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THE INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT — PRELIMINARY RESULTS AND ITS POTENTIAL ASPECTS

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ABSTRACT

The ISCCP (International Satellite Cloud Climatology Project) began its operational data collection phase on 1 July 1983. Considerable research efforts ensured that the compression of basic satellite data did not reduce the information content on cloudiness. At present an operational algorithm has been developed and tested with data from several months, where as a target for very intensive use by the research community the data from April 1985 are selected. These concur with a simultaneous data set of the ERBE.

Special efforts are now underway to map also clouds over both polar regions and may lead to the development of new specific algorithms. Several preliminary results are presented in this paper.

INTRODUCTION

It has always been a dream of the atmospheric scientists and early astronomers to map the earth's cloud fields, since they are an expression of atmospheric dynamics and heat transports; but they also affect those. In more modern terms: clouds - i.e. clusters of atmospheric water in its liquid or solid thermodynamic phase - are believed to be one of the most important constituents of the earth's atmosphere by their manyfold interactions with the atmospheric dynamics through

- transfer of solar and terrestrial radiation
- latent heat release or consumption during phase changes
- release of heat to the surface through precipitation

These interact in various ways with the dynamic processes in the climate system. Thus for a complete understanding of all processes occuring within the climate system, one must know the cloud fields with their spatial and temporal occurance - and moreover with those properties causing feedbacks on the above-mentioned heat fluxes. These properties must also occur in the results of numerical modelling of the present climate - since several sensivity studies have shown the overall controlling effect of clouds and radiation onto dynamical developments.

Therefore, an international project has been started to extract such informations on the cloud fields from the already available imaging data measured daily from operational meteorologial satellites. These are at present the only data sources covering the globe with adequate sampling intervals in space and time, but they "see" clouds only from above.

THE OBJECTIVES OF ISCCP

The objectives of the ISCCP have clearly been defined to

- determine a cloud statistics over the entire earth, and
- encourage research for better understanding of cloud in the climate system.

Quantities to be derived from satellite data, and from other correlative measurements if necessary, are in particular

- the total fractional coverage
- the fractional coverage of low, middle and high clouds
- mean radiances related to cloud top heights, and
- values of radiative transfer characteristics of cloud fields (e.g. transmittance or optical thickness for solar radiation).

To insure that these results can be corrected, once new and more accurate algorithms are developed, the original data sets are stored in an International Central Archive . These basic data are the imaging measurements of at least one polar orbiting satellite of the NOAA series (all data of the Advanced Very High Resolution Radiometer, sampled to a spacing of about 30 km) and of up to five geostationary satellites . The latter are also sampled to maintain a spacing of 30-40 km and time resolution of 3 hours. More details of the data handling system are presented elsewhere (Schiffer and Rossow, 1983; WMO-ICSU, 1985).

Statistical quantities of the above-mentioned results will be provided on a monthly basis with a spatial resolution of 2.5°x2.5° longitude and latitude, where also a mean diurnal variation will be estimated with a time resolution of 3 hours.

THE ISCCP - DATA ANALYSIS ALGORITHM

For extraction of cloud data from digital imaging data certain characteristic signatures have to be found, which provide reliable means to distinguish the cloud signal from ground and clear sky signals and possibly also clouds at different altitudes. In principle these could be obtained from spectral reflection and emission properties, which have been investigated during the past years with various experiments and theoretical means. Thus, as more simultaneous measurements at different wavelengths are available, as more reliable cloud identification would be available from them. Various retrieval algorithms have been investigated in the past years; which range from sophisticated pattern recognition techniques (e.g. Wu et al., 1985), to simpler threshold techniques (e.g. Simmer, 1984). The latter are usually used with some statistical means such as cluster analyses or maximum likelihood estimators (e.g. Bolle, 1984). Rossow et al. (1985) provided a summary of many other algorithms, which had been tested during the preparatory phase for the ISCCP.

Since the imaging data of the operational meteorological satellite were primarily designed to provide the operational meteorologist with adequate means to identify weather patterns as manifested in the structures and variations of cloud fields, these measurements are at present done from most geostationary satellites in only two spectral ranges: in the solar visible portion of the spectrum and the infrared "window" region. Only METEOSAT provides a routine imaging capability at other wavelengths, apart from the multispectral radiometer (VAS) onboard NOAA satellites. Therefore the present operational algorithm can rely only upon these two spectral intervals which are common to all satellites providing data for the purposes of ISCCP.

