Motion Characteristics of Cloud Clearing Boundaries in the Southeast Atlantic

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ENVIRONMENT ANALYTICS

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I. Background

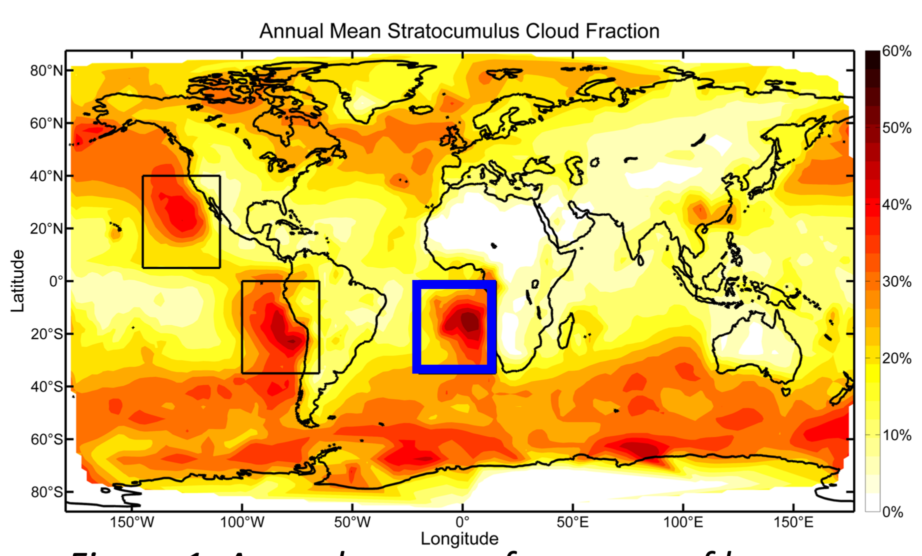
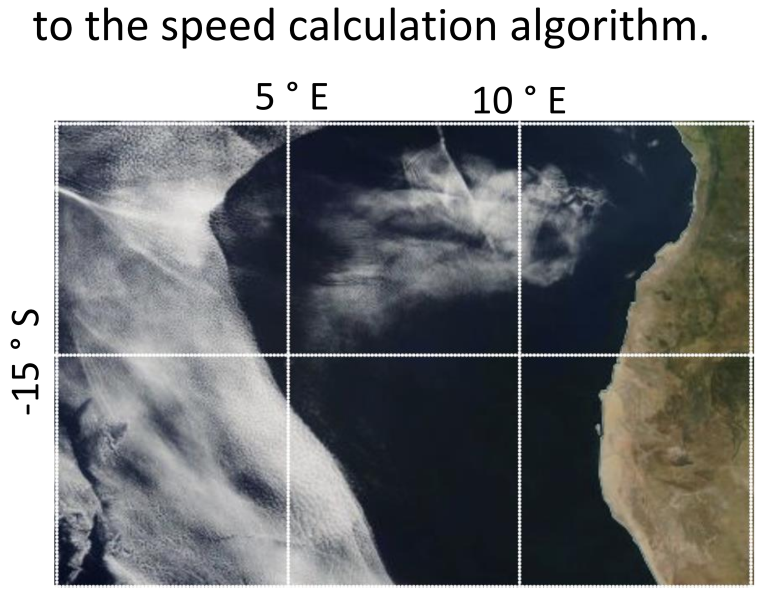


Figure 1: Annual average frequency of low stratocumulus clouds (Hahn and Warren, 2007).

Recent work has shown that vast areas of marine stratocumulus can be eroded along westward-moving, sharp lines 1000+ km long. Processes that can increase or decrease the total global area of cloud cover impact the radiative balance of the Earth and could offset or enhance warming from CO_2 increases. Our study focuses on the southeast Atlantic off the coast of Angola and Namibia (above, blue box), where large decks of low clouds (tops <1.5 km in height) commonly form. We are interested in how the speeds of these cloud-eroding lines change with distance from the coast and with latitude along the line.

