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

Dynamical Downscaling using High-Resolution AGCM Projection data over Taiwan area

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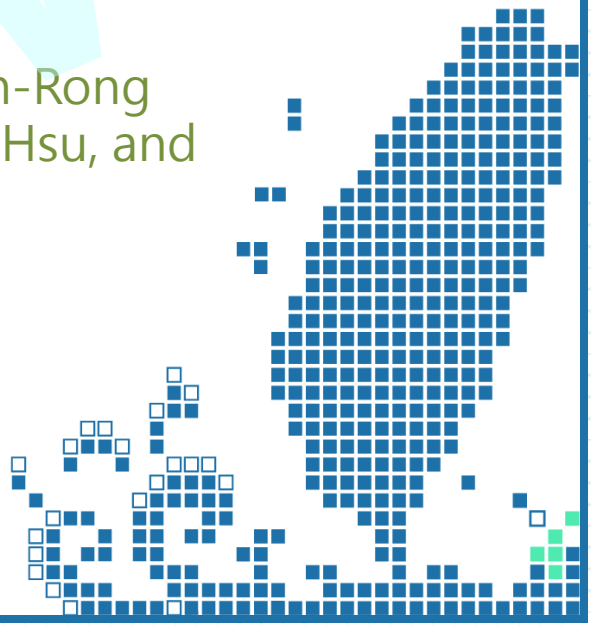

Workshop on High-Resolution Climate Simulation, Project, and Application
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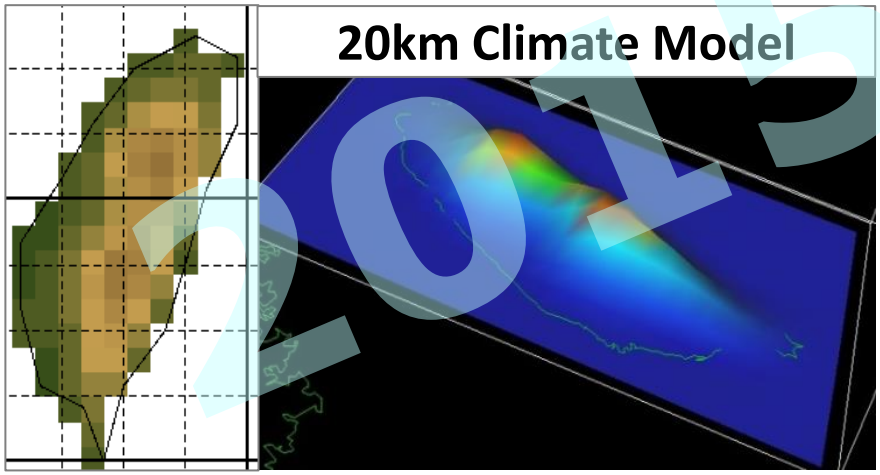
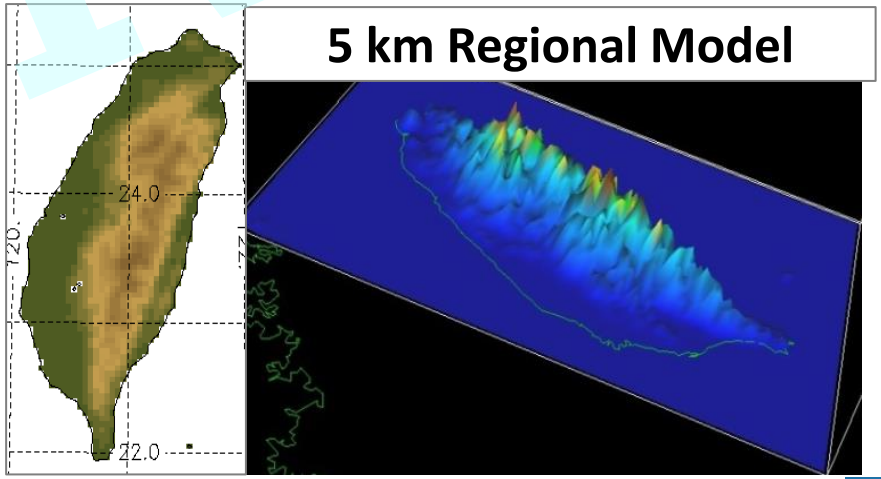
tccip.ncdr.nat.gov.tw

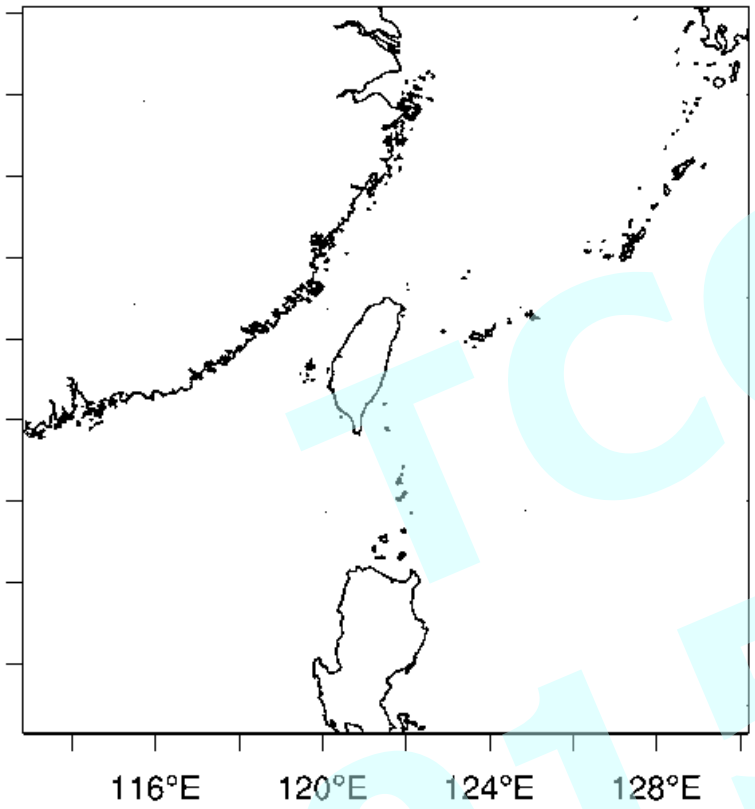
Motivation

- **Dynamical Downscaling**
  - Provide high-resolution climate projection for impact study, mission of **TCCIP** project.
  - Add value due to Taiwan’ s complex terrain & landuse.
- **Super high resolution AGCM**
  - Good performance of AGCM
  - Ability of simulating extremes: Tropical Cyclone
- **Multiple GCM downscaling**
  - Uncertainty for small region mostly comes from GCM. Spread, consensus…
  - Ability of selecting better one





Using WRF 3.5.1 as RCM



Physical Option

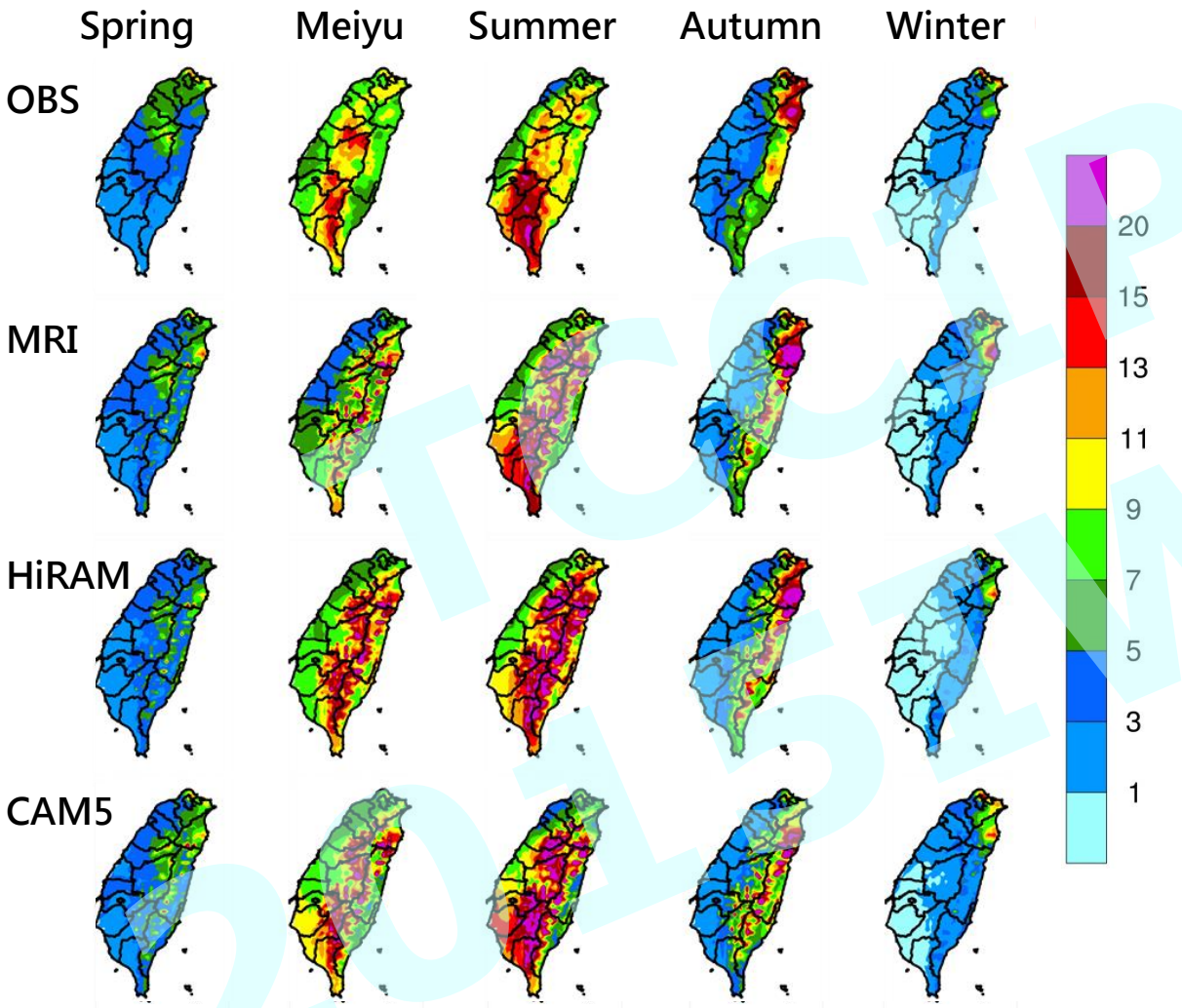
- ❑ Noah land surface
- ❑ YSU Boundary Layer
- ❑ Monin-Obukhov surface layer
- ❑ CAM3 radiation
- ❑ WSM5 microphysics
- ❑ w/o cumulus

