WORKSHOP ON HIGH-RESOLUTION CLIMATE SIMULATION, PROJECTION, AND APPLICATION.

Jan.19-20,2015 Academia Sinica, Taipei, Taiwan

Tropical Cyclones and Extreme Precipitation in GFDL HiRAM

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G - GFDL, NOAA

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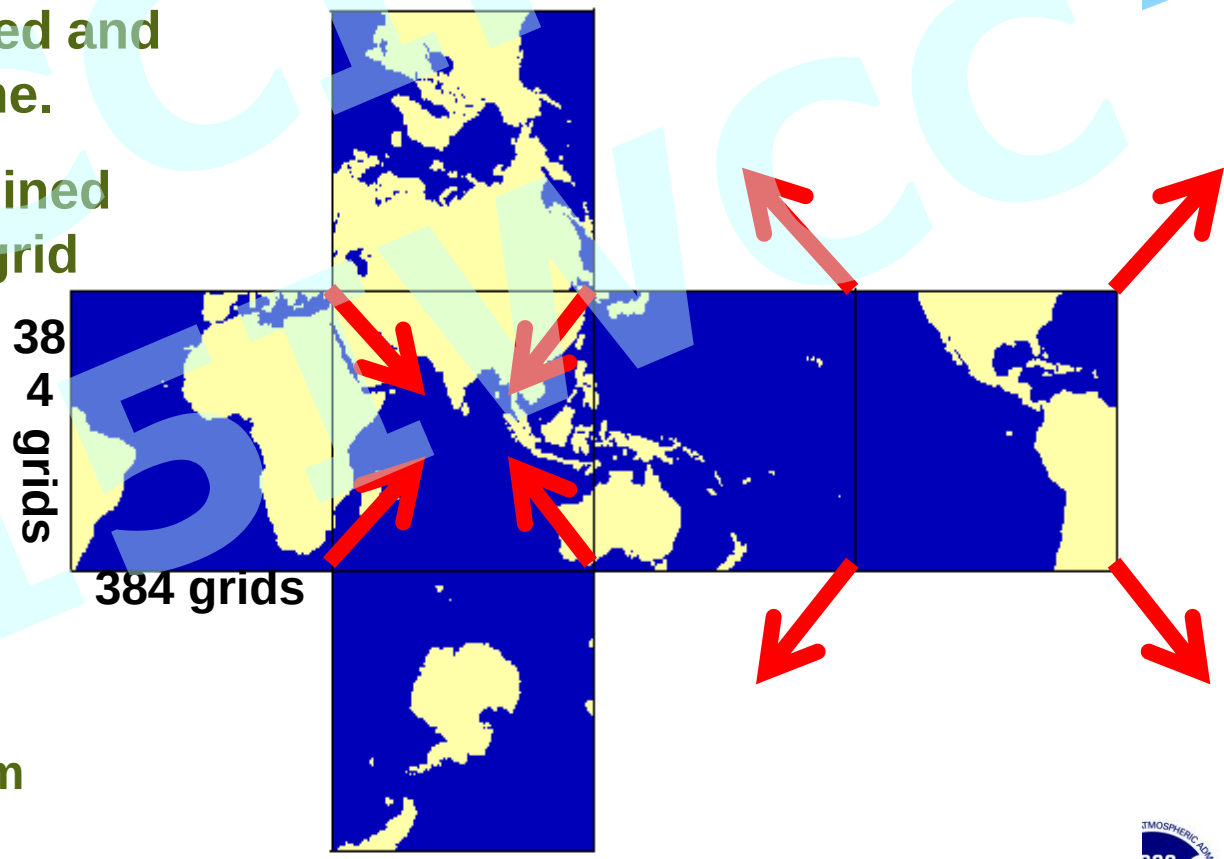
HiRAM - Stretched Cube Sphere Globe

- Grid number for stretched and unstretched are the same.
- ΔT (time-step) is determined according to the finest grid size.



Resolution:

C192, Δx = ~ 50 km

C384 , Δx = ~ 25 km

C384R2.5 , Δx = 10~68 km

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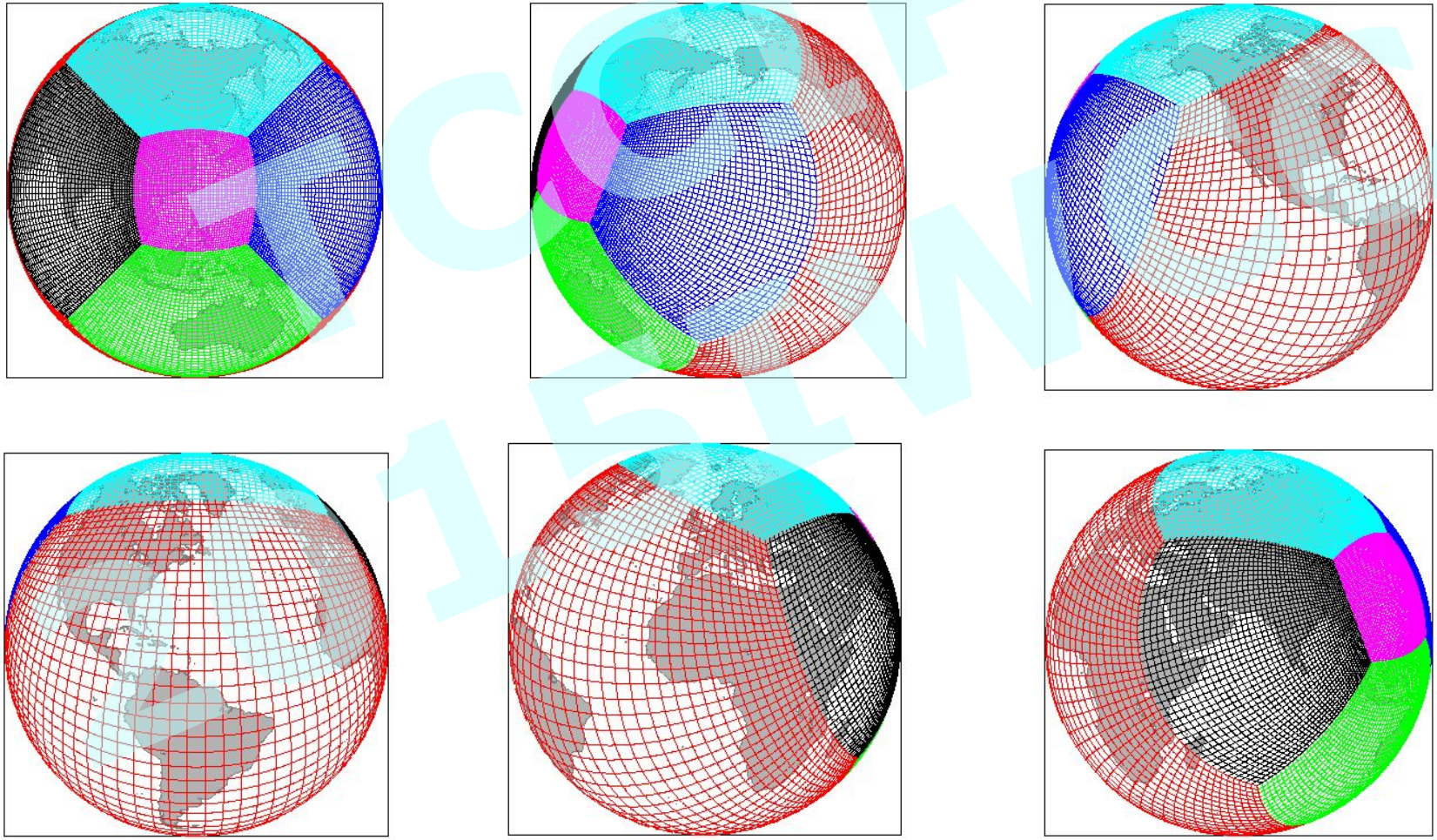
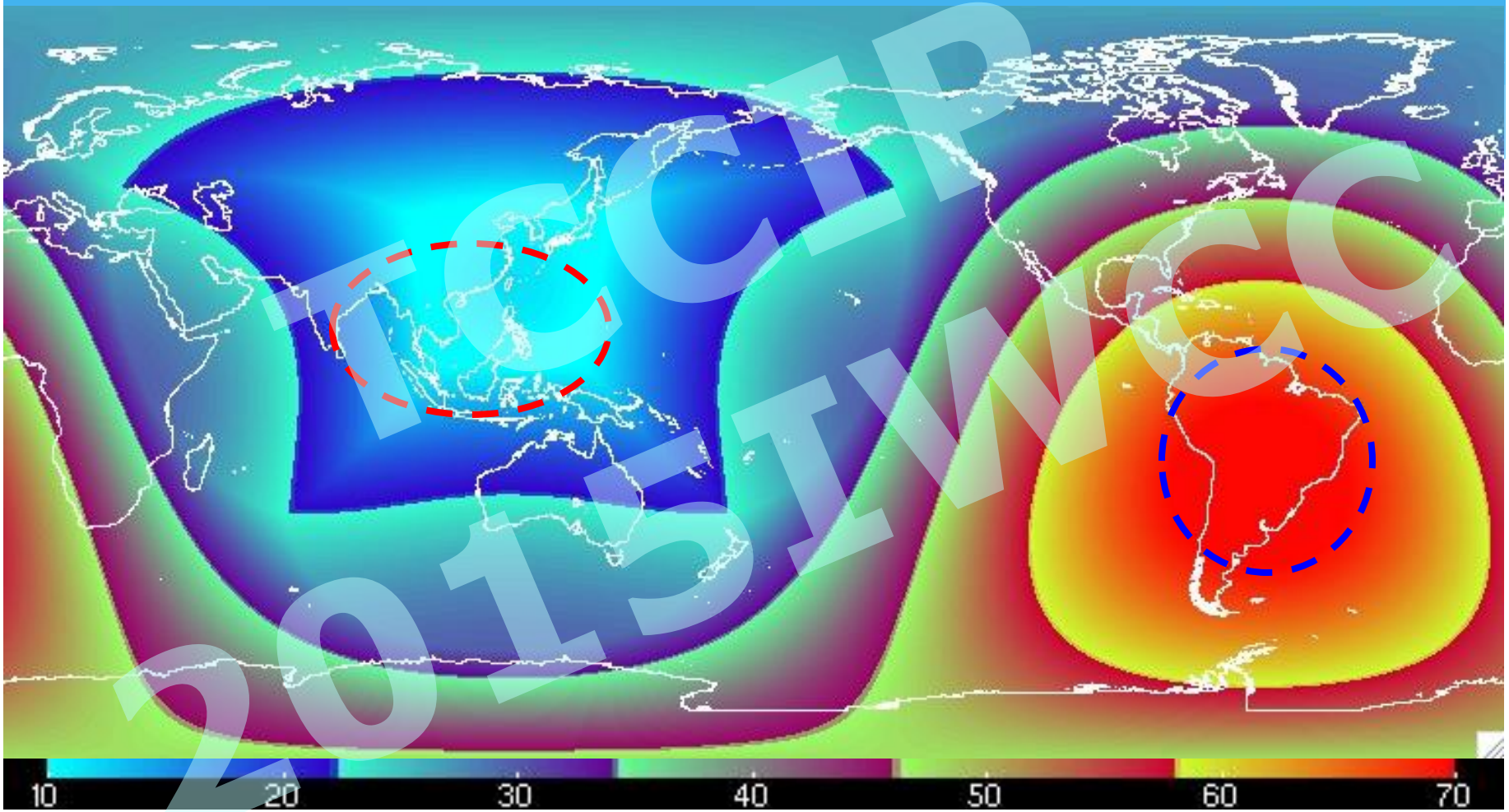
Stretched Cube Sphere Globe (center @ TW) C384 Stretched Factor 2.5 ($\Delta x \approx$ 10km~68km)



Grid Size of Stretched Cube Sphere Globe C384R2.5 center @ Taiwan



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- Horizontal grid size for C384R2.5 ranges from around 10km to 68km.

HiRAM Experiments

Experiment	Years	Horizontal grid spacing	Vertical layers	Physics & Convection	SST & Scenario
C192 amip2	1979~2008	~ 50km	hybrid sigma 32 levels 10hPa model top	6-category single-moment bulk cloud microphysics UW shallow convection	1° HadISST
C384 amip2	1979~2008	~25km			1° HadISST
C384R2.5TW amip2	1981~2008	10~68km			1° HadISST
C192 RCP8.5	2074~2100	~ 50km			1° RCP8.5
C384 RCP8.5	2074~2100	~25km			1° RCP8.5

C384R2.5TW: C384 with stretched factor 2.5, finest resolution centers in Taiwan
1° HadISST : 1° Monthly SST from HadISST 1.1 dataset
1° RCP8.5 : 1° RCP8.5 future SST projection from MRI, Japan

Tropical Cyclones and Extreme Precipitation in GFDL HiRAM

Precipitation in Different Resolution

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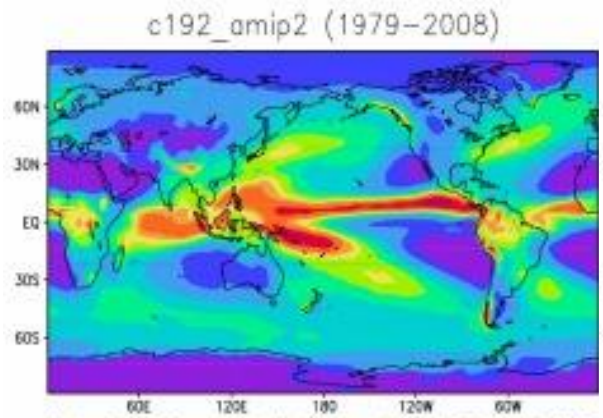
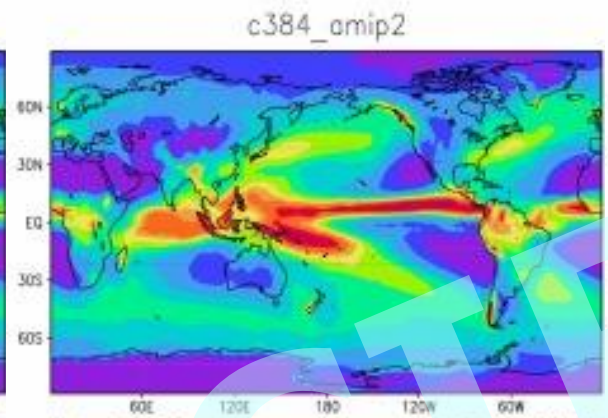
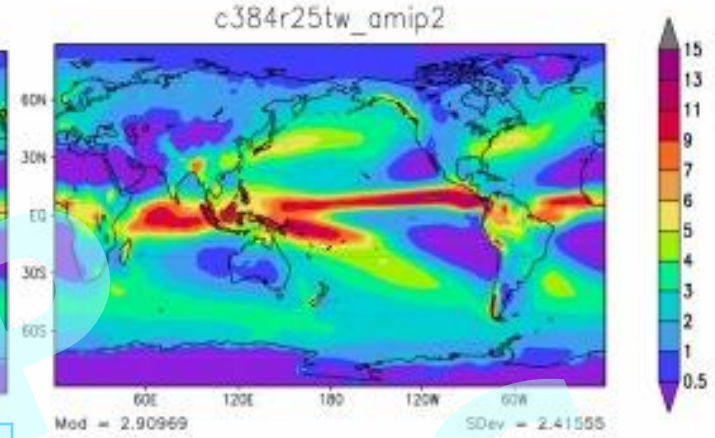
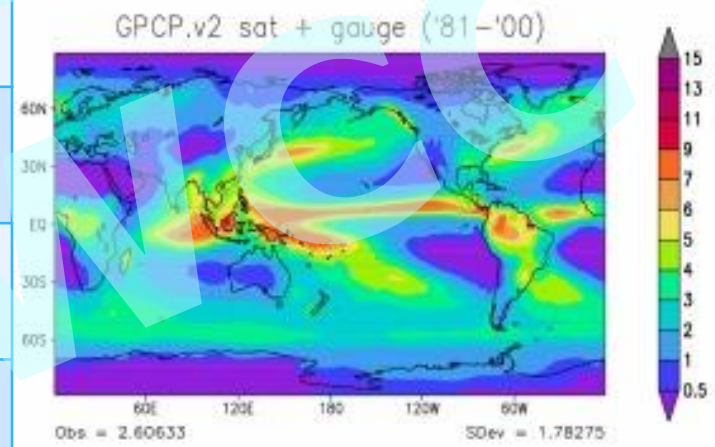
ANN PRECIP (mm/d)

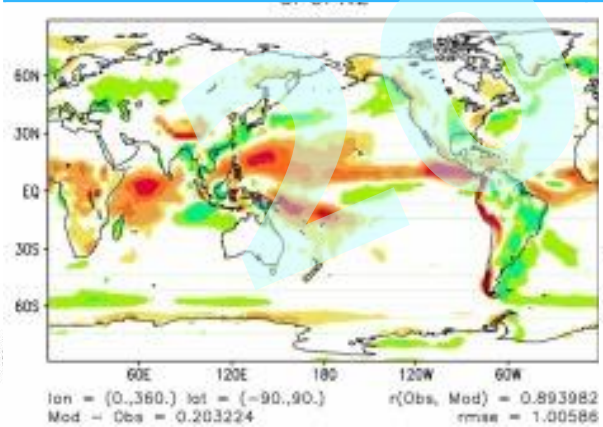


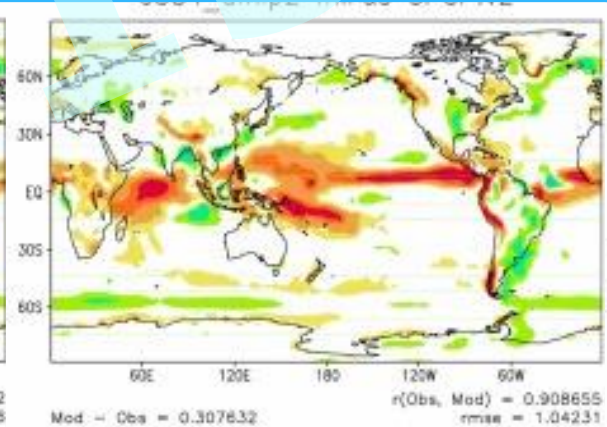


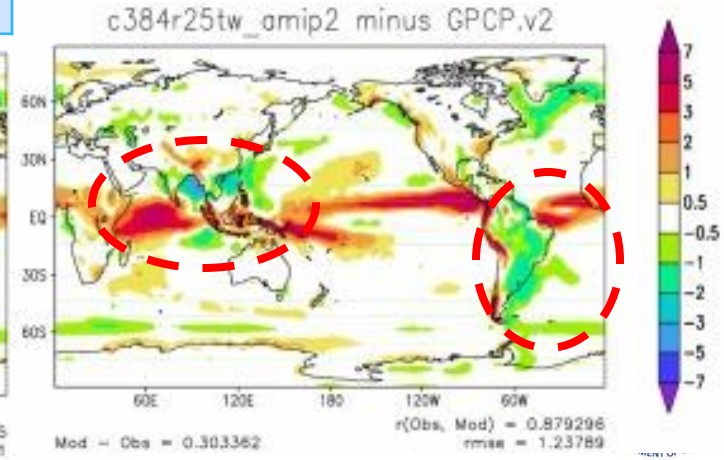


Experiment	C192 amip2	C384 amip2	C384R2.5TW amip2
Model Mean Std. Dev.	2.810 2.170	2.914 2.181	2.910 2.416
Obs. Mean Std. Dev.	2.606 1.783		
Corr. (Mod., Obs.) Diff. (Mod.-Obs.)	0.894 0.203	0.909 0.308	0.879 0.303

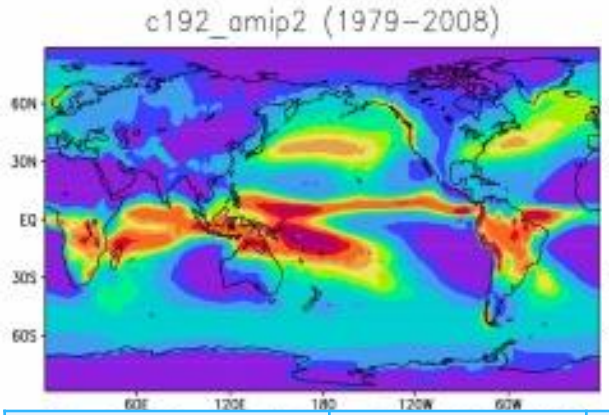


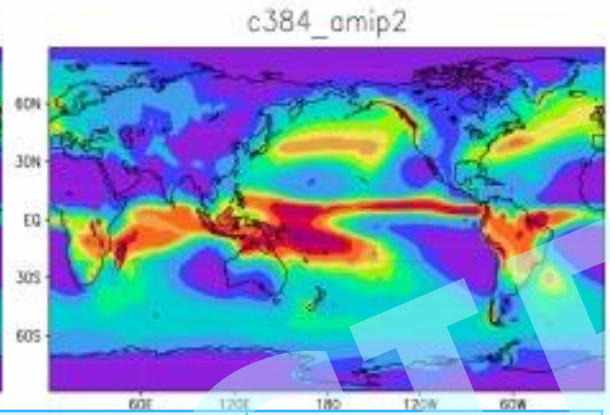


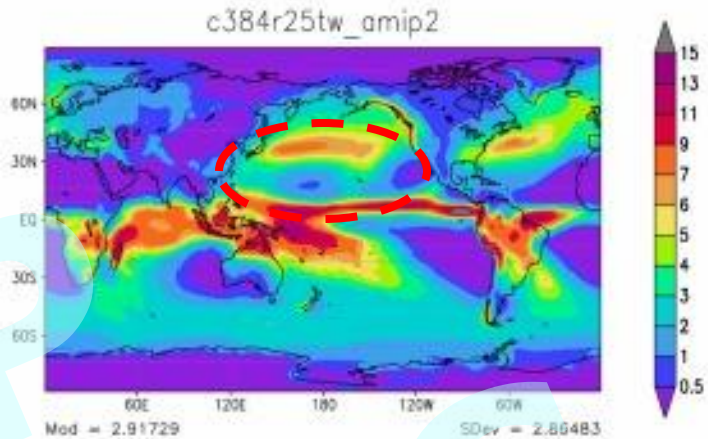




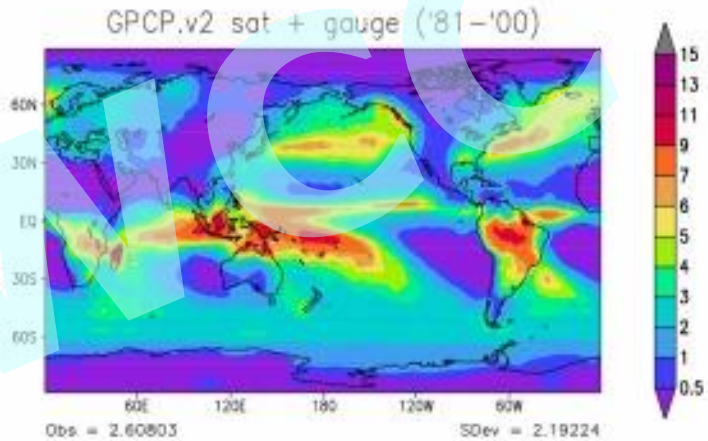
DJF PRECIP (mm/d)

