

COMPARISON OF STABLE BOUNDARY LAYER EVOLUTION IN A SMALL BASIN AND OVER THE SURROUNDING PLAIN

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Abstract: The October 2006 Meteor Crater Experiment (METCRAX) studied stable boundary layer evolution in a simplified topographic basin. The evolution of the stable boundary layer in the crater is compared to the evolution over the surrounding plain.

Keywords: METCRAX 2006, *stable boundary layer, basin, plain, temperature inversions, Meteor Crater, Arizona*

1. INTRODUCTION

The Meteor Crater Experiment (METCRAX) took place during October 2006 in the Arizona Meteor Crater near Winslow, AZ. One of the main goals of the experiment was to better understand the cold pool build-up and break-up in this small idealized basin during periods with weak external forcing. For additional information on the other scientific goals, the experimental design, and field instrumentation see Whiteman et al. (2007, this issue).

There have been several previous studies investigating stable boundary layers in small basins including Peter Sinks, UT (Clements et al., 2003) and Gruenloch, Austria (Whiteman et al., 2004). One of the main shortcomings of these studies was the presence of low passes along the basin rim, complex topography surrounding the basin, and limited information on the background flows outside of and above the basin. METCRAX was designed to overcome these obstacles, since the crater has very little variation in rim height, it lies on a flat plain, and equipment was set up outside the crater to monitor background meteorological conditions. Therefore, we hope to be able to isolate the effects of the basin on the build up and break up of the cold pool more effectively.

Initial analyses have been designed to isolate these effects by comparing cold pool formation inside the crater, as observed with tethersondes and surface-based lines of temperature sensors, to cold pool formation over the surrounding plain, as observed with rawinsondes launched 5 km NNW of the crater (Fig. 1). Here, we limit our discussions to Intensive Observational Period 5 (IOP 5) on 22-23 October 2007.

2. RESULTS AND DISCUSSION

IOP 5 was chosen for our initial analyses because it had one of the best and least disturbed inversion formations during the one-month experimental period. At the surface station 5 km NNW of the crater, winds were variable from 0-4 m/s from the N-SE from mid-afternoon through early evening (Fig. 2). As evening progressed a regional drainage flow began and wind speeds stabilized at about 4 m/s from the SW from 2100 to 0600 Mountain Standard Time (MST).

In mid afternoon (1500 MST), the crater atmosphere was well mixed and the profiles inside and outside the crater matched well, with the North and East lines of HOBOs slightly warmer and the South and West lines of HOBOs slightly cooler than the tethersonde profiles (Fig. 3). The differences in temperature on the HOBO lines are due to the radiational heating and cooling of the crater surface. After sunset (1800 MST) there is rapid cooling at the crater floor and on the plain outside the crater. Along the HOBO lines there is enhanced cooling, but over the crater center the rawinsonde and tethersonde profiles coincide above the forming surface inversion on the plain.

By 2100 MST, the tethersonde profiles over the crater, and the rawinsonde profile over the surrounding plain (Fig. 4) begin to diverge. Enhanced cooling occurs inside the crater while the profiles remain coincident above the crater rim. By 0000 MST the cooling slows at the bottom of the crater and at the surface on the surrounding plain. There is, however, continued cooling in the crater volume. Since the temperature profiles remain coincident above the crater, this leads to the formation of a second inversion above the crater just above the crater rim. Above the surface inversion and below the capping inversion the tethersondes indicate an isothermal temperature structure through most of the crater volume. By 0000 MST the South HOBO line had become colder than the other lines. This will be a point of further analysis, but one theory is

that the regional southwesterly drainage flow on the surrounding plain helps to advect colder air from the surface of the surrounding plain onto the outside sidewalls of the crater (and sometimes over the crater rim into the crater volume).

As the night progresses we see continued cooling both at the bottom of the crater, in the crater volume, at the surface of the surrounding plain, and above the surrounding plain (Fig. 5). The crater volume had continued to cool at a rate faster than the atmosphere above the plain, leading the inversion at the crater rim level to strengthen by early morning (0614 LST). Temperatures on the South outside sidewalls of the crater became colder than the sidewalls at the same elevation inside the crater. A possible explanation for this is that, since the sidewalls outside the crater have a lower-angle slope, there was less horizontal mixing, and temperatures became similar to those on the surface of the plain. This explanation is supported by the fact that temperatures decrease as we move away from the crater towards the plain, and as the slope decreases. Temperatures on the South and West lines are colder than on the other lines. This may be explained by the southwesterly drainage flow bringing cold air from the surface of the plain to these locations.

