Future warming scenario and impacts study over Taiwan: Results from ECHAM5/MPIOM-WRF dynamical downscaling

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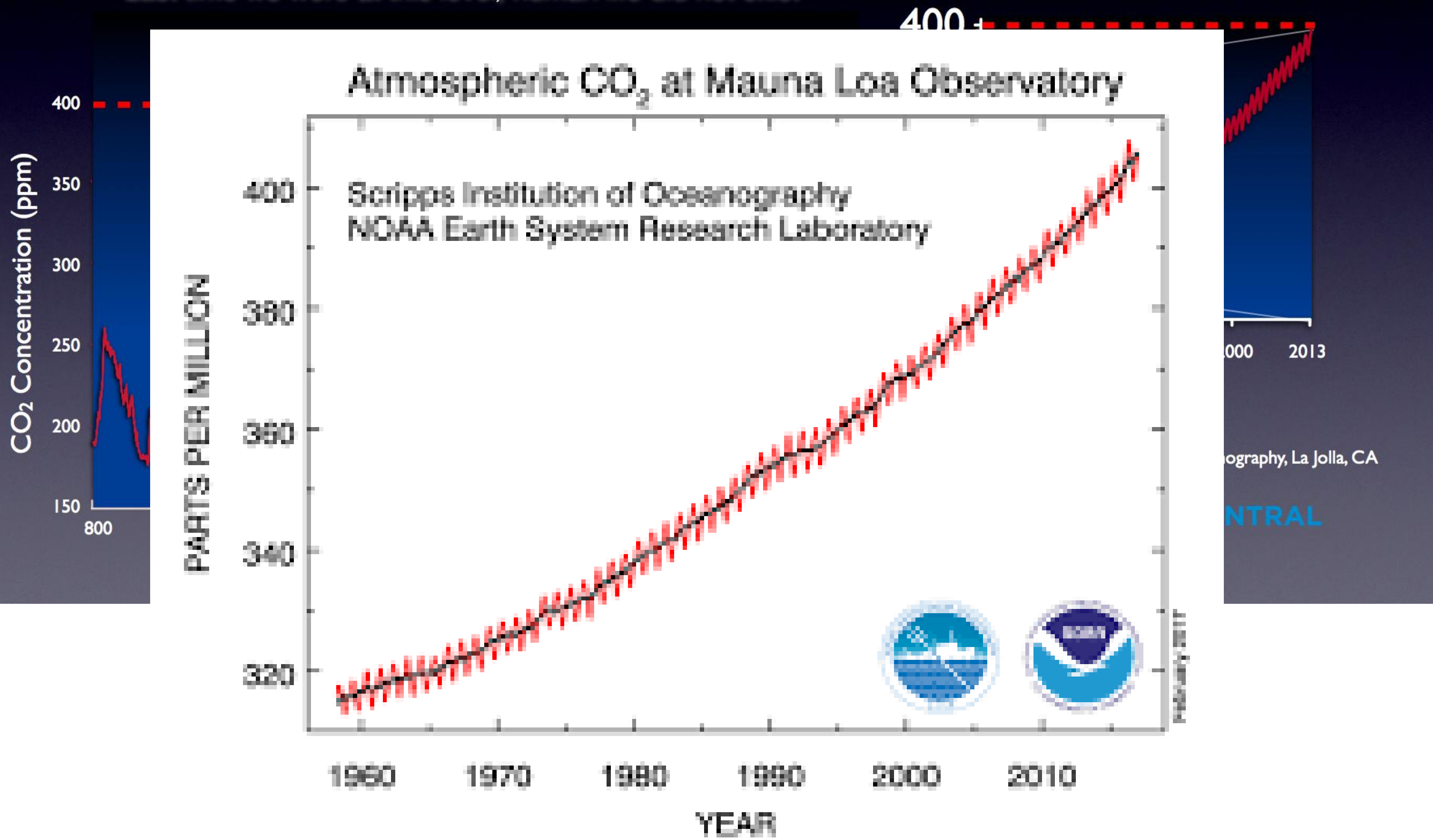
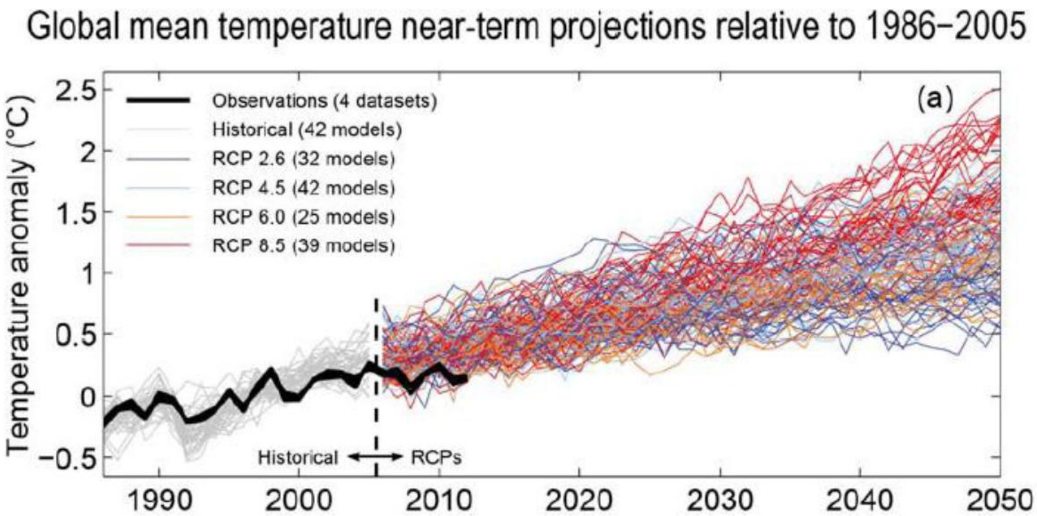
10 March, 2017 ISGC

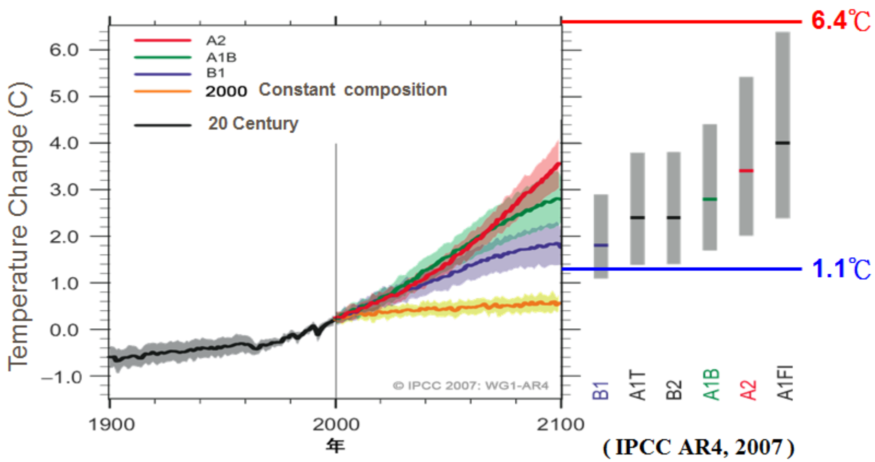
CO_2 400 PPM MILESTONE

- Long-lived, heat-trapping gas
- Hit 400 ppm this month during annual May peak
- Last time we were at this level, human life did not exist

1958 - Present







(IPCC AR4, 2007)

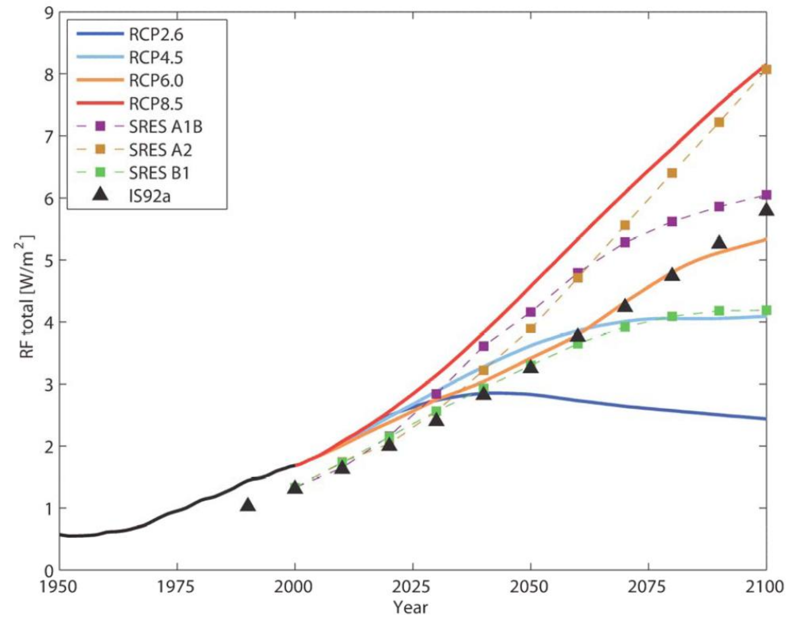


Figure 1.15: Historical and projected total anthropogenic RF (W m^{-2}) relative to preindustrial (~1765) between 1950 and 2100. Previous IPCC assessments (SAR IS92a, TAR/AR4 SRES A1B, A2 and B1) are compared with representative concentration pathway (RCP) scenarios (see Chapter 12 and Box 1.1 for their extensions until 2300 and Annex II for the values shown here). The total RF of the three families of scenarios, IS92, SRES and RCP, differ for example for the year 2000, resulting from the knowledge about the emissions assumed having changed since the TAR and AR4.

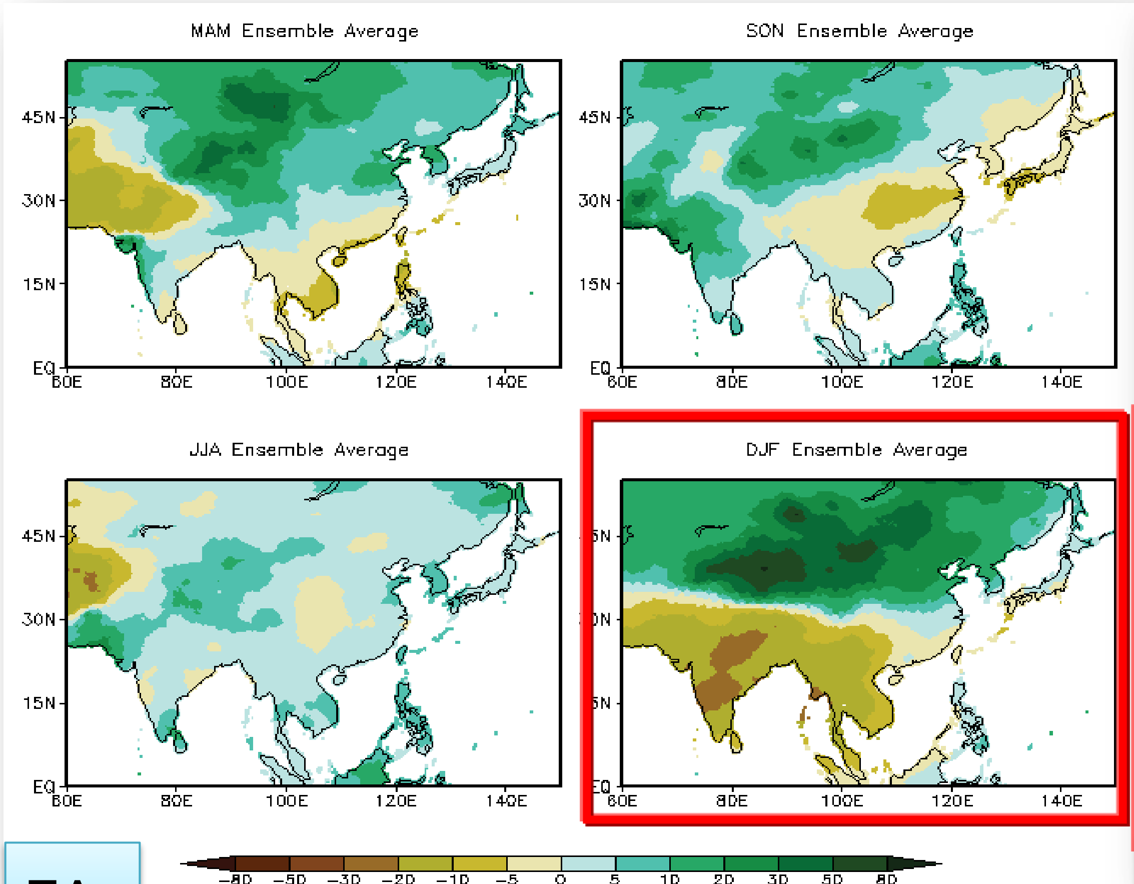
	Global mean warming (°C)			
	2011–2030	2046–2065	2080–2099	2180–2199
A2	0.64	1.65	3.13	
A1B	0.69	1.75	2.65	3.36
B1	0.66	1.29	1.79	2.10
Commit[a]	0.37	0.47	0.56	

