Evaluating future beach reduction in a changing climate: Methodologies and uncertainties

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INSTITUT MEDITERRANI D'ESTUDIS AVANÇATS

*What kind of **tourism** does the Balearic island recieve and why are the **beaches** a paramount resource*

...??

Some points..

Tourims represents almost 36% of GDP of the Island (http://economiademallorca.com/) and recieves annual revenue of almost 16.500€ millions (Ultimahora.es).

16.596.194 turists (2018). 1.56% more than the previous year.

Reasons they come..

*Good weather and amazing **beaches***

So, the beaches are a tourist acclaim and paramount resource for the Balearic economy

Big influence in the regional economy

Threat of climate change

***Sea level** rise and Waves **runup** reduce the beach area*

*Growing **concern** about **coastal retreat** and **loss beaches***

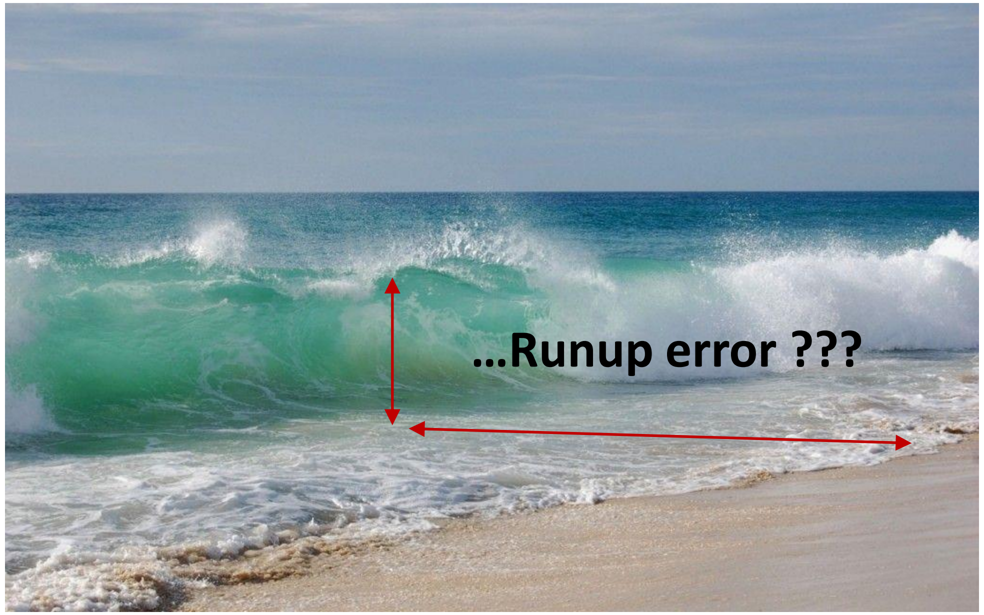
*With what **uncertainty** could we calculate the **shoreline retreat** on sandy beaches... ???*

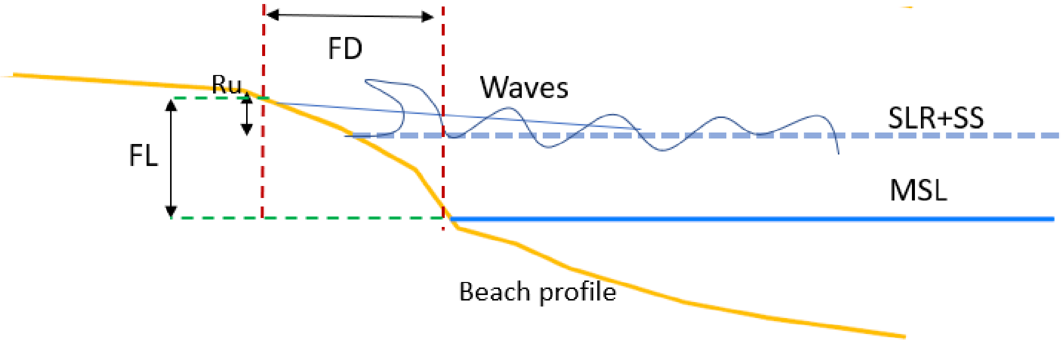
Main goals

1. Estimate the uncertainty when calculating the wave runup on sandy beaches
2. Quantify the shoreline retreat due to climate change

Secondary goals

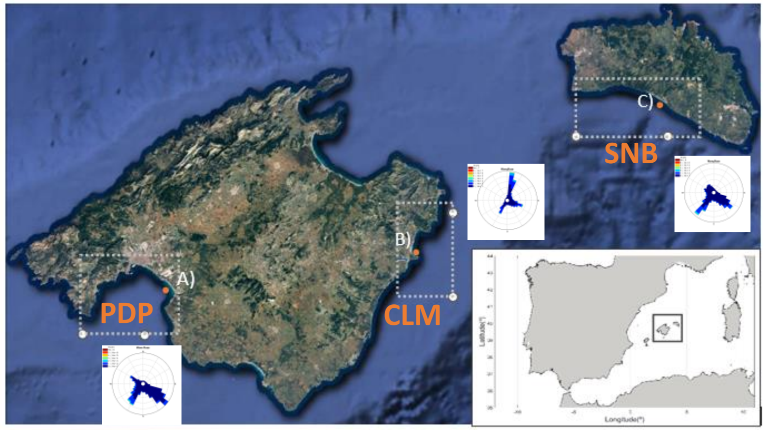
1. To better understand the influence of the beach profile and the offshore/nearshore Wave climate in the wave runup mechanism.
2. What are the pros and cons of each methodology proposed





STUDY SITES

- 3 highly monitored beaches are used to address the objetives proposed. Playa de Palma Beach (PDP), Cala Millor Beach (CLM) and Son Bou Beach (SNB).



DATA AND MATERIALS

Observations:

- Wave recorders onshore (AWACS). ~20m depth. 2012-2018 (*).
- Hourly shoreline images from Cameras located at the beaches. Timestacks (CLM 2011-2018 and PDP 2012-2016) (*)
- Detailed Bathymetries (*)

** Data products used in this work were obtained from SOCIB (www.socib.es), Tintoré et al., 2013. SOCIB.*

Reanalisis

- Waves offshore (SIMAR 1958-2020). *Pilar et al., 2008*

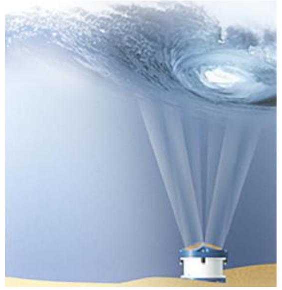
Numerical models

- SWAN (used to simulate the propagation from deep waters to shallow waters)
- XBEACH (used to simulate the Waves interactions in the breaking zone)

bathymetries

cameras

awacs



Mainly, Wave runup depends on the beach profile and the wave climate, so is very influenced of wich data and methods are used. Here we propose 3 pathways to estimate the wave runup and their associated uncertainty.

PATHWAYS TO OBTAIN RUNUP (more information section 4.1)

1- Using the empirical equation proposed by Stockdon et al 2006, taking directly offshore Waves (Ho,Lo).

