Analysing high resolution digital Mars images using machine learning

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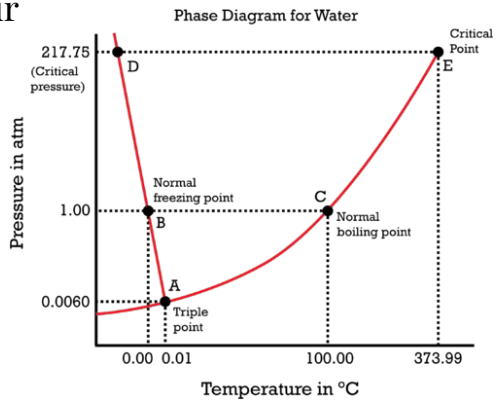
Introduction

- Can Martian water ice remain in warmer temperatures?
- low thermal conductivity of the Martian surface and atmosphere
  - during the recession of the seasonal ice cap, small water ice patches might be left behind
    - these might warm up substantially when direct sunlight hits them during spring
      - melting emerges as a possibility

- melting point of water ice on Mars is 273 K, while it's stable temperature is around 200 K
  - water ice sublimates away as temperature rises
  - in theory, if the temperature rise is quick enough, melting might occur



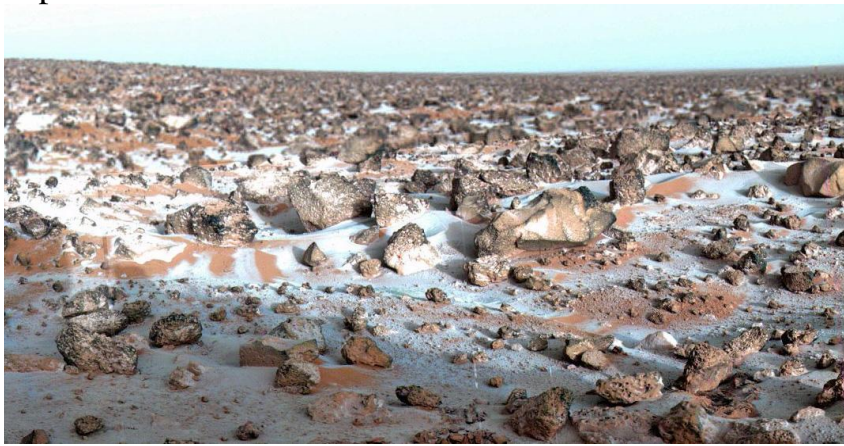
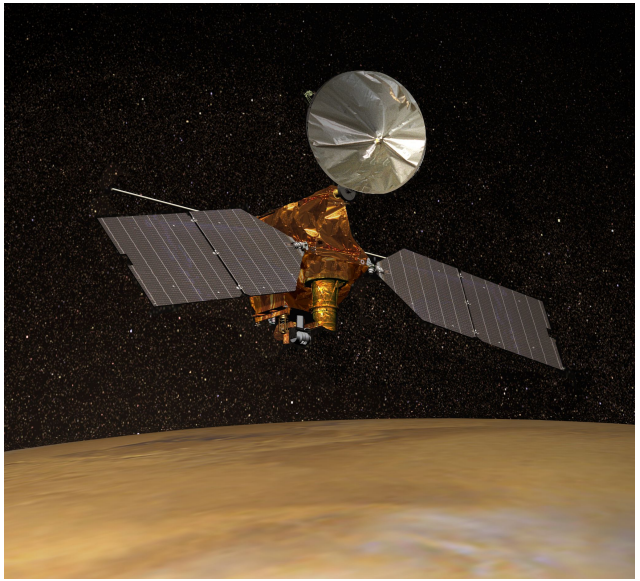


Image of Martian frost taken by the Viking 2 Lander in 1979 (44.57° N)

Methods (Mira A. Gergácz and Ákos Keresztúri, arXiv:2212.02166)

