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Oil Spill Detection by means of Neural Network Algorithms: a Sensitivity Analysis

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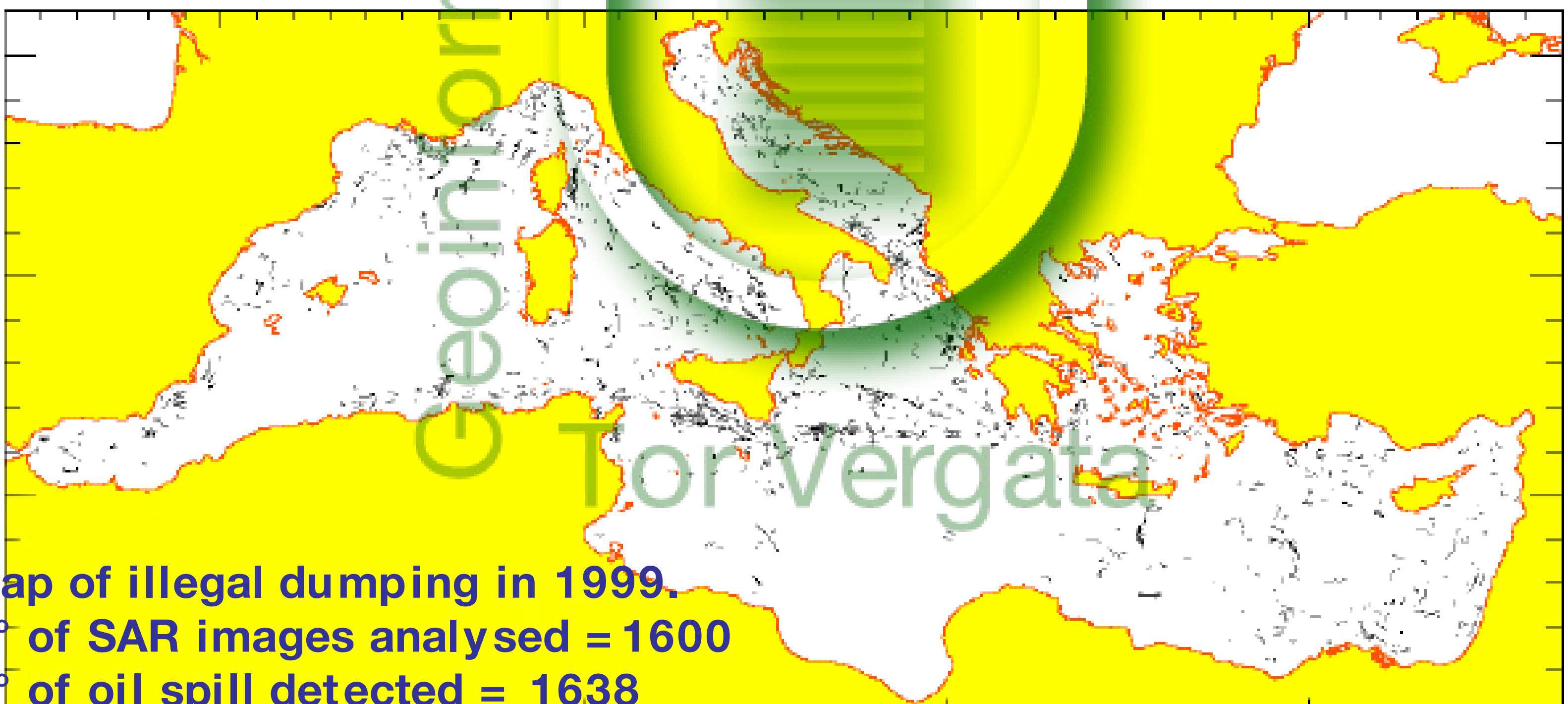
Sea Oil Pollution

Oil spills over the sea surface pollute the marine environment to a varying degree during large oil tanker accidents.

But the total oil pollution worldwide is mainly due to illegal dumping as oil released from ships that clean their tanks.



Map of illegal dumping in 1999.
N° of SAR images analysed = 1600
N° of oil spill detected = 1638

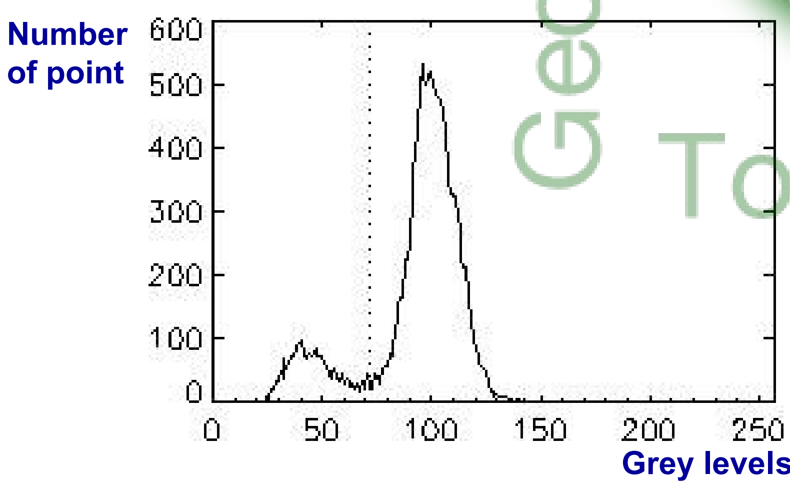
—JRC-Institute for the Protection and Security of the Citizen—

