A swell-dominated shoreline reaches climate-induced recessional tipping point at Ocean Beach, Tasmania*

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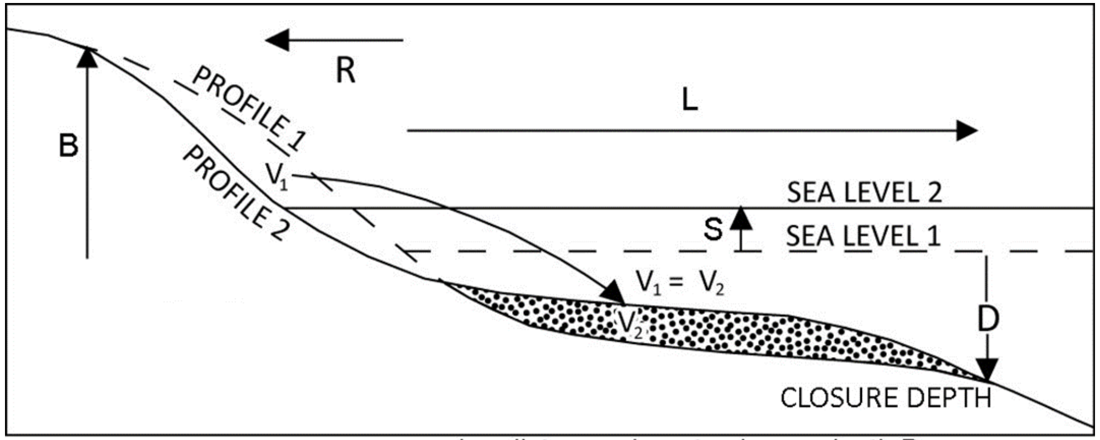
Are we seeing physical responses to recent global sea-level rise in soft coastal landforms yet?

- Sea-level rise should cause shoreline recession (Bruun Rule: well established principle despite much confusion over its implications & application)



Recession: $R = \frac{L}{B + D} S$

L = distance shore to closure depth D
B = dune / berm height
S = sea-level rise

The Bruun Rule of shoreline erosion with sea-level rise: not a complete coastal behaviour model! But a useful coastal process concept used alongside others.

Recent experimental validation by Atkinson *et al.* (2018)

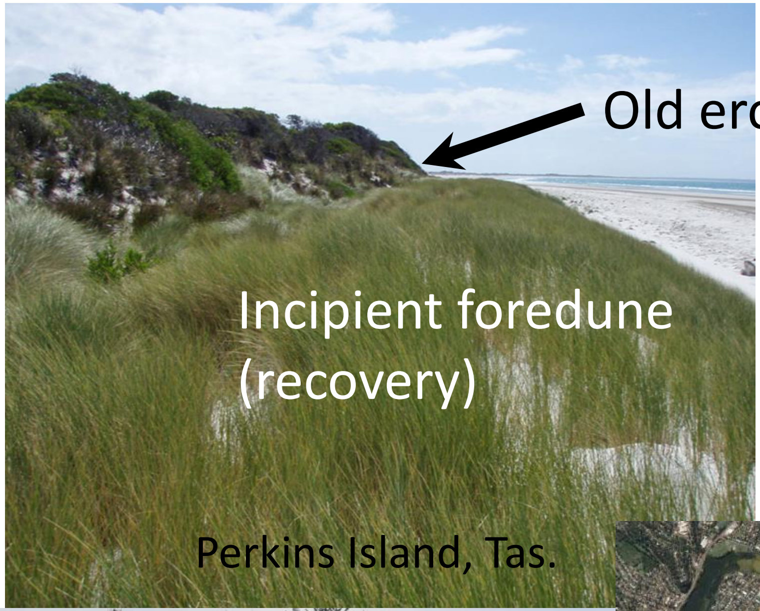
- Global Mean Sea-level (GMSL) has risen ~21 cm since c. 1880s.

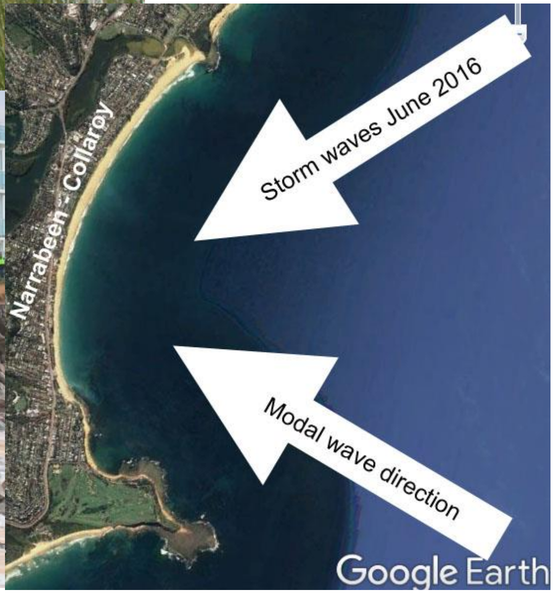
- But there are very few claims in the scientific literature that any coastal erosion & recession to date is specifically attributable to recent global sea-level rise.

