Using Sentinel-1 to detect aquaculture structures in Spain

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Outline

- ✓ **Aquaculture**
- ✓ **Polarimetric detectors Models**
  - ✓ HV-iDPolRAD
  - ✓ HH-iDPolRAD
- ✓ **Results**
  - ✓ COSMO-SkyMed
  - ✓ Sentinel-1
- ✓ **Conclusions**

Motivations

Aquaculture

- ✓ Aquaculture are a very **valuable asset** for many coastal countries
  - ✓ The industry is worth $150bn in 2017 (Financial Times).
- ✓ In the future they will play an important role in **food security**.
- ✓ **Satellite remote sensing** can improve the temporal and geo-spatial analysis of such marine facilities.
- ✓ Detecting platforms used for fish and shellfish farming provides a way to **monitor assets** and check they do not get damaged by **storms**.
- ✓ It also allows to identify **illegal placement** of structures in areas which should not host farms.
  - ✓ As the most of human enterprises aquaculture is not immune to illegal activities: e.g. the illegal bluefin tuna market is double the legal market (Europol)

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Aquaculture

In this work we are interested in monitoring **platforms** used for **shellfish** farms (called bateas).

We also focus on the aria of **Vigo, Spain**.

Radar polarimetry

Scattering from platforms

Credits: ESA/ATG Medialab

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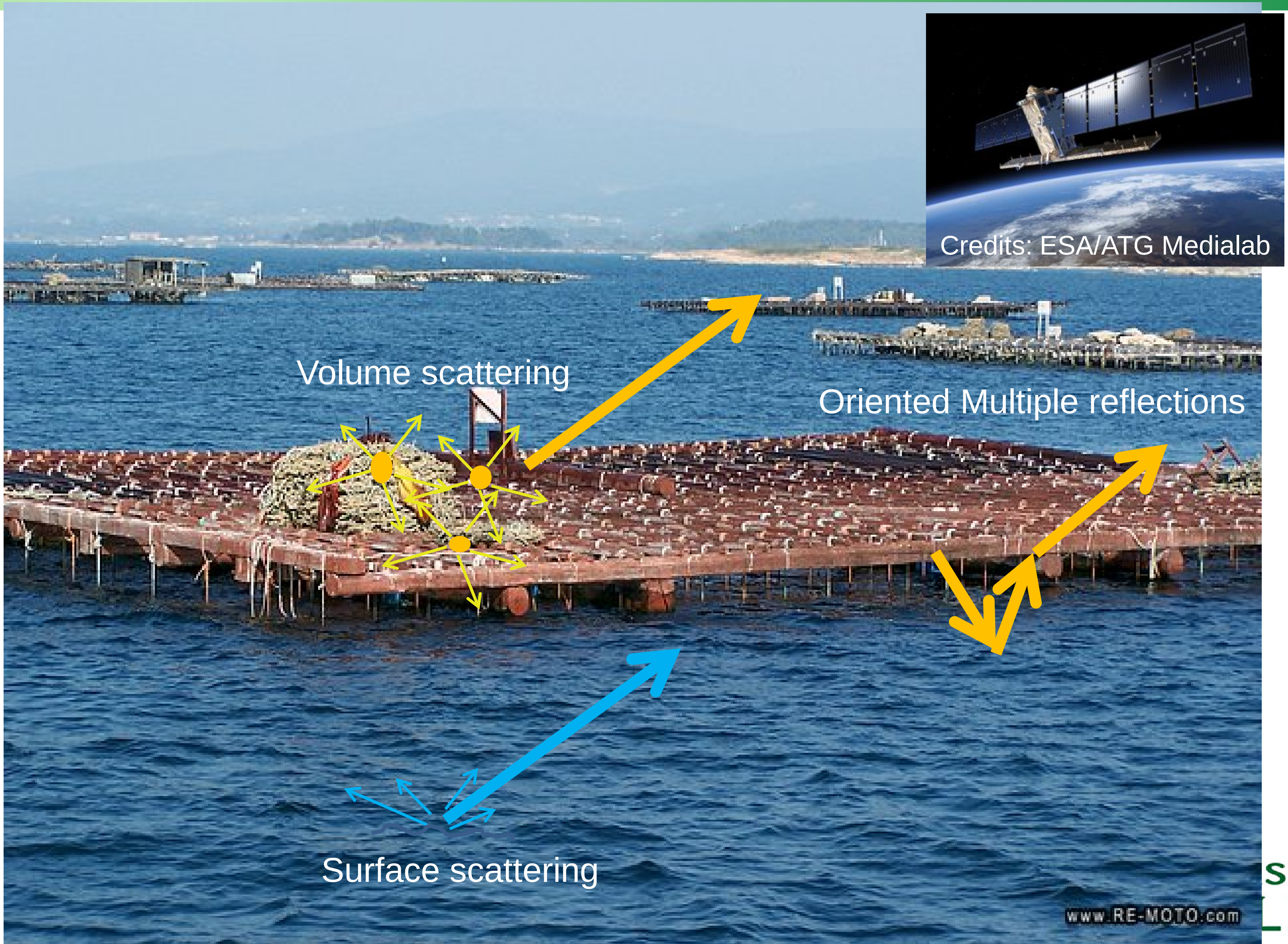
Scattering from platforms



