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U.S. GEOLOGICAL SURVEY

HAWAIIAN VOLCANO OBSERVATORY SUMMARY 94, PART III ELECTRONIC TILT DATA, JANUARY TO DECEMBER 1994

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U.S. GEOLOGICAL SURVEY
HAWAIIAN VOLCANO OBSERVATORY
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+ Arrived during 1994
* Left during 1994

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INTRODUCTION

Electronic tilt monitoring is one of the methods used by the Hawaiian Volcano Observatory (HVO) to measure ground deformation on the island of Hawaii. The tiltmeter sites are shown in Figure 1. It is the only method employed by HVO at present to monitor ground deformation in real time. This report also includes the rainfall record and the watertube tilt data at Uwekahuna, which have a bearing on some of the events detected or measured by the electronic tiltmeters.

INSTRUMENTATION

There are two basic styles of electronic tiltmeters used by HVO: borehole and platform models. The borehole tiltmeters consist of an electrolytic bubble sensor mounted at the bottom end of a buried, vertically oriented pipe about 1 meter in length. HVO does not currently have any borehole tiltmeters of the pendulum type. The platform tiltmeter consists of a sensor mounted on a rectangular or triangular-shaped metal platform designed for surface (floor) mounting.

A detailed description of each type of electronic tiltmeter used at HVO follows under the manufacturer's heading.

ROCKWELL AUTONETICS AND KINEMETRICS

These tiltmeters were originally built by Rockwell Autonetics then subsequently by Kinemetrics, Inc. They have a single sensor with four electrodes mounted orthogonally, forming a dual-axis sensor. The sensor contains a conductive fluid with a small air bubble to indicate the vertical pole. The electrodes indicate the position of the bubble and, hence, any change in tilt. The sensor is mounted at the bottom end of a buried, vertically oriented, meter-long sealed pipe. The pipe is then placed within a hole bored in rock or another, larger diameter pipe. The borehole is backfilled with sand to stabilize and couple the instrument to earth. HVO had six of these tiltmeters operating at the beginning of 1994.

WESTPHAL

This platform tiltmeter was built by J. A. Westphal of Caltech. It utilizes two single-axis electrolytic bubble transducers mounted orthogonally, forming a dual axis instrument. Each transducer contains conductive fluid, two opposing electrodes, and a small air bubble to indicate the vertical pole. The transducers are mounted in holders fastened on a 20.3 cm. square invar plate. HVO operates one Westphal tiltmeter.

IDEAL AEROSMITH

This platform tiltmeter was built by the Ideal Aerosmith Corporation. This single-axis tiltmeter utilizes two cisterns filled with mercury spaced a meter apart. The mercury and the cistern cover act as capacitance plates with an air

ELECTRONIC TILTMETER STATION LOCATIONS

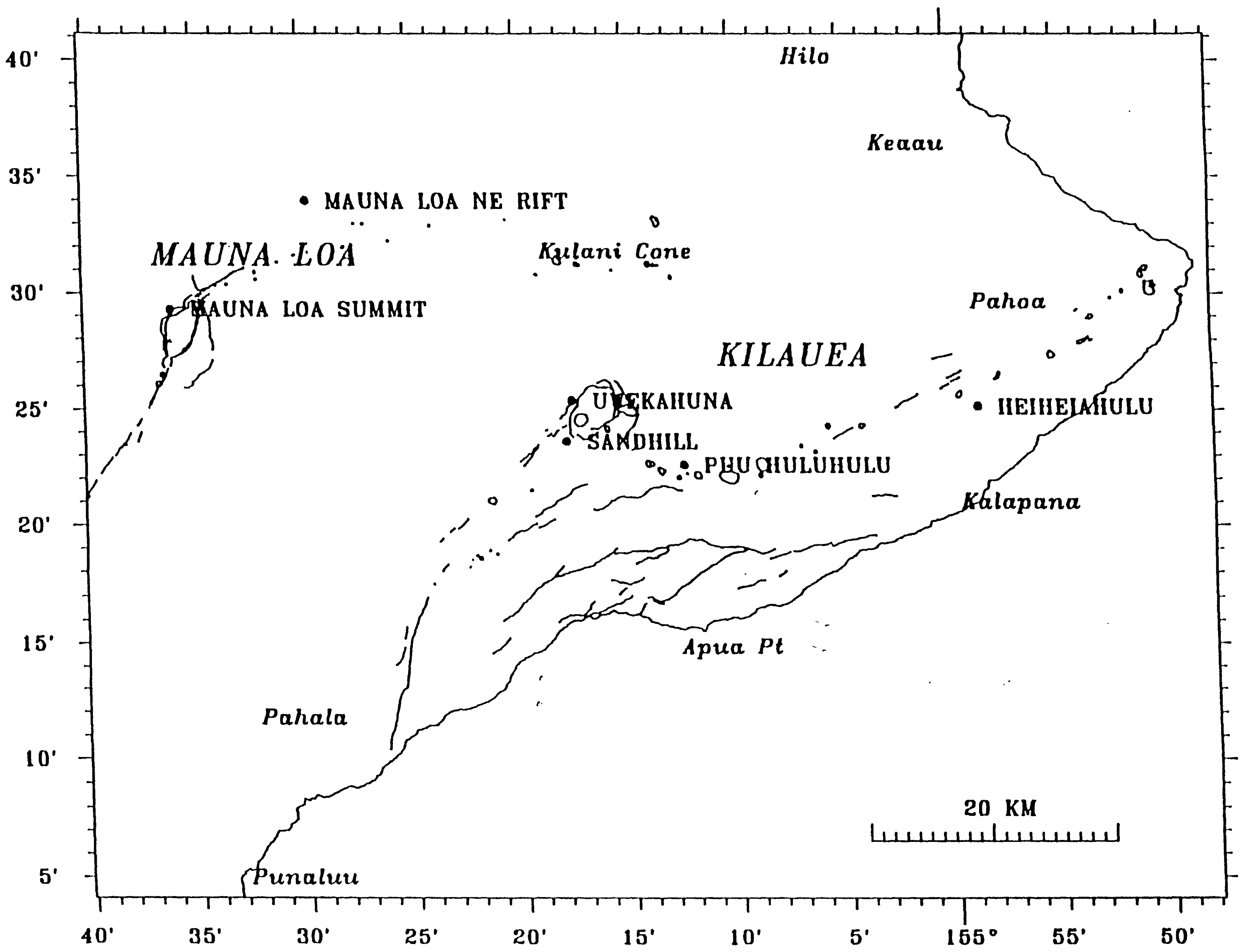


Fig. 1

gap for a dielectric. The capacitance is measured through a wein bridge and converted to a voltage output calibrated in Êradians. HVO operates one Ideal Aerosmith tiltmeter.

APPLIED GEOMECHANICS

HVO operated two tiltmeters made by the Applied Geomechanics Corporation, a borehole and a platform model. The borehole model consists of a dual axis sensor is mounted in the bottom of a .85-m-long sealed pipe. The platform model consists of a dual-axis sensor mounted on a triangular shaped platform about 15 cm. on a side. The sensor contains a conductive fluid with a small air bubble to indicate the vertical pole. The electrodes indicate the position of the bubble and, hence, any change in tilt.

DATA COLLECTION & PROCESSING

All HVO tiltmeters output a 0 to ±5 VDC signal. The tilt signals are sampled by the HVO Polling Telemetry System for Low Frequency Data Acquisition (Puniwai, 1990) every 10 minutes. The polling system converts the voltage into digital form, collects the information in the central polling computer, and then passes the data to the HVO minicomputers for data storage, retrieval and analysis.

The tilt information is stored as 12-bit data values (0 to 4096 bits), converted back to voltage (2.44 mv/bit), translated into microradians (per tiltmeter calibration values), then plotted. All the time-series data plots in this paper have been produced with BOB, an interactive program for accessing, processing, and displaying time-series data (Murray, 1986). The year-long data plots have been cleaned (noise spikes removed/earthquake and instrumental offsets removed).

The station location and vector plots were produced with QPLOT (Klein, 1980). The data for the vector plots were taken from the BOB data files for the corresponding time period.

STATION INFORMATION & DISCUSSION

1. UWEV (Uwekahuna) Latitude 19.4239° Longitude 155.2839°

The UWEV station (labelled "UWEKAHUNA" in the data plots) is located in the Uwekahuna Vault operated by the HVO at Kilauea's summit. This station is used to monitor Kilauea's summit magma chamber. The single wall concrete vault, constructed in 1948, is located 360 meters west of the Hawaiian Volcano Observatory. The vault is 8.6 meters long, 3.6 meters wide, with a 2.1-m-high ceiling. The vault is divided into three rooms: two small entrance chambers and a large instrument room. The instrument room is supplied with 120 VAC uninterruptible power and is dehumidified. The temperature variation in the vault has been measured to be less than 0.5°C per day. The vault floor sits on bedrock, and the roof is under about 1 m of volcanic ash backfill. During periods of heavy rainfall, the vault is susceptible to flooding.

INSTRUMENTATION

Four independent tiltmeters are installed in the Uwekahuna vault. These tiltmeters include: the Ideal Aerosmith, a Westphal, an Applied Geomechanics, and a manually read watertube tiltmeter.

Ideal Aerosmith, Model No. DCTM-31, Serial No. 10567. This electronic single axis instrument is aligned E-W. It has been operating since 1968 with occasional down time for repairs and calibration. The instrument is insensitive to the less than 0.5°C daily temperature fluctuation in the vault.

Westphal Tiltmeter, model WTM-1. This electronic biaxial tiltmeter has been operating since 1984 with occasional down time for repairs and calibration. The instrument is insensitive to daily temperature fluctuations.

Applied Geomechanics, model 702. This electronic biaxial platform tiltmeter was installed in early 1994. No data from this instrument is provided in this report because it was considered unacceptable. The N-S component changed by 280 and the E-W changed by 474 µradians for the year. A single order statistical correction was attempted on each component to see if the data became presentable, but it was still considered unacceptable.

