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Temperature and Precipitation Scenarios for Taiwan: Results from ECHAM5 Dynamical Downscaling

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Introduction: dynamical downscaling

- Existing Global climate models (GCMs) typical run at a scale of 200 km which is too coarse for application regional or local
- Especially for variables that depend on regional topographic, such as precipitation, surface wind and temperature
- Dynamical downscaling with regional climate model is an essential component to fill the gap between GCMs and regional application



ECHAM5-WRF downscaling

Model Description and Experimental setup

■ ECHAM5:

coupled the Max-Planck-Institute Ocean model (MPIOM), T63 spectral resolution (1.875°) and 17 vertical levels with the top extending to 10 hPa.

Periods:

1979-2003 (Present), 2015-2039 (Near-future), 2075-2099 (End 21c)

■ WRF setup:

Domain1 (15km): FDDA, Cumulus option: Kain-Fritsch scheme

Domain2 (5km): no nudging, no cumulus scheme

Cold start every month and run for one month

Physical options

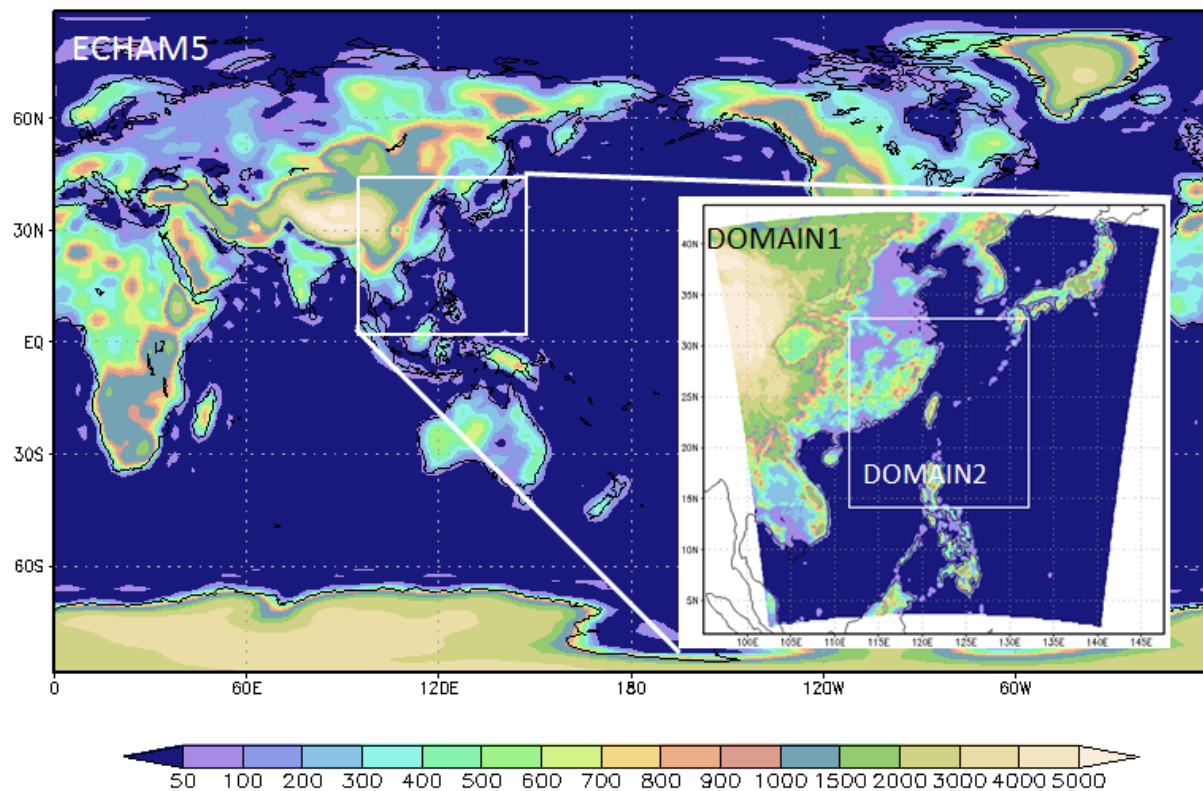
Noah Land surface model, Cam LW Scheme

YSU Boundary Scheme, Cam SW scheme

WSM 5-class microphysics, M-O surface layer scheme

■ Observation: TCCIP 1 km uniform data

ECHAM5-WRF dynamical downscaling



ECHAM5: domain:192x96 $\Delta x=1.875$ degree

WRF:

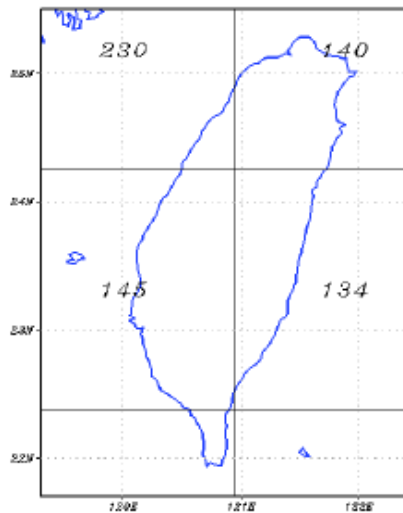
Domain1 : 301x301 $\Delta x,y=15\text{km}$ FDDA

Domain2 : 382x400 $\Delta x,y=5\text{km}$, vertical 45 levels



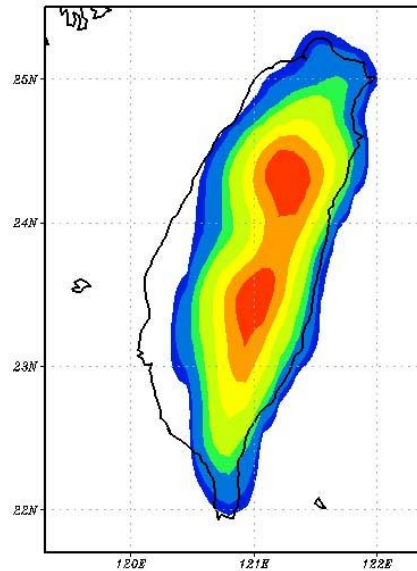
Topographic

ECHAM5 terrain



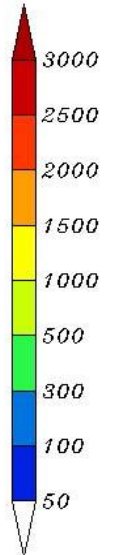
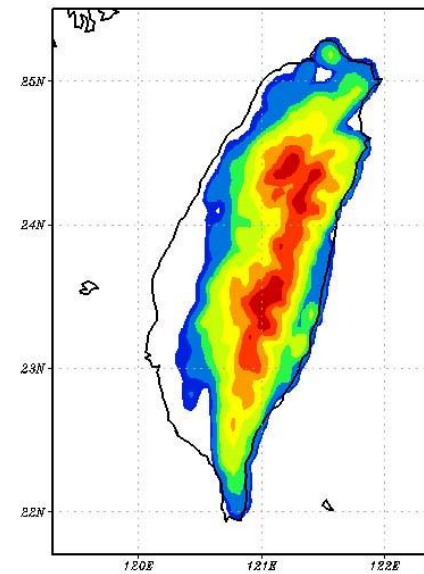
15 Km

WRF domain1 Terrain Height(m)



5 Km

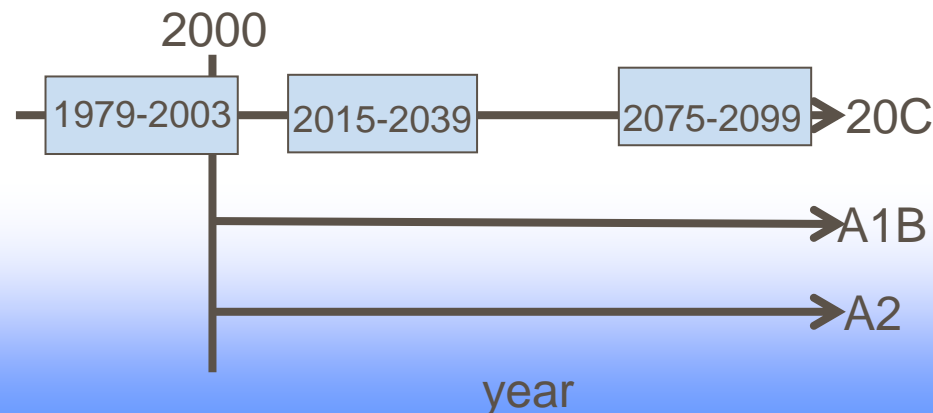
WRF domain2 Terrain Height(m)





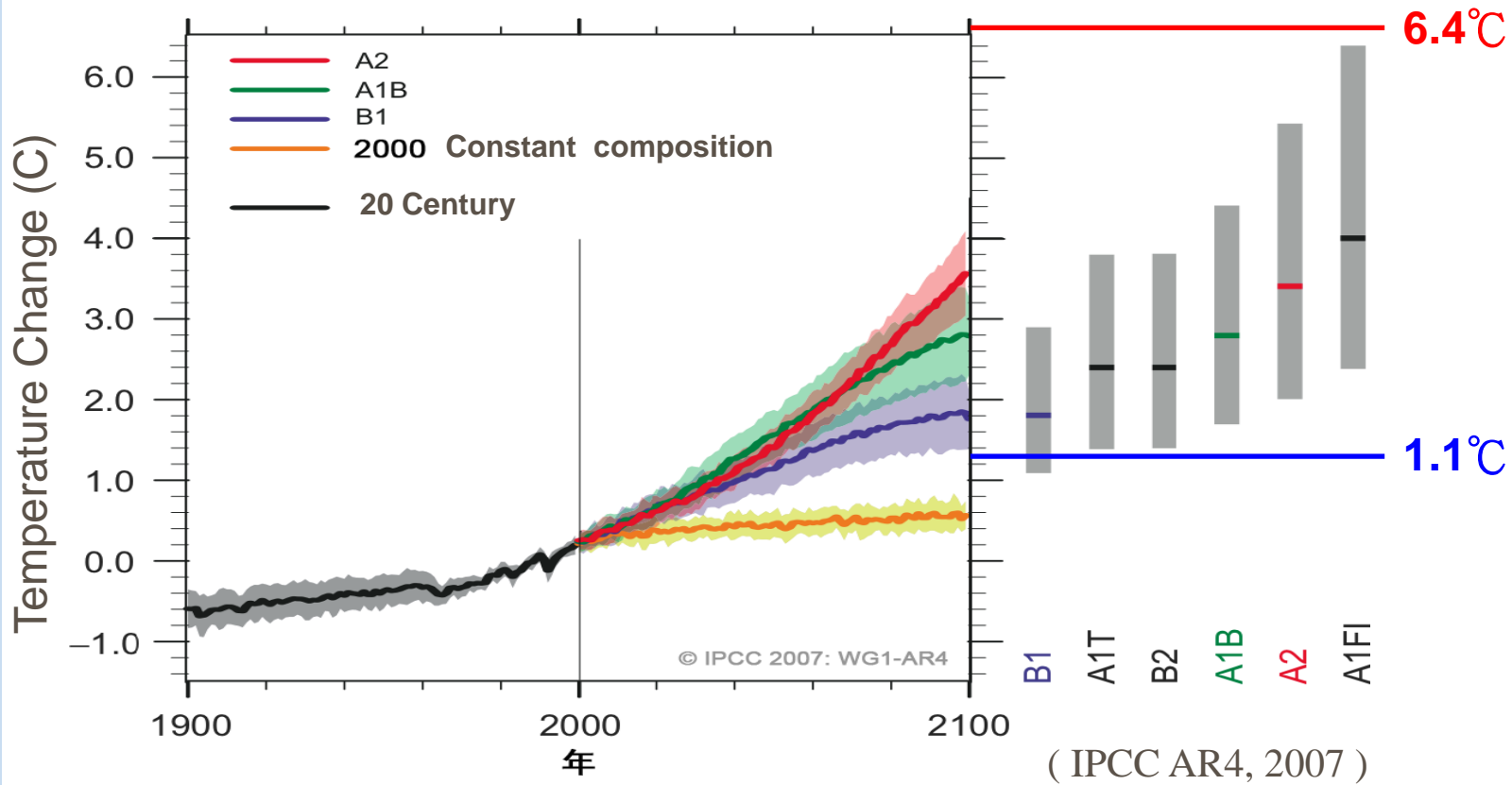
Forcing : IPCC AR4 ECHAM5/MPIOM Model output

- **experiment: EH5-T63L31_OM-GR1.5L40_20C_1_6H :**
- Run20C represent 6 hourly values of a 20th century simulation (including year 2000) with observed anthropogenic forcings (CO₂, CH₄, N₂O, CFCs, O₃ and sulfate). This is followed by a commitment experiment for the 21th century (years 2001-2100) with all concentrations fixed at their levels of the year 2000.
- The A1B scenario has been initialized in year 2000 of the 20C_1 run and continues until year 2100 with anthropogenic forcings (CO₂, CH₄, N₂O, CFCs, O₃ and sulfate) according to A1B. The experiment is extended until year 2200 with all concentrations fixed at their levels of year 2100 (stabilization experiment).
- The A2 scenario experiment has been initialized in year 2000 of the 20C_1 run and continues until year 2100 with anthropogenic forcings (CO₂, CH₄, N₂O, CFCs, O₃ and sulfate) according to A2.
- Related experiments :
 - EH5-T63L31_OM-GR1.5L40_20C_1
 - EH5-T63L31_OM-GR1.5L40_A1B_1
 - EH5-T63L31_OM-GR1.5L40_A2_1