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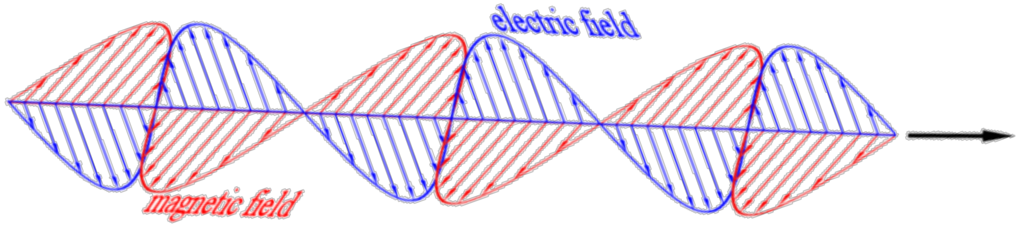
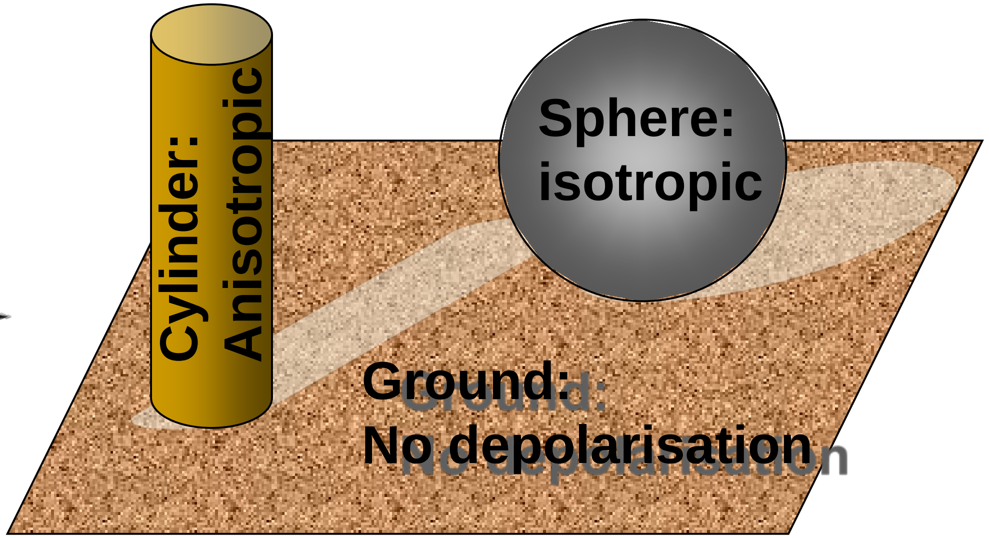
SAR polarimetry

- ✓ **Different targets *generally* interact in a different way when illuminated by differently polarised plane waves**

- ✓ We can **use** polarimetry to:
  - ✓ Classify
  - ✓ Detect
  - ✓ Separate returns





Single targets: same as before, but with math

- ✓ We can arrange the 4 acquisitions discussed before in a matrix: the **Scattering** or **Sinclair matrix**
  - ✓ **H: horizontal linear**
  - ✓ **V: vertical linear**

- ✓ The matrix will represent a **transformation from transmitted polarised waves to received waves**: i.e. it describe the polarimetric behaviour of the target

Cross-polarisations

Scattering matrix

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

Co-polarisations

Scattered (received) wave

Incident (transmitted) wave

$$\underline{E}_r = C(r)\left[S\right]\underline{E}_i$$

Complex scalar depending on distance and medium where the wave propagates (e.g. air)

Depolarisation Anomaly Detector (DePolAD)

- ✓ This **algorithm** is specially tailored for detection of volume.
- ✓ It is based on the idea that a platform will produce an **anomaly in the volume scattering**.
- ✓ **It only needs dual pol detected images. Perfect for Sentinel-1!**

$$\Lambda = \frac{\left\langle \left| HV \right|^2 \right\rangle_{test} - \left\langle \left| HV \right|^2 \right\rangle_{train}}{\left\langle \left| HH \right|^2 \right\rangle_{train}}$$

The detector Λ is large if:

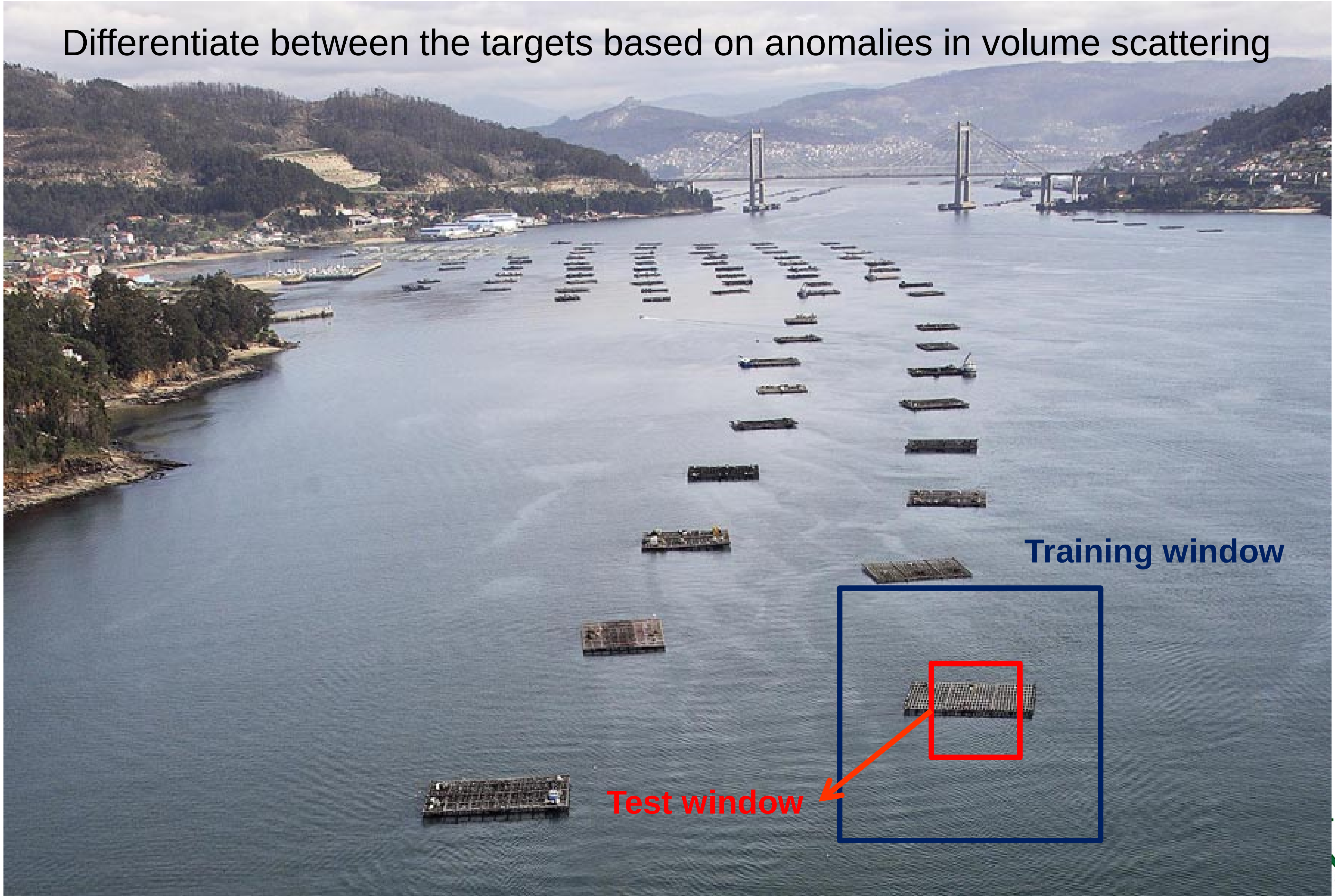
- ✓ **HV increases** between the small and large window
- ✓ If the **ratio HV/HH increases** between the small and large window.

