



SHIP DETECTION AND SEA CLUTTER CHARACTERISATION USING X&L – BAND FULL-POLARIMETRIC AIRBORNE SAR DATA

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r e t u r n o n i n n o v a t i o n

CNES/ONERA study of Space System Concept for maritime surveillance.

Allow observation of non-cooperative boats with temporal revisits compliant with the objectives of reactivity for maritime surveillance

Concept proposed by CNES (French Space Agency) based on radar operating with a very wide swath -> implies grazing conditions of acquisition.

Only few radar data on maritime surfaces available with this geometry: CNES decided to carry out **dedicated campaigns**, with ONERA airborne SAR sensor:

- February 2009 – Mediterranean sea
- November / December 2011 – Atlantic Ocean

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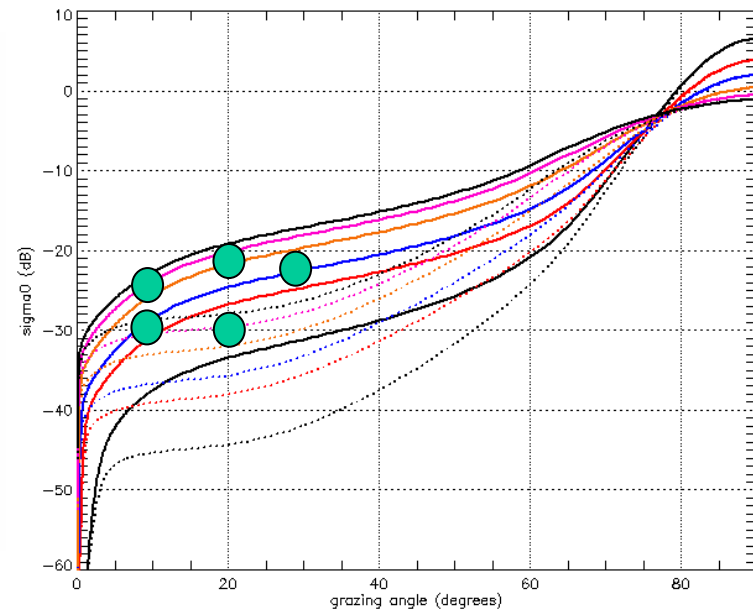
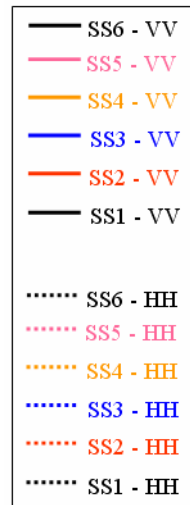
Only few radar data on maritime surfaces available with this geometry: CNES decided to carry out **dedicated campaigns**, with ONERA airborne SAR sensor:

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Context

Sea clutter Sigma0 vs:

- Incidence angle (mainly **low grazing angle**) Ward's modeling (*)
- Azimuth angle
- Sea state
- Polarization state
- Frequency band



Ship signature :

- Depending on size, polarization, line of sight ...



Detection capability



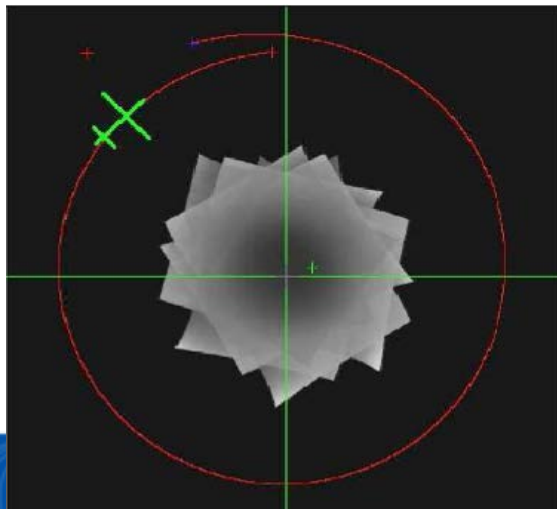
Absolute measurements: **calibration**

SAR facility / ONERA airborne sensor

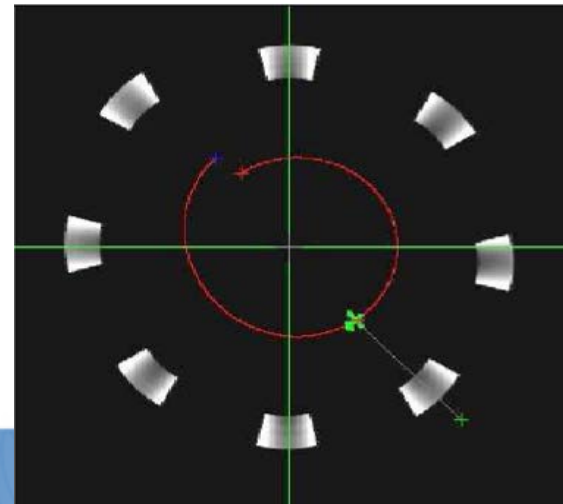
- Airborne platform: SETHI (ONERA)
 - 2 pods under the wings (Falcon 20)
 - Campaign: 5 flights during 6 days
- Acquisition parameters :
 - Waveform -> PolSAR dual-frequency **simultaneously**
 - X-band (Hh, Hv, Vh, Vv): B=300 MHz (rés 0.5m)
 - L-band (Hh, Hv, Vh, Vv): B=100 MHz (rés 1.5m)
 - Trajectory -> linear, octagonal and **circular**
- **Incidence angle: 80, 70 and 60°**



