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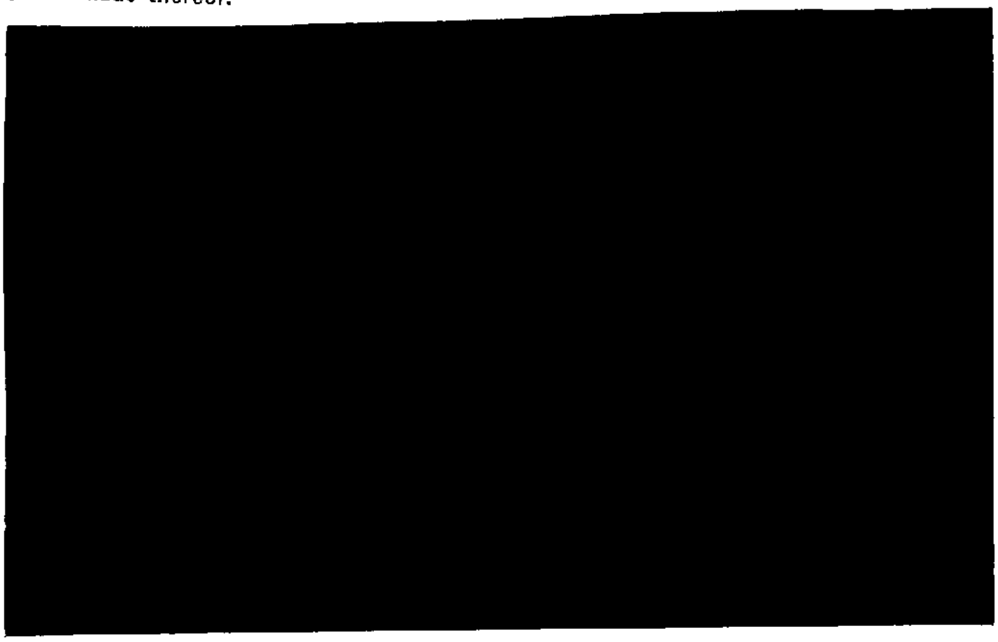

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E74-10051) METEOROLOGICAL INTERPRETATION OF CLOUDS OR CLOUD SYSTEMS APPEARING ON PICTURES OF THE ALPINE REGION RECEIVED FROM THE EARTH RESOURCES (Swiss Inst. of Meteorology) 35 p HC $3.75 CSCL 04B G3/13

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No. 37

First preliminary report on meteorological interpretation of clouds or cloud systems appearing on pictures of the Alpine region received from the

TECHNOLOGY

EARTH RESOURCES SATELLITE ERTS - 1

by

Dr. Alexandre Piaget, Zurich

November 1973

Satellites 551. 507. 362. 2 : 551. 576 (234. 3)

Summary :

Three examples of cloud - interpretation from the ERTS - 1 picture are presented.

- When the wind- speed is large enough, the cumuli are found arranged in lines that are in average two kilometer apart from each other. These lines are grouped in lines made of small cumuli and in lines made up of well develloped ones. These last lines are fused on the APT - picture and appear as single lines.
- Fog-mapping for a given region is possible if the topography of this region is known. The stratified clouds lying over mountains or in valleys begin to dissolve above the middle of the valleys and not against the slopes.
- As water shows a weak albedo in the near infrared, wet surfaces will appear darker than their neighbourhoods. This feature seems to be confirmed by the dark spot in the north of Bozen (Southern Tyrol) that can be seen on the ERTS - 1 picture taken on the 31st of August 1912.

Zusammenfassung :

Es werden drei Beispiele für die Interpretation von Wolken aufgeführt, wie sie auf den Bildern von ERTS - 1 sichtbar sind:

- Wenn die Windgeschwindigkeit genügend gross ist, erscheinen die Cumuli in Linien geordnet, die im Mittel 2 km voneinander entfernt sind. Diese Linien sind sowohl in der Ebene wie auf den Bergen parallel zum Wind. Eine übergeordnete langwelligere Schwingung führt ab - wechlungsweise zu Linien aus grossen Cumuli und zu solchen von weniger grosser konvektiver Aktivität. Nur diese übergeordnete Schwingung erscheint auf den APT - Bilder, auf welchen die sichtbaren Linien aus Gruppen von einzelnen Linien gebildet werden.
- Eine kartographische Erfassung des Nebels wird ermöglicht durch den Vergleich mit den Höhenkurven einer topographischen Karte des Gebiets, über dem er liegt. Die Schichtwolken, ob sie nun im Gebirge oder darüber beobachtet werden, beginnen sich über den Tälern auf - zulösen und nicht gegen die Hänge hin.
- Da das Wasser im nahen Infrarot eine schwache Albedo hat, erscheinen nasse Flächen dunkler als ihre Umgebung. Dies wird durch den dunklen Fleck nördlich von Bozen (Süd -

tirol) bewiesen, der auf dem am 31. August 1972 auf dieser Wellenlänge aufgenommenen ERTS-1-Bild sichtbar ist.

Résumé :

Trois exemples d'interprétation des nuages visibles sur l'imagerie d'ERTS-1 sont présentés :

- Lorsque la vitesse du vent est suffisante, les cumulus s'ordonnent en lignes distantes l'une de l'autre de 2 km en moyenne. Celles-ci sont parallèles au vent, en plaine comme en montagnes. Une organisation superposée modelant les cumulus conduit à une alternance de lignes formées de gros cumulus et de lignes de moindre activité convective. Seule cette organisation superposée apparaît dans les images APT où les lignes visibles sont formées de groupes de lignes individuelles.
- La cartographie du brouillard est possible par comparaison avec les lignes de niveau d'une carte topographique de la région qu'il recouvre. Les nuages stratifiés qu'ils soient observés dans les montagnes ou au-dessus d'elles commencent par se dissoudre au-dessus des vallées et non vers les pentes.
- L'eau ayant un faible albédo dans le proche infrarouge, les surface mouillées apparaîtront plus sombres que leurs alentours. C'est ce que tend à montrer la tache foncée au nord de Bozen (Tirol du Sud) visible sur l'image d' ERTS-1 prise dans cette longueur d'onde, le 31 août 1972.

Riassunto :

Sono presentati tre esempi per la interpretazione delle nubi, come sono visibili nelle immagini di ERTS-1 :

- Quando la velocità del vento è sufficientemente grande, i Cumuli appaiono ordinati in linee, le quali in media so trovano alla distanza di 2 km. Queste linee sono parallele al vento tanto in pianura quanto in montagna. Una oscillazione ad onde più lunghe sovrapposta conduce alternativamente a linee di grossi Cumuli e ad altre con attività meno grande. Solo questa oscillazione sovrapposta appare sulle immagini di APT, sulle quali le linee visibili sono formate da gruppi di singole linee.
- Una rappresentazione cartografica della nebbia viene resa possibile mediante il confronto con le curve di livello di una carta topografica della regione, sulla quale si trova la nebbia: Le nubi a sviluppo orizzontale, tanto se sono osservate in mantagna quanto se lo sono dall'alto, cominciano a dissolversi al disopra delle valli e non verso i fianchi delle montagne.
- Siccome l'acqua nel vicino infrarosso ha un albedo debole, le superfici bagnate appaiono più oscure di ciò che le circonda. Ciò è dimostrato dalla macchia oscura a nord di Bolzano (Tirolo meridionale), la quale è visibile sull'immagine ERTS-1, captata su questa lunghezza d'onda il 31 agosto 1972.

Content

Correction :

Fig. 17 has been uncorrectly reproduced. It must be looked at from the back of the paper.

A first preliminary report on meteorological interpretation of clouds or cloud systems appearing on pictures of the Alpine region [1] received from the Earth's Resources Satellite

ERTS 1 [2]

For this report the following pictures are used :

MSS 4 to 7 images [3]	of August 14, 1972	Cu, Ac, As, Cs
same	of August 31, 1972	Cu, St
same	of Sept. 18, 1972	Cb, Cu, Sc, Ac, As, Cs
same	of Sept. 20, 1972	Cu, fog, contrail

1. Introduction

The primary objective of the Earth's Resources Satellites System is to get a regular global survey of the Earth's resources, as the name of the system says. But for the weatherman it is also most profitable and meteorologically invaluable to use the re - ceived information for studies and investigations of clouds or cloud systems covering some parts of the pictures. One of the scientists will at least be lucky.

There are two reasons for this meteorological interest :

- The meteorologist cannot obtain from other meteorological satellites such a resolution of the pictures
- he actually takes advantage of obtaining nearly simultaneous (time intervals from a few minutes to less than three quarters of an hour) pictures from the operational meteoro - gical satellites

1) The Alpine region is taken here in a wide sense. It englobes the Alps themselves and also the surrounding mountains : the Vosges, the Black Forest and the Plain of the Po.

2) ERTS Earth Resources Technology Satellites (NASA USA)

3) MSS Multispectral Scanner Spectrometer (on board of ERTS-1)

MSS 4	Wavelength	0, 5 - 0, 6 μ	
5	"	0, 6 - 0, 7 μ	
6	"	0, 7 - 0, 8 μ	
7	"	0, 8 - 1, 1 μ	(NIR)

of the ESSA or NOAA series.

A synoptic interpretation is thus possible. The behaviour of mesoscale, even microscale meteorological systems in the synoptic evolution is one of the most promising scopes of such studies.

In the region of the Alps, the summer 1972 was in average cool and rainy. After the middle of September the weather settled. A sunny and warm period in the higher region, a cool and foggy one in the lowerland lasted almost uninterruptedly for two months. Nevertheless, convective clouds (cumulonimbus are only embedded in altostratus and cirrus) are pre - dominant in the pictures. At this time of the year this is not uncommon.

The present report is "a priori " a descriptive one. An analytical investigation will follow, when enough material will be disposible. It's goal is to provide a first meteorological interpretation with the help of conventional means, such as synoptic charts at various levels and vertical profiles of temperature and humidity.

This description is restricted to three aspects :

- organisation of cumulus clouds over mountainous terrain
- problems related to fog or stratus layers
- indication of precipitation patterns.

2. Cumulus populations, especially cloudstreets

A this time of the year, the convection has already started for more than one hour, when ERTS- 1 overflies the country. Depending on the synoptic situation, the night inversion can still persist over the flat region. In the mountains, the cumuli begin to spread out under the first major inversion and it may happen that fog is still lasting in the large ground depressions.

2.1 Case of August 14, 1972

Well developped cloudstreets formed by lines of cumuli clearly appear (fig. 1) over an area delimitated in its southern part by the first mountains bordering the Plain of the Po and in its northern part by the massif of the Gotthard (culminating at 3600 msl) (A) to the west through the massif of Adula (culminating at 3400 m/msl) (B) to the massif of Silvretta (culminating at 3400 m/msl) (C) to the east.

