Applications of machine learning to ARM/ASR science: The Ice Particle and Aggregate Simulator

VANESSA PRZYBYLO - ATMOSPHERIC SCIENCES RESEARCH CENTER

DR. KARA SULIA – ATMOSPHERIC SCIENCES RESEARCH CENTER

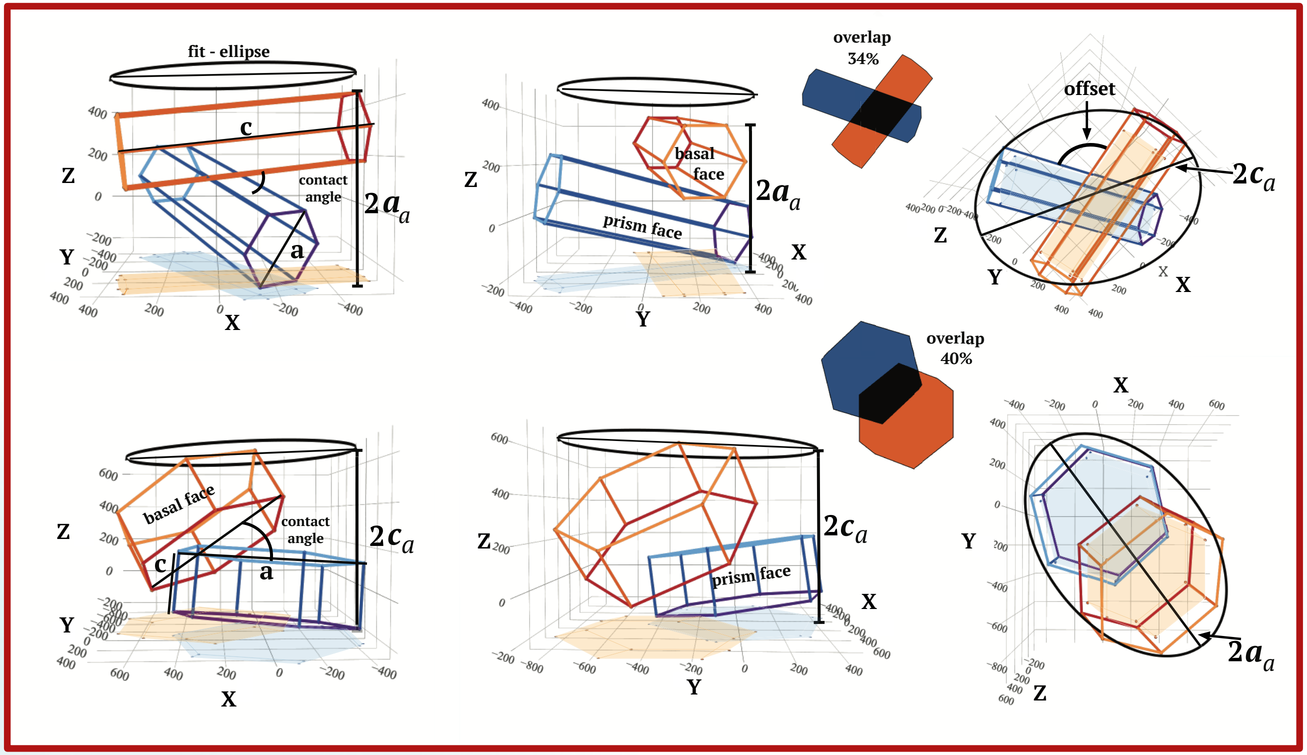
ARNOLDAS KURBANOVAS – ATMOSPHERIC SCIENCES RESEARCH CENTER - xCITE LAB

CARL SCHMITT – NCAR

What is IPAS?

The Ice Particle and Aggregate Simulator

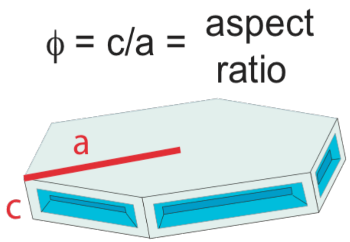
Przybylo et al. 2019



To emulate laboratory data, IPAS acts as a ‘theoretical laboratory' and provides likely aggregate properties given an input number of monomers and shape.