The tilt measured by the electronic tiltmeters in the Uwekahuna vault can be compared with tilt measured with a 3-m-long biaxial watertube tiltmeter installed in the vault. The watertube tiltmeter is usually read on a daily basis. The watertube was installed in 1956 and has provided a long-term record of Kilauea summit tilt changes.

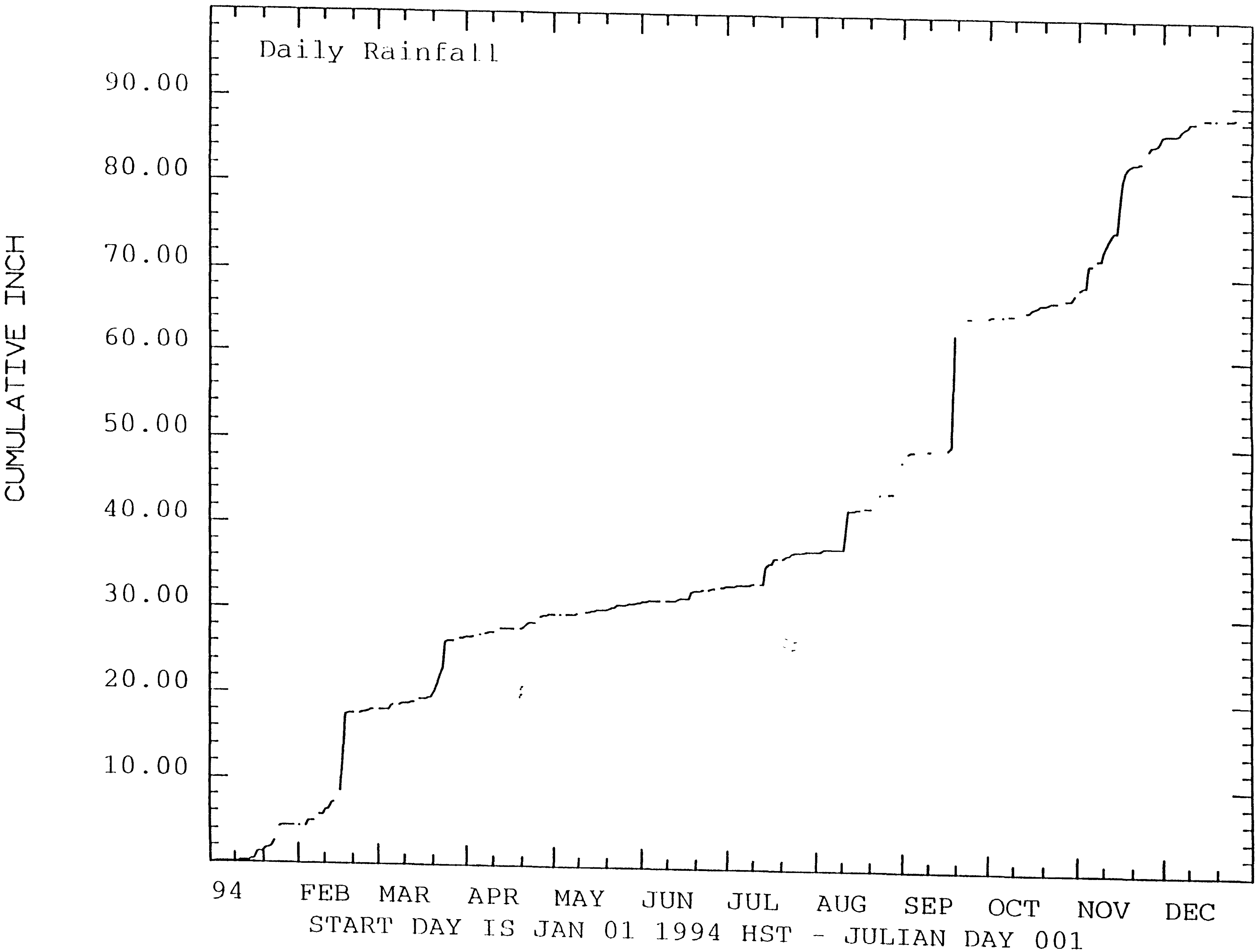
The Uwekahuna rainfall record is introduced here (fig. 2) because of the instrument location and its use as a general indicator for rainfall over Kilauea Volcano as a whole. This standard National Weather Service rain gauge is usually read daily, and the data is plotted as a cumulative record for ease of interpretation. The data is included to correlate any specific tilt event with rainfall. High levels of rainfall can cause tilt events at a specific site or possibly affect the mountain as a whole.

Temperature is also recorded in the Uwekahuna vault (fig. 10A). The LM335, a precision, integrated circuit temperature sensor, is used to monitor temperature at all sites. This sensor has a range of-40°C to +100°C, has a linear output, and typically has less than 0.01% error over the measurement range. The temperature sensor is installed adjacent to the Westphal tiltmeter.

DISCUSSION

The Uwekahuna Ideal Aerosmith tiltmeter E-W record is similar to the watertube record (fig. 3) in the long term. Tilt events recorded by the Ideal Aerosmith and Westphal tiltmeters have similar amplitudes, but these amplitudes tend to be smaller than those recorded by the watertube tiltmeter. The Ideal Aerosmith and the Westphal tiltmeters show effects in February and September coincident with heavy rainfall and vault flooding. No offsets were recorded by the watertube tiltmeter at those times. The Ideal Aerosmith provides a continuous record of deformation with the least long-term drift of any of the electronic tiltmeters.

The Westphal tiltmeter E-W component shows both offsets during periods of heavy rain and drift throughout the year. This tiltmeter and the Ideal Aerosmith generally showed similiar E-W tilt offsets due to rainfall, but neither the Ideal Aerosmith nor the watertube show the long-term drift seen



Daily Rainfall
CUMULATIVE INCH
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
94
FEB
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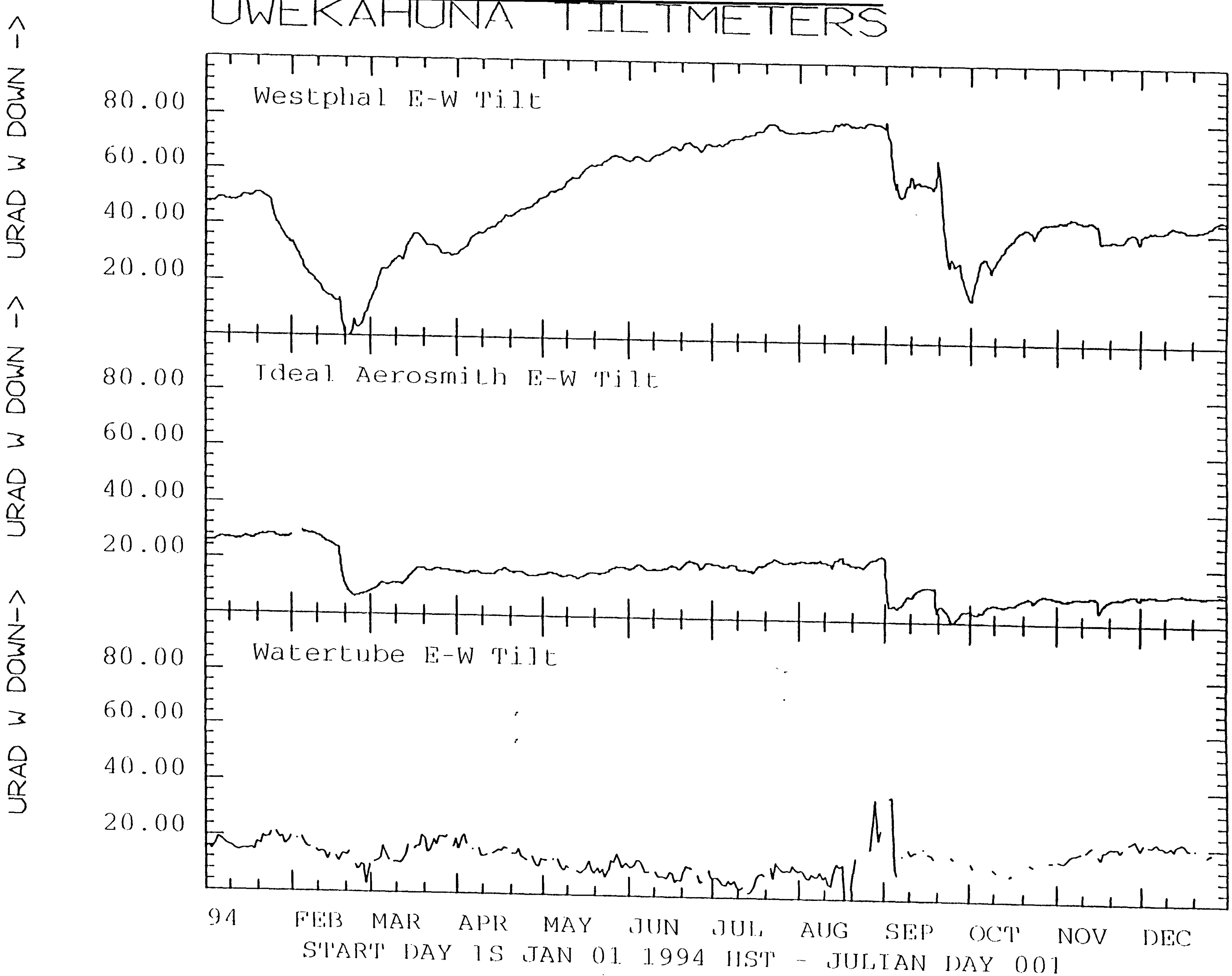
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 2


UWEKAHUNA TILTMETERS
Westphal E-W Tilt
Ideal Aerosmith E-W Tilt
Watertube E-W Tilt
URAD W DOWN ->
URAD W DOWN ->
URAD W DOWN->
80.00
60.00
40.00
20.00
94
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START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 3

