Climate Change – an imminent challenge

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What is Climate ? What is Weather ?

"Climate is what you expect; weather is what you get."
by Robert A. Heinlein

- Weather is the day-to-day state of the atmosphere
- Climate describes the long-term character of all weather variations – the 'expected' weather
- Climate ≈ average of weather

Definition of Climate Change

Intergovernmental Panel on Climate Change (IPCC)

Climate Change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

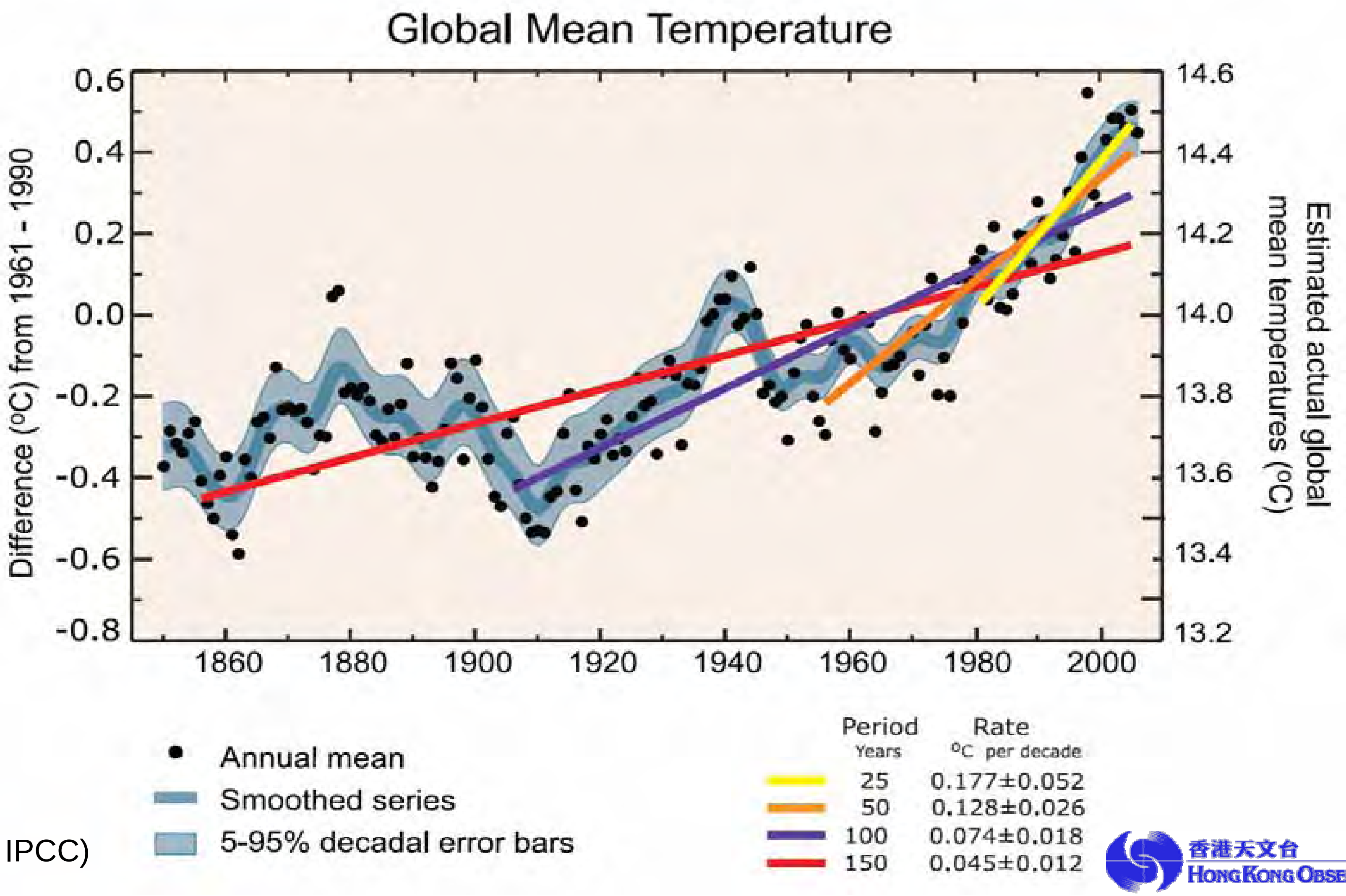
United Nations Framework Convention on Climate Change (UNFCCC)

"*Climate change*" means a **change** of climate which is **attributed** directly or indirectly **to human activity** that alters the composition of the global atmosphere and which is **in addition to natural** *climate* ***variability*** observed over comparable time periods.

(**UNFCC Article 1.2, UNITED Nations 1992)**

The world has been warming faster & faster !

In the last 100 years, global average surface temperature rose by 0.74 °C and the rate of warming has accelerated in the last 50 years.



(Source: IPCC)

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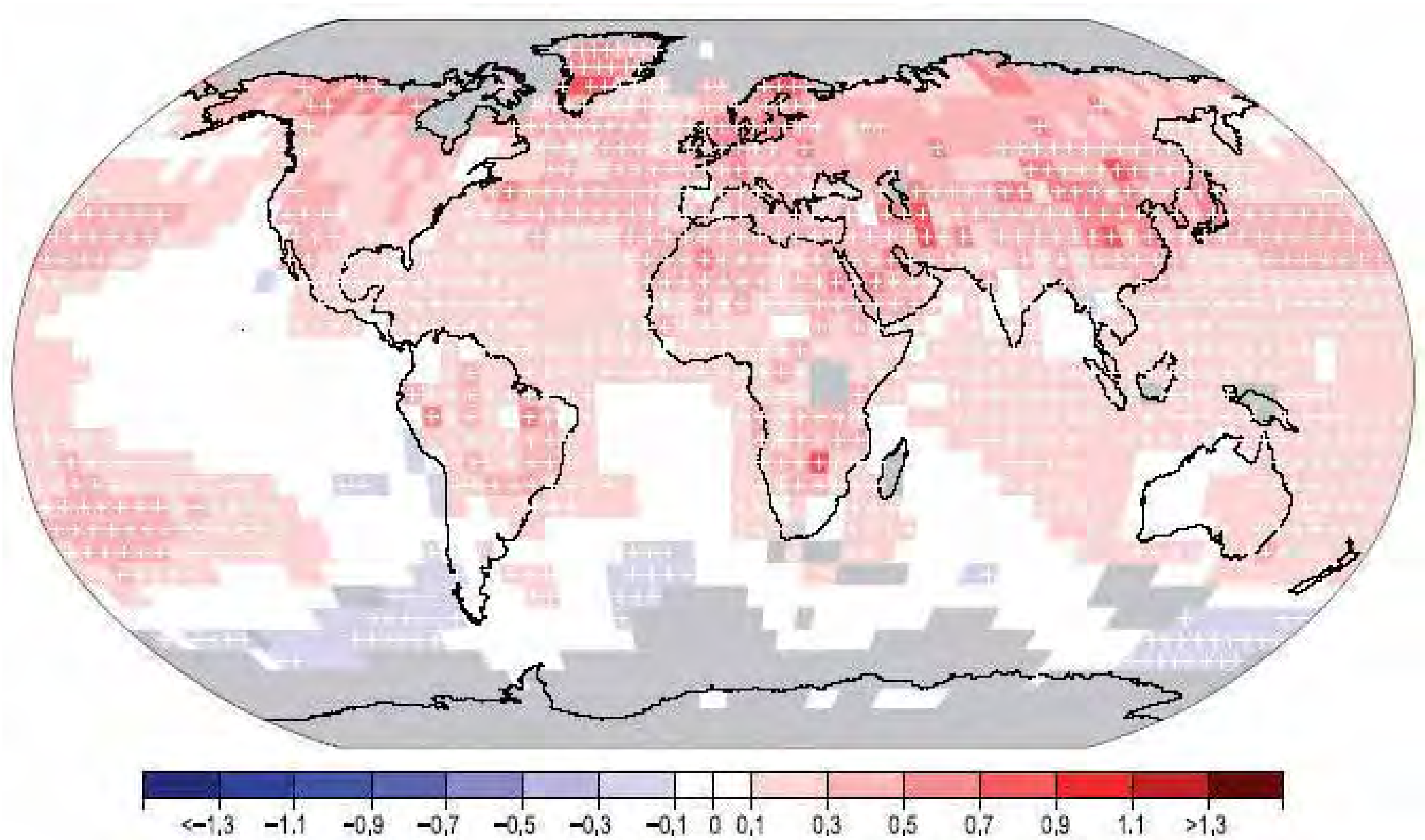
Annual mean temperature trend in 1979-2005

Temperature has been rising in almost all regions, larger rises are observed in high-latitude than low-latitude areas, and in land areas than oceans



degree/decade

(white crosses represent trends are statistically significant at 5% level, areas in grey represent not having enough data for computation of reliable trends)

(Source: IPCC)

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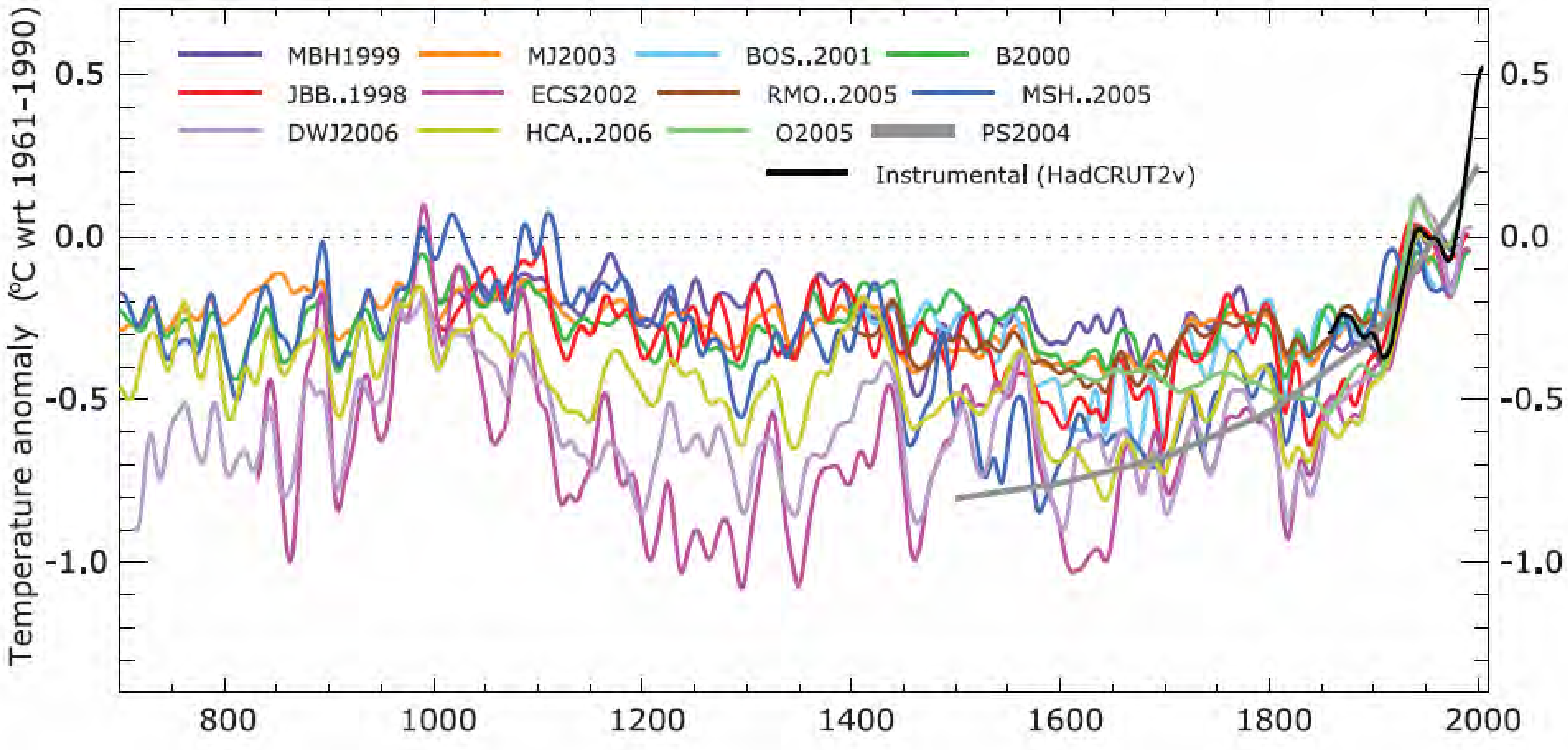
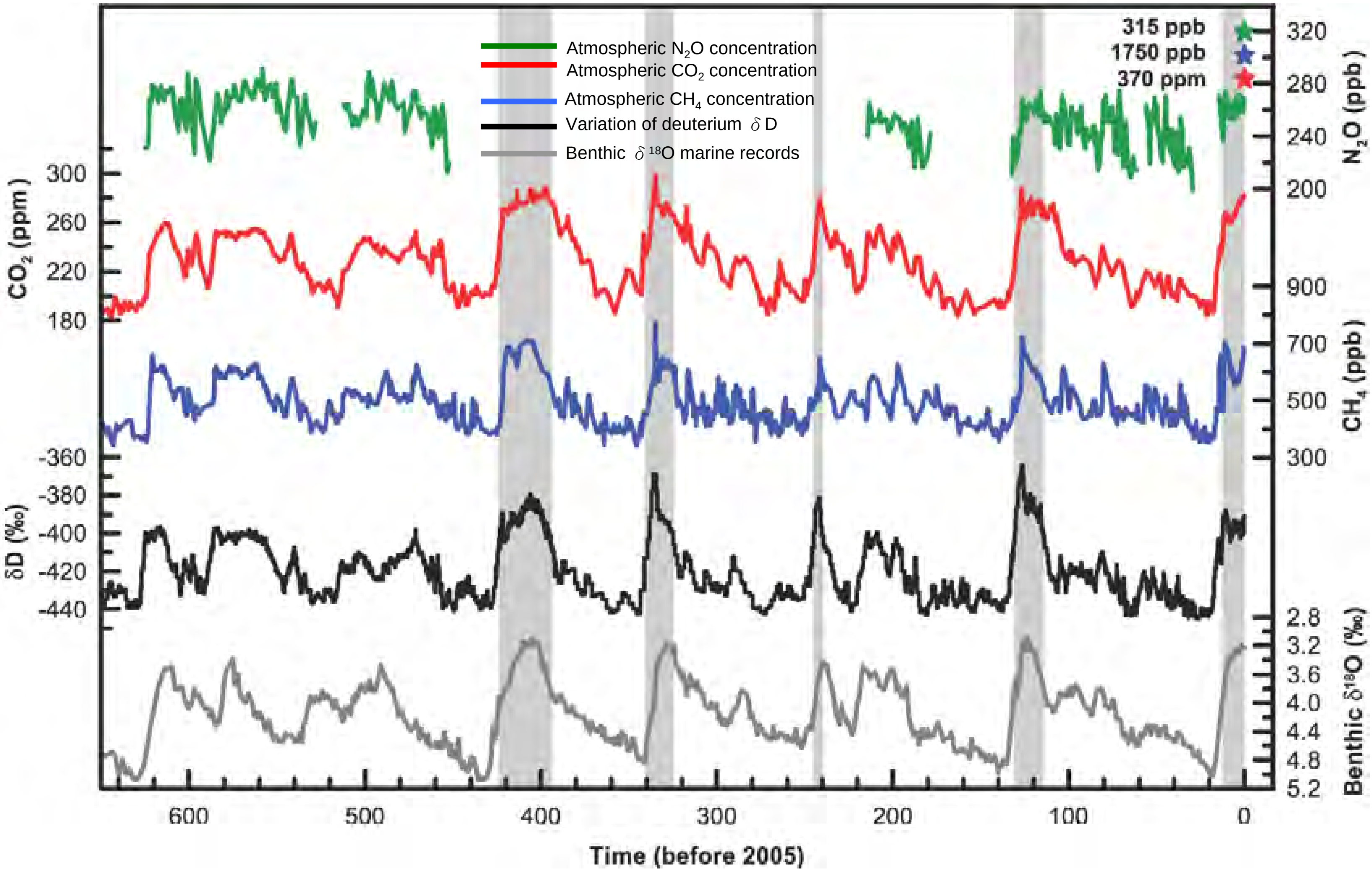
Northern Hemisphere Temperature Reconstructions



(Source: IPCC)

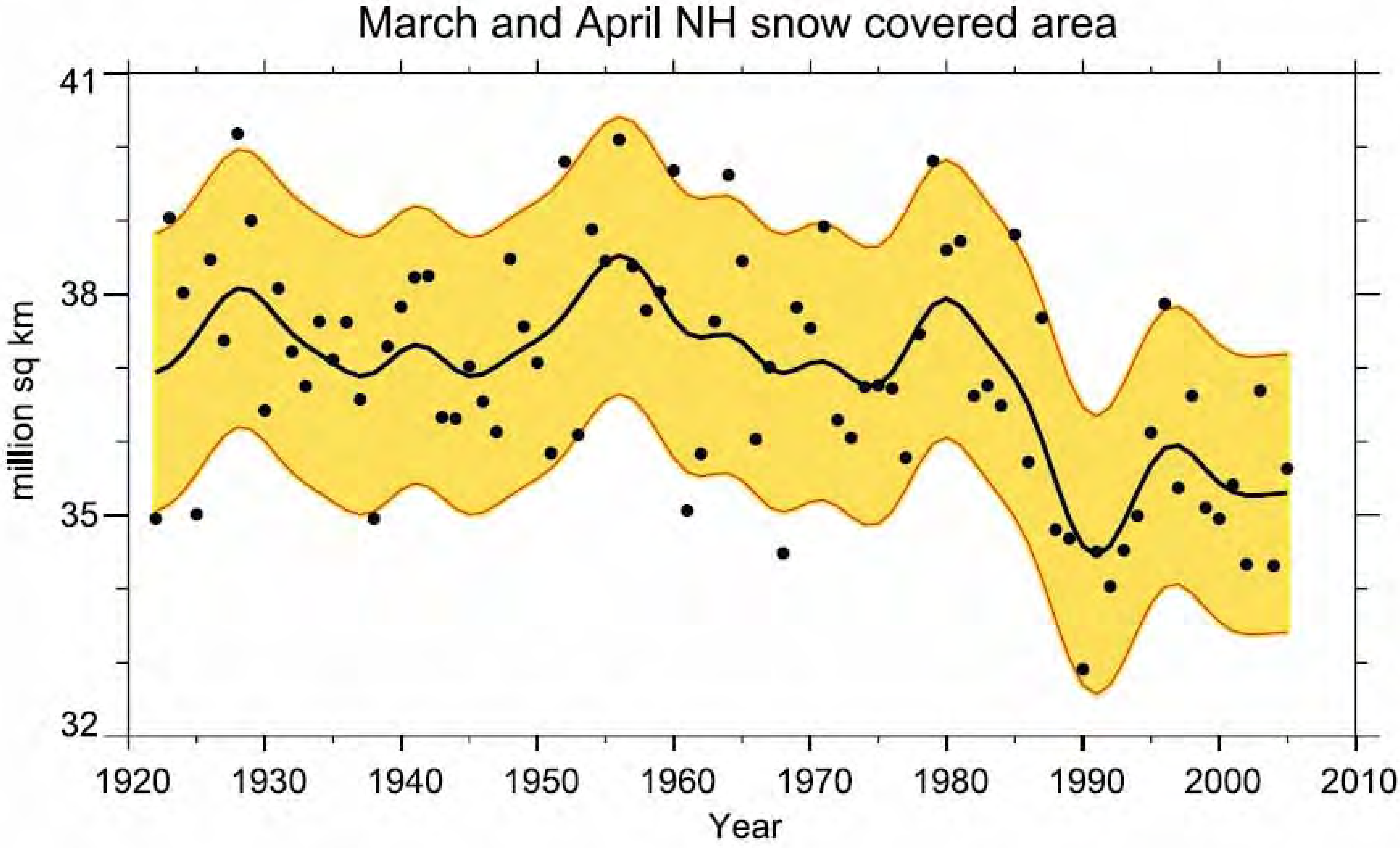
To face where no man has faced before!

Atmospheric CO_2 concentration level in 2007 : about 380 ppm



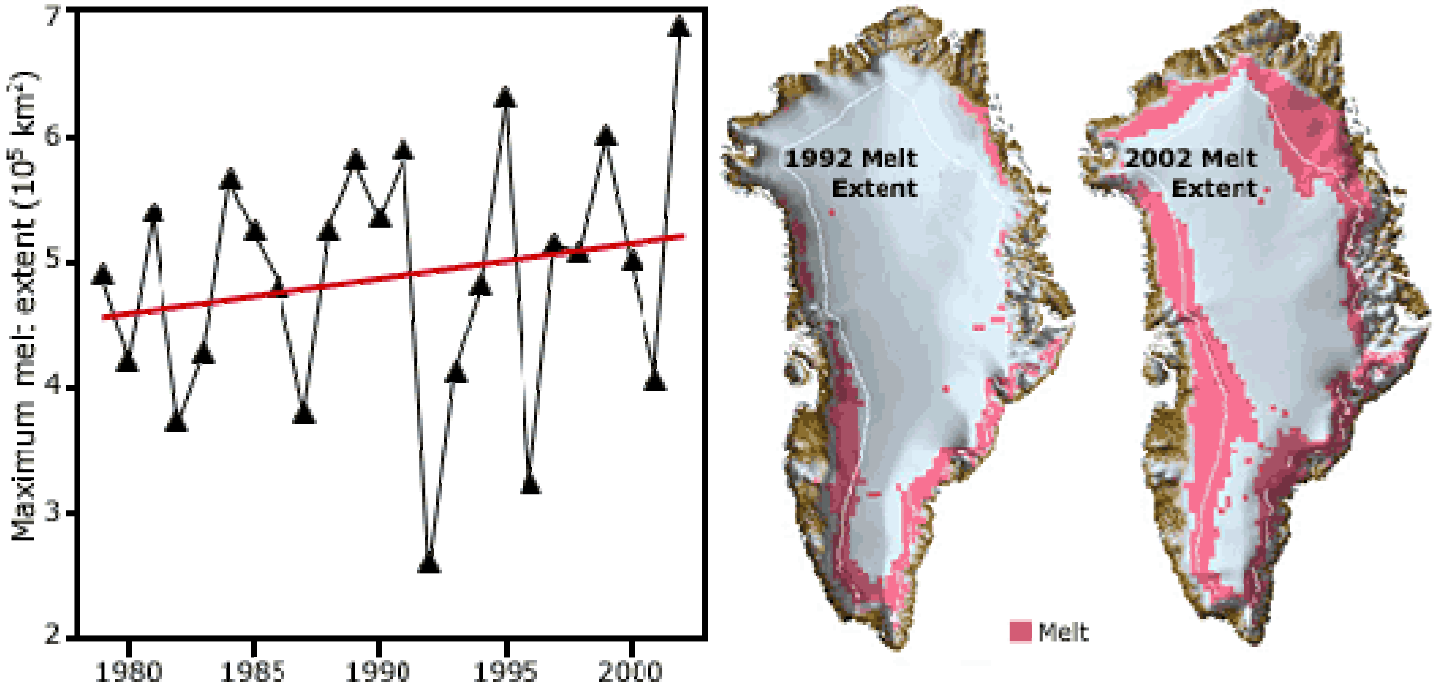
(Source: IPCC)

Changes in Snow Cover



(Source: IPCC)

Diminishing Greenland Ice Sheet



(Source: NASA)

Diminishing Greenland Ice Sheet

- **Greenland Ice Sheet** : ice covering **1.71 million km^2**, roughly 80% of the surface of Greenland.
- **Second largest ice body** after Antarctic Ice Sheet.
- Ice sheet is almost 2,400 km long (N-S) and greatest width is 1,100 km 77° N.
- **Mean altitude** of ice is **2.135 km** and over 3 km at thickest point.
- Not the only ice mass of Greenland – isolated glacier and small ice caps cover between **76,000 and 100,000 km^2** around the periphery.
- Some scientists believe - the entire ice sheet **may melt in a few hundred years** because of global warming.
- If all **2.85 million km^3 ice melted**, global **sea level would rise of 7.2 m**.
- Would **inundate most coastal cities** and **remove some island countries** e.g. Tuvalu & Maldives.

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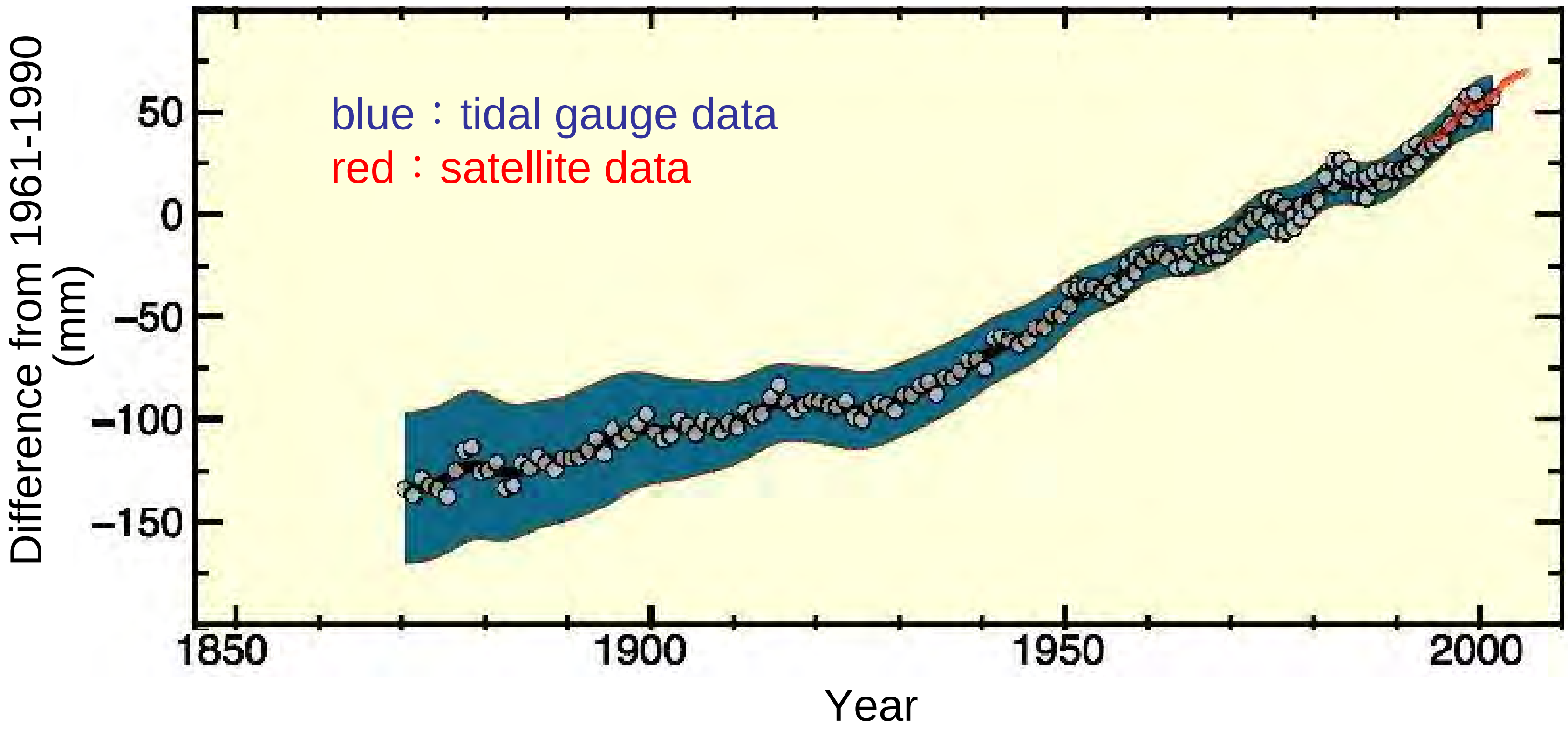
Sea level rise

Global mean sea level has been rising at 1.8 mm per year in 1961-2003.
The rate of sea level rise is higher at 3.1 mm per year in 1993-2003.



