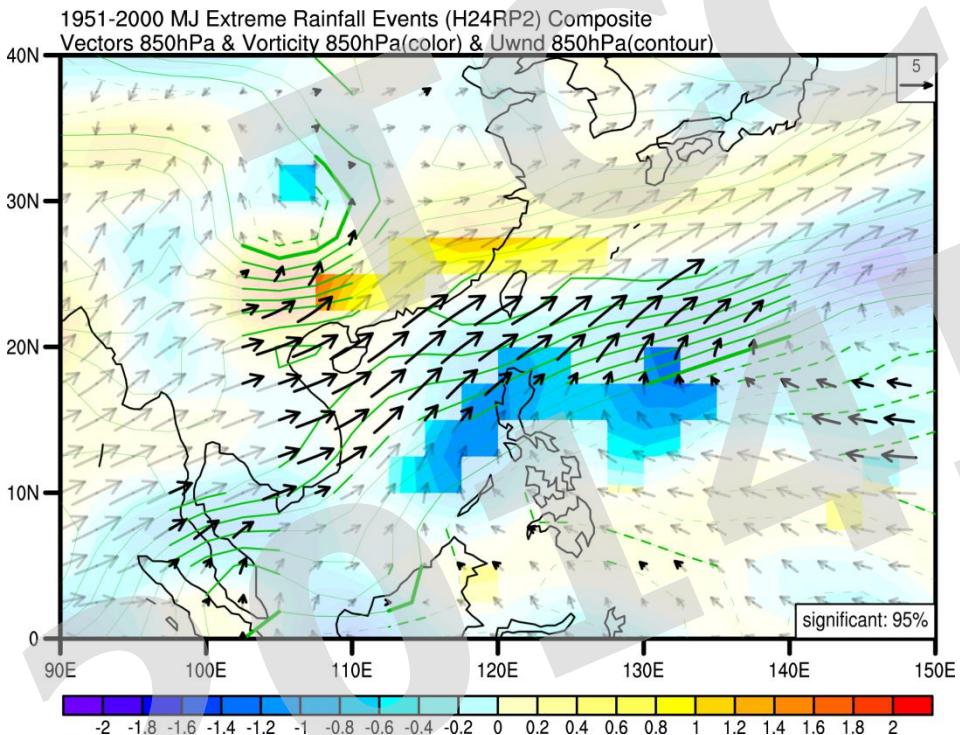
screen out the events with rainfall amount $> 3 \text{ std}$
 - (2) Probability distribution fit

use L-moments method to fit and select a best distribution for the rainfall events screened out in step (1)
 - (3) Return period (F)

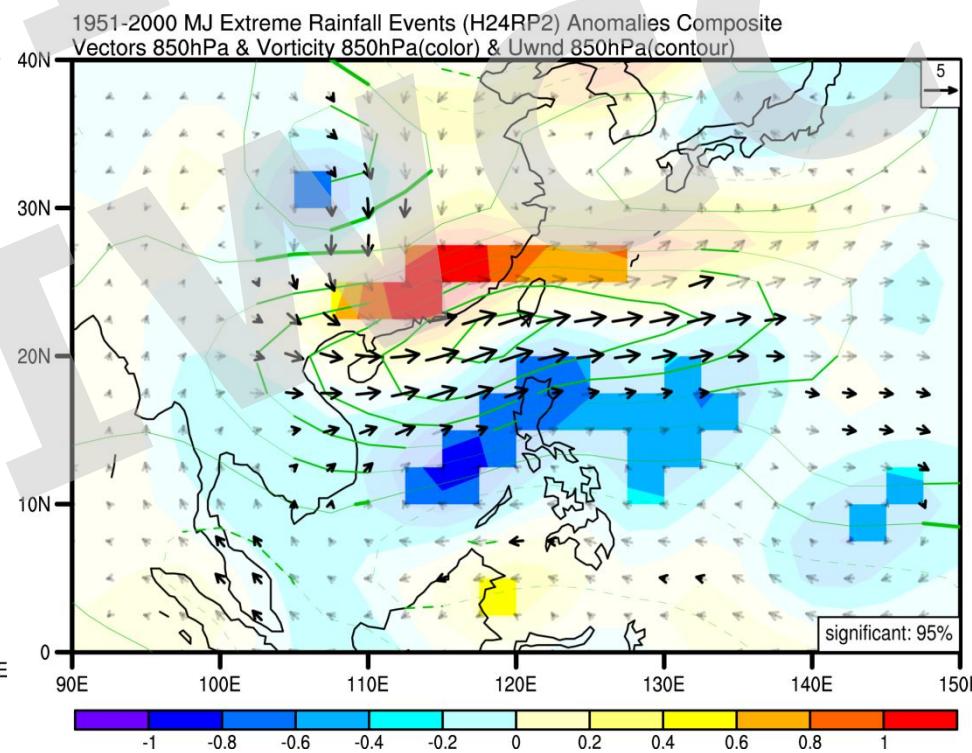
the probability distribution determined in step (2) is used to determine the threshold value of the rainfall amount for a specified return period
 - (4) Identify the extreme events
 - the climate extremes are rare events - with return periods longer than or equal to 2 years
 - an extreme event is characterized by three parameters – duration (D), rainfall amount (R), return period (F)

