Storm waves at the coast: A new dataset with a wide variety of swell-dominated and wind-wave dominated conditions

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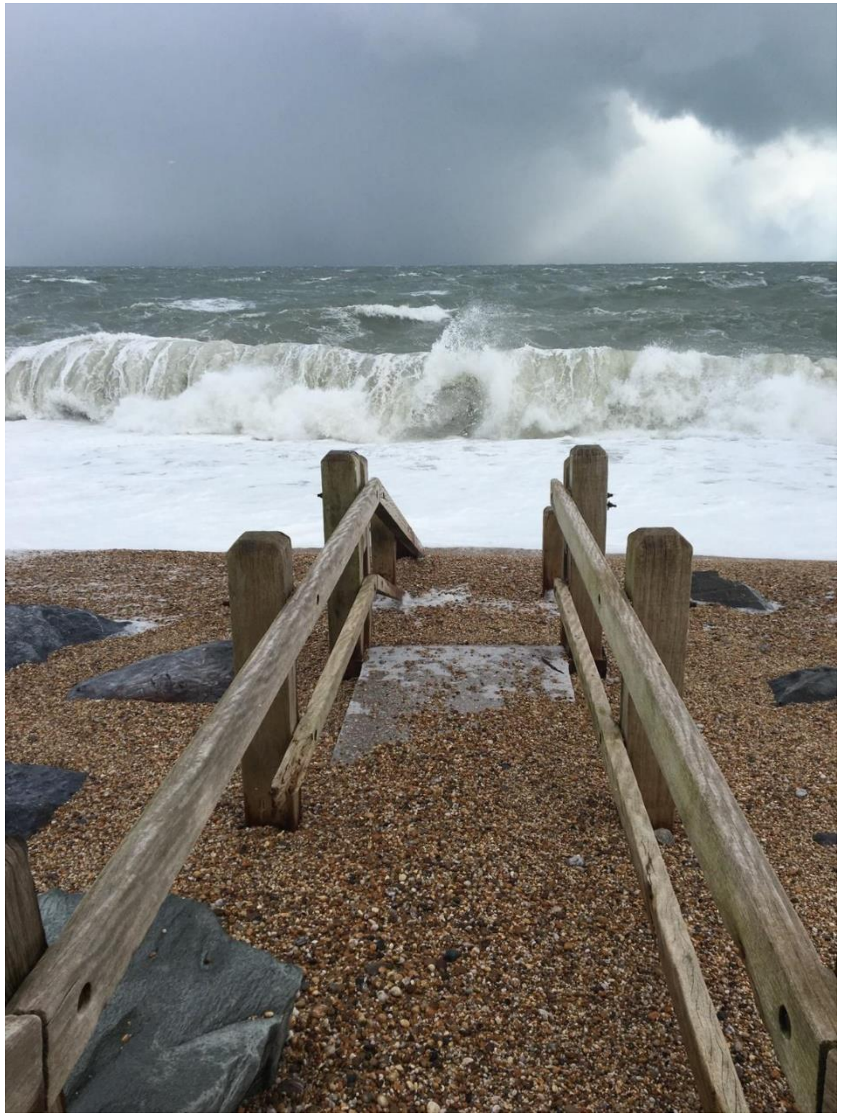
Structure



Background

- Changing Ocean Climate
- Impacts of storm waves at the coast
  - Importance of low frequency (infragravity) waves
- Previously explored parameter space

Method

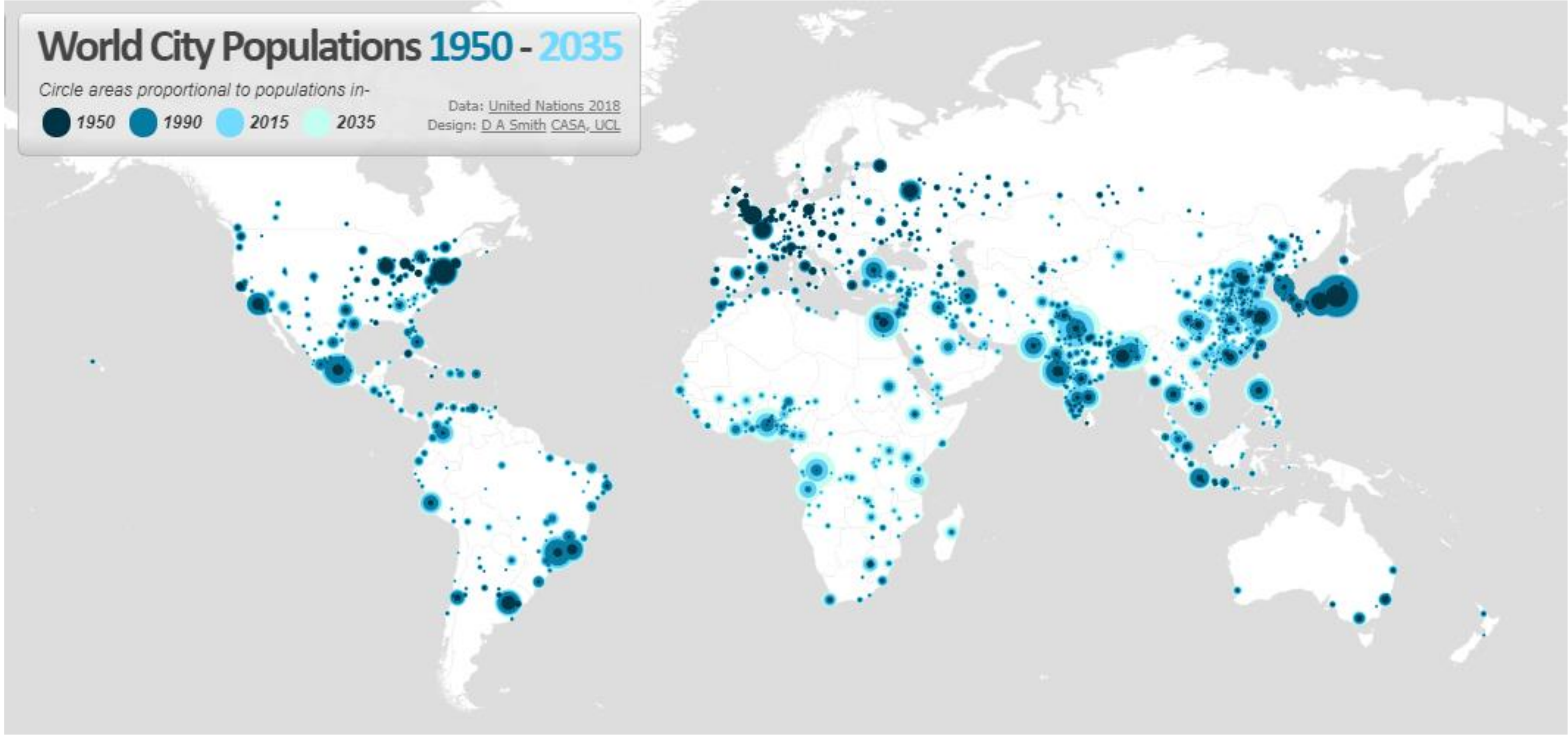
- Rapid Coastal Response Unit (RCRU)
  - New storm wave data set
  - Video Analysis

Example Analysis

- Shoreline infragravity during storms (Billson et al 2019)
  - Magnitude and dominance of shoreline IG
  - Relationships with wave and beach parameters

Background – Changing Ocean Climate

- ~40% of global population is concentrated within 100 km of the coast and is highly vulnerable to the effects of rising sea level and waves.
- Almost two-thirds of the world's cities with populations of over five million are located in areas at risk of sea level rise.



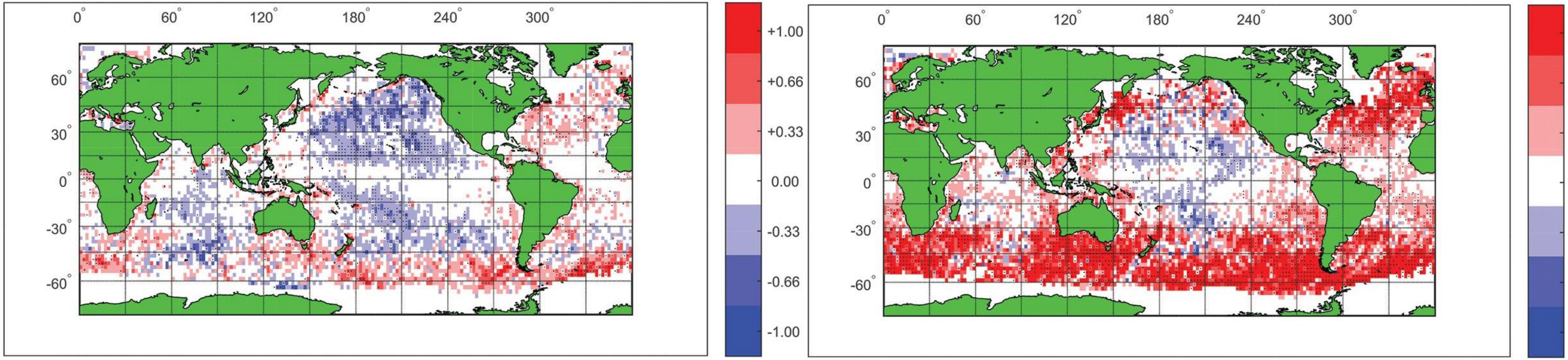
Source: *http://luminocity3d.org/WorldCity/#3/12.00/10.00*

Background – Changing Ocean Climate

- Since 1985, increases have been observed in significant wave heights (H_s), with larger increases in extreme heights (90th percentiles) (Young and Ribal, 2019).

