Two Complementary Approaches for the Numerical Prediction of METEOTSUNAMIS (Rissaga) in CIUTADELLA Harbour(Menorca)

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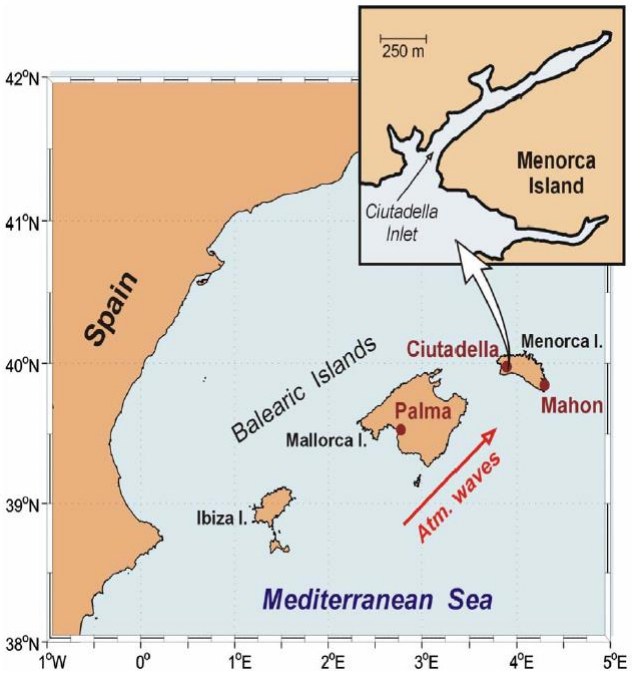
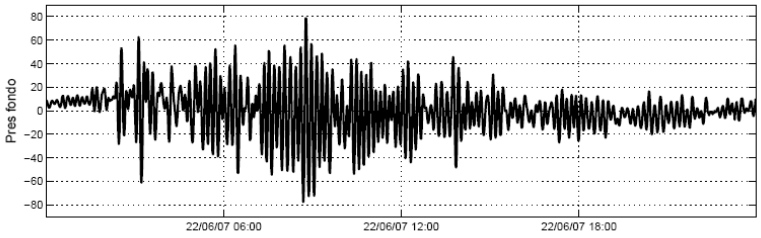
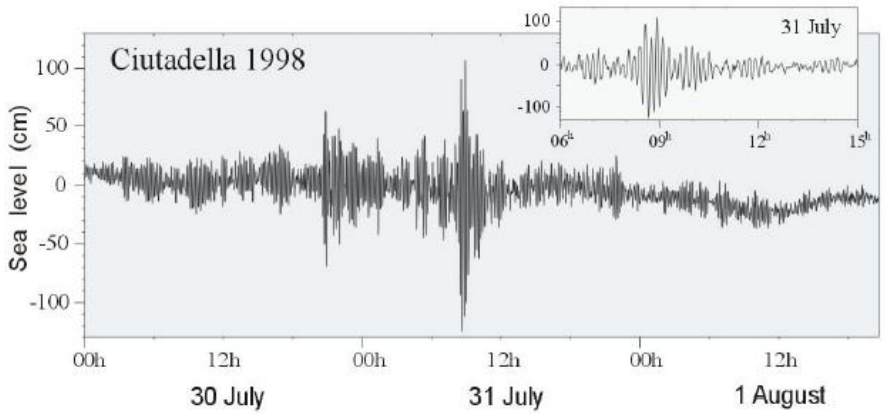
RISSAGA Phenomenon



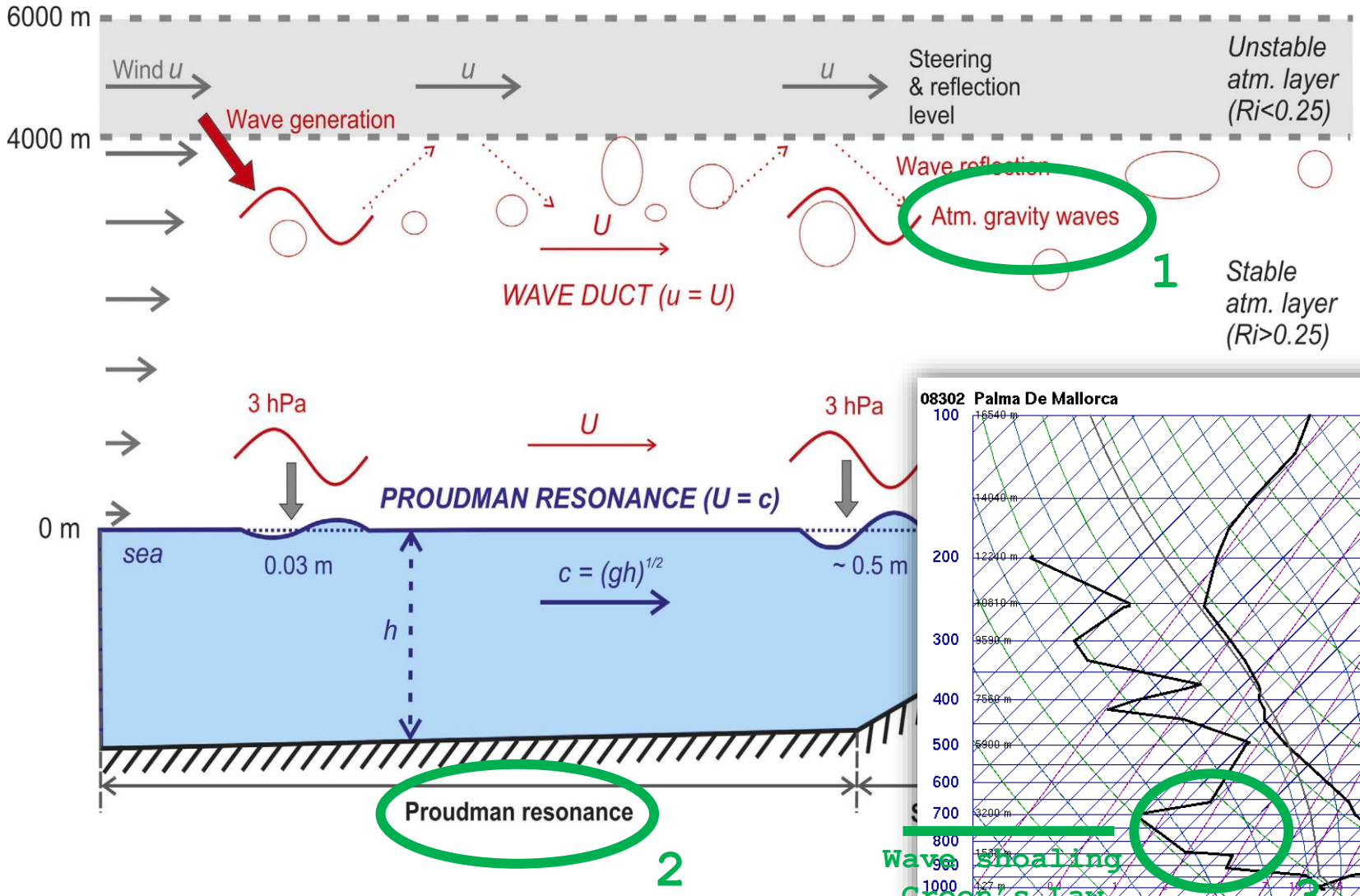
Jansà et al. (2007)

15 June 2006





Šepić et al. (2015)



> 2D version of Euler equations (dry-adiabatic)

$$\frac{\partial \pi'}{\partial t} = -u\frac{\partial \pi'}{\partial x} - w\frac{\partial \pi'}{\partial z} - w\frac{\partial \bar{\pi}}{\partial z} - \frac{R}{c_v}(\bar{\pi}+\pi')\left[\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z}\right]$$

$$\frac{\partial \theta'}{\partial t} = -u\frac{\partial \theta'}{\partial x} - w\frac{\partial \theta'}{\partial z} - w\frac{\partial \bar{\theta}}{\partial z}$$

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - w\frac{\partial u}{\partial z} - c_p(\bar{\theta}+\theta')\frac{\partial \pi'}{\partial x}$$

$$\frac{\partial w}{\partial t} = -u\frac{\partial w}{\partial x} - w\frac{\partial w}{\partial z} - c_p(\bar{\theta}+\theta')\frac{\partial \pi'}{\partial z} + g\frac{\theta'}{\bar{\theta}}$$

