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Quantitative processing of meteosat data: implementation at KNMI: applications

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Contents:

0. Introduction

Meteosat is the European Meteorological Satellite which moves in a geostationary orbit approximately above the Greenwich meridian. Since the launch of the first satellite (Meteosat 1) in 1977 three more satellites have been brought into orbit (Meteosat 2 in 1981, Meteosat 3 1988 and Meteosat 4 in 1989). Meteosat 4 belongs to a newer generation and has slightly enhanced capabilities. Since 1986 the European organisation EUMETSAT is responsible for the Meteosat Operational Program, but the execution of the program is still performed by ESA-ESOC as it was in the preoperational phase. At this moment (August 1990) Meteosat 4 is the principal operational satellite, although both Meteosat 2 and 3 are still able to collect images.

Meteosat data can be received both in digital form (primary data) and in analogue form (secondary data). A description of these data types, usually called PDUS/SDUS (Primary/Secondary Data user Station) data, can be found in the general introduction to the Meteosat system (Mason 1987). Secondary data are analogue data which are intended for presentation as photographs. In this report I will discuss the use of primary data which can be used quantitatively.

A general description of primary data is given in section 1. Section 2 describes the reception and processing at KNMI. Sections 3 and 4 discuss the calibration and localization (navigation) procedures. In section 5 a summary of the need for and use of atmospheric corrections is given. Section 6 gives an overview of different methods for the retrieval of quantitative information about clouds, surface and atmosphere. Finally the software utilities which have been developed at KNMI are described in section 7.

1. General description of Meteosat PDUS data.

Although PDUS data are called 'primary' data, they are not the raw data as observed by the satellite. The raw data are received by the central ground processing station in Darmstadt. There the data are rectified (corrected for the varying position and attitude of the satellite) and some operations are performed on the data themselves (e.g. space data are set to zero counts). In addition the calibration coefficients are determined.

The processed data are dissiminated to the users via Meteosat in the PDUS data format. (see Meteosat System Guide volume 9 (MEP 1989b). Since the launch of Meteosat 4 some modifications to the header have been made which are also described in MDN (Meteosat Dissemination News 1989, no 1). For old Meteosat data a description can be found in Wolf (1984).

The Meteosat radiometer scans the earth from south to north. Each scan takes 25 minutes and starts at the (half) hour. Processing in Darmstadt occurs in near-real-time, so that the data are dissimated to the users immediately after completion of the scan.. First only the European + North-Atlantic sector (B-format) is sent, followed by the image of the whole earth disk (A-format) - see Mason 1987. The nominal time of the image is the (half) hour after completion of the scan. In reality data over the Netherlands are scanned about 8 minures before the nominal time.

PDUS data are available in three channels : IR (infrared, 10.0-13.1 μm), WV (water vapor 5.4-7.4 μm), and VIS (visible 0.3-1.0 μm). The resolution of the data is 5 km sub-satellite (about 5 x 9 km above the Netherlands). In the visible channel also high resolution data are available with a sub-satellite resolution of 2.5x2.5 km. A complete low resolution A-format image consists of 2500x2500 pixels. In Appendix A2 the formulas are given which can be used to calculate the actual resolution for any point on the observable section of the earth.

Due to a limited transmission capability not all available information can be transmitted to the users. Therefore a rather complicated dissemination schedule is followed (see Appendix B and MEP 1989b). This schedule is subject to modification and the most recent version can be obtained from Eumetsat. The general characteristics of the schedule are given in table 1.

Table 1 General characteristics of dissemination schedule.

Channel	format	availability
IR	A, b	half-hourly, all day
WV	B	night: halfhourly; day hourly.
WV	A	all day: about every three hours
VIS	B	day only: half-hourly (alternating low and high resolution)
VIS	A	day only: half-hourly (low resolution, high resolution only once per day)

2. Reception and Processing of Meteosat data

At KNMI Meteosat primary data are received using a VCS (Video Computer Systems) PDUS station. The "raw" PDUS dataformat can be stored (as IMG-files, with some minor modifications to the header, see VCS MHR-PP) by the VCS system, but this is not recommended, as it is very cumbersome to unpack these data. The VCS software also allows direct storage of so-called processed image files (PIF-files) which have a fixed structure and contain only data from one channel per file. A description of the PIF-format is given in the VCS-manuals (Structure of processed image files). All essential information from the raw header is stored in the PIF-header (see Appendix C) together with some parameters needed by the VCS presentation software. The user can choose whether the data in the PIF-files should be calibrated before storage or not. Several modes of calibration are available (a resolution of one degree Celsius with a range of 256 degrees or a resolution of 0.5 degree Celsius with a range of 128 degrees, see the VCS manual 'VAX-SAT user's guide' for details). If the data are calibrated, it is also possible to store the same data in uncalibrated form. In the present software release (2.4) this extra storage is only possible for one channel, but this should be improved in future. For many applications the calibrated data are much easier to use, but if the linearized calibrated data are stored using only one byte per pixel to conserve storage space, some quantization error is introduced, even if half degree steps are chosen.

3. Calibration

3.1 IR and WV channel

Since the launch of Meteosat 4 the calibration procedure has been simplified considerably. The original description in Wolf (1984) is no longer valid, the new procedure is given in MDN (1989) and MEP (1989a and 1989b). Additional information on the calibration status can be found in the calibration reports, MEP (1982-1989). Here we will give a short summary of the present calibration procedure.

3.1.1 Standard procedure

Calibration of the Meteoat IR and WV data is a two step process. In the first step the actual calibration of the measurements is performed: counts are converted to radiances:

$$\text{Radiance} = \text{Calibration factor} * (\text{Count} - \text{Space count}) \qquad 3.1.1.1$$

In the second step radiances are converted to surface (or cloud) temperatures using the conversion table given in the radiation reports (MEP 1982-1989). The table depends on the satellite and the active channel (Meteosat has two IR channels, of which only one is active).
All necessary calibration parameters (calibration factor, space count, the name of the satellite, indicators for the activity of the channels) can be found in the header of the raw image and are retained in the PIF-header. In the header of the raw image, but also in the header of the PIF-image more calibration parameters are present, but these are not really needed. They can be used to monitor the condition of the satellite and its data. A history of calibration information can be obtained form the calibration reports (MEP 1982-1989). Using this two-step process calibration is quite simple. For automatic calibration the conversion tables must be fed into the computer. If this is done manually, typing errors are virtually unavoidable. It is not difficult to derive the conversion table from the filter functions (which contain only a few numbers), but several unexpected complications arise, which we will describe in the next section.

3.1.2 Calculation of the conversion table.

The conversion table can be derived from an integration of the Planck's function weighted with the Meteosat filter over the wavelength:

$$R(T) = \int_{\lambda_1}^{\lambda_2} F(T,\lambda) \,.\, B(T,\lambda) \,.\, d\lambda \qquad 3.1.1.2$$

with R=radiance, T=temperature, F=filter response, B= Planck's funtion, λ = wavelength.
The use of formula 3.1.1.2 is less straightforward than it seems for several reasons:

- The result when calculating integral 3.1.1.2 depends on the discretization of the filter function.
- The calibration and conversion steps are interrelated, because the conversion table is used during the determination of the calibration factor (the calibration factor is determined during the processing of raw Meteosat data in Darmstadt by a comparison with SST observations -which have been corrected for atmospheric influences, see Schmetz 1986 and MEP 1987a).

This means that we may calculate the table, but that we must then use the same filter function as had been used in Darmstadt during the determination of the calibration factor.
The tables in the calibration reports are calculated using a discretization of the filter functions in only six bands (private communication J. Schmetz), and not with the discretized values of the filter functions which are given as tables in the calibration reports and are much better resolved. In the case of Meteosat 3 a quadratic function through the points given in the filter function table gives radiances which are 3.4% higher than the the values given in the tabel in the calibration report (calculated using the six-band discretization of the filter) for channel IR1 and 1.6% too high for channel IR2. For Meteosat 2 and 4 the differences are negligible. If we use this constant correction factor we may calculate the conversion table but it is safer to use the original tables from the calibration report until ESOC makes available the degraded filter data as used during the calibration proces.
An additional complication for Meteosat 2 and 3 was caused by the fact that the calibrations reports only give

the normalized filter functions, while in the derivation of the conversion table a (rather arbritrary) absolute filter function was used (see MEP 1982-1989, especially Meteosat 2 issue 8,1984, and later issues). The difference is just a multiplication factor of about 0.5. Since the launch of Meteosat 4 the normalized filter absorption is used which can be found for both IR and WV channels in MEP 1989a.

3.1.3 Remarks

Only a very small part of the black body radiation passes through the Meteosat filter. Using the normalized filter function IR1 of Meteosat 4 at 300K we find a radiance at the radiometer of about 12 $W.m^{-2}.sr^{-1}$. The absolute absorption factor is about .5, so that about 6 $W.m^{-2}.sr^{-1}$ really reaches the radiometer. The total black body radiance at 300K is 459 $W.m^{-2}.sr^{-1}$. N.B. When calculating the total black body radiance by numerical integration of Planck's function the tails of the function (especially at long wavelengths) must be carefully taken into account. If an error less than 2% (1% at each side of the spectrum) is required the integration at 300 K must at least run from 4.8 to 77 µm. At 220 K this range is 6.6 to 105 µm.

3.2 Visible channel.

Visible data are not calibrated by ESOC. For Meteosat 1 and 2 an external calibration was available (Koepke 1982, Kriebel 1981). It has been announced that the VIS calibration results for Meteosat 4 will be published during the 8th Scientific User Meeting in August 1990.

Often it will be advantageous to normalize the VIS data (i.e. to correct for the height of the sun). A simple correction using the cosine of local solar zenith angle is not applicable at low sun heigths. Formulas to calculate the sun height can be found in Appendix D. Binder (1989) gives a simple method based on a statistical study of image properties, which is also applicable at very low sun heights.

4. Localization (navigation)

When combining Meteosat data and other data the position of a pixel on earth must be known. This localization is often called navigation. Fortunately PDUS data have been rectified during processing of the raw data in Darmstadt, which means that the data are corrected for deviations in the position and attitude of the satellite from a nominal position (see Wolff 1985). Many parameters used during this rectification are given in the PDUS header (although not retained in the PIF-header) but for calculation of the position of a pixel on the earth these parameters are no longer needed. For that purpose we only need the line and column number and the information on the nominal position of Meteosat. The computer program for this conversion is given in MEP 1987b. The derivation of the algorithm can only be found in an unpublished ESOC document (Bowen 1984). The relevant information from this document is repeated in Appendix A3, together with the Fortran program which implements the conversion algorithm. Typically the localization is better than 2 columns or lines (Adamson et al. 1988). More precise localization can be obtained by the use of ground control points (Wannamaker et al. 1986, Muller et al. 1990).

Both Meteosat coordinates, as calculated using Bowen (1984), and coordinates from Wannamaker et al. (1986) are geodetic coordinates. However, it is not unusual to encounter geocentric latitudes in other references, but it is simple to convert these to geodetic latitudes (see Appendix A).

For a combination with information from weather maps conversion to a polar stereographic projection is often necessary. In appendix A1 the basic formulas for this conversion are given.

5. Atmospheric correction

If Meteosat data are used to determine the temperature of the surface (or cloud top), a correction must be applied for the effect of the atmosphere and for the emissivity of the surface. Although the IR channel is located in the so-called atmospheric window, several gases (e.g. H_2O, CO_2), absorb and emit some radiation in this channel. Generally the observed temperature will be lower than the real surface temperature but sometimes it is difficult to predict the magnitude and sign of the correction. This will be the case if the emissivity of the surface is not equal to 1 (the surface does not emit the full black body radiation and will act as a weak mirror for the radiation emitted by the atmosphere) and especially if the temperature of the atmosphere near the surface is very different from the surface.

Corrections for the effect of the atmosphere can be made using theoretical models for the transmission of radiation through the atmosphere. The most precise radiative transfer models are line-by-line models which model all aborption lines explicitly, but these models are very complicated and very (computer-) time consuming. Mainly due to uncertainties in the modelling of the water vapour continuum even the results from line-by-line models are not always correct. For practical purposes different types of band models are more convenient. Band models devide the spectral range into a number of bands . For each of the bands an average transmission is derived. Usually the errors caused by uncertainties in the water vapour continuum are larger than the errors caused by the approximation in the band models but results from band models may be rather inaccurate, so that their results must be handled with care. International comparisons of line-by-line models and band models give an impression of their accuracies (see e.g. Chedin et al. 1988).