Both components are indicators of volume scattering.

Armando Marino, Wolfgang Dierking and Christine Wesche (2016), “A Depolarization Ratio Anomaly Detector to Identify Icebergs in Sea Ice Using Dual-Polarization SAR Images”, IEEE TGRS, 54(9), Sep. 2016

Implementation

Differentiate between the targets based on anomalies in volume scattering



Physical interpretation

$$\Lambda = \rho_{ring} \frac{1+c}{R\rho^{-1} + cRHV^{-1}} - \rho_{tot}$$

ρ: cross-over-co polarization ratio, or depolarisation ratio
$R\rho$: ratio between ρ in the test window over the ring window
RHV: ratio between HV intensity in the test window over the ring window
c: ratio between number of samples in the total area over the test area

- ✓ If the target **does not change** between ring and test, than Λ is zero

$$\Lambda_{homogeneous} = \rho \frac{1+c}{1+c1} - \rho = 0$$

- ✓ If the **volume/reflection increases** between ring and test, than Λ is positive and large
  - ✓ $R\rho$ and RHV will be very large

$$\lim_{R\rho, RHV \to \infty} \Lambda = \rho_{ring} \frac{1+c}{0+c0} - \rho_{tot} = \infty$$

- ✓ If the **volume/reflection decreases** between ring and test, than Λ is negative

$$\lim_{R\rho, RHV \to 0} \Lambda = \rho_{ring} \frac{1+c}{\infty + c\infty} - \rho_{tot} = -\rho_{tot}$$

Intensity DePolAD (iDPolRAD)

- ✓ The detector DPolRAD is **normalised**.
  - ✓ In some situations it may be better to work with not normalised distances.

- ✓ We can use DPolRAD to obtain an **intensity image with enhanced contrast** platform vs sea and use this as the distance

$$\checkmark I_{HV} = \left(\frac{\langle |HV|^2 \rangle_{test} - \langle |HV|^2 \rangle_{train}}{\langle |HH|^2 \rangle_{train}} \right) \langle |HV|^2 \rangle_{test}$$

- ✓ If there is an increase of volume the pixels will be multiplied by a large number. If it is homogeneous or there is a decrease, the pixel is multiplied by a small number.

HH Intensity DePolAD (HH-iDPolRAD)

- ✓ For some target, the HV does not scatter much, although they are mostly composed by volume scattering

- ✓ Using the HH intensity may be more advantageous. We combine:
  - ✓ the reduction of background of DPolRAD
  - ✓ The stronger target return of HH

✓ $$I_{HH} = \left(\frac{\langle |HV|^2 \rangle_{test} - \langle |HV|^2 \rangle_{train}}{\langle |HH|^2 \rangle_{train}}\right) \langle |HH|^2 \rangle_{test}$$

- ✓ If there is an increase of volume the pixels will be multiplied by a large number. If it is homogeneous or there is a decrease, the pixel is multiplied by a small number.

Results

Shellfish farm locations

They are located in the Rias of Vigo and Pontevedra (Galicia, NW Spain)

Shellfish farm locations

In the following we will concentrate on the red area

We will compare two acquisitions:

- ✓ 29/12/2018: Wind speed 15 km/h, direction 75^0. No rain
- ✓ 1/1/2019: Wind speed 5 km/h, direction 100^0. No rain

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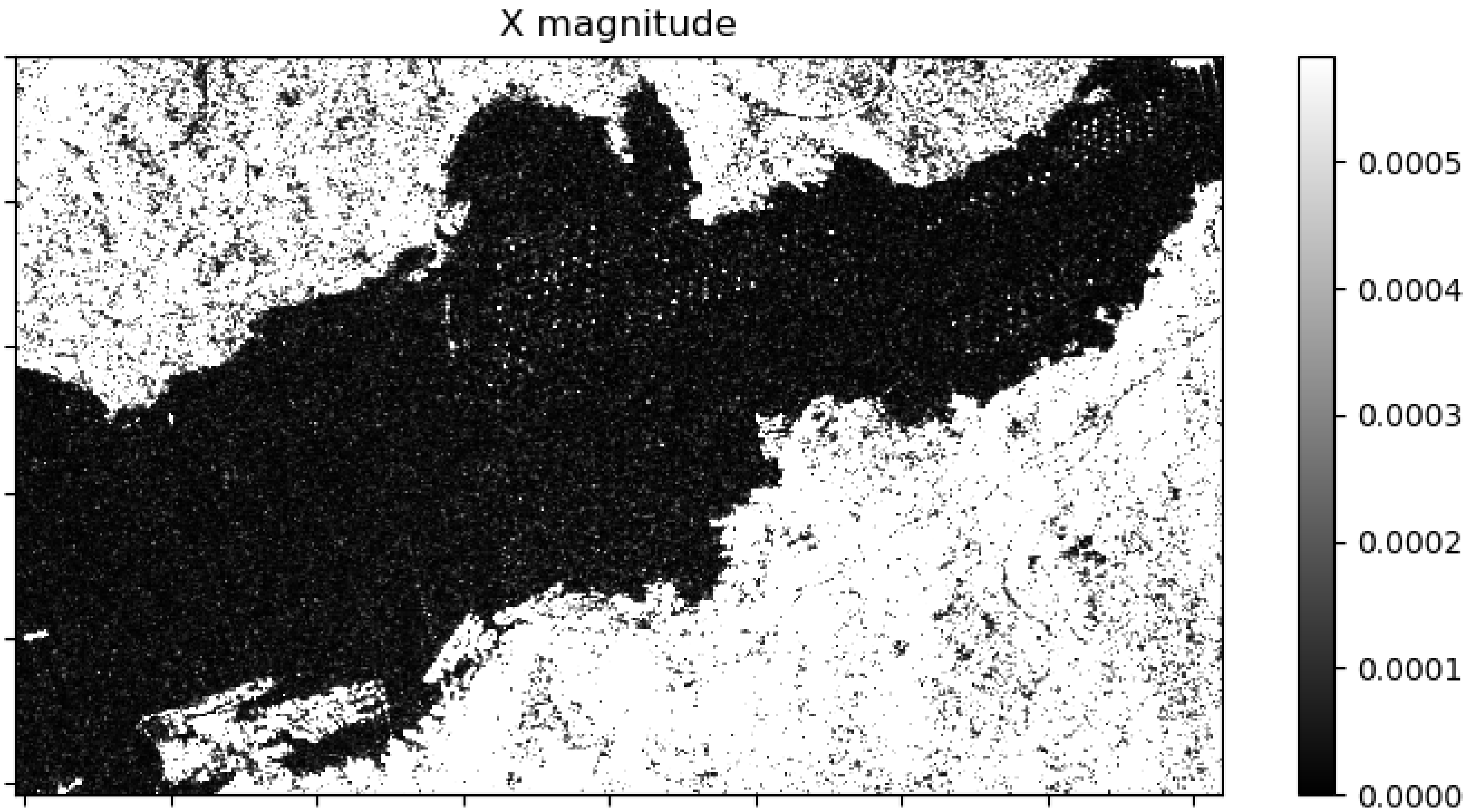
Sentinel-1 data: HV



