Hong Kong's sea-level record from ~0.5 million years

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Presentation to the Climate Realists of Five Dock, Sydney on 27th April, 2023

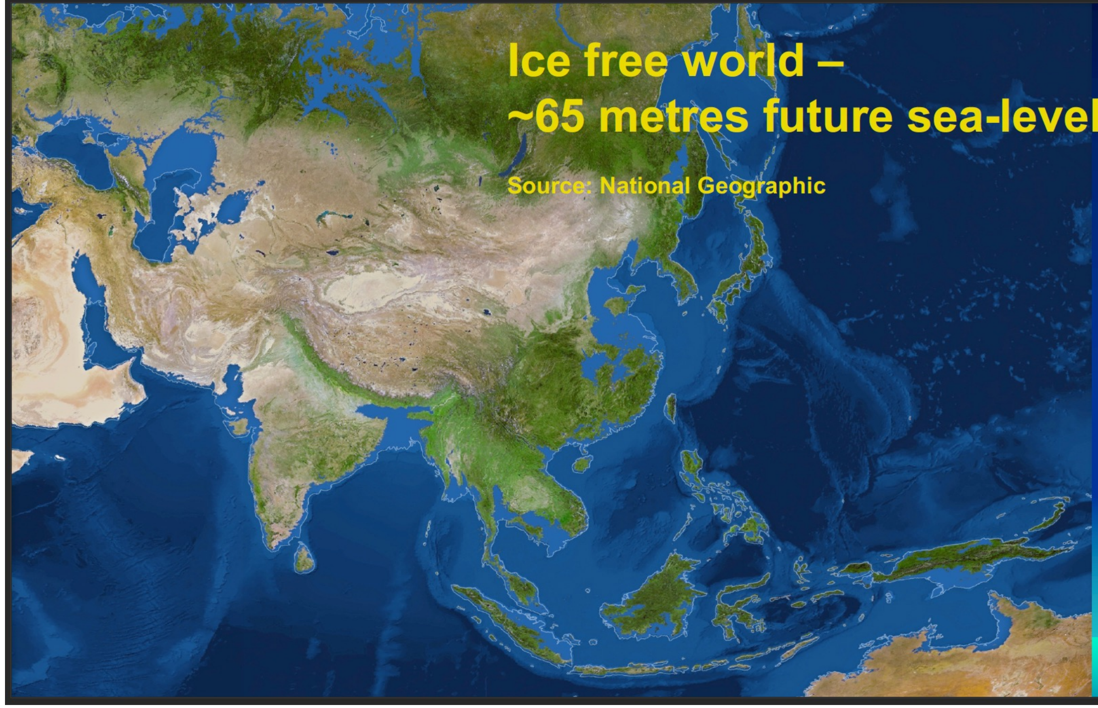
Plan

(1) Introduction

(2) ~0.5 million year record of global sea-level change

(3) Tide gauge records 1954-2022

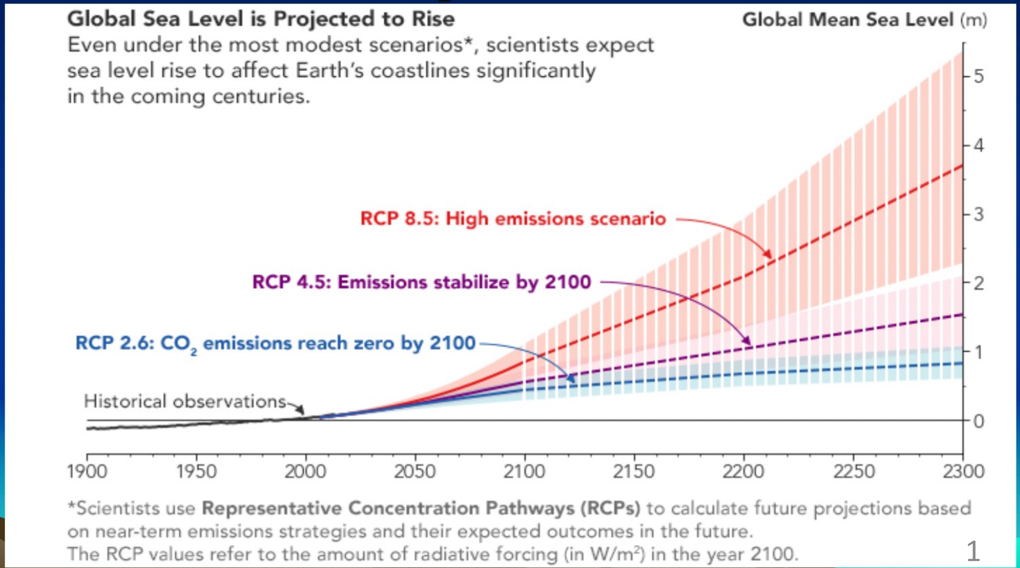
(4) Conclusions



Ice free world – ~65 metres future sea-level rise?

Source: National Geographic

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



Why is this an oversimplification blaming carbon dioxide?

