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A neural network designed to predict meteotsunamis in Ciutadella harbour

M.Vich and R. Romero

Grup de Meteorologia

Universitat de les Illes Balears

#SOM UIB

8th International Conference on Meteorology and Climatology of the Mediterranean (MetMed)

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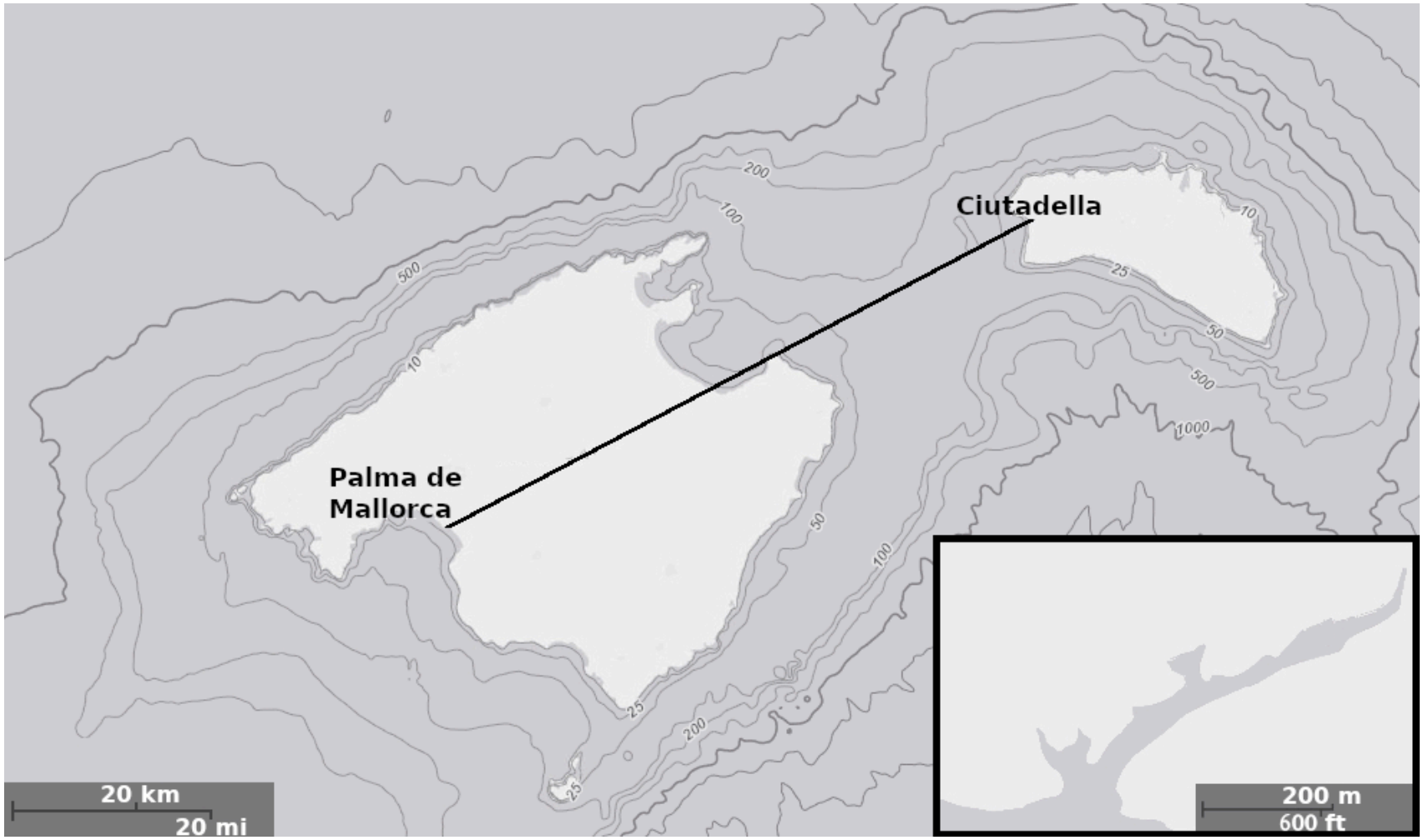
Geographic context



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Motivation

wave heights ≅ **1 m**

several episodes in modern history have reached **2-4 m**

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Motivation

http://www.socib.eu/?seccion=modelling&facility=rissagaforecast

Predicció Probabilística del Risc de RISSAGA al Port de Ciutadella

Grup de Meteorologia

UIB Universitat de les Illes Balears

https://meteo.uib.es/rissaga/

TRAM-rissaga

Computational Cost

+

-

Can we go further?

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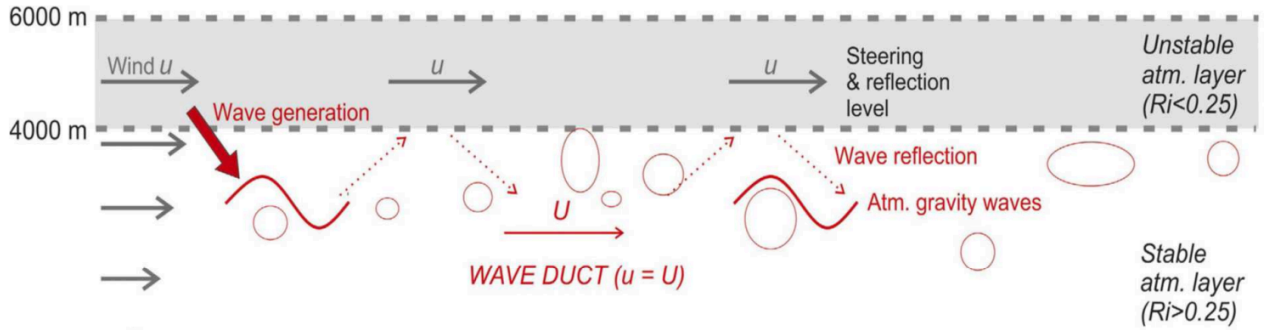
Background

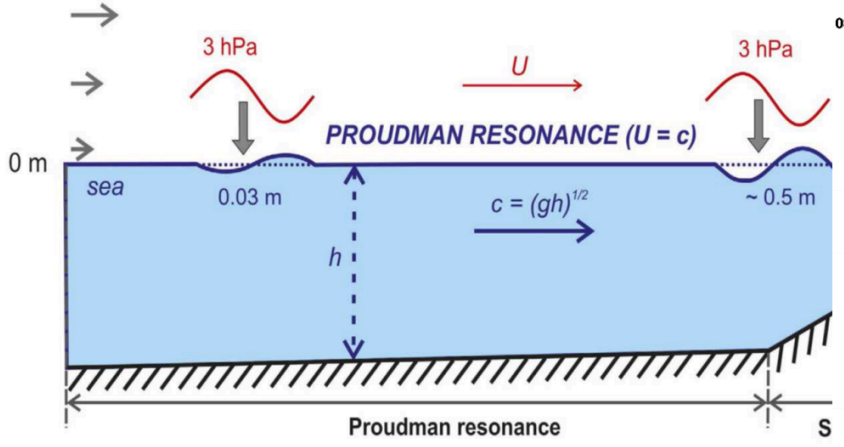
*TRAM_**non_hydro_set1_2D_oroSTRETCH_implicit***

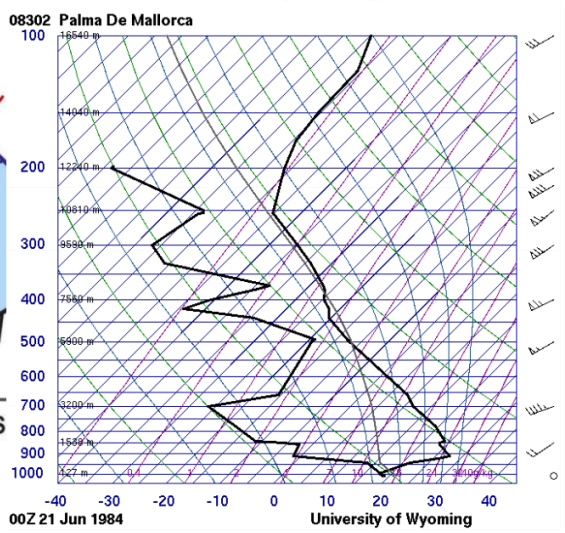
> **"Rissaga" Study**

(dx=250m,dzm=250m,stretch=5,dt=0.75s,Nstep=10,24h)



