Sensors and signature management in the Baltic Sea

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Sensors and low observables

Acknowledgement: The Swedish Armed Forces' R&D programme for Sensors and Low Observables (FoT SoS)

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Research on sensors and low observables

- Evaluate possibilities and limitations w. (new) technologies, system & capability perspectives
- Experimental sensor research in optronics and radar, new sensor techs.
- Advanced signal and image processing
  - AiTR and robust tracking
  - Machine learning and sensor/data fusion
- Low observables
  - New materials
  - Modelling & simulation
  - Signature management

Photo: Sw.AF

Photo: FOI

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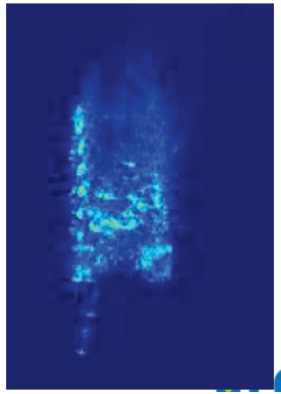


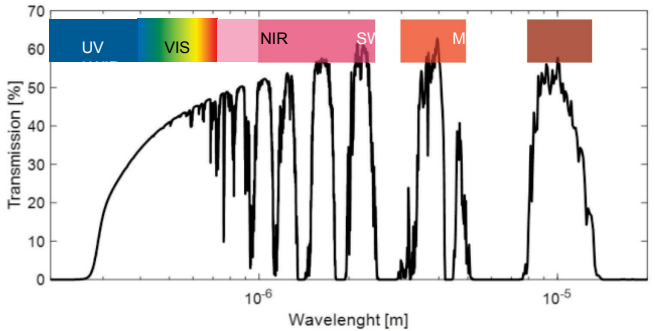
ISAR of T72 (FOI)

Sensors/signatures vs. atmospheric conditions

- Sensor systems are used 24/7/365
- Need for appropriate signature management
- Aim: early warning and transparent battlefield

- The weather in the Baltic area is naturally varying
- In future, Baltic area will have smaller ice coverage, be warmer and be more humid
- Temperature, humidity, aerosols, rain, snow affects ducting and line-of-sight

- Strong development of sensors, AI, machine learning the last 20 years
- Some atmospheric models used today were developed 30-40 years ago or are based on models for other areas



Military Radar Bands

Radar Band	Frequency	Notes
HF	3 - 30 MHz	High Frequency
VHF	30 - 300 MHz	Very High Frequency
UHF	300 - 1000 MHz	Ultra High Frequency
L	1 - 2 GHz	
S	2 - 4 GHz	
C	4 - 8 GHz	
X	8 - 12 GHz	
Ku	12 - 18 GHz	
K	18 - 27 GHz	
Ka	27 - 40 GHz	
mm	40 - 300 GHz	millimeter wavelength

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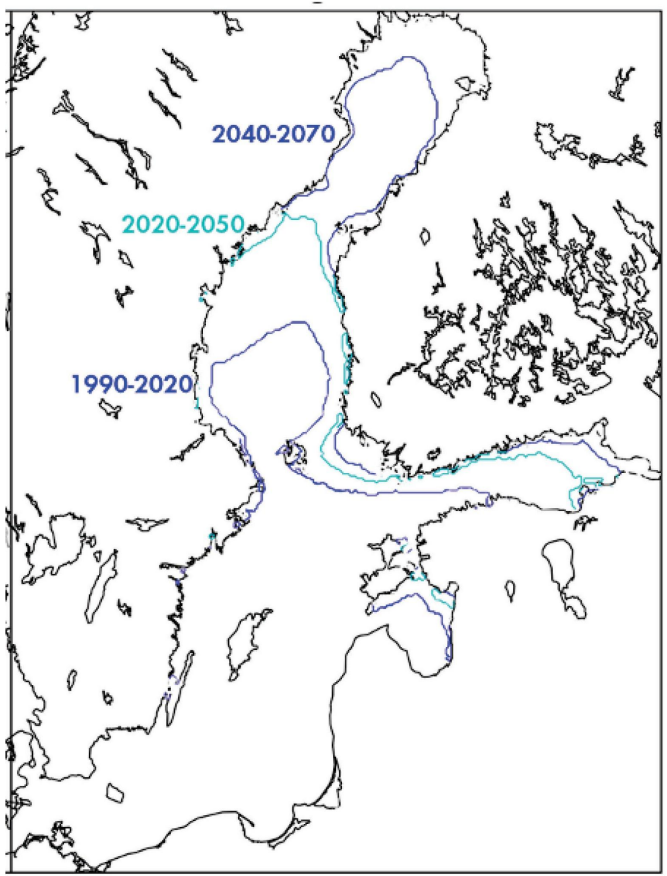
Prediction of maximal, average ice coverage



- Trend: less ice coverage
- Ice coverage will vary year from year
- No/little ice in the Baltic area:
  - more humidity and rain
  - ducting and visibility will be affected

