→ POLINSAR 2013
The 6th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry

Combining polarimetric channels for better ship detection results

Tonje Nanette Arnesen Hannevik
Norwegian Defence Research Est. (FFI)

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European Space Agency

Outline

- Introduction:
  - Norway and ship detection
  - Radar satellites
- AEGIR – automatic ship detection tool
- Polarimetry and ship detection
- Dual-polarisation and results
- Quad-polarisation and results
- Conclusions

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Introduction

- Norway's large ocean areas
- Increased shipping and fishing
- Traditionally: Coarse resolution
- Recently: Space-based AIS -> higher resolution data

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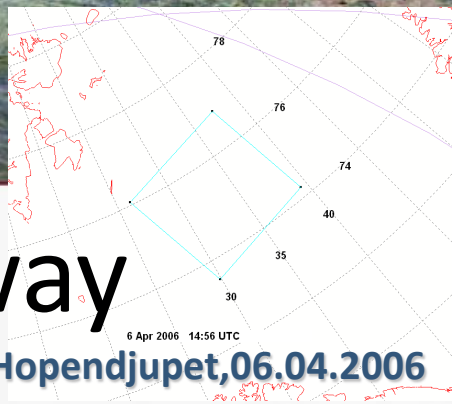
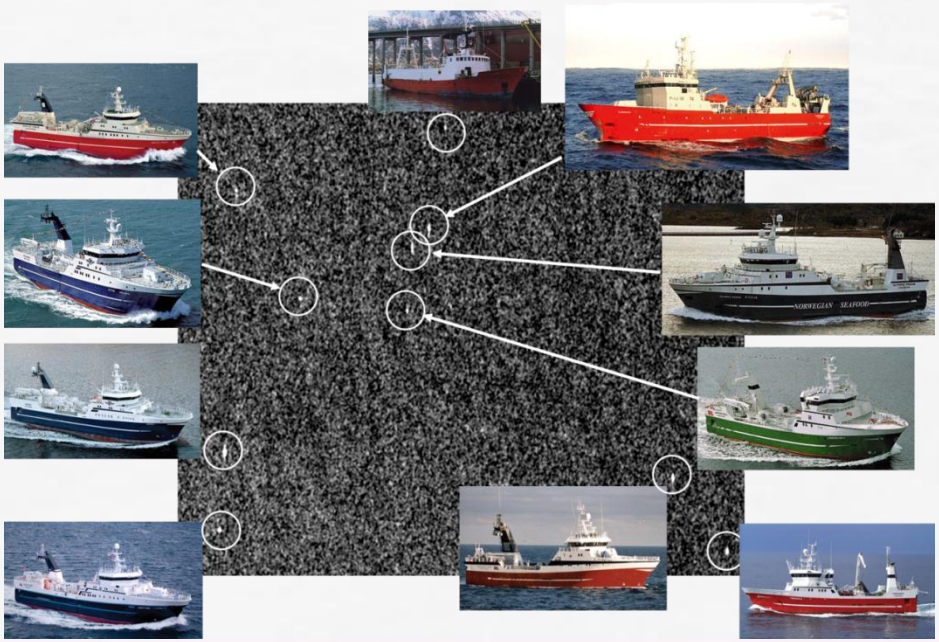


Hopendjupet,06.04.2006

Fisheries surveillance in Norway

- Image volume increased to appr. 1800-1900 images/year
- AIS and SAR – supplement each other
- SAR and AIS used to plan allocation of other resources



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Aegir

- Automatic ship detection algorithm
- Developed at FFI (Olsen, Brekke, Hannevik)

- ENVISAT, RADARSAT-1 and RADARSAT-2
- TerraSAR-X, TanDEM-X and Cosmo SkyMed will be implemented

- Detects bright targets:
  - In all polarisation channels separately
  - after combining the polarisation channels

- Manual verification step
- Extra analyses can be done manually

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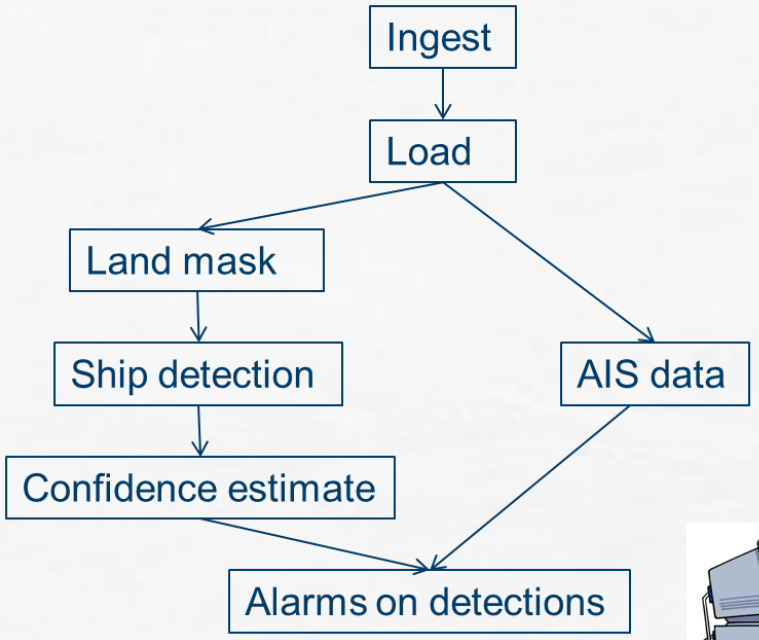
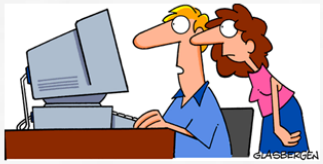
Aegir – Step by step

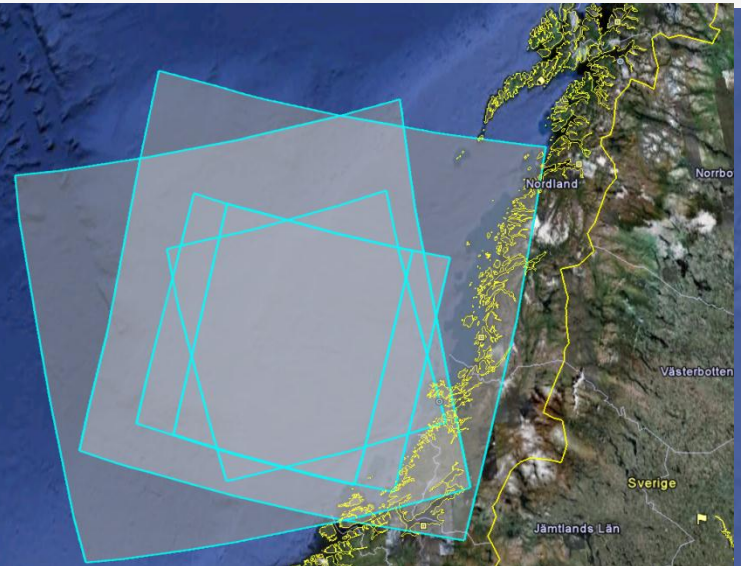




- Analyses each polarisation channel
- Fusion of the results before detection
- Comparison with AIS information

Data for this study (1)

- 33 RADARSAT-2 ScanSAR dual-polarisation images
- 26 RADARSAT-2 quad-polarisation images
- Analysis done both automatic and manually for both dual-pol and quad-pol
- Norne oil production field outside west coast of Norway



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Data for this study (2)

- 3 different vessel sizes:

1. **Large vessel**: Norne Field: Oil production vessel Norne FPSO moored to the ocean floor
2. **Medium vessels**: Eddy Fauna (108 m) & Island Wellserver (116 m)

3. **Small vessels**: Ocean Prince (65 m) & Ocean King (75 m)