2- To use the wave espectral numerical model SWAN, to propagate Waves from Deep Waters (A) to shallow Waters (B) and use Stockdon equation with nearshore Waves.

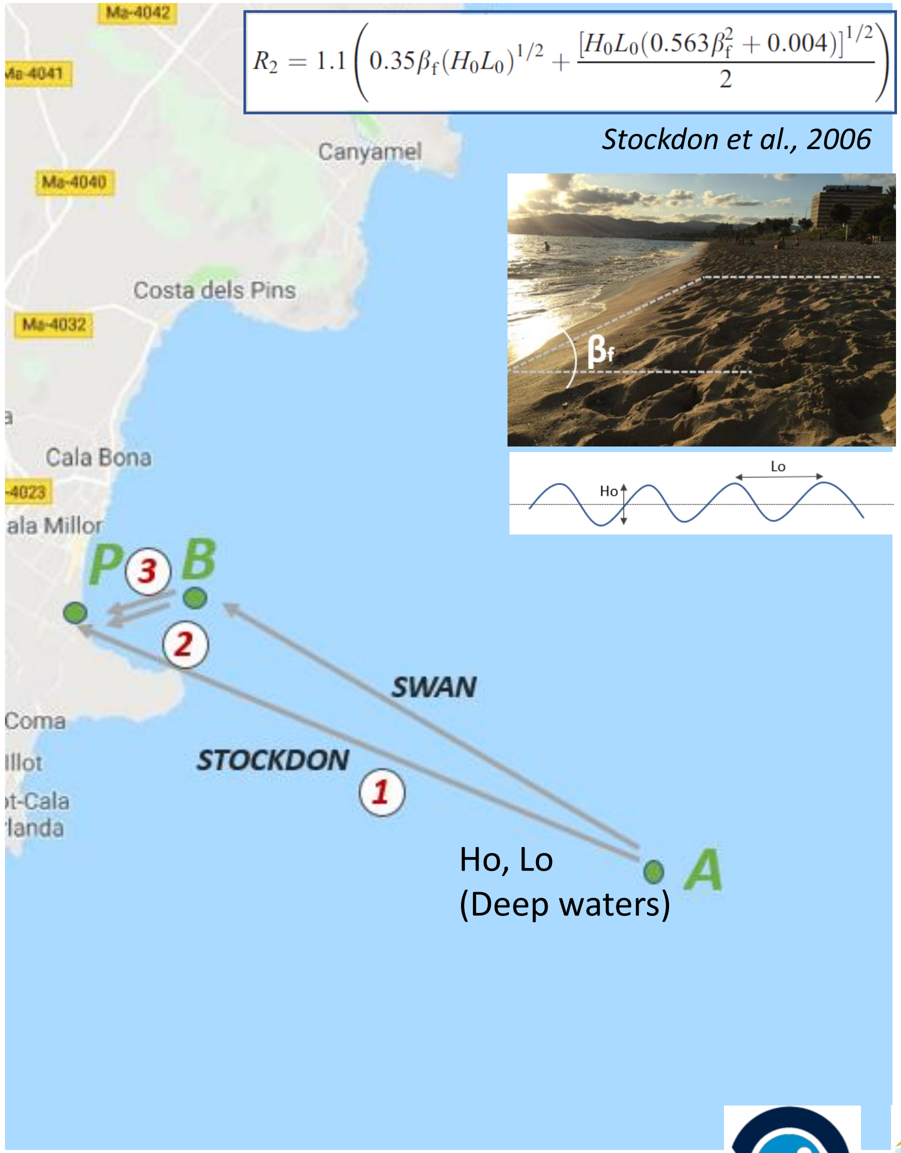
3- Nesting 2 numerical models. SWAN (A-B) and phase-resolved nonlinear numerical model XBEACH, from B to swash zone (P).

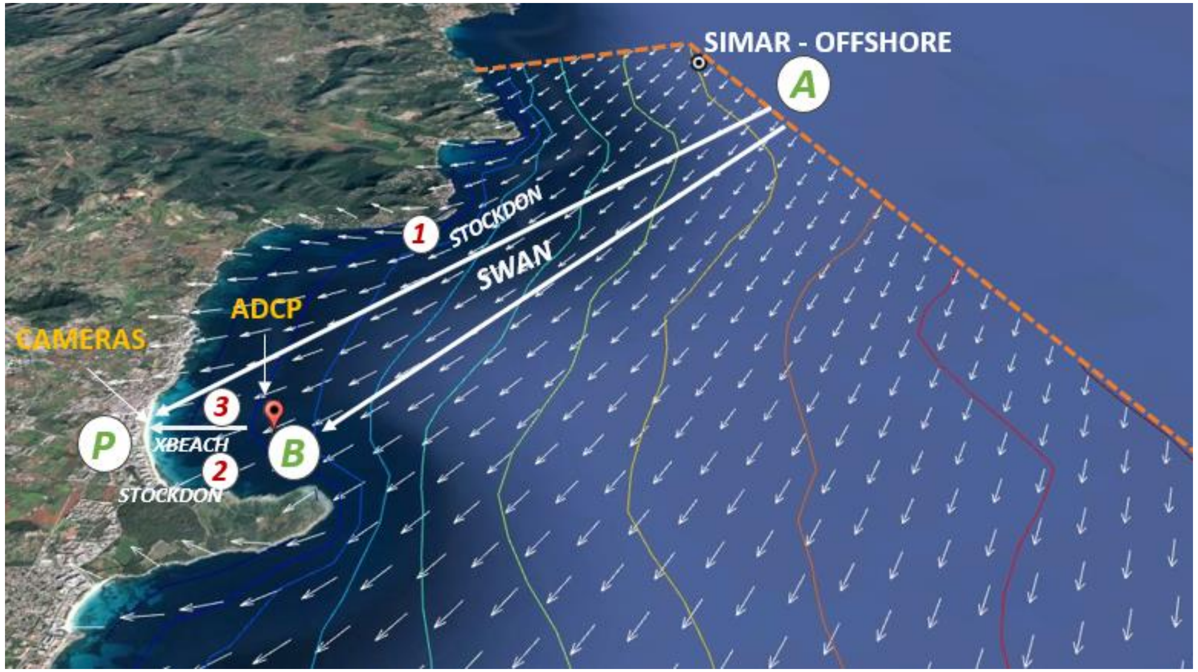
PATHWAY'S ERROR ESTIMATION (more information section 4.2)