Large-scale Circulation Patterns Composited for the Extreme Rainfall Events

1951~2000 MJ : 30 extreme rainfall events

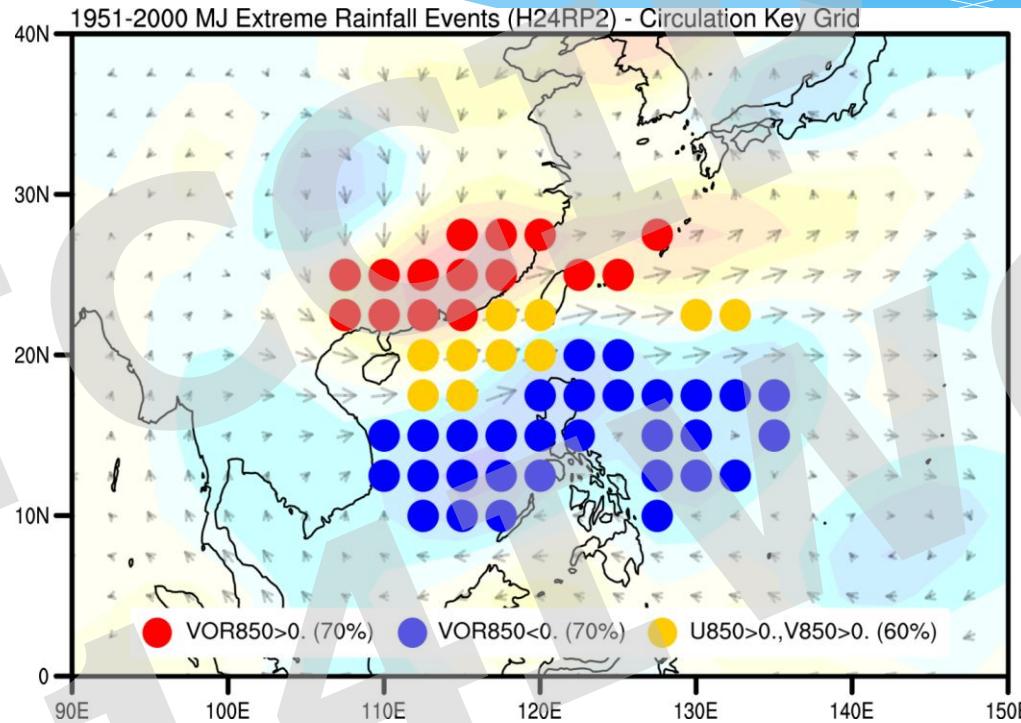


850hPa Vorticity (color) and U (contour)
Total Fields Composite (95% confidence level)



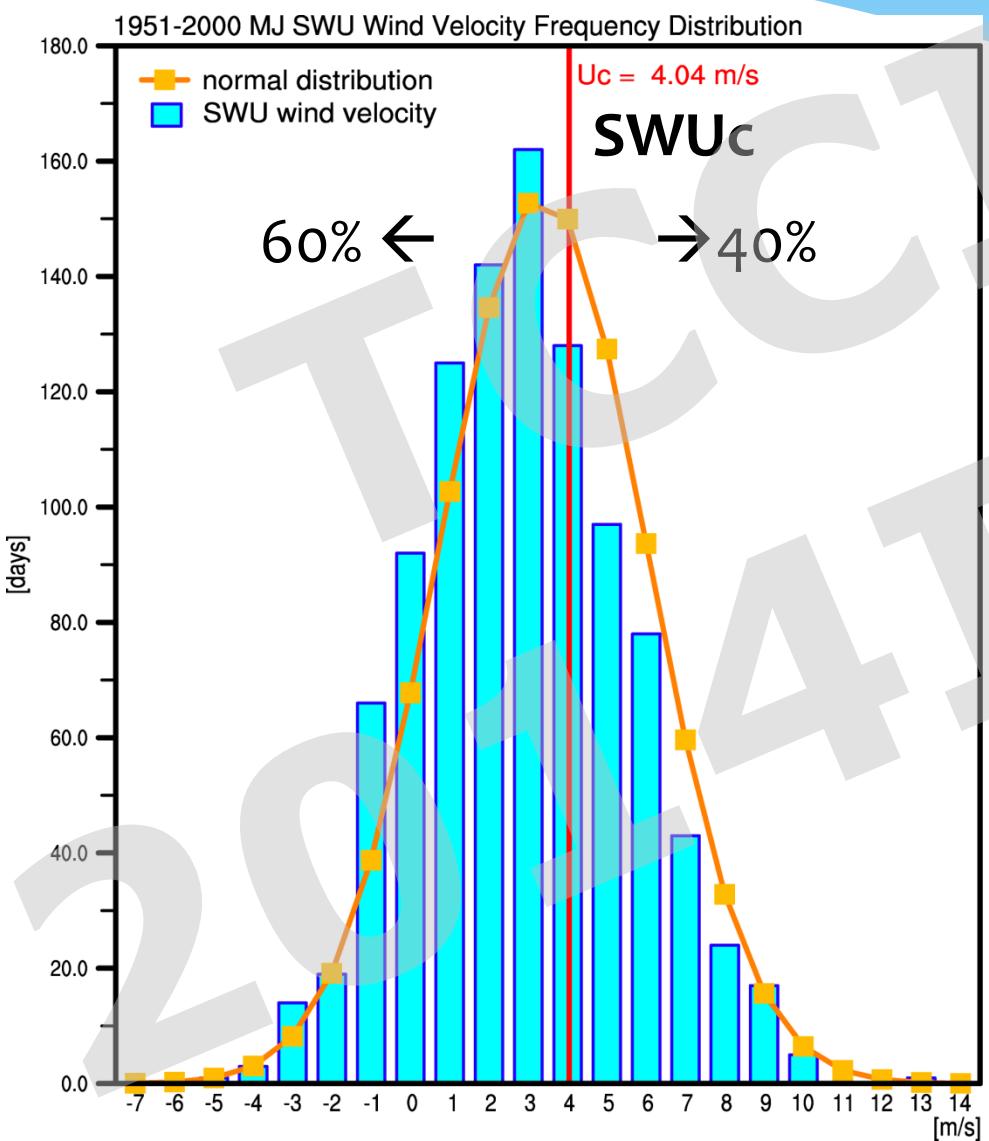
850hPa Vorticity (color) and U (contour)
Anomalies Composite (95% confidence level)