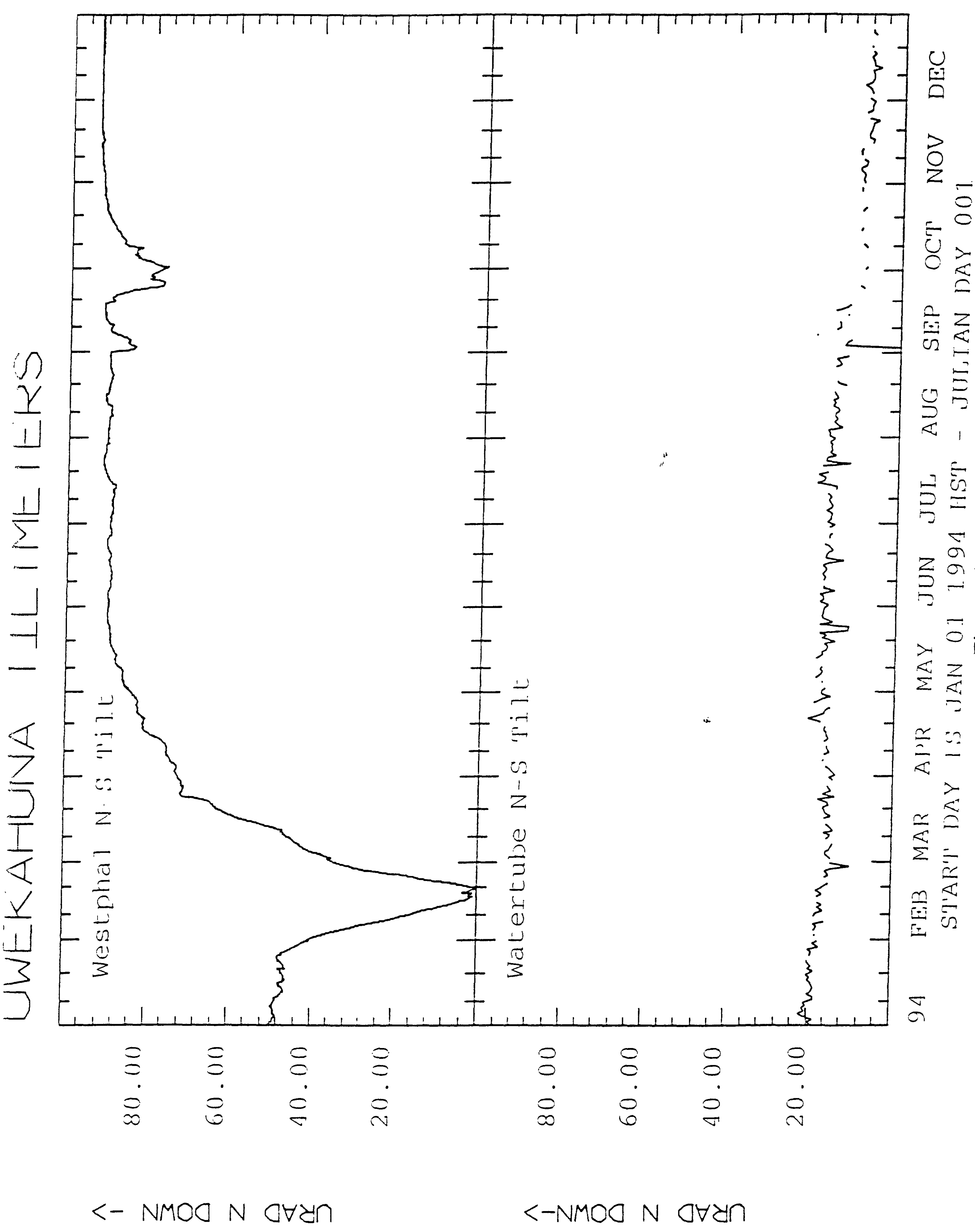

UWEKAHUNA TILTMETERS
Westphal N-S Tilt
Watertube N-S Tilt
URAD N DOWN ->
URAD N DOWN->
80.00
60.00
40.00
20.00
80.00
60.00
40.00
20.00
94 FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 4

in the Westphal tilt plots. This long-term instrumental drift may end in late October, when all three instruments showed little tilt change. Many smaller tilt fluctuations (<5 μradians) are correlated with the Ideal Aerosmith record. The N-S record shows three excursions, all correlated with heavy rainfall (fig. 4). The first excursion, starting in January, did not recover until June. The next two excursions lasted about one to two weeks each. The N-S component seems relatively stable from June to the end of the year, compared with the watertube record. A good correlation can be seen between the temperature record and the Westphal tiltmeter traces (fig. 10a). Analysis of the Westphal tiltmeter record shows that the E-W component is much more susceptible to drift (temperature sensitivity?) than the N-S component, indicating an electronic, and not a mechanical problem.

The watertube tiltmeter E-W record showed no over-all tilt for the year, while the N-S showed a south-down tilt of about 10 μradians. Several small events, less than 5 μradians but lasting from a week to a month, are confirmed by the electronic tiltmeters. This tiltmeter showed some fluctuation at times of heavy rainfall but no large offsets, indicating that either the vault or the volcano were tilted by the rainfall.

2. SDH2 (Sandhill) Latitude 19.3879° Longitude 155.2981°

The SDH2 station (labelled "SANDHILL" in the data plots) is located 400 m SW of the Sandhill benchmark (HVO 119) on Kilauea's summit. This station is used to monitor Kilauea Volcano's summit magma chamber and is much closer to the chamber than the UWEV station. The geology of this site consists of ash, approximately 3-m-thick, underlain by pahoehoe. A meter-long, 15-cm-diameter pipe, is emplaced to house borehole tiltmeters. The top of the pipe is .5 meters below surface level, and is stabilized with ash backfill.

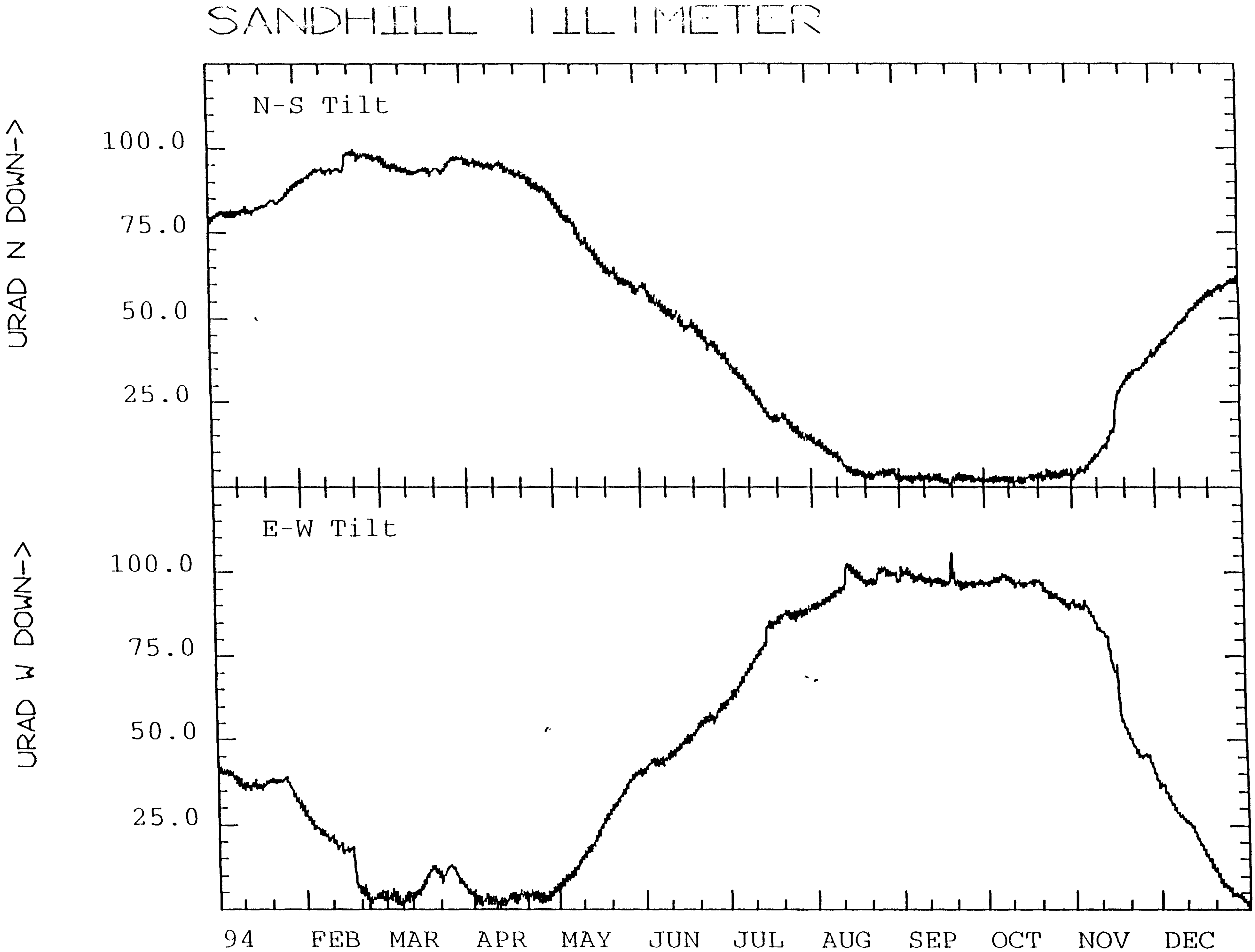
The Sandhill site was established in 1974, and a number of different tiltmeters have been installed at this site over time. The current tiltmeter, an Autonetics borehole (serial no. 0096B), has occupied this site since June 1, 1989. The tiltmeter sits at the base of the pipe, packed in sand.

