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METEOR AND REMOTE SENSING SATELLITES

(A Collection of Articles)

J. Cruette, M. Bled-Charreton, H. Augustin and R. Lasbleiz

Translation of "Une télédétection sans nuage", "Un fichier de la nébulosité sur la France", Les Cahiers de l'OPIT, Dossier No. 2, Winter 1979/80, pp. 26 - 30

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16. Abstract

This document consists of five short articles, all of which discuss satellite sensing of cloud cover.

A detailed atlas of cloud cover of France will be published Early in 1981.

The use of such data is considered, as is the physics of clouds

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CLOUDLESS REMOTE SENSING

Une télédétection sans nuage

M. Bied-Charreton

Principal Research Scientist, ORSTOM

Assistant Director, OPIT

Users of Landsat data all know that cloud cover is the main restriction on this observation system. This is because these satellites do not pick up radiation reflected by objects on the ground when there is cloud cover, and the images they record are thus unusable for remote sensing of earth resources. 27*

Since 1977 OPIT has been concerned with the quality of images acquired by the Fucino receiving station, and has had the idea of using daily recordings from meteorological satellites to mitigate the deficiencies of the former system of information on existence of quality images. Consequently, we have been led to ask a question fundamental to the future of remote sensing in France: what is the probability of obtaining, at a given moment, a useful image of a region or a scene of French territory from the remote-sensing satellites which are and will be regularly orbiting above our country?

A subsidiary question could be the following: knowing the frequency of satellite passage, is there an optimal launch date -- that is, one which would allow a maximum number of useful images to be obtained?

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*Numbers in the margin indicate pagination in the foreign text.

These two questions have led OPIT to encourage systemmatic processing of cloud cover in the daily pictures from meteorological satellites when these satellites pass overhead (between 9:00 and 11:30), compatible with the times of Landsat passages.

This processing allows us to have a file of cloud cover over France for the years 1969 to 1978. The method of setting up the file and the problems of authenticating it are the subject of the article by H. Augustin and R. Lasbleiz on the following page.

To authenticate and also to exploit these data for possible utilizations, some programs have been created and others are being defined. The first programs have been tested on the first three years processed (see box).

The information available in this way is a useful supplement to the catalog of Landsat data normally used in France, except that all the good images have not been indexed systematically. Additional quick-looks can thus be requested for the images not in the catalog which might have cloud-free zones worth studying.

This information could have another fairly immediate application. It can be asked whether it is possible to predict the cloud cover for day j + n, knowing it for day j, over a square degree or over several square degrees. It was for this reason that the CNES, the National Center for Space Research, is interested in this file for simulating use of Spot. One of the trump cards of the French earth-observation satellite under construction is the possibility of side viewing. As a consequence, if clouds interfere with observation of the chosen zone on day j when Spot is orbiting over it, what are the chances of having a useful image on days j + 5, j + 10, j + 11, j + 15, j + 16, j + 21, which are access possibilities for side views within the 26-day cycle of Spot. The answer to this question is the subject of collaboration between CNES and OPIT.

Other applications are being developed.

By combining cloud cover with temperature, wind speed, and relative humidity, Prof. J. Mounier (Note 1) has shown that the idea of "good weather" can be approached objectively. Combined with these other data, our file thus allows analysis of "good weather" over space and time. The value for tourism, leisure management, and weather is obvious.

This file can also give a precise idea of regions which have a minimum of cloud cover throughout the year in one objective of solar "vein" research, to the extent that information acquired in the morning can be validated statistically during the day.

The ten years of the file have been supplemented by partial processing of 1979 data for an extremely definite objective: the Landsat 3 MSS radiometer was interrupted from April to November 1979 (cf. OPIT Cahiers No. 1), although the RBV video camera was functioning normally. Now, the equipment at the receiving station could give no indication of cloud cover from the RBV (2) recordings in the absence of the MSS data which serve to put together the quick-looks. Under a cooperation agreement, OPIT has given the European Space Agency information which has allowed Earthnet to begin manufacture of standard RBV tapes. Thanks to this cooperation, OPIT has available pictures of the regions involved in its planned experiments, and will give the agency the result of its comparisons between these new data and the usual MSS ones.

