ACKNOWLEDGEMENTS

We would like to thank Eugene M. Rubin and Kathleen R. Walker of the KSTP weather service for their considerable effort expended in the development and maintenance of the observer network. Also Bernard King-Smith, of the University of Minnesota, contributed greatly by his analyses of the observer network data. Special thanks to Minnesota state climatologist, Earl Kuehnest, in assisting and selecting sights and personnel for the observer network.

REFERENCES

Kuehnast, E. L., D. G. Baker, and J. W. Enz, 1975: Climate of Minnesota - Part VIII, Precipitation patterns in the Minneapolis-St. Paul Metropolitan Area and Surrounding Counties. *Tech. Bull. No. 301, Agricultural Experimentation Station,* University of Minnesota, 36 pp.

Baker, D. G., and J. H. Strub, Jr., 1963: Climate of Minnesota - Part I, Probability of Occurrence in the Spring and Fall of Selected Low Temperatures. *Tech. Bull. No. 243, Agricultural Experimentation Station,* University of Minnesota, 40 pp.

Frisken, W. R., 1973: The Atmospheric Environment of Cities. *Climatological Studies No. 25,* Environment Canada, 30 pp.

Principle Investigators of Project METROMEX, 1976: METROMEX Update. *Bull. Amer. Meteor. Soc.,* V 57, pp. 304-308.

Lyons, W. A., 1972: Climatology and Prediction of the Chicago Lake Breeze, *J. Appl. Meteor.,* V11, pp. 1255-1270.

Henz, J. F., V. R. Scheetz, and D. O. Doehring, 1976: The Big Thompson Flood of 1976 in Colorado. *Weatherwise,* V 29, pp. 278-285.

VERTICAL WIND PROFILE CHANGES REVEALED BY SATELLITE OBSERVATION OF A VOLCANIC PLUME

by

Laurence G. Lee
National Weather Service Forecast Office
Anchorage, Alaska 99501

1. INTRODUCTION

During the period 4-8 February 1978 an interesting combination of meteorological and geological events provided some spectacular scenery as viewed from the polar-orbiting NOAA-5 satellite. The variable configuration of a volcanic plume indicated changes in the vertical wind structure west of a maturing extratropical cyclone. The imagery also furnished valuable guidance concerning an inflight hazard not likely to face aviation forecasters in most of the Lower 48.

II. METEOROLOGICAL AND GEOLOGICAL SETTING

A deep mid- and upper-level trough developed over western Alaska on 4 February and moved slowly eastward for the next several days. The 1200 GMT 50 kPa and 85 kPa charts for 6 and 8 February (Figures 1 (a) - (d)) depict the general sequence of events and correspond approximately in time to satellite imagery that follows. Intense surface cyclogenesis in the northern Gulf of Alaska accompanied the sharpening trough aloft. Fueled by a temperature gradient featuring surface readings from -46°F over northwest Alaska to +4°C in the Yukon Territory, the storm produced hurricane-force winds that swept across some southern coastal sections. The gradual eastward translation of the system resulted in an extended period of snow in southcentral Alaska. The five day storm total at Anchorage was 52.8 cm.

As the low deepened, very cold air was drawn southward from the Arctic. The NOAA-5 infrared image in Figure 2, taken from approximately 1450 km, clearly shows the numerous convective cloud streets formed as the cold air advected across the relatively warm water. South of the Alaska Peninsula, several streets assumed visual similarity to laboratory-produced von Karman vortices. (An excellent treatment of wake vortices in the lee of the Aleutians is provided by Thomson *et.al.* (1977.)

Coincident with the storm development, a volcano eruption occurred on the western end of Unimak Island (Figure 3). A considerable amount of moisture, ash, and other debris was ejected into the atmosphere. The plume is clearly visible in Figure 2. Similar events have been observed in satellite imagery on several occasions. See, for example, Trapp (1976). The image sequence presented here is of interest because of the plume's response to changes in the vertical wind field.

