CFOSAT mission: Progress report on testing site in the North-Western Russia

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The work presents preliminary results of cooperation of the academic bodies of the Russian Academy of Sciences and the Russian Meteo Service. More specifically, this is a regional branch of the Meteo Serveice that organizes and promotes monitoring of the Russian Great Lakes. These lakes are key elements of water routes connecting the Baltic Sea (i.e. the Northern Europe), with the Volga Basin and then with the Caspian Sea (i.e. Middle and Central Asia) and with the Azov and Black Seas through the channel Volga-Don. The Onega Lake is the transportation hub on routes Baltic-Volga and Baltic-White Sea (then to the Arctic seas.

PLEASE, ADDRESS YOUR QUESTIONS TO

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The team of P.P. Shirshov Institute of Oceanology of Russian Academy of Sciences (SIO RAS) together with North-West Administration for Hydrometeorology and Environmental Monitoring (NWA HEM) proposes experimental facilities available in NWA HEM in the Ladoga Lake (3 wave buoys), Onega Lake (3) and in the Gulf of Finland (one buoy) for development new Cal/Val methods and regular in-situ measurements to support CFOSAT mission for the global monitoring of sea waves. The advantage of the proposed testing areas is a possibility to have in-situ data with essentially different wave regimes.

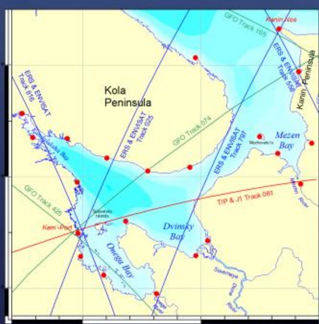
The testing site is shown in the map in a wider perspective. In fact, we are talking about much smaller area: the eastern (Russian) part of the Gulf of Finland and two big lakes: the Ladoga Lake is the largest lake of the Europe, and the number two of the Europe the Lake of Onega. In summer of pre-COVID year 2019 we organized a research campaign for measurements of waves (first of all) in one site in the Gulf of Finland. 3 buoys were deployed in Ladoga and 3 more in Onega.

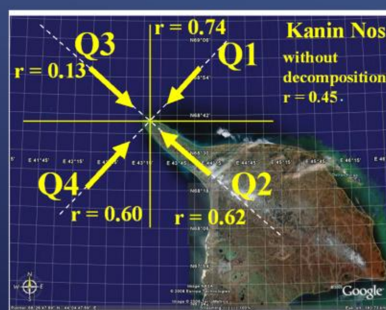
These are specific areas with strong variations of weather from total ice cover in winter time and negative temperature below 30 Celcium up to completely calm water in summer at +20-30 degrees of air temperature and severe storms in autumn.

The areas can be regarded as SUPER-coastal being surrounded by mainland. At the same time, there are rather long fetches up to 200 km and conditions for developing severe storms.

Wave climate is quite peculiar. Local navigation propose special terms for the high, extremely steep and dangerous Onega and Ladoga waves. An essential part of the Mariinskaya waterway (build at the end of XVIII century) was built as along-coast channels to protect cargo ships from harsh wave conditions in the Southern Onega Lake.

It is also very important to calibrate and validate the satellite data based on different data sources and experimental approaches. We will use satellite altimetry data on wind speed and wave height to perform this task, as well as meteo data from the coastal meteo stations located close to the buoy location. This will be done based on our experience on calibration and validation of satellite altimetry data in the coastal zone of the Barents, White, Black, and Caspian Seas. In particular, we will apply a "decomposition" method, we elaborated about 10 years ago during the ALTICORE (ALTImetry for COastal Regions) Project funded by INTAS, which allowed to increase significantly the correlation between wind speed altimetry data and meteo stations.





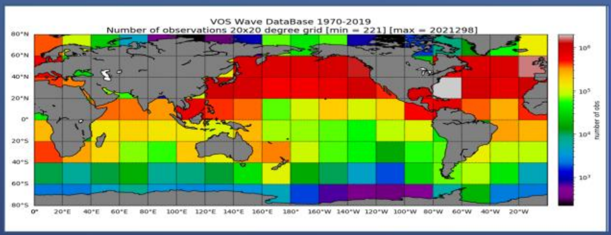
This is why we re-animated our previous findings and approaches on altimetry measurements in the nearshore starting from the Alticore project. In particular, we extensively used the idea of wind decomposition in the coastal zone for Cal/Val. It has been shown within the project AltiCore that wind speed estimates from altimeters correlate with coastal measurements of wind of certain directions: on-shore winds. This idea has been extensively tested in the White Sea almost 10 years ago. But again, this is super-coastal case and the value of the approach should be carefully tested

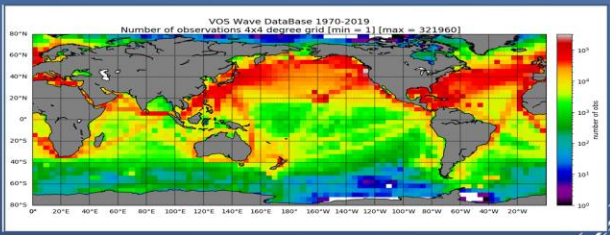
Another direction of the Cal/Val activities is climate studies based on the Voluntary Observing Ship (VOS) global database for the period of 1888-2019 elaborated and supported in SIO RAS https:sail.ocean.ru/atlas/, as well as on new remote sensing methods and theory of sea waves. In addition to standard meteorological parameters, we have derived the records of visually observed heights, periods, and wind sea and swell directions. The key parameters have been supplemented by independent estimates of steepness, wave age, wavelength derived from alternative approaches (e.g. summer experimental campaigns). Multistage quality control has been applied to correct or eliminate spurious values. Data are presented as individual records for each month and as original monthly mean fields for each parameter.

The development of remote sensing methods for sea surface monitoring is based on available novel approaches for altimetry in the near-shore water areas and theoretically based methods of retrieval wave characteristics from satellite altimetry data.

One more feature of the work is to use Voluntary Observing Ship archive data collected from meteo stations and from regular water routes in these areas which play an important role as a transport link between the Baltic, White Seas and rivers and channels of Russia with access to the Caspian and Black Sea.
We also rely upon remote sensing method and new theoretical approaches to make the methods valid for very special environment of the areas.