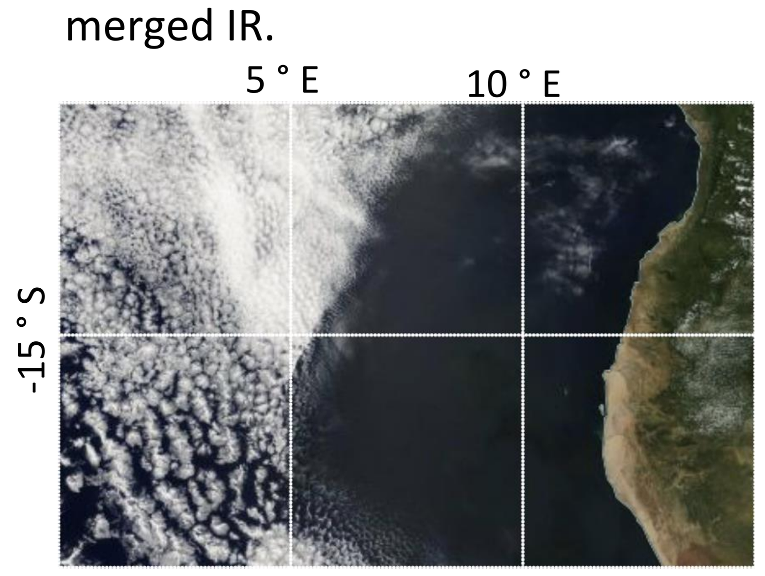
II. Data Sources

Cloud eroding boundaries examined for this study were chosen from a list of several hundred previously identified cases. These boundary events were categorized as "sharp," "somewhat diffuse," or "mostly diffuse" based on subjective visual assessment. Boundaries that were 1) westward-moving, 2) more than 6 hours in duration, and 3) propagated at least 250 km were used for estimation of phase speed. Hovmoller plots were generated from half-hourly IR data, drawing data from focus latitudes of -14 to -16° S, to be passed to the speed calculation algorithm.

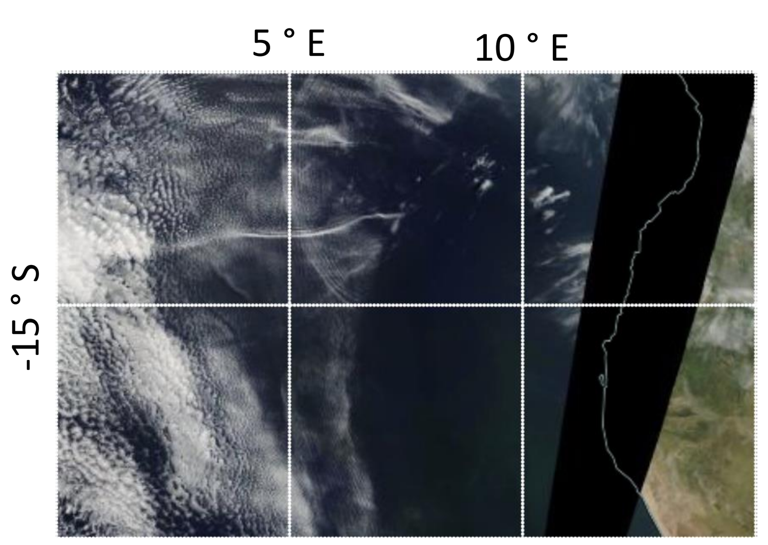


*MODIS-Aqua satellite imagery showing "**sharp**" visible boundary on 26 May 2014.*

Data are from NASA EOSDIS including Aqua, Terra, and Suomi NPP reflectance and 4-km global merged IR.



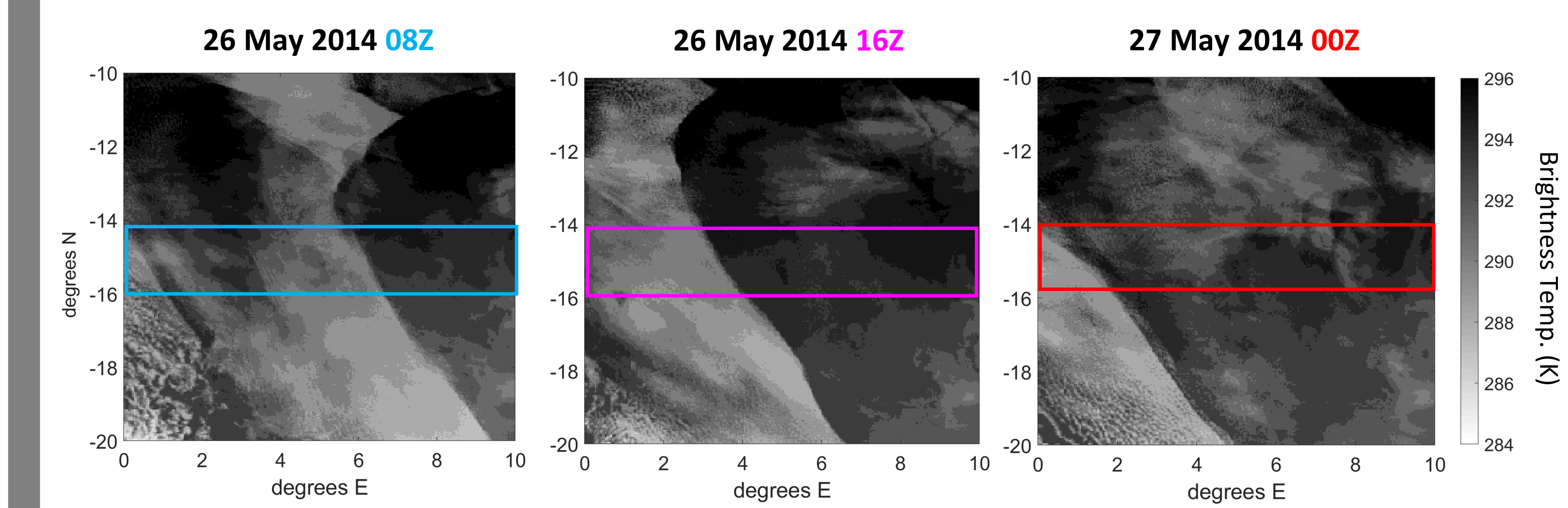
*MODIS-Terra satellite imagery showing "**somewhat diffuse**" visible boundary on 10 April 2010.*