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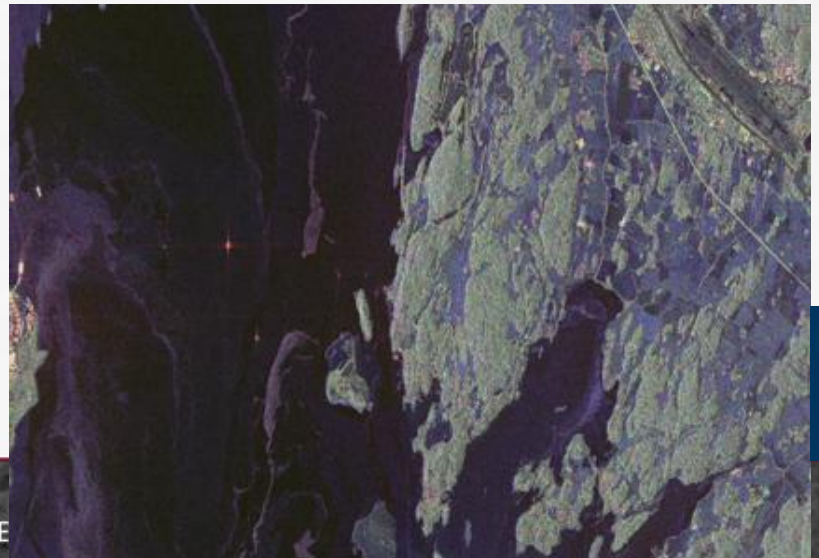
Polarimetry and ship detection

- Polarisation is an important factor
- Reflections can be even (double) and odd (single and triple)
- Corners, edges, cables
- Land, vessels, ocean and ice scatter differently in different polarisation channels
- Combining the polarisation channels increase the detection probability



Dual-polarisation

- Less information, but better for operational use due to wider swath width
- Automatic ship detection (AEGIR) and dual-polarisation
  1. Look at the polarisation channels separately and combine the ship detection results afterwards
  2. Combining the two channels before the ship detection is done by multiplying the amplitude of the two channels and dividing by a constant (Eldhuset, FFI):

$$\frac{|\text{co} - \text{pol}| \cdot |\text{cross} - \text{pol}|}{\text{const}}$$

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Combining two polarisation channels

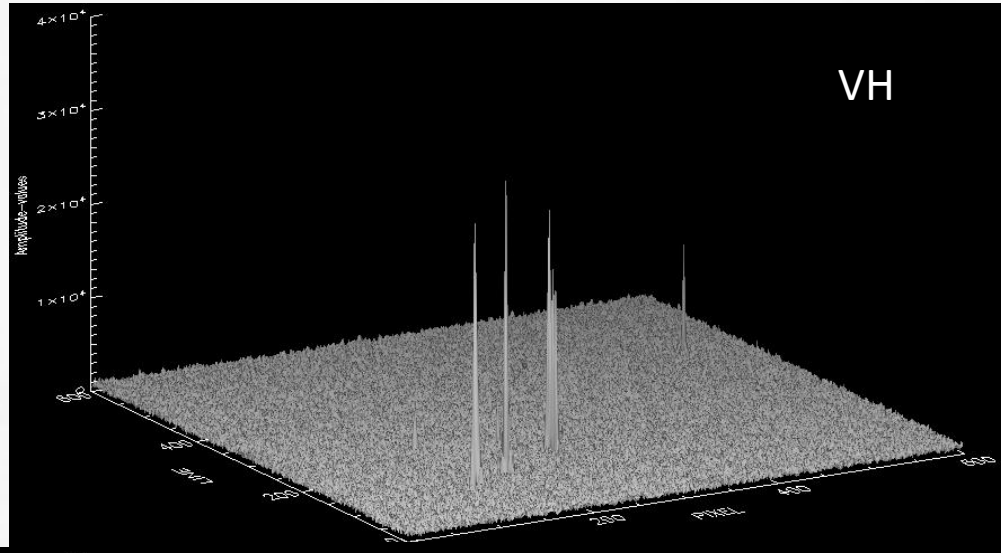
- Combining two channels
  - ship to sea contrast enhanced in most cases
- Constant – average value of typical sea scene

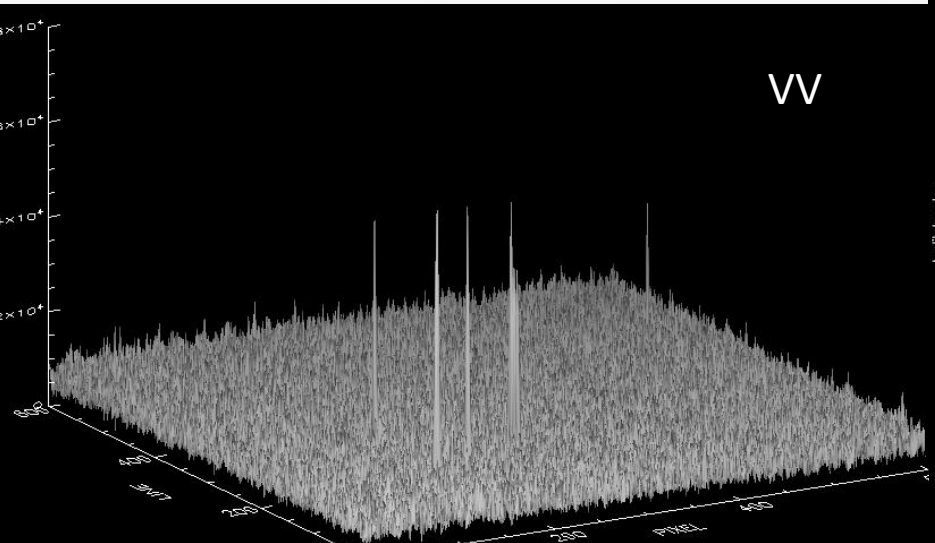
- 5/4-10 ScanSAR Narrow VV/VH:

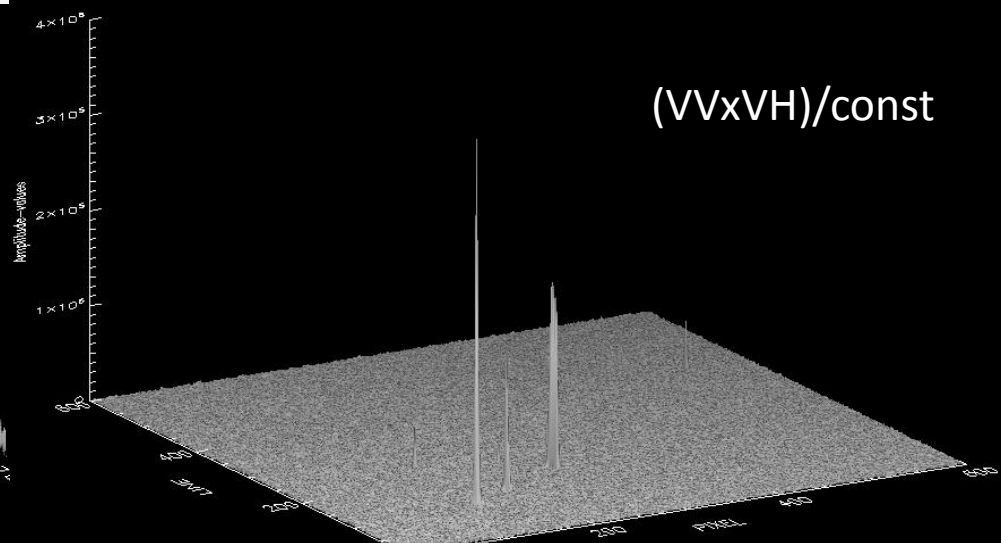
Channel	Max amplitude	Mean sea	R = Max ampl / mean sea
|VV|	53 985	4 316	13
|VH |	27 702	792	35
|VV|·|VH|/const	4,80639*10^8	3 418 713	141

