Mission-Independent Classification of Altimeter Waveforms for Applications in the Open Ocean, at the Coastal Zone and Over Land

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Motivation

- Altimeter waveforms provide important surface type information
- Precise knowledge about the waveform shapes can be used for different applications

- Database for Hydrological Time Series of Inland Waters (DAHITI)
  - Automated target detection of river crossings
  - Improved retracking if waveform shape is known
  - Identification of water returns for the estimation of water levels

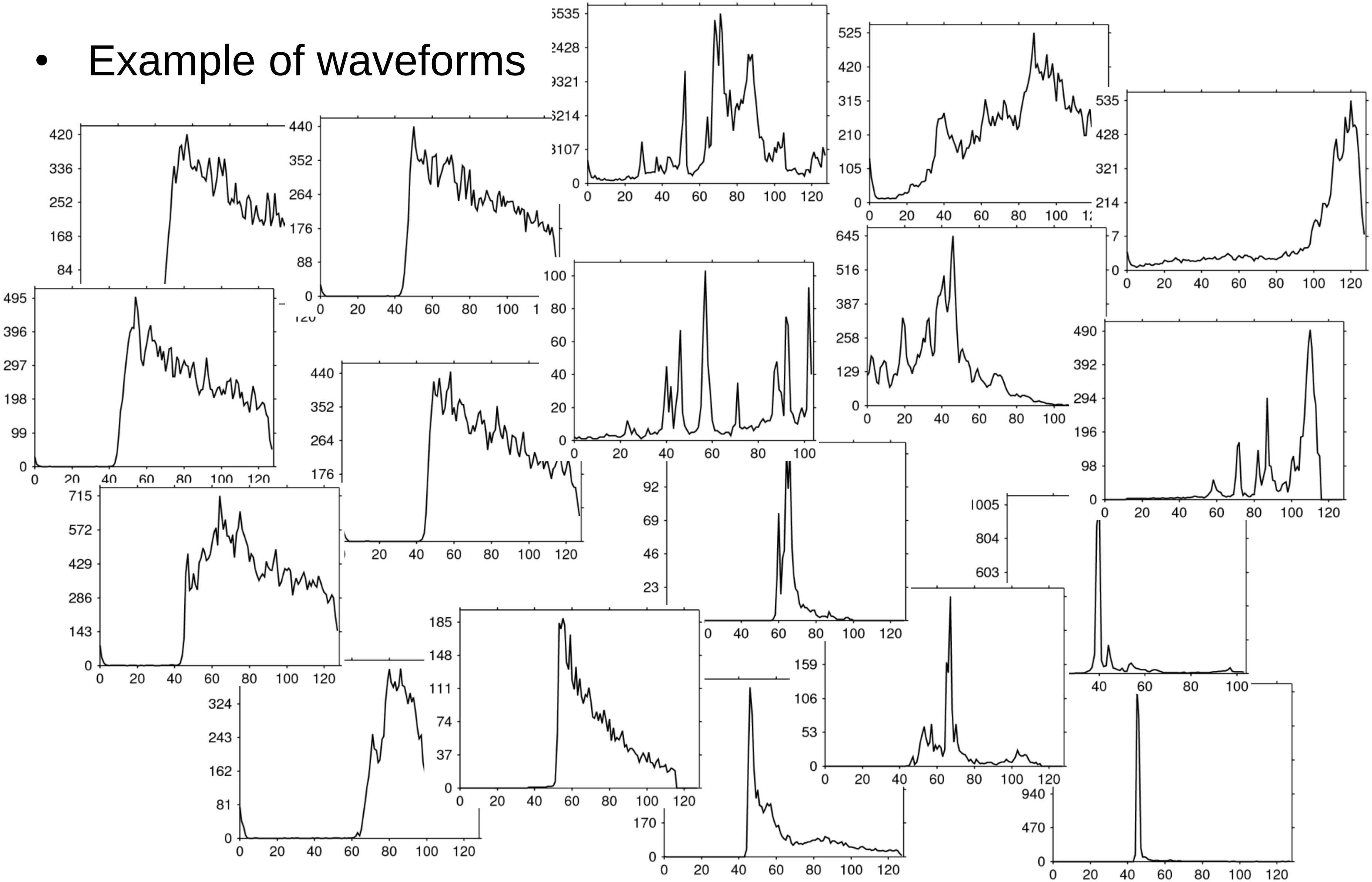
- Possible other applications
  - Ice detection in the open ocean
  - Rejection of corrupted waveforms in the coastal zone
  - Detection of inland waters (rivers, lakes, reservoirs)

Altimeter Data

- Manifold altimeter system configurations of different altimeter mission result in different waveforms because of their
  - Band (Ku-Band, Ka-Band, …)
  - Pulse bandwidth (500 MHz, 320 MHz, 80 MHz, …)
  - Number of waveform bins (128, 104, 64, …)
  - Antenna configuration
  - Satellite height
  - …
- This challenge has to be considered in a mission-independent classification
- In this study, altimeter waveforms of Envisat, Jason-1, Jason-2, Saral, and Cryosat-2 are used for the classification

