

Ice and wave field sensing with Sentinel-1

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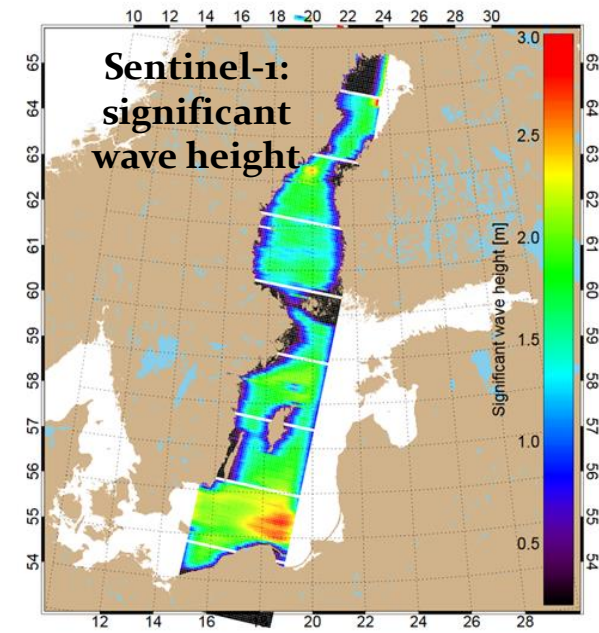
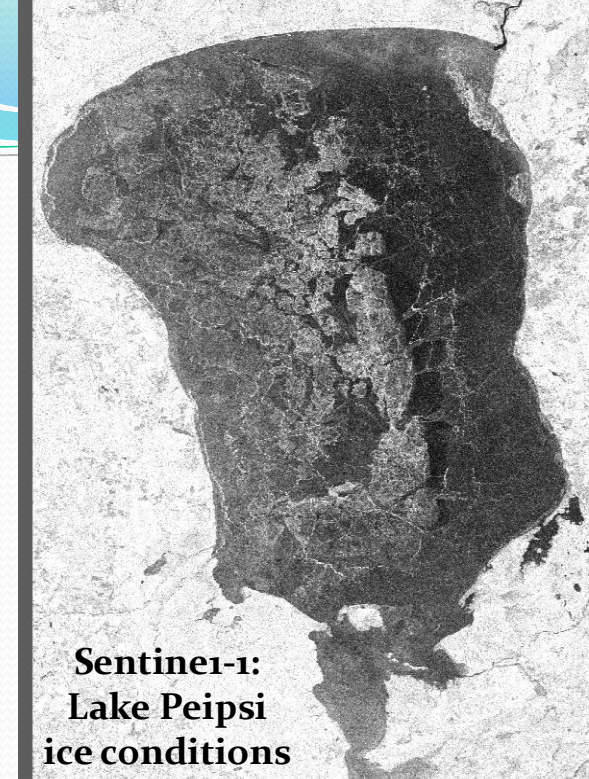


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Outline

- Sea ice monitoring from Sentinel-1 in Estonia
 - Sea ice extent from Sentinel-1
 - Operational ice monitoring
- Sentinel-1 wave information products in the Baltic Sea
 - Improved wave forecast
 - Coastal process studies

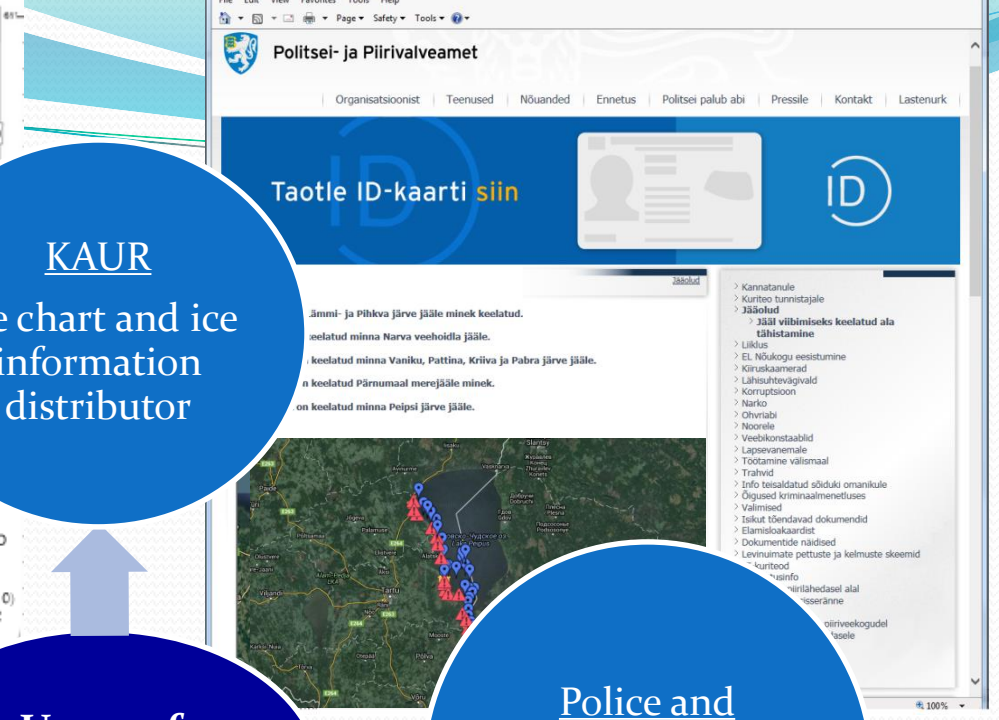


Background: why do we need operational ice monitoring?

- End users- 1000 fishermen on the ice daily.
 - In case of extensive ice coverage the number of fishermen on the Gulf of Riga is over 1000 per day.
 - There have been incidences when 50-80 fishermen have been rescued by border guard from drifting ice.
- Police and Boarder Guard Board is providing ice warnings – permission to go on ice (*eesti k. jääleminekukeeld*).
- Maritime Administration- ice breaking service to assure safe wintertime navigation
 - With improved ice information from SAR imagery the ice breakers can save fuel ~20% on average (over 0.4 MEUR annually)* **
- Environment Agency – **needs Sentinel data/products to produce ice chart and to provide ice information to all users** (*eesti k. Meresõiduohutuse seadus, § 49¹. Hüdrometeoroloogiline teenindamine*)

* „Maa kaugeire ja satelliit-navigatsioon – rakendused, kasutusvõimalused ning mõju Eestis“. (2013). Invent Baltics OÜ & Regio AS. Tellinud ja korraldanud Ettevõtluse Arendamise Sihtasutus.

