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→ SEASAR 2012

The 4th International Workshop on Advances in SAR Oceanography

FFI Forsvarets forskningsinstitutt

SHIP DETECTION USING HIGH RESOLUTION SATELLITE IMAGERY AND SPACE-BASED AIS

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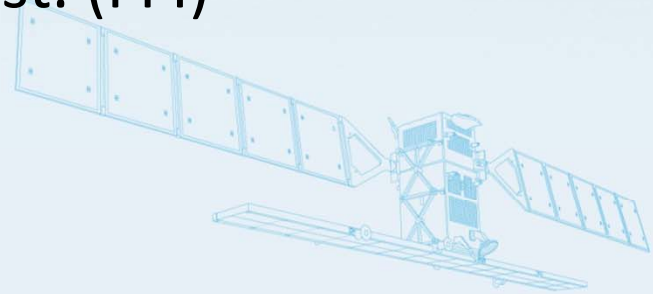


18-22 June 2012 | Tromsø, Norway

Outline

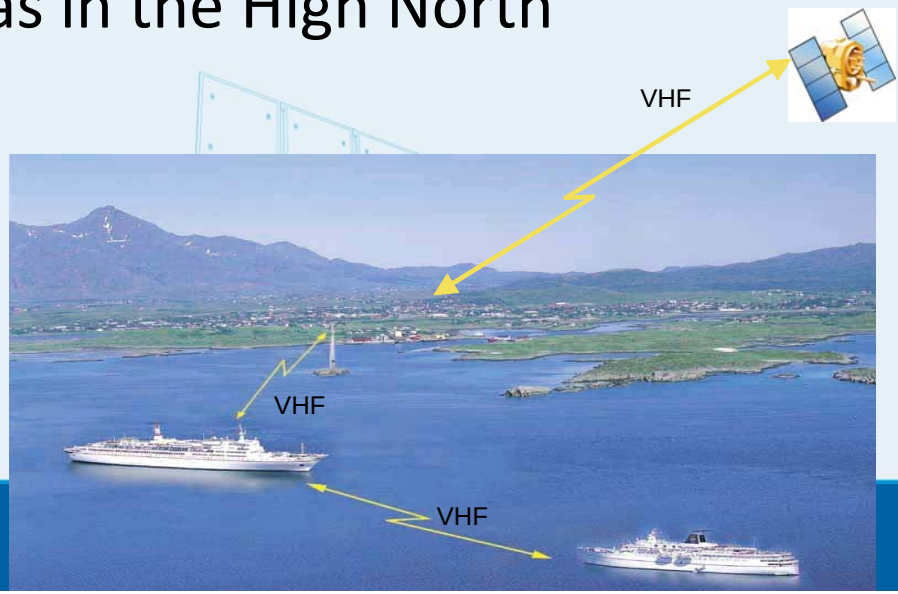
- AIS
- AISSat-1
- Radar satellites
- SAR and AIS
- The Malangen trial
- Results
- Tracking examples
- Conclusions

Introduction

- Increased shipping and fishing along the Norwegian coast and in the Barents Sea
- Spaceborne SAR since 1998 – increase overview
- Traditionally: Coarse resolution SAR imagery
- Recently: Space-based AIS -> Higher resolution SAR data for selected areas of interest
- SAR: RADARSAT-2, TerraSAR-X, Cosmo-SkyMed
- Optical: Worldview-1 and GeoEye
- Presentation:
  - Ship detection in high resolution imagery
  - Combined with space-based and land-based AIS

AIS

- Anti-collision system - shipboard transponders
- Passenger ships, cargo ships over 300 gross tons, fishing vessels > 45 m
- Ship's position, speed, heading, load, size and ship type ++
- Land-based AIS: range 40 nautical miles
- Satellite-based AIS: increases range tremendously to monitor Norway's vast ocean areas in the High North



Space borne AIS

- FFI launched AISSat-1 with AIS transponder July 12th 2010
- Receive AIS signals in space
- Demonstration mission: vessel detection in waters north of Arctic Circle

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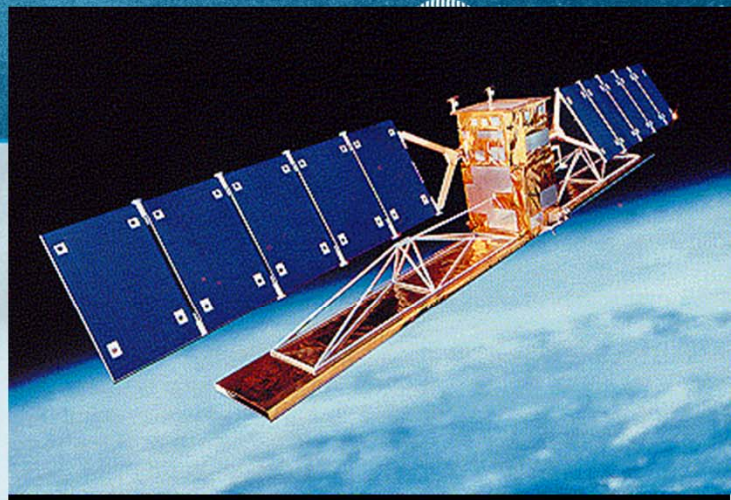
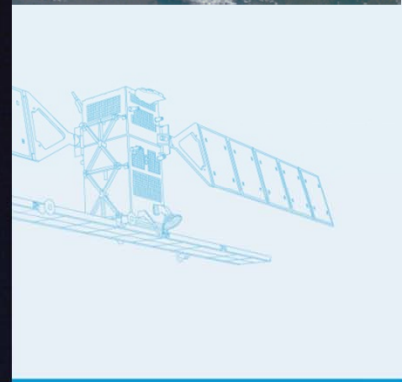
Radar satellites in orbit

- Increasing number of SAR sensors
- In orbit:
  - RADARSAT-1 and RADARSAT-2
  - TerraSAR-X, Tandem-X
  - COSMO SkyMed 1, 2, 3 and 4
  - Military systems





