Hong Kong's Sea-level Record

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ISEIS, Chinese University of Hong Kong /
Association for Geoconservation, Hong Kong /
Commission on Quaternary Shorelines, International Union for Quaternary Research 1991-2003

Acknowledgements –
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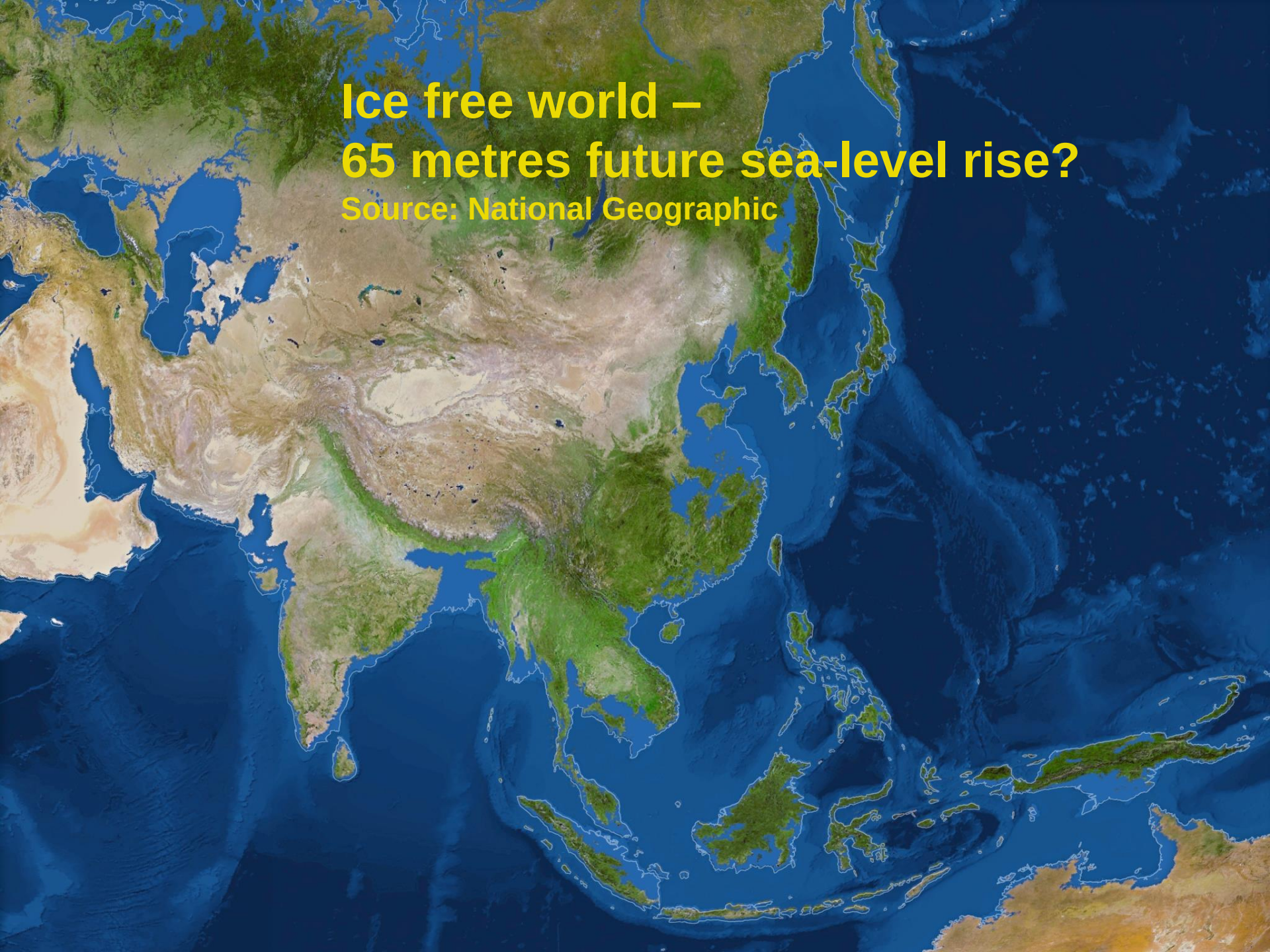
Plan

(1) Background

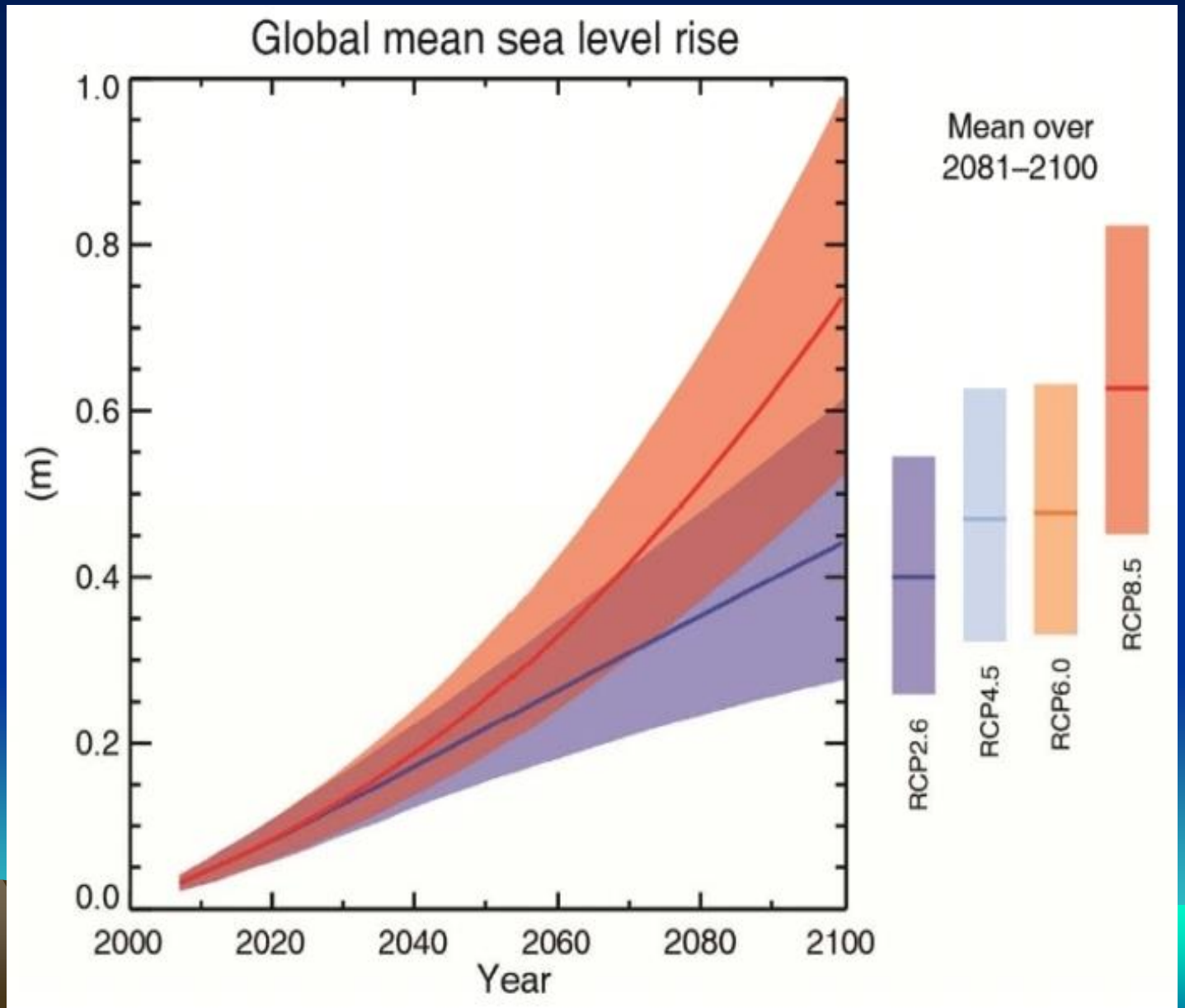
(2) ~0.5 million year record based on sea-floor evidence

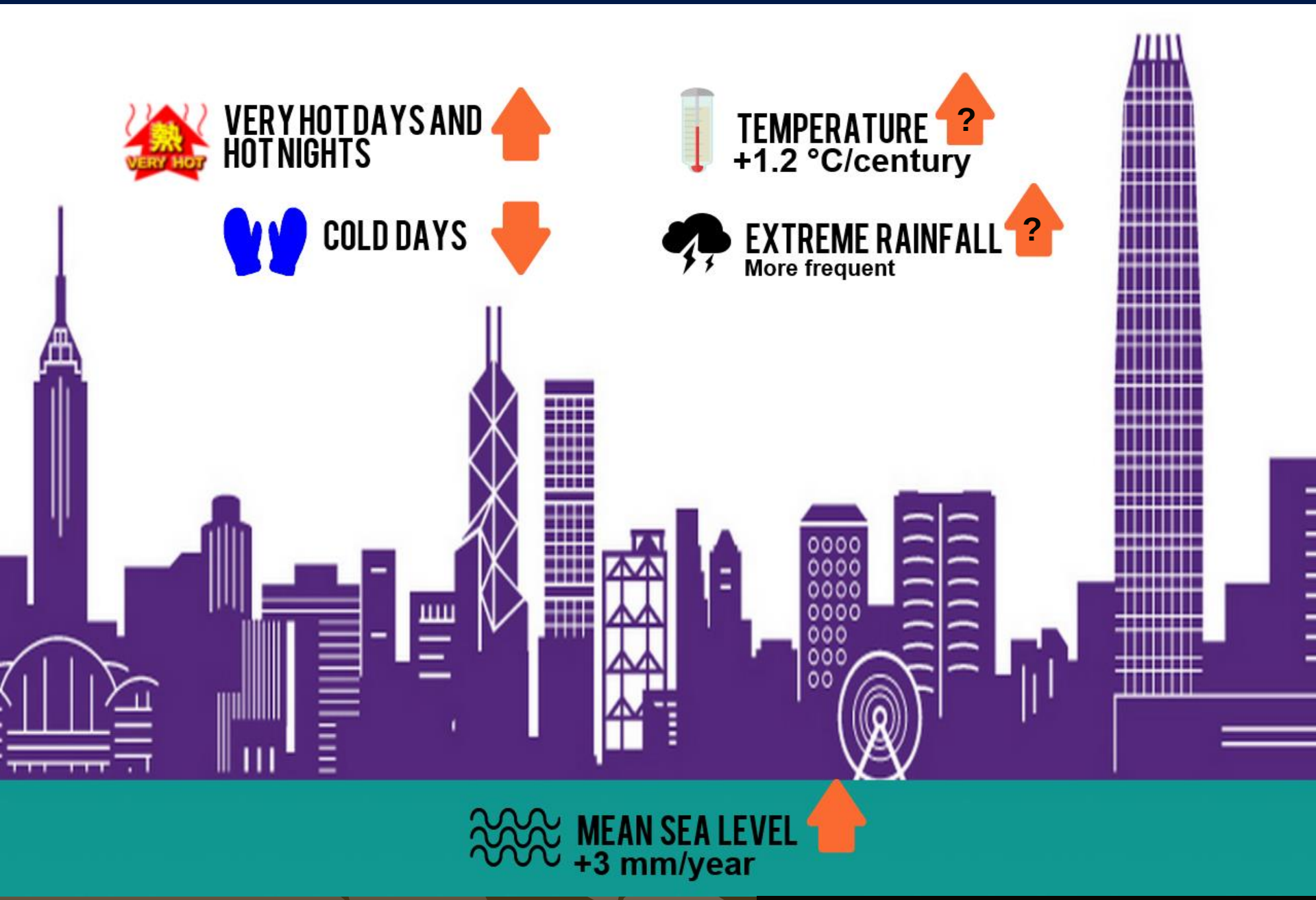
(3) Sea-level measurement records since 1954