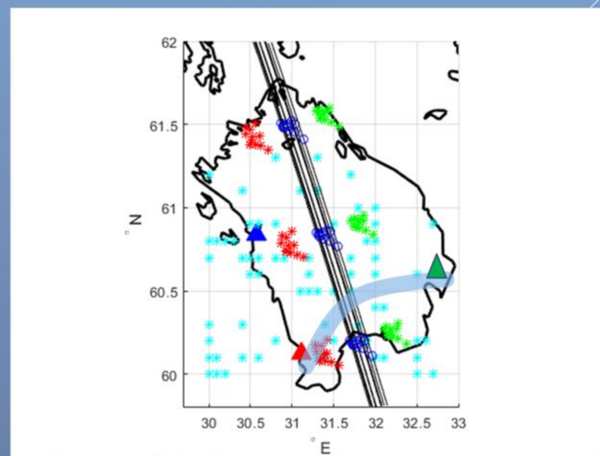
GLOBAL WAVE DATA BASE 1970-2019
https://sail.ocean.ru/gwdb/





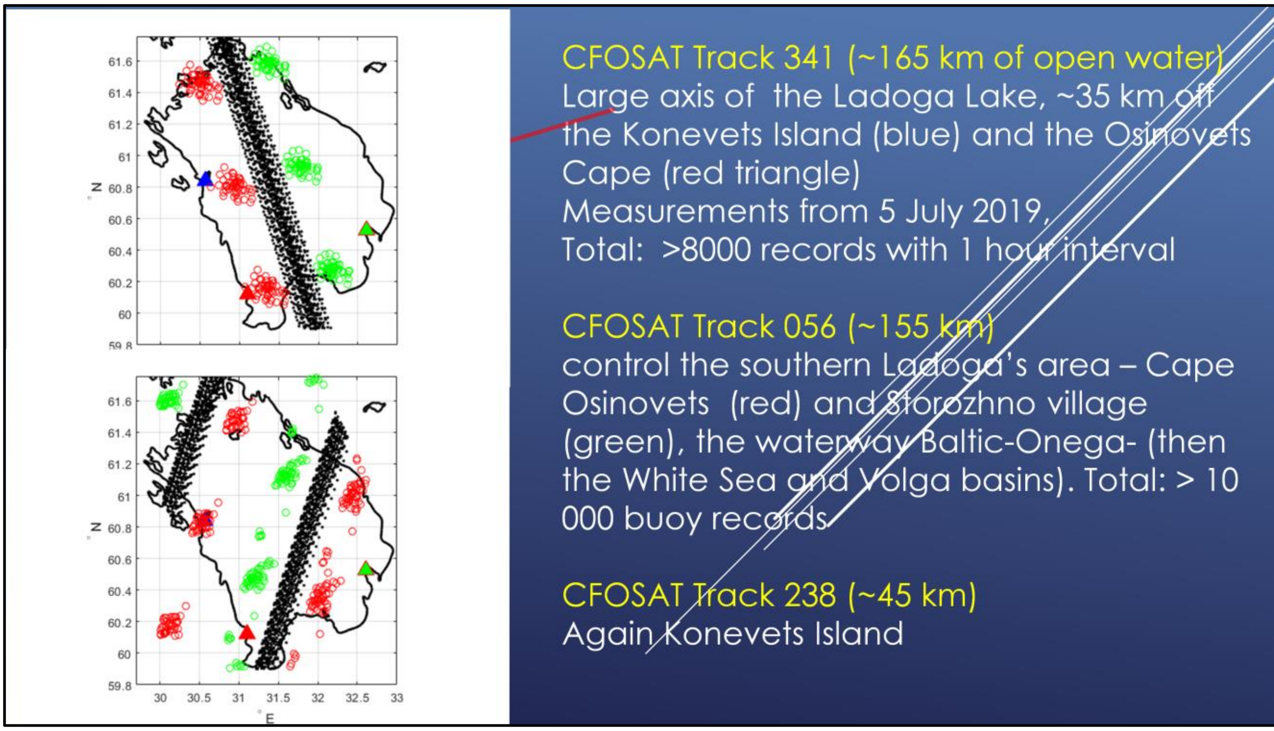
- Original VOS data was taken from the ICOADS archive of marine meteorological observations (https://icoads.noaa.gov/)
- covers the globe from 80N to 80S between 1970 and 2019
- consists of time series of wave characteristics in 3 streams and 2 different bins: 4º by 4 º and 20 º by 20 º
- all data passed thorough multistage quality control
- NetCDF4 format

CFOSAT tracks and location of wave buoys in the Gulf of Finland, Ladoga and Onega Lakes

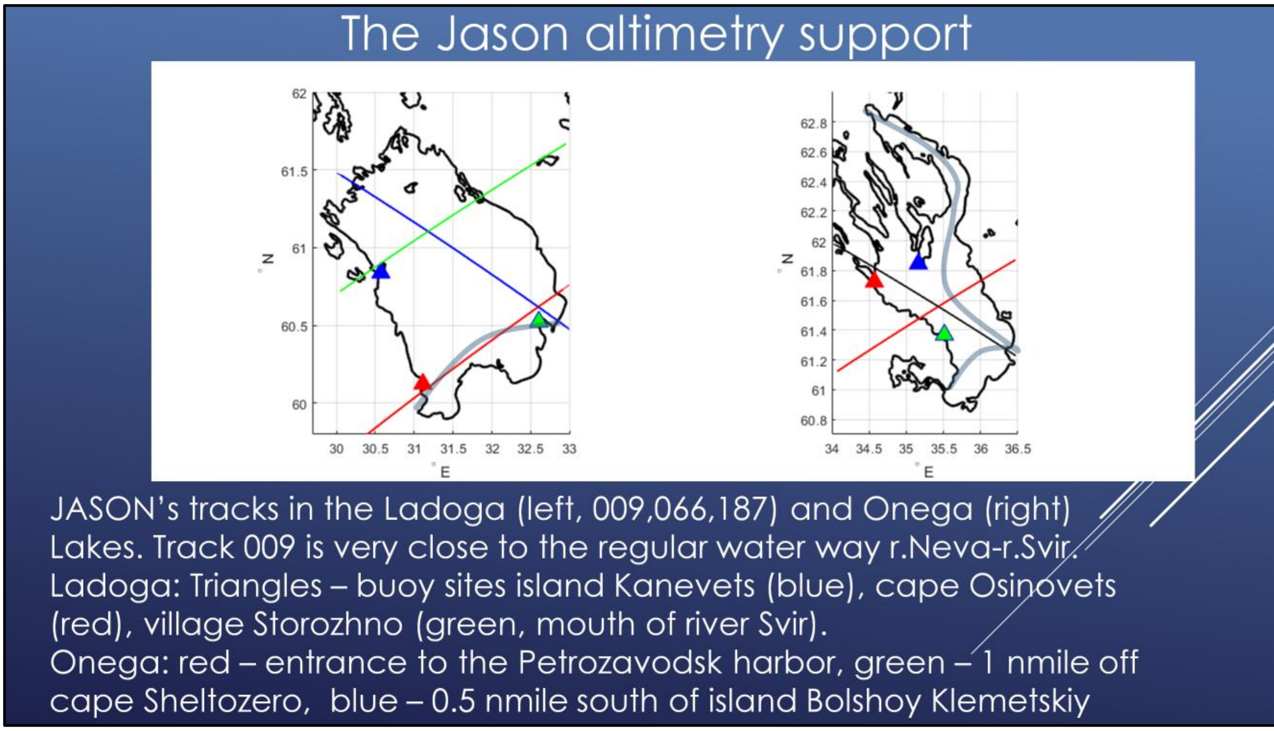


CFOSAT tracks and location of wave buoys in Ladoga Lake. Blue triangle – Konevets Island, red triangle – Osinovets Cape, green – Storozhno village. Cyan stars – visual observations, Red stars – portside (left), green stars – starboard (right) centers of CFOSAT "boxes" for building wave spectra.

