Ship and Pollution detection via SAR monitoring
Synergies between R&D and service activities

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Purpose of this presentation

- Presentation of the activities of CLS in the field of vessel and pollution detection with SAR
  - Infrastructure and services
- Complementarities between services and R&D activities
  - Perspectives and R&D activities
- Presentation of the activities of Telecom Bretagne in the field of earth observation
  - R&D activities

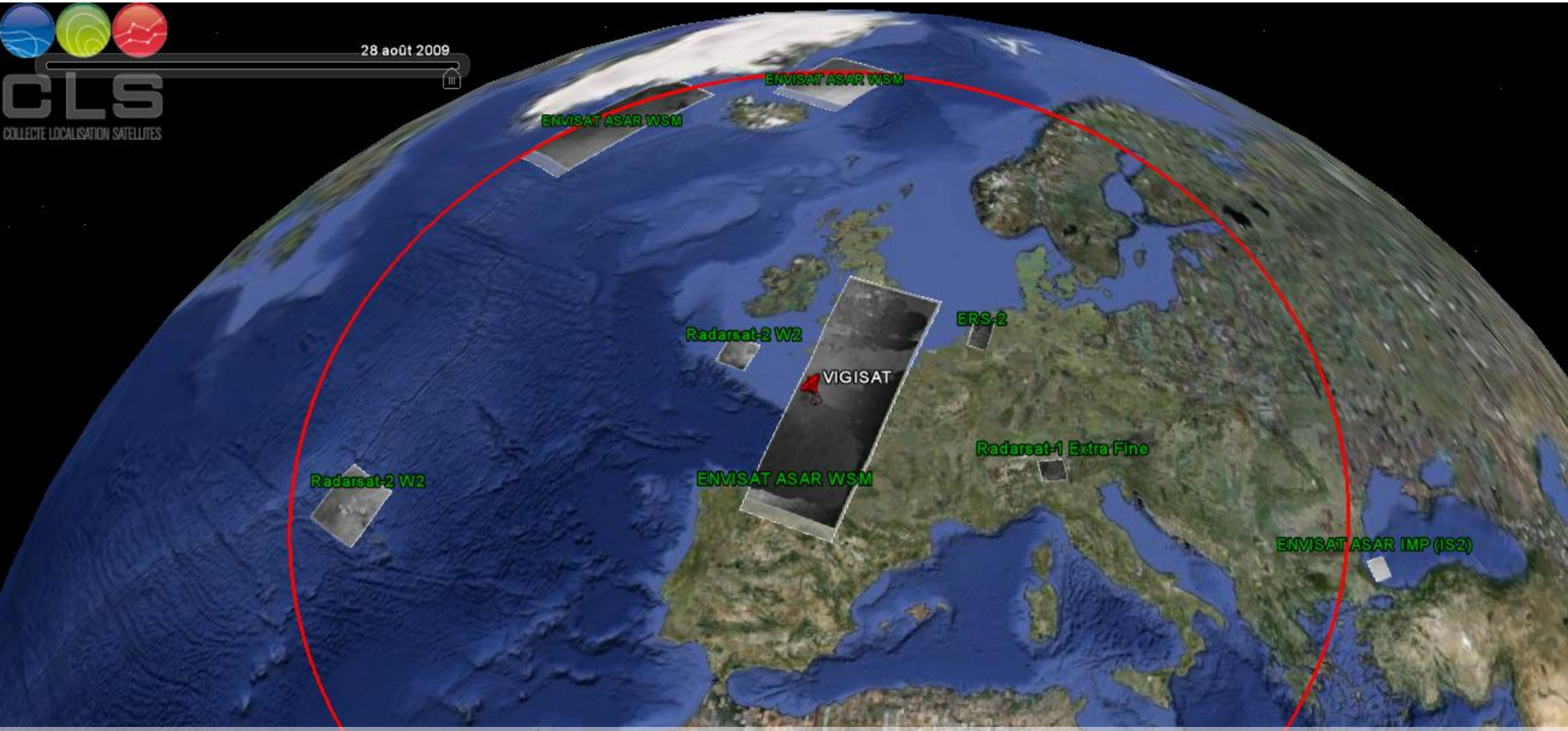
Plan

- The VIGISAT infrastructure
- Example of services operated by CLS
- Synergies between services and R&D activities
- Open issues and progress in vessel and pollution detection
  - R&D activities of both CLS & Telecom Bretagne

The VIGISAT infrastructure

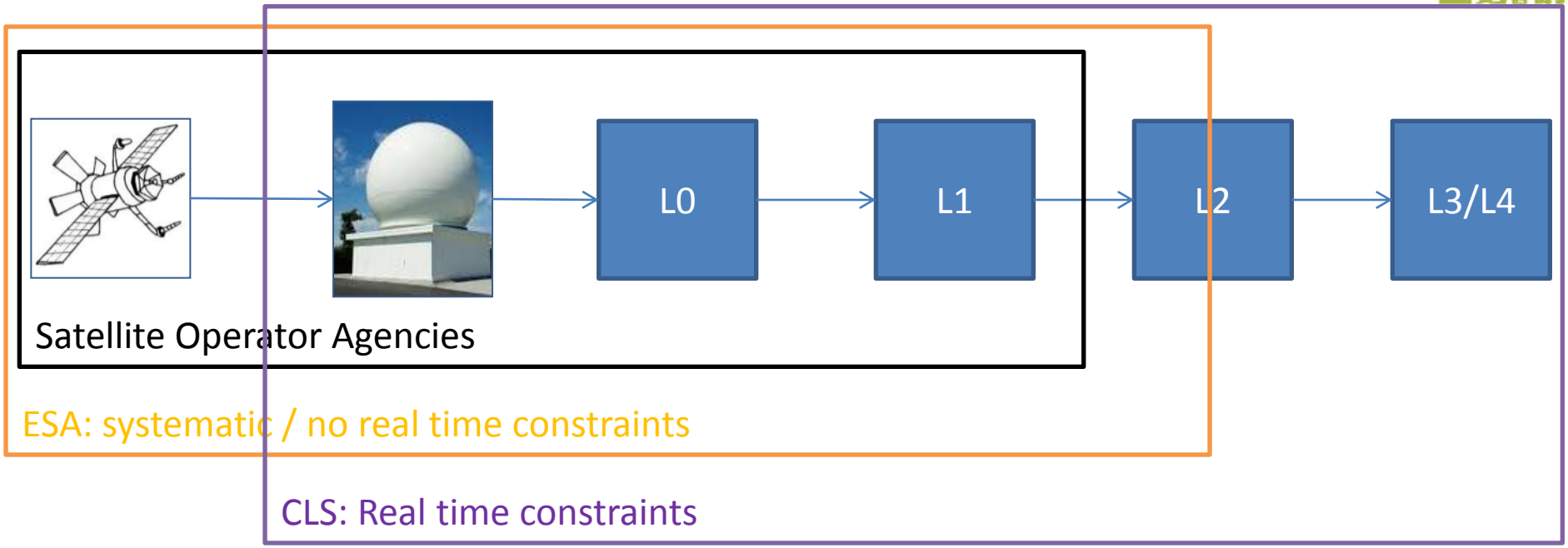
CLS: THE VIGISAT INFRASTRUCTURE

Visibility circle of VIGISAT



- Visibility circle of 2500 km including reception in Near Real Time :
  - East Greenland, Iceland, Baltic Sea, Western Black Sea
  - Azores, Canarias, North Africa, Central and Western Mediterranean Sea
- Satellite missions received:
  - RADARSAT-1 & 2
  - Formerly Envisat & ERS-2

Near Real Time Data production



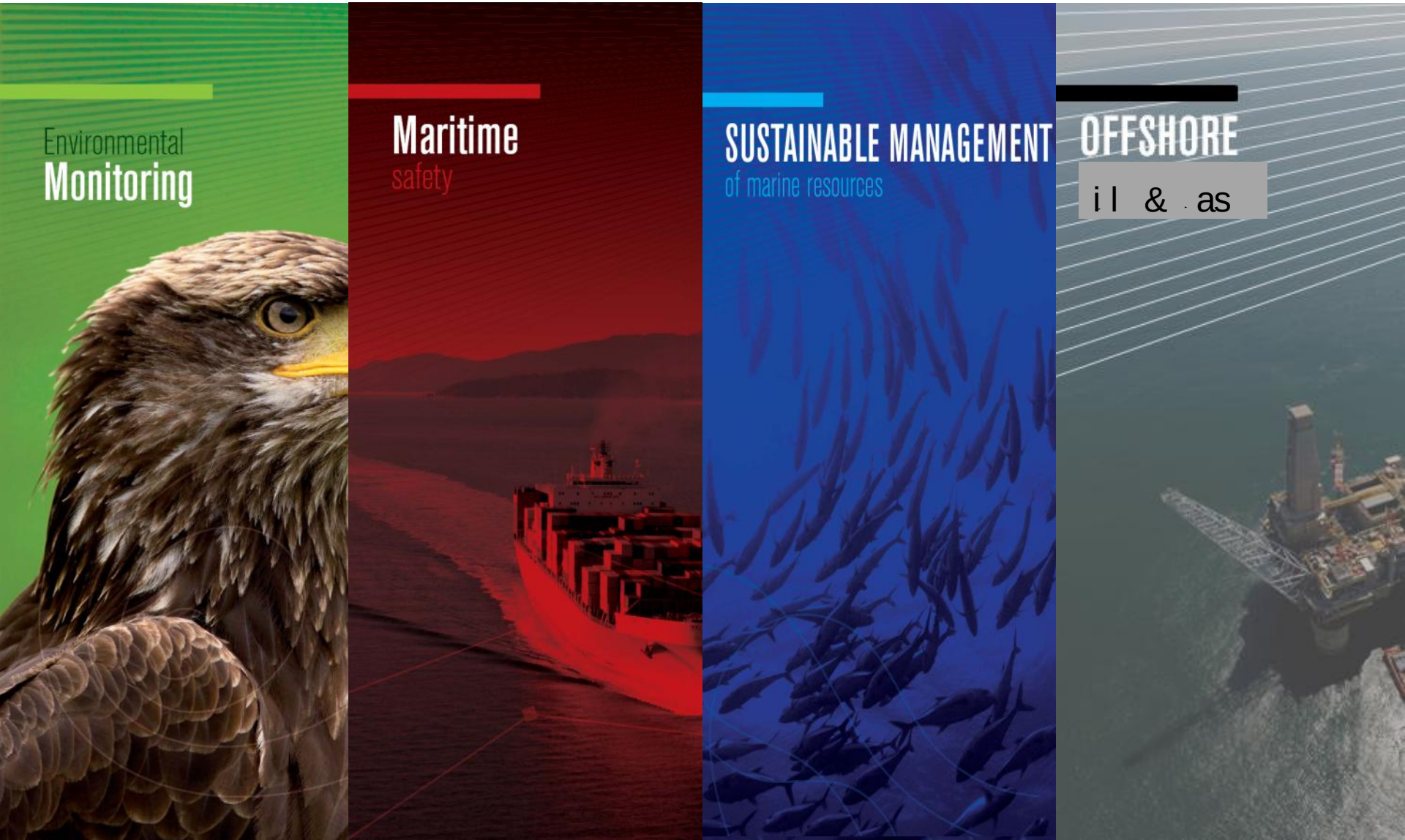
Définitions:

- L0: Raw data.
- L1: Geolocated data with the nominal spatial resolution of the instrument.
- L2: Geophysical Parameters derived from the L1 data. Spatial resolution is often degraded in comparison to L0 data.
- L3: Geophysical parameters that have been spatially or/and temporally resampled . Those regridded products can be a composite of several products from the same sensor.
- L4 : Geophysical products combined with other data (Satellite, mode, in-situ)

Example of services operated by CLS

SERVICES OPERATED BY CLS

CLS is active in following sectors



Surveillance of marine oil pollutions

Satellite Oceanography

+

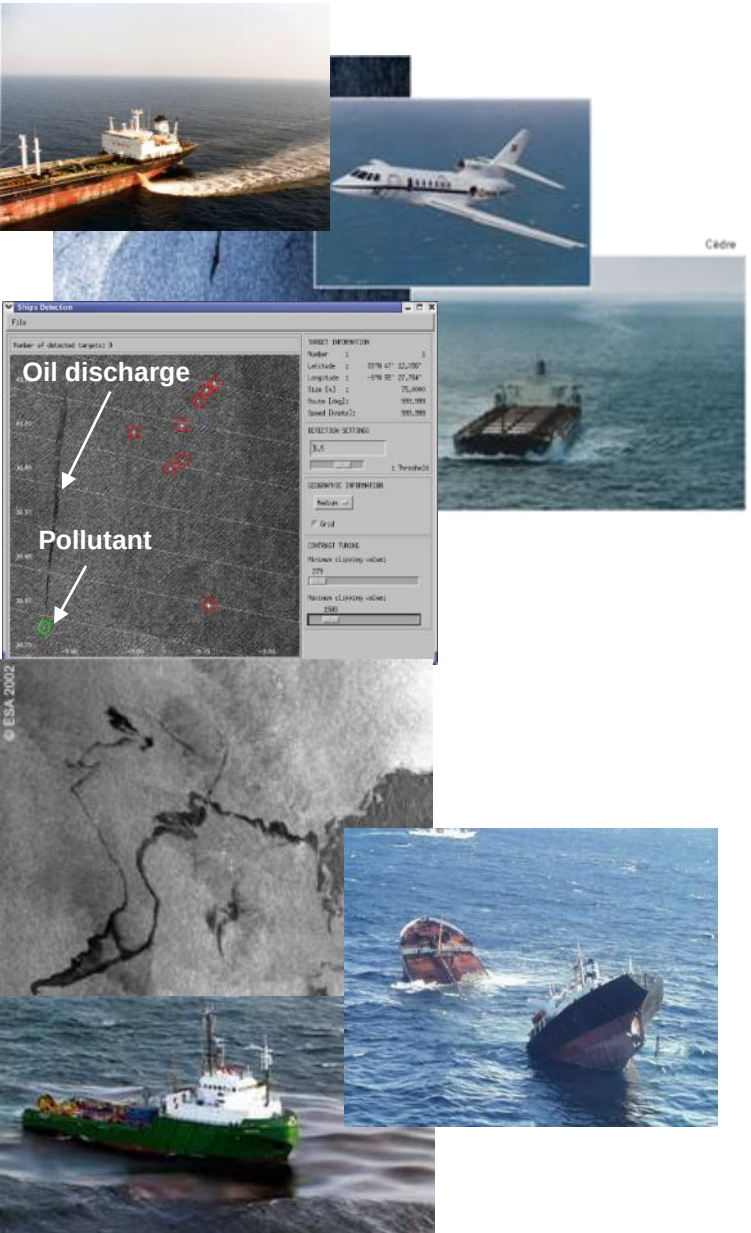
Tracking Systems,
AIS, VMS, LRIT,

+

High resolution SAR imagery

Users:
IMO, EMSA, Customs, Maritime Security Agencies, Coastguards, Maritime Affairs, Offshore companies, etc.

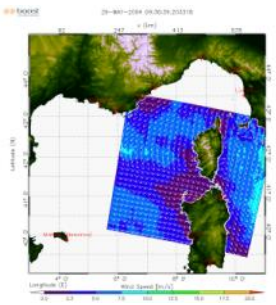
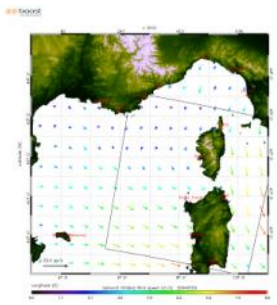
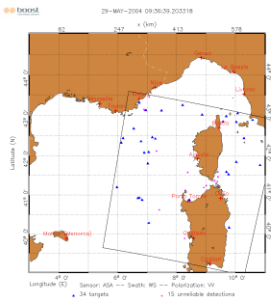
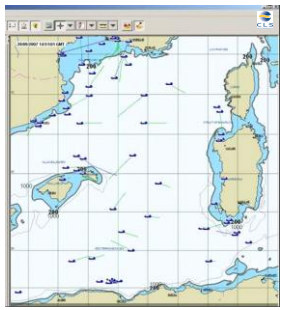
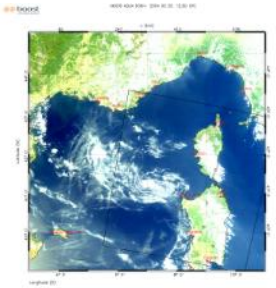
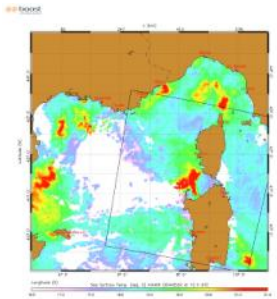
Two types of oil spill scenario
Surveillance of marine oil pollutions



- **Illicit oil discharges** caused by ships enroute observed by:
  - Aerial surveillance
  - Near-real time satellite surveillance (e.g. CleanSeaNet EMSA service)

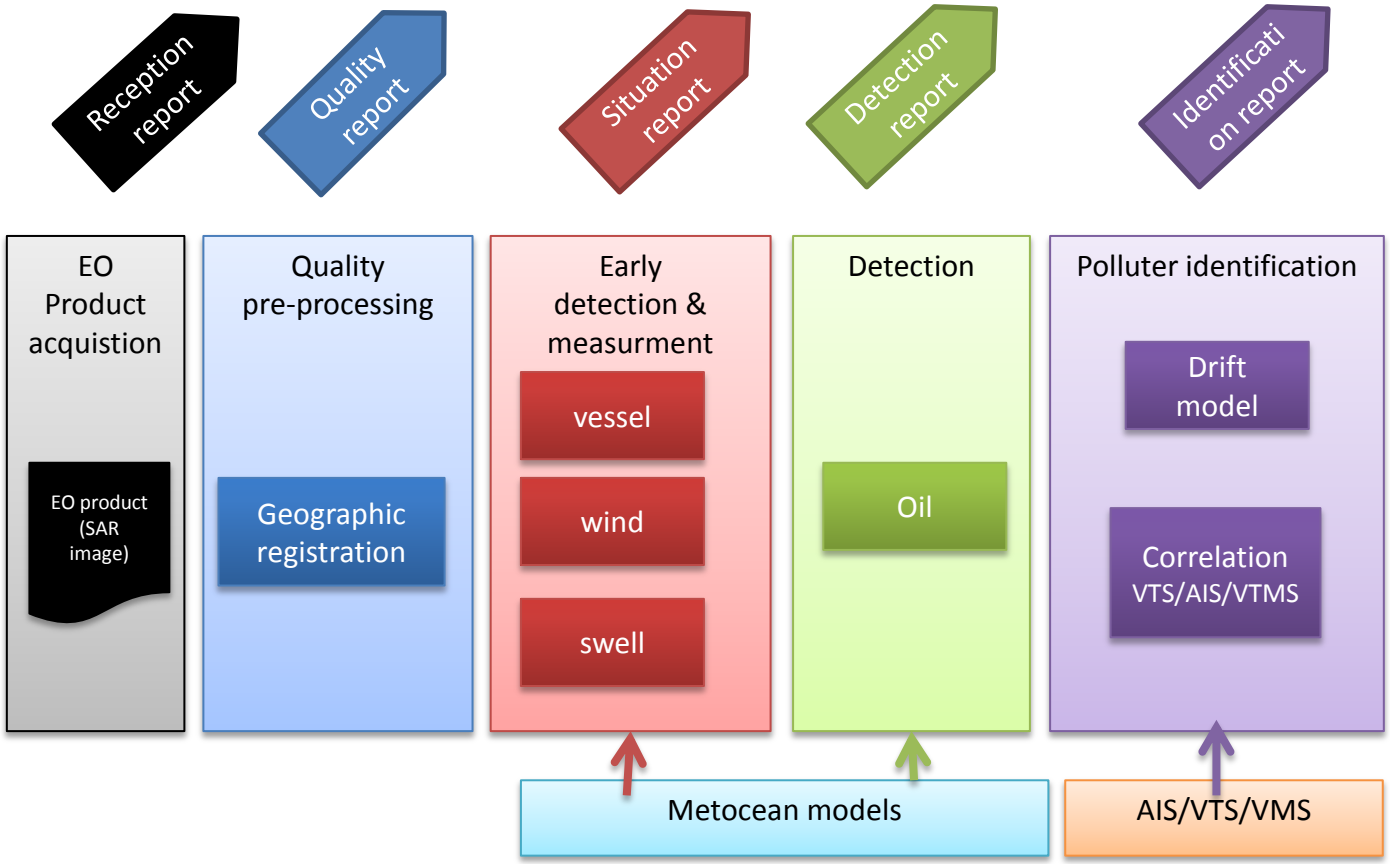
- **Accidental pollutions** further need:
  - Continuous surveillance and in-situ drifters
  - Risk assessment of onshore drift with meteo-oceanic services

