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PRELIMINARY STUDY OF KATABATIC WIND BY USING NOAA AVHRR DATA

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Abstract: The behavior of katabatic wind on the Antarctic ice sheet can be monitored from NOAA AVHRR data. Katabatic wind is visualized as fluctuations of the brightness temperature on the thermal infrared channel. The structure of the fluctuation reveals a well-defined streak feature. We can monitor wind direction, and there is a possibility to monitor wind speed from the satellite images. The fluctuation of brightness temperature is probably caused by fluctuation of wind velocity.

1. Introduction

Katabatic wind is a remarkable climatic feature on the Antarctic ice sheet. It largely affects the atmospheric circulation around Antarctica. Drifting snow caused by the wind creates various types of surface features (WATANABE, 1978) and is also related to material transport on the surface of the ice sheet (OSADA and HIGUCHI, 1990). However, areal variation of the wind field is difficult to grasp due to the lack of sufficient stations on the ice sheet.

Satellite observation is a new tool for the investigation of the atmosphere and cryosphere in the polar regions. Katabatic wind is also a target of the satellite research. D'AGUANO (1986) and BROMWICH (1989) detected katabatic wind in the coastal area by using NOAA AVHRR.

We also utilized NOAA AVHRR and detected the katabatic wind as a fluctuation of T_b (brightness temperature) in the thermal infrared channel satellite images in which we can identify the katabatic wind. We will also discuss possible mechanisms of visualization and possibilities for climatological research on the katabatic wind field by using satellite image data.

2. Data

We used NOAA AVHRR data which were received at Syowa Station, Antarctica and analyzed winter images on the thermal infrared channel (channel–4; 10.5–11.5 μm). Figures 1a and 1b show the analyzed areas in this study: Area-A covers about half of the East Antarctic ice sheet with a spatial resolution of 4.4 km and Area-D with a spatial resolution of 2.2 km covers the region where JARE oversnow traverse observations have been carried out (Fig. 1b).

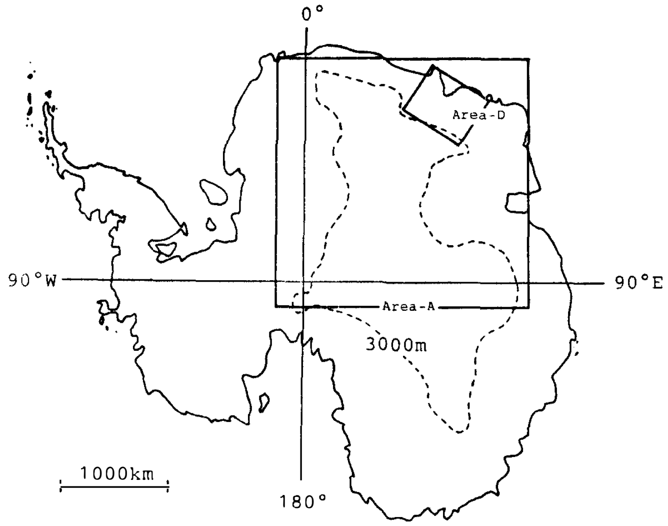

Fig. 1a. Analyzed areas of NOAA AVHRR data. Contour of 3000 m in altitude is shown as a dashed line.

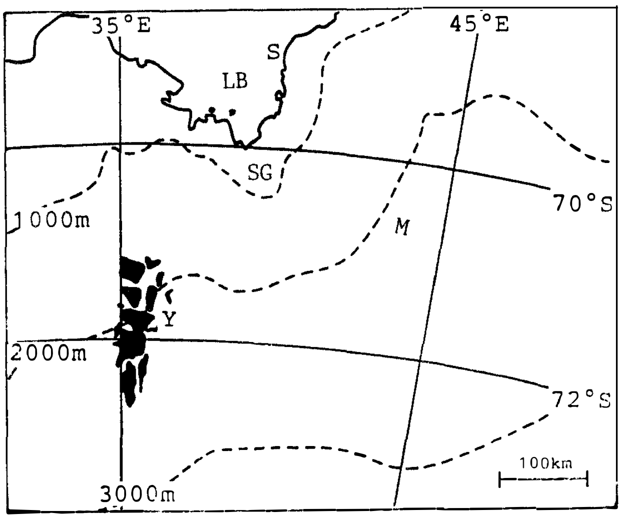

Fig. 1b. Datailed map of Area-D. Topographic names are as S: Syowa Station, M: Mizuho Station, Y: Yamato Mountain, SG: Shirase Glacier, LB: Lützow-Holm Bay.

