# Automatic Detection of Stationary Waves in the Venus Atmosphere Using Deep Generative Models

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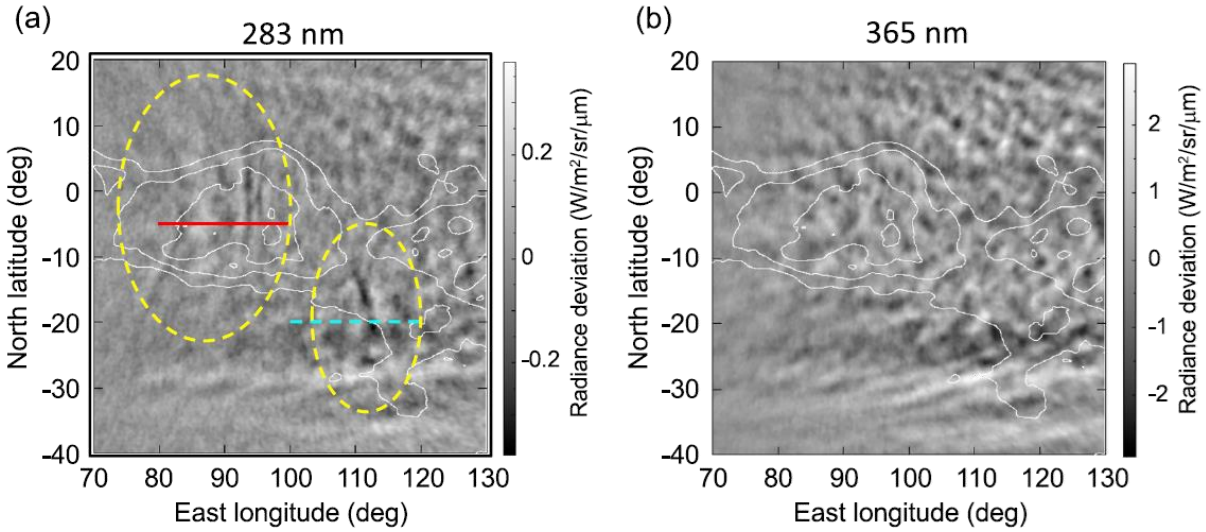
# Stationary features detected with Akatsuki observation

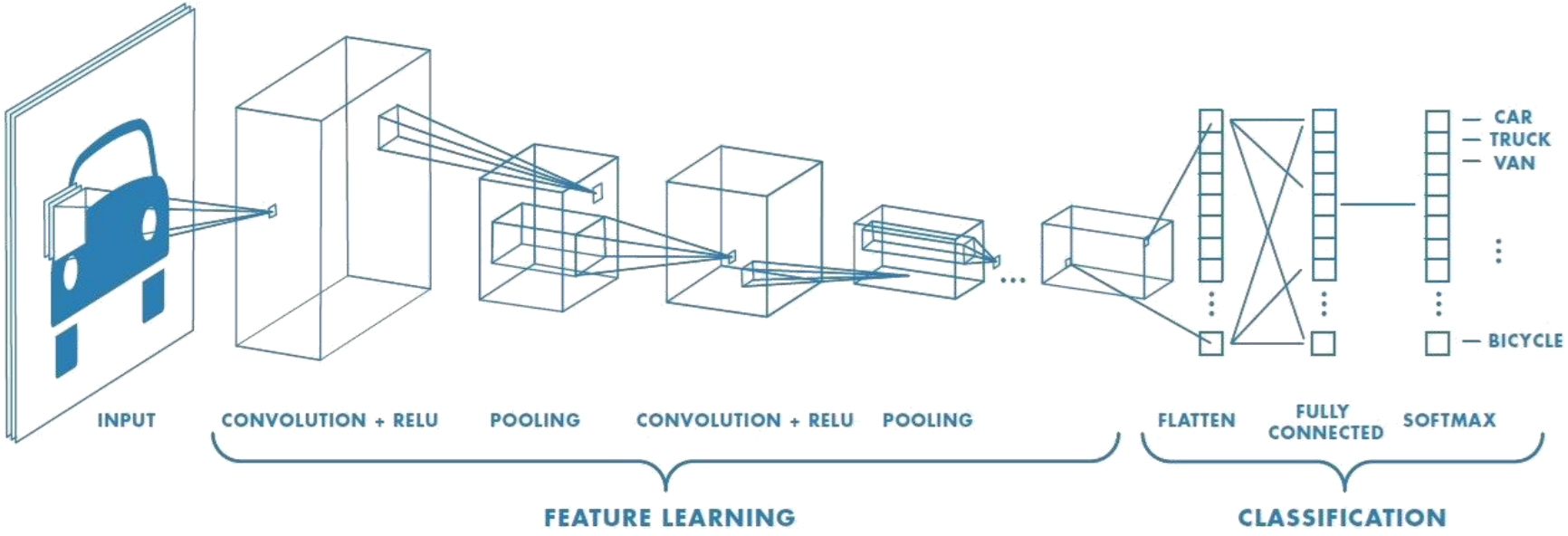
- Large bow-shaped structures observed by LIR and UVI
- Indicative of atmospheric gravity waves, significant in terms of the planet' atmospheric system
- Not a few features found so far … an automatic detection technique is needed




