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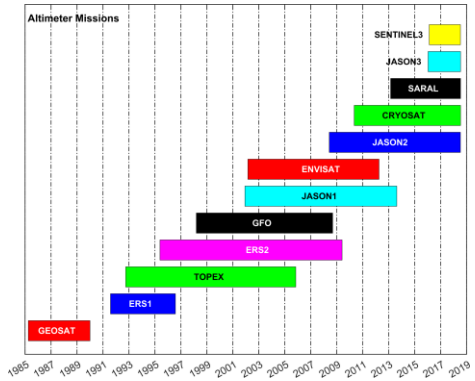
Have historical trends in global waves impacted beaches?

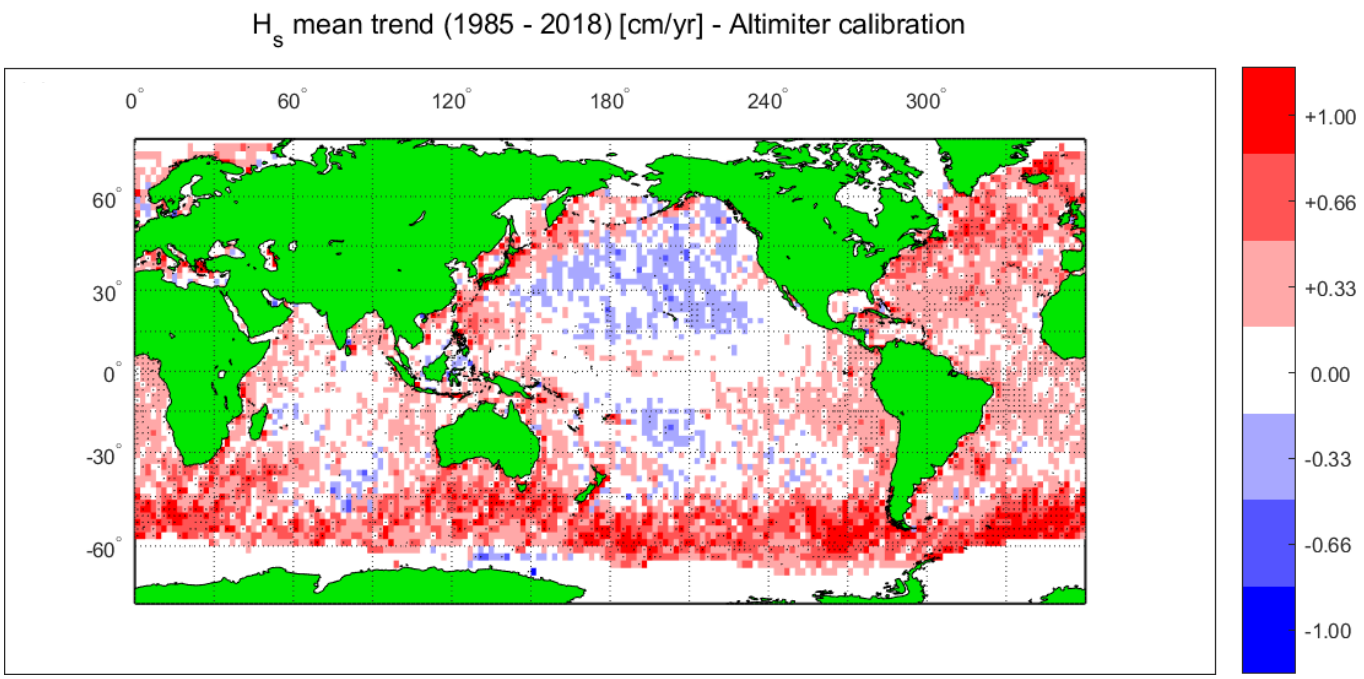
Ian Young and Mandana Ghanavati

Global trends in ocean waves

Multi-mission altimeter data shows global increases in H_s over last 35 years

Largest in southern hemisphere





Young & Ribal, 2022

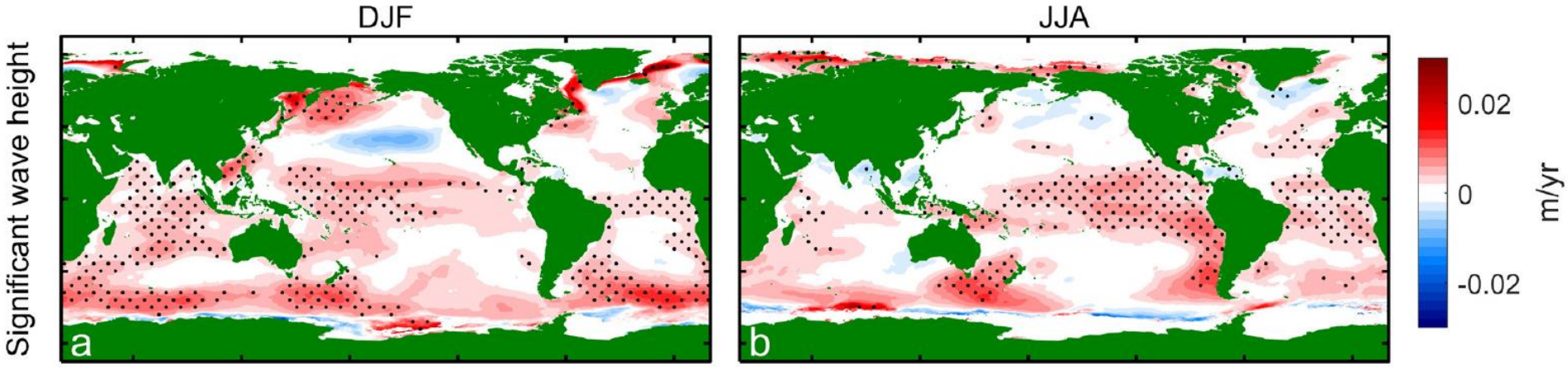
Global trends in ocean waves

Similar results from hindcast wave models

Note, however, both satellite and model show the trends are modest:

Of order 2 cm/year in Southern Ocean - 0.4% per year or approx. 10% over measurement period

Climate models project similar increases out to 2100.



Liu, J. et al., 2023

Impacts of global trend

Many wave climate papers commence with a statement indicating changes in wave climate may have impacts on global coastlines

These changes might potentially exacerbate[12,13], or even exceed in some coastal regions[1,14–16], impacts of future projected sea-level rise. The impacts could be further exacerbated when considering directional changes in wave propagation (θ_m), which is a major driver of coastal stability at all time-scales[5,9,13,17].

Morim et al. (2019)

Wind-wave extremes are also crucial for the determination of coastal sea levels and coastal erosion, and changes in the climate may further exacerbate the already predicted strong societal and economic impacts of wind-waves on the world's coasts (*6*, *7*).

Meucci et al. (2020)

Is there evidence to support such speculation?