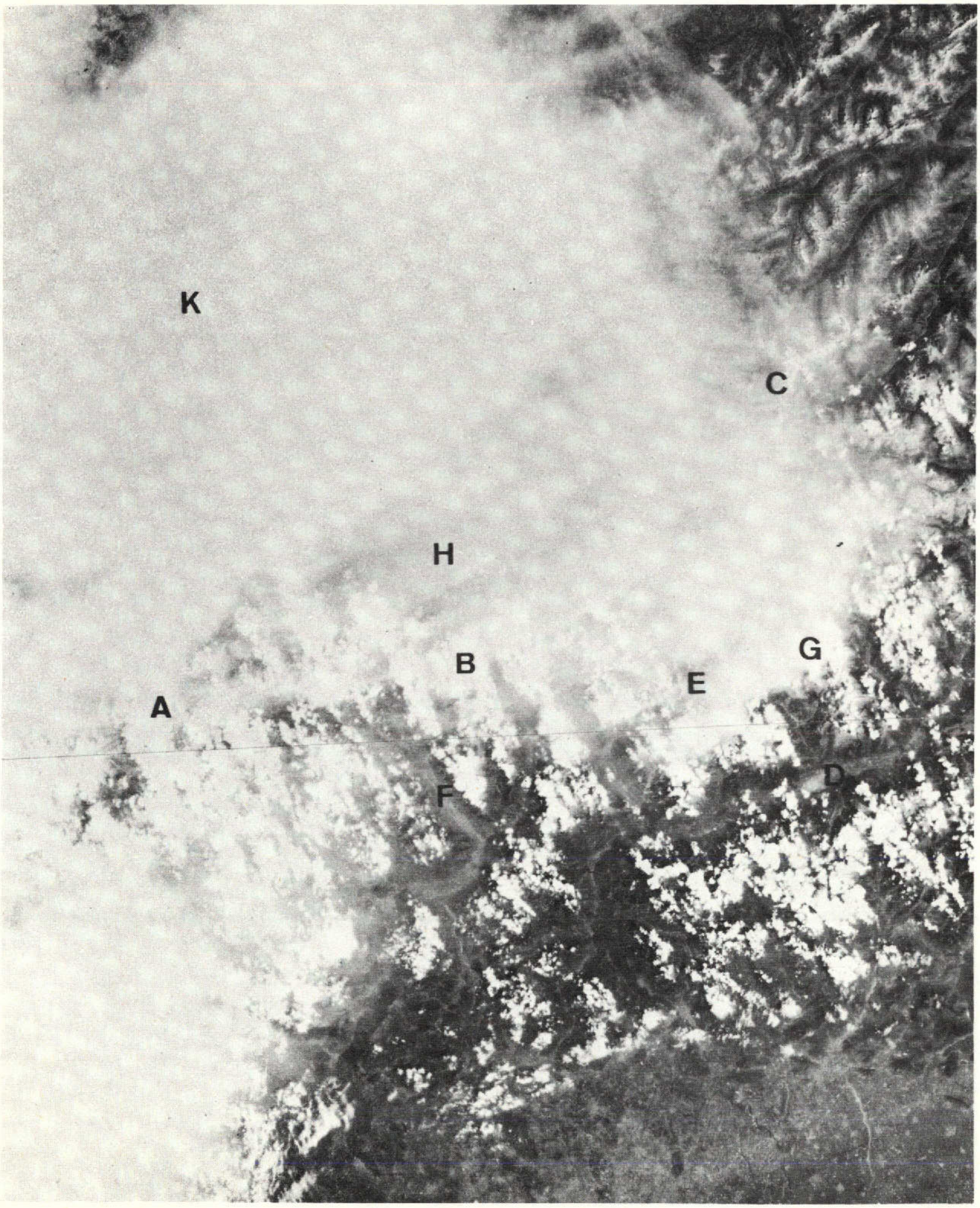

Fig 1

MSS 5 picture from ERTS - 1 on August 14, 1972 at 0943 gmt.
(E - 1022 - 09435 - 5 +E - 1022 - 09442 - 5).
Well developed cloudstreets parallel to the wind direction extend over the southern part of the Central Alps. They are cut over the large valleys being perpendicular to the flow. The cumuli show a tendency to form clusters on the windward slopes.

This area is cut by numerous valleys, the more important longitudinal ones being the Valtelina (D) and the Engadin (E). Both are nearly perpenddicular to the streets. The Leventina (F), the main transversal valley, almost parallel to the streets, is free of clouds.

Figure 2 gives a general view of the topography. The valleys are represented by their rivers. The dots indicate the summits between 2500 and 3000 m/msl, the circles those between 3000 and 3500 m/msl and the crosses those higher than 3500 m/msl. The summit level, the Bernina, just exceeds 4000 m/msl (4049 m/msl) (G). Some main streets are also diagrammatically reported on this figure as an illustration.

The pictures of MSS 7 (NIR 0, 8 to 1, 1 u) are very valuable. They allow the determination of the cumuli tops and under certain circumstances also of their bottoms. The projected shadow appears very dark, mainly black what certainly is due to the strong absorption in this wavelength by the water droplets. It is much darker than the nonilluminated slopes of the mountains covered by snow. The contrast is poor with forest covered shaded slopes (Gfeller, 1973).

The base of the cumulus increases progressively from south to north with the mean alti - tude of the mountains from 2000/2500 m/msl to about 3000 m/msl. The tops of the major clouds reach a height of broadly 4000 to 5500 m/msl. It is interesting to notice that at the Swiss observing station Piotta, northern part of the Leventina, thunder could be heard at 0900 gmt, three quarters of an hour before the passage of ERTS - 1. As the temperature at the top of the clouds does not descend below $-15^{o}C$, the cumulonimbus generating the thunderstorm must already have decayed.

The effect of the orography on cloud generation and decay, but not on the patterns, is obvious :

- there are no cumuli over the Plain of the Po. They first begin over the southernmost mountains. Already there, some have reached the base of the lower inversion while showing a spreading out ot their edges.

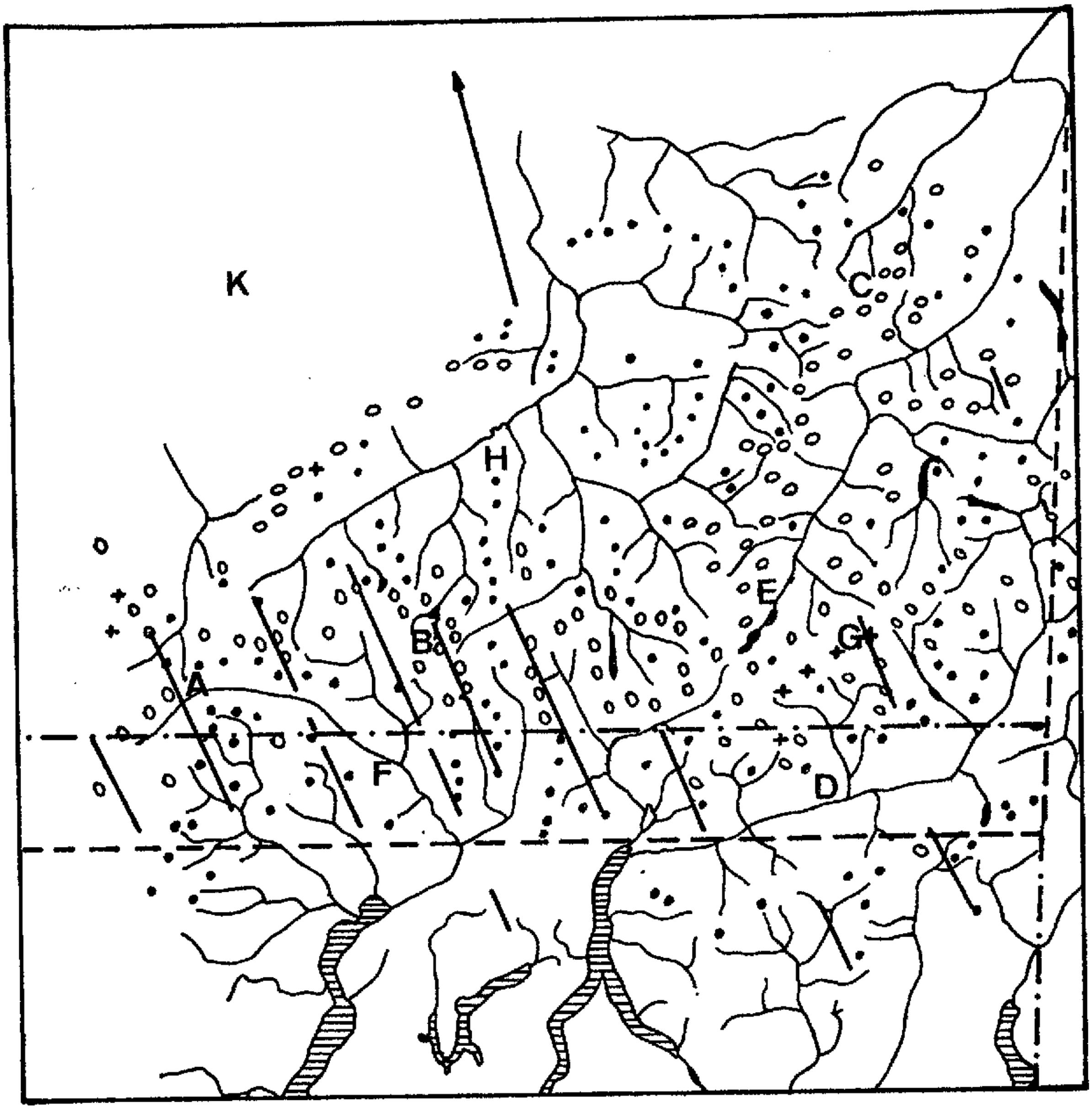

Fig. 2

Geography (schematic) of the region where cloudstreets are observed in figure 1. The river system is represented by continuous lines.

———————	Positions of some cloudstreets
•	Mountain summits between 2500 and 3000 msl
o	Mountain summits between 3000 and 3500 msl
+	Mountain summits above 3500 msl

- on the windside slopes of the mountains (e. g. quite clear over the Bergamese Alps, the southern border of the Valtelina) the cloudiness is more extensive. The individual clouds tend to coalesce in to small clusters.
- over the leeside of the mountains the cloudstreets are cut or at least show a marked diminution of cloudiness. The big transversal valleys are free of clouds, even there, where they are not parallel to the general direction of the streets.

The cloud rows do not seem to be influenced by the relief underneath, as they straight away extend through it, without deviation. The rows around the Bernina illustrate this. There, the tops of the mountains are well above the base of the clouds.

Although cloudstreets are well known, particularly after the manned orbital flights and the enlightenment by glider pilots, few studies deal with them. The most important ones are those by Kuettner (Kuettner, 1967 ; Kuettner and Soules, 1966). The theoretical suppositions also seem to be valid here,as this type of organization of the convection in the direction of the windflow must be an intrinsic property of the air. The orography only increases or starts the convection. In this case, and in opposition to the follwing one, the postulated vertical profile of the wind is not realized. On this day the wind is strongly canalized through the passage between mountains, especially to the west (see also fig. 5) The study of cloudstreets will be a major task of evaluation of Skylab materials to be undertaken by the French group under the leadership of Mr. Villevieille.

The distance between two consecutive rows is about 2 km. Superposed on this wavelength, a larger one of about 10 km in average also seems to be present. Effectively, the rows show alternation of more or less developed cumuli, the former with more spreading out under the inversion and a greater tendence to coalesce into larger streets.

The picture received about 3/4 of an hour later from the USA meteorological satellite ESSA 8 (later simply ESSA 8) distinctly shows the cumuli restrained to the Alps and mainly south of the watershed (fig. 3). The convective activity progressively diminishes to the east. The As/Ac-layer (K)[1)], the southern extension of which is limited by the Glarner Alpen and the overlying cirrus are forerunners of the cloud system (with embeded cumulonimbus) of a cold drop (L).

1) Here and later on, to avoid confusion, the same letters were used in ERTS - 1 and ESSA 8 pictures taken on the same day for a particular region or a cloud system.

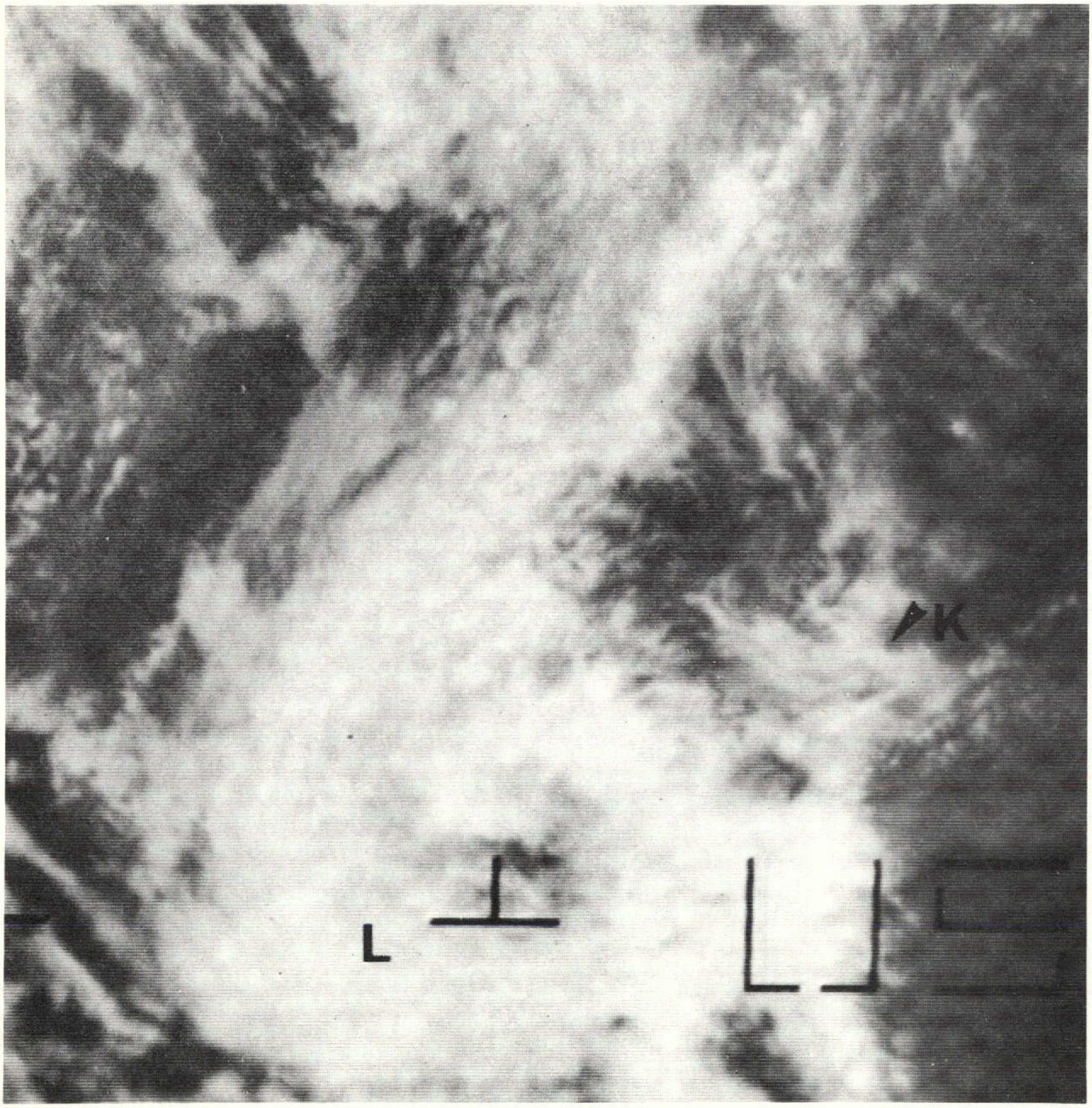

Fig. 3

ESSA 8 picture received on August 14, 1972 at 1036 gmt.
Due to the less good resolution of this picture, the cloudstreets seen on the ERTS-1 picture do not appear as individuals. Nevertheless row structure (south of K) is apparent. (To compare with the other appearance of the clouds over the same region at another day, e. g. on August 31, 1972, fig. 9).

