MaRC Input Files

Creation of Input and User Defaults Files
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1 Overview

The MaRC input file structure was designed to double as both a set of instructions on how to create one map or more and as a hierarchical list of information of what the map contains. The input file follows a category hierarchy. Each category in the input file has its own set of sub-categories or information to be used during map creation. MaRC input files have one or more output map descriptions or entries, where each entry has the following required sections, each of which will be described later on in this document:

- Map Entry Sections
- Map Output File Comments
- Observed Body Data
- Output Data Information
- Latitude/Longitude Grid Options
- Map Projection Selection and Options
- Map Size
- Map Plane Information

The user defaults file allows the user to set standard values for all maps, planes and input images. The form of the information entered into this file is much simpler than that of the input file. However, the detailed descriptions of the information entered into the user defaults file can be found in the input files section since entries in the user defaults file have much in common with their input file counterparts.

2 Input Files

2.1 Input File Comments

The MaRC input file scanner ignores any text to the right of a pound (`#`) sign. Comments may be placed anywhere in the input file. The user should be aware that placing a comment before a desired keyword or value will cause that keyword or value to be ignored by the parser.

2.2 Keywords and Keyword Values

Information is conveyed to MaRC through the use of a specific set of keywords in the input file. Each keyword has a value type associated with it. The format used in the input file is:

```
KEYWORD: keyword value
```

Notice the use of the colon to delimit the end of the keyword and the beginning of the keyword value. The keyword value will also be referred to as the *semantic value* for a given keyword. For example, MaRC may expect a mathematical expression to be used as the semantic value for a given keyword. Currently there are three type of keyword values MaRC supports. They are strings, keyword tokens and mathematical expressions.

MaRC is not case sensitive when parsing keywords. String keyword values, however, are interpreted by MaRC as string literals. Whatever string is passed to MaRC remains unchanged in terms of case or content. Keyword tokens are simply strings MaRC expects after some keywords, and are interpreted by MaRC as switches that enable a given feature MaRC may have. A mathematical expression is evaluated by the input file parser. If the computed value is valid for a given keyword, that value is then passed to MaRC. Mathematical expressions may contain a single number or any valid combination of the following mathematical operators and functions:

- Operators

`+`	Addition
`-`	Subtraction or Negation
`*`	Multiplication
`/`	Division
`^`	Exponentiation
`( )`	Arbitrary depth parenthetical expressions

- Functions { Example of usage: `sin(3 * 3.1415 / 2)` }

`sin`	The trigonometric sine of a mathematical expression.
`cos`	The trigonometric cosine of a mathematical expression.
`tan`	The trigonometric tangent of a mathematical expression.
`asin`	The arcsine (inverse sine) of a mathematical expression.
`acos`	The arcsine (inverse cosine) of a mathematical expression.
`atan`	The arctangent (inverse tangent) of a mathematical expression.
`exp`	Raises the number "e" to a given value (exponential function).
`ln`	The natural logarithm of a given expression.
`sqrt`	The square root of a mathematical expression.

Note that the arguments for the trigonometric functions `sin`, `cos` and `tan` should be in radians, **NOT** degrees.

2.3 Angle and Range Entries

Special cases of keyword entries that expect mathematical expressions as their semantic values exists when specifying latitudes, longitudes, position angles and ranges. Here is an example of a latitude and longitude entry, the keywords will be discussed later on:

```
SUB_OBSERV_LAT: 34 N C  # Specifies 34 degrees North bodycentric lat.
SUB_OBSERV_LON: 25.6 W  # Specifies 25.6 degrees West longitude
```

Notice the letters after the numbers. For latitudes `N` denotes north latitude. Similarly `S` denotes south latitude. If neither `N` nor `S` is used then the sign of the mathematical expression entered for the latitude determines the hemisphere of the sub-observation latitude. A positive value indicates the northern hemisphere, where a negative value indicates the southern hemisphere. The letter `C` after `N` in this example denotes a bodycentric latitude. The letter `G` may be used to denote a bodygraphic latitude. If neither `C` nor `G` is used then a bodycentric latitude will be assumed. A space must be placed between the hemisphere and latitude type letters. Longitudes can be denoted by the letters `E` and `W` for east and west longitude, respectively. If neither is specified, then the direction of rotation of the body determines whether the longitude is east or west longitude. Prograde rotation causes the longitude to be west by default, whereas a retrograde rotation defaults to east longitude.

A similar expression may be entered for the position angle as follows:

```
POSITION_ANGLE:  57.32 CW  # 57.32 degrees measured clockwise from vert.
```

Here the token `CW` specifies that the position angle is measured clockwise from the vertical ("up") direction of the image. To specify an angle measured counter-clockwise use the token `CCW` instead of the `CW`. If neither `CW` nor `CCW` is used then MaRC will assume a counter-clockwise positive angle is being entered.

MaRC allows the user to specify the distance unit of a mathematical expression used in a range entry, as follows:

```
RANGE:  1820388 KM      # Kilometers
```

or:

```
RANGE:  0.0121685 AU    # Astronomical Units
```

Both are equivalent. Currently, only units of kilometers (`KM`) and astronomical units (`AU`) may be used. If no unit is entered, kilometers will be used as the default unit. The `RANGE` keyword will be described later (see Section 2.11.2.13 [Image Geometry], page 19).