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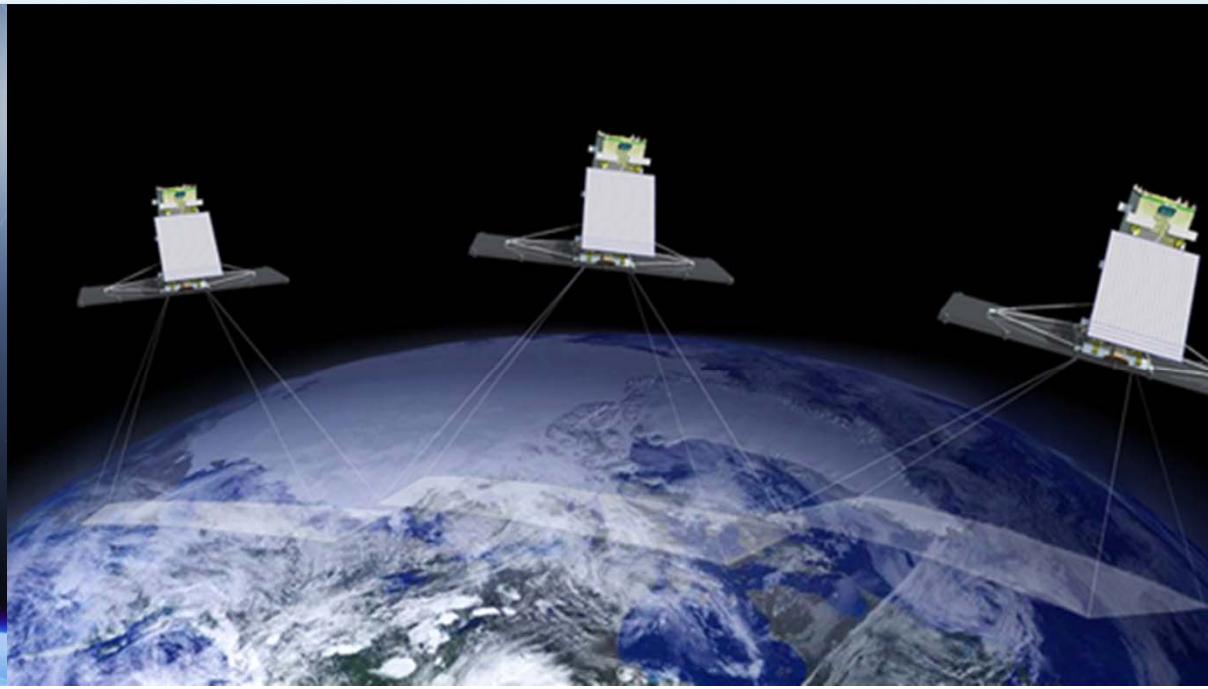
Planned radar satellites

- Sentinel-1A and Sentinel-1B
- RADARSAT Constellation Mission
- Military systems



RADARSAT-2

- Launched December 2007
- New opportunities for spaceborne monitoring of vessel traffic and fishing activities
- Better resolution
- Flexible look direction
- Multiple polarisation options
- Quad-polarisation data: 4 images of same area in diff. pol.

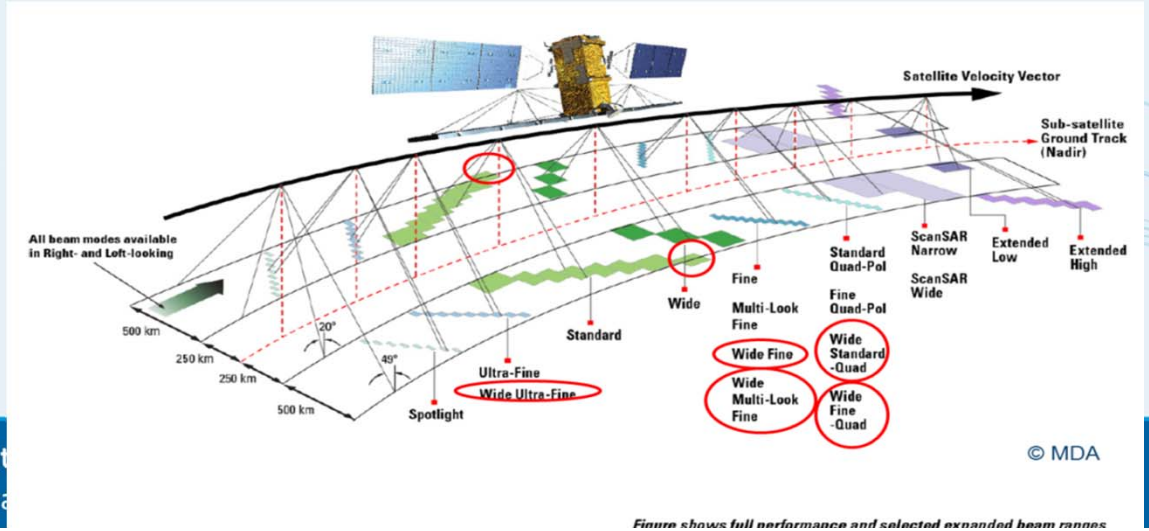


Figure shows full performance and selected expanded beam ranges

SAR and AIS

- Complimentary
- Combination of AIS and SAR for surveillance in remote areas
- AIS: identify vessels detected in SAR images
- SAR: detect vessels not reporting through AIS

Malangen trial and data collection

- Malangen: good test site
  - Possible with multiple observations of same ship
  - AIS data from land-based and space-based AIS
- September 2010
- Data:
  - 4 RADARSAT-2 Standard Quad-Pol images
  - Land-based AIS (aisonline.com)
  - Space-based AIS (AISSat-1)

		Time		
#	Date	SAR	aisonline	AISSat-1
1	19/9	16:31	16:30 & 16:35	16:31 - 16:45
2	21/9	15:33	15:35	15:35 - 15:48
3	23/9	16:14	16:15	16:13 - 16:27
4	29/9	16:39	16:40	16:34 - 16:48