(Source: IPCC)

Recent trends, assessment of human influence on the trend and projections for extreme weather events for which there is an observed late-20th century trend.

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

(Source: IPCC)

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IPCC Terminology

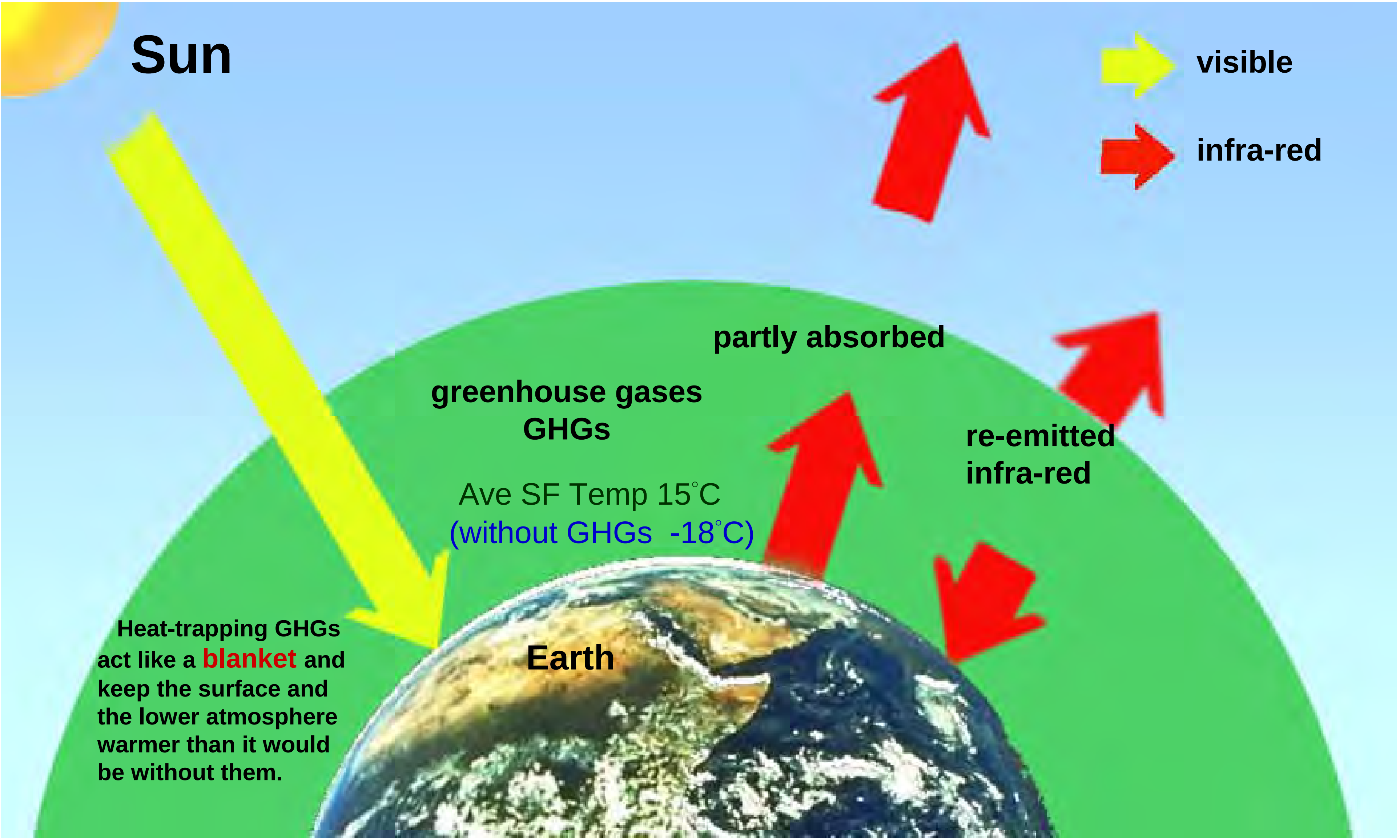
The standard terms used in this report to define the likelihood of an outcome or result where this can be estimated probabilistically are:

Likelihood Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

The terms 'extremely likely', 'extremely unlikely' and 'more likely than not' as defined above have been added to those given in the IPCC Uncertainty Guidance Note in order to provide a more specific assessment of aspects including attribution and radiative forcing.

(Source: IPCC)

Greenhouse Effect



Greenhouse gases (GHGs) in the Atmosphere include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), chlorofluorocarbons (CFCs) , ozone (O_3) **and** water vapour (H_2O)

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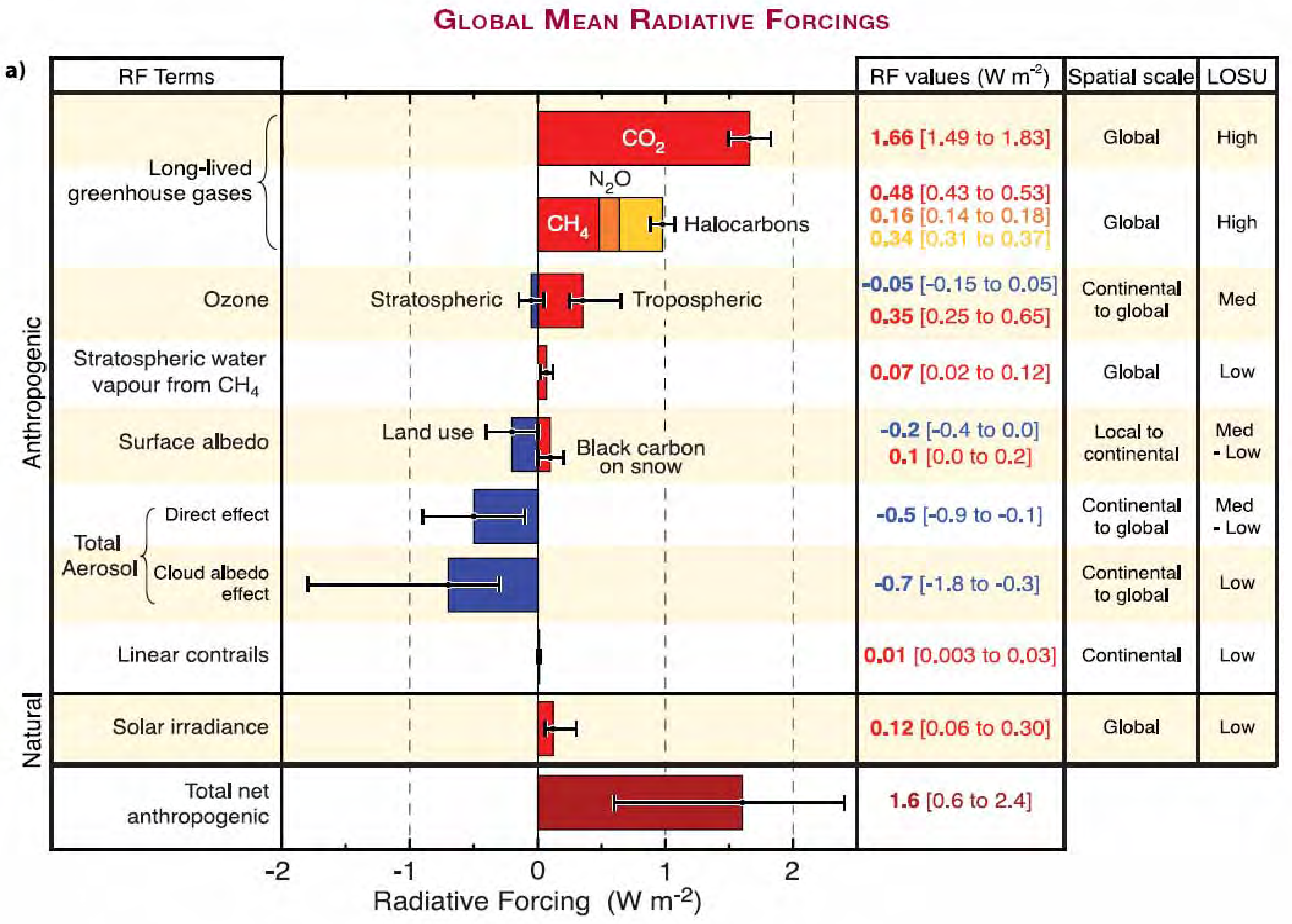

(Source: IPCC)

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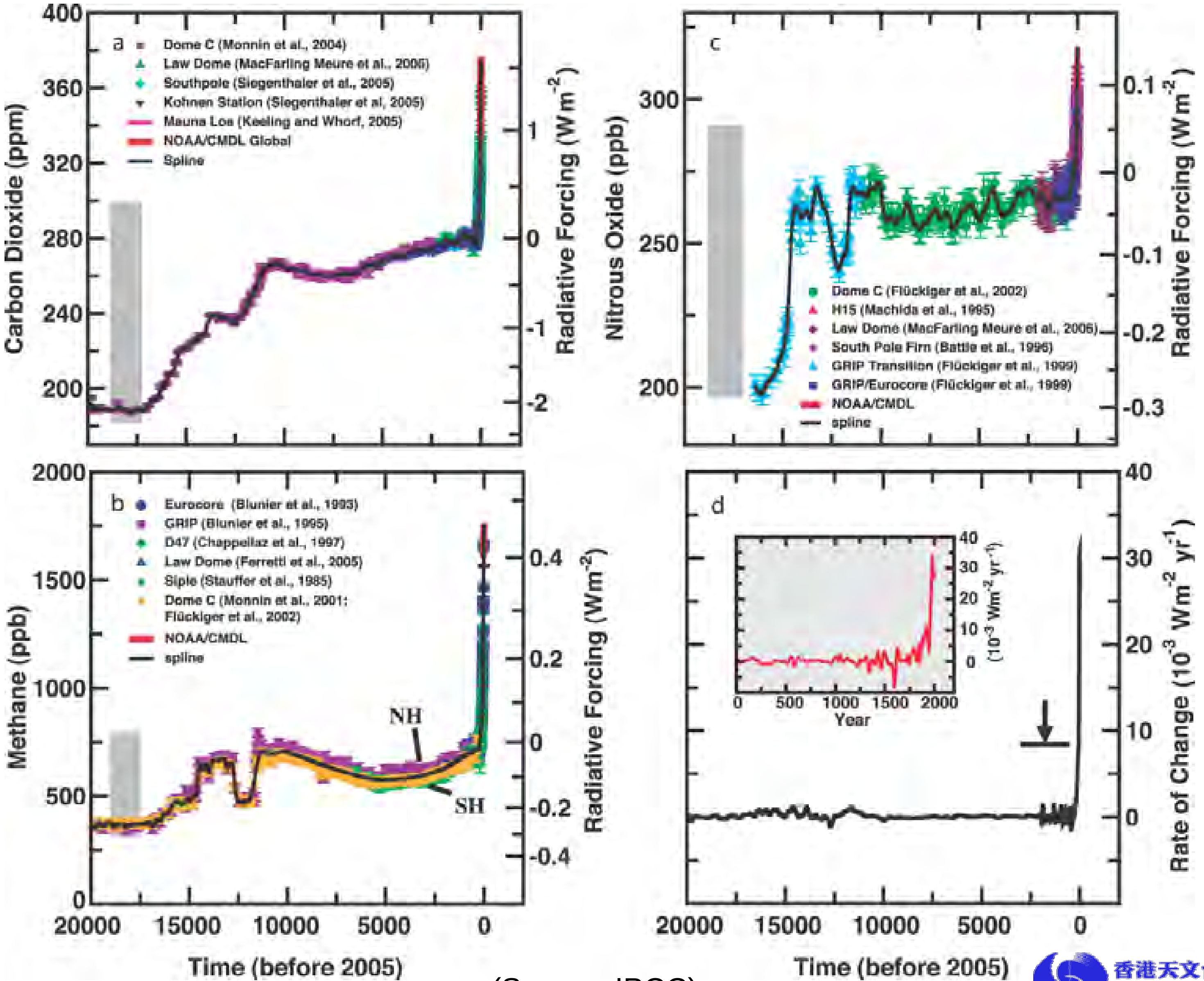
GHGs concentration in the last 20000 years



(Source: IPCC)

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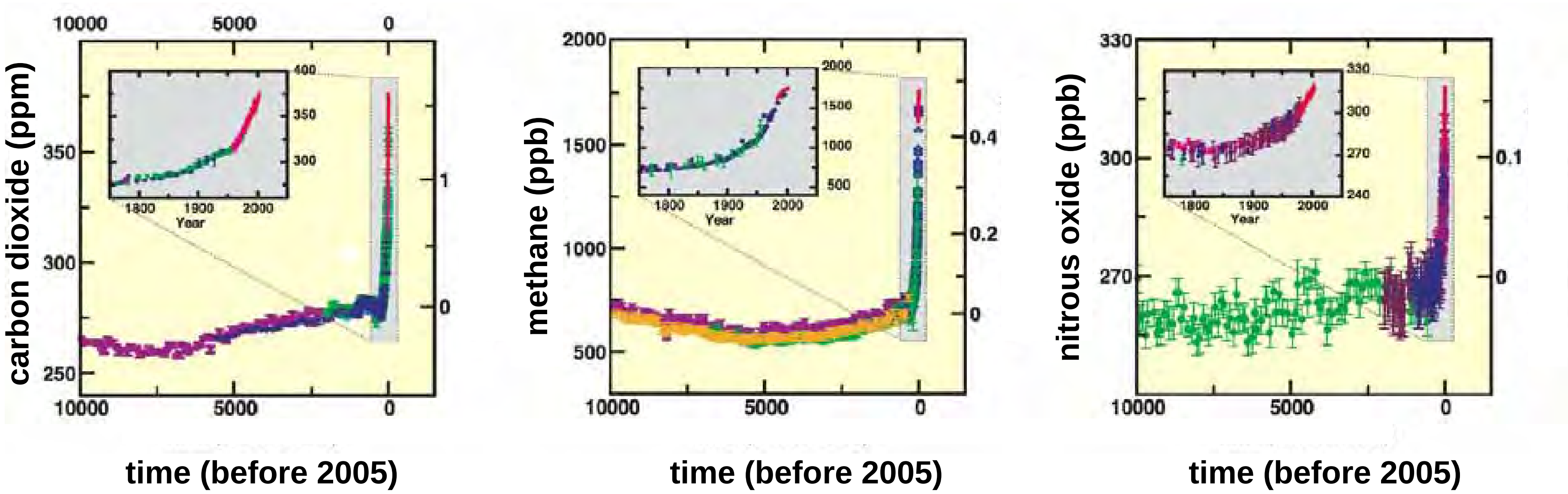
Rising trends of GHGs since 1750



(Source: IPCC)

Since 1750, the concentrations of global atmospheric carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have risen sharply due to human activities

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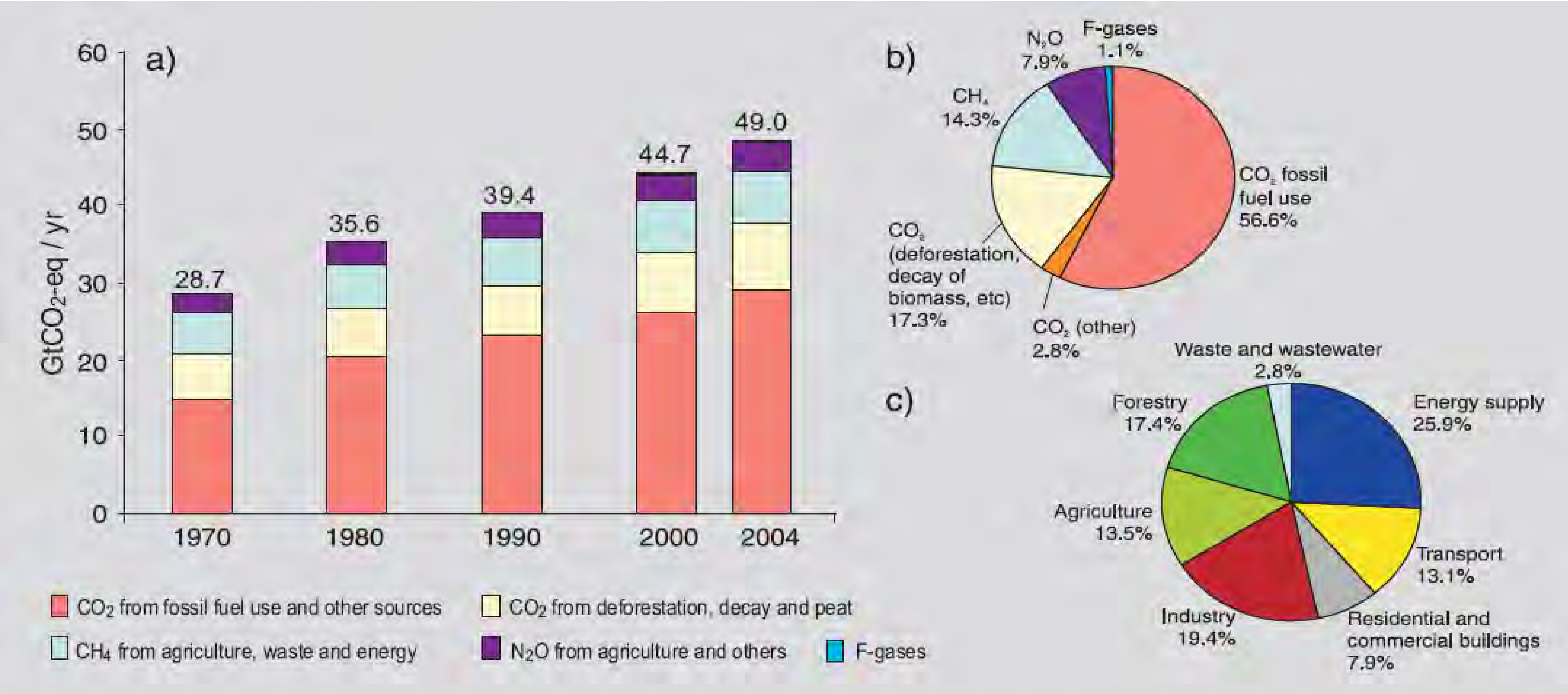
Production of GHGs due to human activities

Burning of fossil fuels and long term **deforestation** have been increasing the concentration of GHG in the atmosphere, thickening the greenhouse blanket



(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.5

(b) Share of different anthropogenic GHGs in total emissions in terms of carbon dioxide equivalents (CO_2-eq) in 2004.

(c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO2-eq.
(Forestry includes deforestation.)

(Source: IPCC)

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Production of GHGs due to human activities

Power plants, industry: CO_2

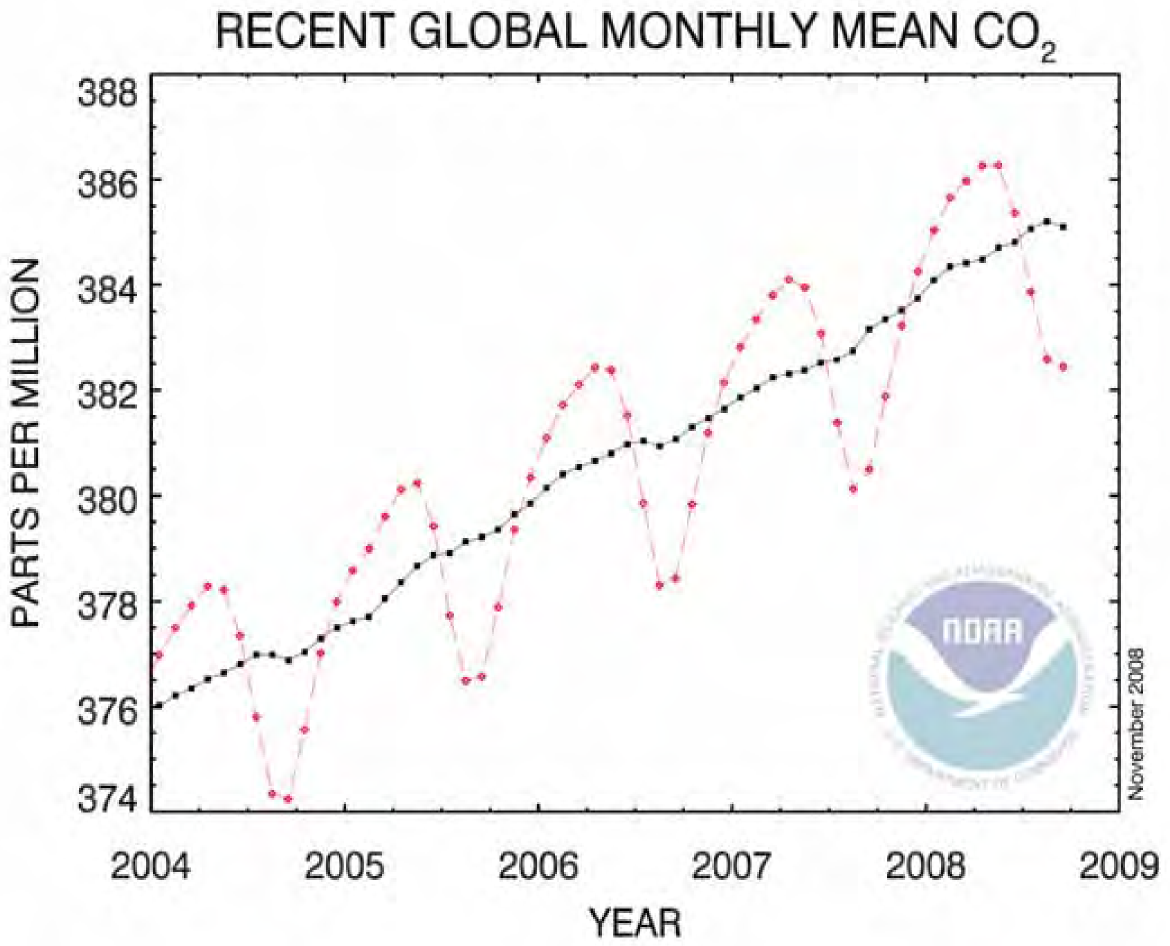
Waste dumping: N_2O

Cattle rearing: CH_4

Vehicle exhausts : O_3

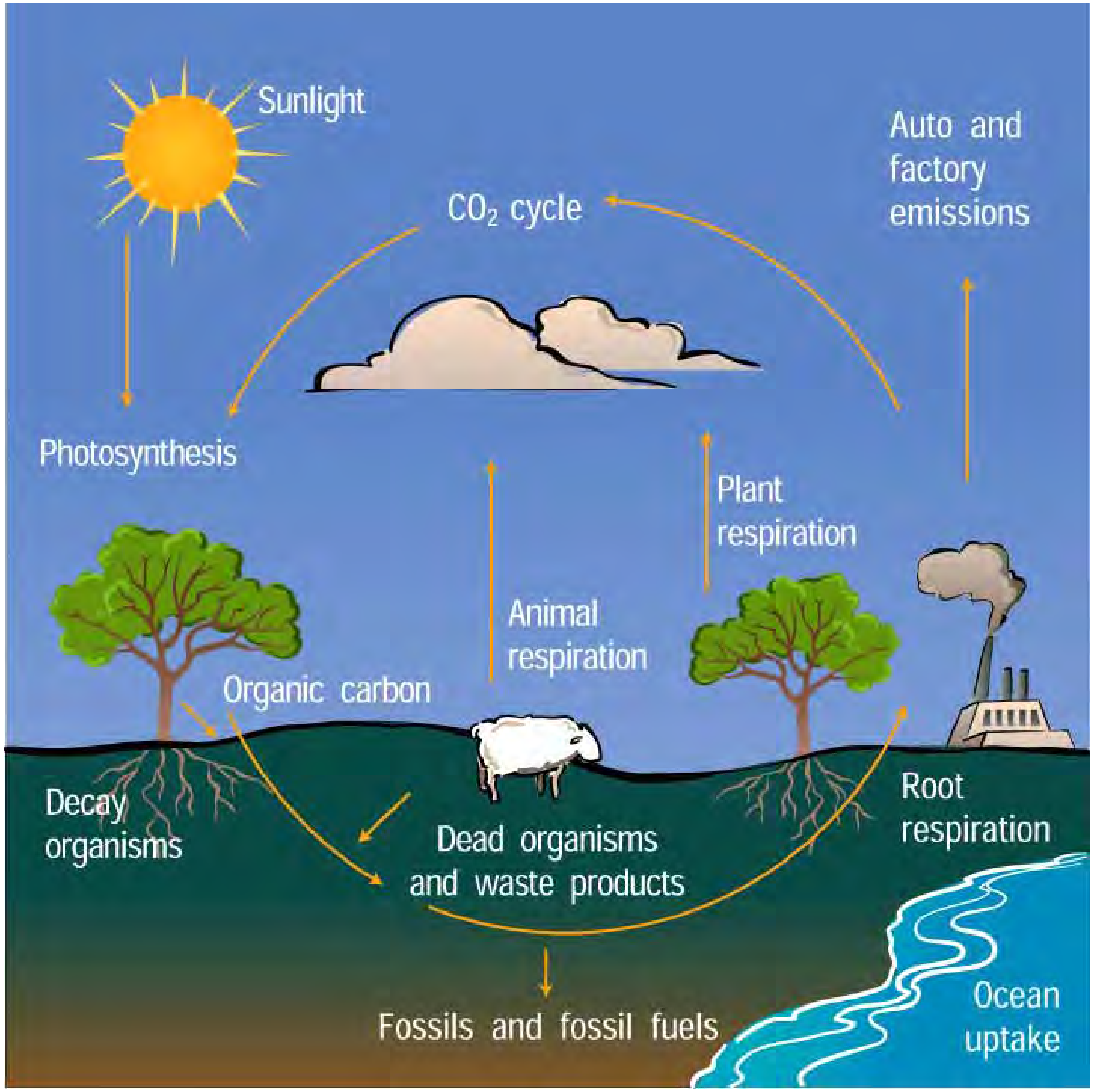
CO_2 is the main contributor responsible for climate change

CO_2 concentration in atmosphere 383 ppm in 2007 is far higher than the natural range over the last 650,000 years and is growing faster than ever in the last few decades.



(Source : NOAA)

The Carbon Cycle



(Source : UCAR)

The energy that we are using originated from the energy of the sun millions of year ago.

We use up in one year what it takes nature millions upon millions of years to reserve for us!