Radiative transfer models can be used to calculate atmospheric properties for any wavelength selection. In our application we will use the transmission bands of the Meteosat filters. For the visible channel the results depend very much on the aerosol profile, which is usually not known. In the WV channel the atmospheric properties are needed in the case of semi-transparent clouds (see section 6.3). Usually radiative transfer calculations are used for the IR channel, so that the observed radiance temperatures may be correded for the effects of the atmosphere. A general description of this application can be found in Schmetz (1986).

As input parameters a radiative transfer model needs:

- the temperature and humidity profile,
- the emissivity (for sea water, see Takashima and Takayama 1981), height, and temperature of the surface (or cloud),
- the viewing angle,
- the characteristics of the filter in the satellite,
- the ozon and aerosol profiles (can usually be neglected for the WV and IR channel).

At KNMI we have implemented several radiative transfer models so that we may obtain an impression of the reliability of the calculated corrections. These models are:

- the model developed by Tjemkes and Nieuwstadt (Tjemkes and Nieuwstadt, 1990, Tjemkes 1988 a,b)
- the public domain models Lowtran 6 and 7 (Kneizys et al. 1983, Kneizys et al. 1988)

An example of the use of radiative transfer model data can be found in Muller et al. (1990)

6. Information retrieval: Clouds, surface, atmosphere

The purpose of the quantitative use of satellite (Meteosat) images is to derive information on the physical state of the surface and the atmosphere which can be compared to or used as input for numerical models. This requires the interpretation of the radiance information in the three channels aided by knowledge about the optical properties of ice and water clouds (although a "cloud" is a not very well defined entity). In many applications Meteosat data are used to determine the temperature of surface or cloud tops and cloud cover . In addition it is possible to use the visible channel to derive the optical thickness (Kriebel 1986,1989, Kriebel et al. 1989). Neither the temperature of surface or cloud-top nor cloud cover can be assimilated directly into current numerical models. Therefore often so-called bogus data are derived (see section 6.2). Frequently a classification of the image (see section 6.1) is used during image analysis prior to the derivation of bogus data. If the cloud cover is semitransparent or broken at sub-pixel scale it is difficult to retrieve useful information. A discussion of this problem is given in section 6.3. When interpreting satellite data it is important to keep track of the position of the sun. Useful references and formulas can be found in Appendix D.

A general overview of the retrieval of meteorological parameters from satellite data can be found in Isaacs (1986). Recent research is focussed on a more fundamental description of the information available in satellite images (e.g. Stephens 1988) and a better use of the combined information from different sources (e.g. Rossow 1989).

6.1 Cloud classification

During the past 20 years a large number of methods has been developed to classify clouds. These methods can be classified according to the type(s) of information which are used:

- Information in different spectral channels
- Information on the spatial variability
- Combination with other observations (e.g. surface observations).
- Combination with complete radiative transfer calculations
- Combination with the output from numerical models.

Comparisons between different methods are very scarce. In Rossow et al. (1985) several algorithms which were proposed for ISCCP (International Satellite Cloud Climatology Project) are compared. In general methods which combine the satellite information with information from other sources tend to be more succesful but are rather scarce because of logistic problems. Many methods rely heavily on the use of different spectral channels. These methods are much more succesful with NOAA- AVHRR data, which are available in five spectral channels. Due to limited computer resources usually only very short range spatial coherence information is used , although most structure and texture in satellite images has a long range coherence. Recent and rather complete reviews of cloud classification can be found in Goodman and Henderson (1988), in Rossow (1989) and in Rossow et al. (1989).

6.2 Bogus data

By combination with e.g. statistical or climatological knowledge quantities are derived which can more directly be combined with the numerical model. These quantities are often referred to as bogus data. A systematic attempt to derive many different meteorological quantities from classified satellite images can be found in Garand (1986,1989, et al. 1989). Other examples of retrieved quantities are:

- Moisture profiles (from classified clouds Mills and Davidson 1987, Timchalk 1986)
- Upper Tropospheric Humidity (UTH, from the water vapour channel, Schmetz and Turpeinen 1988)
- Cloud liquid water path (from optical depth and classified clouds, Kriebel 1989)
- Precipitation, (latent) heating rate. Many attempts have been made to derive precipitation rates from satellite images (Kuittinen 1988, Arkin and Ardanuy 1989, Tsonis 1987) but success is very limited, especially for non-convective or mixed situations. Assimilation of precipation rate in numerical models is often done using the derived heating rate due to latent heat release (Benoit and Roch 1987, Puri 1990, Turpeinen and Garand1990)
- Surface fluxes (from the diurnal cycle of surface temperature, see Price 1982)
- Cloud base. An ingenious method to derive information about cloud base (from Landsat data) can be found in Cahalan (1987).
- Cloud track winds (Nuret 1990,Schmetz and Nuret 1987, Schmetz, 1989; based on WV channel: Eriksson 1988, Stewart et al 1985; including convergence tendency: Podhorsky and Vlcak 1986).
- Outgoing longwave radiation (Schmetz and Liu, 1988, Schmetz 1989).
- Global radiation. Many methods have been developed to estimate global radiation from Meteosat data in the visible channel (Diabaté et al. 1989, Cess and Vulis 1989, Diekmann et al 1988, Le Borgne and Marsouin 1988, Dedieu et al. 1987, Marullo et al. 1987, Grüter et al. 1986) ranging from purely statistical methods to the use of extensive physical radiative transfer models. However all physical methods have to be adjusted/tuned/fitted to observations to achieve an acceptable performance, and their performance is not necessarily better than the statistical methods (Nunez 1988).
- Radiative flux divergence (Stuhlmann and Smith 1988).
- Albedo of surface and clouds, both narrow band and broadband (Pinty et al. 1989, Picon and Desbois 1986, Pinty et al. 1985, Stum et al. 1985, Sthulmann et al. 1985, Pinty and Szjewach 1985, Taylor and Stowe 1984)

6.3 Semitransparent clouds and broken cloud cover at sub-pixel scale.

Semi-transparent cirrus is often neglected, but a very common phenomenon. The average cloud amount of cirrus (Ci +Cs + Cc) is about 20% (Warren et al. 1986). Information about the fraction of semi-transparent cirrus is very scarce. Henderson et al. (1987) give a ratio of about 3:1 between thick and thin cirrus for Western Europe. Moreover it is difficult, if not impossible to define a threshold between clear sky and thin cirrus ("subvisual cirrus", see Sassen et al. 1989).

Although thin clouds are easily observed from the groud using the human eye (sensitive in the visible channel) they are nearly invisible in the visible channel if seen from above (from the satellite). In the infrared satellite channel their temperature is a mixture of the temperature of the cirrus clouds and the temperature of the surface (or an opaque cloud layer below the cirrus), suggesting a cloud layer at a lower altitude than the actual cirrus cloud. Very thin cirrus may be mistaken for a clear scene with surface temperatures which are only slightly too low. In the WV channel the signal from thin cirrus clouds is nearly identical to the signal of an optically thick cirrus cloud. A similar discussion can be given for cloud cover wich is broken at sub-pixel scale. By a combination of the information from different channels and a comparison to theoretical calculations it is nevertheless possible to detect the presence of semi-transparent or broken clouds and to derive the temperature of the cloud layer.

In section 6.3.1 a discussion of methods to check for semi-transparent cirrus is present is given. If cirrus is present, we can only try to determine the temperature of the semi-transparent cirrus (section 6.3.2), but we can no longer determine the temperature of the underlying layer. In section 6.3.3 the problem of broken cloud cover is discussed. Only methods which can be applied to Meteosat data are discussed. For data from NOAA-AVHRR which has a larger number of spectral channels more methods are available.

6.3.1 Cirrus check

For a check on the presence of cirrus we need at least two channels. Although methods which use only the visible channel have been developed (for references see Szejwach 1982), we will not discuss them here because these methods cannot be used at night and are difficult to apply because the visible channel is not calibrated. We will only discuss a method which uses the 6.7 and 11 µm channel (see e.g. Bowen and Saunders 1984). This method uses a radiative transfer model to calculate the expected theoretical relation between the radiances at 6.7 and 11 µm for optically thick clouds at different heights. If the radiative transfer model is fed with realistic input values (water vapour and temperature profile, see section 5), the observed values for the radiances from a pixel at 6.7 and 11 µm should lie on this curve. If transparent cirrus is present the observed infrared temperatures will be too high, so that the points in the affected area deviate significantly from the curve. (see figure 1). Both an insufficient knowledge of the atmosphere and shortcomings of the radiative transfer model (e.g. absence of aerosols, or a deficient treatment of the water vapor continuum) render this check unreliable.

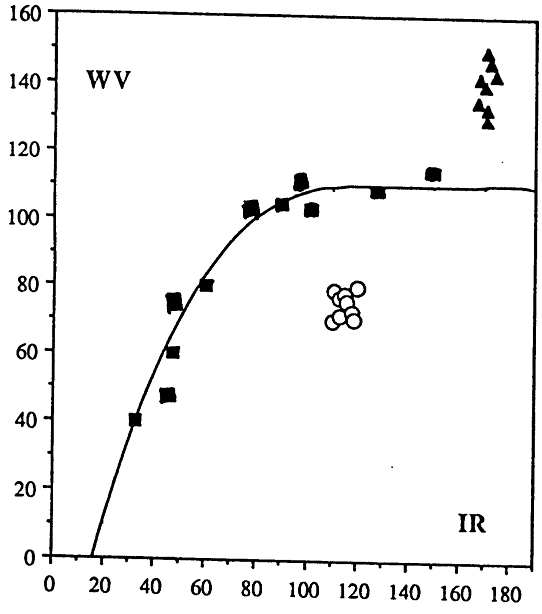

Figure 1

Example of the relationship between IR and WV observations and theoritical relationships.This figure is not based on actual data. Note that the surface points lie well above the curve as is often the case, but not explained. (see also Bowen and Saunders 1984).
Arbitrary units (Counts) along the axes, (a high count correponds to a high temperature).

6.3.2 Cirrus temperatures.

The method discussed in 6.3.1 only checks for the presence of cirrus, it does not yield the temperature of the underlying surface or that of the cloud layer. Under certain assumptions it is possible to derive the temperature of the cirrus clouds from the WV (6.7 µm) and IR (11 µm) radiances without any knowledge of the temperature of the underlying surface. The cirrus must extend over a certain area and must have a varying optical thickness over this area (this is not unusual for cirrus clouds) and the cloud optical properties at 11 and 6.7 μm must be related. Slightly different methods to derive the cirrus temperatures under these conditions can be found in Cayla and Tomassini (1977, Szejwach (1982), Bowen and Saunders (1984) and Pollinger and Wendling(1984).

Essentially all these methods use the following reasoning:
Using two pixels with different cirrus optical properties and both channels we obtain four equations which express the observed radiances in both channels as a combination of the surface radiance and the radiance which an optically thick cloud would have emitted. If we assume that the ratios of the cloud transmissivity at different optical depths are the same for 11 and 6.7 μm (or that the emissivities at 11 and 6.7 μm are about equal), we can eliminate the radiances from the surface and we obtain an empirical (linear) relation between the radiances from an optically thick cloud at 11 and 6.7 μm. In addition we can calculate the theoretical relationship between these radiances using a radiative transfer model (see sections 5 and 6.3.1). Graphically these two equations with two unknowns can easily be solved.

A similar simplification of the original equations which would eliminate the cloud radiances and then yield the surface radiance is not possible. This means that it is impossible to determine the surface temperature using only the Meteosat WV and IR channel if semitransparent clouds are present .

