Image analysis and Segmentation of Polar Mesospheric Summer Echoes

Dorota Jozwicki, Puneet Sharma, Ingrid Mann, Ulf-Peter Hoppe

UiT- The Arctic University of Norway

Tromsø

Summary

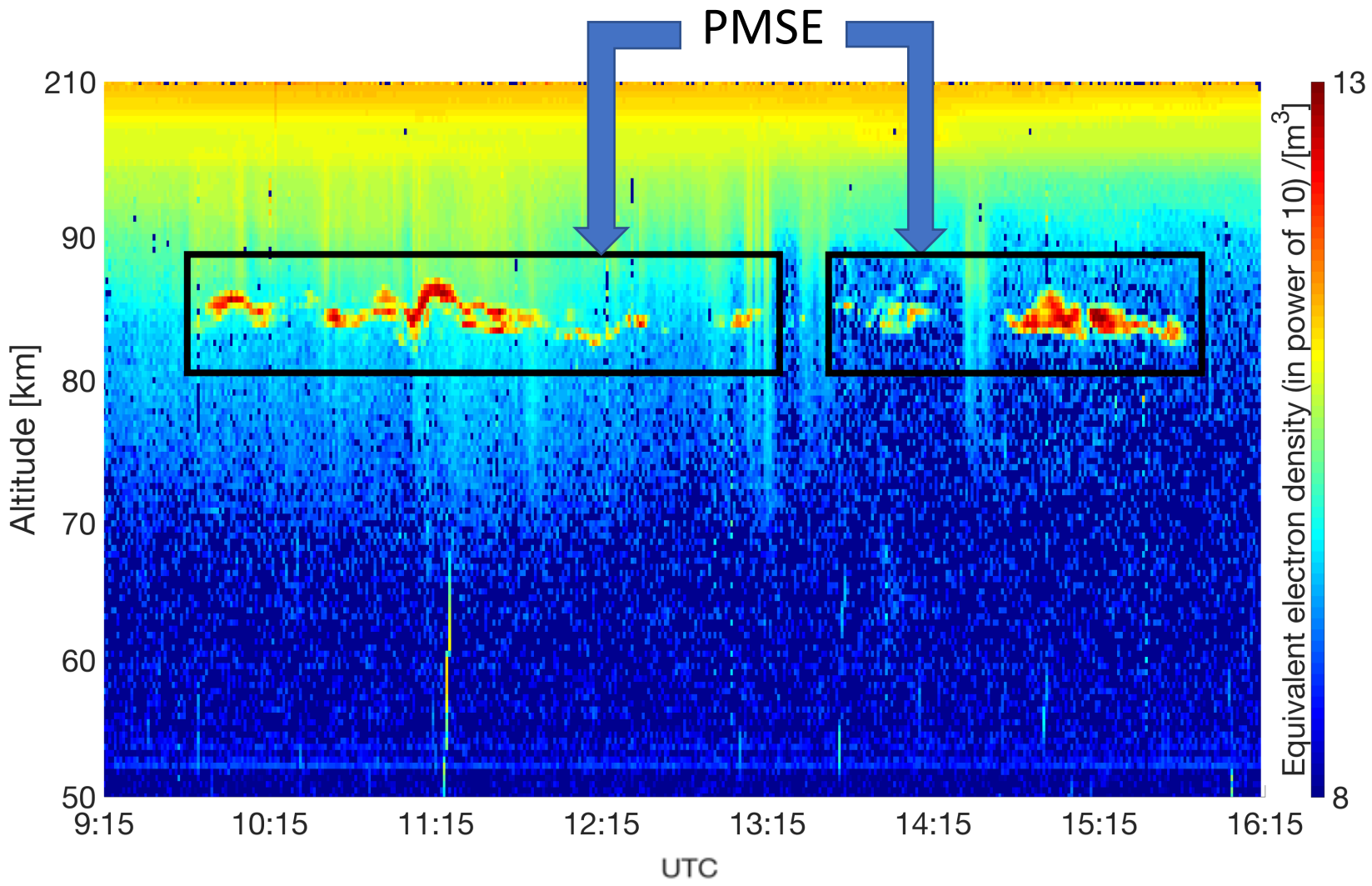
1. What are PMSE?
2. Classification of PMSE
    1. Method employed
    2. Results
    3. Conclusion
3. Segmentation of PMSE
    1. Method employed
    2. Results
    3. Conclusion
4. Future work

1- What are PMSE ?