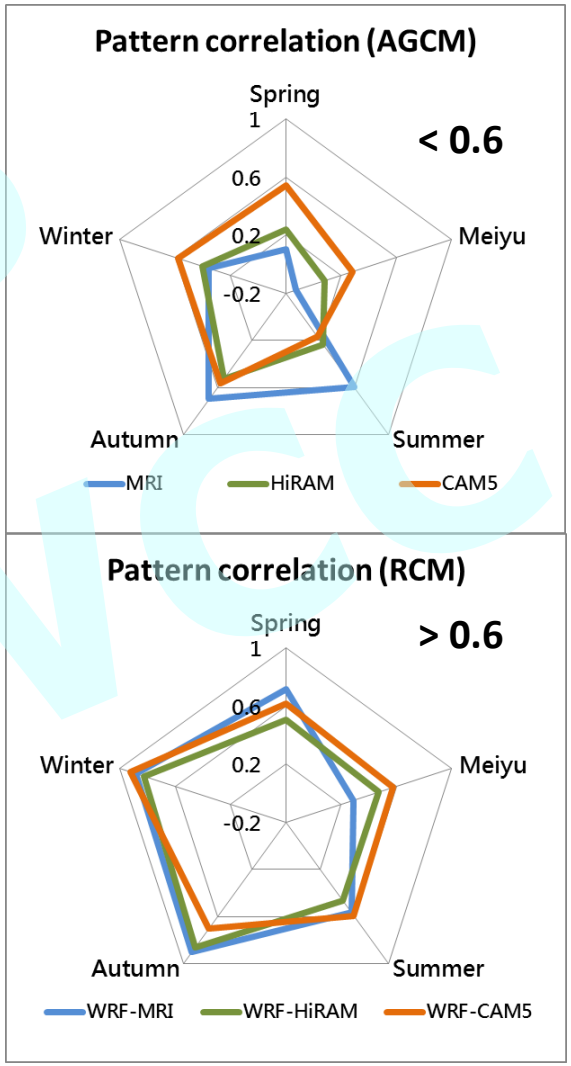
Other setting

- ❑ Spectral nudging for U, V, Φ, and T above PBL.
- ❑ RCP8.5 GHG in radiation scheme.
- ❑ Taiwan land use data.
- ❑ Simulation of 2 time slices, 1979-2003 and 2075-2099.
- ❑ Cold start for atm. circulation once a year.
- ❑ No cold start for ground layers, except at beginning of 25-year periods.

- RCM with 5km resolution.
- 380 × 400 grid points, cover an area of ~20° × 20°.
- Driven by 3 super high-resolution AGCM: MRI-AGCM[1], HiRAM[2], and CAM5[3].
- Thanks to 1: SOUSEI program, 2: CCliCS project, 3: Michael Wehner LBNL

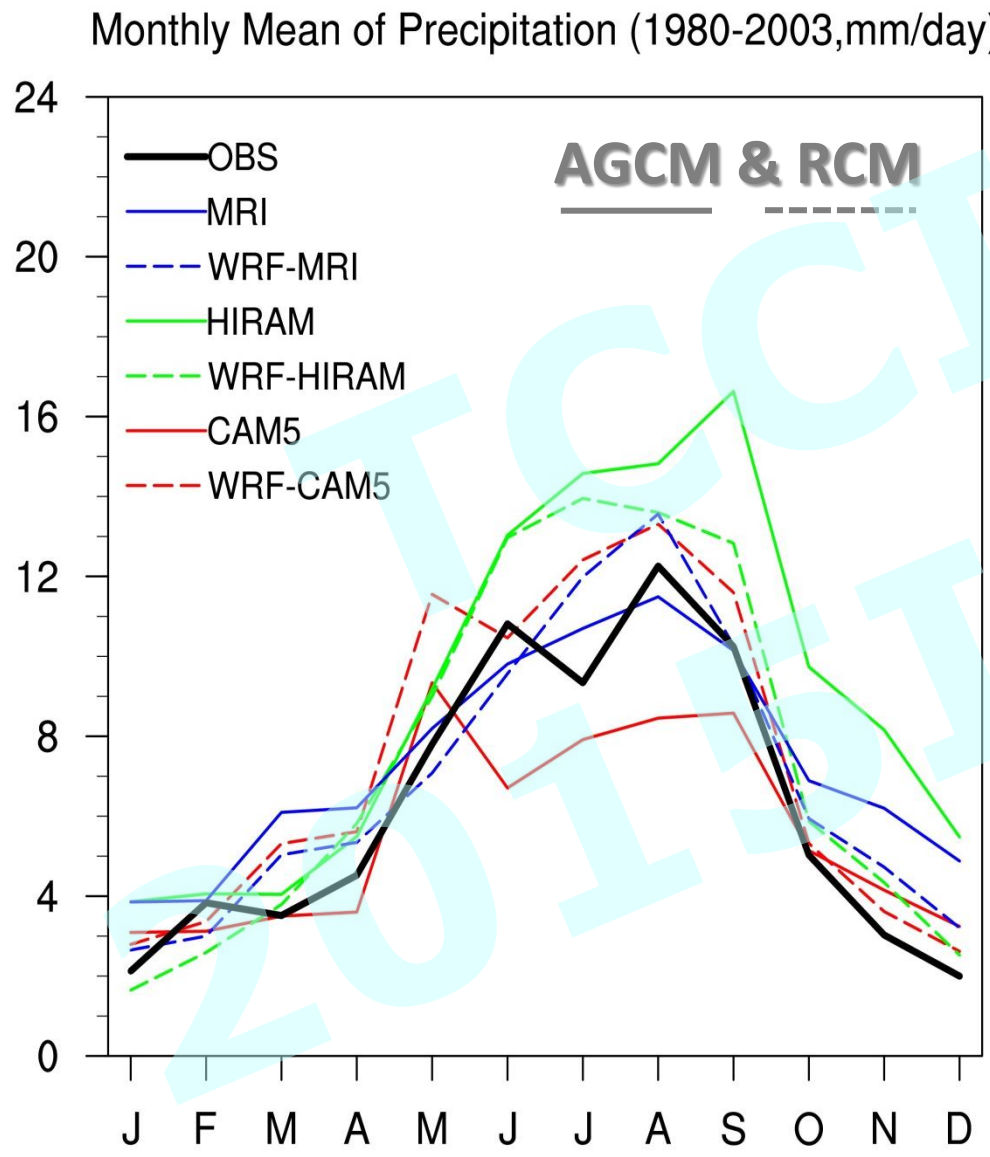
Seasonal Precipitation





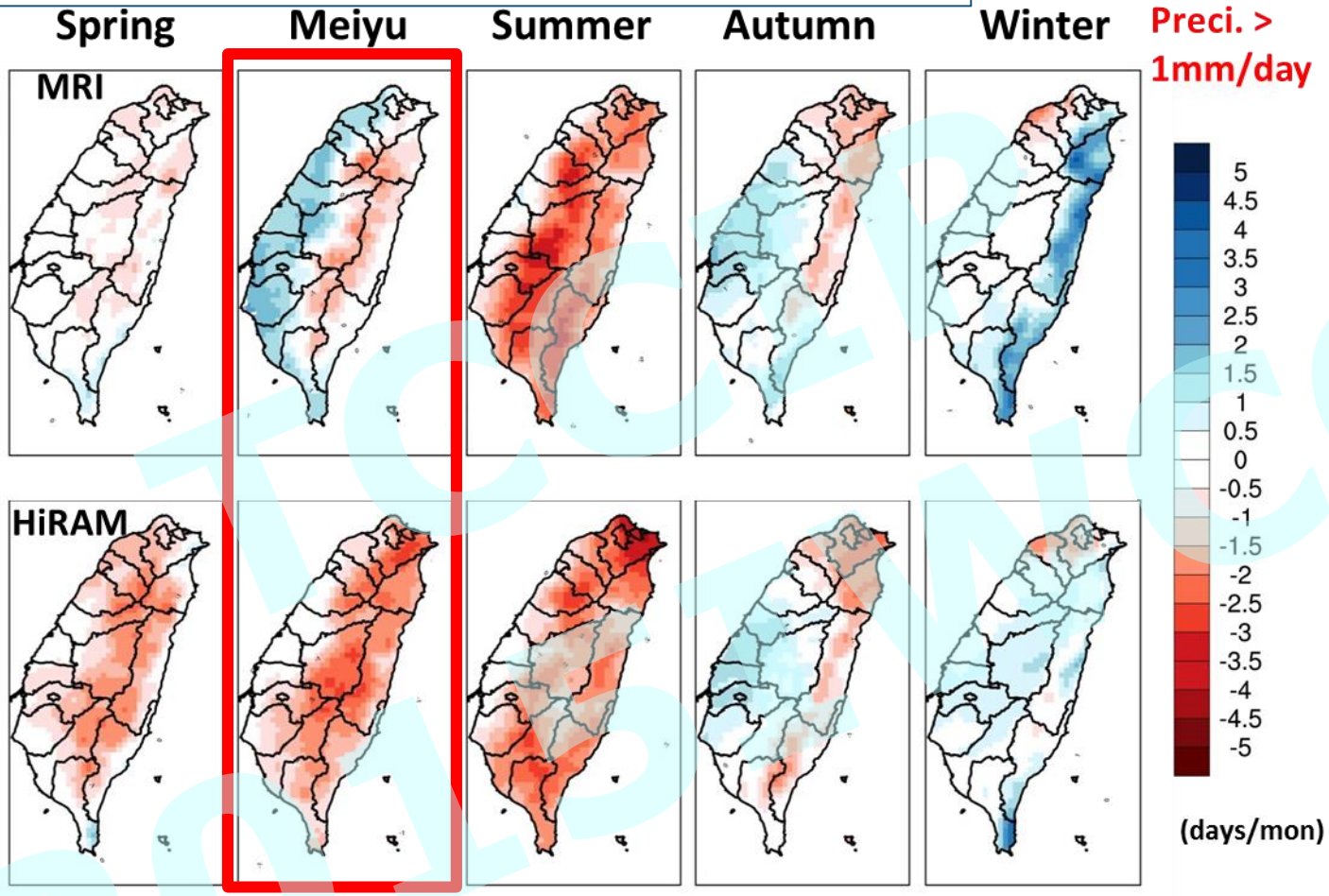
- Pattern correlations (vs. Obs) increase a lot after downscaling.
- Difference in RCM are much smaller than GCM (less diverse)

