High-resolution climate projections for SE Asia: Downscaling of 6 GCMs and two RCPs

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Australian AID

CSIRO

Outline

- Introduction to the downscaling approach
- GCM selection
- SST bias correction
- Climate Projections for Vietnam
- Sample Projections for Taiwan at 25 km and 50 km

CCAM dynamics and physics

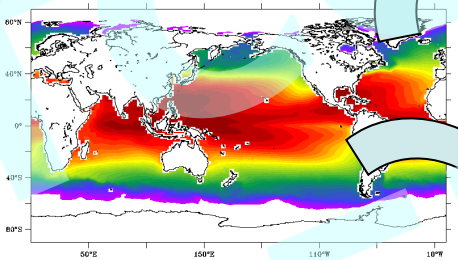
- Atmospheric GCM with variable resolution
  - Schmidt transformation
- 2 time-level semi-Lagrangian, semi-implicit
- Total-variation-diminishing vertical advection
- Non-hydrostatic
- Reversible staggering
  - produces good dispersion properties
- *a posteriori* conservation of mass and moisture

- Cumulus convection: McGregor
- Explicit modelling of water vapour, liquid and ice: Rotstayn
- Parameterization of turbulent boundary layer
- 6 layers for soil temperatures and moisture
- CABLE surface representation: 5 land-use types per grid box
- Latest GFDL radiation
  - ➢ Prognostic aerosols

Downscaling with CCAM

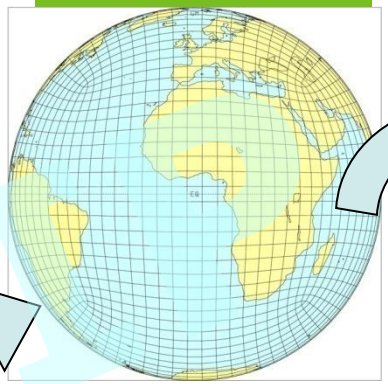
GCM (~200 km)

Bias correction



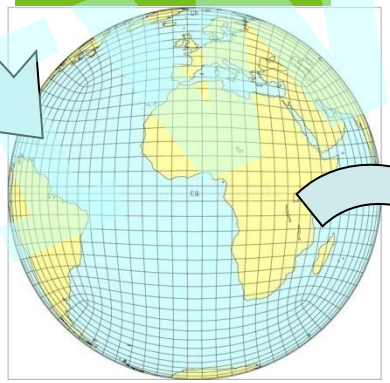
GCM SST/SIC

CCAM (~100 km)

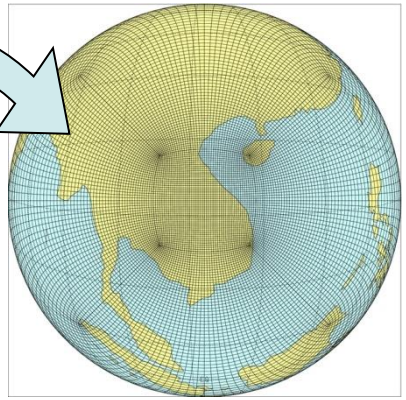


RegCM4 (~20km)

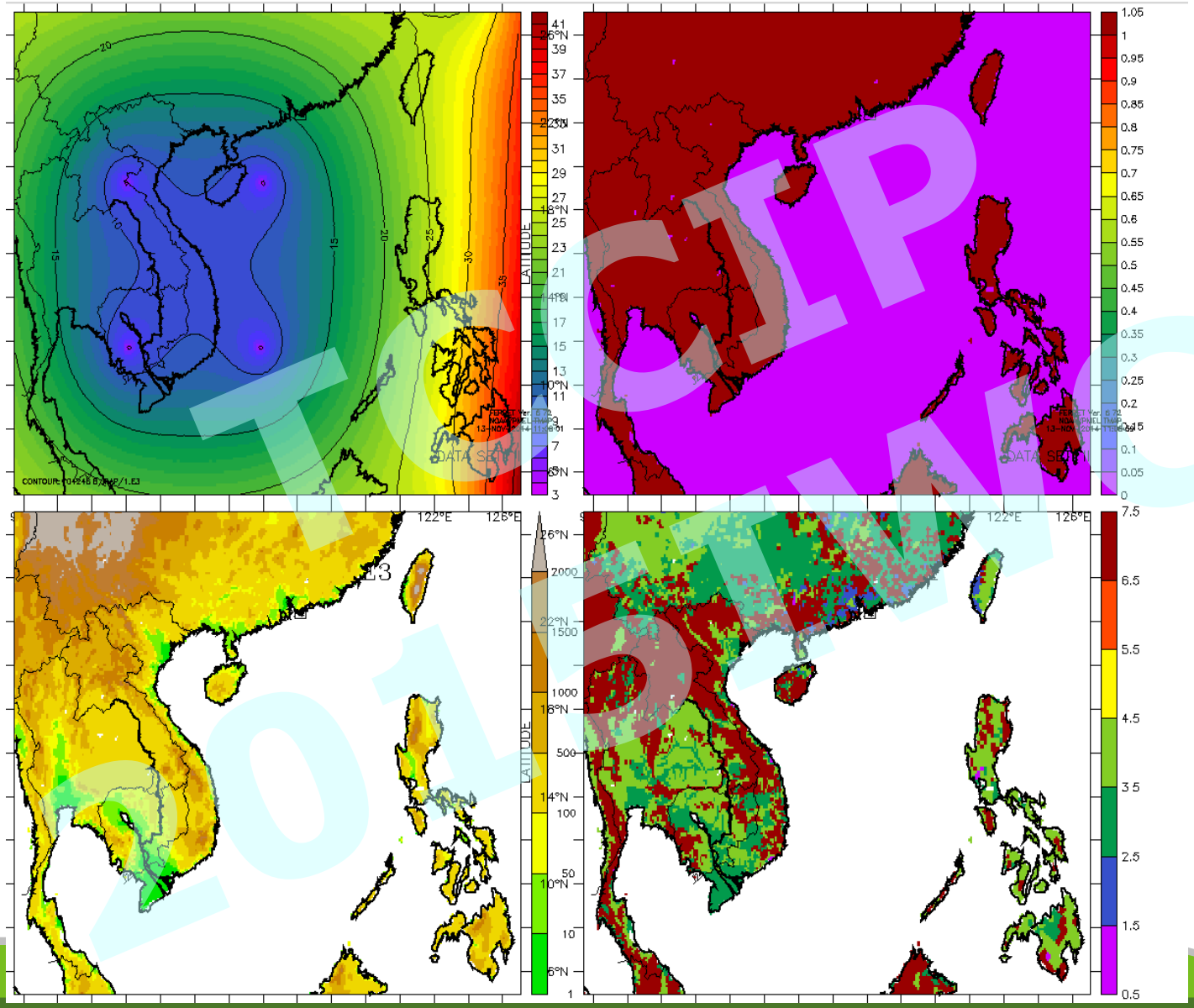
CCAM (~50 km)



CCAM (~10 km)



The Grid, Mask, Topography and Soil types



GCM Selection

GCM Selection

Requirements

- Good performance in present climate
  - Simulation of rainfall, air temperature etc.
  - Reproduce observed trends
- Good SSTs
  - ENSO pattern/frequency
  - SST distribution
- Good spread of climate change signals

- 24 CMIP5 models
- > 20 evaluation studies
- 6 publications with rankings + evaluation used within the project
- Peer-reviewed or submitted