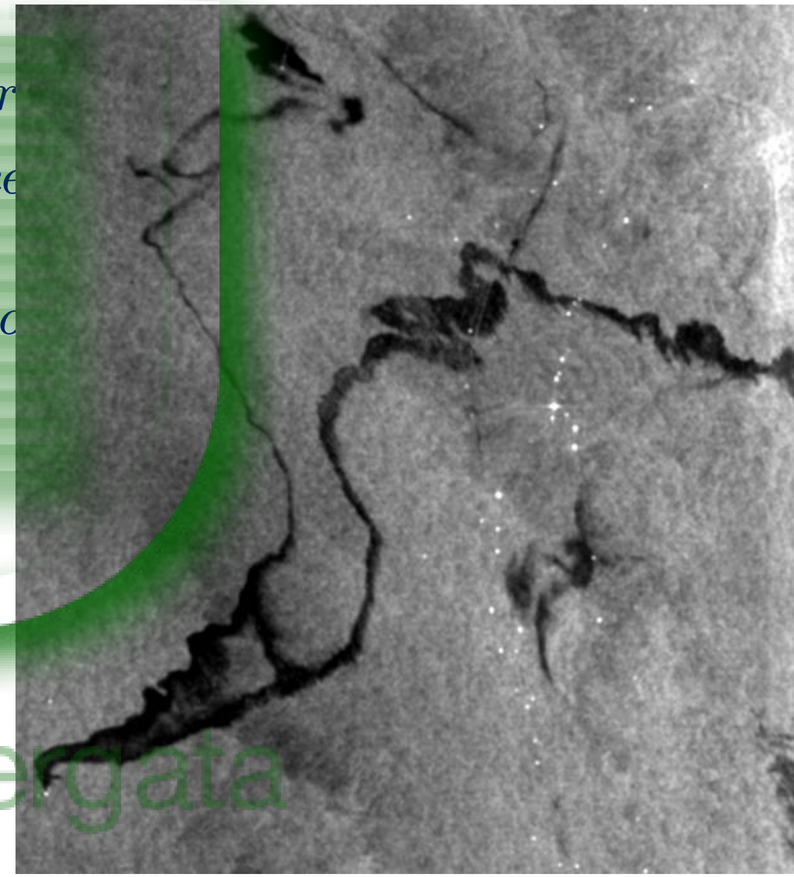
Oil Spill Detection from SAR Images

Radarcrosssectionmainlyduetoshort gravity and gravity‐capillary waves (1÷10^1 cm) accordingtotheBraggscatteringtheor

Thepresenceofanoil filmontheseasurface dampsthesekindsofwavesreducingthe measuredbackscatteringenergy (Marango theory).

Pixel histogram of the polluted region:





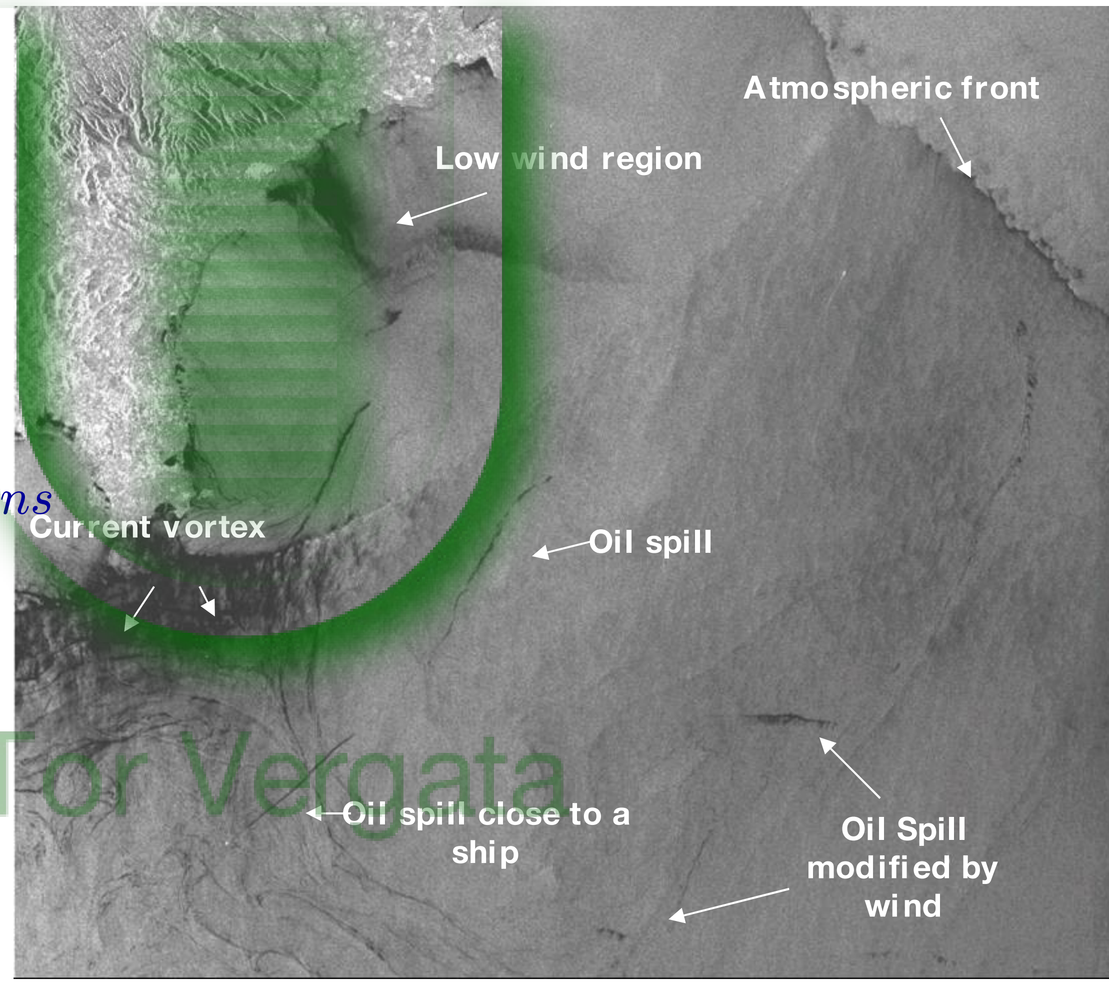
Oil Spill Detection from SAR Images

However careful image analysis is required because dark areas might also be caused by natural phenomena.