Annual cycle of precipitation



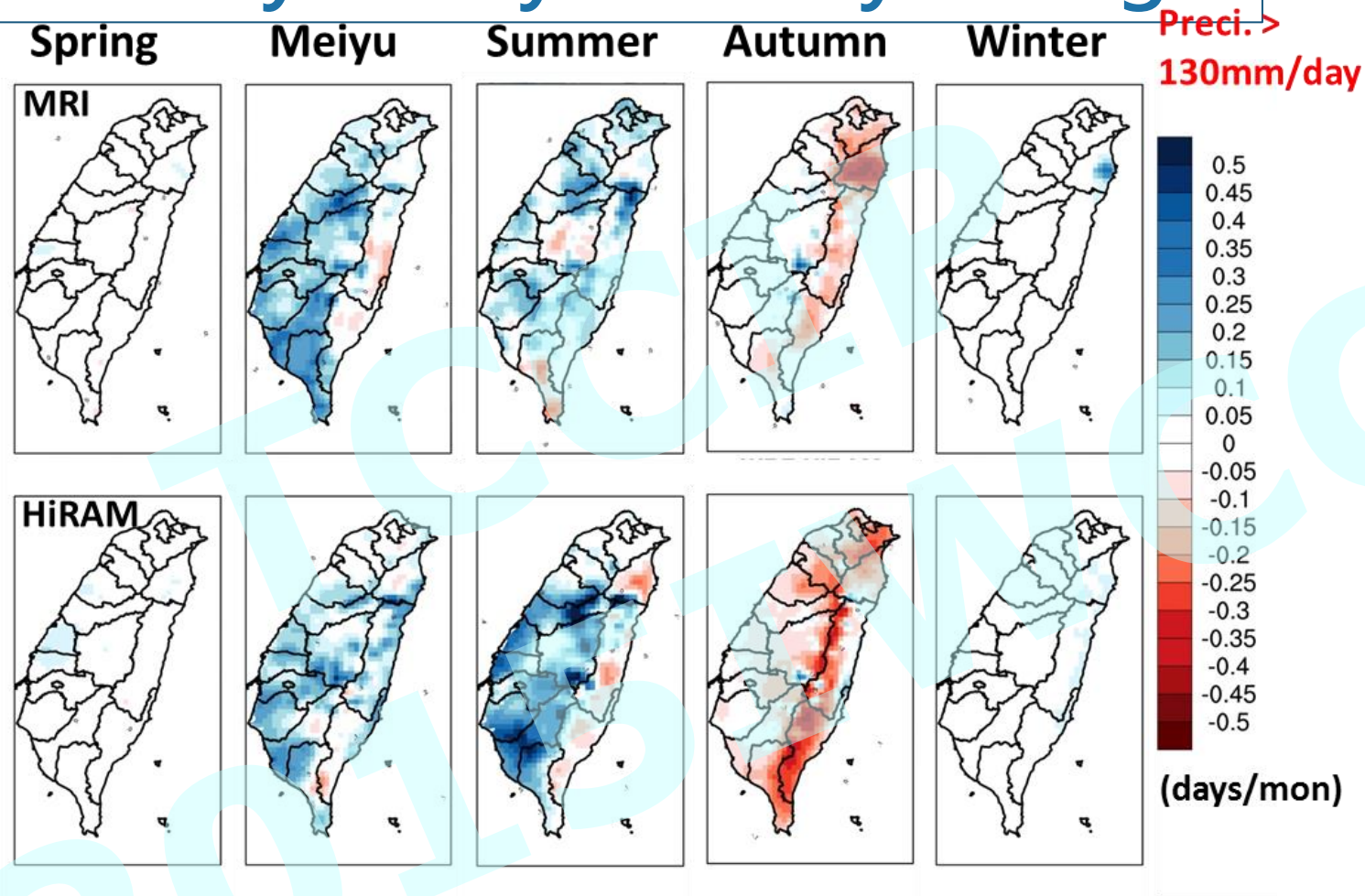
- Annual cycles are similar before and after downscaling.
- Downscaling improves precipitation simulation, reducing over- and under-estimation.
- Differences in RCM are much smaller than in GCM. Downscaling reduces the spread.

Wet Day Change in RCM



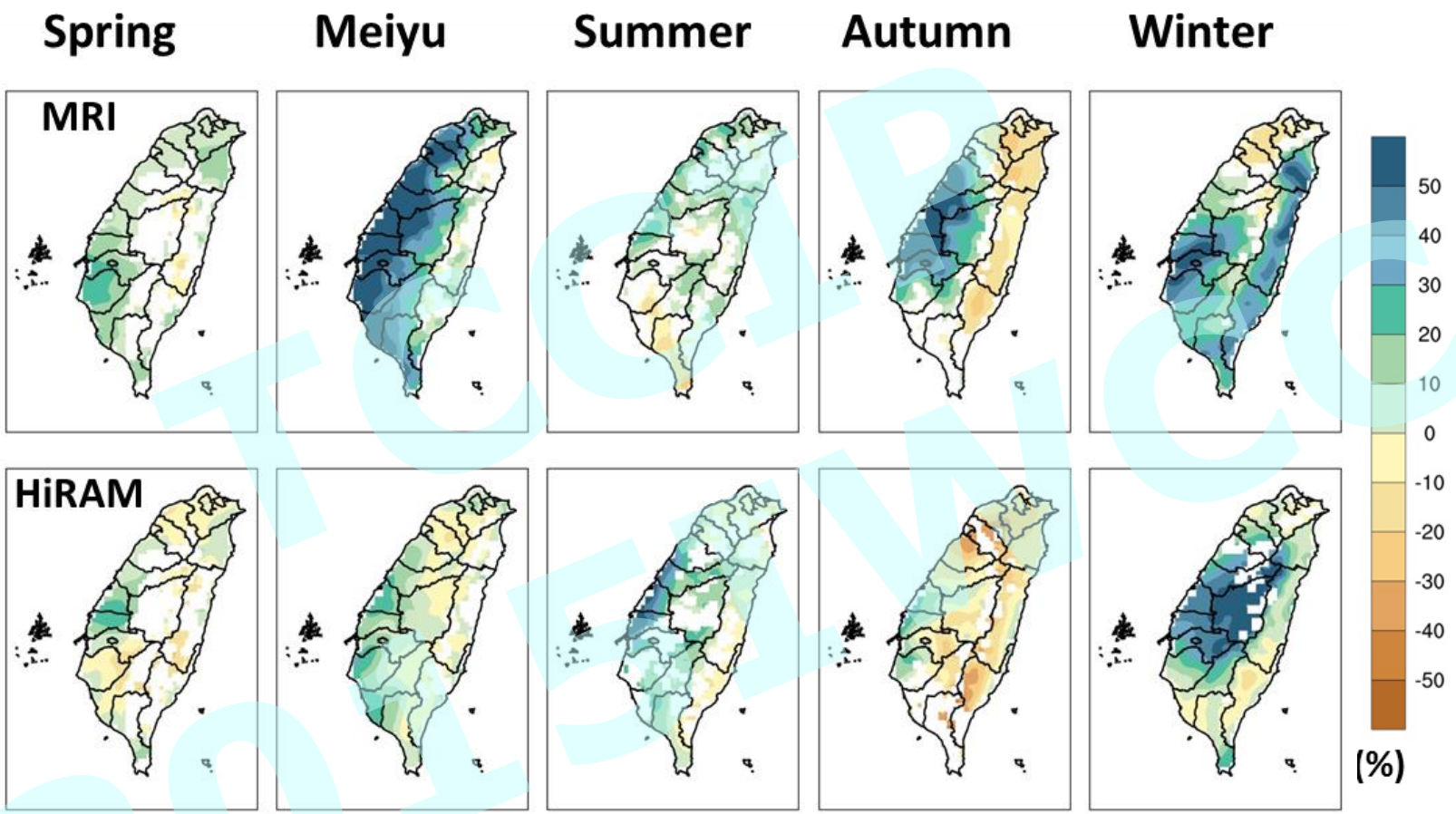
- Wet days decrease for most major rain areas, except in winter & meiyu
- Two projections similar to each other except in Meiyu season

extremely heavy rain day change



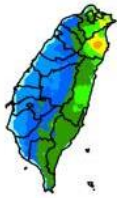
- Decrease in Autumn.
- Less TC should contribute to decrease in Autumn and Summer.
- More active afternoon shower in Summer?

Seasonal rainfall change in RCM



- Rainfalls generally increase except in autumn.
- Projections of two models are similar but somewhat different.
  - which one to use ?

