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SNOW SURVEY AND VEGETATION GROWTH IN HIGH MOUNTAINS
(SWISS ALPS)

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## SUMMARY OF SIGNIFICANT RESULTS

The investigators have identified the following significant results:

A method for mapping snow over large areas was developped combining the possibilities of a Quantimet (QTM 720) to evaluate the exact density level of the snowcover for each individual image (or a selected section of the photo) with the higher resolution of photographic techniques. The density level established on the monitor by visual control is used as reference for the exposure time of a lithographic film, producing a clear tonal separation of all snow- and ice-covered areas from uncovered land in "black" and "white". The data is projected into special maps 1 : 5oo ooo or 1 : 1oo ooo showing the contour lines and the hydrographic features only. The areal extent of the snow cover may be calculated directly with the QTM 720 or on the map. Bands 4 and 5 provide the most accurate results for mapping snow. Using all four bands a separation of an old melting snow cover from a new one is possible. Regional meteorological studies combining data from ground observation, vertical temperature and humidity profiles, weather maps and meteorological satellite pictures with ERTS-images describe the synoptical evolution of mesoscale and microscale meteorological systems over the Alps.

## 1. INTRODUCTION

The progress report covers the 3-months period from the receipt of the first ERTS-images (October 23rd, 1972) up to January 23rd 1973. During this reporting period the study area has been partly covered in 5 series (9 orbits) but never in total and/or in one cycle.

SCC-images, color composites and magnetic tape were not received during the reporting period. Therefore the problems of mapping vegetation and of digital data processing could not be tackled as yet.

## 2. ACCOMPLISHMENTS AND PROBLEMS ENCOUNTERED

### 2.1 Coordination of the research work

After some preliminary experiments and quick look interpretations the following coordinated research plan was established at a Swiss ERTS-investigators meeting at the Department of Geography, University of Zurich, November 14th, 1972.

Department of Geography, University of Zurich: (Prof.Dr.H.HAEFNER, PI, K. ITTEN, M.A., CI, R. GFELLER, M.A. et al.)

- Coordination in general
- Coordination of picture processing in cooperation with the Department of Photography, Fed.Inst.of Technology, Zurich (Prof.W.F.BERG, Dr.K.SEIDEL)
- Distribution of snow cover over total study area
- Distribution of vegetation growth

- Problems of data processing
- Development of interpretation criteria for snow types (melting snow) and plant communities etc.
- Separation of clouds from snow

Department of Geography, University of Berne: (Prof.B.MESSERLI, CI, M. WINIGER, M.A.)

- Regional studies of snow distribution in detail (Western part of Swiss Alps)
- Distribution of fog

Swiss Institute of Meteorology, Zurich: (Dr.A. PIAGET, CI)

- Study of influencing weather elements (from weather satellite pictures) onto the snow and vegetation distribution
- Interpretation of cloud types

Swiss Federal Institute of Snow and Avalanche Research, Weissfluhjoch-Davos: (Prof.M.DE QUERVAIN, CI, Dr.J.MARTINEC, Dr.FOEHN)

- Variation of temporary snow lines
- Ground observation data on snow depth and quality, avalanches etc.
- Snow melt and water runoff forecasting

Department of Cartography, Fed.Inst.of Technology, Zurich: (Prof.E.SPIESS, CI,)

- Thematic mapping from ERTS-images

## 2.2 Department of Geography, University of Zurich

### 2.2.1 Evaluation of snow distribution in different bands

First experiments showed, that snow has to be treated in two categories:

- Snow in sun exposed position, appearing completely white
- Snow in shadow exposed position, appearing in a light gray to gray tone

A comparison of the "white-areas" in all four MSS bands gave as a result: Band 4 produces the largest "white areas" with a continuous decrease to band 7. Photos immediately after a new snow fall do not show this phenomena. It has to be concluded that we have to distinguish between an "old snow cover" and a "new one", or that there appears to be a possibility to separate this two snow types when using all bands. Future studies are planned to investigate if this phenomenon can be related to such criteria as snow type, snow depth, water content, surface temperature etc. In particular a careful ground investigation of the temperature gradients will be carried out during the overflights.

