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Cloud Trails Past Bermuda

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Introduction

Cloud trails are observed downwind of oceanic islands globally, particularly in the tropics and subtropics. Cloud trails offer a real-world test case for the initiation of shallow convection and the transition from shallow to deep convection in a simple domain. Understanding the behaviour of cloud trails on small islands will then help inform the set-up of idealised numerical simulations.

What are cloud trails?

Small, relatively flat, heated islands generate a local area of deeper boundary layer mixing. It is expected that when low-level moisture is sufficient, rising parts of this region can reach their LCL and clouds can form. This locally deeper mixed layer air is advected downwind forming a 'plume' in the lee of the island, often capped with shallow cloud (Fig. 1).

Observations have shown that some environments support transition from shallow to deep convection.

Questions about the larger scale environment that supports shallow cloud trails and particularly the transition from shallow to deep convection could be answered via a combination of an observational study and idealised simulations.

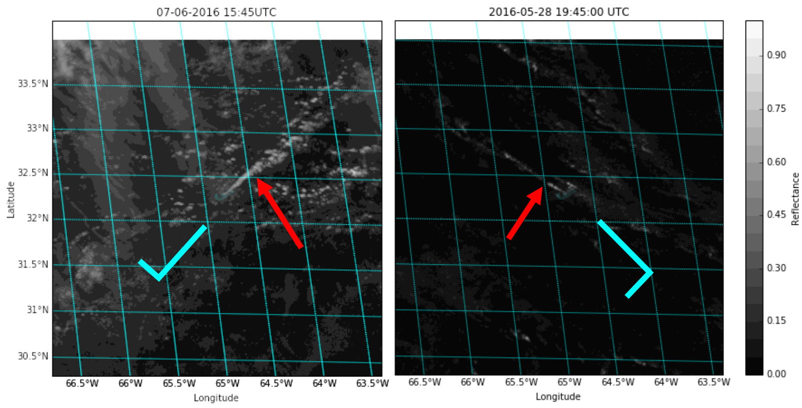

Figure 1. Visible satellite imagery showing cloud trails past Bermuda. The red arrow in each instance points to the cloud trail, while the blue the cyan is the wind barb. An example where winds are parallel to the long axis of the island (left), and winds are perpendicular (right).

Cloud Trail Algorithm

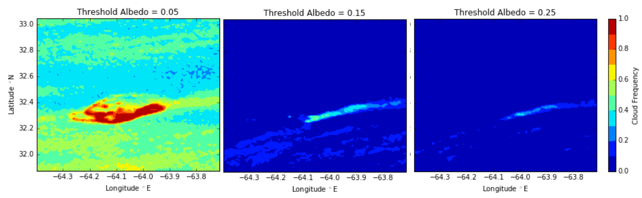

Figure 2. Sensitivity of cloud frequency to threshold used in cloud mask. Increasing threshold from left to right, 0.15 is used in this study. When too low, land and shallow water are misidentified as cloud. Too high and some shallow cloud is missed.

1. Mask clouds using a reflectance (albedo) threshold (Fig. 2)
2. Take daily mean cloud masks as cloud frequency (Fig. 3)
3. Split the area 0.25° around Bermuda into 16 sectors centred on the cardinal directions
4. Use cloud level wind direction to define upwind and downwind sectors
5. Consider the mean cloud frequency in the domain to split into obscured, not-obscured
6. Of the not-obscured cases, consider the difference between downwind and upwind cloud frequency to split further into cloud trail and not-trail cases

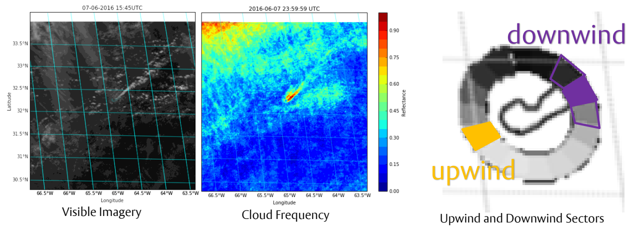

Figure 3. Some of the steps for discriminating between cloud trail, non-trail, and obscured cases. From left to right, mask the cloud and not cloud areas. Calculate the cloud frequency to find the cloudier areas, if the whole domain is cloudy then classify it as obscured. If the scene is not cloudy and the downwind cloud frequency is significantly larger than the upwind, then classify as a cloud trail. Otherwise, it is non-trail.

Study Island: Bermuda

- Bermuda is a small (54 km²) relatively flat (76 m) island in the central western Atlantic
- More than 1000 km from the nearest land in North America and the Caribbean
- Bermuda is in the subtropics and is influenced by the Atlantic subtropical high during the warm season

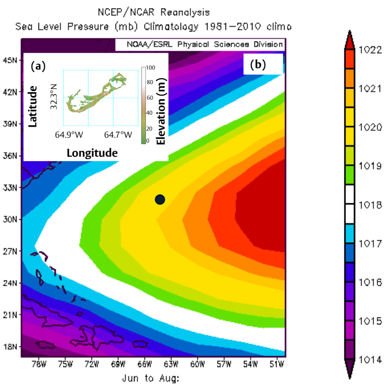

Figure 4. (a) Topographic map of Bermuda showing its small, flat nature.

(b) June/July/August 1981 - 2010 NCEP/NCAR climatology of mean sea level pressure centred near Bermuda (black dot). This illustrates Bermuda's location in relation to general circulation features. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/

Sounding Composites

- First apply the algorithm to separate out days with cloud trails, non-trails, and obscured
- Next composite the 1200 UTC soundings around those categories
- Have started looking at sounding indices, large scale ascent/descent etc.

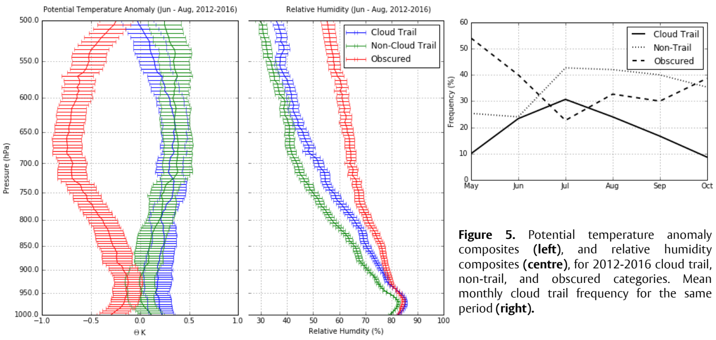

Figure 5. Potential temperature anomaly composites **(left)**, and relative humidity composites **(centre)**, for 2012-2016 cloud trail, non-trail, and obscured categories. Mean monthly cloud trail frequency for the same period **(right)**.

Summary/Future Work

- Cloud trail algorithm is a simple objective way to discriminate between cloud trail, non-trail, and obscured days.
- Obscured days have a more stable boundary layer, are similarly humid in the boundary layer, but much more humid in the free atmosphere when compared to cloud trail days.
- Non-trail days have comparable potential temperature profiles but are drier than cloud trail days through much of the lower troposphere.
- High resolution idealised simulations are planned varying wind speed, direction, shear, large scale environmental characteristics, and island size.
- Assessment of representation at coarse resolutions.

References

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