Airflow analyses using thermal imaging in Arizona's Meteor Crater as part of METCRAX II

Thermal Infrared Method in the Barringer Meteor Crater

Fig. 2 Barringer Meteor Crater and cold air flow Adapted from NASA 1985

Cold-air flow from southwest
1 km

The second Meteor Crater Experiment (METCRAX II) took place in October 2013 at the Barringer Meteorite Crater in Arizona USA (Fig. 1) (Lehner et al. 2016), to investigate nighttime downslope-windstorm-type flows that were discovered in the crater in 2008 during METORAX I. Five thermal infrared (TIR) cameras supplemented the extensive meteorological instrumentation in and around the crater. The cameras looked down into the crater and its surroundings from various locations on the crater’s rim, sensing thermal infrared (TIR) radiation and the effective radiation temperatures of the crater surfaces (Fig. 2). The Barringer Meteorite Crater is a near circular closed basin, surrounded by a uniform plain sloping upwards to the SW with a 2% slope. It has a diameter of 1.2 km, is 170 m deep and its rim extends 30-50 m above the surrounding plain. An indirect means of sensing near-surface airflow is possible using the high temporal and spatial resolution of surface temperatures from sequences of TIR images taken at 2-3 intervals. The images are assembled in time-lapse videos.

TIR data processing, method approach and evaluation

Before the TIR data can be used for airflow analyses they have to be statistically analyzed, corrected and georeferenced as shown in Fig. 3. The TIR method can be evaluated for METCRAX II by correlating the TIR-measured surface radiation temperatures measured in situ near-surface air temperatures. The higher the correlation coefficients, the more suitable is the TIR method for determining air temperature changes. In the correlation between a HOBO temperature sensor at 1.2 m height at the SW088 site (see Fig. 4) with a nearby TIR polygon is shown in Fig. 5. The good results determine display both similar temporal fluctuations. Smoothing of the data by using the polygon assists with this analysis. The frequency response of the TIR is much higher than the in situ temperature sensor, which has a time constant of about 2 minutes. The corrected at this site is u< 0.80, suggesting that the near-surface airflow can be derived from surface temperature changes at this location. The applicability of the TIR method differs, however, among the in situ sensors, highlighting the different locations because of surface properties, air flow characteristics and TIR camera viewing angles.

Cold-air flow visualisation with thermal imaging

The time sequence of airflow within the crater can be visualized by creating TIR videos that reveal flow dynamics and special flow characteristics. One can estimate the size of warm air intrusions at the crater surface (Fig. 6) and the overnight filling up of the cold-air pool (Fig. 7). The airflow at different locations in the crater can be analyzed at a glance by comparing profile lines on the different crater sidewalls (Fig. 8). The intrusion of a south-southwestern cold-air inflow into the crater is visible on the lower SSW sidewall (profile 1). It continues across the crater floor, approaching the north sidewall of the crater (profile 2).

Cold-air flow and cold-pool analyses with thermal imaging

In addition to the visual analyses of airflow dynamics, statistical approaches are possible:
- Cold-air flow: statistical time series allow a quantification of cold-air-influenced surfaces and the corresponding TIR temperature gradients
- Warm air intrusions (WAI): cross correlation between TIR data at the crater floor provides an analysis of warm air intrusions and their spatial structure
- Waves that form in the lee of the crater rim can be identified if they reach down to the crater floor
- Georeferenced TIR data provide spatial position information to assist with the interpretation of airflow within the crater
- Different methods can be evaluated and research questions can be addressed by combining TIR data with other meteorological data in the crater

In addition to the visual analyses of cold-air pool dynamics there are other possible approaches to assess:
1) changes in the convective layer over time
2) determine pseudo-vertical TIR temperature gradients on the crater sidewalls
3) identify boundaries between different atmospheric structure layers
4) investigate high spatial and temporal variation of cold-air pool structure
5) cold-air pool volume
6) identify cold-air layer changes with time
7) calculate cold-air pool volume with georeferenced TIR data
8) determine changes of cold-air pool volume with high spatial and temporal resolution
9) cold-air pool sloshing
10) cross correlate TIR temperature gradients on the north and south crater sidewalls
11) quantify cold-air pool sloshing and dynamics using TIR temperature changes at the crater rim
12) analyze the causes of the sloshing by combining TIR data with other meteorological data

Sources:

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