Hong Kong's climatic record 1884-2016: A new interpretation

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Acknowledgements –
The Hong Kong Observatory for providing meteorological records.

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Plan

(1) Introduction

(2) Temperature record of Hong Kong

(3) Rainfall record of Hong Kong

(4) Sea-level record of Hong Kong

(5) Important recent events

(6) Main conclusions

Climate Change Definitions

UN Framework Convention on Climate Change

A change in climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods

Intergovernmental Panel on Climate Change (IPCC)

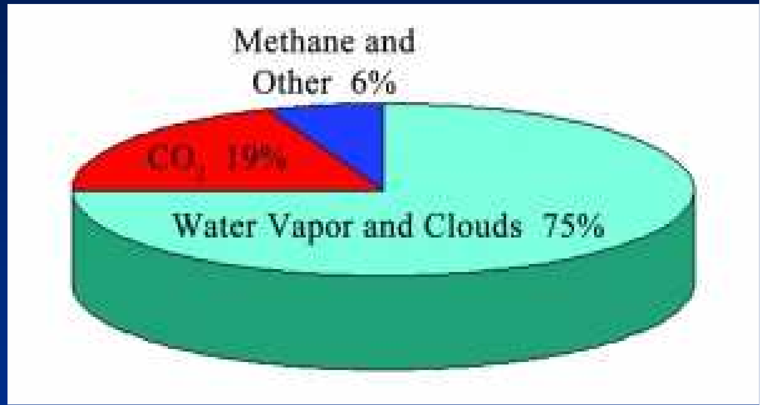
A change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of the properties, and that persists for an extended period, typically decades or longer

Components of Earth's system

- Atmosphere (air)
- Hydrosphere (groundwater, lakes, rivers & oceans)
- Cryosphere (ice)
- Biosphere (living things)
- Pedosphere (soil)
- Lithosphere (Earth crust including volcanoes)

Climate change is a product of astronomical forcing including solar variability and the interactions of the components

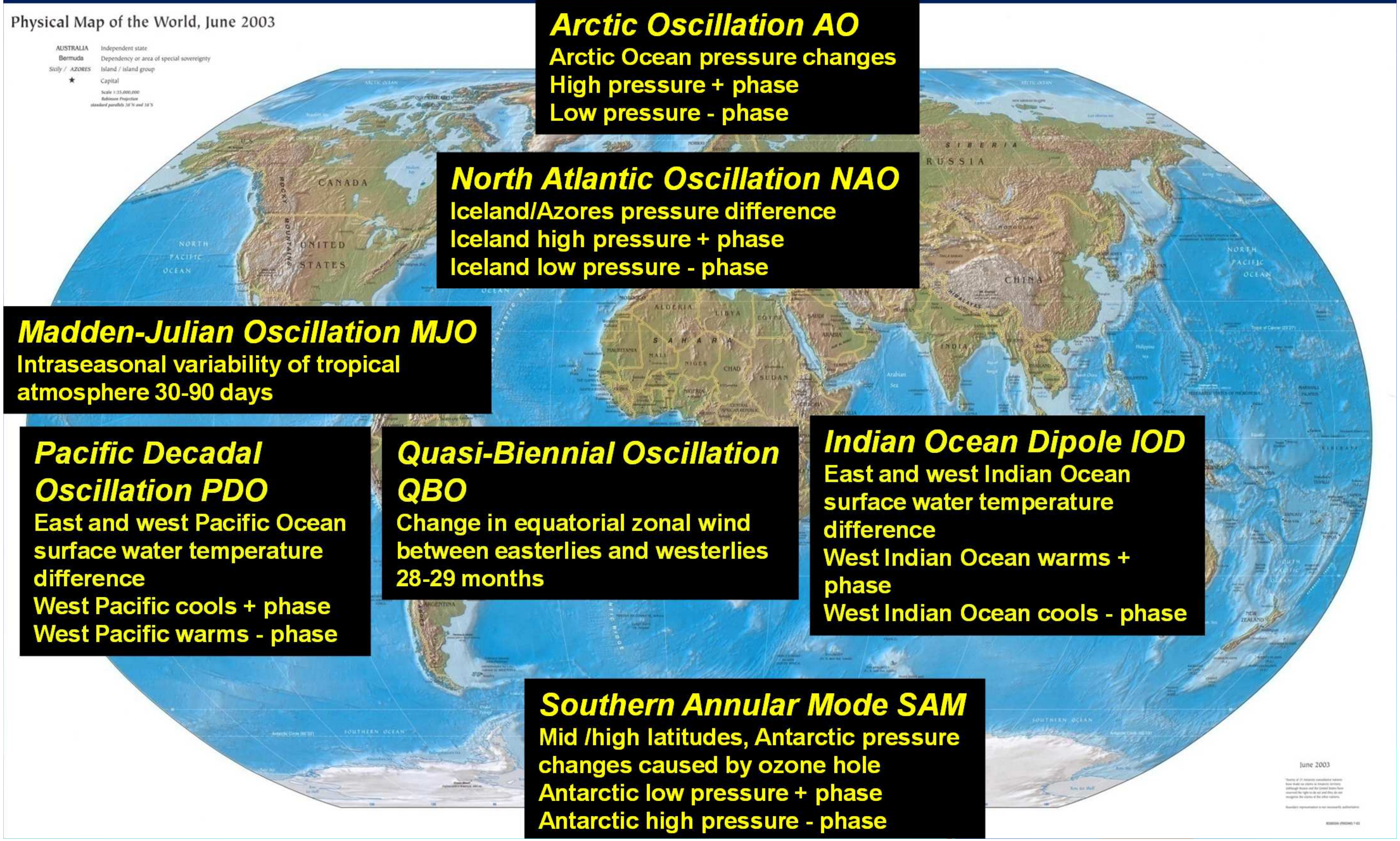
What controls climate on Earth?



Air circulation/pressure changes
Greenhouse gases mainly –
- **Carbon dioxide CO_2**
- **Methane CH_4**
- **Water vapour H_2O (most important)**

Water/cloud/ice distribution
Vegetation distribution
Astronomical factors e.g. sun & orbit changes
Volcanic eruptions (both land & sea)
Clouds and water vapour most important (Royal Society 2010)

Known regional climatic variability additional to monsoons



Arctic Oscillation AO
Arctic Ocean pressure changes
High pressure + phase
Low pressure - phase

North Atlantic Oscillation NAO
Iceland/Azores pressure difference
Iceland high pressure + phase
Iceland low pressure - phase

Madden-Julian Oscillation MJO
Intraseasonal variability of tropical atmosphere 30-90 days

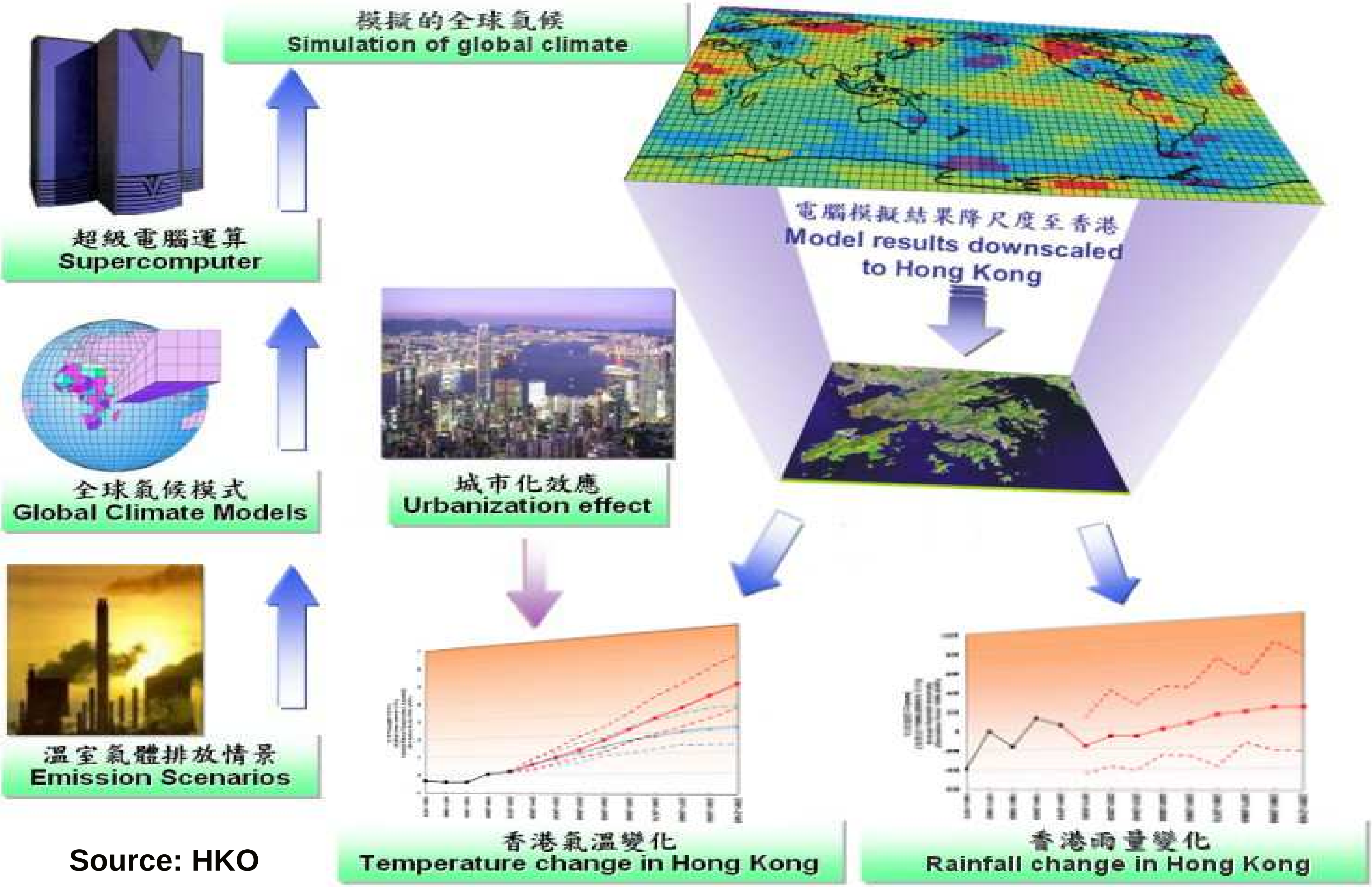
Pacific Decadal Oscillation PDO
East and west Pacific Ocean surface water temperature difference
West Pacific cools + phase
West Pacific warms - phase

Quasi-Biennial Oscillation QBO
Change in equatorial zonal wind between easterlies and westerlies 28-29 months

Indian Ocean Dipole IOD
East and west Indian Ocean surface water temperature difference
West Indian Ocean warms + phase
West Indian Ocean cools - phase

Southern Annular Mode SAM
Mid /high latitudes, Antarctic pressure changes caused by ozone hole
Antarctic low pressure + phase
Antarctic high pressure - phase

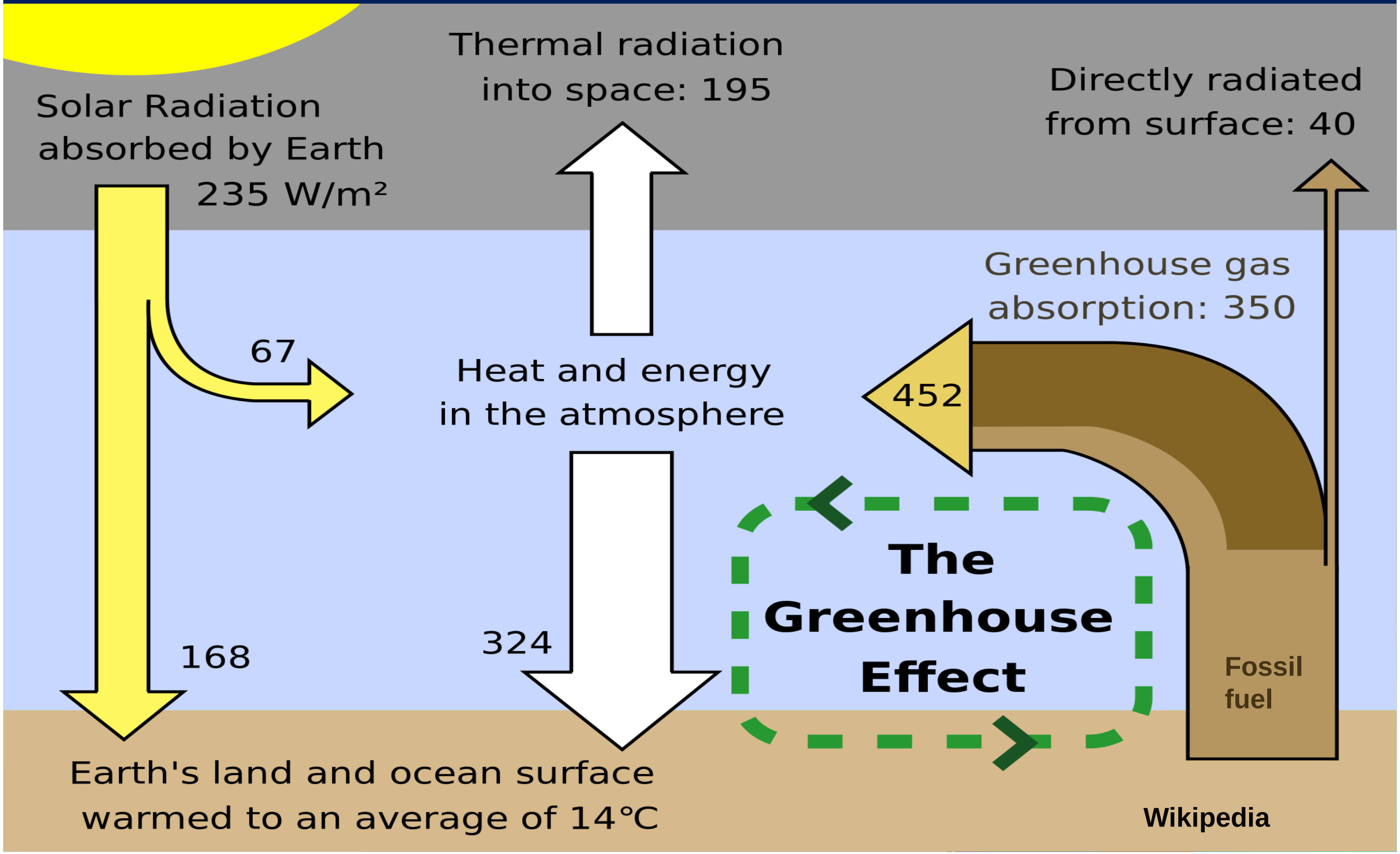
Assumption used in all climatic models –
Man-made CO_2 is causing an increase in global temperatures



