THE NORTHERNMOST UNIVERSITY
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Detection of different phases of water on a wind turbine blade using a NIR camera and three IR wavelengths

Lavan Kumar Eppanapelli, Johan Casselgren and Sara Rosendahl
Luleå university of technology, Sweden

LULEÅ UNIVERSITY OF TECHNOLOGY

Applications of a ice/snow detection system

- To investigate the phases of water in order to control the de-icing system of a wind turbine.
- To measure and understand the physical characteristics of different phases of water.
- To mitigate wind turbine production losses due to ice accretion.
- To design loading conditions on the wind turbine blades.
- To model ice aggregation on the blades.

Our approach

- Results of the previous research at LTU is a technique, where near infrared (NIR) light is used to easily classify different phases of water on roadways and railroad tracks.
- The same technique is applied for a case of investigating the phases of water on a piece of wind turbine blade
- Three wavelengths (980nm, 1310nm and 1550nm) have been used and 7 different phases of water samples have been investigated.
- To simulate a real environment with disturbing light source, the sun, a halogen light is also used along with the NIR light to observe the applicability of the setup.

Absorption rate

- The scattering results in spectral response from each of the phases of water and a dry blade has a specific absorption rate for different wavelengths.
- Based on the absorption properties and previous research, it is possible to classify the different conditions.

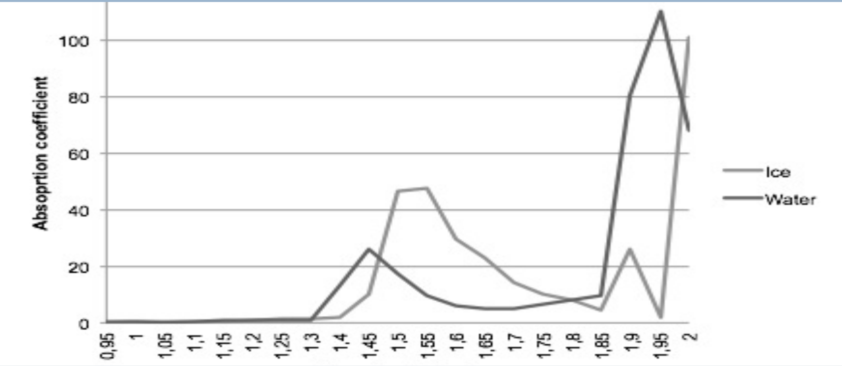


Fig.1. Illustration of absorption rate of ice and water at various wavelengths *(From W. M. Irvine and J. B. Pollack, "Infrared optical properties of water and ice spheres", Icarus , vol. 8, no. 2, pp. 324{360, 1968.)*

Experiment

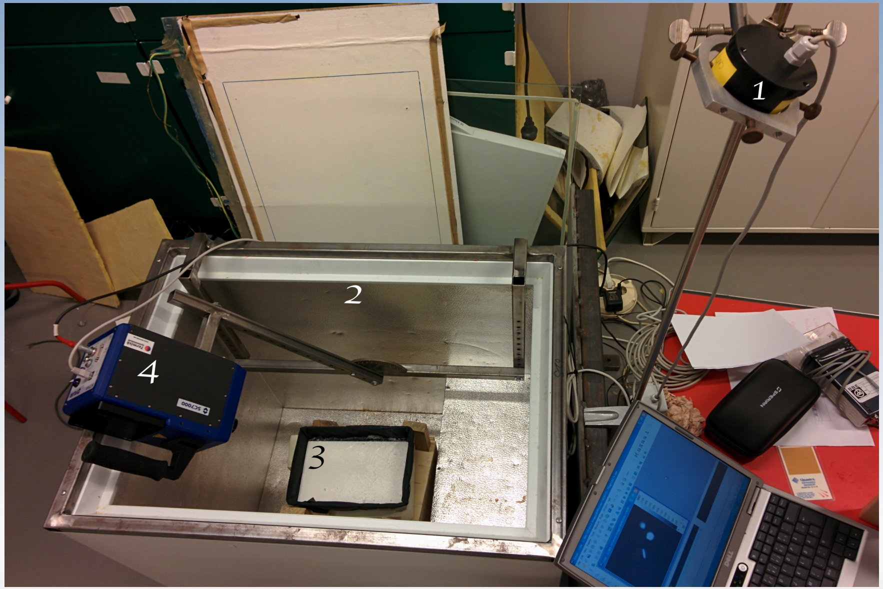


Fig.2. Experimental setup includes an illumination source(1), freezer(2), a piece of wing(3) and a NIR camera(4)

