Impacts of Climate Change on Regional Climate in Taiwan and Southeast Asia

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Topics:

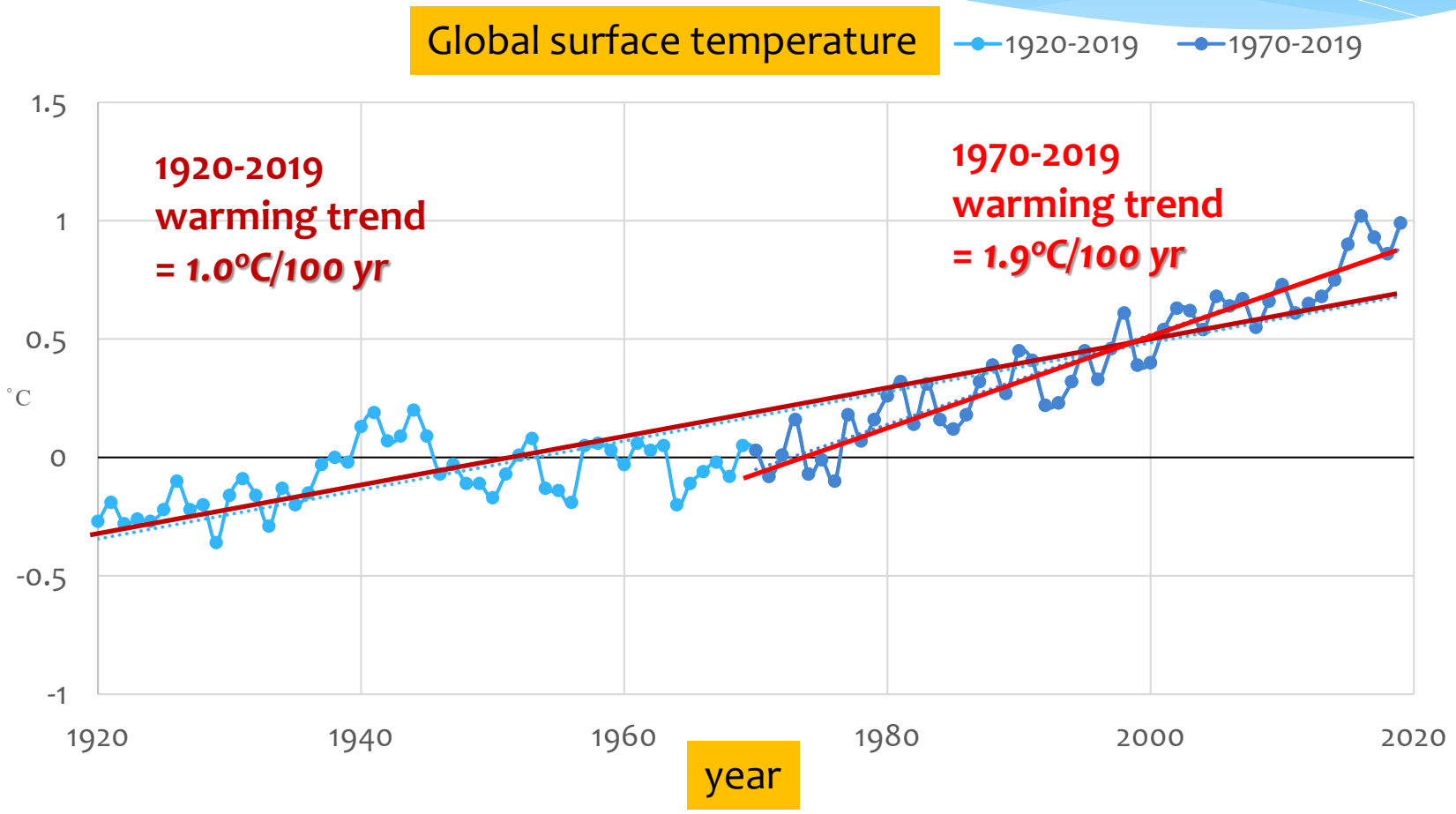
1. Present State of Global Warming

2. Impacts of Global Warming and Urbanization on Taiwan

3. El Niño impacts on Southeast Asia under Global warming

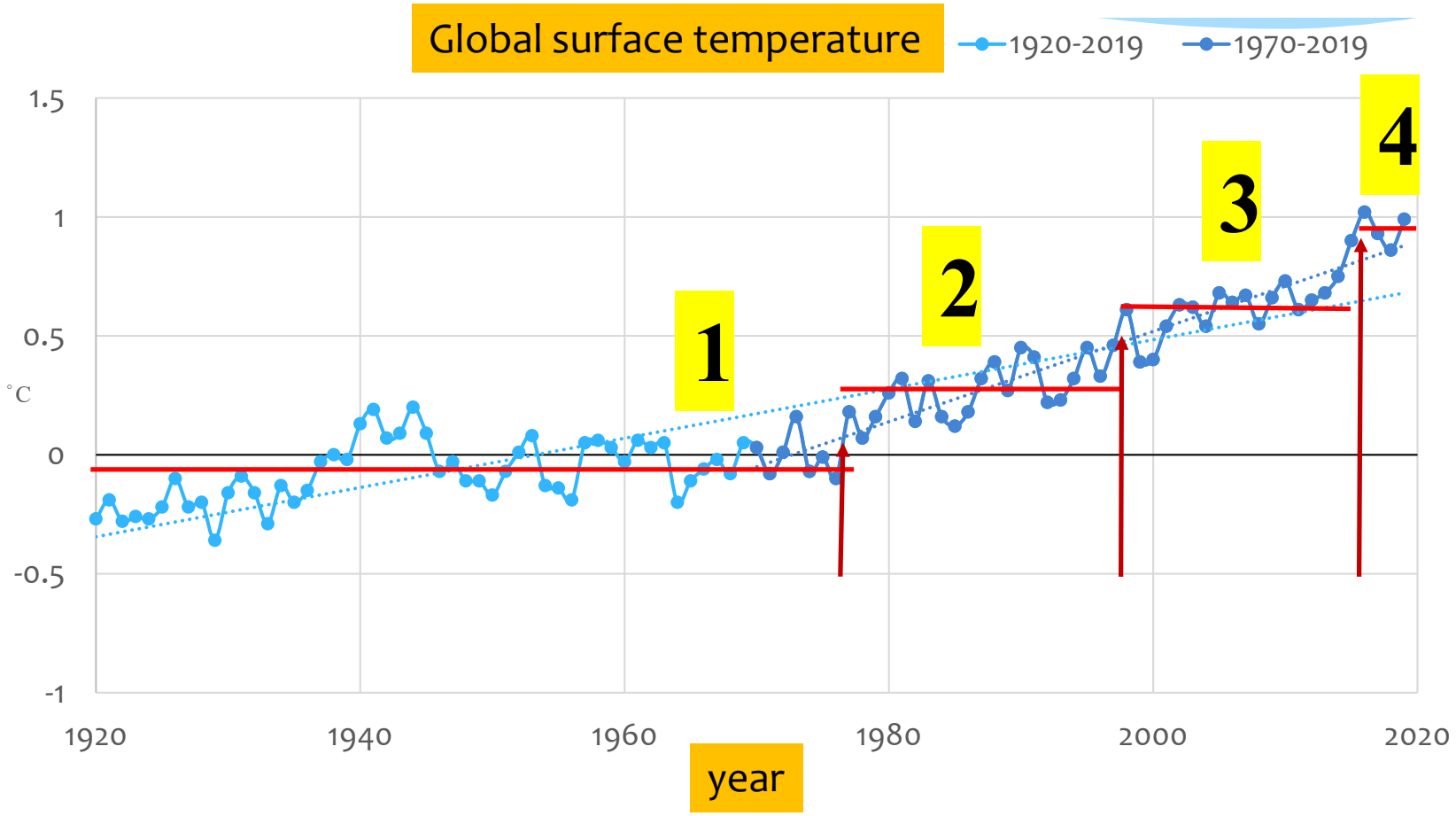
Topic 1:

Present State of Global Warming



- Continuous warming
- Warming is getting faster

4 stair-like warming stages
separated by 3 suddenly-warming years



- **Four stages:** 1920-1976 1977-1997 1998-2015 2016-present
- **Separated by** 1976-77 1997-98 2015-16

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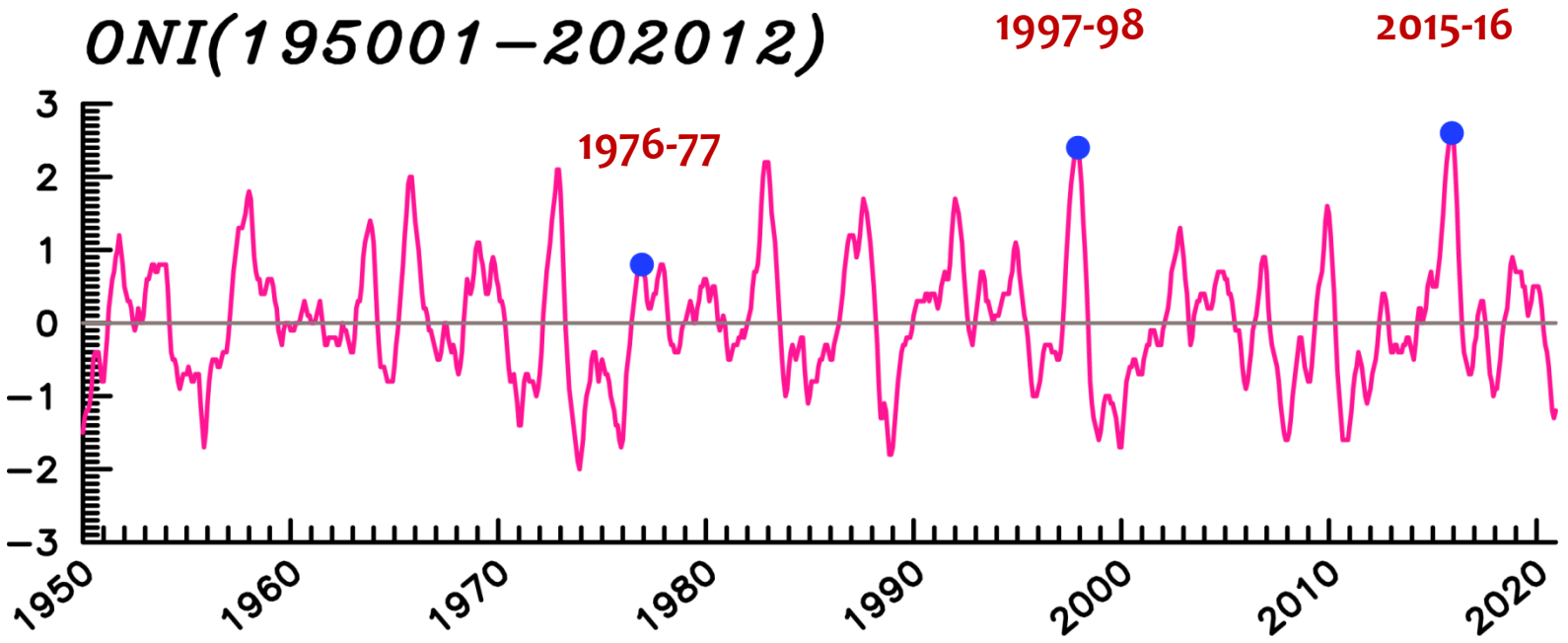


El Niño: positive value >= 0.5°C
La Niña: negative value <=-0.5°C

3 suddenly–warming years correspond to 3 El Niño events.

