SATELLITE DATA DERIVED ESTIMATES OF EROSION PARAMETERS FOR REENTRY VEHICLES

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This pilot study investigates derivation of reentry vehicle erosion parameter estimates based on the inference of rain rate and hydrometeor liquid water content from microwave imagery data from the Defense Meteorological Satellite Program (DMSP) sensors. Specifically, this research focuses on the evaluation of Special Sensor Microwave/Imager (SSM/I) brightness temperature data to obtain a climatology of intense precipitation at selected relevant land-based sites for a four-month summer period. An integral element of the study is the identification of convective cloud models to support the analysis of hydrometeor liquid water content from the inferred surface rainfall rates.

The study consisted of four tasks: (1) development of SSM/I rain rate climatology, (2) development of hydrometeor liquid water content parameterization, (3) application of liquid water parameterization, and (4) documentation.

Software was implemented to (a) read the SSM/I TDRs from the acquired SSM/I data tapes, (b) calibrate and antenna pattern correct the data to obtain brightness temperatures, (c) bin the data according to the location of each desired site by latitude and longitude, (d) apply the rain rate retrieval algorithm to the data, and (e) evaluate relevant climatologies. The latter included four-month summer time series of average rainfall rate, spatial standard deviation, and hydrometeor integrated liquid water content for eleven Eurasian sites.
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1. INTRODUCTION

Reentry vehicle erosion is an adverse environmental impact on weapons delivery systems with potential significance. This phenomenon which directly affects the accuracy of reentry trajectories is attributable to mechanical ablation of vehicle aerodynamic surfaces during reentry due to interaction with atmospheric ice clouds and solid or liquid hydrometeors (i.e. precipitation). Assessment of existing or prediction of future erosion severity potential requires an understanding of the temporal and spatial distribution (i.e. climatology) of contributing meteorological conditions. These include both high altitude cirrus cloud and convective activity at lower altitudes. Thus, appropriate analyses and observation techniques are necessary to characterize cloud and hydrometeors. This report focuses on the latter issue. In particular, due to the site specific nature of the erosion problem, analyses are required at specific land based locations.

Significant effort has been devoted to the development of analysis techniques based on time/altitude cross section analyses to identify regions of likely convective activity (Feteris et al., 1976; Hardy, 1979). These approaches supported by radiosonde and surface station data were labor intensive and subject to the sparcity of available surface and upper air data. For the latter reason, for example, questions of spatial representativeness are always present (Bunting and Touart, 1980). Due to the level of effort involved in implementing these approaches, they are unsuitable for application to large scale climatological studies.

Both cloud and hydrometeors can be observed globally using satellite based sensors (Isaacs et al., 1986). Previous application of visible and infrared satellite imagery data to the cloud problem is discussed by Conover and Bunting (1977). The advent of remotely sensed microwave imagery such as that from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) provides the capability to directly sense hydrometeor liquid water content (Savage et al., 1987). Due to the radiative transfer physics relevant to the remote sensing of precipitation, the phenomenology of rain rate retrieval is different over land and oceans. This is due to the inherent differences in land type and ocean surface emissivities (Isaacs et al., 1989). Retrieval techniques have been identified to provide quantitative measurements of rainfall rates over the ocean based on microwave imager data (Wilheit et al., 1977) and oceanic climatologies have been developed (NASA, 1976).

Due to the spatial variation of emissivities over land and temporal features such as snow (which have signatures similar to precipitation), there are caveats related to the retrieval of rain rate over land. However, in optically thick situations when surface contributions to measured brightness temperatures are small, precipitation can be inferred. Such optically thick cases are those which characterize intense convection and these can be mapped over land (Spencer and Santek, 1985). The recently completed SSM/I calibration/validation study provides further confidence in the validity of seeking quantitative inferences of rain rate over both ocean and land. The specific analysis tool available in this regard is the rate rate retrieval algorithm developed by the University of Wisconsin research group (Olson et al., 1988).

While rainfall rate brightness temperature relationships have been validated based on the MJCS 154-86 requirements for precipitation measurements, the physics of the reentry erosion phenomenon indicates that a knowledge of the liquid water content profile is necessary. This can be achieved by adoption of a suitable model of the vertical distribution of liquid water content resulting in the desired surface rainfall rate. The selection of the meteorologically appropriate liquid water content vertical distribution model is important due to the relationship between liquid water content and radiometric signature through the dropsize distribution (Falcone et al., 1979). For example, many investigators commonly use the Marshall Palmer (1948) relationship which was derived for stratiform rain. Erosion severity is a function of precipitation severity and, therefore, convective situations are of greater potential interest. For these cases, other relationships are likely valid (Ulbrich, 1983; Willis and Tattleman, 1989).
This research study applies SSM/I based precipitation remote sensing technology to the characterization of reentry vehicle erosion environments over selected sites. Three complementary areas of investigation were identified in our study proposal: (a) data acquisition and application of the SSM/I rain rate retrieval algorithm to the development of a four month summer climatology of rain rate over selected sites with an emphasis on the identification and analysis of heavy rain rate situations, (b) identification and assessment of appropriate convective cloud models to establish a parameterization of the relationship between surface rainfall rate and the vertical profile of hydrometeor liquid water content, and (c) testing of the parameterization of hydrometeor liquid water content on the determination of liquid water content profiles for selected cases with emphasis on intense convection. These issues are explored in the following sections.

2. BACKGROUND

2.1 Rain Rate Retrieval Concepts

At microwave wavelengths, precipitation sized droplets provide a source of atmospheric attenuation analogous to the effect of cloud droplets in the infrared spectrum (Savage, 1978; Falcone et al., 1979). This attenuation mechanism suggests a direct causal relationship between rainfall and microwave atmospheric emission which has been exploited to infer rainfall rate (Weinman and Wilheit, 1981). Furthermore, the presence of precipitation within the field of view of microwave sensors is itself of considerable interest since the quality of resultant retrievals of other quantities is most certainly degraded (Liou et al., 1981). For example, microwave sounding brightness temperatures such as those from the SSM/I must be corrected for rain in much the same way as infrared radiances are for cloud. To provide a theoretical microwave brightness temperature/rainfall rate relationship applicable to rain rate retrieval, models of both the rain layer (including a rain layer height and thickness) and of rain microphysics are required. These models determine the vertical distribution of hydrometeor liquid water content. Both of these factors, of course, vary synoptically introducing some uncertainty into the retrieval process.

Collectively, these factors determine the atmosphere's scattering and absorption contribution to total satellite incident brightness temperature which is evaluated as a multiple scattering calculation assuming that the rain layer fills the field of view. Microwave radiative transfer theory accounting for multiple scattering has been extensively applied to the study of atmospheric precipitation and clouds (Weinman and Guetter, 1977; Wilheit et al., 1977; Tsang and Kong, 1977; Jin and Isaacs, 1985). The surface background against which the rain is modeled consists of surface emission and surface reflected atmospheric contributions, which must be included.

Over the ocean, surface emissivity is low and relatively uniform, providing good contrast for the quantification of precipitation. This approach was applied over the ocean by Wilheit et al. (1977) to data from the NIMBUS 5 Electronically Scanning Microwave Spectrometer (ESMR) operating at 19.35 GHz. Accuracies of 2 mm/h and a dynamic range up to about 20 mm/h were achieved using ground based radar for validation. Results based on retrievals obtained using the Seasat and Nimbus 7 SMMR instruments, for example, indicate that the retrieved rainfall rates generally underestimate those measured at the surface with rain gages (cf. Gloerson et al., 1984). Lipes (1982) found that the Seasat SMMR failed to detect showery precipitation associated with convective cloud in midlatitudes and underestimated rain rates for heavy precipitation. This behavior was attributed to both loss of incremental sensitivity to precipitation at higher rainfall rates and insufficient sensor resolution (about 30 km at 37 GHz) in convective situations. Sensor resolution plays a role since intense precipitating cells with horizontal scales of a few kilometers will not fill the microwave radiometer's field of view. Similar results were obtained in midlatitudes by Alishouse (1983).

Theoretical calculations suggest that over land, higher frequency, dual polarized measurements can distinguish atmospheric scattering due to rain from surface contributions (Savage and Weinman, 1975; Weinman and Guetter, 1977; Huang and Liou, 1983).
However, in practice the dynamic range of measurable rainfall rates is so much reduced at
37 GHz that these measurements are virtually useless and considerable ambiguity of
surface and atmospheric contributions still exists. In addition to the problems of specifying
appropriate rain models and obtaining measurements over land, another problem arises
because the typical horizontal scale of precipitating cloud elements is generally much less
than the field of view of the ESMR instrument (50 km). Integration over a large field of
view creates a negative bias which underestimates instantaneous rainfall rates. In spite of
these difficulties, areas of intense precipitation can be identified (Spencer and Santek,
1985). Based upon the above discussion, there will be some difficulties in providing
accurate rain rates in intense convective situations from microwave data alone. The rainfall
rates in the higher ranges of the desired domain will almost always be due to energetic
convective cells with spatial scales on the order of a few kilometers which cannot be fully
resolved with the 25 km FOVs of the SSM/I instrument. In such cases it has been noted
that high rain rates are always associated with minima in the equivalent blackbody
temperature (EBBT) field observed from infrared imagers (Negri and Adler, 1987a,b).
The converse of this is not true, however, i.e., low EBBTs can be due to other than
precipitation, therefore, it is advantageous to exploit both microwave (for lower rain rates
and to identify the presence of intense convective precipitation) and infrared (at higher rain
rates) data. At the higher rain rates (and to help in the determination of beam filling at
lower rates), OLS infrared imager data can be used. The specific approach adopted could
be based on that described by Adler and Negri, 1988. They used GOES imager data to
delineate convective rain areas by searching for minima in the EBBT field and then
assigned rain rates based on the results from a one dimensional cloud model which
provided the relationship between convective development (cloud top height) and the
resulting rain rate. Stratiform rain rates were delineated based on EBBT threshold criteria.
Due to level of effort constraints, however, this study will focus on the use of SSM/I data
alone to derive convective rainfall climatology.

2.2 SSM/I Data Characteristics

The Defense Meteorological Satellite Program (DMSP) Special Sensor
Microwave/Imager (SSM/I), launched on 19 June 1987, is a passive microwave radiometer
which provides brightness temperature data of particular relevance to the monitoring of
global precipitation properties. The SSM/I sensor antenna observes seven microwave
channels (three dual polarized frequencies: 19.35, 37.0, and 85.5 GHz and a vertically
polarized channel at 22.235 GHz) and scans conically with an angle of incidence on the
surface of the earth of 53.1 degrees (Savage et al., 1987). Using a single antenna to span
this frequency range results in a sensor field-of-view (FOV) which varies with frequency:
about 50 km at the two lowest frequencies, 25 km at 37 GHz, and 13 km at 85.5 GHz.

The exact spatial resolution of each FOV depends on the definition used and the
antenna response pattern. Based on the polar orbiting DMSP satellite, SSM/I data
potentially provides global coverage daily, with twice daily coverage possible at northern
latitudes due to orbital overlap. SSM/I data are archived through the DoD-NOAA Shared
Metsat Processing agreement by NOAA/ NESDIS through the Cryospheric Data
Management System (CDMS) at the National Snow and Ice Data Center (see Weaver et al.,
1987). These data consist of both satellite data records (SDRs, i.e. the calibrated
brightness temperatures) and environmental data records (EDRs, i.e. the retrieved
parameters). Table 1 illustrates the sensitivity SSM/I microwave imager channels to a
variety of desired geophysical parameters (the DMSP assigned priorities for these
parameters are in brackets).

The retrieval of precipitation from SSM/I data follows the statistical method outlined
in Lo (1983) and used in simulation for SSM/I data sets in Jin and Isaacs (1987). While
simulation retrieval results suggest that the required accuracies of a few mm/h are possible
at the lower rain rates a number of important factors are often neglected. These include the
degree of beamfilling, the vertical extent of the precipitation, the rain drop size distribution,
Table 1. Microwave Imager Channel Applications

<table>
<thead>
<tr>
<th>Sensor Parameters</th>
<th>Frequency (GHz)</th>
<th>19.35</th>
<th>22.235</th>
<th>37</th>
<th>85.5</th>
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<td>Spatial resolution (km)</td>
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<td>50</td>
<td>25</td>
<td>12.5</td>
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<tr>
<td>Sensitivity (K)</td>
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<td>0.8</td>
<td>0.8</td>
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<th>Geophysical Parameters, [Priority]</th>
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<tr>
<td>Precipitation (ocean) [5]</td>
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<td>Snow cover [10]</td>
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<td>Sea ice (extent, type) [18]</td>
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<td>Sea surface temperature [8]</td>
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<tr>
<td>Wind speed (ocean) [4]</td>
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<td>Atmospheric water (total) [3]</td>
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<td>Soil Moisture [9]</td>
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<td>Vegetation (e.g. Albedo [1]</td>
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<td>Cloud Liquid Water [7]</td>
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Channels which are important for determining each parameter are indicated using the following code: * = Critical; O = Important; x = Helpful.

The temperature profile through the precipitating layer, and the presence of glaciated precipitation which can significantly alter the brightness temperature signature. These factors are often kept constant in simulations whereas they vary in the natural atmosphere. Uncertainties associated with these factors certainly impact the accuracy of rainfall rate determination, and it is perhaps more reasonable to expect that a few broad rainfall rate categories are retrievable from the SSM/I. Retrievals of precipitation (both liquid and glaciated) and surface emissivity from simulated SSM/I data were discussed in a journal article by Jin and Isaacs (1987) which also described a specially developed multiple scattering model which was designed to simulate dual polarized brightness temperatures in the presence of inhomogeneous, nonisothermal distributions of atmospheric precipitation.

The capability to simulate inhomogeneous (i.e., those varying with height) distributions of precipitation is necessary to treat the realistic variation of rain rate with altitude within developing frontal systems and the phase change (from water to ice) occurring in convective situations. In that paper brightness temperature simulations specifically applicable to the SSM/I were shown. Figure 1, for example, illustrates the dependence of simulated dual polarized 85.5 GHz brightness temperature on rain rate and the presence of an upper layer of frozen precipitation. The figure inset illustrates a model of the simulated atmosphere with a 5 km rain layer over the ocean surface and either a 3 km ice layer or another 3 km rain layer above. It can be seen from these results that due to enhanced multiple scattering at this frequency, the brightness temperature is significantly lowered by the ice layer. At lower frequencies such as 19.35 GHz, the ice layer has little or no effect and, therefore, using the multispectral SSM/I data, the phase of the upper levels of precipitation can be identified in the retrieval/analysis procedure in addition to the rain rate. This provides a method to probe the vertical structure of the precipitation.

A significant calibration/validation effort (Olson et al., 1988) has focused on the SSM/I precipitation retrieval algorithm. The resulting investigation provides simple formulae to obtain rainfall rates over ocean and land and addresses the loss of the 85.5V channel data. The latter issue is of significance for the inference of rain rate over land. We propose to employ the most recent land regression coefficients obtained from the University of Wisconsin group. The steps in the retrieval are essentially: (1) antenna pat., (2) apply existing SSM/I precipitation screening logic, and (3) apply
regression formulae for rain rate. Step (1) is part of the coding available with the compacted SSM/I data from Remote Sensing System, Inc. (F. Wentz, personal communication). The coding for steps 2 and 3 will be obtained via GL from the University of Wisconsin. We note that due to the additional computational load imposed by the antenna pattern correction step, it might be prudent to develop a prescreening algorithm to identify precipitating situations directly from the antenna temperatures themselves. If this is possible, only those cases identified need be antenna pattern corrected.

2.3 Convective Cloud Models

As discussed in the previous section, the SSM/I retrieval algorithm provides rain rate as an output parameter although the radiative transfer physics indicates that radiometer brightness temperatures are fundamentally sensitive to hydrometer liquid water content (LWC). Assessment of reentry vehicle erosion indices require determination of a hydrometeor liquid water content vertical profile. The required interface between surface rainfall rate and LWC profile is a model of the vertical distribution of hydrometeors appropriate to the observed synoptic situation. Previous studies such as Peirce et al. (1975) have focused on the applicability of specific hydrometer LWC models for this purpose. Notably, Falcone et al. (1979) have specified climatological cloud and hydrometeor liquid water content models applicable to the simulation of microwave and millimeter wave data sets which provide strawman cloud model candidates as functions of precipitation intensity categories (i.e. light, moderate, heavy). Since the application driven climatological emphasis will be on the delineation of convective precipitation, our focus will be on convective cloud models.

Table 2 provides a list of candidate models which characterize a range of synoptic situations, including: frontal rain, thunderstorms, tropical squall lines, and cumulus towers. For example, a simple one-dimensional convective cloud model is that based on the work of Cotton (1972a,b) and Simpson and Wiggert (1969). The model dynamics are
Table 2. Candidate Convective Cloud Models

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<td>Tropical Squall Line</td>
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<td>Tropical Storm</td>
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</tr>
<tr>
<td>Convective Cloud</td>
<td>Cotton, 1972a,b</td>
</tr>
</tbody>
</table>

based on the conservation of vertical momentum including the buoyancy effects of perturbation temperature and liquid water loading. Physical processes included in this simple model are the latent heating by condensation, entrainment of environmental air, conversion of cloud liquid water to rain (and its fallout), and the freezing of condensate. The microphysical parameterizations are kept intentionally simple, both in the interests of run time and because of the likely uncertainties in the input data. In Section 5, we discuss the hydrometeor cloud model in greater detail and identify parameterization for stratiform and convective precipitation.

3. TECHNICAL APPROACH
3.1 Rain Rate Estimation Procedure

A functional flow diagram of the project analysis approach is shown in Figure 2. The essential steps are: (a) reading of the SSM/I TDRs from the acquired SSM/I data tapes, (b) calibration and antenna pattern corrections applied to the data to obtain brightness
temperatures, (c) geographical binning of the data according to the location or each desired site by latitude and longitude, (d) application of the rain rate retrieval algorithm to the data, and (e) evaluation of relevant climatologies. The last step includes calculation of time series for the four month period for the rain rate and integrated liquid water content of precipitation. The latter time series required adoption of appropriate hydrometeor cloud models which are described in Section 5.

The software for reading the SSM/I tapes was implemented on the Air Force Geophysics Laboratory Interactive Meteorological System (AIMS) cluster (Gustafson and Felde, 1988). The unmodified software was run and its performance verified. Certain modifications of the software were made to enhance this project's performance. The first aspect of the software modification concerned the performance time of the entire package. In its unmodified form, the tape reading package took about 8 hours to read an entire SSM/I data tape. Since there are 32 tapes, at best a minimum of 32 tape reads will have to be performed, which would translate into over 6 weeks of work just to extract the data necessary for this project. After closely examining the individual modules and command/data flow design of the software, we optimized the performance time such that it now takes: slightly more than 1 hour to read a data tape. The data extracted by the modified software has been verified and validated compared to data extracted by the unmodified package. Software was developed that: (a) loaded the site locations into the program, and (b) filtered the input data stream from any SSM/I data tape such that it would determine "local" data points relevant for each site, and group them into respective data sets. The data is binned using the exact latitude/longitude coordinates of each site such that a region defined by a square, whose center is the point in question, is generated. Any data points which fall within this defined region are considered associated with the point in question. Upon completion of this filtering, a file for each region is written, containing the data observed by the SSM/I for the time period in question. Software to read the SSM/I tapes and do the geographical binning by site is contained in Appendix A. A sample output from the tape reading algorithm is contained in Appendix B. Output are the time (number of seconds since the SSM/I sensor was first turned on), latitude, longitude and brightness temperatures for 19.35 v,h, 22.235, and 37 v,h GHz. The 85.5 GHz channel is read in a second pass due to the different sampling.

A data display software package was also prepared that utilizes NCAR and GKS routines to project the user's choice of either an orthographic, or cylindrically equidistant projection of the earth, and then superimposes either the data observed for a specific site, or the surface scan track for the SSM/I sensor during the periods in question. This software is given in Appendix C. Sample map output illustrating the data density as a function of site at various scales is shown in Appendix D.

Software was also written to evaluate the desired climatologies. These elements include: (a) the calculation of average rain rates and spatial standard deviations within each site region, and (b) the evaluation of liquid water content and integrated liquid water content time series based on the adopted hydrometeor cloud parameterization. This software is also provided in Appendix A.

3.2 SSM/I Data Set

A list of the SSM/I data used in this study is given in Appendix E. Provided are: (a) the tape number, (b) the beginning and end time of data set, and (c) the number of files.

The data files were acquired as part of this study and are available for further analysis. The software capabilities assembled and developed during the course of this pilot study, i.e. data reading, data categorization, data plotting, and data analysis, should be generally applicable to the analysis of this SSM/I data set.

While no comprehensive examination of the data set was made for purposes other than those of this study, it should be noted that this global data set should be extremely useful for a variety of other study purposes.
4. SSM/I RAIN RATE CLIMATOLOGIES

4.1 Eurasian Sites

The study focused on eleven USSR stations of the Environmental Definition Program. Data on these sites was obtained from GL. The eleven sites are: (a) Aktyubinsk, (b) Blagoveschensk, (c) Chita, (d) Kiev, (e) Leningrad, (f) Moscow, (g) Murmansk, (h) Perm, (i) Semipalatinsk, (j) Simferopol, and (k) Tashkent. The latitude and longitude coordinates for these sites used in the study can be found in subroutine "estreg" in Appendix A.

Of these sites, Murmansk is the northernmost and Tashkent is the southernmost. Blagoveschensk and Chita are in the far east bordering China. Leningrad, Moscow, and Kiev are the most western sites. Murmansk is the only coastal site. For the purposes of this study all of the sites were treated as land based.

This study did not call for the collection or investigation of conventional data sources such as surface and upper air data which might be available for these locations or for the comparison of the SSM/I derived rainfall rate climatologies with these data. In retrospect, this is an important consideration. Essentially, the subsequent analysis assumes that the statistical relationship between rain rate and brightness temperature inherent in the SSM/I algorithm regression coefficients (which were validated over the United States and the United Kingdom), are equally valid over the set of Eurasian sites.

4.2 Site Specific Rain Rate Climatologies

Referring to the data flow diagram presented in Figure 2, the next step in the data processing is the coding and application of the University of Wisconsin SSM/I rain rate retrieval algorithm to the four month data set. This has been accomplished. Data for each of the eleven sites was binned according to lat/long and time tag and rain rate retrievals were performed as a function of field-of-view within 400 km boxes centered at each site. This bin size was selected somewhat arbitrarily, however, consideration was given to capturing precipitation events of synoptic scale which passed in the vicinity of the site as well as mesoscale/convective activity. Considerations of time-space sampling for area-averaged precipitation (WMO, 1985) were considered in formulating our approach, however, there was insufficient time to fully explore these issues.