Dual-pol March 31st 2010

- 600 pixels x 600 pixels
- VV, VH, (VVxVH)/const
- Contrast Norne FPSO:
  - VV: 8.7
  - VH: 34.7
  - Combined: 39.7







Co-, cross-pol and combined for low and medium incidence angles

					R = Maximum amplitude / mean sea			
Date	Time	Mode	A/D	Inc. angle	HH	VV	HV/ VH	Co x cross / const
14/4-10	16:39:35	SCN	A	Low		5	20	19
7/4-10	16:43:44	SCN	A	Low		8	33	69
15/4-10	06:18:07	SCN	D	Low		4	14	4
25/6-10	16:39:37	SCN	A	Low	6		30	22
26/6-10	06:18:08	SCN	D	Low	4		28	10
23/12-09	06:14:02	SCN	D	Low/med	8		26	47
31/3-10	16:47:54	SCN	A	Low/med		9	35	40
22/4-10	06:13:58	SCN	D	Low/med		12	27	64
12/7-10	16:43:01	SCN	A	Low/med	7		23	19
20/12-09	06:01:09	SCW	D	Med	8		11	24
30/12-09	06:09:52	SCN	D	Med	8		24	74
5/4-10	06:09:47	SCN	D	Med		13	35	141
30/6-10	06:09:52	SCN	D	Med	43		34	908
5/7-10	16:47:10	SCN	A	Med	14		29	98
10/7-10	06:09:47	SCN	D	Med	19		37	589
28/6-10	16:51:21	SCN	A	Med	21		20	134

Co-, cross-pol and combined for high incidence angles

					R = Maximum amplitude / mean sea			
Date	Time	Mode	A/D	Inc. angle	HH	VV	HV VH	Co x cross / const
18/12-09	16:51:10	SCN	A	Med/high	14		21	91
24/3-10	16:52:04	SCN	A	Med/high		51	24	7942
12/4-10	06:05:37	SCN	D	Med/high		8	26	47
17/4-10	16:52:05	SCN	A	Med/high		19	14	115
24/4-10	16:47:56	SCN	A	Med/high		14	24	78
23/6-10	06:05:38	SCN	D	Med/high	67		40	2286
14/12-09	17:08:56	SCW	A	High	24		24	175
10/4-10	16:56:14	SCN	A	High		23	41	172
21/6-10	16:55:31	SCN	A	High	19		39	430
3/4-10	17:00:24	SCN	A	High		24	28	295
19/4-10	06:01:27	SCN	D	High		15	26	83

Quad-polarised data (1)

- More complete information
- Scattering matrix can be decomposed in many ways
- Pauli decomposition
  - Surface scattering - |HH+VV|
  - Cross-pol - |HV| or |VH|
  - Double bounce - |HH-VV|
- Circular basis decomposition

$$\begin{bmatrix} S_{RR} & S_{RL} \\ S_{LR} & S_{LL} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} 1 & -i \\ -i & 1 \end{bmatrix}\begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}\begin{bmatrix} 1 & i \\ i & 1 \end{bmatrix}$$

- |HH-VV|*|HV|

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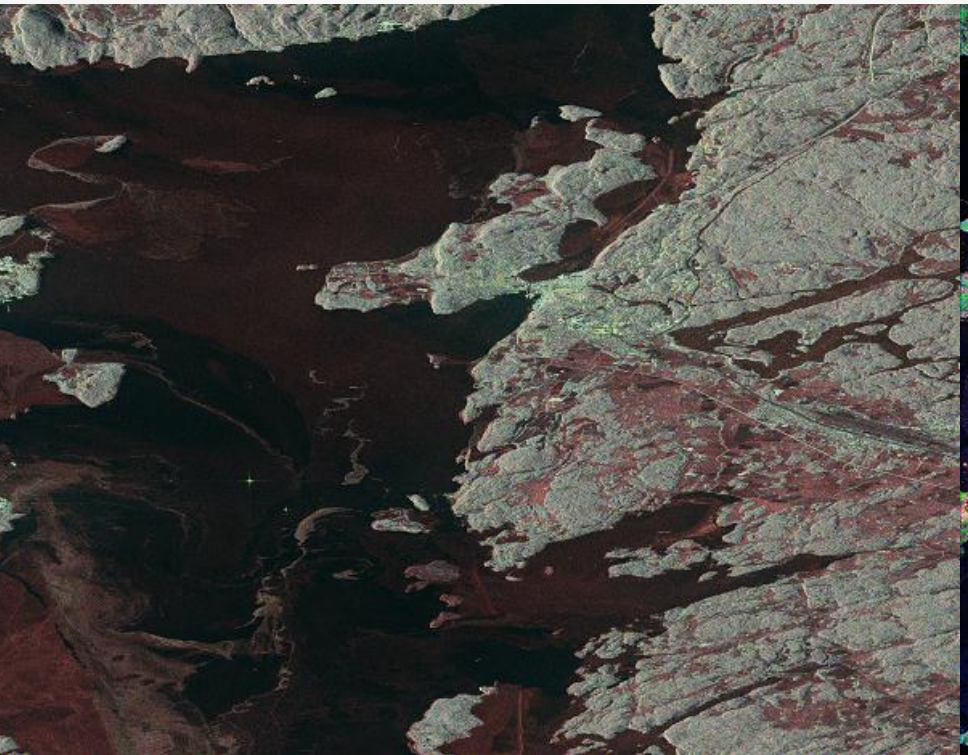
Quad-polarised data (2)

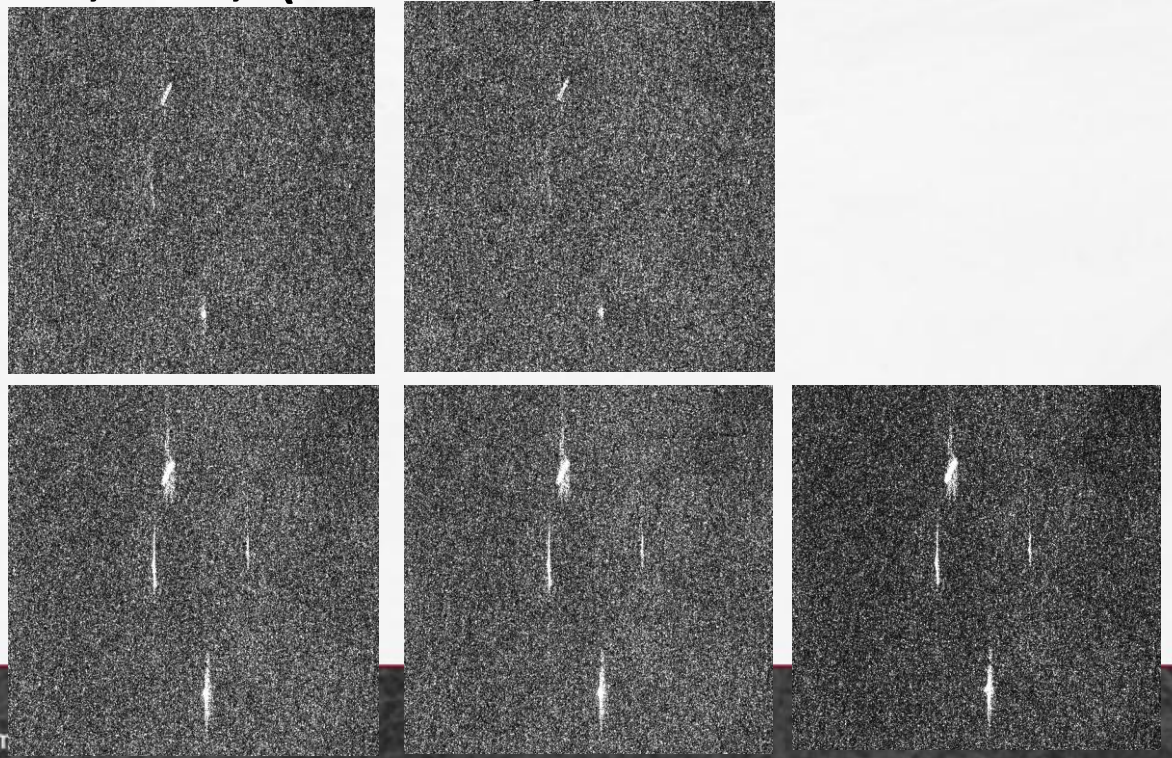
- Krogager – decomposed into three coherent components (left)
- Yamaguchi four-component scattering model (right)
  - With rotation
  - Without rotation