Story of UN IPCC (Intergovernmental Panel on Climate Change)

To summarize and report the present states and future projections of climate change

First Assessment Report (AR1): 1990
Second Assessment Report (AR2): 1995
Third Assessment Report (AR3): 2001
Fourth Assessment Report (AR4): 2007
Fifth Assessment Report (AR5): 2014
Sixth Assessment Report (AR6): 2021 (Aug.)

During early 1990s, the releases of AR1 and AR2 were strongly challenged by scientific community.

Questions raised at that time:

- What is "global warming"? (It is a new concept)
- Is it strong and fast enough to affect us?
- What is wrong for using cheap gasoline and coal?
- Can it continue on?
- Is it a part of the natural oscillation of climate system?

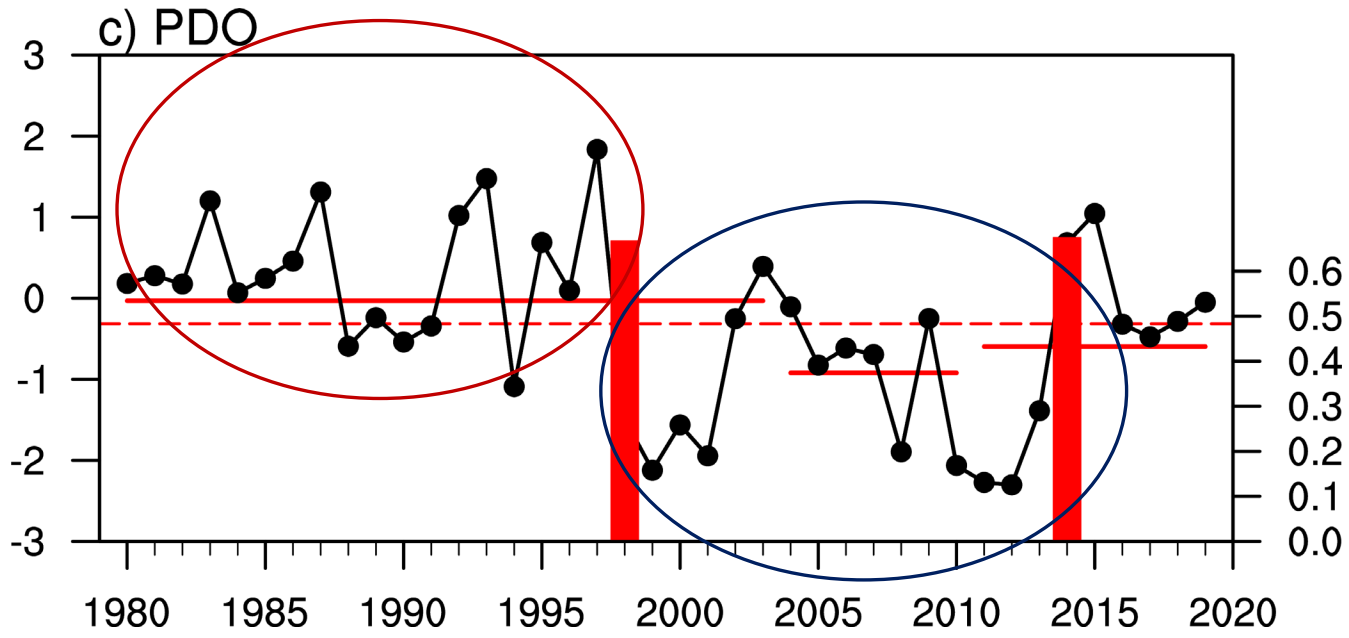
Natural Oscillation

Pacific Decadal Oscillation: around 20-30-year oscillations

1980-1997: positive phase

1998-2019: negative phase

PDO phase **changes from positive to negative around late 1990s**, **but temperature continues to increase**, rather than decrease .



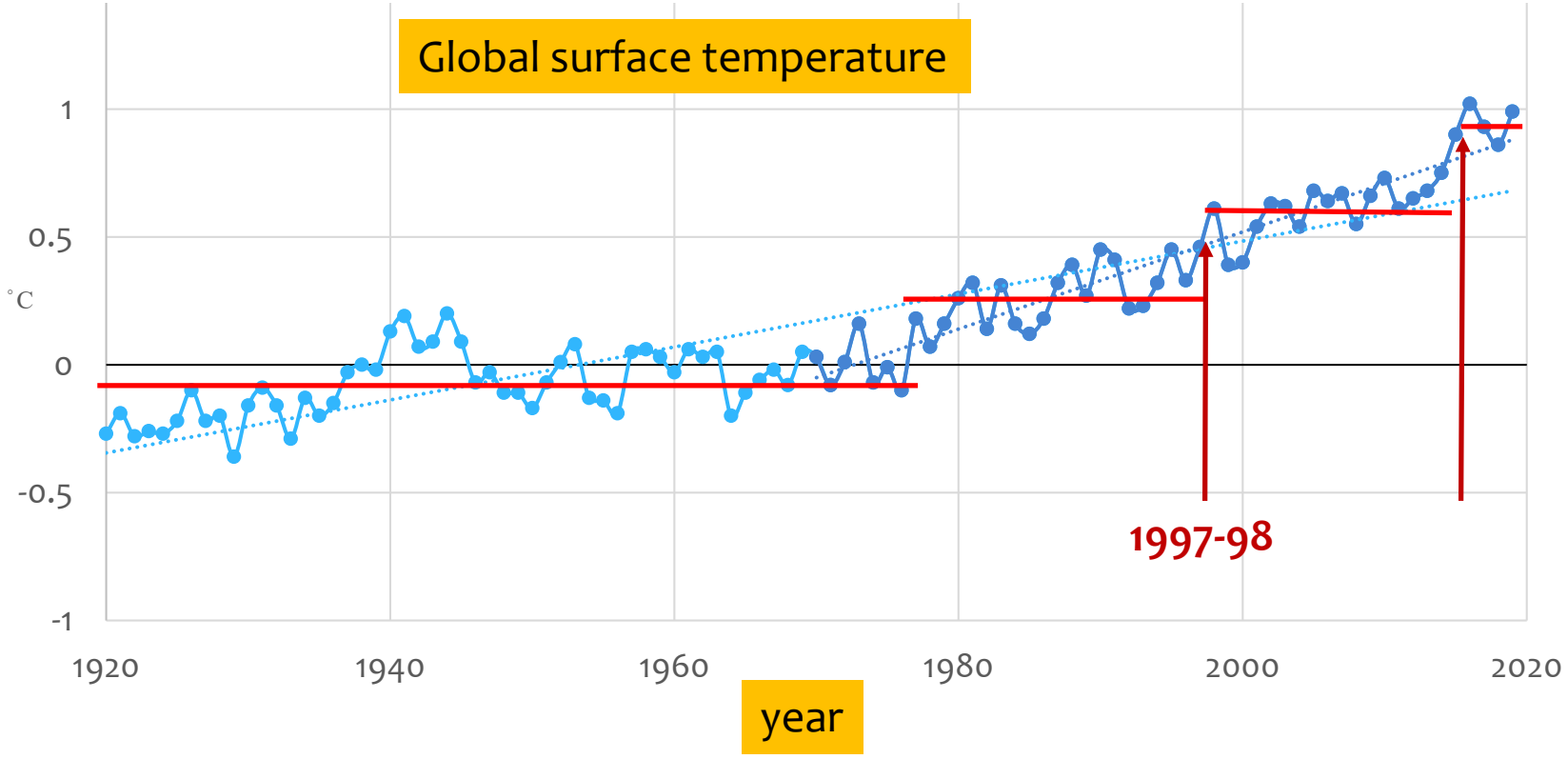
1997-98 El Niño event results in a record-breaking annual-mean temperature in 1998.

Afterwards, temperature stays at the high level during the third stage.

Warming exists and continues.

This is the main reason to stop questions about the existence of global warming .

Warming is not affected by natural variability, but by man-made forcing.



After 1997-98 El Niño event, AR3 in 2001 and AR4 in 2007 have attracted major attentions from the world.

In 2007, IPCC and Al Gore Jr. (former vice present of USA, Author of "An Inconvenient Truth") were awarded of the ***Nobel Peace Prize***.

"For their efforts to build up and disseminate greater knowledge about ***man-made climate change***, and to lay the foundations for the measures that are needed to ***counteract*** such change".

The current warming states reported by AR6 (released in ***Aug. 2021***)

- Human-induced climate change is already affecting many weather and climate extremes in every region across the globe.
- ***Hot extremes (heatwaves) and heavy precipitation*** have become more frequent and more intense.
- Monsoon precipitation increases after 1980s due to increased greenhouse gases (**GHG**).
- With the radiative forcing induced by ***current GHG concentration***, the equilibrium climate sensitivity is estimated ***to have a temperature rise of 2.5°-4°C***.

Projection of future climate

Adopted from IPCC AR6 WGI

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

weak emission

strong emission

With respect to the mean temperature of 1850-1900.

- **2001-2020 was 0.99°C higher than 1850-1900.**
- **2030 and 2050 are likely to be 1.5°C and 2.0°C higher than 1850-1900, respectively.**

SSP: Shared Socio-economic pathway

IPCC AR6: Many changes due to past and future greenhouse gas emissions are **irreversible** for centuries to millennia, especially changes in the **ocean, ice sheets and global sea level**.