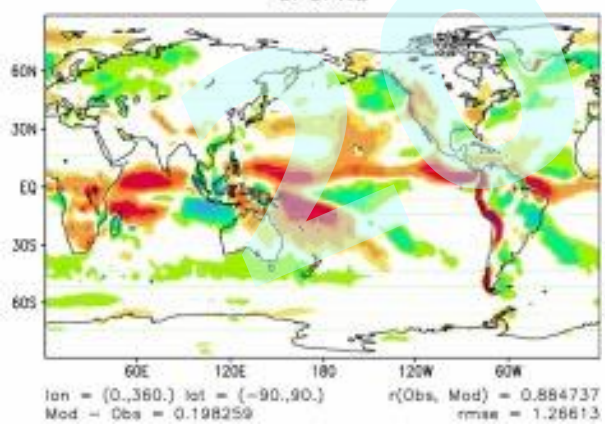


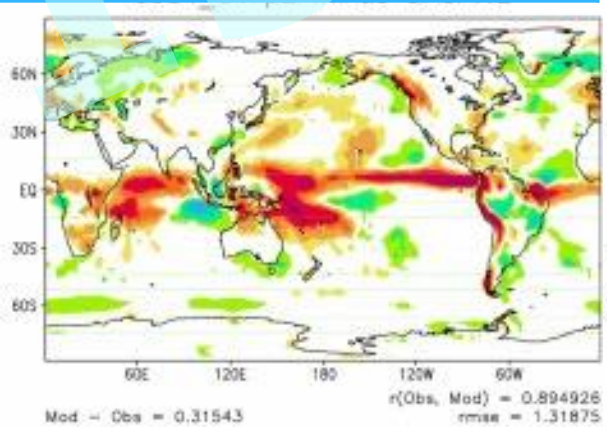


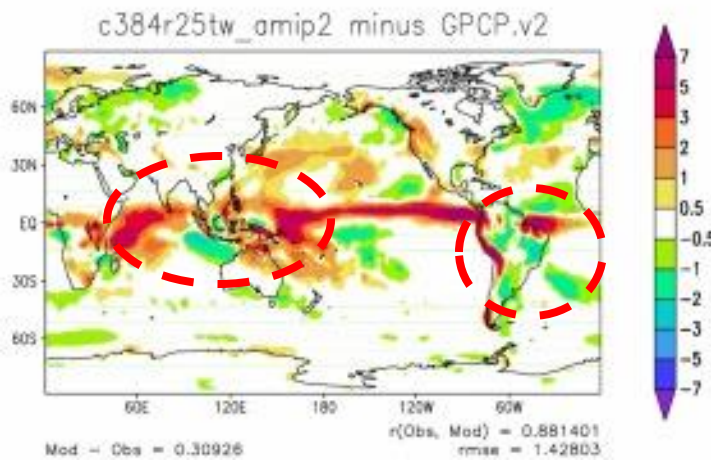


Experiment	C192 amip2	C384 amip2	C384R2.5TW amip2
Model Mean Std. Dev.	2.806 2.660	2.923 2.788	2.917 2.865
Obs. Mean Std. Dev.	2.608 2.192		
Corr. (Mod., Obs.) Diff. (Mod.-Obs.)	0.885 0.198	0.895 0.315	0.881 0.309

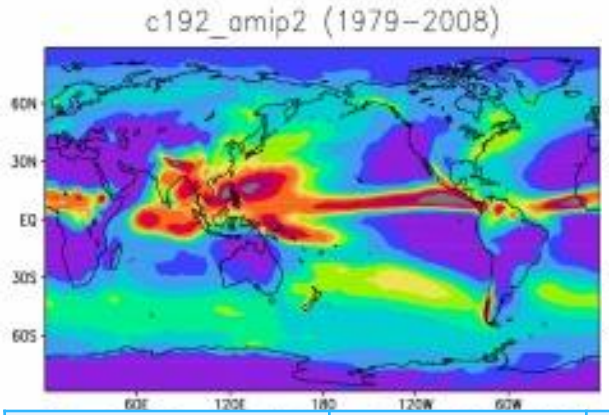


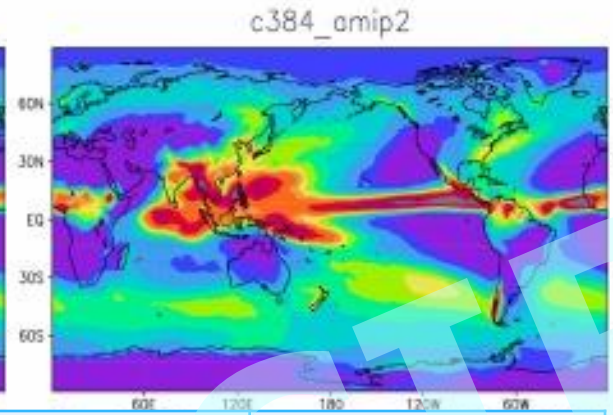


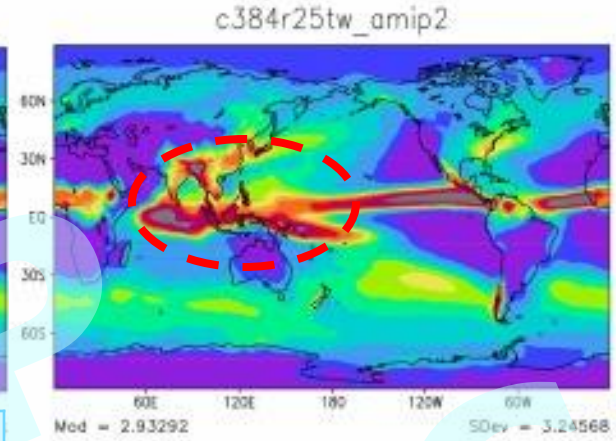


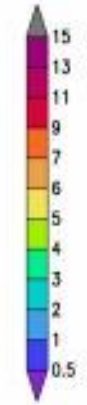


JJA PRECIP (mm/d)

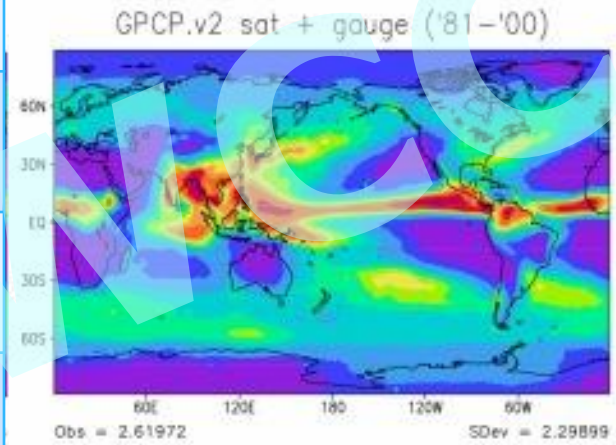


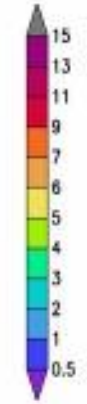


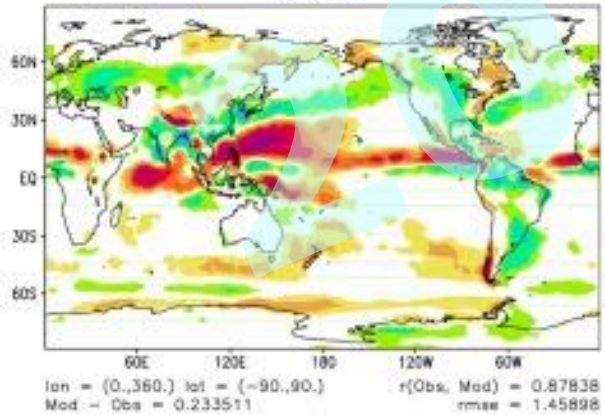


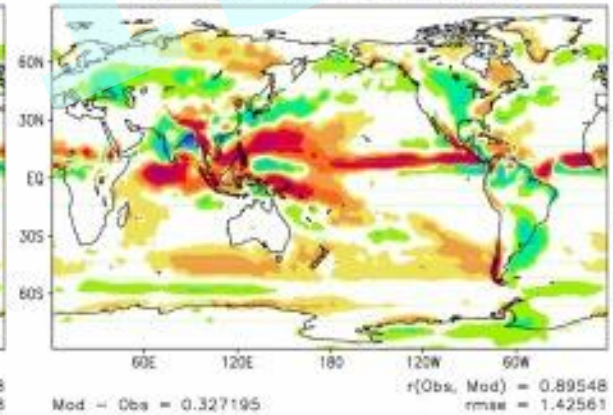


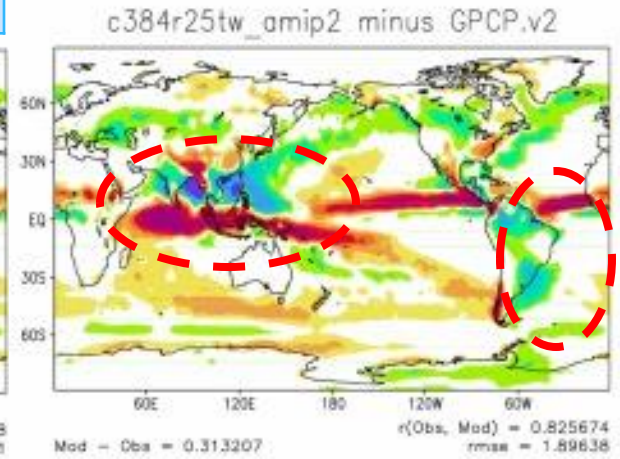
Experiment	C192 amip2	C384 amip2	C384R2.5TW amip2
Model Mean Std. Dev.	2.853 2.949	2.947 2.995	2.939 3.246
Obs. Mean Std. Dev.	2.620 2.299		
Corr. (Mod., Obs.) Diff. (Mod.-Obs.)	0.878 0.234	0.895 0.327	0.826 0.313

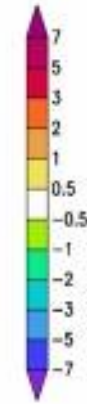




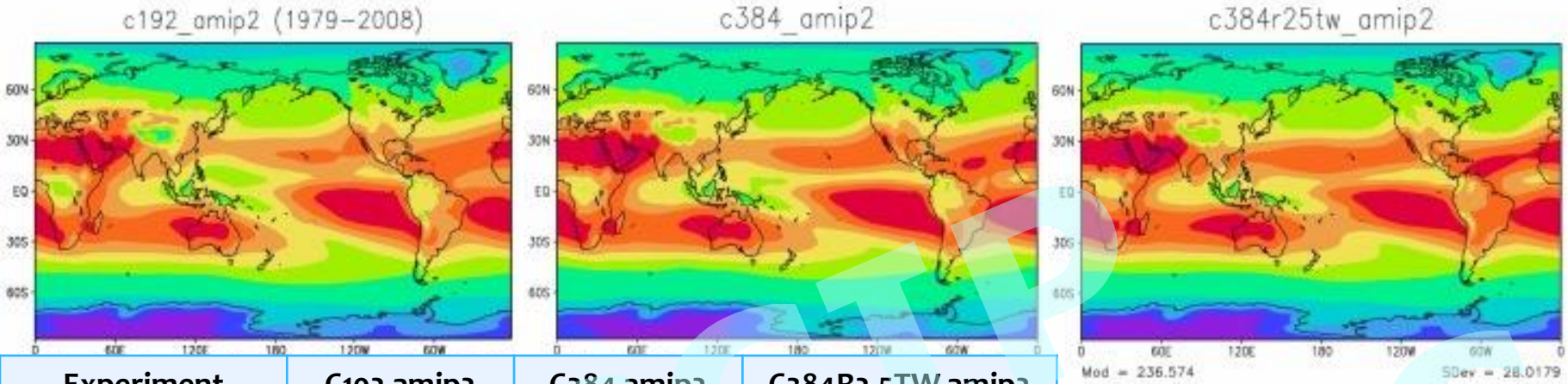




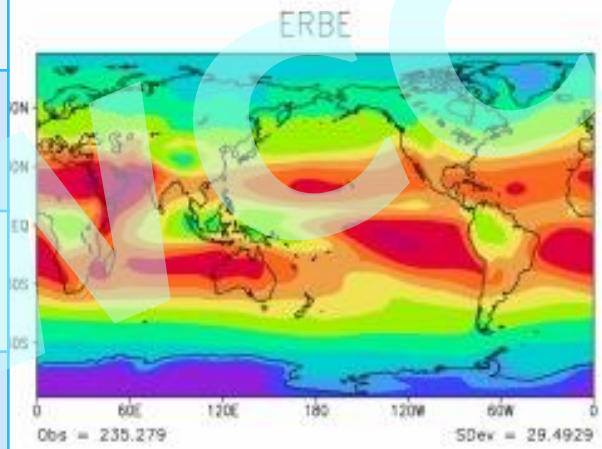


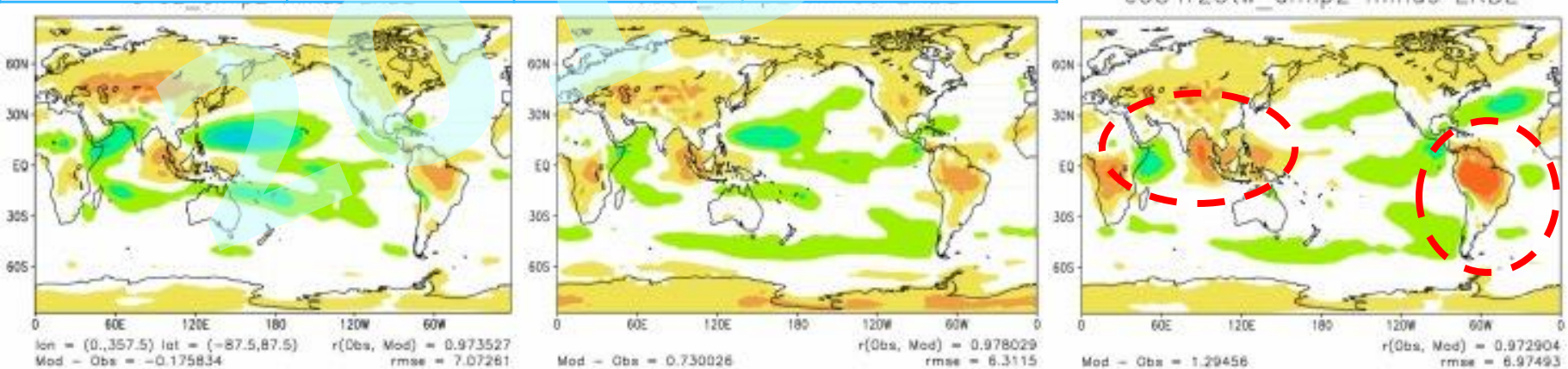


ANN OLR (W/m²)

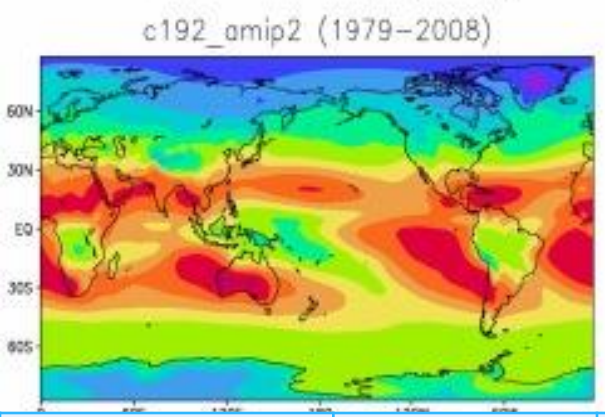


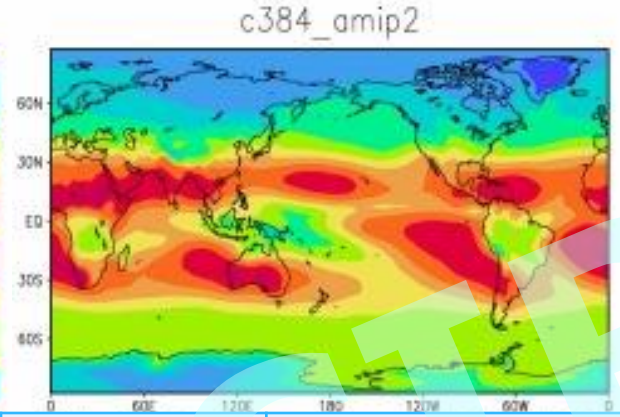
Experiment	C192 amip2	C384 amip2	C384R2.5TW amip2
Model Mean Std. Dev.	**235.079** 26.582	**236.009** 27.623	**236.574** 28.018
Obs. Mean Std. Dev.	**235.279** 29.493		
Corr. (Mod., Obs.) Diff. (Mod.-Obs.)	**0.974** -0.200	**0.978** 0.730	**0.973** 1.295

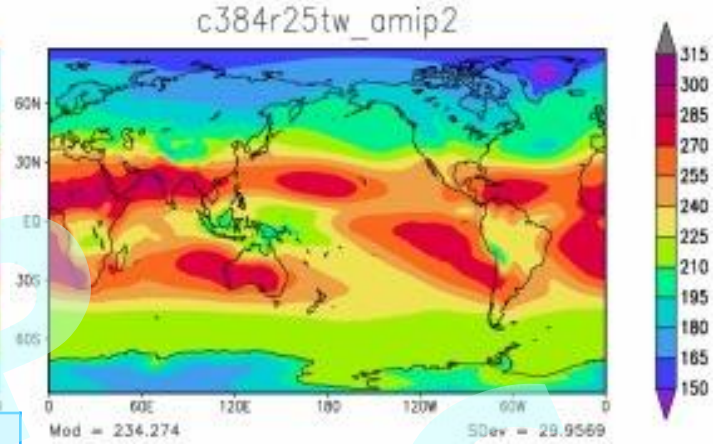


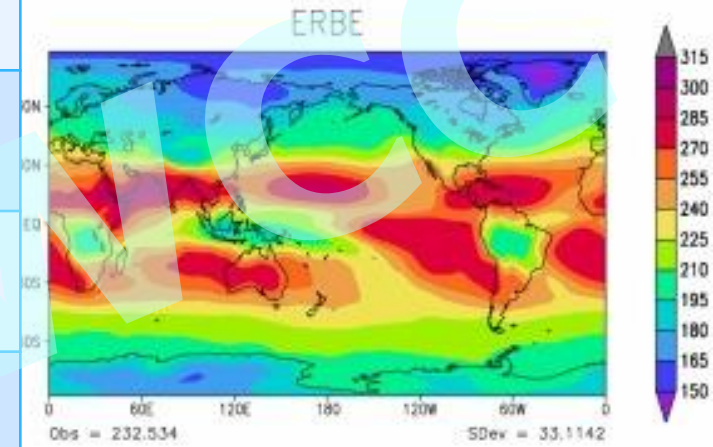


DJF OLR (W/m²)