B1: 1.1~2.9 ℃

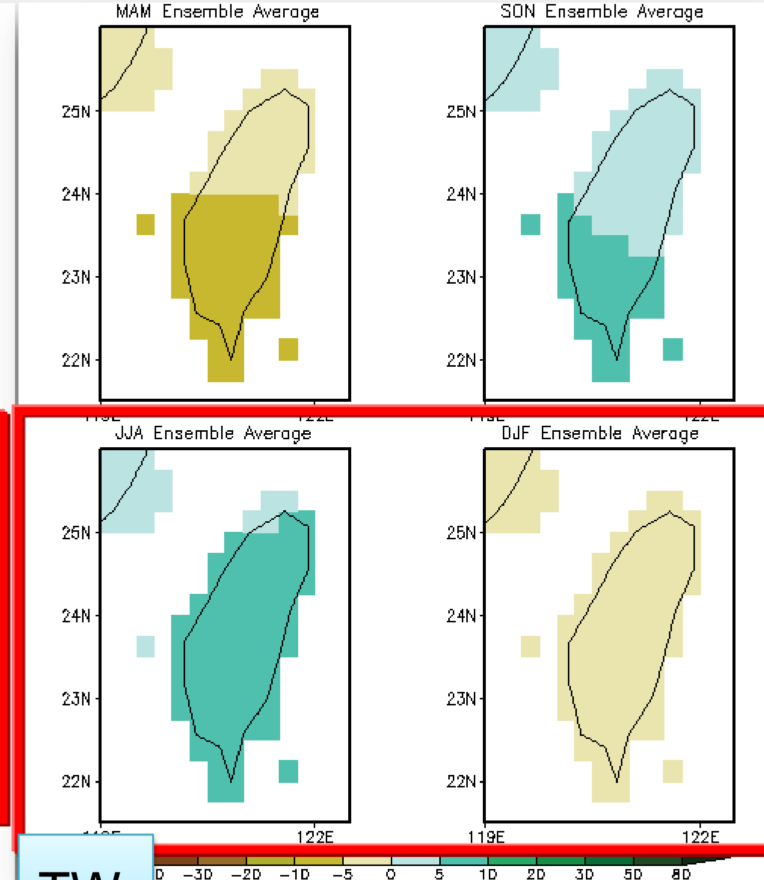
A1F1: 2.4~6.4 ℃

Statistical Downscaling

Change rate of projected monthly rainfall climatology (2020~2039) A1B



EA

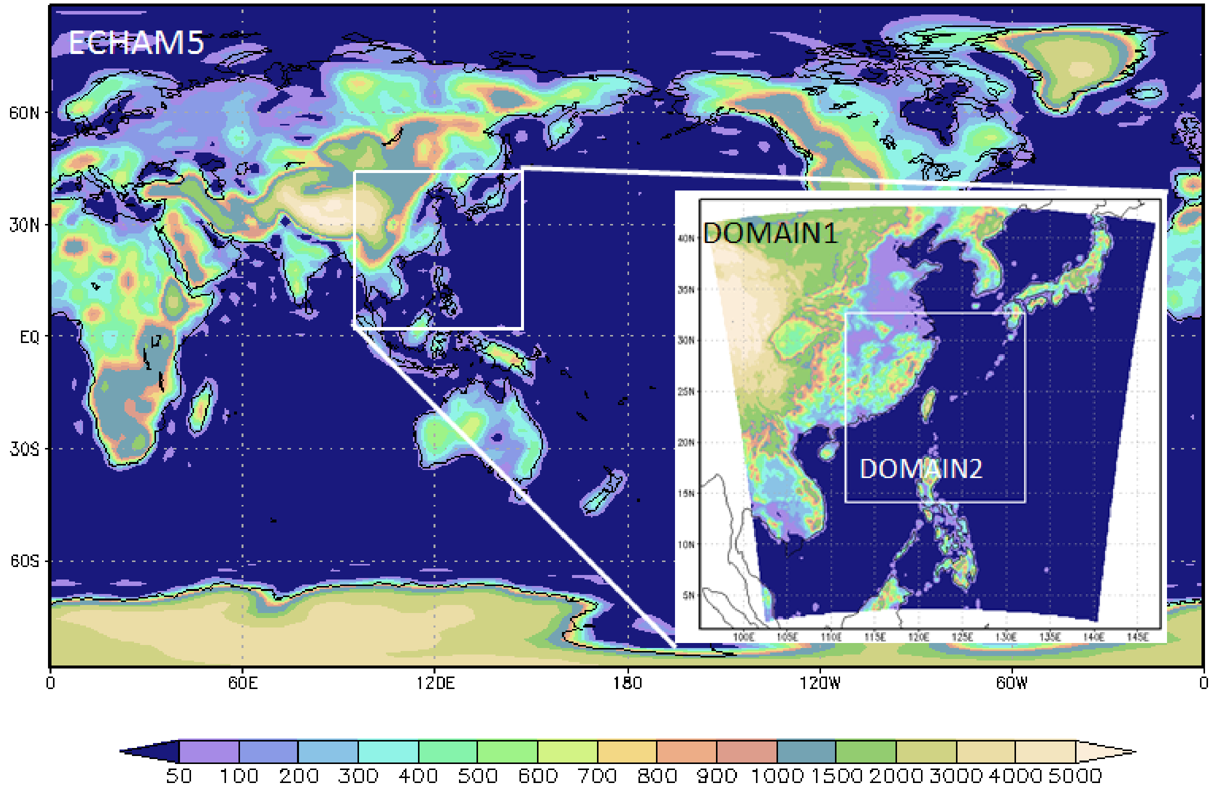


TW

1. Increasing rainfall is expected for most of EA in general
2. Decreasing rainfall is found in mid-China and Japan
3. change of rainfall is evident in Winter

1. Decreasing in DJF and MAM
2. Increasing in JJA and SON

ECHAM5-WRF dynamical downscaling



ECHAM5: domain:192x96 Δx=1.875 degree

WRF:

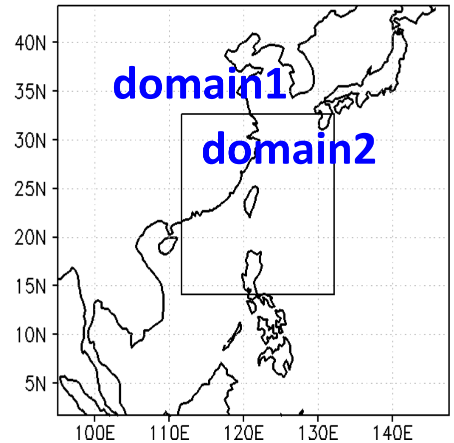
Domain1 : 301x301 Δx,y=15km FDDA

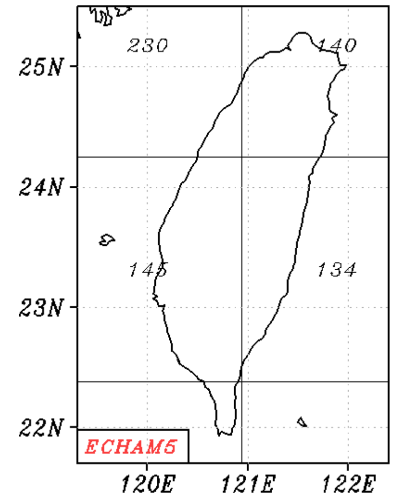
Domain2 : 382x400 Δx,y=5km, vertical 45 levels

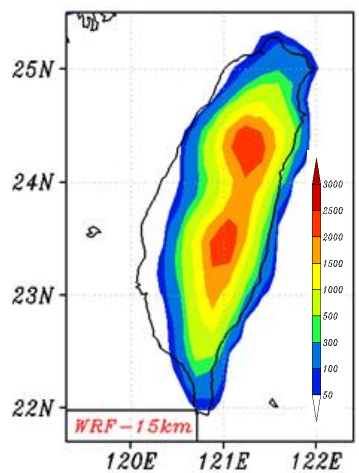
75 years simulation:

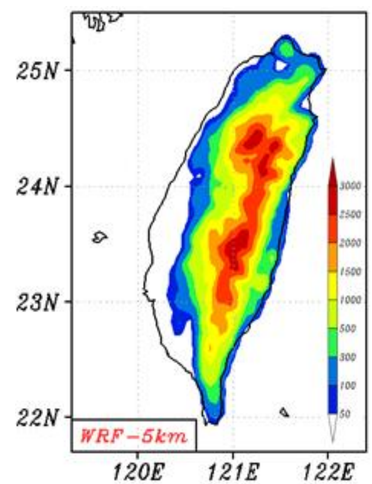
1979-2003; 2015-2039; 2075-2099

Why Dynamic downscaling ?









Why 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

Model evaluation (1979-2003)

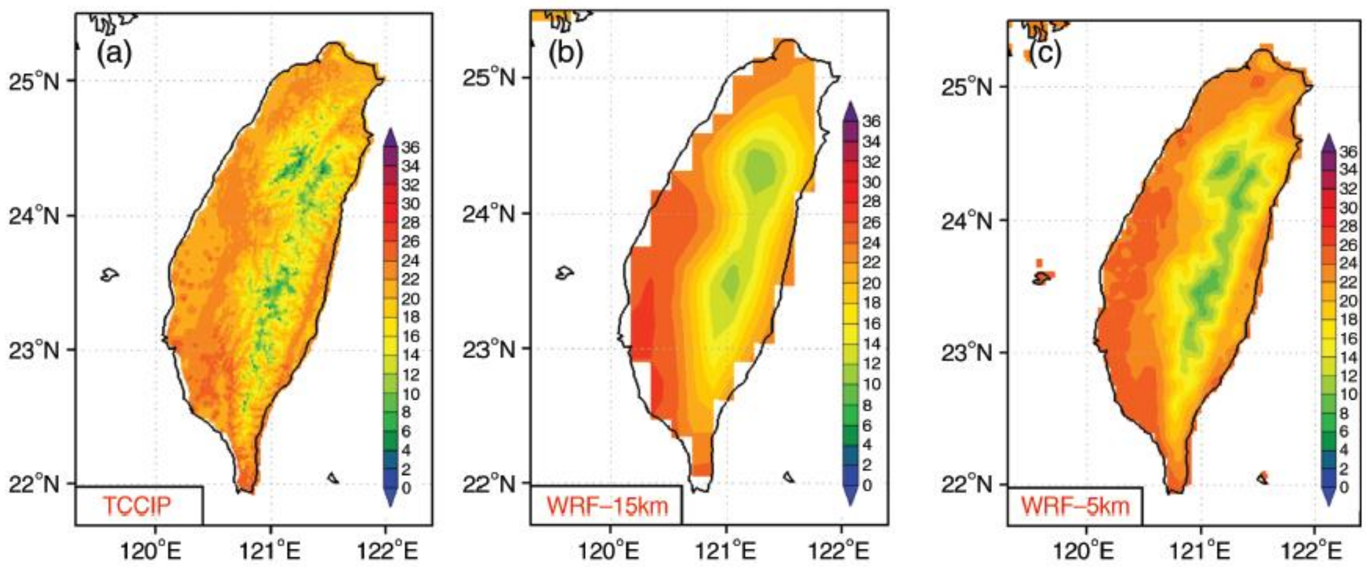


Table 1. Bias and root mean square error (RMSE) (unit: °C) of mean surface air temperature over plain (altitude < 500 m) and mountain (altitude > 500 m) in Taiwan during 1979–2003.