6.3.3 Broken (sub-pixel) cloud cover.

Also small sub-pixel clouds will disturb the interpretation of satellite data. In the case of high clouds their effect can not be distinguished from the effect of semi-transparent clouds, and the methods described in 6.3.1 and 6.3.2 can be applied. For low clouds the water vapour channel cannot be used (this channel only yields information between about 3 and 7 km height). Therefore we must return to methods which use the visible channel (see Szejwach 1982 for references) or try some methods which are used in the more general cloud classification techniques (see 6.1, e.g. above sea sub-pixel clouds will probably cause an increase in standard deviation).

7. Utilities

A number of programs and subroutines have been developed and/or implemented at KNMI to assist in many of the operations which are described in this report. Three different groups of utilities are available:

- for the retrieval of information from VCS PIF-files (section 7.1)
- for the use of the three atmospheric transfer models (section 7.2)
- for the conversion of coordinates and the calculation of useful parameters (e.g. sun heigth, daily temperature variation, section 7.3)

All software is written in VAX Fortran and available on the Meteosat Microvax as well as on VAX tape. Source codes, command files for compilation and/or linking and executables can be found in the directories dua0:[knmi..pdus...] and dua1:[knmi.radtran...]. Software developed at KNMI is written using the "Doctor" naming conventions. Some software which has been implemented from elsewhere has been converted to this standard, but the longer codes, like the three atmospheric transfer models have not been rewritten.

Only programs and subroutines which can be used simply (using this documentation and the comments in the code itself) are described in this section. Subroutines which are for internal use only are not described in this report.

7.1 Retrieval of information from PIF-files

The VCS sytem stores the Meteosat data in PIF-files (see section 2). This is an unformatted file type with fixed record length of 256 bytes, containing one header record followed by the image data (miminal one record per image line)- see VCS Manuals, (Structure of processed image files). In the newest VCS record optional extra header records are possible, but this is not yet supported by the KNMI utilities. For small images the use of disk space is very inefficient, so that a new file type has been defined which is identical to the PIF-files except that the recordlength is16 bytes. These unformatted file types are not easily transported to other computer types, so that also a formatted file type (ASC) has been defined (see Muller et al. 1990). Note that also the transfer to other computer types of routines which use unformatted files (PIF, C16) may not be straightforward.

VCS standard software can be used to show the images in the PIF-files on a graphical display. KNMI utilities have been developed which enable the user to:

- show or print the data from any of the three file types on monitor or printer
- to extract data into a new file of any file type
- to select the required area during printing, showing or extraction
- to decide that only every nth pixel must be used during printing, showing or extraction
- to choose between averaging and sampling to convert high resolution VIS data to low resolution.
- to convert the file type
- to calibrate IR and WV data (using Callcal.FOR and Cal.FOR, see section 7.2)

Except for the calibration all utilities can be called using subroutine Conversie.FOR (see flow chart in figure 2). Conversie.FOR can be used with manual input (manual input is not shown on the flow chart), and in several automatic modes for which information is taken from the files Fileconv.DAT (file to be used), Fileprod.DAT (name of new file), Printpifdef.DAT (specifications of extraction/printing area). A description of these input files can be found in appendix E. A main program Conv.FOR is available which can be used for interactive calls of Conversie.for. Subroutines Zoek*.FOR illustrate the fully automatic use of Conversie.FOR.

Many of the subroutines used by Conversie.FOR can also be used separately, but this requires a more thorough understanding of the programs which can be obtained by studying the documented source codes. In particular the transfer of arrays of varying sizes between the Fortran subroutines must be carefully studied.

Principally the routines are designed for files which contain data in Meteosat projection. Then all manipulations are based on Meteosat line and column numbers. The routines can also be used for files containing images in other projections, but then only arbritrary line and column numbers are used, which must be interpreted by the user using the information in the VCS Manuals (Structure of Processed Image Files) and the conversion rountines which are described in section 7.3. When extracting, printing, or showing image data the user can select the image area. In addition the user can specify that .

Overview of programs and subroutines for retrieval in directory:$disk1:[knmi.pdus.retrieval]:

Program	Subroutine	Purpose
Conv.FOR	Conversie.FOR	Main routines, see text
	Filedef.FOR	Manual input of filenames
	Leesxxx.FOR*	Reading an image of file type xxx (xxx=PIF, C16, ASC)
	Sryfxxx.FOR**	Writing an image of file type xxx (xxx=PIF, C16, ASC)
	Printpif.FOR	Showing of printing image data.
	Snijpif.FOR	Extracting image data with storage in PIF-file.
	Snijc16.FOR	Extracting image data with storage in C16-file.
	Lbyte.FOR	Conversion from integer to byte, used by many subroutines
Zoekfile, Zoek ned, Zoekvis.FOR		Examples of the use of lib$find_file for automatic file selection

* Leesxxx.FOR calls subroutines Leesheaderxxx.FOR, Toonheadpif.FOR, and Leesimagexxx.FOR
** Sryfxxx.FOR calls subroutines Sryfheaderxxx.FOR, and Sryfimagexxx.FOR

7.2 Radiative transfer models

Shell programs to facilitate calls of the atmospheric transfer models band model, Lowtran 6 and Lowtran7 are available. Transfer.FOR gives access to the radiation models Lowtran6 or KNMI band model, Transfer7.FOR to Lowtran7.

The shells can be used to calculate the upward and downward radiation at any level of the atmosphere for any height of the surface. The KNMI band model performs both calculations simultaneously and yields integrated information for the whole spectral range (weighted with the filter function). Lowtran yields information for all narrow (user specified) spectral bands, which are then integrated using the weighting as prescibed by the filter data. Using Lowtran it is also possible to calculate the atmospheric transmittance for a horizontal path. This has only been implemented in Transfer7. It is not possible to run the short wave options of Lowtran 6 or 7 from the present version of the shells.

Finally, it is possible to use Transfer.FOR to generate a radiance/temperature table which gives the relation between the measured radiance and the black body temperature temperature for any filter. The temperature is given in steps of 2°C between 100 and 420K. The values are stored in a file with extension .TBL. Routine Cal.for converts counts to temperatuers using a radiance/temperature table (see also section 3.1).

Flowcharts of Transfer.FOR and Transfer7.FOR are given in Figures 3 and 4. In the flow chart of Transfer7 only the structure for a horizontal radiative path is given, since its general structure is identical to that of Transfer except that it is not possible to choose for the KNMI band model. Not all manual data input is indicated in the flow charts.

In addition two programs (Atmcor.FOR and Atmcor7.FOR) are available which can be used to calculate the surface temperature from temperatures observed by the satellite by iterative calls of the radiative models. The first estimate of the surface temperature is equal to the satellite temperature plus a first estimate for the atmospheric correction which depends on the time of the day and varies between 1.5 and 6 °C.:
TSest = Tsat + Tcor, whereTcor is estimated as 4 + 2.5 sin(π/12 (GMT-6)).
The second iteration uses TSest + 2(Tsat - TSmodel) where TSmodel is the upward radiance temperature, resulting from the calculations with a surface temperature of TSest.
The next estimates for the surface temperature are interpolations between the previous two estimates. The

procedure stops if |TSmodel-TSest| is less than 0.1°C. Typically three iteration steps are enough to reach this value.

Although written as separate main programs, the structure of Atmcor and Atmcor7 is nearly identical to the automatic part of Transfer and Transfer7 so that no separate flowcharts are given.

The following input data are needed to run Transfer(7) (see section 5): radiosonde data, initial altitude, surface temperature at initial altitude, spectral filter, satellite zenith angle, surface emission coefficient. If only a temperature/radiation table is required filter data are sufficient. In addition to the input data needed to run Transfer(7), satellite IR data for the temperature must be available to run Atmcor(7). Both Transfer(7) and Atmcor(7) can be used in manual and in automatic mode. In automatic mode all input data are taken from files. A description of input and ouput files can be found in Appendix F.

The following programs and subroutines (only those subroutines are listed which can be used separetely) are available in directory $disk1:[knmi.pdus.radtran]:

Program	Subroutine	Purpose
Transfer.FOR	many (see Appendix F)	call of band model or Lowtran 6
Transfer7.FOR	"	call of Lowtran 7
Atmcor.FOR	"	iterative calculation using satellite data and Lowtran6/band model
Atmcor7.FOR	"	iterative calculation using satellite dataand Lowtran7
	Pzt.FOR	conversion of pressure/height and of humidity variables
	Radtemp.FOR	calculation of radiance table
	Filter.FOR	manipulation of filter information
Callcal.FOR	cal.for	calibration of ir/wv count to temperatures

7.3 Conversion programs and calculation of useful parameters

This section lists the various utility routines and program which are available in directory $disk1:[knmi.pdus.utils]. Most of these routines can be simply written using the information given in this report. When this is not the case (for Daytemp, Geodis, Geolam and Meteolam) the source code is given in Apppendix G.

Program	Subroutine	Purpose
Callsol.FOR:	Sol.FOR	solar elevation and azimuth
Calldaytemp.FOR	Daytemp.FOR	daily variation of surface temperature
Callgeolam.FOR	Geolam.FOR	conversion geographical coordinates -> shifted LAM coordinates*
	Meteolam.FOR**	conversion Meteosat coordinates -> nearest shifted LAM coordinates
Callconvpd.FOR	Convpd.FOR	conversion Meteosat coordinates ***<-> geographical coordinates
Geodis.FOR		distance between two points in geographical coordinates
Meteodis.FOR	Convpd.FOR	distance between two points in Meteosat coordinates*
Map.FOR	Point.FOR	geographical coordinates -> cartesian coordinates polar stereo map

* shifted LAM coordinate are polar stereographic coordinate with a shifted pole, as used in KNMI LAm and HIRLAM.

** Meteolam calls subroutines Convpd and Geolam

*** Meteosat coordinates: Meteosat column and line numbers

8. References

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9. List of acronyms

ESA	European Space Agency	
ESOC	European Space Operations Center	
Channel names:	IR	Infra-Red
	WV	Water Vapour
	VIS	Visible
Filetypes:	.PIF	Processed Image File, recordlength 256
	.ASC	Processed image in ASCII format
	.C16	Processed Image File, recordlength 16
	.IMG	Raw image file
	.FOR	Fortran progran
	.DAT	Data
ISCCP	International Satellite Cloud Climatology Project	
MDN	Meteosat Dissemination News	
MEP	Meteosat Exploration Project	
NOAA-AVHRR	Advanced Very High Resolution Radiometer on board NOAA satellite	
PDUS	Primary Data User Station	
SDUS	Secondary Data User Station	
VAX	Digital computer series	
VCS	Video Computer Systems	