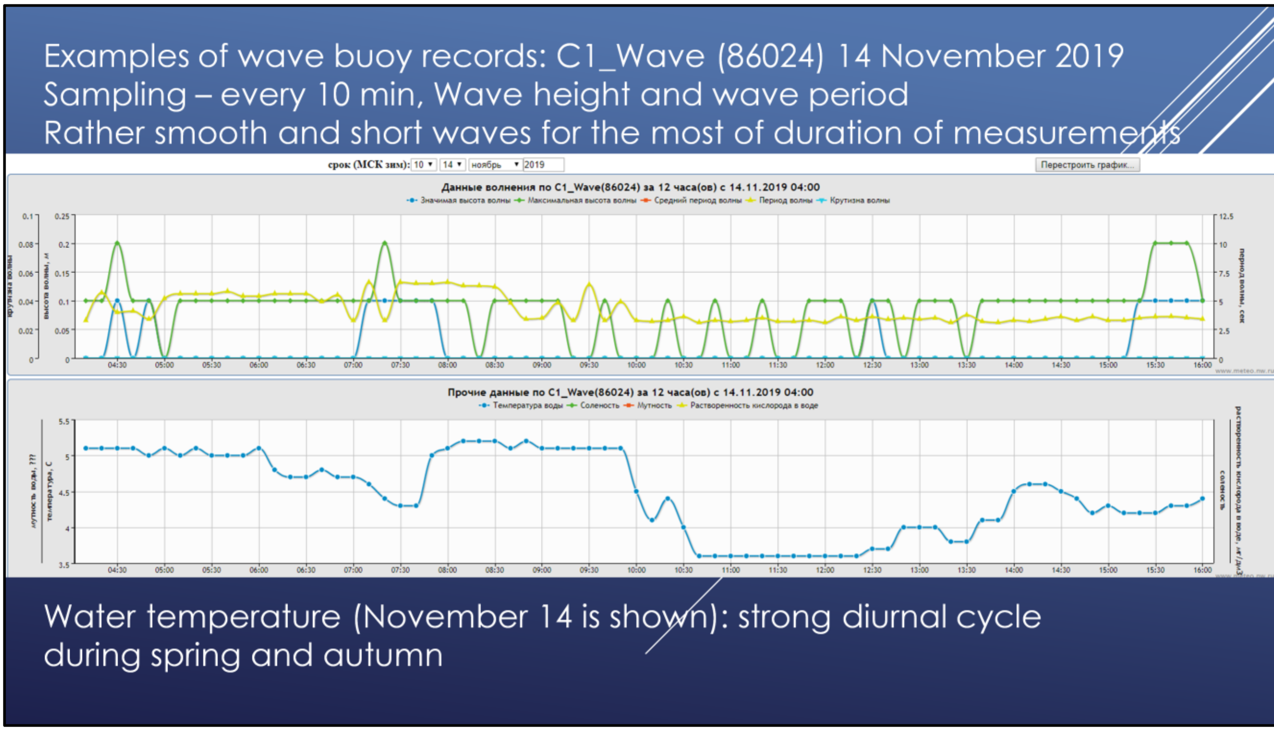
We show locations of the in situ measurement sites in the gulf and lakes and track of the mission CFOSAT. For the Ladoga Lake the tracks look quite attractive. Track 341 realizes the maximal fetch about 165 km along its nadir track (black lines). These track shown for consecutive cycles travel within 10-20 km from a mean position, i.e. not so perfect as regular altimeter tracks. The feature of the CFOSAT measurements is panoramic measurements of wave spectra. The centers of the corresponding boxes are shown in the right panel.
The buoys are deployed 0.5-2 miles off the coast near stationary manned meteo stations, thus, providing regular information on parameters of both water and coast. The issue of safety of devices aginst possible vandalism is also essential. Sites of Osinovets (blue triangle) and Storozhno (green triangle) are close to the waterway gates of Neva river mouth (West) and Svir river coming from the Onega Lake (East). The water way is shown in grey.
Points of visual observations are taken from shown by cyan stars and show quite strange distribution. We do not see an abundance of the data that is also quite strange.



Tracks 341 and 056 are shown here and we see the track proximity to the sites of our interest.



Jason's tracks provide even more pleasant covering of our area. Track 9 (red) covers the water way Neva-Svir across the Southern part of the Ladoga. This track can provide valuable data for navigation but can be affected by ships during the summer navigation period.

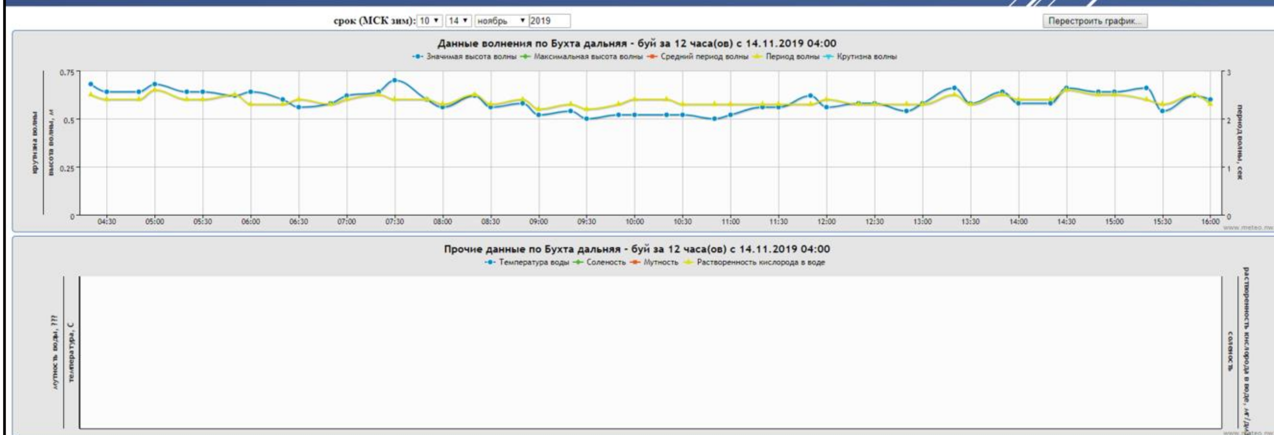


We go to in situ measurements as soon as they are the only solid support of our satellite exercises. One of the first typical figures for a summer day is shown in the slide. It shows nothing but quite low wave heights below 0.15 meters and wave periods about 5 s. Quite smooth and long waves.
The ice-free winter (end of 2019 – January 2020) with wave height exceeding 4 meters, unfortunately, has not been captured by buoy measurements