(4) Conclusions


Ice free world –
65 metres future sea-level rise?
Source: National Geographic

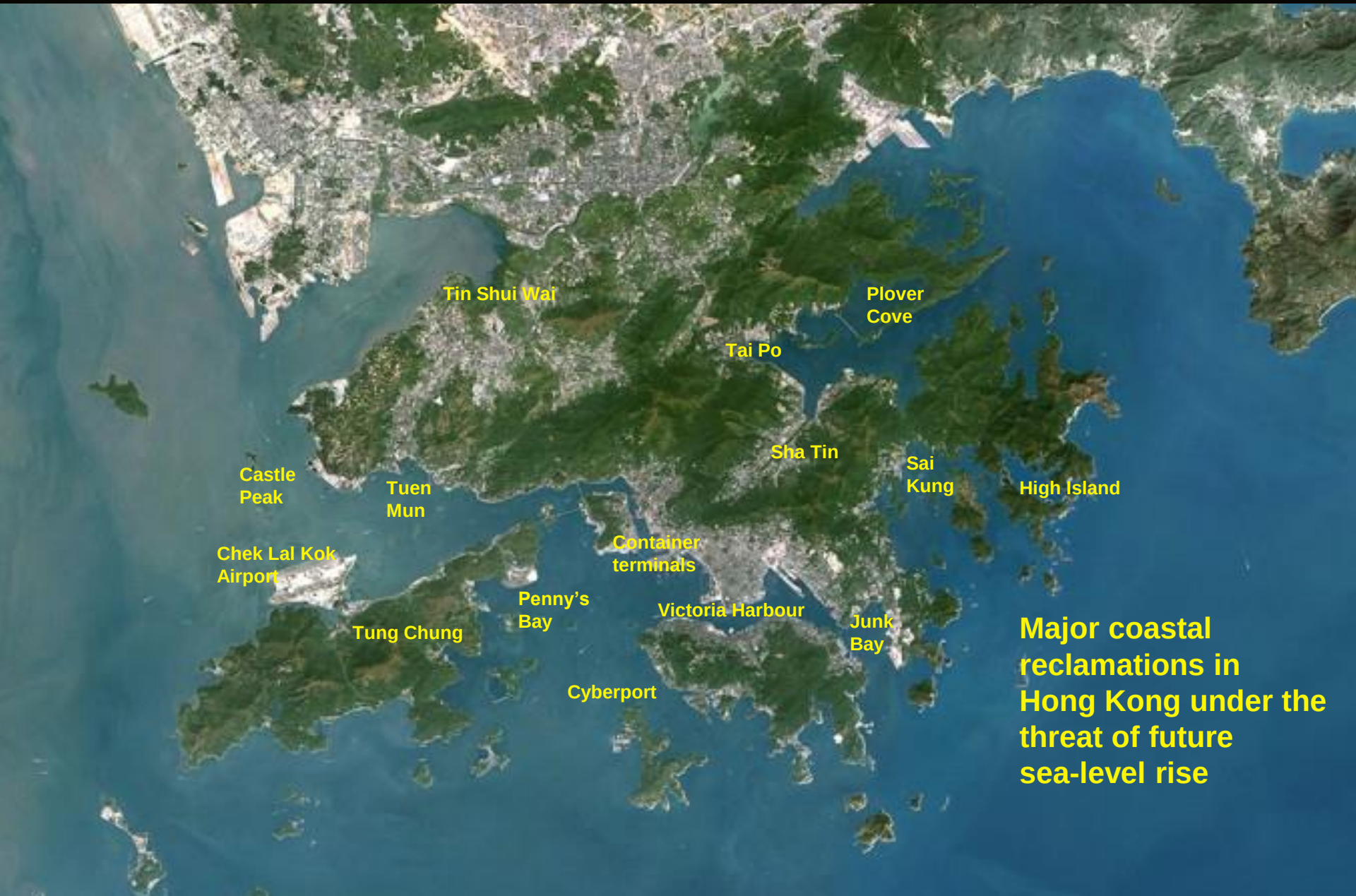
Projected rate of future sea-level rise by 2100 based on IPCC CO_2 emission scenarios





Source: Hong Kong Observatory

About 15% of Hong Kong's total land area of 1100 km^2 is comprised of low-lying coastal reclamation below 5 m above mean sea level



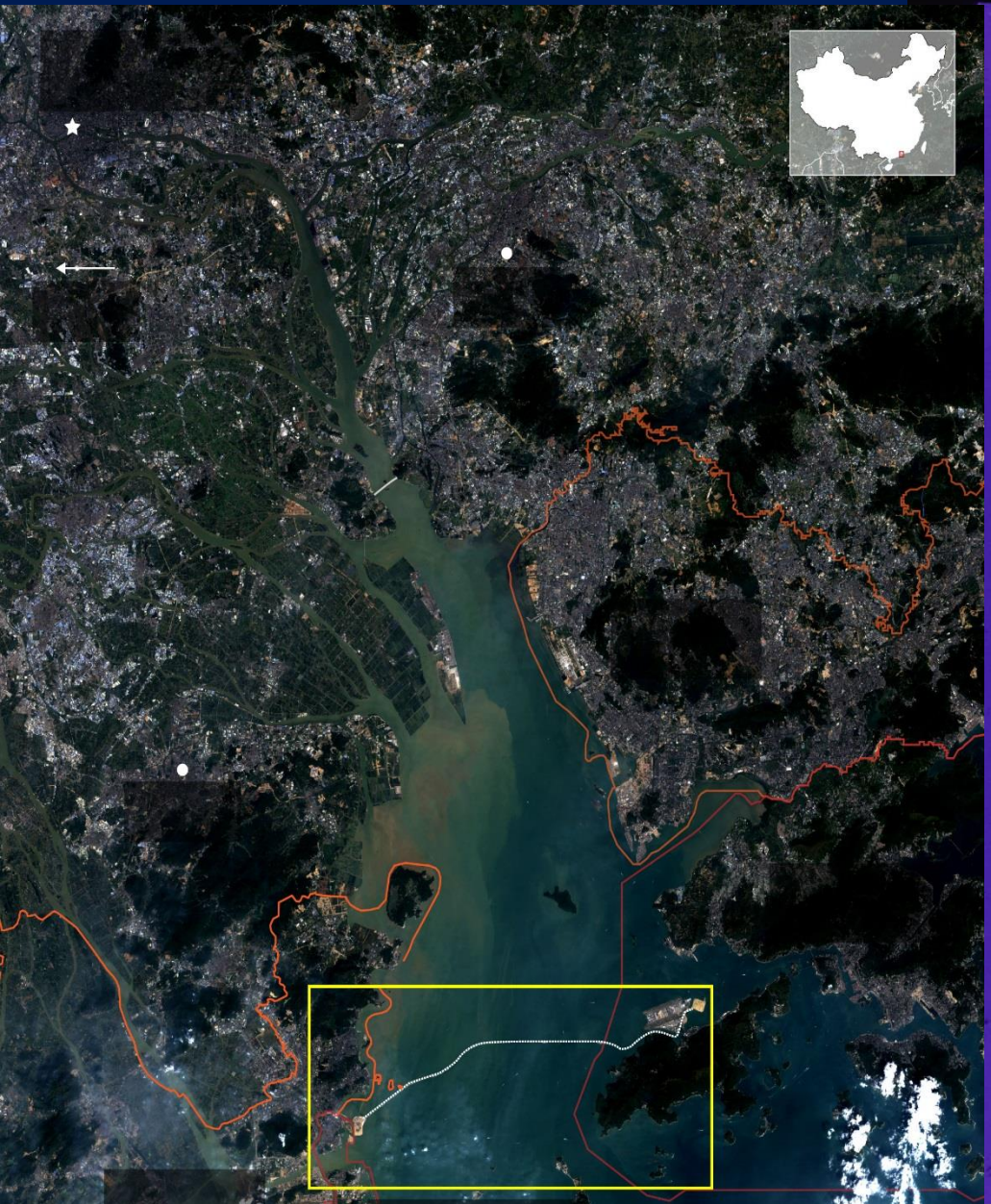
Possible variables affecting the stability of sea levels
After Morner (2013) with modifications

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

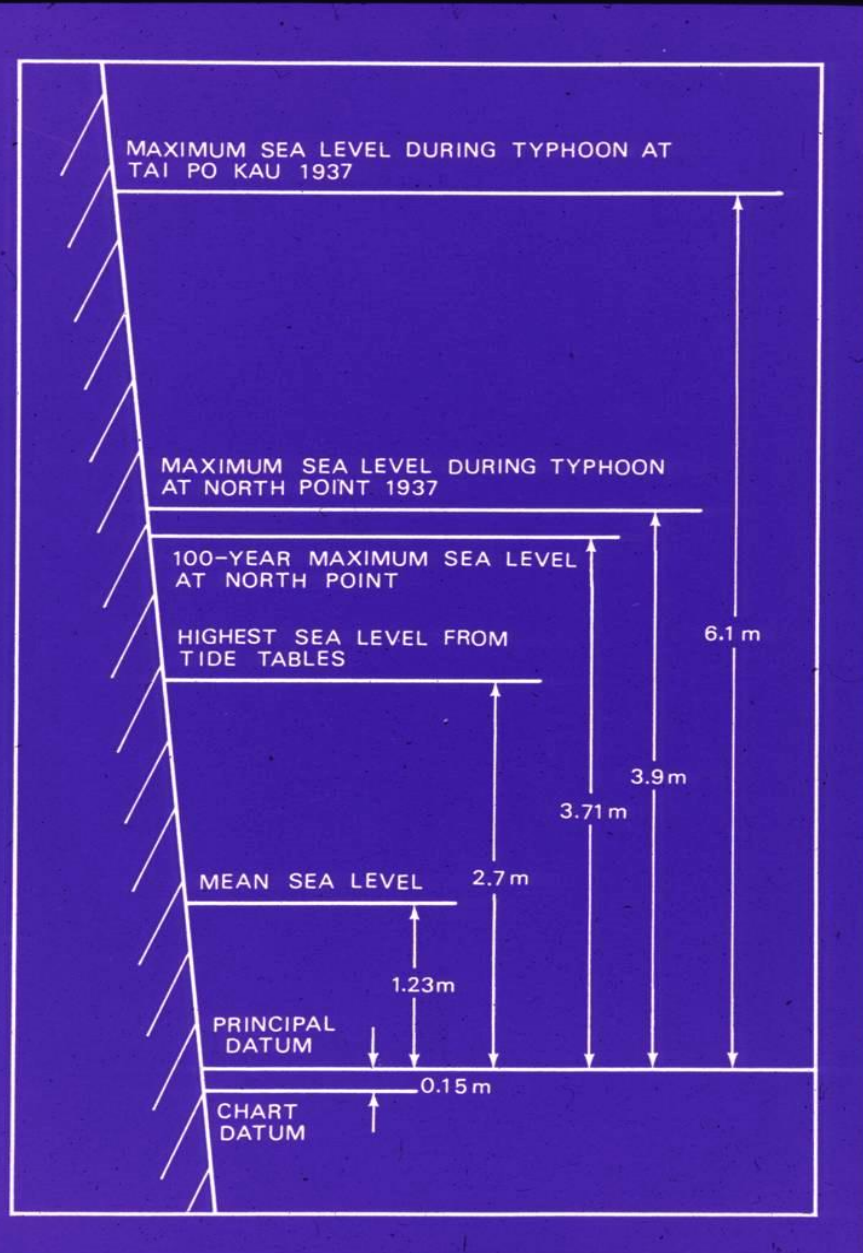
Venice - Best known drowning city caused mainly by excessive groundwater extraction

Source: www.unisdr.org

Satellite photo of Hong Kong and the Pearl River Estuary



Sea-level datums



Sea-level in Hong Kong during the past 0.5 million years

Discoveries from excavations and sea-floor drilling

(1) Excavation of the High Island damsites

(2) Western Harbour Crossing excavation

(3) Sheung Wan Station excavation, Island Line, MTR

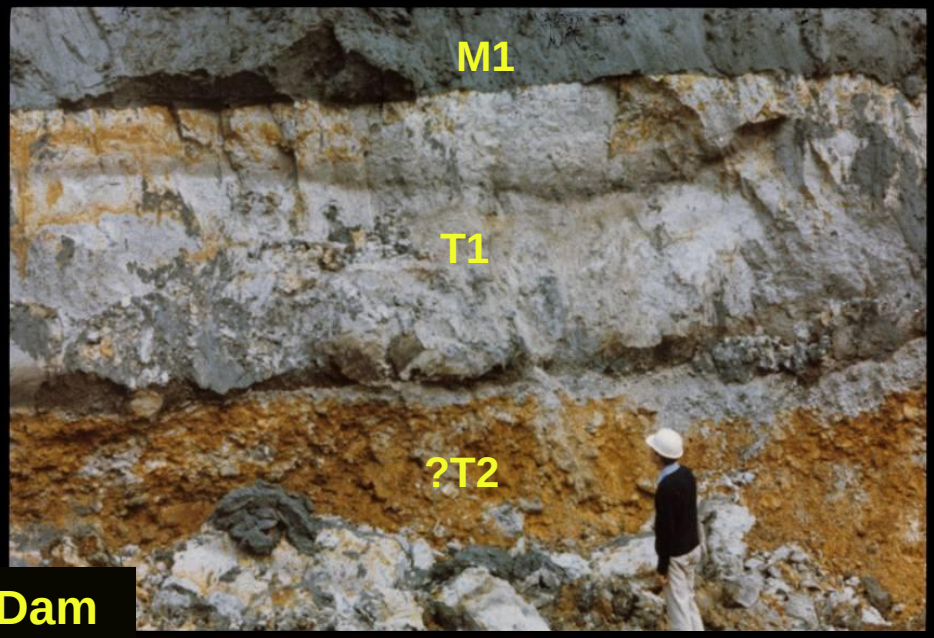
(4) Drilling for marine sand search

(5) Drilling for engineering investigation in the West Lamma Channel

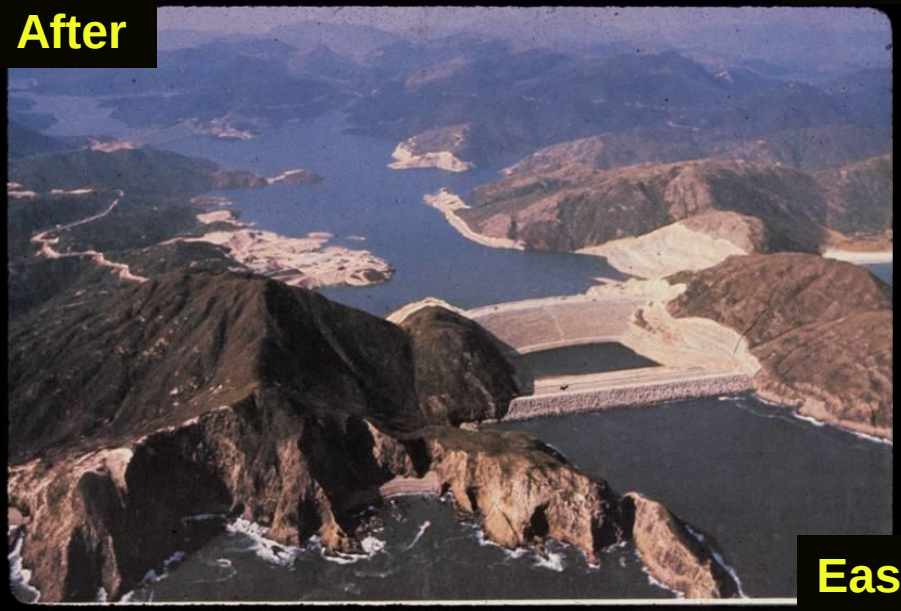
High Island Reservoir damsites excavation