Figure 2 Flowchart of Conversie.for

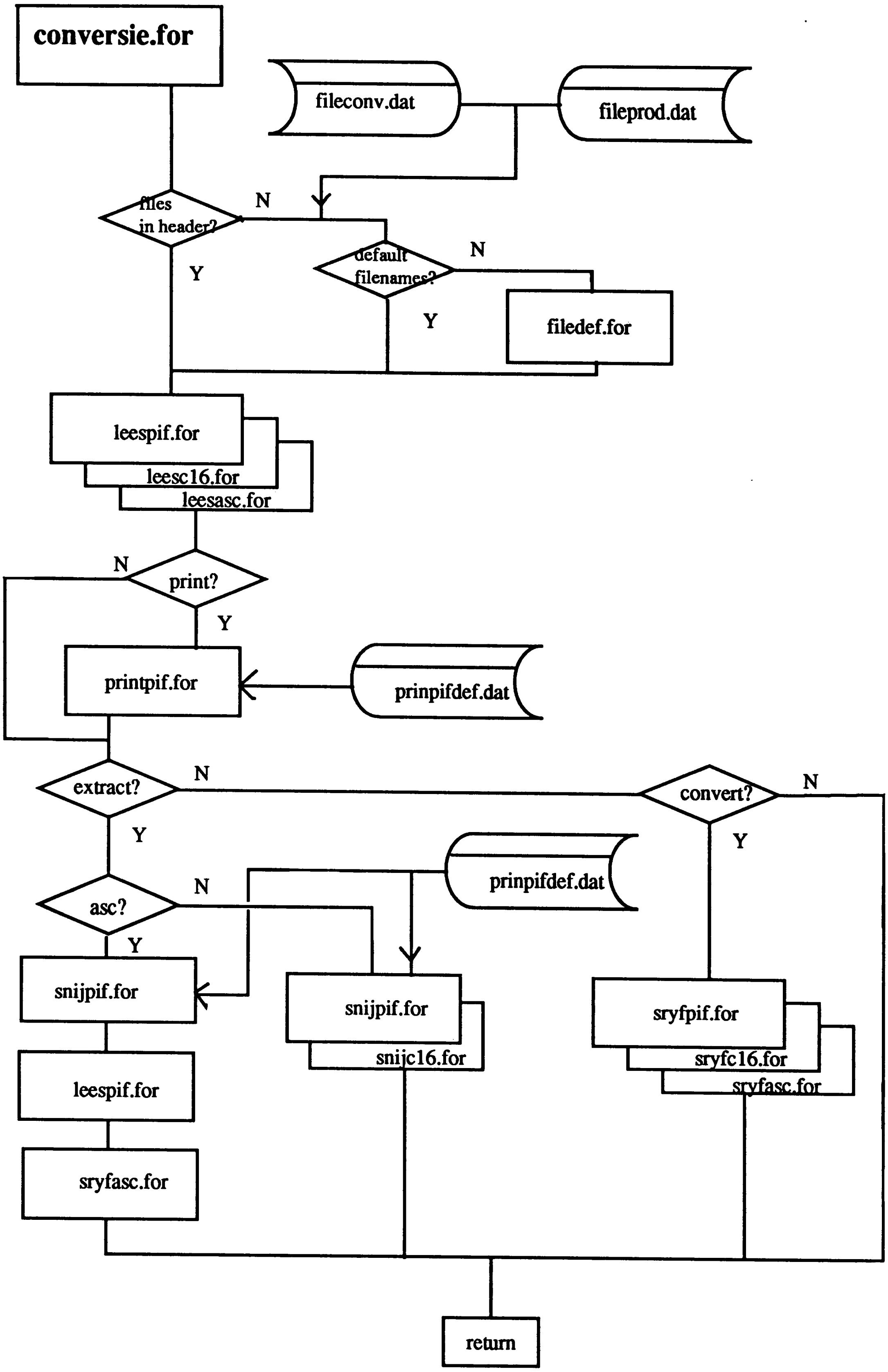


Figure 3 Flowchart of Shell.for

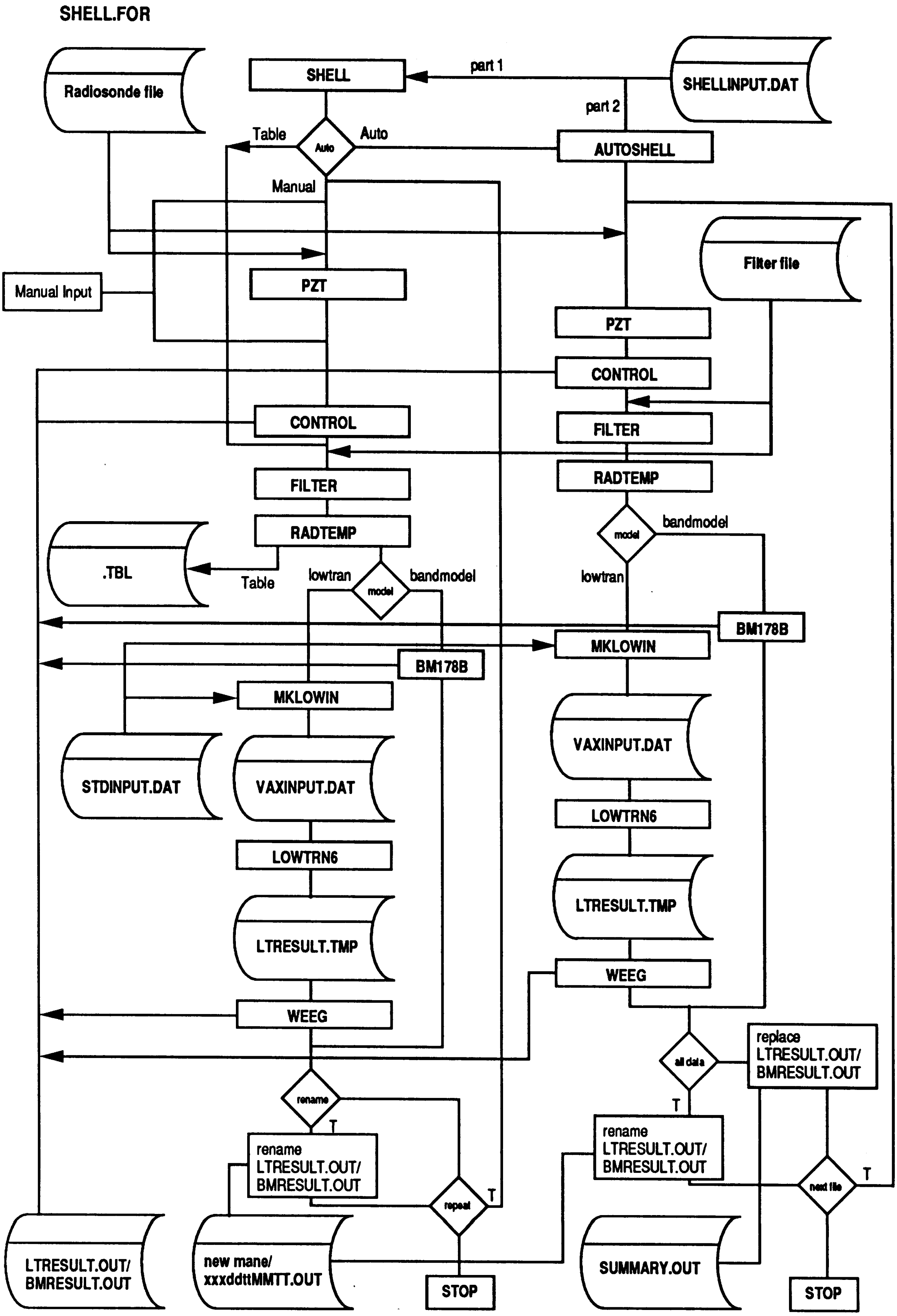
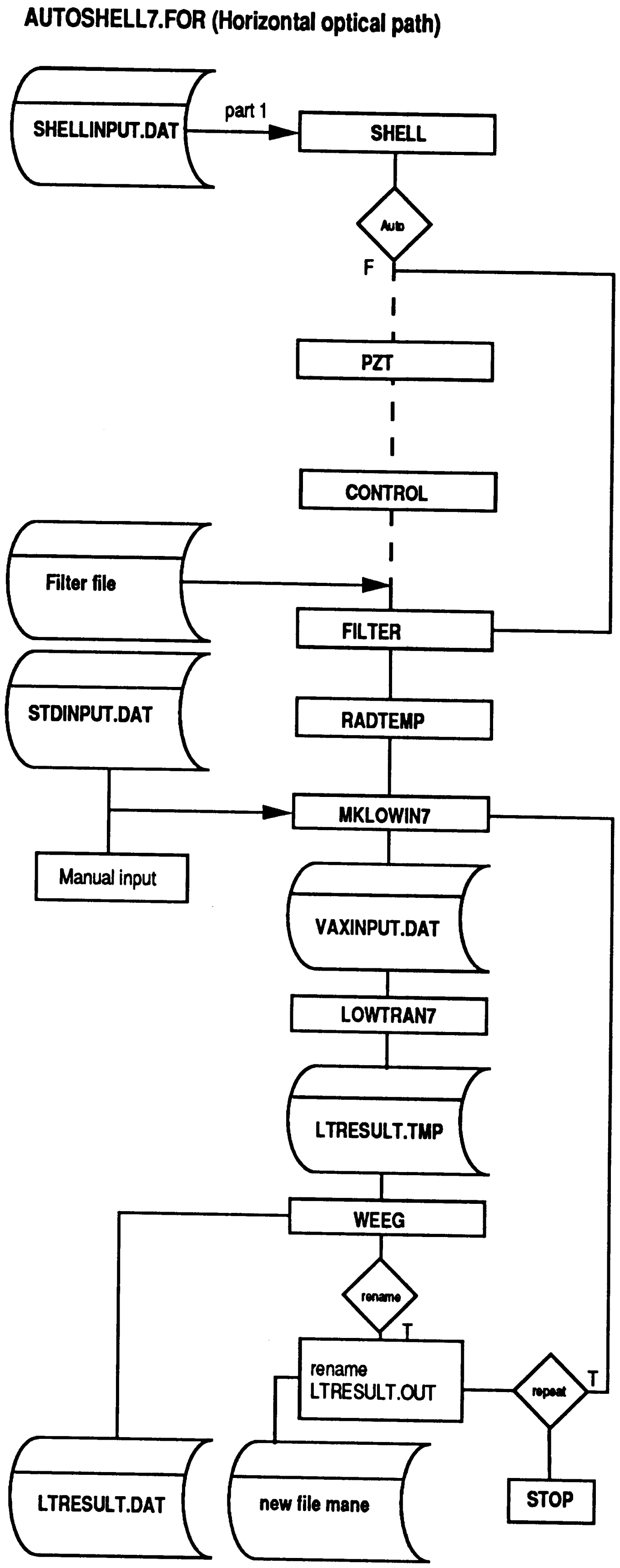


Figure 4 Flowchart of Shell7.for (horizontal path only)



Appendix A Coordinate systems, projections

In meteorology different projections are used. Weathermaps for Western Europe are usually presented in polar stereographic projection with respect to 0° longitude (with the scale factor given at 60° NB). Satellite (NOAA, Meteosat) and radar images represent the earth in a flat plane, each in their own way.

Usually the geodetic coordinate system is used, although occasionally the geocentric is found (see Wannamaker et al. 1986, Jackson 1987). The relation between geodetic (ϕ_d) and geocentric (ϕ_c) latitude is (e=eccentricity): $\tan(\phi_d) = (1 - e^2)\tan(\phi_c)$. Geodetic and geocentric latitudes coincide at 0° and 90°. At a latitude of 45°the geocentric value is smaller by a maximum of about 0.2°

In order to compare data from different sources it is necessary to perform transformations. The formulas are relatively simple if the earth is considered a perfect sphere , but more complicated for an spheroidal earth. Especially for high resolution data (radar,NOAA-AVHRR) deviations using spherical formulas are too large. A general introduction to as well as advanced formulas for coordinate systems and projection can be found in Jackson (1987). In section A1 we will only summarize the formulas for a polar stereographic projection. Section A2 discusses the calculation of Meteosat ground resolution. In section A3 the conversion from Meteosat to geodetic coordinates is given. In this conversion an ellipsoidal approximation of the earth is used with a polar radius of 6356583.8 m and an equatorial radius of 6378169 m. The latter differs slightly from the equatorial radius of Clarke's ellipsoid (6378206.4 m), but this difference is negelctable compared to Meteosat ground resolution. An overview of commonly used earth radii and other useful information on coordinate conversions can also be found in a note by H.R.A. Wessels (KNMI): Coordinate conversion for presenting and compositing weather radar data, march 1990.

A1 Polar stereographic projections

$$e = \mathrm{sqrt}[(a^2-b^2)/a^2]$$

a: equatorial radius; b: polar radius; e: eccentricity

$$\rho = \frac{2a}{\mathrm{sqrt}(1-e^2)} \cdot \left[\frac{1-e}{1+e}\right]^{e/2} \cdot \left[\frac{1+e\sin\phi}{1-e\sin\phi}\right]^{e/2} \cdot \tan(\pi/4 - \phi/2)$$

ρ: cartesian distance pole-point(ϕ,λ) on polar stereographic map; ϕ: geodetic latitude

$$\theta = \lambda - \lambda_o$$

λ: longitude;. λ_o: reference longitude for polar stereographic projection

$$x = s_{90}\,\rho\cos\theta$$
$$y = s_{90}\,\rho\sin\theta$$

x,y : cartesian coordinates on map; s_{90}: scale factor at the pole

for e = 0:

$$\rho = 2a\cdot\tan(\pi/4 - \phi/2) = 2a\cdot\frac{\cos(\phi/2)-\sin(\phi/2)}{\cos(\phi/2)+\sin(\phi/2)} = 2a\cdot\frac{\cos\phi}{1+\sin\phi}$$

Sometimes the colatitude $\psi = \pi/2-\phi$ is used, giving $\rho = 2a \tan(\psi/2)$.