Data: comes from EISCAT VHF (224MHz) in Tromsø

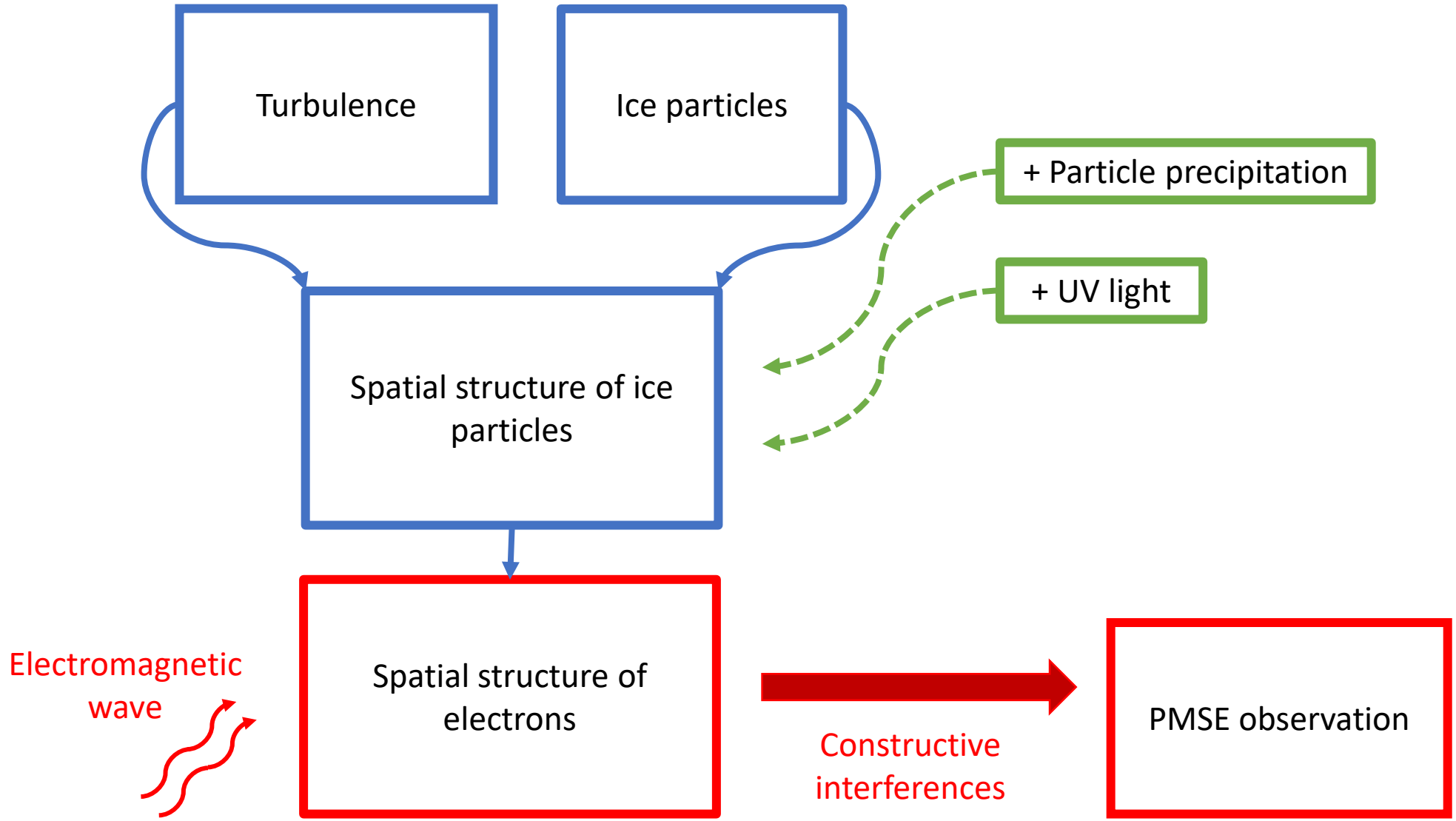
Date: 10th of August 2015

Typical PMSE altitude : 80 km to 90 km during summer months

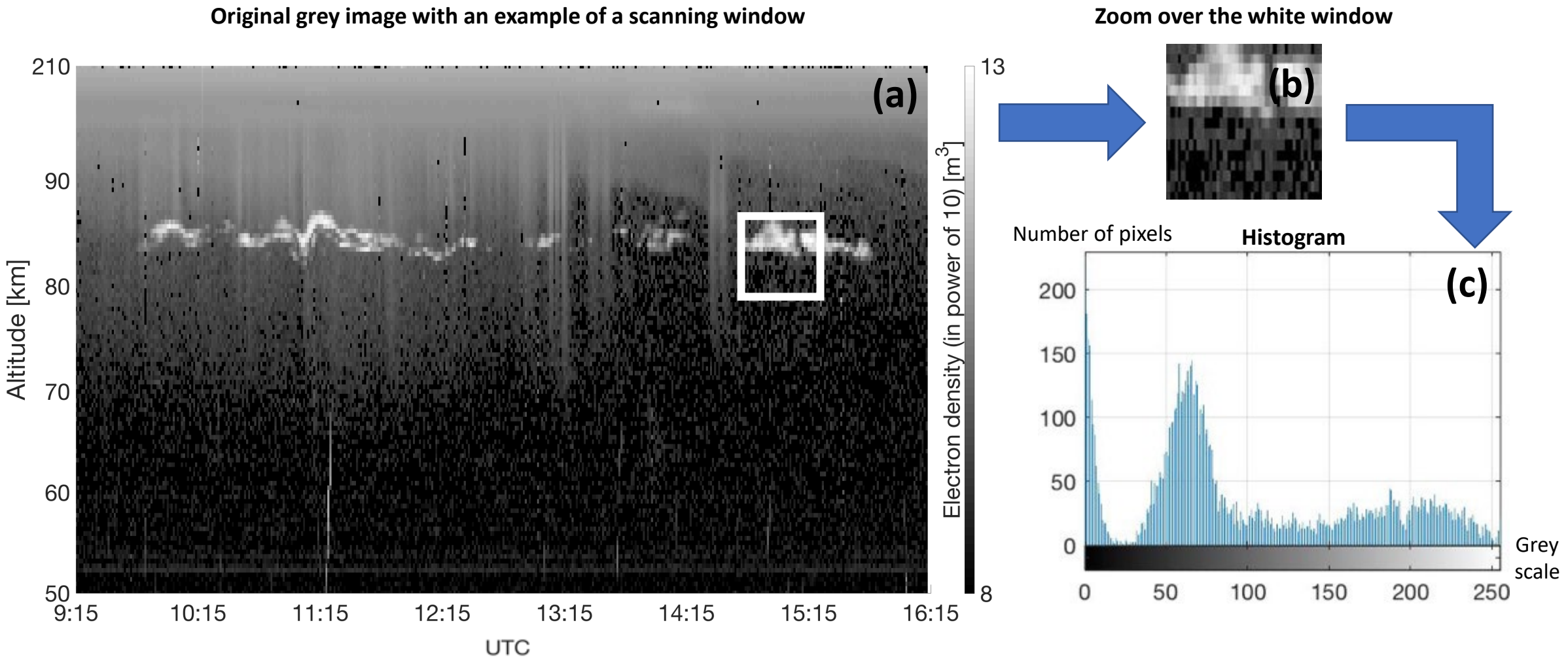


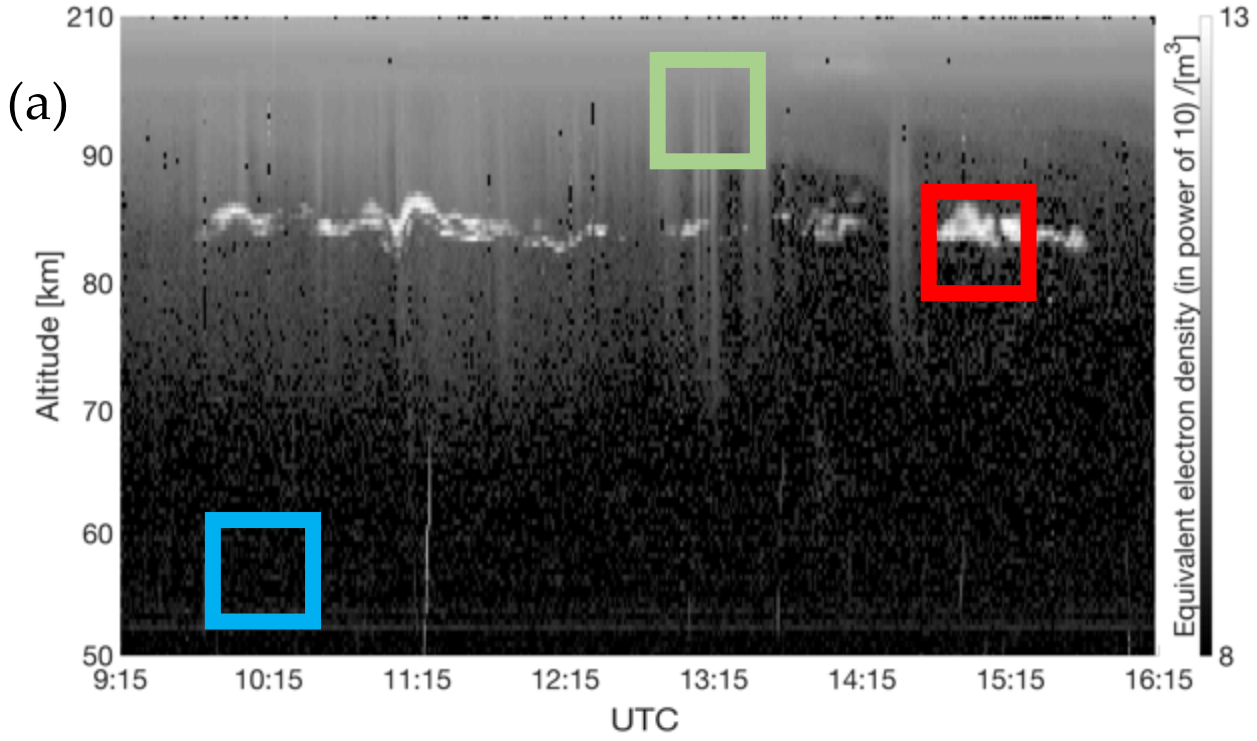
The equivalent electron density is equivalent to the backscattered power