GCM Selection

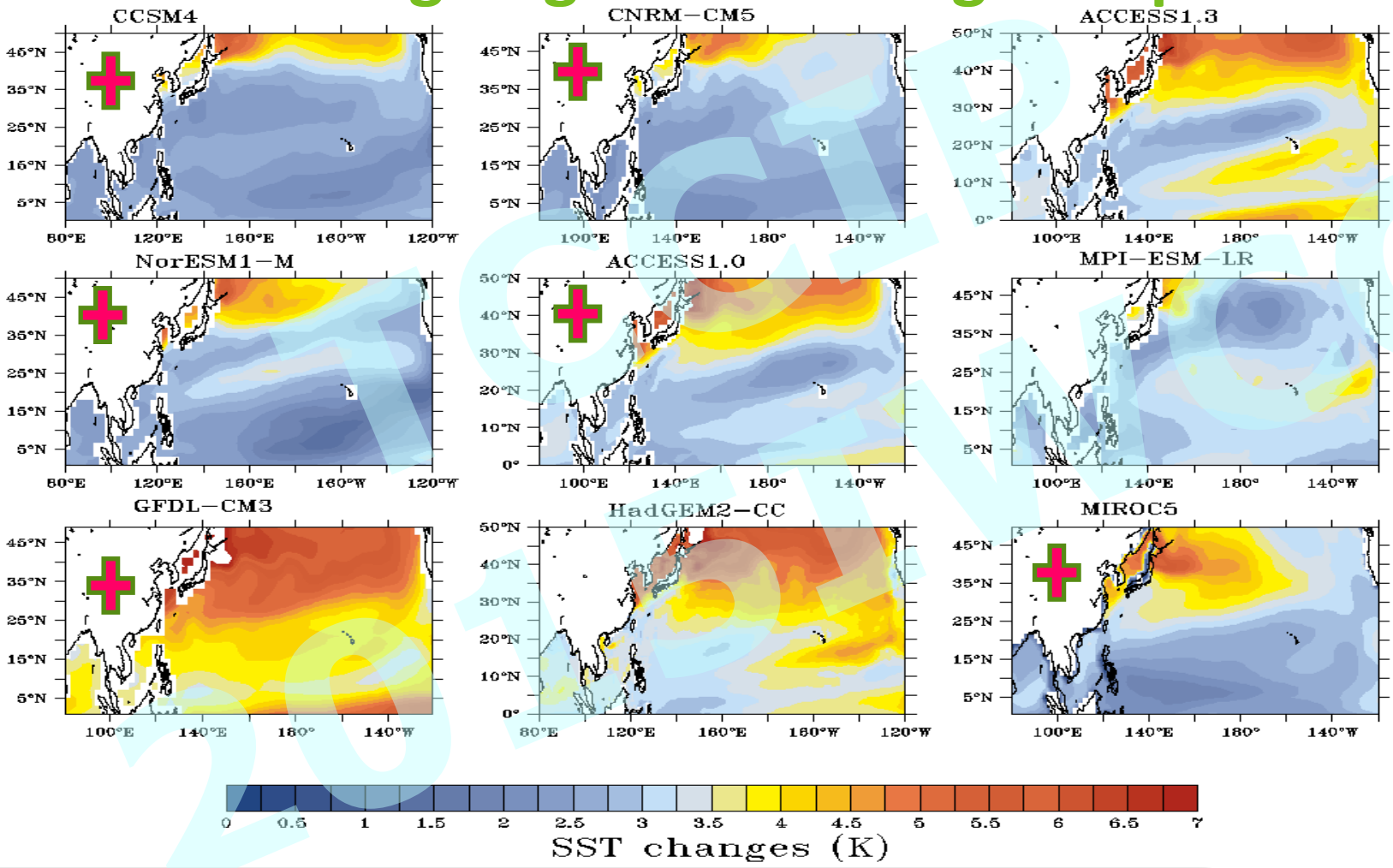
Final ranking

The rankings of the 6 individual studies are averaged to yield a final ranking of the models.

Rank	GCM	Average Score
1	**CNRM-CM5**	**0.31**
2	**CCSM4**	**0.34**
3	ACCESS1.3	0.35
4	**NorESM1-M**	**0.35**
5	**ACCESS1.0**	**0.39**
6	**MPI-ESM-LR**	**0.41**
7	**GFDL-CM3**	**0.42**
8	HadGEM2-CC	0.44
9	MIROC4h	0.46
10	MIROC5	0.47
11	GFDL-ESM2M	0.48
12	MRI-CGCM3	0.51
13	HadCM3	0.53
14	IPSL-CM5A-MR	0.53
15	HadGEM2-ES	0.54
16	FGOALS-g2	0.57
17	CSIRO-Mk3.6.0	0.57
18	inmcm4	0.61
19	CanESM2	0.61
20	MIROC-ESM-CHEM	0.69
21	GISS-ES-H	0.70
22	IPSL-CM5A-LR	0.71
23	FGOALS-s2	0.80
24	MIROC-ESM	0.84

GCM Selection

climate change signal JJA - good spread

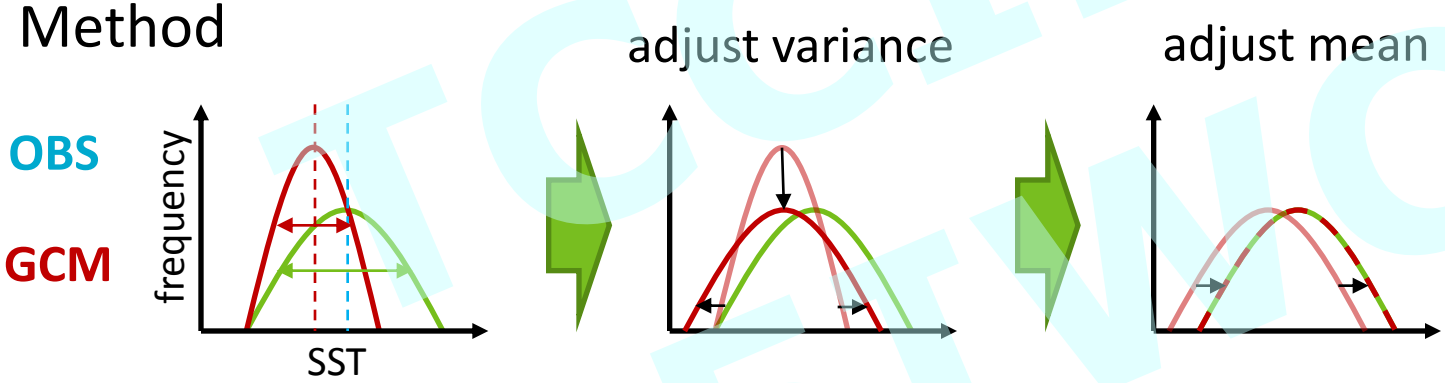


SST correction

Method

SST correction

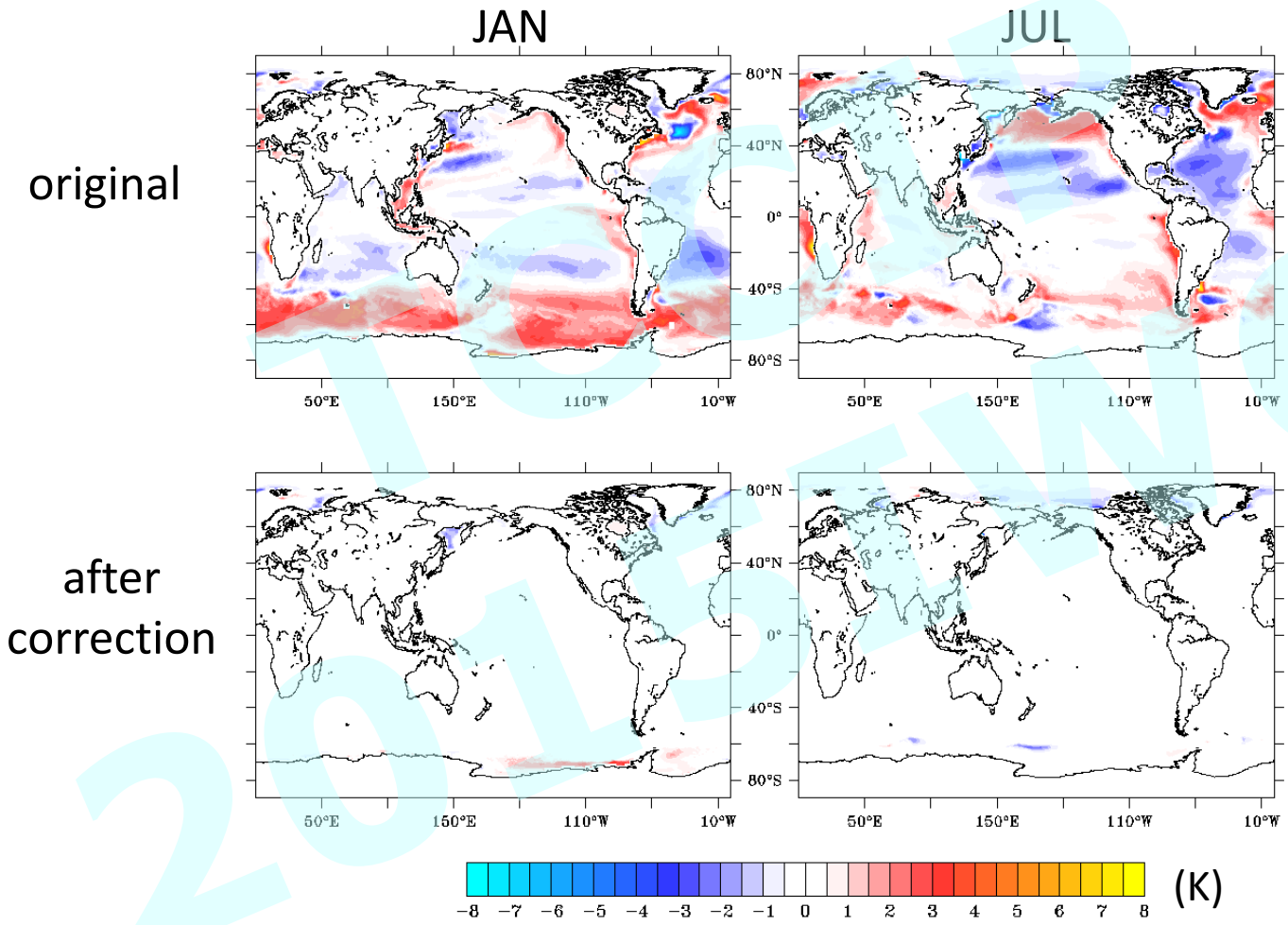
- Observations
  - daily optimum interpolation SST & SIC (Reynolds et al., 2007)
  - 1/4° resolution for 1982-2011
- Method



- Modifications
  - variance correction decreases linearly with latitude
  - no variance correction North (South) of 50° N (° S)
  - reduction of bias correction with sea ice concentration