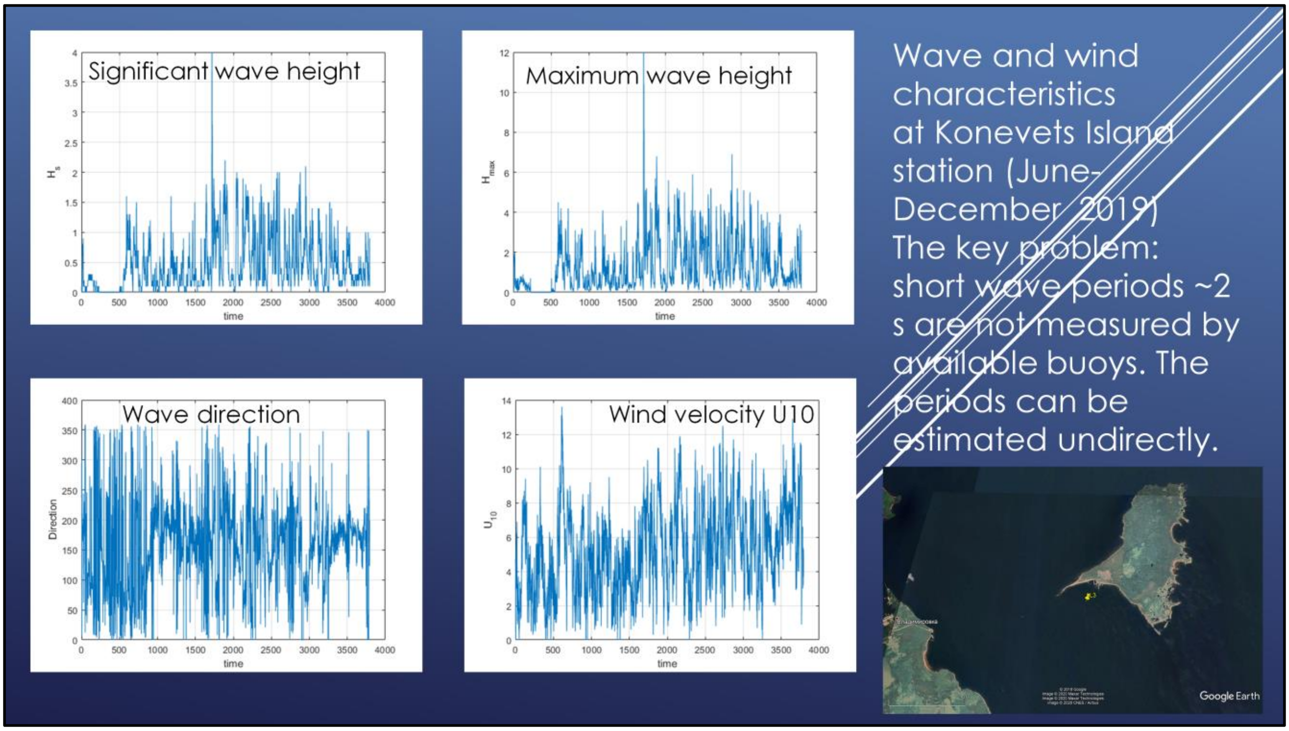
Examples of wave buoy records: Bay Dalnyaya 14 November 2019

Sampling – every 10 min

Wave height and wave period. Wave height ~70 cm and wave period 2.5 s (~10 meters wavelength) give wave steepness > 0.1. Quite dangerous conditions for for local boats.

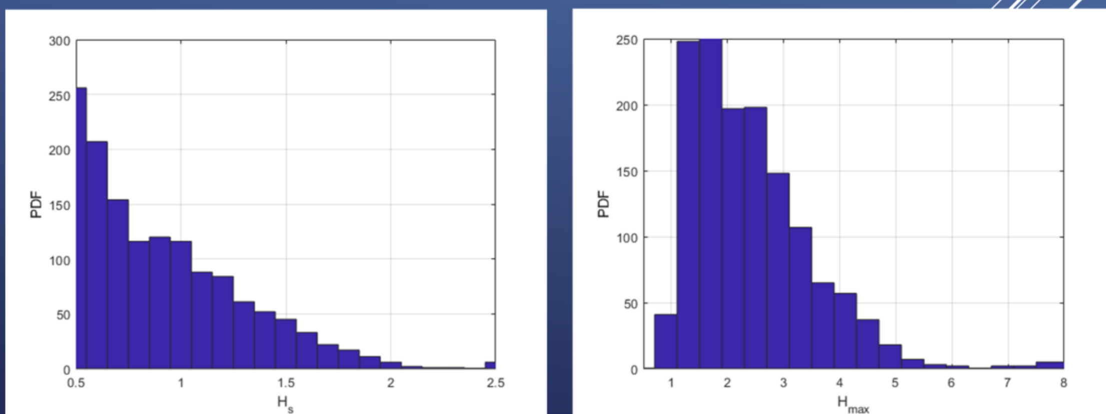


Next slide shows more actual case. Significant height is about 70 cm but wave periods 2.5 s and wave steepness exceeds 0.1. Very steep waves, especially, for summer time.