After sunrise, surface temperatures inside the crater quickly rise so that the shallow surface inversion is destroyed within minutes, as seen from tethersonde profiles at these times (not shown). The crater top inversion takes more time to remove, since a larger volume of air must be heated. However, by the time the sun has illuminated most of the crater (0913 MST), the crater volume became nearly isothermal, and may actually have warmed more than the atmosphere above the surrounding plain due to the increased surface area and lower volume subject to heating in the crater. The East HOBO line lagged behind in heating because of the late sunrise caused by shading from the crater rim. The other three HOBO lines are consistently warmer than the tethersonde profiles at this time, showing us that the heating of the crater volume is driven by the heating at the sidewalls.

From this analysis, surface temperatures from the lines of HOBOs can be used as a first guess to free-air temperature profiles over the crater, but they would introduce considerable error. They do, however, give us a much better idea of the three-dimensional temperature structure of the crater volume. Furthermore, from the HOBO lines we see that even during nighttime stable periods, temperature structure varies with location in the crater. We hypothesize that this asymmetry is caused by the interaction of the crater with the background flow on the plain surrounding the crater.

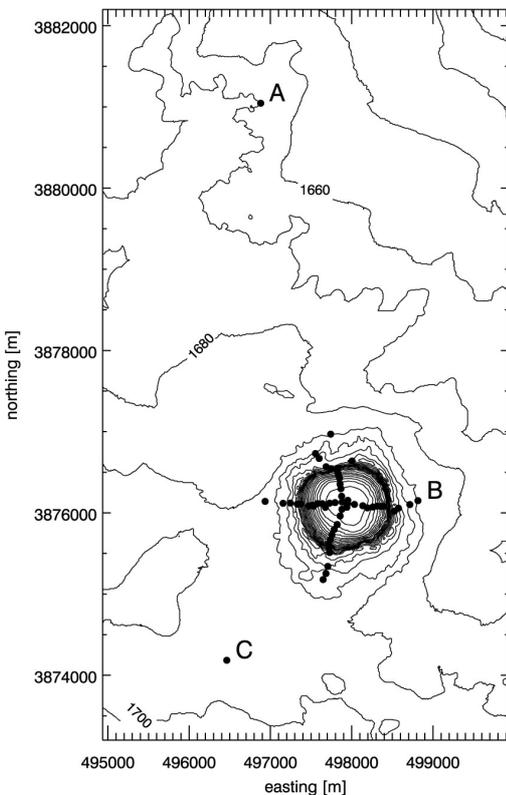


Figure 1: Equipment locations. Site A instrumentation included the rawinsonde set and the automatic weather station. The instrumentation in and around the crater (Site B) included the HOBO lines (shown) and the tethersonde launch sites. Site C and instrumentation at other sites are described more fully by Whiteman et al. (2007, this volume).

3. CONCLUSIONS

Comparisons of the boundary layer evolution within and above the crater to the boundary layer evolution above the surrounding plain indicate marked differences. Temperature profiles generally converge by about 200-250 m above the crater floor (i.e., 50-100 m above the crater rim), but below this show distinctly different structures. The rawinsonde profiles showed an initial rapid surface inversion formation and then a slow cooling of the boundary layer throughout the night. The tethersonde profiles also indicate this rapid surface inversion formation, but then show a higher rate of cooling in the crater volume. At 200-250 m above the crater floor the cooling is equal to that over the surrounding plain. This leads to a temperature structure over the crater of a strong surface inversion, then an isothermal layer through most of the crater volume, followed by a capping inversion at the crater rim level which acts to connect the colder air in the crater to the warmer air above the surrounding plain.

The HOBO profiles indicate that the three-dimensional temperature structure within the crater is not symmetrical, and it is possible that the background flows on the surrounding plain are important in creating and maintaining this three-dimensional structure. Colder air present on the South sidewalls inside and outside the crater may be a result of a Southwesterly drainage flow transporting cold air from the surface of the plain towards and possibly into the crater.