Swell-exposed open coast sandy beaches: most not yet responding to recent global mean sea-level rise

In most cases the magnitude of any recession tendencies due to sea-level rise are still much smaller than normal coastal sand movements, which still overwhelm the sea-level rise effects; e.g.:

- Erosion and recovery cycles;
- Episodic wave direction variability causing "beach rotation", e.g., on NSW coast;
- Onshore – offshore shelf sand transport
- Alongshore sand drift





Erosion at Collaroy Beach June 2016; related to beach rotation, NOT sea-level rise (Mortlock et al 2017)

Are there any open coast (swell exposed) sandy beach early responders?

Most beaches are expected to require significantly more sea-level rise than has yet occurred before any change in their behaviour is discernible:

Le Cozannet *et al*. (2016) have suggested a “Time of Emergence” for many open coast sandy beach responses to recent sea level rise might be circa 2050.

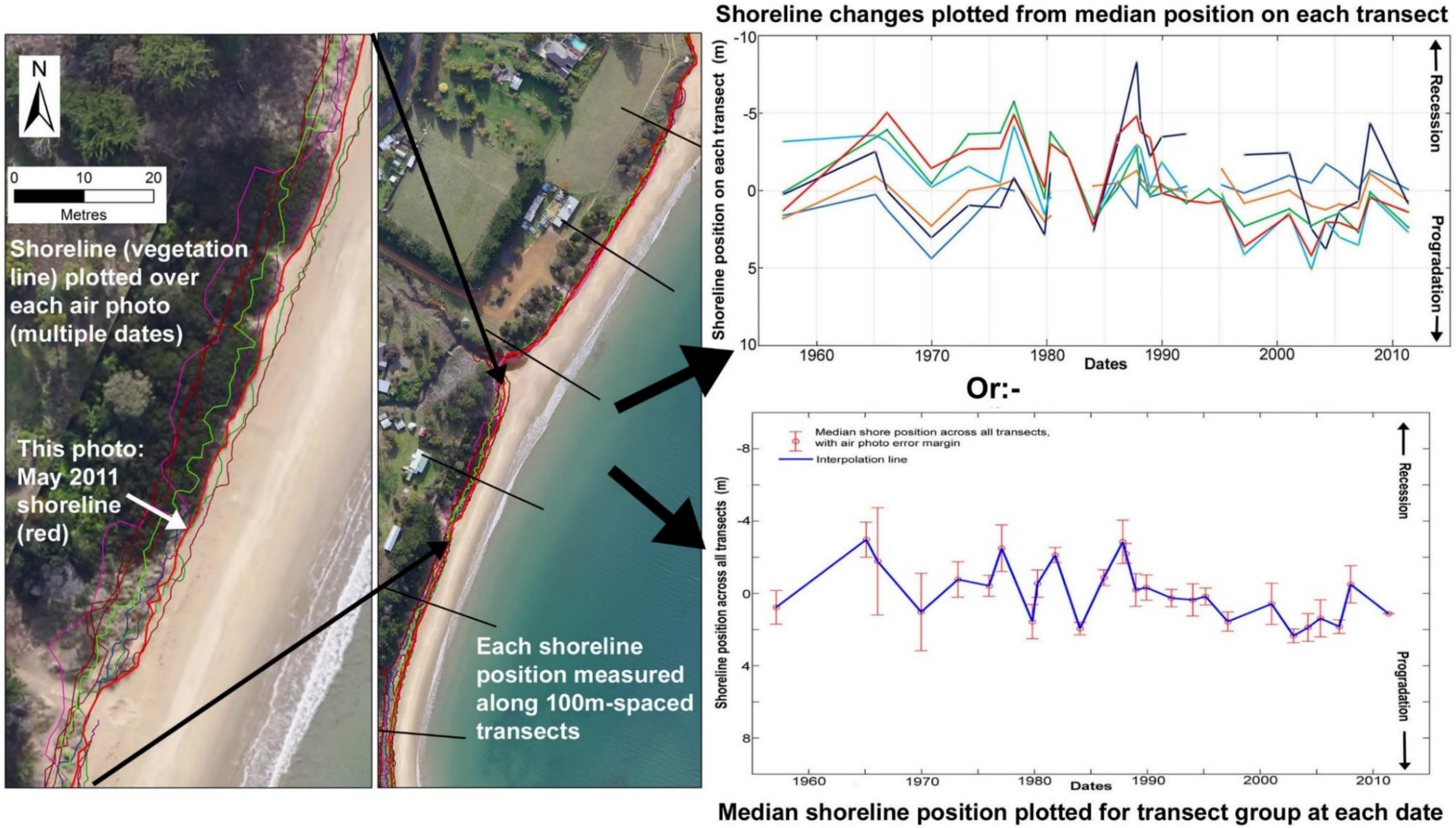
My project asks are there earlier responders to sea-level rise, if so how can we detect them, and what makes them different?

Expect to see a long-term (multi-decadal) change in shoreline behaviour if responding to sea-level rise (typically a switch to persistent shoreline recession).

This presentation describes one potential early responder.