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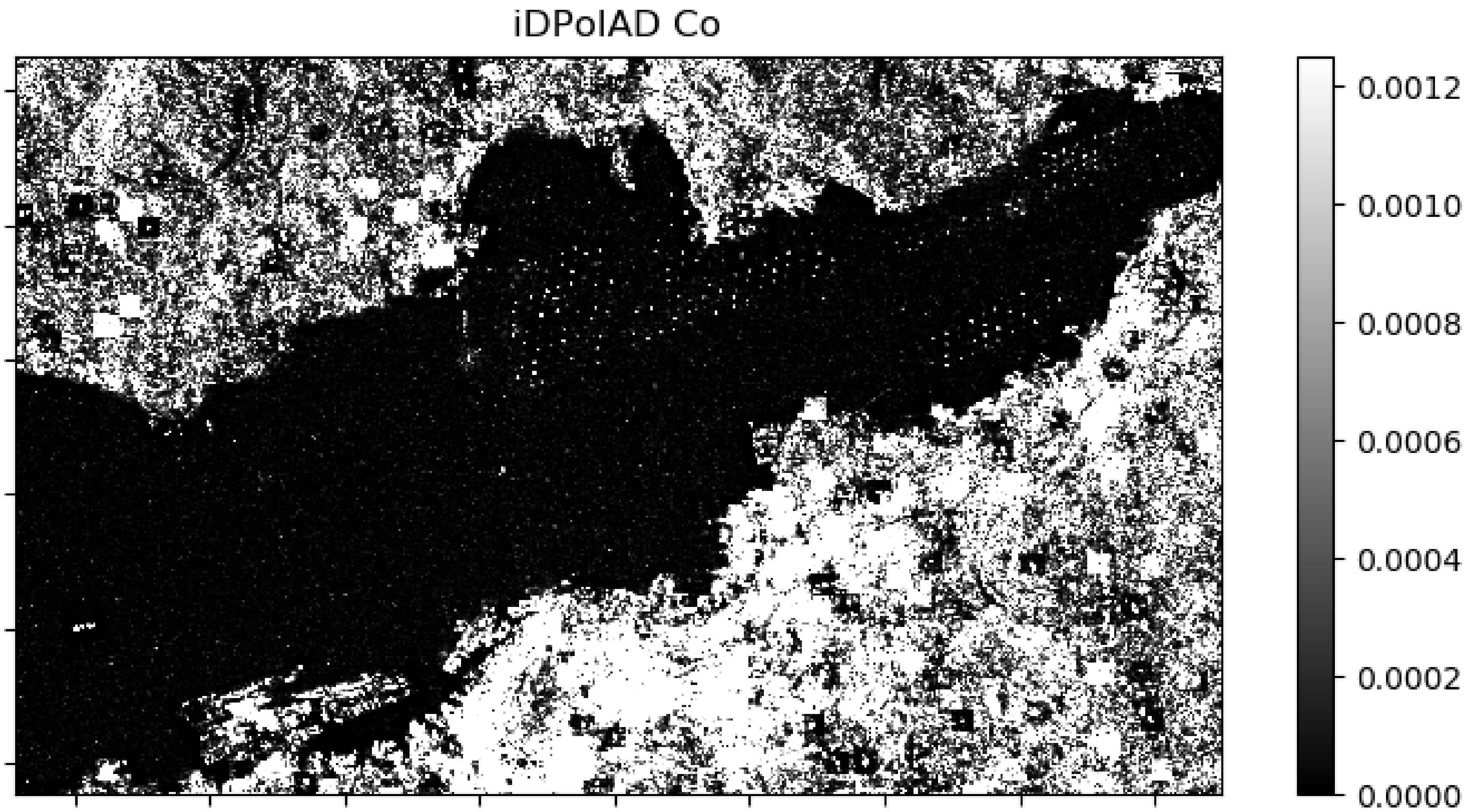
Sentinel-1 data: HH-iDPolRAD