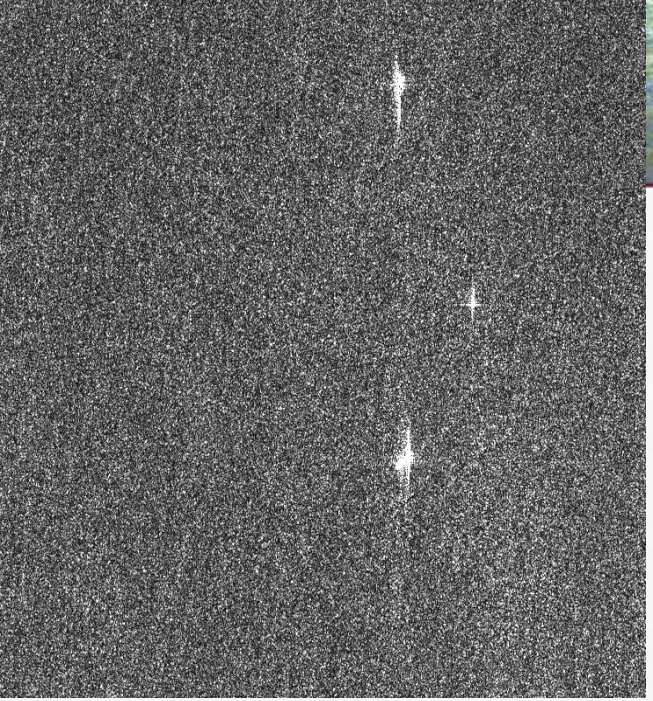


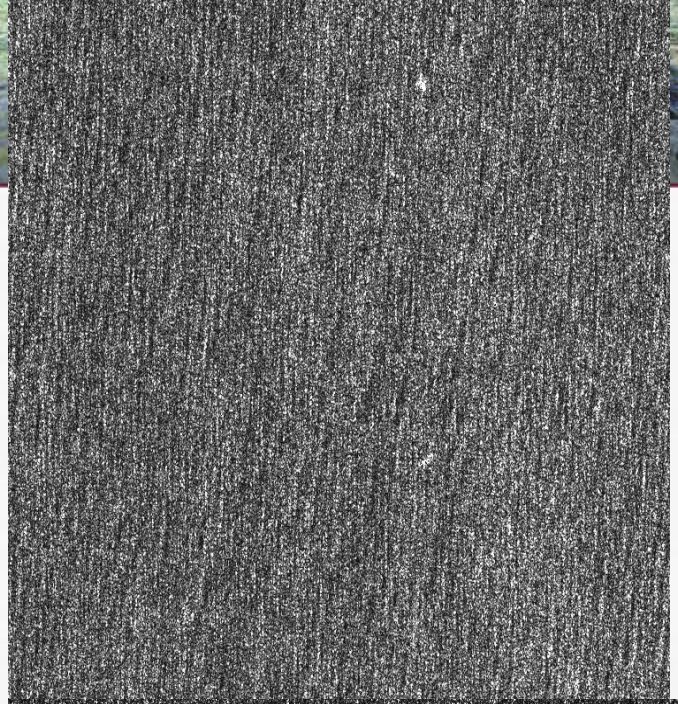
1/12-09

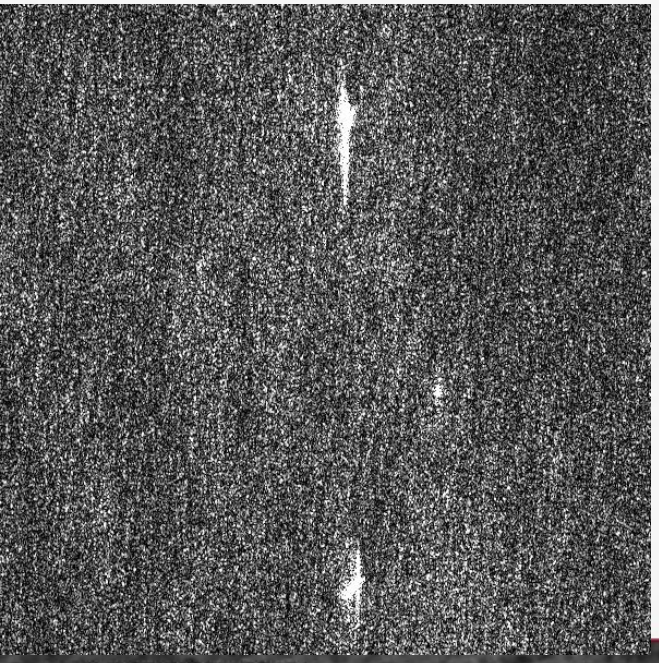
- Low incidence angle ≈ 30 degrees
- Full-resolution: HH, VV