Coastal impacts of changes in waves and storm surge

Initially consider global scale evidence

Datasets:
Waves – Liu, Q. et al. (2021) – global hindcast
Storm Surge – Muis et al. (2016) – Global Tide and Surge Reanalysis (GTSR)
Shoreline – Luijendijk et al (2018) – global shoreline dataset

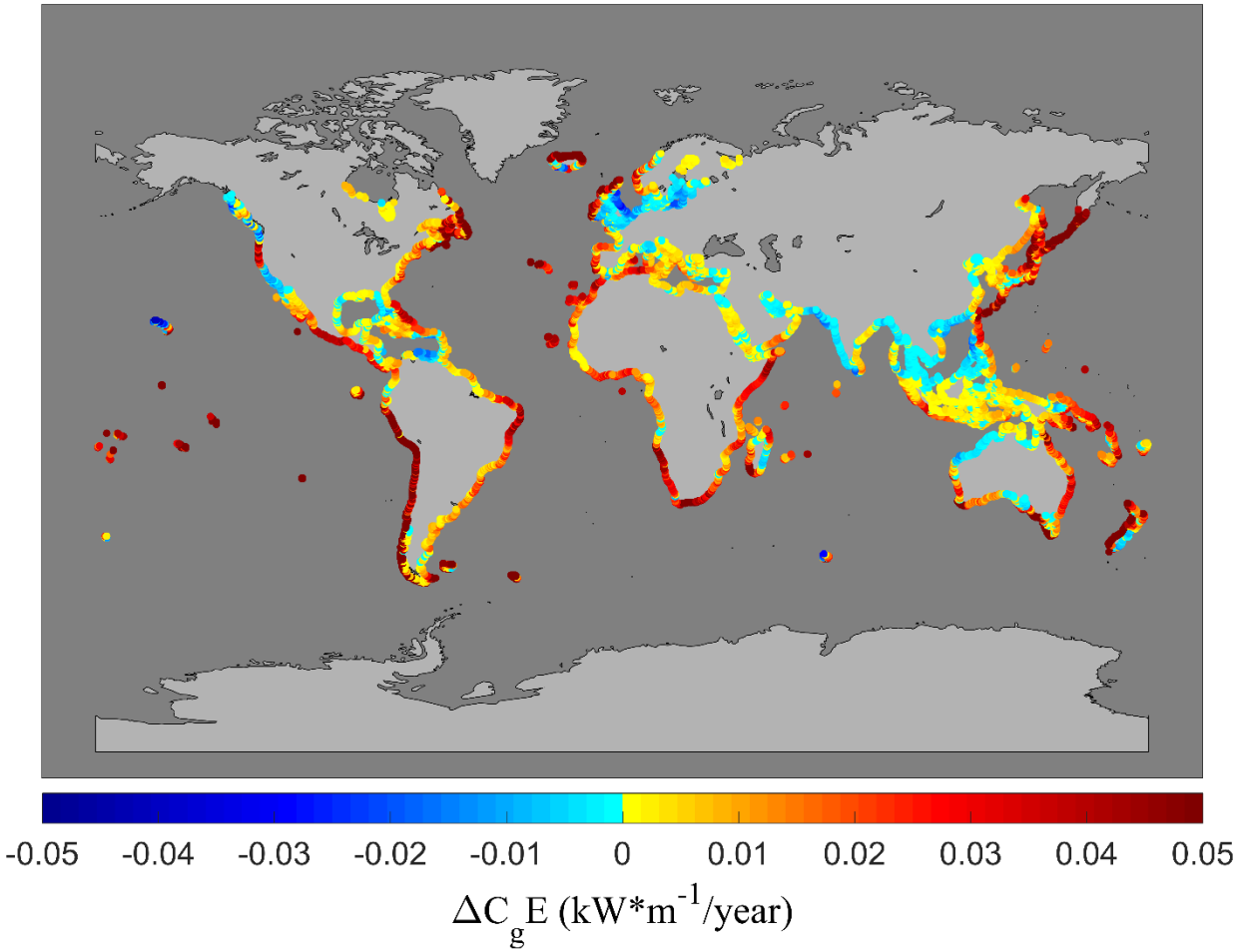
Notes on resolution:

- Waves (deep water) – assume that a positive trend offshore means a positive trend at the beach – tested with a regional model

- Storm Surge – GTSR will not adequately resolve tropical cyclones

- Shoreline – dataset measures fluvial, human induced and environmental impacts – filter to ± 1m/year to exclude non-environmental