Satellite image of Hong Kong, Pearl River Delta and Estuary

Features –

Submerged highland

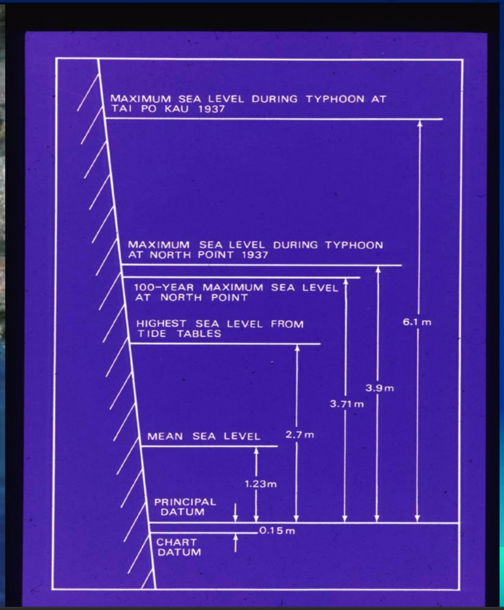
Prograding delta with sediment loading

Neotectonics

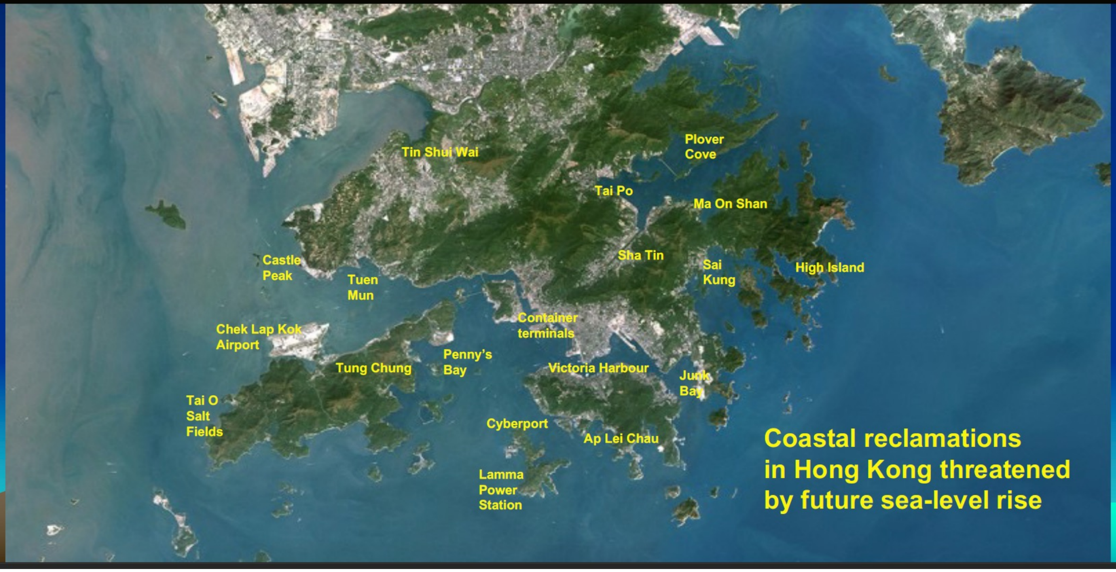
Man-made reclamations and crustal loading

Groundwater withdrawal

Sea-level datums in Hong Kong



About 15% of Hong Kong's total land area of 1100 km² is comprised of low-lying coastal reclamation under 5 m above mean sea level



Coastal reclamations in Hong Kong threatened by future sea-level rise

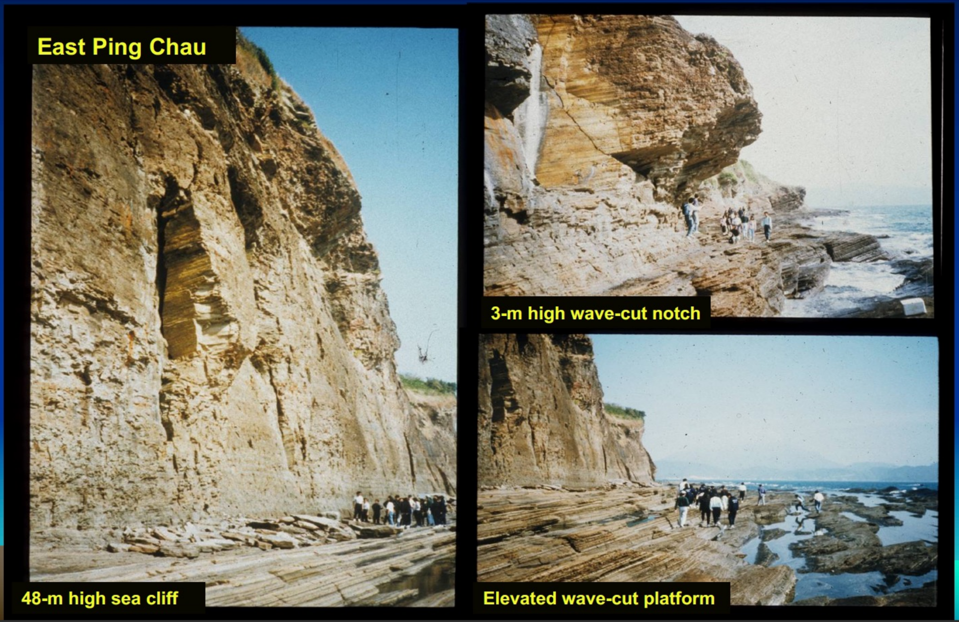
Factors affecting sea-level stability after Morner (2013) with modifications

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

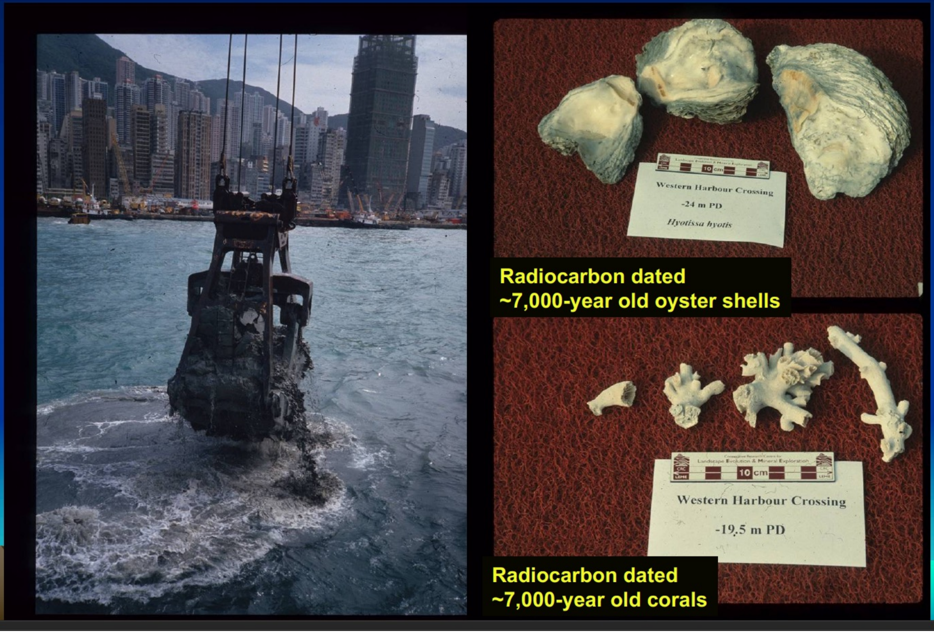
~0.5 million year sea-level record of global climate change

How high was sea levels during past interglacials?