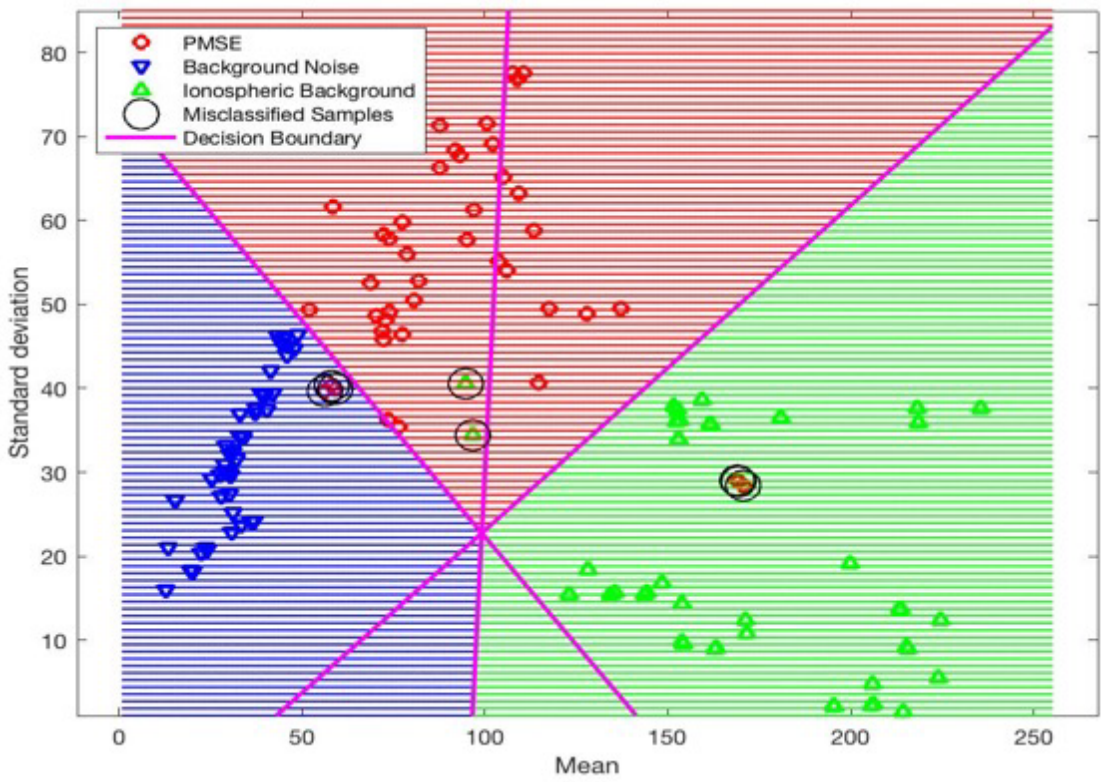
Prerequisites for PMSE observation

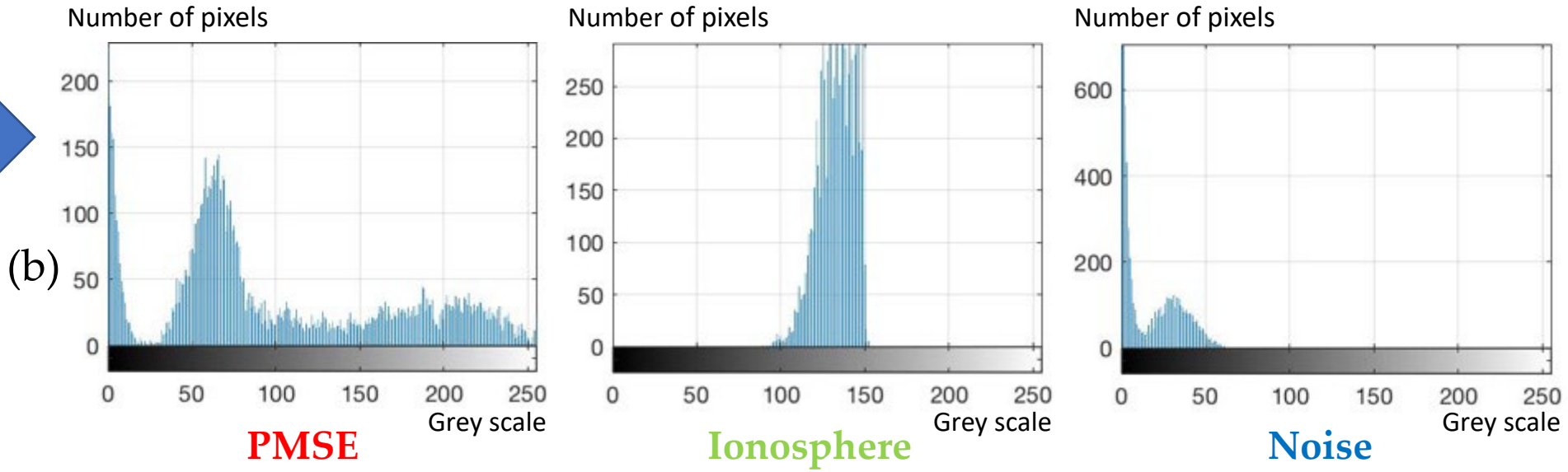


2- Classification of PMSE




(a)
Altitude [km]
210
90
80
70
60
50
9:15
10:15
11:15
12:15
13:15
14:15
15:15
16:15
UTC
Equivalent electron density (in power of 10) /[m^3]
13
8


(c)
PMSE
Background Noise
Ionospheric Background
Misclassified Samples
Decision Boundary
Standard deviation
Mean
80
70
60
50
40
30
20
10
0
50
100
150
200
250


(b)
Number of pixels
Grey scale
PMSE
Number of pixels
Grey scale
Ionosphere
Number of pixels
Grey scale
Noise

Mean, expected value:

$$\mu \equiv \mathrm{E}[X]$$

Standard deviation:

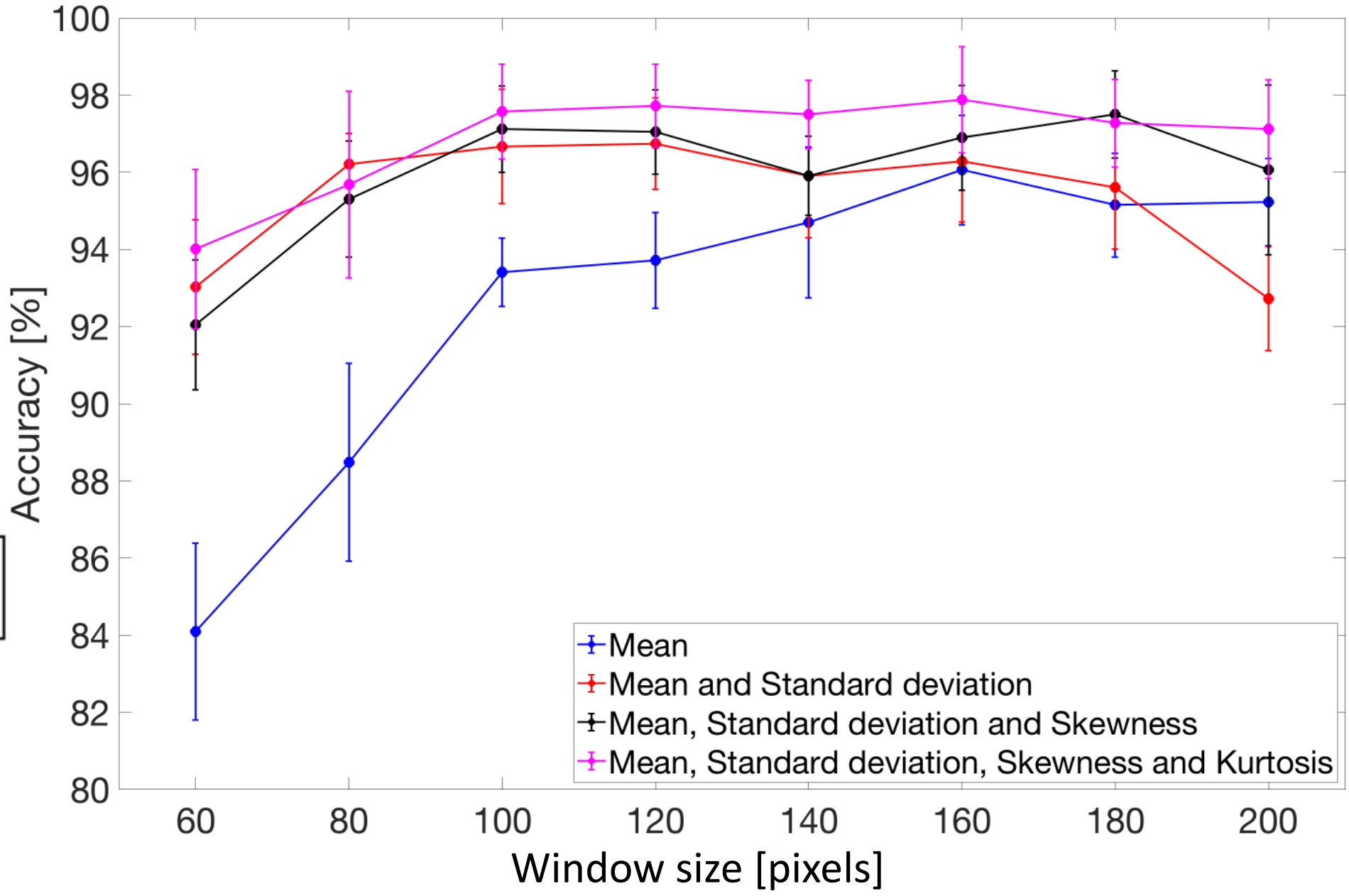
$$\sigma \equiv \sqrt{\mathrm{E}\left[(X-\mu)^2\right]}$$