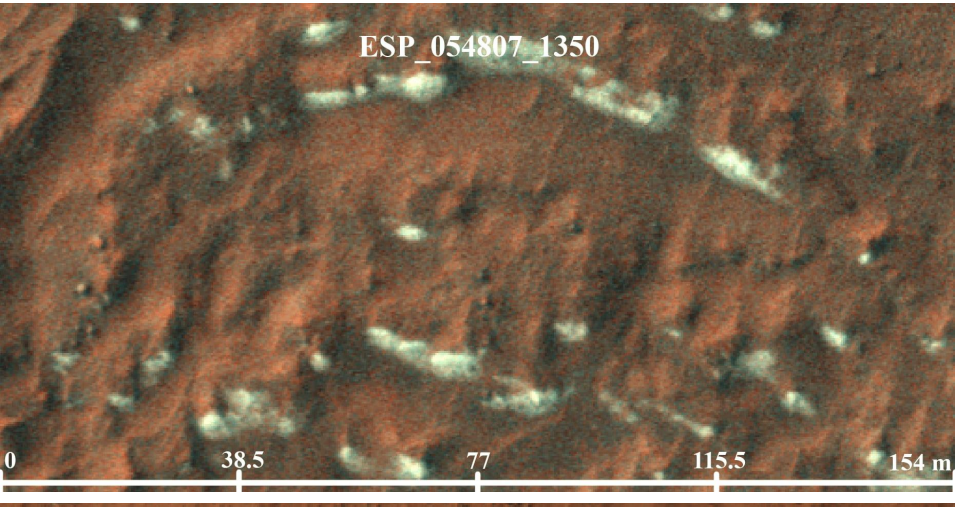
- images taken by the HiRISE camera on board the Mars Reconnaissance Orbiter
  - 0.3 m/pixel resolution
- on the southern hemisphere 110 images analyzed out of the 1400 available ones that fit the selection criteria
  - 37 images with smaller ice patches on them identified
- images were analyzed manually
- separation from other bright patches were possible by their strong connection to the local topographic shading and colour

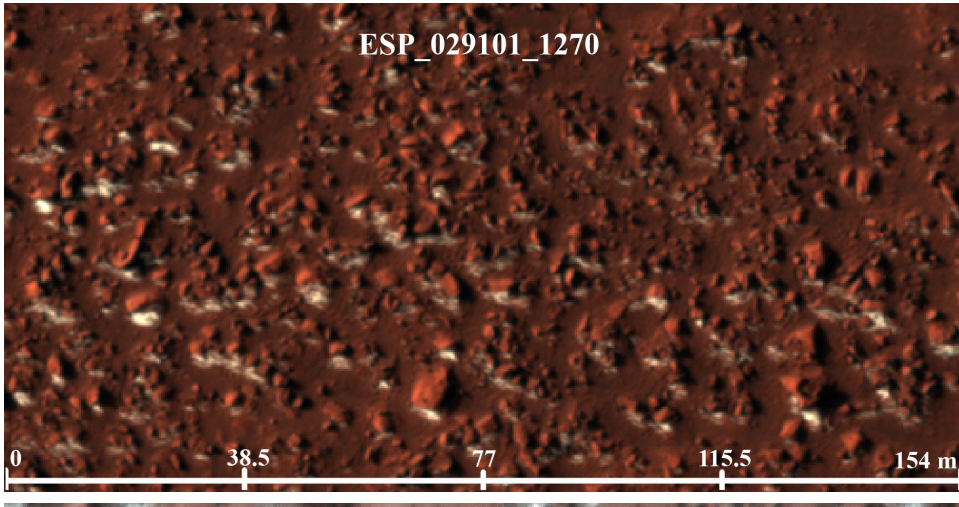
- using simulations with the help of The Mars Climate Database (MCD)
  - average noon temperatures
    - gives information generally on the area
    - not suitable for detecting small temperature fluctuations
  - predicted CO_2 and H_2O ice coverage