Examples of a stationary wave observed at (a) 283 nm and (b) 365 nm [Kitahara et al., 2019]

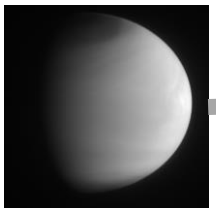
# Image recognition using deep learning

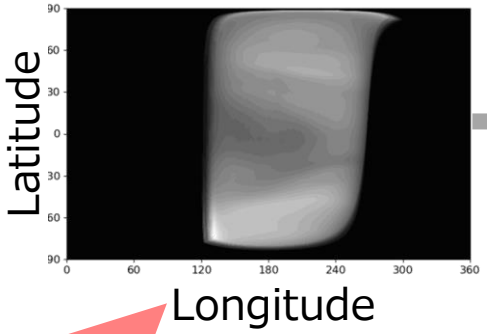
- Automatic, robust, and accurate




Example of classification task using deep learning
[Image from Towards Data Science HP]

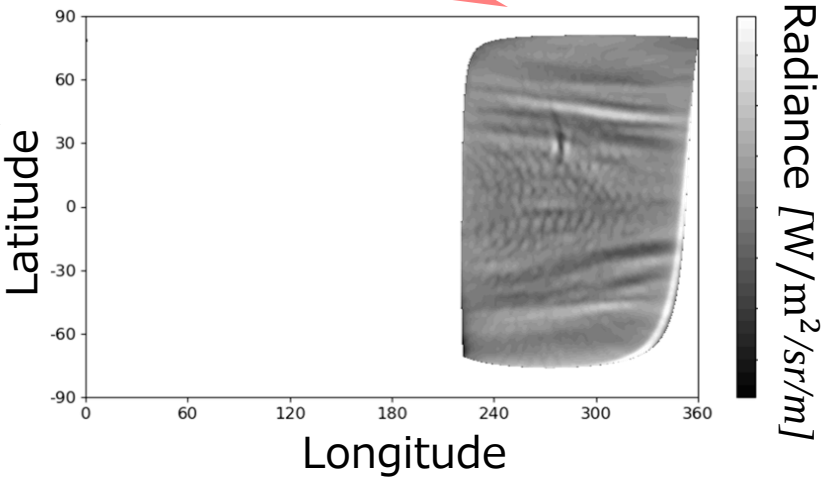
# Data preprocessing

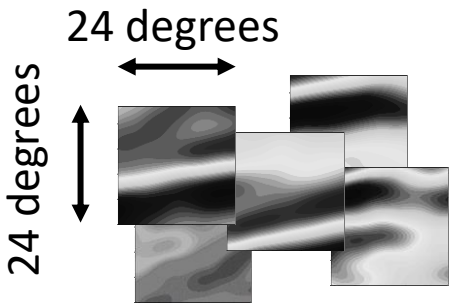





Averaging images taken successively in 24 hours