2.4 Map Entries

An input file can contain more than one map description to facilitate batch jobs. Alternatively, map descriptions may be placed in separate files and then passed to MaRC as a of command line arguments, each argument being an input file. The latter has the advantage of occupying less memory while MaRC is running, but also has the disadvantage that input files are not parsed immediately. Any combination of these two methods of creating maps may be used.

A map entry begins with the MAP keyword. Each map entry in the input file begins with this keyword. The semantic value of the MAP keyword is the name of the output file where the map is to be stored. An example of how a map entry begins follows:

```
MAP: map01.fits
```

This states that the name of the file where the map described in the rest of the map entry is called “map01.fits.” Currently all maps are stored in the Flexible Image Transport System (FITS) format.

2.5 Map Output File Comments

The FITS file format allows comments to be placed in the primary array header, the section of the FITS file where the map is stored, and in the image extension header, the section of the FITS file where the latitude/longitude grid stored. Comments for the map that are to be placed in the output file are specified by using the COMMENT and XCOMMENT keywords for the primary array (map) and the image extension (grid image), respectively. The string value for comment keywords should not be longer than 70 characters, can be comprised of any ASCII character and must end with carriage return. Any number of COMMENT and XCOMMENT entries can be used. However, the XCOMMENT entries must come after the COMMENT entries. An example of usage is:

```
COMMENT:This is a primary array comment.
COMMENT: Placing a space immediately following the colon will also place
COMMENT: a space in the output file comments, but is unnecessary since
COMMENT: the FITS routines that MaRC uses places a space before a
COMMENT: comment (part of the FITS standard).  However, extra spacing
COMMENT: may be used, if so desired.
XCOMMENT:This is an image extension comment.    Tabs may also be used in
XCOMMENT:both comment entries.  Again any ASCII character may be used.
XCOMMENT:Remember, each comment entry must end with a carriage return.
```

2.6 Observed Body Data

Information of the body being mapped is needed. The name of the body, its geometry and direction of rotation are used in the input file as follows, also notice the use of input file comments:

```
BODY:   Jupiter  #Name of the body to be stored in the map file header.
        EQ_RAD:         71492   # The equatorial radius. (Kilometers)
        POL_RAD:        66854   # The polar radius.
        ROTATION:       PROGRADE  # e.g.: Venus would be RETROGRADE.
```

The body is modeled as an oblate spheroid. Alternatively, the geometry may be specified by using the flattening of the body, the ratio of the difference of the equatorial radius and the polar radius and the equatorial radius (i.e. (a-c)/a) may be used with either the equatorial radius or the polar radius instead, as follows:

```
        EQ_RAD:         71492
        FLATTENING:     0.06487
```

or:

```
        POL_RAD:        66854
```

```
        FLATTENING:     0.06487
```

The body entry must follow the above order, where the name of the body is first, then the geometry, and then the direction of rotation.

2.7 Output Data Information

The data stored in the output file can be stored in several formats. Data being mapped may have been transformed in some way. Only linear transformations may be specified in the input file. MaRC provides two optional keywords to specify how the data was transformed. They are the `DATA_OFFSET` and `DATA_SCALE` keywords. Both of these keywords expect a mathematical expression as their semantic value. Data described by these keywords would be of the form:

```
(Actual Data) = DATA_OFFSET + DATA_SCALE * (Stored Data)
```

The `DATA_OFFSET` and `DATA_SCALE` keywords are analogous to the `BZERO` and `BSCALE` keywords defined by the FITS standard. Using either one of the `DATA_OFFSET` or `DATA_SCALE` keywords, or both, causes MaRC to place `BZERO` and `BSCALE` entries in the output file primary array header (text that precedes the map data). Both, the `DATA_OFFSET` and `DATA_SCALE` keywords, are optional. Either one of the two or both may be used. By default, `DATA_OFFSET` is set to zero and `DATA_SCALE` is set to one. Specifying these two keywords does **NOT** modify the data being stored in the output file in anyway. It may, however, cause other applications that read the output file to transform the data to their proper values. The `DATA_OFFSET` entry must be entered immediately before the `DATA_SCALE` entry. Immediately following these two keywords is the `DATA_TYPE` keyword. The `DATA_TYPE` keyword is required. It specifies the number format that the mapped data will be stored as. Available data types are:

`BYTE`	1 byte (8 bits) unsigned integer
`SHORT`	2 byte (16 bits) signed integer
`LONG`	4 byte (32 bits) signed integer
`FLOAT`	4 byte (32 bits) floating point number
`DOUBLE`	8 byte (64 bits) floating point number

Be aware, for example, that a `DOUBLE` type map will occupy four times as much memory and storage space then a `SHORT` type map of the same dimensions. An example of how all three keywords are used follows:

```
DATA_OFFSET:    -1.3        # This is optional.  The default is zero.
DATA_SCALE:     0.0001      # This is optional.  The default is one.
DATA_TYPE:      SHORT       # This is required.
```

2.8 Latitude/Longitude Grid Options

A latitude/longitude grid image may be generated by MaRC if desired. The grid image is stored in a separate part of the output file called the image extension. It is left to the user to determine how to overlay the grid image on the map. The grid image is comprised of zeroes and ones, in terms of intensity. Actually it is stored in an unsigned integer (8 bits) format. As such, the minimum value is zero and the maximum value is 255. Grid points and lines have an intensity value of 255. It is also possible to specify the interval between points of constant latitude and of constant longitude. By default the interval between grid points is 10 degrees (bodycentric where applicable). Both are used in the following fashion:

```
GRID:           YES     # This is required.  Enter "YES" or "NO."
GRID_INTERVAL:  5       # This is optional.
```

The `GRID` keyword must come before the `GRID_INTERVAL` keyword.