Data source: aerial photography

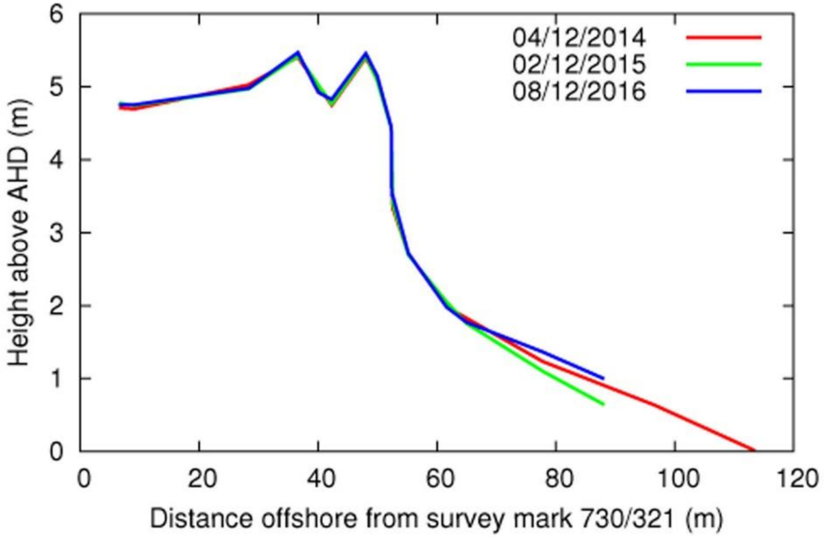
- ~70 year record of shoreline behaviour (for many Australian beaches)
- Mapped shoreline proxy: vegetation line tracks inter-annual to inter-decadal shoreline position change, not shorter term (e.g., seasonal) beach face variability.
- For each site, *all* usable photos ortho-rectified (not just two end dates!)



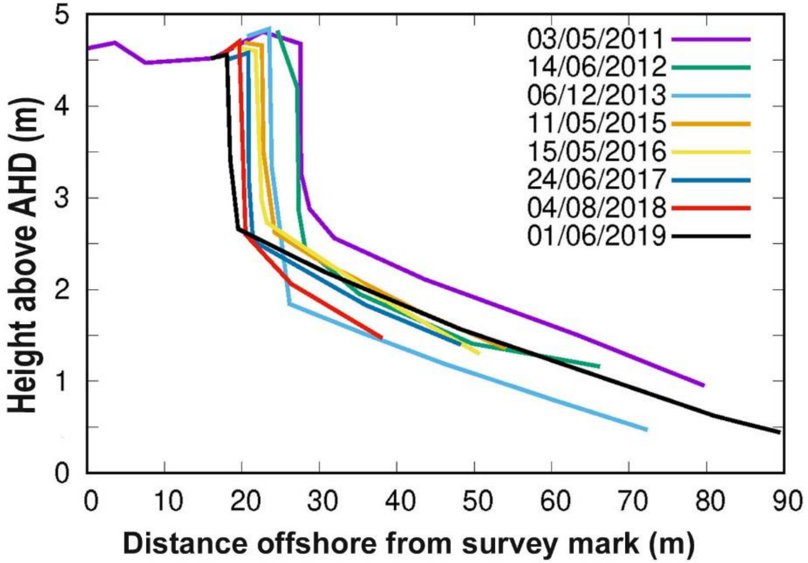
This example shows typical plot for beach undergoing erosion and recovery cycles but no long-term change

Data source: beach profiles

- ~15 year record of shoreline behaviour (for some Tasmanian beaches)
- TASMARC project uses professional surveyors (mainly Nick Bowden) plus "citizen science" amateur surveyors .
- High-resolution data compared to air photos
- All data freely available online; see: www.tasmarc.info