The scale factor (s=dr/dm) is the ratio between small distances on the map (dr) on the earth (dm). Using $dr/dm = dr/d\phi \, . \, d\phi/dm$ formulas can be derived from Jackson (1987: $dr/d\phi=-dr/d\psi$ on p111, $d\phi/dm$ on p 55)

For a sphere: $s = 1 / [\cos(\pi/4-\phi/2)]^2$

For a spheroid: $s = \rho(\phi) \cdot (1 - e^2 \sin^2\phi)^{1/2} / (a \, . \cos(\phi))$

Note that the scale factor is generally given at the pole but in meteorological applications for Western Europe the reference latitude is often chosen at 60°N. The difference is a factor of about 1.07173 for a spheroid (1.071797 for a sphere).

A2 Calculation of the ground resolution of Meteosat.

Resolution is usually given in km at the subsatellite point. A geometrical correction is neccessary to calculate the actual ground resolution at other points. However 'resolution' is not a very well defined concept. It is often interpreted as the field of view of the detector, but electronic filtering and numerical processing will determine the actual resolution, which will moreover depend on the contrast in the scene. If we are not only interested in the surface but also in the clouds, definition of resolution becomes even more complicated. Therefore very precise calculation of resolution is usually not meaningful. The formulas given here are approximations for a spherical earth. More accurate formulas can be derived using appendix D or can be found in Beni et al. (1986).
For points on the Greenwich meridian the resolution will mainly be changed in the meridional direction and for points on the equator mainly in zonal direction. For all other points the pixel will be distorted into a complicated shape. We will only estimate the magnitude of the maximum change, without a statement on the final shape of the pixel.

For a point with geographical coordinates ϕ, λ (ϕ = latitude, λ = longitude) the angle ξ (earth center-point, earth center- meteosat) is (rememter that Meteosat is located above $\phi=0$, $\lambda = 0$):

$$\cos(\xi) = \cos(\phi) \cdot \cos(\lambda)$$ (see e.g. Jackson p11)

Then the zenith angle ζ of Meteosat in point (ϕ, λ) follows from:

$$\tan(\zeta) = D \sin(\xi) \; / \; [D \cos(\xi) - R]$$

D = distance between center of the earth and Meteosat = 42164 km
R = average radius of the earth = 6371 km

The maximum change in resolution of the pixel is then given by $1 / \cos(\zeta)$

A3 Conversion from Meteosat coordinates to geographical/geocentric coordinates

A theoretical desciption of the conversion algorithm and the constants wich define the nominal position of Meteosat are followed by a Fortran program in which the algorithm is implemented (both from Bowen 1984).

The conversion method

A model of the earth's surface is used in which it is taken to be an oblate spheroid; that is that any part on the surface may be expressed by -

$$\frac{x^2 + y^2}{a^2} \cdot \frac{z^2}{r^2} = 1$$

so that for a point on the equator $x^2 + y^2 = R_e^2$ and for a point on the plane at right angles to the satellite direction

$$\frac{x^2}{R_e^2} + \frac{z^2}{R_p^2} = 1$$

From this it follows that for an observation angle of (α, β) in the satellite's frame of reference the corresponding point on the earth's surface is defined by

$$R_n = (b - d^{1/2})/a$$

where

$$b = H \cos\alpha \cdot \cos\beta$$

$$a = \cos^2\beta + \frac{R_e^2}{R_p^2} \sin^2\beta$$

$$d = b^2 + a\,(R_e^2 - H^2)$$

H being the earth centre - satellite centre distance

R_e being the earth's equatorial radius

R_p being the earth's polar radius.

From this a transformation to the earth frame of reference and in terms of distance is as follows:

$$\bar{R} = \begin{vmatrix} R_1 \\ R_2 \\ R_3 \end{vmatrix} = \begin{vmatrix} H \\ 0 \\ 0 \end{vmatrix} + R_n \begin{vmatrix} -\cos\alpha \cos\beta \\ -\sin\alpha \cos\beta \\ \sin\beta \end{vmatrix}$$

If we use

R_{xy} for the radius from the earth's axis $\left((R_1^2 + R_2^2)^{1/2}\right)$

then the latitude and longitude in radians are given by

$$\text{long} = \tan^{-1}\left(\frac{R_2}{R_1}\right)$$

$$\text{lat} = \tan^{-1}\left(\frac{R_3}{R_{xy}} \cdot \frac{R_e^2}{R_p^2}\right)$$

finally latitude and longitude in degrees can be obtained as

$$\text{long}^0 = \frac{180}{\pi}\,\text{long}$$

$$\text{lat}^0 = \frac{180}{\pi}\,\text{lat}$$

Conversely starting with an earth surface latitude and longitude in degrees the corresponding position on a sphere is obtained by first converting to radians

$$\text{lat} = \frac{\pi}{180}\,\text{lat}^0$$

$$\text{long} = \frac{\pi}{180}\,\text{long}^0$$

sere $\cancel{R}\text{lat} = \tan^{-1}\left(\tan(\text{lat}) \cdot \frac{R_p^2}{R_e^2}\right)$

This apparent latitude is then used to calculate the radius of the earth at the location chosen

$$R_L = R_p \Big/ \left(1 - \left(\frac{R_e^2 - R_p^2}{R_e^2}\right)\cos^2(\text{lat})\right)^{1/2}$$

A transformation can then be applied to give the components of the normalised radius

$$\overline{R} = \begin{vmatrix} R_1 \\ R_2 \\ R_3 \end{vmatrix} = \begin{vmatrix} H \\ 0 \\ 0 \end{vmatrix} + R_L \begin{vmatrix} -\cos(\text{lat}) \; \cos(\text{long}) \\ -\cos(\text{lat}) \; \sin(\text{long}) \\ \sin(\text{lat}) \end{vmatrix}$$

from which the satellite angles can be calculated as

$$\alpha = \tan^{-1}(R_2/R_1)$$
$$\beta = \sin^{-1}(R_3/R_n)$$

where $R_n = (R_1^2 + R_2^2 + R_3^2)^{1/2}$.

Conversion constants

It is assumed that the spin rate, radiometer stepping angle and satellite height are nominal.

The polar and equatorial radius of the earth is not assumed to have the 1910 international values, but some difficulty was found in selecting values most generally acceptable.

In the event the "ESOC values" used are:

Radiometer stepping angle	0.00004π radians (72 degrees^{-3})
Spin step angle	0.00004π radians (72 degrees^{-3})
Centre of earth - satellite	42164.0 km
Equatorial radius	6378.1690 km
Polar radius	6356.5838 km

Pixel range	1-2500
Line range	1-2500
Sub Satellite Point	1250.5, 1250.5

Segment Range in columns	1-80
Segment Range in rows	1-80
Sub Satellite Point	between segments 40 & 41 in column and 40 & 41 in row

Implications

These calculations apply to points on the earth's surface at nominal sea level. A cloud above a ground point will not in general appear at the same pixel as the ground point in the image. The effect of this parallax error is of the order of 0.2 pixels per km elevation near the horizon and along the axes.

Similarly a satellite - earth centre variation of 1km gives a difference of about 0.009 pixels near the horizon along the axes.

The horizon is at about 79° of latitude or longitude on the axes.

```
      subroutine convpd(iidir,pixel,line,long,lat,iret)
c
c     ------------------------------------------------
c
c     Pixel/geographical conversion in double precision
c
c     Routine written by R. Bowen, ESOC
c
c     Explanation
c     Finds the geographical location on the surface of an oblate earth
c     in geodetic coordinates of a pixel in the Meteosat reference image
c     and vice - versa.
c
c     Although the outside communication is in real*4 values all the
c     internal work is performed in double precision.
c
c     The subroutine has a reversible accuracy of better than
c     0.0005 pixels
c
c     Arguments
c     iidir   input   int          +1 = reference --> geographical
c                     -1 = geographical position
c     pixel I or O    real          pixel column position (1-2500)
c     line  I or O    real          pixel row position (1-2500)
c     long  O or I    real          longitude in degrees
c     lat   O or I    real          latitude in degrees
c     iret  output    int            0 = conversion completed
c                     +1 = point not on surface or earth
c                     -1 = direction no clear
c
c     Parameters
c     Some of the internal parameters signifantly affect the results
c     pi
c     equatorial radius of earth (km)
c     polar radius of earth (km)
c     distance form satellite to earth centre of gravity (km)
c
c     ----------------------------------------------------------------

      real*4  pixel,line,lat,long
      integer*4      iidir,iret

      real*8  r(3),rnorm,rl,rlat,rlong
      real*8  alpha,beta,sina,sinb,consa,cosb,a,b,discr
      real*8  qn,re2,rp2,rep2,rpe2,re2h2,epsi2
      real*8  rxy,fact,fpi180
c
      real*8  dpi/    3.141592653589793 D 0/
      real*8  re / 6378.169             D 0/
      real*8  rp / 6356.5838            D 0/
      real*8  h  /42164.                D 0/
c
c
      fpi180  = dpi / 180.0 D 0
      fact  = 180.0 D 0 / dpi
      re2   = re * re
      rp2   = rp * rp
      rep2  = re2 / rp2
      rpe2    = rp2 / re2
      re2h2 = re2 - h*h
      epsi2 = (re2 - rp2) / re2
      qn    = 4.0 D -5 * dpi

      if (iidir.eq.1)then
c
c     pixel to lat/long
c
         alpha= qn * (pixel - 1250.5)
         beta = qn * (line  - 1250.5)
         sina = dsin (alpha)
         sinb = dsin (beta)
         cosa = dcos (alpha)
         cosb = dcos (beta)
         a = cosb * cosb + rep2 * sinb * sinb
         b = cosa * cosb * h
         discr = b*b + a * re2h2
c
c           check visibility ( if pixel on earth)
c
         if (discr.lt.0.0D0) then
           iret = 1
           long = 0.0
           lat = 0.0
         else
           iret = 0
```

```
            rnorm = (b - dsqrt (discr)) / a
            r(1)  = h - rnorm * cosa * cosb
            r(2)  =   - rnorm * sina * cosb
            r(3)  =     rnorm * sinb
            rl = dsqrt (r(1)*r(1) + r(2)*r(2) + r(3)*r(3))
            if (rl.gt.0.0D0) then
               rxy = dsqrt (r(1)*r(1) + r(2)*r(2))
c              avoid trouble around pi/2
               if (dabs(r(1))/rl .gt. 1.0D-16) then
                 rlong = datan (r(2)/r(1))
               else
                 rlong = dpi / 2.0 D0
               endif
               if (r(1) .lt. 0.0D0) rlong = rlong + dsign(dpi,r(2))
c              avoid trouble around pi/2
               if (rxy/rl .gt. 1.0D-16) then
                 rlat = datan (r(3)*rep2/rxy)
               else
                 rlat = dsign((dpi/2.0D0),r(3))
                 rlong = 0.0D0
               endif
            else
               rlat  = 0.0D0
               rlong = 0.0D0
            endif
              lat  = fact * rlat
            long = fact * rlong
          endif

      else if (iidir.eq.-1) then

c     lat/long to pixel

         rlat  = fpi180 * lat
         rlong= fpi180 * long
         rlat  = datan(dtan(rlat) * rpe2)
         cosb  = dcos (rlat)
         sinb  = dsin (rlat)
         sina  = dsin (rlong)
         cosa  = dcos (rlong)
         rl = rp/dsqrt(1.0D0 - epsi2 * cosb * cosb)
         r(1)  = h - rl * cosb * cosa
         r(2)  =   - rl * cosb * sina
         r(3)  =     rl * sinb
         rnorm= dsqrt( r(1)*r(1) + r(2)*r(2) + r(3)*r(3) )
         alpha= datan(r(2)/r(1))
         sina  = dsin (alpha)
         cosa  = dcos (alpha)
         sinb  = r(3) / rnorm
         beta  = dasin (sinb)
         cosb  = dcos(beta)
         a  = cosb * cosb + rep2 * sinb * sinb
         b  = cosa * cosb * h
         discr= b - a * rnorm

c        check visibility
         if (discr.lt.0.0D0) then
            iret = 1
            pixel = 0.0
            line = 0.0
         else
            iret = 0
            pixel= alpha/ qn + 1250.5D0
            line = beta / qn + 1250.5D0
         endif
      else
c     direction not a valid one
         iret = -1
      endif
c
      return
      end
```

Appendix B Example of the dissemation schedule

An explanation of the schedule is given in MEP (1989b).