Note 1 - Of the Institute for Physical Geography of the University of Rennes.

The first RBV image available shows the Marseille region. It was chosen because of the major interest of planners and urbanists in improved spatial resolution for studying urban areas; this topic is now the subject of an OPIT experiment on Marseille-Arles. Other applications are certainly possible, and we await your suggestions.

BOX /26

First treatments tested

76-77-78

A program for "extracting" the cloud cover allows the user access to "clouds" information for a region and at dates within the 10 years processed which interest him.

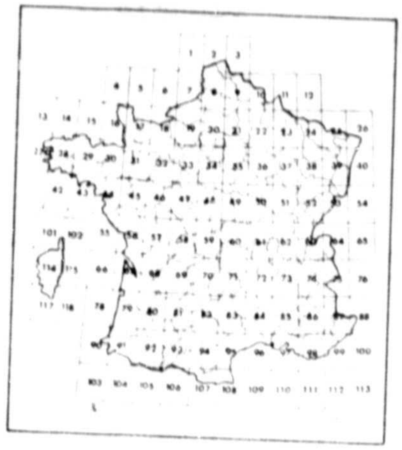
Simple programs give the percentage of days having such and such cloud cover, by square degree and by season. Three types of distribution are thus found, whatever the season: the first type has a peak on the high cloud-cover side (7 and 8), and is met in winter, except along the Mediterranean. The second has a single peak on the low cloud-cover side (0 and 1) and is met particularly along the Mediterranean and over all of France in Spring and during the summer of 1976. The third shows two peaks, one at each end of the cloud-cover scale. This is the most frequent type, except in the Mediterranean region. There are tables for comparing the curves obtained over the 118 square degrees for each season of the three years studied.

A first correlation program is intended to look for groups of square degrees which have a certain uniformity of cloud-cover throughout a season, and to see how the cloud covers over different square degrees are related on the same day--which amounts to looking for remote sensing of periods of time with the lowest possible cloud-cover for a given square degree, and also looking for the large groupings of square degrees exposed on a given day.

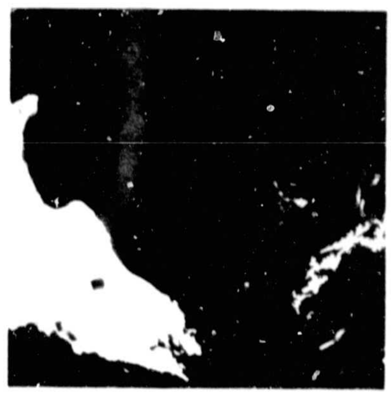
Over the three years studied, the continuous character of the cloud cover has been provisionally detected--that is, the cloudiness of one square degree is similar to that of its immediate neighbors in longitude and latitude; it seems to be hard to show groupings uniform and stable over time except in the Mediterranean region.

One can also go on to additional correlations in space and time by creating blocks of square degrees to study their state of cloud cover over time and space.

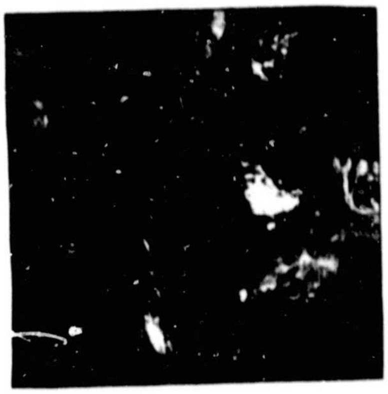
Figures



Top right, page 27 -- Map of 118 square degrees.