3. Image Processing and Typical Examples

First, winter images on rather clear days were selected. Then, a spatial high-pass filter was applied for the enhancement of structures smaller than 100 km in horizontal scale. We use the term 'ΔT_b image' to describe the high-pass filtered image hereafter.

Figures 2a and 2b show typical winter images before and after filtering, respectively. A typical pattern which is believed to be associated with katabatic wind can be seen as a streak feature, while in Fig. 2a large-scale variation of T_b is dominant because it reflects the variation in altitude of the ice sheet. After the filtering (Fig. 2b), T_b no longer reflects the ice sheet altitude and streak features (in small boxes) and other structures (in a large box) are clearly cited. The former pattern fluctuates its position and shape in different days' image. The latter pattern is constant and is caused by surface topographies on the ice sheet (SEKO *et al.*, 1992). We will focus former pattern in this study.

Each streak is visualized as T_b fluctuation of 1 K on average. The separation of

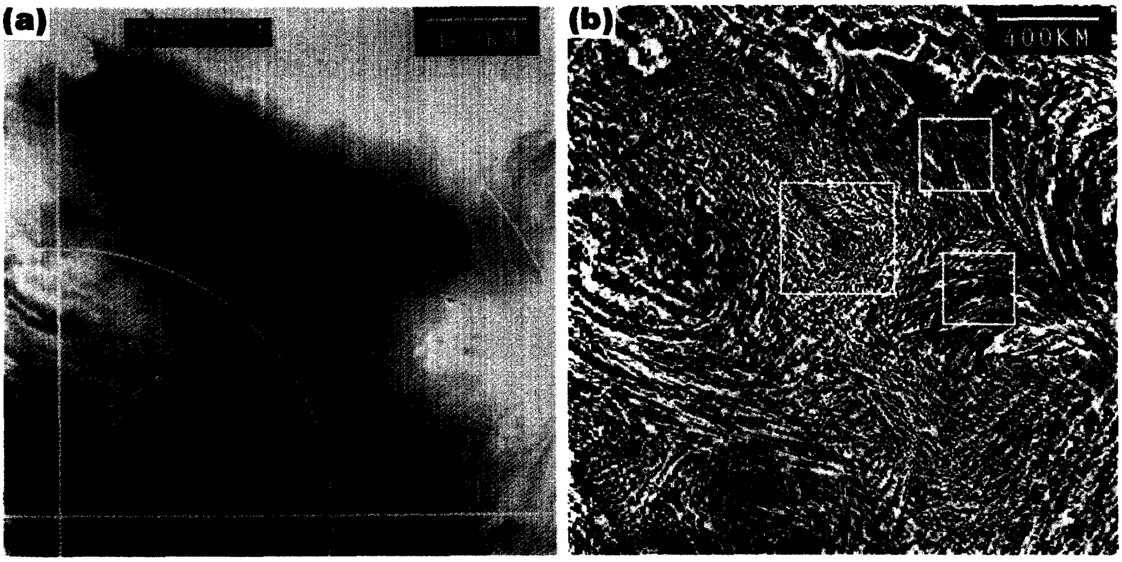

Fig. 2. T_b *(a),* ΔT_b *(b) image on July 1, 1988 in Area-A. Small and large boxes are small scale structures.*

two adjacent streaks ranges from a few kilometers to a few tens of kilometers. It is noteworthy that the streaks are maintained through a few hundred kilometers. The orientation of streaks deviates from the fall line of large-scale topography of the ice sheet with an approximate angle of 45° left. The orientation of streaks approximately coincides with the katabatic wind direction supposed from the orientation of sastrugi (WATANABE, 1978).

4. Mechanism of Visualization

We will describe the mechanism of the visualization. Possible mechanisms of visualization are

a. cloud,
b. temporal accumulation of drifting snow,
c. variation of snow surface temperature caused by fluctuation of wind speed,
d. variation of density of blowing snow.

The possibility of cloud as the cause of the T_b fluctuation seems unplausible because mountains and surface features on the ice sheet can be seen clearly in the image. It is also difficult to consider that temporal accumulation can vary T_b so largely.

The ground temperature increases if strong wind causes intense vertical mixing within the inversion layer. Furthermore, stronger blowing snow in stronger wind makes T_b higher because it emits warmer temperature at a higher position. A similar mechanism was suggested by BROMWICH (1989) who analyzed the katabatic wind signal in satellite images in the coastal region. However, the streaks in this study appear on an ice sheet surface without any prominent topography. The mechanism causing the fluctuation of wind speed on the almost flat surface may be an instability problem of katabatic wind and will be discussed later.