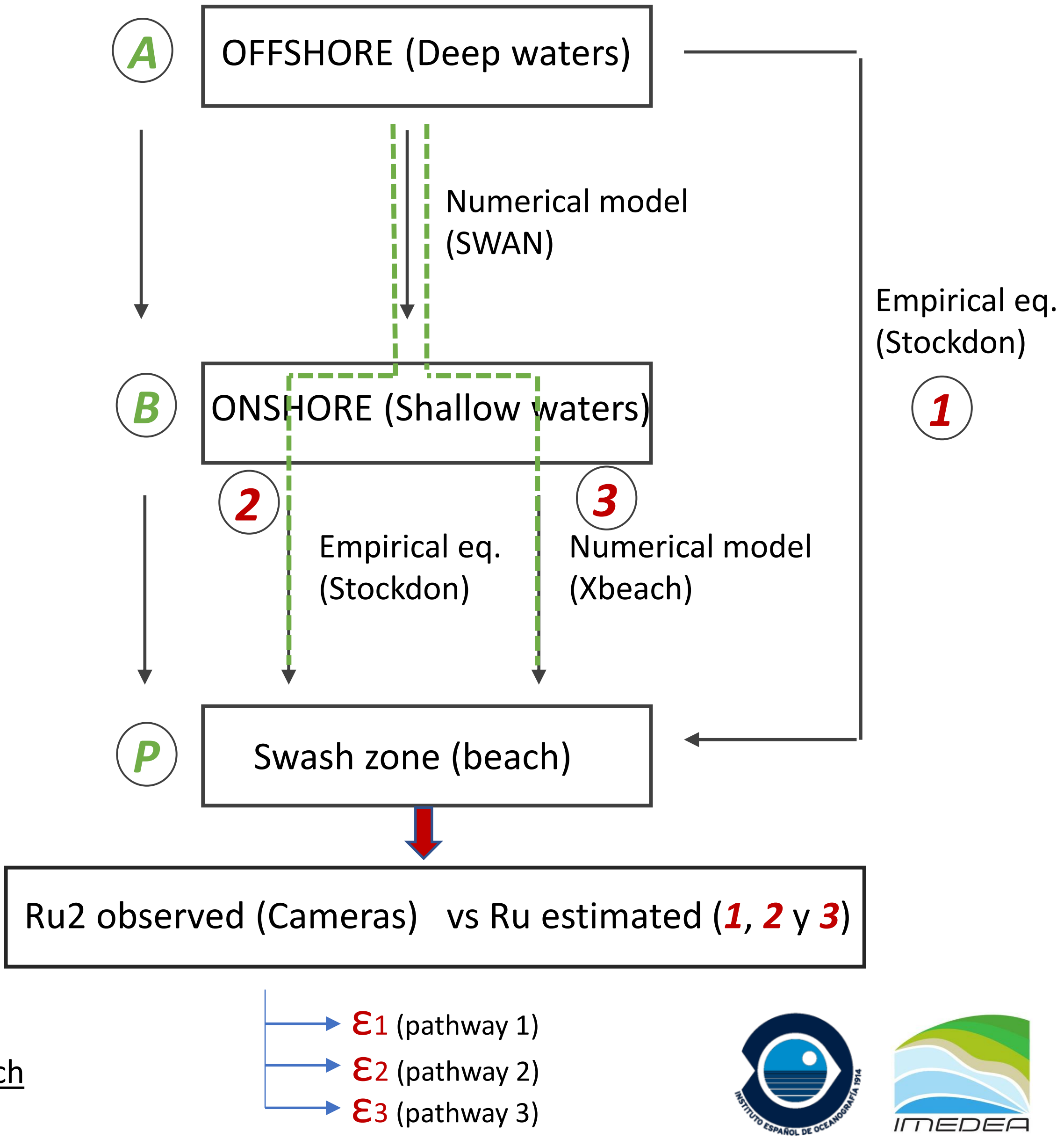
- Shoreline Images (hourly timestacks) from Playa de Palma Beach (2012-2016) and Cala Millor Beach (2011-2018) have been used to quantify the Runup observed on the beaches. After a strict quality control, ~2.000 timestack images representative of each beach have been used to obtain the observed wave runup.

$$R_2 = 1.1\left(0.35\beta_f(H_0L_0)^{1/2} + \frac{[H_0L_0(0.563\beta_f^2+0.004)]^{1/2}}{2}\right)$$

Stockdon et al., 2006




SIMAR - OFFSHORE
A
1
STOCKDON
SWAN
ADCP
CAMERAS
3
XBEACH
2
STOCKDON
P
B


A
OFFSHORE (Deep waters)
Numerical model
(SWAN)
Empirical eq.
(Stockdon)
1
B
ONSHORE (Shallow waters)
2
3
Empirical eq.
(Stockdon)
Numerical model
(Xbeach)
P
Swash zone (beach)
Ru2 observed (Cameras) vs Ru estimated (1, 2 y 3)
ε1 (pathway 1)
ε2 (pathway 2)
ε3 (pathway 3)

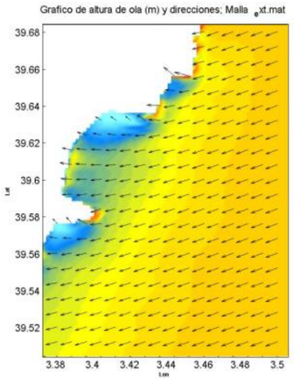
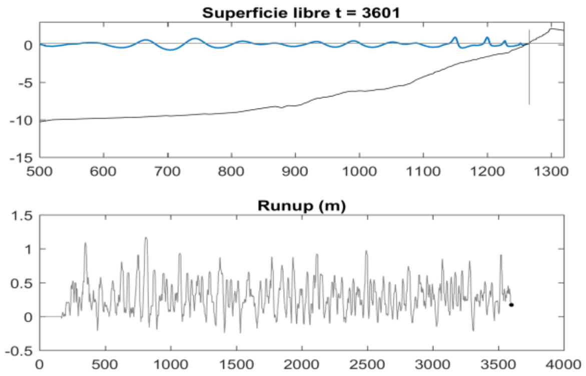


Grafico de altura de ola (m) y direcciones; Malla

Swan


Superficie libre t = 3601
Runup (m)

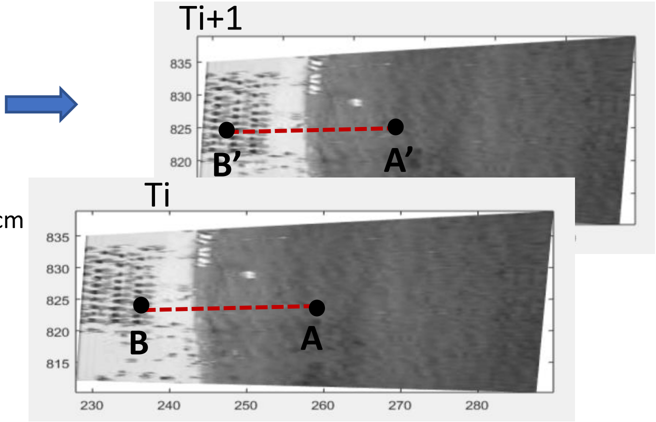
Xbeach

__Runup observations have been obtained after 3 steps__

1- To obtian the pixel size. Controlling the real pixel coordinates.

2- To identify pixels that represent land-water transition along the timestack.