In Figure 2 the plume and cloud streets are nearly parallel. This is not surprising since the 1200 GMT 6 February Cold Bay sounding (Figure 4 (a)), taken approximately 161 km to the east, indicates northwesterly winds throughout the entire troposphere.

By 0624 GMT 8 February, the time of Figure 5, the plume had acquired an entirely different appearance. An enlargement (Figure 6) reveals some of the interesting details. The plume seems to consist of two branches, particularly downwind from the source. A broad portion with a distinct western edge remains nearly parallel to the cloud streets. In addition, a narrower branch is oriented in a more west to east direction.

The 1200 GMT 8 February Cold Bay sounding (Figure 4 (b)) indicates the wind had backed with height from about 70 kPa to the tropopause. At this stage in the storm system's evolution, the characteristic westward tilt of the trough's vertical axis was decreasing. (The deepest portion of the complex low-level circulation had been centered near Fairbanks 48 hours earlier.) Meanwhile, the upper trough extended north-south over western Alaska. By February, the 85 kPa low in the Gulf of Alaska had organized into one center located just to the east of the 50 kPa trough. The result was an eastward progression of the upper trough relative to the surface center. The trough movement thus allowed the upper ridge to translate from the central Aleutians toward the Alaska Peninsula.

Since the low-level cyclonic circulation remained in the northern Gulf of Alaska, winds near the surface over Unimak Island continued from the northwest. At the same time, the mid- and upper-level winds backed gradually due to the changing flow pattern aloft. Apparently, the most buoyant portion of the plume rose to levels where winds with a more westerly component existed. The less buoyant materials were carried downstream in the northerly flow closer to the surface.

The distinct western edge persisted downstream since no easterly component existed to disrupt the initial flow pattern. The plume's fan shape near the source (Figure 6) can be attributed to fallout from the higher levels entering lower levels with increasingly prominent northerly components.

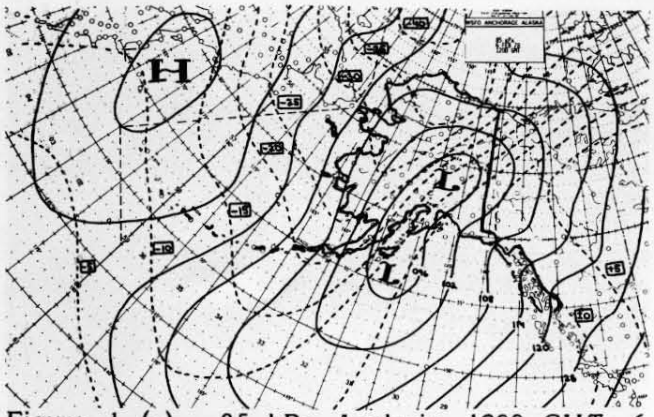

Figure 1 (a). 85 kPa Analysis, 1200 GMT, 6 February 1978, Heights in Geopotential Meters, Temperatures in Degrees Celsius.

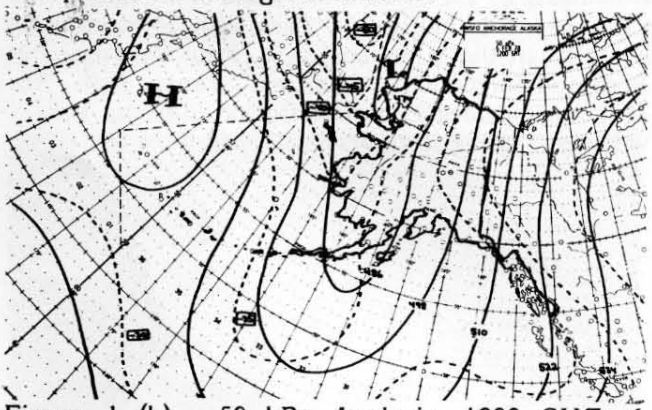

Figure 1 (b). 50 kPa Analysis, 1200 GMT, 6 February 1978.