September 19th

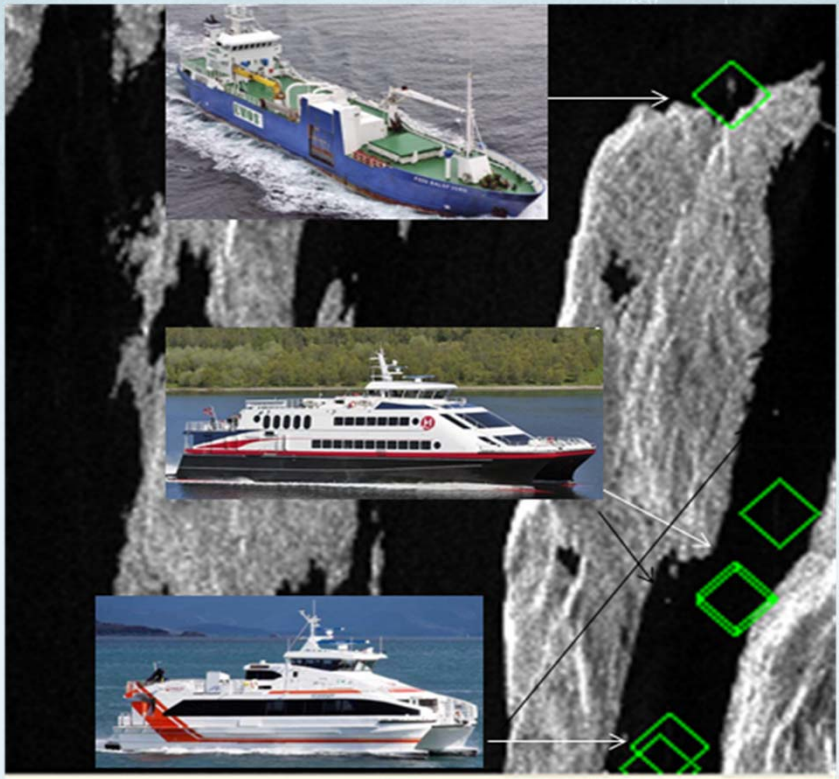
- SAR: 16:31
- Aisonline.com: 16:30 & 16:35
- AISSat-1: 16:31 – 16:45

	Detections September 19th		
Ship	**SAR**	**aisonline**	**AISSat-1 Class, detected?**
1	Detected	OK	B, detected
2	Detected	OK	A, detected
3	Detected	OK	A, detected
4	Detected	OK	B, -
5	Detected	OK	A, -
6	Detected	OK	A, -
7	Detected	OK	A, -
8	Detected	OK	A, -
9	Land	OK	B, detected
10	Land	OK	B, -

September 29th

- SAR: 16:39
- Aisonline.com: 16:40
- AISSat-1: 16:34 – 16:48

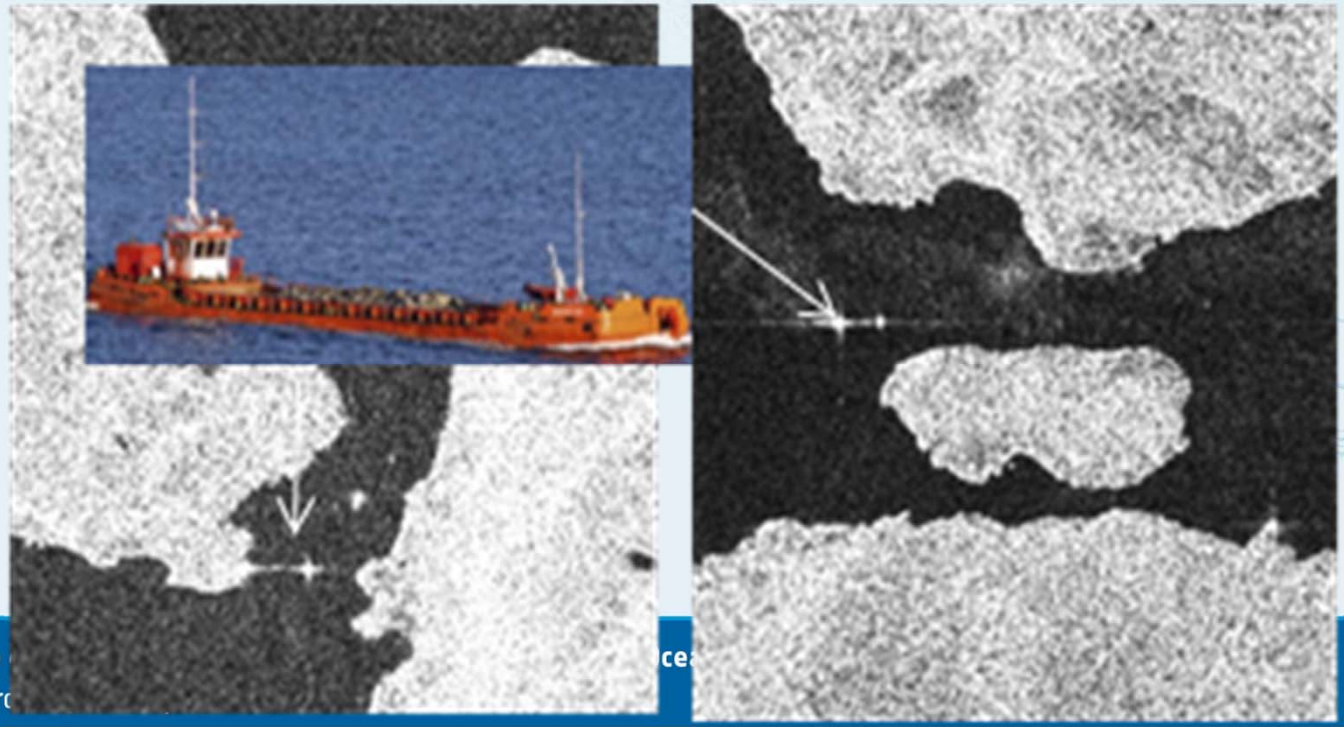
	Detections September 29th		
Ship	**SAR**	**aisonline**	**AISSat-1 Class, detected?**
1	Detected	OK	B, detected 4 times at 08:37
2	Detected	OK	A, detected 3 times between 07:00-07:02
3	Detected	OK	B, detected 2 times at 16:45
4	Land, detected	OK	B, -