Underneath light rain is locally reported. The cold drop slowly drifts eastward. The corresponding surface synoptic map (fig. 4) shows a typical summer situation where pressure gradients are very weak. An elongated low extends from the middle of France to Czechoslovakia and the associated cold front lies along the Alpes Maritimes and extends over the Central Mediterranean. The small depression over Denmark corresponds with the second cold drop lying north of the former one (fig. 3).

At the upper levels the low is more accentuated. Over the western and central Alps the flow is oriented SSE to NNW up to about 600 mb (4 km). The 700 mb chart is reproduced on figure 5. Some winds observed at or near this level are conventionally plotted. Above the 600 mb level, the winds veer to S and SSW, as shown on the 300 mb chart (fig. 6). The jet stream bordering the eastern side of the cold drops is not very strong. Its maximum windspeed over the North Sea does not exceed 90 knots.

Over the area in view the windspeed increases from about 20 - 25 knots at the level of the bottom of the clouds up to about 30 - 35 knots at the level of the tops. To the west they are progressively increasing up to 10 - 15 knots more than mentioned. The effect of canalization strengthens the speed of the wind during the passages between mountains, still at levels where clouds are present (see fig. 5 : the plotted 50 knots wind speed was registered at the Jungfraujoch slightly west of the Gotthard (A) at 3500 m / msl).

The cloudstreets are parallel to the wind direction at the corresponding level, in this case oriented 170° / 350°. They are not different from similar rows over sea or flat region where the convective activity is also developed. The airflow crosses the Alps from south to north. Although no large precipitation areas are observed on the windside, foehn or foehnlike winds are blowing in the leeside valleys, especially in the upper Rhine valley (H). It has already been noticed that the cloud rows generally do not extend north of the main mountain range. North of the watershed the Alps are cloudfree with the exception of a samll row composed by half a dozen of individuals near the Kuchen- Spitz (I). This lack of convective activity with full insolation is due to the diffluence and subsiding motions prevailing over this area, the air mass being the same on both sides of the watershed.

Fig. 4

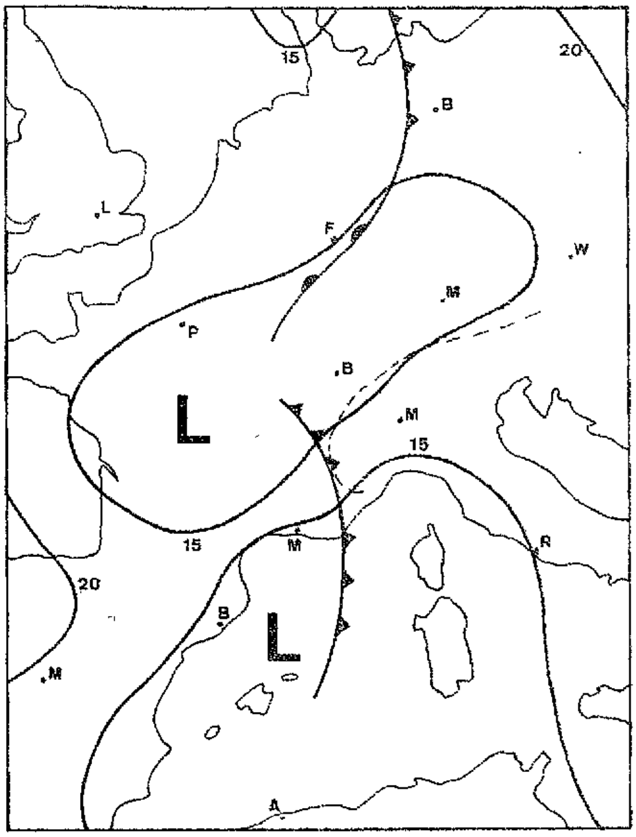

Fig. 5

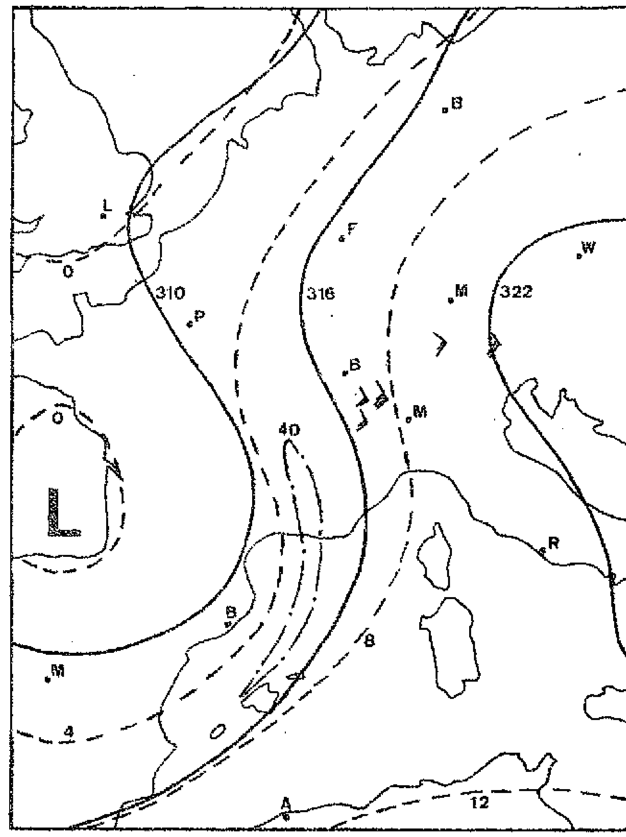

Fig. 6

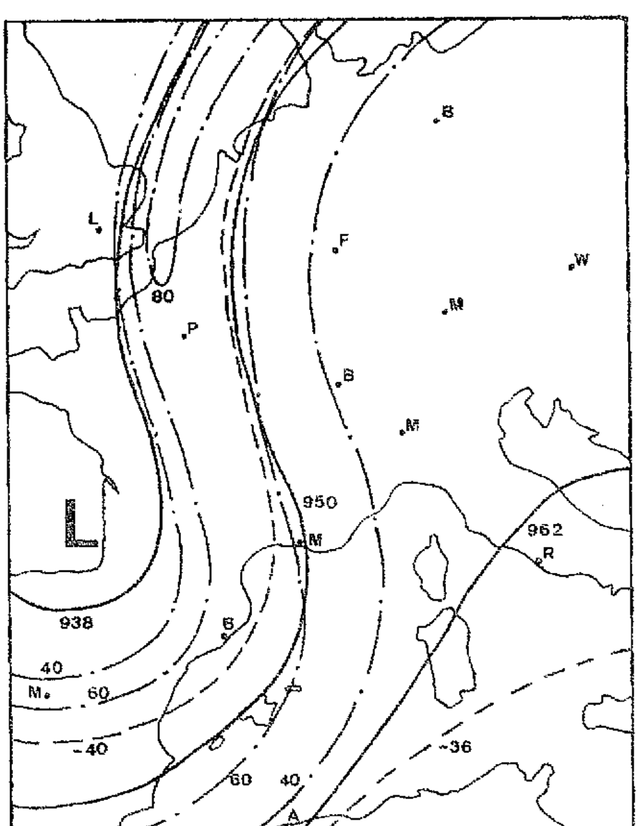

Fig. 4

Surface chart August 14, 1972 at 0945 gmt.

Cold front

Warm front

Isobars, each 5 millibars

Fig. 5

700 mb chart August 14, 1972 at 0945 gmt.

Isohypses, each 6 decameters

Isotherms, each 4°C

Isotachs, each 20 knots from 40 knots

Observed winds at or near 700 mb level

Fig. 6

300 mb chart August 14, 1972 at 0945 gmt.
Legend : see fig. 5

2.2 Case of August 31, 1972

On this day, the repartition of convective clouds over the Bavarian Alps and Tyrol, as seen by ERTS-1 near 1030 loc time (0930 gmt), is highly interesting (fig. 7). Two types of distribution appear. In the larger one, the cumulus lies just over the ridge up to the height of 2600 m/msl and above the tops of the mountains lower than 2200m/msl. In the smaller one, cloudstreets extend over the eastern Bavarian Alps (A). The valleys are entirely free of clouds, except for a layer of small extension around the town of Landeck in Austria (B). This last feature will be discussed in chapter 3. The mountains are almost snowfree, only the topmost ones are covered by glaciers or remainings of snow. The picture shows a gentle summer day's convection.

The rows of clouds are less sketched than in the former case. They are roughly located $070^0/240^0$. The distance from one line to the other in this case, too, is about 2 km. It is not possible to determine if a superposed organisation is also present due to the small extension of the cloud cover. The streets appear to be affected by the orography up to a certain extent, some valleys being nearly parallel to it.

Clouds are met only over the hills and mountains, the plain being cloudless as in the former case. The cloud base at 1800/2000 m/msl in the border of the Alps and the big valleys (see for instance the region around Bozen in South Tyrol, Italy (C), incrases up to about 2600 m/msl near the main massifs. Nowhere the tops reach an altitude higher than 2800/3000 m/msl. Thus as noticed before, ridges and summits higher than 2600 m/msl are free of clouds. The higher the base the smaller the vertical extent and consequently the smaller the cloud cover. This clearly appears in the picture. The clouds diminish in size towards the top of the mountains. Over the lower mountains, as near Bozen, they already tend to coalesce into small clusters.

The vertical repartition of temperature and humidity is plotted in figure 8 where the sounding of Munich is given as an example. The lower inversion lies at 2300 m/msl on both sides of the Alps. It increases towards the east (outside of the region in the picture) to 3000 m/msl. The inversion must be higher in the Alps where convection is present. Otherwise, the top of the St-layer around Landeck fits in well with the height of the inversion as determined by the ascents. Unfortunately, this problem cannot be solved without soundings in the heart of the Alps, which are not available at the present time. The distribution of the temperature above the inversion leads to the conclusion that the clouds belong to the same air mass as the one under the inversion. This does not represent a special case but is the general rule.