Causes of Climate Change

Natural factors

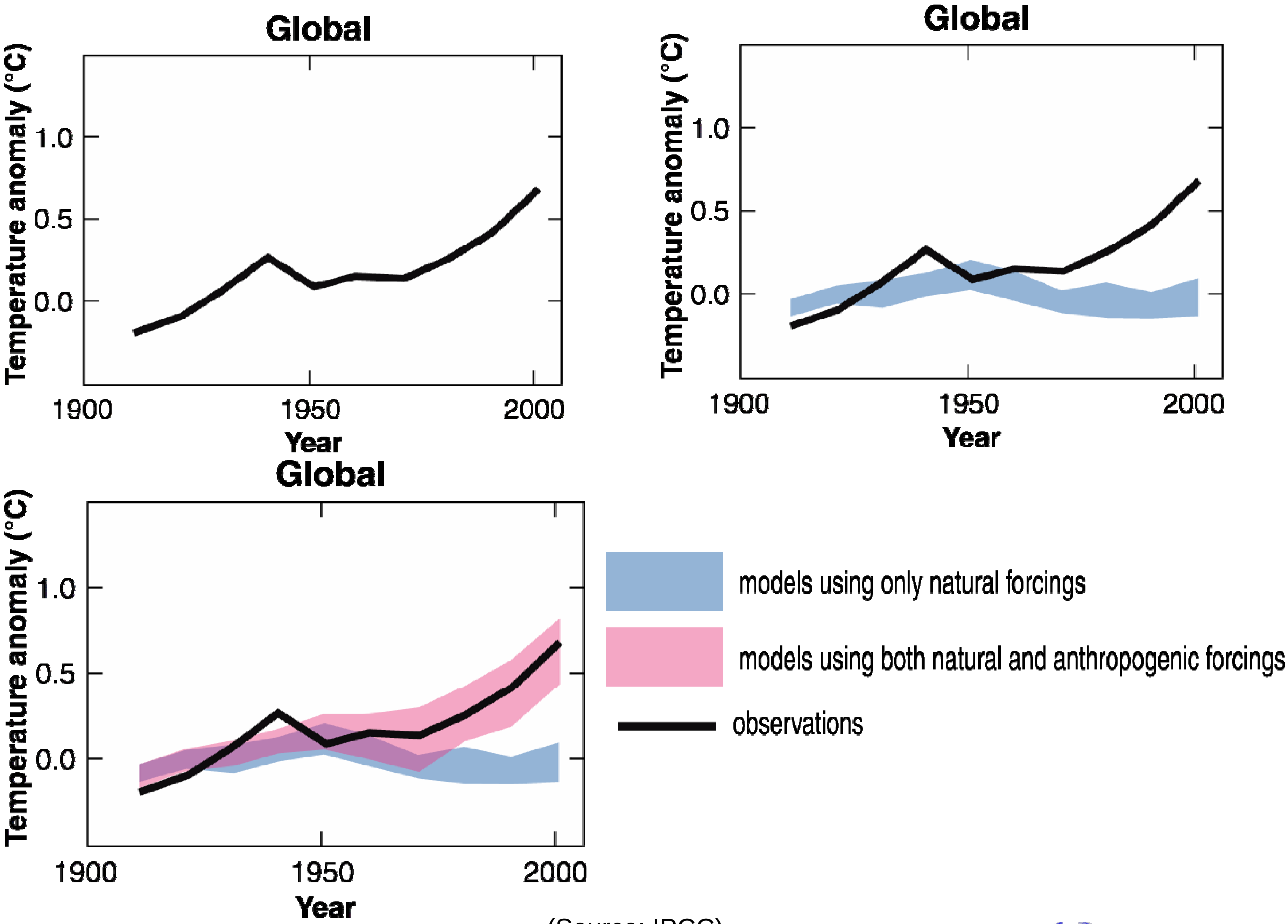
- Solar activity,
- Volcanic gases
- Dust in the atmosphere (aerosols)
- Distribution of heat in the ocean

Anthropogenic (human-causes) factors

- Greenhouse gas emission
- Land use changes / Deforestation

Global Warming - **Warming Of The Climate System Is Unequivocal**

- Most of the **observed increase** in global average temperatures since the mid-20th century is ***very likely*** *due to the* ***observed increase in anthropogenic*** **greenhouse gas concentrations** (IPCC)


Global
Temperature anomaly (°C)
1.0
0.5
0.0
1900
1950
2000
Year
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1.0
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0.0
1900
1950
2000
Year
models using only natural forcings
models using both natural and anthropogenic forcings
observations

(Source: IPCC)

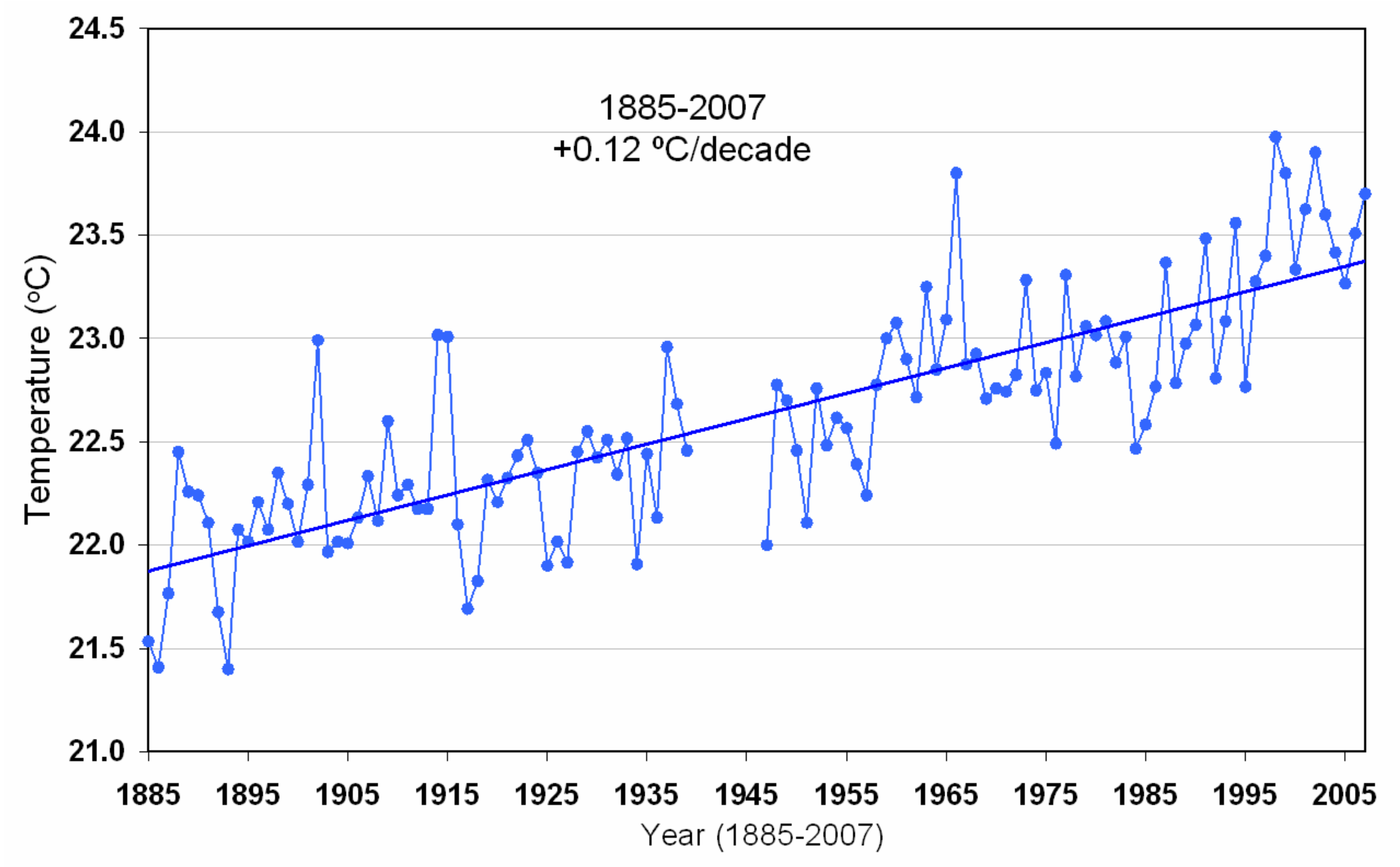
Climate Change in Hong Kong – Observations

Climate change in HK = Global Warming +

Local Urbanization Effect

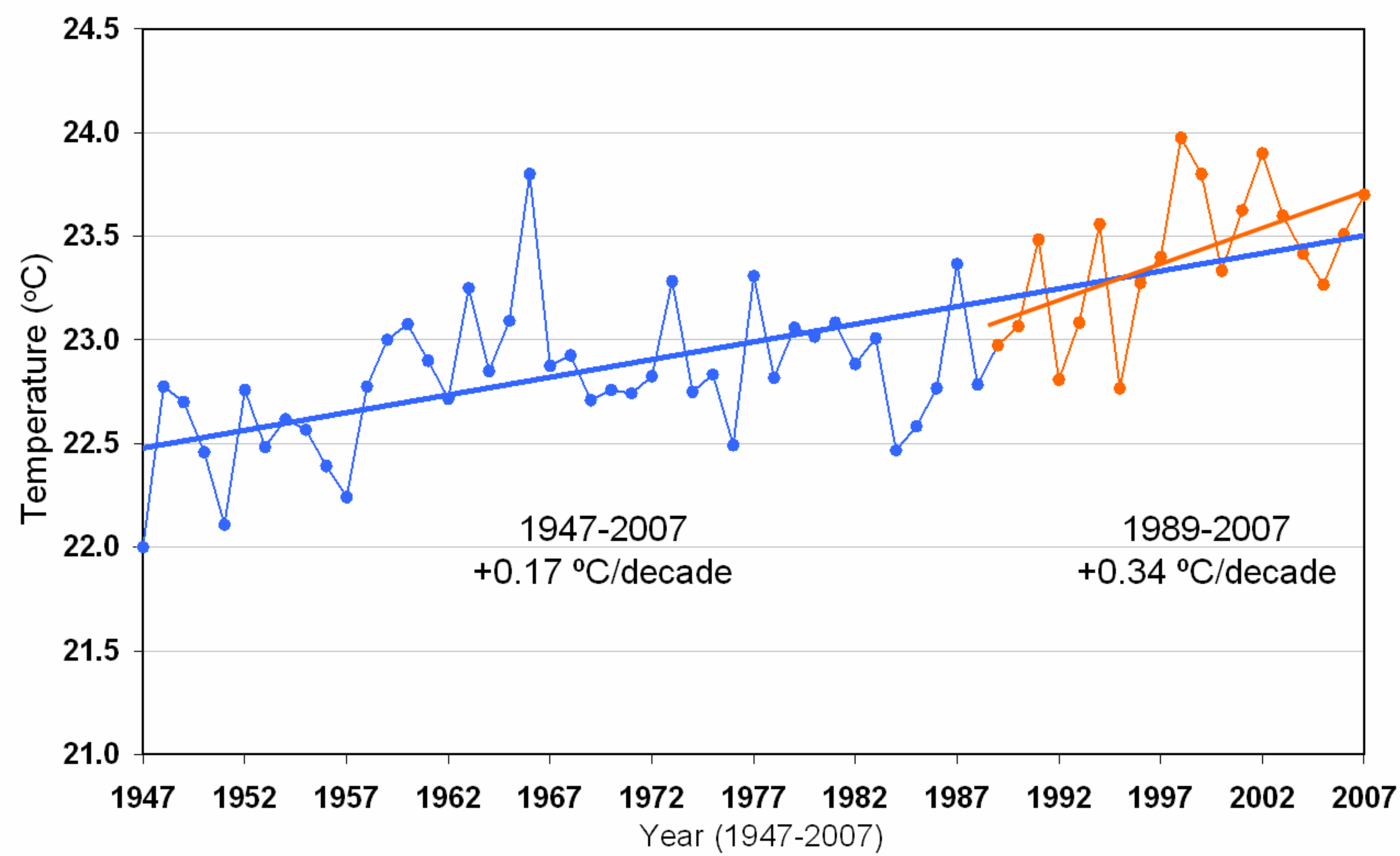
- Rise in mean air temperature (global warming + urbanization)
- Increase in rainfall
- Rise in sea level
- Decrease in wind speeds (urban sheltering)
- Rise in the frequency of reduced visibility
- Increase in cloud amount
- Reduction in the amount of solar radiation

Annual mean temperature at the HK Observatory Headquarters
(1885-2007)



There was an **average rise of 1.2°C per 100 years** from 1885 to 2007.
Globally, the average surface temperature rose by 0.74°C during 1906-2005 (IPCC, 2007)

Annual mean temperature at the HK Observatory Headquarters
(1947-2007)



Warming at the Hong Kong Observatory Headquarters has become significantly **faster in the period 1989 to 2007, at a rate of 0.34°C/decade**.

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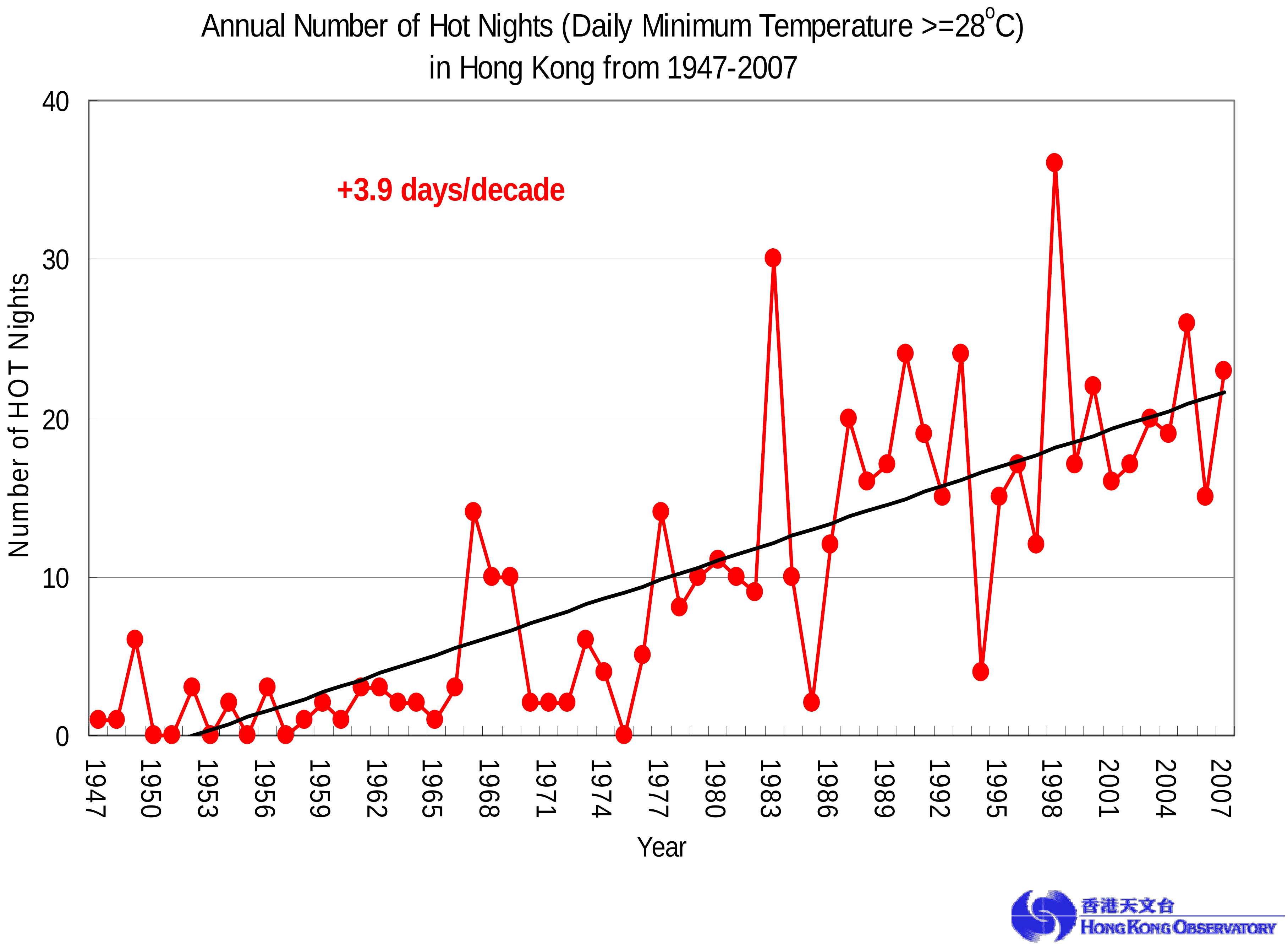

Annual Number of Hot Nights (Daily Minimum Temperature >=28°C) in Hong Kong from 1947-2007
+3.9 days/decade
Number of HOT Nights
Year
0
10
20
30
40
1947
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
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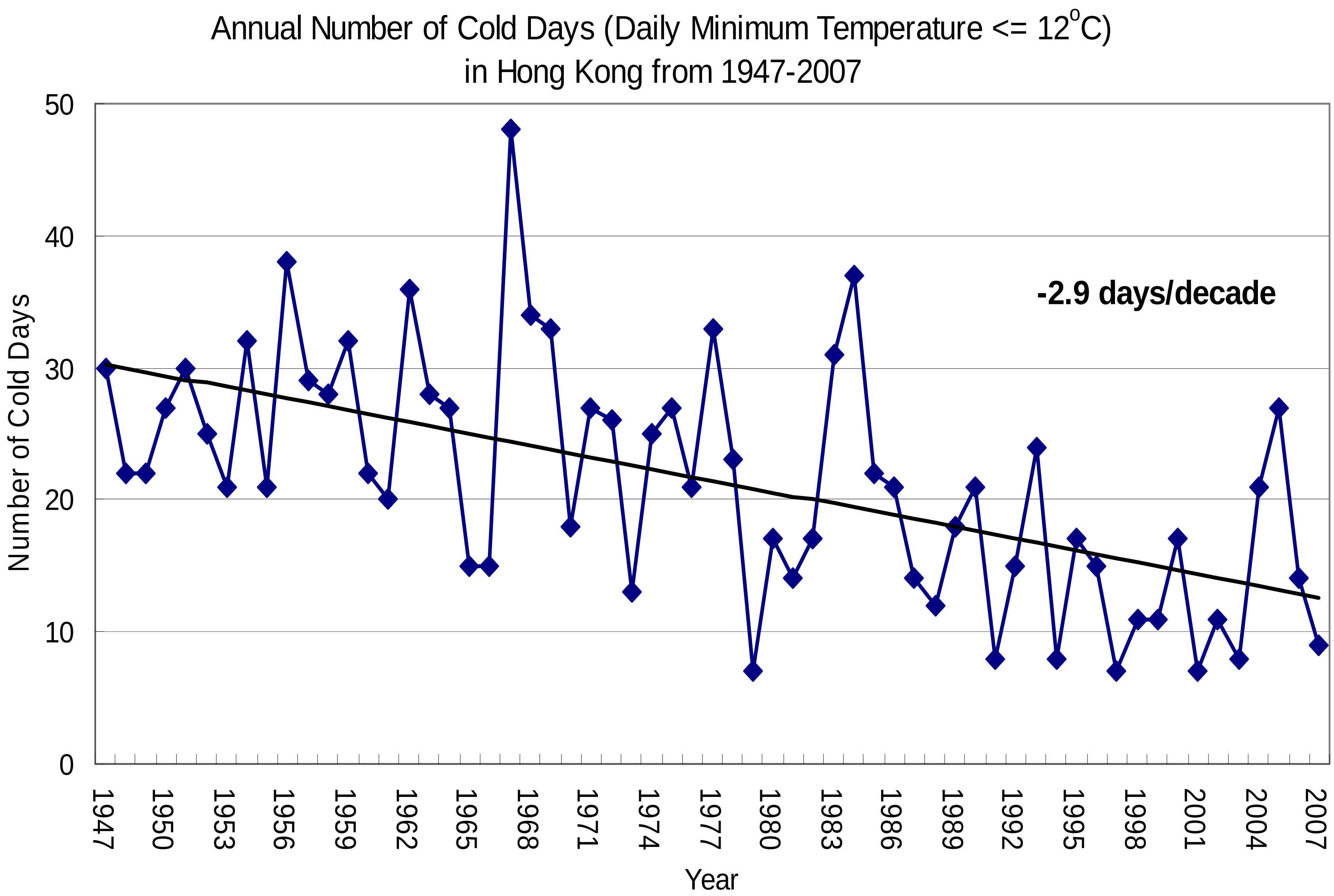

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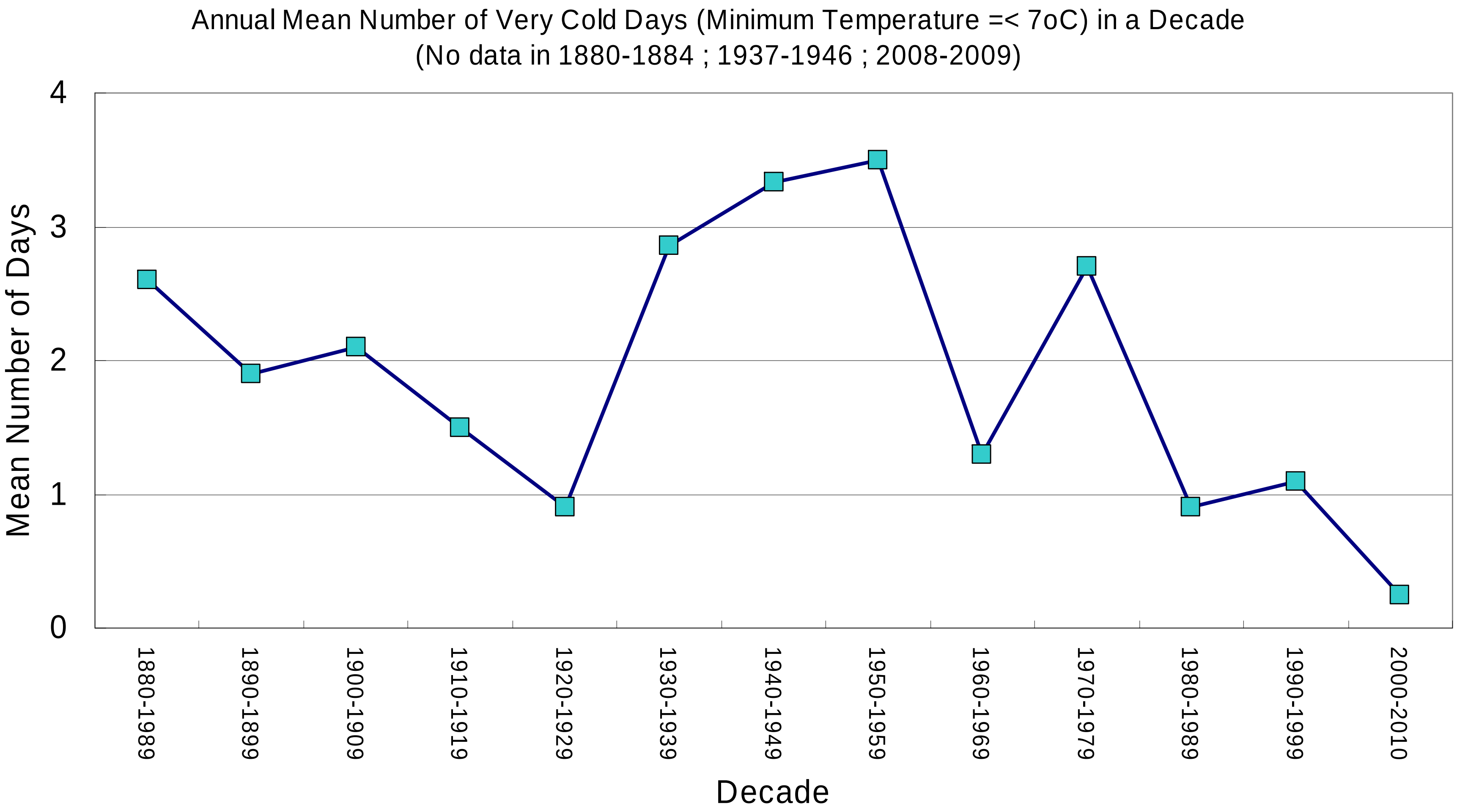
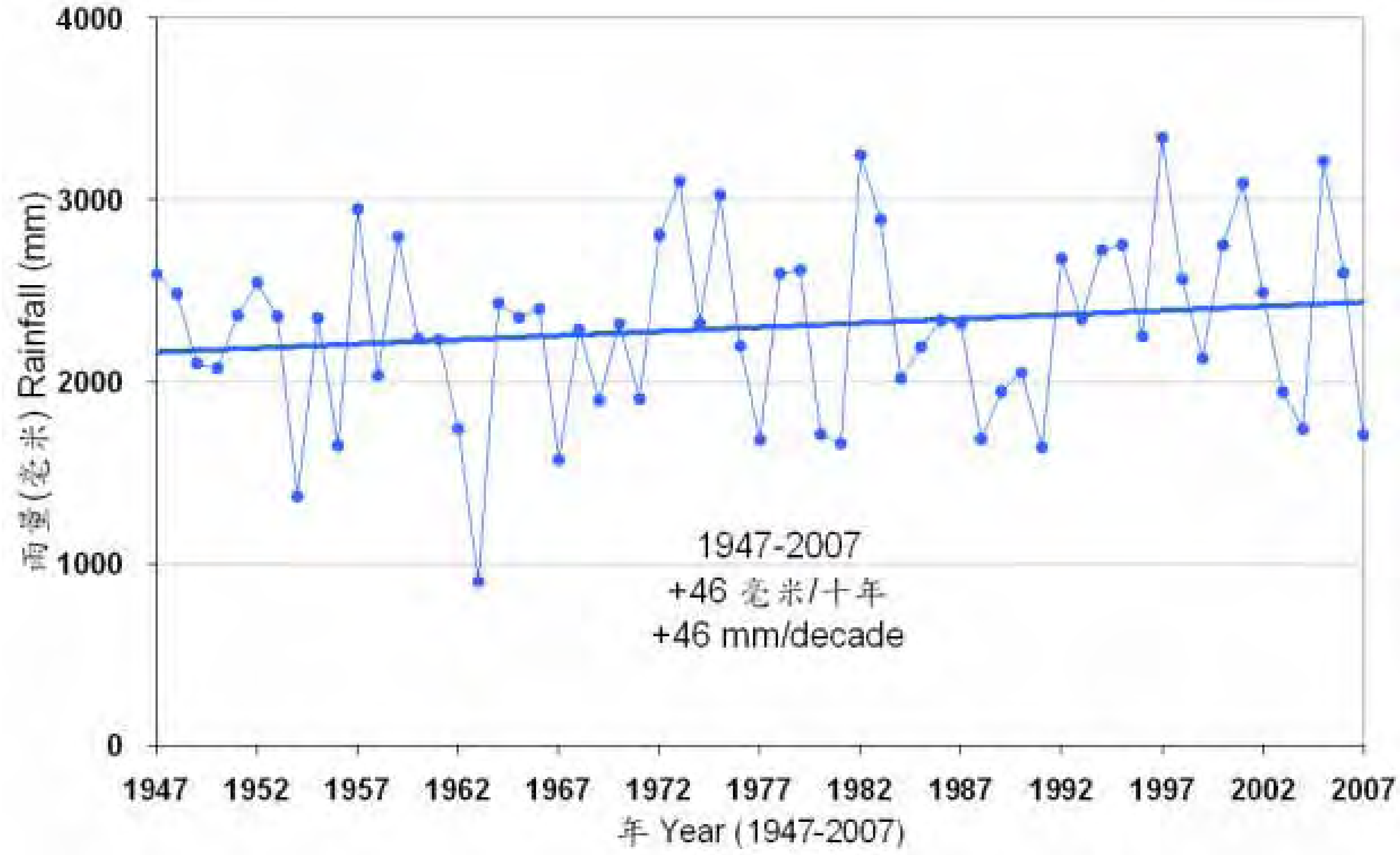
Annual Mean Number of Very Cold Days (T_{min} =< 7^{o}C) in a decade

(No data in 1880-1884 ; 1937-1946 ; 2008-2009)



Annual rainfall at the Hong Kong Observatory Headquarters (1947-2007)

The annual total rainfall at the Hong Kong Observatory Headquarters has been risen at a rate of 46mm/decade, though not statistically significant at 5% level.