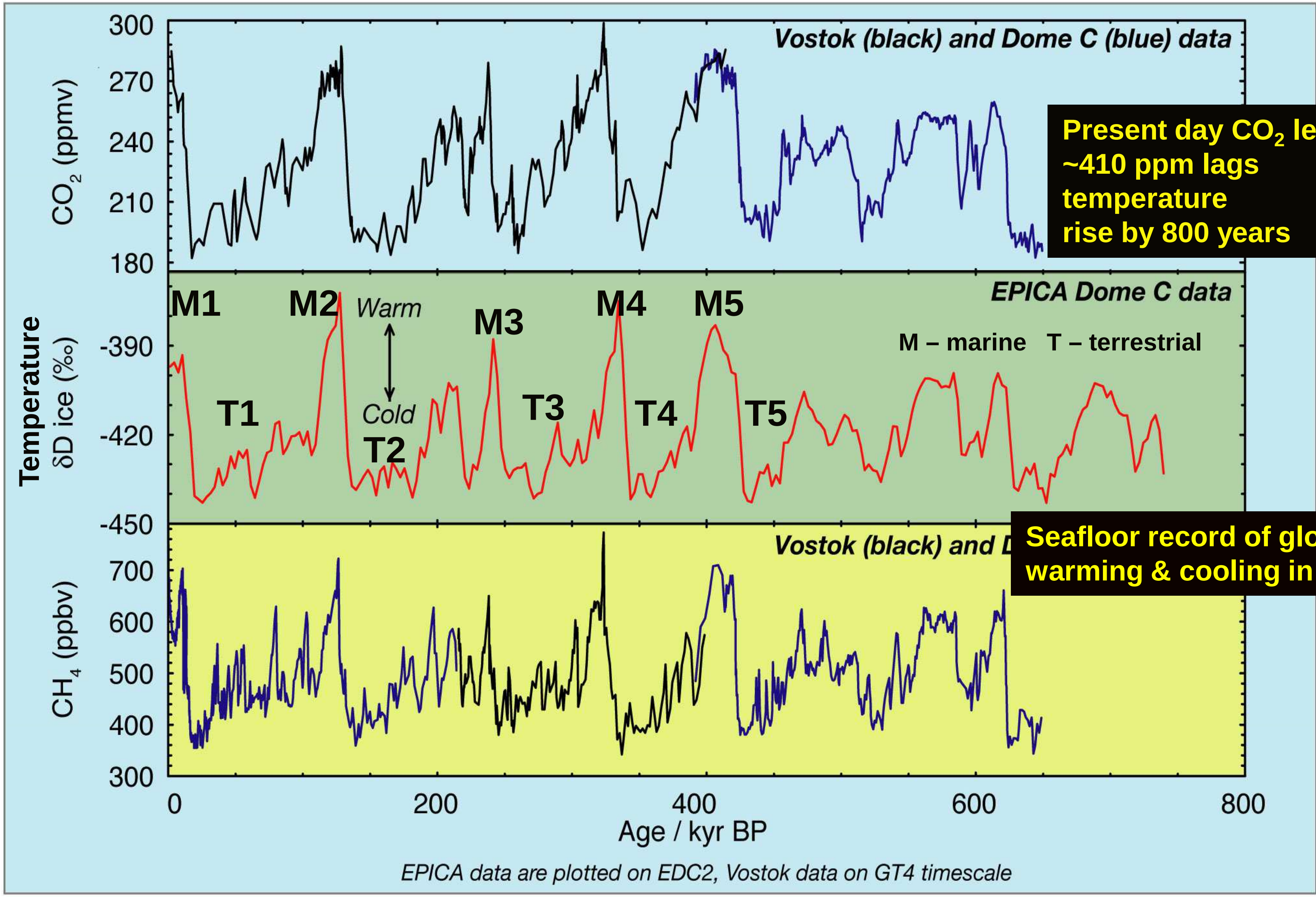
Source: HKO

Greenhouse effect

Without it Earth's surface would average ~33ºC colder



Antarctic ice core records: Vostok and EPICA CO_2, CH_4 and δD



Present day CO_2 level ~410 ppm lags temperature rise by 800 years

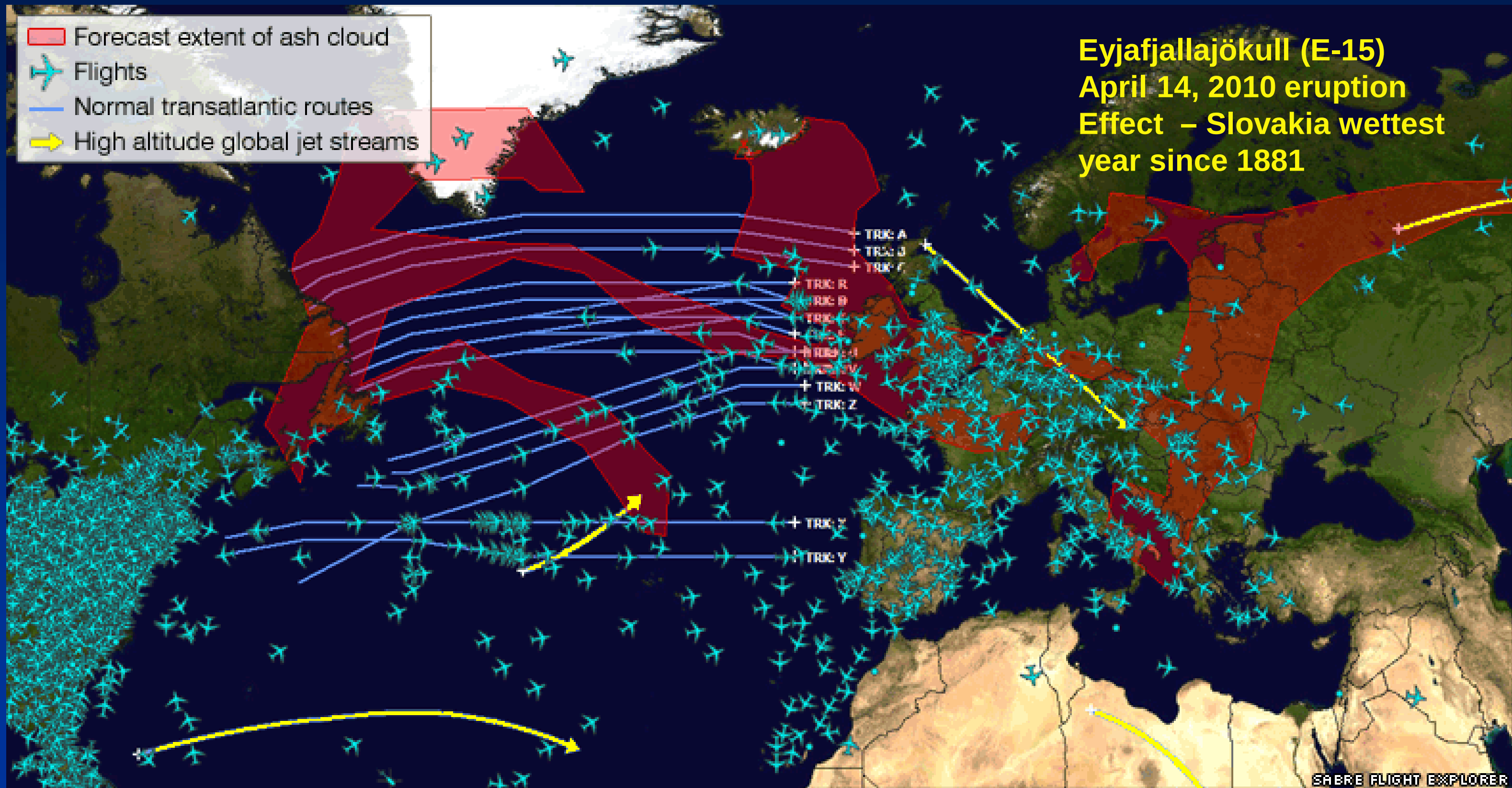
Seafloor record of global warming & cooling in HK

Petit et al., 1999 (Vostok), Siegenthaler et al., 2005 (Dome C - CO_2), Spahni et al., 2005 (Dome C - CH_4), EPICA community members, 2004 (δD)

GLOBAL IGBP CHANGE

PAGES PAST GLOBAL CHANGES

Why study present day volcanic eruptions?



Most reliable record –
Information age
Applications –
Farming/climatic variability

(Meteorological observations
(Satellite observations since ~1980
(Weather disaster media reports
(Aviation safety

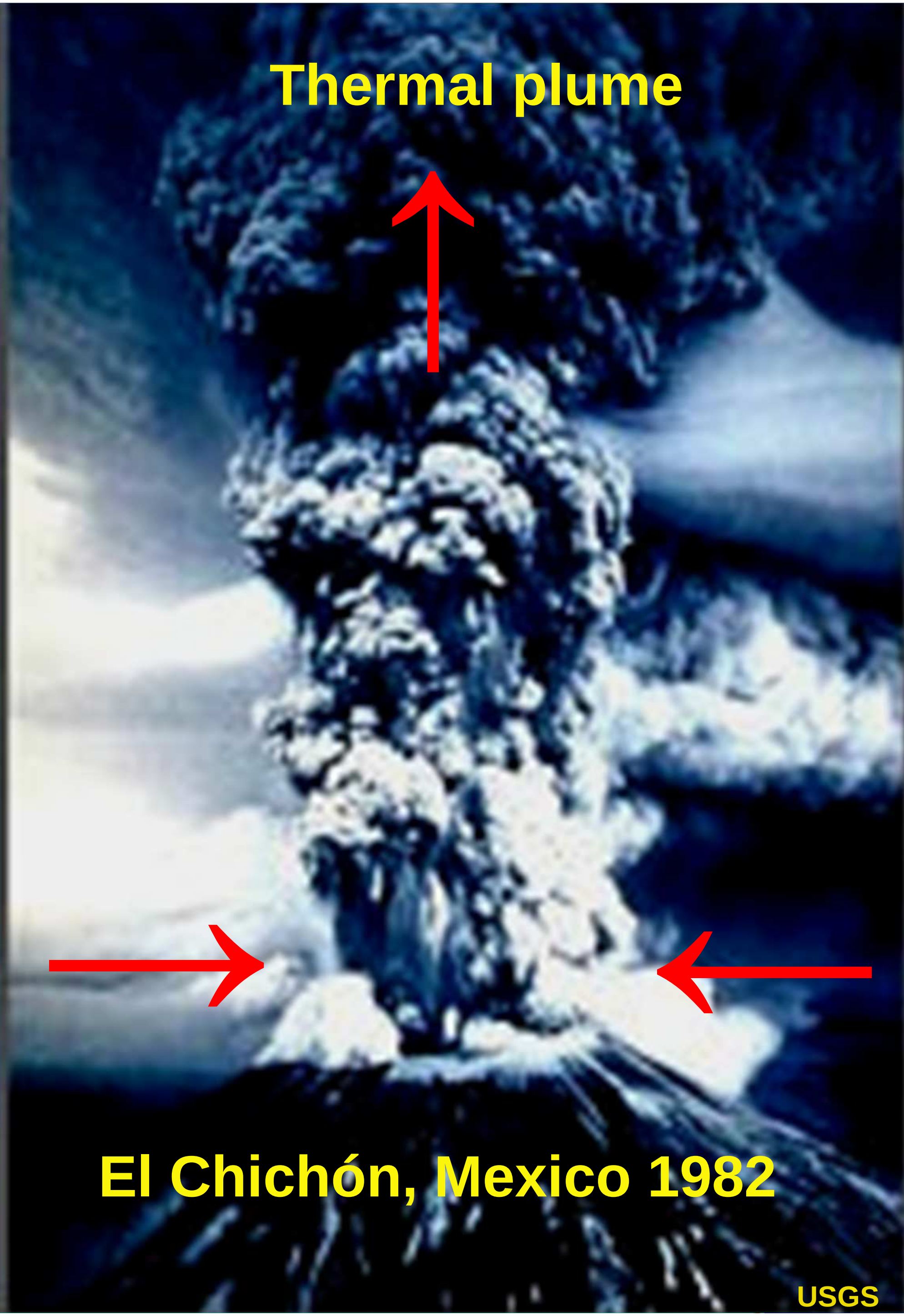
Sub-aerial volcano model

Ash & aerosols reduce solar radiation leading to cooling

Warm air stores more moisture – water vapour redistribution

Air pressure changes (low)

Cooling



Eruption changes normal air circulation / creats clouds / destroys O_3

SO_2, HCl & H_2O

Cool air stores less moisture

Cooler air

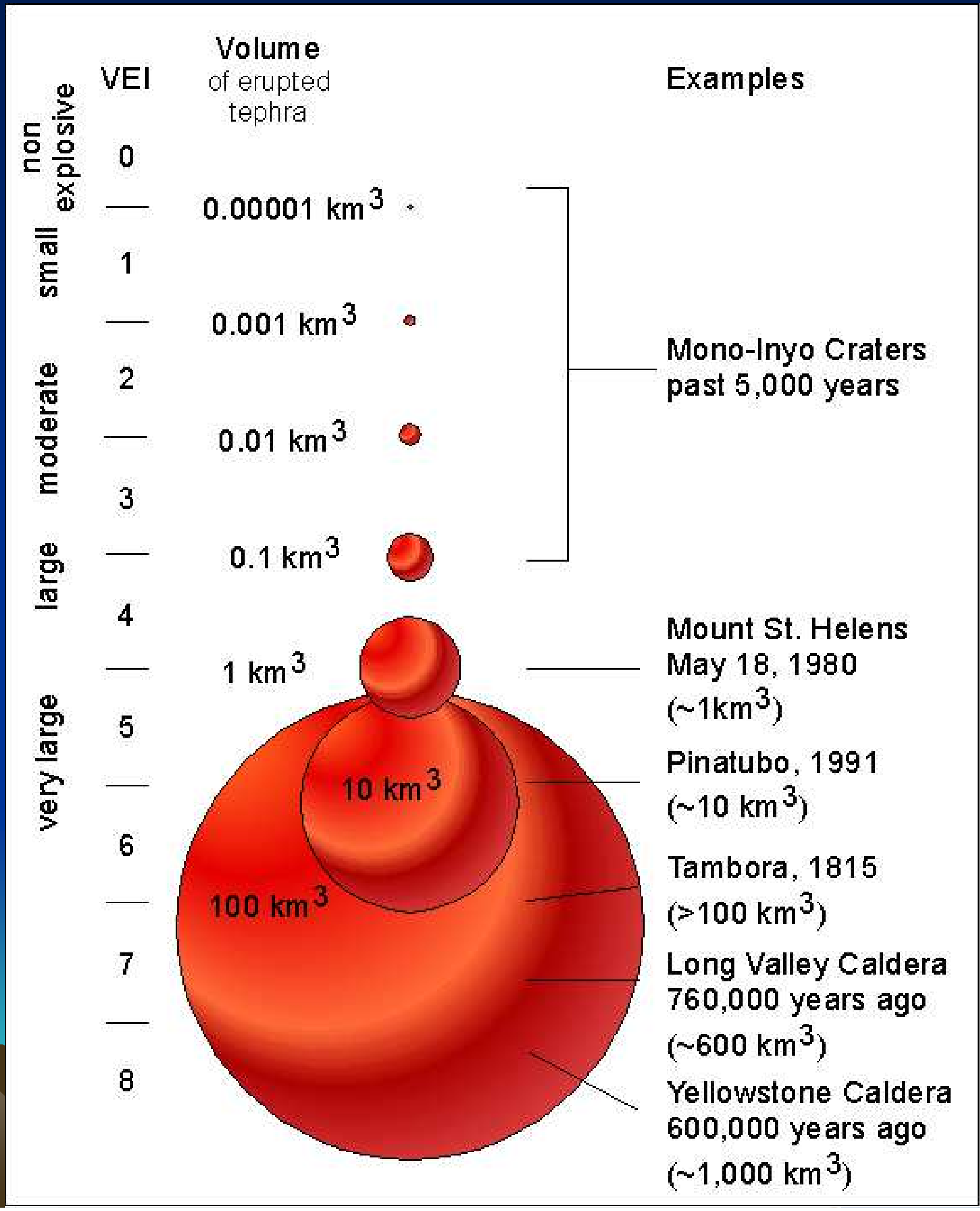
Impact longer lasting if higher VEI

Volcanic Explosivity Index (VEI)

Used for the estimation of explosiveness of volcanic eruptions on land (subaerial)

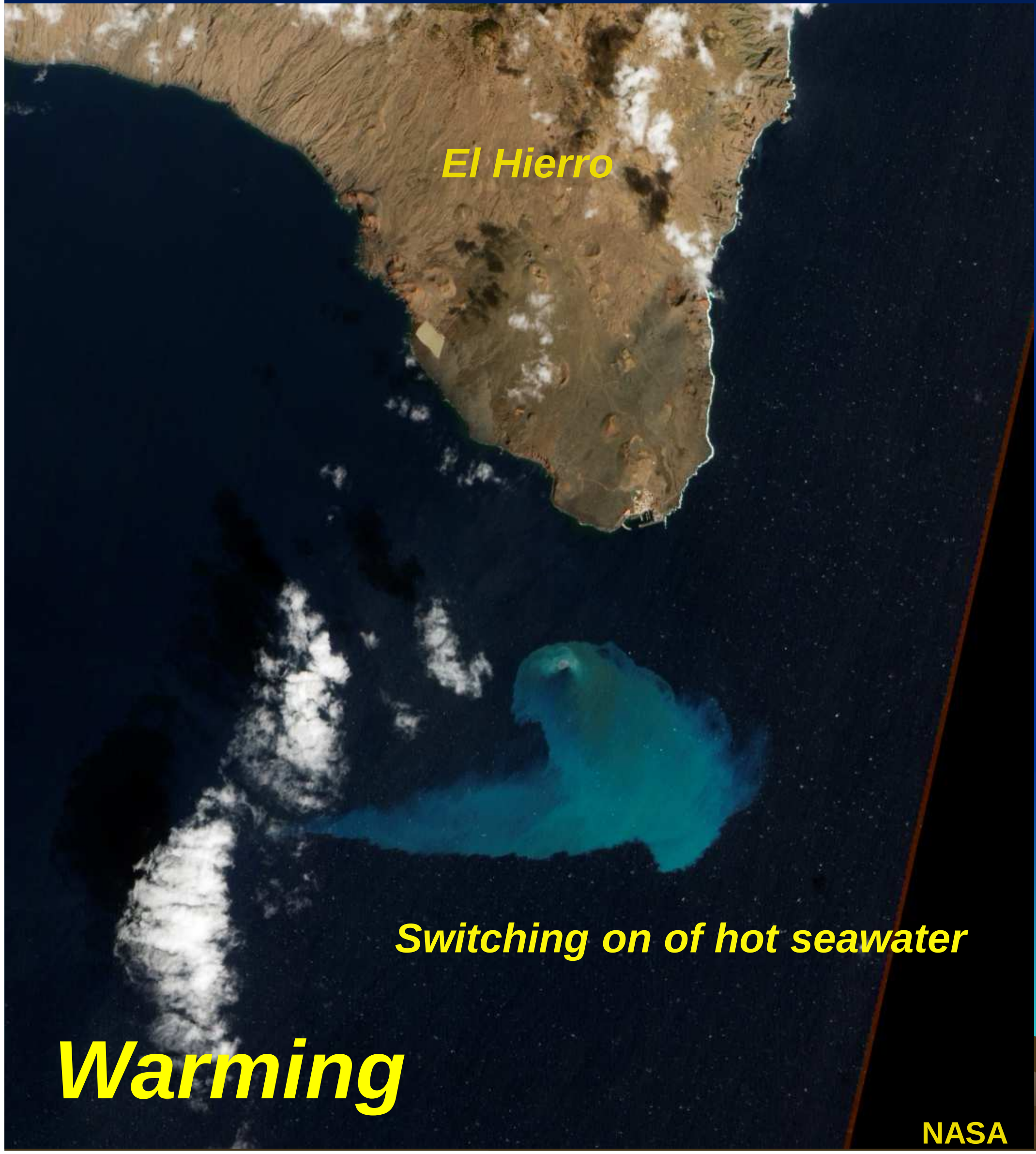
(Newhall and Self 1982)

