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Validating a ship detector based on the notch filter with RADARSAT-2 Fine quad-pol data

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(3) eOsphere, Newbury, UK

(presented by Stefan V. Baumgartner[(2)])

DLR

eOsphere

Motivations

The past:

- We developed a ship (**maritime features**) detector using SAR polarimetry (**dual or quad**), called the Notch Filter [1]
- The **theoretical performance** of the detector was tested with simulations [2]

The present:

- Here, we would like to provide a more exhaustive real data validation

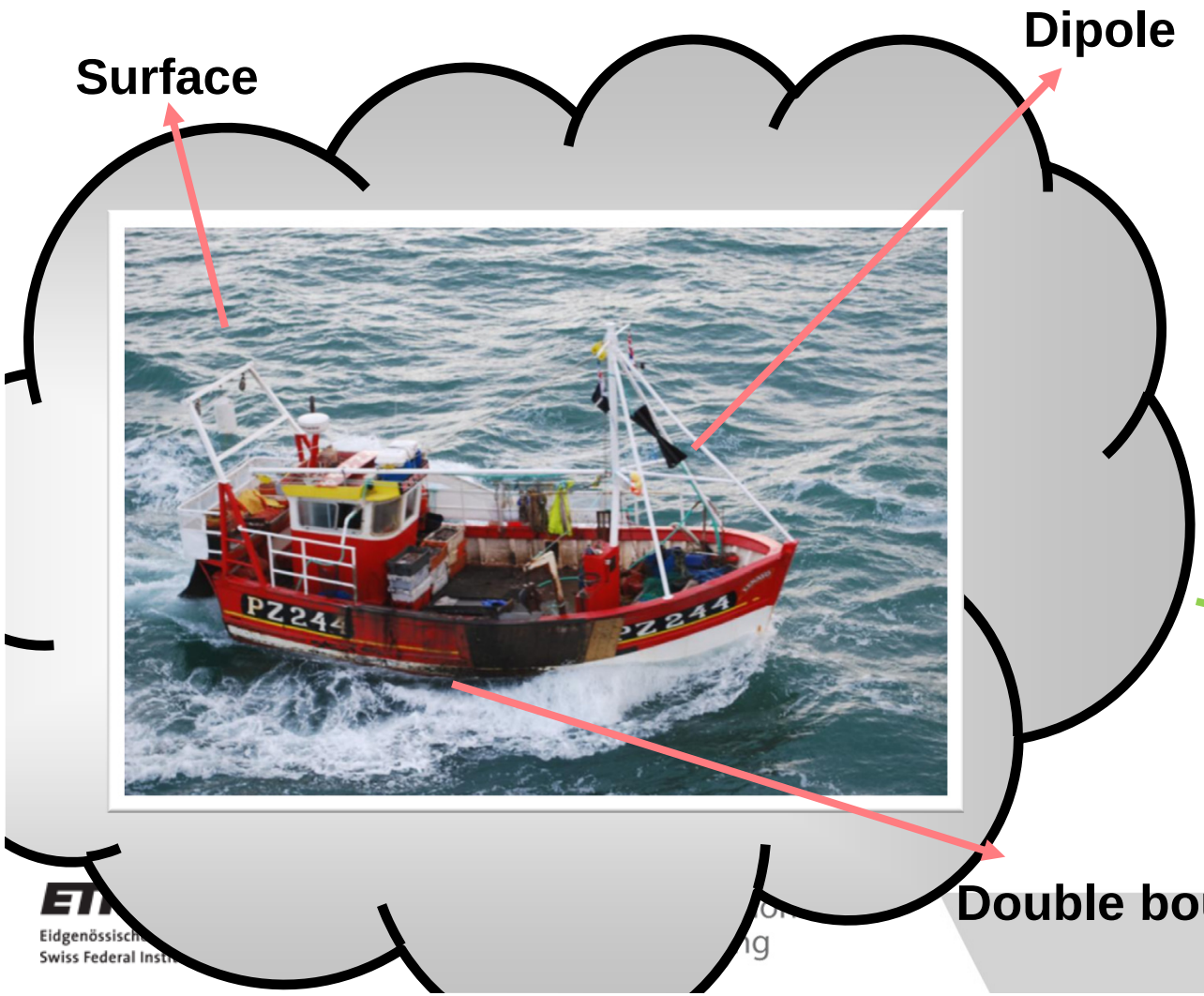
[1] Armando Marino, Nick Walker & Iain H. Woodhouse (2010), Ship Detection using SAR Polarimetry. The Development of a New Algorithm Designed to Exploit New Satellite SAR Capabilities for Maritime Surveillance, *Proceedings on SEASAR'10, Frascati, Italy, January 2010.*

[2] Armando Marino & Nick Walker (2011), Ship Detection in Variable Sea States and Depolarised Sea Clutter: a Polarimetric Notch Filter, *Proceedings on POLinSAR'11, Frascati, Italy, 24th-28th January 2011*

Polarimetric Detector

Radar Polarimetric Observations

Polarisation: Scatterers have different polarisation behaviour



Single Targets

Most real targets are composed by **several** scatterers (over more pixels):

Partial Targets

Partial vs single targets

Scattering matrix:

$$[S]=\begin{pmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{pmatrix}$$

Scattering mechanism:

$$\underline{\omega}=\underline{k}/|\underline{k}|$$

Scattering vector:

$$\underline{k}=\frac{1}{2}Trace([S]\Psi)=[k_1,k_2,k_3,k_4]^T$$

Backscattering & reciprocity

$$\underline{k}=\frac{1}{2}Trace([S]\Psi)=[k_1,k_2,k_3]^T$$

The second order statistics are necessary.

$$[C_3]=\langle \underline{k}\ \underline{k}^+ \rangle$$

Covariance matrix:

$$[C_3]=\begin{bmatrix} \langle |k_1|^2 \rangle & \langle k_1 k_2^* \rangle & \langle k_1 k_3^* \rangle \\ \langle k_2 k_1^* \rangle & \langle |k_2|^2 \rangle & \langle k_2 k_3^* \rangle \\ \langle k_3 k_1^* \rangle & \langle k_3 k_2^* \rangle & \langle |k_3|^2 \rangle \end{bmatrix}$$

Notch Filter

The algorithm is based on the Partial Target Detector however here, it is reversed and focused on the complementary space.

The **sea** is the **clutter** and the **rest** is **target of interest**

In this way we detect everything is not sea: **ship, iceberg, oil spills** etc.

$$P_{Sea} = \left| \underline{t}^{*T} \cdot \hat{\underline{t}}_{Sea} \right|^2$$

$$\gamma_n = \frac{1}{\sqrt{1 + RedR \dfrac{P_{Sea}}{P_{tot} - P_{Sea}}}}$$

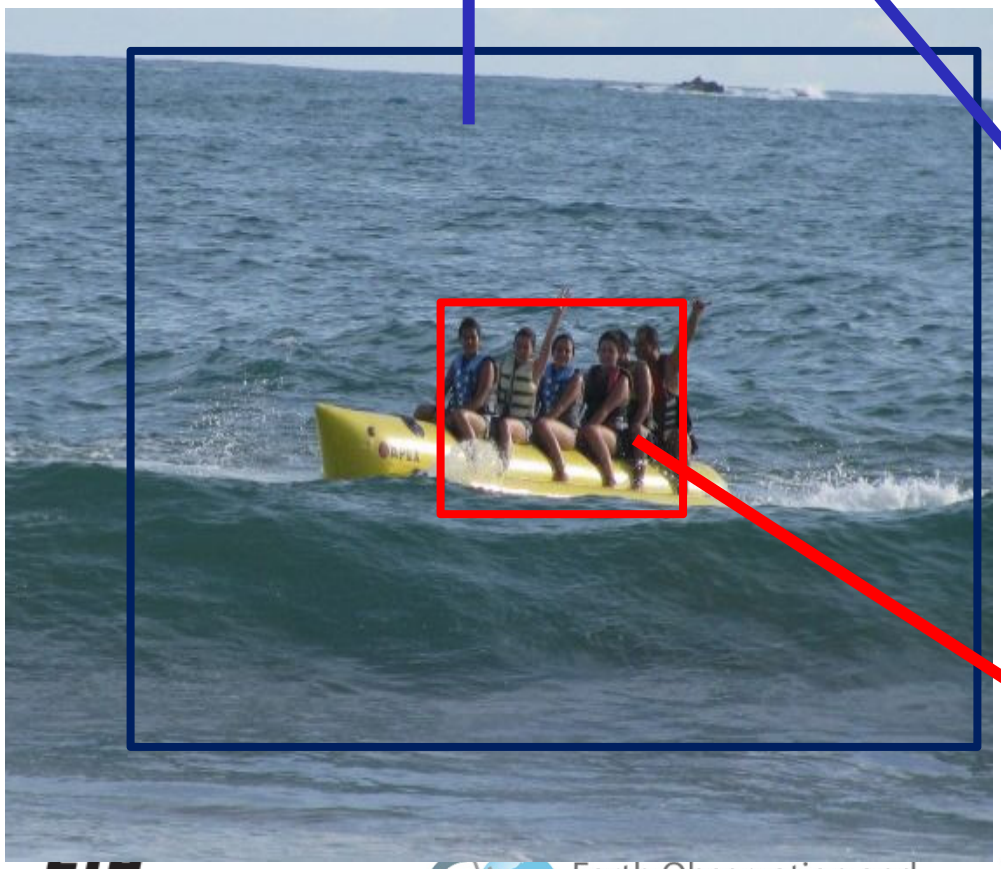
$$P_{tot} = \left| \underline{t}^{*T} \cdot \underline{t} \right|^2$$

Partial scattering vector:

$$\underline{t} = \left[\underline{\omega}_1^{*T}[C]\underline{\omega}_1, \underline{\omega}_2^{*T}[C]\underline{\omega}_2, \underline{\omega}_3^{*T}[C]\underline{\omega}_3, \underline{\omega}_1^{*T}[C]\underline{\omega}_2, \underline{\omega}_1^{*T}[C]\underline{\omega}_3, \underline{\omega}_2^{*T}[C]\underline{\omega}_3 \right]^T$$

$$\hat{\underline{t}}_{sea} = \frac{\underline{t}_{sea}}{\left\| \underline{t}_{sea} \right\|} : \text{target to reject (Null)}$$