H_s Mean Trend (1985 – 2018) [cm/yr]

H_s 90th percentile trend (1985 – 2018) [cm/yr]

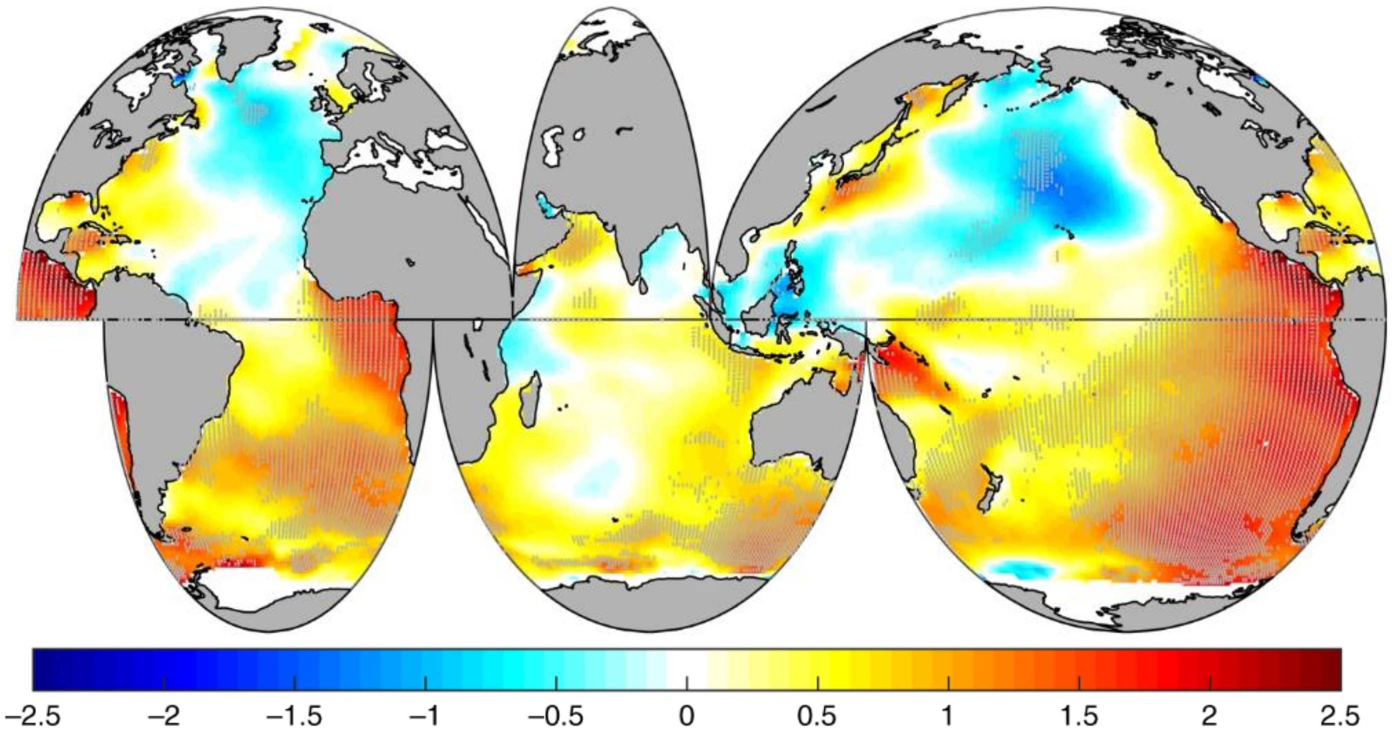


(A) Mean trend and (B) 90th percentile trend in altimeter Hs. Values that are statistically significant according to the Seasonal Kendall test are marked with a black dot. Adapted with author's permission (Young and Ribal, 2019)

Background – Changing Ocean Climate

- Further, a 0.4% rise in global wave power has seen it identified as a 'potentially valuable climate change indicator' (Reguero et al, 2019)

Spatial trend (percent change per year) in mean Wave Power from 1985 to 2008



Spatial trend (percent change per year) in mean Wave Power from 1985 to 2008. Hatched areas represent points that are statistically significant at the 95% confidence level according to the Mann–Kendall test and the Wang and Swail method for autocorrelation.
Adapted with author's permission (Reguero et al, 2019)

Background – Impacts of storm waves at the coast

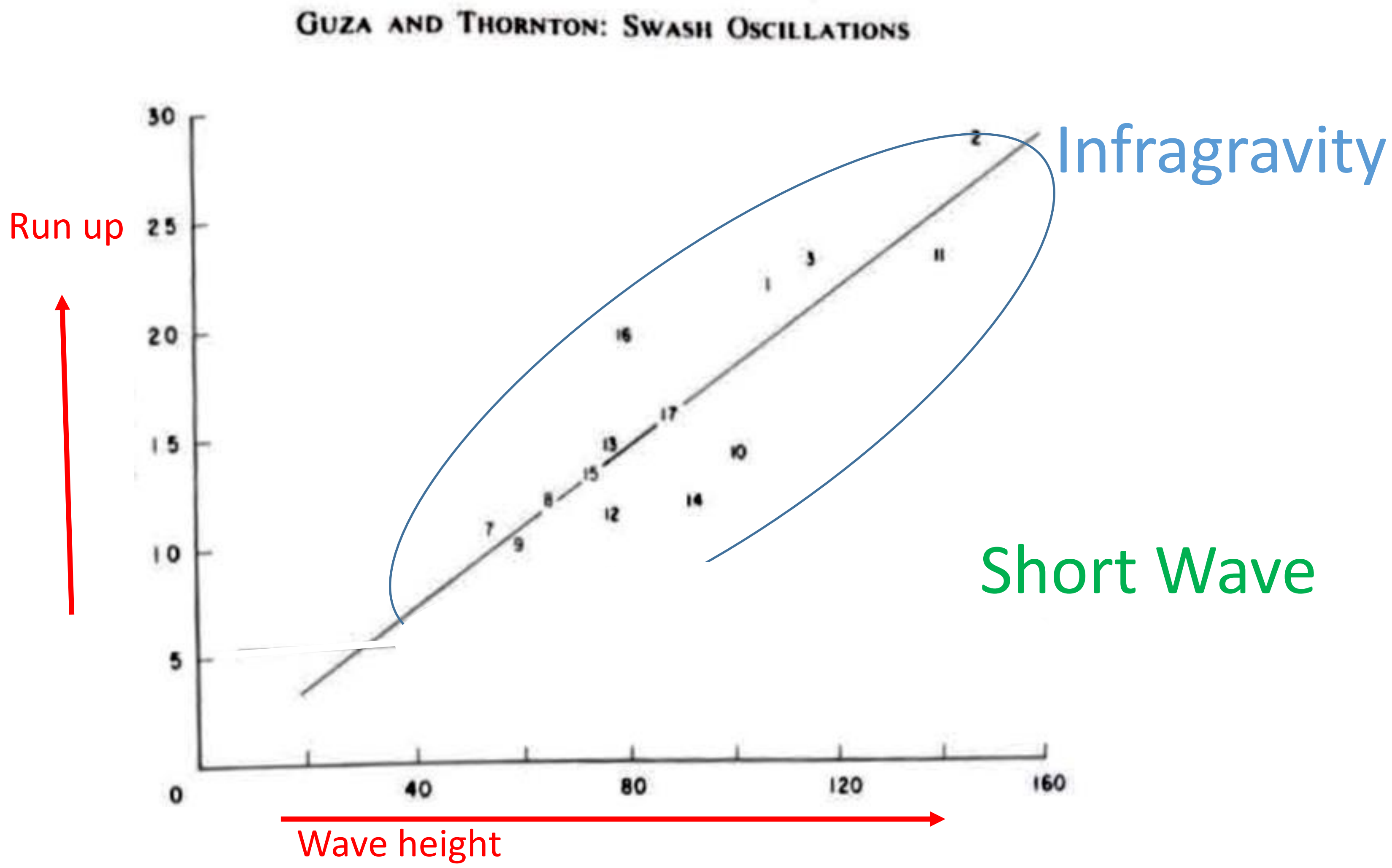
- Extreme wave heights and powers associated with coastal storms drive severe inundation and potentially irreversible erosion.

Gravel barrier over wash – Chesil Beach – February 2014

Background – Importance of low frequency (infragravity) waves

- In addition to a steady increase from sea level rise, coastal total water levels are episodically enhanced by wave action, termed wave runup.
- Specifically, an increase in the contribution of low frequency (infragravity) wave energy (f = 0.004 – 0.04 Hz) to wave runup has been shown to increase during storms, on sandy beaches.