Global Warming

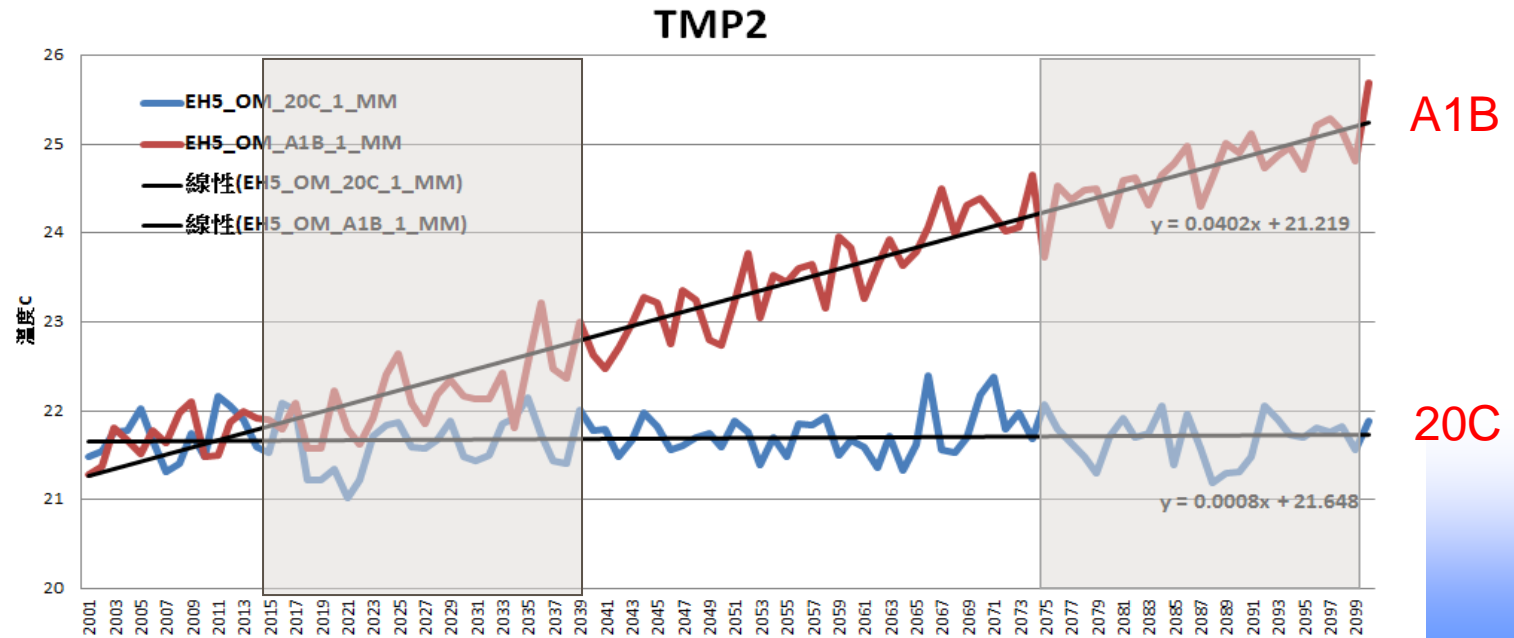
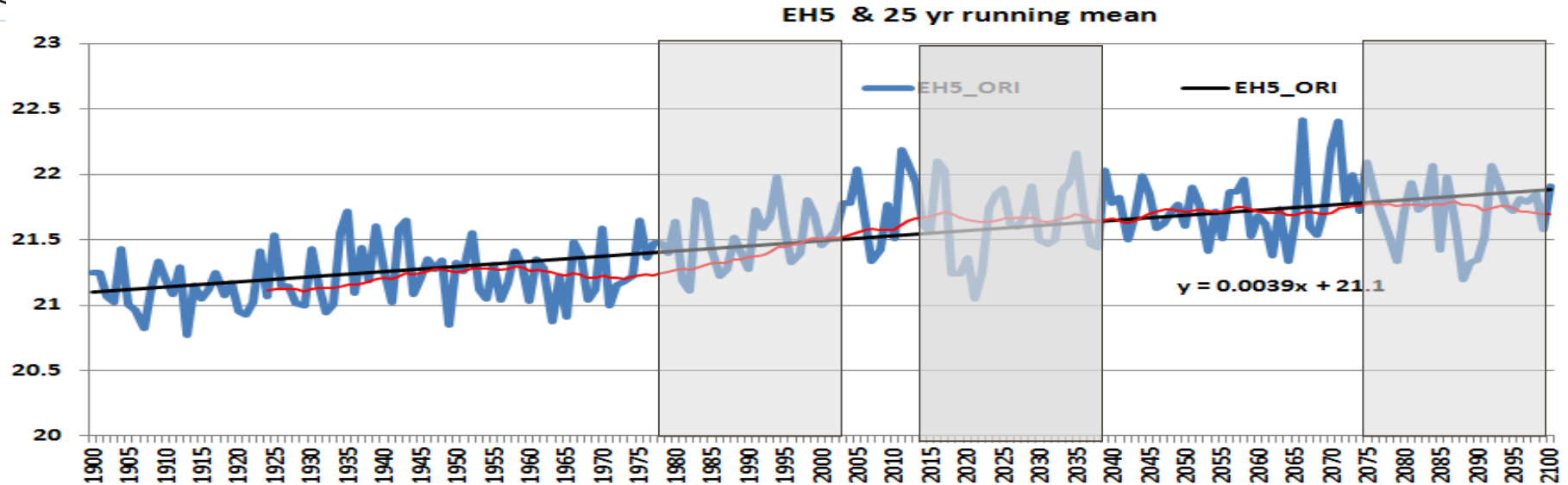