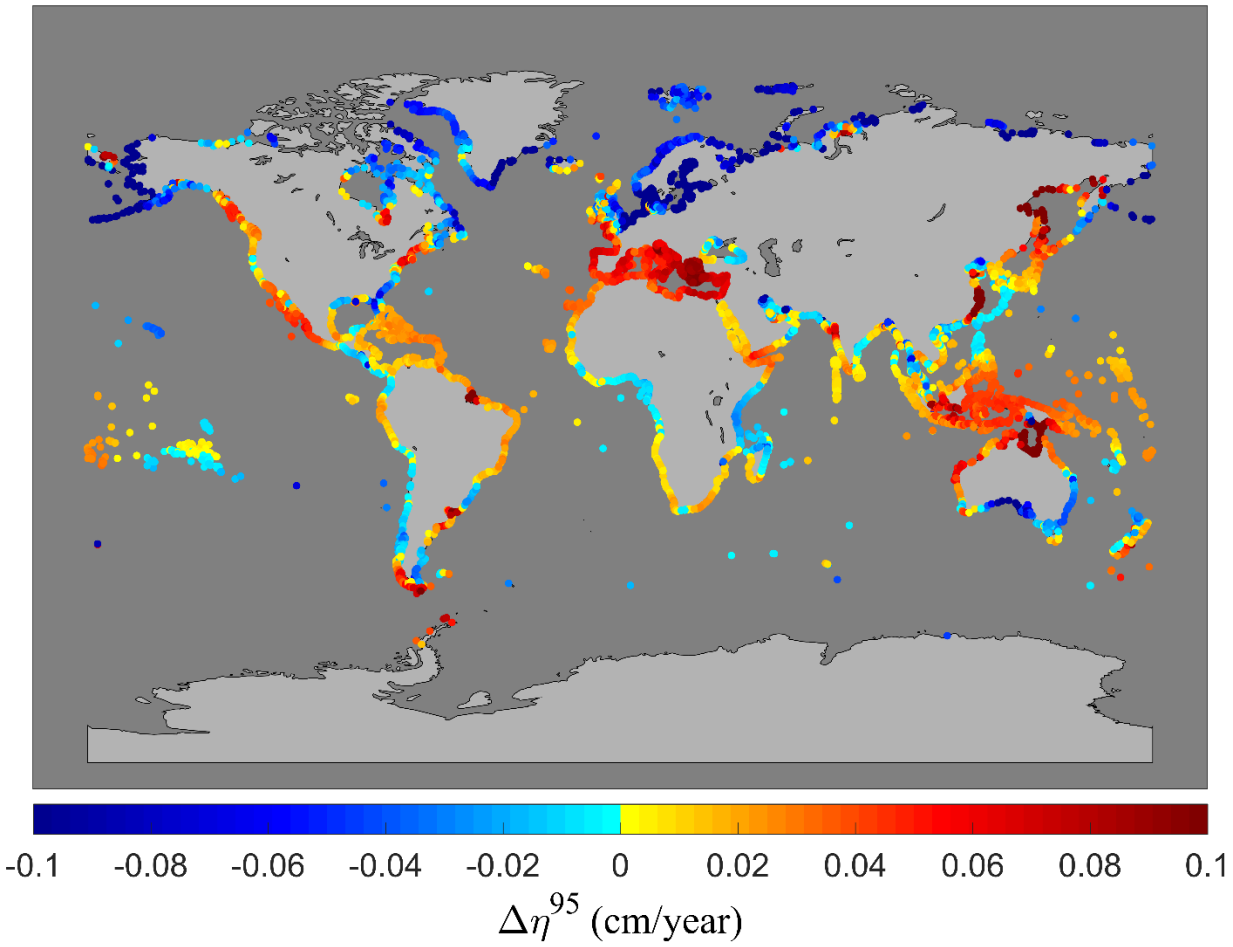
Trends at coasts – wave energy flux



$$C_g E = \rho g^2 H_s^2 T_m / (64\pi)$$

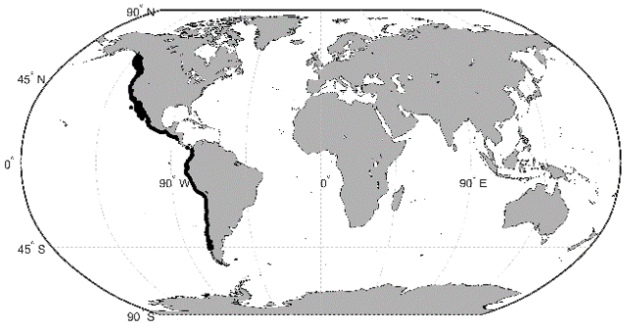
Ghanavati et al., 2023

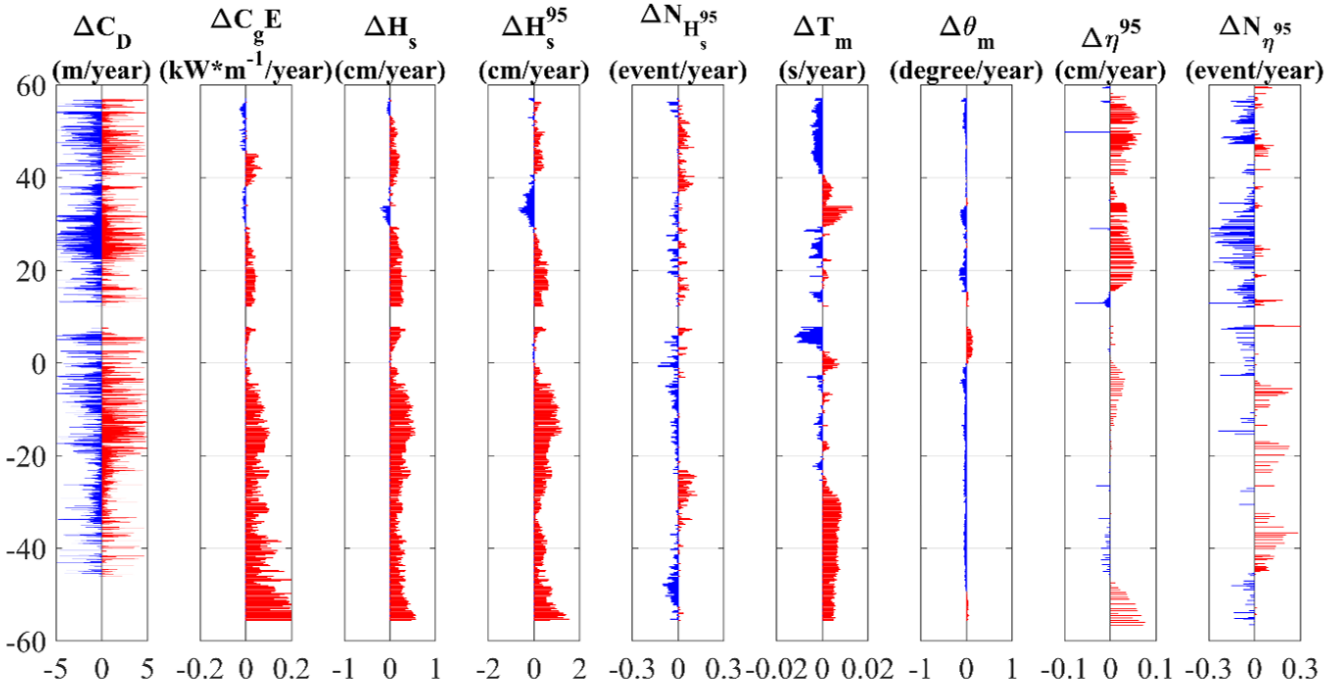
Trends at coasts – storm surge



Ghanavati et al., 2023

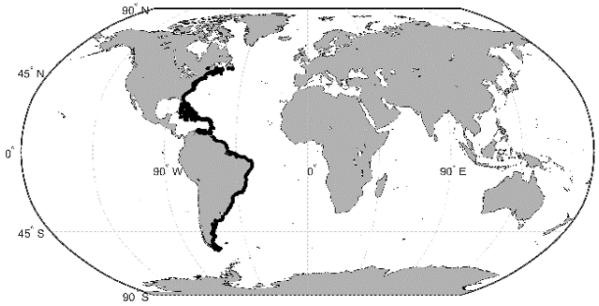
Trends at coasts – impacts on recession/progradation