Internal looking: Ship RCS study

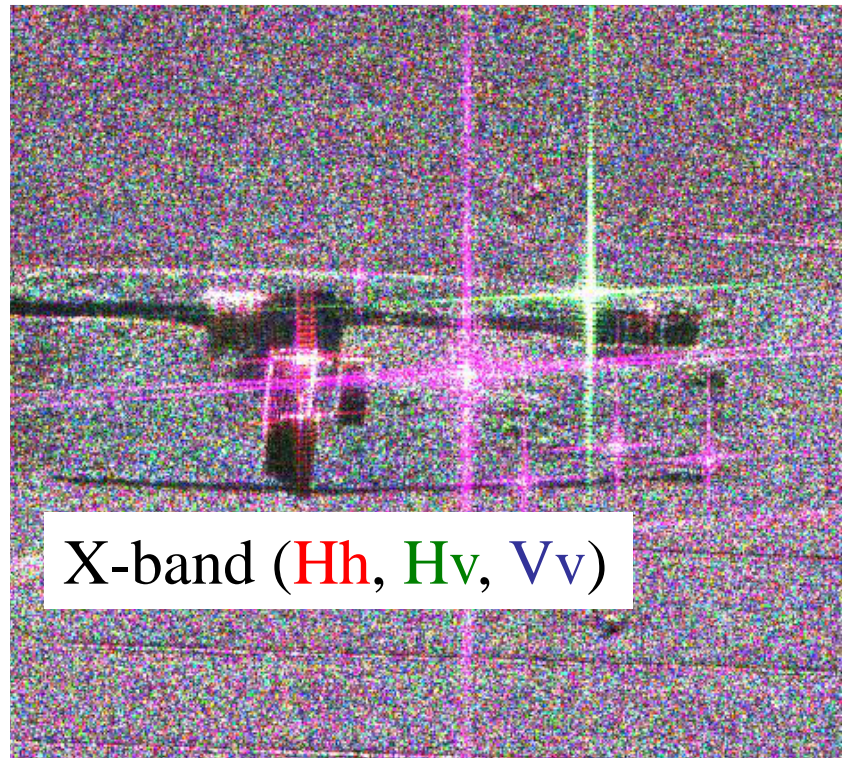


External looking: Sea clutter study



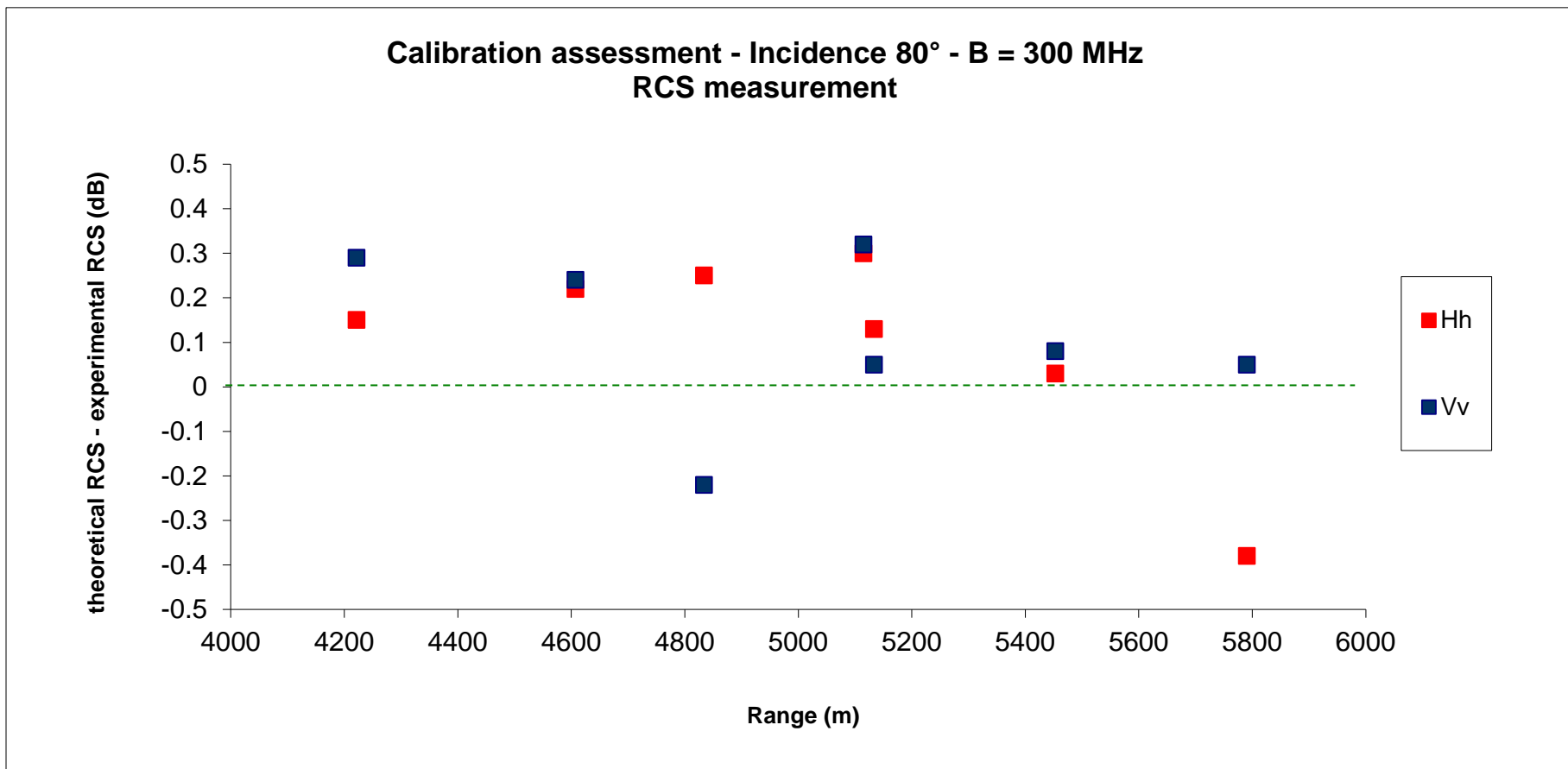
Dedicated calibration area: Lann-Bihoue

14 reflectors along the swath: 1 dihedral and 13 trihedrals

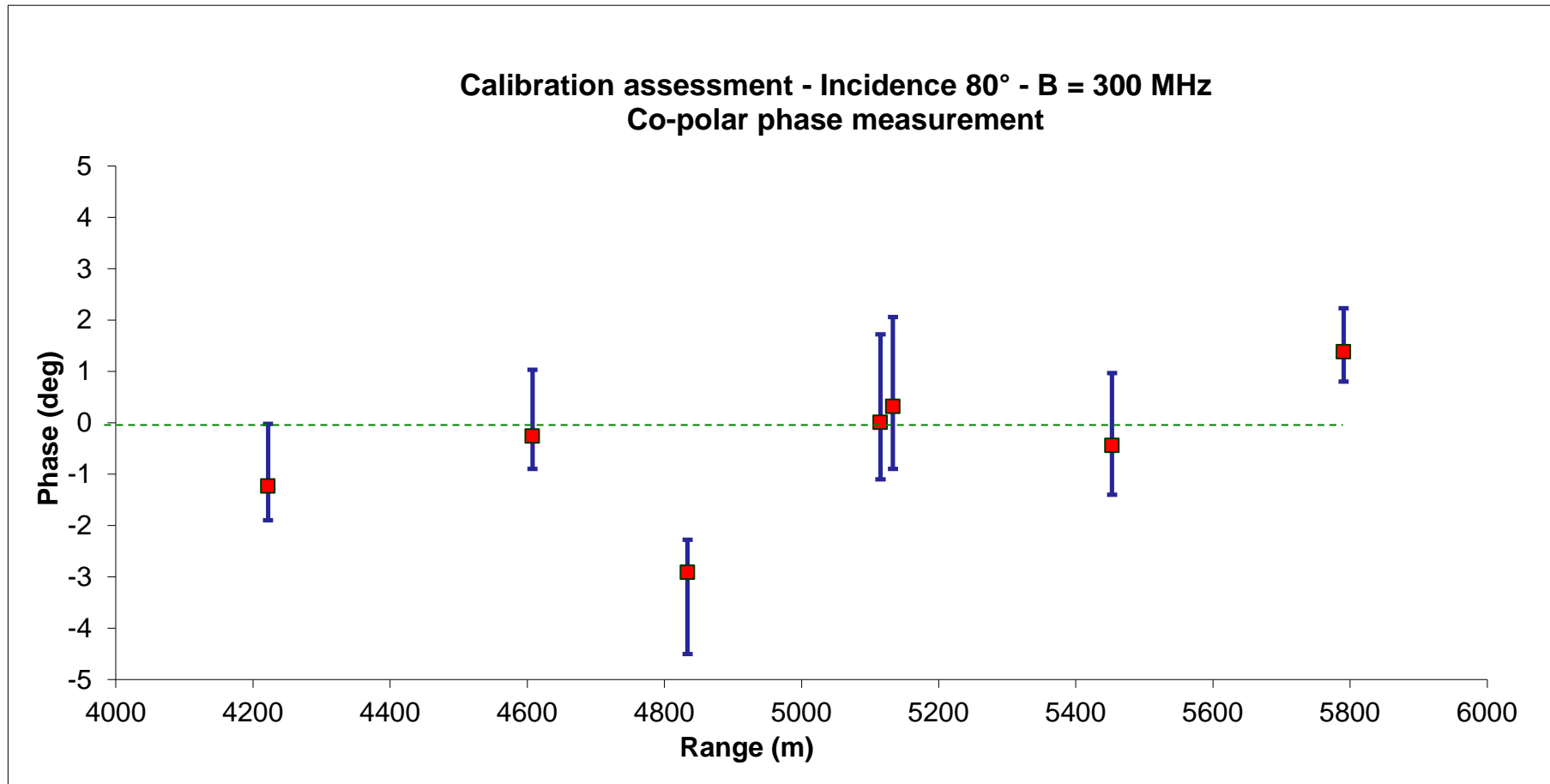


X-band (Hh, Hv, Vv)

Response stability in the swath: **Amplitude stability**

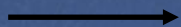


Response stability in the swath: **Co-polar phase stability**



Campaign of acquisition: region of interest

#1



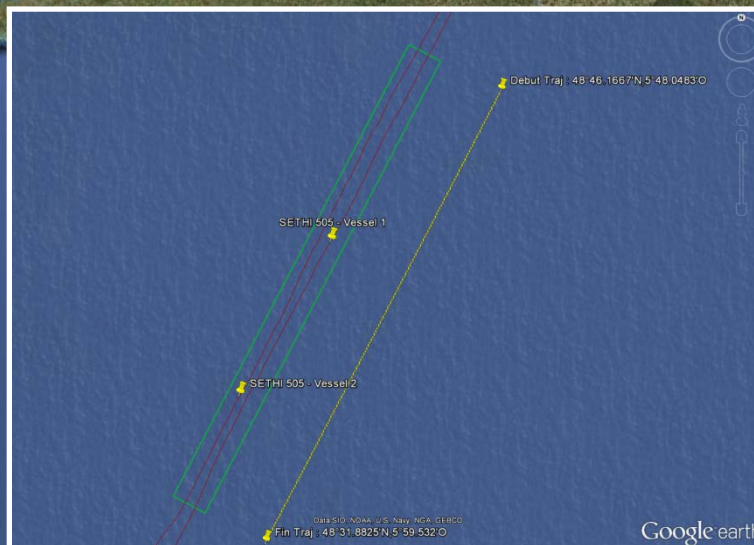
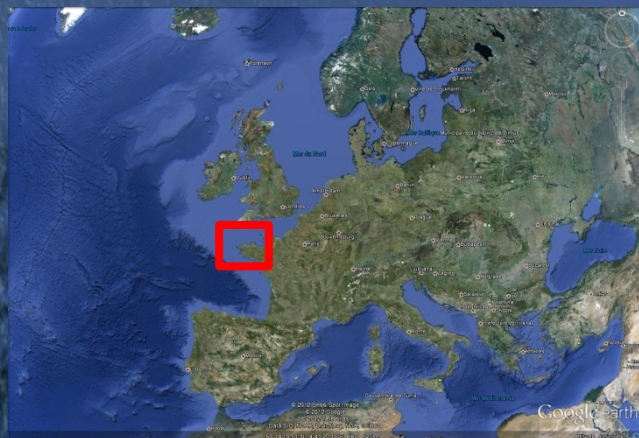
#1 Ushant traffic separation scheme:

3 flights -> sea state 4-5 & 5-6

Boat -> large size (>100m)

Ground truth:

- Sea state: buoy, Météo France, ...
- AIS (provided by CETMEF)



Data SIO, NOAA, U.S. Navy, NGA, GEBCO

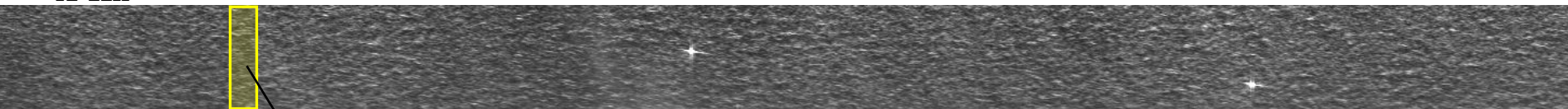
47°56'12.27"N 4°10'13.21"O élév. 20 m

American Shelf

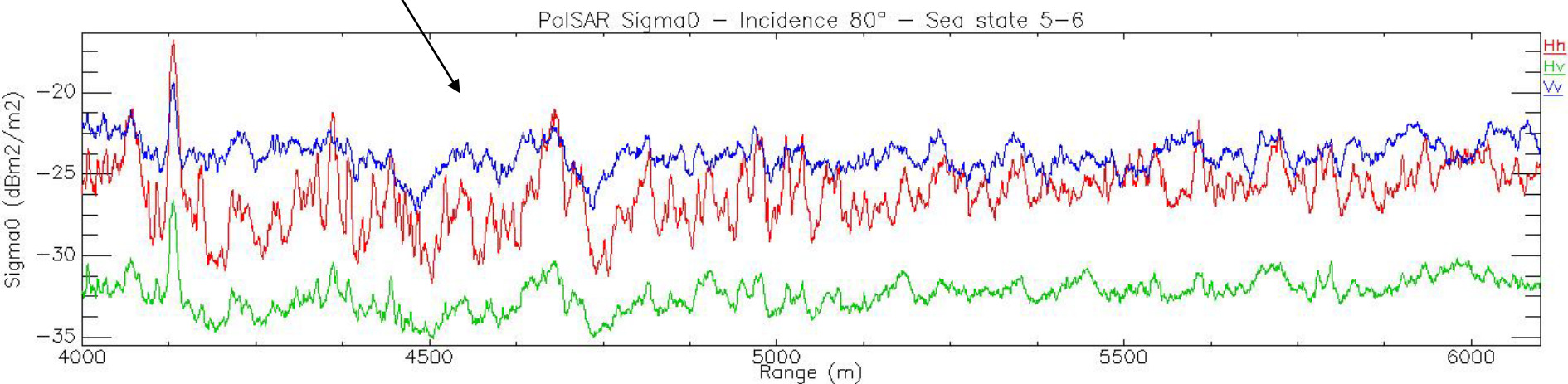
Altitude 318.81 km

#1 Ushant traffic separation scheme: incidence 80°

X-Hh

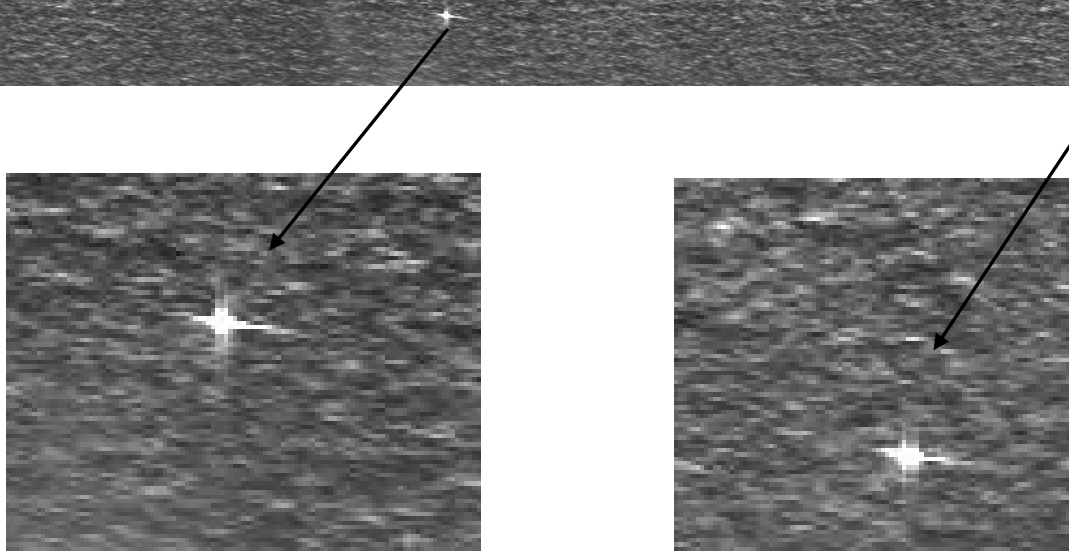


30 km



#1 Ushant traffic separation scheme: incidence 80°

X-Hh



AIS		
	Ship #1	Ship #2
Lenght	105m	89m
Heading	212°	212°
Speed	7.2knts	7knts
Experimental RCS		
Hh	50 dBm ²	48 dBm ²
Hv	25 dBm ²	26 dBm ²
Vv	42 dBm ²	42 dBm ²

Campaign of acquisition: region of interest

#2 10 NM South of *Le Guilvinec* :

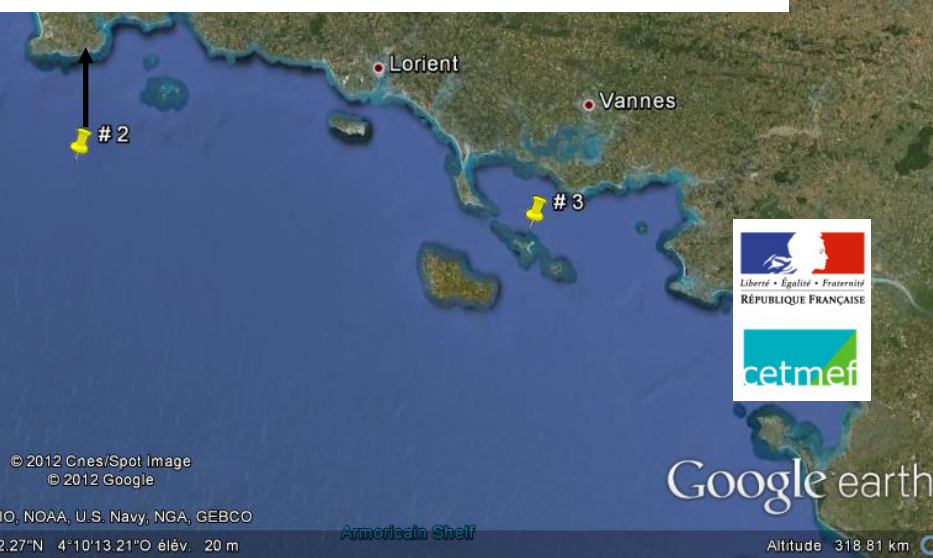
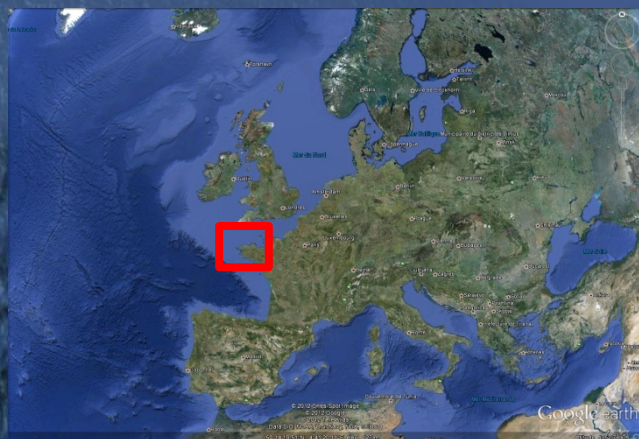
1 flight -> sea state 3-4