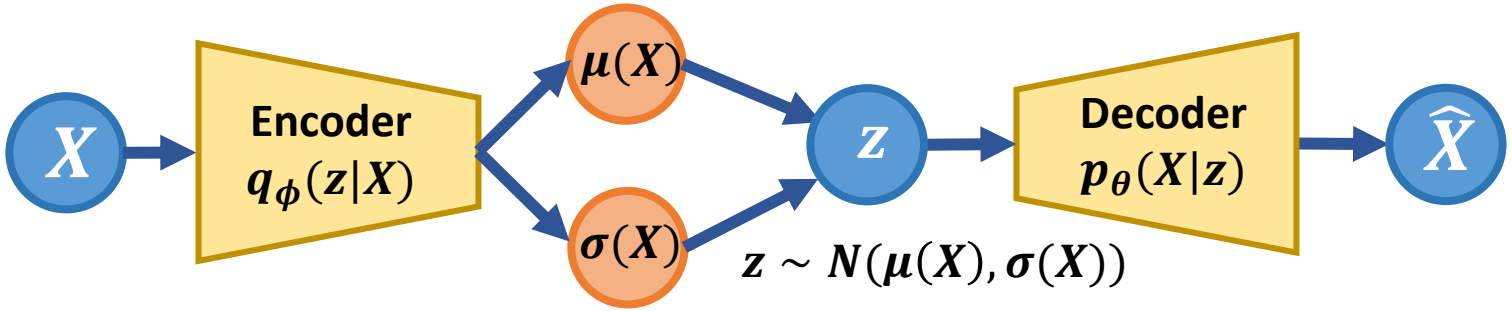
High-pass filtering ($\sigma_{x,y}$= 6° )




Make Image patches

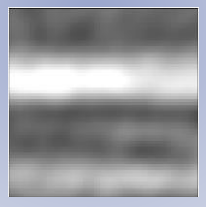
# Variational auto-encoder (VAE)



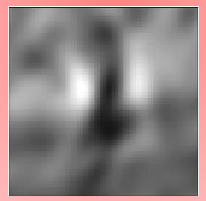

Advantages:

- Have good results in dimensionality reduction fields
- Well-known for an image reconstruction method

Normal class
(not stationary feature)

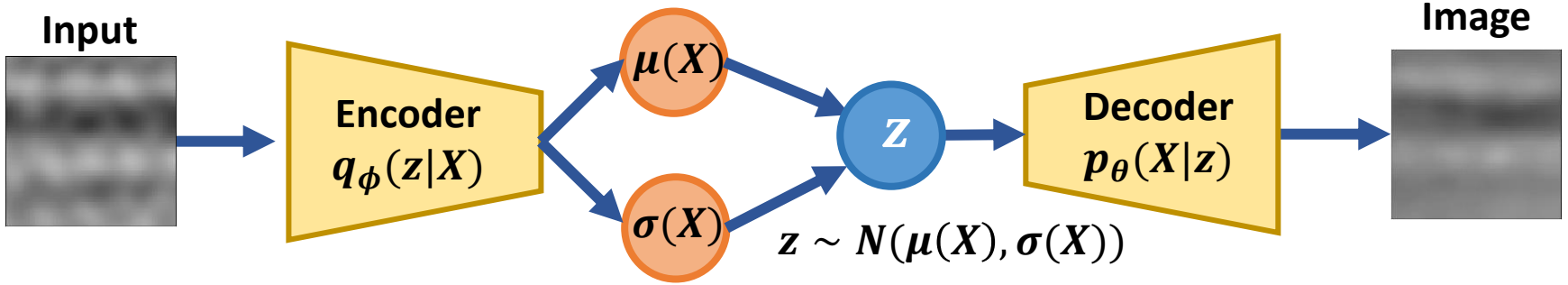


Anomaly class
(stationary feature)