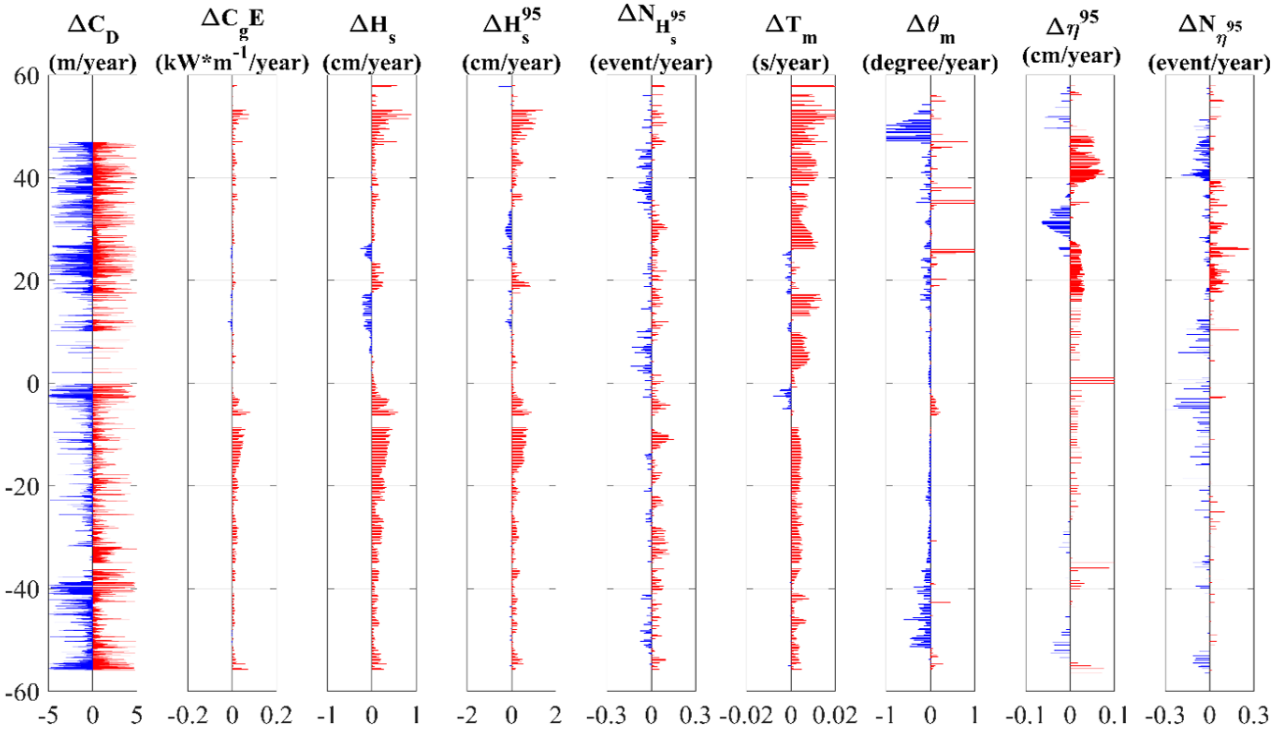




Ghanavati et al., 2023

Trends at coasts – impacts on recession/progradation





Ghanavati et al., 2023

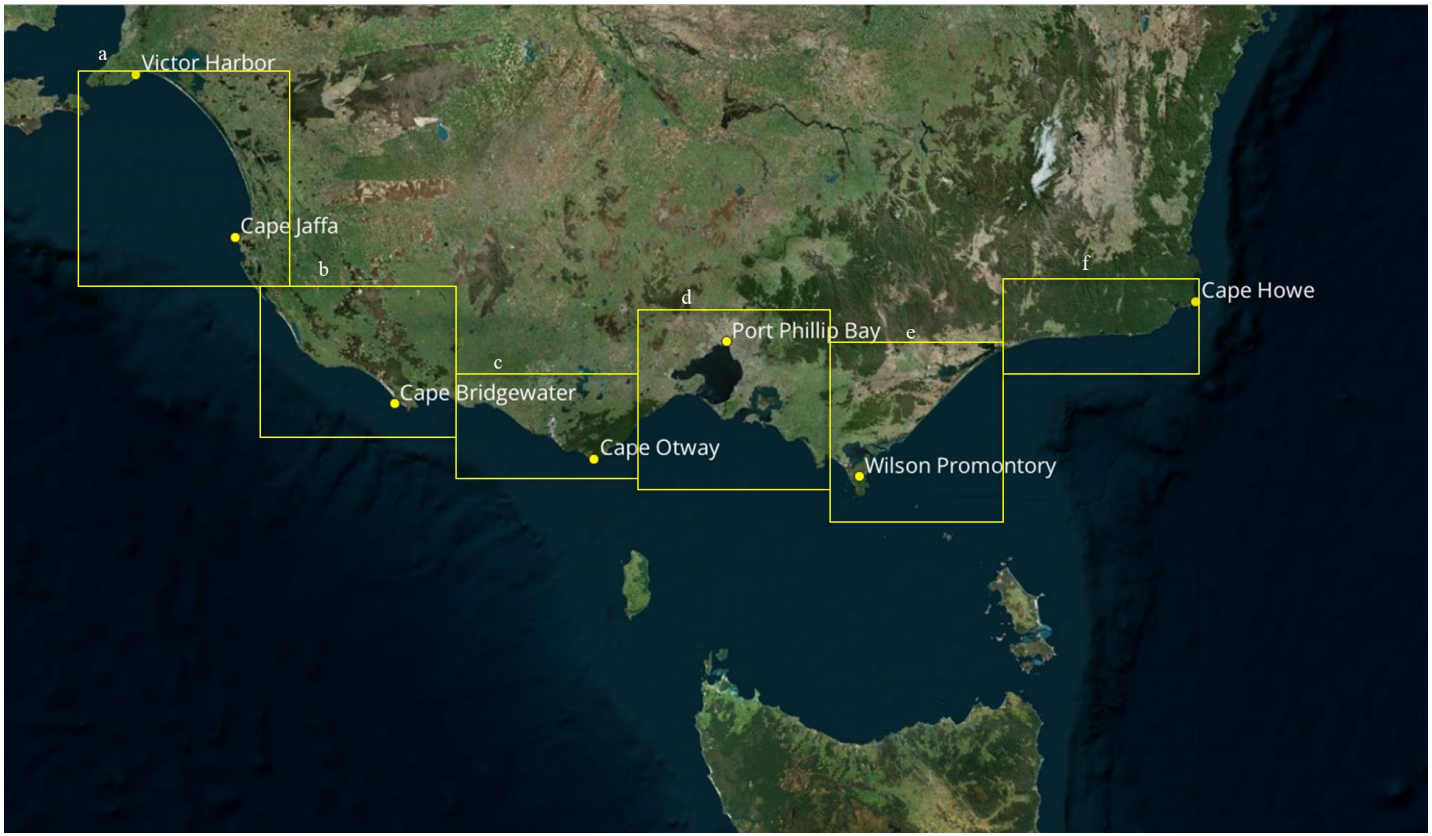
Conclusions at global scale

- Results shown for America repeated globally
- No clear relationship between changes in waves and storm surge and recession/progradation
- May be that trends are too small
- May be that other processes mask such effects (e.g. sediment supply, regional effects, fluvial transport etc.)

