臺灣氣候變遷推估與資訊平台
Taiwan Climate Change Projection and Information Platform

利用ECHAM5/MPIOM-WRF動力降尺度結果探討全球暖化對台灣之影響

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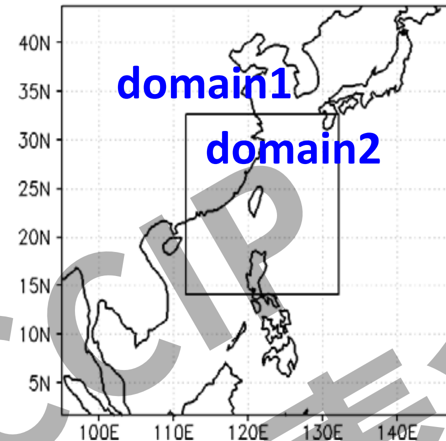
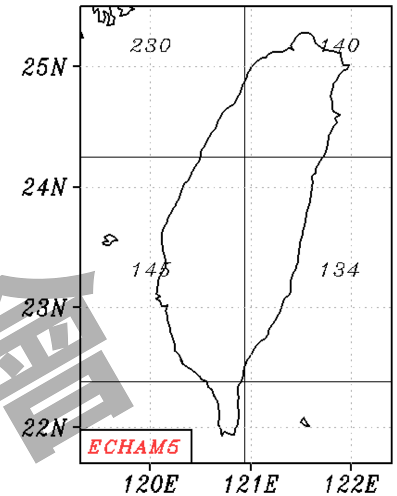
National Science and Technology Center
for Disaster Reduction

2017,1/18

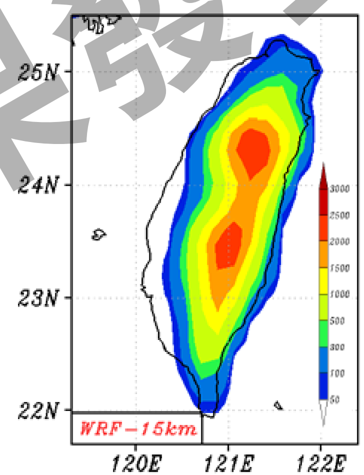
Dynamic downscaling





ECHAM5: domain:192x96
Δx=1.875 degree

WRF:
Domain1 : 301x301
Δx,y=15km FDDA
Domain2 : 382x400
Δx,y=5km, vertical 45 levels



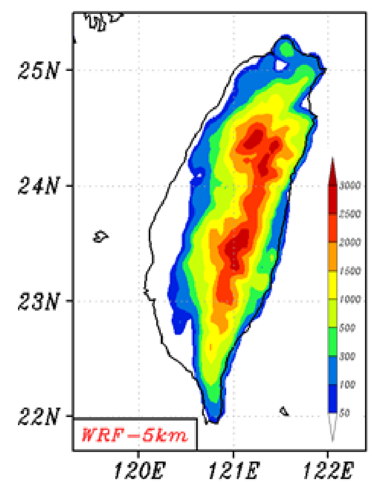


Figure 1

Dynamic downscaling

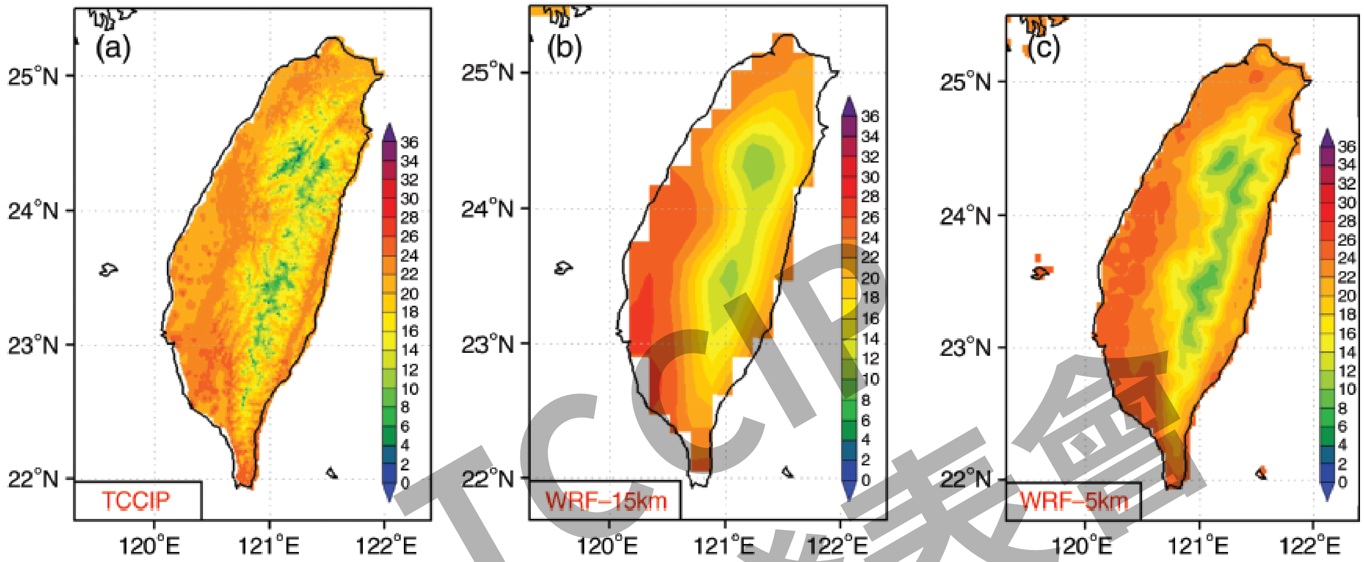


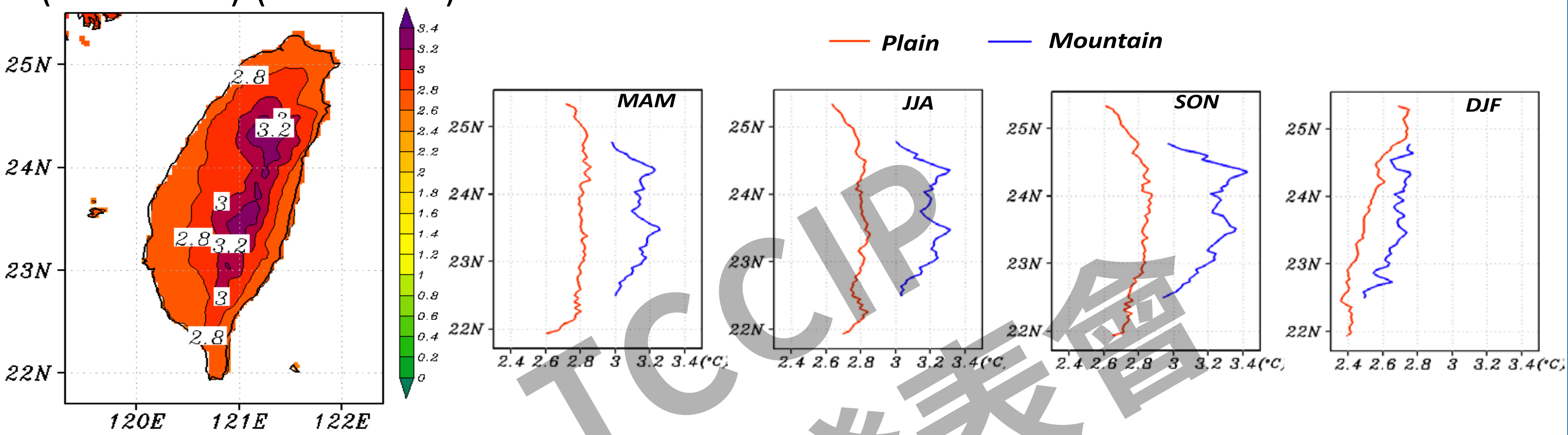
Table 1. Bias and root mean square error (RMSE) (unit: °C) of mean surface air temperature over plain (altitude < 500 m) and mountain (altitude > 500 m) in Taiwan during 1979–2003.