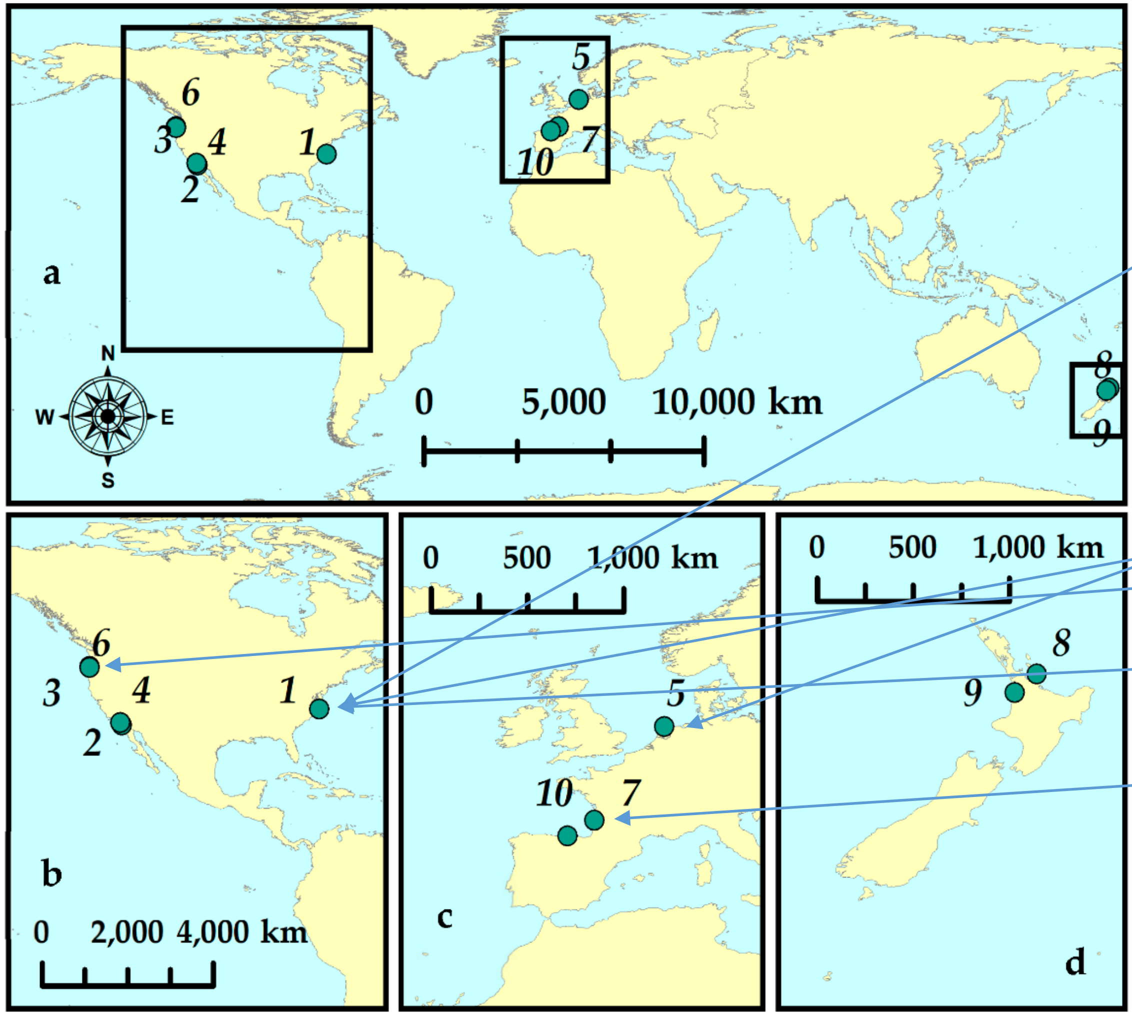
Background – Importance of low frequency waves



Adapted from Guza and Thornton (1982)

Background – Previously Explored Parameter Space

- *Previous observations of infragravity swash have been **mostly limited** to **sandy beaches** and **non storm conditions**, with a small number of exceptions:*



Billson et al (2019)

Map Nº	Site/Experiment	Date	H_o (m)	Tp (s)	Tan β	D50 (mm)
1	Duck, NC (USA) Duck82	5 – 25 Oct 1982	0.7–4.1	6.3–16.5	0.09–0.16	0.75
2	Scripps, CA (USA)	26-29 Jun 1989	0.5–0.8	10–10	0.03–0.06	0.20
1	Duck, NC (USA) Duck90 – Delilah	6-19 Oct 1990	0.5–2.5	4.7–14.8	0.03–0.14	0.36
4	San Onofre, CA (USA)	16-20 Oct 1993	0.5–1.1	13–17	0.07–0.13	-
3	Gleneden, OR (USA)	26-28 Feb 1994	1.8–2.2	10.5–16	0.03–0.11	-
5	Tersheling (Netherlands)	2-22 Apr 1994 1-21 Oct 1994	0.5–3.9	4.8–10.6	0.01–0.03	0.22
1	Duck, NC (USA) Duck94	3-21 Oct 1994	0.7–4.1	3.8–14.8	0.06–0.1	0.20-2.5
6	Agate, OR (USA)	11-17 Feb 1996	1.8–3.1	7.1–14.3	0.01–0.02	0.20
1	Duck, NC (USA) Duck97 – SandyDuck	3-30 Oct 1997	0.4–3.6	3.7–15.4	0.05–0.14	0.90-1.66
7	Truc Vert (France)	3 Mar – 13 Apr 2008	1.1–6.4	11.2–16.4	0.05–0.08	0.35
8	Tairua (New Zeland)	15 – 17 Jul 2008	0.7–1.0	9.9–12.5	0.09–0.13	0.4
9	Ngarunui (New Zeland)	8-9 Nov 2010	0.6–1.3	8.1–12.4	0.01–0.03	0.29
10	Somo (Spain)	4 May 2016	0.3–0.7	11.0–13.0	0.04–0.1	0.28-0.35

Method – Rapid Coastal Response Unit (RCRU)

- Versatile and sheltered base, facilitating the collection of **hydrodynamic** and **topographic** data during **extreme storms**.
- Housing an array of **in-situ** and **remote instrumentation**, suitable for **rapid deployment (hours)**
- Observations collected during:
  - Approach, peak, and decay of the storm
  - From offshore, through the surf zone, to the shoreline.

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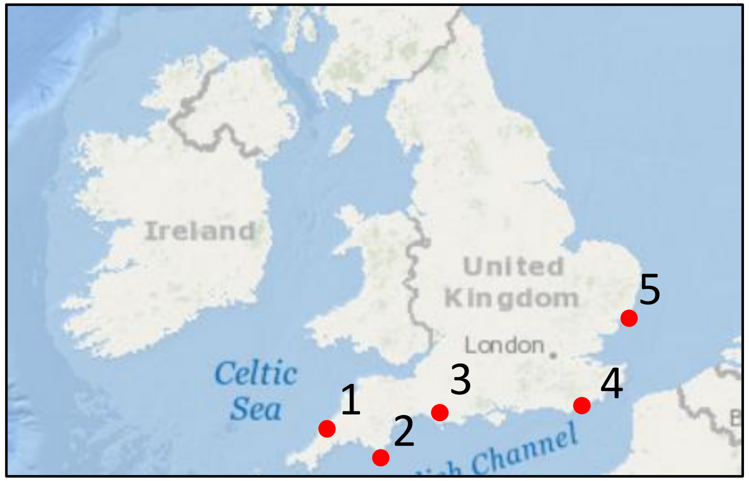
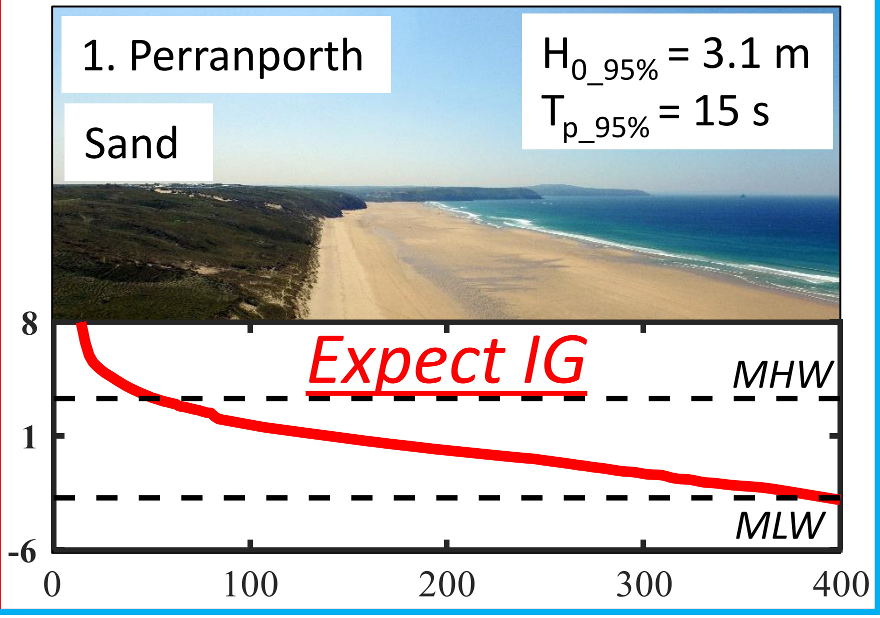
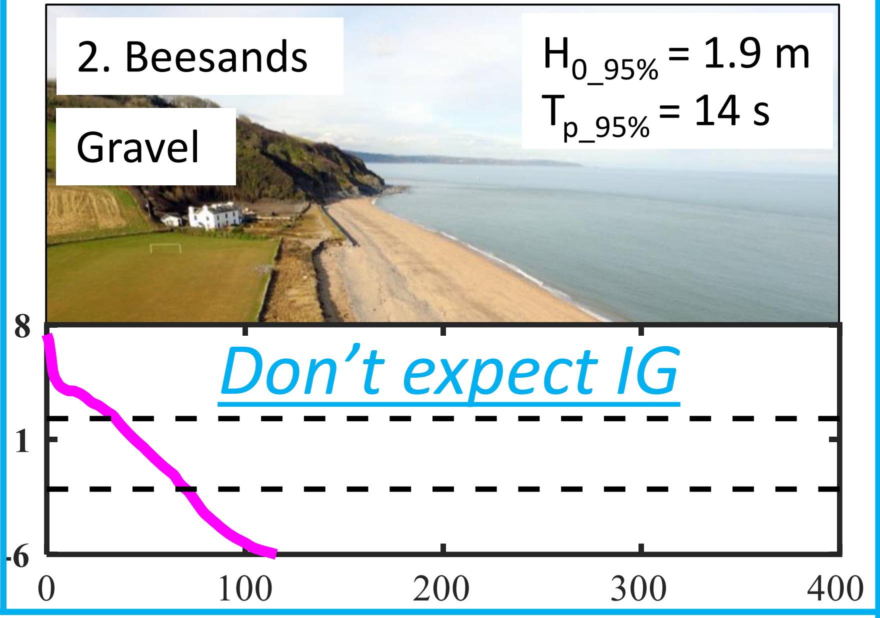
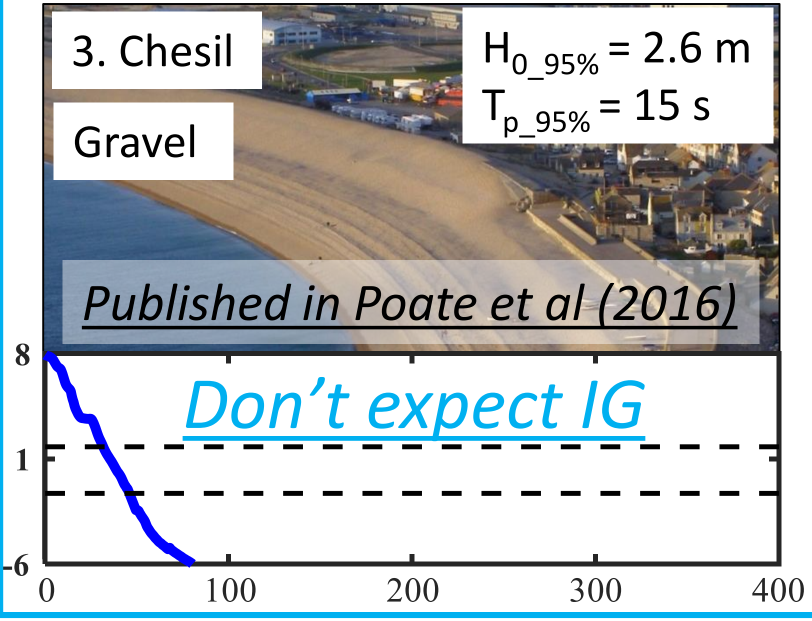
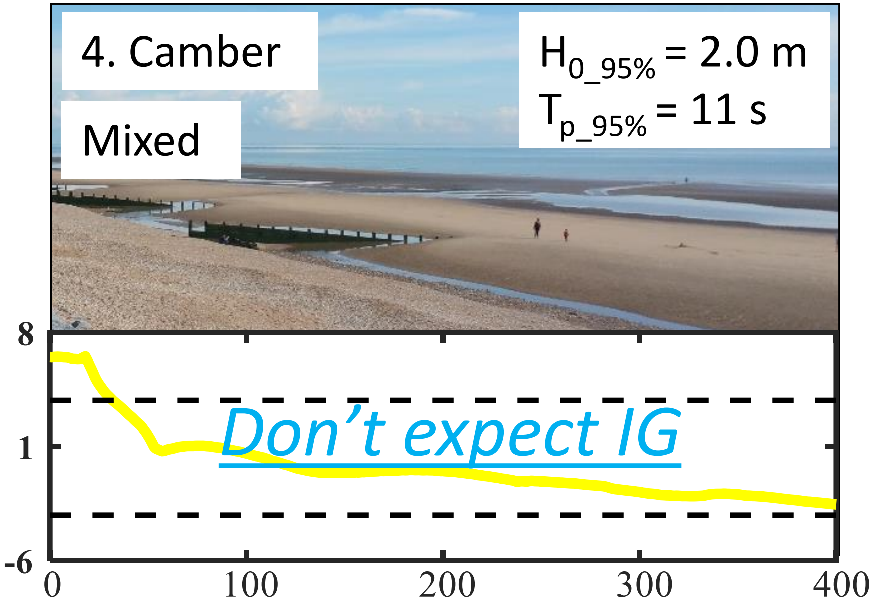
Method - Storm Survey Sites