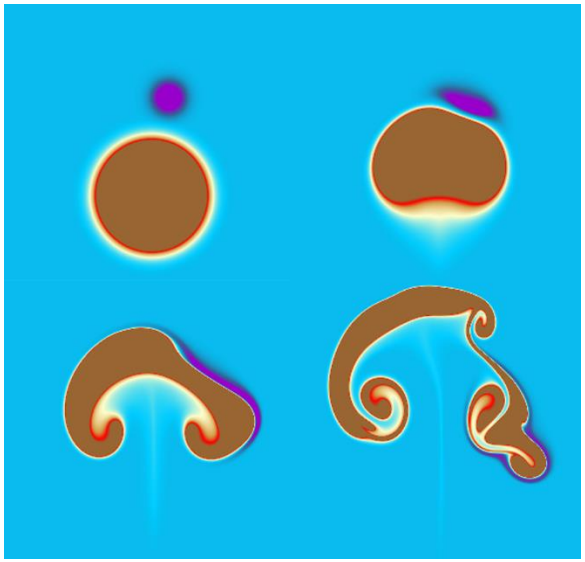
NO rotation

NO physics, etc …

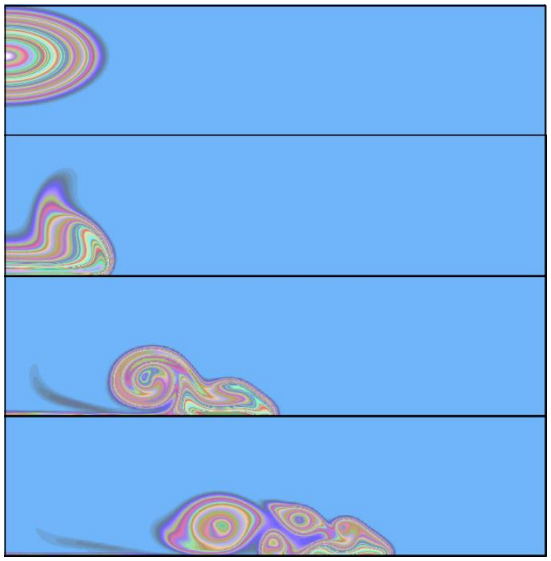
> Numerical implementation [CFL $\xrightarrow{c_s > 300\ m/s}$ $\Delta t \approx 3\ \Delta x(\Delta z)$]

* Forward-Backward integration of "forcings" in RK2 cycle
* REA (V and H) integration of advection every 6-10 Nsteps
* Stabilized acoustic vertical modes (Implicit Scheme)