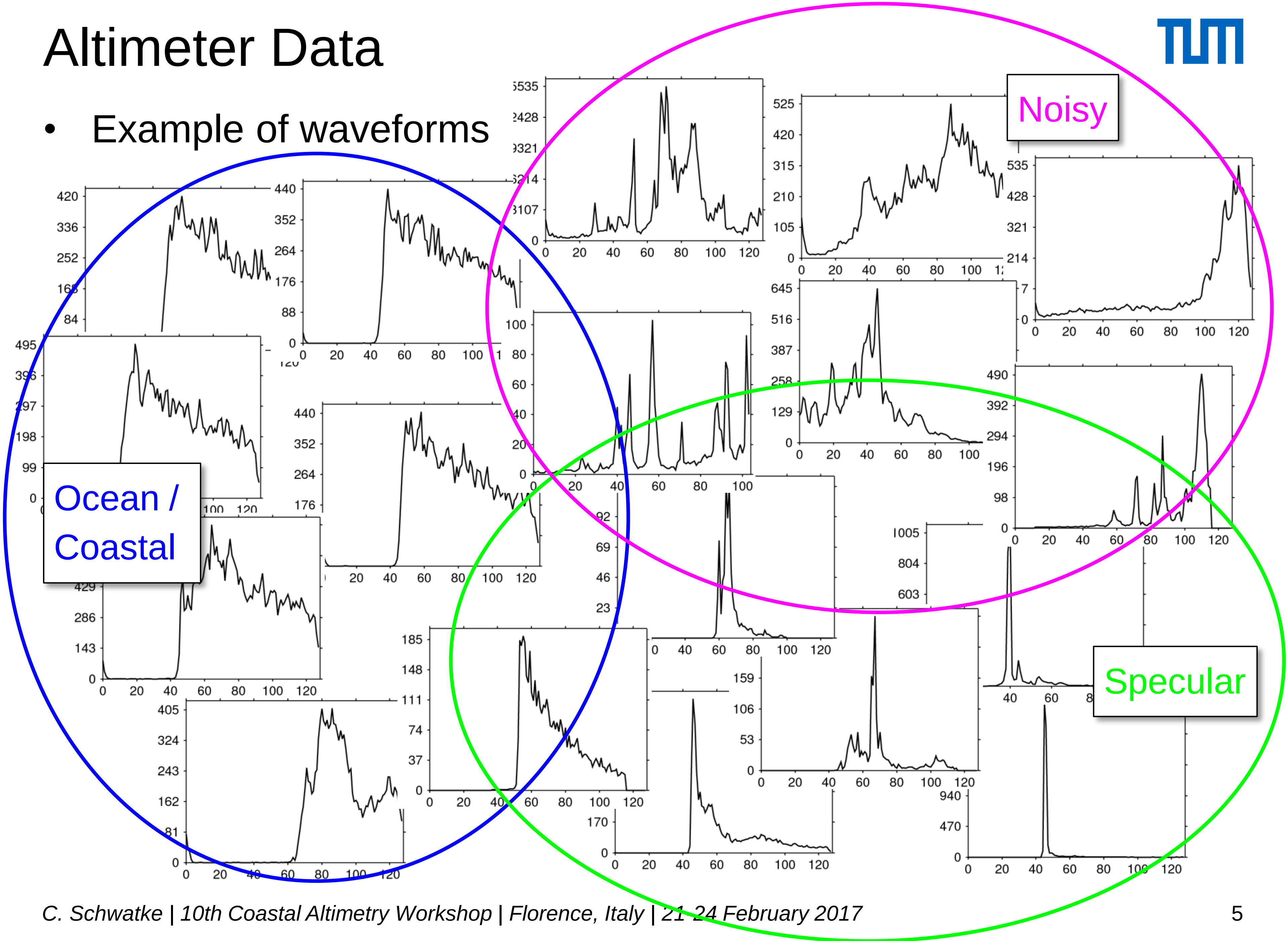
Altimeter Data

- Example of waveforms



Altimeter Data

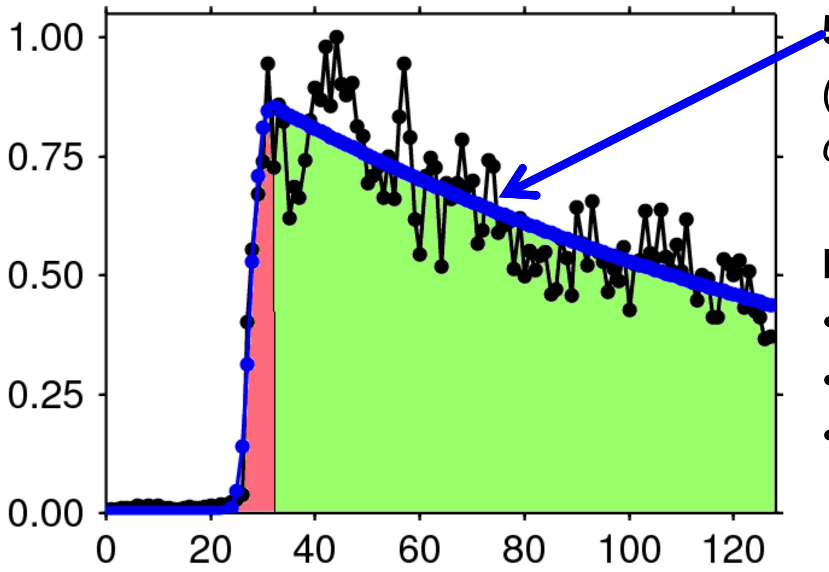
- Example of waveforms



Methodology

- Normalized altimeter waveforms are used as input data
- The new method for the waveform classification is based on a combination of
  - **Statistical waveform parameters** *(e.g. peakiness)*
  - **Function fitting** *(e.g. modified Beta5 retracker)*

- Fitting example:



5 parameter function fitting
(Thermal noise, leading edge, amplitude, width of leading edge, trailing edge slope)

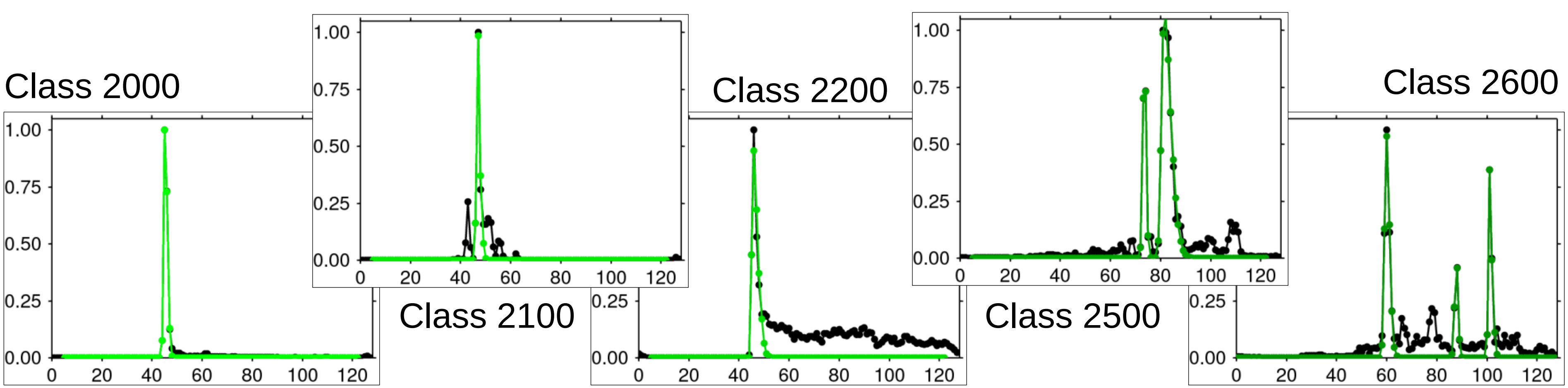
Resulting quality parameters:
- RMS of leading edge fit (red)
- RMS of trailing edge fit (green)
- RMS of full waveform fit

Methodology – Major Classes

Unclassifed	• No classes
Corrupted	• ***5 sub-classes***
Specular	• ***21 sub-classes*** • Single Peak, Double Peak, Triple Peak
Ocean	• ***20 sub-classes*** • Brown-like, Coastal waveforms
Noisy	• ***5 sub-classes***

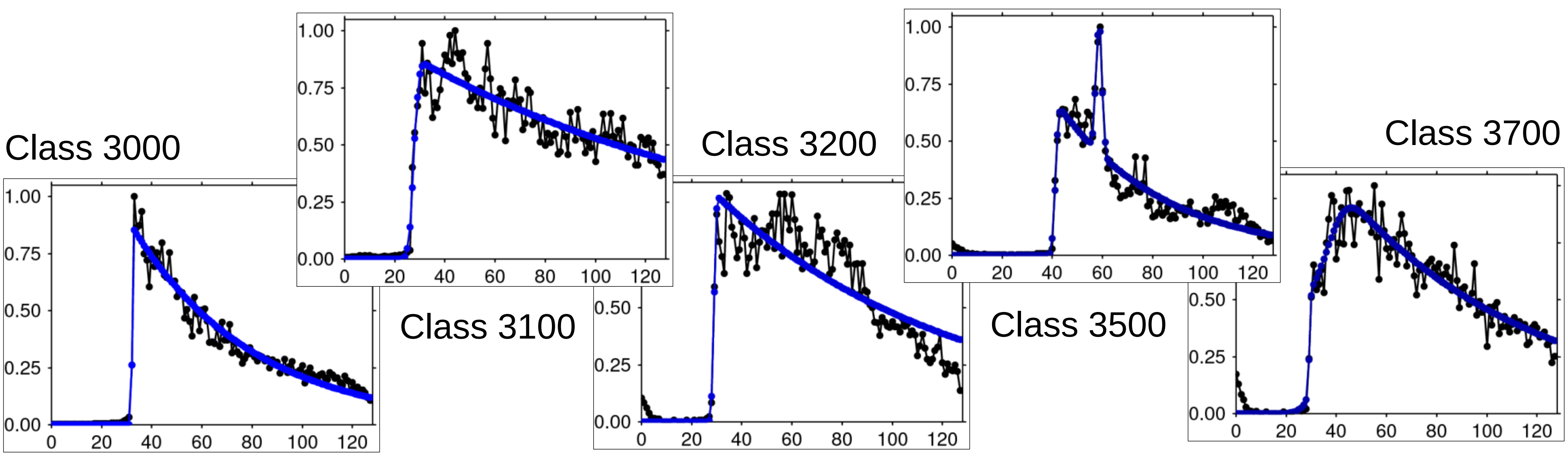
Specular Class

- The fitting function of a single peak waveform is a combination of
  - ***Normal probability density function (PDF)***
  - ***Normal cumulative distribution function (CPF)***
  - and ***scaling factor for width and height***
- Four parameter are fitted for each single peak
- This combined function leads to a better fit of not symmetrical peaks
- Classification of specular waveforms into 21 sub-classes using RMS thresholds and statistical parameters



Ocean Class

- The fitting functions for ocean-like or coastal waveforms are
  - ***modified Beta5 retracking function*** or
  - ***modified Beta5 retracking function + single peak function***
- Five, respectively 9 parameters are fitted for ocean/coastal waveforms
- Classification of ocean-like specular waveforms into 20 sub-classes using RMS thresholds and statistical parameters