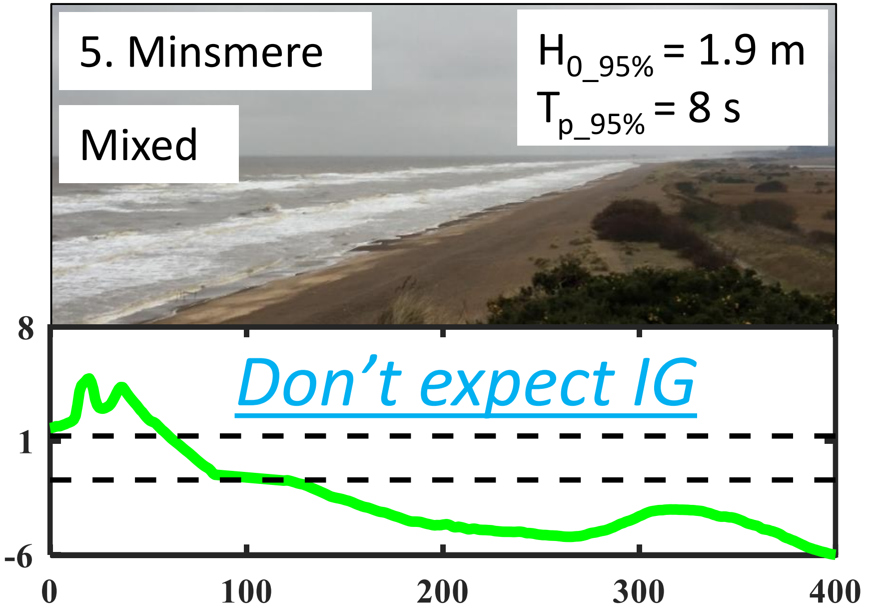












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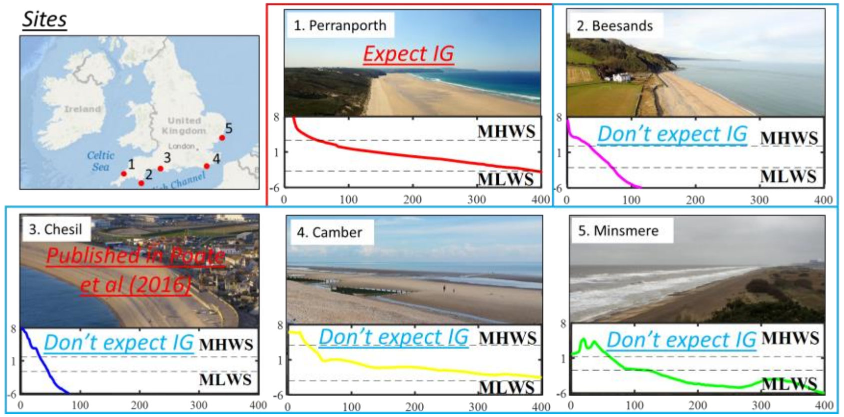
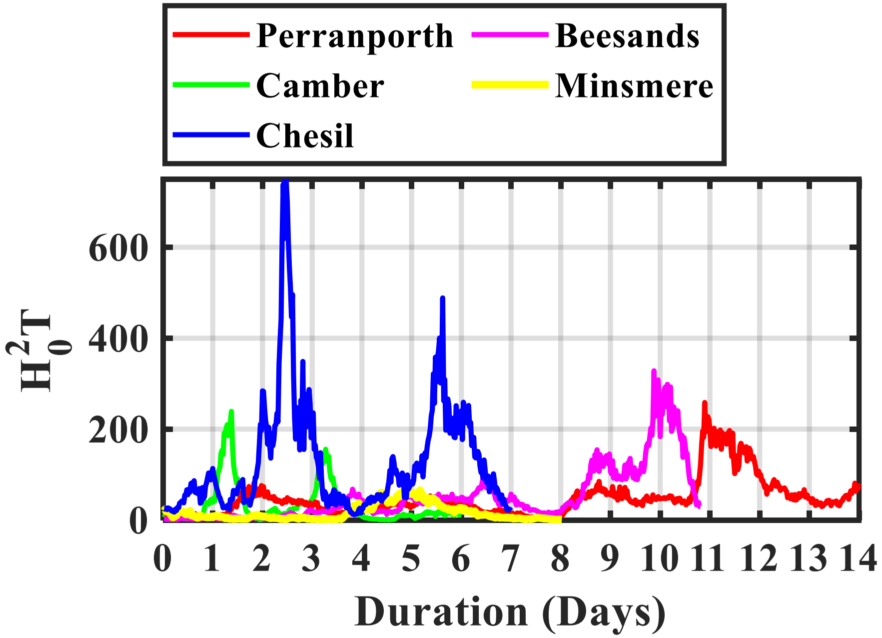
Method - New storm wave data set

Name	Date	Site	Height Hs (m)	Period Tp (s)	Slope Tan (β)	Grainsize D_{50} (mm)	Return period (years)



project (Poate et al 2016)