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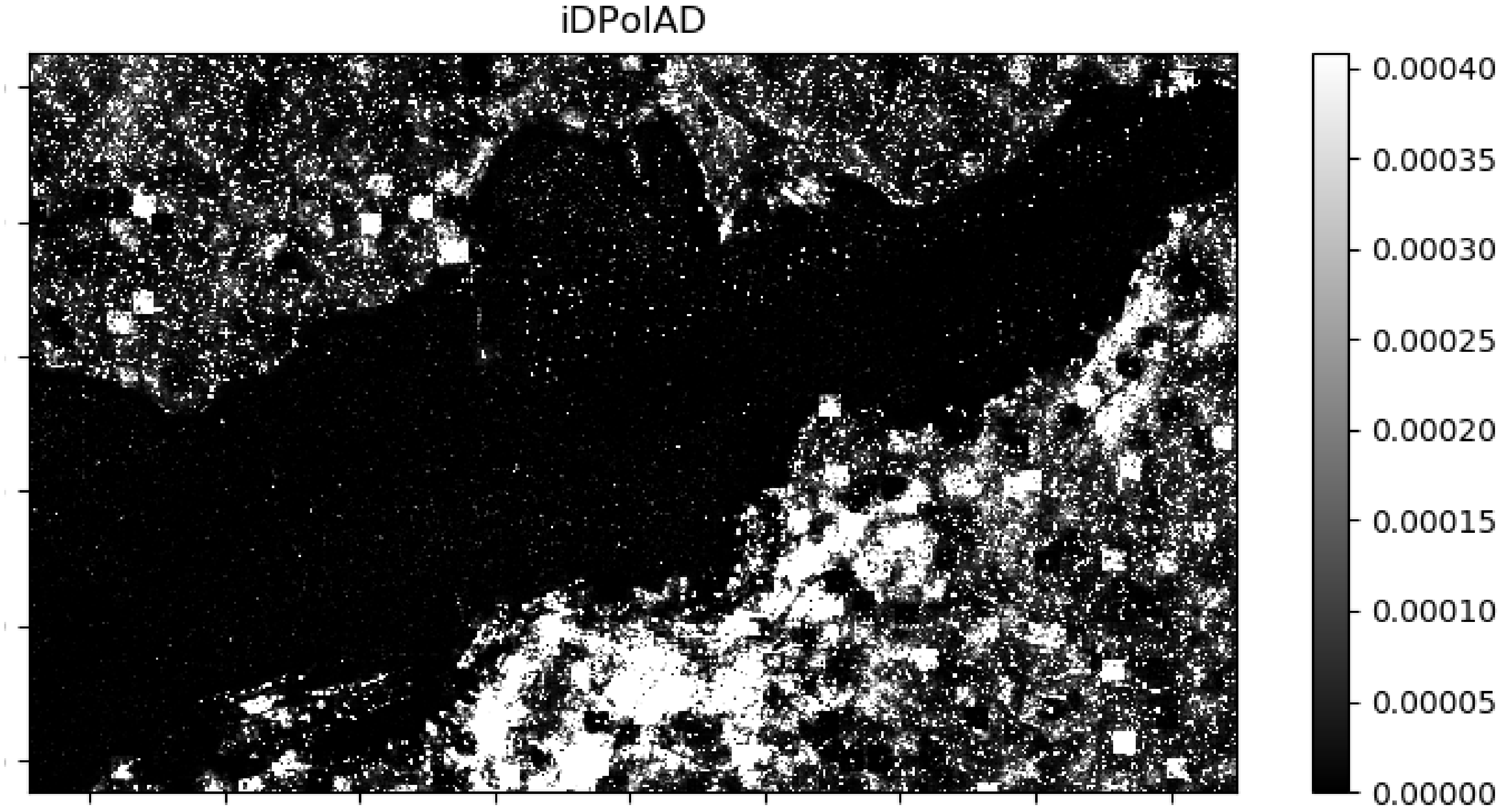
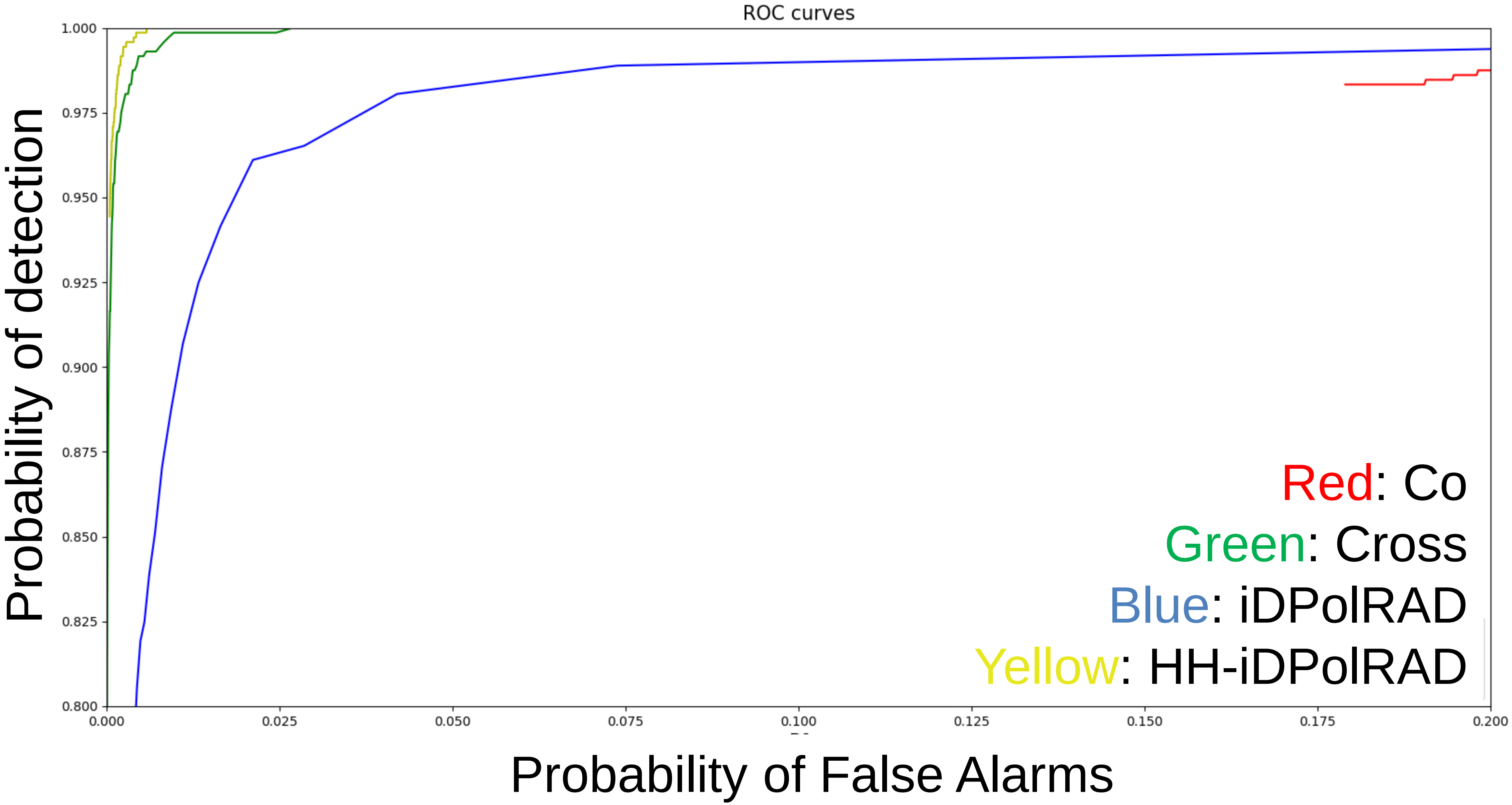
Sentinel-1 data: iDolRAD