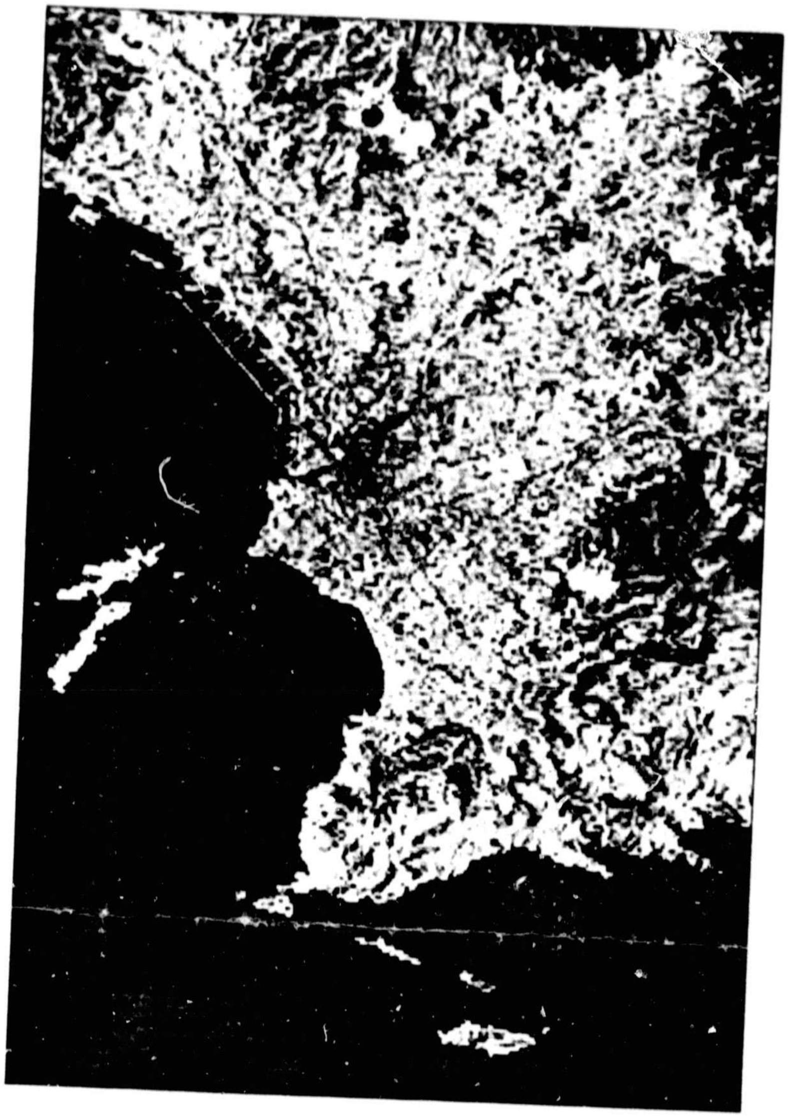


Center -- NOAA 4 images for 8/6/75 at 09:30 UT.



Bottom, page 27 -- Above - the "visible" channel: fog and Atlantic stratus clouds moving into South of France. The infra-red channel below allows them to be identified for certain: warm tips at low altitude; note the low contrast between sea and cloud. The cirrus clouds which extend from the Rhone Valley to Denmark in the IR image are practically non-existent in the visible, which, however, does show the Alpine snows distinctly.

Top, page 30 -- Cloud cover on track 211, 29/07/79.



Bottom, page 30 -- Colored composite, at the same scale, of channels 4, 5, and 7 of the MSS radiometer, for the same part of this scene 211-30, 20/06/76, over the TRIAS system. SEMIO reconstruction by IGN.

A FILE OF CLOUD COVER OVER FRANCE

Un fichier de la nébulosité sur la France

Henri Augustin and Raoul Lasbleiz

Henri Augustin
Engineer-in-chief for Meterology Assistant to the Director of the Meterological Research and Development Establishment

Raoul Lasbleiz
Engineer-in-chief for Meterology Head, Space Meterology Center Lannion

The need felt by OPIT for statistics on visibility of the ground from low-orbit satellites was the beginning of an applied research effort which brought together the Space Meteorology Center (CMS) at Lannion, the Meteorological Research and Development Establishment (EERM), and the Institute for Physical Geography of the University of Rennes (IGP) in a more general perspective aimed at setting up an Atlas of Cloud Covers of France. /28*

The members of the multidisciplinary team which was set up have divided the tasks as a function of the available techniques and of the particular scientific interests of the organization which sponsor them.