Methodology

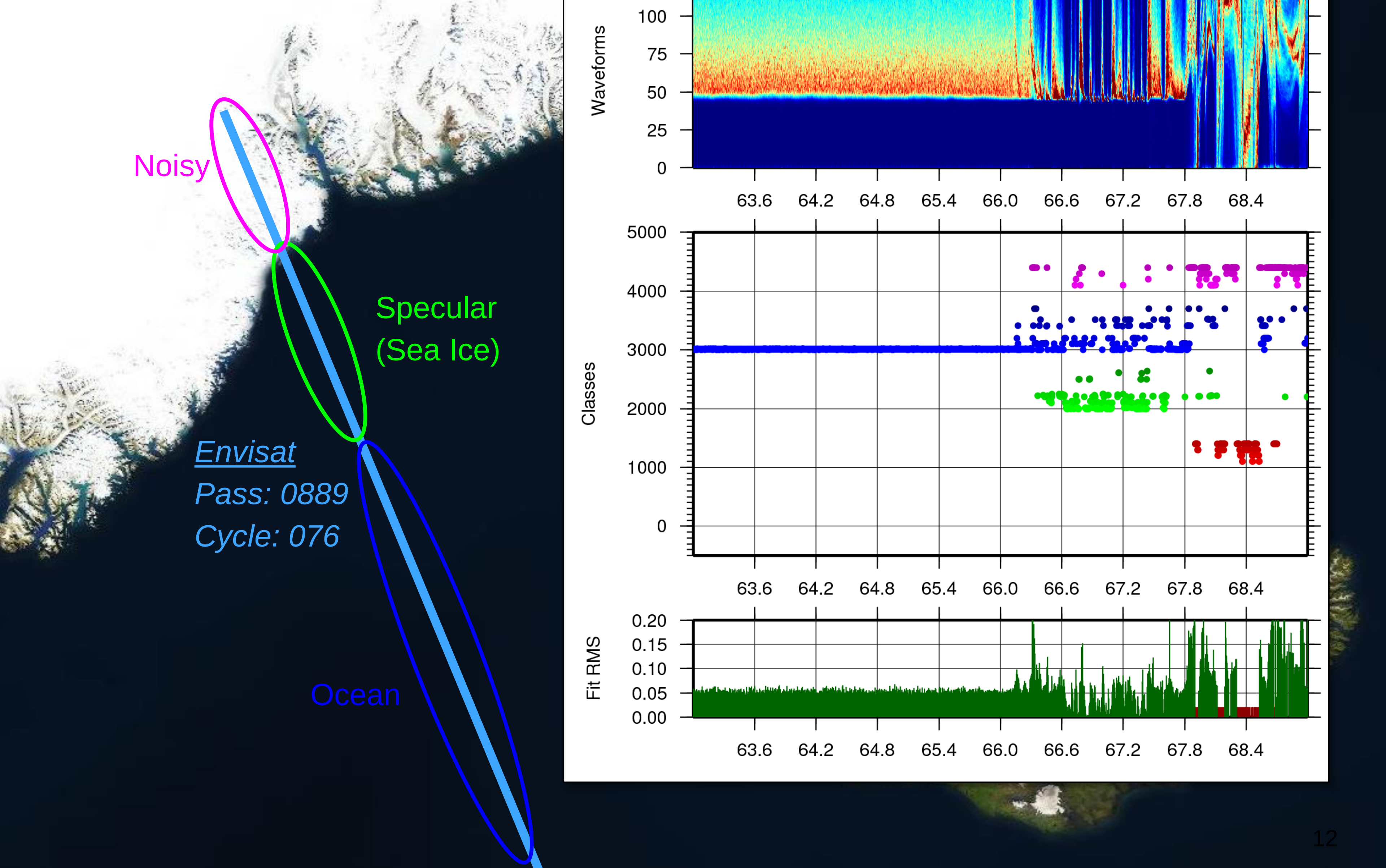
- The classification of altimeter waveforms into classes is realized by checking sequentially 51 classes for defined thresholds
- Examples of applied thresholds

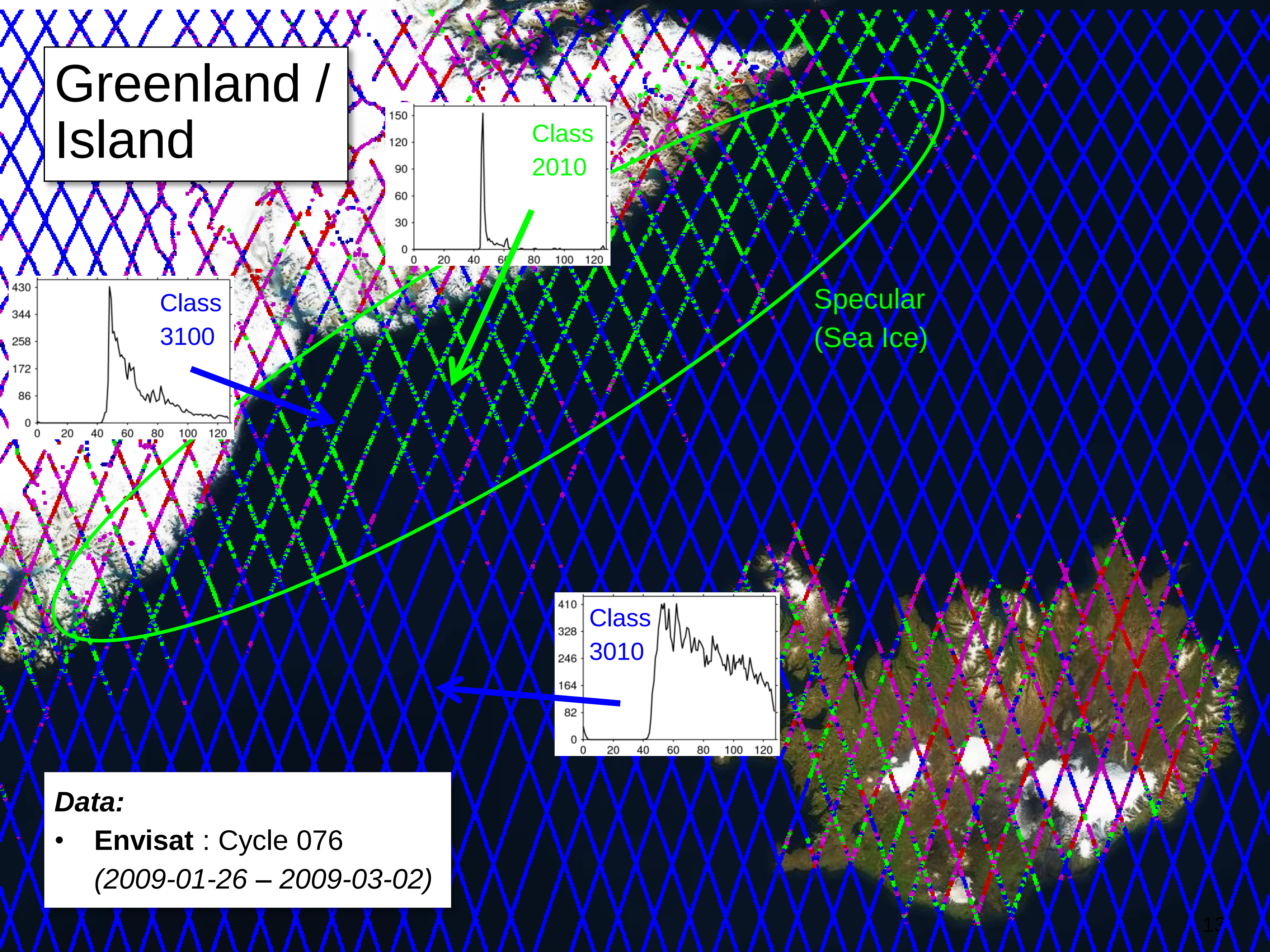
Class	Function	Min. Power	LE RMS	TE RMS	TE slope	Max. Residuals
1100	---	> 40%				
1200	---	> 30%				
3000	OceanExp		< 0.015	< 0.05	0.0 … 0.025	0.15
3010	OceanExp		< 0.015	< 0.05	0.0 … 0.025	0.25
3100	OceanExp		< 0.035	< 0.075	0.0 … 0.035	0.25
3110	OceanExp		< 0.035	< 0.075	0.0 … 0.035	0.35
3200	OceanExp		< 0.02	< 0.15	0.0 … 0.035	0.35
2000	SinglePeak		< 0.005	< 0.005		0.25
2500	DoublePeak		< 0.025			0.15
3500	OceanExpPeak		< 0.005	0.025		0.15