- natural sea slicks
- particular atmospheric conditions
- locally low winds

These phenomena are called.

"*look alikes*"



Classification by means of Neural Networks

Neural Networks have already demonstrated their effectiveness in discriminating between "real" oil spills and "look-alikes"

It is necessary to extract some salient features which characterize the selected dark spot "slicks" and that will be included in the neural network input vector.

The features can be of three different types

- Containing information on the backscattering intensity in dB-gradient along the border of the dark spot.
- Containing information on the backscattering intensity values in the dark spot and/or in the background.
- Containing information on the geometry and the shape of the dark spot.

The Local Wind Speed

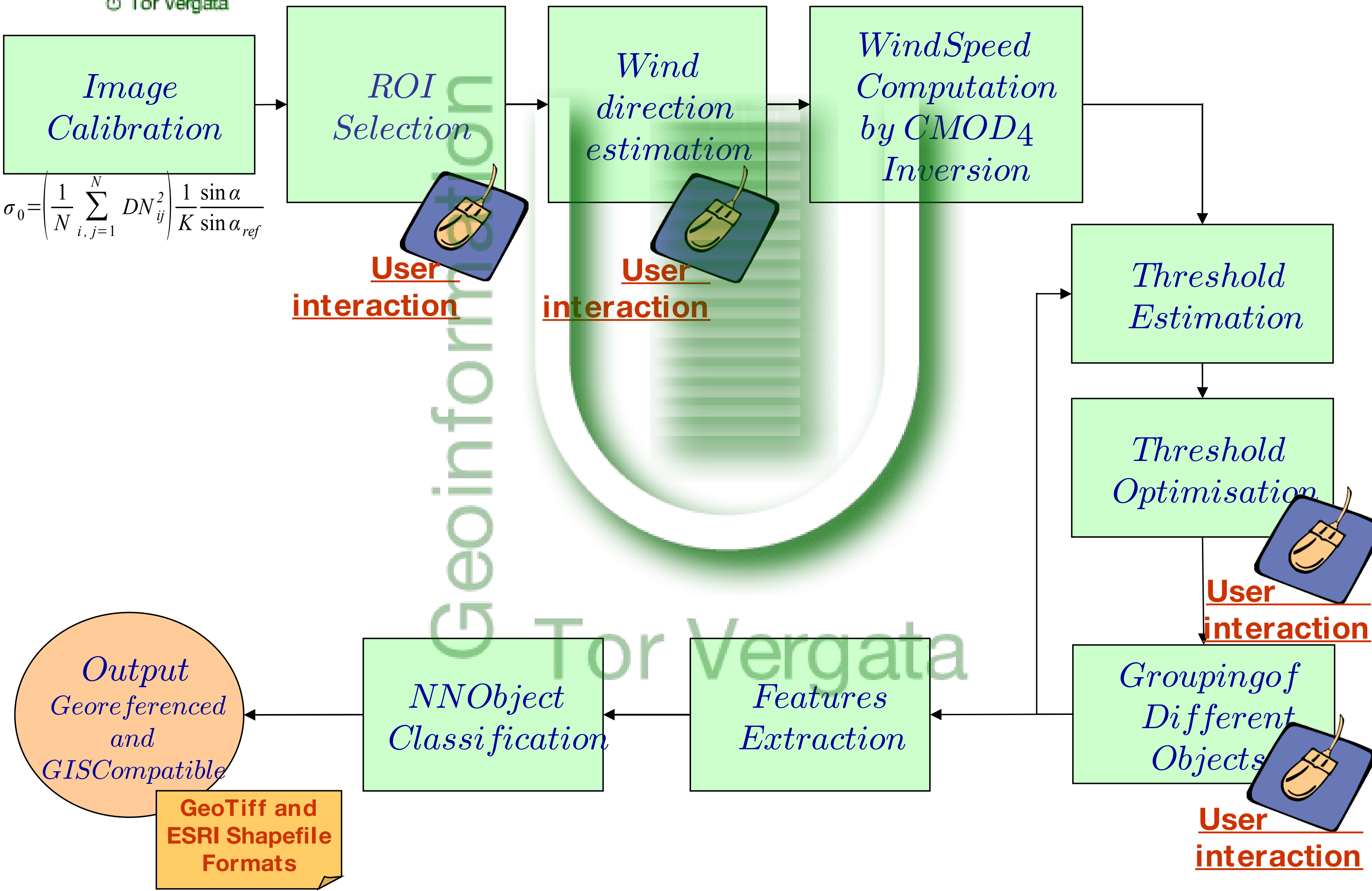
In this work we considered an additional feature containing information on the <u>local wind speed</u> (WS).

The wind speed is the responsible of the short gravity and of the gravity-capillary waves, so it can strongly influence the appearance of the oil slicks in the SAR images.

- *Wind Speed calculated by inverting the CMOD4 model*

• <u>**WS < 2-3 m/s**</u>	→	**presence of dark areas due only to the lack of wind**
• <u>**7-8 m/s < WS < 15 m/s**</u>	→	**natural slicks are dispersed whereas oil slicks remain still connected**
• <u>**WS > 15 m/s**</u>	→	**possibly emulsion between water and oil → oil slick invisible to the SAR**

Oil Spill Detection Algorithm



$$\sigma_0 = \left(\frac{1}{N} \sum_{i,j=1}^{N} DN_{ij}^2 \right) \frac{1}{K} \frac{\sin \alpha}{\sin \alpha_{ref}}$$