Adaptive Notch Filter

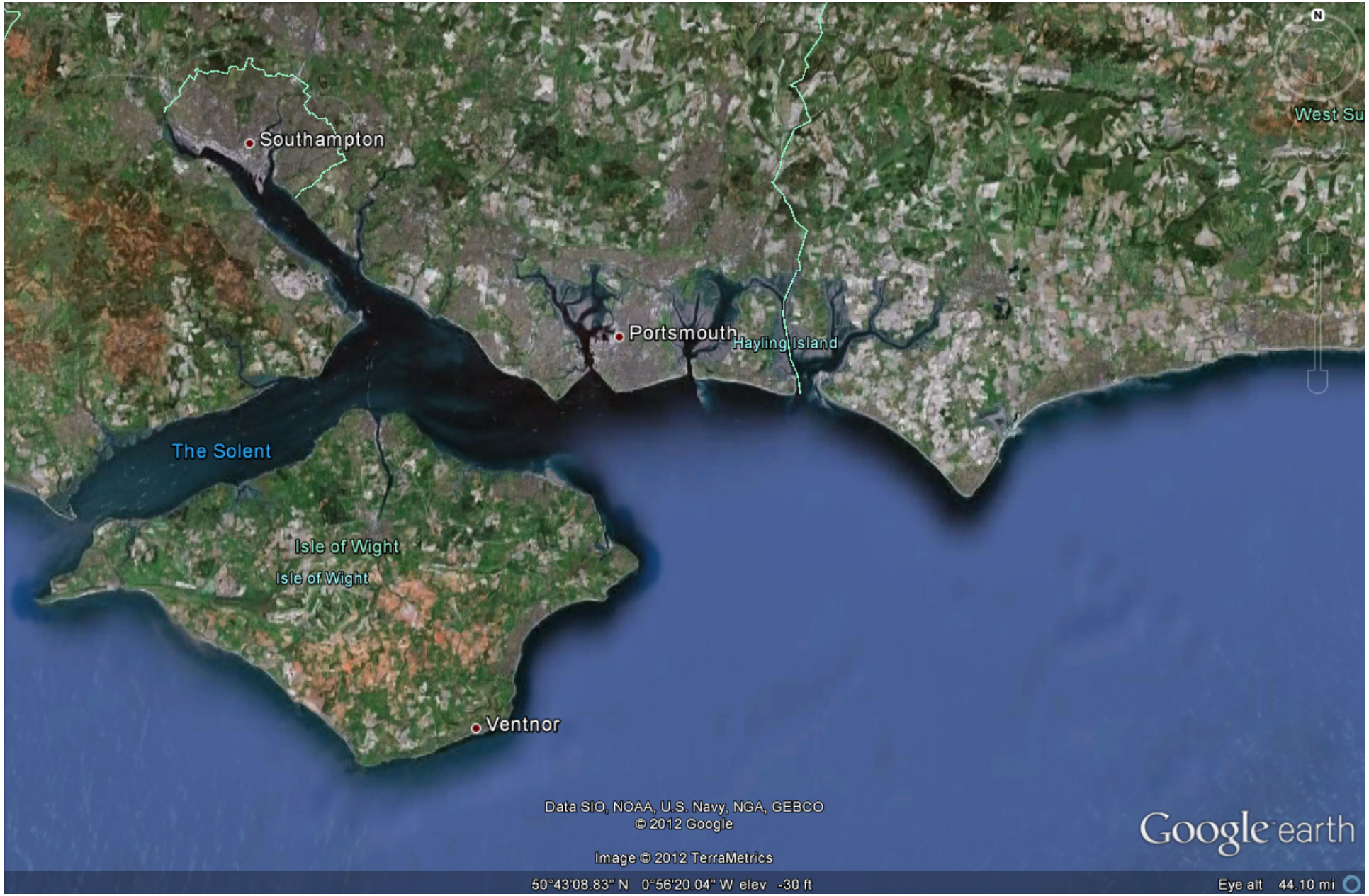


- For different **sea states** the backscattering from the sea will influence the **SCR** used to set the RedR.
- To give **independence** of the sea state, the sea backscattering is extracted **locally, as well as its polarimetric signature**

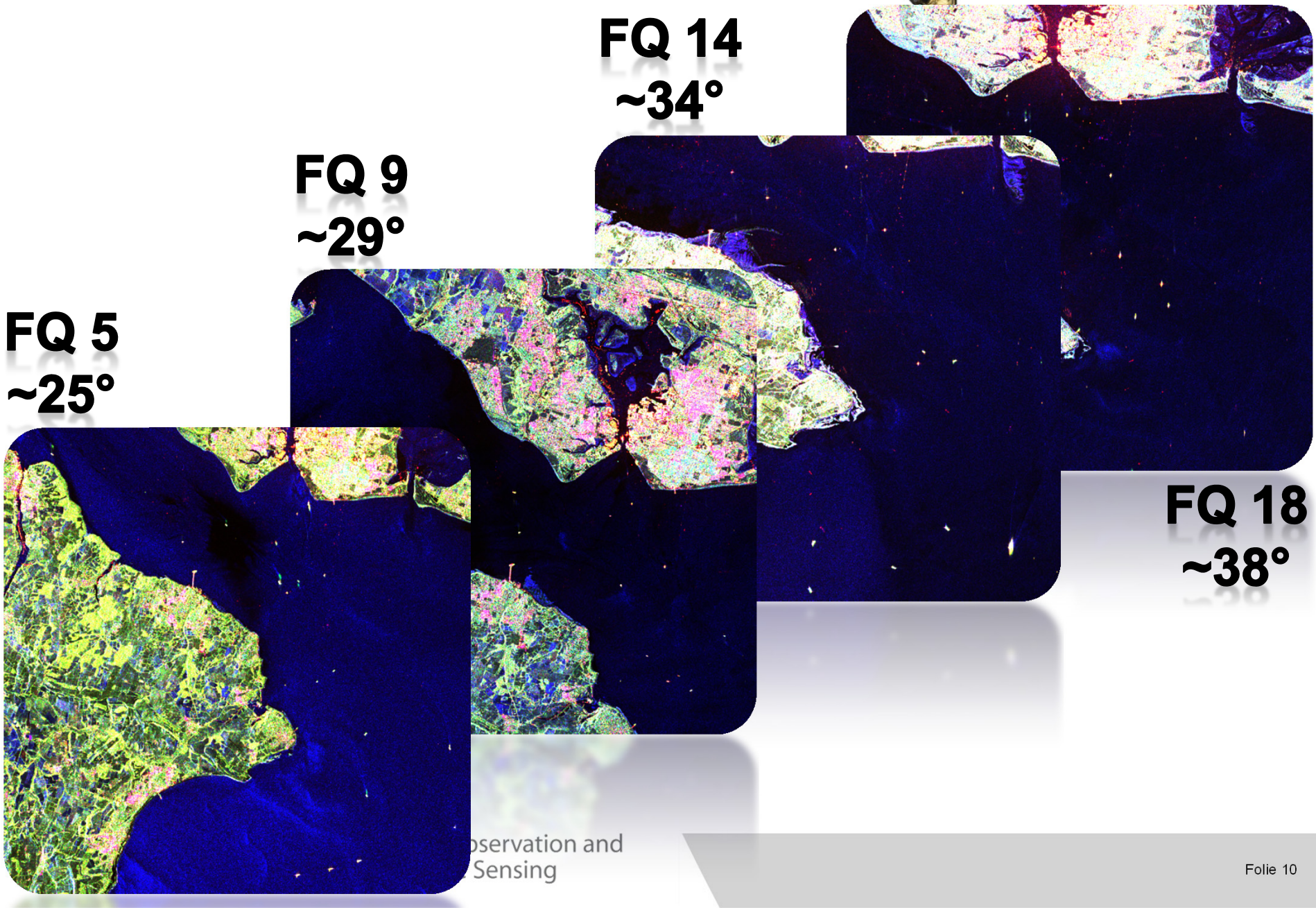
$$\gamma_n = \frac{1}{\sqrt{1 + RedR\left(\frac{\left|\underline{t}^{*T}\,\hat{\underline{t}}_{sea}\right|^2}{\underline{t}^{*T}\,\underline{t} - \left|\underline{t}^{*T}\,\hat{\underline{t}}_{sea}\right|^2}\right)}}$$

The Portsmouth Experiment: ships

Test site: Portsmouth (Google Earth)