LE: leading edge *TE : trailing edge* *TE slope : slope of trailing edge*

Greenland / Island

Greenland / Island



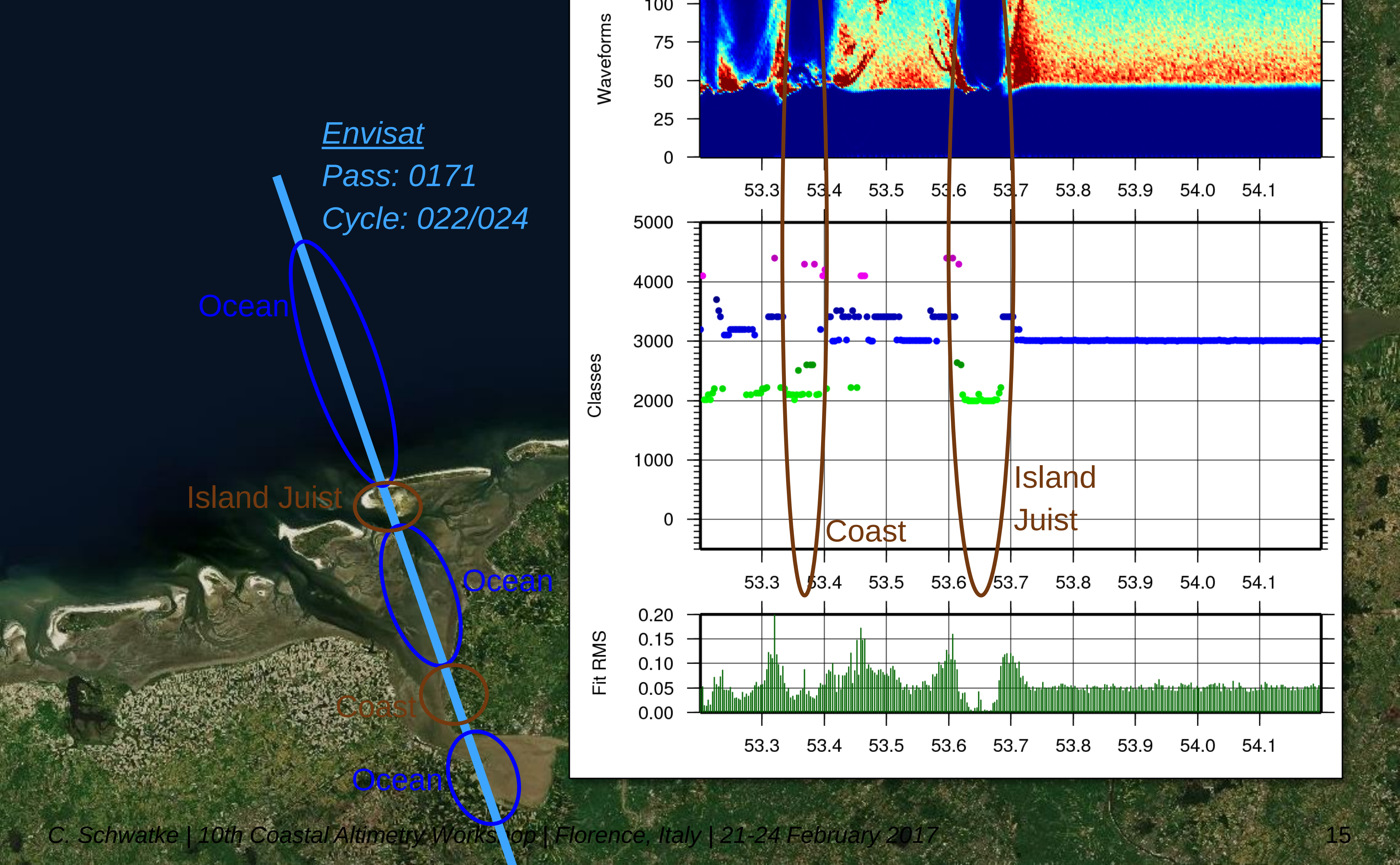


Greenland / Island
Class 2010
Class 3100
Class 3010
Specular (Sea Ice)
Data:
• Envisat : Cycle 076
(2009-01-26 – 2009-03-02)