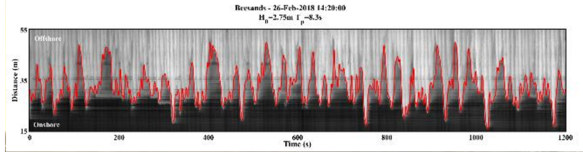


Method – Video Analysis

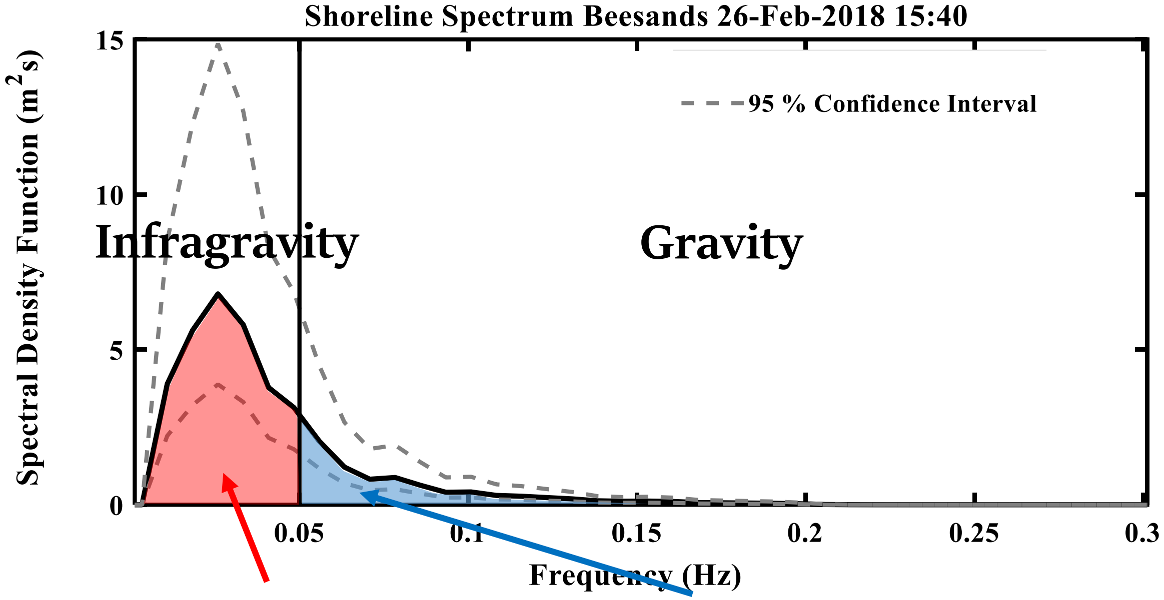
1. Images collected at 4Hz

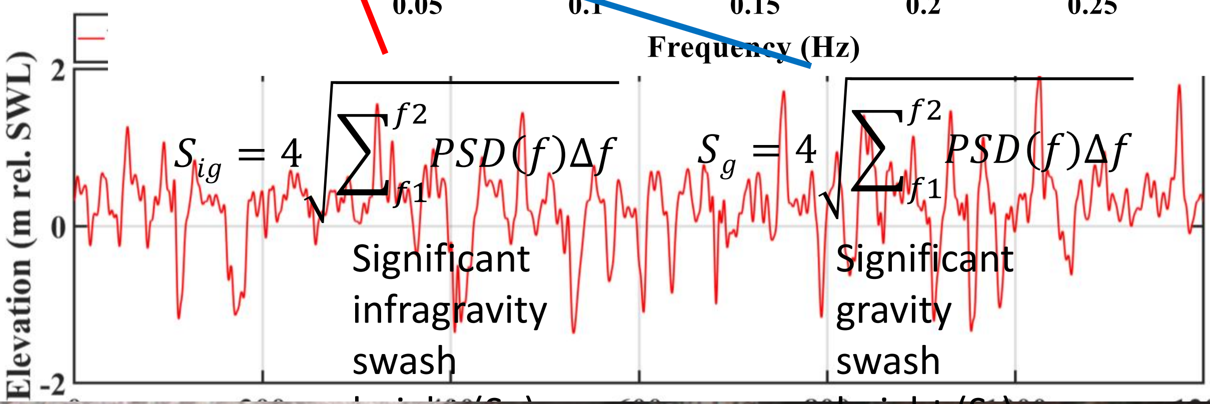
2. Extra

3. Stack pixels horizontally



4. Extr





$$S_{ig} = 4\sqrt{\sum_{f1}^{f2} PSD(f)\Delta f}$$

Significant infragravity swash

$$S_{g} = 4\sqrt{\sum_{f1}^{f2} PSD(f)\Delta f}$$

Significant gravity swash height (S_g)

/ **0.91m** =

Measure of IG ‘dominance’ S_{ig}/S_g

2.01

Example Analysis

- What is the relationship between infragravity swash height (S_{ig}) and:
  - H_o
  - T_p
  - Tanβ
- Previously published relationships:
  - Stockdon et al (2006) – Sand specific
  - Poate et al (2016) – Gravel specific

  - New, universal equation?

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Article

Storm Waves at the Shoreline: When and Where Are Infragravity Waves Important?

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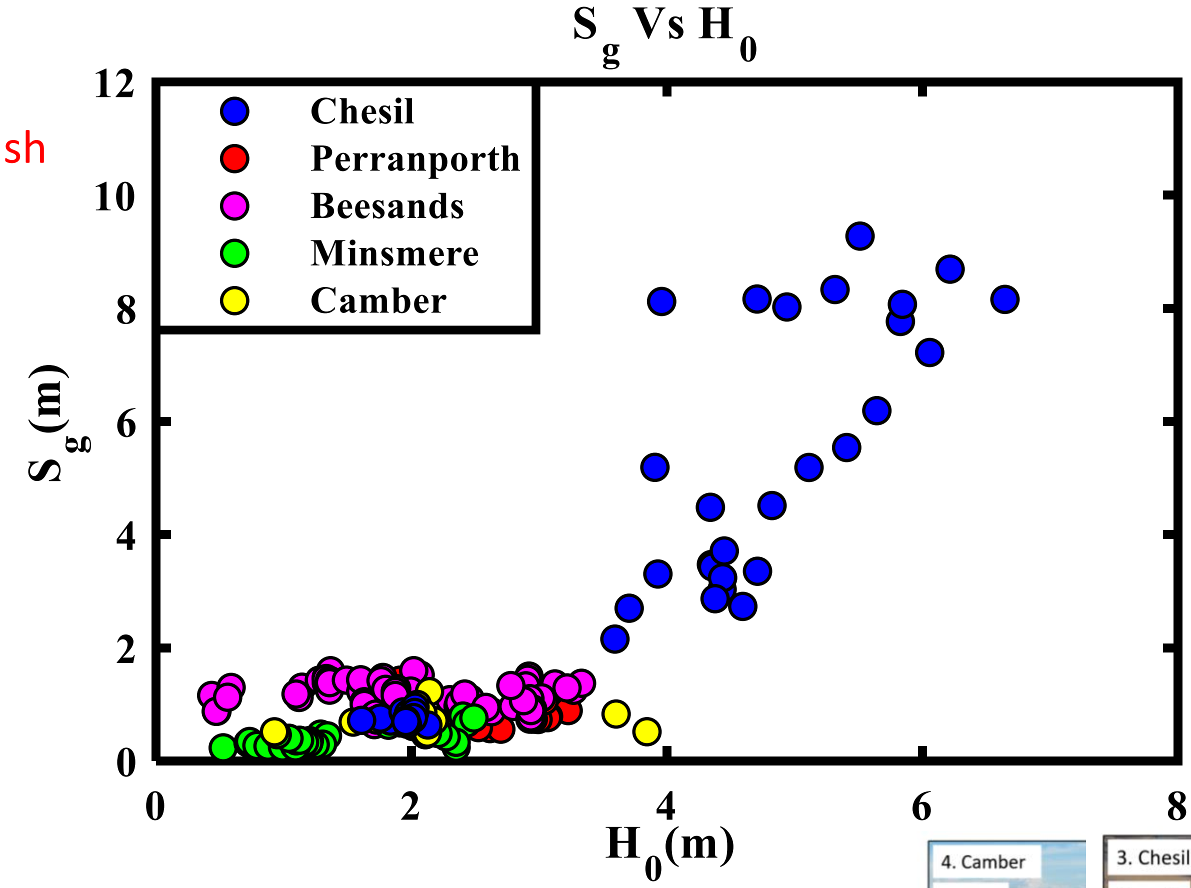
check for updates

Results – IG magnitude and Relationship with H_o

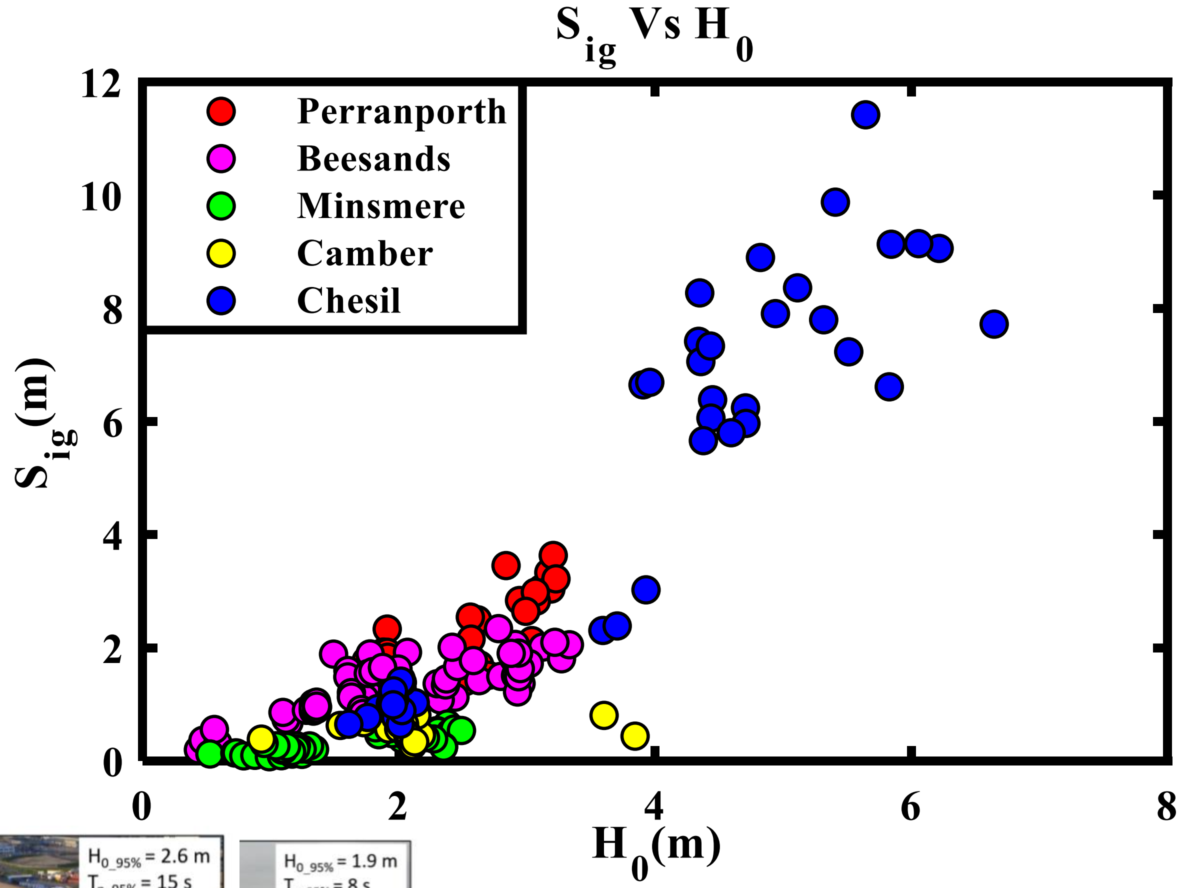
Gravity Swash (S_g)