In addition to the spectral information available in the SSM/I brightness temperature data used to derive the surface rainfall rates, it was recognized that the spatial distribution of rain within the binned area could be used for the purpose of helping to characterize the meteorological properties of the situation. This information is particularly useful to aid in the selection of an appropriate parameterization of precipitation liquid water content (both vertical distribution and integrated) based on the SSM/I derived surface rain rates. It is the liquid water content which can be related to reentry vehicle erosion.

For this reason, both the average daily rain rate (defined as the simple arithmetic average of the individual SSM/I derived rain rates falling within the site specific bin) and the spatial standard deviation (SD) within the bin were evaluated to analyze the spatial coherence of the rain rate field. These data were plotted as time series to produce rain rate climatologies for each site for the four month period. Climatologies for each site are illustrated in Figures 3-13. Illustrated are average rain rate (Figs 3a-13a) and standard deviation (Figs. 3b-13b), respectively. The time series are labelled in days from 1 June 1989, the beginning of the four month data set. All time series plots have been put on a common scale (truncated at 2.5 mm/h) so that intercomparisons can be made.

Examining Figure 7a for Leningrad, it can be seen that there are obvious high (in a relative sense averaged over 400 km squares) rain rate situations (e.g. days 60-65) and low rain rate days (e.g. days 35-45). The standard deviations are also illustrative (Fig. 7b). For days 60-65, the high rain rates are accompanied by a large spatial standard deviation (also days 27-30, 75, and 82). This might be indicative of cellular convection. Moderate rain rates with smaller standard deviations might indicate more uniform precipitation. The Leningrad data set does not show this behavior.
Figure 3a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 3b. Sample time series of SSM/I derived rain rate: standard deviation.
Figure 4a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 4b. Sample time series of SSM/I derived rain rate: standard deviation.
Figure 5a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 5b. Sample time series of SSM/I derived rain rate: standard deviation.
Figure 6a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 6b. Sample time series of SSM/I derived rain rate: standard deviation.
Figure 7a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 7b. Sample time series of SSM/I derived rain rate: standard deviation.
**MOSCOW**

Figure 8a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 8b. Sample time series of SSM/I derived rain rate: standard deviation.
**MURMANSK**

**Figure 9a.** Sample time series of SSM/I derived rain rate: average rain rate.

**Figure 9b.** Sample time series of SSM/I derived rain rate: standard deviation.
Figure 10a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 10b. Sample time series of SSM/I derived rain rate: standard deviation.
Figure 11a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 11b. Sample time series of SSM/I derived rain rate: standard deviation.
Figure 12a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 12b. Sample time series of SSM/I derived rain rate: standard deviation.
Figure 13a. Sample time series of SSM/I derived rain rate: average rain rate.

Figure 13b. Sample time series of SSM/I derived rain rate: standard deviation.
In addition to the time series, we can look at the contoured daily SSM/I derived rain rates for given sites. This gives the opportunity to study the structure of the precipitation for a desired day at the resolution of the SSM/I footprints. An example is shown in Figure 14 for Moscow. Based on the time series data given in Figures 8a,b, the figure illustrates: (a) a low rain, high SD case (day 15, [4]), (b) a high rain, high SD case (day 44, [0.4]), and (c) a high rain, low SD case (day 61, [0.2]), and (d) a low rain, low SD case (day 95, [0.1]). The numbers in brackets are the contour intervals on each plot in mm/h. A heavy convective cell can be seen in Figure 14a, but there is little precipitation elsewhere resulting in a very low average rate for the region. Cells of moderate intensity can be seen in Figures 14b,c also. In these cases most of the region is active resulting in high average rainfall rates. In Figure 14d by comparison, there is light rain throughout the region (note the contour interval changes). The importance of examining both the average rainfall rate and the spatial standard deviation in characterizing an event is obvious.

4.3 Discussion

The type of meteorological event resulting in precipitation is likely to be related to the distribution of hydrometeor signatures within the region examined. High standard deviation indicates that the precipitation is scattered over the area of the view box, e.g. convective type precipitation, and the low standard deviation means the rainfall is uniform over the area of the view box, e.g. stratiform type precipitation. If high rainfall rate is associated with high standard deviation, it might be precipitation from individual thunderstorms. The passage of a frontal rainband, on the other hand, could be characterized by high rainfall rate associated with low standard deviation. The association of low rainfall rate with low standard deviation could mean the passage of a warm front, and/or precipitation from stratiform cloud. If low rainfall rate associates with high standard deviation, it could mean that the weather system which causes precipitation passes through only part of the view box. The other possibilities of low rainfall rate with high standard deviation could indicate that the weather system is too weak to produce a sufficient amount of precipitation and/or the environment is too dry, thus only part of the rainfall could be detected at the surface when the weather system passes through the view box.

Regions of convective and stratiform precipitation are hard to define, because several well-developed and decaying convective cells might still overhang into the stratiform region (Tao and Simpson, 1989). Therefore, it is hard to use the rain rate to clearly define the type of precipitation. From the data, we can see that the two stations located at the eastern part of the USSR have higher rainfall rate and higher standard deviation. The difference between these two stations might be that individual thunderstorms occur in Blagoveschensk more than Chita. Although both data show that the frontal rainfall occurs very often at both sites. It might be that the Blagoveschensk site is much closer to the ocean. Other sites have less rainfall rate and show the situation of steady precipitation occurs more frequently in these locations, despite the fact that some individual thunderstorms (maybe afternoon thunderstorms) occurred in the period.

We employ these spatial coherence concepts to the application of our precipitation cloud models (Section 5) to the determination of integrated hydrometeor liquid water content in Section 7.

5. CONVECTIVE CLOUD MODEL PARAMETERIZATIONS

Task 2 required definition of cloud models to relate SSM/I derived surface rain rates to precipitation liquid water content. We have completed this task by defining parameterizations of liquid water content vertical distribution and total integrated liquid water content of precipitation for stratiform and convective rain with the capability to decide between the two using the spatial coherence data derived from the SSM/I rain rate fields.
Figure 14. Sample contour map of SSM/I derived rain rate.
5.1 Cloud Process Overview

The formation of raindrops or ice crystals involves complicated microphysical and dynamical processes. The thermodynamical effects from the phase changes of water in turn affect the evolution of the weather system in which those processes are embedded. Several papers have studied the dependence of the formation of precipitation on microphysical and dynamical processes. The results show that both the microphysical and the dynamical processes are important. For example, the growth and fallout of rain can interact with the updraft, or can evaporate in the subsaturated downdraft region, which in turn, affects formation of the hydrometeors. Since measurement of the microphysical processes is difficult, the only way to simulate these processes is to parameterize them with respect to the large scale dynamical motion. Due to recent theoretical developments and laboratory experiments, several models have been proposed to treat these processes and some of the results have been compared with the measurements from the field experiments.

In this study we conducted a survey of different hydrometeor cloud models focusing on those which can be used to simulate the vertical distribution of liquid water content based on the surface precipitation rate. A simple parameterized relationship based on climatological statistics is derived and the vertical distribution of the liquid water content is expressed as a function of height and surface rainfall rate.

5.2 Review of Cloud Vertical Distribution Models

5.2.1 Simulation Studies

A high correlation between cloud top height and rainfall rate has been shown by Zawadzki and Ro (1978) and Dennis et al. (1975). Adler and Mack (1984) used a one dimensional cloud model to study the relationship of the thunderstorm cloud height-rainfall rate and the cloud height-volume rainfall rate with satellite infrared data. The variation of the vertical velocity and precipitation efficiency has been shown to dominate both the slopes and the difference of the two curves which represent the relation between the cloud top height and the rainfall rate. Information on the convection from numerical model output is needed to derive the cloud-rain relationship, and the vertical shear is considered to be the important parameter to estimate the volume rainfall rate.

Larger scale factors such as the synoptic environment, topographical situation, and the location of the station with respect to the thunderstorm or frontal rainband are important in determining the desired relationship. Therefore, empirical rain estimation techniques developed in one area cannot be applied directly to other areas. Simple adjustments may be inadequate because of differences in slopes of rainfall rate-height in different locations. To determine convective rain rate and the volume rain rate, the moisture source, the vertical velocity, and the rain efficiency are important. Additionally, the updraft area is important in determining the volume rain rate. Ideally all of these data should be used to adjust the value of the input parameters to get a more representative profile. Thus, full use of a numerical cloud model with the inclusion of the adequate dynamical processes is necessary.

Kessler (1959, 1961, 1963) devised parameterized equations for microphysical processes (cloud water and rain) with an assumed vertical motion profile and water generation function. Simpson and Wiggert (1969) used a one dimensional cloud model with the Kessler (1965) type of parameterization to study the precipitation in tropical cumulus clouds. The microphysical processes include the autoconversion from cloud water to precipitation water, collection and coalescence, terminal velocity, and fallout of the precipitation with the evaporation due to entrainment of drier air in a downdraft. The initial conditions include the information from the sounding data: the saturation at cloud base or lifting condensation level at environment temperature, the excess of the temperature at cloud base, and the vertical velocity at the cloud base. The assumptions made with the above model rule out the feedback between the microphysical and dynamical processes in the
model. The new model corrects this problem and the results are more reasonable. However, the treatment of the ice phase is insufficient and, therefore, the parameterization needs to be updated in order to include the ice phase change effect. The results from this study reveal that more complicated microphysical processes should be introduced and the interaction with dynamical effects should be included. The amount of the rain which reaches the ground as precipitation cannot be calculated in the context of this study and, therefore, we cannot use the information of the surface rainfall rate to derive the vertical distribution of the liquid water content.

Cotton (1972a, 1972b) studied precipitation processes within the supercooled cumuli environment, and the interaction between the microphysical process and cloud dynamics. Precipitation formation in warm clouds (1972a) and a model which includes the ice phase (1972b) have been studied. A more complicated parameterization to simulate the microphysical processes in midlatitudes, which includes the processes of phase change between cloud ice, snow and graupel, cloud water and rain water has been developed by Lin et al. (1983). This parameterization is used in the study by Rutledge and Hobbs to investigate the precipitation within warm clouds (1983) and seeded ice phase (1984) environments. Three different precipitation zones categorized according to the surface precipitation rate are described in the study. Their results are in a good agreement with those from field experiments.

Tao and Simpson (1989) use the Kessler type of microphysical (cloud water and rain water) and Lin et al. (1983) parameterizations (cloud water, rain, cloud ice, snow and graupel) to study the structure of tropical squall-type convective lines. Two-dimensional models and three dimensional models have been used. The role of the ice-phase and the mesoscale ascent in middle and high-levels has also been investigated. The model output of the ice runs have been compared with that of the ice-free runs. The results show that the ice-phase microphysical processes are crucial for a realistic stratiform structure and its precipitation statistics. Also, their results show that the mesoscale ascent in the middle level was the main mechanism responsible for the extended region of the stratiform precipitation at the rear of the squall line, which has been suggested by Rutledge (1986).

5.2.2 Measurement Studies

Wei et al. (1989) use five different methods to estimate path-integrated (columnar) cloud liquid water. The methods include one-channel (31.65 GHz) and two-channel (20.6 GHz and 31.65 GHz) physical retrievals, the standard method of linear statistical inversion using two channels, and two statistical methods that proceed from an initial determination of several empirical regressions between measured and computed quantities. With brightness temperature data and/or the absorption coefficients (for oxygen, the water vapor and the cloud), the optical thickness of the clear air and the cloud water can be calculated. The calculation of cloud water content with microwave radiometer data is encouraging, however, their results lack comparison with independent observations, e.g. radar.

During the period of interest, there is no precipitation occurring in the study of Wei et al. (1989), thus they only estimate the cloud water content without estimating the precipitation amount. The study needs sounding data (vertical distribution of pressure, temperature, humidity, and cloud water content), and knowledge of the absorption coefficients to resolve the answer. Also, a hypothetical liquid water profile from an archival sounding needs to be specified in order to calculate the radiative transfer. These conditions require almost the same effort of running a more sophisticated dynamical cloud model.

Heymsfield and Fulton (1988) studied the measurement of precipitation in thunderstorms from high altitude remote aircraft. In their studies, the comparisons between the microwave data at 92 GHz and 183 GHz with the data from radar, lidar or GOES IR data reveal that using 92 GHz microwave data to detect the rainfall area is advantageous. The liquid water content (LWC) or ice water content (IWC) can be calculated based on the
convective area, IWC for the snow aggregates in the convective region and IWC in nonprecipitating anvil region. The relation of the rainfall rate with the vertical liquid and/or ice structure is unclear in this study.

Wilheit et al. (1982) used the 19.35 GHz and 183 GHz data from a microwave radiometer to study the precipitation in a tropical storm. The tendency of the rainfall rate can be matched by the tendency of the brightness temperature at 92 GHz, and the 183 GHz providing some information on the vertical extent of the frozen hydrometeors. This is a more direct way to determine the vertical distribution of the liquid water, and it is worth further study.

5.3 Discussion

Simpson and Wiggert (1969), Cotton (1972a,b), Rutledge and Hobbs (1983, 1984) and Tao and Simpson (1989) used cloud models to simulate the spatial distribution of the liquid water distribution. Since the vertical distribution of liquid water depends on the stage of evolution, the position away from the core of the updraft and the type of the system, the dynamical processes are as important as the microphysical process. Forvell and Ogura (1988) found that the addition of ice was responsible for the achievement of more realistic scale features in the convective region of the simulated squall line. More complex microphysical process which included the ice-phase parameterization have been simulated by Lin et al. (1983). Rutledge and Hobbs (1984) and Tao and Simpson (1989) show that the model output is in good agreement with the field experiment data. The two-dimensional cloud model of Tao and Simpson (1989) is capable of simulating stratiform precipitation and the areal coverage of the stratiform region. Therefore, if a numerical approach is desired, it is recommended to use this cloud model for the stratiform precipitation cases.

The model of the Rutledge and Hobbs (1984) is good in the situation of frontal rain bands and convective precipitation. In order to obtain the vertical structure of the liquid water from model output, several initial conditions are needed. Using this model requires the specification of additional sources of information. Since the liquid water field from model output is specified at each grid point, a simple relationship between the vertical distribution of liquid water field and surface rain fall rate is unnecessary. If we have more specific description of the liquid water field, the snow field and the cloud water field, the total liquid water content in a column can be obtained by integrating vertically. Also, the rainfall rate is determined by the conditions of the environment, such as the relative humidity, the wind shear and updraft. Therefore, it is hard to find a simple relationship which will satisfy all of the dynamical conditions in determining the vertical distribution of liquid water depending on the surface rainfall rate alone.

An alternative approach to derive a simple relation between the surface rainfall rate and the vertical distribution of liquid water content is using the climatological record. From the result of Adler and Mack (1984), the height-rainfall rate relation is different from place to place. For example, high rainfall rate for moderate and small storms occurs in the coastal regimes, while fairly deep convection in Midwest thunderstorms produces only moderate rain rate (Adler and Mack, 1984). Therefore, our derivation of the relationships between the surface rainfall rate and the vertical distribution of the liquid water content based on the climatological data depend on the geographical distribution too.

In the study of Adler and Mac (1984), the statistical retrievals of columnar liquid water and water vapor are found to be more accurate than physical retrievals. Therefore, we will use the climatological data to derive the simple relationship based on the vertical distribution of the liquid water content from Falcone et al. (1979). The important features of these distributions are (see Figure 15):

(1) A maximum liquid water content is located between the cloud top and the surface (Rutledge and Hobbs, 1983, 1984; Tao and Simpson, 1989). From the model output, the height of the maximum liquid water content is strongly influenced by the
vertical velocity, therefore, the maximum height of the cumulus convection is normally higher than the stratiform precipitation, and

(2) The amount of the liquid water content is nearly uniform below the cloud base, or the liquid water content below the freezing level in the convective region is almost constant with height (Tao and Simpson, 1989).

5.4 Liquid Water Content/Rainrate Relationships

Based on the results from the diagnostic studies, a statistical polynomial fit like the one used in Wei et al. (1989) is used to simulate the climatological profiles for the four precipitation models given in Falcone et al. (1979). Models I-IV (pp. 46-47) correspond to two stratiform (I, II) and two convective (III, IV) models, respectively. The following conditions are used to derive the coefficients of the polynomial fits:

- the liquid water content reaching the surface, $M_S$, is derived from the rain rate retrieved from the SSM/I microwave,
- the maximum liquid water content is $M_m$ and is at height $Z_m$,
- the liquid water content at the cloud top ($Z_t$) is zero,
- the first derivation of the polynomial at the height ($Z_m$) equals zero, and
- the first derivative of the polynomial at the surface equals zero.

These values are read from Figures 14-17 in Falcone et al. (1979), see Table 3.

The relationship between the rainfall rate and the liquid water content can be found in Falcone et al. (1979) and Simpson and Wiggert (1969). We use the relationship of Falcone et al. (1979)

$$M = 0.07 \times RR^{0.83},$$

where $M$ is the liquid water content (g/m$^3$) and $RR$ is the rainfall rate (mm/h), and apply it at the surface and use $M_s$ to denote the liquid water content here.

A fourth order polynomial fit is used to simulate convective precipitation (models III and IV). The result, as shown in Fig. 15a, shows the simulation of the vertical distribution of the liquid water content with the polynomial equation and the input values of $Z_t, Z_m, M_m, M_s$ corresponding to the four precipitation categories from Falcone et al. (1979) (Models I-IV, pp 46-47), given in Table 3. The cloud top of curve 2 is lower than that specified by Falcone et al. (1979) in their Fig. 15. If we look at the curves carefully, we can find that the slope is nearly the same above and below the maximum height. In steady rain cases like stratiform precipitation, most of the cloud water and the precipitation is located in the lower troposphere. The maximum liquid water accumulation is near 1 to 2 km, the height of the maximum liquid water field is lower. Thus, if the slopes above and below the maximum height are the same, the liquid water content will vanish at a height below the specified cloud top. For this reason, only curves 3 and 4 are used to model convective rain.

A third order polynomial equation is used to simulate the stratiform precipitation. Three tests have been run with the equations satisfying four out of the five given
Figure 15. Simulation of the vertical distribution of the liquid water content with polynomial equations (see text).
Table 3. Polynomial Fit Data

<table>
<thead>
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<th>Curve</th>
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<th>Z_m (km)</th>
<th>M_m (g/m^3)</th>
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<td>6.1</td>
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<td>6.2</td>
</tr>
</tbody>
</table>

conditions. Test one satisfies the conditions 1, 3, 4, 5, test two satisfies the condition 1, 2, 3, 4 and test three satisfies conditions 1, 2, 3, 5. The test two results (Figure 15b) are the best fit for the simulation of stratiform precipitation.

The equation for the vertical distribution for the convective type of precipitation (e.g. Falcone models III and IV), is:

\[ \text{LWC} = a \cdot z^4 + b \cdot z^3 + c \cdot z^2 + d, \]

where

\[ a = \frac{-1}{z_m^5 z_t^2 - 2z_m^4 z_t^3 + z_m^3 z_t^4} \left[ (3z_m z_t^2 - 2z_t^3 - z_m^3) m_s - (3z_m^2 z_t^2 - 2z_t^3) m_m \right] \]

\[ b = \frac{-1}{z_m^5 z_t^2 - 2z_m^4 z_t^3 + z_m^3 z_t^4} \left[ (4z_m^2 z_t^2 - 2z_t^4 - 2z_m^4) m_s - (4z_m^2 z_t^2 - 2z_t^4) m_m \right] \]

\[ c = \frac{-1}{z_m^5 z_t^2 - 2z_m^4 z_t^3 + z_m^3 z_t^4} \left[ (z_m^4 - 4z_m z_t^3 + 3z_t^4) m_s + (4z_m z_t^3 - 3z_t^4) m_m \right] \]

\[ d = m_s \]

Curves 3 and 4 in Figure 15a provide the vertical distribution for convective situations.

The equation for the stratiform type of precipitation (e.g. Falcone models I and II) is:

\[ \text{LWC} = e \cdot z^3 + f \cdot z^2 + g \cdot z + h, \]

where
\[ e = \frac{-1}{z_m^2 z_i (z_i - z_m)^2} \left[ (z_i - z_m)^2 m_i + z_i (2z_m - z_i) m_m \right] \]

\[ f = \frac{-1}{z_m^2 z_i (z_i - z_m)^2} \left[ (3z_m^2 z_i - z_i^3 - 2z_m^3) m_i - (3z_m^2 z_i - z_i^3) m_m \right] \]

\[ g = \frac{-1}{z_m^2 z_i (z_i - z_m)^2} \left[ (z_i^4 - 3z_m^2 z_i^2 + 2z_i^3) m_i + (3z_m^2 z_i^2 - 2z_i^3) m_m \right] \]

\[ h = m_i \]

Curves 1 and 2 in Figure 15b provide the vertical distribution for stratiform situations for different input parameters.

The vertical integrated liquid water content is:

\[ ILWC = a/5 * Z_t^5 + b/4 * Z_t^4 + c/3 * Z_t^3 + e * Z_t + M_s \]

for the convective precipitation, and

\[ ILWC = e/4 * Z_t^4 + f/3 * Z_t^3 + g/2 * Z_t^2 + h * Z_t + M_s \]

for the stratiform precipitation.

Some studies show that the height of the cloud top and the surface rainfall rate are closely related (Dennis et al., 1975). Thus we can derive the statistics of the relationship for different sites, and rewrite the cloud top as a function of the surface rainfall rate to derived a more precise vertical distribution of the liquid water field.

5.5 Summary

These studies reveal that the formation and evolution of hydrometers have close relationships with both microphysical and the dynamical processes. The inclusion of the ice-phase parameterization is important in simulating these processes.

Since the vertical distribution of the liquid and/or ice content is highly dependent on the type of the precipitation, the evolution stage of the thunderstorm, and the distance away from the core of the thunderstorm (in the area near the convection core or in the anvil area), a simple relationship between the surface rainfall rate and vertical liquid water distribution is quite site and time specific. A climatological record of the different sites should be collected and used to derive the simulation equation. The instant observation afforded by the satellite can be used to adjust some input parameters, e.g. cloud top and surface rainfall rate, which allow the simulation to be as close as possible to the real situation.