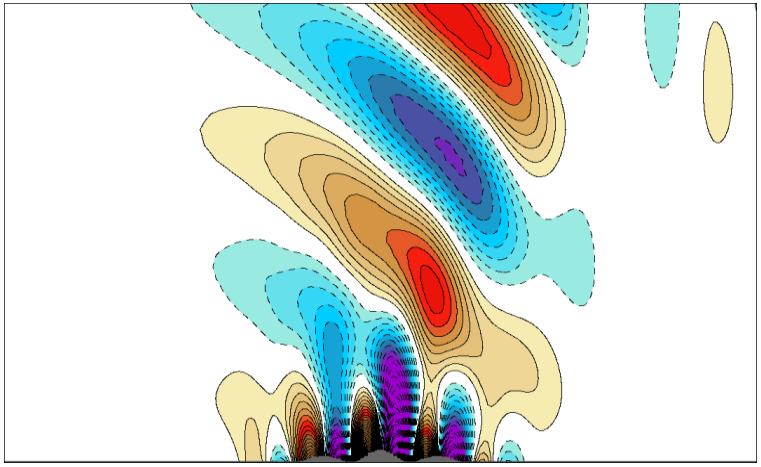
Large Warm & Small Cold Bubble



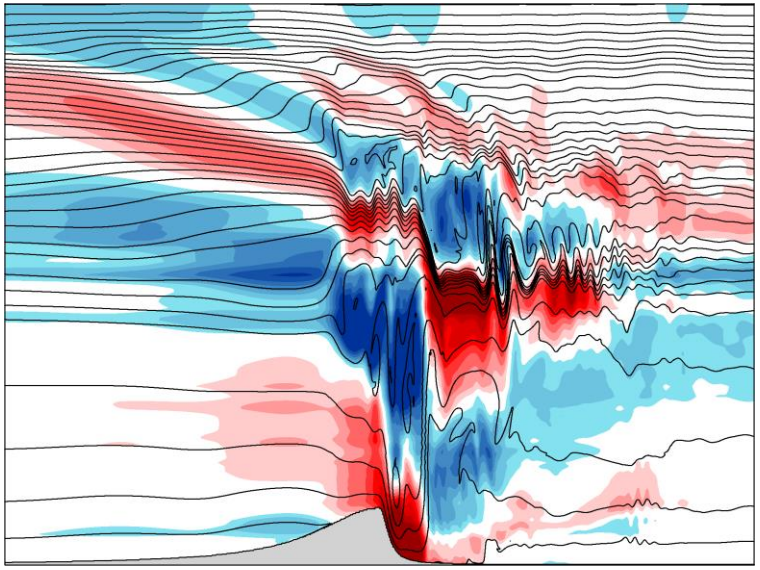
Density Current



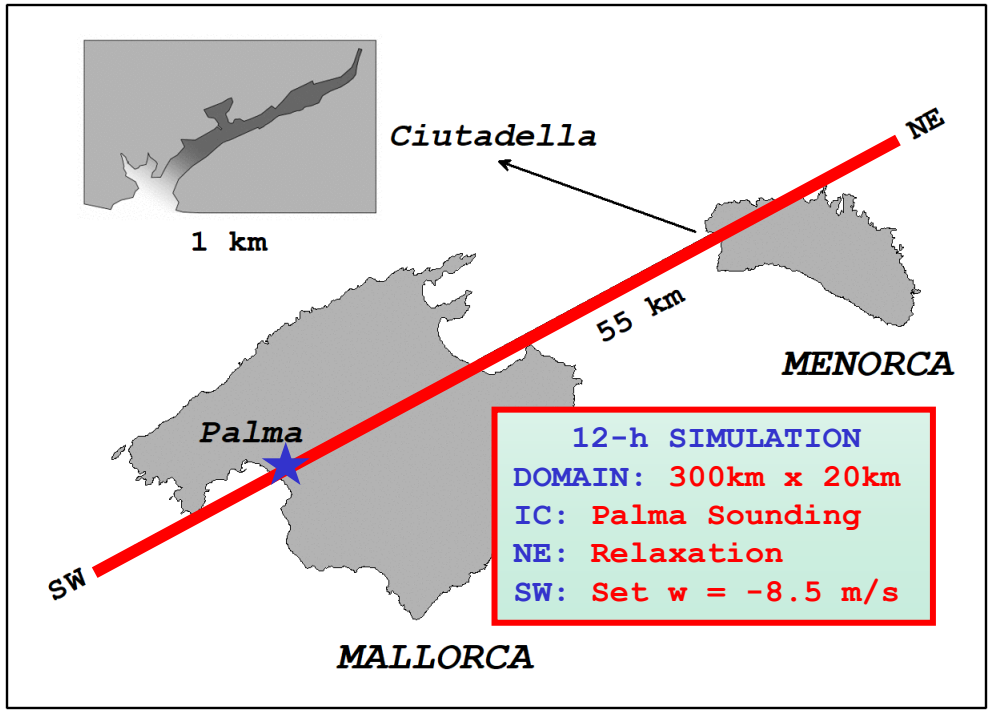
Schär Mountain

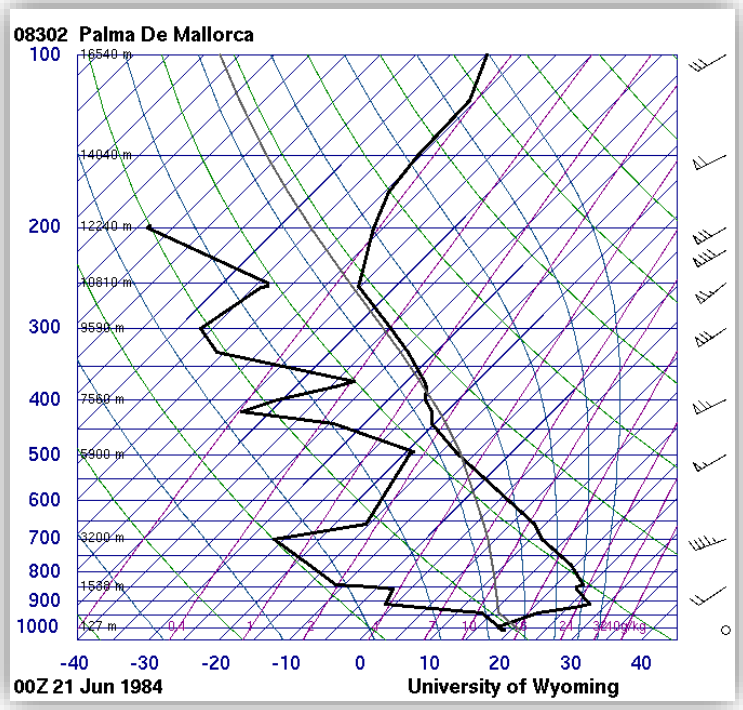


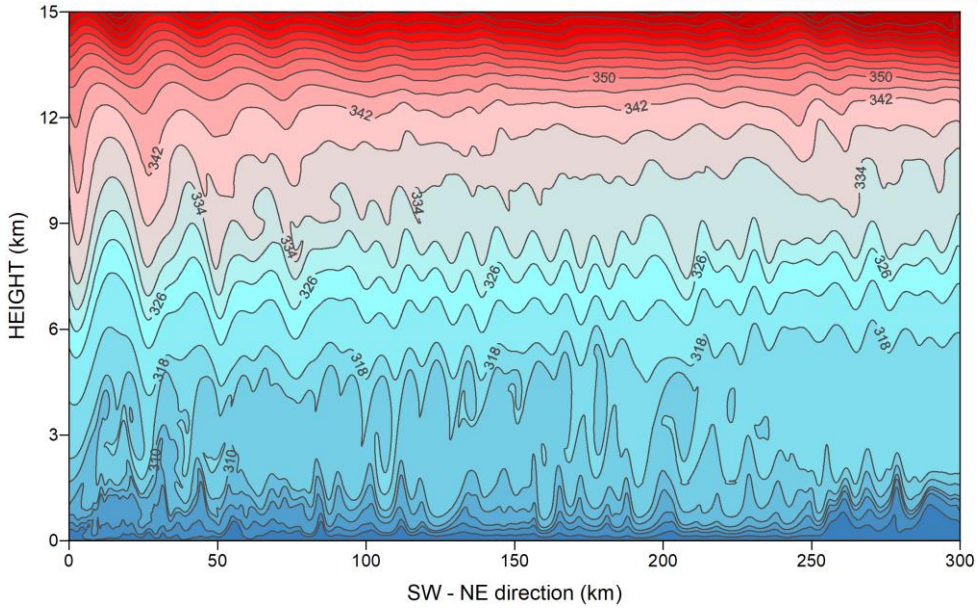
T-REX Intense Mountain-Wave



GRAVITY WAVE Generation & Progagation

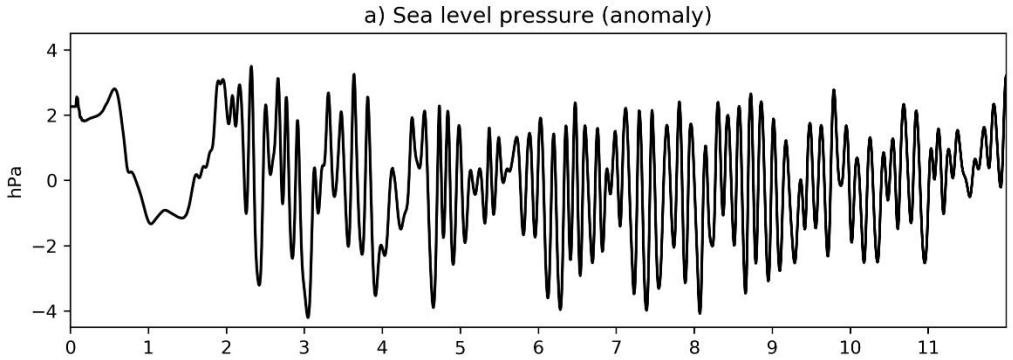


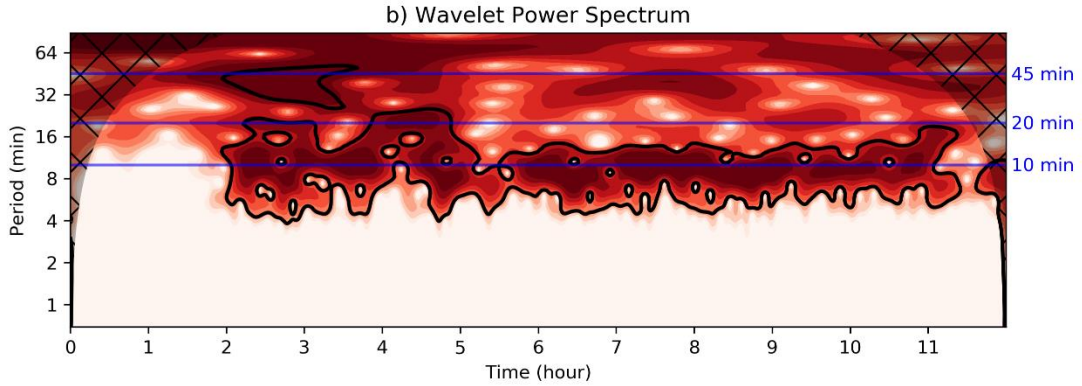


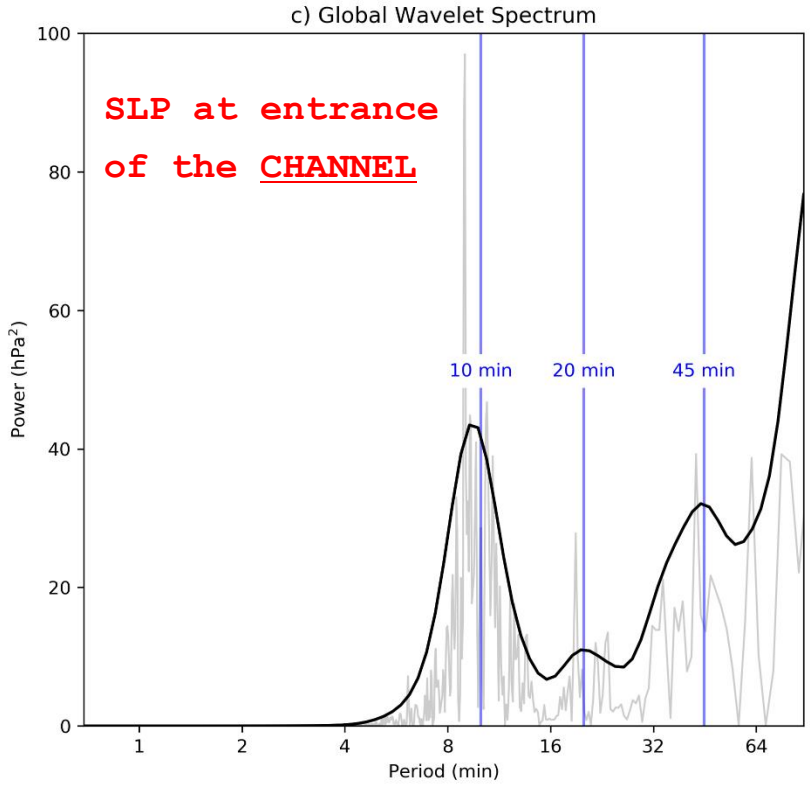


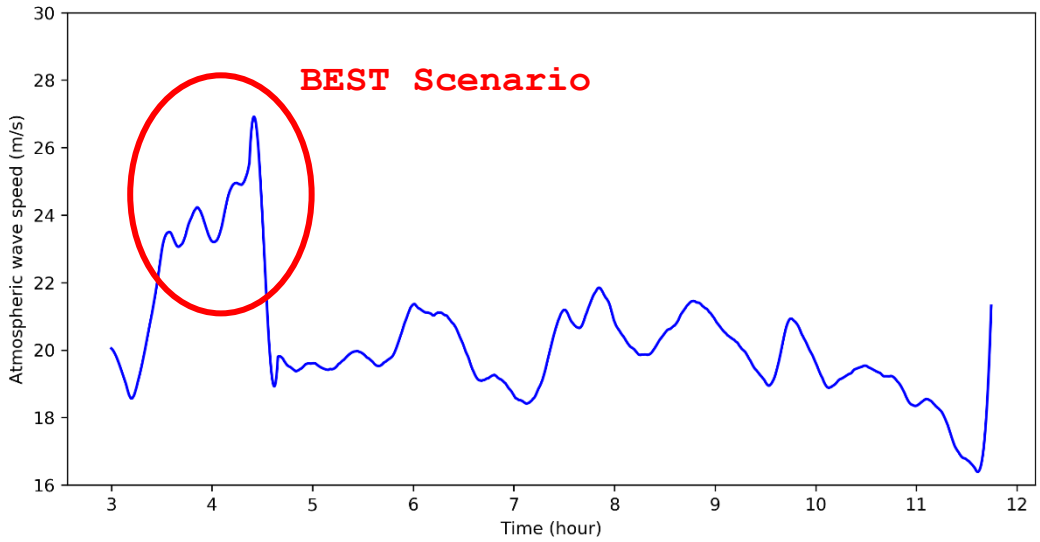
With ORIGINAL
(t=5h)

