A step towards the characterization of SAR Mode Altimetry Data over Inland Waters – SHAPE Project

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Context

The SHAPE project :

“Sentinel-3 Hydrologic Altimetry Processor prototypE”

Funded by ESA through the SEOM Programme Element to prepare for the exploitation of Sentinel-3 data over the inland water domain, with Objectives :

- **Characterize available SAR mode data over inland water.**
- Assess the performances, in Hydrology, of applying the Sentinel-3 IPF to CryoSat-2 data and emulating repeat-orbit Alti-Hydro Products (AHP).
- Analyse weaknesses of the Sentinel-3 IPF at all levels.
- Assess the benefits of assimilating the SAR/RDSAR derived AHP into hydrological models.
- **Design innovative techniques to build and/or to refine the L1B-S and assess their impact onto L1B and AHP.**
- **Improve SAR/RDSAR retracking over river and lakes.**
- Provide improved L2 Corrections (tropospheric, geoid) for Sentinel-3 over land and inland water.
- Specify, prototype, test and validate the Sentinel-3 Innovative SAR Processing Chain for Inland Water.

Context

Even with SAR mode, Alti-Hydrology is a difficult topic

- Very wide variety of scenarios
- Wide across-track integration → loss of accuracy & precision.
- Off-NADIR hooking: tracker window not always centered at NADIR
- Space and time variability of the water area with :
  - low waters → contaminated waveforms due to sand banks …
  - High waters → flooded areas sometimes (outside water masks)

Questions

- How to characterize Sentinel-3 waveforms over inland from CryoSat-2 data ?
- Is geodetic orbit an issue ?

Objectives

Look for specific features of SAR data over inland waters to be exploited @ :

- Stack Masking → production of “decontaminated” Waveforms
- Retracking → provide context information for parameters tuning

SAR data is here :

- Individual Echoes from CryoSat-2 (FBR or L1A)
- Stacks or L1B-S
- SAR waveforms (and RDSAR)

Despite a huge variety of scenarios BUT this Characterization Exercise shall be : an automated (massive), Simple and quantitative classification of cases with the available auxiliary data :

- Water mask information
- Instrument footprints
- Lets try to classify from the Water Fraction

Method

Method

- Compute the Intersection Area of the Footprint and Water Mask
- WaterFraction = Intersection_Area / Instrument_Footprint_Area
- Define **N color coded classes** according to the Water Fraction :
  - Class 1 : [0 , 20[%
  - Class 2 : [20, 40[%
  - Class 3 : [40, 60[%
  - Class 4 : [60, 80[%
  - Class 5 : [80, 100] %
- **Statistics** (from beam behaviour param.) per class.
- **Mean Waveforms** per class.
- Analyse these results for classes with **equalized population**

Method

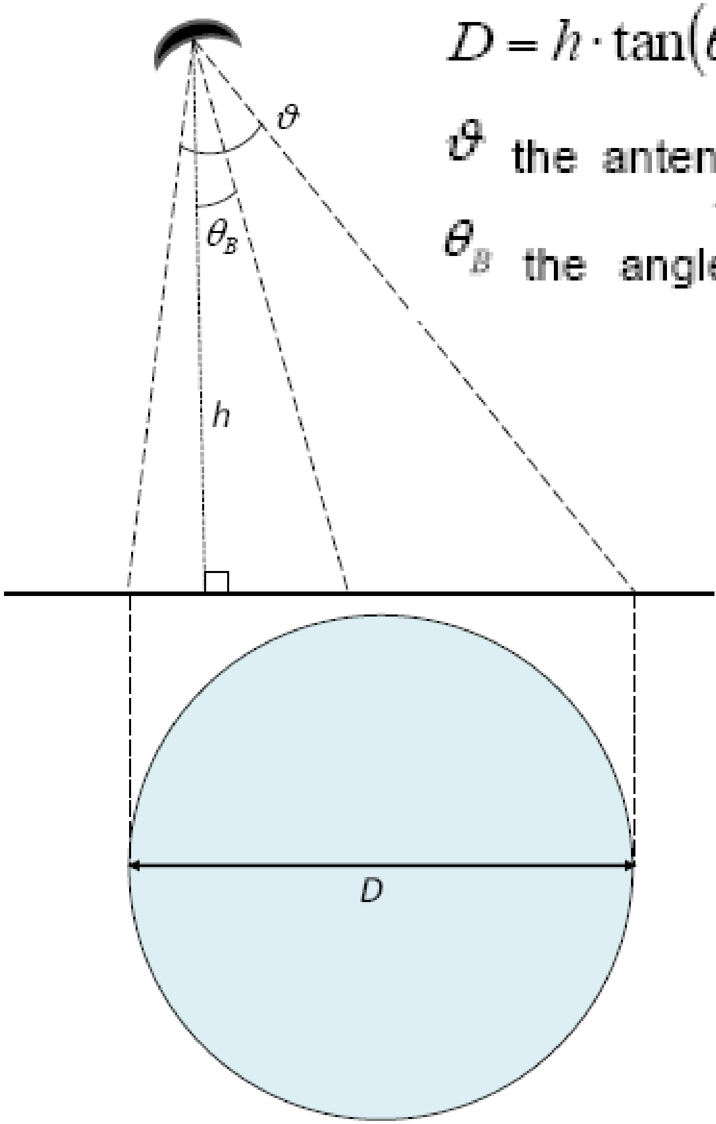
Beam Behaviour Parameters employed to **characterize the Stacks** via their across-track integration → **Range Integrated Power** (**RIP**) :

- **Mean STDEV** of the Gaussian PDF fitting the RIP **(1 per record)**
- **Mean Centre** of the Gaussian PDF fitting the RIP **(1 per record)**
- **Scaled Amplitude** : amplitude scaled in dB/100 **(1 per record)**
- **Skewness** : asymmetry of the stack RIP distribution **(1 per record)**
- **Kurtosis** : peackiness of the stack RIP distribution **(1 per record)**

Method

Beam-Doppler footprint (eq. From CryoSat-2 handbook)

Across-track beam size



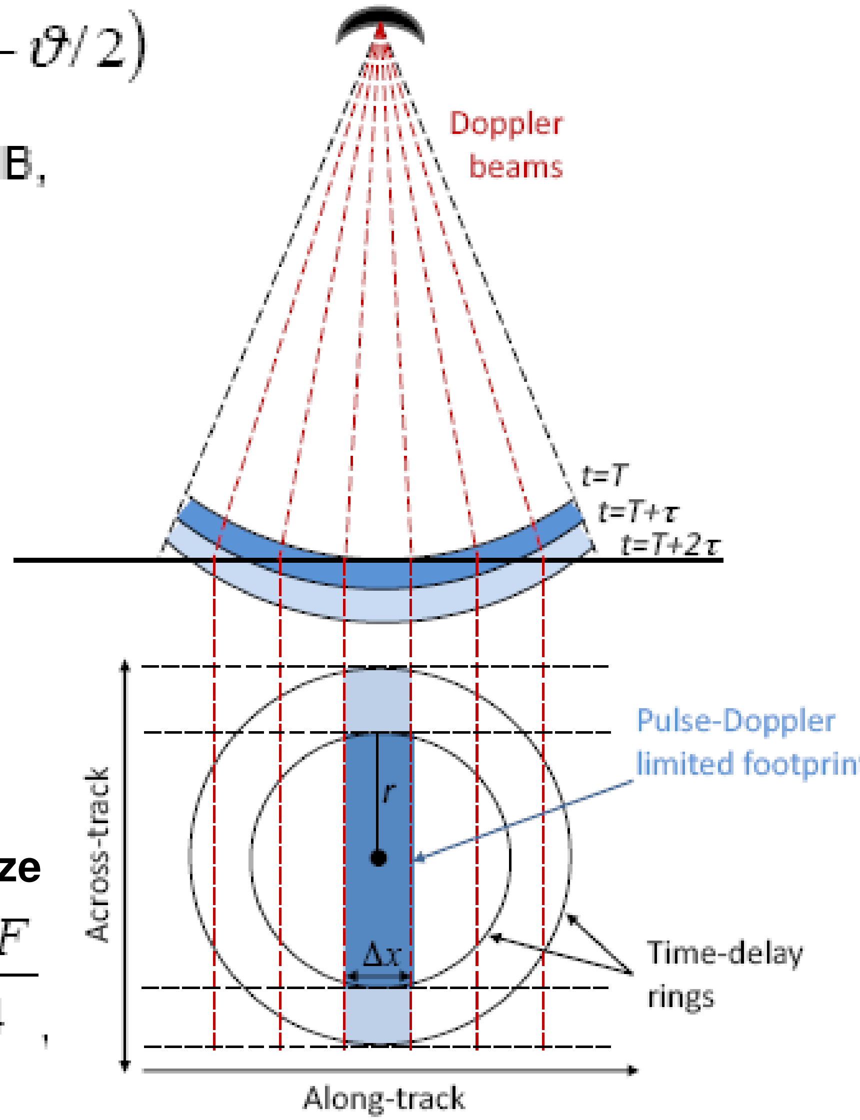
$$D = h \cdot \tan(\theta_B + \vartheta/2) - h \cdot \tan(\theta_B - \vartheta/2)$$

ϑ the antenna beam width at -3 dB,

θ_B the angle of the central beam

Along-track beam size

$$\Delta x = h \frac{\lambda}{2v} \frac{PRF}{64},$$



Experiment Set-Up

Experiment Set-Up

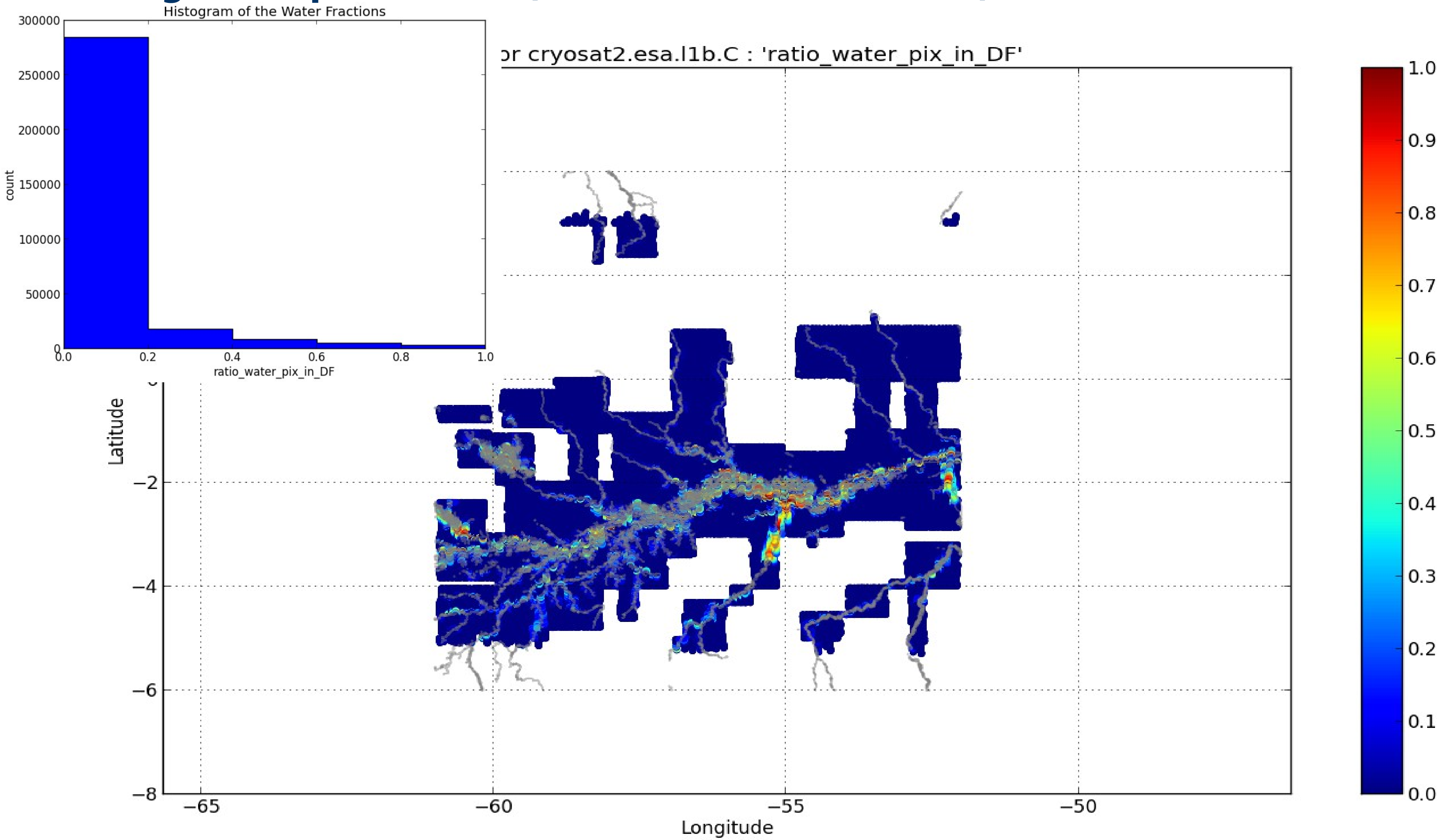
- CryoSat-2 L1-B **Baseline C** data over **Amazon**
- Time Period : The whole year 2014
  - 280 L1B files (319523 records)
- Variable Instrument parameters read in the L1-B files
  - Satellite velocity
  - Tracker range
  - Latitude, longitude of the records
- Fixed Instrument Parameters :
  - Bandwidth
  - PRF
  - Antenna dimensions
  - Carrier frequency
- Auxiliary data : old SWBD water masks covering Amazon

Results

Results

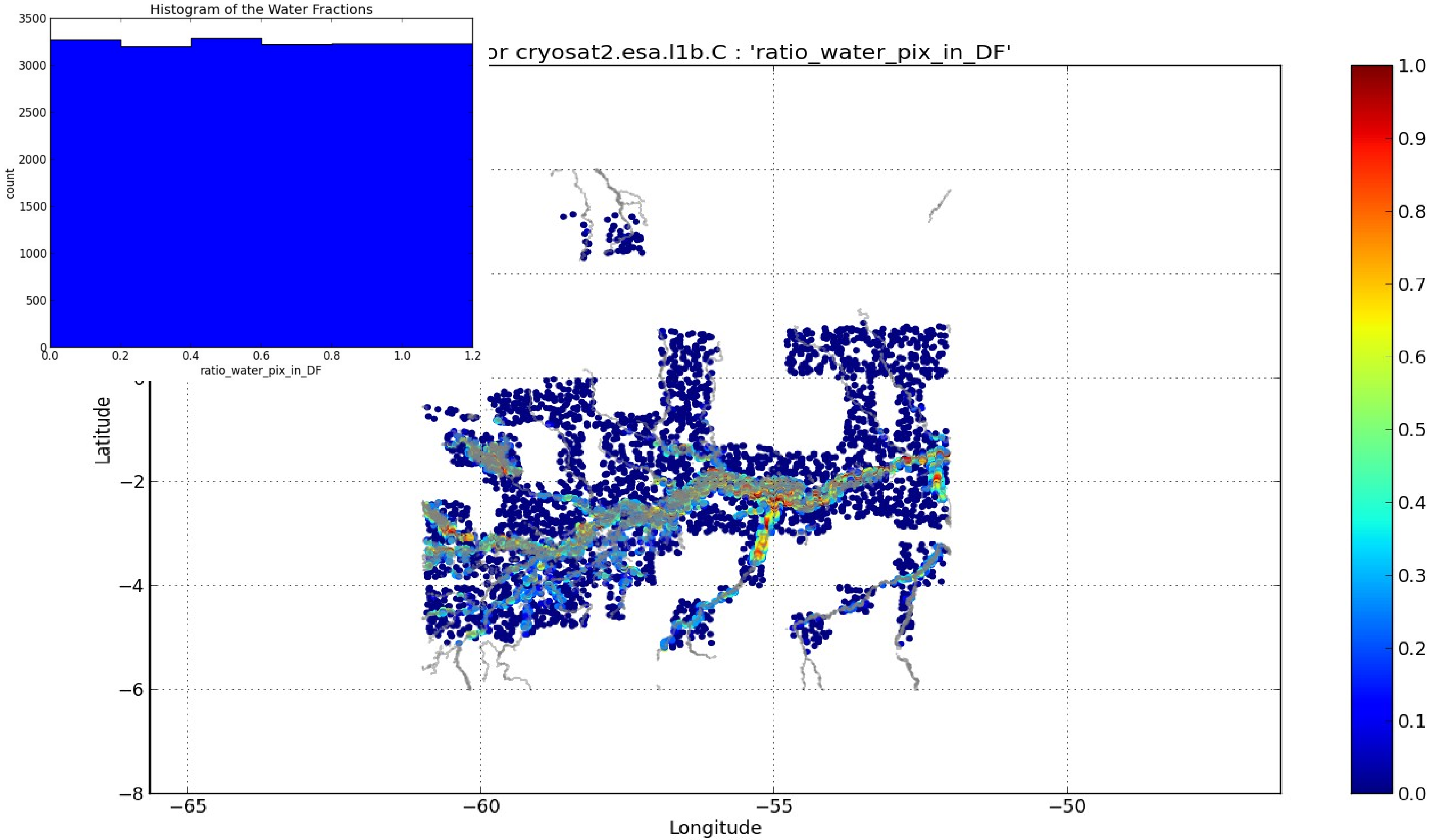
Raw data selection : 319523 records, smallest 3200 records

Histogram Equalisation (random data selection) : 2000 records/class



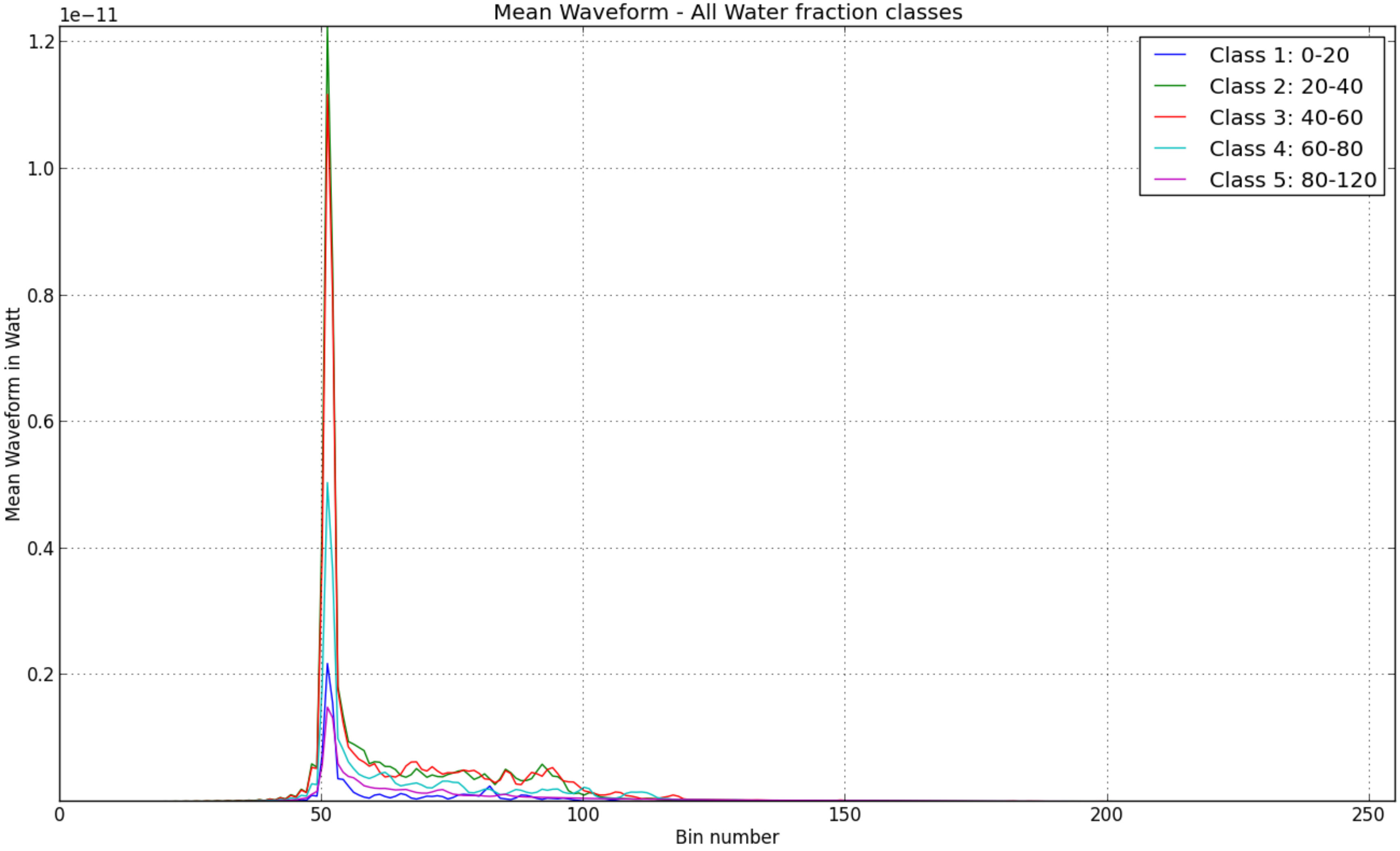
Results

Histogram Equalisation (random data selection) : ±3200 records/class



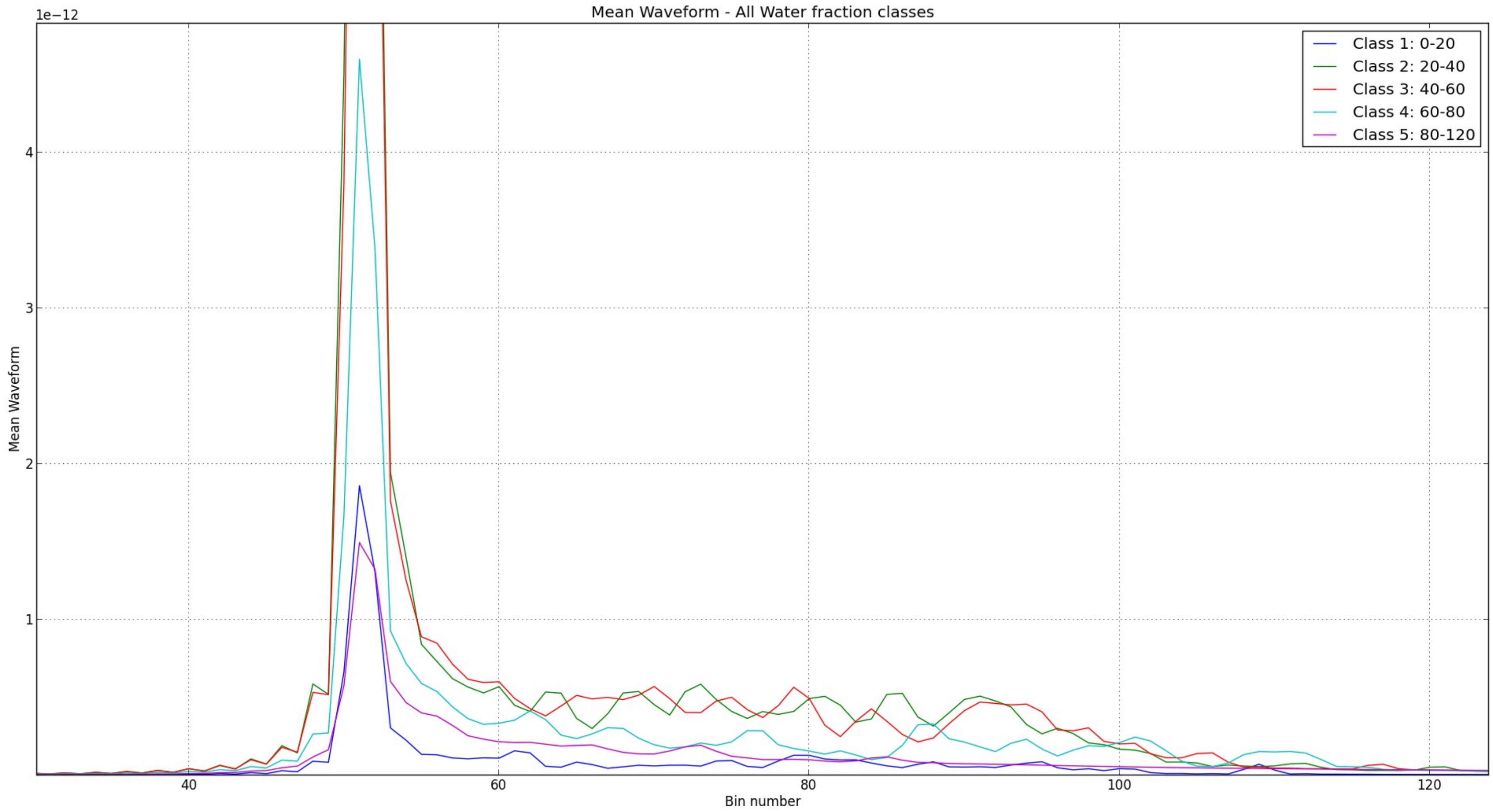
Results

Mean Waveforms in Watt (linear scale)