# Overview of the system

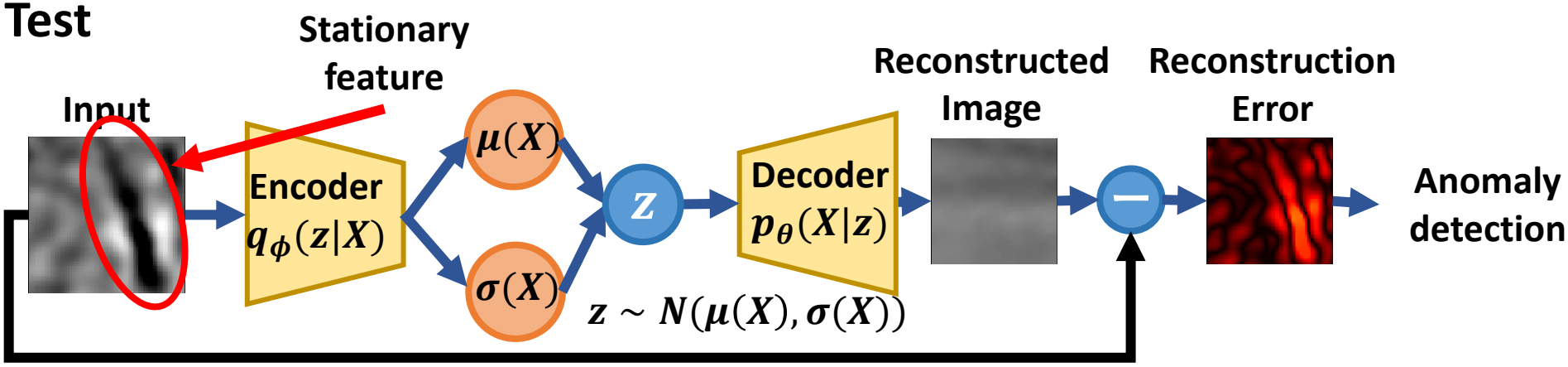
**Training**




Learn only from the normal class images

⇒**Extract the features of normal cloud structures**

**Test**




Evaluate using the test data including the normal class and anomaly classes

# Result

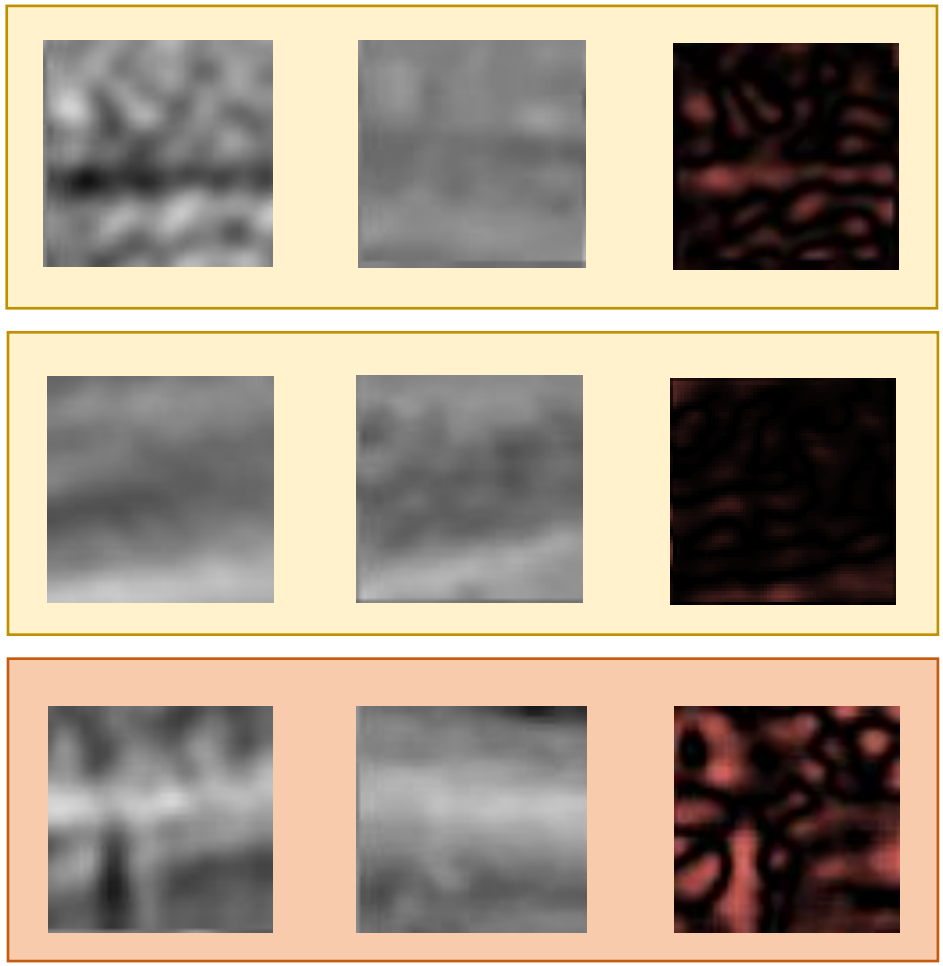
| | VAE-based |
|---|---|
| AUROC | 0.865 |
| Precision | 0.861 |
| Recall | 0.976 |