		WRF(15 KM)-TCCIP	WRF(5 KM)-TCCIP
BIAS	Plain	1.97	1.31
	Mountain	0.11	−0.18
RMSE	Plain	2.24	1.80
	Mountain	1.53	1.23

BIAS describes the mean error between dynamic downscaling results and TCCIP observation data. RMSE is the measurement of the differences between dynamic downscaling results and TCCIP observation data.

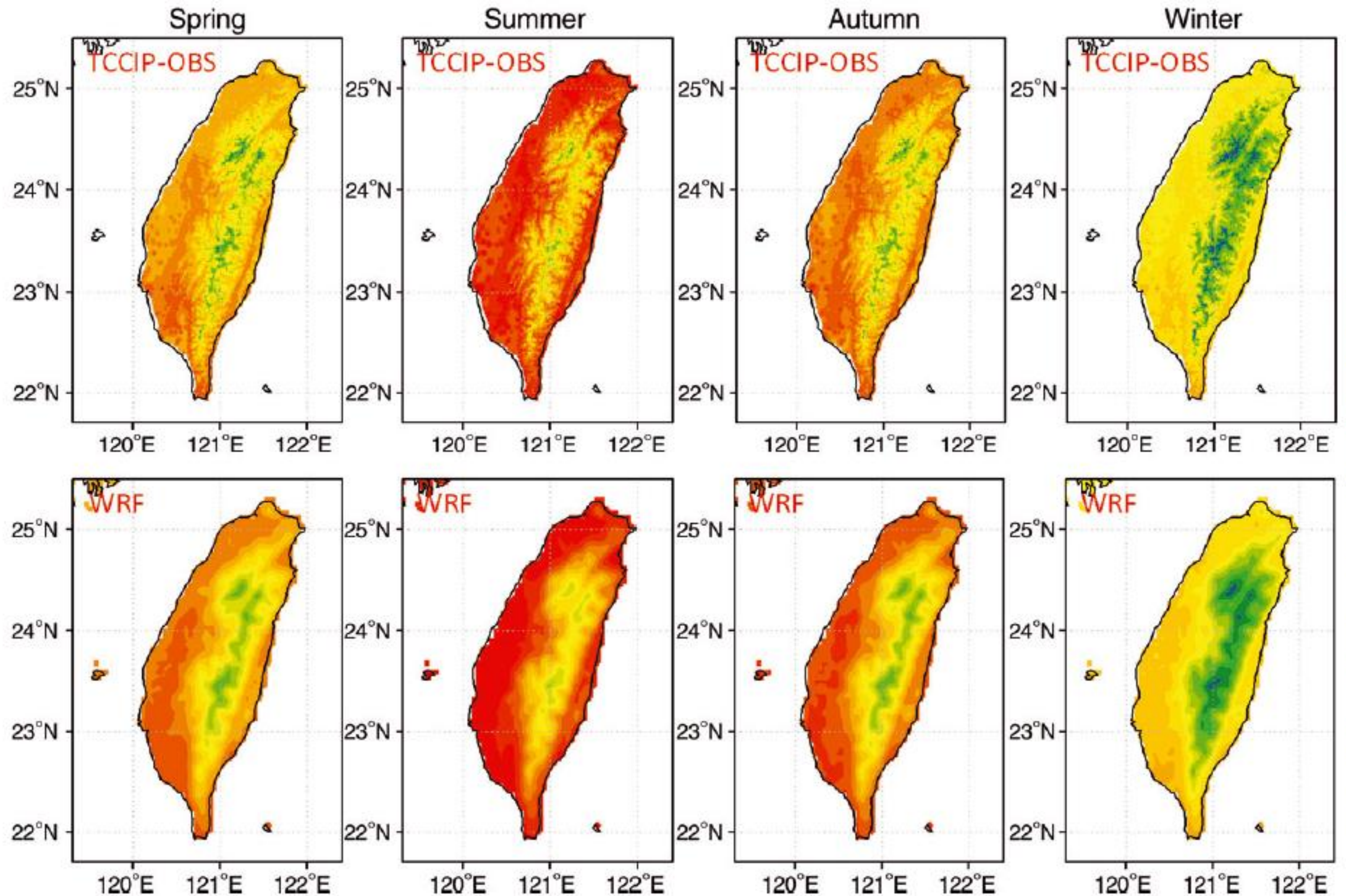


Figure 3. Seasonal variations of average air temperature during 1979−2003. Upper panel: temperature observed by TCCIP, and botto temperature obtained by ECHAM5/MPIOM-WRF at 5-km resolution dynamic downscaling. Spring (MAM), Summer (JJA), Autumn (S Winter (DJF).

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Royal Meteorological Society

Altitudinal and latitudinal dependence of future warming in Taiwan simulated by WRF nested with ECHAM5/MPIOM

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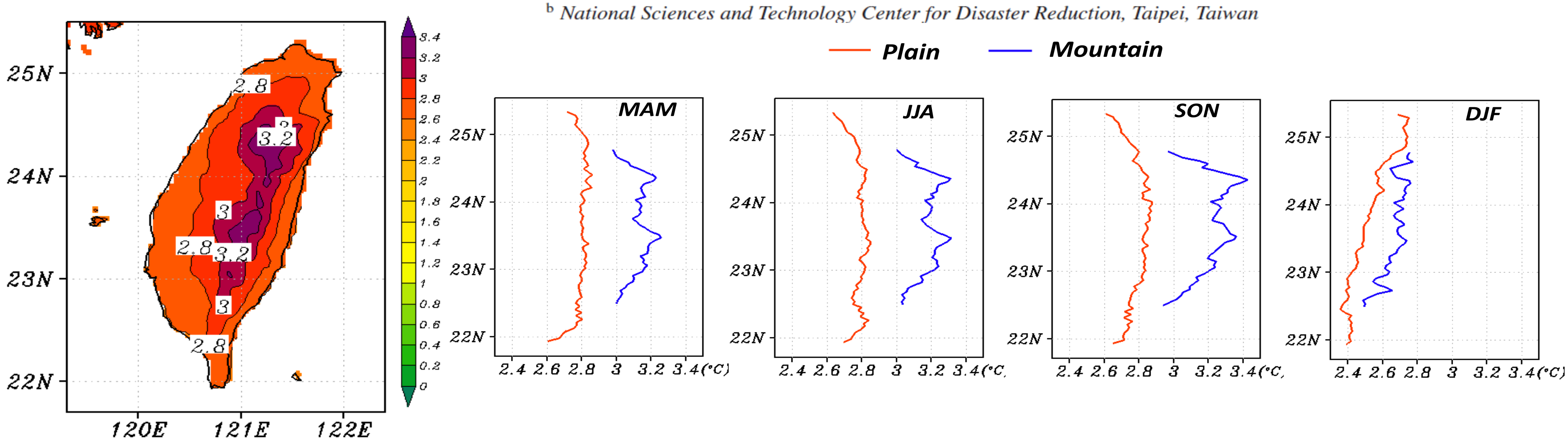
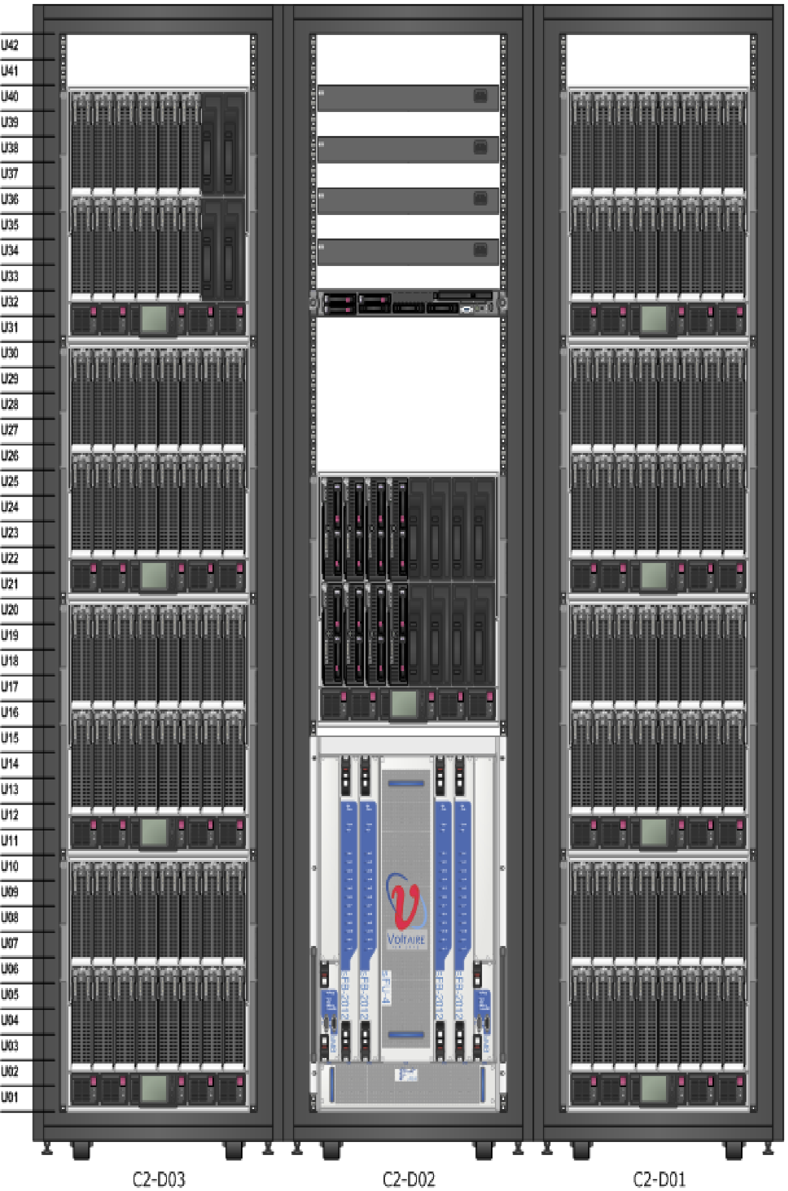


- The projected warming trend shows altitudinal variations with more significant temperature increase in mountain areas (altitude > 1000 m) than in plain areas (altitude < 500 m) and greater increase in the distant future 2075-2099.