Precipitation biases in RCM

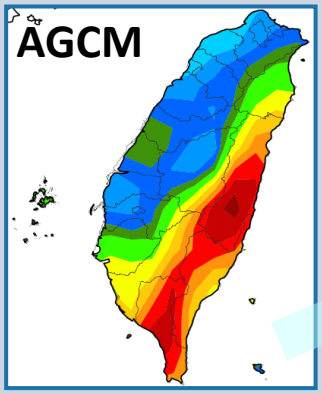
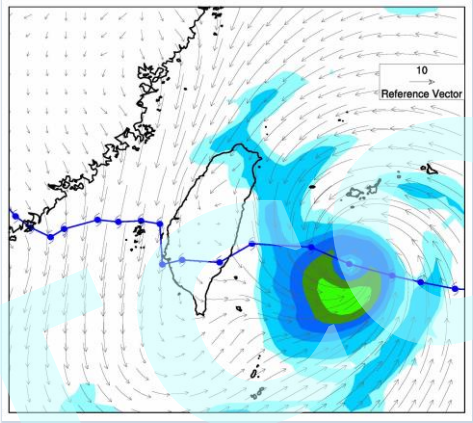
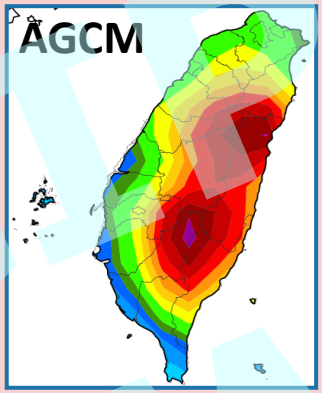
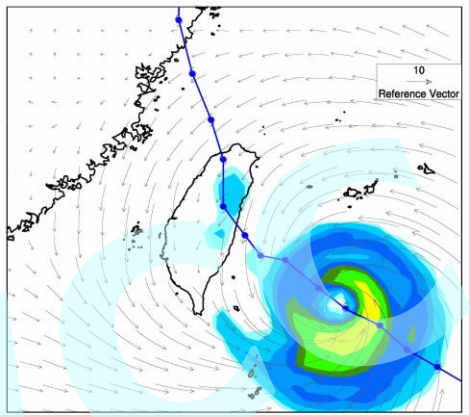
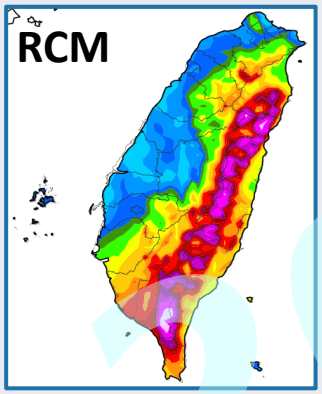
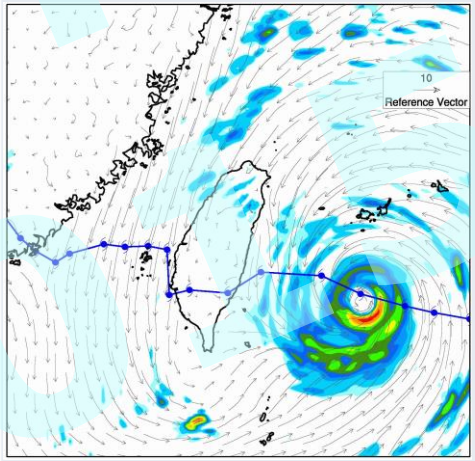
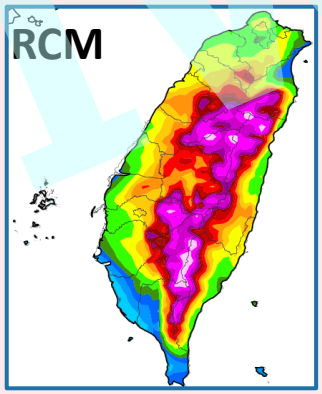
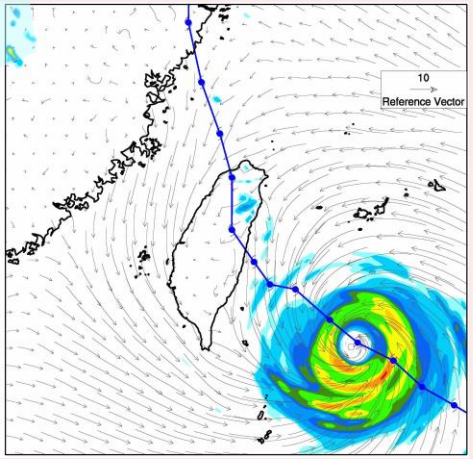
		Spring (FMA) 			Meiyu (MJ) 			Summer (JA) 			Autumn (SON) 			Winter (DJ) 		
		MRI	HIRAM	CAM5	MRI	HIRAM	CAM5	MRI	HIRAM	CAM5	MRI	HIRAM	CAM5	MRI	HIRAM	CAM5
North		-17.9%	-35.1%	**-15.7%**	-32.8%	-6.1%	-3.5%	30.1%	36.2%	7.4%	-8.5%	3.6%	-22.1%	33.9%	-26.8%	**23.0%**
Center		4.7%	-7.8%	5.4%	-24.4%	**10.3%**	16.4%	**19.8%**	29.0%	40.2%	8.3%	48.2%	64.1%	1.9%	-32.0%	12.7%
South		38.5%	28.8%	49.2%	-17.8%	**5.0%**	17.2%	**4.6%**	-2.4%	10.6%	1.8%	9.1%	9.8%	39.7%	20.2%	42.1%
East		47.6%	49.3%	71.7%	32.4%	63.2%	43.4%	31.4%	61.1%	21.4%	35.4%	40.8%	**20.8%**	64.1%	**35.6%**	47.4%
Taiwan		12.5%	2.4%	20.7%	-10.3%	18.7%	19.2%	19.2%	28.4%	20.5%	15.8%	28.0%	15.1%	40.7%	0.7%	32.3%
Pattern Correlation		**0.72**	**0.50**	**0.61**	**0.29**	**0.47**	**0.57**	**0.57**	**0.46**	**0.59**	**0.90**	**0.86**	**0.70**	**0.88**	**0.82**	**0 .93**

- Consider the rainfall amount in major rain areas
  - WRF-MRI is better in spring and summer.
  - WRF-HiRAM is better in meiyu and winter.
  - WRF-CAM5 is better in spring and autumn.
- In term of patter correlation, WRF-HiRAM is worst

Summary -1

- WRF model is used as RCM to downscale data of super high resolution AGCM MRI, CAM5 and HiRAM. Result shows significant improvement in precipitation simulation.
- Downscaling also reduce the precipitation spread in GCM.
- Difference between GCM is larger than that between RCM and GCM. RCM performance depends on GCM.
- With multi GCM downscaling, the evaluation of regional bias, pattern correlation, and circulation validation can be used as guideline to select wanted projection data.

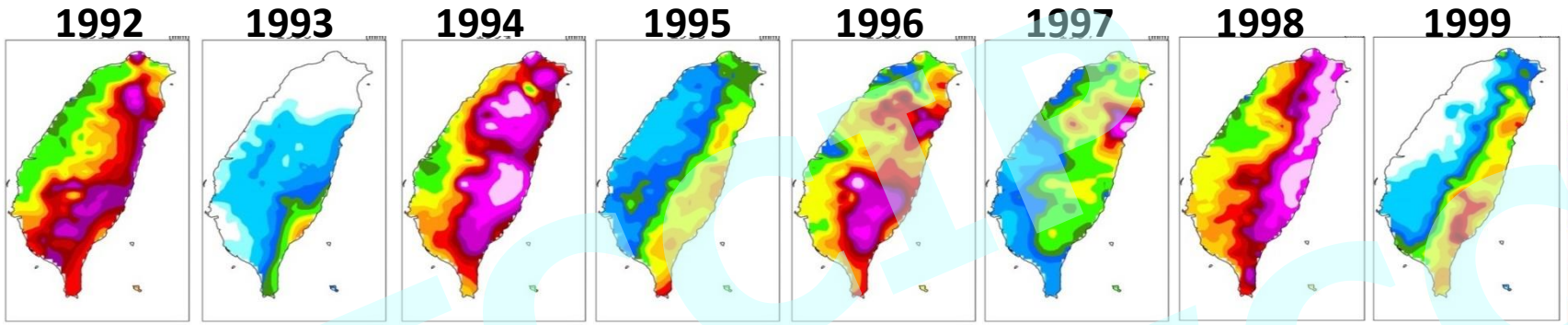
Typhoon Precipitation

MRI 200505		HiRAM 199701	
			
			

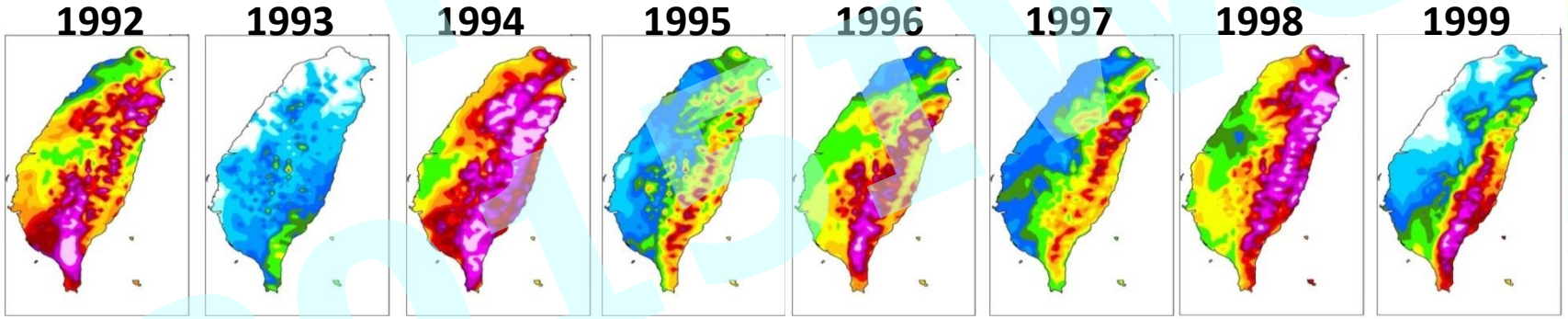
- Typhoons can be explicitly simulated by super high resolution AGCM.
- RCM can provide more realistic and detailed information.

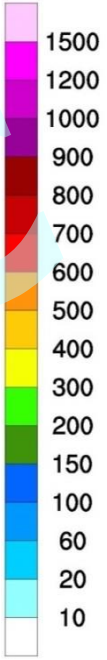
Typhoon Precipitation

OBS



WRF-CFSR

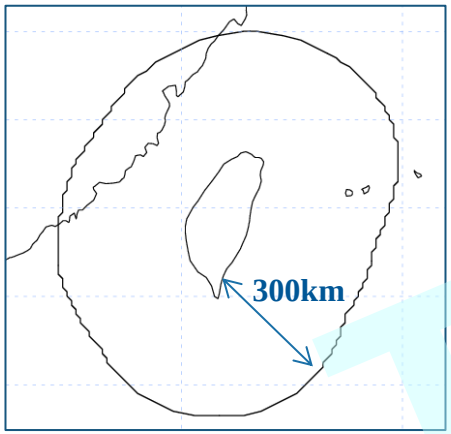




mm/yr

- Downscaling can simulate reasonable and detailed TC rainfall.
- For RCM-AGCM, there still are biases to be corrected for impact study.