Skewness:

$$\mathrm{Skew}[X] = \mathrm{E}\left[\left(\frac{X-\mu}{\sigma}\right)^3\right]$$

Kurtosis:

$$\mathrm{Kurt}[X] = \mathrm{E}\left[\left(\frac{X-\mu}{\sigma}\right)^4\right]$$



Where X is a random variable and E[X] is the expected value of X (which is equivalent to arithmetic mean)

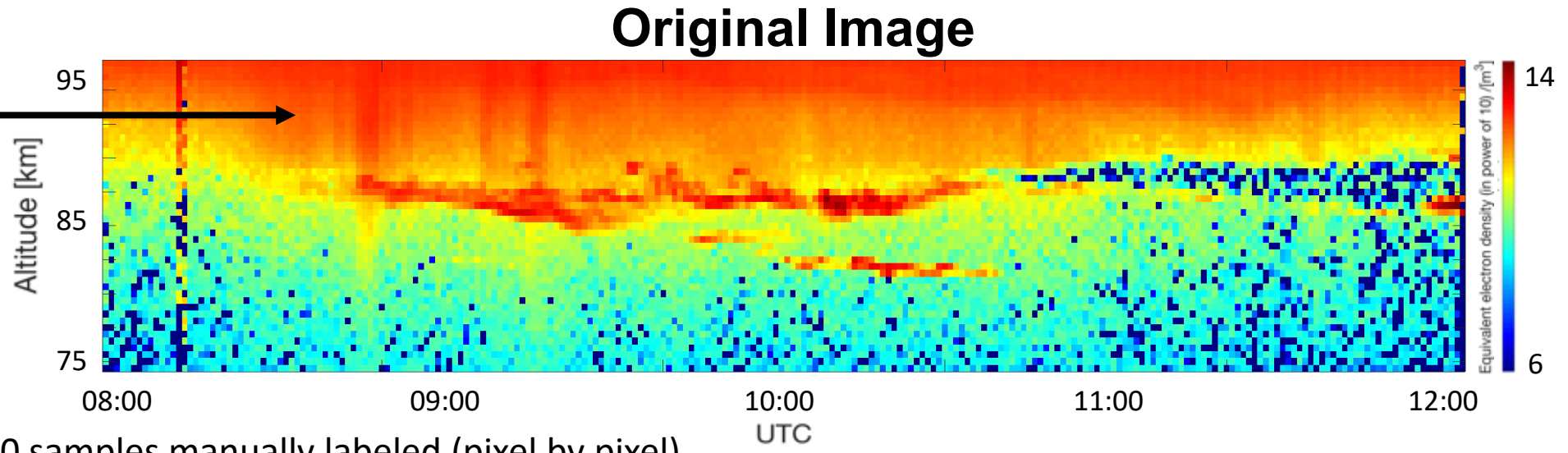
Conclusion of PMSE investigation with LDA

- LDA can be used to distinguish image regions containing PMSE from those with noise or ionospheric background with up to 98% accuracy

- Our proposed method can be used to pre-select data for further analysis of the shape of the PMSE

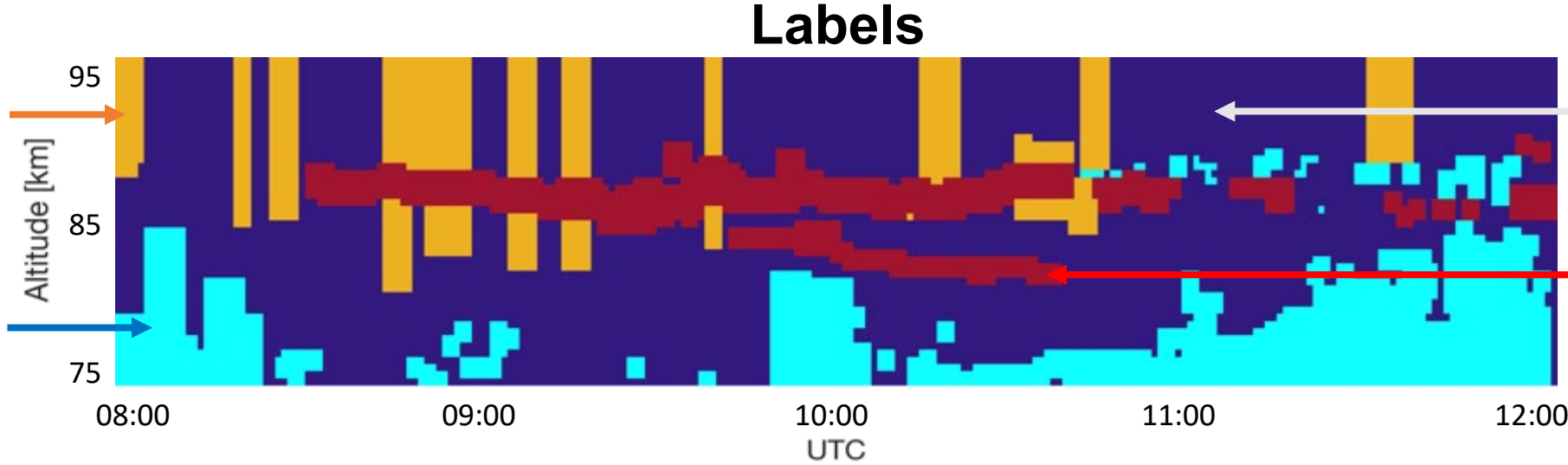
3- Segmentation of PMSE

Original Data from EISCAT VHF radar



Date: 30th of June 2008

Dataset : 56 250 samples manually labeled (pixel by pixel)