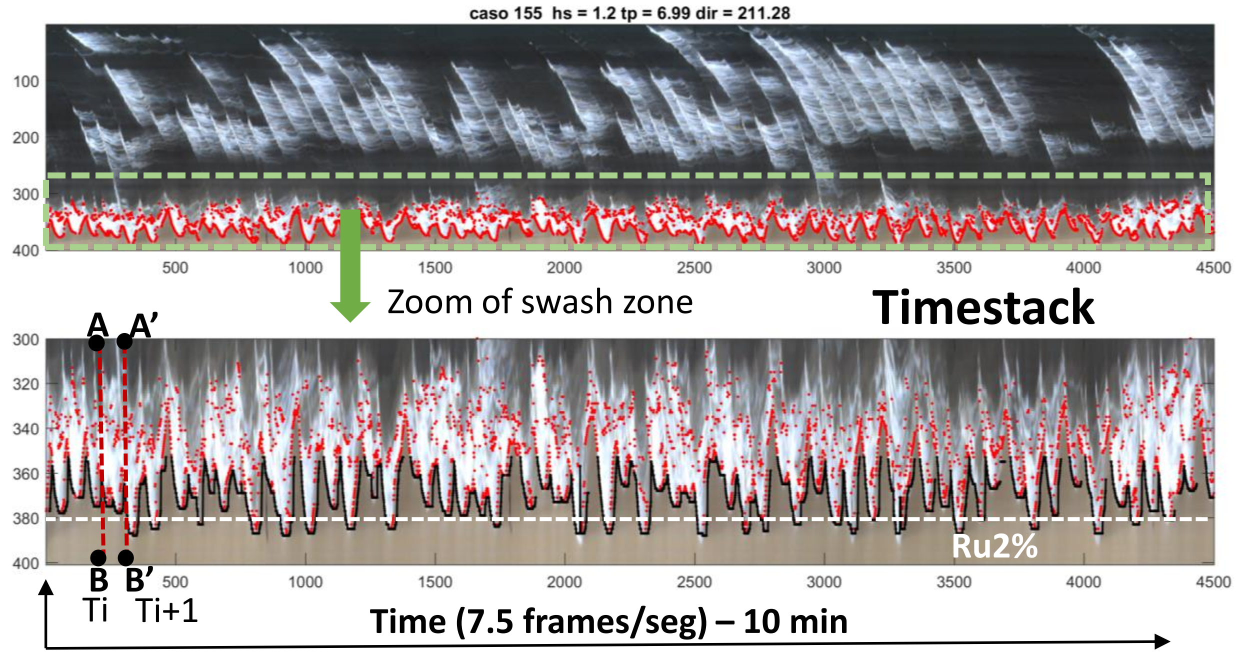
3- Finally, obtain the RU2% for all the quality controlled images.



1

Pixel size ~ 22 cm

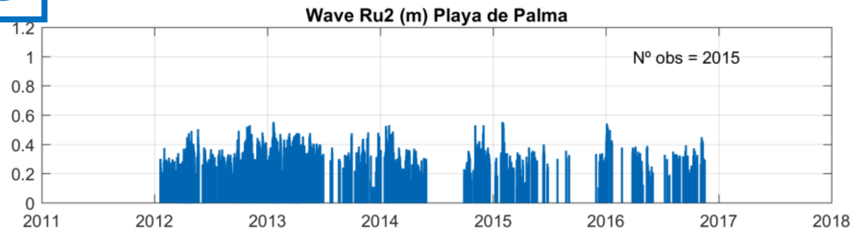
2

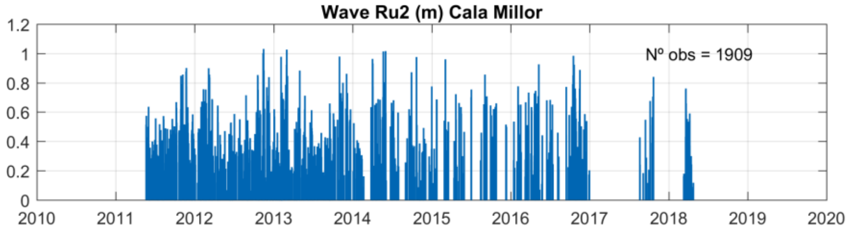


- *Data products used in this work were obtained from SOCIB (www.socib.es), Tintoré et al., 2013. SOCIB.*

3

Ru2% observed





Total ru2% gathered after passing differents qc filters.
~30.000 images (Before qc) --- ~ 2.000 (After qc).

This section is showed in 3 main parts...

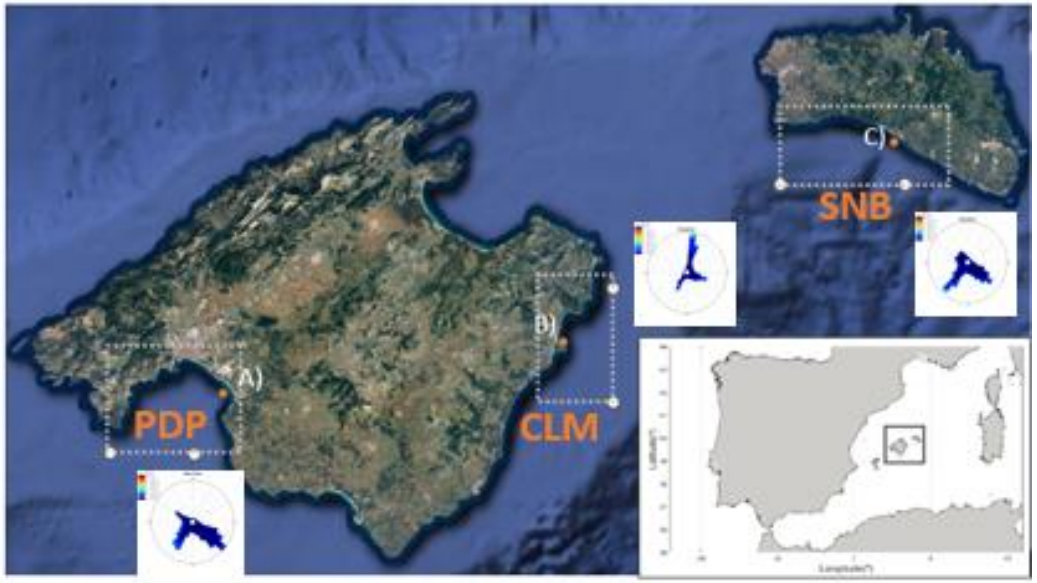
5.1 Wave Runup uncertainties (PDP-CLM)