The Large-scale Circulation Index: SWFI



1. Positive vorticity over S. China (**red** dots) and negative vorticity over the SCS and Philippine Sea (**blue** dots)
2. Calculate the SWU – the mean U850 over the grids with strong vorticity gradient (**orange** dots)
3. Define the critical value of strong U850: **SWU_c**
4. **SWFI** is defined as the number of days that **SWU** \geq **SWU_c**

SWUc of the “Perfect Model” (NCEP/NCAR Reanalysis)



1951-2000 Taiwan Mei-Yu Extr. Rain Cases

	Date	SWU		Date	SWU
1	1951-05-14	7.49	16	1981-05-27	4.77
2	1951-06-07	6.24	17	1983-05-31	7.59
3	1956-05-29	-0.66	18	1984-06-02	4.55
4	1959-06-05	6.47	19	1985-05-26	1.55
5	1966-06-07	3.75	20	1986-05-14	5.51
6	1967-05-21	9.12	21	1986-06-04	5.05
7	1968-06-18	5.62	22	1990-06-07	3.96
8	1970-05-25	4.76	23	1991-06-21	6.57
9	1971-06-05	6.02	24	1993-06-04	6.13
10	1972-06-11	4.03	25	1994-05-01	0.22
11	1974-06-21	8.15	26	1997-05-14	-0.96
12	1975-06-10	1.97	27	1997-06-02	4.58
13	1976-05-28	7.94	28	1997-06-29	1.78
14	1977-06-04	3.83	29	1998-06-01	6.61
15	1979-06-11	3.88	30	1999-06-19	2.49

SWFI: a proxy of Taiwan May-yu extreme rain frequency

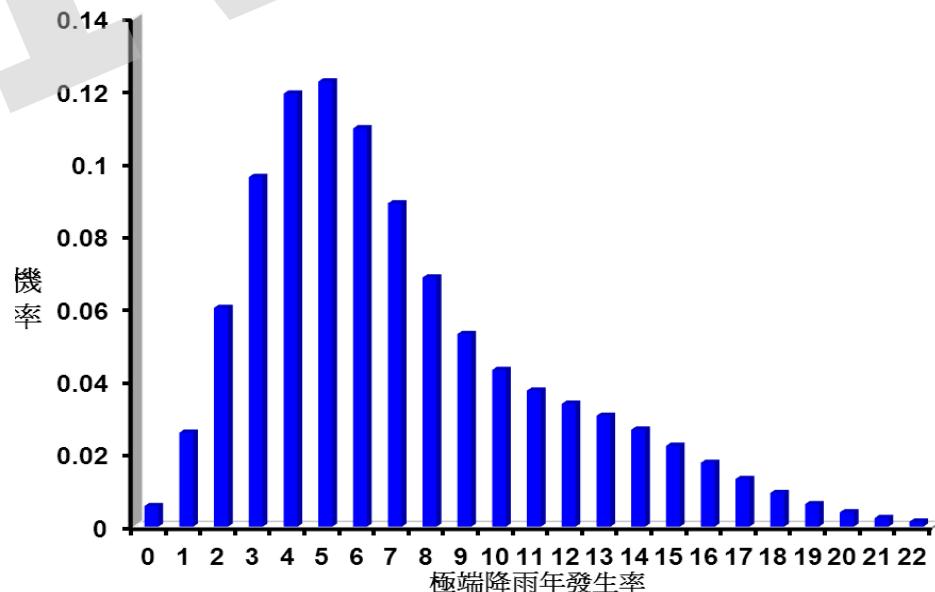
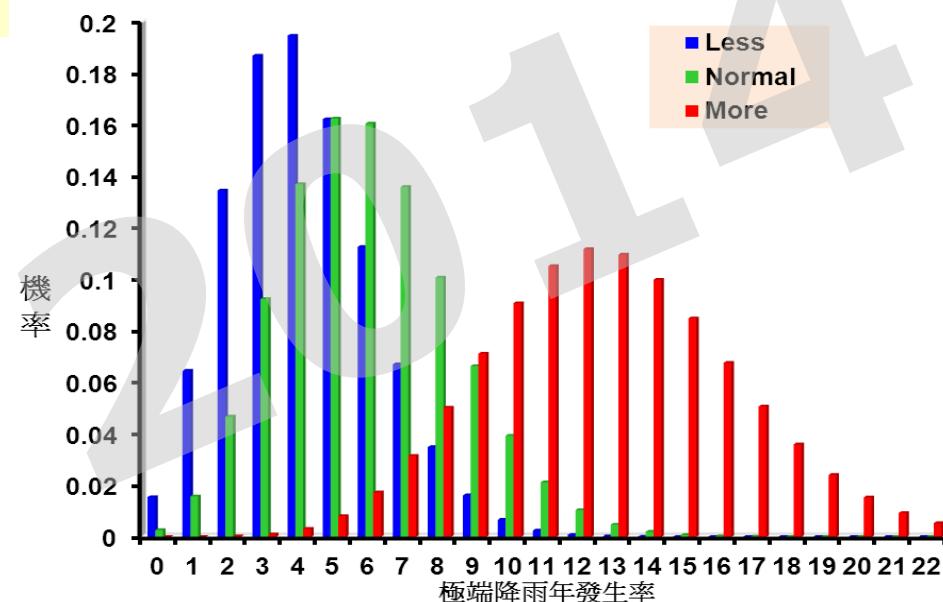
$SWFI = \text{the number of days that } SWU \geq SWU_c$