Run





Šepić et al. (2015)

https://meteo.uib.es/rissaga/

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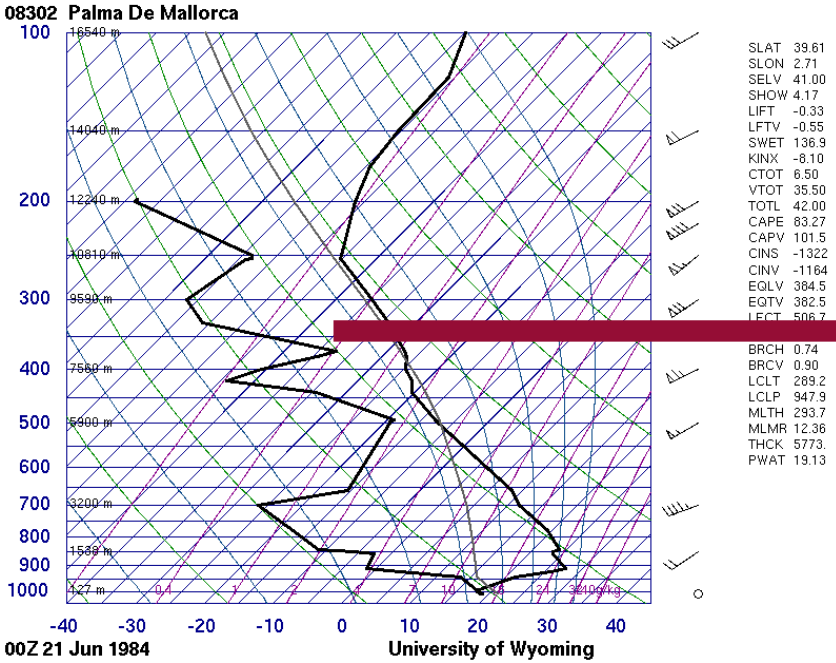
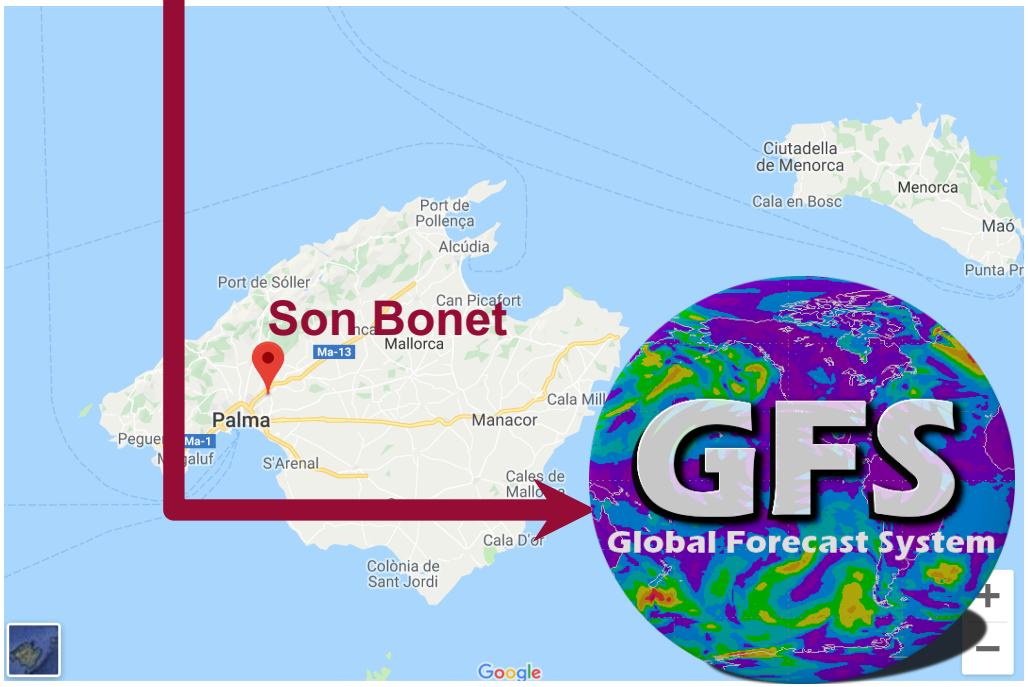
Background



GFS *soundings*

for daily running



https://meteo.uib.es/rissaga/

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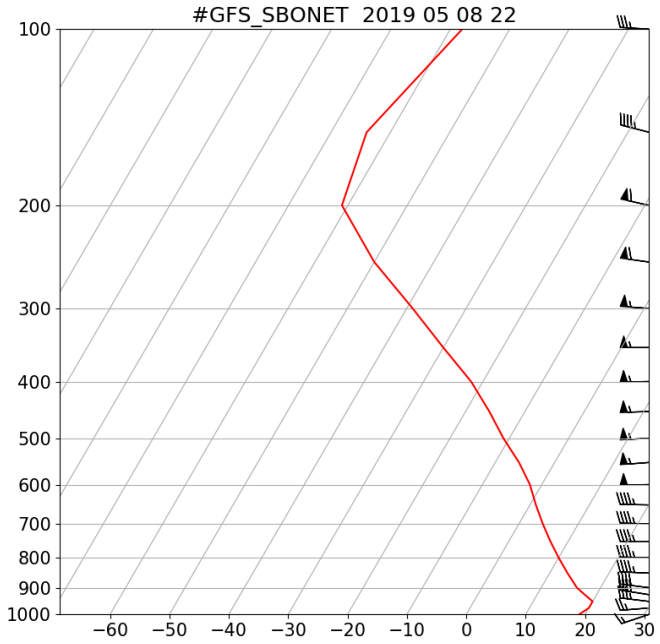
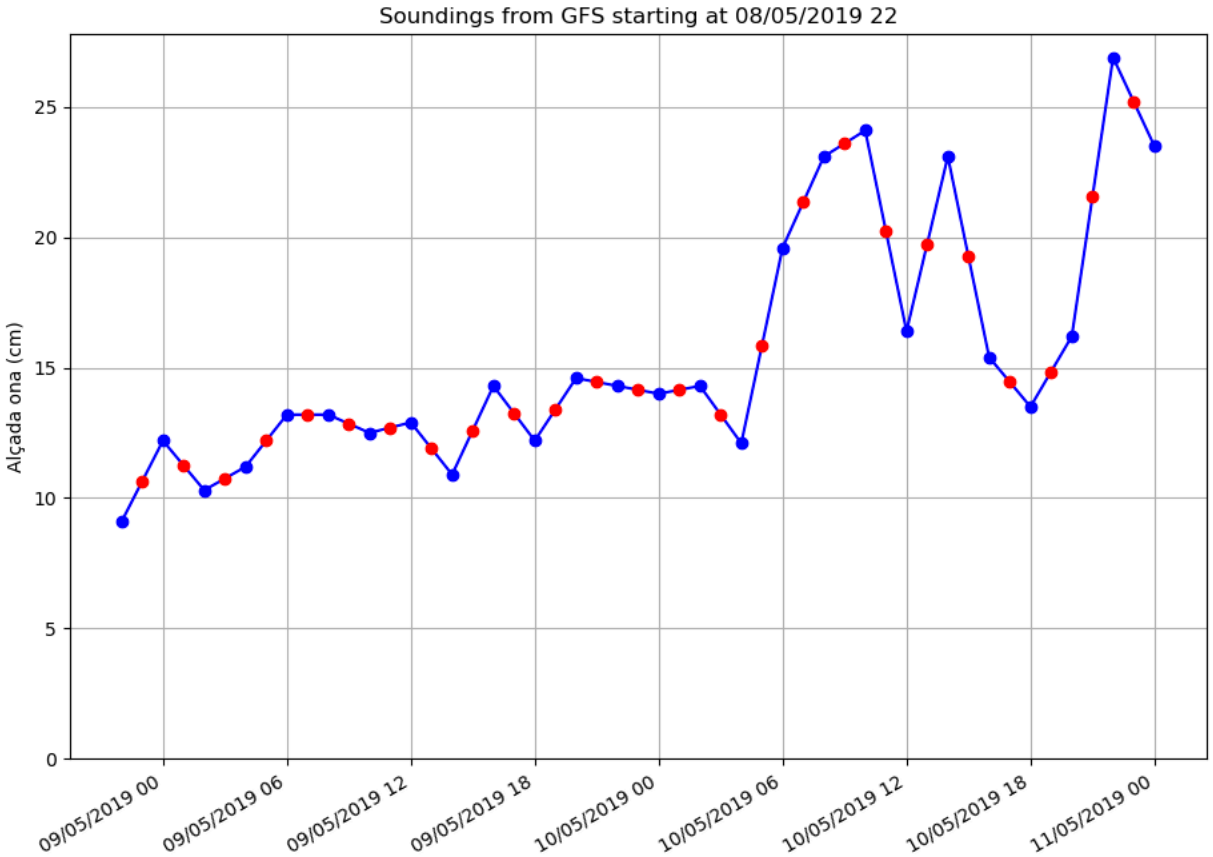
Background