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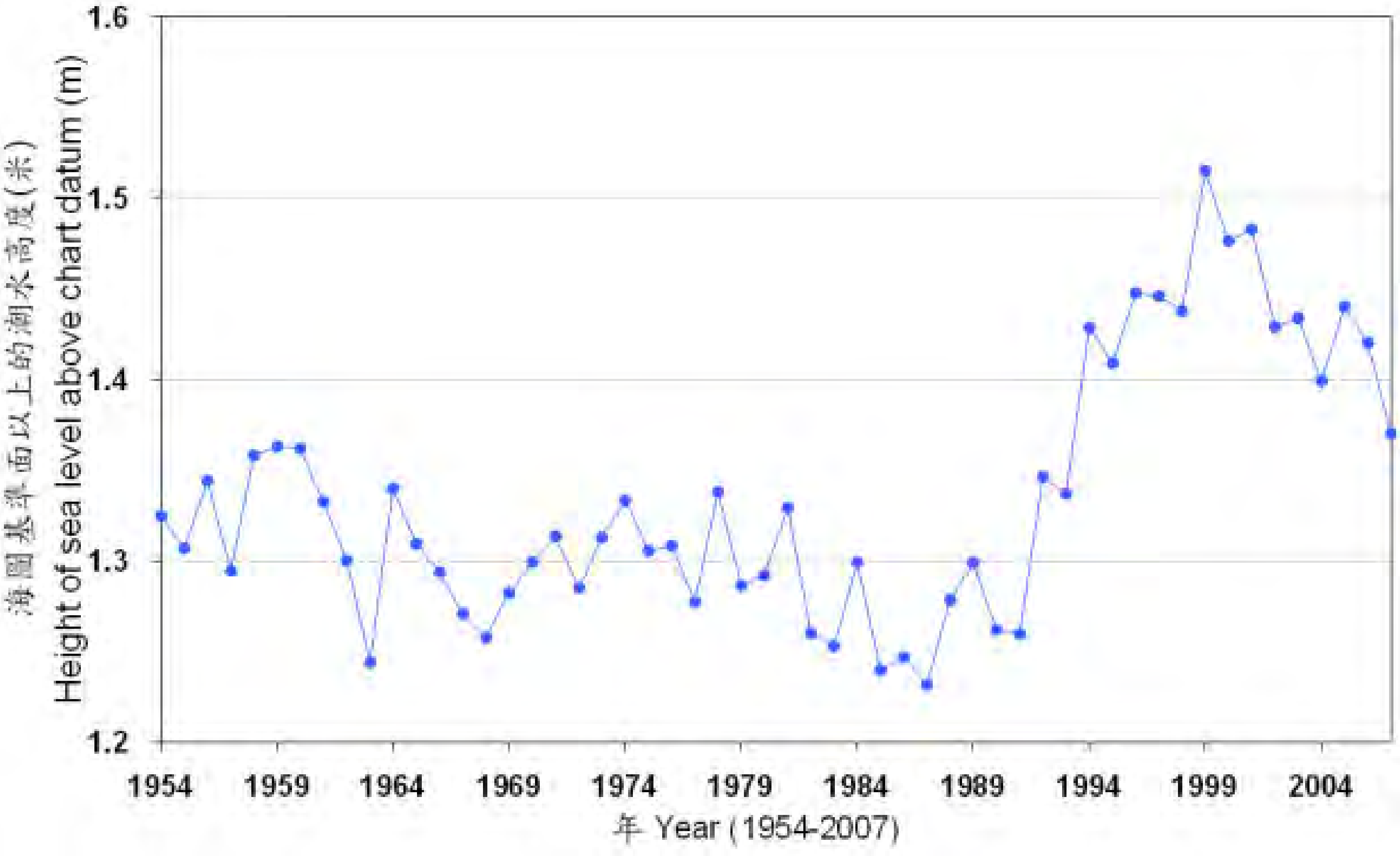
Annual mean sea level at North Point/Quarry Bay (1954-2007)

The mean sea level in the Victoria Harbour has risen 0.13 m from 1954 to 2007, at an average rate of 2.4 mm per year



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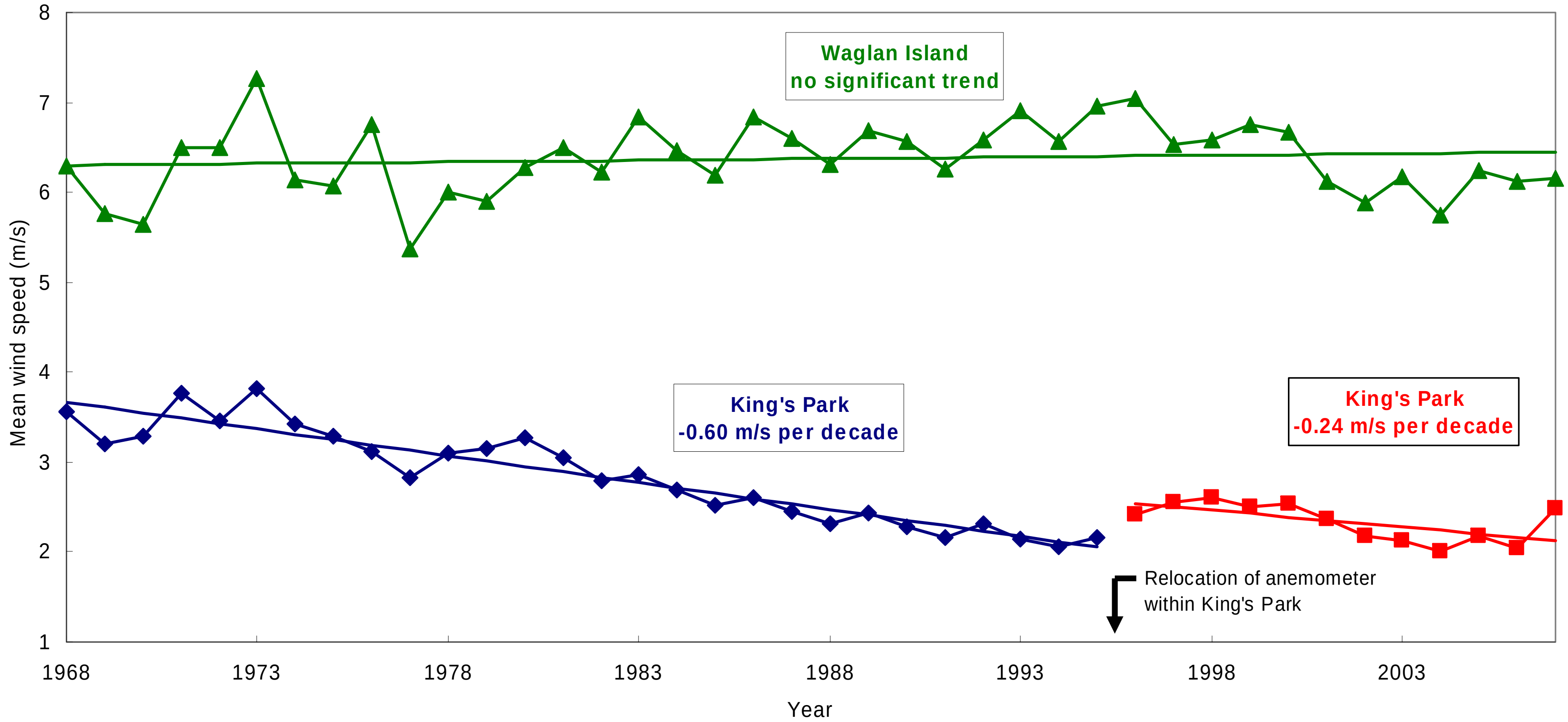
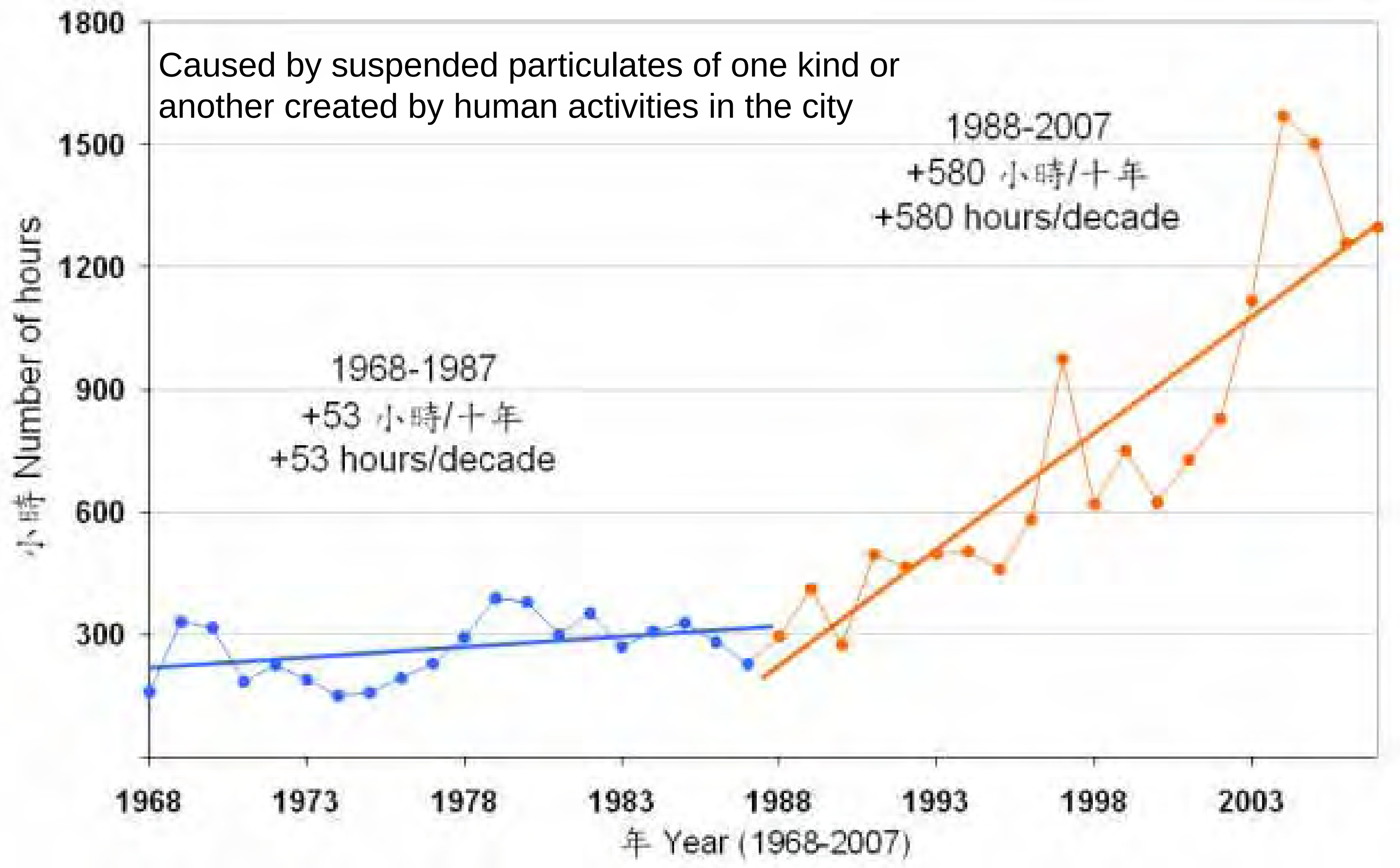
Annual average of 12-hourly 10-minute mean wind speed of King's Park and Waglan Island (1968-2007)



Growing of tall buildings increases the roughness of the surface underlying the atmosphere and exerts a drag on the low-level winds

Annual total number of hours with visibility at the Hong Kong Observatory Headquarters below 8 km from 1968 to 2007

(relative humidity below 95 % and not counting rain, mist or fog)



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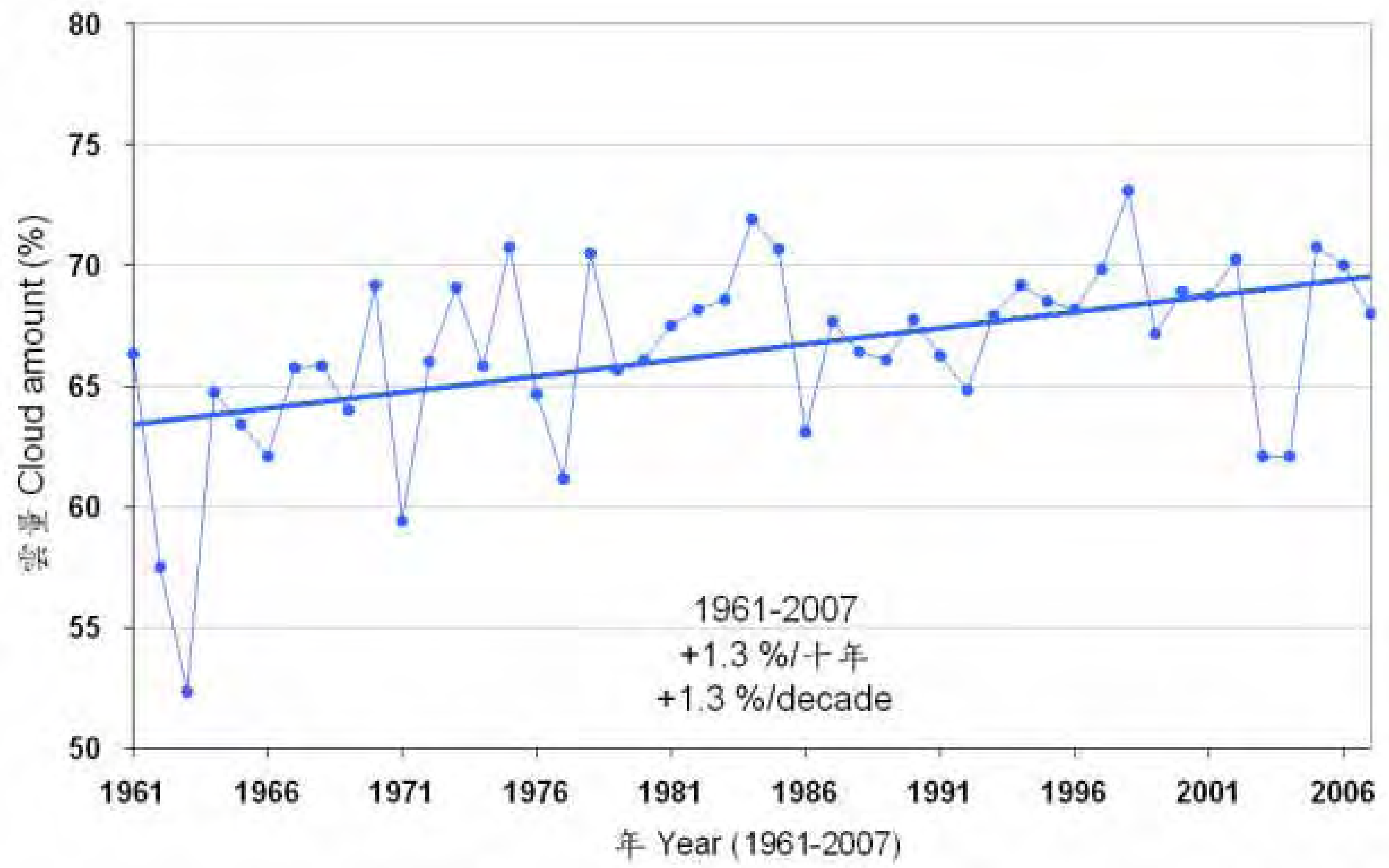
Annual mean cloud amount recorded at the Hong Kong Observatory Headquarters (1961-2007)



Urbanization causes the increase in the concentration of condensation nuclei in the air (a factor favourable to the formation of cloud)

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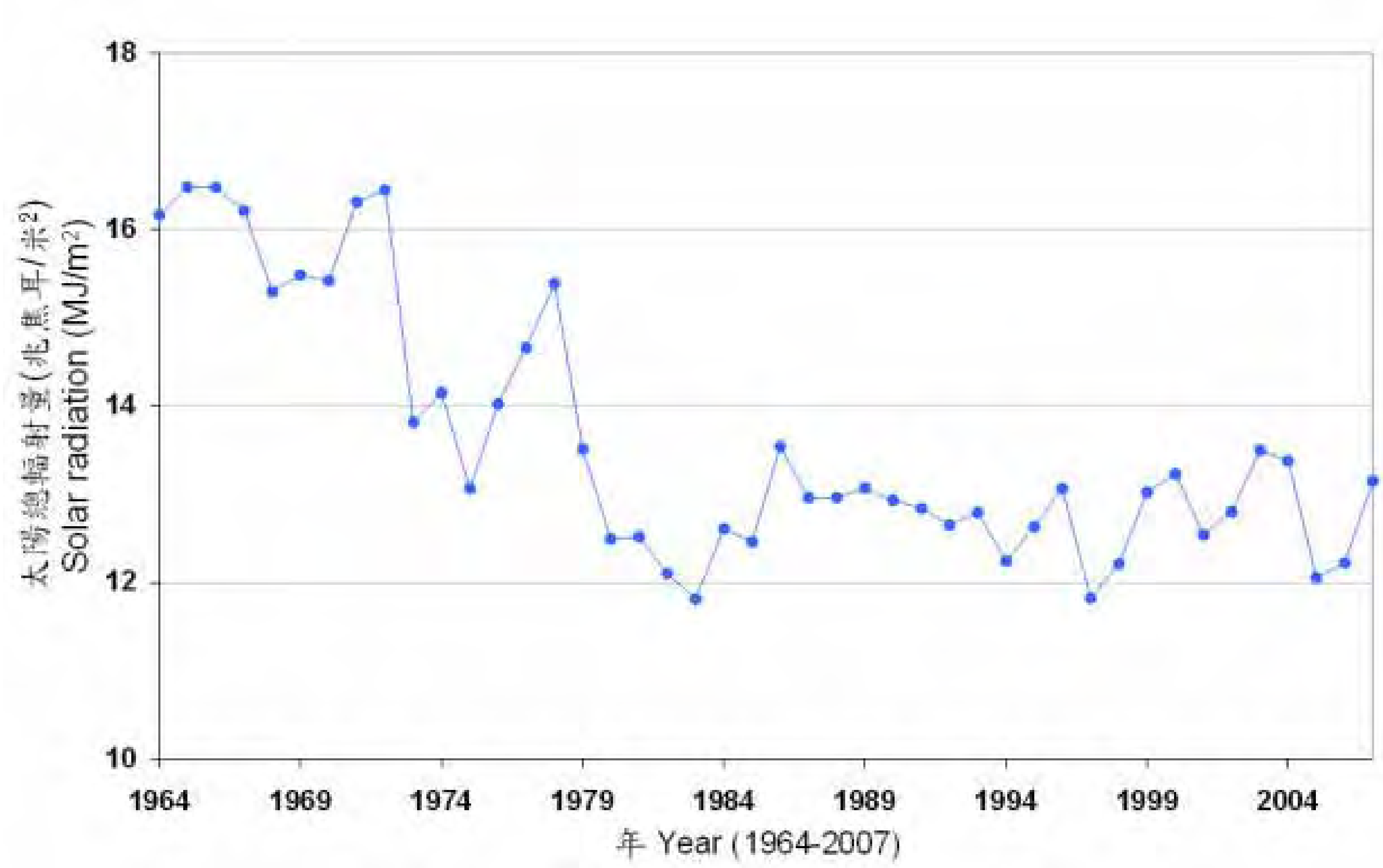
Annual mean daily total global solar radiation at King's Park (1964-2007)

the annual mean daily global solar radiation has decreased at a rate of 0.84 MJm^{-2} per decade from 1964-2007.



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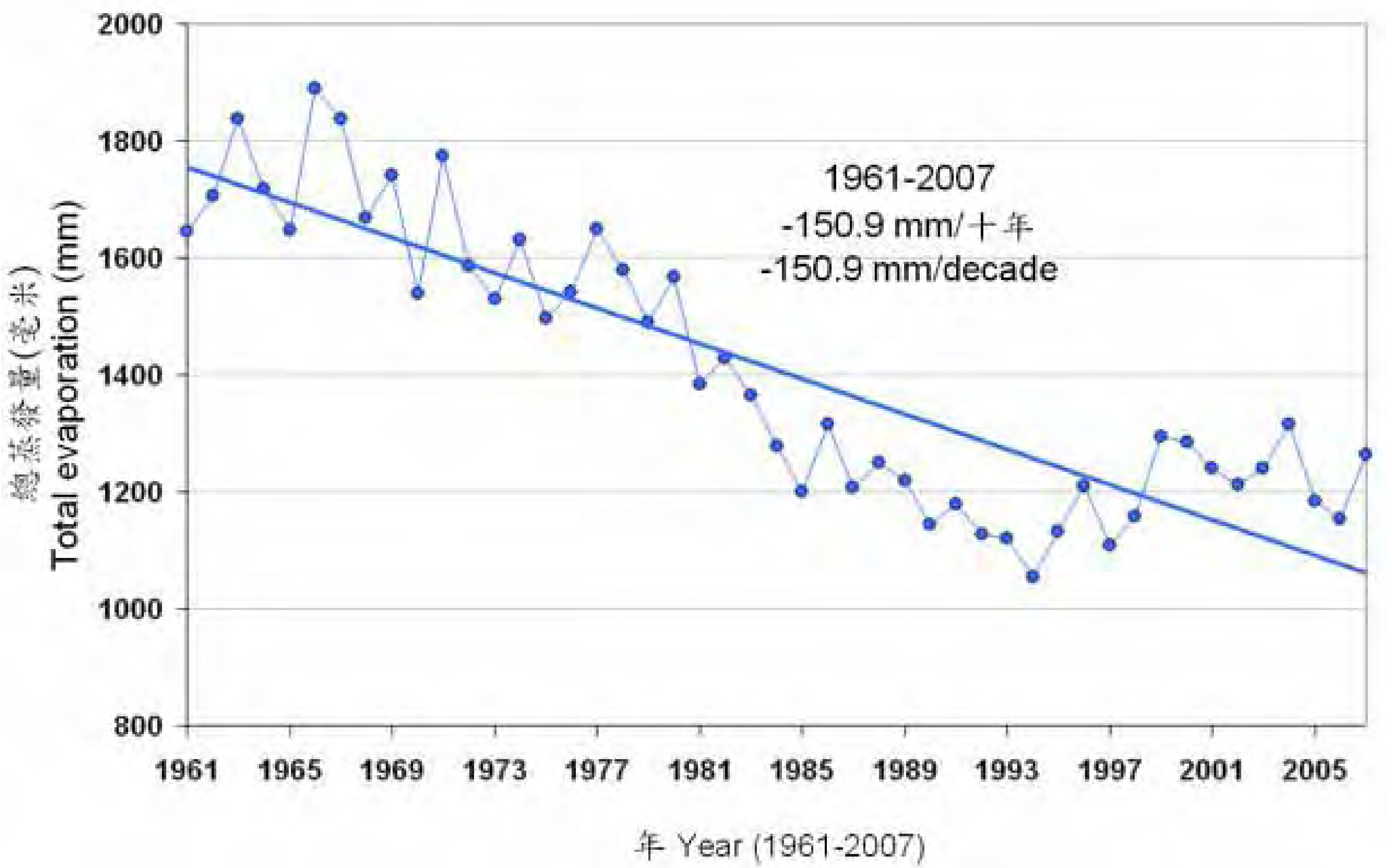
Long term trend in annual total evaporation, 1961-2005



Attributed to greatly decreased prevailing wind speed and reduced amount of solar radiation reaching the ground

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Some questions

1. Why can scientists project the future climate, say in the next 100 years?
2. How do scientists make the projections?
3. How reliable are the projections?
4. Can individual extreme events be explained by Greenhouse warming?
5. How likely are major or abrupt climate changes, such as loss of ice sheets or changes in global ocean circulations?
6. If emissions of GHGs are reduced, how quickly do their concentration in the atmosphere decrease?

Ref - IPCC website and the AR4 reports

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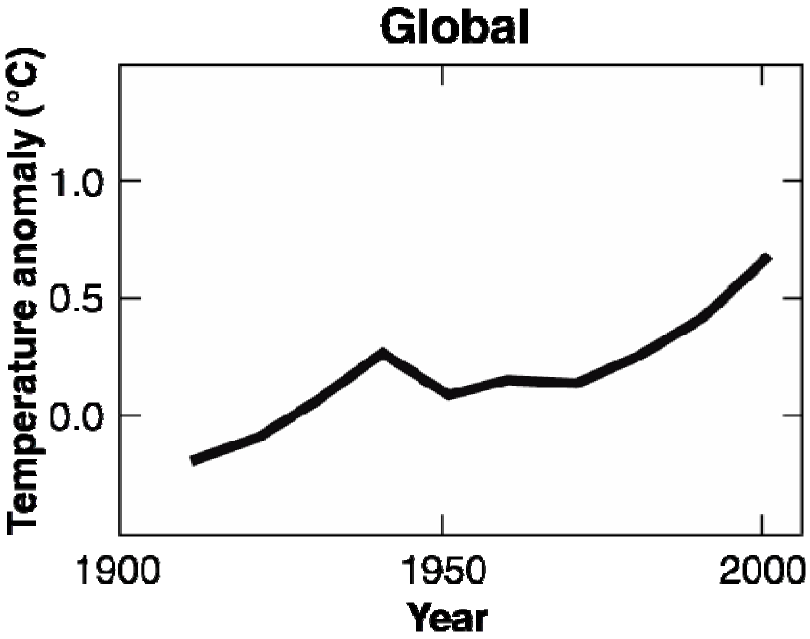
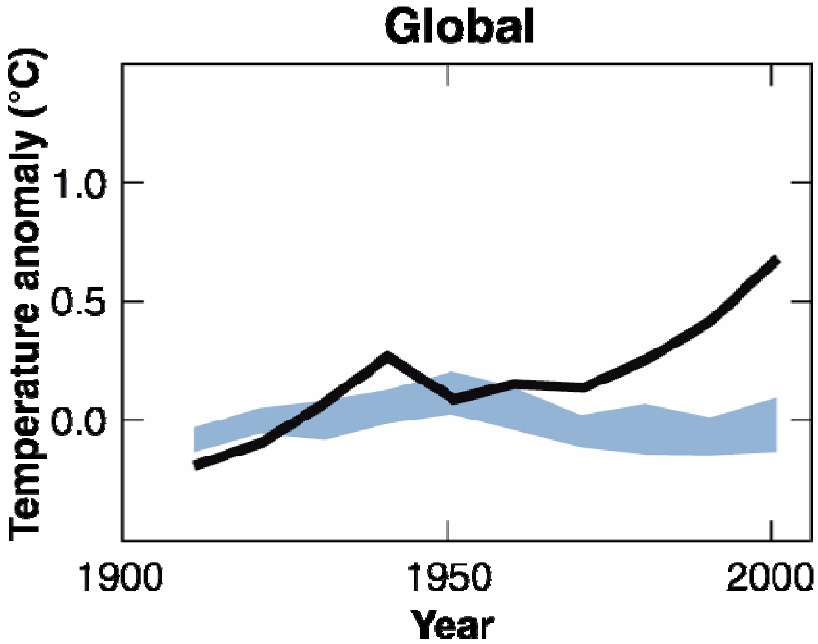