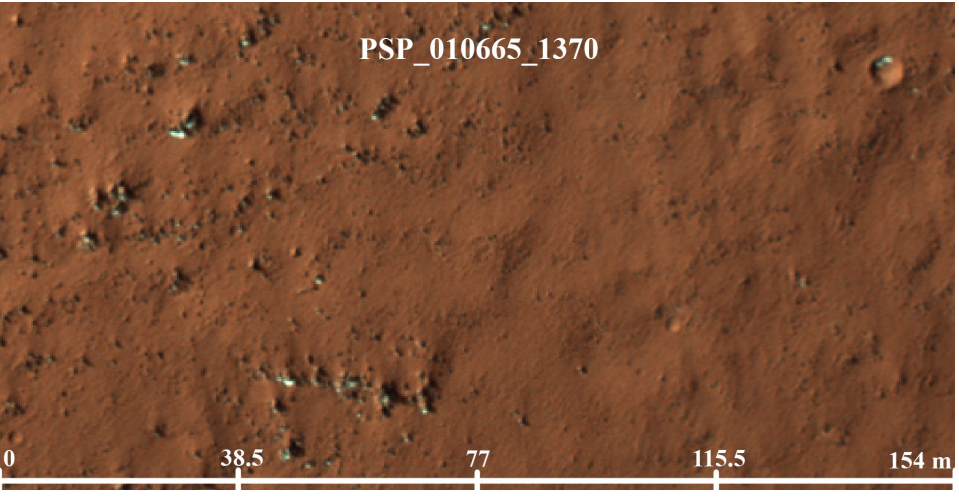


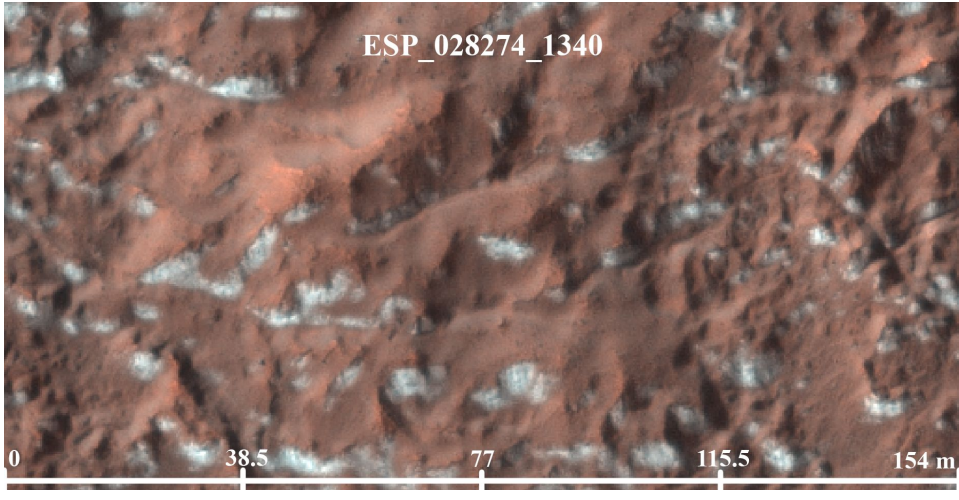
Mars Reconnaissance Orbiter with the HiRISE camera on board (source: NASA)