- During winter, the projected warming trend shows latitudinal variations with more significant temperature increase in northern Taiwan than in southern Taiwan

Computer Resources



The HPC cluster with HP Blade System BL2x220c blade servers with **256 nodes (2048 cores)** via **InfiniBand** interconnection

2 x 3.GHz Xeon Quad-Core 5450 CPU

The performance of the HPC benchmark is expected to reach around **24 TFlops**

1 month simulation/5 days (128 CPU)

75 years' simulation =1.5 year computer time

75 TB storage

Application example: Heat wave over Taiwan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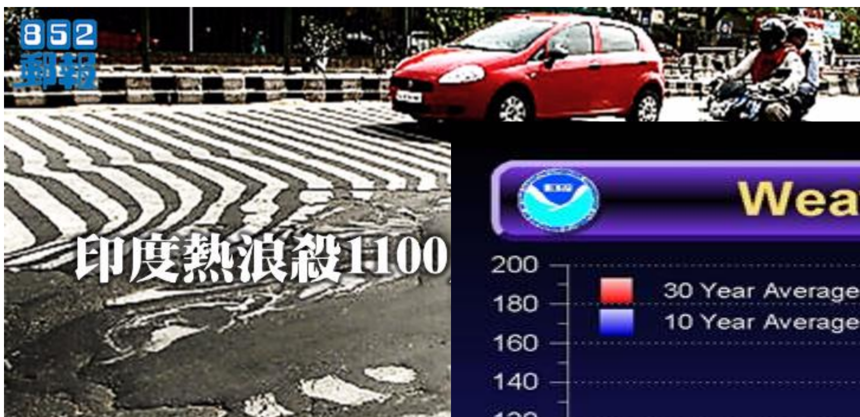
More Than 2,300 People Have Now Died in India's Heat Wave
Rohit Inani / New Delhi @josefkisdrunk
June 2, 2015


熱死人了 北基4老人猝死
自由時報 自由時報 – 2012年7月12日 上午4:25
〔自由時報記者吳岳修、林嘉東、林嘉琪、陳曉宜、盧賢秀、邱奕統／綜合報導〕熱浪持
當天，光是萬華區就有三名老人
「熱死」的可能。基隆昨天高溫
人疑似熱死事件。
一天就傳3憾事
環河南路的七十五歲曹姓老
氣太熱睡不著覺，十日凌晨四
客廳乘涼，悶熱導致身體不適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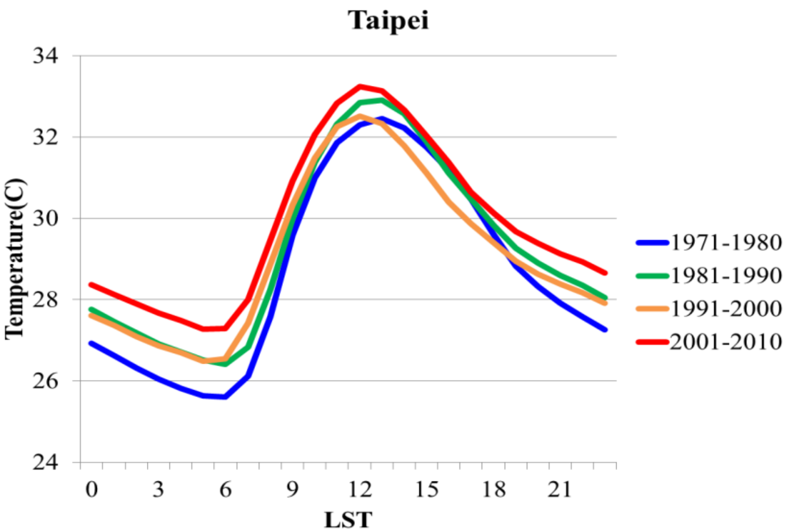
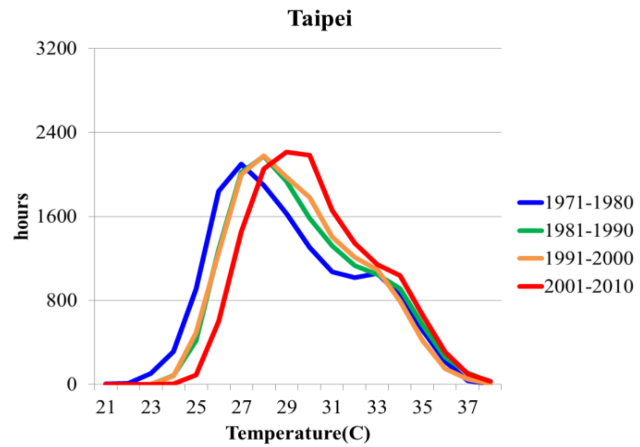
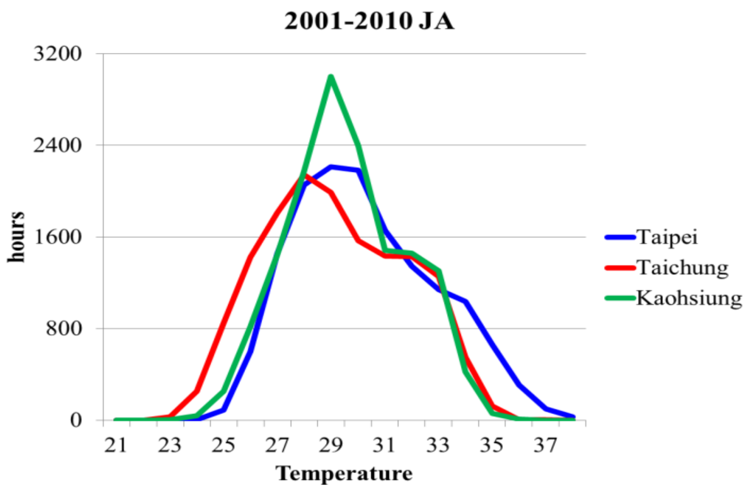
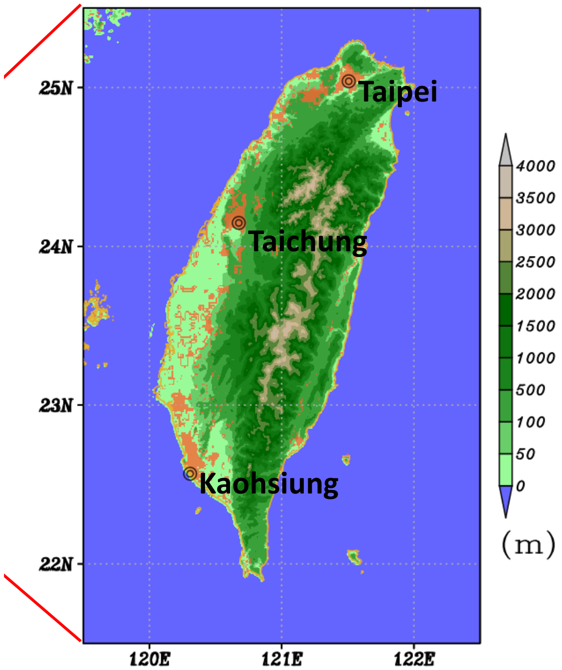
Weather Fatalities
30 Year Average (1977-2006)
10 Year Average (1997-2006)
200
180
160
140
120
100
80
60
40
20
0
99
74
62
44
54
62
49
117
170
18
41
47
Flood
Lightning
Tornado
Hurricane
Heat
Cold
Winter Storm
Wind

Temperature variations:









Heat wave definition

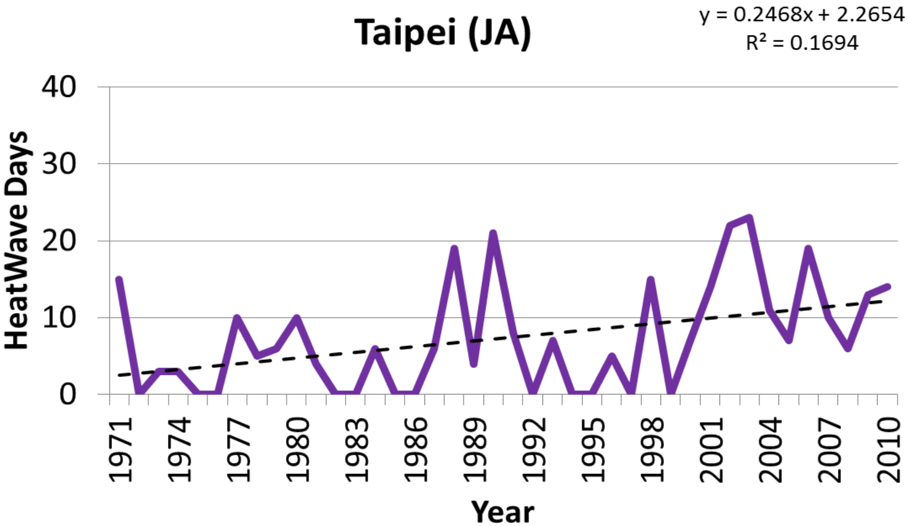
- Definition: Daily maximum temperature:
- Hot day threshold: daily maximum temperature above their respective 95th percentile for the whole simulation period.
- Heat wave event: a hot spell of at least 3 consecutive hot days.

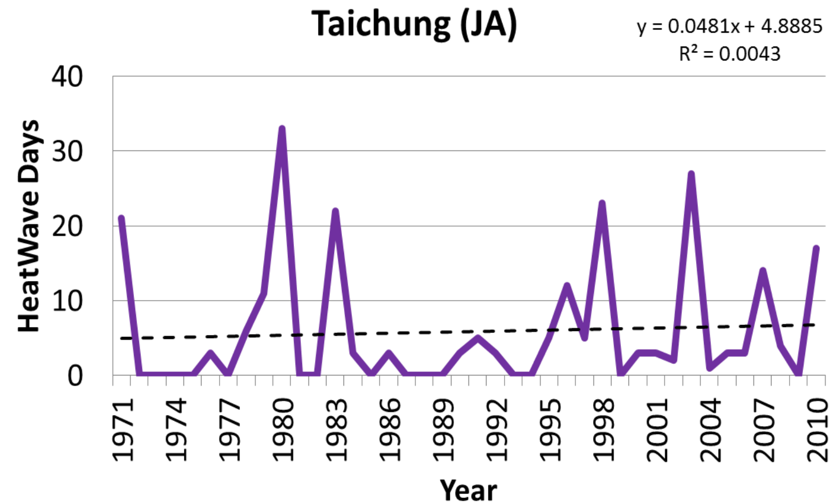
	Taipei (TP)					Taichung (TC)					Kaohsiung (KH)			
	HW temperature (top 5%)	HW events	HW days	HW duration		HW temperature (top 5%)	HW events	HW days	HW duration		HW temperature (top 5%)	HW events	HW days	HW duration
1971-1980	35.1	16	62	3.8		34.0	20	102	5.1		33.3	20	119	5.1
1981-1990	35.0	15	68	4.5		33.8	6	36	6		32.8	6	38	6.3
1991-2000	35.1	13	62	4.7		34.0	14	79	5.2		33.1	13	68	5.2
2001-2010	35.7	29	150	5.2		34.1	20	90	4.5		33.7	35	223	6.3

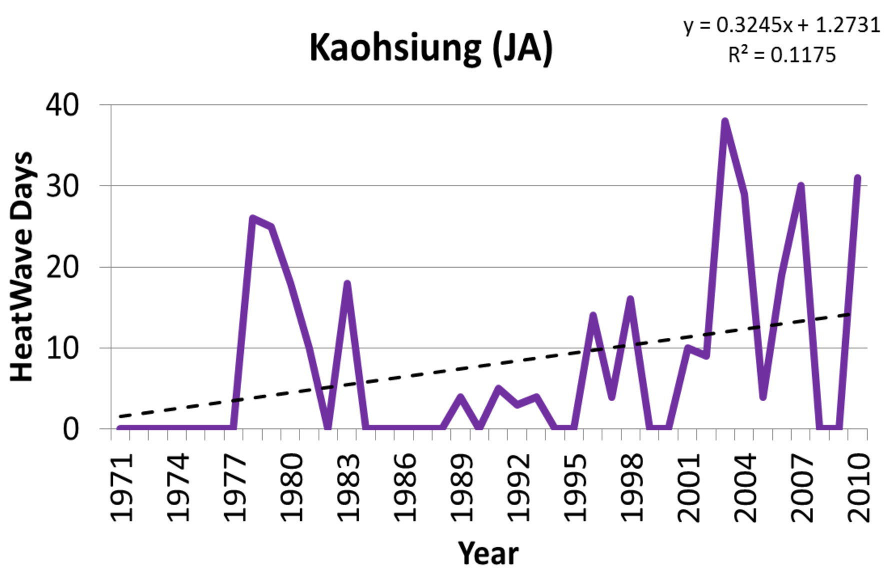
Table 1. The heat wave (HW) criteria air temperature (95 percentile daily maximum air temperature), HW events, HW days and HW duration in the past four decades during 1971-2010 for Taipei, Taichung and Kaohsiung.