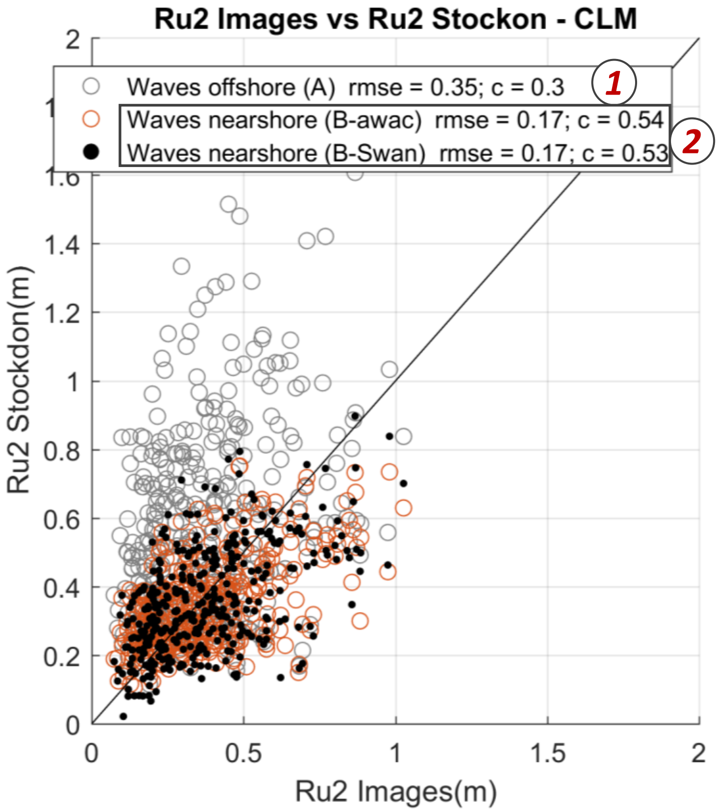
The wave runup results, using the diferents pathways proposed (see 4.1), are compared with the runup observed. Rmse and correlations are showed. Results of CALA MILLOR BEACH (5.1a) and PLAYA DE PALMA BEACH (5.1b).

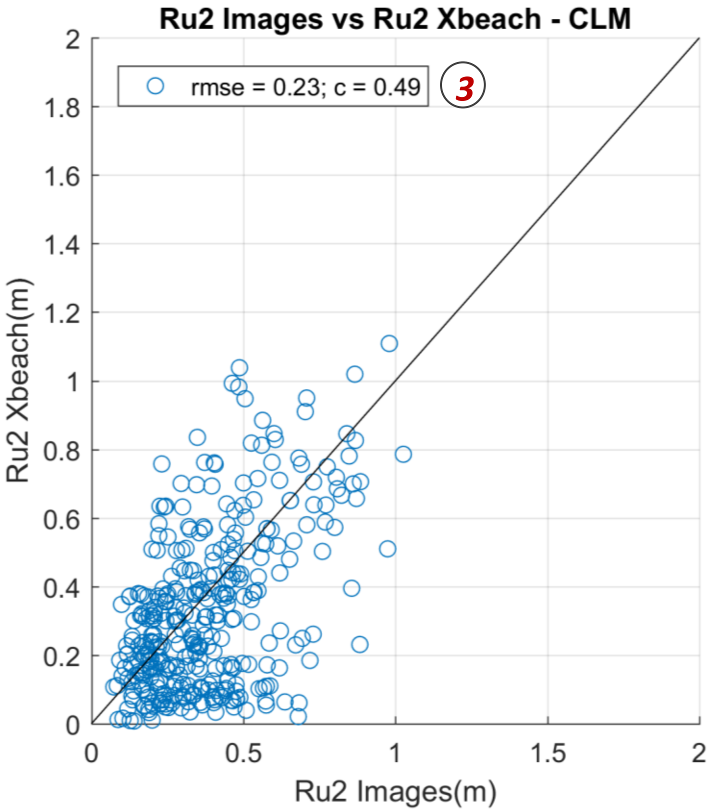
5.2 Final results and uncertainties projected on CLM and PDP

The uncertainties showed in 5.1 are projected in georreferenced images under 0.25m mean sea level rise, value representative of mid-century sea level projections, both for mean and extreme conditions.

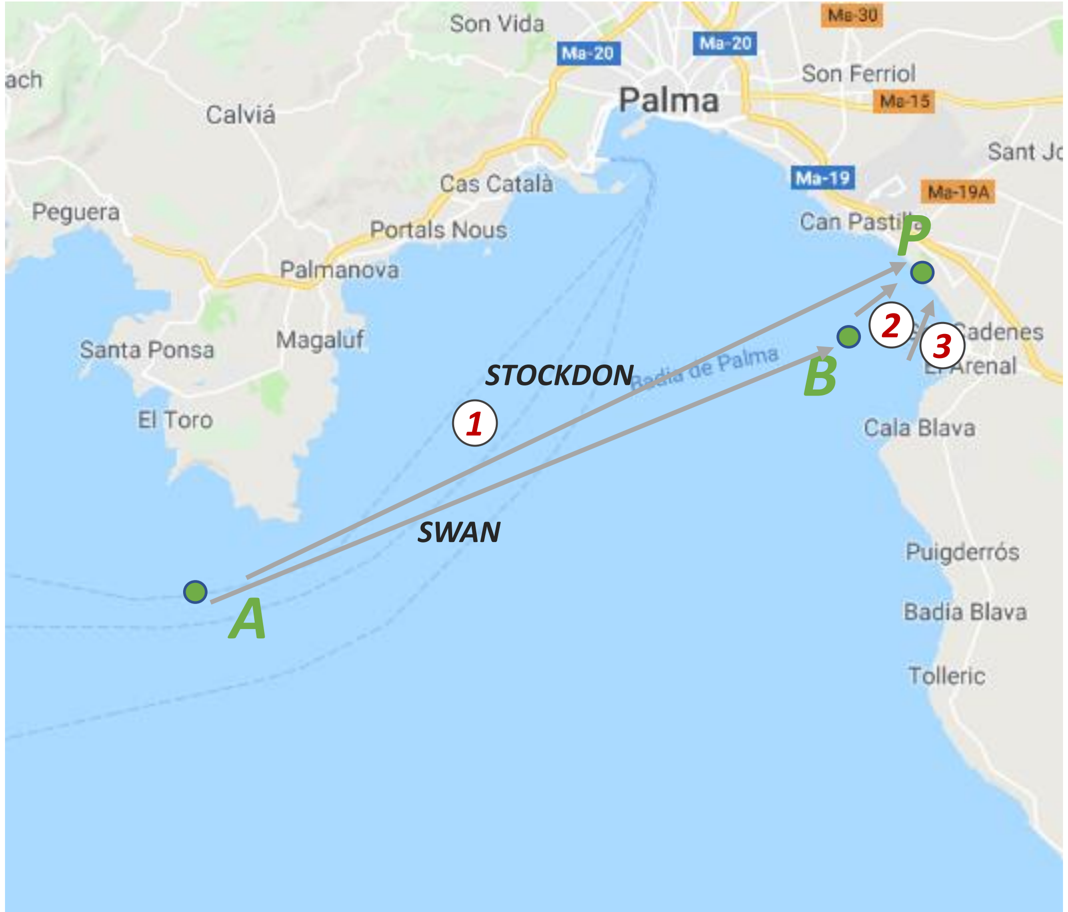
5.3 Stockdon vs XBEACH correlation (PDP-CLM-SNB)