Typical HiRISE Images with Ice





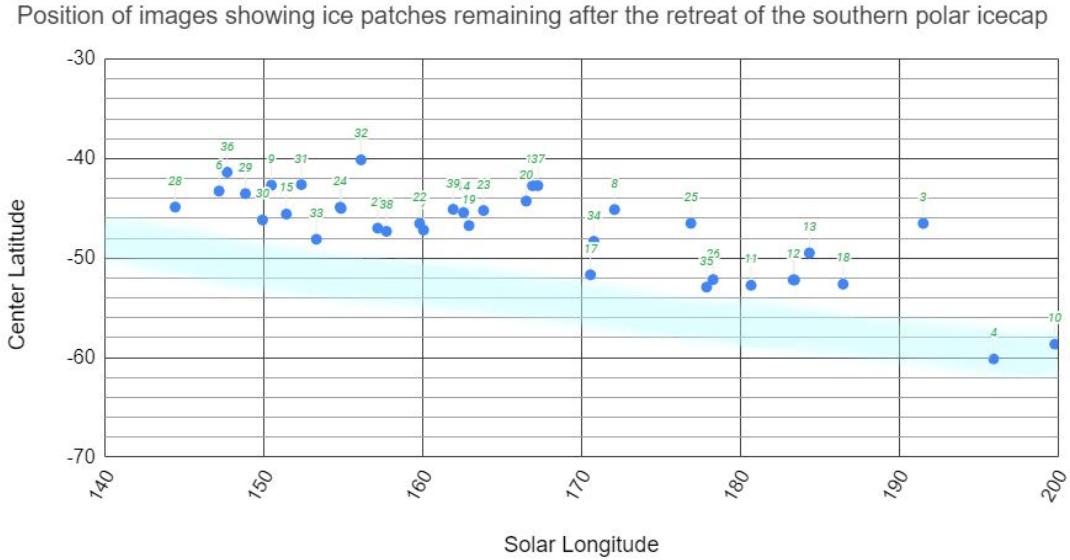




First Results (arXiv:2212.02166)

- ice patches are distinguishable from other bright areas on HiRISE images
- remnant ice patches range between Ls=140°-200° in the latitude band between -40° and -60°
- they remain for the duration range of 19-133 Martian days

- judging by the temperature simulations, the occurrence of liquid water on the macroscopic scale is highly unlikely
- however an interfacial premelting of ice might form
  - a few nanometer thick waterlayer
  - if it emerges it might influence low temperature chemical changes on Mars



Distribution of images of ice patches that meet the criteria follow the width averaged TES (Thermal Emission Spectrometer) Crocus line of the retreating CO_2 ice cap

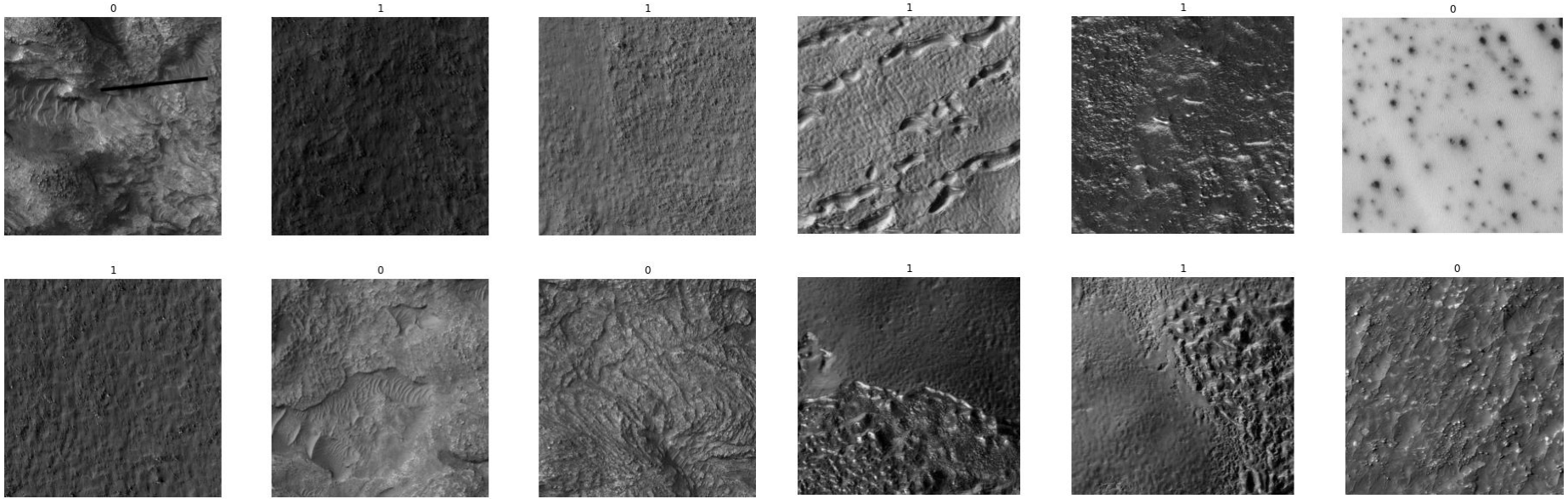
Using a Neural Network

- the problem is similar to the cat-dog case, we have two types of images that we want to distinguish between
  - images that show small icy patches
  - images that show none
- HiRISE images of these two types need to be collected and organized into two groups
  - the program will learn the difference between the two group and will be able to recognise ice patches on images it has not seen before