Several research groups joined their efforts to find the best possible operational cloud algorithm (Rossow et al., 1985). The final version as now applied to the available ISCCP data sets of both polar orbiting and geostationary satellites is outlined in Fig. 1 as a flow diagram. Besides the spectral reflection and emission characteristics of clouds, as often clearly seen in the images, it also uses correlative data from the operational meteorological analyses of surface properties (e.g.: temperatures, snow cover) and temperature fields in the atmosphere. In a first stop it determine "clear sky background" radiances. A histogram technique, which in principle is similar to threshold techniques is used to extract cloud informations. The final results, named at the end as C_1 and C_2 data, correspond to the cloud statistics mentioned earlier above. This algorithm has not yet been tested for clouds over the polar snow and ice fields.

SOME PRELIMINARY RESULTS (APRIL 1985)

The operational data collection phase for the ISCCP began on 1 July 1983. Some preliminary results are now available, with particular attention paid to the data from July 1983 and April 1985. During April 1985 simultaneous measurements of planetary radiation budget parameters began in the ERBE - project (Barkstrom et al., 1985). Both data sets would provide for modellers and also for diagnostic research activities an ideal basis for studies of cloud-radiation interaction and verifications of model results.

The results in Figure illustrate the monthly mean cloud properties of clouds for July 1983 from METEOSAT 2. The estimated skill for values of total fractional cloudiness, if compared with visual inspections - the only possible means - of original satellite images is about 80 percent. Difficulties still occur with identifications of the high-level thin cirrus layers, which often occur in tropical and subtropical regions and also of low level stratus fields, in particular during the night over continents. These "slip" through the network of the algorithm.

The algorithm determines additional quantities, where correlative data are required (see Fig. 1) which are obtained either from observations and from radiative transfer calculations. Such quantities are (Fig. 2) the mean optical thickness for solar radiation in the visible, a mean cloud top pressure and cloud top temperature.

Once the ISCCP cloud data sets are available with concurrent data on the planetary radiation budget at the top of the atmosphere, they will provide a fundamental source for investigations of radiative energy budget and forcing of dynamical processes within the earth's atmosphere. There are already methods under development (e.g. Gautier et al., 1980; Raschke and Möser, 1983; Schmetz et al., 1986) to map, on the basis of satellite and other correlative data, the radiation budget components at ground over the entire globe. Also oceanographic experiments, such as TOGA and WOCE will gain from this data set, since solar radiation is the dominate heat source of oceans. An example of map of relative values of the downward solar radiation is shown in Fig. 3 in form of a photograph. In principle the mean map of optical thickness data, if only those of the daylight period are taken, should correspond to that of values in Fig. 3, which correspond to the transmittance of cloud fields for solar radiation. Such maps, and also for the downward atmospheric radiation at ground will also be derived from ISCCP data as a product of the recently defined "Radiation Budget Climatology Project" (WMO-ICSU, 1986).

CLOUDS OVER POLAR REGIONS

These clouds may cause largest difficulties to be identified over snow and ice fields. They show much smaller contrasts in both the visible and images to cloud free areas. In fact they are even sometimes reversed. In the infrared, cloud layers topping the boundary layer inversions even are often warmer than adjacent cloud-free areas. Thinner cloud layers above fields occur even darker. Fortunately both polar regions are excellently covered with the multispectral measurements of the AVHRR, whose measurements can be so combined to enhance the contrast of ice and water clouds against the cold snow and ice covered background. Of particular interest are the measurements in the spectral range at 3.7 µm. In these combinations one makes use of the well documented fact that the indices of refraction of liquid water and solid ice particles deviate in the solar and thermal infrared, causing relevant differences also in reflection and emission properties of water and ice clouds, and snow fields, respectively.

During night, channel 3 receives, as the other two "window" channels, thermal heat radiation only. However, due to spectral behaviour of the indices of refraction, water clouds emit less efficiently than ice clouds. Although often warmer than the surface - and with these properties identified with measurements at 10 - 12 µm - they may appear then considerably colder at 3.7 µm. Simply determined radiation temperature differences between simultaneous measurements (e.g. as shown by Eyre et al., 1984, can than be used to identify low level "water clouds" and high level cirrus.

During the daylight period this channel also receives reflected solar radiation, where after a unfortunately incomplete correction for the contribution of thermal heat radiation, water clouds can be identified to reflect more solar radiation than adjacent ice and snow surfaces, or clouds in the ice phase.

In a case study a threshold technique Raschke et al. (1986) developed, which makes use of the simultaneous measurements of all five channels and of some combinations of them (e.g.: ratio of reflectances in the solar channels, or differences of equivalent blackbody temperatures in the infrared) and also of the a-priori knowledge of the surface properties (ocean, continent or island) at each picture element.