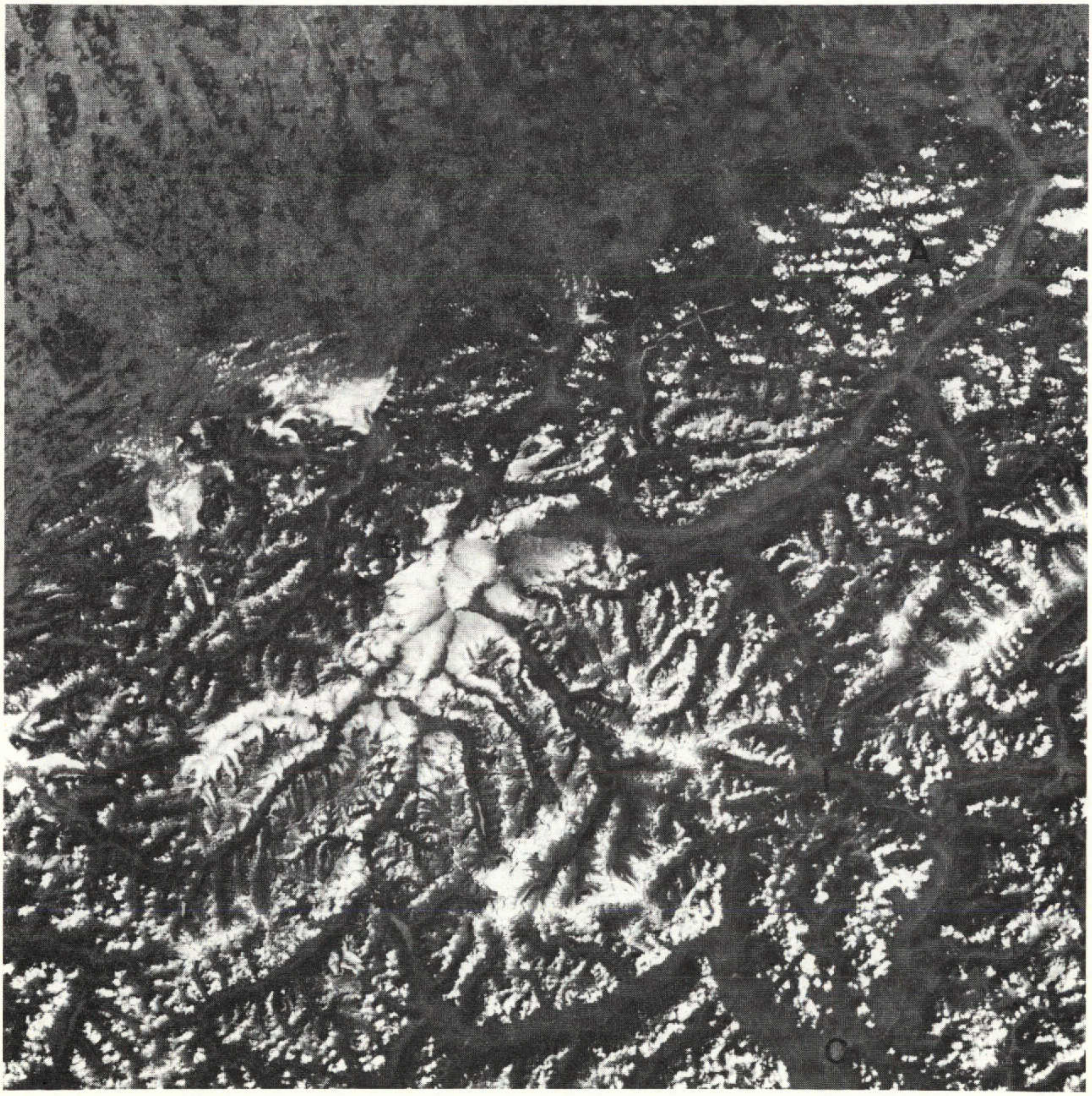

Fig. 7

MSS 4 picture from ERTS-1 on August 31, 1972 at 0938 gmt (E-1039-09381-4). Cloud populations (cumuli and stratus) of different patterns are observed this day over the north-eastern part of the Central Alps. The cumuli lie over the ridges and mountain summits lower than 2600 msl, the wind being weak less than 5 knots inside the Alps. Stronger on the northern side the wind conducts the cumuli to organize in rows (A). A " dissected " stratus layer covers the surroundings of Landsberg in Austria (B).

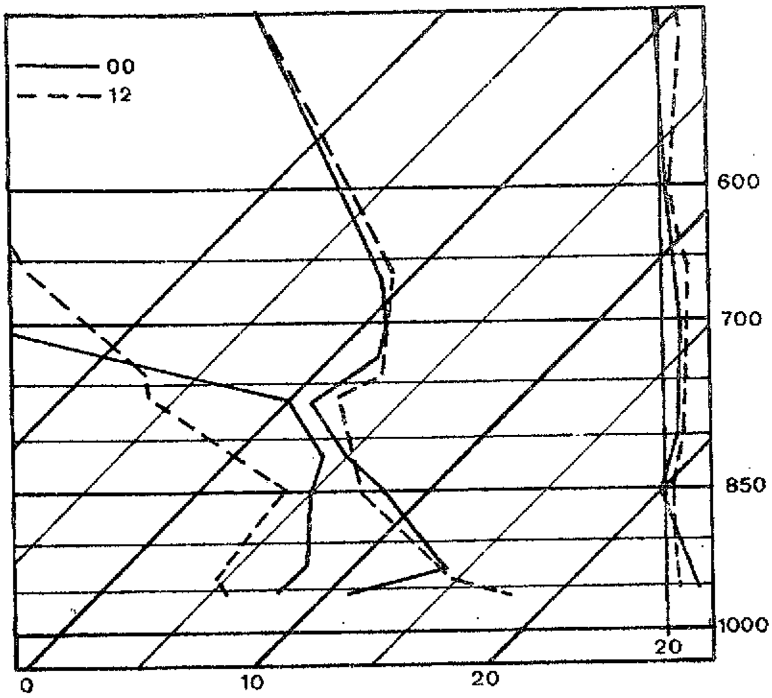

Fig. 8

Vertical temperature, dew point and wind (right) profiles over Munich (10866) on August 31, 1972.

———————— Sounding of 0000 gmt

- - - - - - - - - - Sounding of 1200 gmt

This is one example for the profit derived from ERTS pictures, since the pictures received from the operational satellites are not suitable for such investigations.

A cold front (D-G in fig. 9) crossed the Alps the preceding night. No very important precipitations were observed on the northern slopes. On the southern part the weather remains dry with the frontal passage. The frontal cloudiness still covers the western part of the Alps (D) as may be seen on the picture received from ESSA 8. The convective activity is limited to the Alps only (E) and is well developed over the eastern part. The stratus layer over Landeck is also visible on the picture from ESSA8. Over Bohemia (F) there are cloudstreets. The distance from one street to the other is here of the order of 10 km. This leads to the conclusion that only the superposed organisation is visible on the pictures of ESSA 8 and not each cloudstreet. They are oriented ENE to WSW.

The surface synoptic chart shows weak pressure gradients. The pressure constantly decreases southward and reaches values under 1010 mb over North Africa. (fig. 10). Figure 11 outlines the situation at 850 mb. A weak low lies over the central Mediterranean. An easterly wind blows over central and western Europe. Some winds observed or measured at or near this level are plotted. In the Alps themselves, the wind becomes light and variable. Above the inversion, the situation is very flat as the 500 mb chart shows (fig. 12).

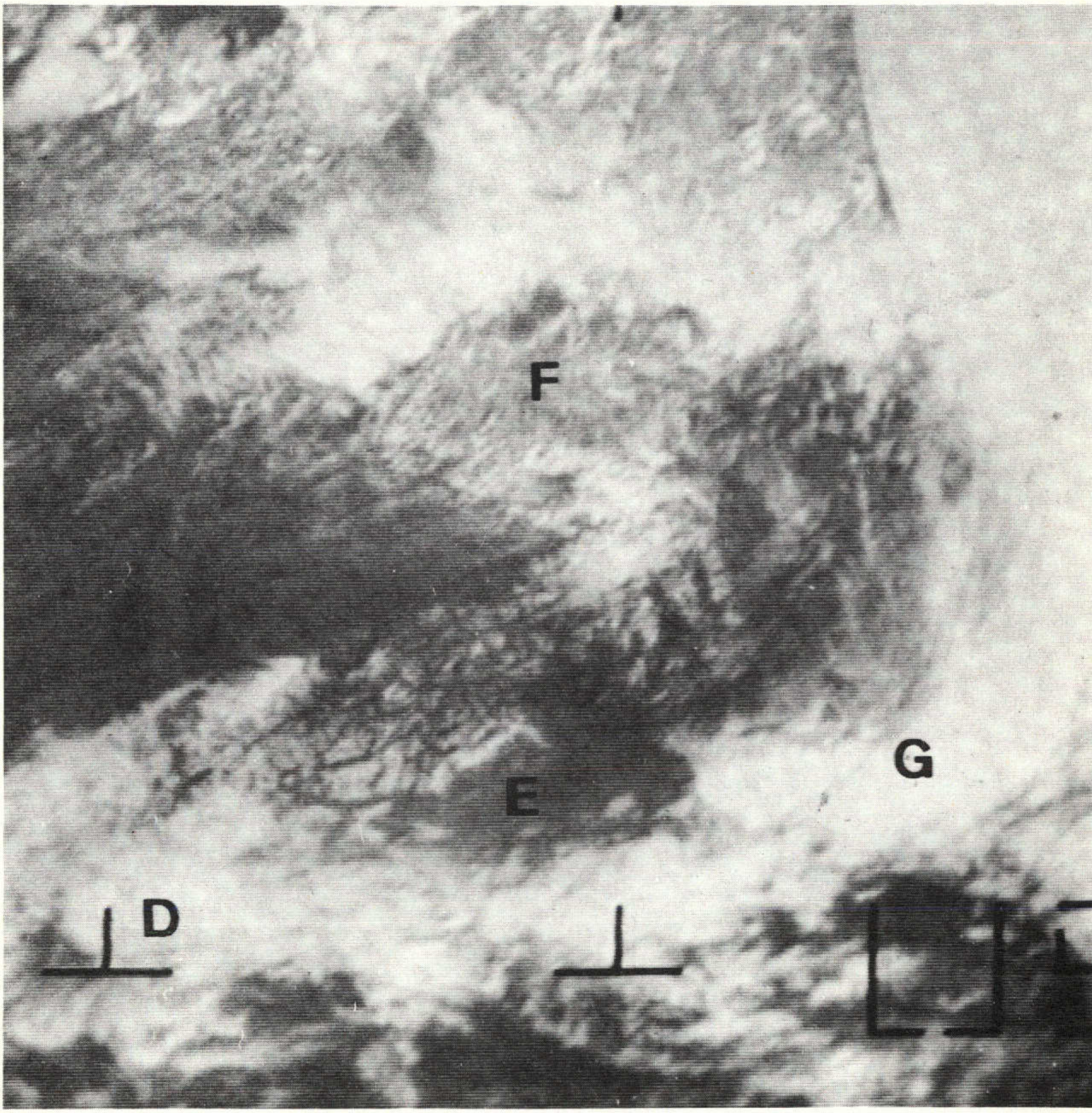

Fig. 9

ESSA 8 picture received on August 31, 1972 at 0948 gmt.
The convective activity is restrained to the eastern part of the Alps (E). Rows are observed over Bohemia. Here too the remark in the legend of figure 3 is valid.