2.9 Map Projection Selection and Options

2.9.1 Map Projection Overview

The type of map being created must be specified. There are several types of map projections available. They are conformal, equivalent and miscellaneous projections. A projection is selected using the `TYPE` keyword in a given input file.

Conformal map projections are projections that preserve shape, but not necessarily size. Currently, MaRC supports four conformal map projections:

- Normal Conformal Conical Lambert Projection – One Standard Parallel
- Normal Conformal Conical Lambert Projection – Two Standard Parallels
- Transverse Mercator Projection
- Polar Stereographic Projection

Equivalent map projections are projections that preserve area, but not necessarily shape. MaRC supports five equivalent map projections:

- Normal Equivalent Albers Projection – One Standard Parallel
- Normal Equivalent Albers Projection – Two Standard Parallels
- Lambert's Cylindrical Normal Equivalent Projection
- Lambert's Polar Azimuthal Equivalent Projection
- Sanson-Flamsteed (Sinusoidal) Equivalent Projection

The miscellaneous map projections are simply projections that do not fit in the conformal or equivalent projection categories. The three available projections in this category are:

- Orthographic Projection
- Perspective Projection
- Simple Cylindrical Projection

2.9.2 Averaging Techniques

MaRC is capable of mapping several images on to one map plane. Sometimes, there exist regions of overlap between images. Data in these overlap regions are averaged. The user has the option of specifying an averaging technique to use in overlap regions. Currently, there are two averaging techniques available to the user: unweighted averages (weights are equal) and weighted averages (weights are unequal).

Unweighted averages are performed simply by taking the sum of all data involved and dividing by the total number of data elements involved in the sum. In weighted averaging, data is first multiplied by a weight and then added to form a sum. That weighted sum is then divided by the sum of the weights.

Regions of overlap on a map sometimes contain seams. Taking the average may help to remove seams. The best way to keep seams from appearing is by using the weighted average technique with the sky removal feature that are both offered by MaRC (see Section 2.11.2.5 [Sky Removal], page 17).

Averaging techniques in overlap regions are selected using the `AVERAGING` keyword under the `OPTIONS` entry for a given projection (see Section 2.9 [Projections], page 6). To enable *unweighted* averages use the `UNWEIGHTED` semantic value. To enable *weighted* averages instead use the `WEIGHTED` semantic value. It is also possible to entirely disable averaging in overlap regions by using the `NONE` semantic value. Disabling averaging simply causes the data from the first contributing image to be mapped within a given map pixel. For example, if there are three images that would normally contribute to the average in a map pixel, disabling averaging would force data only from the first image to be mapped in that pixel. It should be noted that even though there may be four images in a given map, for example, it is not necessarily the case that all four images contribute to all of the map pixels. For instance, only two of the four images may overlap in a given map pixel.

To enable unweighted averages use the following:

```
AVERAGING:  UNWEIGHTED   # Perform unweighted averaging
```

The `OPTIONS` entry would look like:

```
OPTIONS:
          AVERAGING:  UNWEIGHTED
            .
            .   other projection options
            .
```

It is important that the `AVERAGING` keyword appear before any other projection specific options. The `AVERAGING` keyword entry is optional. By default, MaRC uses weighted averaging in overlap regions.

2.9.3 North and South Pole Selection For Some Projections

Polar projections such as the Conical projections place one of the poles (North/South) at the center of the map. For these projections, a pole to be placed at the center of the map can be selected. By default, MaRC places the North Pole at the center. However, projections which allow the user to set standard parallels (see Section 2.9.4 [Std and Max Lats], page 7) must set the pole at the center of the map prior to selecting standard parallels. A pole can be set with the `POLE` keyword with the form:

```
POLE:    NORTH
```

Valid values for the `POLE` keyword are `NORTH` and `SOUTH`. `NORTH` and `SOUTH` can be abbreviated with `N` and `S`, respectively.

2.9.4 Standard Parallels and Maximum Latitudes

Several of the available projections allow the user to set standard parallels and maximum latitudes. Standard parallels are simply latitudes along which there is no distortion. The closer a feature is to a standard parallel, the less distorted it is. Note that the pole to be placed at the center of the map (see Section 2.9.3 [Poles], page 7) must be set before any standard parallels are set. For maps with one standard parallel, the entry used to set the value for the standard parallel is of the form:

```
STD_LAT:  30 N
```

Maps with two standard parallels can have an entry of the form:

```
STD_LAT_1:  60 N
STD_LAT_2:  20 S
```

There are restrictions to the standard parallels a user can select. For maps with one standard parallel, if the North pole is to be placed at the center (e.g. see Section 2.9.5 [Lambert Con 1], page 8) then the standard parallel should be greater than zero and less than 90. Maps with the South pole at the center must have the standard parallel less than zero and greater than -90 (90 `S`). Maps that allow two standard parallels to be set have the same restrictions for the first standard parallel as stated above for the single standard parallel maps. The second standard parallel has the restriction that its absolute value must be less than the absolute value of the first standard parallel. Similarly, the second standard parallel cannot be 90 `N` or 90 `S`. Furthermore, the absolute values of the first and second standard parallels cannot be equal.