The specific simulated liquid water field can be obtained from the results of a numerical cloud model, however, this requires a significant amount of additional data. For this reason, we have adopted vertical profile models based on climatological models requiring a minimum of input data. The relationships provide a parameterization of vertical
hydrometeor liquid water content with surface rain rate and other input such as the height of the cloud and location and magnitude of the maximum. The latter are also provided by the Falcone et al. (1979) model classes.

6. CLOUD LIQUID WATER

Recognizing the difficulties associated with low correlations between SSM/I brightness temperatures and cloud liquid water content over land (and snow), the SSM/I calibration validation team recommended that retrievals of cloud liquid water not be attempted over land (Alishouse et al., 1988). In this study we have specifically undertaken to explore the parameterization of hydrometeor liquid water content vertical distribution and integrated amount for the purpose of characterizing intense convective activity. In the absence of other data sources (e.g. visible and infrared satellite data), some correlation can be inferred between precipitation events and cloud presence. To that extent, climatological cloud models can be applied in an attempt to characterize the cloud liquid water content based on SSM/I determination of the hydrometeor properties.

To this end we have adopted the cloud models proposed by Falcone et al. (1979) which accompany his respective precipitation event vertical profiles. A relationship between rainfall rate and cloud liquid water of the form:

\[
M = 0.05 \ast RR,
\]

is proposed to provide a climatological cloud liquid water adjunct to the hydrometeor liquid water content discussed in the previous section. Following Falcone et al (1979), the vertical distribution of the cloud is assumed to have the same vertical dependence as the rain, except that its magnitude is scaled by the above relationship. Results for two sites, Tashkent and Perm are illustrated in Figures 16 and 17.

7. APPLICATION TO SELECTED PRECIPITATION EVENTS

In order to apply the liquid water content parameterizations for convective and stratiform situations defined in the previous sections, criteria had to be developed based on the mean areal rainfall rates and spatial standard deviation data available in the time series. This was accomplished by examining the ensemble properties of these two parameters for the four month study period using a simple clustering approach. The mean areal rainfall rates and spatial standard deviation for each site were plotted against one another. Results are given in Figures 18-28. These figures were plotted on the same scale so that comparisons can be made among the sites. Note that area averaging reduces local values considerably. Based on these cluster diagrams an approach was developed to differentiate between stratiform and convective precipitation regimes.

Notably there is a general similarity in the behavior of the cluster diagrams. Two regions are definable from the data. In the first region, there is a systematic increase of areal standard deviation with average rain rate. For some sites this increase is gradual and near linear (see Chita, Figure 20), while for other sites it is rapid and nonlinear (see Leningrad, Figure 22). The first region occupies the lower left quadrant of the available data. The second region occurs at higher rain rates and standard deviations than the first region, occupying more of the upper right quadrant of the data. The break points defining the transitions from region one to region two vary with site. Based on our examination of daily contours, we have defined region one to consist largely of stratiform events and region two to consist largely of convective events. There was not sufficient time in the study to provide detailed analyses to support this hypothesis. This should be explored using conventional data sources.

The implications of the categorization defined above based on examination of the cluster diagrams, is to provide criteria based on the rain rates and standard deviations to define membership in one of the clusters (i.e. either stratiform or convective) and then use
Figure 16. Cloud liquid water time series for Tashkent.

Figure 17. Cloud liquid water time series for Perm.
Figure 18. Cluster diagram for Aktyubinsk

Figure 19. Cluster diagram for Blagoveschensk
Figure 20. Cluster diagram for Chita

Figure 21. Cluster diagram for Kiev
Figure 22. Cluster diagram for Leningrad

Figure 23. Cluster diagram for Moscow
Figure 24. Cluster diagram for Murmansk

Figure 25. Cluster diagram for Perm
Figure 26. Cluster diagram for Semipalatinsk

Figure 27. Cluster diagram for Simferopol
the appropriate liquid water content relationship developed in Section 5 to evaluate time series of this and related quantities for each site.

We have applied this approach to the data for Moscow displayed in Figure 23. The Moscow cluster diagram shows a region of low standard deviation days (SD < ~1.3) with increasing rain rate (region 1) bounded by high SD days. The highest SD days are those for which the rain rates are the highest. We have defined this latter cluster as region 2 in the context of the previous discussion. Therefore, the criteria adopted for this site is that days for which the SD is less than 1.3 are defined as stratiform and others are convective. The time series corresponding to application of this criterion for Moscow is shown in Figure 29a. For comparison, Figures 29b and 29c show the same time series when it is assumed that all precipitation events are stratiform or convective, respectively.

It should be noted that this criteria applies only to the Moscow time series and that a more general criteria for other sites has not been developed. Our approach would be to develop the generalized criteria based on normalized values using the mean average rainfall rate (i.e. the mean of the time series of areal averages) and mean standard deviation (i.e. the mean of the time series of spatial standard deviations).
Figure 29a. Time series of ILWC for Moscow employing two region criteria

Figure 29b. Time series of ILWC for Moscow assuming stratiform only
To illustrate application of this approach to two additional sites the cluster diagrams were examined and Blagoveschensk and Leningrad (Figures 19 and 22, respectively) were selected. The cluster structure for Blagoveschensk is much more diffuse than for Moscow. There is a much greater variation in standard deviation which is qualitatively manifested in a much less organized stratiform arch. In this case we have based the definition of convective events on high average rainfall rate (> 1.5 mm/h) rather than on standard deviation as was done in the Moscow case. The results of applying this criterion for the determination of ILWC for the Blagoveschensk time series data are shown in Figures 30a-30c.

The cluster data for Leningrad exhibits yet another form of behavior. Rather than being diffuse as in the previous case, there is a very tight cluster of low rain rate/low standard deviation near the origin with some outlying points of higher rain rate and standard deviation. We have defined the former class as stratiform events and the latter as convective. The results of applying these criteria for the determination of ILWC for the Leningrad time series data are shown in Figures 31a-31c.

8. CONCLUSIONS

This study has established the feasibility of establishing climatologies of stratiform and convective precipitation events for site specific regions of interests based on the use of SSM/I microwave imager brightness temperature data. The application of SSM/I microwave imager brightness temperature data to the determination of precipitation climatologies for eleven selected sites has been investigated. The SSM/I precipitation retrieval algorithm has been applied to the determination of surface rainfall rates within a 400 km region surrounding each site and additionally algorithms have been developed to provide areal averaged rain rates and spatial standard deviations. A novel application of the spatial standard deviations provides information on spatial inhomogeneities of the retrieved rain rates in addition to exploiting the spectral information content of the microwave brightness temperature data.
Figure 30a. Time series of ILWC for Blagoveschensk employing two region criteria

Figure 30b. Time series of ILWC for Blagoveschensk assuming stratiform only
Figure 30c. Time series of ILWC for Blagoveschensk assuming convective only

Figure 31a. Time series of ILWC for Leningrad employing two region criteria
Figure 31b. Time series of ILWC for Leningrad assuming stratiform only

Figure 31c. Time series of ILWC for Leningrad assuming convective only
Time series of the areal averaged rain rates and spatial standard deviations have been calculated for a four month summer period for each of the sites. This climatology of precipitation events can be used to provide an indication of intense convective activity which is of interest in the determination of reentry vehicle erosion. In order to distinguish convective precipitation events, the areal averaged rainfall rates and standard deviations for each site have been displayed in cluster diagrams for the entire four month period. Based on these cluster diagrams, a set of preliminary criteria has been discussed to distinguish between stratiform and convective situations. Parameterizations of the vertical distributions of hydrometeor liquid water content for both stratiform and convective situations have been developed based on climatological precipitation cloud models. These parameterizations were developed after review of the relevant dynamical cloud model literature. Furthermore, these vertical profiles of hydrometeor liquid water content have been integrated to provide functional relationships between SSM/I retrieved surface rain rates and total hydrometeor liquid water content. Time series of the total hydrometeor liquid water content have also been provided for selected sites.

It is recognized that cloud liquid water content profiles are also desired to calculate reentry vehicle erosion parameters. While cloud liquid water content is not directly retrievable over land based on the use of the SSM/I brightness temperature data, model based and climatological correlations between the vertical distribution of hydrometeor liquid water content and that of cloud liquid water content allows for a rudimentary characterization of cloud liquid water. A simple approach correlating hydrometeor and cloud liquid water vertical distributions has been explored based on climatological models available from the microwave attenuation literature. These models assume that the cloud liquid water content is proportional to the rainfall rate and that the shape of the vertical distribution of cloud liquid water is similar to that of the precipitation. Using this approach, time series of total cloud liquid water content is also provided for selected sites.

9. RECOMMENDATIONS

As proposed this study has focused exclusively on the use of SSM/I microwave imager brightness temperature data to develop rain rate climatologies. Precipitation events are indicative of meteorological situations which are inherently problematic with respect to reentry vehicle erosion. A novel aspect of the investigation is the application of spatial coherence concepts to the characterization of precipitation regimes such as stratiform and convective which determine the vertical distribution of hydrometeor liquid water content. Rain also acts as a surrogate for the presence of cloud which is not easily measured over land with microwave sensors.

A number of avenues of additional study are recommended based on the results reported here:

- More work should be done to exploit the identification of convective precipitation using the spatial information content of the microwave data. The examination of the spatial coherence properties of each site for the study period should be augmented with conventional observations to help in stratifying the observed arches and clusters according to the nature of the precipitation event. For example, surface and upper air data should be available from ETAC to be used in the analysis;

- As noted in Section 5 it is possible to identify numerical models of precipitation dynamics to support parameterization of rain rate/liquid water content relationships. In this study we resorted to climatological relationships for expediency. A fully interactive mesoscale model could be used as a vehicle for satellite data fusion and retrieval purposes;

- The algorithms developed here can be readily applied to the examination of alternate sites and changes in the statistical computations such as the time period and spatial
averaging field. Additionally, although bandpass limited by the inherent instantaneous fields-of-view of the SSM/I data, the spatial power spectrum of precipitation events could be determined. This would provide additional degrees of freedom beyond the simple measure provided by the spatial standard deviation;

- The clustering of rain rate and spatial standard deviations can be extended to use surface observations to further stratify the precipitation regime characterization. For example, frontal and various thunderstorm categories could be added along with their respective vertical distribution models. Available surface observations should also be employed to verify and validate the SSM/I time series. This was not investigated here;

- Data fusion with sensor data sources colocated aboard the DMSP spacecraft (OLS, SSM/T, SSMI'-2) should be investigated. Visible and infrared imagery provide a means to specify the presence of cloud, cloud cover, cloud type, and cloud top height. The evolution of multispectral imagery will provide the capability to identify high, middle, and low cloud in conjunction with nephanalysis techniques (d'Entremont, 1986). The use of microwave and millimeter wave sounder channels provides a means to sense the vertical distribution of liquid water content for precipitation analogous to the “slicing” approach for clouds employed using infrared sounder channels. The SSM/T microwave temperature sounder provides a signature in each channel which is proportional to the presence of precipitation elements at altitudes characteristic of its weighting function. Grasiewski and Staelin (1989) have suggested utilizing the impact of precipitation on microwave oxygen band (60GHz) and line (118GHz) absorption to obtain precipitation vertical structure information. An application of these concepts to the profiling of hydrometeor liquid water from DMSP SSM/T data could be fruitful in this regard. This would give a direct measurement which frees one from the climatological precipitation vertical distribution models employed in this study. The vertical distribution of cloud liquid water can then be obtained using the simple climatological based correlations suggested in this study;

- The SSMI moisture sounder is also sensitive to precipitation, however, due to its shorter wavelength response, it also provides a cloud liquid water signature (Isaacs and Deblonde, 1987). Although the number of available channels (five) is not as extensive as that potentially available from an infrared sounder, the millimeter wave channels respond to cloud liquid water content which can be directly related to cloud vertical structure and erosion parameter indices. The problem of high, variable surface emissivity inherent in the use of the SSM/I imager data is mitigated by the use of the SSMI-2 sounder data. This is due to the vertical resolution properties of the sounding weighting functions which selectively sense the middle and upper tropospheric cloud liquid water (for increasingly absorbing channels of the sounder);

- Finally, it is recommended that the use of data available from civilian satellites including both the Tiros polar orbiters and the GOES geosynchronous platforms be investigated. Use of multispectral cloud imagery from the Tiros Advanced Very High Resolution Radiometer (AVHRR) can be used for multispectral nephanalysis. High resolution Infrared Sounder (HIRS) data can be used for applying the CO2 slicing method. The GOES VAS (VISSR Atmospheric sounder) provides visible and infrared imagery and infrared sounder data. GOES infrared data could be particularly useful. The specific approach adopted could be modeled on that described by Adler and Negri, 1988). They used GOES imager data to delineate convective rain areas by searching for minima in the equivalent black body brightness temperature (EBBT) field and then assigned rain rates based on the results from a one dimensional cloud model which provided the relationship between convective development (cloud top height) and the resulting rain rate. Stratiform rain rates were delineated based on EBBT threshold criteria.
10. ACKNOWLEDGEMENT

We thank Dr. Ken Champion and G. Felde of the Geophysics Laboratory for their assistance during this effort.

11. REFERENCES


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Appendix A  SSM/I Data Extraction Software
PROGRAM NAME: RDSSMI

LAST UPDATE: 28FEB90

A USER FRIENDLY, GENERALIZED PROGRAM FOR READING FROM THE
WENTZ COMPRESSED SSN/I TAPES.

BEFORE RUNNING THE PROGRAM ISSUE THE FOLLOWING VAX COMMAND:

ALLOCATE HSC19MU00: FOR001:
MOUNT/FORTRAN/DENSITY=6250/BLOCKSIZE=28544/RECORDSIZE=1784
FOR001:/COMMENT="TAPE XXX"

QUESTIONS ABOUT THE PROGRAM? CONTACT:
Mark Goodberlet
13 Marcus Hall
University of Massachusetts
Amherst, MA 01003
(413) 545-4615

program rdssmi

CHARACTER*1,IDUM

C**************

C SPECIFY COMMON /INDATA/

C**************

CHARACTER*1 LREC(1784)
INTEGER*4 KBT,IBYT,IFLAG
COMMON/INDATA/LREC,KBT,IBYT,IFLAG

DATA KBT/1/

Program set to work on VAX computer

10 CONTINUE
KFLAG=0

WRITE(6,1000)

1000 FORMAT(1/'23X,32('*')/
425X,'SSN/I DATA RETRIEVAL PROGRAM'/'34X,
L'MAIN MENU'/'23X,32('*')/'23X,
L'C = EXTRACT SENSOR HEALTH DATA'/'23X,
L'B = EXTRACT TB AND MSP SMAT DATA'/'23X,
L'H = EXTRACT ALL 850NH TA DATA'/'23X,
L'Q = QUIT'/'27X,'ENTER SELECTION <CR>: ','$}

READ(5,1100)CSSEL

1100 FORMAT(A1)

IF(CSSEL.EQ. 'C' .OR. CSSEL.EQ. 'E')CALL CALDAT(KFLAG)
IF(CSSEL.EQ. 'B' .OR. CSSEL.EQ. 'D')CALL SMATH(KFLAG)
IF(CSSEL.EQ. 'H' .OR. CSSEL.EQ. 'I')CALL SMATH(KFLAG)
IF(CSSEL.EQ. 'Q' .OR. CSSEL.EQ. 'Q')GO TO 999

C**************

C VARIABLE KFLAG INTERPRETATIONS

KFLAG=0 => INVALID OPTION SELECTED BY USER
KFLAG=1 => SUCCESSFUL COMPLETION OF A USER SELECTED OPTION
KFLAG=2 => USER SELECTED A VALID OPTION NOT AVAILABLE AT THIS TIME
KFLAG=3 => VALID OPTION SELECTED BUT EXECUTION ERROR ENCOUNTERED

C**************
RDSSMI

0058 IF(KFLAG.EQ.0)WRITE(6,2100)
0059 IF(KFLAG.EQ.2 .OR. KFLAG.EQ.0)GO TO 10
0060 WRITE(6,2200)
0061 IF(KFLAG.EQ.3) WRITE(6,2400)
0062 2100 FORMAT(///'21X,'INVALID SELECTION - PLEASE TRY AGAIN'///)
0063 2200 FORMAT(///'21X,'REWRIND THE TAPE BEFORE RERUNNING THE PROGRAM'///)
0064 2400 FORMAT(/21X, 'PROGRAM TERMINATED DUE TO ERRORS'///)
0065 999 STOP
0067 END

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COMPILATION STATISTICS

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C PROGRAM USED TO STRIP SENSOR HEALTH DATA FROM THE WENTZ SSMI TAPES   *
C NOTE:
C * ONLY A-SCAN CALIBRATION COUNTS ARE OUTPUTTED *
C * OTHER SENSOR HEALTH ITEMS AVAILABLE ARE: *
C (1) AGC SETTINGS
C (2) REF VOLTAGES 1 & 2
C (3) CALIB SLOPE VALUES
C (4) CALIB OFFSET VALUES
C (5) B-SCAN HOT AND COLD LOAD COUNTS
C******************************************************************************

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C******************************************************************************

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INTEGER*4 ITOIL, ISPAN2

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C READ PAST THE TAPE HE, IERS *
C******************************************************************************

CALL READHD

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C ****************************
C WRITE HEADERS TO THE OUTPUT FILE *
C ****************************
0081

0082 1600 FORMAT(' OUTPUT LINE #1=> SCAN TIME, 3 HOT LOAD TEMPS, ',
0083   ' RF MIXER TEMP, AND FWD RADIATOR TEMP',
0084   ' OUTPUT LINE #2=> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 19V',
0085   ' OUTPUT LINE #3=> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 37V',
0086   ' OUTPUT LINE #4=> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 55V',
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0091 IREC=0
0092 IREC2=0
0093 WRITE(6,1900)
0094 1900 FORMAT('// REC NO')
0095 10 IEOF=0
0096 11 READ(1,2000,END=12) LREC
0097 2000 FORMAT(178'A1')
0098 0100 GO TO 14
0099 0101 12 IEOF=IEOF-1
0100 0101 WRITE(6,2001) IEOF
0102 0102 2001 FORMAT(' IEOF= ',I2)
0103 0103
0104 0105 C******************************
0106 C DOUBLE END-OF-FILE MEANS END-OF-TAPE *
0107 C******************************
0108 0108 IF(IEOF .EQ. 2) GO TO 999
0109 0109 GO TO 11
0110 0111 14 CONTINUE
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LABELS

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FUNCTIONS AND SUBROUTINES REFERENCED

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<td>INT44</td>
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COMMAND QUALIFIERS

/FORM/DEBUG/LIST/NOOBJ CALDAT

/DEBUG=(SYMBOLES, Traceback)
/SHOW=(NOINPUT, NOCOPY, MAP, NODEPARTMENT, SINGLE)
/WARNINGS=(NODEPARTMENT, GENERAL, NOELDANO, NOAXL)
/CONTINUATIONS=19 /NOODERENSIONS /NOOD_LINES /NOEXTEND_SOURCE
/F77 /NOOO FLOATING /14 /NOOSMACHINE_CODE /NOOPTIMIZE /NOSPARALLEL
/NOOANALYSIS_DATA
/NOOANALYSIS_DATA
/DEBUGD/DEBUGD/DEBUGD
/IPLUSD/IPLUSD/IPLUSD
/NOOJECT

COMPILATION STATISTICS

Run Time: 1.35 seconds
Elapsed Time: 4.32 seconds
Page Faults: 293
Dynamic Memory: 400 pages
subroutine estreg (regions)

Subroutine ESTREG establishes the coordinates of 11 Eurasian sites in a 2-D array. This is a specific example. This routine can be easily modified to accept user-defined locations.

The first dimension of the 2-D array refers to the location in question. The ordering is as follows: (east longitudes!)