Strategy to reduce the False Alarm Rate
Surveillance of marine oil pollutions

- Use SAR-derived wind information to assess the feasibility of oil spill detection on SAR images
  - 2-3 < |V| < 12-15 m/s in C-band
- Couple SAR with AIS/VMS/LRIT information to support the identification of polluting ships
- Use ancillary information to help in understanding the origin of ambiguous slicks on SAR images

Pollution Operational Service



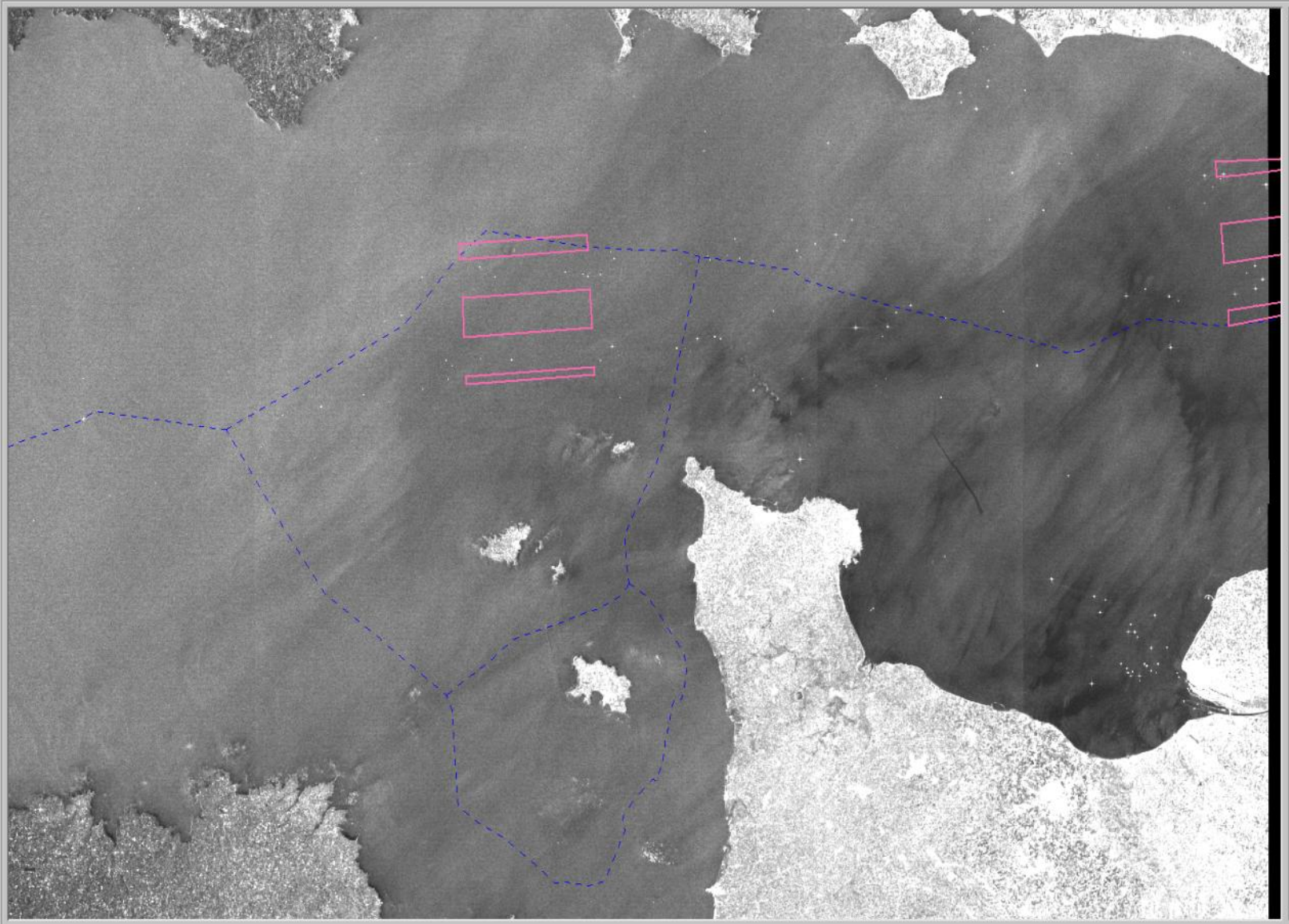
CLS involved in all those activities:

- R&D : define, improve specific sub processing (vessel detection, oil detection...)
- Integration : integrate all processing into one self consistent service chain
- Operational services : operate this kind of chain with real time constraints

SARTool: The SAR Way to Heaven

File Visualization Full Resolution Applications Ancillary Mouse Mode Help

PLATFORM: ASAR ENVISAT
PRODUCT TYPE: WSM_1P
ACQUISITION UTC TIME: 18-MAY-2009 21:52:58.2
ID: ASA_WSM_1PNPDE20090518_215215_000000912079_00101_37730_2065



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Look Ang. [deg] 18.8521
Lat dms +049d59' 30.00''
Lon dms -002d32' 48.00''

GEOGRAPHIC PARAMETERS
Charts | Other | Limits | Proj | Delta
No mask +High
Grid Land
Maritime Misc

CONTRAST TUNING
Clip | Levels | Hist. | Clip limits
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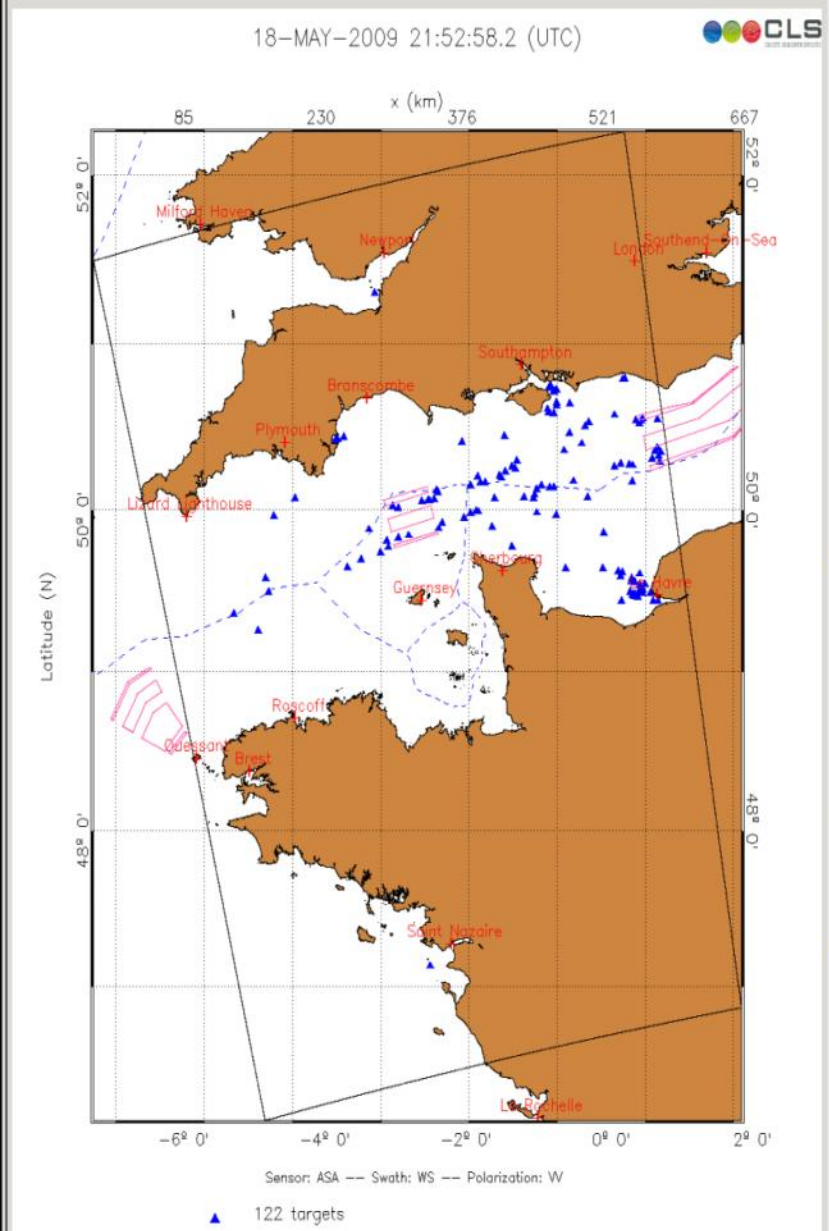
Minimum
264
Maximum