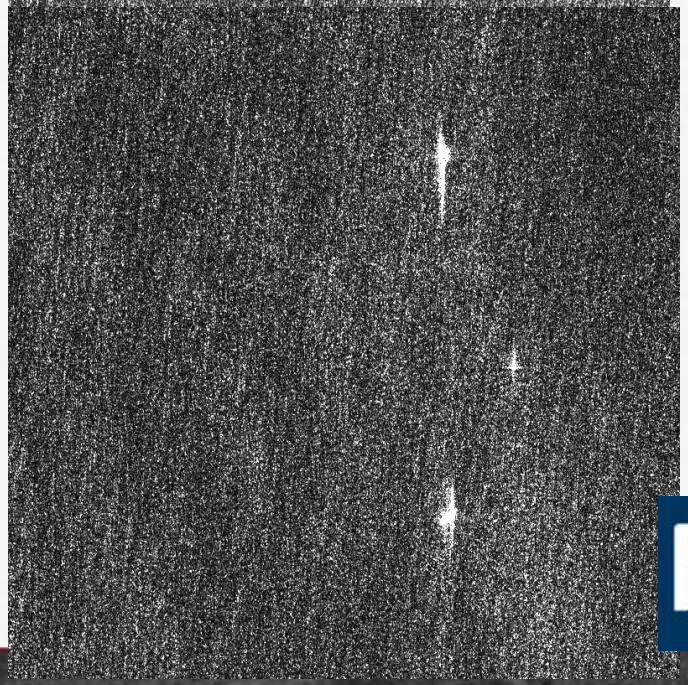
  HV, VH, (HH-VV)*HV











29/11-09

|HH-VV|, |HH+VV|

|HV|, |HH-VV|*|HV|

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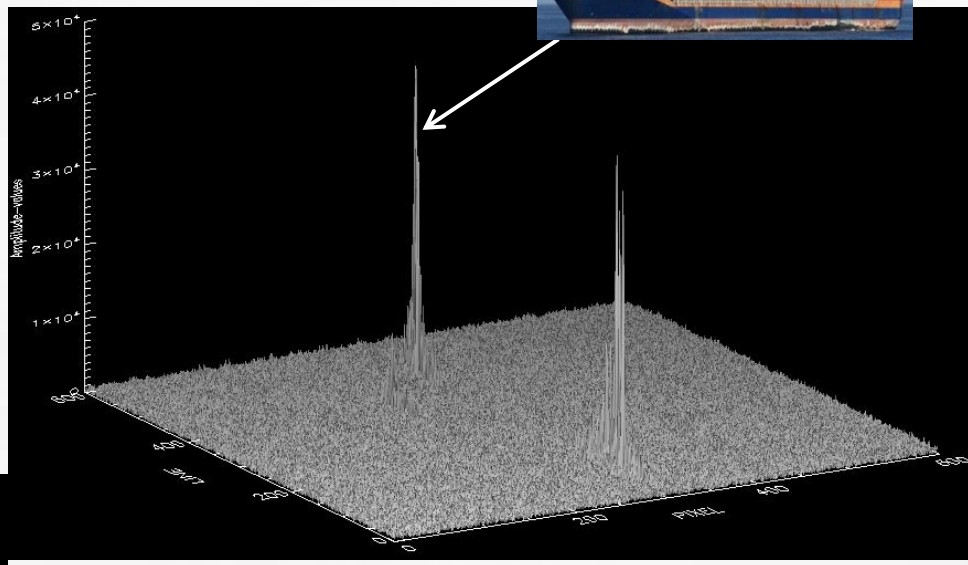
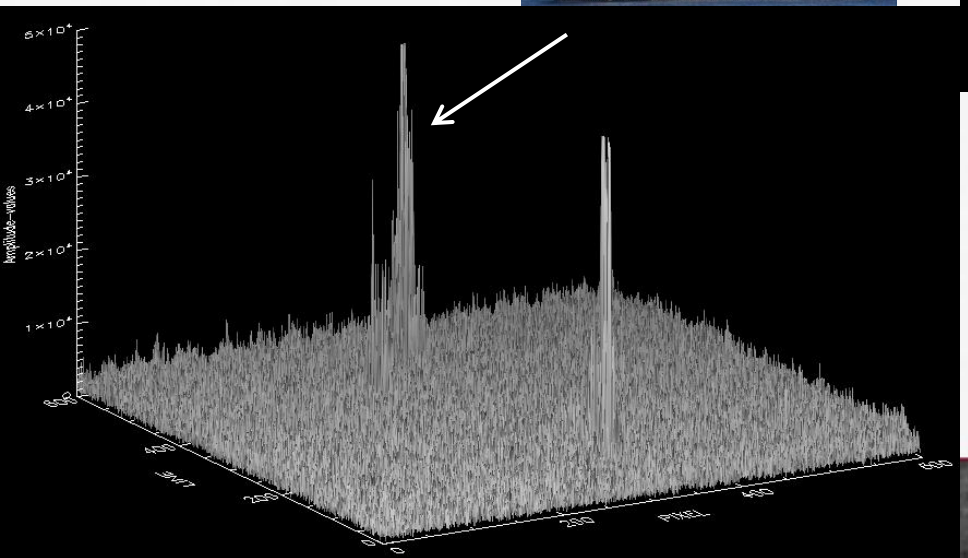
10/12-09 – Standard Quad-Pol

- HH & HV
- Norne FPSO
- High sea state





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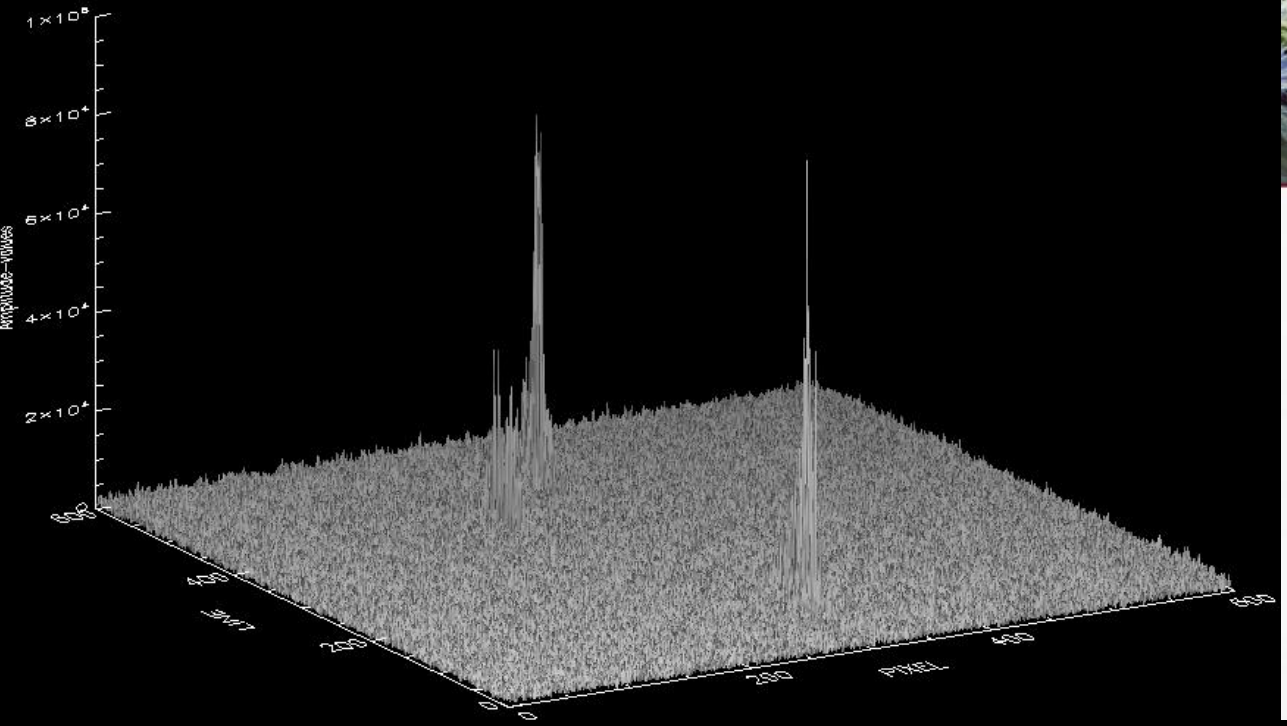