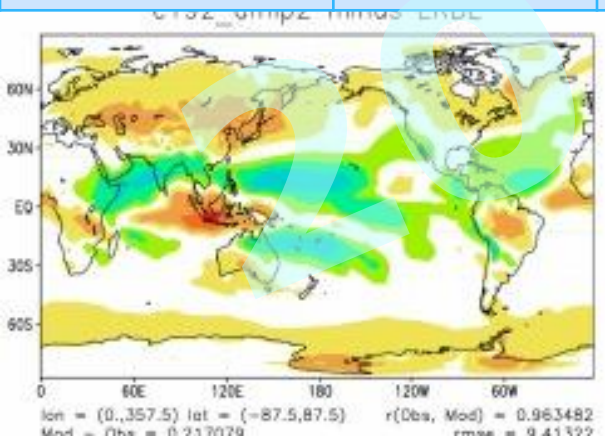


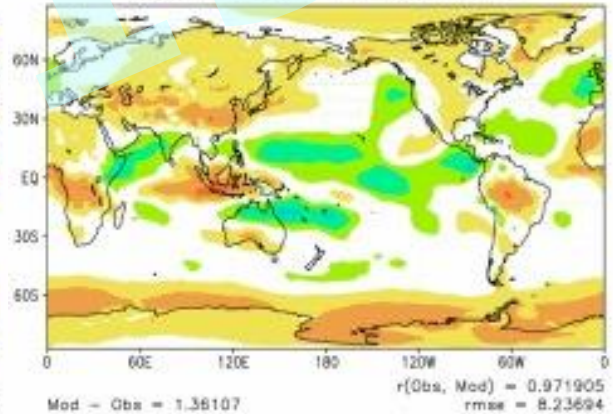


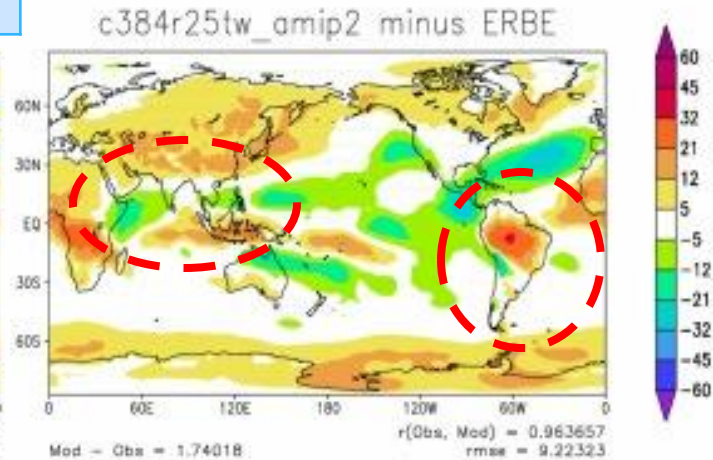




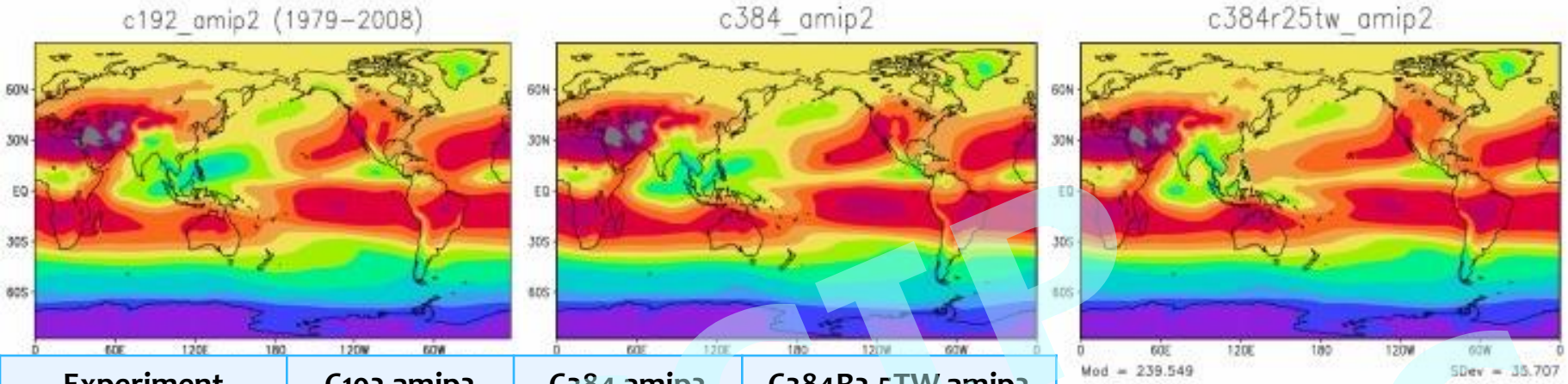
Experiment	C192 amip2	C384 amip2	C384R2.5TW amip2
Model Mean Std. Dev.	232.717 28.750	233.895 29.891	234.274 29.957
Obs. Mean Std. Dev.	232.534 33.114		
Corr. (Mod., Obs.) Diff. (Mod.-Obs.)	0.963 0.183	0.972 1.361	0.964 1.74



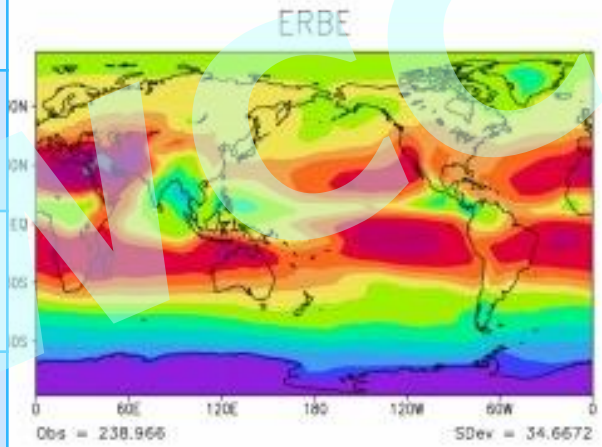


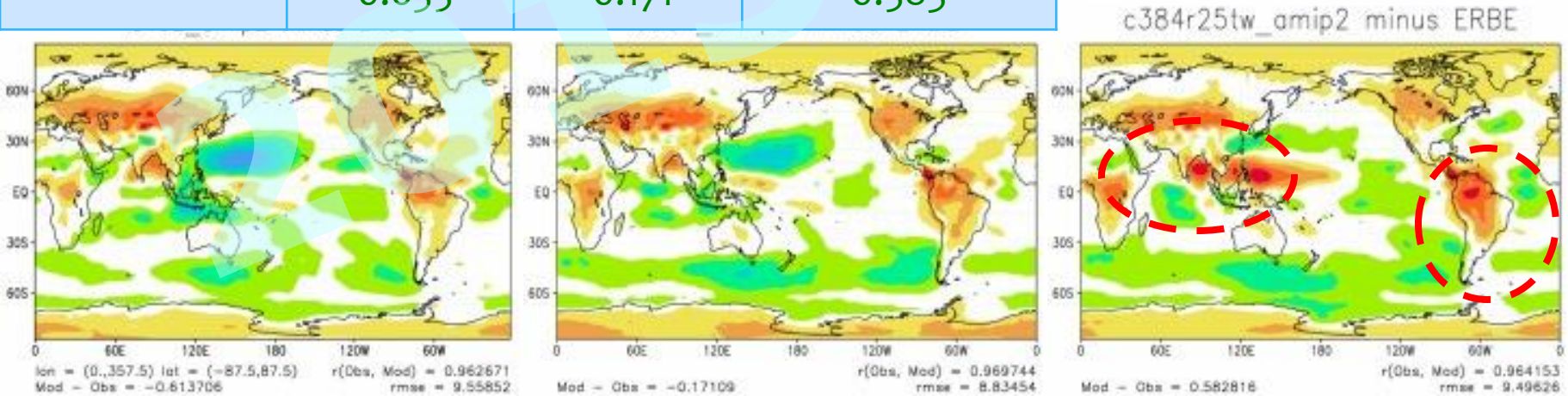


JJA OLR (W/m²)



Experiment	C192 amip2	C384 amip2	C384R2.5TW amip2
Model Mean Std. Dev.	**238.331** 35.079	**238.795** 36.148	**239.549** 35.707
Obs. Mean Std. Dev.	**238.966** 34.667		
Corr. (Mod., Obs.) Diff. (Mod.-Obs.)	**0.963** -0.635	**0.970** -0.171	**0.964** 0.583





Tropical Cyclones and Extreme Precipitation in GFDL HiRAM

Typhoon and Hurricanes

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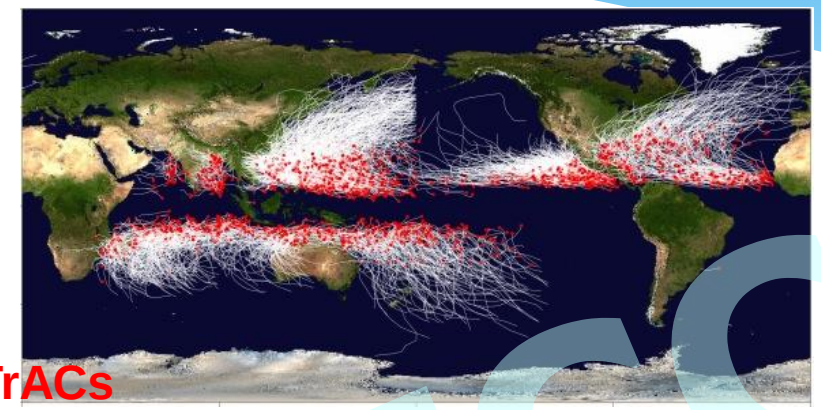
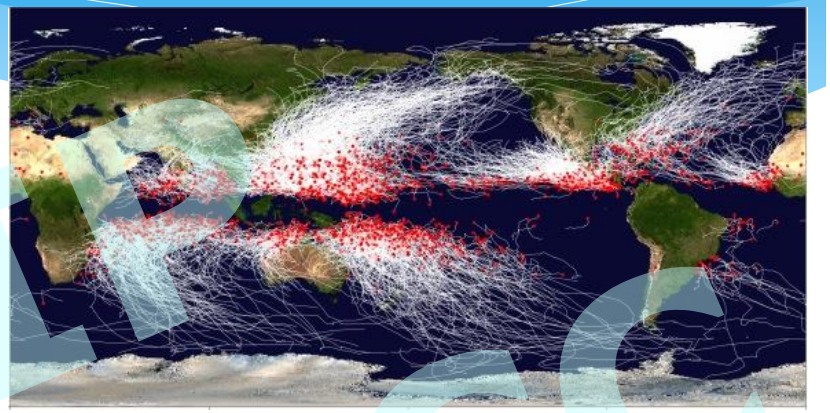
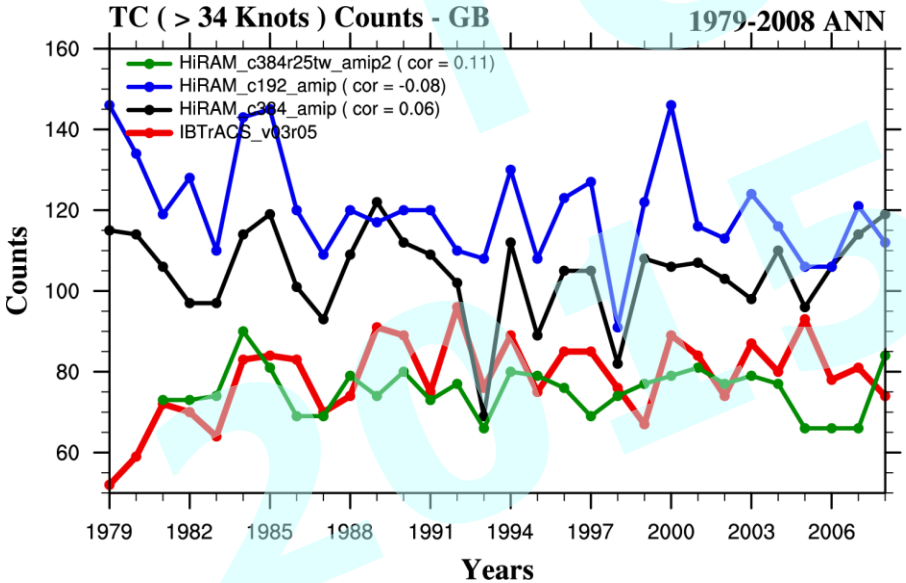
Typhoon Tracks (1979~2008)

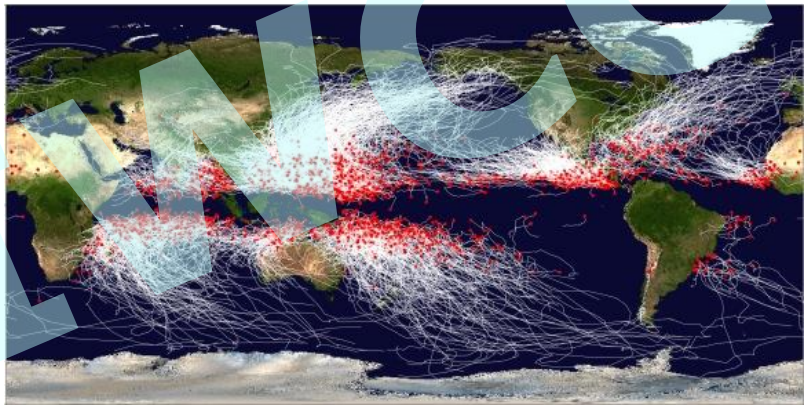


IBTrACs

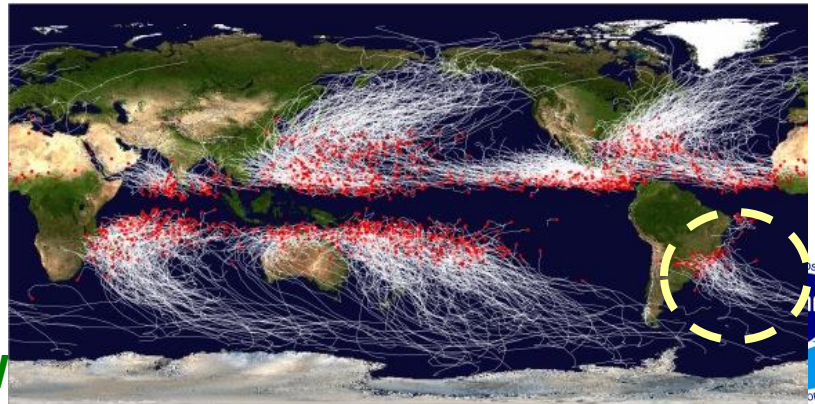


C192





C384



C384R2.5TW

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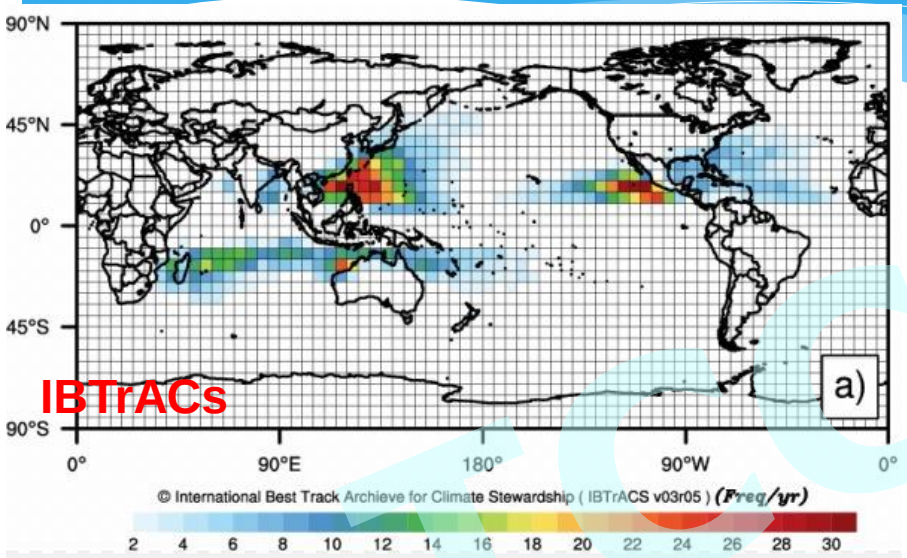
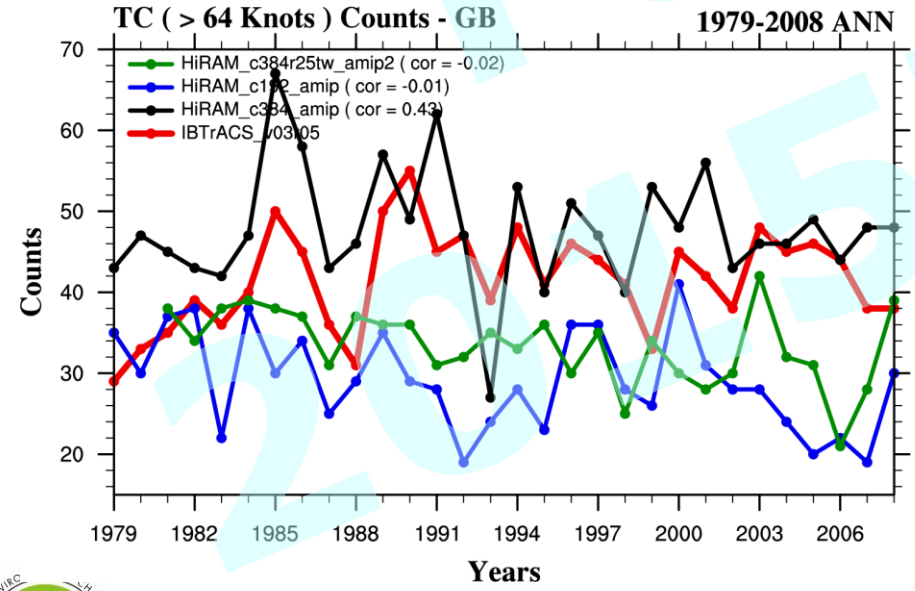
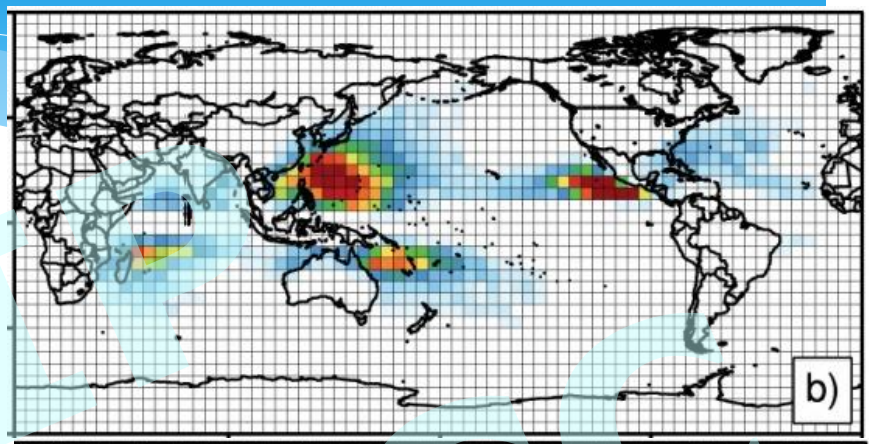
Typhoon Density (1979~2008)



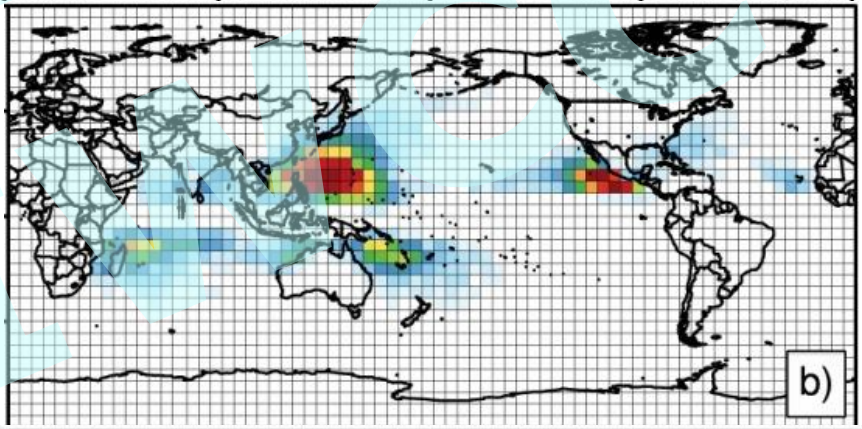
IBTrACs



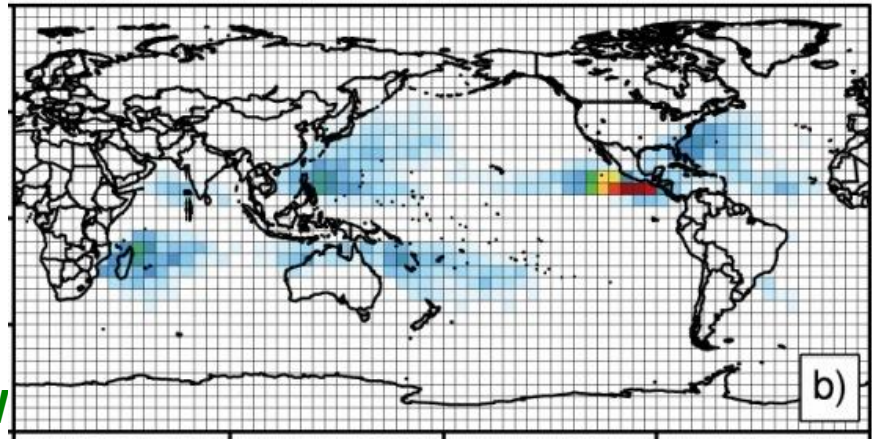
C192



C384

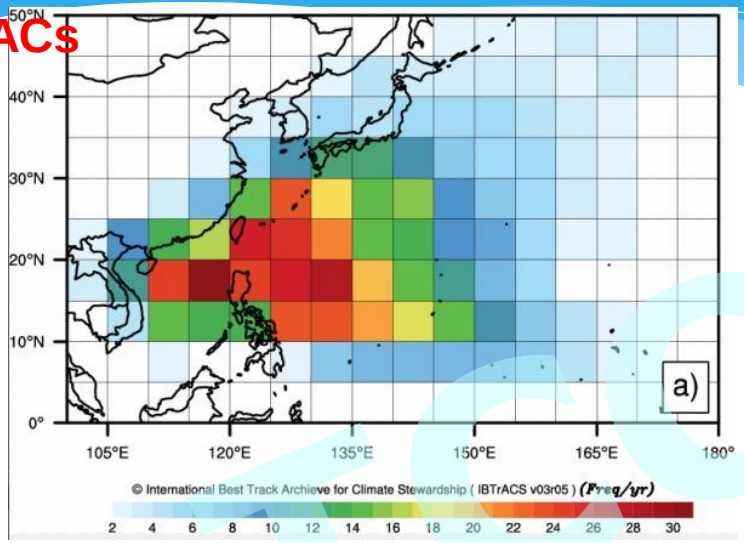


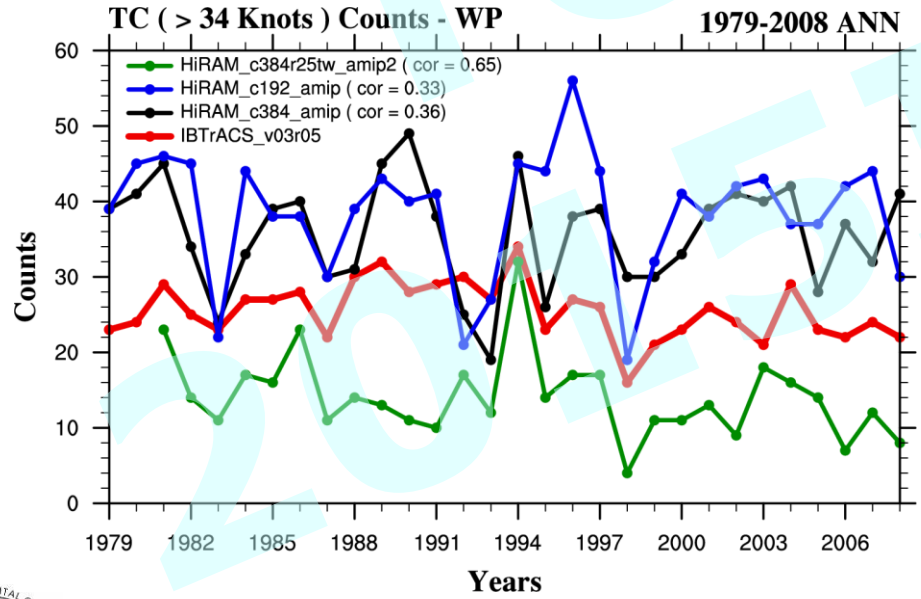
C384R2.5TW



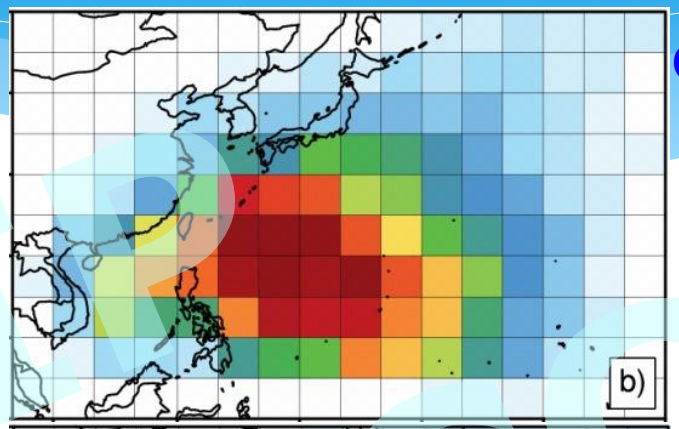
Western North Pacific - Typhoon Density (1979~2008)

