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Exploring the diversity in pyroclastic deposits and volcanic vents on Mercury with deep learning techniques

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Introduction

Evidences of **explosive volcanism** (vents, pyroclastic deposits) have been identified in Mercury (Head et al. 2008, Goudge et al. 2014, Jozwiak et al. 2018)

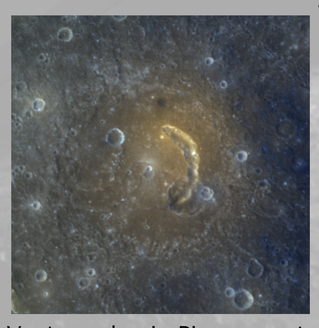
Unkowns

For each vent
- Age
- Source of activity
- Composition

Challenges

→ Variety of features in
- Morphology
- Shape
- Location, distribution
- Spectral properties

→ Large amount of data



Vent overlap in Picasso crater MDIS 11 filters

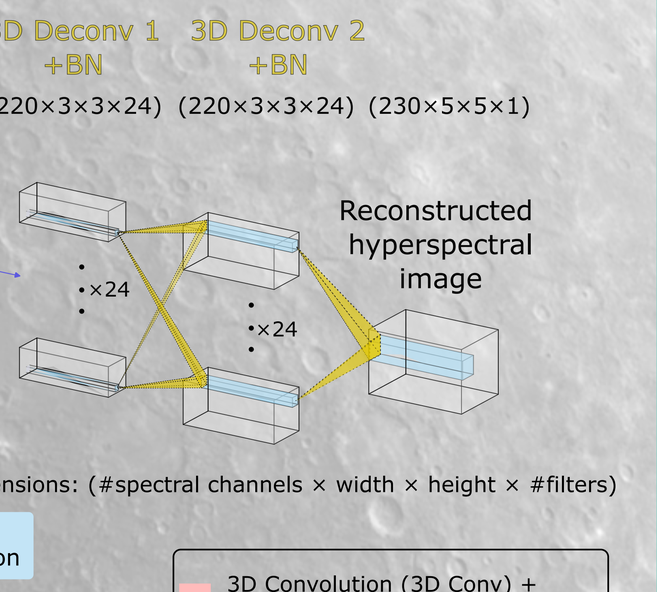
Objective

Apply Deep Learning to:
- Analyse spectral/spatial data
- Find underlying patterns
- Classify vents/deposits
- Find new vents/deposits

Methodology

Pre-processing

1. Obtain MASCS data from MeSS database
2. Filter footprints by area and quality
3. Process hyperspectral images



Post-processing

1. Cluster HSI based on latent representation
2. Re-construct cluster spectra
3. Analyse filters
4. Characterise vents and find new features

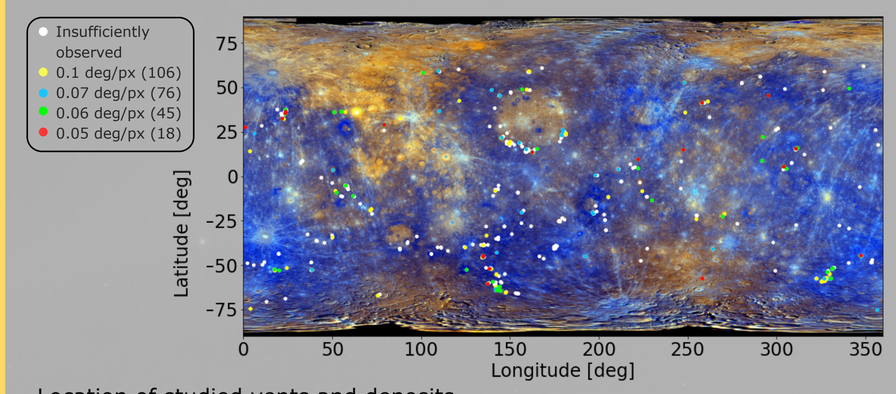
Data

- MESSENGER/MASCS reflectance spectra
- 404 vents/pyroclastic deposits
- 380,000 footprints

1 Data retrieved from **MeSS**, a relational database containing the reflectance spectra from MASCS instrument, associated measurement conditions and footprint area

2 Filtered for

- Footprint area < 25 km^2
- Sensor temperature < 40 °C
- Emission angle < 80 deg
- Incidence angle < 75 deg



Location of studied vents and deposits

Deep Learning Architecture

Training parameters
- Number of convolutional layers
- Number of latent dimentions
- Number of training epochs
- Number of filters ...