26 simulations!!
6 h a regular day



https://meteo.uib.es/rissaga/

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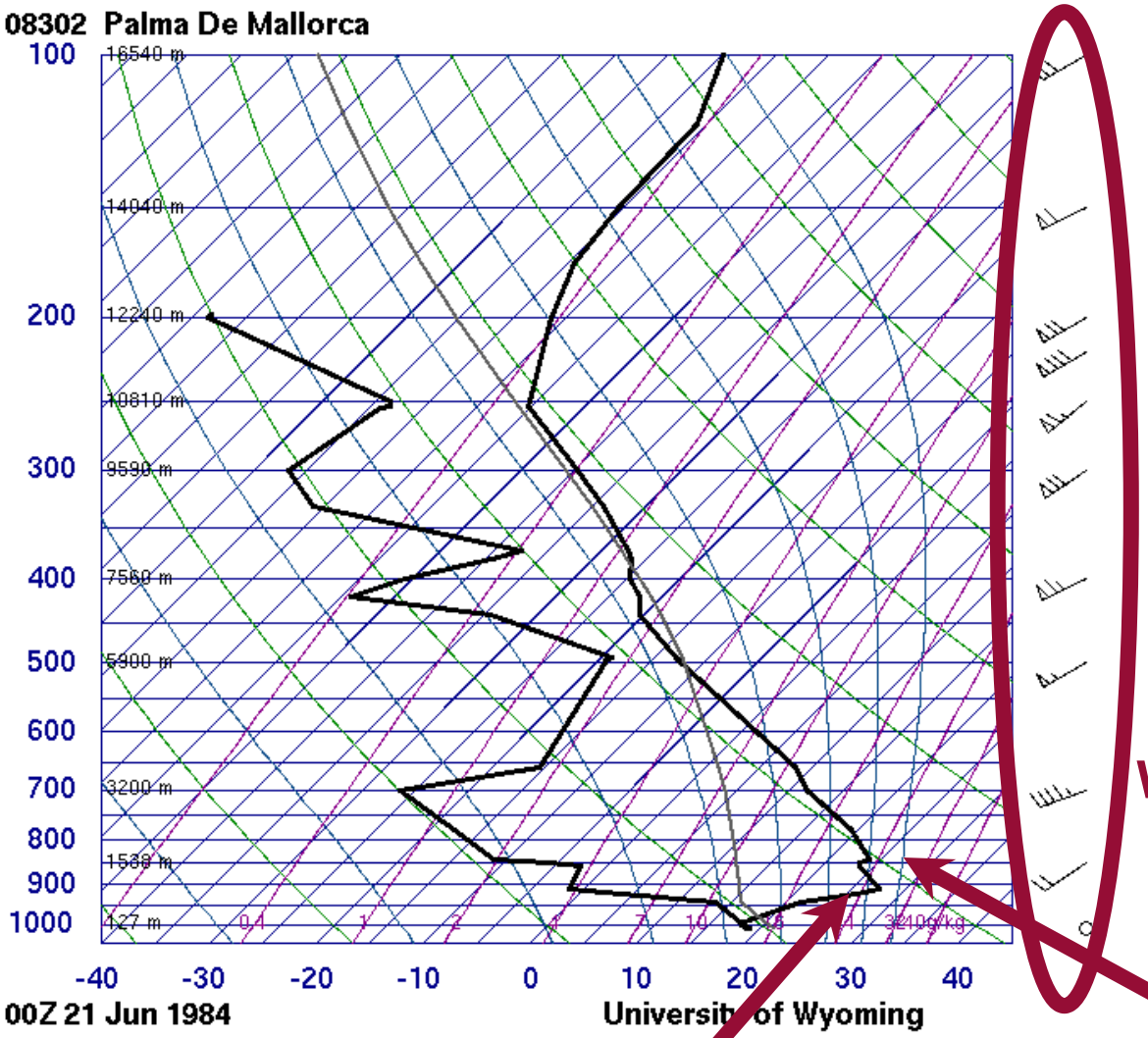
Background

Typical rissaga sounding



SLAT 39.61
SLON 2.71
SELV 41.00
SHOW 4.17
LIFT -0.33
LFTV -0.55
SWET 136.9
KINX -8.10
CTOT 6.50
VTOT 35.50
TOTL 42.00
CAPE 83.27
CAPV 101.5
CINS -1322
CINV -1164
EQLV 384.5
EQTV 382.5
LFCT 506.7
LFCV 510.9
BRCH 0.74
BRCV 0.90
LCLT 289.2
LCLP 947.9
MLTH 293.7
MLMR 12.36
THCK 5773.
PWAT 19.13

Wind shear

Unstable layer

Stable layer

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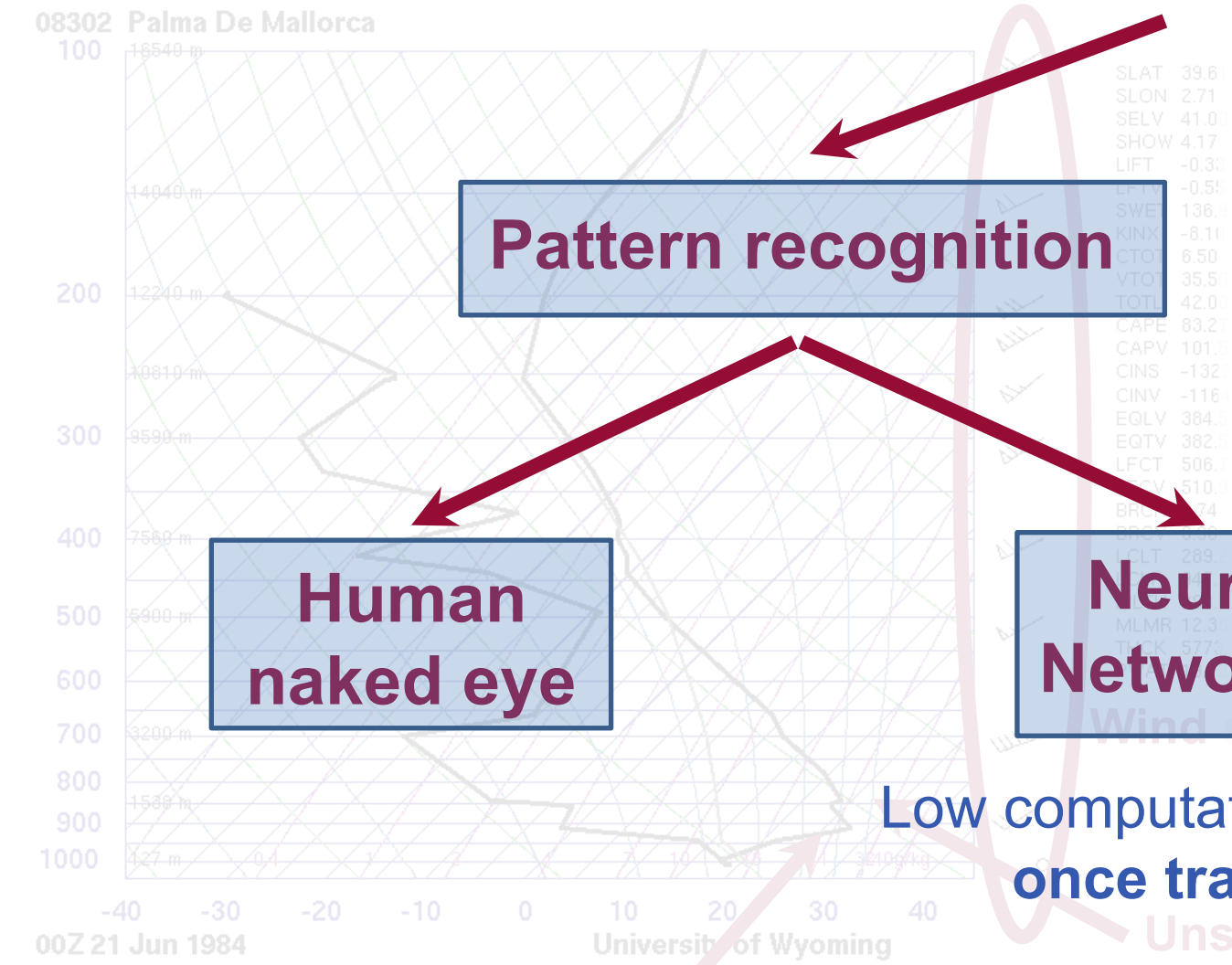
Background

Typical rissaga sounding



Pattern recognition

Human naked eye

Neural Networks

Low computational cost, **once trained**!