5. Preliminary Studies for Katabatic Wind Climatology

We will discuss the possibility of climatological studies of katabatic wind by using the satellite data.

5.1. Wind direction

By tracing the streaks in ΔT_b images, we can map the surface wind direction on the ice sheet as far as no overcast cloud exists.

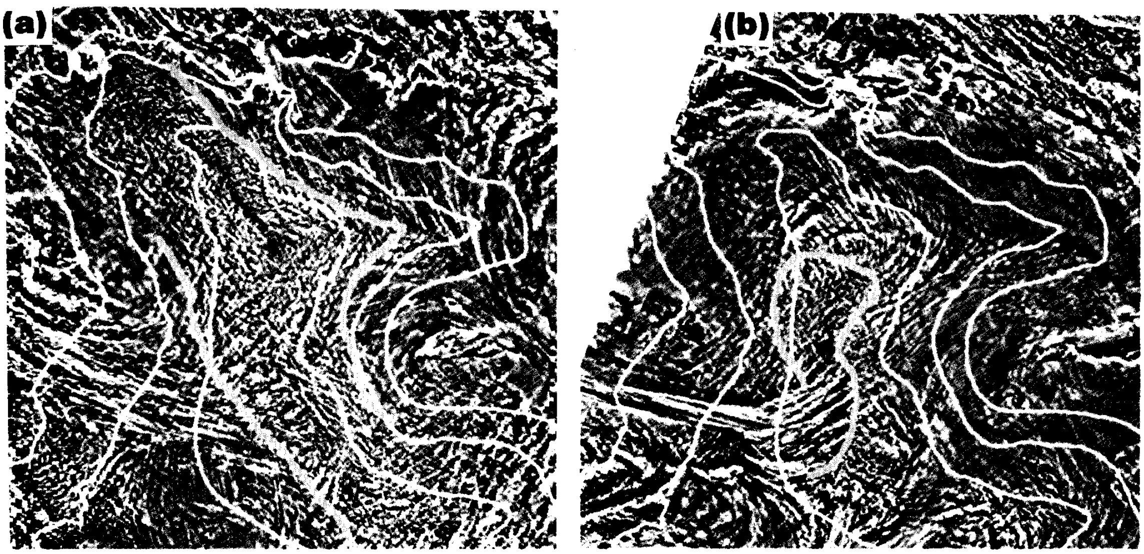

Fig. 3. (a) ΔT_b images in Area-A on July 1, 1988. Contours of altitude of 2500, 3000 and 3500 m (DREWRY, 1983) are shown. Thick lines show the boundaries from which streak patterns start to emerge. (b) Same as (a), except on June 11, 1988.

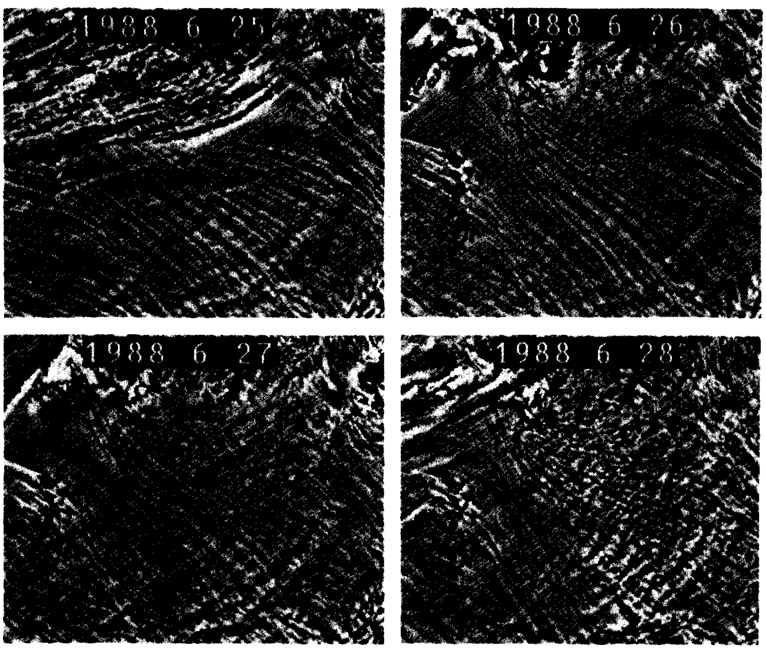

Fig. 4. ΔT_b images in 4 successive days (from June 25 until June 28, 1988) in Area-D.