The conformal maps allow the user to set a maximum latitude at the smallest dimension of the map since conformal maps theoretically extend on to infinity as latitudes move from the pole at the center of the map to the other pole at the extremities of the map (yes, the pole is no longer a point at the extremities of the map!). For example, on a map with 800 samples, 400 lines and a maximum latitude at 45 degrees North, the 45 degree maximum latitude will be placed at line 1 and line 400 since there are less lines than there are samples. Maximum latitudes are set with the `MAX_LAT` keyword, as follows:

```
MAX_LAT:  30 N
```

Note that a negative (south) maximum latitude on a map with the North pole at the center of the map will be "greater" than the northern latitudes since the southern latitudes lie further out radially. The same goes for maps with the South pole at the center: northern latitudes lie further out radially than the southern latitudes.

2.9.5 The Normal Conformal Conical Lambert Projection - One Std. Parallel

Lambert's Normal Conformal Conical projection with one standard parallel allows the user to specify a standard parallel. A pole to place at the center of the map must also be chosen. A maximum latitude can also be set. Here is an example of a MaRC input file entry for this projection:

```
TYPE:   LAMCNF1
        OPTIONS:
                    AVERAGING:  NONE
                    POLE:       SOUTH
                    STD_LAT:    30 S
                    MAX_LAT:    20 N
```

Note that the standard latitude is in the southern hemisphere since the South pole is at the center of the map. The order of the keywords must follow the order illustrated in the above example.

2.9.6 The Normal Conformal Conical Lambert Projection -Two Std. Parallels

Lambert's Normal Conformal Conical projection with two standard parallels allows the user to specify two standard parallels. A pole to place at the center of the map must also be chosen. A maximum latitude can also be set. Here is an example of a MaRC input file entry for this projection:

```
TYPE:   LAMCNF2
        OPTIONS:
                        AVERAGING:  UNWEIGHTED
                        POLE:       NORTH
                        STD_LAT_1:  70 N
                        STD_LAT_2:  10 S
                        MAX_LAT:    30 S
```

The order of the keywords must follow the order illustrated in the above example.

2.9.7 The Transverse Mercator Projection

The Mercator projection is selected using the `MERCATOR` keyword token. Currently there are no options available for this projection. The input file entry would look something like:

```
TYPE:   MERCATOR
```

2.9.8 The Polar Stereographic Projection

The Polar Stereographic projection is selected using the `P_STEREO` keyword token. Available options are the pole at center of the map using the `POLE` keyword and the maximum latitude using the `MAX_LAT` keyword. An example of an input file entry for this projection is:

```
TYPE:   P_STEREO
        OPTIONS:
                        AVERAGING:  WEIGHTED
                        POLE:       NORTH
                        MAX_LAT:    30 S
```

The order of the keywords must follow the order illustrated in the above example.

2.9.9 The Normal Equivalent Albers Projection - One Standard Parallel

The Normal Equivalent Albers projection with one standard parallel allows the user to specify a standard parallel. A pole to place at the center of the map must also be chosen. Here is an example of a MaRC input file entry for this projection:

```
TYPE:   ALBEQV1
        OPTIONS:
                        AVERAGING:  NONE
                        POLE:       SOUTH
                        STD_LAT:    30 S
```

Note that the standard latitude is in the southern hemisphere since the South pole is at the center of the map. The order of the keywords must follow the order illustrated in the above example.

2.9.10 The Normal Equivalent Albers Projection - Two Standard Parallels

The Normal Equivalent Albers projection with two standard parallels allows the user to specify two standard parallels. A pole to place at the center of the map must also be chosen. Here is an example of a MaRC input file entry for this projection:

```
TYPE:   ALBEQV2
        OPTIONS:
                       POLE:      NORTH
                       STD_LAT_1: 70 N
                       STD_LAT_2: 20 N
```

The order of the keywords must follow the order illustrated in the above example.

2.9.11 Lambert's Cylindrical Normal Equivalent Projection

Lambert's Cylindrical Normal Equivalent projection is selected using the `LAMCYLEQ` keyword token. Currently there are no options available for this projecton. The input file entry would look something like:

```
TYPE:   LAMCYLEQ
```

2.9.12 Lambert's Polar Azimuthal Equivalent Projection

Lambert's Polar Azimuthal Equivalent projection is selected using the `LAMPOLEQ` keyword token. The pole at the center of the map may be set using the `POLE` keyword. A sample input file entry would be:

```
TYPE:   LAMPOLEQ
        OPTIONS:
                       AVERAGING:  NONE
                       POLE:       NORTH
```

2.9.13 Sanson-Flamsteed (Sinusoidal) Equivalent Projection

The Sanson-Flamsteed (Sinusoidal) Equivalent projection is selected using the `SINUSOID` keyword token. The input file entry would look something like:

```
TYPE:   SINUSOID
        OPTIONS:
                        AVERAGING:   UNWEIGHTED
```

2.9.14 Identity Projection

The Identity projection is a projection that does not modify the supplied map image array. It simply returns exactly what it is given. This project is useful for testing purposes or for "practicing" with MaRC.

