CLOUD CLIMATOLOGY FROM SATELLITES

E. Raschke
Universität Köln, F.R. Germany

1. Introduction

Clouds modify the radiation budget of the earth-atmosphere system in various ways, by

- absorption and reflection of solar radiation,
- absorption and emission of heat radiation,
- diabatic heating or (cooling) of the atmosphere by the heat of condensation (evaporation)
- transport of water vapour and precipitation.

Their generation and dissipation is closely linked to atmospheric circulation and heat exchange processes between the atmosphere and the earth's surface. Therefore, their continuous observation and accurate monitoring provides a fundamental data base for the explanation of the physics of the general circulation - and climate.

All ground-based observations which are routinely made from weather stations and commercial ships are primarily done to describe the state of weather. They are based on the well-known classification schemes. Airliners report clouds and cloud fields to support the flight activities of their fellows. All present climatological investigations of cloudiness and of associated physical properties of effects in the radiation fields suffer under basic sampling errors:

- Observations from ground do not allow registrations of upper level cloudiness, when low level clouds cover totally the field of view of the observer.
- The classical classification schemes allow only crude estimates of properties affecting the atmospheric energy budget.
- The spatial and temporal sampling of such observations is too sparse for unbiased quantitative investigations of the climate.

During the recent years these "classical" eyeball observations, whose systematic analyses in energetic terms have been tried in a large variety of earlier investigations (e.g. Budyko, 1963; Landsberg, 1945; London, 1957; Hastenrath, 1980), have been supported by remote sensing procedures. Radar networks report routinely on convective and precipitating cloud fields, but also on clouds with sufficiently large droplets. Satellites provide since more than 15 years daily or twice informations on the cloud fields over the entire globe.

However little use has been made to extract from these data informations on the temporal and spatial distribution of cloud fields. Malberg's (1974) analyses over Europe and Sadler's (1969) atlases for the tropical and subtropical belts are entirely based on subjecitve analyses of imagery. Miller and Feddes (1971) tried a visual cloud-climatology averaging digital satellite imagery despite of inherent calibration and gray-scale problems. Earlier work has been summarized by Winston (1969).

A more comprehensive description of the present studies of cloud archives has been given by R. Jenne (1980).

2. Satellite Cloud Climatology - Problems

2.1 General

Our present interest to understand and model the climate calls also for a very comprehensive statistics of the temporal and spatial variations of cloud fields - or of their inherent physical properties. Ideally, this could be accomplished only by combinations of data from various sources - and a normalization of them to well defined physical properties. For a variety of purposes, e.g. determination radiation flux divergences within various atmospheric layers, one needs to determine

- fractional coverage,
- the geometry of cloud fields (heights of cloud beases and tops, multiple layers, deep convection),
- the content (budget?) of water in its various phases,
- the radiative transfer properties (e.g.: reflectance and transmittance for solar radiation, emittance for heat radiation).

However non of the presently available observational methods or tools allow by themselves or proper combination with others a world-wide statistics of the cloud properties cited above. Therefore methods are sought to parametrize the interacting cloud variables (such as liquid water content, opitcal properties, etc.) in terms of quantities which are most easily obtainable with global observing systems. The only complete global coverage can be obtained with satellites.

2.2 Satellite data

The present day polar orbiting satellites provide almost four times a day imagery of the earth measured in up to four different spectral intervals (e.g. AVHRR) of reflected solar and emitted terrestrial radiation. The spatial resolution is of the order of 1 to 4 km^2 per picture element. Over almost 70 percent of the earth's surface cloud fields are observed from geostationary altitude up to 48 times a day within at least two spectral intervals and with a spatial resolution ranging between 4 and 8 km^2. Furthermore informations on the cloud cover, height and possibly the ice-water content can be derived (estimated?) from the data of sounders for temperature and humidity. These are measurements in the infrared and microwave portions of the spectrum with a coarser spatial resolution ranging from 6 to 60 km^2 per picture element. Thus they provide only rather crude data over such areas with finer cloud elements. Here and elsewhere basic research is still necessary to consider the effect of finite cloud elements on the radiative transfer properties of larger cloud ensembles.

Future satellite systems to be flown in the next decade will certainly have laser-ranging instrumentation on board which give much more accurate data on cloud-top heights and vertical thickness of optically thin clouds - such as cirrus - than the present passive measurements.

2.3 Inversion and data handling problems

Most passive - and future active - satellite-borne measurements over the earth are not yet planned to derive the cloud parameters mentioned above. The imagery is primarily made to obtain informations on the location and structure of major cloud-fields and their dynamics. It is obvious to make best use of these multispectral informations - including also stereo capabilities (wherever possible: overlapping portions of geosynchronous data; overlapping of polar orbiting portions of geosynchronous data; overlapping of polar orbiting satellite paths at high latitudes) to derive via parametrized inversion techniques the cloud quantities mentioned above.

These techniques may require also a set of additional field experiments for their verification. A-priori-knowledge needs to be employed on the surface albedo and temperature and also on atmospheric aerosols.

However, there is a serious problem of handling the instant and archival data sets. Since there could not yet be developed an algorithmus which would be accepted for worldwide use by the different space agencies, one needs the develope methods to store the enormous amount of data most economically and without loss of information.
Several techniques have been studied for these purposes. They are primarily based on

- selective sampling of picture elements at larger intervals in space (e.g. every tenth and time)
- one - or multidimensional histograms or cluster analyses of grid areas
- frequency analyses based on Fourier or more complex orthogonal functional representations.

Only little use has yet been made in meteorology of known pappern recognition techniques.

3. Conclusive Remarks

It is too early to present now results on a cloud climatology from satellites which is entirely based on well defined physical quantities. The need of such statistical informations either for diagnostics of the energetics of the earth-atmosphere system or for control of numerical simulation experiments, and the vast amount of satellite data calls for urgent developments of methods, which are well enough defined to analyse the presently available measurements. In addition ways must be sought the measure in future satellite systems the required cloud characteristics directly.

4. References

Budyko, M.I.,1963: Atlas of the Heat Balance of the Earth. Kartfabrika Gosgeoltehizdata, Leningrad, 75 pp.

Hastenrath, S.,1980: Heat Budget of Tropical Ocean and Atmosphere. J. Phys. Ocean., 10, 159-170.

Landsberg, H., 1945: Climatology. In: Handbook of Meteorology Mc-Graw-Hill, New York, 928-997.

London, J., 1957: A Study of Atmospheric Heat Balance. New York Univ., Final Report No.131, Contract AF 49 (122)- 165.

Malberg, H., 1973: Mittlere jahreszeitliche Bewölkungsverteilung und Häufigkeit von heiterem, wolkigem und stark bewölktem Wetter im europäisch-atlantischen Bereich nach Satellitenaufnahmen. Meteorol. Rundschau, 187-192.

Miller, D.B. and R.G. Feddes, 1971: Clobal Atlas of Relative Cloud Cover 1976 - 1970. US Dept. of Commerce an US Air Force, Washington DC, 237 pp.

Mohr, T., 1971: Ein Vergleich von Satelliten - mit Bodenbeobachtungen - Die Bedeckungsverhältnisse im Gebiet Nordatlantik/Europa. Meteorol. Rundschau, 112-120

Sadler, J.C., 1969: Average Cloudiness in the Tropics from Satellite Observations. Honolulu East-West Center Press.

Winston, J.S., 1969: Global Distribution of Cloudiness and Radiation as Measured from Weather Satellites. In: "World Survey of Climatol., Vol. 4" (ed. Res), Elsevier, 247-280.