Proyecciones hacia finales de siglo del nivel del mar extremo sobre la base del escenario de emisiones RCP 8.5

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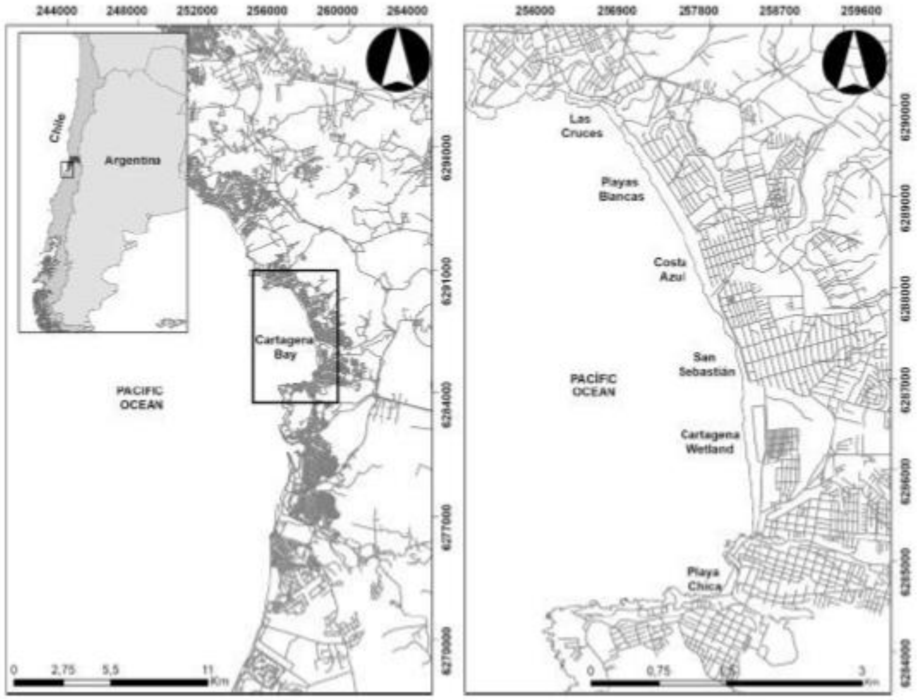
INTRODUCCIÓN

SECTOR DE ESTUDIO - CARTAGENA BAY (33.5°S)

Cartagena is a Chilean commune located in the San Antonio Province, Valparaíso Region. The commune spans an area of 245.9 km2. Is one of the largest in central Chile and currently one of the most anthropized by urbanization. Its physical-natural attributes and history of occupancy allow its risk conditions, including the following, to be contextualized:



Source: Martinez et al. 2020

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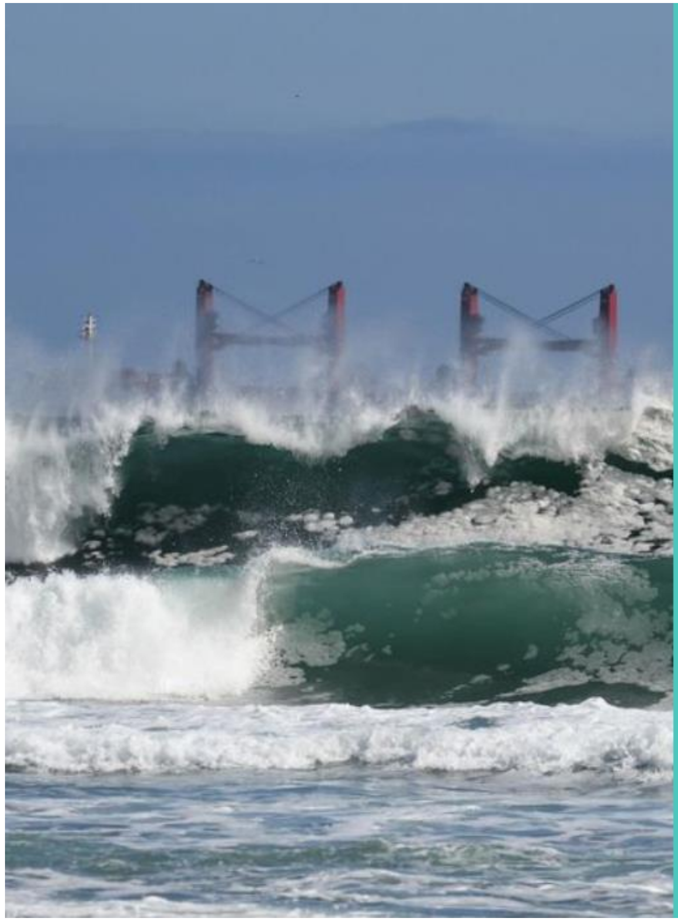
MOTIVACIÓN
INUNDACIONES COSTERAS EN CARTAGENA



Qué Pasa de La Tercera | 30 AGO 2022 02:09 PM | Tiempo de lectura: 5 minutos

Puertos chilenos bajo sitio: Cambio climático, marejadas y alza del nivel de mar impactarán infraestructura portuaria

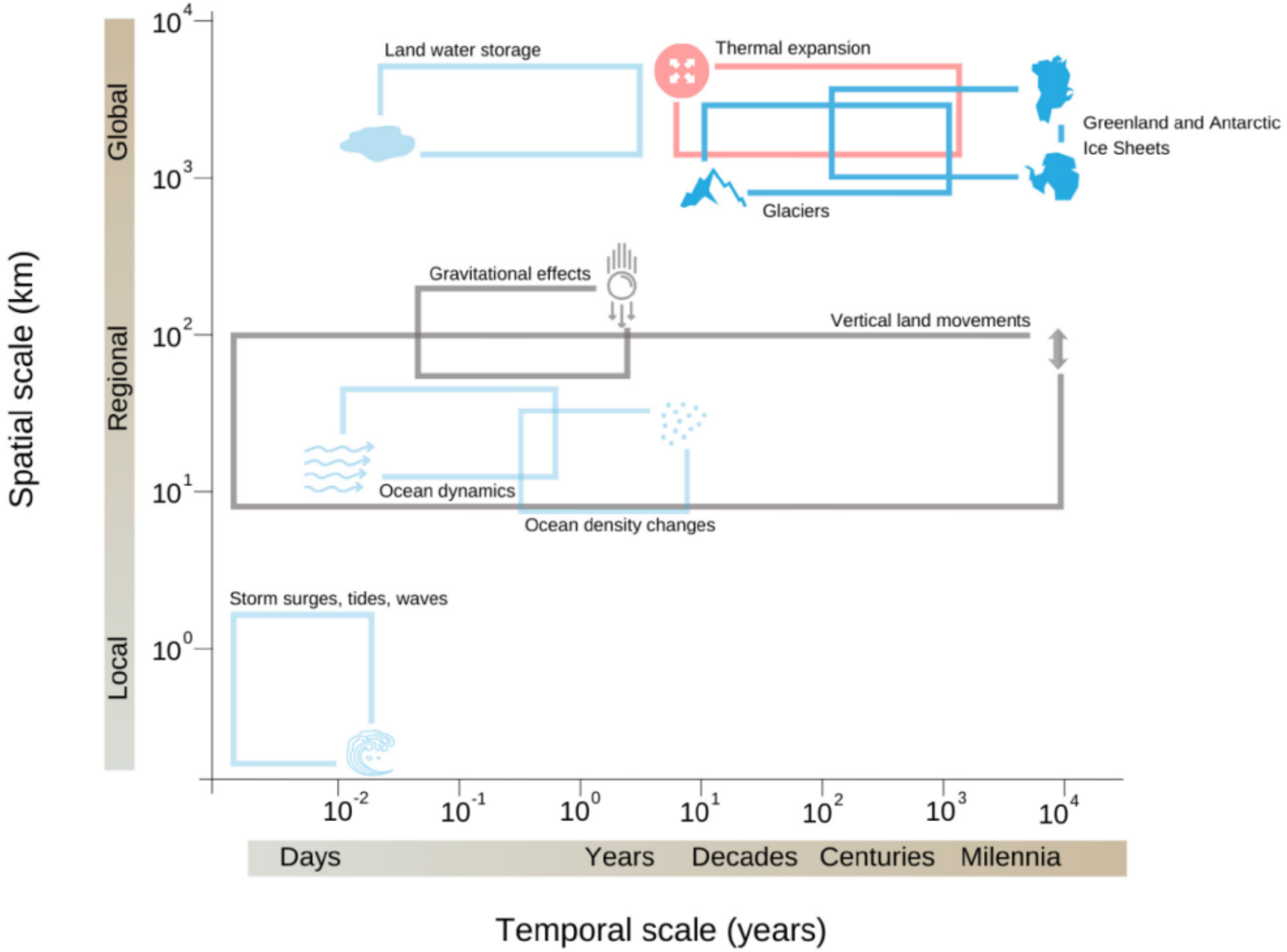
Estudio liderado por el académico de la U. de Valparaíso e investigador de CIGIDEN, Patricio Winckler, abordó el impacto del clima en las condiciones de operatividad de siete grandes puertos estatales de Chile, encargados del 90% del comercio internacional.

QUÉ PASA Ciencia Clima ...

Marejada 21-22 Agosto 2021 Humedal de Cartagena. Fuente: P. Cortez (IMCartagena).