An analysed example is shown in Figs. 4 and 5. Fig. 4 shows the Antarctic continent with a large cloud vortex, which is difficult to discern in the measurements of channel 1 (0.58 - 0.68 µm) only. It mainly consists of high and cold cirrus; water clouds are to be observed over the ice fields of the Weddell-Sea, the Atlantic Sector of Antarctica and with some small fractions over the Antarctic continent. The results of the analysis in color - are shown in Fig. 5. A visual inspection of this Figure reveals, that this algorithm provides already much information. Only optically thin clouds are missed. This algorithm will in future include also statistical means (e.g. maximum likelihood estimator).

In order to insure that more experience is gained on the nature and detectibility of polar clouds, several research groups are joining their efforts to compare different techniques. A first workshop has been held in August 1986 at the Polar Research Institute of Japan in Tokyo.

POTENTIAL ASPECTS - REGIONAL EXPERIMENTS

The ISCCP will be accompanied by several regional field experiments with intensive modelling studies to validate samples of the ISCCP results and to gain more understanding of the formation, maintenance and radiative transfer properties of clouds - in particular of high - level cirrus and boundary layer topping stratiform layers - which is necessary to include clouds and their interactions with various energy transfers in forecast, circulation and climate models.

There are now three regional experiments under preparation:

FIRE: First ISCCP Regional Experiment, to investigate cirrus over the continental territory of the **United States** and boundary layer stratus over the Eastern Tropical Pacific with participation of scientists from the **US** and **UK**. The experimental phase of FIRE begins in fall 1986.

NWPE: North West Pacific Experiment, to investigate clouds and their properties over the North West Pacific near Japan, with participation of scientists from **Japan** and **China**. Its experimental phase starts in 1987.

ICE : International Cirrus Experiment, to study cirrus over Europe and possibly later over the vast areas of the Sahara, with participation of scientists from **France**, **FRG**, **Sweden** and **UK**. Field phases are planned for fall 1987 and fall 1988.

The results of these investigations will also enhance the value of a Radiation Budget Climatology Data Project, which is now under definition within the WCRP.

These experiments will provide more coordinated measurements of various properties of cloud systems and also a sequence of theoretical studies is planned, where coulds are seen within their radiating and turbulent environment. One of such studies has recently been made by O'Starr and Cox (1986), where the behaviour of cirrus had been modelled. These authors could show, that the maintenance of cirrus is very sensitive to vertical motions and the radiation fields.

Since one can expect that the operational ISCCP algorithm will be subject to systematic errors, where clouds over certain regions might be either over or underestimated, there is a need for further detailed regional studies. Of particular interest are all subtropical regions where radiation is dominantly forcing the atmospheric dynamics - with exception during to the period of the summer Monsoon over India. These arid zone climates are possibly very sensitive to fluctuations within of the climate system itself and, therefore, should be understood very deeply. Therefore, the WMO is formulating a longterm research project to monitor the climate and in particular the radiation budget in these regions. Also for these purposes the ISCCP data set could be of excellent value.

Conclusive Remarks

The ISCCP, although it began originally as a very dedicated project to map clouds only over the entire globe with satellite data, is now the first project which is in operation within the framework of the WCRP. Its data sets will need considerable efforts of validation to avoid interpretations which could lead to predictions of climate changes.

The original data will also serve the purpose to monitor radiation budget components at both boundaries and possibly also within the atmosphere. There have even been attempts to map on the basis of such imaging data the atmospheric moisture fields.

Three Regional Experiments are already under preparation as multinational efforts to improve our understanding of particular cloud systems like cirrus over continents and boundary layer clouds over oceans.

