A-train Observations of Volcanic Cloud-Top Height and Thickness for the 2008 Chaitén Eruption

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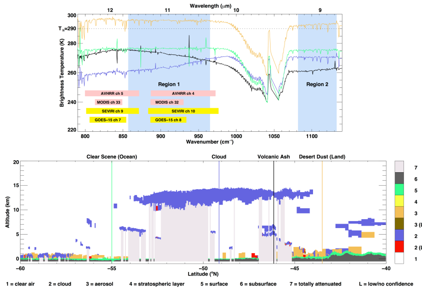
1. Introduction

Chaitén experienced three major eruptions on 2, 6 and 8 May 2008 (Carn *et al.*, 2009). The ash clouds were long-lived and were subject to long range (4000 km) transport, putting aircraft at risk. The A-train passed over the event several times during 2-10 May and captured the synoptic scale movement of the ash clouds. The need for accurate ash detection and high resolution measurements of Volcanic Cloud-Top Height (VCTH) was highlighted by this event.

1. (a) Hyperspectral infrared ash detection

- Natural extension to traditional broadband ash detection algorithms (e.g. Prata *et al.*, 1989b)



Top panel: Spectral signals of ash, ice, dust and a clear scene from AIRS on 3 May 2008 (granule 187).
Bottom panel: Vertical Feature Mask (VFM) product from corresponding CALIOP profile.

1. (b) Ash detection algorithm

- From the available AIRS channels, 12 are selected and averaged to form 4 ``ash" channels.

$$BT_1 = \sum_{563}^{566} w_i T_i,$$

$$BT_2 = \sum_{802}^{805} w_i T_i,$$

$$BT_3 = w_{1088} T_{1088} + w_{1092} T_{1092},$$

$$BT_4 = w_{1004} T_{1004} + w_{1005} T_{1005}.$$

	Channel number, i	Wavenumber (cm^{-1})	Weight, w_i
BT_1			
	563	856.435	0.25
	564	856.746	0.25
	565	857.057	0.25
	566	857.368	0.25
BT_2			
	802	964.247	0.25
	803	965.044	0.25
	804	965.443	0.25
	805	966.242	0.25
BT_3			
	1088	1131.79	0.50
	1092	1133.96	0.50
BT_4			
	1004	1080.92	0.50
	1005	1082.41	0.50

- The ash channels are combined to give a single brightness temperature difference, as follows,

$$\Delta BT_a = BT_1 - BT_2 + BT_3 - BT_4.$$

- Criteria (1) and (2) must be met before the AIRS pixel is deemed ash affected,

$$\Delta BT_a > \Delta T_c \quad (1)$$

$$BT_i < T_h \quad (2)$$

where, ΔT_c is a threshold set to eliminate noise and false detections from clear scenes and T_h is a threshold set to eliminate false detections due to low elevation dust aerosol over land.

2. Data and methods

AIRS

- Hyperspectral infrared brightness temperature difference algorithm applied to AIRS for ash detection.

CALIOP

- Collocation of CALIOP profile to allow ash detection within 532 nm backscatter profiles.
- Thresholding algorithm used to extract height information at high resolution.

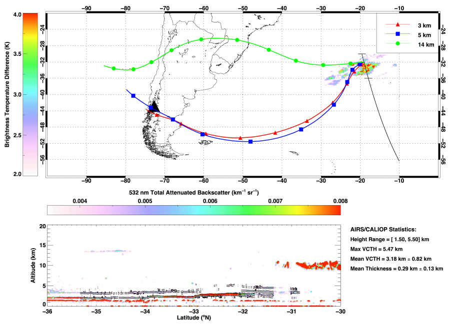
HYSPLIT

- Back trajectories used to verify heights and to estimate initial VCTHs.
- Forward trajectories used to generate a dummy forecast.

3. Results and discussion

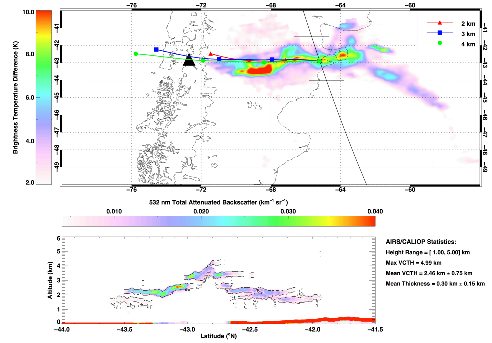
- Setting, $\Delta T_c = 2$ K and $T_h = 290$ K, was best compromise between false detections and clear ash signal.
- 12 VCTHs and thicknesses recorded. Heights ranged from 3.68-16.56 km with an average height of 7.74 km.
- Thicknesses ranged from 270-670 m with over 80% of thicknesses being less than 400 m.
- Volcanic ash detected and tracked for 72 h at distances of up to 4000 km from the source.
- Back trajectories allowed determination of volcanic ash when two or more features were present in the vertical but at the same location in the horizontal.
- Initial plume heights of 4, 4.5 and 5 km estimated from back trajectory analysis, were used to create a dummy forecast.
- Dummy forecast agreed well with observations.

3. (a) 5 May 2008 at 15:17 UTC



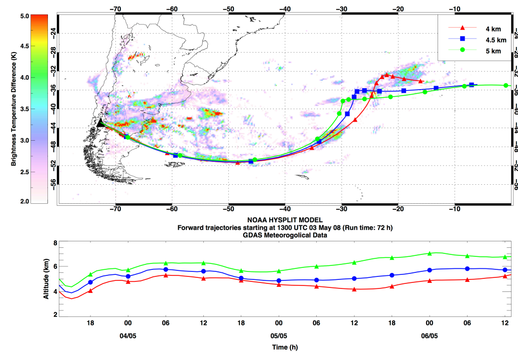
Top panel: AIRS brightness temperature differences with back trajectories over plotted.
Bottom panel: CALIOP 532 nm backscatter profile with AIRS collocation (black outlines).

3. (b) 5 May 2008 at 18:29 UTC



Top panel: AIRS brightness temperature differences with back trajectories over plotted.
Bottom panel: CALIOP 532 nm backscatter profile with AIRS collocation (black outlines).

3. (c) Dummy forecast



Top panel: Averaged AIRS data from 2-10 May 2008 with forward trajectories over plotted.
Bottom panel: Changes in the forward trajectory altitudes with time.

4. Conclusions and future work

- Ash detection algorithm is simple, fast and effective.
- AIRS/CALIOP method is able to detect and quantify thin ash layers.
- Back trajectories initialised with CALIOP heights were useful in estimating initial VCTHs.
- Long-lived ash clouds that were transported large distances were likely to have travelled through the mid-troposphere (4-5 km).
- Intend to apply method to different eruptions (test robustness) and use different meteorological datasets to test sensitivity of HYSPLIT.

References

Carn, S. A., J. S. Pallister, L. Lara, J. W. Ewert, S. Watt, A. J. Prata, R. J. Thomas, and G. Villarosa (2009), The Unexpected Awakening of Chaitén Volcano, Chile, *Eos*, 90, 205–212.

Prata, A. J. (1989b), Observations of volcanic ash clouds in the 10-12 μm window using AVHRR/2 data, *International Journal of Remote Sensing*, 10 (4-5), 751–761.