B1: 1.1~2.9 °C

A1F1: 2.4~6.4 °C



ECHAM5: 20C and A1B scenario in Domain1





ECHAM5 & NCEP

ECHAM5 1000 hPa

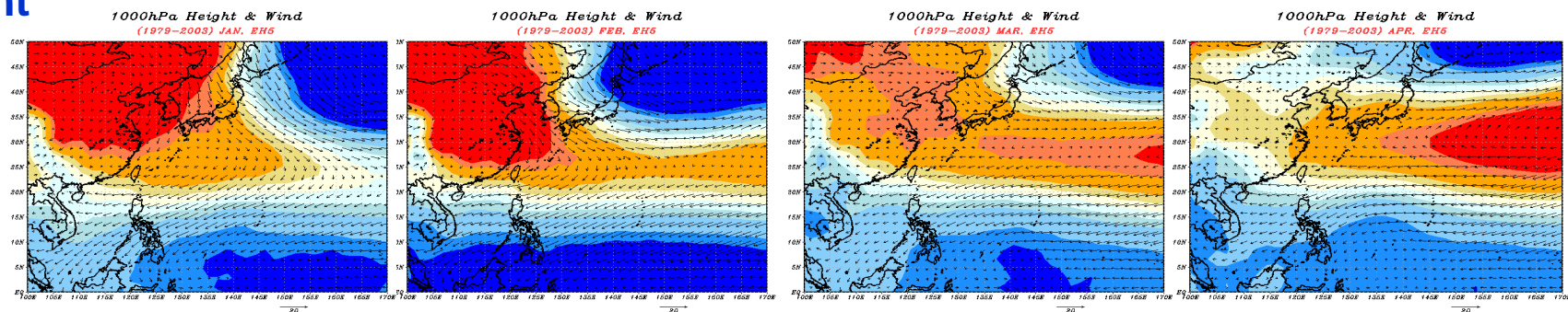
JAN

FEB

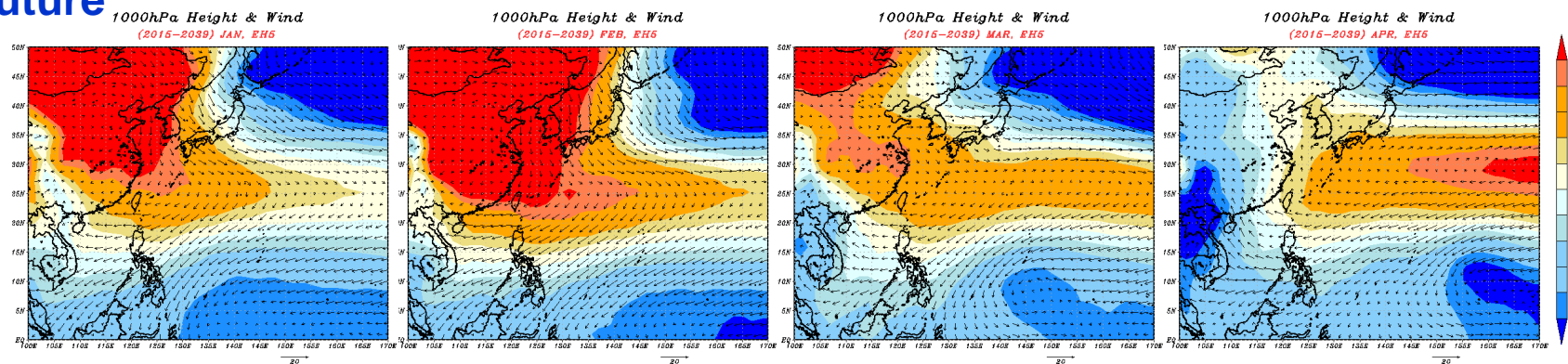
MAR

APR

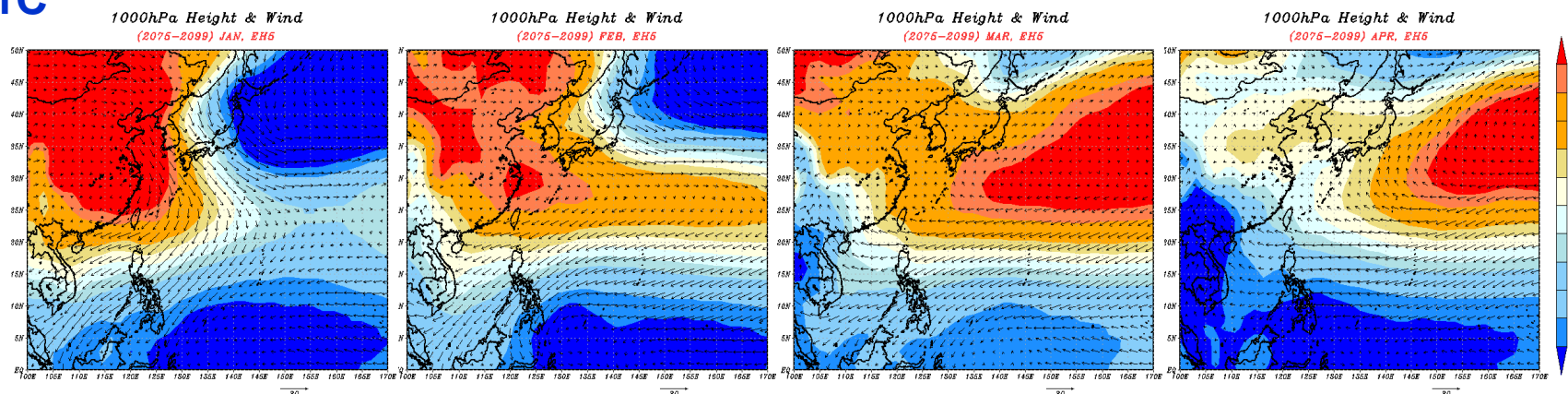
Present



Near Future

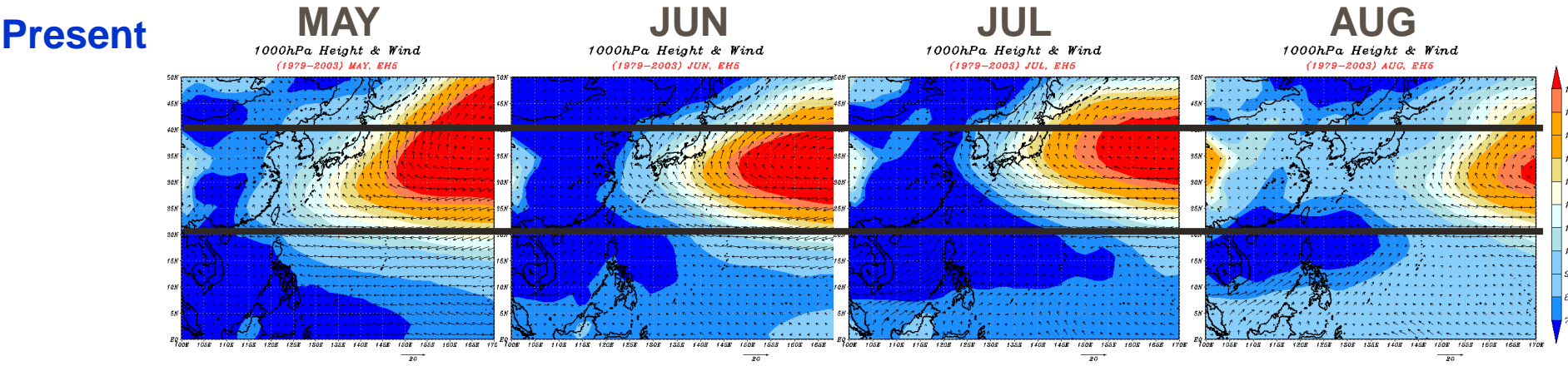


End-21C

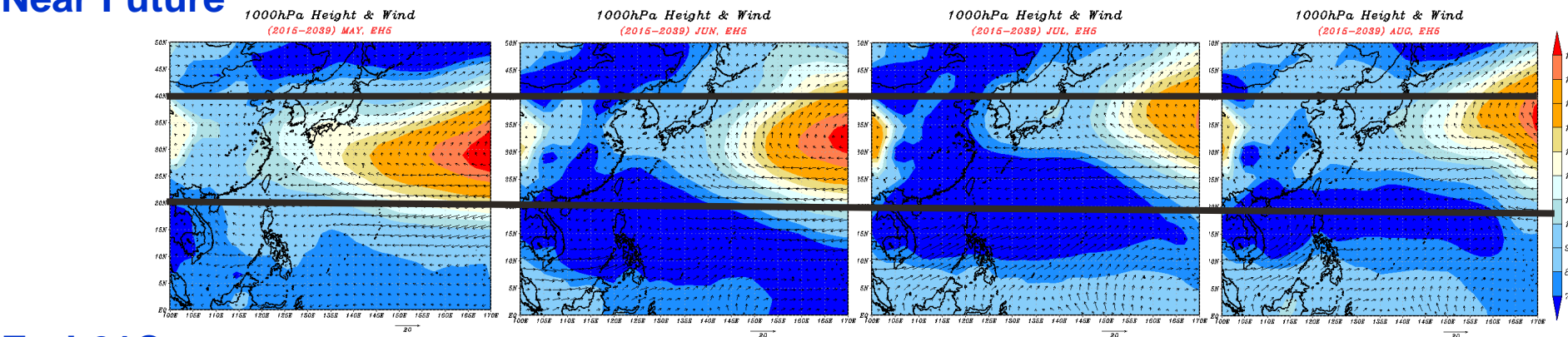


ECHAM5 1000 hpa

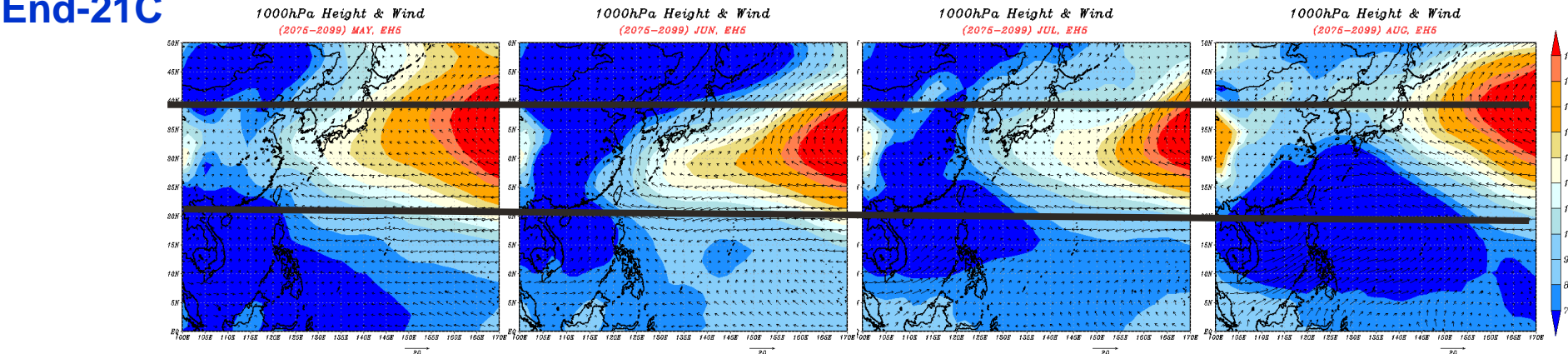
Present



Near Future

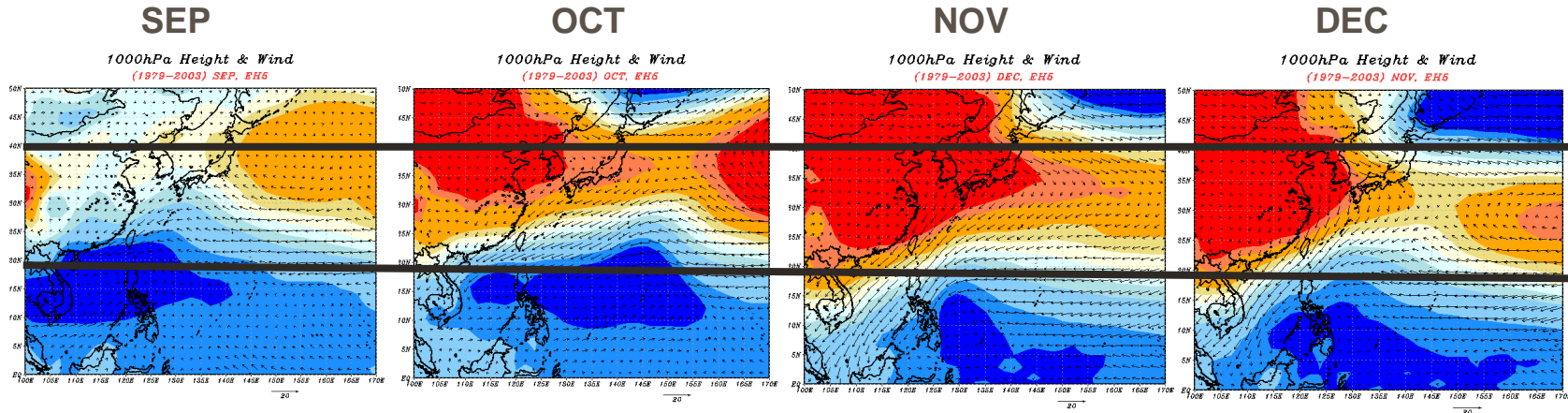


End-21C

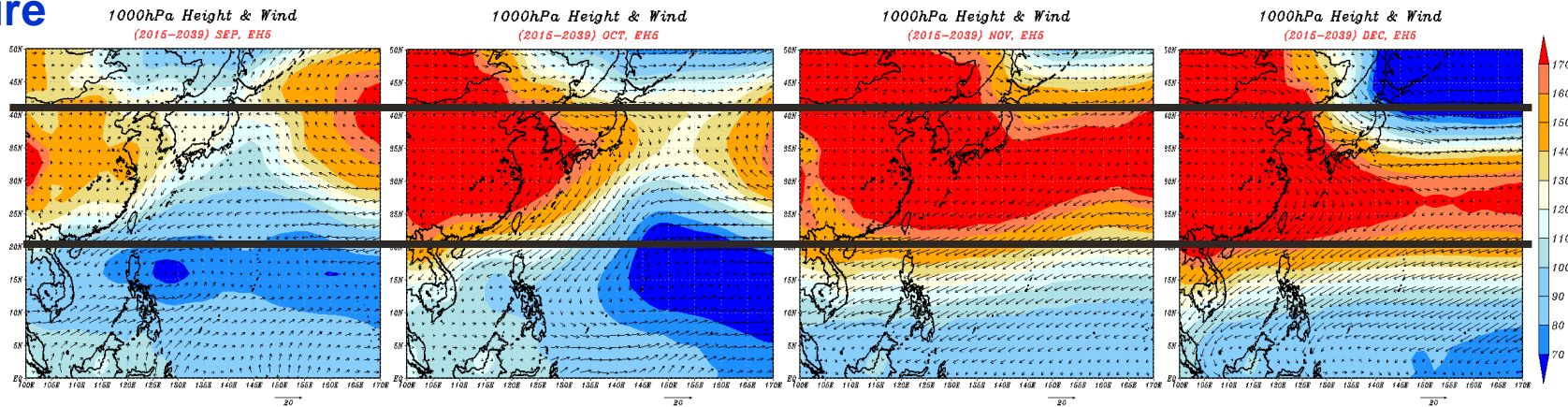


ECHAM5 1000 hpa

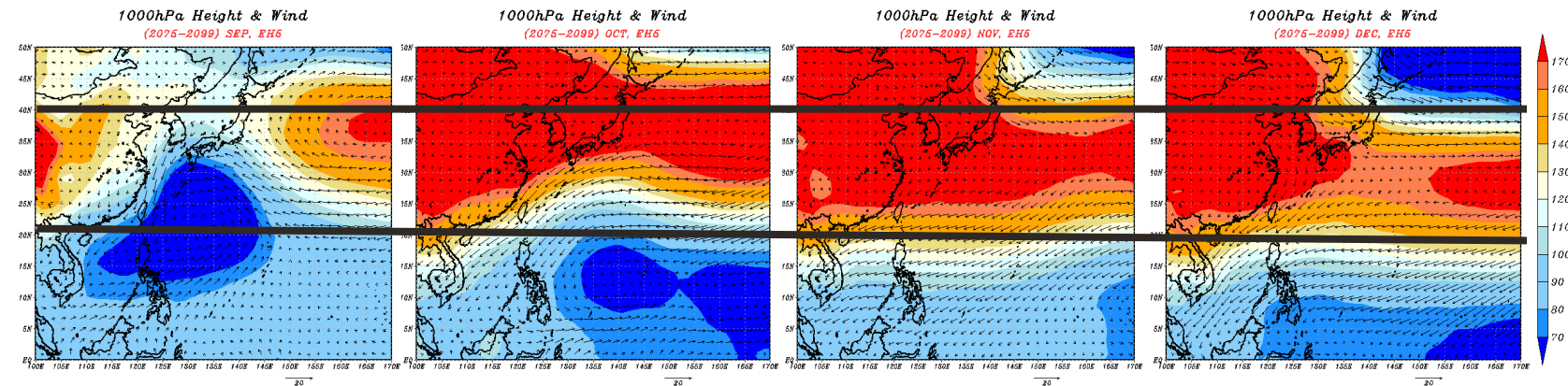
Present



Near Future



End-21C



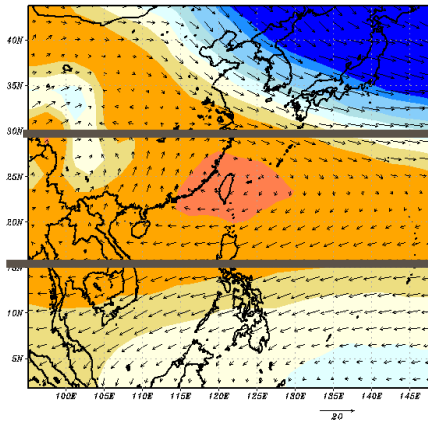


850hPa Height & Wind: ECHAM5 and NCEP (1979-2003)

ECHAM5

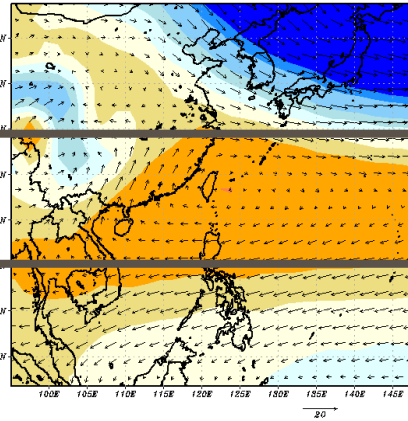
JAN

850hPa Height & Wind
(1979-2003) JAN, EH5



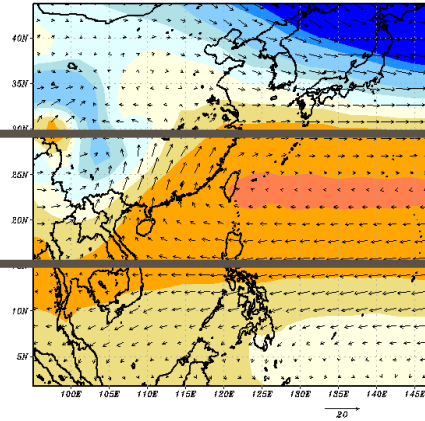
FEB

850hPa Height & Wind
(1979-2003) FEB, EH5



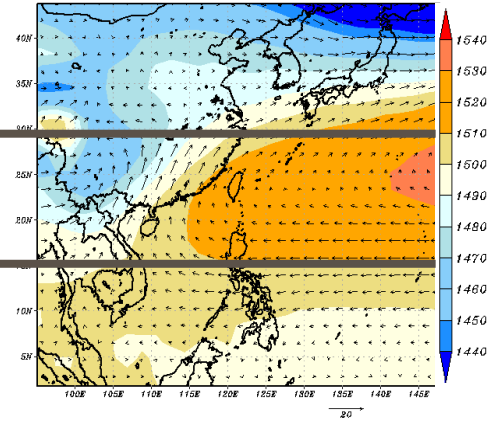
MAR

850hPa Height & Wind
(1979-2003) MAR, EH5



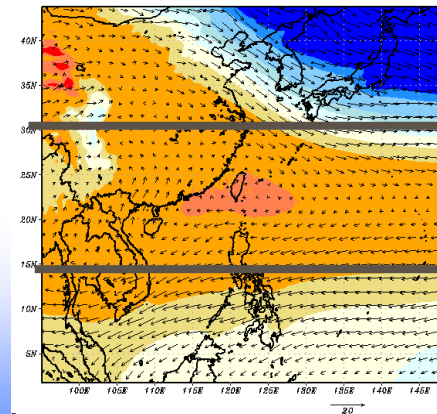
APR

850hPa Height & Wind
(1979-2003) APR, EH5

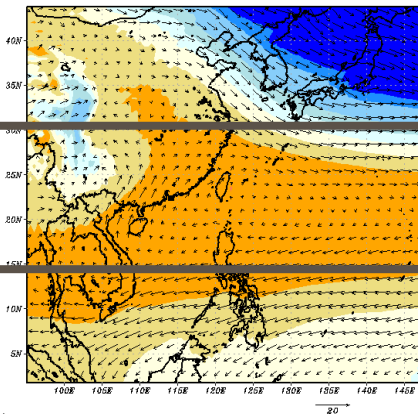


NCEP

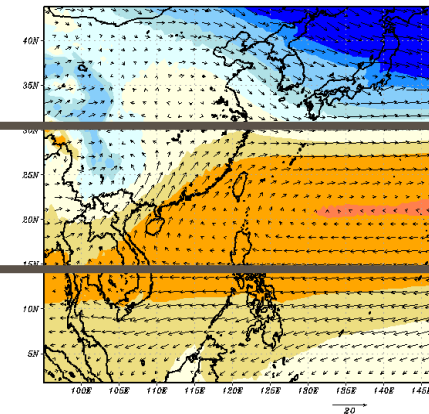
850hPa Height & Wind
(1979-2003) JAN, NCEP



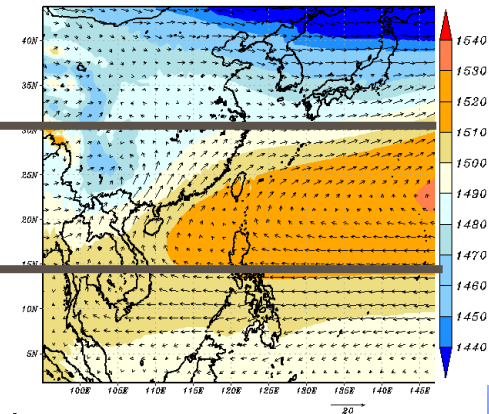
850hPa Height & Wind
(1979-2003) FEB, NCEP



850hPa Height & Wind
(1979-2003) MAR, NCEP



850hPa Height & Wind
(1979-2003) APR, NCEP



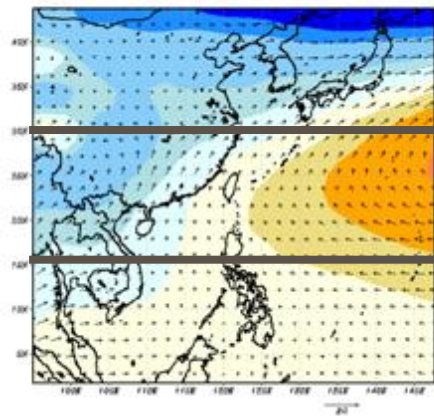


850hPa Height & Wind: ECHAM5 and NCEP

ECHAM5

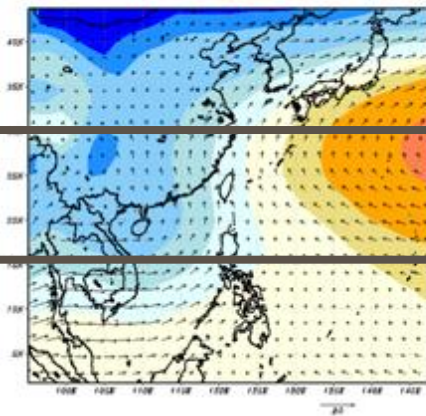
MAY

850hPa Height & Wind
(1979-2003) MAY, ECHAM5



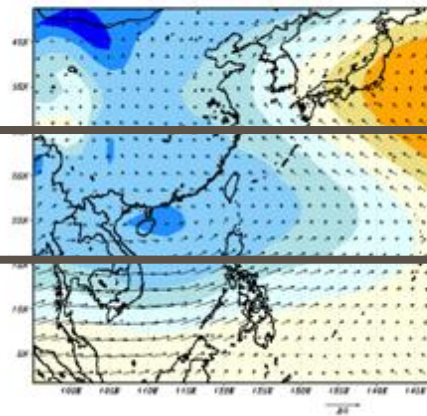
JUN

850hPa Height & Wind
(1979-2003) JUN, ECHAM5



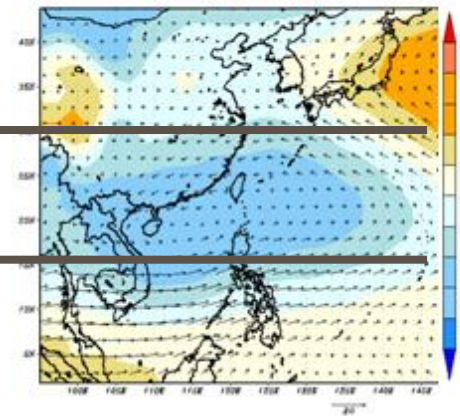
JUL

850hPa Height & Wind
(1979-2003) JUL, ECHAM5



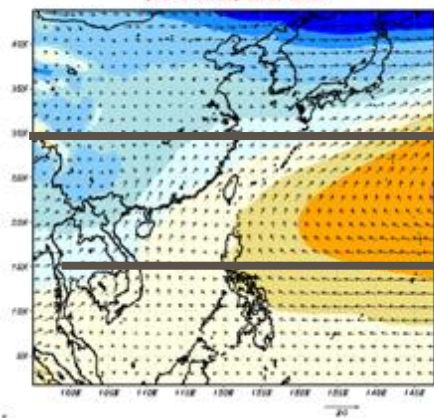
AUG

850hPa Height & Wind
(1979-2003) AUG, ECHAM5

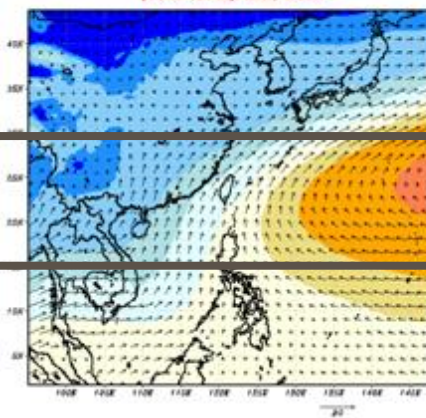


NCEP

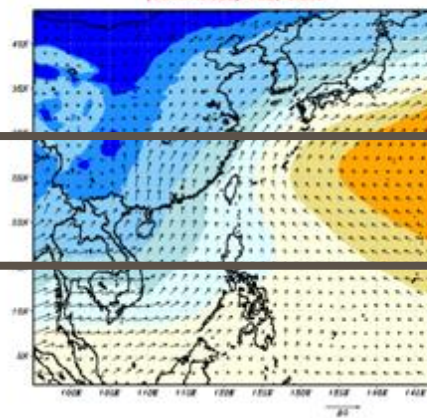
850hPa Height & Wind
(1979-2003) MAY, NCEP



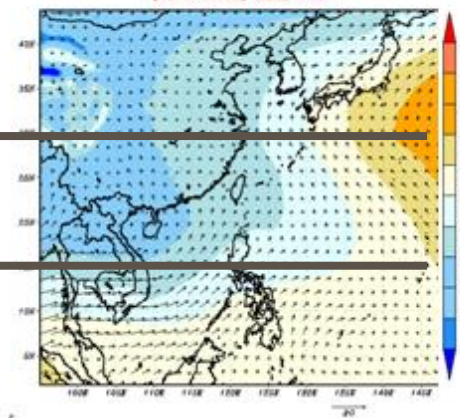
850hPa Height & Wind
(1979-2003) JUN, NCEP