Figures 3a and 3b show ΔT_b images on different days in Area-A. The curvature of the streaks in Fig. 3b is larger than that in Fig. 3a and streaks develop further inland on the plateau above 3500 m a. s. l. in Fig. 3b. The coastal area is almost covered by clouds in Fig. 3b. The strong pressure gradient which is caused by cyclonic disturbances in the coastal area influences the katabatic wind field. This tendency coincides with the change of surface wind direction during stormy weather (AGETA and KOBAYASHI, 1978) on the katabatic wind slope.

Figure 4 shows succeeding 4 days' ΔT_b images in Area-D. It is noticed that topography of scale larger than a few tens of kilometers affects the wind direction. A typical example is seen on the coastal area near Lützow-Holm Bay where streaks converge into the valley-shaped topography of Shirase Glacier drainage. This behavior agrees with the results of numerical models (KIKUCHI and AGETA, 1989; PARISH, 1988).

5.2. *Wind speed*

It is difficult to obtain accurate information on wind speed from the satellite data. However, there may be some relationship between the wind speed and some parameters of T_b fluctuation. In the daily sequence in Fig. 4, the streak pattern gradually becomes ambiguous and a different pattern, which aligns at right angle to the streaks, appears. The latter pattern results from undulations on the ice sheet (SEKO *et al.*, 1992).

Figure 5 shows the time sequences of pressure at Syowa Station and wind velocity automatically recorded at Mizuho Station during this period. From June 25 to 26, a cyclonic disturbance approached the coast; the pressure was low at Syowa Station and wind at Mizuho Station was strong. Clouds associated with the disturbance can be seen in the image on 25. After the passage of the disturbance, pressure rose and wind became weak. The katabatic wind speed gradually became weak within

Fig. 5. Time series of surface air pressure at Syowa Station (solid line) and wind velocity recorded at Mizuho Station (dashed line) from June 24 until June 29, 1988.

this period. This synoptic condition corresponds to the images in which the streak pattern becomes weak gradually and surface features appear clearly on later days. This example suggests that wind speed can be monitored by monitoring the pattern change. Wind velocity is possibly related to the intensity of T_b fluctuation; it seems reasonable to assume that strong wind makes a clear streak pattern.

6. Discussion

6.1. Mechanism causing fluctuation of wind speed

It is interesting to consider the mechanism of fluctuation of wind velocity along the wind direction.

An instability like that which causes cumulus cloud streaks (KUETTNER, 1971) is unlikely to occur, because stratification of the atmosphere on the ice sheet is highly stable in winter. While Görtner instability (SCORER and WILSON, 1963) is a candidate for the mechanism, the curvature of the undulations on the ice sheet seems to be too small to initiate the instability. However, we cannot deny the possibility of some kind of instability which forms longitudinal vortices.

Self acceleration of wind can occur due to abundant drifting snow particles (KODAMA *et al.*, 1985). The streak pattern may be caused by the loading of snow particles which accelerates wind. It is worth noting that spectacular band-structures of blowing snow were often noticed during oversnow traverse or slopes on the ice sheet edge (KIKUCHI, personal communication). It is a future problem to investigate the nature of katabatic wind including snow particles.

6.2. Interaction of undulations and katabatic wind

Under low temperature and strong winds on the Antarctic ice sheet, fallen snow can easily drift. Variation of snow drift transport due to wind velocity changes topography (TAKAHASHI *et al.*, 1988), and the topography alters the katabatic wind field again (KIKUCHI and AGETA, 1989). This forms a geomorphological feed-back system between the cryosphere and atmosphere.

SEKO *et al.* (1992) found that surface undulations on katabatic wind slope develop normal to the wind direction. It is interesting to consider why undulations are aligned at a right angle to the wind; this is a different alignment from the prevailing direction of streaks in this study. Seif dunes on the desert are a famous aeolian feature aligned along the wind direction (HANNA, 1969). Probably, wind converging into the valley-shaped topography along wind direction causes convergence of drifting snow and this alignment vanishes in the katabatic wind field.

7. Conclusion

NOAA AVHRR data reveal comprehensive images of the katabatic wind field on the Antarctic ice sheet. Katabatic wind is visualized as fluctuations of brightness temperature. It reveals a well defined streak feature. We can monitor the wind direction and there is a possibility to monitor the wind speed from the satellite images. The T_b fluctuation probably results from the fluctuation of wind velocity. The mechanism causing fluctuation of wind velocity may be the self-acceleration of wind.

Previous studies of katabatic wind by using satellite data (D'AGUANO, 1986; BROMWICH, 1989) treated phenomena in the coastal region. We have detected wind fields over the interior ice sheet. This is a new tool to investigate the surface wind which can contribute to studies of tropospheric circulation and material transport on the ice sheet.

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