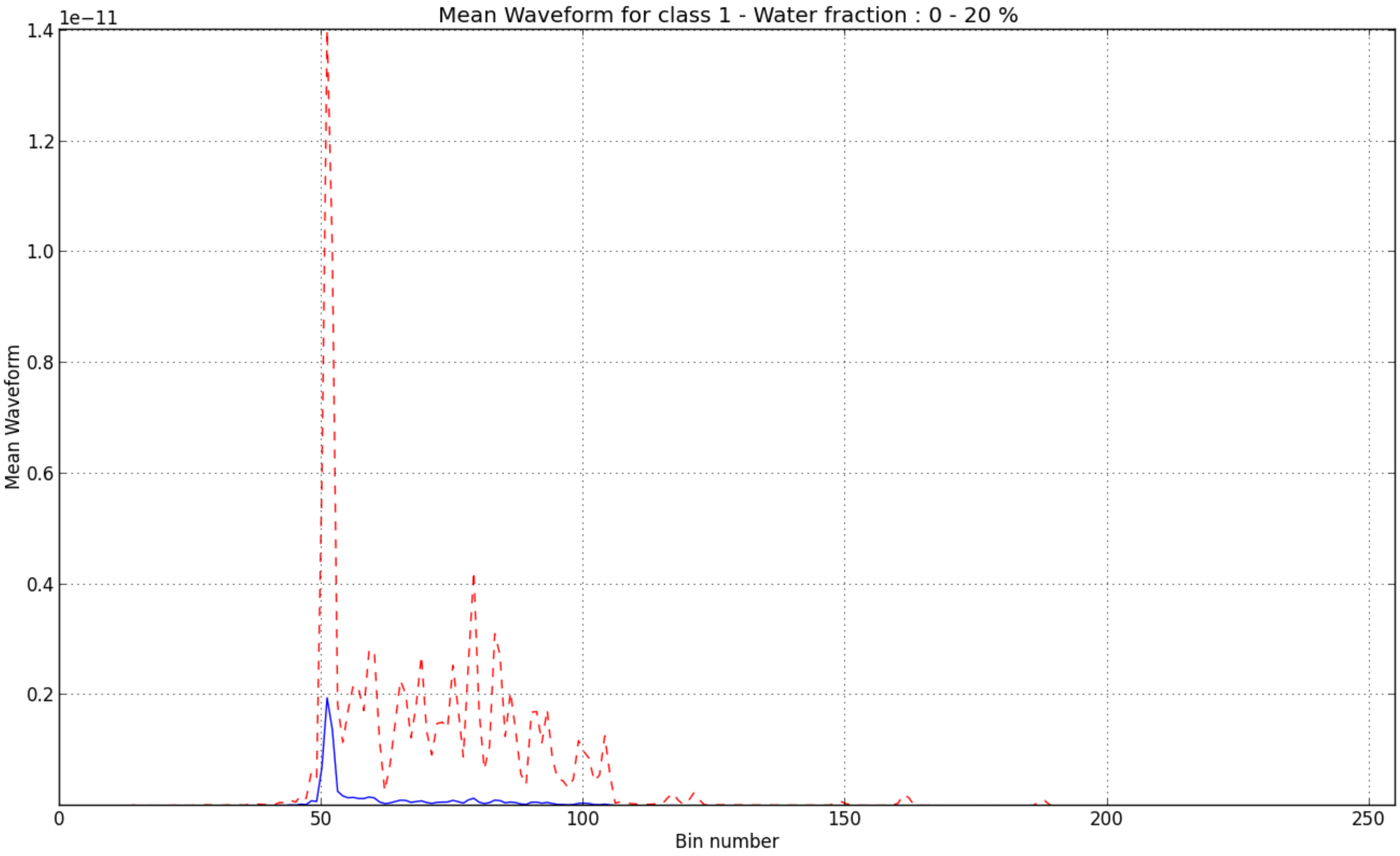


Results

Mean Waveforms in Watt (linear scale) (Zoom)

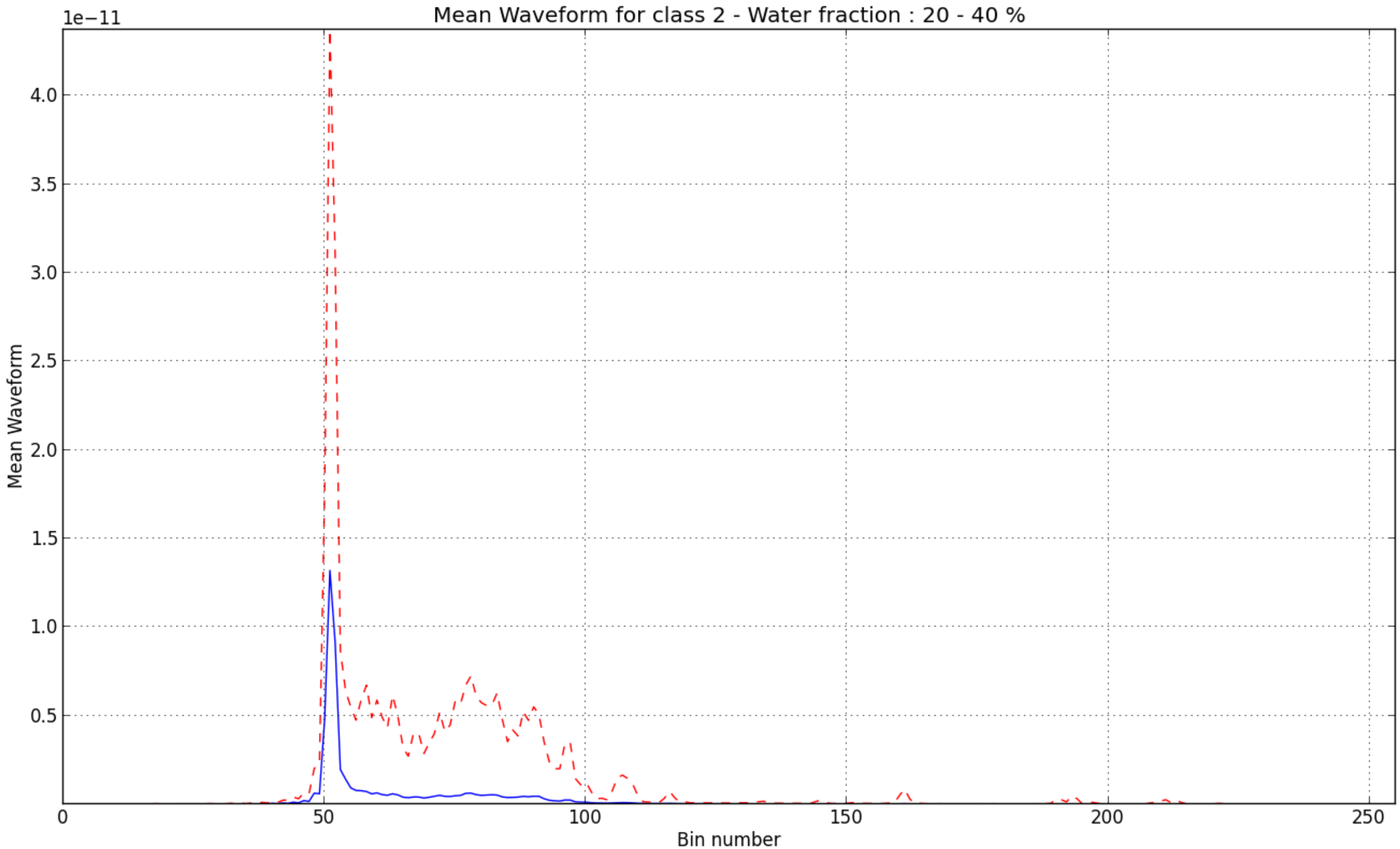


Results



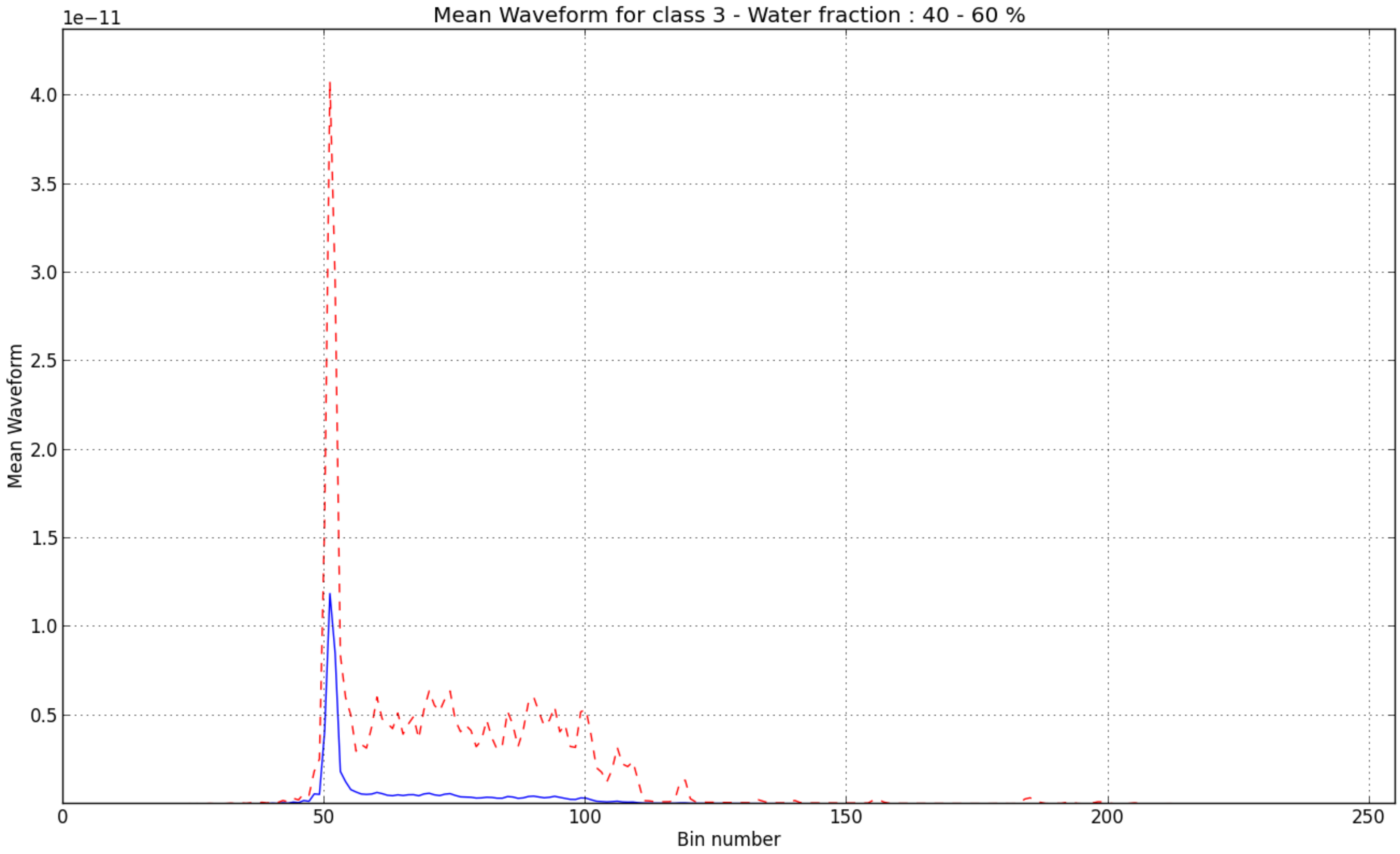
Mean Waveform for class 1 - Water fraction : 0 - 20 %
1e−11
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Mean Waveform
0
50
100
150
200
250
Bin number

Results



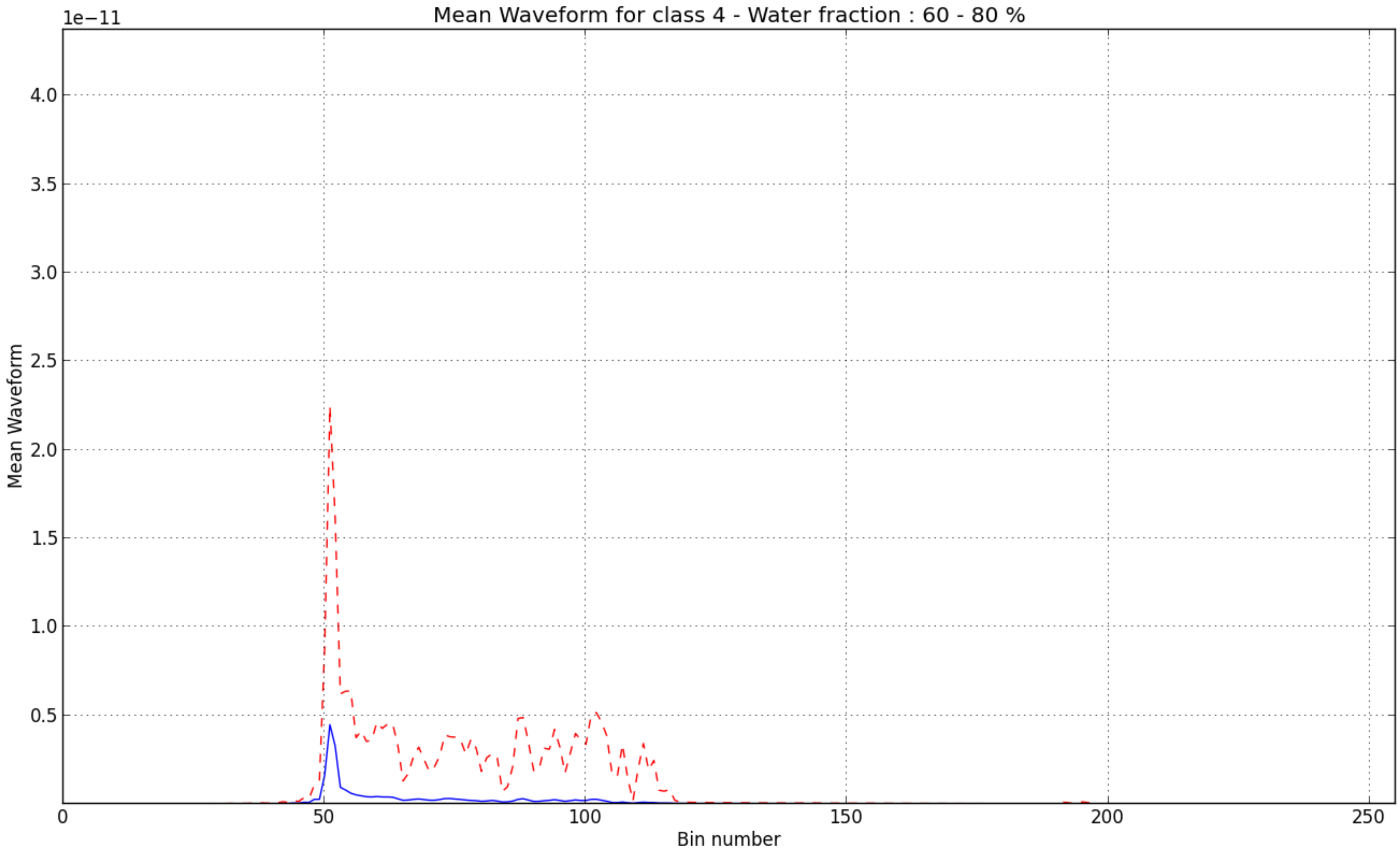
Mean Waveform for class 2 - Water fraction : 20 - 40 %
1e−11
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Mean Waveform
0
50
100
150
200
250
Bin number

Results

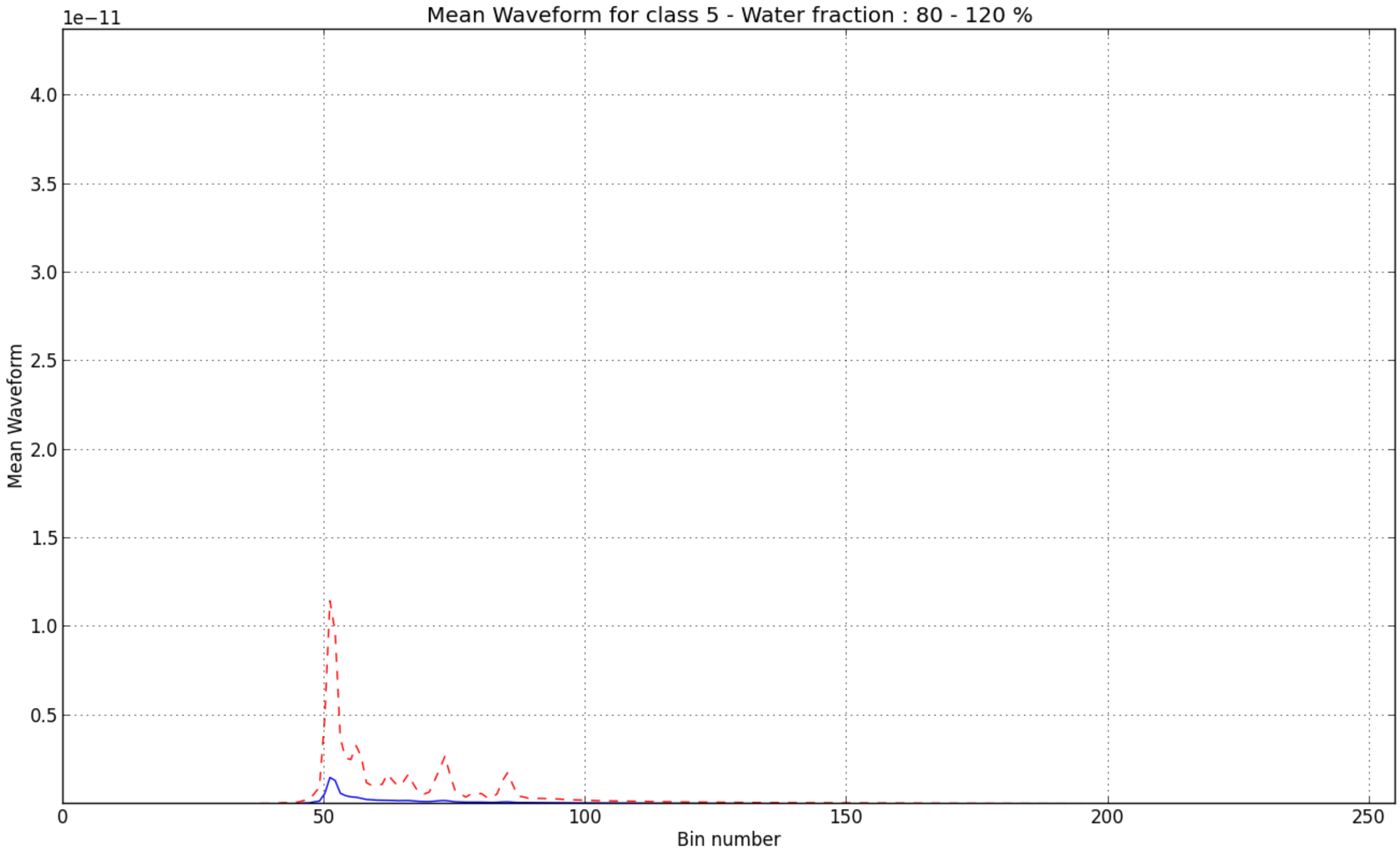


Mean Waveform for class 3 - Water fraction : 40 - 60 %
1e−11
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Mean Waveform
0
50
100
150
200
250
Bin number

Results

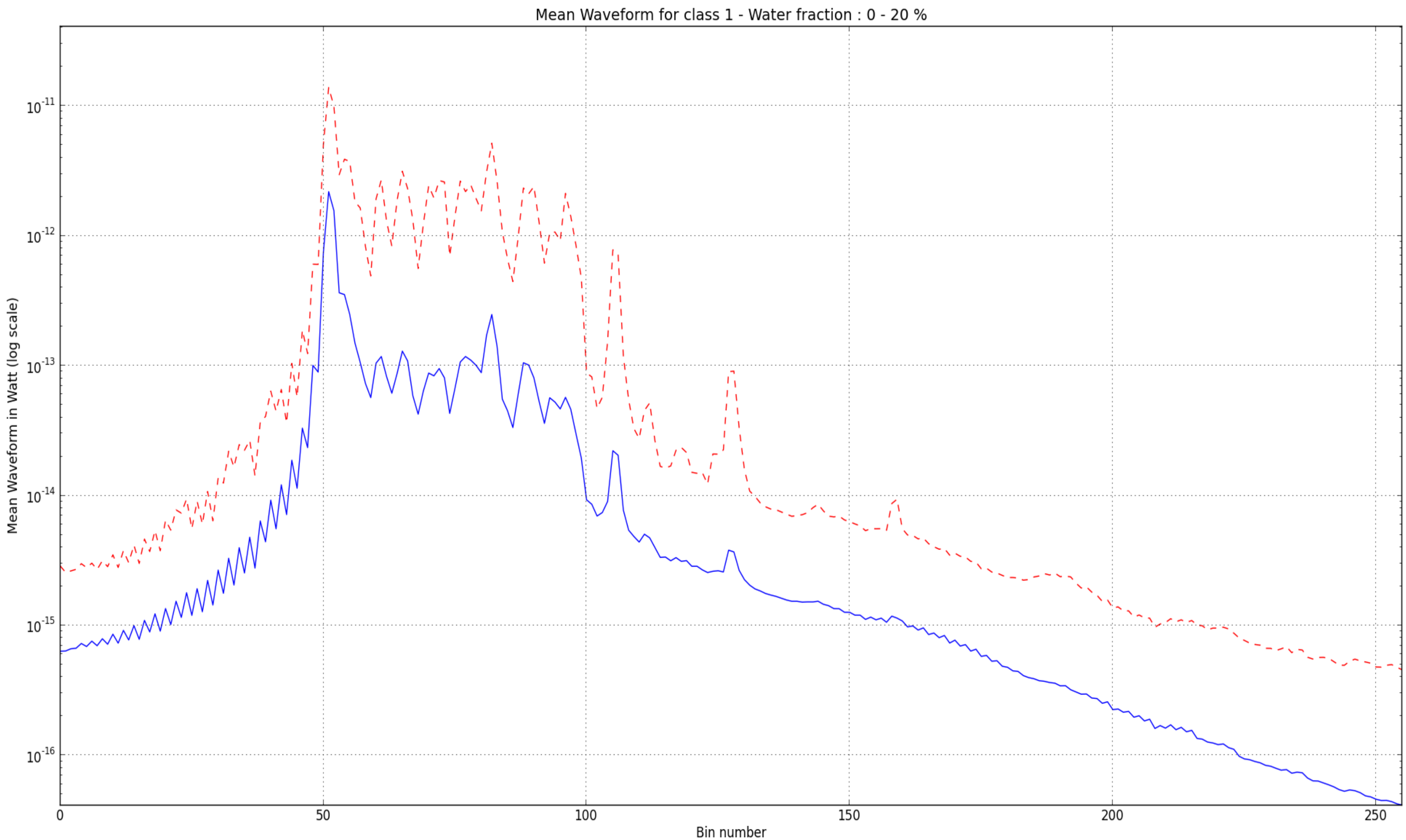

Mean Waveform for class 4 - Water fraction : 60 - 80 %
1e−11
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Mean Waveform
0
50
100
150
200
250
Bin number

Results


Mean Waveform for class 5 - Water fraction : 80 - 120 %
1e−11
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Mean Waveform
0
50
100
150
200
250
Bin number