Unstable layer

Stable layer

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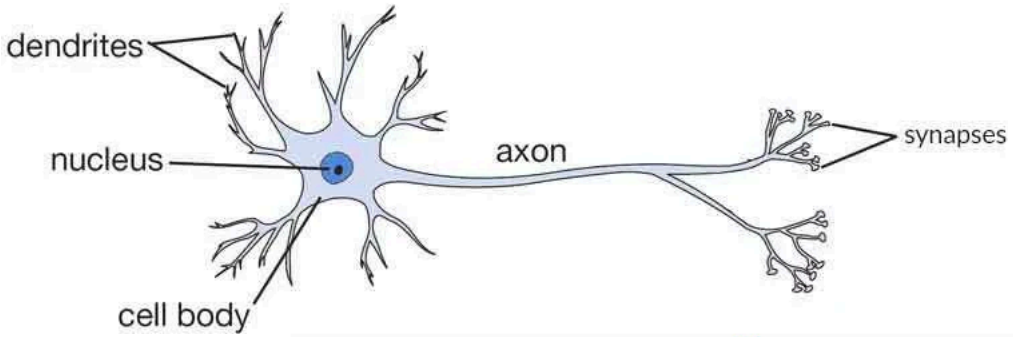
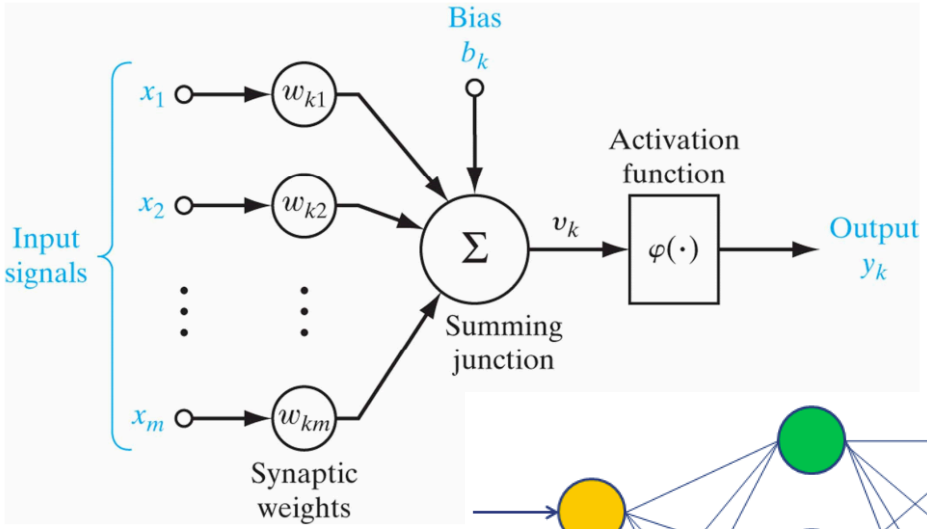
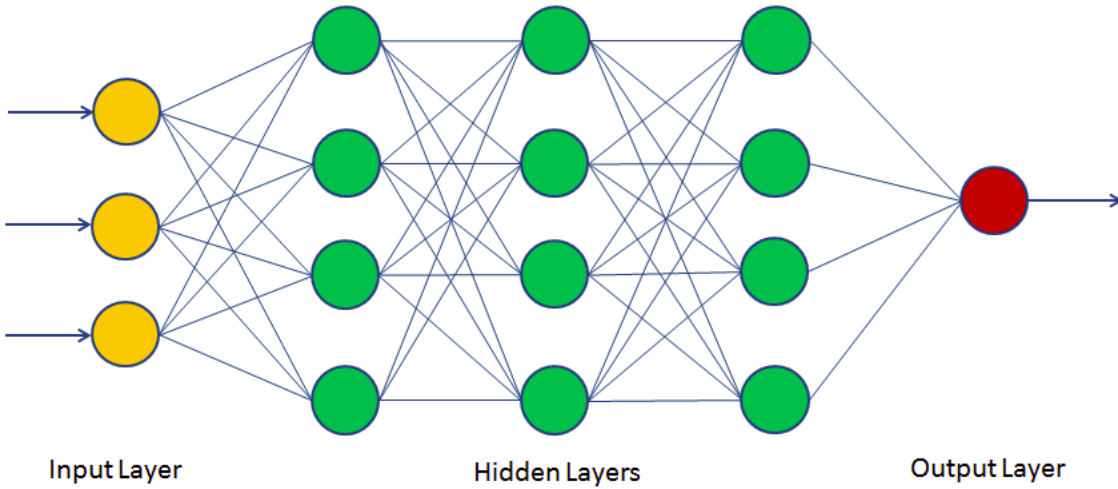
Neural networks







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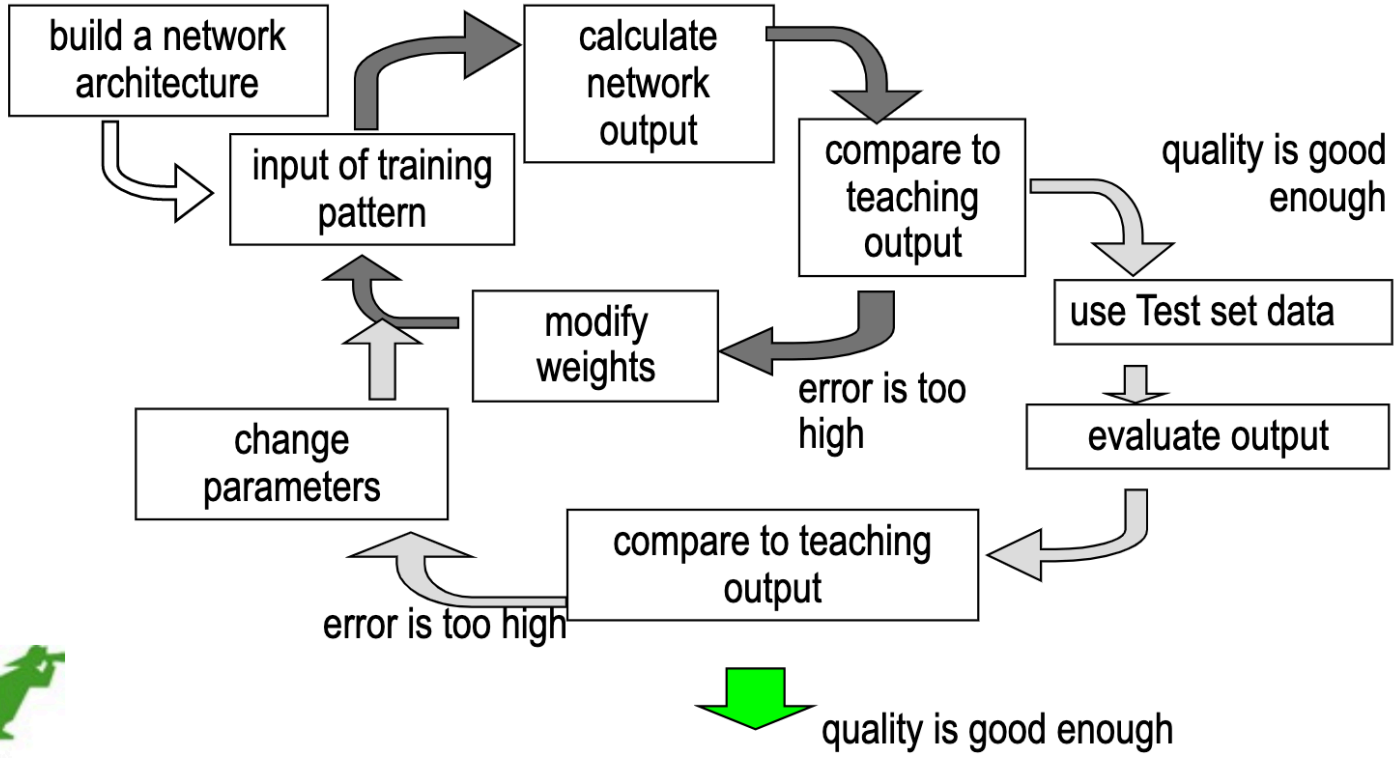
Neural networks



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Our neural network setup

Database

Training (75%) – Test (25%)

- **126 rissaga days**
  Extending heterogeneously from July 1981 to July 2018 (plus one old case from September 1975).