- OPIT, promotor of the project, is in charge of data acquisition and processing for remote-sensing applications, and also for various planning needs.

*Numbers in margin indicate pagination in the foreign text.

- The Lannion Space Meteorology Center has obtained 10 years of archives consisting of pictures transmitted daily by meteorological satellites. It is also participating in data acquisition, is providing validation for them, and is contributing to their interpretation in terms of dynamic climatology.

- The University of Rennes (IGP) is taking part in exploitation of the validated data, especially for regional climatology, and will be responsible for cartographic presentation of the results.

The cooperative work should result in publication of a detailed atlas early in 1981.

THE DATA

Meteorological satellite pictures from 1 January 1969 to 31 December 1978 have been received at Lannion and are stored there as black-and-white photographs. Several satellites of different technologies and performances, but with similar orbits, contributed to formation of this file:

1/01/69 to 31/12/70 = ESSA 8
1/01/71 to 31/10/71 = ESSA 8 + NOAA 1
1/11/72 to 31/12/78 = NOAA 2/3/4/5

Image characteristics vary with the satellites, and show gradual improvement in product quality, due both to improved geometric and radiometric resolution and to improved ground-based display equipment.

Table I shows the principal properties of the systems in action during this period.

The daily observations thus constitute a record of 242 characters (2 x 118 + 6 characters for the date); the complete decade represents 3652 records.

The file, available on CCT tape (9-track, 1600 bpi) is a matrix of 118 columns and 3652 lines.

An associated matrix allows reconstruction of the real geometry of the 118 square degrees.

SIGNIFICANCE OF THE MEASUREMENTS

Changes in satellite technology, geometry of photography, or image interpretation affect the value of the data received.

It is necessary to examine the main limiting factors to be able to define procedures for validating the file, to choose applicable statistical treatments, and to guide later interpretation of the results.

Geometric resolution: Elements with dimensions below the resolution threshhold are not detected. For the period studied, the ground resolution of the sensors used ranged from 0.9 to 3.7 km in the visible part of the spectrum.

One must thus expect an underestimate of the cloud cover for cumulus-humilis clouds (Note 1) (weak convection).

Geometry of photography (see Box "Estimation of cloud cover): The perspectives of the satellite and an observer on the ground are very different. It follows that there is a complication in comparing data obtained by the two systems.

Note 1 - Small fair-weather cumulus whose base area is typically 1 ha.

The ground observer has excellent spatial resolution, but has a tendency to overestimate cloud cover from low-altitude pictures, to the extent that the report is representative of a given area. Under the same conditions it can be expected that the sightings of a ground observer for clouds located near the horizon will lead to highly erroneous results.

Use of infra-red: The appearance in late 1972 of sensors operating in the thermal infra-red simultaneously with photography in the visible channel has given invaluable aid to data interpretation, especially for discriminating clouds by altitude (identification of fog and stratus, clouds of great vertical extent, etc.), or separation of snow on the ground from clouds.

TABLE I

Satellites Used to Measure Cloud Cover

Satellite Telemeter	Camera System	Visible Channel	IR Channel	VIS Resolution	IR Resolution	Overall Signal-to Noise Ratio	Dynamic Range
		µm	µm	km	km	dB	quanta
ESSA 8 APT	Vidicon	0.5-0.7	/	3.5	/	32	40
NOAA 1 APT/SR	Vidicon Radio-meter	0.5-0.7	10.5-12.5	3.5	7.4	40	100
NOAA2-5 SR	Radio-meter	0.55-0.7	10.5-12.5	3.7	7.4	40	100
VHRR	Radio-	0.55-0.7	10.5-12.5	0.9	0.9	44	158

APT: Automatic picture transmission
SR: Scanning radiometer
VHRR: Very high resolution radiometer

CLOUDS AND THEIR PHYSICS

Cloud physics depends on microphysics. Clouds are "aerosols" of water droplets or ice particles which, because of their very small gravitational acceleration (Stokes' Law) cannot separate from the gaseous medium in which they find themselves dispersed.