GRAVITY WAVE Generation & Progagation









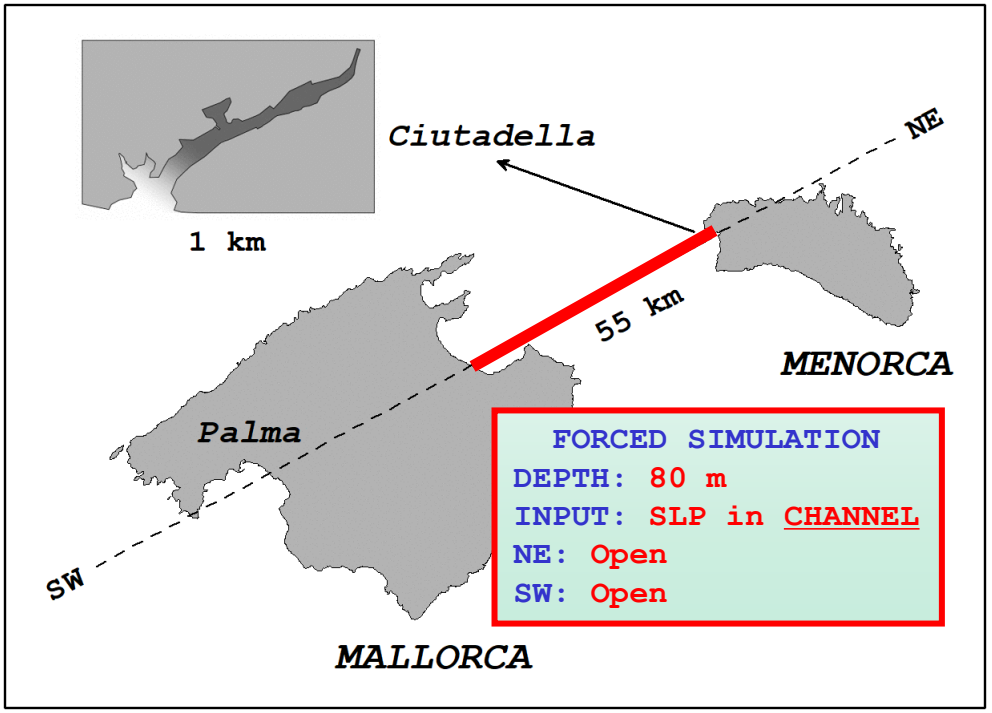
SLP-wave speed
in the CHANNEL

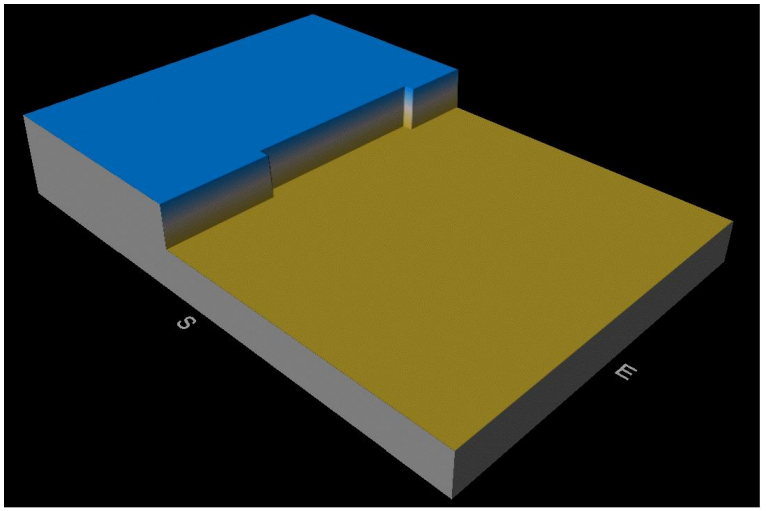
2. OCEANIC Component (MALLORCA-MENORCA Channel)

> Shallow-Water equations

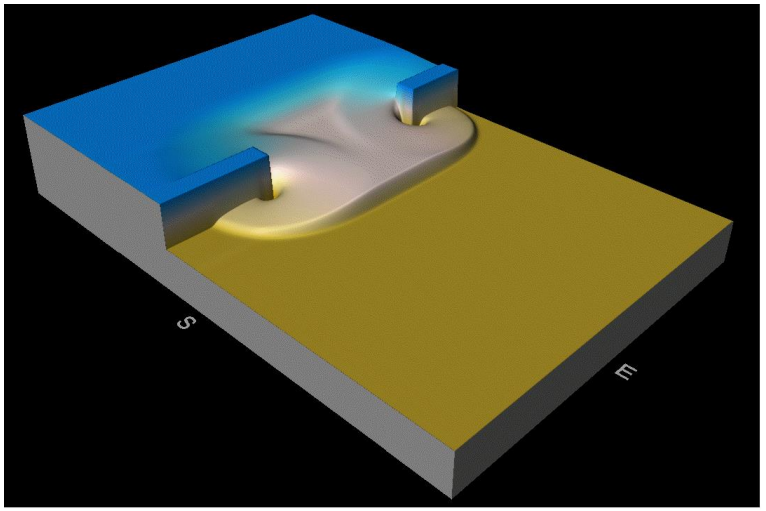
$$\frac{\partial h}{\partial t} = -u\frac{\partial h}{\partial x} - h\frac{\partial u}{\partial x}$$

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - g\frac{\partial h}{\partial x} - \frac{1}{\rho}\frac{\partial P}{\partial x} - \frac{gu^2}{hC^2}$$

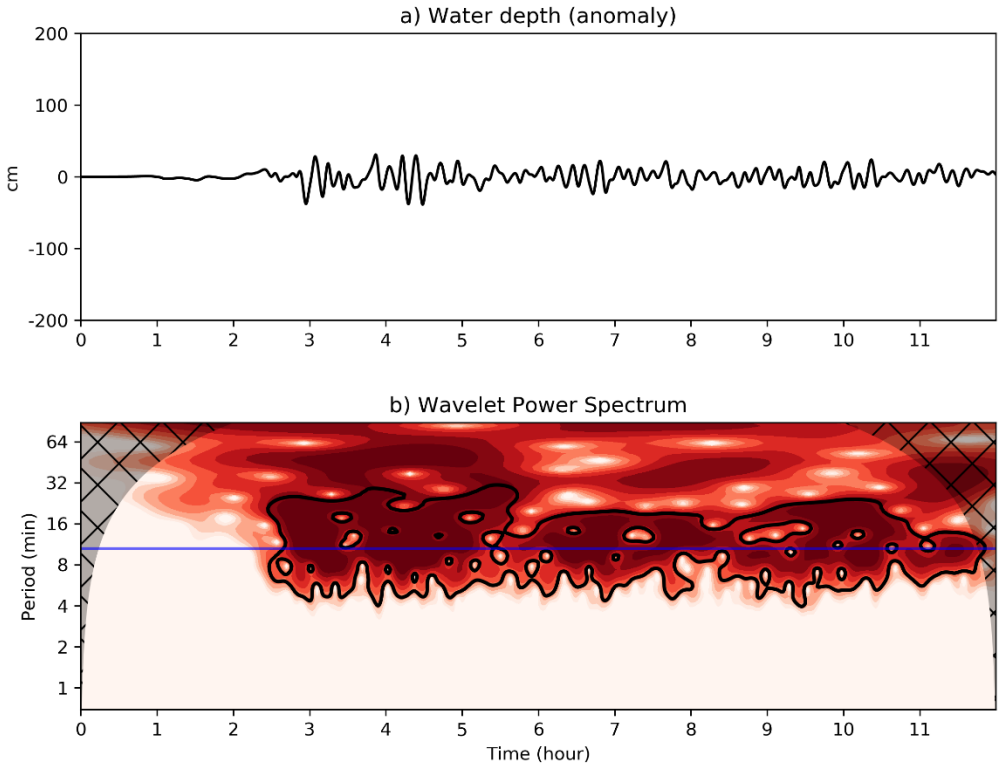


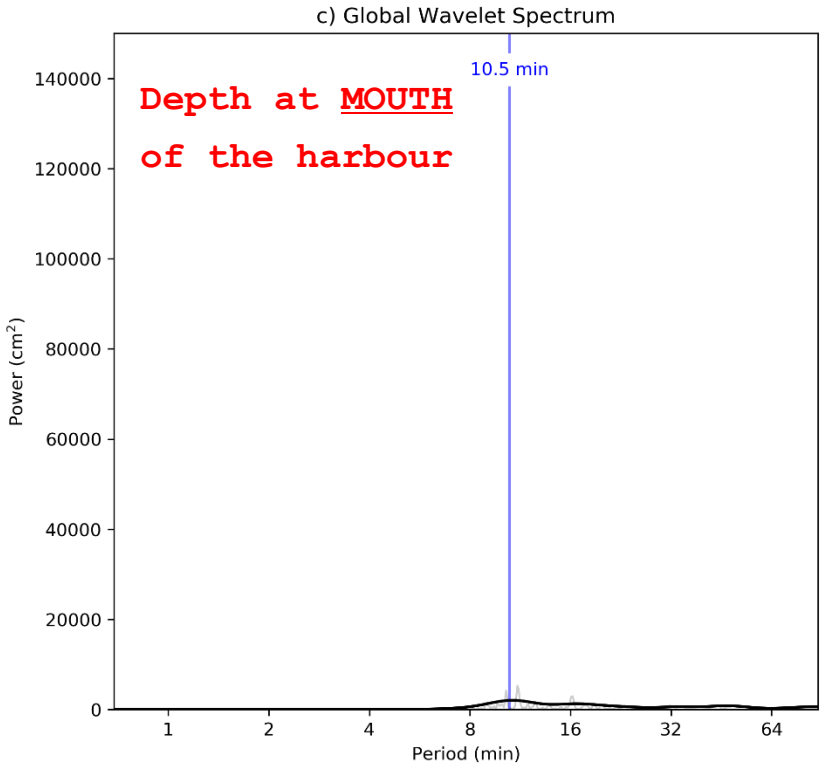


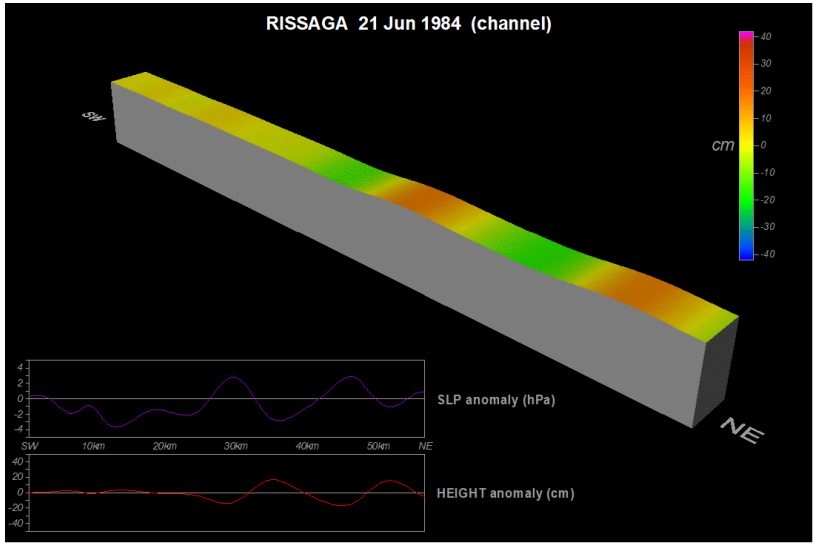
Partial Dam Break 10-5 m



LONG OCEAN WAVES (Proudman Resonance & Wave Shoaling)