Boat -> 2 cooperative boats (15 & 20m)

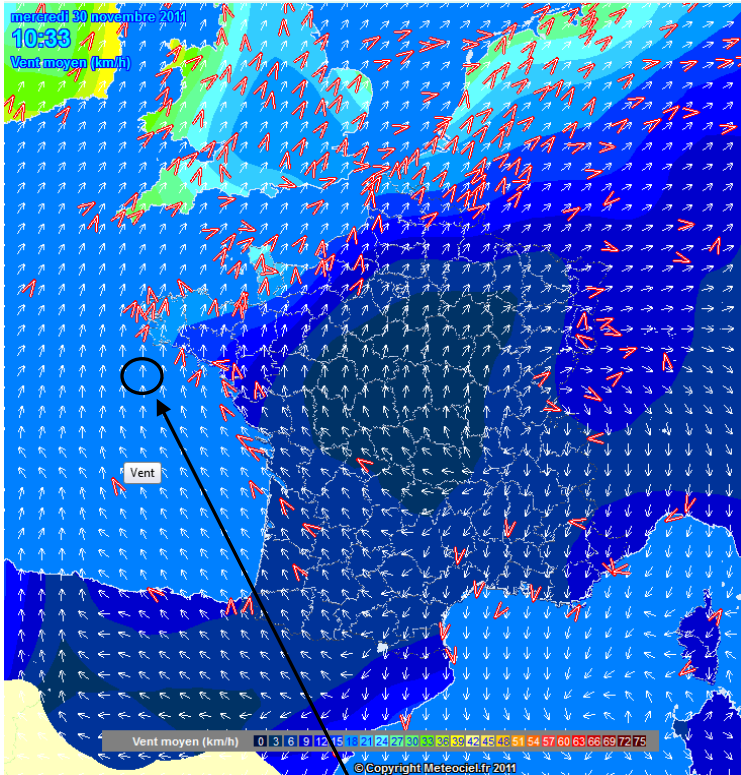
Circular acquisitions over clutter & cooperative boats

Ground truth:

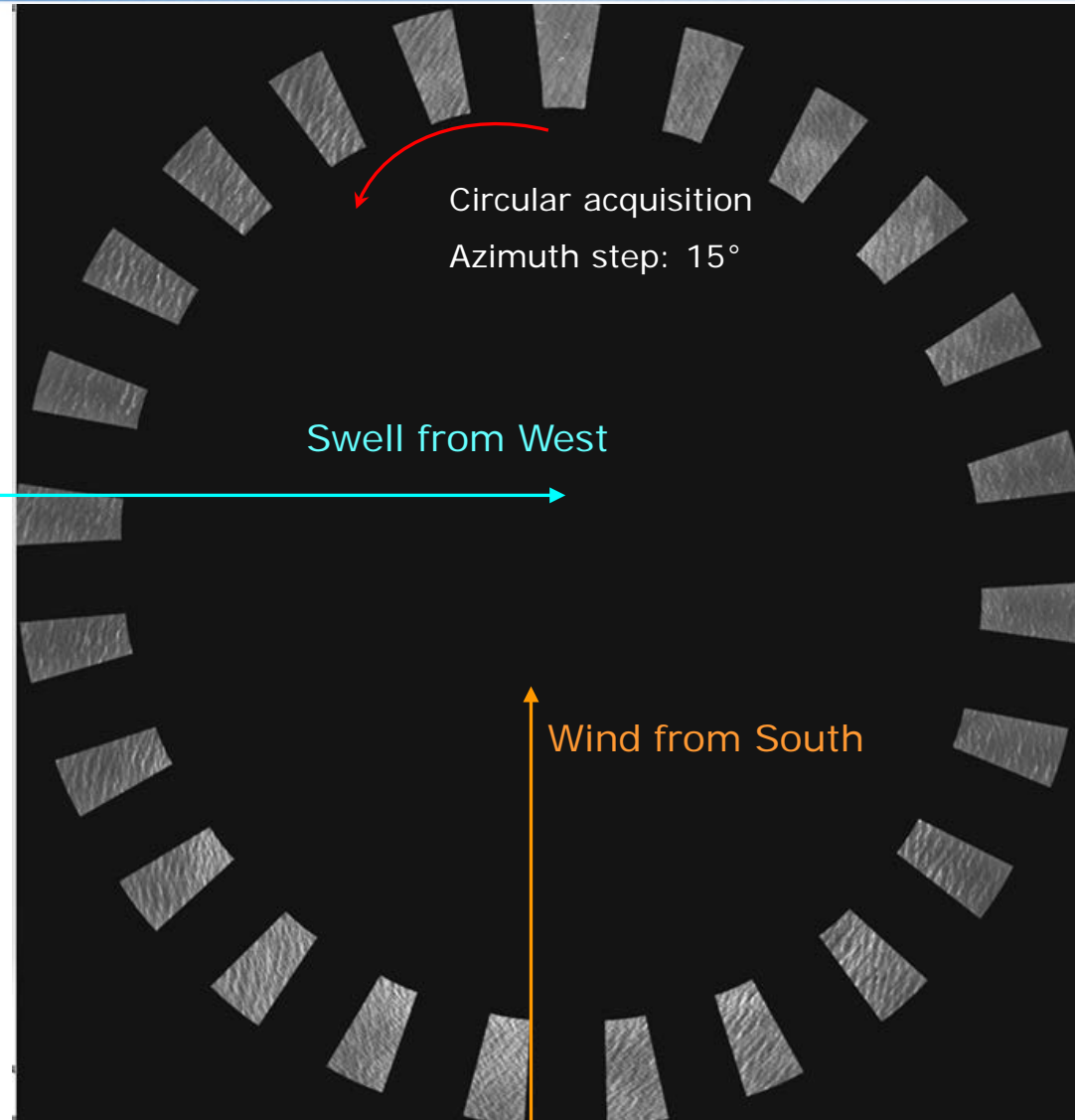
- Tracking GPS for both cooperative ships and an Inertial Measurement Unit installed into one of them.
- AIS signal from the non-cooperative boat (CETMEF).
- Sea state: buoys, Signal station, Météo France, ...