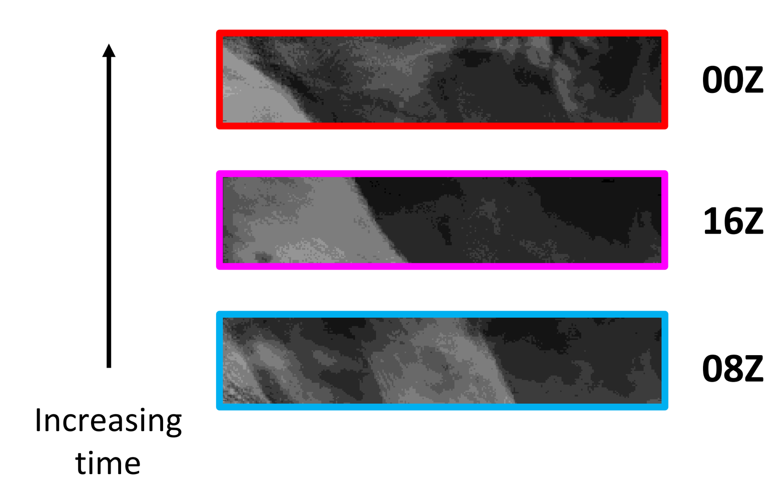


*MODIS-Terra satellite imagery showing "**mostly diffuse**" visible boundary on 25 April 2008.*

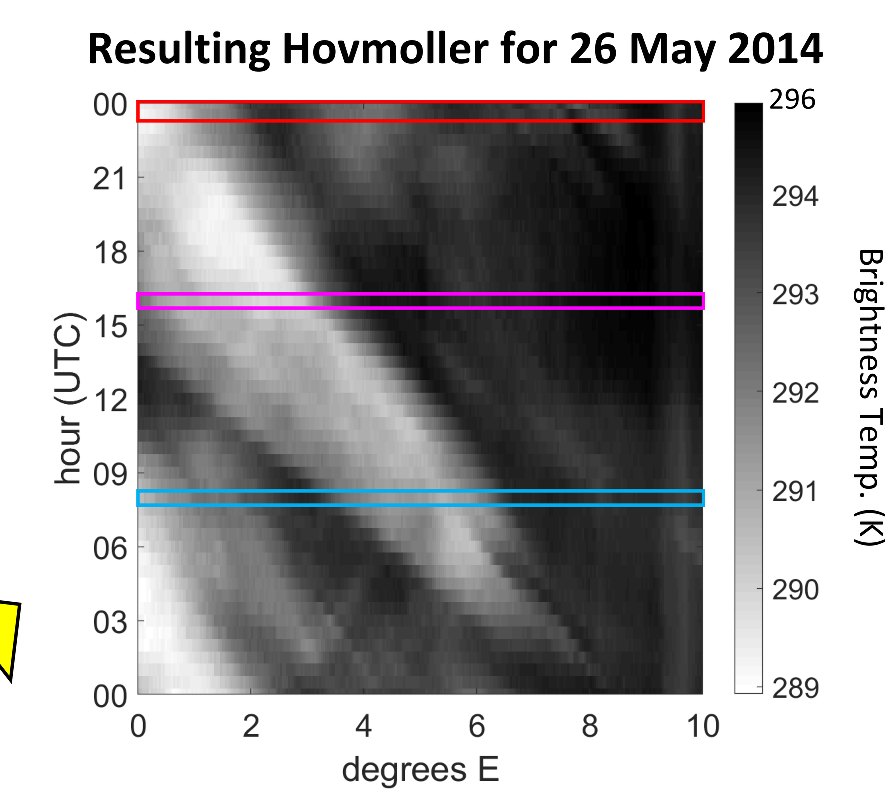
QR code for web link to movie showing regional view of a westward moving cloud-eroding boundary.