Oil Spill Detection Algorithm

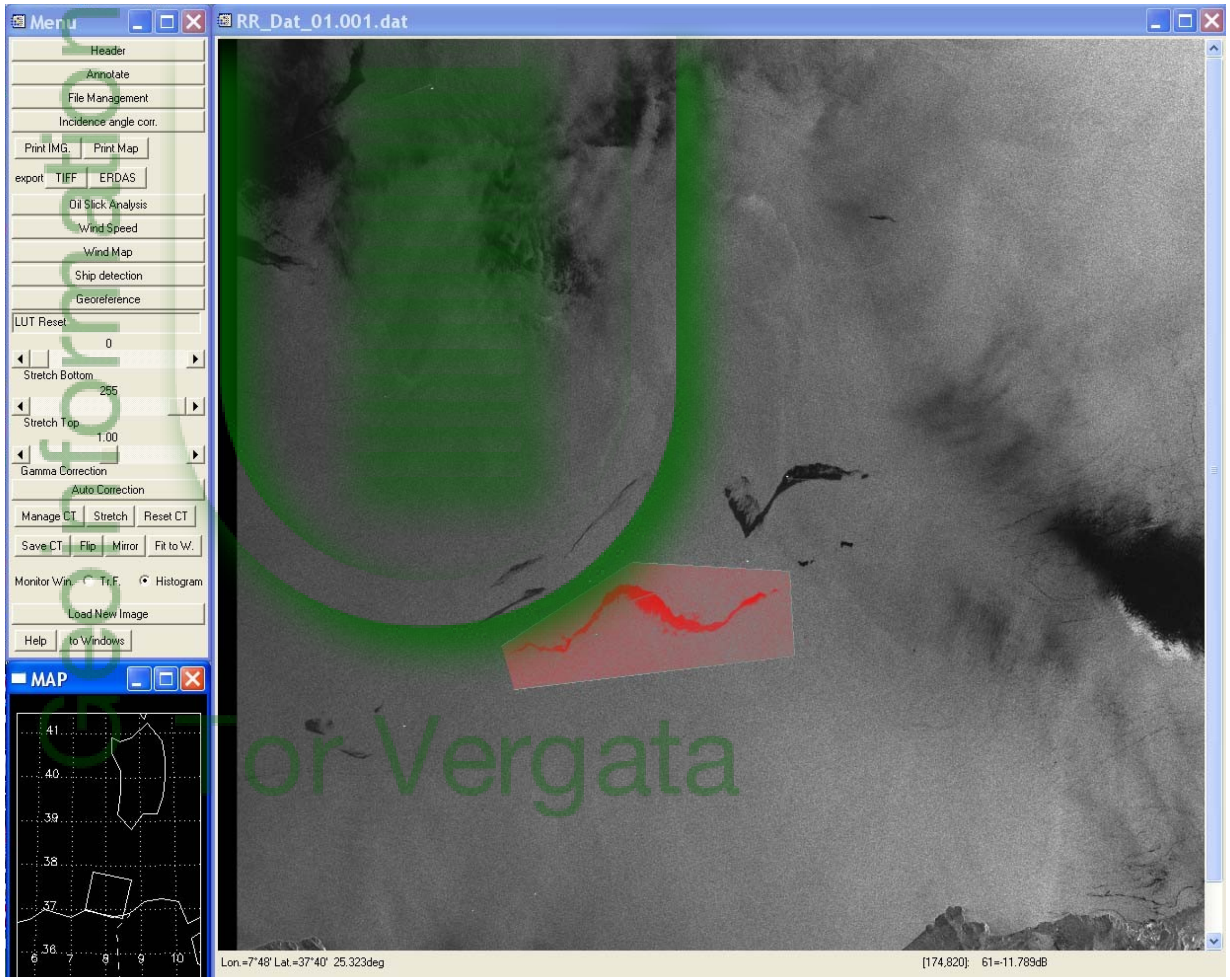
ROI Selection and Slick Extraction

↓

Wind Speed

↓

Features Extraction and NN Slick Classification