Typhoon Affecting Taiwan

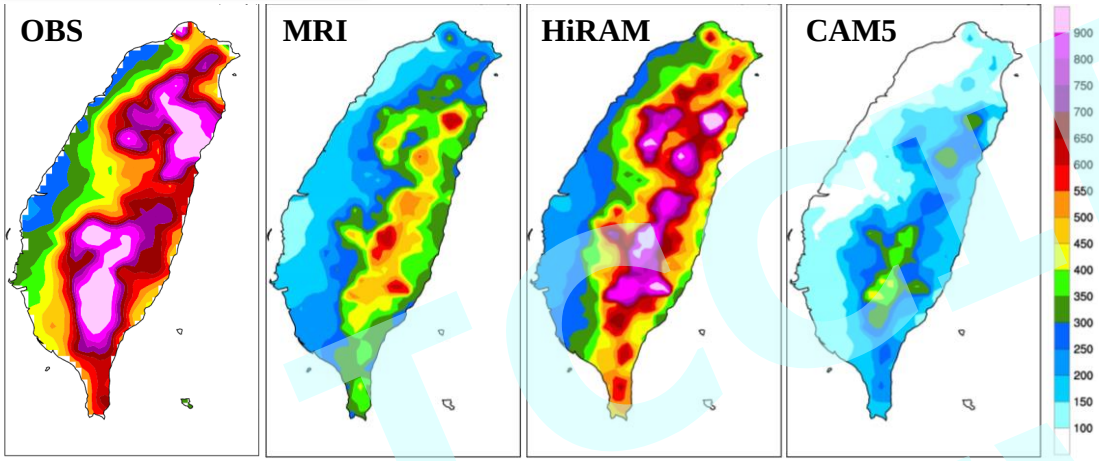


AGCM	Period	Number	# percentage (%)			Hr/event
			TS	Cat ≤3	Cat>3	
MRI	1979-2003	85	17.7	50.6	31.8	31
	2075-2099	43	14.9	44.7	40.4	34
HiRAM	1979-2003	128	50.0	50.0	0.0	34
	2075-2099	44	38.6	50.0	11.4	31
CAM5	1979-2003	35	14.3	40.0	45.7	46
OBS	1979-2003	130	36.2	48.5	15.4	48

- Too few typhoons in CAM5 (~1/3)
- MRI underestimated typhoon number by 35%.
- Affecting duration is underestimated by 35%.
- Total # reduces but the # intense ones increases in the future .

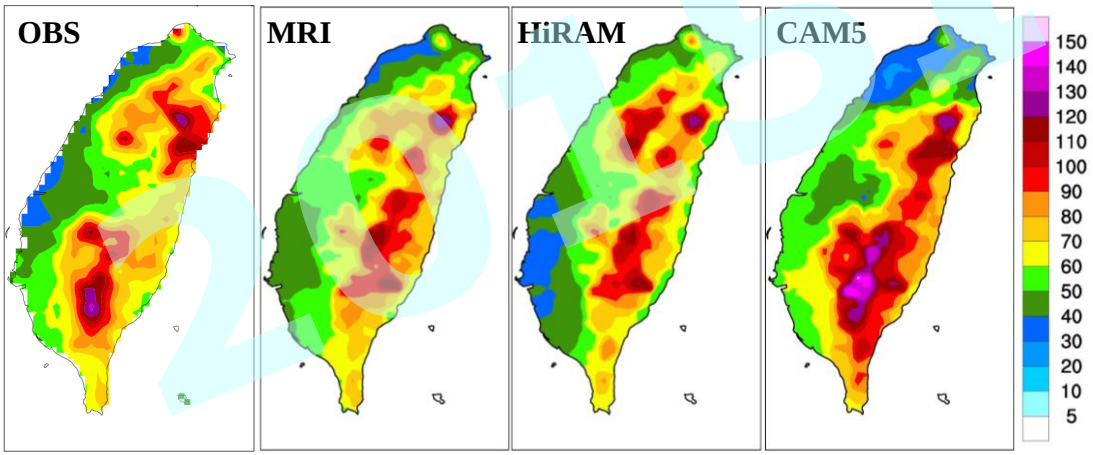
Typhoon Precipitation

Mean Prec.



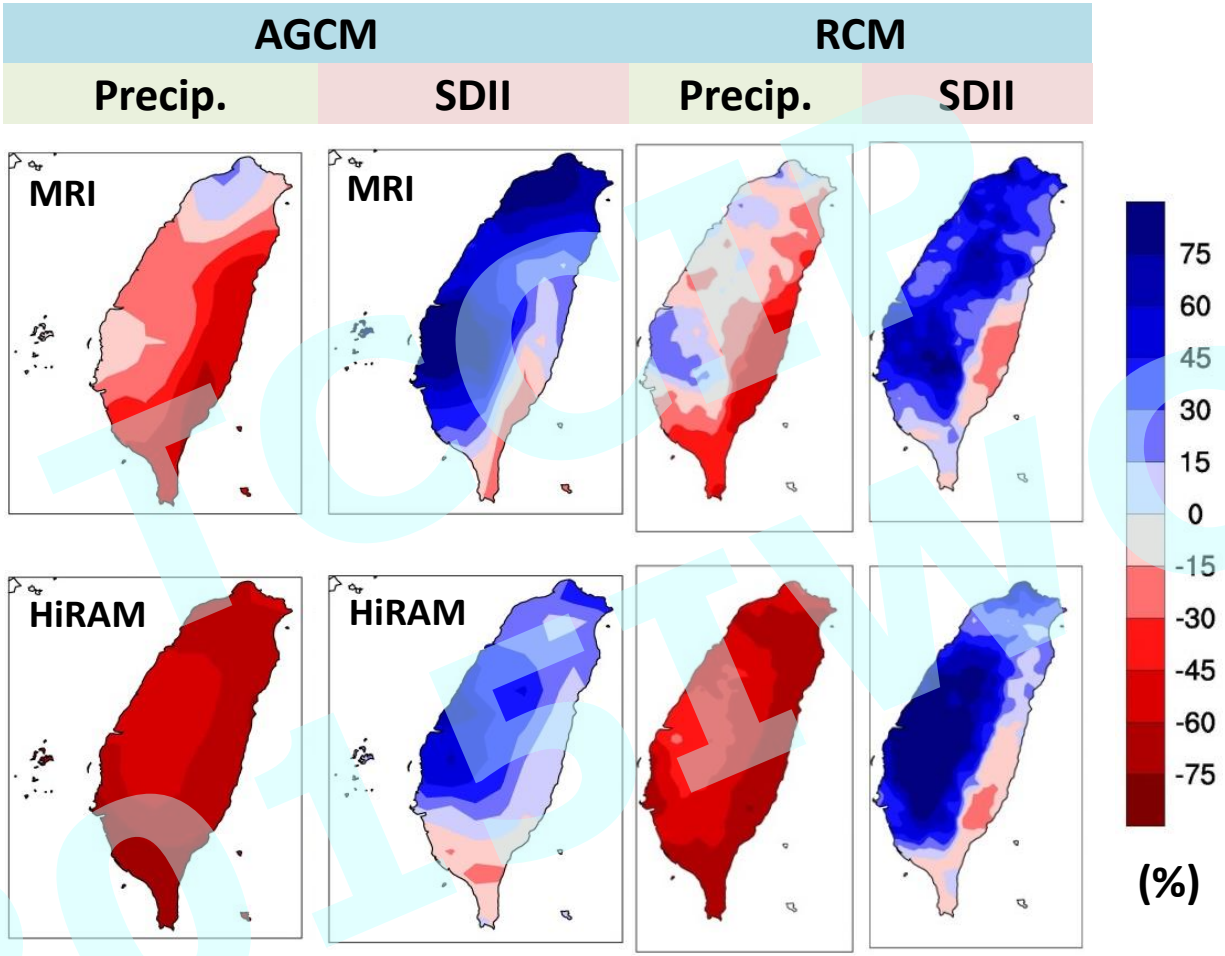
- Fewer typhoon results in less typhoon rainfall amount.

SDII



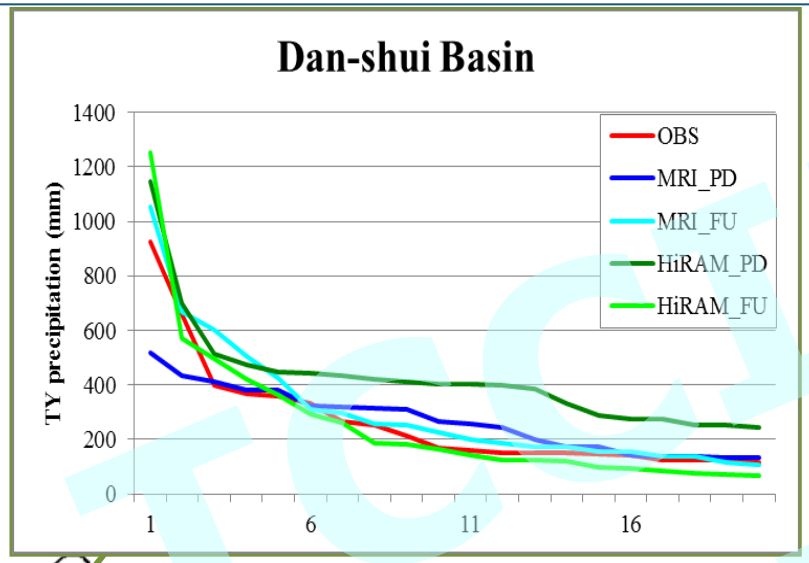
- Rainfall intensity are similar. (Higher in CAM5 could be to do with track bias)

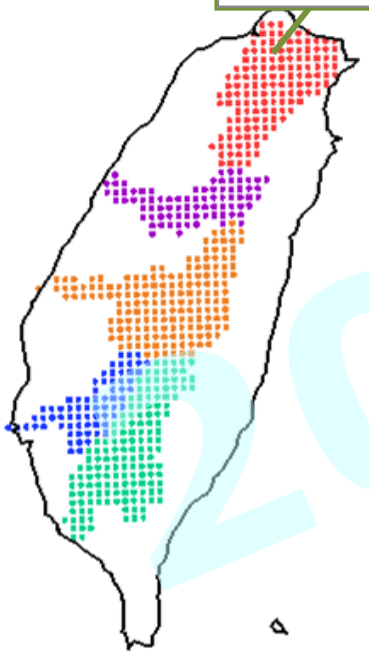
Changes in typhoon precipitation



- Similar before/after downscaling. AGCM dominates.
- TC rainfall amount decreases but intensity increases in the end of 21st century under RCP8.5 scenario.