Before

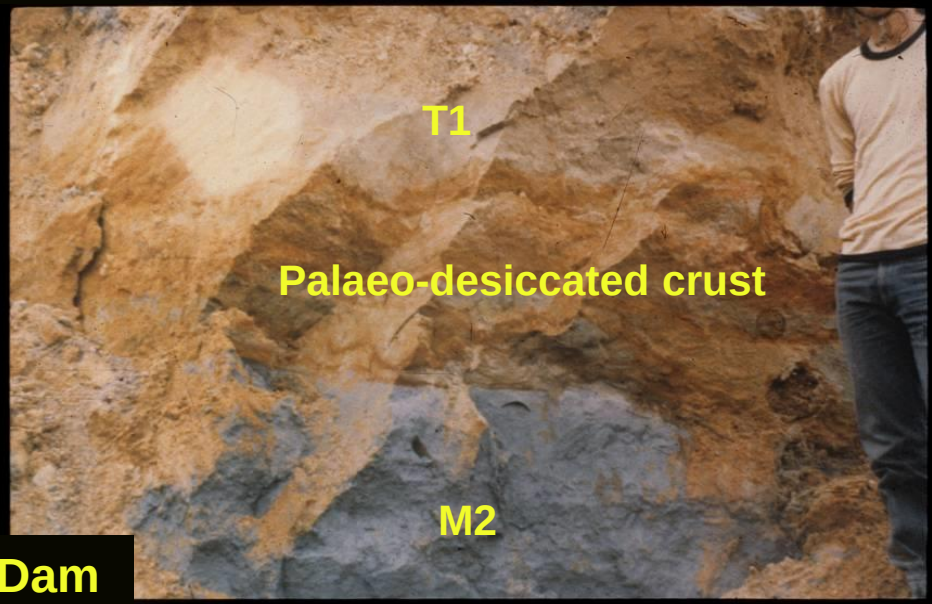
West Dam



After



East Dam



Sea-floor excavation of Victoria Harbour for the Western Harbour Crossing

Radiocarbon dated 7,000-year old oyster shells

Corals

Excavation of the Sheung Wan Station, Island Line, MTR

MTR construction

Radiocarbon age ~30 ka
Uranium-series age ~130 ka

Oyster shells from the M2 layer

Offshore drilling for marine sand

A drill barge

Drilling in action

A continuous 60-m core

Drillhole in the West Lamma Channel for the Western Harbour Development Study

Samples at about 0.5 m Intervals in Borehole WB7

Borehole WB7

Legend	Depth in m P.D.	Origin	Description
	0.00		Sea level
	-10.20		Sea bed
	-17.20	M1	Very soft, grey clayey silt with shell fragments and subangular gravel in the top metre
	-23.80	M2	Soft to firm, grey clayey silt with occasional shell fragments and large bivalves at the base
	-27.60	T2	Yellow, brown and grey subrounded sand and gravel
	-35.70	M3	Firm; mottled, grey, yellow and brown clayey silt to -31.20 m; dark grey, clayey silt with a little sand and gravel below -31.20 m
	-37.05	T3	Mottled, white and grey silty sand with gravel below -36.85 m
	-51.20	M4	Soft to firm; mottled, grey, yellow and brown clayey silt to -46.13 m ; dark grey and grey clayey silt below -46.13 m
	-53.20	M5	Firm, mottled, grey, yellow and brown clayey silt becoming more grey at the base
	-60.20	T5	Firm to stiff, locally mottled, white,pink and grey clay to sand with occasional gravels
+ + + + + + + + + + + + + + +	-70.20	Residual soil	Completely decomposed rock (? granite)

Simplified logsheet

Offshore geological model of Hong Kong

Unit	Age	Estimated age (ka)	Maximum thickness (m)
M1	Postglacial	< 8.2	21.5
T1	Last glacial	8.2 – 70	6.5
M2	Last interglacial	90 – 140	15.7
T2	2nd last glacial	150 – 180	9.5
M3	2nd last interglacial	190 – 240	12
T3	3rd last glacial	250 – 300	7.3
M4	3rd last interglacial	310 – 340	14.1
T4	4th last glacial	350 – 370	6
M5	4th last interglacial	380 – 420	3.5
T5	5th last glacial	> 440	7

M – marine T – terrestrial

Main differences of marine & terrestrial deposits

Feature	Marine deposits	Terrestrial deposits
Fossils	Marine fossils may be present e.g. corals, clams, snails, etc.	Terrestrial fossils may be present e.g. plant remains, pollen, etc.
Colour	Usually darker [R]	Usually paler [O]
Grain size	Usually finer	Usually coarser
Compaction	Usually softer	Usually firmer
Water content	Usually higher	Usually lower
Iron content	Usually lower	Usually higher

How is age determined?

(1) Order of marine and terrestrial deposits

(2) Dating of suitable samples

Methods used -

Radiocarbon (reliable when younger than 8.2 ka)

Uranium-series (up to 500 ka)

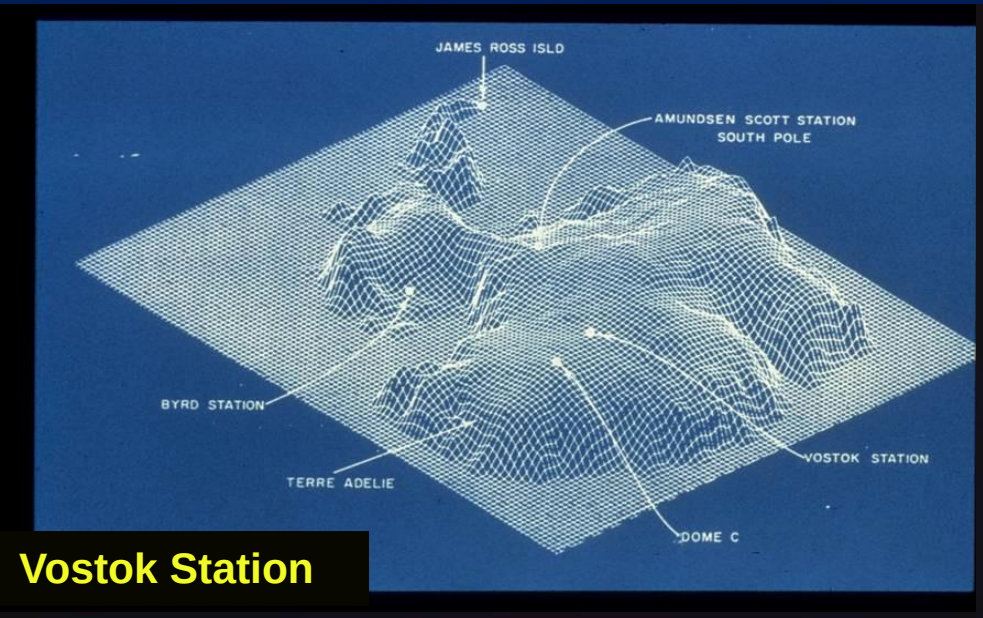
Luminescence (up to 1000 ka)

Cosmogenic nuclides (up to 5000 ka)

(3) Correlation with other parts of the world with ice cores, deep sea cores, loess deposits, etc.

(4) Use of indirect methods e.g. fossils, engineering properties, etc.

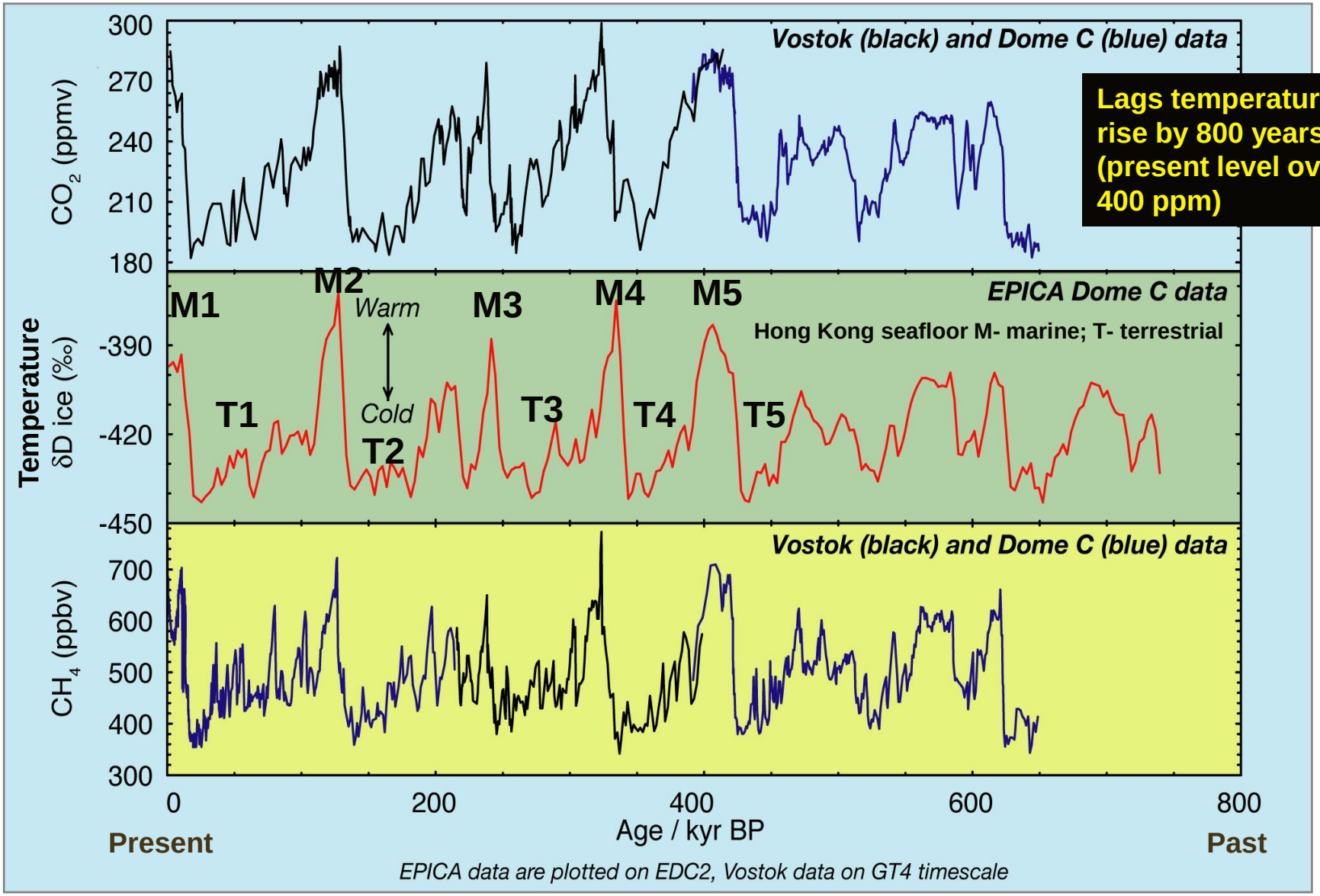
Vostok ice core in Antarctica



Vostok Station

Annual layers

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



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)

How high was sea levels during past interglacial periods?