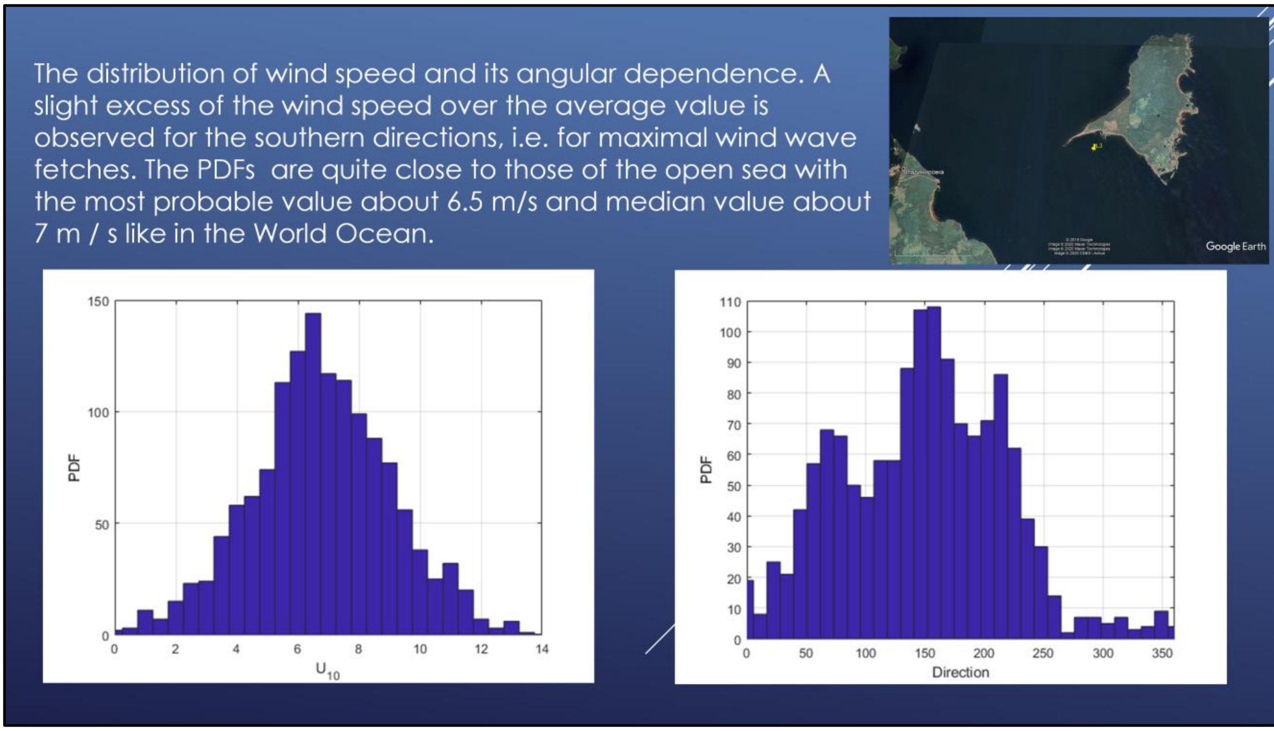
This slide shows variability of key wave parameters during all the period of measurements in the Ladoga Lake from June to December of 2019 from the buoy of the Kanevets Island. Rather high waves were observed even for the wind protected site

Distributions of significant and maximum wave heights. These distributions are qualitatively different from the oceanic ones, which have a pronounced peak for a significant wave height of about 2 meters and fall to both sides of the peak. A local peak at the significant height distribution stands out at 0.9 meters.

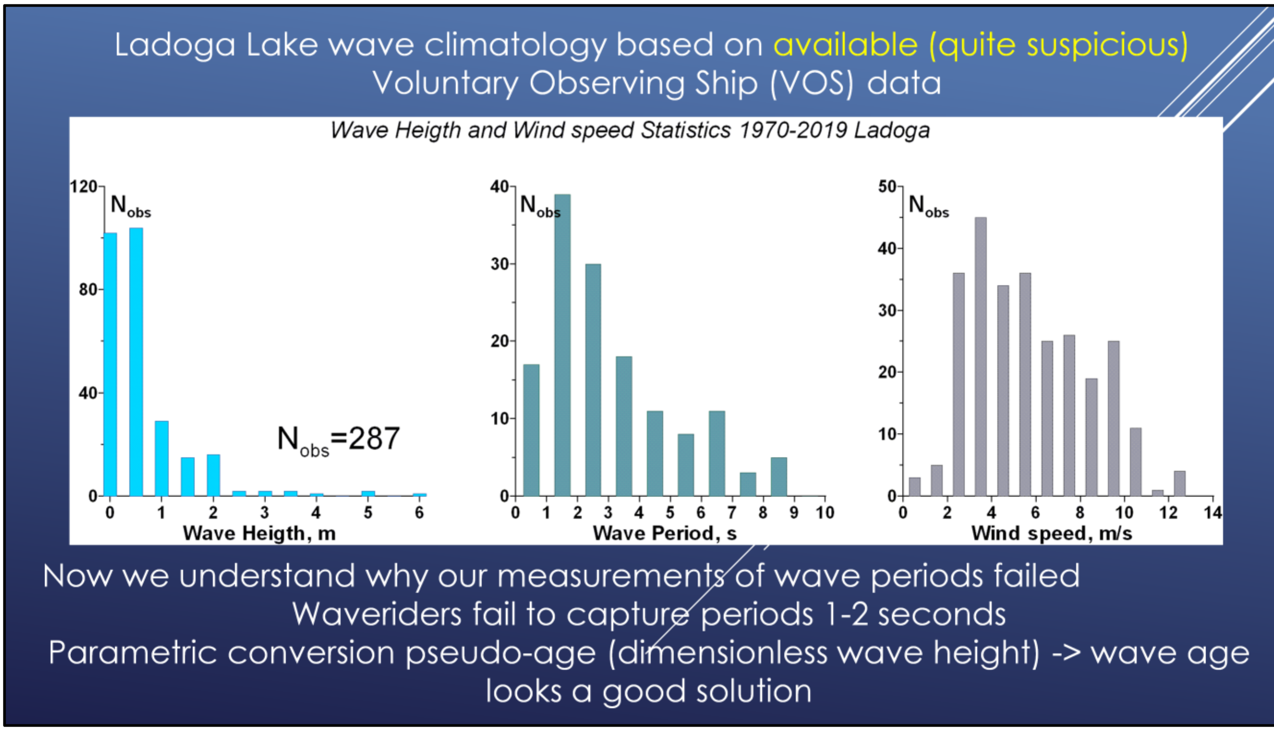


Histograms of the distribution of significant and maximum wave heights

Probability density functions of wave heights (significant and maximal) is essentially bi-modal, thus, signifying a pronounced seasonality of wave climate with calm summer time and harsh autumn stroms. The auumn-winter distribution is close to the open sea pattern with smaller peak value about 1 meter. A low amplitude background exists for the calm summer records.

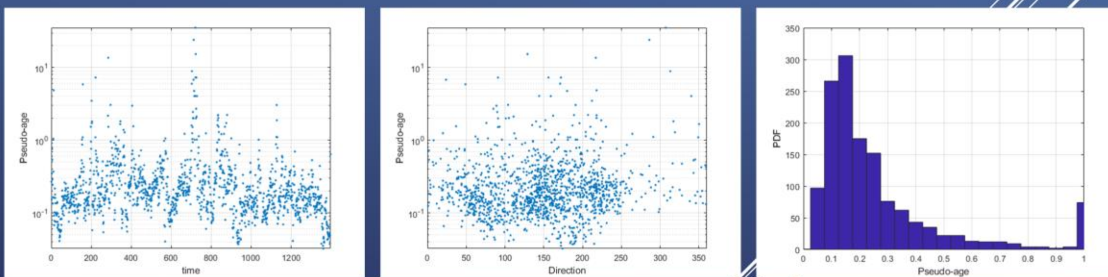


While the wave heights are low, winds are rather strong with the most probable 7 m/s like in the ocean. The island damps waves but does not suppress the wind.