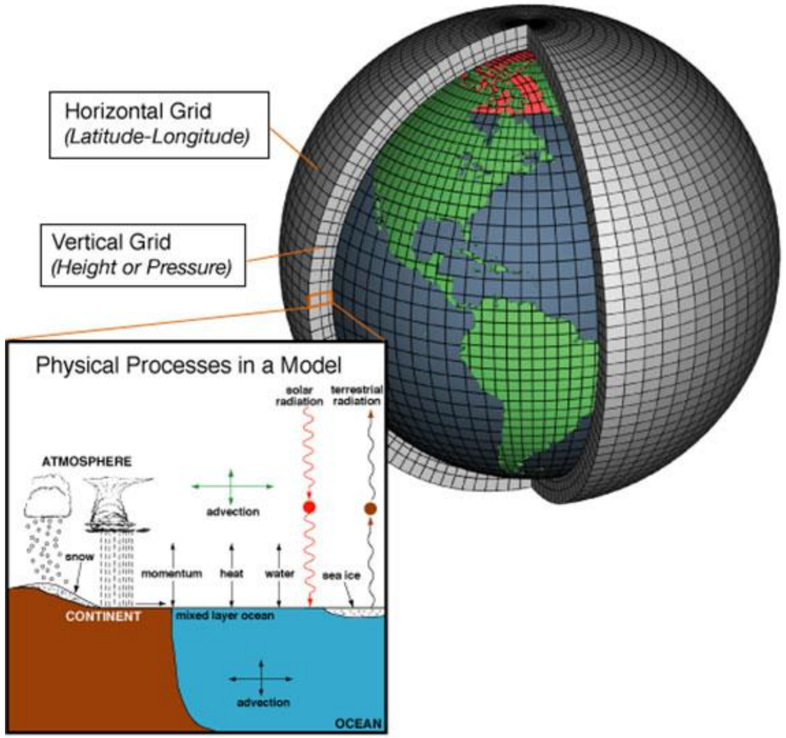
NIVEL DEL MAR EXTREMO

MULTIPLES ESCALAS



Source: Durand et al. (2022)

GLOBAL CLIMATE MODELS (GCM)



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WCRP CMIP5
World Climate Research Programme

NLHPC
National Laboratory
for High Performance
Computing
Chile

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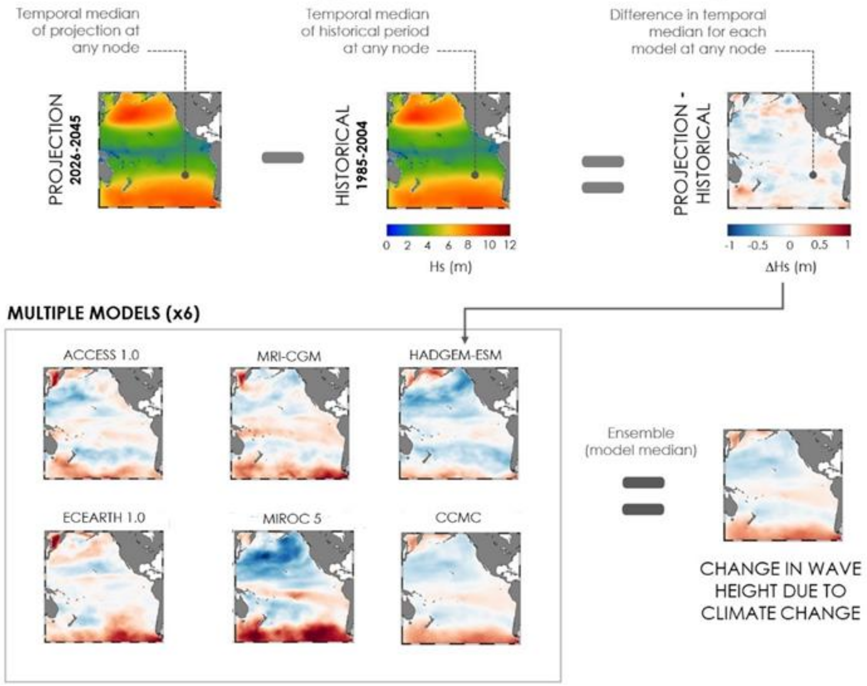
GCM [proyección]	Institución	Resolución Atmosférica Lon x Lat	Resolución temporal (viento) x (hielo marino)	Ensemble
ACCESS 1.0 historical: 1985-2004 midRCP85: 2026-2045 endRCP85: 2081-2100	CSIRO-BOM	1.88 × 1.25	3hrs x 1dia	r1i1p1
MRI-CGM3 historical: 1985-2004 midRCP85: 2026-2045 endRCP85: 2081-2100	Meteorological Research Institute	1.1 × 1.1	3hrs x 1dia	r1i1p1
MIROC5 historical: 1985-2004 midRCP85: 2026-2045 endRCP85: 2081-2100	Atmosphere and Ocean Research Institute, The University of Tokyo	1.4 × 1.4	3hrs x 1dia	r1i1p1
HadGEM2-ES historical: 1985-2004 midRCP85: 2026-2045 endRCP85: 2081-2100	Met Office Hadley Centre UK	1.88 × 1.25	3hrs x 1dia	r1i1p1
CMCC-CM historical: 1985-2004 midRCP85: 2026-2045 endRCP85: 2081-2100	Centro Euro-Mediterraneo per i Cambiamenti	0.7484 × 0.75	3hrs x 1dia	r1i1p1
EC-EARTH historical: 1985-2004 midRCP85: 2026-2045 endRCP85: 2081-2100	European Consortium	1.1215 × 1.125	3hrs x 1mes	r8i1p1

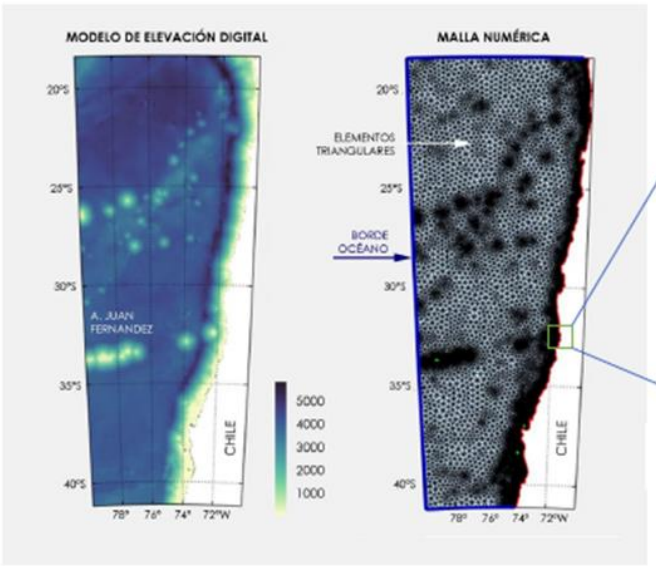
CMIP5 involves 20 climate modeling research groups around the world with 40 GCMs. CMIP5 outputs

Source: https://www.climate.gov/maps-data/climate-data-primer/predicting-climate/climate-models

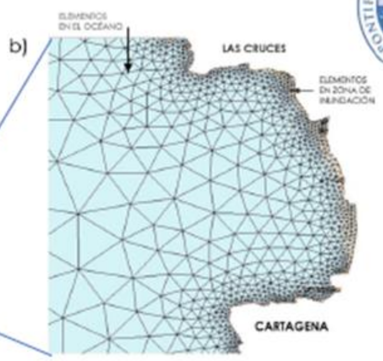
Multimodel ensemble of six GCM – significant wave height (WAVEWATCH III v6.07)



ADCIRC v55



Latitdue 33.5S



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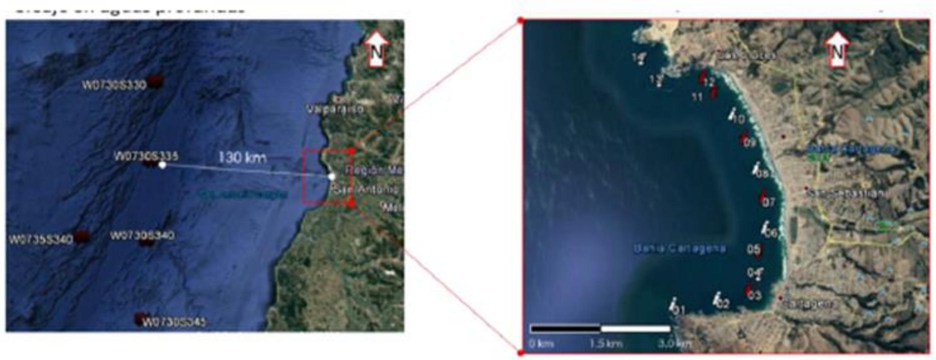
Sea Level Rise (21 GCMs)

Additive linear model

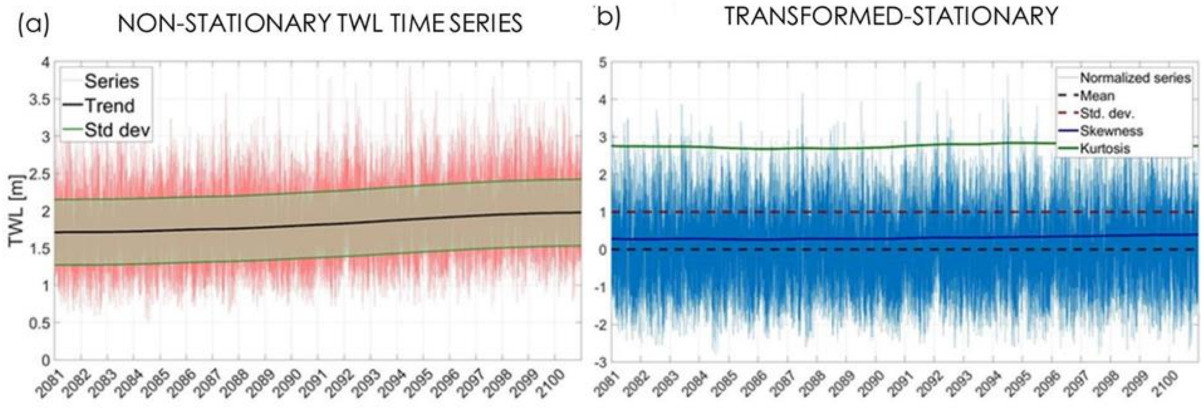
$$TWL(t) = h_{runup}(t) + h_{\substack{storm\\surge}}(t) + h_{\substack{sea\\level\\rise}}(yearly) + h_{astro}$$