The Identity projection is selected using the `IDENTITY` keyword token. Its input file entry would look something like:

```
TYPE:   IDENTITY
```

2.9.15 The Orthographic Projection

The orthographic projection is a projection whose perspective point approaches infinity. This projection is a good approximation to images that are observed from Earth, for example. It can produce what the observed body would look like at a given viewing geometry.

An orthographic projection can be defined in several ways in MaRC. In general, the user enters the viewing geometry and the desired resolution.

2.9.15.1 Viewing Geometry

The viewing geometry is comprised of what will be referred to as the sub-observer point (analogous to the sub-earth point), the position angle, which is the direction that the projection of the north pole in the image plane points, measured counter clockwise positive from the "up" direction in the image, and the body center location.

The sub-observer point is the point on the surface of the body which a line connecting the center of the observer (a spacecraft, for example) and the center of the body passes through. The sub-observer point is set by using the `SUB_OBSERV_LAT` and `SUB_OBSERV_LON` keywords as follows:

```
SUB_OBSERV_LAT: 34 N C  # Specifies 34 degrees North bodycentric lat.
SUB_OBSERV_LON: 25.6 W  # Specifies 25.6 degrees West longitude
```

The position angle, sometimes referred to as the north angle is specified by the following keyword entry:

```
POSITION_ANGLE: -20  # 20 degrees clockwise from North in the projection
```

Again, by convention, positive values are measured counter-clockwise from the vertical ("up") direction in the map, unless the `CW` or the `CCW` tokens are used, as described earlier (see Section 2.3 [Angle & Range], page 3). An equivalent expression for the above example would be:

```
POSITION_ANGLE: 20 CW  # 20 degrees clockwise from North (in projection)
```

It is also possible to choose where to place the center of the projected body. Two methods exist. The user can either enter where the center, relative to the lower left corner of the map image, is in the map image, or specify what latitude and longitude are at the center of the map image, from which the center of the planet will be automatically computed. To specify the center of the planet, the user, for example, would enter:

```
SAMPLE_CENTER:  -23  # Center in pixels measured from the left edge.
LINE_CENTER:    400  # Center in pixels measured from the bottom edge.
```

If the latitude and longitude at the center of the image are to be specified, then the input file would contain an entry similar to the following:

```
LAT_AT_CENTER:  45 N  # Lat. to place at the center of the map image.
LON_AT_CENTER:  34 E  # Long. to place at the center of the map image.
```

Note that only one of these two methods of specifying centers can be used in a given orthographic projection. If neither is specified, than MaRC places the center of the projected body at the center of the map image.

2.9.15.2 Resolution or Scale

The resolution determines how many kilometers per pixel are to be used in the projection. The higher the number of kilometers per pixel the lower the resolution. However, the resolution can only be as good as the resolution of the images used to create the map. If the number of kilometers per pixel for the orthographic projection is not specified, MaRC will compute the number of kilometers per pixel that would cause the entire projection to take up 90% of the shortest dimension of the image. Kilometers per pixel are entered in the following manner:

```
KM_PER_PIXEL:   31.5    # Valid values are greater than zero.
```

2.9.15.3 The Orthographic Projection Input File Entry

The orthographic projection is selected by using TYPE keyword and the ORTHO keyword token in the input file. Combining all of the previously described options, an example of how an orthographic projection entry would look in the input file is:

```
TYPE:   ORTHO
        OPTIONS:
                        AVERAGING:              WEIGHTED
                        SUB_OBSERV_LAT:         3.73 S G
                        SUB_OBSERV_LON:         303.54 W
                        POSITION_ANGLE:         -181.51
                        KM_PER_PIXEL:           300
                        SAMPLE_CENTER:          250
                        LINE_CENTER:            250
```

This keyword order must be followed.

2.9.16 The Perspective Projection

Of all the available projections in MaRC, the perspective projection most closely reproduces what a given instrument actually "sees." The finite distance between the observer and the target is taken into account when creating the projection, meaning that this projection is a true perspective projection. Many of the options available for the orthographic projection are also available for the perspective projection.

2.9.16.1 Perspective Viewing Geometry

The viewing geometry is comprised of the body center location, what will be referred to as the sub-observer point (analogous to the sub-earth point), and the position angle, which is the direction that the projection of the north pole in the image plane points, measured counter clockwise positive from the vertical ("up") direction.

It is possible to choose where to place the center of the projected body. Two methods exist. The user can either enter where the center, relative to the lower left corner of the map image, is in the map image, or specify what latitude and longitude are at the center of the map image, from which the center of the planet will be automatically computed. To specify the center of the planet, the user, for example, would enter:

```
SAMPLE_CENTER:  -23  # Center in pixels measured from the left edge.
LINE_CENTER:    400  # Center in pixels measured from the bottom edge.
```

If the latitude and longitude at the center of the image are to be specified, then the input file would contain an entry similar to the following:

```
LAT_AT_CENTER:  45 N  # Lat. to place at the center of the map image.
LON_AT_CENTER:  34 E  # Long. to place at the center of the map image.
```

Note that only one of these two methods of specifying centers can be used in a given perspective projection. If neither is specified, than MaRC places the center of the projected body at the center of the map image.