- **549 non-rissaga days**
  Quasi-continuous record from December 2016 to July 2018. After filtering out a dozen of rissaga days happened in period and discarding those days without thermodynamic soundings available.

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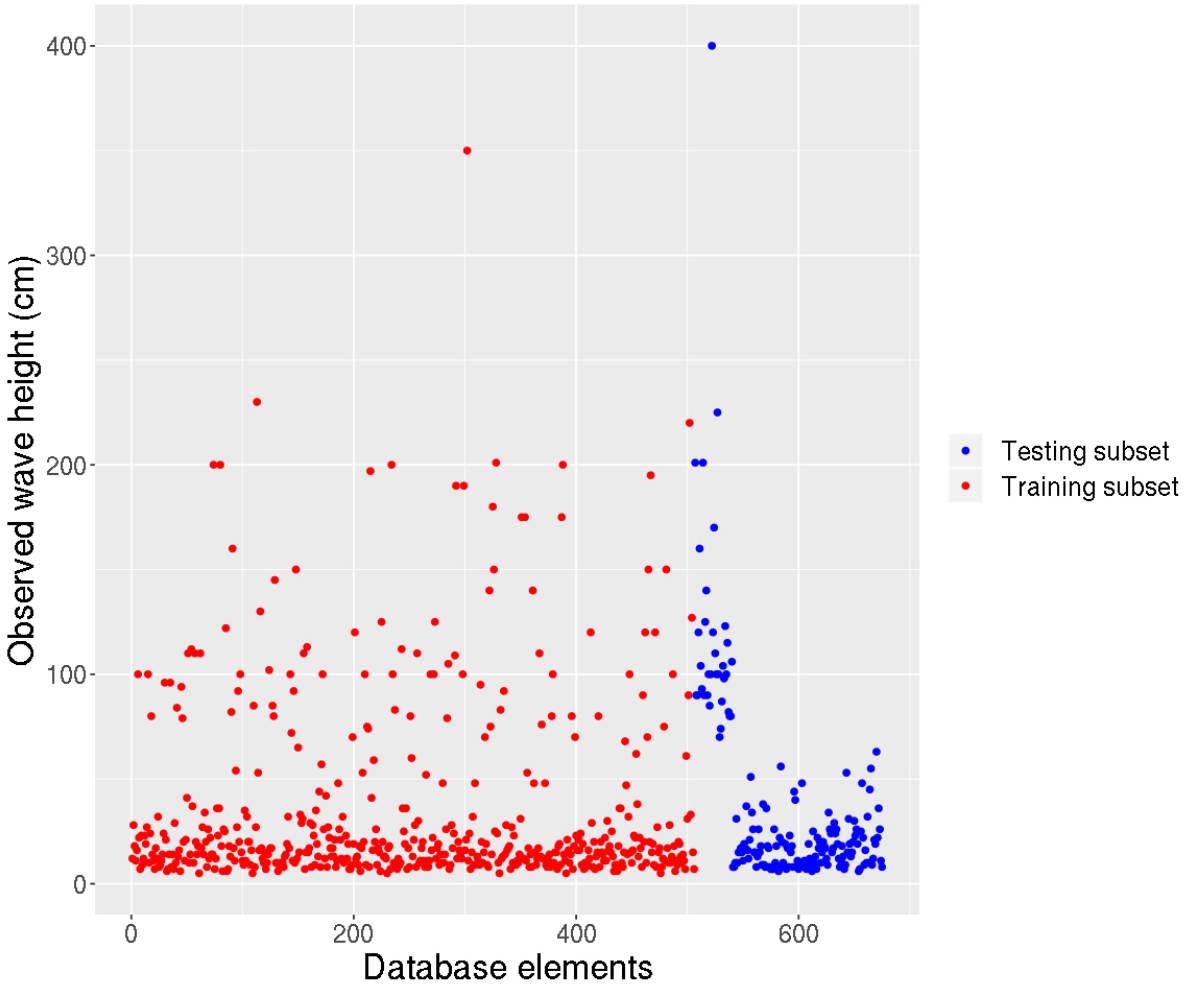
Our neural network setup

Database

Training (75%) – Test (25%)



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Our neural network setup

-  statistics package Neuralnet
- Rprop+, Resilient backpropagation with weight backtracking, is the algorithm used to calculate the NN
- The logistic function is used as activation function - a characteristic S-shaped curve

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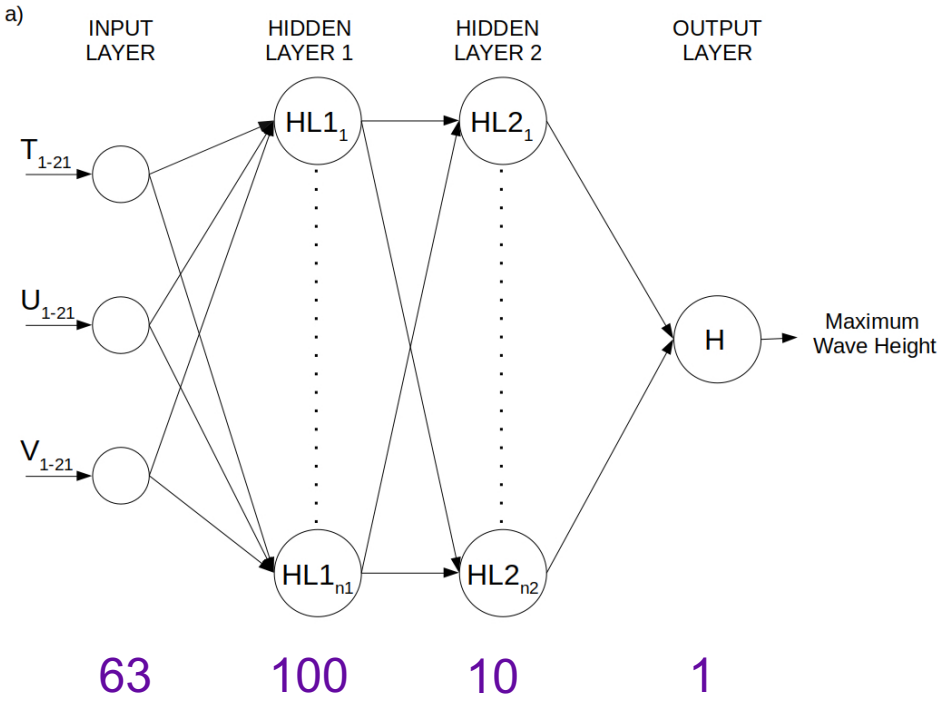
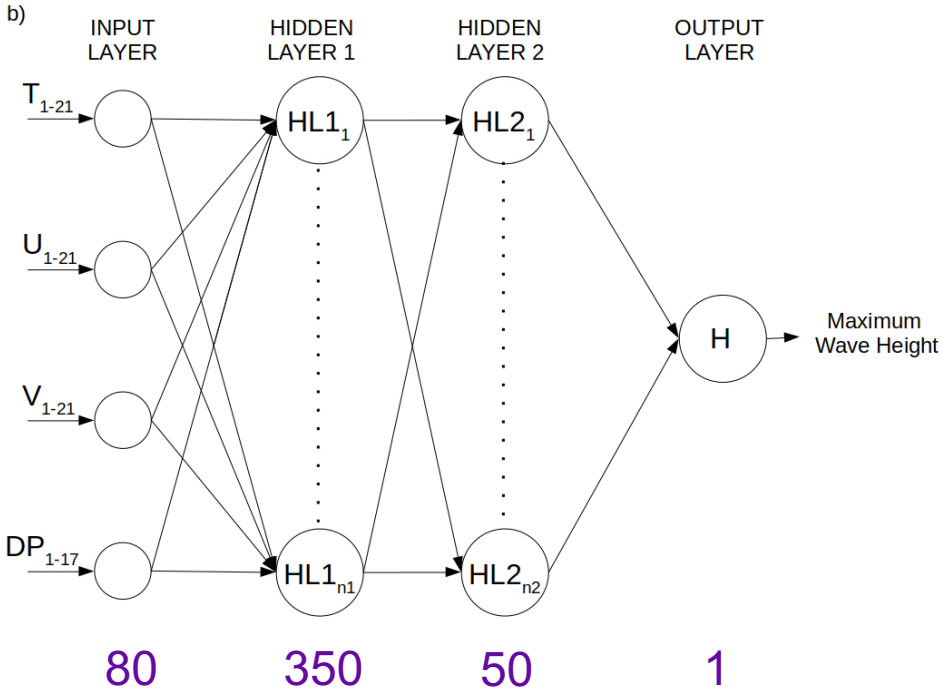
Our neural network setup