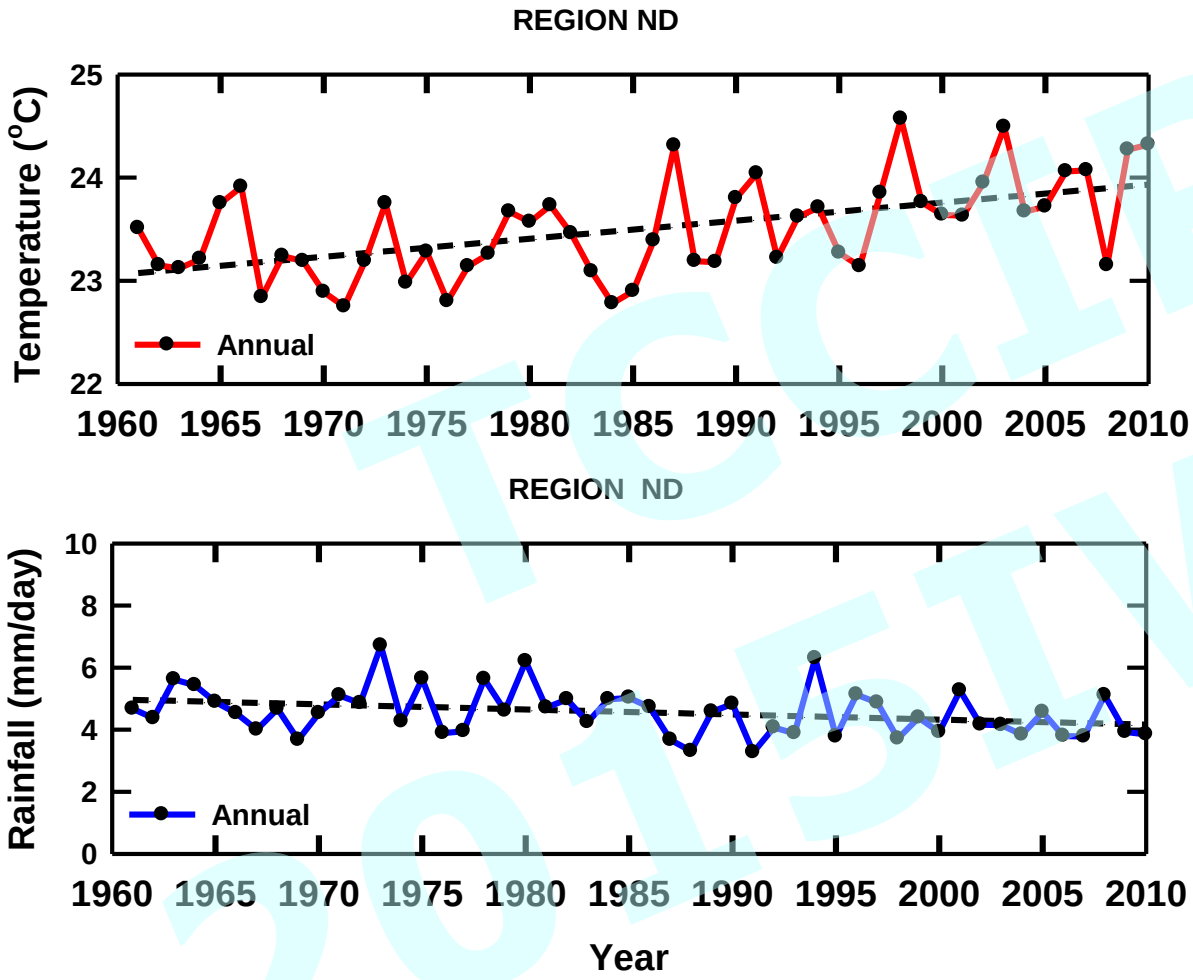
SST bias correction

Results: SST BIAS ACCESS1.0



HCPV - Summary

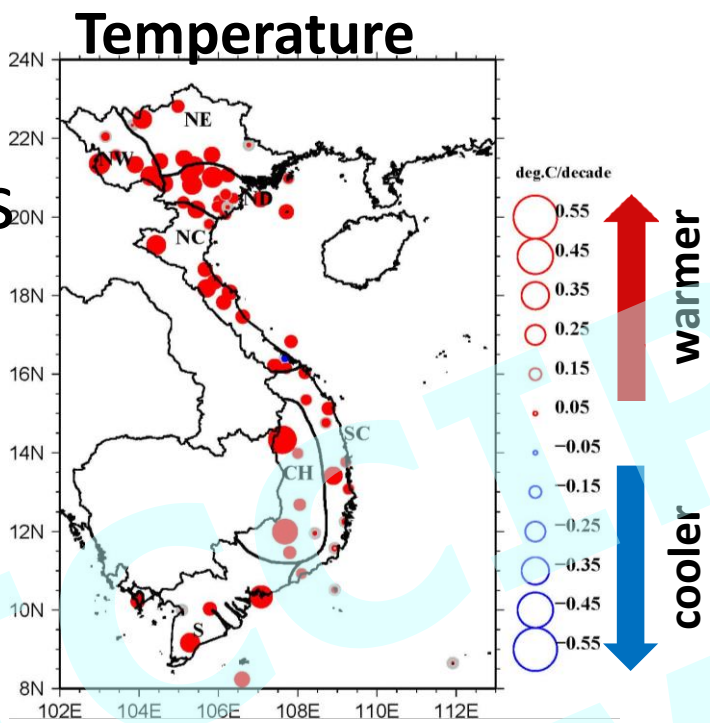
Observed North Delta Region Changes

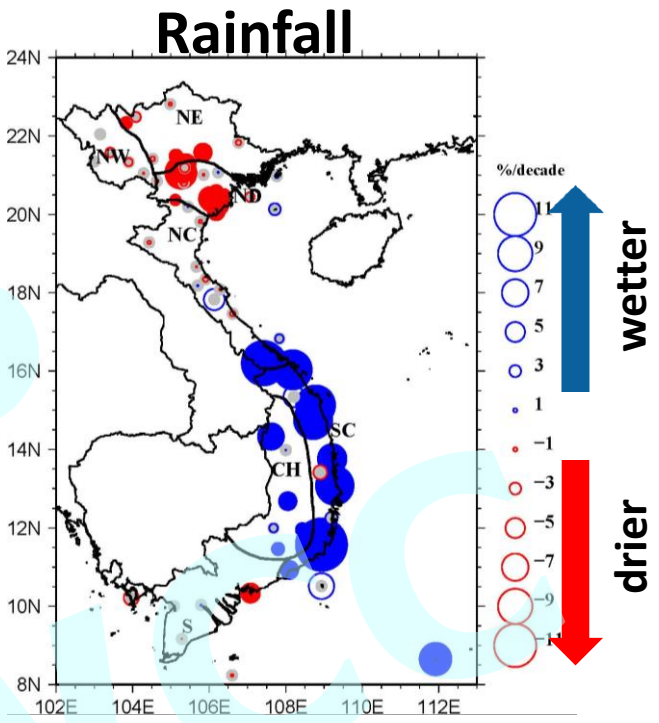


Time series of regionally-averaged annual surface air temperature (°C, red) for the ND region with a trend line (dashed black line). Annual values are shown by black dots.

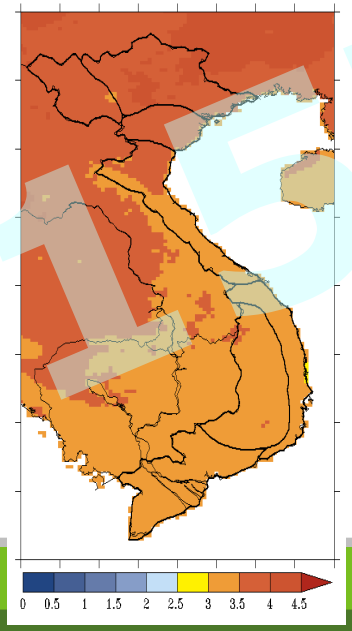
Time series of regionally-averaged annual rainfall (mm day^{-1}, blue) for the ND with a trend line (dashed black line). Annual values are shown by black dots.

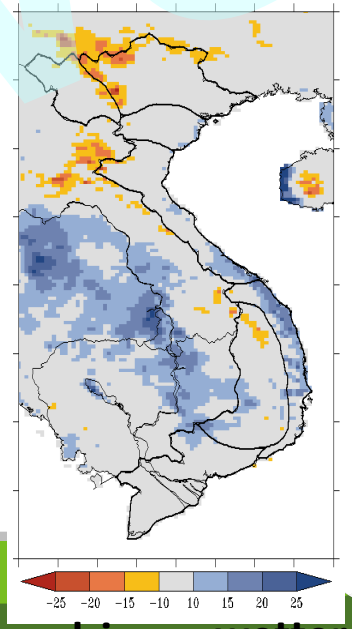
Observed **annual** trends (1960-2010) from stations