Sentinel-1 data: ROC curves

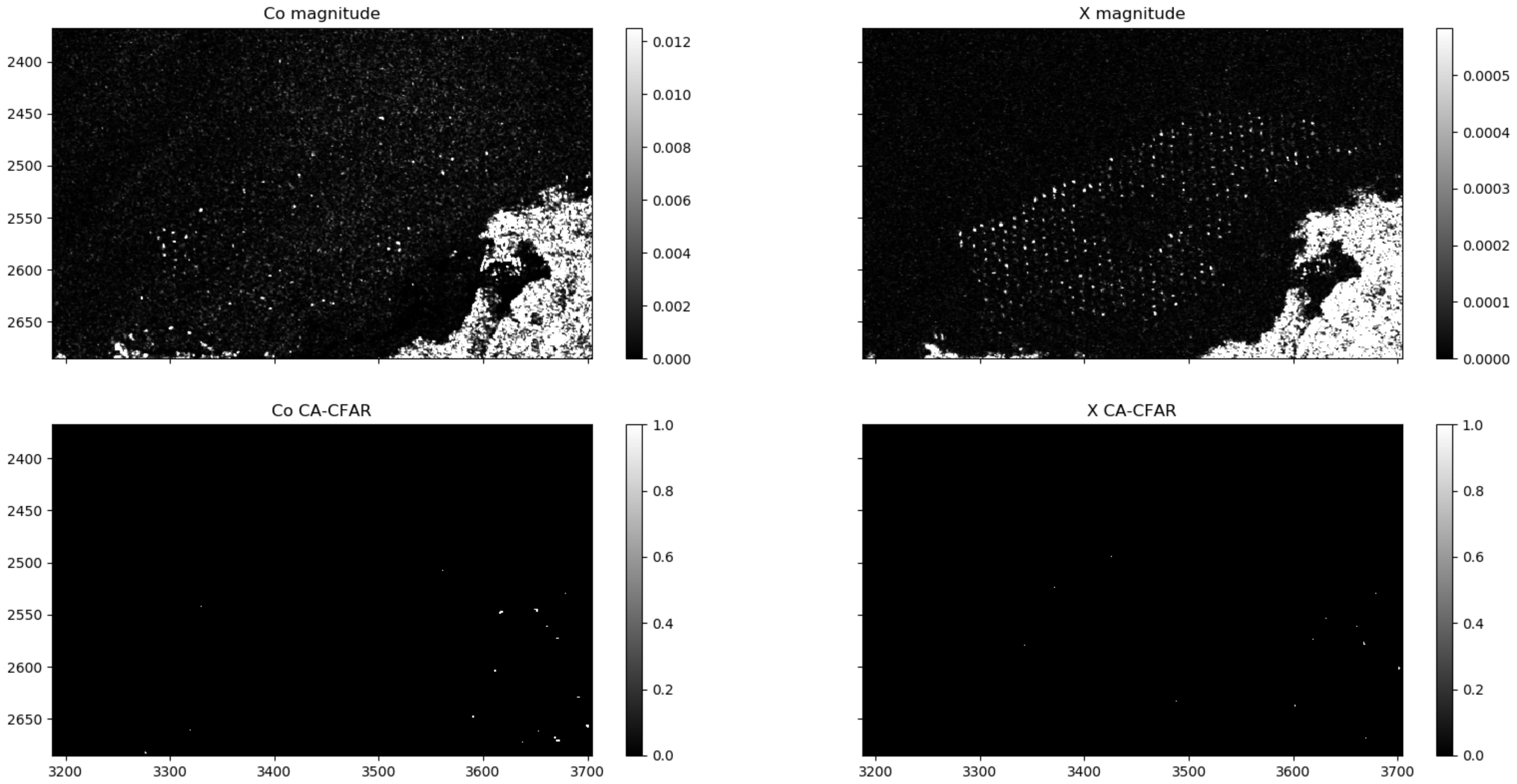
Doing a 1x4 average



We used **validation data** to evaluate the probabilities

Sentinel-1 data

We applied a Cell-Averaging-CFAR, visually