On Identification of Hail-Bearing Clouds from Satellite Photographs

By
H. Riehl and R.A. Schleusener

Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado

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Introduction: Meteorological satellites of the TIROS series have permitted observations of cloud patterns over large areas. The forthcoming NIMBUS series will afford even better observations of cloud patterns and other meteorological parameters. For maximum utilization of such information, understanding is needed in the physical interpretation of satellite data. Regarding possible relation between cloud arrangements and associated severe weather, a study was made of eight cases during the summer of 1960. Results may assist operational use of the NIMBUS series data.

Hypothesis: Much observational and theoretical work has suggested frequent existence of band or "street" arrangements of convective clouds, with a connection between such structure and severe weather. Kuettner (1) has given an excellent discussion of this subject. In view of these observations,

a limited sample of satellite photos from TIROS I has been analyzed in a test of the following hypothesis:

> Hail occurrence should be correlated with the occurrence of convective clouds in well-ordered streets. Such streets suggest concentration of low-level mass convergence into narrow elongated zones, hence also concentration of water vapor, condensation and production of water available for hail formation.

Procedure: Satellite photographs were analyzed and maps of cloud photographs were prepared for eleven TIROS I photographs from eight days in 1960 (see Table I).

Table I. Dates and times of TIROS I photographs analyzed in pilot study of the relation between cloud streets and hail.

Date 1960	Time GMT	Orbit
16 May	20:55:34	659
16 May	20:54:35	659
18 May	20:53:31	688
23 May	19:55:21	760
25 May	23:21:30	791
28 May	22:26:21	834
28 May	22:27:21	834
30 May	22:22:41	863
5 June	20:32:50	949
6 June	19:39:52	963
6 June	19:38:22	963

For each of the dates listed in this table, the publication "Storm Data" (2) was examined for state reports of damaging hail equal to or greater than "category 4" (dollar damage $5,000-$50,000). Whenever hail of this category was reported, a "hail day" was considered to have occurred in the given state.

This type of "verification" was made for each state for which the cloud structure was available from the satellite photographs. It was then compared with a "forecast" of hail occurrence for each of the same states, based on the cloud-street hypotheses stated above. The synoptic situations were completely unknown to the forecaster.

Table II. Contingency table for "Forecasts" of hail occurrence, based on the hypothesis that hail occurs in well-defined cloud streets only. (Verification for individual states from "Storm Data").

		Forecast: Yes	Forecast: No	
Observed: Yes		10	6	16
Observed: No		8	59	67
		18	65	83

Per cent correct: 83

Per cent skill score: 50

Results: The results of this pilot study (see Table II) indicate that the hypothesis deserves further study. The preliminary results, illustrated in figs. 1-4, appear encouraging. But it is recognized that the following factors create uncertainties:

(1) The satellite photos provide only a snapshot of the clouds at one or two instances for a given day. Hence the pattern that existed at the time of the photo may not be representative at the time of severe weather.

(2) On some occasions there may have been extensive cirrus shields which obscured organization of cumulus clouds below.

(3) The evolution of cloud systems may be as important as the instantaneous cloud pattern with respect to type and intensity of severe weather.

(4) The data on hail extent and intensity in "Storm Data" is at best an estimate of hail occurrence. In many cases, this statistic may not furnish an accurate account of the exact extent and intensity of a storm.

With these reservations it may be possible to incorporate satellite data into operational forecasts of convective severe weather, if the skill score shown in Table II is in fact representative of the degree of correlation between organization of clouds into well-ordered streets and hail occurrence.

Conclusions:

(1) Results from this study indicate a skill score of 50 per cent in "forecasting" the occurrence of hail damage equal to or greater

than $5,000-$50,000 in a given state from observations of well-defined cloud streets in one or two TIROS I cloud photographs.

(2) Further study is required to determine the validity of the hypothesis of correlation between cloud streets and hail.

(3) If the hypothesis is valid, it can be operationally useful for short-range weather forecasts from satellite observations.

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References:

(1) Kuettner, J., The Band Structure of the Atmosphere. Tellus, 11, 267-295, 1959.

(2) Storm Data. U. S. Department of Commerce, Weather Bureau. Government Printing Office, Washington, D. C.

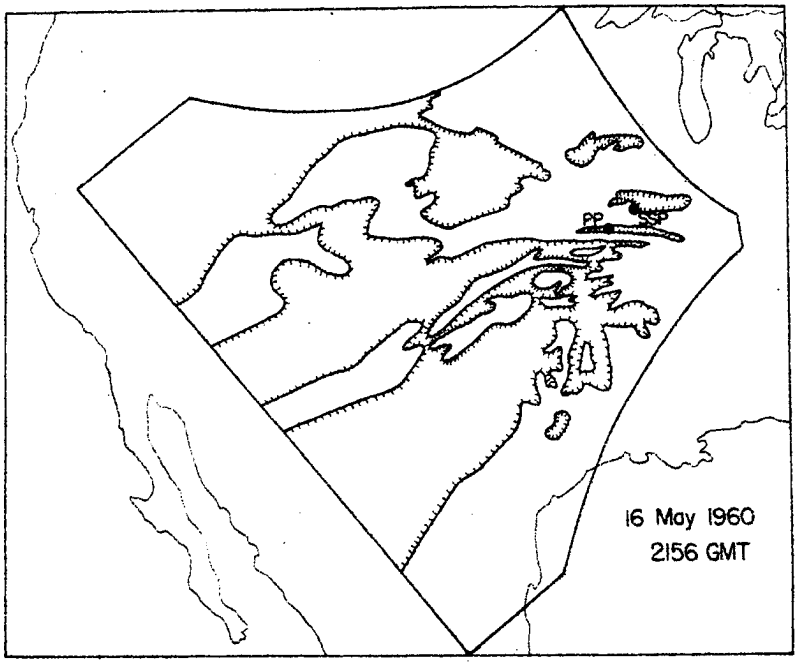

Fig. 1. TIROS I cloud map, 16 May 1960, 2156 GMT. SSP and PP indicate sub-satellite and principal points, respectively. Shading points toward cloudy area.