Radarsat-2 Fine Quad-pol



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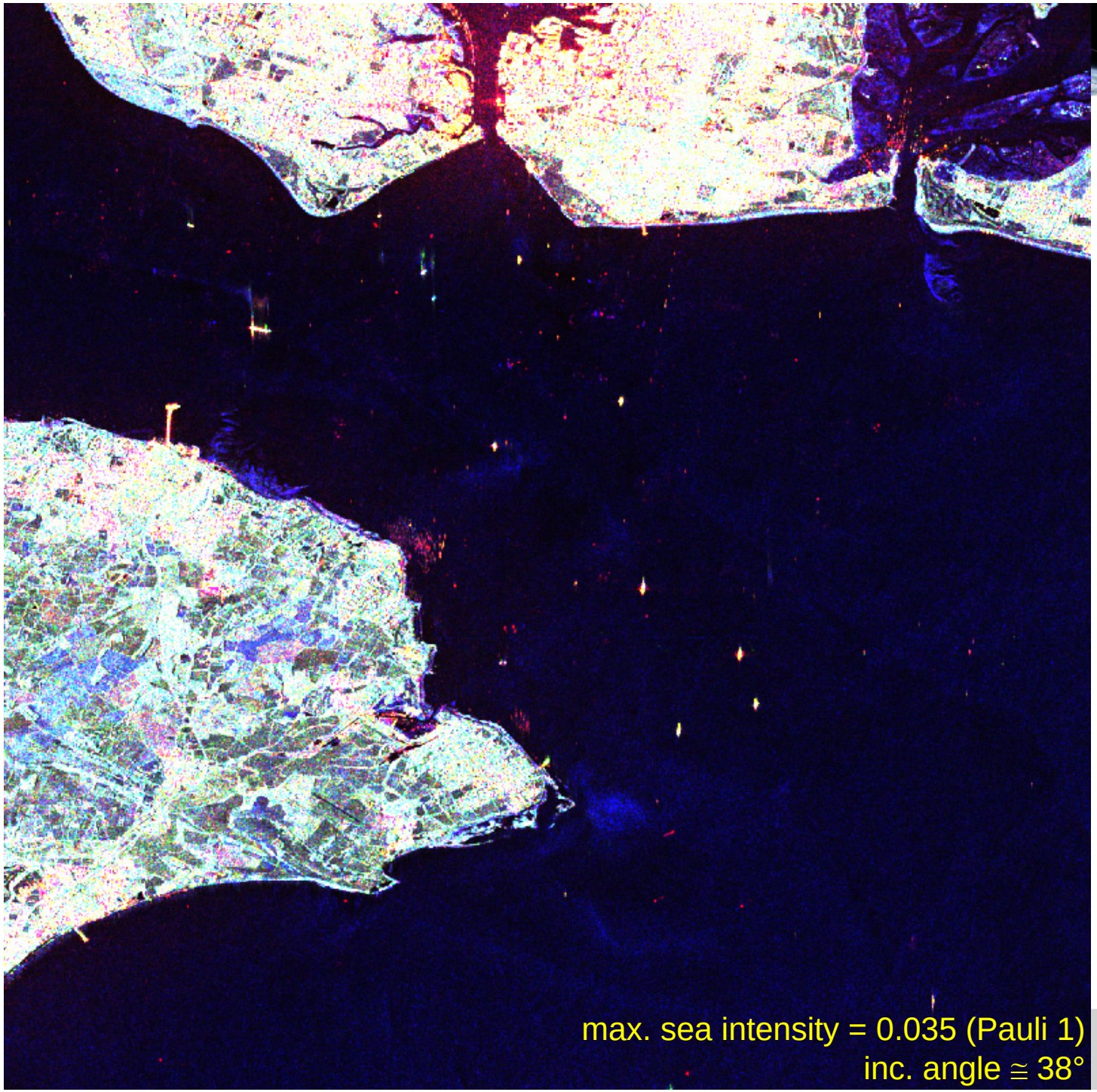
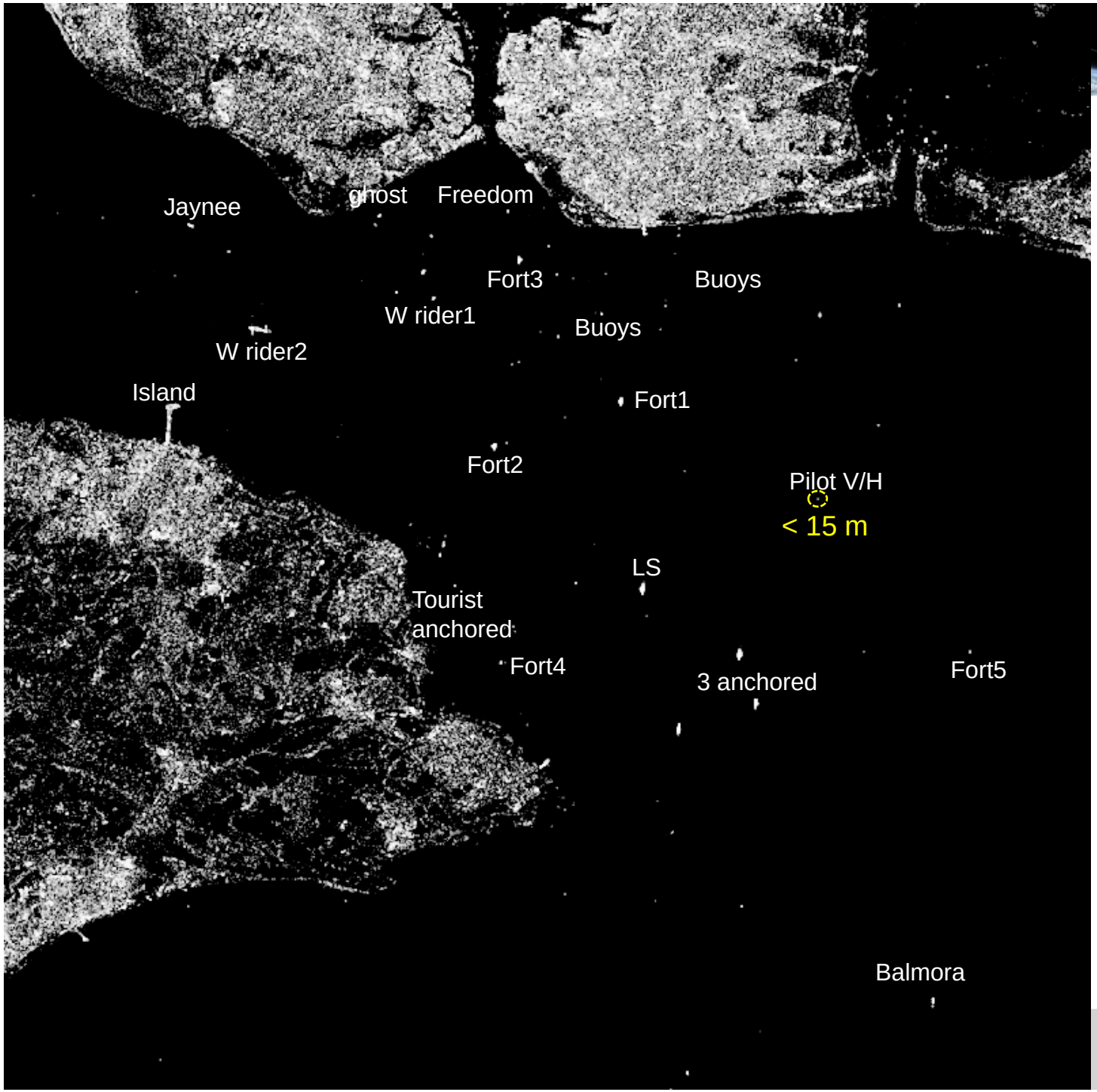