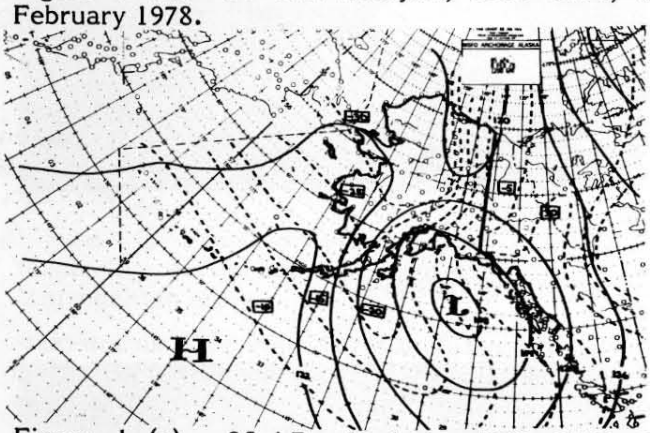

Figure 1 (c). 85 kPa Analysis, 1200 GMT, 8 February 1978.

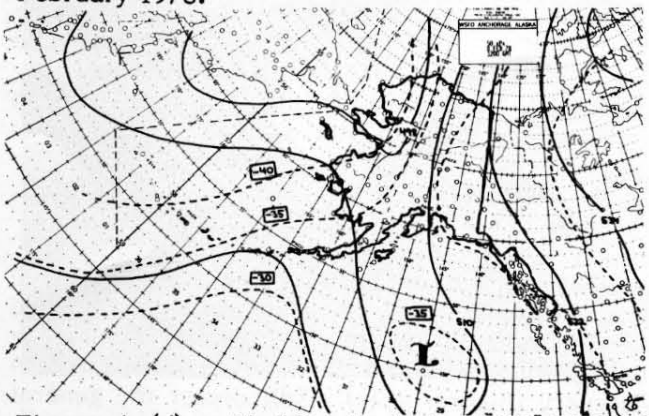

Figure 1 (d). 50 kPa Analysis, 1200 GMT, 8 February 1978.

The plume appears to have two distinct branches well downstream. The sorting process removed most of the heavier material and only cloud plus light dust and ash survived. Also, another von Karman vortex pattern is visible in the low-level cloudiness and debris south of Unimak Island (Figure 5).

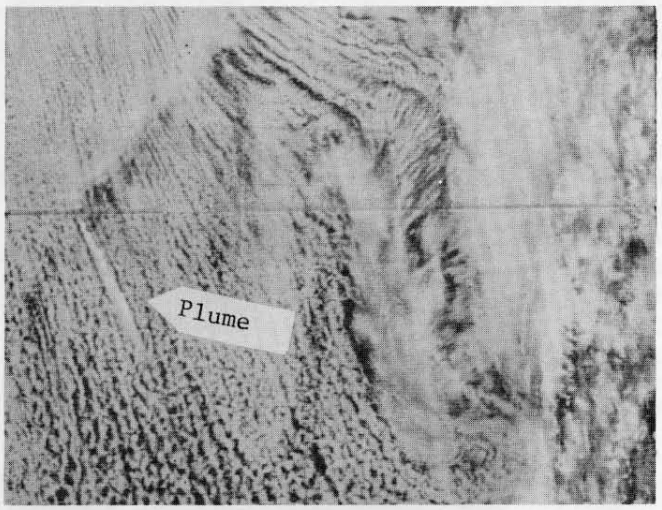

Figure 2. NOAA-5 Visual Infrared Spinscan Radiometer (VISR) Infrared Image, 1952 GMT, 6 February 1978.