850hPa Height & Wind
(1979-2003) JUL, NCEP



850hPa Height & Wind
(1979-2003) AUG, NCEP





850hPa Height & Wind: ECHAM5 and NCEP

ECHAM5

SEP

OCT

NOV

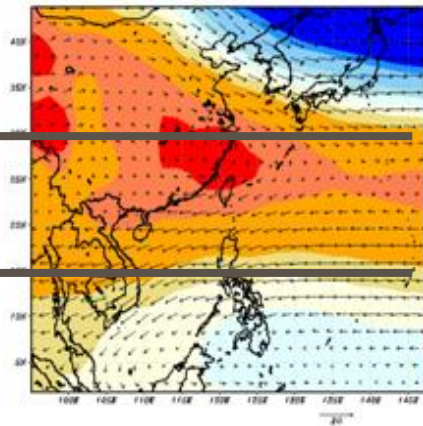
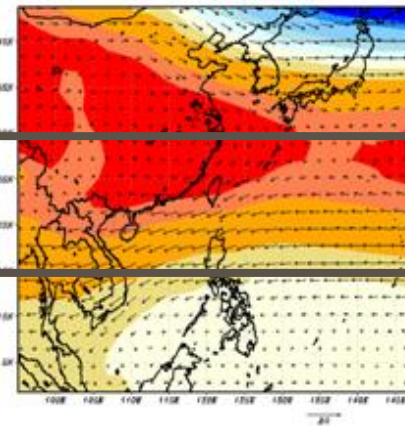
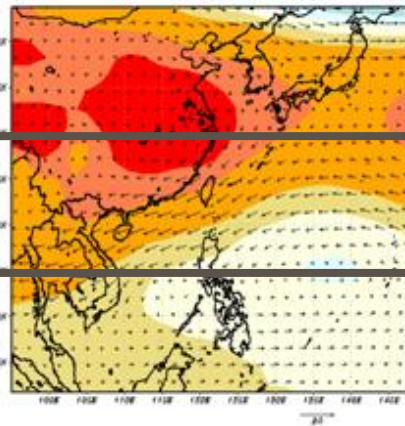
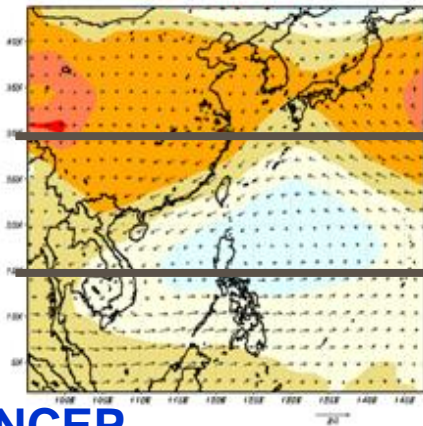
DEC

850hPa Height & Wind
(1979-2003) SEP, ECHAM5

850hPa Height & Wind
(1979-2003) OCT, ECHAM5

850hPa Height & Wind
(1979-2003) NOV, ECHAM5

850hPa Height & Wind
(1979-2003) DEC, ECHAM5



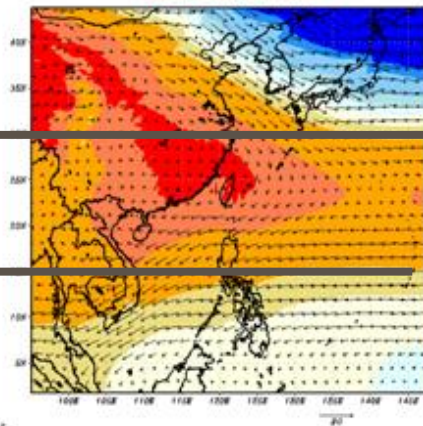
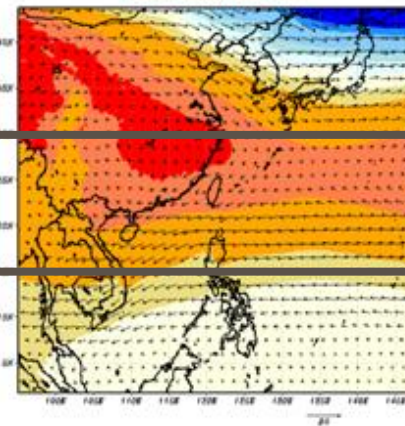
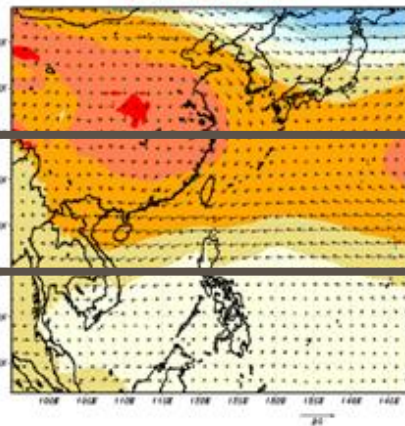
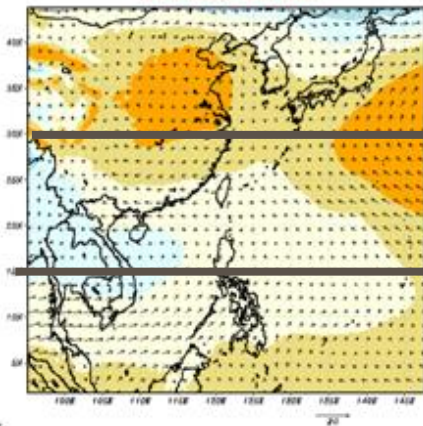
NCEP

850hPa Height & Wind
(1979-2003) SEP, NCEP

850hPa Height & Wind
(1979-2003) OCT, NCEP

850hPa Height & Wind
(1979-2003) NOV, NCEP

850hPa Height & Wind
(1979-2003) DEC, NCEP





Spatial Correlation coefficient with NCEP in Domain 1 (20C & A1B)

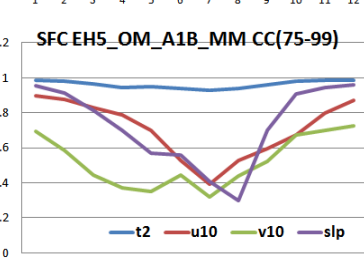
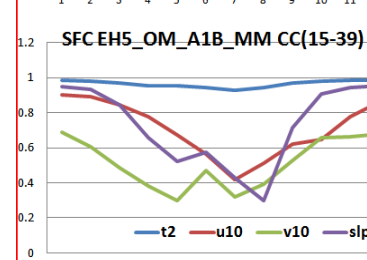
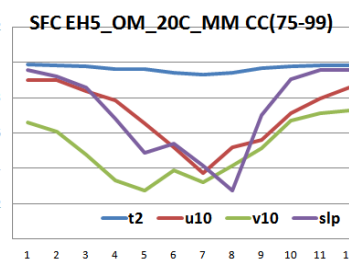
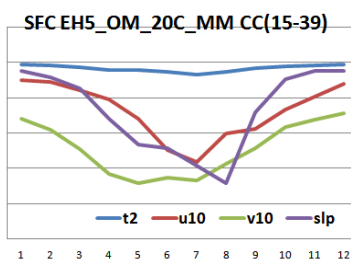
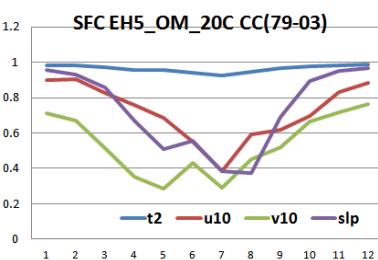
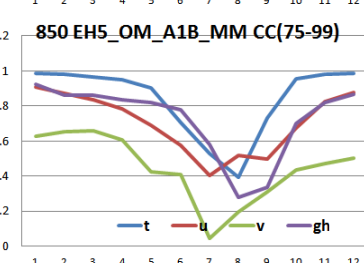
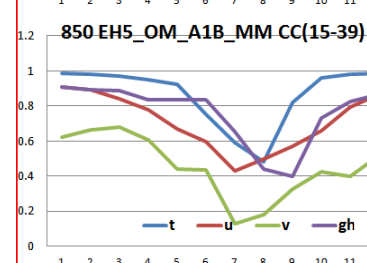
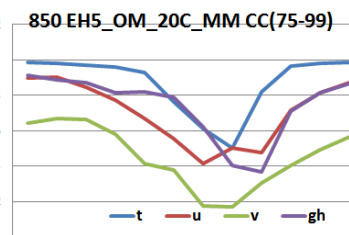
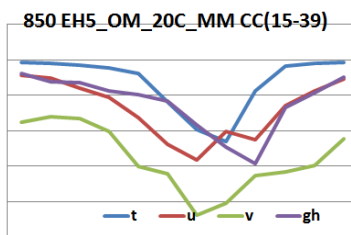
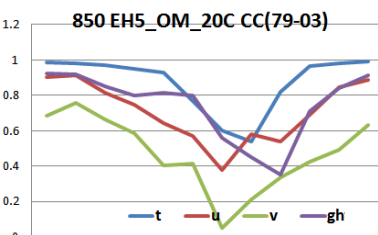
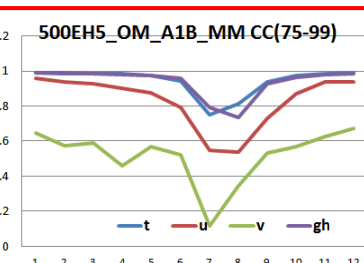
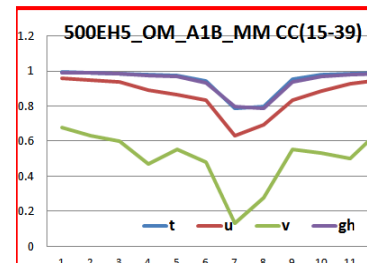
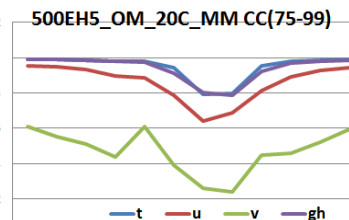
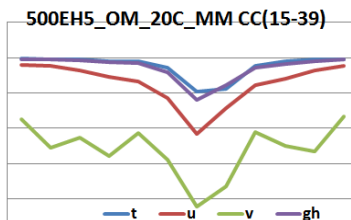
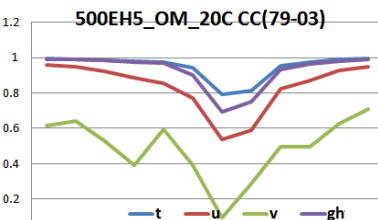
Present

Near Future

E21c

Near Future

E-21c



20C

A1B



Mean Error in domain1 (with NCEP)

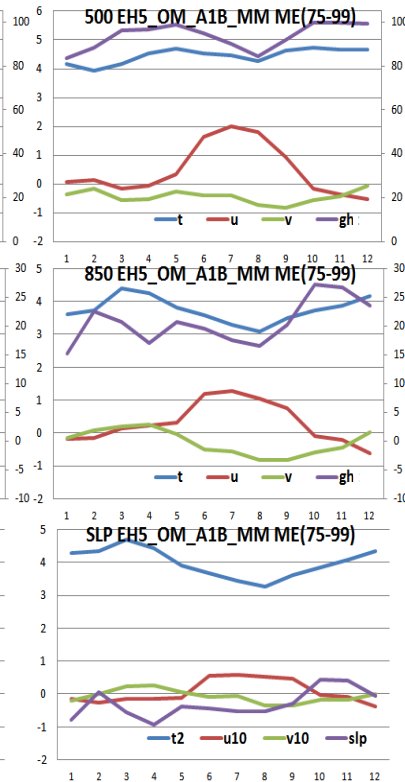
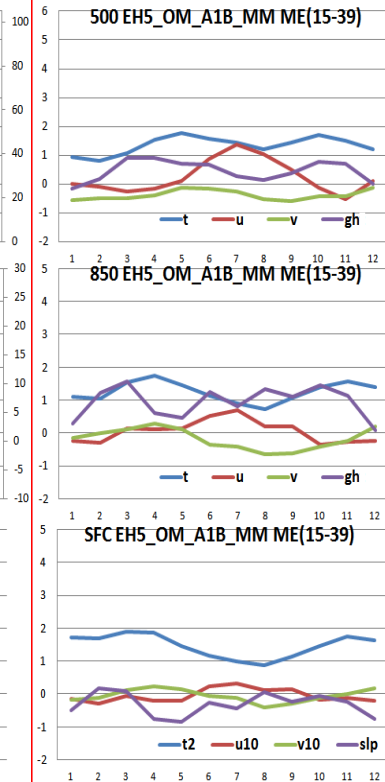
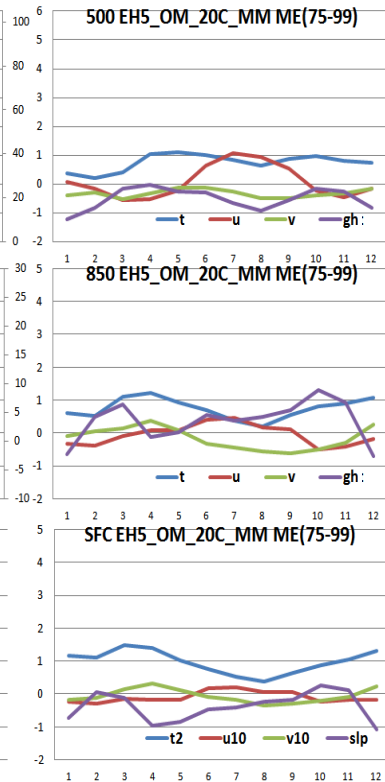
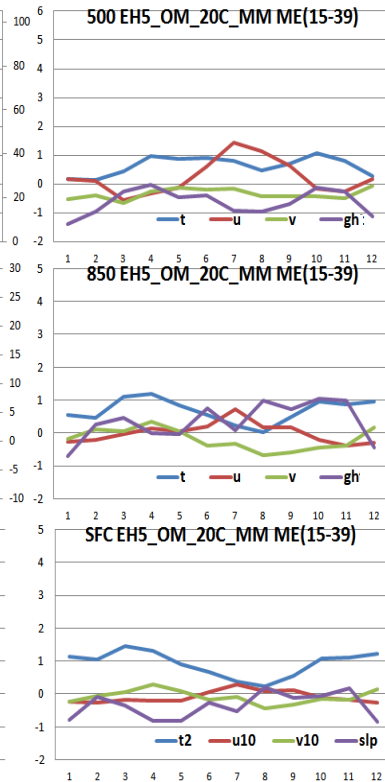
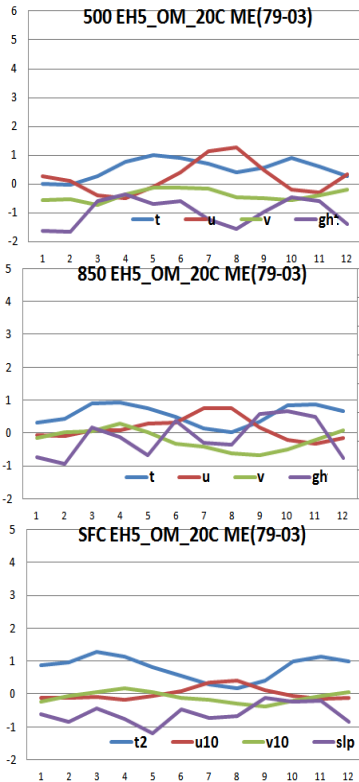
Present