III. Calculation of Hovmoller Plots from IR Data

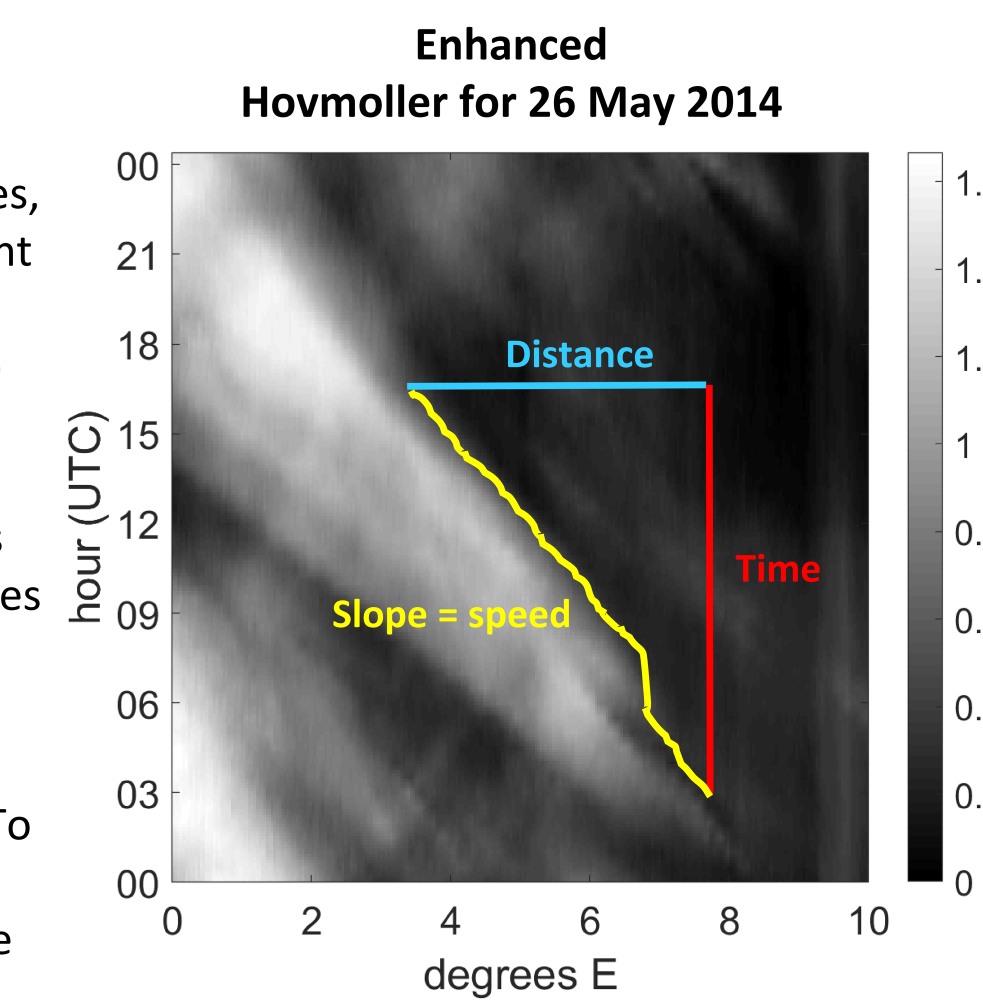




To get a row for each time, we *average* across latitudes



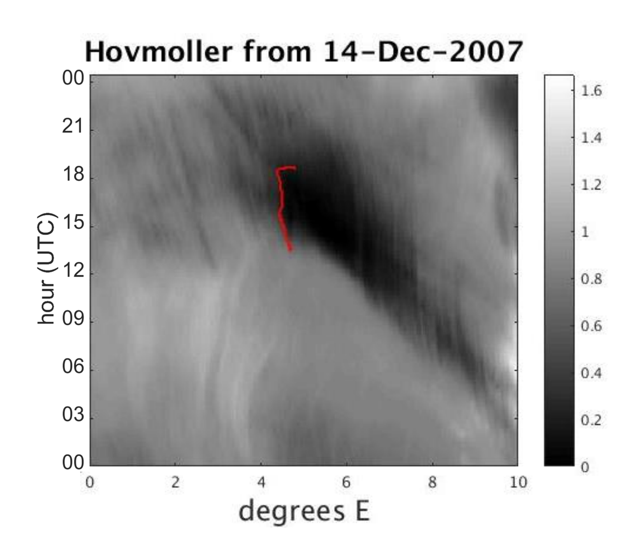
IV. Identifying Boundaries for Phase Speed Estimation