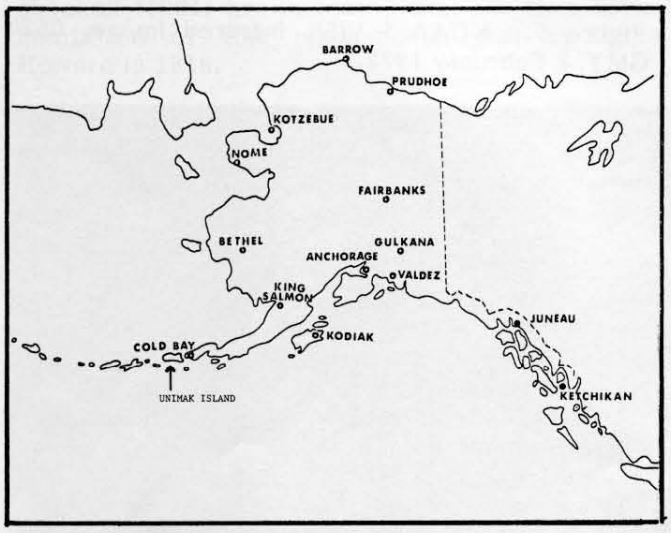

Figure 3. Location Map of Alaska.

Close examination of the enlargement (Figure 6) reveals the small warm area associated with the actual volcanic eruption. (On infrared imagery of this type, shades of gray indicate relative temperatures. Warm radiating surfaces appear dark while progressively colder surfaces assume lighter shades.) In addition, two or three cold spots are evident in the plume branch carried downstream in the westerly flow. These were probably cumuliform clouds of significant vertical development, but may have been high points in the plume as it oscillated in the vertical, seeking an equilibrium level.

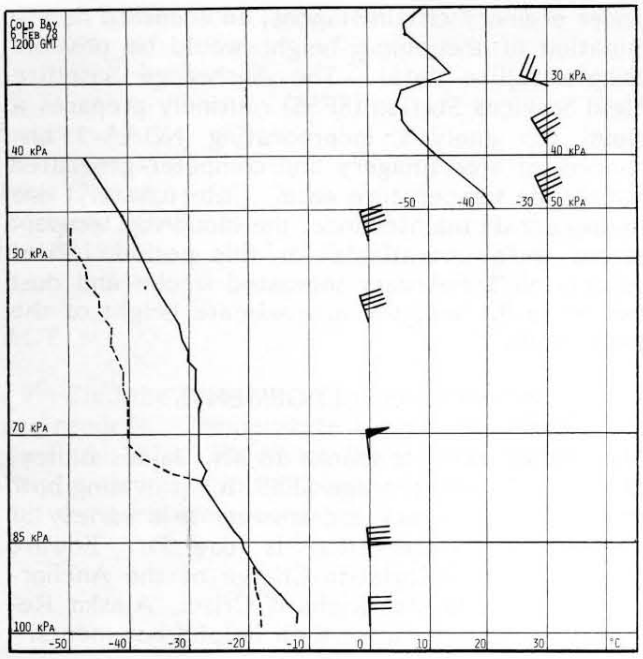

Figure 4 (a). Cold Bay Sounding, 1200 GMT, 6 February 1978. Left side surface to 40 kPa. Right side 50 kPa to 12.5 kPa.

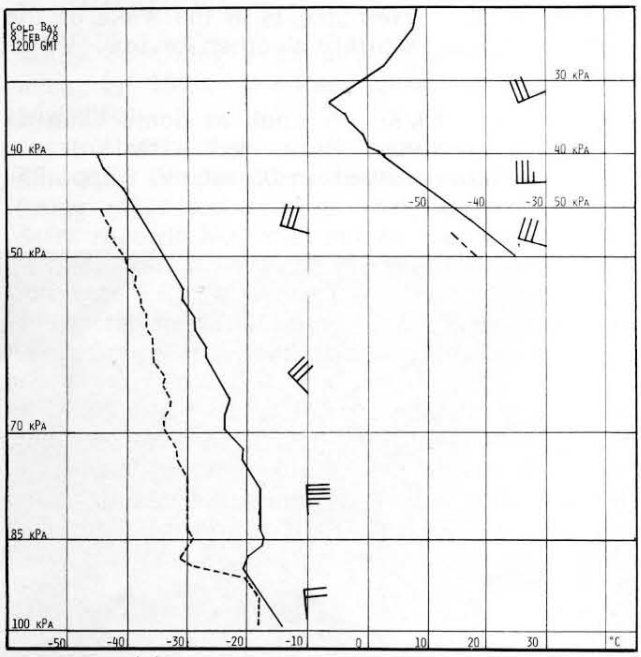

Figure 4 (b). Cold Bay Sounding, 1200 GMT, 8 February 1978.