Coastal Wave Propagation Nodes (STWAVE 6.0)

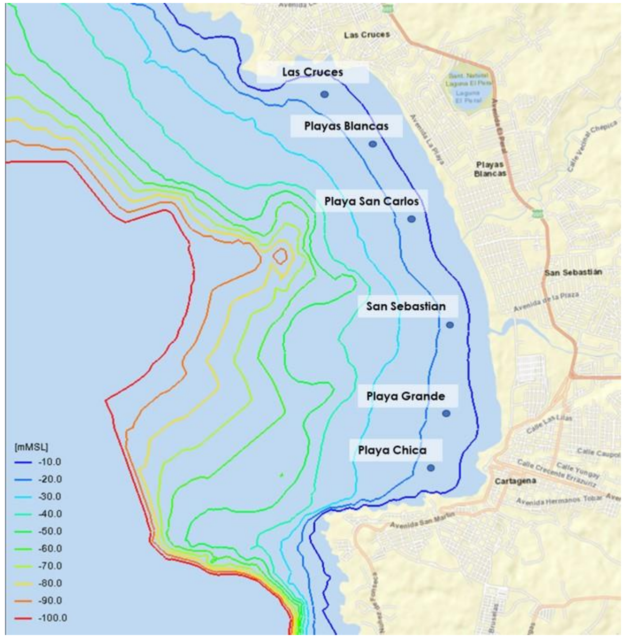


Run-up Stockdon (2006)

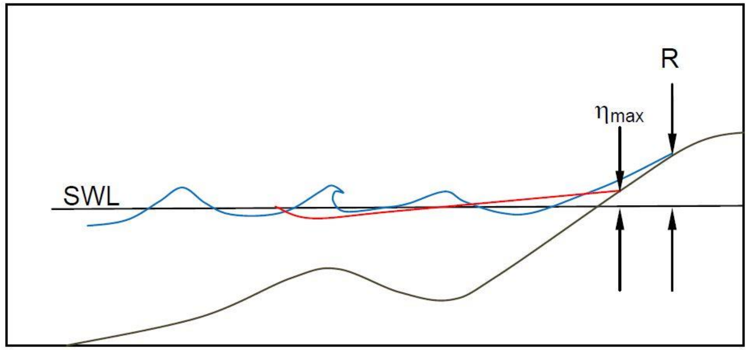
Total Water Level TWL time series



COASTAL RUNUP - STOCKDON ET AL. (2006)



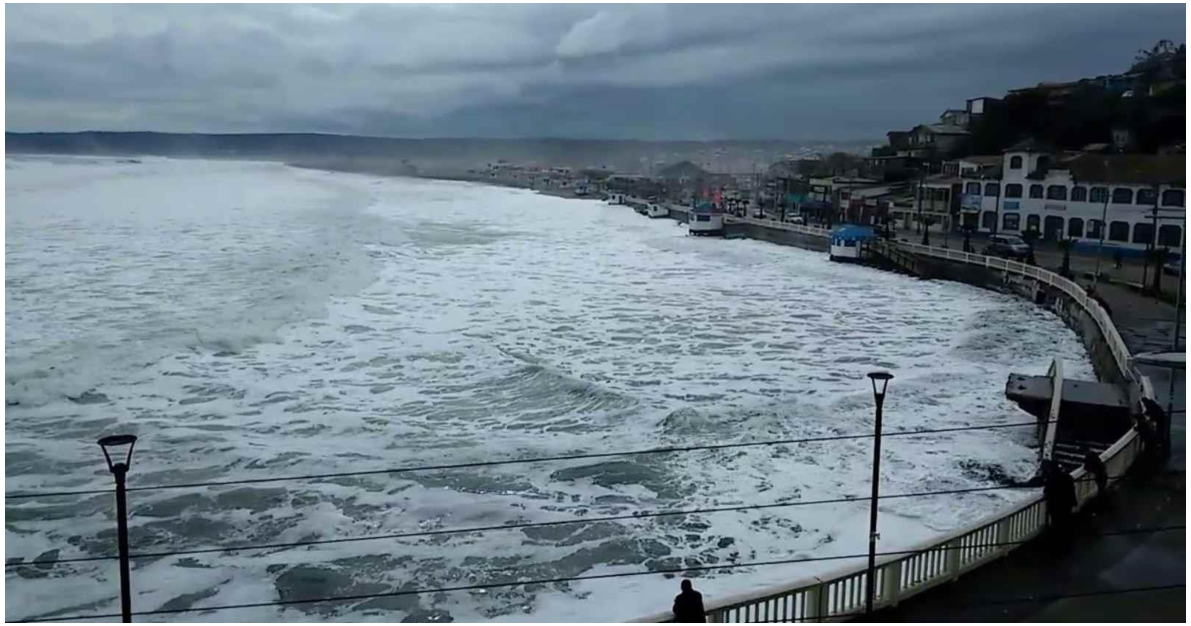
Beach	Transect	Transect slope	Slope used
Playa Chica	1	0.040	0.050
	2	0.060	
Playa Grande	3	0.060	0.070
	4	0.070	
	5	0.070	
	6	0.080	
Playa San Sebastian (wetland)	7	0.085	0.0850
	8	0.085	
	9	0.085	
	10	0.085	
Playa San Carlos	10	0.085	0.0913
	11	0.125	
	12	0.070	
	13	0.085	
Playas Blancas	13	0.085	0.0875
	14	0.110	
	15	0.085	
	18	0.070	
Playa Las Cruces	15	0.085	0.1033
	16	0.115	
	17	0.110	

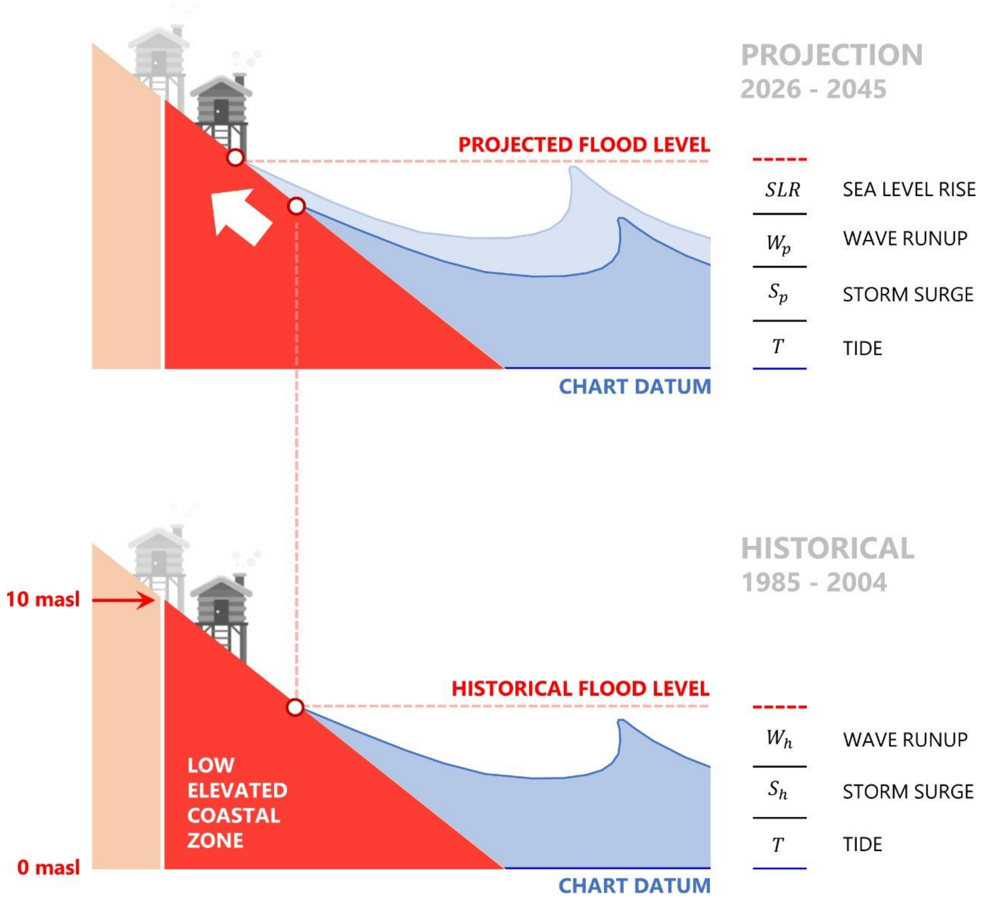


$$R_{2\%} = 1.1\left[0.35\tan\beta_f (H_0 L_0)^{1/2} + \frac{H_0 L_0 (0.5625 \tan\beta_f^2 + 0.0004)^{1/2}}{2}\right]$$

METODOLOGÍA
TOTAL WATER LEVEL

$$TWL(t) = h_{runup}(t) + h_{\substack{storm\\surge}}(t) + h_{\substack{sea\\level\\rise}}$$