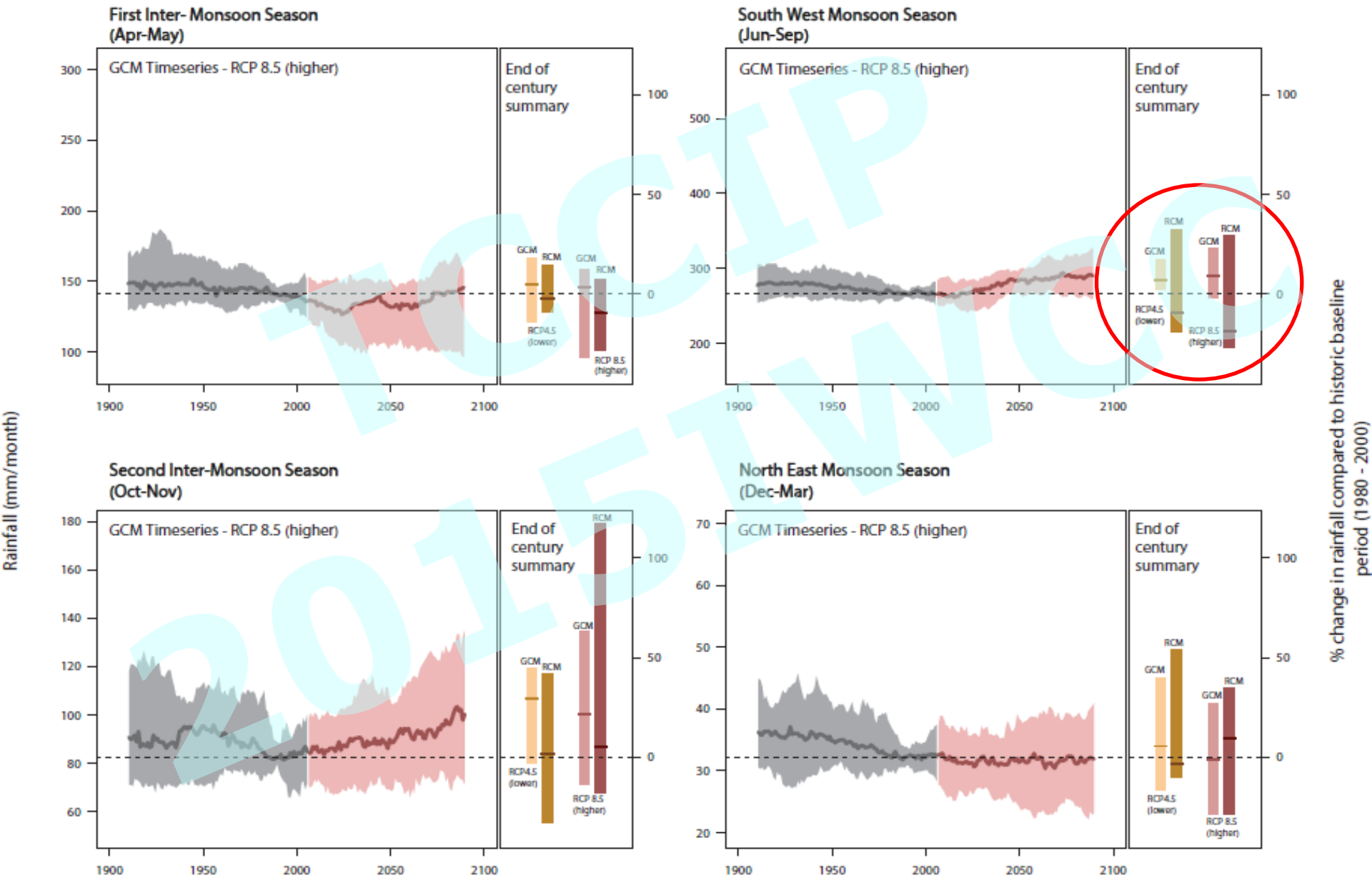


Projected **annual** changes by end-of-century for RCP 8.5 from RCMs





RAINFALL CHANGES FOR NORTH DELTA REGION



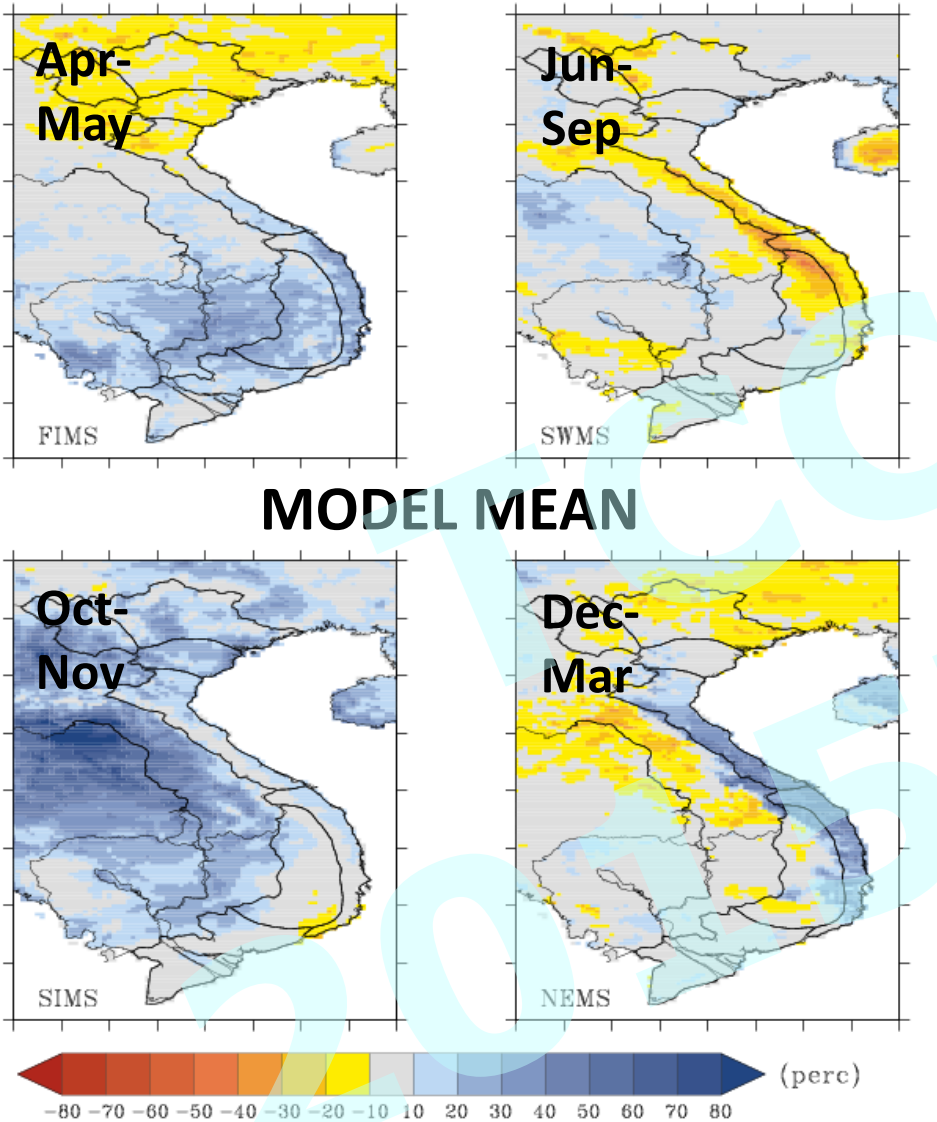
Projected Rainfall Changes - ND

Rain % change	Mid-Century (2045-2065)					End of the Century (2080-2100)				
	Annual	NEMS Dec-Mar	FIMS Apr-May	SWMS June-Sep	SIMS Oct-Nov	Annual	NEMS Dec-Mar	FIMS Apr-May	SWMS June-Sep	SIMS Oct-Nov
Multi-model mean	-1	1	1	-1	2	-6	1	-12	-9	34
Range	-13 to +27	-21 to +28	-13 to +12	-20 to +42	-19 to +85	-24 to +25	-30 to +53	-30 to +2	-29 to +35	-39 to +230

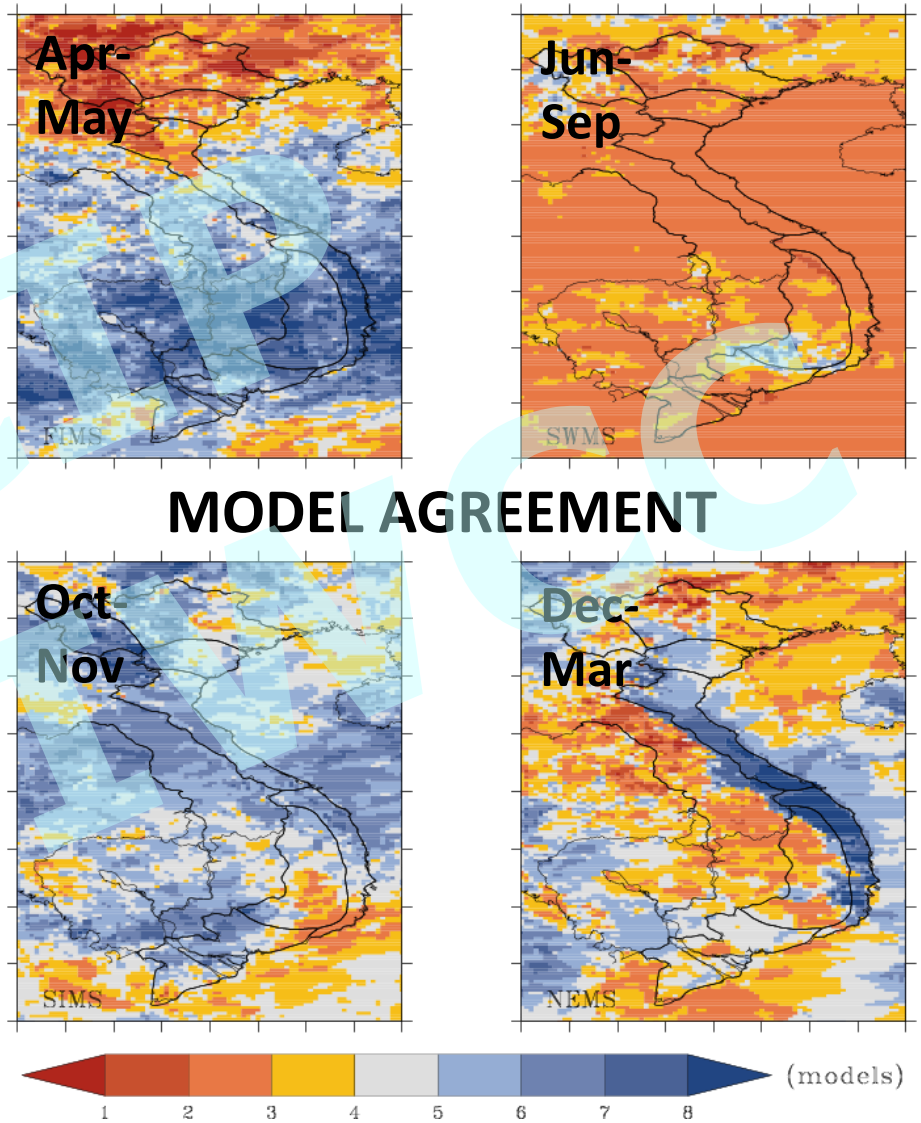
Rain (%)	Mid-Century (2045-2065)					End of the Century (2080-2100)				
	Annual	NEMS Dec-Mar	FIMS Apr-May	SWMS June-Sep	SIMS Oct-Nov	Annual	NEMS Dec-Mar	FIMS Apr-May	SWMS June-Sep	SIMS Oct-Nov
	MONRE 2012					MONRE 2012				
B1	3	0	-2	5	1	4	0	-2	7	1
B2	4	0	-2	6	1	6	0	-3	9	1
A2	4	0	-2	6	1	7	0	-3	11	2