Model parameters
- Pixel resolution
- Patch size
- Number of clusters

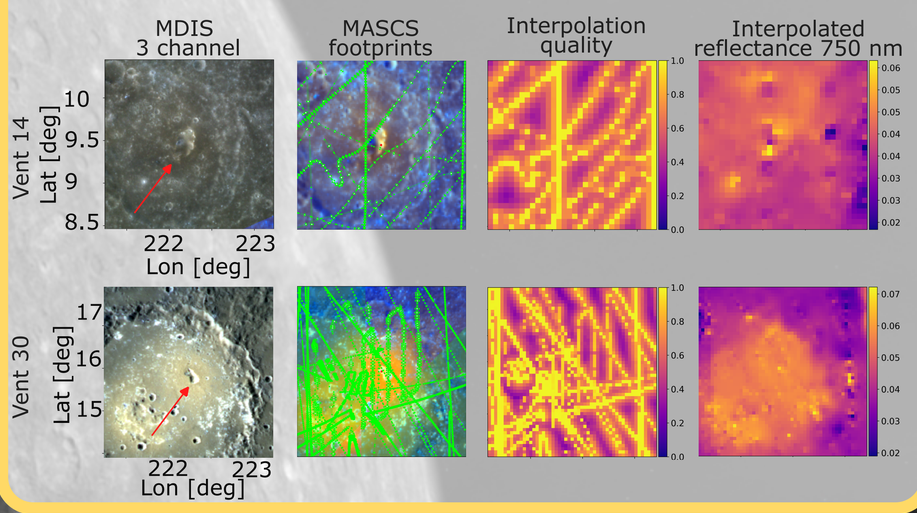
...

3D Convolution (3D Conv) + Batch Normalisation (BN)
3D Max Pooling
3D Deconvolution (3D Deconv) + Batch Normalisation (BN)
Reshape

Hyperspectral image processing

3 Process individual measurement footprints into a grid

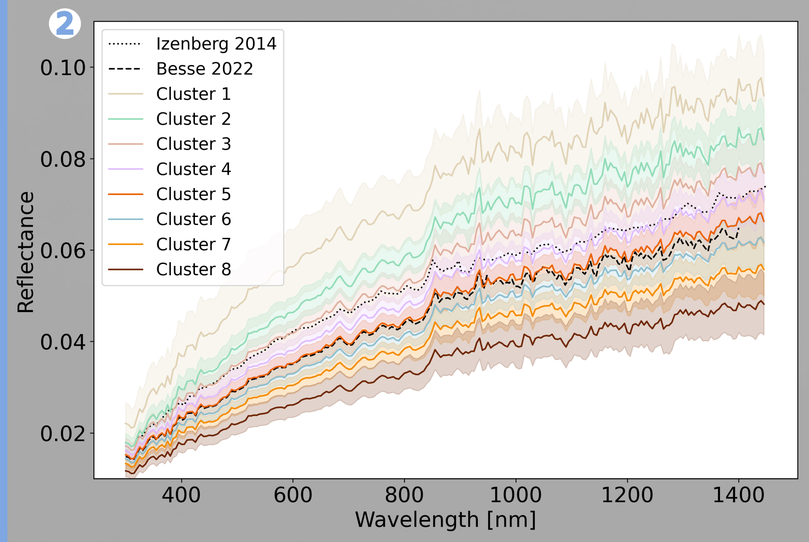
Method: Modified inverse distance weighted interpolation
Criteria: Distance to grid point and footprint area
Evaluation: Interpolation quality determined by the number, distance to the grid point and footprint area of the measurements used for each grid element
Output: 230 channels image of each vent/deposit



