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Tracking Polar Mesospheric Clouds Using Unbinned Correlation Methods

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Keywords
Polar Mesospheric Clouds, Unbinned Correlation, Cloud-Tracking, AIM satellite

Abstract
We are experimenting with a correlation method that allows us to cross-correlate images that have geolocated pixels without having to bin the pixels and lose resolution. In addition to preserving resolution, this correlation method also allows us to perform transformations on the images that would be difficult to perform with other correlation methods. We are working on this correlation method in order to use cross-correlations to track polar mesospheric clouds (PMCs) using the data from the Cloud Imaging and Particle Size (CIPS) instrument on the Aeronomy of Ice in the Mesosphere (AIM) satellite.

Comments
This research was conducted at Hampton University through the Crest Undergraduate Research Experience (CURE) Program (http://cure.hamptonu.edu).
Abstract

We are experimenting with a correlation method that allows us to cross-correlate images that have geolocated pixels without having to bin the pixels and lose resolution. In addition to preserving resolution, this correlation method also allows us to perform transformations on the images that would be difficult to perform with other correlation methods. We are working on this correlation method in order to use cross-correlations to track polar mesospheric clouds (PMCs) using the data from the Cloud Imaging and Particle Size (CIPS) instrument on the Aeronomy of Ice in the Mesosphere (AIM) satellite.

Polar Mesospheric Clouds (PMCs)

Polar mesospheric clouds (PMCs) are water ice clouds that form in the mesosphere under extremely cold temperatures. They are the highest clouds in the Earth’s atmosphere, located at a height of about 83 kilometers, near the mesopause, which is the upper boundary of the mesosphere and the coldest region on Earth, reaching temperatures below 130 K. As the name suggests, PMCs only form near the poles, where the mesosphere is coldest, at latitudes greater than about 55°.

The AIM Satellite

The Aeronomy of Ice in the Mesosphere (AIM) satellite is a satellite in a nearly circular, 600-km, sun-synchronous orbit launched by NASA in 2007 and the first satellite whose main mission is to study PMCs. It orbits the Earth almost 15 times per day. One of the main instruments on the AIM satellite is the Cloud Imaging and Particle Size (CIPS) instrument, which consists of four identical cameras arranged in a cross pattern. The CIPS instrument takes 27 images of a pole per orbit.

Cloud-Tracking Using Cross-Correlations

We can employ cloud-tracking methods on the data gathered by CIPS in order to learn more about the mesosphere and PMCs. Cloud-tracking algorithms allow us to generate cloud velocity maps, which we can use to further illustrate the symmetry from (c).

Dynamical “Rebinning” Correlation Method

In order to get around the issue of losing resolution due to binning data, we are working on a correlation method that does not require the data to be binned. This correlation method works by essentially “rebinning” the data dynamically as it performs the correlation (instead of before performing the correlation). This correlation coefficient is calculated using the formula

\[
\text{Corr}(x, y) = \frac{\sum_{i,j} x_i y_j w_{ij}}{\sigma_x \sigma_y \sum_{j} w_{ij}}
\]

where \(w_{ij} = \begin{cases} 1 & \text{if } d(i,j) \leq d_b \\ \frac{d_b}{d_b - d(i,j)} & \text{if } d(i,j) > d_b \end{cases} \)

is the weighting function, \(x\) and \(y\) have have had their means subtracted from them, \(d(i,j)\) is the distance between the \(i\)th pixel in \(x\) and the \(j\)th pixel in \(y\), and \(d_b\) is the distance threshold, \(n_i\) is the number of pixels in \(y\) that are within a distance \(d_b\) of the \(i\)th pixel in \(x\), and \(n_j\) is the number of pixels in \(x\) that are within a distance \(d_b\) of the \(j\)th pixel in \(y\).

Conclusion

By tracking PMCs we hope to gain a better understanding of wind systems in the mesosphere, which is one of the regions of the atmosphere that we know least about. We can also learn more about PMCs themselves by tracking them. PMCs are believed to be a fairly recent phenomenon (the first known documentation of them dates back to 1885), and we have been observing an increase in their occurrence over the past few decades. It is thought that the warming of the lower atmosphere and the high emissions of methane in the atmosphere are increasing the production of these clouds, which means we could potentially use them as a miner’s canary for climate change.

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