Acidic magma most explosive



Above VEI 2 regional impacts on weather/climate may already be detectable

Submarine volcano model



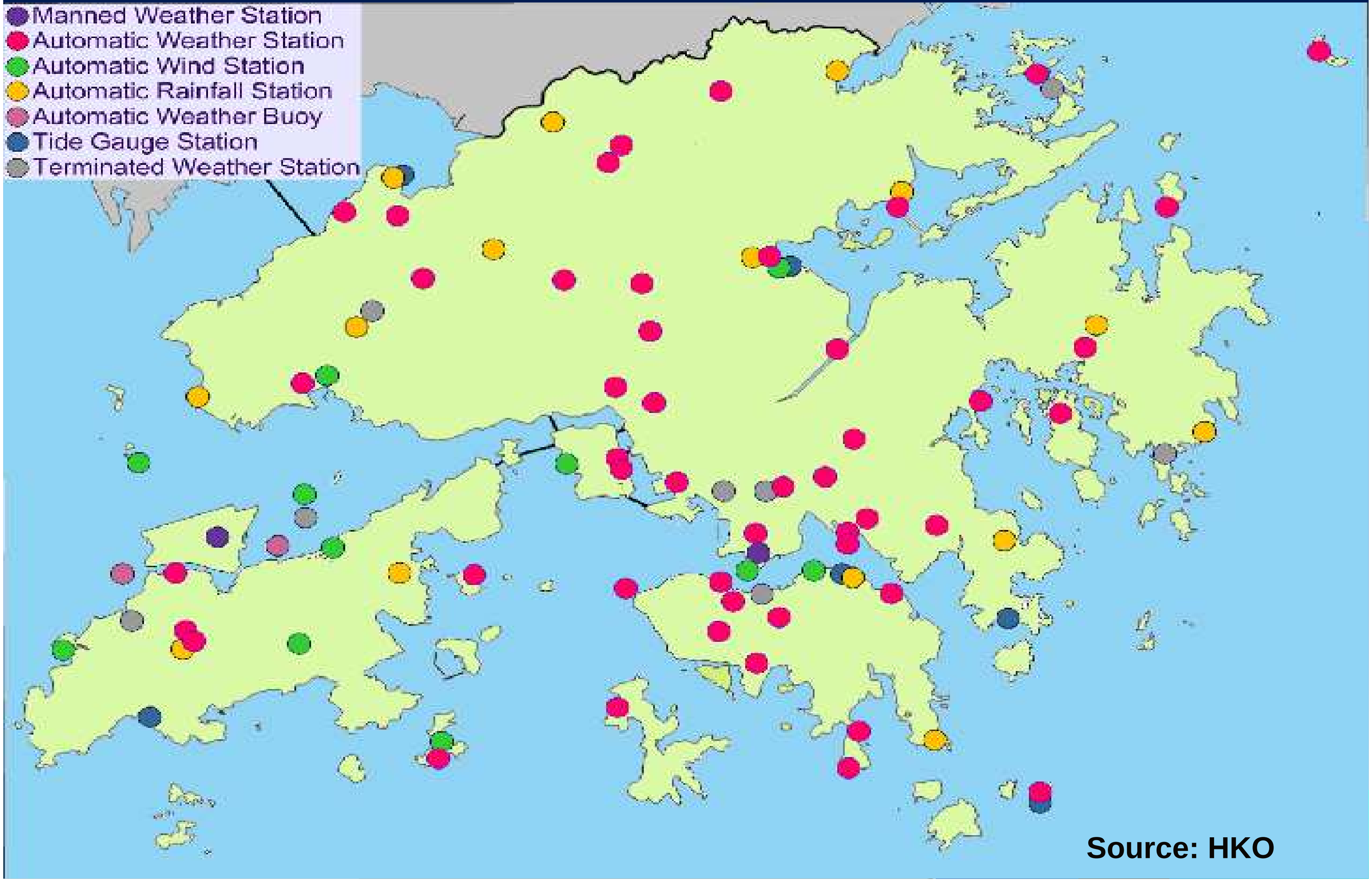
Examples studied –

El Hierro volcano,
Canary islands during
October 2011 to March 2012

Hunga volcano,
Tonga during
December 2014 to January 2015

Possible impacts –
Warming of seawater
Ocean circulation changes
Polar sea ice changes
Pressure changes
Surface wind changes
Sea-level changes

Past and present weather stations in Hong Kong



Source: HKO

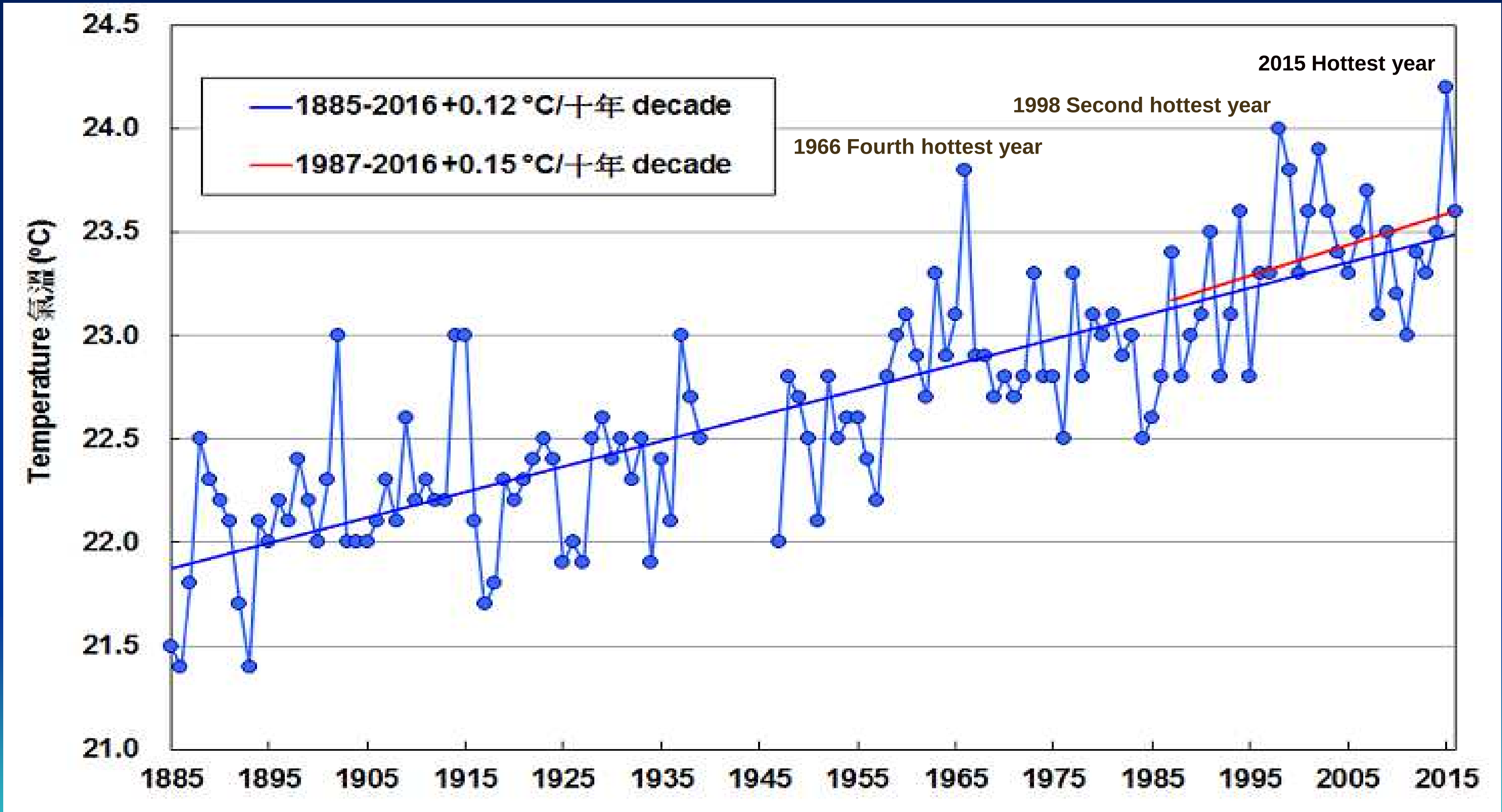
Hong Kong temperature statistics 1884-2016

Number of manned stations	2
Number of automatic weather stations	48
Station with the longest record	HKO Headquarters
Length of record	1884-1940/1947-2016
Mean annual temperature	~22.6ºC
Coldest year on record	21.3ºC (1884)
Hottest year on record	24.2ºC (2015)

Location map of Hong Kong Station, Pak Tam Chung Station and Waglan Island Station

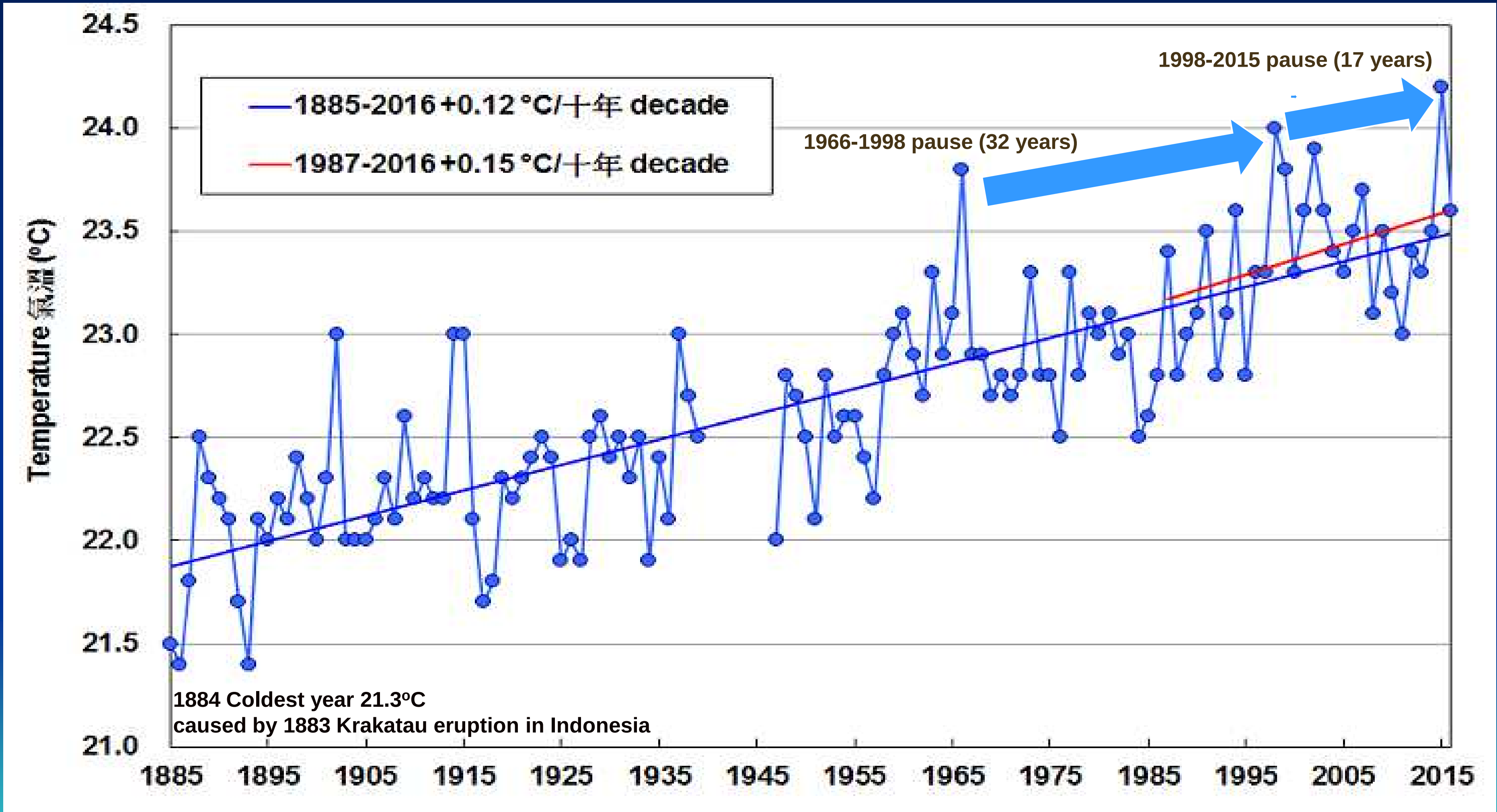
** Best urban station and best rural station (Siu and Hart 2013)*

Annual mean temperature record of the Hong Kong Station 1884-2016



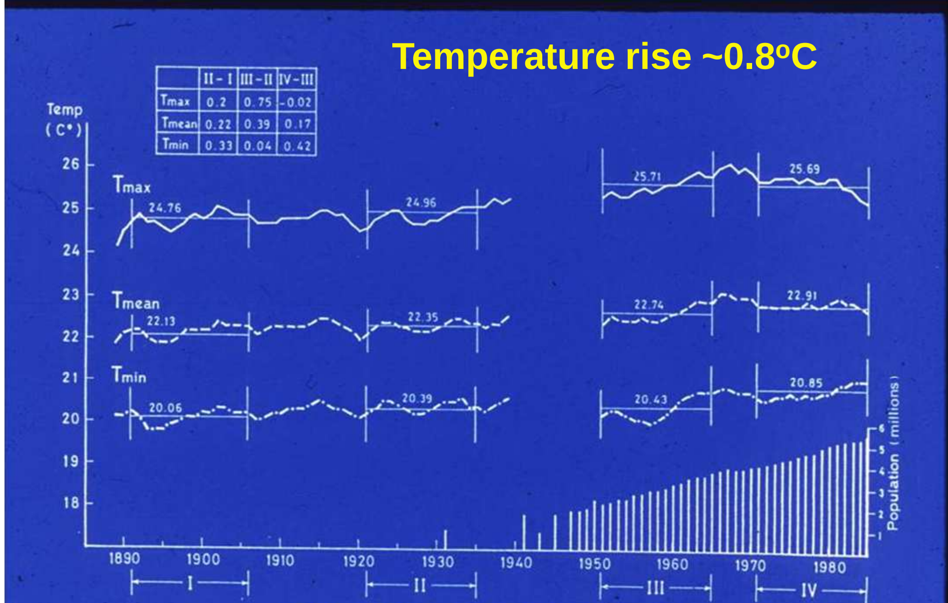
Source: HKO

Two recent pauses of annual mean temperature rise inconsistent with CO_2 increase



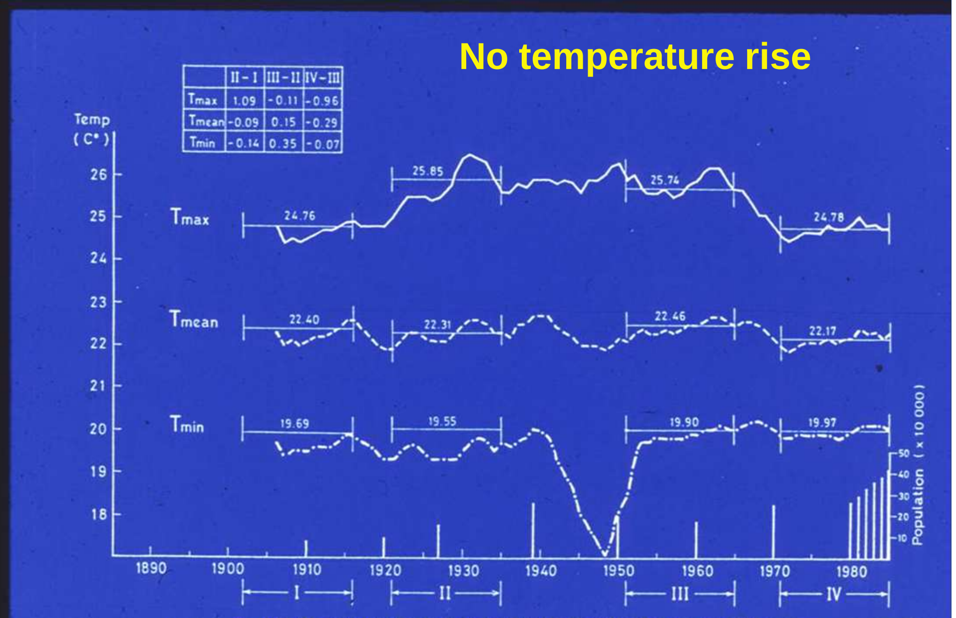
Source: HKO

Comparsion between annual temperature records of Hong Kong Station and Macau Station 1884-1985 (after Koo 1988)



Hong Kong

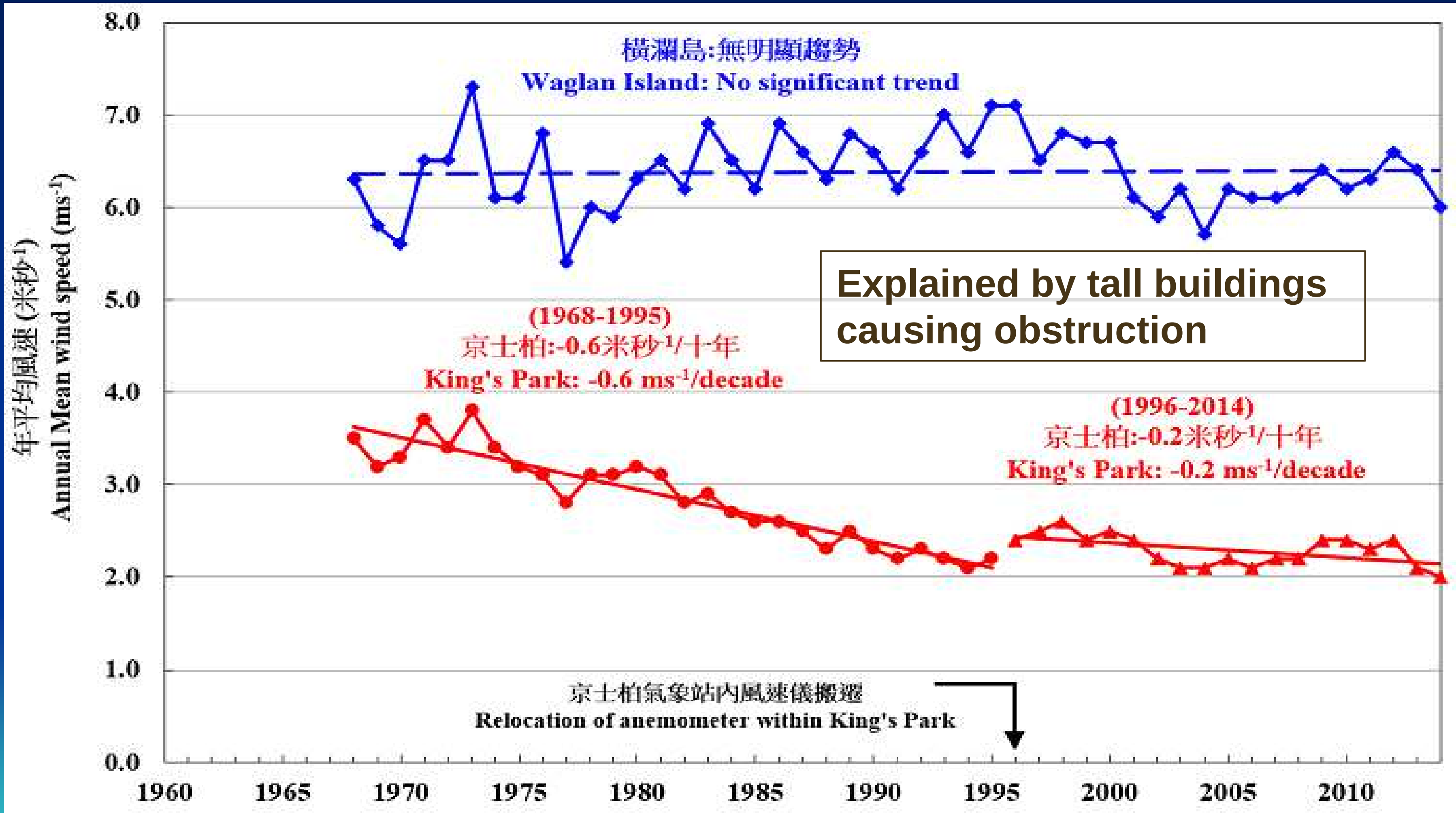
5-year running mean temperatures at Hong Kong Station (affected by urban heat island because of the Victoria Harbour basin)