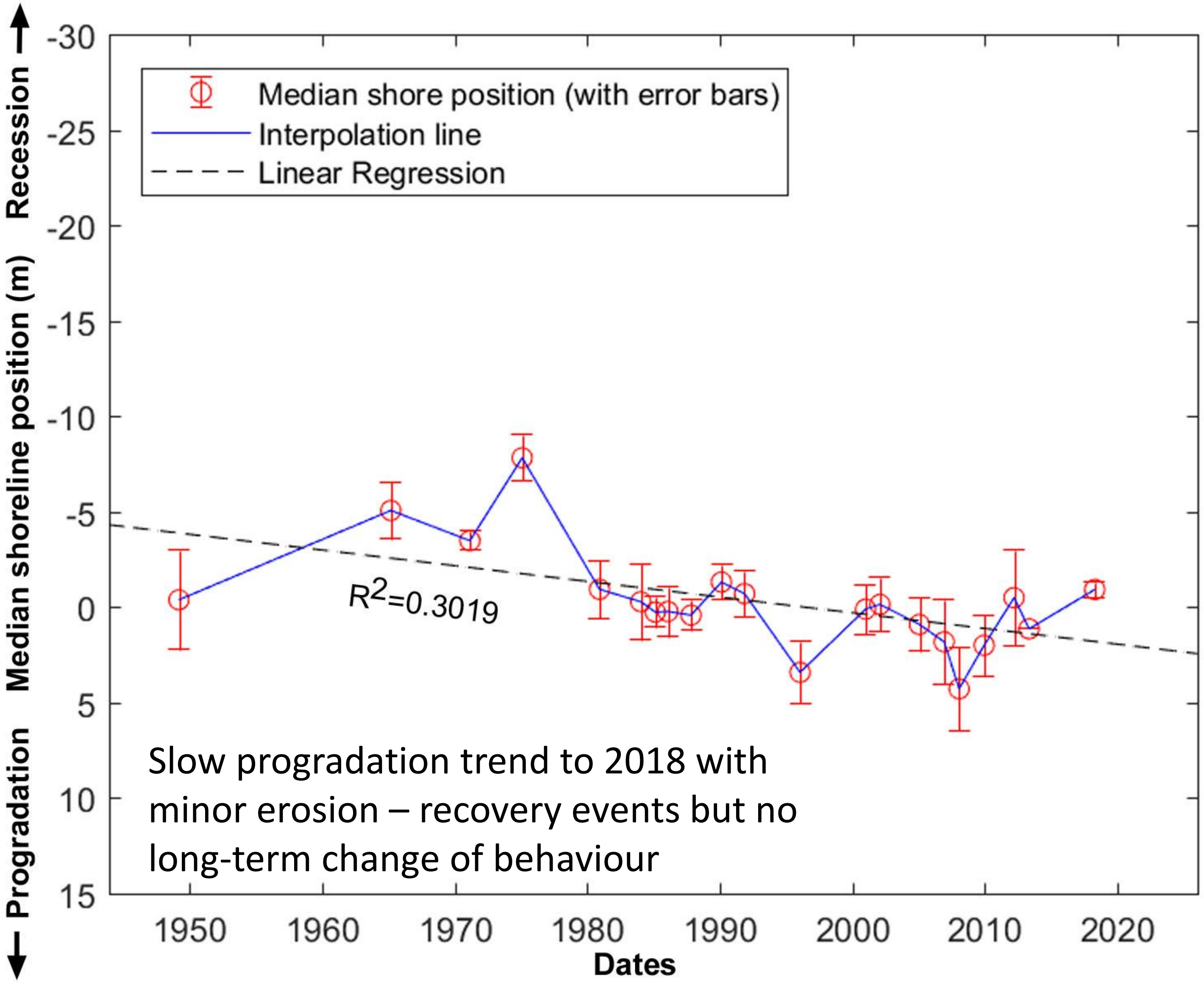


Stable beach profiles



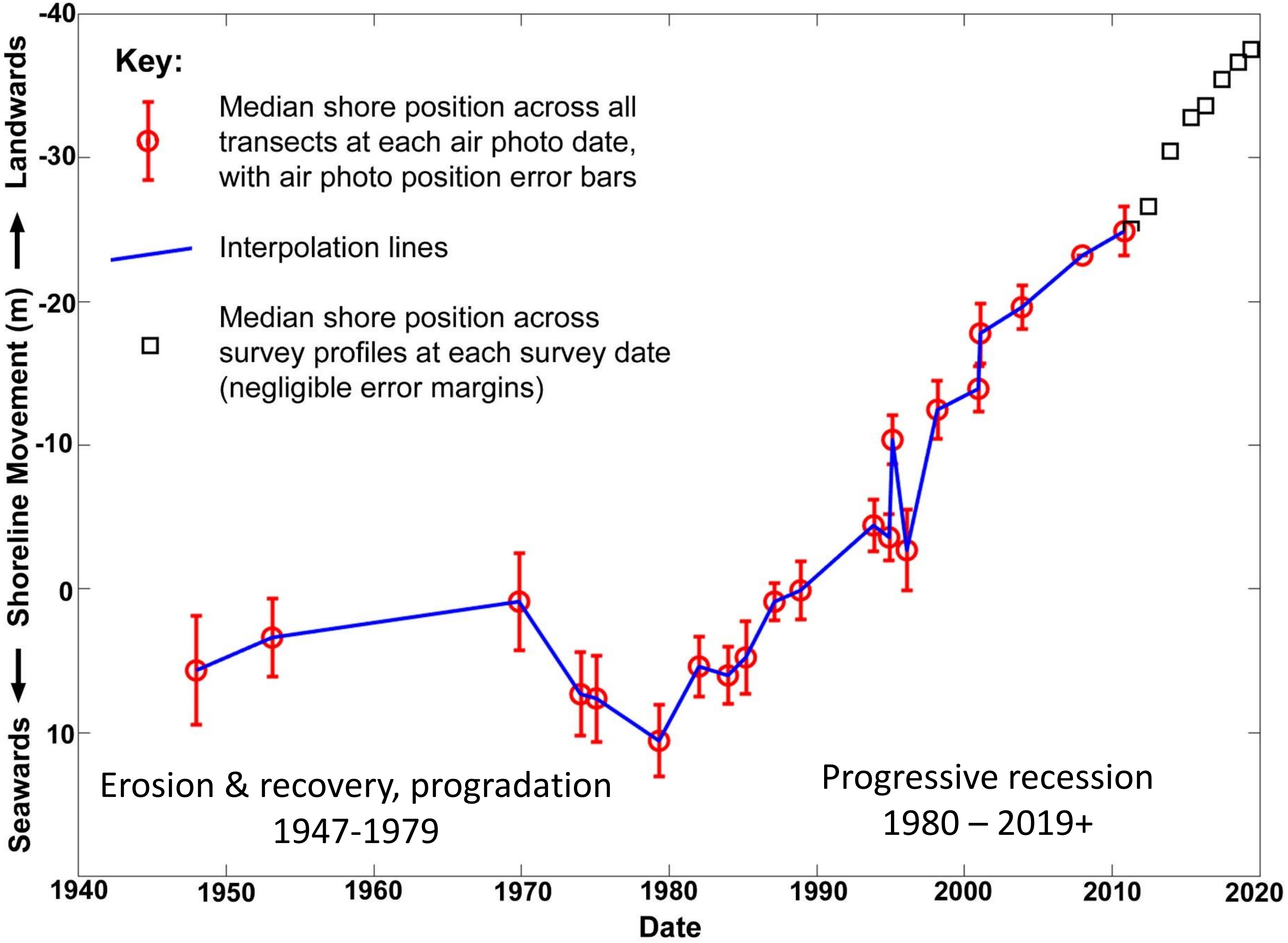
Receding beach profiles

Typical open coast (swell-exposed) sandy beach showing no response to sea-level rise (as yet)