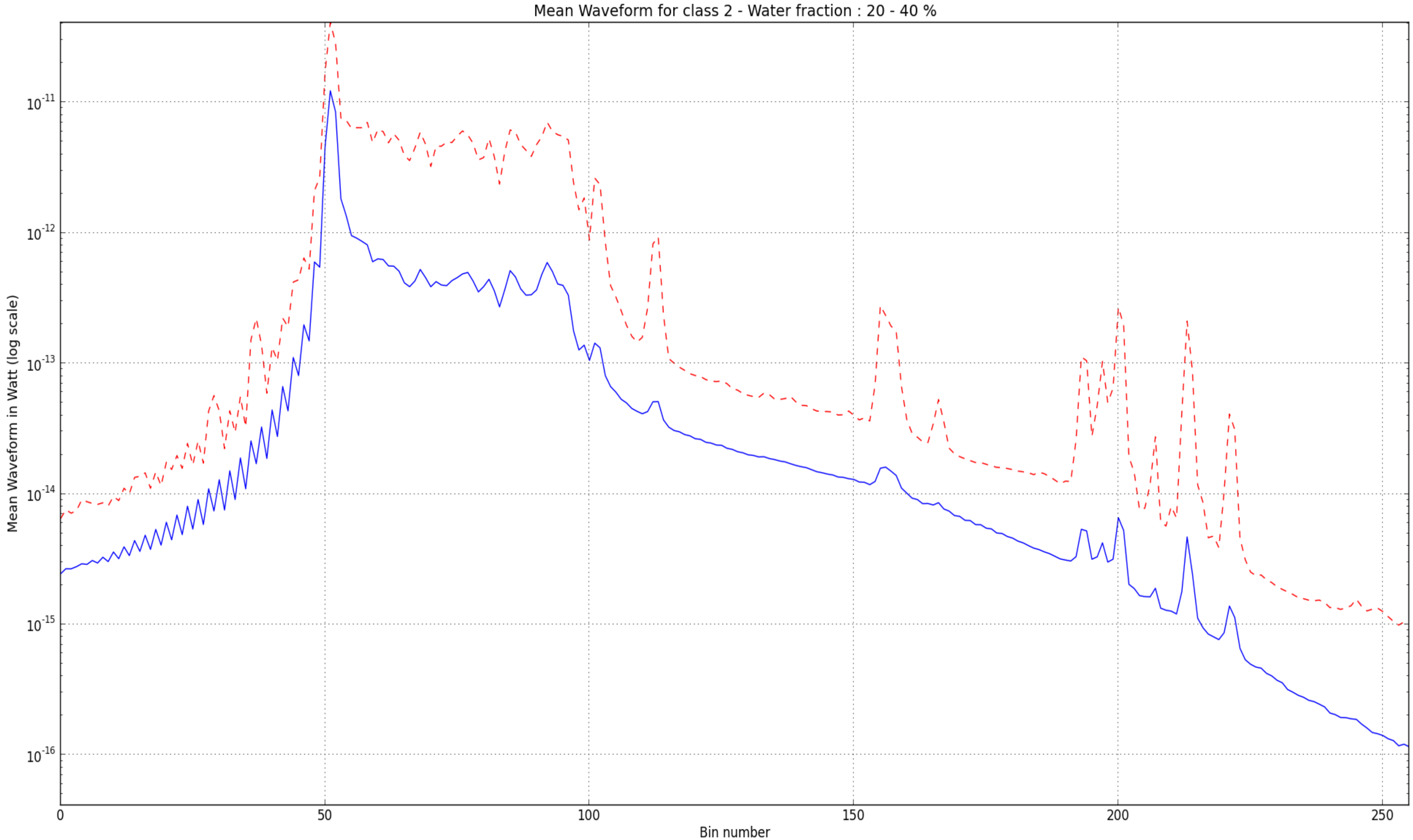
Results

Log scaled Mean Waveform (Blue) in Watt for Class 1



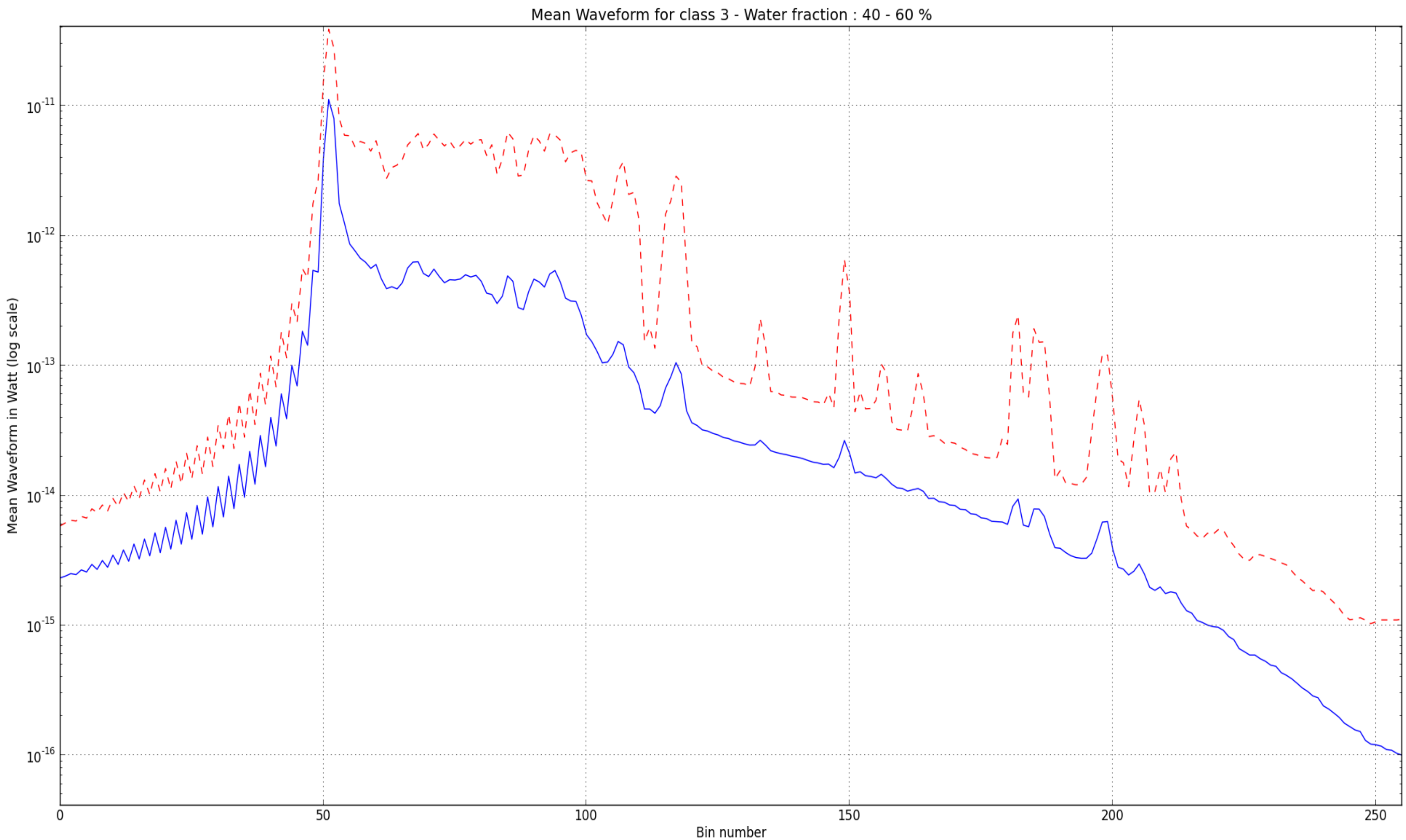
Results

Log scaled Mean Waveform (Blue) in Watt for Class 2



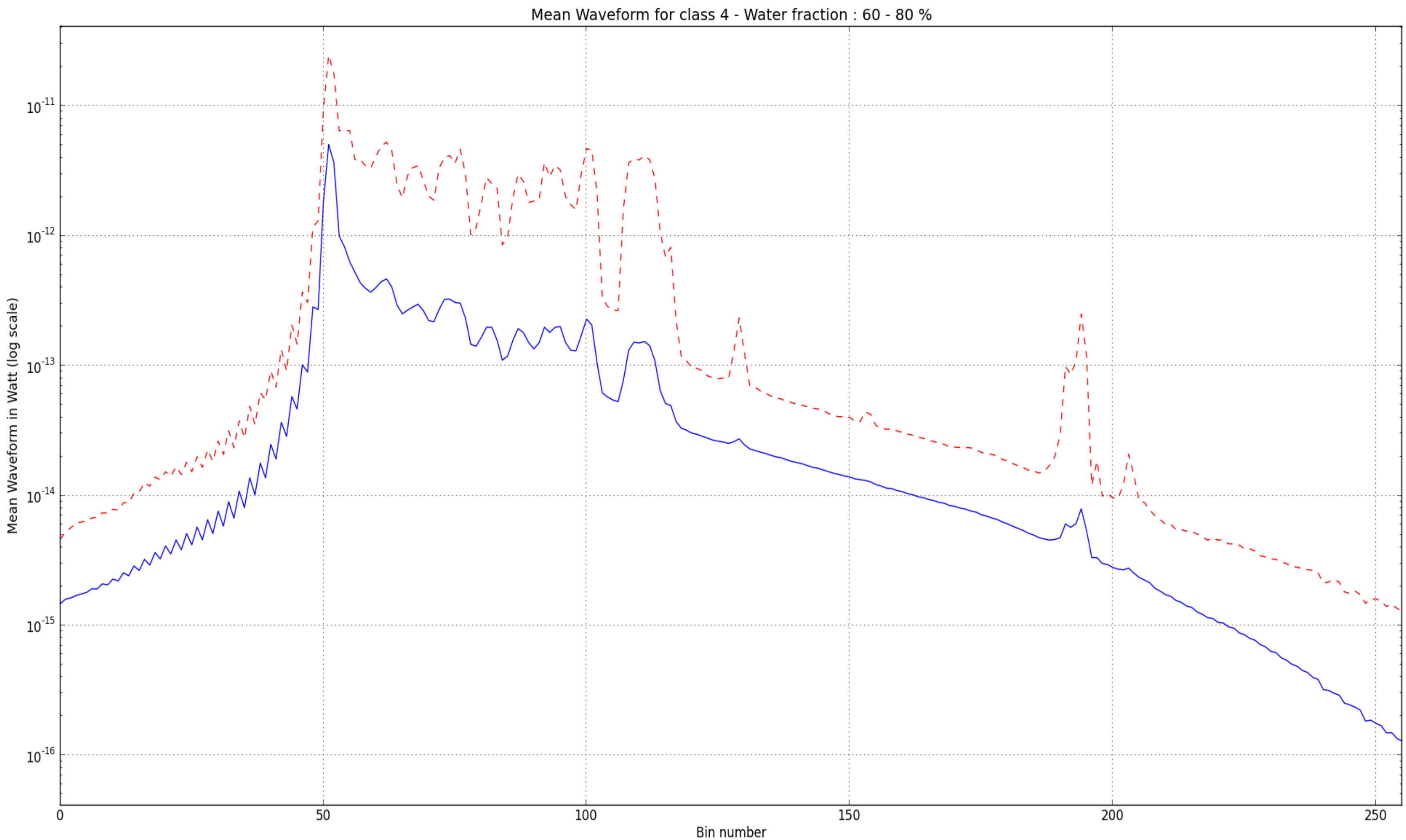
Results

Log scaled Mean Waveform (Blue) in Watt for Class 3



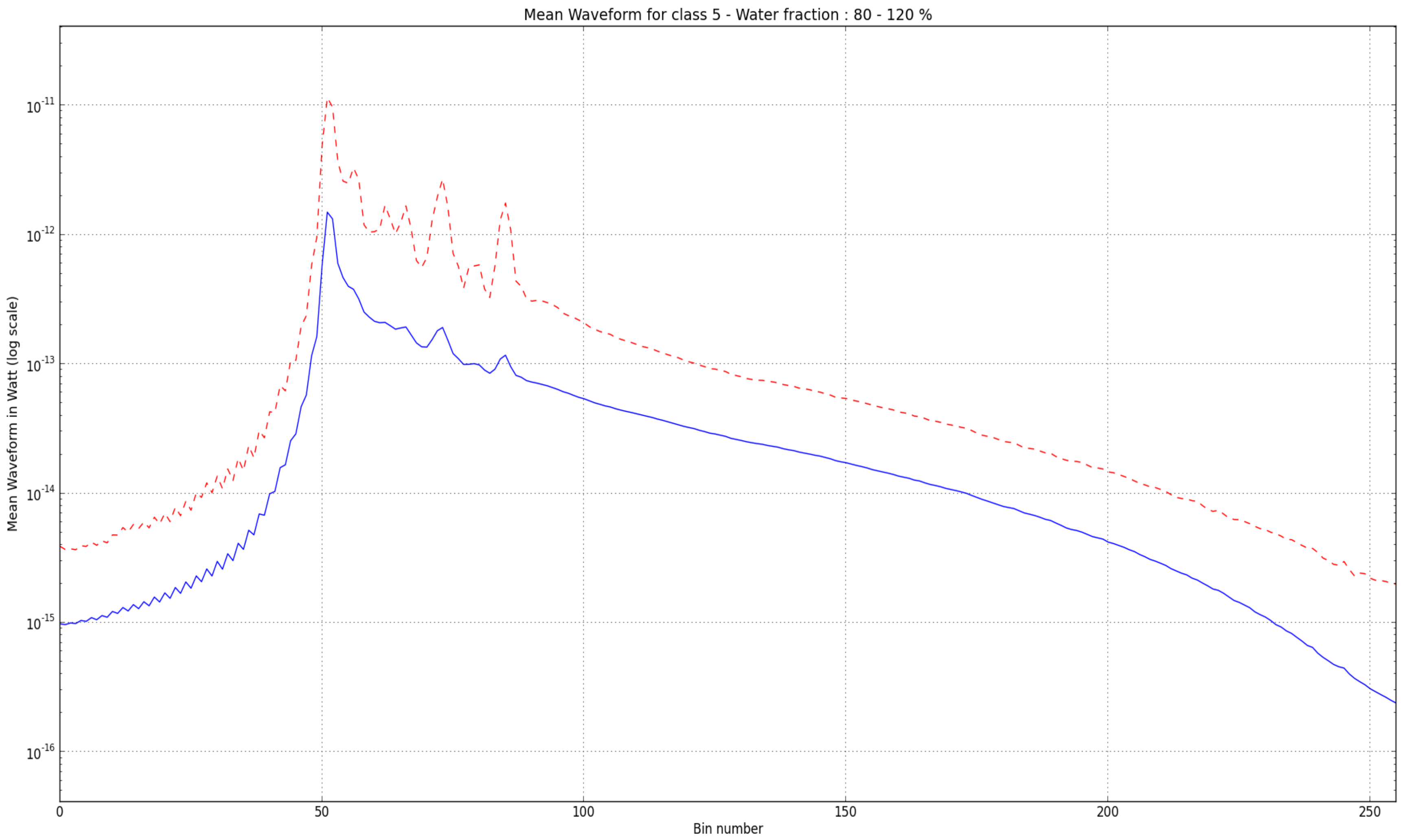
Results

Log scaled Mean Waveform (Blue) in Watt for Class 4



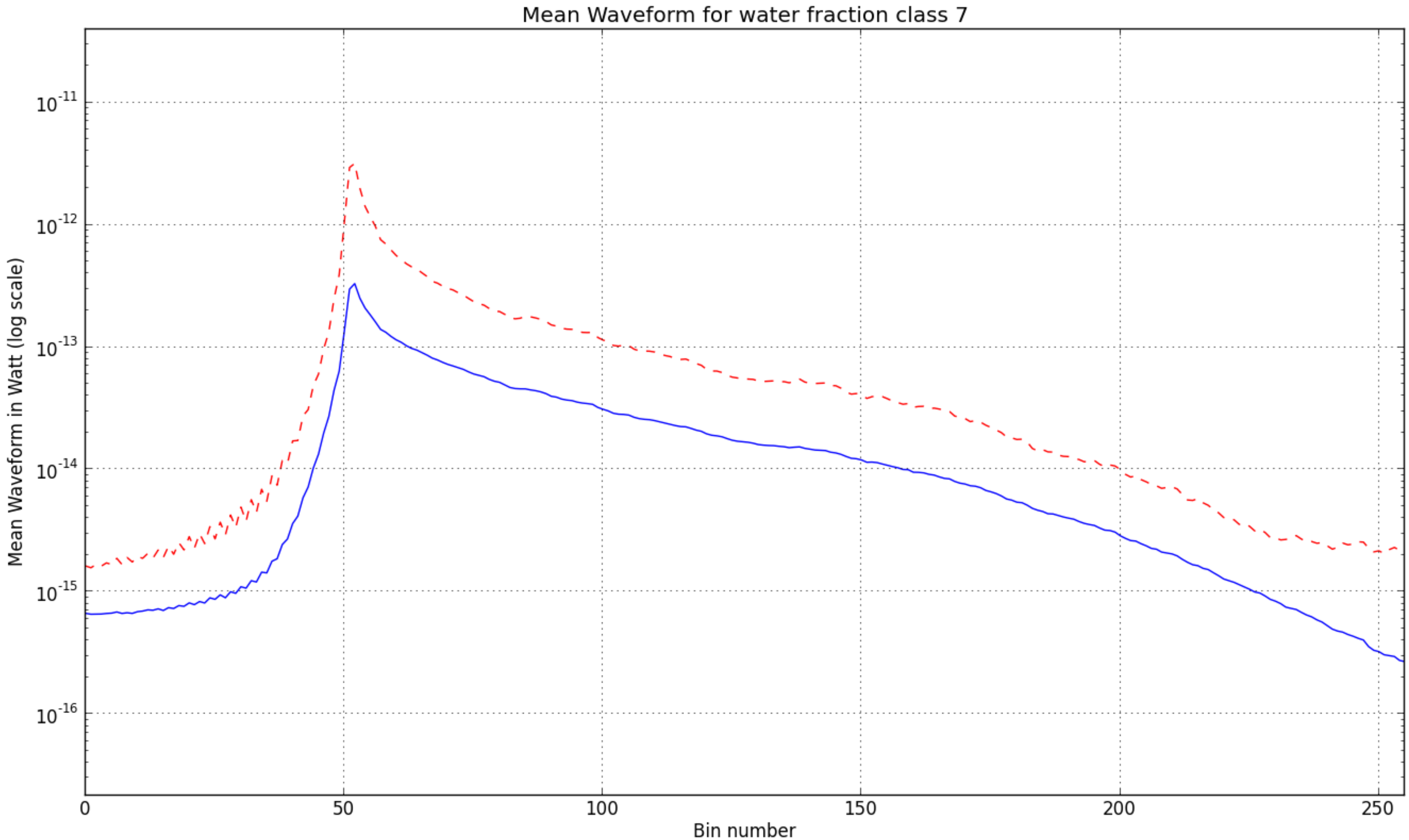
Results

Log scaled Mean Waveform (Blue) in Watt for Class 5



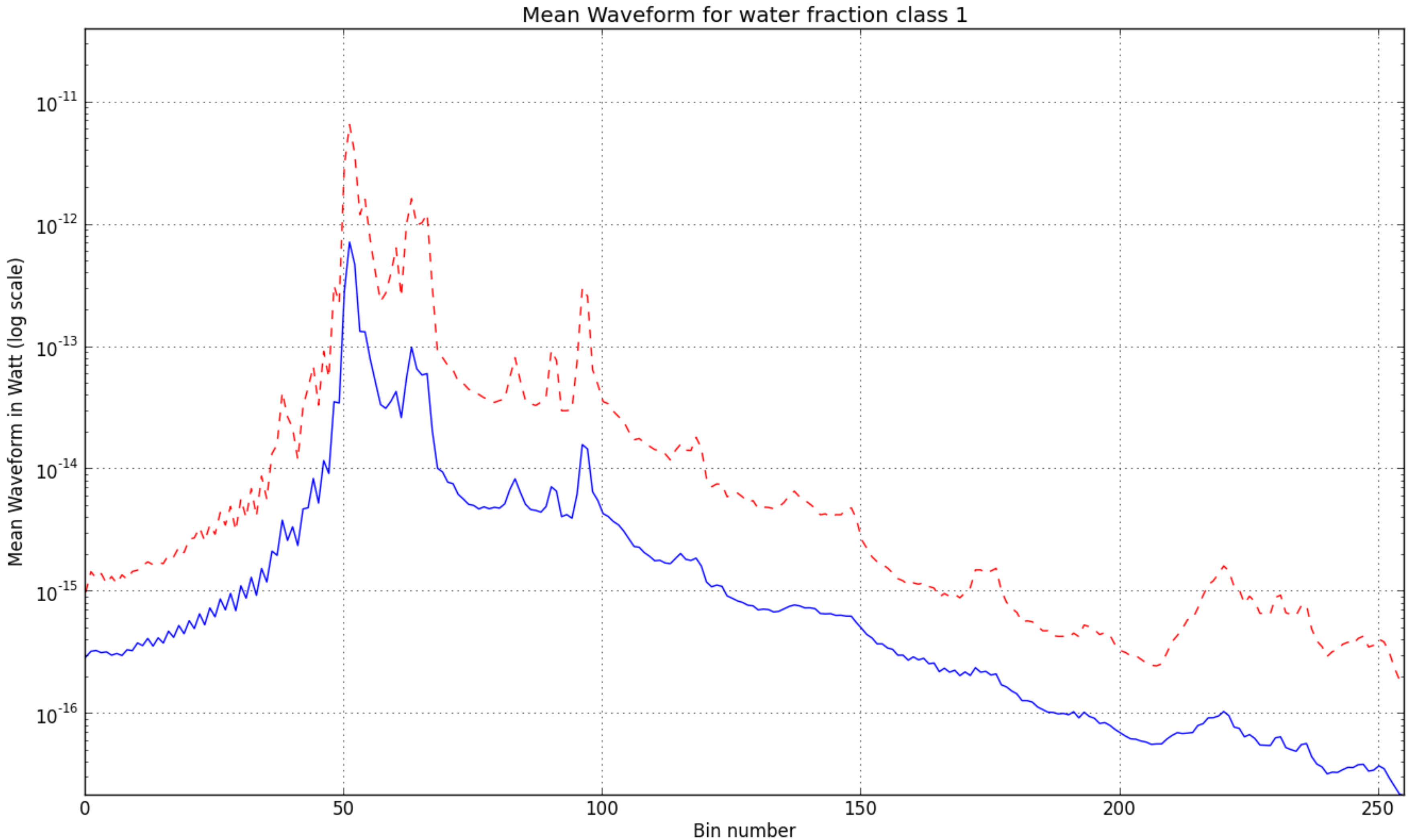
Results

Log scaled Mean Waveform (Blue) in Watt for WFR=100%



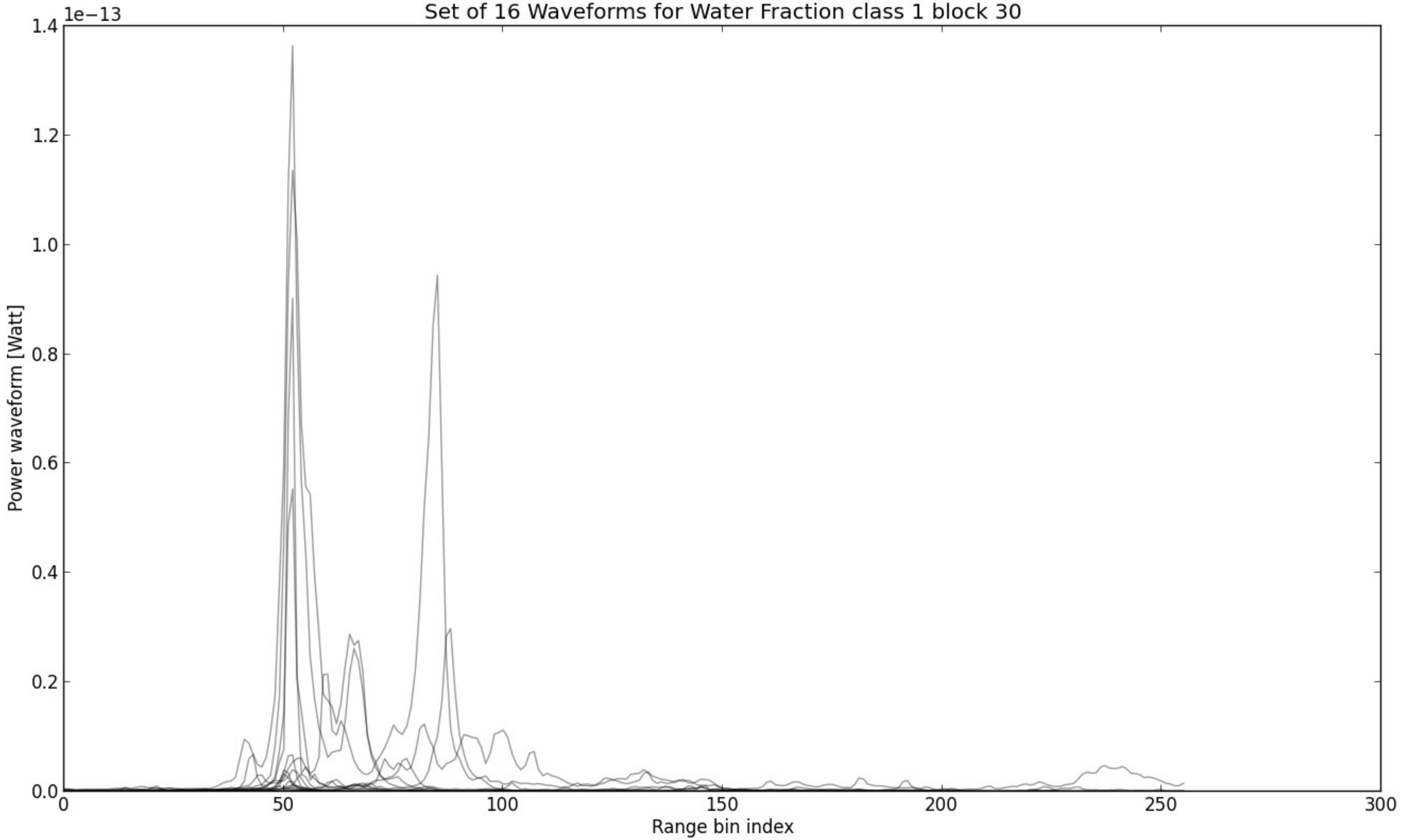
Results

Log scaled Mean Waveform (Blue) in Watt for WFR=0%



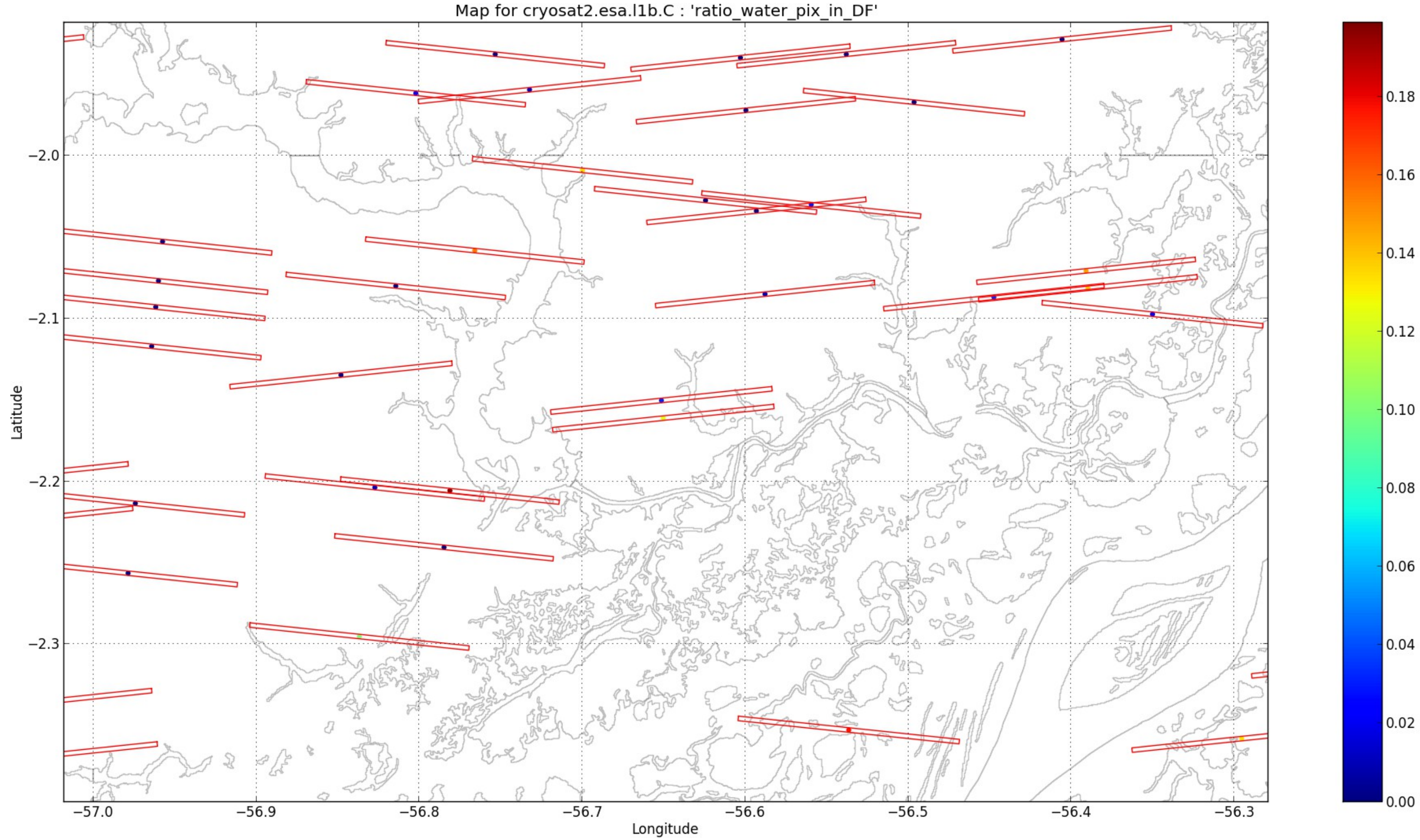
Results

Huge variety of waveforms within classes (class 1 here)



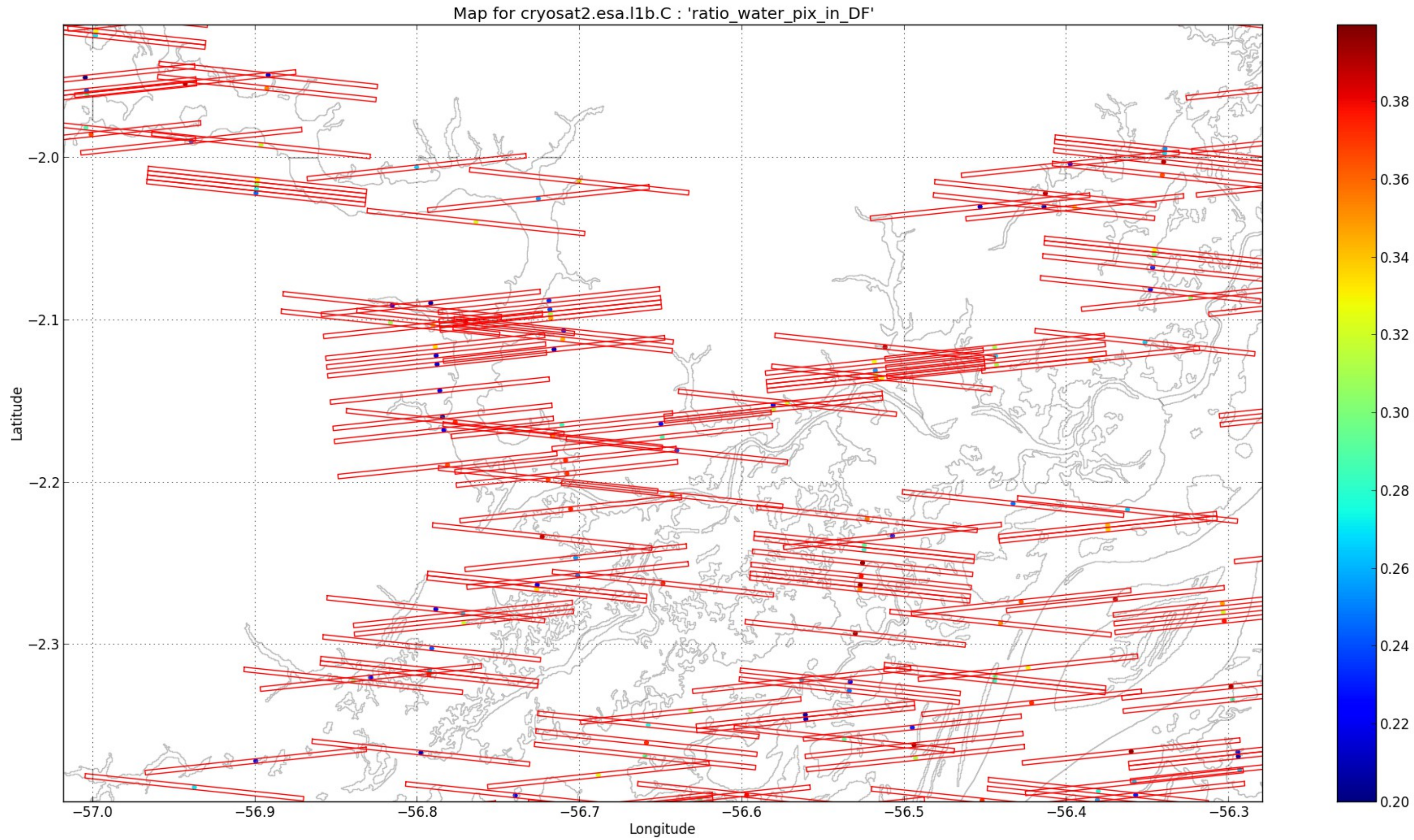
Results