Source: Swedish Meteorological and Hydrological Institute (SMHI)

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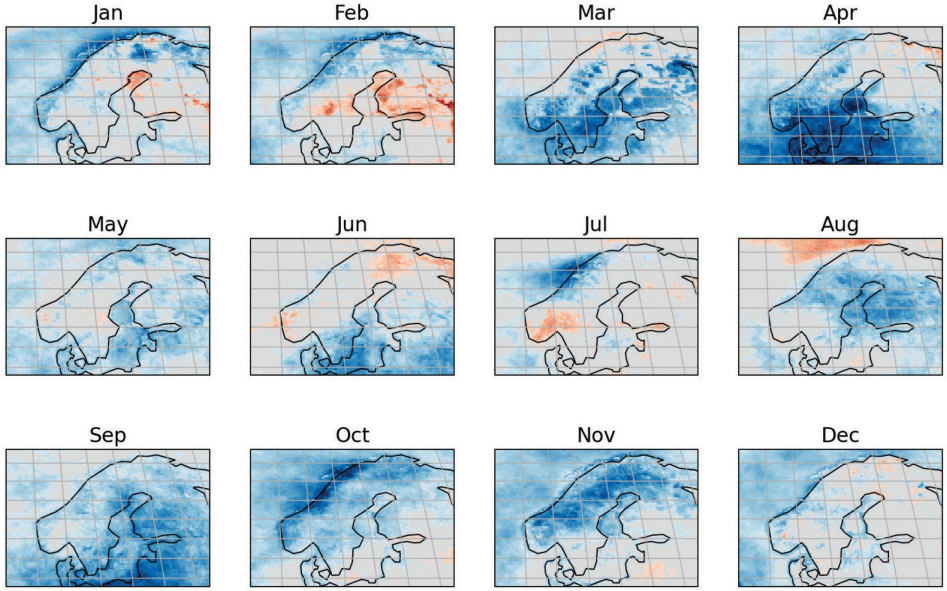
Trends in cloudiness

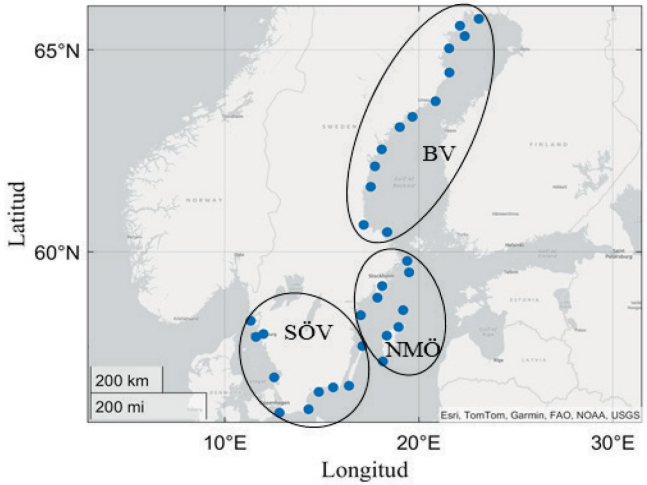
- December-February: almost no trend in ice-free parts of the Baltic Sea
- Dec.-Feb.: trend towards more clouds in the Gulf of Bothnia and the Gulf of Finland
- March-June, August-September: trend towards less clouds in the Baltic Sea
- Exception is south part of the Baltic Sea in August, trend towards more clouds



Photos: Swedish Armed Forces

Trends in cloudiness, %/decade, 1982 - 2020
Source: EUMETSAT CM SAF

Atmospheric effects in EO/IR near sea level



	Oct-Mar Day	Oct-Mar Night	Apr-Sep Day	Apr-Sep Night
SÖV	40%	35%	60%	55%
NMÖ	60-65%	60-65%	80%	75%
BV	65%	65%	85%	80%

- Visual sight measured by SMHI 2010-2023
- Visual sight reduced by aerosols, rain, snow, fog
- Visual sight > 25 km in table
- Visual sight < 1km 1-3% of the time, all areas

Rahm, FOI-R-5694-SE, 2025.