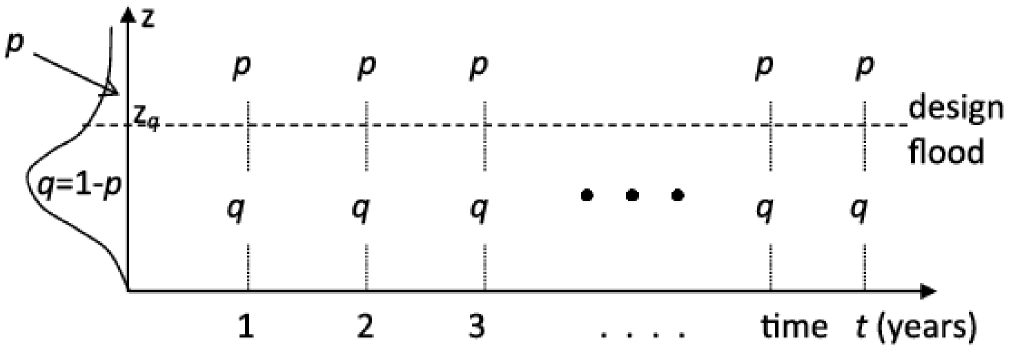




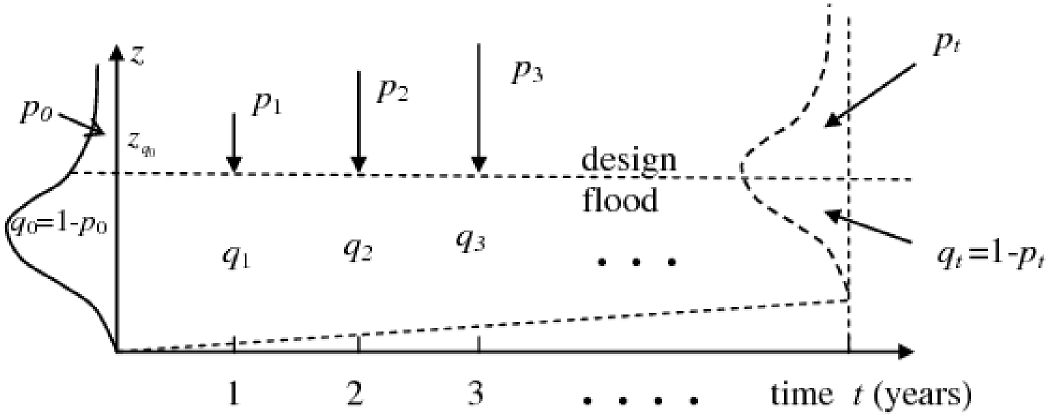
Winckler et al. (2022)

METODOLOGÍA

EXTREME VALUE – TRANSFORMED STATIONARY METHOD (MENTASCHI ET AL. 2016)

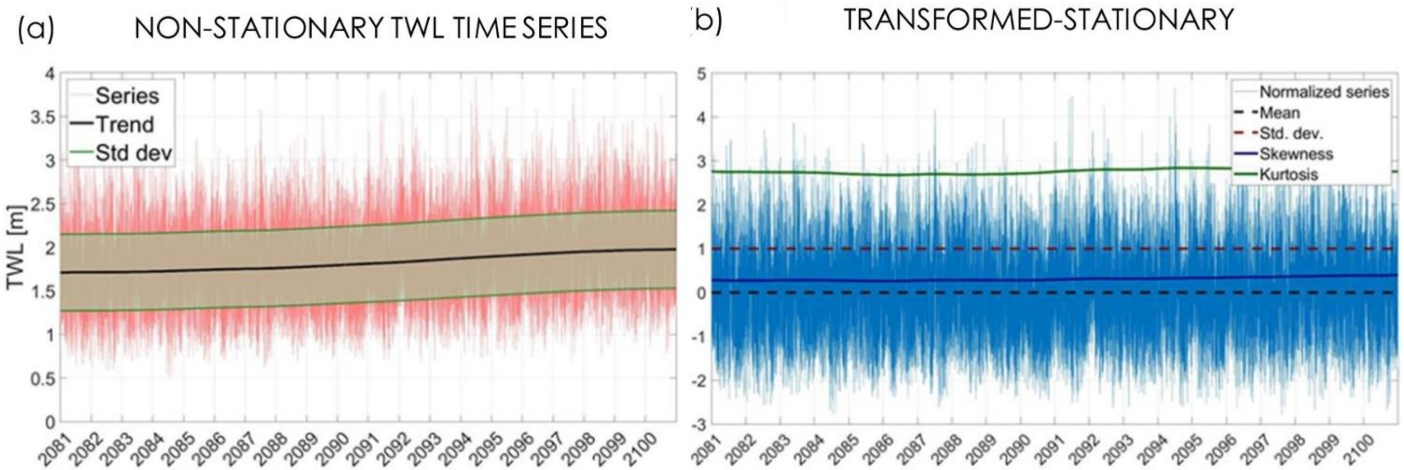


Source: Salas and Obeysekera (2014)



Normalize in time (remove non stationarity)

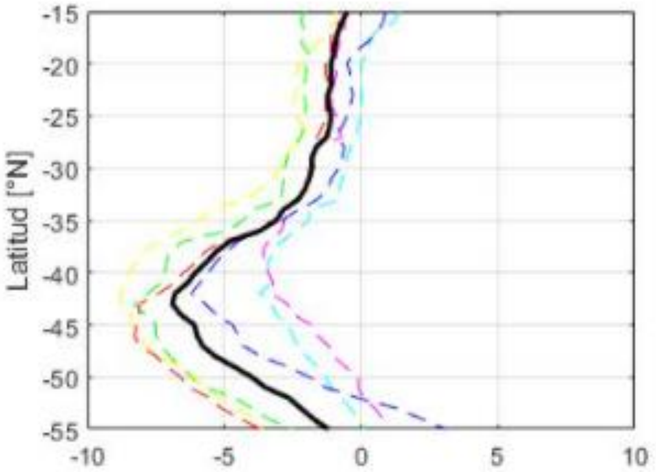
$$x(t) = \frac{y(t) - tr_y(t)}{std_y(t)}$$



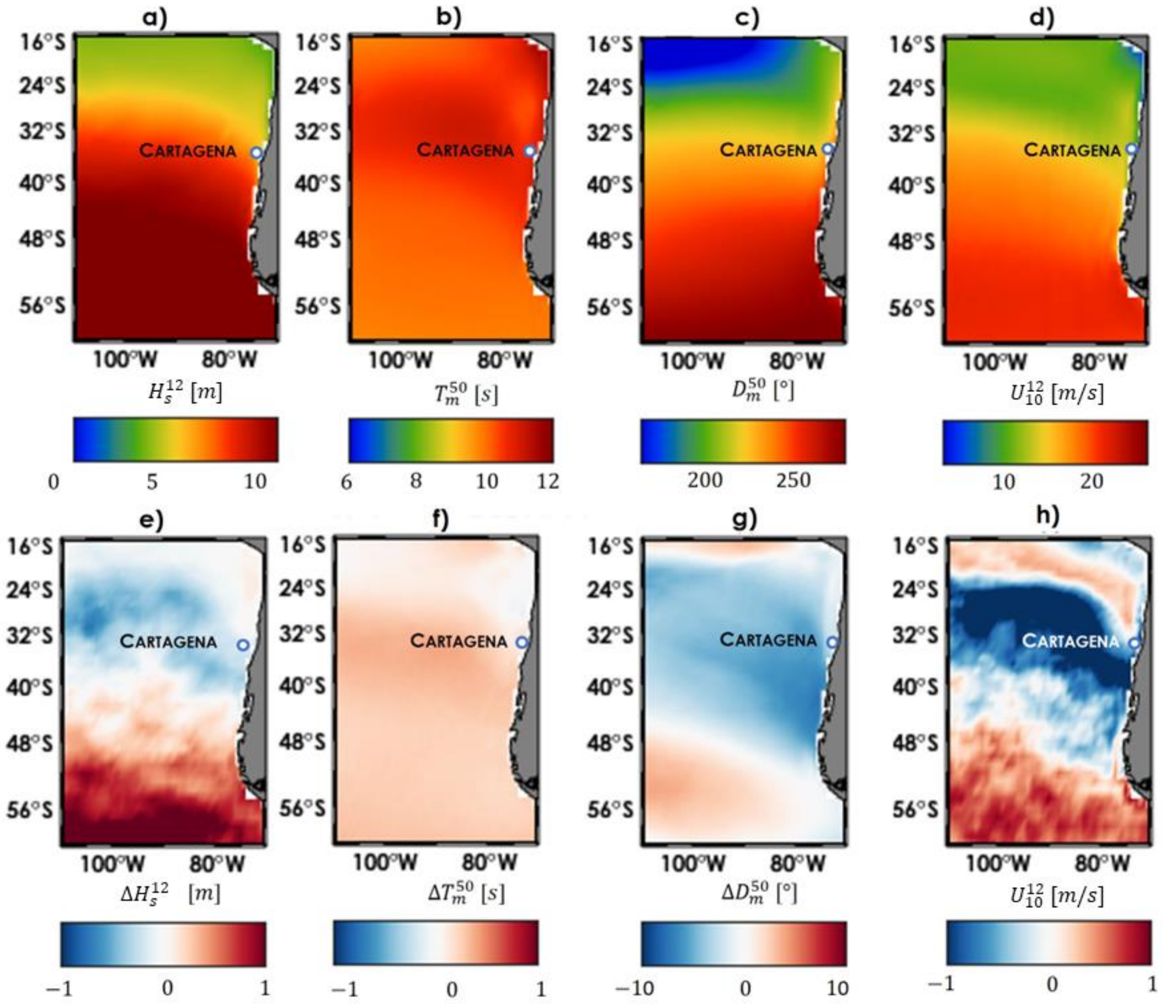
For the ESL we use the method of peak over threshold (POT) and the generalized Pareto distribution (Pickands, 1975).