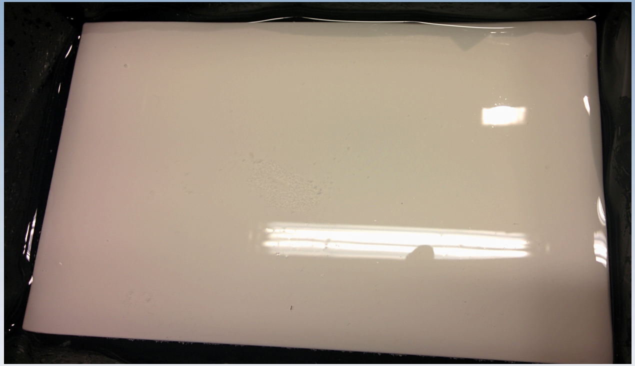
- The integration time of the camera was set at 10 ms for all the experiments.
- The temperature of the freezer is maintained around -10°C.
- The focal number of imaging was kept fixed at f/1.4, where f is the focal length.

Samples

Moist

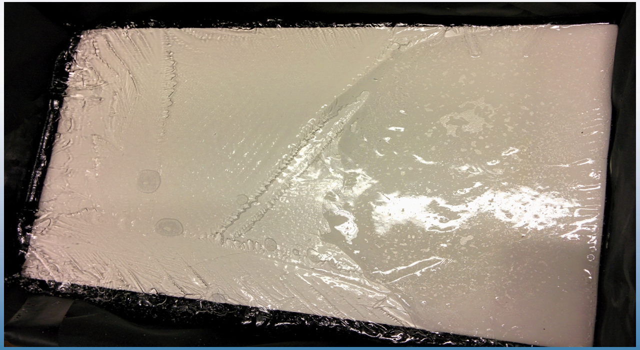
Frozen moist

Wet



Ice water

Ice air



Clear ice

Road eye | Road eye+ Halogen | Halogen

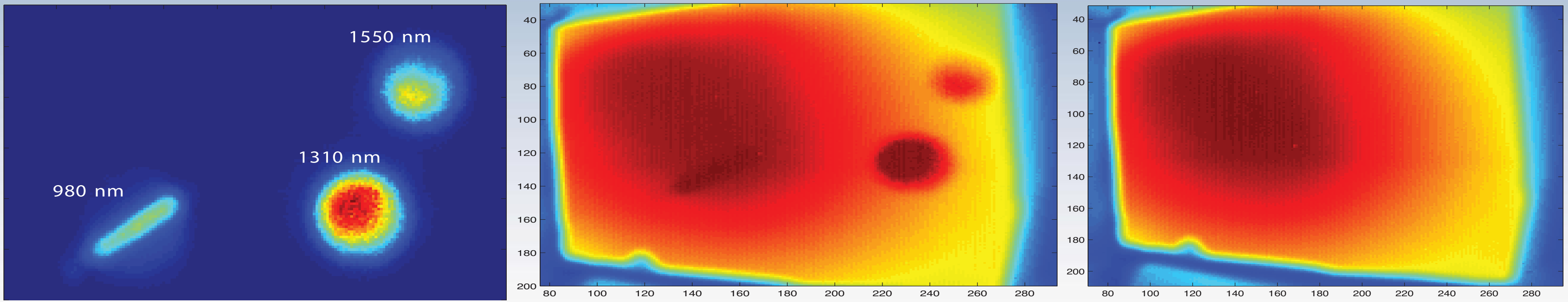


Fig.3. Raw images of scattered light on the dry wing

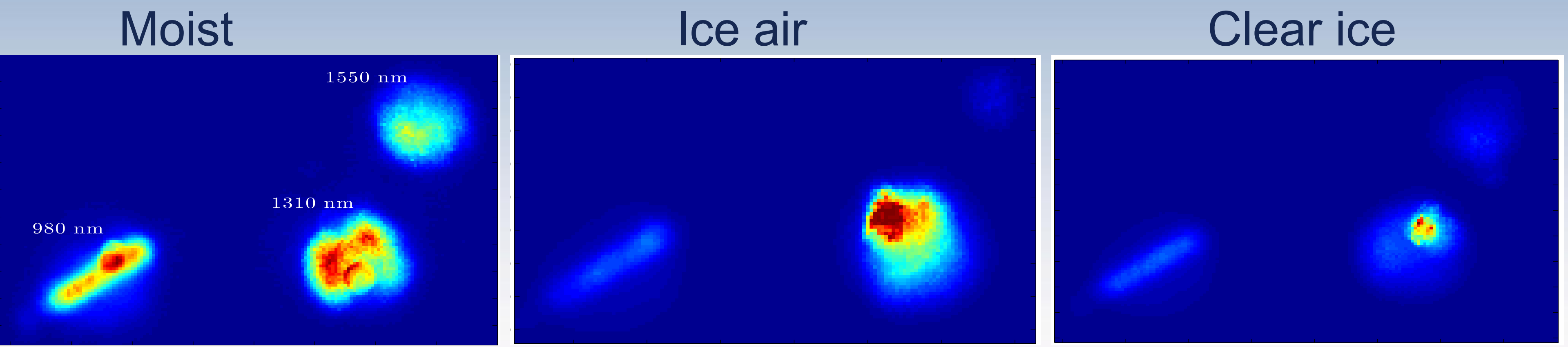


Fig.4. More raw images of captured Road eye signal in the dark

Analysis

- Each image is normalized with the respective white paper measurements to have more stable reading of signal from Road eye.
- To simulate the method in a real life environment a technique is developed that take one picture of Road eye with the background light which is then subtracted from the picture with only halogen light. The result should be close to the measurements of Road eye in the dark.
- Results of the scattered light from each wavelength for a specific phase of water, are later converted into a RGB matrix for visual classification.

