Quasi-stationary Rainfall Systems and Climate Change—future projection

準滯留性降水系統與氣候變遷—未來預測

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Introduction

- Use the 21st century CMIP5 projection runs to estimate future climate change Δ_{RCP} for the RCP8.5.

- By subtracting CMIP5 historical climate from warming scenarios RCP8.5 to estimate the supposed Δ_{RCP}. We add Δ_{RCP} on NCEP FNL data and then simulate the same quasi-stationary rainfall system in the future climate background.

- We would like to understand how much global warming contribute to the extreme rainfall associated with quasi-stationary rainfall system.

Data

A. Model initial and boundary condition

- NCEP FNL Operational Model Global Tropospheric Analyses, 0.25°x0.25°, 6 hourly

B. CMIP5 experiments (38 models)

- Historical,

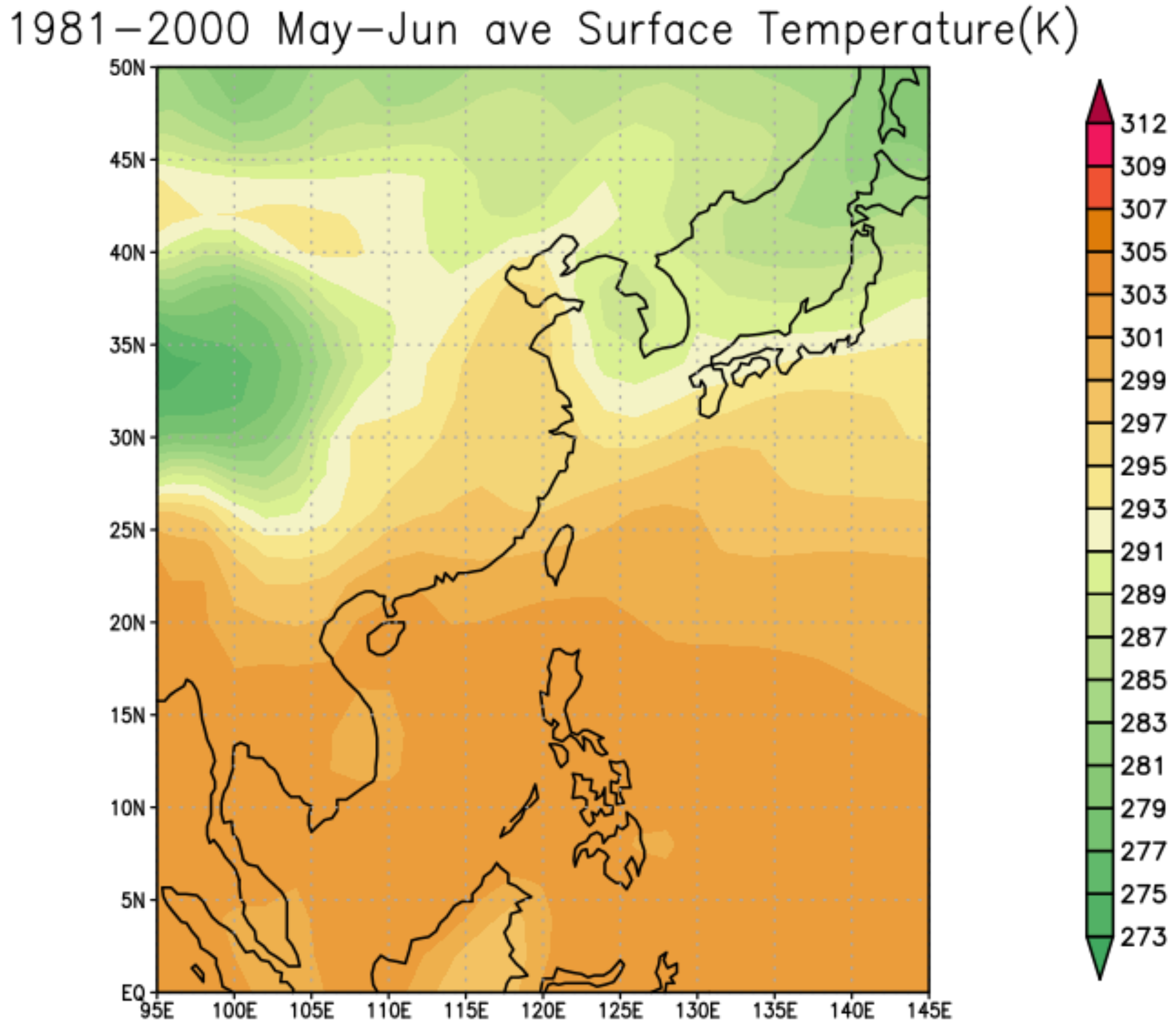
  1981~2000, monthly, May~Jun ave

- RCP8.5,

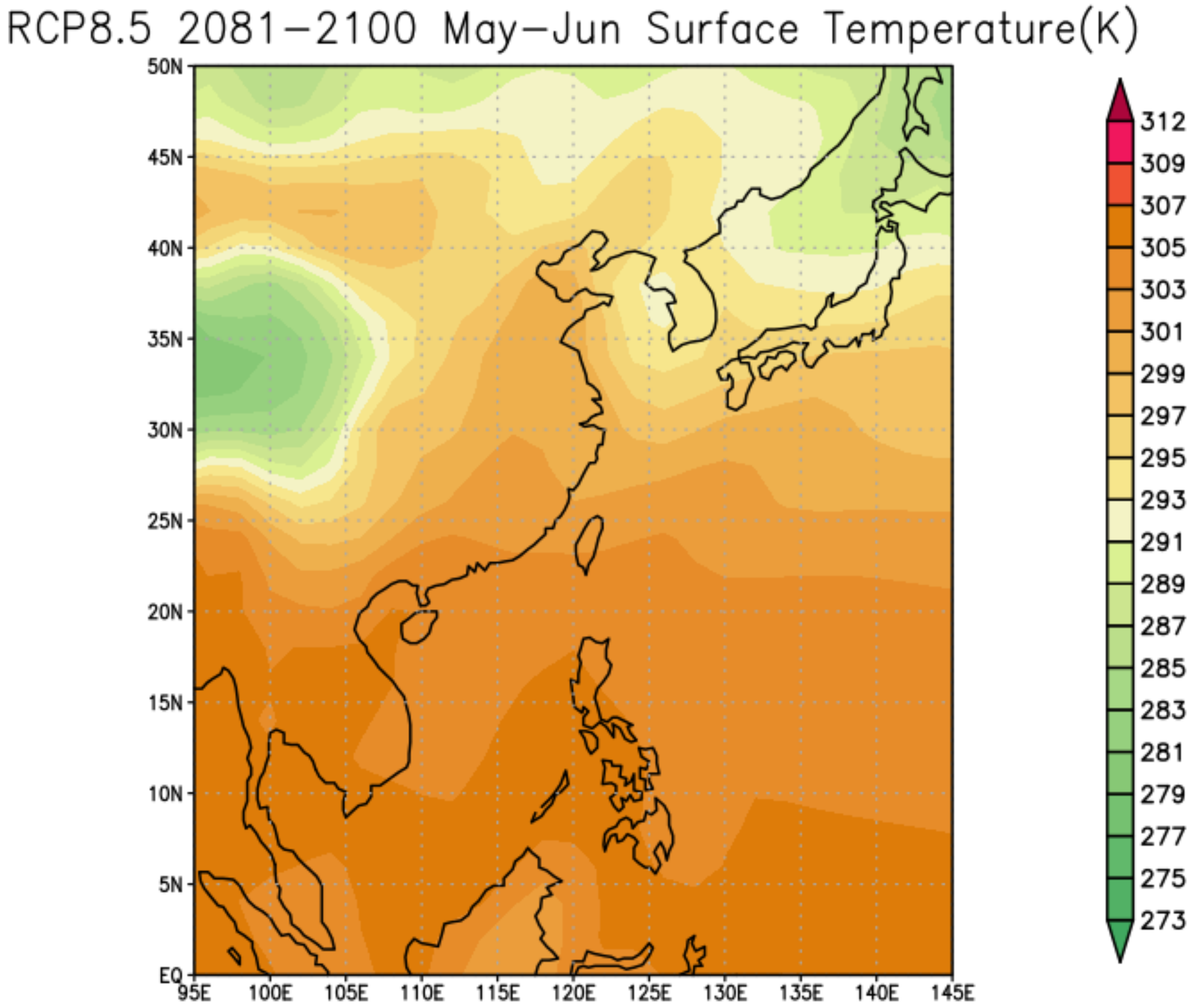
  2081~2100, monthly, May~Jun ave

Models	Institues	Countries
ACCESS1.0, ACCESS1.3	Commonwealth Scientific and Industrial Research Organization, Australia and Bureau of Meteorology	Austalia
BCC-CSM1.1, BCC-CSM1.1(m)	Beijing Climate Center, China	China
CanESM2	Canadian Centre for Climate Modelling and Analysis	Canada
CCSM4	National Center for Atmospheric Research	America
CESM1(BGC), CESM1(CAM5)	National Science Foundation, Department of Energy, National Center for Atmosphere	America
CMCC-CM, CMCC-CMS	Centro euro-Mediterraneo sui Cambiamenti Climatici	Italy
CNRM-CM5	Centre National de Recherches Météorologiques / Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique	France
CSIRO-Mk3-6-0	Commonwealth Scientific and Industrial Research Organization	Austalia
FGOALS-g2, FGOALS-s2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University	China
FIO-ESM	The First Institute of Oceanography, SOA	China
GFDL-CM3	Geophysical Fluid Dynamics Laboratory	America
GFDL-ESM2G, GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory, Princeton University Forrestal Campus	America
GISS-E2-H, GISS-E-H-CC, GISS-E2_R, GISS-E2-R-CC	NASA Goddard Institute of Oceanography, SOA	America
HadGEM2-AO	National Institute of Meteorological Research/Korea Meteorological Administration	America
HadGEM2-ES	The European Network for Earth system modelling	Germany
HadGEM2-CC	Met office Hadley Centre	UK
INM-CM4	Institute for Numerical Centre	Russia
IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR	Institute Pierre-Simon Laplace	France
MIROC5,MIROC-ESM-CHEM, MIROC-ESM	Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan
MPI-ESM-LR, MPI-ESM-MR	Max Planck Institute for Meteorology	Germany
MRI-ESM1. MRI-CGCM3	Meteorological Research Institute	Japan
NorESM1-M, NorESM1-ME	Norwegian Climate Centre	Norway