Ionospheric background

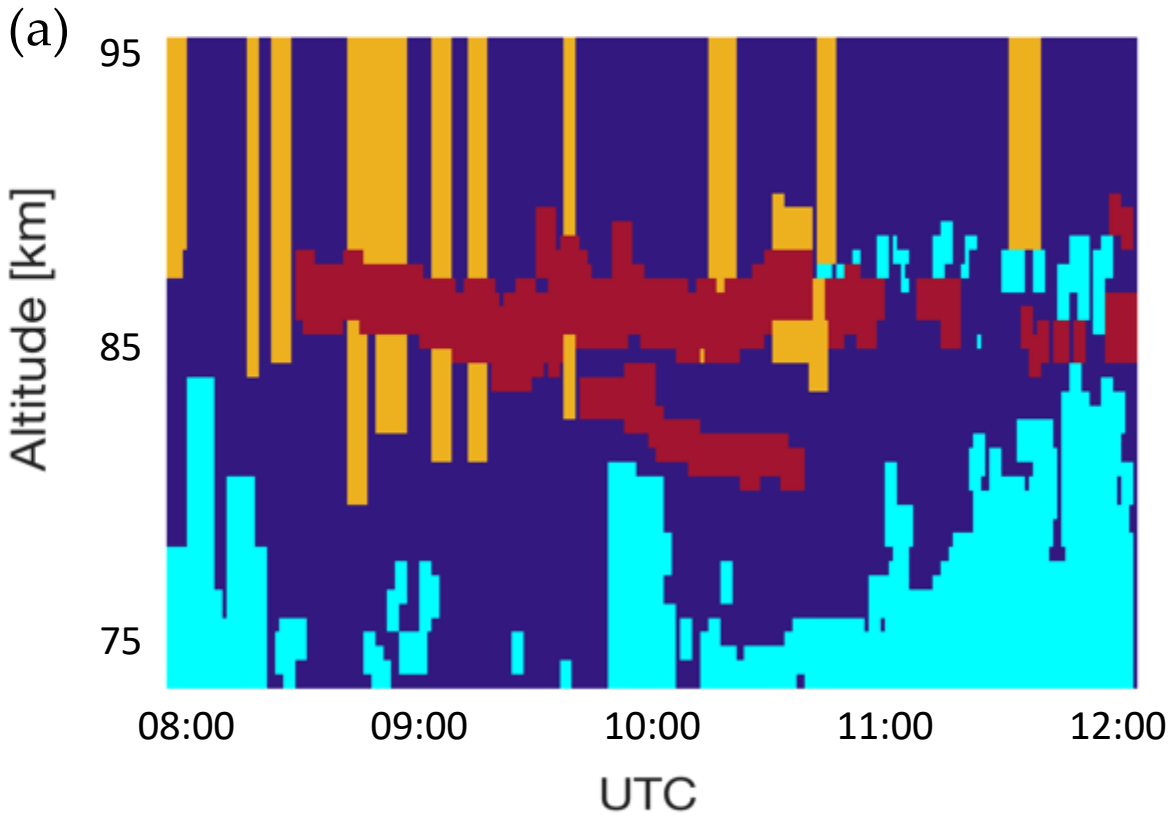
Background noise

Unlabeled data

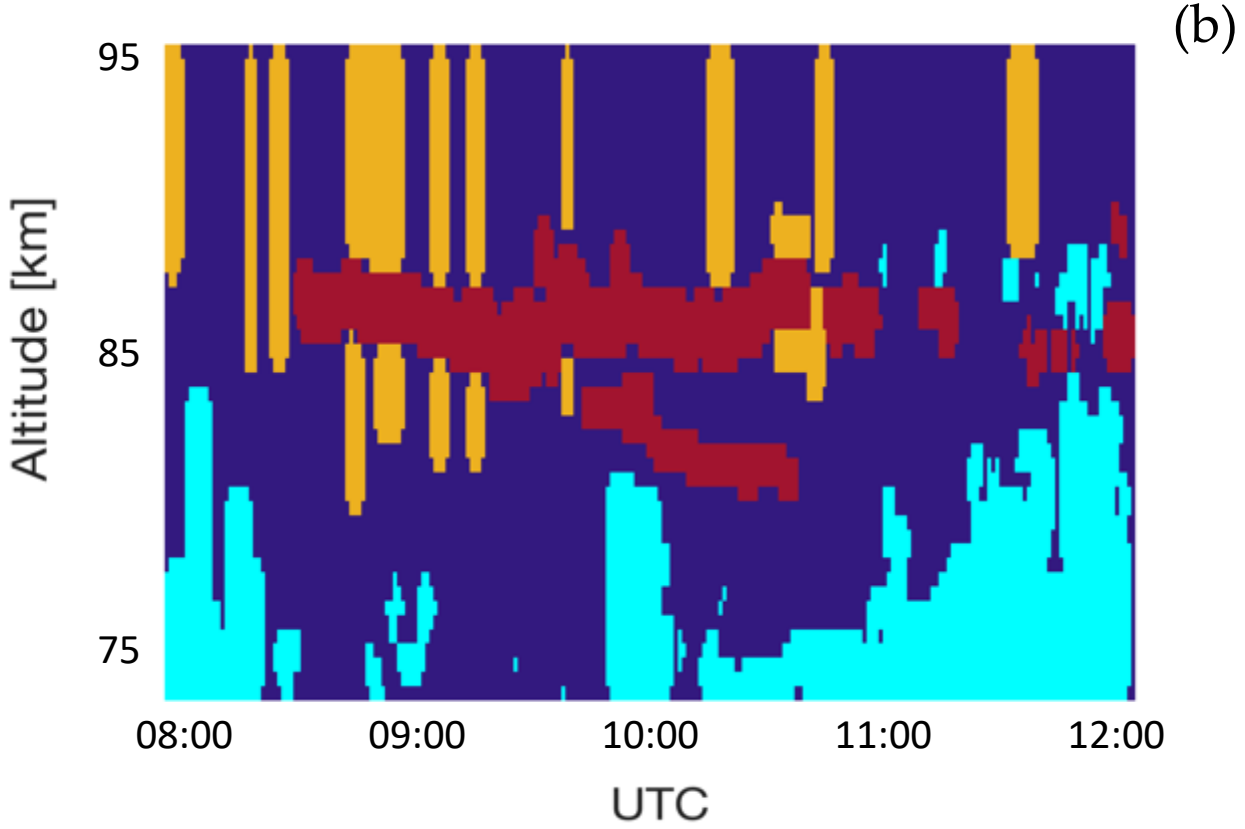
PMSE

Labels with reduced weighting from Almeida et. al. (2021)

Original Labeled Pixels



Weighted-down Labeled Pixels

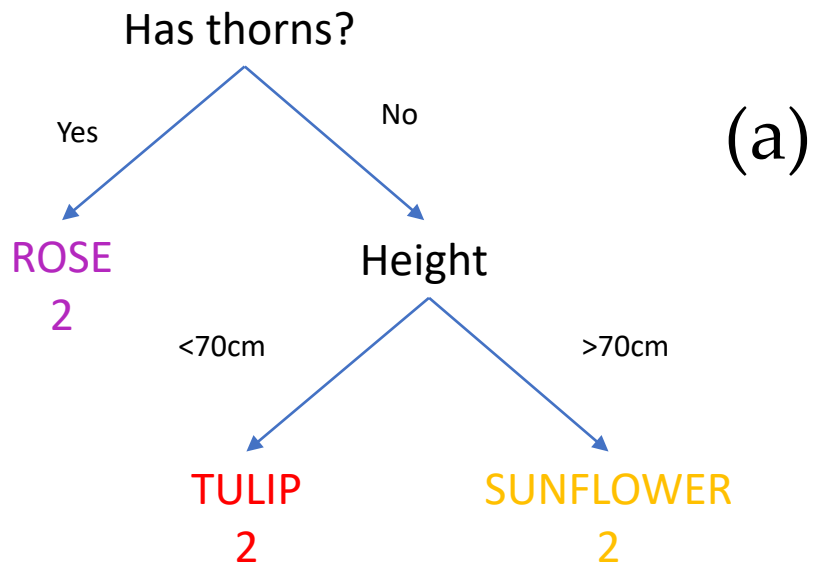


30 images in total - 18 labeled images (56250 labelled samples in total)

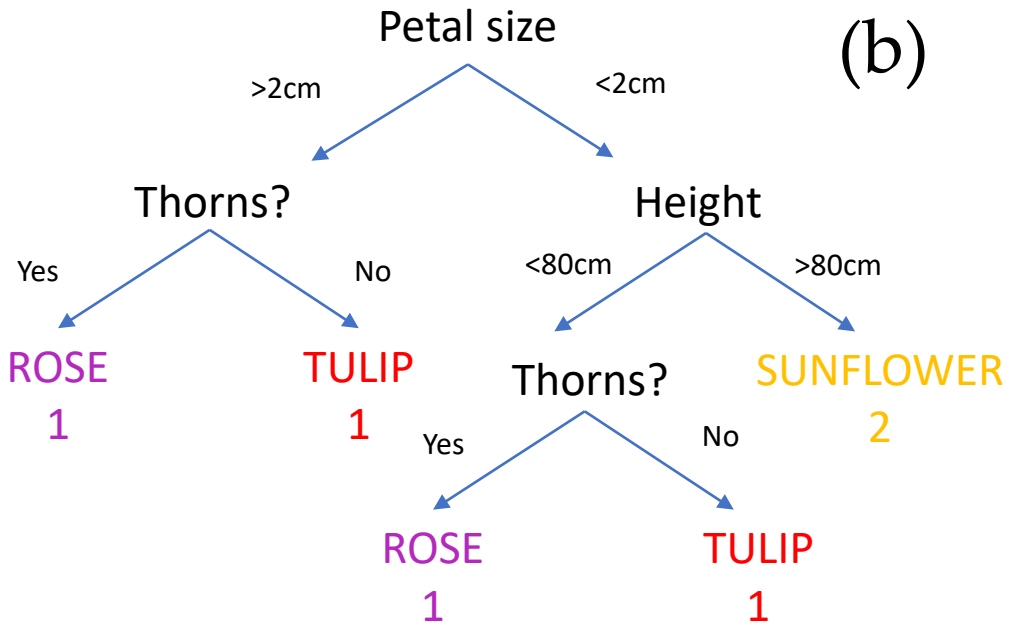
After wighting-down the data: - 60% use for training - 40% used for quantitative testing