1 = Leningrad
2 = Kiev
3 = Simferopol
4 = Moscow
5 = Murmansk
6 = Perm
7 = Aktyubinsk
8 = Tashkent
9 = Semipalatinsk
10 = Chita
11 = Blagoveschensk

real regions(11,4), box(4)

C******************************

C Leningrad
C******************************

call geobox (59.96, 30.30, 200.00, box)
regions(1,1) = box(1)
regions(1,2) = box(2)
regions(1,3) = box(3)
regions(1,4) = box(4)

C******************************

C Kiev
C******************************

call geobox (50.40, 30.45, 200.00, box)
regions(2,1) = box(1)
regions(2,2) = box(2)
regions(2,3) = box(3)
regions(2,4) = box(4)

C******************************

C Simferopol
C******************************

call geobox (45.01, 33.98, 200.00, box)
regions(3,1) = box(1)
regions(3,2) = box(2)
regions(3,3) = box(3)
regions(3,4) = box(4)

C******************************

C Moscow
C******************************

call geobox (55.96, 37.41, 200.00, box)
regions(4,1) = box(1)
ESTREG

0115   C********************************************************************
0116   C       Blagoveschensk  :
0118   C********************************************************************
0119     call geobox (50.26, 127.50, 200.00, box)
0120   regions(11,1) = box(1)
0121   regions(11,2) = box(2)
0122   regions(11,3) = box(3)
0123   regions(11,4) = box(4)
0124     return
0125     end

PROGRAM SECTIONS

Name                   Bytes  Attributes
0 $CODE                 511    PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
1 $PDAREA               92     PIC CON REL LCL   SHR   NOEXE  RD NOWRT QUAD
2 $LOCAL                280    PIC CON REL LCL   NOHR  NOEXE  RD   WRT QUAD

Total Space Allocated  881

ENTRY POINTS

Address  Type   Name
0-00000000  ESTREG

ARRAYS

Address  Type   Name          Bytes  Dimensions
2-00000000  R*4  BOX          16     (4)
AP-00000000  R*4  REGIONS      176    (11, 4)

FUNCTIONS AND SUBROUTINES REFERENCED

Type   Name
       GEOBOX
ESTREG
01

COMMAND QUALIFIERS

/NOOPT/DEBUG/LIST/NOOBJ ESTREG
/CHECK=(NOBOUNDS, OVERFLOW, NOUNDERFLOW)
/DEBUG=(SYMBOLS, TRACEBACK)
/NOCOMMENTS, NOPLACEHOLDERS)
/SHOW=(NODICTIONARY, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEMANTIC, NOSOURCE_FORM, NOSINTAX)
/WARNINGS=(NODECRACTIONS, GENERAL, NOULTRIX, NOVAXELN)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /NOD_LINES /NOEXTEND_SOURCE
/77 /NOC_FLOATING /I4 /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOANALYSIS_DATA
/NODIAGNOSTICS
/LIST=USERSDISK_26:[BELFIORE.SSMI.SRC.RDSSMI]ESTREG.LIS:1

/NOOBJECT

COMPILED STATISTICS

Run Time: 1.08 seconds
Elapsed Time: 1.55 seconds
Page Faults: 514
Dynamic Memory: 392 pages
SUBROUTINE FDCAL
0003 INTEGER*4 IBH, IBC
0004 REAL*4 SCALE1(10)
0006 c*****************************************
0007 c SPECIFY COMMON /INDATA/
0008 c*****************************************
0010 CHARACTER*1 LREC(1784)
0011 INTEGER*4 KBT, IBYT, IFLAG
0012 COMMON /INDATA/LREC, KBT, IBYT, IFLAG
0014 c*****************************************
0015 c REAL*4 REV
0016 c*****************************************
0019 INTEGER*4 ITIME, ITMSC, IVOLT, IAGC, ICOLDA, IHTA, ICOLDB, IHTB, ISPARI
0020 INTEGER*4 ITOIL, ISPARI
0023 REAL*4 XLATSC, XLONSC, ALTSC, HLTEMP, RTTEMP, FTTEMP, CALSLP, CALOFF
0026 REAL*4 ALAT, ALON, BLAT, BLON, TALO, TAOI, TANI, TALH
0029 COMMON /OUTDAT/ REV, ITIME, ITMSC, XLATSC, XLONSC, ALTSC, HLTEMP(3), IVOLT(2), RTTEMP, FTTEMP, IAGC(6), CALSLP(7), CALOFF(7),
0032 ICOLDA(5, 7), IHTA(5, 7), ICOLDB(5, 2), IHTB(5, 2), ISPARI(2),
0035 3 ALAT(128), ALON(128), BLAT(128), BLON(128),
0038 4 TALO(5, 64), TAOI(5, 64), TANI(8, 64), TALH(4, 64), ISPARI(64)
0040 c*****************************************
0043 c DATA INITIALIZATION
0045 c*****************************************
0048 DATA SCALE1/3*1.E-2, 2*1., 2*1.E-2, 3*1.*/
0051 c*****************************************
0054 c BEGIN EXECUTION
0057 c*****************************************
0059 ITIME=INT44(KBT, LREC(1), LREC(2), LREC(3), LREC(4))
0062 REV=1. D-4*INT44(KBT, LREC(5), LREC(6), LREC(7), LREC(8))
0065 ITMSC=INT44(KBT, LREC(9), LREC(10), LREC(11), LREC(12))
0068 XLATSC=1. D-6*INT44(KBT, LREC(13), LREC(14), LREC(15), LREC(16)) - 90.
0071 ISPARI=INT44(KBT, LREC(17), LREC(18), LREC(19), LREC(20))
0074 XLONSC=1. D-6*INT44(KBT, LREC(21), LREC(22), LREC(23), LREC(24))
0077 ALTSC=1. D-3*INT44(KBT, LREC(25), LREC(26), LREC(27), LREC(28))
0080 IHTB=29
0083 DO 100 IP=1, 3
0086 HLTEMP(4-IP)=0.01*INT24(KBT, LREC(IBYT), LREC(IBYT+1))
0089 IBYT=IBYT+2
0092 CONTINUE
0095 IVOLT(2)=INT24(KBT, LREC(35), LREC(36))
0098 IVOLT(1)=INT24(KBT, LREC(37), LREC(38))
0101 RTTEMP=0.01*INT24(KBT, LREC(39), LREC(40))
0104 FTTEMP=0.01*INT24(KBT, LREC(41), LREC(42))
DO 100 IP=8,10
IAGC(11-IP)=INT24(KBT,LREC(IBYT),LREC(IBYT+1))
IBYT=IBYT+2
100 CONTINUE

DO 300 ICH=1,7
CALSF(IP,ICH)=1.E-5*INT24(KBT,LREC(IBYT),LREC(IBYT+1))
IBYT=IBYT+4
300 CONTINUE

IBC=IBYT
IBH=IBYT+70
DO 400 ICH=1,7
IBC=IBC+2
400 CONTINUE

IBH=IBH+2

DO 500 IP=1,3
IAGC(7-IP)=INT24(KBT,LREC(IBYT),LREC(IBYT+1))
500 CONTINUE

IBH=IBH+2

DO 600 ICH=1,2
IBH=IBH+2
600 CONTINUE

RETURN
END
**Program Sections**

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<td>PIC OVR REL GBL</td>
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<tr>
<td>4 OUTDAT</td>
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Total Space Allocated: 10772

**Entry Points**

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COMMAND QUALIFIERS

FORTRAN=NOOPT/DEBUG/LIST/NOOBJ FD CAL

/ CHECK= (NOBOUNDS, OVERFLOW, NOUNDERFLOW)
/ DEBUG=(SYMBOLS, TRACBACK)
/ DESIGN=(NOCOMMENTS, NOPLACEHOLDERS)
/ SHOW=(NODICTIONARY, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE)
/ STANDARD=(NOSEMANTIC, NOSOURCE_FORM, NOSYNTAX)
/ WARNINGS=(NODECLARATIONS, GENERAL, NOULTRIX, NOVAXELN)
/ CONTINUATIONS=19 /NOCROSS_REFERENCE /MOD_LINES /NOEXTEND_SOURCE
/ F77 /NOG Floating /I4 /NONUMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/ NOANALYSIS_DATA
/ NODIAGNOSTICS
/ LIST=USER$DISK26:BELFIORE.SSMI.SRC.RSMSMI/FD CAL.LIS;1
/ NOOBJECT

COMPILATION STATISTICS

Run Time: 1.33 seconds
Elapsed Time: 1.92 seconds
Page Faults: 590
Dynamic Memory: 440 pages
SUBROUTINE FDLTLK(ISCAN)
C*-----------------------------------------------------*
0004 C ISCAN = 1 ==> "ODD $ PIXEL" LAT/LON FROM "A" SCAN ARE DECODED *
0005 C ISCAN = 2 ==> ALL LAT/LON FROM "A" AND "B" SCAN ARE DECODED *
C*-----------------------------------------------------*
0007 C*-----------------------------------------------------*
0008 INTEGER*4 INDEX(19),JINDEX(3,109),IBLET,IBLEN,IBLED,ISCAN
0009 C*-----------------------------------------------------*
0011 C SPECIFY COMMON /INDATA/ *
0012 C*-----------------------------------------------------*
0014 CHARACTER*1 LREC(1784)
0015 INTEGER*4 KBT,IBYT,IFLAG
0016 COMMON/INDATA/LREC,KBT,IBYT,IFLAG
0017 C*-----------------------------------------------------*
0019 C SPECIFY COMMON /OUTDAT/ *
0020 C*-----------------------------------------------------*
0021 REAL*8 REV
0022 INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,ICHOTA,ICOLDE,ICHOTB,ISPAR1
0023 INTEGER*4 IIOTH,ISPAR2
0024 INTEGER*4 XLATSC,XLONSC,ALTSC,HLTEMP,FRTEMP,FRTEMP,CALSLP,CALOFF
0025 REAL*4 ALAT,ALON,BLAT,BLON,TALO,TANO
0026 C*-----------------------------------------------------*
0028 COMMON/OUTDAT/ REV,ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,ICOLDE,ICHOTA,ICHOTB,ISPAR1
0029 1 HLTEMP(3),IVOLT(2),FRTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
0030 2 ICOLDA(5,7),ICHOTA(5,7),ICOLDE(5,2),ICHOTB(5,2),ISPAR1(5,2),
0031 3 ALAT(128),ALON(128),BLAT(128),BLON(128),
0032 4 TALO(128),TANO(128),TANO(128),IIOTH(128),IIOTH(128),ISPAR2(64)
0033 C*-----------------------------------------------------*
0035 C DATA INITIALIZATION *
0036 C*-----------------------------------------------------*
0038 DATA RAD/0.017453293/
0039 DATA INDEX/1,9,17,25,33,41,49,57,65,73,81,89,97,105,113,121,123,
0040 1 127,128/
0041 DATA JINDEX/
0042 1 5, 1, 9, 13, 9, 17, 21, 17, 25, 29, 25, 33, 37, 33, 41,
0043 1 45, 41, 49, 53, 49, 57, 61, 57, 65, 69, 65, 73, 77, 73, 81,
0044 1 89, 81, 89, 93, 89, 97,101, 97,105,109,105,113,117,121,123,
0045 1 3, 1, 5, 7, 5, 9, 11, 9, 13, 15, 13, 17, 19, 17, 21,
0046 1 23, 21, 25, 27, 25, 29, 31, 29, 33, 35, 33, 37, 39, 37, 41,
0047 1 43, 41, 45, 47, 45, 49, 51, 49, 53, 55, 53, 57, 59, 57, 61,
0048 1 63, 61, 65, 67, 65, 69, 71, 69, 73, 75, 73, 77, 79, 79, 81,
0049 1 83, 81, 85, 87, 85, 89, 91, 89, 93, 95, 93, 97, 99, 97,101,
0050 1 103,101,105,107,105,109,111,109,113,115,113,117,119,117,121,
0051 1 125,123,127, 2, 1, 3, 4, 3, 5, 6, 5, 7, 8, 9, 11,
0052 1 10, 9, 11, 12, 11, 13, 14, 13, 15, 16, 15, 17, 14, 17, 19,
0053 1 20, 19, 21, 22, 21, 23, 24, 23, 25, 26, 25, 27, 28, 27, 29,
0054 1 30, 29, 31, 32, 31, 33, 34, 33, 35, 36, 35, 37, 38, 37, 39,
0055 1 40, 39, 41, 42, 41, 43, 44, 43, 45, 46, 45, 47, 48, 47, 49,
0056 1 50, 49, 51, 52, 51, 53, 54, 53, 55, 56, 55, 57, 58, 57, 59,
0057 1 60, 59, 61, 62, 61, 63, 64, 63, 65, 66, 65, 67, 68, 67, 69,
0058 1 70, 69, 71, 72, 71, 73, 74, 73, 75, 76, 75, 77, 78, 77, 79.
0059 1 80, 79, 81, 82, 81, 83, 84, 83, 85, 86, 85, 87, 88, 87, 89.
0060 1 90, 89, 91, 92, 91, 93, 94, 93, 95, 96, 95, 97, 98, 97, 99.
0063 1 120,119,121,121,121,123,124,123,125,126,125,127/
0064
0065 C*********************************************************
0066 C BEGIN EXECUTION                                      *
0067 C*********************************************************
0069 C SET TABLE LAT/LON FOR A-SCAN                      *
0070 C*********************************************************
0075 IBYT=263
0076 IBLT=IBYT
0077 IBLN=IBYT+38
0078 DO 100 JCEL=1,19
0079 ICCEL=INDEX(JCEL)
0080 C*********************************************************
0081 ALAT(ICCEL)=0.01*((INT24(KET,LREC(IBLT),LREC(IBLT+1))=9000)
0082 ALOM(ICCEL)=0.01*INT24(KET,LREC(IBLT),LREC(IBLT+1))
0083 IF(ALOM(ICCEL).LT.0.) ALOM(ICCEL)=ALOM(ICCEL)+360.
0084 IF(ALOM(ICCEL).GT.360.) ALOM(ICCEL)=ALOM(ICCEL)-360.
0086 IBLT=IBLT+2
0087 IBLN=IBLN+2
0088 100 CONTINUE
0090 C*********************************************************
0091 C SET MID-POINTS FOR A-SCAN                          *
0092 C*********************************************************
0094 NCEL=46
0095 IF(ISCAN.EQ.2) NCEL=109
0096 J0 200 JCEL=1,NCEL
0097 ICCEL=INDEX(1,JCEL)
0098 I1=INDEX(2,JCEL)
0099 I2=INDEX(3,JCEL)
0100 DIPLAT=ALAT(I2)-ALAT(I1)
0101 AVGLAT=0.5*(ALAT(I1)+ALAT(I2))
0102 DIFLOM=ALON(I2)-ALON(I1)
0103 IF(DIFLOM.GT.180.) DIFLOM=DIFLOM-360.
0104 IF(DIFLOM.LT.-180.) DIFLOM=DIFLOM+360.
0105 AVGLOM=ALON(I1)+0.5*DIFLOM
0106 XSQ=(2.*RAD*AVGLAT)**2
0107 XPC=(1.-16627142*XSQ-0.00807934*XSQ*XSQ-.000151880*XSQ*XSQ*XSQ
0108 ALAT(ICCEL)=AVGLAT*(1.+0.125*(RAD*DIFLOM)**2*XPC)
0109 X=RAD*(90.-ABS(AVGLAT))
0110 TANLAT=1./(X*X+X/2.)
0111 IF(AVGLAT.LT.0.) TANLAT=-TANLAT
0112 IF(ALON(ICCEL).GE.360.) ALON(ICCEL)=ALON(ICCEL)-360.
0114 IF(ALON(ICCEL).GE.360.) ALON(ICCEL)=ALON(ICCEL)-360.
FDLTLN

200 CONTINUE
IF(ISCAN.NE.2) RETURN
C SET TABLE LAT/LONG FOR B-SCAN
C NOTE THAT IDEL AND BLAT CHARs ARE READ AS SIGNED 2-BYTE INTEGERS.

DO 300 JCEL=1,19
  IDEL=INDEX(JCEL)
  LATDEL=(IDEL+30000)/1000-30
  LONDEL=IDEL+29100-1000*(LATDEL+30)
  BLAT(IDC)=.01*(INDEX(IDC),LREC(IDC),LREC(IDC),LREC(IDC))
  1=0.0000000000000002
  BLOH(IDC)=.01*(INDEX(IDC),LREC(IDC),LREC(IDC),LREC(IDC))+LONDEL)
  IF(BLOH(IDC).LT.0.) BLOH(IDC)=BLOH(IDC)+360.
  IF(BLOH(IDC).GT.360.) BLOH(IDC)=BLOH(IDC)-360.
  IBLOT(IDC)+2
  IBLN(IDC)+2
  IBLD(IDC)+2
  300 CONTINUE
C SET MID-POINTS FOR B-SCAN

DO 400 JCEL=1,109
  IDEL=INDEX(1,JCEL)
  I1=INDEX(2,JCEL)
  I2=INDEX(3,JCEL)
  DIFLAT=BLAT(I2)-BLAT(I1)
  AVGLAT=0.5*(BLAT(I1)+BLAT(I2))
  DIFLON=BLOH(I2)-BLOH(I1)
  IF(DIFLON.GT.180.) DIFLON=DIFLON-360.
  IF(DIFLON.LT.-180.) DIFLON=DIFLON+360.
  AVGLOH=BLOH(I1)+0.5*DIFLON
  XSQ=(2.*RAD-AVLAT)**2
  XAC=-1.-16617142*XSQ+0.0087934*XSQ*XSQ+.0000151880*XSQ*XSQ*XSQ
  LAT(IDC)=AVGLAT+1.00-0.125*(RAD*DIFLON)**2*XAC
  X=RAD+(-ABS(AVLAT))
  TANLAT=1.0/(X*X*X*3.)
  IF(AVLAT.LT.0.) TANLAT=-TANLAT
  400 CONTINUE
### LABELS

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<tr>
<th>Address</th>
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### FUNCTIONS AND SUBROUTINES REFERENCED

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COMMAND QUALIFICATIONS

FORTRAN/NOOPT/DEBUg/LIST/NOJF DFLTDL

/\CHECK=(NOBOUNDS,OVERFLOW,UNDERFLOW)
/\DEBUG=(SYMBOLS,TRACEBACK)
/\DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
/\SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
/\STANDARD=(NOSTANDARD,NORESOURCE_FORM,NOSTAX)
/\WARNINGS=(NODERECLARATIONS,GENERAL,NOULTRIX,NOVALLEN)
/\CONTINUATIONS=19 /\NOCROSS_REFERENCE /\NOUP#INES /\NOEXTEND_SOURCE
/\FORTRAN=1 /\NOFLOATING /\NOEXTENSION /\NOOPTIMIZE /\NOPARALLEL
/\NOSANALYSIS_DATA
/\NODIAGNOSTICS
/\LIST=USER_DISK_26:(BELFIORE.SSMI.SRC.RDSSMI|DFLTDL.LIS;1
/\NOOBJECT

COMPILATION STATISTICS

Run Time: 2.01 seconds
Elapsed Time: 2.72 seconds
Page Faults: 638
Dynamic Memory: 476 pages
SUBROUTINE FD&A(ISCAN)
0001 C**************************************************************
0002 C ISCAN=1 ==> DOES TA'S FOR A-SCAN, ODD-NUMBERED PIXELS ONLY.
0003 C ISCAN=2 ==> DOES ALL OF ISCAN=1 PLUS 85GHZ TA'S FOR ALL OTHER A-SCAN
0004 C AND B-SCAN PIXELS
0005 C**************************************************************
0006 INTEGER*4 IWORK4, IBL, IBH, ISCAN
0007 C**************************************************************
0008 C SPECIFY COMMON /INDATA/ *
0009 C**************************************************************
0010 CHARACTER*1 LREC(1784)
0011 INTEGER*4 KBT, IBY, IFLAG
0012 COMMON/INDATA/LREC,KBT,IBY,I_FLAG
0013 C**************************************************************
0014 C**************************************************************
0015 REAL*8 REV
0016 INTEGER*4 ITIME, ITMSC, IVOLT, IAGC, ICOLDA, IINOTA, ICOLDB, IINOTB, IISPAR1
0017 INTEGER*4 ITOSL, IISPAR2
0018 REAL*8 XLATSC, XLOMSC, ALTSC, XHTEMP, RHTEMP, RHTEMP, CALSLP, CALOFF
0019 REAL*8 ALAT, ALON, BLAT, BLON, TALO, TAL1
0020 C**************************************************************
0021 C SPECIFY COMMON /OUTDAT/ *
0022 C**************************************************************
0023 C**************************************************************
0024 REAL*8 REV
0025 INTEGER*4 ITIME, ITMSC, IVOLT, IAGC, ICOLDA, IINOTA, ICOLDB, IINOTB, IISPAR1
0026 INTEGER*4 ITOSL, IISPAR2
0027 REAL*8 XLATSC, XLOMSC, ALTSC, XHTEMP, RHTEMP, RHTEMP, CALSLP, CALOFF
0028 REAL*8 ALAT, ALON, BLAT, BLON, TALO, TAL1
0029 COMMON/OUTDAT/ REV, ITIME, ITMSC, XLATSC, XLOMSC, ALTSC,
0030 1 XHTEMP(3), IVOLT(3), RHTEMP, RHTEMP, IAGC(6), CALSLP(7), CALOFF(7),
0031 2 ICOLDA(5,7), IINOTA(5,7), ICOLDB(5,2), IINOTB(5,2), IISPAR1,
0032 3 ALAT(128), ALON(128), BLAT(128), BLON(128),
0033 4 TALO(5,64), TAL1(5,64), ITOSL(4,64), IISPAR2(64)
0034 C**************************************************************
0035 C**************************************************************
0036 C BEGIN EXECUTION *
0037 C**************************************************************
0038 C**************************************************************
0039 IBY = 377
0040 IBL = IBY
0041 IBH = IBY+640
0042 DO 100 IC=1,64
0043 C**************************************************************
0044 C FIND THE TA'S FOR THE 3 LOWER FREQUENCIES *
0045 C**************************************************************
0046 DO 50 ICH=1,5,2
0047 IWORK4=INT34(KBT,LREC(IBL),LREC(IBL+1),LREC(IBL+2))
0048 IBL = IBL+1
0049 ITAV=INT(IWORK4/4096)
0050 TALO(ICH,ICL)=0.1*ITAV
0051 IF(ITAV.GT.3800) TALO(ICH,ICL)=ITAV-3420
0052 ITAV=IWORK4-4096*ITAV
0053 IF(ICH.EQ.5) GO TO 60
PROGRAM SECTIONS

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Total Space Allocated: 10024

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0001 C****************************
0002
0003

COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOOBJ FDTA

/CHECK=(NOSOUNDS, OVERFLOW, NOUNDERFLOW)
/DEBUG=(SYMBOLS, TRACEBACK)
/DESIGN=(NOANNOTATION, NOLITTLE)
/SHOW=(NODICTIONARY, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSMEMATIC, NOSOURCE FORM, NOSYNTAX)
/WARNING=(NODECLARATIONS, GENERAL, NOUNTRIX, NOUNAXELN)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /MOD_LINES /NOEXTEND_SOURCE
/F77 /NOG FLOATING /I4 /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NODIAGNOSTICS
/List=USER'sDISK_26:{BELFIORE.SSMI.SRC.RDSMI}FDTA.LIS:1
/NOOBJECT

COMPILATION STATISTICS

Run Time: 1.20 seconds
Elapsed Time: 1.67 seconds
Page Faults: 555
Dynamic Memory: 396 pages
subroutine geo_box (lat, lon, dp1c, box)
  
0002  c predict the corners of a box on the earth's surface
0003  c surface given its center, and an arbitrary surface displacement
0004  c from said center. The boundary values of this box are stored in
0005  c an array for later use.
0006  c
0007  c real lat, lon, dp1c, box(4), rad2deg
0008  c real e_rad, dp1c_angle
0009  c
0010  c Earth radius (polar orbit; kilometers)
0011  c
0012  c e_rad = 6356.913
0013  c
0014  c Compute (infer) the 'corners' of a box with the given lat/lon
0015  c coordinates as its center. Return the min/max latitude and
0016  c longitude in the 4-element 1-D array "box()", the contents of
0017  c which are:
0018  c box(1) = minimum latitude
0019  c box(2) = maximum latitude
0020  c box(3) = minimum longitude
0021  c box(4) = maximum longitude
0022  c
0023  c rad2deg = 180.0 / 3.14159265
0024  c dp1c_angle = asin(dp1c / e_rad) * rad2deg
0025  c box(1) = lat - dp1c_angle
0026  c box(2) = lat + dp1c_angle
0027  c box(3) = lon - dp1c_angle
0028  c box(4) = lon + dp1c_angle
0029  c return
0030  end
PROGRAM SECTIONS

Name          Bytes   Attributes
0 $CODE       97      PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL      44      PIC CON REL LCL NOSHR NOSXE RD WRT QUAD

Total Space Allocated 141

ENTRY POINTS

Address Type Name
0-00000000 GEBOX

VARIABLES

Address Type Name Address Type Name Address Type Name Address Type Name
AP-00000000C8 R*4 DPLC 2-00000008 R*4 DPLC_ANGLE 2-00000004 R*4 E_RAD AP-000000048 R*4 LAT
AP-000000008 R*4 LON 2-00000000 R*4 RAD2DEG