- it'll becomes a realistic goal to analyse all available surface images
  - automatized search for ice patches
  - time efficient
- more throughout
  - a CNN might be more effective in identifying ice in black and white images
  - scans the whole image, no ice patch goes undetected

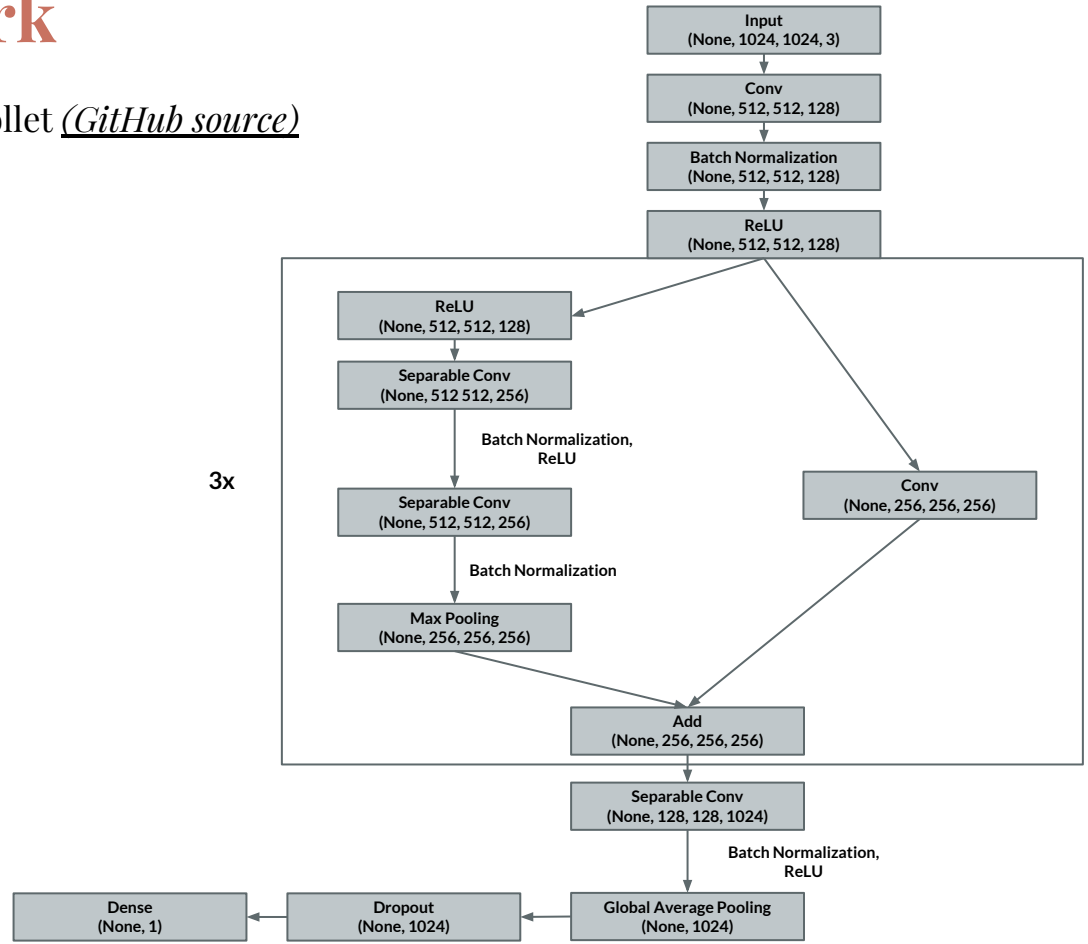
Preparation of Data

- increasing the dataset
  - out of the 110 analyzed images 34 is used for training
  - each cut into hundreds of chunks, creating over 6000 images
    - 42% of the images have small icy patches on them
    - the rest shows none or CO_2 ice sublimation on the surface
  - image size is 1024 x 1024 since the surroundings can be important



The Deep Neural Network

- small version of a Xception network by fchollet *(GitHub source)*
- batch size of 30
- 25 epochs
- 0.5 dropout
- 20% of images used for validation
- Adam optimizer
- 2.7 million trainable parameters



Summary

- the data has been uniformized
- dataset expanded to a sufficient size
- what's next:
  - training the model
  - testing

Thank you for your attention!

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