** „Asutuste ülese teenuse analüüs ja kontseptsioon – Copernicuse satelliitandmete jaotuskeskus“ (2015). AS PricewaterhouseCoopers Advisors. Majandus- ja Kommunikatsiooniministeerium



Maritime Administration:
Ice breaking;
Safe and cost
effective
navigation

Users of Sentinel-1 ice information

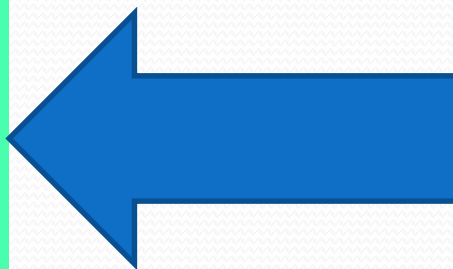
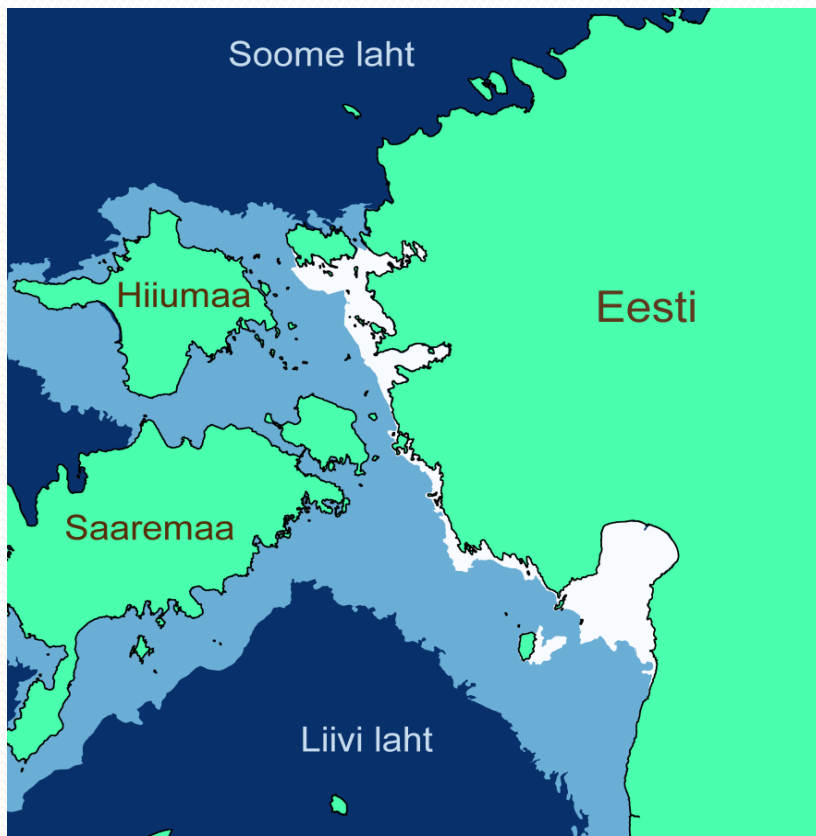
Police and
Boarder Guard –
permission to go
on ice

Endusers:
navigating
vessels and
fishermen



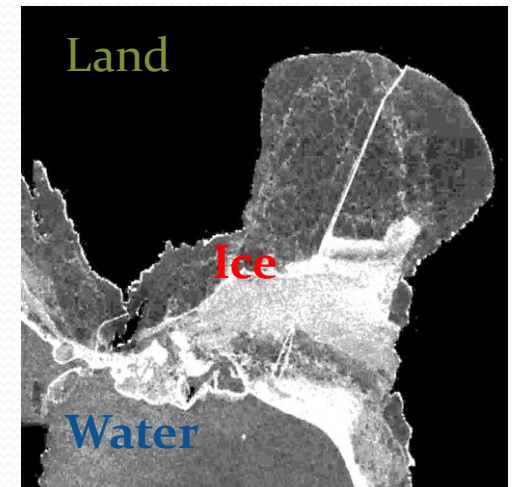
Ice service concept

- Integration of radar imagery/products and ancillary data (including observations and Copernicus products) to map the ice conditions with the level of detail required by different users.
- Machine learning algorithms for ice classification from Sentinel-1 SAR imagery.

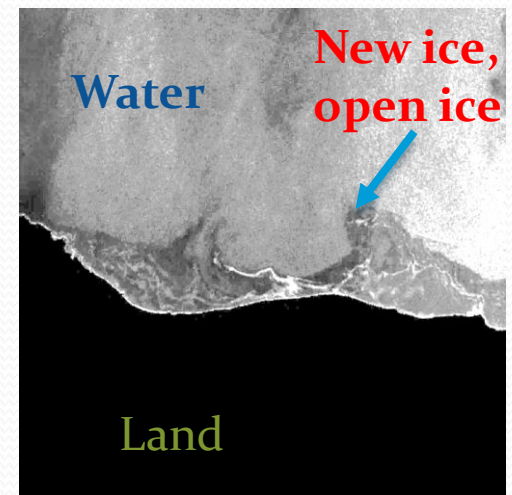


Separating different ice types based on SAR backscatter signatures

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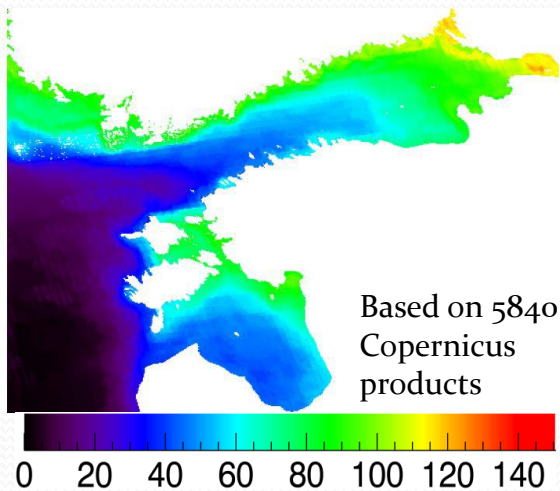
Sentinel-1 images



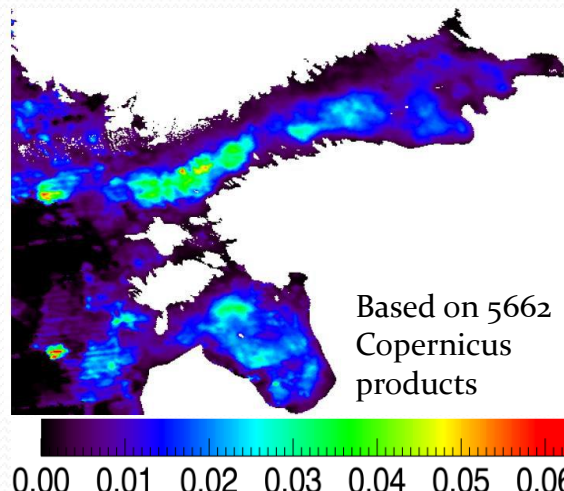
Copernicus ice products for Maritime Spatial Planning

- Statistical analysis of Copernicus ice products:
 - Ice concentration product- SST_BAL_SST_L4_REP_OBSERVATIONS_o10_o16 (Høyer,2013)
 - Ice drift product - SEAICE_BAL_SEAICE_L4_NRT_OBSERVATIONS_o11_o11 (Eastwood et al. 2016).