- White and green: AISSat-1
- Black: SAR

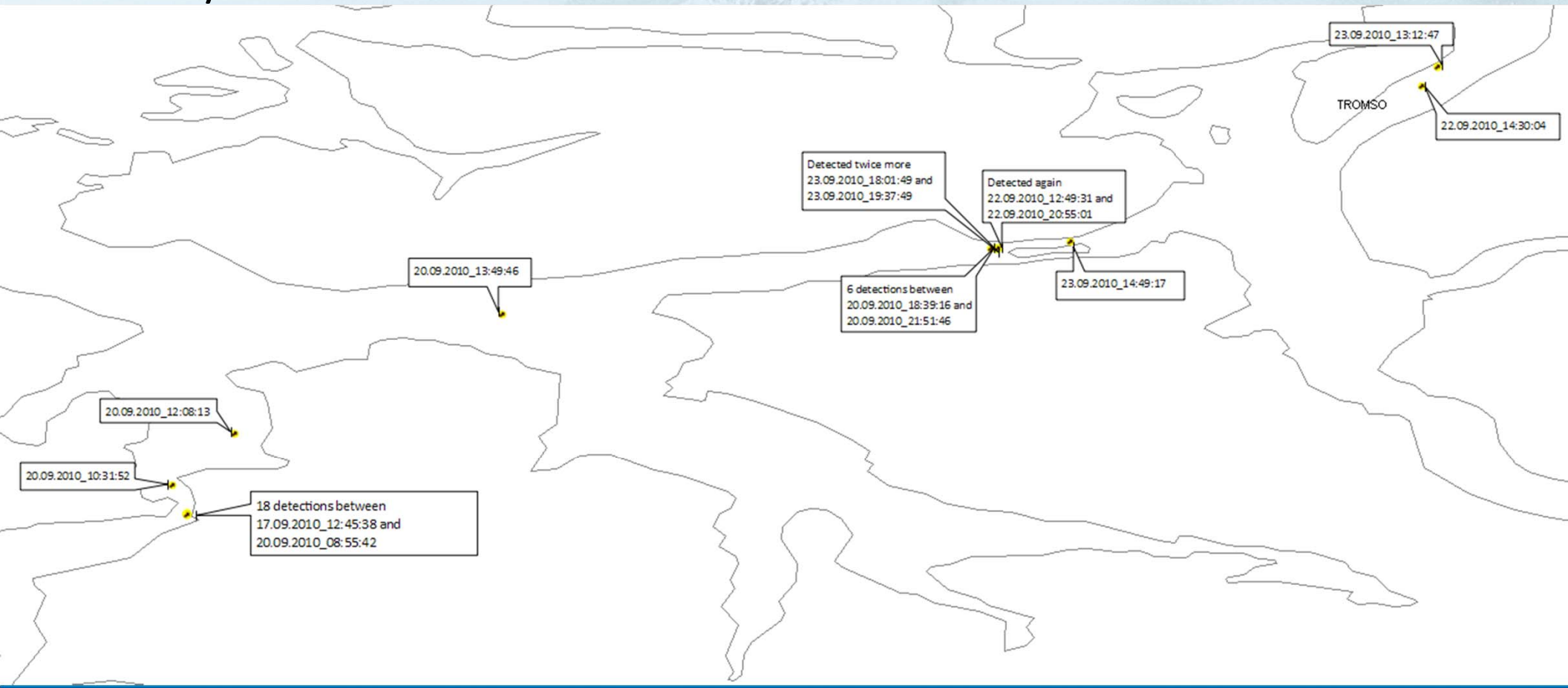
Tracking ships

- AISSat-1: new opportunity to track ships not within the 40 nautical miles range of the land-based AIS
- Example 1: Muddr080 detected using SAR September 19th and 23rd
- Ship detected several times from AISSat-1