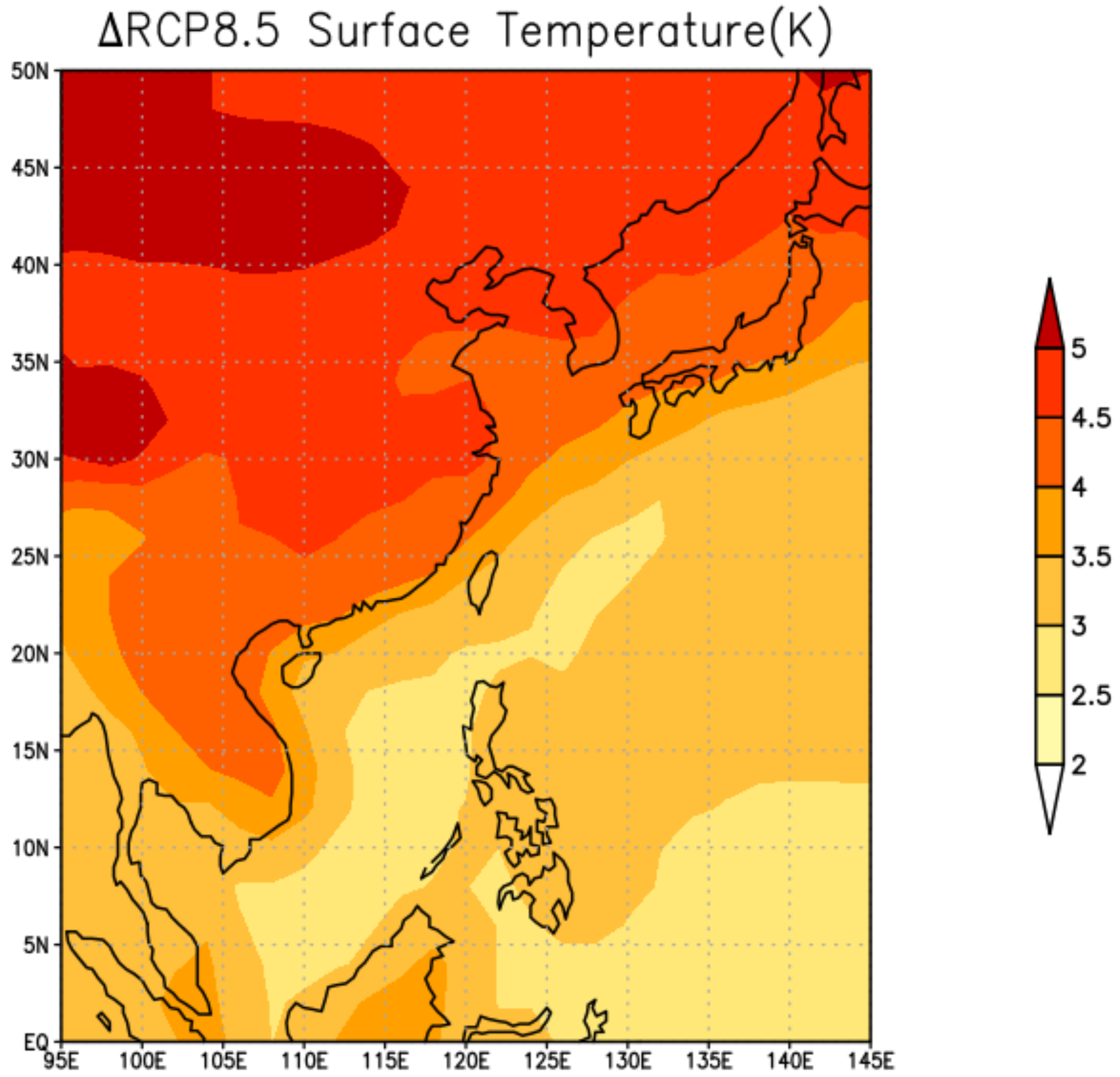
Historical

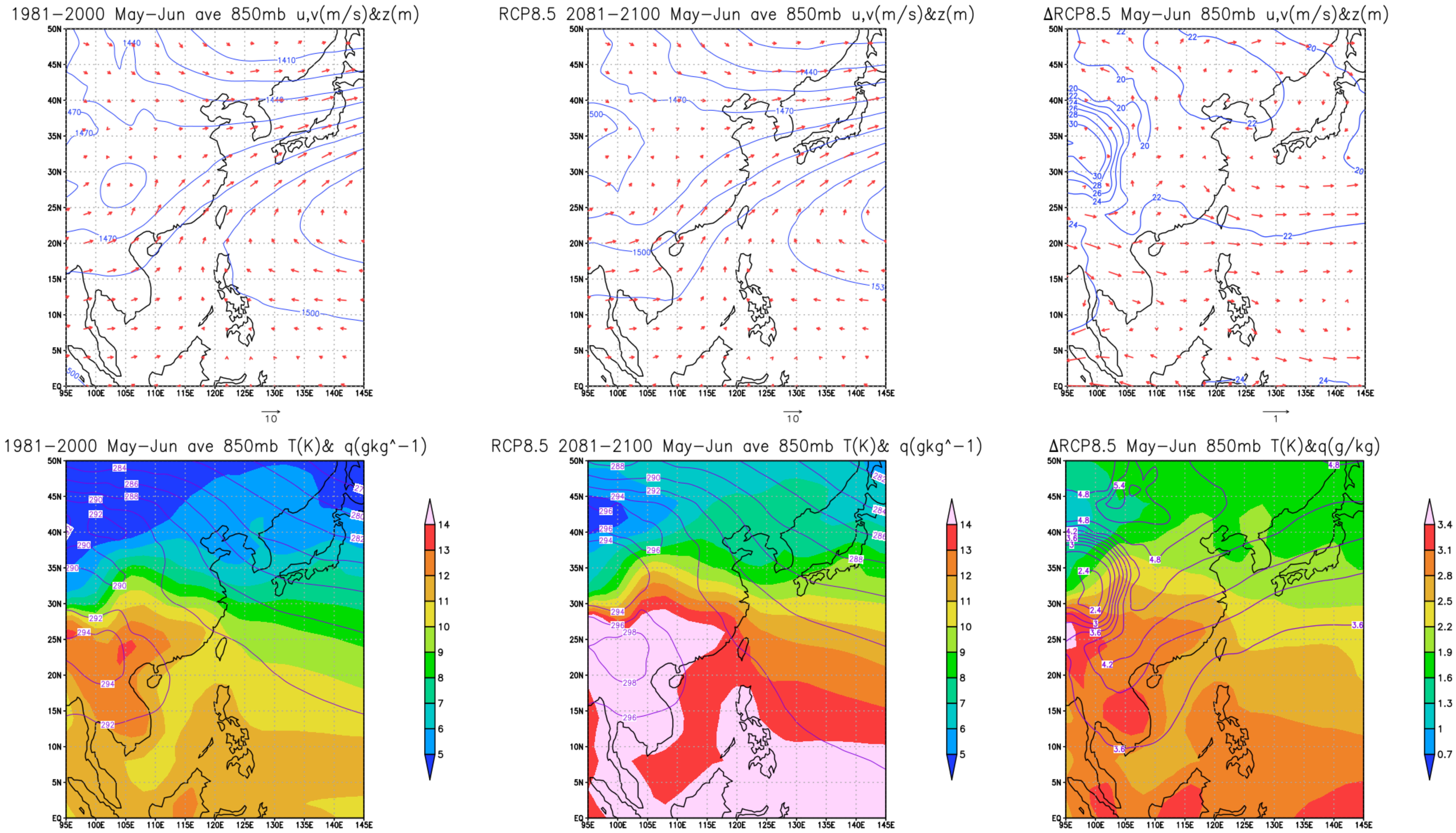


RCP8.5



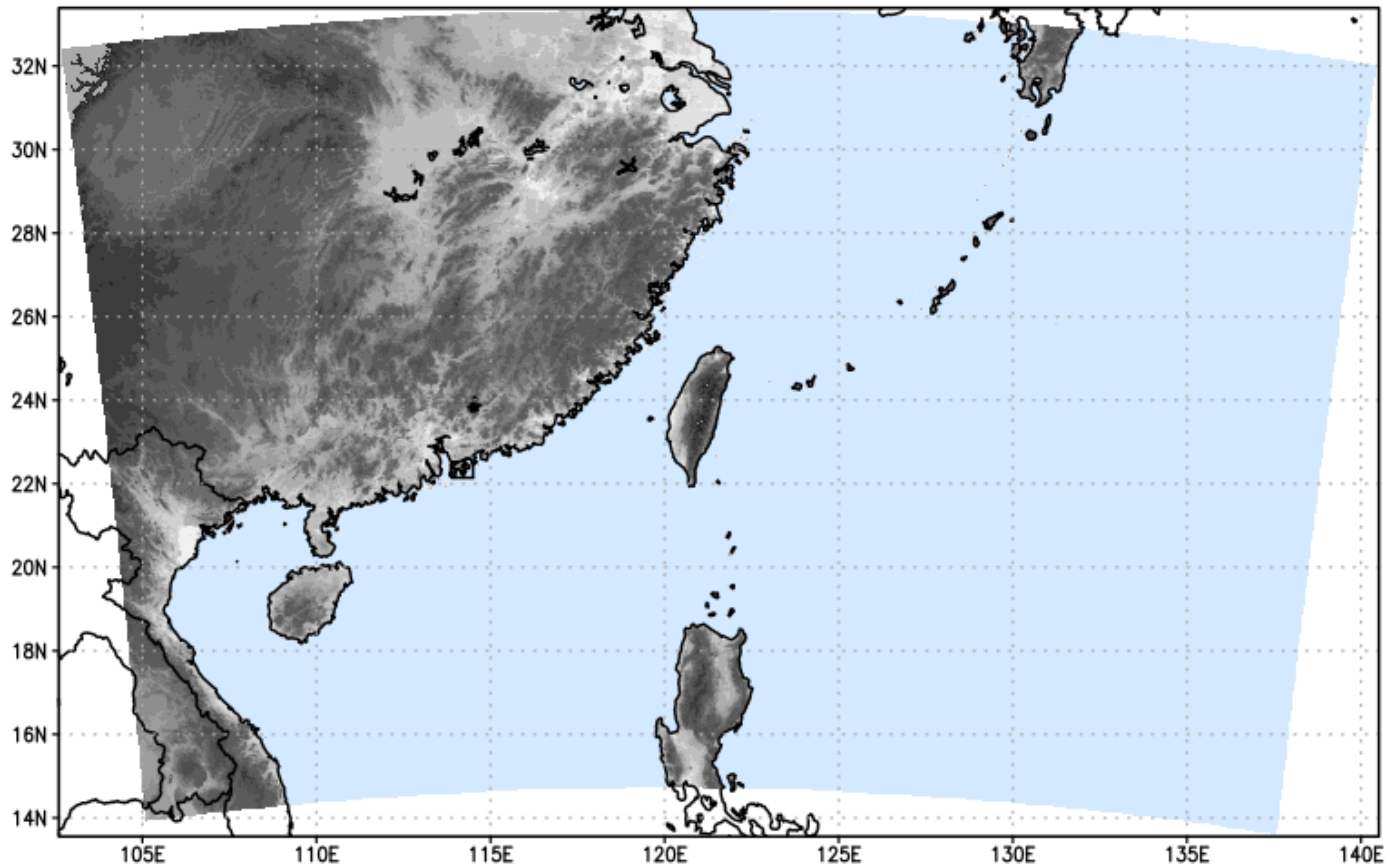
RCP8.5 - Historical




1981−2000 May−Jun ave 850mb u,v(m/s)&z(m)
RCP8.5 2081−2100 May−Jun ave 850mb u,v(m/s)&z(m)
ΔRCP8.5 May−Jun 850mb u,v(m/s)&z(m)
1981−2000 May−Jun ave 850mb T(K)& q(gkg^−1)
RCP8.5 2081−2100 May−Jun ave 850mb T(K)& q(gkg^−1)
ΔRCP8.5 May−Jun 850mb T(K)&q(g/kg)
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
95E
100E
105E
110E
115E
120E
125E
130E
135E
140E
145E
10
10
1
1440
1410
1470
1500
22
20
24
26
28
30
284
286
288
290
292
294
296
298
4.8
5.4
4.2
3.6
3
2.4
14
13
12
11
10
9
8
7
6
5
3.4
3.1
2.8
2.5
2.2
1.9
1.6
1.3
1
0.7