East Ping Chau

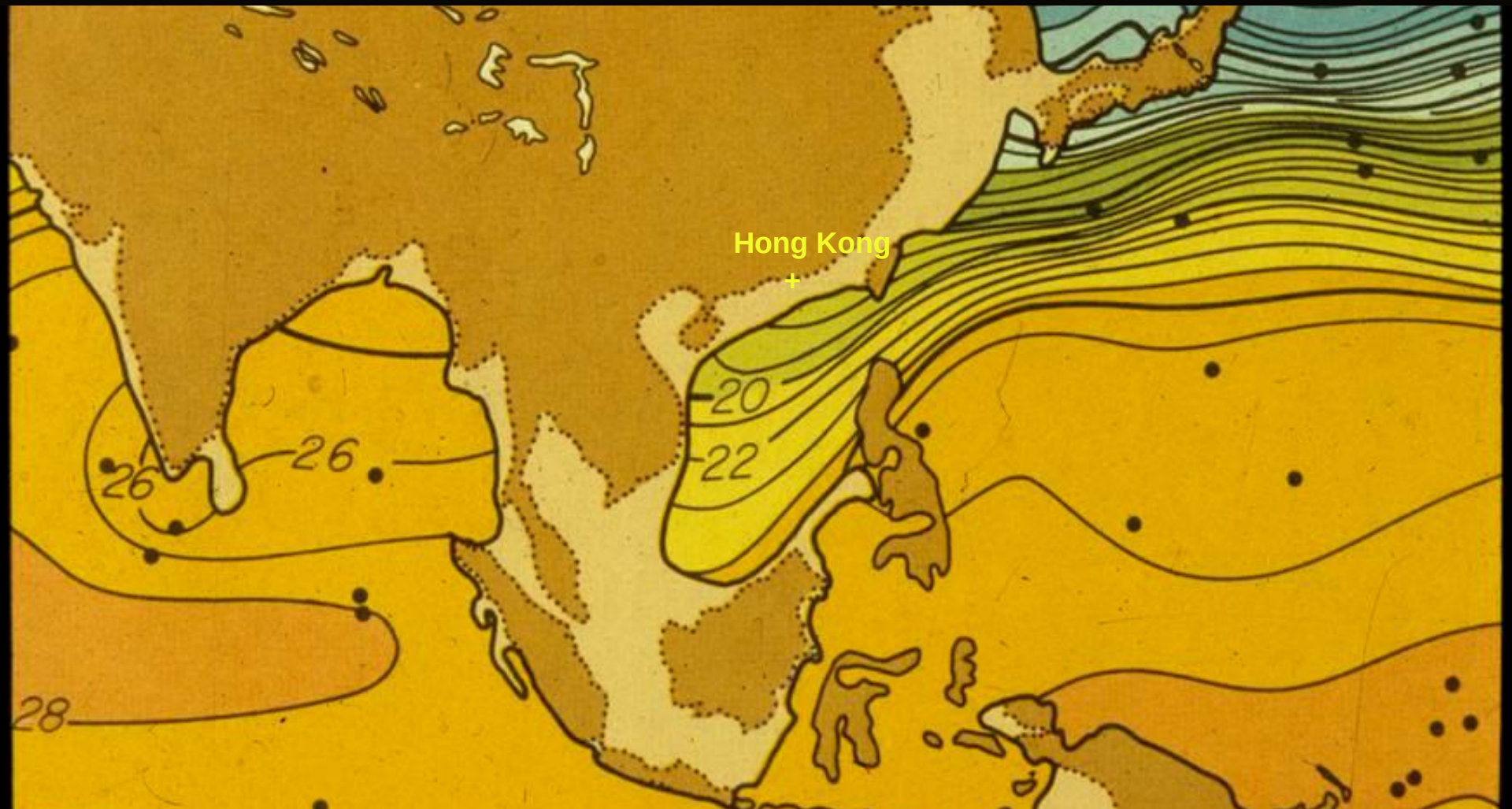
48-m high sea cliff

3-m high wave-cut notch

Wave-cut platform

Raised beach deposits at Po Chu Tam, Lantau Island

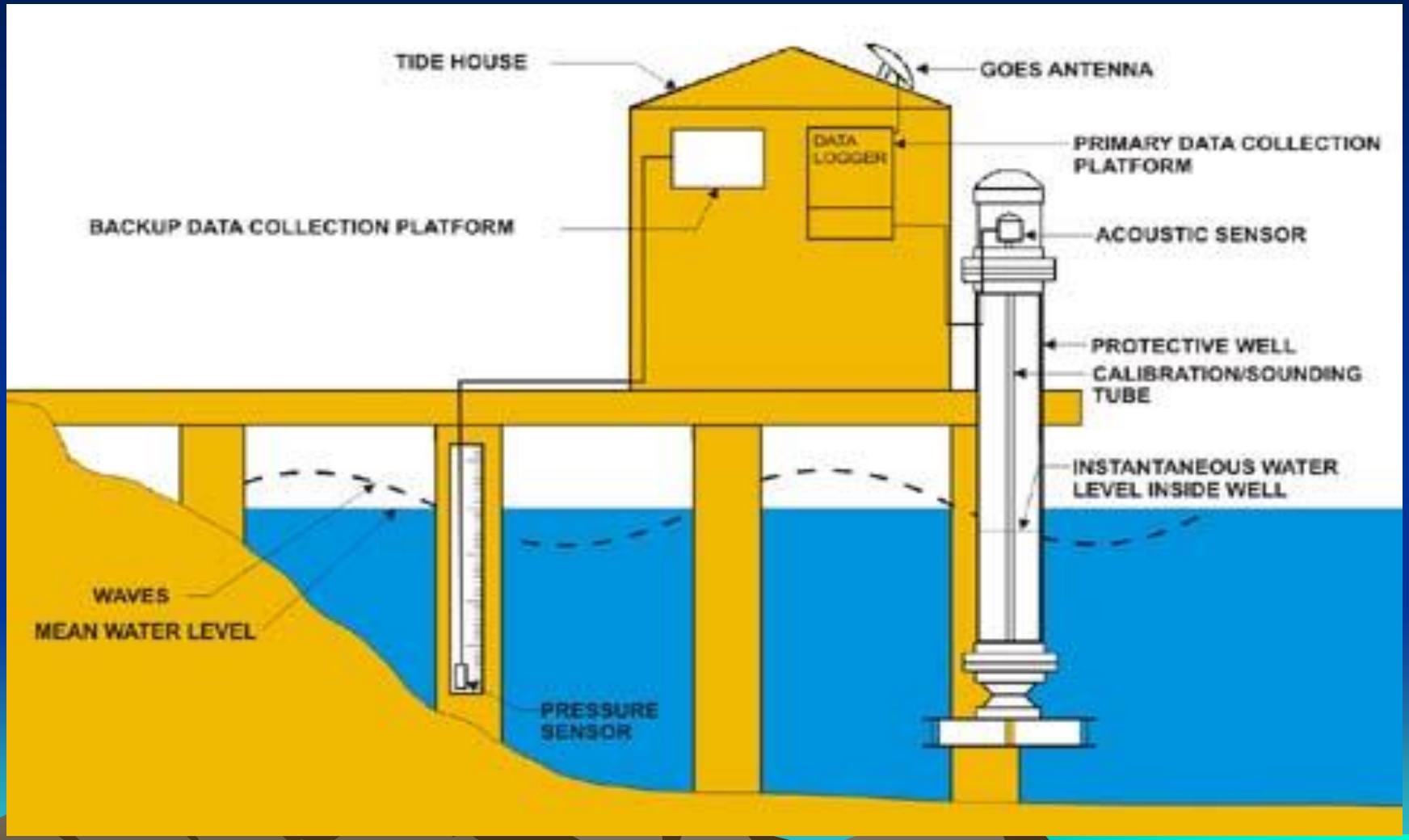
How low was sea levels during glacial periods?
~ 120 m



Sea-level measurement records since 1954

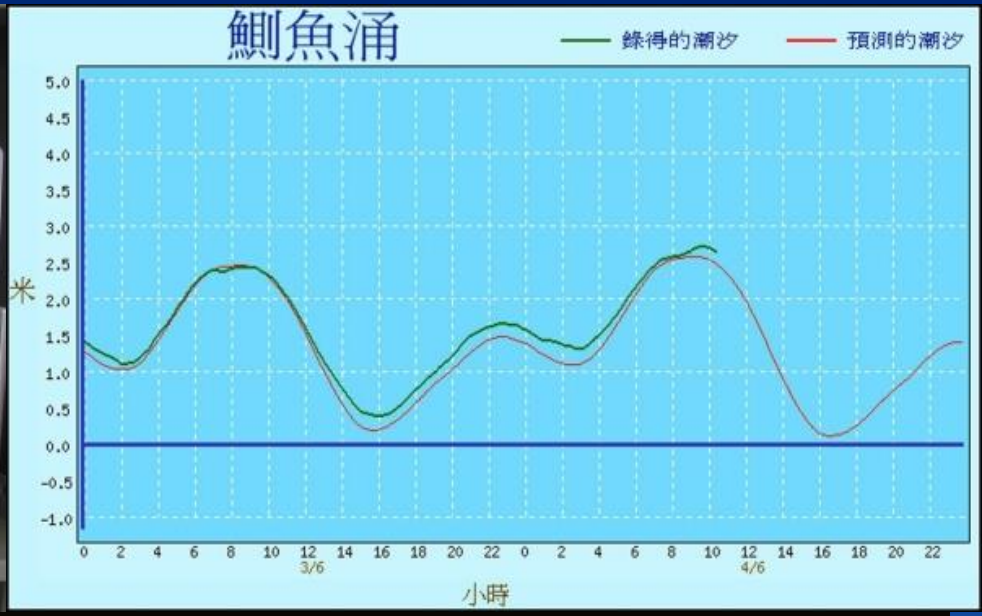
Location of tide gauges of the Hong Kong Observatory