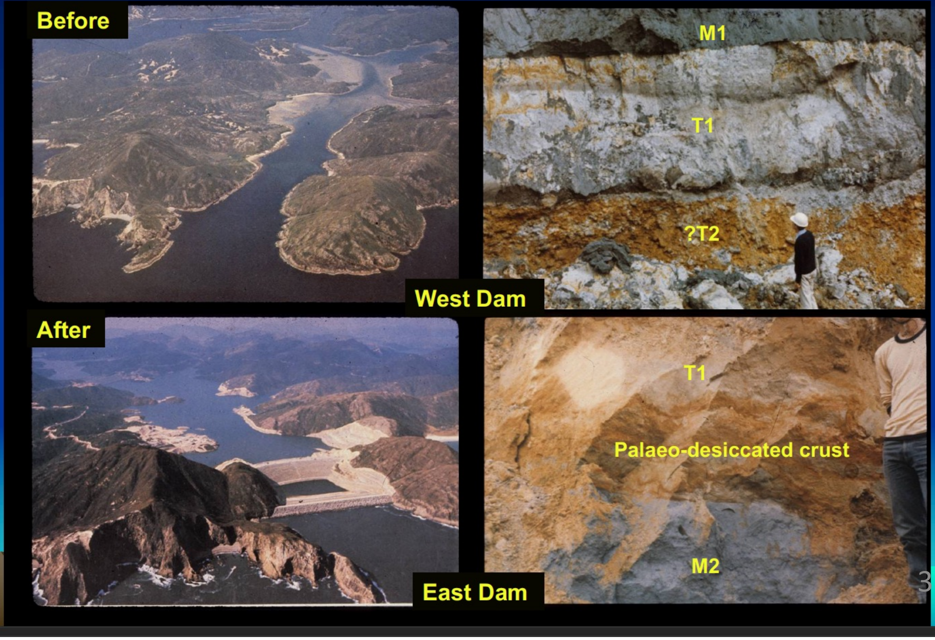
Pleistocene inheritance (Hopley)



Sea-floor dredging for the Western Cross Harbour Tunnel



Excavation of marine dam foundations, High Island Reservoir



Excavation of the Sheung Wan Station, Island Line Mass Transit Railway

Last interglacial oyster shells – Radiocarbon age 30 ka Uranium-series age 130 ka

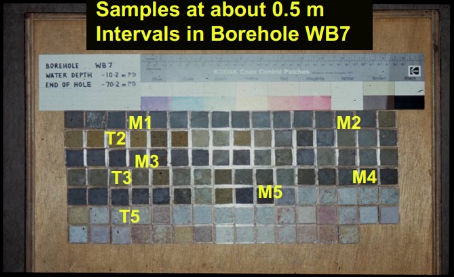
Evidence from continental shelf drilling

A drill barge

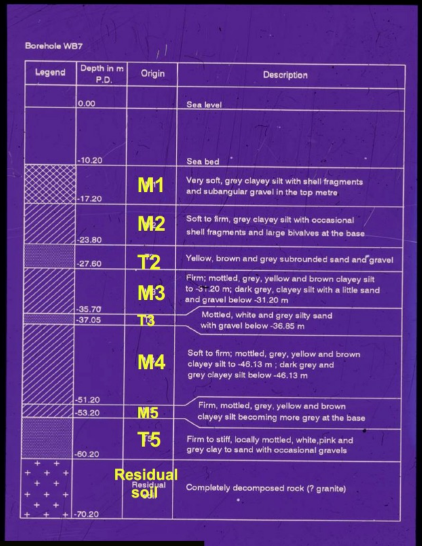
Drilling in action

A continuous 60-m core

Drillhole in the West Lamma Channel showing five interglacial-glacial cycles



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

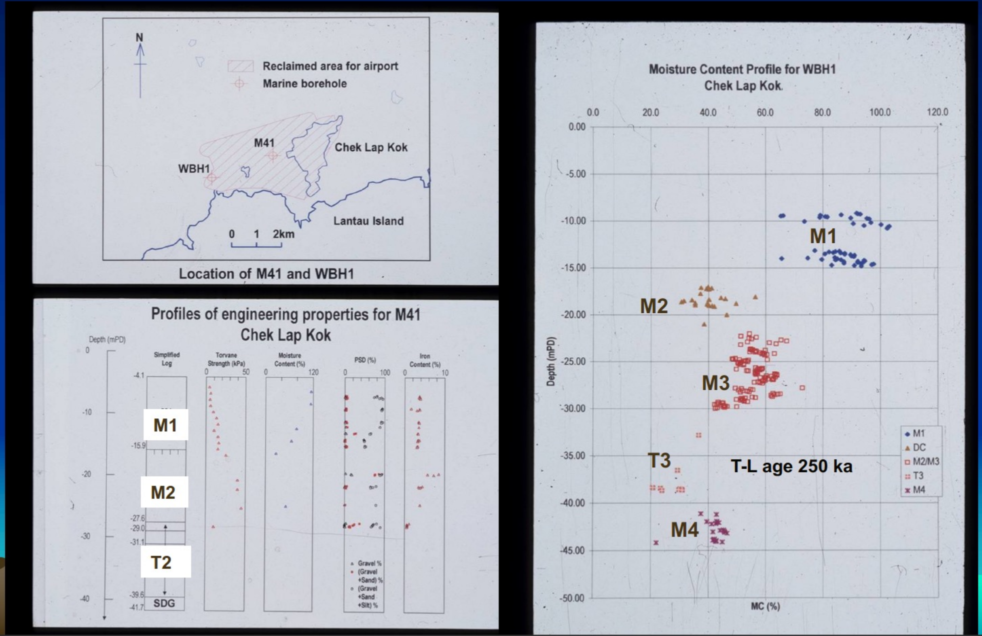
Unit	Age	Estimated age (ka)	Maximum thickness (m)
M1	Postglacial	< 8.2	21.5
T1	Last glacial	8.2 – 70	6.5
M2	Last interglacial	90 – 140	15.7
T2	2nd last glacial	150 – 180	9.5
M3	2nd last interglacial	190 – 240	12
T3	3rd last glacial	250 – 300	7.3
M4	3rd last interglacial	310 – 340	14.1
T4	4th last glacial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