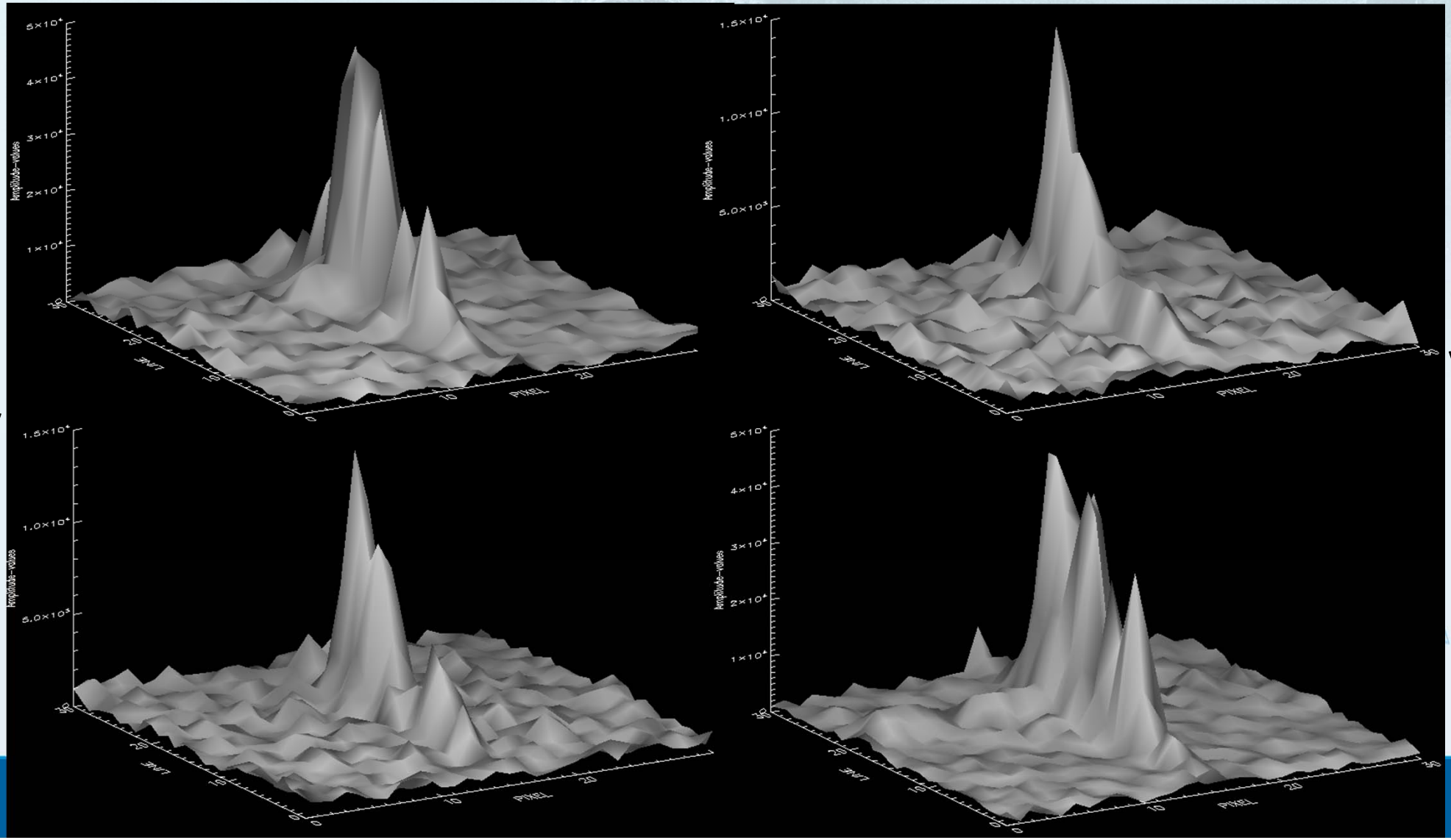


Muddr080

- Detected 35 times by AISSat-1 between 17/9 12:45 and 23/9 19:38 in 2010

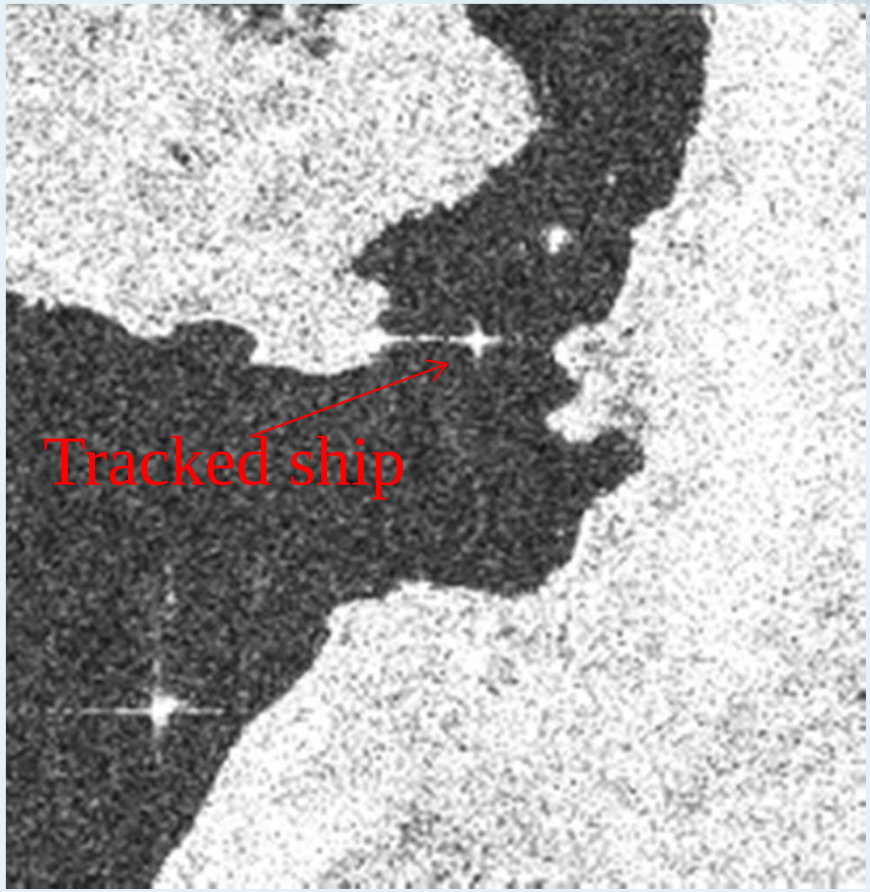


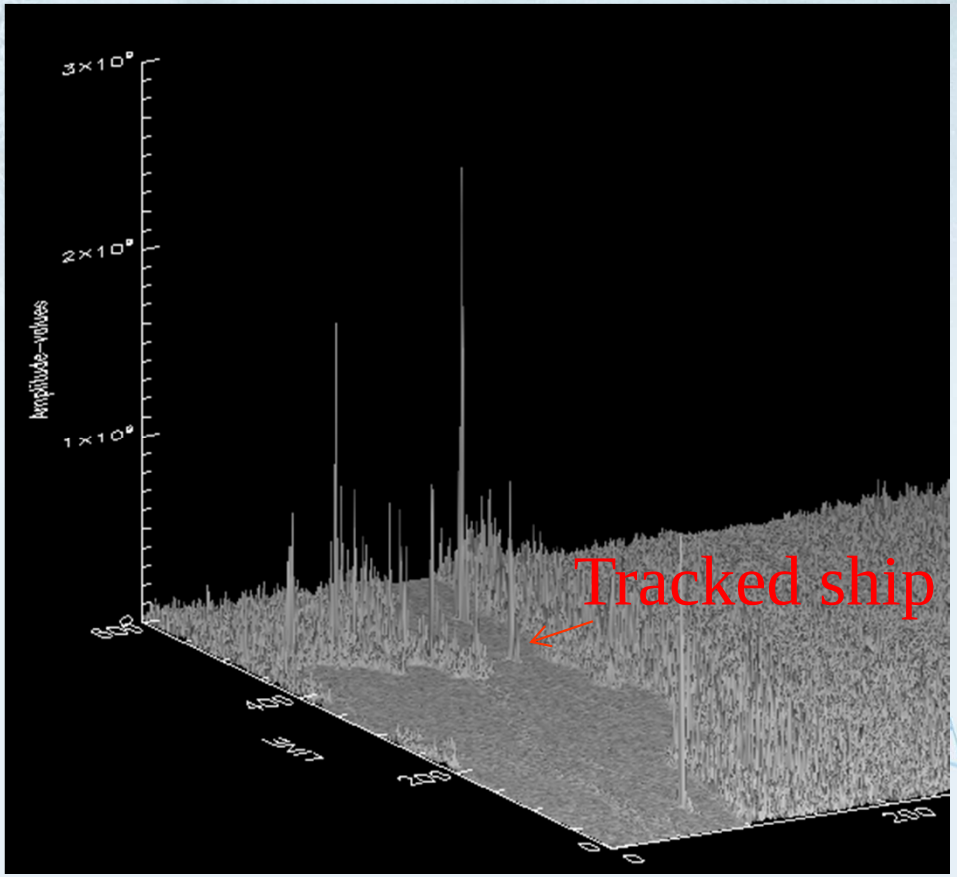
Quad-polarised data – signatures of tracked ship – high incidence angle