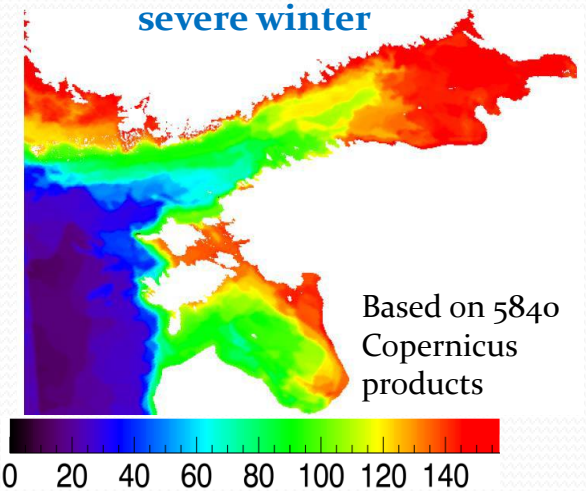
Mean ice season length (days)



Mean ice drift (m/s)



Ice season length (days)
severe winter



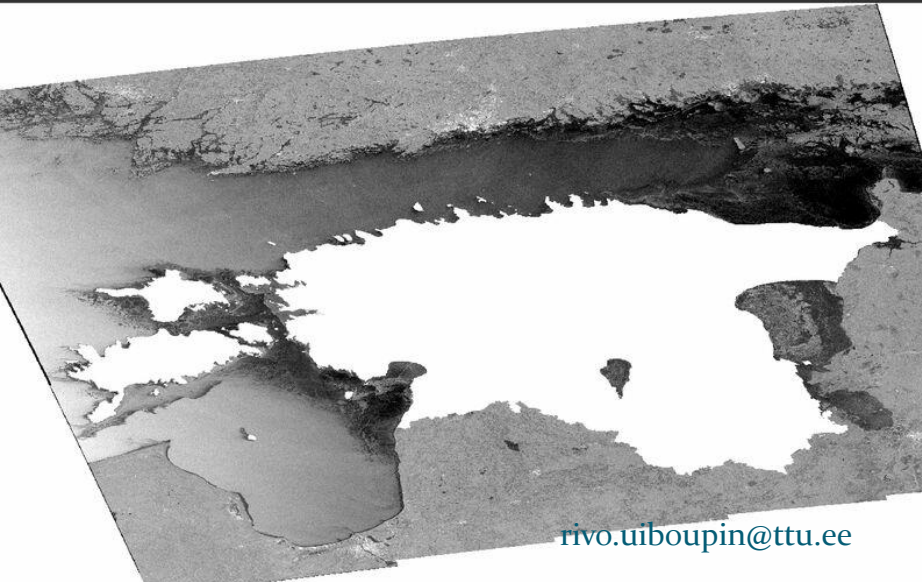
Project „Research on marine spatial planning: analysis of ice condition and compilation of map layers“ (client: Ministry of Finance, 2016)

Siitam, L.; Sipelgas, L.; Pärn, O.; Uiboupin R. (2017). Statistical characterization of the sea ice extent during different winter scenarios in the Gulf of Riga (Baltic Sea) using optical remote-sensing imagery. *International Journal of Remote Sensing*.

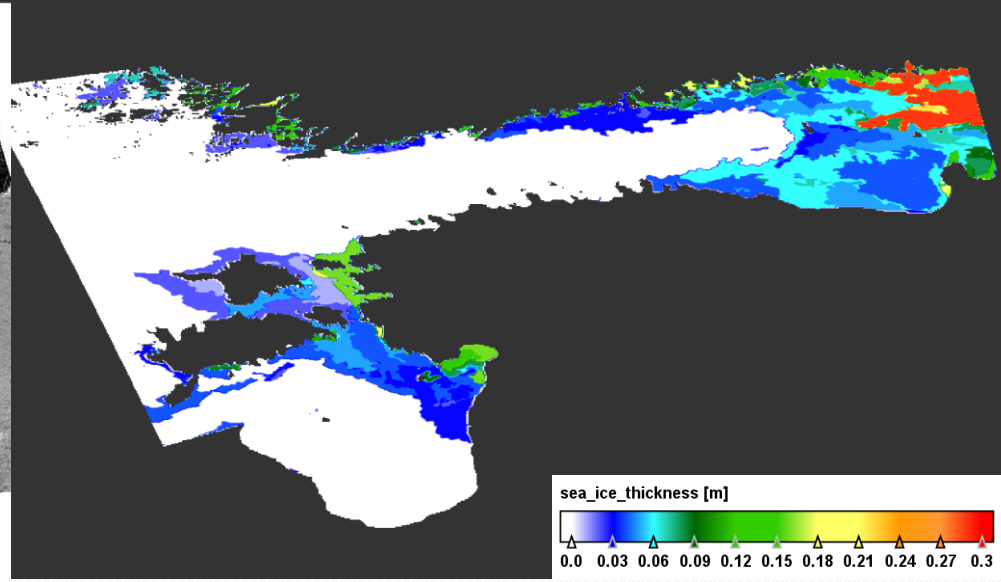
Need to improve the current CMEMS products

- Sentinel-1 Level-1 data contains information with the level of detail necessary for navigation purposes - ship channel, ice leads ect.
- Current CMEMS products are not detailed enough for detecting ice leads, cracks and shipping channels (CMEMS product res. 0.5-2.0 km)
- CMEMS products do not cover large lakes (e.g. Peipsi)
- The resolution of the products should be close to the original resolution of the data.