Huge variety of cases within class 1



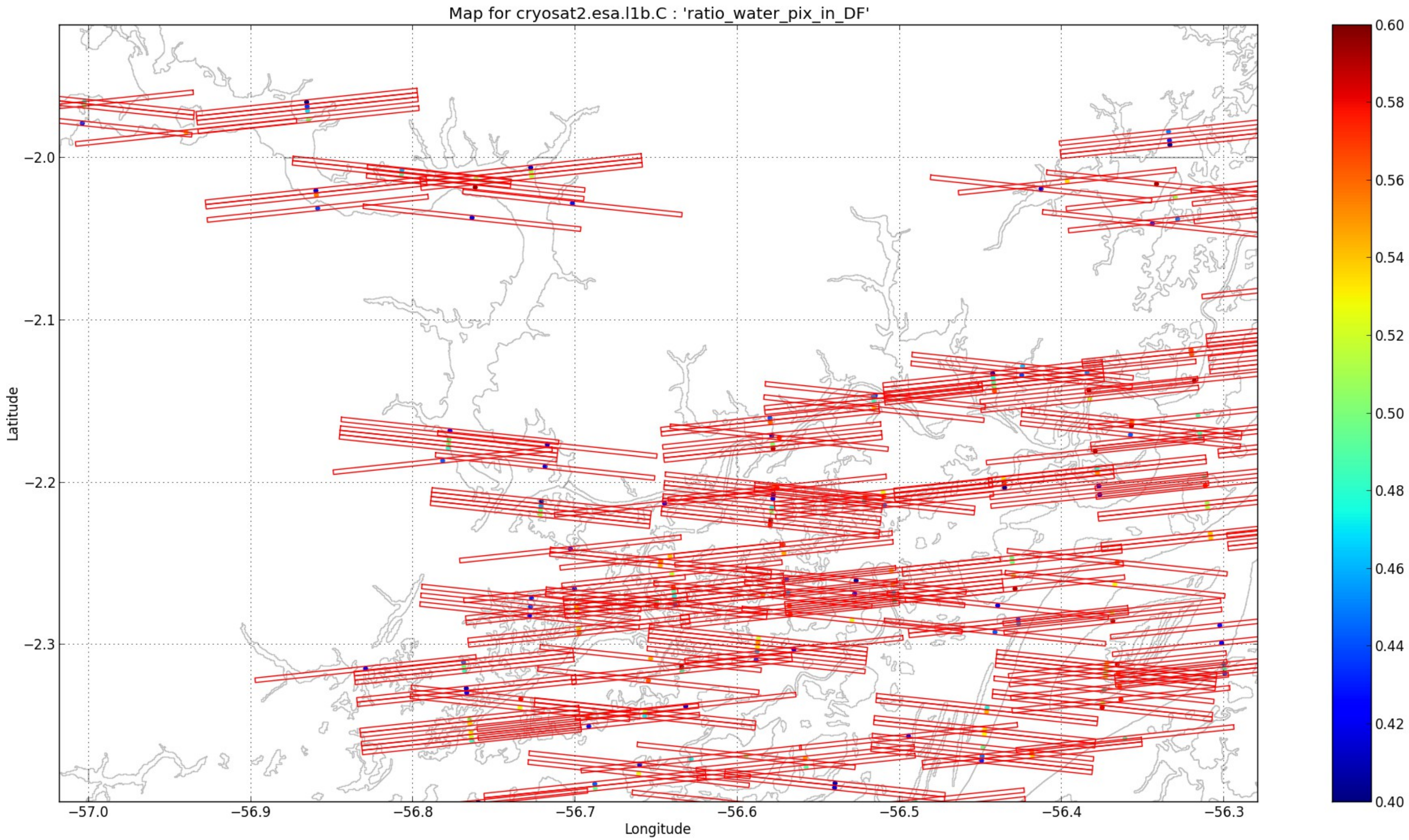
Results

Huge variety of cases within class 2



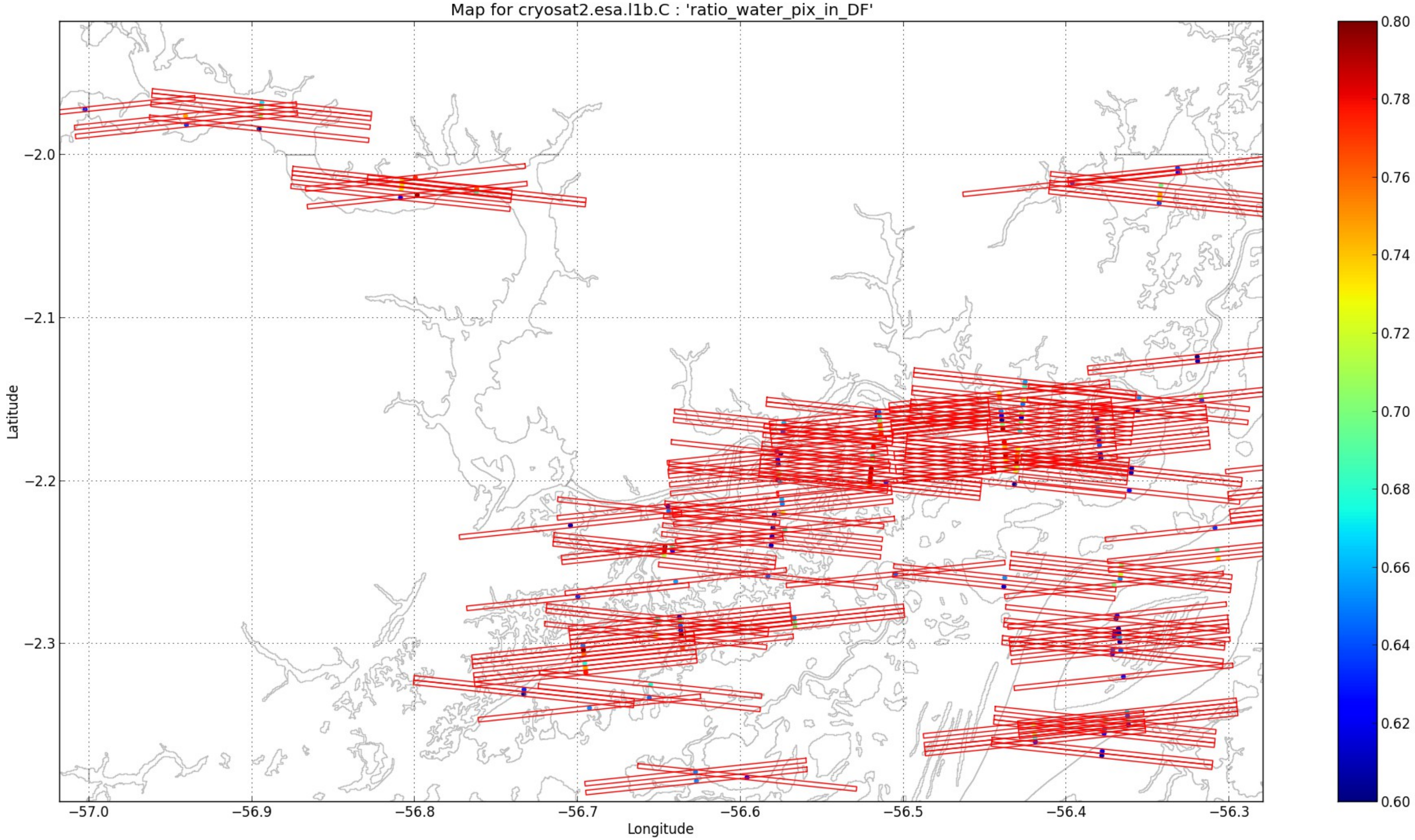
Results

Huge variety of cases within class 3



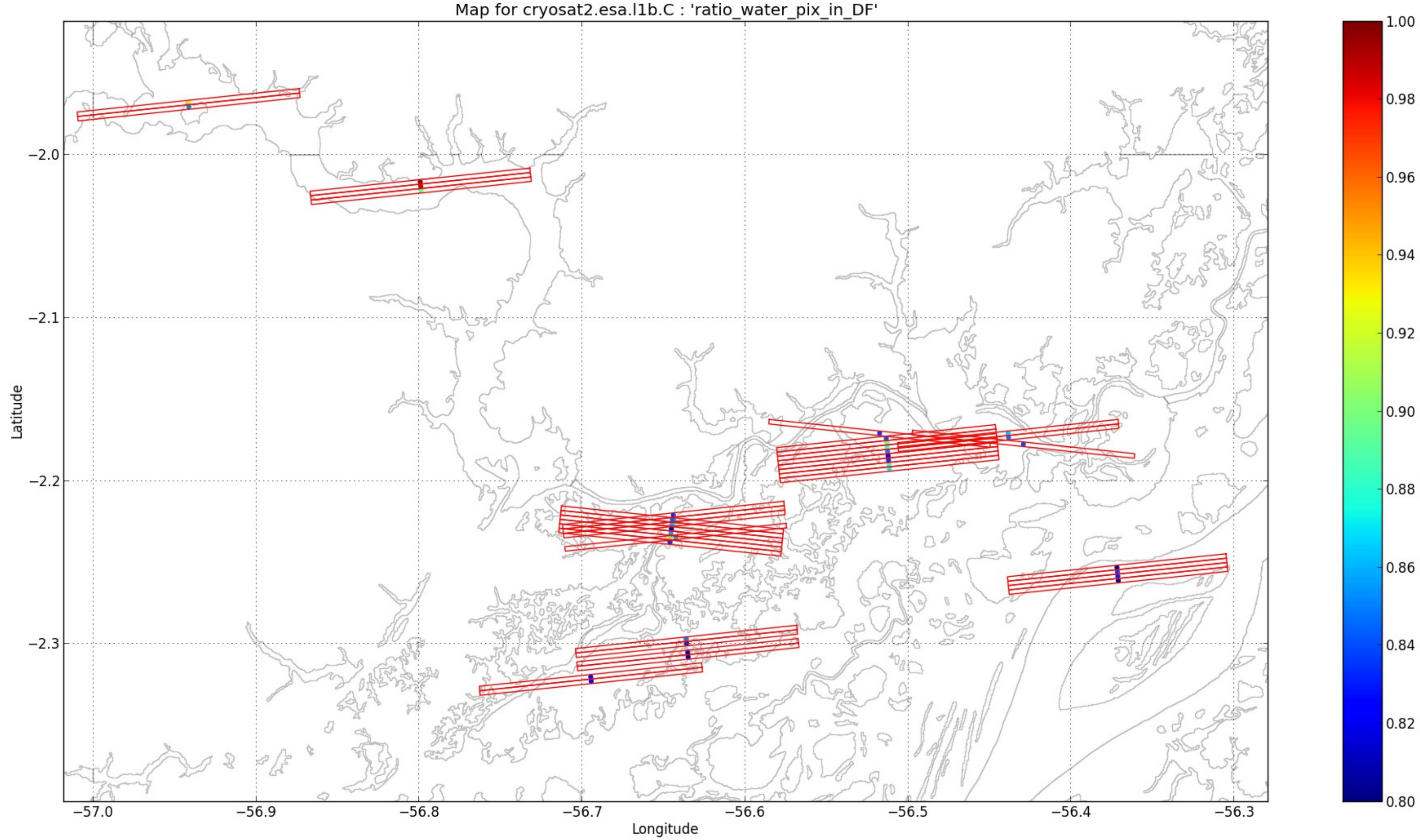
Results

Huge variety of cases within class 4

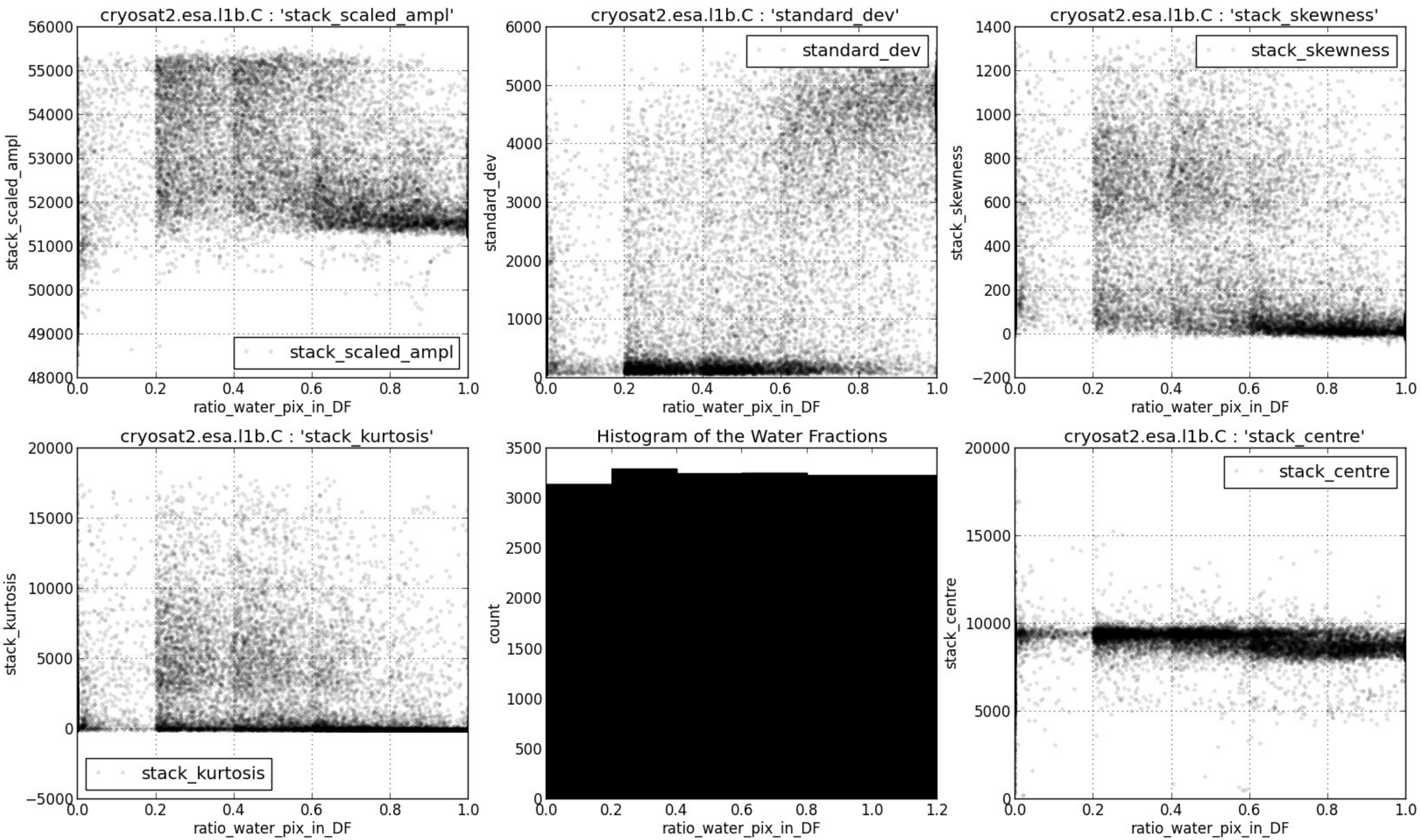


Results

Less variety of cases within class 5



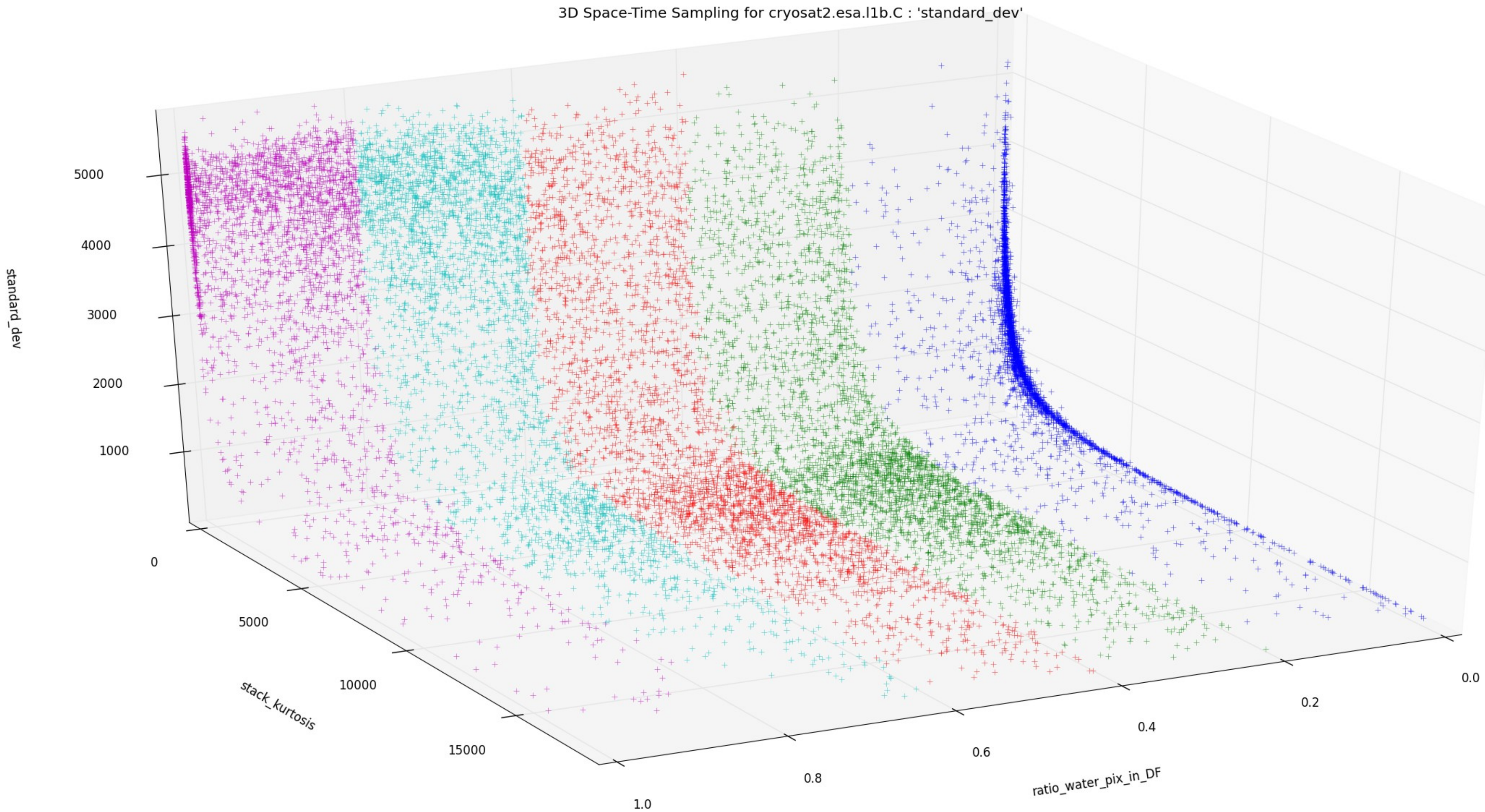
Results



cryosat2.esa.l1b.C : 'stack_scaled_ampl'
stack_scaled_ampl
ratio_water_pix_in_DF
cryosat2.esa.l1b.C : 'standard_dev'
standard_dev
ratio_water_pix_in_DF
cryosat2.esa.l1b.C : 'stack_skewness'
stack_skewness
ratio_water_pix_in_DF
cryosat2.esa.l1b.C : 'stack_kurtosis'
stack_kurtosis
ratio_water_pix_in_DF
Histogram of the Water Fractions
count
ratio_water_pix_in_DF
cryosat2.esa.l1b.C : 'stack_centre'
stack_centre
ratio_water_pix_in_DF