ARRAYS

Address Type Name Bytes Dimensions
AP-000000010@ R*4 BOX .16 (4)

FUNCTIONS AND SUBROUTINES REFERENCED

Type Name
R-4 MTHSASIN

COMMAND QUALIFIERS

FORTRAN,NOCOPY/DEBUG/LIST/NOOBJ GEOBOX

/NOOPT=/NOBOUND,OVERFLOW,NOUNDERFLOW)
/DEBUG=(SYMBOL,TRACEBACK)
/UNIT=(NOCOMMENTS,NOLISTENERS)
/SHOW=(MODIFICATION,NOINCLUDE,MAP,NOREPROCESSOR,SINGLE)
/STANDARD=(NOSEMANTIC,NOSEX Included,NOSEX)
/GOALS=(NODEFinitions,GENERAL,NOEXIT,NOBACK)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /MOD_LINES /NOEXTEND_SOURCE
/77 /UOP FLOATING /4 /NOSEX Included /NOSEX Included /NOSEX Included
/NOASCII DATA /NODIAGNOSTICS
/LIST=USERDISK_26:[BELFIORE.SSMI.SRC.RDSSMI]GEOBOX.LIS:1
/NOOBJECT
SUBROUTINE GTLAT(GTL)
C*****************************************************************************
C  CALCULATES LATITUDE OF GROUND TRACK POINT FROM REGRESSION
C  ON SCAN PIXELS 3.63 AND 125 (IE. 2, 32, 63 IN 64 PIX SCAN)
C*****************************************************************************
REAL CF(4)
C*****************************************************************************
C  SPECIFY COMMON /OUTDAT/
C*****************************************************************************
REAL*8 REV
INTEGER*4 ITIME, ITIMSC, IVOLT, IAGC, ICOLDA, INOTA, ICOLDB, INOTB, ISPAR1
INTEGER*4 ITOIL, ISPAR2
REAL*4 XLATSC, XLOMSC, ALTSC, NLTEMP, RFTEMP, FRTEMP, CALSLF, CALOFF
REAL*4 ALAT, ALON, BLAT, BLOH, TALO, TAH1
COMMON /OUTDAT/ REV, ITIME, ITIMSC, XLATSC, XLOMSC, ALTSC,
  1 NLTEMP(3), IVOLT(2), RFTEMP, FRTEMP, IAGC(6), CALSLF(7), CALOFF(7),
  2 ICOLDA(5,7), INOTA(5,7), ICOLDB(5,2), INOTB(5,2), ISPAR1,
  3 ALAT(128), ALON(128), BLAT(128), BLOH(128),
  4 TALO(5,64), TAH1(8,64), ITOIL(4,64), ISPAR2(64)
DATA CF/-0.129,1.533,-1.928,1.411/

GTL = CF(1)+CF(2)*ALAT(3)+CF(3)*ALAT(63)+CF(4)*ALAT(125)
RETURN
END
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<tr>
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**ENTRY POINTS**

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<td>I*4</td>
<td>ICOLDI</td>
</tr>
<tr>
<td>3-00000020</td>
<td>I*4</td>
<td>ICOLDK</td>
</tr>
<tr>
<td>3-00000012</td>
<td>I*4</td>
<td>IHOTA</td>
</tr>
<tr>
<td>3-00000012</td>
<td>I*4</td>
<td>INJSTI</td>
</tr>
<tr>
<td>3-00000012</td>
<td>R*4</td>
<td>ISDA32</td>
</tr>
<tr>
<td>3-00000012</td>
<td>R*4</td>
<td>ITOIL</td>
</tr>
<tr>
<td>3-00000028</td>
<td>R*4</td>
<td>IVOLT</td>
</tr>
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<td>3-00000028</td>
<td>R*4</td>
<td>TANI</td>
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<tr>
<td>3-00000034</td>
<td>R*4</td>
<td>TALO</td>
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Bytes Dimensions:

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>512</td>
<td></td>
<td>(128)</td>
</tr>
<tr>
<td>512</td>
<td></td>
<td>(128)</td>
</tr>
<tr>
<td>512</td>
<td></td>
<td>(128)</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>(7)</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>(4)</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>(3)</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>(6)</td>
</tr>
<tr>
<td>140</td>
<td></td>
<td>(5, 7)</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>(5, 2)</td>
</tr>
<tr>
<td>140</td>
<td></td>
<td>(5, 7)</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>(5, 2)</td>
</tr>
<tr>
<td>256</td>
<td></td>
<td>(64)</td>
</tr>
<tr>
<td>1024</td>
<td></td>
<td>(4, 64)</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td>2048</td>
<td></td>
<td>(8, 64)</td>
</tr>
<tr>
<td>1280</td>
<td></td>
<td>(5, 64)</td>
</tr>
</tbody>
</table>
COMMAND QUALIFIERS

FORTRAN/NOCOP/DEBUG/LIST/NOOBJ GTLAT
/CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
/DEBUG=(SYMBOLS,TRACEBACK)
/DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
/SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
/STANDARD=(NOSEMANTIC,NOSOURCE_FORM,HOSYNTAX)
/WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXLN)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /MOD_LINES /NOEXTEND_SOURCE
/F77 /NOG_FLOATING /14 /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOANALYSIS_DATA
/NOARGUMENTS
/LIST=\&CDR_26:[BELFIORE.SSMI.SRC.RDSSMI]GTLAT.LTS;1
/NOOBJECT

COMPILED STATISTICS

Run Time: 0.39 seconds
Elapsed Time: 0.83 seconds
Page Faults: 425
Dynamic Memory: 200 pages
FUNCTION INT24(KBT,BYT1,BYT2)

C***********************************************************************************************
C THIS ROUTINE CONVERTS A 2-BYTE ARRAY INTO A 4-BYTE POSITIVE INTEGER
C
C *** USE FUNCTION INT24S IF DECODING A 2-BYTE SIGNED INTEGER ***
C
C KBT=1 ==> VAX, KBT=2 ==> IBM OR HP
C***********************************************************************************************

INTEGER*4 NUM,KBT
INTEGER*2 ISWP(2,2)

CHARACTER*1 BAR(4),BYT1,BYT2

EQUIVALENCE (BAR(1),NUM)

DATA ISWP/2,1,3,4/

NUM = 0
BAR(ISWP(1,KBT)) = BYT1
BAR(ISWP(2,KBT)) = BYT2

INT24 = NUM
RETURN
END

PROGRAM SECTIONS

<table>
<thead>
<tr>
<th>Name</th>
<th>Bytes</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CODE</td>
<td>70</td>
<td>PIC CON REL LCL SHR EXE RD NOWRT QUAD</td>
</tr>
<tr>
<td>$LOCAL</td>
<td>32</td>
<td>PIC CON REL LCL NOSHR NOEXE RD WRT QUAD</td>
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Total Space Allocated 102

ENTRY POINTS

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-00000000</td>
<td>I*4</td>
<td>INT24</td>
</tr>
</tbody>
</table>

VARIABLES

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP-00000000</td>
<td>CHAR</td>
<td>BYT1</td>
</tr>
<tr>
<td>AP-00000000C</td>
<td>CHAR</td>
<td>BYT2</td>
</tr>
<tr>
<td>AP-000000004</td>
<td>I*4</td>
<td>KBT</td>
</tr>
<tr>
<td>2-00000000</td>
<td>I*4</td>
<td>NUM</td>
</tr>
</tbody>
</table>

ARRAYS

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
<th>Bytes</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-00000000</td>
<td>CHAR</td>
<td>BAR</td>
<td>4</td>
<td>(4)</td>
</tr>
<tr>
<td>2-00000000</td>
<td>I*2</td>
<td>ISWP</td>
<td>8</td>
<td>(2, 2)</td>
</tr>
</tbody>
</table>
FUNCTION INT24S(KBT,BYT1,BYT2)

C ***********************************************************************
0004  C THIS ROUTINE CONVERTS A 2-BYTE ARRAY INTO A 4-BYTE INTEGER
0005  C ***********************************************************************
0006  C *** THIS PROGRAM WILL WORK IF THE 2-BYTE ARRAY IS INTENDED TO
0007  C *** REPRESENT A SIGNED 2-BYTE INTEGER.
0008  C *** NOTE THAT WE CANNOT DIRECTLY PUT THE BYTES INTO A 4-BYTE INTEGER
0009  C *** BUFFER OTHERWISE WE WILL NOT RECOVER THE SIGN BIT.
0010  C ***********************************************************************

0014  INTEGER*4 KBT
0015  INTEGER*2 ISWP(2,2),NUM
0017  CHARACTER*1 BAR(2),BYT1,BYT2
0018  EQUIVALENCE (BAR(1),NUM)
0022  DATA ISWP(2..1,2/)
0023  BAR(ISWP(1,KBT)) = BYT1
0024  BAR(ISWP(2,KBT)) = BYT2
0025  INT24S = NUM
0026  RETURN
0027  END

PROGRAM SECTIONS

<table>
<thead>
<tr>
<th>Name</th>
<th>Bytes</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CODE</td>
<td>67</td>
<td>PIC CON REL LCL SHR EEXE RD NOWRT QUAD</td>
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<tr>
<td>LOCAL</td>
<td>32</td>
<td>PIC CON REL LCL NOSHR NOEEXE RD WRT QUAD</td>
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</table>

Total Space Allocated 99

ENTRY POINTS

Address Type Name
0-00000070 4*4 INT24S

VARIABLES

Address Type Name Address Type Name Address Type Name Address Type Name
AP-00000000 CHAR BYT1 AP-00000000 CHAR BYT2 AP-00000004 INT KBT
2-00000000 INT NUM
<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
<th>Bytes</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-00600000</td>
<td>CHAR-BAR</td>
<td></td>
<td>2</td>
<td>(2)</td>
</tr>
<tr>
<td>2-00500000</td>
<td>I*2</td>
<td>ISMP</td>
<td>8</td>
<td>(2, 2)</td>
</tr>
</tbody>
</table>
FUNCTION INT44(KBT,BYT1,BYT2,BYT3,BYT4)

C**\*\*\* THIS ROUTINE CONVERTS A 4-BYTE ARRAY INTO A 4-BYTE INTEGER **\*\*\*\*

C KBT=1 => VAX, KBT=2 => IBM OR HP

C *** THIS PROGRAM WILL WORK IF THE 4-BYTE ARRAY IS INTENDED ***

C *** TO REPRESENT A NEGATIVE INTEGER.(IE. SIGN BIT USED) ***

INTEGER*4 NUM,KBT
INTEGER*2 ISWP(4,2)
CHARACTER*1 BAR(4),BYT1,BYT2,BYT3,BYT4
EQUIVALENCE (BAR(1),NUM)
DATA ISWP/4,3,2,1,1,2,3,4/
NUM = 0
BAR(ISWP(1,KBT)) = BYT1
BAR(ISWP(2,KBT)) = BYT2
BAR(ISWP(3,KBT)) = BYT3
BAR(ISWP(4,KBT)) = BYT4
INT44 = NUM
RETURN
END

PROGRAM SECTIONS

Name Bytes Attributes
0 SCODE 118 PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL 56 PIC CON REL LCL MOSHR NOEXE RD WRT QUAD

Total Space Allocated 174

ENTRY POINTS

Address Type Name
0-60000000 1'4 INT44

VARIABLES

Address Type Name Address Type Name Address Type Name Address Type Name
AP-0000000000 CHAR BYT1 AP-0000000000 CHAR BYT2 AP-0000000100 CHAR BYT3 AP-0000000140 CHAR BYT4
<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
<th>Bytes</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-00060000</td>
<td>CHAR</td>
<td>BAR</td>
<td>4</td>
<td>(4)</td>
</tr>
<tr>
<td>2-00060004</td>
<td>I*2</td>
<td>ISWP</td>
<td>16</td>
<td>(4, 2)</td>
</tr>
</tbody>
</table>
C*************************************************************
FUNCTION INT34(KBT,BYT1,BYT2,BYT3)

C THIS ROUTINE CONVERTS A 3-BYTE ARRAY INTO A 4-BYTE POSITIVE INTEGER *
C KBT=1 => VAX, KBT=2 => IBM OR HP *
C *** THIS PROGRAM WILL PRODUCE ONLY POSITIVE INTEGER OUTPUTS *** *
C*************************************************************

INTEGER*4 NUM,KBT
INTEGER*2 ISWP(3,2)
CHARACTER*1 BAR(4),BYT1,BYT2,BYT3
EQUIVALENCE (BAR(1),NUM)
DATA ISWP/3,2,1,2,3,4/
NUM = 0
BAR(ISWP(1,KBT)) = BYT1
BAR(ISWP(2,KBT)) = BYT2
BAR(ISWP(3,KBT)) = BYT3
INT34 = NUM
RETURN
END

PROGRAM SECTIONS

<table>
<thead>
<tr>
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<th>Bytes</th>
<th>Attributes</th>
</tr>
</thead>
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</tr>
<tr>
<td>LOCAL</td>
<td>44</td>
<td>PIC CON REL LCL MOSHR NOSHR NOEXE RD WRT QUAD</td>
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</table>

Total Space Allocated 138

ENTRY POINTS

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-000000000</td>
<td>I*4</td>
<td>INT34</td>
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VARIABLES

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP-0000000000</td>
<td>CHAR</td>
<td>BYT1</td>
</tr>
<tr>
<td>2-0000000000</td>
<td>I*4</td>
<td>NUM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
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<td>CHAR</td>
<td>BYT2</td>
</tr>
<tr>
<td>AP-0000000100</td>
<td>CHAR</td>
<td>BYT3</td>
</tr>
<tr>
<td>AP-000000000040</td>
<td>I*4</td>
<td>KBT</td>
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## ARRAYS

<table>
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<th>Type</th>
<th>Name</th>
<th>Bytes</th>
<th>Dimensions</th>
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</thead>
<tbody>
<tr>
<td>2-0000000000</td>
<td>CHAR</td>
<td>BAR</td>
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<td>(4)</td>
</tr>
<tr>
<td>2-0000000004</td>
<td>I*2</td>
<td>ISWP</td>
<td>12</td>
<td>(3, 2)</td>
</tr>
</tbody>
</table>
C***************************************************************
0001 FUNCTION INT14(KBT,BYT1)
0002 C THIS ROUTINE CONVERTS A 1-BYTE ARRAY INTO A 4-BYTE POSITIVE INTEGER *
0003 C KBT=1 => VAX, KBT=2 => IBM OR HP *
0004 C *** THIS PROGRAM WILL PRODUCE ONLY POSITIVE INTEGER OUTPUTS *** *
0005 C***************************************************************
0006 INTEGER*4 NUM,KBT
0007 INTEGER*2 ISWP(2)
0008 CHARACTER*1 BAR(4),BYT1
0009 EQUIVALENCE (BAR(1),NUM)
0010 DATA ISWP/1,4/
0011 NUM = 0
0012 BAR(ISWP(KBT)) = BYT1
0013 INT14 = NUM
0014 RETURN
0015 END

PROGRAM SECTIONS

Name            Bytes Attributes
0 $CODE          45 PIC CON REL LCL SHR EXE RD N$MRT QUAD
2 $LOCAL         20 PIC CON REL LCL NOSHR NODEXE RD WRT QUAD

Total Space Allocated  65

ENTRY POINTS

Address Type Name
0-00000000  I*4 INT14

VARIABLES

Address Type Name    Address Type Name    Address Type Name
AP-00000000$0 CHAR BYT1    AP-00000000$0 I*4 KBT    2-00000000  I*4 NUM

ARRAYS

Address Type Name    Bytes Dimensions
2-00000000  CHAR BAR    4 (4)
2-00000000:  I*2 ISWP    4 (2)
COMMAND QUALIFIERS

FORTRAN/N0OPT/DEBUG/LIST/N0OBJ INTFUNC

/NOFLAGS, OVERFLOW, NOUNDERFLOW
/DEBUG=(SYMBOLS,TRACEBACK)
/NOFLAG=(NOCOMMENTS,NOLINKS,NOREPLACE)
/NOFLAGS=(NOMODULES,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
/WARNINGS=(NODEFINDINGS,GENERAL,NOLINK,NOAXEL)
/CONTINUATIONS=I9 /NOCROSS_REFERENCE /MOD LINES /NOEXTEND_SOURCE
/P77 /N0G FLOATING /14 /NOMACHINE_CODE /NOCOMPRESS /NOPARALLEL
/NODIAGNOSTICS
/LIST=USERS_DISK_26:[BEFLIONE.SSMI.SRC.RDSSM1]INTFUNC.LIS;1
/N0OBJ

COMPILED STATISTICS

Run Time: 0.92 seconds
Elapsed Time: 1.66 seconds
Page Faults: 443
Dynamic Memory: 328 pages
subroutine openreg()

C Subroutine OPENREG simply opens the output files necessary to keep
    C track of the regional microwave data processed from the SSM/I data
    C Type in question.

open (11, status='unknown', file='Lenigrad.dat')
open (12, status='unknown', file='Keiv.dat')
open (13, status='unknown', file='Simferopol.dat')
open (14, status='unknown', file='Moscow.dat')
open (15, status='unknown', file='Hurnansk.dat')
open (16, status='unknown', file='Pern.dat')
open (17, status='unknown', file='Aktyubinsk.dat')
open (18, status='unknown', file='Tashkent.dat')
open (19, status='unknown', file='Samipalatinsk.dat')
open (20, status='unknown', file='Chita.dat')
open (21, status='unknown', file='Biagoveshensk.dat')

return
end

PROGRAM SECTIONS

Name          Bytes  Attributes       R/W
0 $CODE       105  PIC CON REL LCL SHR  EXE  RD NOWRT QUAD
1 $DATA       146  PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL      352  PIC CON REL LCL MOSHR NOEXE RD WRT QUAD

Total Space Allocated 602

ENTRY POINTS

Address Type Name
0-000000000 OPENREG

FUNCTIONS AND SUBROUTINES REFERENCED

Type Name
FOROPEN
SUBROUTINE QTIME(ITREF, ITNOW, ITIME, IERR, IFUNCT)

C SUBROUTINE CREATED: 11 JULY 1985
C USE THIS SUBROUTINE TO CONVERT A (YEAR,MONTH,DAY,HR,MIN,SEC) "NOW" TIME INTO A TIME, ITIME, (IN SECONDS) WHICH IS COUNTED FROM THE YEAR 1940 THRU 1999.
C TIME GROUP AND "ITIME", THE PROGRAM WILL CALCULATE THE "NOW" TIME GROUP.
C PROGRAM WILL HANDLE ANY TIME GROUP FROM THE YEARS 1940 THRU 1999.
C VARIABLE DESCRIPTIONS:
IIFUNCT - VARIABLE INDICATING WHAT IS TO BE CALCULATED
1 => GIVEN ITREF AND ITNOW CALCULATE ITIME
2 => GIVEN ITREF AND ITIME CALCULATE ITNOW
C ITREF(.) - 7 ELEMENT ARRAY CONTAINING REFERENCE TIME GROUP
ITREF(1) = YEAR, RANGE = (1940,1999)
ITREF(2) = MONTH, RANGE = (1,12)
ITREF(3) = DAY, RANGE = (1,31)
ITREF(4) = HOUR, RANGE = (0,23)
ITREF(5) = MINUTE, RANGE = (0,59)
ITREF(6) = SECOND, RANGE = (0,59)
ITREF(7) = LEAP YEAR INDICATOR, 1=NORMAL, 2=LEAP
C ITNOW(.) - 7 ELEMENT ARRAY CONTAINING "NOW" TIME GROUP
C ITIME - DIFFERENCE IN SECONDS BETWEEN REF TIME AND NOW TIME
C IERR - ERROR FLAG
0 => NO ERRORS
1 => ITNOW(I) OR ITREF(I) IS OUT OF RANGE
C JUAN(J) - ARRAY CONTAINING THE JULIAN DAY CORRESPONDING TO THE START OF EACH MONTH "I".
J=1 => NORMAL YEAR
J=2 => LEAP YEAR
C IYEAR(.) - ARRAY CONTAINING NUMBER OF SECONDS IN NORMAL YEAR AND IN A LEAP-YEAR
C
INTEGER ITREF(7), ITNOW(7), JUAN(12,2), IYEAR(2), LY(60)
INTEGER IRANGE(6,2)
DATA IYEAR/31536000,31622400/
DATA JUAN//1,32,60,91,121,152,182,213,244,274,305,335,1,32,61,92,122,153,183,214,245,275,306,336/
DATA IRANGE/ 40, 1, 1, 0, 0, 0, 99,12,31,22,59,59/
IERR=0
DO 5 I=1,6
IF(ITREF(I).LT.IRANGE(I,1).OR.ITREF(I).GT.IRANGE(I,2))IERR=1
5 CONTINUE
IF(IERR.NE.0) RETURN
C FILL LEAP-YEAR INDICATOR ARRAY
I=1
DO 10 I=1,15
LY(II)=2
10 I=I+1
QTIME

0058         LY(I1)=1
0059         IL=I1=1
0060         LY(I1)=1
0061         IL=I1=1
0062         LY(I1)=1
0063         IL=I1=1
0064   10 CONTINUE
0065  C   CALCULATE "REF" TIME IN SECONDS FROM BEGINNING OF REF YEAR
0066        IY1=ITREF(1)-39
0067        IL=LY(IY1)
0068        ISTART=(JULIAN(ITREF(2),I1)+ITREF(3)-2)*86400
0069        ISTART=ISTART+ITREF(4)*3600+ITREF(5)*60+ITREF(6)
0070        IF(IFUNCT.EQ.2)GO TO 100
0071  C   ** IFUNCT=1 MODULE follows
0072  C   ** IFUNCT=2 MODULE follows
0073  C   ** IFUNCT=3 MODULE follows
0074  C   ** IFUNCT=4 MODULE follows
0075  C   ** IFUNCT=5 MODULE follows
0076  C   ** IFUNCT=6 MODULE follows
0077  C   ** IFUNCT=7 MODULE follows
0078  C   ** IFUNCT=8 MODULE follows
0079  C   ** IFUNCT=9 MODULE follows
0080  C   ** IFUNCT=10 MODULE follows
0081   100 CONTINUE
0082         IY2=IY1
0083         ISUM=IYEAR(LY(IY2))-ISTART
0084   110 CONTINUE
0085         IF(ISUM.GT.ITIME)GO TO 120
0086         IY2=IY2+1
0087         ISUM=ISUM+IYEAR(LY(IY2))
0088         GO TO 110
0089   120 IEND=ITIME-ISUM+IYEAR(LY(IY2))
0090         IL2=LY(IY2)
0091         IY2=IL2
0092         JDAY=IEND/86400+1
0093         IEND=IEND-(JDAY-1)*86400
0094         ITOWN(4)=IEND/3600
0095         IEND=IEND-ITOWN(4)*3600
0096         ITOWN(5)=IEND/60
0097         ITOWN(6)=IEND-ITOWN(5)*60
0098         IM=1
0099   130 CONTINUE
0100         IF(JDAY.LT.JULIAN(IM,IL2))GO TO 140
0101         IM=IM+1
0102         GO TO 130
0103   140 IM=IM-1
0104         ITOWN(2)=IM
SUBROUTINE SWATH(ISCAN, KFLAG)