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

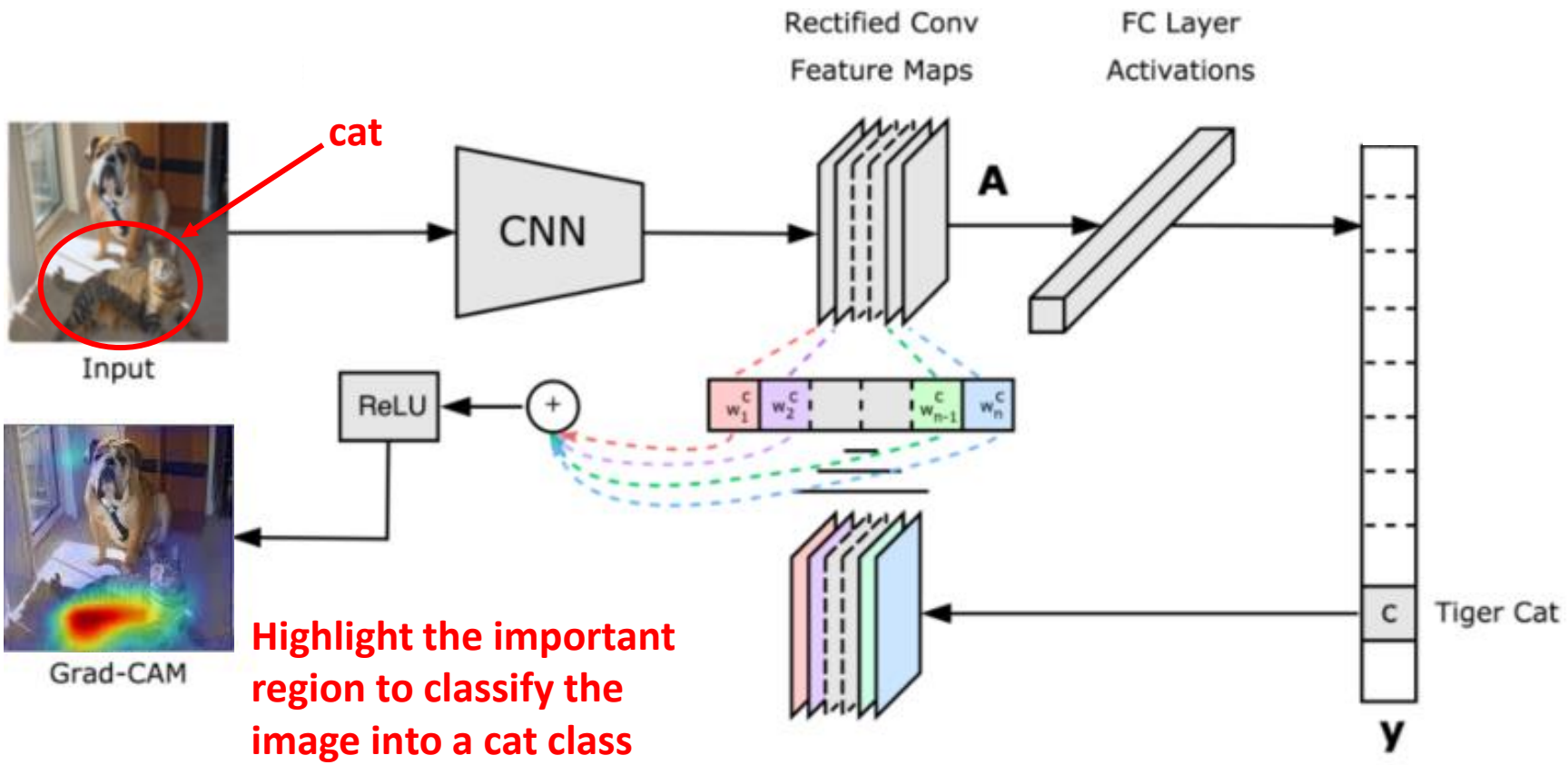
| Predicted \ Reality | | |
|---|---|---|
| | TP | FP |
| | FN | TN |