Experiments

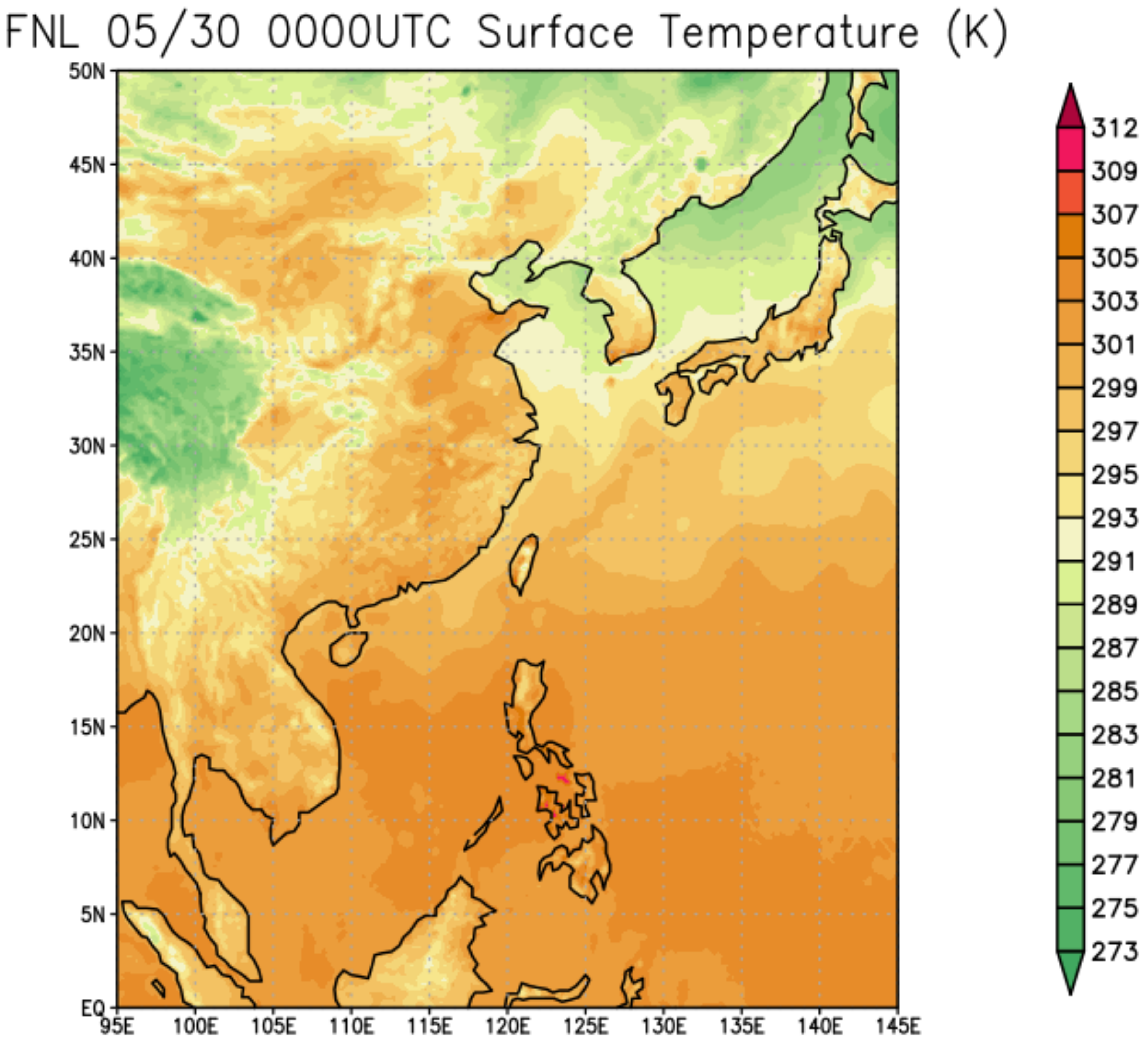
- Control Run, CTL
  - NCEP FNL provide IC/BC
- Sensitivity Run, SE
  - NCEP FNL + Δ_{RCP} provide IC/BC



