Anvil Cirrus Outflow During the Maritime Continent Thunderstorm Experiment

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The Maritime Continent Thunderstorm Experiment (MCTEX) took place from 13 November to 10 December 1995, on the Tiwi Islands, Australia. The primary objective of the experiment was to study the lifecycles of the thunderstorms, which occur almost daily on these islands during the transition between wet and dry seasons. As part of this experiment, a suite of remote sensing instruments including a dual-wavelength millimeter radar, a 10-cm vertically pointing radar, a microwave radiometer, a lidar and broad-band solar, and infrared (IR) radiometers were deployed at the village of Garden Point located on the northwest corner of Melville Island (11.4S, 130.41E). Soundings were acquired at Maxwell Creek (11.55S, 130.56E), and a scanning Doppler radar was operated at Nguiu (10.23S, 130.616E) on Bathhurst Island.

This study concentrates on the 27 November case. On this date, convection developed over the channel between Melville and Bathhurst Islands at about 0330 UTC (1330LT). This convective cell drifted towards the west leaving a trailing cirrus anvil. The cirrus spread north/south, arriving over the Garden Point site at about 0530 UTC at a height of 12 to 15 km. Figures 1 and 2 show the geostationary meteorological satellite (GMS) visible satellite images for 0530 UTC and 0630 UTC, showing the spread of the cirrus anvil covering all of Bathurst Island and extending over the eastern portion of Melville Island. A few hours later (0730 UTC), the radar shows a lower but thicker cirrus layer extending from 6 to 13 km and lasting until 1230 UTC. As the cirrus anvil moved over the site, the downward solar irradiance dropped from 900 to about 150 W/m^2 (0530 UTC).

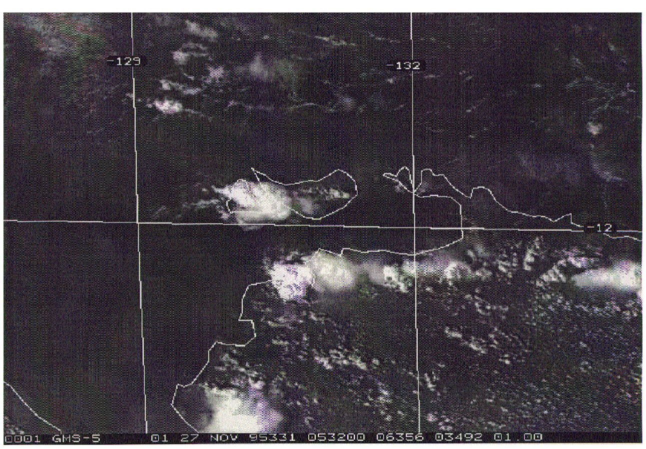

Figure 1. Geostationary Meteorological Satellite visible satellite image 0530 UTC 27 November 1995 showing the development of the convective cell over Aspley Strait and the westward development of the cirrus anvil.

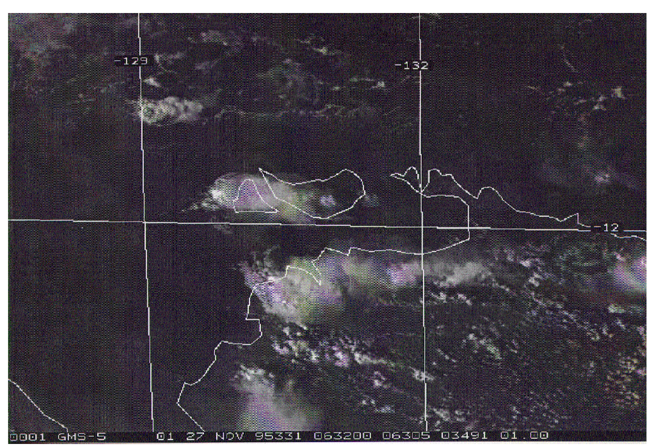

Figure 2. Geostationary Meteorological Satellite visible satellite image 0630 UTC 27 November 1995 showing the westward movement of the convective cell and the further development of the cirrus anvil.

In order to estimate an optical depth for the cirrus anvil, the vertical-average Ka-band radar reflectivity was determined. This average reflectivity was converted into an ice water content using Sassen's (1987) relationship M (ice mass content in g/m^3) $= 0.037 Z_i^{0.696}$ (where $Z_i = 5.28 Z_e$). A specific extinction of 0.04 m^2/g (Kinne et al. 1992, Ackerman et al. 1988) was used. The optical depth of the cirrus layer was found to vary between 110 and 20 between 0700 and 0800 UTC.

Heating rate profiles for an optical depth of 100 were calculated using a two-stream model (Toon et al. 1989) with optical properties calculated using a correlated-k technique. The cloud thickness and height were taken from the radar images. A mean ice particle size of 50 microns was assumed, and the number density was adjusted to give the appropriate optical depth. Heating rates are averaged for layers with depth of 1 km. These model calculations are presented in Figure 3 and show cloud-top IR cooling rates

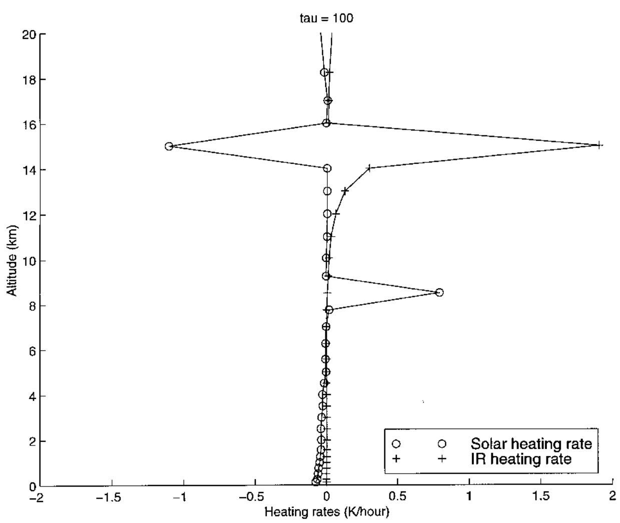

Figure 3. Solar and IR heating rate as a function of height calculated for a cloud with optical depth = 100. Cloud boundaries are indicated by the dotted lines.

on the order of 24-27 K/day, cloud-top solar heating of 19-48 K/day, and cloud-base IR heating of 14-19 K/day. Preliminary analysis of MCTEX anvil case study events shows high ice water paths and large optical depths. These anvils, therefore, have significant impacts on the radiation budget of the surface and upper troposphere.

The MCTEX dataset lends itself to more case study analyses of cirrus anvils. We have identified at least two more well-documented anvil events. In addition, we will coordinate these measurements with data from a scanning Doppler radar located about 50-km south of the Garden Point site at Nguiu.

References

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