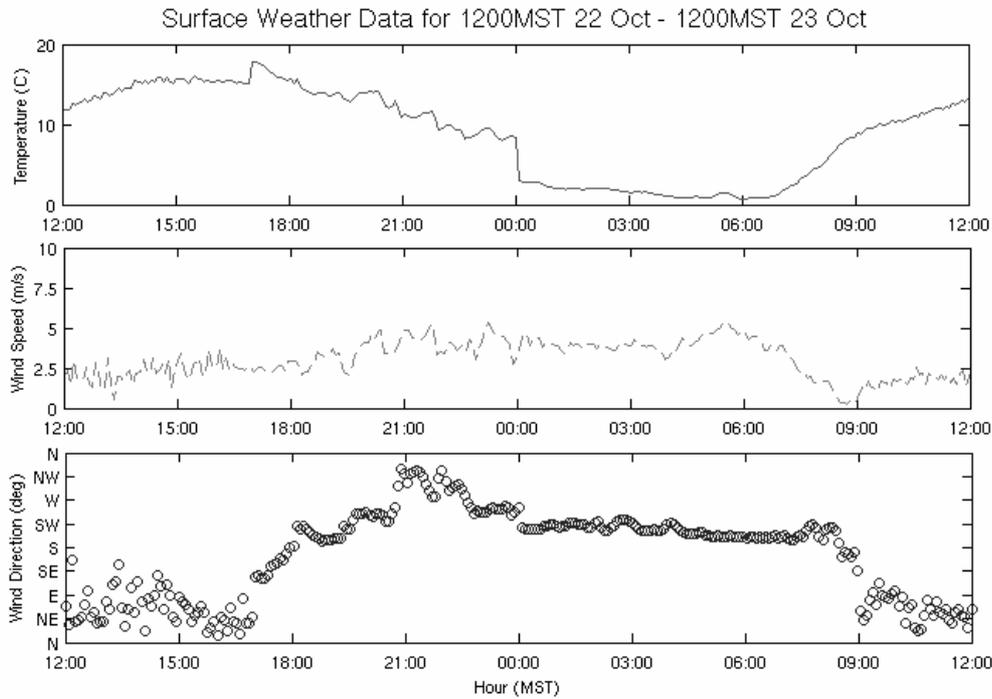


Figure 2: Surface weather data (temperature, wind speed, and wind direction) from an automatic weather station on the plain 5 km NNW of the crater. This station was co-located with the rawinsonde launches.

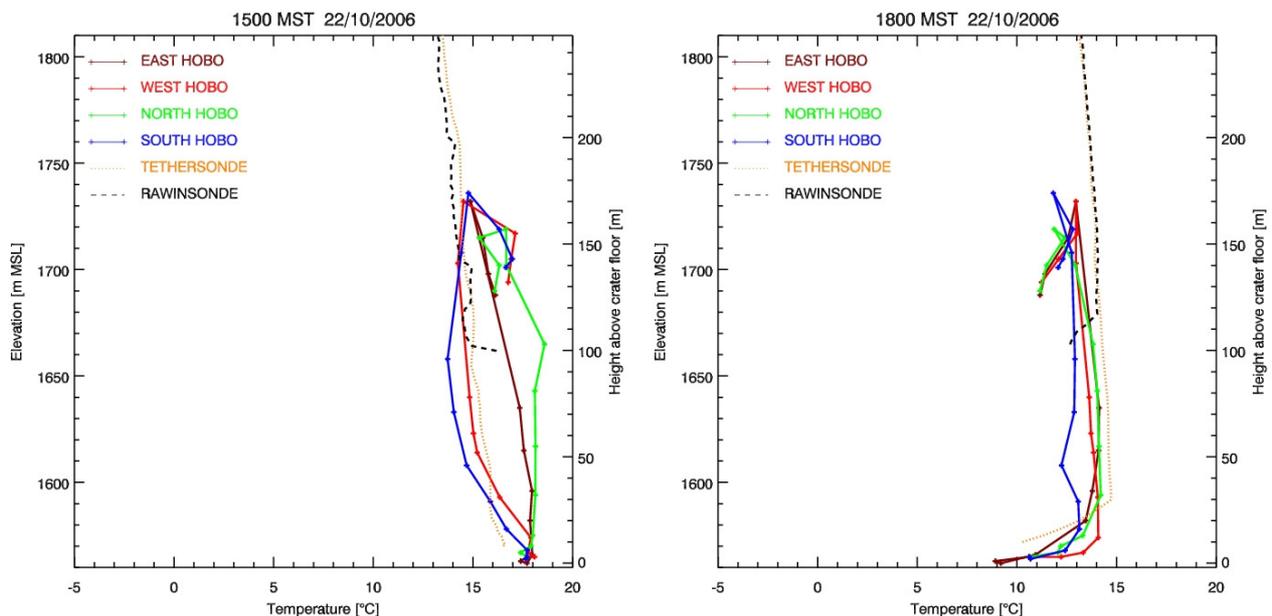


Figure 3: Coincident temperature profiles and pseudo-vertical profiles during IOP 5 from HOBO lines running east, west, north, and south in the crater, tethersondes at the center site in the crater, and a rawinsonde at a site 5 km NNW of the crater. Profiles are for 22 October at 1500 and 1800 MST.