Adventure Bay Beach (SE Tas.) shoreline history (median of shoreline positions across 20 transects at 21 air photo dates 1949 - 2018)

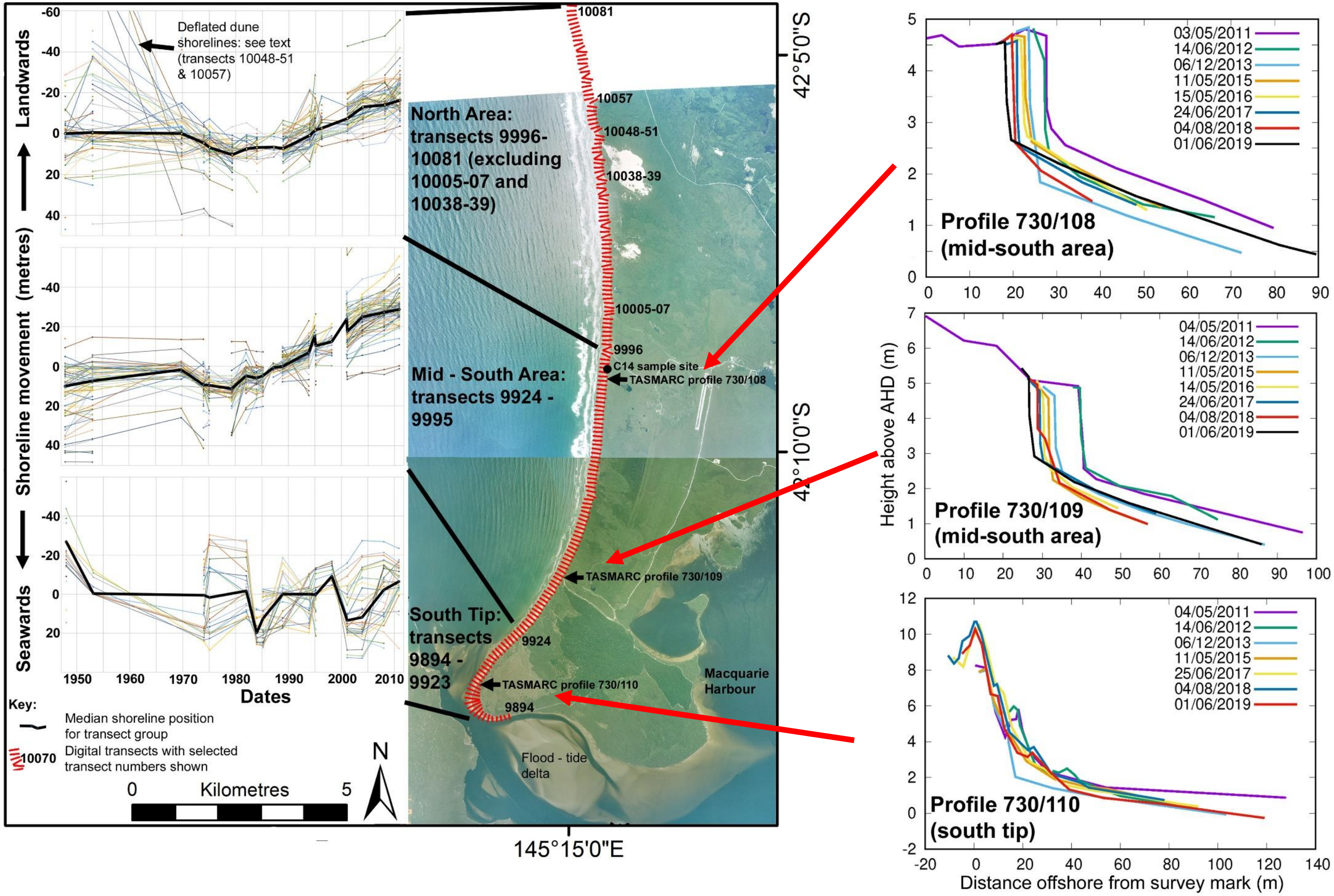
A long-term shoreline behaviour change at Ocean Beach (W. Tas.): a response to sea-level rise?