Real environment case

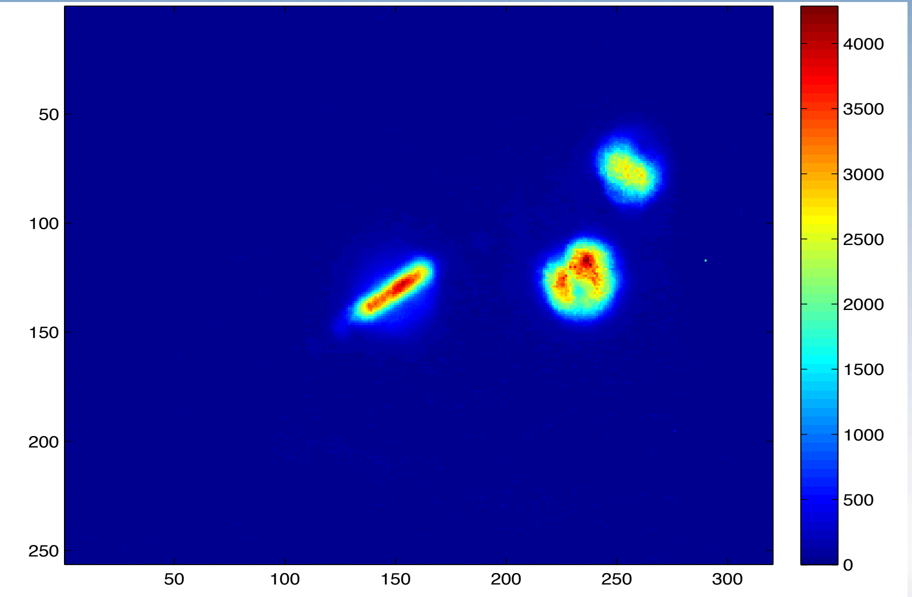


Fig.5(a). Road eye signal in the dark

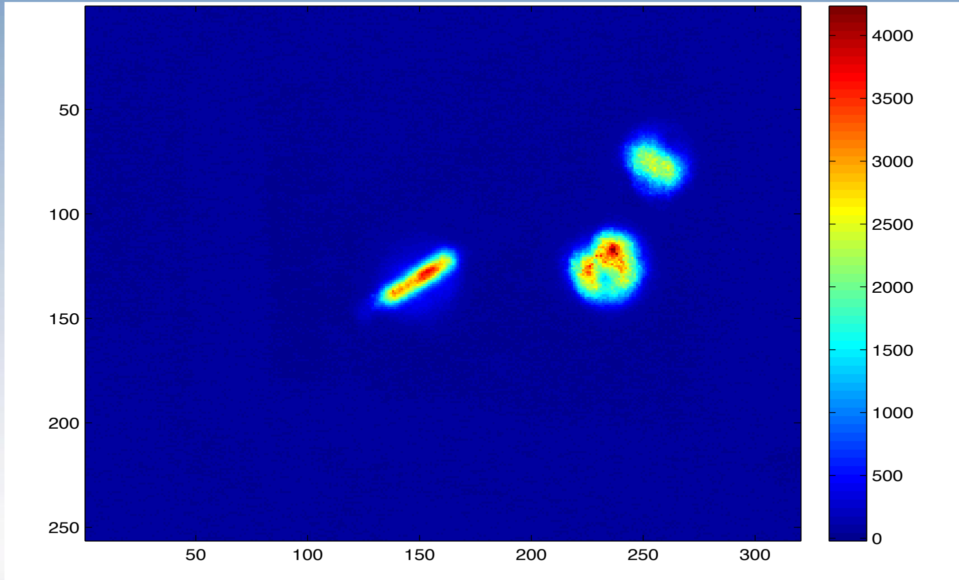


Fig.5(b). Road eye signal when the