DISCUSSION

The Sandhill tiltmeter showed large tilt changes throughout the year (fig. 5). A similar ±50 μradian sinusoidal pattern of tilt change was observed in 1992 and 1993. We do not understand the source of this instrumental drift. A temperature probe (fig. 10b) installed with the tiltmeter does not reveal any seasonal temperature changes (negative correlation) to explain the apparent drift in the tilt signals.

The Sandhill tiltmeter showed a NE-down tilt vector (about 36 μradians) for the first three months of the year, then a strong SW-down vector (about 117 μradians) for April to August, very little change from August through October, then a NE-down vector (about 105 μradians) for November and December.

This station suffers from the effects of heavy rain. Heavy rains affected this site in late January, mid-February, mid-July, mid-August, mid-September, and early November. These events are easily discernible in the E-W record.


SANDHILL TILTMETER
N-S Tilt
E-W Tilt
URAD N DOWN->
URAD W DOWN->
100.0
75.0
50.0
25.0
94
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START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 5

3. PUHH (Pu'u Huluhulu) Latitude 19.3762° Longitude 155.2068°

The PUHH station (labelled "PU'U HULUHULU" in the data plots) is located on the north-facing slope of Pu'u Huluhulu, a forested, consolidated cinder cone on Kilauea's East Rift Zone (ERZ). This site is intended to monitor Kilauea's upper ERZ. The geology of the site is interbedded cinder and very thin pahoehoe flows and welded pyroclastics. A meter-long, 11-cm-diamater, pipe is cemented in place, the top of which is about 20 cm below ground level.

The Puu Huluhulu site was established in 1974, and a series of tiltmeters has occupied this site over time. The current tiltmeter, an Autonetics borehole (serial no. 008b), has occupied this site since March 1, 1991. The tiltmeter sits on the base of the pipe, packed in sand.

DISCUSSION

There is no large tilt event recorded by this station for this year (fig. 6). From January to September, the site shows a N-down vector of 24 μradians, and from September to the end of the year the site shows a SW-down vector of 15 μradians.

This site responds well to intrusive events in the upper east rift zone. The site is generally insensitive to rainfall, although the N-S component was offset in a September rainstorm. This station seems very stable when the long-term record is analyzed, having no large excursions like some other stations. The tiltmeters' N-S component has a large daily (4-8 μradian) diurnal signature, which may mask small events. The very low diurnal (<1 μradian) component on the E-W channel makes it useful for detecting small events. There is an apparent inverse correlation between temperature (fig. 10C) and the E-W tilt component and a possible positive correlation between temperature and the N-S tilt component, although there is a time lag of three months between the temperature peak and the N-S tilt peak.

4. HHHS (Heiheiahulu) Latitude 19.4170° Longitude 154.9757°

The HHHS station (labelled "HEIHEIAHULU" in the data plots) is located 1.8 km SE of Heiheiahulu cinder cone on Kilauea's ERZ. This site is intended to monitor changes near Heiheiahulu in the middle ERZ. The geology of the site consists of thick pahoehoe flows. The tiltmeter is installed at the bottom of a 1.5-meter-deep borehole.

This site was established in 1977, and a series of tiltmeters has occupied this site over time. An Autonetics borehole tiltmeter (serial no. 0107B), had occupied this site from June 7, 1989 to August 8, 1994. The current instrument, an Applied Geomechanics borehole tiltmeter (serial no. 1776), was installed on August 9, 1994.

DISCUSSION

This tiltmeter site did not record any significant events in its area (fig. 7) while it showed a coherent record. The initial tiltmeter record was seriously disturbed by an infestation of ants, whose tunnels caused the tiltmeter to shift, starting in late February. The Autonetics tiltmeter (both components) showed a positive correlation with temperature (fig. 10D) changes, for the very short period of good record. A new tiltmeter was installed in August but did not show

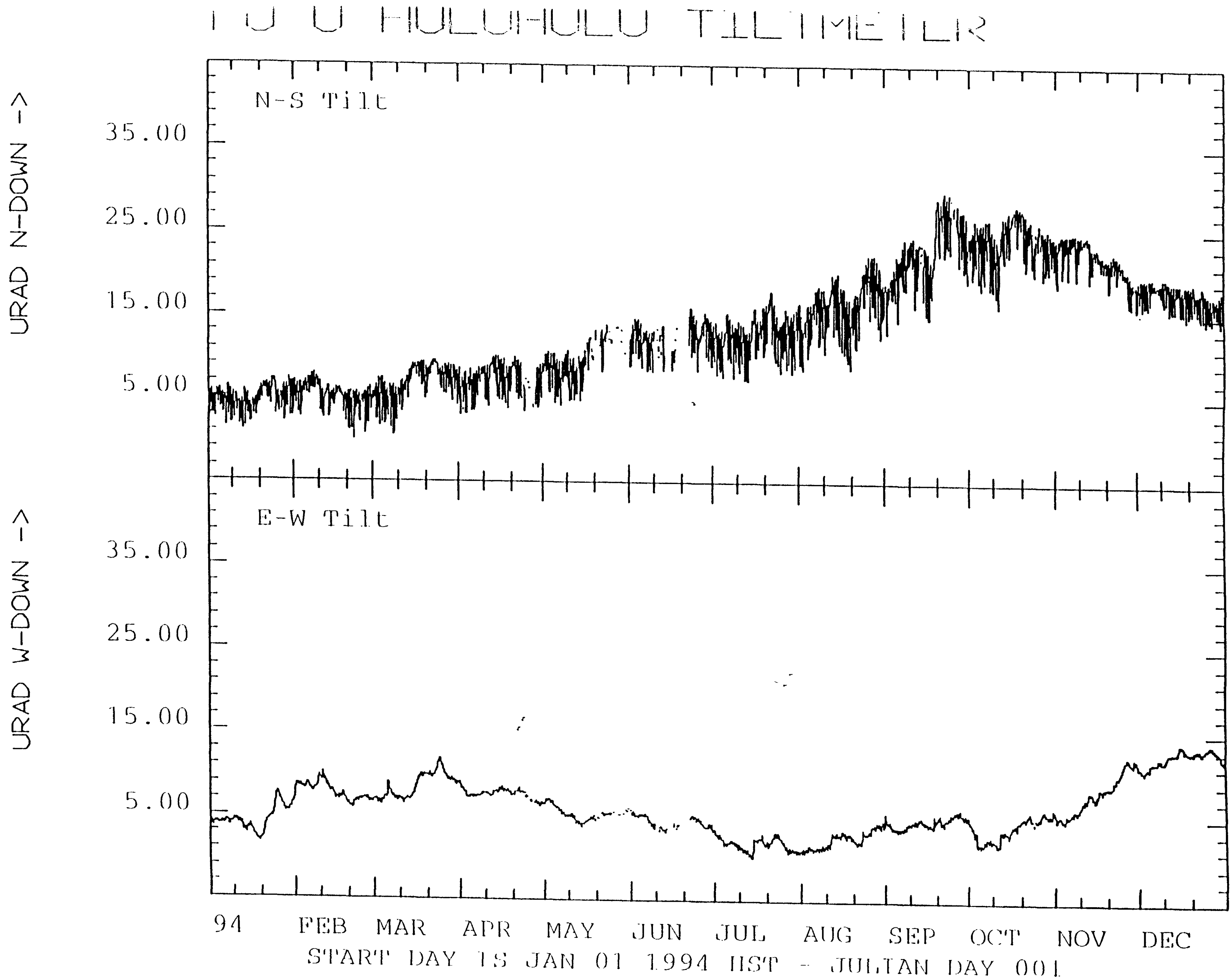
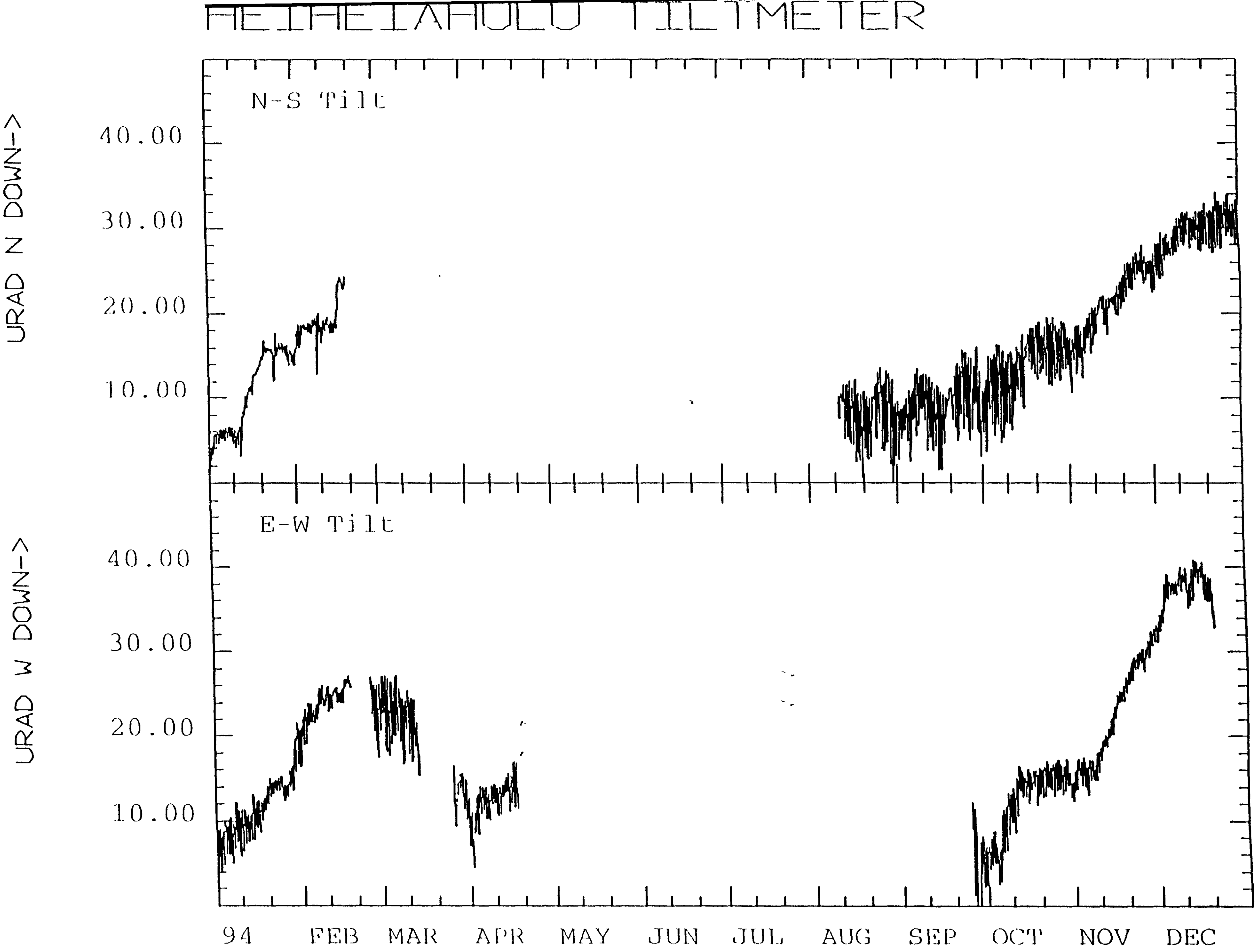