IBTrACs

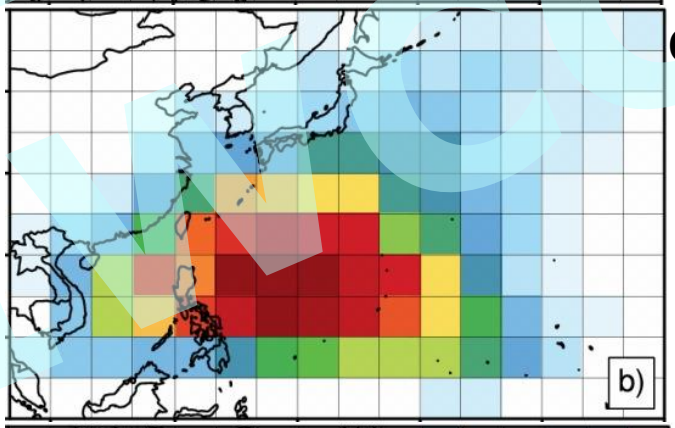




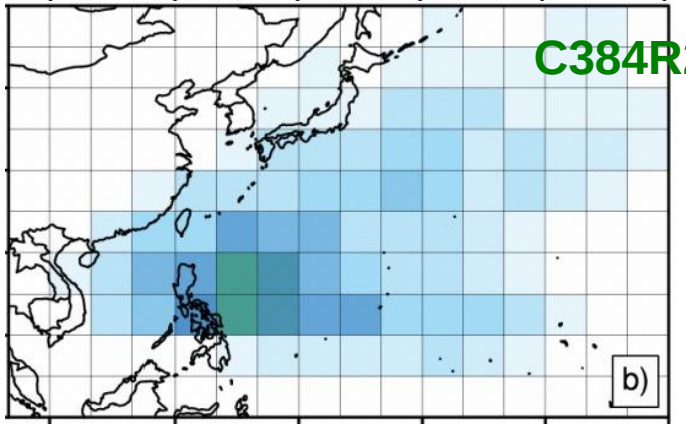
C192



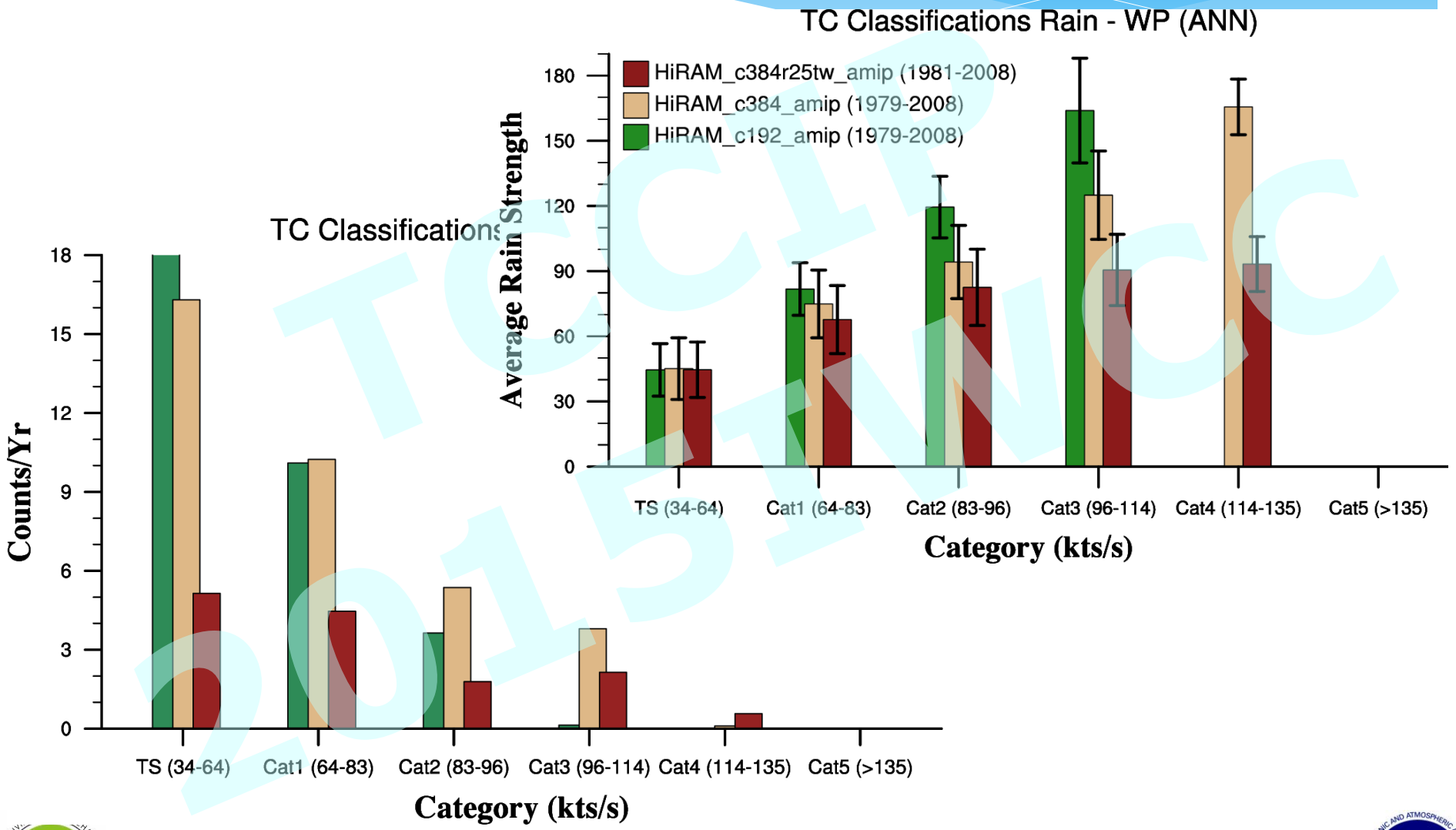
C384



C384R2.5TW

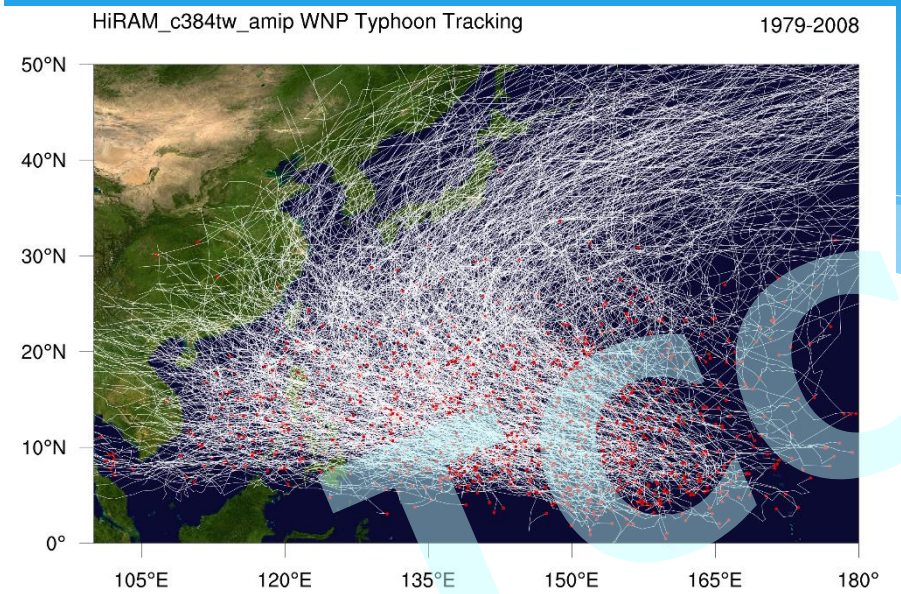


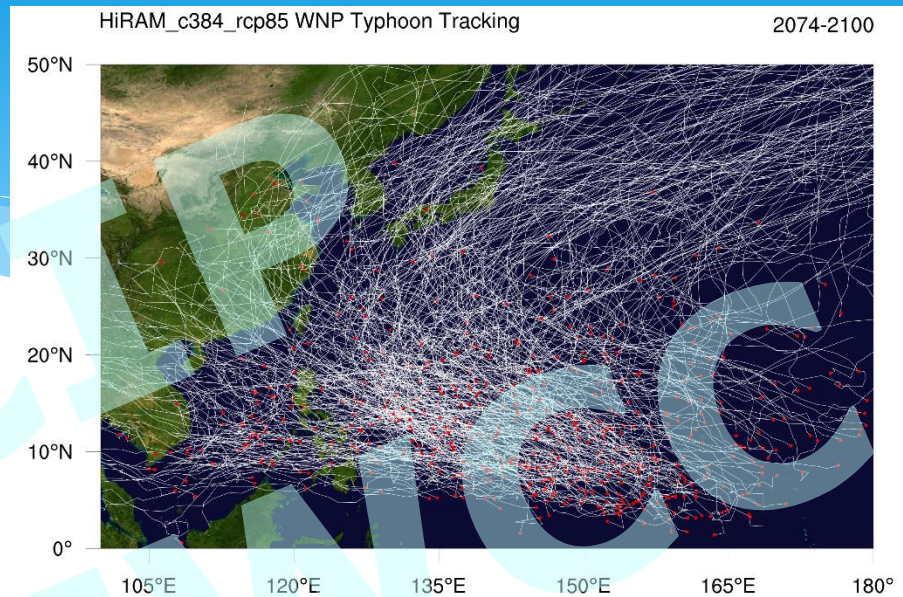
Western North Pacific - Typhoon Counts & Precipitation