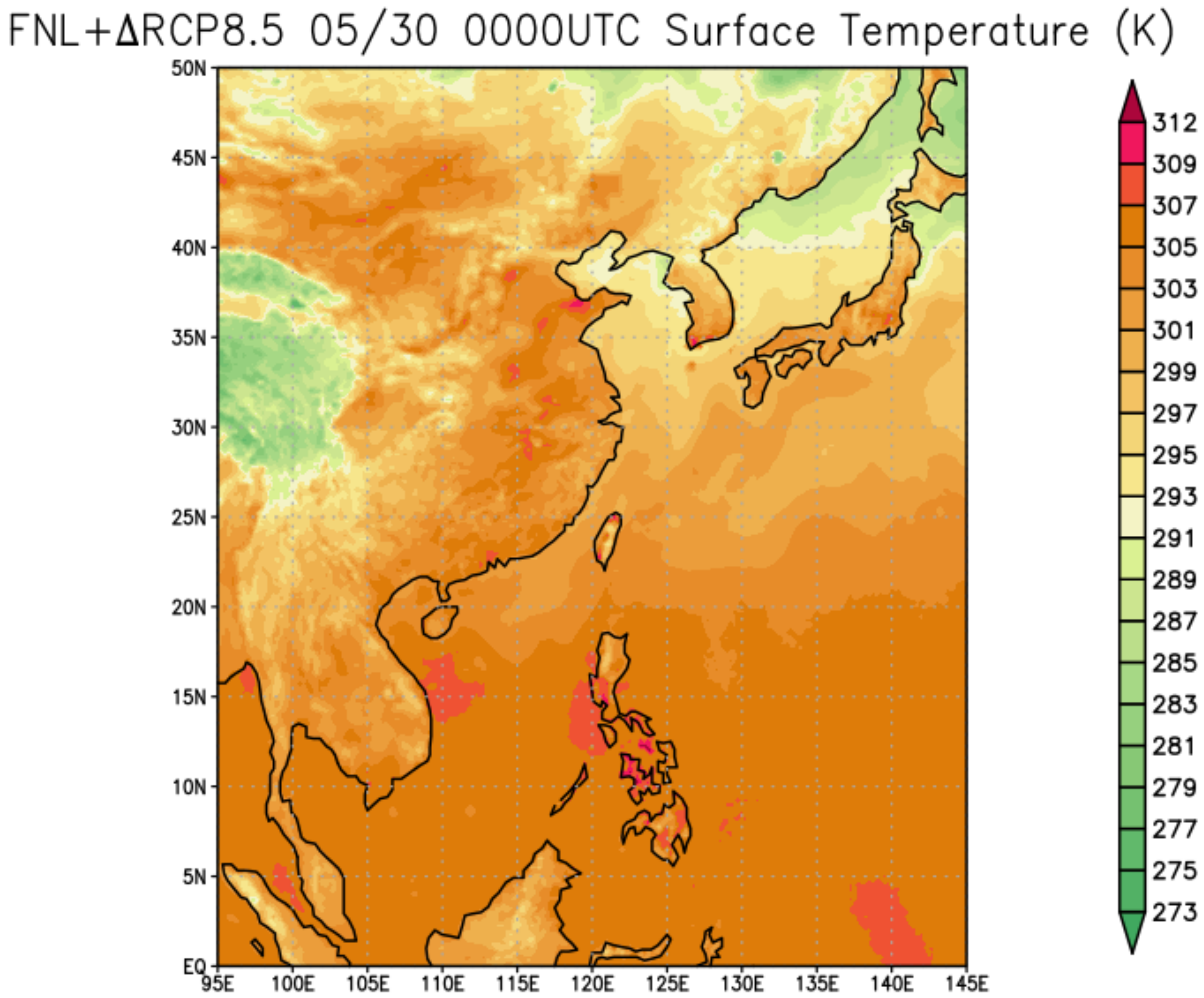
Numeric model

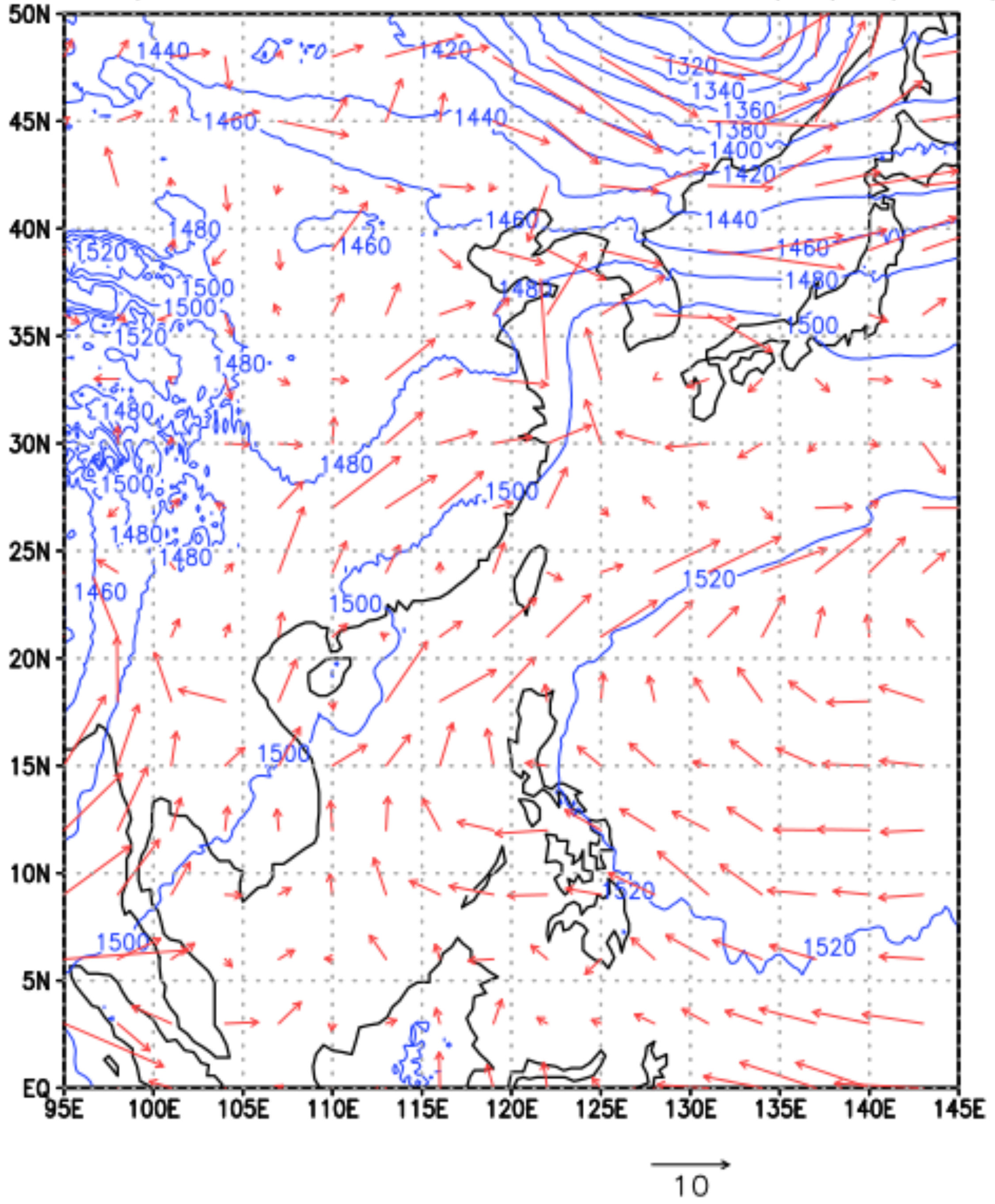
- Cloud-Resolving Strom Simulator (CReSS)
- Projection : Lambert conformal conic
- Grid : 1152 x 672, 3km x 3km
- Levels : 52 levels, 100~25786 meters
- Simulate time : 2017.05.30 0000UTC ~ 2017.06.04 0000UTC
- Integration time interval : 3sec & 1sec