M – marine T – terrestrial

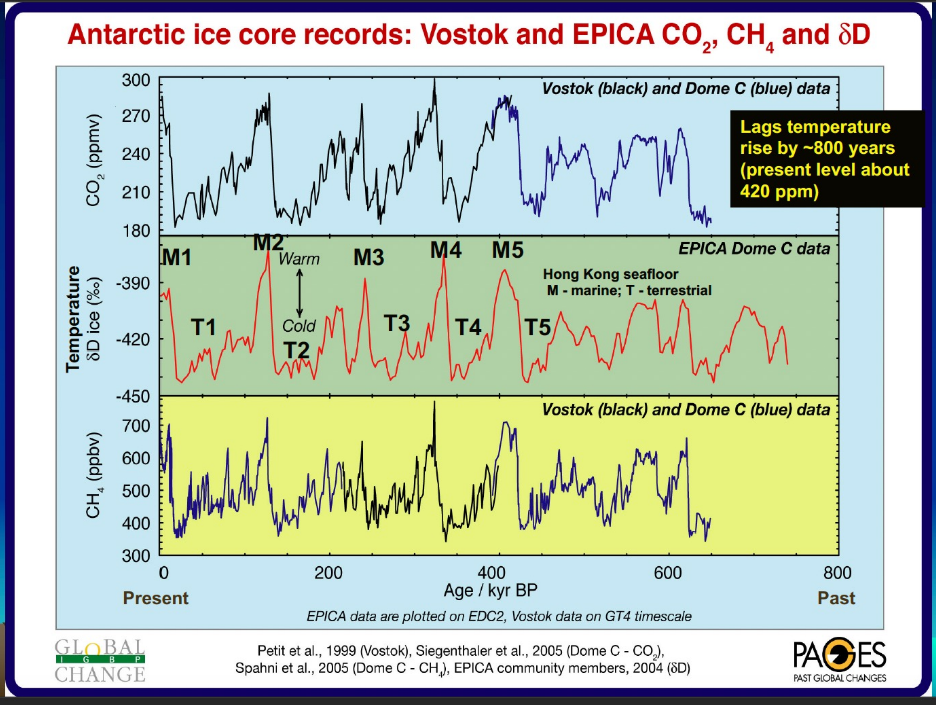
Age determination

(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.

Evidence from moisture content after Choy (2004)



Hong Kong's record



Analysis of tide gauge records 1954-2022

Tide gauges operated by the Hong Kong Observatory

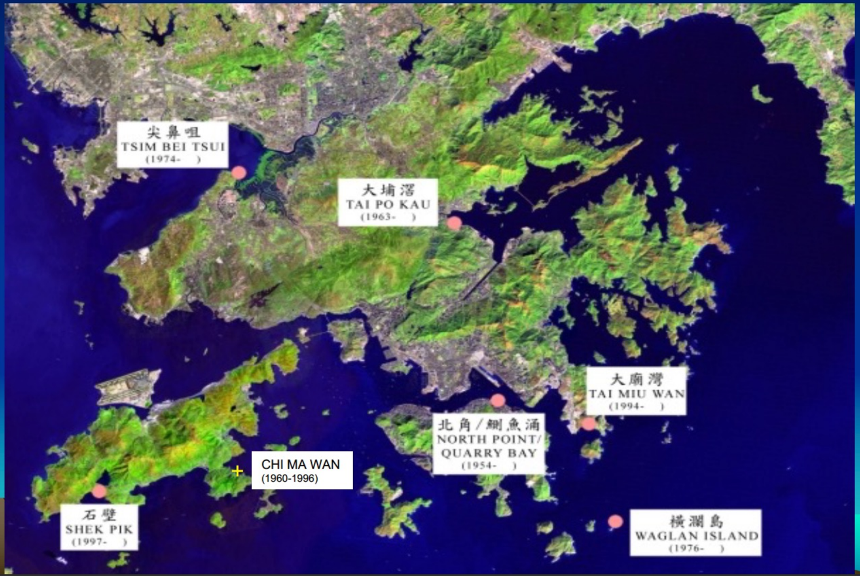
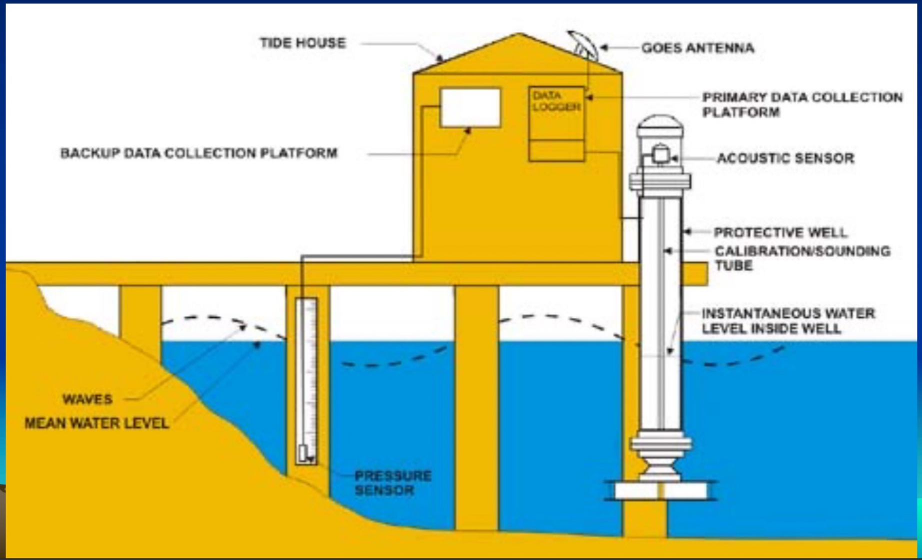