Oil Spill Detection Algorithm

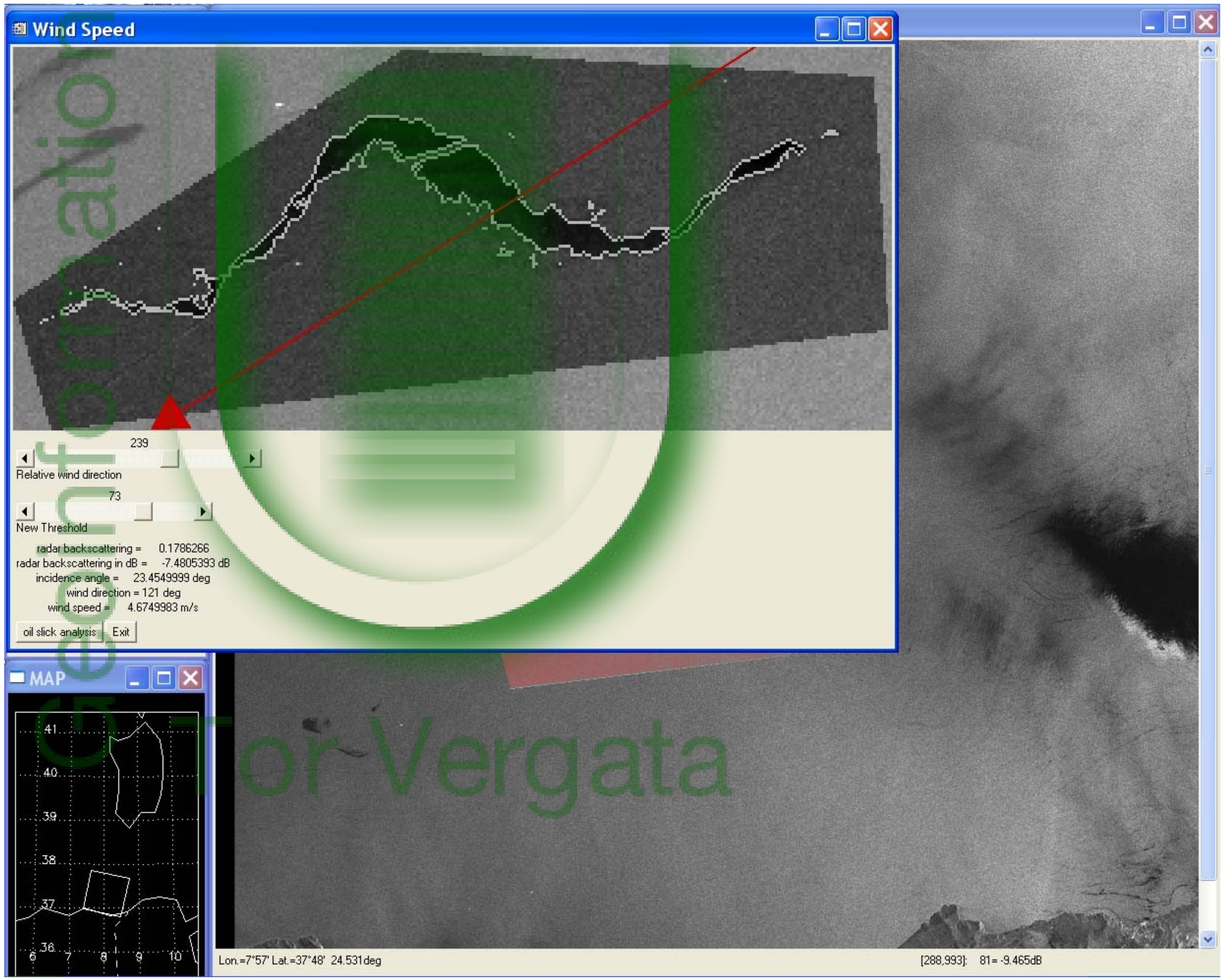
ROI Selection and Slick Extraction

↓

Wind Speed

↓

Features Extraction and NN Slick Classification



Oil Spill Detection Algorithm