RESULTS - END CENTURY WAVE PROJECTIONS (2081-2100)

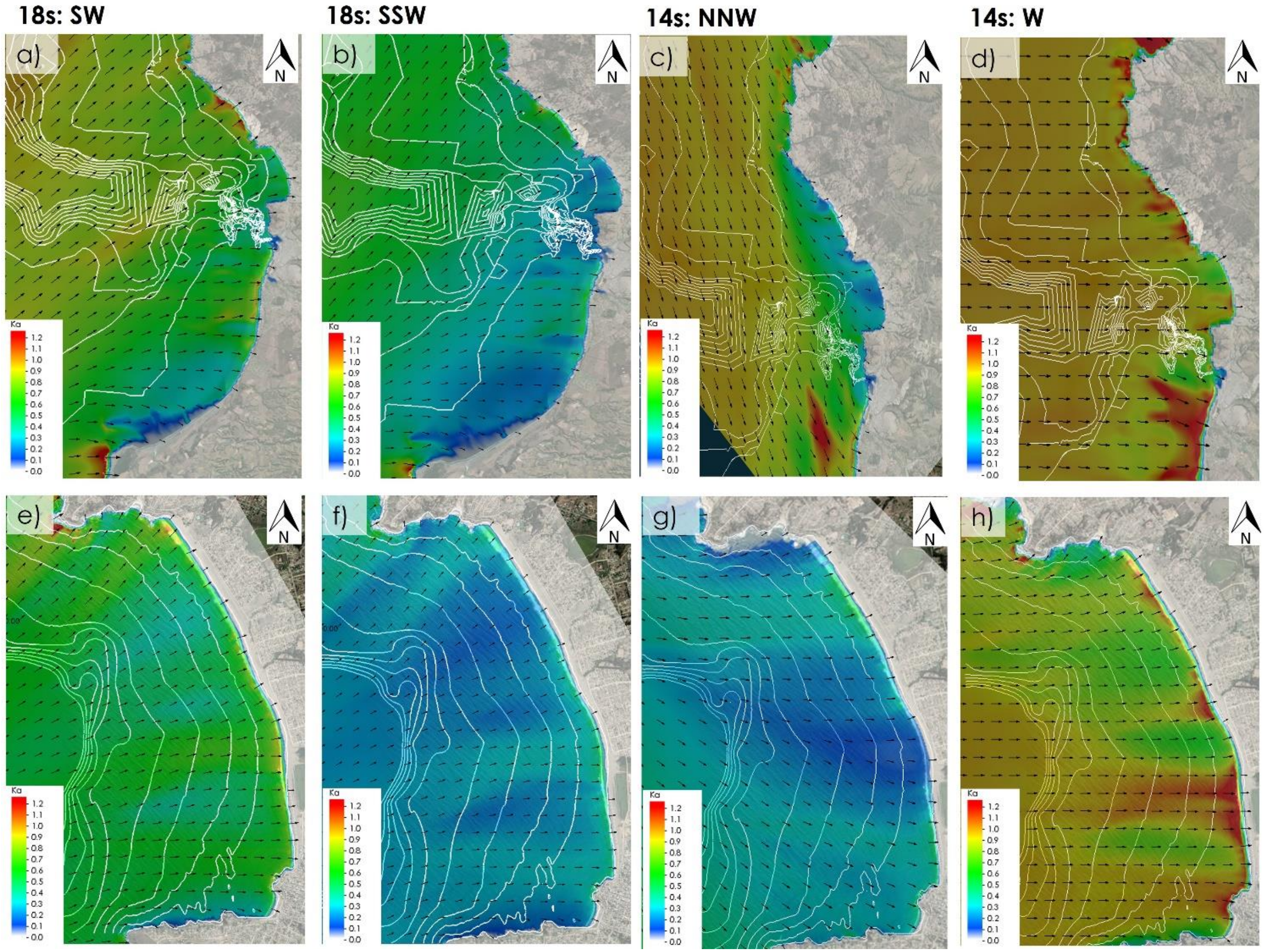
- Significant wave height yearly 12hrs exceedance: decreasing in central Chile (30-35°S). Increasing above latitudes 50°S
- Mean wave period 50th percentie: increasing in all Chilean coasts.
- Mean wave directions: *counter clockwise shift*

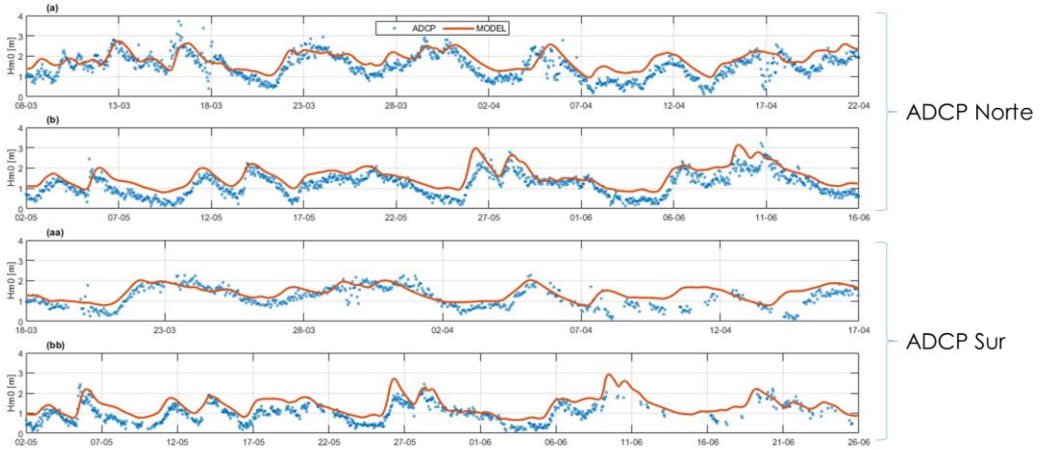


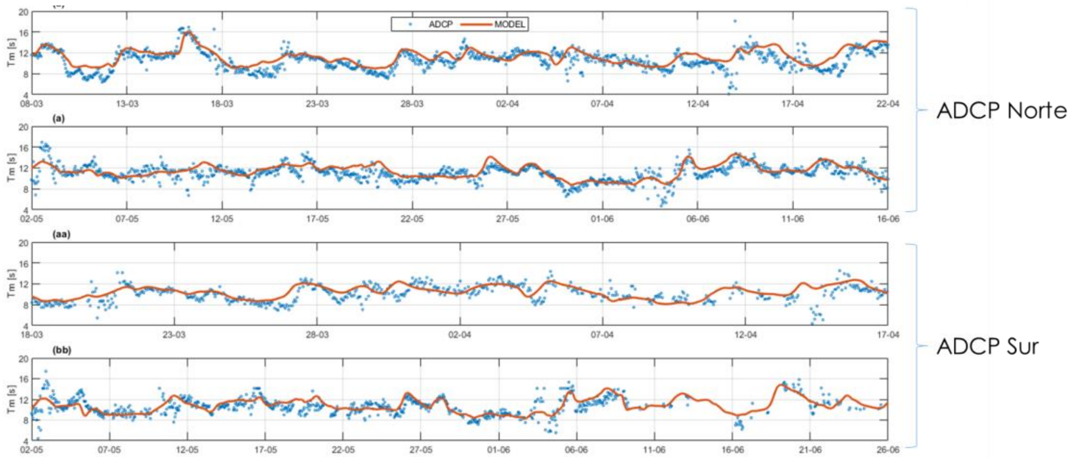
Projected – historical 50th percentile mean wave direction [°]