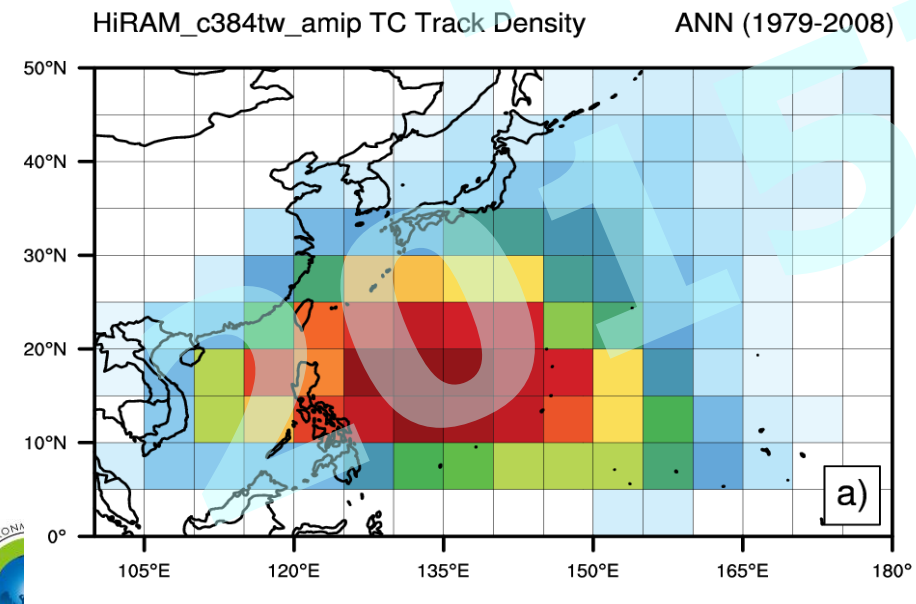


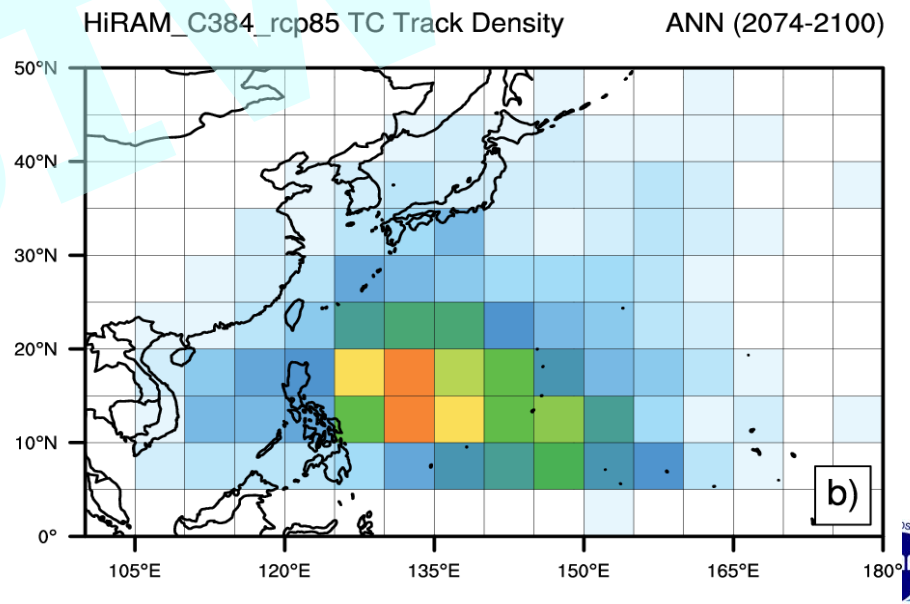
TCCIP 2015TWCC

Western North Pacific – Typhoon Future Trend

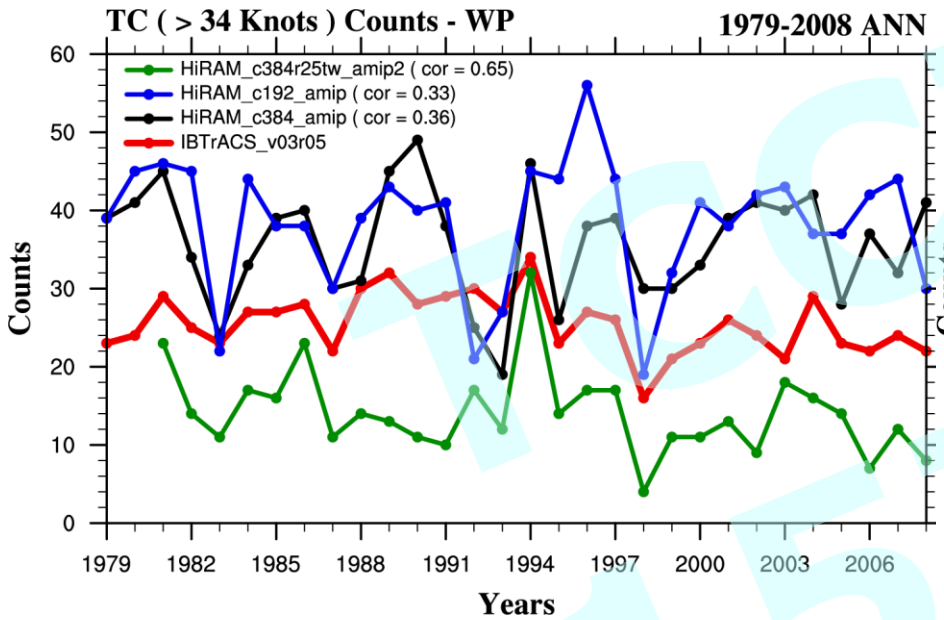


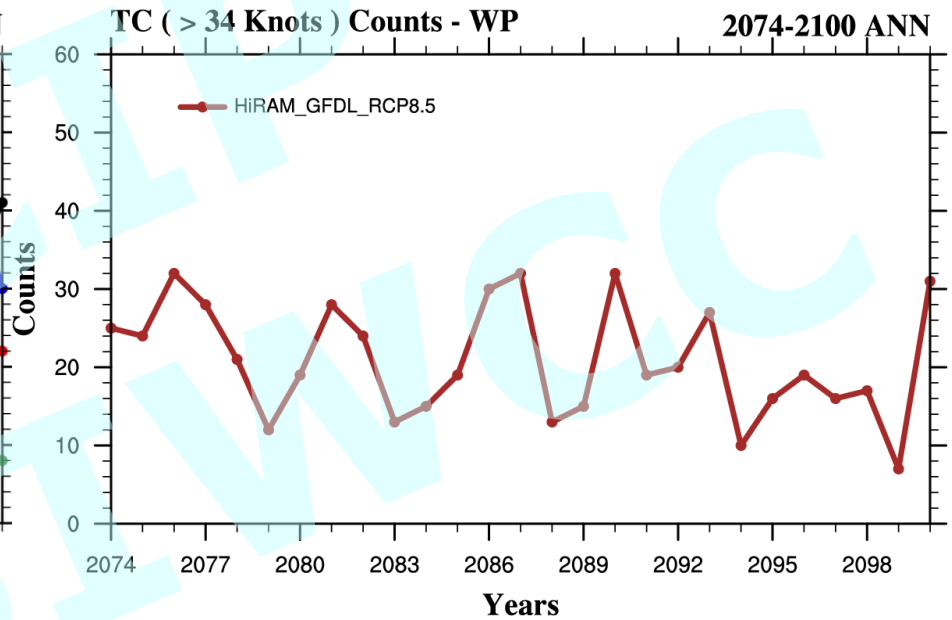






Western North Pacific – Typhoon Future Trend

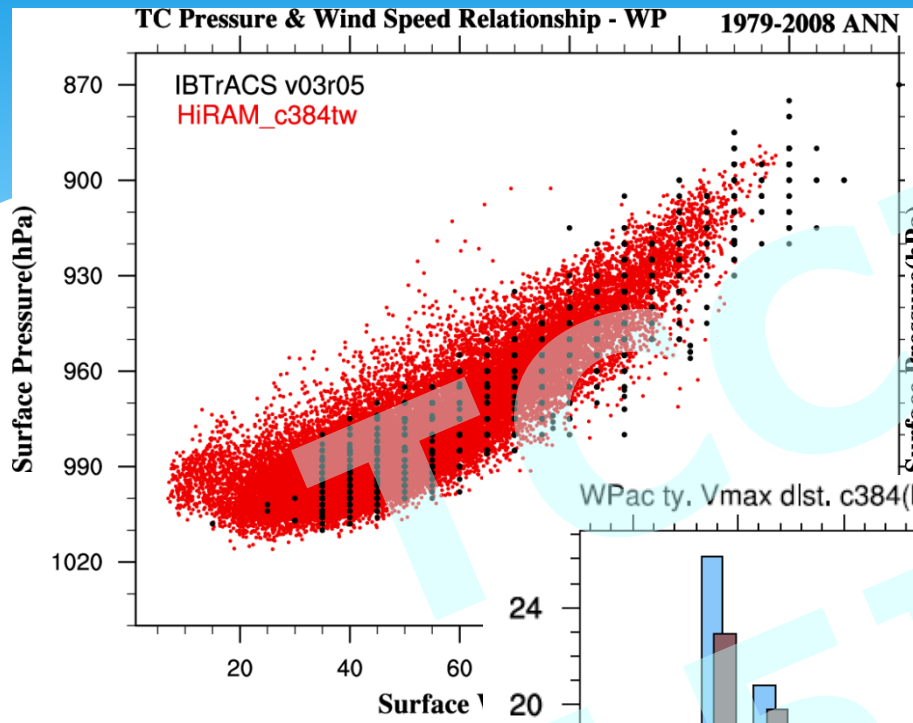


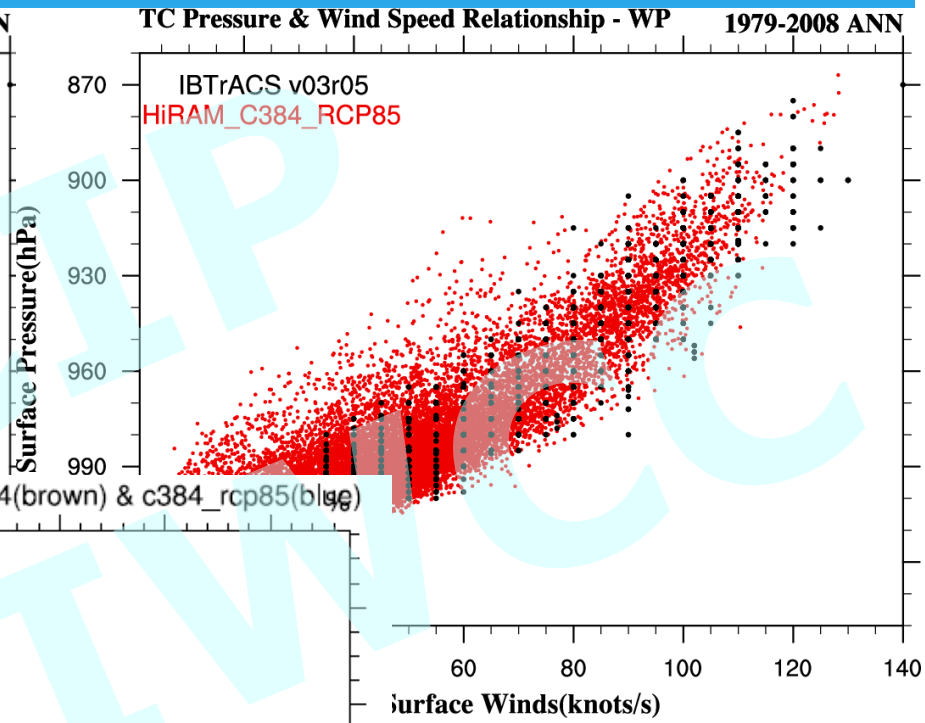


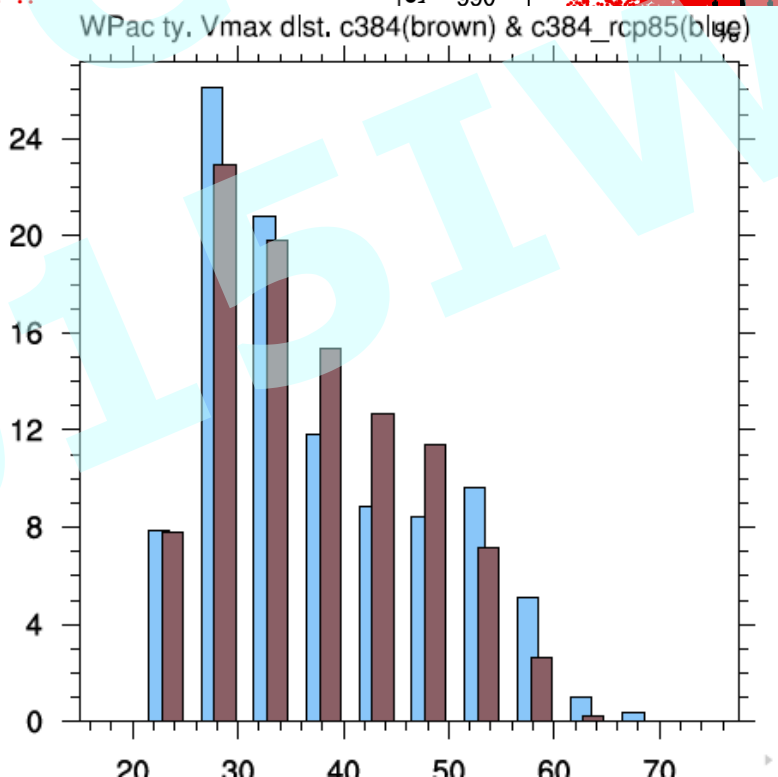
	> 34 knots (TS)	> 64 Knots (Cat1)
IBTrACs_v03r05	25.5	14.3
HiRAM_c384tw_amip	35.8	19.5
HiRAM_c384_rcp85	20.89	10.78

2015 TWCC

Western North Pacific – Typhoon Future Trend







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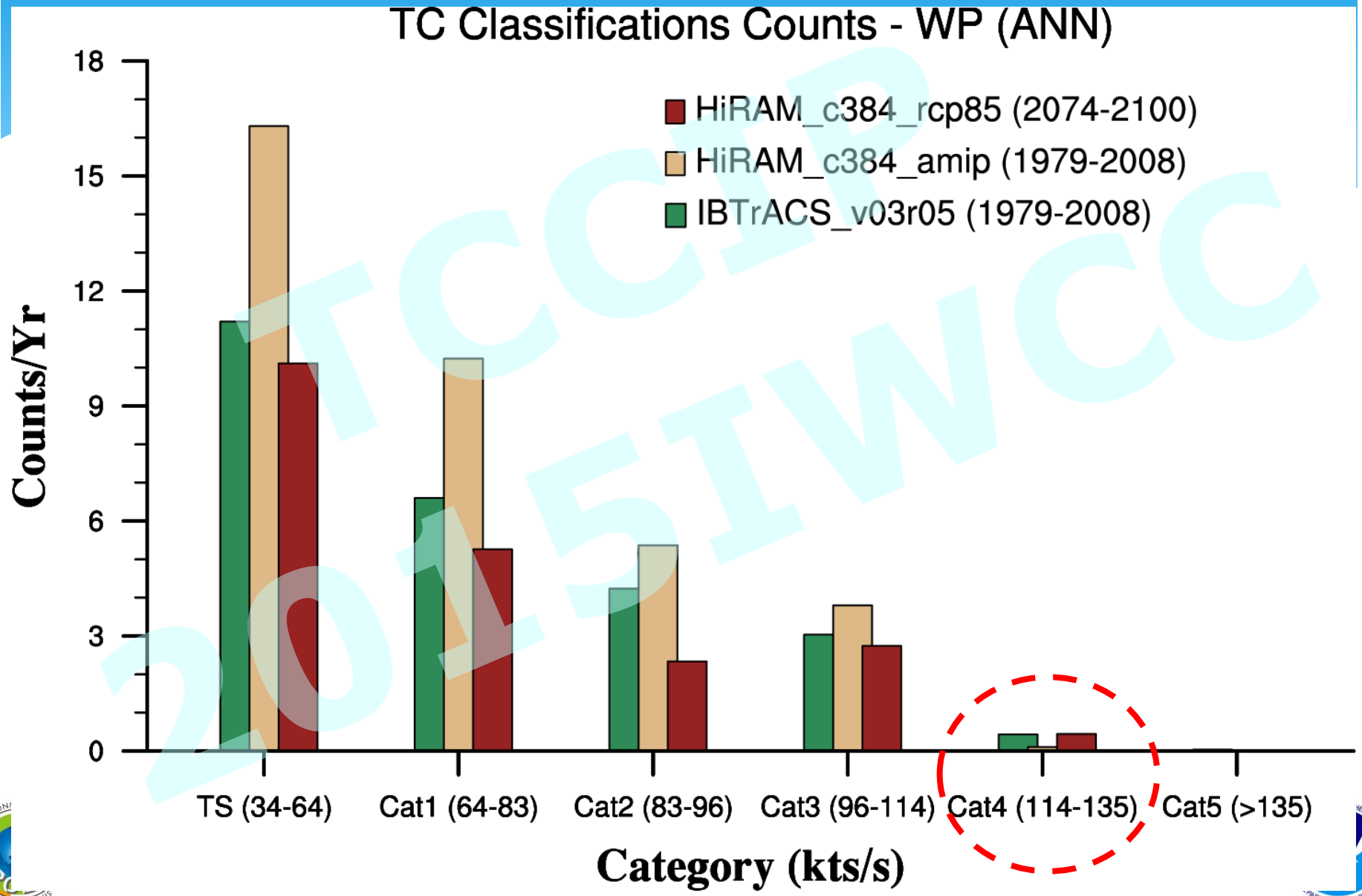
Western North Pacific – Typhoon Future Trend



TCCIP 2015IWCC

Tropical Cyclones and Extreme Precipitation in GFDL HiRAM

Asian Monsoon

(courtesy of Nicolas Freichet)

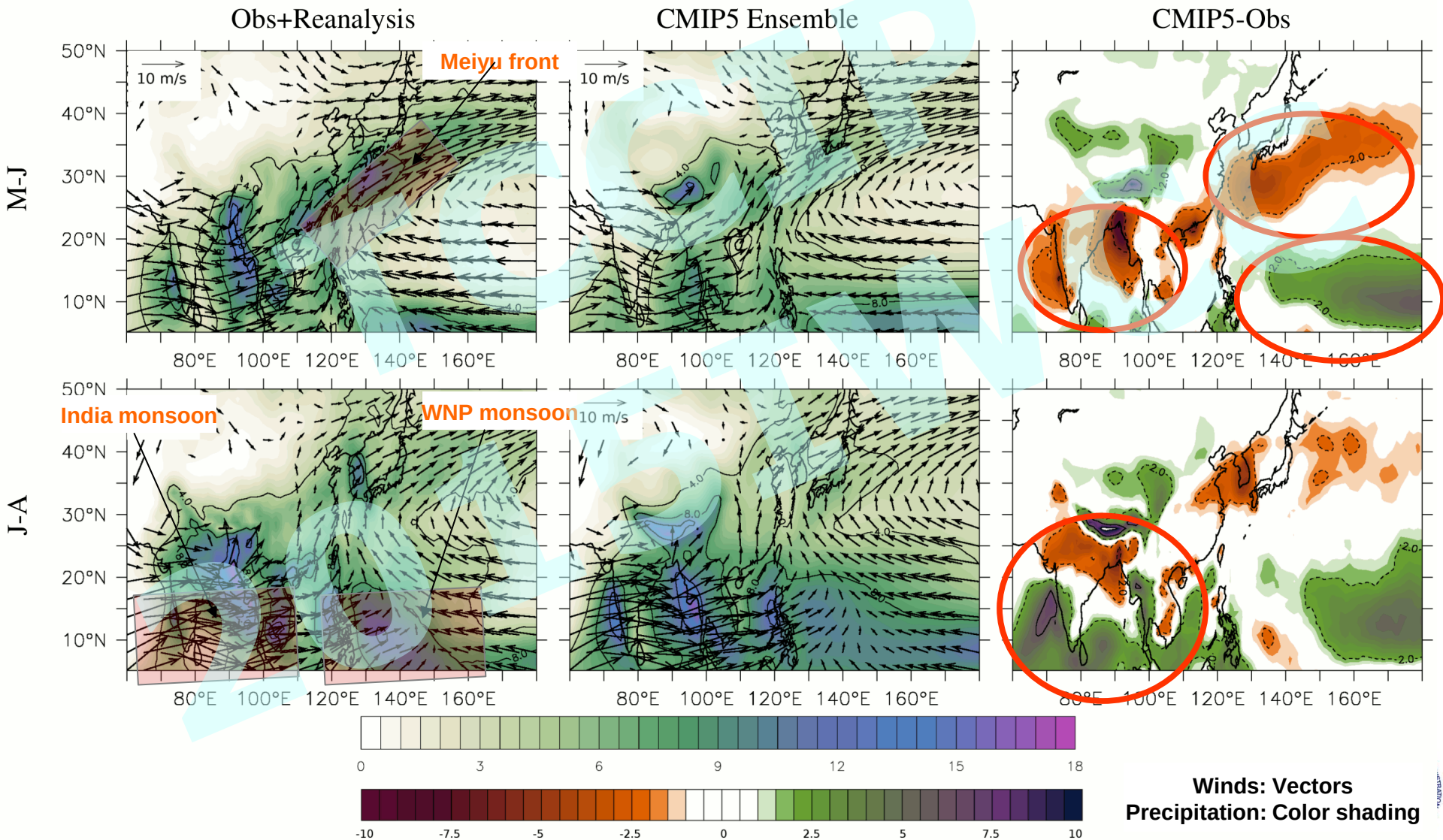
TCCIP 2015TWCC

Aisan Monsoon & Extremes

Model	Horizontal Resolution	Historical Run	Future Scenarion
HadGEM3-GC2 coupled (ORCA0.5°)	~ 0.5°	1976~2000	RCP4.5 2025~2041 1% CO_2 2071~2100 (some data missing)
HiRAM C192	~ 0.5°	1979~2008	RCP8.5 2074~2100
HiRAM C384	~ 0.25°	1979~2008	RCP8.5 2074~2100
CMIP5 Ens. (30 models)	1.5 ° ~ 3.5°	1976~2005	RCP8.5 2071~2100
NCEP Reanalysis	~ 2.5°	1976~2005	----
GPCP Daily Precipitation	~ 1°	1996~2013	----

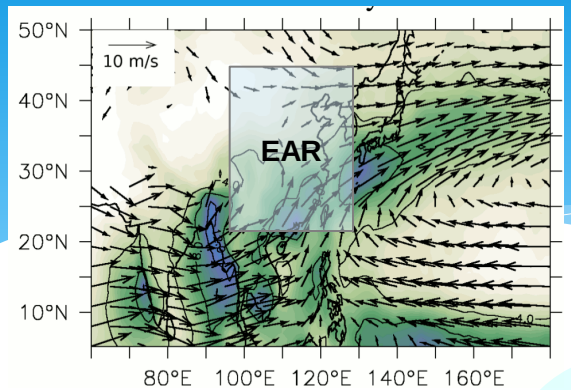
Asian Monsoon

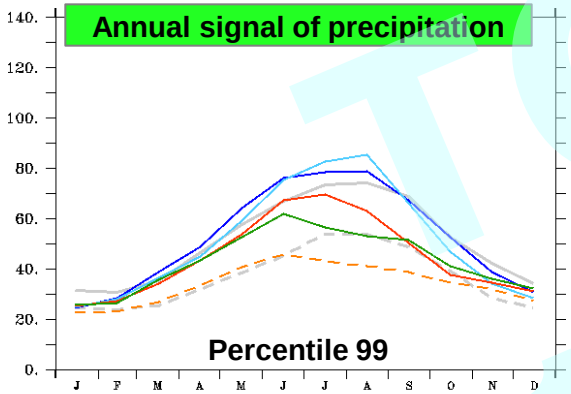
Winds: NCEP-NCAR Reanalysis
Precipitation: GPCP

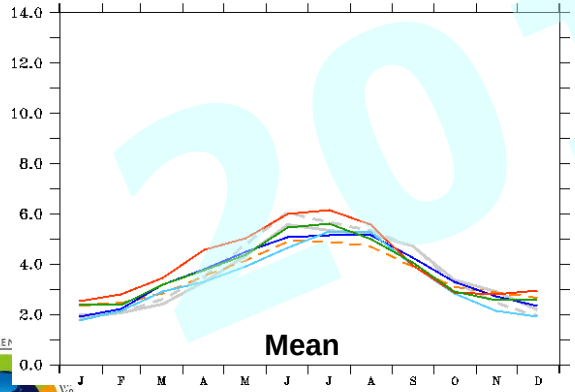


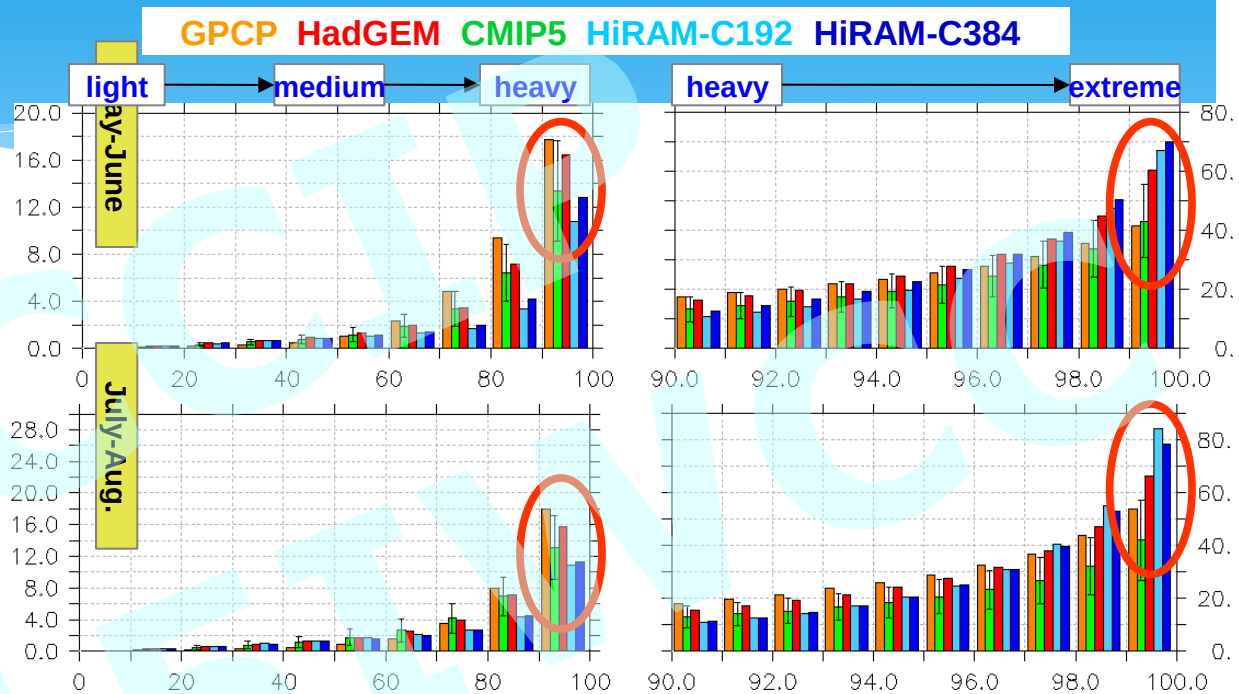
Winds: Vectors
Precipitation: Color shading

Asian Monsoon Precipitation









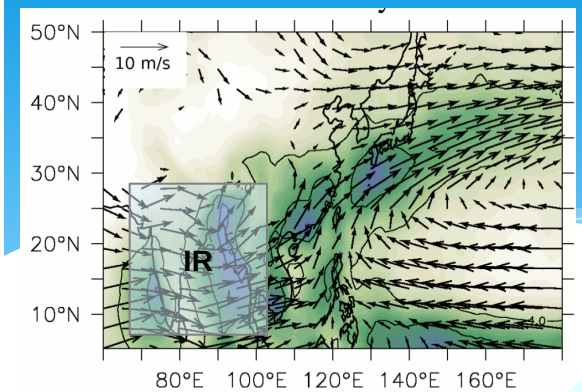
Distribution of precipitation during summer

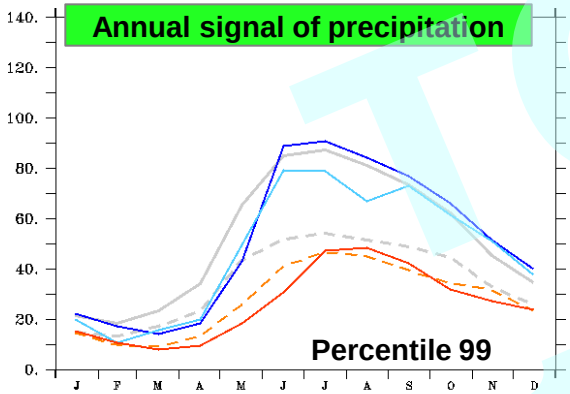
HadGEM
-mean precip ok
-overestimate extreme?

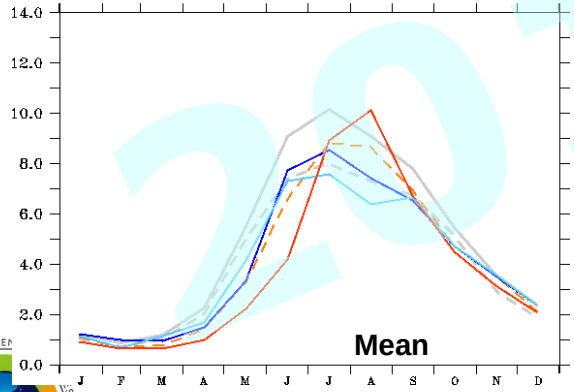
HiRAM
-slightly underestimate mean precip during summer
-overestimate extreme?