background halogen light is manually subtracted

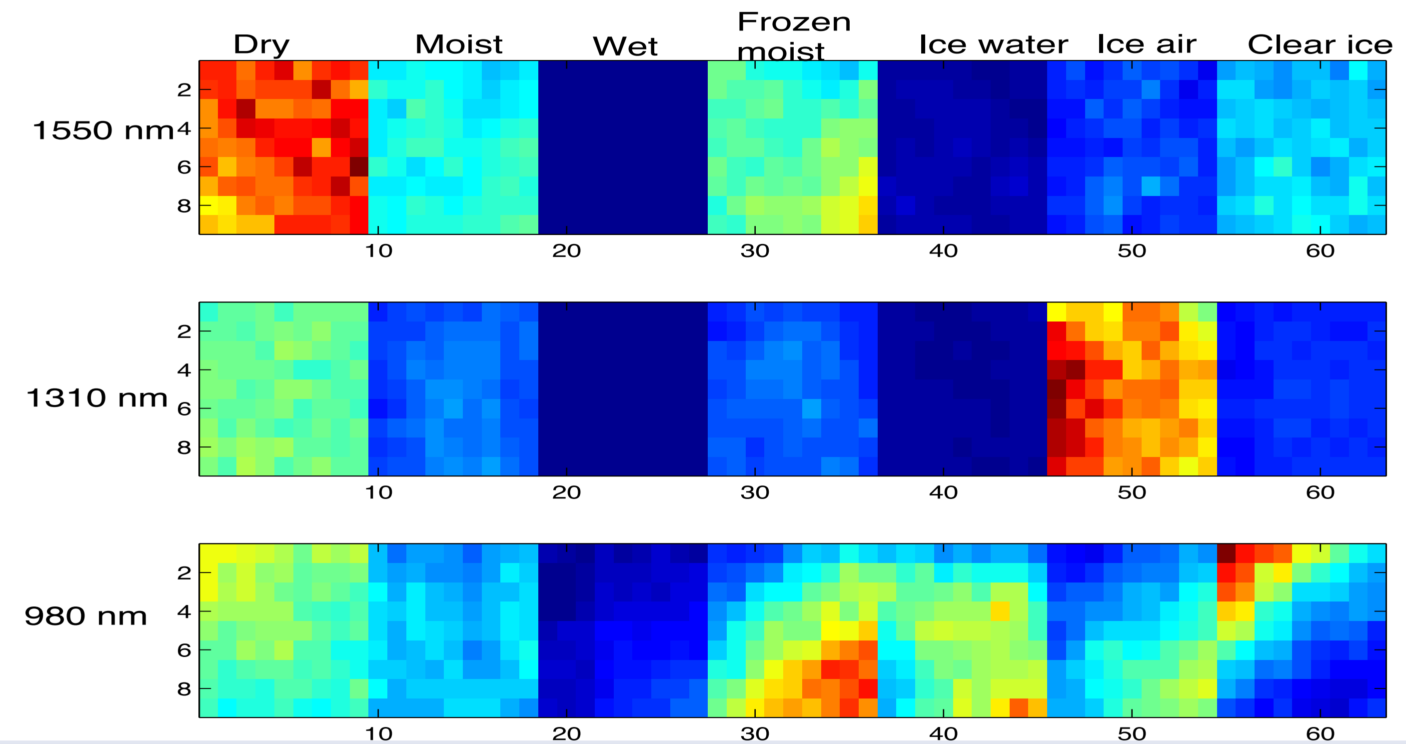


Fig.6. Illustration of images from Road eye at all the wavelengths after normalization

