Dust Layers, Cirrus, Blowing Snow and Diamond Dust in ICESat-2 Atmospheric Data Products: Application of the Density-Dimension Algorithm

Camden Opfer[1], Ute Herzfeld[1], Thomas Trantow[1], Stephen Palm[2], Kristine Barbieri[2], Mark Vaughan[3], Adam Hayes[1], Huilin Han[1], Matthew Lawson[1]

[1]University of Colorado, Boulder: Department of Electrical, Computer, & Energy Engineering, [2]NASA Goddard Space Flight Center, [3]NASA Langley Research Center

Summary

- The ICESat-2 satellite's ATLAS Lidar is capable of detecting clouds and aerosols
- The density dimension algorithm (DDA) for atmosphere is used to maximize data retrieval
- Tenuous smoke and dust layers can be identified by the DDA

Background

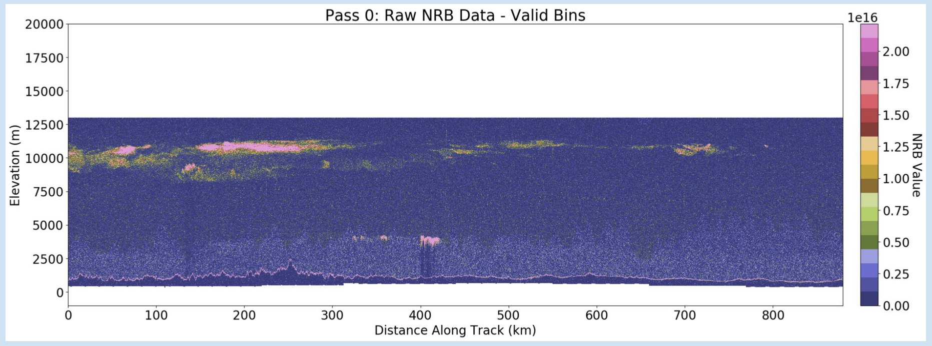
Tenuous Layers

Optically thin atmospheric layers such as cirrus clouds, dust, smoke, and smog play a critical role in the penetration of incoming and outgoing radiation. Systematically mapping these layers with satellite data allows improved modeling and understanding, including climatic impacts.

ICESat-2

Launched in 2018, the ICESat-2 satellite carries a 532nm, multi-beam, photon-counting LiDAR called ATLAS. This provides radiative backscatter at a horizontal resolution of 280*m* and vertical resolution of 30*m* up to an altitude of 14*km*.

Image Credit: NASA



Motivation: The End of CALIPSO

The CALIPSO satellite carried the CALIOP LiDAR, specifically designed for atmospheric sensing, but that mission has ended. A continuous data record is useful for answering a variety of science questions.