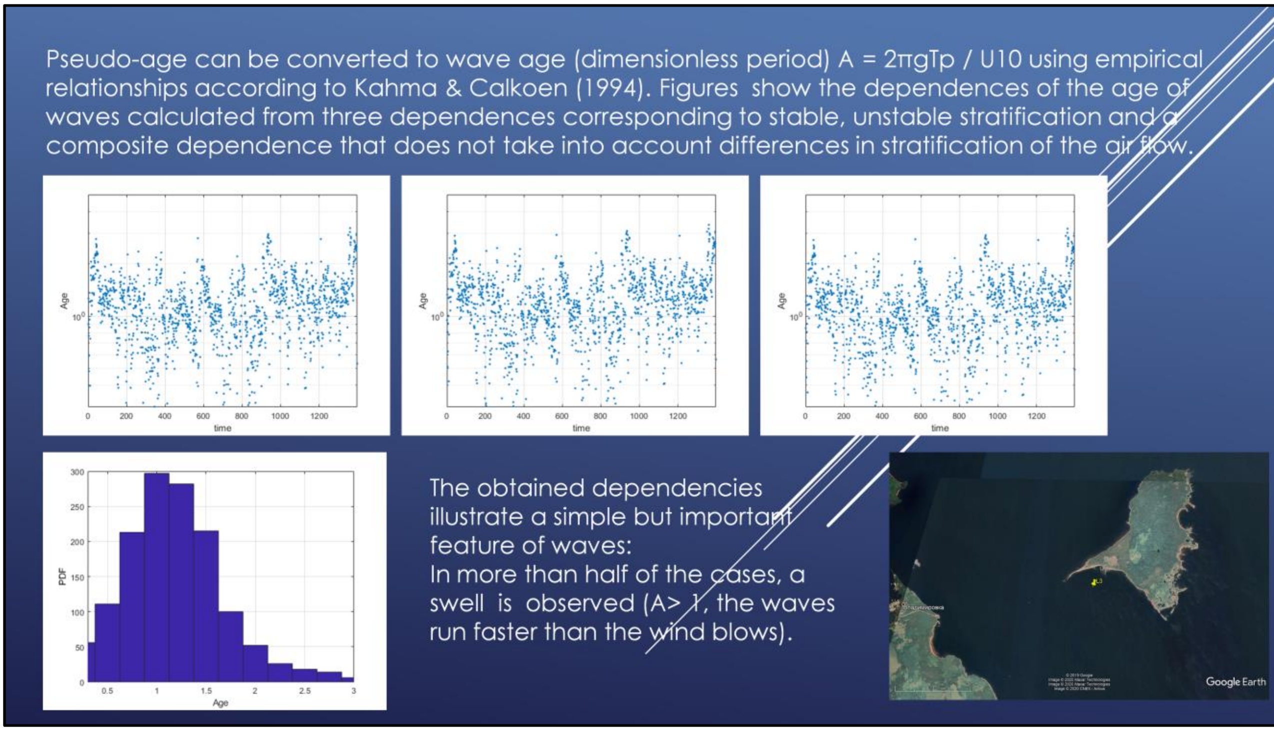
Look at the probability of wave parameters in VOS data. We have very high probability of low amplitudes and, what is more important, low periods. Our observation: measurements of low periods are not reliable. A standard wave buoy has discretisation 0.5 s at the best. For the period 2 secs (6 meters wavelength) it measures waveheights but fails to measure short wave periods.

A significant drawback of the measurements is the lack of information on the characteristic periods (lengths) of the waves. For estimates, we used the empirical dependences of the dimensionless period (age) on the dimensionless wave height.



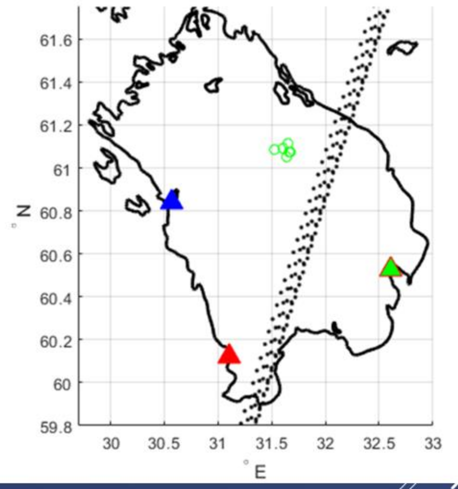
Pseudo-age of waves as a function of time (left), direction (middle), and histogram for pseudo-age (right)

A problem of wave measurements is smallness of wave periods and high errors. Wave buoys are not able to measure the periods reliably. We decided to make indirect estimates from pseudo-age (dimensionless wave heights).



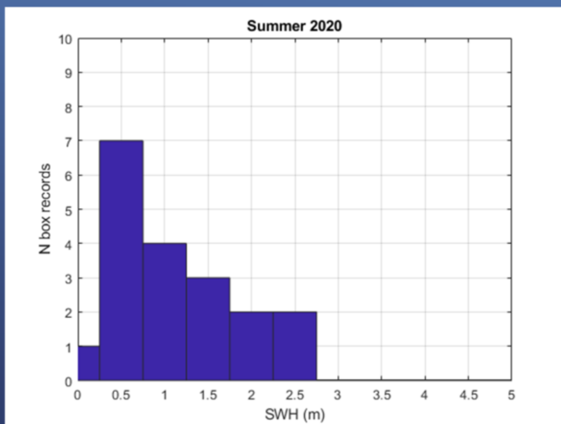
Results of the conversion from pseudo-age to wave age (dimensionless wave period) are shown here. Three different parameterizations were used for different wind stratification (stable, unstable, a composite model). Qualitatively results are similar. In the Kanevets case we have mostly swell traveling faster than wind and coming from the south.