CO_2 tends to resolve in cold waters like carbonated drink (Coke)

Oceans are the major sink of CO_2:

1. Ocean absorbs CO_2 → acidification
2. Increased GHG → global warming → higher water temperature

→ **reducing** ocean's capability in **absorbing CO_2**

→ **GHG concentration increases** in the atmosphere

→ Stronger global warming

→ **higher temperature in ocean waters**

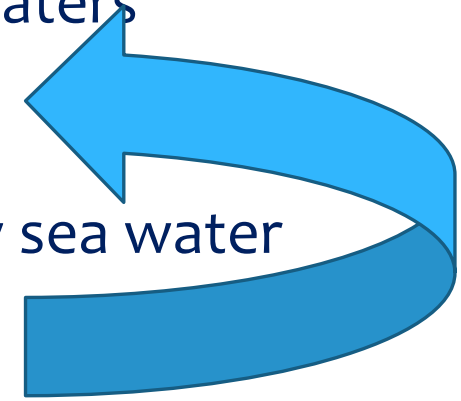
Positive feedback process

Self-intensification process

Melting of Arctic sea ice

Incoming solar heating:
white sea ice : 90% reflection, 10% absorption
blue sea water: 10% reflection, 90% absorption

Global warming
→ Higher temperature in air and sea waters
→ more melting of Artic sea ice
→ More sea waters exposed to Sun
→ More absorption of solar heating by sea water
→ Higher temperature in sea waters
→ more and faster melting of sea ice



positive feedback process

Serious consequence
Arctic sea ice: to cool the Earth by reflecting back solar heating
Arctic sea water: to heat the Earth by absorbing solar heating
→ Faster warming

Points for attentions:

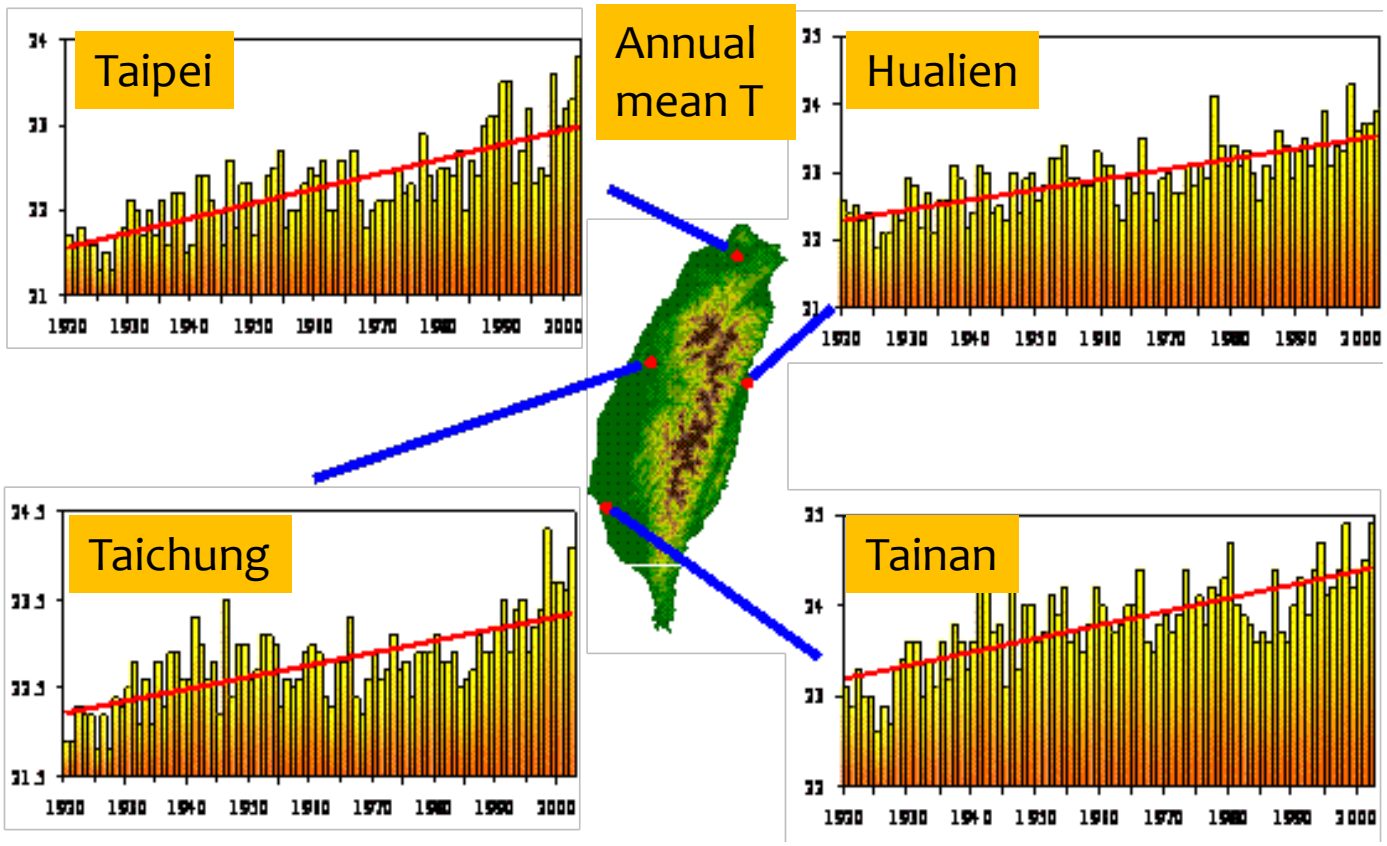
- Global warming process seems to be irreversible with its impacts getting stronger from now on.

- Climate refugees may escape from unbearable environments in the near future.

Topic 2:

Impacts of Global Warming and Urbanization on Taiwan

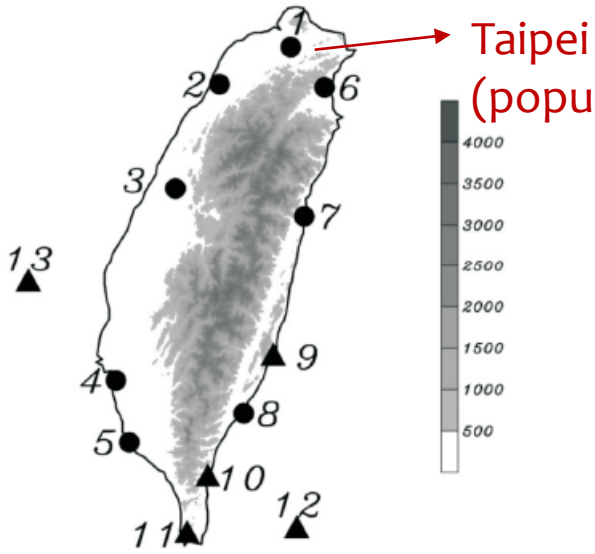
Signature of global warming over Taiwan: persistent warming trends over every sectors of Taiwan



Reference:
J.-M. Chen (2006) Climate Variability

Urbanization effect

urban: ●
suburban: ▲

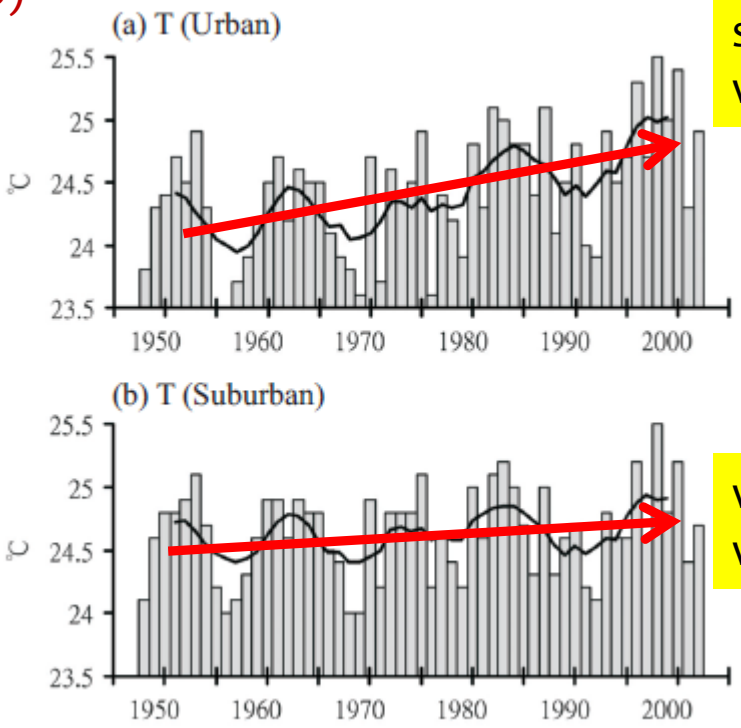


Penchiayu
(population: 100)

Taipei
(population: 2.6M)

Fig. 1. Geographical distributions of 14 meteorological stations in Taiwan, eight in urban regions (marked by ●) and six in suburban regions (marked by ▲). Detailed information of these stations is listed in Table 1.