Random forests are a multitude of decision trees

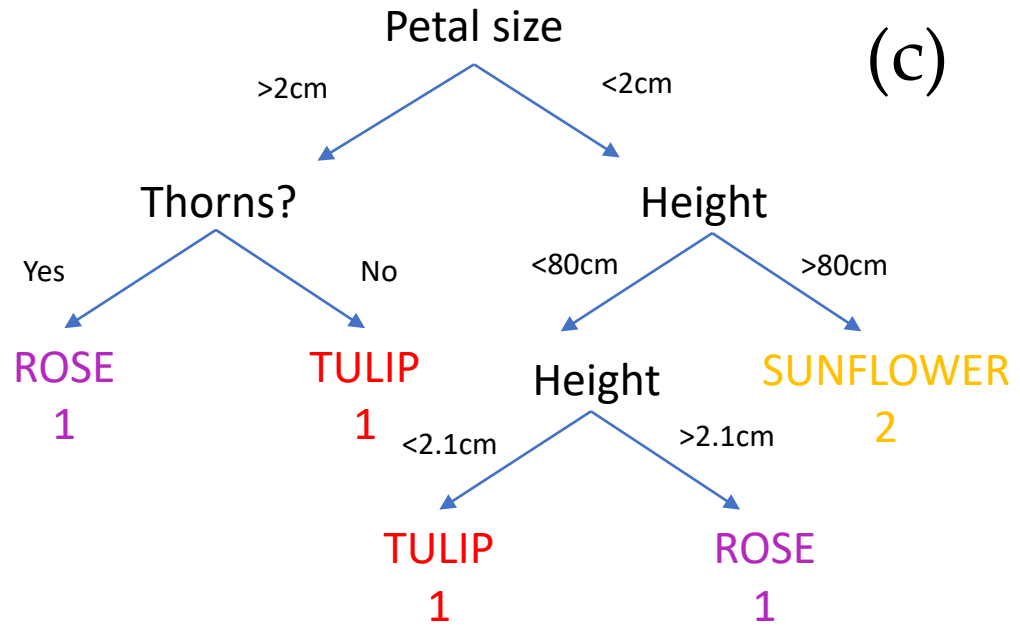
	Height	Thorns	Average Petal size	Type
Flower1	55 cm	Yes	1.9cm	ROSE
Flower2	13 cm	No	2cm	TULIP
Flower3	20 cm	No	1.5 cm	TULIP
Flower4	150 cm	No	8cm	SUNFLOWER
Flower5	60 cm	Yes	2.2 cm	ROSE
Flower6	130 cm	No	9cm	SUNFLOWER



(a)



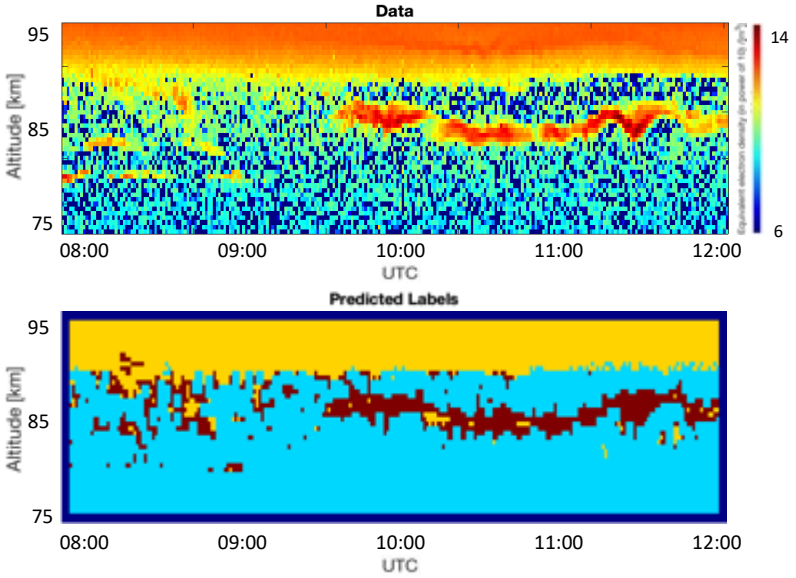
(b)



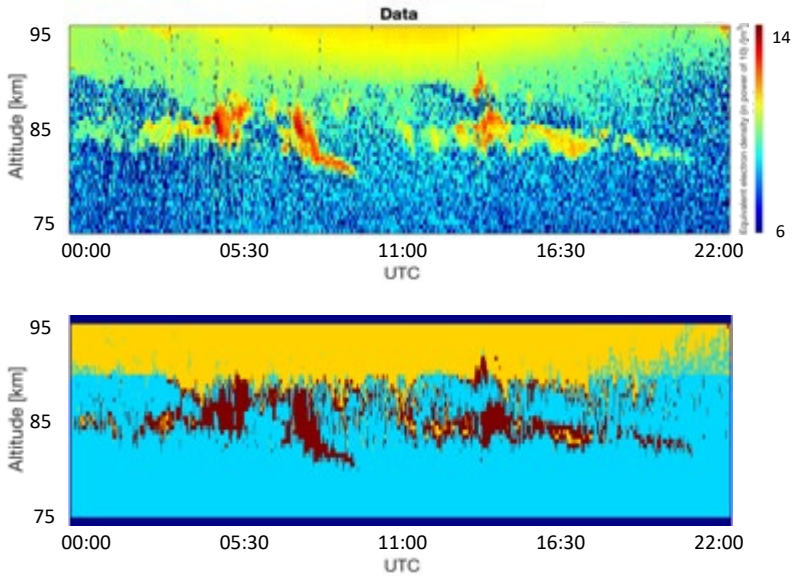
(c)

Predicted labels

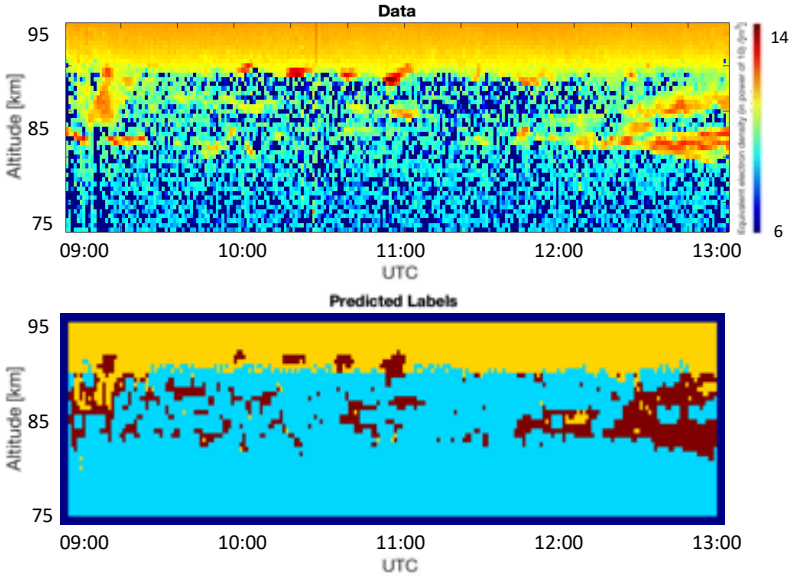
17 July 2009



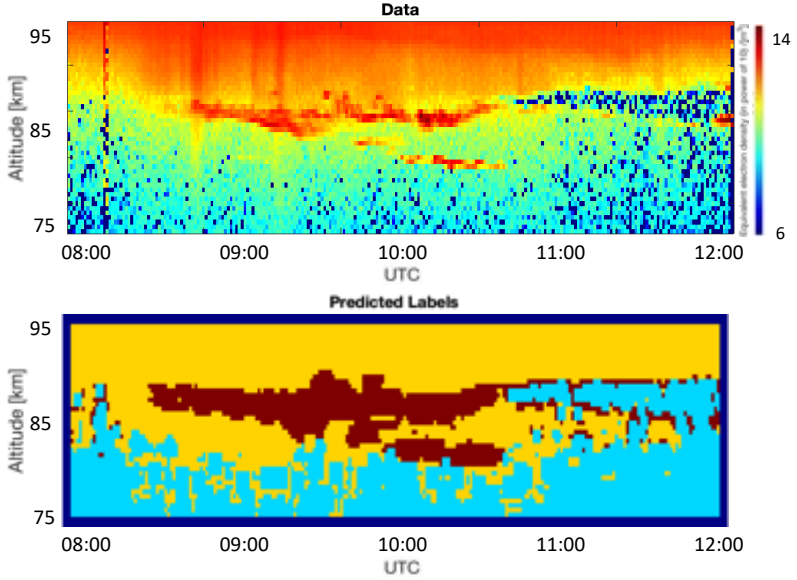
7 July 2010



8 July 2010



30 June 2008



Conclusion of PMSE segmentation with Random forests

- It is possible to segment PMSE from the data by using random forests.
- The weighted-down labels technique we used improves the performance of the random forests method.
- Some refinement needs to be done to be able to use it automatically in our future work plans