Diagram of a mechanical float tide gauge
Source: NOAA



Mechanical float tide gauge

Tide data recoding equipment

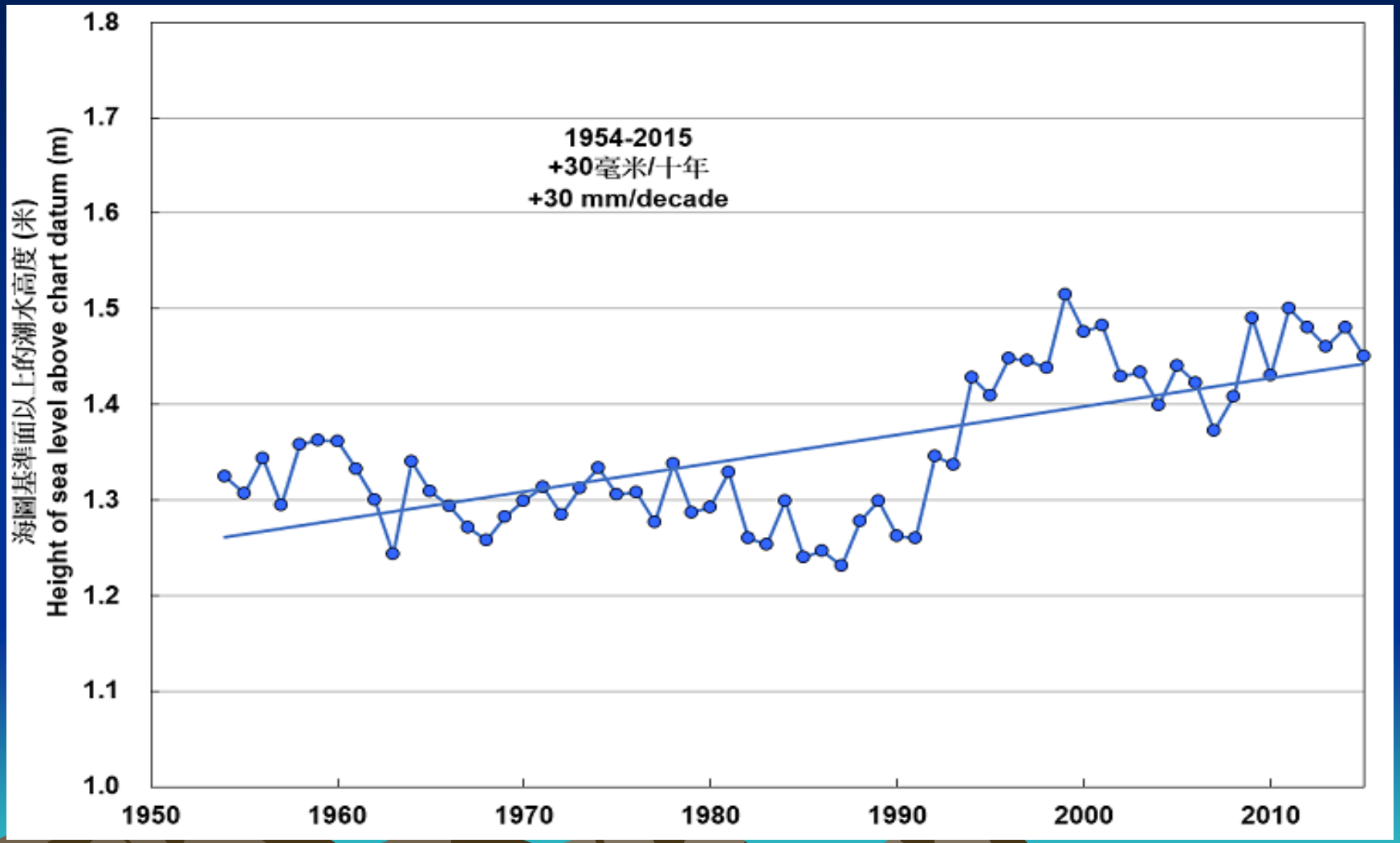


Tide chart for Quarry Bay Tide Gauge Station

North Point Tide Gauge 1954-1986

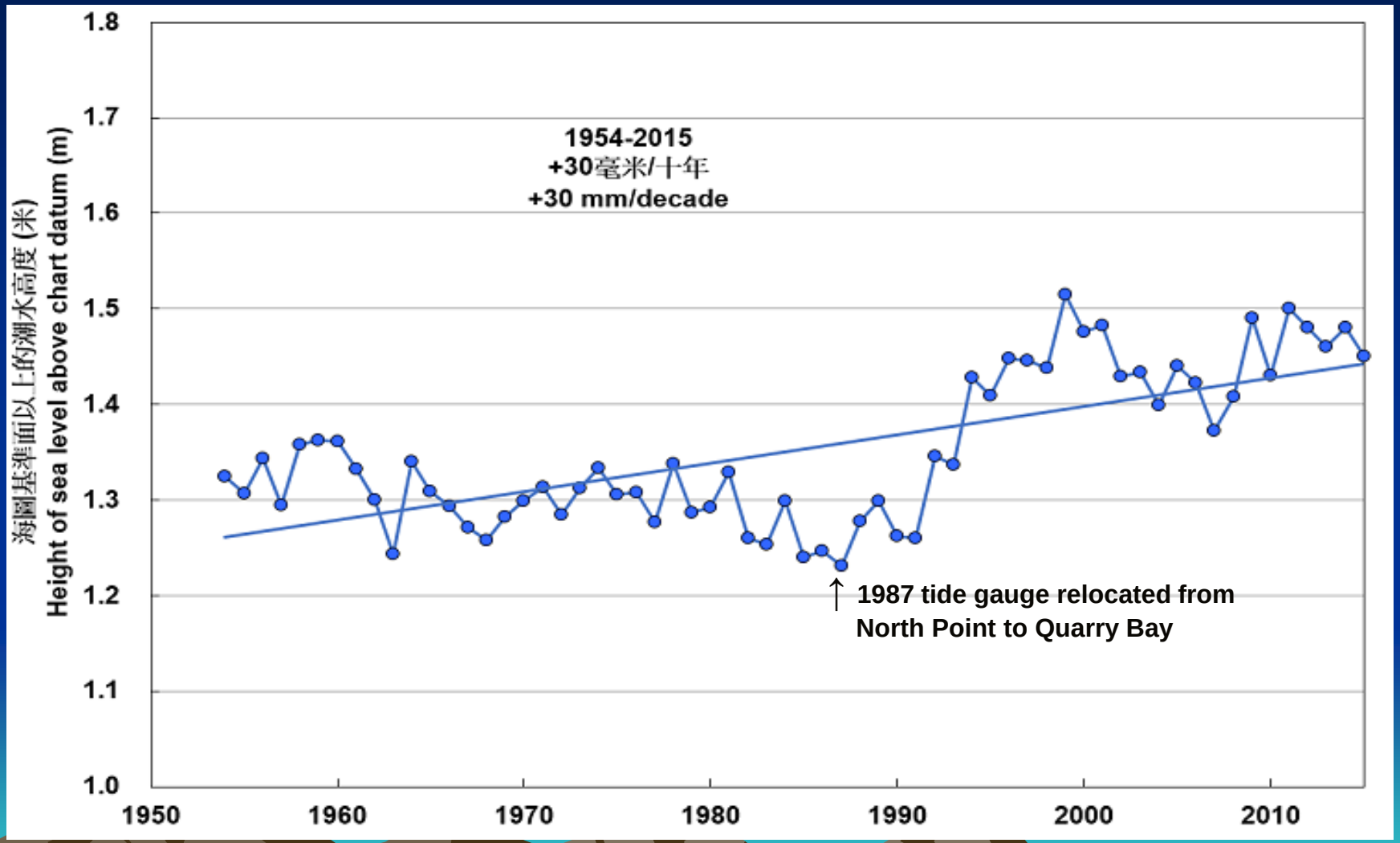
Quarry Bay Tide Gauge 1987- present

Changes in height of sea level in Victoria Harbour 1954-2015



Source: HK Observatory

Changes in height of sea level in Victoria Harbour 1954-2015



Source: HK Observatory

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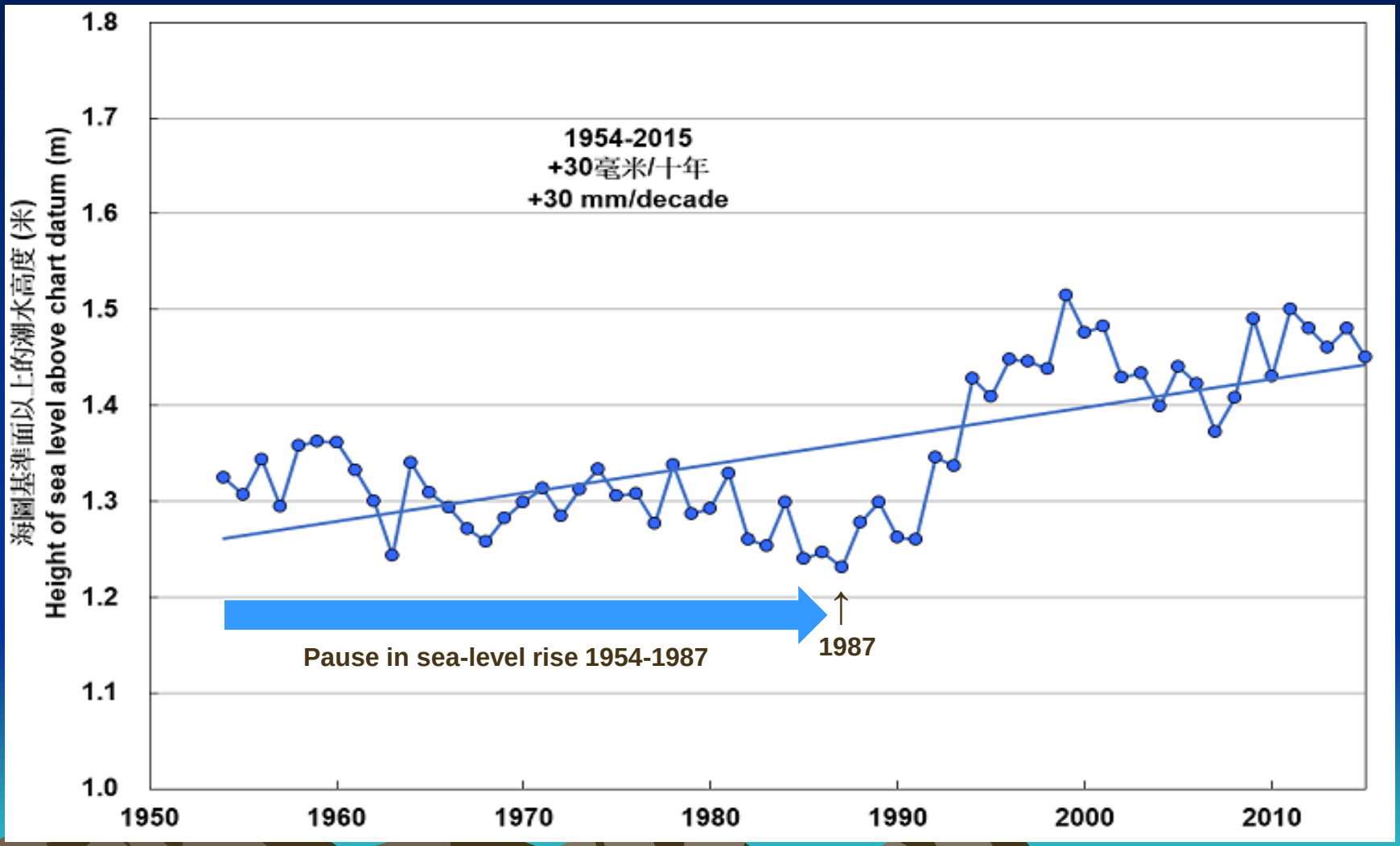
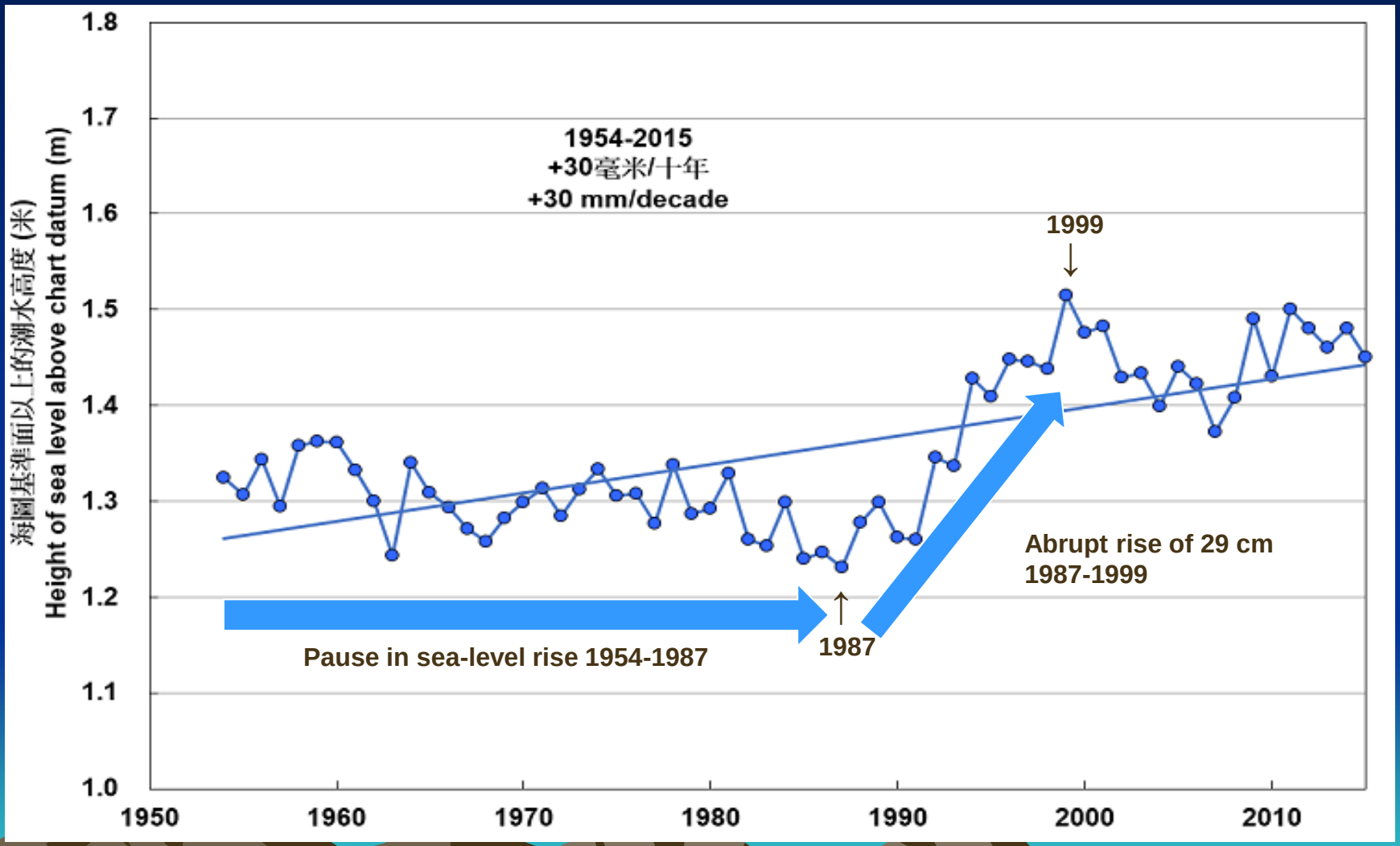