- Whole period: Taipei=35.2; Taichung=34.C ; KH=33.3

Heat waves variation







Heat wave index: WBGT

- Fischer and Schar (2010), the climatic factors contributing to enhanced morbidity and mortality were a combination of extremely **high temperature and relative humidity**.
- WBGT (Wet Bulb Globe Temperature): used in national (e.g. UK, China, Japan, USA, Australia etc.) and regional (e.g. European)
- Consider temperature, humidity, wind speed and solar radiation on the perception of temperature

$$WBGT = 0.7 \times Tnwb + 0.2 \times Tg + 0.1 \times Ta$$

Tg : *black globe thermometer*
Tnwb : *natural(unventilated) wet-bulb temperature*
Ta: *(shade) air temperature*

-used across the globe to control heat stress in many contexts including military, industrial, domestic, sporting and commercial application.

WBGT estimation

- $WBGT = 0.7T_w + 0.2T_g + 0.1T_d$ (1)

  Where Tw denotes natural wet-bulb temperature (°C) ; Tg = Globe thermometer temperature (°C) and Td = Dry-bulb temperature (°C) ;

Stull R. (2011):

$$\mathrm{Tw} = \mathrm{T}\,\mathrm{atan}\left[0.151977(RH\% + 8.313659)^{\frac{1}{2}}\right] + \mathrm{atan}(T + RH\%) - \mathrm{atan}(RH\% - 1.676331) + 0.00391838(RH\%)^{3/2}\,\mathrm{atan}(0.023101RH\%) - 4.686035$$

Tonouchi et al. (2006):

$$T_g - T_d = 0.017 * S - 0.208 * U$$

Where T_g is globe temperature (°C), T_d is dry bulb temperature (°C). S is a solar radiation (W/m^2) and U is wind speed (m/s)

WBGT estimation from Observation during summer (JA)

- 95th percentile

	Taipei
2003-2012	32.6

分類 Category	WBGT ˚F	WBGT ˚C	旅 F
1	<= 79.9	<= 26.6	
2	80-84.9	26.7-29.3	
3	85-87.9	29.4-31.0	
4	88-89.9	31.1-32.1	
5	=> 90	=> 32.2	

(Ref:美國陸

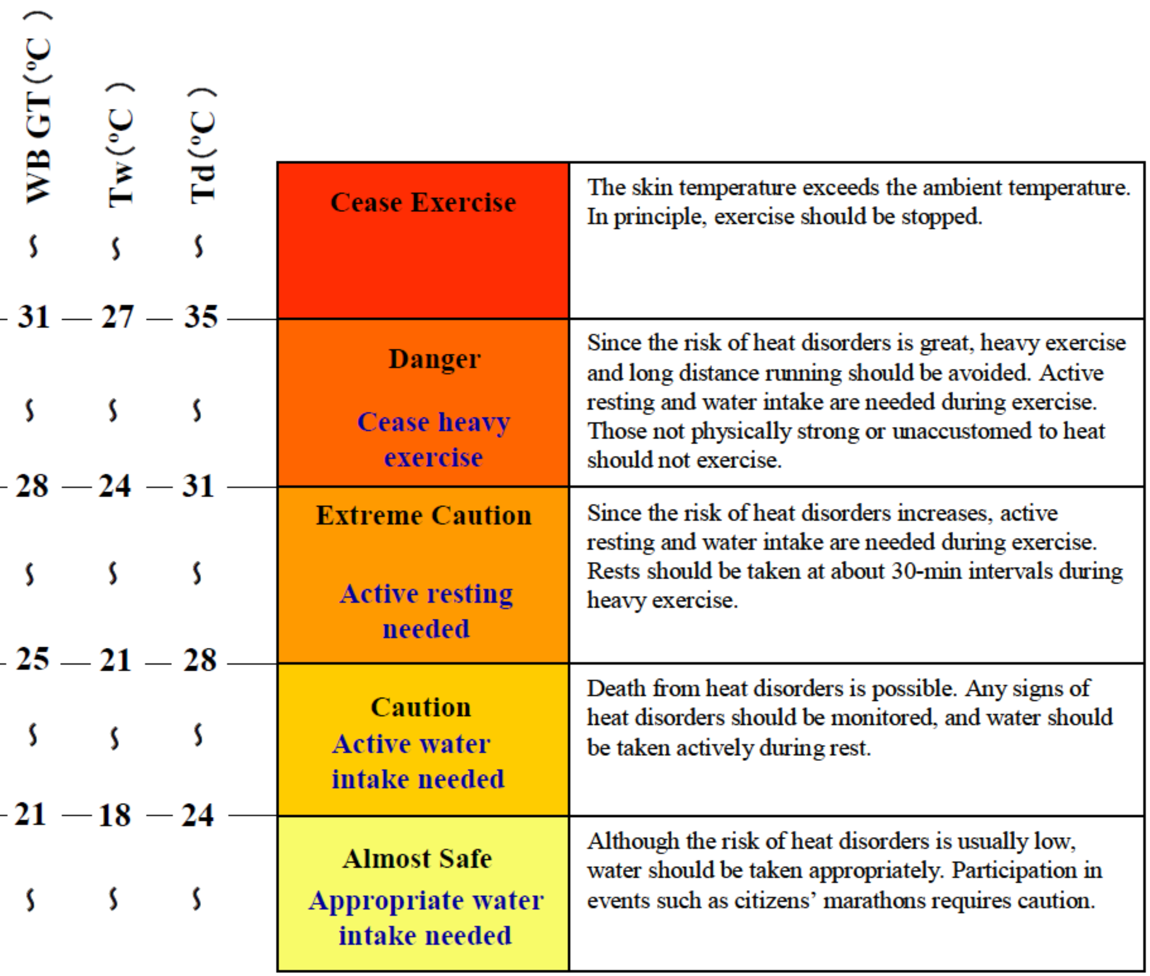
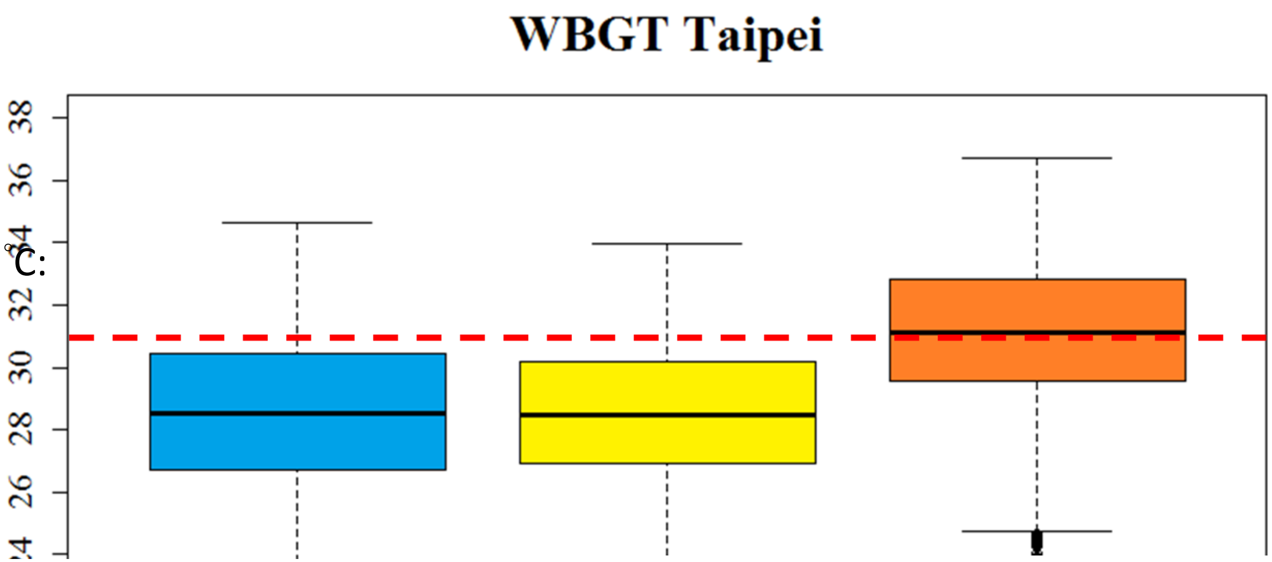
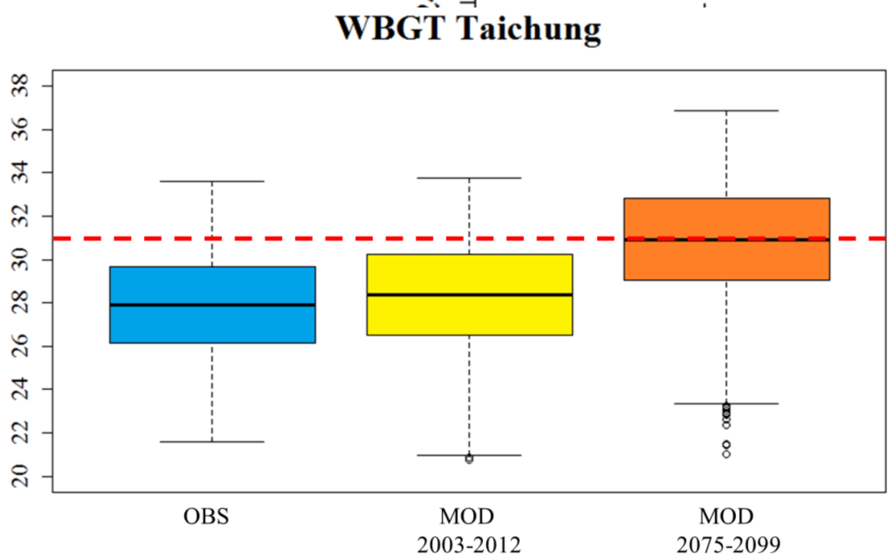