TOP: Projected changes in annual and seasonal mean rainfall and its ranges (%) for the ND region relative to the baseline period (1980-2000) for RCP 8.5. Changes are the multi-model means from eight simulations.
BOTTOM: Projected changes in annual and seasonal rainfall (%) for the ND region relative to the baseline period (1980-2000) for SRES emission scenarios (B1, B2, A2, A1B) from a previous study (MONRE, 2012) and the latest PRECIS projections (ensemble means).
Orange colouring is for decreases less than -10%, green for changes between -10% to +10% and blue for increases greater than +10%. Source: IMHEN.

RAINFALL CHANGE (end of century)



MODEL MEAN



MODEL AGREEMENT

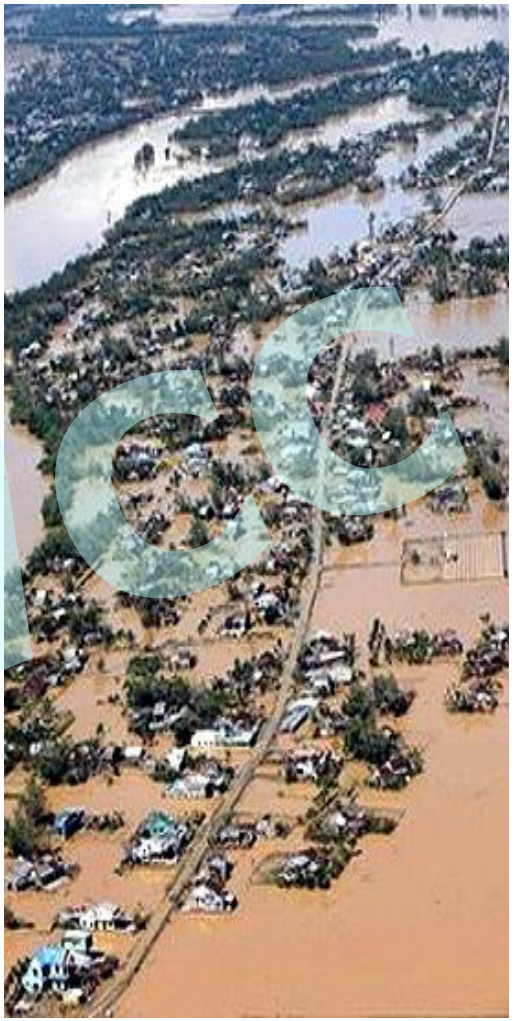
All agree decrease

All agree increase

EXTREME RAINFALL

Source: BBC News
Second flood swamps Vietnam, 6 Dec 1999

Source: Ketsana flood

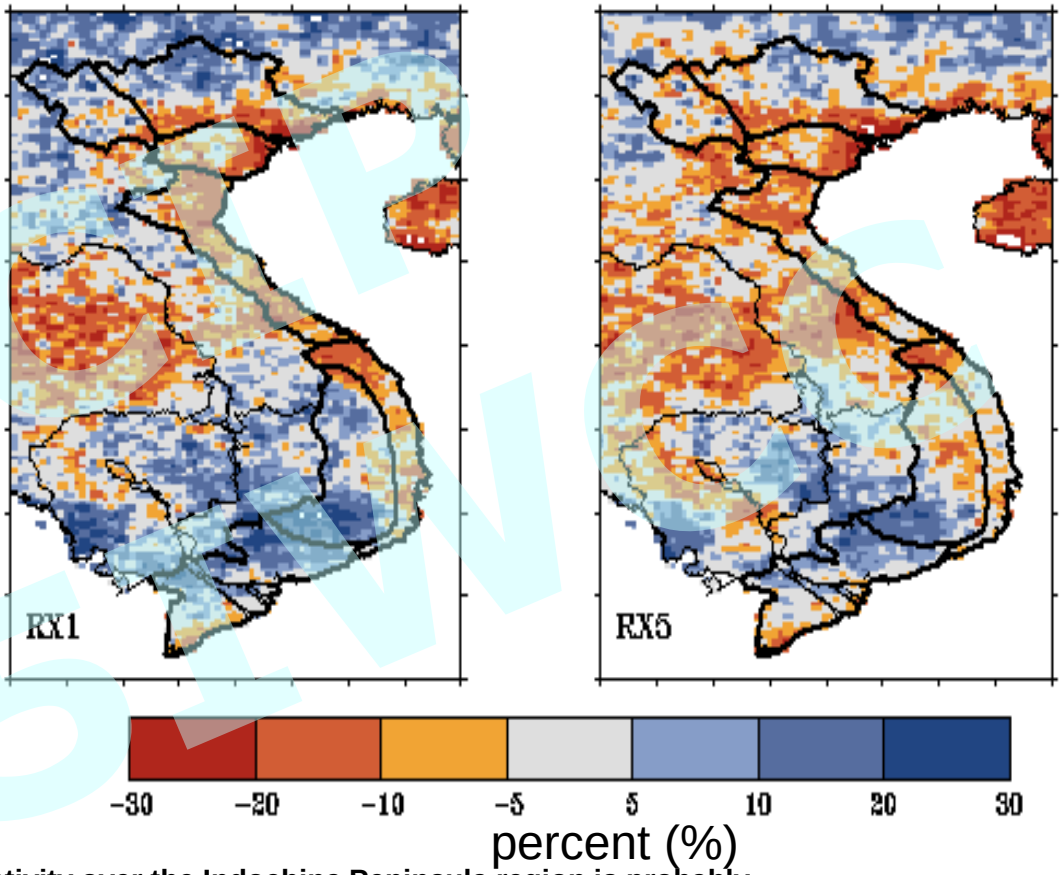


PROJECTED CHANGES IN EXTREME RAINFALL

Extreme rainfall amounts decrease except in Central Highlands and North East regions.

Tropical cyclones contributes up to 18% to heavy rainfall along the east coast (Nguyen et al. 2013)

Decrease in extreme rainfall along the east coast maybe due to decrease in TCs activity (Takahashi, 2009).



Takahashi et al. (2009) "**Weakening tropical-cyclone activity over the Indochina Peninsula region is probably responsible for the decrease in September rainfall over Indochina Peninsula".**

Nguyen et al. (2013) **"The relation among heavy rains and geomorphic patterns at the central coastal region of Vietnam from Thanh Hoa to Khanh Hoa provinces" MAHASRI/HyARC**

DROUGHTS

Hanoi 2009

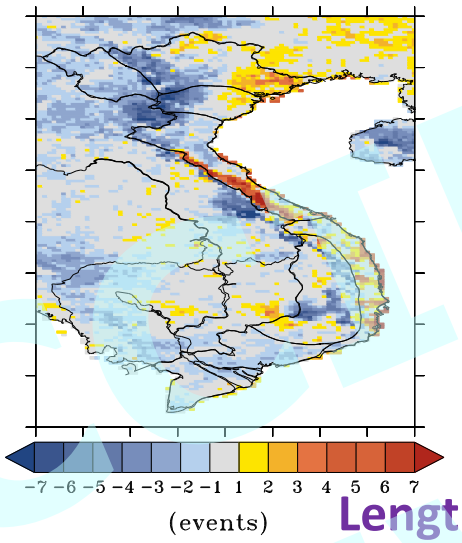
Central Highlands & South Vietnam 2013

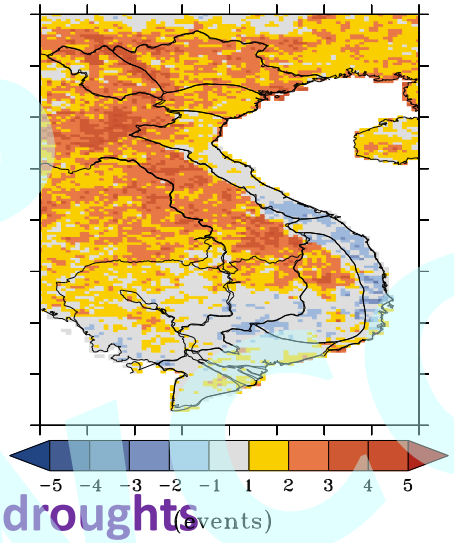
CHANGES IN DROUGHTS

Short-term drought
(severe rainfall deficit ≥3 months)