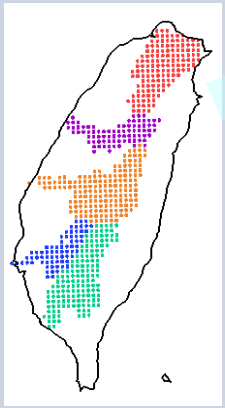
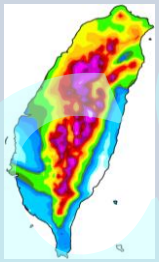
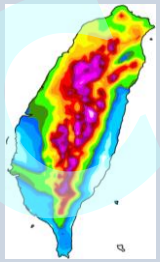
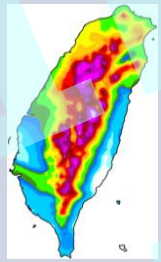
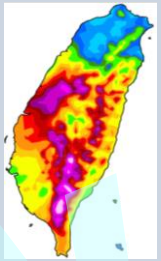
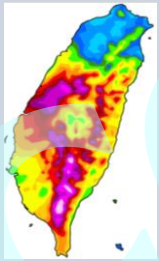
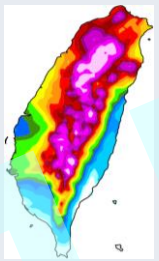
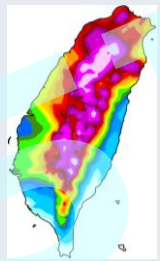
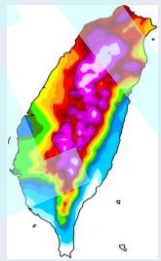
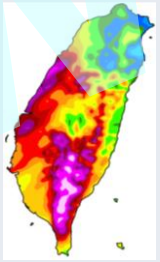
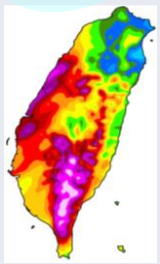
Selection of extreme typhoons

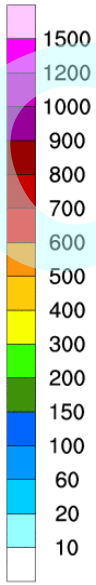




- Select "Top" typhoons for local for impact study.
- Calculate averaged precipitation over basins.
- Rank typhoon based on accu. rainfall or max 24 hr rainfall for different basins and periods.
- Precipitation of top typhoons mostly increase in the end of century??

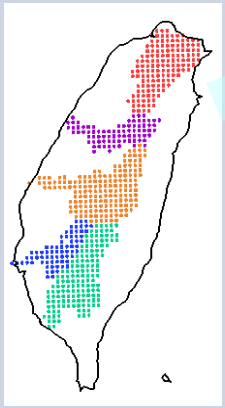
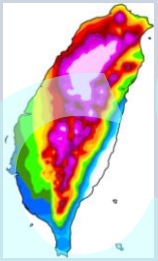
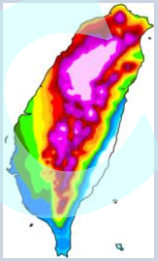
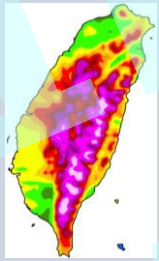
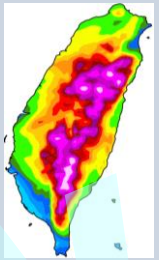
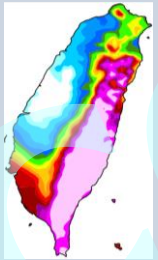
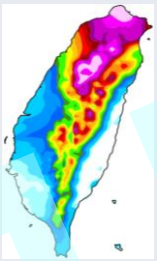
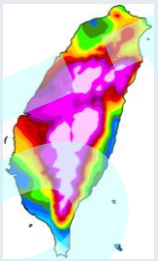
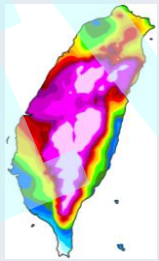
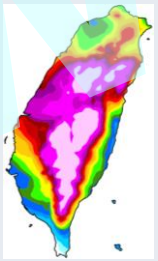
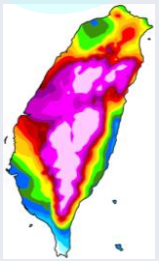
Precip. of Top 1 Typhoon (worst case) for basins

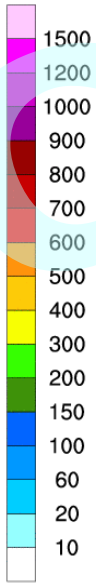
	Bsasin	Danshui	Da-Jia	Jhuoshuei	Tsen-wen	Kao-ping
MRI 	1979-2003	519.07 mm 	788.67 mm 	740.06 mm 	556.08 mm 	783.18 mm 
	2075-2099	1054.8 mm 	995.08 mm 	910.23 mm 	686.73 mm 	951.35 mm 



- Different worst typhoon for different basins are selected for impact study.
- Worst?? Biases in translation speed, track, and sample size....

Precip. of Top 1 Typhoon (worst case) for basins

	Bsasin	Danshui	Da-Jia	Jhuoshuei	Tsen-wen	Kao-ping
HiRAM 	1979-2003	1144.58 mm 	1416.61 mm 	1031.8 mm 	633.97 mm 	1337.34 mm 
	2075-2099	1253.96 mm 	1467.8 mm 	1541.02 mm 	947.01 mm 	1203.07 mm 



- Typhoon # decided sample size and statistic
- Larger sample size than MRI (128 > 85), more chance to be affected by server typhoons.

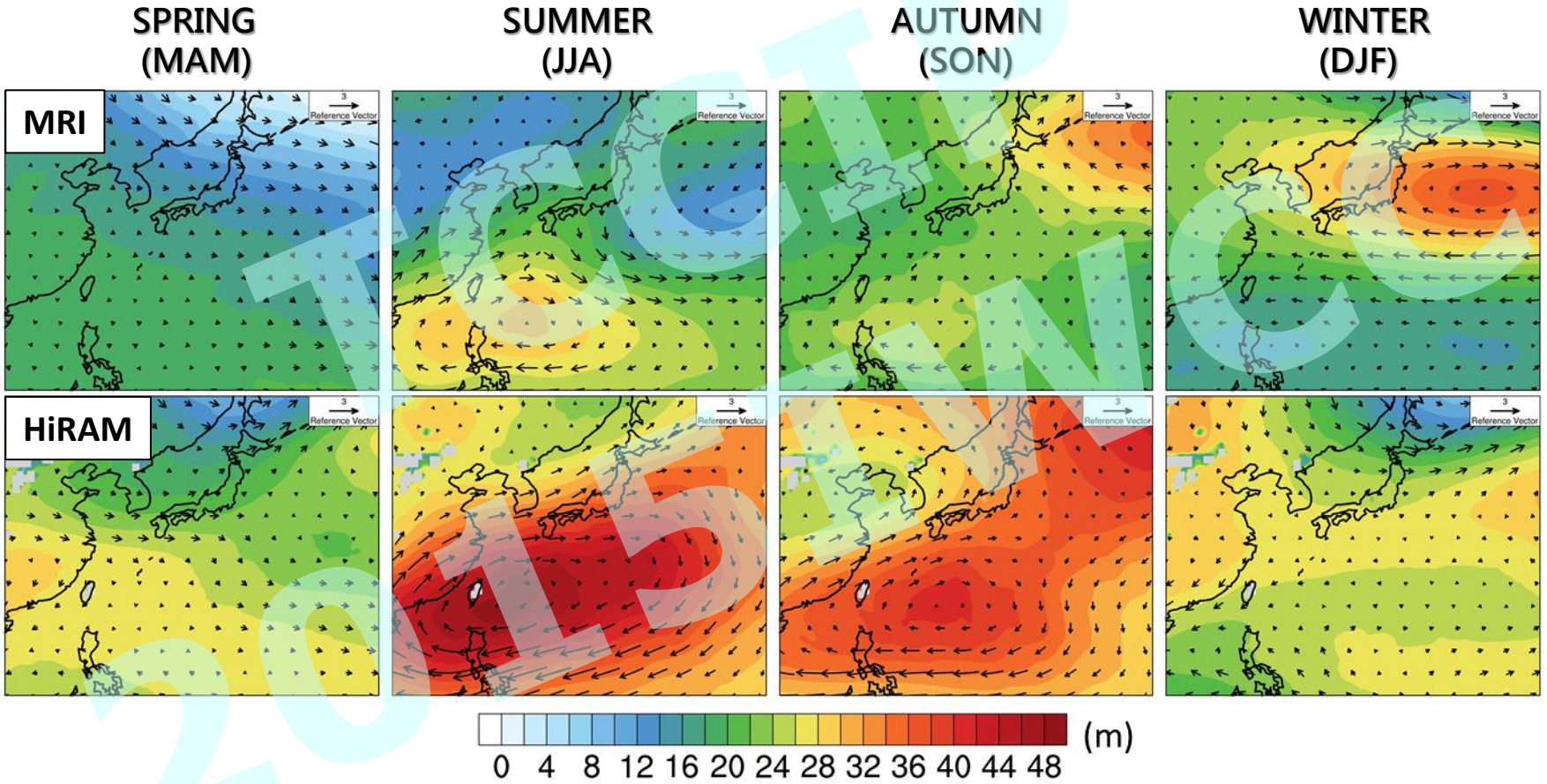
Summary - 2

- RCM can simulate more realistic rainfall distribution and intensity. Good news for disaster impact study.
- Typhoon rainfall amount decreases but intensity increases in both HiRAM & MRI. Projections of precipitation changes are still dominated by GCM.
- Top typhoons for impact study may be selected from all explicitly simulated typhoons in individual GCM. However, big different in sample size may affect the how worst the selected typhoons are.
  - HiRAM has larger typhoon sample and can offer more extreme typhoons (in terms of rainfall).
  - Biases in tracks are another factor.
  - Pick the most severe from all GCMs can be one answer.