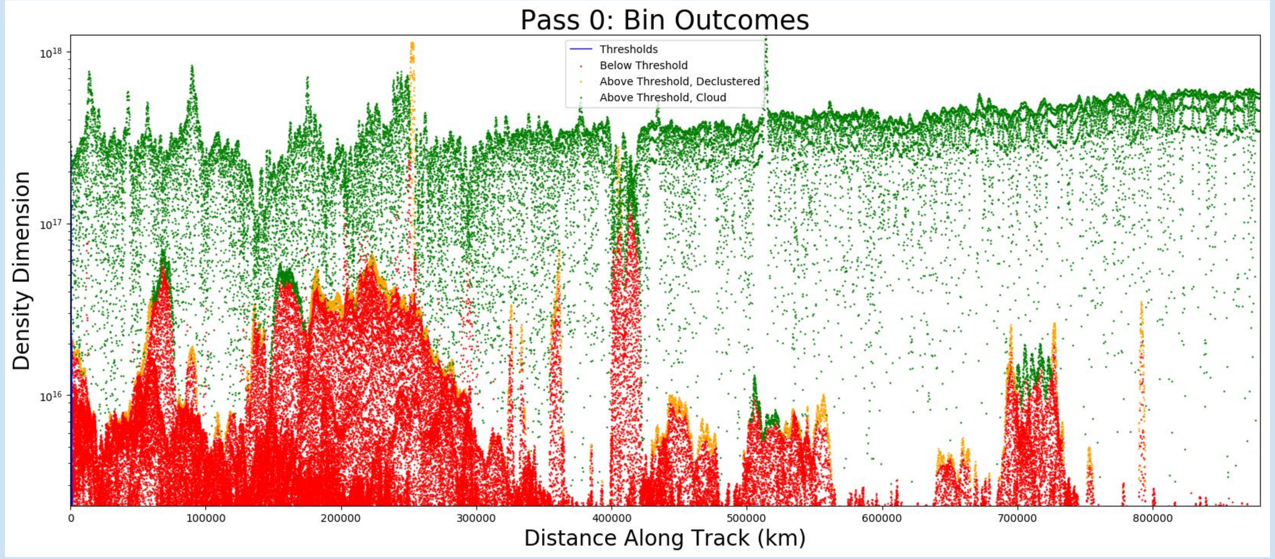
Methods

The DDA-Atmos is an algorithm which identifies cloud and aerosol layers in normalized radiative backscatter data. First, a gaussian radial basis function is applied to find the density of returns.

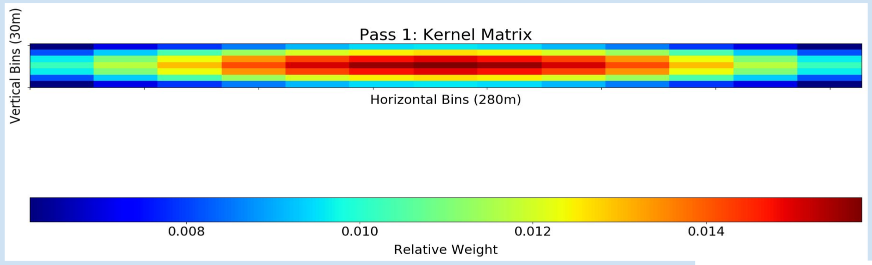
$$\Phi(r) = \exp\left[-\left(\frac{r}{\sqrt{2}s}\right)^2\right]$$

r distance, s data values

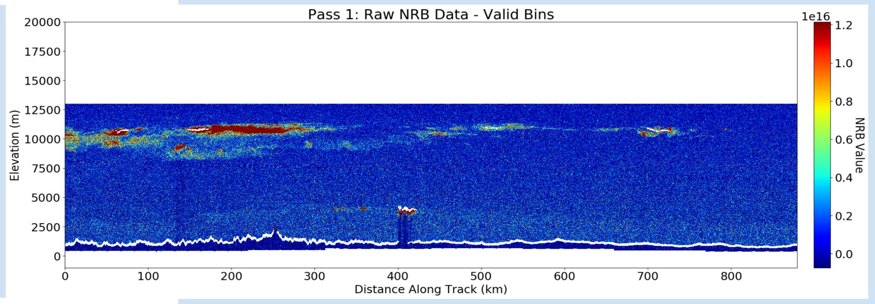
Once this is completed, thresholding is applied, identifying bins with greater photon return density as potential cloud/aerosol. A declustering algorithm is used to remove isolated bins which passed thresholding, avoiding non-physical, single-bin layers being detected.



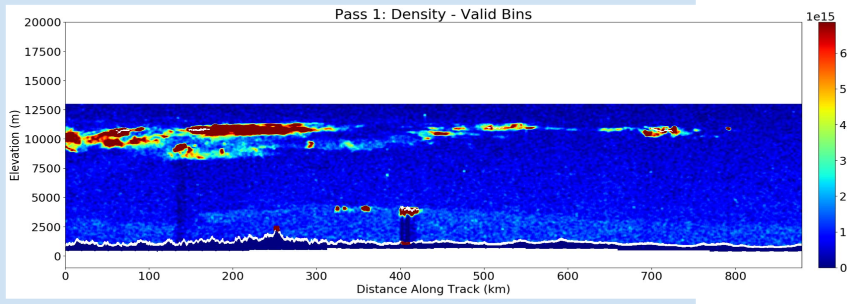
This process is repeated at least twice, though configurations called density-n and smooth pass add more iterations of the algorithm to identify thinner layers, which are harder to detect. Finally, a mask representing the location of aerosol/cloud is returned.