The characteristic size here is about ten micrometres, with a corresponding mass of liquid water of the order of a few tenths of a gram per cubic metre. The number of droplets associated with these low values is large, however: typically 100 to 500 droplets per cm^3.

Formation of the droplets or ice crystals takes place around micro-particles (from 0.001 to a few micrometres) contained in the air, which are hygroscopic or isocrystalline with ice. They are called "condensation nuclei" for water or "deposition nuclei" for ice.

These particles are very numerous in the lower layers of the atmosphere, but may be lacking in the upper layers. This lack is associated with "supersaturation" phenomena, the most common of which is aircraft "contrails", sometimes visible in Landsat images: the engine exhaust gases supply the missing nuclei.

The clouds have an effect on radiation. The cloud droplets scatter all visible wavelengths of the solar spectrum equally (white Mie scattering), unlike the clear sky, where the molecules give preference to the blue in the solar spectrum (Rayleigh scattering). This scattering, absorption, and re-emission by clouds also extends into the infra-red, invisible to the human eye.

Thermodynamics appears in the phenomena of water-vapor saturation, close to which nucleation becomes possible.

The partial pressure of water vapor increases because of evaporation from the surface, or even by mixing with moister layers of the atmosphere. It becomes saturated by cooling. This cooling can be caused by a drop in pressure (or "expansion") or by an uncompensated emission of radiation, or even by contact with cold ground or mixing with cold air.

The process of expansion by ascent is the most common one.

The simplest model of a cloud corresponds to ascent of the air along a slope perpendicular to the wind.

This model of the expansion of uniform air, with no exchange of heat or matter with the surface or with nearby atmospheric layers, is called "adiabatic." The clouds created by slopes are called "orographic" or "relief" clouds.

Fluid dynamics and mechanics impose their effects on those we have just described.

In our simplified model of a slope cloud, above, they control the wind which produces the ascent. But it also turns out that the effect of a slope may be created by the thrust of a mass of warm air over a mass of cold air.

In addition, with or without wind, heating of the ground by the sun forms bubbles of hot, moist air, lighter than the surrounding air, which rise in it. These movements, called "convection," are accompanied by near-adiabatic expansion, and create "convective" clouds.

These ascents, associated with processes of radiation, mixing, contact, and finally atmospheric turbulence, give rise to clouds of various forms, whose development is often comparable to that of a living being. One can thus describe their birth, growth, maturity, and disappearance, with or without precipitation of rain or snow. HA

ESTIMATION OF CLOUD COVER

Whether from the ground or from satellite pictures, estimation of the fraction of the sky covered by clouds, or "cloud cover," cannot be done automatically, and requires involvement of a specialist.

Traditionally, this estimation is made by eights of the vault of the sky, or "octas." An entirely covered sky thus corresponds to a cover of 8 octas, and a clear sky to 0 octas.

On the ground, an experienced observer will succeed in estimating both partial cover of the main cloud layers - low, middle, high - and total cloud cover from all clouds present at the time of observation, with astonishing accuracy.

Geometry can give a rough idea of the problems posed by comparison of this "ground" cover with "satellite" cover.

The sketch below, showing clouds which do not extend very far vertically, shows that the ground observation is a conical projection onto the vault of the sky, while the satellite observation corresponds to a cylindrical projection.

The area observed by both has a radius R on the ground, typically about twenty kilometres or so, representing for the observer, if one neglects the depression of the horizon, an identical radius of the vault of the sky.

Calculations show that the ground cover N_o is generally higher than the satellite cover N_s. This is only a first approximation, however, which neglects the effects of visibility and cloud movement.

Visibility is almost always decreased near the horizon, which complicates the shape of the sky vault.

Cloud movements, if they are rapid and if the observer takes enough time to estimate an average value, lead to a result which is closer to that for satellite observation.

The study described here ought to allow statistical estimation of these two effects. In addition, the file will supply information for those parts of the country which do not have observing stations. The area covered by the 150 existing stations is only about a third of the country.

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