For details see : https://www.mdpi.com/2072-4292/14/13/2976/htm

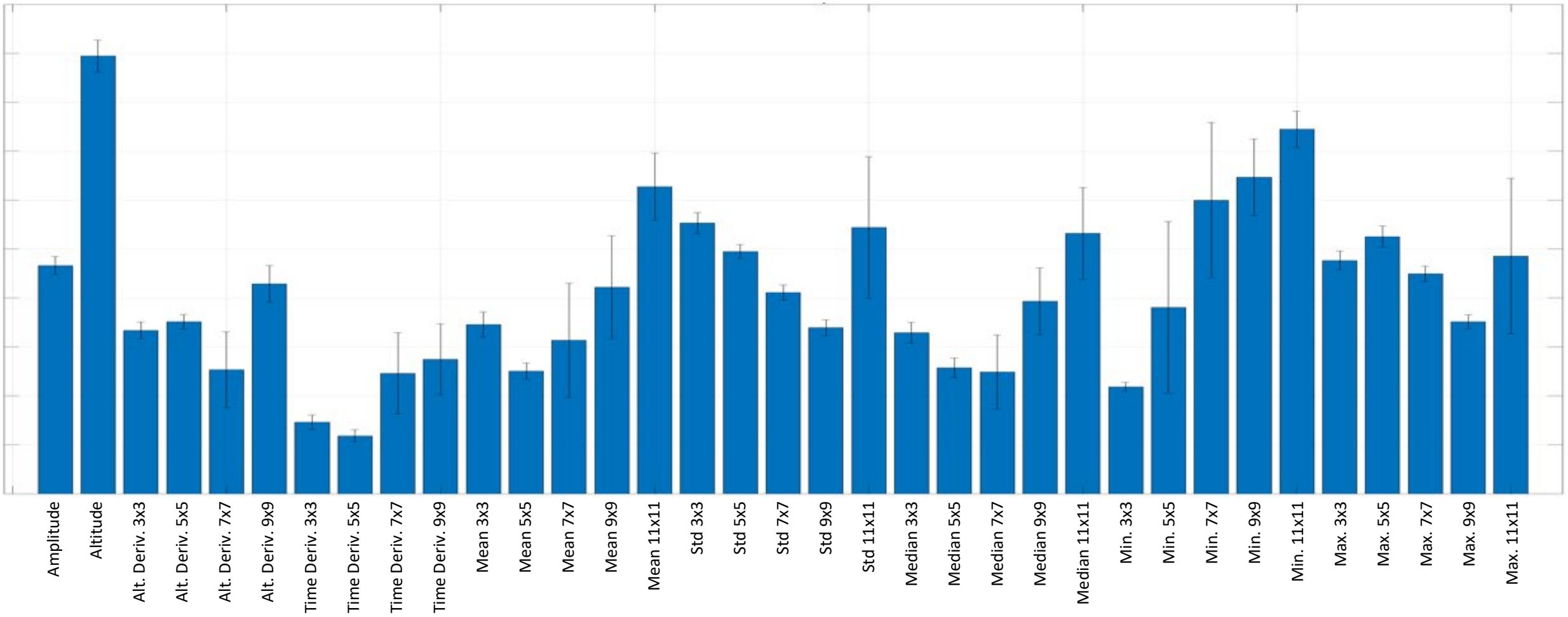
Future work

- Study of PMSE under different geophysical conditions
- Study PMSE over many years and see if there are any change in their shape, thickness, number of layers, altitude, etc... Use of archived EISCAT data in the first place.
- We would have access to a lot of data through EISCAT 3D in a further future
- Aknowledgement : all data from EISCAT Madrigal