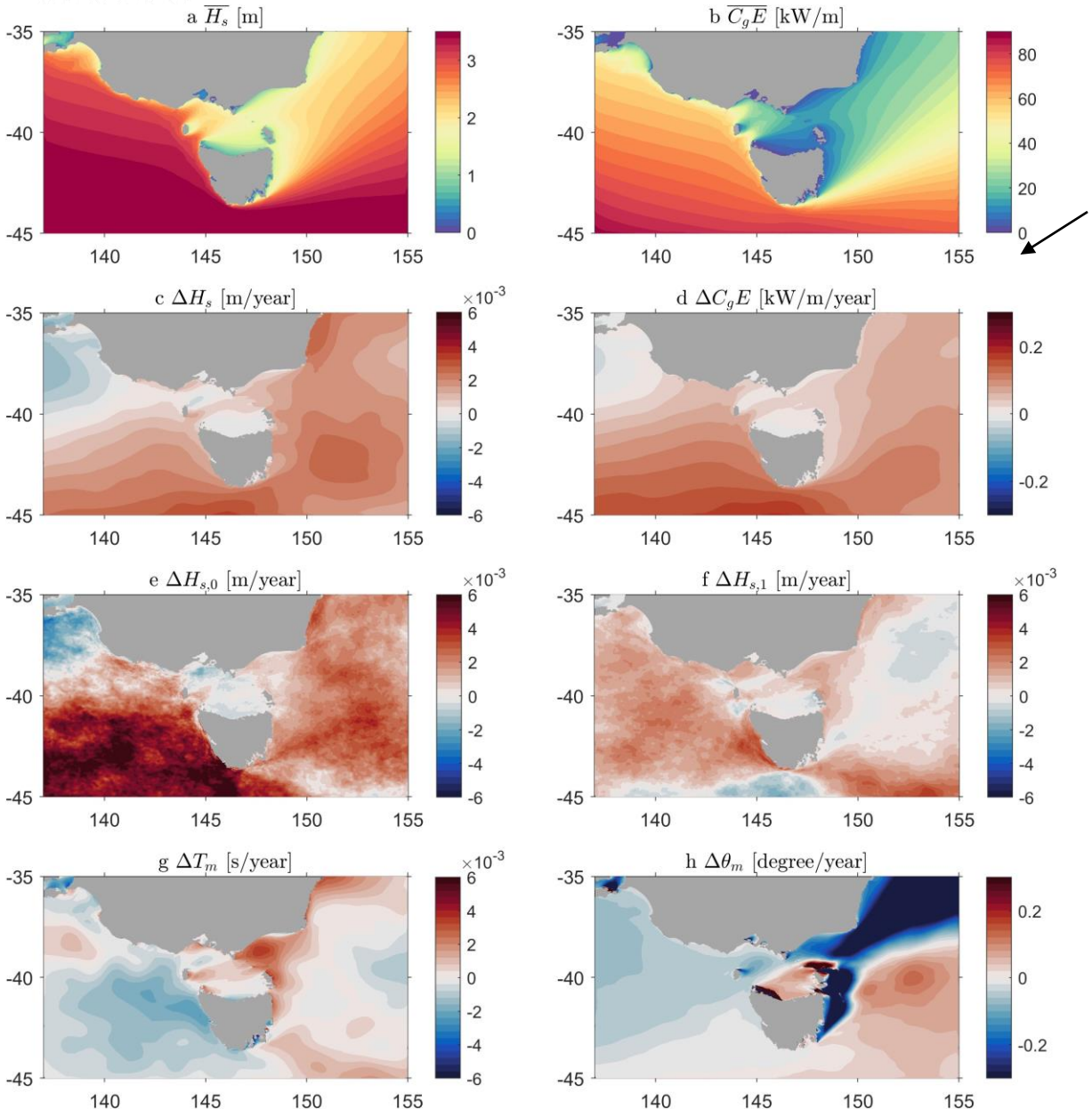
Regional-scale study – South-east Australia

Region where there are:

- Major variation in wave energy flux
- Some of the largest trends in wave energy flux globally



Wave climate, trends and datasets

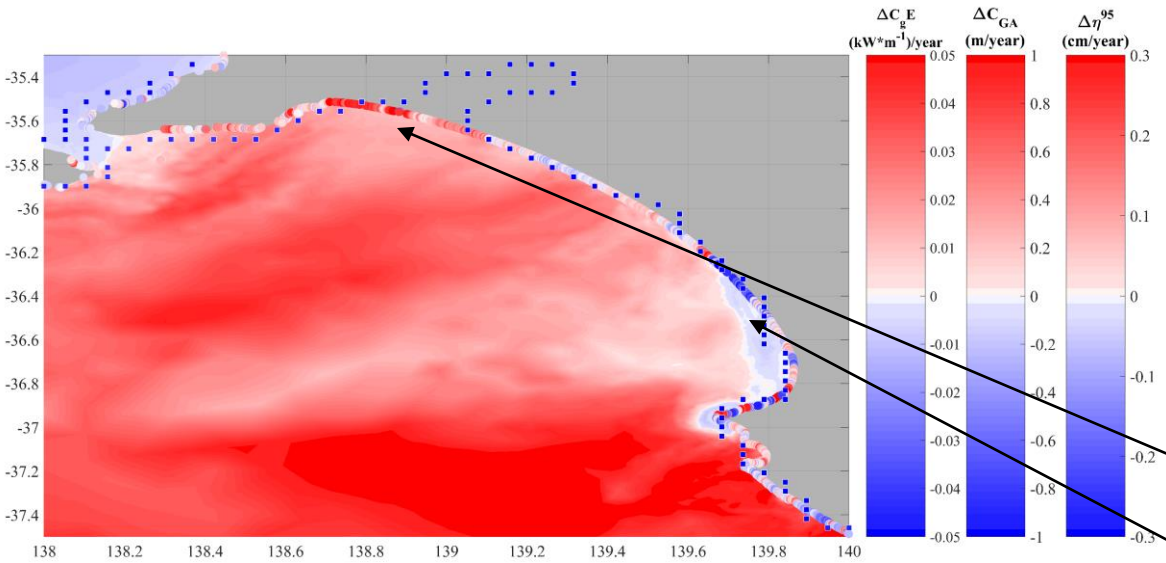


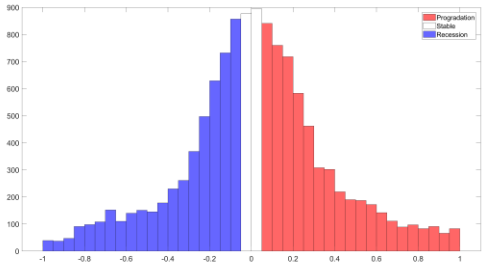
Waves
Liu, J. et al. (2022)
High-res. hindcast 300m to 10km

Storm Surge
Colberg, et al. (2018) – 5km

Shoreline change
Bishop-Taylor et al., (2021)