Fig. 10

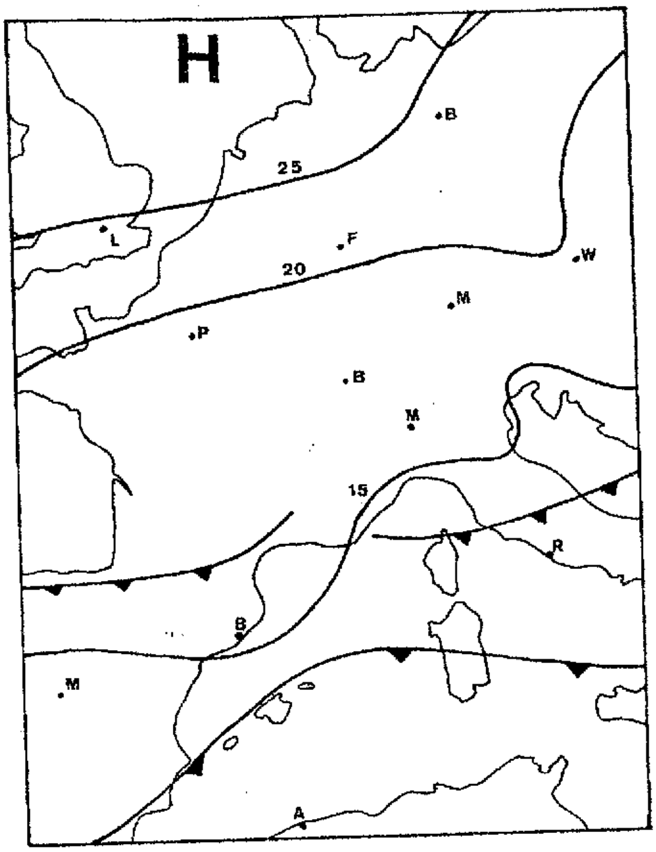

Fig. 11

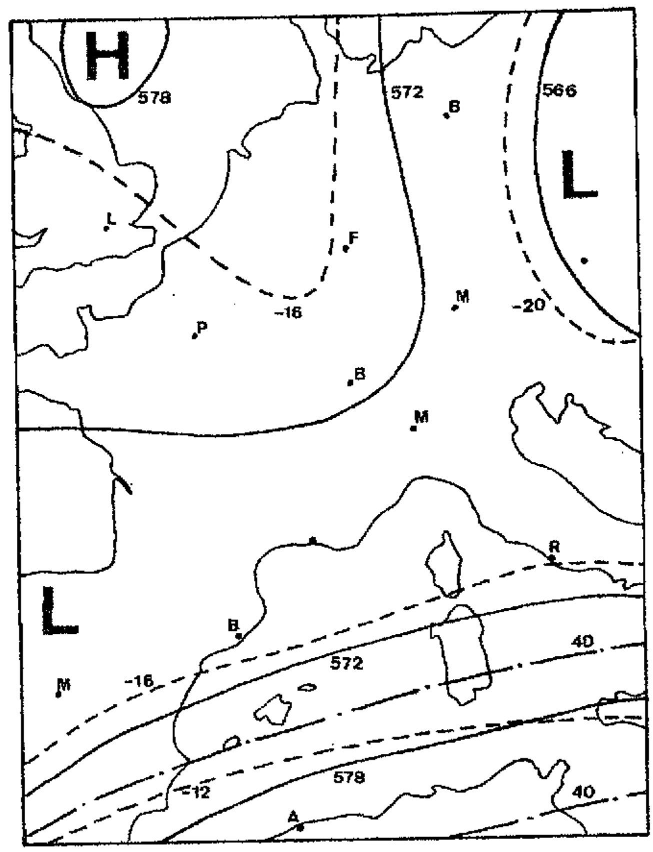

Fig. 12

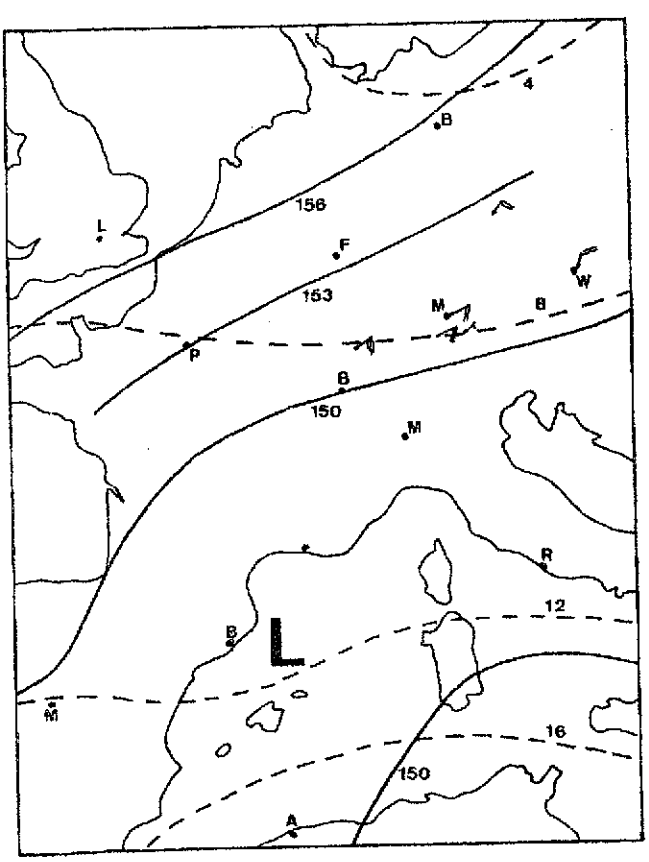

Fig. 10

Surface chart August 31, 1972 at 0930 gmt.
Legend : see fig. 4

Fig. 11

850 mb chart August 31, 1972 at 0930 gmt.
Legend : see fig. 5

Fig. 12

500 mb chart August 31, 1972 at 0930 gmt.
Legend : see fig. 5

The vertical wind profile postulated by Kuettner (windmaximum at the height of the cumuli) is present where the cloudstreets are observed.

2.3 Case of September 20, 1972.

The Mittelland (A) or Plateau in French, the so-called flat region of Switzerland north of the Alps, part of Bavaria (B) and the Rhine valley (C) downstream of Basle (D) were still covered with fog at the time when ERTS- 1 took the pictures (MSS 4 is reproduced in fig. 13), 1050 loc time or 0950 gmt, although cumuli were already well developed over the snowfree mountains of the Bernese Alps (E) and over the Black Forest (F). The circulation leading to the formation of cumuli is well established, the clouds spread out under the inversion. No cumuli are observed over the mountains which are covered with snow. This contrast is surprising. Both get the same amount of insolation, no clouds being present before. It has to be remembered that cumulus over snow can be clearly delineated with the help of MSS 7 pictures. The snow line is at 1800 m/msl on the northern slopes and at 2000 m/msl on the southern ones of the Bernese Alps (see also Gfeller, 1973). The base of the cumuli is above 2000 m/msl. The cooling of the air above the snow covered surface (freezing - level is at 2300 m /msl) hinders the full development of the valley - mountain air circulation which leads to cumulus formation. They will appear later on : the observing stations report cumuli at noon in these regions. The tops of clouds remain under the layer with small temperature decrease which lies at 3300 m/msl as shown in the ascent of Payerne (06610) and Milan (16080) reproduced in figure 14. Here too the tops of the cumuli are partly higher between 3300 and 3700 m/msl. The inclination of the cumuli towards north-west comes from a gentle wind from the south-east. In opposition to the large cumulus population discussed in the first case in this one, where the mountain slopes are higher than the base of the clouds, the cumuli are bordering the ridges.

The cumuli covering the Black Forest are arranged in diffluent rows, the orientation shifting from E to W in the northern part to ENE to WSW in the south. Here too the distance from one street to the other is about 2 km in average. The superposed organisation cannot be seen on the picture of ERTS- 1. Surprisingly the picture received at the same time from ESSA 8 (a few minutes earlier) shows element of rows (F) corresponding to a superposed orga - nisation but skew to the individual streets (fig. 15). On the picture of ERTS- 1, effectively, this corresponds with an increase of convective activity.

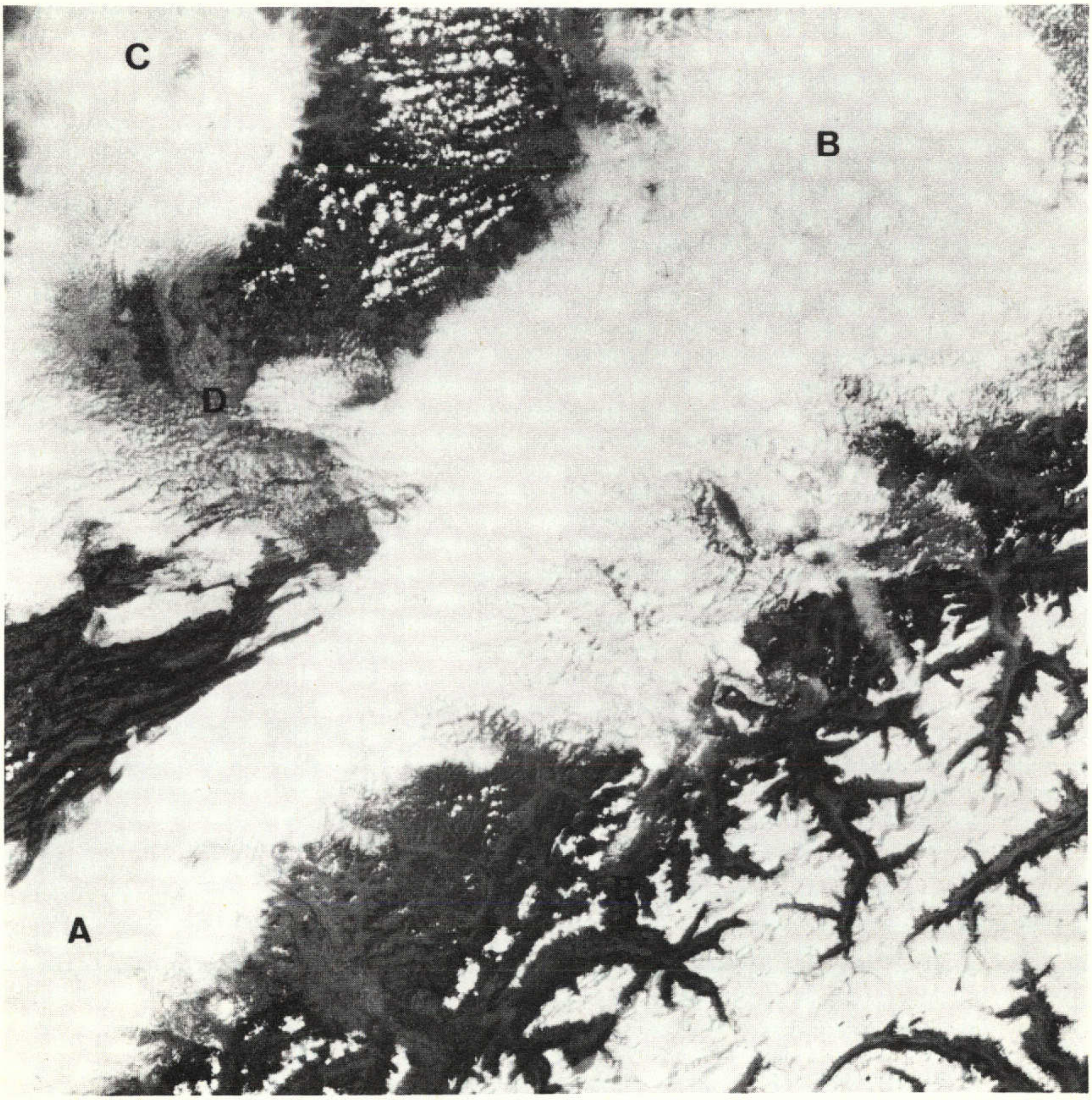

Fig. 13

MSS 4 picture from ERTS-1 on September 20, 1972 at 0949 gmt. (E-1059-09493-4)
Fog persists in the lower land while cumuli have already developed over snow free mountains (E and F) but not over the snow covered ones (lower right corner).

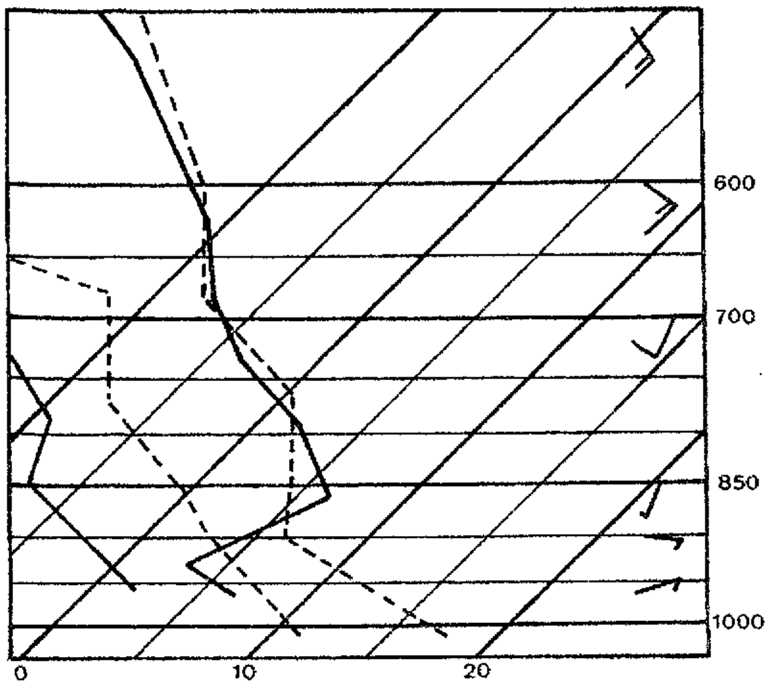

Fig. 14

Vertical temperature and dew point profiles over Payerne (06610) and Milan (16080) on September 20, 1972 at 1200 gmt.

———————— Payerne

- - - - - - - - Milan

- Small cumuli cover the part in view of the Plain of the Po (G, fig. 16). Their base is at 600 m /msl, their tops vary from 800 to 1200 m/msl limited by the first inversion of the ascent of Milan (fig. 14). They begin to arrange in rows. These are located more or less SW/NE in the lower part of the picture. N/S in the upper part of the plain. The distance from crest to crest varies from 1, 5 to 4, 5 km. On the ESSA 8 picture they appear as a mottled veil (G).

At the surface the situation is dominated by a high pressure over central Europe. An almost stationary cold drop lies over the Bay of Biscay. The winds are weak at each level up to 500 mb all over the viewed region. They blow from east over the Black Forest where the rows are parallel to the wind and from south-east over the Alps. The speed is between 5 and 10 knots over the Black Forest where the streets are distinct, less than 5 knots in the region of the Plain of the Po.