Design

Dry NN scheme



Wet NN scheme



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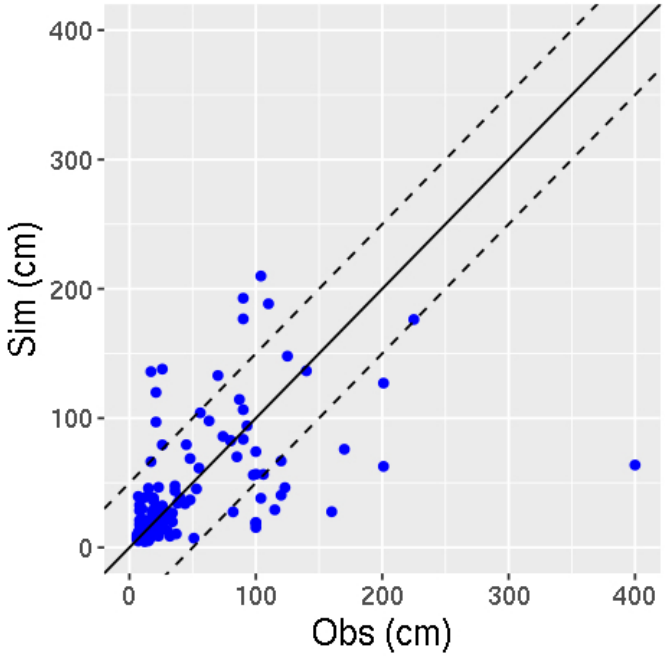
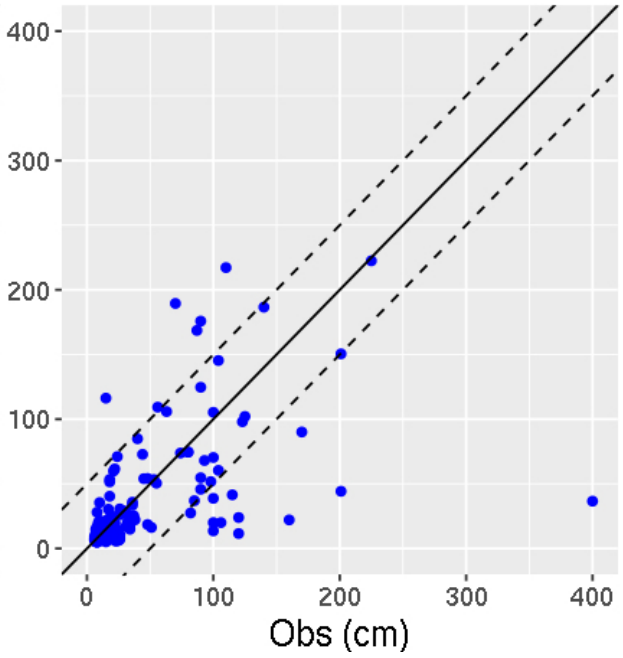
Results

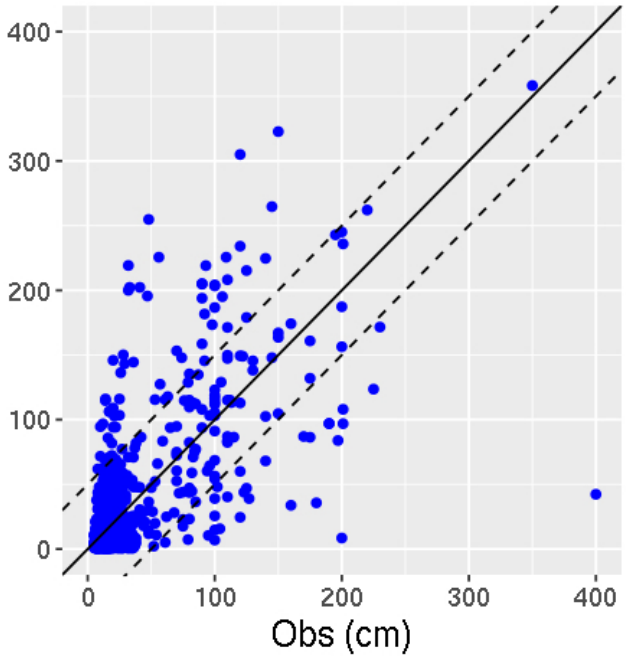
Dry NN



Wet NN



TRAM-rissaga



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Results

Performance statistics

	OBS mean (cm)	SIM mean (cm)	RMSE (cm)	CC
Dry NN	39.2	36.7	44.2	0.307
Wet NN	39.2	33.4	44.3	0.315
TRAM-rissaga	37.0	42.8	45.4	0.431

Database NN
Training (75%) – Test (25%)

Database TRAM-rissaga
Training (0%) – Test (100%)

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Results
Deterministic verification

	Observed		
	Yes	No	Total
Forecast			
Yes	Hit	False alarm	Forecast yes
No	Miss	Correct rejection	Forecast no
Total	Observed yes	Observed no	Total

Scale	Category	Wave height (cm)
Dichotomous	Non-rissaga	< 70
	Rissaga	≥ 70
Expanded	Small oscillations	< 20
	Moderate oscillations	$\in [20, 70)$
	Ordinary rissaga	$\in [70, 100)$
	Intense rissaga	$\in [100, 200)$
	Extreme rissaga	≥ 200