Global
Temperature anomaly (°C)
1.0
0.5
0.0
1900
1950
2000
Year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2000
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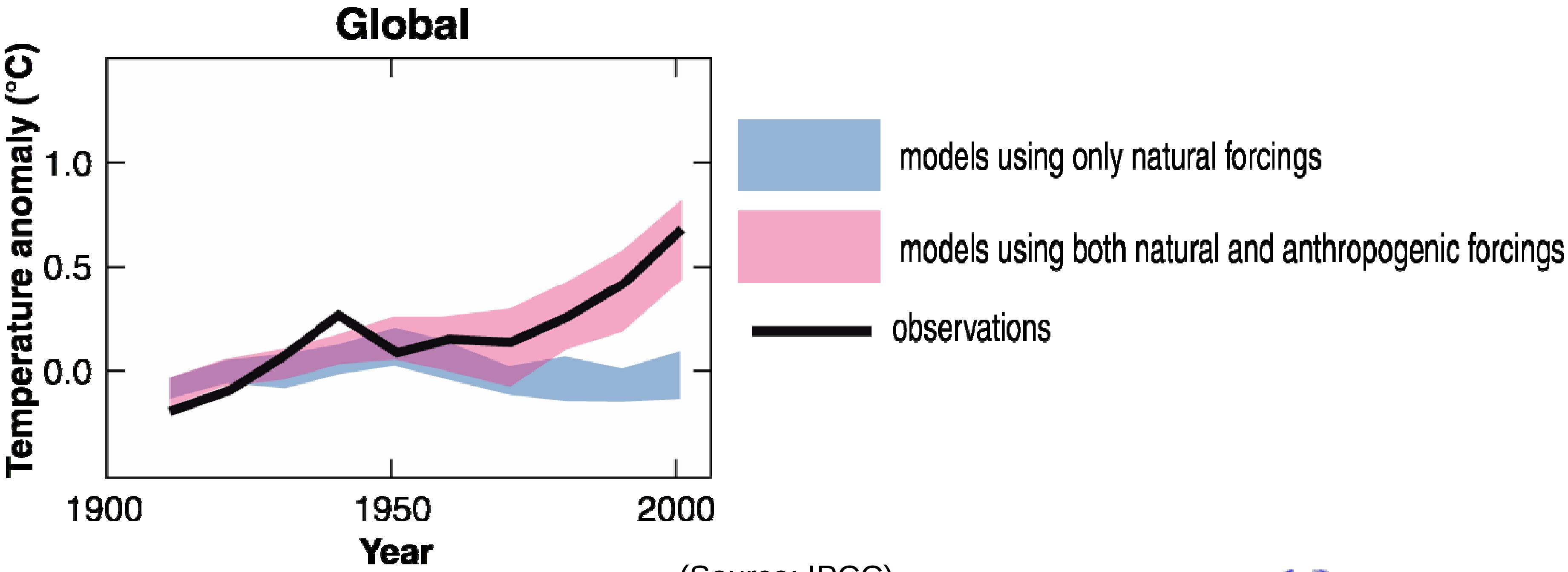
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1.0
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0.0
1900
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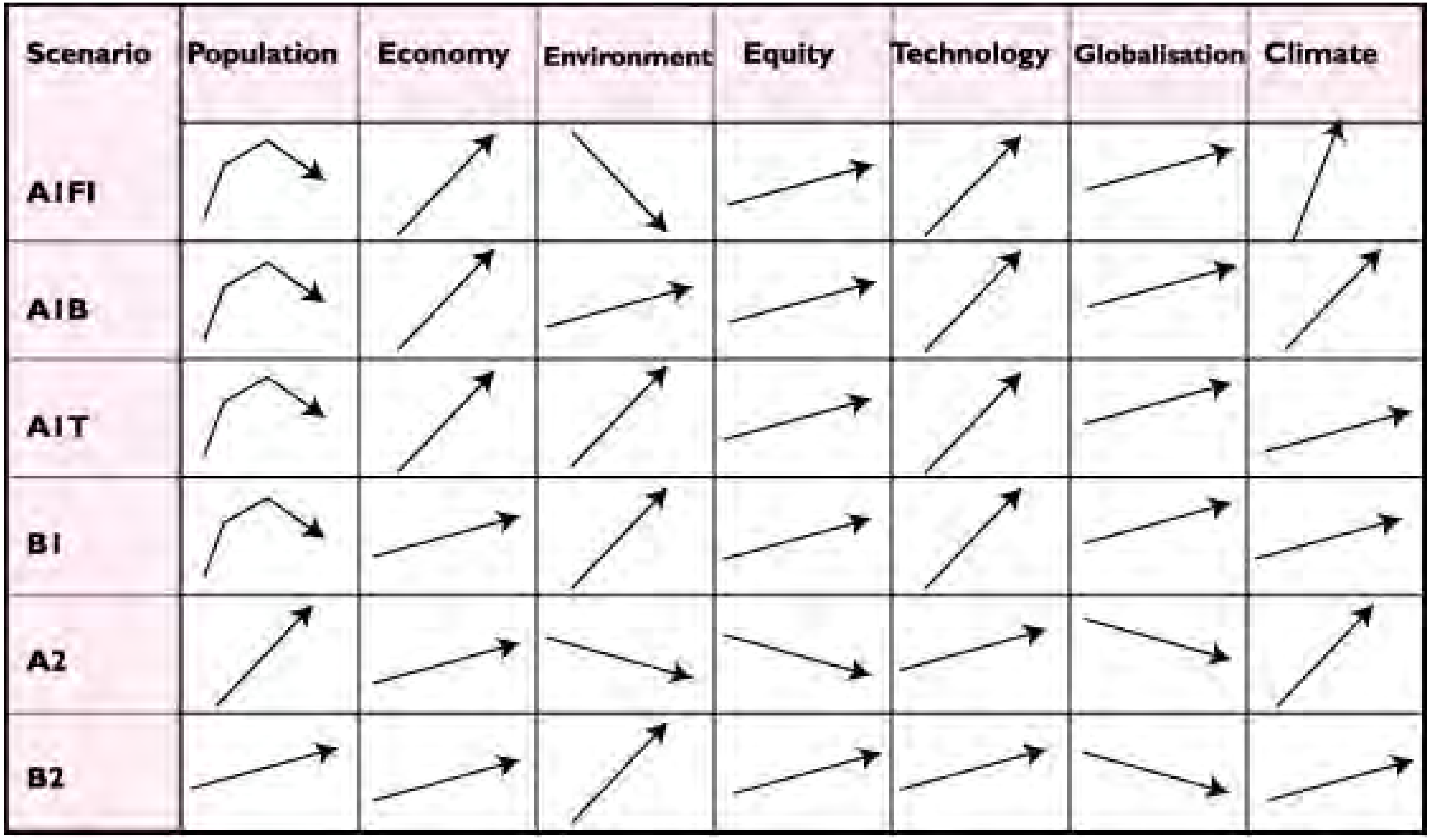
models using only natural forcings
models using both natural and anthropogenic forcings
observations

(Source: IPCC)

A Qualitative Description of the SRES Scenarios



(Source: IPCC)

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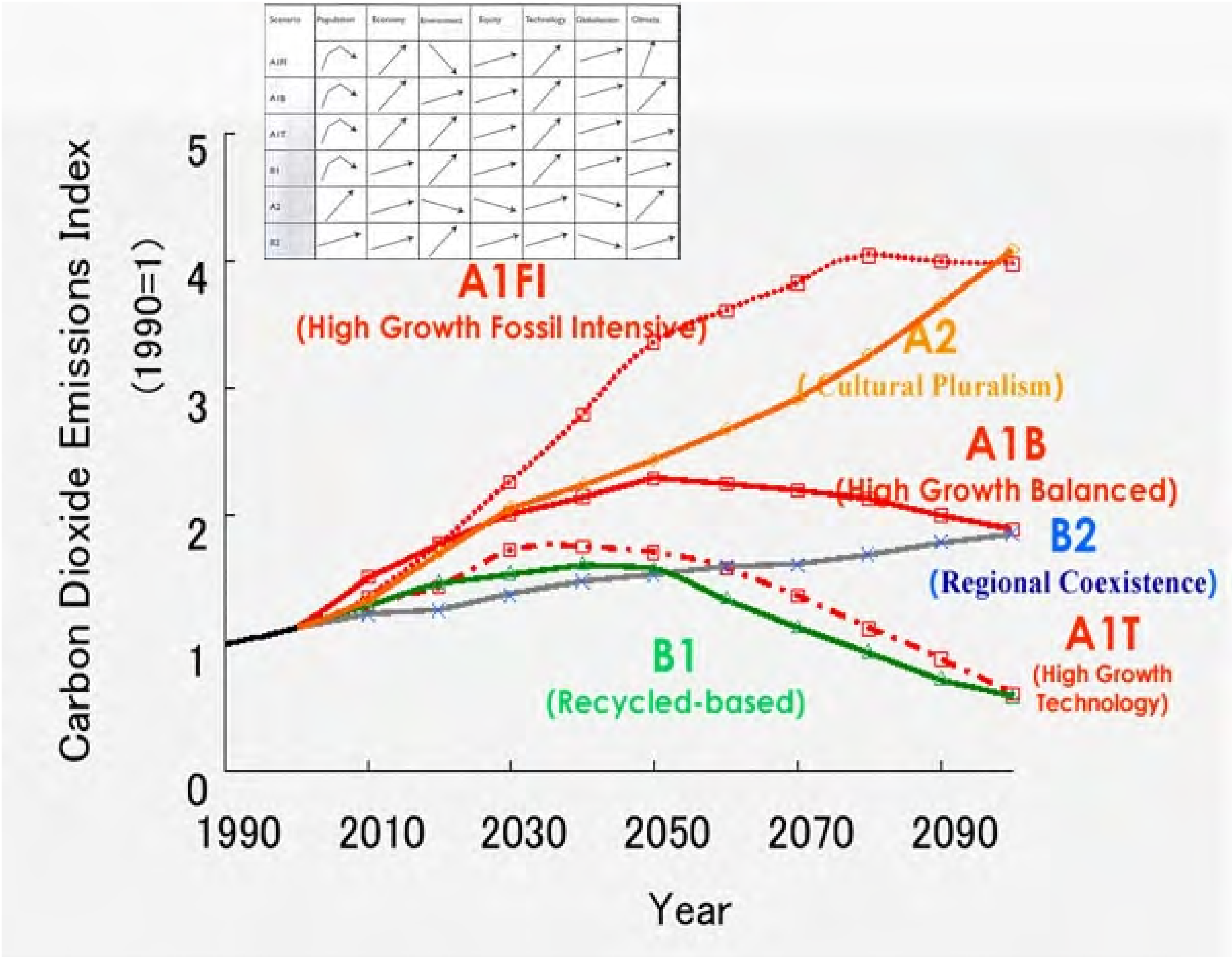
The inset reflects the various assumptions made on the future:

1. Population;
2. Economy;
4. Environment;
5. Equity;
6. Globalisation; and
7. Climate.



Projections of carbon dioxide emission under the six emission scenarios (SRES scenarios)

(Source: IPCC)

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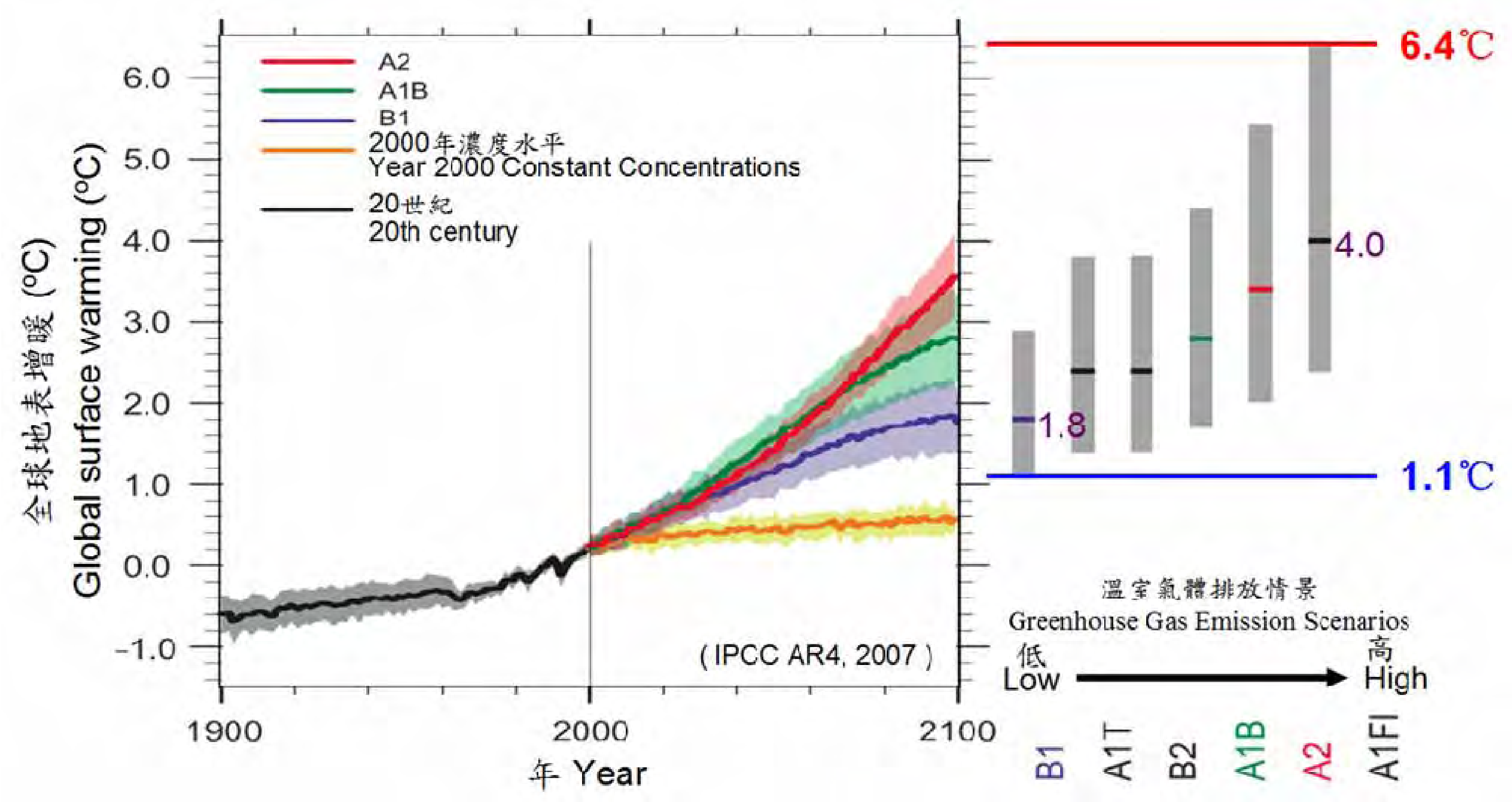
Projected global warming by climate models for different greenhouse gas emission scenarios



(Source: IPCC)

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Projected global climate change in the 21st century

IPCC model projections by the end of the 21st century :

- global average sf temp will rise by a further 1.1 - 6.4°C (best estimate 1.8 - 4.0°C)
- the global mean sea level will rise 0.18 to 0.59 meters
- changes relative to 1980-1999

Case	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]		Sea level rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations[b]	0.6	0.3 – 0.9	Not available
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

(Source: IPCC)

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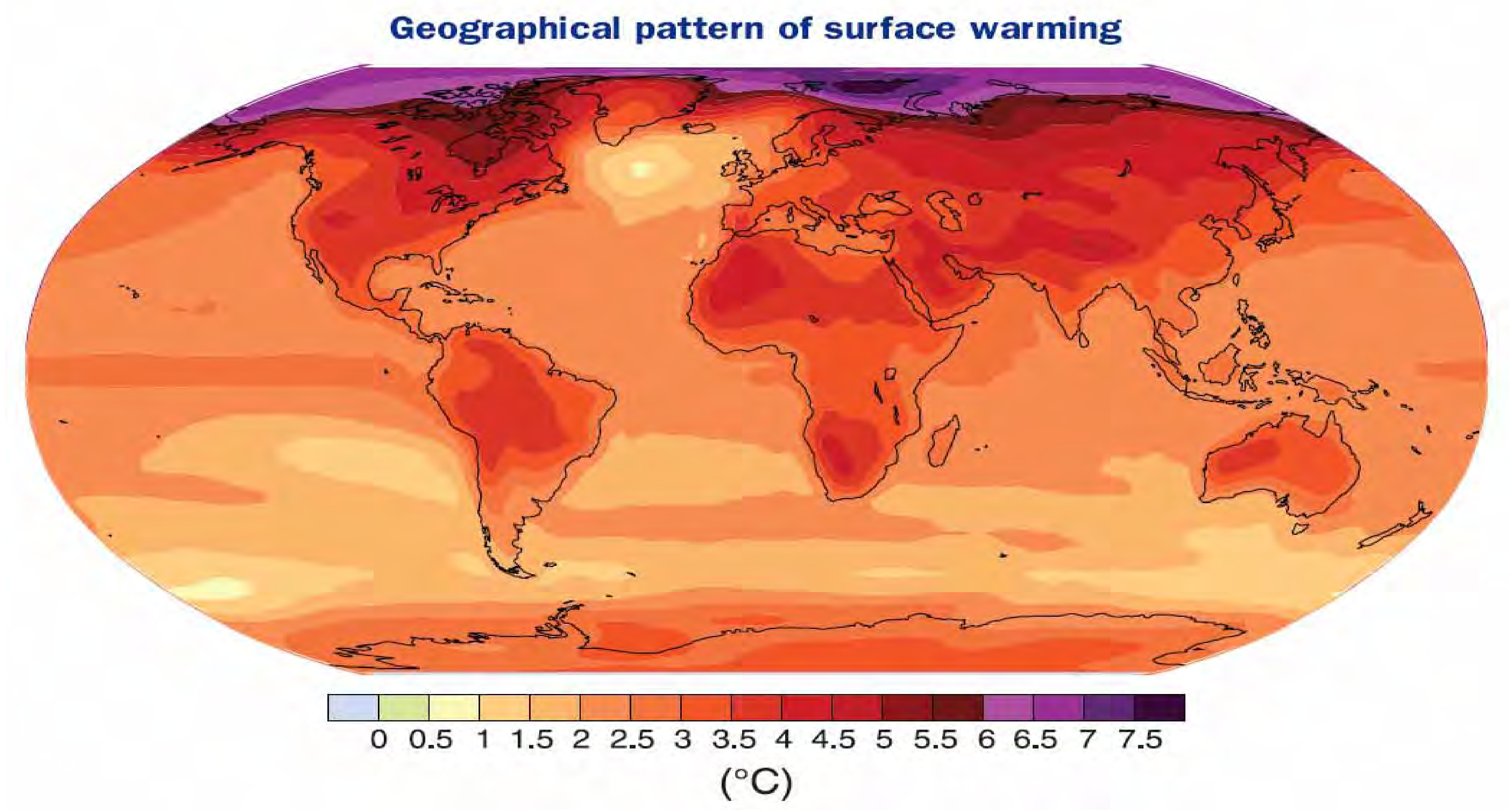
Project surface temperature change for the late 21st century (2090-2099)
Multi-AOGCM average projection for A1B SRES scenario. Temp relative to 1980-99



(Source: IPCC)

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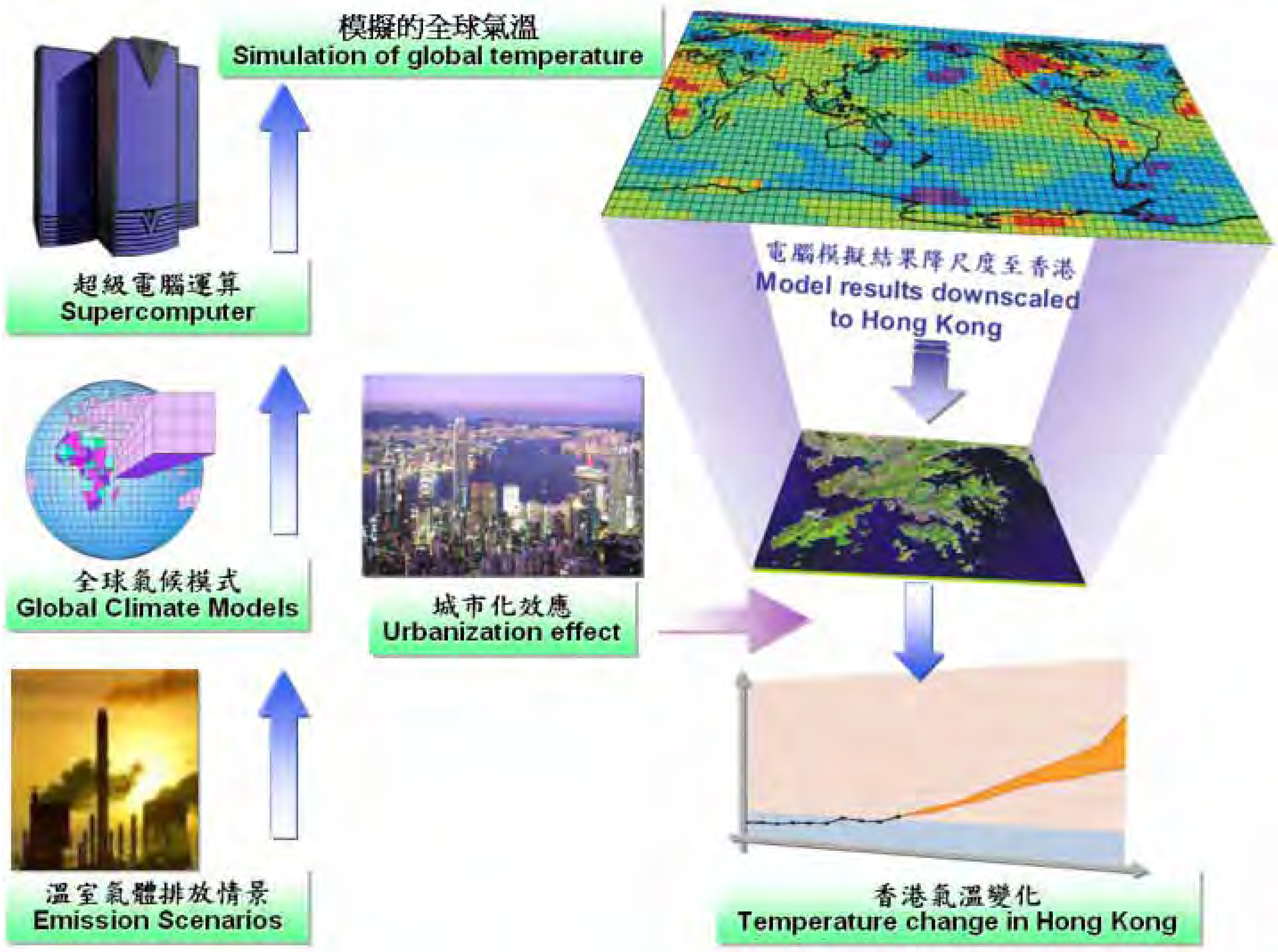
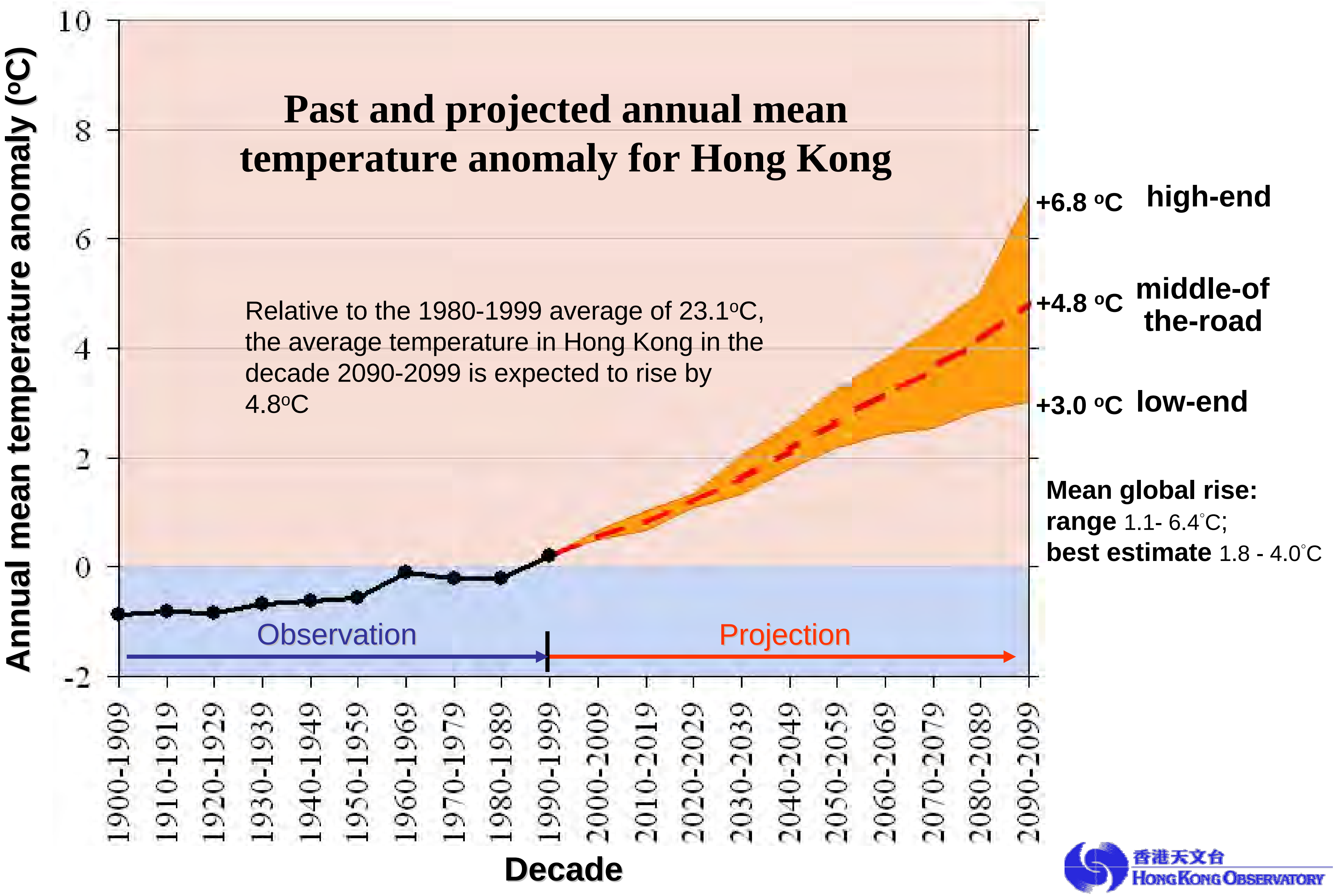
Schematic diagram showing the downscaling technique for future temperature in Hong Kong



Past and projected temperature for Hong Kong



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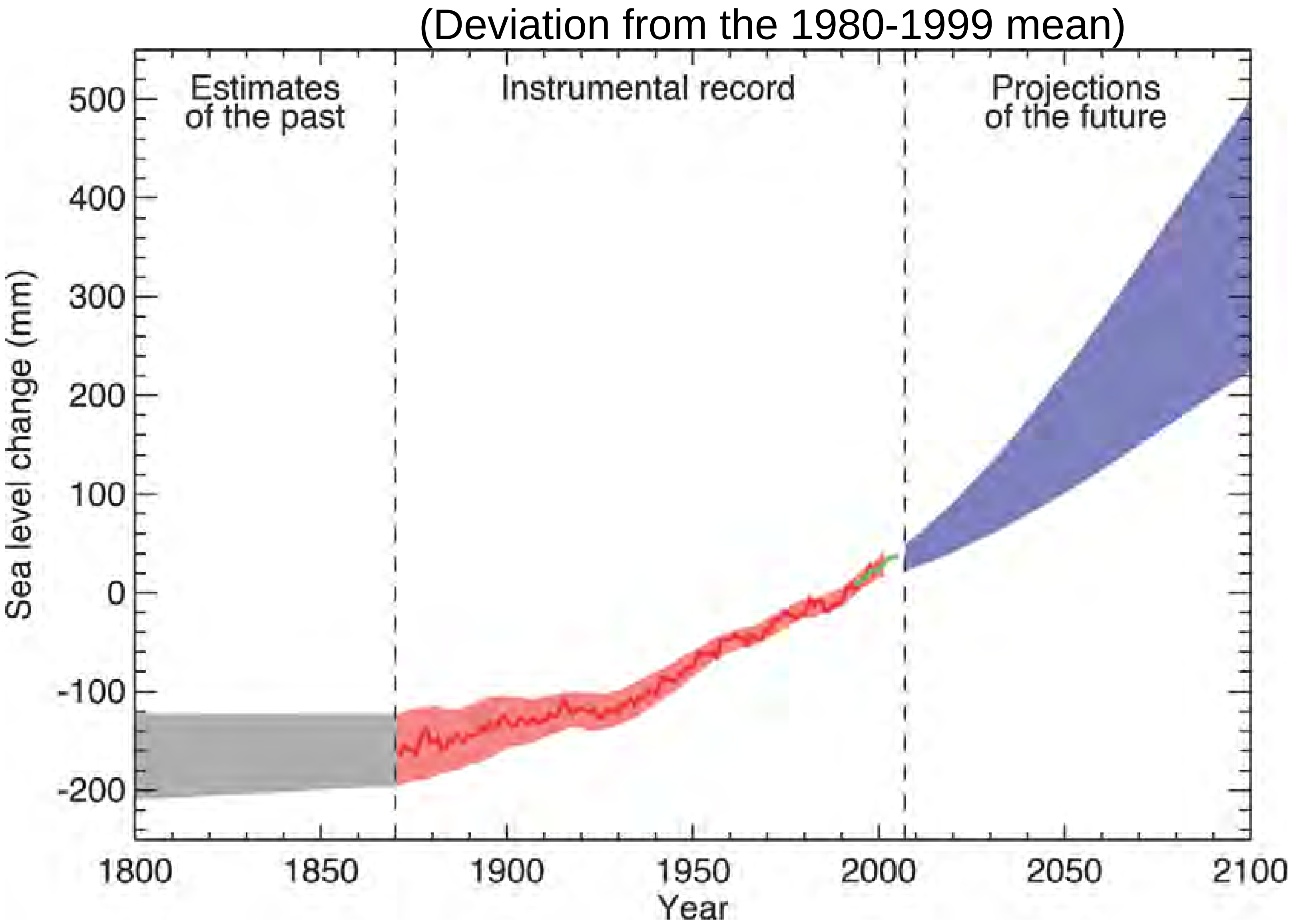
Global Sea Level Rise – past & Future



Over many centuries or millennia, sea level could rise by several meters

(Source: IPCC)

More Extreme weather events in future?