		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.

Results from ECHAM5-WRF

(2075-2099)-(1979-2003)



- 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

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **35**: 1800–1809 (2015)
Published online 21 July 2014 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.4118

RMetS
Royal Meteorological Society

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

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REVIEW ARTICLE
PUBLISHED ONLINE: 23 APRIL 2015 | DOI: 10.1038/NCLIMATE2563
nature climate change

Elevation-dependent warming in mountain regions of the world

Mountain Research Initiative EDW Working Group*

There is growing evidence that the rate of warming is amplified with elevation, such that high-mountain environments experience more rapid changes in temperature than environments at lower elevations. Elevation-dependent warming (EDW) can accelerate the rate of change in mountain ecosystems, cryospheric systems, hydrological regimes and biodiversity. Here we review important mechanisms that contribute towards EDW: snow albedo and surface-based feedbacks; water vapour changes and latent heat release; surface water vapour and radiative flux changes; surface heat loss and temperature change; and aerosols. All lead to enhanced warming with elevation (or at a critical elevation), and it is believed that combinations of these mechanisms may account for contrasting regional patterns of EDW. We discuss future needs to increase knowledge of mountain temperature trends and their controlling mechanisms through improved observations, satellite-based remote sensing and model simulations.

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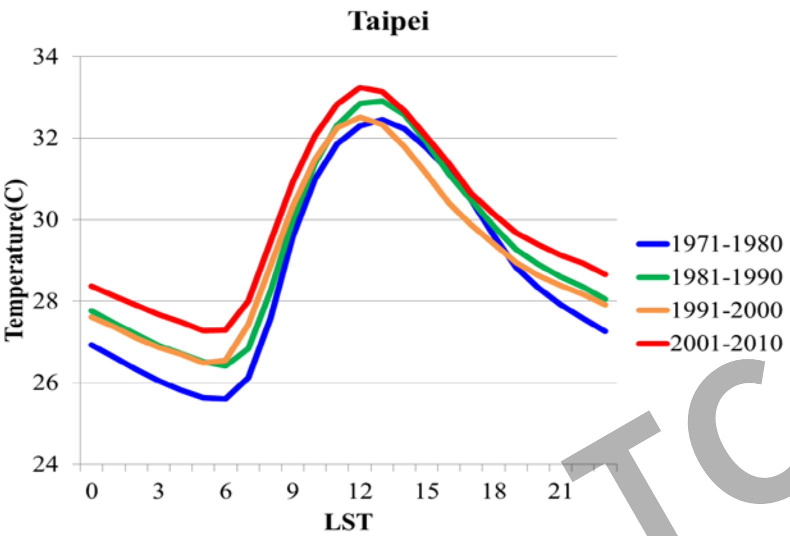
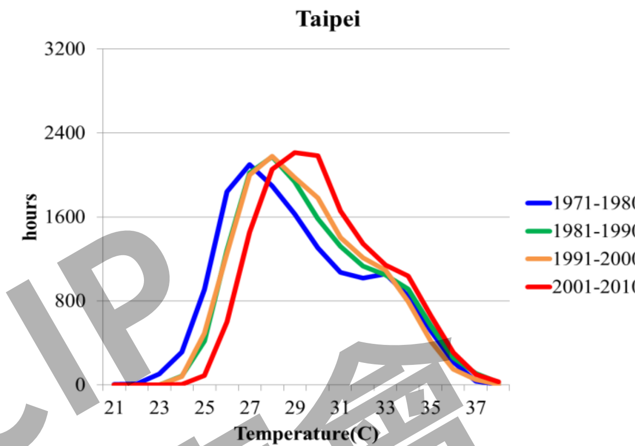
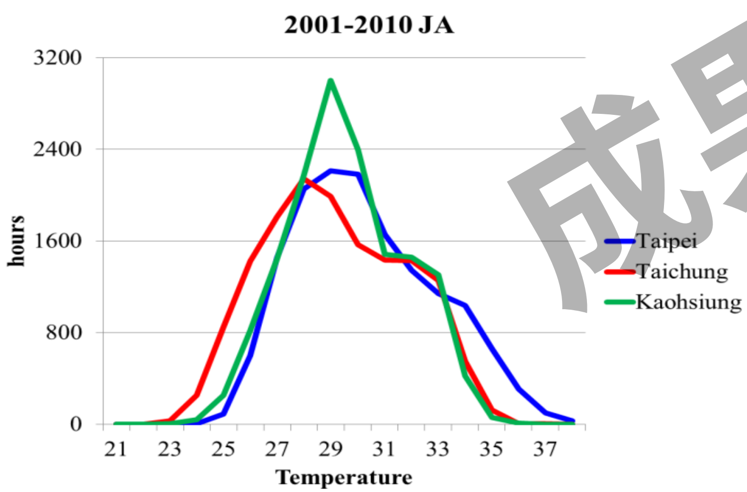
Heat waves in Taiwan:

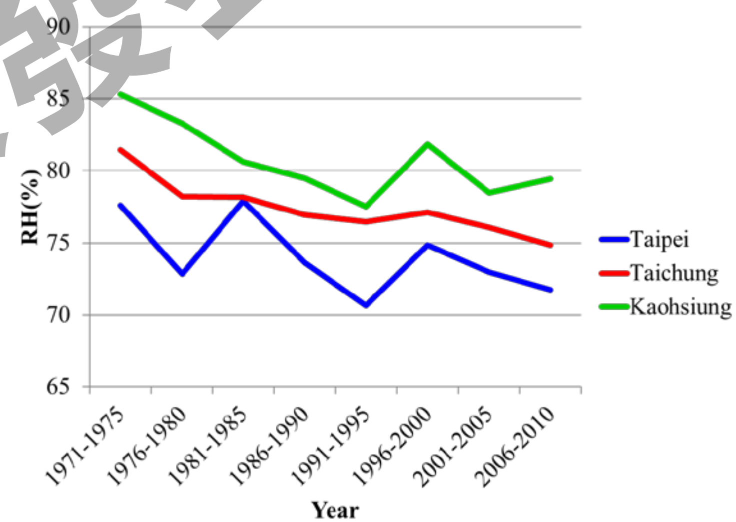
WBGT, western North Pacific subtropical high and climate variability

Temperature variations:









Application: Heat wave study

- **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.

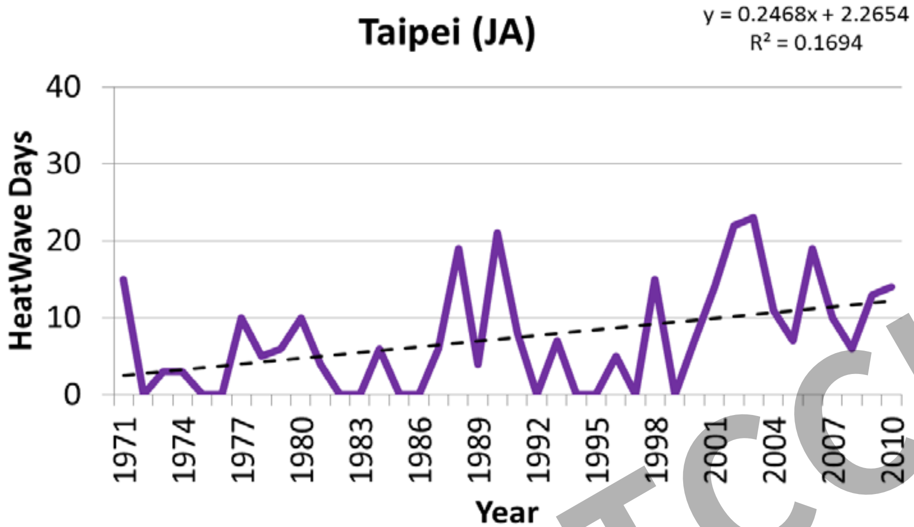
	Taipei (TP)				Taichung (TC)				Kaohsiung (KH)			
	HW temperature (top 5%)	HW events	HW days	HW duration	HW temperature (top 5%)	HW events	HW days	HW duration	HW temperature (top 5%)	HW events	HW days	HW duration
1971-1980	35.1	16	62	3.8	34.0	20	102	5.1	33.3	20	119	5.1
1981-1990	35.0	15	68	4.5	33.8	6	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