Macau

5-year running mean temperatures at Macau station (hill top location no obvious rise in temperature}

Wind speed changes at Waglan Island and King's Park 1968-2014



Source: HKO

10 years showing the greatest temperature difference between the Hong Kong Station and the Waglan Island Station 1968-2016

Year	Difference (^oC)	Explanation
1997	1.5	Handover year infrastructure development
1995	1.5	Pre-handover “ “
1994	1.5	“ “ “
1990	1.4	Early handover infrastructure development
1998	1.3	Post-handover year infrastructure development
1996	1.3	Pre-handover infrastructure development
2005	1.1	
1999	1.0	Post-handover infrastructure development
2000	0.9	“ “ “
1991	0.9	Early handover infrastructure development

Source: HKO

Comparison of number of cold days <= 12^{o}C between HK station and Pak Tam Chung station 1995-2016

Year	HKO	PTC	% difference	Year	HKO	PTC	% difference
1995	15	81	540	2006	9	48	533
1996	17	70	412	2007	32	75	234
1997	7	51	728	2008	14	62	443
1998	11	45	409	2009	23	52	226
1999	4	72	1800	2010	26	73	281
2000	5	59	1180	2011	23	65	283
2001	9	53	589	2012	8	45	562
2002	11	49	445	2013	25	53	212
2003	19	66	347	2014	11	68	618
2004	24	59	246	2015	7	47	671
2005	20	48	240	2016	21	40	190

Source: HKO

Annual mean temperature comparison between HK International Airport Station and HK Station 1997-2016

Year	HKIA	HKO	Difference	Year	HKIA	HKO	Difference
1997	23.7	23.3	0.4	2007	24.5	23.5	0.8
1998	24.4	24.0	0.4	2008	23.7	23.1	0.6
1999	24.1	23.8	0.3	2009	24.3	23.5	0.8
2000	23.9	23.3	0.6	2010	24.1	23.2	0.9
2001	24.1	23.6	0.5	2011	23.6	23.0	0.6
2002	24.4	23.9	0.5	2012	24.1	23.4	0.7
2003	24.2	23.6	0.6	2013	24.0	23.3	0.7
2004	24.0	23.4	0.6	2014	24.4	23.5	0.9
2005	23.8	23.3	0.5	2015	25.0	24.2	0.8
2006	24.3	23.5	0.8	2016	24.5	23.6	0.9

Source: HKO

Conclusions on temperature record

- Unlike Macau Station, Hong Kong Station is severely affected by man-made heat generation

- Low annual mean temperatures in the early record of Hong Kong Station was caused by the 1883 Krakatau volcanic eruption

- Pak Tam Chung Station shows much higher number of cold days during winter than Hong Kong Station

- Heat generation through infrastructure development was responsible for differences in annual mean temperatures between Hong Kong Station and Waglan Island Station

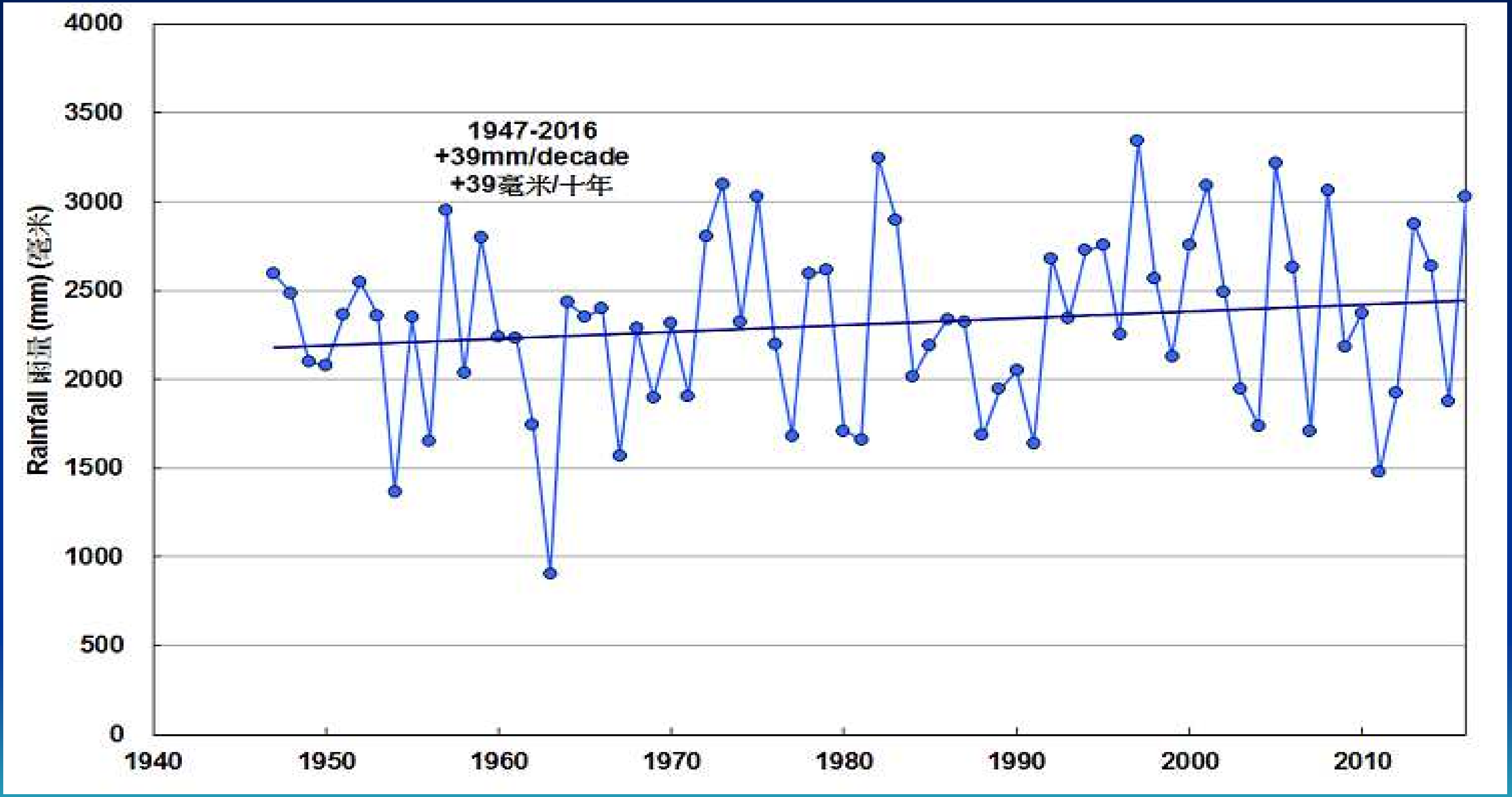
- Both Kai Tak Airport and Chek Lap Kok Airport are important contributors of heat affecting temperature measurements

- Climatic models based on CO_2 warming failed to predict the 1998-2015 pause and 1966-1998 pause in temperature rise

Hong Kong rainfall statistics 1884-2016

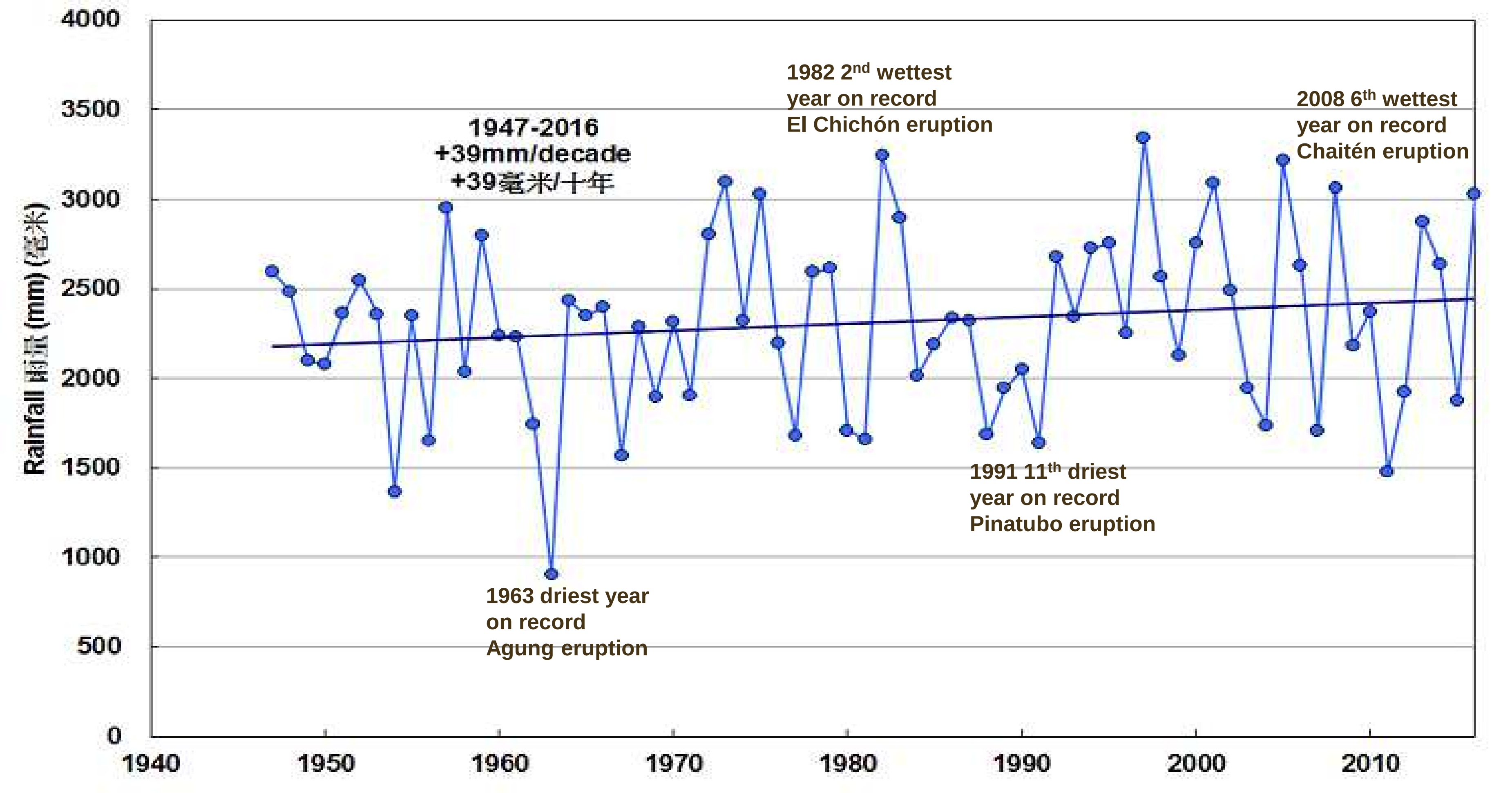
Number of manned stations	2
Number of automatic weather stations	48
Number of automatic rainfall stations	15
Mean annual rainfall	~2225 mm
Driest year on record	901.1 mm (1963)
Wettest year on record	3343 mm (1997)

Hong Kong's rainfall record 1947-2016

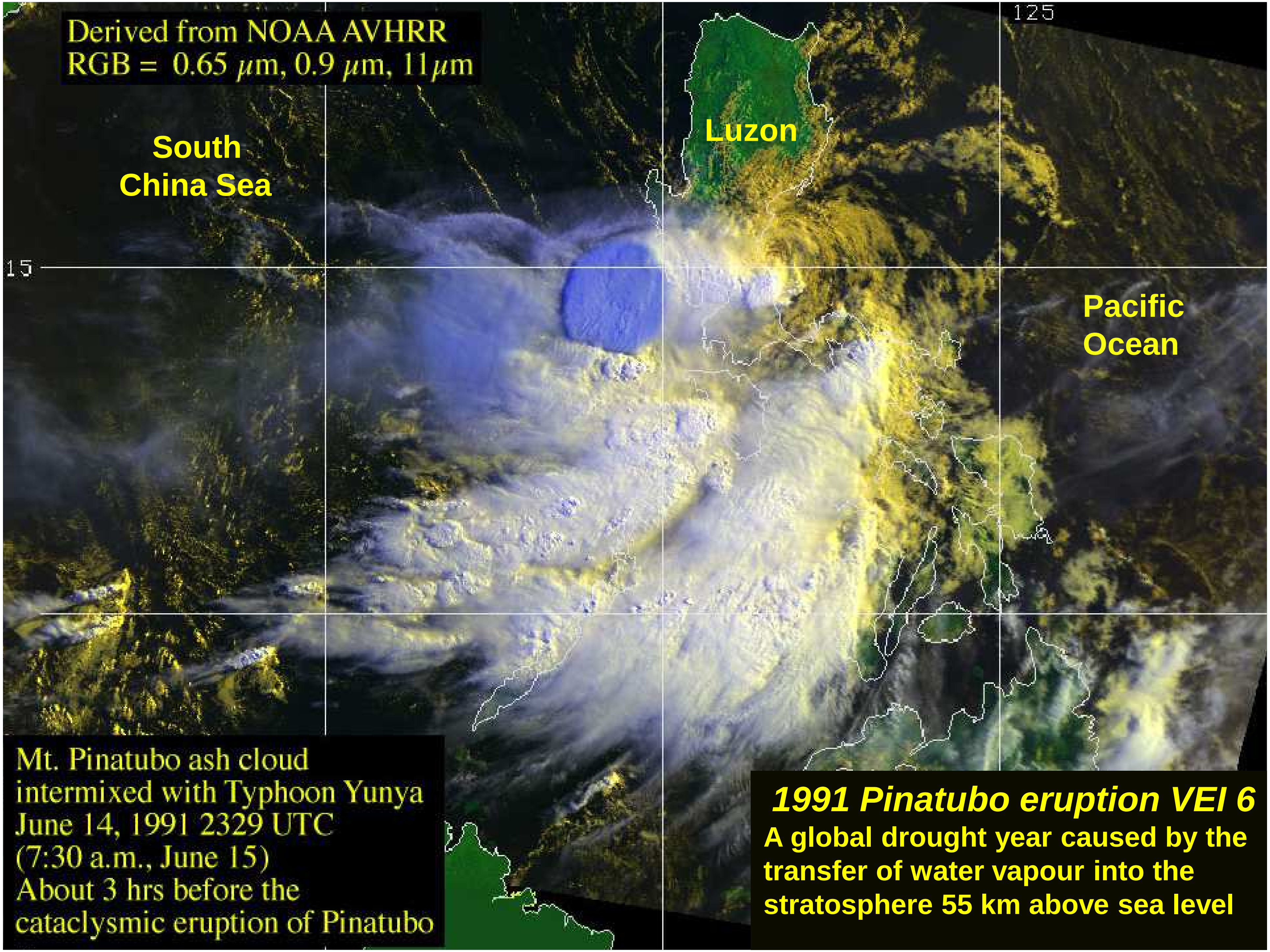


Source: HKO

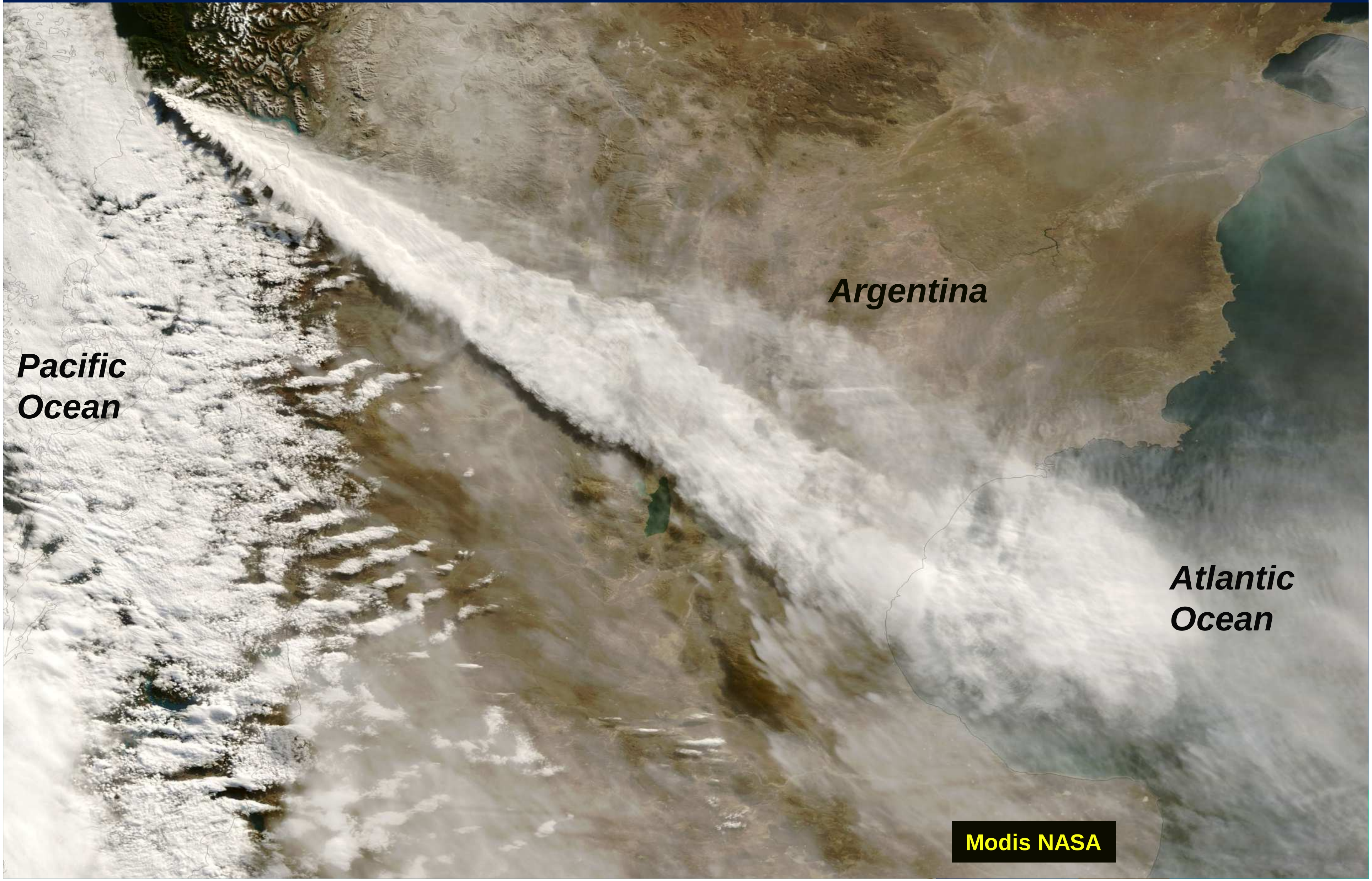
Abnormally dry and wet years explained by volcanic eruptions