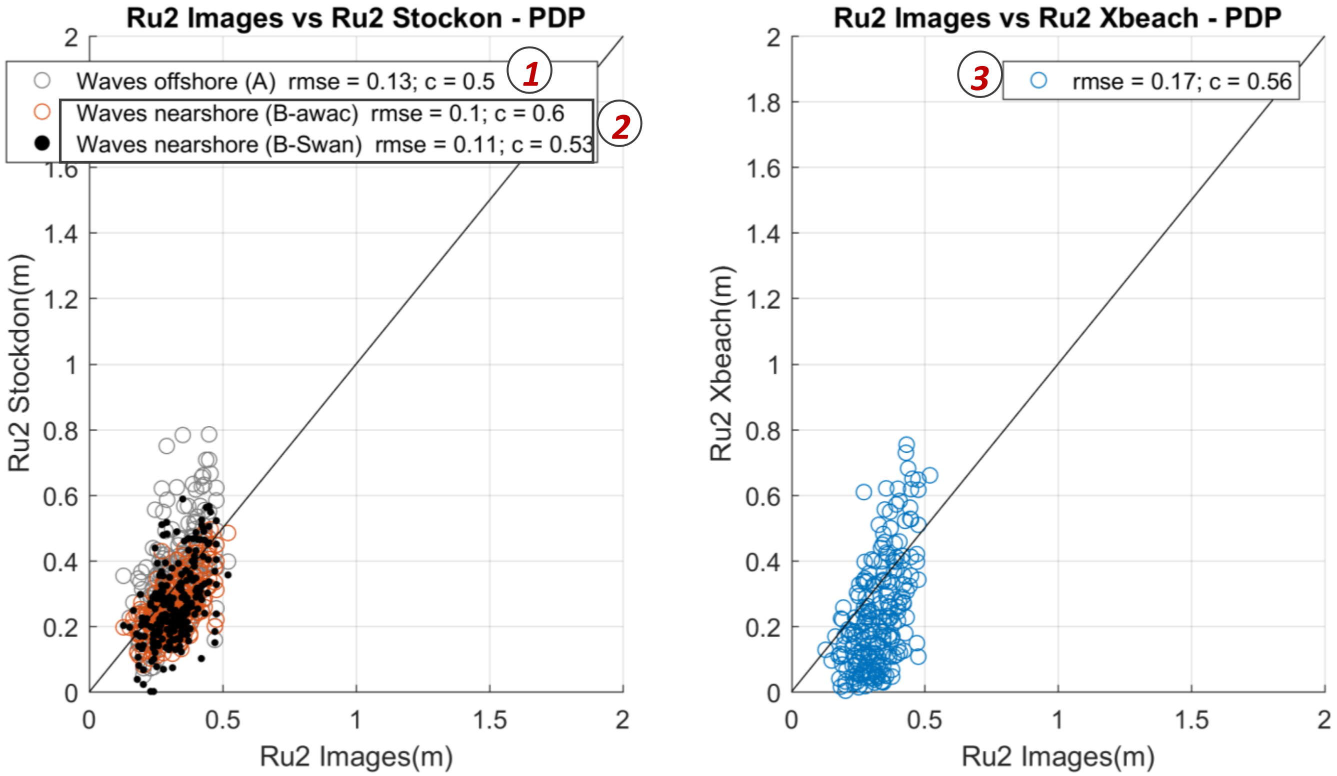






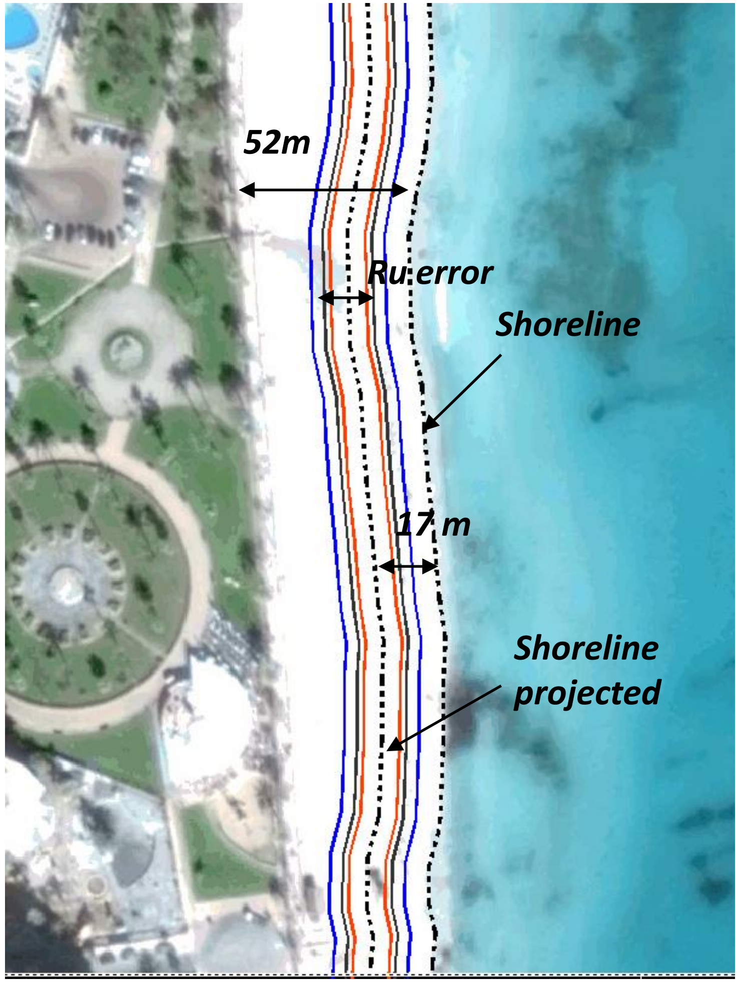
CLM (Bf ~ 0.034)	εv(m)	εh(m)
1 Stockdon from **A**	0.35	10.3
2 Swan (A-B) + Stockdon from **B**	0.17	5
3 Swan (A-B) + Xbeach from **B**	0.23	6.8