The sub-observer point is the point on the surface of the body which a line connecting the center of the observer (a spacecraft, for example) and the center of the body passes through. The sub-observer point is set by using the SUB_OBSERV_LAT and SUB_OBSERV_LON keywords as follows:

```
SUB_OBSERV_LAT: 34 N C  # Specifies 34 degrees North bodycentric lat.
SUB_OBSERV_LON: 25.6 W  # Specifies 25.6 degrees West longitude
```

The position angle, sometimes referred to as the north angle is specified by the following keyword entry:

```
POSITION_ANGLE: -20  # 20 degrees clockwise from North in the projection
```

Again, by convention, positive values are measured counter-clockwise from the vertical ("up") direction in the map, unless the CW or the CCW tokens are used, as described earlier (see Section 2.3 [Angle & Range], page 3). An equivalent expression for the above example would be:

```
POSITION_ANGLE: 20 CW  # 20 degrees clockwise from North (in projection)
```

2.9.16.2 Perspective Projection Range

The range is the distance from the observer to the center of the target being observed (line of sight passing through sub-observer point on the surface of the body). Range can be specified either in Kilometers or Astronomical units, as explained earlier, in the *Keywords and Keyword Values* section. The keyword used to enter the range is RANGE, as follows:

```
RANGE:     1820266 KM
```

To specify Astronomical Units, use the AU keyword token instead.

2.9.16.3 Perspective Resolution or Scale

The resolution determines how many kilometers per pixel are to be used in the projection. The higher the number of kilometers per pixel the lower the resolution. However, the resolution can only be as good as the resolution of the images used to create the map. If the number of kilometers per pixel for the perspective projection is not specified, MaRC will compute the number of kilometers per pixel that would cause the entire projection to take up 90% of the shortest dimension of the image. Kilometers per pixel are entered in the following manner:

```
KM_PER_PIXEL:   31.5    # Valid values are greater than zero.
```

Other ways of specifying the perspective projection scale are by using the ARCSEC_PER_PIX keyword to set the number of arcseconds per pixel or by using the FOCAL_LENGTH and the PIXEL_SCALE keywords to set the focal length and the pixel scale lens attributes, respectively.

The number of arcseconds per pixel is an optical characteristic of the instrument used to observe the body. To set the number of arcseconds per pixel, use:

```
ARCSEC_PER_PIX: 0.125   # This number must be greater than zero.
```

A valid number of arcseconds per pixel must be greater than zero.

If the lens geometry is to be specified, the focal length and the pixel scale at the focal plane of the instrument must be set. An example of how to set these values is:

```
FOCAL_LENGTH:   1501.039        # Millimeters
PIXEL_SCALE:    65.6168         # Pixels per millimeter
```

Units are not specified here. However, the distance units used in both entries must be the same. In this example, the unit for focal length was millimeters. As such, the units for the pixel scale **MUST** be pixels per millimeter and **NOT** pixels per centimeter, for example. If a conversion was needed, a mathematical expression could be entered to perform the conversion. Remember that mathematical expressions are valid for any keyword that is expecting a numerical value.

2.9.16.4 The Perspective Projection Input File Entry

The Perspective projection is selected by using `TYPE` keyword and the `PERSPECTIVE` keyword token in the input file. Combining all of the previously described options, an example of how a perspective projection entry would look in the input file is:

```
TYPE:   PERSPECTIVE
        OPTIONS:
                        AVERAGING:             NONE
                        LAT_AT_CENTER:         -23 S
                        LON_AT_CENTER:         77 E
                        SUB_OBSERV_LAT:        3.73 S G
                        SUB_OBSERV_LON:        303.54 W
                        POSITION_ANGLE:        -181.51
                        RANGE:                 1.3 AU
                        FOCAL_LENGTH:          1500 # cm
                        PIXEL_SCALE:           3.5  # pixels/cm
```

This keyword order must be followed.

2.9.17 The Simple Cylindrical Projection

The simple cylindrical projection is a projection that simply maps latitudes as horizontal lines and longitudes as vertical lines. Pixel distances between latitude lines are uniform throughout the map, and similarly for longitudes. It is possible to map data using either bodycentric or bodygraphic latitudes. Also, latitude and longitude ranges to be mapped can also be specified. The latitude type is set using the `LATITUDE_TYPE` keyword. To choose a bodycentric latitude map, the keyword token `CENTRIC_LAT` is used. Bodygraphic latitudes are selected by using the `GRAPHIC_LAT` keyword token. The latitude range is set by using the `LO_LAT` and `HI_LAT` keywords, while the longitude range is set by using the `LO_LON` and `HI_LON` keywords. The latitude and longitude options as described earlier (see Section 2.3 [Angle & Range], page 3) also hold for these latitude/longitude range keywords. Both latitude range keywords must be used if setting a latitude range and similarly for the longitude range. However, the latitude and longitude range keywords need not always be used. If the latitude range is not specified MaRC will then default to the full latitude range, and similarly for the longitude range. The following is an example of how a simple cylindrical projection is entered in to a MaRC input file:

```
TYPE:   SIMPLE_C
        OPTIONS:
                        AVERAGING:      UNWEIGHTED
                        LATITUDE_TYPE:  GRAPHIC_LAT # or CENTRIC_LAT
                        LO_LAT:         38 S  # CENTRIC lat. by default
                        HI_LAT:         8 S
                        LO_LON:         282 W
                        HI_LON:         337 W
```

Note that it is valid to enter a value for LO_LON that is greater than HI_LON, if so desired.