TRMM GPCP(dashed) HadGEM CMIP5(dashed) HiRAM-C192 HiRAM-C384 MRI20km

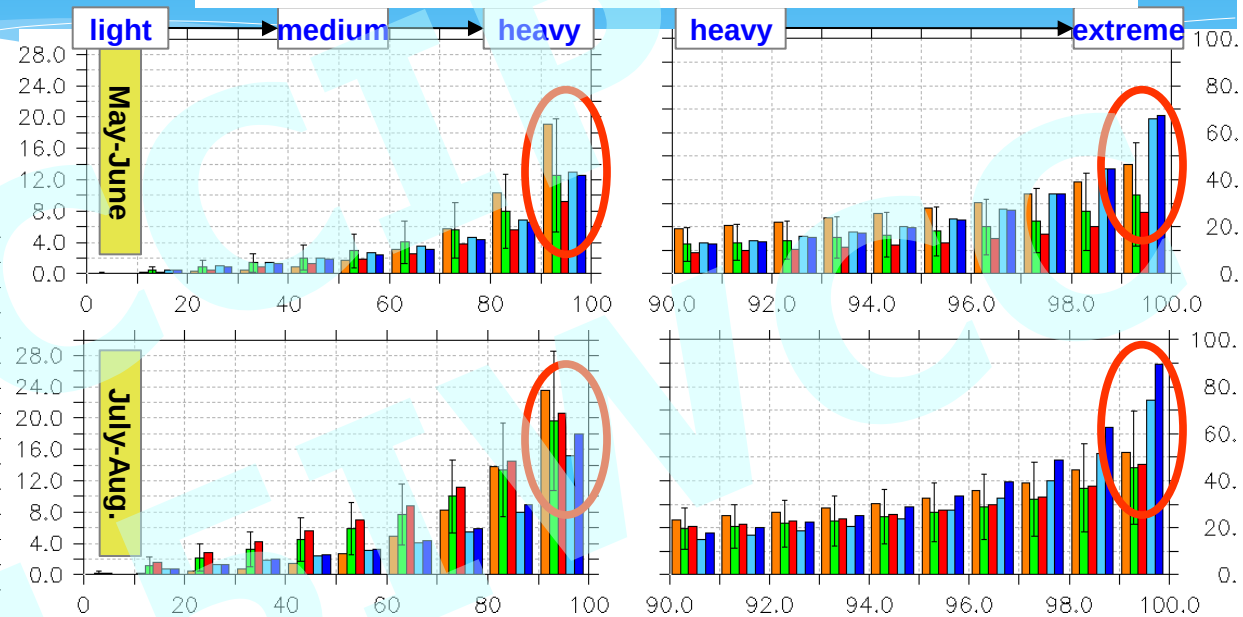
Asian Monsoon Precipitation







GPCP HadGEM CMIP5 HiRAM-C192 HiRAM-C384



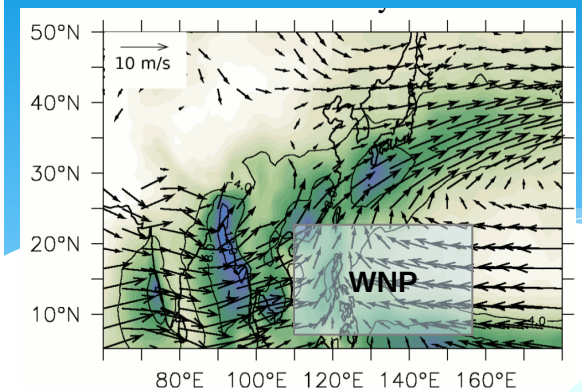
Distribution of precipitation during summer

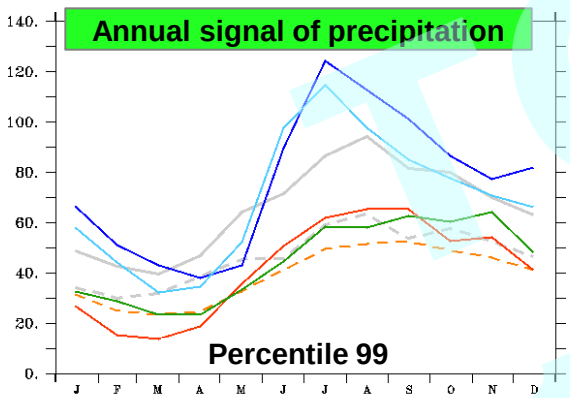
HadGEM
-bad signal on mean precip
-underestimate extreme

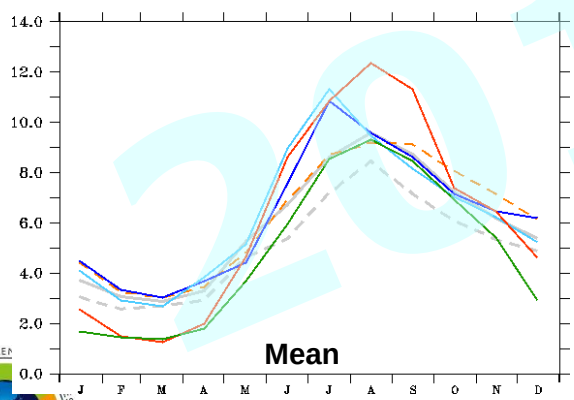
HiRAM
-good signal on mean precip (C384 better than C192)
-overestimate extreme

TRMM GPCP(dashed) HadGEM CMIP5(dashed) HiRAM-C192 HiRAM-C384 MRI20km

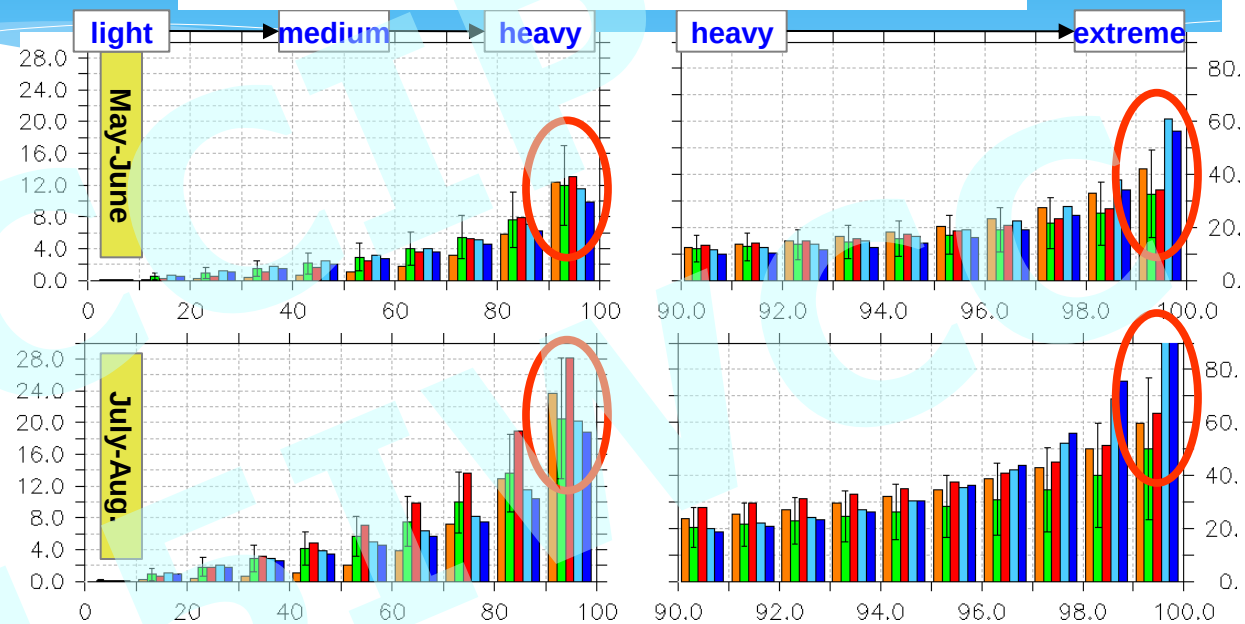
Asian Monsoon Precipitation







GPCP HadGEM CMIP5 HiRAM-C192 HiRAM-C384



Distribution of precipitation during summer

HadGEM
-bad mean precip
-extreme seems ok during summer

HiRAM
-overestimate mean precip during summer
-extreme??

TRMM GPCP(dashed) HadGEM CMIP5(dashed) HiRAM-C192 HiRAM-C384 MRI20km

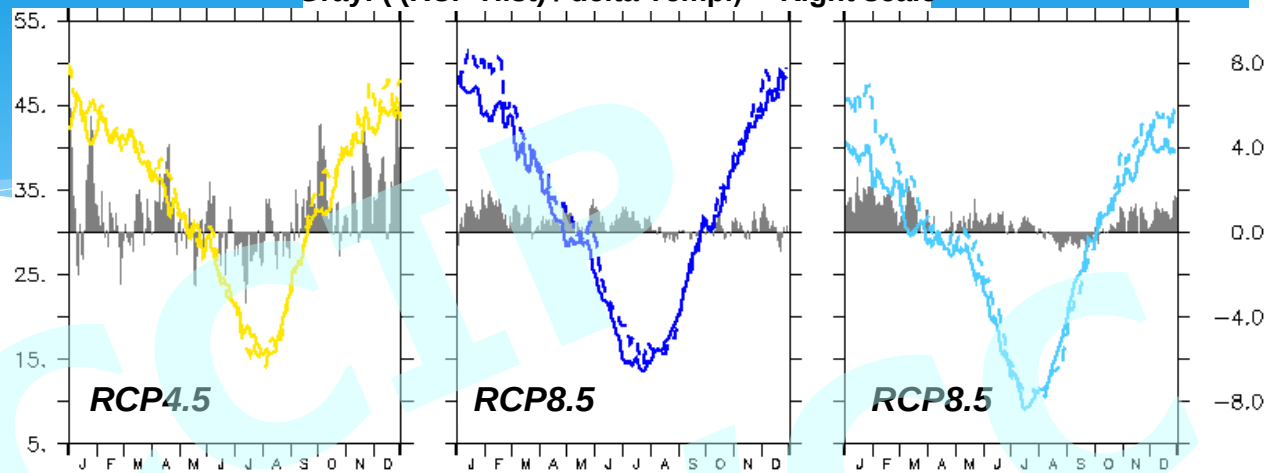
Asian Monsoon Monsoon Index

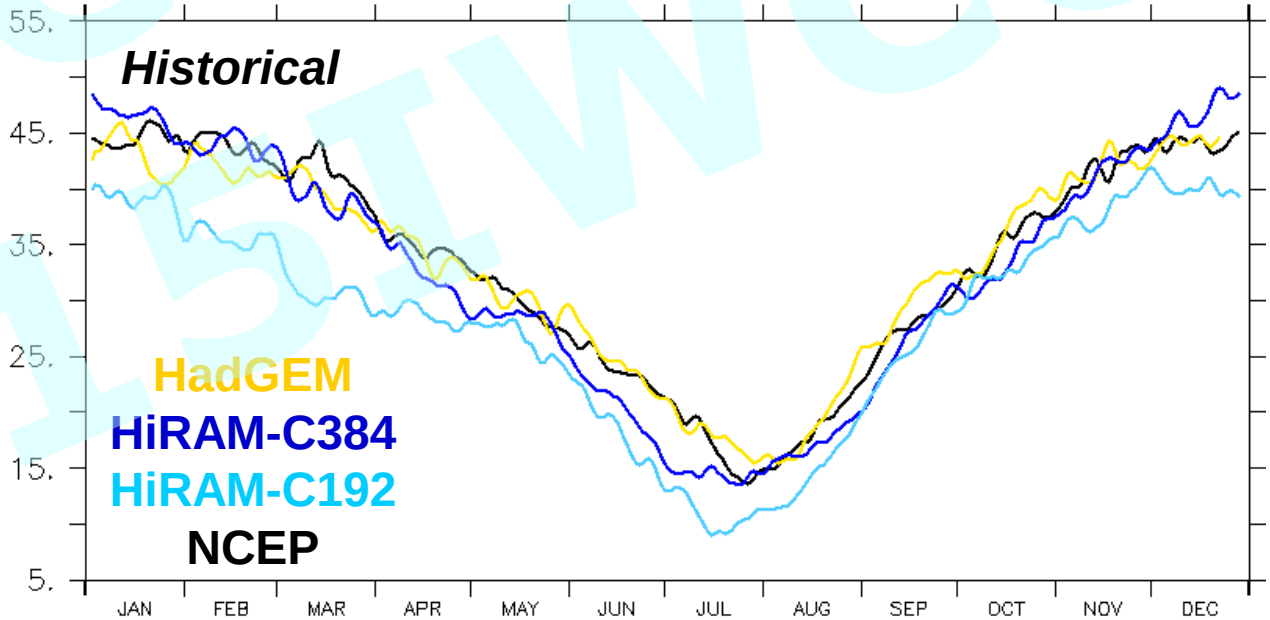
EASJ

-East Asia Summer Jet-

U200 (110-140E,30-50N)

Full: Historical / Dashed: RCP → Left scale
Gray: ((RCP-Hist) / delta Temp.)→ Right scale





HadGEM
-very good signal of the Jet
-RCP no clear

HiRAM
-C384 better than C192
-rcp: strenghten? (winter)

EASJ Index – NCEP(Black), HadGEM(Yellow), HiRAM(dark blue), HiRAM–C192(light blue)

Top: HIST (full lines) and RCP (dashed lines) + Diff (RCP–HIST)/K (gray, right scale)

TCCIP 2015TWCC

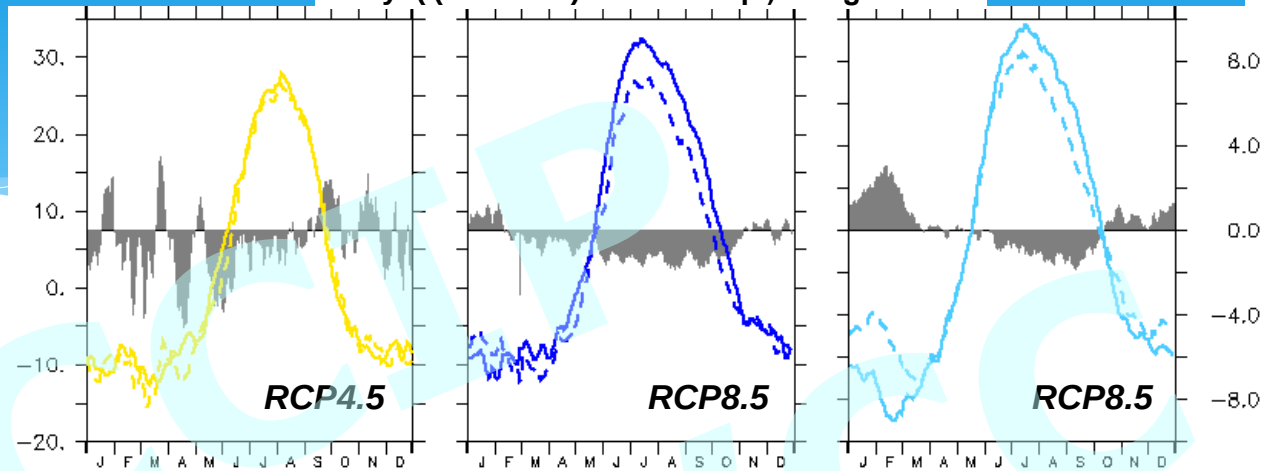
Asian Monsoon Monsoon Index

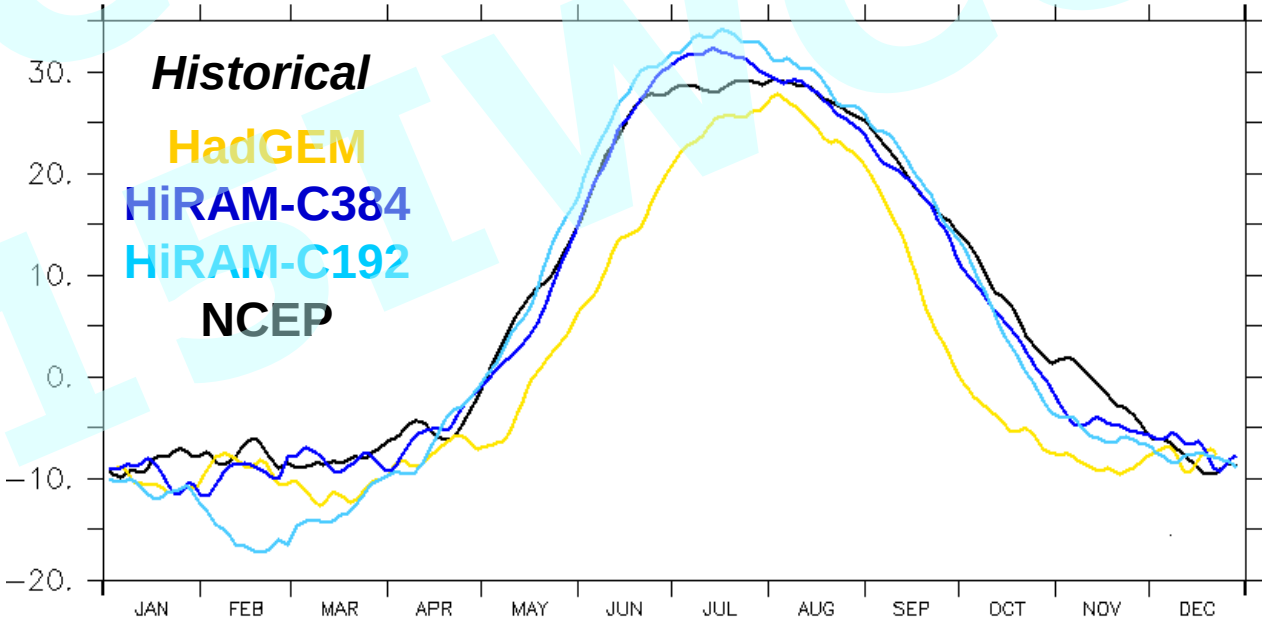
WYI

-Webster and Yang Index-

U850-U200 (40-110E,0-20N)

Full: Historical / Dashed: RCP → Left scale
Gray: ((RCP-Hist) / delta Temp.)→ Right scale





HadGEM
-bad Indian monsoon
-projection??

HiRAM
-good signal
-rcp: decrease during summer

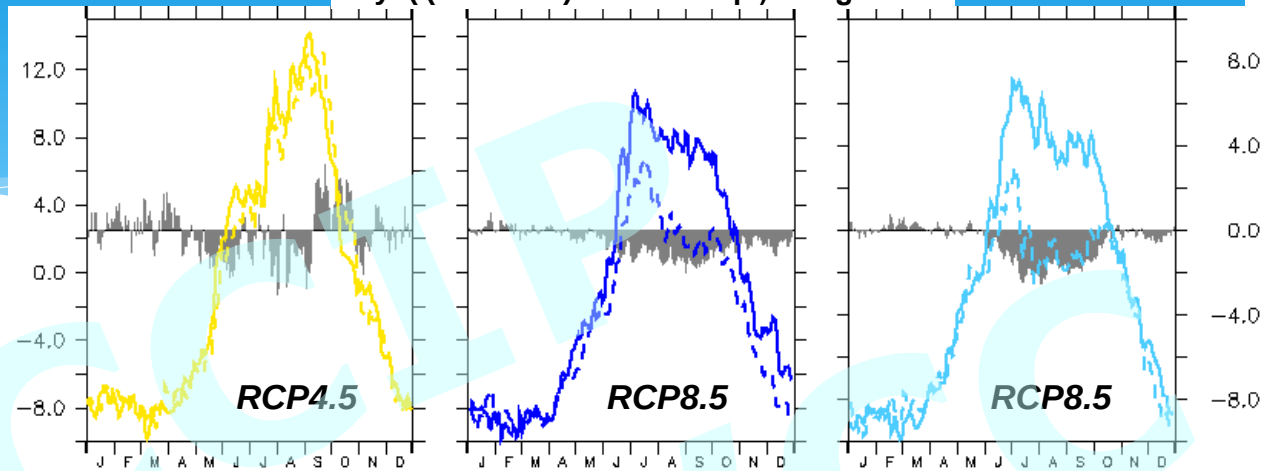
WYI Index – NCEP(Black), HadGEM(Yellow), HiRAM(dark blue), HiRAM−C192(light blue)

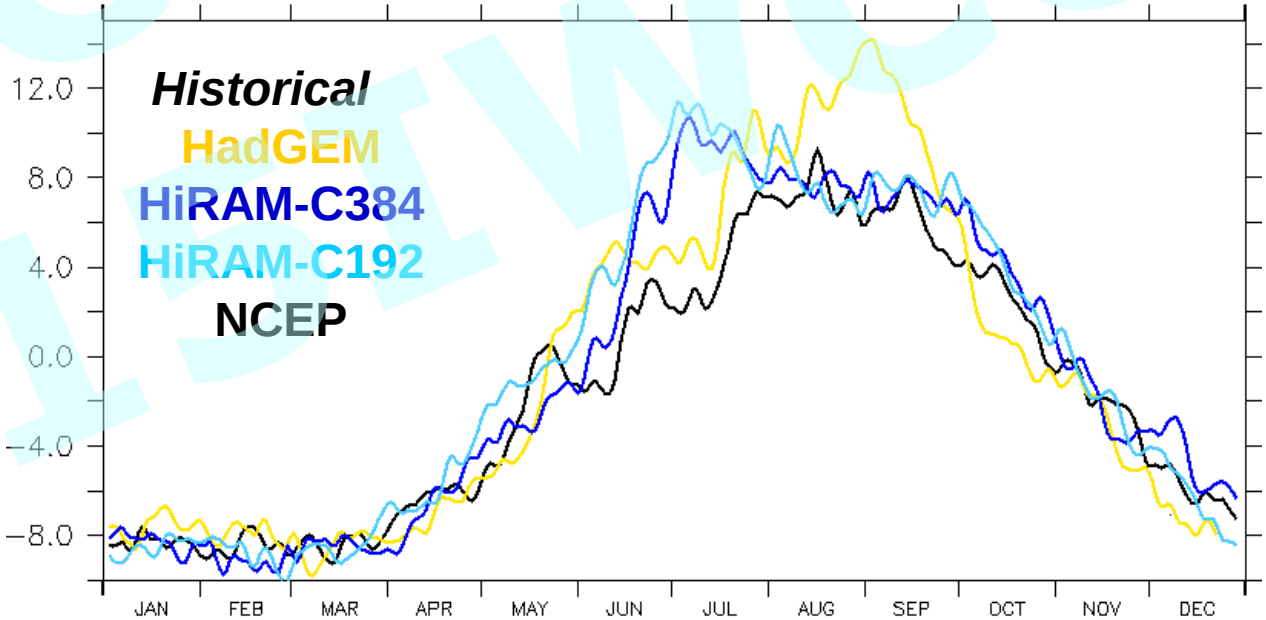
Top: HIST (full lines) and RCP (dashed lines) + Diff (RCP−HIST)/K (gray, right scale)