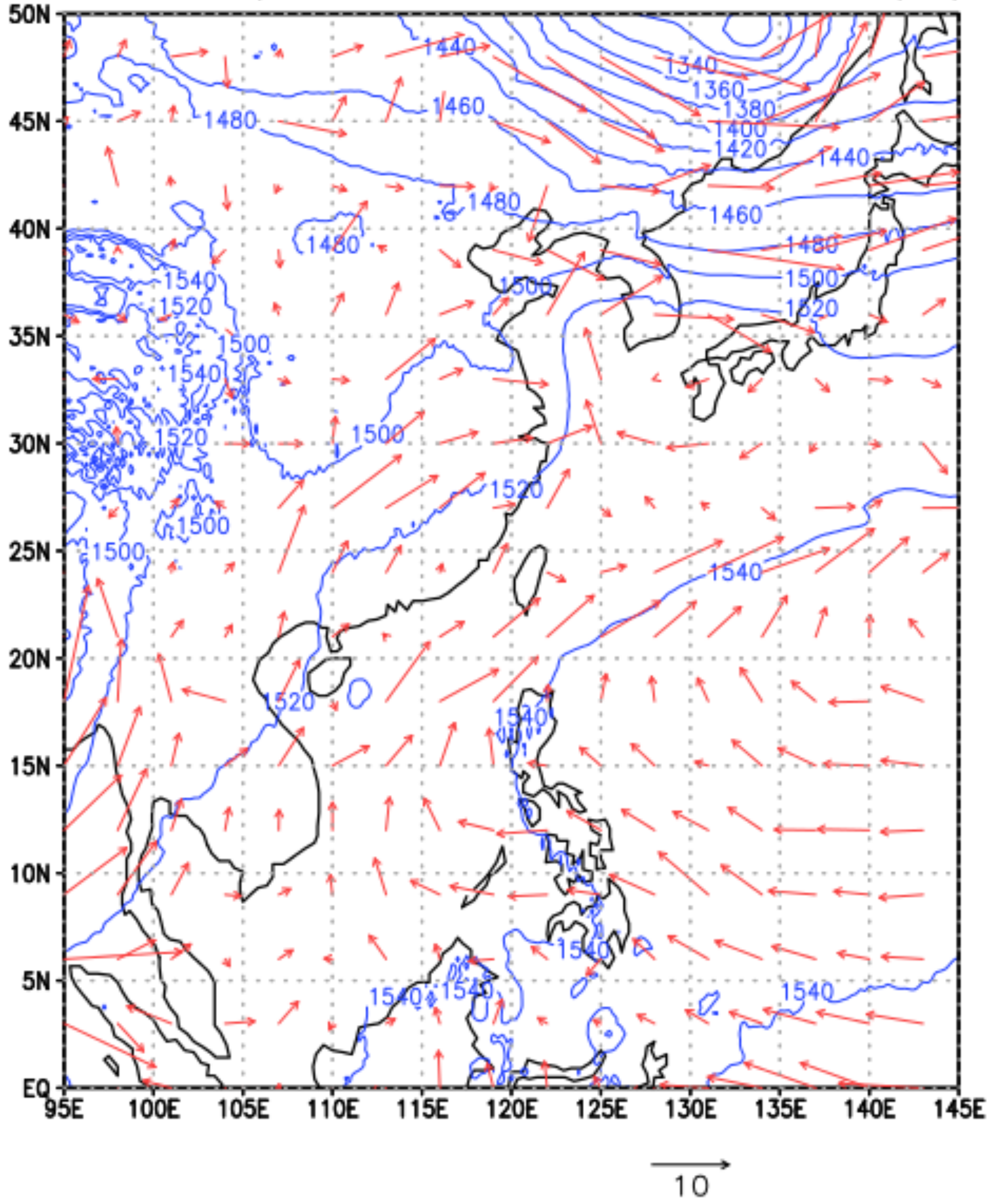
FNL

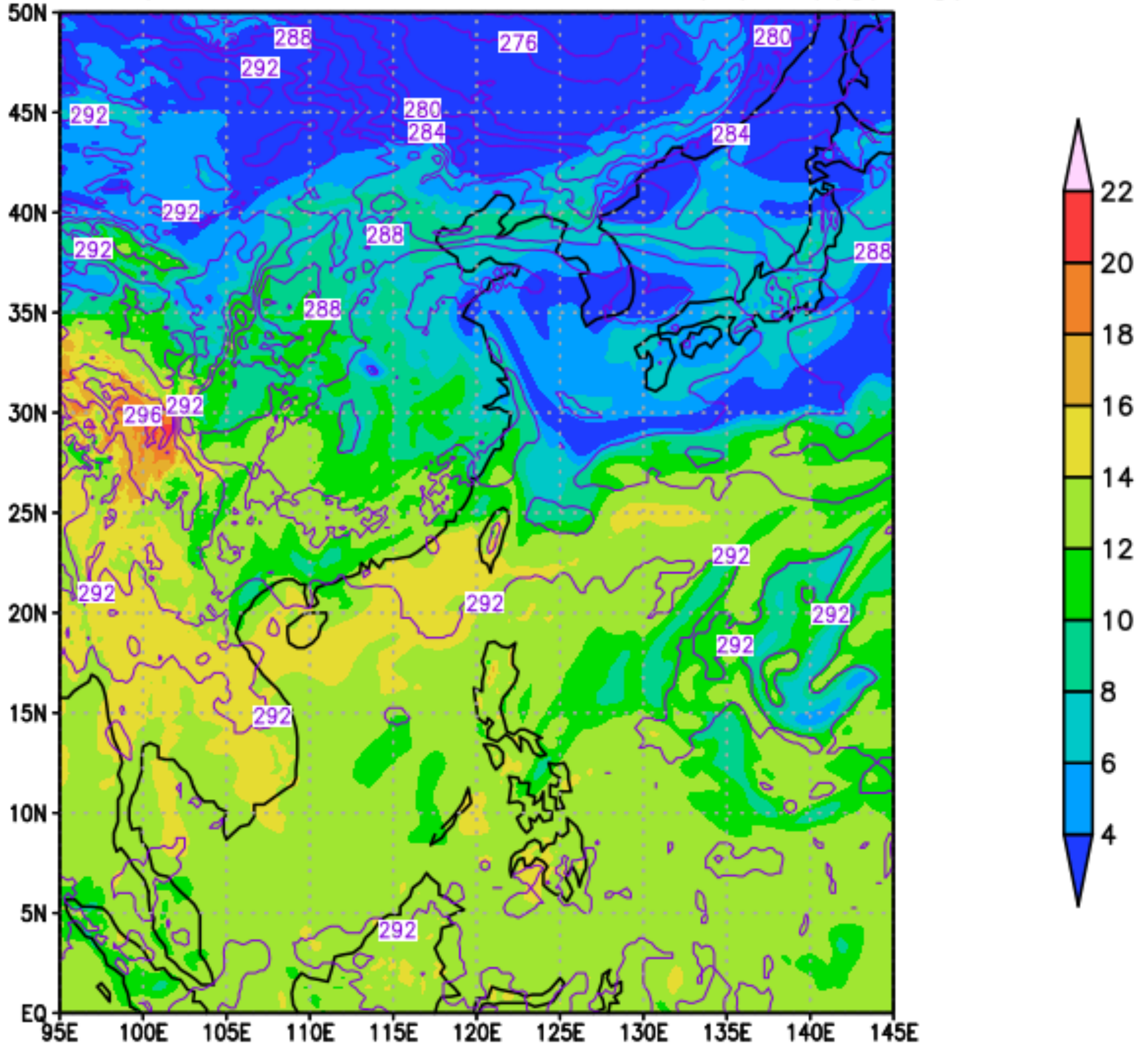


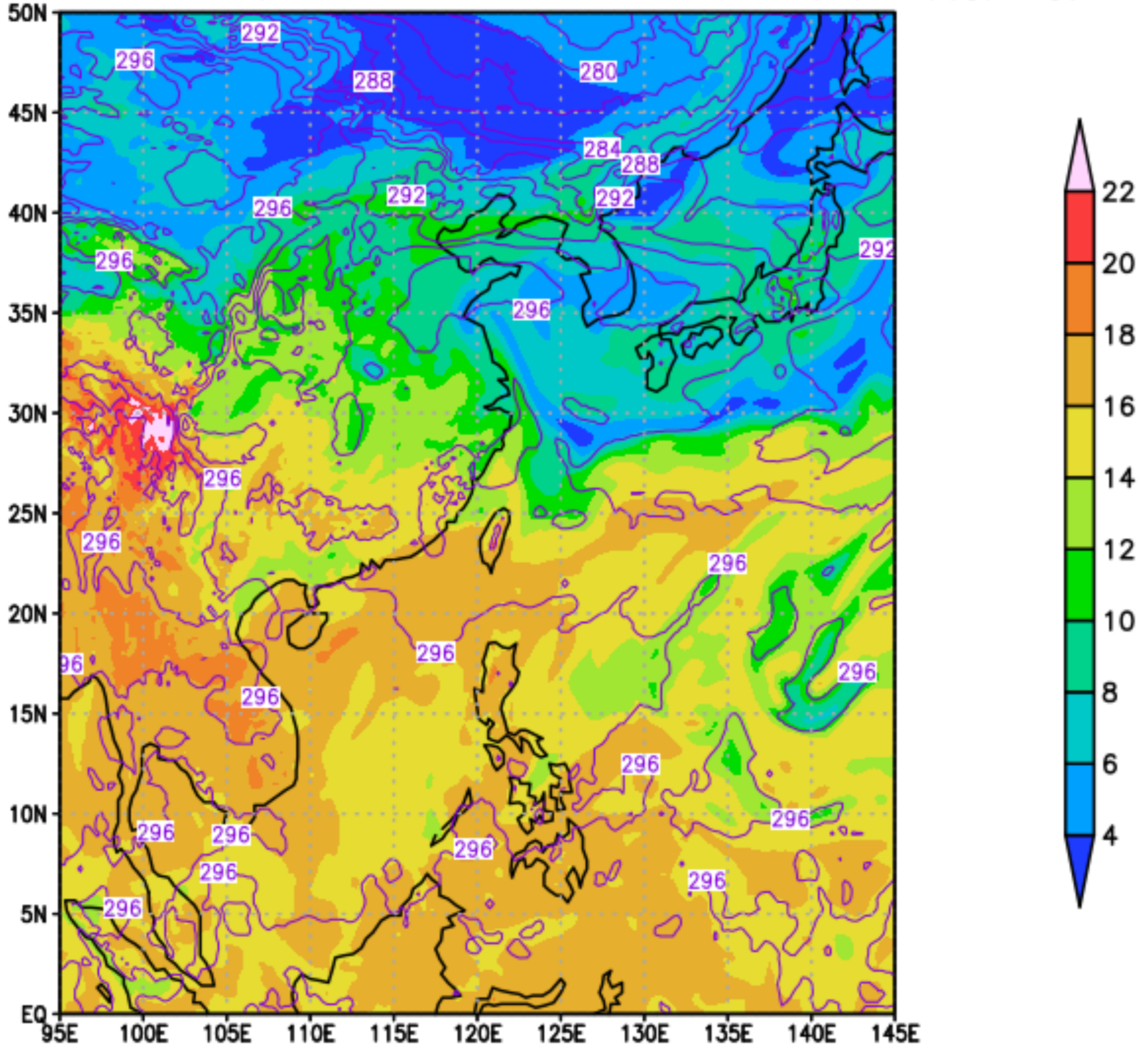
FNL + ΔRCP8.5

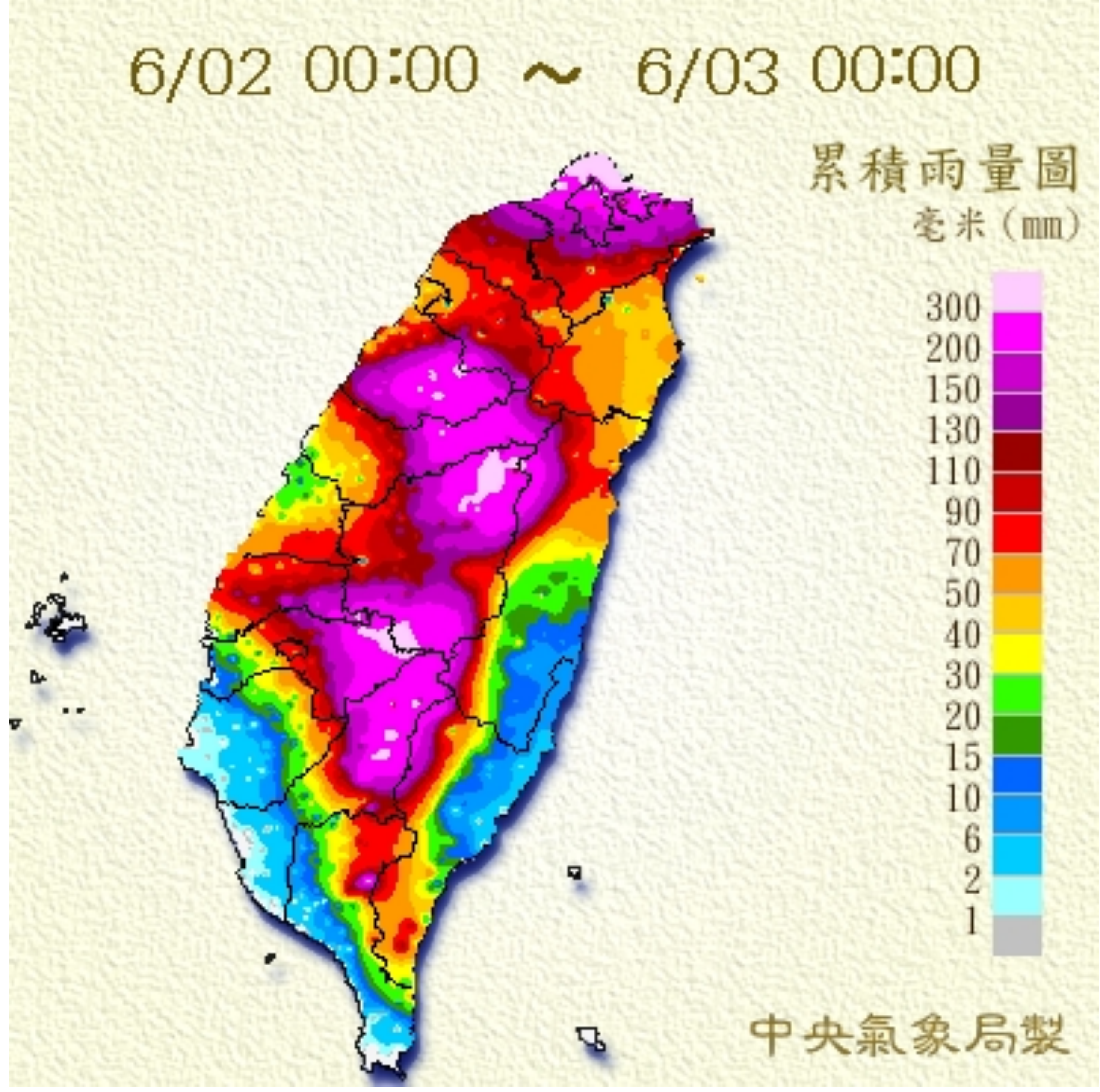