- Temperature
- Wind
- Rainfall
- RH, Pressure
- Tropical cyclones

What are these extreme events?

Extreme weather in HK

HKO Temperature

Lowest : 0.0 ˚C (18 Jan 1893)

Highest：36.1 ˚C (19 Aug 1900)

(18 Aug 1990)

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Extreme weather in HK

Highest Wind Gust

HKO：259km/h
(1 Sept 1962，Typhoon Wanda)

Waglan Island：234 km/h

(16 Sept 1999，Typhoon York)

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Extreme weather in HK

Rainfall records (HKO)

Hour：145.5mm (7 June 2008)

Day：534.1mm (19 July 1926)

Month：1,346.1mm (June 2008)

Year：3,343.0mm (1997) **[min 901.1mm** (1963) **]**

Rainfall intensity：513mm/h (Tate's Cairn, 17 Aug 1971)

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Extreme weather in HK

Relative Humidity (HKO)

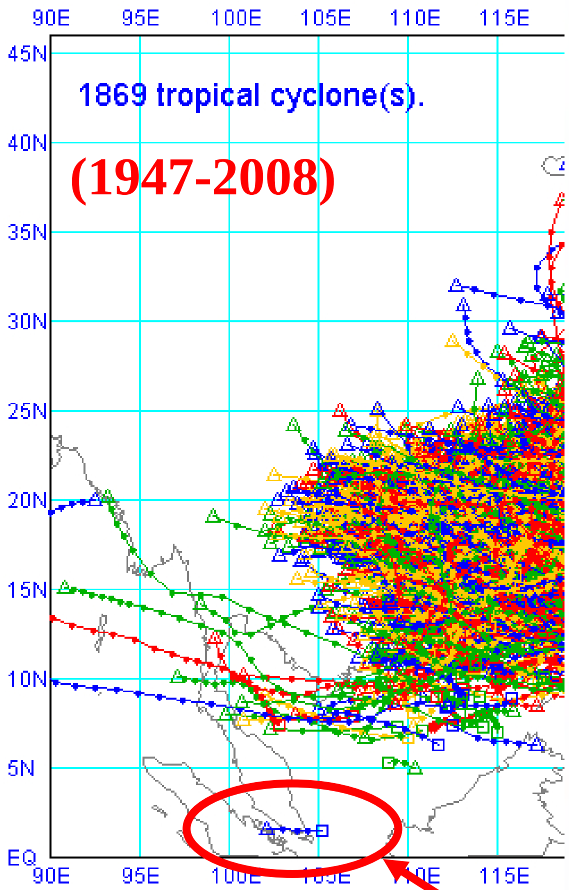
Lowest：10% (16 Jan 1959)

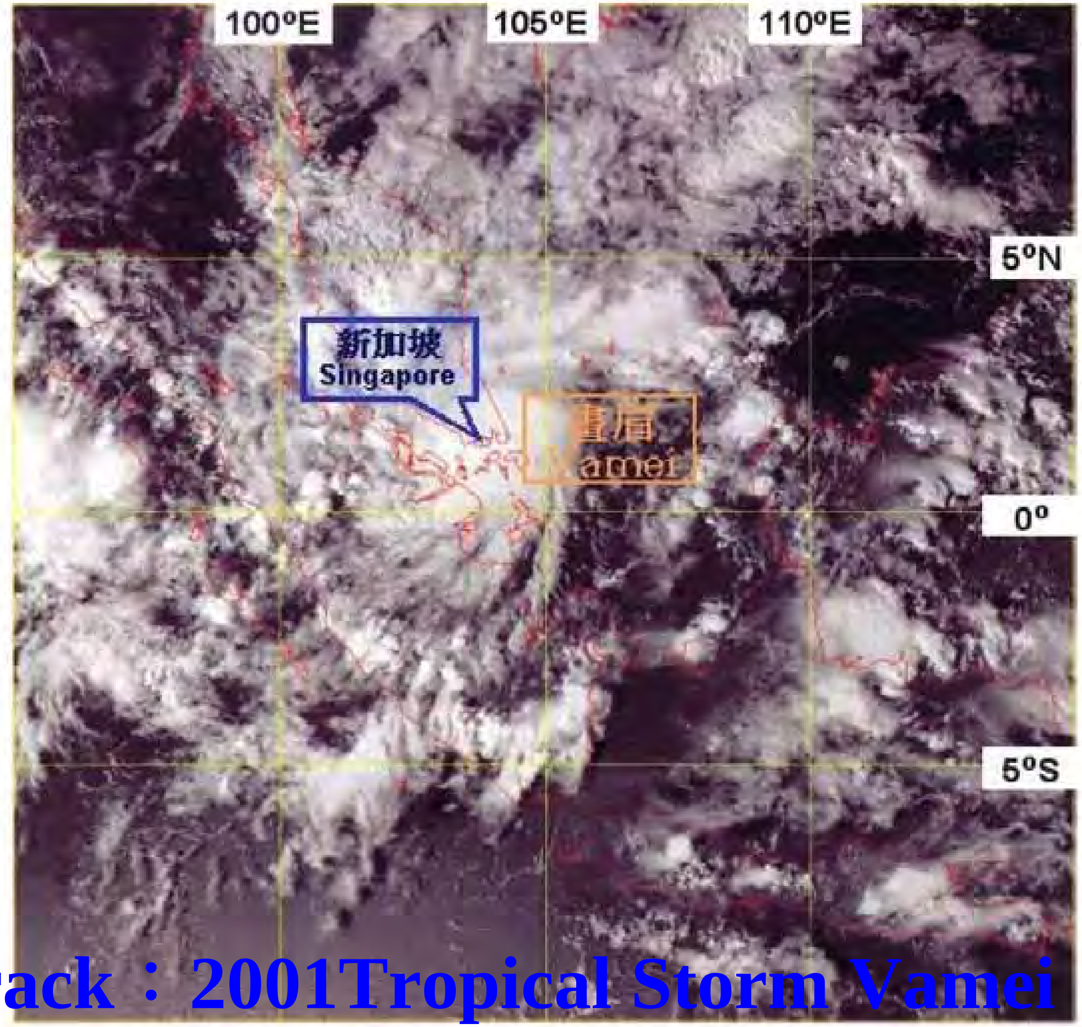
Pressure (HKO)

Lowest：953.2 hPa (1 Sept 1962)

Highest：1035.4 hPa (6 Jan 1903)

Tropical Cyclone Extremes





Southern most TC track：2001Tropical Storm Vamei

圖 2.4 二零零一年十二月二十七日約下午4時30分的可見光衛星圖片，顯示當時畫眉在新加坡附近。
[此衛星雲圖接收自日本氣象廳的地球同步氣象衛星(GMS-5)]

Figure 2.4 Visible imagery at around 4.30 p.m. on 27 December 2001 showing that Vamei was close to Singapore.
[The cloud imagery was originally captured with the Geostationary Me
Meteorological Agency]

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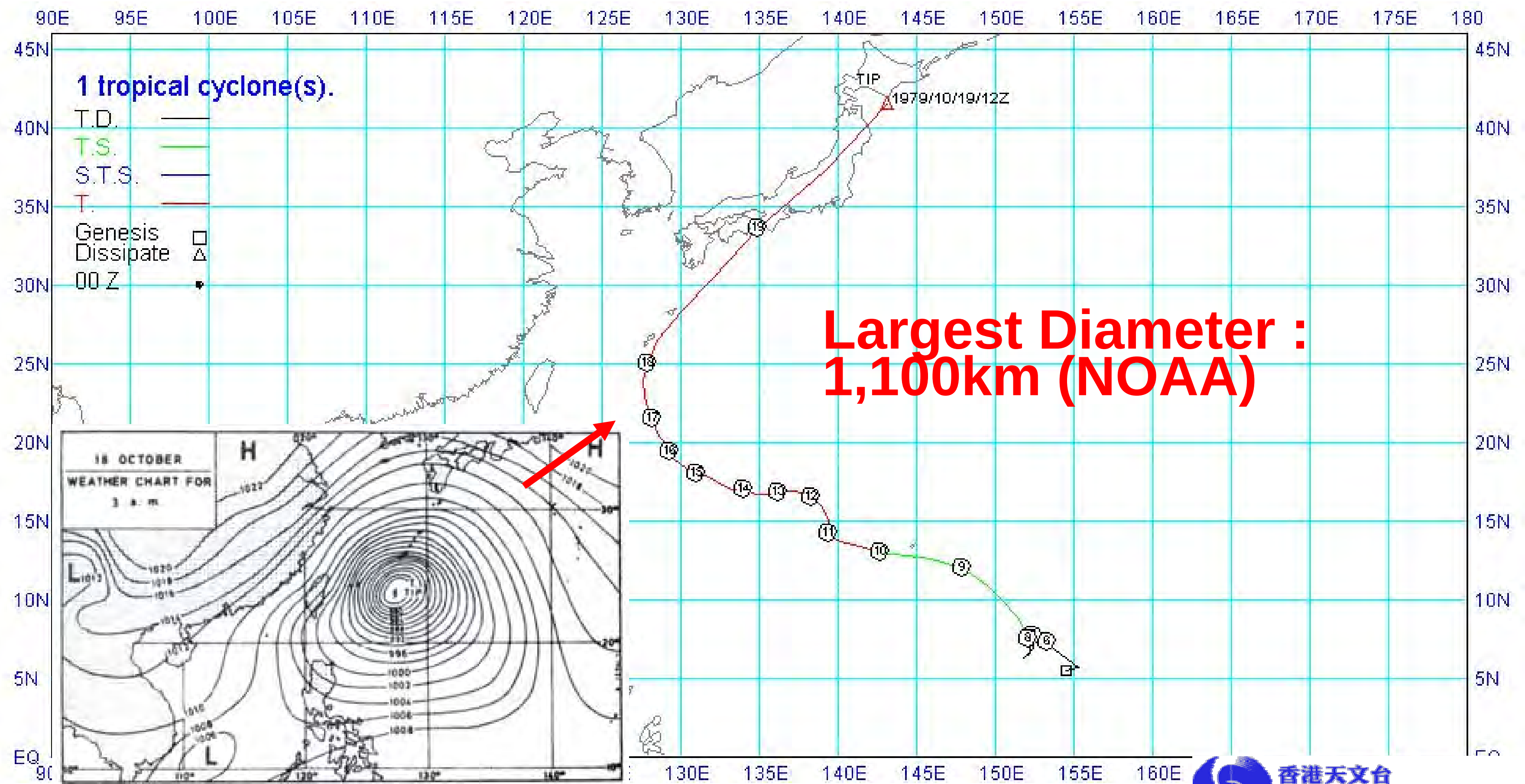
Tropical Cyclone Extremes

Most intense: Typhoon Tip 06UTC 12 Oct 1979

165 kt or 306km/h 870hPa



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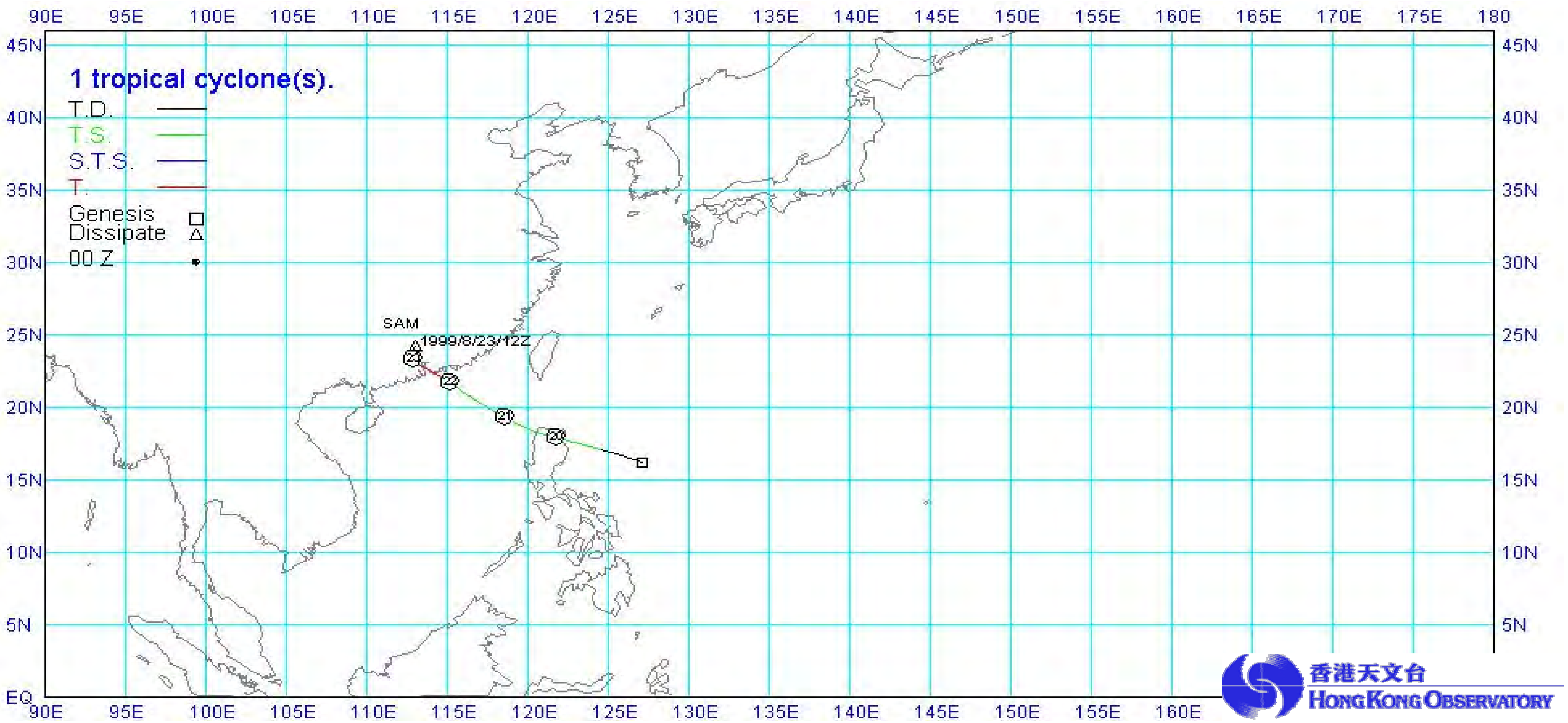
Tropical Cyclone Extremes

Wettest ：Typhoon Sam (21-26 Aug 1999)
616.5 mm HKOHq #

 # Rainfall at HKOHq on entering 600km & leaving 600km or 72h after dissipation



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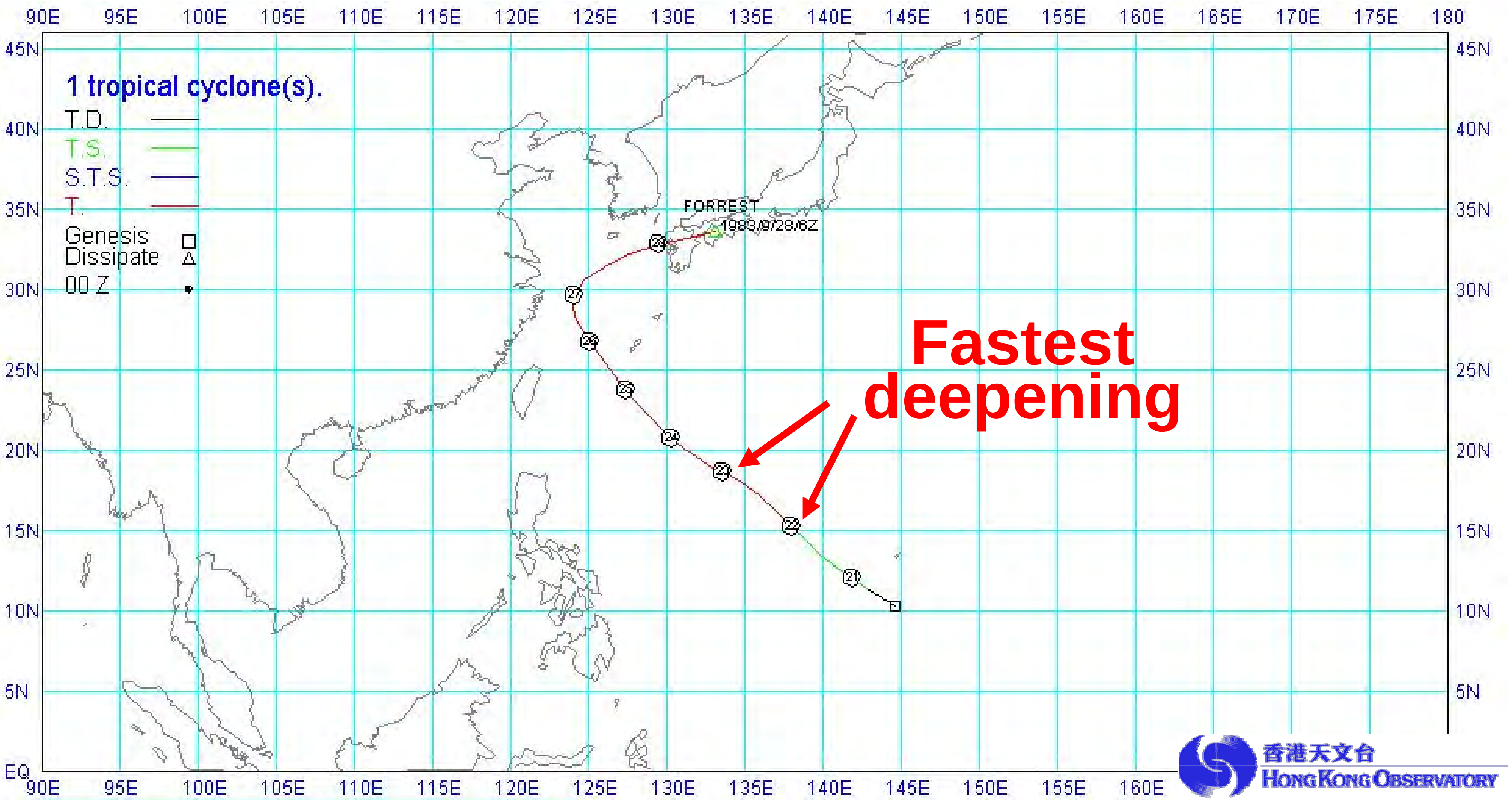
Tropical Cyclone Extremes

Fastest intensification：Typhoon Forrest (Sept 1983)

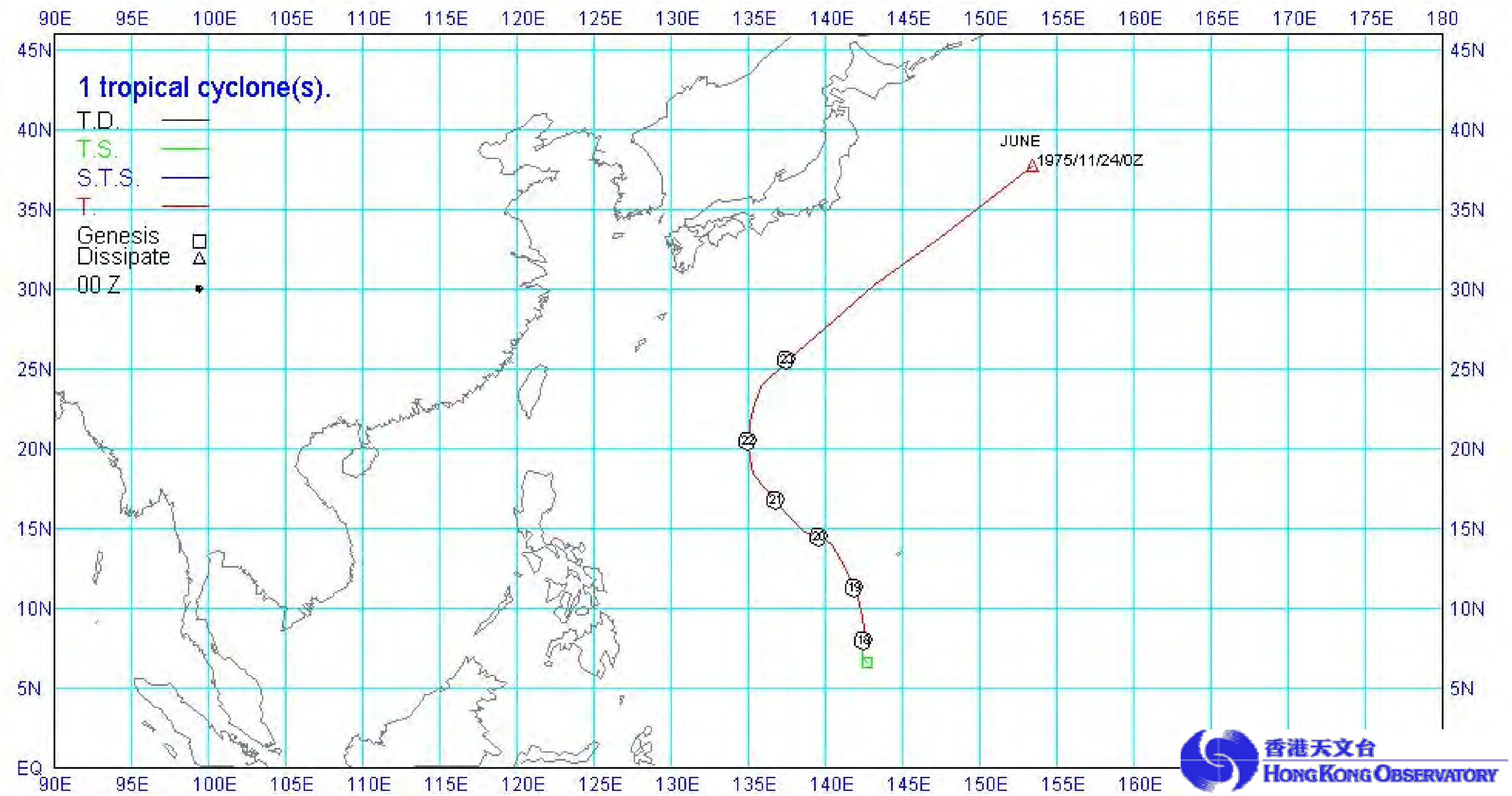
976hPa → 876hPa in 24 hours (NOAA)



Tropical Cyclone Extremes

Fastest speed：Typhoon June (Nov 1975)

(70 kt or 130km/h in 6 hours)



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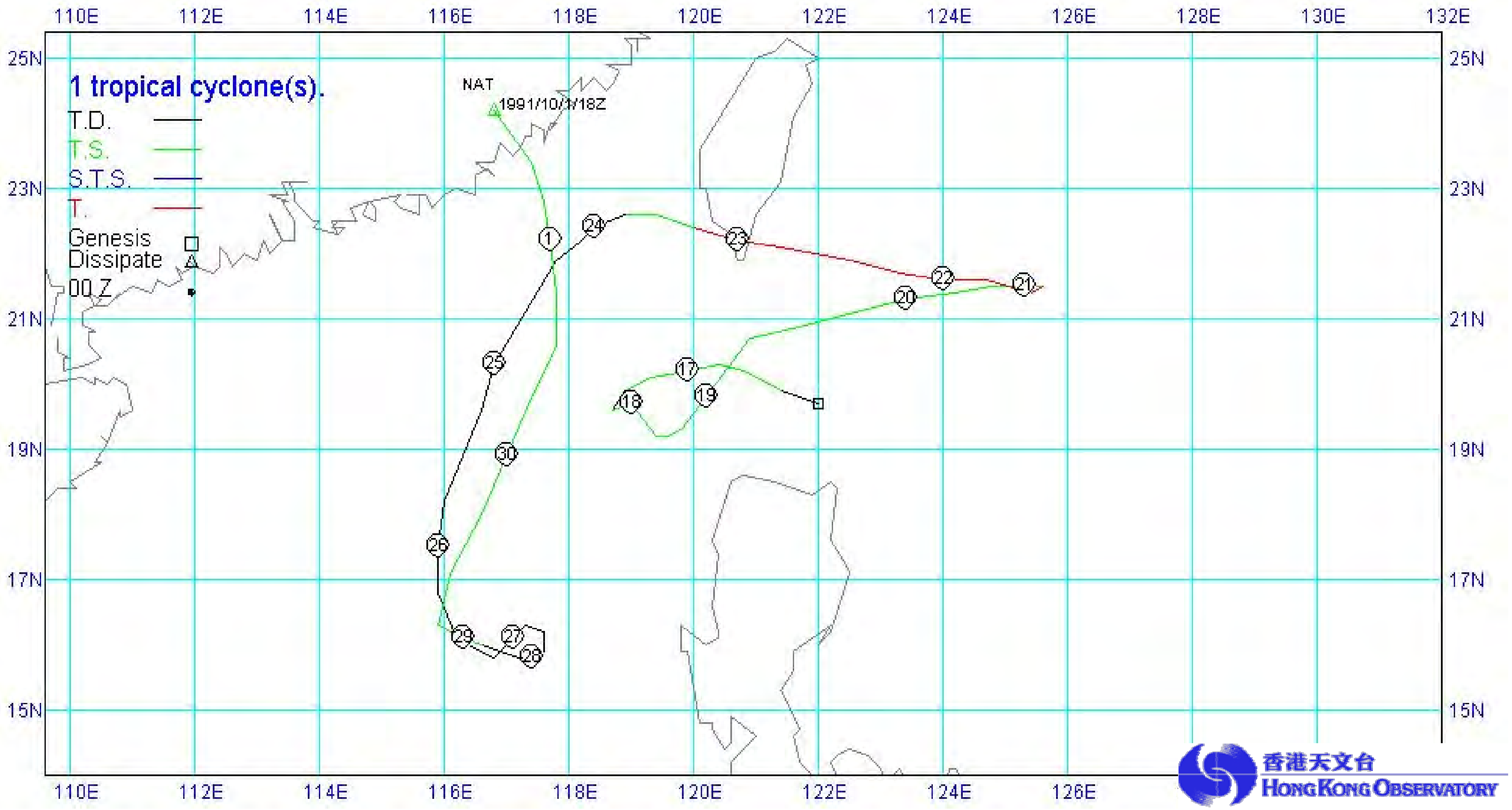
Tropical Cyclone Extremes