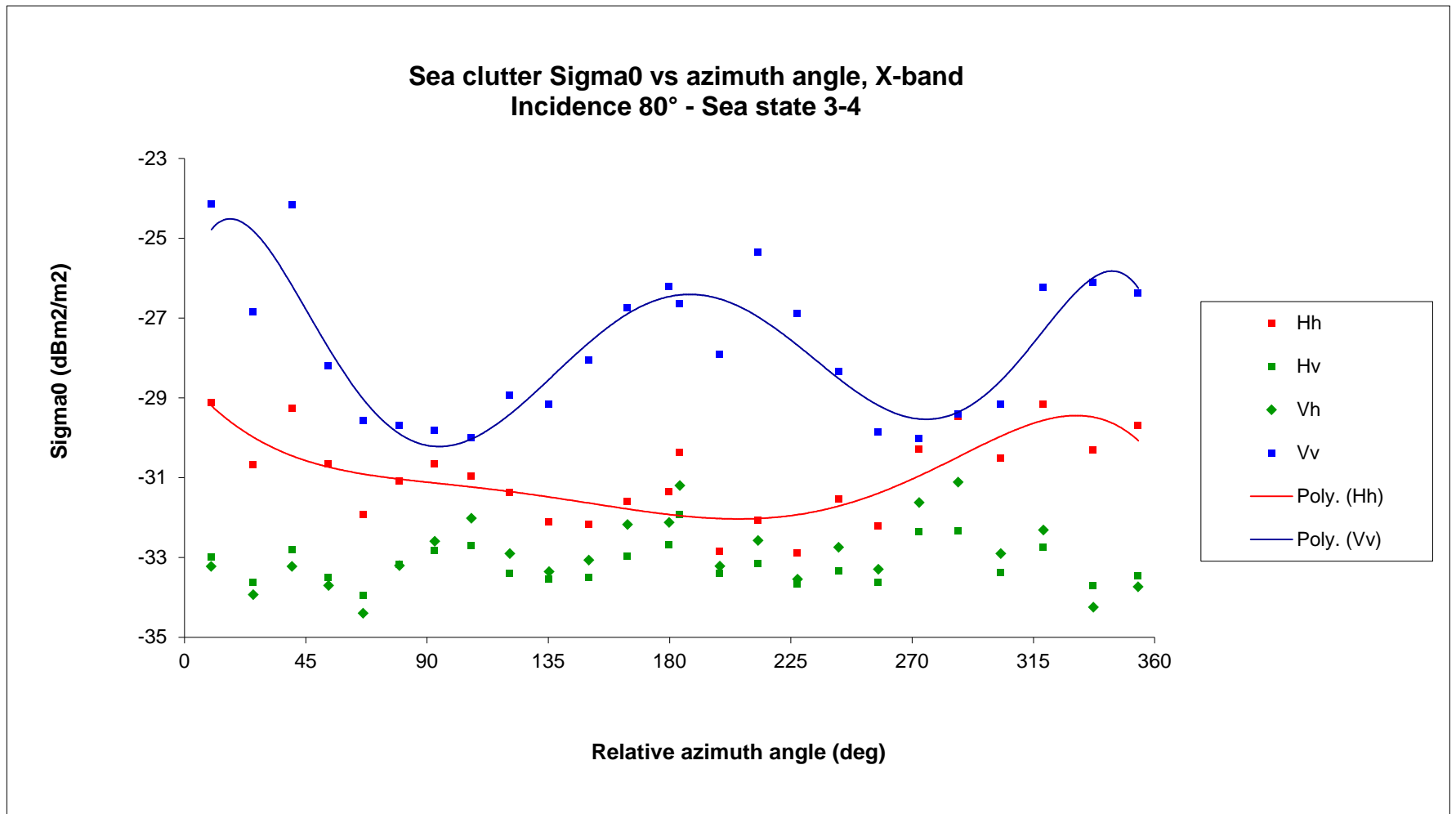
Ground truth for #2: sea state information



Wind map

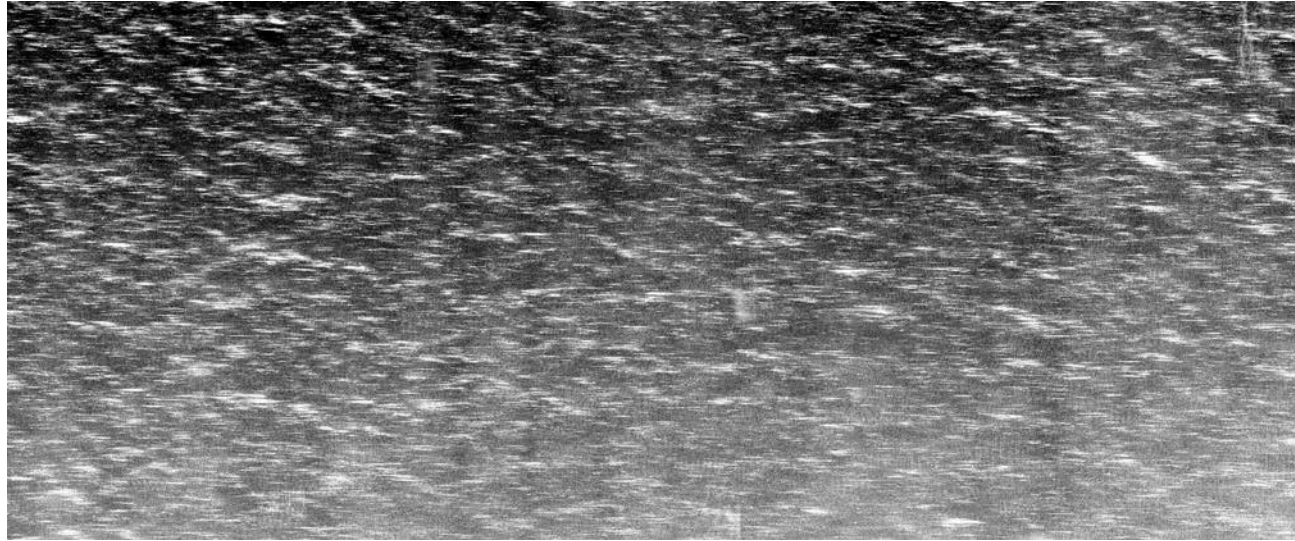


Sea clutter over the full 360° in azimuth: 80°



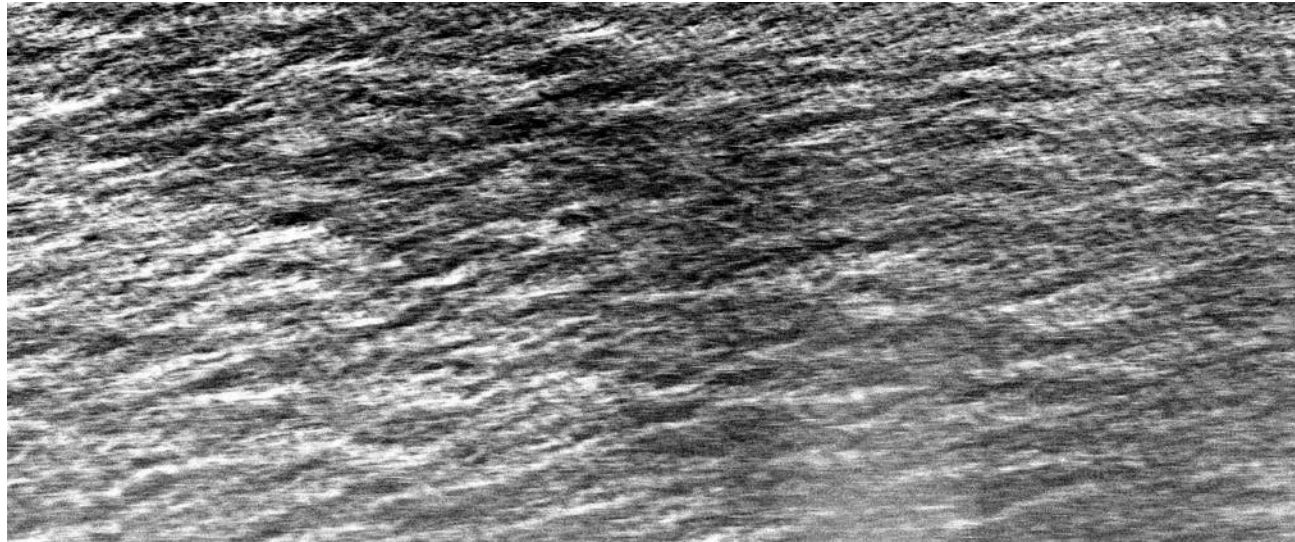
Azimuth 0° ⇔ Upwind / Azimuth 180° ⇔ Downwind

Sea clutter response: the physical behavior



Incidence 80°

Hh polarization



Vv polarization

Ground truth for #2: cooperative boat

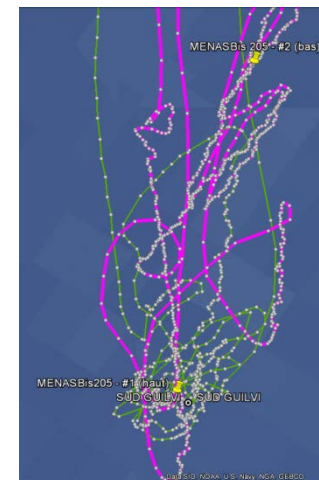
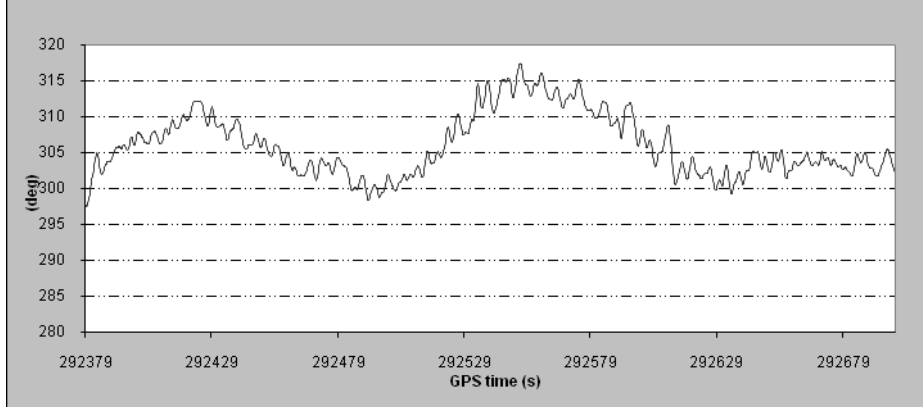
Rescue (15.5 m)