METEOSAT DISSEMINATION SCHEDULE S9008M01 - CHANNELS A1 (1691MHz) AND A2 (1694.5MHz) VALID FROM 1 AUGUST 1990

GMT HH	00		03		06		09	
MM	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2
2	D1 48	AI 48	D1 6	AI 6	C02 12	AIVH 12	C02 18	AIVH 18
6	D3 48	" "	D3 6	" "	C03 12	" "	C03 18	" "
10	D4 48		D4 6		D1 12	" "	D1 18	" "
14	D5 48	DTOT 48	D5 6	DTOT 6	D3 12	DTOT 12	D3 18	DTOT 18
18	D6 48	ETOT 48	D6 6	ETOT 6	D4 12	ETOT 12	D4 18	CTOT 18
22	D7 48		D7 6		D5 12	WEFA 2	D5 18	ATEST 0
26	D8 48		D8 6		D6 12	" "	D6 18	" "
30	D2 1	BIW 1	D2 7	BIW 7	D2 13	BIV 13	D2 19	BIV 19
34	D9 1	AI 1	D9 7	AI 7	C02 13	AIVH 13	C02 19	AIVH 19
38	D1 1	" "	D1 7	" "	C03 13	" "	C03 19	" "
42	D3 1	LY 1	D3 7	LY 7	C3D 13	" "	C8D 19	" "
46		LR 1		LR 7	C2D 13	LY 13	C9D 19	LY 19
50					D3 13	LR 13	C2D 19	LR 19
54					D1 13		D1 19	
58	D2 2	BIW 2	D2 8	BIW 8	D2 14	BIVW 14	D2 20	BIVW 20

GMT HH	12		15		18		21	
MM	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2
2	C02 24	AIVH 24	C02 30	AIVH 30	D1 36	AI 36	D1 42	AI 42
6	C03 24	" "	C03 30	" "	D3 36	" "	D3 42	" "
10	D1 24	" "	D1 30	" "	D4 36		D4 42	
14	D3 24	DTOT 24	D3 30	DTOT 30	D5 36	DTOT 36	D5 42	DTOT 42
18	D4 24	CTOT 24	D4 30	CTOT 30	D6 36	ETOT 36	D6 42	ETOT 42
22	D5 24		D5 30		D7 36		D7 42	ATEST 0
26	D6 24		D6 30		D8 36		D8 42	" "
30	D2 25	BIV 25	D2 31	BIV 31	D2 37	BIV 37	D2 43	BIW 43
34	C02 25	AIVH 25	C02 31	AIVH 31	D9 37	AI 37	D9 43	AI 43
38	C03 25	" "	C03 31	" "	D1 37	" "	D1 43	" "
42	C3D 25	" "	C8D 31	" "	D3 37	LY 37	D3 43	LY 43
46	C2D 25	LY 25	C9D 31	LY 31		LR 37		LR 43
50	C1D 25	LR 25	D3 31	LR 31		WEFA 5		
54	D1 25		D1 31			" "		
58	D2 26	BIVW 26	D2 32	BIVW 32	D2 38	BIVW 38	D2 44	BIW 44

GMT HH	01		04		07		10	
MM	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2
2	D1 2	AI 2	D1 8	AI 8	C02 14	AIVH 14	C02 20	AIVH 20
6	D3 2	" "	D3 8	" "	C03 14	" "	C03 20	" "
10			E1 8		D7 14	" "	D7 20	" "
14		LXI 1	E2 8	LXI 7	D8 14	LXI 13	D8 20	LXI 19
18		AW 2	E3 8	AW 8	D9 14	AW 14	D9 20	AW 20
22		" "	E4 8	" "	D3 14	" "	D3 20	" "
26			E5 8					
30	D2 3	BIW 3	D2 9	BIW 9	D2 15	BIV 15	D2 21	BIV 21
34	D1 3	AI 3	D1 9	AI 9	C02 15	AIVH 15	C02 21	AIVH 21
38	D3 3	" "	D3 9	" "	C03 15	" "	C03 21	" "
42			E6 9		D1 15	" "	D1 21	" "
46			E7 9		D3 15		D3 21	
50		WEFA 1	E8 9				C1D 21	
54		" "	E9 9		C2D 15		C2D 21	
58	D2 4	BIW 4	D2 10	BIW 10	D2 16	BIVW 16	D2 22	BIVW 22

GMT HH	13		16		19		22	
MM	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2
2	C02 26	AIVH 26	C02 32	AIVH 32	D1 38	AI 38	D1 44	AI 44
6	C03 26	" "	C03 32	" "	D3 38	" "	D3 44	" "
10	D7 26	" "	D7 32	" "	E1 38			
14	D8 26	LZ 25	D8 32	LZ 31	E2 38	LZ 37		LXI 43
18	D9 26	AW 26	D9 32	AW 32	E3 38	AW 38		AW 44
22	D3 26	" "	D3 32	" "	E4 38	" "		" "
26					E5 38			
30	D2 27	BIV 27	D2 33	BIV 33	D2 39	BIV 39	D2 45	BIW 45
34	C02 27	AIVH 27	C02 33	AIVH 33	D1 39	AI 39	D1 45	AI 45
38	C03 27	" "	C03 33	" "	D3 39	" "	D3 45	" "
42	D1 27	" "	D1 33	" "	E6 39			
46	D3 27		D3 33		E7 39			
50	C1D 27	LXIV 25	C1D 33	LXIV 31	E8 39	LXIV 37		
54	C2D 27	" "	C2D 33	" "	E9 39	" "		
58	D2 28	BIVW 28	D2 34	BIVW 34	D2 40	BIW 40	D2 46	BIW 46

GMT HH	02		05		08		11	
MM	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2
2	D1 4	AI 4	D1 10	AI 10	C02 16	AIVH 16	C02 22	AIVH 22
6	D3 4	" "	D3 10	" "	C03 16	" "	C03 22	" "
10		AW 4		AW 10	C3D 16	" "	C3D 22	" "
14		" "		" "			C4D 22	
18	TEST 0	ADMIN 0	ADMIN 0	TEST 0	TEST 0	ADMIN 0	ADMIN 0	TEST 0
22								
26								
30	D2 5	BIW 5	D2 11	BIW 11	D2 17	BIV 17	D2 23	BIV 23
34	D1 5	AI 5	D1 11	AI 11	C02 17	AIVH 17	C02 23	AV 23
38	D3 5	" "	D3 11	" "	C03 17	" "	C03 23	" "
42			E1 11		C5D 17	" "	E1 23	" "
46			E2 11		C6D 17	WEFA 3	E2 23	" "
50			E3 11		C7D 17	" "	E3 23	" "
54	CTH 0				CTH 0			" "
58	D2 6	BIW 6	D2 12	BIVW 12	D2 18	BIVW 18	D2 24	BIVW 24

GMT HH	14		17		20		23	
MM	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2	CH A1	CH A2
2	C02 28	AIVH 28	C02 34	AIVH 34	D1 40	AI 40	D1 46	AI 46
6	C03 28	" "	C03 34	" "	D3 40	" "	D3 46	" "
10	C3D 28	" "	C1D 34	" "		AW 40		AW 46
14	C4D 28		C4D 34			" "		" "
18	TEST 0	ADMIN 0	ADMIN 0	TEST 0	TEST 0	ADMIN 0	ADMIN 0	TEST 0
22								
26								
30	D2 29	BIV 29	D2 35	BIV 35	D2 41	BIW 41	D2 47	BIW 47
34	C02 29	AIVH 29	D1 35	AI 35	D1 41	AI 41	D1 47	AI 47
38	C03 29	" "	D3 35	" "	D3 41	" "	D3 47	" "
42	C5D 29	" "	E1 35				E1 47	
46	C6D 29	WEFA 4	E2 35			WEFA 6	E2 47	
50	C7D 29	" "	E3 35			" "	E3 47	
54	CTH 0				CTH 0			
58	D2 30	BIVW 30	D2 36	BIVW 36	D2 42	BIW 42	D2 48	BIW 48

SOME VISIBLE IMAGE FORMATS ARE SUBJECT TO SUPPRESSION DUE TO SEASONAL UNDERILLUMINATION

Appendix C Stucture of a PIF-Header.

A description of the general PIF-format can be found in VCS manuals (1989, VAX-SAT Structure of processed image files). An explanation of the calibration parameters can be found in MDN (1989). The total length of the header is 256 bytes.

```
c   1. PIF-group
      integer*1        pifk           ! number of integer*1s per pixel
      integer*2        pifn           ! number of records per line
      integer*4        pifl           ! number of lines
      integer*4        pifc           ! number of columns
      integer*1        spare1(5)
c   2. NAV group
      integer*1        navfunc        ! navigation function code (nr of projection see page 30)
      integer*4        navloff        ! line offset (VCS units)
      integer*4        navcoff        ! column offset (VCS units)
      integer*4        navlres        ! line resolution (VCS units)
      integer*4        navcres        ! column resolution (VCS units)
c   2.2 optional navigation parameters
c   2.2.1 specific parameters for (METEOSAT) PIFs
        integer*2      navpdusline                  ! METEOSAT line number of PIF-line 1
        integer*2      navpduscol                   ! METEOSAT column numberof PIFcolumn 1
        integer*2      navpdusstep2                 ! METEOSAT line number step
                                                    ! from PIF-line to next PIF-line multiplied by 2
c   2.2.2 variable parameters for general use
        integer*1      navdata(89)                  ! function specific data
c   3. DAT group
c   3.1 Mandatory data description parameters
      integer*1        datf                         ! data function code (type of data, see page 39)
      integer*1        datnam(16)                   ! data name (e.g. TEMP2)
      integer*1        datenh(16)                   ! default enhancement (name of colourtable)
c   3.2 Optional data description parameters
c   3.2.1 Specific parameters for files generated by SATMHRPROC (VAX-PDUS)
        integer*1      datpdusgrid                  ! greylevel for grids
c   3.2.2 Specific parameters for general use
        integer*1      spare2(30)
c   4. SRC group
c   4.1 Mandatory source parameters
      integer*1        srcobj(16)                   ! source object (e.g. METEOSAT4)
      integer*2        srcyear                      ! source year (xxxx)
      integer*2        srcday                       ! day of year
      integer*2        srchour                      ! time (hhmm)
c   4.2 Optional source parameters
c   4.2.1 Source parameters for METEOSAT images generated by SATMHRPROC
        integer*4      srcpduscal                   ! absolute calibration value * 10E5 (set to 0 for VIS)
        integer*2      srcpdusspc                   ! space count * 10 (set to 0 for VIS)
        integer*2      srcpduscalday                ! Julian day of calibration (set to 0 for VIS)
        integer*1      srcpduscalslot               ! calibration time slot set to 0 for VIS)
        integer*4      srcpdusbbc1                  ! space view mode BB count * 10E3 (0 for VIS)
        integer*2      srcpdusbbsd1                 ! st dev of space view mode BBC*100(0 for VIS)
        integer*4      srcpdusbbc2                  ! nominal cal mode BB count * 10E3 (0 for VIS)
        integer*2      srcpdusbbsd2                 !st dev of nominal cal mode BBC*100(0 for VIS)
        integer*4      srcpdusbb1t                  ! temperature of cold BB *100/K
        integer*4      srcpdusbb2t                  ! temperature of hot BB *100/K
        integer*1      srcpdusgain                  ! gain IR/WV/VIS1 or VIS4
        integer*1      srcpdusgain2                 ! gain VIS2 or VIS3
        integer*1      srcpdusdetflags              ! detector flags (0=off,1=on)
bit0-IR1  bit1-IR2  bit2-WV1  bit3-WV2  bit4-VIS1  bit5-VIS2  bit6-VIS3  bit7-VIS4
        integer*2      srcpdusimstat                ! image status flags (1=true)
bit0 - horizon analysis  bit1 - spin speed fit  bit2 - orbit offset fit
bit3 - sampling rate fit  bit4 - attitude refinement  bit5- aut landmark registration
bit6 - actual image frame movement based on landmark results
bit7 - calculation of deformation vector field  bit8 - geometrical processing  completed
bit9 - rectification complete  bit10 - ampl processing completed  bit11-bit15- set to 0
c   4.2.2 Optional source parameters for general use
      integer*1                     spare(8)
```