AUROC (Area under the ROC curve) …
$0 \leq x \leq 1$; 0.5 when the algorithm is random



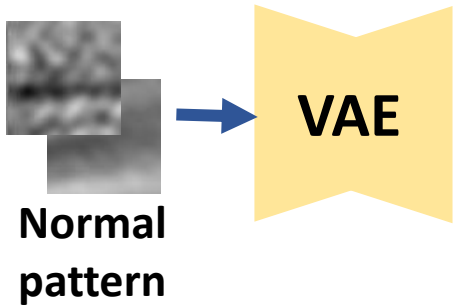
# Attention map (Grad-CAM)

- Attention method that visualizes the region where the neural network sees when classifying images

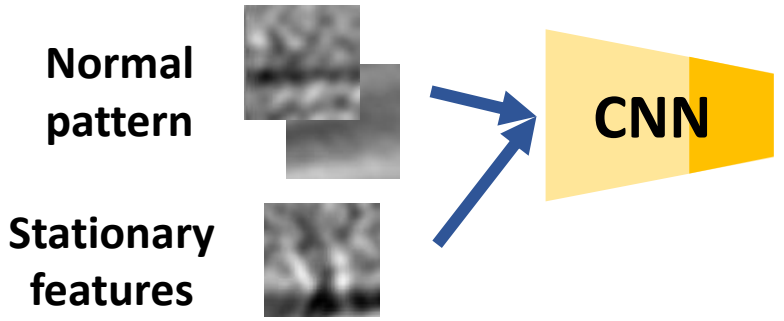


# VAE + Attention map

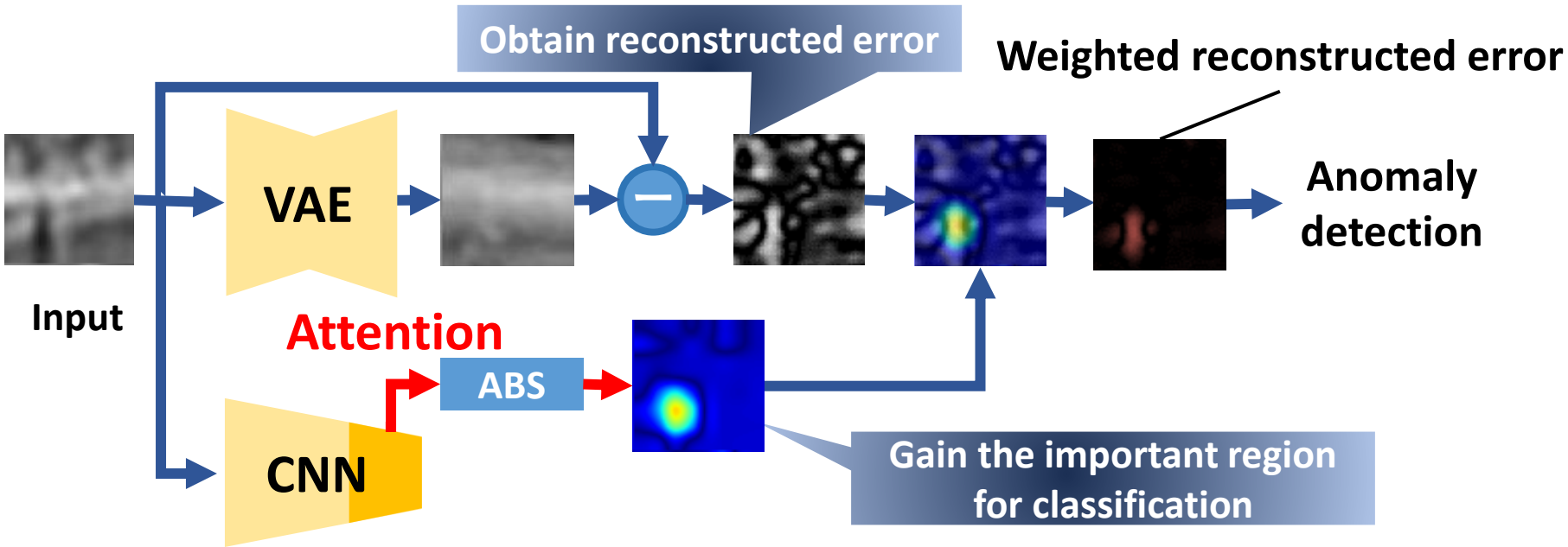