Asian Monsoon Monsoon Index

WNPSM
-West North Pacific
Summer Monsoon-
U850 (100-130E,5-15N
minus 110-140E,20-30N

Full: Historical / Dashed: RCP → Left scale
Gray: ((RCP-Hist) / delta Temp.)→ Right scale



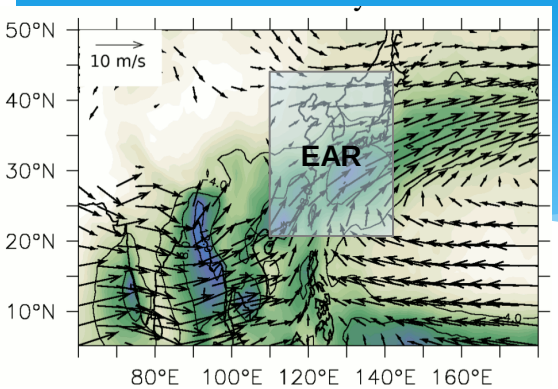


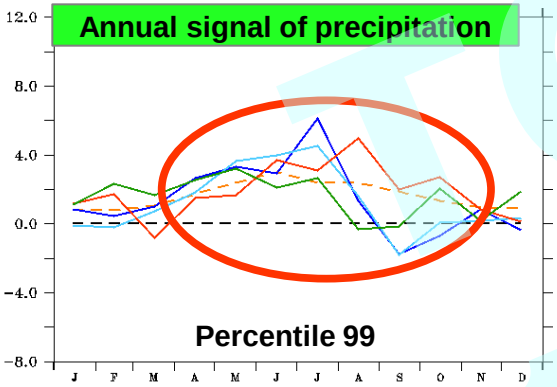
HadGEM
-good onset of the WNPSM, but to strong in late summer

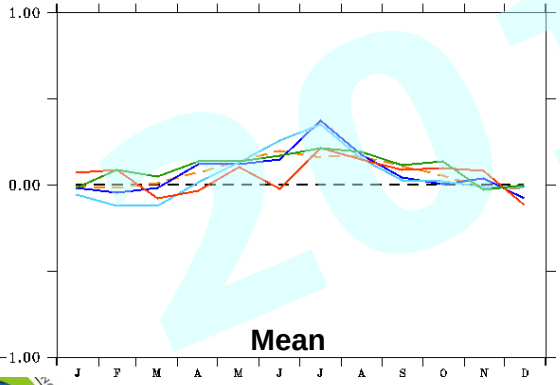
HiRAM
-onset too soon
-rcp: weakens during summer

WNPSM Index – NCEP(Black), HadGEM(Yellow), HiRAM(dark blue), HiRAM–C192(light blue)
Top: HIST (full lines) and RCP (dashed lines) + Diff (RCP–HIST)/K (gray, right scale)

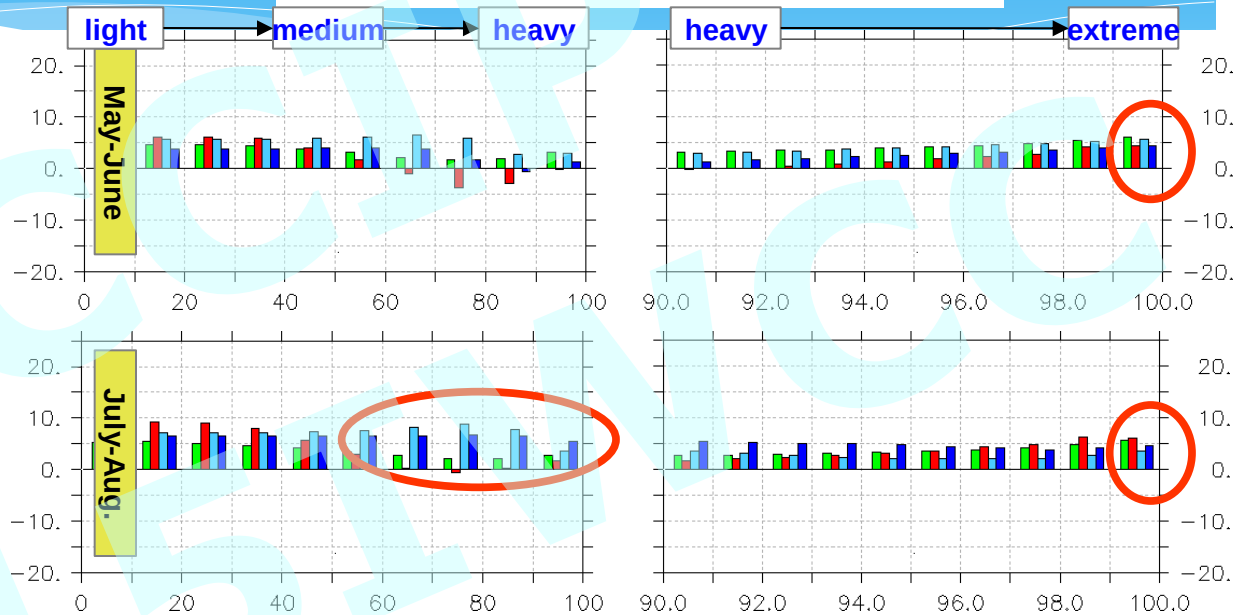
Asian Monsoon
Precipitation in future projection







HadGEM CMIP5 HiRAM-C192 HiRAM-C384



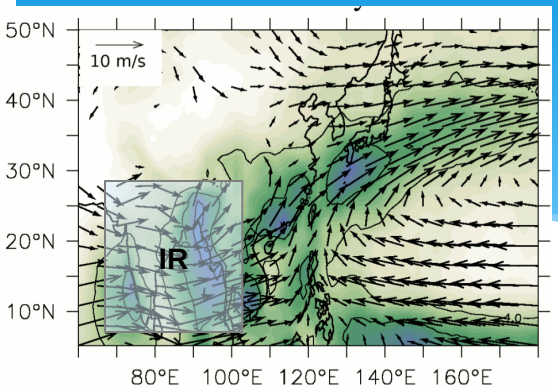
Distribution of precipitation during summer
(% / K)

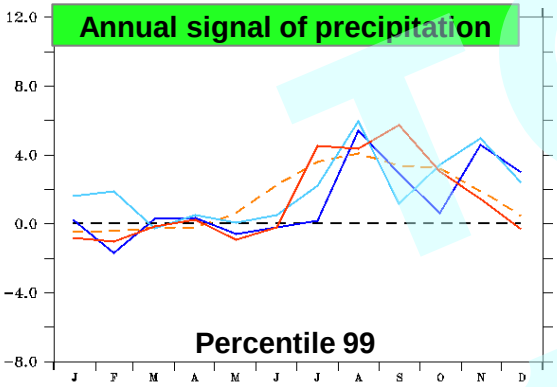
-all models show good agreement on extreme projection

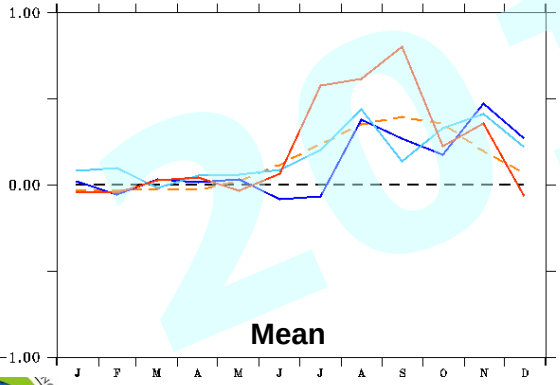
-HiRAM has higher increase in mean precipitation
-HiRAM has a different annual signal on extreme : increase during spring then decrease during late summer

TRMM GPCP(dashed) HadGEM CMIP5(dashed) HiRAM-C192 HiRAM-C384 MRI20km

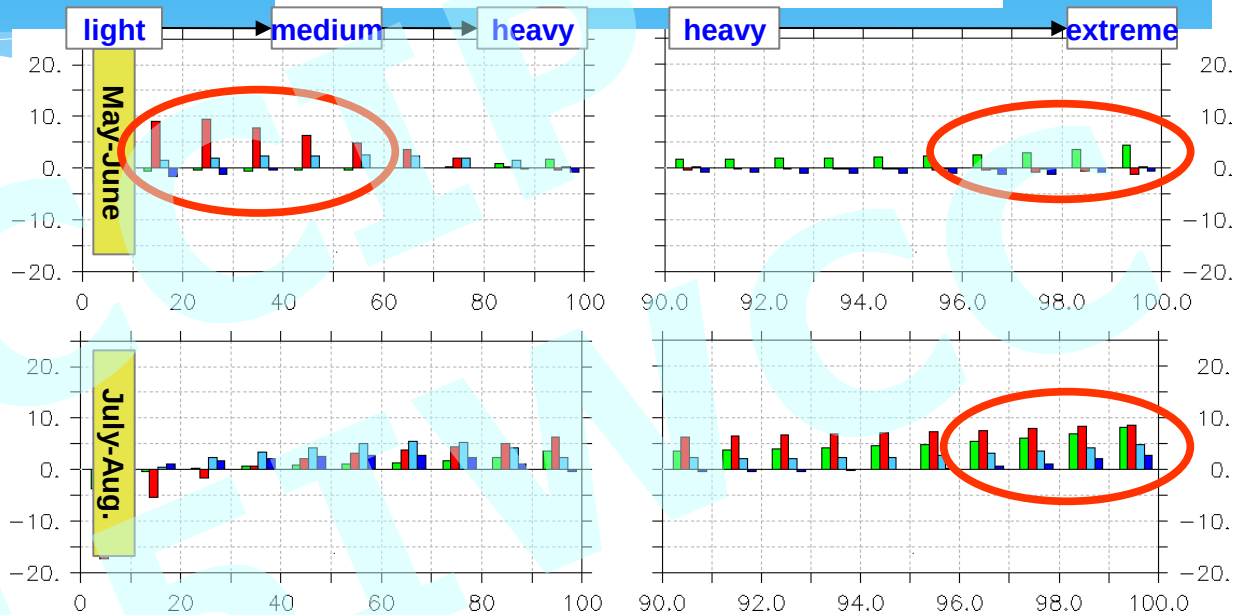
Asian Monsoon
Precipitation in future projection







HadGEM CMIP5 HiRAM-C192 HiRAM-C384



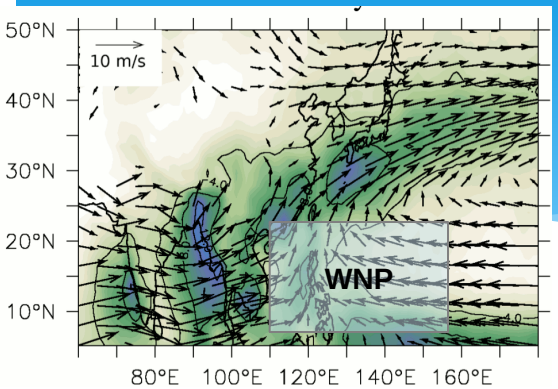
Distribution of precipitation during summer
(% / K)

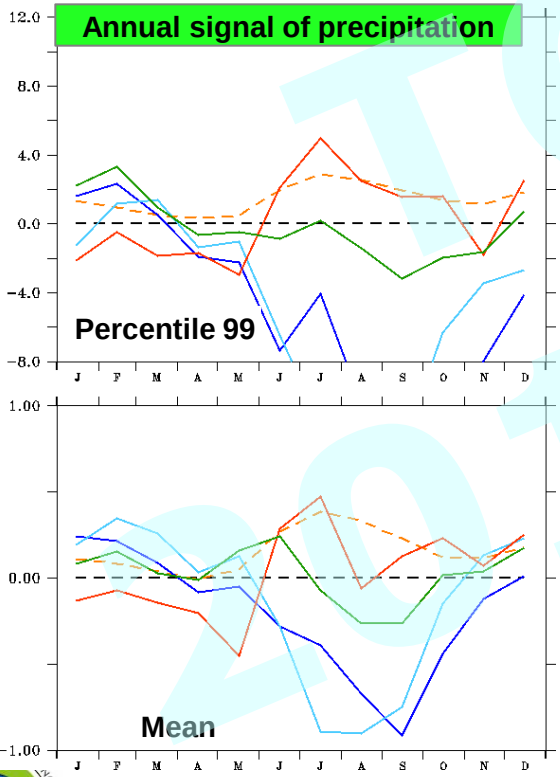
-HadGEM3 should not be considered because of it's bad representation of the monsoon in the region

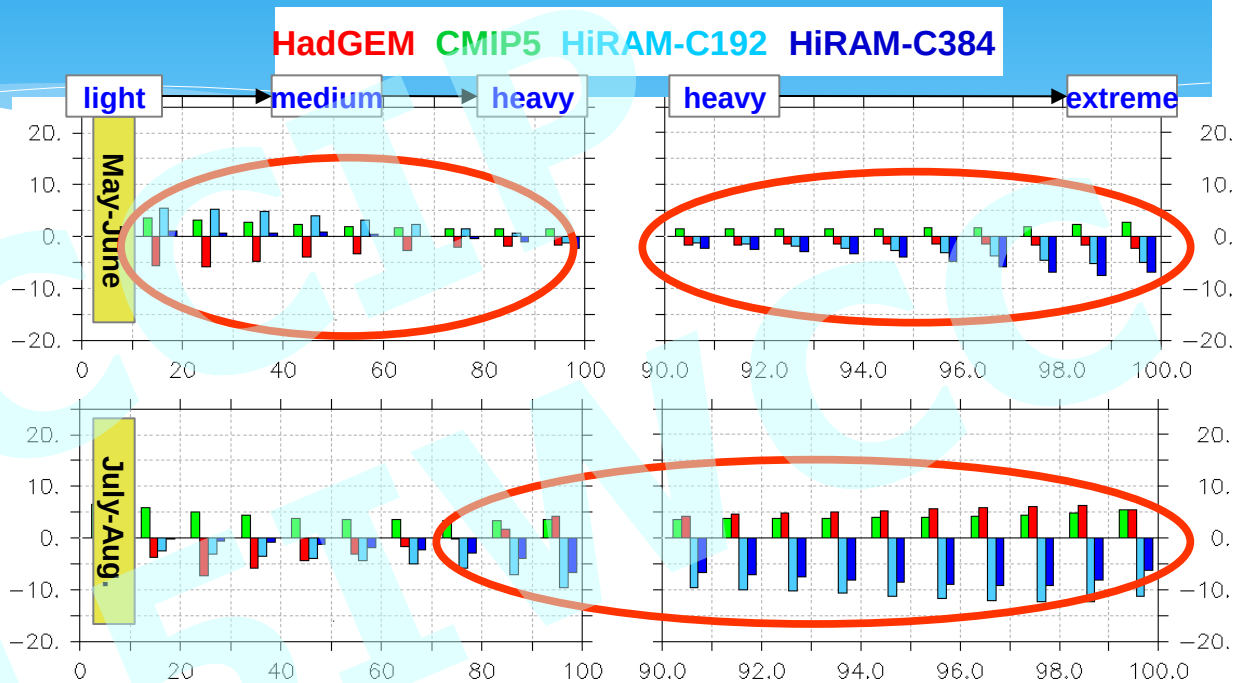
-HiRAM has lower increase in early summer (compare to CMIP5)

TRMM GPCP(dashed) HadGEM CMIP5(dashed) HiRAM-C192 HiRAM-C384 MRI20km

Asian Monsoon
Precipitation in future projection







Distribution of precipitation during summer
(% / K)

-Spring: HadGEM3 and HiRAM both show decrease on extremes

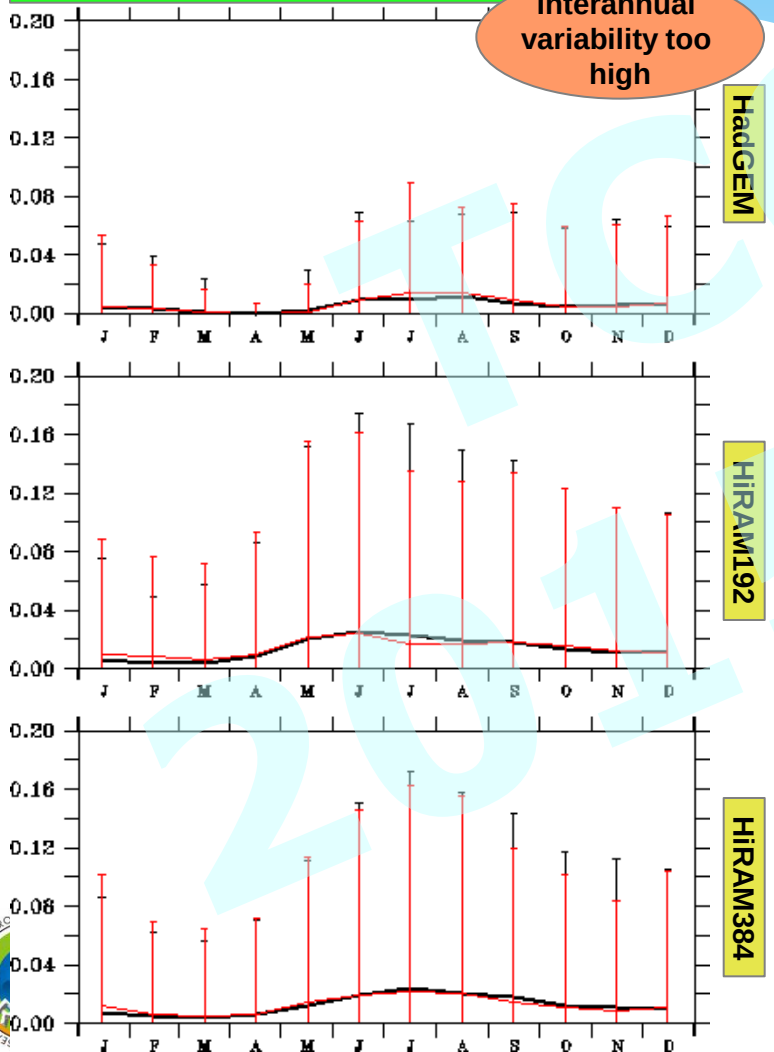
-Summer: HadGEM3 and CMIP5 tend to show increase, but HiRAM has large decrease

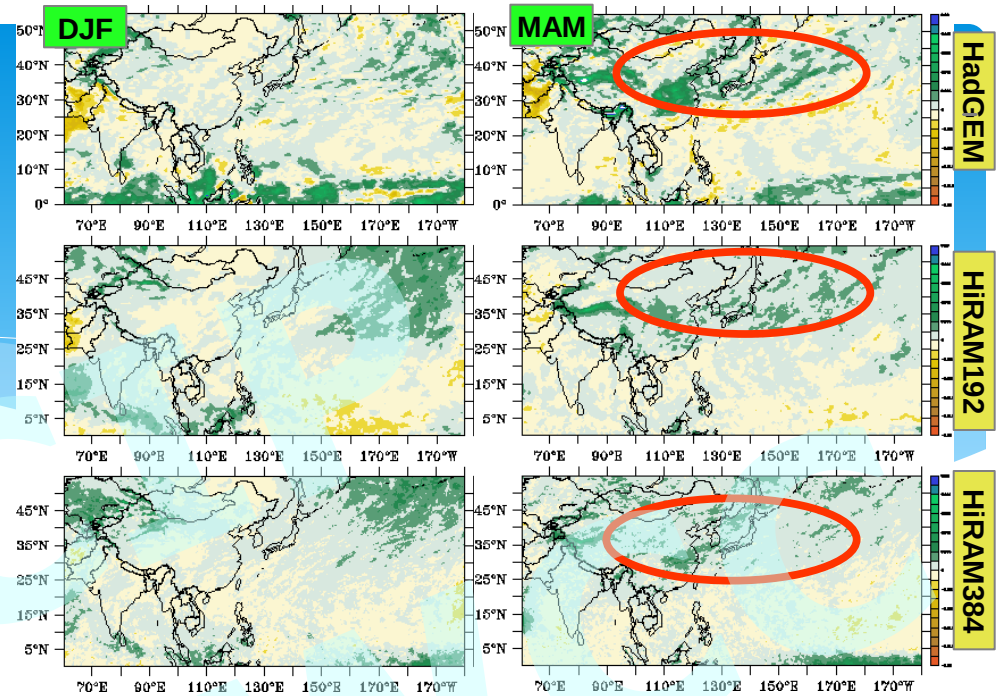
TRMM GPCP(dashed) HadGEM CMIP5(dashed) HiRAM-C192 HiRAM-C384 MRI20km