N-S Tilt
URAD N-DOWN ->
35.00
25.00
15.00
5.00
E-W Tilt
URAD W-DOWN ->
35.00
25.00
15.00
5.00
94
FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 6


HEIHEIAHULU TILTMETER
N-S Tilt
URAD N DOWN->
40.00
30.00
20.00
10.00
E-W Tilt
URAD W DOWN->
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30.00
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10.00
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START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 7

a very good record. The Applied Geomechanics N-S component seems reasonable, but the E-W component displayed unacceptable changes (most likely electronic). The new tiltmeter (both components) showed an inverse correlation with temperature change for the periods with good record.

5. **MOKE (Mokuaweoweo)** Latitude 19.4980° Longitude 155.5866°

The MOKE station (labelled "MAUNA LOA SUMMIT" in the data plots) is located on the northwest side of Mokuaweoweo (fig. 1), Mauna Loa's summit caldera. It is situated about 300 meters from the caldera edge, at the end of the summit access road. The geology of the site consists of pahoehoe flows. The tiltmeter sits at the bottom of 1.5-m-deep hole, drilled within a 1-m-deep partially collapsed lava bubble.

This site was established in 1975, and a series of tiltmeters has occupied this site over time. The current instrument, an Autonetics borehole tiltmeter (serial no. 0008B), has occupied this site since July 23, 1991.

DISCUSSION

The tiltmeter has shown no dramatic changes for the year, except for several small events related to weather (rain or snow) (fig. 8). The cumulative tilt changes for the year indicates summit inflation, a northwest vector of about 7 μradians. Temperature recorded at the tiltmeter (fig. 10e) indicates good correlation with the E-W tilt pattern and no apparent correlation with the N-S component.

6. MLCC (Mauna Loa Cinder Cone)
Latitude 19.5661° Longitude 155.4949°

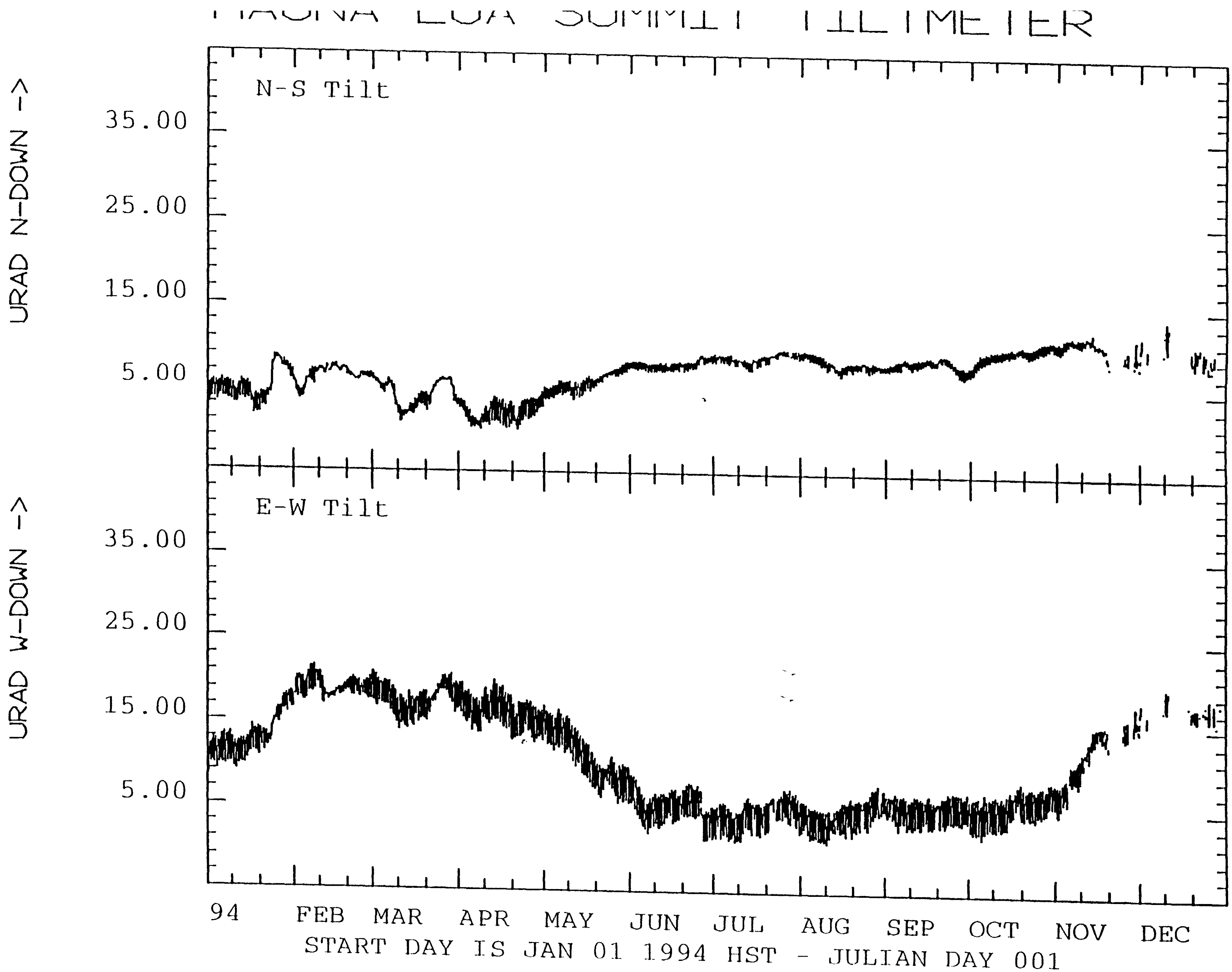
The MLCC station (labelled "MAUNA LOA NE RIFT" in the data plots), is located about 4 km north of Mauna Loa's NE rift zone and 4.5 km NW of Pu'u Ulaula. The station is located on an unconsolidated cinder cone. A 1.5-m-long, 11-cm-diameter pipe installed in the cinder houses the tiltmeter. The top of the pipe is at ground level.

This site was established in 1975, and a series of tiltmeters has occupied this site over time. The current instrument, an Autonetics borehole tiltmeter (serial no. 0003), has occupied this site since October 17, 1989. The top of the tiltmeter is a few centimeters below ground level.

DISCUSSION

This station has shown no recognized volcanic events during this reporting period (fig. 9). For the year, this station displays a northwest vector of about 8 μradians (fig. 13), indicating slight inflation of the rift zone. Both components also showed the general typical yearly pattern which has been displayed in the past. Temperature measured at the site (fig. 10f) indicates good timing for short-and long-term correlation with the N-S tilt component. The E-W component does show short-term correlation with temperature, but the long-term tilt signal low in August shows a two-month time lag from the temperature and N-S tilt low of June.

Several small events in the MLCC instrument data, such as in mid-March and mid-December (correlated with small events on the MOKE record), are related to weather.