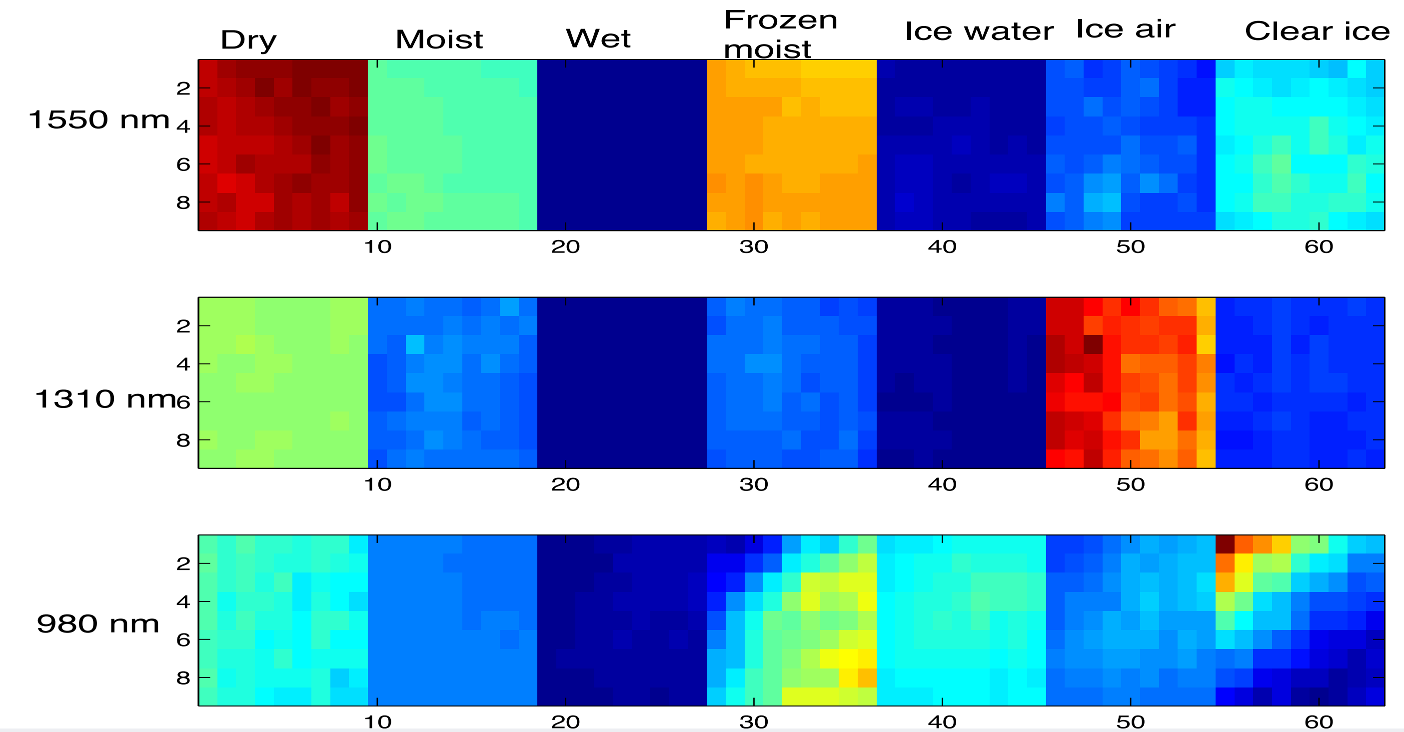


Fig.7. Illustration of images at all the wavelengths. Signals from Road eye when background light is subtracted, are calibrated manually to equalize the camera saturation