Ocean Beach shoreline history (median of shoreline positions across ~150 transects at 21 air photo dates 1947-2010)

Evidence of shoreline behaviour change

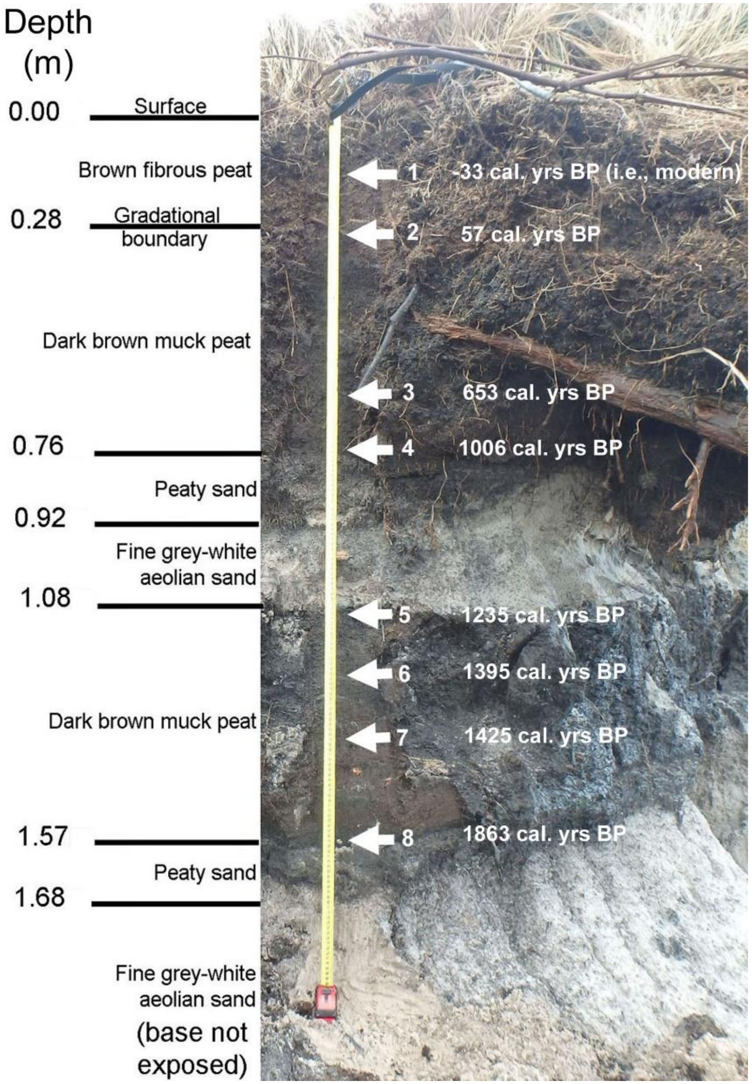
Air-photo beach histories at 21 air photo dates 1947 to 2010 at 150 transects



Beach profiles at 3 sites 2011 - 2019

Age of exposed back-barrier peat indicates recession is not just a cyclic phenomenon: degree of shoreline recession today is unprecedented in circa 1,800 years

Exposure of back-barrier swamp peats in receding shoreline scarp at Ocean Beach: up to ~ 1980, air photos show a foredune between swamp and beach.



C14 dates on exposed back-barrier peats imply present recession is most extensive since at least ~1800 years BP.
Radiocarbon dating: Quan Hua, ANSTO

Key geomorphic processes and conditions at Ocean Beach:

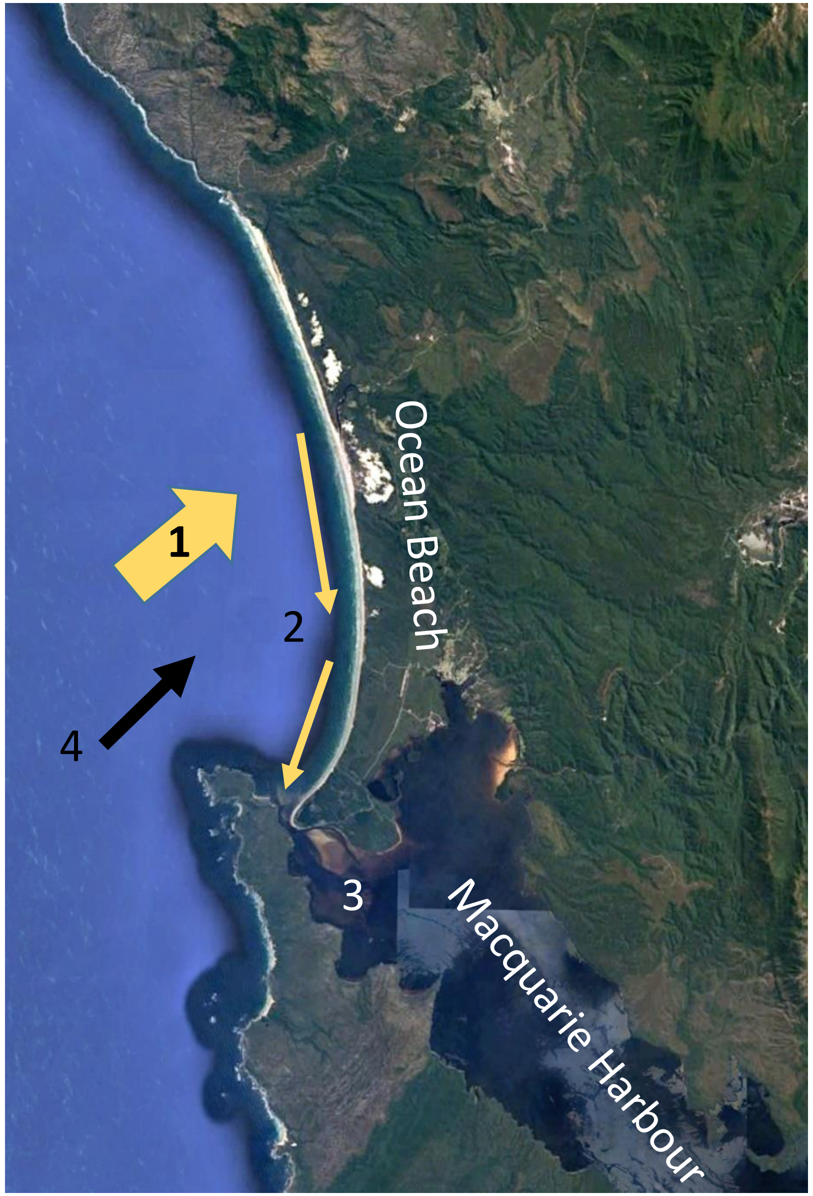
1. **Probable swell-driven onshore supply of sand from the continental shelf** (indicated by shelf sediment mobility modelling by Geoscience Australia, necessary to explain aspects of air photo beach history).