N-S Tilt
E-W Tilt
URAD N-DOWN ->
URAD W-DOWN ->
35.00
25.00
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35.00
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94
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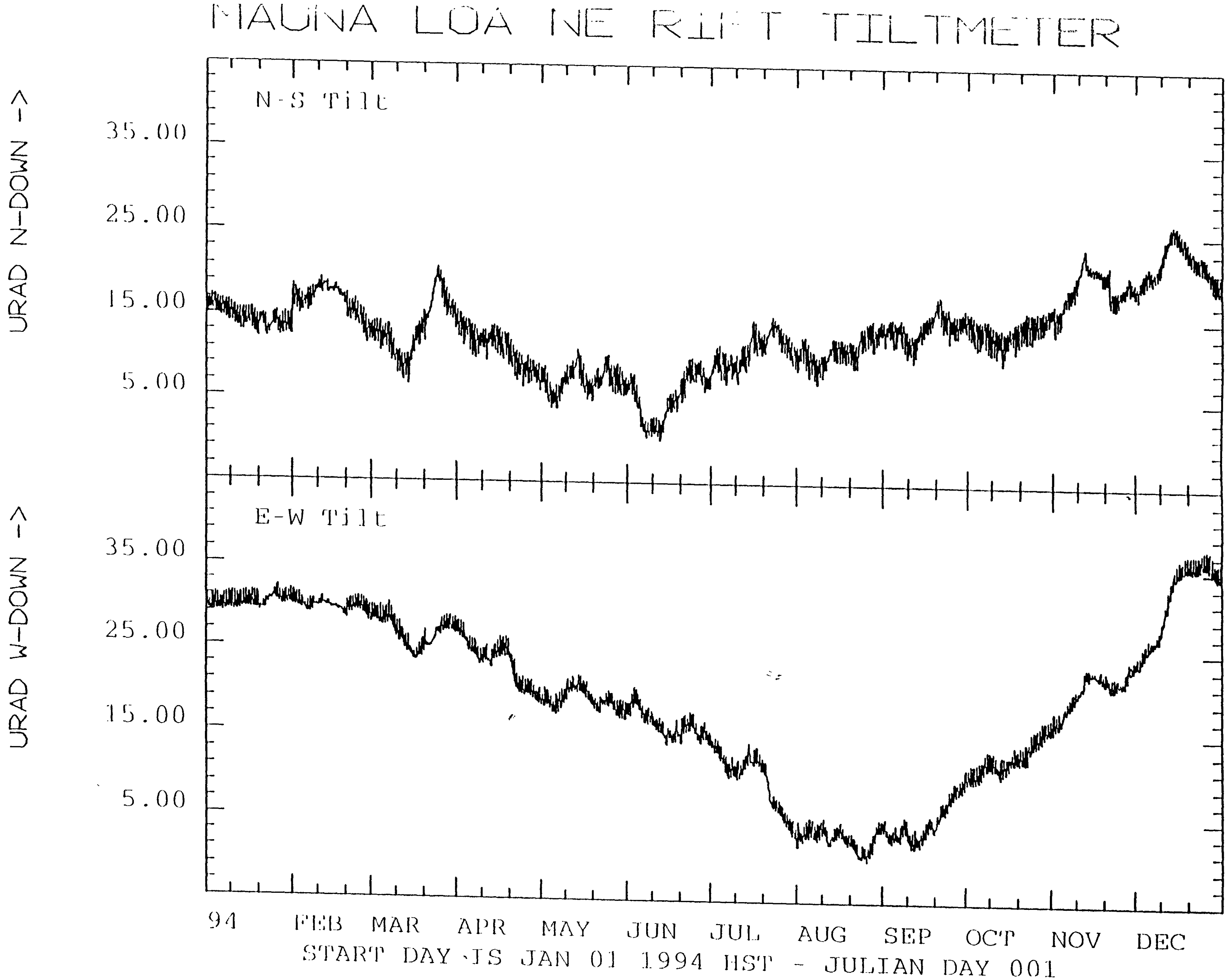
DEC
START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 8



MAUNA LOA NE RIFT TILTMETER
N-S Tilt
E-W Tilt
URAD N-DOWN ->
URAD W-DOWN ->
35.00
25.00
15.00
5.00
94
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MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 9

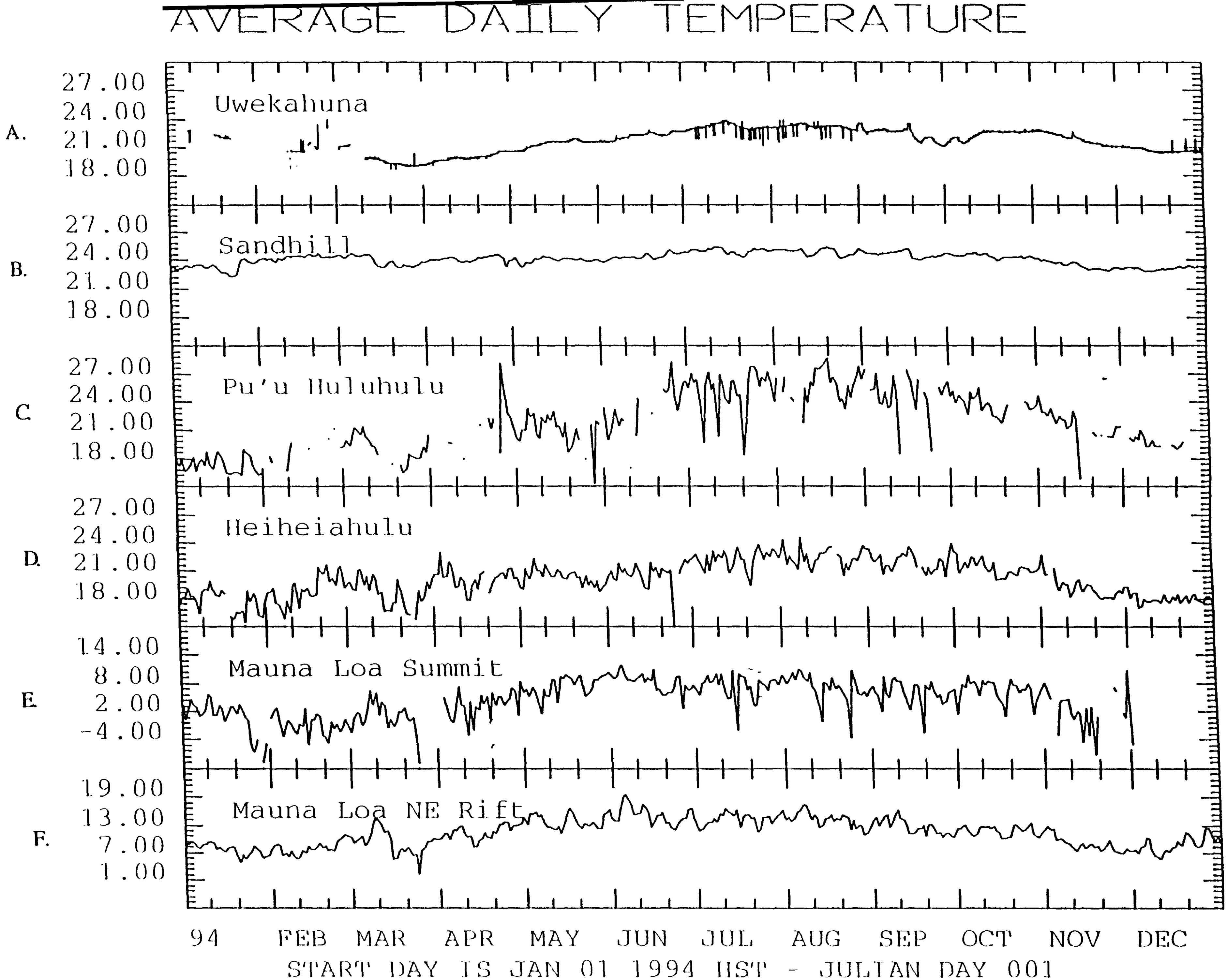
AVERAGE DAILY TEMPERATURE
A.
27.00
24.00
21.00
18.00
Uwekahuna
B.
27.00
24.00
21.00
18.00
Sandhill
C.
27.00
24.00
21.00
18.00
Pu'u Huluhulu
D.
27.00
24.00
21.00
18.00
Heiheiahulu
E.
14.00
8.00
2.00
-4.00
Mauna Loa Summit
F.
19.00
13.00
7.00
1.00
Mauna Loa NE Rift
94 FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
START DAY IS JAN 01 1994 HST - JULIAN DAY 001

Figure 10

CONCLUSION

There were no intrusive events or seismic swarms detected by the tiltmeters for this year.

The electronic tiltmeters can be a very good tool in the remote monitoring of volcanoes. The tiltmeters may provide important information on the sequence of events and changes that occur during intrusive events. An inspection of the tilt vector plots reveals that the tiltmeters can provide a coherent view to the changes occurring on a volcano as a whole.

Care must be given to installation of the tiltmeters, and the history and the quality of the data signal from each site must be understood. The data is generally good in the short term but must be critically questioned in the long term due to uncertainties in instrumental and site stability.

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6. Puniwai, G.S., and Largo, A.J., 1995, The Hawaiian Volcano Observatory Summary 93, Part III, Electronic tilt data, January to December 1993: U.S. Geological Survey Open-File Report 95-268, 35 p.

APPENDIX I.

VECTOR PLOTS

The time periods were chosen by looking at all stations and delineating periods by change in direction of tilt.