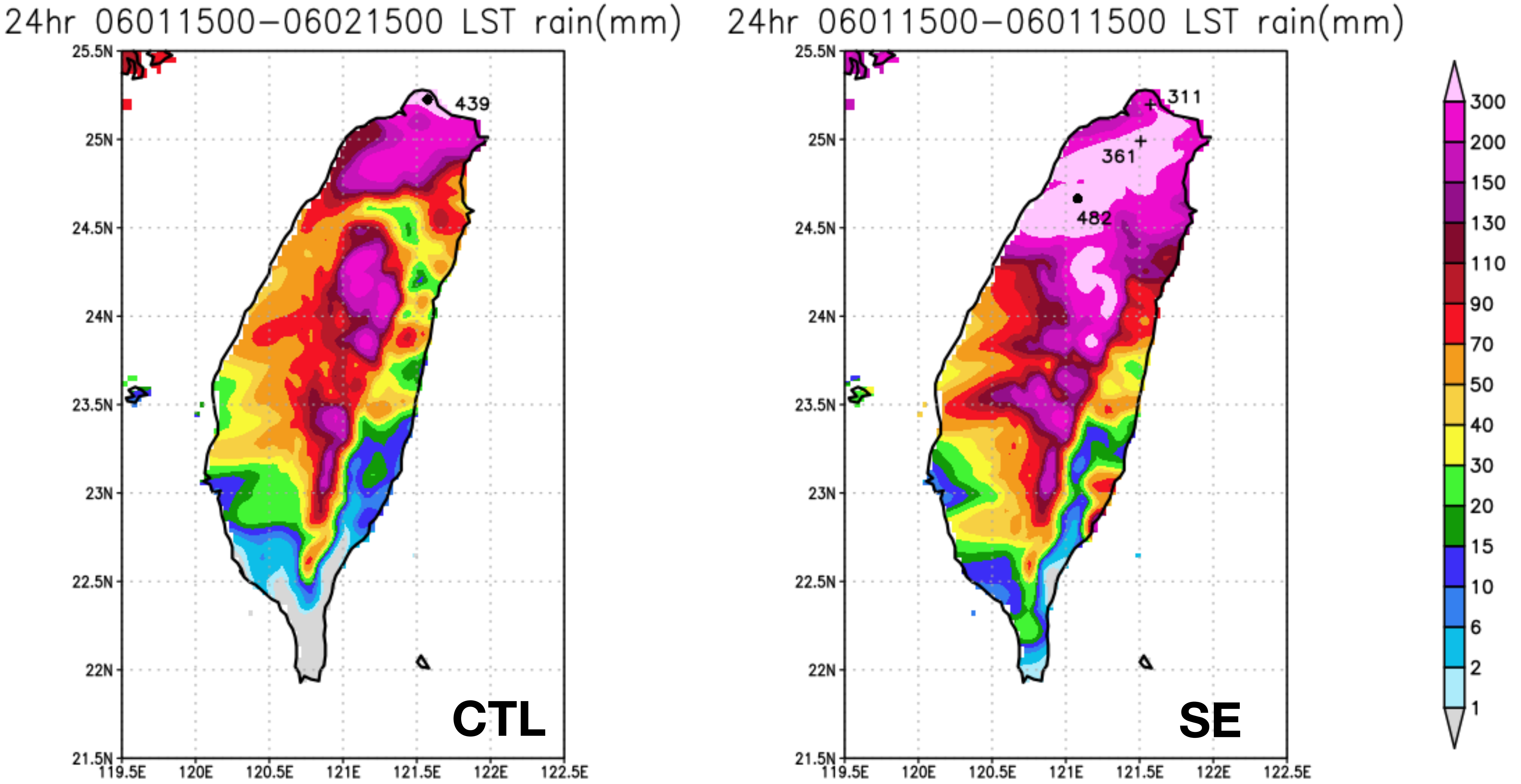

FNL 05/30 0000UTC 850mb u,v(m/s)&z(m)


FNL+ΔRCP8.5 05/30 0000UTC 850mb u,v(m/s)&z(m)


FNL 05/30 0000UTC 850mb T(K)&q(g/kg)


FNL+ΔRCP8.5 05/30 0000UTC 850mb T(K)&q(g/kg)