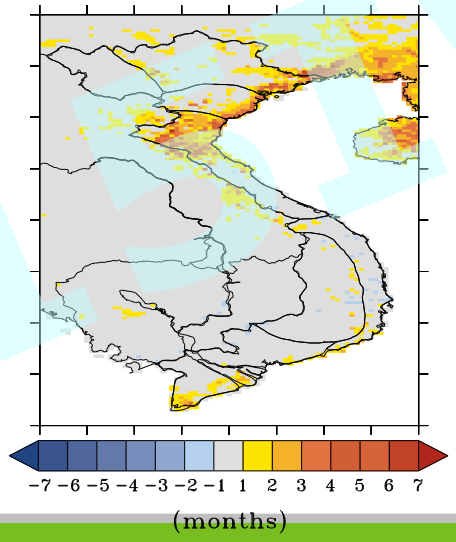
Long-term drought
(severe rainfall deficit ≥12 months)

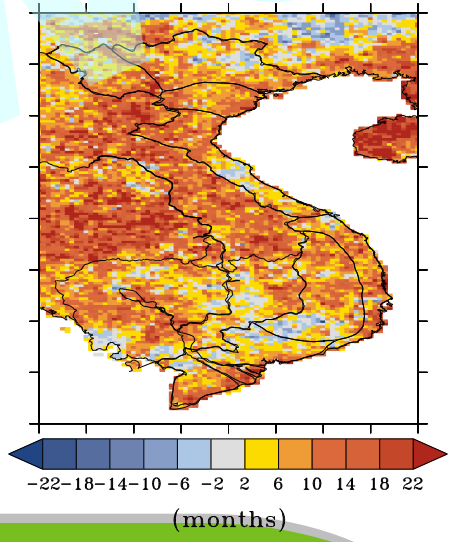
Number of droughts





Length of droughts





Nguyen Trong Hieu et al. "Effect of ENSO to drought in Vietnam, 1960-2010", IMHEN Tech Rep No. 16, page 10-16, 2013, (evaporation/precipitation)

Nguyen van Thang et al. "Study on the drought characteristic of southern region, 1979-2010", IMHEN Tech Rep No. 16, page 55-61, 2013, (evaporation/precipitation)

Vu-Thanh et al. "An analysis of meteorological drought features in Vietnam during the 1961-2007 period", The third international MAHASRI/HyARC Workshop on Asian Monsoon and Water cycle, 2013, Da Nang, page 117-124.
(J , Ped, SPI used Temperature and Precipitation)

TROPICAL CYCLONES - TYPHOONS

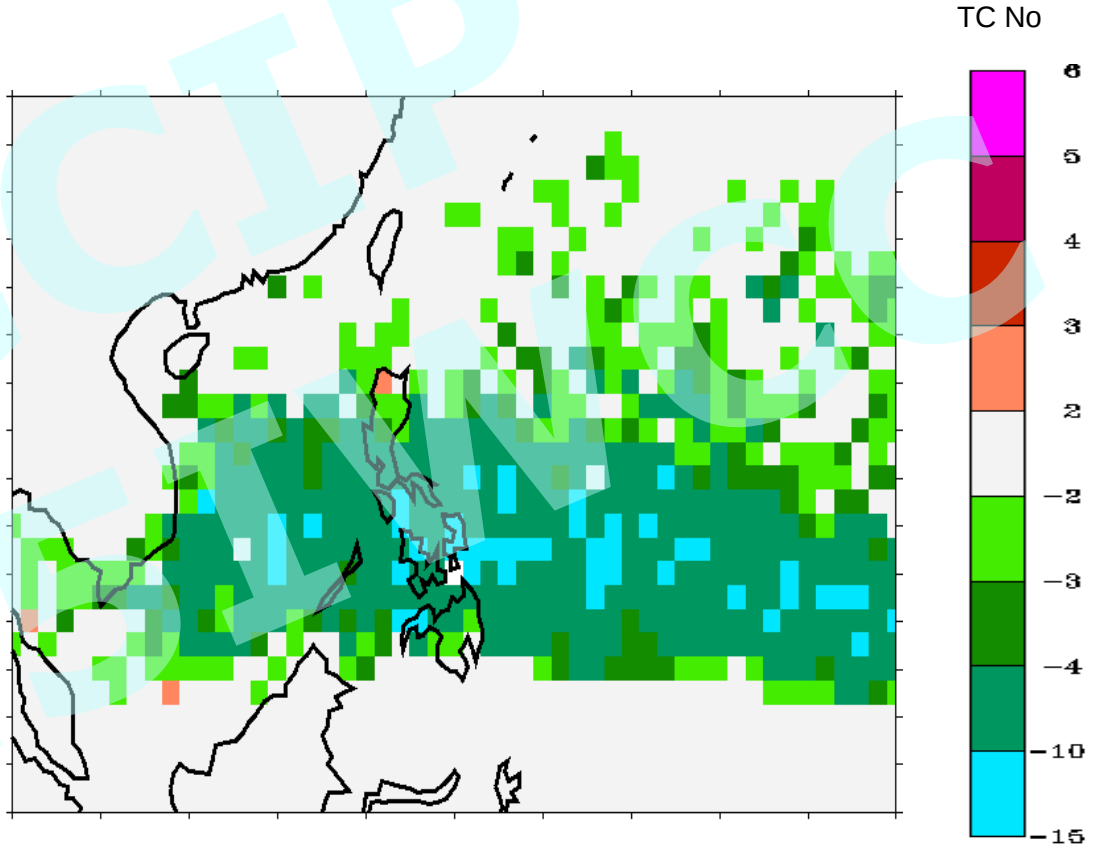
Depression in East Sea to develop into storm

Change of TC formation frequency end-of-century

UNCERTAINTY:

1. Different detection methods produce large variation in results

2. Our results consistent with other methods



CONCLUSIONS by end-of-century

Monsoon rainfall intensity and **length** to **decrease**

Tropical Cyclone frequency **decrease,** but intensity changes needs further investigation

Extreme rainfall:

Decrease along **east coast**

Increase in **Central Highlands**

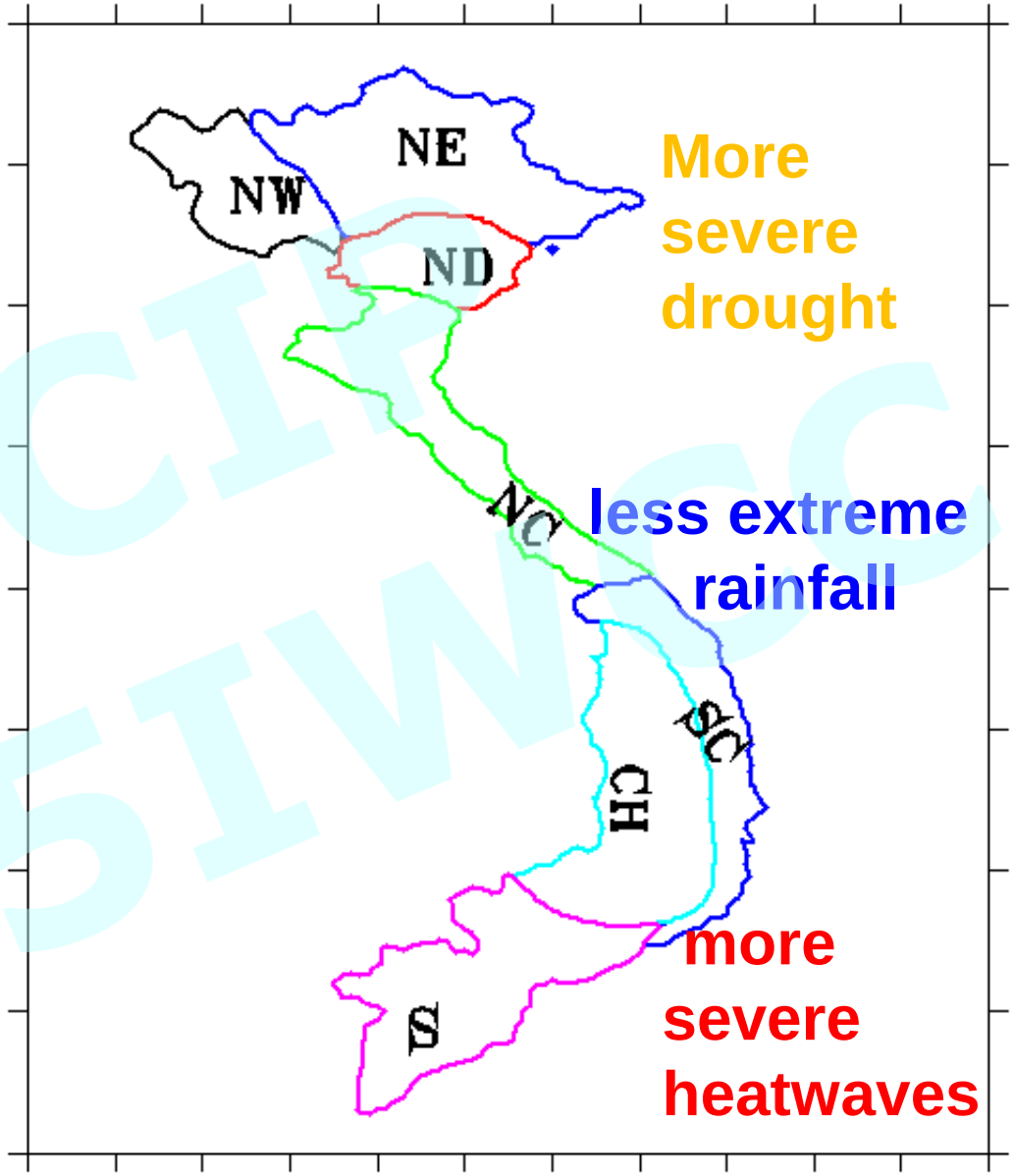
Short term droughts become **more** frequent