KILAUEA SUMMIT AND EAST RIFT ELECTRONIC TILT VECTORS

January thru April, 1994

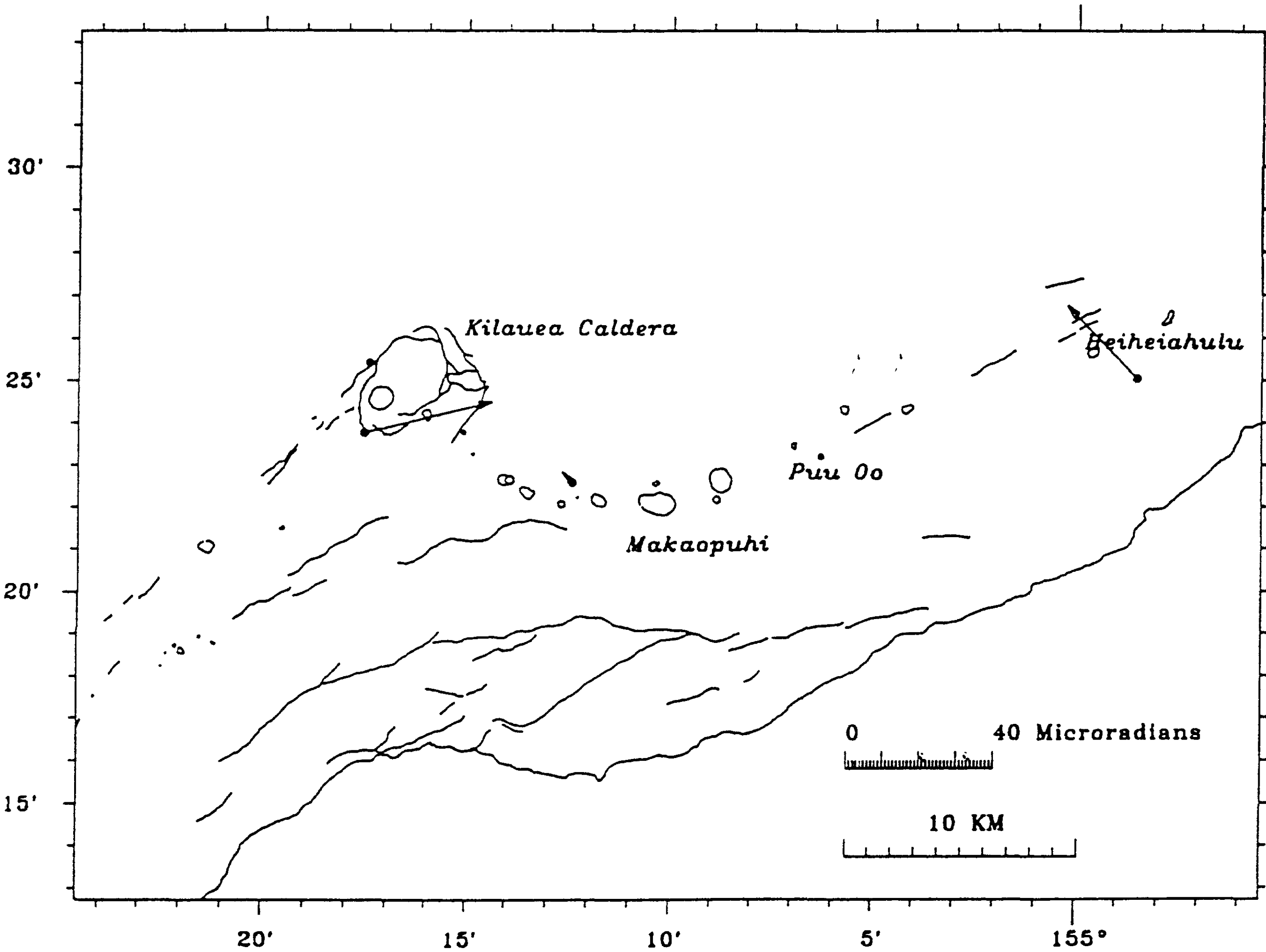

Figure 11. Kilauea summit and east rift electronic tilt vectors, January through April 1994. All tiltmeters show deflation of their respective areas. The Uwekahuna meter was not plotted because of its drift problem.

KILAUEA SUMMIT AND EAST RIFT ELECTRONIC TILT VECTORS

MAY thru OCTOBER, 1994

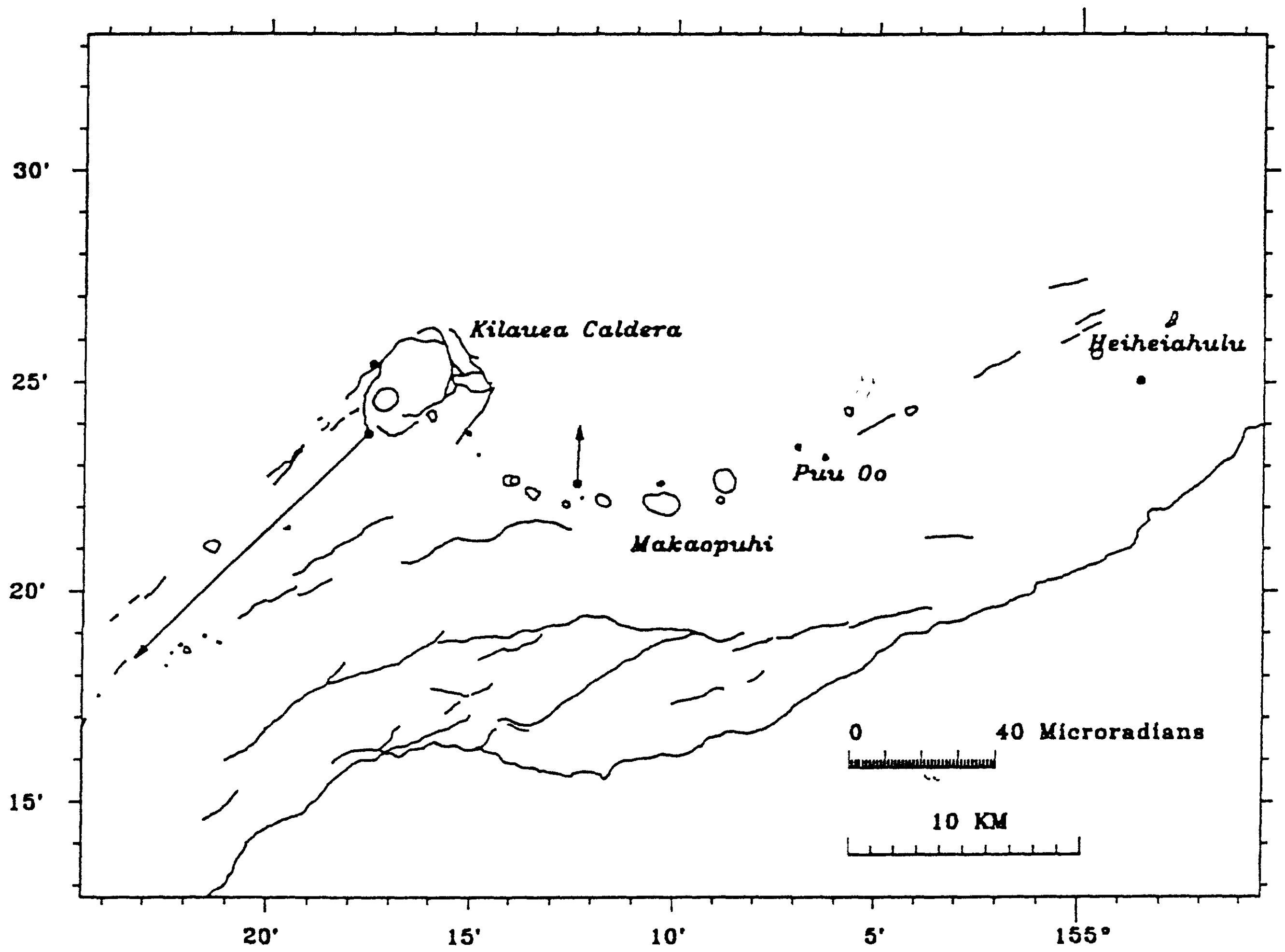

Figure 12. Kilauea summit and east rift electronic tilt vectors, May through October 1994. The two tiltmeters plotted indicate inflation of their respective areas. The Uwekahuna meter was not plotted because of its drift problem, and the Heiheiahulu meter was not operational.

KILAUEA SUMMIT AND EAST RIFT ELECTRONIC TILT VECTORS
NOVEMBER thru DECEMBER, 1994

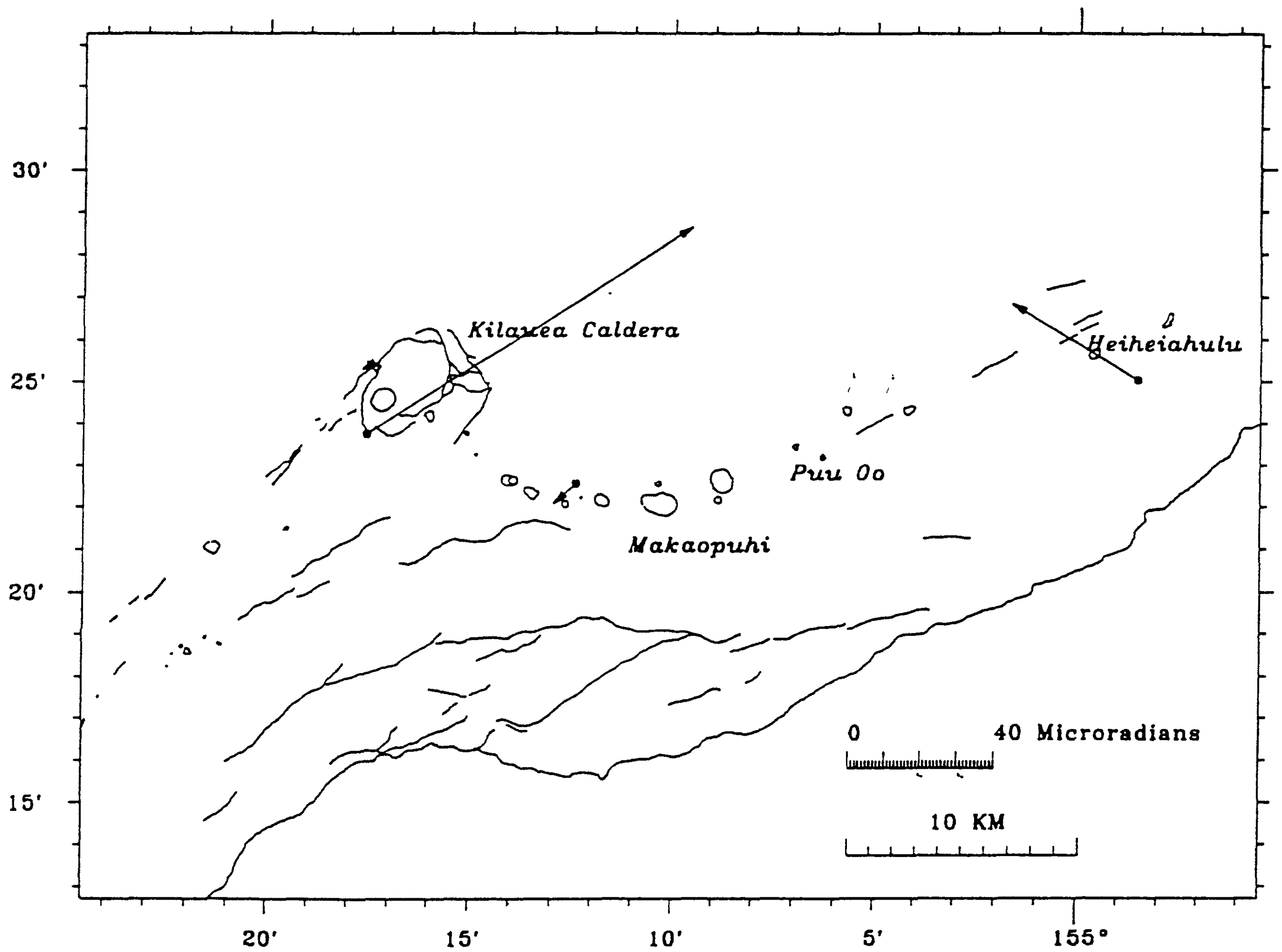

Figure 13. Kilauea summit and east rift electronic tilt vectors, November through December 1994. All tiltmeters indicate deflation in their respective areas.