Note: SWFI value is data set/model dependent

Downscaling procedure:

- (1) SWFI classification - **Less : Normal : More = 3 : 4 : 3**
- (2) Use a Poisson distribution to describe the PDF of the extreme event frequency in each category
- (3) Use a combined PDF to describe the probabilities of extreme event frequency:

$$PDF_{rate} = 0.3 * PDF_{more} + 0.4 * PDF_{normal} + 0.3 * PDF_{less}$$



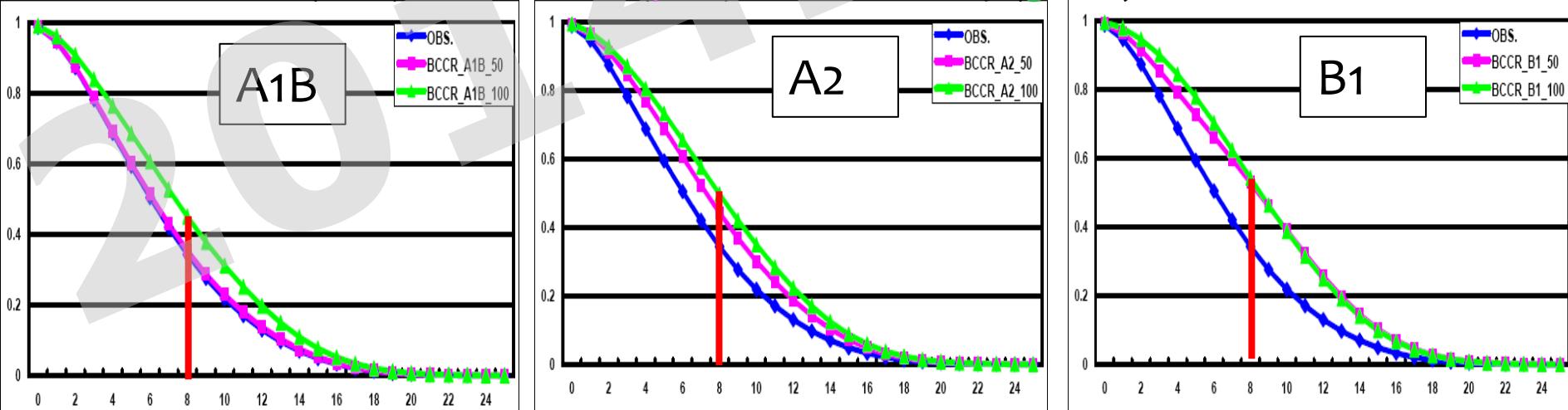
Future Projections based on CMIP3 models

◆ Model : IPCC AR4

Name	Originating Group	Country
BCCR_BCM20	Bjerknes Centre for Climate Research	Norway
CCCMA_CGCM31_T63	Canadian Centre for Climate Modelling and Analysis	Canada
CSIRO_MK30	Commonwealth Scientific and Industrial Research Organisation Atmospheric Research	Australia
CSIRO_MK35	Commonwealth Scientific and Industrial Research Organisation Atmospheric Research	Australia
MIROC32_HR	The University of Tokyo/CCSR, NIES, and JAMSTEC/FRCGC	Japan
MPI_ECHAM5	Max Planck Institute for Meteorology	Germany

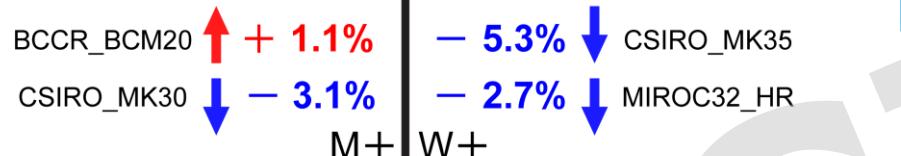
Example Projection Result: BCCR_BCM20

Present climate (blue), Near future (pink), End of century (green)