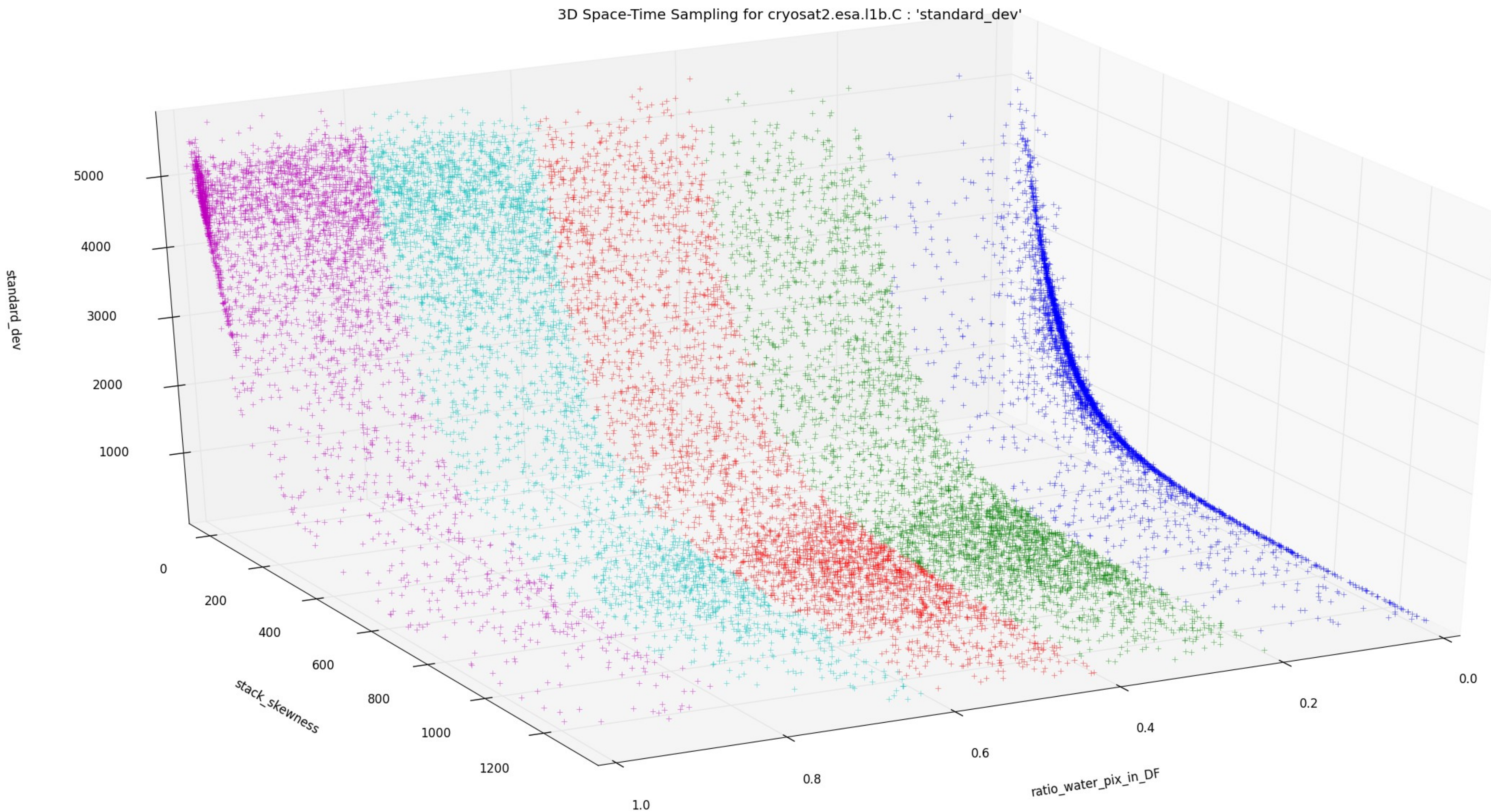
Results

RIP STDEV vs (RIP Kursosis, Water Fraction)



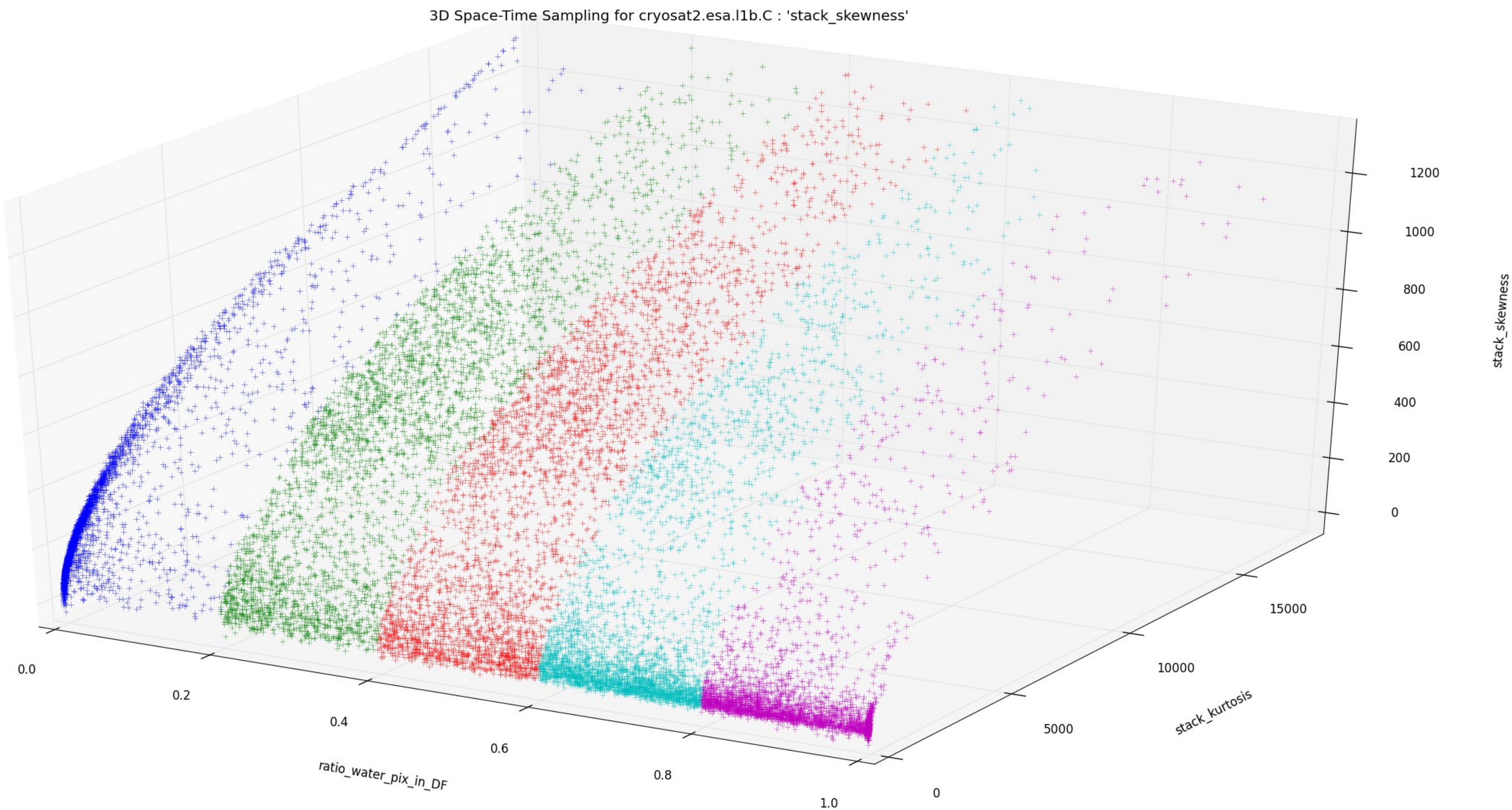
Results

RIP STDEV vs (RIP Skewness, Water Fraction)



Results

RIP Skewness vs RIP (Kurtosis, Water Fraction)



Results

- Overview : all classes are quite heterogeneous but some statistical trends can be detected :
- **High Water Fraction** classes :
  - **STDEV** often **High**, **Kurtosis** often **Low** : **along-track angular distribution of backscattered power varies smoothly from beam to beam (azimuth look angle)** but
    - CAUTION : RIP peackiness (along-track) is not not linked to waveforms peakiness (across-track).
    - Skewness (asymmetry) is often Low : The High Water Fraction class offers a more symmetric power response as a function of the azimuth look angle than others
- **Intermediate Water Fraction** classes:
  - **wide span** of both **STDEV** and **Kurtosis** :

(wide variety of angular responses) ← ? → (wide variety of water body sizes, locations and roughness).

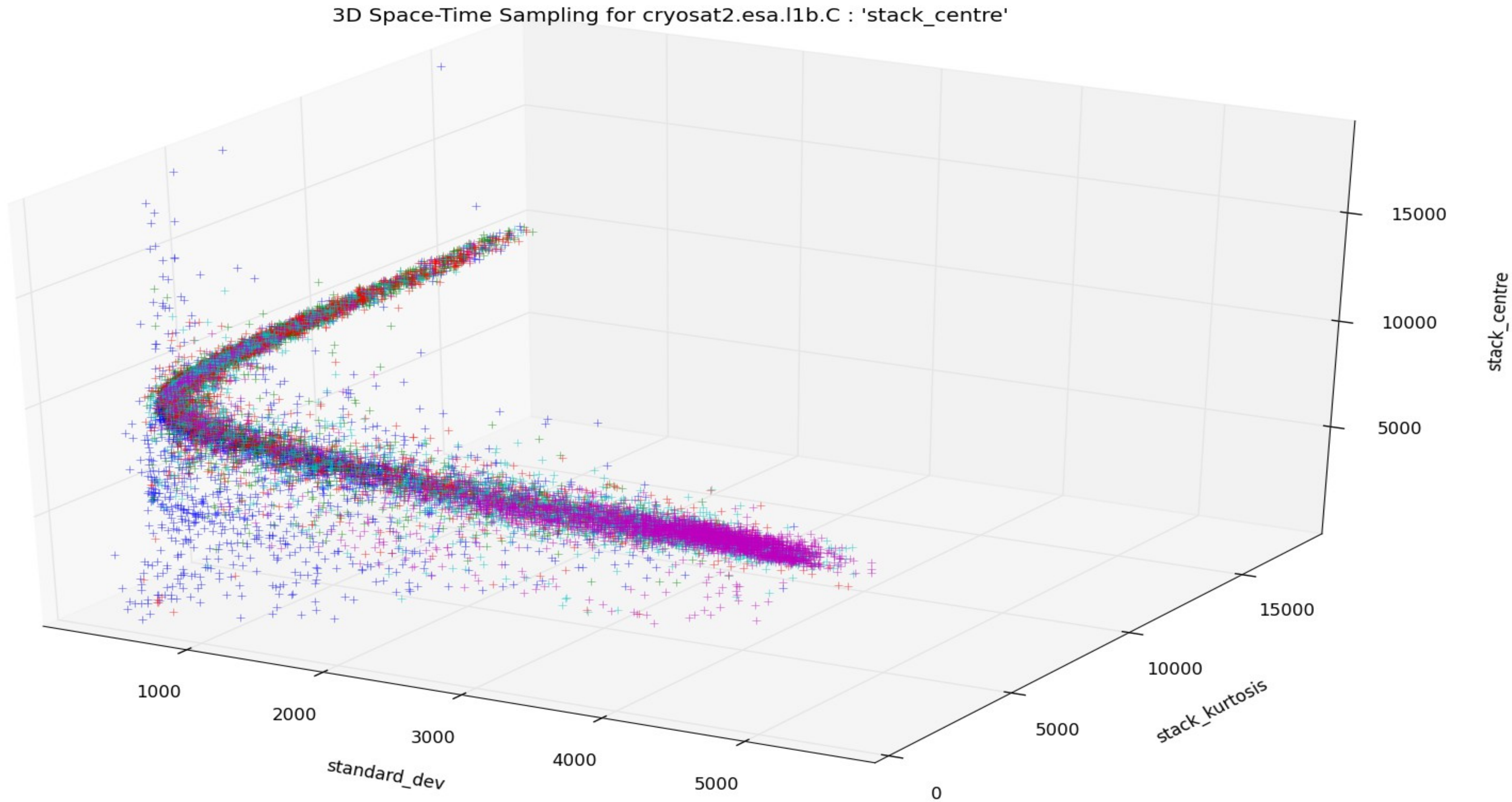
  - **wide span** of **Skewness** : probably for the same reasons.

Cases with assymetric backscattered power ← ? → cases with side lobes contamination.

- **Low Water Fraction** cases:
  - Difficult to interprete since the NO WATER case seems to dominate the class and it encompasses a big variety of targets and backscattering properties. This **pushes to add the 0% class**.

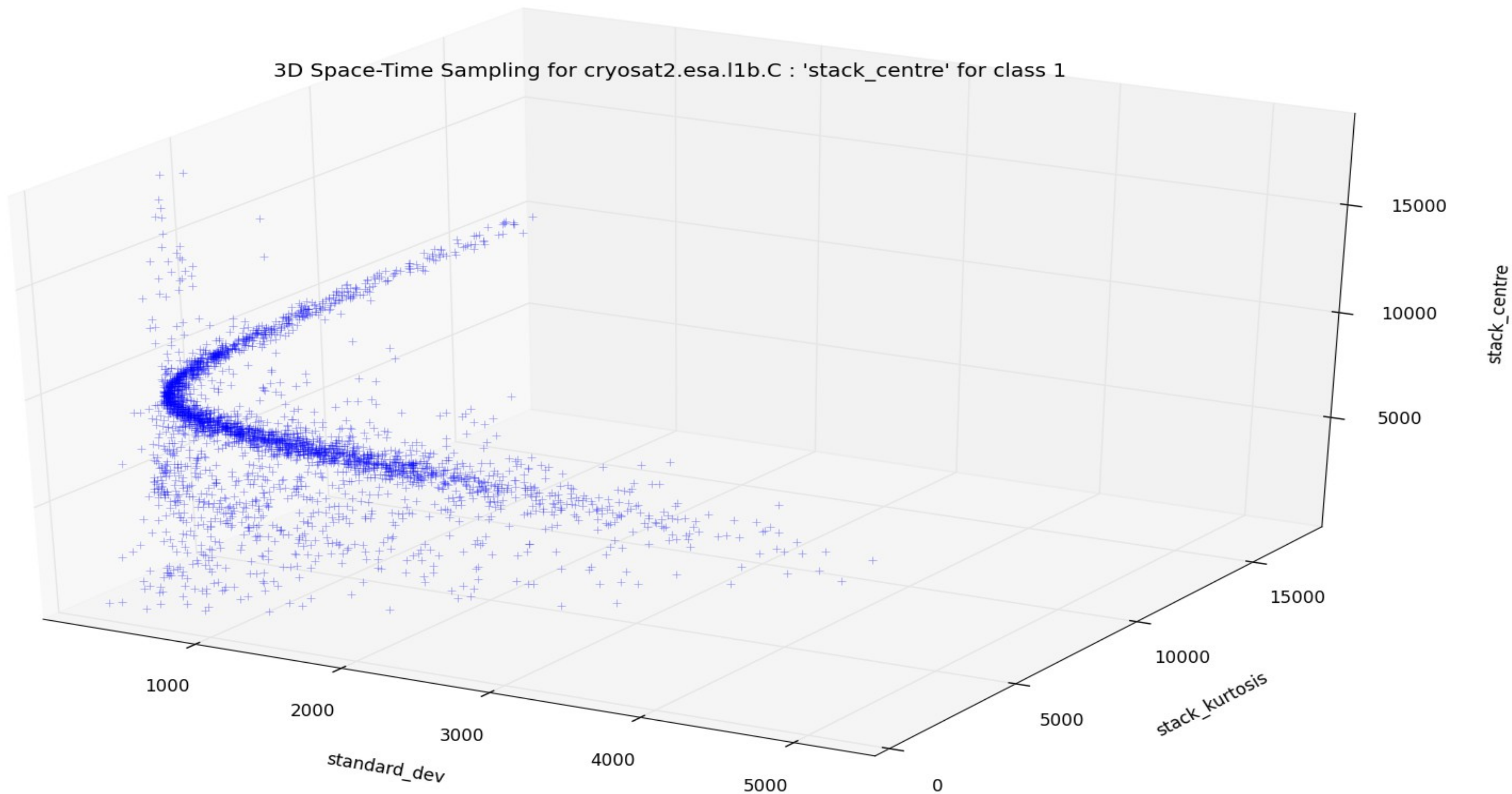
Results

RIP Centre vs RIP(STDEV, Kurtosis) for ALL classes



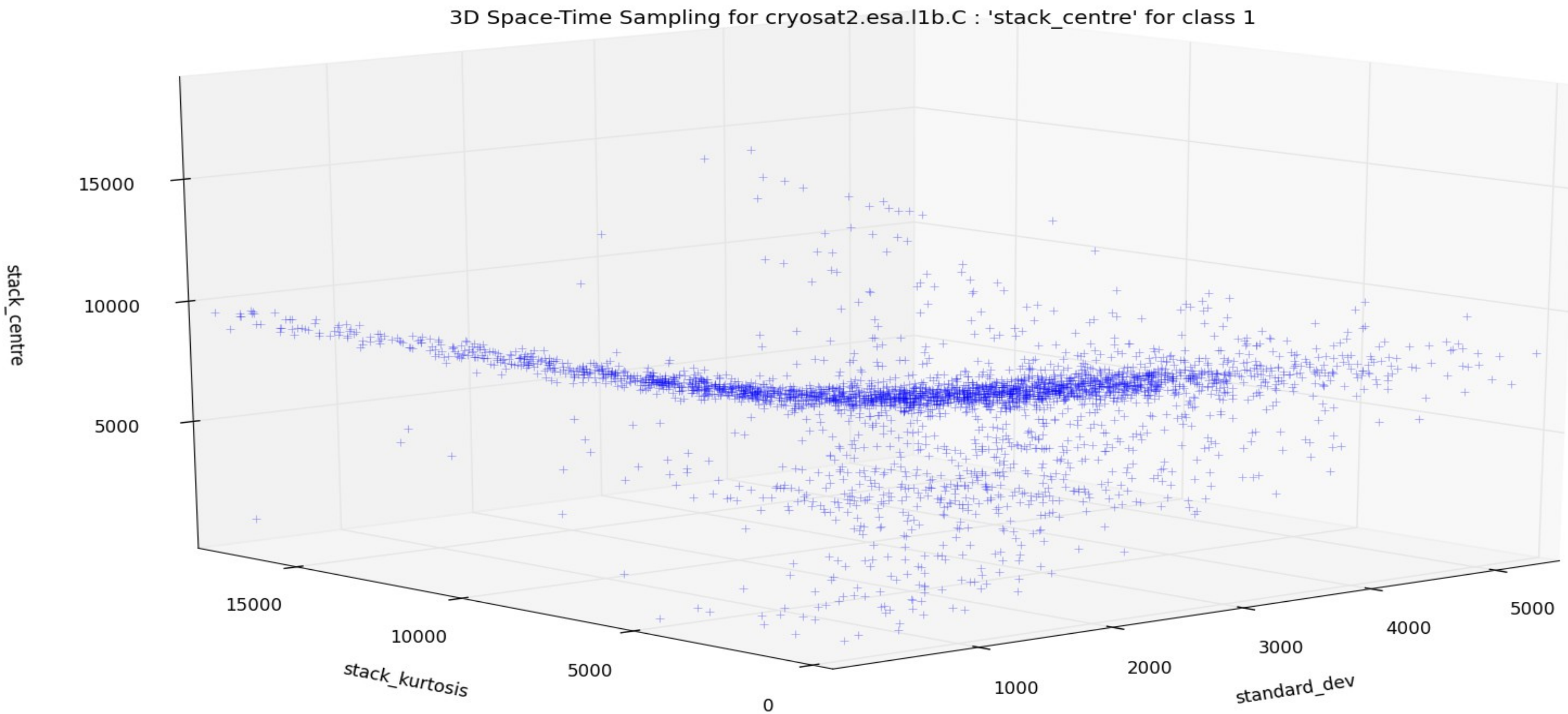
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 1** view 1