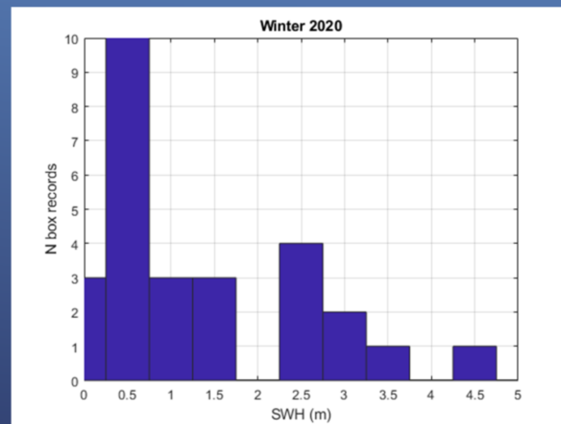
- The land/water ratio does not exceed 50% in the only partition location of the pass 056



CFOSAT WAVE SPECTRA

At the moment we have 6 passes available with spectral partitions. All other cases are masked likely because of low water/land ratio.

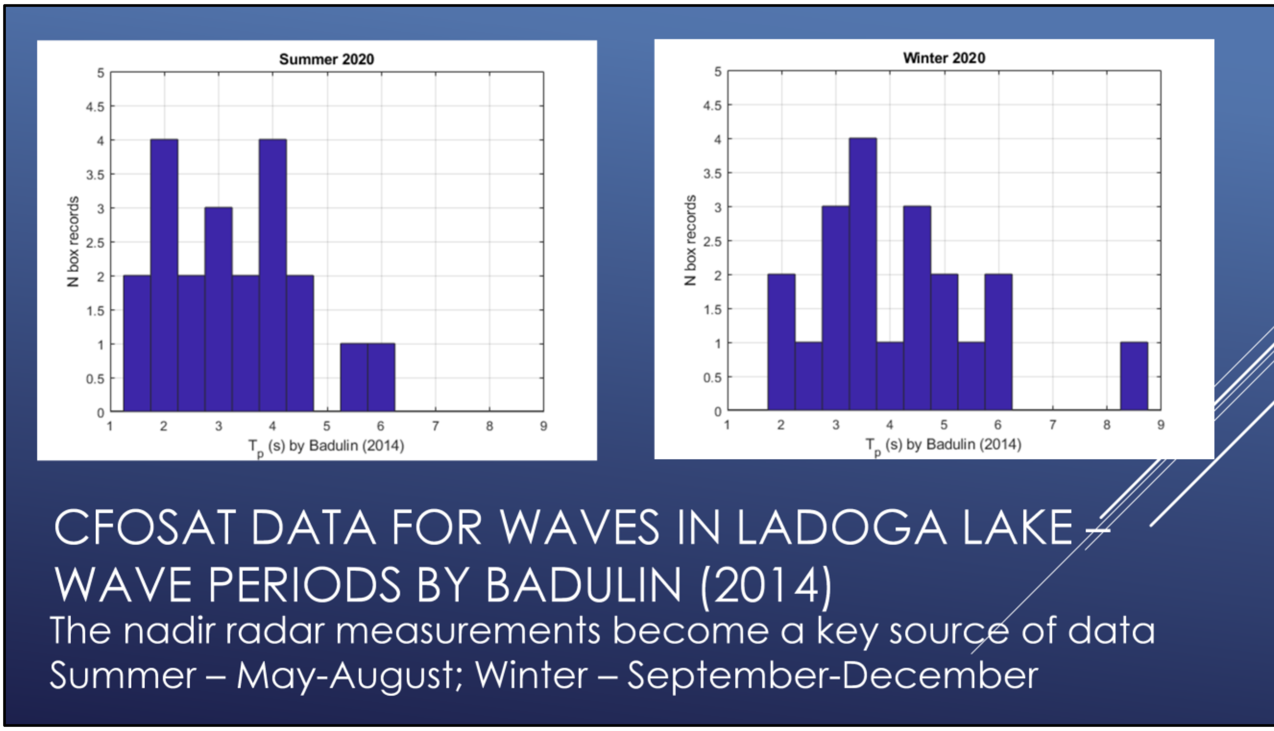




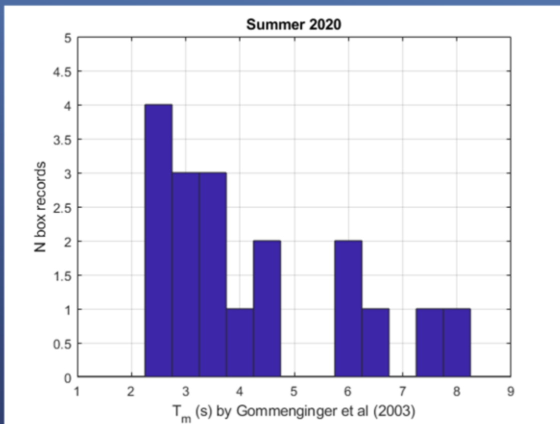
CFOSAT DATA FOR WAVES IN LADOGA LAKE - SWH

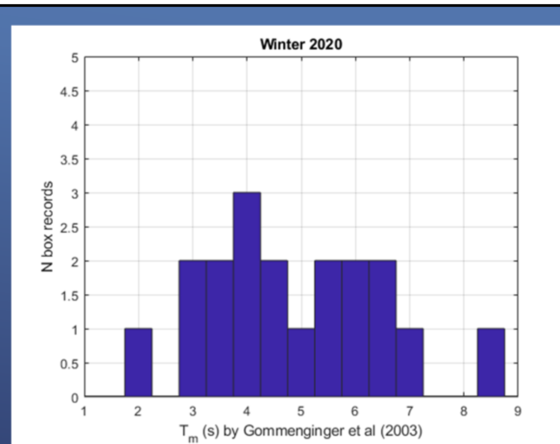
The nadir radar measurements become a key source of data
Summer – May-August; Winter – September-December

The significant wave heights show different patterns. In winter time strong storms co-exist with relatively long periods of calm and smooth waves



The physical model of wave periods derived from altimetry data show relatively long waves in winter as compared to the summer time





CFOSAT DATA FOR WAVES IN LADOGA LAKE – WAVE PERIODS BY GOMMENGINGER ET AL. (2003)

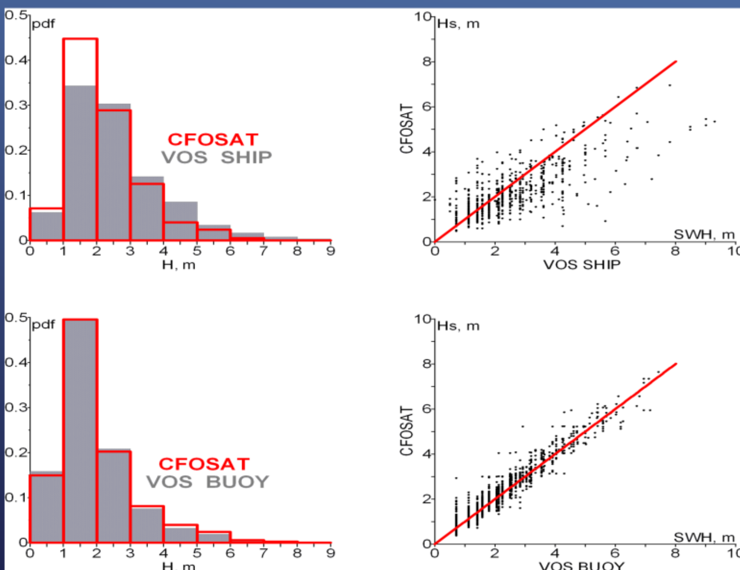
The nadir radar measurements become a key source of data
Summer – May-August; Winter – September-December