C*****************************************************************************
C PROGRAM USED TO STRIP SWATH DATA FROM THE WENTZ SMM TAPES
C "THIS LATEST VERSION (19FEB88) ALLOWS USER TO STRIP MORE THAN**
C "ONE SWATH AT A TIME"
C ISCAN=1 => OUTPUT A-SCAN, ODD-PIXEL, TB'S AND MJP
C ISCAN=2 => OUTPUT ONLY 85GHz TA DATA FOR ALL A&S SCAN PIXELS
C Severe modifications made for AGL/LSI by James S. Belfiore, Jr.
C (30-APR-1990) and AER, Inc.
C*****************************************************************************

INTEGER JULIAN(12,2),STIME(10),ETIME(10),RAINF(64)
INTEGER ITREF(7),ITNOW(7)
CHARACTER FNAME(10)*10, SC*1, DECIS*1
REAL*4 WIND(64),TB(7,64)
REAL regions(11,4)
LOGICAL reg_fil
C SPECIFY COMMON /INDATA/
C*****************************************************************************
C CHARACTER*1 LREC(1784)
INTEGER*4 KBT, IBT, IFLAG
COMMON/INDATA/LREC, KBT, IBT, IFLAG
C*****************************************************************************
C SPECIFY COMMON /OUTDAT/
C*****************************************************************************
REAL*8 REV
INTEGER*4 ITIME, ITIMSC, IVOLT, IAGC, ICOLDA, IHOTA, ICOLDB, IHOTB, ISPARI
INTEGER*4 ITIOIL, ISPARI
REAL*4 XLATSC, XLOMSC, ALTSC, HLTTEMP, RTTEMP, FRTTEMP, CALSLP, CALOFF
REAL*4 ALAT, ALON, BLAT, BLON, TALO, TAH1
C*****************************************************************************
COMMON/OUTDAT/ REV, ITIME, ITIMSC, XLATSC, XLOMSC, ALTSC,
1 HLTTEMP(3), IVOLT(1), RTTEMP, FRTTEMP, IAGC(6), CALSLP(7), CALOFF(7),
2 ICOLDA(5,7), IHOTA(5,7), ICOLDB(5,2), IHOTB(5,2), ISPARI,
3 ALAT(128), ALON(128), BLAT(128), BLON(128),
4 TALO(5,64), TAH1(6,64), ITIOIL(4,64), ISPARI2(64)
C*****************************************************************************
DATA ITREF/87,11,1,0,0,0,1/
DATA JULIAN/1,32,60,91,121,152,182,213,244,274,305,335,
1,32,61,92,122,153,183,214,245,275,306,336/
OPEN(1,STATUS='OLD', BLOCKSIZE=2564, RECL=1784,
1,4 RECORDTYPE='FIXED', FORM='FORMATTED')
C*****************************************************************************
C READ PAST THE TAPE HEADERS
C*****************************************************************************
CALL READHD
SWATH

WRITE(6,1010)
1010 FORMAT//" THIS OPTION ALLOWS THE USER TO STRIP SWATH DATA FROM''/
4 THE TAPE. MORE THAN ONE SWATH CAN BE EXTRACTED AT A''/
4 TIME HOWEVER, THE SWATH TIMES MUST BE ENTERED IN''/
4 "ASCENDING" ORDER.'/

IFILE=0
1 IFILE=IFILE+1
WRITE(6,1000)
1000 FORMAT//" FOR THE SWATH DATA TO BE EXTRACTED ENTER,'''/
4 START DATE (YR MM DD)(e.g. 87 1 25): '''/
READ(5,*)ITNOW1,ITNOW2,ITNOW3
WRITE(6,1100)
1100 FORMAT//' START TIME (HH MM SS)(e.g. 0 0 0): '''/
READ(5,*)ITNOW4,ITNOW5,ITNOW6
CALL QTIME(ITREF,ITNOW1,ITNOW2,Err1)
STIME(IFILE)=ITIME
WRITE(6,1200)
1200 FORMAT//' END DATE (YR MM DD): '''/
READ(5,*)ITNOW1,ITNOW2,ITNOW3
WRITE(6,1100)
1100 FORMAT//' END TIME (HH MM SS): '''/
READ(5,*)ITNOW4,ITNOW5,ITNOW6
CALL QTIME(ITREF,ITNOW1,ITNOW2,Err1)
ETIME(IFILE)=ITIME
WRITE(6,1400)
1400 FORMAT//' OUTPUT FILE NAME: '''/
READ(5,1500)FILENAME(IFILE)
WRITE(6,1550)
1500 FORMAT(A20)
FILENAME(IFILE)
WRITE(6,1550)
1550 FORMAT//" WOULD YOU LIKE TO EXTRACT OTHER SWATH DATA FROM',/
& THIS TAPE? (Y/N): '''/
READ(5,1560)DECIS
1560 FORMAT(A1)
IF(DECIS.EQ.'Y').OR.DECIS.EQ.'y'GO TO 1
DUM=0.0
IREC=0
IREC2=0
WRITE(6,1800)
1800 FORMAT//' REC NO')
DO 990 IF=1,IFILE
990 call openreg ()
open (2, status='new', name=FILENAME(IFILE))
C*************************************************************************
C WRITE HEADERS TO THE OUTPUT FILE *
C*************************************************************************
IF(ISCAN .EQ. 1) WRITE(2,1600)
IF(ISCAN .EQ. 2) WRITE(2,1700)
1600 format (' time lat lon tbl9v tbl9h',
& ' tbl22v tbl37v tbl37h')
1700 format (' time lat lon tbl85v tbl85h')
C** Establish target regions **
0112 call estreg(regions)
0113
0114 10 IEOF=0
0115 reg_flag = .false.
0116 11 READ(1,2000,END=12) LREC
0117 2000 FORMAT(17B4AI)
0118
0119 go to 14
0120 12 IEOF=IEOF+1
0121 WRITE(6,2001) IEOF
0122 2001 FORMAT(' IEOF= ',I2)
0123
0124 C** DOUBLE END-OF-FILE MEANS END-OF-TAPE **
0125 C**
0126
0127 IF(IEOF.EQ.2) GO TO 999
0128 GO TO 11
0129 14 CONTINUE
0130 IREC=IREC+1
0131 IREC2=IREC2+1
0132
0133 IF(IREC.EQ.25) WRITE(6,2010) IREC2, IFE
0134 2010 FORMAT(' RECS READ=',I10,' SEARCHING FOR SWATH ',I2)
0135
0136 IF(IREC.EQ.25) IREC=0
0137 ITIME=INT44(KBT,LREC(1),LREC(2),LREC(3),LREC(4))
0138 REV=1.0-4*INT44(KBT,LREC(5),LREC(6),LREC(7),LREC(8))
0139
0140 IF(ITIME.LT.STIME(IF))GO TO 10
0141 IF(ITIME.GT.ETIME(IF))GO TO 980
0142
0143 CALL FDALT(1SCAN)
0144
0145 C** Scan (array platform) filter **
0146
0147 do 42 i=2,63
0148 ii = i+2-1
0149 call testreg(alat(ii),alon(ii),regions,reg_flag)
0150
0151 C** If any of the elements are in the right spot, skip to output section **
0152
0153 if(reg_flag)then i = 63
0154
0155 continue
0156
0157 CALL FDALT(1SCAN)
0158
0159 IF(ISCAN.EQ.2) GO TO 30
0160
0161 CALL WINDX(WIND,TB,RAINF)
0162 CALL GTLAT(GLT)
0163
0164 DO 20 I=2,63
0165
0166
0167
0168
0169
0170
0171
0172 II=I**2-I
0173 DO 101 J=1,11
0174 IF ((LAT(I) .GT. REGIONS(J,1)) .AND.
0175 (ALAT(I) .LT. REGIONS(J,2)) .AND.
0176 (ALON(I) .GT. REGIONS(J,3)) .AND.
0177 (ALON(I) .LT. REGIONS(J,4))
0178 WRITE (J=10, 2101) II, I, J, LAT(I), ALAT(I), ALON(I), TB(1,I),
0179 CB(2,I), TB(5,I), TB(3,I), TB(4,I)
0180 101 CONTINUE
0181 2101 FORMAT (1X, 11I8, 2X, 1F6.2, 3X, 1F6.2, 3X, 5(2X,F6.2))
0182 20 CONTINUE
0183 GO TO 10
0184 30 CONTINUE
0185 C****************************************************************************
0186 C  PRINT OUT THE 85GHZ DATA --> A-SCAN THEN B-SCAN *
0187 C****************************************************************************
0188 SC = 'A'
0189 II=1
0190 0191 DO 40 I=1,64
0192 WRITE(2,2200)ALAT(I),ALON(I),TAHI(1,I),TAHI(2,I),
0193 4 II,SC,ITOIL(1,I)
0194 40 CONTINUE
0195 SC='B'
0196 II=1
0197 0198 DO 50 I=1,64
0199 WRITE(2,2200)BLAT(I),BLON(I),TAHI(3,I),TAHI(4,I),
0200 4 II,SC,ITOIL(3,I)
0201 50 CONTINUE
0202 0203 FORMAT(4(X,F6.2),X,I3,A1,X,I2)
0204 0205 GO TO 10
0206 0207 II=II+1
0208 0209 WRITE(2,2200)BLAT(I),BLON(I),TAHI(7,I),TAHI(8,I),
0210 4 II,SC,ITOIL(4,I)
0211 0212 II=II+1
0213 0214 2200 CLOSE(2)
0215 0216 980 CONTINUE
0217 990 RETURN
0218 0219 999 END
### SWATH 01

**Program Sections**

<table>
<thead>
<tr>
<th>Name</th>
<th>Bytes</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 $CODE</td>
<td>1945</td>
<td>PIC CMN REL LCL SHR RXE RD NOWRT QUAD</td>
</tr>
<tr>
<td>1 $PDATA</td>
<td>745</td>
<td>PIC CMN REL LCL SHR NOEXE RD NOWRT QUAD</td>
</tr>
<tr>
<td>2 SLOCAL</td>
<td>1236</td>
<td>PIC CMN REL LCL MSHR NOEXE RD WRT QUAD</td>
</tr>
<tr>
<td>3 INDATA</td>
<td>1796</td>
<td>PIC OVR REL GBL SHR NOEXE RD WRT QUAD</td>
</tr>
<tr>
<td>4 OUTDAT</td>
<td>7156</td>
<td>PIC OVR REL GBL SHR NOEXE RD WRT QUAD</td>
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**Total Space Allocated**: 14878

### Entry Points

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<thead>
<tr>
<th>Address</th>
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<th>Name</th>
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<tr>
<td>0-00000000</td>
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### Variables

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<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
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<tbody>
<tr>
<td>4-00000018 R*4</td>
<td>ALTSC</td>
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<tr>
<td>2-000000AFD I*4</td>
<td>CHAR DECIS</td>
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<tr>
<td>2-0000008C R*4</td>
<td>DUM</td>
<td></td>
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<tr>
<td>4-0000003A R*4</td>
<td>PRTMP</td>
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### Arrays

<table>
<thead>
<tr>
<th>Address</th>
<th>Type</th>
<th>Name</th>
<th>Bytes</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-000000F4 R*4</td>
<td>ALAT</td>
<td>512 (128)</td>
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</tr>
<tr>
<td>4-0000005F4 R*4</td>
<td>BLAT</td>
<td>512 (128)</td>
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</tr>
<tr>
<td>4-0000007F4 R*4</td>
<td>BLOH</td>
<td>512 (128)</td>
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<tr>
<td>4-0000005F4 R*4</td>
<td>CALFF</td>
<td>28 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-0000002C R*4</td>
<td>KTEMP</td>
<td>12 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-00000038 I*4</td>
<td>TASC</td>
<td>24 (6)</td>
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<tr>
<td>4-0000008E I*4</td>
<td>TCOLDA</td>
<td>140 (5, 7)</td>
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<tr>
<td>4-00000010 I*4</td>
<td>TCOLOB</td>
<td>40 (5, 2)</td>
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<tr>
<td>4-00000012 I*4</td>
<td>THTA</td>
<td>140 (5, 7)</td>
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<tr>
<td>4-0000002C I*4</td>
<td>THTHE</td>
<td>40 (5, 2)</td>
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<tr>
<td>4-0000002C I*4</td>
<td>SPAR2</td>
<td>256 (64)</td>
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<td>4-0000002C I*4</td>
<td>TITIMG</td>
<td>28 (7)</td>
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<tr>
<td>4-00000002 I*4</td>
<td>TITMIL</td>
<td>1024 (4, 64)</td>
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<td>4-0000002C I*4</td>
<td>TITREF</td>
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<tr>
<td>4-0000002C I*4</td>
<td>IVOLT</td>
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SWATH

01

0-00000000 14 JUAN 96 (12, 2)
3-00000000 CHAR LREC 1784 (1784)
2-00000C00 I4 RAHP 256 (64)
2-000009E8 R4 REGIONS 176 (11, 4)
2-00000C60 14 STIME 40 (10)
1-00000CF4 R4 TAHAI 2048 (128, 64)
4-000009F4 R4 TAILO 1280 (5, 64)
2-000002E8 R4 TB 1792 (7, 64)
1-000001E8 R4 WIND 256 (64)

LABELS

<table>
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<tr>
<th>Address</th>
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<td>0-00000001</td>
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<td>0-00000009F</td>
<td>10</td>
</tr>
<tr>
<td>0-0000000A4</td>
<td>11</td>
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<tr>
<td>0-0000000C2</td>
<td>12</td>
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<tr>
<td>0-0000000E3</td>
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<tr>
<td>0-000000078</td>
<td>99</td>
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<td>1-000000079</td>
<td>999</td>
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<tr>
<td>1-0000000C0</td>
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<td>1-0000000D4</td>
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<td>1-0000000E3</td>
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FUNCTIONS AND ROUTINES REFERENCED

<table>
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<tr>
<th>Type Name</th>
<th>Type Name</th>
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<tbody>
<tr>
<td>ESTREG</td>
<td>INT44</td>
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<tr>
<td>FDLTN</td>
<td>OPENREG</td>
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<tr>
<td>FDIA</td>
<td>QTIE</td>
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<td>FORCLOSE</td>
<td>FORSOPEN</td>
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<td>READHD</td>
<td>TESTREG</td>
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<tr>
<td>GYLAT</td>
<td>WINDMX</td>
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</table>

COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOOBJ SWATH

/*CHECK*/NOBOUND, OVERFLOW, NOUNDERFLOW /*DEBUG*/SYMBOLS, TRACEBACK /*DESIGN*/NOCOMMENTS, NOPACKAGES/*NOHELP */ /*SHOW*/NOOBJECT, NOINCLUDE, MAP, NOREPROCESSOR, SINGLE /*STANDARDS*/NOSEMANTIC, NOSOURCE FORM, NOERROR /*WARNINGS*/NODECLARATIONS, GENERAL, NOULTRIX, NOVAXELN */CONTINUATIONS=19 /*NOCCROSS_REFERENCE */NOG_LINES /*NOEXTEND_SOURCE */NOG_ULONG /*NOFLOATING */NOHMACINE_CODE /*NOOPTIMIZE */NOPARALLEL /*NOANALYSIS_DATA */NOBJECTS */LIST=USER/DSK_26: [BELFOIRE.SSMI.SRC.RDSSM] SWATH.LIS: 1
*/NOOBJ

COMPILATION STATISTICS

Run Time: 2.10 seconds
Elapsed Time: 2.63 seconds
Pages Faults: 692
Dynamic Memory: 484 pages
subroutine testreg (lat, lon, regions, reg_flg)

C**********************************************************************
C Subroutine TESTREG tests a set of lat/lon coordinates to determine
C whether or not said coordinates fall within a specified region. The
C regions in question are pre-defined and passed in via a 2-D array
C for the third input parameter. Since the application of this
C routine is such that it will be called again and again to test
C literally millions of coordinates, it has been tailored to conserve
C cpu usage as much as possible, by implementing a "first pass"
C criterion. That is, the first time the coordinates in question
C passes any of the conditions given in the routine, it assigns a
C positive value to a logical variable and then terminates the
C remaining comparisons.
C**********************************************************************

real lat, lon, regions(11,4)
logical reg_flg
integer i

reg_flg = .false.
do 10 i=1,11
  if ((lat .gt. regions(i,1)) .and.
     *    (lat .lt. regions(i,2)) .and.
     *    (lon .gt. regions(i,3)) .and.
     *    (lon .lt. regions(i,4))) reg_flg = .true.
  if (reg_flg) then i = 11
     continue
10 continue
return
end
PROGRAM SECTIONS

Name                      | Bytes | Attributes
------------------------ |-------|---------------------
0 $CODE                   | 91    | PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL                  | 52    | PIC CON REL LCL NOISR NOEXE RD WRT QUAD

Total Space Allocated    | 143   |

ENTRY POINTS

Address  Type  Name
0-00000000  TESTREG

VARIABLES

Address  Type  Name          | Address  Type  Name          | Address  Type  Name          | Address  Type  Name          | Address  Type  Name
2-00000000  R*4  I           | AP-00000004  R*4  LAT         | AP-00000008  R*4  LON         | AP-00000010  L*4  REG_FLG    
2-00000004  R*4  THENI        |

ARRAYS

Address  Type  Name          | Bytes  Dimensions
AP-0000000C  R*4  REGIONS    | 176  (11, 4)

LABELS

Address  Label
0-00000056  10

COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOBJ TESTREG

/SHOW=/(NOBOUND, OVERFLOW, NOUNDERFLOW)
/DEBUG=/SYMBOL, TRACEBACK
/SHOW=/NOdictionary, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE
/STANDARD=/NOSEMANTIC, NOSOURCE FORM, NOSYNTAX
/WARNINGS=/NODECLARATIONS, GENERAL, NOFILE, NOXENL
/CONTINUATIONS=19
/NOCROSS REFERENCE /NOOUT LINES /NOEXTEND SOURCE
/FP77 /NOFOATING /I4 /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOANALYSIS_DATA
/NOANALYSIS_GCS
/LIST=/BElFIORE.SSMI.SRC.RDSSMI]TESTREG.LIS;1
/NOOBJEXT
COMPILATION STATISTICS

- Run Time: 0.40 seconds
- Elapsed Time: 0.93 seconds
- Page Faults: 449
- Dynamic Memory: 204 pages
SUBROUTINE WINDMX(DMXWIN,TB,RAINF)
0002 REAL*4 C0(9),C1(9),C2(9),C3(9),C4(9)
0003 INTEGER*4 INDEX(12,8),JCHFX(7),RAINF(64)
0004 INTEGER*4 ITREF(7),JULIAN(12,2),ITNOW(7)
0005 REAL*4 TB(7,64),DMXWIN(64),APC(4,7)
0006 C*****************************************************************************
0007 C SPECIFY COMMON /OUTDAT/ +
0008 C*****************************************************************************
0009 REAL*4 REV
0010 INTEGER*4 ITIME,ITIMSC,IVOLT,IAHC,ICOLDA,ICOLDB,ICOTB,ISPAR1
0011 INTEGER*4 ITOIL,ISPAR2
0012 REAL*4 XLATSC,XMLONG,ALTSC,HLTEMP,RFTEMP,FRTMP,CALSLP,CALOFF
0013 REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI
0014 COMMON/OUTDAT/ REV,ITIME,ITIMSC,IVOLT,IAHC,ICOLDA,ICOLDB,ICOTB,ISPAR1,
0015 1 HLTEMP(3),RFTEMP,FRTMP,CALSLP(7),CALOFF(7),
0016 2 ICOLDA(5,7),ICOTB(5,7),ICOLDB(5,2),ICOTB(5,2),ISPAR1,
0017 3 ALAT(128),ALON(128),BLAT(128),BLON(128),
0018 4 TALO(5,64),TAHI(8,64),ITOOIL(4,64),ISPAR2(64)
0019 C*****************************************************************************
0020 INTEGER INITIALIZE DATA *
0021 C*****************************************************************************
0022 DATA ITREF/87,1,1,0,0,0,0,1/
0023 DATA JULIAN/1,32,60,91,122,153,184,215,246,277,308,339,360/
0024 1 1,32,61,92,123,154,185,216,247,278,309,340/
0025 DATA JCHFX/2,1,4,3,0,2,1/
0026 DATA APC/1.00471,0.0049,0.0072,0.0029,
0027 2 1.0472,0.0043,0.0080,0.0028,
0028 3 1.0422,0.0225,0.0012,0.0022,
0029 4 1.0428,0.0272,0.0010,0.0004,
0030 5 0.0513,0.0111,0.0080,0.0055,
0031 6 0.0341,0.0142,0.0040,0.0037,
0032 7 0.0359,0.0201,0.0027,0.0009/
0033 DATA SLF2/MDF/1,0.563,96.6/
0034 DATA C5/191.56,168.39,177.315,147.76,127.13,163.07,
0035 1 95.994,130.42,117.59/
0036 DATA C1/.4903,.5366,.3913,.5077,.4788,.2923,.6106,.3676,.4225/,
0037 DATA C2/-3.4322,-4.548,-8.2818,-3.5477,-2.5346,-12.044,
0038 1 -.3034,-.1580,-.1899/
0039 DATA C3/-1.9199,-1.7656,-1.0083,-.7409,-.7162,-1.0967,
0040 DATA C4/-1.4638,-.8400,-.7096/,
0041 DATA C5/3.5777,2.6255,4.0955,2.3333,2.0302,4.6122,.0192,.0306,.0281/,
0042 DATA INDEX/9,9,9,9,8,8,8,8,8,8,8,9,9,
0043 2 7,7,5,5,5,6,6,5,5,5,5,7,
0044 3 4,4,4,4,4,3,3,3,3,3,3,4,
0045 4 2,2,2,2,1,1,1,1,1,1,1,2,
0046 5 1,1,1,1,2,2,2,2,2,2,2,1,
0047 6 3,3,3,3,3,4,4,4,4,4,4,3,3,
0048 7 6,6,5,5,5,7,7,7,5,5,5,5,5,6,
0049 8 8,8,8,8,8,9,9,9,9,9,9,8,8/
C BEGIN EXECUTION
C**********************************************************
C THE FIRST AND LAST PIXELS WE CANNOT COMPUTE TB OR WINDS FOR
C**********************************************************
C
DO 90 I=1,7
TB(I,1)=999.99
TB(I,64)=999.99
90 CONTINUE
C
RAINF(1)=0
RAINF(2)=0
DNXWIN(1)=99.99
DNXWIN(64)=99.99
CALL QTIME(ITREF,ITNOW,ITIME,IERR,2)
JNOW=ITNOW(2)
C**********************************************************
C LOOP THRU CELLS IN SCAN
C**********************************************************
C
DO 300 ICEL=2,63
C**********************************************************
C COMPUTE TB'S, TB() = 19V,19H,37V,37H,21V,55V,55H
C**********************************************************
C
DO 200 ICH=1,5
JCH=JCHFX(ICH)
IF(ICh.NE.5) TAXPOL=TALO(JCH,ICEL)
IF(ICh.EQ.5) TAXPOL=OFF22H+SLP22H*TALO(2,ICEL)
TB=APC(1,ICH)*TALO(ICH,ICEL-1)-APC(4,ICH)*TALO(ICH,ICEL+1)
TB(ICH,ICEL)=0.1*INT(10.*TBX)
200 CONTINUE
C
DO 202 ICH=6,7
JCH=JCHFX(ICH)
TAXPOL=TAHI(JCH,ICEL)
TB=APC(1,ICH)*TAHI(I,ICEL)-APC(2,ICH)*TAXPOL-
TB=APC(1,ICH)*TAHI(I,ICEL-1)-APC(4,ICH)*TAHI(I,ICEL+1)
TB(ICH,ICEL)=0.1*INT(10.*TBX)
202 CONTINUE
C
C CHECK TOIL
C
IF(ITOIL(1,ICEL).GE.4.AND.ITOIL(1,ICEL).LE.5) GO TO 203
DNXWIN(ICEL)=31.
RAINF(ICEL)=0.
203 CONTINUE
DELTA=TB(3,ICEL)-TB(4,ICEL)