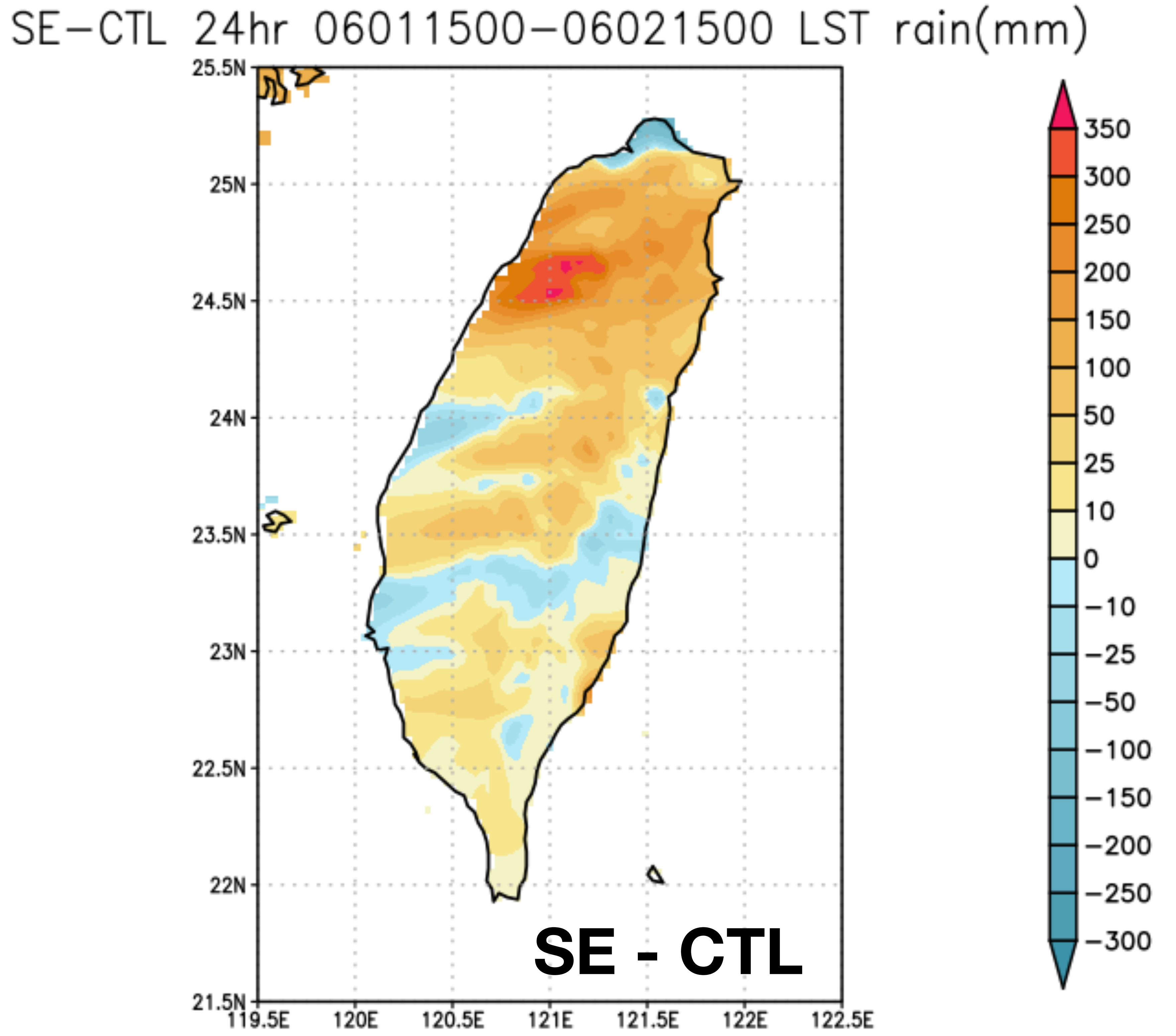


24hr 06011500−06021500 LST rain(mm)

24hr 06011500−06011500 LST rain(mm)

CTL

SE



SE−CTL 24hr 06011500−06021500 LST rain(mm)

SE - CTL

Water budget

$$p + \underbrace{\frac{\partial}{\partial t}(w_v + w_h)}_{\textbf{TDC}} = \underbrace{-\int \nabla \cdot (\rho_v V) dz}_{\textbf{CVF}} - \int \nabla \cdot (\rho_h V) dz + E + R$$

$$\overset{\textbf{CVF}}{\boxed{-\int \nabla \cdot (\rho_v V) dz}} = \overset{\textbf{CONV}}{\boxed{-\int \rho_v (\nabla \cdot V) dz}} \overset{\textbf{ADV}}{\boxed{-\int (V \cdot \nabla) \rho_v dz}}$$

w_h **Hydrometeors**

w_v **Vapor**

P : precipitation
TDC : tendency of total water content
CVF : convergence of vapor flux
E : evaporation
R : residual

Trenberth and Guillemot (1995)

Taiwan：119~123E, 21.5~25.5N, 4°x4°

	P	TDC	CVF	CONV	ADV	E	R
CTL	1.519	0.096	1.101	1.344	-0.243	0.122	0.389
SE	2.035	0.013	1.227	1.676	-0.449	0.116	0.706
$SE - CTL$	0.516	-0.083	0.126	0.332	-0.206	-0.006	
$\frac{SE - CTL}{CTL}$	34%	-86%	11%	25%	85%	-5%	

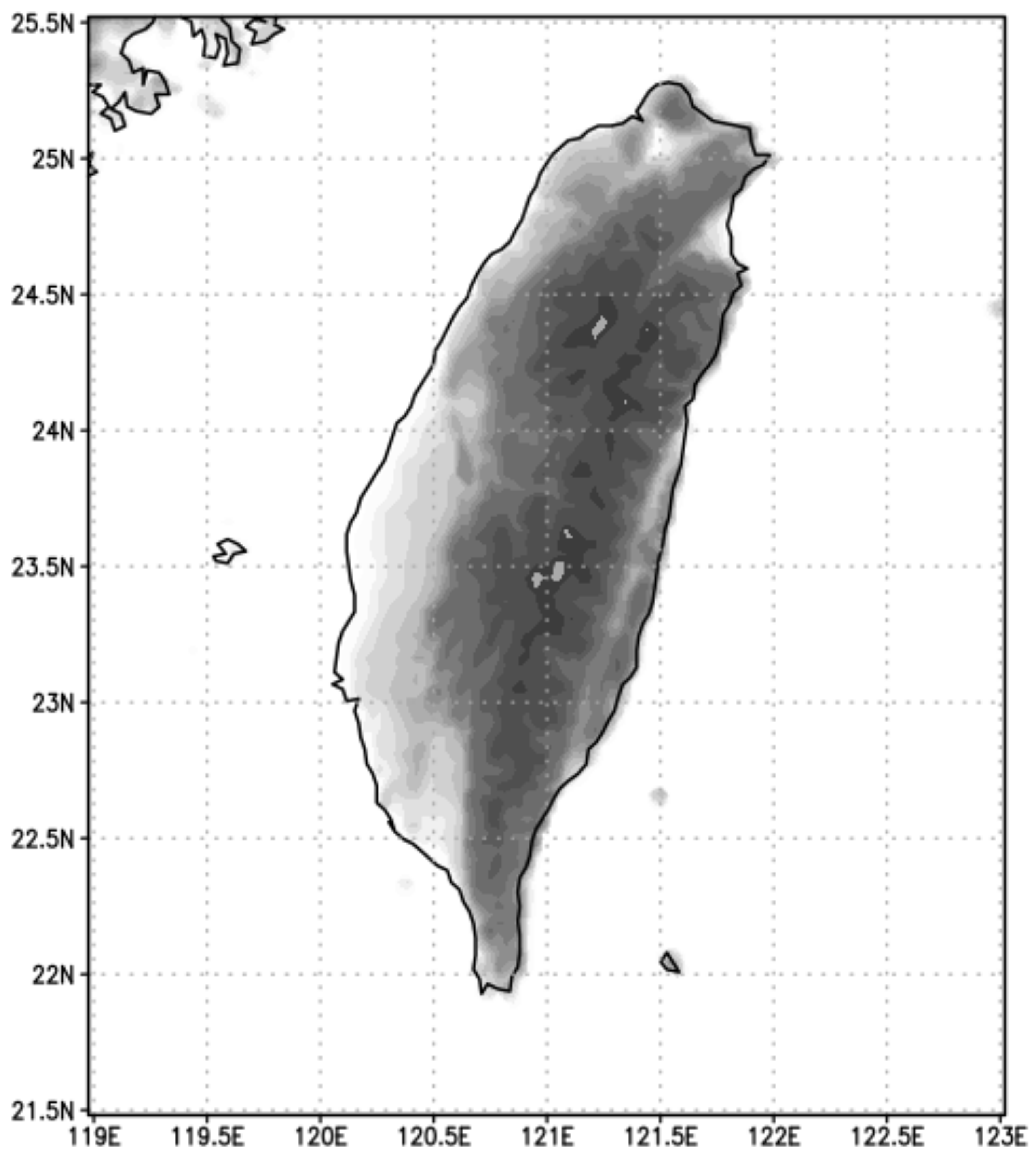
P : precipitation

TDC : tendency of total water content

CVF : convergence of vapor flux

E : evaporation

R : residual



$$\underbrace{-\int \rho_v(\nabla \cdot V)dz}_{\textbf{CONV}} = \underbrace{\int_0^{5.5km} \rho_v dz}_{\textbf{PW}} \cdot \underbrace{-\int_0^{5.5km} (\nabla \cdot V)dz}_{\textbf{IHC}}$$

PW : precipitable water

IHC : integrated horizontal convergence

	PW	IHC
CTL	1.519	0.096
SE	2.035	0.013
$SE - CTL$	0.516	-0.083
$\frac{SE - CTL}{CTL}$	34%	-86%

mm/day	6/1	6/2	6/3
CTL	27.68	42.179	36.536
SE	58.156	48.073	37.859
$SE - CTL$	30.477	5.893	1.323
$\frac{SE - CTL}{CTL}$	110%	14%	4%

Conclusion

- In the future climate, the moister and warmer environment may make the quasi-stationary rainfall system produce more extreme rainfall in most parts of Taiwan and the associated rainband appears to become wider that may affect the spatial distribution of precipitation.
- From water budget analysis, we can see that the CVF mainly contributes the precipitation (P) about 60 ~ 70 %.
- The CVF is primary attributed to CONV, but ADV has a small negative feedback due to dry inflows from surroundings, and the thermodynamics is more dominant than secondary circulation.

Q & A