11B.4 THE THERMAL FIELDS OF THE WAKES AND THE CIRCULATION ON THE LEESIDE OF THE ISLAND OF HAWAII

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1. Introduction

Over the last decades, several projects and studies have been done on the island circulations over the island of Hawaii; however, most of the research work is on the windward side. The lee-side research is rather limited. Schroeder (1981) used data collected at six stations in the Northwest Hawaii and show that: "sea breeze variability appears to be related to both synoptic-scale cloud and wind distributions and to the thermal properties of lava surface." Chen and Nash (1994) used HaRP data to analyze the island-scale diurnal rainfall and airflow patterns. In the leeside of the island of Hawaii, more rainfall occurs in Kona than the other lee-side areas of the island.

The Hawaii wake is one of the main features of island-induced circulations. The first direct evidence for the existence of vortices in Hawaii's wake was presented by Nickerson and Dais (1981). They suggest that the wake is unstable with vortices being periodically shed from the edge of the island. With HaRP data, Smith and Grubisic (1993, hereafter referred as SG1993) suggest the wake consists of two elongated counter-rotating eddies and a strong reverse flow along the wake axis. A small Kohala wake is embedded between the accelerating trades to the north and the Waimea jet to the south (Fig.18 in SG 1993). However, thermal fields were not analyzed in SG1993.

The objective of this paper is to analyze the thermal fields in the wake zone and the lee side of the island, as well as their relationship with the lee side diurnal circulation and rainfall distribution under the summer trade-wind weather.

2. Data

In this paper soundings taken by NCAR Electra downstream of the island of Hawaii during HaRP were used. Horizontal distributions of the thermal fields about 480 m above the sea level in the wake zone were analyzed. Because the data collected by the NCAR Electra is usually not at the same height, we presented the deviations of the downstream value from its upstream counterpart at the same level on the same day.

During HaRP, an early morning upstream aircraft sounding was taken about 60 miles east of the island of Hawaii on 22 days. These soundings were averaged to construct the average thermodynamic profiles. We assume that the mean early morning sounding represents the mean upstream thermodynamic structure of the trade-wind flow.

During HaRP, there were 12 strong trade-wind days and 12 weak trade-wind days. The 12 strongest (weakest) trade-wind days are determined on the basis of the average daily (0000-2400 UTC) resultant wind speeds for the northern most and the southern most stations (Chen and Nash, 1994). In the 22-day's upstream sounding during HaRP, only 5 days belong to strong trades and 5 days belong to weak trades. The average trade wind speed upstream during strong trades is 1.5 ~ 2 $m\ s^{-1}$ larger than during weak trades.

Over the island, the deviations of the thermal fields at the lee-side PAM stations from the upstream conditions at the same level were made using the upstream soundings taken by NCAR Electra aircraft. For HaRP mean, the mean of the 22 upstream soundings is used as the reference. For strong (weak) trade-wind composite, the average of the 5 days strong (weak) trade-wind aircraft soundings is used as the reference.

3. **Summary and conclusions**

The temperature in the wake is higher than its upstream value at the same level. Mixing ratio and relative humidity are lower. Higher temperature deviation (2~3 K) (Fig. 1) and lower mixing ratio deviation (2~4 $g\ kg^{-1}$) can be found off the northwest and southwest coasts of the island because of the adiabatic descent in the lee side of mountains with tops below the trade-wind inversion. The trade-wind inversion base in the wake is lower (~ 350 m) than that of the upstream environment. The returning airflow in the wake off Kona coast is more humid than other areas in the wake. The depth of the returning flow in the wake is about 1.8 km.

In the Kona area (Fig. 2), because of the relatively humid returning flow offshore, LCL (200~400 m in the late afternoon and early evening, Fig. 3) is lower with higher orographic precipitation than those along the northwest and southwest coasts. For strong trade-wind days, the surface air along the Kona coast is more humid (~1 $g\ kg^{-1}$) than weak trade-wind days, possibly due to stronger return flow offshore. Therefore, slight more precipitation occurs during strong trades than during weak trades. The timing of maximum rainfall during the diurnal cycle occurs in the late afternoon/early evening hours. Along the lower slope, the maximum rainfall occurs at ~1800 HST whereas along the coast, the orographic precipitation extends to the early evening, possibly because of the convergence between the land breeze and the offshore returning flow.

Adiabatic decent is the main reason for the relatively higher temperature and lower precipitation in the northern and southern lee sides (Fig. 4). Sea-breeze duration and strength in the northwestern lee side depend on the trade-wind strength. During strong trade-wind days, the temperature

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along the northwestern and southwestern lee sides is higher (0.5~1.0 K) than during weak trades as stronger trade winds move over the mountains and descend in the lee side. Because of stronger adiabatic descent during strong trades than during the weak trades, the precipitation is much less in these areas when the trade winds are stronger.