North Sea

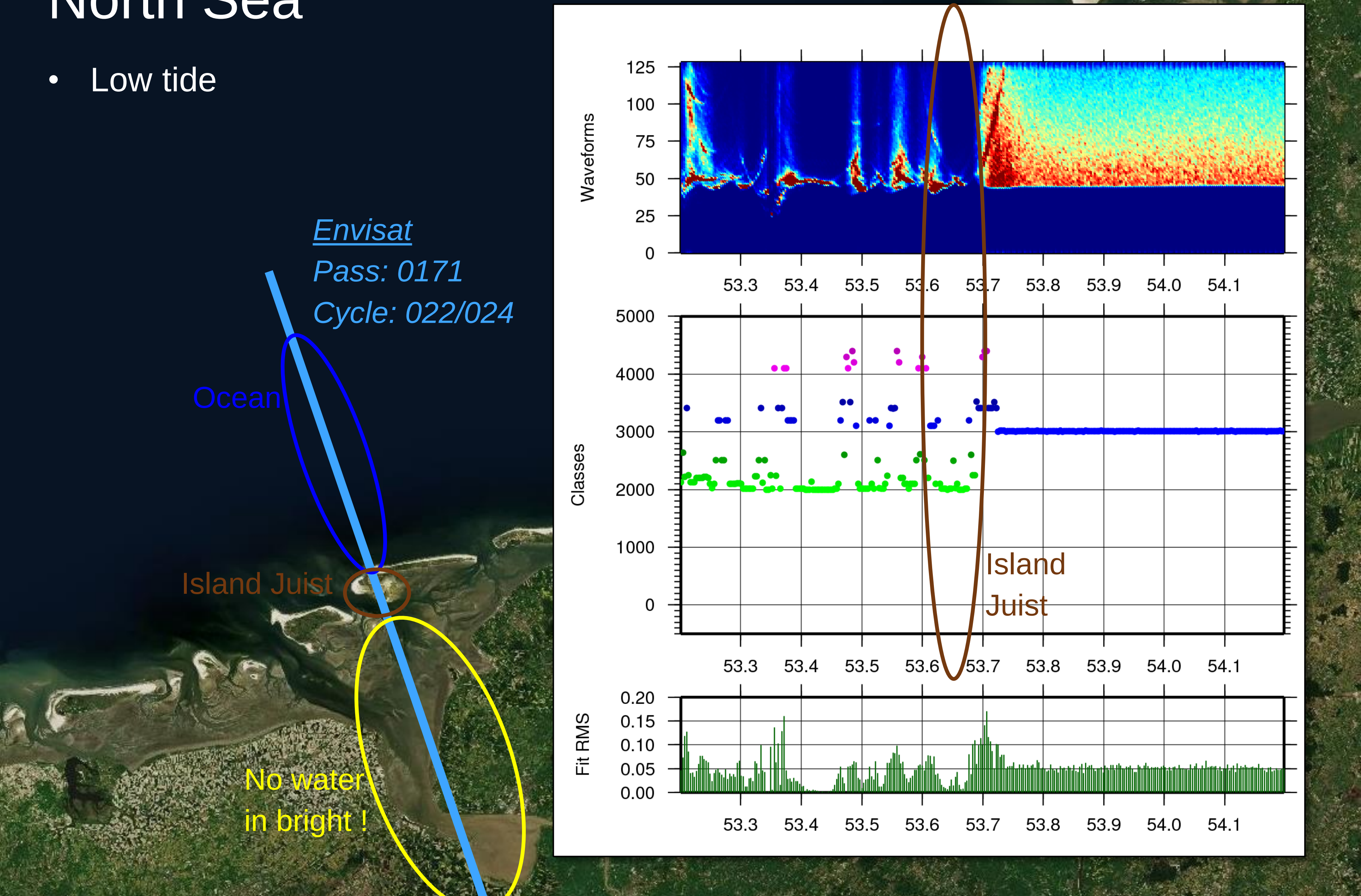
North Sea

- High tide



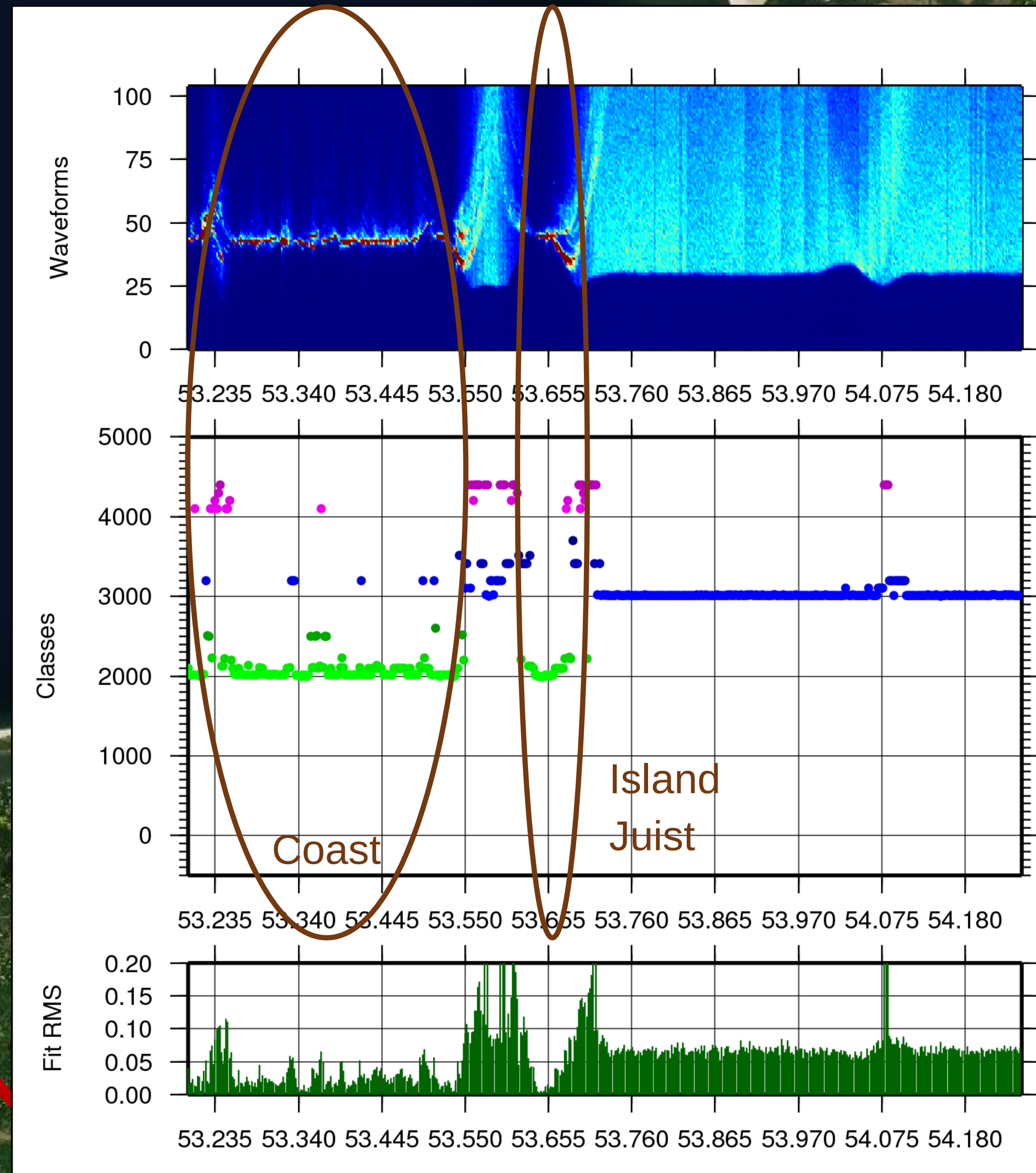
North Sea

- Low tide



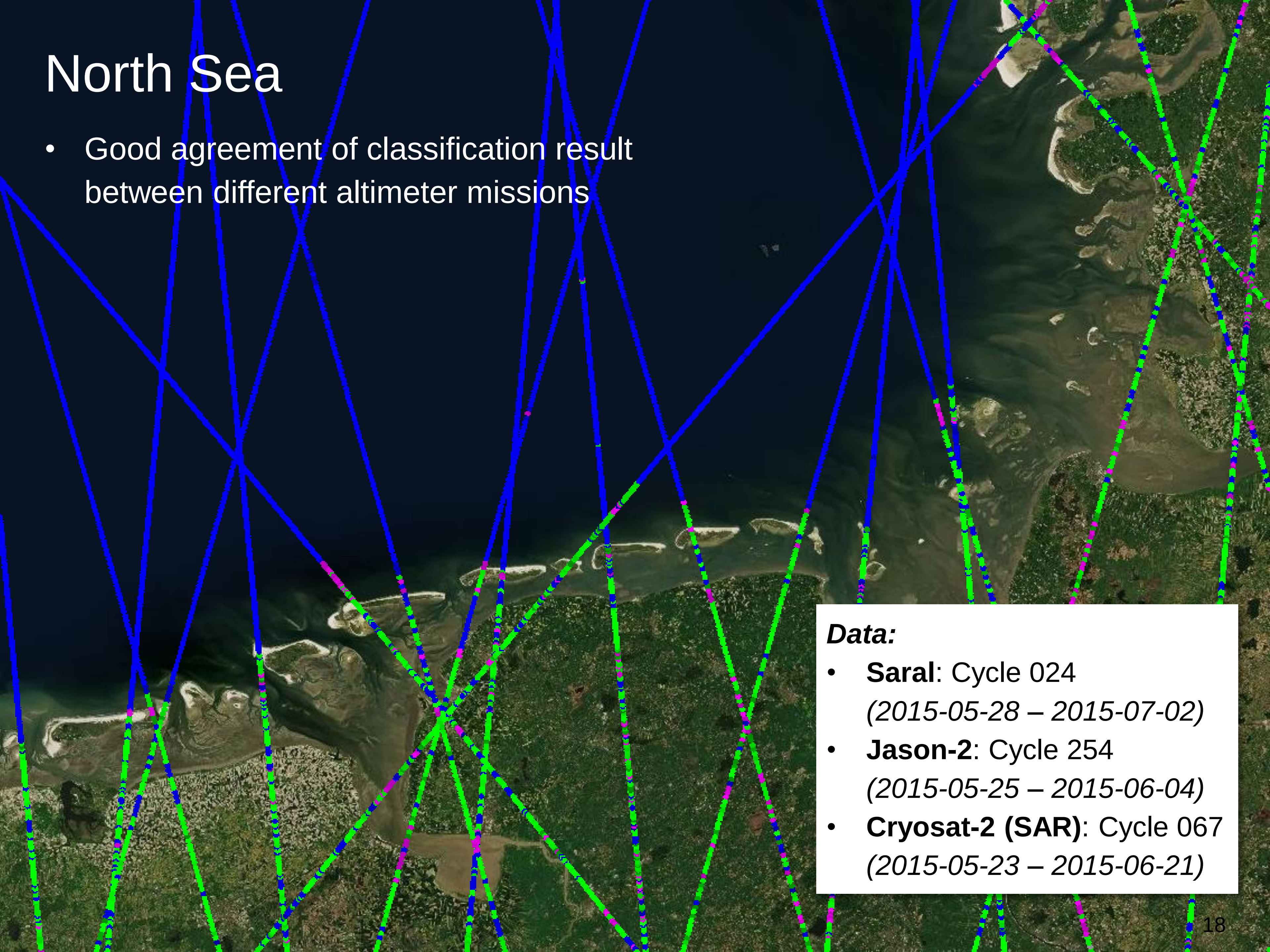
North Sea

- High tide



North Sea

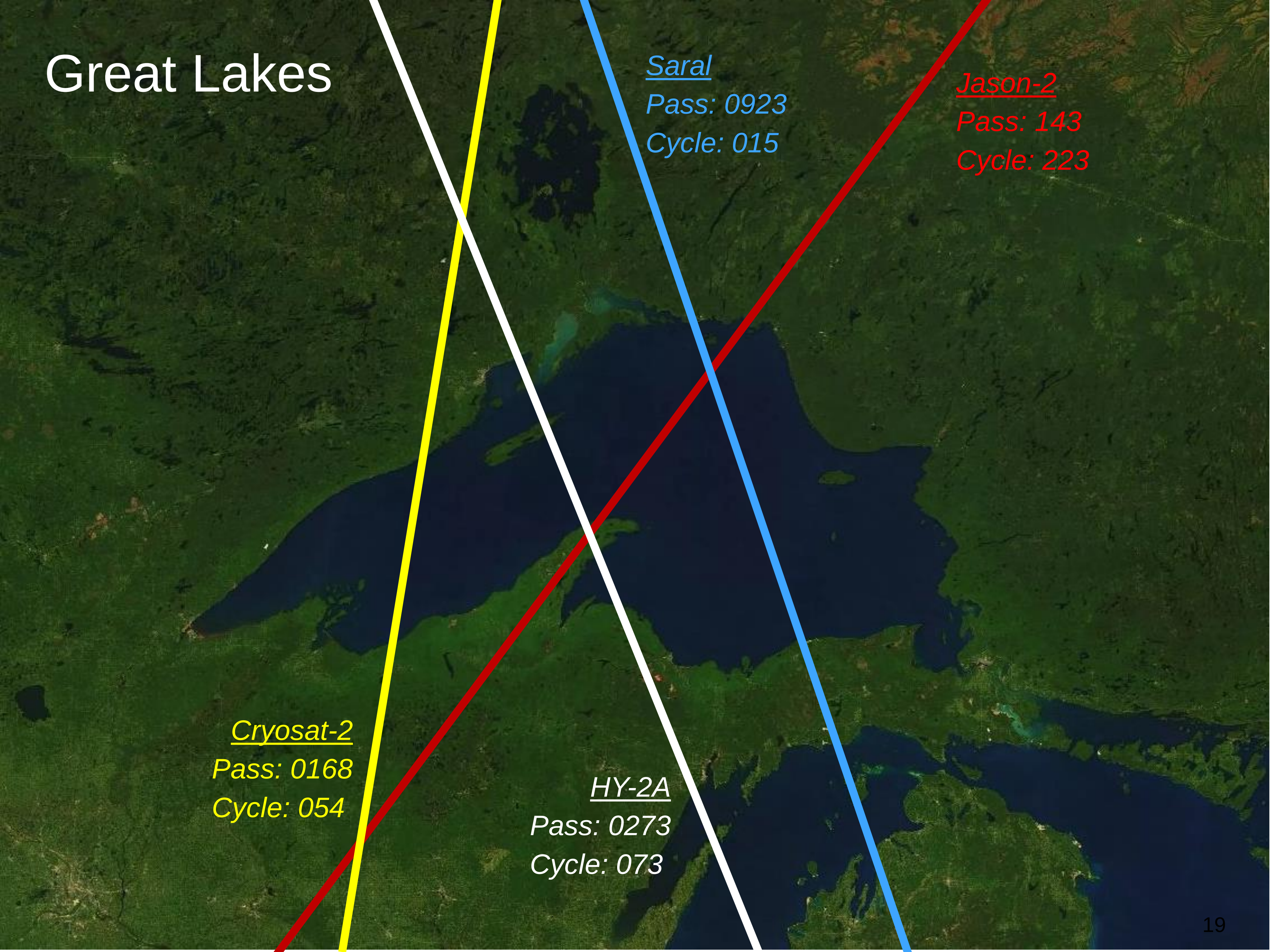
- Good agreement of classification result between different altimeter missions