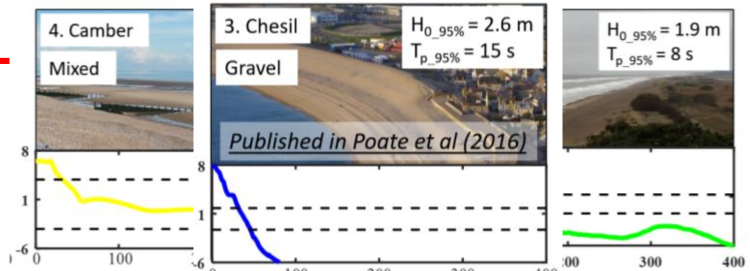
Swash



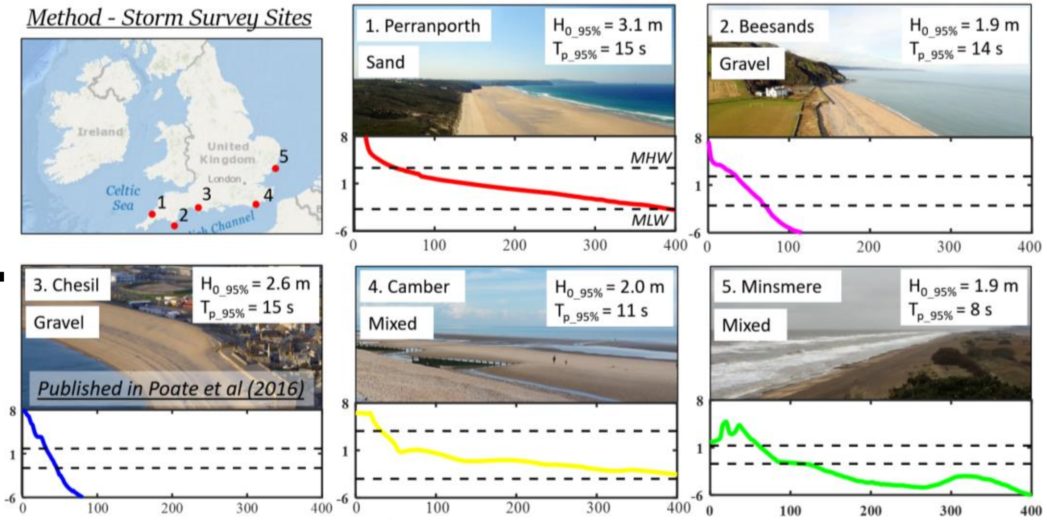
Wave height

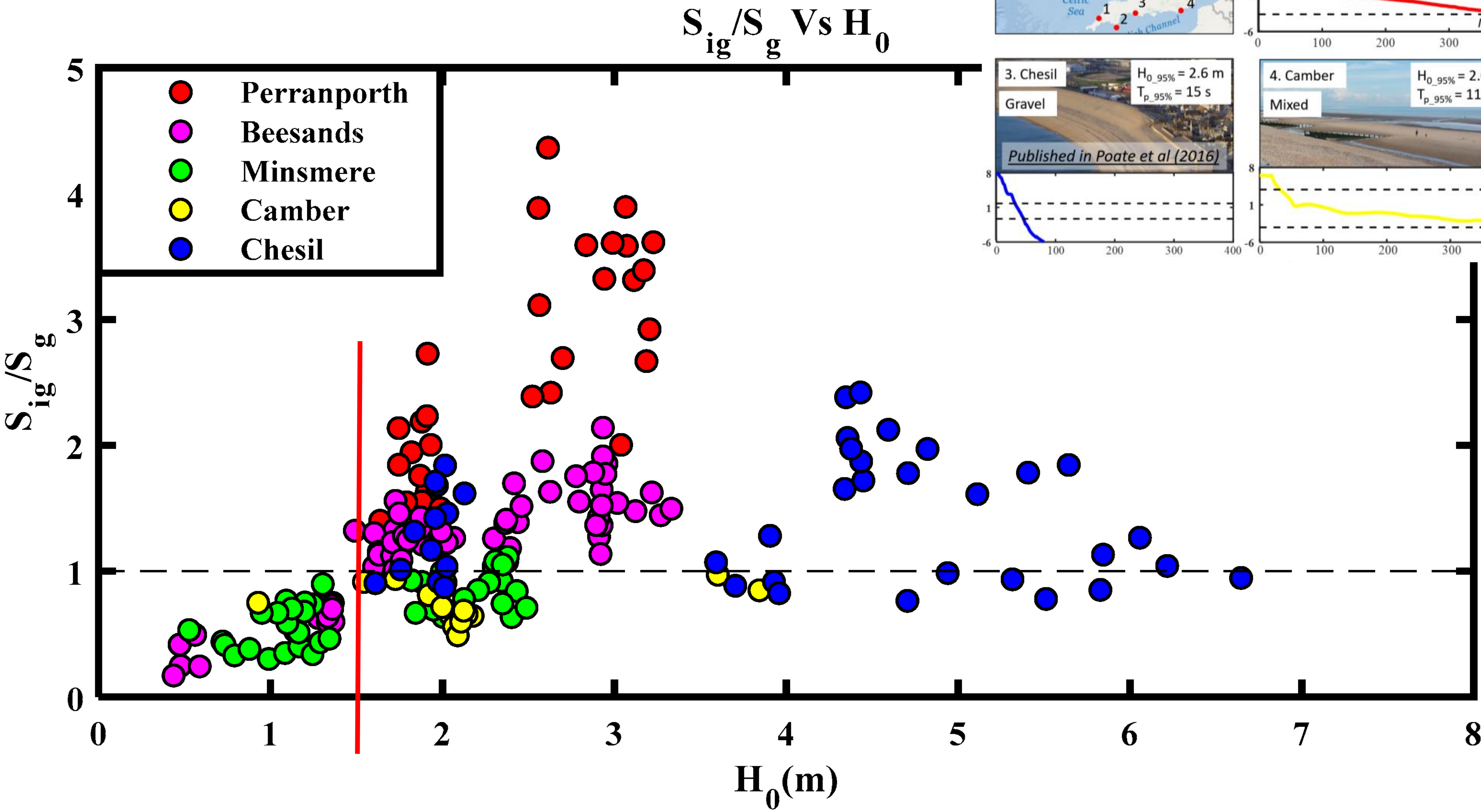
Infragravity Swash (S_{ig})