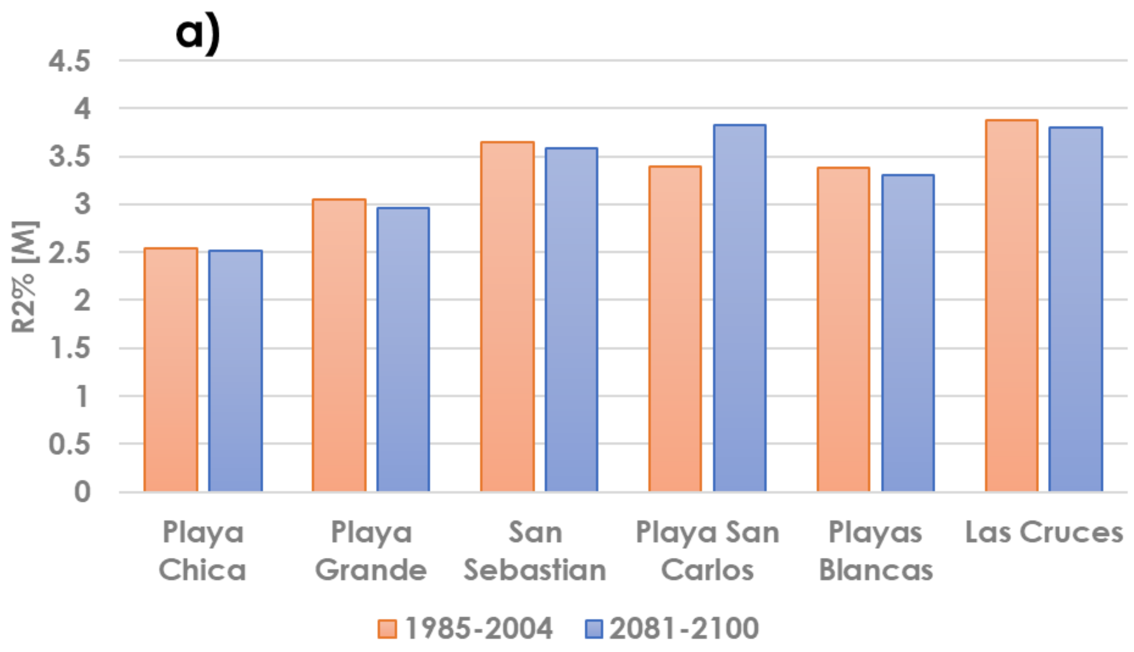
WAVE DOWNSCALING VALIDATION

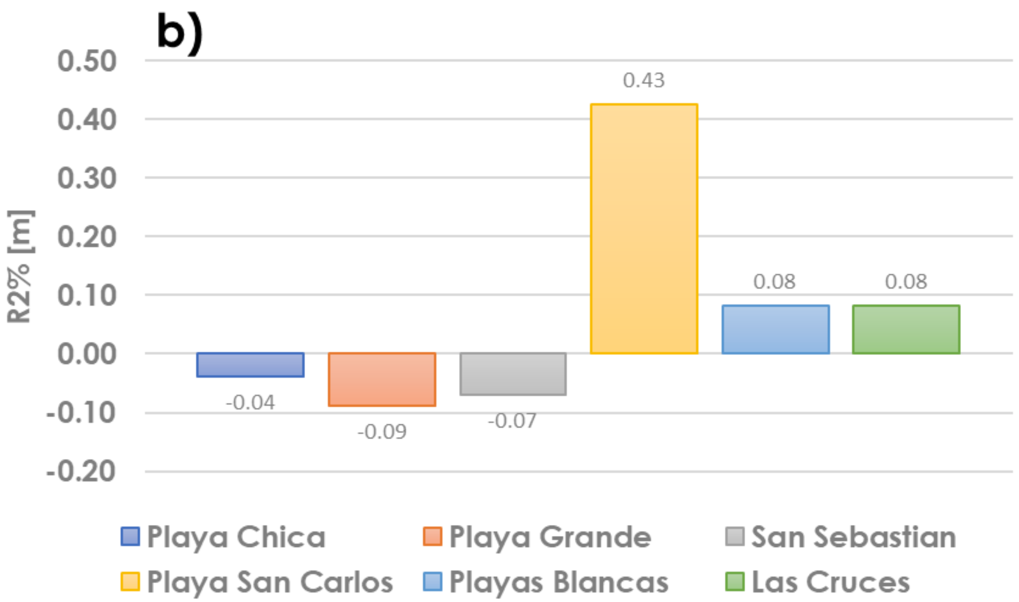






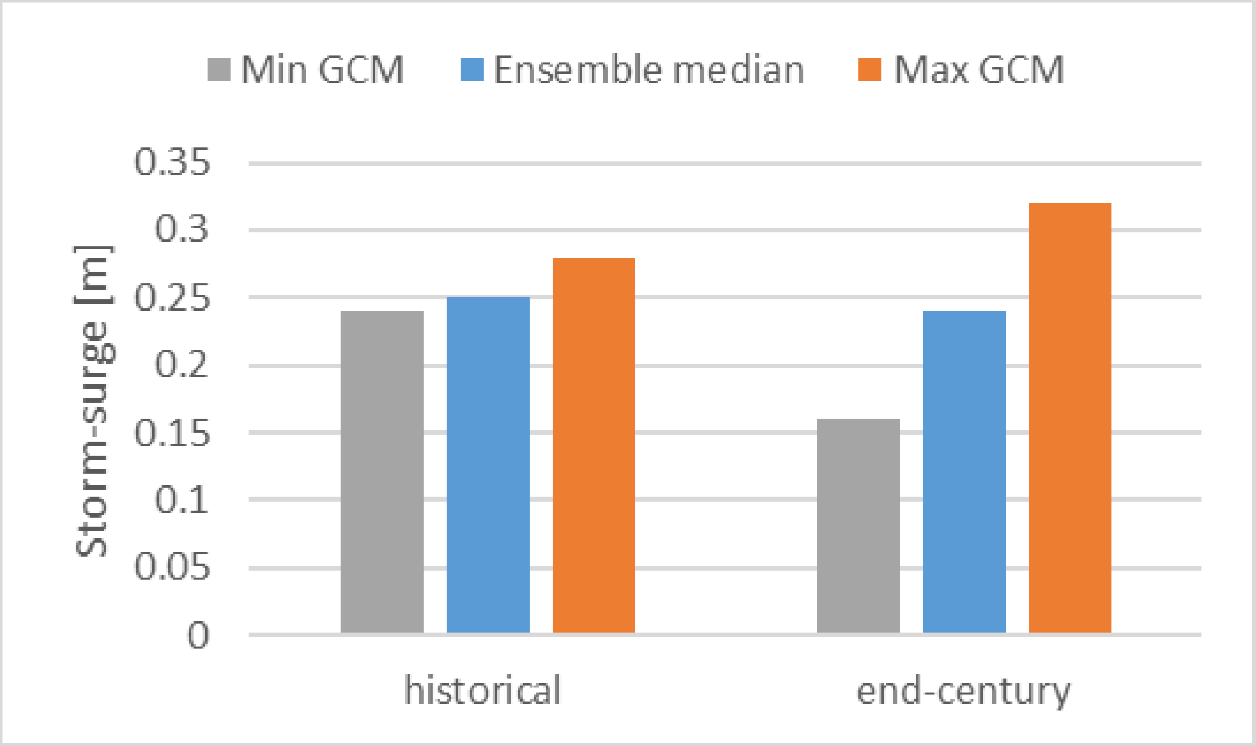
RESULTS – 100 YEAR RETURN LEVEL WAVE RUNUP PROJECTIONS (2081-2100)





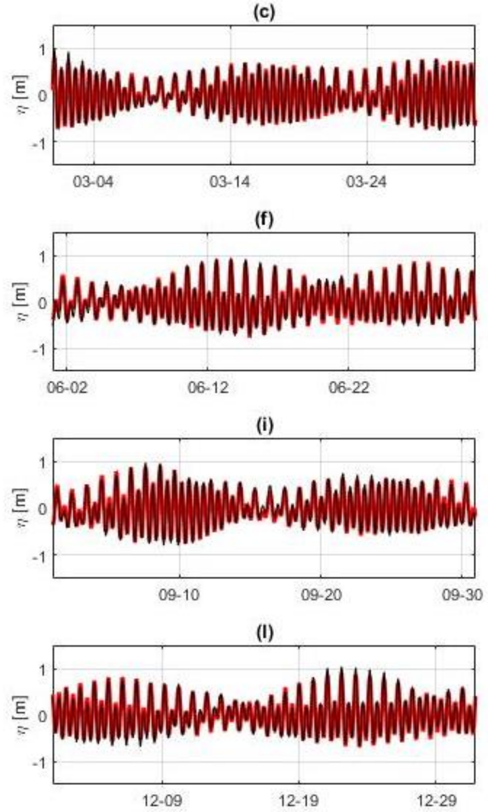
$$R_{2\%} = 1.1\left[0.35\tan\beta_f(H_0L_0)^{1/2} + \frac{H_0L_0(0.5625\tan\beta_f^2 + 0.0004)^{1/2}}{2}\right]$$

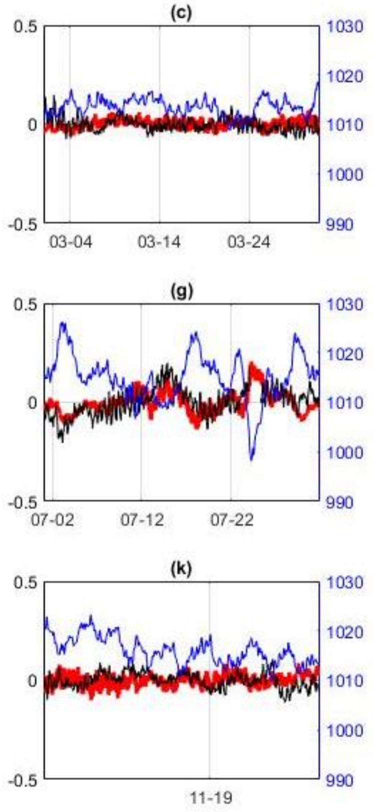
STORM-SURGE 100 YEAR RETURN LEVEL MODELO ADCIRC v55