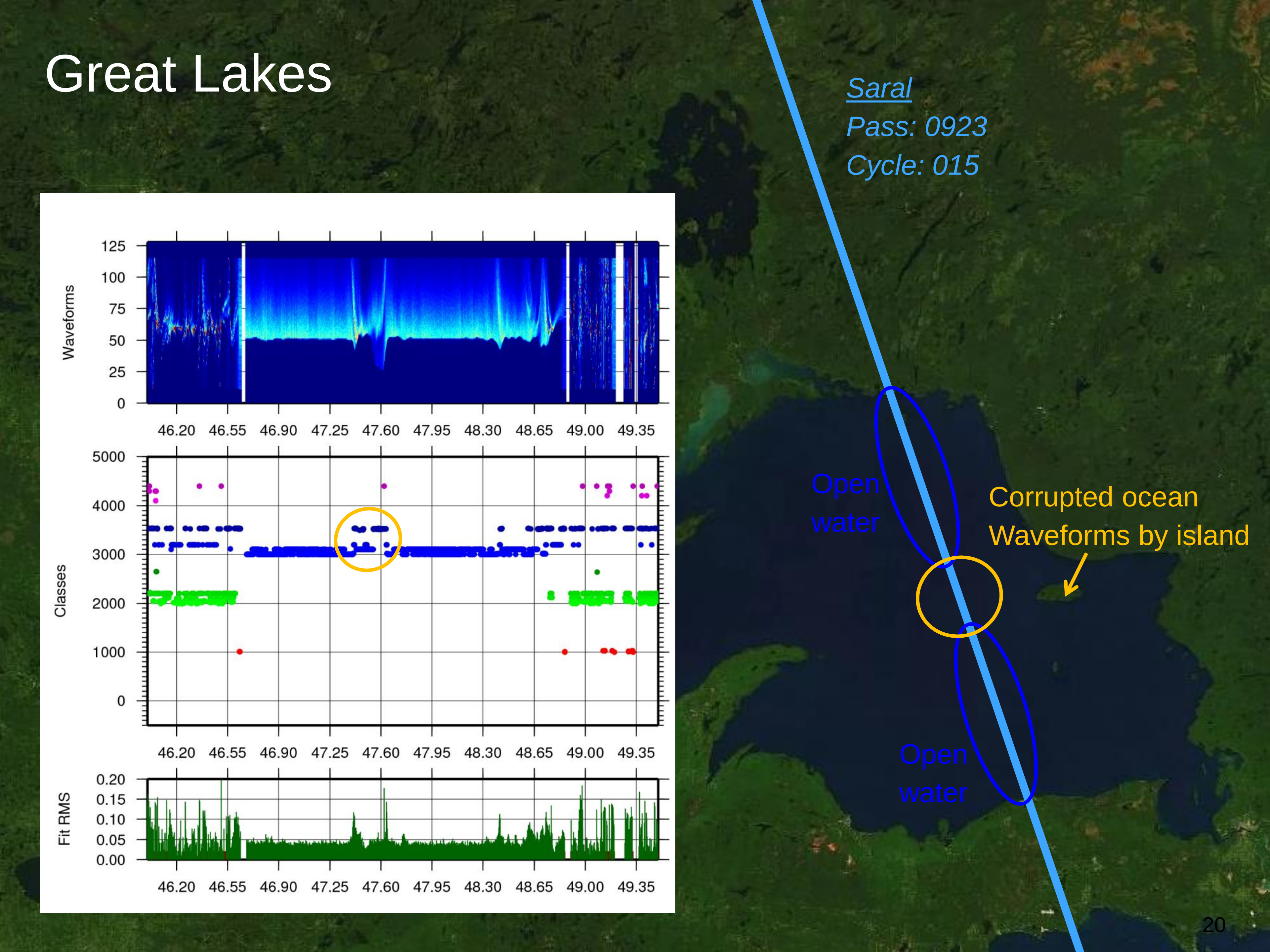
Data:

- **Saral**: Cycle 024
  (2015-05-28 – 2015-07-02)
- **Jason-2**: Cycle 254
  (2015-05-25 – 2015-06-04)
- **Cryosat-2 (SAR)**: Cycle 067
  (2015-05-23 – 2015-06-21)

Great Lakes


Saral
Pass: 0923
Cycle: 015
Jason-2
Pass: 143
Cycle: 223
Cryosat-2
Pass: 0168
Cycle: 054
HY-2A
Pass: 0273
Cycle: 073

Great Lakes



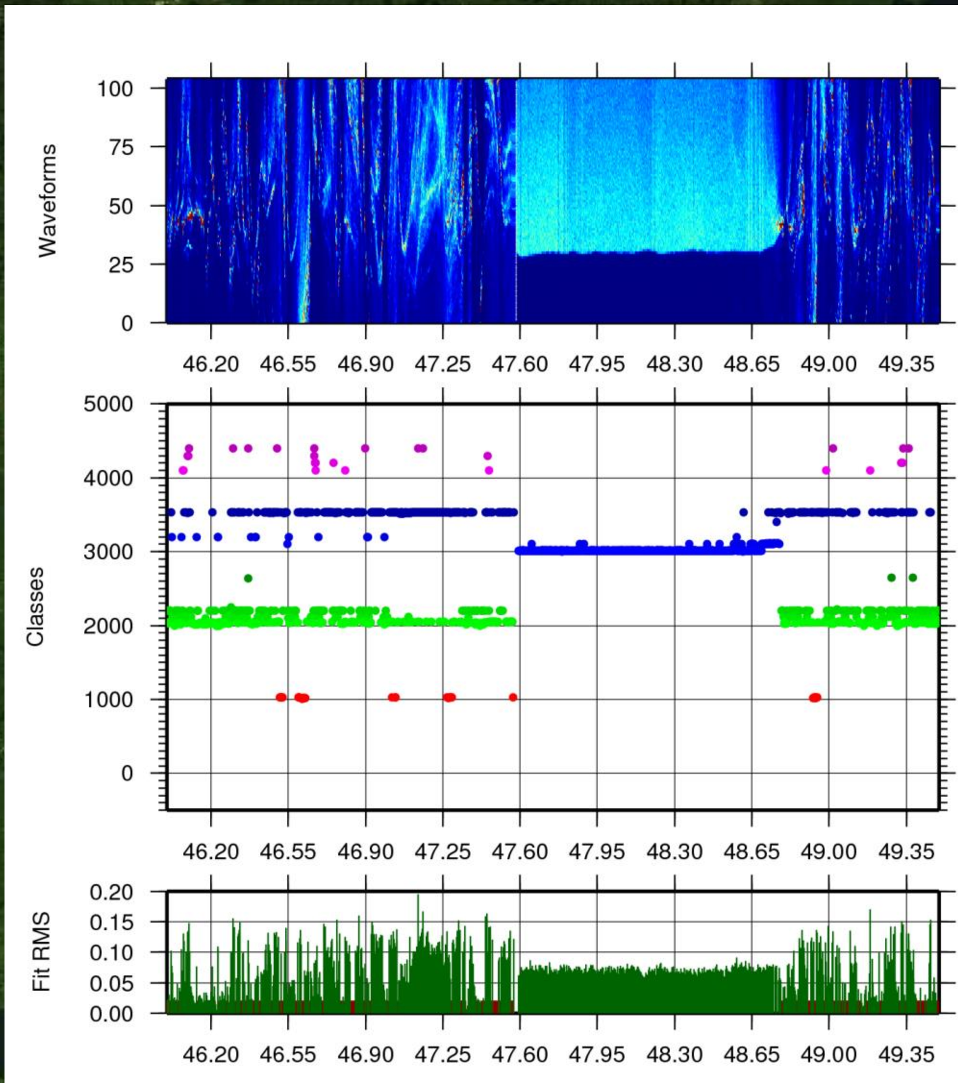
Waveforms
125
100
75
50
25
0
46.20
46.55
46.90
47.25
47.60
47.95
48.30
48.65
49.00
49.35
Classes
5000
4000
3000
2000
1000
0
Fit RMS
0.20
0.15
0.10
0.05
0.00
Saral
Pass: 0923
Cycle: 015
Open water
Corrupted ocean Waveforms by island
Open water