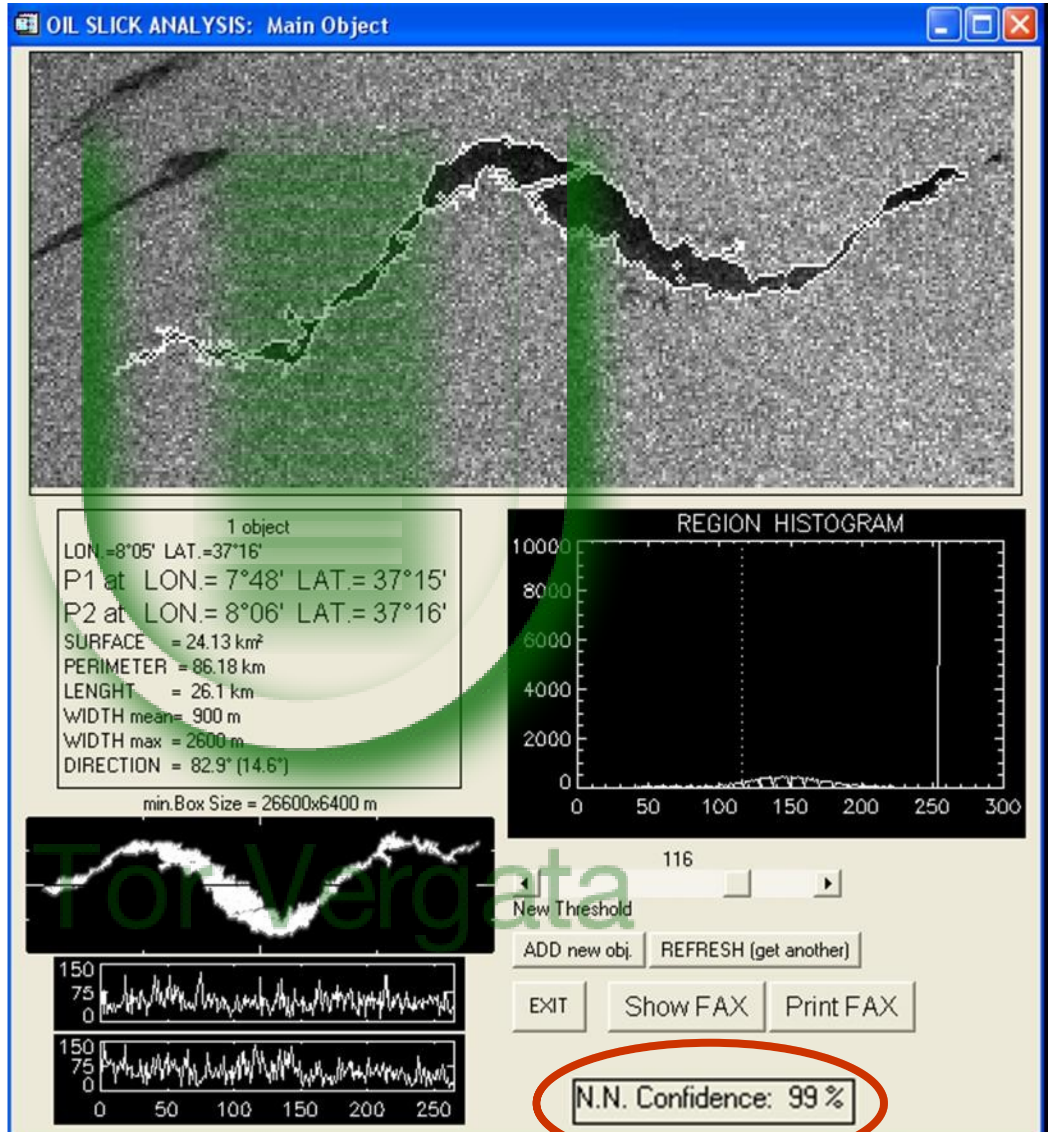
ROI Selection and Slick Extraction

↓

Wind Speed

↓

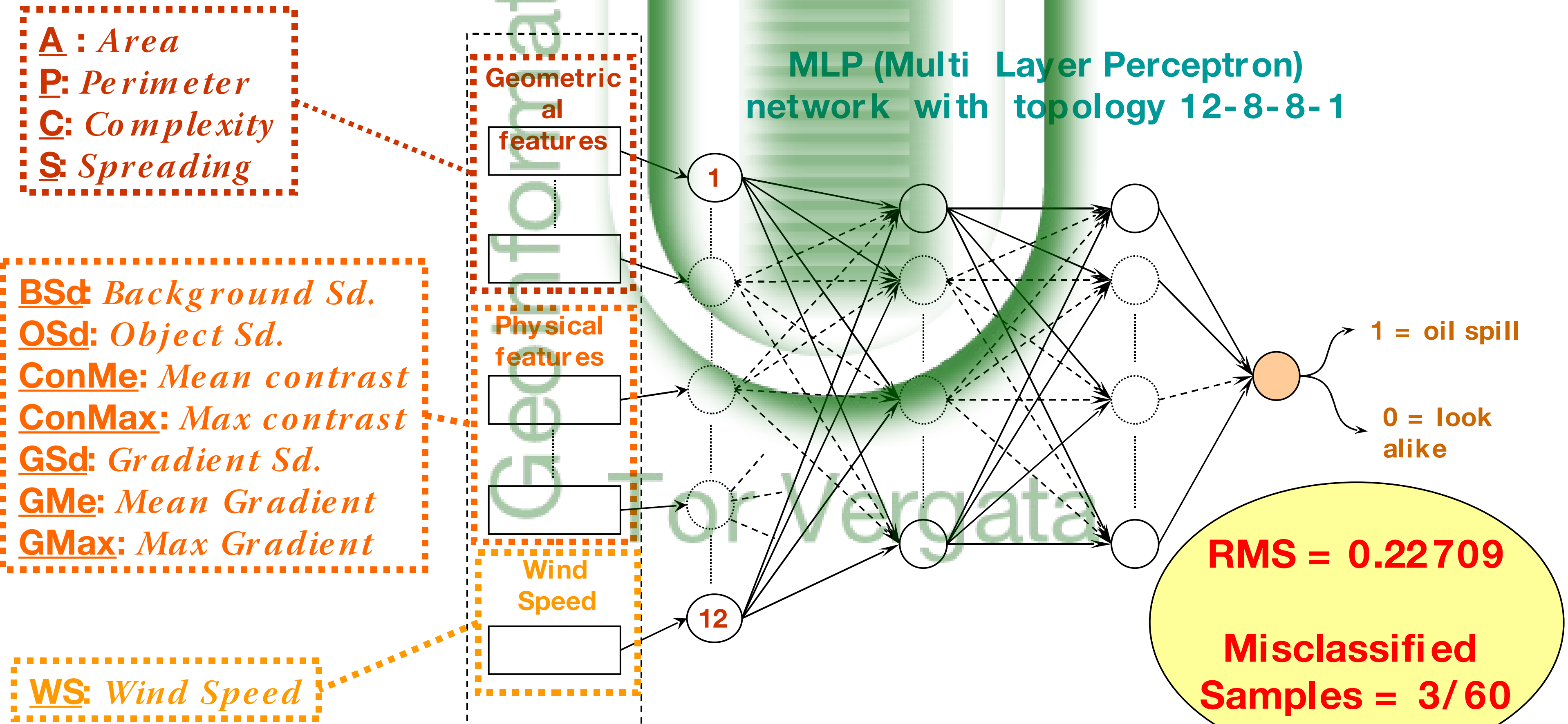
Features Extraction and NN Slick Classification