Near Future

E-21c

Near Future

E-21c



20C

A1B



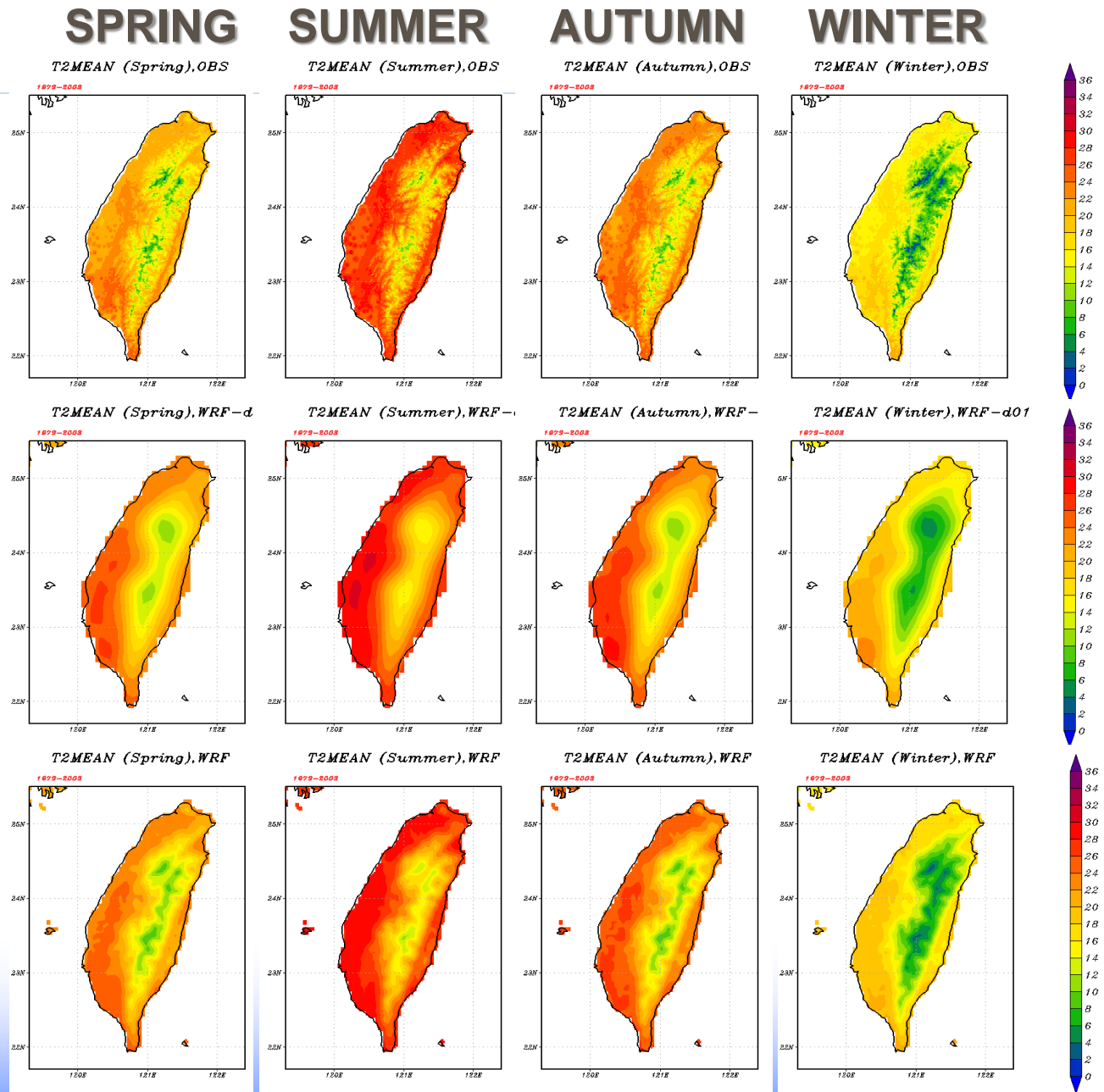
Temperature



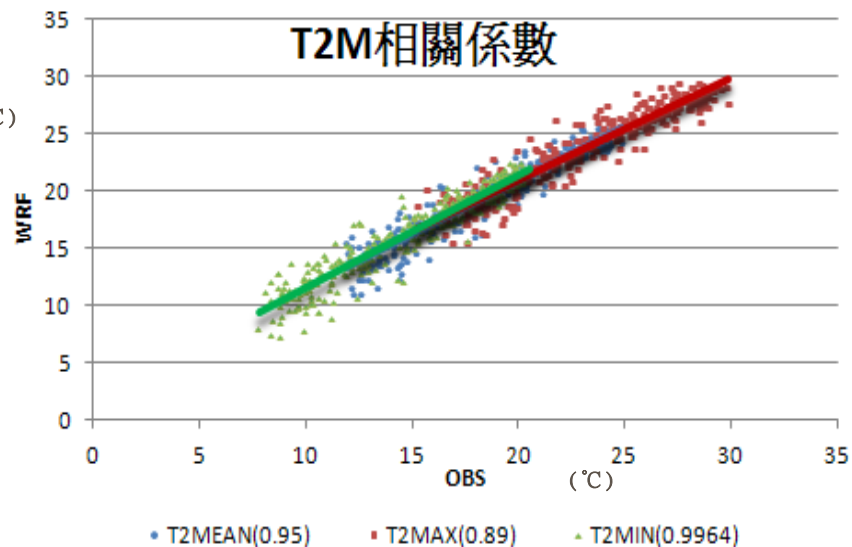
OBS(1979-2003)

**WRF-D1 (15 km)
(1979-2003)**

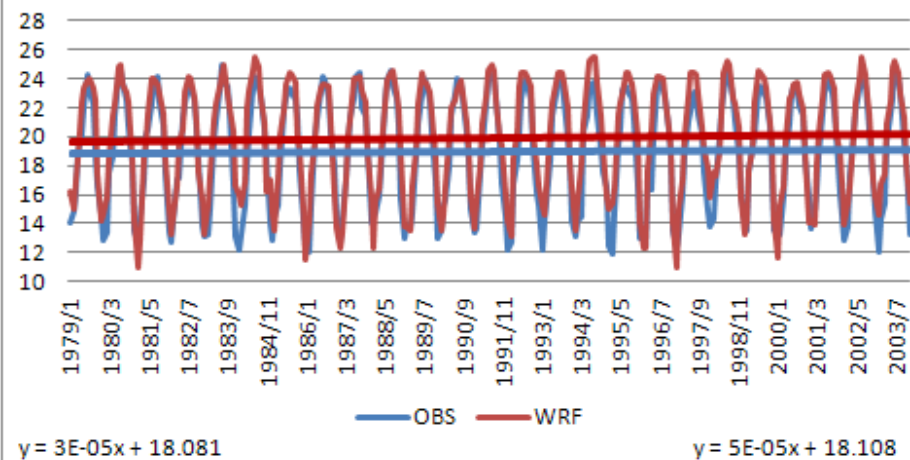
**WRF-D2 (5 Km)
(1979-2003)**



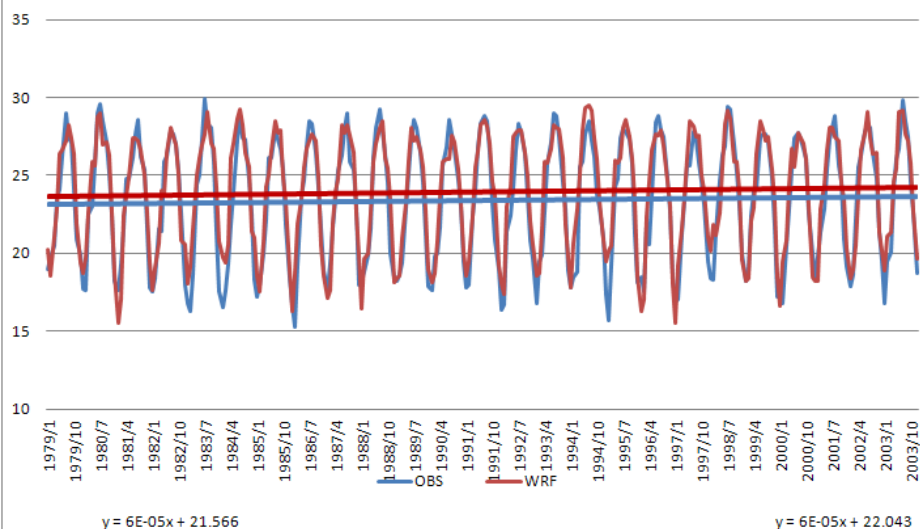
T2M相關係數



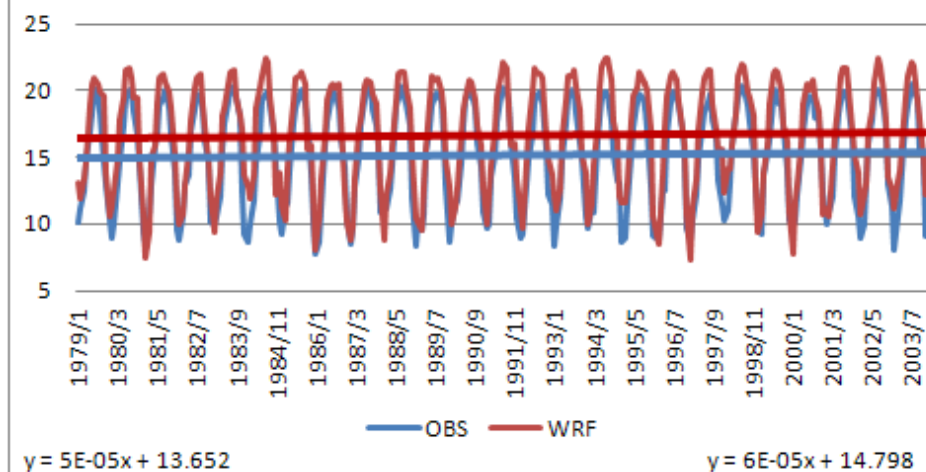
1979-2003 台灣溫度



1979-2003 最高溫度



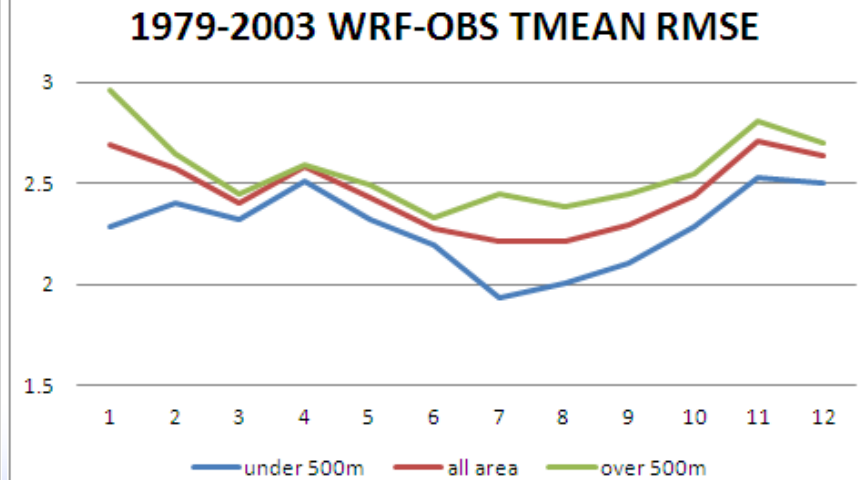
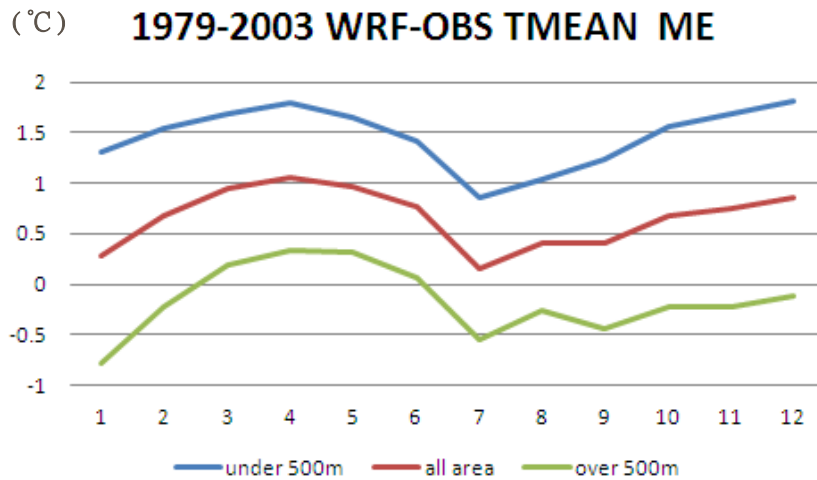
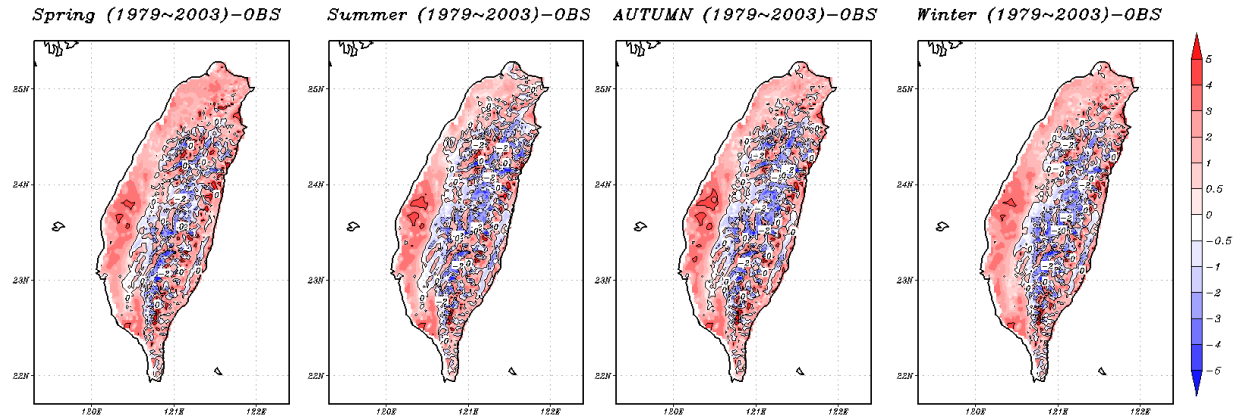
1979-2003 最低溫度





Temperature (WRF&OBS)

WRF(1979-2003)-OBS(tccip)





ECHAM5 downscaling: T2 differences

20C

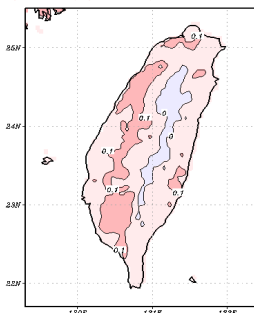
SPRING

SUMMER

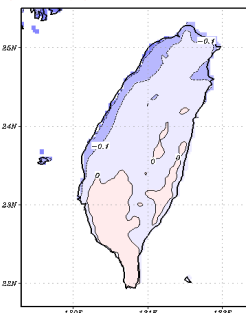
AUTUMN

WINTER

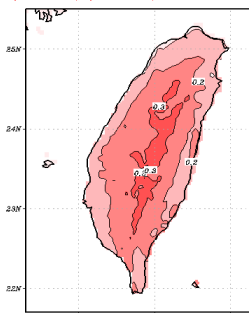
T2MEAN Change (Spring), WRI
(2016~2039)-(1979~2003)



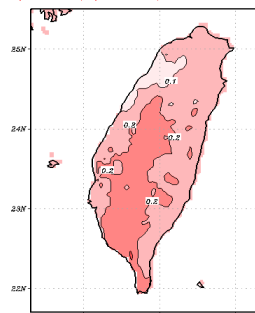
T2MEAN Change (Summer), WRI
(2016~2039)-(1979~2003)



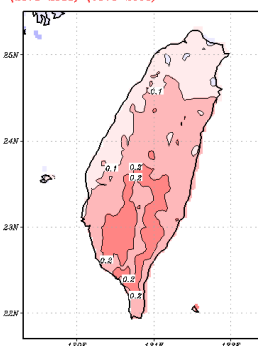
T2MEAN Change (Autumn), WRI
(2016~2039)-(1979~2003)



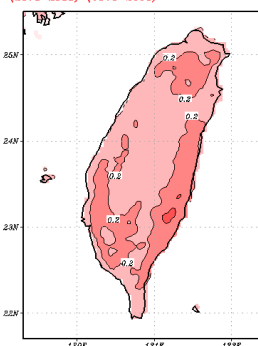
T2MEAN Change (Winter), WRI
(2016~2039)-(1979~2003)



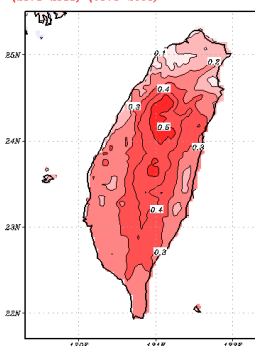
T2MEAN Change (Spring), WRI
(2076~2099)-(1979~2003)