III. OPERATIONAL ASPECTS

This satellite imagery together with half hourly SMS-2 data (not shown) was helpful in providing guidance for several aviation-oriented forecasts and advisories issued by the Anchorage Weather Service Forecast Office (WSFO). The Anchorage Area Forecast (FA), prepared three times daily, contained information concerning the extent of the smoke and dust. In addition, an International SIGMET was issued to alert high level jet traffic to the possible hazard.

Under ordinary circumstances, an accurate determination of the plume height would be possible using satellite data. The Anchorage Satellite Field Services Station (SFSS) routinely prepares a cloud top analysis incorporating NOAA-5 enhanced infrared imagery and computer-generated radiosonde temperature data. Unfortunately, due to spacecraft maintenance, the cloud top temperatures were unavailable for this period. Pilot reports on 5 February indicated smoke and dust extend to 9.1 km, the approximate height of the tropopause.

ACKNOWLEDGEMENTS

The author extends thanks to Mr. James Bailey, Manger of the Anchorage SFSS, for providing both the satellite imagery and answers to a variety of questions. Appreciation is due Dr. Edward Diemer, Meteorologist-in-Charge of the Anchorage WSFO, and Mr. Richard Crisci, Alaska Regional Headquarters, for their helpful comments.

REFERENCES

Thomson, R. E., J. F. R. Gower, and N. W. Bowker, 1977: Vortex Streets in the Wake of the Aleutian Islands. *Monthly Weather Review*, V 105, pp. 873-884.

Trapp, G. H., 1976: A Look at Some Unusual Convective Activity Associated with Volcanic Eruption. *National Weather Digest*, V 1, pp. 25-29.

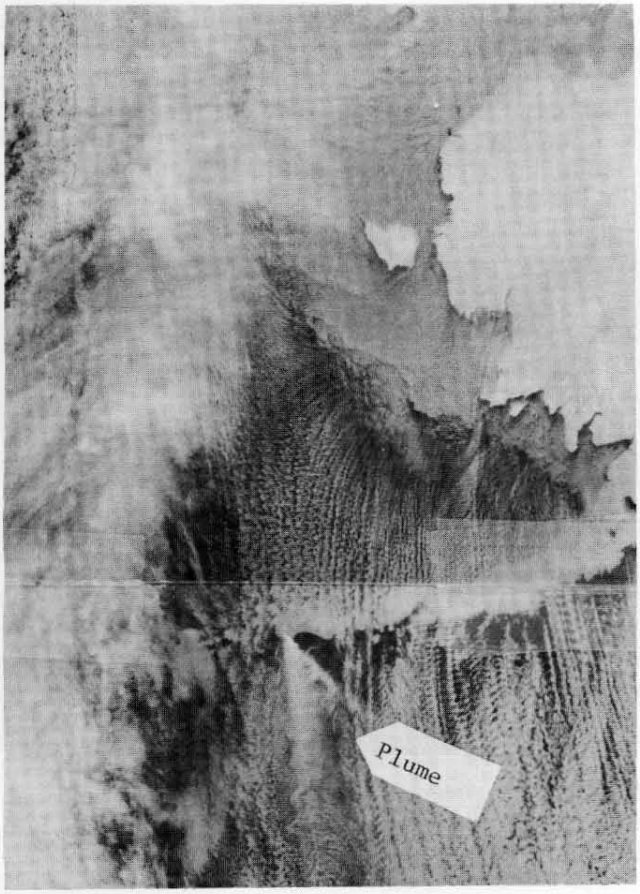

Figure 5. NOAA-5 VISR Infrared Image, 0624 GMT, 8 February 1978.