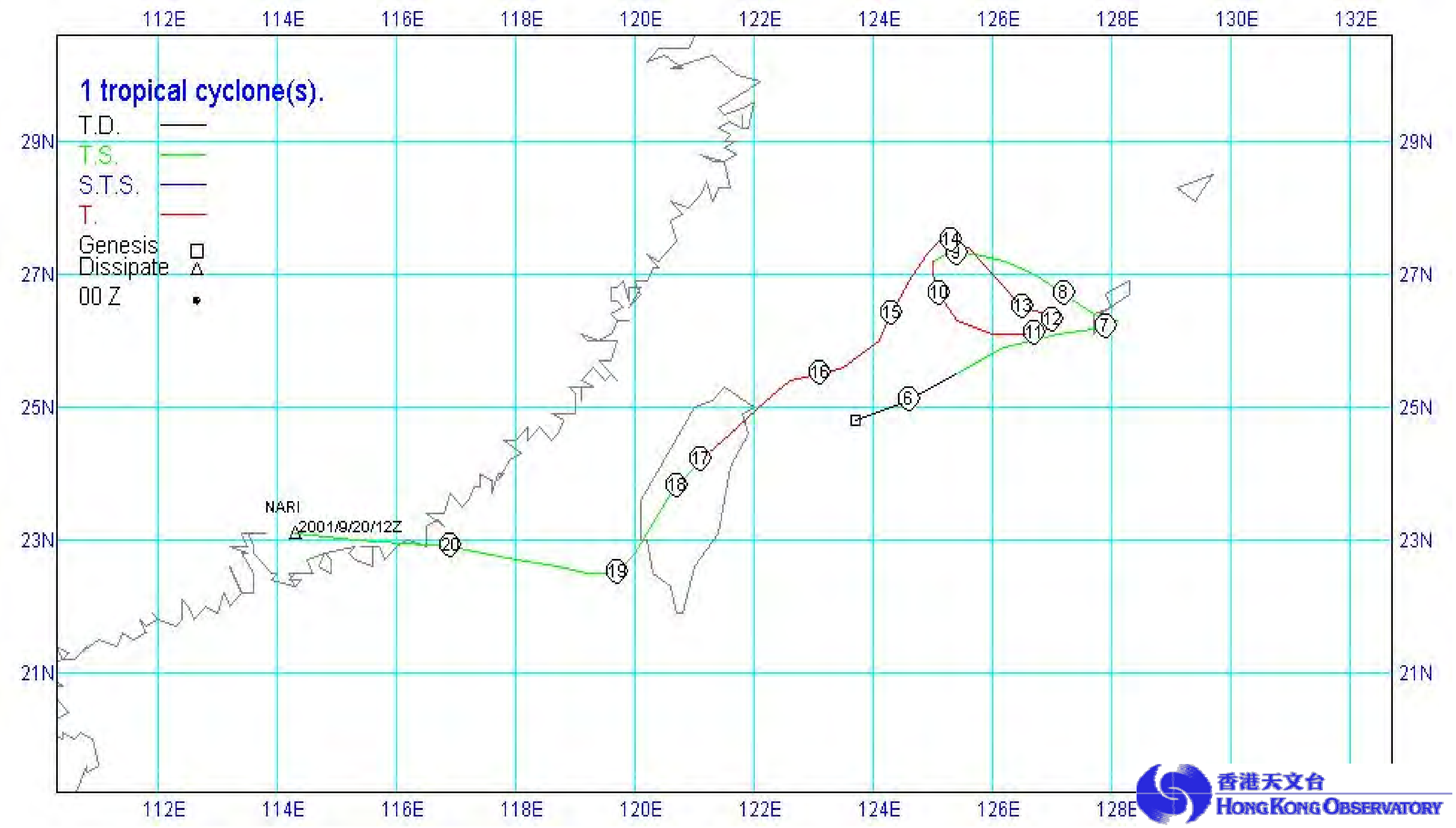
Strange track： ：Typhoon Nat

16 Sept – 2 Oct 1991



Tropical Cyclone Extremes

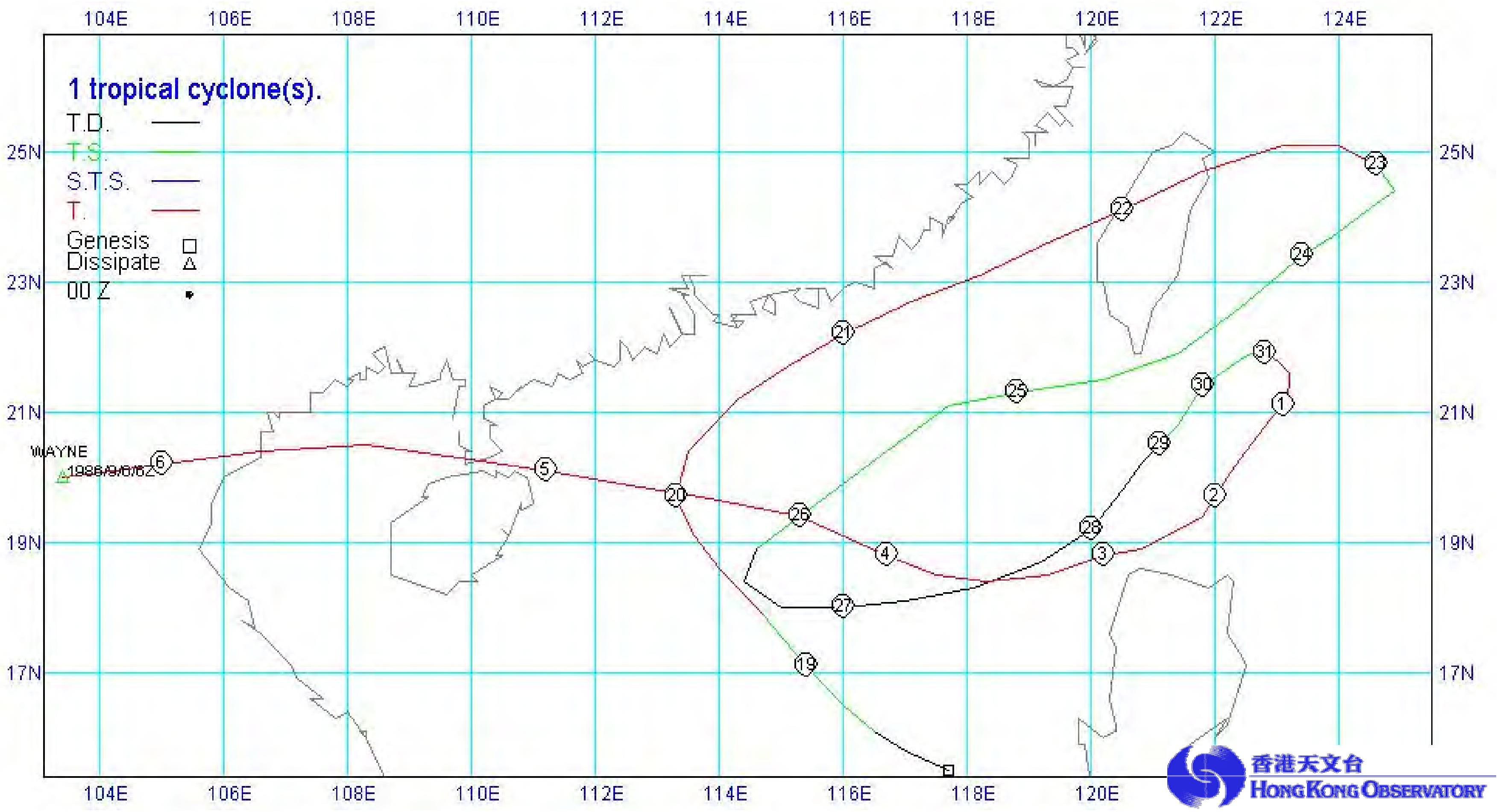
More strange track：Typhoon Nari (6-20 Sept 2001)



Tropical Cyclone Extremes

Very Strange track：Typhoon Wayne

18 Aug – 6 Sept 1986

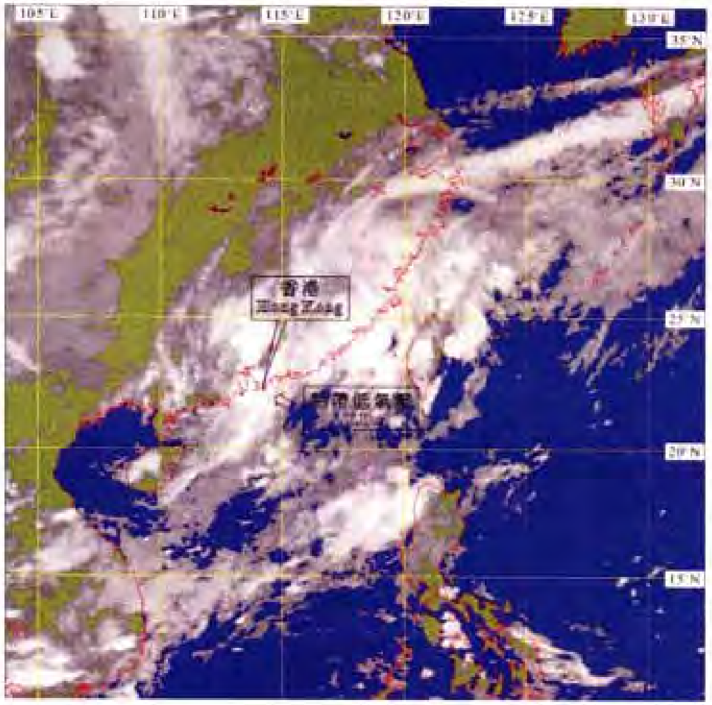


Tropical Cyclone Extremes

Shortest living：TD (June 2000) 5 hours

HKO issued the No.3 Strong Signal directly

圖 3.1.1.a 二零零零年六月十八日至十九日熱帶低氣壓的路徑圖。
Figure 3.1.1.a Track of the Tropical Depression : 18 - 19 June 2000.



二零零零年六月十八日約下午10時30分的紅外線衛星圖片。當時，熱帶低氣壓正在登陸香港。（此衛星雲圖接收自日本氣象廳的地球同步氣象衛星（GMS-5））
.1.6 Infra-red imagery at around 10.30 p.m. on 18 June 2000 when the tropical depression was making landfall over Hong Kong. (The cloud imagery was originally captured by GMS-5 of JMA)

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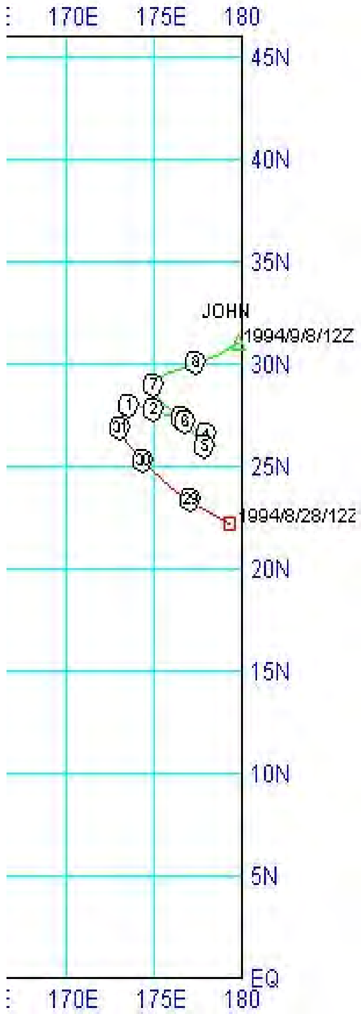
Tropical Cyclone Extremes

Longest life span:Typhoon John 31 days

(Aug – Sept 1994)



Source : NASA and National Hurricane Centre

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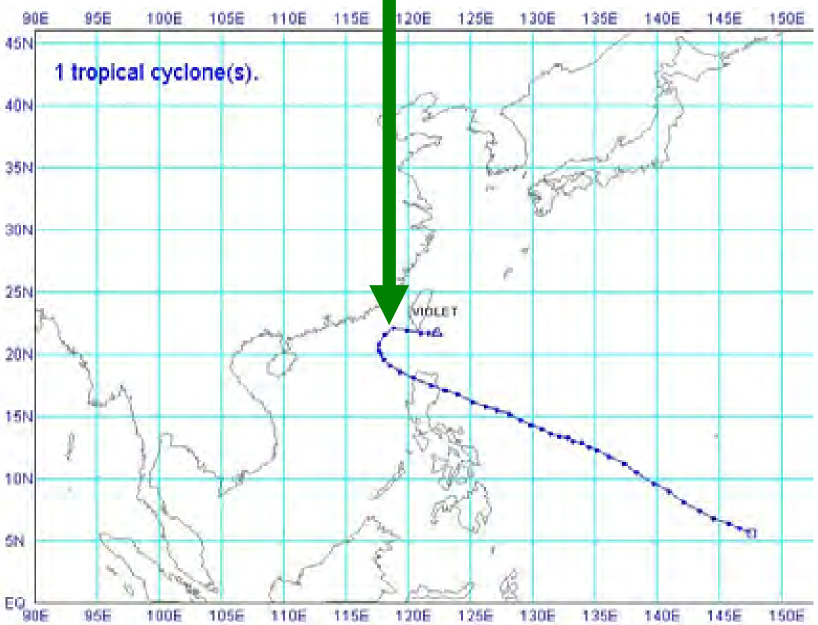
Tropical Cyclone Extremes

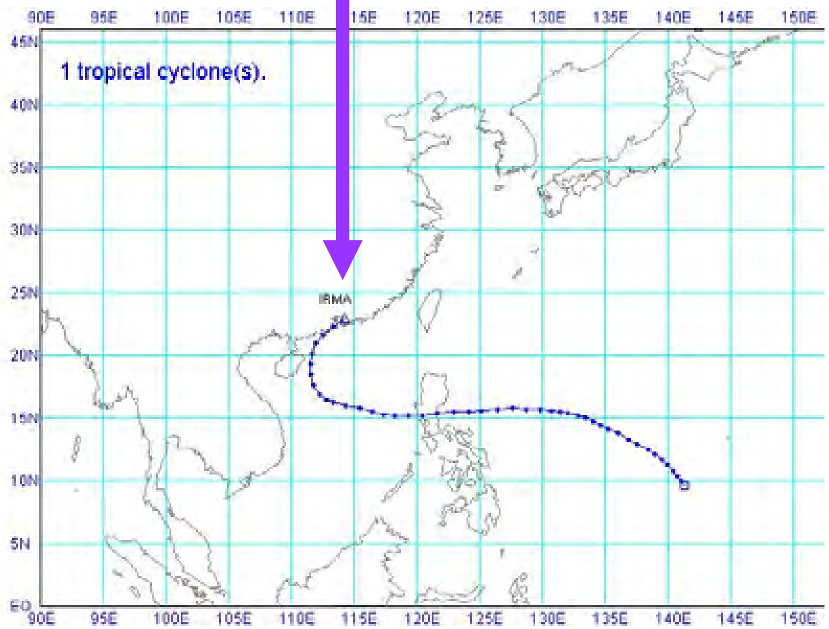
Tropical Cyclone affecting HK

Max：11 (1974) Min：2 (1959、1997 & 2007)

Earliest：Typhoon Violet (9 April 1967)

Latest：Typhoon Irma (2 Dec 1974)





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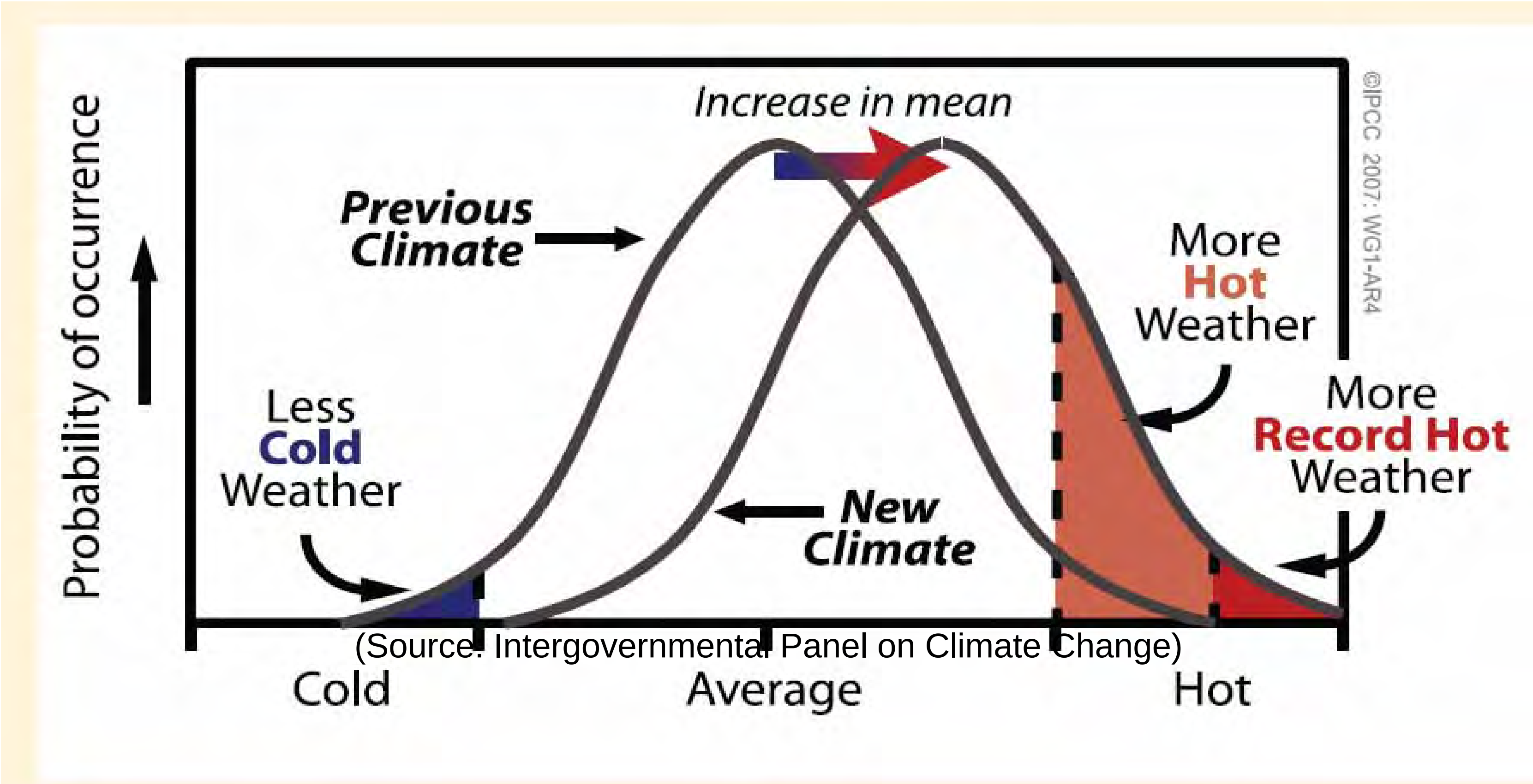

Schematic showing the effect on extreme temperatures when the mean temperature increases

(Source: IPCC)

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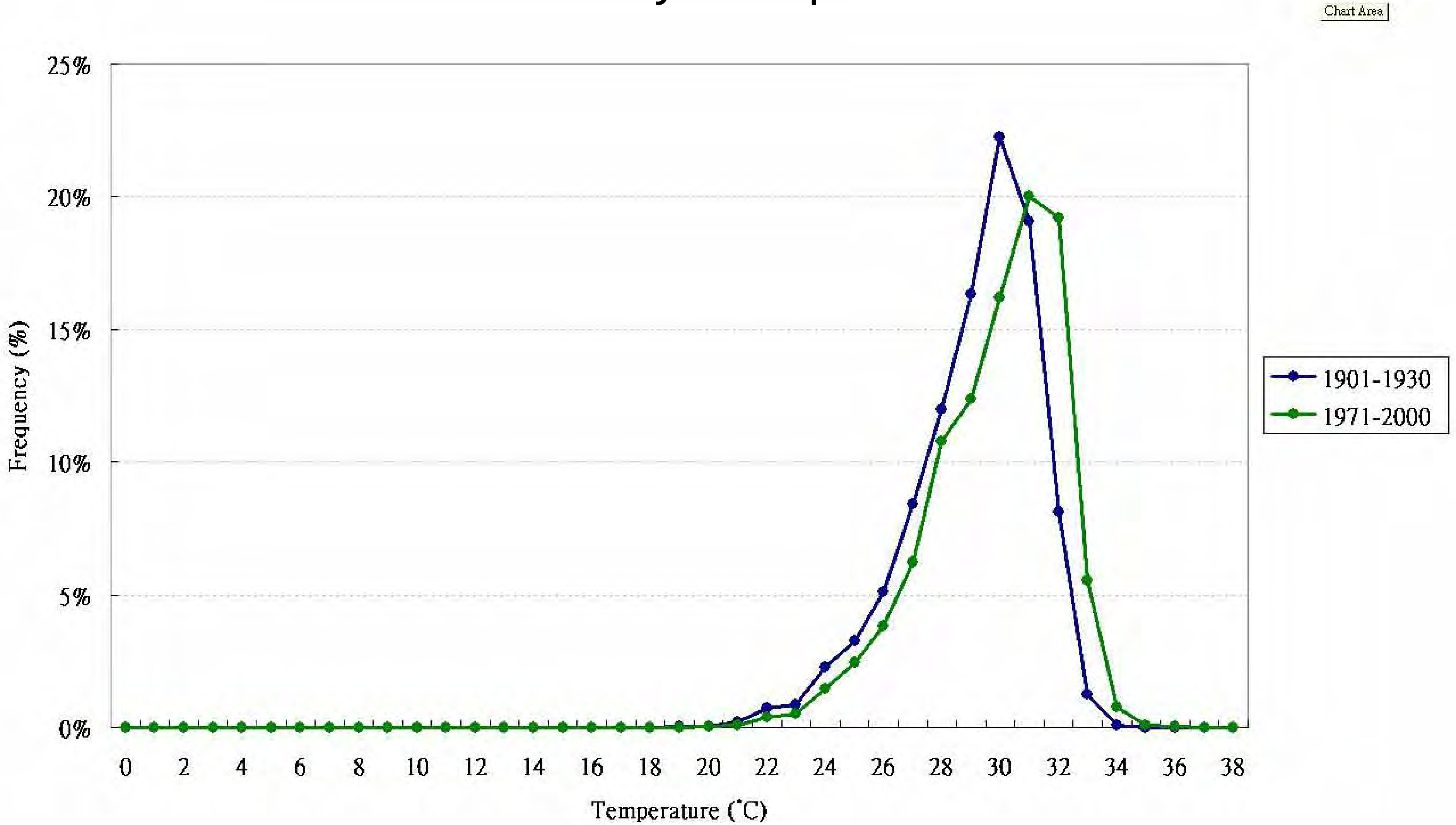
Shift in frequency distribution of T_{max}

29.6°C (1901-1930) to 30.3°C (1971-2000) or 0.7°C

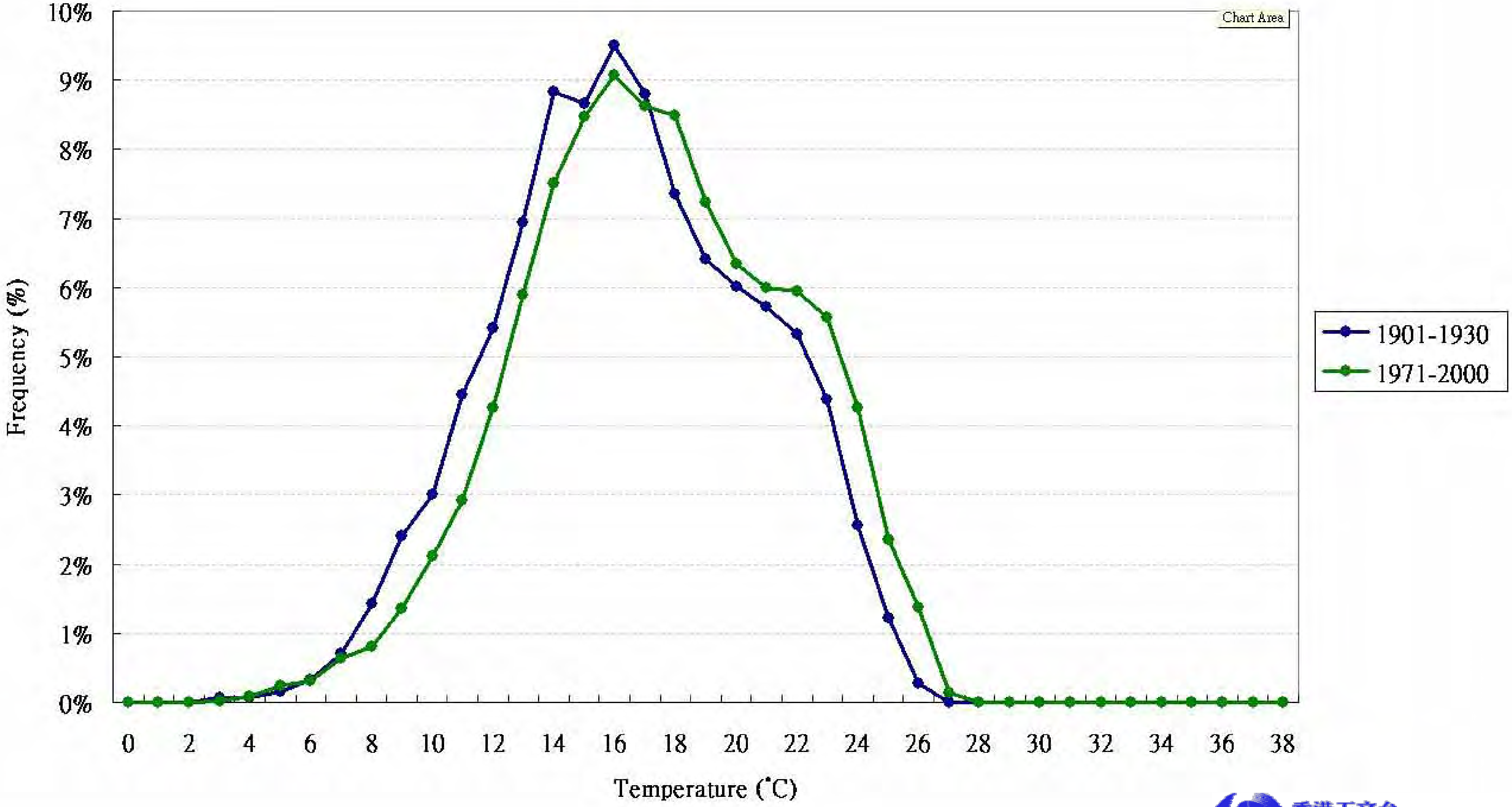
May to Sept



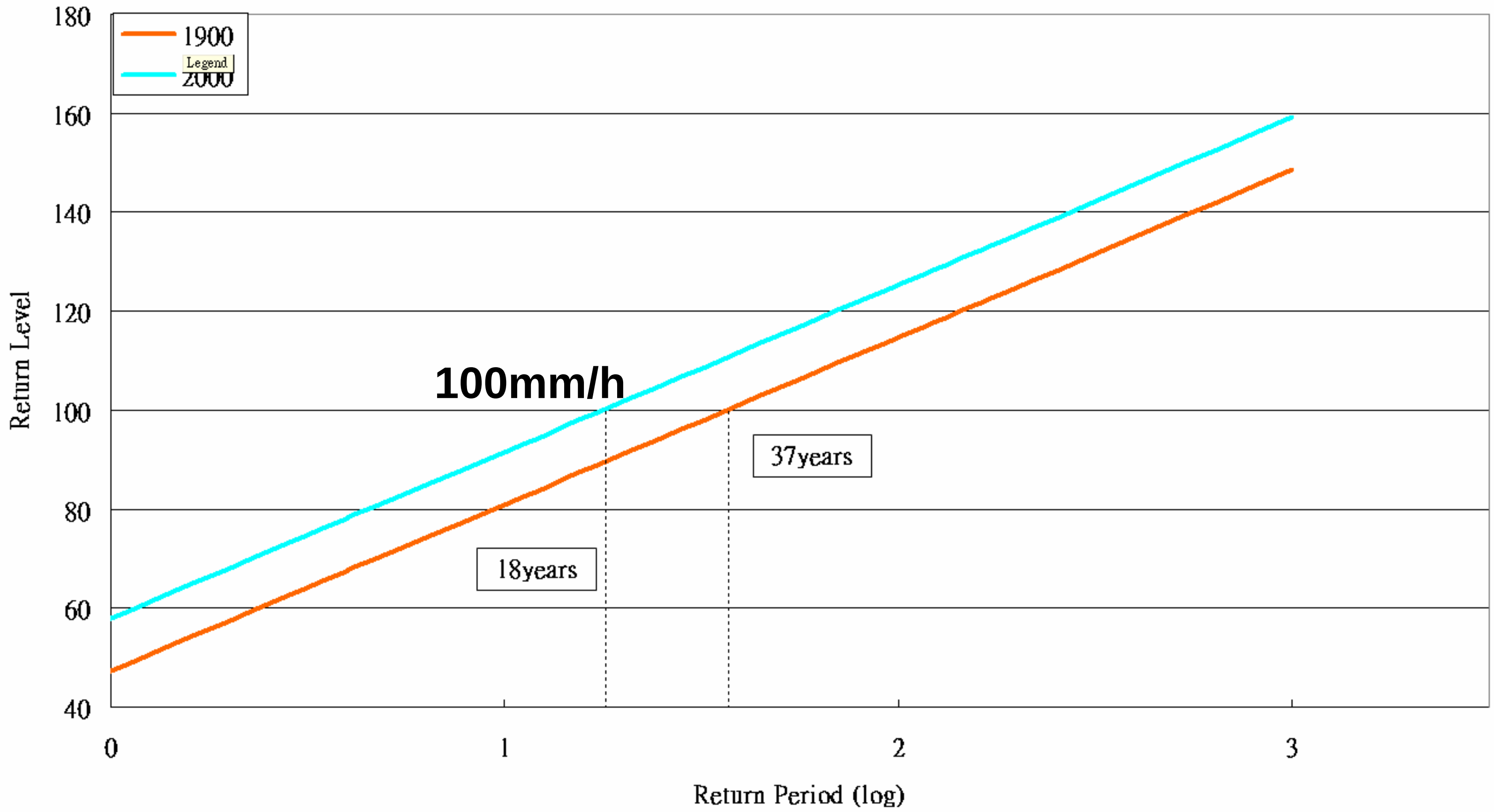
Shift in frequency distribution of T_{min}