Source: HK Observatory

Changes in height of sea level in Victoria Harbour 1954-2015



Source: HK Observatory

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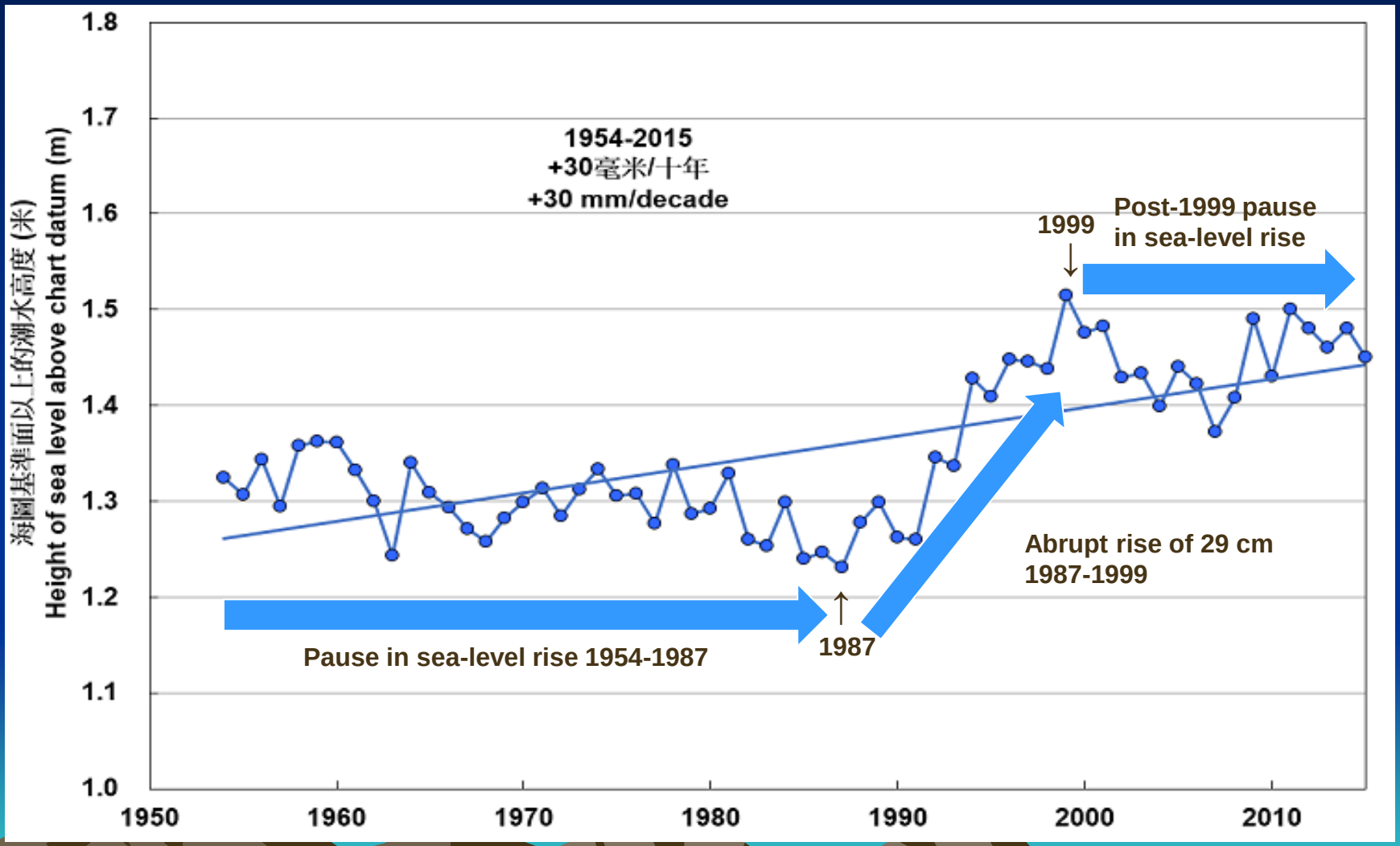
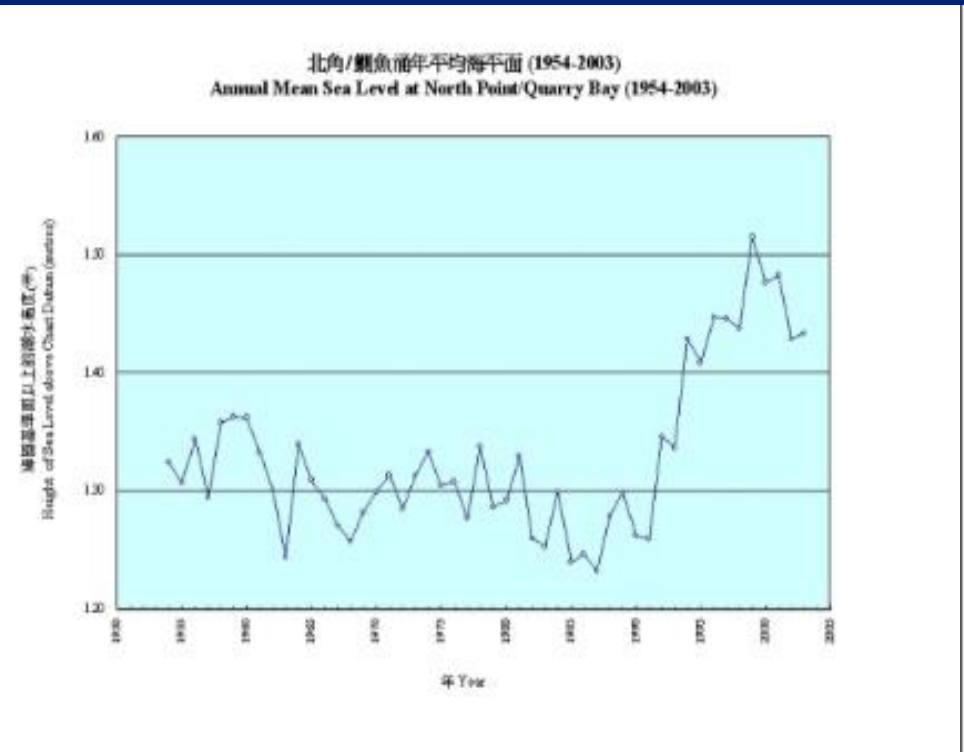
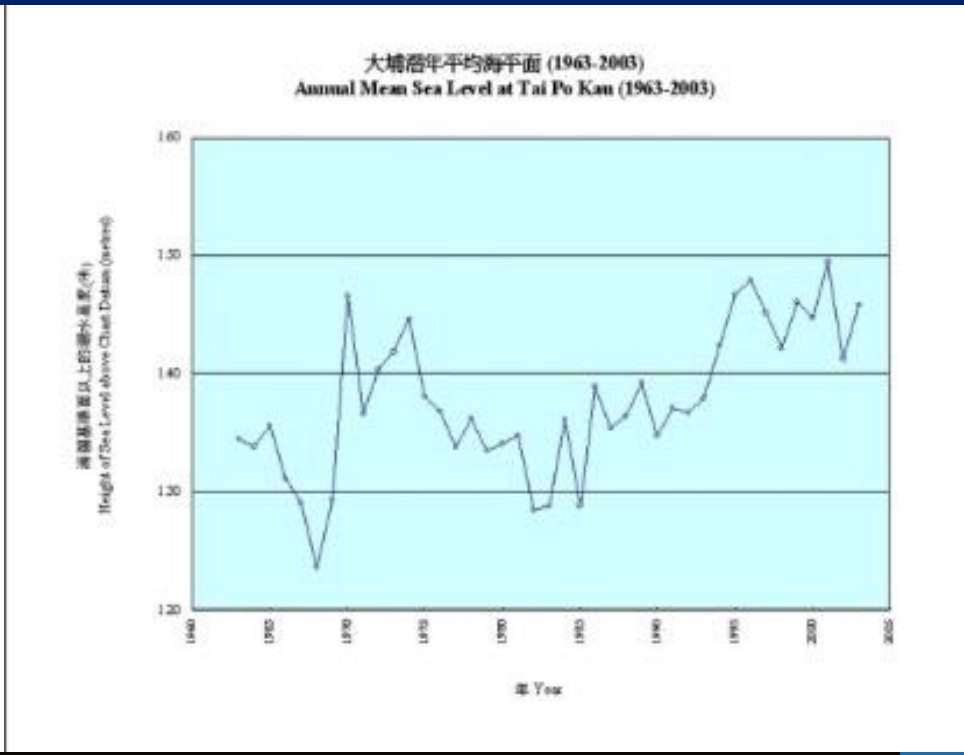


Source: HK Observatory

Comparison between tide gauge records at North Point/Quarry Bay and Tai Po Kau 1963 to 2003