C IF HEAVY RAIN SET WIND TO 31
C
IF(DELTA.GT.10)GO TO 205
RANF(ICEL)=2
DMXW(I)=31.
GO TO 300

205 IF(ITOIL(1,ICEL).EQ.5) GO TO 210

C CHECK FOR ICE

C IF(TB(2,ICEL).GT.140..AND.DELTB.GT.5..AND.DELTB.LT.62)
1 DMXW(I)=31.
IF(TB(2,ICEL).GT.140..AND.DELTB.GT.5..AND.DELTB.LT.62)
GO TO 300

C PROCEED TO COMPUTE D-MATRIX WIND

CONTINUE
RAINF(I)=0
JCEL=2*ICEL-1
XLAT=ALAT(JCEL)
ILAT=8
IF(XLAT.GT.-55.) ILAT=7
IF(XLAT.GT.-25.) ILAT=6
IF(XLAT.GT.-20.) ILAT=5
IF(XLAT.GT. 0.) ILAT=4
IF(XLAT.GT. 20.) ILAT=3
IF(XLAT.GT. 25.) ILAT=2
IF(XLAT.GT. 52.) ILAT=1
INDEX(JM0N,ILAT)
DMXW(I)=C0(I)+C1(I)*TB(2,ICEL)+C2(I)*TB(5,ICEL)+C3(I)*TB(3,ICEL)+C4(I)*TB(4,ICEL)
IF(DMXW(I).GT.29.) DMXW(I)=30.
IF(DMXW(I).LE.-2.) DMXW(I)=30.
IF(DMXW(I).LE.-6.) DMXW(I)=0.

CONTINUE
RETURN
END
### PROGRAM SECTIONS

<table>
<thead>
<tr>
<th>Name</th>
<th>Bytes</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCODE</td>
<td>1065</td>
<td>PIC CON REL LCL SHR EXE RD NOWRT QUAD</td>
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<tr>
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**Total Space Allocated**: 9269

### ENTRY POINTS

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### VARIABLES

- **Address**
- **Type**
- **Name**

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<td>0-0000036C</td>
<td>T*4</td>
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<td>0-000007F4</td>
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<td>ALON</td>
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### ARRAYS

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**Bytes Dimensions**

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**Bytes Dimensions**

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**Total Bytes**: 5220
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**LABELS**

Type | Name
--- | ---

**FUNCTIONS AND SUBROUTINES REFERENCED**

QTIME
COMPILE QUALIFIERS

FORTRAN/HOOP7/DEBUG/LIST/HOOBJ WINDMX

/CHECK=(NOBUOnds, OVERFLOW, NOUNDERFLOW)
/DEBUG=(SYMBOLS, TRAeBACK)
/HAOW=(NODIRECTORY, NOINClude, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEMANTIC, NO SoUrCE FORM, NOSYNTAX)
/MARKINGS=(NODECLARATIONs, GENERAL, NOUTRiEX, NOVAXELN)
/CONTINUATIONS=19 /NOCROSS_REFERENCe /NO LINES /NOEXTEND SRCE
/F77 /NOG FLOATING /14 /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOMANALYSIS_DATA
/NODIAGNOSTICS
/LIST=USERS DISK_16; [BELFIORE.SSMI.SRC.RDSMII]WINDMX.LIS:1
/NOOBJECT

COMPILATION STATISTICS

Run Time: 1.70 seconds
Elapned Time: 2.23 seconds
Page Faults: 617
Dynamic Memory: 444 pages
RAINRATE

0058 ' 
0059 '(({t19v+t17v})/2) - ((t19h+t37h)/2) .ie. 4.0) .and.
0060 ' (t19v .gt. 262.0) then
0061 rate = rain_land (t19h, t19v, t22v, t37h, t37v)
0062 if (rate .lt. 0.0) then
0063 write (i+11,150) time, lat, lon, 0.0
0064 else
0065 write (i+11,150) time, lat, lon, rate
0066 endif
0067 0068 else
0069 endif
0070
0071 20 continue
0072 10 ieof = 0
0073 continue
0075
0076 C**************
0077 C Formats 
0078 C**************
0079 100 format (1x, 11s, 2x, 1f6.2, 3x, 1f6.2, 3x, 5(2x,f6.2))
0080 150 format (1x, 11s, 2x, 1f6.2, 3x, 1f6.2, 3x, 1f10.4)
0081
0082 end

PROGRAM SECTIONS

Name                        Bytes Attributes
0 $CODE                      455 PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $DATA                      51  PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL                     92  PIC CON REL LCL NO SHR NOEXE RD WRT QUAD

Total Space Allocated       598

ENTRY POINTS

Address Type Name
0-000000000 RAINRATE

VARIABLES

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<td>2-00000028</td>
<td>I*4</td>
<td>idof</td>
<td>2-00000024</td>
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<td>2-00000000</td>
<td>R*4</td>
<td>lat</td>
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<tr>
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<td>lon</td>
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<td>R*4</td>
<td>t19h</td>
<td>2-0000000C</td>
<td>R*4</td>
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<td>2-00000010</td>
<td>R*4</td>
<td>t22v</td>
<td>2-00000014</td>
<td>R*4</td>
<td>t37h</td>
<td>2-00000018</td>
<td>R*4</td>
<td>t37v</td>
<td>2-00000002</td>
<td>I*4</td>
<td>time</td>
</tr>
</tbody>
</table>
subroutine openrain()

C Subroutine OPENRAIN opens the output files necessary to keep track of the regional rainfall data processed from the SSM/I data tape in question.

C******************************************************************************

open (22, status='unknown', file='Lenigrad_rain.dat')
open (23, status='unknown', file='Kiev_rain.dat')
open (24, status='unknown', file='Simferopol_rain.dat')
open (25, status='unknown', file='Moscow_rain.dat')
open (26, status='unknown', file='MurmanSK_rain.dat')
open (27, status='unknown', file='Perm_rain.dat')
open (28, status='unknown', file='Aktyubinsk_rain.dat')
open (29, status='unknown', file='Tashkent_rain.dat')
open (30, status='unknown', file='Semipalinsk_rain.dat')
open (31, status='unknown', file='Chita_rain.dat')
open (32, status='unknown', file='BlaqVeschensk_rain.dat')

return
end

PROGRAM SECTIONS

Name          Bytes      Attributes
0 $CODE      105       PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $DATA      200       PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL     352       PIC CON REL LCL MOSHR NOEXE RD WRT QUAD

Total Space Allocated: 657

ENTRY POINTS

Address  Type  Name
0-00000000  OPENRAIN

FUNCTIONS AND SUBROUTINES REFERENCED

Type  Name
FOR$OPEN
OPENRAIN
01

COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOOBJ OPENRAIN

/CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
/DEBUG=(SYMBOLS,TRACEBACK)
/SHOW=(NODICTIONARY,NONInclude,MAP,NOPREPROCESSOR,SINGLE)
/STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
/WARNINGS=(NODEclarations,GENERAL,NOULTRIX,NOVAXELN)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /NOD_LINES /NOEXTEND_SOURCE
/IF77 /NOG_FLOATING /IAS /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NANALYSIS_DATA
/NODIAGNOSTICS
/LIST=USER5DISK_26:[BELFIORE.SSMI.SRC.RAINRATE]OPENRAIN.LIS:1
/NOOBJECT

COMPILATION STATISTICS

Run Time: 0.29 seconds
Elapsed Time: 0.85 seconds
Page Faults: 359
Dynamic Memory: 200 pages
function rain_land (t19v, t19h, t22v, t37v, t37h)

C Function LANDING determines the rate of rainfall over a land mass

C utilizing the collocated SSM/I brightness temperature measurements.

C This algorithm is taken directly from Olson et al (1990).

C Note: This algorithm determines the rate of rainfall, independent

C of the 85 GHz brightness temperatures.

C

real t19v, t19h, t22v, t37v, t37h
real exp_term, term1, term2, term3, term4, term5

term1 = 0.04150 * t37v
term2 = 0.01638 * t37h
term3 = 0.03561 * t22v
term4 = 0.05079 * t19v
term5 = 0.01875 * t19h

exp_term = (1.32526 - term1 + term2 + term3 + term4 - term5)

rain_land = (exp (exp_term) - 8.0)

return

end

PROGRAM SECTIONS

<table>
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<tr>
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<tr>
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Total Space Allocated

132

ENTRY POINTS

Address Type Name

0-00000000 R'4 RAIN_LAND

VARIABLES

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<td>AP-0000000008 R'4</td>
<td>T19H</td>
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<td>T17H</td>
<td>AP-0000000004 R'4</td>
<td>T19V</td>
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FUNCTIONS AND SUBROUTINES REFERENCED

Type    Name
R*4    MTMEXP

COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOOBJ RAIN_LAND
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/DEBUG=(SYMBOLS, TRACEBACK)
/DESIGN=(NOCOMMENTS, NOPLACEHOLDERS)
/HOWN=(NODIRECTORY, NOINCLUDER, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEMANTIC, NOSOURCE_FORM, NOSYNTAX)
/WARNINGS=(NODECLARATIONS, GENERAL, NOUNIT, NOVAXELK)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /MOD_LINES /NOEXTEND_SOURCE
/F77 /NOG FLOATING /I4 /NOMACHINE_CODE /NOCOMPRESS /NOPARALLEL
/NODIAGNOSTICS
/LIST=USERSD_6:[BELFORE.ES{} SRC.RAINRATE]RAIN_LAND.LIS;1
/NOOBJECT

COMPILATION STATISTICS

Run Time:          0.32 seconds
Elapsed Time:      0.85 seconds
Page Faults:       393
Dynamic Memory:    188 pages
program rainavg
  c---------------------------------------------------------------------
  c Program RAINAVG takes data generated from the RAINRATE program, and
  c determines the following:
  c  - Spatial average of rainfall (per site, per pass)
  c---------------------------------------------------------------------
  integer arrcnt, pntcnt, ieof, time, prevtim
  real lat, lon, rainrate, ratearr(500,500)
  call openrain ()
  call openavg ()
  do 10, j=1,11
   ieof = 0
   prevtim = 0
   pntcnt = 1  ! Point Counter
   arrcnt = 0  ! Array Counter
  10 do 15, i=1,5000
    read (21+j, 100, iostat=ieof) time, lat, lon, rainrate
    if (ieof .eq. 0) then
      go to 15
    endif
  15 C--------------------
  C Load rainrate and time arrays
  C--------------------
    if ((time - prevtim) .lt. 600) then
      pntcnt = pntcnt + 1
      ratearr(arrcnt,pntcnt) = rainrate
    else
      if (arrcnt .gt. 0) then
        call average (prevtim, ratearr, arrcnt, pntcnt, 32+j)
      endif
      pntcnt = 1
      arrcnt = arrcnt + 1
      ratearr(arrcnt,pntcnt) = rainrate
    endif
  30 prevtim = time
  35 continue
  40 call average (prevtim, ratearr, arrcnt, pntcnt, 32+j)
  45 continue
  50 C Formats
  51 C************************
  52 100 format (1x, 1i8, 2x, 1f6.2, 3x, 1f6.2, 3x, 1f10.4)
  54 end
### PROGRAM SECTIONS

<table>
<thead>
<tr>
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<td>20</td>
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<td>2 SLOCAL</td>
<td>1000108</td>
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Total Space Allocated: 1000396 bytes

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<th>Name</th>
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### ARRAYS

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### FUNCTIONS AND SUBROUTINES REFERENCED

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</tbody>
</table>
subroutine average (time, array2d, ar_index, numpts, filecnt)

C ************** Subroutine AVERAGE is an averaging routine customized for the RAINAVG **************
C program. It takes the two dimensional array 'array2d' and averages
C the values for a given data array of specified array index.
C
C ************** 26-Jun-1990: The subroutine has been modified to determine the
C standard deviation for each average.
C
C **************
integer ar_index, time, numpts, filecnt
real array2d(500,500), arr_total, arr_avg, days, var_tot
real variance, std_dev

arr_avg = 0.0
arr_total = 0.0

do 10, i=1,numpts
   arr_total = arr_total + array2d(ar_index,i)
10 continue

C **************
C Compute Average
C **************
arr_avg = arr_total / floatj(numpts)
days = earth_time(time)

C **************
C Compute Variance
C **************
var_tot = 0.0

do 15, i=1,numpts
   var_tot = var_tot + ((array2d(ar_index,i) - arr_avg)**2)
15 continue

variance = 0.0
if (numpts .gt. 1) then
   variance = var_tot / (floatj(numpts) - 1)
endif

C **************
C Compute Standard Deviation
C **************
std_dev = 0.0
if (variance .gt. 0.0) then
   std_dev = sqrt(variance)
endif

C **************
C Write our results
C **************
write (filecnt,100) time, days, arr_avg, std_dev, numpts

C **************
C Formats
C **************
100 format (1X, 1I8, 2X, 1F16.8, 2X, 1F10.4, 2X, 1F10.4, 2X, 1F4)

return
end
AVERAGE
01

3-Dec-1990 10:53:27  VAX FORTRAN V5.5-93  Page 2
26-Jun-1990 09:06:06  (BELFIORE.SSMK.SRC.RAINAVG)AVERAGE.FOR:11

PROGRAM SECTIONS

Name     Bytes        Attributes
0 $CODE   261 PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $PDATA  24  PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL  80  PIC CON REL LCL NOHR NOEXE RD WRT QUAD

Total Space Allocated  373

ENTRY POINTS

Address Type Name
0-00000000   AVERAGE

VARIABLES

Address Type Name   Address Type Name   Address Type Name   Address Type Name
2-000000004 R*4 ARR_AVG  2-00000000 R*4 ARR_TOTAL  2-0000000000 I*4 AP_INDEX  2-00000000 R*4 DAYS
AP-000000014 I*4 FILECNT  2-000000018 I*4 I  AP-000000010 I*4 NUMPTS  2-000000014 R*4 STD_DEV
AP-000000040 I*4 TIME  2-000000010 R*4 VARIANCE  2-00000000 C R*4 VAR_TOT

ARRAYS

Address Type Name   Bytes Dimensions
AP-000000006 R*4 ARRAY2D  1000000  (500, 500)

LABELS

Address Label   Address Label   Address Label
0-0000003D 10  0-00000089 15  1-00000000 100'

FUNCTIONS AND SUBROUTINES REFERENCED

Type Name   Type Name
R*4 EARTH_TIME  R*4 MINSQRT
AVERAGE 01
26-Jun-1990 09:06:06 [BELFIORE.SSMI.SRC.RAINAVG]AVERAGE.FOR:11

COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOOBJ AVERAGE

/DEBUG=(SYMBOLS, TRACEBACK)
/DESIGN=(NOCOMMENTS, NOPLACEHOLDERS)
/SHOW=(NODICTIIONARY, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEMANTIC, NOSOURCE FORM, HOSTNTAX)
/WARNINGS=(NODECLARATIONS, GENERAL, NOULTRIX, NOVAXLN)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /NO_INDICES /NOEXTEND_SOURCE
/F77 /NOG_FLOATING /NOHMACINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOANALYSIS DATA
/NOOBJECT

COMPILATION STATISTICS

Run Time: 0.54 seconds
Elapsed Time: 0.97 seconds
Page Faults: 541
Dynamic Memory: 360 pages
function earth_time(sat_time)
C************************************************************************************
0003 C Function EARTH_TIME computes the decimal number of days elapsed since 
0004 C 01-Jan-1989, 00:00 hours (GMT). The input is the mission elapsed time 
0005 C in seconds, from the SSN/I sensor array switch on.
C************************************************************************************
0007 integer sat_time
0008 real elaps_Time
0010 elaps_time = sat_time - 76204800
0011 earth_time = elaps_time / 86400.0
0012 return
0014 end

PROGRAM SECTIONS

<table>
<thead>
<tr>
<th>Name</th>
<th>Bytes</th>
<th>Attributes</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>2 $LOCAL</td>
<td>6</td>
<td>PIC CON REL LCL NOSHR NOEXE RD WRT QUAD</td>
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Total Space Allocated

43

ENTRY POINTS

Address Type Name
0-00000000 R*4 EARTH_TIME

VARIABLES

<table>
<thead>
<tr>
<th>Address Type Name</th>
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</thead>
<tbody>
<tr>
<td>2-00000000 R*4 ELAPTS_TIME</td>
<td>AP-000000040 R*4 SAT_TIME</td>
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</table>

COMMAND QUALIFIERS

FORTRAN/HOOP/DEBUG/LIST/HOOBJ EARTH_TIME

/HECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
/DEBUG=(SYMBOLS,TRACEBACK)
/DIEN=(NODOCUMENTS,NOPLACEHOLDERS)
/SH=(MODIFICATION,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
/STANDARD=(ROSEMANDIC,NOSOURCE FORM,NOSYNTAX)
/WARNINGS=(NODECLARATION,GENERAL,NOUNITR.NOVALN)
/CURRENTS=19 /NOFROSS_REFERENCE /NOFLINES /NOEXTEND_SOURCE
/S7 /NOFLOG FLOATING /14 /NOHACHINE_CODE /NOOPTIMIZE /HOPARALLEL
/NOANALYSIS_DATA
/NOIDENTIFICATICS
/LIST=USER5DISK_25: \BELFIORE.SSMI.SRC.RAINAVG|EARTH_TIME.LIS:1
COMPILATION STATISTICS

Run Time: 0.22 seconds
Elapsed Time: 0.70 seconds
Page Faults: 384
Dynamic Memory: 188 pages
subroutine openavg ()
C Subroutine OPENAVG opens the output files necessary to keep track of the regional rainfall averages processed from RAINRATE program data run in question.
C
open (33, status='unknown', file='Lenigrad_avg.dat')
C
open (34, status='unknown', file='Kiev_avg.dat')
open (35, status='unknown', file='Simfropol_avg.dat')
open (36, status='unknown', file='Moscow_avg.dat')
open (37, status='unknown', file='Murmansk_avg.dat')
open (38, status='unknown', file='Perm_avg.dat')
open (39, status='unknown', file='Aktyubinsk_avg.dat')
open (40, status='unknown', file='Tashkent_avg.dat')
open (41, status='unknown', file='Semipalatinsk_avg.dat')
open (42, status='unknown', file='Chita_avg.dat')
open (43, status='unknown', file='Blagoveschensk_avg.dat')
return
end

PROGRAM SECTIONS

Name | Bytes | Attributes
--- | --- | ---
0 $CODE | 105 | PIC CON REL LCL SHR EXEC RD NOWRT QUAD
1 $PDATA | 189 | PIC CON REL LCL SHR NOEXEC RD NOWRT QUAD
2 $LOCAL | 352 | PIC CON REL LCL NOSHAR NOEXEC RD WRIT QUAD

Total Space Allocated | 646

ENTRY POINTS

Address Type Name
0-00000050 OPENAVG

FUNCTIONS AND SUBROUTINES REFERENCED

Type Name
FOR$OPEN
OPENAVG

COMMAND QUALIFIERS

FORTRAN/3OOPT/DEBUG/LIST/NOOBJ OPENAVG

/CHECK=(NOGARDS, OVERFLOW, NOUNDERFLOW)
/DEBUG=(SYMBOLS, TRACEBACK)
/DESIGN=(NOCOMMENTS, NOPLACEHOLDERS)
/SHOW=(NODICTIONARY, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEMANTIC, NOSOURCE FORM, NOSYNTAX)
/WARNINGS=(NODECLARATIONS, GENERAL, NOULTRIX, NOVAXELN)
/CONTINUATIONS=19 /NOCROSS REFERENCE /NOD_LINES /NOEXTEND_SOURCE
/F77 /NOG_FLOATING /14 /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOANALYSIS_DATA
/NODIAGNOSTICS
/LIST=USERSDISK:26:/BELFIORE.SSMO.SRC.RAINAVG]OPENAVG.LIS;1
/NOOBJECT