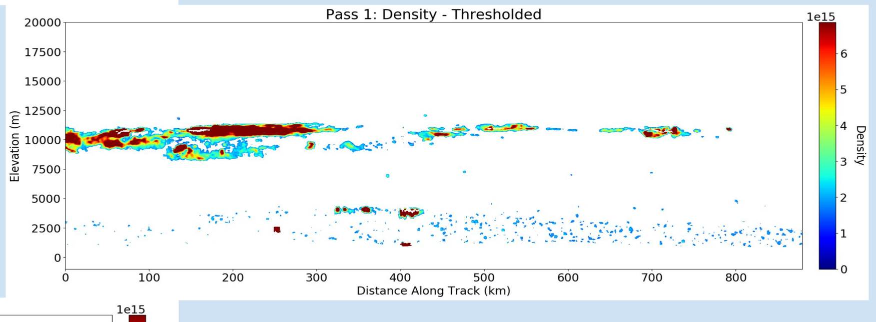
An example kernel used by the RBF.



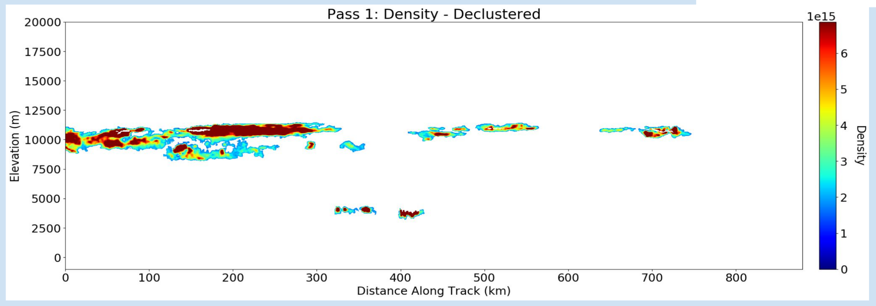
Normalized radiative backscatter data taken as input by the algorithm.



Density of radiative return, found by applying the RBF to the above data.

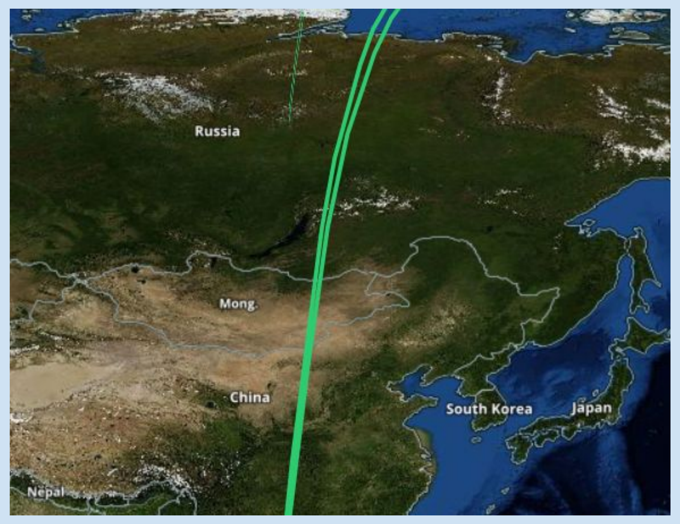


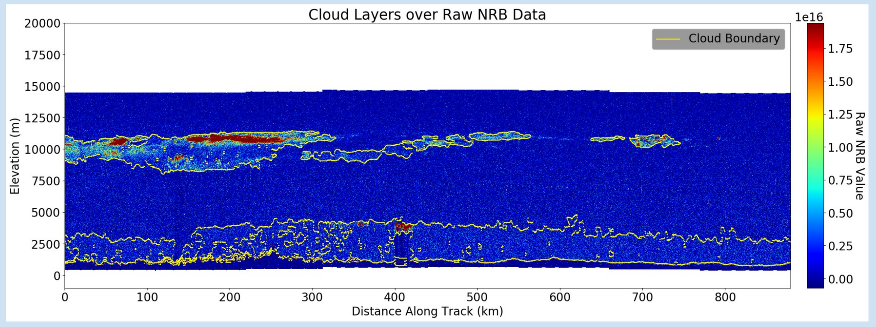
Only bins within the top *q* percent of density data pass. The parameter *q* is determined by user-defined.