Appendix D Position of the sun

Detailed information about the calculation of the position can be found in Sonntag (1989). A procedure to estimate the solar elevation is given in Holtslag and van Ulden and summarized here:

$sl = 4.871 + 0.0175\ d + 0.033 \sin(0.0175\ d)$

sl: solar longitude (radians); d: day number ($\cong 30\ (\text{month} - 1) + \text{day}$)

$\delta = \arcsin[0.398 \sin(sl)]$

δ: solar declination

$h = -\lambda_w + 0.043 \sin(2sl) - 0.033 \sin(0.0175d) + 0.262\ t - \pi$

h: hour angle; λ_w: western longitude (radians); t: universal time (hours)

$\sin(se) = \sin\delta \sin\phi + \cos\delta \cos\phi \cos h$

se: solar elevation; ϕ: latitude (radians)

Using this procedure the accuracy for se is better then 0.05 radians

In addition we can calculate the solar azimuth (sa) using Jackson (1987,p23)

$\cot(sa) = [\cos\phi \tan\delta - \sin\phi \cos h] / \sin h$

Appendix E Description of input data files for data retrieval

The retrival routines may use three different input files: Fileconv.DAT, Fileprod.DAT and Printpifdef.DAT. In manual mode the contents are only used as defaults, in automatic mode the contents of the files are essential. In all three files information in additional records is not used by the retrieval routines.

Fileconv.DAT contains the file specifiation of the image file which is used as input.
Fileprod.DAT contains the file specifiation of the image file which is produced after extraction or conversion.

Format of both files:

record 1	Default file keyword (Directory specification), character string, no quotes.
record2	Filename, character string, no quotes.

The file extension may be given in either record (but not in both).
The use of logical names is permitted.

Example of Fileconv.DAT or Fileprod.DAT

```
dua0:[knmi.pdus.results}.C16
temporary
<EOF>
```

Printpifdef.DAT contains the specifications for extraction or printing/showing of the image data.
Format:

record 1	p or t	data shown on terminal or printed on printer
record 2	y or n	if y: high resoultion VIS data averaged to obtain low resolution if n: high resoultion VIS data sampled to obtain low resolution
record 3	integer n	only every nth pixel is shown/printed/extracted
record 4	first column	
record 5	last column	
record 6	first line	
record 7	last line	

Example of Printpifdef.DAT

```
p
y
2
2100
2200
1120
1200
<EOF>
```

Appendix F Description of input and output data files for radiative transfer calculations (author H.The)

Format description of the input files of Transfer(7) and Atmcor(7)

All data files can be given in free format. The following input files may be needed:

- Shellinput.DAT
- Stdinput.DAT (not for band model)
- Radiosonde files (not necessary for a horizontal path)
- Filter file (no other files are require if only a temperature/radiance table must be produced)
- Satellite data (only for Atmcor(7)).

Shellinput.DAT

This file contains information that is needed for file management and some initializations. The first part is always used, the second part is optional and is needed only to run the automatic version of the Transfer. In the manual version, the records 1, 3 and 6 are used as default values, whereas the information of record 7,10, and 11 must be supplied manually.

The name of the directories in record 1,2 and 4 should not be closed with a bracket: e.g.: $DISK1:[the instead of $DISK1:[the].

If running the automatic version, the parameters in records 1-7 are fixed during the whole run. When using Atmcor(7) it is not possible to combine Lowtran6 and the band model in one run. The model choice must be done manually at the beginning of the program. The indication L/B in record 11 of Shellinput.DAT is neglected.

Format:

part 1

record 1 directory name for the radiosonde files (max. length: 35 char)
(when using the automatic version, this is overruled by the specification in record 8)

record 2 directory name for the filter files (max. length: 35 char)

record 3 name of filter file (7 char)
(NB: take only the identifier part}

record 4 directory name for storage of results (max. length: 35 char)

record 5 boundary conditions at the top of the atmosphere (used by Lowtran):
altitude [m]
pressure [mb]
temperature [°C or K]

record 6 'Z'/"C'
(letter indicating whether the satellite zenith angle or the geographical coordinates of the site is included. Note that the geographical coordinates are used to calculate the zenith angle of METEOSAT. If no METEOSAT data are used this option should not be implemented.)
angle1, angle2 [deg.]
(If 'Z' then angle1 indicates the zenith anlge. If 'C' then angle1 indicates the latitude and ANGLE2 the longitude.)
emission coefficient for water

part2

record 7 logical, indicating whether all data are to be saved (TRUE) or not (FALSE)

record 8 number of files that are listed in record 9-11

record 9 directory, containing the radiosonde file(s), specified in record 9.
(max. length: 35 char)

record 10 radiosonde filename (max . length: 50 char)
(Wild cards are accepted. If wild cards are used, it only counts for one file in record 6)

record 11 'L'/'B'
(letter, indicating whether Lowtran or band model is run)
version
(6 or 7. Obsolete)
initial altitude [m]
(the altitude is rounded to the nearest altitude from the radiosonde file. An initial altitude of -9999 indicates that the program runs the calculations for initial altitudes of 1km, 2km, etc. for the same radiosonde file.)
indication for default surface temperature or manual input
(0 is default value, i.e. the value is adopted from the radiosonde data or from the surface temperature, as indicated by the radiosonde file. Additional information is given at the description of the radiosonde file. Any other value can be used to indicate manual input.)
stepsize frequency calculations
(used in Lowtran only. Set stepsize to 10 cm-1 for a suitable value)

record9/11 are repeated as often as indicated in record 8.

Example of Shellinput.DAT:

```
$DISK2:[THE.RS
$DISK2:[THE.FILTER
M02IR1X
$DISK2:[THE.RESULT
'c'   43.67  4.8  1.
11000. 230. -60.
.false.
2
$DISK2:[THE.RS.DAY12
zcra*.*
'L'  7  0.  0  10.
$DISK2:[THE.RS.DAY17
zcra*.*
'B'  7  0.  0  10.
<EOF>
```

Stdinput.DAT (not needed for when running band model)

The first part of Stdinput.DAT contains input data for both Lowtran6 and Lowtran7. The second part contains additional data for Lowtran7. For a user supplied model-atmosphere or radiosonde data, the first 2 parameters in card 1 must be: MODEL=7 and ITYPE=2 (for an upward radiative path to space) or ITYPE=3 (for a downward path from space). For a horizontal path, MODEL=0 and ITYPE=1.

Format:

part 1 (page numbers refer to the manual of Lowtran6, Kneizys et al 1983)

record 1 MODEL, ITYPE,IEMSCT,M1,M2,M3,IM,NOPRT,TBOUND,SALB (p 83-84)
N.B.: for radiation at top of the atmosphere into upward direction, ITYPE must be 2 (i.e. radiation between two levels).

record 2 IHAZE,ISEASN,IVULCN,ICSTL,ICIR,IVSA,VIS,WSS,WHH,RAINRT (p 84-88)

record 3 H1,H2,ANGLE,RANGE,BETA,RO,LEN (p 91-92)
The radiative path is from H2 to H1. H1 and H2 must be given in km (shortest distance: 0.0001 km).
A radiative path from H2 to space is indicated by: H1=999. In this case, the actual calculations will be performed between the initial altitude given by record 11 (or manual input) and the altitude, given by record 5 in Shellinput.DAT. H2 will be neglected.
For a horizontal path, the altitude is determined by H1.
The zenith angle is always given between 0° and 90° (also for upward radiation)

record 4 IRPT (p. 96)

part 2 (page numbers refer to the manual of Lowtran7, Kneizys et al 1988)

record 5 IMULT,M4,M5,M6,MDEF (p. 21-23)

record 6 comment. Aid to determine the character position in record 7.

record 7 JCHAR(14) (p 31-32)
This value must be 'ABD   ' (internal use only . It does not interfere with the types used in the radiosonde files).

Example of Stdinput.DAT:

```
7, 2, 1, 0, 0, 6, 1, 1, 0., 0.,              ! CARD1
0, 0, 0, 0, 0, 0, 0, 0., 0., 0., 0.,         ! CARD2
999., 0., 0., 0., 0., 0., 0,                 ! CARD3
0,                                  ! CARD5
0,6,6,6,1,                                            ! CARD1 additional data for LT7
C12345678901234  position in JCHAR ! LT7
'ABD            ',                                    ! CARD2C1 additional data for LT7
<EOF>
```

Radiosonde files (not necessary for a horizontal path)

Name: Zxxxddtt.RSD
xxxddtt can be any identifier of 7 characters. However, if this file is also used to calculate the surface temperature with program ATMCOR.FOR then the 'dd' and 'tt' have to indicate day and time (hour). For a horizontal path the data that are required to determine the atmospheric conditions are given manually.

Format:

record 1 <u>number of RSdata</u>
<u>pressure at ground level</u> [mbar]
<u>initial altitude</u> [m]

'Z'/'P'
(indicates whether data for altitude are given in meters or in mbar)
'D'/'M'
(indicates whether data for humidity are given as dewpoint or mixing ratio)
true surface temperature [K or °C]

This temperature is only needed in automatic mode. Missing data are indicated by -9999. The surface temperature is neglected if the initial altitude (record 11 in Shellinput.DAT) is greater than the ground level or if the indicator for default surface temperature (record 11) is 0. In the latter case, the surface temperature is taken identical to the air temperature at the given level. If the initial level is the ground level and the surface temperature is missing but not automatically set to the default value, then no calculations are performed and the program skips to the next case.

Note that the air temperature just above the ground surface is usually different from the surface temperature.

record 2 altitude [m or mbar]
temperature [K or °C] no additional indication needed
humidity (dewpoint [°C or K] or mixing ratio)
record 2 is repeated as often as indicated in record 1.

Example of radiosonde file: ZCRA0512.RSD

```
 16  1008.6  2. 'p'  'd' 309.9
  1008.6    23.7     6.0
  1000.0    22.4     5.7
   974.9    18.9     5.4
   950.0    16.8     3.8
   925.0    14.6     2.8
   900.0    12.3     2.1
   850.0     6.9     1.2
   800.0     6.5    -6.2
   750.0     3.8   -12.6
   700.0     1.9   -18.7
   650.0    -0.9   -24.3
   611.3    -3.1   -21.9
   600.0    -3.8   -16.1
   500.0   -13.9   -26.4
   453.4   -19.7   -32.7
   316.2   -40.0   -48.6
<EOF>
```

Filter file

This file contains the filter transmittance. The wavelengths can be randomly choosen (not necessarily in regular intervals).

Name: Yxxxxxxx.FIL
xxxxxxx can be any 7-character specifier. The present structure uses: xxxxxxx=SNNFFMM, where:
S=indicates the satellite;
NN=satellite number;
FF=filter type;
MM=filter number.

Format:

record 1 calibration factor (no longer used)
record 2 number of data. This should be less than 40.
record 3.. wavelength (µm)
transmittance.

Example of filter file: YM02IR1X.FIL

```
0.533
20
10.13, 0.000,
10.26, 0.009,
10.39, 0.058,
10.53, 0.176,
10.67, 0.454,
10.81, 0.722,
10.96, 0.837,
11.11, 0.906,
11.27, 0.951,
11.43, 1.000,
11.59, 0.869,
11.76, 0.797,
11.94, 0.628,
12.12, 0.475,
12.31, 0.360,
12.50, 0.165,
12.70, 0.041,
12.90, 0.015,
13.11, 0.004,
13.33, 0.000,
<EOF>
```

The following filter files are available and ready for use:

YM02IR1X.FIL	IR filter for METEOSAT2
YM02WVXX.FIL	WV filter for METEOSAT2
Y_PEIR26.FIL	2.6μ filter (Koshiek)
Y_PEIR42.FIL	4.2μ filter (Koshiek)

Satellite data file (only for Atmcor(7))

The file name is requested by manual input.
The corresponding radiosonde file must be available, otherwise the case will be skipped.
The data can be given in an arbitrary sequence. At most 31 different day can be stored.