Results – Infragravity Swash Dominance





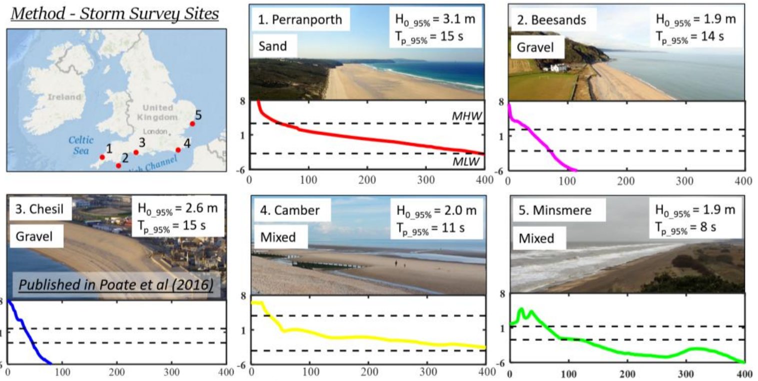
IG Dominated

Gravity Dominated

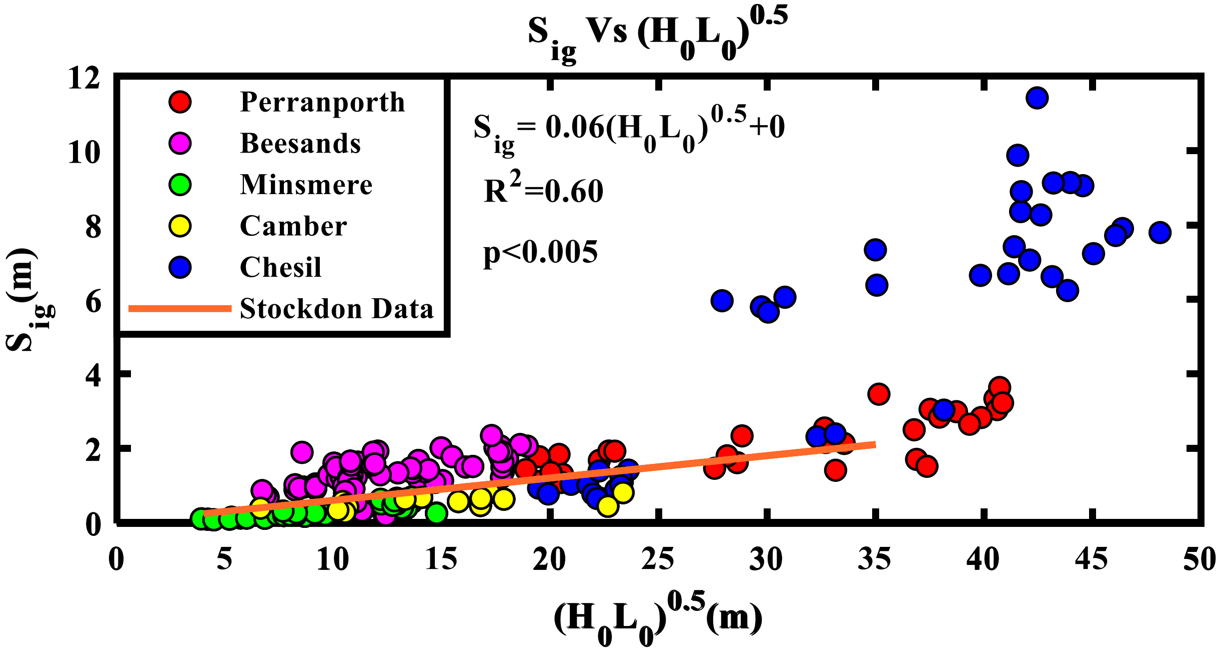
IG dominance when H_0 > 1.5 m on sand and gravel beaches

Results – Stockdon equation

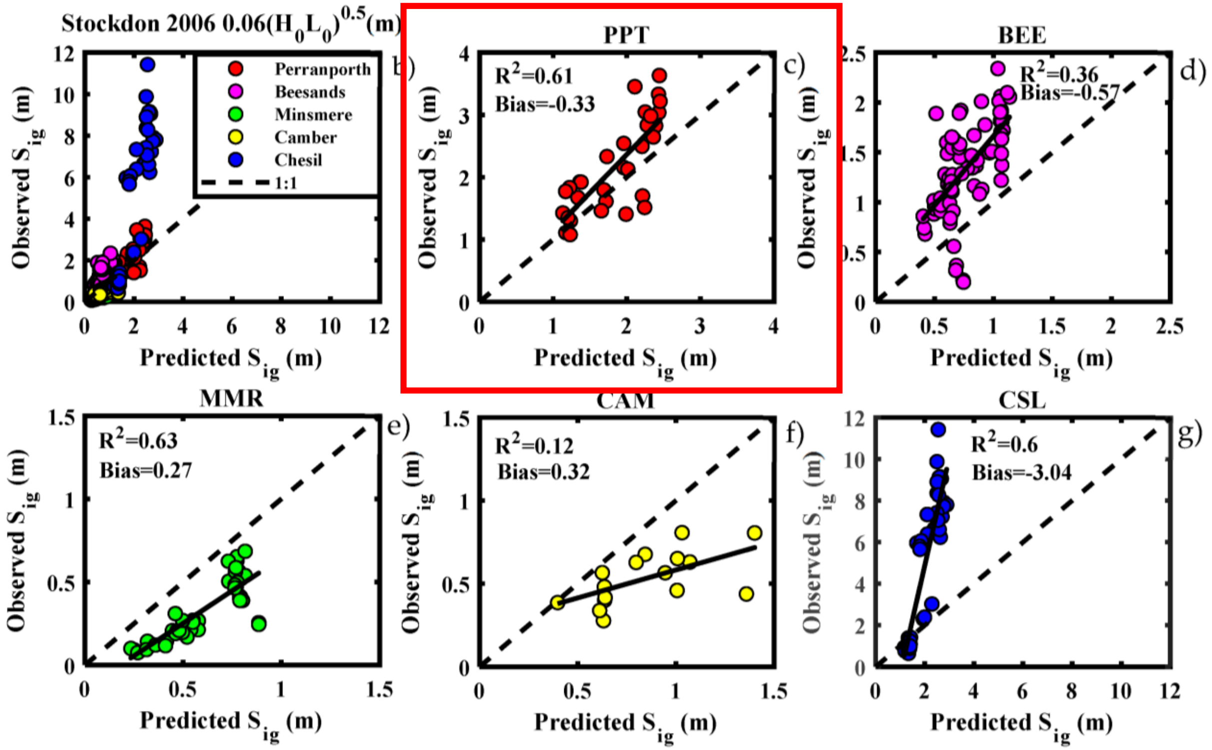
- $S_{ig} = (H_o L_o)^{0.5}$ – developed on sandy beaches
- Worked best for the sand beach