CLS

Applications Raccourcis Système lun 14 sep, 16:46:49

SAR_Ships.0.png

Fichier Édition Affichage Image Aller à Aide



SARTool: The SAR Way to Heaven

Help

730_2065

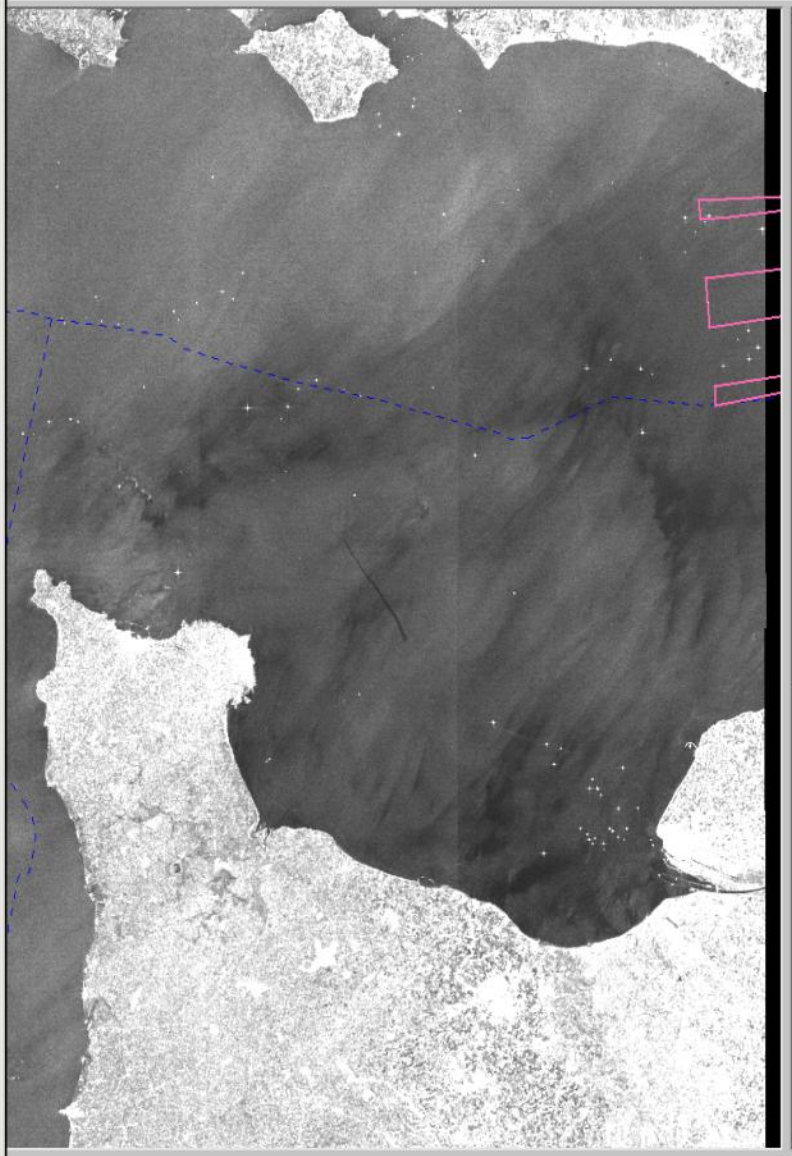


IMAGE PARAMETERS

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Look Ang. [deg]	19,8176
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Lon dms	-001d47' 36,50''

GEOGRAPHIC PARAMETERS

Charts | Other | Limits | Proj | Delta

No mask | +High

Grid | Land | Maritime | Misc

CONTRAST TUNING

Clip | Levels | Hist. | Clip limits

0

Minimum

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Maximum

CLS

Applications Raccourcis Système

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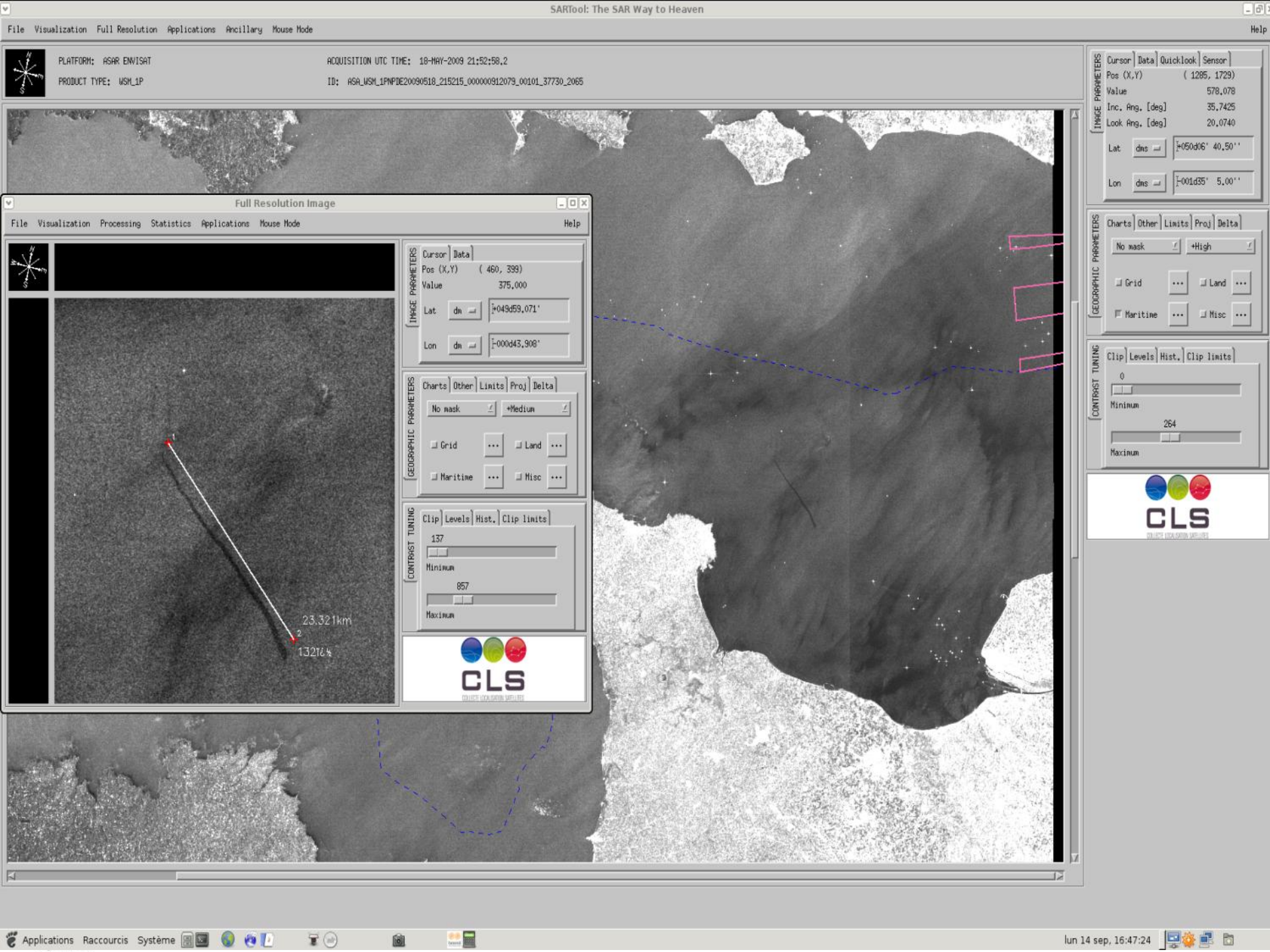
SARTool: The SAR Way to Heaven
File Visualization Full Resolution Applications Ancillary Mouse Mode Help
PLATFORM: ASAR ENVISAT
PRODUCT TYPE: WSM_1P
ACQUISITION UTC TIME: 18-MAY-2009 21:52:58.2
ID: ASA_WSM_1PNPDE20090518_215215_000000912079_00101_37730_2065
IMAGE PARAMETERS
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Inc. Ang. [deg] 35.7425
Look Ang. [deg] 20.0740
Lat dms +050d06' 40.50''
Lon dms +001d35' 5.00''
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Lat dm +049d59.071'
Lon dm +000d43.908'
GEOGRAPHIC PARAMETERS
Charts Other Limits Proj Delta
No mask +Medium
Grid Land
Maritime Misc
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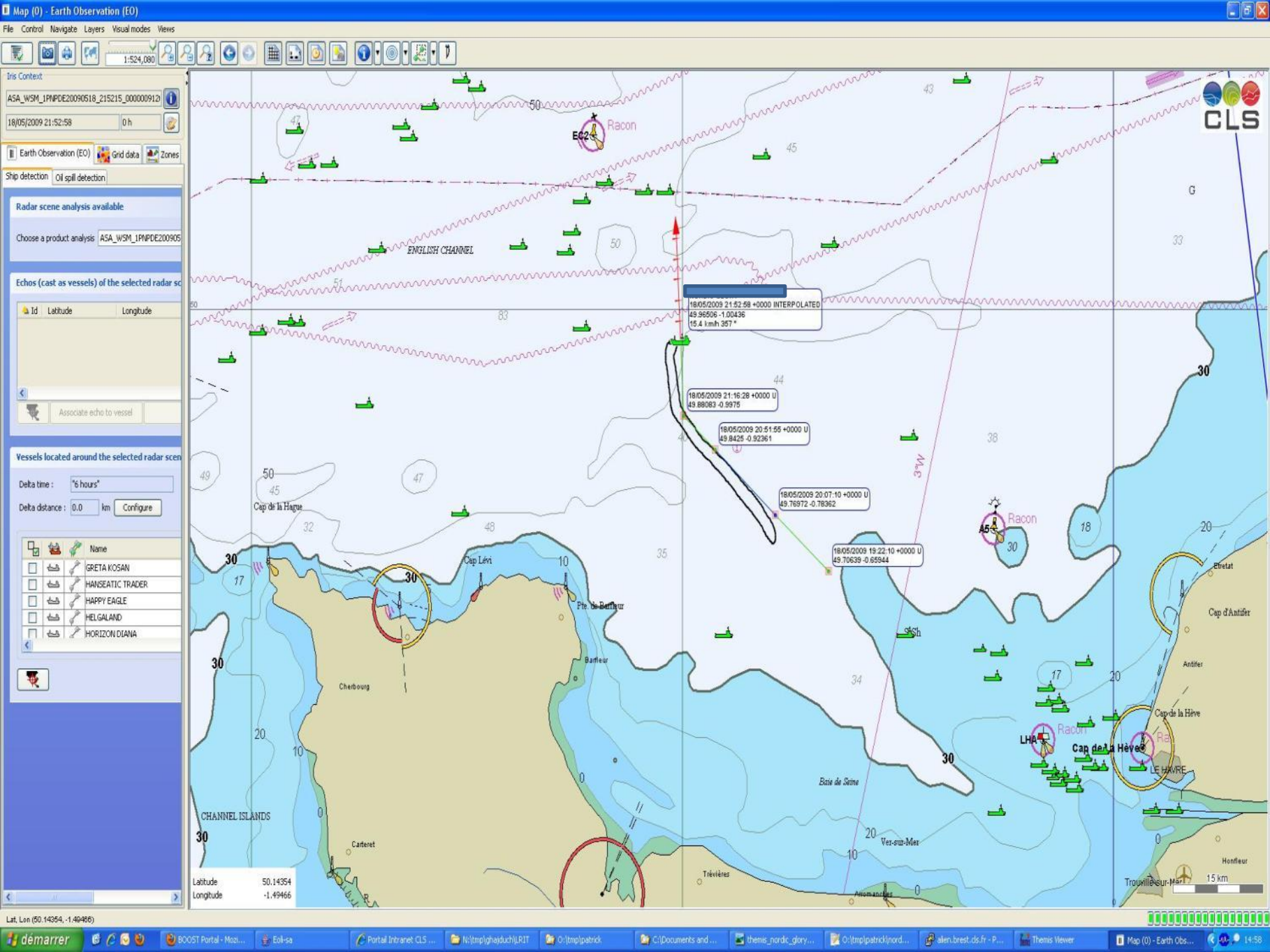
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Oil spill detection
Radar scene analysis available
Choose a product analysis
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Latitude
Longitude
Associate echo to vessel
Vessels located around the selected radar scen
Delta time :
"6 hours"
Delta distance :
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HANSEATIC TRADER
HAPPY EAGLE
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15.4 km/h 357 °
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49.88083 -0.9975
18/05/2009 20:51:55 +0000 U
49.8425 -0.92361
18/05/2009 20:07:10 +0000 U
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18/05/2009 19:22:10 +0000 U
49.70639 -0.65944
Racon
A5
Cap de la Hague
Cap Lévi
Pte. de Barfleur
Barfleur
Cherbourg
CHANNEL ISLANDS
Carteret
Trévières
Ver-sur-Mer
Baie de Seine
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LE HAVRE
Etretat
Cap d'Antifer
Antifer
Honfleur
Trouville-sur-Mer
15 km
Latitude 50.14354
Longitude -1.49466
Lat, Lon (50.14354, -1.49466)
CLS
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Map (0) - Earth Obs...
14:58