## 1. Train VAE



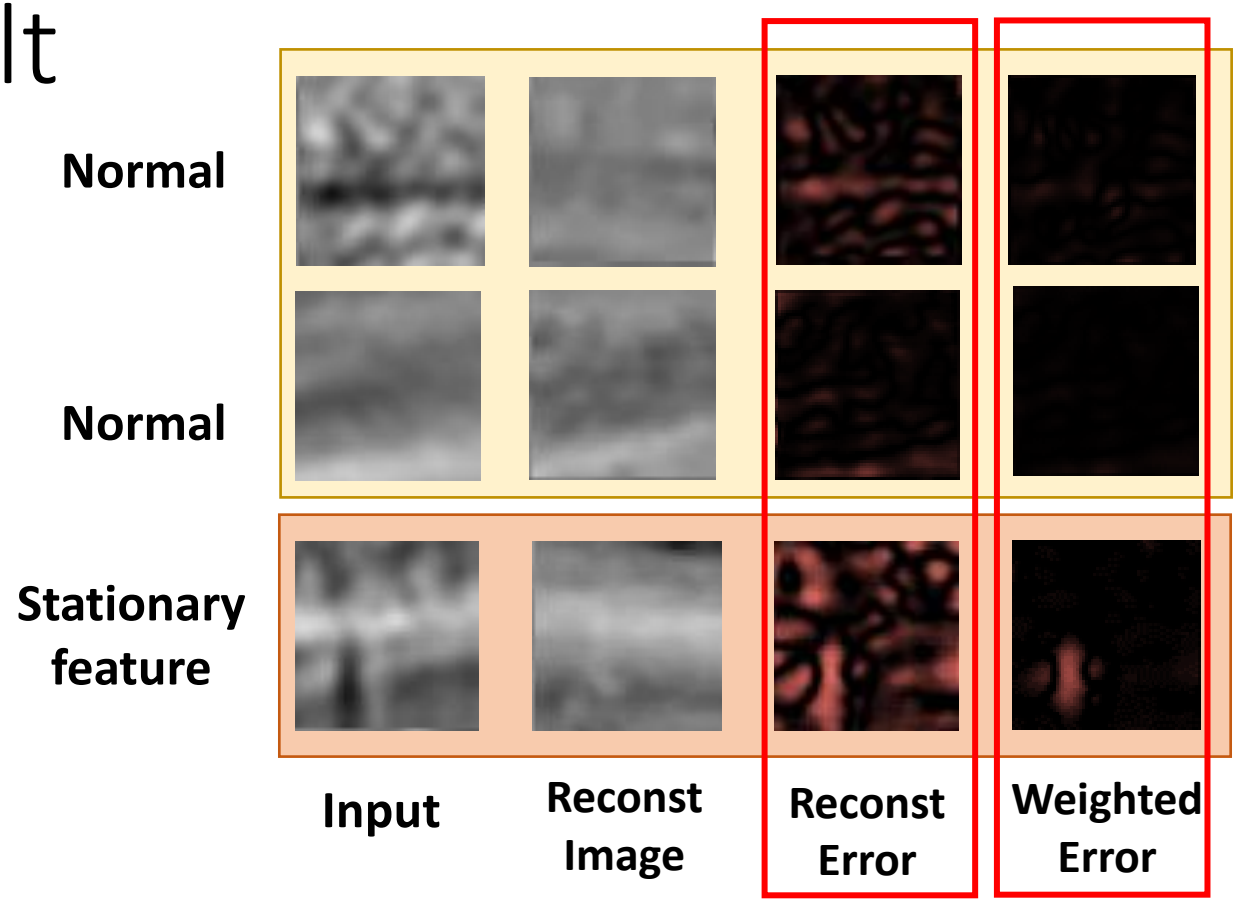

## 2. Train convolutional neural network




## 3. Test



# Result




| | AUROC |
|---|---|
| VAE-based[1] | .901 |
| CNN[2]-based | .865 |
| VAE + Attention | **.910** |

# Conclusion

- Automated detection of stationary features seen in UVI
- Using attention maps to focus on the important region further improved the accuracy