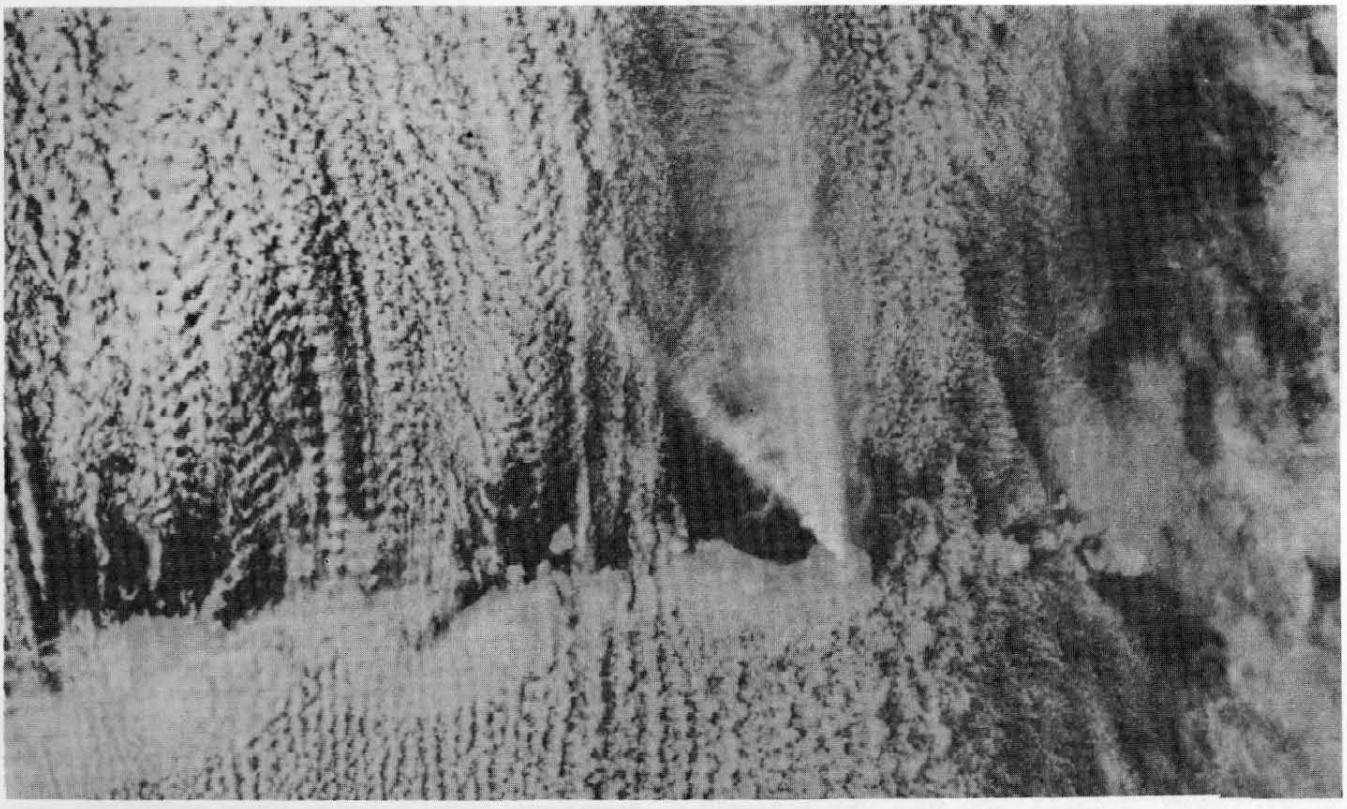

Figure 6. NOAA-5 VISR Infrared Image, 0622 GMT, 8 February 1978.