Map (0) - Earth Observation (EO)
File Control Navigate Layers Visual modes Views
Themis Viewer
Application Management Reports Display options Alerts Data Help
Locations info
Mobile Location Status
Vessel : NORDIC GLORY / CQOS / /
Flag : PT
Fishing gears :
Ship owner :
Active beacon : No active beacon
Date : 18/05/2009 22:46:43
Location : 50.06389 / -0.94444
Speed / heading : 15 km/h / 69 °
Active/Inactive vessel
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49.96506 -1.00436
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ENGLISH CHANNEL
Racon
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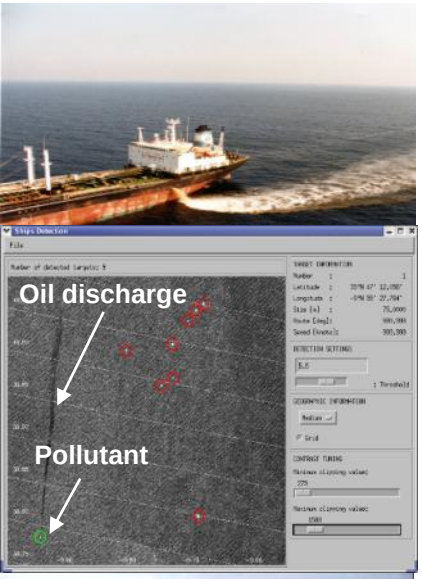
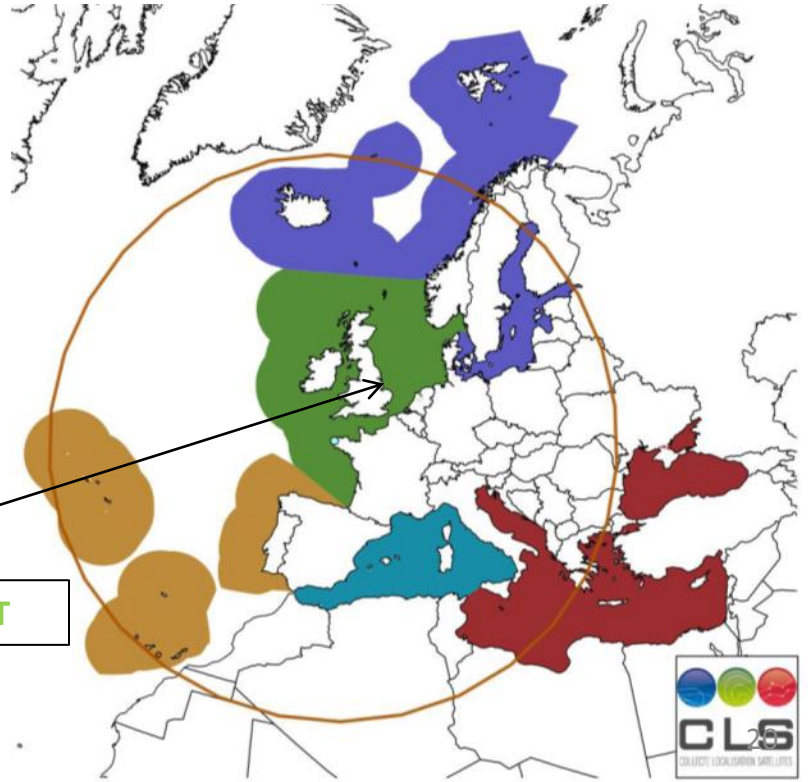
Cap de la Hève
LE HAVRE
Pte. de Barfleur
Baie de Seine
Ver-sur-Mer
Trouville-sur-Mer
Honfleur
Cap d'Antifer
Etretat
15 km
CLS

Pollution detection : The CleanSeaNet service

CleanSeaNet / European Maritime Safety Agency

- A near real-time detection service of oil spills and ships at sea using SAR imagery
  - Delivered by EMSA (Lisbon) since 17 April 2007
  - To apply the European directive 2005/35/EC :
    - Detect from space oil spills at sea
    - To identify the source of pollution