Long-term droughts become **more** severe

Heat waves

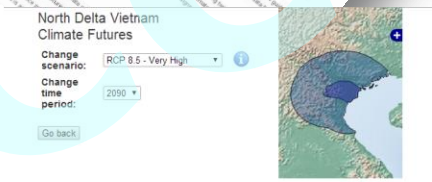
More frequent and **longer**

More severe in the **south**



CLIMATE FUTURES TOOL: *A risk-based approach*

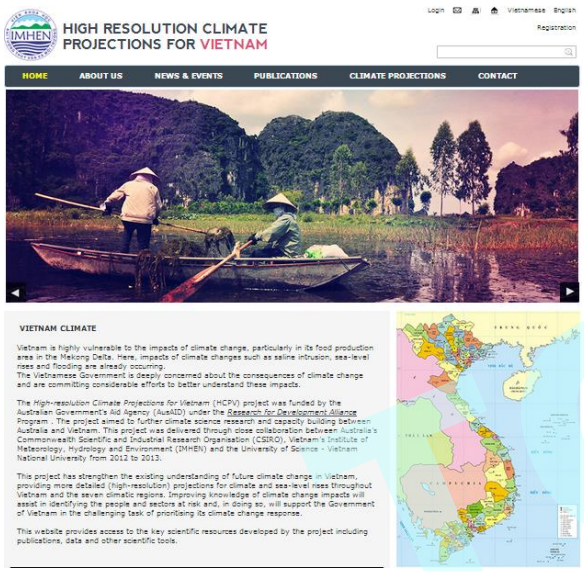
- Web-based tool (vnclimate.vn)
- Simplified data access
- User-relevant and scientifically coherent
- Groups projections into small range of 'plausible' cases (water resources):
  - ➢ most representative (most evidence)
    10 out of 30 GCMs
  - ➢ best (most desirable for application)
    6 out of 30 GCMs
  - ➢ worst (least desirable for application)
    9 out of 30 GCMs



		Annual Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (mm)	Much Drier < -15.00				1 of 4 RCM models
	Drier -15.00 to -5.00			1 of 30 GCM models	2 of 4 RCM models 1 of 30 GCM models
	Little Change -5.00 to 5.00			1 of 30 GCM models	1 of 4 RCM models 9 of 30 GCM models
	Wetter 5.00 to 15.00			1 of 30 GCM models	10 of 30 GCM models
	Much Wetter > 15.00			1 of 30 GCM models	6 of 30 GCM models

Likelihood	Proportion of models
Not projected	No models
Very Low	< 10%
Low	10% - 33%
Moderate	33% - 66%
High	66% - 90%