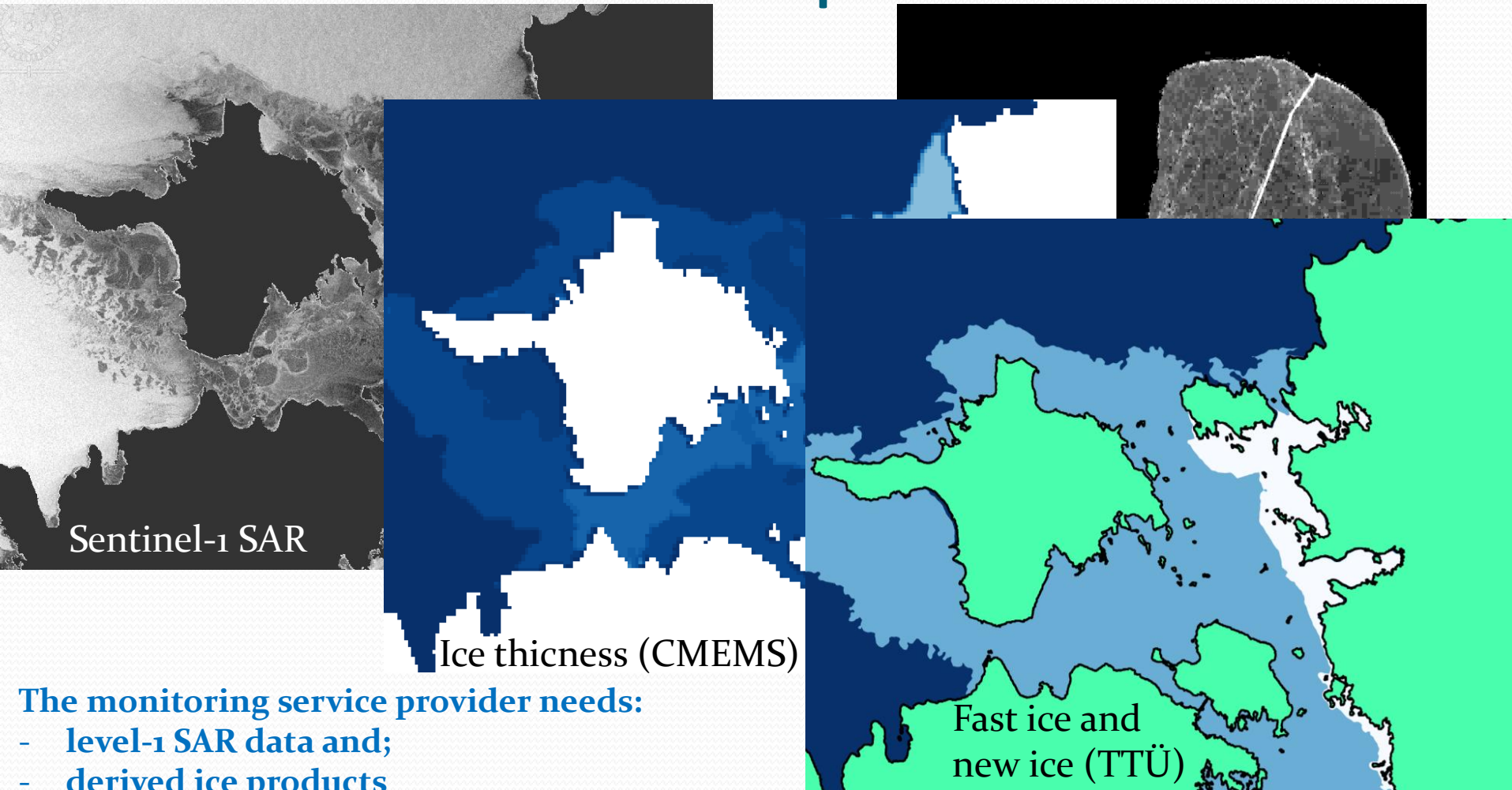
Sentinel-1 image



CMEMS sea ice thickness product



Level of detail to be lost in reduced resolution CMEMS products



The monitoring service provider needs:

- level-1 SAR data and;
- derived ice products

9 November 2017

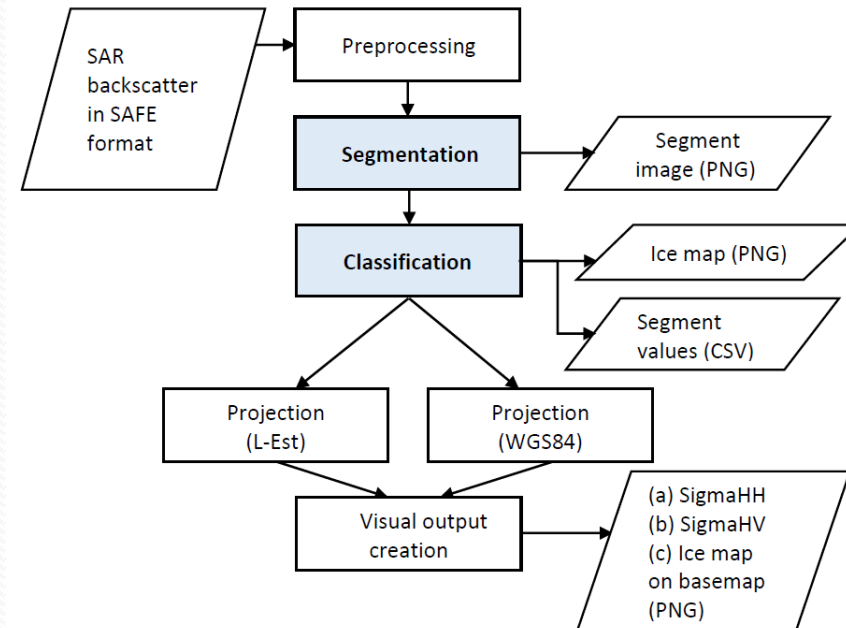
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Operational Sentinel-1 SAR processing at TTÜ for ice charting (1)

- Level-1 Sentinel data
CopernicusOpen Access Hub
with 3h interval data query
- Surface specific pre-processing
of SAR imagery: geo-referencing, radiometric calibration, surface type dependant incidence angle correction ect.
- Image segmentation and texture analysis.
- Ice/water classification.
- Data products available via html or ftp.

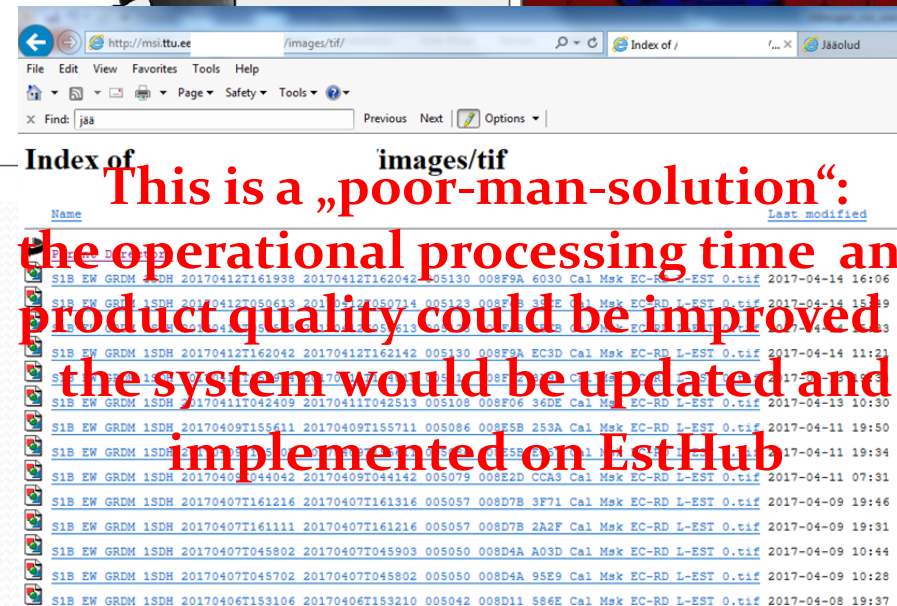
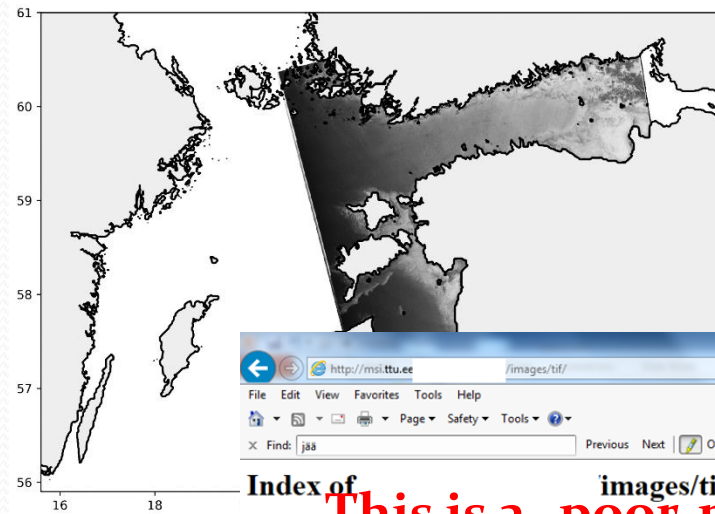
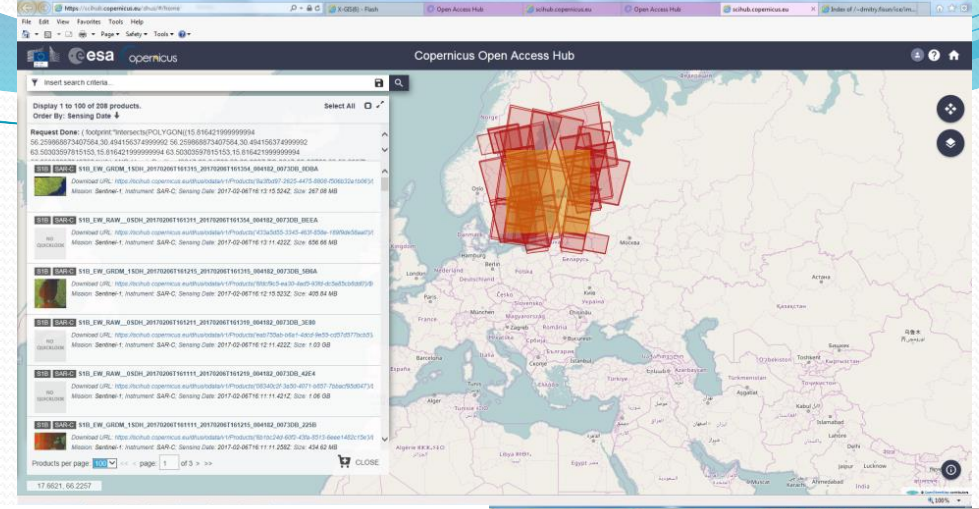
Software:

- Linux shell scripts
- SNAP functions
- Python



Operational Sentinel-1 SAR processing at TTÜ for ice charting (2)

- Data download from Sentinel Datahub
- Preprocessing and masking for expert user who need Level-1 data
- Segment based ice classification for optimizing the computation time
- Products available for users
 - *.GeoTiff
 - *.png



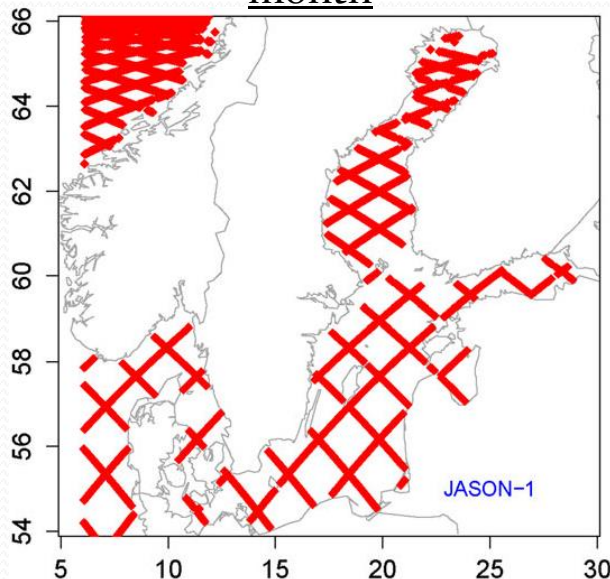
S-1 wave products for Baltic Sea

- It is essential to have high resolution wave information to understand better coastal processes (including wave current interaction)
- Wave products over open ocean have proven to be useful and reliable in the dedicated environment.
- However, the low resolution altimetry wave products/algorithms and open ocean SAR wave mode products are not sufficient for local and regional applications in the complex Baltic Sea environment which has:
 - a number of islands and staggered coast line
 - limited fetch resulting in relatively small and short waves
- Developing a dedicated „Baltic Sea/Coastal ocean“ SAR wave product (which takes into account regional limitations/peculiarities) would be valuable for a number of communities: wave modelling, operational monitoring and forecast, coastal processes ect.
- Sentinel-1 SAR data could be basis for more detailed wave information than altimetry products.

The spatial resolution and coverage of altimetry and SAR wave products

Coverage and resolution of Jason-1 altimeter data

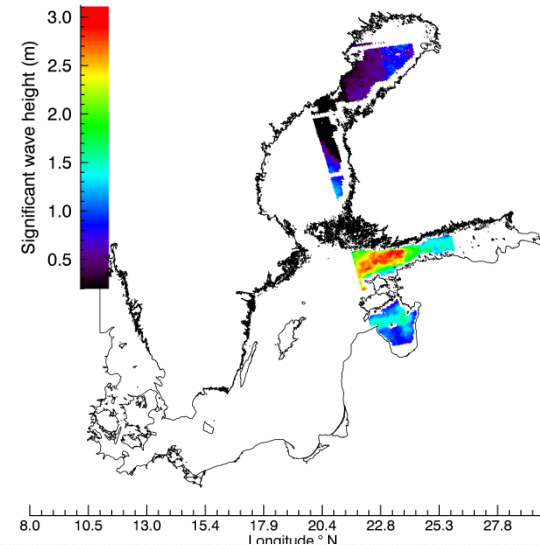
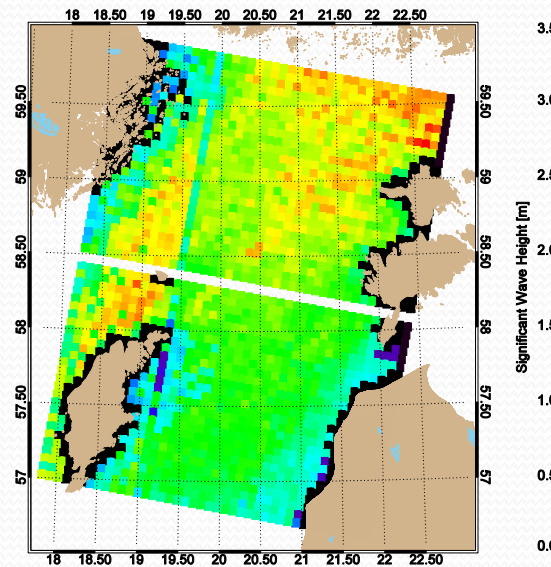
Altimeter tracks during one month



Kudryavtseva and Soomere (2016) "Validation of the multi-mission altimeter wave height data for the Baltic Sea region", *Est.J-Earth.Sci*

Sentinel-1 SAR coverage

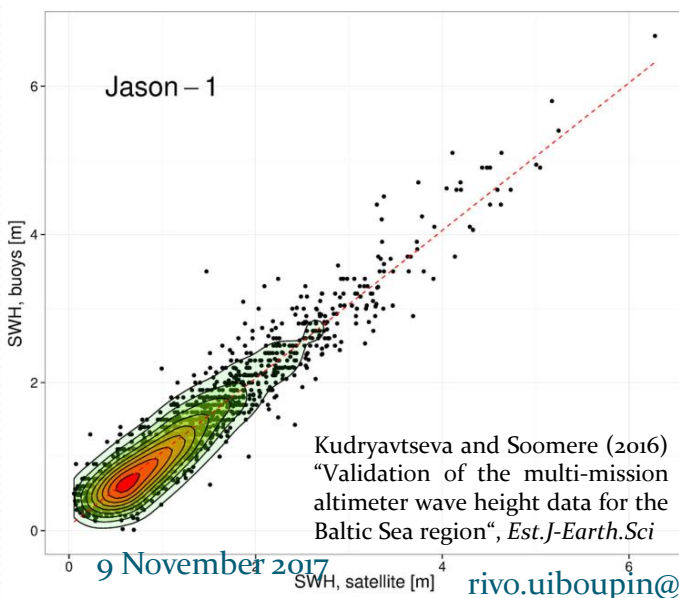
Examples of SAR data from single overpass