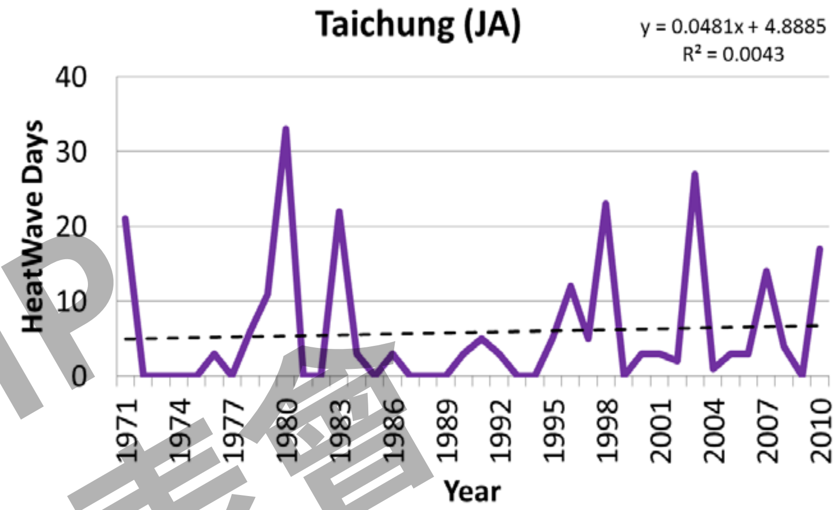
Table 1. The heat wave (HW) criteria air temperature (95 percentile daily maximum air temperature), HW events, HW days and HW duration in the past four decades during 1971-2010 for Taipei, Taichung and Kaohsiung.

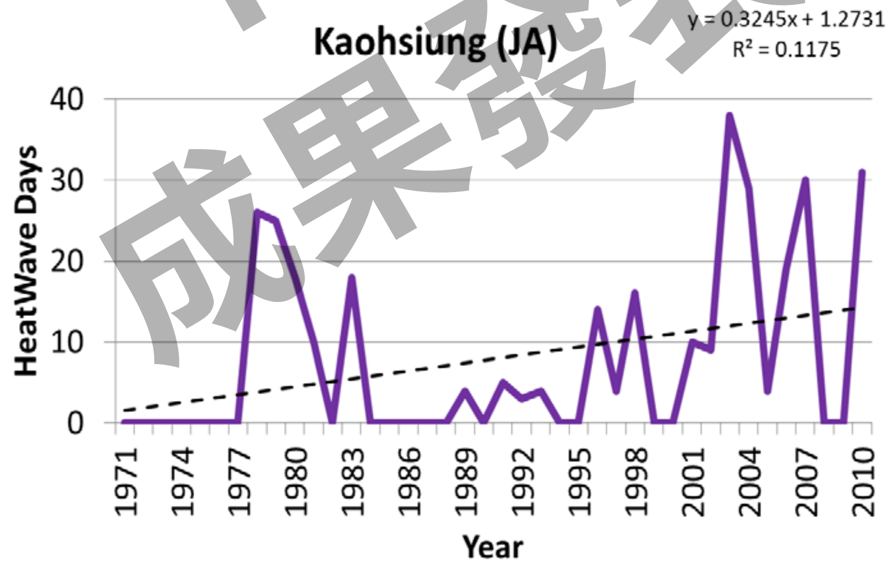
- Whole period(1971-2010):

  TP= **35.2 °C**; TC=**34.0 °C**; KH=**and 33.3 °C**

Heat waves variation







WBGT estimation

Wet Bulb Globe Temperature (WBGT):

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):

$$T_g - T_d = 0.017 * \mathrm{S} - 0.208 * \mathrm{U}$$

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 WBGT

	Taipei	Taichung	Kaohsiung
2003-2012	32.6	31.5	32.2

分類 Category	WBGT °F	WBGT °C	旗幟顏色 Flag color
1	<= 79.9	<= 26.6	White
2	80-84.9	26.7-29.3	Green
3	85-87.9	29.4-31.0	Yellow
4	88-89.9	31.1-32.1	Red
5	=> 90	=> 32.2	Black

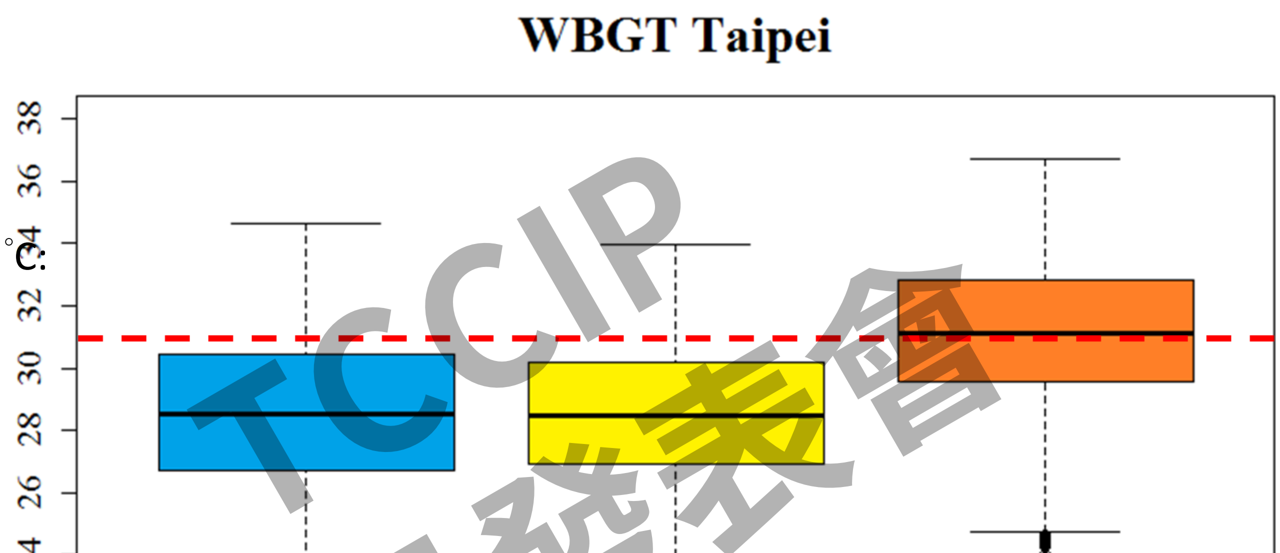
(Ref:美國陸軍)

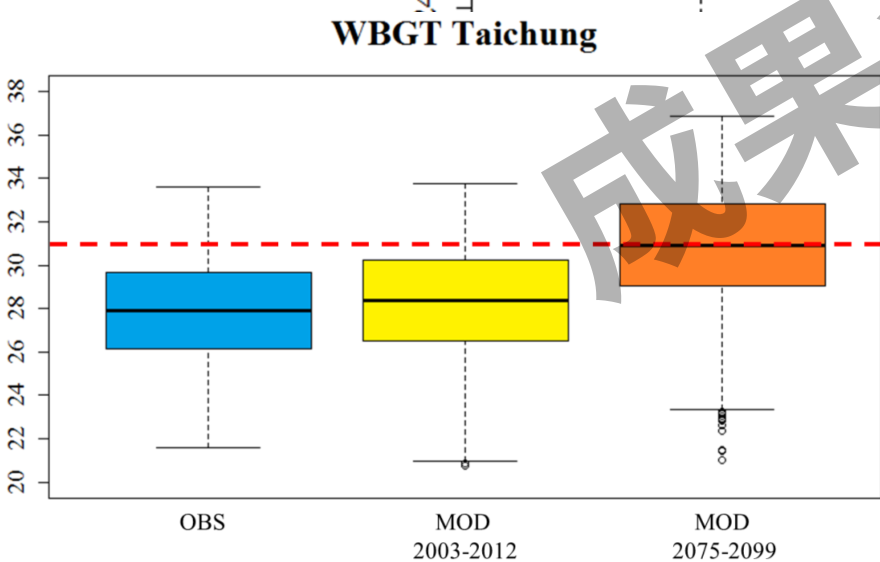
Japan sports association (2006), the five categories of heat stress risk level by using WBGT are danger (WBGT >=31 °C), alert (28<WBGT<31 °C), advisory (25<WBGT<28 °C), caution (21<WBGT<25 °C) and mostly save when WBGT <21 °C.