COMPILATION STATISTICS

Run Time: 0.35 seconds
Elapsed Time: 0.76 seconds
Page Faults: 359
Dynamic Memory: 200 pages
program ilwctot
  integer i, time, numpts
  logical w rif
  real avg_rate, days
  real std_dev
  real ilwc
  real z, zm, zt
  write (*, *) ' Enter Cloud Top (m): '
  read (*, *) zt
  write (*, *) ' Enter Cloud Height of Maximum LWC (m): '
  read (*, *) zm
  write (*, *) ' Enter Maximum LWC (units): '
  read (*, *) ilwc
  open (1, file='blagoveschensk_to.dat',
        status='unknown') ! - Tot file
  open (2, file='blagoveschensk_ilwc.dat',
        status='unknown') ! - Ilwc file
  do 10, i=1,161
    read (1,100) time, days, avg_rate, std_dev, numpts
    if (abs(avg_rate) .ge. 1.5) then
      call ilwc_conv (zm, zt, mm, avg_rate, ilwc, w rif)
    else
      call ilwc_strat (zm, zt, mm, avg_rate, ilwc, w rif)
    end if
  10 continue
  rewind (1)
  open (3, file='blagoveschensk_conv.dat', status='unknown')
  open (4, file='blagoveschensk_strat.dat', status='unknown')
  do 15 i=1,161
    read (1,100) time, days, avg_rate, std_dev, numpts
    call ilwc_conv (zm, zt, mm, avg_rate, ilwc, w rif)
    if (w rif) then
      write (3,110) days, ilwc
    end if
    call ilwc_strat (zm, zt, mm, avg_rate, ilwc, w rif)
    if (w rif) then
      write (4,110) days, ilwc
    end if
  15 continue
  100 format (1X, 1F6.2X, 2X, 1F16.8, 2X, 1F10.4, 2X, 1F10.4, 2X, 1X)
  110 format (1X, 1F16.8, 2X, 1F16.4)
end
ILWC_TOT

3-Dec-1990 11:02:40 VAX FORTRAN V5.5-98 Page 2
3-Dec-1990 09:06:11 [BELFIORE.SMII.SRC.ILWC]ILWC_TOT.FOR:11

PROGRAM SECTIONS

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<tr>
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<tr>
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</table>

Total Space Allocated 1117

ENTRY POINTS

Address Type Name
0-00000000 ILWC_TOT

VARIABLES

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<th>Type</th>
<th>Name</th>
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<td>2-00000010 R*4 AVG_RATE</td>
<td>2-00000014 R*4 DAYS</td>
<td>2-00000000 I*4 I</td>
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<tr>
<td>2-00000020 R*4 MH</td>
<td>2-00000002 I*4 NUMPTS</td>
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<td>2-00000000 R*4 WRIF</td>
<td>2-00000004 R*4 2N</td>
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LABELS

<table>
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<tr>
<th>Address</th>
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<th>Address</th>
<th>Label</th>
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<th>Label</th>
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<tbody>
<tr>
<td>0-00000156 10</td>
<td>0-00000234 15</td>
<td>1-000000C4 100'</td>
<td>1-000000DC 110'</td>
<td></td>
<td></td>
</tr>
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</table>

FUNCTIONS AND SUBROUTINES REFERENCED

Type Name            Type Name            Type Name
FORSOPEN ILWC_CONV ILWC_STRAT

COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOOBJ ILWC_TOT

CHECK=(NOBOUND,OVERFLOW,NOUNDERFLOW)
DEBUG=(SYMBOLS,TRACEBACK)
/DNOMENT=(NODEFALNMENTS,NOPLACEHOLDERS)
/SHOW=(NOCLASSIFIER,NOINCLUDE,MAP,NOHELP,NOHELP,NOHELP,NOHELP)
/STANDARD=(NOSEMANTIC,NO SOURCE_FILE,NO SYNTAX)
/WARNINGS=(NODECLARATIONS,NOVL,NOVXNL)
/CONTINATIONS=19 /NOCROSS_REFERENCE /MOD_LINES /NOEXTEND_SOURCE
/F77 /NOFLOATING /I4 /NOHIMMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOANALYSE_DATA /NOSTISTICS
/List=USER5DISK_26:[BELFIORE.SMII.SRC.ILWC]ILWC_TOT.LIST/31
/NOOBJECT
ILMC_TOT
01

COMPILATION STATISTICS

Run Time: 0.71 seconds
Elapsed Time: 1.18 seconds
Page Faults: 497
Dynamic Memory: 360 pages
subroutine ilwc_conv (zm, zt, mm, avg_rate, ilwc, urif)

logical urif
real avg_rate
real cst_a, cst_a1, cst_a2, cst_a3, cst_a4
real cst_b, cst_b1, cst_b2, cst_b3, cst_b4
real cst_c, cst_c1, cst_c2, cst_c3, cst_c4
real cst_d
real ilwc
real mm, ms, zm, st
real term_1, term_2, term_3, term_4, term_5

if (avg_rate .eq. 0.0) then
    urif = .false.
else
    return
endif

urif = .true.
mm = 0.07 * (avg_rate**0.83)
cst_a1 = 1.0/ (((zm**5)*((zt**2)) - (2.*(zm)**4)*(zt**3))
           + ((zm**3)*(zt**4)))
cst_a2 = ((3.*(zm)*(zt**2))) - (2.*(zt**3)) - (zm**3)**ms

if (zm .lt. 200.4) then
    term_1 = ((4.*(zm)**2)*(zt**2)) - (2.*(zt**4))
    term_2 = (2.*(zm)**4)**ms
    term_3 = ((4.*(zm)**2)*(zt**2)) - (2.*(zt**4))**ms
    term_4 = cst_c2 + cst_c3
    term_5 = ms
else
    term_1 = (cst_a1/5.0) * (zt**5)
    term_2 = (cst_b1/4.0) * (zt**4)
    term_3 = (cst_c1/3.0) * (zt**3)
    term_4 = (cst_d) * (zt)
    term_5 = ms
end

ilwc = term_1 + term_2 + term_3 + term_4 + term_5
return
end
ILMC_CONV
01

PROGRAM SECTIONS

Name       Bytes Attributes
0 $CODE     680 PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL    88 PIC CON REL LCL NO SHR NO EXE RD WRT QUAD

Total Space Allocated
768

ENTRY POINTS
Address Type Name
0-00000003   ILMC_CONV

VARIABLES

Address Type Name       Address Type Name       Address Type Name       Address Type Name
AP-0000000010# R*4 AVG_RATE 2-00000000 R*4 CST_A 2-000000004 R*4 CST_A1 2-000000008 R*4 CST_A2
2-0000000000 R*4 CST_A3 2-000000010 R*4 CST_A4 2-000000014 R*4 CST_B 2-000000018 R*4 CST_B1
2-0000000010 R*4 CST_B2 2-000000020 R*4 CST_B3 2-000000024 R*4 CST_B4 2-000000028 R*4 CST_C
2-0000000020 R*4 CST_C1 2-000000030 R*4 CST_C2 2-000000034 R*4 CST_C3 2-000000038 R*4 CST_C4
2-0000000030 R*4 CST_D 2-000000014# R*4 ILMC 2-00000004# R*4 MM 2-000000040 R*4 MS
2-000000040 R*4 TERM_1 2-000000048 R*4 TERM_2 2-000000044 R*4 TERM_3 2-000000050 R*4 TERM_4
2-000000054 R*4 TERM_5 2-000000018# L*4 WRIF 2-000000004# R*4 ZM 2-000000008# R*4 ZT

COMMAND QUALIFIERS

FORTRAN/WOOP/DBUG/LIST/NOOBJ ILMC_CONV

/CHECK=(NOBOUNDS, OVERFLOW, NOUNDERFLOW)
/DEBUG=(SYMBOLS, TRACEBACK)
/DESIGN=(NOCOMMENTS, NOPLACEDHOLDERS)
/SHOW=(NOREFERENCE, NOSUMMARY, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEMANTIC, NOSORT, NOSEMANTIC, NOSYNTAX)
/CONTINUATION=19 /NOCROSSREFERENCE /NOD_LINES /NOEXTEND_SOURCE
/F77 /NOG_FLOATING /I4 /HOMACHINE_CODE /NOOPIMIZE /NOPARALLEL
/NOANALYSIS_DATA
/NOEXPLOIT
/NOERRORS
/NOOBJ

LIST=USERSDISK_26:[BELFIORE.SSRM.SRC.ILMC]ILMC_CONV.LIST;1
/NOOBJ

COMPIIATION STATISTICS

Run Time: 0.88 seconds
Elapsed Time: 1.27 seconds
Page Faults: 454
Dynamic Memory: 360 pages
subroutine ilwc_strat (zm, st, am, avg_rate, ilwc)
!
logical wif
real avg_rate
real std_dev
real*4 cst_a, cst_a1, cst_a2, cst_a3, cst_a4
real*4 cst_b, cst_b1, cst_b2, cst_b3, cst_b4
real*4 cst_c, cst_c1, cst_c2, cst_c3, cst_c4
real*4 cst_d
real*4 ilwc
real*4 mm, ms, zm, st
real*4 term_1, term_2, term_3, term_4, term_5
!
if(avg_rate .eq. 0.0) then
  wif = .false.
  return
endif
!
wif = .true.
ms = 0.07 * (avg_rate**0.83)
!
cst_a1 = -1.0 / ((zm**2) * (st) * ((zm - zm)**2))
cst_a2 = ((zm - zm)**2) * ms
cst_a3 = (st) * (2.0 * zm - st) * mm
cst_a4 = cst_a2 + cst_a3
!
cst_b1 = cst_a1
!
cst_b2 = ((3.0*(zm**2)*st) - (zm**3) - (2.0*(zm**3))) * ms
cst_b3 = ((zm**2)*st) - (zm**3) * ms
!
cst_b4 = cst_b2 - cst_b3
!
cst_b = cst_b4 * cst_b1

!
cst_c1 = -1.0 / ((zm*st) * ((zm - zm)**2))
cst_c2 = ((zm**3) - (3.0*zm*(zm**2)) + (2.0*(zm**3))) * ms
cst_c3 = ((3.0*zm*(zm**2)) - (2.0*(zm**3))) * mm
!
cst_c4 = cst_c2 + cst_c3
!
cst_c = cst_c1 * cst_c4
!
cst_d = ms
!
term_1 = (cst_a/4.0) * (st**4)
term_2 = (cst_b/3.0) * (st**3)
term_3 = (cst_c/2.0) * (st**2)
term_4 = (cst_d) * (st)
term_5 = ms
!
ilwc = term_1 + term_2 + term_3 + term_4 + term_5
!
return
end
### PROGRAM SECTIONS

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<thead>
<tr>
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<th>Bytes</th>
<th>Attributes</th>
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<tbody>
<tr>
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<td>464</td>
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<td>$LOCAL</td>
<td>96</td>
<td>PIC CON REL LCL NOXHR NOEXEC</td>
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Total Space Allocated: 560

### ENTRY POINTS

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<td>0-00000000</td>
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<td>ILWC_STRAT</td>
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### VARIABLES

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<th>Name</th>
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<th>Name</th>
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<td>2-00000000</td>
<td>R*4</td>
<td>CST_A</td>
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<td>R*4</td>
<td>CST_A1</td>
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<tr>
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<td>CST_A3</td>
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<td>TERN_5</td>
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<td>R*4</td>
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### COMMAND QUALIFIERS

```
FORTRAN/HOOPT/DEBUG/LIST/HOOBJ ILWC_STRAT
/CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
/DEBUG=(SYMBOLS,TRACEBACK)
/DESIGN=(NOCOMMENTS,NOGACHEROLDERS)
/SHOW=(NODICIONARY,NOINCLUDE,MAP,NOVHPPROCESSOR,SINGLE)
/STANDARD=(NOSEMANTIC,NORESOURCE_FORM,NOSYNTAX)
/WARNING=(NODECLARATIONS,GENERAL,NODEBUG,NOVAKHEL)
/CONTINUATIONS=19 /HOCROSS_REFERENCE /HOD_LINES /NOEXTEND_SOURCE
/177 /HOF_FLOATING /I4 /HONUMachine_CODE /HOOPTIMIZE /HOPARALLEL
/NOANALYSIS_DATA
/NODIAGNOSTIC
/LIST=USER$DISK_26:{BELFIORE.SMI.SRC.ILWC}ILWC_STRAT.LIS;1
/NOOBJECT
```

### COMPILED STATISTICS

- Run Time: 0.70 seconds
- Elapsed Time: 1.17 seconds
- Page Faults: 425
- Dynamic Memory: 216 pages
Appendix B Sample Output from the Tape Reading Algorithm
<table>
<thead>
<tr>
<th>Time (Seconds)</th>
<th>Longitude (Degrees)</th>
<th>Latitude (Degrees)</th>
<th>Brightness Temperature (K)</th>
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</table>

B-2
Appendix C  Mapping Software
program where

C******************************************************************************
C Program WHERE prompts the user for an elapsed time in the SSH/I data *
C mission (zero time defined as 00:07:31 - 01-June-1990), and a time *
C "window". It then, via HCAR and GKS, projects a map of the world. *
C and superimposes the track of the satellite scanning platform at that *
C time.
C******************************************************************************
C
0010 include 'syslibrary;gksdefs.for'
0020 integer ws_id, linelim
0028 data ws_id/1/
0029
0030 character*60 fname
0031 real lat, lon, rot, xmax, ymax
0032 real dlal, dlon, dl1, d2, d3, d4, d5
0033 real dummy
0034 integer i, time, choice, prevtime
0035 integer ws_type, error, dummyi
0036 common /us_vars/ ws_id, xmax, ymax, lat, lon
0037
0039 C*************:
0040 C Get data file :
0041 C*************:
0042 write ('**') ' Enter file name (in quotes): ' 
0043 read ('**') fname
0044 open (4, file=fname, status='unknown')
0045 read (4,150) time, lat, lon, d1, d2, d3, d4, d5
0046 rewind (4)
0047 write ('**') ' Enter (1) for orthographic or (2) for cylindrical
0048 *equidistant projection: '
0049 read ('**') choice
0050 write ('**') ' Enter number of lines to be read: '
0052 read ('**') linelim
0053 C*************:
0055 C Open gks *
0056 C*************:
0057 call gks$open_gks ('sys$error: ')
0058 call gks$open_ws (ws_id, gks$gcon_id_default, *
0059 gks$gcon_ws_default)
0060 call gks$inq_ws_type (ws_id, error, dummy, ws_type, dummyi)
0061 call gks$inq_max_da_size (ws_type, error, dummyi, xmax, ymax, *
0062 dummyi, dummyi)
0063 call gks$activate_ws (ws_id)
0064 C*************:
0066 C Set color indices *
0067 C*************:
0068 call SETUSV('IN',3) : 3 possible colors
0069 call SETUSV('TR',1) :RED
0070 call SETUSV('TG',0)
0072 call SETUSV('IB',0)
WHERE

1130 prevtime = time
1131 100 continue
1132 150 format (1X, 11H, 2X, F6.2, 3X, F6.2, 5X, 5(F6.2, 2X))
1133 call gks$update_ws (ws_id, gks$k_postpone_flag)
1134 call gks$update陉s (ws_id, gks$k_postpone_flag)
1135 c pause
1136 c**************
1137 C Close GKS
1138 c**************
1139 call gks$deactivate_ws (ws_id)
1140 call gks$close_ws (Ws_id)
1141 call gks$close_gks
1142 END

PROGRAM SECTIONS

<table>
<thead>
<tr>
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<th>Attributes</th>
</tr>
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<tbody>
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<td>2 $LOCAL</td>
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<tr>
<td>3 WS_VARS</td>
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Total Space Allocated 1888

ENTRY POINTS

Address Type Name
0-00000000 WHERE

VARIABLES

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WHERE
01

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FUNCTIONS AND SUBROUTINES REFERENCED

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COMMAND QUALIFIERS

FORTRAN/NOOPT/DEBUG/LIST/NOOBJ WHERE

/CHECK=(NOSOUNDS, OVERFLOW, NOUNDERFLOW)
/DEBUG=(SYMBOLS, TRACEBACK)
/DESIGN=(NOCOMMENTS, NOPlaceholders)
/SHOW=(NODICITIONARY, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEAMANTIC, NOSOURCE_FORM, NOSYNTAX)
/WARNINGS=(NODECLARATIONS, GENERAL, NOULTRIX, NOVAXLE)
/CONTINUATIONS=19 /NOCROSSREFERENCE /NOLINES /NOEXTENDSOURCE
/F77 /NOG_FLOATING /14 /NOMACHINE_CODE /NOOPTIMIZE /NOPARALLEL
/NOANALYSIS DATA
/NODIAGNOSTICS
/LIST=USERS_DISK_26:[BELFIORE.SSMI.SRC.DISPLAY]WHERE.LIS;1
/NOOBJECT

COMPILATION STATISTICS

Run Time: 3.01 seconds
Elapsed Time: 4.74 seconds
Page Faults: 747
Dynamic Memory: 560 pages
subroutine ce_map
0003 common /ws_vars/ ws_id, xmax, ymax, lat, lon
0005 call gks$set_ws_viewport (ws_id, 0.0, xmax, 0.0, ymax)
0006 call gks$set_ws_window (ws_id, 0.0, 1.0, 0.25, 0.75)
0007 call gks$update_ws (ws_id, gks$k_perform_flag)
0009 C******************************************************************
0010 C Use cylindrical equidistant projection   *  
0012 C******************************************************************
0014 C Specify the angular distances to the edges of the map   *
0016 C******************************************************************
0017 call ma_set('CO',90.,-180.,-90.,180.)
0019 return
0020 end

PROGRAM SECTIONS

Name       Bytes   Attributes
0 $CODE       50      PIC CON REL LCL    SHR       EXE      RD NOWR QUAD
1 $DATA       38      PIC CON REL LCL    SHR    HOEXE      RD NOWR QUAD
2 $LOCAL      124     PIC CON REL LCL    LNOHR  HOEXE      RD    QUTQ QUAD
3 $WS_VARS   20       PIC OVR REL GSL    SHR    HOEXE      RD    QUTQ QUAD

Total Space Allocated  232

ENTRY POINTS

Address  Type  Name
0-00000000  CE_MAP

VARIABLES

Address  Type  Name
2-00000000  R*4  gksk_perform_flag
3-00000010  I*4  lon
3-00000014  R*4  xmax
FUNCTIONS AND SUBROUTINES REFERENCED

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<tr>
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<tr>
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<td>MAPSET</td>
</tr>
<tr>
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COMMAND QUALIFIERS

FORTRAN/HOOPT/DEBUG/LIST/NOOBJ CE_MAP

/CHECK=(NOSOUNDS, OVERFLOW, NOUNDERFLOW)
/DEBUG=(SYMBOLS, TRACEBACK)
/DESIGN=(NOCOMMENTS, NOPHACENENDERS)
/SHOW=(NODICTIONARY, NOINCLUDE, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD=(NOSEMANTIC, NOSOURCE_FORM, NOSYNTAX)
/WARNINGS=(NODELARATIONS, GENERAL, NOULTRIX, NOVAEXL)
/CONTINUATIONS=19 /NOCROSS_REFERENCE /NO_LINES /NOEXITEND_SOURCE
/F77 /NOFLOATING /I4 /NOMACHINE_CODE /NOWOPTIMIZE /NOPARALLEL
/NOANALYSIS_DATA
/NODIAGNOSTICS
/LIST=USERS_DISK_26:(BElFIORE.SSMI.SRC.DISPLAY)CE_MAP.LIS:1
/NOOBJECT

COMPILATION STATISTICS

Run Time: 0.30 seconds
Elapsed Time: 1.05 seconds
Page Faults: 383
Dynamic Memory: 200 pages
```
subroutine or_map

real left, right, bottom, top
common /ws_vars/ ws_id, xmin, xmax, lat, lon

call gks$set_ws_viewport (ws_id, 0.0, xmax, 0.0, ymax)
call gks$set_ws_window (ws_id, 0.0, 1.0, 0.0, 1.0)
call gks$update_ws (ws_id, gks$k_perform_flag)

C*************************************************************************
C Use a circular perimeter
C*************************************************************************
c Call MAPSTI ('XL',1)

C*************************************************************************
C Use orthographic projection
C*************************************************************************

Call MAPROJ ('OR', lat, lon, 23.0)

write (*,*) ' Enter left, right, bottom, & top offset angles: '
read (*,*) left, right, bottom, top
call MAPSET ('AR', left, right, bottom, top)

return
end

PROGRAM SECTIONS

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<tr>
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<th>Bytes</th>
<th>Attributes</th>
</tr>
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<td>1 SPDATA</td>
<td>67</td>
<td>PIC CON REL LCL SHR NOEXE RD NOMRT QUAD</td>
</tr>
<tr>
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<td>148</td>
<td>PIC CON REL LCL NSHR NOEXE RD WRT QUAD</td>
</tr>
<tr>
<td>3 WS_VARS</td>
<td>20</td>
<td>PIC OVR REL GBL SHR NOEXE RD WRT QUAD</td>
</tr>
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</table>

Total Space Allocated 368

ENTRY POINTS

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VARIABLES

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FUNCTIONS AND SUBROUTINES REFERENCED

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<tr>
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<td>MAPSET</td>
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</tr>
</tbody>
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COMMAND QUALIFIERS

FORTRAN/HOOPT/DEBUG/LIST/NOOBJ OR_HAP

/NUJEC= (NOSOUNDS, OVERFLOW, NOUNDERFLOW)
DEBUG= (SYMBOLS, TRACEBACK)
/SHOW= (NODEBUG, NOERROR, MAP, NOPREPROCESSOR, SINGLE)
/STANDARD= (NOSEMANTIC, NOSOURCE_FORM, NOSYNTAX)
/WARNINGS= (NODECLARATIONS, GENERAL, NOUMLINES, NOXELM)
/CONTINUATIONS=19 /NOZERO_REFERENCE /NOZERO_LINES /NOEXTEND_SOURCE
/NO77 /NOG_FLOATING /11 /NOH NearMACHINE_CODE /HOOPTIMIZE /HOPARALLEL
/NOANALYSIS_DATA
/NODEBUG
/LIST=USERS_DISK_26:[BELFIORI.SSMI.SRC.DISPLAY]OR_HAP.LIS;1
/NOOBJECT

COMPILATION STATISTICS

Run Time: 0.37 seconds
Elapsed Time: 1.18 seconds
Page Faults: 431
Dynamic Memory: 200 pages
Appendix D  Sample Mapping Software Output
Appendix E  SSM/I Data Catalog
SSM/I Data Received

<table>
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</tr>
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There is no data missing from our requested set.