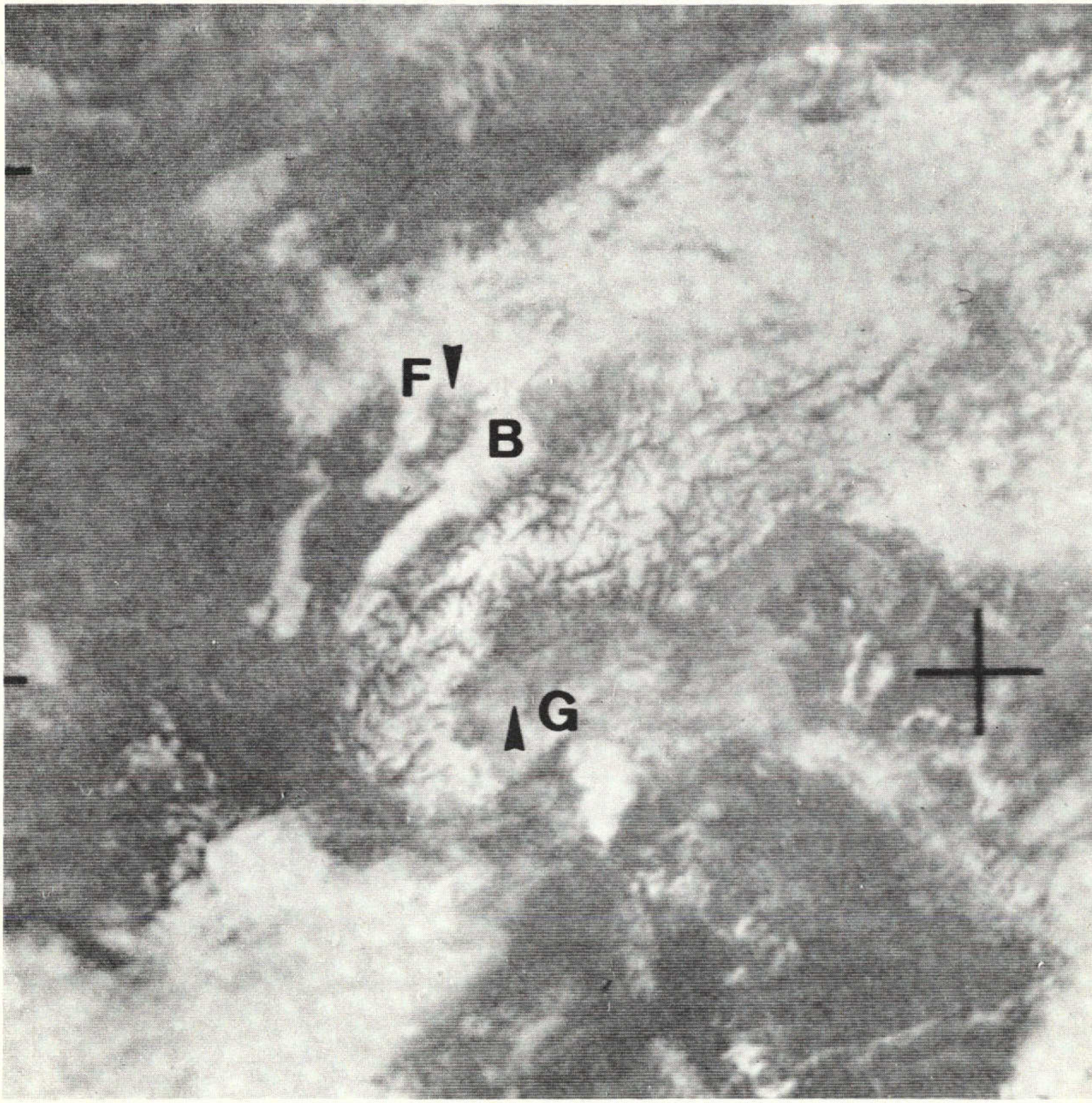

Fig. 15

ESSA 8 picture received on September 20, 1972 at 0942 gmt.
The snow covering the Alps and the fog areas are clearly visible. By comparison with figure 13, the difference in patterns between snow covered mountains and cumulus population over the ridges and summits is evident. The larger rows in this picture are skew to the individual ones seen over the same region (Black Forest, F in both figures) in the ERTS-1 picture.

Fig. 16

MSS 4 picture from ERTS - 1 on September 20, 1972 at 0950 gmt. (E - 1059 - 09500 - 4). Over the Plain of the Po (G) the cumuli are more or less organized in rows. As in figure 13 the snow covered mountains are free of clouds. The only exception is just south of the centre of the picture. There the convective activity is much stronger than elsewhere. It already begins to extend over the snow covered slopes.

2.4 Some preliminary conclusions

These few examples allow some first preliminary conclusions, but it is to early to deduce definitive information on the behavior of convective cloudiness in mountainous regions. For the first time on a regular basis, the meteorologist gets an extended view of cumuli populations in the Alps, so to speak in the mountains in general. Some large views were possible from high - flying aircrafts, but due to the small angle of sight in the pictures, border cloud organisations were more feeled than seen. The following conclusions can be made :

- When the wind speed is above 5 knots at the clouds height, cumuli are organized in rows even in or over mountains. The rows are parallel to the wind direction. As the arrangements of the clouds do not show essential differences if observed over sea, flat land, in or over mountains, this type of organisation is proper to the air masses involved
- As stated before, the organisation in rows is independent of the ground underneath. Nevertheless the orography plays an essential role in the sense that there the convection is more active. Cumuli form and grow there while the surrounding plains may remain free of clouds.
- When the basis of clouds is lower than the ridges or summits of the mountains, the cumuli are enhanced along the windward side of the ridges bordering the cross-oriented large valleys. The grade of enhancement depends on the wind speed. Since there the clouds tend to coalesce, the rows loose more or less their individuality. Over the valleys, due to the subsiding motion over the leeside slopes, the rows are generally cut. Where the valleys are more or less parallel to the wind direction, they are generally free of clouds. Due to these two modelling factors of the underlying topography the overall appearance of the cloudstreet system looks less regular or quiet as over flat regions or seas.
- In the discussed cases where the observed wind speed range between about 8 knots to nearly 50 knots, no important variations of the distance between two consecutive rows are found. The cloudstreets are separated from each other in average of about 2 km. If the wind speed is less or equal to 5 knots over the flat terrain the distance from one row to the next varies strongly from 1,5 km to 4,5 km as over the Plain of the Po. On the other hand by weak wind in the Alps the cumuli do not arrange themselves in streets. Under these conditions, they either top the ridges and summits of the mountains or, if the basis of the clouds is lower, they border the windside slopes.
- A superposed organisation is certainly present. In fact, independent of the terrain, rows or parts of rows with a greater convective activity regularly alternate with rows or parts of rows with less developed cumuli. The passage from one type to the other is not sharp but progressive. If the distance between two regions of strong rows is at an average of the order of 10 km, it proportionally varies more strongly than the spacing of individual

rows. This overall organisation is generally parallel to the prevailing wind direction. In the case of August 31, 1972, it is skew to it. As the intervals between cloudstreets which are observed in the pictures received from the ESSA are of the same order, these streets are probably not individuals but appear as such due to the resolution power of the cameras. The assumption seems acceptable that they are composed of more than one row.

- Two facts were already known, namely that cumuli reach quite soon after the beginning the first major inversion and that they tend to coalesce. New is that rows themselves tend to coalesce together as shown by the pictures from ERTS - 1 received on August 14, 1972 (fig. 1), in this case often in pairs.

None of these cases show any particular synoptic conditions other than those leading to the formation of cloudstreets. So far this type of organisation in rows is not a particular one but rather the normal arrangement when enough wind is blowing. It is certainly not restricted to this time of the day or of the year, as it was here observed.

3. Fog and stratus layers

3.1 Case of September 20, 1972

The hilly rather than flat region which lies between the Alps and the Jura (see A in fig. 13) is often covered with fog or low stratus in the winter half-year. The latter can stay sometimes for weeks, but in fall and spring the sky is clearing about noon. The top of fog generally remains below 900 msl, that of stratus can reach 1500 - 1800 msl. In this region about 2/3 of the whole Swiss population lives and works. As a consequence it is also the region with the " greatest pollution potential ". Thus the study of fog conditions and extension is very important for the planning of new settlements or the growth of the infrastructure, as the fog is a useful indicator of stagnant air.

The meteorologist cannot get a complete view or sufficient information on fog appearance and extension from the classical observation network alone even in its most shophisticated form. The surface obersvations must be completed by an overall survey made with the help of satellites. Up to now the operational polar orbiting satellites seldom give more than a picture (two with IR equipment) per day of the region in question. Later a complete survey will be possible by means of remote sensing from geostationary satellites.

The expected resolution of the pictures will be similar to the one of the actual ESSA pictures at the medium latitudes. The methods, which have so far been developed by the meteorologist, will thus retain their validity. Nevertheless some promising results can already be obtained, as will be shown by Schacher (1973).

Due to the above mentioned reasons, the comparison of ESSA 8 pictures with pictures received at almost the same time from ERTS - 1 is fruitful. The characteristic of the features observed on the ESSA 8 pictures can be adapted or if necessary corrected by the information contained in the ERTS 1 pictures. This helps and leads to a better interpretation of the other pictures. The case of September 20, 1972 will serve as an illustration (fig. 13 and 15).

All the main features of the fog seen in the ERTS - 1 pictures are likewise distinguishable in the ESSA 8 pictures . This is due primarily to the great contrast between the fog layer and the free terrain around it. This constrast proceeds from the strong albedo of the top of the fog layer. Another reason, evident in mountainnous regions, is its sharp border. Surprising enough, over flat land the border is generally well definite too, as e. g. over Bavaria (B in fig. 13, see also fig. 15).

Due to these facts the determination of the altitude of the top does not offer great difficulties. The mentioned techniques used by Itten (1971) and Gfeller (1973) for the determination of the snowline can be applied accordingly with the same success. The accuracy is within 20 m near steep slopes, within 30 m otherwise, by means of ERTS - 1 pictures, and within 150 m with the help of ESSA 8 pictures. After the experience gained by comparative inter - pretation it is now possible to get an accuracy better than 100 m, sometimes even of the order of 50 m with ESSA 8 pictures. The determination is often greatly facilitated, especially in the case of ERTS - 1 pictures, to a much less extent with ESSA 8 pictures, by some typical orographical peculiarities.

In the above discussed case the top of the layer is smoothly sloped towards north and east being just lower than 1000 msl in the southern part, 850 msl in the northern 750 msl in the eastern one. This is in accordance with the altitude of the temperature inversion deduced from the uppersounding of Payerne (06610)(fig. 14) and Munich (10866).

The fog has penetrated the breaks (the local name is " cluse " in French or " Klus " in German)in the first range of the Jura partly to the southern valleys of the Jura. No ambi - guities in the interpretation are possible in the picture of ERTS - 1 (fig. 13). As the under - lying area in the large valley left in the picture is at 750 msl, the fog begins to disperse. Taking into account the resolution of the pictures of ESSA 8 , from the three penetrations which are visible on fig. 13, only the left one will weakly appear in ESSA 8 picture (fig. 15). The one in the middle is just marginal. The right one will not be isolated from the main layer. This creates a wavelike appearance at the border of the fog as seen in the ESSA 8 picture which is not in accordance with the one of the first mountain slopes at the top altitude. As this feature quite often appears in other ESSA 8 pictures, it can be deduced that fog has penetrated in the valleys. No observation being available in these regions, this interpretation was only hypothetical before. The area surveyed by ESSA 8 pictures is much larger than the one on ERTS- 1 pictures. Therefore it is now possible to gain a more detailed information not only on the extension of the fog layer itself but also about the trials to find out the relationship between the extension and the prevailing synoptic situation. A new improvement will be the use of the better pictures received from the VHRR on board of the NOAA satellites.

The other particularities will not be discussed further here as the former example illustrates quite well the existing possibilities. It is still worth to notice that in the case where the albedo is very high on the ERTS- 1 picture, the fog remains on the ground. This is not as clear on the ESSA 8 pictures as on the ERTS- 1 ones.

3. 2 Inversion layers

The same facts as discussed in the former paragraph are also valid for the survey of stratus layers inside the mountains like the one covering the Austrian town of Landsberg and its surroundings, visible in the ERTS- 1 pictures of August 31, 1972 (B in fig. 7).

Due to the advanced stage of dissipation the drawing of this layer is interesting because it looks like " dissected ". The clouds have already cleared above the bottom of the valley giving a tuning fork form to the remaining cloudiness of the small side valleys. That the clearing first begins over the middle of the valleys is not new, this was observed earlier from aircrafts or from mountains but never to such an extent.