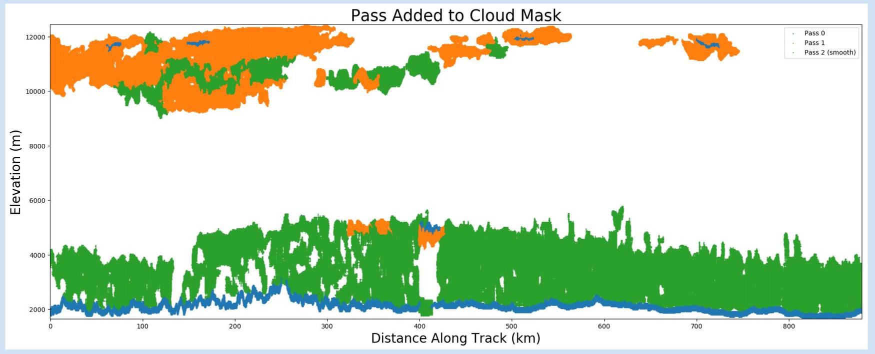


Declustering removes bins which are not topologically connected.

Results: Asian Dust







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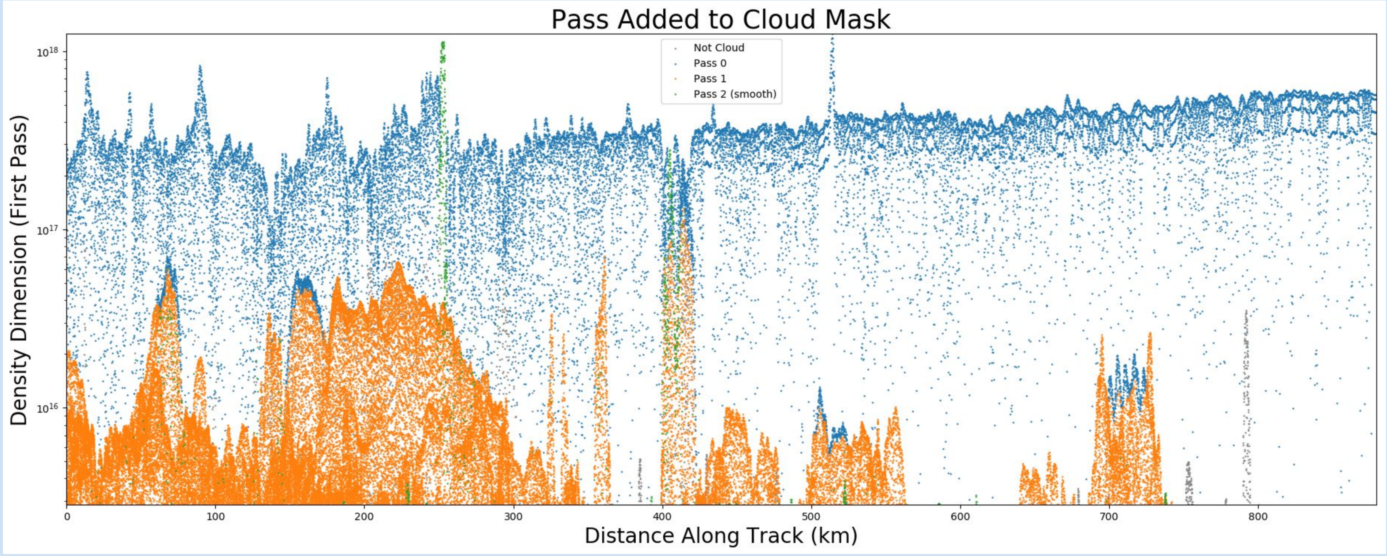
Along track profiles 43125 to 60800

Conclusions & Future Work

Overall, the DDA-Atmos has proven to be effective in detecting the spatial boundaries of clouds and aerosols within ICESat-2 data. A key strength of the algorithm is that its thresholding and configurations allow for adaptability to a variety of atmospheric conditions (day/night, thin aerosol/thick cloud).



Potential for improvement remains in further improvement of parameters, and the automatic determination of which algorithm configuration is most useful for each scene. This could include machine learning approaches, or a statistical formula like a measure of the maximum density remaining (not detected as cloud/aerosol).

Acknowledgements

This work is supported by NASA Earth Sciences and the ICESat-2 Project.

References

Herzfeld, U., Hayes, A., Palm, S., Hancock, D., Vaughan, M., & Barbieri, K. (2021). Detection and height measurement of tenuous clouds and blowing snow in ICESat-2 ATLAS data. Geophysical Research Letters, 48, e2021GL093473. https://doi.org/10.1029/2021GL093473