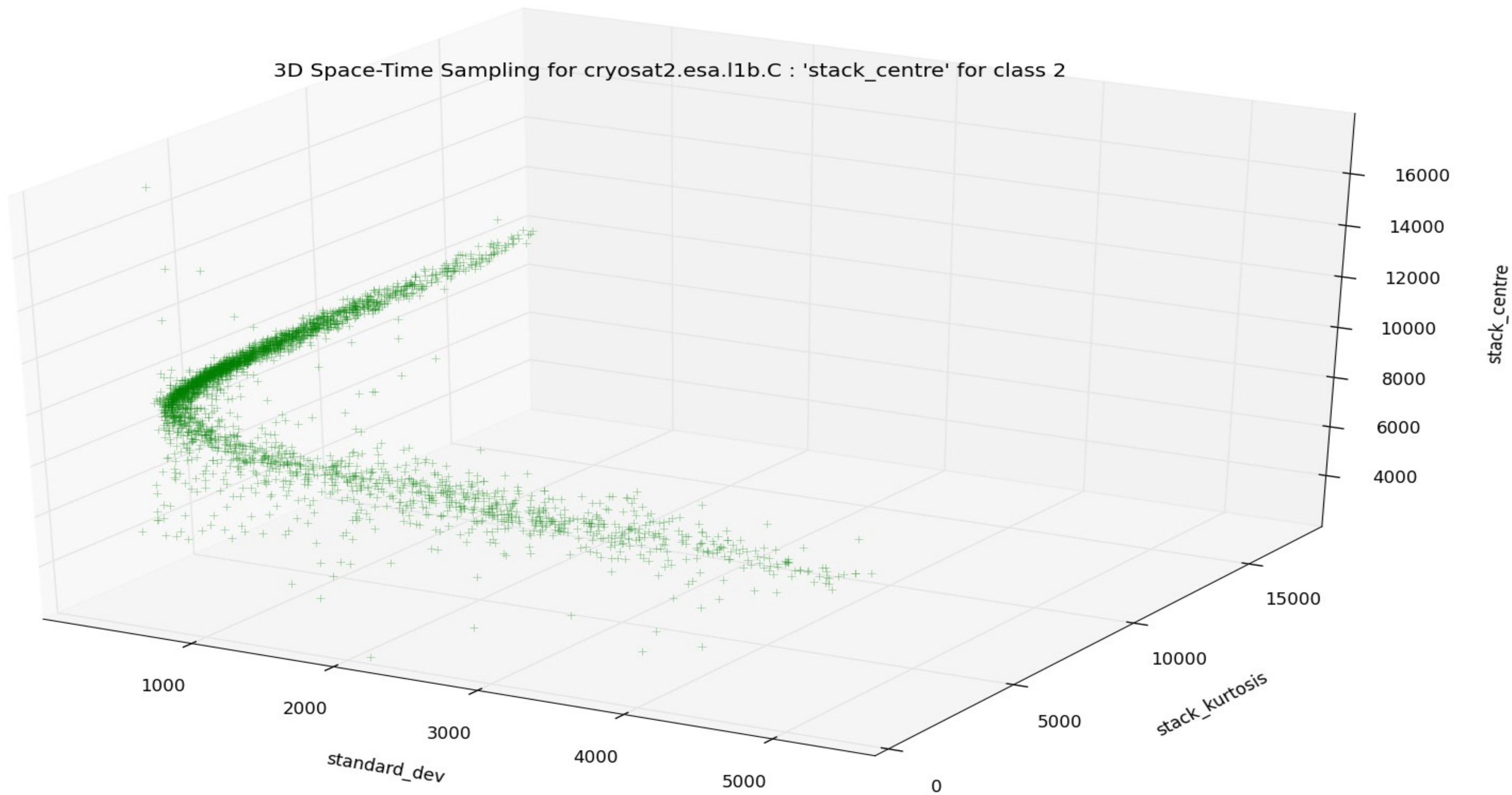
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 1** view 2



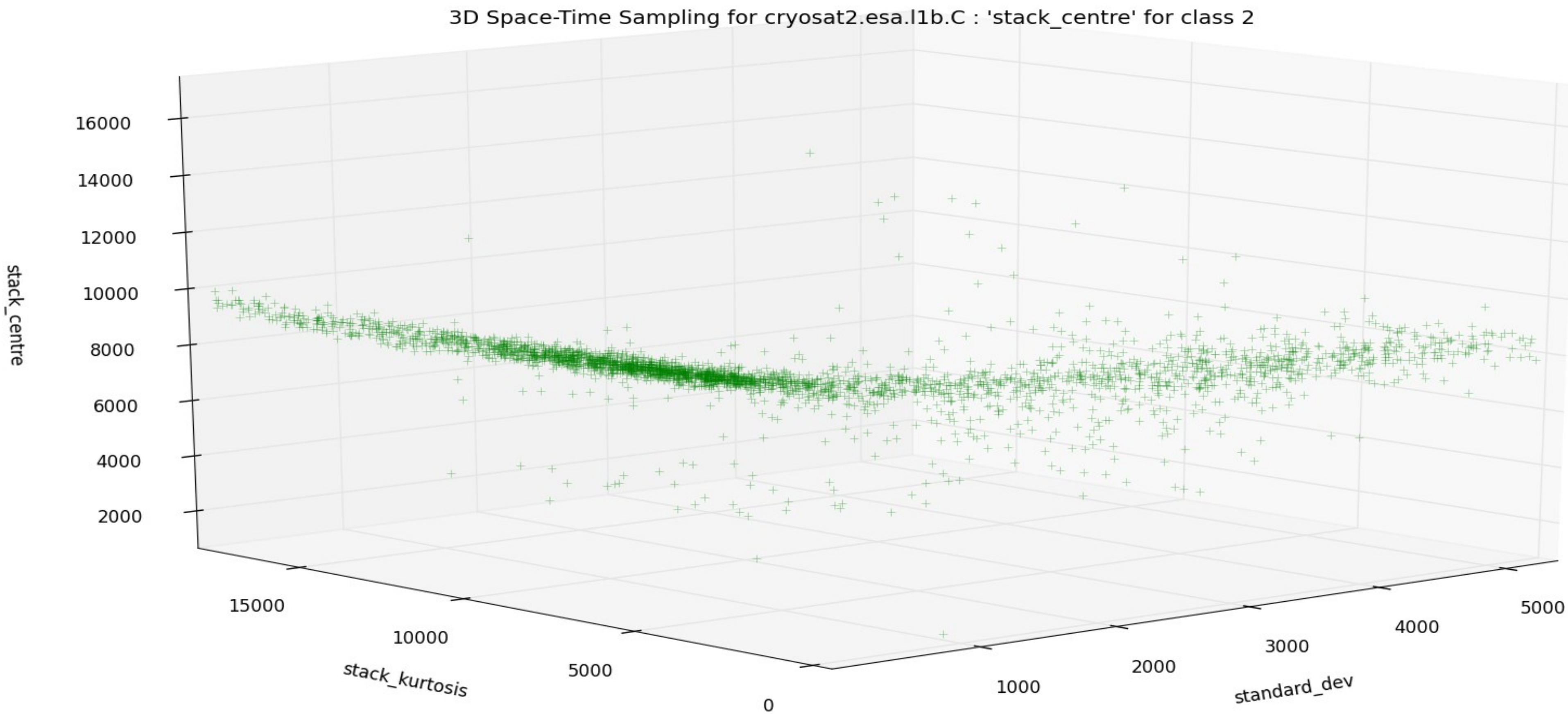
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 2** view 1



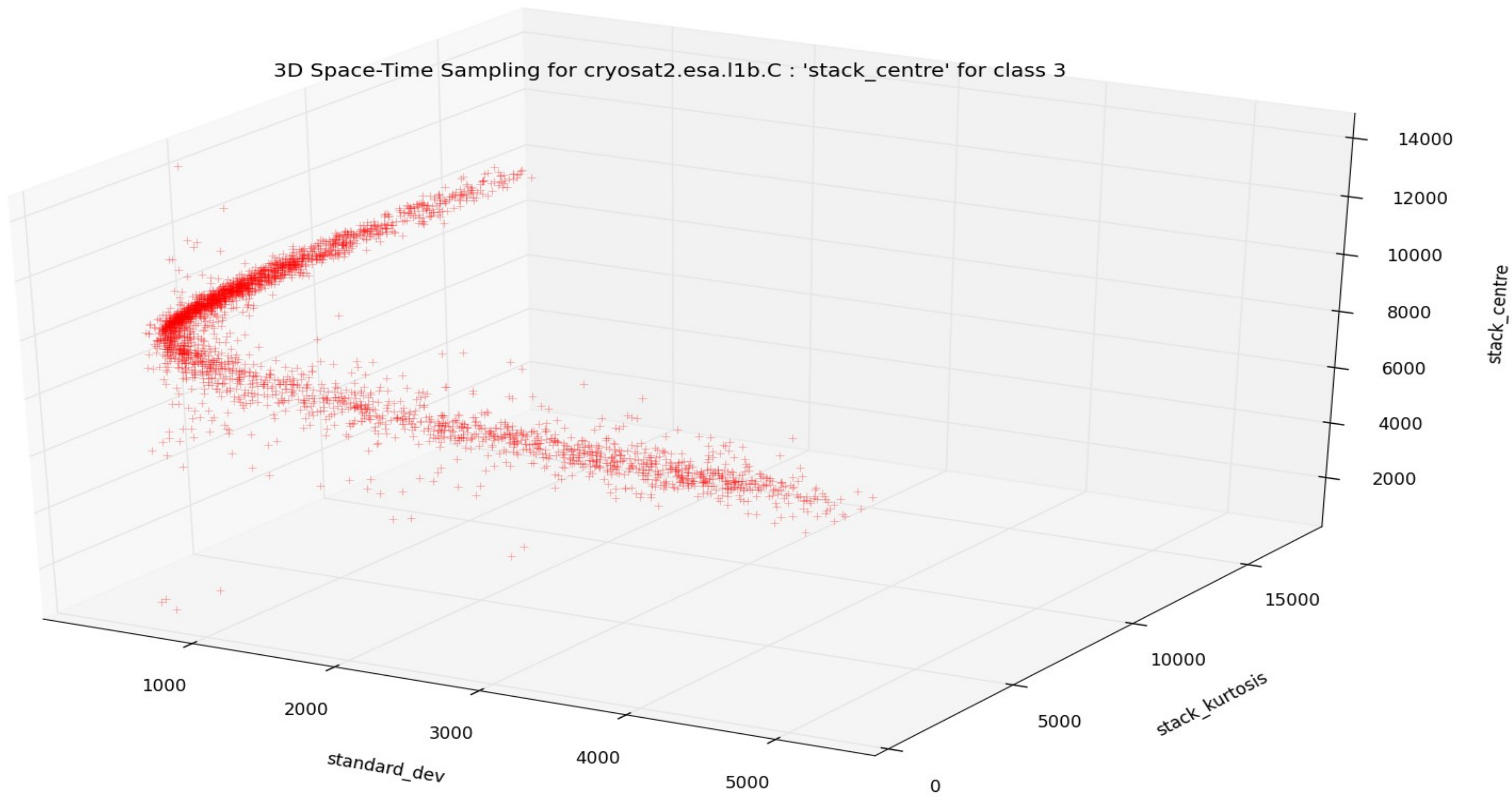
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 2** view 2



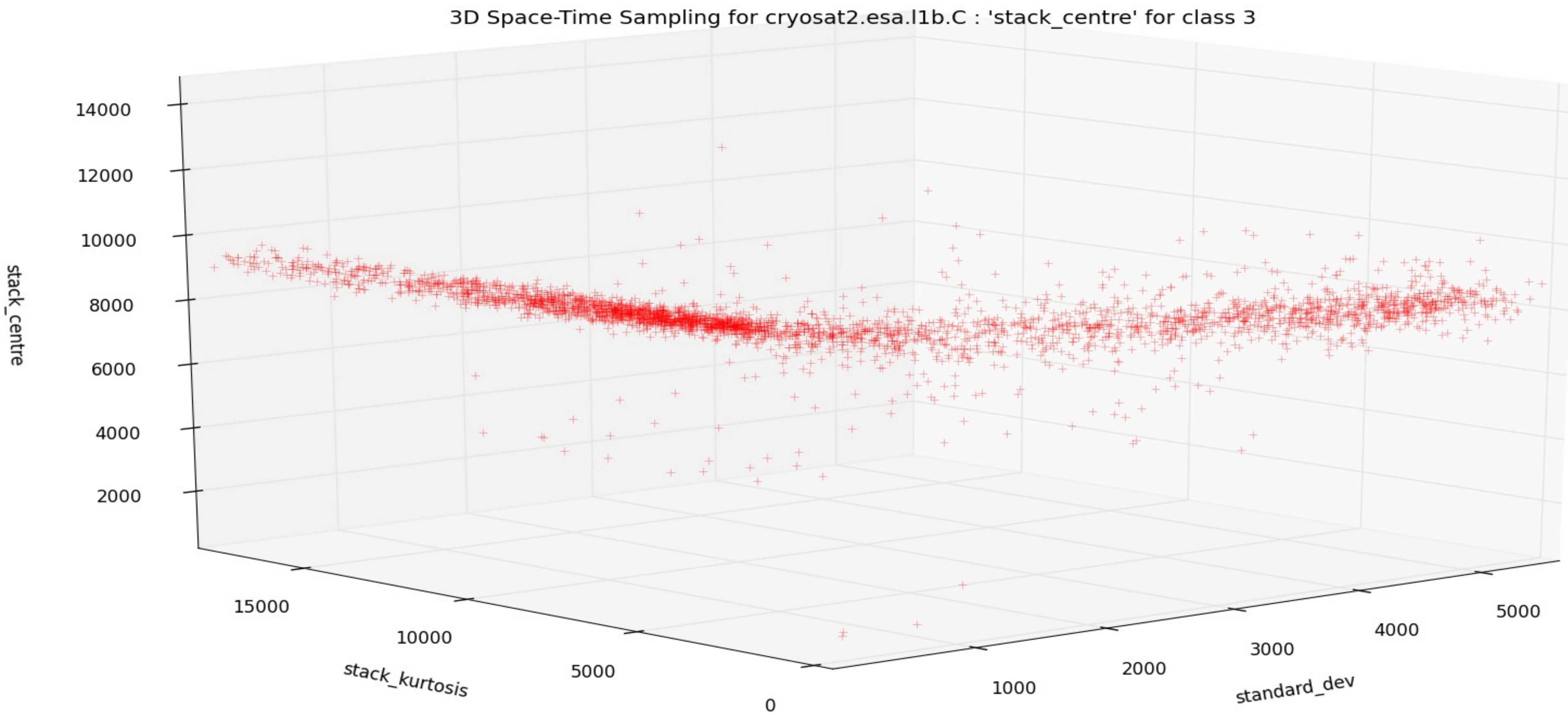
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 3** view 1



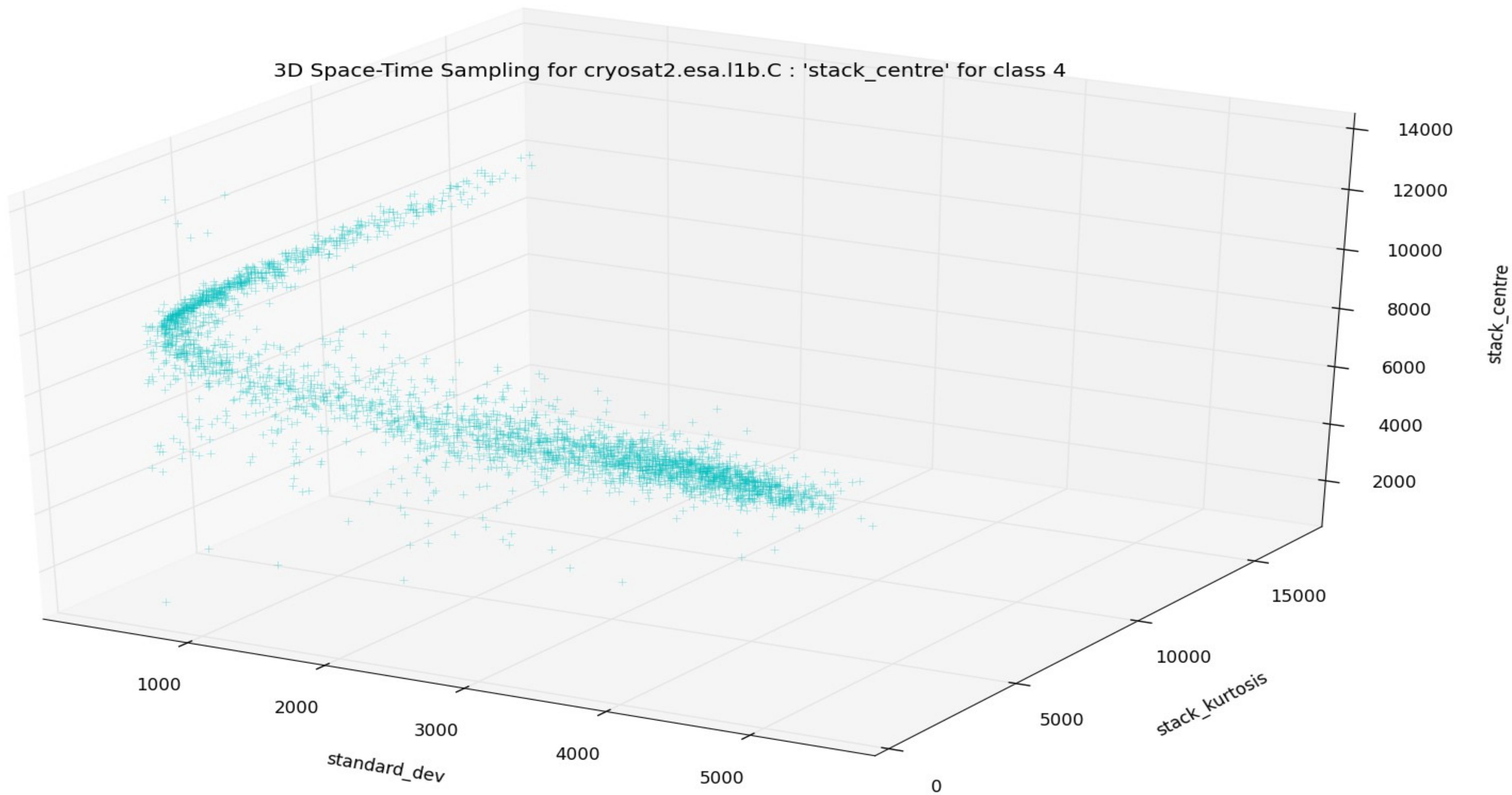
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 3** view 2



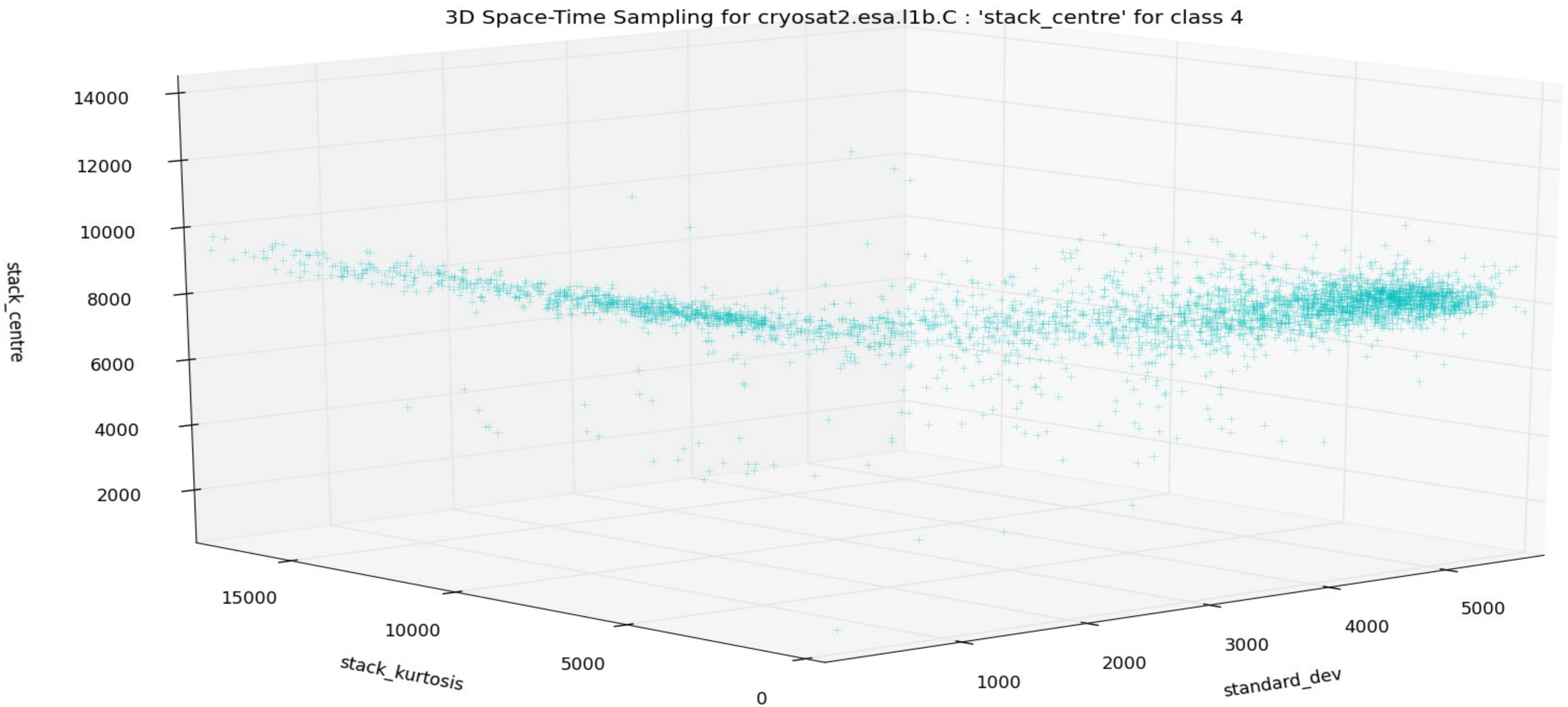
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 4** view 1



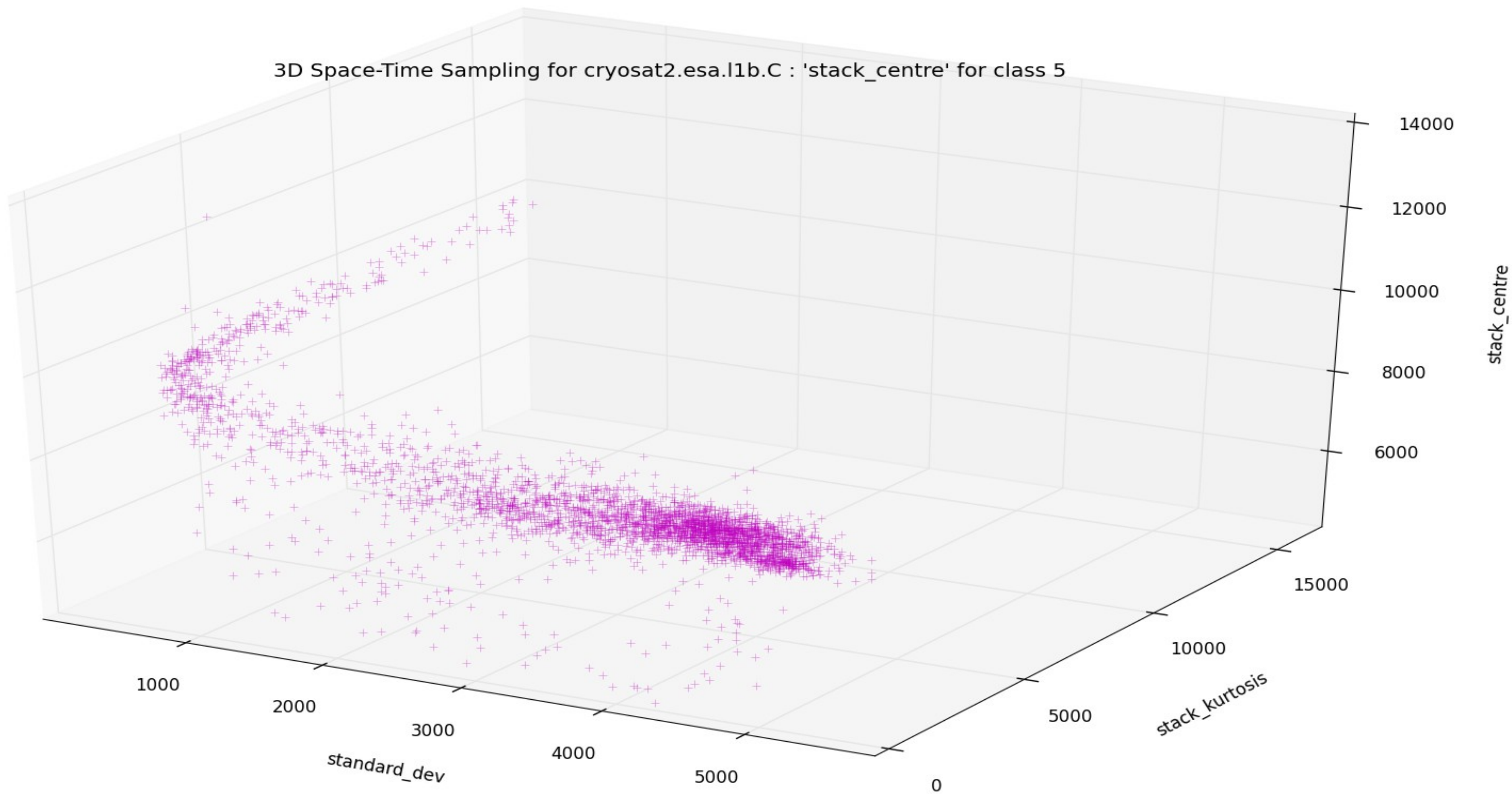
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 4** view 2