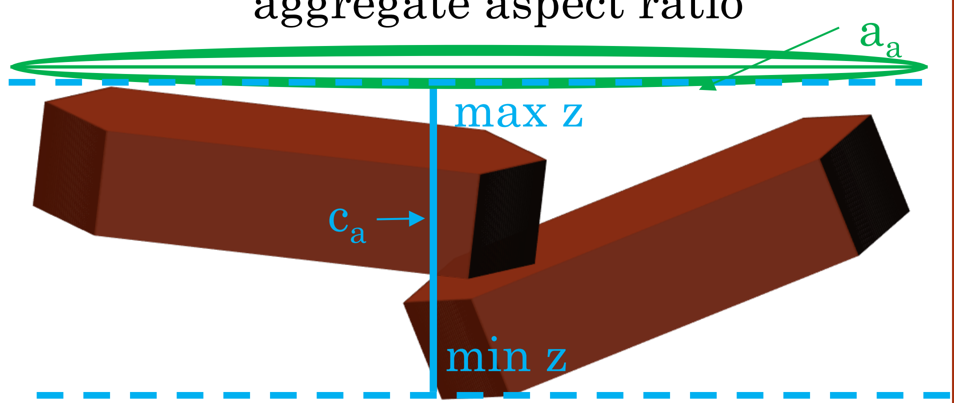
The expected falling orientations, overlap of each monomer, and any contact angle that may form through so-called constrained randomization can be recorded.

Systematic approach for calculating the aggregate aspect ratio

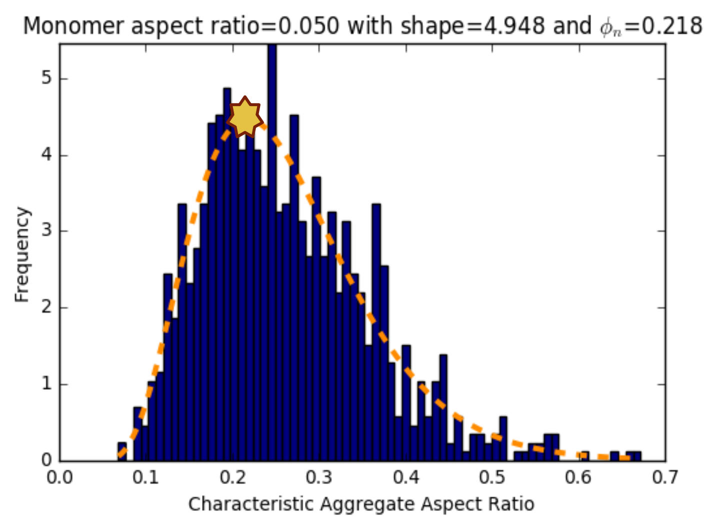


Original monomer aspect ratio

Form aggregate



x 300



Use the peak of the distribution in bulk models

Machine Learning

Objective:

- To compare and analyze the aggregate properties computed in IPAS with properties of observed aggregates