FQ 18
18/08/2011

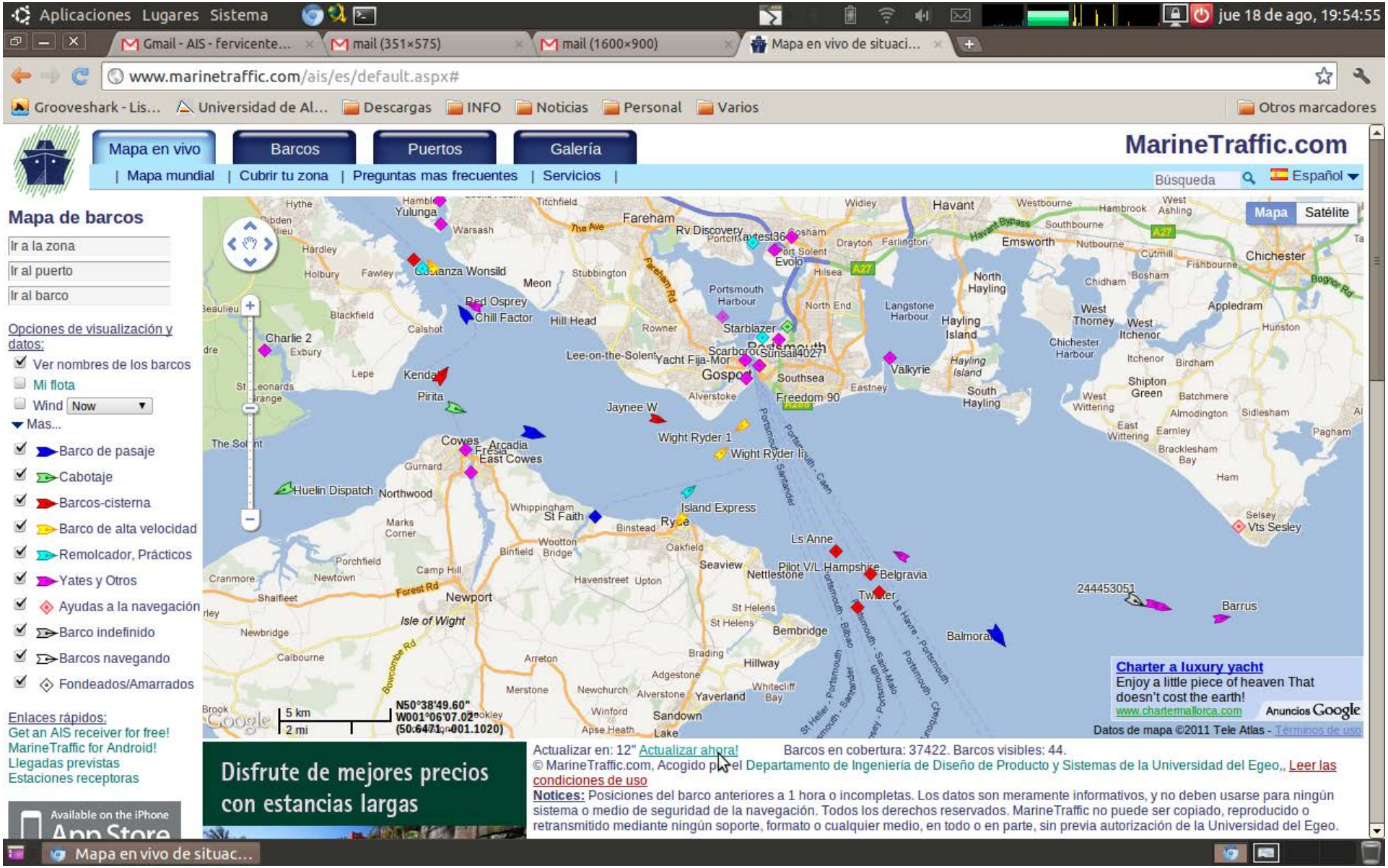
Detection



FQ 18

18/08/2011

AIS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Yaverland
Sandown
Freedom 90
Wight Ryder I
Wight Ryder II
Jaynee W
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Starblazer
Island Express
Ls Anne
Pilot V/L Hampshire
Belgravia
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244453051
Barrus
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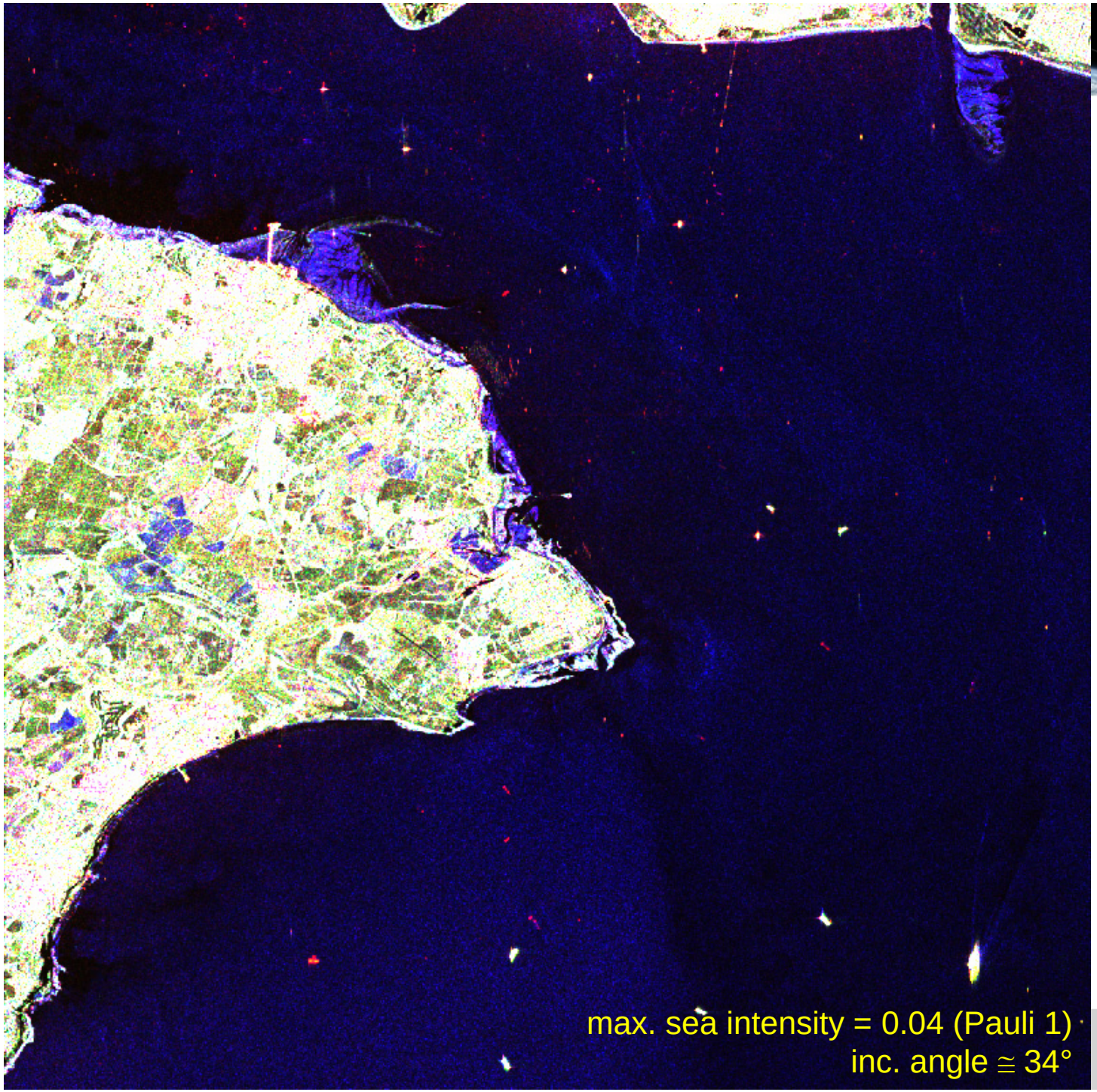
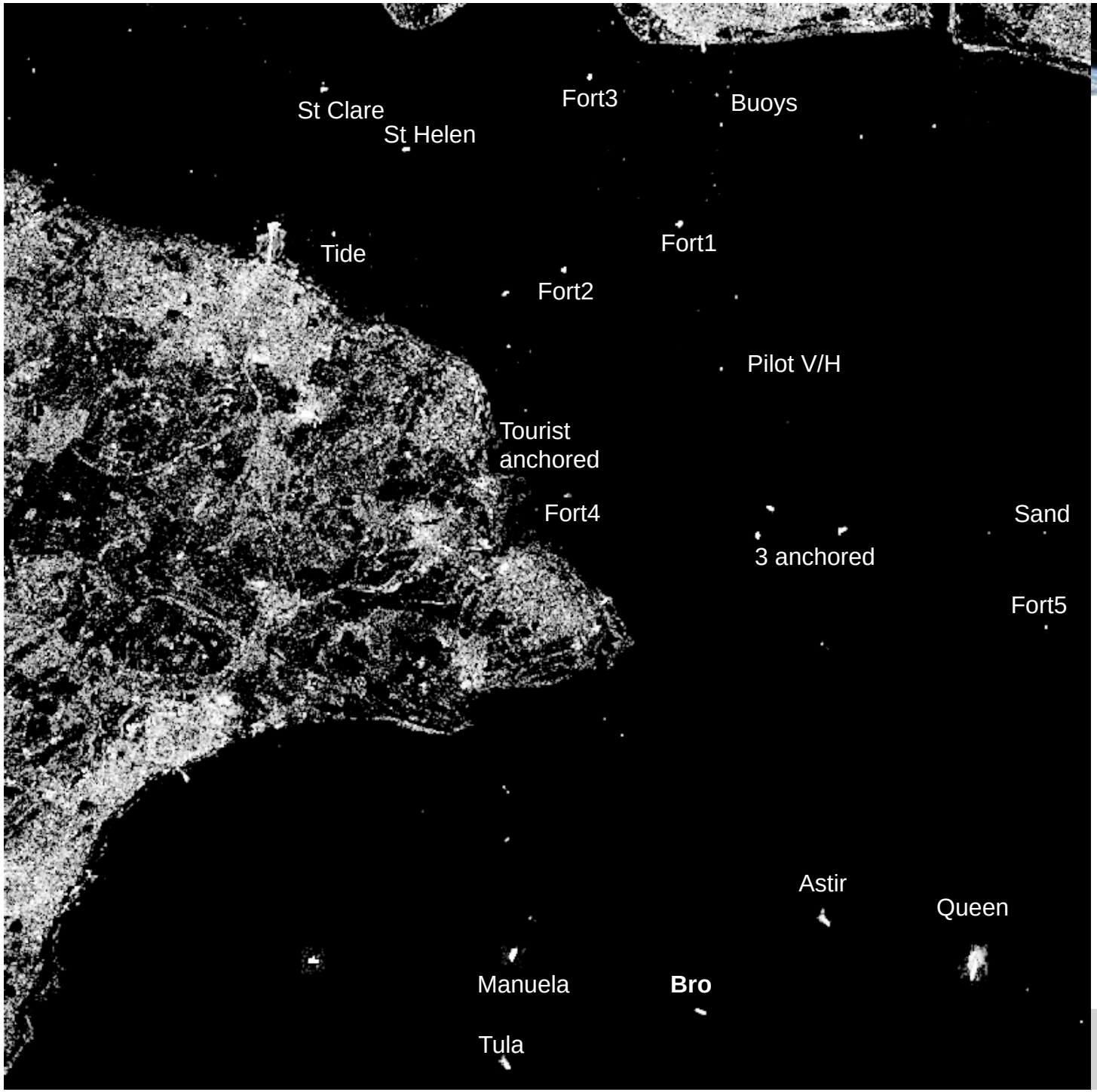
RGB