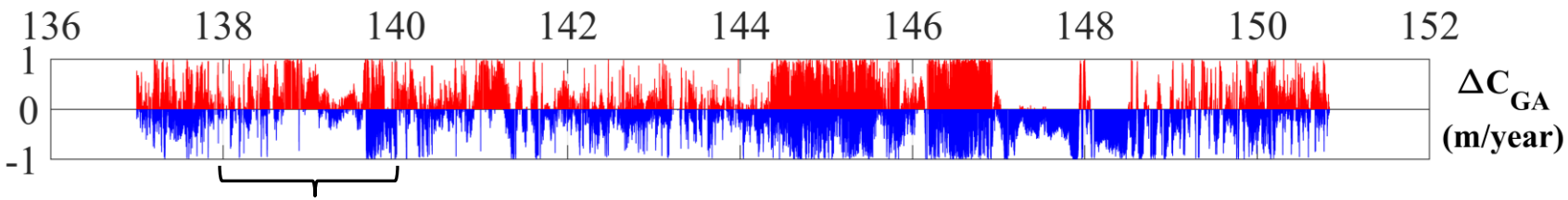
Section (a) 138^0 - 140^0





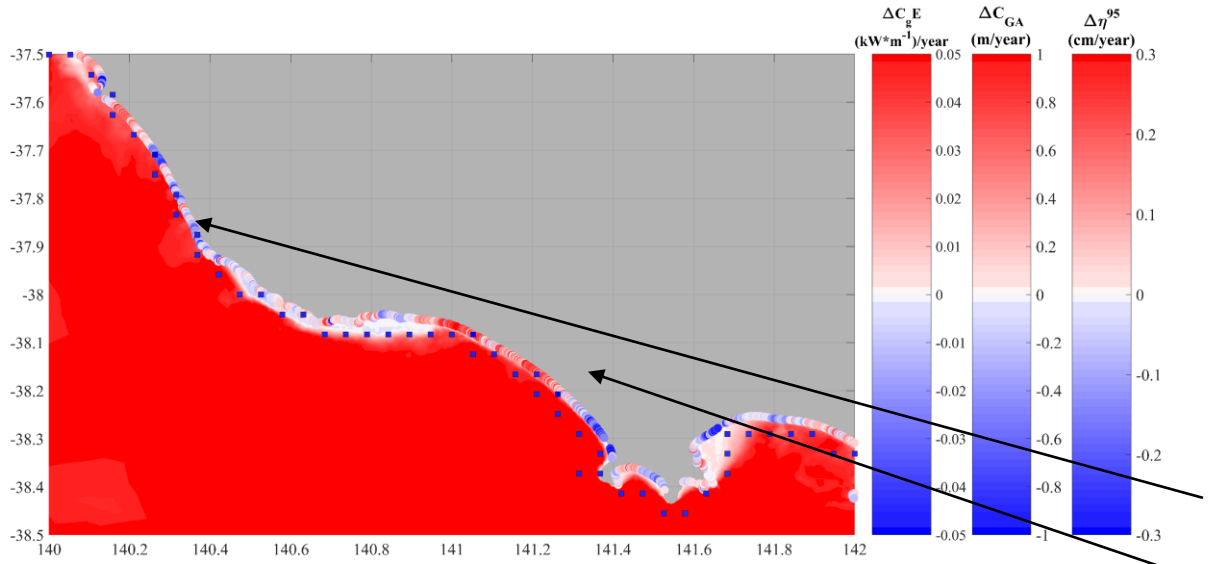
Murray River - fluvial

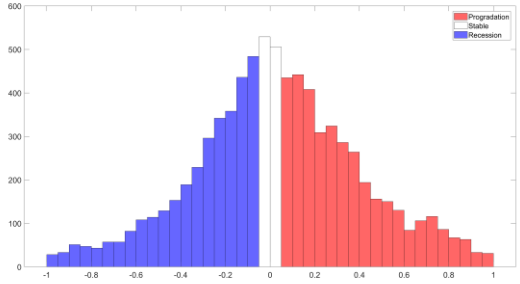
Some recession?