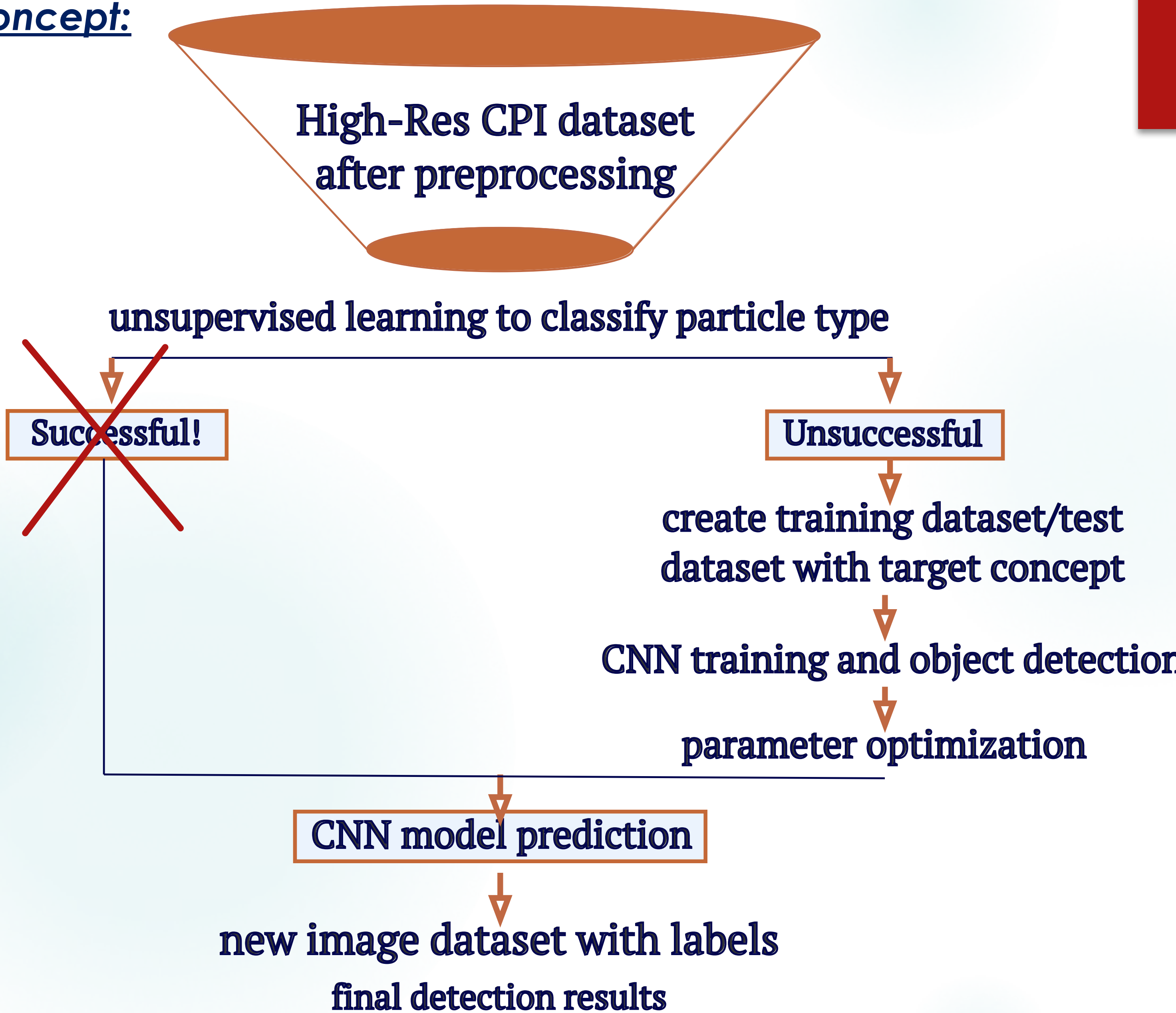
Methodology:

- Apply machine learning (ML) algorithms to classify images from a cloud particle imager (CPI) aircraft probe based on ice particle type