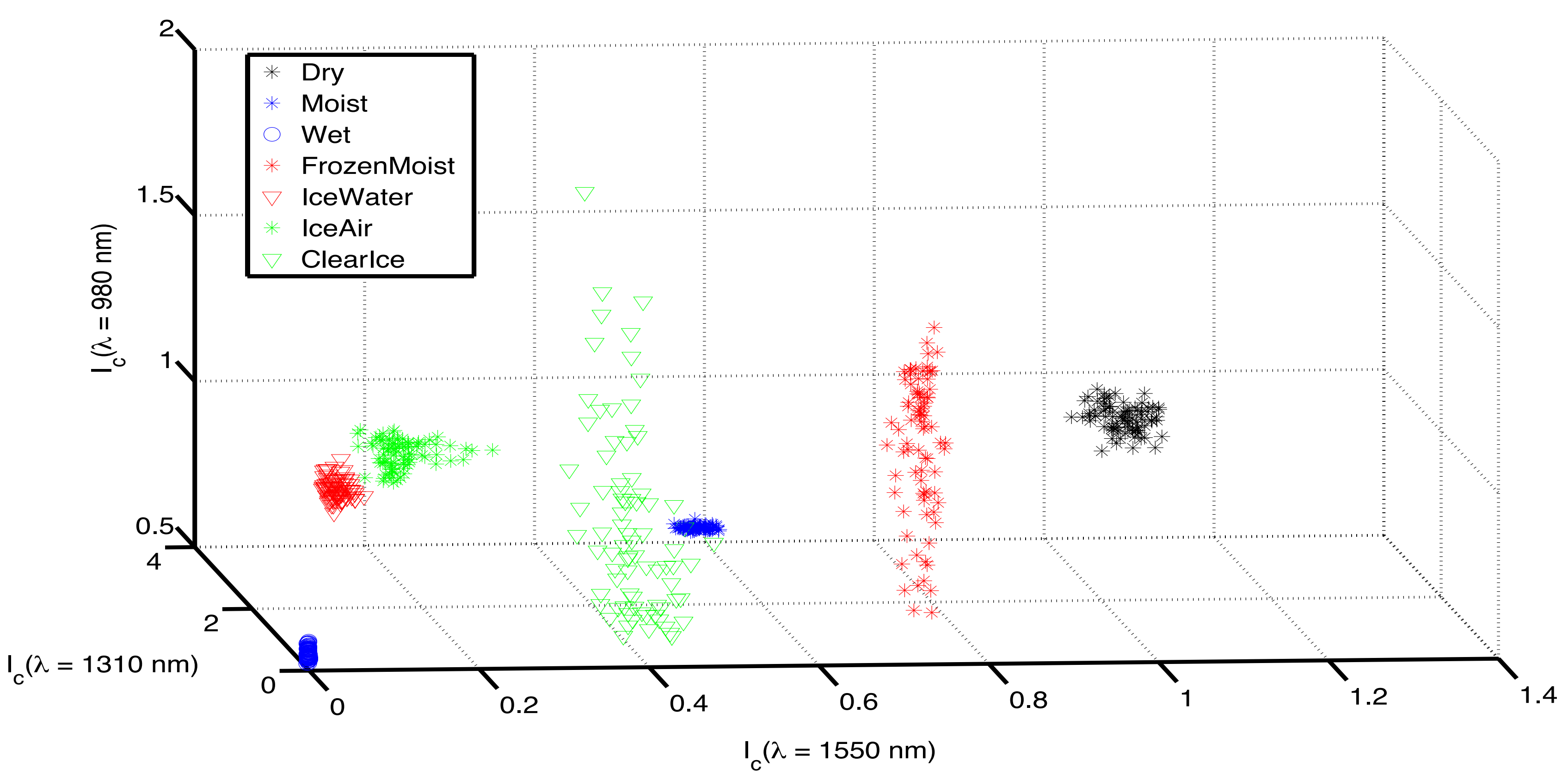


Fig.8. 3D-plot of the classification of phases of water, in the case of Road eye when background light is subtracted

Fig.9. Visualization of classification based on RGB concept. These results are from Road eye when background light is subtracted

- Results from 3 wavelengths are converted into a RGB matrix as shown in Fig.9.
- One can understand from Fig.8 that our approach is good enough in classifying different phases of water on a piece of wind turbine blade.

Conclusions

- It is possible to classify different phases of water on a wind turbine blade using our approach.
- The visualization of classification based on RGB concept, shows that the outcomes from the experiments are promising.
- Our approach also gives a possibility to understand the physical characteristics of ice and water, which can be useful to simulate the ice build up on the blade.
- Our approach/technique is simple and easy to implement.

Future works

- We plan to test this technique on a small wind turbine at LTU, to extend the detection on a full length blade.
- Further research is needed to, have the results without any manual calibration techniques.
- More snow samples can also be investigated further along with wet and icy surface.
- Long-distance measurements (example: 15m) should also be considered, before taking the set up to a small wind turbine to investigate the essential complications with respect to the short-distance measurements.