Judging from the first experiments the best suited band for snow mapping are 4 and 5. The investigations are not advanced enough to draw definite conclusions but the research will be increased along this lines.

### 2.2.2 Determination of snow lines

A new method to determine and map snow-lines was developed by SEIDEL and GFELLER, combining the possibilities of the Quantimet with photographic techniques, using photos of bands 4 and 5. The method is described in chapter 3.

### 2.2.3 Problems of the true snow areas

Problems to estimate the true areal extent of a snow field occur from the great altitudinal differencies between valley bottom and mountain peaks and from the various slope angles. Studies are under progress to eliminate these errors, if possible in connection with the estimation of snow volumes.

### 2.2.4 Estimation of Snow volumes

Snow volumes will be determined by combining areal measurements with results from ground observation for different water-sheds.
The results for the Rhine watershed will be correlated with runoff data, especially with the water gage in Altenrhein (where the Rhine flows into Lake Constance.)

### 2.2.5 Ground truth

Field investigations were carried out during several potential overflights along profile lines across the Alps (Lake of Walenstadt - Tödi - Vorderrheintal - Lukmanierpass - Bleniotal - Biasca and Chur - Hinterrhein - San Bernardino - Biasca), to determine the exact position of the temporary snow line in various locations and exposures etc.

## 2.3 Department of Geography, University of Berne

### 2.3.1 Detailed mapping of snow lines

For detailed regional studies other methods of mapping temporary snow lines were used. After a new snowfall the snow line runs moreor less parallel to the contour lines, but if the snow cover is relatively old and melting there are altitudinal differences in various exposures up to 1000 meters. Linear features of high contrast (as between snow and vegetation) can be detected with a resolution of less than 50 meters, sometimes up to 20 m. Mapping snow lines therefore could be achieved very precisely. Taking into account that the snow line generally represents a small transition zone and an average slope angle of $30^{\circ}$ a vertical accuracy of $\pm$ 60 meters is possible. Experiments with the following mapping methods were undertaken:

- By using all reference points which could be located exactly along the snow line in the photos as well as on the topographic maps, the position of the snow line could be interpolated point by point. If the topography is relatively uniform over larger areas the method is quite accurate and fast.

- Much more time consuming is the same visual interpolation of the snow line in its total extent on topographic maps 1 : 5o ooo and 1 : loo ooo. Near the timber line (a very significant boundary, which is easy to recognize on ERTS-pictures) the errors could be less than $\pm$ 50 meters of vertical distance.

- A transparent contour line map 1 : 3oo ooo was produced from a map 1 : loo ooo with 200 meters contour intervals and copied into the enlarged ERTS-pictures of the same scale, using all well indentifiable reference points. The average position of the snow line as well as its deviations can be determined exactly for different regions and exposures. The influence of the geometric distortions has to be studied carefully when SCC-images are available.

These methods are not suitable for an operational determination of snow lines over large areas but well suited for detailed studies of local variations, e.g. of a small alpine valley.

Image No E - 1059 - 09500 - 4 of September 20th, 1972, was used an an example for testing the last mentioned mapping method. The results obtained were:

| | |
|---|---|
| Haslital | 1650 - 1800 m |
| Gadmental | 1600 - 1700 m |
| Grindelwald | 1700 - 1800 m |
| Lauterbrunnental | 1800 - 1900 m |
| Engelberg | 1550 - 1600 m |
| Goms | 1550 - 1650 m |
| Simplon | 2200 m |
| Bedretto | 1750 - 1850 m |
| Vorderrheintal | 1600 - 1800 m |

There are only little differences in various exposures indicating that the snow cover must be only a few hours or days old. In fact it had snowed less than 24 hours ago down to approx. 1400 meters, and the melting process had just started.