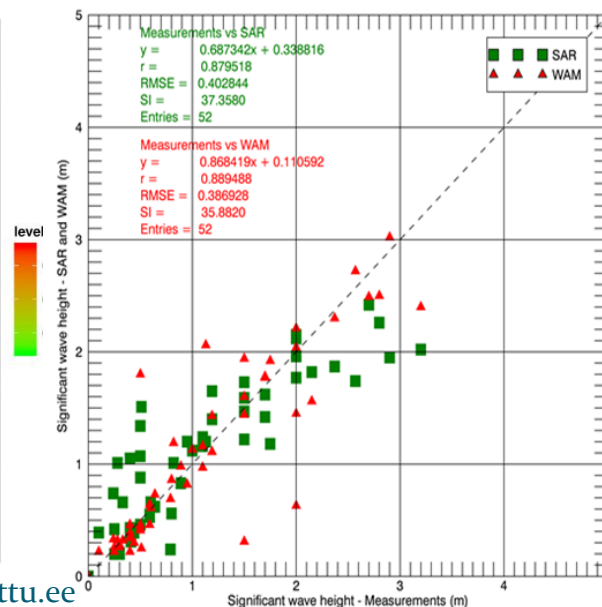
SAR wave product accuracy

- Integration of high spatial resolution SAR based wave fields into model would improve wave forecast quality and therefore contribute to evolution of wave monitoring/forecasting services and applications focused on coastal region.
- The value of high res. wave field information retrieved from SAR imagery even in as complex region as Baltic Sea or German Bight of the North Sea has been demonstrated:
 - Pleskachevsky, Rosenthal, Lehner (2016) *ISPRS J Photogramm.* „Meteo-marine parameters for highly variable environment in coastal regions from satellite radar imagery“
 - Rikka, Uiboupin; Alari. (2017).) *Int. J. Remote Sens.* „Applicability of SAR based wave retrieval for wind-wave interaction analysis in the fetch-limited Baltic“
 - Rikka, S.; Pleskachevsky, A.; Uiboupin, R.; Jacobsen, S. (2017). Sea State in the Baltic Sea from Space-borne High Resolution Synthetic Aperture Radar Imagery. *International Journal of Remote Sensing*
- Comparison with the limited number of validation points in the Baltic Sea indicates that SAR wave retrieval algorithms can provide information with the same accuracy/quality as altimetry products.
- While the coverage (swath width 250km) and spatial resolution (500m-1nm) of the SAR product would be much better.
- There is a need for operational and systematic provision of high resolution satellite wave products over the Baltic Sea region.

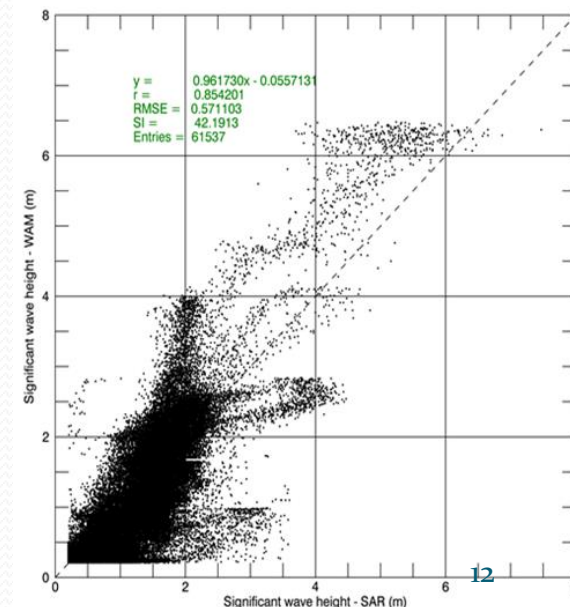
Altimetry vs. measurements



Sentinel-1 vs. measurements



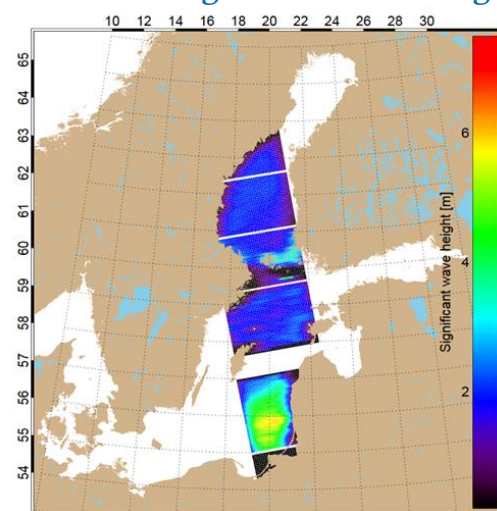
Sentinel-1 vs. model



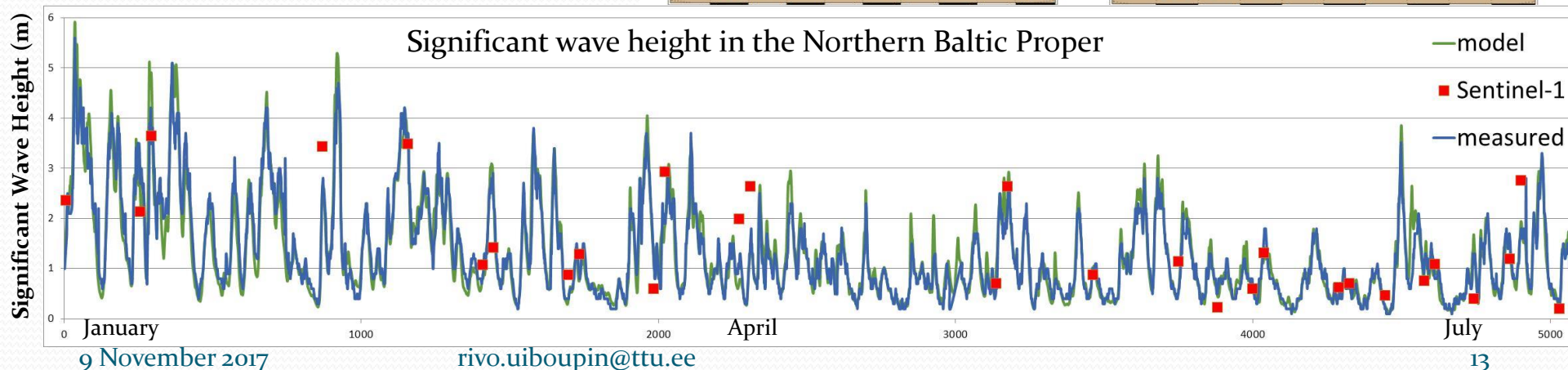
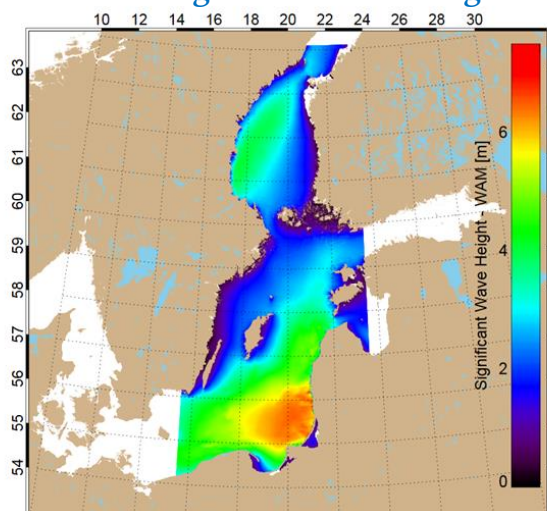
Wave forecast improvement using Sentinel-1 wave height products