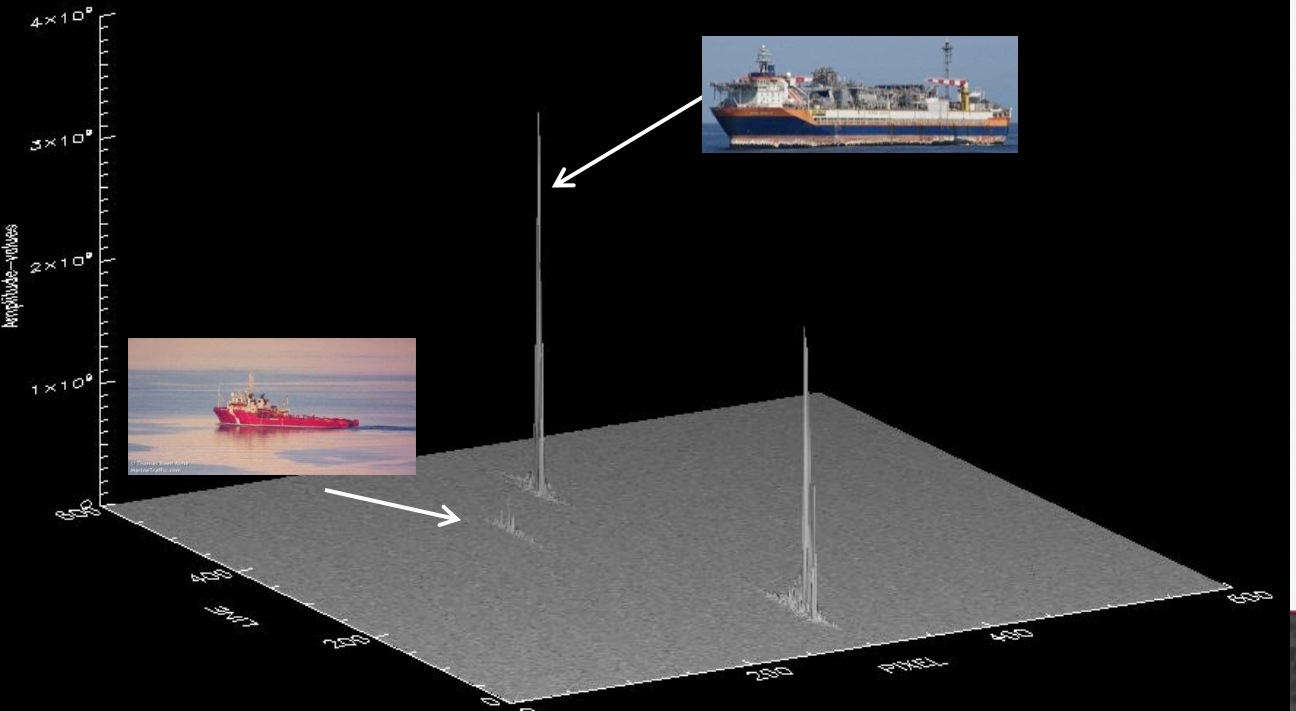

|HH-VV|

|HH-VV|*|HV|

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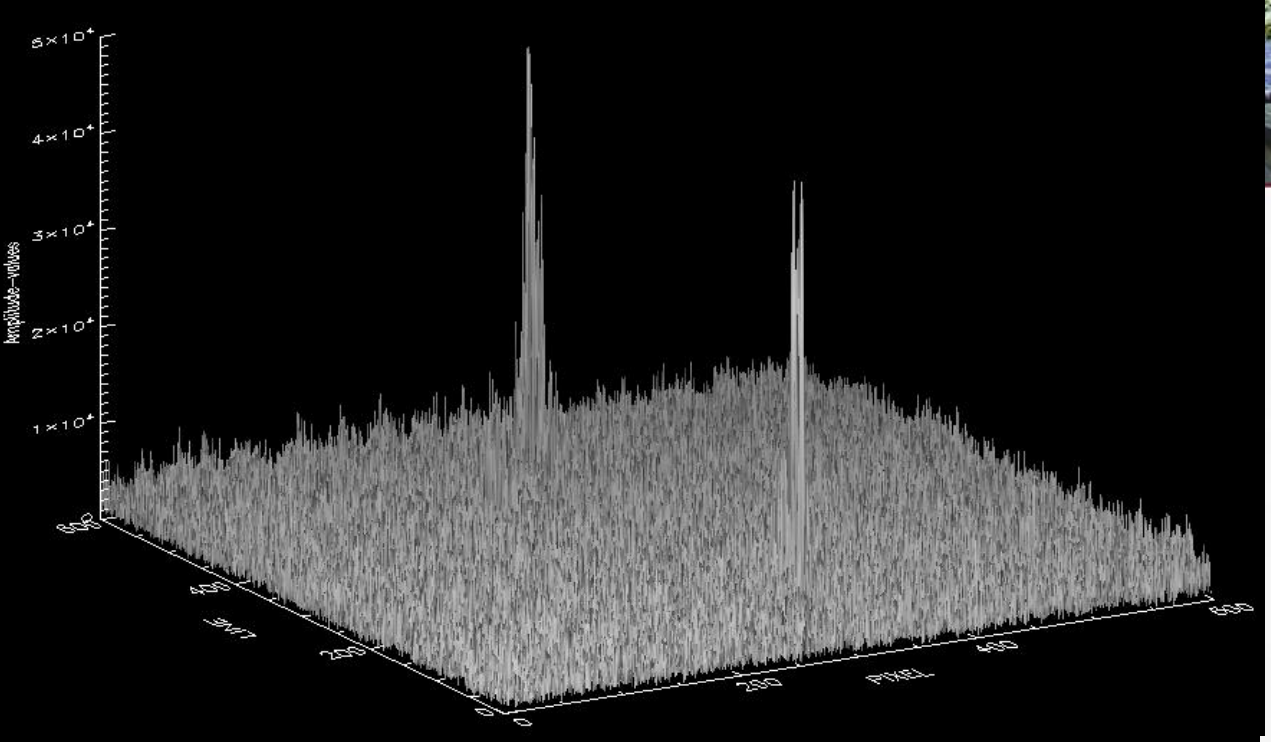

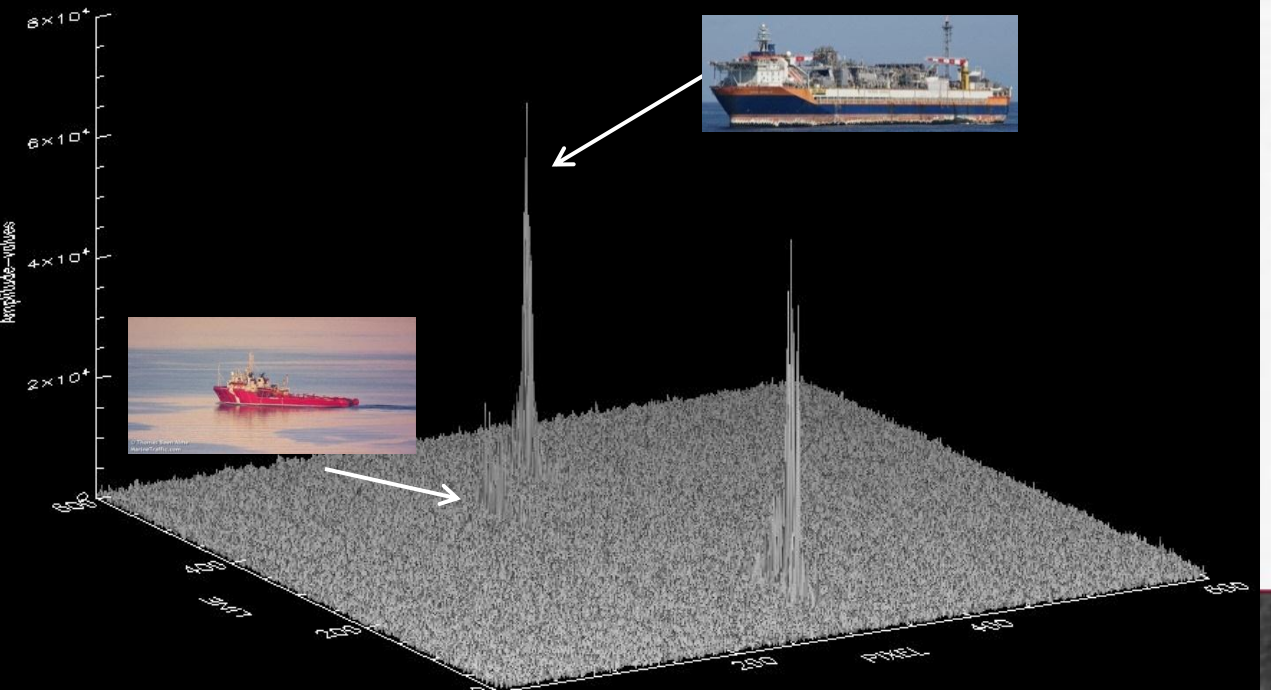

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Circular basis decomposition