Results on the wave periods with the statistical model of Gommenginger et al. (2003) are consistent with the above physical model but generally overestimate the periods

TO BUILD THE REGIONAL STUDY INTO WIDER CONTEXT OF OCEAN DYNAMICS (VOS DATA)

- ‘The first glance’ analysis of global data set of CFOSAT and Voluntary Observing Ship data showed general agreement in terms of statistical distributions

CFOSAT-VOS: point-wise comparison of SWH (2019)
distance < 50 time lag < 30



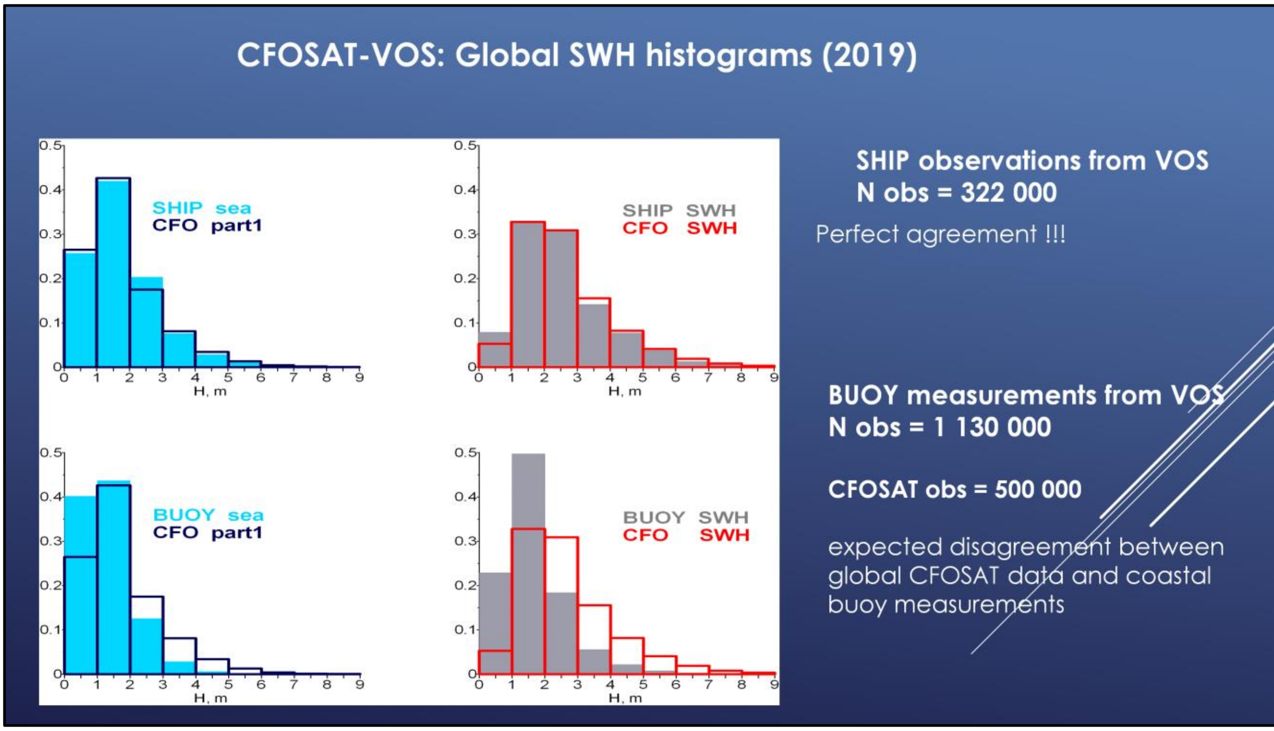
SHIP observations from VOS

Npoints = 700

BUOY measurements from

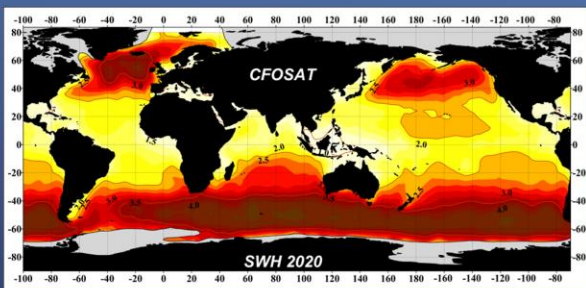
VOS**Npoints = 2100**

Rather strong scatter of data in upper panel does not cancel a satisfactory agreement in terms of probability density functions

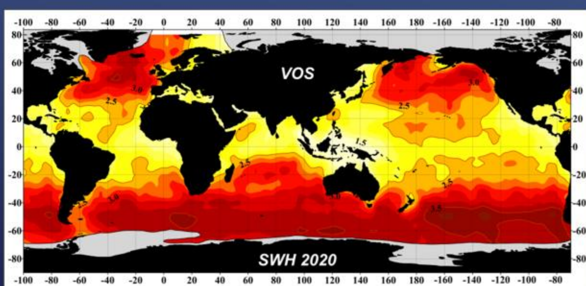


Moreover, for global distributions ship data appear more consistent with CFOSAT measurements than the data of local measurements by ocean buoys (bottom panel

CFOSAT-VOS: SWH climatology (2020)



CFOSAT 2020 – annual SWH



VOS annual SWH 2020

good agreement on yearly scale

Climatology of VOS data vs CFOSAT measurements

Summary

1. The proposed sites of in situ measurements are of interest for Cal/Val prosedures of CFOSAT and altimetry missions in the context of SUPER-coastal altimetry for monitoring sea state.

The sites are acceptable for many tasks but can be changed for optimizing Cal/Val procedures. ;

1. Specific wave conditions (steep growing waves) require an extensive use of empirical dependencies and adequate experimental tools. Remote methods for wave period assessment look more effective in comparison with in situ measurements of wave buoys.

Parametric approaches are welcome!

3. The data of the enclosed basins are worth to be considered in a general context of sea wave dynamics

Quality control of CFOSAT data should be less restrictive for the inland bodies

Summary of our proposal and very preliminary assessment of our methods

We invite you for collaboration on CFOSAT data in inland water bodies of NW Russia

Kizhi Island, the Onega Lake, the Transfiguration Church (1714)

Thank you for attention!