max. sea intensity = 0.04 (Pauli 1)
inc. angle ≅ 34°

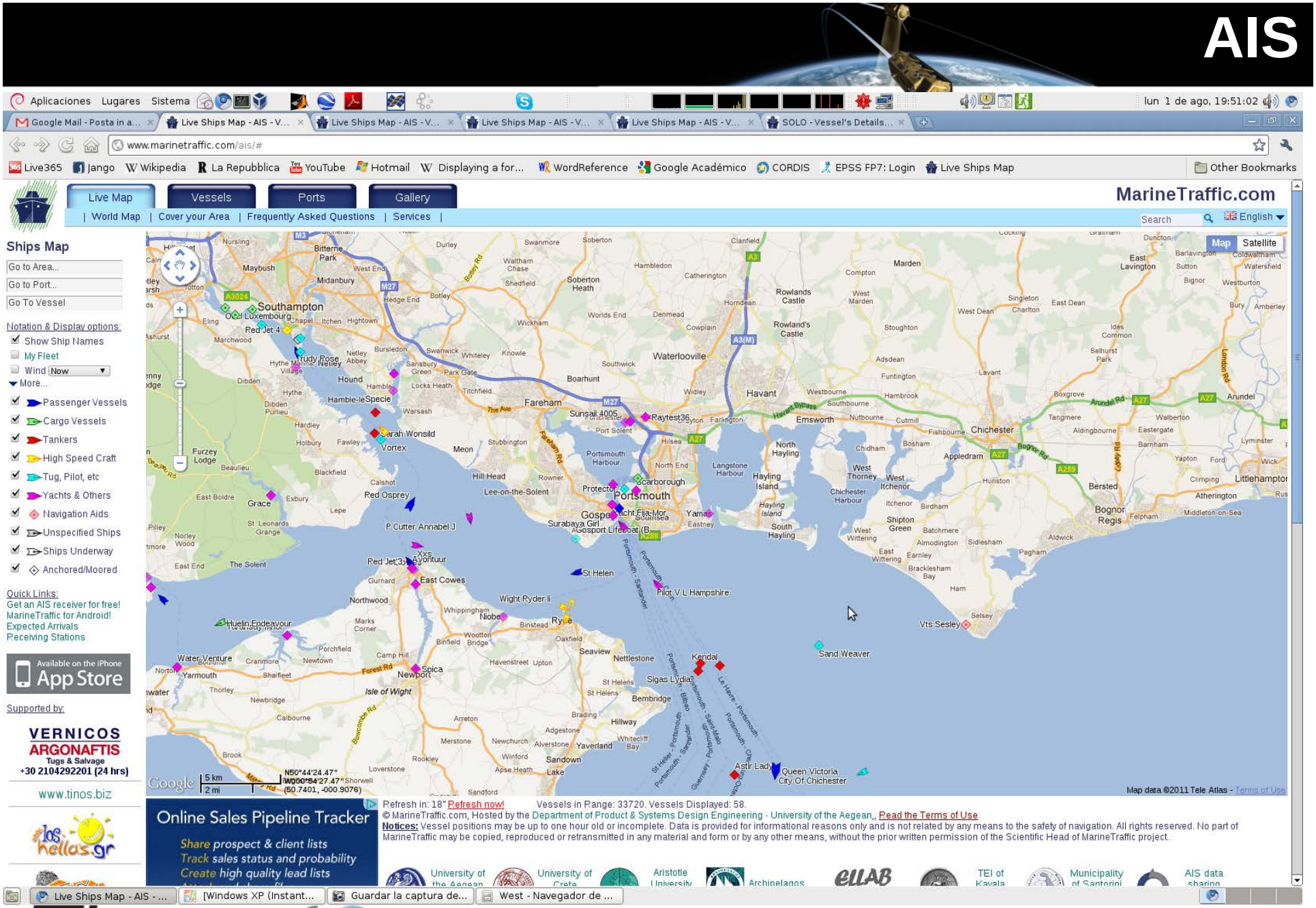
FQ 14
01/08/2011

Detection



FQ 14
01/08/2011

AIS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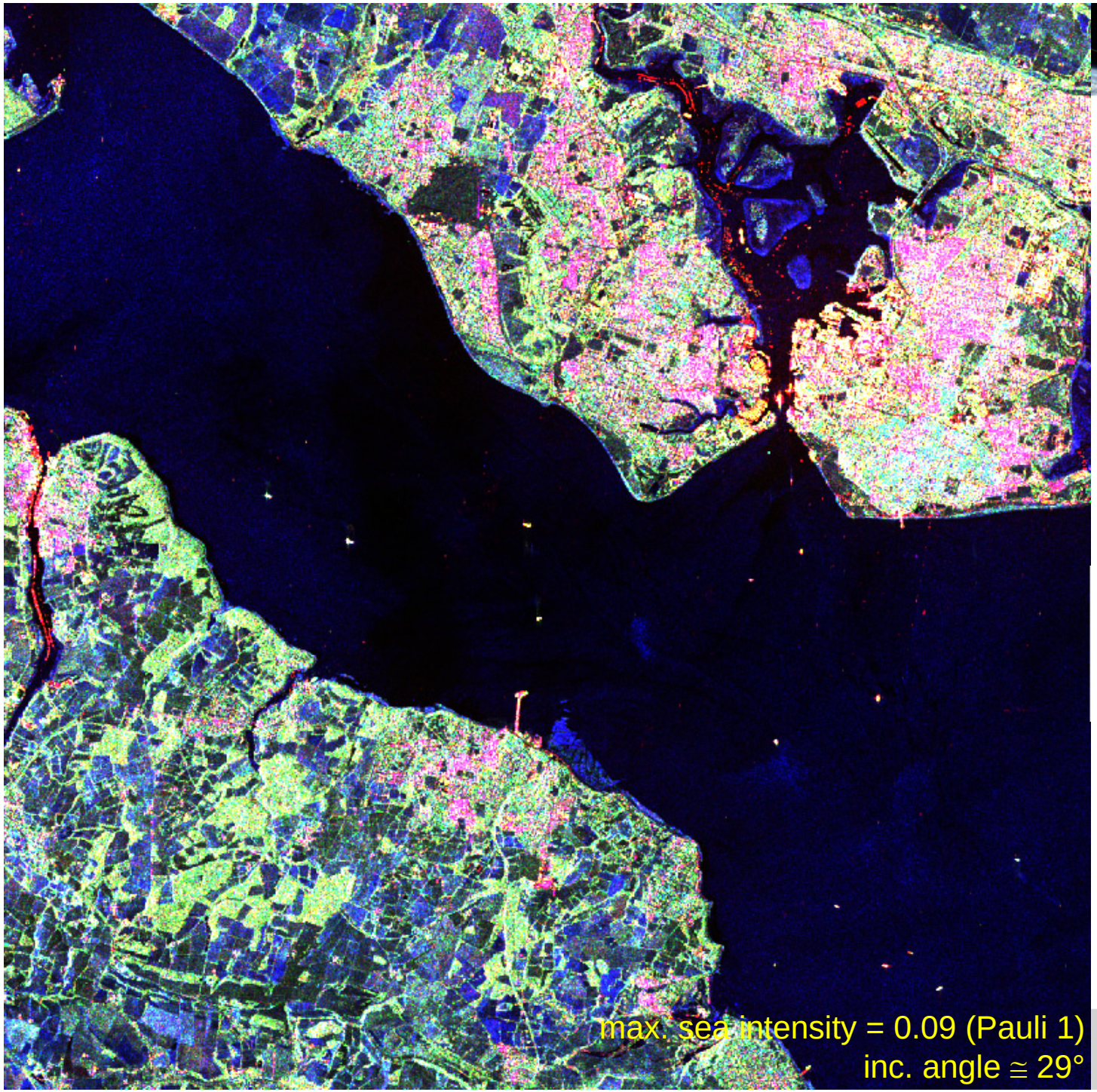

FQ 9
17/03/2011

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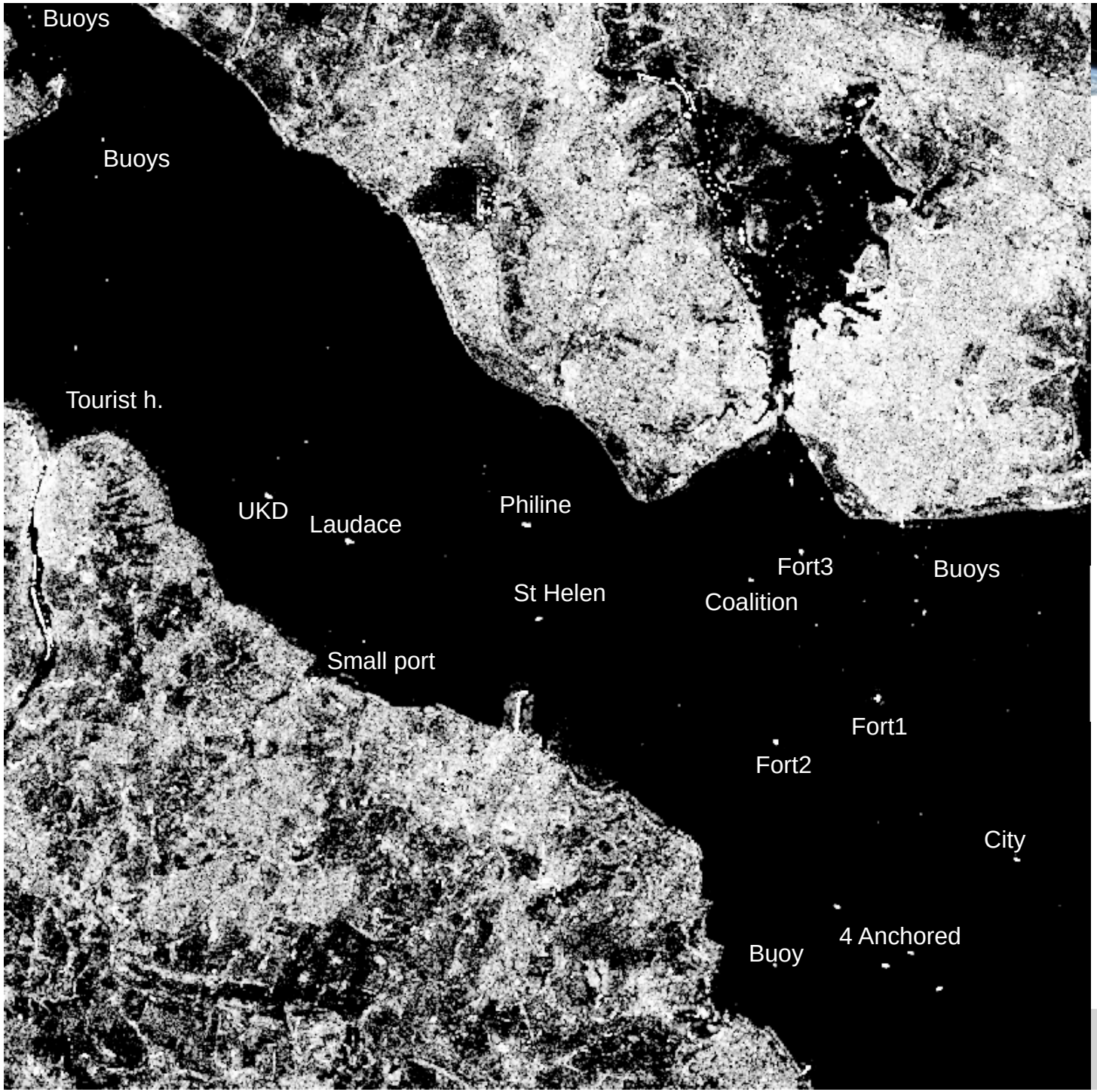

FQ 9
17/03/2011

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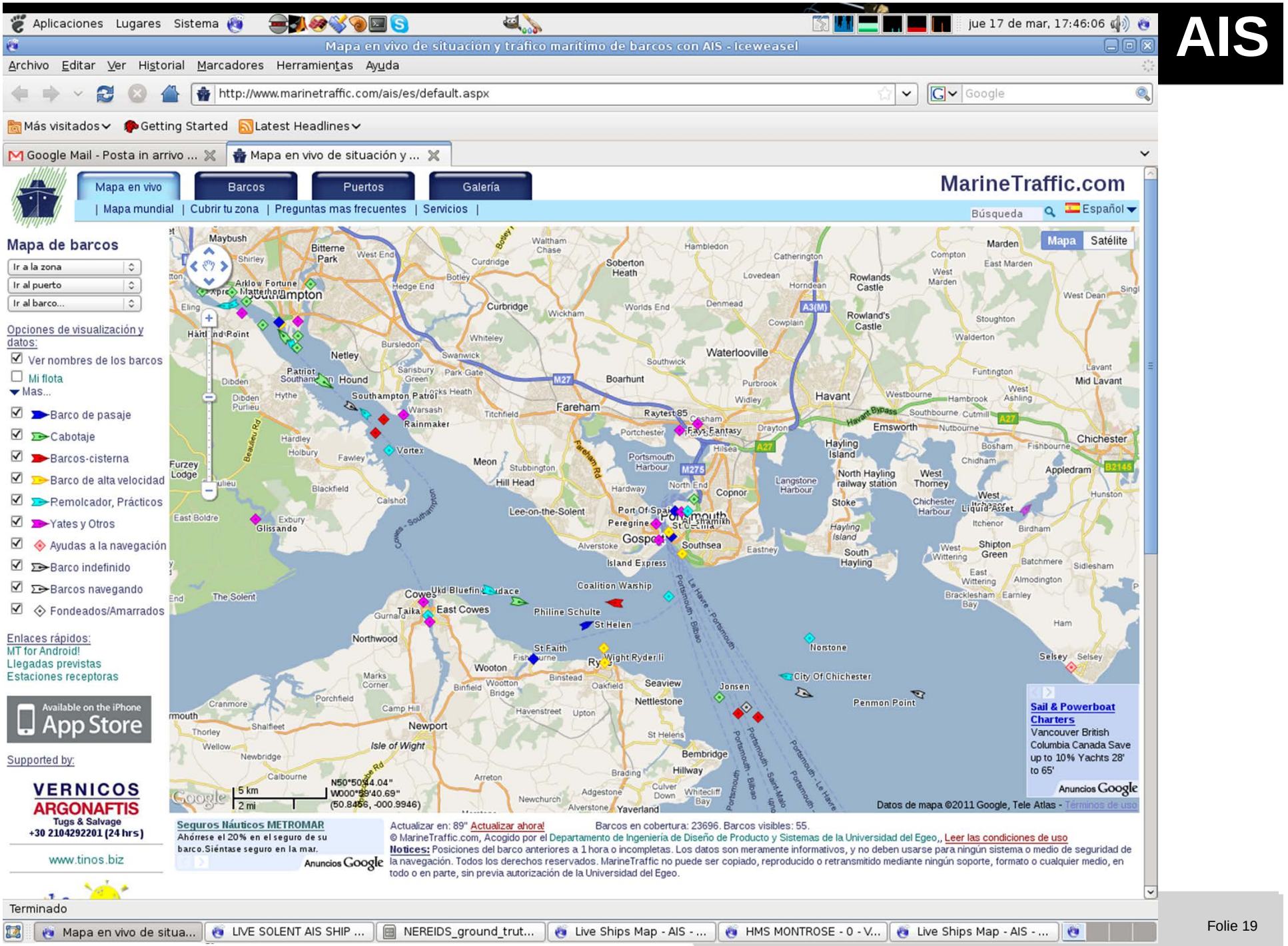
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FQ 5