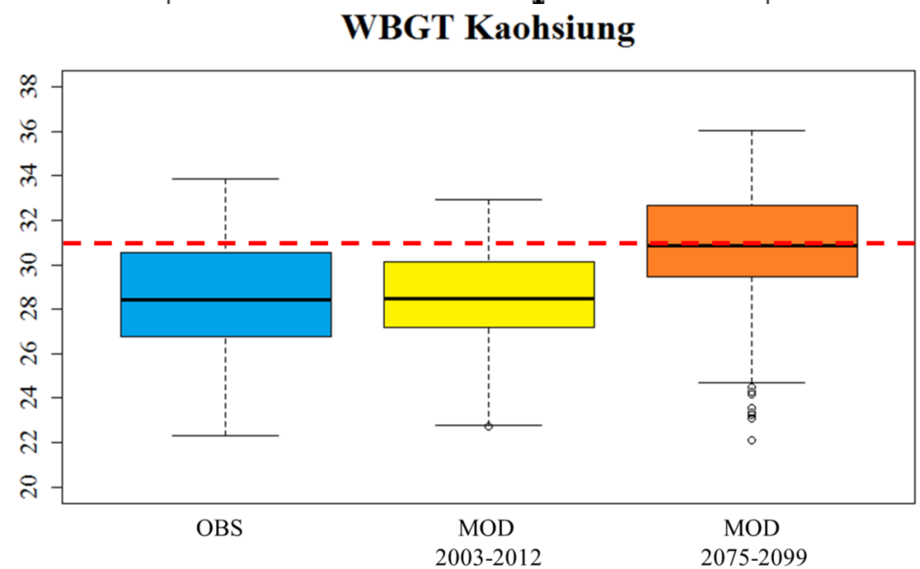
Fig. 3 Exercise guideline for preventing heat disorders proposed by the Japan Sports Association.
WBGT: Wet Bulb Globe Temperature (Source: Kawahara, *et al*., 1994)

WBGT estimation from Observation and ECHAM5-WRF during summer (JA)

2003-2012 WBGT >31 °C:
Taipei : 10.74%
Taichung: 4.22%
Kaohsiung: 11.28%







Application: Future warming and cooling energy estimation

Energy and Buildings xxx (2016) xxx–xxx

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Spatial and temporal analysis of urban heat island and global warming on residential thermal comfort and cooling energy in Taiwan

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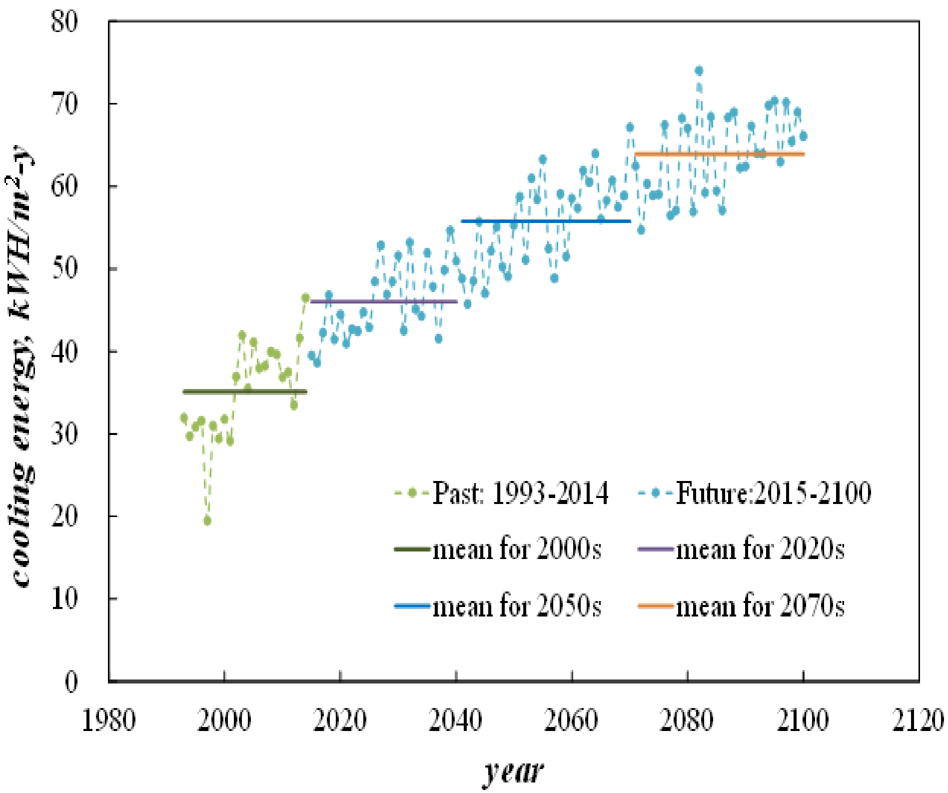
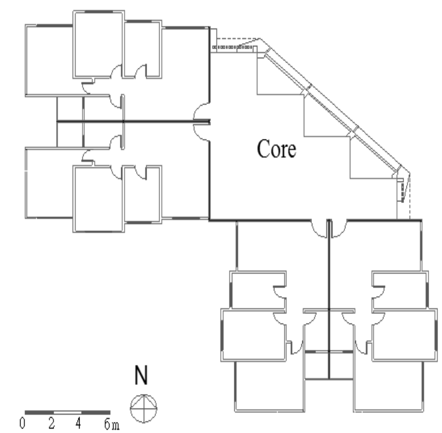
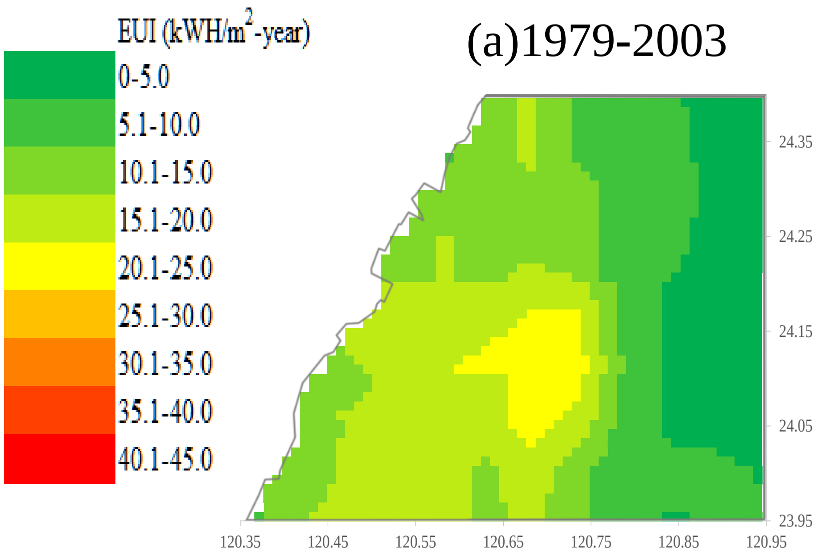
[b] Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan
[c] Department of Bioenvironmental Systems Engineering, National Taiwan University, No.1, Sec.4, Roosevelt Rd., Taipei, 10617 Taiwan

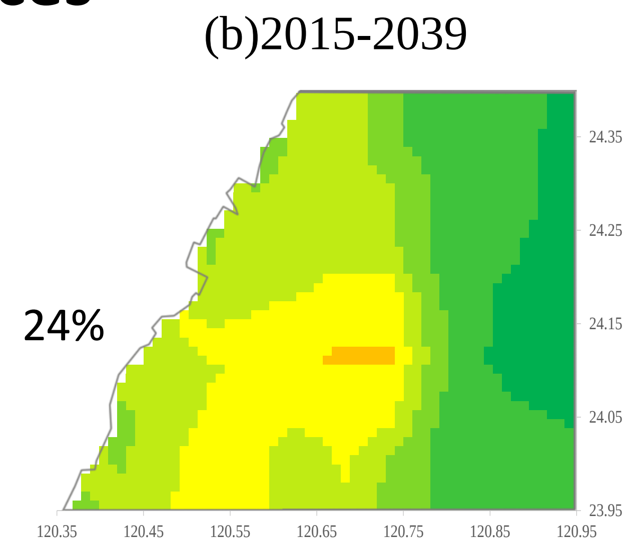




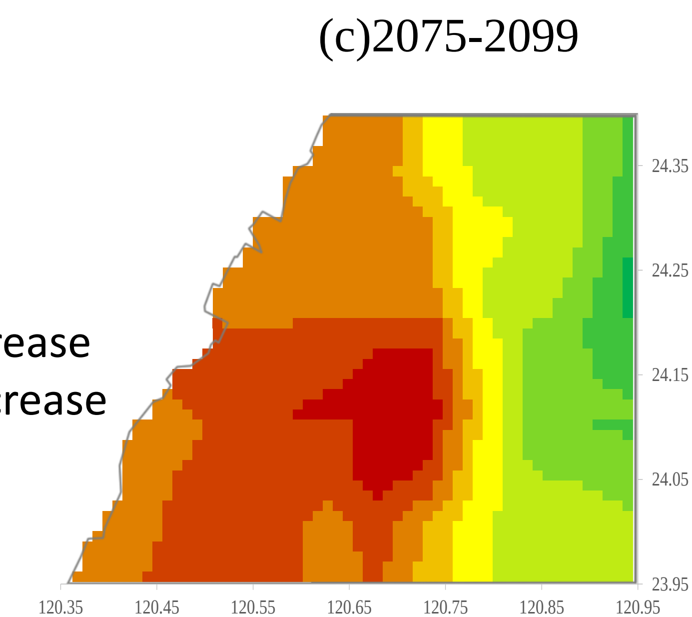
- The annual cooling energy consumption in the time slices of the 2000s, 2020s, 2050s, and 2080s are respectively 35.1, 46.0, 55.8, and 63.9 kWh/m^{2}y. The average ratios of increase are 31%, 59%, and 82% over that of the 2000s.