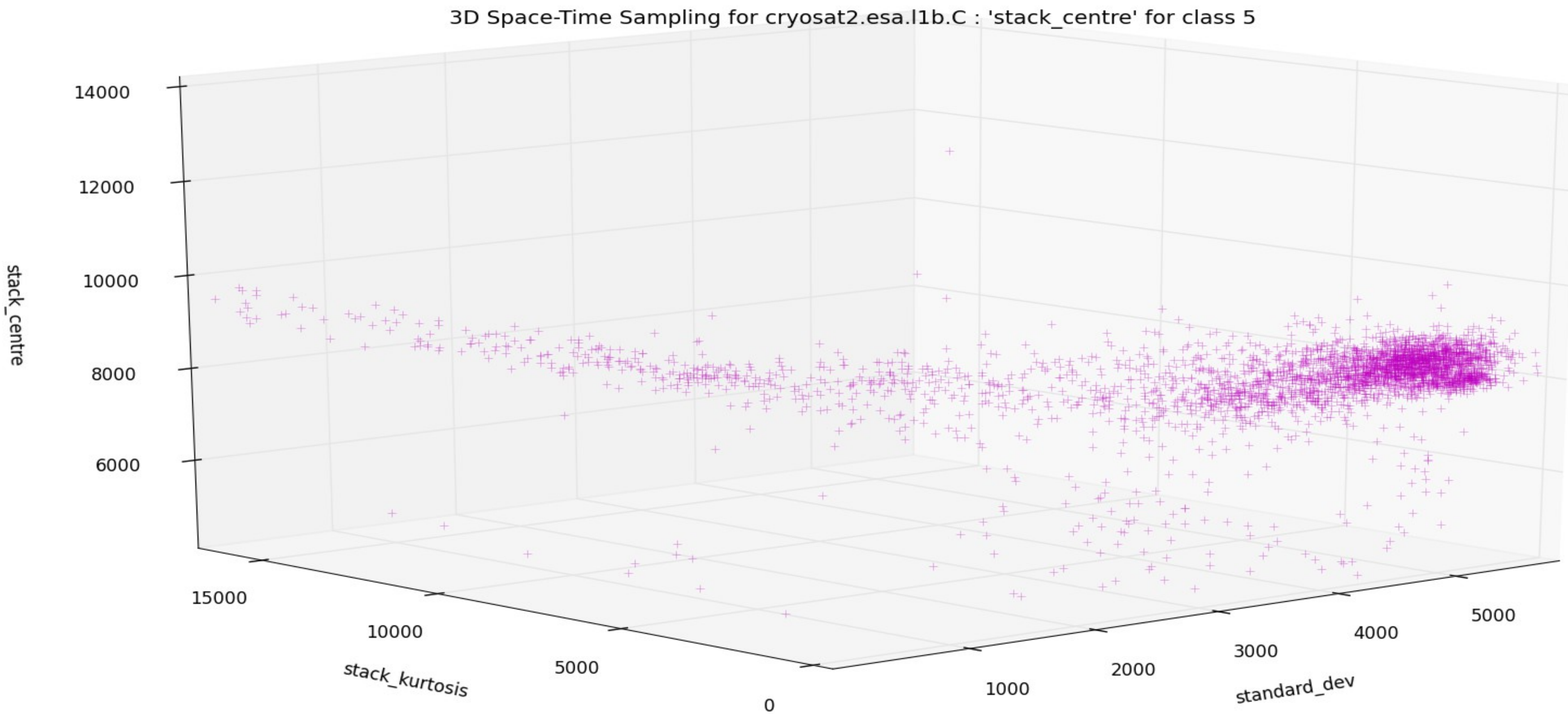
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 5** view 1



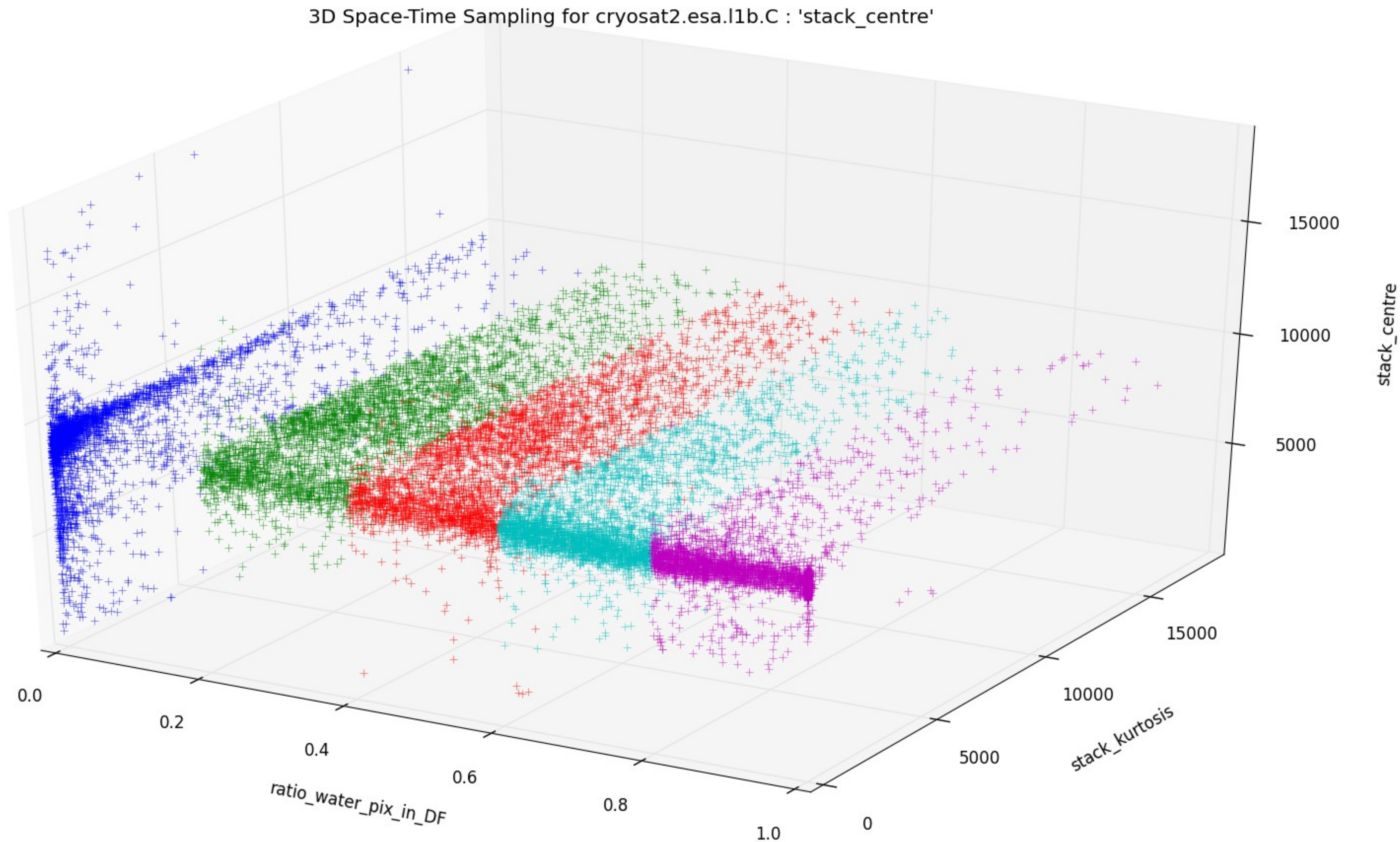
Results

RIP Centre vs RIP(STDEV, Kurtosis) for **class 5** view 2



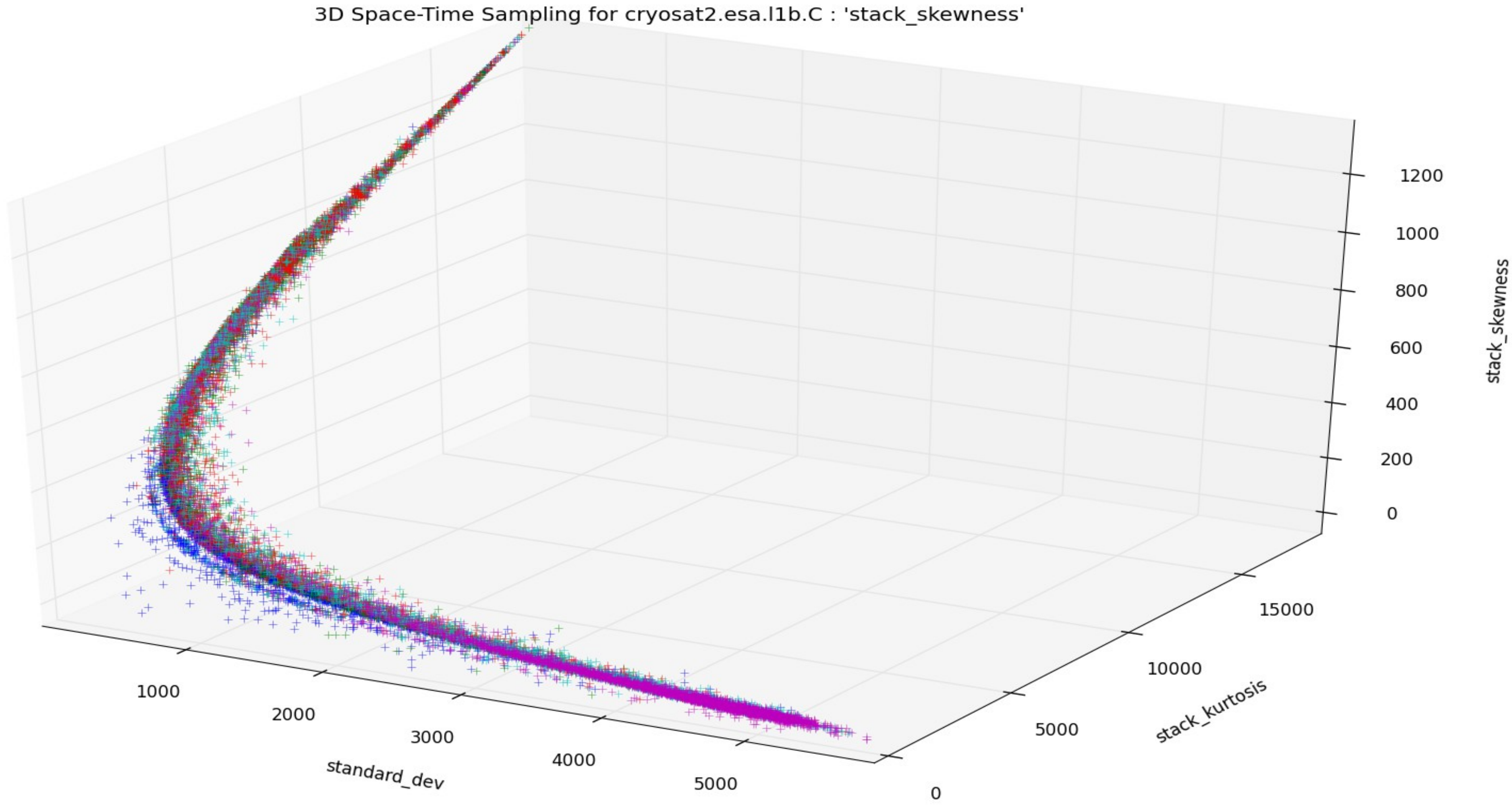
Results

RIP Centre vs (Kurtosis, Water Fraction)



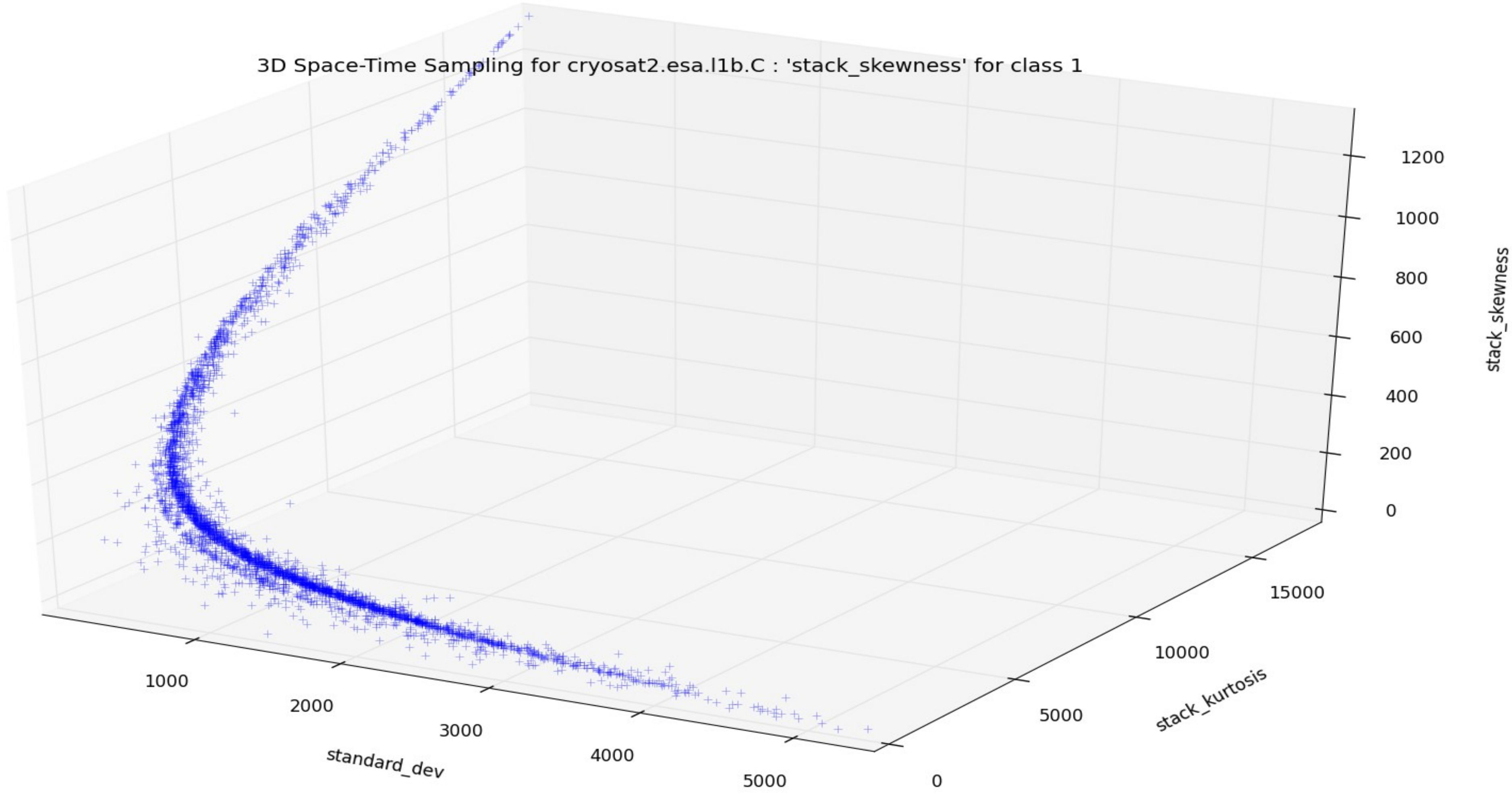
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for ALL classes



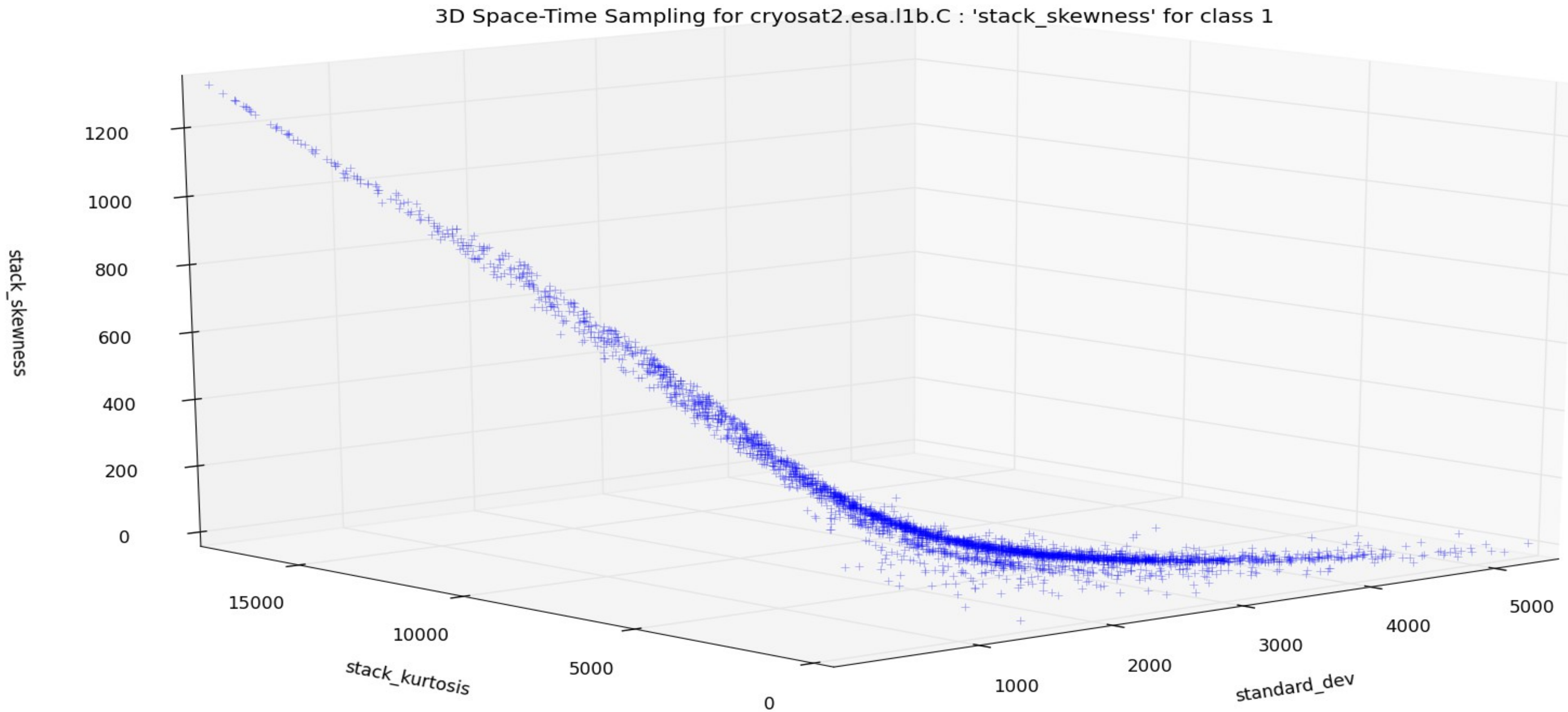
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 1** view 1



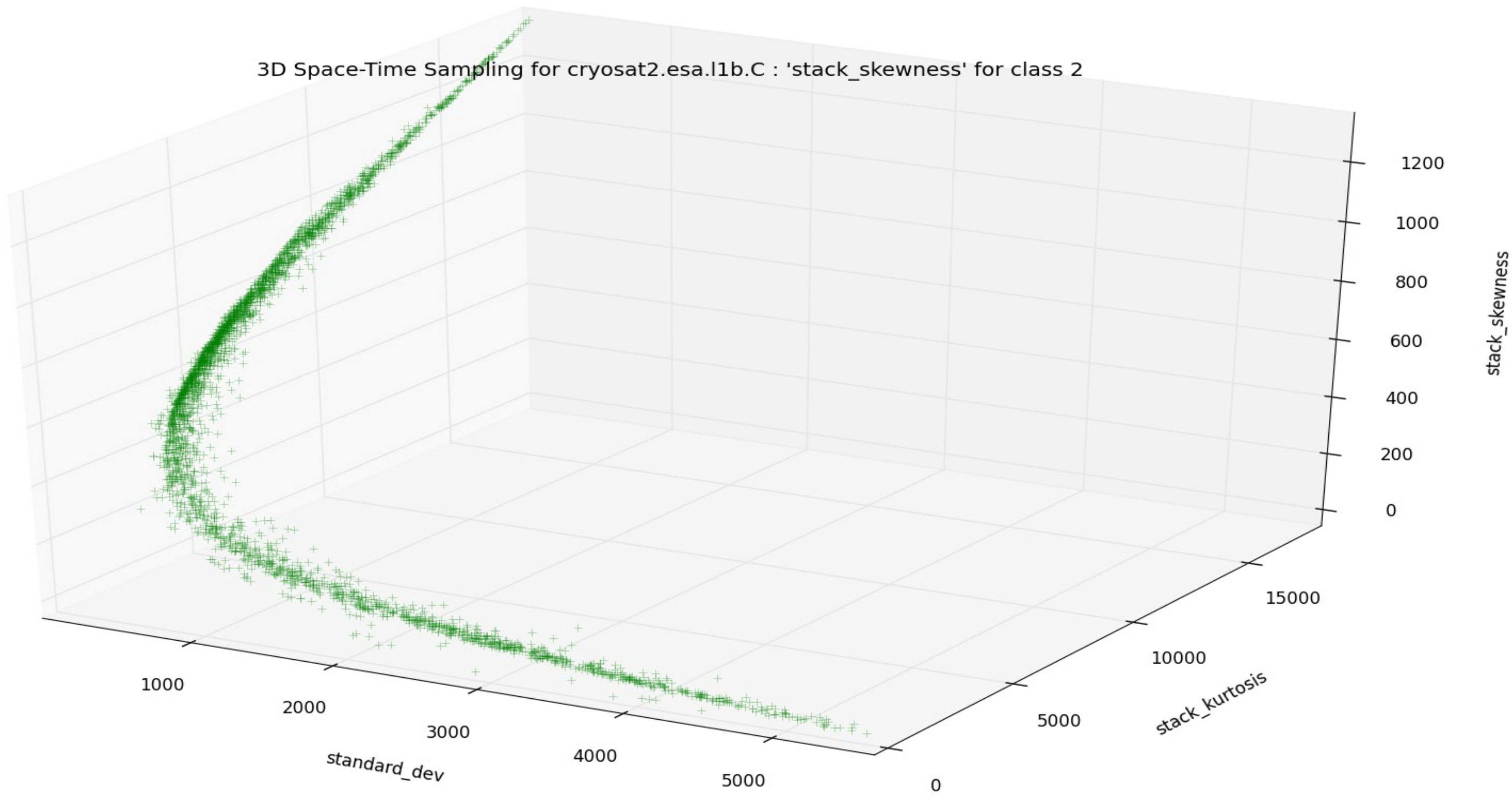
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 1** view 2



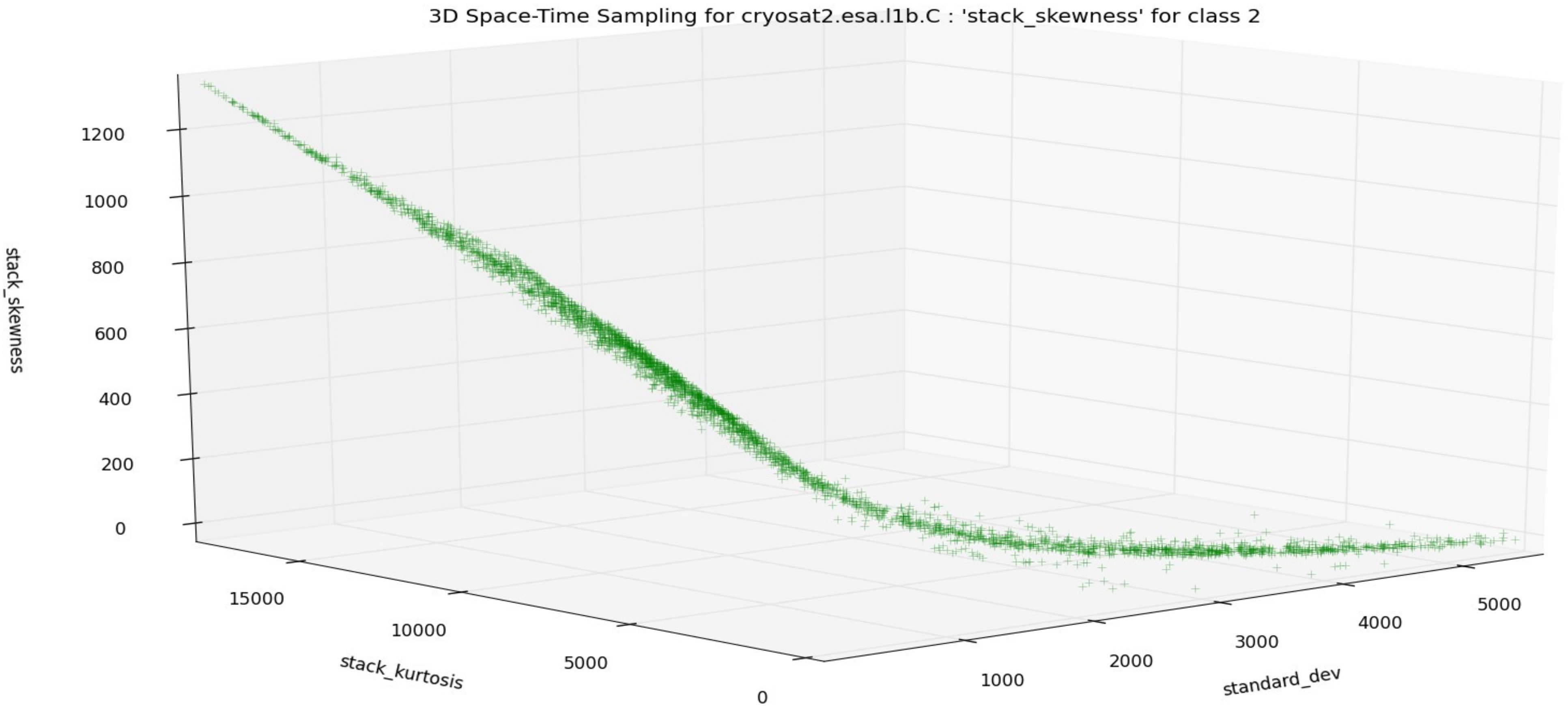
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 2** view 1