Ships, land and sea

- SAR 2D image and SAR 3D amplitude image





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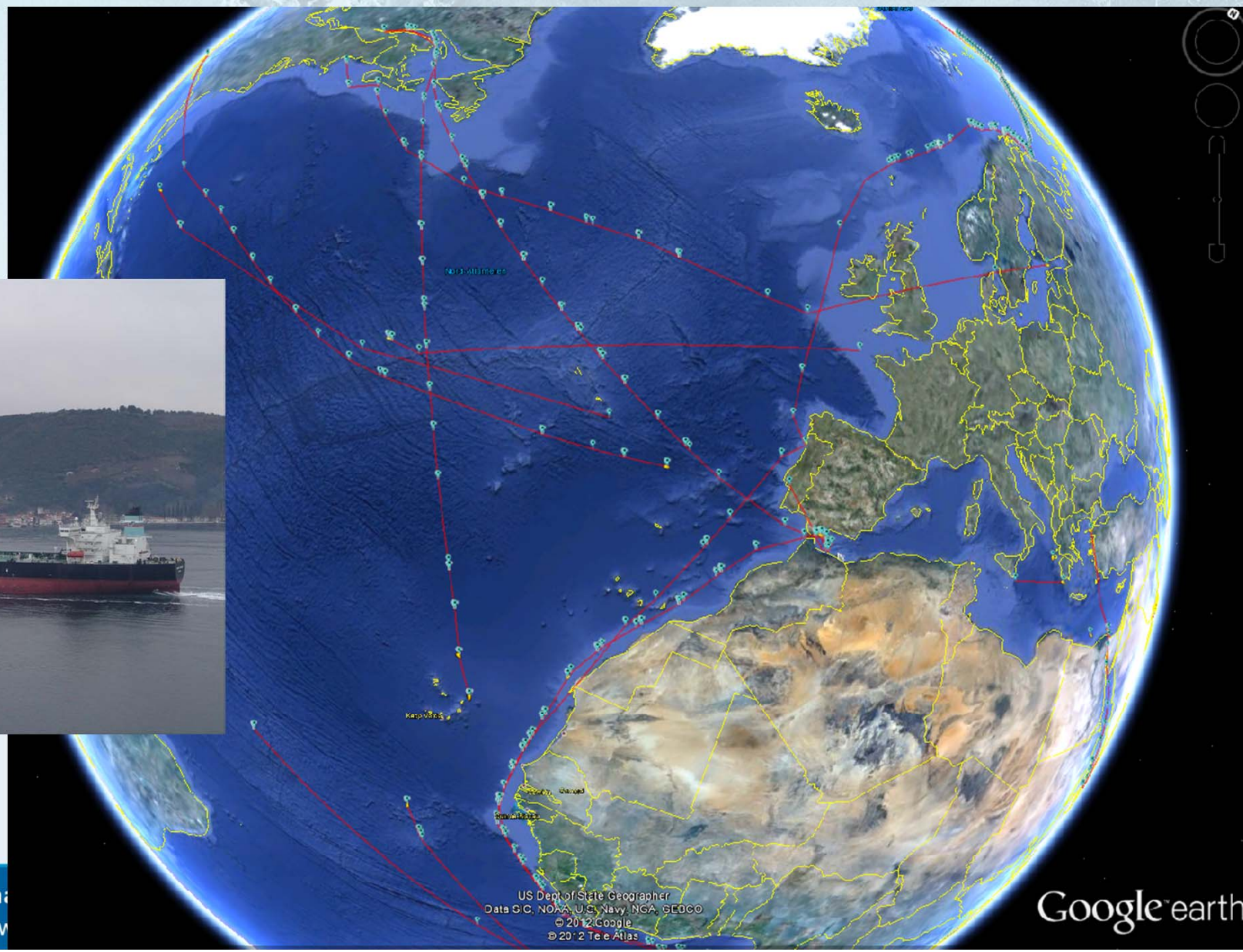
Tracking of Vladimir Tikhonov – 24/11-10 to 18/6-12



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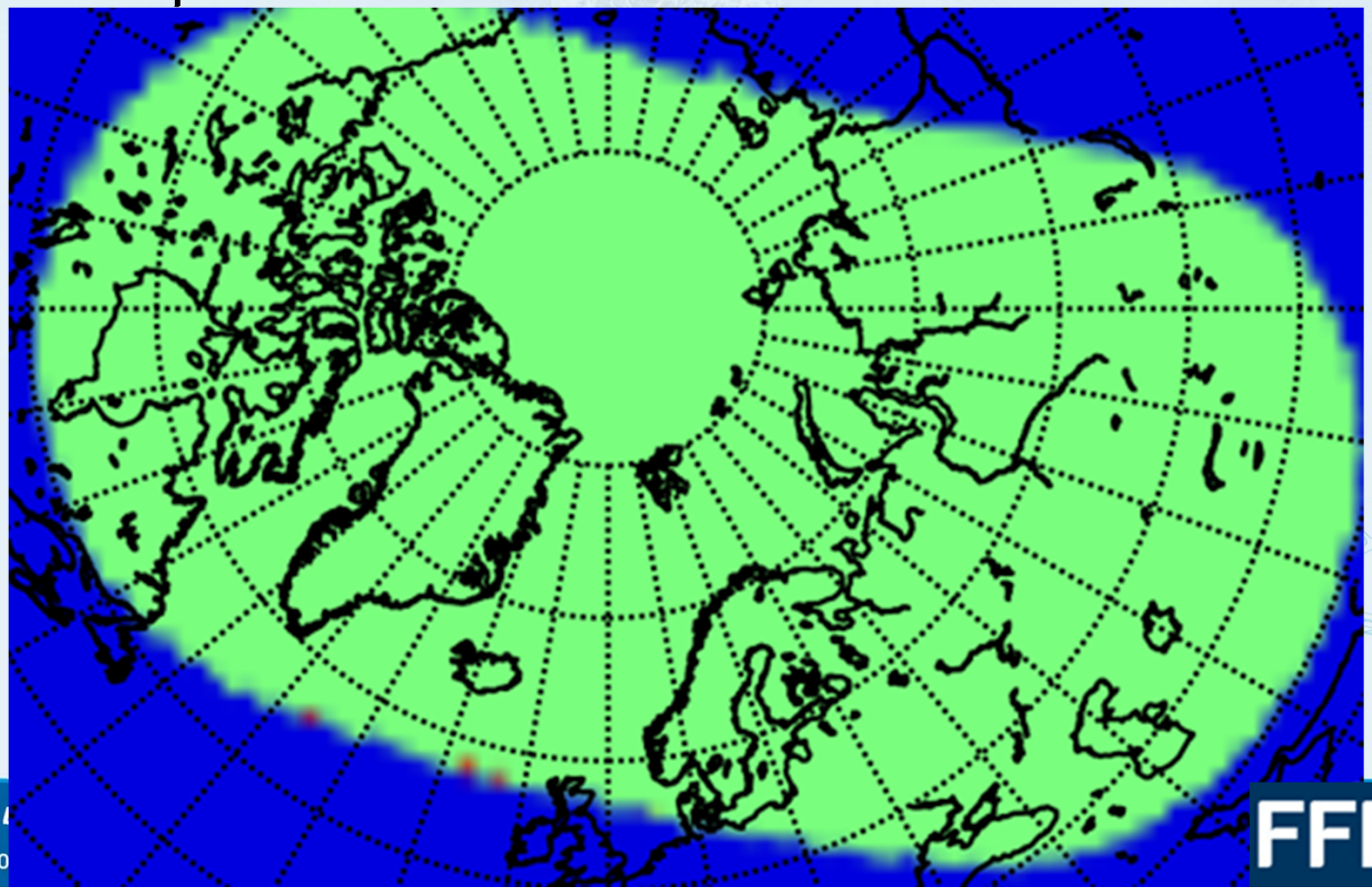
Tracking of Vladimir Thikanov