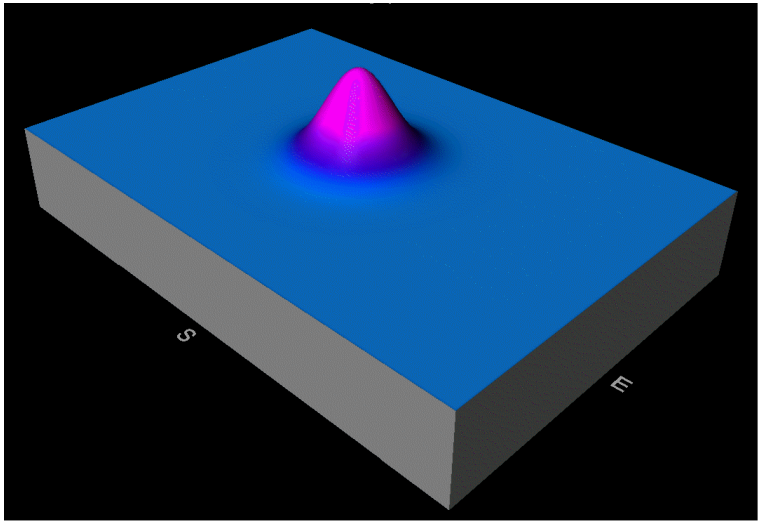




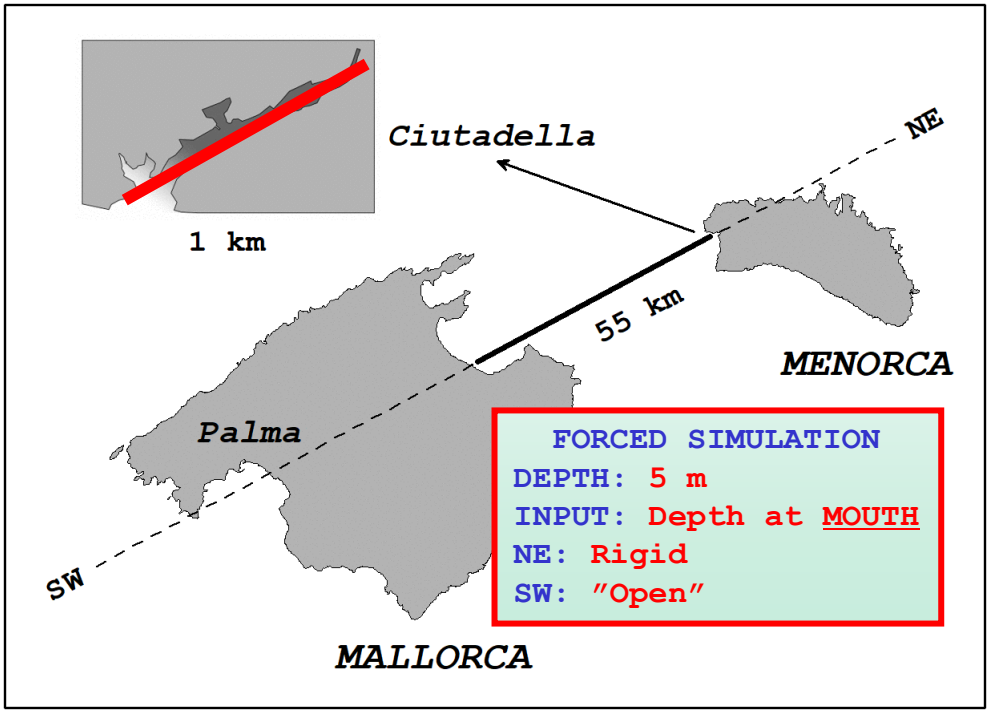
> Shallow-Water equations

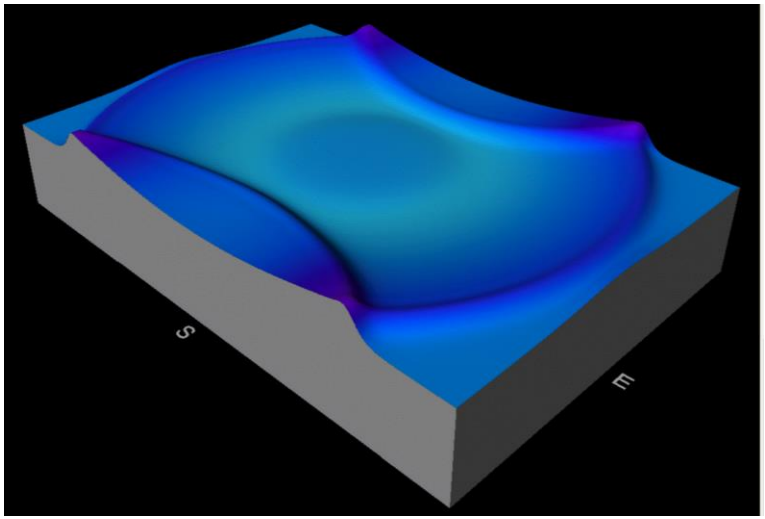
$$\frac{\partial h}{\partial t} = -u\frac{\partial h}{\partial x} - h\frac{\partial u}{\partial x}$$

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - g\frac{\partial h}{\partial x} - \frac{gu^2}{hC^2}$$