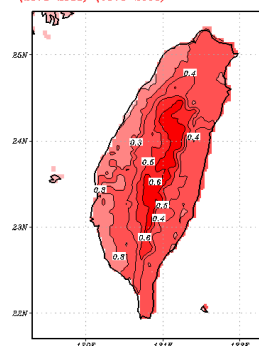
T2MEAN Change (Summer), WRI
(2076~2099)-(1979~2003)



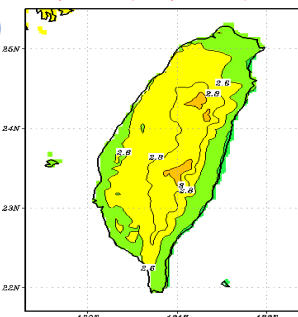
T2MEAN Change (Autumn), WRI
(2076~2099)-(1979~2003)



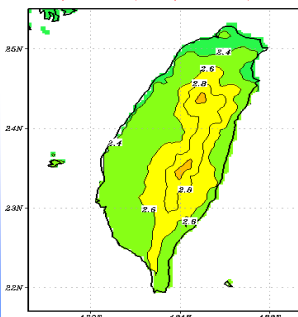
T2MEAN Change (Winter), WRI
(2076~2099)-(1979~2003)



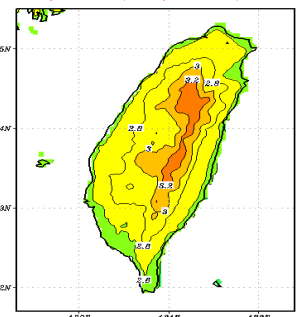
T2MEAN Change Spring(MAM)
A1B(2076~2082)-20C(1979~2003)



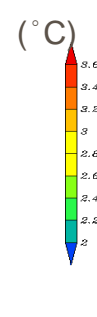
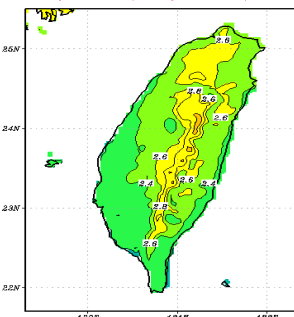
T2MEAN Change Summer(JJ)T2MEAN Change Autumn(SON)
A1B(2076~2082)-20C(1979~2003)



T2MEAN Change Autumn(SON)
A1B(2076~2082)-20C(1979~2003)



T2MEAN Change Winter(DJF), WRI
A1B(2076~2082)-20C(1979~2003)



Near Future
-Present

End 21c
-Present

A1B (2075-2082)

End21c-Present



ECHAM5-20C downscaling

T2 max differences

NF-present

E21c-present

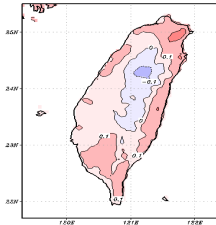
SPRING

SUMMER

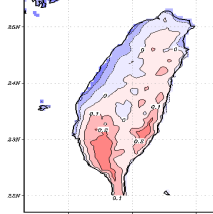
AUTUMN

WINTER

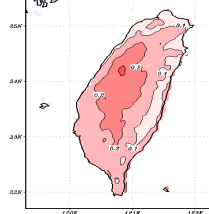
T2MAX Change (Spring), WRF
(2016-2038)-(1979-2003)



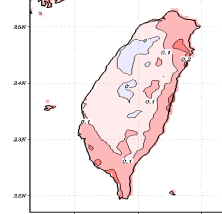
T2MAX Change (Summer), WRF
(2016-2038)-(1979-2003)



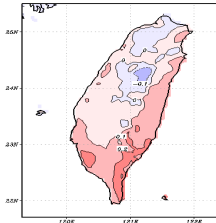
T2MAX Change (Autumn), WRF
(2016-2038)-(1979-2003)



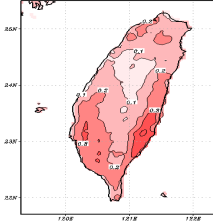
T2MAX Change (Winter), WRF
(2016-2038)-(1979-2003)



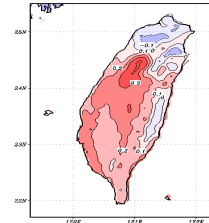
T2MAX Change (Spring), WRF
(2016-2038)-(1979-2003)



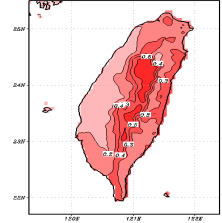
T2MAX Change (Summer), WRF
(2016-2038)-(1979-2003)



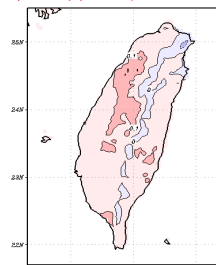
T2MAX Change (Autumn), WRF
(2016-2038)-(1979-2003)



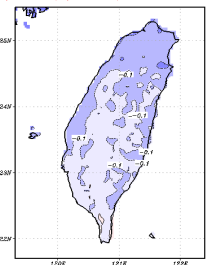
T2MAX Change (Winter), WRF
(2016-2038)-(1979-2003)



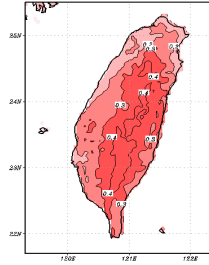
T2MIN Change (Spring), WRF
(2016-2038)-(1979-2003)



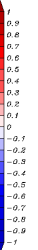
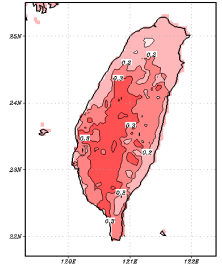
T2MIN Change (Summer), WRF
(2016-2038)-(1979-2003)



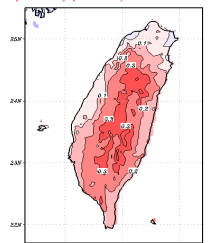
T2MIN Change (Autumn), WRF
(2016-2038)-(1979-2003)



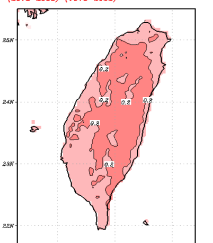
T2MIN Change (Winter), WRF
(2016-2038)-(1979-2003)



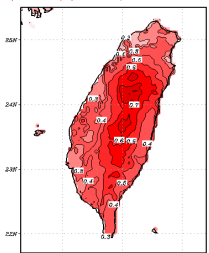
T2MIN Change (Spring), WRF
(2016-2038)-(1979-2003)



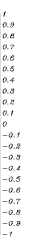
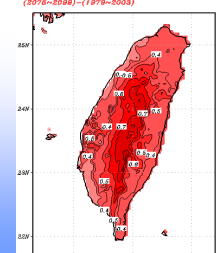
T2MIN Change (Summer), WRF
(2016-2038)-(1979-2003)



T2MIN Change (Autumn), WRF
(2016-2038)-(1979-2003)



T2MIN Change (Winter), WRF
(2016-2038)-(1979-2003)



T2 min differences

NF-present

E21c-present



Precipitation



SPRING

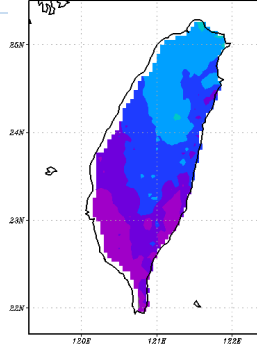
MEIYU

SUMMER

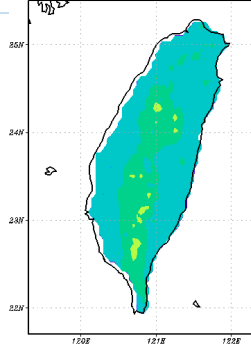
AUTUMN

WINTER

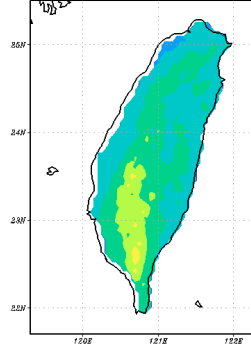
Average Precip (mm/day)
1979-2003 Spring(FMA), OBS



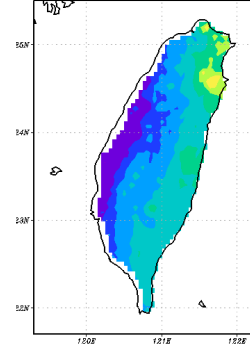
Average Precip (mm/day)
1979-2003 MJ, OBS



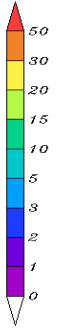
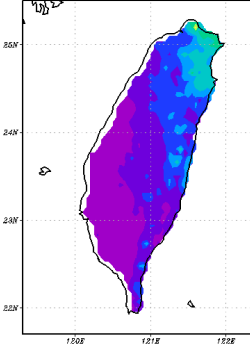
Average Precip (mm/day)
1979-2003 Summer(JA), OBS



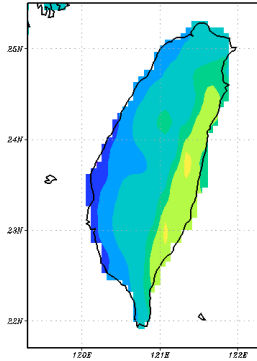
Average Precip (mm/day)
1979-2003 Autumn(SON), OBS



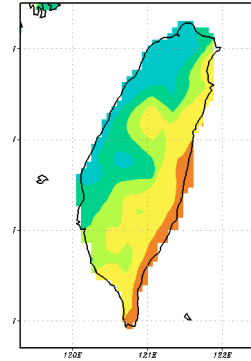
Average Precip (mm/day)
1979-2003 Winter(DJ), OBS



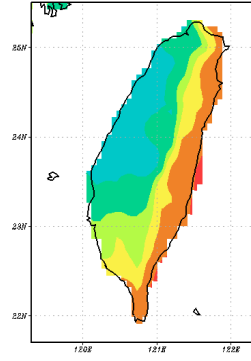
Average Precip (mm/day)
1979-2003 Spring(FMA), WRF-d01



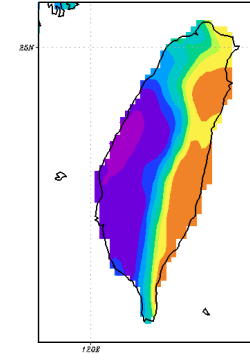
Average Precip (mm/day) & W_{et}
1979-2003 MEIYU, WRF-d01



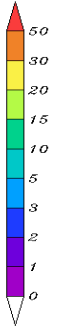
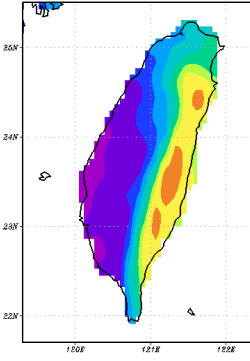
Average Precip (mm/day)
1979-2003 Summer(JA), WRF-d01



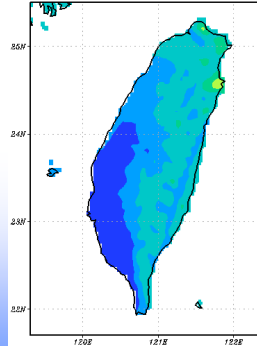
Average Precip (mm/day)
1979-2003 Autumn(SON), WRF-d01



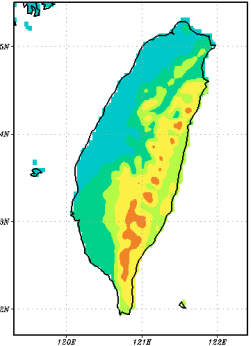
Average Precip (mm/day)
1979-2003 Winter(DJ), WRF-d01



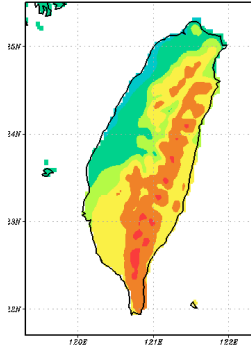
Average Precip (mm/day)
1979-2003 Spring(FMA), WRF



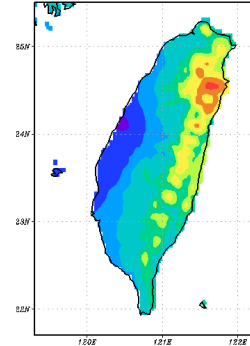
Average Precip (mm/day)
1979-2003 MJ, WRF



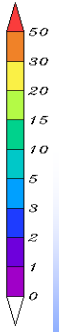
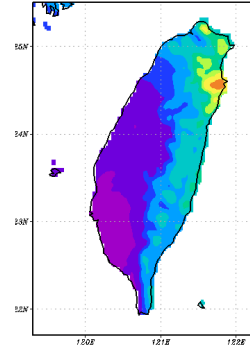
Average Precip (mm/day)
1979-2003 Summer(JA), WRF



Average Precip (mm/day)
1979-2003 Autumn(SON), WRF



Average Precip (mm/day)
1979-2003 Winter(DJ), WRF



OBS(1979-
2003)

WRF-D01
(1979-2003)

WRF Do2
(1979-2003)



WRF & TCCIP OBS differences (1979-2003)