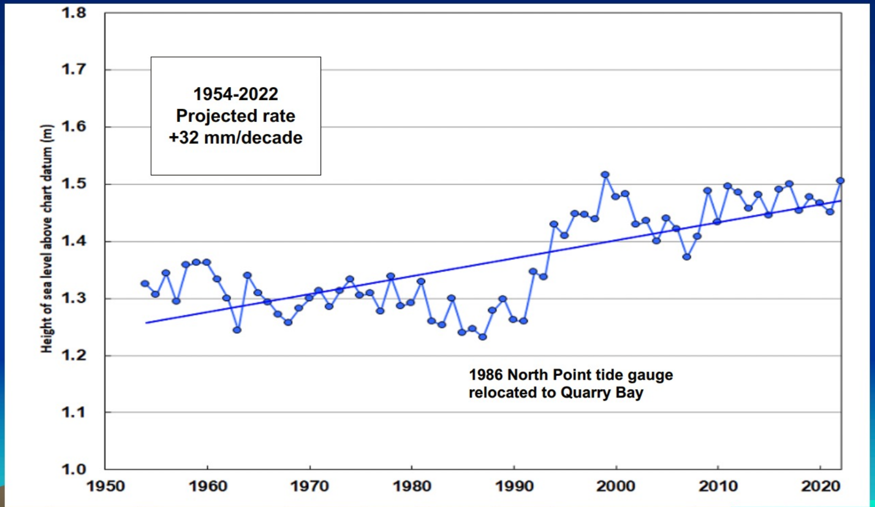
Diagram of a mechanical float tide gauge
Source: NOAA



North Point Tide Gauge 1954-1986
located on seawall of reclaimed land

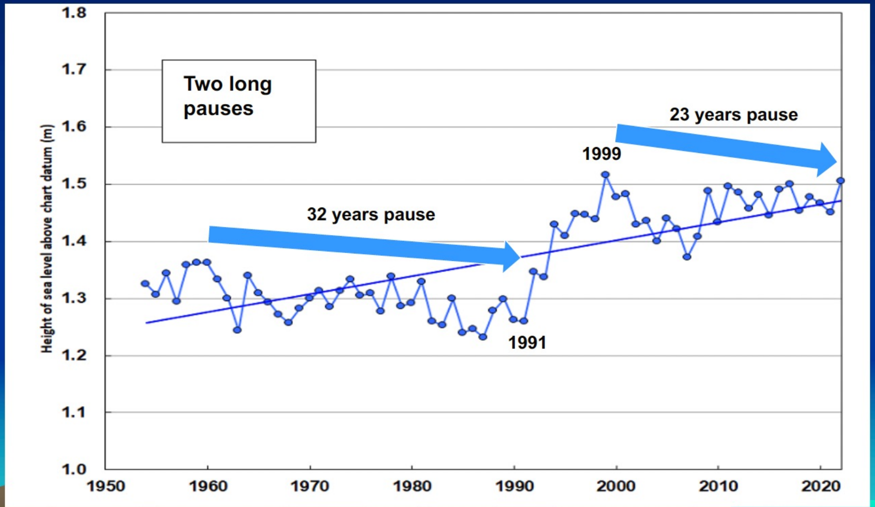
Quarry Bay Tide Gauge 1986-present
located on seawall of reclaimed land

Annual mean sea level in Victoria Harbour based on the combined records of the North Point/Quarry Bay Stations

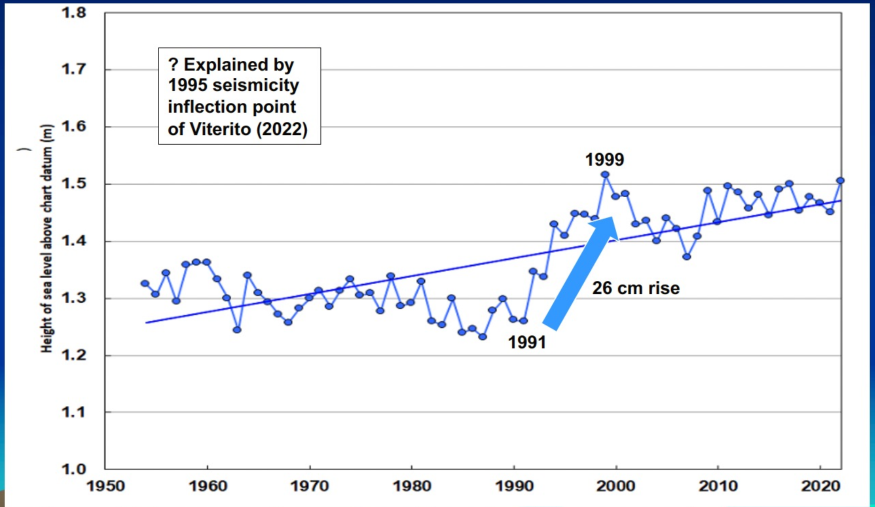


Source: HK Observatory

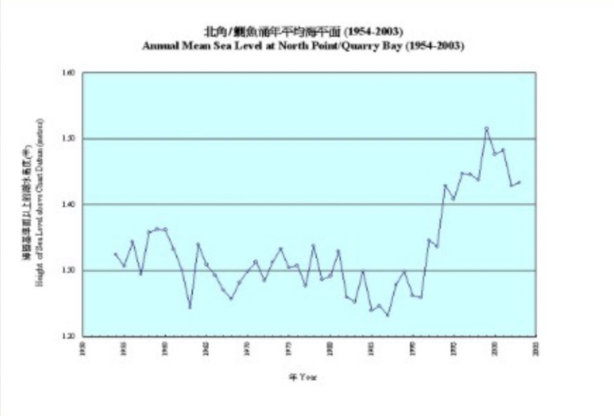
Pauses in sea-level rise of 32 years and 23 years during 1959-1991 and since 1999 respectively