MAUNA LOA ELECTRONIC TILTMETER VECTORS

January thru December, 1994

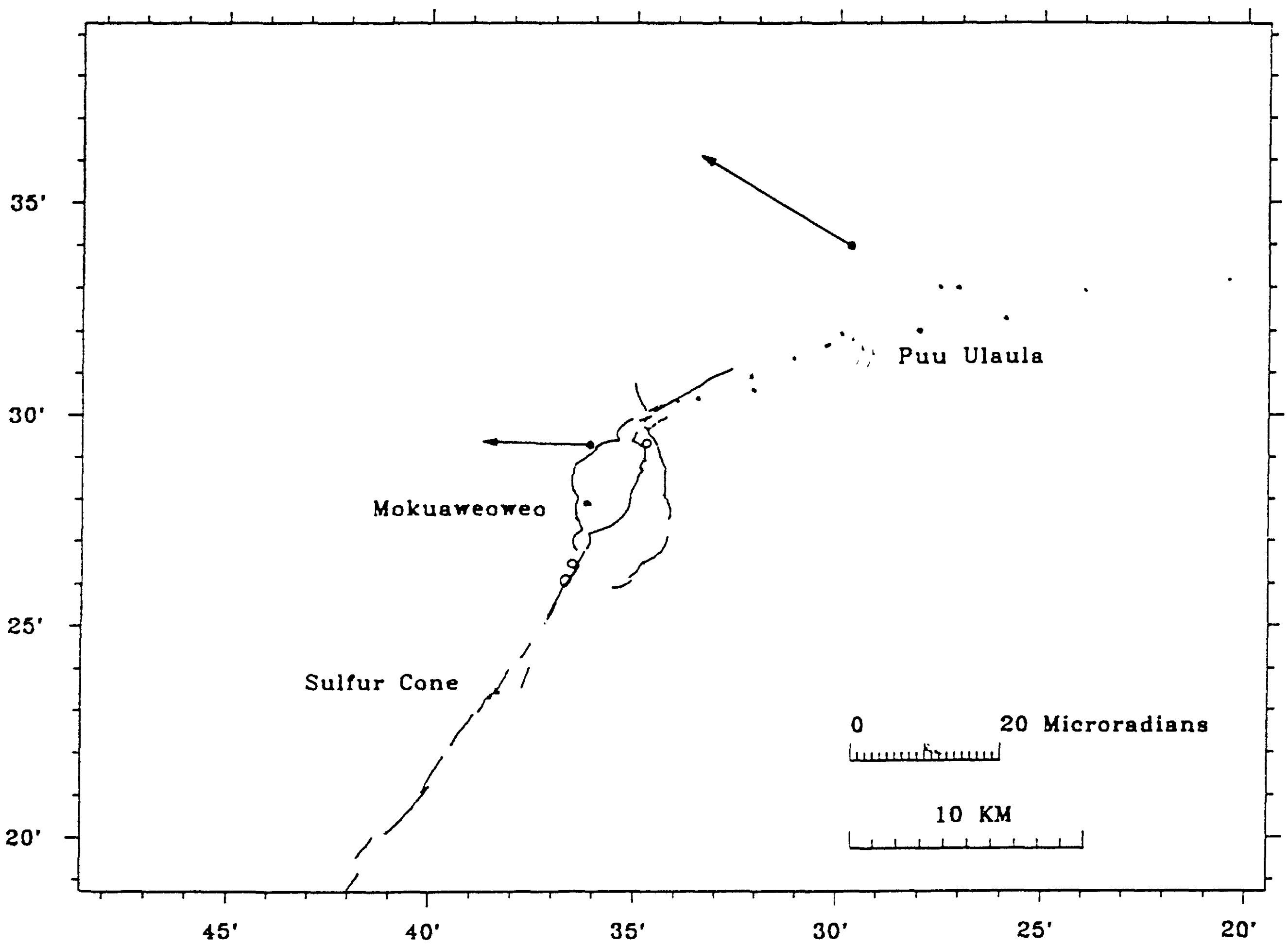

Figure 14. Mauna Loa electronic tiltmeter vectors, 1994. The summit and NE rift tiltmeters indicate inflation of Mauna Loa Volcano.

APPENDIX II. MAINTENANCE LOG

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UWEKAHUNA

Tiltmeter make & serial no.: Westphal, WTM-1
Calibration factors: X (NS) = 10.0 mv/μradian
Y (EW) = 10.0 mv/μradian
Tiltmeter make & serial no.: Ideal Aerosmith, sn: 10567
Calibration factor: 100.0 mv/μradian
Tiltmeter make & serial no.: Applied Geomechanics, sn: 1436
Calibration factors: X (NS) = 21.16 mv/μradian
Y (EW) = 21.06 mv/μradian
Digital system inputs:
1: Westphal Tiltmeter, X component
2: Westphal Tiltmeter, Y component
3: Temperature
4: Ideal Aerosmith
5: Applied Geomechanics, X component
6: Applied Geomechanics, Y component
7: Short
8: Battery

03/11/94
0952 Problem: Applied Geomechanics tiltmeter off scale
Reset tiltmeter
Battery: 15.0 V

Before	After
X= 2.94 V	X= -0.168 V
Y= 1.55 V	Y= -0.155

08/16/94
1412 Calibration of Ideal Aerosmith tiltmeter
Nullmeter: -15.0 Volts: -1.425

Nullmeter	Analog Voltage
Right: -0.286	-1.718
Back: 4.451	-1.256
Right: -0.474	-1.733
Back: 0.476	-1.292
Left: 0.433	-0.830
Back: -0.433	-1.284
Left: 0.422	-0.810
Back: -0.466	-1.296

1431 Cal: 0.453
Nullmeter: -13.0 Volts: -1.296

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SANDHILL

Tiltmeter make & serial no.: Autonetics, sn: 0096B
Calibration factors: X (NS) = 18.4 mv/μradian
Y (EW) = 20.5 mv/μradian
Digital system inputs:
1: Tiltmeter, X component
2: Tiltmeter, Y component
3: Temperature
4:
5:
6:
7: Short
8: Battery

01/25/94
1318 Remarks: Station visit
Battery: 13.02 V.
Analog Voltages
X= 0.237 V
Y= -3.52 V
Temp1= 2.84 V
X= -2.10 V
Y= 2.62 V
Temp2= 2.89 V
Batt: 4.10 @ 12.90

01/25/94
1318 Problem: Station visit after heavy rains
Remarks: Borehole surface looks dry although data shows excursions from rainstorms.
Battery: 13.49
Analog voltages
X= 0.434
Y= -4.24
Temp1= 2.90
X= -2.61
Y= 2.35
Temp2= 2.90

****

PUU HULUHULU

Tiltmeter make & serial no.: Autonetics, sn: 0008B
Calibration factors: X (NS) = 58.68 mv/μradian
Y (EW) = 47.28 mv/μradian
Digital system inputs:
1: Tiltmeter, X component
2: Tiltmeter, Y component
3: Temperature

4: THTN
5: THTE
6: Battery
7: None
8: Solar Battery

****

HEIHEIAHULU

Tiltmeter make & serial no.: Autonetics, sn: 0107B
Calibration factors: X (NS) = 18.75 mv/µradian
Y (EW) = 20.67 mv/µradian
Digital System Inputs:
1: Tiltmeter, X component
2: Tiltmeter, Y component
3: Temperature
4: Short
5: None
6: None
7: None
8: Battery

03/09/94
1102 Problem: Station visit
Battery: 12.97
VOLTAGES

Before	After
X: 4.92	X: 4.92
Y: 0.039	Y: 0.039
Temp: 2.963	Temp: 2.963

08/08/94
1117 Problem: Noisy channels
Remarks: Found ants nesting around the sensor, removed Autonetics tiltmeter
Battery: 13.90 V
VOLTAGES

Before	After
X:	X: 0.999
Y:	Y: 0.641
Temp:	Temp: 3.04

08/09/94
1451 Remarks: Installed new borehole tiltmeter.
Applied Geomechanics, model 722, serial no. 1776
Calibration factors: X (NS)= 10.74 mv/Êradian
Y (EW)= 10.39 mv/Êradian
Analog readings
X= 1.192
Y= 1.494
Temp: 3.07

08/10/94

0929 Problem: new tiltmeter off scale due to sand settling

Remarks: reset tiltmeter

VOLTAGES

Before	After
X= 1.021	X= 1.695
Y= 7.53	Y= -0.391
1117 Temp= 3.00	Temp= 3.07

****

MOKUAWEOWEO

Tiltmeter make & serial no.: Autonetics, sn: 0097B

Calibration factors: X (NS) = 24.23 mv/μradian

Y (EW) = 25.40 mv/μradian

Digital system inputs:

1: Tiltmeter, X component
2: Tiltmeter, Y component
3: Temperature
4: Short
5: None
6: Battery
7: None
8: None

08/18/94

1144 Problem: Station visit

Remarks: Station checks ok

Battery: 12.21 V

Analog readings

X= 1.689

Y= 2.66

Temp= 2.92

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MAUNA LOA CINDER CONE

Tiltmeter make & serial no.: Autonetics, sn: 0003B

Calibration factors: X (NS) = 30.0 mv/μradian

Y (EW) = 35.0 mv/μradian

Digital system inputs:

1: Tiltmeter, X component
2: Tiltmeter, Y component
3: Temperature
4: Short
5: Battery

08/02/94

0909 Problem: Station not transmitting

Remarks: Antenna down due to broken guy wires

Replaced guy wires

Battery: 13.35 V

Analog readings
X= 2.73
Y= -1.916