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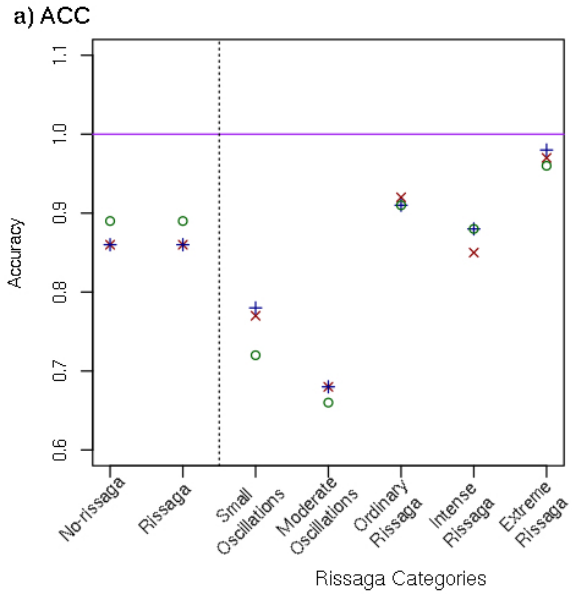
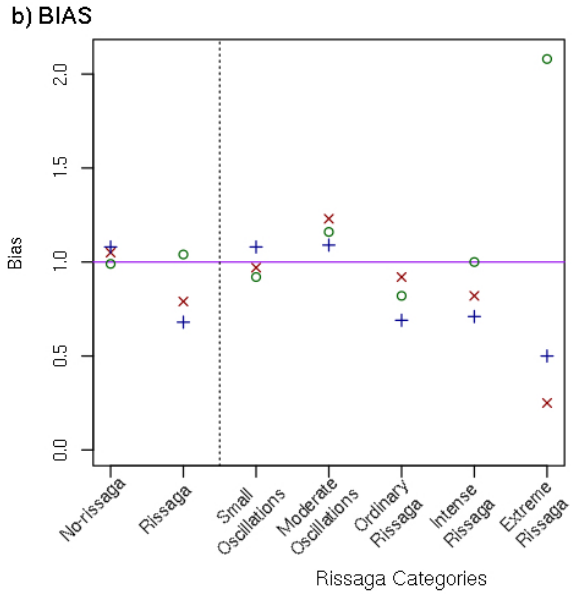
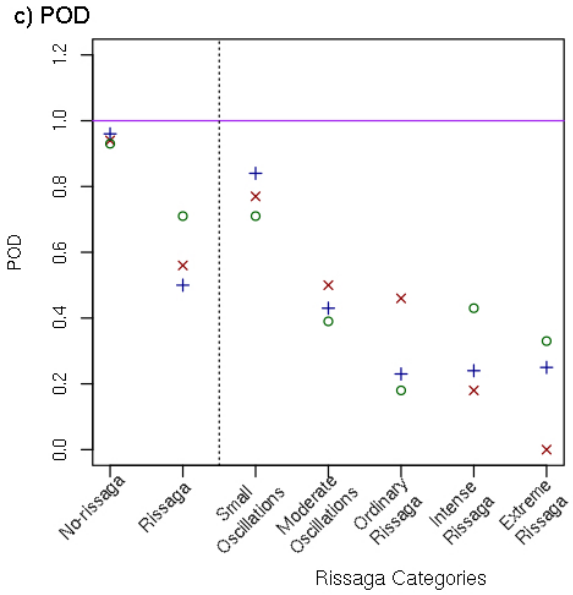
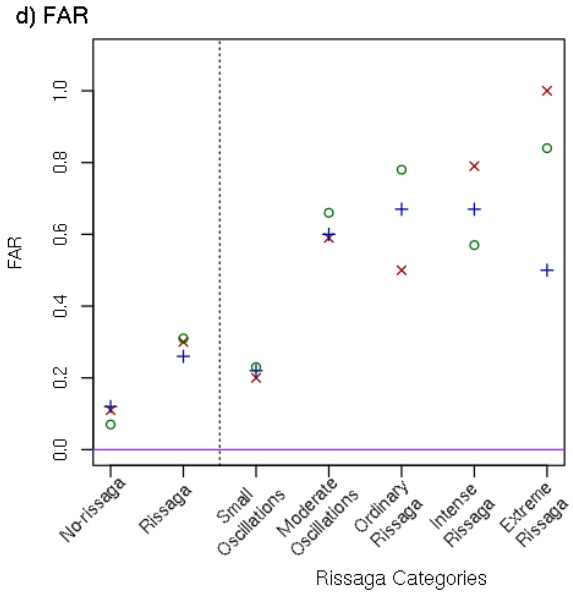
Results

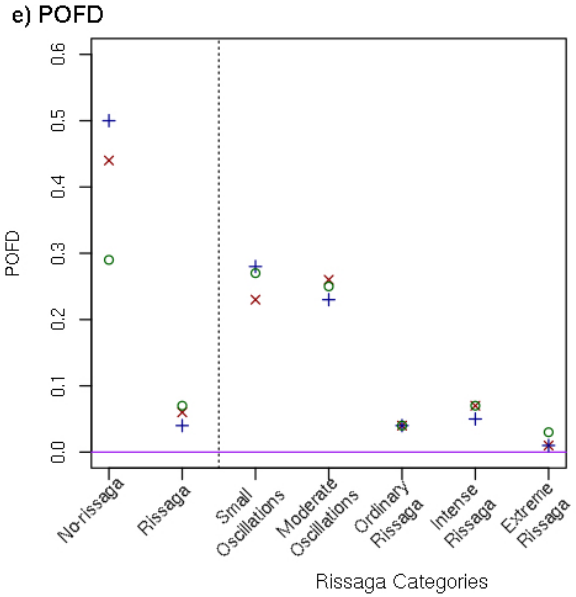
Deterministic verification

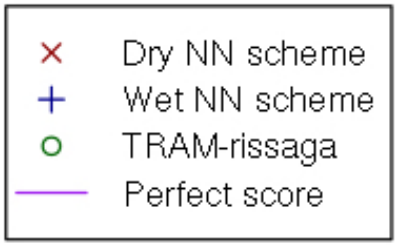












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Conclusions

- The NNs results show a skill **comparable** to that of TRAM-rissaga (coupled ocean-atmosphere simulations) at a **cheaper computational cost**

- The verification results show a limited improvement of the wet scheme over the dry scheme. This fact is tied to the training database limited size

- The results do confirm the potential of a NN approach to implement an operational rissaga NN forecasting system

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MetMed

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Natural Hazards
https://doi.org/10.1007/s11069-020-04041-5

ORIGINAL PAPER

Forecasting meteotsunamis with neural networks: the case of Ciutadella harbour (Balearic Islands)

Maria-del-Mar Vich[1] · Romualdo Romero[1]

Received: 1 December 2019 / Accepted: 29 April 2020

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Our neural network setup

Algorithm type to calculate the neural network (NN)

Rprop+

Resilient backpropagation with weight backtracking

- First order minimizing algorithms - a general method for **gradient based optimization**.
- Particularly used for the optimization the weights of Artificial Neural Networks due to its **faster convergence**.
- Takes into account only the **sign of the partial derivative over all patterns (not the magnitude)** to indicate the direction of the weight update, and acts independently on each "weight".
- Weight backtracking means **retracting a previous weight update** for some or all weights. Whether to take back a step or not is decided by means of a heuristic.

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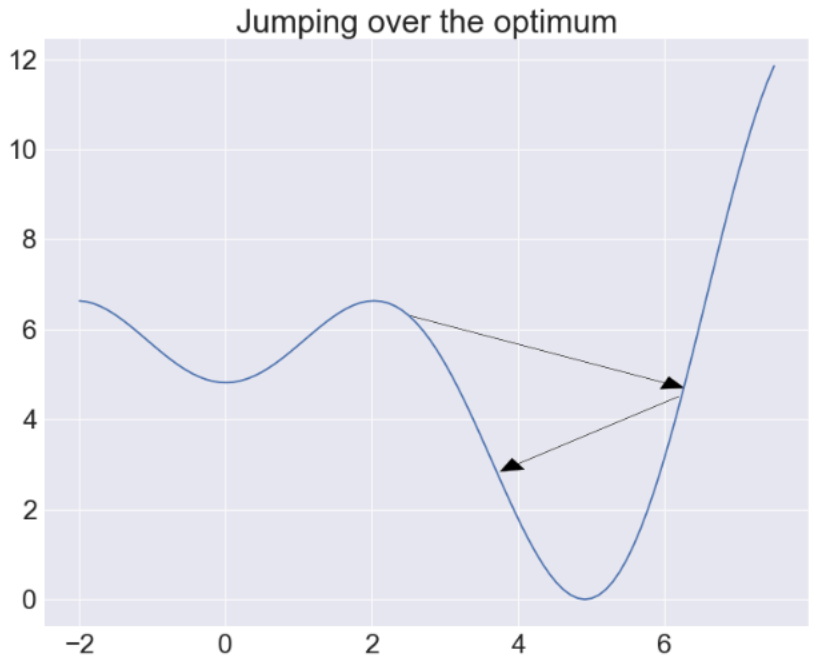