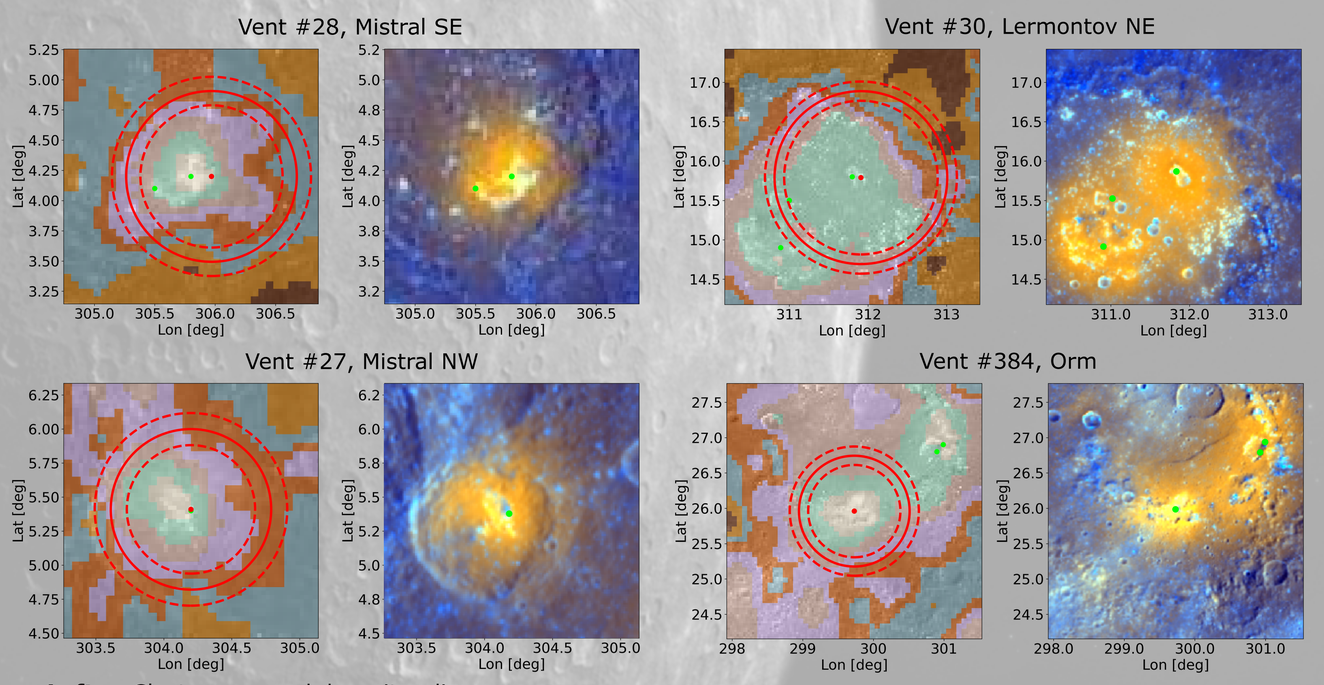
Results

1 From the reduced latent representation, each pixel in the hyperspectral image is classified into a cluster. The spectra of each cluster is reconstructed, revealing that:

- The mean spectra of each cluster presents a decreasing trend in slope, reflectance and curvature
- Clusters spectra overlap ⟶ spatial dimension
- Clusters tend to extend concentrically and sequentially from the vent center with an irregular outline, decreasing in cluster number
- The central cluster (closer to the vent) is not necessarily cluster #1: different types of deposits (e.g., vent #30, Lermontov NE)
- The "cluster rings" change in size and dispersion rate between deposits



Mean reflectance spectra of each cluster ± 1σ



Left: Cluster map and deposit radius
Right: Enhanced color image :R = PCA 2 component, G = PCA 1 component, B =430/1000 nm reflectance
Deposit perimeter ± 1σ (Barraud et al. 2021)
Vent location

Discussion 3 4

Clusters are not only defined by spectral properties, but also include spatial information. From a comparison with previously defined deposit radius (Barraud et al. 2021), the extent of the deposit is delimited by clusters 1 — 4, without imposing any constraints on the shape. Analysing the size and layer dispersion of the clusters around each vent can provide insight in studying:

- Deposit age
- Relation with morphology
- Formation process
- Mixing with underlying terrain

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