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Detection of ice core particles via deep neural networks

Content

Insoluble particles in ice cores carry signatures of the Earth past climate and have a primary role as geochronological markers. Their analytical detection often relies on intensive manual microscopic investigations and a series of pre-processing steps that limit the number of investigated samples. We present an analytical framework based on Flow Imaging Microscopy that allows a continuous stream of meltwater to be imaged by an optical camera. The result of the acquisition is a continuous collection of particle digital images. The system is coupled to a Deep Neural Network classification model aimed at autonomously differentiating and counting different types of particles, following a supervised-learning approach. We train the model to recognize the following types of particles: mineral dust, volcanic ash (Felsic and Basaltic) and 3 types of pollen (Corylus Avellana, Quercus Robur, Quercus Suber). The trained model achieves an overall 96% classification accuracy across all categories. The developed system can confidently distinguish fine-sized dust and has a detection limit of 10 ppb. It is thus an effective alternative to laser or electric-based dust detectors with the advantage of being sensitive to the particle type. Investigation on pollen samples reveals that the two Quercus species can be classified with 90-95% accuracy while Corylus Avellana can be classified with 98-99% accuracy. The size and representativeness of the pollen training datasets is found to be of critical importance. We tested our system on a few selected Greenland ice core samples containing known volcanic horizons. The model can identify tephra shards alongside a mix of volcanic-looking minerals, possibly quartz and feldspar. Analyses of the Quelccaya ice core samples reveal the presence of freshwater lake diatoms, advocating the possibility of extending the model to automatically identify other types of particles by providing specific training datasets. The system requires a few hundreds of µL, accepts particles from 1-2 to 80 µm, is non-destructive and can operate in series with other detectors in continuous-flow melting systems. Its employment can cut down processing time and costs, assists humans in bench microscopy investigations and unlocks so far unexplored analyses of ice core impurities. The framework and the model advantages and limitations will be discussed alongside suggested modifications for future improvements.

Primary author: MAFFEZZOLI, Niccolo (University of Venice)

Co-authors: STØREN, Eivind Wilhelm Nagel (University of Bergen); VAN DER BILT, Willem G.M (University of Bergen); COOK, Eliza (Centre for Ice and Climate, Niels Bohr Institute, University of Copenhagen); FESTI, Daniela (Austrian Academy of Sciences, Institute for Interdisciplinary Mountain Research, Innrain 25, 6020 Innsbruck, Austria); MUTHREICH, Florian (University of Bergen); SEDDON, Alistair (University of Bergen); BURGAY, Francois (PSI - Paul Scherrer Institut); BACCOLO, Giovanni (University of Milano-Bicocca); MYGIND, Amalie (Niels Bohr Institute); PETERSEN, Troels (Niels Bohr Institute); SPOLAOR, Andrea (CNR-Institute of Polar Sciences (CNR-ISP)); VASCON, Sebastiano (University of Venice); PELILLO, Marcello (University of Venice); FERRETTI, Patrizia (University of Venice); DOS REIS, Rafael (Universidade Federal do Rio Grande do Sul); SIMÕES, Jefferson (Universidade Federal do Rio Grande do Sul); RONEN, Yuval (University of Bergen); DELMONTE, Barbara (Department of Earth and Environmental Sciences, University of Milano-Bicocca,); VICCARO, Marco (Università degli Studi di Catania); STEFFENSEN, Jorgen Peder (Physics of Ice, Climate and Earth, Niels Bohr Institute); DAHL-JENSEN, Dorthe (Physics of Ice, Climate and Earth, Niels Bohr Institute); NISANCIOGLU, Kerim (University of Bergen); BARBANTE, Carlo (Institute for Polar Sciences (ISP), CNR)

Presenter: MAFFEZZOLI, Niccolo (University of Venice)

Track Classification: Progress in proxy development and interpretation