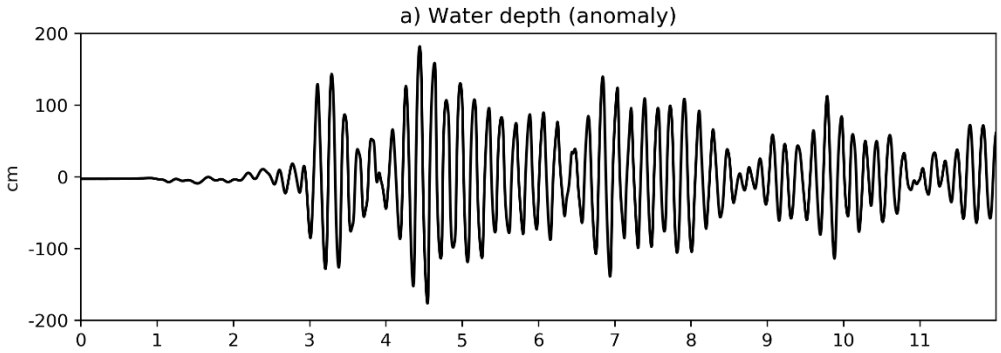


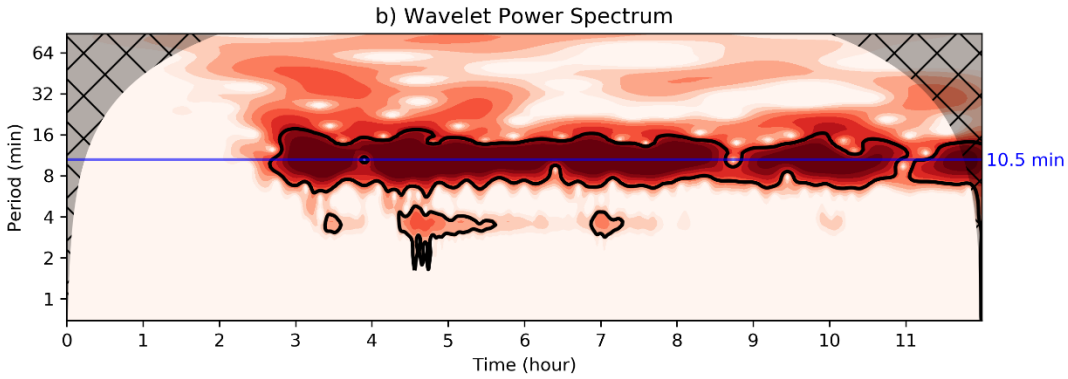
Gaussian Bump in 10 m

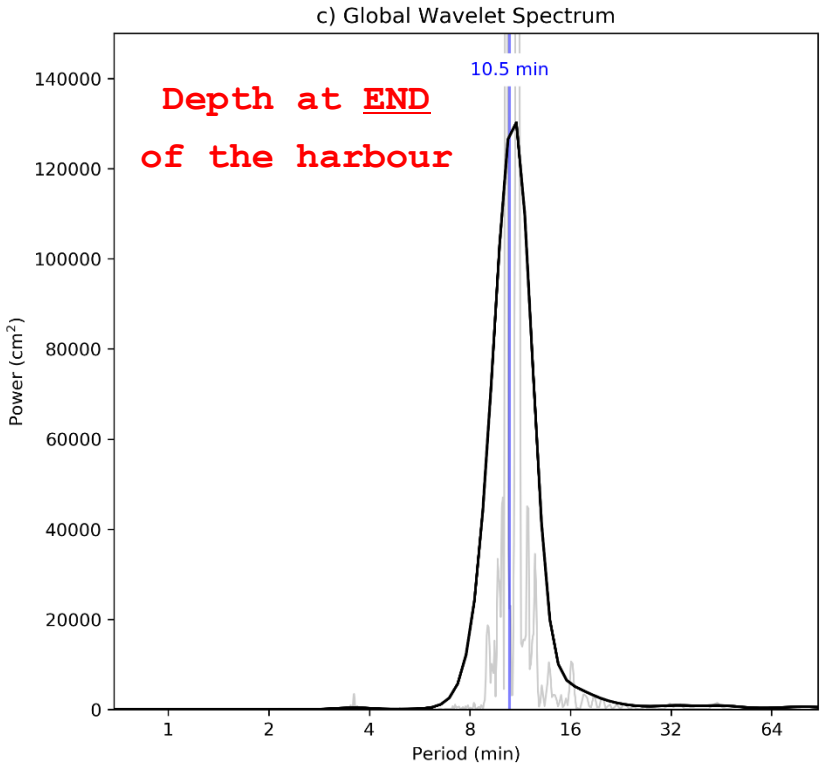


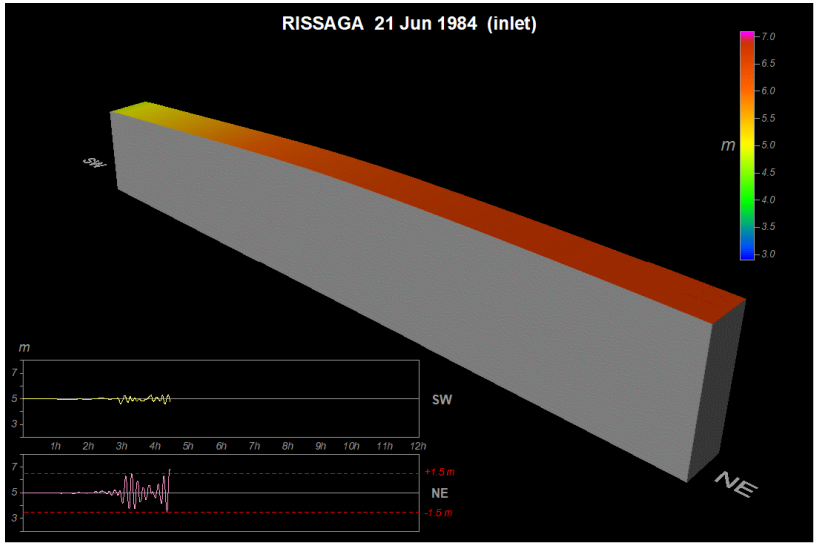


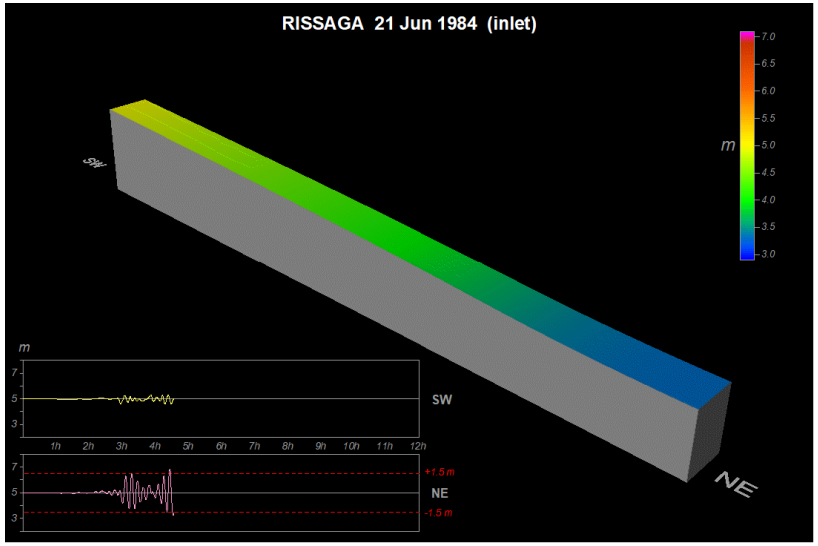
RISSAGA (Harbour Resonance)



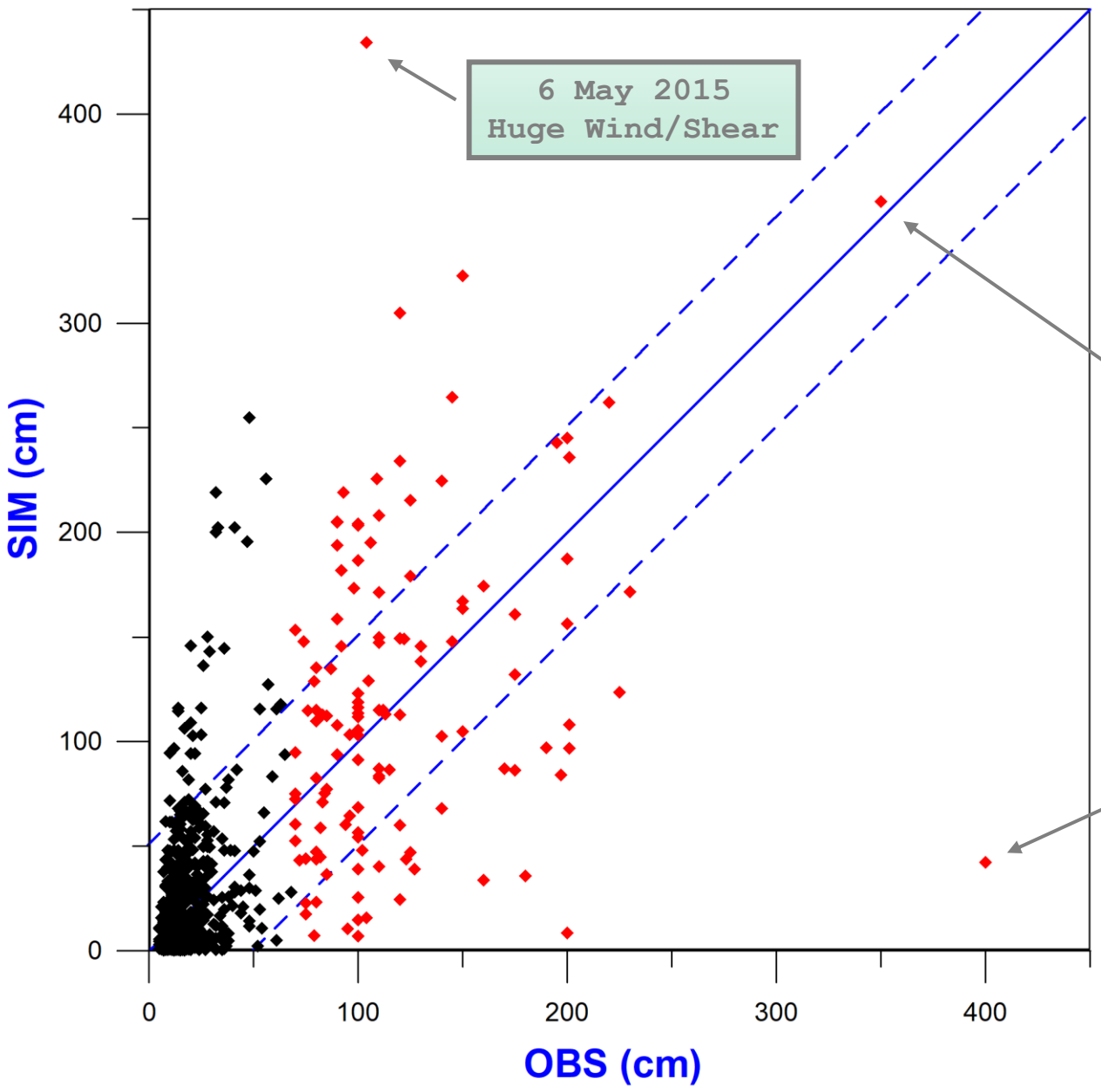








RISSAGA (GLOBAL Results)



126 RISSAGA Events

Mean OBS 120.8 cm
Mean SIM 119.6 cm

549 NON RISSAGA Days

Mean OBS 17.8 cm
Mean SIM 25.1 cm

RISSAGA (CATEGORIES of Practical Interest)

- Petites Oscil·lacions (H < 20 cm)
- Oscil·lacions Moderades (20 - 70 cm)
- Rissaga (70 - 100 cm)
- Rissaga Forta (100 - 200 cm)
- Rissaga Extrema (H > 200 cm)

FORECAST (%)

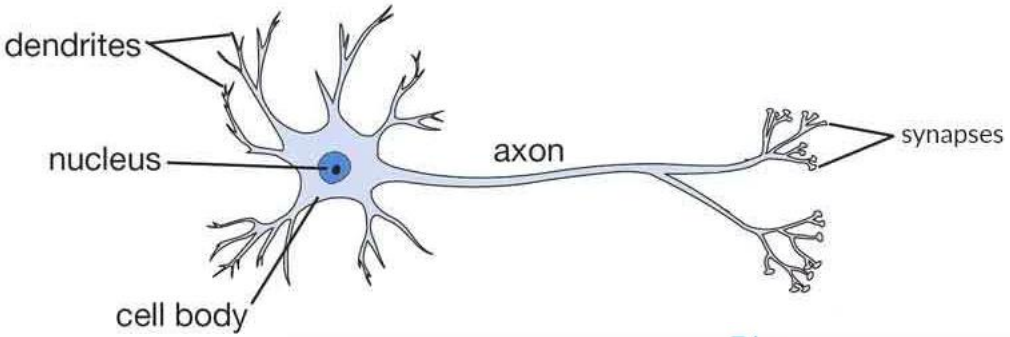
OBSERVED					
	71.2	25.9	1.8	1.0	0.0
	43.1	38.9	6.0	8.4	3.6
	6.8	29.5	18.2	38.6	6.8
	4.3	21.4	14.3	42.9	17.1
	8.3	8.3	8.3	41.7	33.3

What fraction of the events are (are not) correctly forecast ???