Trawler (16m)

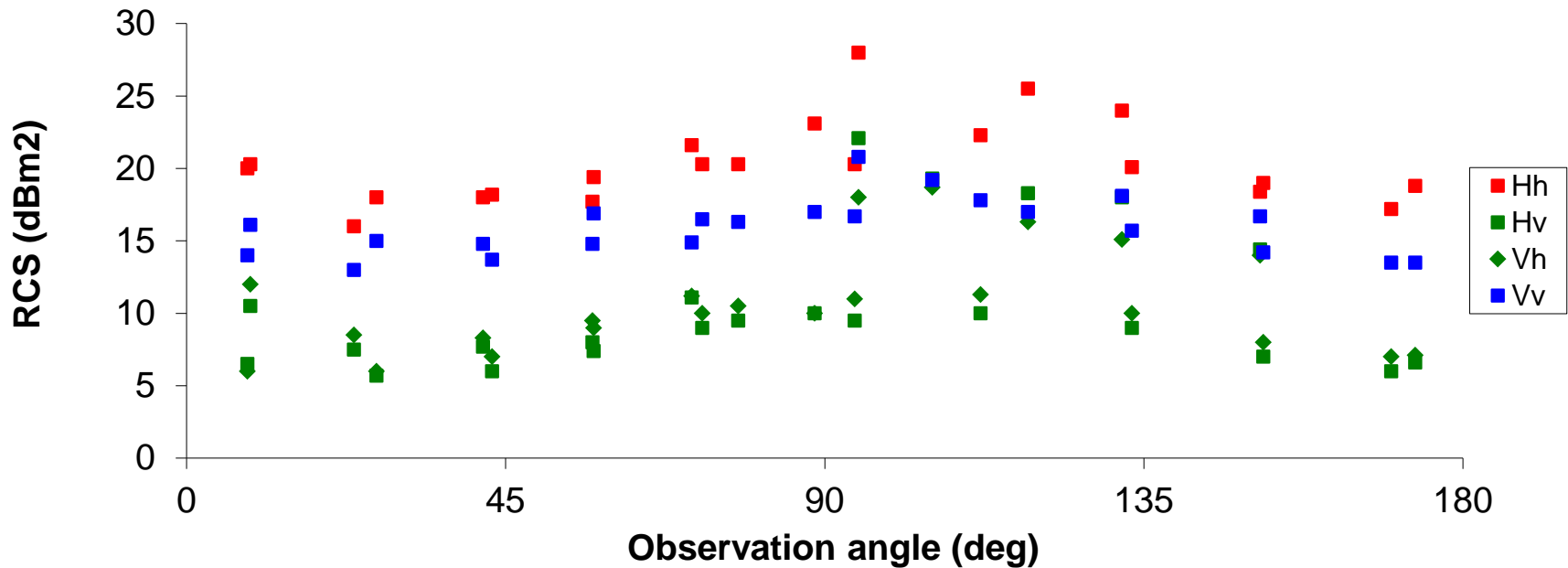


MENASBis Flight 2 run 5 : SNSM ship - Heading



Ship measurements over the full 360° in azimuth: 70°

Flight 2 run 8: incidence 70° - cooperative boat (SNSM)



90° : cross viewing
0° : front viewing
180° : back viewing

Maximum RCS: cross viewing
Dihedral effect (max Hv) in one of the two sides

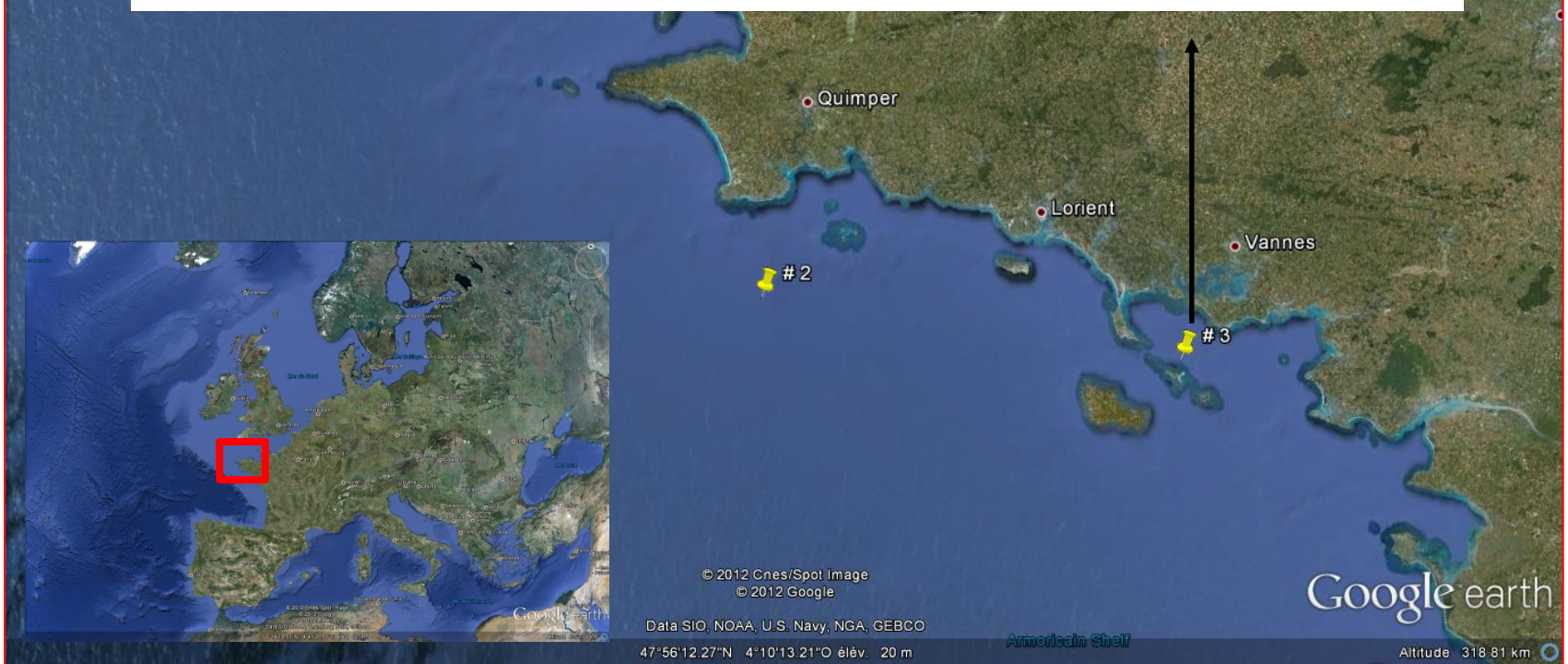
Cam #3 Around Quiberon :