This particularity is not restricted to the cloudiness inside the mountains, but also appears when the layer is above the topmost summits. In this case only the major valleys have a discernible influence. A theoretical study will be performed, when enough material will have been collected.

For this wide vertical extension not only the local but also the synoptic circulation must be involved.

The pictures received from ERTS- 1 on September 18, 1972 show a good example (fig. 17). The whole region covered by the picture (the lake of Garda (A) and its surroundings and South Tyrol) is obscured by clouds. Not only a multilayered cloudiness is present but also convective clouds and cloud clusters with spreadings at cirrus level. Active thunder - stroms near the lake of Garda (A) are reported by the ground observers. Except for the cirrus the layered cloudiness is disrupted more or less strongly over all the major valleys. This can be seen best in the MSS 7 (0, 8 - 1 , 1 μ) picture (fig. 17) where the cirrus are the most " transparent ". The camera on board of ESSA 8 being sensitive in shorter

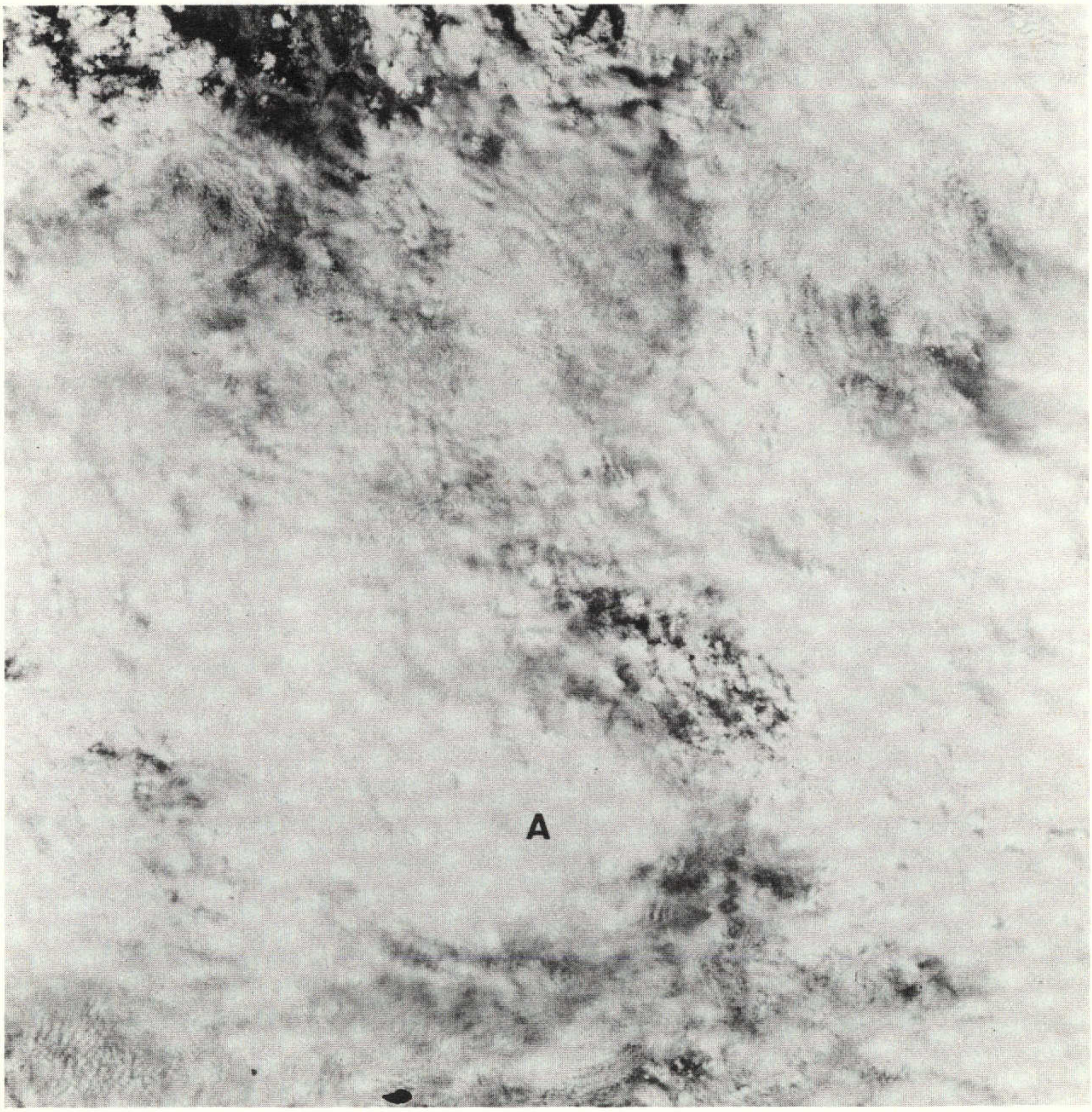

Fig. 17

MSS 7 picture from ERTS-1 on September 18, 1972 at 0938 gmt. (E-1057-09383-7). The elongated breaks or the large interruptions in the layered cloudiness shadowed by the overlying cirrus veils, are to be found above the major valleys and parallel to their direction. Through the larger ones the convective clouds are partly visible. Thunder - stroms are reported by ground observers in the region of the lake of Garda (A). The wide opening in the lower part of the picture is over the Plain of the Po. The cloudless region, nearby at the upper right, lies south of Bozen (South Tyrol, Italy ; B in figure 7) wavelength, the presence of the extensive cirrus shadows this organization (B, fig. 18). On the ESSA - 8 picture the visible breaks seem to be disposed erraticaly, independently of the underlying surface.

Interesting are the several wave pattern which are differently oriented and whose wavel - ength varies from 300 m for the shorter ones to 3 km for the longer ones.

The prevailing synoptic conditions are reproduced in fig. 19 to 21. On the surface, the pressure gradients are slight, a weak depression being located over North Germany, a more complex one covers the western half of the Mediterranean. At 500 mb the isotherm -24° C delineates the colder part of the cold drop. The wind speed is increased along that isotherm. This division persists above as indicated by the wind field of the 300 mb surface. On both levels the low center is south of the center of the corresponding cloud - vortex (C).

The cloudiness as depicted in the ERTS - 1 picture drifts eastward along the colder part of the drop. This limit is indeed shown in the ESSA 8 picture where the clouds do not extend farther north. The cold core cloudiness (C) is of another type. The subtropical jet stream is located more to the south and is not directly associated with this development.

4. Precipitation patterns

" Are precipitation patterns disclosed by the multispectral information received from satellites ?" is one of the questions, the answer to which the meteorologist hopes to receive from ERTS - 1. One of the important applications e. g. will be in the field of locusts control.

As water absorbs the NIR, the contrast between water and land is well marked. For this reason relative small rivers and lakes can easily be detected in the pictures, received from the MSS 7 of ERTS - 1. On the other hand, it has already been mentioned that lower clouds can be distinguished from snow on NIR - pictures because their shadows are much darker than the unilluminated slopes of the mountains or hills, due to the presence of absorbing water droplets. Thus it is to expect that wet ground will appear darker as its surroundings.

On the MSS 7 picture of ERTS - 1 received on August 31, 1972 at 0938 gmt. (fig. 22) a " Black Spot " is portrayed which is not seen on the other MSS pictures of the day (see fig. 7). The corresponding region lies south of the Brenner in South Tyrol (Italy). The darker look does not provide from any geological or ecological features, since on the pictures taken later in the year this region shows no difference at all with the other parts of the country. Thus this appearance is only a momentary one.

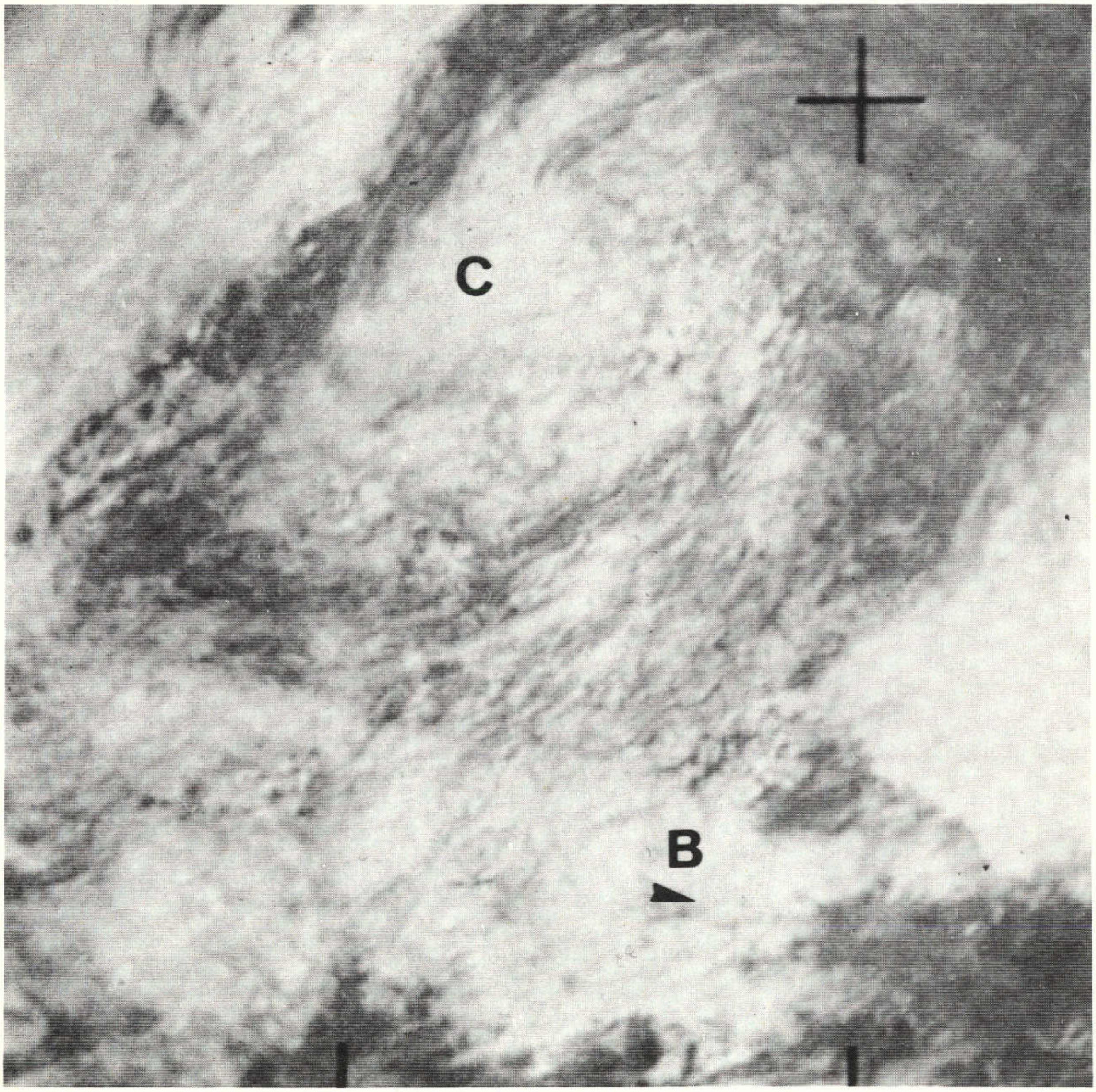

Fig. 18

ESSA 8 picture received on September 18, 1972 at 0951 gmt.
The cold drop lying over Europe is indicated by the decaying cloud vortex (C) . North and south of it, cloudiness in different air masses illustrates the circulation around it. In the wavelength in which the picture is taken the cirrus layers are less transparent than in the NIR (fig. 17). They obscure (B) the underlying cloudiness which is partly seen in the preceding figure. The breaks appear to be erracticly dispersed.