|RR|

|RL|

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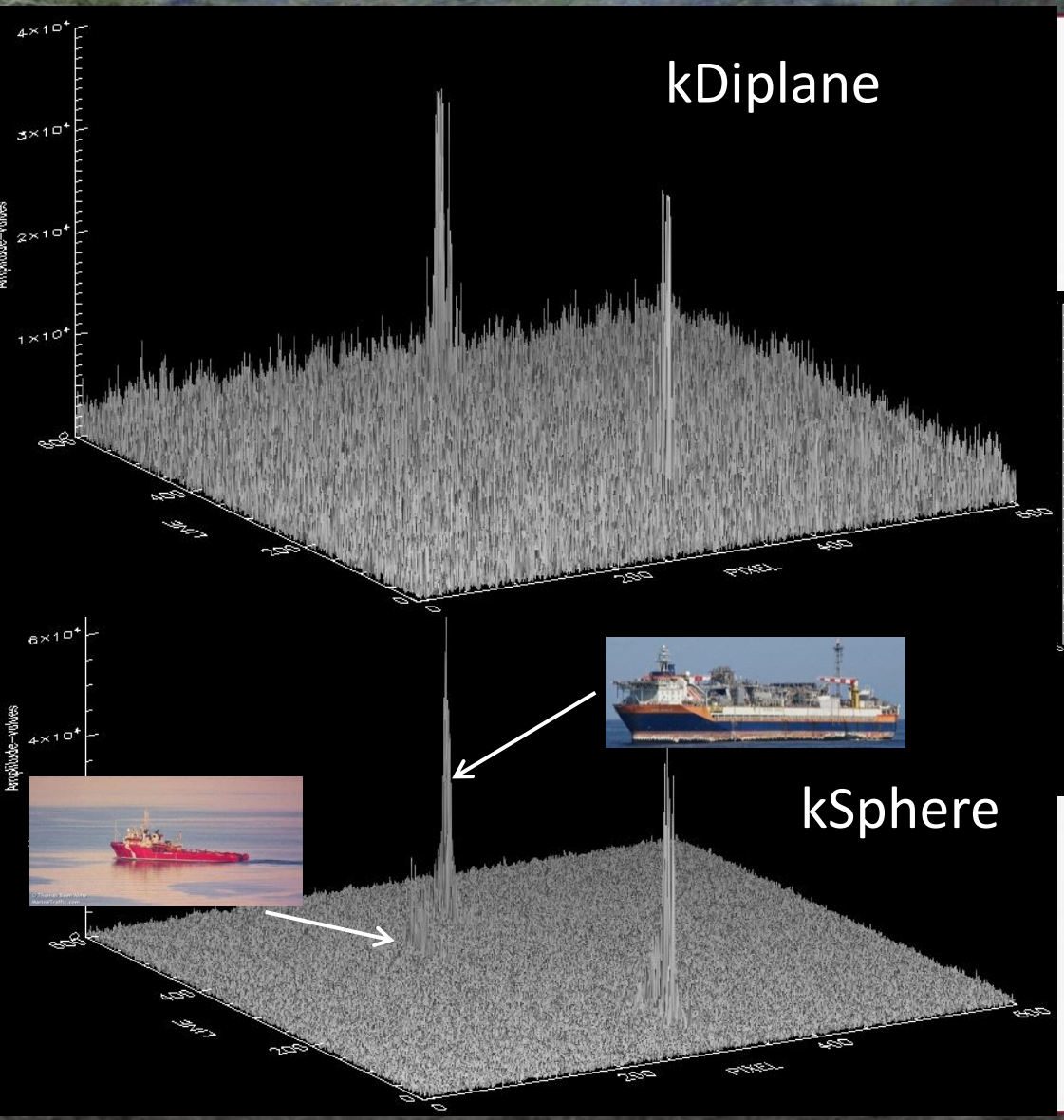
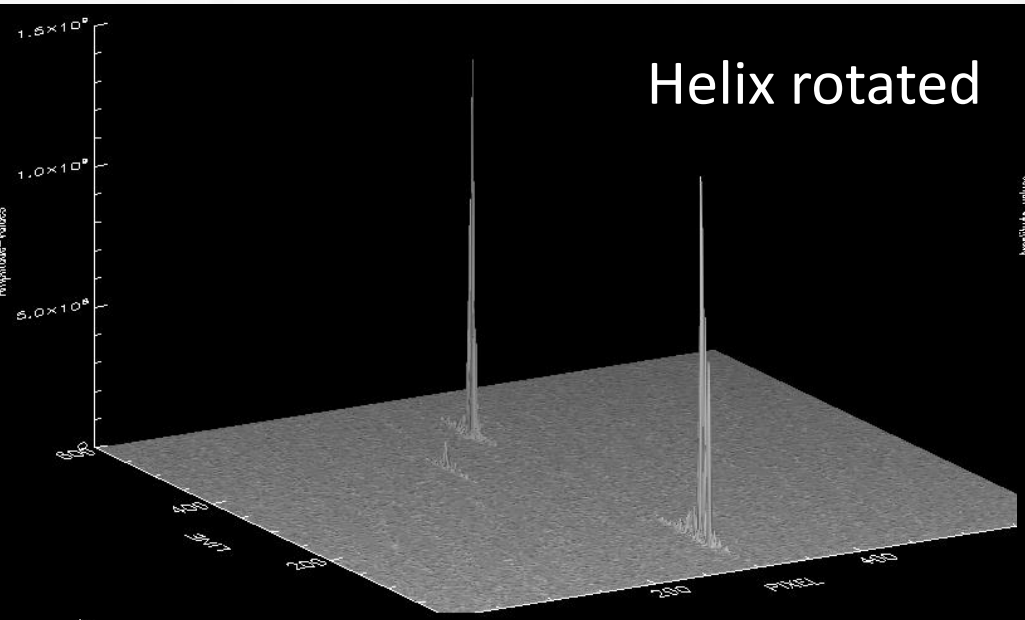
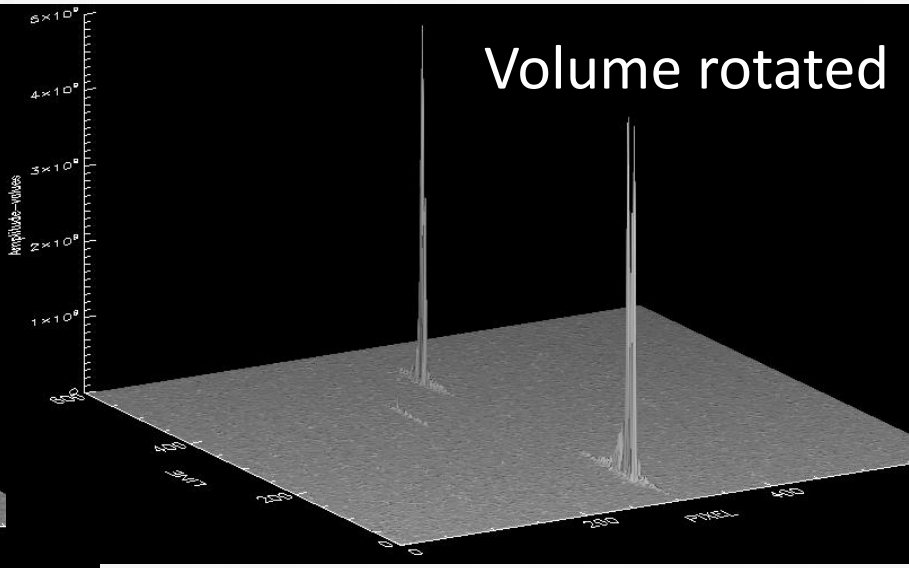
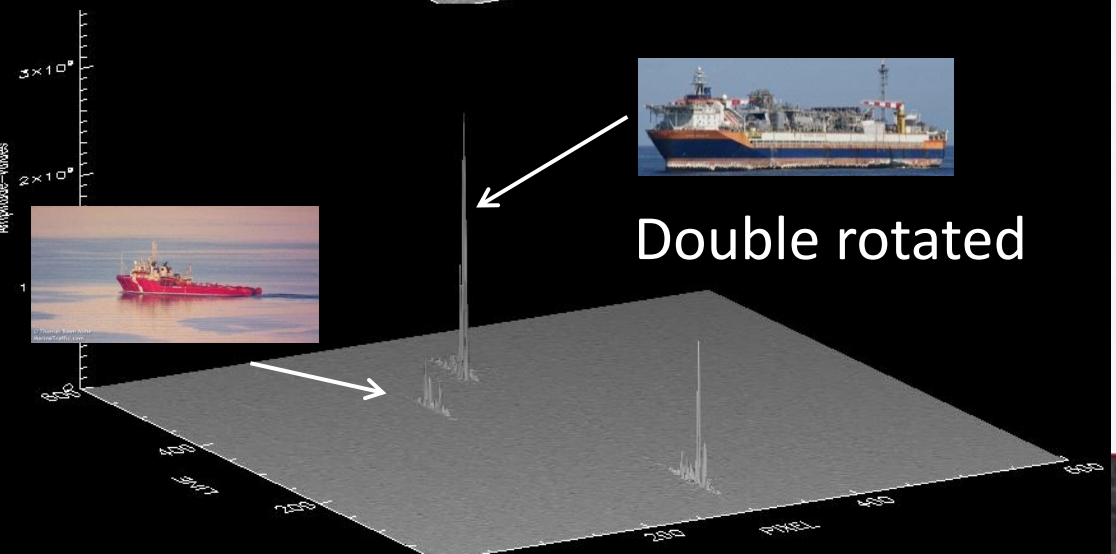
Krogager decomposition