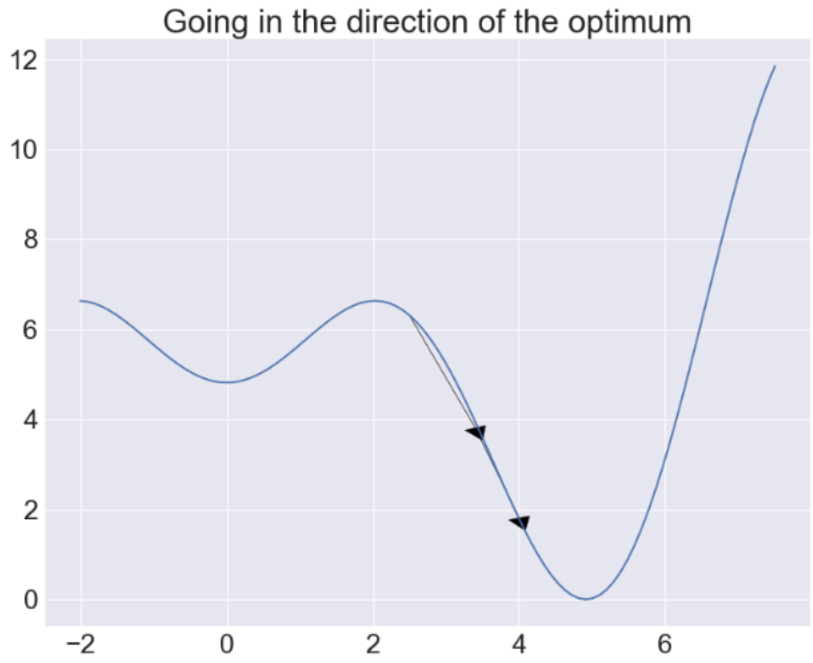

The gradient direction changes when jumping over optima

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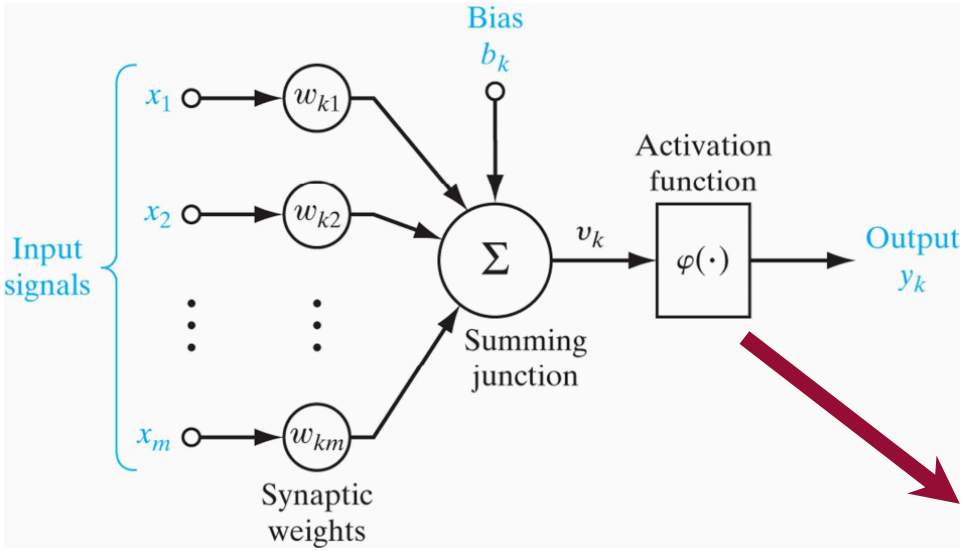
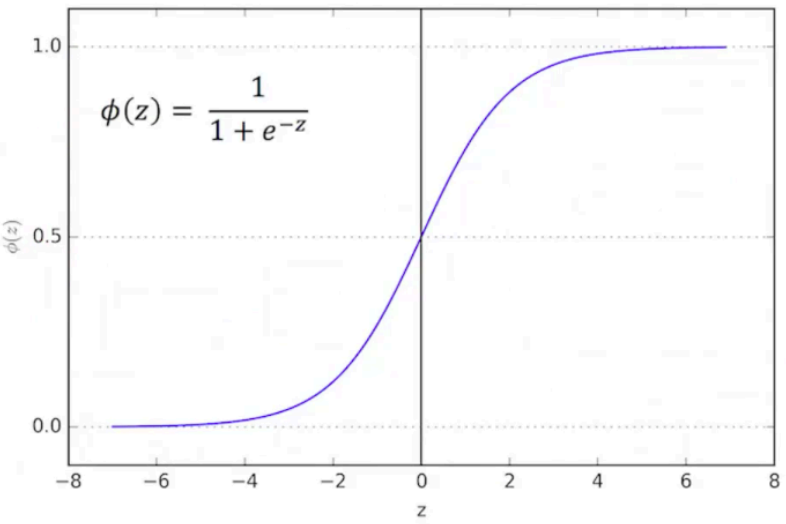
Our neural network setup



Activation function: Logistic function



Activation functions

- Determine the output of a neural network and each individual neuron.
- Help normalize the output of each neuron to a range between 1 and 0 or between -1 and 1.

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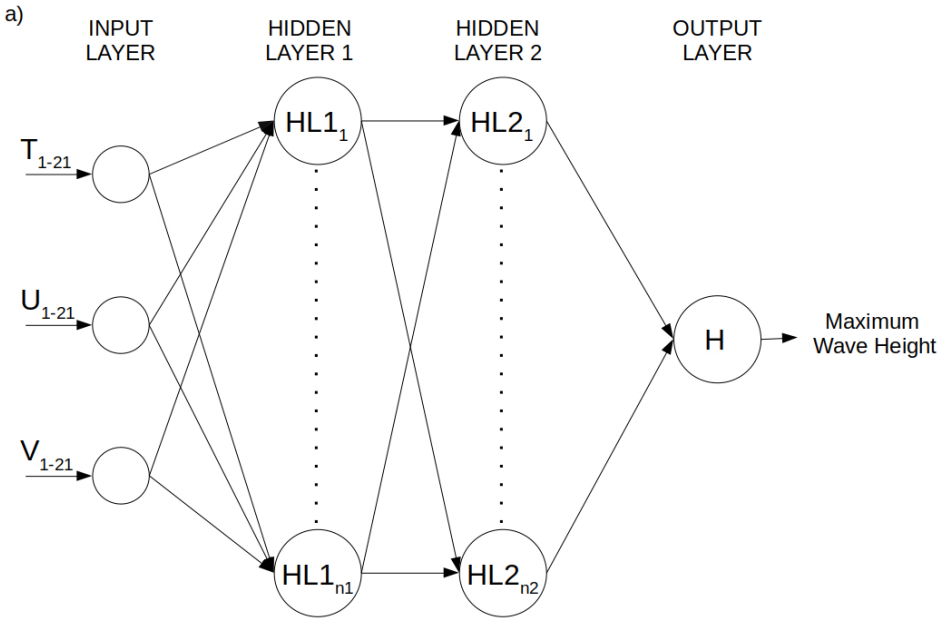
Our neural network setup

Design

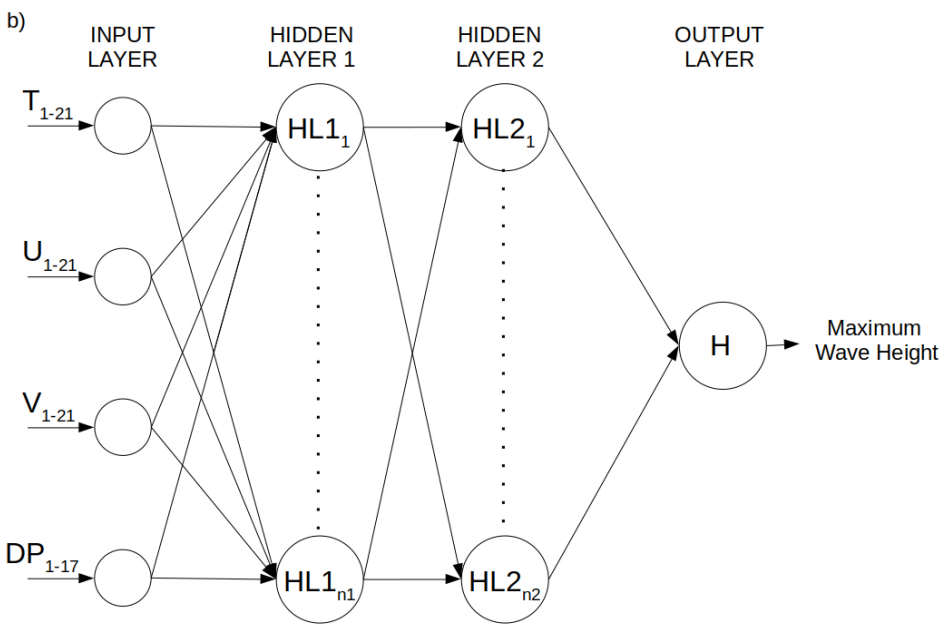
NNs inputs: GFS *soundings*

Dry NN scheme



63 ? ? 1

Wet NN scheme



80 ? ? 1

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Our neural network setup

Design

the best NN configuration