SPRING

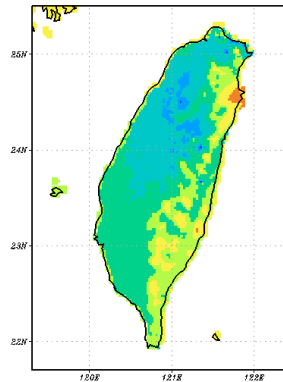
MEIYU

SUMMER

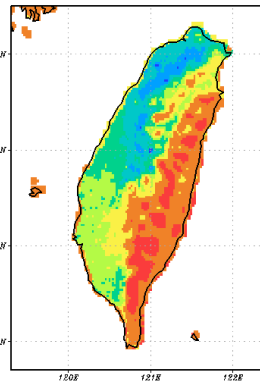
AUTUMN

WINTER

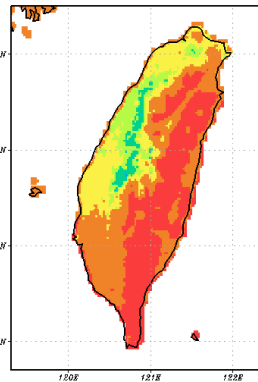
WRF-TCCIP ME SPRING
1979-2003



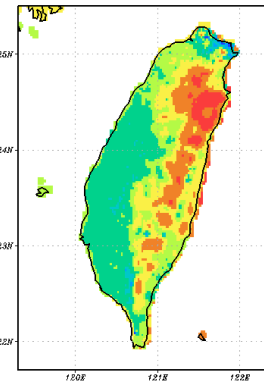
WRF-TCCIP ME MEIYU
1979-2003



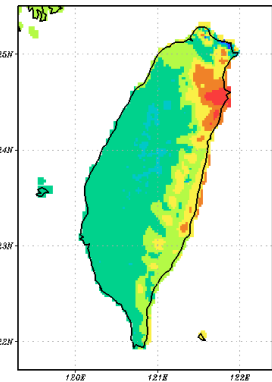
WRF-TCCIP ME SUMMER
1979-2003



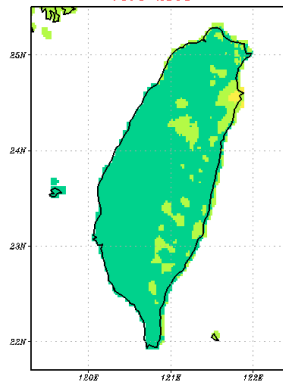
WRF-TCCIP ME AUTUMN
1979-2003



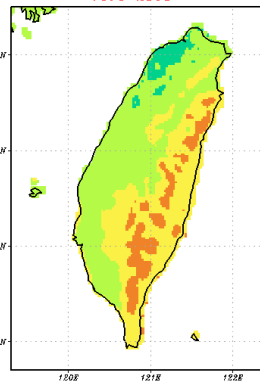
WRF-TCCIP ME WINTER
1979-2003



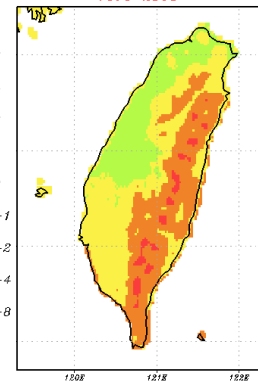
WRF-TCCIP RMSE SPRING
1979-2003



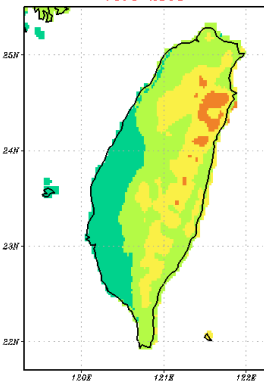
WRF-TCCIP RMSE MEIYU
1979-2003



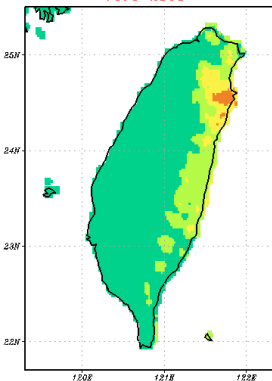
WRF-TCCIP RMSE SUMMER
1979-2003



WRF-TCCIP RMSE AUTUMN
1979-2003



WRF-TCCIP RMSE WINTER
1979-2003



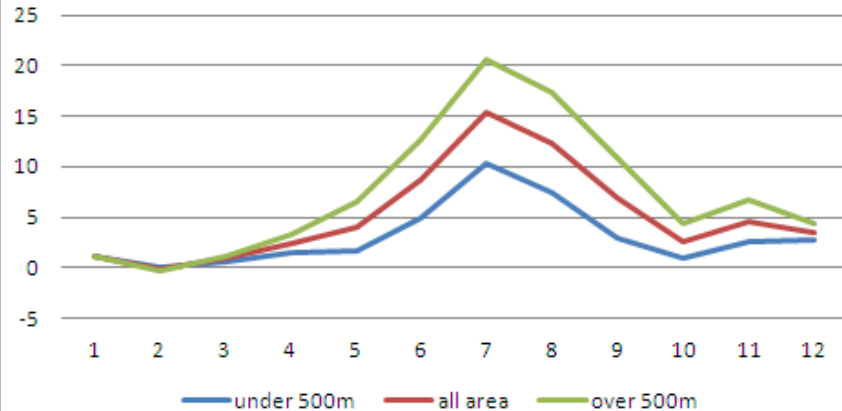
MEAN
ERROR

RMSE

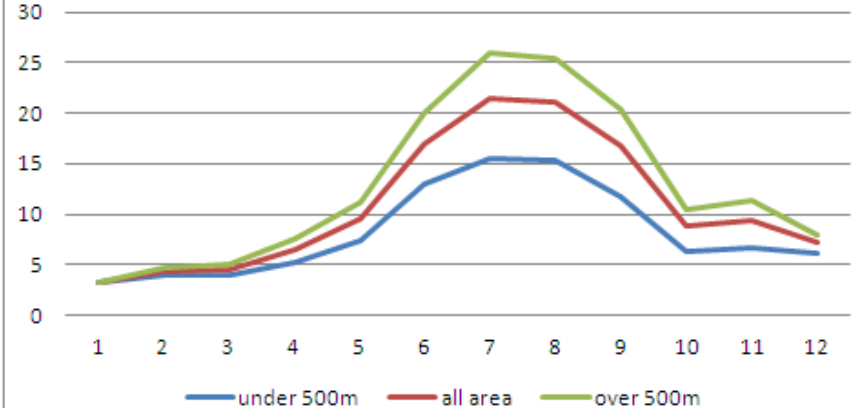


Precipitation, WRF& OBS

1979-2003 WRF-OBS RAIN ME



1979-2003 WRF-OBS RAIN RMSE

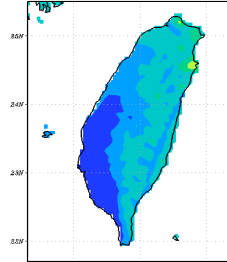




WRF Prediction differences

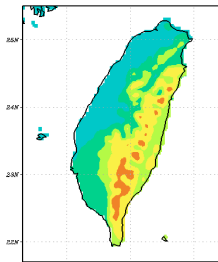
SPRING

Average Precip (mm/day)
1979-2003 Spring(FMA) . WRF



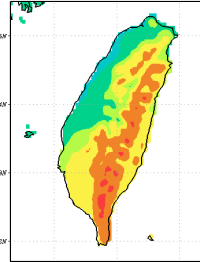
MEIYU

Average Precip (mm/day)
1979-2003 MJ . WRF



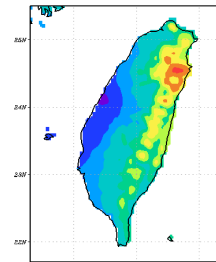
SUMMER

Average Precip (mm/day)
1979-2003 Summer(JA) . WRF



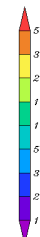
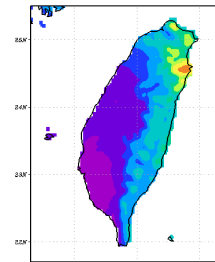
AUTUMN

Average Precip (mm/day)
1979-2003 Autumn(SON) . WRF

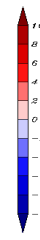
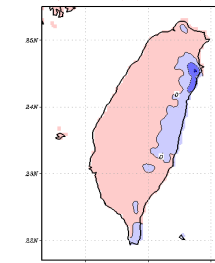
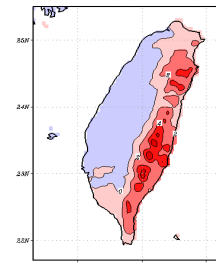
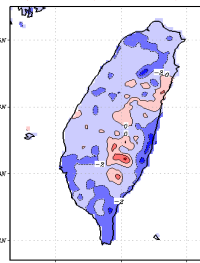
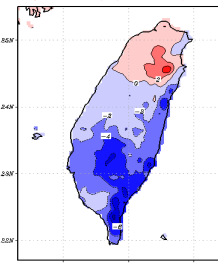
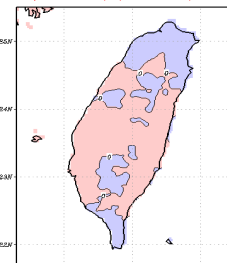


WINTER

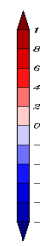
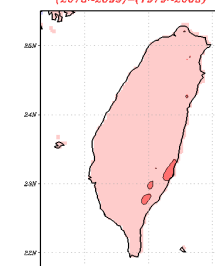
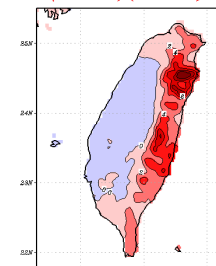
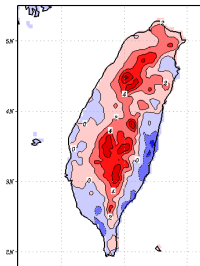
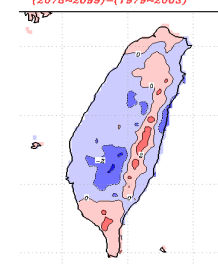
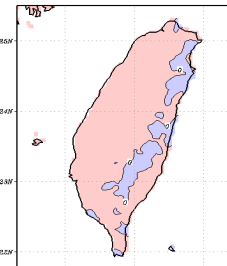
Average Precip (mm/day)
1979-2003 Winter(DJ) . WRF



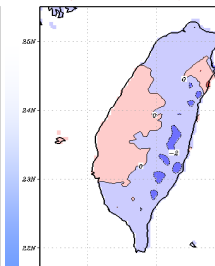
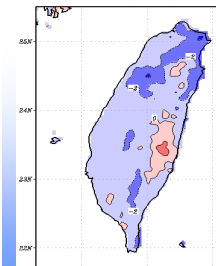
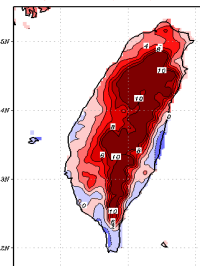
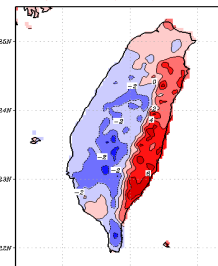
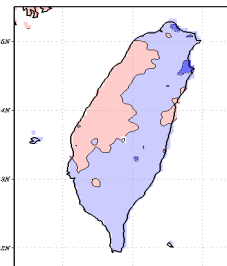
SPRING rainfall difference, WRF (2016-2039)-(1979-2003) MEIYU rainfall difference, WRF (2016-2039)-(1979-2003) SUMMER rainfall difference, WRF (2016-2039)-(1979-2003) AUTUMN rainfall difference, WRF (2016-2039)-(1979-2003) WINTER rainfall difference, WRF (2016-2039)-(1979-2003)



SPRING rainfall difference, WRF (2075-2082)-(1979-2003) MEIYU rainfall difference, WRF (2075-2082)-(1979-2003) SUMMER rainfall difference, WRF (2075-2082)-(1979-2003) AUTUMN rainfall difference, WRF (2075-2082)-(1979-2003) WINTER rainfall difference, WRF (2075-2082)-(1979-2003)



SPRING rainfall difference, A1B (2075-2082)-20C(1979-2003) MEIYU rainfall difference, A1B (2075-2082)-20C(1979-2003) SUMMER rainfall difference, A1B (2075-2082)-20C(1979-2003) AUTUMN rainfall difference, A1B (2075-2082)-20C(1979-2003) WINTER rainfall difference, A1B (2075-2082)-20C(1979-2003)



WRF(1979-2003)

Near Future-
Present

End 21c-Present

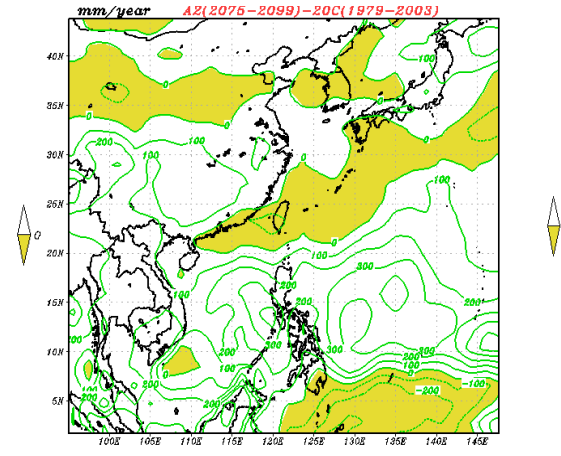
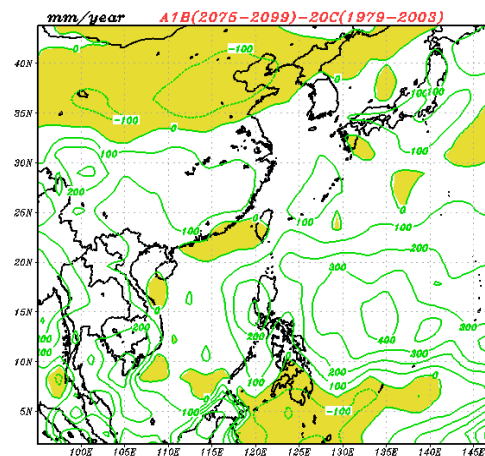
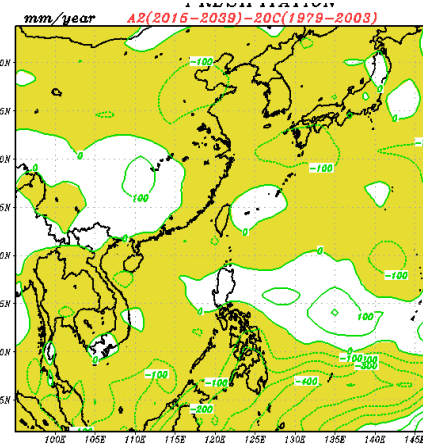
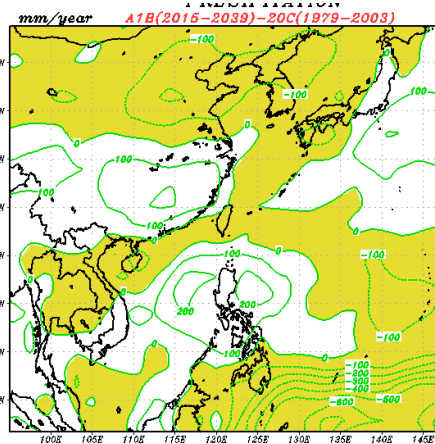
A1B (2075-2082)
End21c-Present



ECHAM5 (A1B, A2) precipitation

A1B

A2

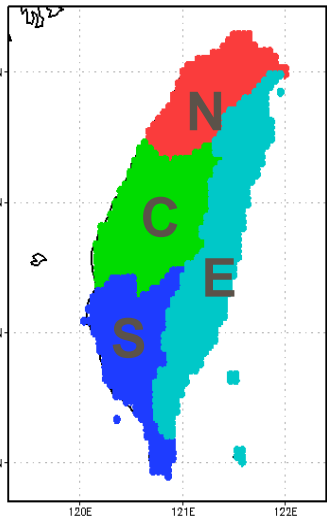
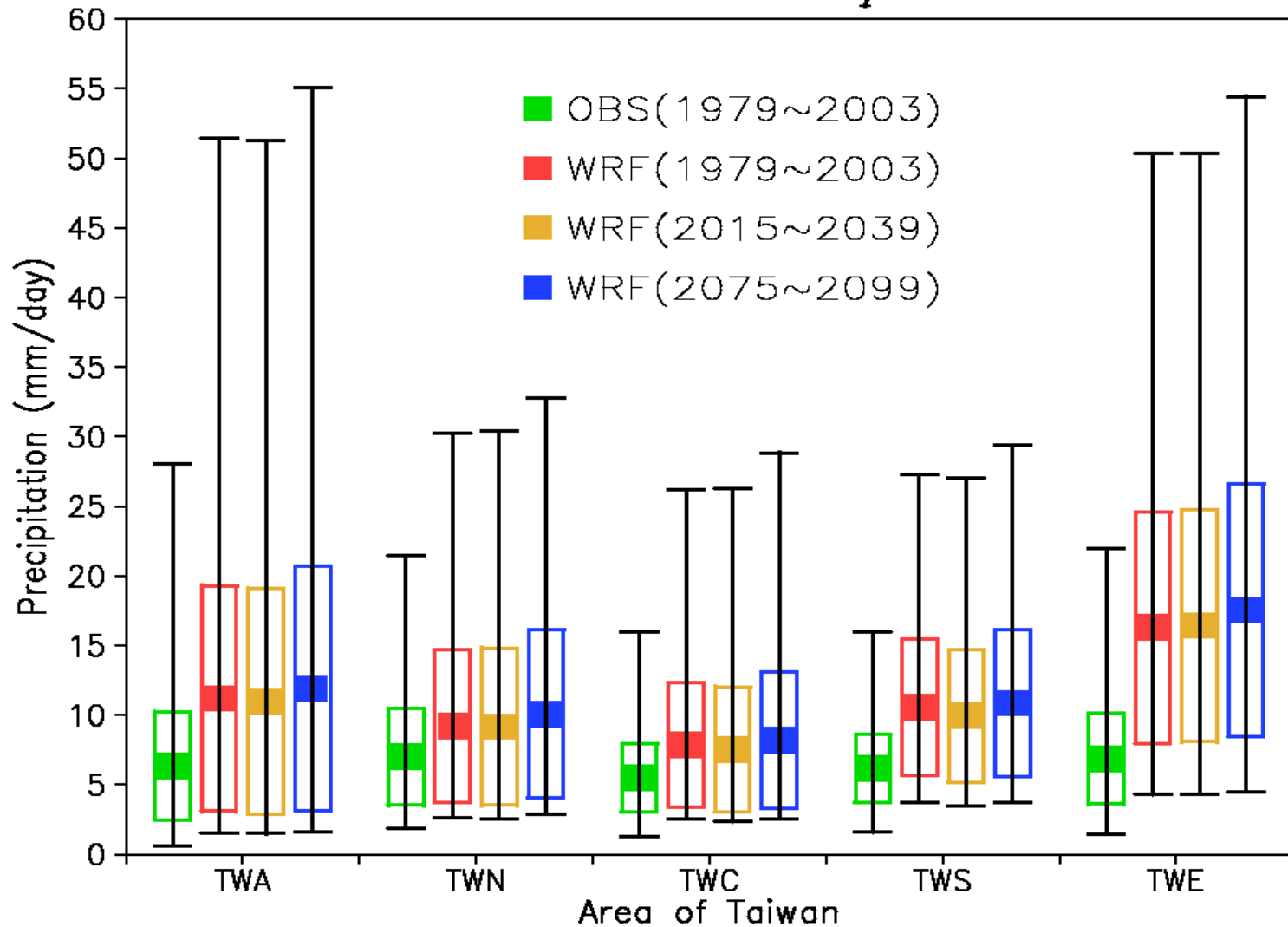