Format

Format per record (indefinite number of records):
imonth, iday, itime, temperature (free format)
Time is in hours and must be an integer (0-23). Day and time correspond with dd and tt in the radiosonde filenames.
Month is a dummy variable.
Temperature in Kelvin.

Format description of the output files of Transfer(7) and atmor(7)

The output from the Lowtran models differ from the output of the KNMI band model. The band model gives the upward and downward radiation for each layer. Lowtran only gives the radiation, measured by the observer, so that two separate calculations are necessary to calculate both upward and downward radiation. On the other hand, Lowtran gives the results for the bands separately and the band model gives an integrated radiance. The width of the Lowtran bands is determined manually (non-auto version) or by Shellinput.DAT (record 11), if running the auto-version.

The results are stored in Bmresult.OUT/Ltresult.OUT. The output files can be renamed by the user and stored in a separate directory. Before each run, all previous versions of Bmresult.OUT and Ltresult.OUT are deleted.

If running the automatic version, it is possible to save the complete output or the calculated temperature only. In that case, the data are stored in Summary.OUT.
The data that are stored in Summary.OUT are:
— for Lowtran: initial altitude, atmospheric radiation, satellite temperature, surface temperature and weighted transmission; and
— for the band model: radiation, fluxes and temperatures at the initial level and at the top of the atmosphere.

If the option in record 7 of Shellinput.DAT is set TRUE then Bmresult.OUT, c.q. Ltresult.OUT is automatically renamed after each cycle and stored into the directory, selected in Shellinput.DAT using the new filename xxxddttMMTT.OUT, where
xxxddtt is adopted from the radiosonde file;
MM is 'BM', 'L6' or 'L7';
TT is the surface temperature in Kelvin, omitting the first digit (if the temperature is 285 K, then TT='85'; if the temperature is 306 K, then TT='06').

The results from Atmcor(7) (satellite temperature and calculated surface temperature) are stored in Corresult.OUT

Appendix G Source codes of daytemp.FOR, geodis.FOR, geolam.FOR, meteolam.FOR

In this Appendix the source codes for those utility programs which can not simply be derived from the information given in this report. Daytemp is identical to the program given in Parton and Logan (1981), except that some essential typing errors have been corrected.

```
      subroutine daytemp(phour,pmin, pmax, kjulday, ptemp)
c     Purpose
c     This subroutine calculates the surface temperature on time 'phour'
c     from the maximum and minimum temperature and the daylength which
c     is calculated from the daynumber
c
c     Method
c     A combination of a sine during the day and an e-power during the night
c     is used, see Parton en Logan, Agric Met 23, p205-216, 1981.
c     In this version the station is located at a latitude of 52 degrees.
c     The time should be local time.
c
c     Interface
c     call (daytemp(phour,pmax,pmin,ptemp)
c     phour   input   time of day
c     pmax    input   maximum temperature
c     pmin    input   minimum temperature
c     kjulday input   julian day
c     ptemp   output  temperature at phour
c
c     Author
c     S.H. Muller, KNMI 19890309

      Implicit none
      real    phour, pmax, pmin, ptemp
      integer kjulday

      real    za, zb, zc                !constants, see Parton en Logan
      real    zphi                      !latitude of station (radians)
      real    zpi                       !pi
c determination of length of day and night:
      real    zdelta,zt1,zt2,zday,znight
      real    zsunrise,zsunset          !time of sunrise/sunset
      real    zreltime!time relative to sunrise/sunset
      real    ztempsunset               !temperature at sunset
      real    zhulp

      zpi = 3.1415927
      za = 0.5
      zb = 2.0
      zc = -0.18
      zphi = 52.0
      zphi = zpi * zphi /180.

      zdelta = 0.4014 * sin(2.*zpi*(kjulday-77.)/365.)
      zt1 = sqrt(  1. - (-tan(zphi)*zdelta)**2  )
      zt2 = -tan(zphi) * tan(zdelta)
      zday = (atan2(zt1,zt2)/zpi)*24.
      znight = 24. - zday

      zsunrise = 12. - zday/2. + zc
      zsunset = 12. + zday/2.
      if ((phour.ge.zsunrise) .and. (phour.le.zsunset)) then
c day time
              zreltime = phour-zsunrise
              ptemp = (pmax-pmin)*sin((zpi*zreltime)/
     +                (zday+2*za)) + pmin
```

```
      else
c night time
              if (phour.gt.zsunset) then
                    zreltime = phour-zsunset
              else
                    zreltime = (24.- zsunset) + phour
              endif
              zhulp = zday - zc
              ztempsunset = (pmax-pmin)*sin((zpi*zhulp)/
     +              (zday+2*za)) + pmin
              ptemp = pmin + (ztempsunset-pmin) *
     +              exp(-zb*zreltime/znight)
      endif
      return
      end
```

---

program geodis

```
c     Purpose
c     This program calculates the great circle distance between two points on
c     the earth surface of a circular sphere with radius 6371000 meter
c

      Implicit none
      Real*4  zphi1,zphi2,zlambda1,zlambda2,zpi,zd,zr,zrtd

      zr = 6371.
      zpi = atan(1.)*4.
      zrtd = zpi/180.
      write (*,*) 'soutern hemisphere, western longitudes negative'
1000  write (*,*) ' '
      write (*,*) 'latitude,longitude first point'
      read (*,*) zphi1,zlambda1
      write (*,*) 'latitude,longitude second point'
      read (*,*) zphi2,zlambda2
      zphi1 = zphi1*zrtd
      zphi2 = zphi2*zrtd
      zlambda1 = -zlambda1*zrtd
      zlambda2 = -zlambda2*zrtd
      zd = (2.*zpi*zr/360./zrtd)*acos( sin(zphi1)*sin(zphi2) +
     1        cos(zphi1)*cos(zphi2)*cos(zlambda1-zlambda2) )
      write (*,*)
      write (*,*) 'distance ',zd, ' km'
      go to 1000
      end
```

---

subroutine geolam(plambda2,pzphi2,plambda3,pzphi3)

```
c     Purpose
c     this program converts geo coordinates to 'shifted' geoLAM coordinates
c
c     Method
c     Using the calculation of great circle distance and initial direction
c     the polar sterographic projection is turned until 60N,0E is at 0N,0E
c     D distance(excluding constant), H initial direction
c     phi1,lambda1 origin first:(60N,0E) later:(0N,0E)
c     phi2,lambda2 with restpect to (60N,0E) destination which must be
c     converted to phi3,lambda3 with respect to (0N,0E)
c     cos(D) = sin(phi1)*sin(phi2) + cos(phi1)*cos(phi2)*cos(lambda1-lambda2)
c     cos(H) = ( sin(phi2)-sin(phi1)*cos(D) ) / ( sin(D)*cos(phi1) )
c
c      'soutern hemisphere, western latitudes negative'
c
c     Interface
c     call geolam(plambda2,pzphi2,plambda3,pzphi3)
```

```
c      plambda2        input          geolongitude, degrees
c      pzphi2          input          geolatitude, degrees
c      plambda3        output         shifted LAM longitude, degrees
c      pzphi3          output         shifted LAM latitude, degrees
c
c      Externals
c      none
c
c      Author,date Muller,KNMI,890517
c

       Implicit none
       Real*4  pzphi3,pzphi2,plambda3,plambda2,zphi1,zlambda1
       real*4 zphi2,zlambda2
       real*4  zpi,zrtd
       real*4  zsp1,zcp1,zsp2,zcp2,zcp3,zhulp

       zpi = atan(1.)*4.
       zrtd = zpi/180.
       zphi1 = 60. *zrtd
       zlambda1 = 0. * zrtd

       zphi2 = pzphi2*zrtd
       zlambda2 = plambda2*zrtd

       zsp1 = sin(zphi1)
       zsp2 = sin(zphi2)
       zcp1 = cos(zphi1)
       zcp2 = cos(zphi2)

       zhulp = zsp1 * zsp2 + zcp1 * zcp2 * cos(-zlambda2-zlambda1)
       pzphi3 = asin(   (zsp2 - zsp1*zhulp ) / zcp1 )
       zcp3 = cos(pzphi3)
       plambda3 = acos( zhulp/zcp3 )
       if (zlambda2.lt.0) plambda3 = - plambda3

       pzphi3 = pzphi3/zrtd
       plambda3 = plambda3/zrtd

       return
       end
```

```
       subroutine  meteolam(kmetcol,kmetline,klamcol,klamline,
       1      plamlonorg,plamlatorg,knumcol,knumline,
       1      plamcincr,plamlincr,kindent,
       1      oscherm,kstatus)

c      Purpose
c      Conversion from Meteosat to nearest LAM grid coordinates
c
       implicit none
       integer*2       kmetcol,kmetline         !Meteosat line and column
       integer*2       klamcol,klamline         !lam nearest line and column
       real            plamlonorg               !corner LAM grid, longitude
       real            plamlatorg               !corner LAM grid, latitude
       integer         knumcol,knumline         !size LAM grid
       real            plamcincr,plamlincr      !distance between gridpoints LAM
c                                                         in shifted LAM coordinates
       integer         kindent                           !scan mode LAM
       logical*1       oscherm                           !output to screen
       integer         kstatus                           !kstatus=0 OK

       real*4          zphi,zlambda             !LAM shifted coordinates
       real*4          zlong,zlat               !geographical coordinates
       integer*2       inz,iwe                           !scan direction lam
       integer*4       idir,iret                !parameters convpd
```

```
      real*4          zmetcol,zmetline

      idir = 1
      iret=0
      kstatus = 0
      inz = 1
      iwe = 1

c conversion Meteosatcoordinates to geographical coordinates
      zmetcol = kmetcol
      zmetline = kmetline
      call convpd(idir,zmetcol,zmetline,zlong,zlat,iret)
      if (iret.ne.0) go to 9000

c conversion geographical coordinates to shifted LAM coordinates
      call geolam(zlong,zlat,zlambda,zphi)

      if (oscherm) then
        write (*,*) ' in convpd met c,l:' ,zmetcol,zmetline
        write (*,*) ' from convpd long,lat:' ,zlong,zlat
        write (*,*) ' from geolam long,lat:' ,zlambda,zphi
      endif

c decoding of lam origin position
      if (btest(kindent,1)) inz=-1   !offset on south side
      if (btest(kindent,2)) iwe=-1   !offset on east side
      if (oscherm) write(*,*) ' nz, 1=n->z',inz,' we,1=w->e',iwe

c determination of lam grid point, depends on grid filling mode
      if (btest(kindent,0)) then              !vertical grid filling
      if (oscherm) write (*,*) ' vertical grid filling'

      klamline = 1 + nint( (zlambda-plamlonorg) / inz / plamcincr)
      if ((klamline.le.0).or.(klamline.gt.knumline)) go to 9010

      klamcol = 1 + nint( (plamlatorg - zphi) / inz / plamlincr)
      if ((klamcol.le.0).or.(klamcol.gt.knumcol)) go to 9020

      else                                    !horizontal grid filling
      if (oscherm) write (*,*) ' horizontal grid filling'

      klamcol = 1 + nint( (zlambda-plamlonorg) / iwe / plamcincr)
      if ((klamcol.le.0).or.(klamcol.gt.knumcol)) go to 9020

      klamline = 1 + nint( (plamlatorg - zphi) / inz / plamlincr)
      if ((klamline.le.0).or.(klamline.gt.knumline)) go to 9010

      endif   !btest

      goto 10000
c errorhandling

9010  if (oscherm) write(*,*) ' meteolam: lamline out of range',
      1       ' kindent =',kindent
      kstatus=1
      go to 10000

9020  if (oscherm) write(*,*) ' meteolam: lamcol out of range',
      1       ' kindent =',kindent
      kstatus=1
      go to 10000

9000  if (oscherm) write(*,*) ' meteolam, convpd: ',
      1       ' Meteosatlines out of range'
      kstatus=1
      go to 10000

10000 return

      end
```