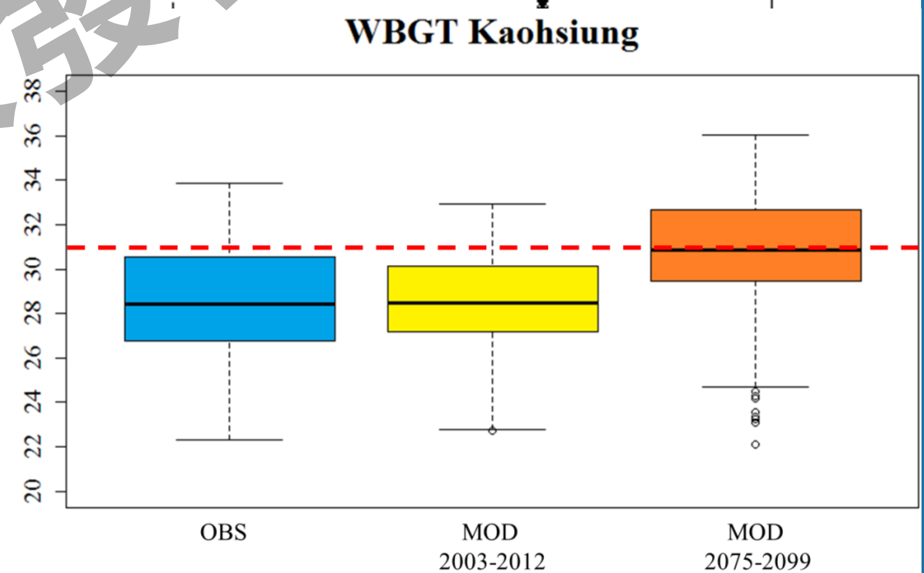
WBGT estimation from Observation and ECHAM5-WRF during summer (JA)

2003-2012 WBGT >31 °C:
Taipei : 10.74%

Taichung: 4.22%
Kaohsiung: 11.28%







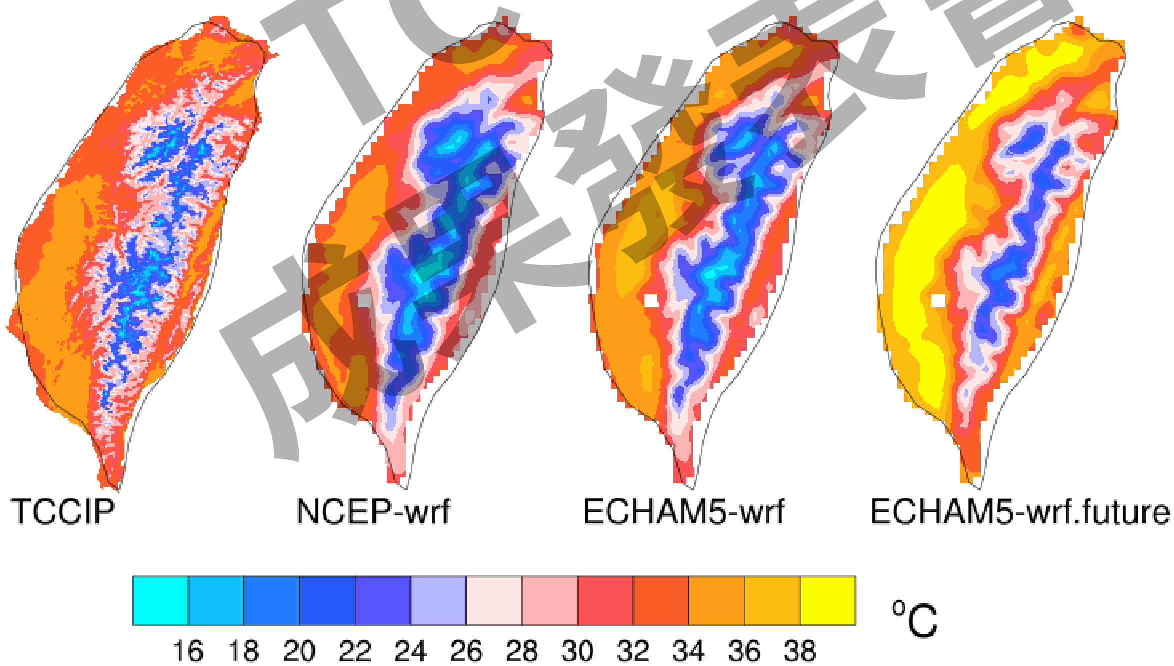
Spatial distribution of composite Heat Wave

Definition:

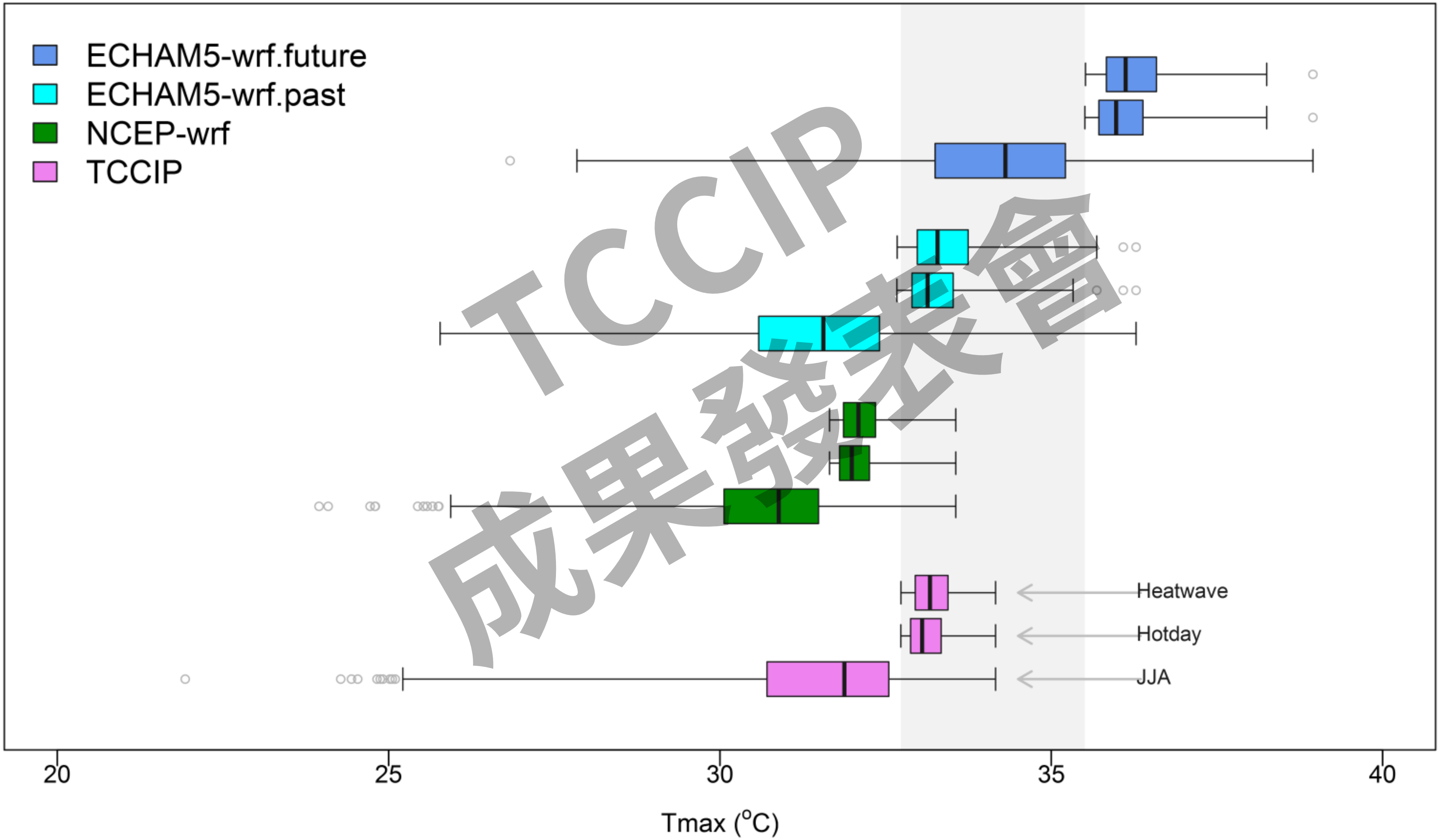
1. Tmax: plain-averaged (<500 m) daily maximum temperature
2. Hot day threshold: the 95^{th} percentile of annual Tmax [25 years, all seasons=9131 daily samples]:457 days
3. Heat wave event: Tmax exceeding 95^{th} percentile for at least 3 consecutive days