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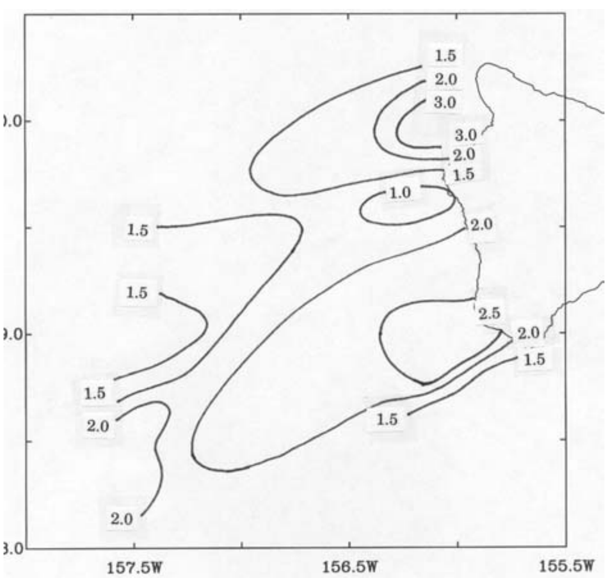

Fig.1. Deviations of the temperature from the open ocean conditions in the large wake at about 490 m above sea level from ~ 0640 to ~ 1000 HST on July 24.

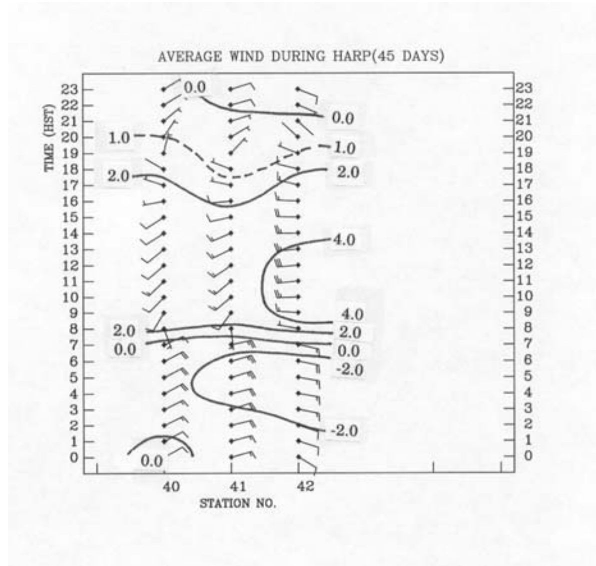

Fig.2. The mean diurnal cycles of the wind vectors and temperature deviations (K) (solid line) from the upstream composite sounding during HaRP for stations 40, 41 and 42 in the Kona area.

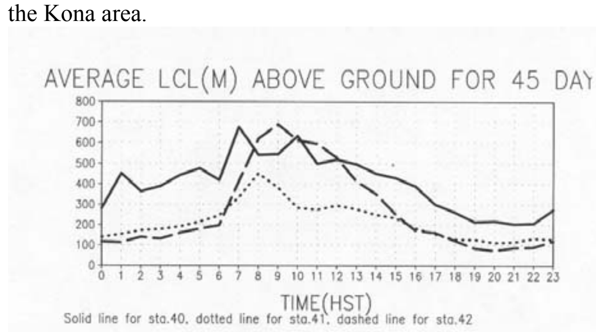

Fig.3. The average LCL (m) above ground during HaRP at stations 40 (solid line), 41 (dotted line) and 42 (dashed line).

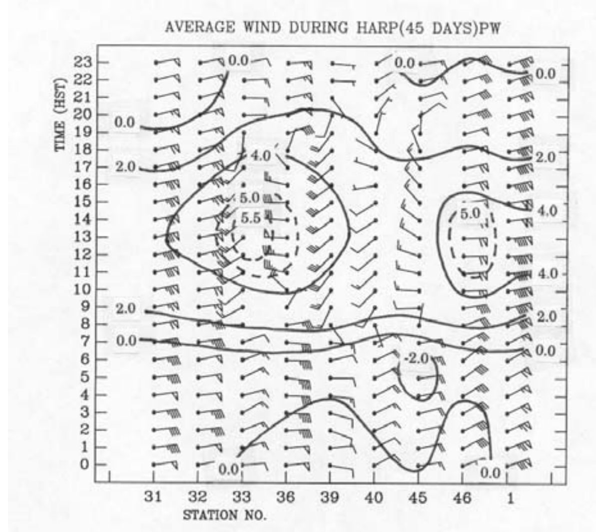

Fig.4. As in Fig.2 but for stations along the lee-side coastal line transect. Station 31 (1) is the northern (southern) most station.