Source: HKO


Derived from NOAA AVHRR
RGB = 0.65 μm, 0.9 μm, 11μm
125
15
Luzon
South China Sea
Pacific Ocean
Mt. Pinatubo ash cloud intermixed with Typhoon Yunya
June 14, 1991 2329 UTC
(7:30 a.m., June 15)
About 3 hrs before the cataclysmic eruption of Pinatubo
1991 Pinatubo eruption VEI 6
A global drought year caused by the transfer of water vapour into the stratosphere 55 km above sea level

May 2, 2008 Chaiten eruption, Chile VEI = 4

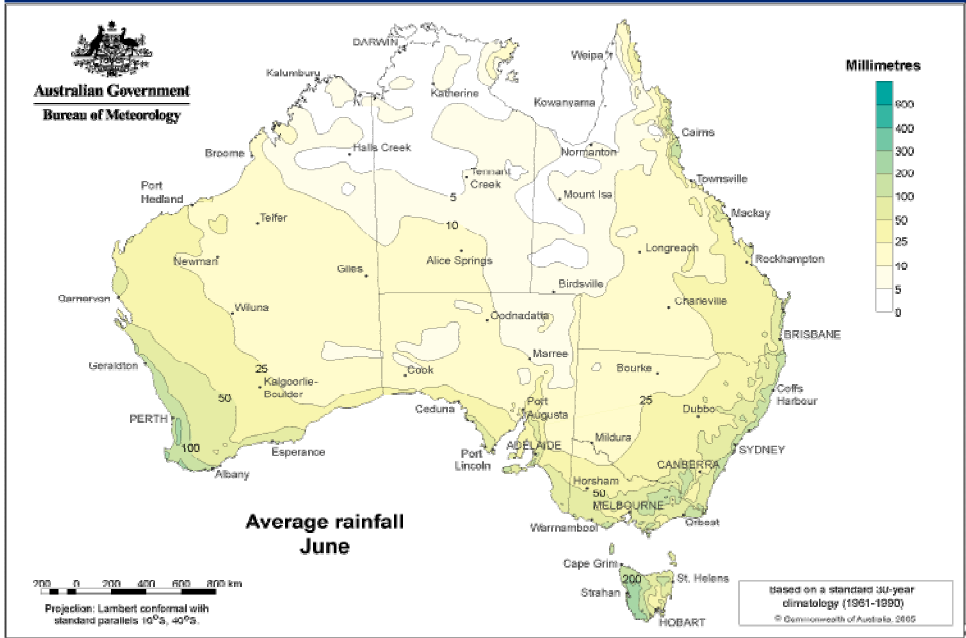


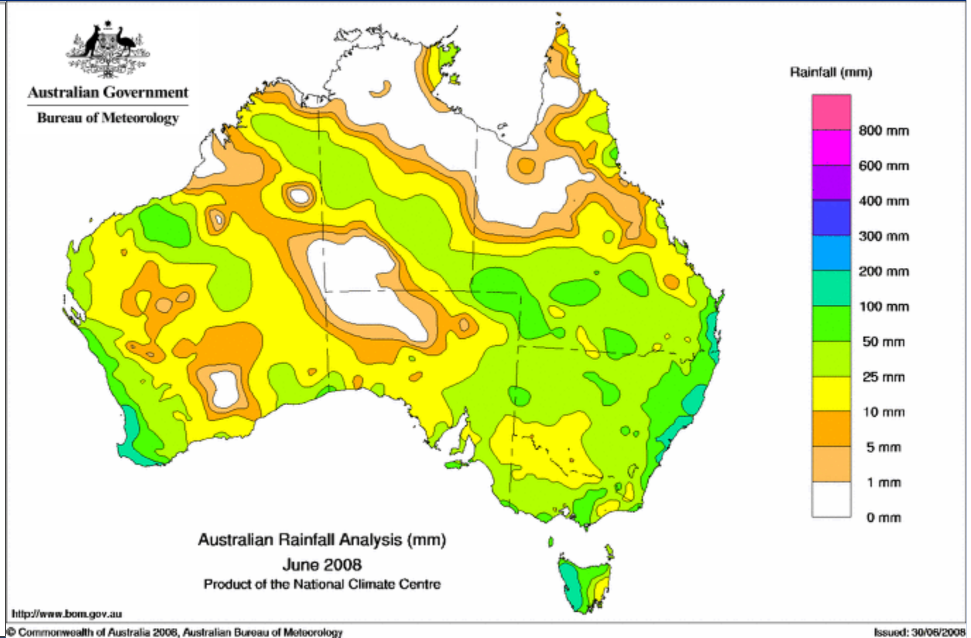
Selected impacts on regional rainfall following eruption

- A wet May/June in South Africa
- A wet June in Australia including the continental interiors causing the flood of tourists to watch desert flowers blooming
- Record rainfall in western Tasmania
- Wettest June in Hong Kong since record began in 1884 (1346.1 mm or 346.8% above average including an 1-1100 year rainstorm with record hourly rainfall of 145.5 mm causing ~2400 landslides on Lantau Island)

Comparison between average June rainfall with June 2008 rainfall over Australia attributable to the May 2, 2008 Chaitén eruption in Chile

(Zhang et al., 2016)





Cause of flowers blooming in desert regions

Supporting evidence

- Eruption timing during the southern hemisphere autumn was favourable for aerosol transportation across the ITCZ second time around the globe
- Eruption cloud height reached an altitude of over 21 km penetrating the stratosphere
- CALIOP tracking of aerosols detectable over Southeastern Australia causing international flight cancellations
- Volcanic debris impacted Hong Kong under southwest monsoon condition
- E-folding time of 35 days found for SO_2 conversion into sulphate from the study of the 1991 Pinatubo eruption was near perfect for the June 7, 2008 rainstorm

Conclusions on rainfall record

- Volcanic eruptions may be responsible for both abnormally wet and dry years in Hong Kong

- Major volcanic eruptions in southeast Asia may cause drought years in Hong Kong because of a shift to prevailing offshore wind

- The 1991 eruption cloud of Pinatubo with a maximum altitude of 55 km was responsible for a global drought year explained by the transfer of water vapour into the stratosphere

- The 2008 eruption cloud of Chaitén with an altitude of over 21 km was tracked by satellite to cause heavy rainfall in South Africa, Australia and after 35 days, the worse rainstorm in Hong Kong’s history triggering ~2400 landslides on Lantau Island

- Heavy rainfall in Western Tasmania through the influence of Chaitén debris helped the Hydroelectric Commission of Tasmania to make 2008-2009 windfall profits

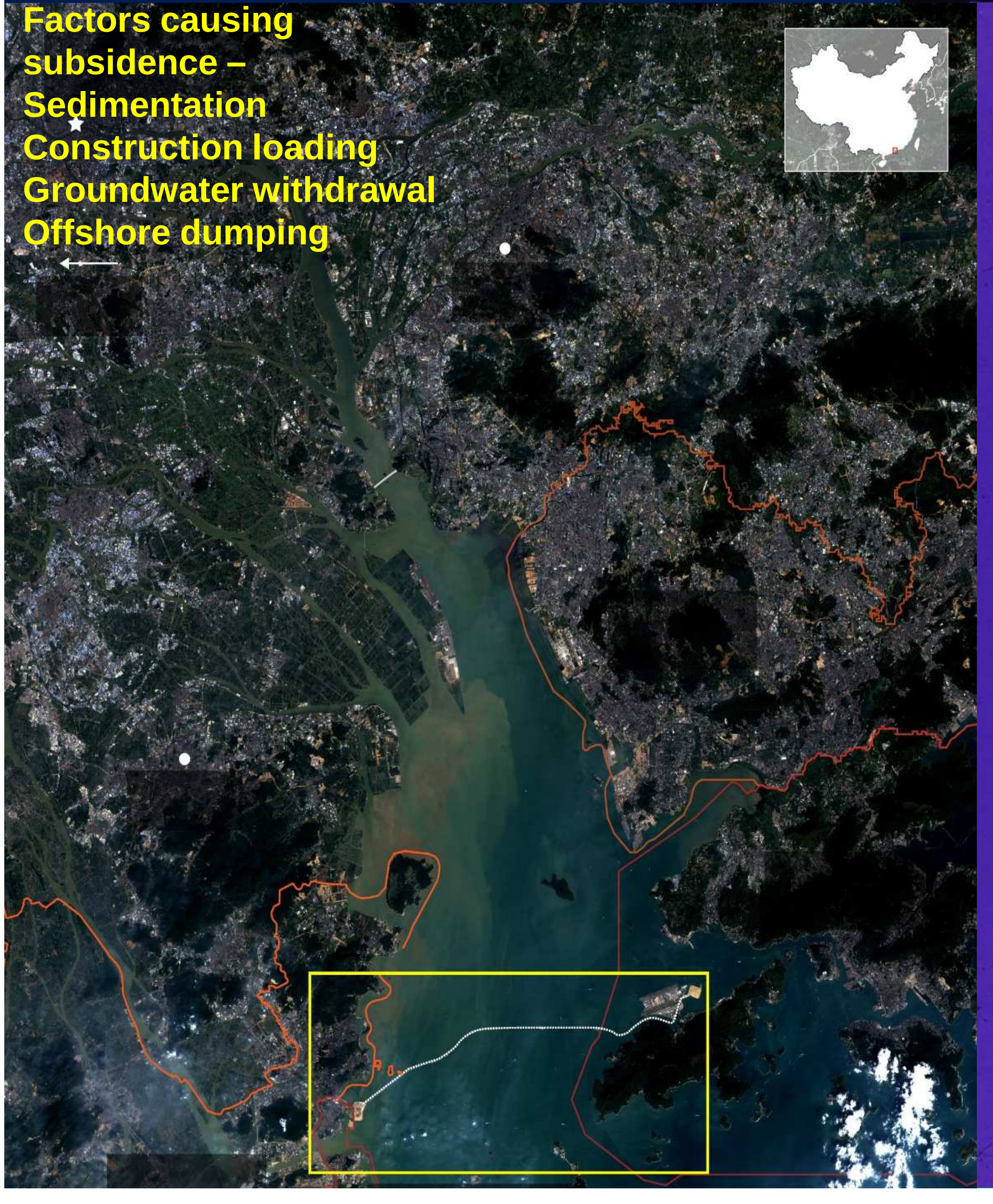
Changes affecting sea levels
After Morner (2013) with modifications

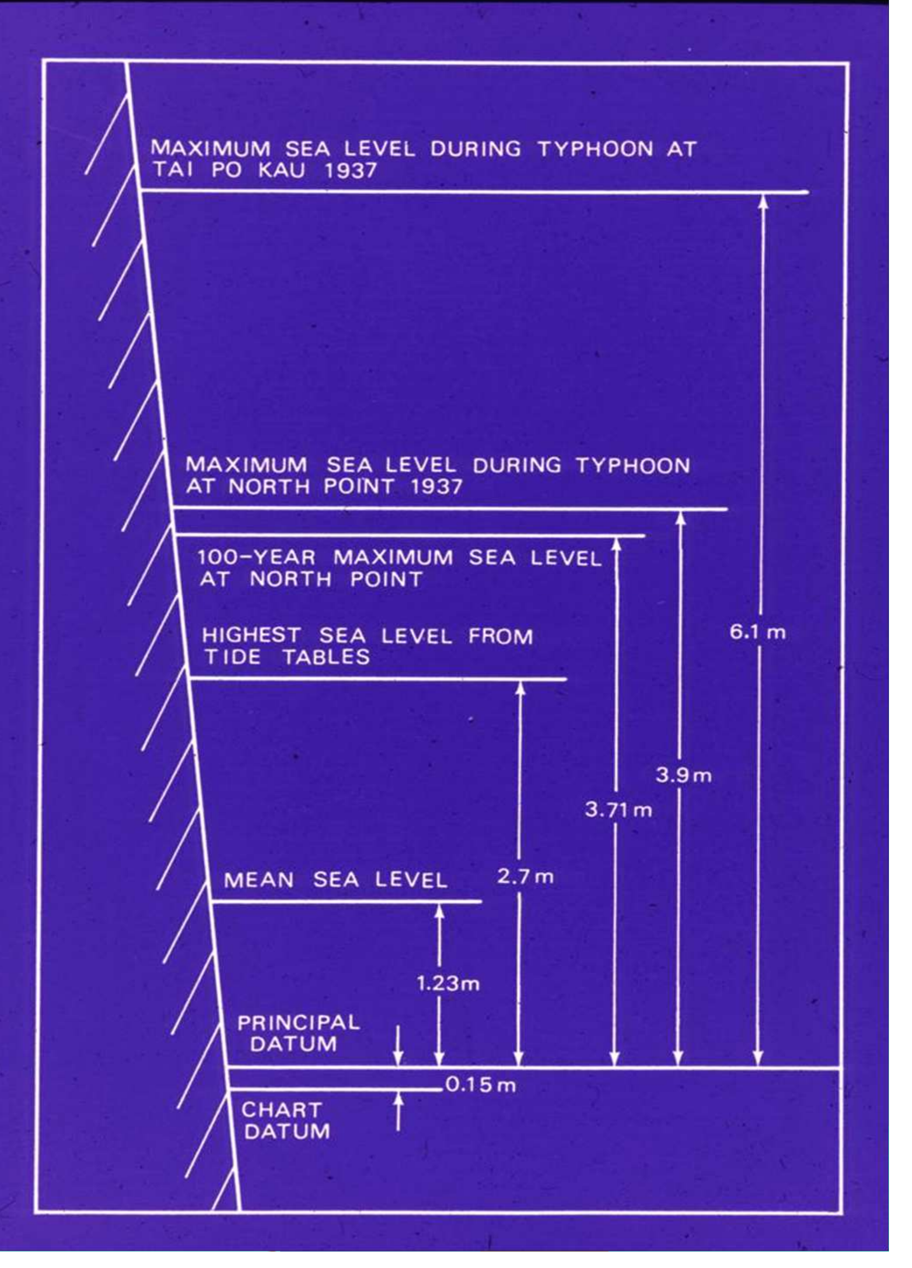
Type of changes	Main types
Coastal dynamics	Erosion / Silting up / Sediment transport / Land runoff / Air pressure changes / Prevailing wind direction / Storms including typhoons / Tsunamis
Land level changes	Compaction / Geoid deformation / Earthquakes / Groundwater extraction / Hydro-isostasy / Sediment isostasy / Glacial isostasy / Loading / Excavation
Sea-level changes	Glacial eustasy / Geoid deformation / Steric effects – temperature and salinity / Basin volume changes – long-term tectonics and glacial rebound

Satellite photo of Hong Kong and the Pearl River Estuary

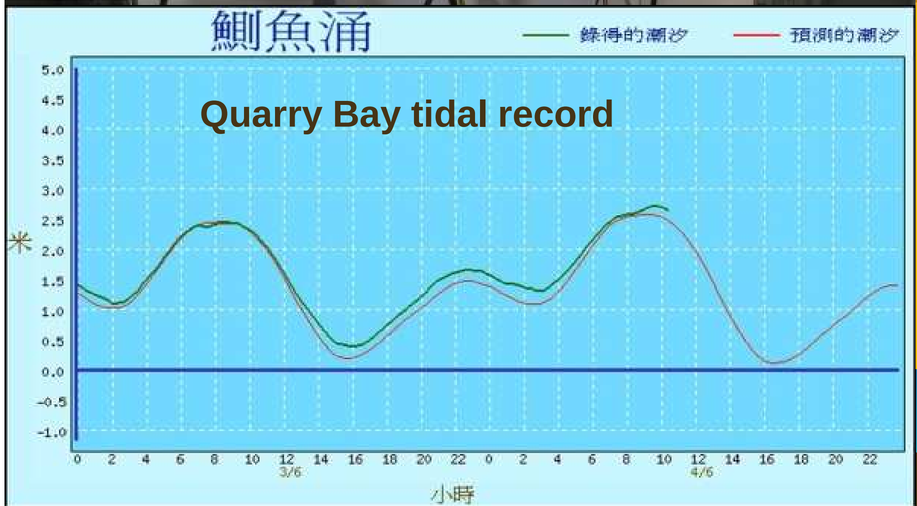
Sea-level datums

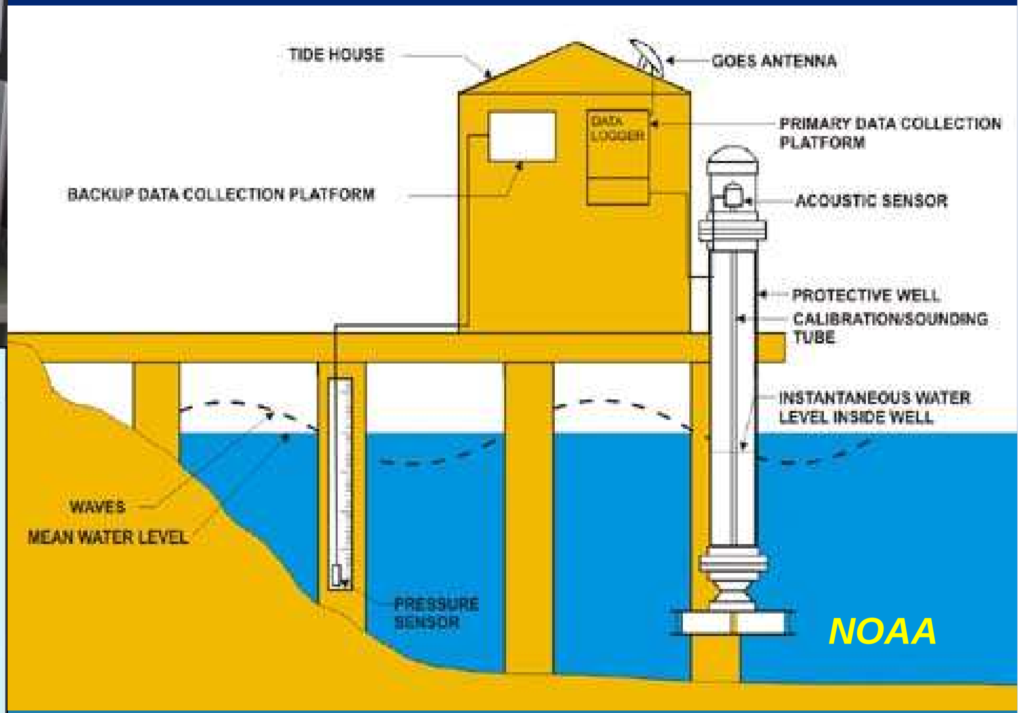
Factors causing subsidence –
Sedimentation
Construction loading
Groundwater withdrawal
Offshore dumping