2.10 Map Size

In general most maps have only two dimensions: the number of *samples* and the number of *lines*. Each of these dimensions are set with the SAMPLES and LINES keywords, respectively. The keyword SAMPLES refers to the number of columns in a map. The LINES keyword refers to the number of rows in a map. An example of a map size entry is:

```
SAMPLES:        800     # In units of pixels
LINES:          400     # In units of pixels
```

MaRC can also create multi-plane maps. Such a map or "map cube" would have several planes each with a different set of data. Both single plane maps and multi-plane maps are defined using the same keywords, the only difference being more than one *plane* (see Section 2.11 [Map Planes], page 15) definition in the multi-plane map case. Note that a map must have at least one plane.

2.11 Map Plane Information

Multiple planes, each containing a different set of data for the map projection, may exist. This section describes how different types map planes may be configured. A map plane may either contain data retrieved from a static source (e.g. an image file) or data dynamically computed at run-time.

2.11.1 Beginning a Plane

If there is more than one plane in a map, simply place another map plane entry immediately following the previous entry. Map plane entries will now be described. Each map plane entry contains the range of valid values that can be mapped and a description of what is being mapped. A plane entry begins with the PLANE keyword. Following this is an optional entry for the valid data range. The data range is specified by the DATA_MIN and DATA_MAX keywords. All data greater than DATA_MIN and less than DATA_MAX will be mapped. If one or both of these keywords are not specified then they are assigned the smallest and largest possible values, a given platform may have for double precision floating point numbers (usually on the order of 1E+300 or more), respectively. Here is an example of the beginning of a plane entry:

```
PLANE:
        DATA_MIN:       -3.14   # This is optional.
        DATA_MAX:       300     # This is optional.
```

Next, the data set must be specified. Data sets may be made up of a set of images or may be the dynamically computed values of the cosine of the incidence, emission or phase angle at given latitudes and longitudes. For example, one map plane could contain a map of a set of images and the next plane could be a map of the cosines of the incidence angles. The supported plane types are defined by the IMAGE, MU, MU0, PHASE, LATITUDE and LONGITUDE entries.

2.11.2 The Image Entry

This section describes how images containing static data, such as those found in an image file, may be mapped.

2.11.2.1 Image Overview

A given plane can be made up of several images. Where each image is placed in the map is determined by the information in each image entry. An image entry is made up of the input image filename, the image type and the input image geometry. If there is more than one image per plane simply place other image entries immediately after the previous one (see Section 2.11.2.19 [Sample Entry], page 21 and Section 2.12 [Sample Input File], page 24). There are several options which may be specified for an image entry, including a flat field image, pixel interpolation and geometric lens aberration correction. An image entry begins with the `IMAGE` keyword. Its semantic value is the filename of the input image, as follows:

```
IMAGE: orbit1/frame002.fits    # absolute or relative paths
```

NOTE: MaRC expects images to be read in upside down.

2.11.2.2 Nibbling

Following the input image filename, is the *nibbling* setup. Some times it is desirable to ignore or to not map pixels on the edges of an input image since they are prone to being "bad pixels," pixels with invalid or unwanted data. This is called "nibbling" in MaRC and other image processing programs. MaRC allows the user to either set the same nibbling value for all sides of an input image or to set the nibble value for each side individually. The

`NIBBLE` keyword is used when setting the same nibble value for all sides, while the `NIBBLE_LEFT`, `NIBBLE_RIGHT`, `NIBBLE_TOP` and `NIBBLE_BOTTOM` keywords are used to set the nibble value for the left, right, top and bottom sides, respectively. The `NIBBLE` keyword cannot be used with the individual nibble keywords, and vice versa. An example of how to use `NIBBLE` keyword is:

```
NIBBLE: 10      # Ignore all pixels within 10 pixels of each edge.
```

where as the individual nibbling keywords are used as follows:

```
NIBBLE_LEFT:    10
NIBBLE_RIGHT:   6
NIBBLE_TOP:     14
NIBBLE_BOTTOM:  20
```

Note: `NIBBLE_BOTTOM` *refers to the number of pixels to be ignored on the top of a properly oriented (i.e. not upside-down) image, and similarly for* `NIBBLE_TOP`

Any combination of the individual nibbling entries may be used. For example, if the user wishes only to ignore pixels on the right edge and the top edge, then only the `NIBBLE_RIGHT` and `NIBBLE_TOP` keywords need to be used.