ADCIRC vs San Antonio Tidal Gauge

Astronomical Tides | **Storm-Surge: residual**





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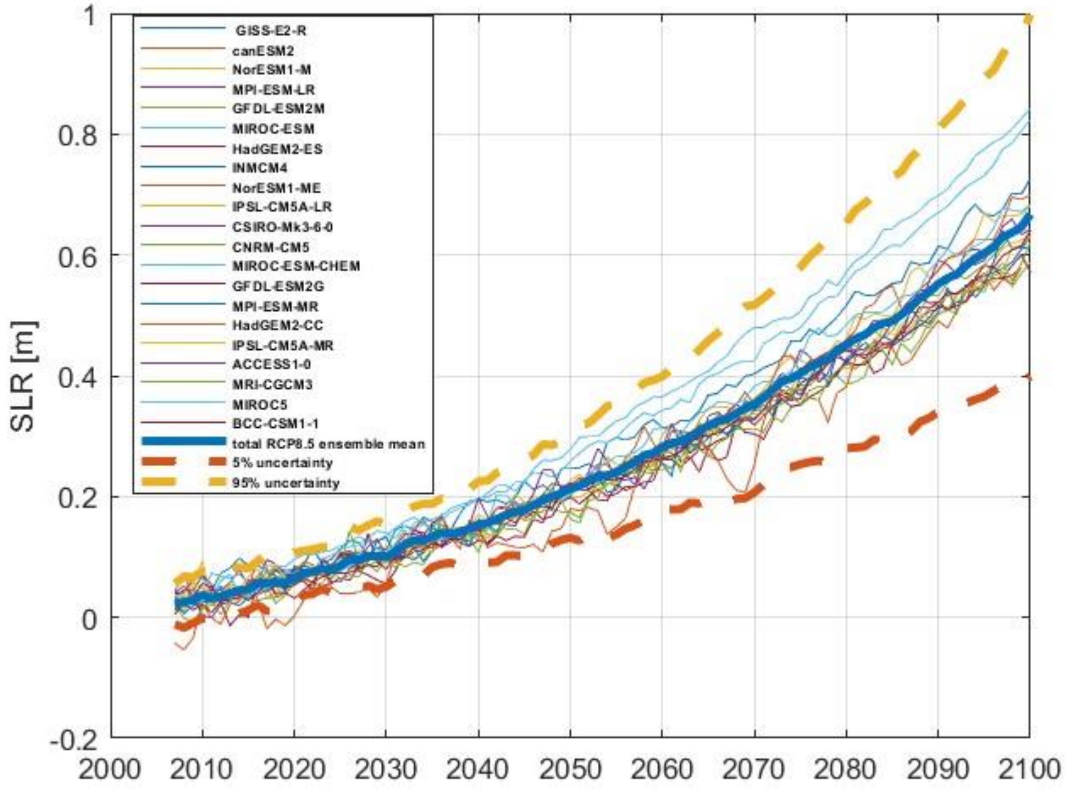
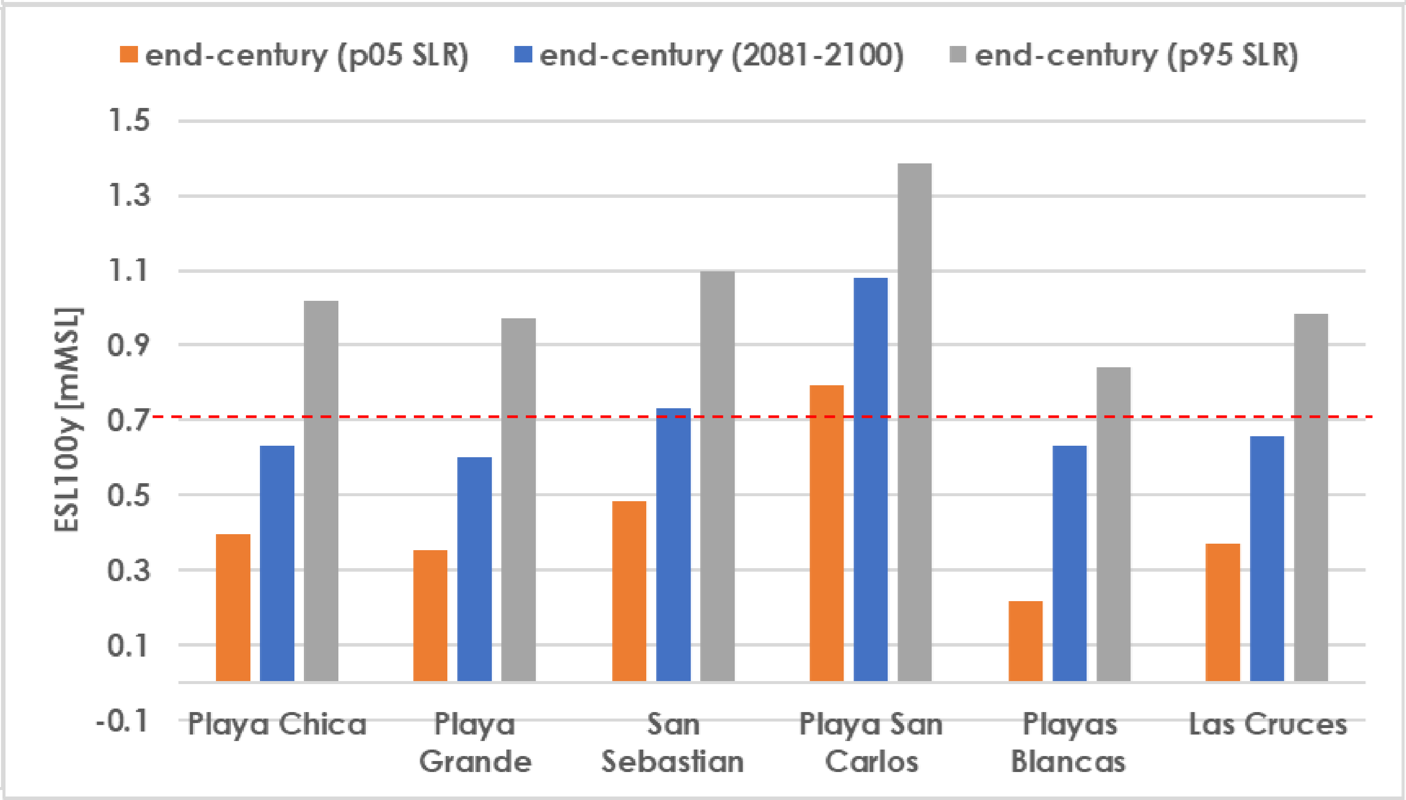
SEA LEVEL RISE
21 Climate Models (Hamburg University database)



Mean sea level rise projection with RCP 8.5						
Sea level rise process	**2045**			**2100**		
	5% (optimistic)	**mean**	**95%** (pessimistic)	**5%** (optimistic)	**mean**	**95%** (pessimistic)
Ocean Dynamics (Steric + dynamic + Inv. Barometer effect)	0.019	0.067	0.115	0.154	0.275	0.396
Glaciers	0.031	0.059	0.089	0.102	0.178	0.259
Greenland Dynamic	0.013	0.022	0.032	0.027	0.068	0.109
Antarctic Dynamic	0.002	0.018	0.033	-0.014	0.057	0.128
Greenland SMB	0.007	0.016	0.035	0.048	0.116	0.266
Groundwater depletion	0.003	0.016	0.028	-0.014	0.043	0.101
Antarctic SMB	-0.017	-0.008	-0.002	-0.086	-0.045	-0.016
GIA	-0.029	-0.012	0.005	-0.061	-0.025	0.011
Total SLR	**0.100**	**0.177**	**0.261**	**0.399**	**0.667**	**0.998**