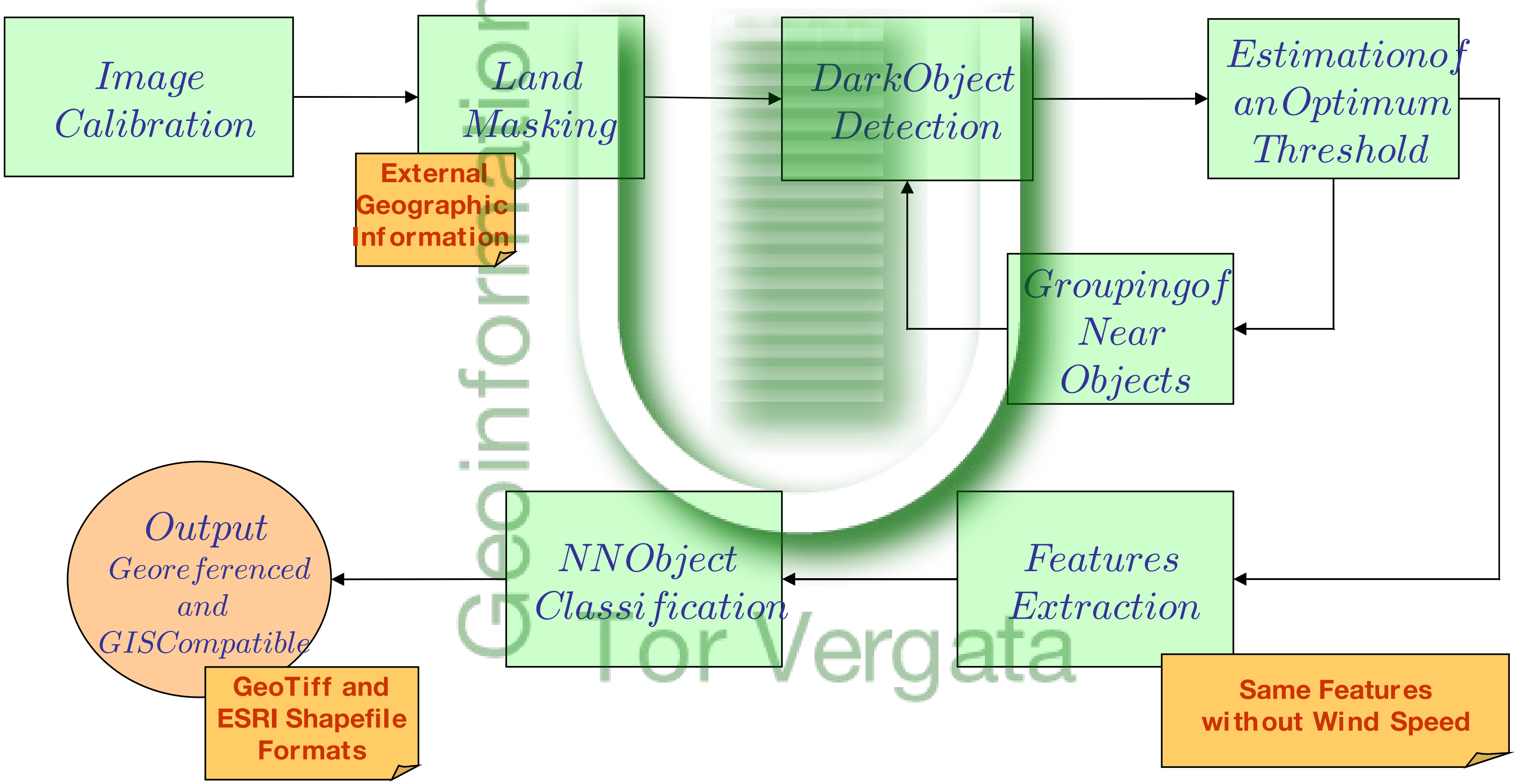
Neural Network response

The Training of the Neural Network

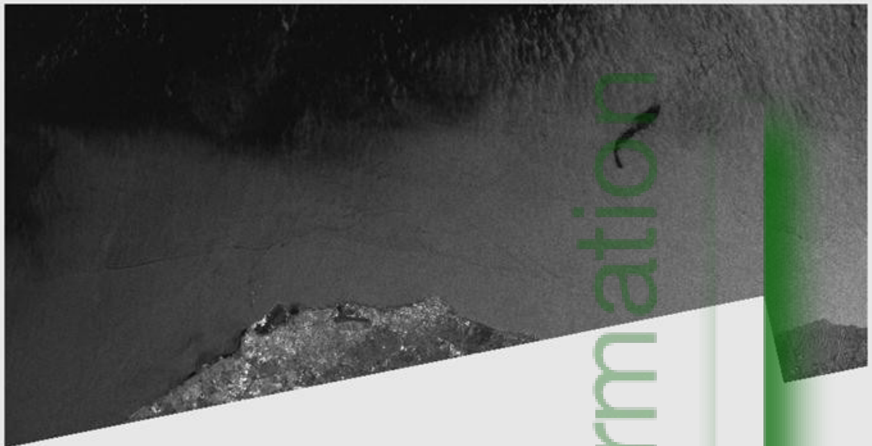
Starting from an archive of about 70 ERS-SAR images mainly taken over the Mediterranean basin in the time period between 1996 and 2003 we extracted 189 dark objects (111 oil spills and 78 look-alikes).



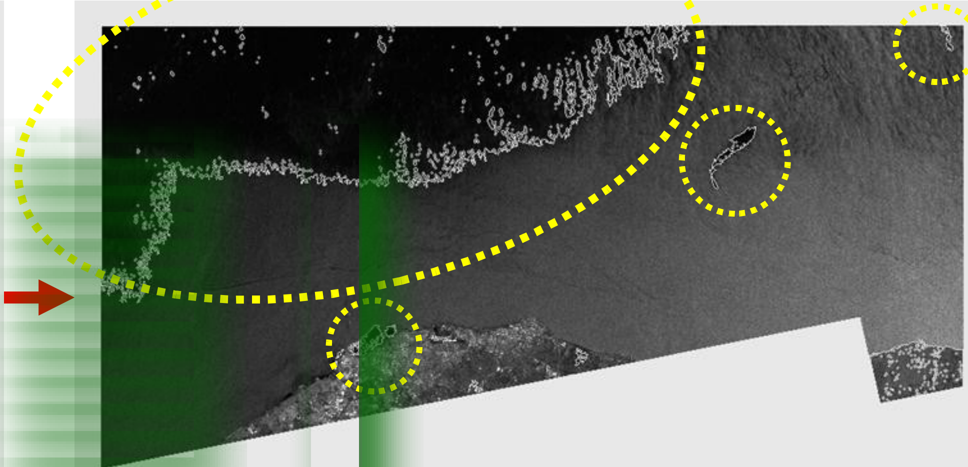
TowardAutomaticOilSpillDetection



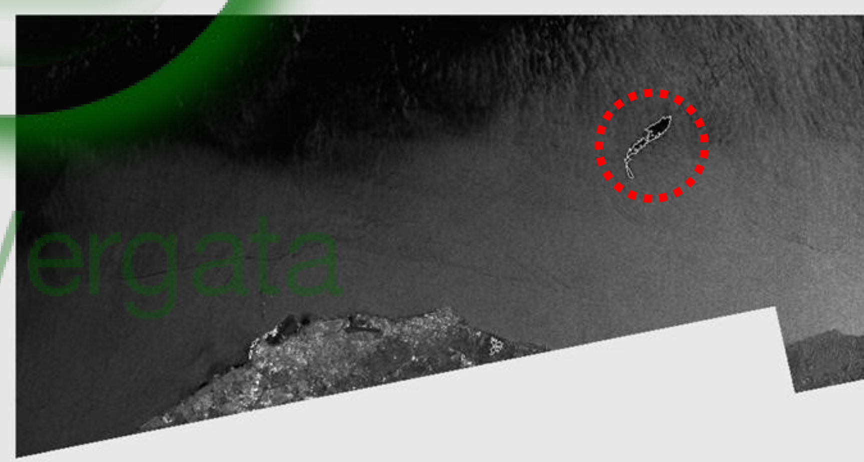
Automatic Oil Spill Detection



a ← SAR Image



b ← Detection of Dark Objects



c ← Identification of the Oil Spills

The Sensitivity Analysis

- *Importanceofcorrectlymanagingtheedgedetectionutilities*▷
  ↼*Correctthresholdestimation*↽

- *In a* <u>*fullyautomatictool*</u>*it is reasonabletosupposethattheS/N ratioma*
  significantlydecrease▷*Butlossof accuracy acceptable consideringth*
  importanceofanautomaticalgorithmwhichcanworkautonomouslyan
  continuously

- *A selectionofthe mostimportantinputsmighteliminateunnecessaryo*
  misleadinginputs▷

→ **<u>Sensitivity Analysis</u>** ↼*weconsideredtwomethods*↽.