Access: how will you obtain the information

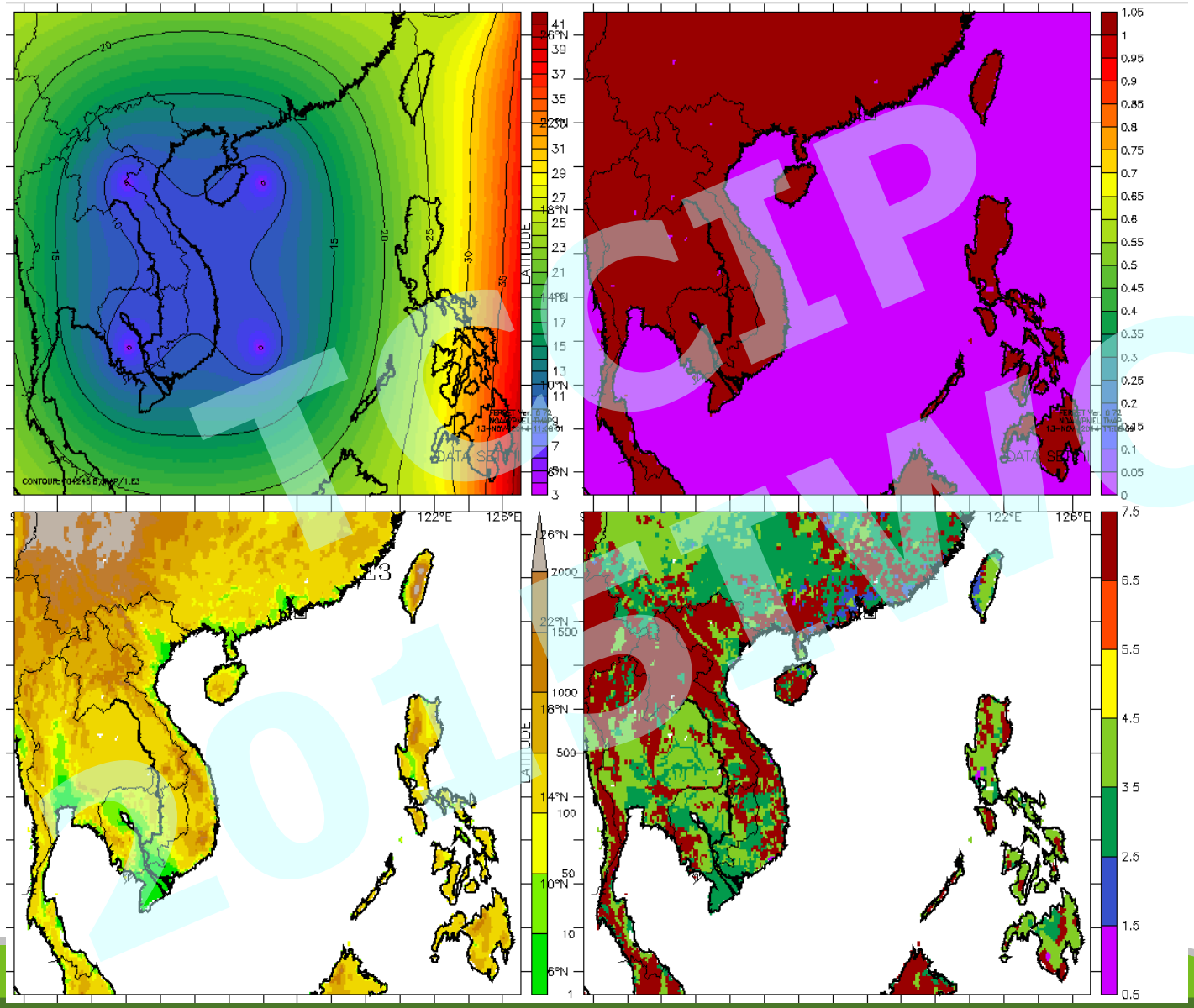


Website: Vnclimate.vn

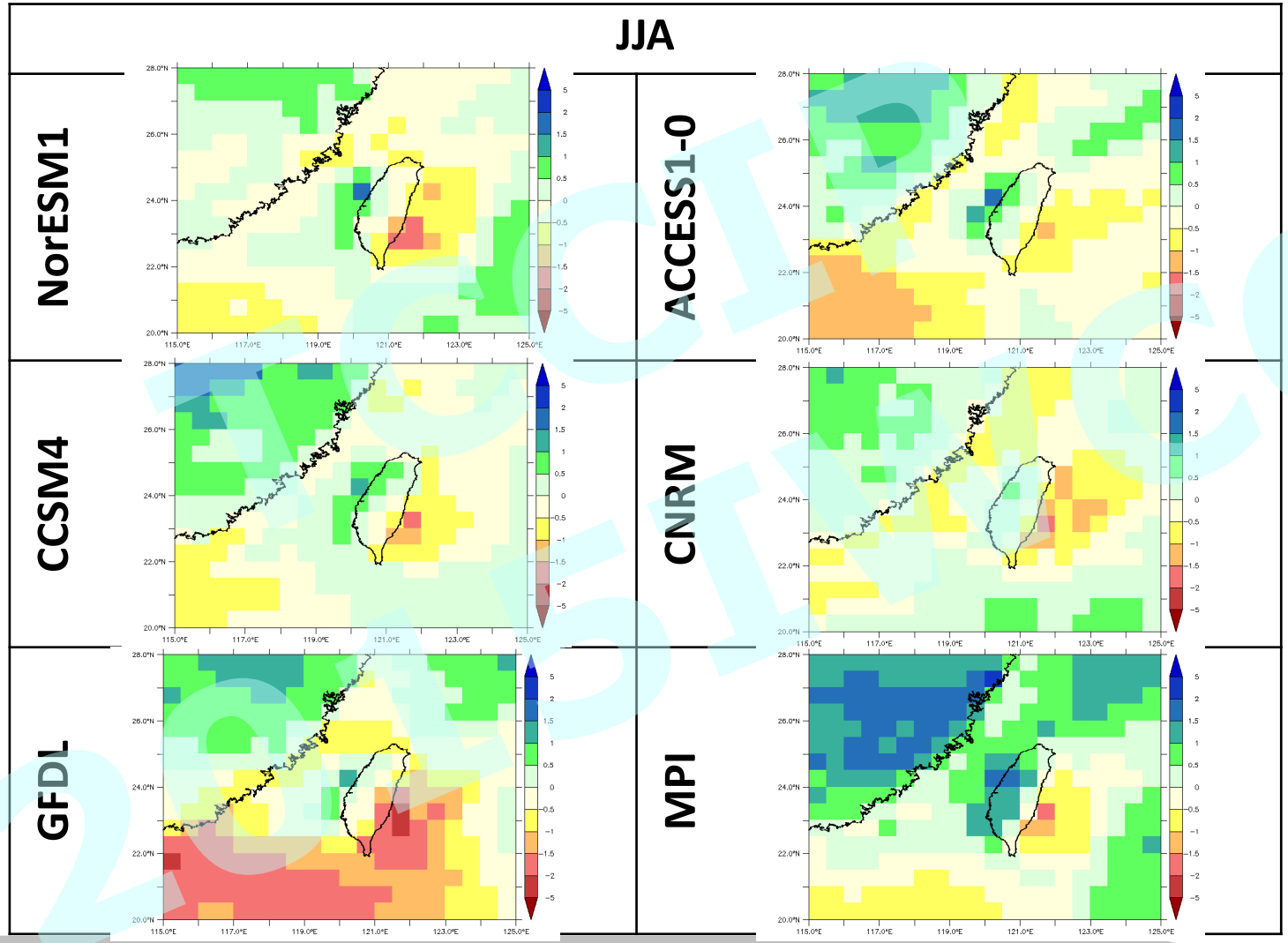
Workshop & training

Summary Report, Regional Reports, Technical Report & publications

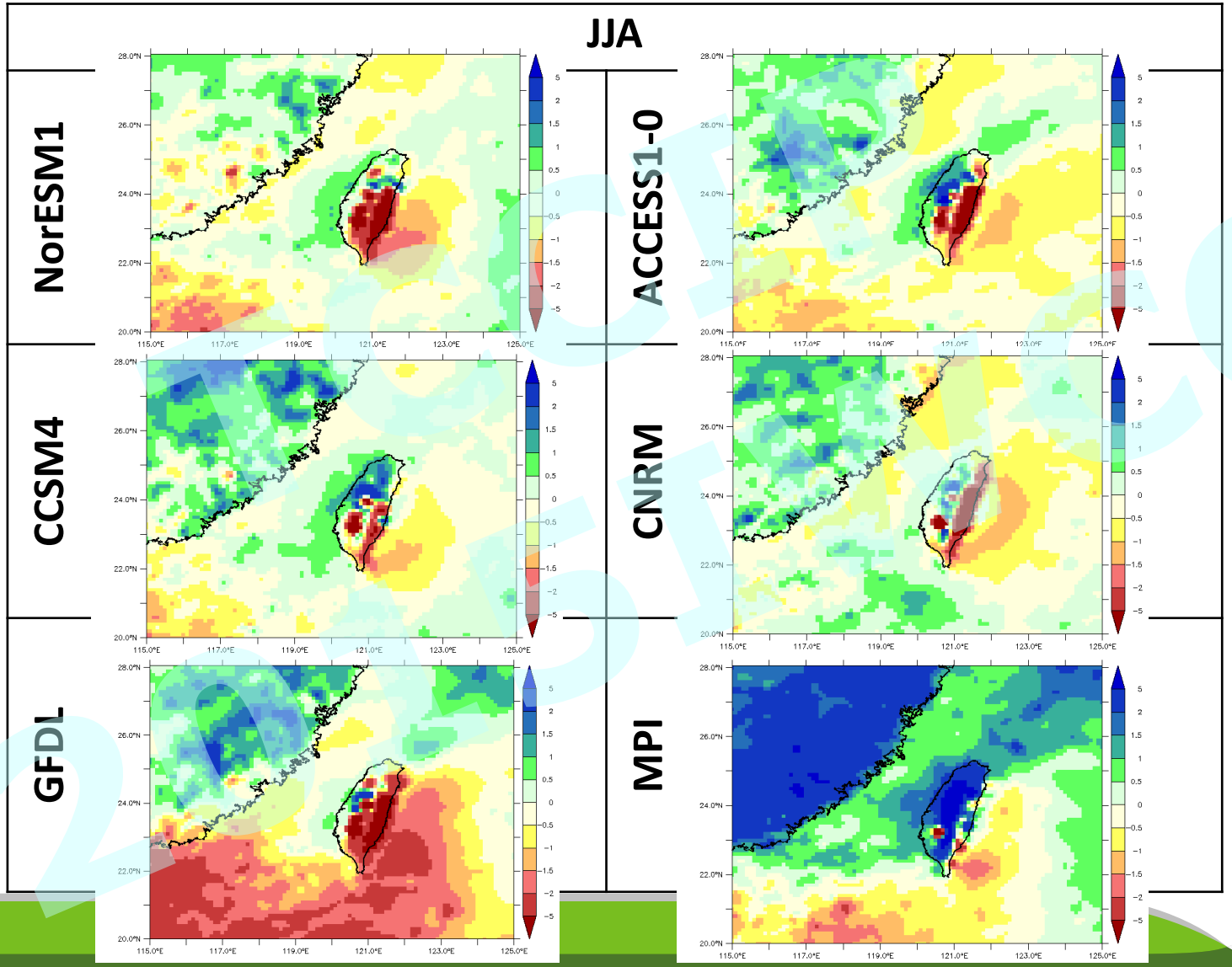
Results for Taiwan: grid



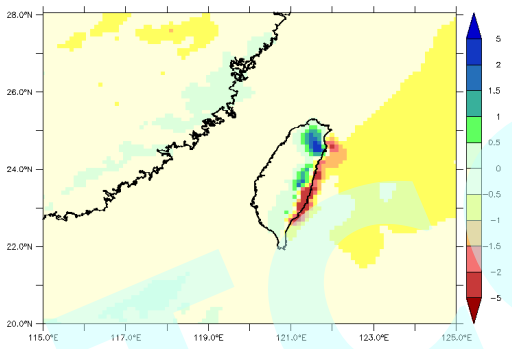
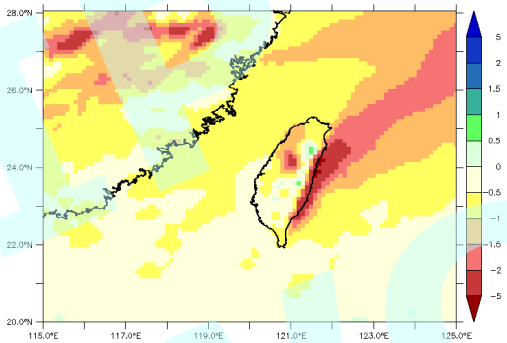
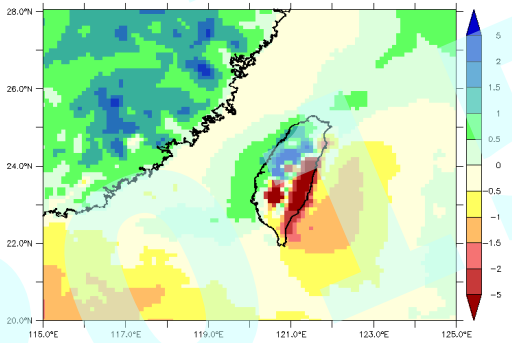
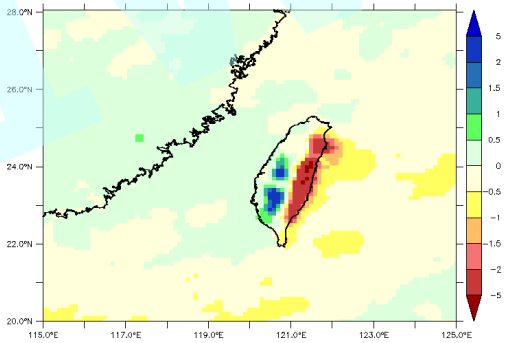
Rainfall change (mm/day) 2090-1995
~50km RCP8.5 ENSEMBLE mean

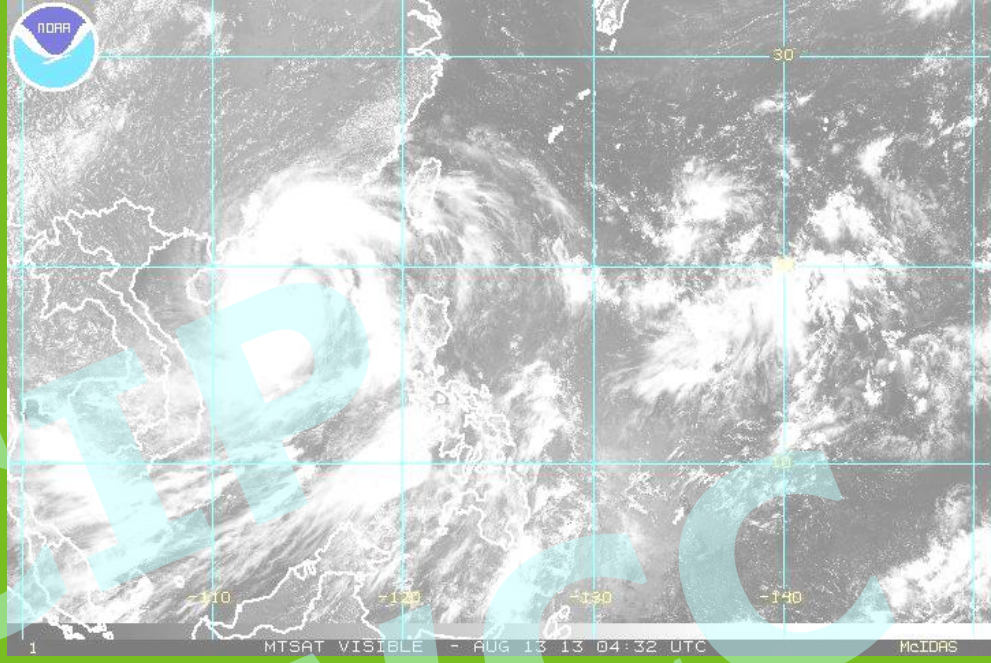


Rainfall change (mm/day) 2090-1995
~25km RCP8.5 ENSEMBLE mean



Rainfall change (mm/day) 2090-1995
~25km RCP8.5 ENSEMBLE mean

DJF	MAM
	
JJA	**SON**
	



Thank you

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