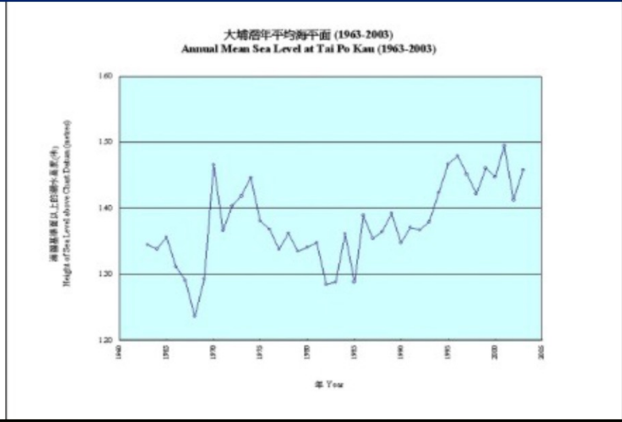


Accelerated sea-level rise during 1991-1999



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



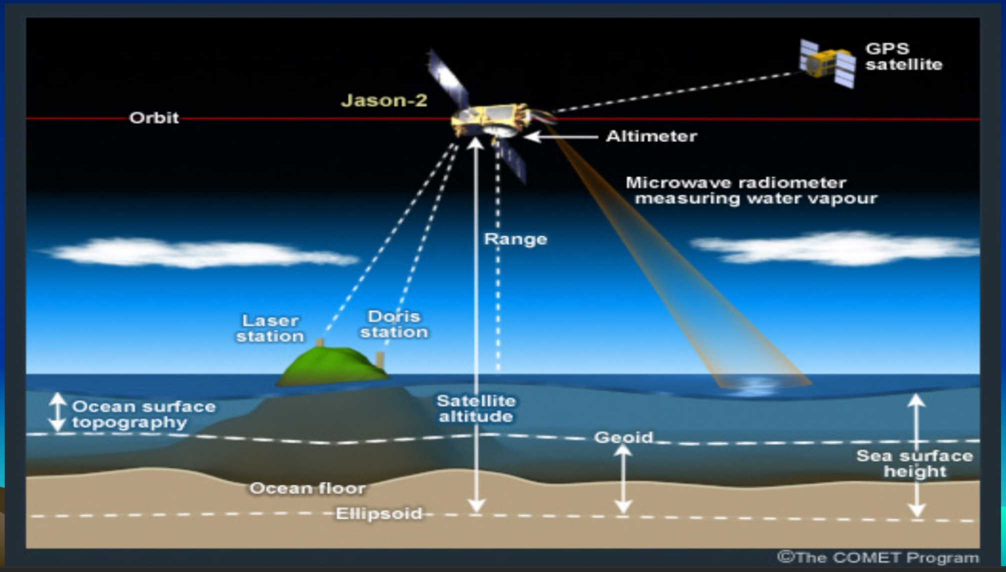


Abrupt rise of 29 cm from 1987-1999

Rise of 12 cm from 1987-1999

~17 cm (59%) difference can be attributed to ground settlement of the Quarry Bay tide gauge

Satellite altimetry record available since 1993

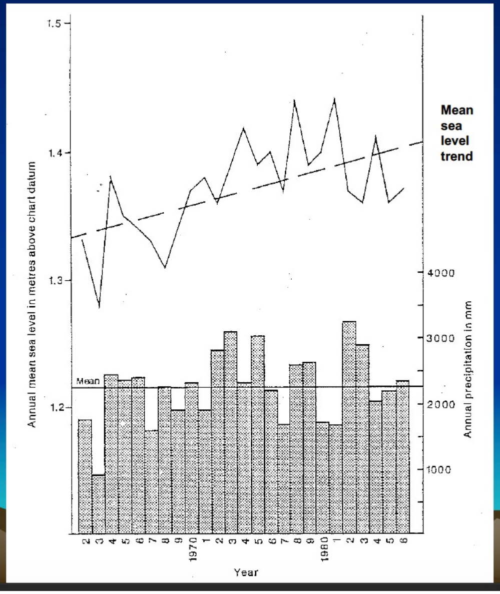


Rates of sea-level change in Hong Kong and the South China Sea based on various studies

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

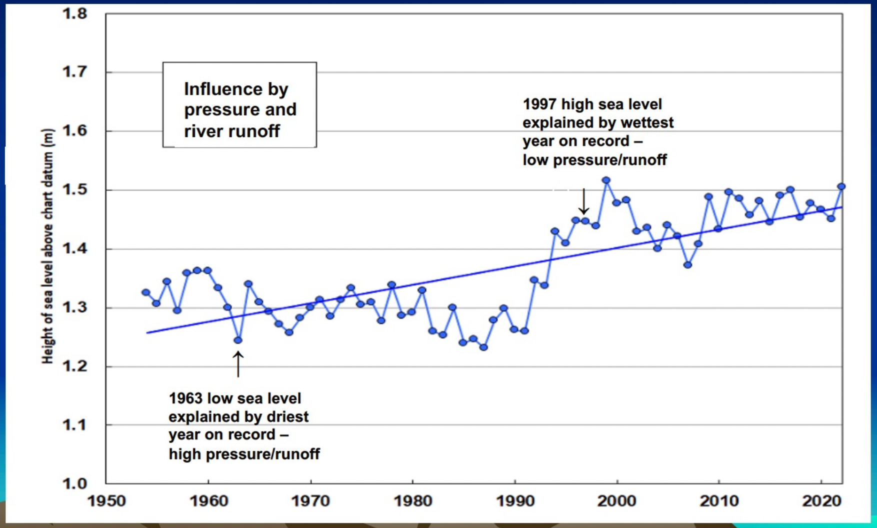
+ The rate of change found is similar to Ding et al. (2002) who studied 1954-1999 data