Fall temperature in Taiwan



strong warming

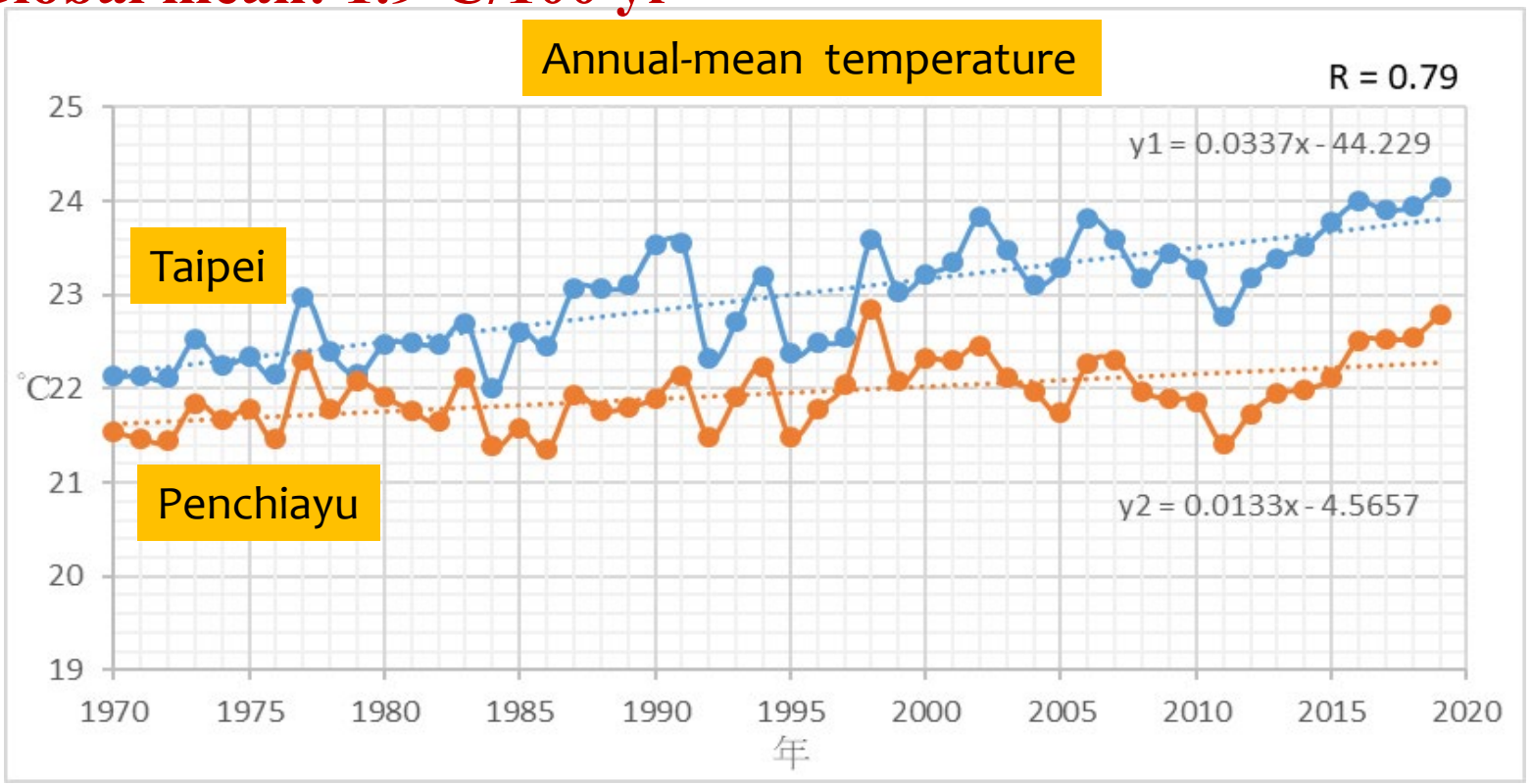
weak warming

Stronger warming trend in urban region than suburban region.
→ Difference caused by urbanization effect.

Reference:
J.-M. Chen et al. (2007), TAO

1970-2019 warming trend
Taipei: 3.37°C/100 yr
Penchiayu: 1.33°C/100 yr

Global mean: 1.9°C/100 yr

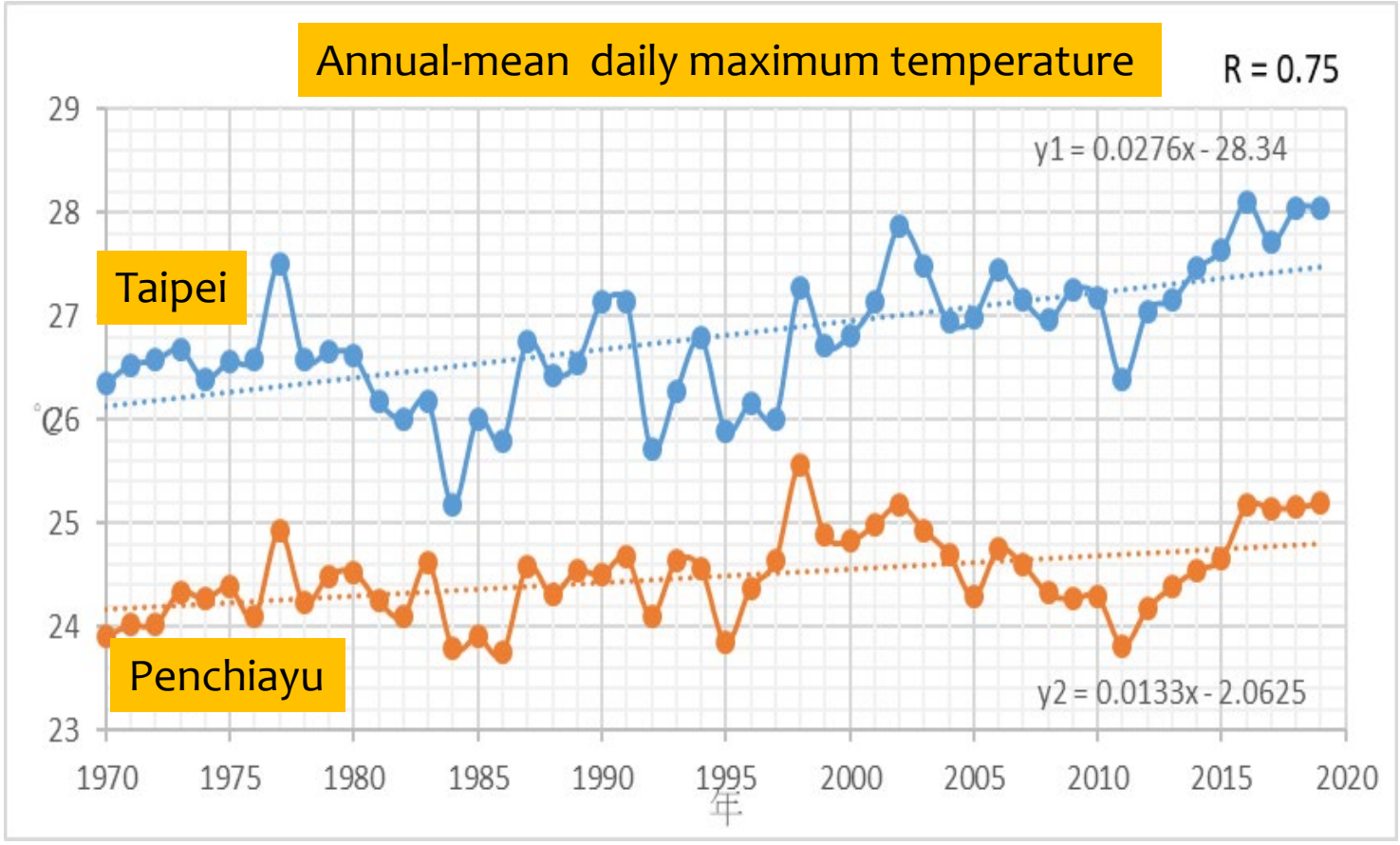


Faster warming in Urban region than suburban region

1970-2019 warming trend

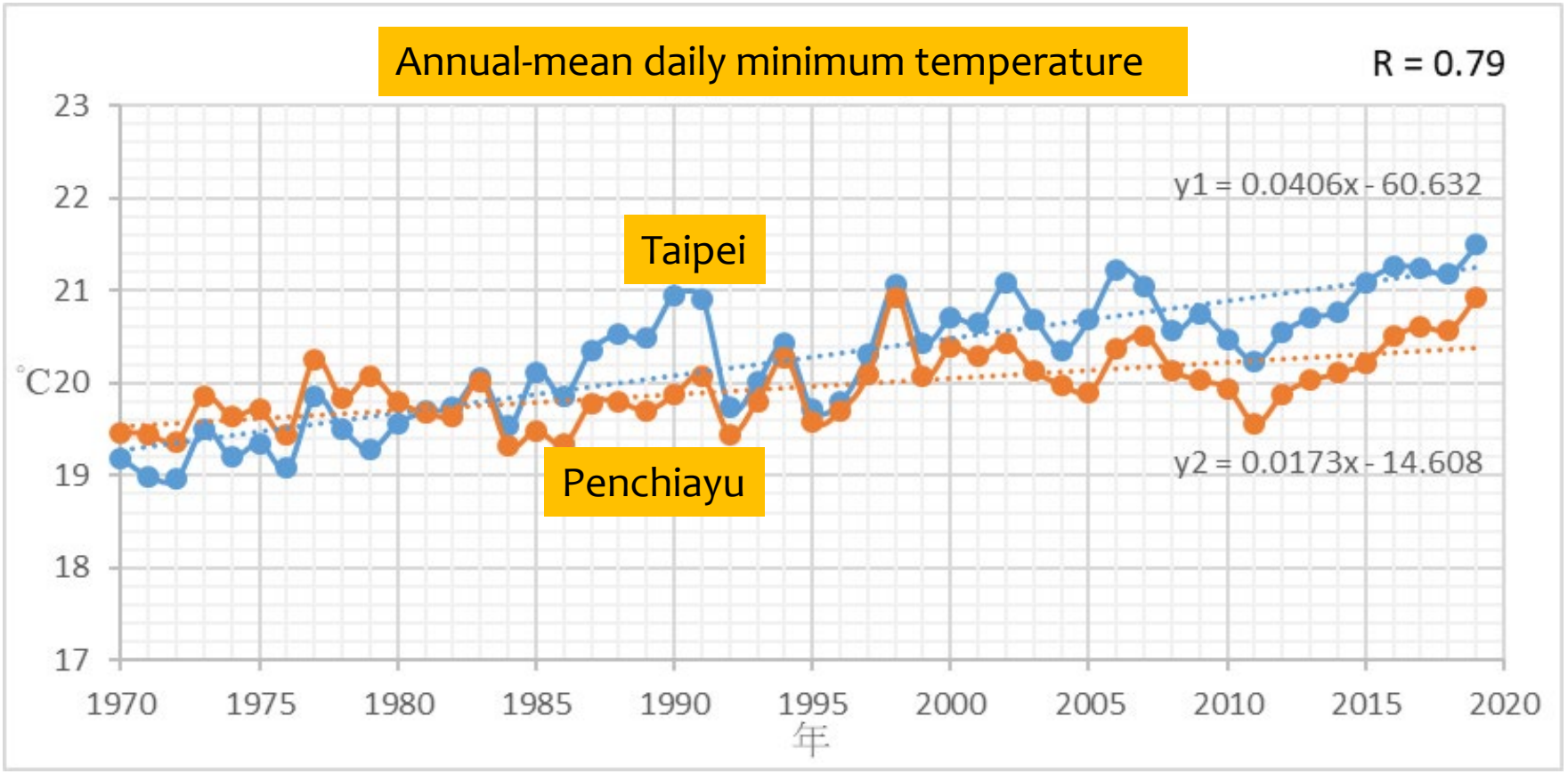
Taipei: 2.76°C/100 yr

Penchiayu: 1.33°C/100 yr



Warming of day-time temperature

1970-2019 warming trend
Taipei: 4.06°C/100 yr
Penchiayu: 1.73°C/100 yr



Warming trend of night-time temperature is larger than that of day-time temperature. Why?