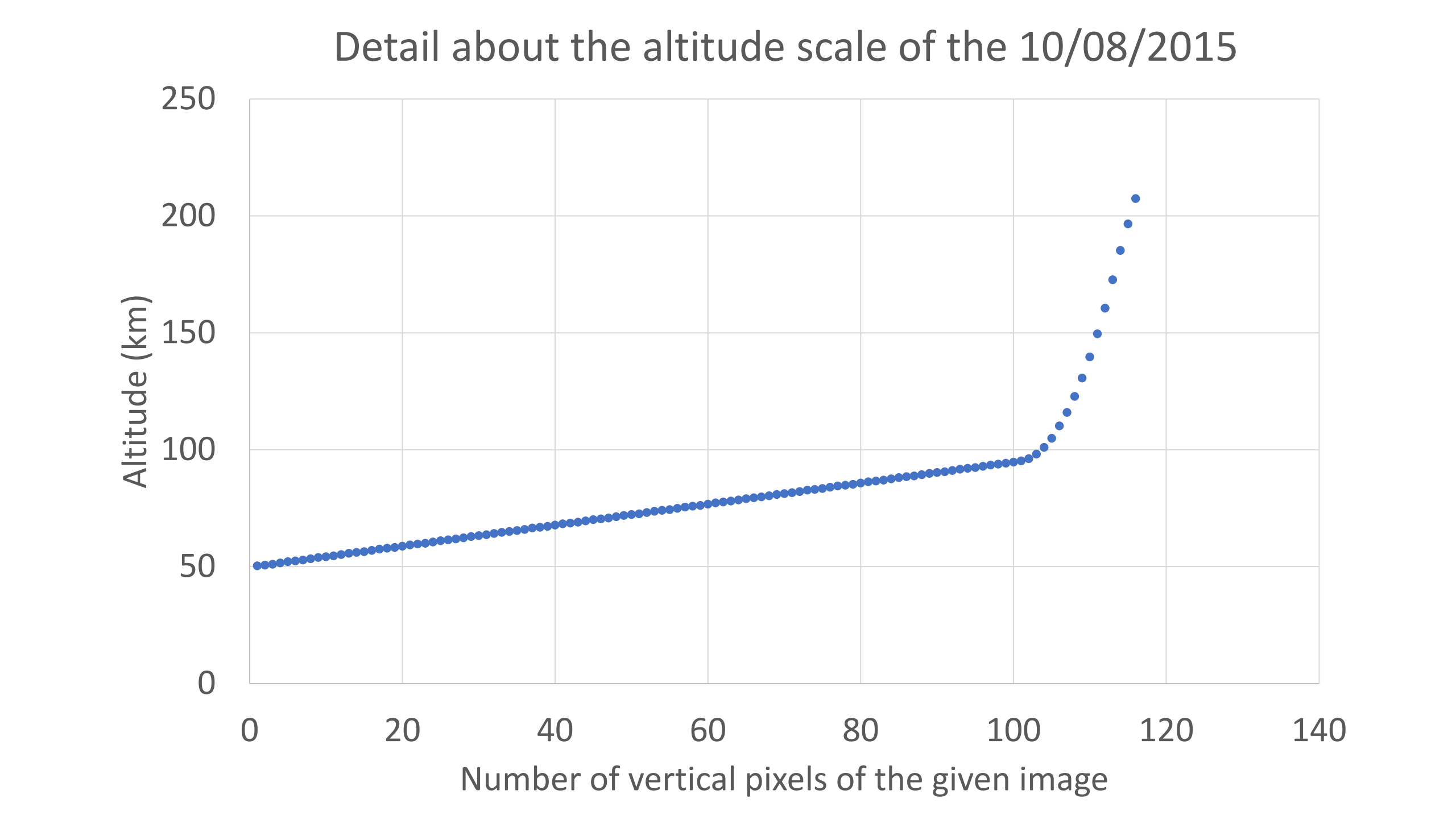
Thank you for your attention

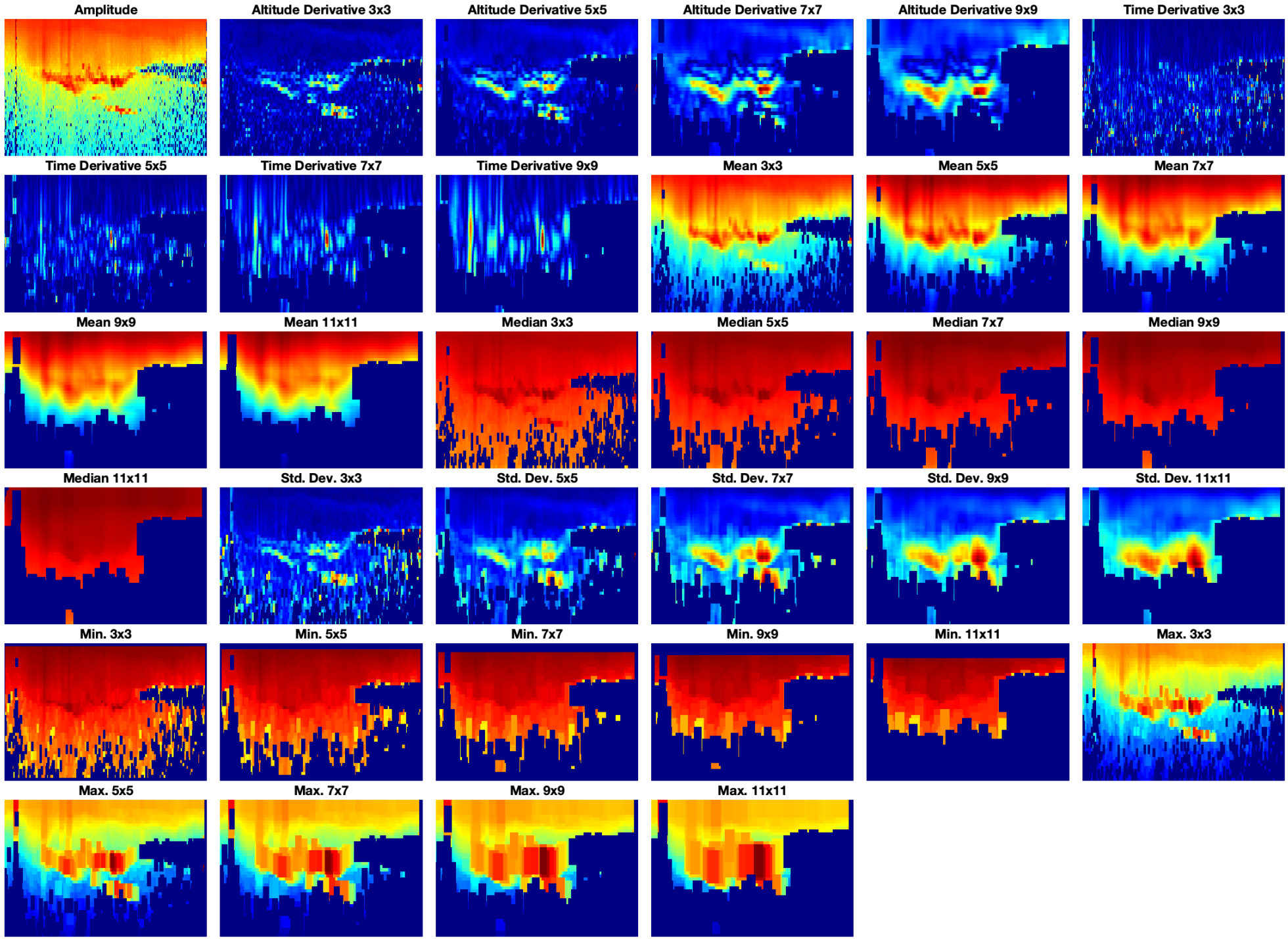
Bonus slides

Predictor importance

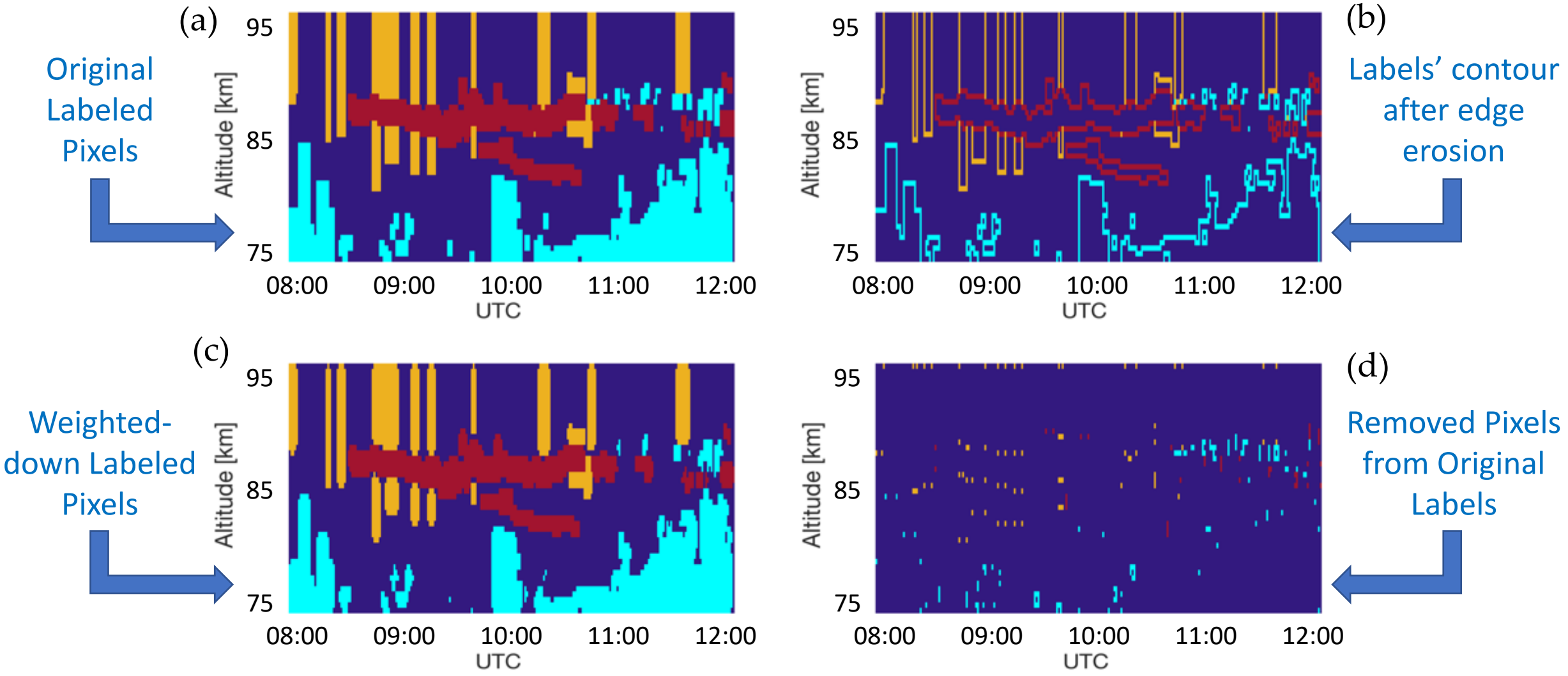


Classification error for these results is: 0.12580 ± 0.01500


Detail about the altitude scale of the 10/08/2015
Altitude (km)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
Number of vertical pixels of the given image


Amplitude
Altitude Derivative 3x3
Altitude Derivative 5x5
Altitude Derivative 7x7
Altitude Derivative 9x9
Time Derivative 3x3
Time Derivative 5x5
Time Derivative 7x7
Time Derivative 9x9
Mean 3x3
Mean 5x5
Mean 7x7
Mean 9x9
Mean 11x11
Median 3x3
Median 5x5
Median 7x7
Median 9x9
Median 11x11
Std. Dev. 3x3
Std. Dev. 5x5
Std. Dev. 7x7
Std. Dev. 9x9
Std. Dev. 11x11
Min. 3x3
Min. 5x5
Min. 7x7
Min. 9x9
Min. 11x11
Max. 3x3
Max. 5x5
Max. 7x7
Max. 9x9
Max. 11x11

Labels with reduced weighting from Almeida et. al. (2021)



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