Datasets (HWs)

TCCIP (324); NCEP-wrf(272); ECHAM5(268); ECHAM5.future(276)

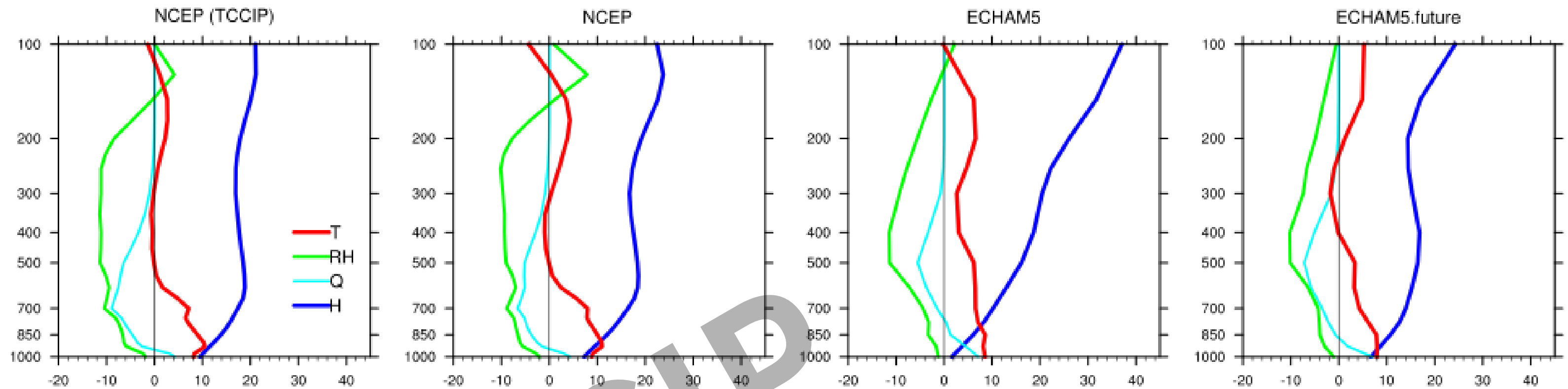


Plain averaged T-max

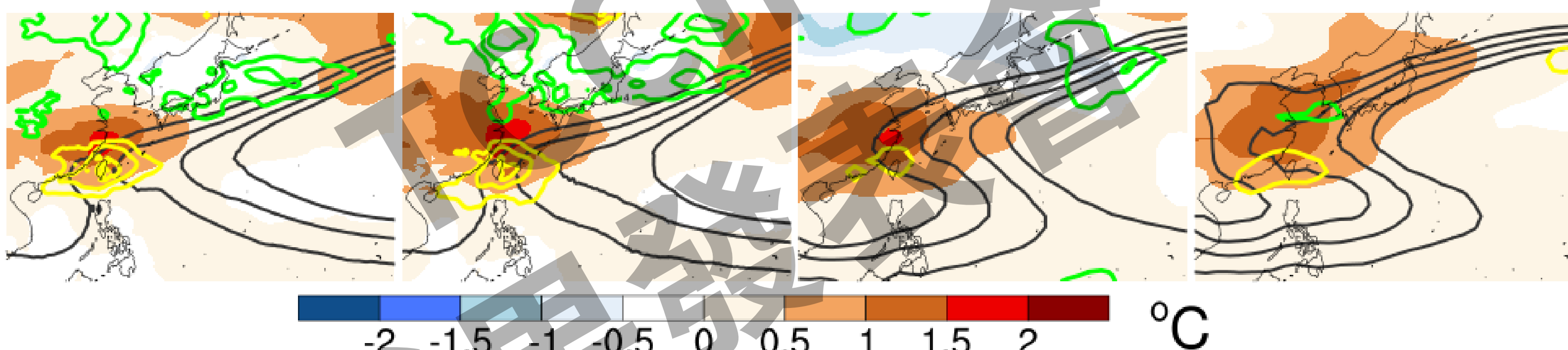


Heat waves Composite anomalies

Q*10.
T*10.

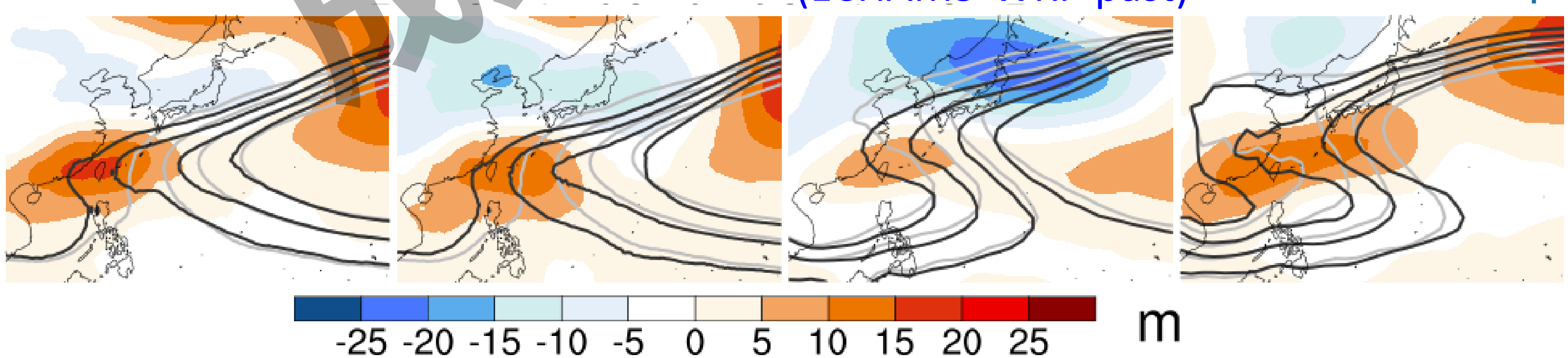


850 hPa
Tm and RH
(green +,
yellow -)