The Sensitivity Analysis – *First Methodology*

Network performance in terms of rmse and of misclassification rate, removing, in turn, one of the input

		RMS	Misclassified samples over a total of 60 samples	Δ% (RMS)	Δ% (misclassification rate)
All 12 inputs		0.22709	3		
11 inputs without:	A	0.23987	3.9	+ 5.62 %	+ 30%
	P	0.22894	3.2	+ 0.81 %	+ 6.666%
	C	0.23574	3.4	+ 3.81	+ 13.33 %
	S	0.23642	3.1	+ 4.1%	+ 3.33 %
	Osd	0.24055	4	+ 5.92 %	+ 33.33 %
	BSd	0.39811	13	+ 75.31 %	+ 433.33 %
	ConMax	0.23416	3.5	+ 3.11 %	+ 16.66 %
	ConMe	0.23327	3.5	+ 2.72 %	+ 16.66 %
	GMax	0.23112	3.8	+ 1.77 %	+ 26.66 %
	GMe	0.22906	3.1	+ 0.87 %	+ 3.33 %
	GSd	0.24406	4	+ 7.47 %	+ 33.33 %
	WS	0.22765	3.8	+ 0.24 %	+ 26.66 %

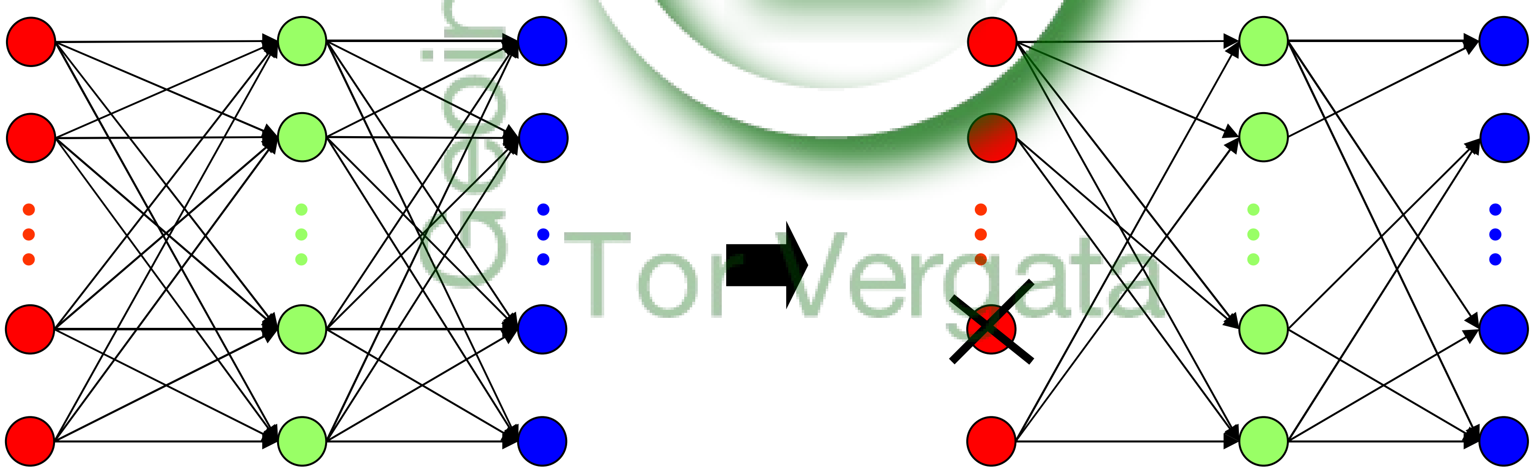
- Decrease of the of the classification accuracy
- => Ability of the NNs to constructively use the different pieces of information.
- In most cases, the worsening does not exceed the value of 10% in terms of rmse.
- Most significant exception is represented BSd.
- In general physical features seem to be more significant then

The Extended Pruning Procedure

1 ← *Evaluation of the relative importance of connections*

2 ← *Removal of the weakest connection*

3 ← *The procedure is prolonged to the input layer until 11 of the 12 initial inputs are removed*



The Sensitivity Analysis – Second Methodology

The results are in good agreement with the first analysis.

Pruning Procedure: Order of Removal	
1	BSd, GSd, OSd, WS
2	ConMax, ConMe, P, A
3	C, S, GMax, GMe

- *BSd feature is the last one to be removed during the input units elimination process*▷
- *Also the information content brought in by wind speed is important*▷

In agreement with the fact that the general conditions of the sea surface surrounding the slicks affects the actual capability of the SAR to detect the slicks▷

Conclusions and Future Developments

•A new algorithm for the oil spill detection which consider also the wind speed information has been realized.

•The neural network created has been able to correctly discriminate over a set of independent examples between oil spills and look-alikes with a largely acceptable rate of success

•The possibility of making the oil spill detection completely automatic has also been explored, producing a prototypal system, and is still matter of study.

•A new technique of sensitivity analysis, based on an extended pruning procedur has been carried out together whit a more "classical" one.
Both the analysis pointed out that, in general, the information content of physic parameters seems to be larger than the one of geometrical and shape parameters.

•The designed procedure can process both ERS and ENVISAT imagery, but they can be easily adapted to other formats.