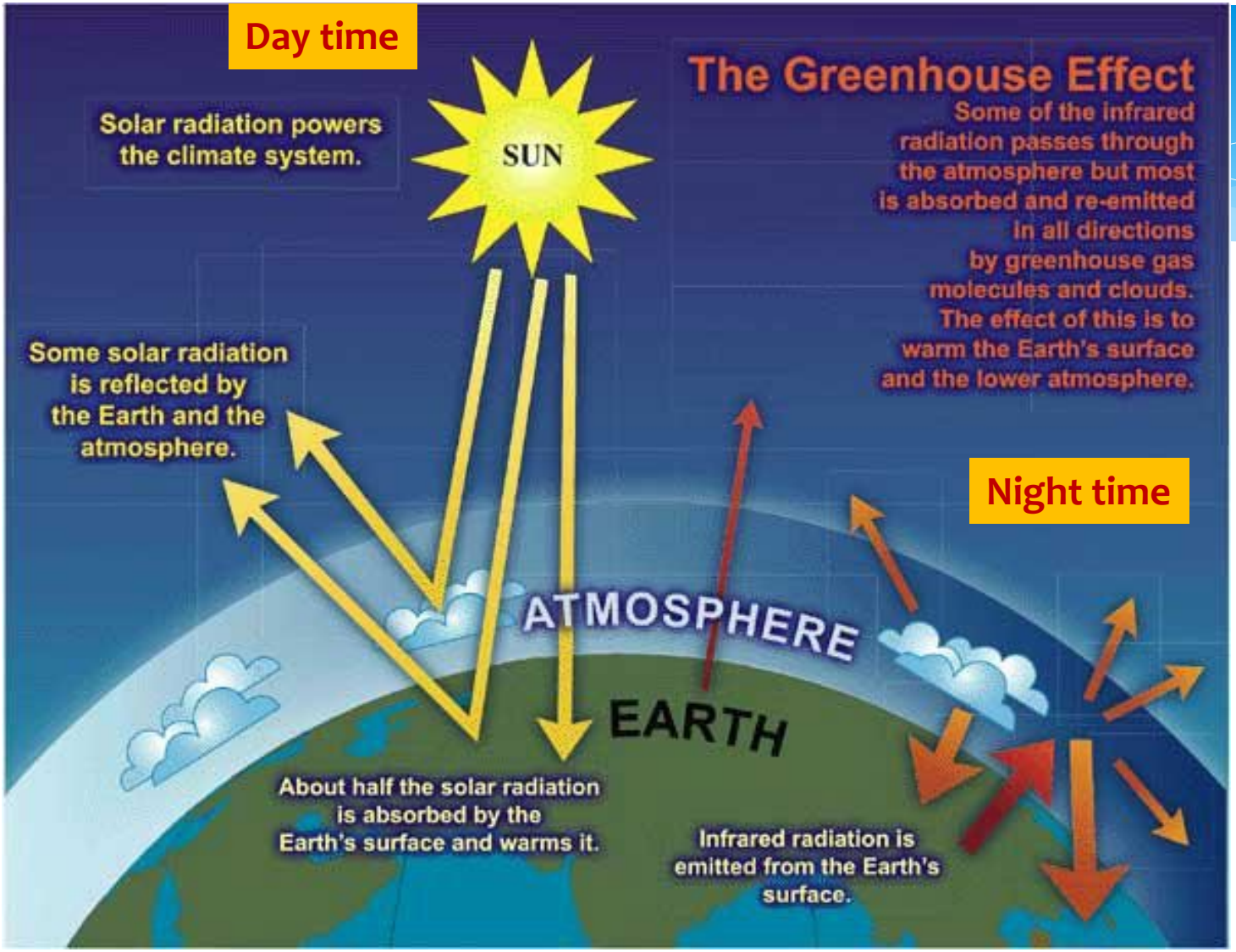


Figure Source: National Institute of Water and Atmospheric Research

Sun's surface (~6000°C): solar radiation → high energy → short wave
Earth's surface (~15°C) : earth radiation → low energy → long wave

Greenhouse gases only absorb long wave, but not short wave.

Day time: half of solar radiation penetrates atmosphere to heat the Earth.
Night time: Earth radiation releases heat back to atmosphere
→ Partial long-wave radiation is absorbed by GHGs to warm atmosphere
→ Without greenhouse effects, Earth's surface temperature is expected to be around -19^{o}C, not current 15^{o}C.

More GHGs → more absorptions during night time
→ to directly increase night-time temperature
→ the remaining heat to indirectly increase day-time temperature

Warming trend in night time is larger than day time.

The long-term impact of CO_2

The major component of GHGs is CO_2 .

→ Once existence, CO_2 can exist in nature for **60-100 years**.

→ Even without any more GHG emission from now on, the current warming state needs 60-100 years to gradually decrease.

→ It needs to plant a tree with a life time longer than 60 years to efficiently reduce CO_2 concentration.

Urbanization effect

When solar heating reaches Earth's surface:

Urban region:

roads and buildings absorb solar heating in day time and release it back to atmosphere in night time

→ processes to heat the city → heat-island effect

Suburban region:

solar heating can be absorbed by waters on surface or underground

→ heating changes water into water vapor via evaporation

→ water vapor rises into the sky to form cloud and release heating into the upper-level atmosphere

→ cloud causes rainfall to cool the surface

→ processes of afternoon thunderstorm

→ pay attentions to reductions of thunderstorm over urban regions

Urbanization effects in Taiwan

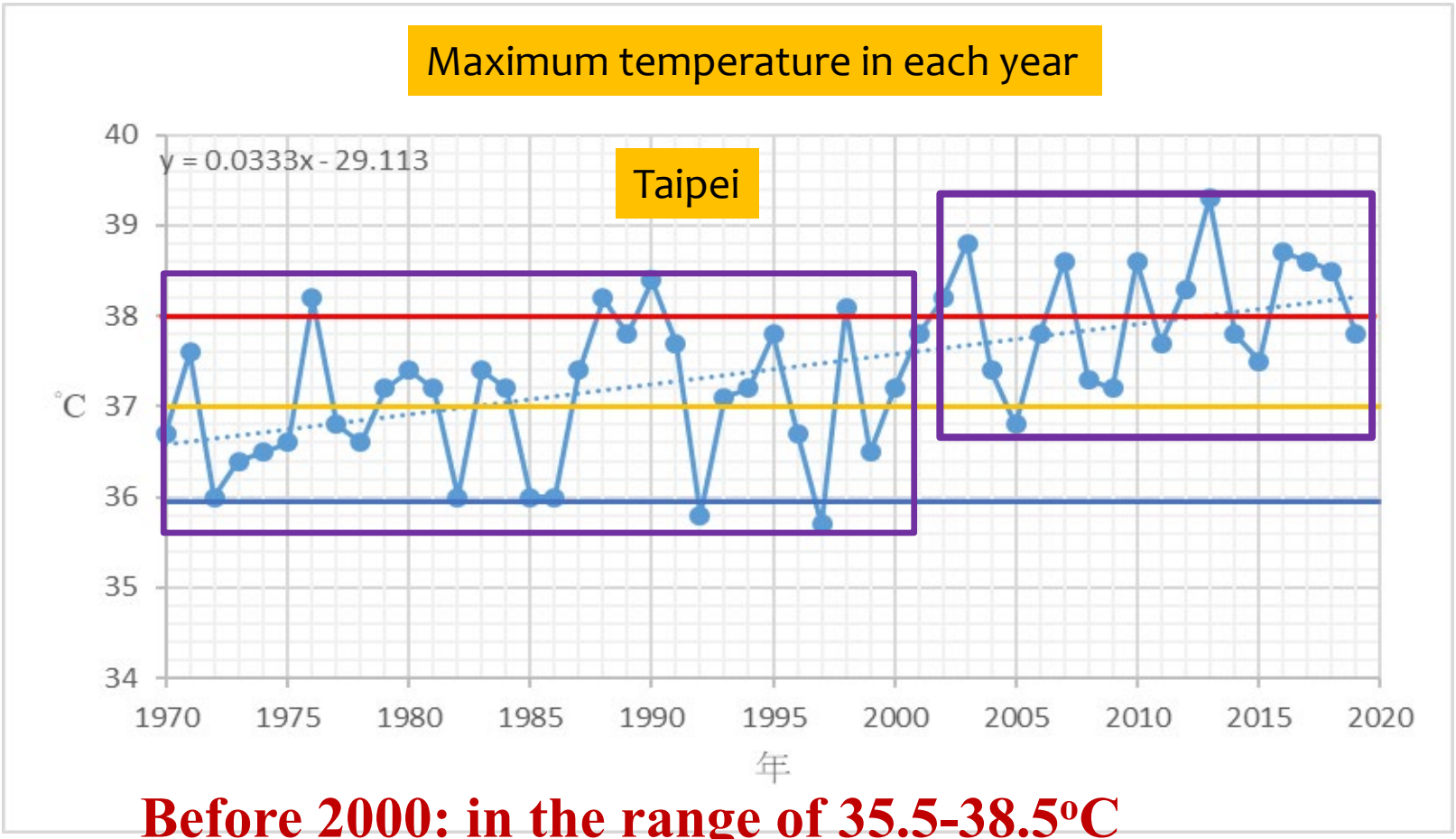
	(population)	1970-2019 warming trend of annual-mean T
Urban	Taipei (2.6M)	3.37˚/100 yr
	Taichung (2.8M)	3.18˚/100 yr
	Tainan (1.9M)	2.21˚/100 yr
	Average	**2.92**
Suburban	Penchiayu (0.1K)	1.33˚/100 yr
	Jihyuehtan (15K)	0.77˚/100 yr
	Lanyu (5K)	0.66˚/100 yr
	Average	**0.92**
Urban/Suburban		**3.17**

Urban warming is about 3 times larger than suburban warming.