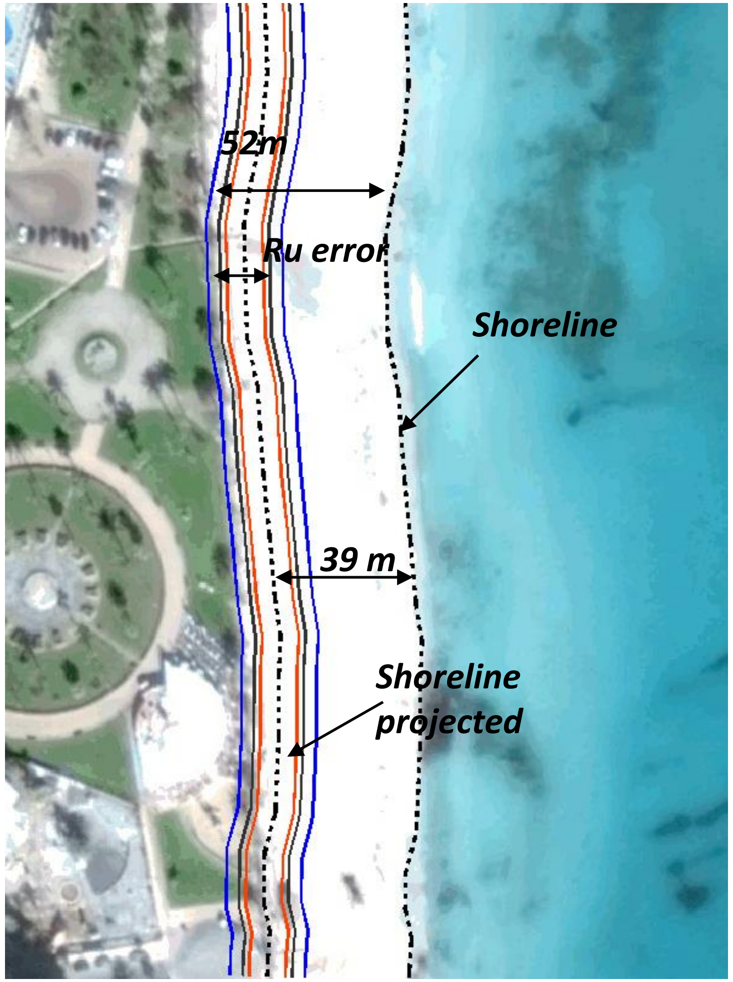


PDP (Bf ~ 0.021)	εv(m)	εh(m)
1 Stockdon from **A**	0.13	6.2
2 Swan (A-B) + Stockdon from **B**	0.10~0.11	4.7~5.2
3 Swan (A-B) + Xbeach from **B**	0.17	8

Mean Conditions



Extreme Conditions



Estimation of coastal retreat (CR) / mid-century 2050:

CR = TSWL/BEACH SLOPE;
TSWL = MSLR+SS+RU2;

Mean conditions:

TSWL = 0.25+0+0.33 = 0.58m
CR = 0.58/0.034 = 17m

Extreme conditions:

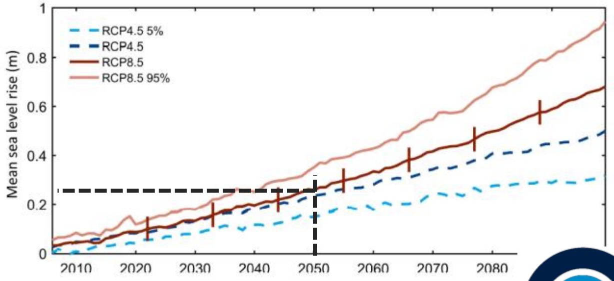
TSWL = 0.25+0.15+0.93 = 1.33m
CR = 1.33/0.034 = 39m

Error (εh) depending on methodology:

SWAN+STOCKDON (ORANGE LINE) = ±5 m
SWAN+XBEACH (GRAY LINE) = ± 6.8m
STOCKDON (BLUE LINE) = ± 10.3

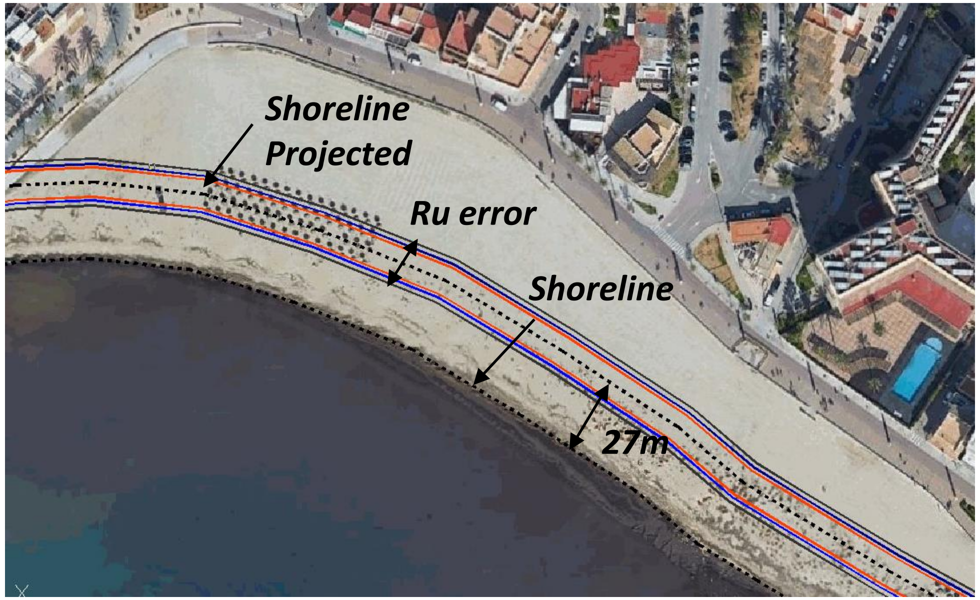
DEFINITIONS:

TSWL = TOTAL SEA WATER LEVEL
MSLR = MEAN SEA LEVEL RISE
SS = STORM SURGE
RU2 = WAVE RUNUP

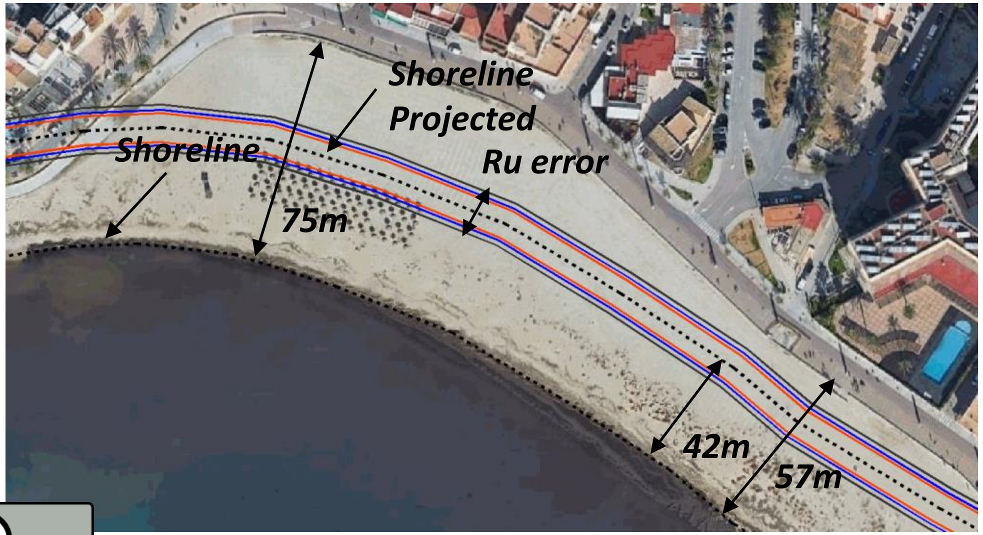


Rodriguez et al. 2017

Mean Conditions



Extreme Conditions



Estimation of coastal retreat (CR) / mid-century 2050 :

CR = TSWL/BEACH SLOPE;
TSWL = MSLR+SS+RU2;

Mean conditions:

TSWL = 0.25+0+0.32 = 0.57m
CR = 0.57/0.021 = 27m

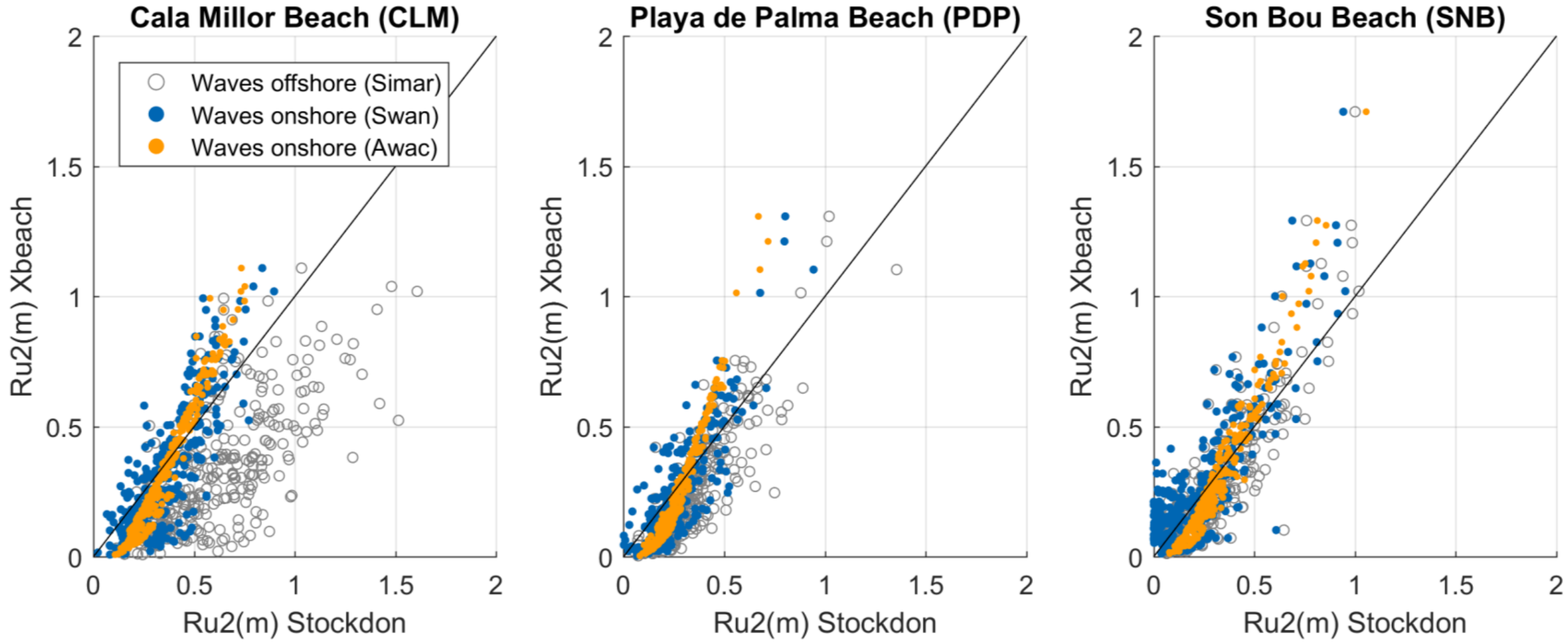
Extreme conditions:

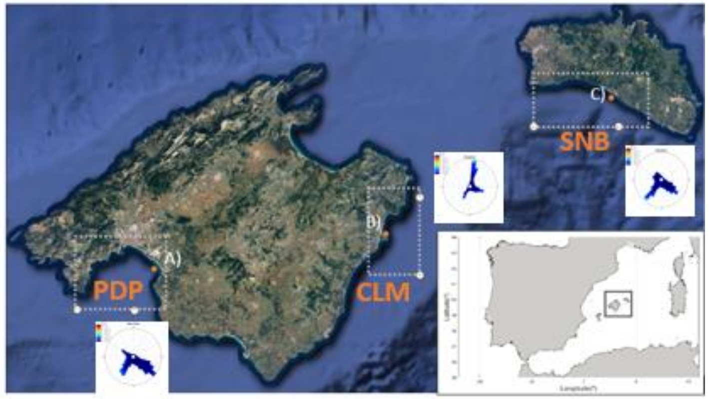
TSWL = 0.25+0.15+0.52 = 0.92m
CR = 0.92/0.021 = 44m

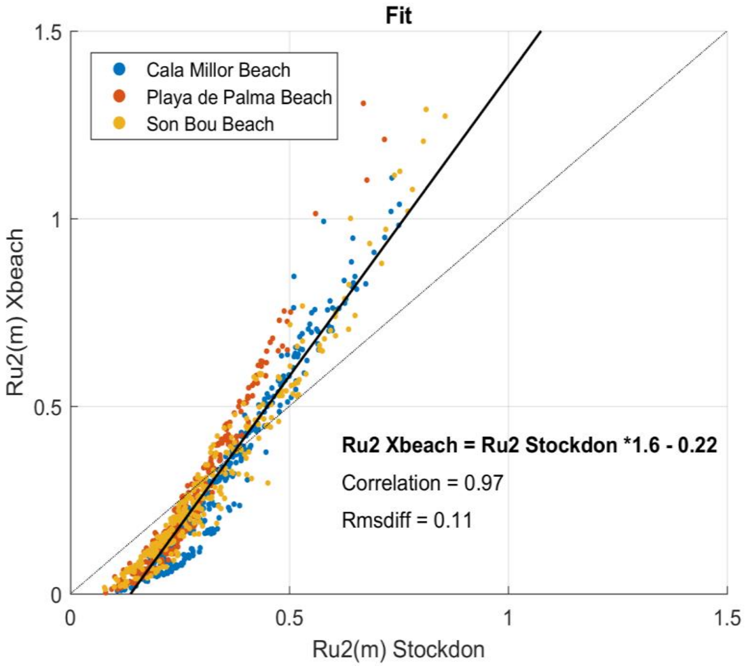
Error (εh) depending on methodology:

SWAN+STOCKDON (ORANGE LINE) = ±(4.7-5.2) m
SWAN+XBEACH (GRAY LINE) = ± 8 m
STOCKDON (BLUE LINE) = ± 6.2 m

DEFINITIONS:
TSWL = TOTAL SEA WATER LEVEL
MSLR = MEAN SEA LEVEL RISE
SS = STORM SURGE
RU2 = WAVE RUNUP







The empirical equation of Stockdon is used to obtain the wave runup considering waves from diferent sources. Offshore waves (gray dots), onshore waves after propagating with SWAN model (blue dots) and observed waves from AWACs. Those runups are compared with XBEACH results (awacs Waves input).

- *The wave runup uncertainty depends largely on the beach slope and the offshore wave climate.*

- *Applying the Stockdon equation using onshore wave climate improves the accuray of the wave Runup by 20% (PDP) and 50% (CLM), respect to consider offshore Waves.*

- *The pathway that fits the best wave runup is the number 2, SWAN+STOCKDON, giving an horitzontal error ~5m, both for PDP and CLM.*

- *Wave runup results among Stockon and Xbeach are highly correlated with a correlation value of 0.97.*

- *XBEACH overestimate the extreme wave runup respect to observations and Stockdon.*

- *The average uncertainty of the wave runup respect to the width of beach is 20% and 28%, for PDP and CLM repectively.*


Thank you...