Mechanical float tide gauge record since 1954

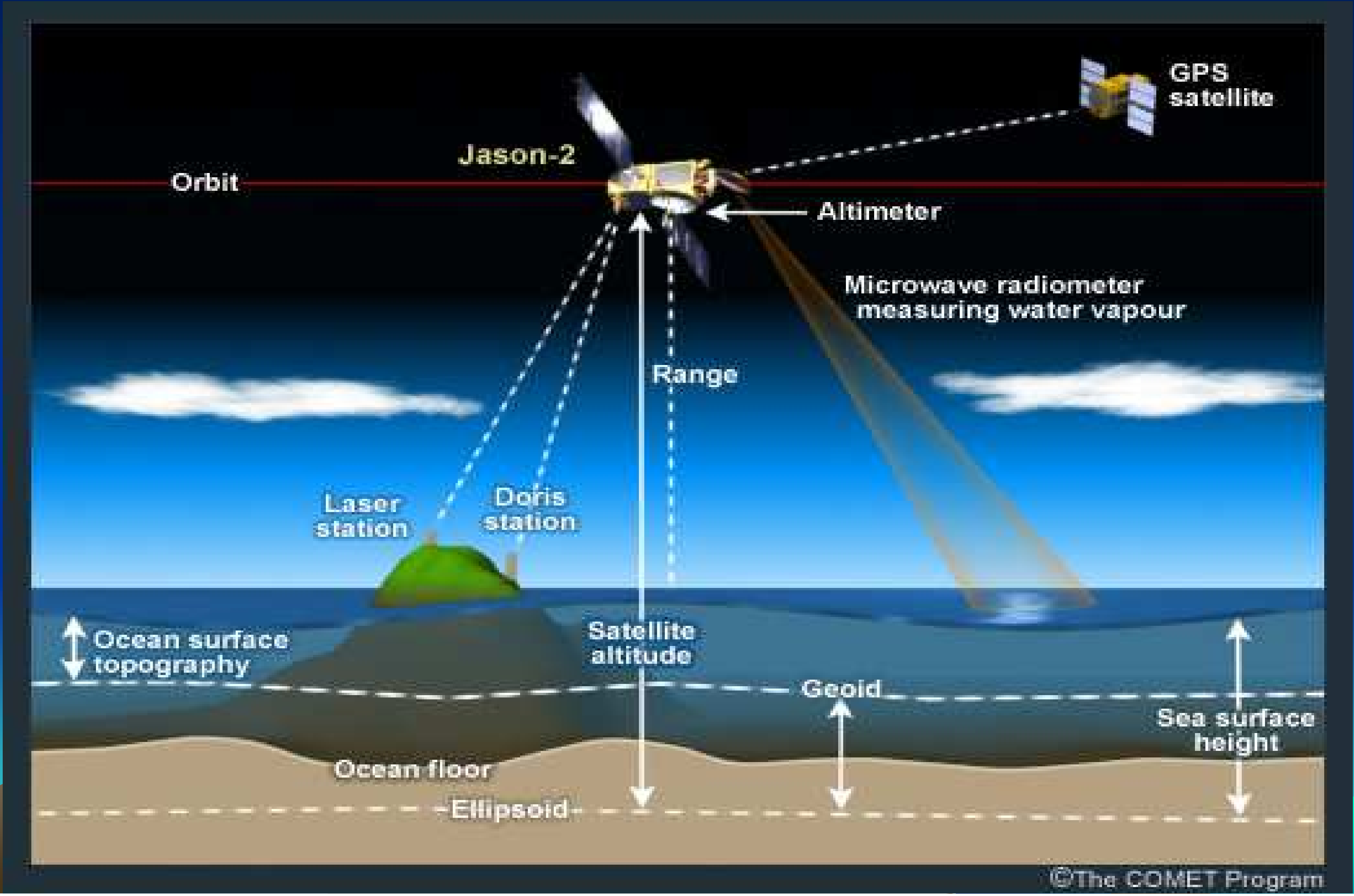




Source: HKO

Tide gauges of the Hong Kong Observatory

Satellite altimetry record since 1993

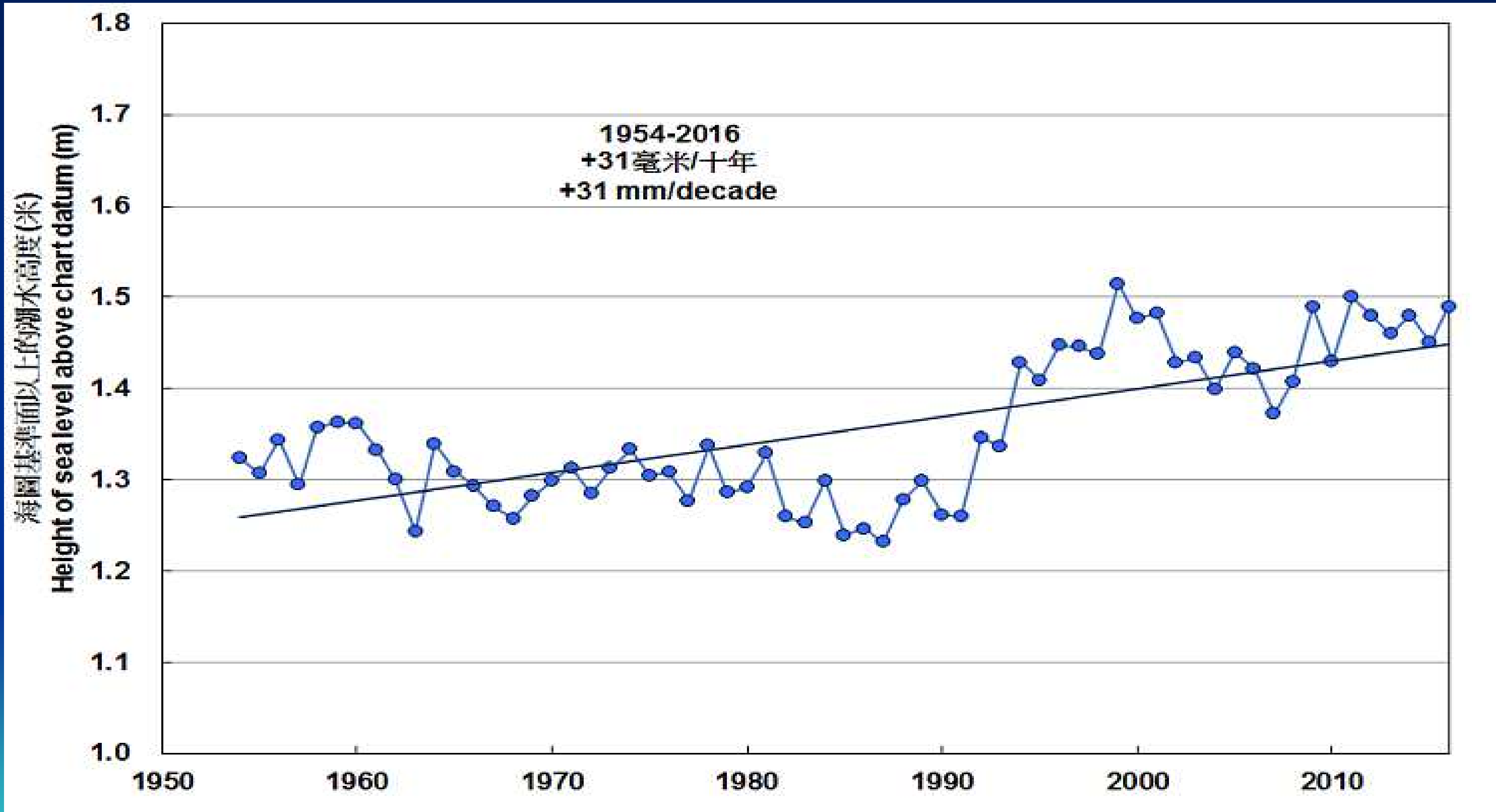


Rates of sea-level change in Hong Kong and the South China Sea based on different studies

Source	Area studied	Years examined	Data analysed	Rate of change
Wong et al. (2003)	Hong Kong	1954-1987	Tide gauge data	Fall of 2 mm/yr
Wong et al. (2003)	Hong Kong	1987-1999	Tide gauge data	Rise of 22.1 mm/yr
Wong et al. (2003)	Hong Kong	1999-2003	Tide gauge data	Fall of 21 mm/yr
Wong et al. (2003)	Hong Kong	1954-2003	Tide gauge data	Rise of 2.3 mm/yr+
Cheng and Qi (2007)	South China Sea	1993-2000	Merged altimetry	Rise of 11.3 mm/yr
Cheng and Qi (2007)	South China Sea	2001-2005	Merged altimetry	Fall of 11.8 mm/yr

+ The rate of change found is similar to Ding et al. (2002) who studied 1954-1999 data