2.92°C (total warming) = 0.92°C (global warming)

\+ 2.0°C (urbanization effect)

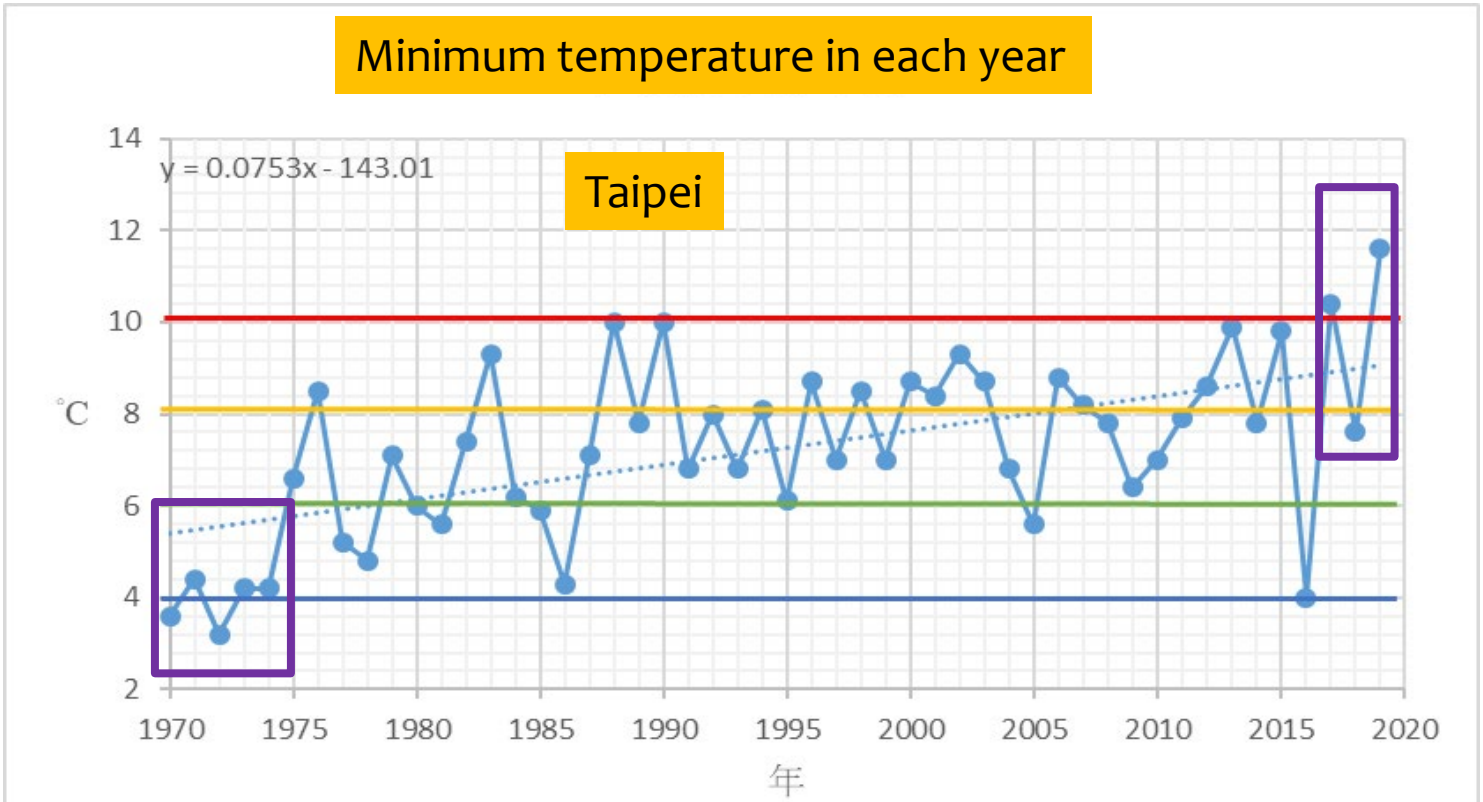
1970-2019 trend
Taipei: 3.33°C/100 yr



Before 2000: in the range of 35.5-38.5°C

After 2000: in the range of 36.5-39.5°C

1970-2019 trend
Taipei: 7.53°C/100 yr



In 2017 and 2019, daily temperature was never lower than 10°C

→ No cold surge in Taiwan for these two years.

→ Longer summer with shorter or no winter

Points for attentions:

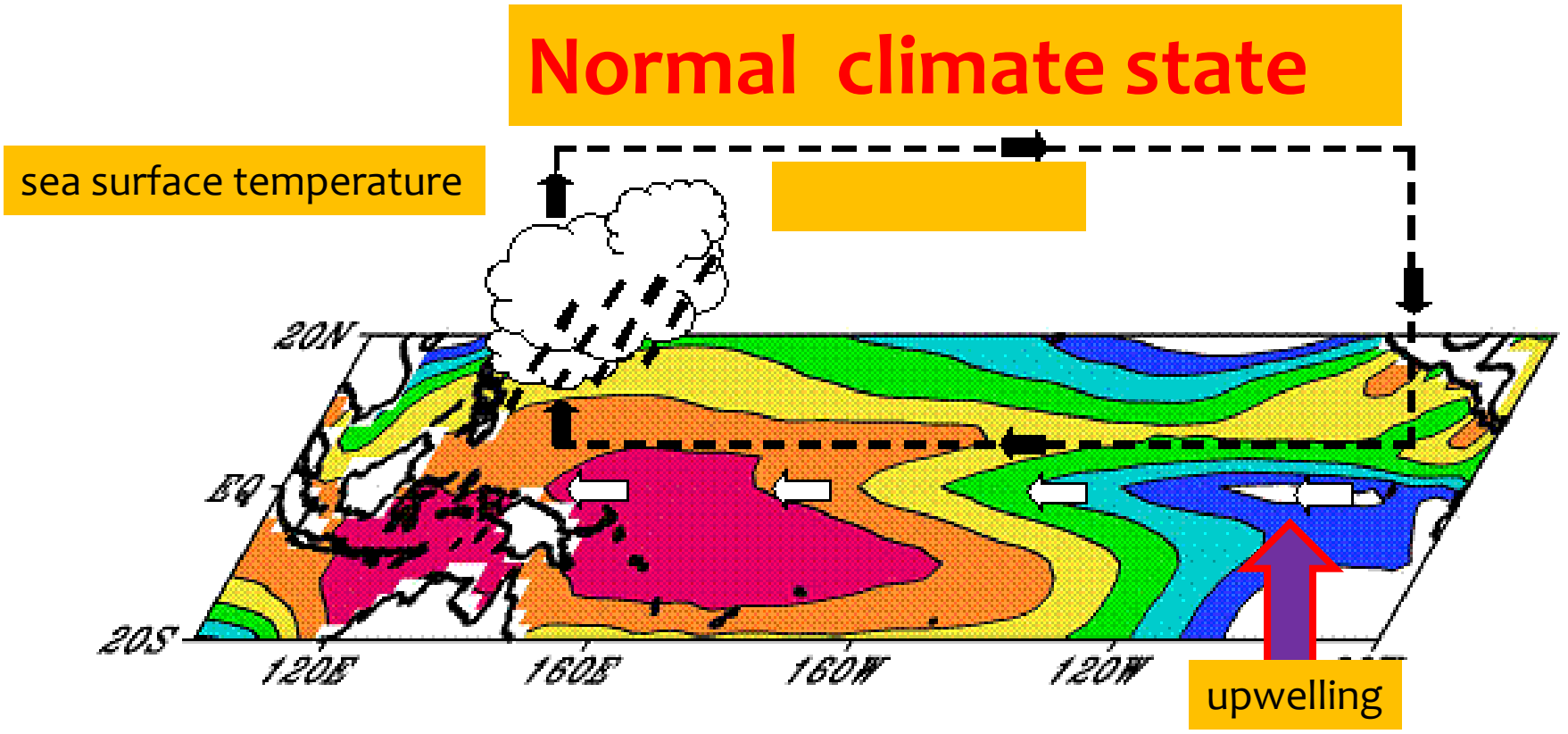
- For the metropolitan areas in the populous Asia, a longer summer with a shorter or no winter will appear in the near future

- More energy is needed to cool people for their survival from the abnormal warming environments.

Topic 3:

El Niño impacts on Southeast Asia under Global warming

Cold upwelling in the tropical eastern Pacific
Cold water was driven westward by tropical trade (west-bound) winds
Heated by sun, waters are warmer as they move more westward
Tropical Pacific: **warm in the west and cold in the east**

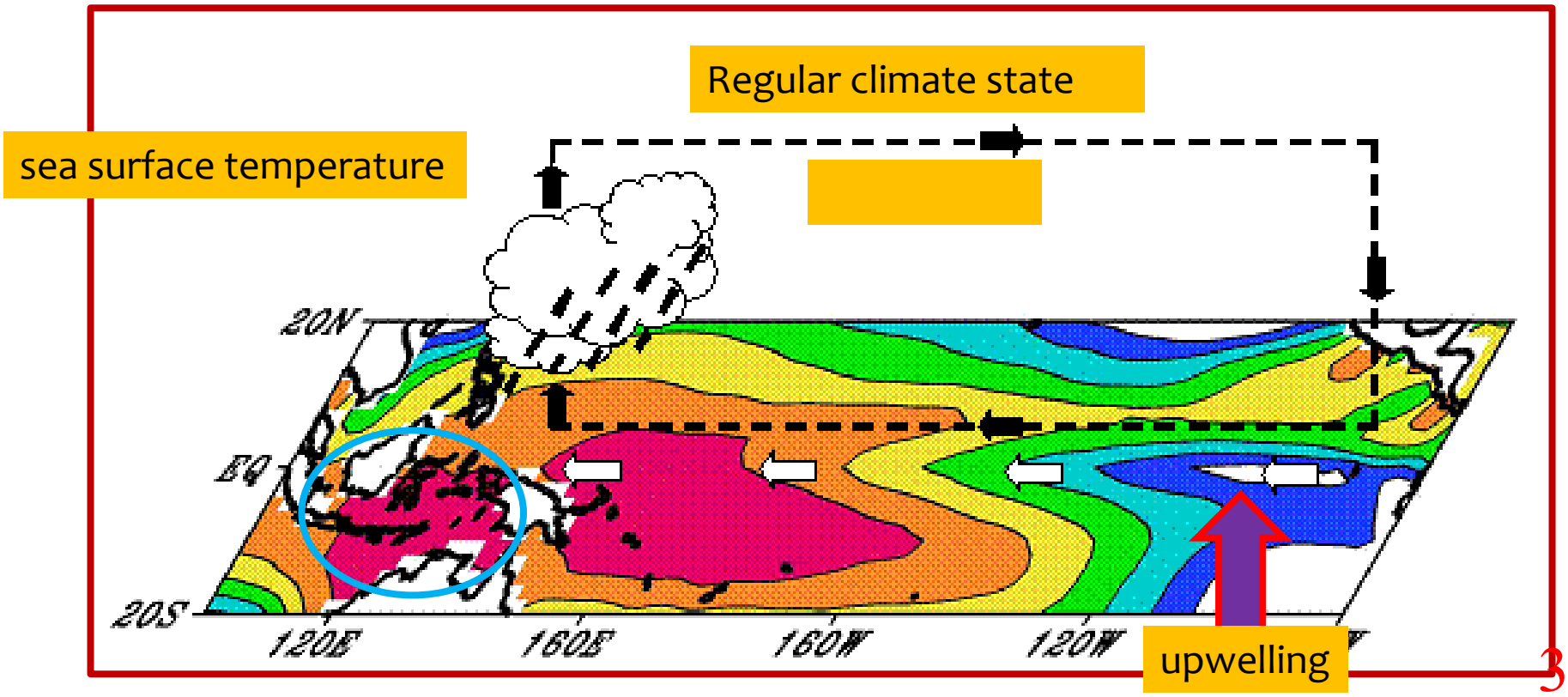


Warm water in the **west** heats airs to rise
→ upward motion of water vapor → cloud → **rain**