16.9°C (1901-1930) to 17.8°C (1971-2000) or 0.9°C

Oct to April



Comparing return periods of rainfall in 1900 & 2000 by GEV analysis



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Diminishing return periods for heavy rain at HKOHq

- Hourly RF 100mm – once every 37yr in 1900
- Hourly RF 100mm – once every 18yr in 2000
- **Hourly RF 100mm – once every 9yr in 2100**

(preliminary results)

Increasing return Periods for T_{min} at HKOHq

- T_{min} of 7°C (4°C) – 1.3yr (6yr) in 1900
- T_{min} of 7°C (4°C) – 2 yr in (163yr) 2000
- **T_{min} of 7°C (4°C) – 12yr ($\rightarrow \infty$) in 2100**

T_{min} of 4°C is rare (return period of over 600yr) and 0°C a non-occurrence in 2008

(preliminary results)

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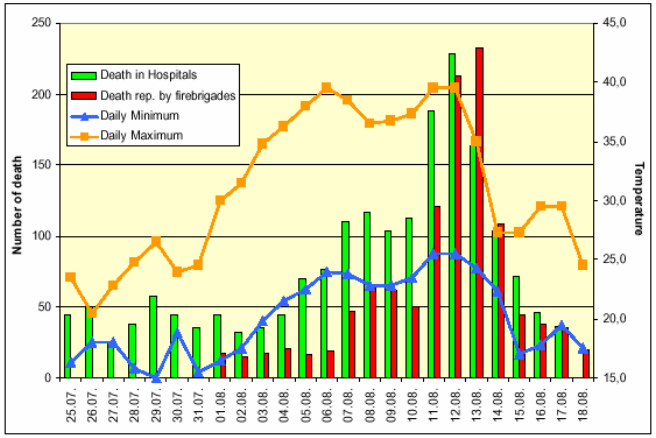
Potential Impacts of Climate Change

- Rising temperatures with more frequent heat waves
- Sea level rise
- Further melting of snow cover, glaciers and ice sheets
- Frequent floods and droughts
- Changes in agriculture production and food supplies
- Ecological and environmental imbalance
- Enhanced spread of infectious diseases

Heat waves

- More than 20,000 excess deaths in Western and Southern Europe in the summer of 2003



(Daily number of excess death during the heatwave in summer 2003 in Paris)

- The number of excess deaths due to heat is projected to increase in the future

Country	Casualties
France	14 082
Germany	7 000
Spain	4 200
Italy	4 000
UK	2 045
Netherlands	1 400
Portugal	1 300
Belgium	150

INSERM: "Surmortalité liée à la canicule de l'été 2003", AP September 25, 2003

With a **death toll** estimated to exceed **30,000**, the **2003 heat wave is one of the ten deadliest natural disasters in Europe for the last 100 years** and the worst in the last 50 years. Elderly people were most affected.

Source :
- Kovats S, Wolf T, Menne B. Heatwave of August 2003 in Europe: provisional estimates of the impact on mortality. Eurosurveillance Weekly. 11 March 2004; 8(11). http://www.eurosurveillance.org/ew/2004/040311.asp
-Environmental Alert Bulletin, United Nations Environment Programme
-WHO

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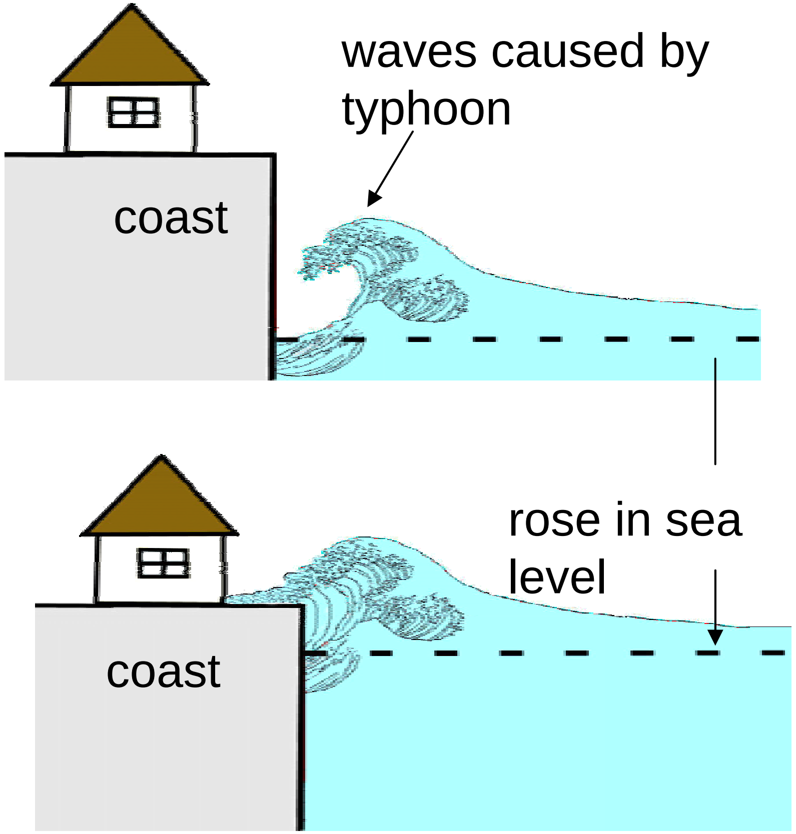
Sea level rise causes flooding of coastal areas easier



(Source: NOAA)

Flooding of the coastal areas becomes easier during typhoon approaches or heavy rain

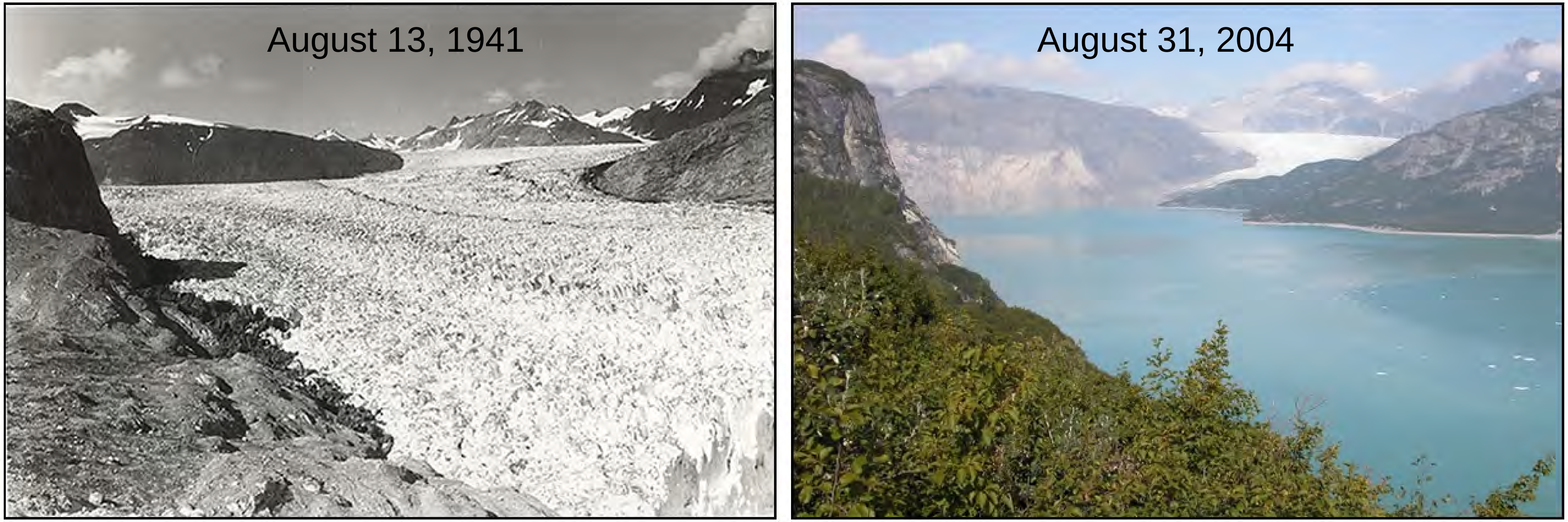
Sea level rise leads to increase flooding risk in coastal areas

(Source : USGS)

Melting of ice caps and glaciers

Global warming leads to the melting of ice caps and glaciers.
Melted ice-water flows into the sea & contributes to sea level rise.

Muir Glacier, Alaska's Glacier Bay



(Image Credit: NSIDC)

Between 1941 and 2004 the glacier retreated more than twelve kilometers and thinned by more than 800 meters.

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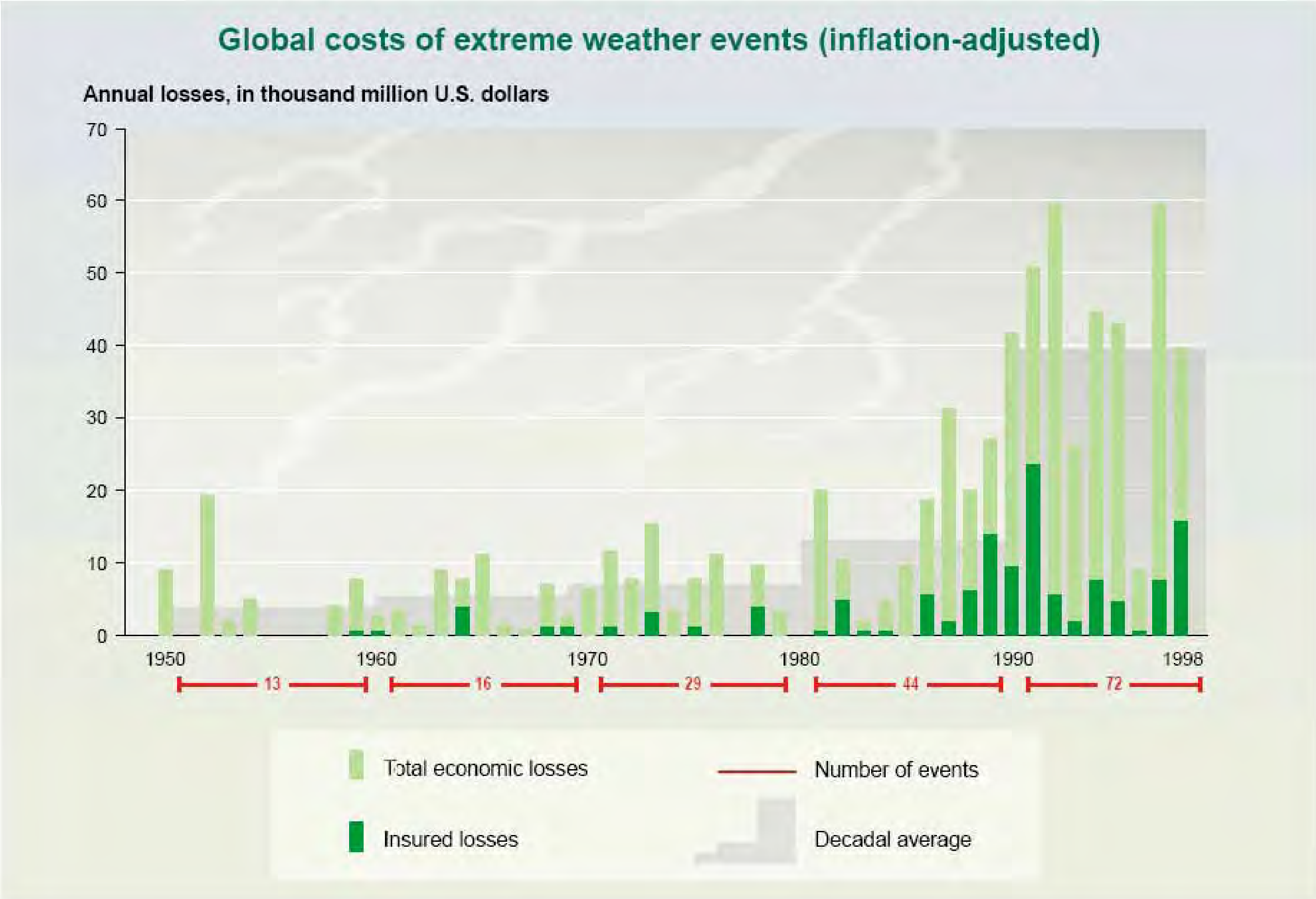
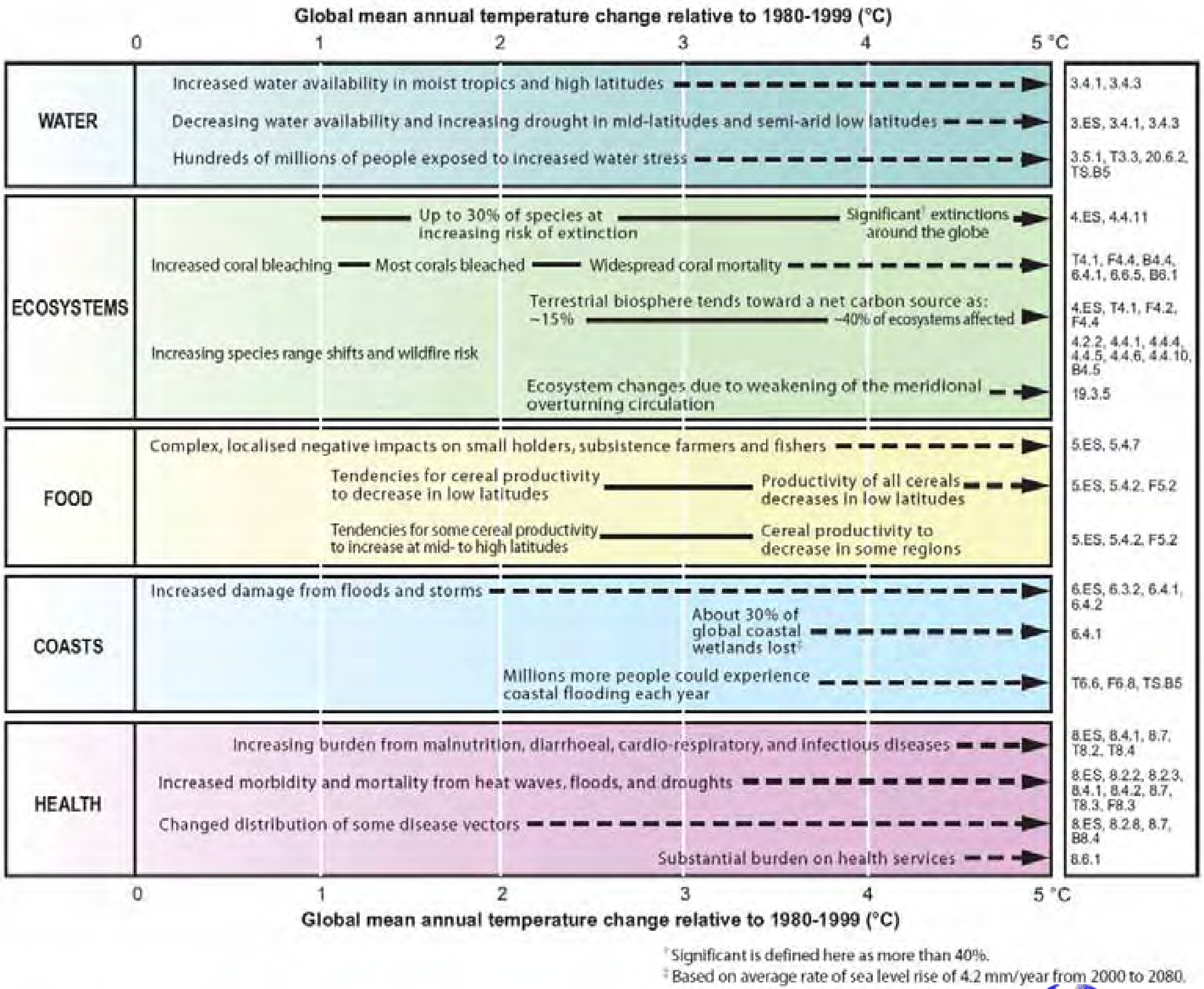


The economic losses from catastrophic weather events have risen globally 10-fold since the 1950s, after accounting for inflation. Part of the trend is linked to growing wealth and population, which increases economic vulnerability to extreme events, and part is linked to regional climatic factors (eg. changes in precipitation and flooding).

Source: Intergovernmental Panel on Climate Change, Third Assessment, Climate Change 2001: Synthesis report (Figure 2-7)

Key impacts as a function of increasing global average temperature change

(Impacts will vary by extent of adaptation, rate of temperature change, and socio-economic pathway)



(Source: IPCC)

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Projected Regional Impacts of Climate Change

Asia	• By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease. • Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers. • Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation and economic development. • Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle.
Australia and New Zealand	• By 2020, significant loss of biodiversity is projected to occur in some ecologically rich sites, including the Great Barrier Reef and Queensland Wet Tropics. • By 2030, water security problems are projected to intensify in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions. • By 2030, production from agriculture and forestry is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in some other regions. • By 2050, ongoing coastal development and population growth in some areas of Australia and New Zealand are projected to exacerbate risks from sea level rise and increases in the severity and frequency of storms and coastal flooding.
Europe	• Climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods and more frequent coastal flooding and increased erosion (due to storminess and sea level rise). • Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses (in some areas up to 60% under high emissions scenarios by 2080). • In southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity. • Climate change is also projected to increase the health risks due to heat waves and the frequency of wildfires.

(Source: IPCC)

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Impacts due to changes in extreme wx/climate events

(mid-late 21st century)

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	*Likely*	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	*Likely*	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	*Likely*[d]	Salinisation of irrigation water, estuaries and fresh-water systems	Decreased fresh-water availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

(Source: IPCC)

Examples of planned adaptation by sector

Sector	Adaptation option/strategy	Underlying policy framework	Key constraints and opportunities to implementation (Normal font = constraints; *italics = opportunities*)
Water	Expanded rainwater harvesting; water storage and conservation techniques; water re-use; desalination; water-use and irrigation efficiency	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers; *integrated water resources management; synergies with other sectors*
Agriculture	Adjustment of planting dates and crop variety; crop relocation; improved land management, e.g. erosion control and soil protection through tree planting	R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	Technological and financial constraints; access to new varieties; markets; *longer growing season in higher latitudes; revenues from 'new' products*
Infrastructure/ settlement (including coastal zones)	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance	Financial and technological barriers; availability of relocation space; *integrated policies and management; synergies with sustainable development goals*
Human health	Heat-health action plans; emergency medical services; improved climate-sensitive disease surveillance and control; safe water and improved sanitation	Public health policies that recognise climate risk; strengthened health services; regional and international cooperation	Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; *upgraded health services; improved quality of life*
Tourism	Diversification of tourism attractions and revenues; shifting ski slopes to higher altitudes and glaciers; artificial snow-making	Integrated planning (e.g. carrying capacity; linkages with other sectors); financial incentives, e.g. subsidies and tax credits	Appeal/marketing of new attractions; financial and logistical challenges; potential adverse impact on other sectors (e.g. artificial snow-making may increase energy use); *revenues from 'new' attractions; involvement of wider group of stakeholders*
Transport	Realignment/relocation; design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Integrating climate change considerations into national transport policy; investment in R&D for special situations, e.g. permafrost areas	Financial and technological barriers; availability of less vulnerable routes; *improved technologies and integration with key sectors (e.g. energy)*
Energy	Strengthening of overhead transmission and distribution infrastructure; underground cabling for utilities; energy efficiency; use of renewable sources; reduced dependence on single sources of energy	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards	Access to viable alternatives; financial and technological barriers; acceptance of new technologies; *stimulation of new technologies; use of local resources*

(Source: IPCC)

What we can do – sectoral mitigation

Sector	Key mitigation technologies and practices currently commercially available. *Key mitigation technologies and practices projected to be commercialised before 2030 shown in italics.*	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities (Normal font = constraints; *italics = opportunities*)
Energy supply	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas); *CCS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics*	Reduction of fossil fuel subsidies; taxes or carbon charges on fossil fuels	Resistance by vested interests may make them difficult to implement
		Feed-in tariffs for renewable energy technologies; renewable energy obligations; producer subsidies	*May be appropriate to create markets for low-emissions technologies*
Transport	More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; *second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries*	Mandatory fuel economy; biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
		Taxes on vehicle purchase, registration, use and motor fuels; road and parking pricing	Effectiveness may drop with higher incomes
		Influence mobility needs through land-use regulations and infrastructure planning; investment in attractive public transport facilities and non-motorised forms of transport	*Particularly appropriate for countries that are building up their transportation systems*
Buildings	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycling of fluorinated gases; *integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar photovoltaics integrated in buildings*	Appliance standards and labelling	Periodic revision of standards needed
		Building codes and certification	*Attractive for new buildings.* Enforcement can be difficult
		Demand-side management programmes	Need for regulations so that utilities may profit
		Public sector leadership programmes, including procurement	*Government purchasing can expand demand for energy-efficient products*
		Incentives for energy service companies (ESCOs)	*Success factor: Access to third party financing*
Industry	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies; *advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture*	Provision of benchmark information; performance standards; subsidies; tax credits	*May be appropriate to stimulate technology uptake.* Stability of national policy important in view of international competitiveness
		Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
		Voluntary agreements	Success factors include: clear targets, a baseline scenario, third-party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry
Agriculture	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertiliser application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; *improvements of crop yields*	Financial incentives and regulations for improved land management; maintaining soil carbon content; efficient use of fertilisers and irrigation	*May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation*
Forestry/ forests	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use; *tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change*	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests; land-use regulation and enforcement	Constraints include lack of investment capital and land tenure issues. *Can help poverty alleviation*
Waste	Landfill CH_4 recovery; waste incineration with energy recovery; composting of organic waste; controlled wastewater treatment; recycling and waste minimisation; *biocovers and biofilters to optimise CH_4 oxidation*	Financial incentives for improved waste and wastewater management	*May stimulate technology diffusion*
		Renewable energy incentives or obligations	Local availability of low-cost fuel
		Waste management regulations	Most effectively applied at national level with enforcement strategies

(Source: IPCC)

Outreaching Activities by HKO

School visits & talks promoting awareness and understanding of climate change

Website on Climate Change

Educational package & DVD on climate change

Some questions

1. Why can scientists project the future climate, say in the next 100 years?
2. How do scientists make the projections?
3. How reliable are the projections?
4. Can individual extreme events be explained by Greenhouse warming?
5. How likely are major or abrupt climate changes, such as loss of ice sheets or changes in global ocean circulations?
6. If emissions of GHGs are reduced, how quickly do their concentration in the atmosphere decrease?

Ref - IPCC website and the AR4 reports

Some answers

4. Can individual extreme events be explained by Greenhouse warming?

Very difficult if not impossible because of 1) extremes are usually by a combination of factors & 2) a wide range of extreme events is a normal occurrence even in an unchanging climate.

5. How likely are major or abrupt climate changes, such as loss of ice sheets or changes in global ocean circulations?

Abrupt changes, such as rapid loss of the Greenland Ice Sheet or large scale changes of ocean circulation systems, are not considered likely in the 21st century based on currently available model results. However such changes becomes increasing more likely as the perturbation of the climate system progress.

6. If emissions of GHGs are reduced, how quickly do their concentration in the atmosphere decrease?

Adjustment of GHG concentrations depends on chemical & physical processes that remove them from the atmosphere. Some GHG decrease immediately in response to emission reduction while others can actually continue for centuries even with reduced emissions.

Acknowledgement & references

My various colleagues at HKO, especially Dr TC Lee

http://www.weather.gov.hk/climate_change/climate_change_e.htm

Intergovernmental Panel on Climate Change (IPCC)

http://www.ipcc.ch/

United Nations Framework Convention on Climate Change (UNFCCC)

http://unfccc.int/

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“This report (IPCCC AR4) makes it clear, more convincingly than ever before, that human actions are writ large on the changes we are seeing, and will see, to our climate.

The IPCC strongly emphasises that **substantial climate change is inevitable**, and **we will have to adapt to this**.

This should compel all of us - world leaders, businesses and individuals - **towards action rather than the paralysis of fear.**

We **need both to reduce our emissions of greenhouse gases** and to **prepare for the impacts of climate change.**

Those who would claim otherwise can no longer use science as a basis for their argument.

Prof Martin Rees

President of the Royal Society,

Professor of Cosmology & Astrophysics, Cambridge University

THANK YOU!

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Abbreviations

IPCC : Intergovernmental Panel on Climate Change

NOAA : National Oceanic Atmospheric Administration

NASA : National Aeronautics and Space Administration

UCAR : University Corporation for Atmospheric Research

USGS : US Geological Survey

WHO : World Health Organization

NSIDC : National Snow and Ice Data Center