24/03/2011

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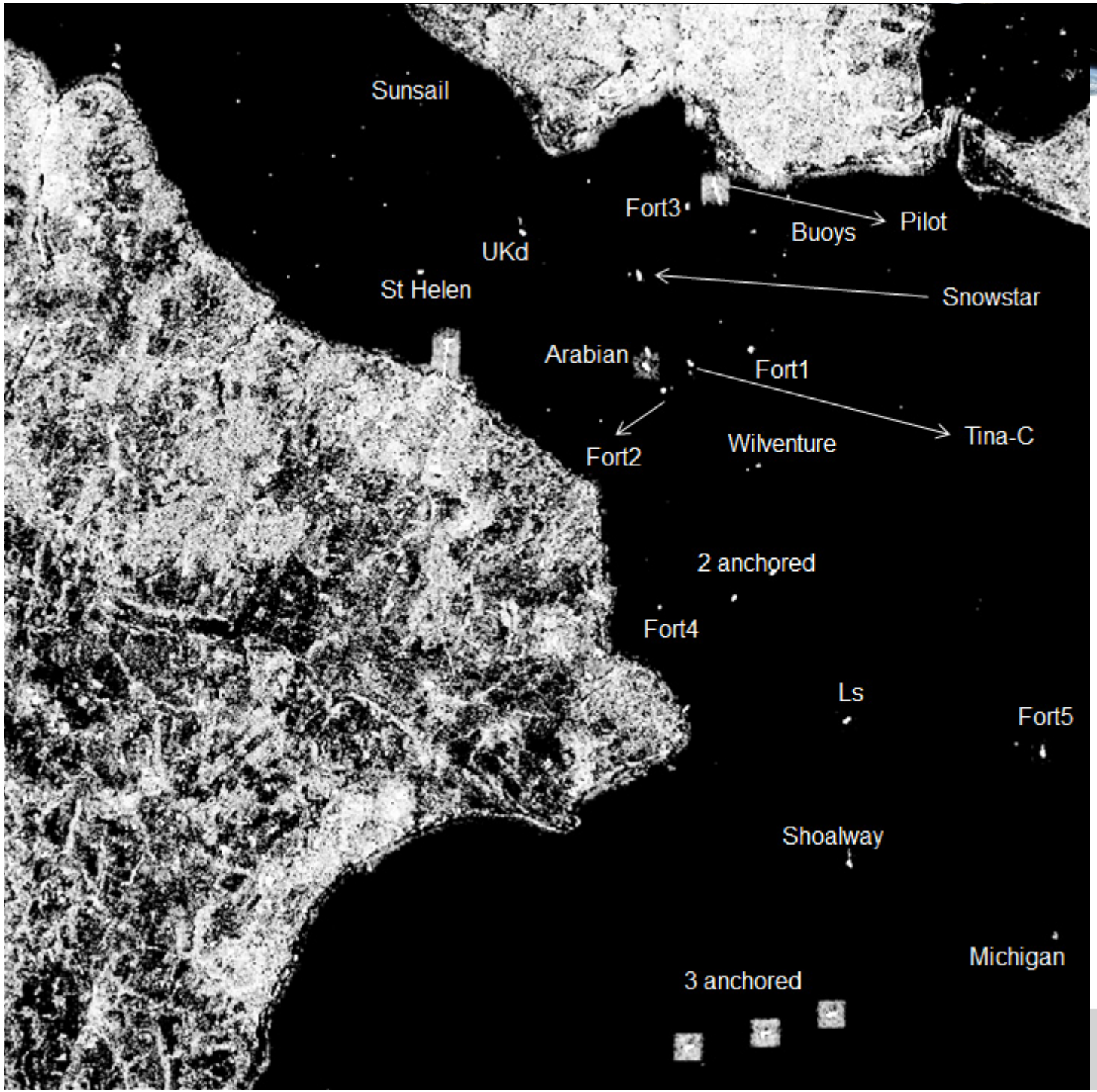

FQ 5

24/03/2011

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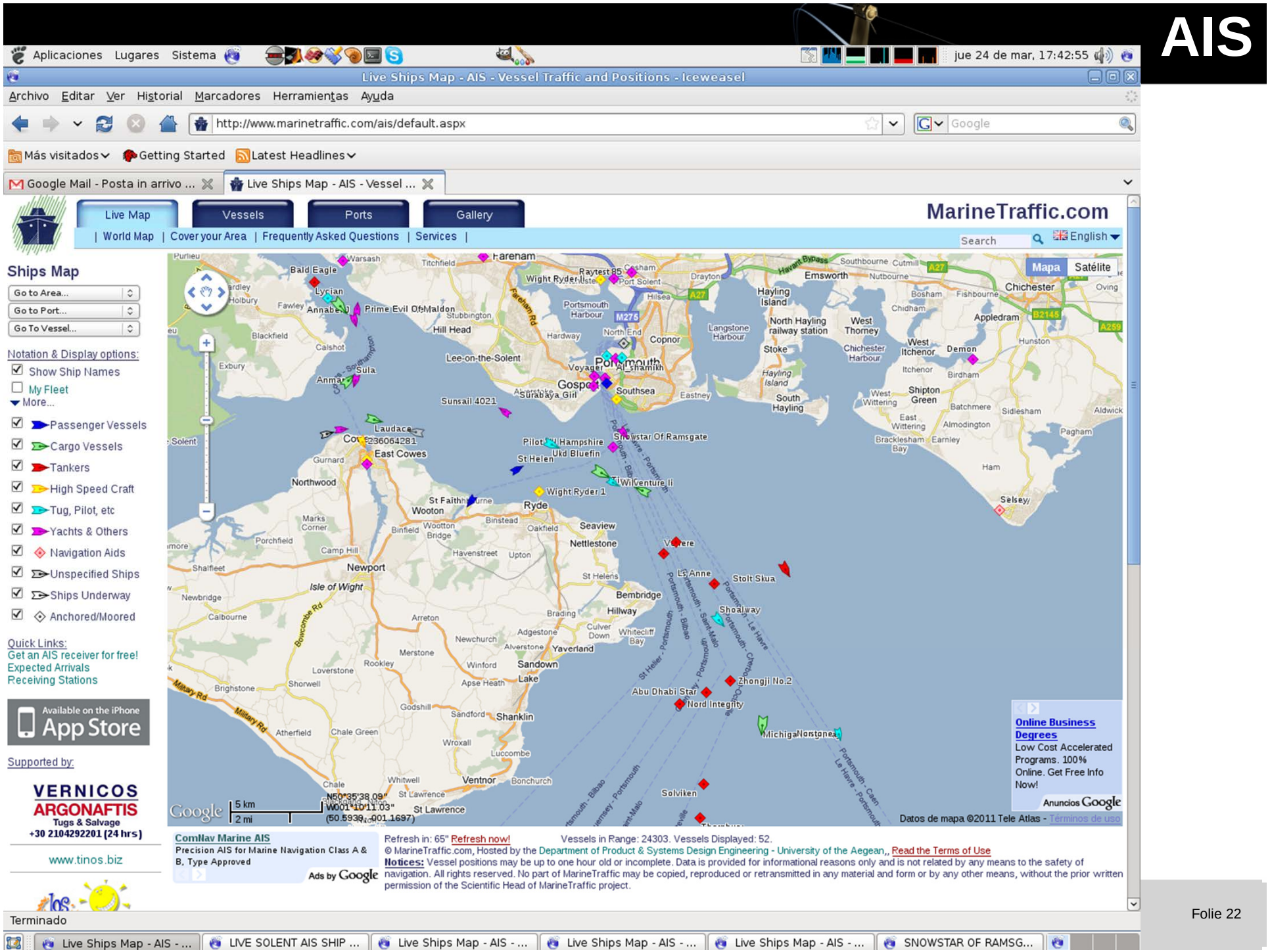
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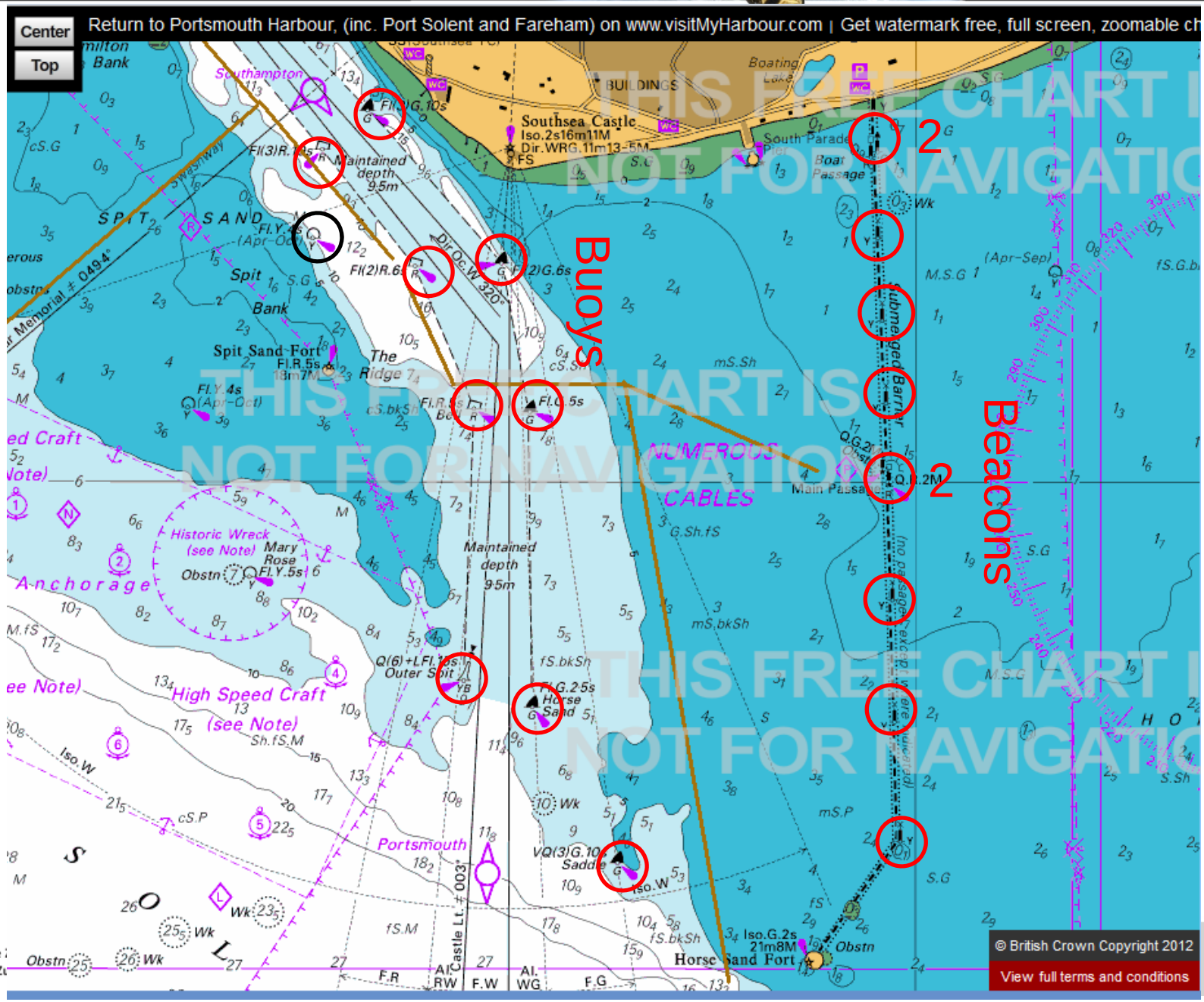
SNOWSTAR OF RAMSG...