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



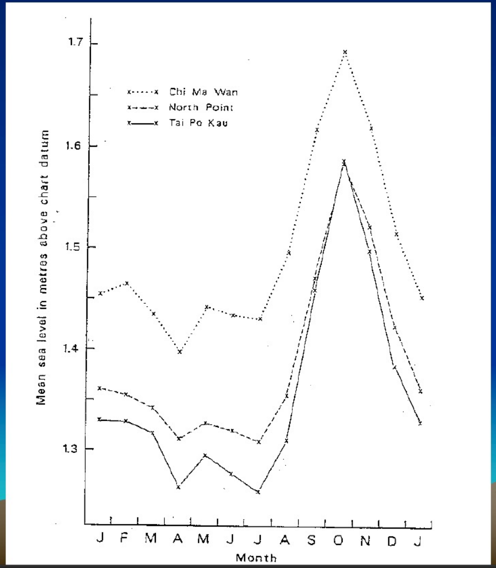
Moderate positive correlation coefficient between mean sea level and annual precipitation r = 0.4 suggests high regional runoff into the sea or low pressure may be a contributor

Annual mean sea level in Victoria Harbour based on the combined records of the North Point / Quarry Bay Station



Source: HK Observatory

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



Differences found explained by monsoonal variability and coastal configuration i.e. pressure and rainfall

Tai Po Kau maximum

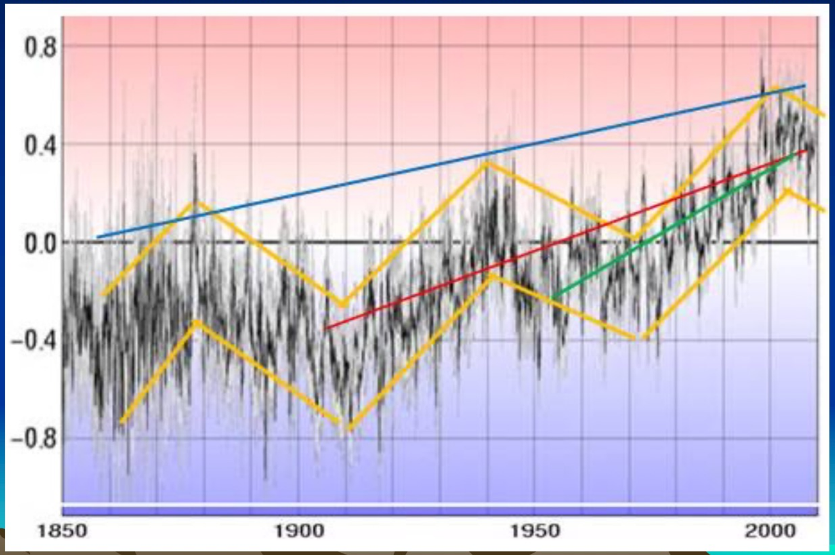
Chi Ma Wan intermediate

North Point minimum

Comparison of monsoonal forcing

Global temperature anomalies and 60-year cycles

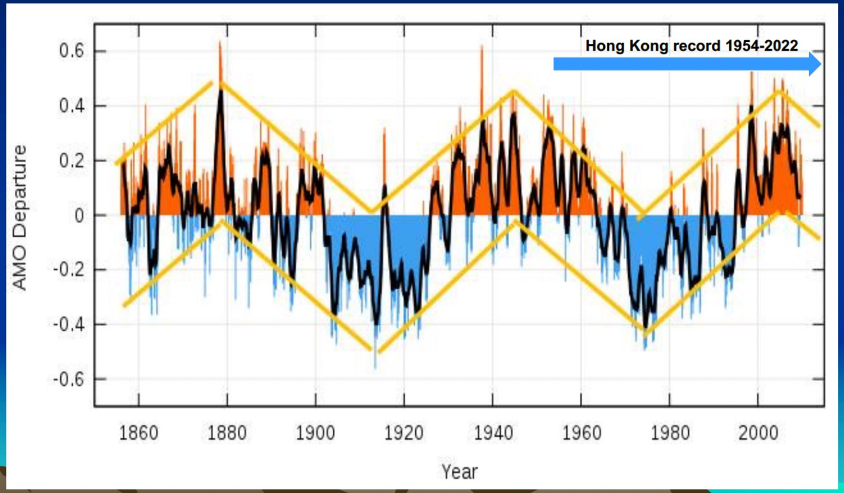
Blue – since 1850 Red – since 1900 Green – since 1950

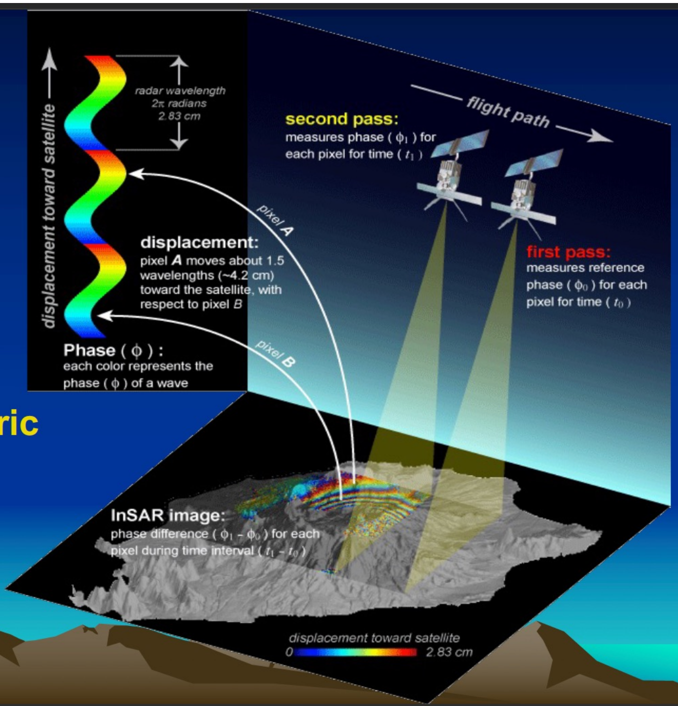


Basis of Chinese calendar

Atlantic Multidecadal Oscillation time series with a 12 month moving average 1856-2013 with 62-year cycles (Knudsen et al. 2011)