- North-East-Passage: 20/8-11 to 7/9-11

Discussion – missed detections

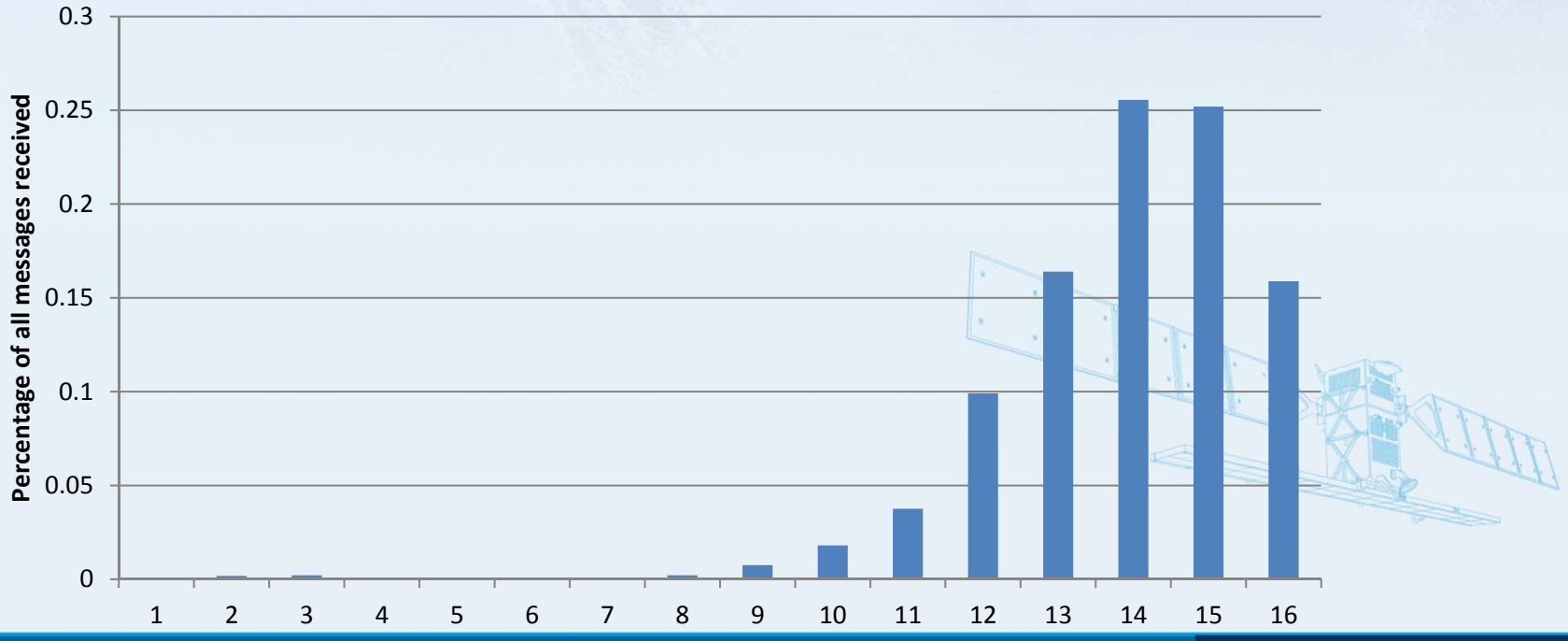
- AISSat-1 passes from south -> saturation - North Sea/Baltic Sea
  - Signals arriving at the antenna at the same time (message coll.)
  - But part of pass should be unaffected



Received messages 19/9/2010

- Achieved performance
- ≈ no messages received for the first 8-9 minutes
- Effective pass duration reduced from 15 min. to 6-7 min.