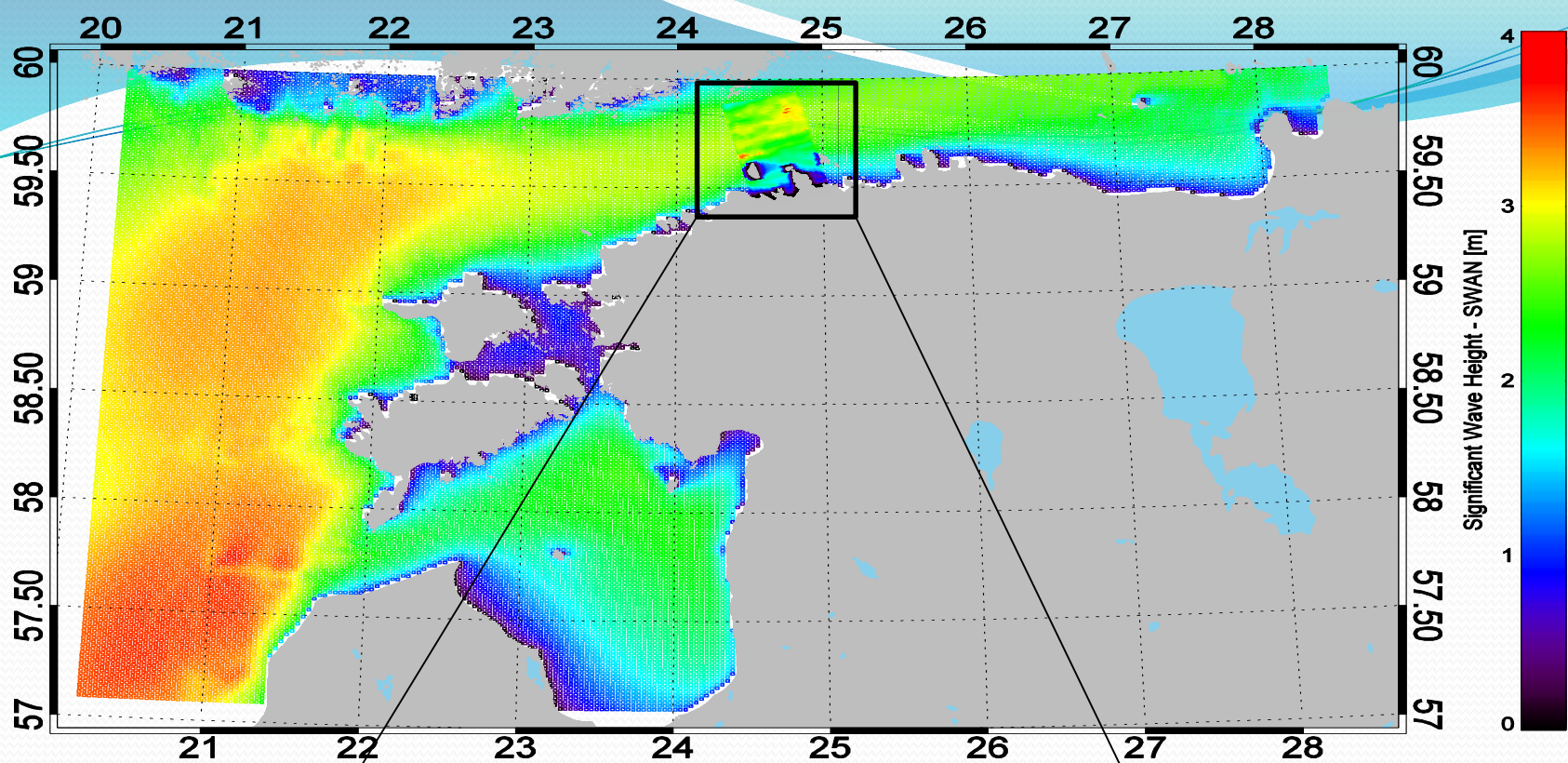
- Spatial coverage of the SAR wave product provides added value for wave modelling (model validation, data assimilation)
- Number of validation/assimilation points over 7 months period:
 - Sentinel-1 products – 600 000 points
 - Measured data with 1h interval from 7 stations around the Baltic – 50 400
- Thus, SAR wave products enable to resolve detailed spatial variability while in situ data describes detailed temporal variability in the limited number of locations.

Sentinel-1: significant wave height



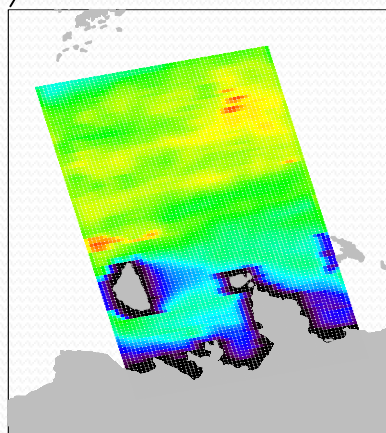
Model: significant wave height



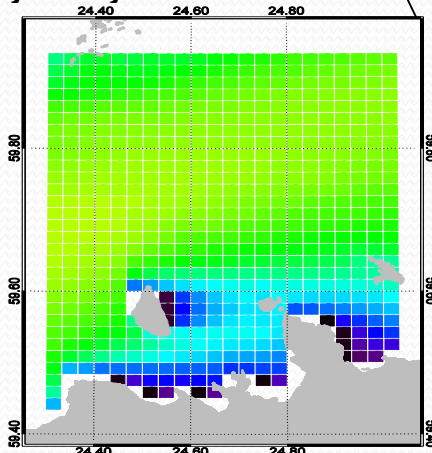


SWAN wave model wave field at 16:00 UTC overlaid by TSX scenes in Tallinn Helsinki transect

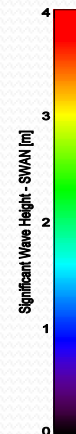
Example of the level of spatial detail that can be retrieved from SAR wave products to improve the model fields.



TSX SAR
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SWAN Model



SAR providing fine-scale spatial variability of the wave field in the coastal zone

Conclusions

- A number of institutional and end users need operational ice information.
- The quality of operational ice monitoring service in Estonia should increase.
- Smart exploitation of Sentinel-1 data (and derived products) together with input from voluntary contributors and ancillary data would help to satisfy the needs of users.
- Sentinel-1 data could be used for operational sea and lake ice monitoring in Estonia more efficiently by improving the operational processing chain and using the capabilities of EstHub
- Copernicus sea ice products are suitable for statistical analysis in the context of maritime spatial planning.
- The advantages of Sentinel-1 SAR wave products in Baltic Sea have been demonstrated.
- Developing a dedicated „Baltic Sea/Coastal ocean“ SAR wave product (which takes into account regional limitations/peculiarities) would be valuable for a number of communities:
 - wave modelling,
 - operational monitoring and forecasting
 - coastal processes ect.

Thank you!

Questions?