2. **Persistent southwards alongshore sand drift throughout air photo period** (indicated by multiple geomorphic features at all air photo dates, e.g., persistent southwards river mouth deflection across beach).

3. **Large active sand-sink (flood tide delta) in Macquarie Harbour** (end-point of alongshore sand drift, plenty of capacity)

4. **Low-variability high-energy wave climate** (high storm frequency, minimal directional variability, driven by Southern Annular Mode – very different to east Australia wave climate)

This combination is very unusual for Australian beaches

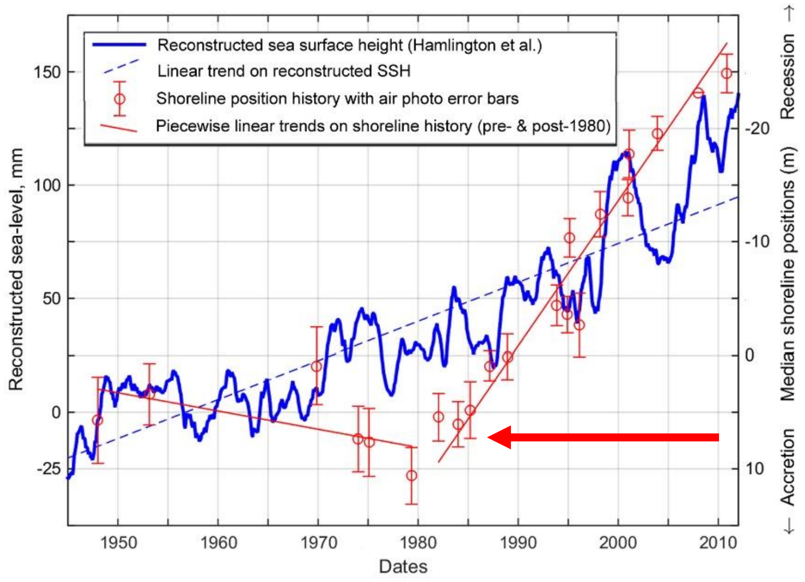


What has changed at Ocean Beach?
Sea-level and onshore winds

- **Higher mean sea-level** (= more frequent erosion events)
- **Stronger mean and extreme onshore wind speeds** (=higher wave set-up at shore, more frequent erosion events)

But:

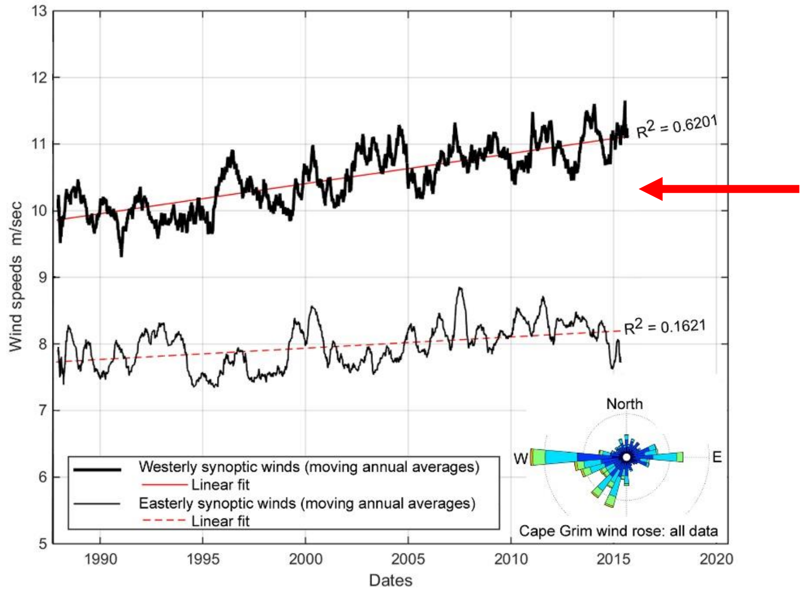
- **No increase in storm wave heights and frequencies** (Cape Sorell wave-rider buoy data since 1985 (Hemer 2010)



Mean sea-level change for Ocean Beach, reconstructed from satellite altimetry (no local tide gauges).

A gradual net rise with inter-annual variability.