Cold water in the **east** cools airs to sink
→ downward motion → no cloud → **no rain**

Rain forests exist in Southeast Asia around the tropical western Pacific

Warm West – Cold East



El Niño event

The occurrence of anomalous westerly (east-bound) flows to drive warm waters from the tropical western Pacific toward the central and eastern Pacific

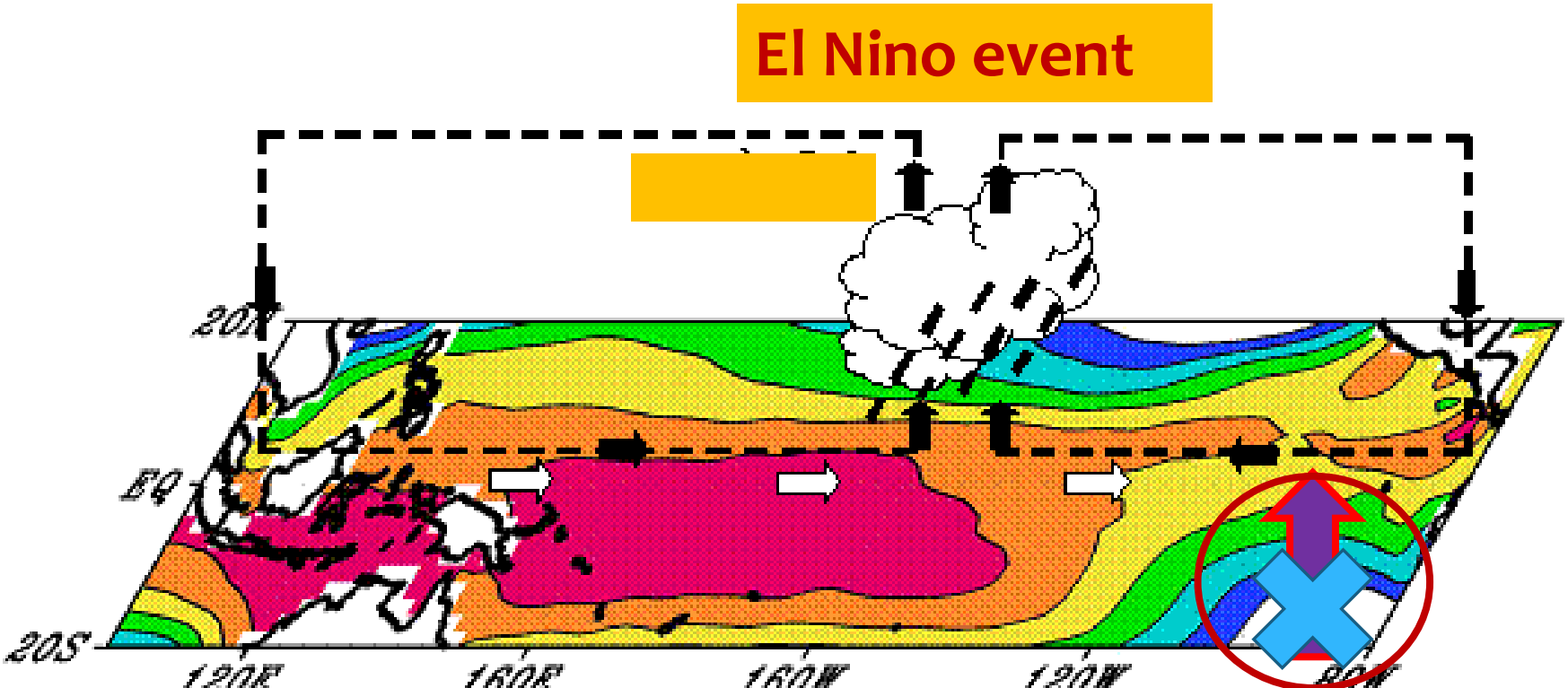
→ More surface waters flow into the tropical eastern Pacific

→ **Upwelling is blocked** → less cold water from deep sea into surface

→ Surface waters **becomes warmer in the tropical eastern Pacific (Warm Event)**

→ The leaving of warm water makes the **western Pacific colder**

→ **Colder in the West – Warmer in the East**



La Niña event

The enhancement of tropical trade winds (west-bound)

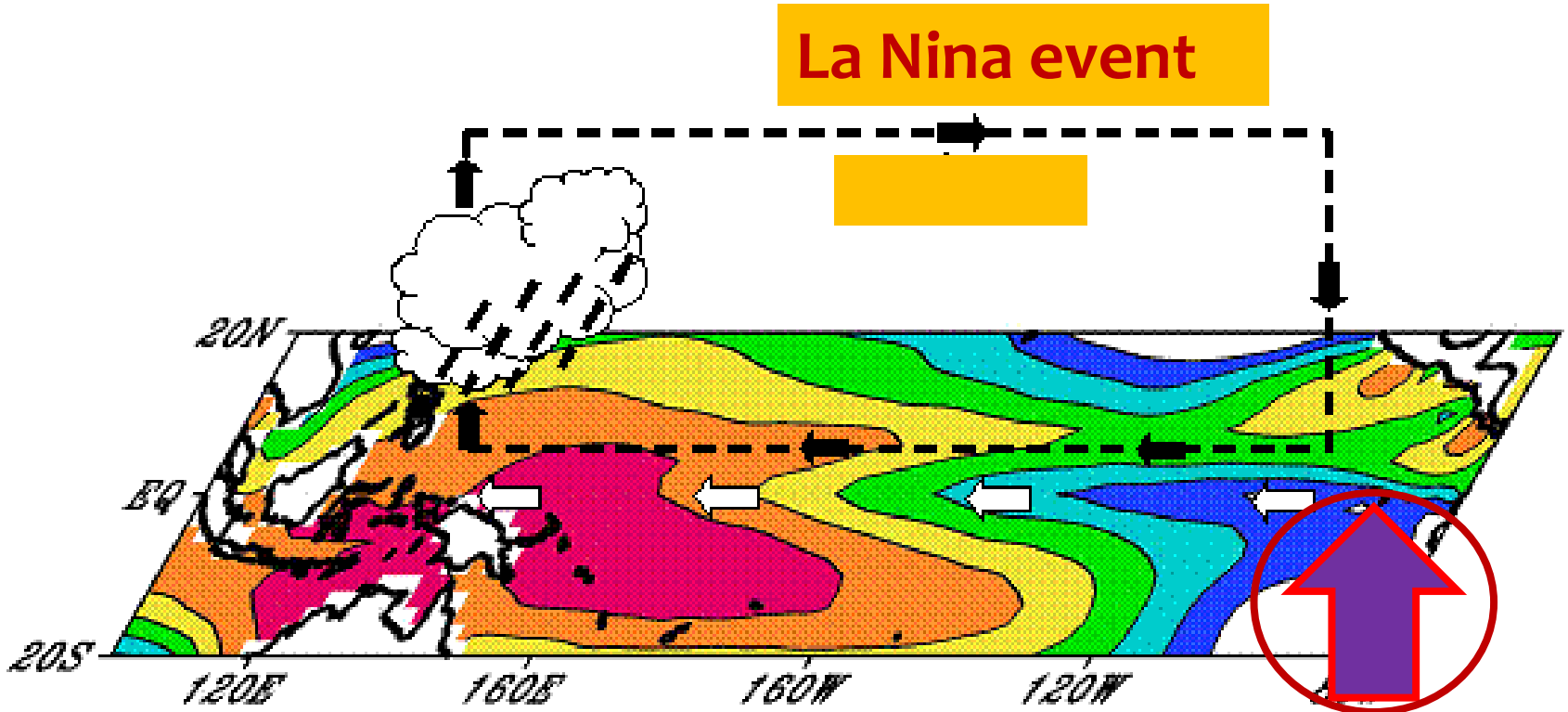
→ More warm waters gather in the tropical western Pacific

→ The leaving of water from the eastern Pacific

→ **Enhanced upwelling** cools the eastern Pacific **(Cold Event)**

→ Surface waters becomes warmer in the western Pacific and colder in the eastern Pacific

→ **Warmer in the West – Colder in the East**



	Sea Surface Temperature	
	western Pacific	Eastern Pacific
Climate state:	warm	cold
El Niño :	becomes colder	becomes warmer
La Niña :	becomes warmer	becomes colder

El Niño tends to induce a variability state opposite to the climate state

→ Colder waters in the western Pacific induce downward motions

→ Reduced clouds and rains over the SE Asia

→ Likely to have a dry condition during an El Nino event.