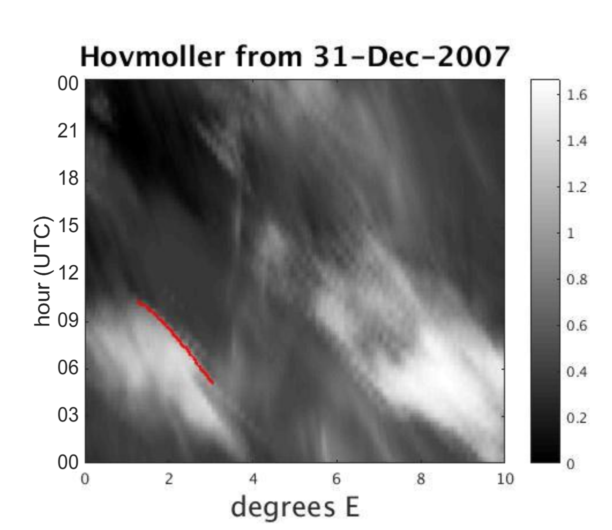
We detect boundary edges, which represent the transition from cloudy to clear, using Canny edge detection. This method requires input with sufficient contrast and a square array. To meet these constraints, we enhanced contrast by modifying brightness temperatures in reference to the absolute difference between maximum and minimum brightness temperature. We then interpolated with regard to time to obtain a square array.

Shown above is an enhanced Hovmoller plot sufficient to be passed to the phase speed detection algorithm, with scale representing relative brightness temperatures.

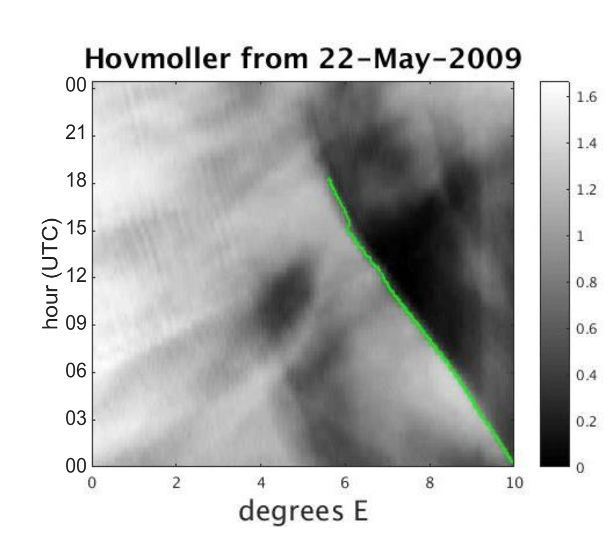
V. Phase Speed Detection Results



- "Mostly diffuse" boundary
- Edge detection threshold decreased to 0.5
- Fails westward propagation and propagation distance criteria



- "Somewhat diffuse" boundary
- Noticeable boundary shown but not detected in whole by algorithm
- Indicates need for increased robustness



- "Sharp" boundary
- Analyzed speed: 16.7 m/s
- Slope deviation: 0.38
- Example of case in which default edge detection threshold picks up on entire expanse of boundary

Key — "Bad" boundary: fails one or more criteria. — "Good" boundary: meets all criteria.

Summary

Edge detection is useful to identify cloud-eroding boundaries in Hovmoller plots. Using an edge detection algorithm to calculate the speed of the boundary currently produces good results in extremely sharp cases. The analyzed speed of a transition can vary with time and from boundary to boundary.

Future Work

- Refine input image processing and edge detection method to identify boundaries with less defined cloudiness transitions and weaker brightness gradients.
- Determine motion characteristics for our dataset of several hundred boundaries.
- Analyze distribution of motion characteristics in relation to regional environmental conditions.

Reference: Yuter, S. E., Hader, J. D., Miller, M. A., & Mechem, D. B. (2018). Abrupt cloud clearing of marine stratocumulus in the subtropical southeast Atlantic. *Science*. doi:10.1126/science.aar5836.

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