Yamaguchi decomposition







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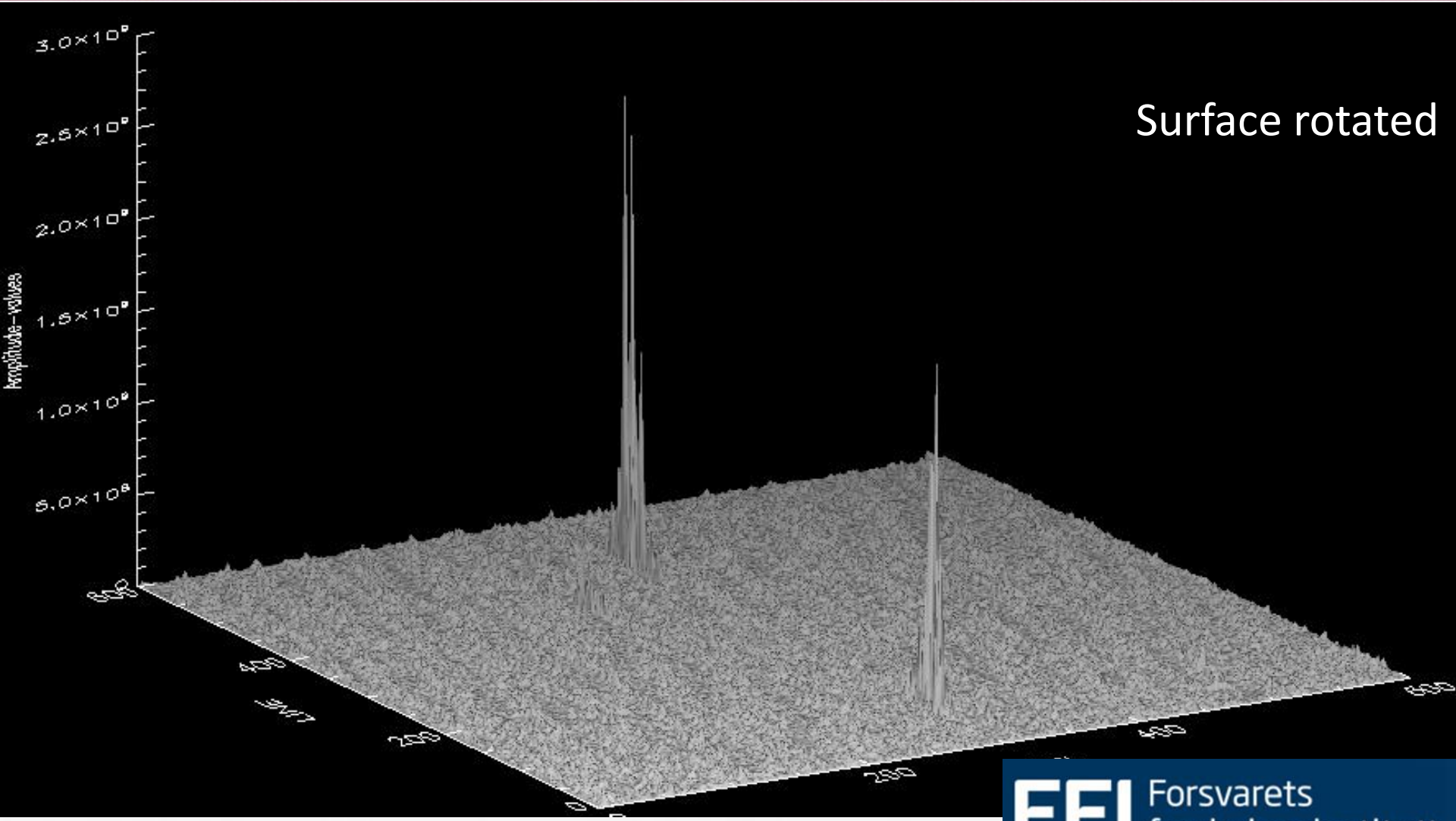
Yamaguchi decomposition



Standard Quad-Pol image 10/12-09

Maximum amplitude divided by mean sea of Norne FPSO for different polarisations and polarisation combinations

		R = Maximum amplitude / mean sea								
Date	Time	|HH|	|VV|	|HV|	|RR|	|RL|	|HH-VV|	|HH-VV|*|HV|	|kSphere|	|kHelix|
29/11-09	06:14	25	17	91	21	79	54	4493	79	8

		R = Maximum amplitude / mean sea			
Date	Time	|YHelix|	|YVolume|	|YDouble|	|YDoubleRot|
29/11-09	06:14	3261	3336	4682	7749

Quad-pol – AEGIR

- 18 images
- Low, medium and large θ
- 65 m - 264 m
- Cross-pol and comb. perform very well
- Co-pol: Miss more vessels for all θ
- Co-pol:
  - performs well for high θ, but not as good as cross-pol and combined case
  - Poor for low and medium θ

Date	θ	HH	VV	HV, VH & Comb.	Exp. det.
29/11-09	L	-2	-1	OK	6
9/12-09	L	-5	-5	OK	5
15/12-09	L	-5	-5	OK	5
22/12-09	L	-1	-1	OK	3
21/3-10	L	-4	-4	OK	4
22/3-10	L	0	0	OK	7
29/3-10	L	OK	OK	OK	6
28/3-12	L	-3	-3	OK	4
1/12-09	M	-4	-7	OK	7
17/3-10	M	-1	-1	OK	6
19/3-10	M	-1	-1	OK	5
21/12-09	H	0	0	0	0
16/3-10	H	-1	OK	OK	6
20/3-10	H	OK	OK	OK	5
23/3-10	H	OK	OK	OK	5
26/3-10	H	-1	-3	OK	4
22/3-12	H	OK	OK	OK	4
29/3-12	H	OK	-1	OK	5

Conclusions

- Dual-pol and quad-pol images analyzed both manually and automatic
- Combining the available polarisation channels increase the ship to sea contrast
- Dual-pol: Cross-pol and (co-pol*cross-pol)/const are best for ship detection.
- Quad-pol: Cross-polarisation and (HH-VV)*HV perform well for ship detection
- Yamaguchi decomposition method gives high ship-to-sea-contrast
- HH works well for high incidence angles

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