Annual mean sea level in Victoria Harbour 1954-2016



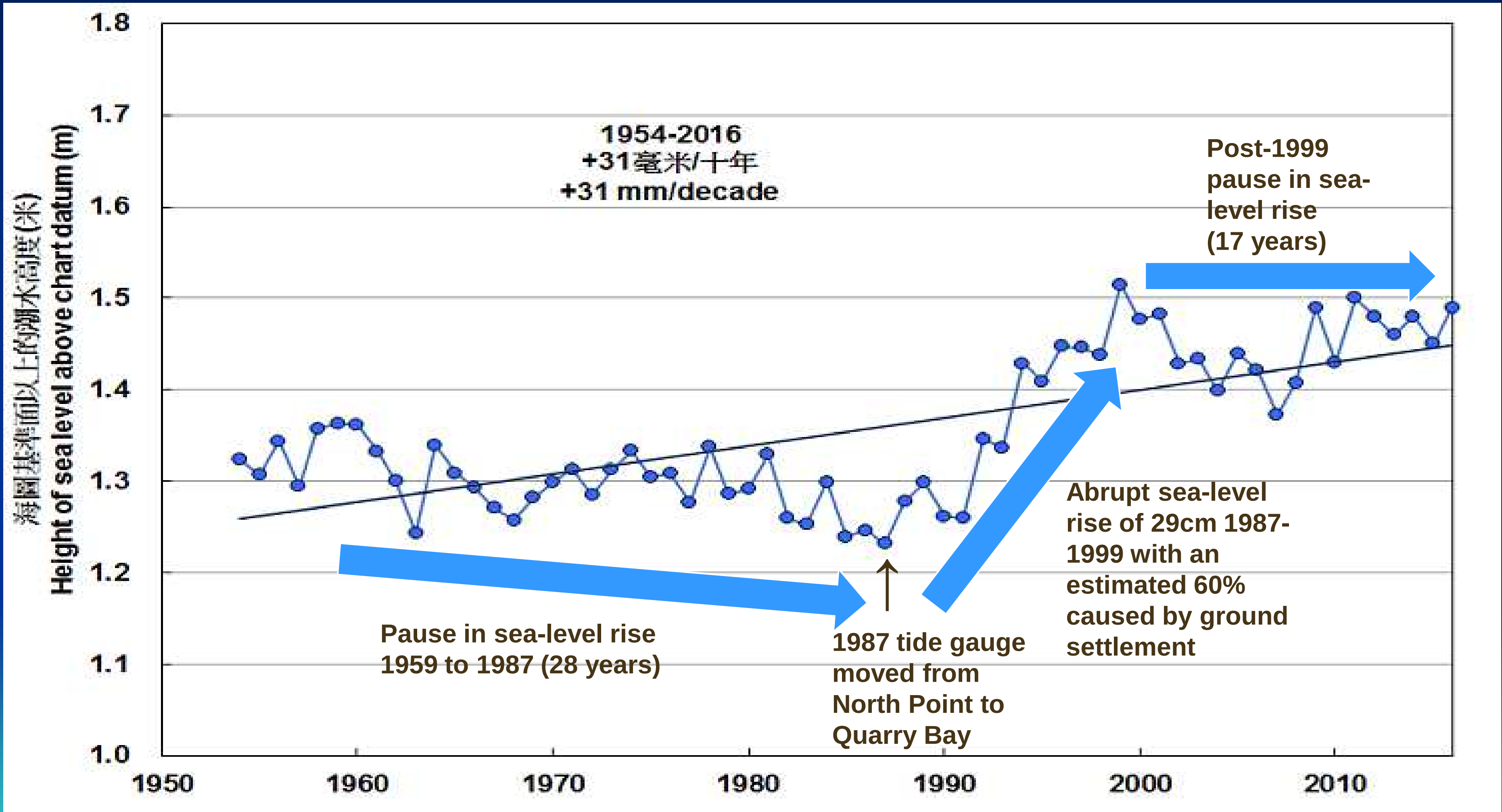
Source: HKO

Victoria Harbour tide gauges
- both sited on coastal land reclamations

North Point 1954 – 1986

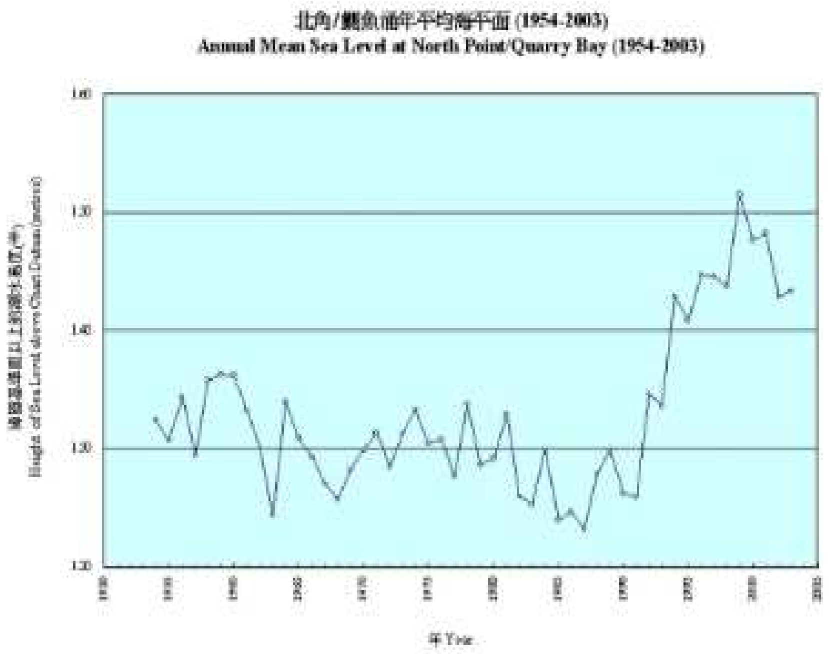
Quarry Bay 1987 – present

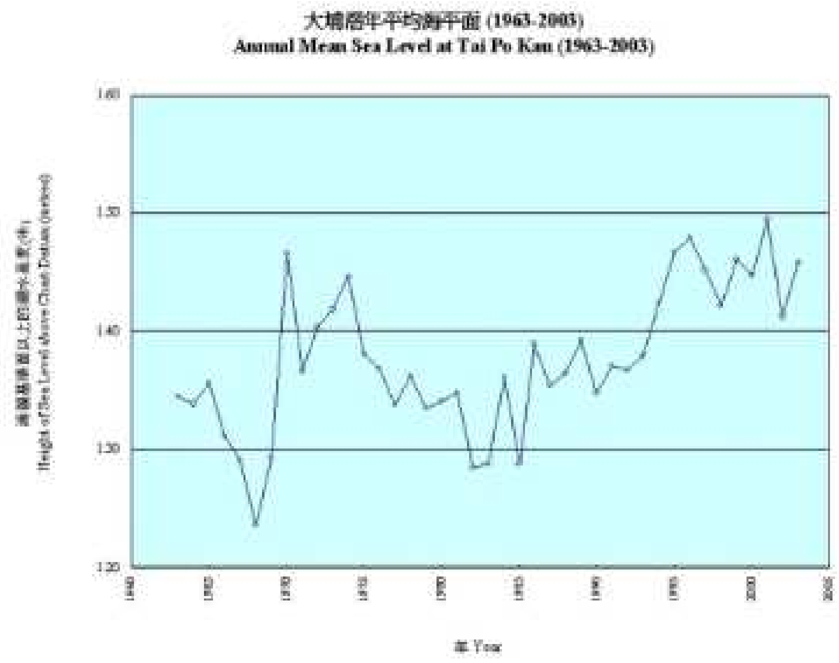
Victoria Harbour sea-level record



Source: HKO

Comparison between records in Victoria Harbour and Tai Po Kau 1963-2003



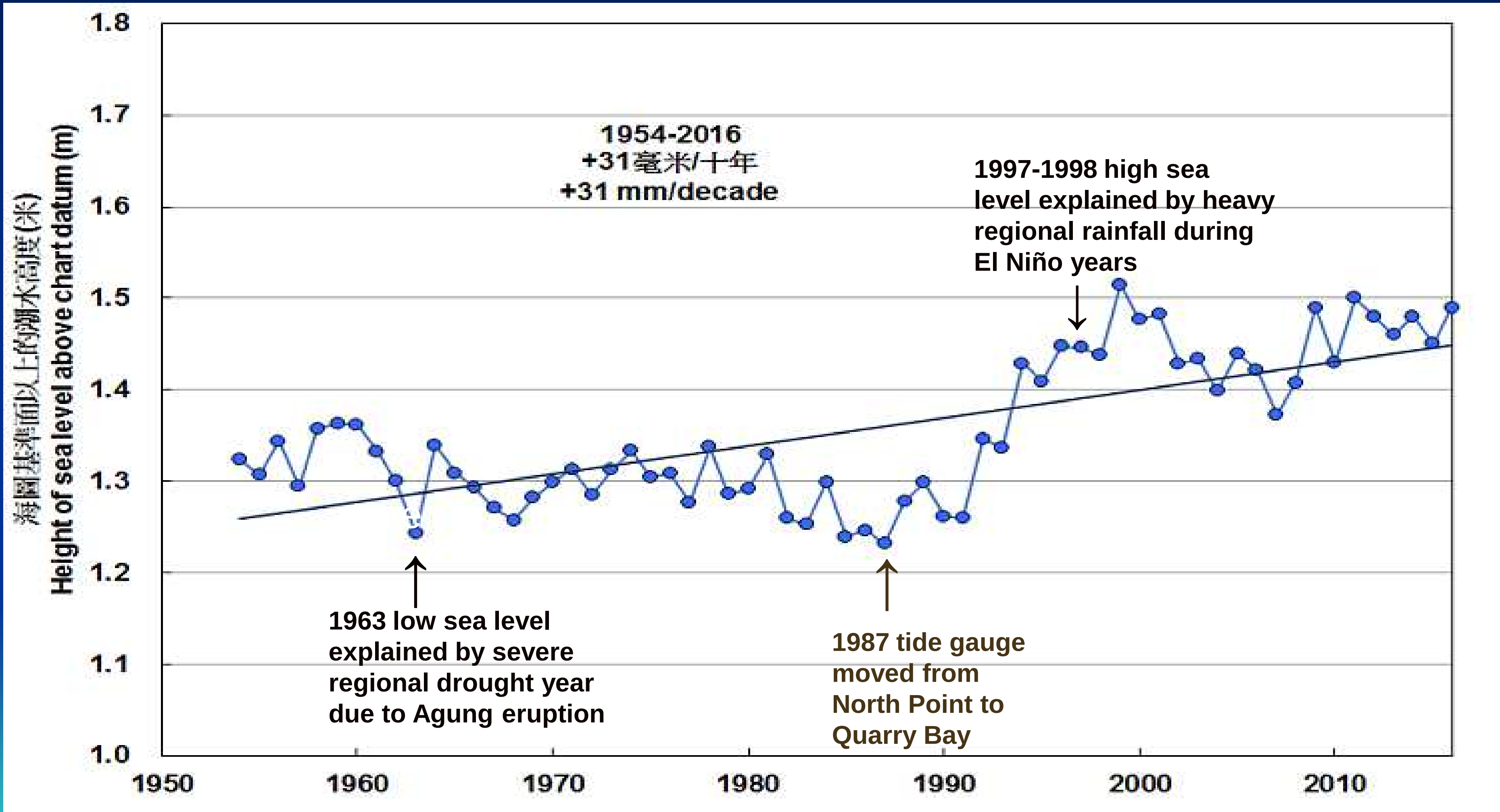


Abrupt rise of 29 cm from 1987-1999 | **Rise of 12 cm from 1987-1999**

~17cm difference may be attributed to ground settlement of the Quarry Bay tide gauge

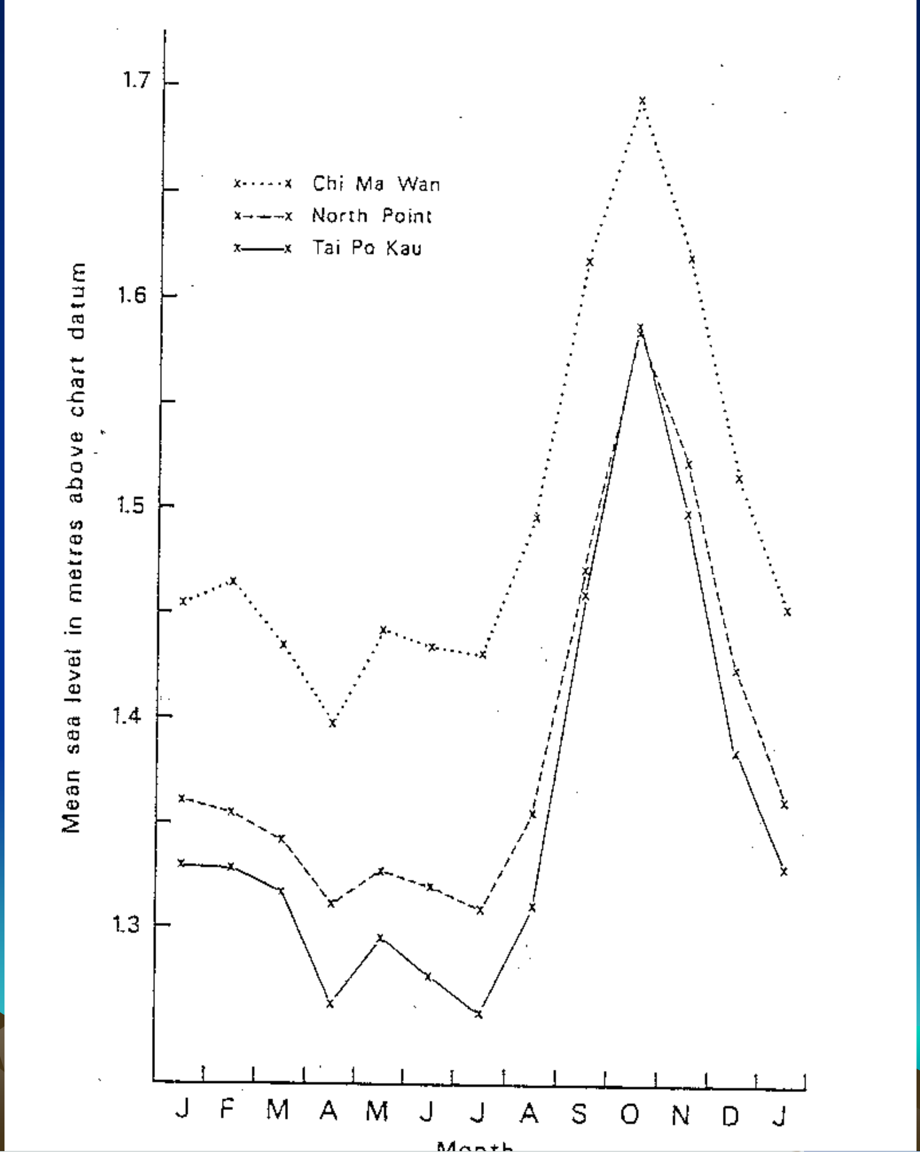
Source: HKO

Influence of river discharge during dry and wet years



Source: HKO

Comparison of 15-year monthly sea level during 1970-84 at the North Point, Tai Po Kau and Chi Ma Wan tide gauge stations (Yim 1993)



Difference explained by coastal configuration –

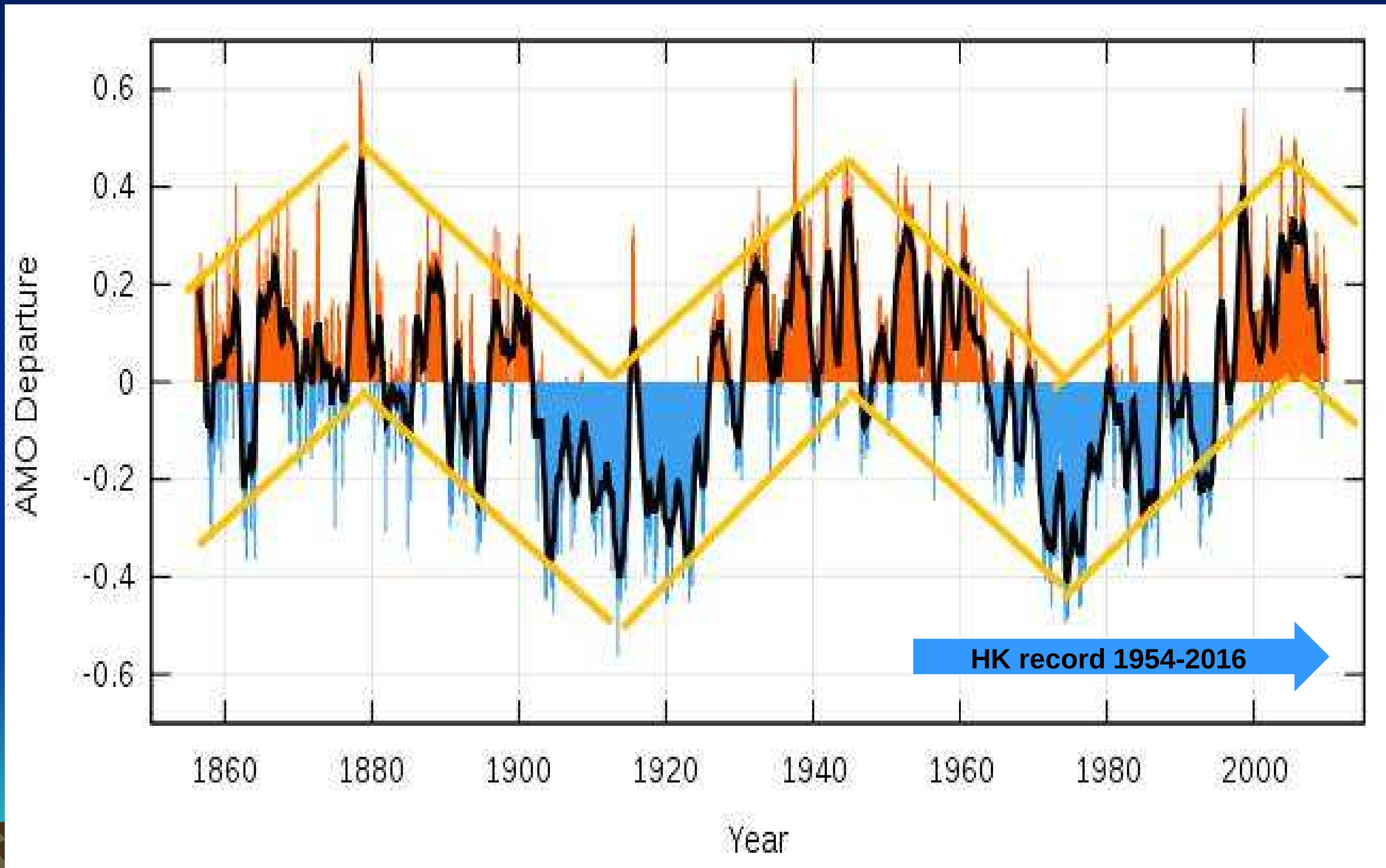
Tai Po Kau highest

Chi Ma Wan intermediate

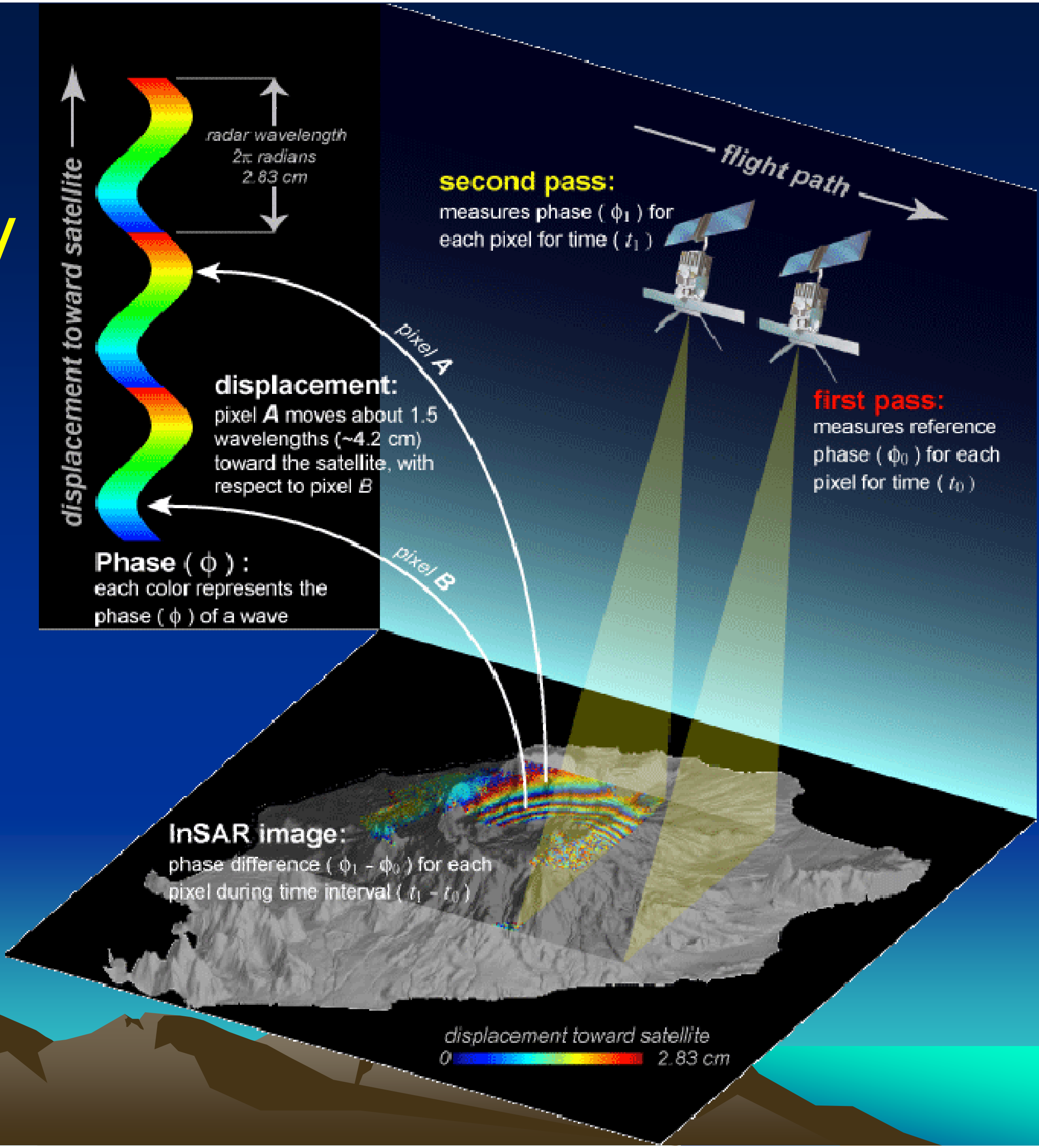
North Point lowest

Atlantic Multidecadal Oscillation anomalies 1850-2009 with 62-year cycles (Knudsen et al. 2011)

Maxima at 1878, 1943 and 2004 **Minima at 1912 and 1974**



Detection of ground movement / crustal stability



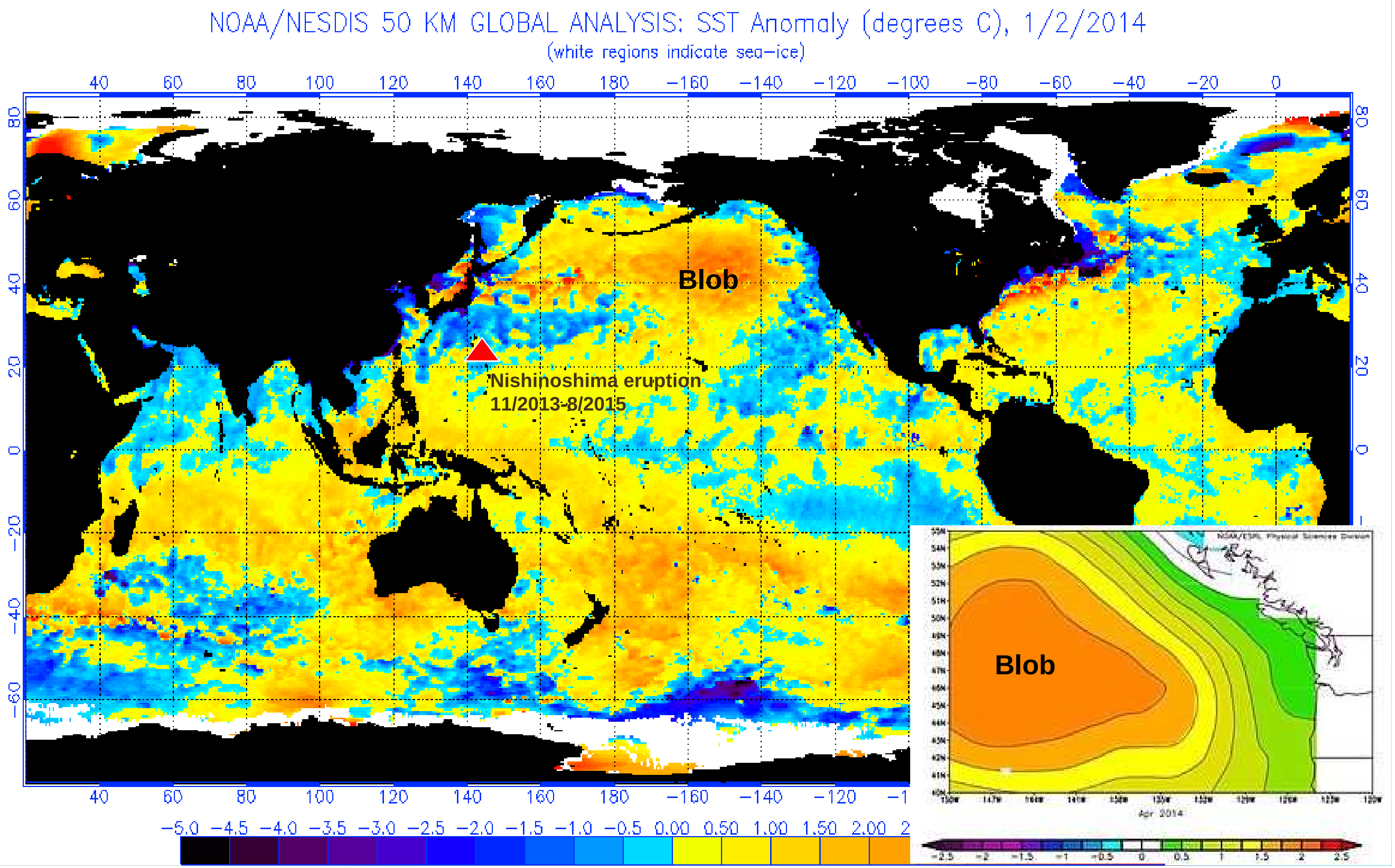
Interferometric
Synthetic
Aperture
Radar