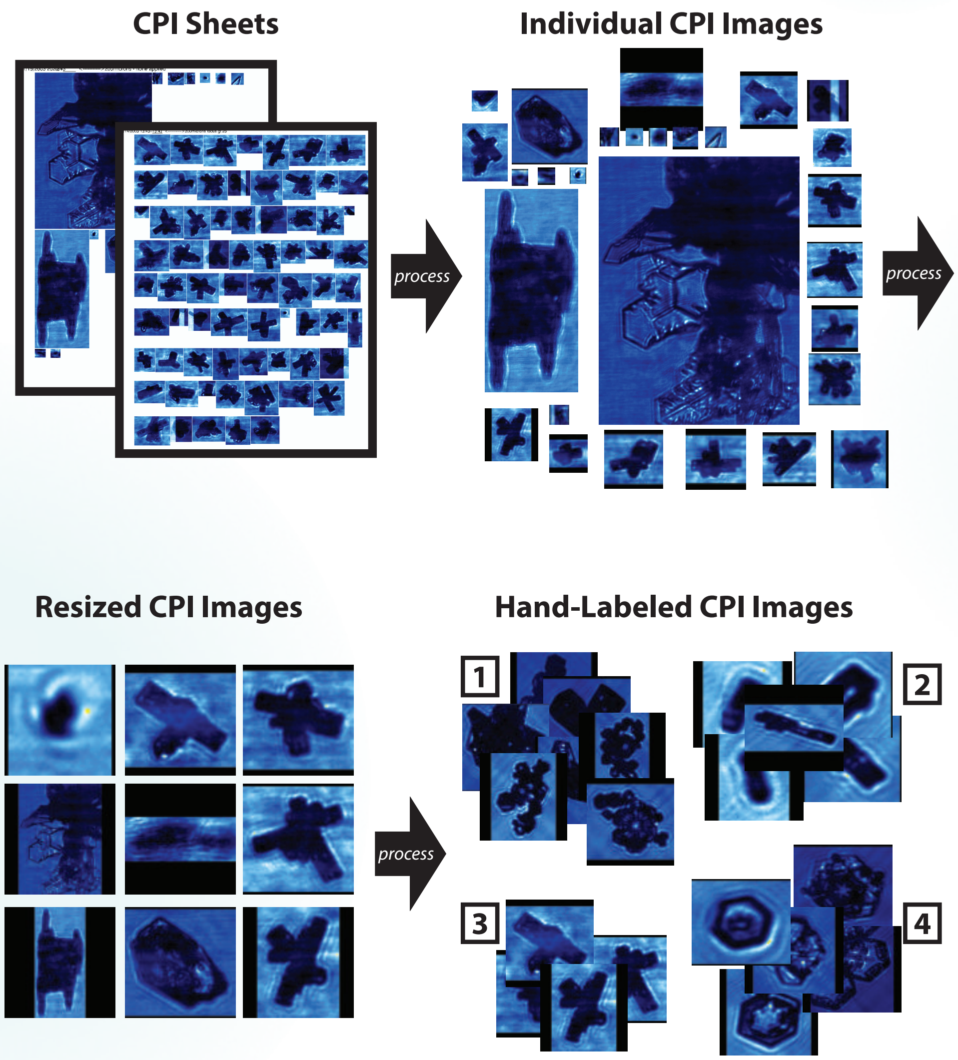
- Once the images are sorted and labeled, another algorithm (or statistical analysis through PDFs) will be used to determine particle dimensional characteristics such as perimeter, area, 2D length and width, etc.
    - Compare these characteristic values to IPAS to further refine simulations for the AHM