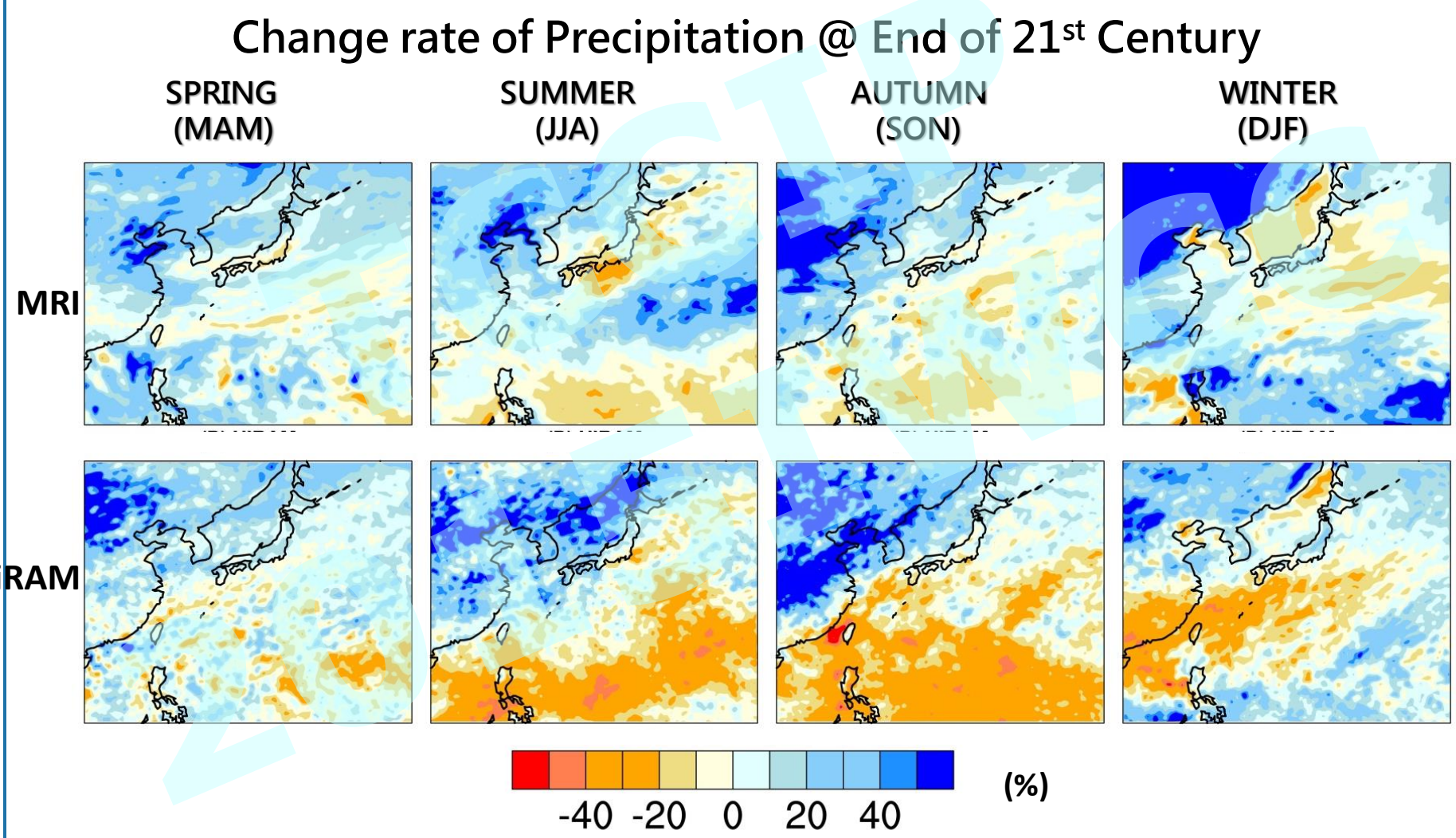
Thanks for your attention!

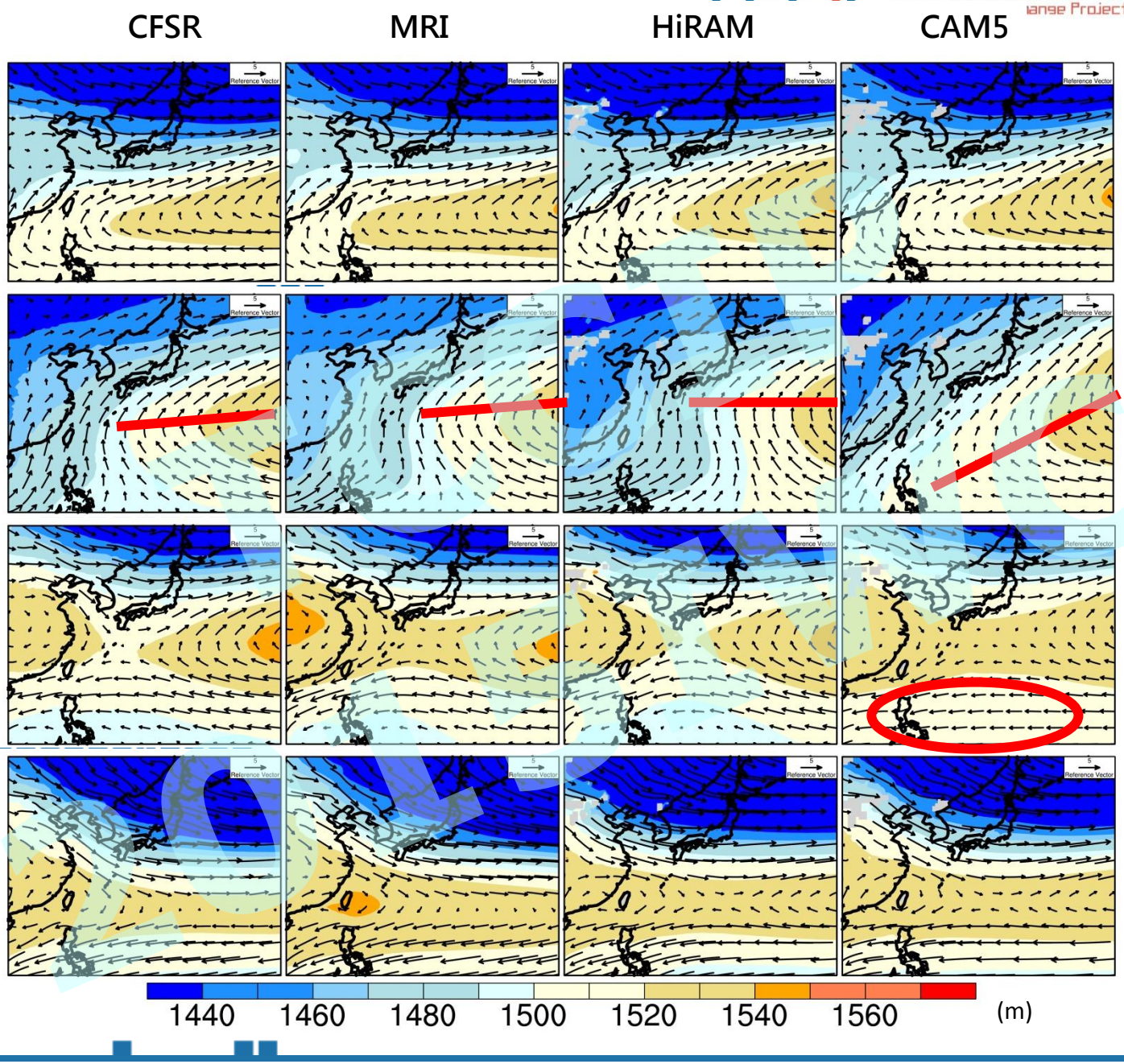
Multiple GCM downscaling consensus or discrepancy

Change of 850hPa Circulation @ End of 21st Century



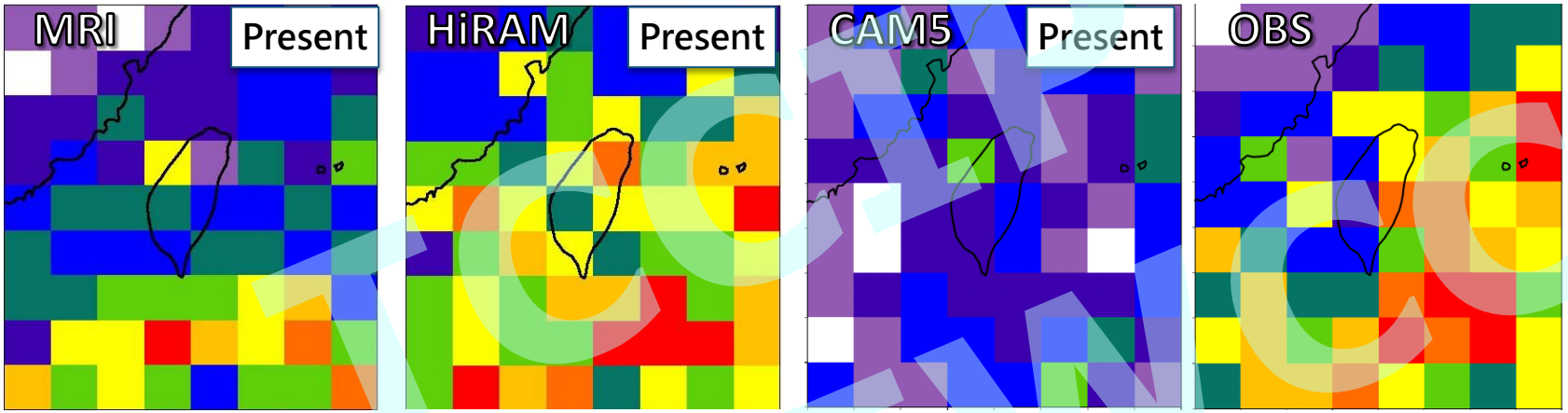
Multiple GCM downscaling consensus or discrepancy