Spatial distribution of cooling energy variation in three time slices





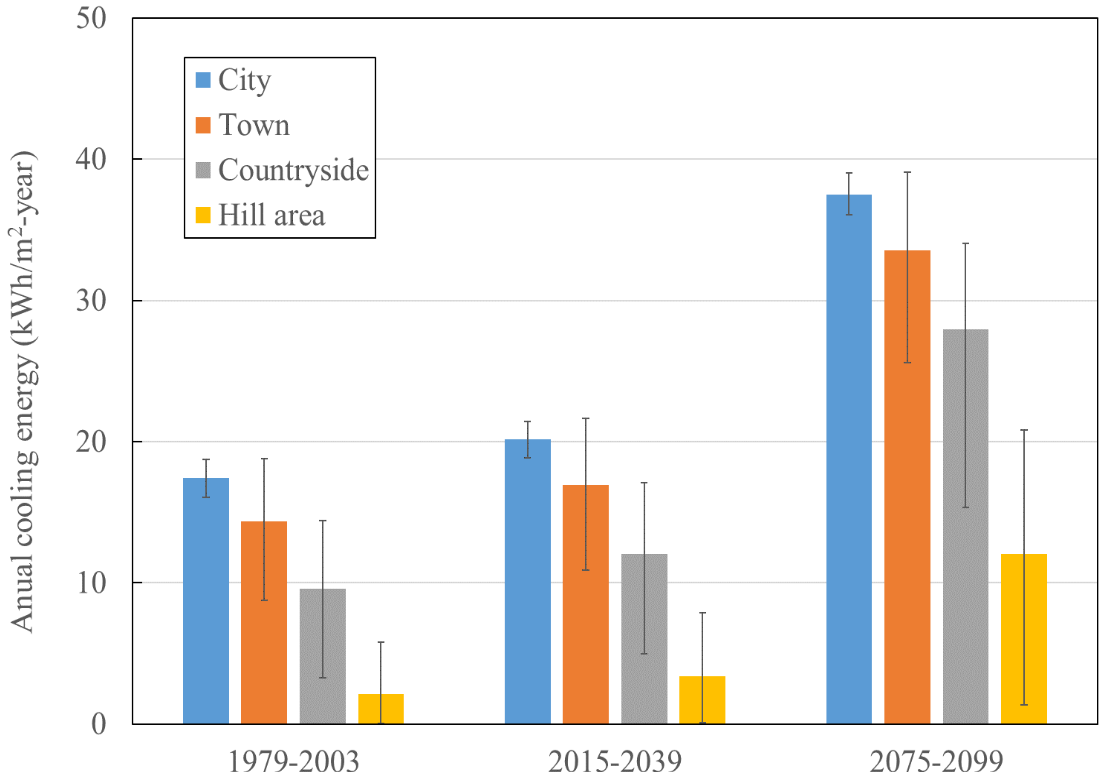
24%



2015-2039: 0.07-21.64 kWH/m2-year about 24% increase

2075-2099: 1.36-39.08 kWH/m^2-year about 184% increase

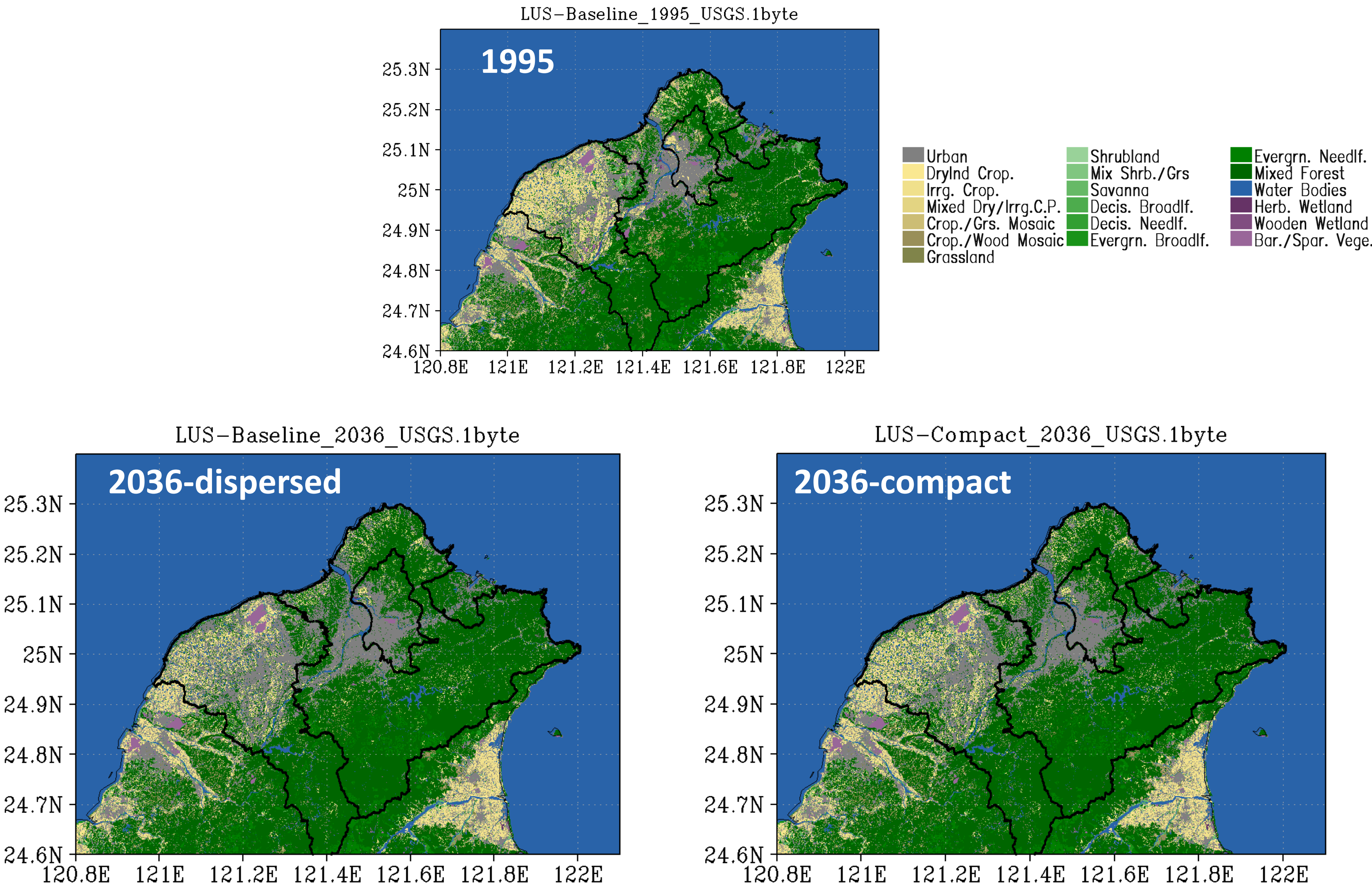
Increase in residential cooling energy by the UHI effect



UHI效應在都會及城鎮地區的冷氣能耗
在過去時期分別提高了6.58 kWH/m2-y (61％)和5.03 kWH/m2-y(46%)，
在近未來時期為6.89 kWH/m2-y(52％)和5.26 kWH/m2-y(40%)，以及
在遠未來為7.99 kWH/m2-y(27％)和6.06 kWH/m2-y(21%)d

Future urban planning and Regional Climate Changes

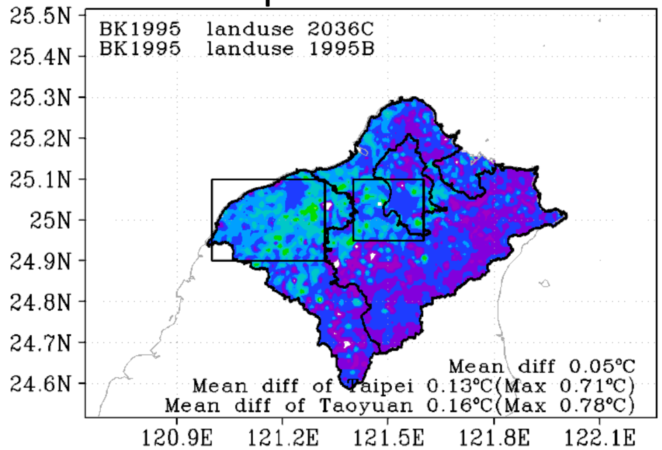
Future Urban planning scenarios



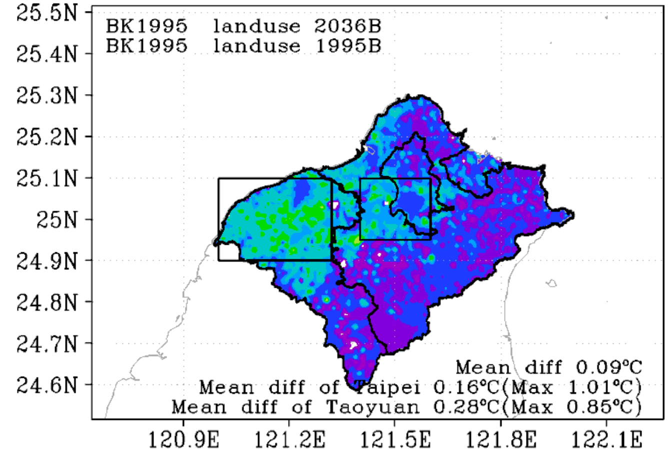
(by Prof. 詹士樑&陳 亮全)