there are many missing targets



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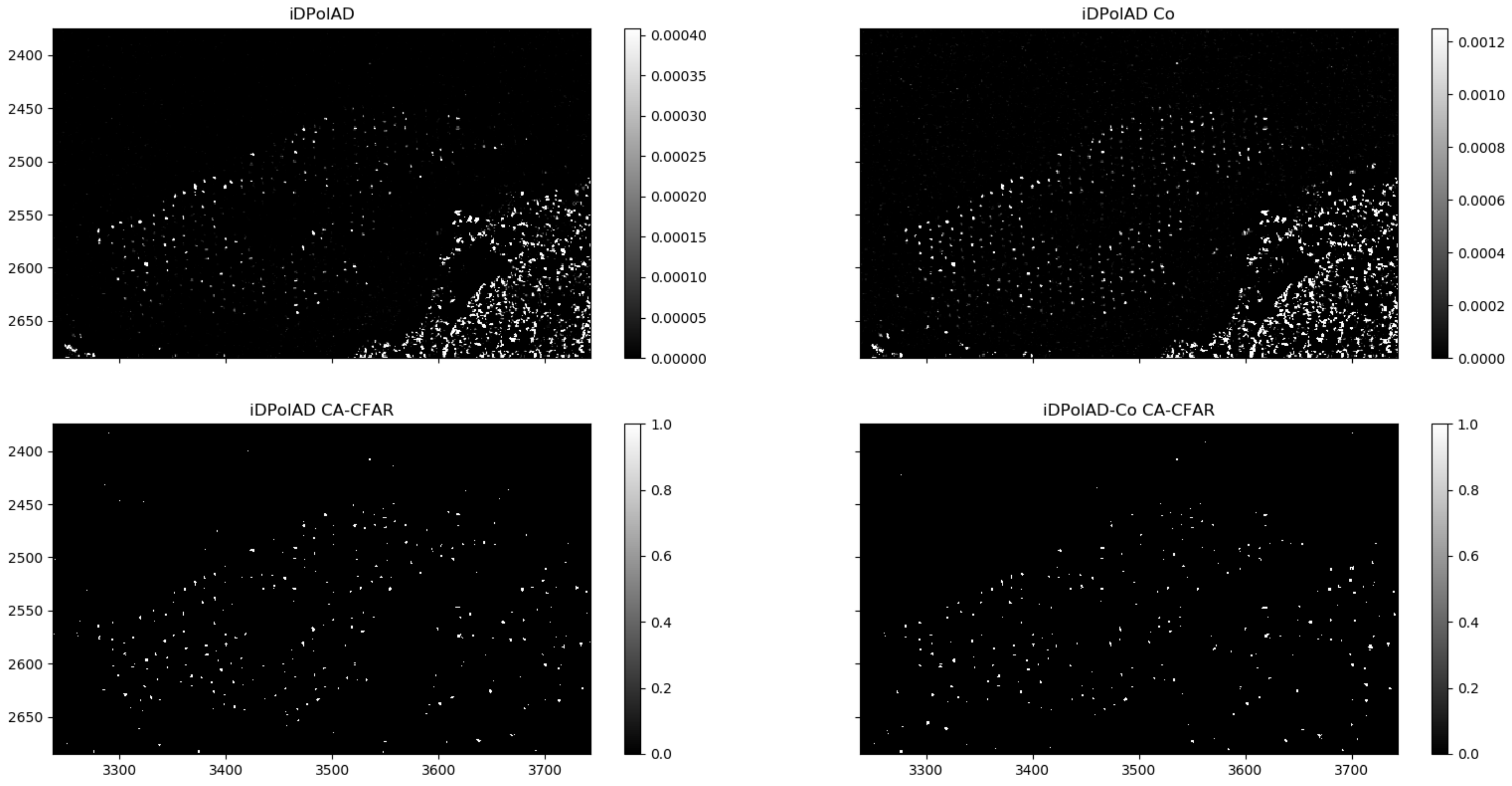
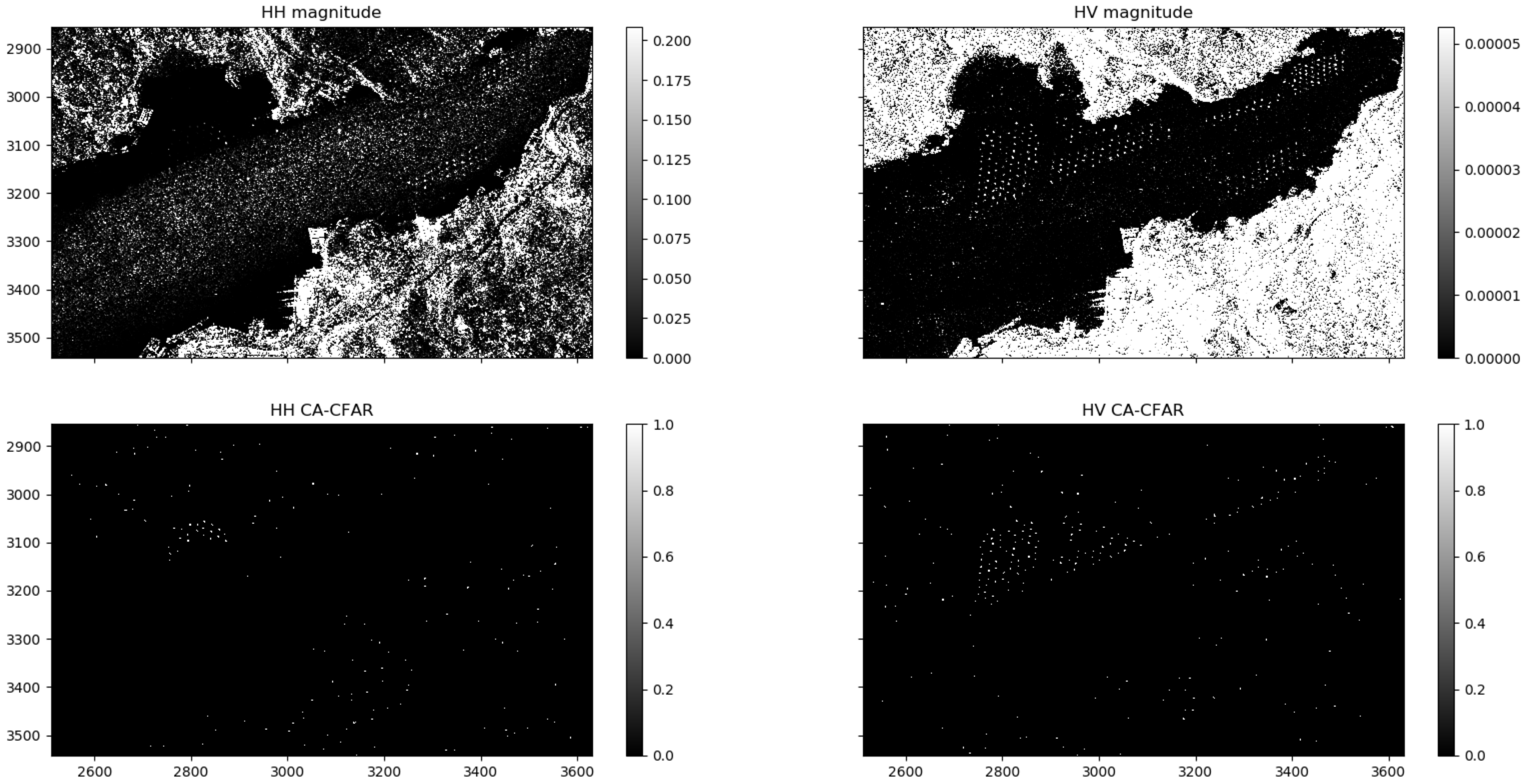
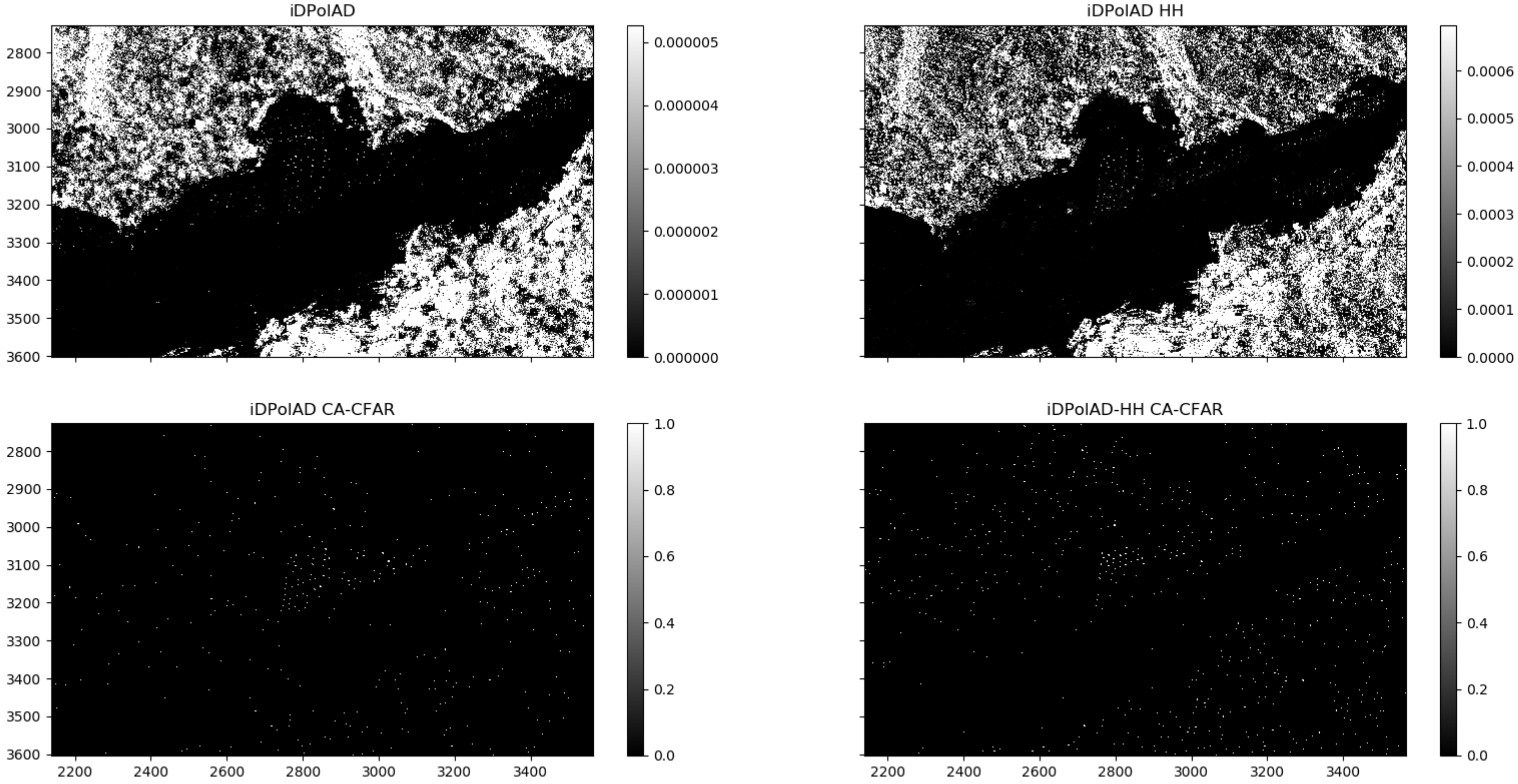