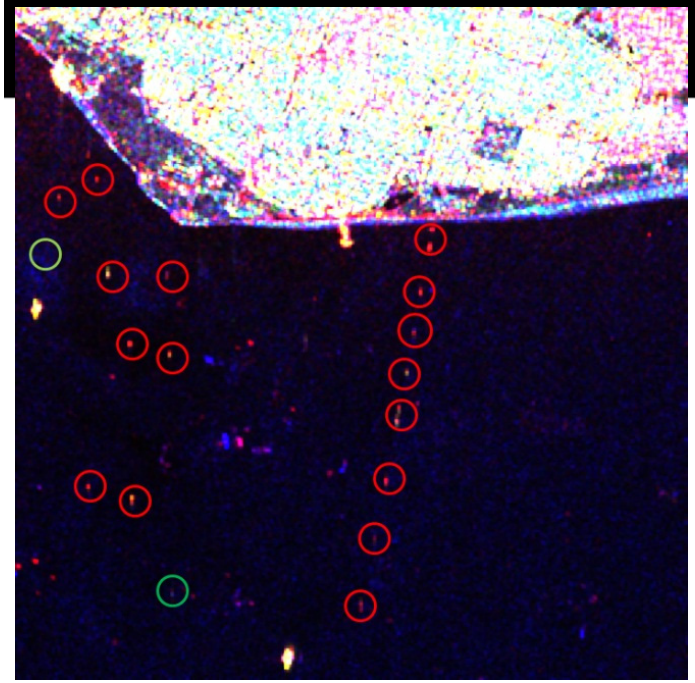
The Portsmouth Experiment: buoys

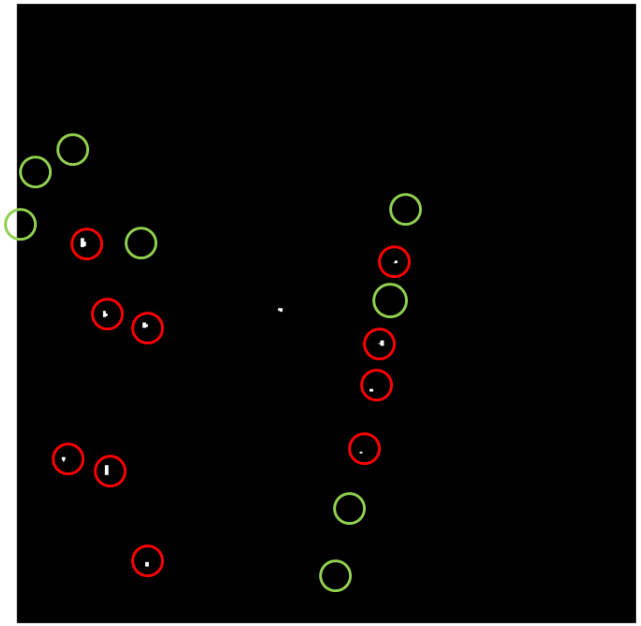
Nautical Chart: buoys

20 Buoys/ Beacons

The one in black is spherical: invisible to radar!