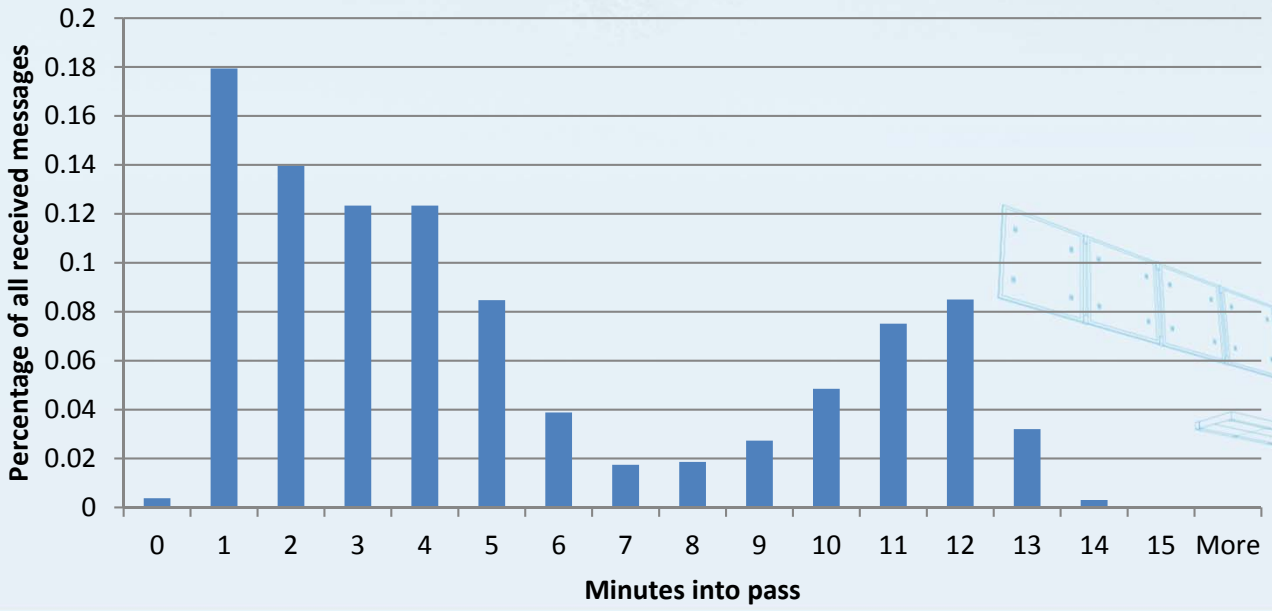
Percentage of all received messages by AISSat-1 as a function of time into the pass at 16:30 - 16:46



Simulated results for similar pass geometry

- Discrepancy not alone because of:
  - No ships in the area in the beginning (last slide 9/19)
  - Large # of ships in North Sea and Baltic

Percentage of all received messages by AISSat-1 in simulation as a function of time into the pass at 16:22 - 16:38 6/8/2011

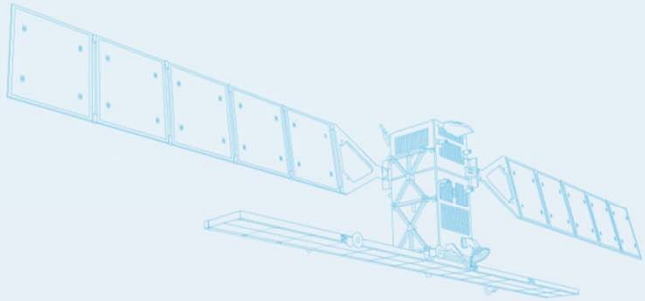


Discussions – missed detections

- Relationship between incr. performance and decr. land area
- Malangen area close to land
  - Interference from land-based re-use of AIS frequencies 1 and 2 that are also used on AISSat-1
  - Signal collisions – prob. of det. decreases
- Fjords around Tromsø – elevation angle small in beginning of pass
  - No line of sight due to high mountains (beg. and end of pass) – further reducing the effective pass duration
- High mountains makes shadows for AISSat-1 in Malangen area

Discussion – missed detections

- Vulnerable for reduced effective pass duration:
  - Class B ships send AIS signals using lower power and less frequent than Class A ships
  - Ships at port transmits messages at a lower rate -> harder to detect from space due to lower transmit rate & limited time in satellite's field of view
- AIS equipment not installed properly onboard ships



Conclusions – sum of challenges

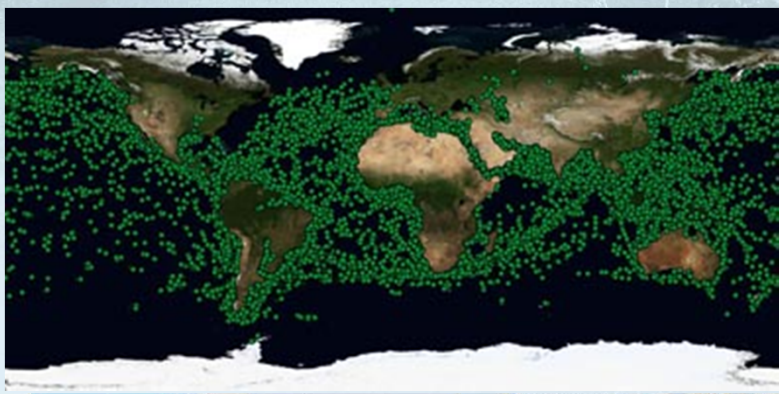
- Detection probability in a single pass varies considerably
- Even in a low traffic area (close to land!) such as the north of Norway
- AISSat-1 performance varies with the satellite antenna pointing configuration
- AISSat-1 - still in its commissioning phase (during trial)
  - No active antenna control
  - Now antenna control is possible – better performance in future trials
- Over time: ship detection probability increases greatly - tracking
- Space-based AIS has larger probability to detect ships in the open ocean areas than close to the coast

Conclusions

- Ships reported by aisonline.com are detected in SAR images (except ships close to land or very small ships < 10 m)
- Tracking examples shown using AISSat-1
- Satellite-based AIS increases AIS range tremendously - cover larger ocean areas
  - Important for Norway with vast ocean areas
- Space-based AIS larger prob. to detect ships in open ocean areas due to lower number of messages and interference
- AISSat-1 still in commisioning phase
- AISSat-1 first generation technology demonstrator – focus on the Norwegian areas in the High North

NORAIS, AISSat-2 and AISSat-3

- NORAIS
  - Now on International Space Station
- AISSat-2
  - Identical design as AISSat-1
  - Flight model is finished
  - Environmental tests will be done
  - Increased coverage and backup
  - Launch 3rd or 4th quarter of 2013?
- AISSat-3
  - Better receiver
  - Next generation AIS satellite
  - Another payload as well on the satellite?



Aknowledgements

- AIS data – courtesy of Norwegian Coastal Administration: aisonline.com operated by Christian Michelsen Research (CMR)
- Thanks to the Norwegian Space Centre for sponsoring AISSat-1