Service area covered by VIGISAT

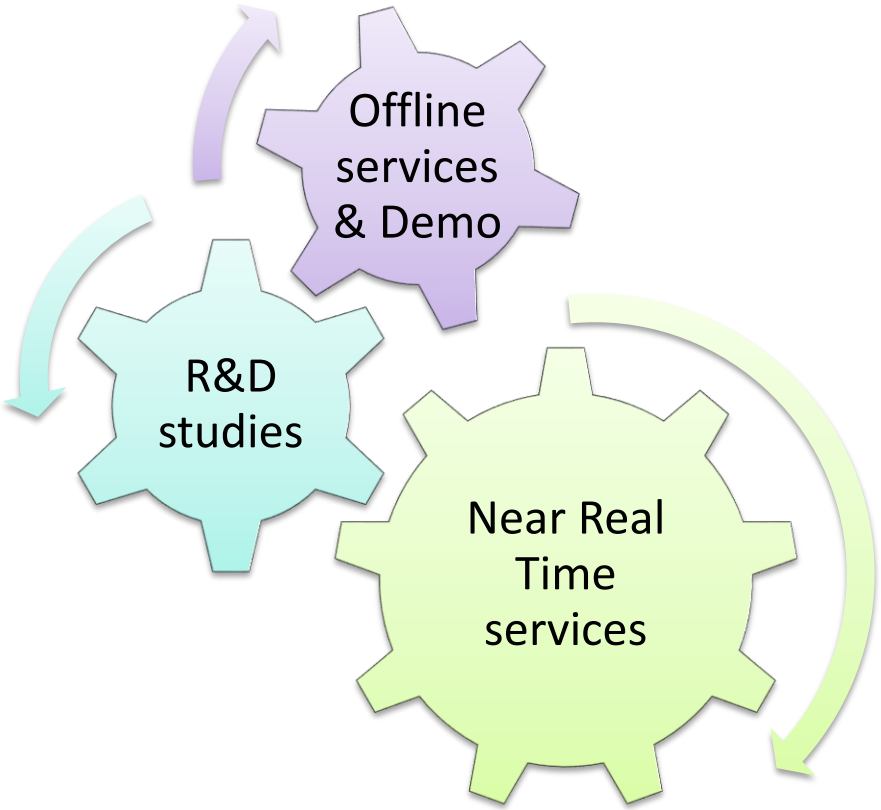
Other services

- Monitoring of illegal or unreported fishing:
  - Fishing licenses
  - Fish farms
- Border surveillance
- Marine Traffic surveillance
- Environmental monitoring
  - Wind
  - Swell
  - Currents
- etc

Synergies between services and R&D activities

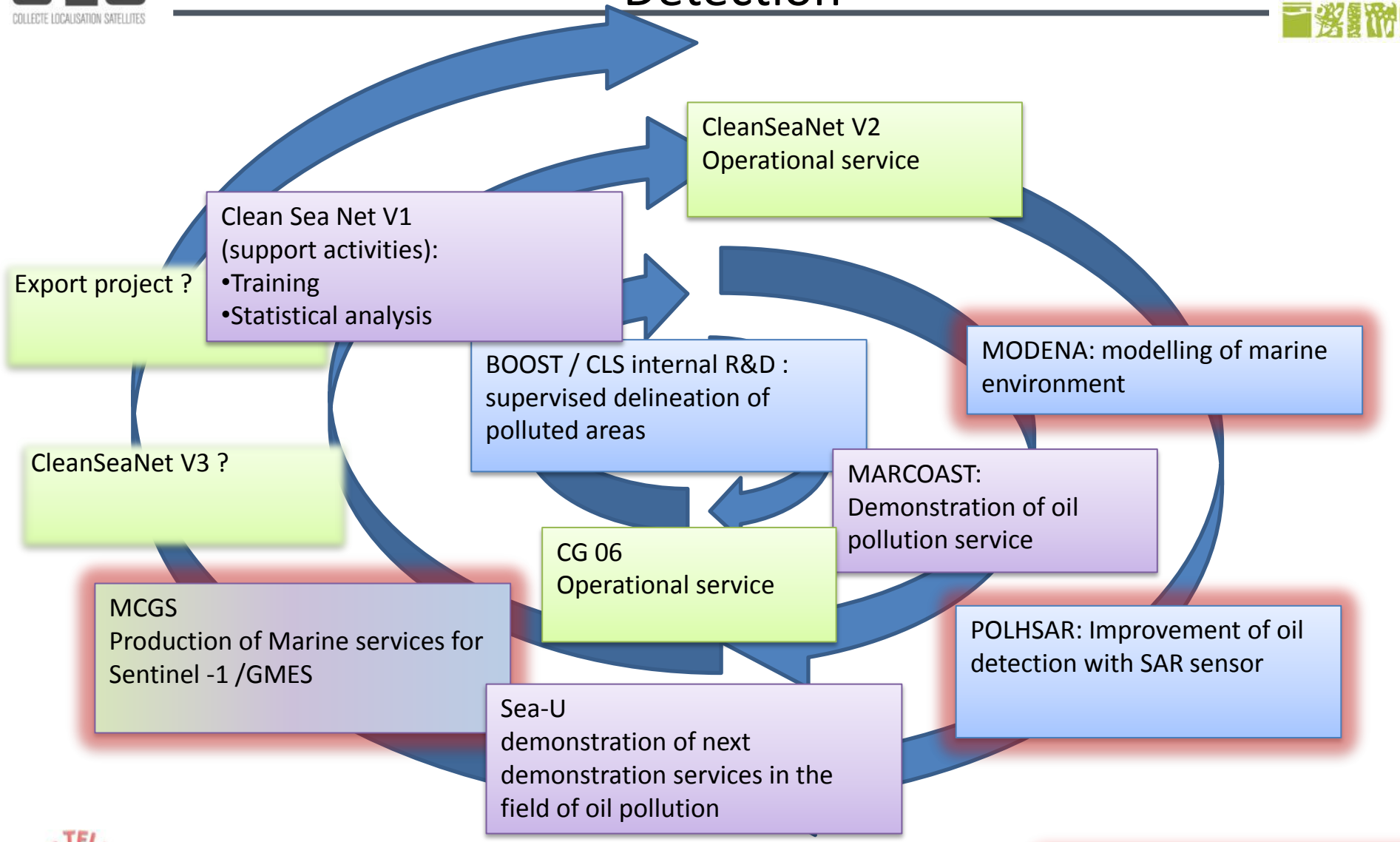
CLS : FROM R&D ACTIVITIES TO SERVICES... AND BACK

Coordination of R&D and Services



- R&D studies:
  - Preliminaries studies
  - Improvements of processing
- Offline services
  - Statistical analysis
  - Quality & performance assessment
- Real time services
  - Operational delivery of products and analysis

Example: projects related to Oil Spill Detection



R&D	Off line services & Demo	NRT Services

Regional projects
Involving multiple partners in at least one regional competitive cluster

MODENA : Modelling of Marine Environment

- Founded by:
  - FUI, Conseil Régional Bretagne, City of Brest, ANR
- Multi partners:
  - ARTAL Technologies, Telecom Bretagne, Ifremer, ENSTA Bretagne, IETR, CLS, Marée…
- Purpose of CLS contribution
  - Modelling of medium resolution backscattering of the sea surface in X and C band
  - Provision of satellite SAR data for the validation of the MODENA simulator
  - Validation of the calibration of the MODENA simulator
- Benefits for oil spill detection
  - Better knowledge of backscattering of clean sea

POLHSAR : Improvement of pollution detection with SAR

- Founded by:
  - ANR
- Multi partners:
  - Thales Systèmes Aéroportés, IETR (IREENA)
- Purpose of CLS contribution
  - Modelling of medium resolution backscattering of the sea surface in X band from new CosmoSkymed Data
  - Characterisation of polluted area
  - Characterisation of instrumental artefacts
  - Extension of pollution detection at high and low incidence angle and in X Band
  - Provision of satellite SAR data for validation of backscattering model of polluted area
- Benefits for oil spill detection
  - Oil spill detection at low/high incidence angle and in X-band

MCGS : Environmental monitoring

- Founded by:
  - FUI
- Multi Partners
  - ACRI, CLS, GIS Bretel (Telecom Bretagne, Ifremer)
- MCGS : Marine Collaborative Ground Segment
  - Complement of Core Ground Segment of ESA for the GMES / Sentinel program
  - European coverage
  - Real time service & reprocessing services
  - High resolution measurement of wind, wave, current
  - Help for prediction of marine situation

Open issues and progress in vessel and pollution detection

ISSUES AND PROGRESS OF SHIP AND VESSEL DETECTION

Vessel detection: extension of operational requirements

- Pre processings
  - Automatic correction of mis registration
- Better detection
  - Detection of smaller vessels
  - In higher resolution products
- Better characterisation of detected vessels
  - Better measurement of length and type
  - Better Iceberg detection
- Detection in difficult scenarios
  - Detection of vessel in ice pack
- Improvement in computation time
  - Preparation for Sentinel 1 : multiplication by 300 of the volume of data
- Better exploitation of detected vessel
  - Automatic correlation of detected vessels and AIS

Preprocessing : Automatic geographic registration of SAR image

Mutual Information Metric Mattes et al. Implementation* et *Transformation Affine

Difference SAR image & reference mask before

Difference SAR image & reference mask after

Objective: Automatic and Real Time registration of shifted data

Center X = 551.5
Center Y = 1025.5
Translation X = -1.45075
Translation Y = -38.4239
Iterations = 43
Metric value = -0.250858
Scale 1 = 1.00121
Scale 2 = 0.999051
Angle (degrees) = -0.0523533

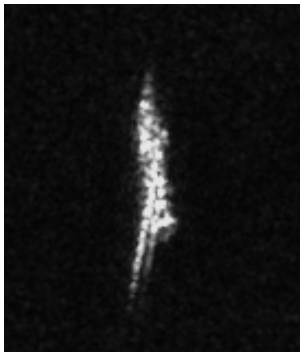
Characterisation : better length estimation

- Improvement in length estimation
- Standard technique:
  - Measurement of the shape of the detected echo
- Implemented technique:
  - Measurement of the shape
  - Measurement of the radar cross section of the echo and estimation of the corresponding size
  - Fusion of both measurements (fuzy logic)

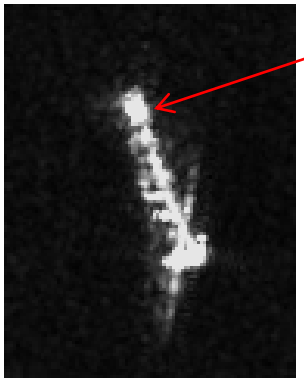
Characterisation : Attempts of Vessel recognition in RS2 Multi Look Fine data