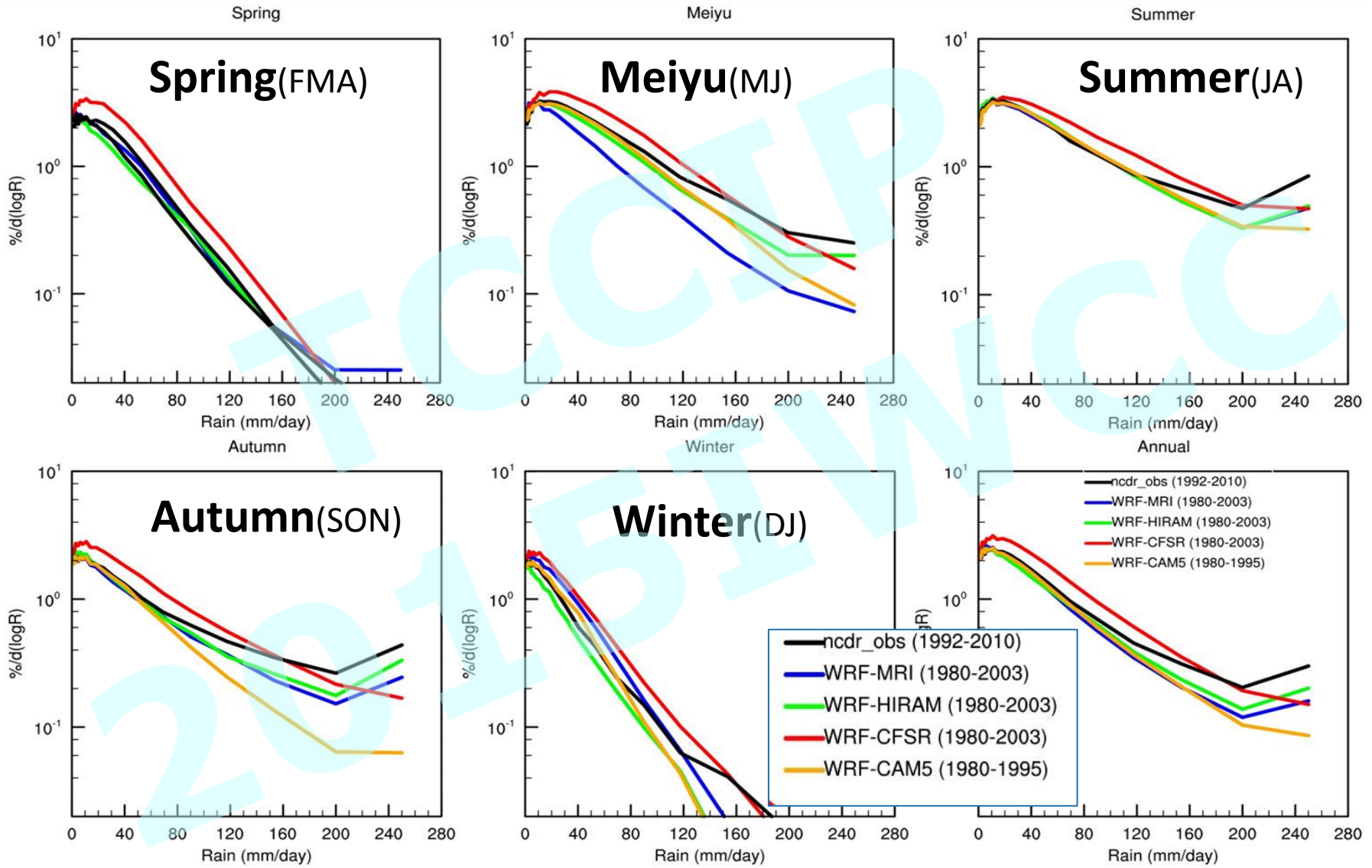
850hPa Circulation (Present Day)

Typhoon Affecting Taiwan

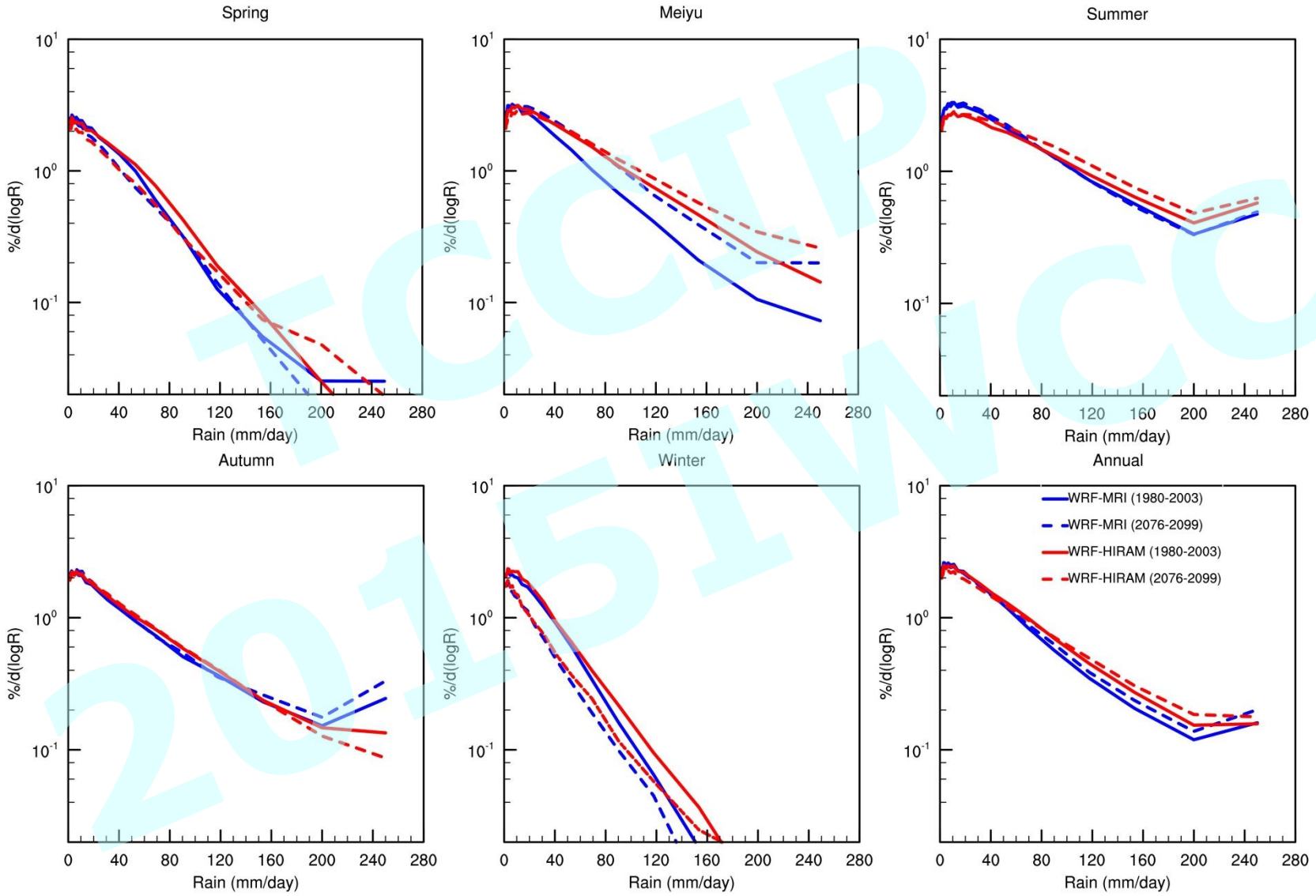


- Too few typhoon in CAM5
- MRI underestimated typhoon # by 35%.
- Total # reduces but the # intense ones increases in the future .

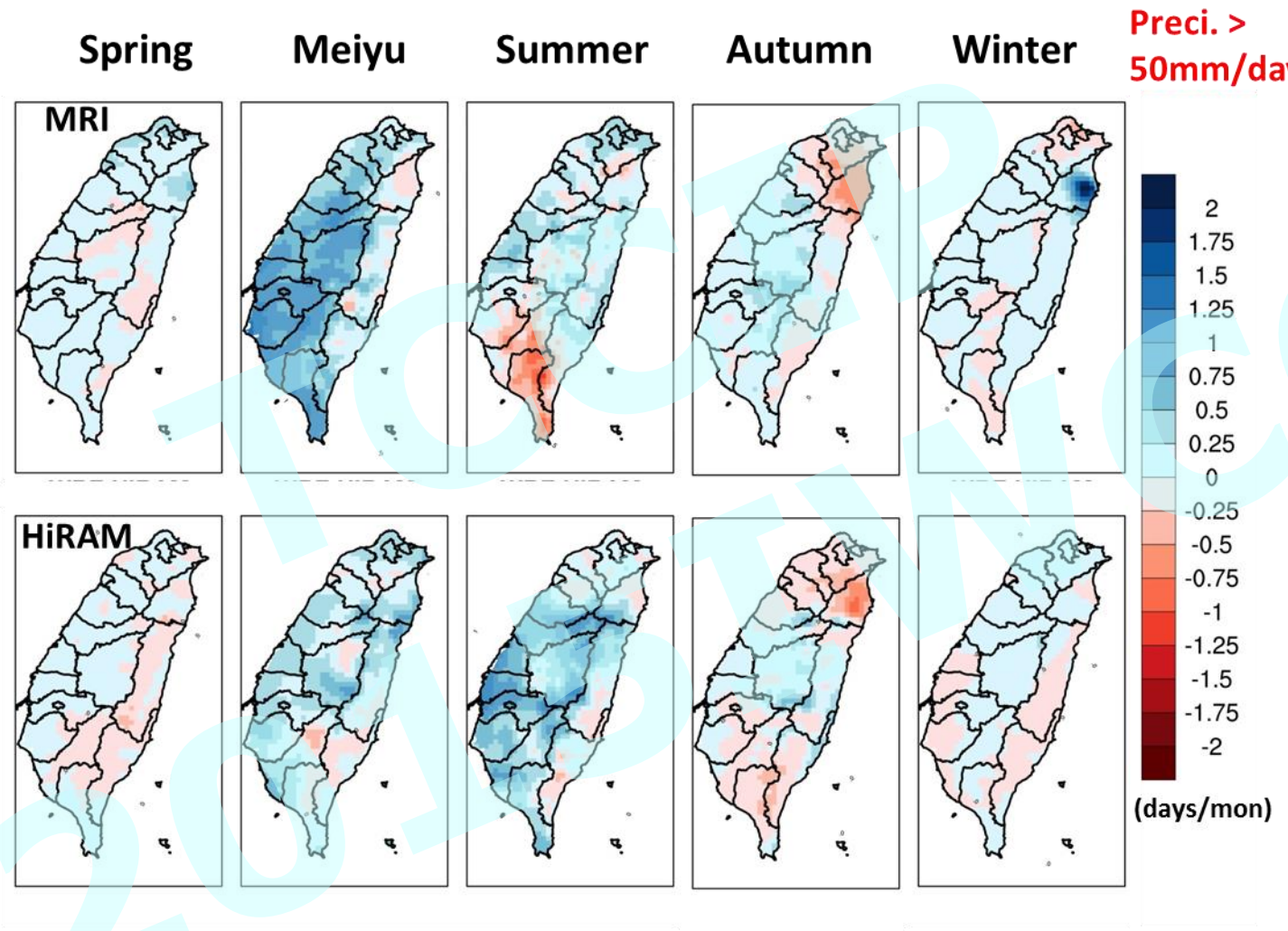
PDF of Daily Rainfall over Taiwan area



PDF of Taiwan area



Heavy rain day change



- Heavy rain day changes.