Great Lakes

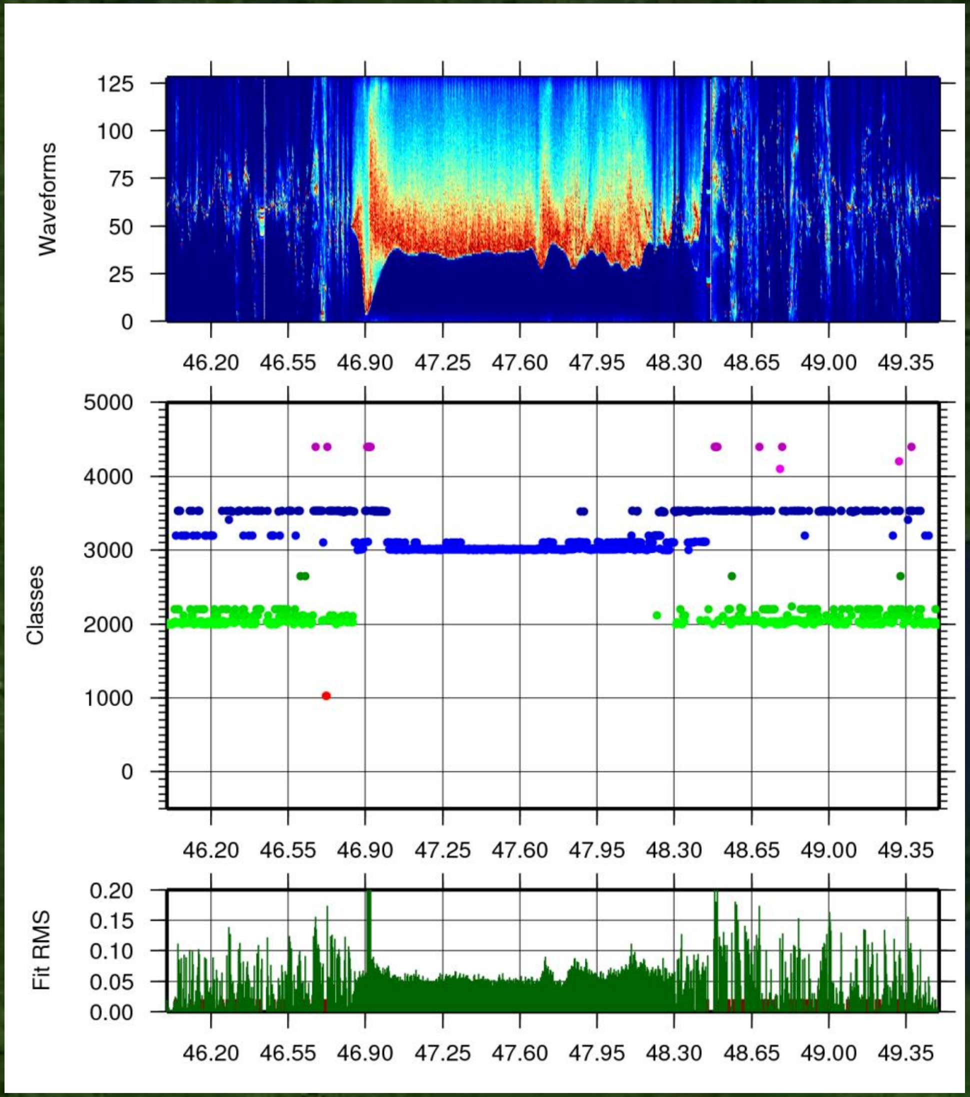
Jason-2

Pass: 143

Cycle: 223



Great Lakes

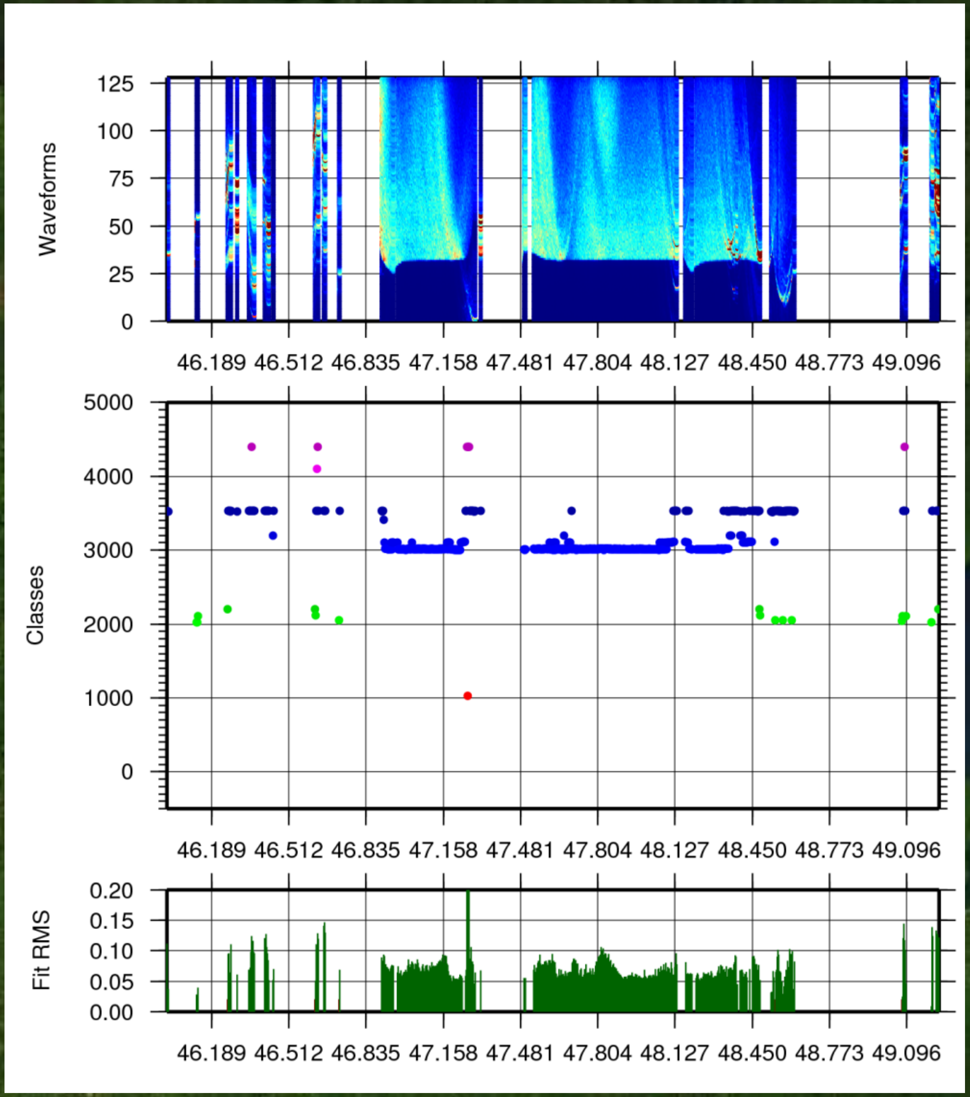


Cryosat-2

Pass: 0168

Cycle: 054

Great Lakes

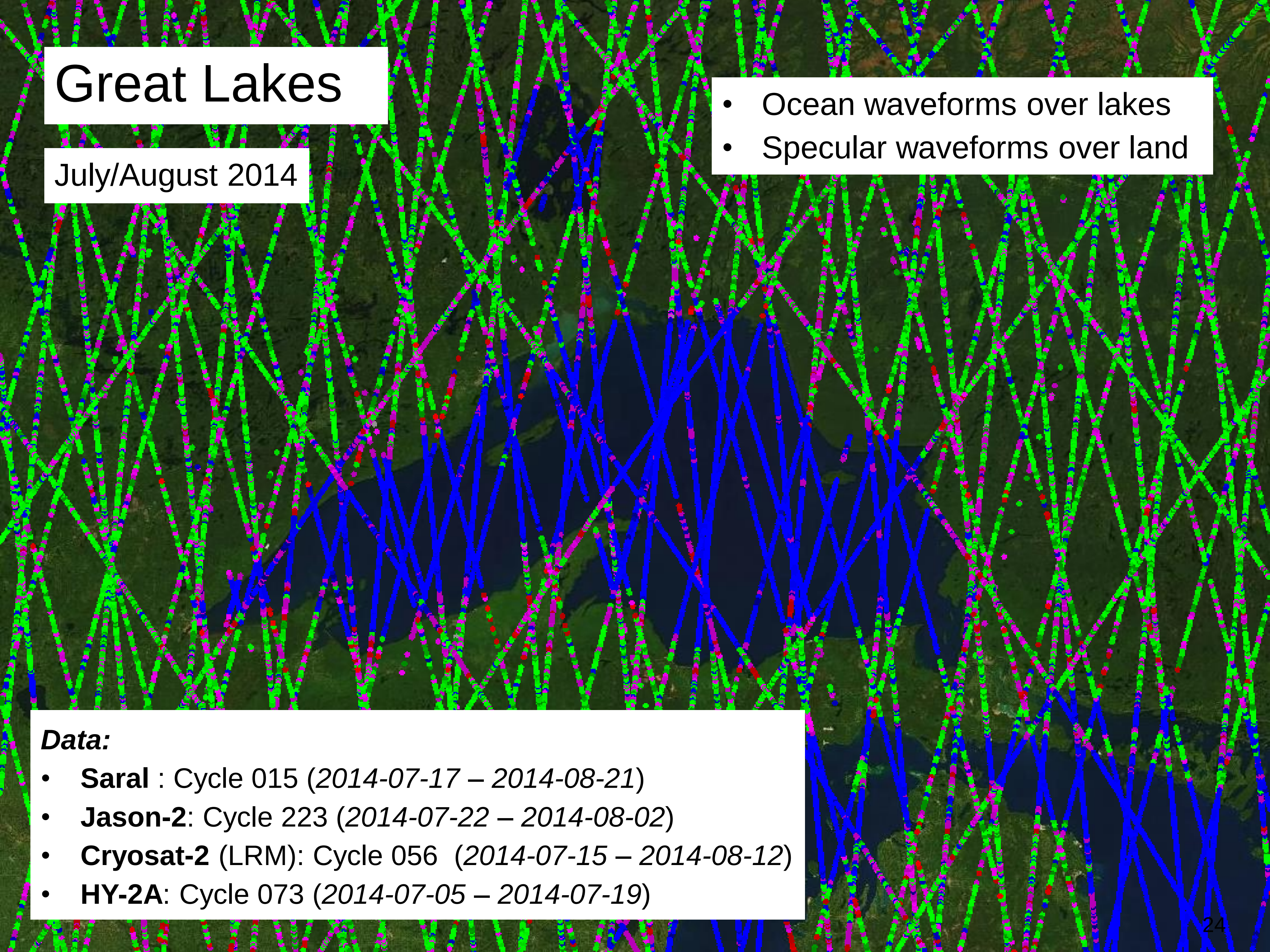


HY-2A
Pass: 0273
Cycle: 073

Great Lakes

July/August 2014

- Ocean waveforms over lakes
- Specular waveforms over land



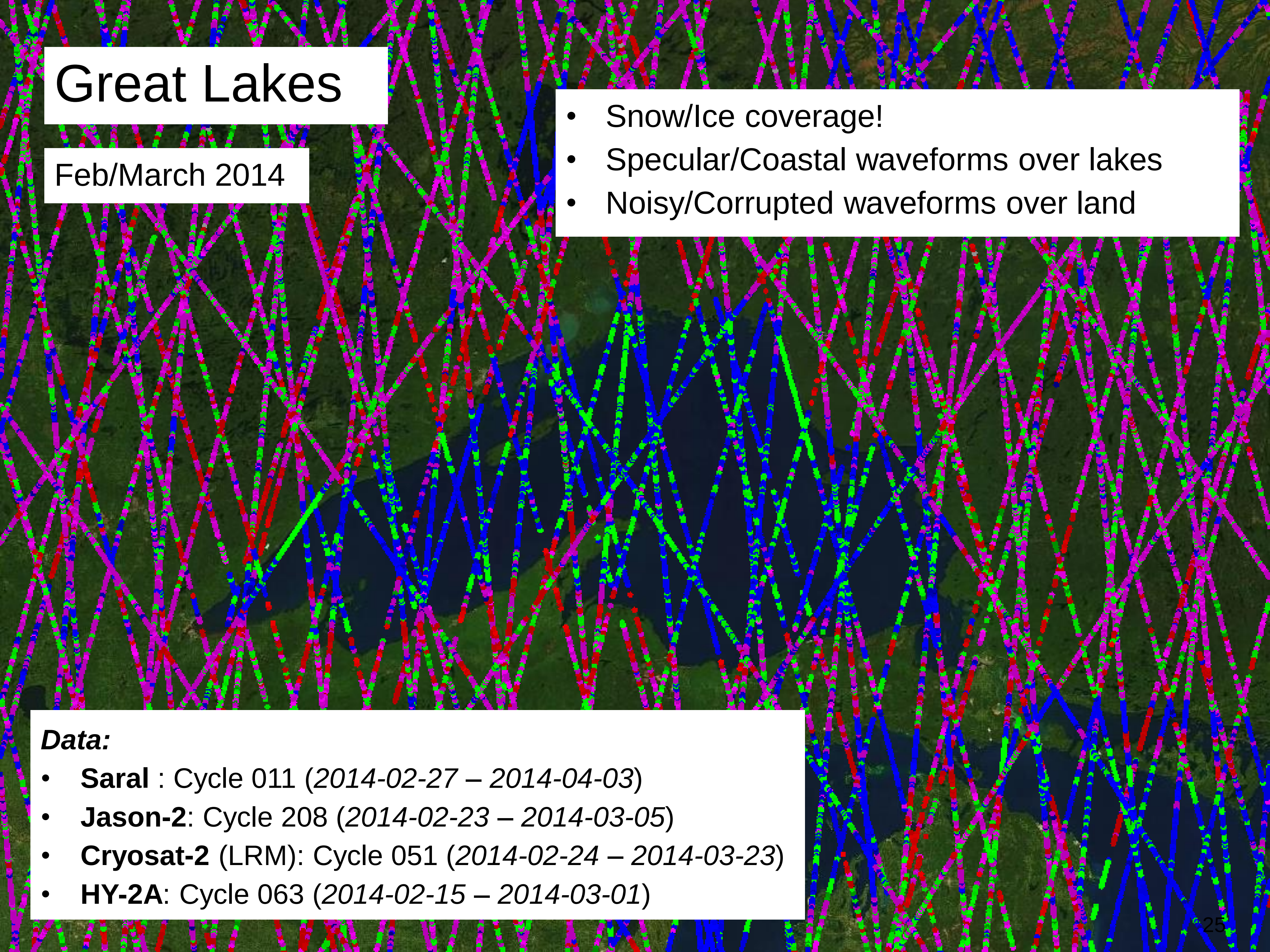
Data:

- **Saral** : Cycle 015 (*2014-07-17 – 2014-08-21*)
- **Jason-2**: Cycle 223 (*2014-07-22 – 2014-08-02*)
- **Cryosat-2** (LRM): Cycle 056 (*2014-07-15 – 2014-08-12*)
- **HY-2A**: Cycle 073 (*2014-07-05 – 2014-07-19*)

Great Lakes

Feb/March 2014

- Snow/Ice coverage!
- Specular/Coastal waveforms over lakes
- Noisy/Corrupted waveforms over land



Data:

- **Saral** : Cycle 011 (*2014-02-27 – 2014-04-03*)
- **Jason-2**: Cycle 208 (*2014-02-23 – 2014-03-05*)
- **Cryosat-2** (LRM): Cycle 051 (*2014-02-24 – 2014-03-23*)
- **HY-2A**: Cycle 063 (*2014-02-15 – 2014-03-01*)

Conclusion / Outlook

- The new classification approach leads to successful classification results of altimeter waveforms into 51 classes
- Handling of different characteristics of altimeter missions
  is not a limiting factor for the classification (antenna configuration, pulse bandwidth, satellite height, etc.)
- Potential applications for the new classification method
  - Ice detection in the open ocean
  - Identification of corrupted waveforms in the coastal region
  - Ice detection over lakes
  - Detection of rivers and lakes
- In future, the classification will be used in Database for Hydrological Time Series of Inland Waters (DAHITI)
  - Automated target detection of river crossings
  - Improved retracking if waveform shape is known
  - Identification of water returns for the estimation of water levels