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

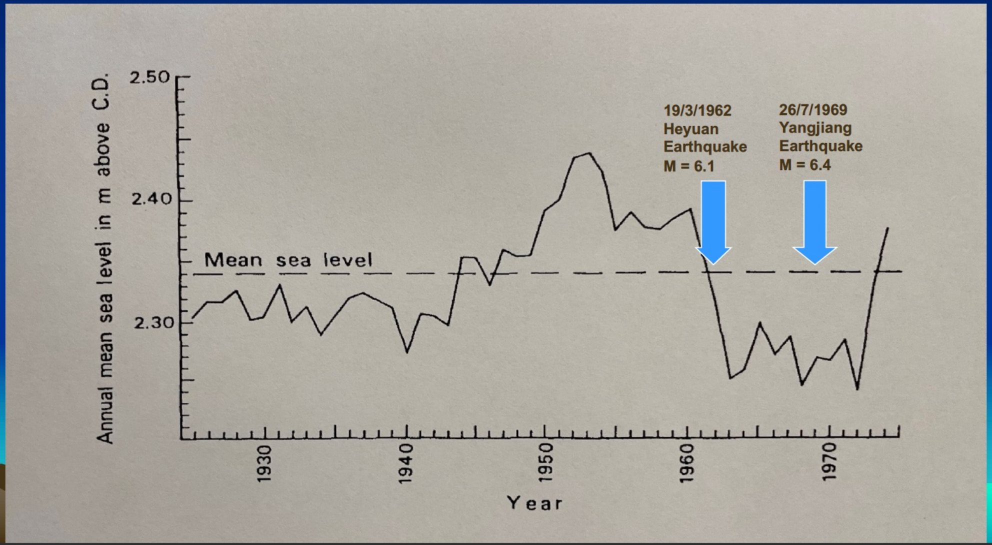




Interferometric
Synthetic
Aperture
Radar

INSAR

Annual mean sea level of the Macau Siac tide gauge station supplied by Macau Marine Department indicating earthquake-induced crustal subsidence



Controlling factors of sea levels in Hong Kong

Type	Feature	Explanation
Astronomy	Cyclic changes in sea level	Cycle length approximately 60 years tracking the Atlantic Multidecadel Oscillation
Tectonics	Crustal instability through loading and unloading	Tectonic movement, erosion and deposition including mass movement and sedimentation
Climate	Lowest uncorrected mean sea level of 1.28m above Chart Datum in 1963	Driest year since record began in Hong Kong's Observatory's Headquarters Station, high local/regional pressure and low Pearl River discharges
	Highest uncorrected mean sea level of 1.51m above Chart Datum in 1999	Possible influence by the wettest year on record in 1997; low local/regional pressure and high Pearl River discharges
	Accelerated sea-level rise 1991-1999	26 cm; partially explained by cyclic climate change
Man-made	Low relative sea level 1985-1987	Uncertainty introduced by the relocation of the North Point Station to Quarry Bay
	Isostasy related sea-level change	Activities including coastal reclamation, construction loading, landfills, quarrying and dredging

Order of importance

1st order

Astronomical forcing and the Sun resulting in cyclic changes e.g. glacial/interglacial cycles, monsoons, seasons and daily

2nd order

Geothermal heat/plate climatology (James Kamis 2014)

www.plateclimatology.com

How geological forces affect the hydrosphere and atmosphere including terrestrial and submarine volcanic eruptions, their associated circulation changes and the release of gases including water vapour, SO_2 and CO_2

3rd order

Human-induced changes including heat generation, water cycle changes and emissions of greenhouse gases

Conclusions

(1) ~0.5 million year record of sea-level change representing five interglacial-glacial cycles driven by ‘real’ global climate change have been identified in Hong Kong.

(2) Uncertainties in the tide gauge record are caused by the location of tide gauge stations and their relocation on reclaimed land prone to ground settlement.

(3) The projected rate of sea-level rise of 32 mm/decade of the Hong Kong Observatory is an overestimate because of a variety of local factors have not been taken into account.

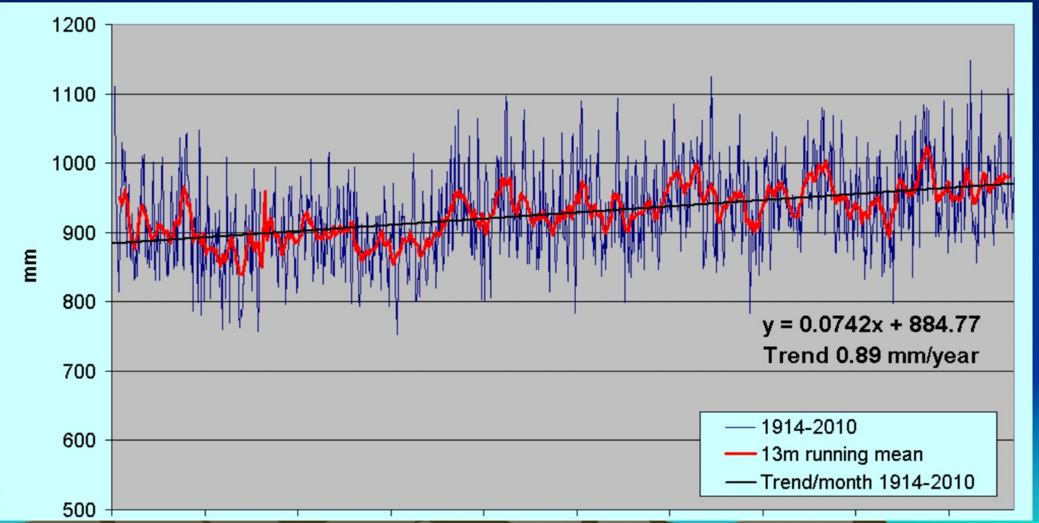
(4) Up to 17 of the 29 cm accelerated sea-level rise observed in the Quarry Bay tide gauge during 1987-1999 may be accounted for by ground settlement.

(5) Natural and man-made factors contributing to sea-level change include sedimentation, crustal loading and unloading, neotectonics, rainfall and river runoff, wind forcing and pressure changes.

(6) Storm surge flooding of low-lying land during typhoons is a past and present concern.

(7) Another fifty years of observations assisted by INSAR are needed to confirm cyclic changes.

Record of Fort Denison, Sydney 1914-2010



Advantages –

Bedrock site unaffected by ground settlement

136-year record

Rising rate over 3 times slower than the rate of Hong Kong Observatory

No scary sea-level rise as shown by the late Bob Carter

Thank you