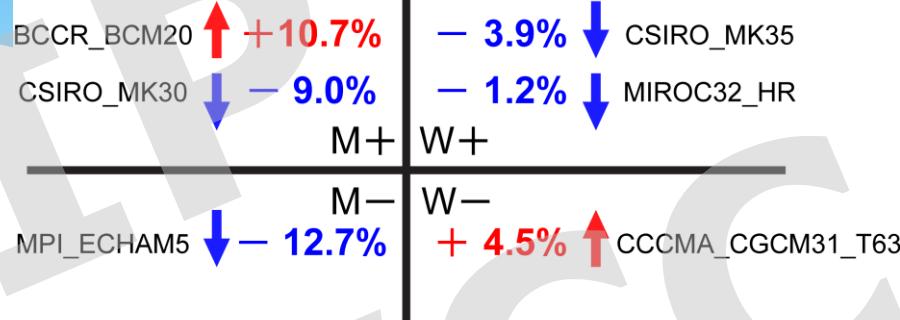


Taiwan Mei-yu Extreme Event Frequency Future Projections

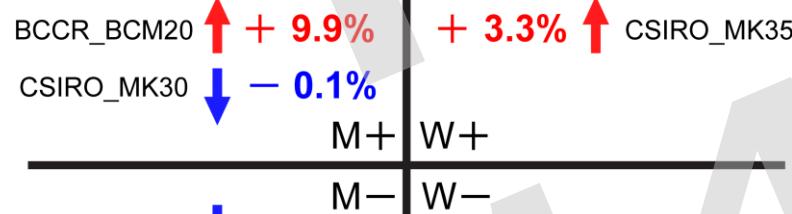
A1B中期(2046-2065) 梅雨季極端降雨年發生率變化
比較年：1961-2000



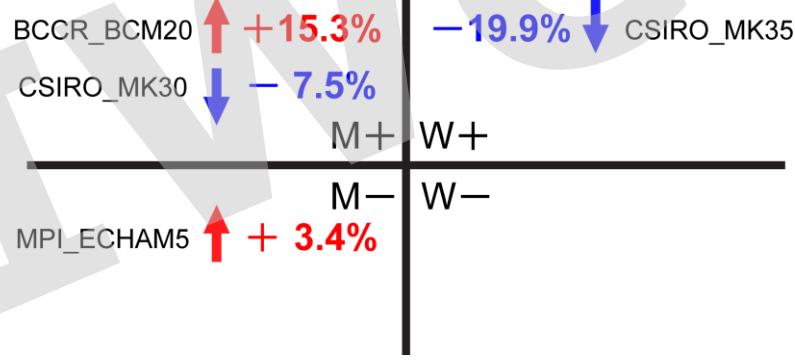
A1B後期(2081-2100) 梅雨季極端降雨年發生率變化
比較年：1961-2000



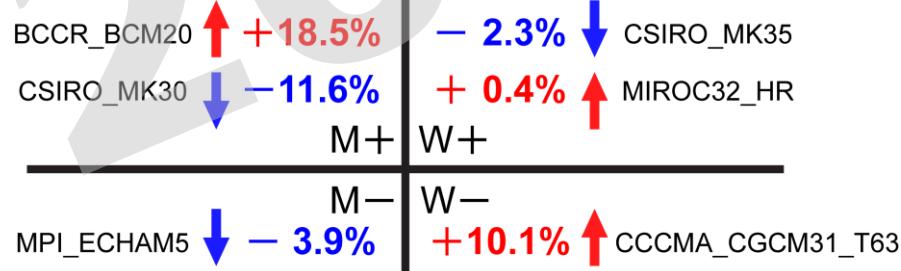
A2中期(2046-2065) 梅雨季極端降雨年發生率變化
比較年：1961-2000



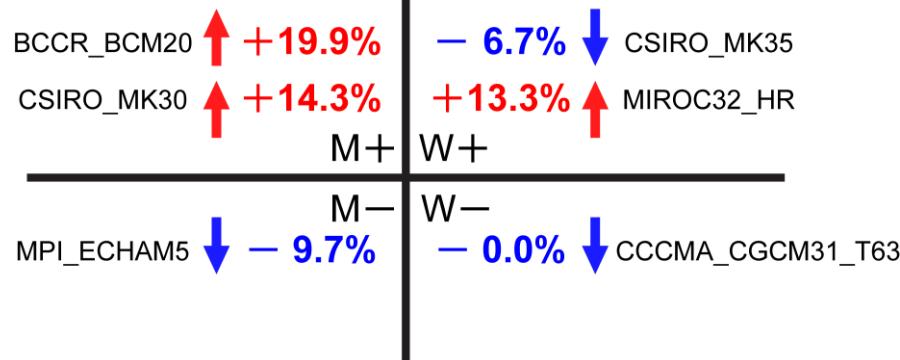
A2後期(2081-2100) 梅雨季極端降雨年發生率變化
比較年：1961-2000



B1中期(2046-2065) 梅雨季極端降雨年發生率變化
比較年：1961-2000



B1後期(2081-2100) 梅雨季極端降雨年發生率變化
比較年：1961-2000





**Need more models for making the
future projections !**

TCCLP
2014 IN CC

Ongoing Work: CMIP5 model output analysis

◆ Model Selection

Basic criteria

- Transition from East Asian Winter Monsoon to East Asian Summer Monsoon
- Correlation of Taiwan Mei-yu (MJ) rain and SWU