INSAR

Conclusions on sea-level record

- Tide gauge and satellite remote sensing records are too short at present to be conclusive
- Tide gauges must be located on bedrock to eliminate noise caused by ground settlement
- The average rate of sea-level rise of 30 mm/decade of the HKO is an overestimate
- An estimated 60% of the 29 cm sea-level rise observed during 1987-1999 at the Quarry Bay tide gauge may be attributed to ground settlement
- Short-term noise in sea-level change include river discharges and the Pacific Decadal Oscillation
- Storm surge flooding generated by typhoons is our immediate enemy

Sea-surface temperature anomalies showing the North Pacific Blob on January 2, 2014



Nishinoshima submarine/sub-aerial eruption
940 km south of Tokyo
March 2013 to August 2015

Image on November 13, 2013: Japan Coast Guard
Submarine eruption began in March 2013

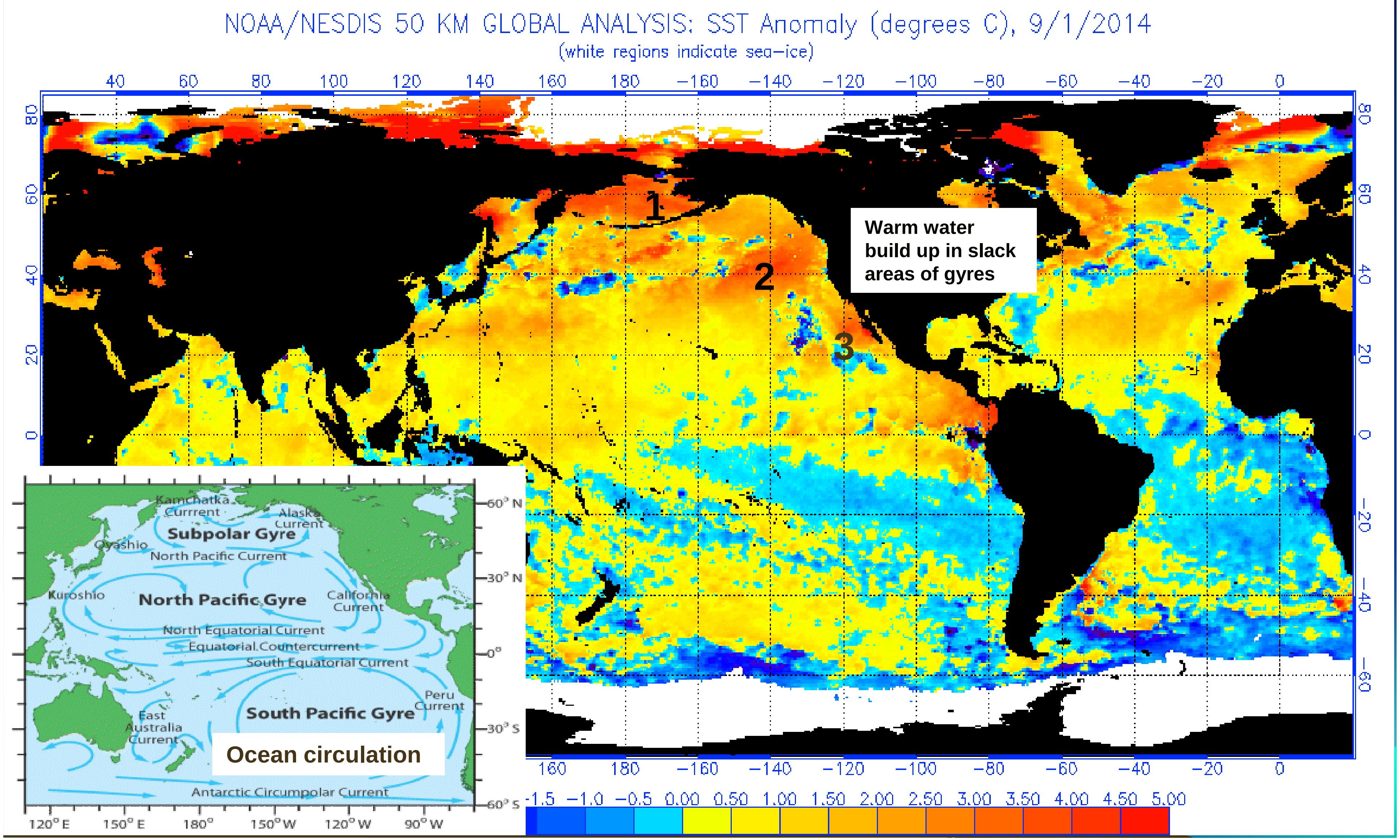
Image on December 8, 2013: NASA

Observations connecting Nishinoshima with the Blob

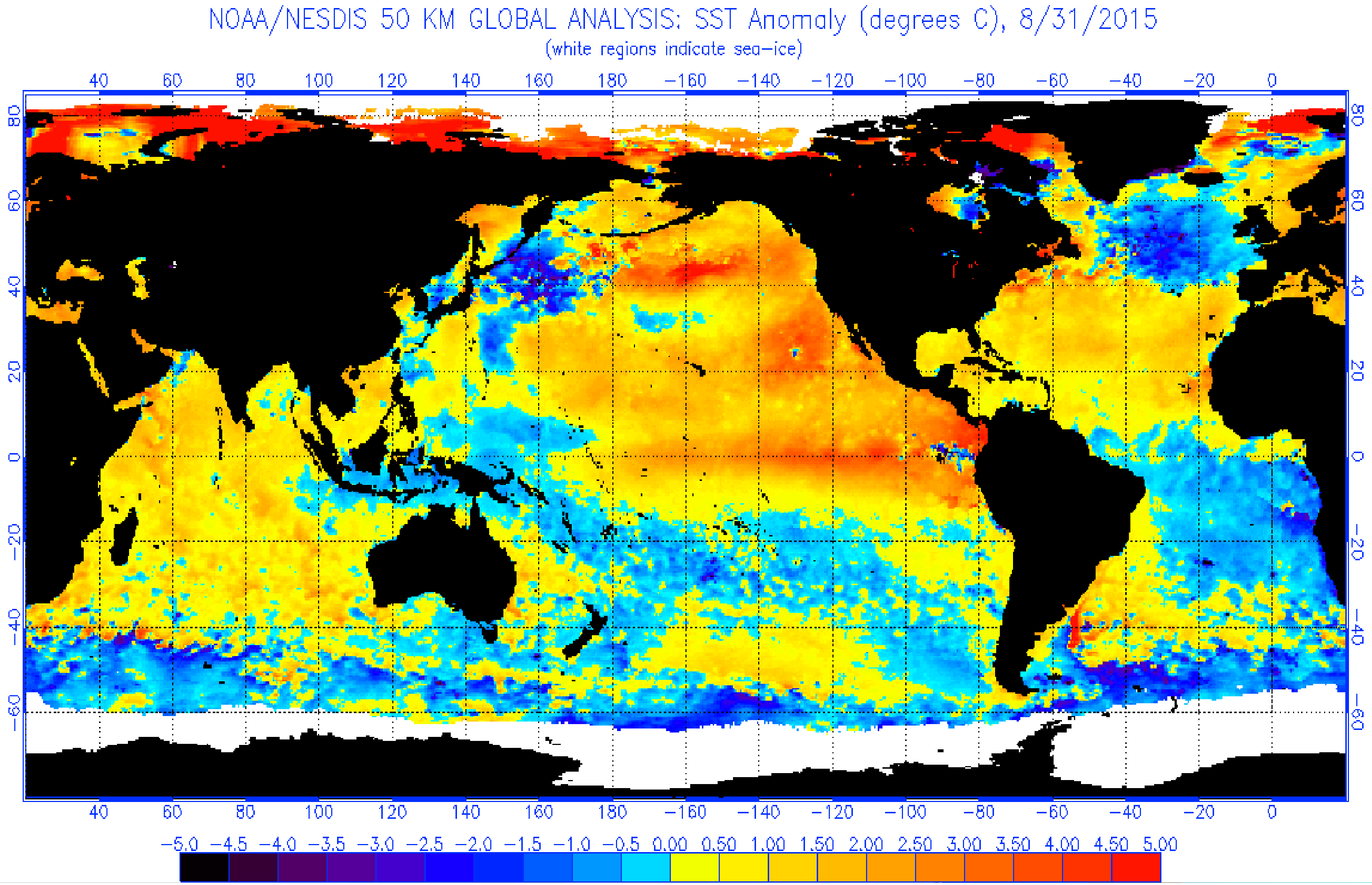
Date	Eruption activity	Northern Pacific Blob
November 2013	Submarine eruption created new island	Initial Blob 800 km wide and 91 m deep
December 2013	Island area reached 5.6 km^2 and ~25 m above sea level	-
February 2014	-	Temperature was ~2.5^{o}C above normal
June 2014	-	Name Blob was coined by Nicholas Bond Size reached 1600 km x 1600 km and 91 m deep Spread to the coast of North America with patches off Alaska, Victoria/California and Mexico
December 2014	Island now ~2.3 km in diameter and ~110 m above sea level	Year without winter in western North America coast and first mass bleaching of Hawaiian coral reefs
January-August 2015	Episodic eruption with lava flows	-
Early 2016	-	Blob persisted and ended

Source: Wikipedia

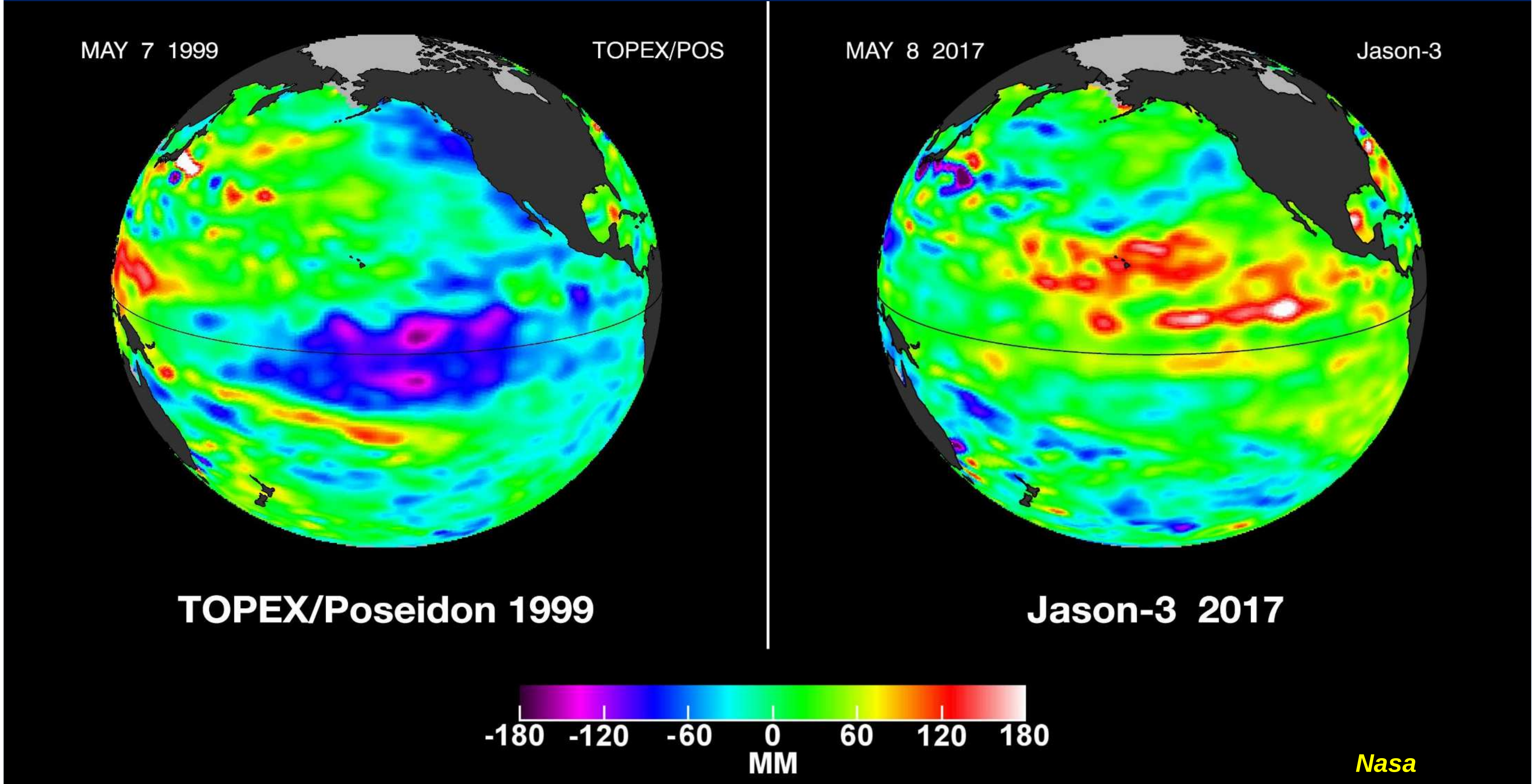
The Blob separated into three parts on September 1, 2014



Establishment of the strong 2015-2016 El Niño August 31, 2015



Comparison of ocean surface topography during El Niño 1997-1998 and 2015-2016



Nasa

Why CO_2 reduction is ineffective?

- **Carbon dioxide is a life-giving gas in plant photosynthesis**
- **Man-made carbon dioxide has only a small role in warming**
- **Carbon dioxide lags temperature rise by ~800 years in Antarctica ice cores**
- **Clouds and water vapour distribution are more important than CO_2 in temperature changes**
- **Climate models cannot explain the two recent pauses in HK temperature rise**
- **Subaerial and submarine volcanic eruptions are underestimated natural causes of cooling and warming**
- **~60-year cycles may be operating**
- **El Niño years in existence even before the pre-industrial revolution was responsible for warming during 2015-2016**

Release of geothermal heat into the Pacific Ocean by Kilauea since July 2016

Question: Will this trigger the next El Niño?

Main conclusions

- Sea level is not rising rapidly but another fifty year of measurement is needed to be certain

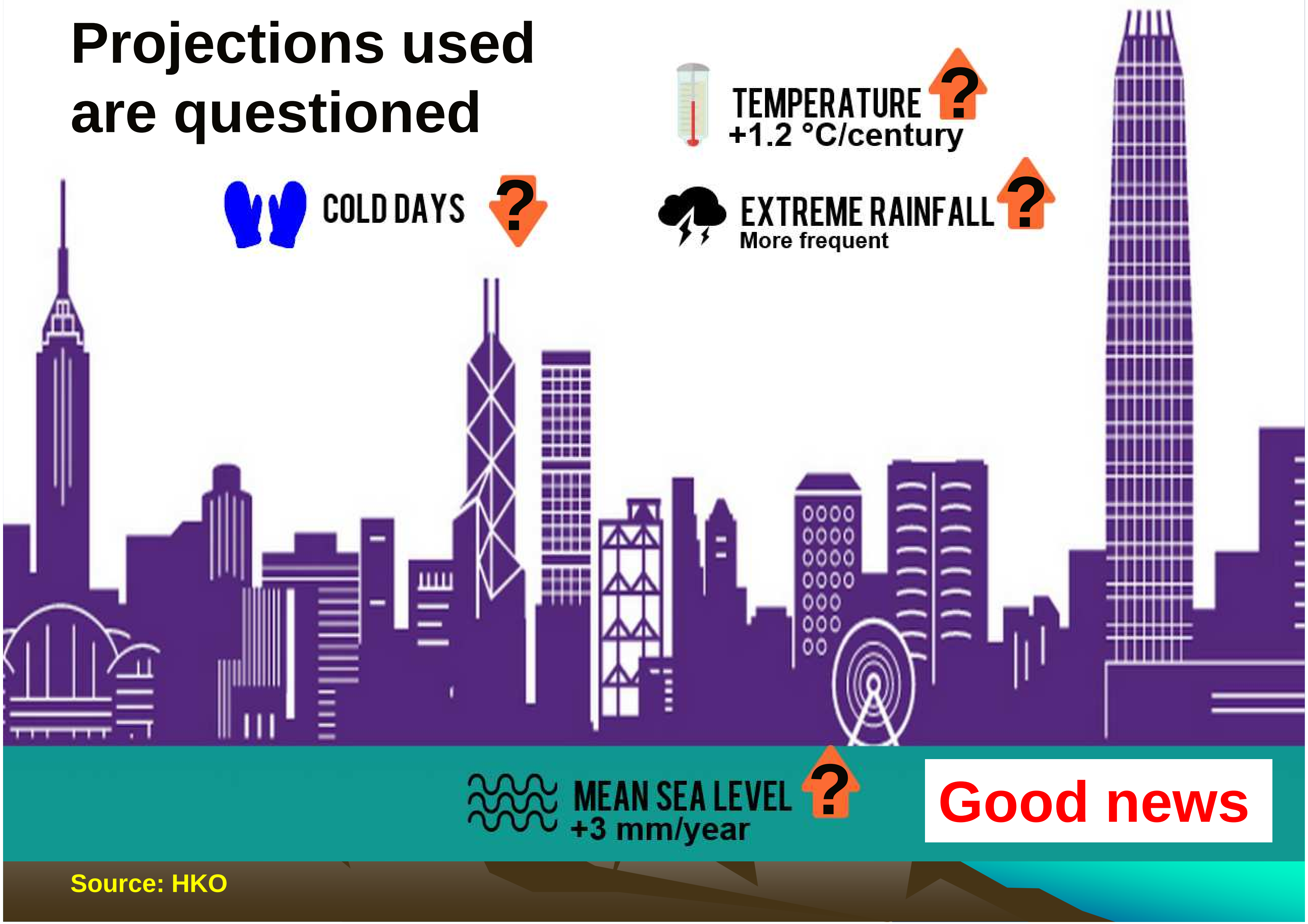
- Temperature rise is directly caused by heat generation through human activities

- The reduction of CO_2 is not a solution to the problem of human-induced temperature rise

- Skeptics with good scientific reasons has the right to challenge decisions made by the United Nations and governments to justify unnecessary spending on reducing CO_2 which will have undesirable consequences

- The role of volcanic eruptions in climate change (both cooling and warming) is underestimated … our dynamic Earth

Projections used are questioned



May 23, 2006 Cleveland, Aleutian islands

Thank you

Note – Majority of my publications are available on ResearchGate.