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FIGURES

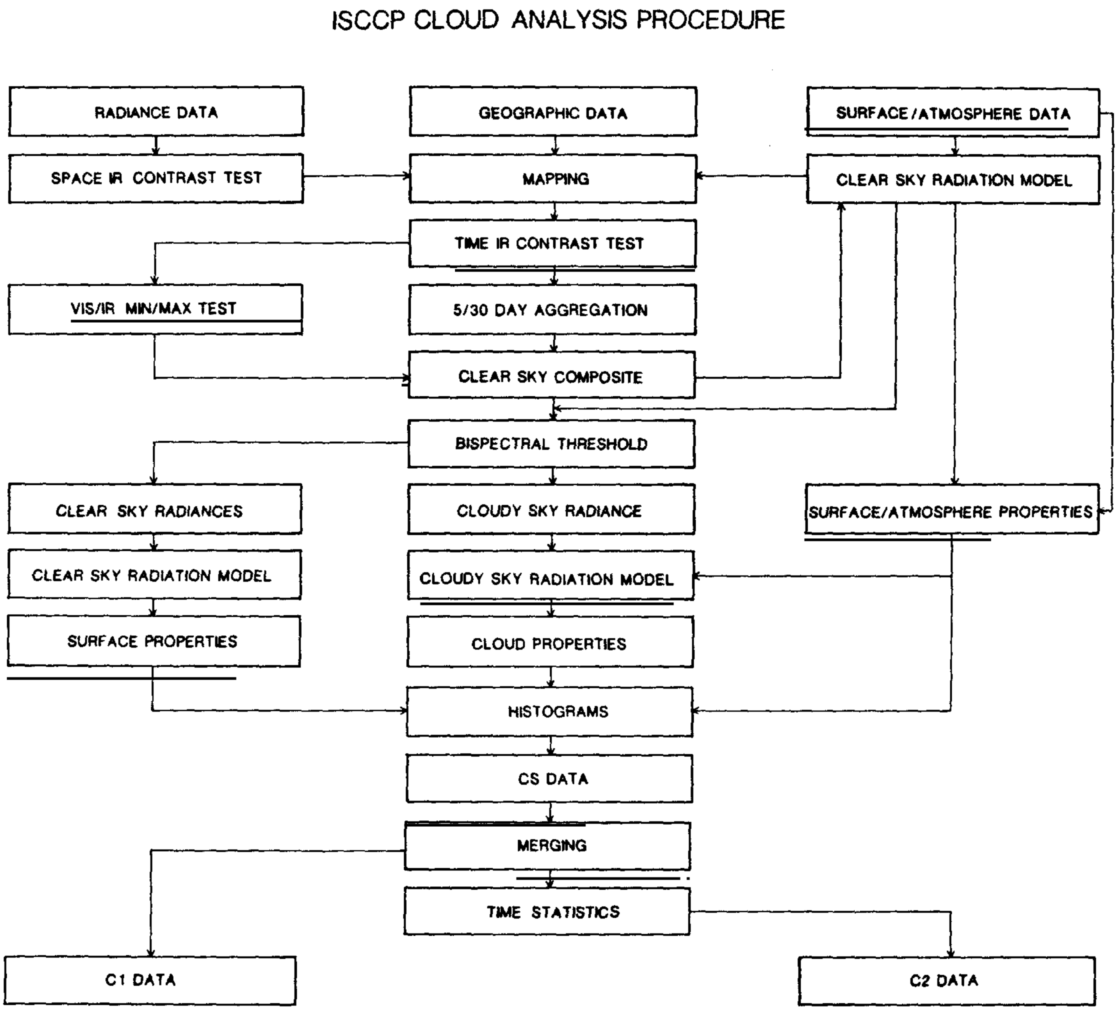

Fig. 1: Flow diagram of ISCCP cloud algorithm

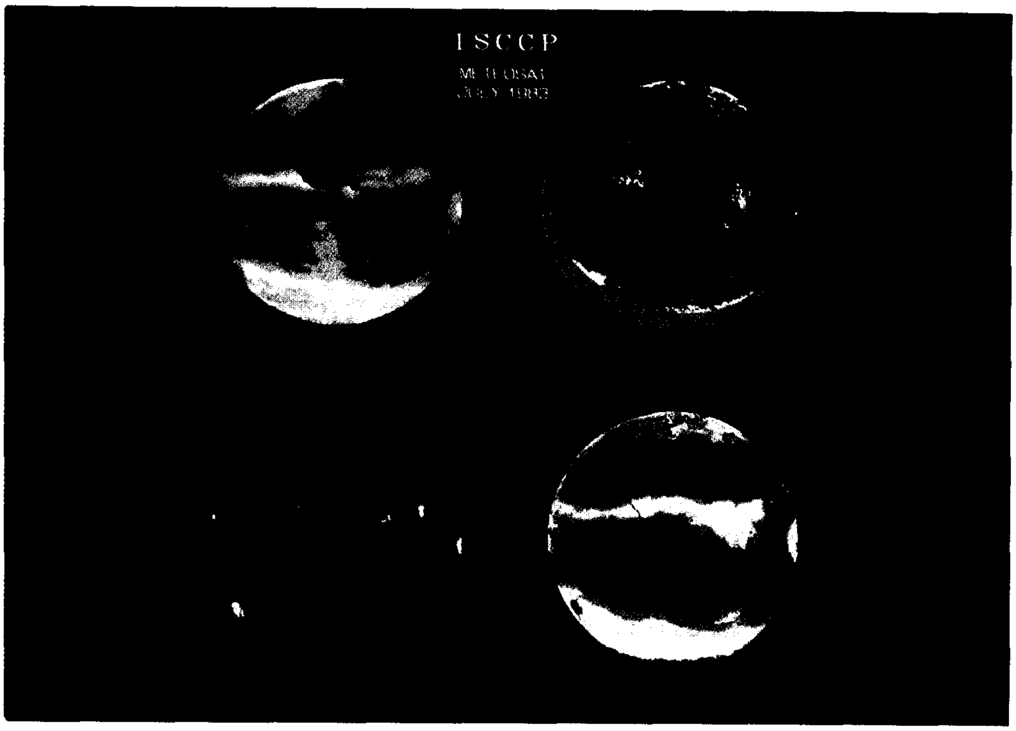

Fig. 2: Monthly mean clouds - July 1983, from METEOSAT data

2a:	fractional cover (percent)	optical thickness (1)
black	0 - 5	0
dark green	5 - 15	1 - 4
light green	15 - 25	4 - 8
dark blue	25 - 35	8 - 16
light blue	35 - 65	16 - 24
white	65 - 100	24 - 100

2b:	top pressure (h Pa)	top temperature (K)
red		335 - 305
orange	600 - 400	305 - 295
yellow	700 - 600	295 - 285
dark green	1000 - 800	285 - 280
medium green		280 - 275
light green	800 - 700	275 - 270
light grey		270 - 250
white	400 - 100	250 - 190