Model Name	Institution
ACCESS1.0	Commonwealth Scientific and Industrial Research Organization and Bureau of Meteorology, Australia (CSIRO-BOM)
BCC-CSM1.1	Beijing Climate Center, China Meteorological Administration, China (BCC)
CanESM2	Canadian Center for Climate Modelling and Analysis, Canada (CCCma)
CCSM4	National Centre for Atmospheric Research, USA (NCAR)
CNRM-CM5	Centre National de Recherches Meteorologiques and Centre Europeen de Recherches et Formation Avancees en Calcul Scientifique, France (CNRM-CERFACS)
CSIRO-Mk3.6.0	Queensland Climate Change Centre of Excellence and Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO-QCCCE)
FGOALS-g2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences and CESS, Tsinghua University, China (LASG-CESS)
GFDL-CM3	Geophysical Fluid Dynamics Laboratory, NOAA, USA (NOAA GFDL)
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory, NOAA, USA (NOAA GFDL)
GISS-E2-R	Goddard Institute for Space Studies, NASA, USA (NASA GISS)
HadGEM2-CC	Met Office Hadley Centre, UK (MOHC)
HadGEM2-ES	Met Office Hadley Centre, UK (MOHC)
INM-CM4	Institute for Numerical Mathematics, Russian (INM)
IPSL-CM5A-LR	Institute Pierre Simon Laplace, France (IPSL)
IPSL-CM5A-MR	Institute Pierre Simon Laplace, France (IPSL)
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan (MIROC)
MIROC-ESM	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan (MIROC)
MPI-ESM-LR	Max Planck Institute for Meteorology, Germany (MPI-M)
MRI-CGCM3	Meteorological Research Institute, Japan (MRI)
NorESM1-M	Norwegian Climate Centre, Norway (NCC)

Evaluate the seasonal transition in CMIP5 model

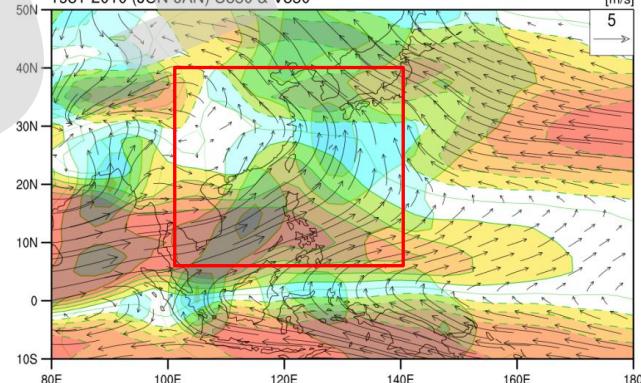
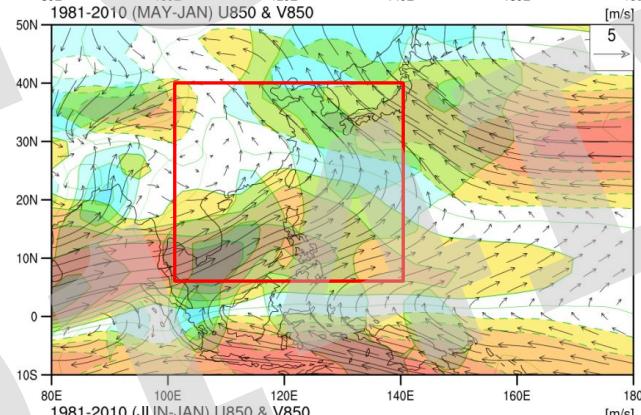
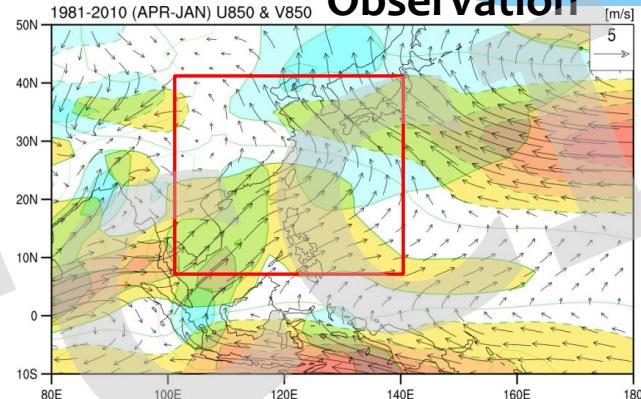
monthly data

Observation

Example: Wind transition

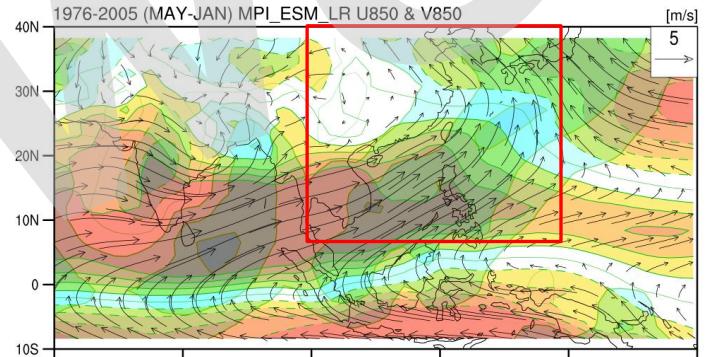
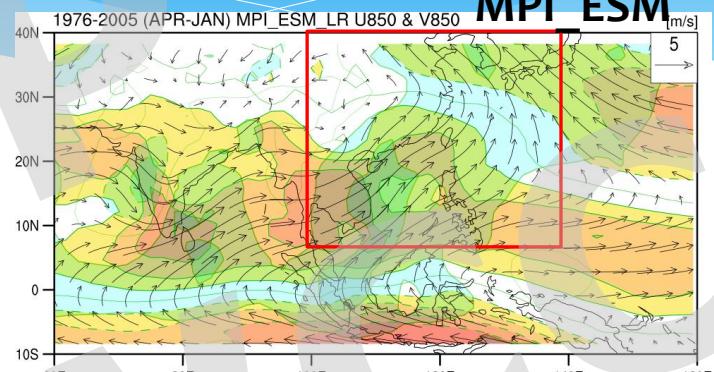
Apr minus Jan