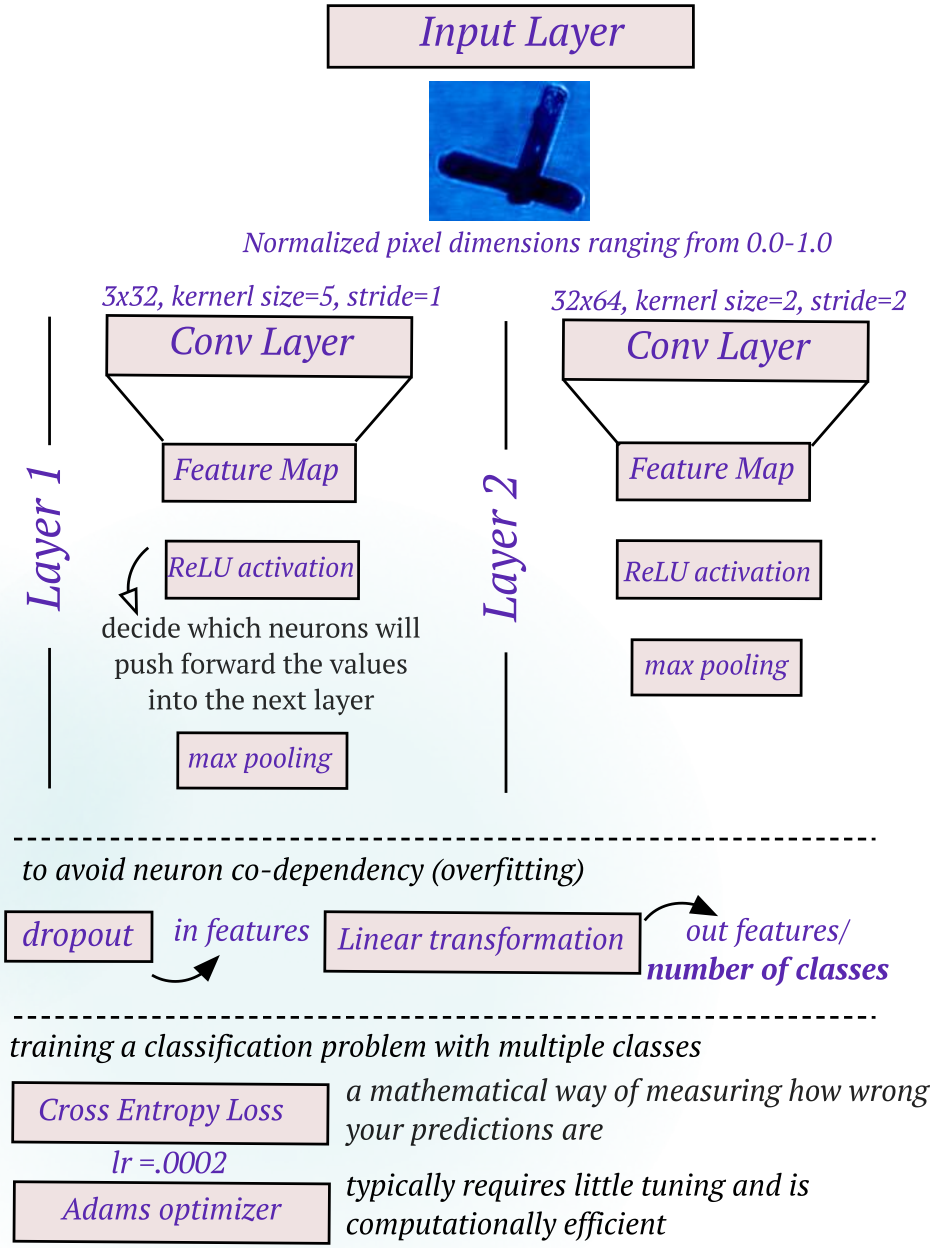
- Potentially determine trends or patterns in the particle type/size/shape as a function of height, temperature, relative humidity, etc. (e.g., by plugging in an image of a given particle, the model would be able to "predict" what environment it was likely in).

Concept:


High-Res CPI dataset
after preprocessing
unsupervised learning to classify particle type
Successful!
Unsuccessful
create training dataset/test
dataset with target concept
CNN training and object detection
parameter optimization
CNN model prediction
new image dataset with labels
final detection results

Pre-processing





ML hyperoptimization packages:

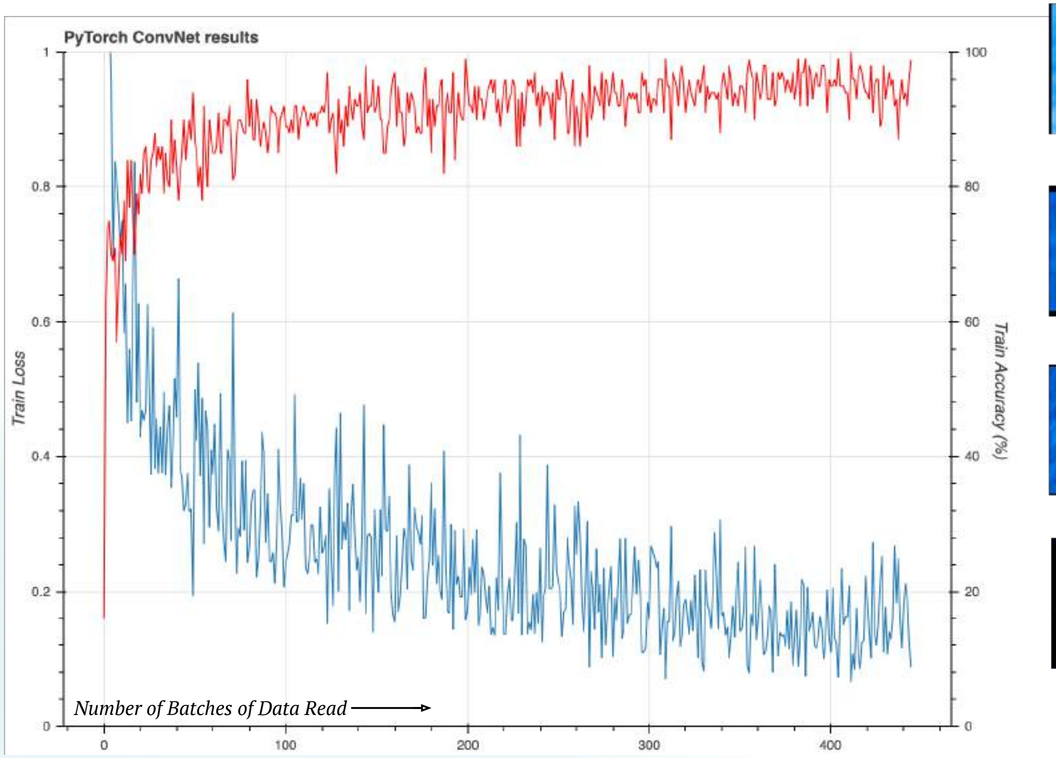
Pytorch

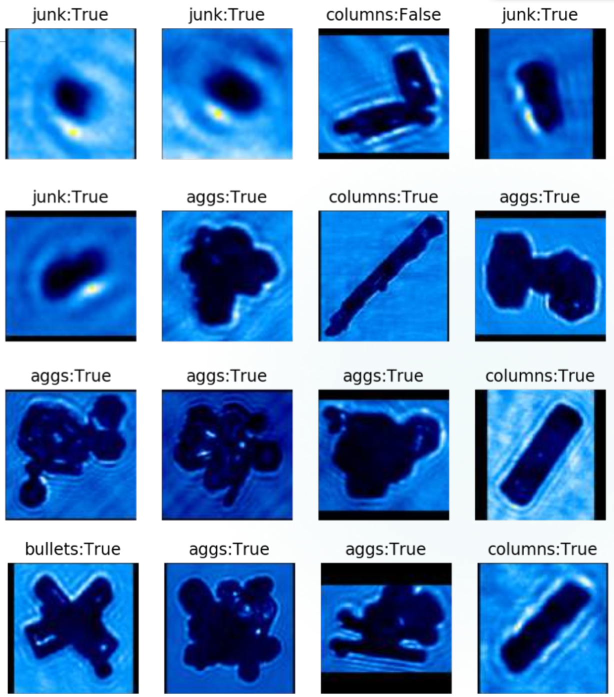
- Randomized Search CV
- Comet optimizer

Keras

- Tensorflow backend
- Hyperas
- Comet Optimizer

Final Model:



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Accuracy of  aggs : 94.444444 %
Accuracy of bullets : 54.545455 %
Accuracy of columns : 85.365854 %
Accuracy of  junk : 96.000000 %
```

Conclusions

- Automatized classification through use of a CNN is generating realistic hydrometeor categories, which is useful to other scientists by reducing image pre-processing time
- A generous, automated, and classified dataset is useful toward better prediction of aggregate properties and segregation of the dynamical processes taking place based on environmental conditions (e.g., aggregation, riming, etc.)
- The results of the proposed work will guide future improvements of both IPAS and bulk models while identifying regions of inadequate predictability

- *Next Steps:*
    - Build the database of hand-labeled images
        - Apply nested classification
            - Potential for primary and secondary habits
    - Extend results to more probes
    - Perform simulations in IPAS given observed particle properties to compare and validate theoretical aggregates
    - Statistically quantify any similarities and differences

Thank You!
Questions?