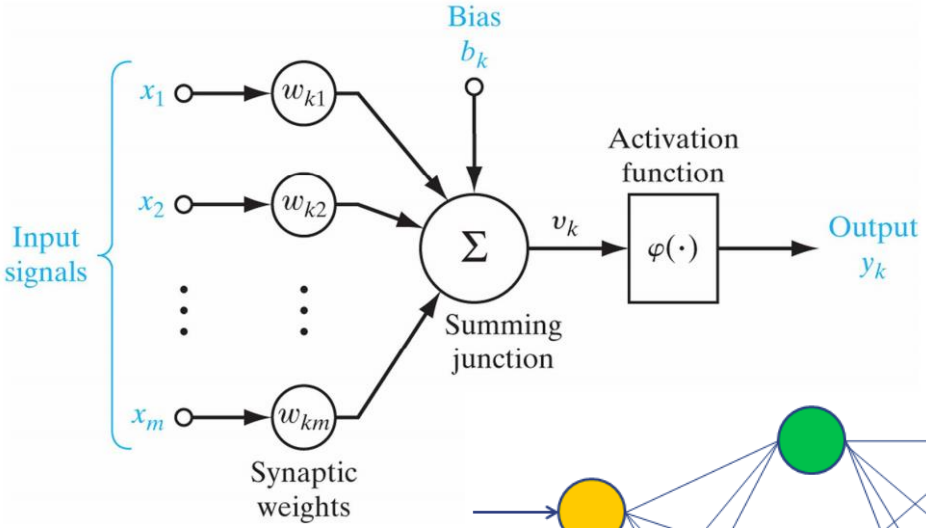
OBSERVED (%)

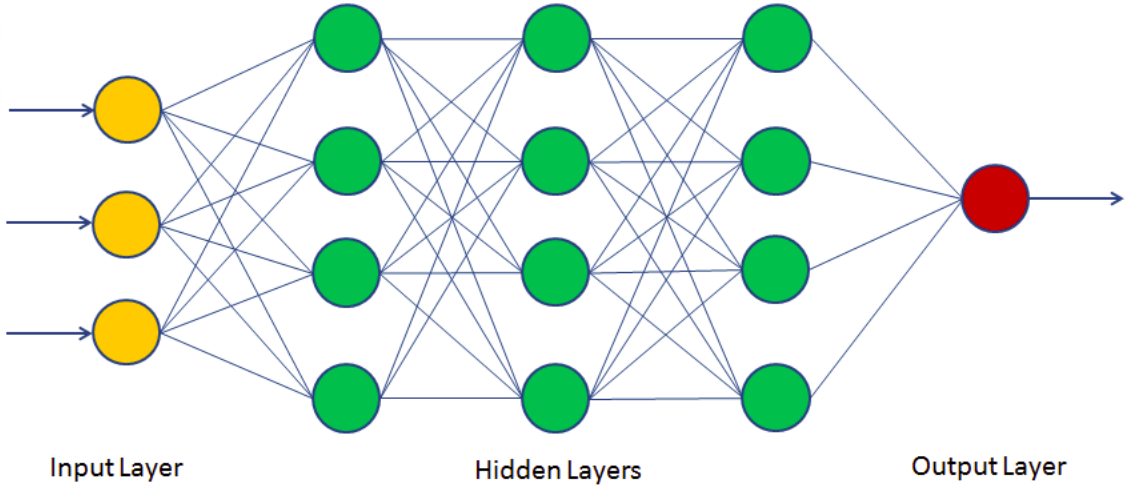
FORECAST					
	77.5	20.5	0.9	0.9	0.3
	51.3	33.7	6.7	7.8	0.5
	19.4	27.8	22.2	27.8	2.8
	5.7	20.0	24.3	42.9	7.1
	0.0	24.0	12.0	48.0	16.0

What fraction of the forecasts are (are not) correct ???