1 flight -> sea state 2-3

Boat -> opportunity and 4 Speedboats

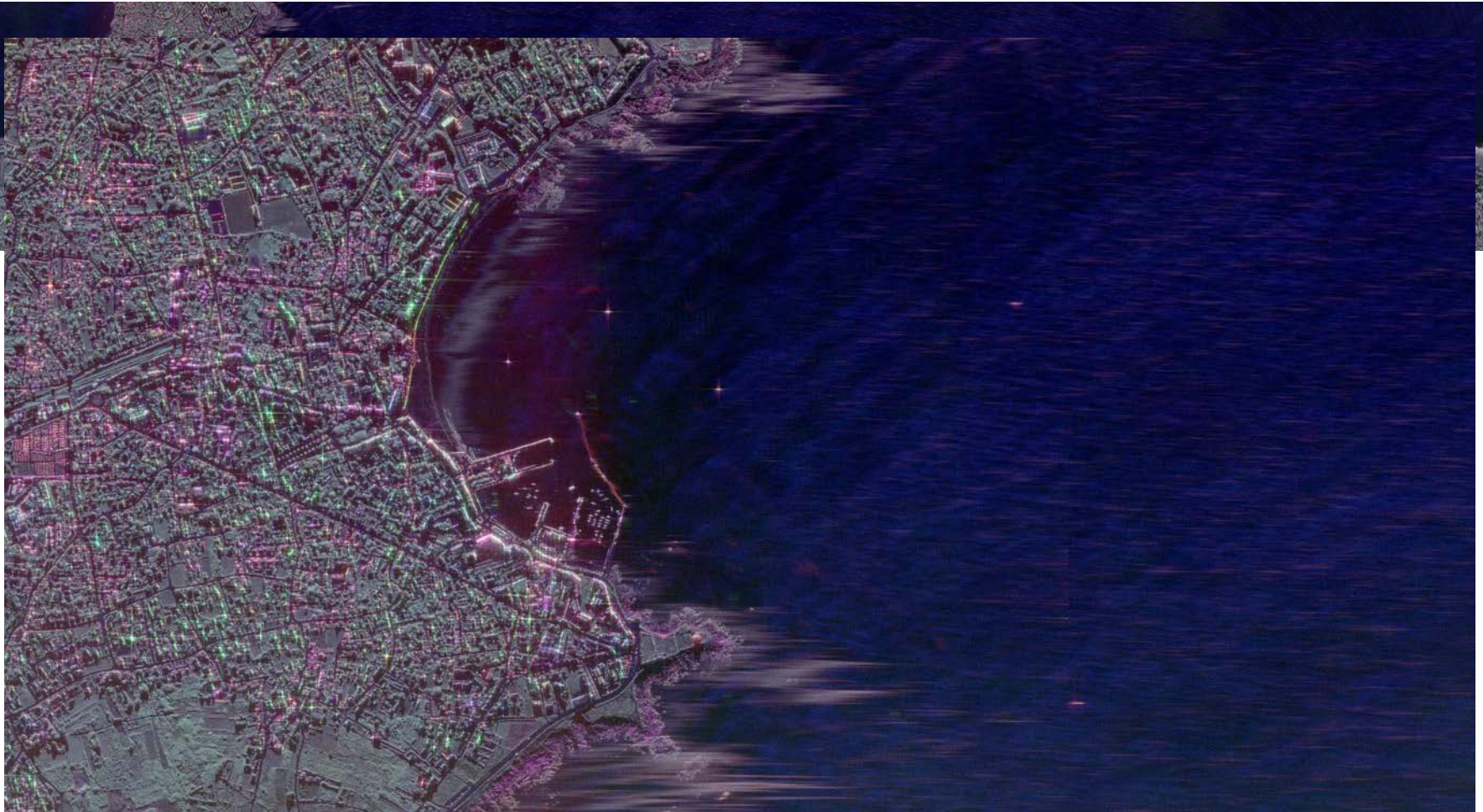
Ground truth:

- Tracking GPS for cooperative ship
- AIS signal from the non-cooperative boat (CETMEF).
- Sea state: buoys, Signal station, Météo France, ...



#3 : Quiberon bay : incidence 70°

X-band polarimetric SAR imagery (R, G, B) = (Hh, Hv, Vv)



#3 : Quiberon bay : incidence 70°

X-band polarimetric SAR imagery (R, G, B) = (Hh, Hv, Vv)



Opportunity boat (48m, 12 knts):

$$\text{RCS(Hh)} = 41.2 \text{ dBm}^2$$

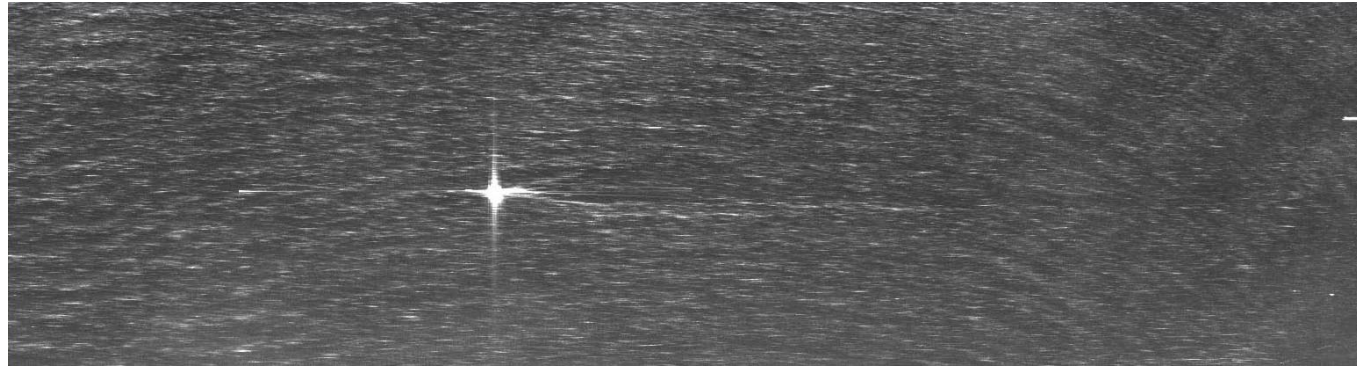
$$\text{RCS(Hv)} = 22.0 \text{ dBm}^2$$

$$\text{RCS(Vh)} = 22.3 \text{ dBm}^2$$

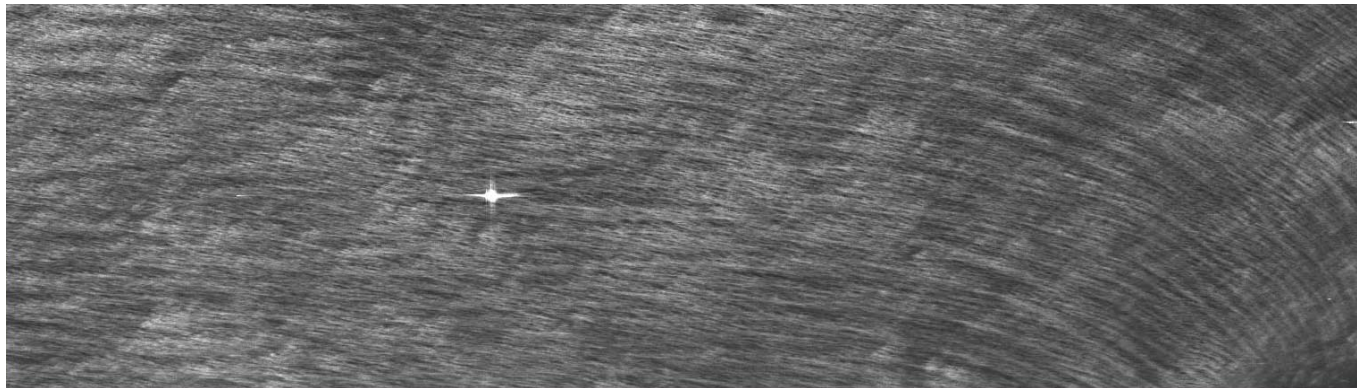
$$\text{RCS(Vv)} = 36.9 \text{ dBm}^2$$

Sea clutter response: the physical behavior

Incidence 70°



Hh polarization



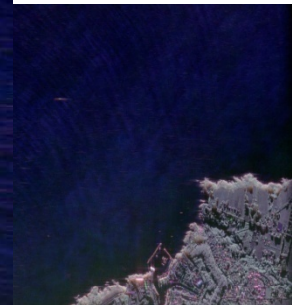
Vv polarization

#3 : Quiberon bay : **incidence 70°**

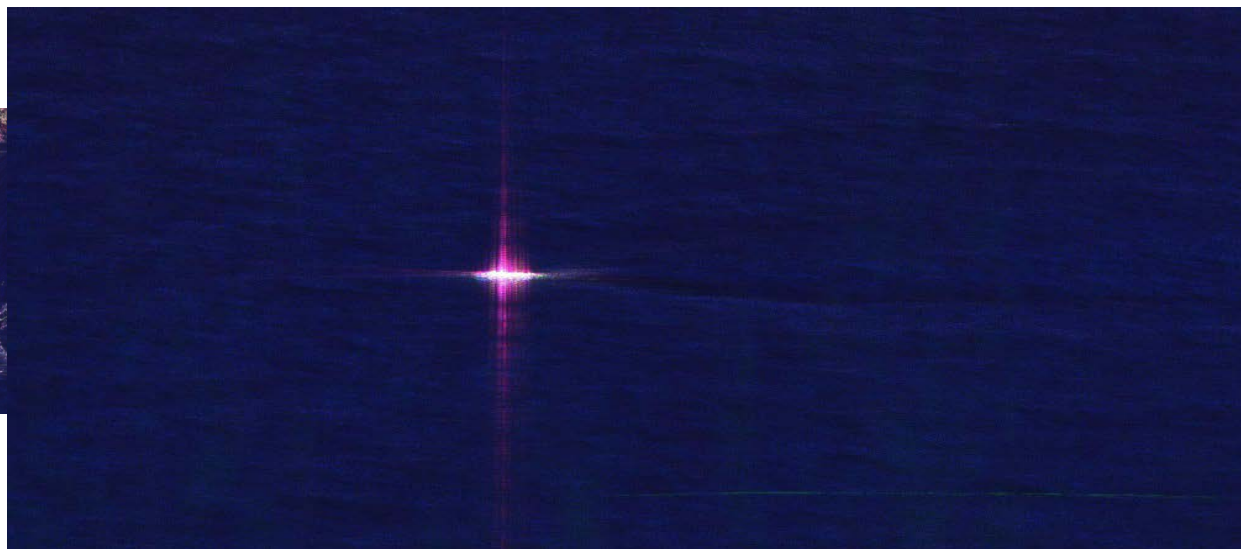
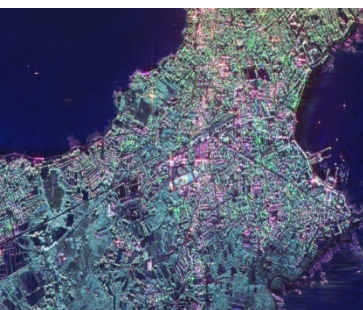
X-band