### 2.3.2 Other investigations

Preliminary studies which are investigated further deal with

- Fog distribution over the Swiss Plateau and the correlation of the ERTS-data with ground observation and weather satellite pictures, e.g. the wind system as indicated in the cloud pattern.
- Water pollution: Indications for water pollution are clearly visible in picture E - 1078 - 09553 - 7 of October 9th, 1972, especially in the Lake of Murten. There the effect is caused by the "Burgondy blood sea-weed" (Oscillaria rubescens), which can be detected by a linear texture (white stripes).
- Air pollution: In the same photo a specific air mass of opaquish tone can be recognized in band 5 and 4 between the Lake of Murten, Bienne and Neuchâtel. If this air is polluted by the industries of the area (oil raffinery, cement plants) is still matter of veri-

fication with the local authorities and considering the local meteorological conditions.

## 2.4 Swiss Institute of Meteorology, Zurich

ERTS-images and pictures of operational meteorological satellites (ESSA, NOAA) were used to combine the advantages of high resolution with thoseof daily repetitive coverage to study cloud systems and effects relevant to earth resources. Almost simultaneously taken images (time intervals of a few minutes to less than three quarters of an hour) were available to serve as a starting point for the investigation. This allows a synoptic interpretation of the evolution of mesoscale, even microscale meteorological systems.

So far only a few selected images could be interpreted in comparison with meteorological satellite pictures, weather maps and vertical temperature and humidity profiles, resulting in a description of the organization of cumulus clouds over mountain terrain, generation and decay of cloud pattern (especially cumulus), aspects of cloud laysers just before discipation in or over mountain valleys, the effects of the orography, distribution of fog, the development of fading of convections, night inversions, the determination of cumulus tops and partly of its bottoms, using the shadow projection on the ground etc. More analysis are needed before definite conclusions may be drawn. The following pictures were used:

No E - 1022 - 09442 M of August 14th, 1972
No E - 1039 - 09381 M of August 31st, 1972
No E - 1057 - 09383 M of September 18th, 1972
No E - 1059 - 09493 M of September 20th, 1972

## 2.5 Color Composites

First experiments were successfully conducted in a joint effort by the Department of Photography, Fed.Institute of Technology and the Department of Geography, University of Zurich from the following images:

No E - 1060 - 09552 - 4, 5, 7 of September 21st, 1972
No E - 1076 - 09440 - 4, 5, 7 of October 7th, 1972
No E - 1076 - 09442 - 4, 5, 7 of October 7th, 1972

The transparencies show significant color variations especially in the red tones, indicating

- different land use types in the Po Valley, such as rice, irrigated fields, unirrigated fields, forests etc.
- vertical zonation in the mountains changing from red in the valley bottom to yellow in the slopes above the timber line.

A careful investigation of the color composites has just started.

An additional color composite was produced by the Department of Geophysics, University of Milano (Prof. CASSINIS) of images

No E - 1039 - 09381 - 4, 5, 6 of August 31st, 1972

The color combination allows a distinct separation of all settlements, differences in the snow cover etc.

## 2.6 Aerial Coverage

During the following orbits in December underflights could be arranged with the Swiss Airforce. The weather conditions were ideal over the Alps but unfortunately we do not know as yet if our test area was covered during these orbits.

The technical data of the aerial photographs are:

| | | |
|---|---|---|
| Date | December 18th, 1972 | January 24th, 1973 |
| Time | 11 h | 11 $^{15}$ h |
| Flight lines | Mollis- Biasca - Belp (Berne) | Ilanz - Sion - Thun-Mollis |

| | |
|---|---|
| Film | panchromatic |
| Camera | Oméra 11 x 11 cm |
| Objectives | 44 and 100 mm |
| Photos | vertical: with 44 and 100 mm objective<br>oblique : with 100 mm objective (both sides, about 30°) |
| Flight altitude | 12 000 meters |
| Quality | excellent |

## 3. SIGNIFICANT RESULTS

A method for operational snow mapping over large areas was developped (2.2.1) by Dr.SEIDEL (Dept. of Photography, Fed.Inst.of Technology, Zurich) and R. GFELLER, M.A. (Dept, of Geography, University of Zurich).