NCEP (TCCIP)
NCEP (NCEP-WRF)
ECHAM5
(ECHAM5-WRF-past)
ECHAM5
(ECHAM5-wrf Future

850 hPa
geopotential
height



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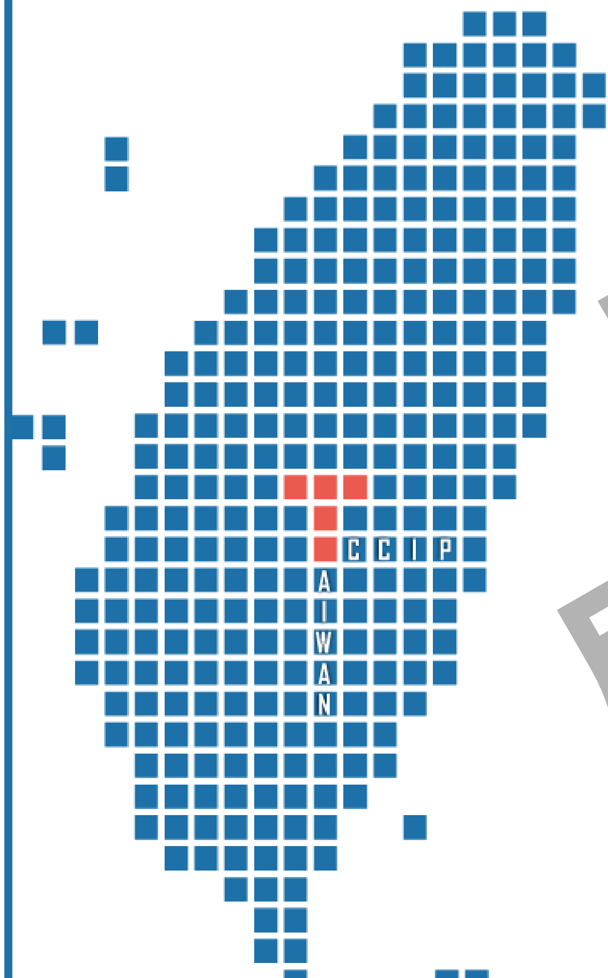

Global warming and cooling energy in Taiwan

Energy and Buildings xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Energy and Buildings

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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
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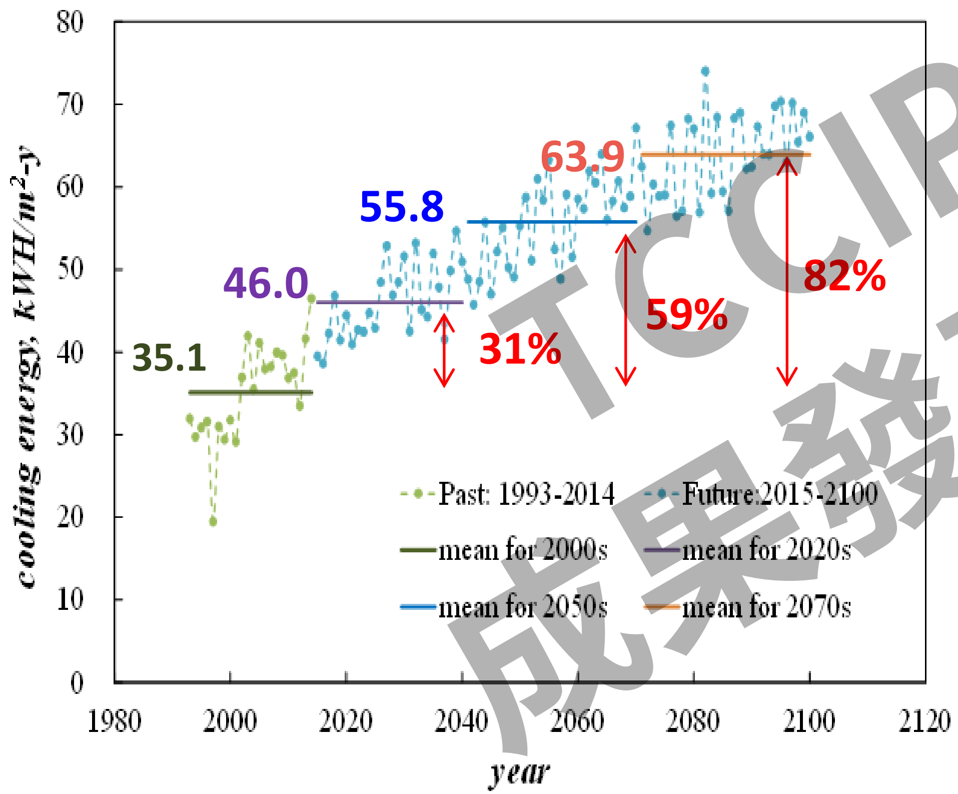
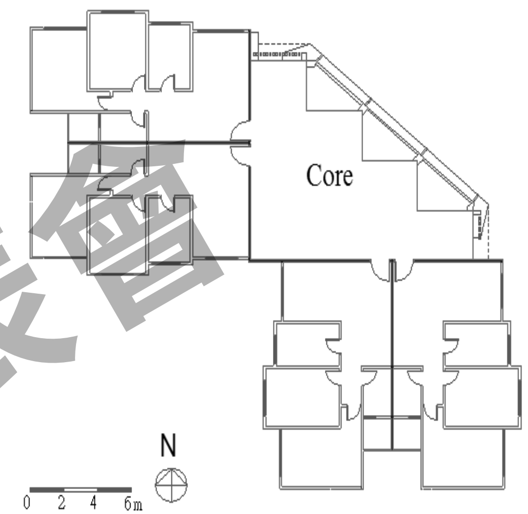
Tradition: Morphing Method + GCM





- The annual cooling energy consumption in the time slices of the 2000s, 2020s, 2050s, and 2080s

Cooling/Heating degree day analysis of meteorological data

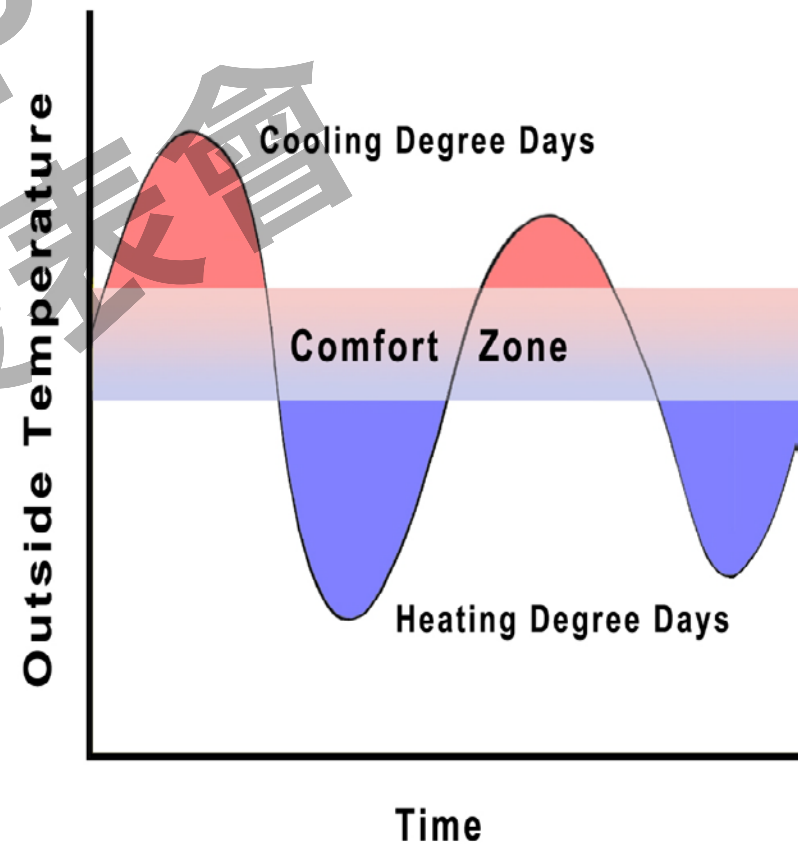
CDD and HDD calculated against the base temperatures of 23°C and 18°C

Heating degree-day:

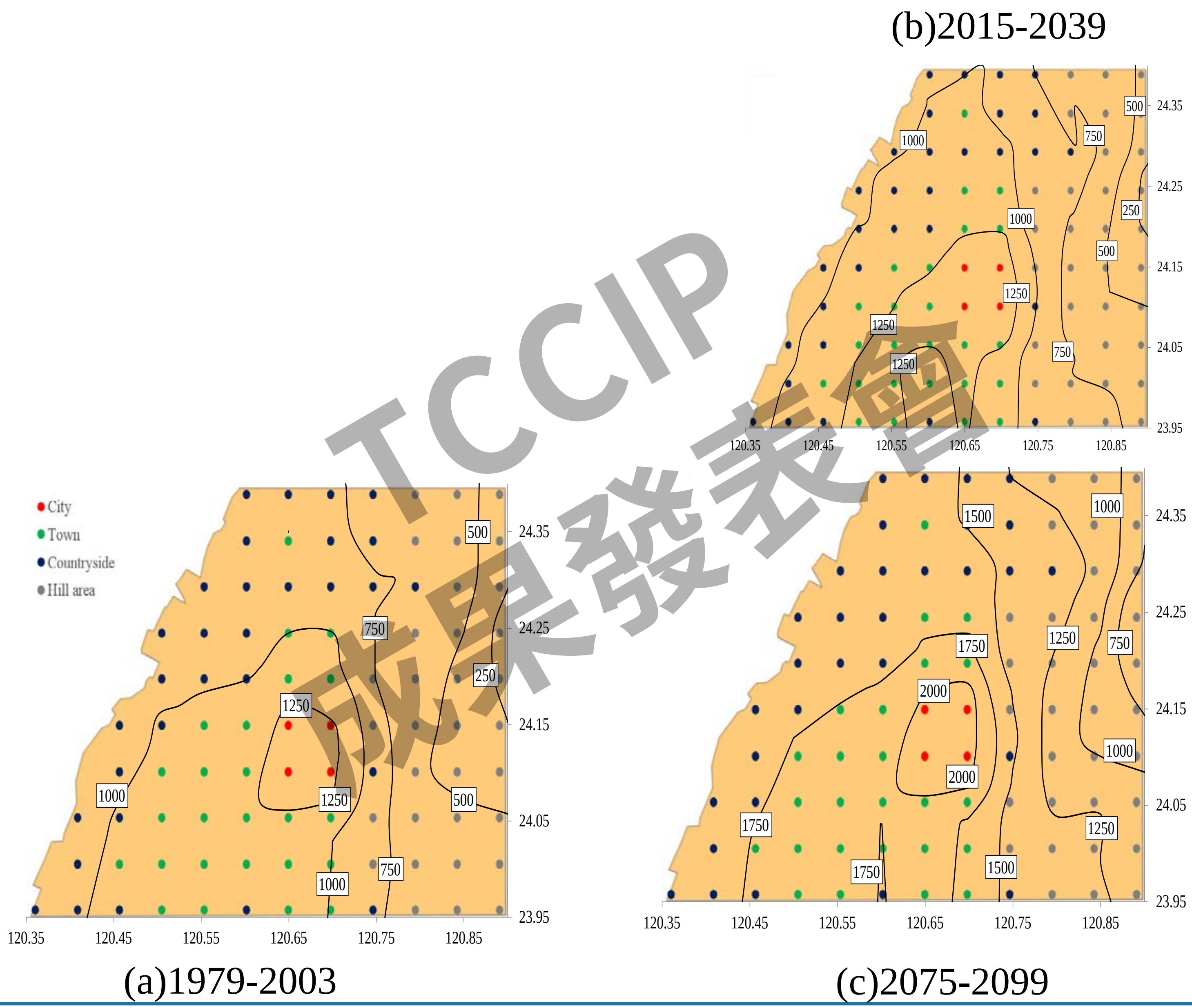
$$DD_h(t_{bal}) = (1\ \text{day}) \sum_{\text{days}} (t_{bal} - t_o)^+$$

Cooling degree-day:

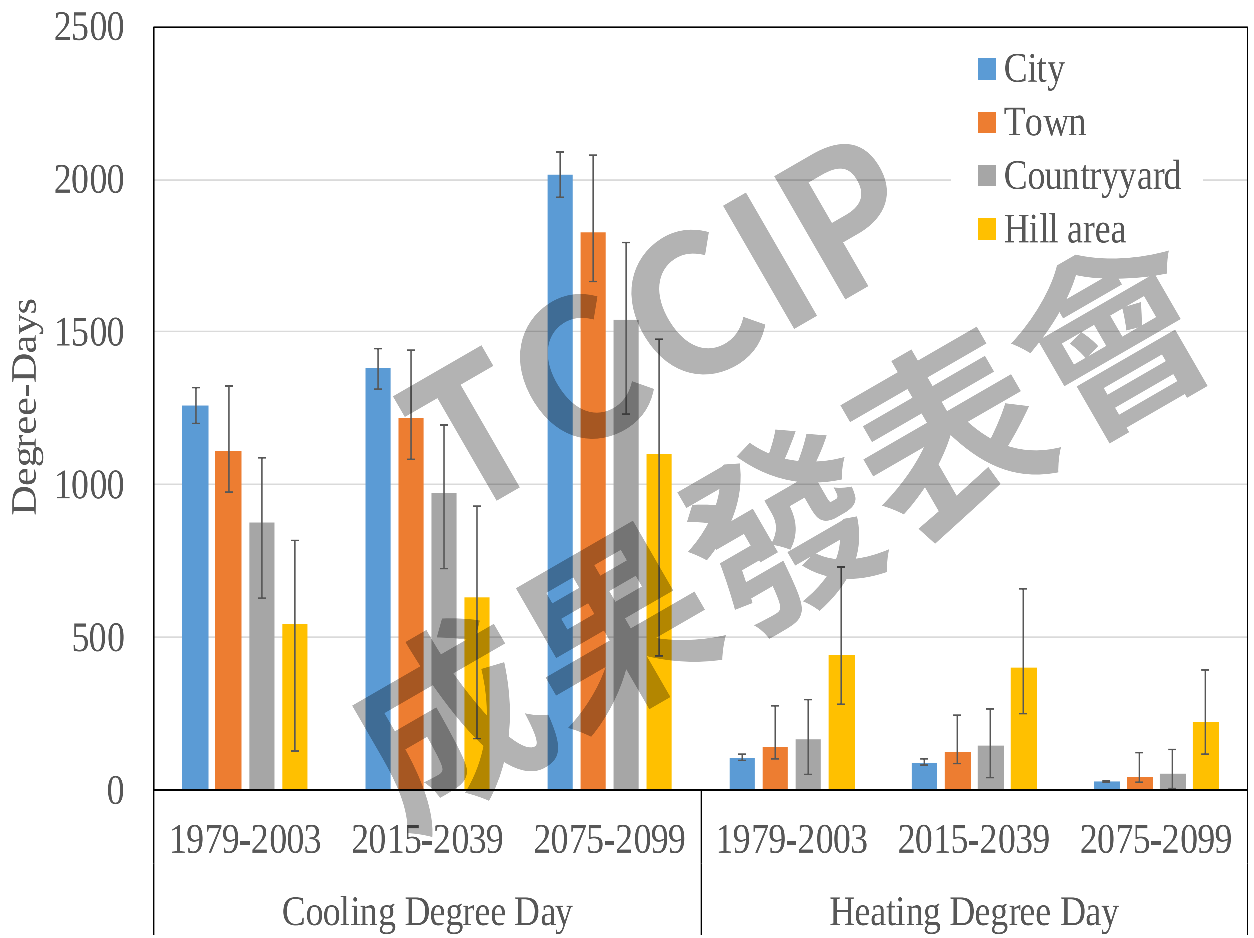
$$DD_c(t_{bal}) = (1\ \text{day}) \sum_{\text{days}} (t_o - t_{bal})^+$$