- No clear impacts

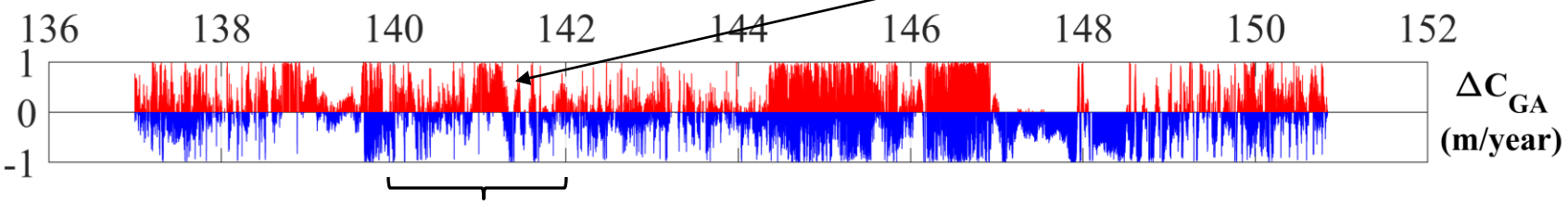
Section (b) 140^0 - 142^0





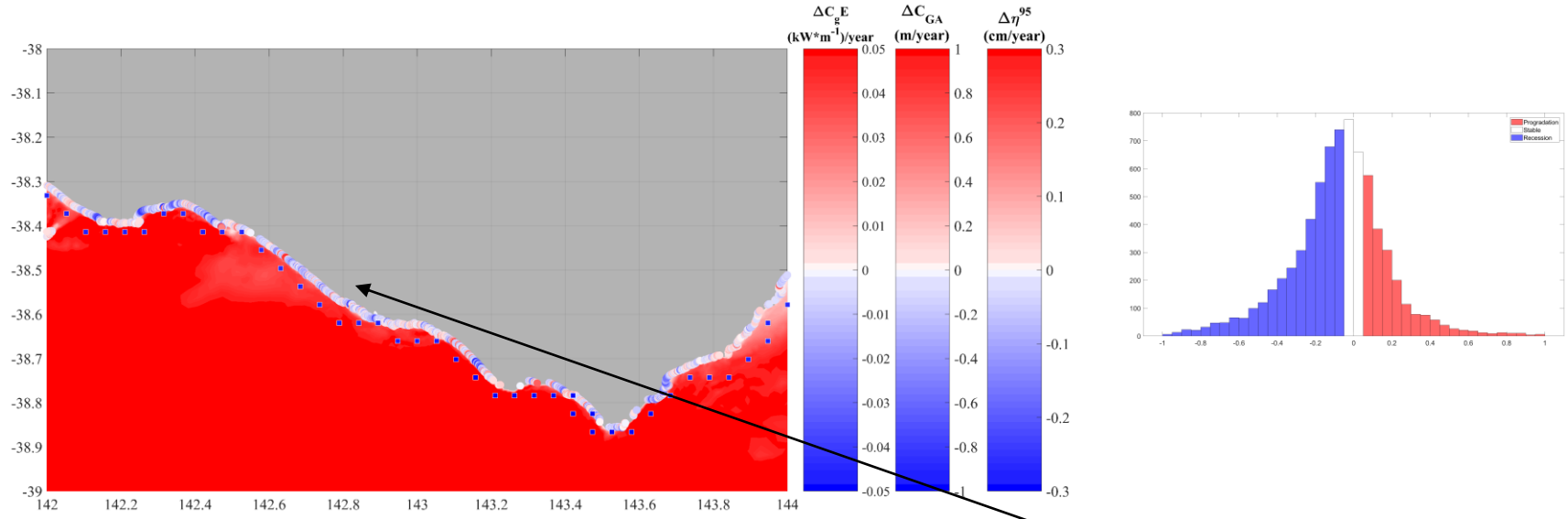
Recession

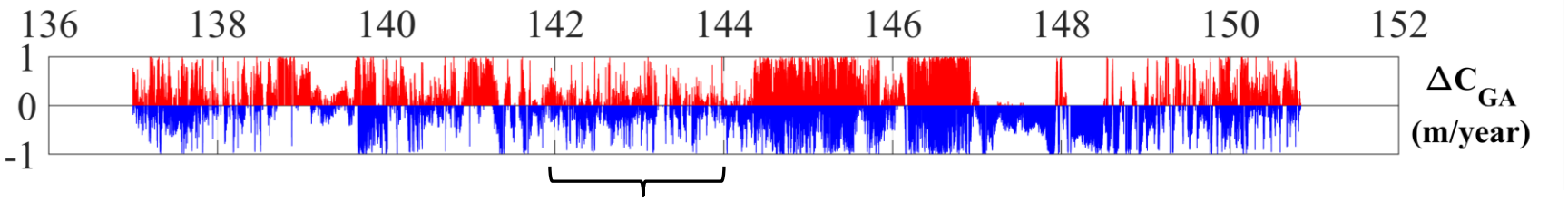
Progradation?