COSMO SkyMed Pingpong

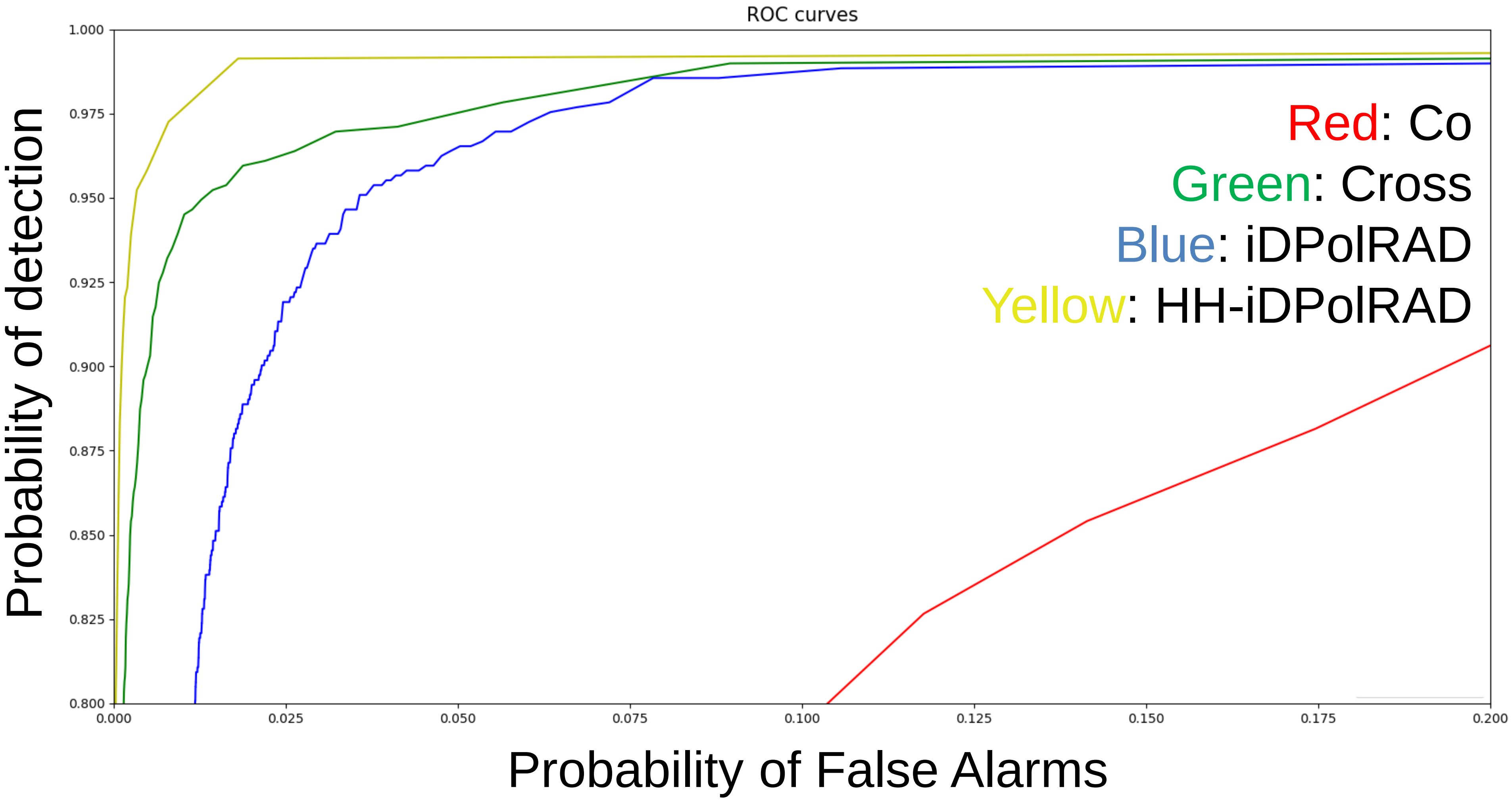
Acquired on the 1st January 2019. The resolution is 10x10m



COSMO SkyMed Pingpong



COSMO SkyMed Pingpong: ROC



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Conclusions

- ✓ We tested the iDPolRAD ship detector for the detection of shellfish platforms

- ✓ The methodology improves the contrast, ROC curve and CA-CFAR detection
  - ✓ However, the CA-CFAR is still missing several platforms.

- ✓ Sentinel-1 seems to provide very good detection performance despite the lower resolution of COSMO-SkyMed

Future work:

- ✓ We need to design a local methodology that detect targets very close to each other.

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Thank you very much for your attention.

Acknowledgement

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