03 : NORGAS TRADER
Pavillon : Singapour
Type : Transport de gaz liquéfié
Dimensions : 119 m x 18 m
Dimensions SAR: auto 145 m, manuelle 135 m
Code MMSI : 563662000

04 : GRAND SAPPHIRE
Pavillon : Panama
Type : Transport de véhicule
Dimensions : 199 m x 32 m
Dimensions SAR: auto 402 m, manuelle 206 m
Code MMSI : 372516000



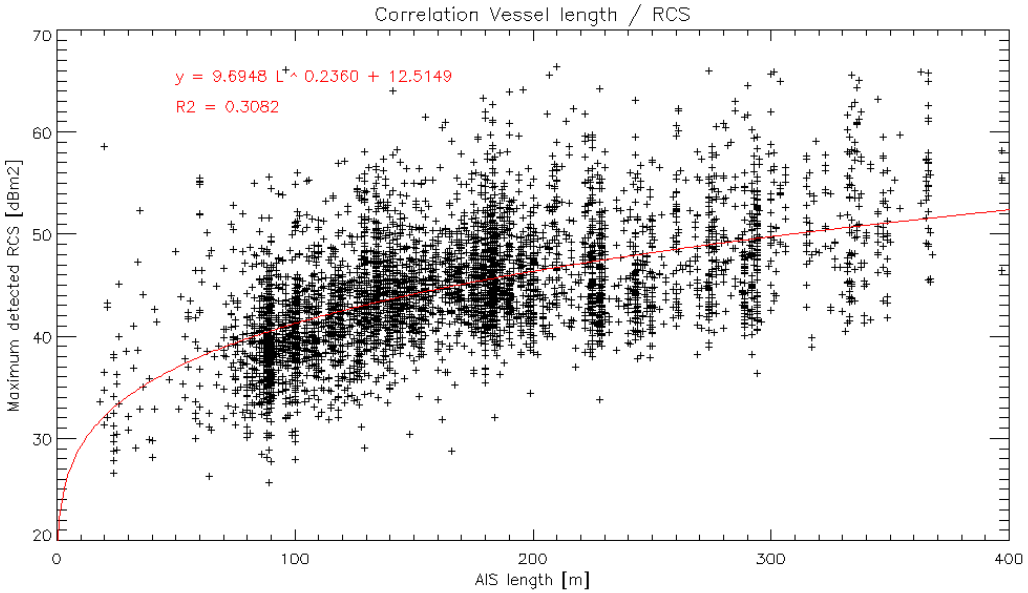
05 : HARMEN OLDENDORFF
Pavillon : Liberia
Type : Minéralier
Dimensions : 225 m x 32 m
Dimensions SAR: auto 348 m, manuelle 221 m
Code MMSI : 636090932



Détection de la flèche

Characteristion : RCS model of vessels

- Modelling of vessel backscattering



Coupling between SAR & AIS
Empirical modelling of vessel RCS with respect to it's size and incidence angle

$\boldsymbol{\sigma} = g(L, \boldsymbol{\theta})$

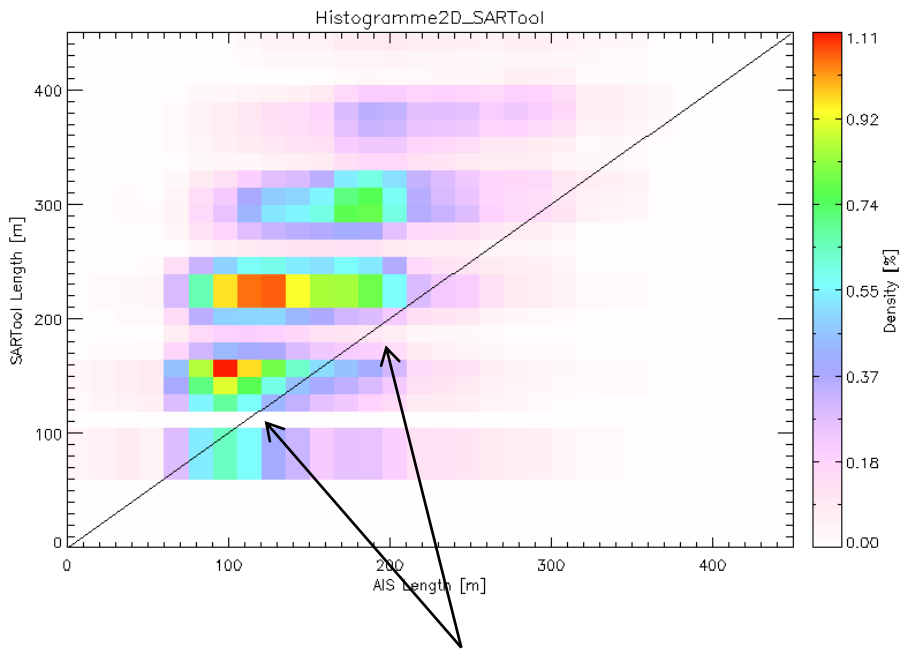
$L = h(\boldsymbol{\sigma}, \boldsymbol{\theta})$

Mode	a_0	a_1	a_2	a_3
ASA WSM VV	0.7240	32.7967	0.1131	0.1499
ASA WSM HH	0.5557	32.7650	0.1036	0.1663
ASA IMM HH	0.6216	43.5251	0.1086	0.6216
CSK HR HH	0.9327	38.1860	0.2005	0.0977
RS2 SCNA HH	0.9099	41.2843	0.3883	0.0956

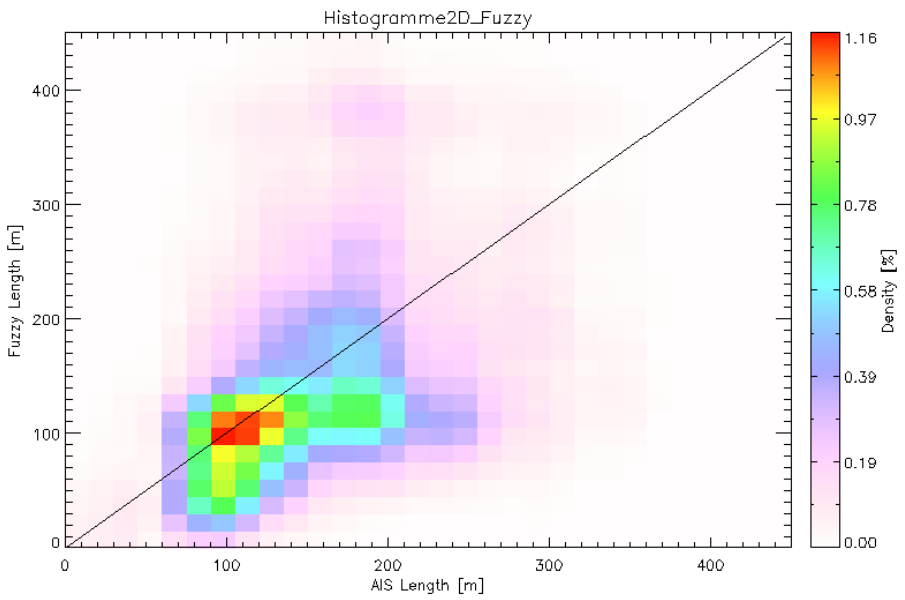
$$L = \frac{\sigma}{a_0(a_1 - a_2\theta)}^{\frac{1}{a_3}}$$

Results of fuzy logic size estimation

Geometric criteria only



Fused Geometric & Radiometric



• geometric approach with step effect : related to the geometric estimation + pixel spacing.

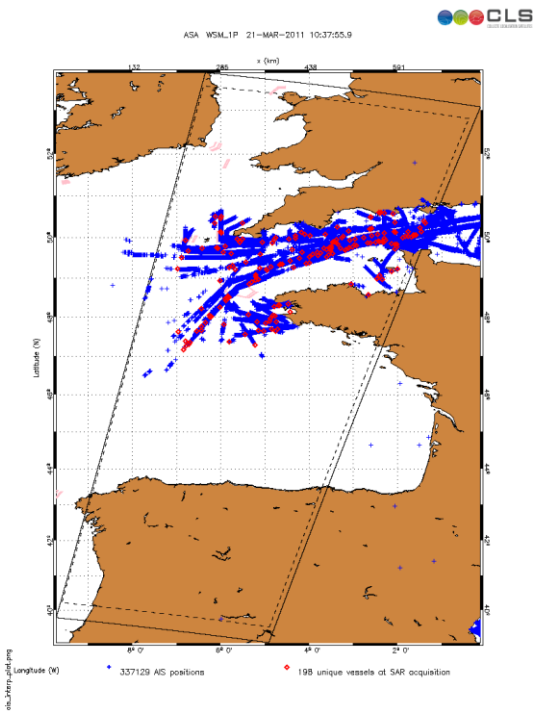
•Improvement of length estimation (better fit of the data, no step effect)
• Effective fusion for medium resolution products

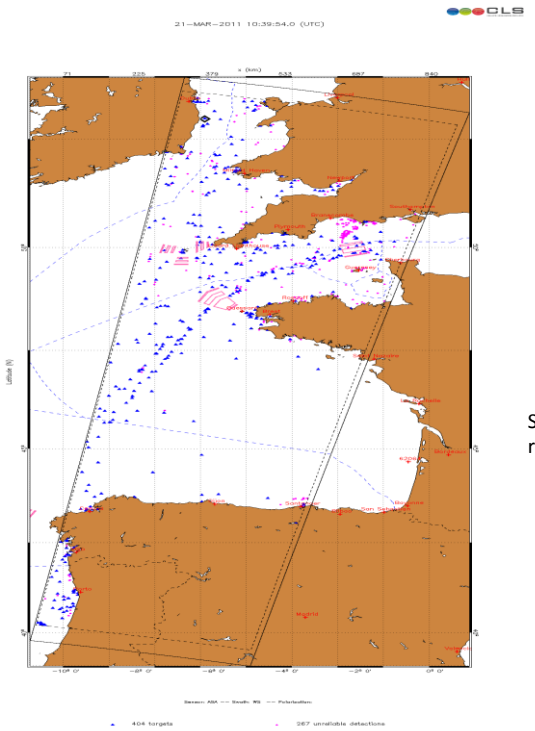
• 6447 vessels for the test, 1930 for the learning of the RCS low and fusion.