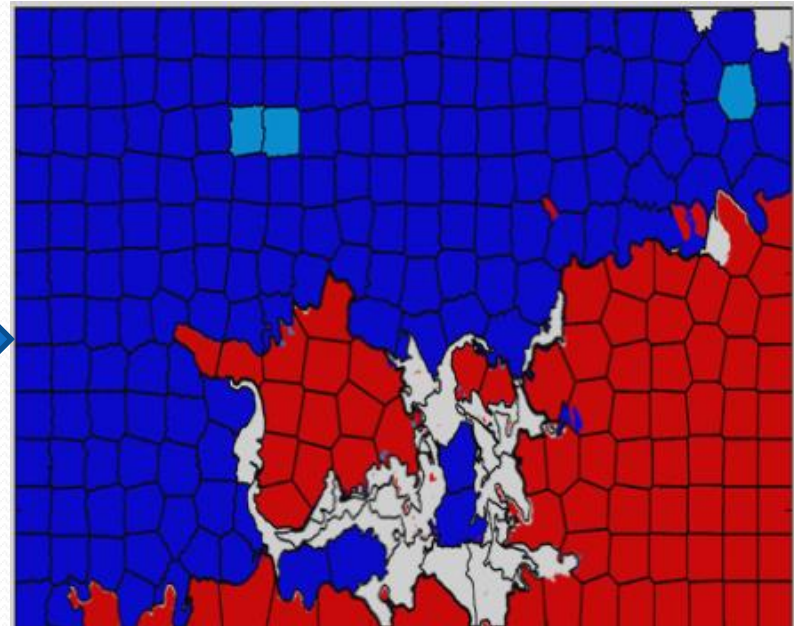
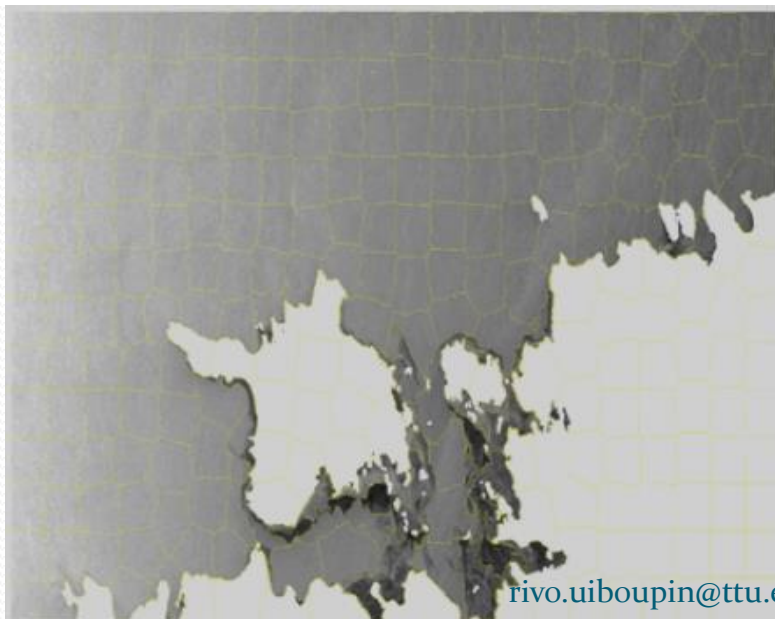
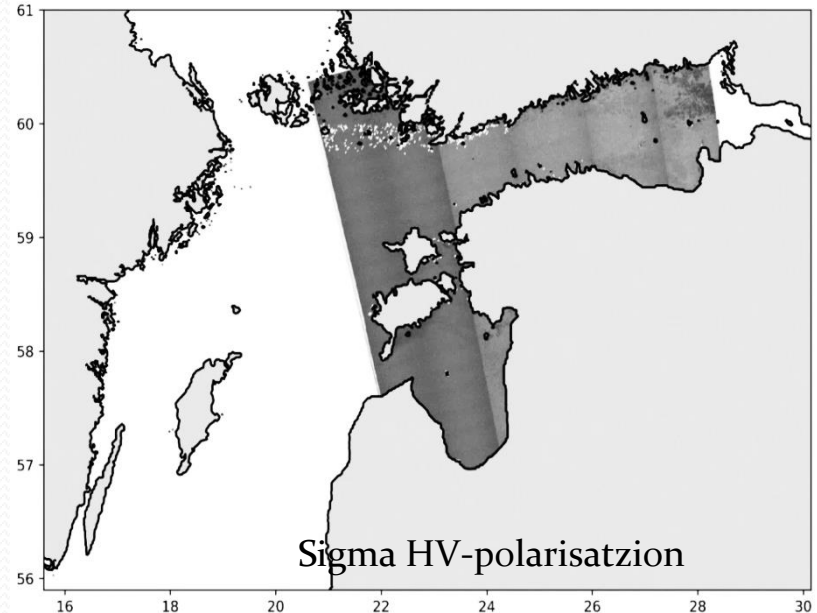
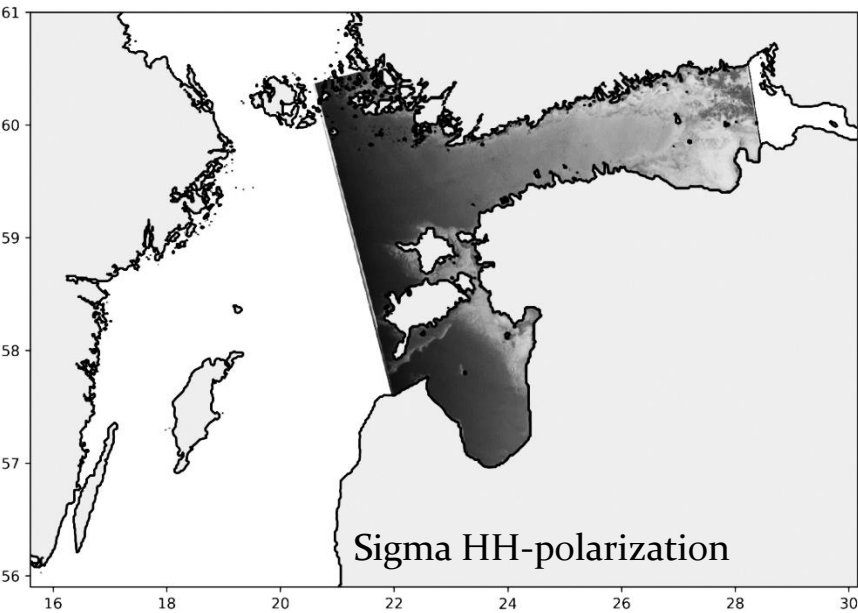
Krisjanis Tutans Ristna, Estonia



References

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- <https://www.youtube.com/watch?v=Y6o5udA53jo>
- Siitam, L.; Sipelgas, L.; Pärn, O.; Uiboupin R. (2017). Statistical characterization of the sea ice extent during different winter scenarios in the Gulf of Riga (Baltic Sea) using optical remote-sensing imagery. *International Journal of Remote Sensing*, 38 (3), 617–638.10.1080/01431161.2016.1268734.
- Rikka; Uiboupin; Alari. (2017).) *Int. J. Remote Sens.* „Applicability of SAR based wave retrieval for wind-wave interaction analysis in the fetch-limited Baltic“
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Examples



Examples