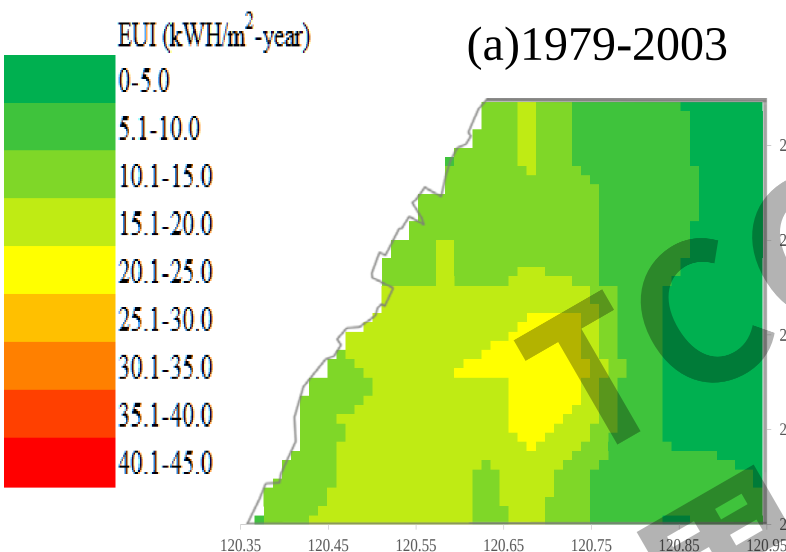
Cooling degree day analysis



UHI on the increase of CDD and the decrease of HDD

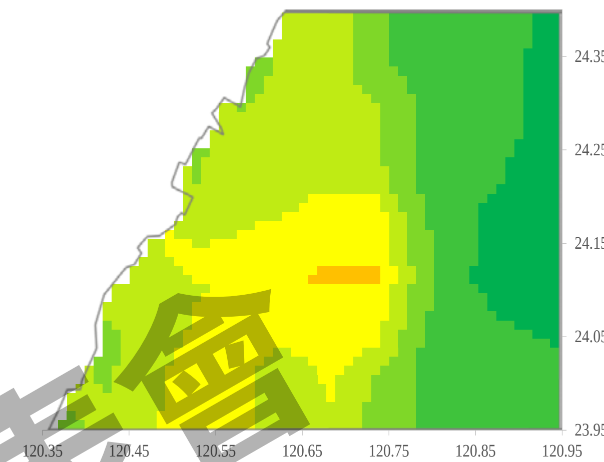


Spatial distribution of cooling energy variation in three time slices

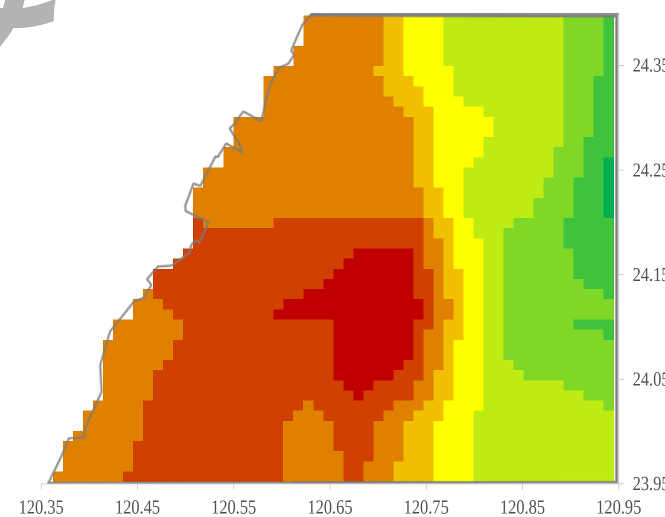


(a)1979-2003

(b)2015-2039



(c)2075-2099



在近未來，範圍為0.07-21.64 kWH/m^2-year，相較於過去期間平均增幅為24%；
在遠未來，範圍為1.36-39.08 kWH/m^2-year，相較於過去期間平均增幅為184%。

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.
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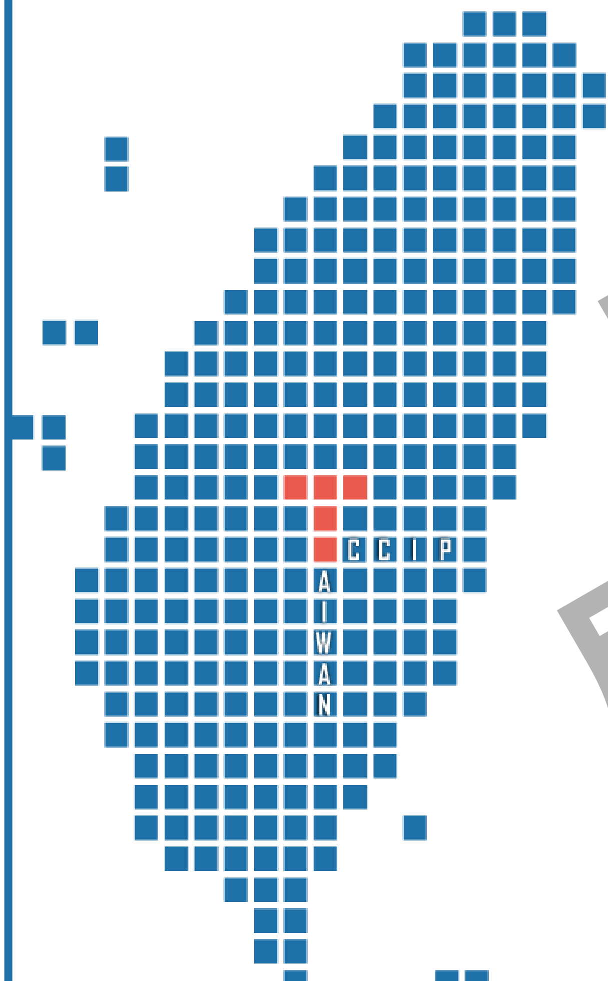
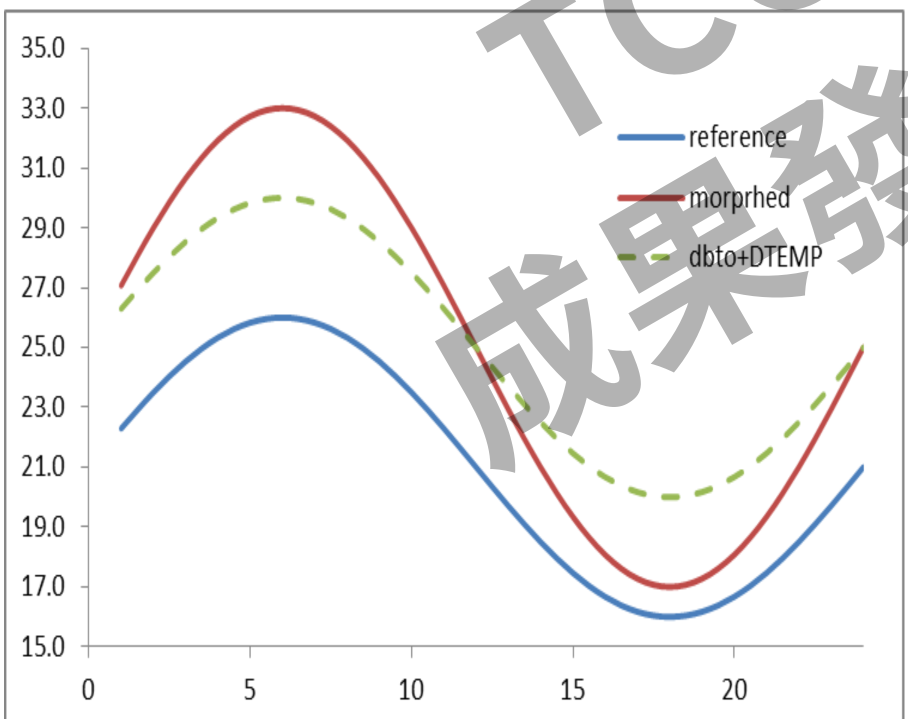


Thanks!!!

Morphing Method + GCM

- Shifting: $x = x_0 + \Delta x_m$
- Linear stretching: $x = \alpha_m x_0$
- Combination of shifting and stretching: $x = x_0 + \Delta x_m + \alpha_m (x_0 - x_{0,m})$



$$t = t_0 + \Delta t_m + \alpha_{t,m}(t_0 - t_{0,m})$$

$$\alpha_{t,m} = \frac{\Delta t_{\max,m} - \Delta t_{\min,m}}{t_{0,\max,m} - t_{0,\min,m}}$$

Future: MIRCO3.2-MED (Japan

Reference: TMY