- Possible non-stationary longshore drift drive by trend in wave energy flux

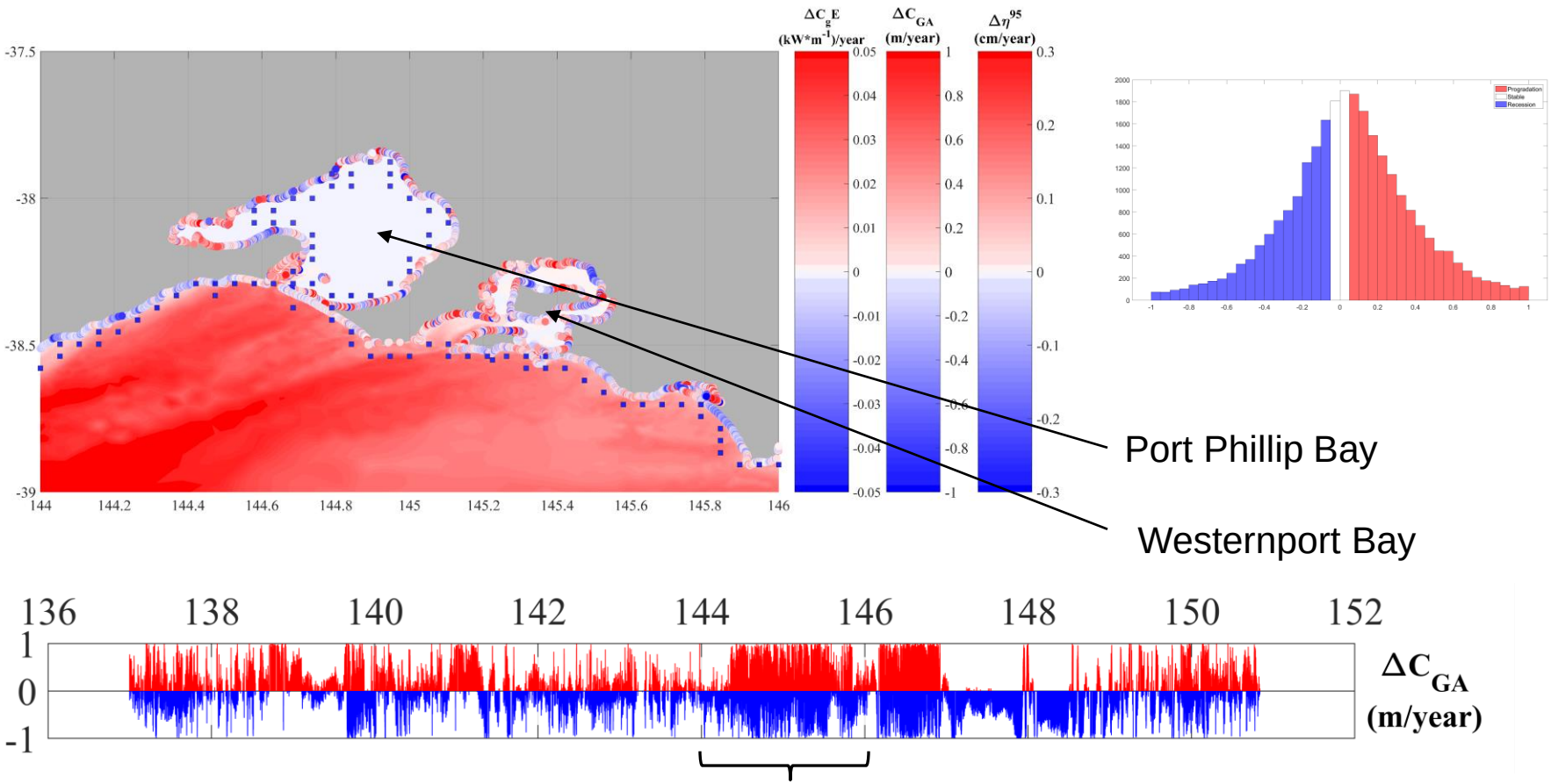
Section (c) 142^0 - 144^0





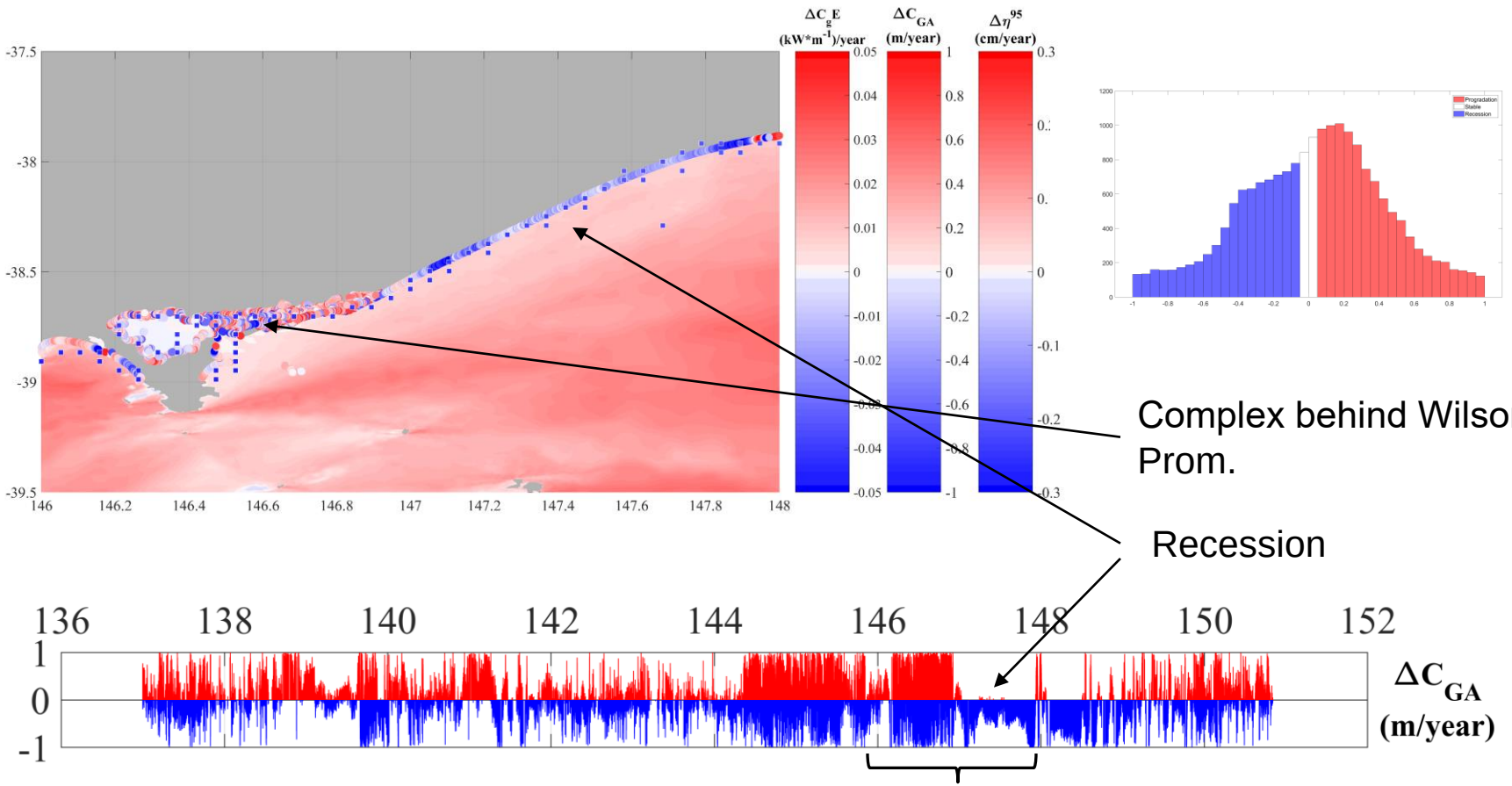
- Recession (longshore?) driven by trends in wave energy flux

Section (d) 144^0 - 146^0



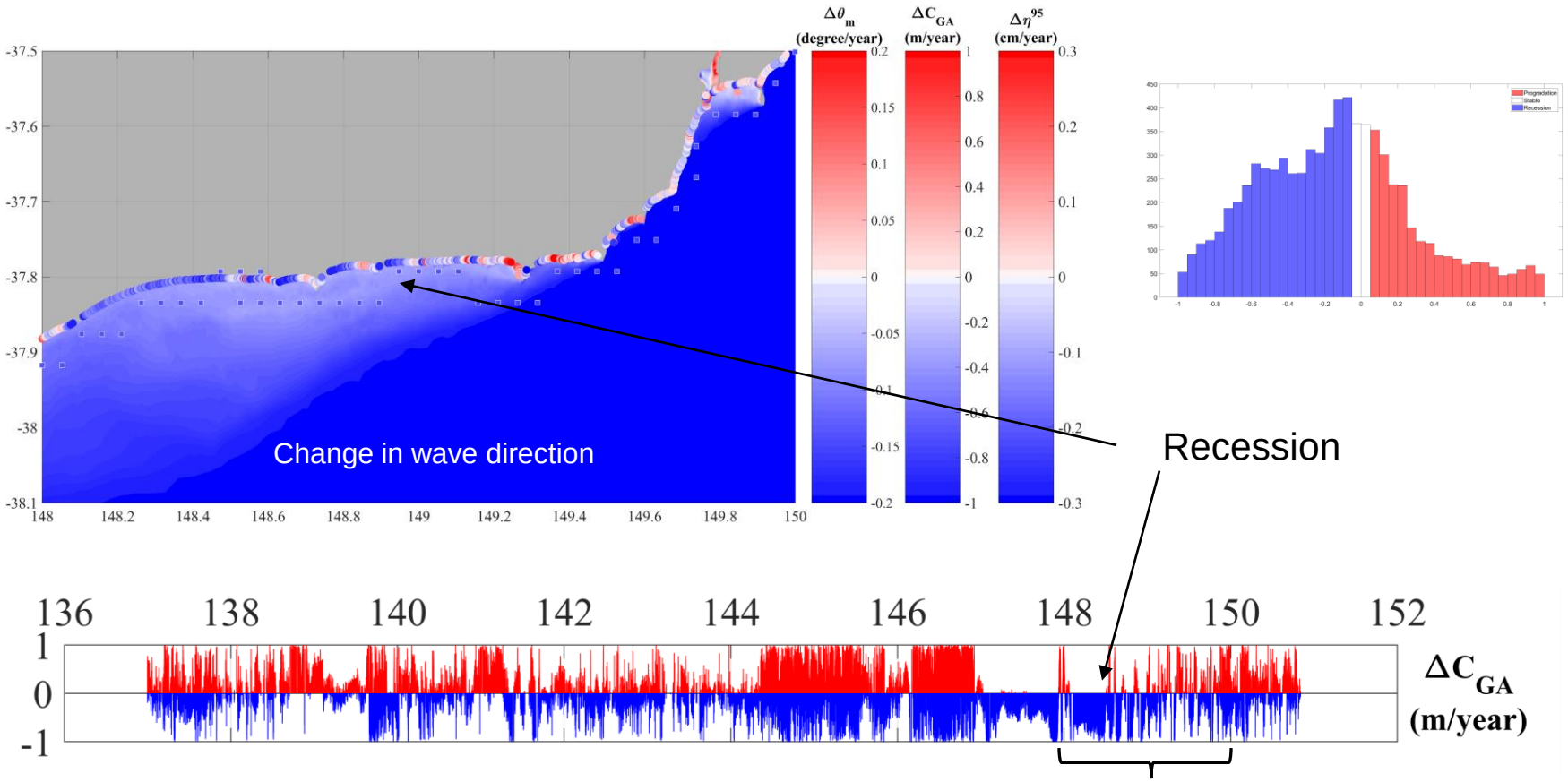
- Complex coastline with much human impact
- Ocean coast slowly receding

Section (e) 146^0 - 148^0



- Large sections of coast receding
- Probably driven by change in wave direction rather than wave energy flux changes

Section (f) 148^0 - 150^0



- Recession most likely driven by change in wave direction

Conclusions

- No clear global impacts on beaches – noting other processes
- In areas where there are relatively large trends – beach recession evident
- Recession driven by increasing wave energy flux and wave direction changes
- Magnitude, less than 1m/year!
- Global analysis provides some insights but regional understanding important

Western coast
Great Ocean Road

Eastern coast
Ninety mile beach

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