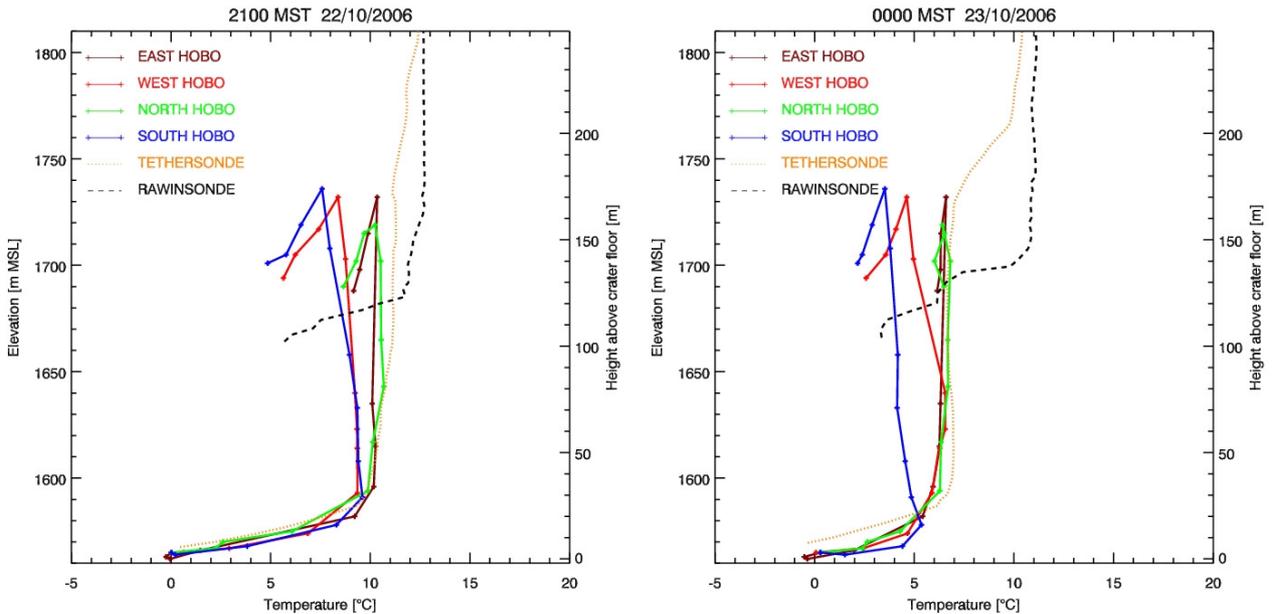


Figure 4: Same as Fig. 3, but for 2100 MST 22 October and 0000 MST 23 October.

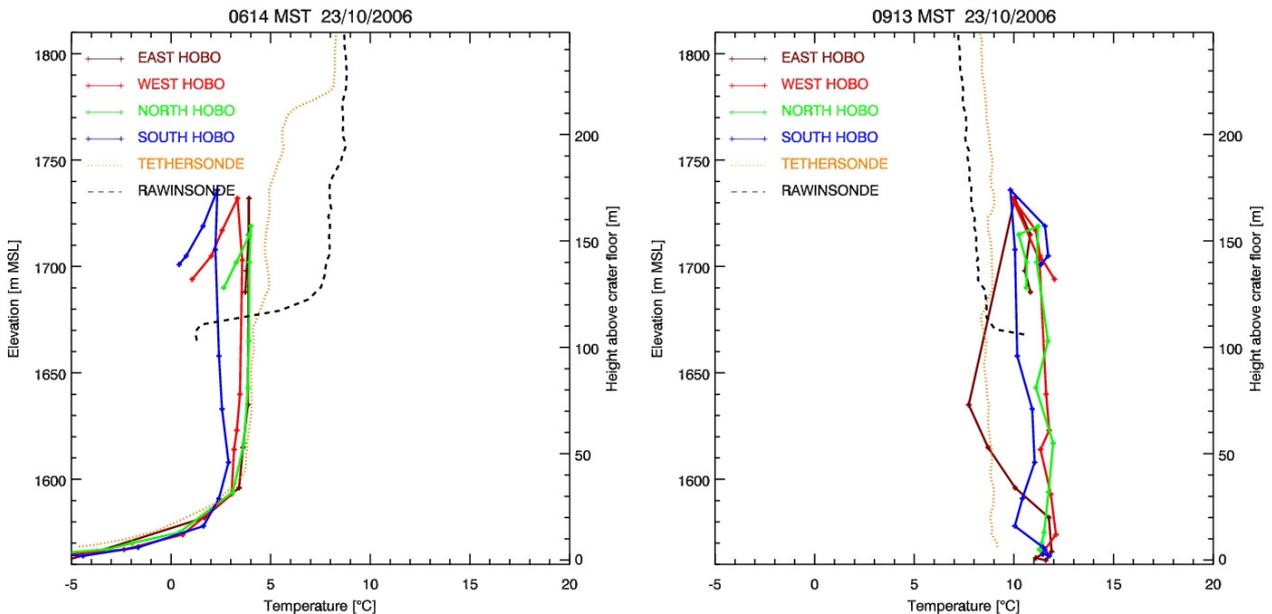


Figure 5: Same as Fig. 3, but for 0614 and 0913 MST 23 October.

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