Vv)



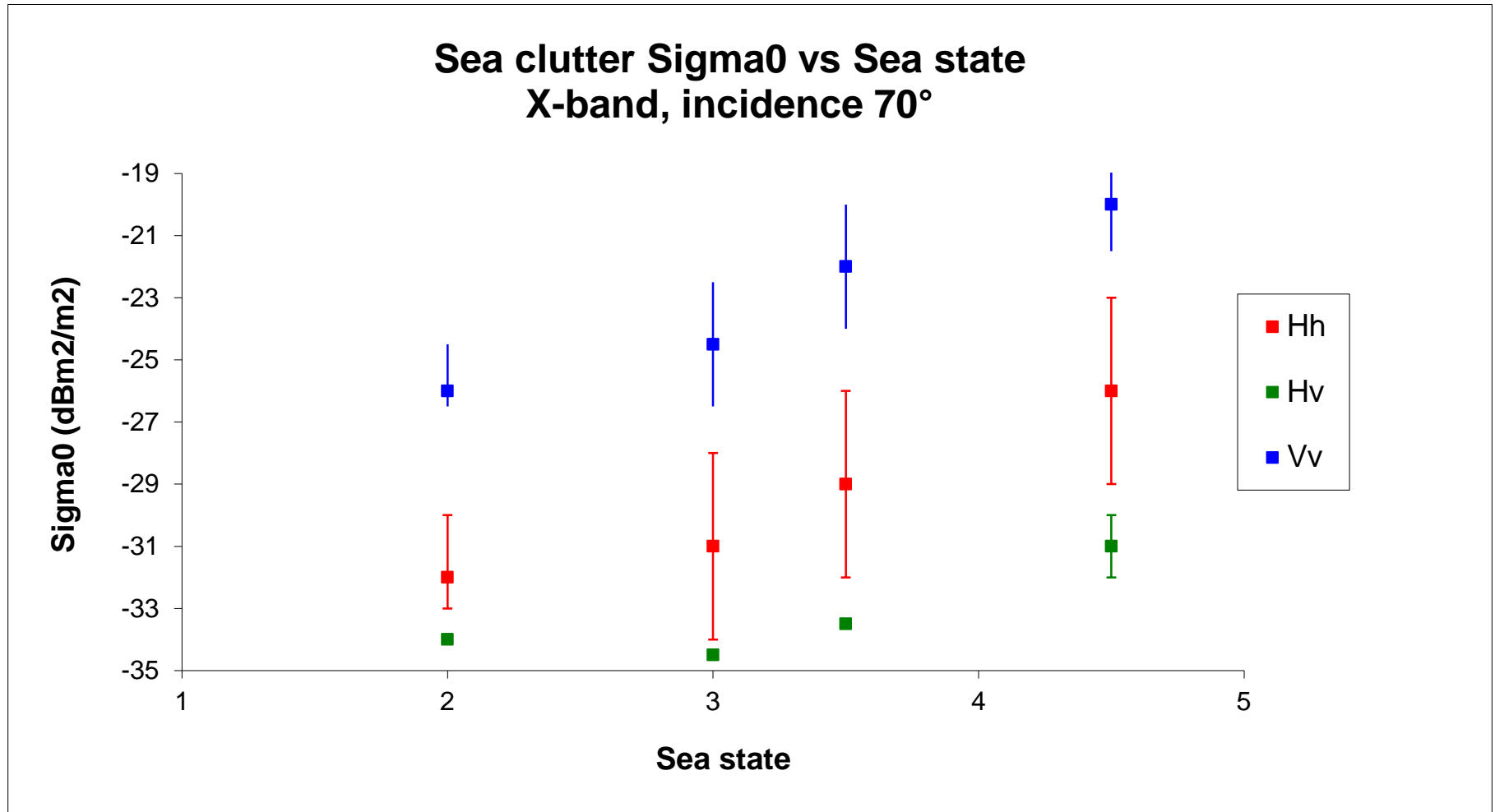
L-band



Vv)



Sea response: multi-temporal analysis



X-band SAR data now processed and calibrated

Ongoing work:

- Sea clutter response analysis (sea state, angles, polarization) – done
- Ship RCS measurements (type of boat, angles, polarization) – ongoing
- Detection capability (Ship to Clutter ratio) – to do

Future work:

- Polarization synthesis -> study the best polarization state (Em & Re)
- Detection algorithm
- Multy-frequency analysis

Conclusion

ONERA has performed an extended airborne SAR campaign of acquisition dedicated to maritime surveillance analysis

PolSAR data perfectly calibrated (amplitude and phase) at low grazing angle

A special effort has been made on ground truth (sea state, wind, boat ...)

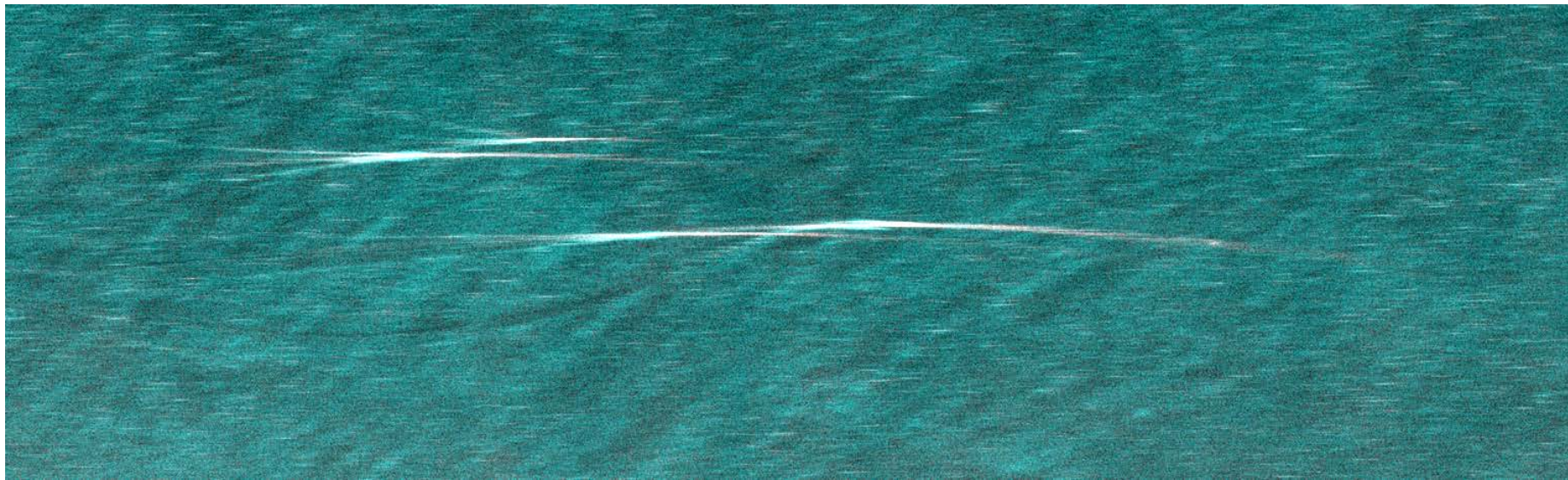
Step 1 : Sea clutter response is being analysed,

Step 2 : Ship response will be analysed soon,

Step 3 : Detection capability study, polarization synthesis ...

Speedboats

X-band polarimetric SAR imagery (R, G, B) = (Hh, Vv, Vv)



Speed: 45 knt