Fig. 19

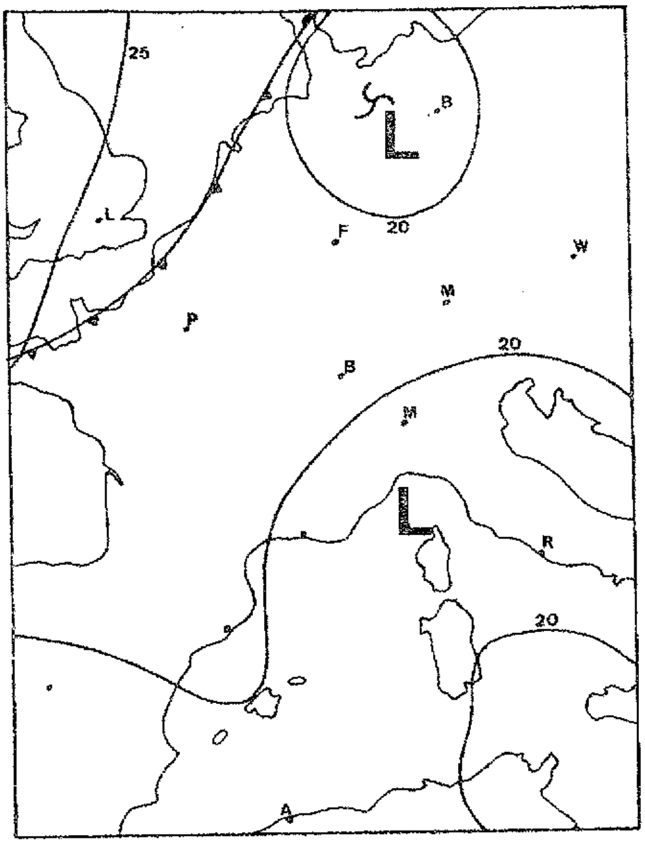

Fig. 20

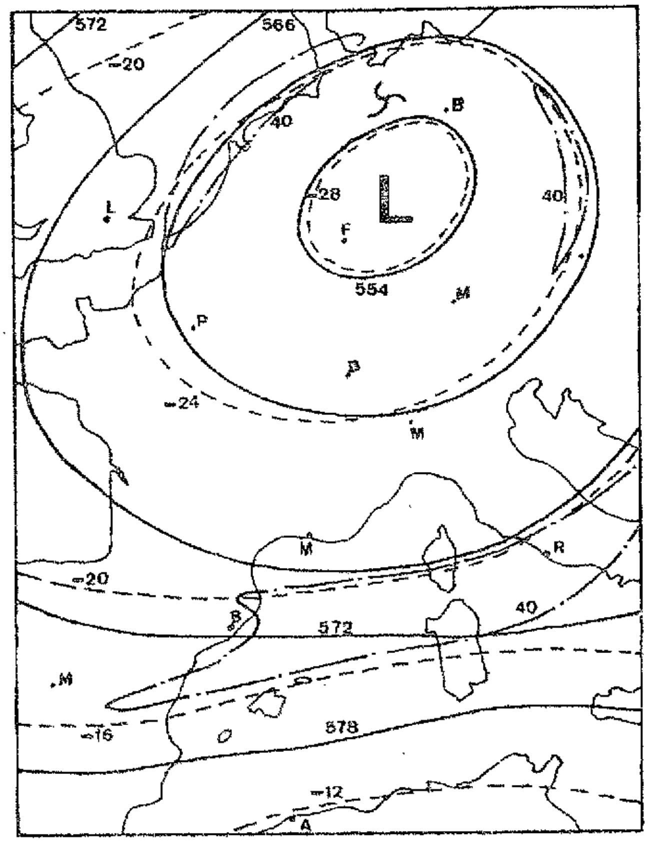

Fig. 21

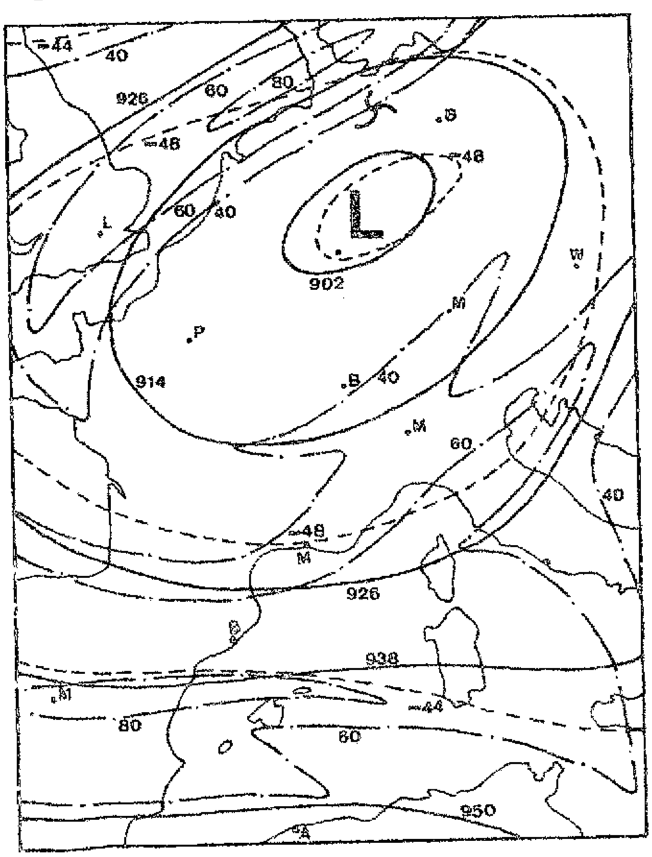

Fig. 19

Surface chart September 18, 1972 at 0930 gmt.
Legend : see fig. 4

Fig. 20

500 mb chart September 18, 1972 at 0930 gmt.
Legend : see fig. 5

Fig. 21

300 mb chart September 18, 1972 at 0930 gmt.

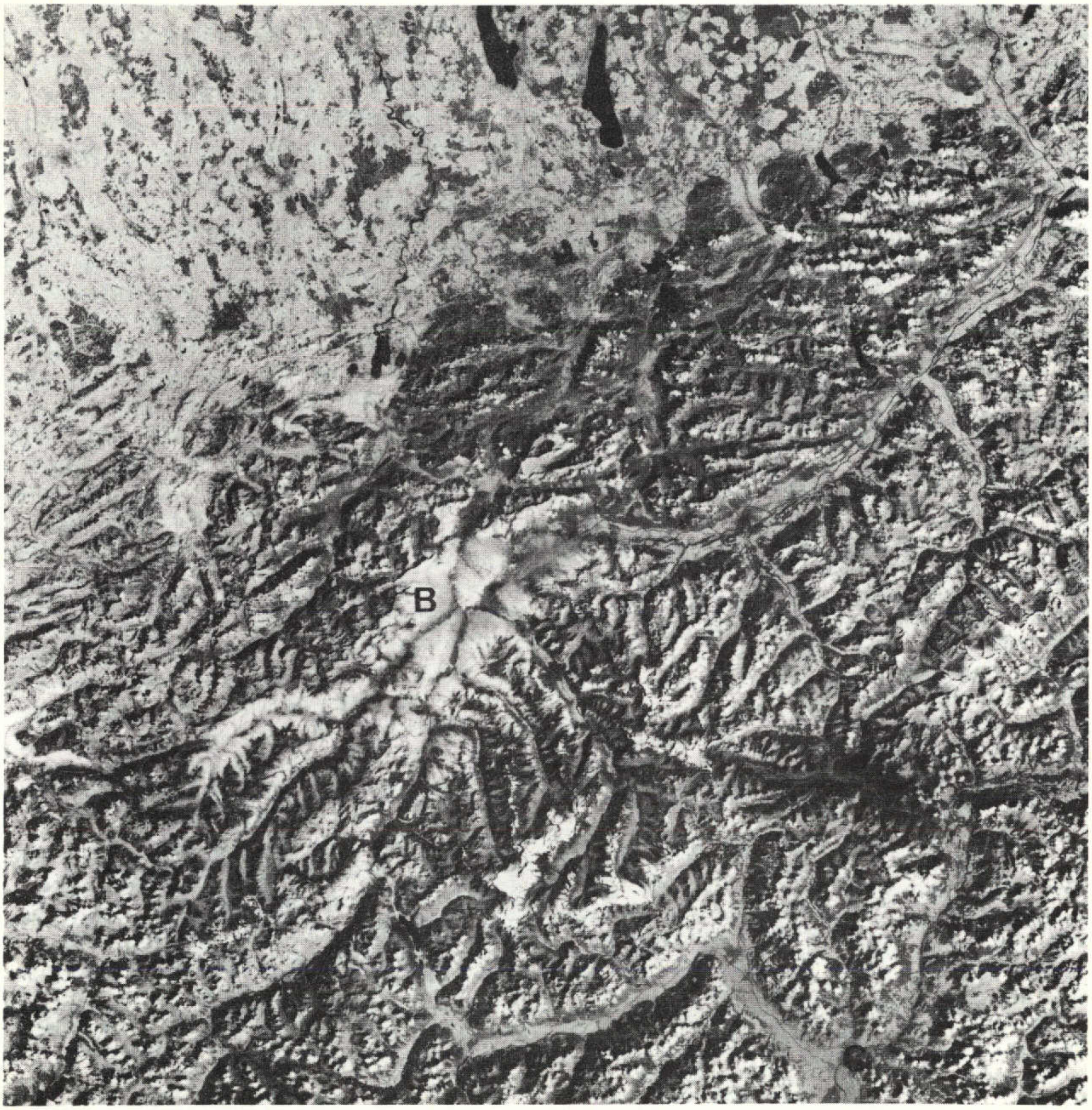

Fig. 22

MSS 7 picture from ERTS - 1 on August 31, 1972 at 0938 gmt. (E - 1039 - 09381 - 7). The ground features of this part of the Alps do not show any essential differences as the ones in other pictures received from ERTS - 1. An exception is seen in the MSS 7 picture received on August 31, 1972 and only on that day. The region south of the Brenner (I) is darker than its surroundings.

As water has a poor reflexion in this wavelength, this may proceed from a moist ground, though the precipitation pattern is not a common one.

Except for the population of cumuli topping the ridges and summits of mountains lower than 2600 msl and the " dissected " stratus layer (fig. 7) which were discussed in the preceding chapters, no clouds are present. Settled weather is viewed that day. The present synoptic situation is reproduced in fig. 10 to 12.

A weak cold front crossed the eastern Alps during the night still lasting over the western part (D, fig. 9). On the north side of the Alps rain failed with the front passage but was never important excepted in some high valleys. No or no measurable precipitations were reported for the south side of the Alps. If the darker spot is due to a wet terrain, the precipitation which caused it is not directly connected with the front passage. It is to be mentioned that no observing stations are located in this area.

The " Black Spot " shows a peculiar characteristic : the whole region appearing dark on the MSS 7 picture is lower than 2000 msl. No higher slopes indeed appear darker as their surroundings. In a sense the " Black Spot " can be considered as the " negative " of a stratus layer similar to that which at the same time covers the region around Landsberg (B, fig. 7). The following hypothesis seems quite valid : in the early morning extended a stratus layer over the region. It cleared just before the passage of the satellite. From the stratus a gentle drizzle fell down, strong enough to moisten the ground surface. As the dissipation occurred shortly before the picture was taken, the sun radiation did not have sufficient time to dry soil, rocks and trees. Another explantion can be the following one : Here too the presence and the dissipation of a stratus layer just before the picture is taken is needed, but the origin of the precipitations is different. With the front passage, scarse thunderstorms occurred also in the southern part of the Alps, but were not observed by the personnel of the observing stations. Stratus layers, at least over the region of the " Black Spot ", have formed subsequently to the thunderstorms. The amount of insolation received during the time before the satellite overflew the region was enough to dry the terrain above the layer, the soils underneath remaining wet.

In fact the Brenner observing station (1400 msl) reported at 0900 gmt a broken layer of stratus with a basis slightly above 600 m/ground. Besides, the dark forests and the grey fields are there all darker than their correspondings in the sorroundings. If the supposition is right, the drizzle fell from the whole layer.

The basis of an inversion was found at 2300 msl on the north side of the Alps. As no dif - ference in the population of cumuli is seen on both sides of the Alps the supposition may be allowed that the top of the precipitating stratus layer was also at 2300 m/msl. The temperature inside the cloud decreases from $+3^{o}$ C at the bottom to $+1^{o}$ C at the top, the freezing level being that day at 3200 msl. The precipitation starts at the top of the stratus in the cloud, the droplets growing downward. Such drizzle or light rain where the cloud temperature remains positive is common in middle latitudes.

5. Conclusion

As stated in the introduction this study is not a scientific one but rather a descriptive interpretation of some of the pictures received from ERTS- 1. The purpose is to illustrate the advantages the meteorologist is able to gain by them, even if the contrasts between the different white levels of the pictures are not optimal.

The satellite's survey consisting in sequences of pictures one time per day at best for an area as Switzerland for three consecutive days each 18 days, the most profit comes from the better interpretation of the pictures received from the operational meteorological satellites by comparing them to the pictures of ERTS-1. Since for the future European meteorological geostaionary satellite METEOSAT the resolution of the pictures will be of the same order as that of the pictures from ESSA 8, the developed methods will be still suitable.

Today such problems are essential not only for forecasting purposes but also for the protection of the environment, as for instance

- recognition of regions of stagnating air under different meteorological conditions,
- penetration of air into the alpine valleys,
- meso- and microstructure of clouds in high mountains range,
- snow growth and snow melting survey

can only very broadly be undertaken. They need a complete survey over the whole region which not only by one, but by several satellites can be obtained. This of course does not exclude ground bounded observation systems.

Acknowledgements

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