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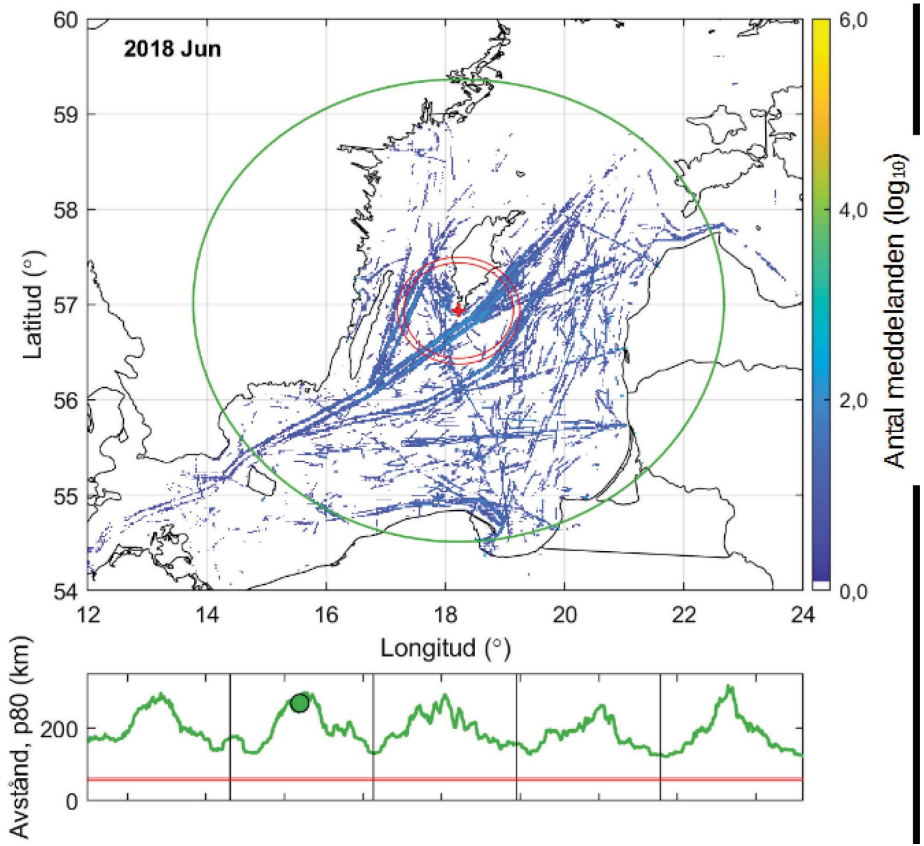
Atmospheric effects in radar near sea level



- Histogram of # AIS messages received at south part of Gotland
- Blue lines: traffic lines
- Red circles: normal radar horizon for two heights above sea level (one day)
- Green circle: 80% of received messages (one day)
- Below: time series of radius for 80% of all received messages (5 years)
- Bigger radius in the summer

Bergander, et al., FOI-R-5697, 2025.

Also, natural and artificial islands

Country	#Islands	# Inhabited islands
Sweden	267,570	984
Norway	239,057	60+
Finland	178,947	780
Japan	120,792	430
Canada	52,455	260
UK	6,346	129

List of countries by number of islands – Wikipedia


Photo: Swedish Armed Forces

Most islands are not inhabited and lacks infrastructure

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Effects on sensors and signature management

- Analysed data is from sensors used for meteorological purposes
- Need more knowledge in military interesting wavebands/frequencies
- Development of sensor systems the last 20 years
  - High-resolution sensors
  - Long range EO/IR sensors
  - AI/machine learning, ATR, change detection
- High-fidelity models specific for Baltic area needed
- Decision support systems based on current and predicted weather conditions are needed

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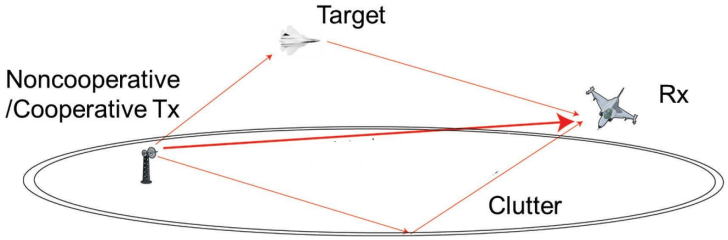
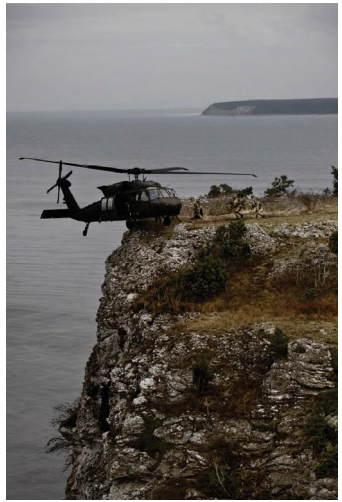
Towards tactical use



- Signature management
  - Adapt to the current atmospheric conditions
  - Adapt the platform´s signature
  - Plan when to move vessels, ships, logistics etc.
  - Islands, real or man-made, can be used tactically
- Sensor use
  - Plan when to use what sensor
  - Multi-static sensor configurations/sensor networks
  - Systems of multimodal sensors
  - Multi-static sensor setups
  - Algorithms that can find the weak signals gives early warning
- Tactical decision aid needed for real-time estimate/predictions of sensor range
- Tactical decision aid can also be used for planning of signature management
- Red-blue scenarios:
  - Predictions can show both own and the adversaries' sensor range
  - Can be used to predict effects of own and the adversaries' signature management



Photos: Swedish Armed Forces

Thank you for your attention!

Photo: Swedish Armed Forces