Impact of future urban planning on air temperature

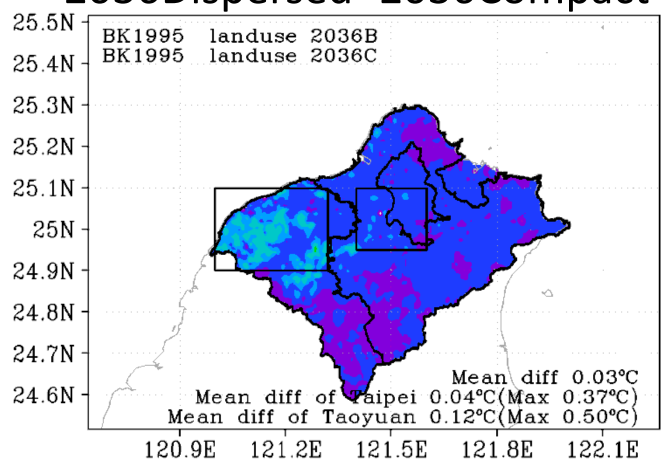
2036Compact - 1995Baseline



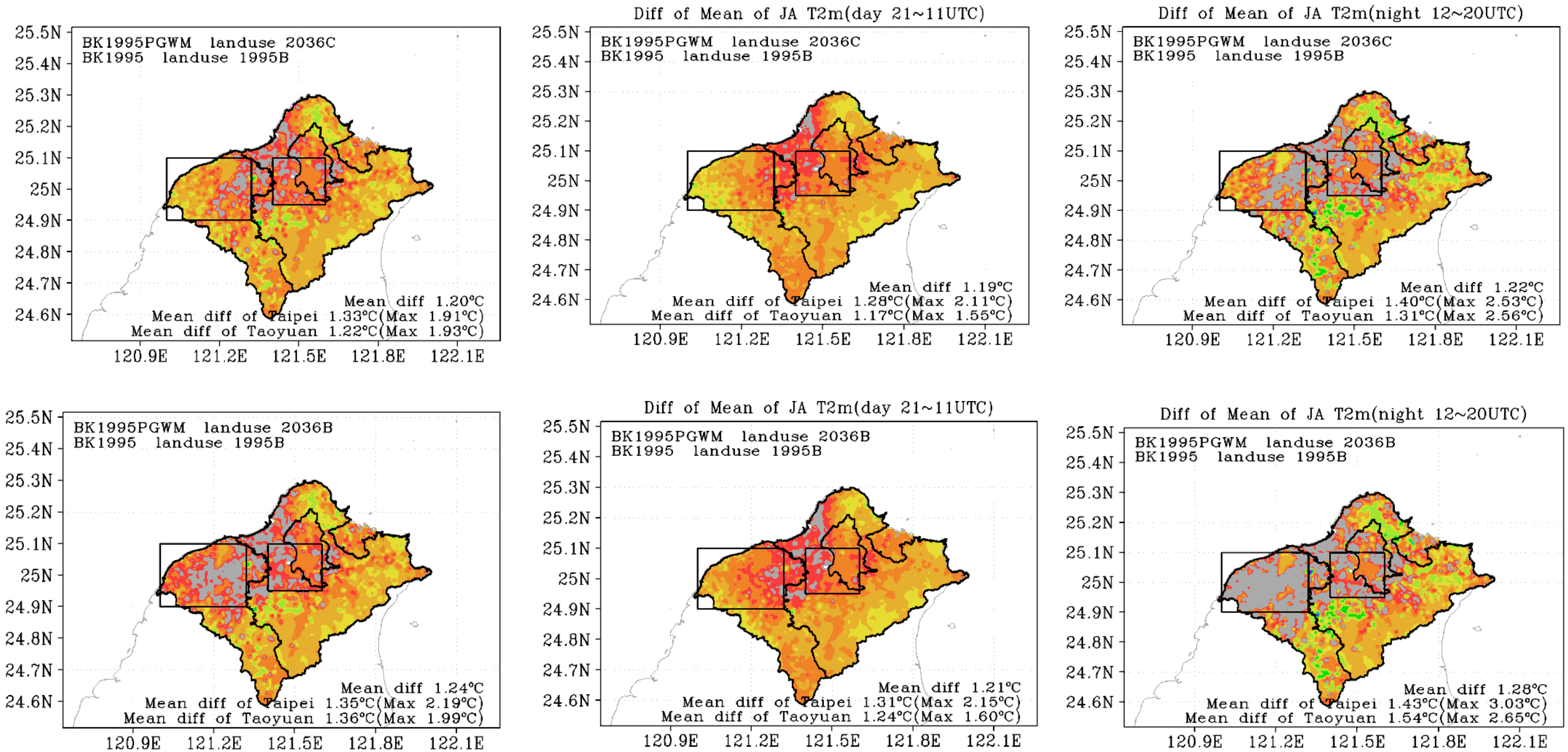
2036Dispersed - 1995Baseline



2036Dispersed -2036Compact

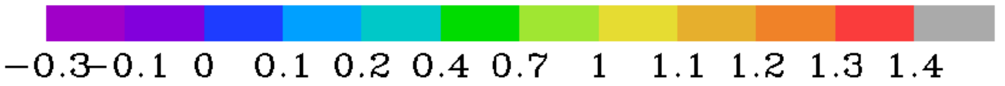


Impact of future urban planning and climate change on air temperature



Daytime

Nighttime

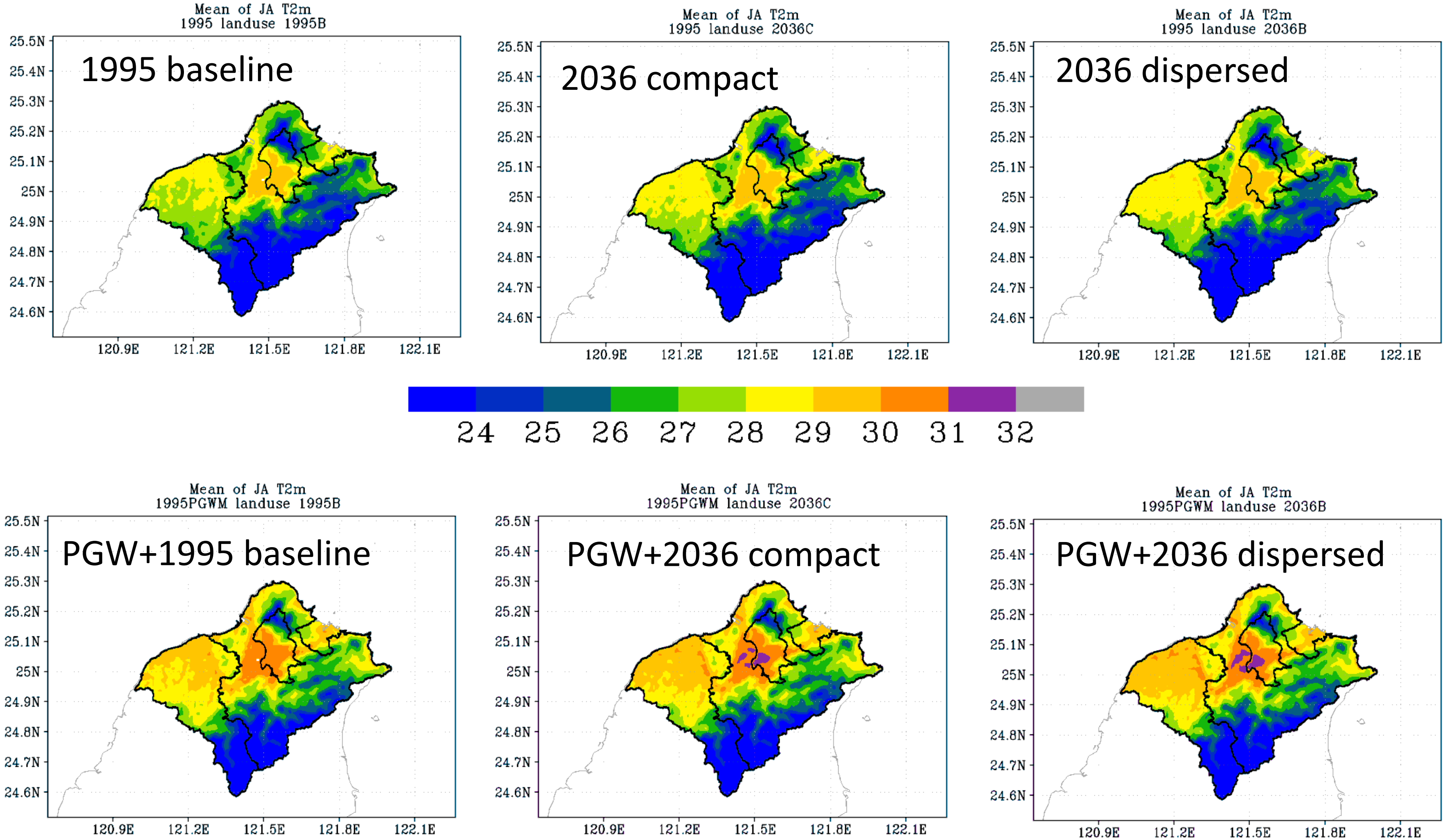


References:

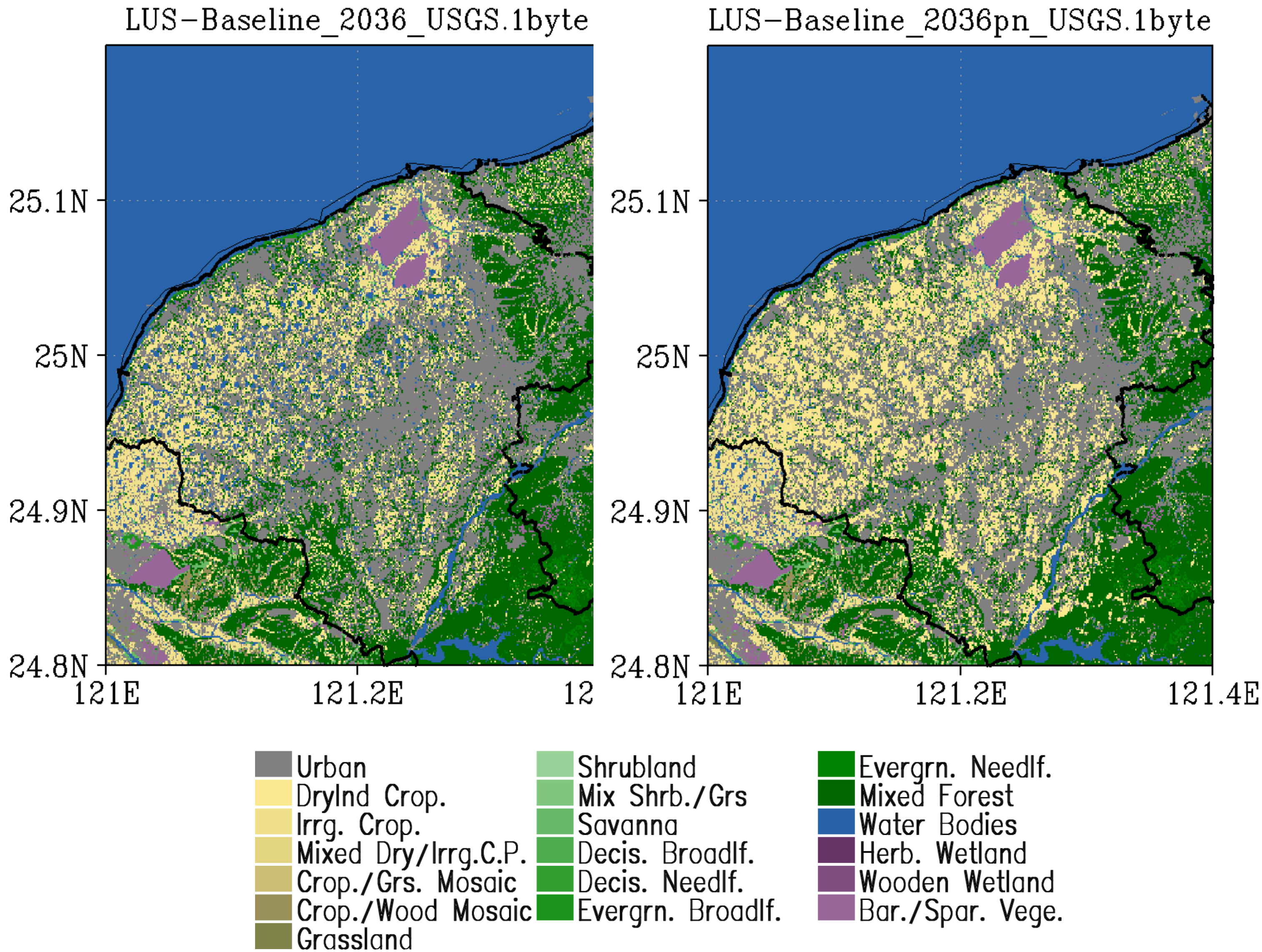
- Lin C.-Y.*, Y.J. Chua, Y.F. Sheng, H.H. Hsu, C.T. Cheng, Y.Y. Lin, 2015: Altitudinal and latitudinal dependence of future warming in Taiwan simulated by WRF nested with ECHAM5/MPIOM; *International Journal of Climatology*, 35,1800-1809,DOI: 10.1002/joc.4118.
- Hwang R.L., C.-Y. Lin, and K.T. Huang, 2016: Spatial and temporal analysis of urban heat island and global warming on residential thermal comfort and cooling energy in Taiwan, Energy & Buildings, http://dx.doi.org/10.1016/j.enbuild.2016.11.016
- Lin C-Y.*, Yi-Yu Chien, Y.-F. Sheng, M.-T Kuth, S.-C. Lung, 2017: Climate variability of heat wave and future warming scenario in Taiwan. Climatic changes (Ready to Submit)

Thank you !!!!

Impact of future urban planning and climate change on air temperature



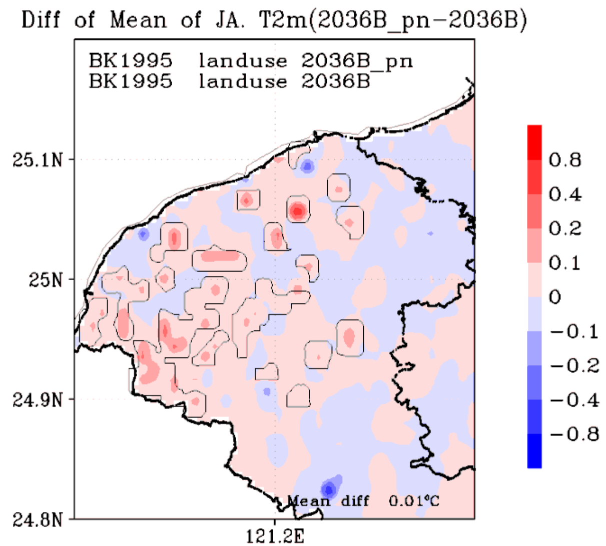
Impact of farm pond (埤塘) fill-up on air temperature in Taoyuan



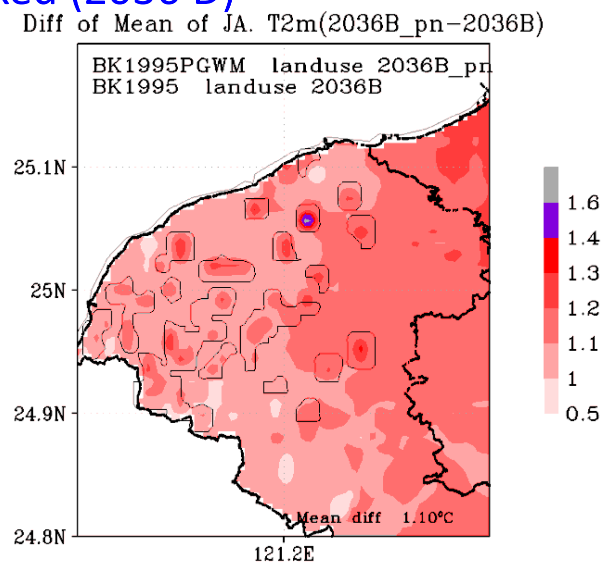
(Provided by Prof. 詹士樑&陳 亮全)

Impact of farm pond (埤塘) fill-up on air temperature in Taoyuan

Farm pond change+
Land use fixed 2036D



PGW+ farm pond change+
(land use fixed (2036 D)



PGW+ farm pond change
+land use(1995D→2036D)