The problem is to determine the critical tone level above which all gray tones represent snow or ice in a cloudfree image and the darker ones the snow- and icefree land. The critical tone level varies from image to image according to illumination, exposure, processing techniques etc. and has to be determined individually. For this the Quantimet 720 (QTM 720) is used. The instrument allows an electronical tone separation in a selected section of an image and additional measurements of the areal extent of the discriminated density levels.

The image is reproduced with a high resolution TV-camera (720 lines) on a monitor. Simultaneously 500 000 picture points can be classified by a detector device according to its graytone level and projected on the monitor, too. All picture points with a graytone below the critical tone level appear"white", the ones above in "black" (or vice versa). In addition all "white" points are counted and registered on a digital output. The critical tone level between "white" and "black" can be varied continuously with a potentiometer and correlated exactly with the tone level of the snow line in the image on the screen. The 720 lines resolution of the QTM 720 are not sufficient for an accurate analysis of a total ERTS-image. For an exact analysis the image is devided into four equal sections or even smaller areas.

In a first phase the critical graytone level is adjusted with the potentiometer and with visual control on the monitor in such a way that the boundary of the selected object (e.g. snow and ice) corresponds with the critical tone level of the picture points and therefore appears discriminated.

In the second phase the position of the calibrated potentiometer is read off, indicating the corresponding density level. This value is used as reference for the exposure time for a photographic copying process of the analysed image. Using a high resolution lithographic film a complete tonal separation of the total ERTS-image as partially simulated in the QTM 720 is achieved photographically in "black" and "white".

In the third phase interfering clouds, shadows etc. may be eliminated by masquing techniques and repeated reproduction in the QTM 720 as well as analysis and measurements of individual regions, watersheds etc.

Snow and ice in different exposures (sun exposed or in the shadow) may be treated in two steps.

In the <u>fourth phase</u> the different photographic tone separations of all different 4 MSS bands are compared and processed further additively or subtractively.

The <u>fifth phase</u> consists in the projection of the tonal separation on the lithographic film into a topographic map. For this special maps 1 : 5oo ooo or 1 : 1oo oo of the Swiss Alps, showing the contour lines and the hydrographic features only will be used. SCC-images will be of great advantage for this purpose.
So far the following images were used for testing the method:

No E - 1076 - 09442 - M of October 7th, 1972.

The first experiments indicate that the snow covered area when measured in all four bands separately differs in its extent (band 4 gives the largest, band 7 the smallest area) and that the pictorial aspects between an older, melting snow cover are rather different from a newly fallen snow. Bands 4 and 5 provide the most accurate results for snow mapping. Using all four bands a separation of the two types of snow cover is possible. For a better understanding of the snow distribution regional meteorological studies before and during the overflights are essential, combining the data from ground observation, vertical temperature and humidity profiles, weather maps and meteorological satellite pictures with ERTS-images. The dynamics of mesoscale or microscale meteorological systems over the Alps in a synoptic evolution could be described for several ERTS-images (2.4)

## 4. PUBLICATIONS

No articles have been published as yet but three manuscripts were completed or are under progress, summarizing the findings as outlined in this progress report. They will be published as fast as possible.

## 5. ERTS IMAGE DESCRIPTOR FORM

A first form was transfered to NASA on November 25th 1972 for the ERTS-images from August 31st, to October 9th, 1972. The second form for the time period up to October 24th 1972 will be completed with this report.

## 6. OVERVIEW OF INVESTIGATION

The experiments by the different investigators are progressing on schedule and without major problems. In addition to the proposal a collaboration with the Department of Photography, Swiss Federal Institute of Technology, Zurich, (Prof.Dr.W.F.BERG, Head, and Dr.K.SEIDEL, Research Associate) could be established enabling us to make use of its laboratories and other facilities and to enlarge our studies in data processing.

A serious handicap so far is that the test site was never covered in one serie as yet and that it is not possible to learn the date when data is taken over the test site prior to or immediately after the overflight. Therefore the timing of the field work and the arrangement of underflights is rather difficult. If some kind of communication regarding the flight schedule could be arranged, this could help our project tremendously.

H. Haefner

Prof.Dr. H. Haefner