100y RETURN LEVEL EVENT
EXTREME SEA LEVELS AT CARTAGENA BAY

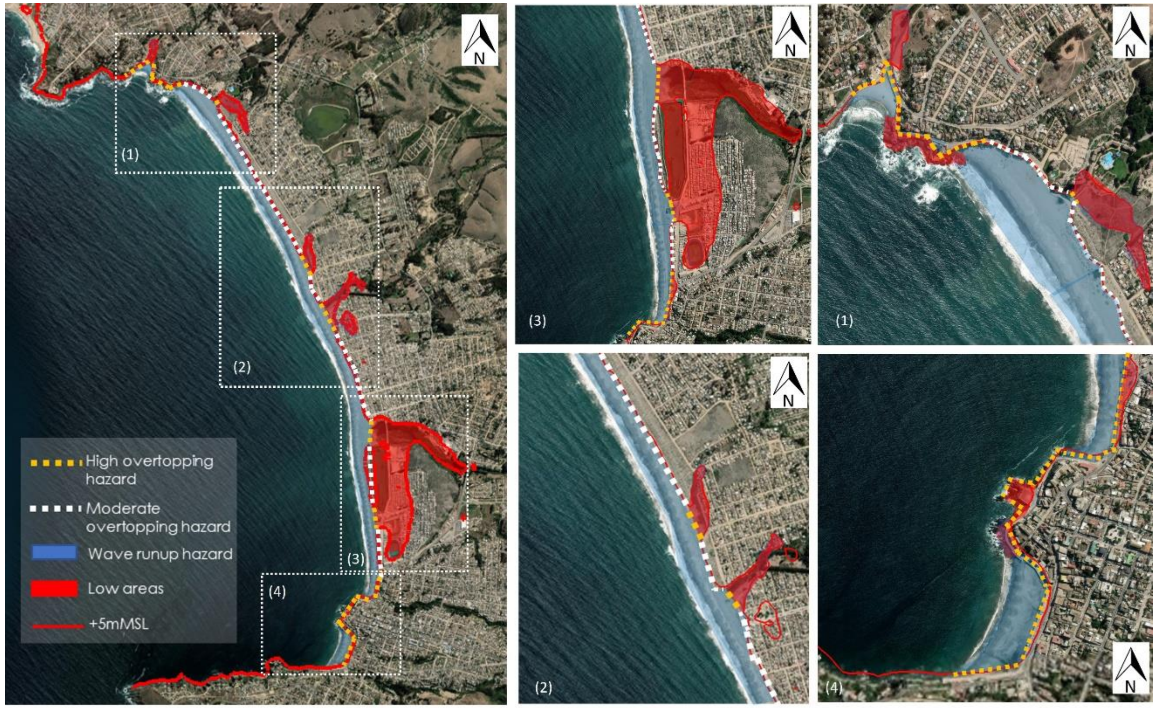


CONCLUSIONES

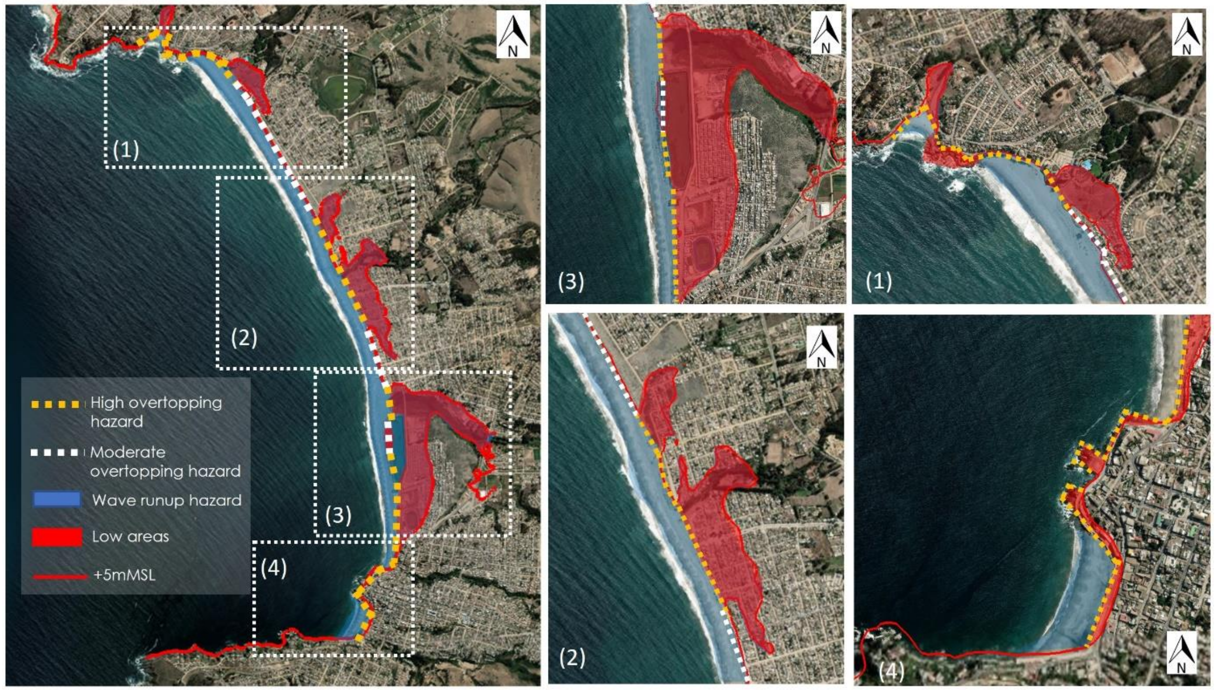
- Hacia finales de siglo, la zona de generación de olas de tormenta se desplazará gradualmente hacia latitudes más altas debido a un desplazamiento hacia el polo del cinturón de tormentas (de acuerdo con Hemer et al. 2013, Lobeto et al. 2021 y Morim et al. 2021). Esto inducirá olas de oleaje más largas de 0,5 a 1s.
- Además, la dirección de la onda media tenderá a desplazarse en sentido contrario a las agujas del reloj, con una rotación de unos 3°.
- Estos resultados sugieren la presencia de un "bloqueo" atmosférico a los sistemas de bajas presiones en latitudes más bajas, que puede explicarse por la migración hacia el sur del Anticiclón Subtropical del Pacífico (SPSA) (De acuerdo con Rykaczewski, 2015).
- En los sectores protegidos (parte norte y sur de la bahía de Cartagena). La amplificación prevista de la ESL será consecuencia del SLR, que podría superar los 60 cm a finales de siglo
- En las partes centrales de la bahía de Cartagena, el aumento previsto del ESL hacia finales de siglo estará por encima del SLR. Esto se debe principalmente al aumento del periodo de oleaje; sin embargo, esto debe confirmarse con modelos basados en procesos y modelación física
- Otro aspecto importante que no se ha considerado en este trabajo es que la zona costera de Chile es tectónicamente activa, por lo que la cota de inundación debe estimarse bajo una perspectiva de riesgos múltiples.

ESL vs COTA 10mMSL

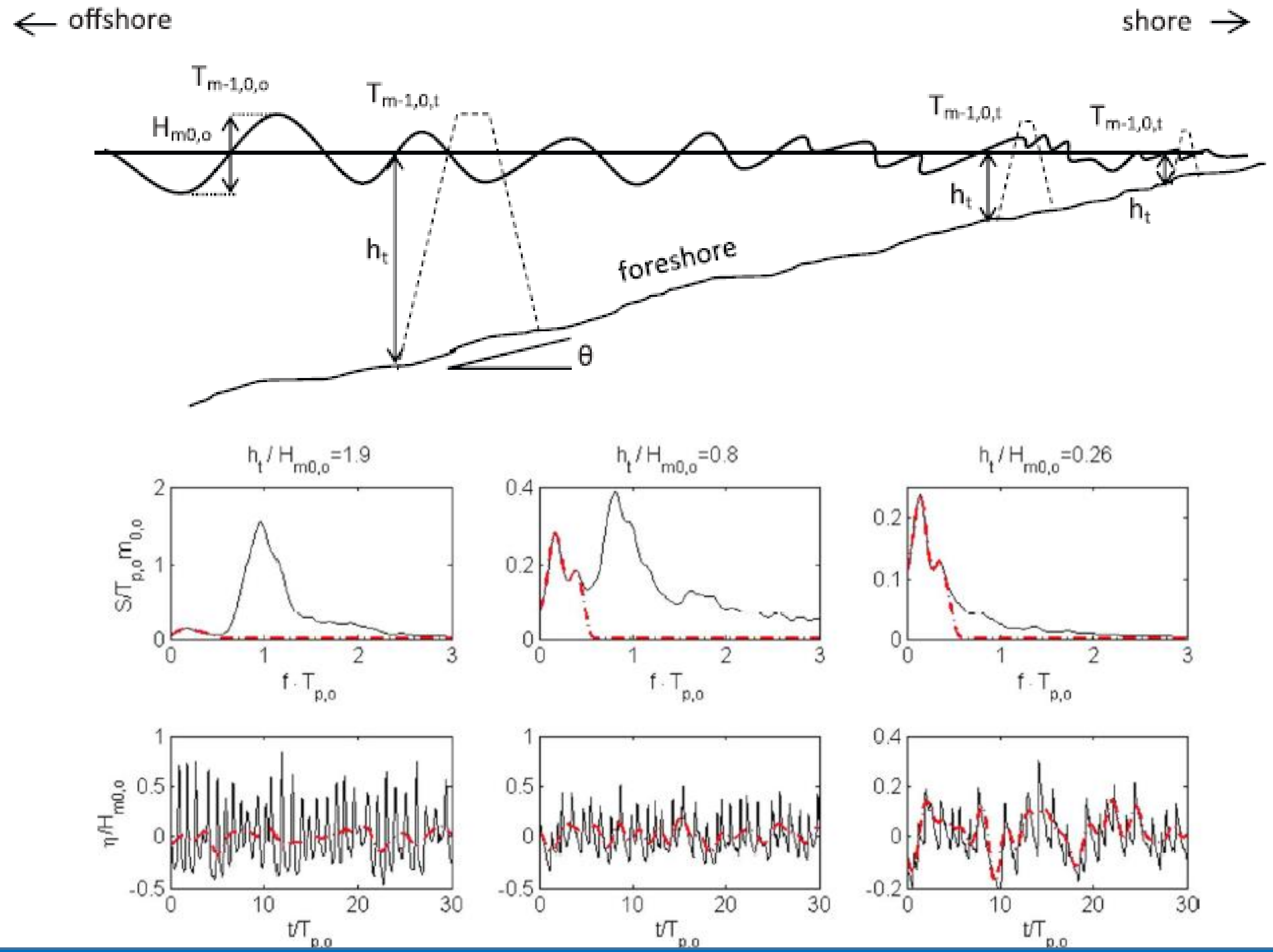
1985-2004

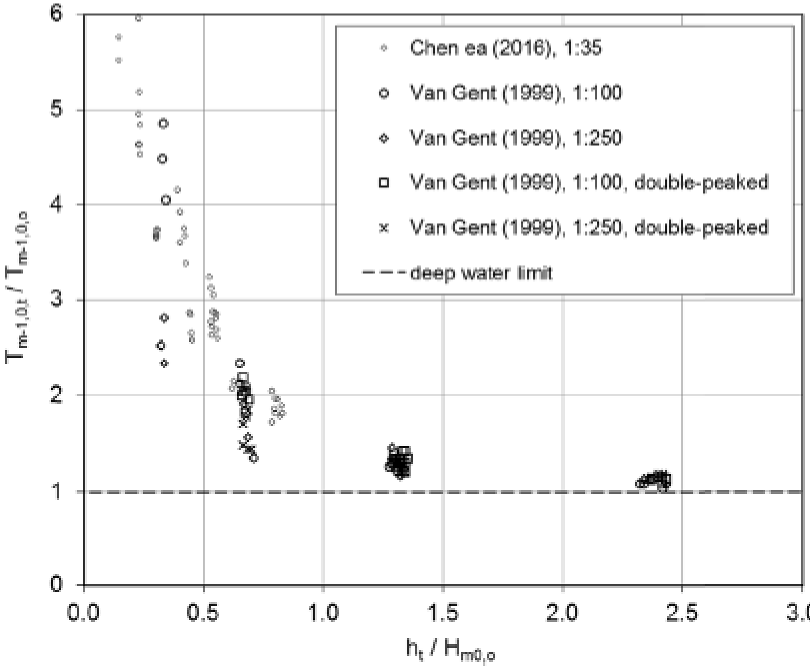


2081-2100



NEXT STEP: PHYSICAL MODELLING (MY PHD ☺)





Prof. Tom Bruce

Prof. Rodrigo Cienfuegos

¡Gracias!