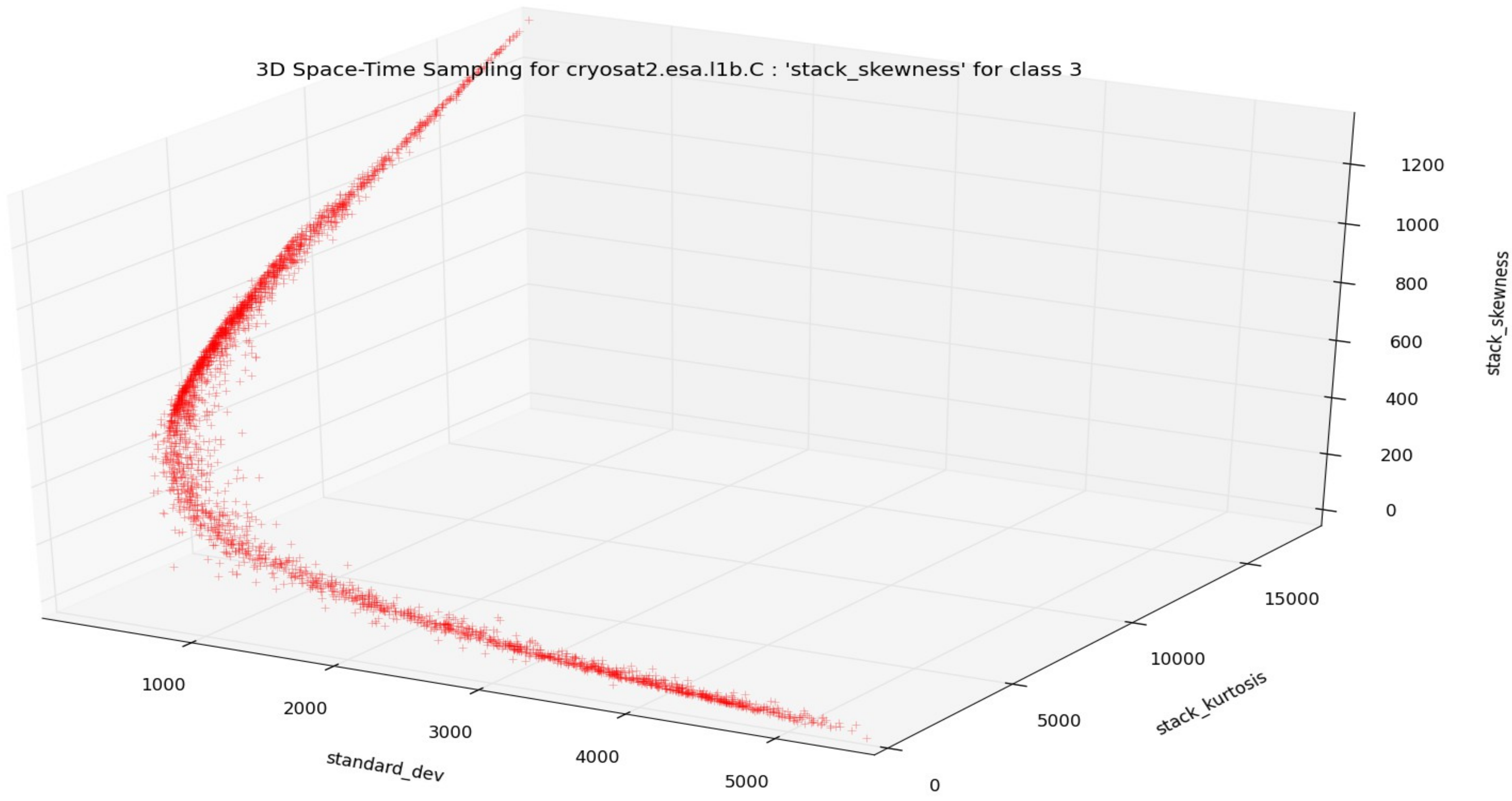
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 2** view 2



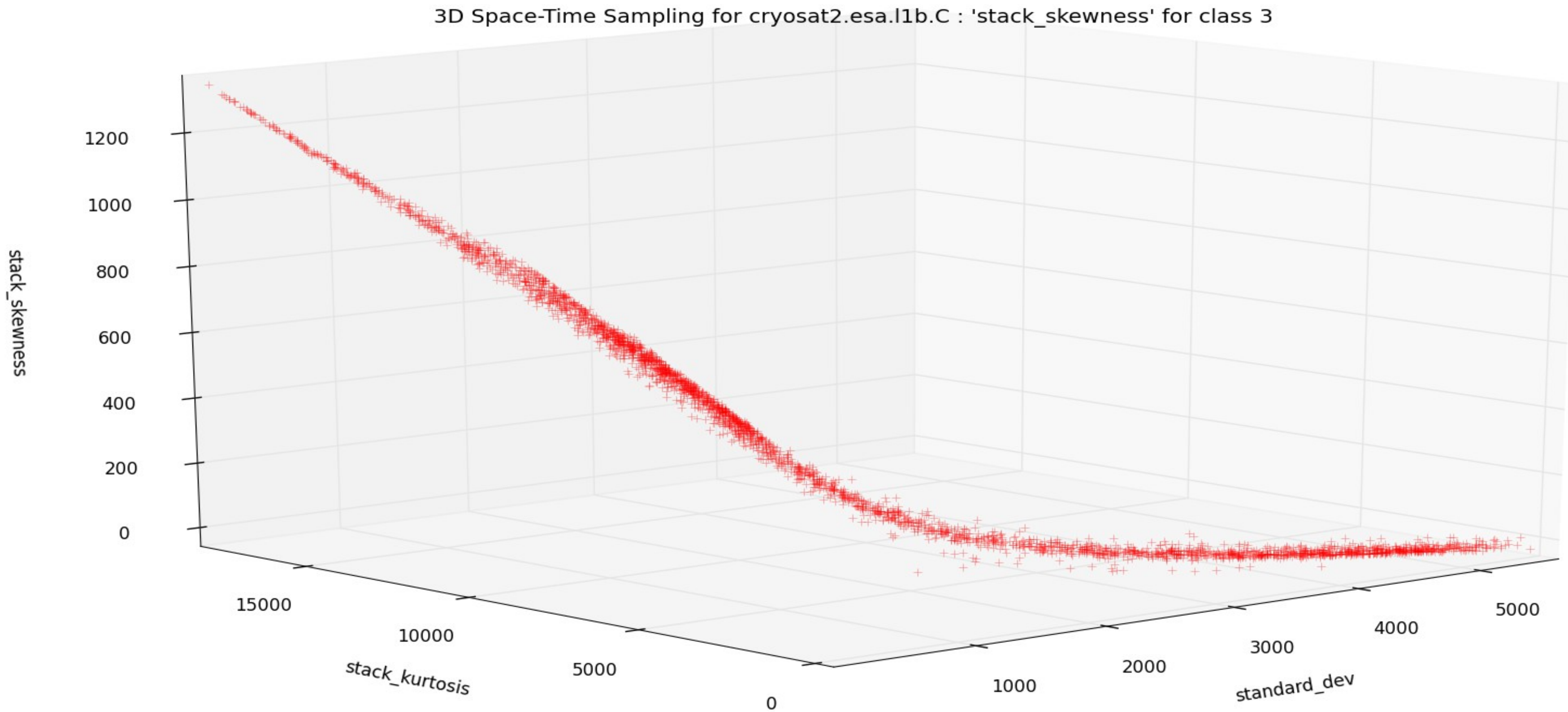
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 3** view 1



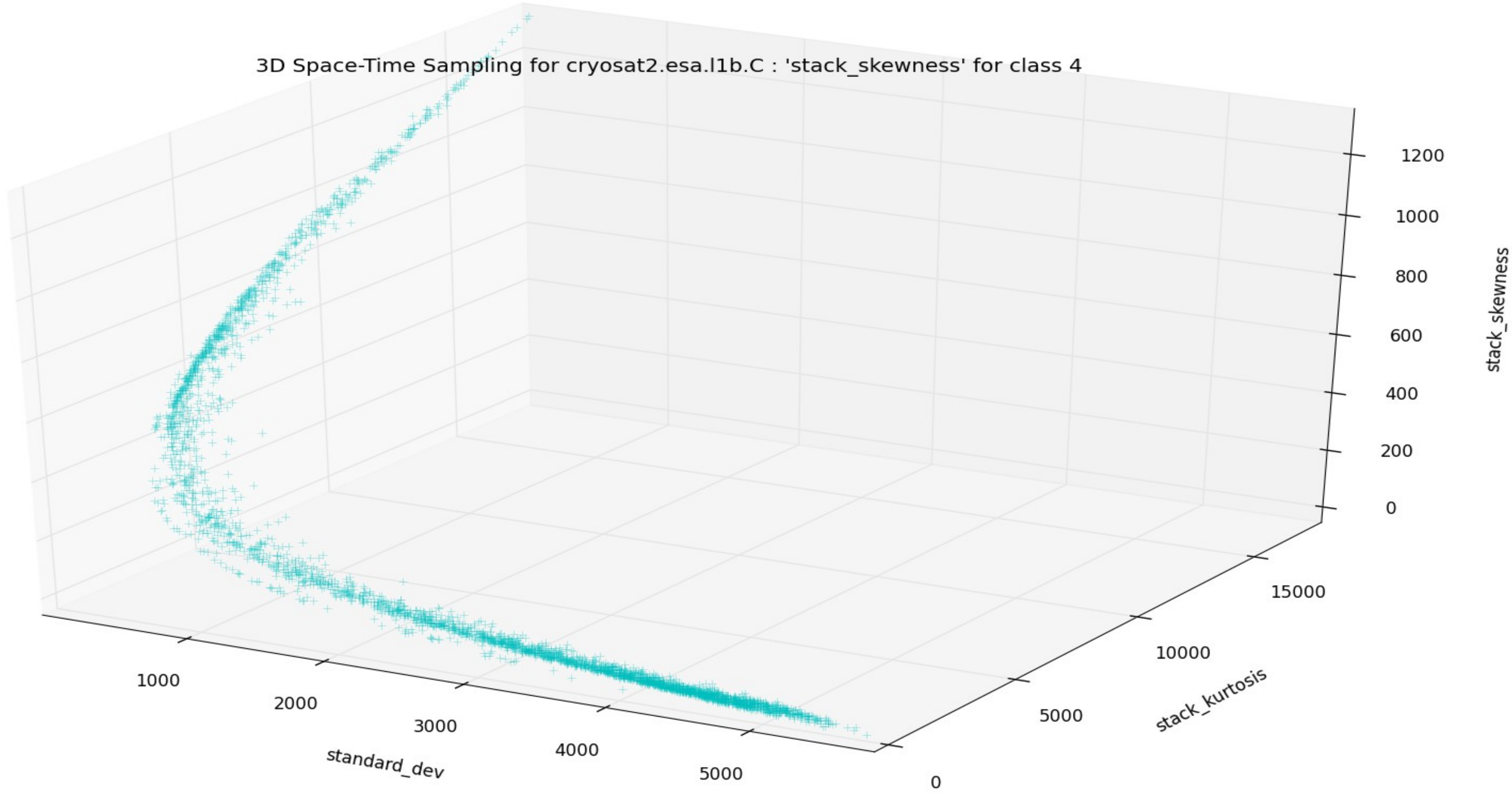
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 3** view 2



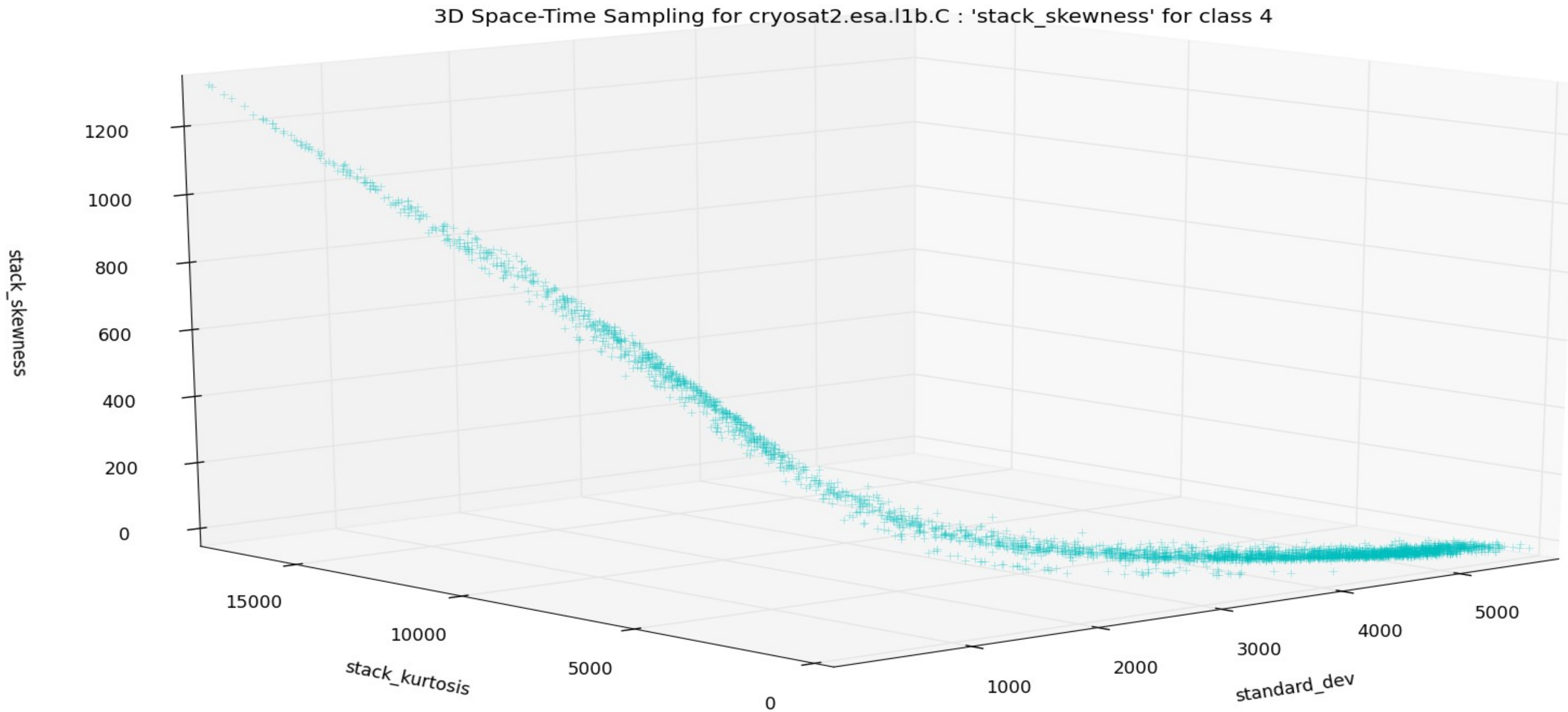
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 4** view 1



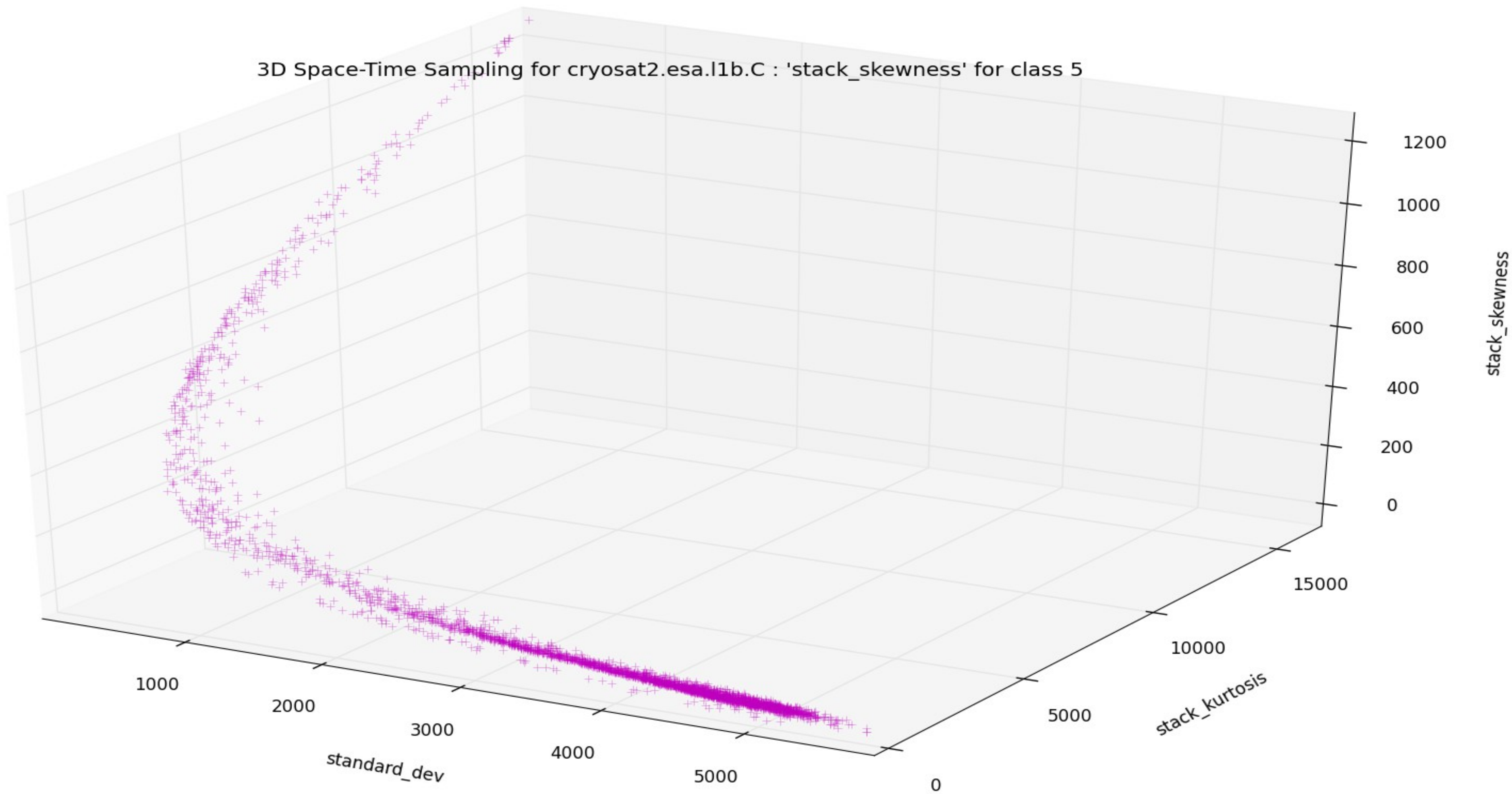
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 4** view 2



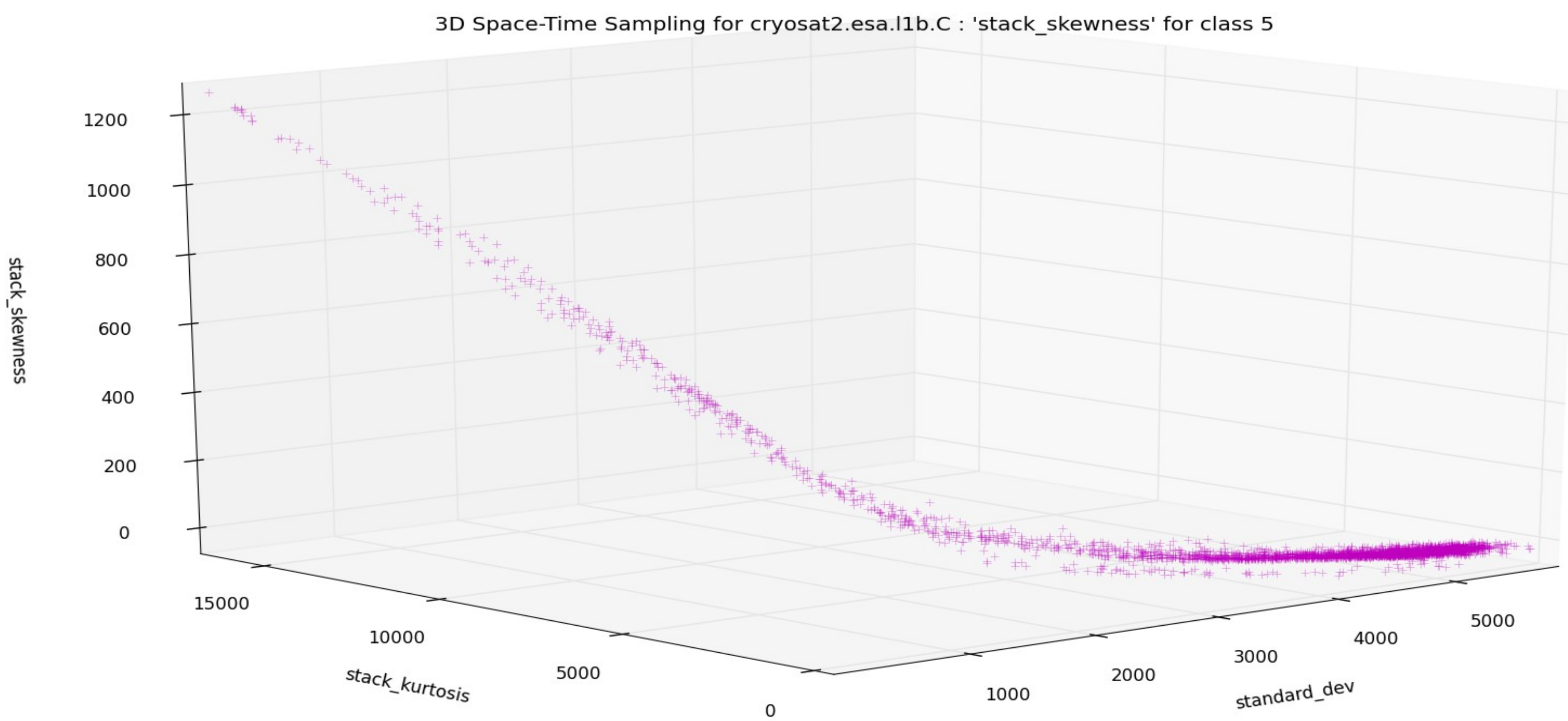
Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 5** view 1



Results

RIP Skewness vs RIP(Kurtosis, STDEV) for **class 5** view 2



Conclusions

Conclusions

- As expected : Mean Waveforms vary from very chaotic at Low Water Fraction to very smooth at High Water Fraction (ocean like).

- Water Classes are quite heterogeneous and trends are not sharp.

- High Water Fraction classes exhibit smooth and symmetrical along-track angular responses.

- Intermediate Water Fraction classes : wide span of both STDEV, Kurtosis and skewness (Stacks are statistically more peaky and assymetric in the along-track direction).

- **Skewness, Kurtosis and Standard Dev of the RIP** seems to be inter-dependent parameters, nevertheless they could help estimate the water **Water Fraction classes as a self standing method from the altimetry data** only (flagging).

Next Steps ?

- Strange jumps found in Baseline-C L1B data could be related to the changes in the platform attitude processing in this baseline→ redo same exercise over Baseline-B and compare the rough results with those of the Baseline-C then decide to keep going or not with baseline-C.
- Extend the Scaled Amplitude to Watt conversion to the RIP.
- Analyse the diversity of Waveforms in each class.
- Repeat the exercise with updated water masks & Use platform attitude for an improved footprint placement.
- Compute Antenna Gain weighted Water Fraction instead of Water Fraction.
- More editing: use products quality flags
- Seasonal Climatologies to better understand the Relationships between parameters within a Water Fraction Class
- Refine the Analysis with using the Pulse-Doppler Footprint as well and **discriminate when water at NADIR**.
- Repeat the whole analysis for the full STACKS instead of the RIP.

THANK YOU FOR YOUR ATTENTION