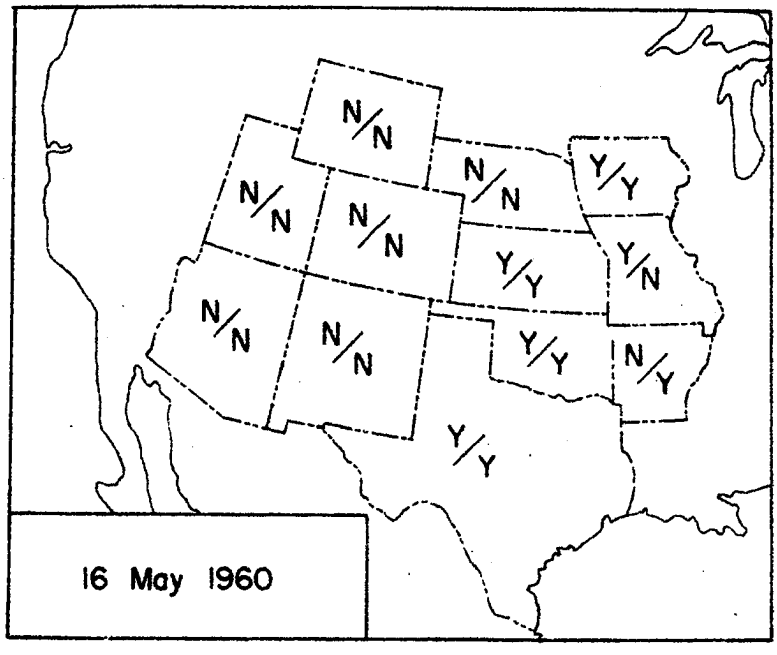

Fig. 2. Hail "forecast" verification by states, 16 May 1960 (from two photos). Y denotes yes; N, no. Scheme: forecast/observed.

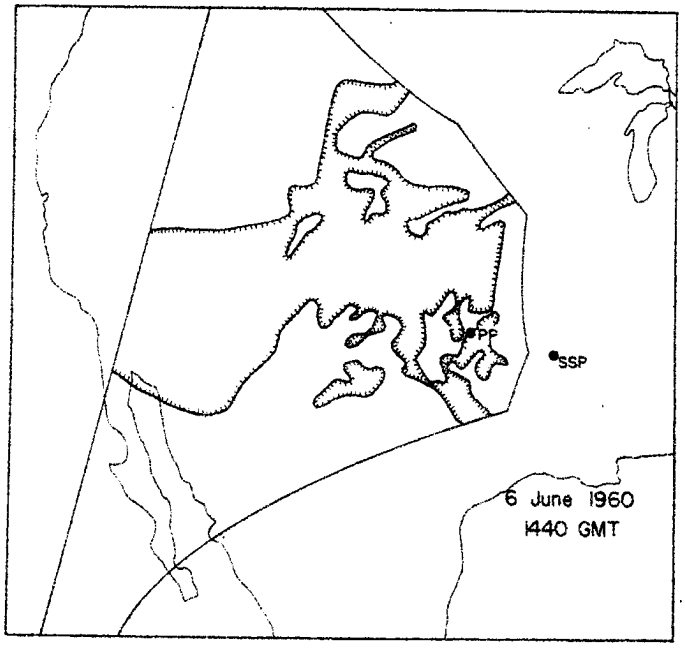

Fig. 3. TIROS I cloud map, 6 June 1960, 1440 GMT.

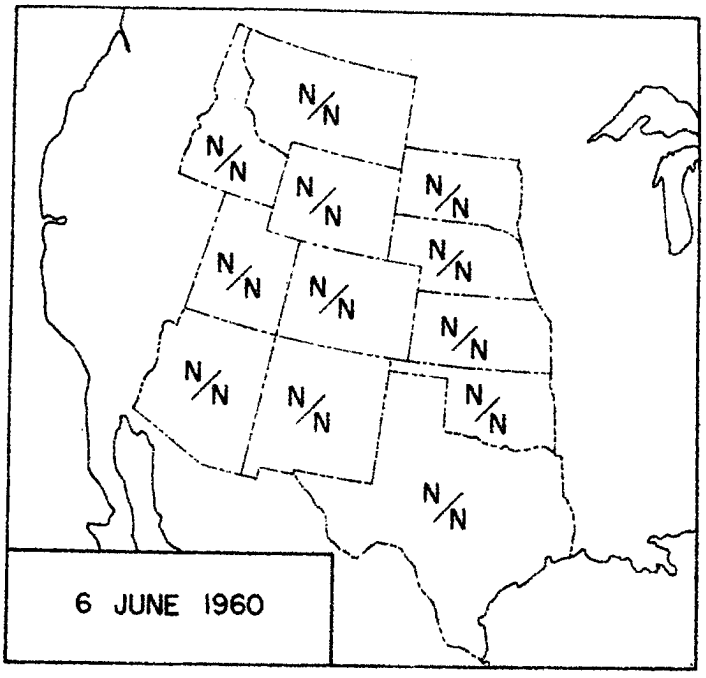

Fig. 4. Hail "forecast" verification, 6 June 1960.