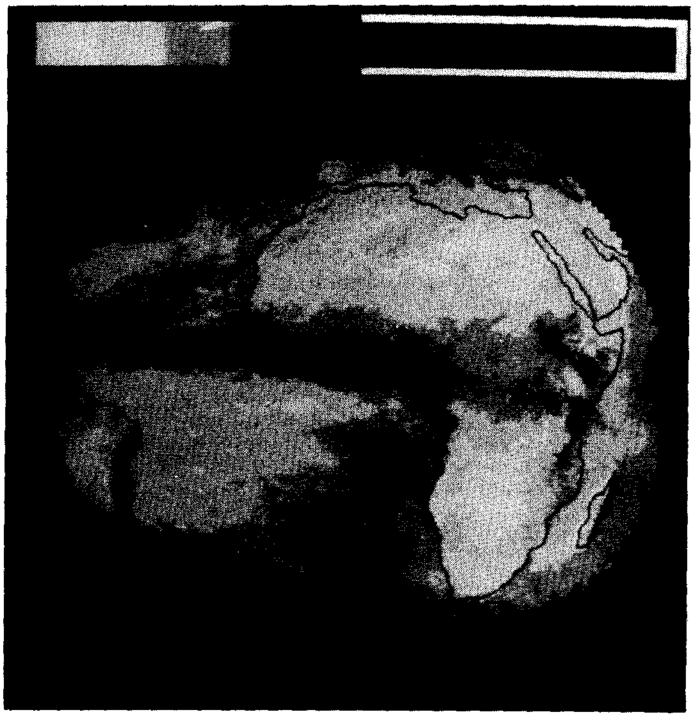

Fig. 3: Monthly averages of daily sums of downward solar radiation (July 1983: from METEOSAT data; accuracy: 8 percent) in relative units of the clear sky global radiation. These values can be interpretated as transmittances of atmospheric clouds. The grey scale on top ranges from values of 0.9 to 1 (brightest tone) linearly to 0.0 to 0.1 (darkest tone black).

Fig. 4: Atlantic sector of Antarctica (channel 1 of AVHRR)

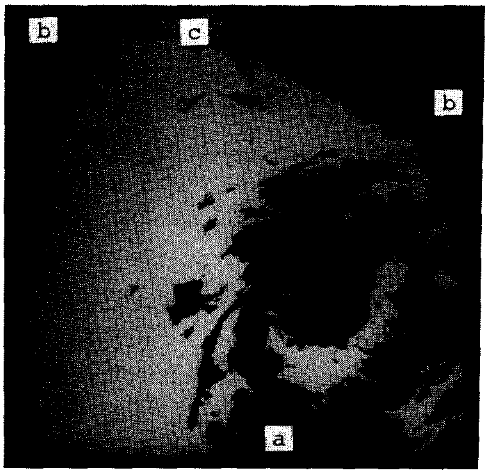

Fig. 5: Cloud types analysed from AVHRR data (black and white representation)
red = ice clouds(a) blue = cloud free ocean(c)
yellow = water clouds(b) white: = snow and sea ice