Corr. U850 0.92
Corr. V850 0.83



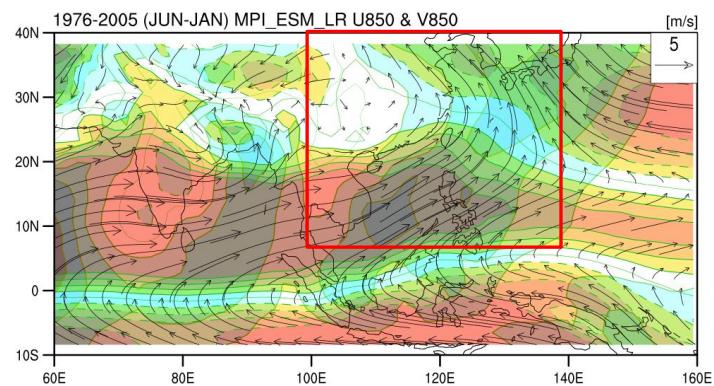
May minus Jan

0.95
0.83

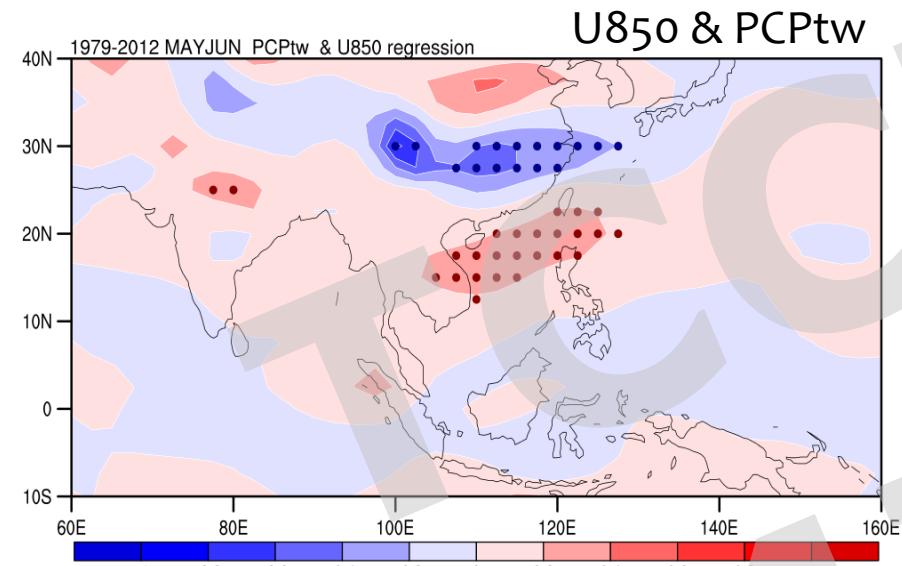


Jun minus Jan

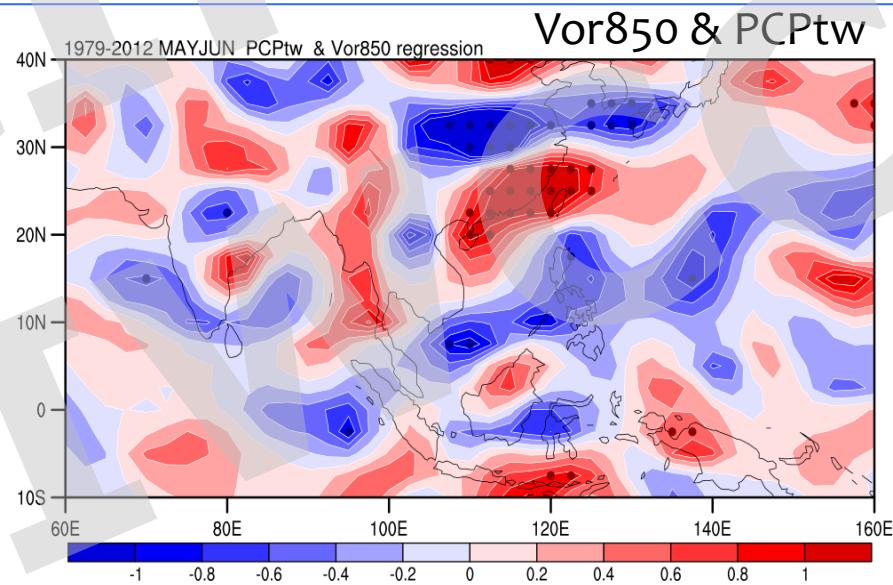
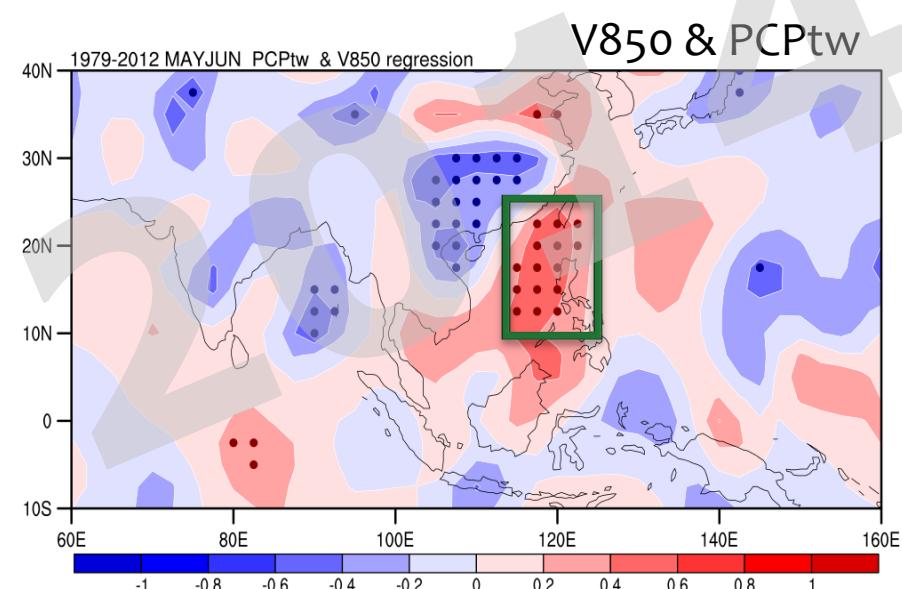
0.93
0.87