Exploitation : Automatic AIS-SAR coupling: methodology

- *Spatial interpolation of AIS positions*
  - *2 possibles cases:*
    - *Several positions known: interpolation (polynomial) with geographical positions*
    - *Only one position available: interpolation interpolation with speed and route information*
- *Temporal interpolation*
    - *Fonction of azimuthal position*
- *Counter-balancing of azimuthal offset for AIS positions*
    - *Depending on radial velocity, incidence angle, speed and satellite height*
- *Automatic coupling: iterative research of minimum AIS-SAR distance*

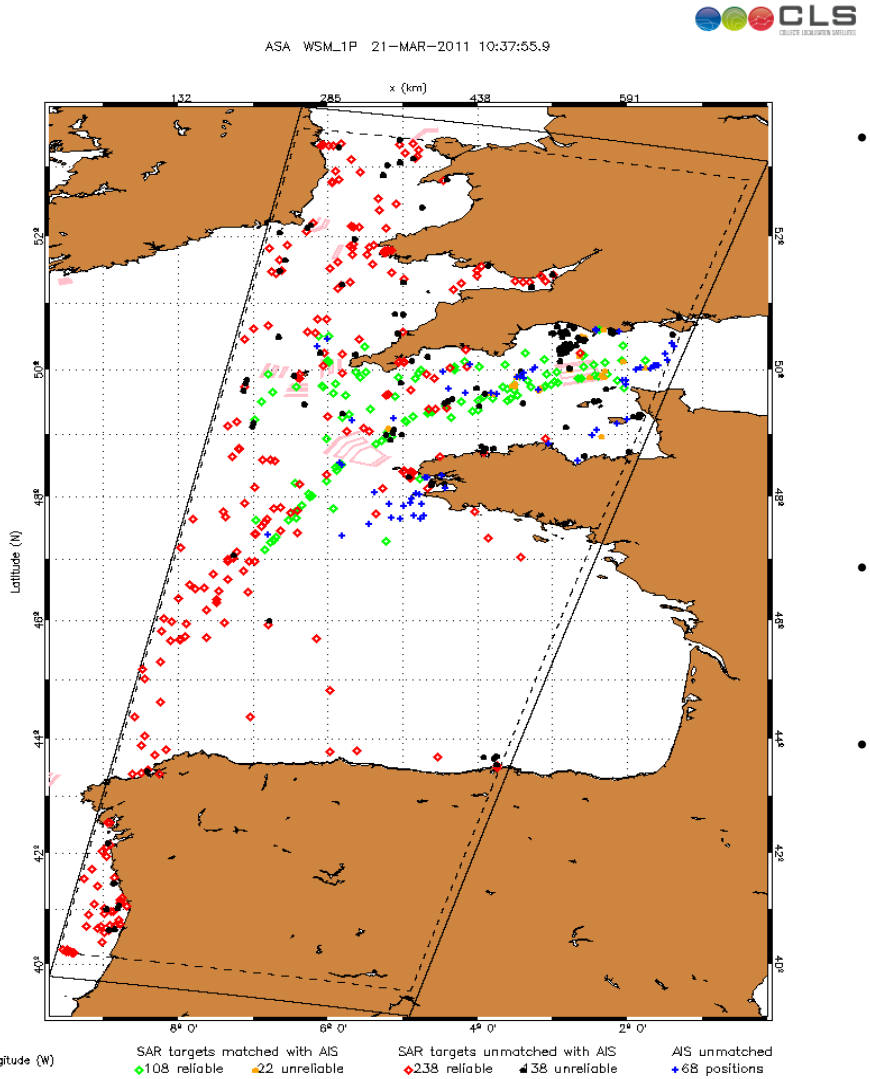
AIS positions within +- 2 hours with positions at SAR acquisitions





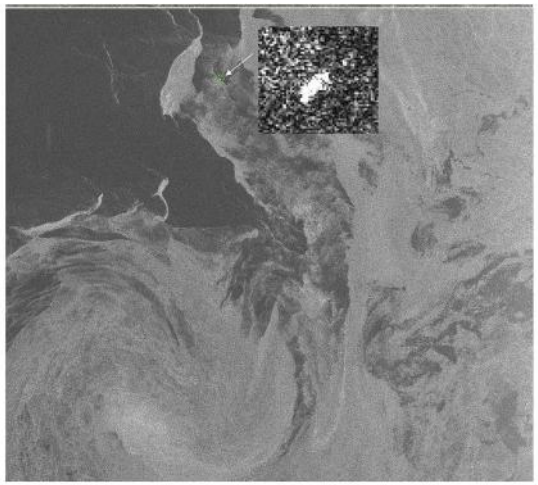
SAR-based detected target with reliable and unreliable

Exploitation : Qualitative assessment of ship detection



- *Color code:*
  - *Green: reliable SAR targets matched with AIS position*
  - *Orange: unreliable SAR targets matched with AIS position*
  - *Red: Reliable SAR targets unmatched with AIS position*
  - *Black: Unreliable SAR targets unmatched with AIS position*
  - *Blue: AIS position unmtached*
- *2 main issues*
  - *Many red points: range of AIS reception or false alarms*
  - *Many blue points: non detection by SAR image*
- *Perspectives*
  - *Need for a comprehensive understanding of:*
  - *AIS data reception for each station: range, angular aspect, sea state/atmosphere dependency…*
  - *Non detection linked to the SAR image itself*

Other Scenarios : Vessel detection in sea-ice

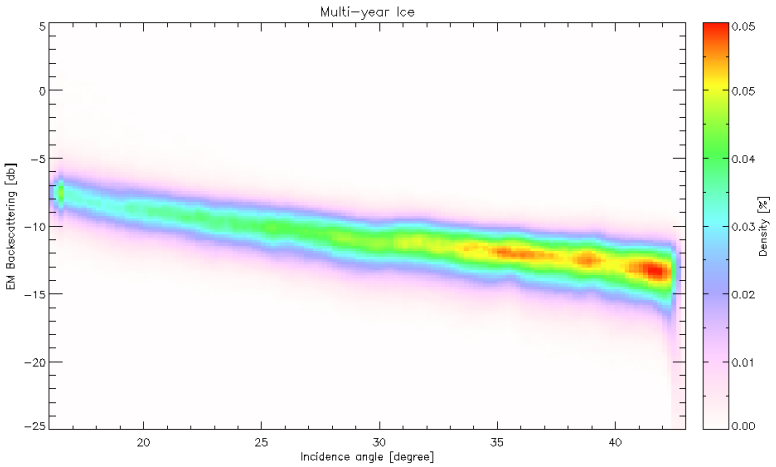


© C Brekke et al. Ship detection in ice infested waters based on dual-polarization SAR imagery, GRSL, vol 8(3) may 2011.

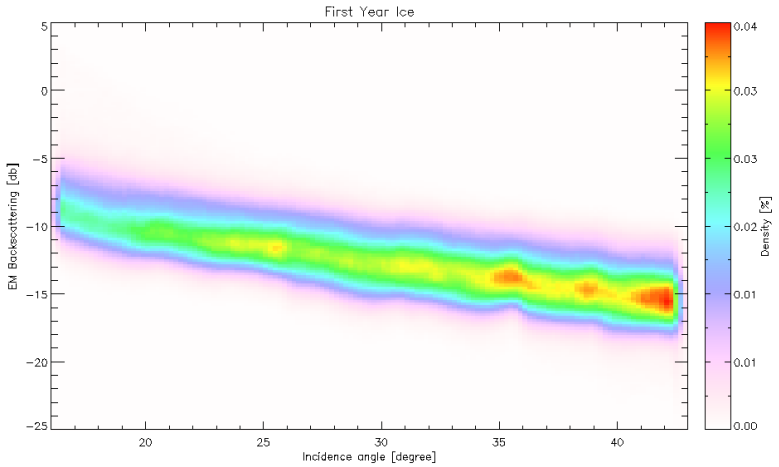
- Academic tour
  - Poor bibliography
  - Use dual pol and low incidence angle
  - Based on `classical' statistical tests used for target detection

Other scenario: Sea Ice Characterisation

NRCS vs incidence angle for Multi Year Ice



NRCS vs incidence angle for First Year Ice



Oil detection: extension of operational requirements

- Better detection
  - Semi-automated oil spill detection
- Better characterisation of detected pollution
  - Automated coupling of polluted area and detected vessels based on drift model
- etc

Conclusion

- Synergies of R&D / off line services / near real time services
- Mutual interest on those subjects from private companies, academics…
- Links between those actors through:
  - GIS
  - Regional Clusters
- Large number of research and services topics in vessel detection, oil spill detection and environmental monitoring
  - MCGS
  - Sea-U (FP7) on oil spill detection services
  - DOLPHIN (FP7) on vessel detection services