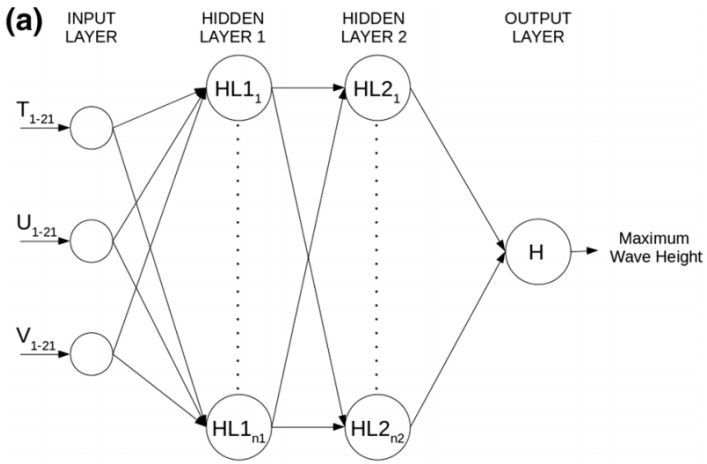
Operating PRINCIPLE

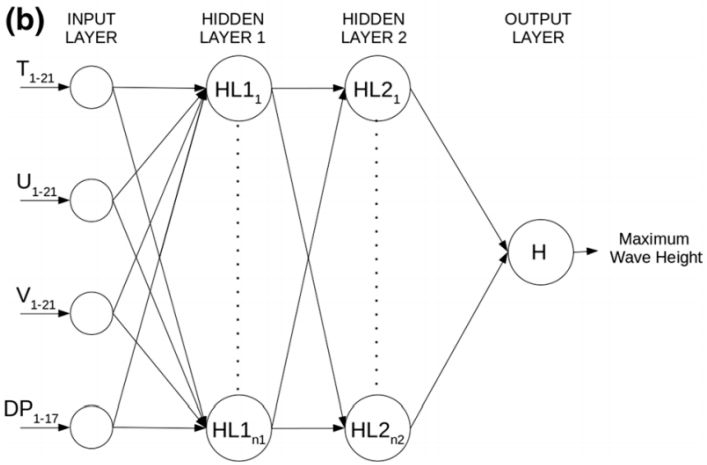


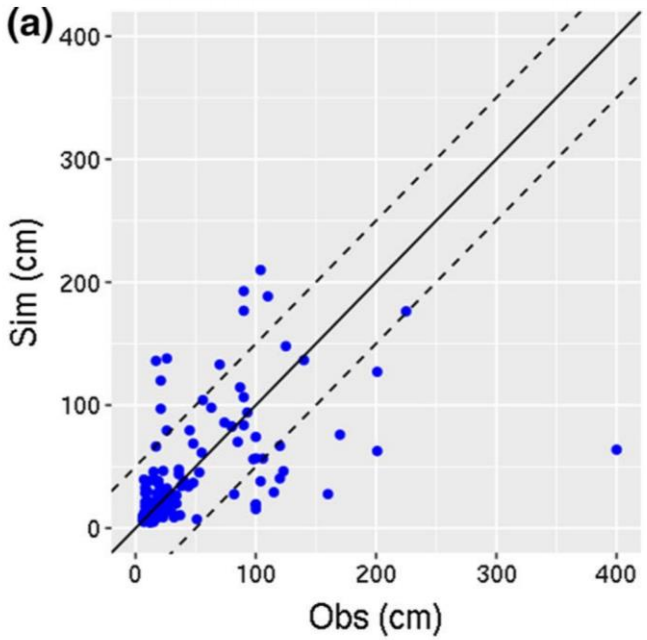


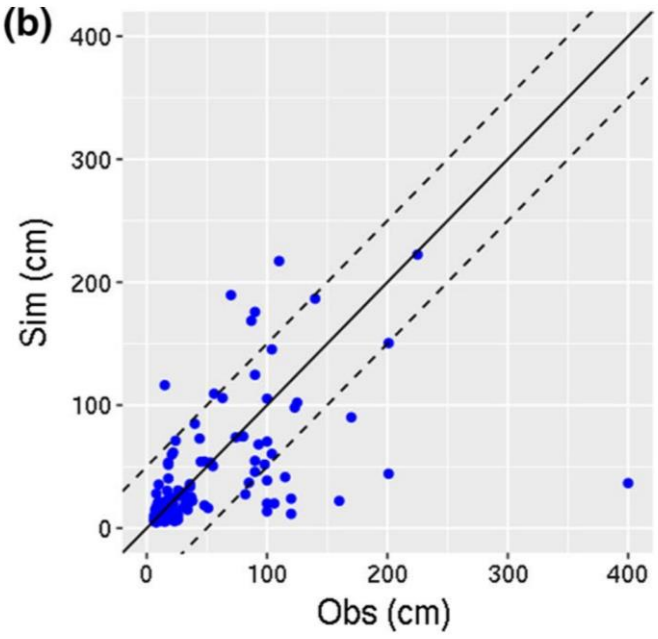
DRY Scheme

WET Scheme

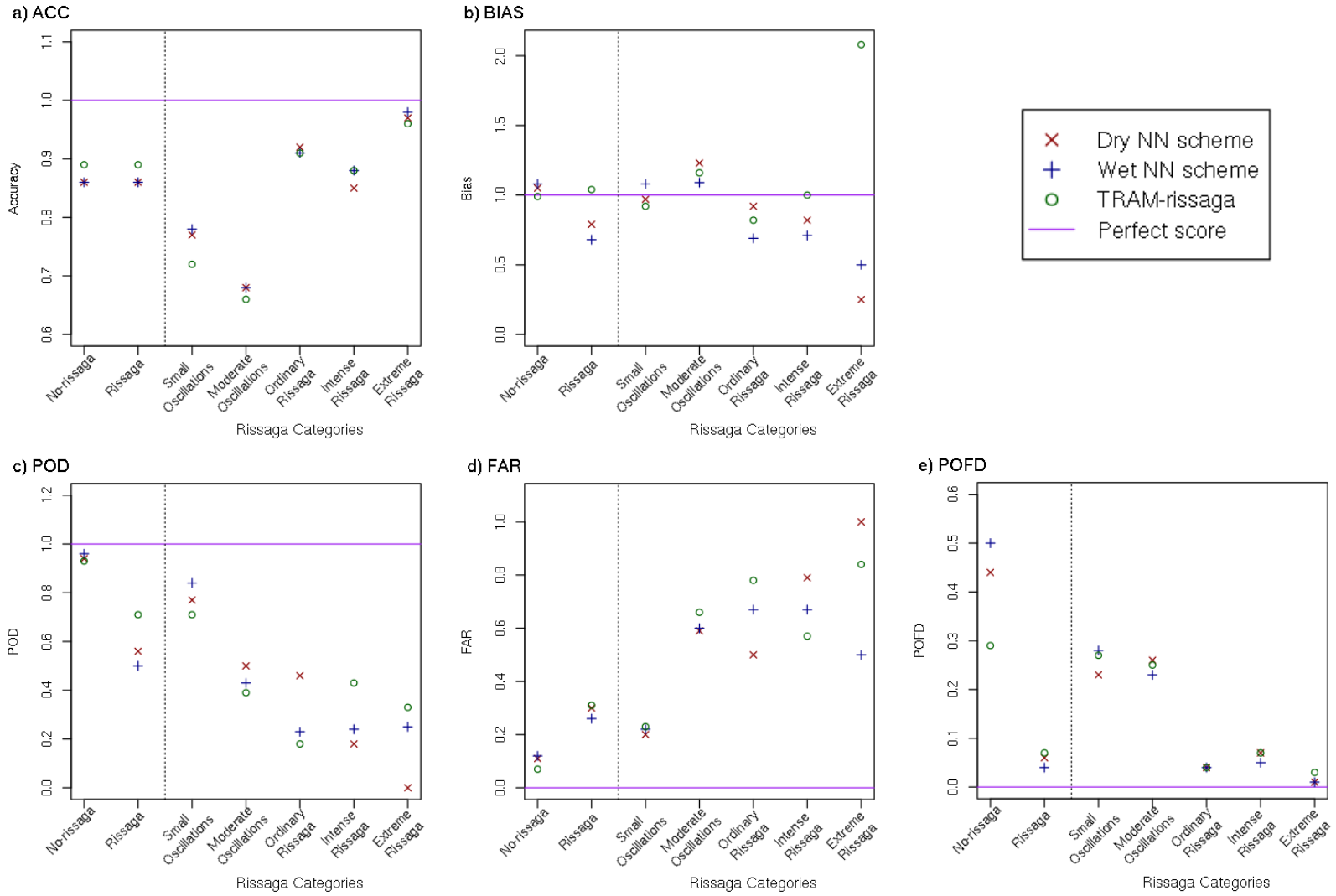








INTER-COMPARISON of Methods



> Two PRAGMATIC (and computationally CHEAP) numerical APPROACHES aimed at PREDICTING the occurrence and magnitude of meteotsunamis in Ciutadella (RISSAGAS): SKILL for the recognition of RISK situations and for a categorization among WEAK, MODERATE and INTENSE

> SOME ISSUES to explore: Sounding representativity; Type and amount of GW triggering; Inclusion of moist physics (MCS); Second-order oceanic influences... AND Other types of NN; More cases for a proper training...

> The systems could be applied as a DOWNSCALING METHOD to assess quantitatively the future risk of rissagas

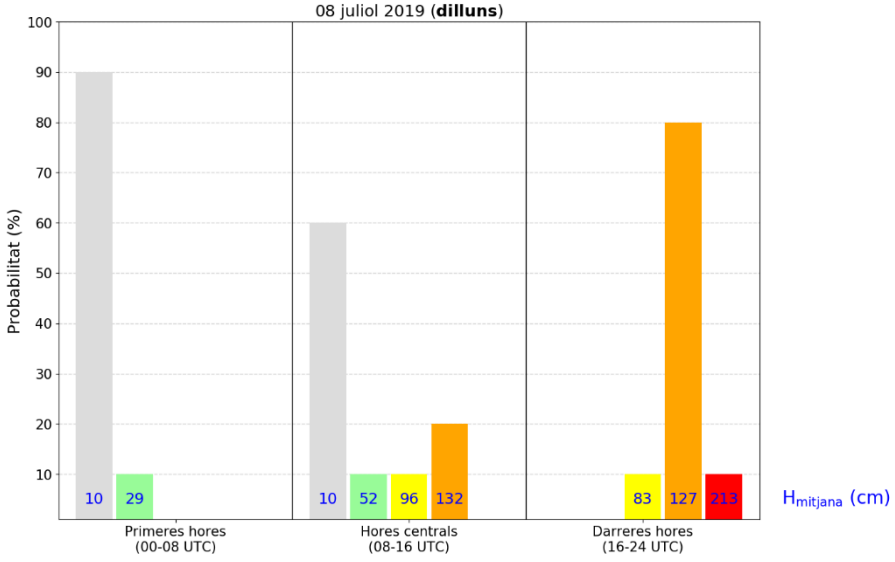
> It is now in operation, running daily driven by GFS forecast soundings for the next 3 days and providing PROBABILISTIC PREDICTIONS: http://meteo.uib.es/rissaga

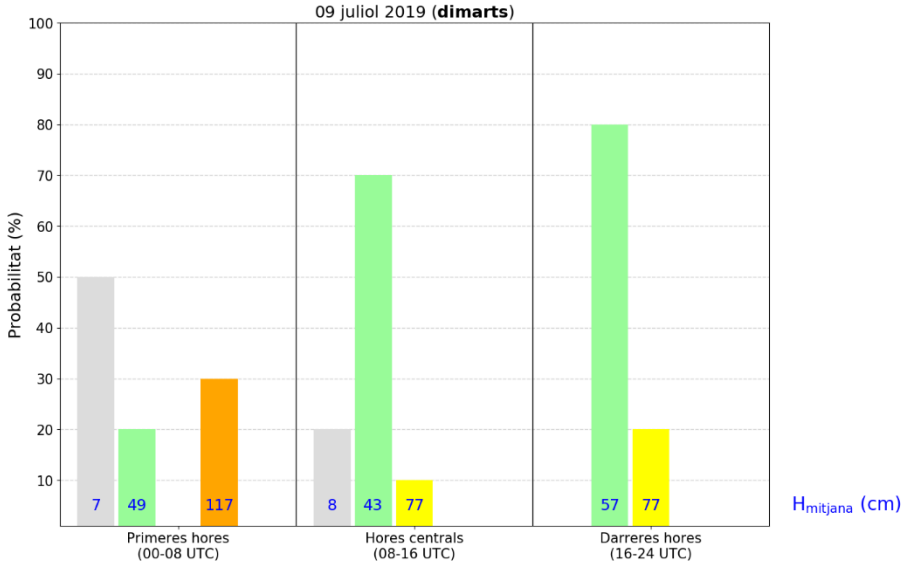
OPERATIONAL Implementation (Probabilistic)

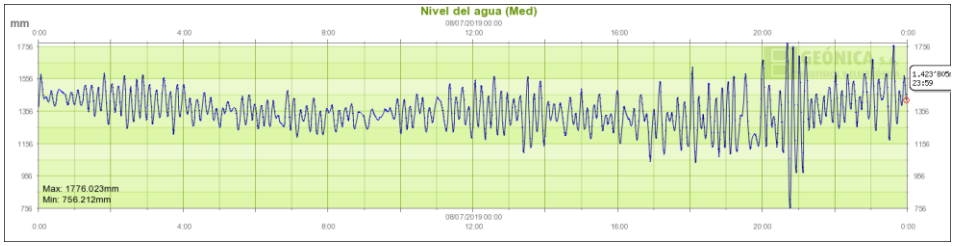
Petites Oscil·lacions (H < 20 cm) | Oscil·lacions Moderades (20 - 70 cm) | Rissaga (70 - 100 cm) | Rissaga Forta (100 - 200 cm) | Rissaga Extrema (H > 200 cm)

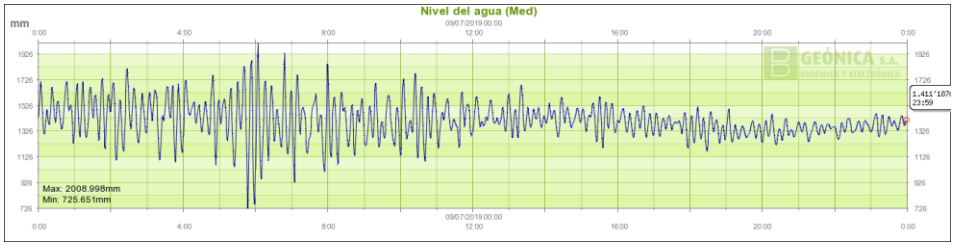
> http://meteo.uib.es/rissaga

Example









THANK YOU
for
your attention