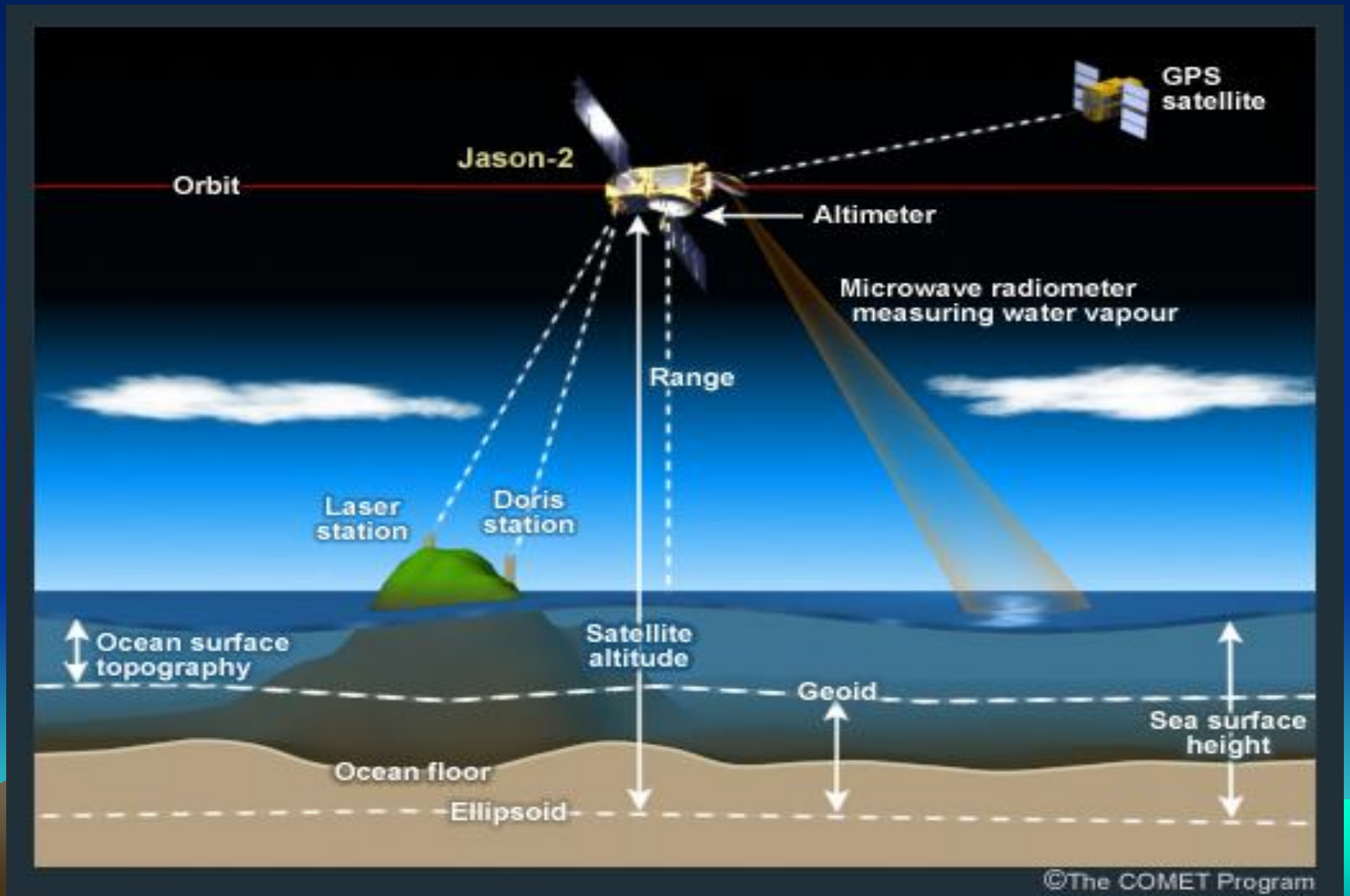


Abrupt rise of 29 cm from 1987-1999

Rise of 12 cm from 1987-1999

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

Satellite altimetry record available since 1993

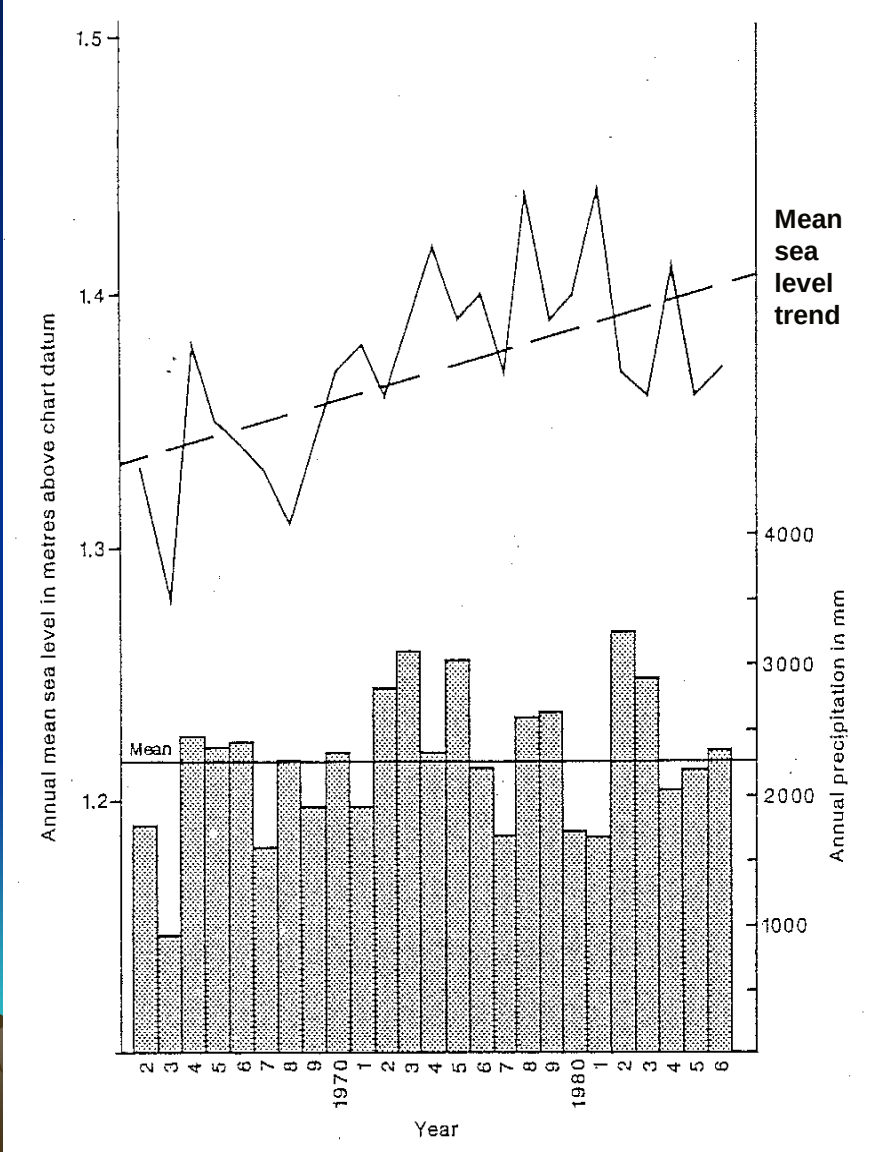


Rates of sea-level change in Hong Kong and the South China Sea based on different studies

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

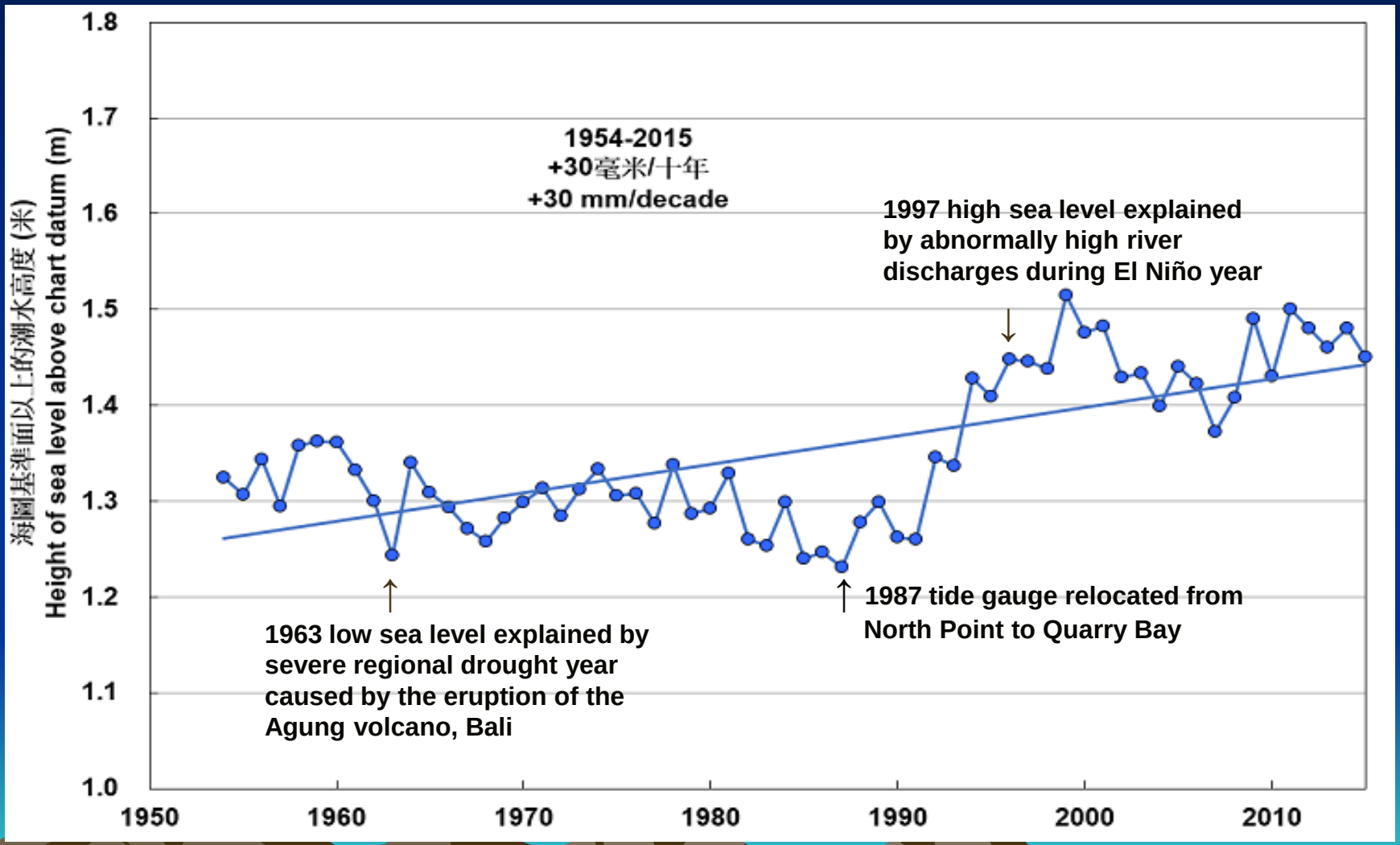
+ The rate of change found is similar to Ding et al. (2002) who studied 1954-1999 data

Annual mean sea level trend of the North Point tide-guage station and annual rainfall of the Hong Kong Observatory Station during 1962-86 (from Yim 1993)



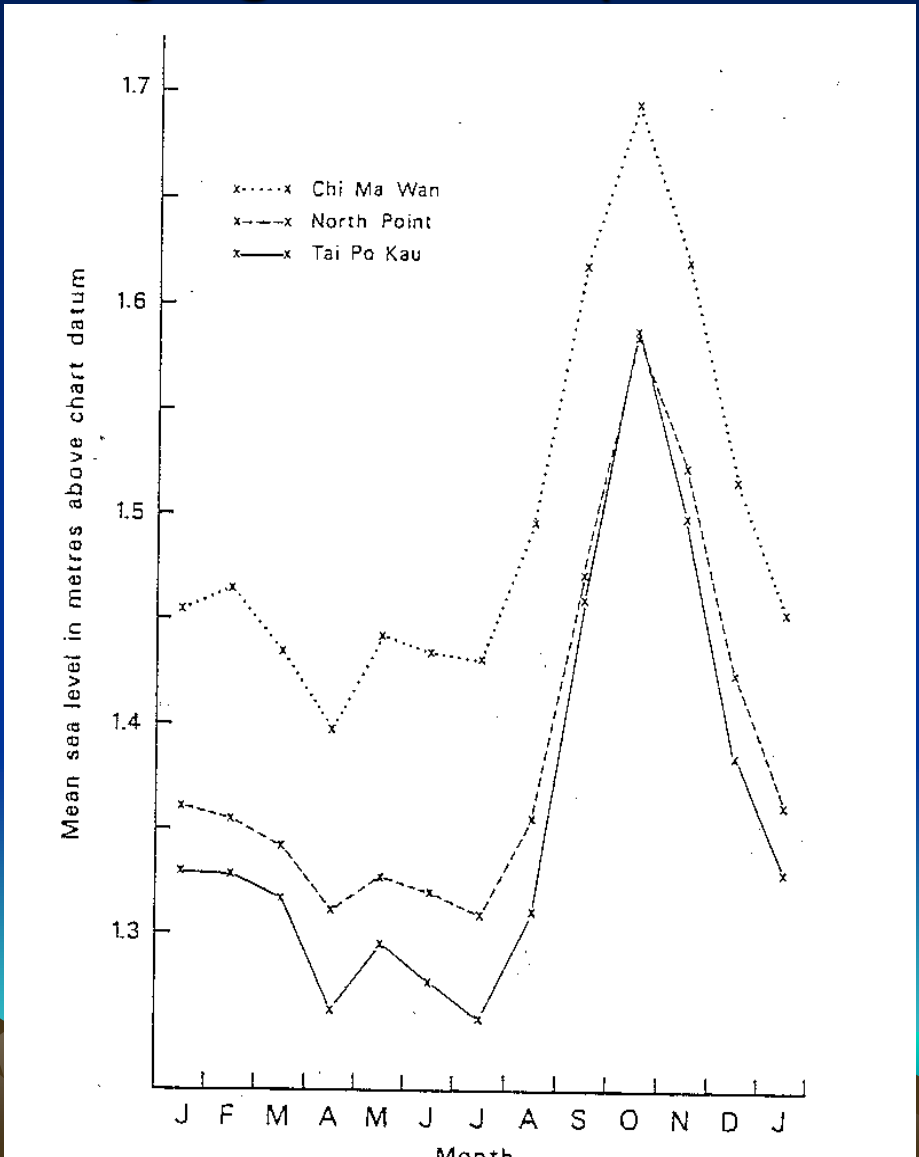
Moderate positive correlation coefficient between mean sea level and annual precipitation (r = 0.4) suggests regional runoff into the sea or low central mean sea level pressures may be causing sea level to rise

Changes in height of sea level in Victoria Harbour 1954-2015



Source: HK Observatory

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

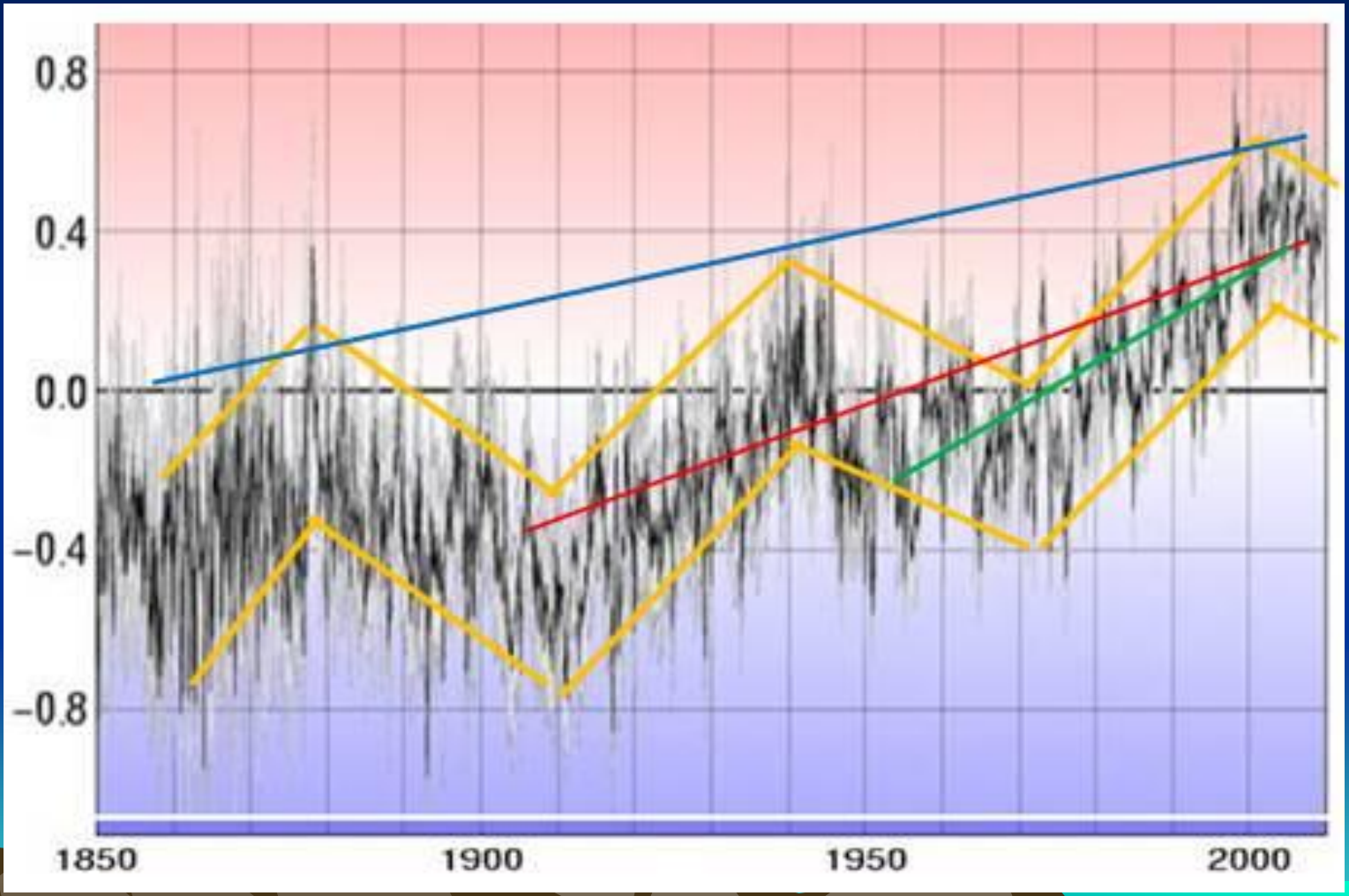


Difference explained by coastal configuration –
Tai Po Kau highest
Chi Ma Wan intermediate
North Point lowest