Note shoreline behaviour change NOT related to any notable change in sea-level behaviour

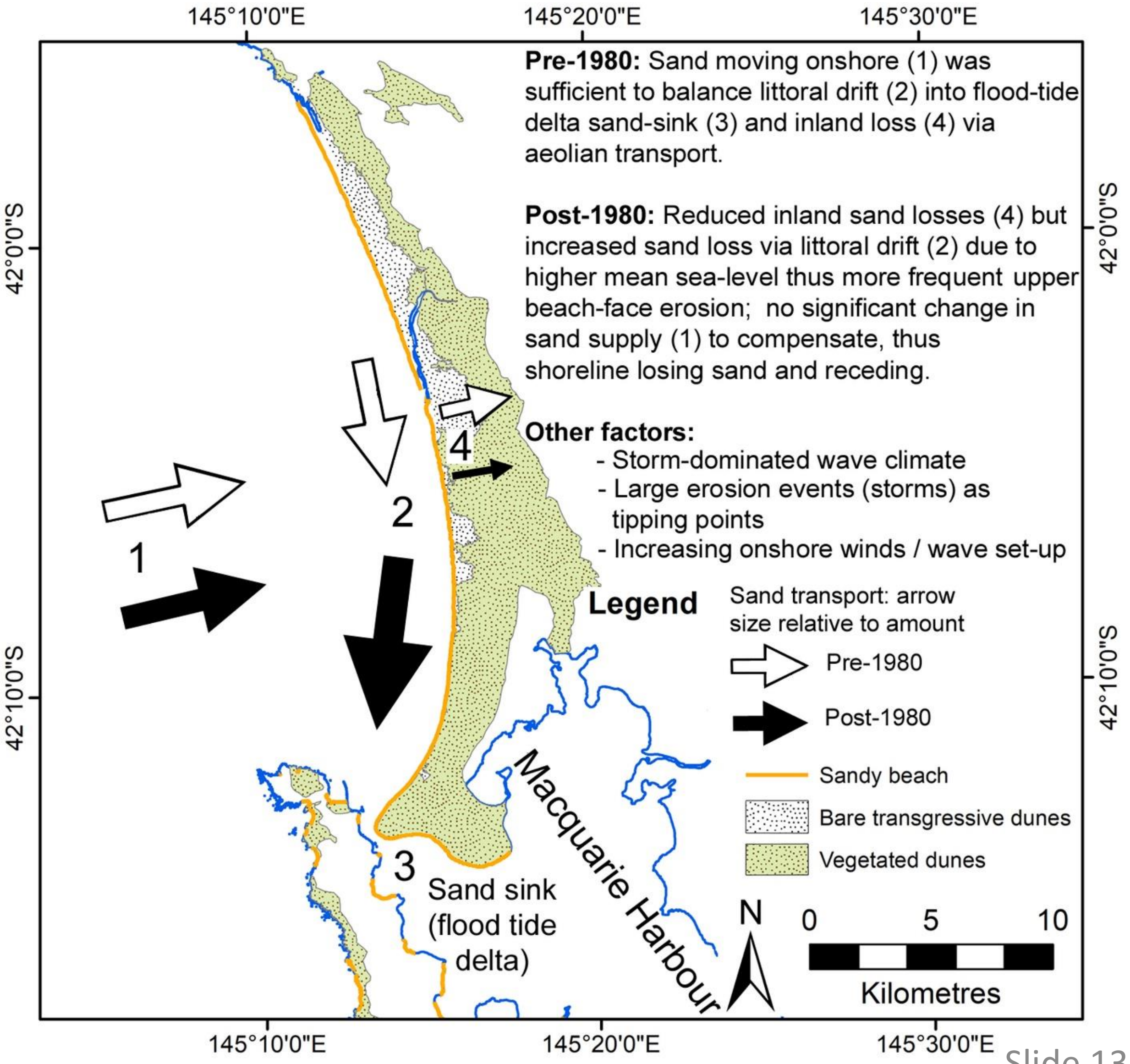


Increasing westerly (onshore) wind speeds at Cape Grim, north-west Tasmania (likely similar change at Ocean Beach but problems with local wind records).

A gradual net rise with inter-annual variability.

A model for observed Ocean Beach shoreline behaviour change around 1980:

Given the wave climate and sand transport processes at Ocean Beach, a simple model can explain the observed shoreline behaviour changes as a response to increasingly frequent erosion events due to sea-level rise and/or more frequent higher wind-waves and wave-setup due to increasing onshore winds.



Key points

1. Climatically-driven global mean sea-level rise (GMSLR) is expected to eventually cause most soft shorelines to erode and recede.

2. However the "noise" of other coastal processes still overwhelms the effects of GMSLR on most soft shores, and it will require more sea-level rise before most soft shores start showing attributable effects.

3. "Early responder" shorelines already showing changes attributable to GMSLR are limited to unusually susceptible coastal environments (but should be of critical interest to planners and managers!).

Thank You

Four key factors pre-disposing shores to early physical responses to sea-level rise

Work to date is suggestive of at least 4 factors which may (individually or in combination) dispose a soft shoreline towards relatively early recessional responses to sea-level rise:

Sand budget switches from balanced to losing –
Active sand sinks able to receive more sand released by increasing shoreline erosion on rising sea-levels = less sand available for recovery.

Swell-sheltered environments (estuarine/tidal lagoon) -
Less affected by open coast wave climate and sand supply variability;
No swell-driven return of sand to shorelines, slower recovery from local wind-wave erosion events.

High storm frequency -
Faster switch to dominantly receding beach/dune face on rising sea-levels?
Effects may dominate over other aspects of wave & storm climate variability?

Soft-rock erodible shores –
Non-recovering shores, always receding, increasing recession rate expected with rising sea-levels.
Common in Tasmania and Victoria (& UK, etc.).