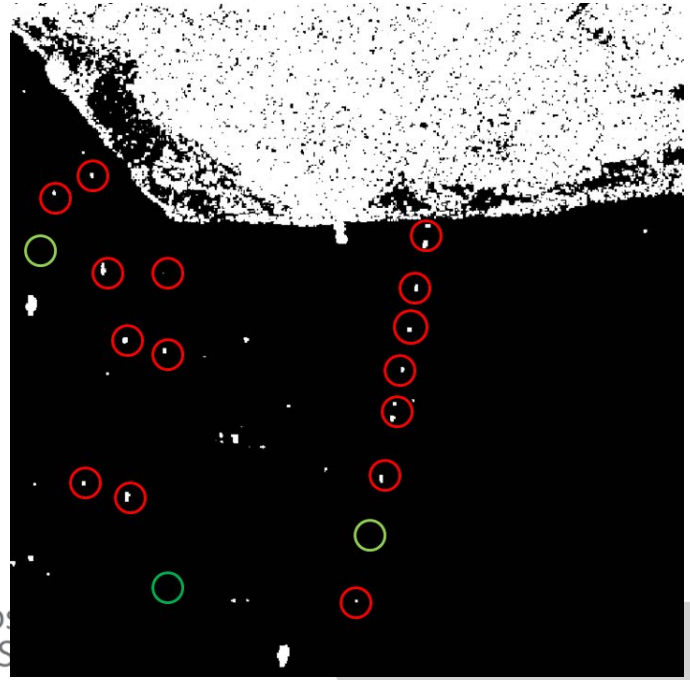


HV K-DISTR. CFAR

10 over 20

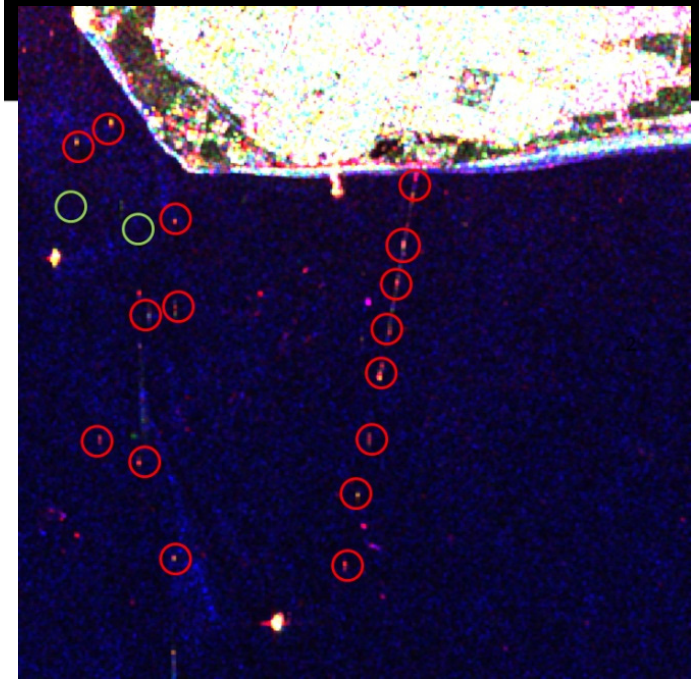
RGB INSPECTION

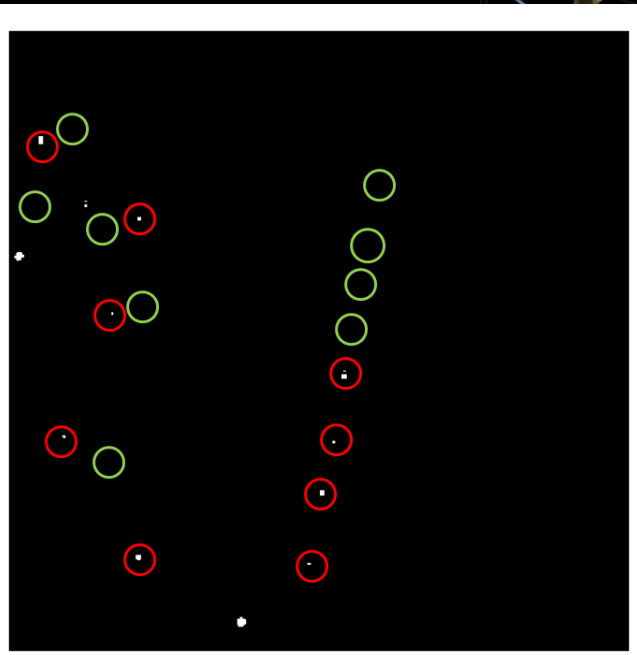
18 over 20



DETECTOR

17 over 20



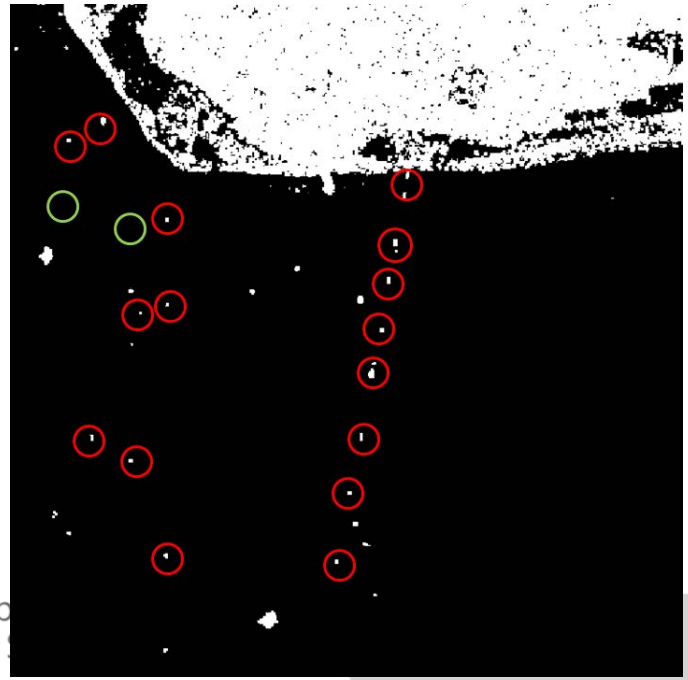


HV K-DISTR. CFAR

9 over 20

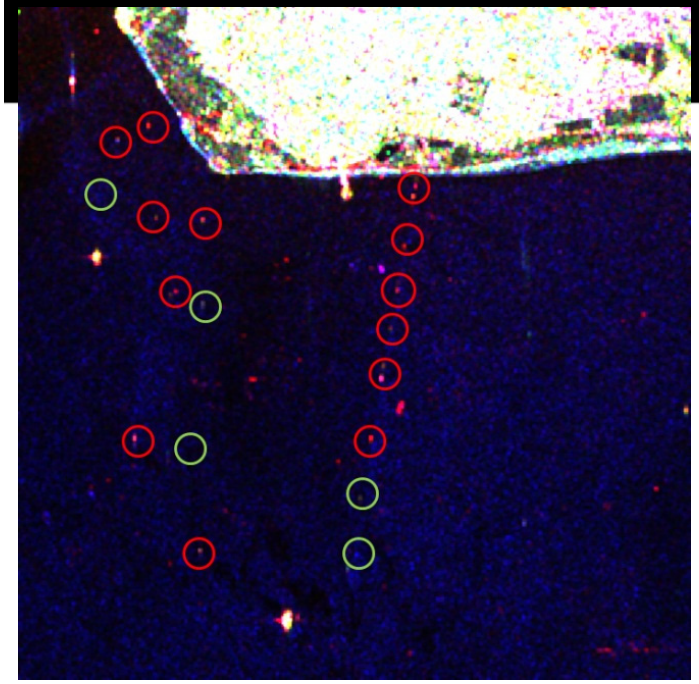
RGB INSPECTION

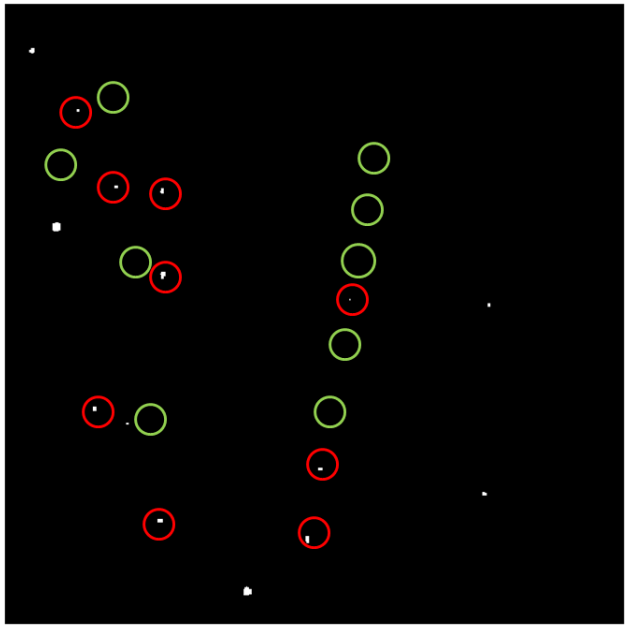
18 over 20



DETECTOR

18 over 20



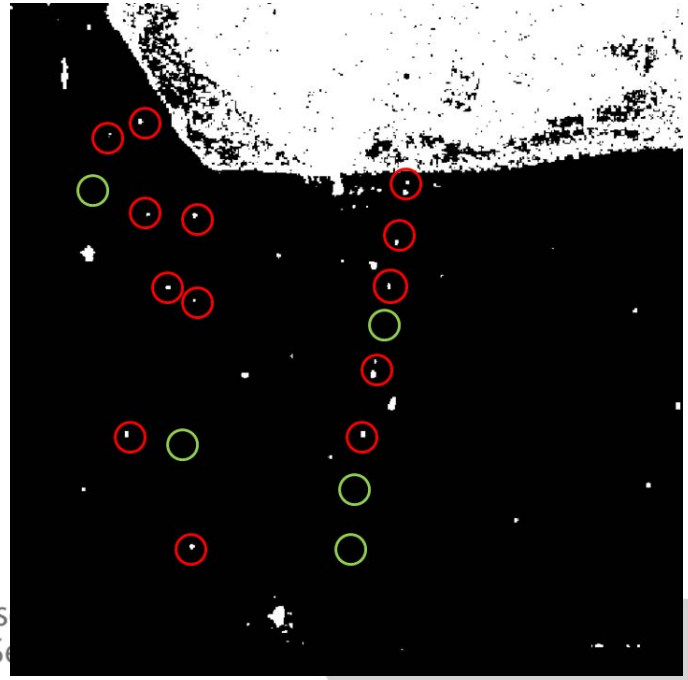


HV K-DISTR. CFAR

9 over 20

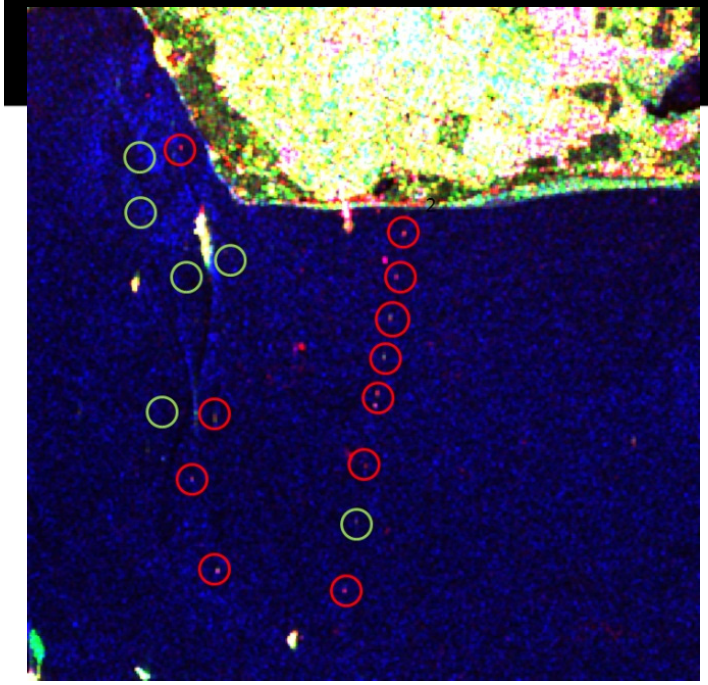
RGB INSPECTION

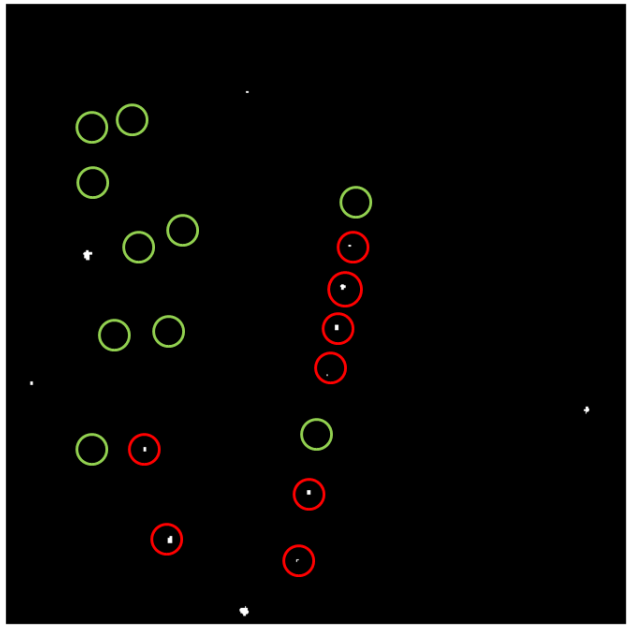
15 over 20



DETECTOR

15 over 20



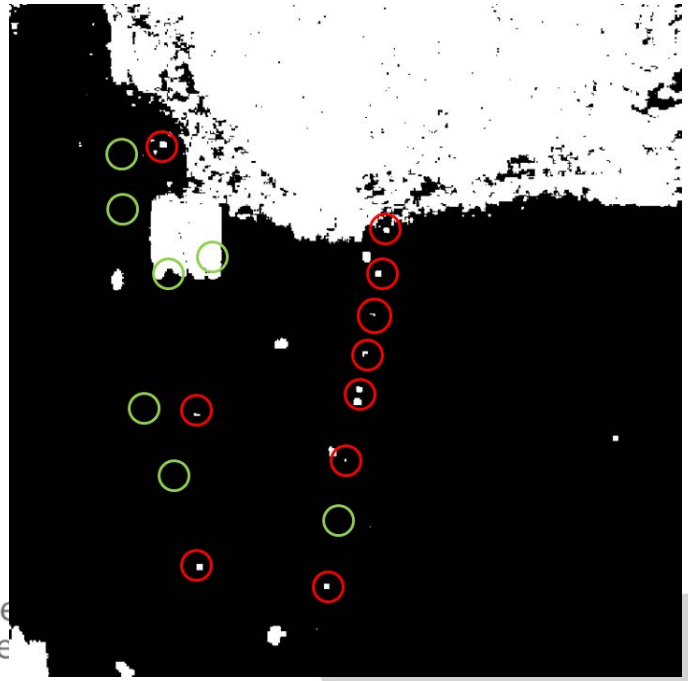


HV K-DISTR. CFAR

8 over 20

RGB INSPECTION

12 over 20



DETECTOR

11 over 20

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Earth Obse
Remote Se

FQ 5

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Summary of results

VESSELS

Detector	PNF	CFAR HV
FQ18	11/11	10/11
FQ14	12/12	11/12
FQ9	10/10	10/10
FQ5	16/16	14/16
Total	49/49 100%	45/49 91.8%

BUOYS

Detector	PNF	CFAR HV
FQ18	17/20	10/20
FQ14	18/20	11/20
FQ9	15/20	9/20
FQ5	11/20	8/20
Total	61/80 76%	38/80 48%

Conclusions

- A negative filter was developed for marine target detection
- The filter is able to detect the features different from the sea
- An adaptive processing makes the algorithm suitable for different sea states
- The validation over Portsmouth data shows:
  - All the vessels listed in the AIS were detected
  - The 76% of small buoys were detected
  - The Notch Filter performs better than the HV CFAR

Thank you for your attention.