Near Future-present

End21C-present

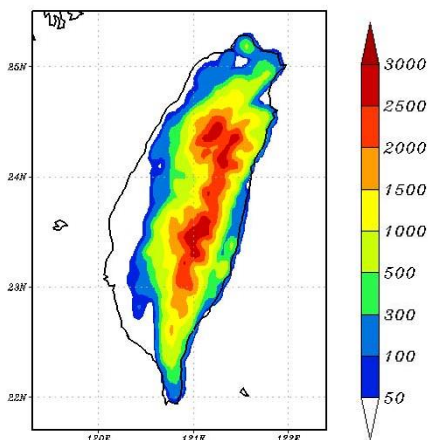


25-Year Mean Precipitation

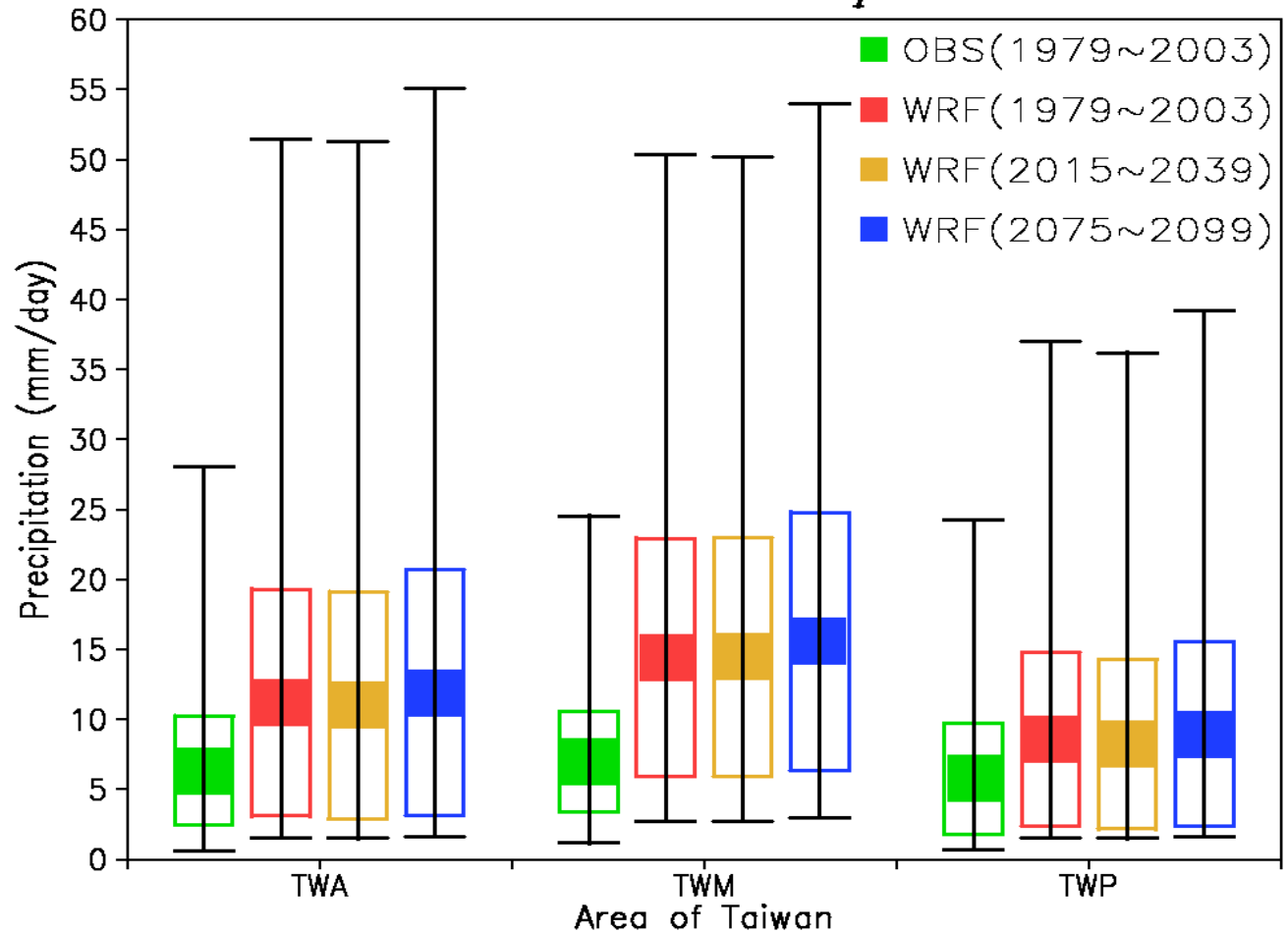




WRF domain2 Terrain Height(m)

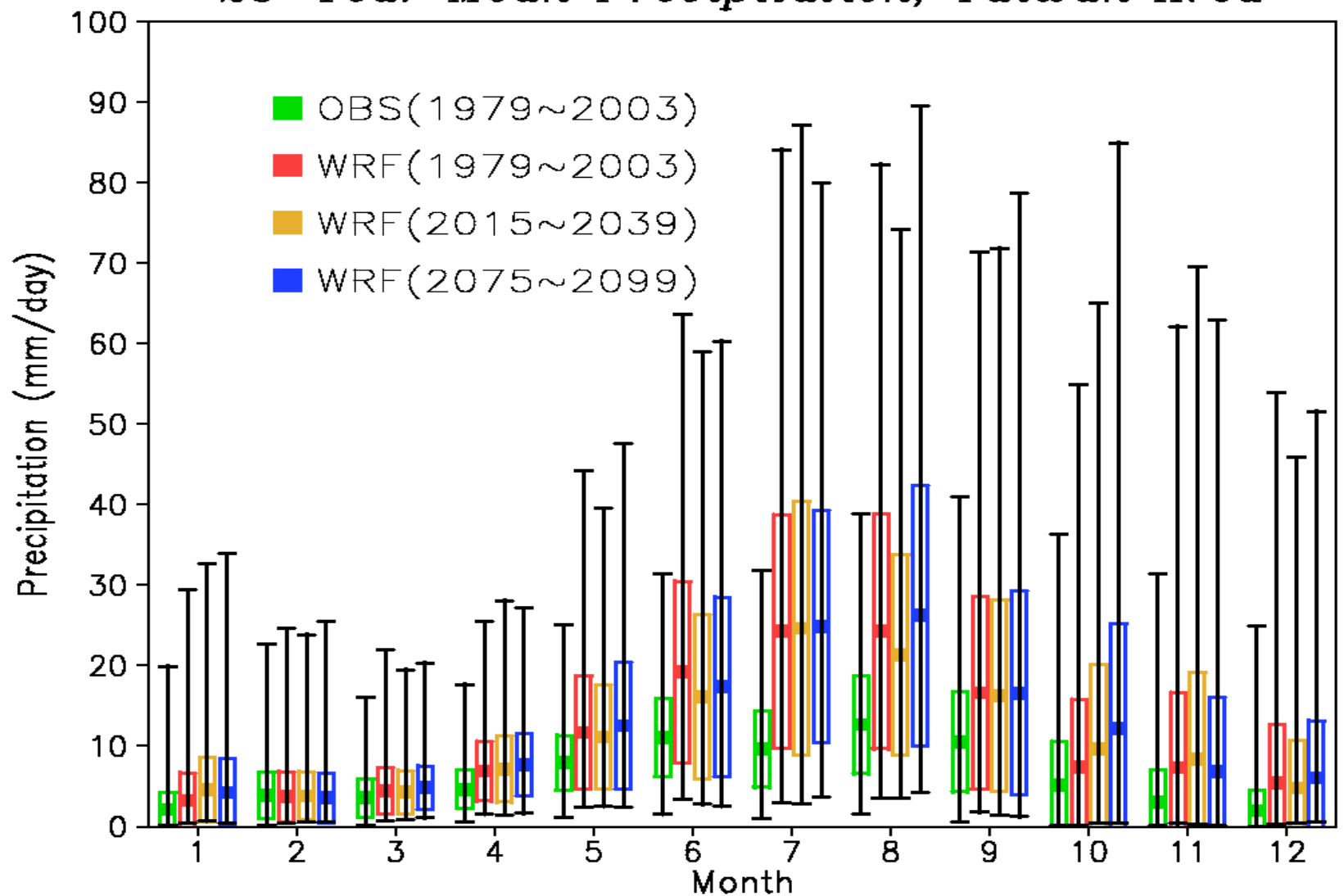


25-Year Mean Precipitation





25-Year Mean Precipitation, Taiwan Area





Summary and ongoing study

- Characteristics of ECHAM5 simulation over East Asia:
 1. Pacific high ridge shifted northward between Jun. and Sep., especially in July about 10 degree.
 2. Scenario A1B has a similar spatial correlation coefficient with run 20c in T,u,v and h. However, A1B scenario indicates global warming will significantly impact on T, geopotential height and u- component.
- Temperature:

In general, ECHAM5 predicted well about air temperature over Taiwan. T2 min has an increase trend and greater than T2 max increase.
- Precipitation:

Precipitation overestimate over mountain area and eastern Taiwan, especially in summer season.
- Ongoing : A1B Scenario, A2 Scenario





Scenario 20C and A1B

SPRING

MEIYU

SUMMER

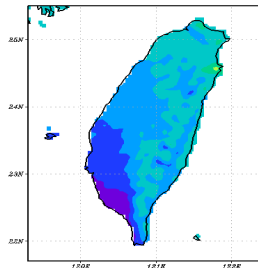
AUTUMN

WINTER

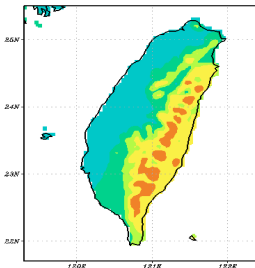
A1B

(2075-2082)

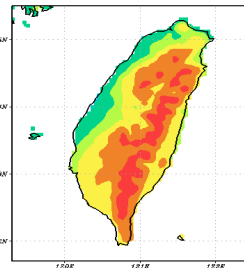
Average Precip (mm/day)
2075-2082 Spring(FMA), WRF



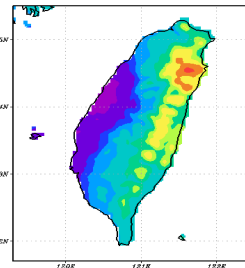
Average Precip (mm/day)
2075-2082 MEIYU(MJ), WRF



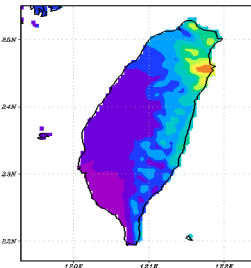
Average Precip (mm/day)
2075-2082 Summer(JA), WRF



Average Precip (mm/day)
2075-2082 Autumn(SON), WRF



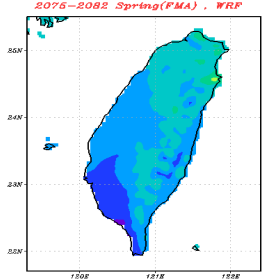
Average Precip (mm/day)
2075-2082 Winter(JD), WRF



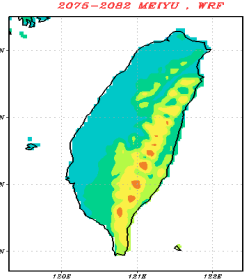
20C

(2075-2082)

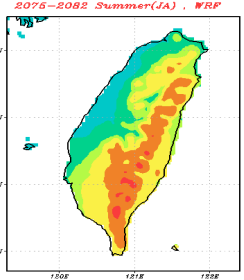
Average Precip (mm/day)
2075-2082 Spring(FMA), WRF



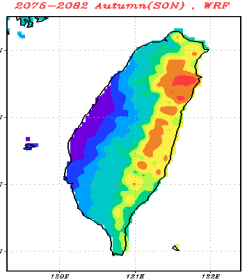
Average Precip (mm/day)
2075-2082 MEIYU(MJ), WRF



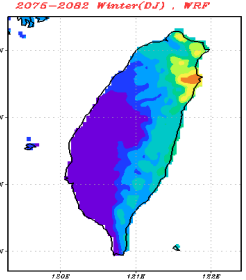
Average Precip (mm/day)
2075-2082 Summer(JA), WRF



Average Precip (mm/day)
2075-2082 Autumn(SON), WRF



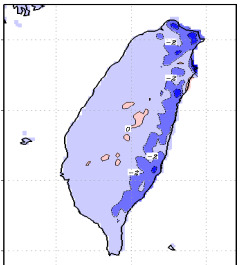
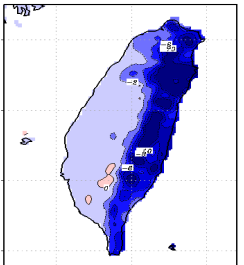
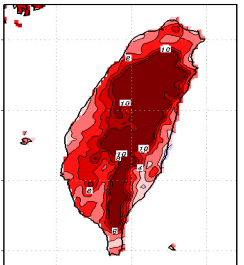
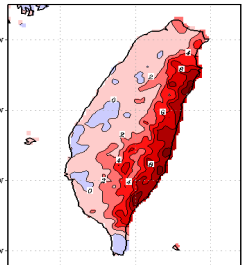
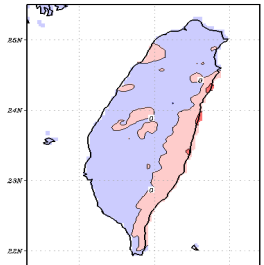
Average Precip (mm/day)
2075-2082 Winter(JD), WRF



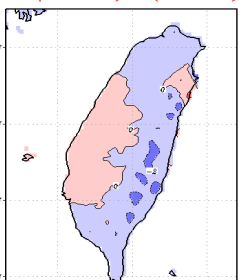
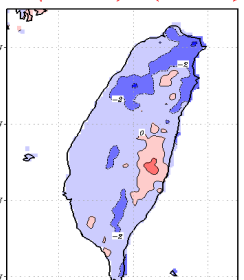
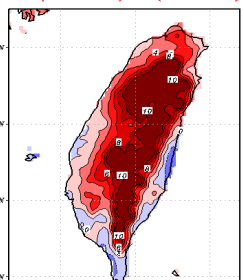
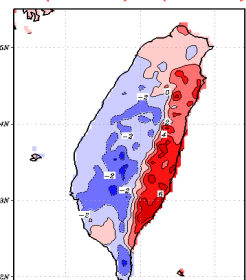
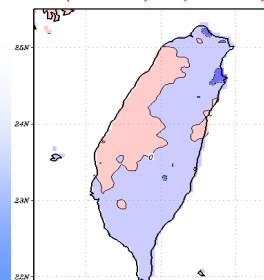
A1B-20C

(2075-2082)

SPRING rainfall difference, W. MEIYU rainfall difference, W. SUMMER rainfall difference, AUTUMN rainfall difference, WINTER rainfall difference, WRF
A1B-20C



SPRING rainfall difference, W. MEIYU rainfall difference, W. SUMMER rainfall difference, AUTUMN rainfall difference, WINTER rainfall difference, WRF
A1B(2075-2082)-20C(1979-2003)



A1B

End21c-Present