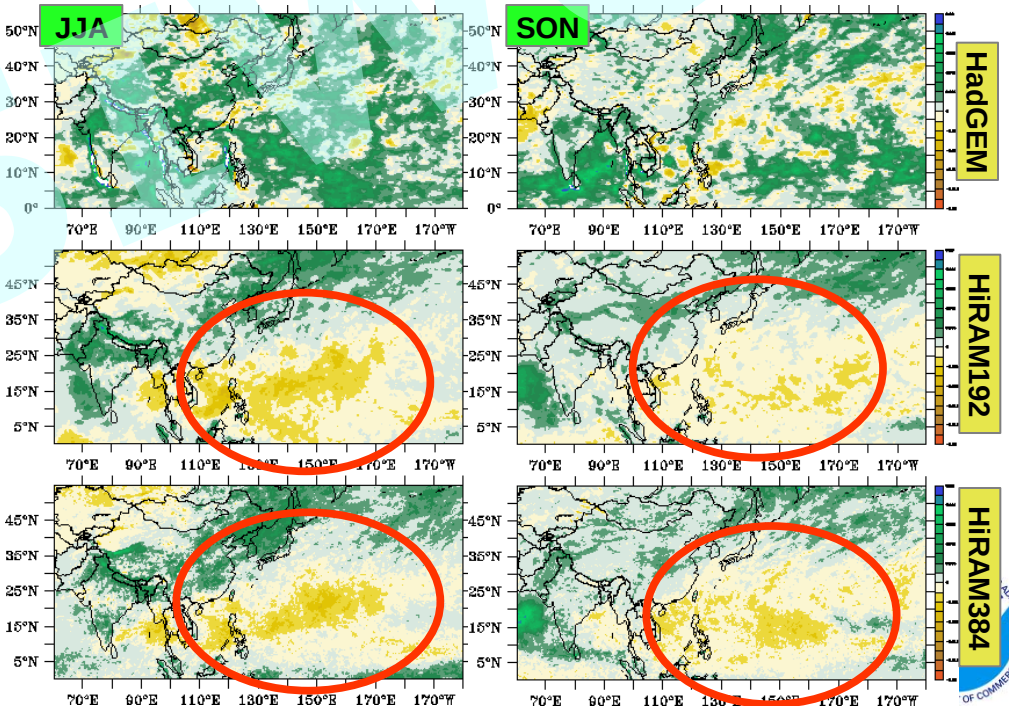
Asian Monsoon Extreme projection

WNP
Montly extreme + interannual variability (bars)
Black:Hist - Red: RCP

Interannual variability too high







Tropical Cyclones and Extreme Precipitation in GFDL HiRAM

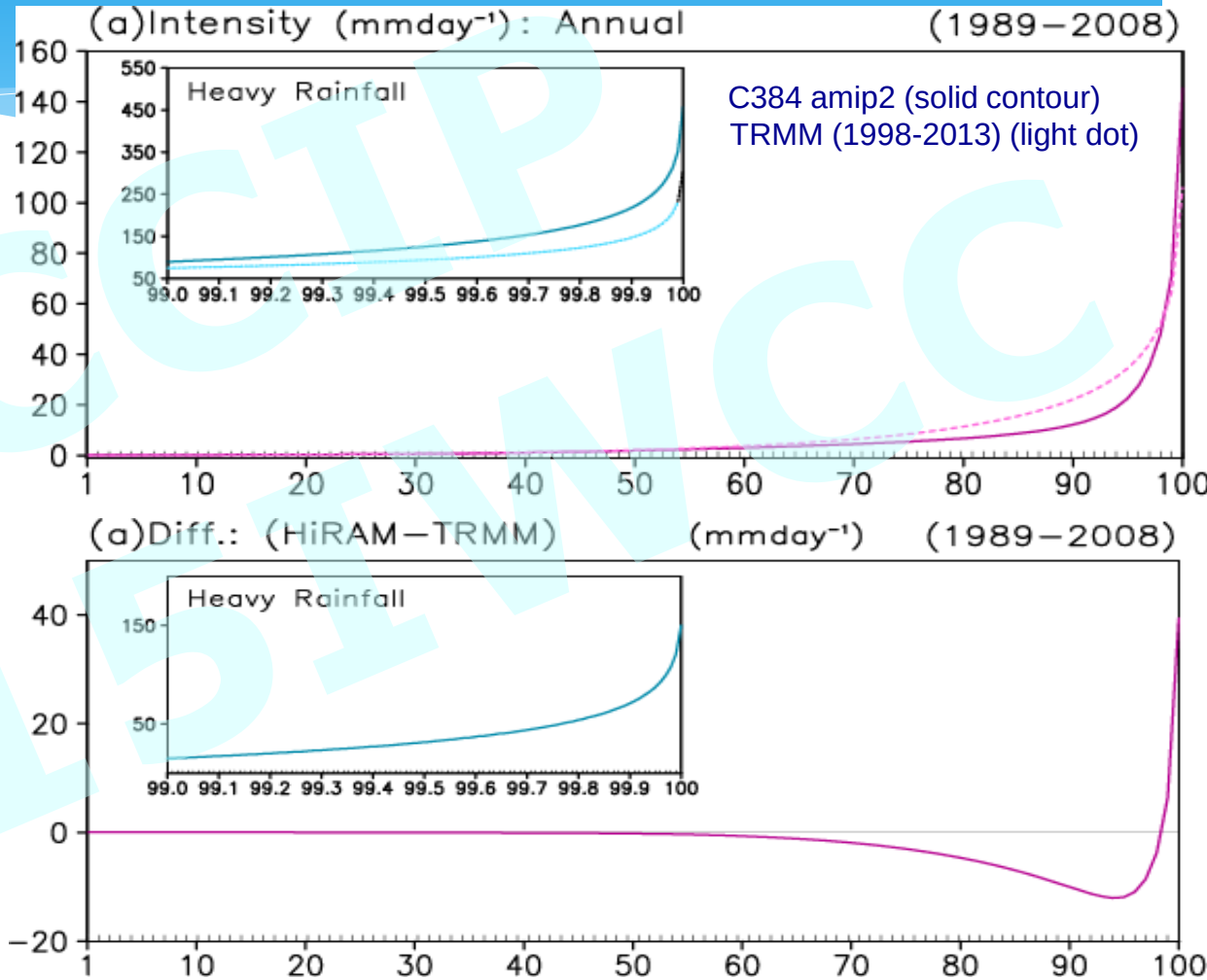
Extreme Precipitation

(courtesy of Chao-An Chen)

TCCIP 2015TWCC

Global Precipitation - Changes in rainfall intensity

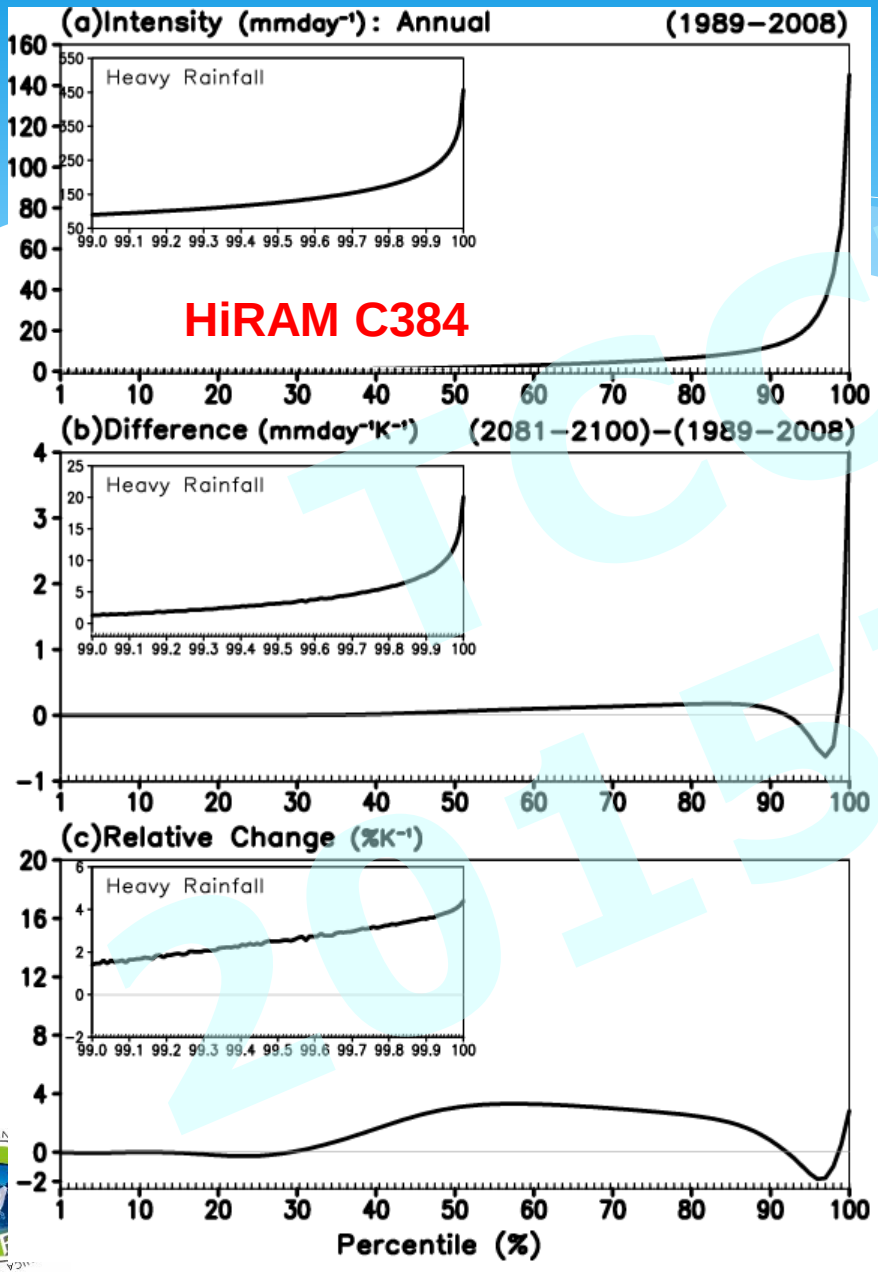
* Observation
  * TRMM,CFSR: Prec=0: 70%
* HiRAM
  * Prec=0 : ~ 3%
  * Prec<0.1mm/day : ~47%

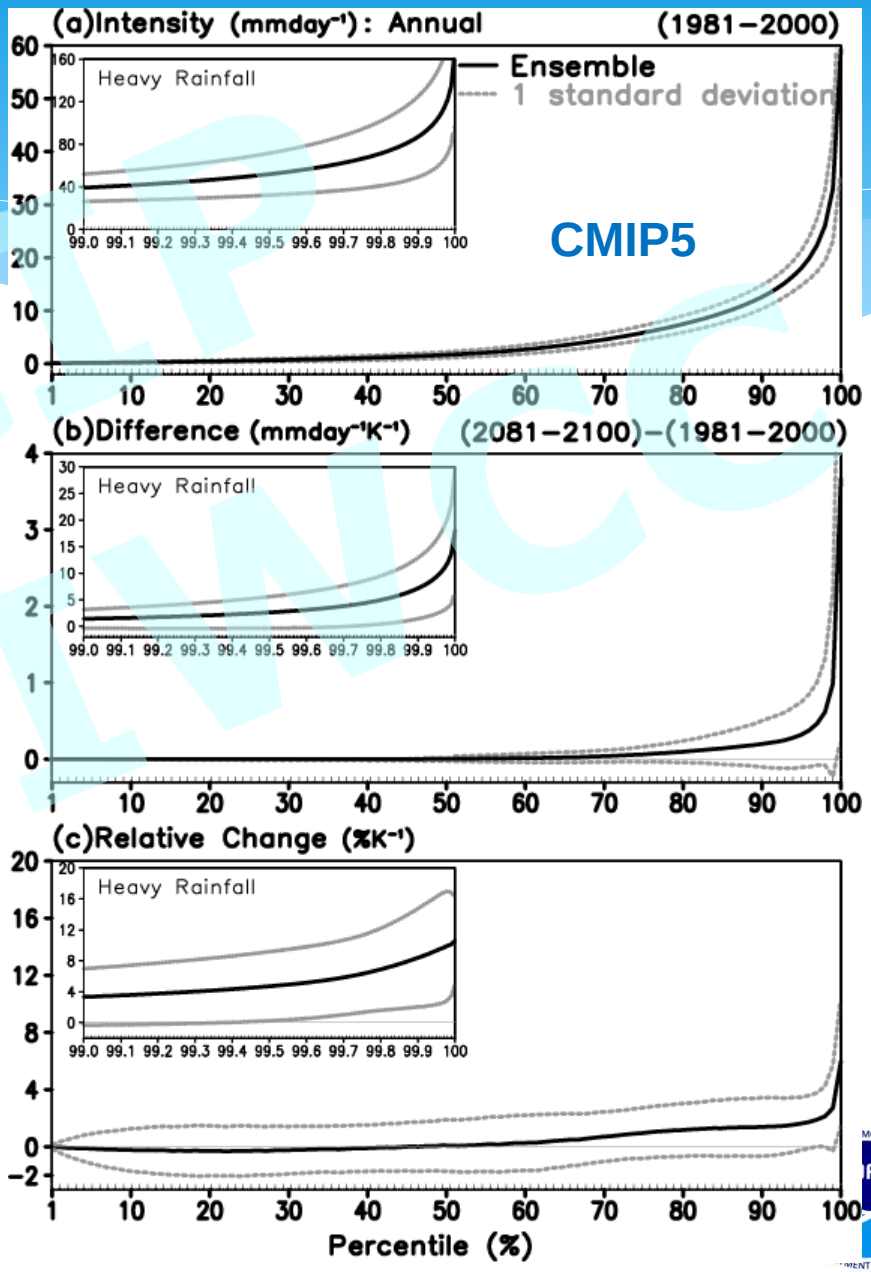


1% for each bin to total rainfall events
0.01% is used for the strongest percent of precipitation, i.e. the 99th percentile

TCCTP 2015 IWCC

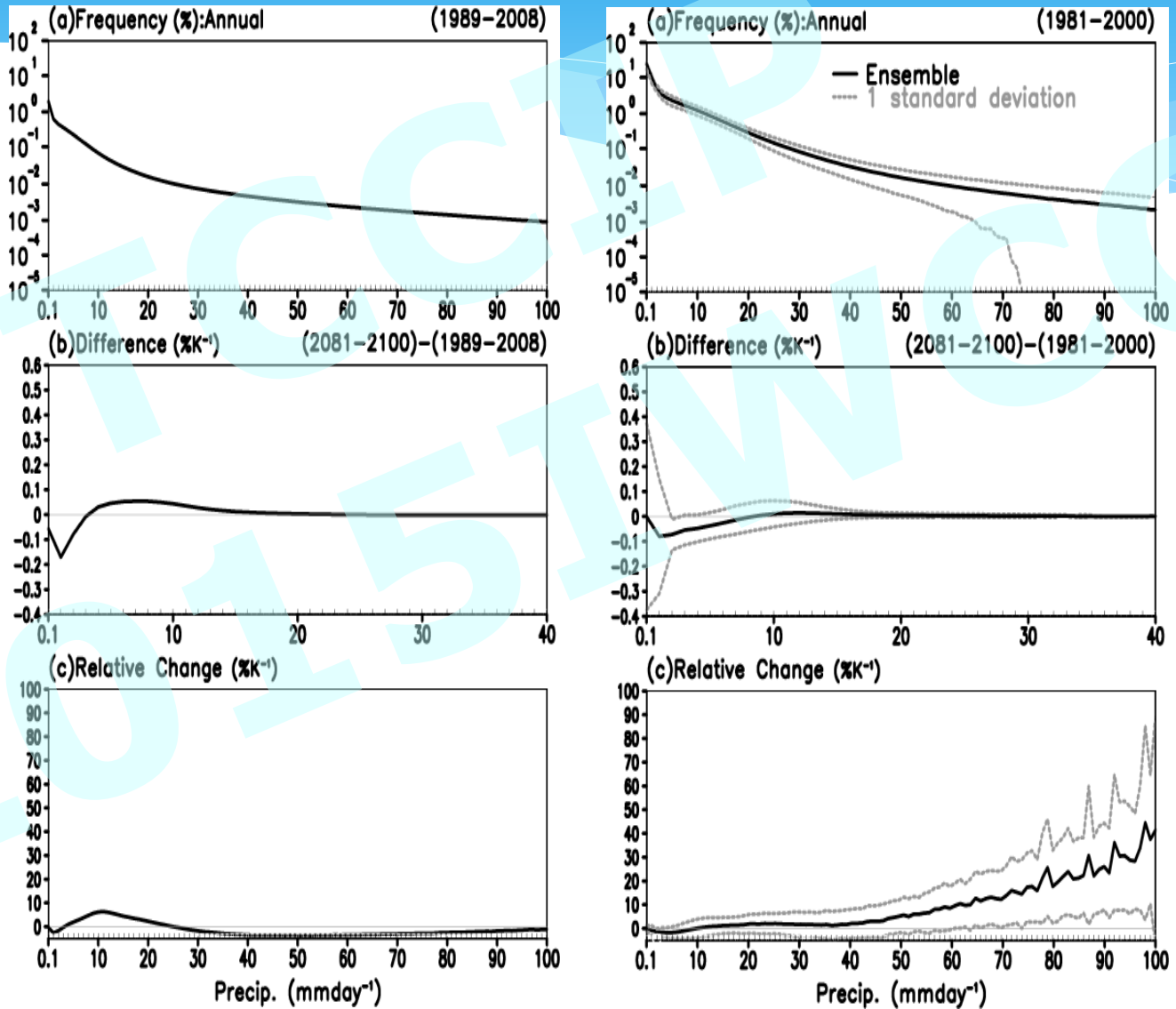
Global Precipitation - Changes in rainfall intensity





Global Precipitation - Changes in rainfall frequency

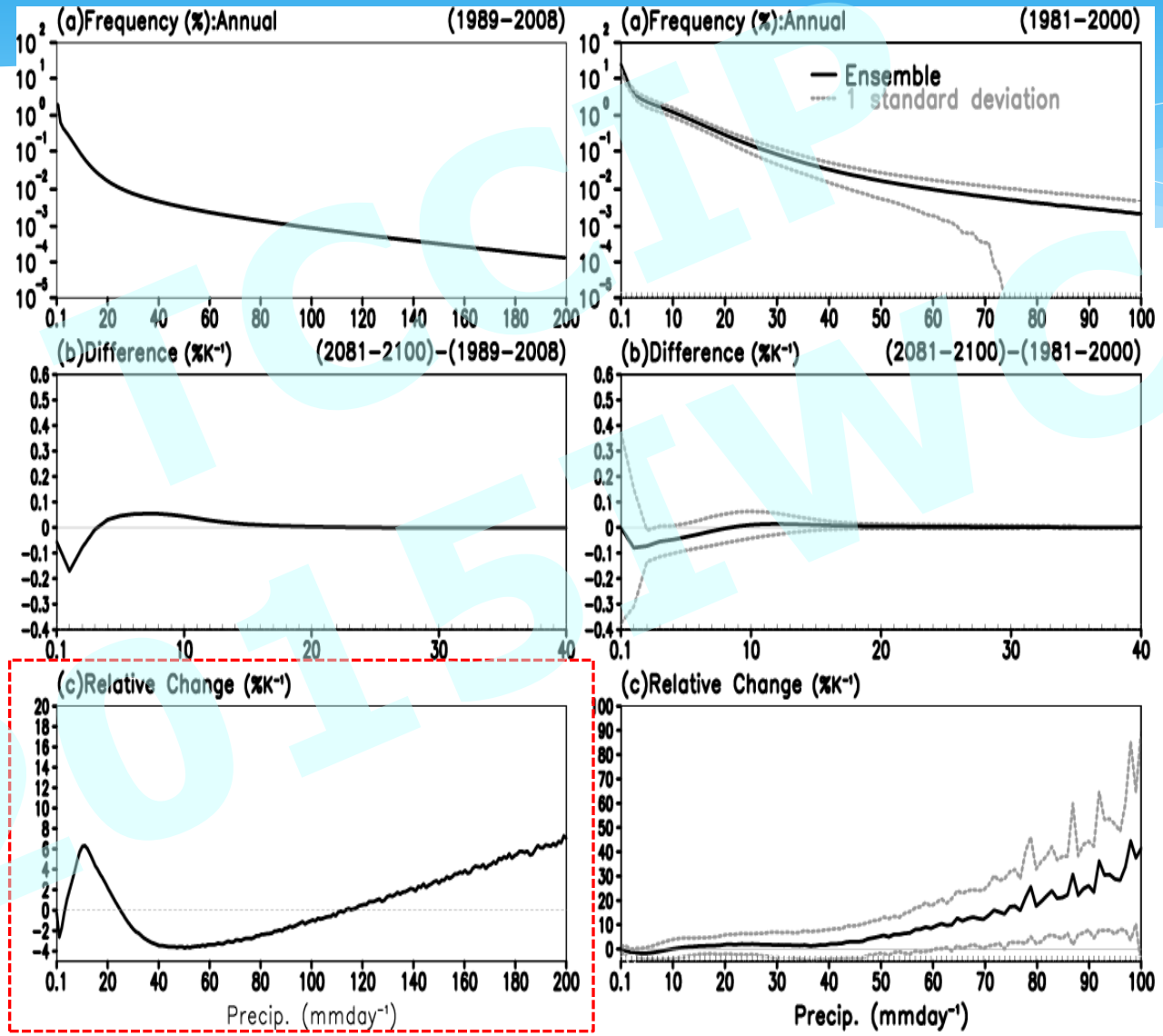
HiRAM C384 | **CMIP5**



ICCTP 2015TWCC

Global Precipitation - Changes in rainfall frequency

HiRAM C384 | **CMIP5**



ICCIP 2015 IWCC

Summary

- ***For variable resolution HiRAM, scale aware parameterization should be adopted.***

- **Improving HiRAM resolution simulates less typhoons/hurricanes, but intensity is stronger.**

- **In future projection, HiRAM C384 produces less typhoons/hurricanes, but stronger intensity.**

- **HiRAM C384 and C192 tend to overestimate extreme precipitation in Asian Monsoon regions in current and future climate.**

- **HiRAM C384 for current climate tends to overestimate extreme precipitation comparing to TRMM observation. In future projection, HiRAM C384 produces more stronger extreme precipitation than CMIP5 models.**

TCCTP 2015IWCC