Location of tide gauges of the Hong Kong Observatory

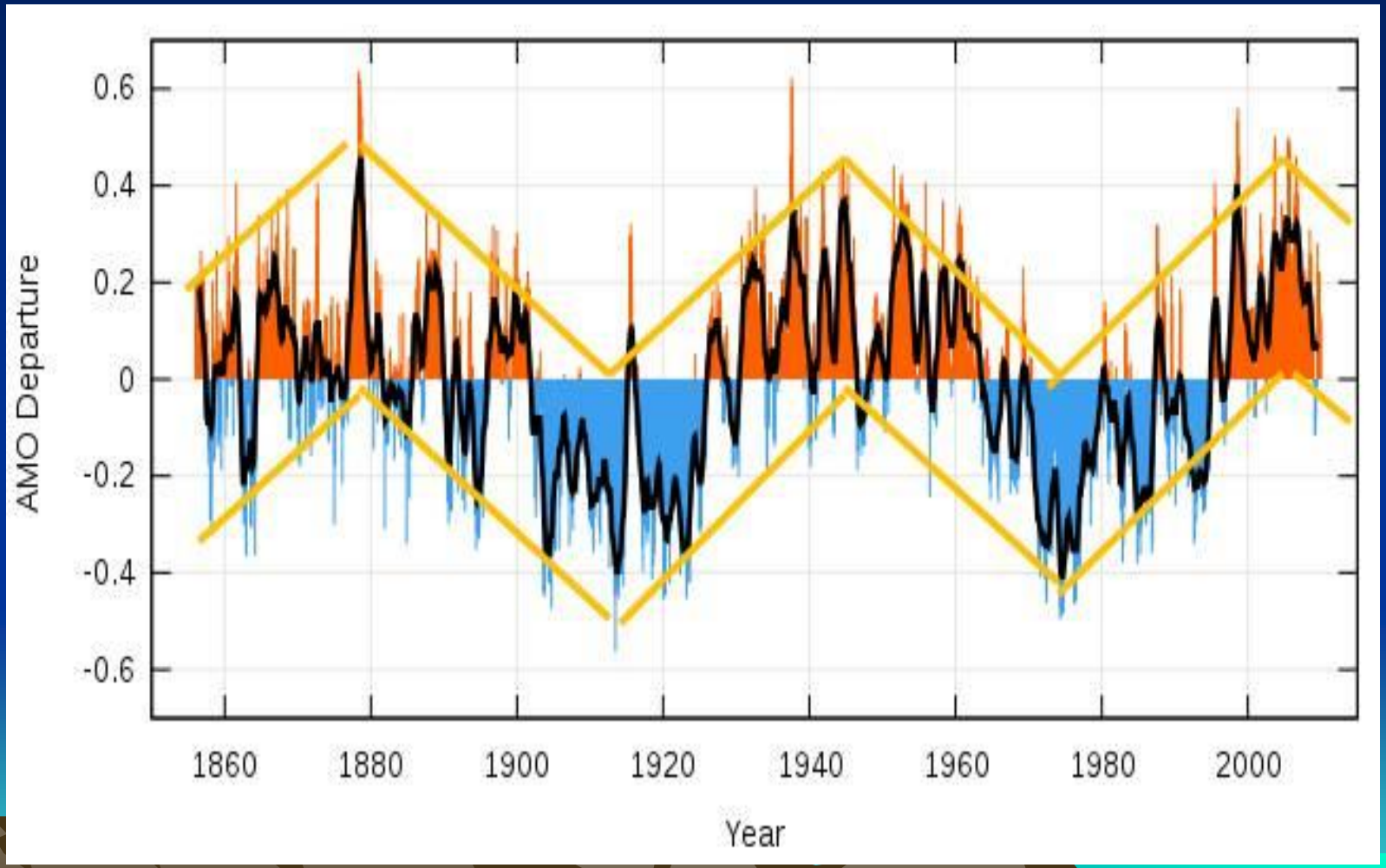
Global temperature anomalies and 60-year cycles

Blue – since 1850 **Red – since 1900** **Green – since 1950**

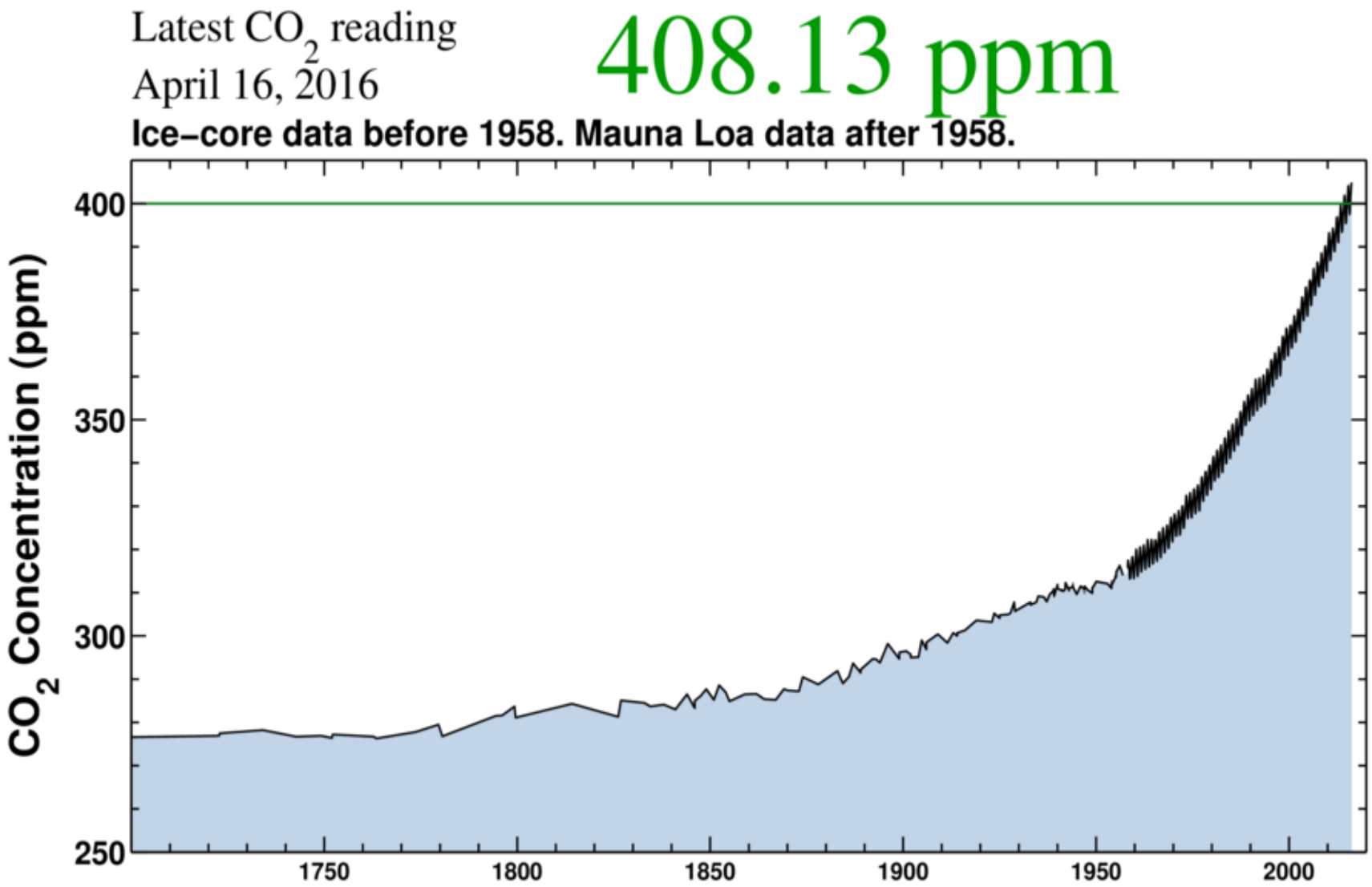


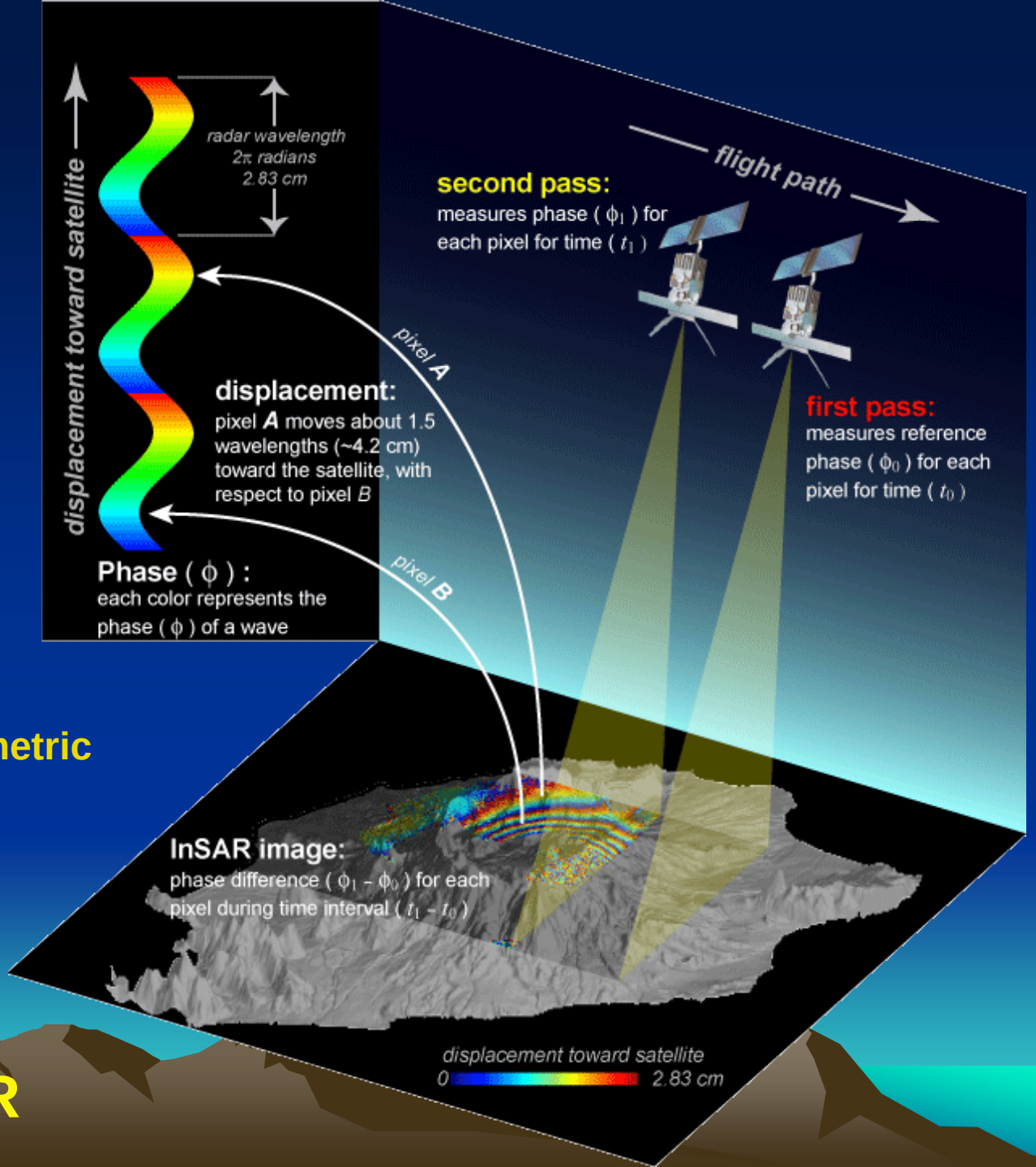
Atlantic Multidecadal Oscillation anomalies 1850-2009 with 62-year cycles (Knudsen et al. 2011)

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



Atmospheric carbon dioxide concentrations from ice cores before 1958 and Mauna Loa data after 1958





Interferometric Synthetic Aperture Radar

INSAR

Conclusions

(1) Tide gauge and satellite remote sensing record are too short at present to be conclusive.

(2) Tide gauges must be located on bedrock to eliminate noise caused by ground settlement.

(3) The average rate of sea-level rise of 30 mm/decade of the HKO is an overestimate.

(4) 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.

(5) Short-term noise in sea level identified include river discharges and the Pacific Decadal Oscillation.

(6) Storm surge flooding generated by typhoons is an immediate enemy.

Thank you