Observed Data and Stockdon data

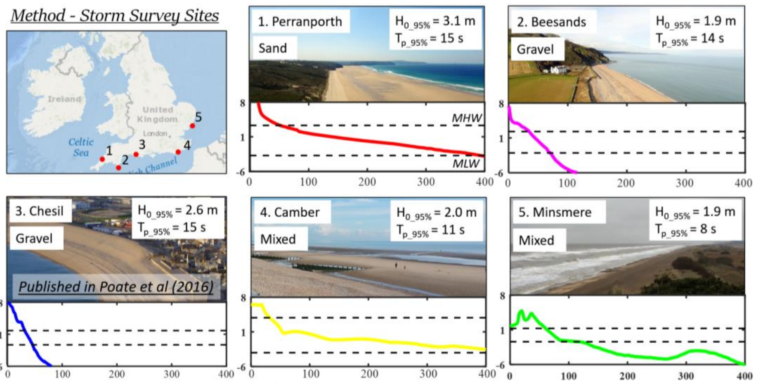


Observed Data vs Stockdon prediction

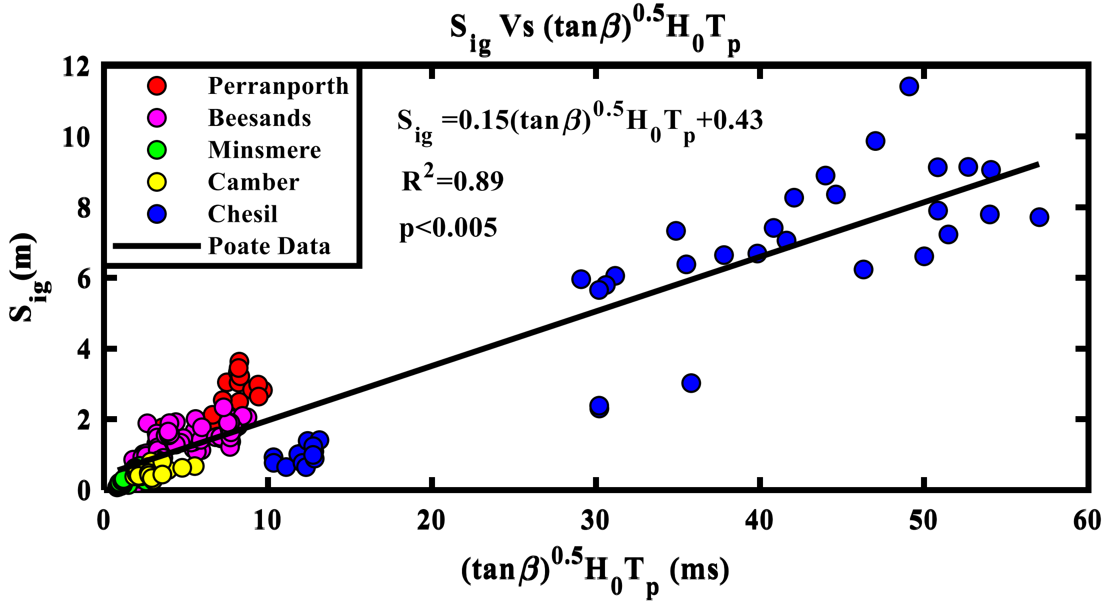


Results – Poate Equation

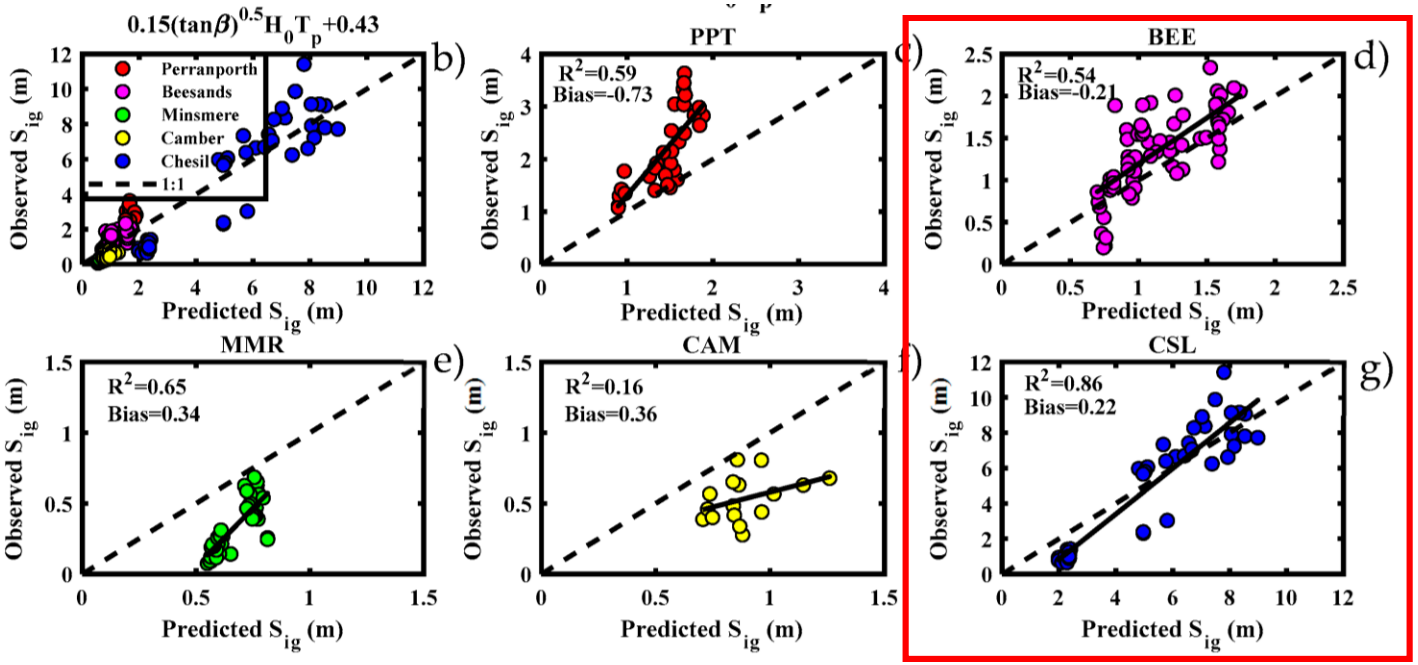
- $S_{ig} = (\tan\beta)^{0.5} H_o T_p$ – developed on gravel beaches
- Worked best on gravel beaches



Observed Data and Stockdon data

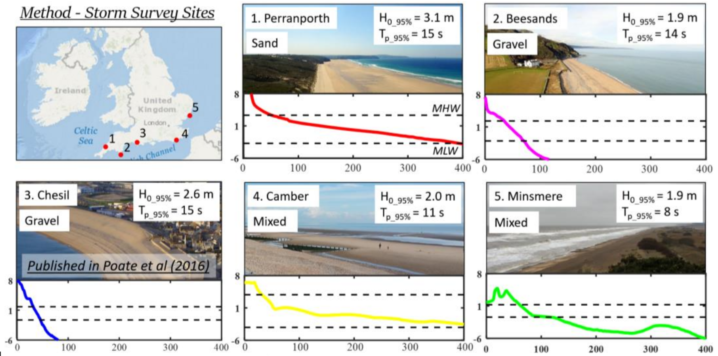


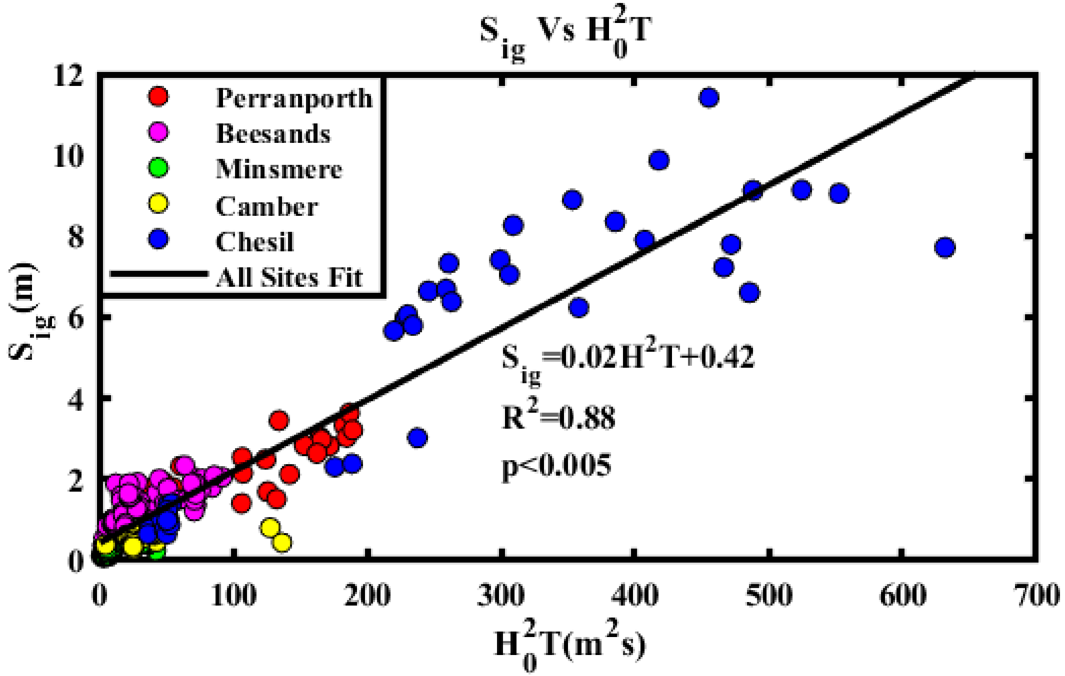
Observed Data vs Stockdon prediction

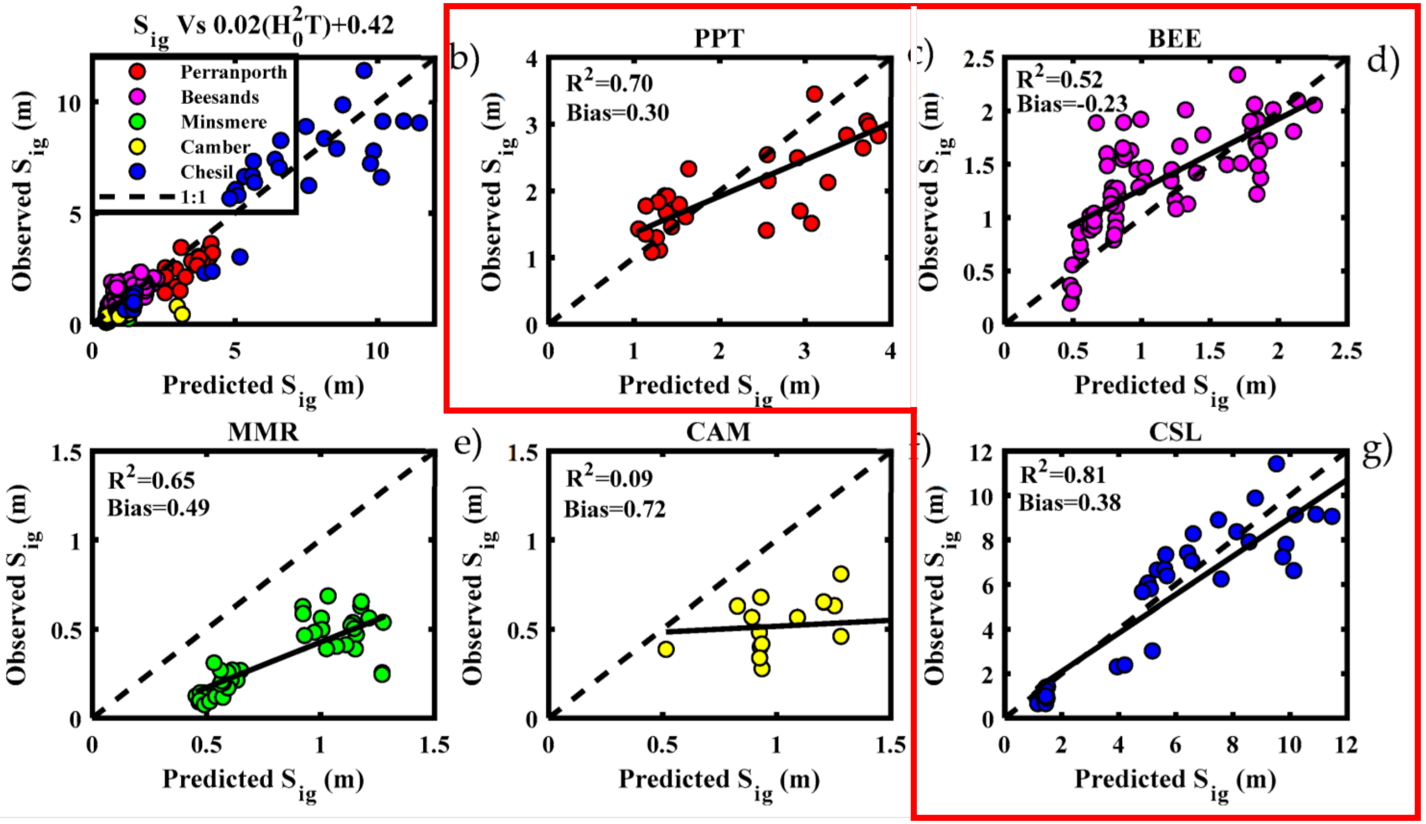


Results – $H_o{}^2T$

- $S_{ig} = H_o{}^2T$ – Parameterisation of wave power
- Reasonable across IG dominated sites
- If waves are powerful enough, IG can become apparent in the swash, across morphologies







Conclusions

- Shoreline IG measured under an unprecedented range of wave and beach conditions $H_o < 6$ m, $T_p < 20$ s, $\tan\beta < 0.32$, $D_{50} < 60$ mm
- Shoreline IG present at all sites, but only dominant over G on 'pure' morphologies
- Parametrised wave power (H_o^2T) shown to explain variability reasonably well at contrasting IG dominated site, compared with previous empirical fits
- Implication that if H_o^2T is large enough, IG can become important at the shoreline regardless of morphology

- Leaving a **range of coastal environments** vulnerable to **IG driven inundation and erosion**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