La Niña tends to induce a variability state enhancing the climate state

→ More clouds and rains over the SE Asia

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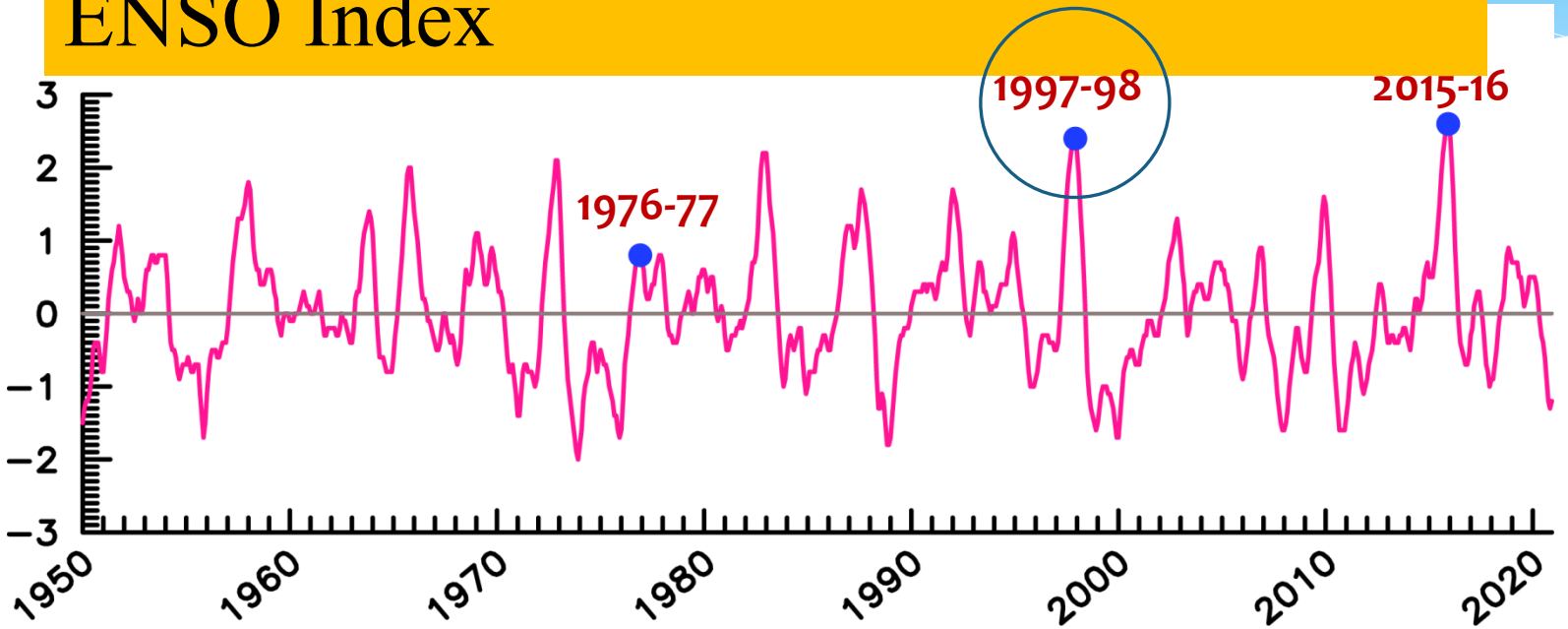
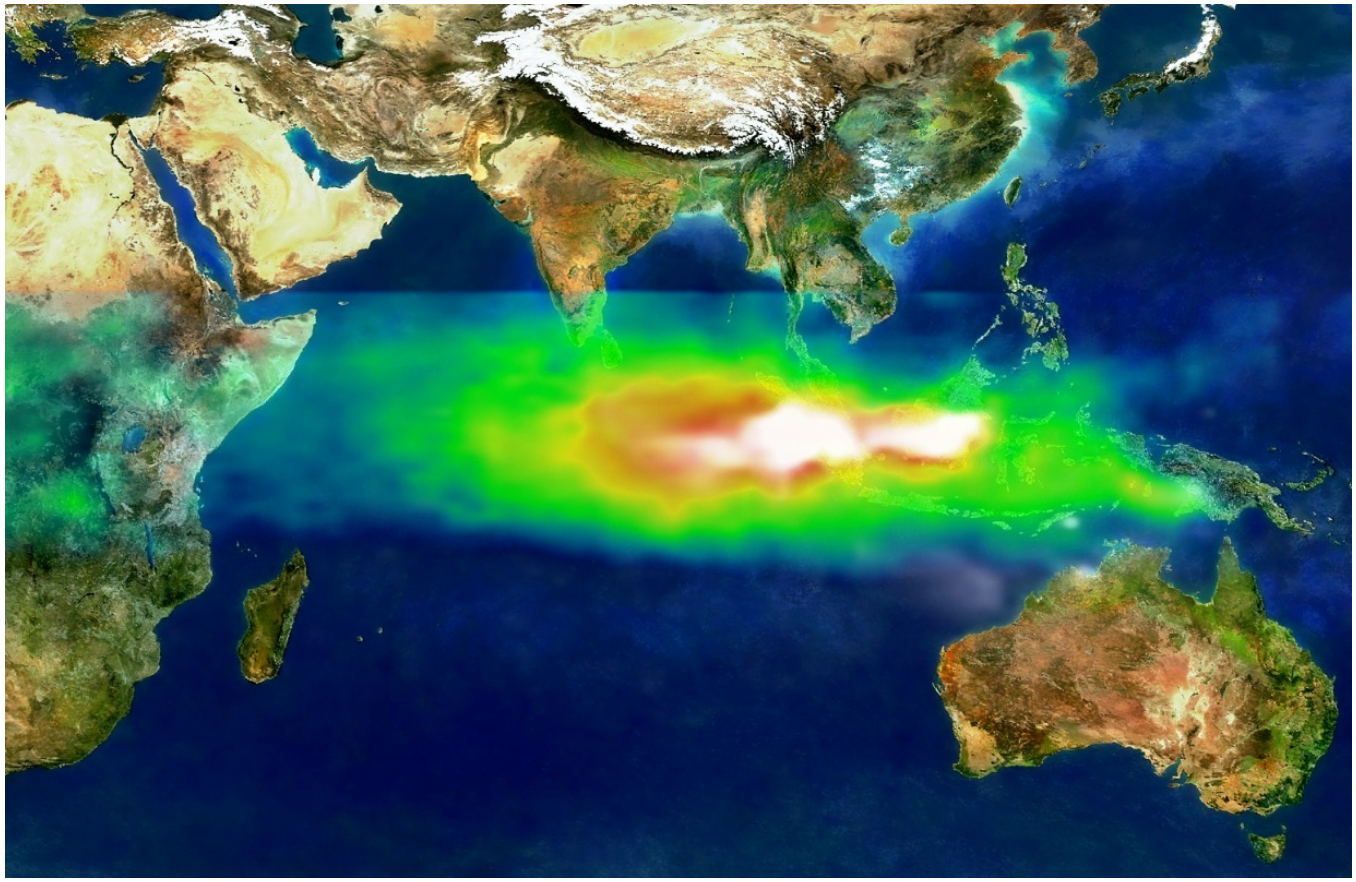


El Niño: positive value >= 0.5°C
La Niña: negative value <=-0.5°C

1997-98 El Nino event

1997-98 El-Niño event: drought first and forest fire next

The 1997 group of forest fires in Indonesia that lasted well into 1998 were probably among the two or three, if not the largest, forest fires group in the last two centuries of recorded history. (From Wikimedia Commons)

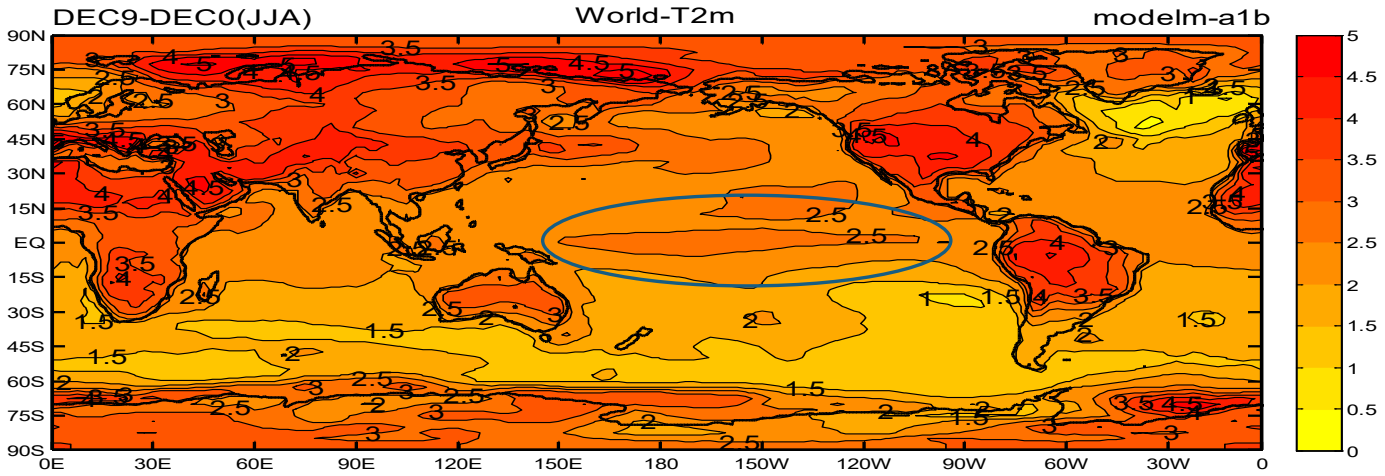


Countries affected

- Indonesia
- Singapore
- Malaysia
- Thailand
- Brunei
- Vietnam
- Philippines
- Sri Lanka

Smoke and ozone pollution from Indonesian forest fires, 1997 (photo from NASA)

Why is El Nino event important for SE Asia?



Future change [(2090-2100) – (2000-2010)] of surface temperature projected by IPCC AR4

Major features:

- Overall warming around the globe.
- More warming in the polar regions than the tropical regions.
- More warming in the eastern Pacific than the western Pacific.
  (Additional heating transfers toward the colder regions first)

Sea Surface Temperature

	western Pacific	Eastern Pacific
Global warming:	less warming	more warming
El Niño :	becomes colder	becomes warmer

Variability features of surface temperature in the tropical Pacific tend to be in phase between El Niño and global warming

→ Their double impacts act to enhance drought conditions in the SE Asia during an El Niño event.

→ To cause a higher temperature rise during an El Niño year under global warming

El Niño → a warm event → to cause a temperature rise
→ more warming

La Niña → a cold event → to cause a temperature decrease
→less warming

Points for attentions:

- The occurrence of another strong El Niño event may raise global temperature to another higher stage.

- Higher temperature speeds up water evaporation.
  → A better chance causes an agricultural drought.
  → Water resources are getting more important to secure people's living in the future.

Summary:

- Be prepared for faster global warming and more hazardous weather and climate impacts.
- More energy powers will be needed to cool the metropolitan regions.
- Heatwaves and droughts will occur more frequently with stronger intensity to affect agricultures and our daily life, particularly for SE Asia during El Niño years.

Thanks for your attentions!