Define Large-scale circulation index based on CMIP5 model & Taiwan Rain monthly data



PCPtw: mean normalized MJ rain over 20 stations

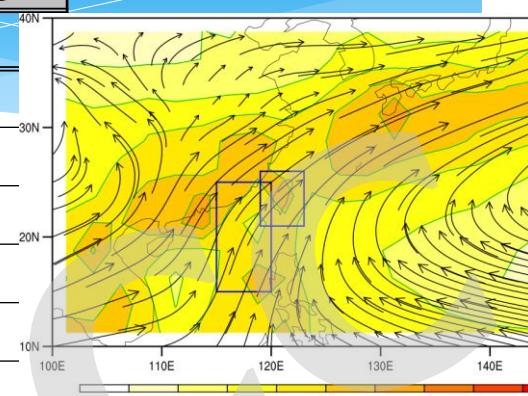


$$SWK = \text{Sum}(U^{**2} + V^{**2})/N$$

U and V are the wind velocity at the selected grids where correlation of V850 and PCPtw is positive; only the grids (total number = N) where $U \geq 0$ and $V \geq 0$ are included in the Sum

Correlation of SWK & Precipitation over Taiwan

Model Name	MAY	JUN	MAY-JUN
NCEP_R1 VS GPCP	0.37	0.65	0.61
ACCESS1.0	0.37	0.40	0.55
BCC-CSM1.1	-0.06	0.49	0.34
CanESM2	0.45	0.69	0.76
CCSM4	0.13	0.07	0.17
CNRM-CM5	0.13	0.56	0.47
CSIRO-Mk3.6.0	0.20	0.58	0.61
FGOALS-g2	0.25	0.21	0.15
GFDL-CM3	-0.19	0.57	0.29
GFDL-ESM2M	0.32	0.47	0.32
GISS-E2-R	0.37	0.68	0.65
HadGEM2-CC	0.08	0.61	0.56
HadGEM2-ES	0.04	0.54	0.51
INM-CM4	0.07	0.34	0.17
IPSL-CM5A-LR	-0.43	0.42	0.45
IPSL-CM5A-MR	0.03	0.38	0.64
MIROC5	0.60	0.68	0.71
MIROC-ESM	0.33	0.33	0.33
MPI-ESM-LR	0.23	0.78	0.63
MRI-CGCM3	0.36	0.43	0.44
NorESM1-M	0.49	0.68	0.53



CMIP5 Model Selection

Model Name	MAY	JUN	MAY-JUN
NCEP_R1 VS GPCP	0.37	0.65	0.61
ACCESS1.0	0.37	0.40	0.55
BCC-CSM1.1	-0.06	0.49	0.34
CanESM2	0.45	0.69	0.76
CCSM4	0.13	0.07	0.17
CNRM-CM5	0.13	0.56	0.47
CSIRO-Mk3.6.0	0.20	0.58	0.61
FGOALS_g2	0.25	0.21	0.15
GFDL_CM3	0.19	0.57	0.29
GFDL-ESM2M	0.32	0.47	0.32
GISS-E2-R	0.37	0.68	0.65
HadGEM2-CC	0.08	0.61	0.56
HadGEM2-ES	0.04	0.54	0.51
INM-CM4	0.07	0.34	0.17
IPSL-CM5A-LR	-0.43	0.42	0.45
IPSL-CM5A-MR	0.03	0.38	0.64
MIROC5	0.60	0.68	0.71
MIROC-ESM	0.33	0.33	0.33
MPI-ESM-LR	0.23	0.78	0.63
MRI-CGCM3	0.36	0.43	0.44
NorESM1-M	0.49	0.68	0.53

11 models
selected

Ongoing

1. CMIP5 model monthly data analysis

→ Use the selected models to project how Taiwan's Mei-yu changes in the warmer climate and attribute the possible physical basis such as the SST and monsoon (E Asian and W Pacific) relationship

2. Future projections of the large-scale circulation index

→ Use the large-scale circulation index to infer the future PDF of the annual frequency of Mei-yu seasonal extreme rainfall events

**THANK YOU
FOR
YOUR
ATTENTION !**

Any Question ?