2.11.2.3 Image Inversion

Some source images are written with the data inverted horizontally, vertically or both. Since MaRC needs images to be oriented with sample (column) numbers increasing left to right and line (row) numbers increasing top to bottom, MaRC provides a keyword that forces MaRC to invert a given source image prior to any image processing. This keyword is the `INVERT` keyword. Allowable values for this keyword are `HORIZONTAL`, `VERTICAL` and `BOTH`. `HORIZONTAL` causes MaRC to invert a given source image over its central vertical axis. Similarly, `VERTICAL` causes MaRC to invert a given source image over the central horizontal axis. Using the value `BOTH` causes MaRC to invert over both horizontal and vertical axes. Here is an example of how the `INVERT` keyword is used:

```
INVERT:    VERTICAL     # Invert over central horizontal axis
```

2.11.2.4 Interpolation

Since all data being mapped is discretized data, the data value between two points is not know. Normally this problems is resolved by taking the value of the nearest point. However, it may sometimes be desirable to estimate the value between to points by interpolating between them. MaRC performs bilinear interpolation between the four surrounding pixels around a desired point. To enable this feature, use the following:

```
INTERPOLATE:    YES   # Enter "NO" to disable.  The default is "NO."
```

If the `INTERPOLATE` keyword is not used, the default setting of `NO` is used.

2.11.2.5 Removing the Sky From Input Images

MaRC has the ability to perform weighted averages in regions of overlap when mapping. A high quality map shows little or no seams where input images overlap. In general, the highest quality maps occur when using weighted averaging in conjunction with MaRC's sky removal feature. The sky removal feature fills pixels in the image that are not part of the target with "invalid" data. These invalid points will not be used when determining the weights for a given pixel during weighted averaging.

By default, the sky removal feature is enabled. To disable sky removal, set the `REMOVE_SKY` keyword to `NO`. Disabling sky removal also cuts down on the time it takes to complete a map since an input image that has sky removal disabled does not have to scan for and remove the sky. If so desired, the user can also explicitly enable sky removal by setting the `REMOVE_SKY` keyword to `YES`; however, this is unnecessary since sky removal is enabled by default.

Here is what an input file entry to disable sky removal would look like:

```
REMOVE_SKY:   NO     # Do not scan for sky.
```

2.11.2.6 The Center of the Body in the Image

In order for MaRC to map a body in a given photo properly, its location in the image must be given. Specifically, the center of the body in the horizontal and vertical directions must be given by using the `SAMPLE_CENTER` and the `LINE_CENTER` keywords, in the following fashion:

```
SAMPLE_CENTER:  -2756.684    # The center may lie off the image.
LINE_CENTER:    1293.4014
```

`SAMPLE_CENTER` denotes the center in the horizontal direction and `LINE_CENTER` denotes the center in the vertical direction.

Note that since MaRC expects images to be read in upside down, the line center is measured from the top of the upside down image (i.e. line numbers increase downward). Furthermore, when mapping images from the Galileo spacecraft the *object space* body center must be used.

2.11.2.7 The Optical Axis

The optical axis, sometimes called the boresight, specifies where in the image the observing instrument is actually "looking." By default, MaRC assumes that the optical axis is at the center of the image. However, the user has the option of setting it manually by using the `SAMPLE_OA` and `LINE_OA` keywords. The `SAMPLE_OA` keyword denotes the sample (i.e.: horizontal) component of the optical axis, as measured from the left side of the image. The `LINE_OA` keyword denotes the line (i.e.: vertical) component of the optical axis, as measured from the top of the *upside-down* image. Here is an example of how these keywords would be used in an input file:

```
SAMPLE_OA: 400  # Measured from the left side
LINE_OA:   400  # Measured from the top of the upside-down image
```

2.11.2.8 The Flat Field Image

For calibration purposes, it may sometimes be necessary to "subtract" an image from the data set. This image is referred to as the flat field image. All data values in the flat field image will be subtracted from their corresponding data values points in the data set being mapped. A flat field image is entered by using the `FLAT_FIELD` keyword. A file name should be entered as the semantic value of the `FLAT_FIELD` keyword, as follows:

```
FLAT_FIELD:     101_410flat.big.fits    # A flat field image
```

The flat field image and the image being mapped should be the same size, otherwise an error will occur. If the `FLAT_FIELD` keyword is not used, then no flat fielding will be performed. Please note that MaRC also expects the flat field image to be read in upside down.

2.11.2.9 Photometric Correction

Data points on an image of an ellipsoidal body, such as a planet, tend to get darker the closer they are to the edge of the body. Such an edge on a celestial body, for example, is a called a limb. To compensate for this "limb darkening," photometric correction may be performed on data in an image. Currently MaRC supports the Minnaert model for photometric correction. To use it when creating maps, use the `MINNAERT` keyword. The `MINNAERT` keyword accepts three types of values:

- a mathematical expression which will be used as the exponent in the Minnaert model.
- the keyword token `AUTO` - automatically computes a value for the exponent in the Minnaert model.
- the keyword token `TABLE` - automatically computes a *table* of Minnaert exponent values for a set number of latitudes. Interpolation will be used when obtaining values not in the table.

An example of its usage is:

```
MINNAERT: AUTO      # Automatically compute Minnaert exponent
```

2.11.2.10 Geometric Lens Aberration Correction

The lens in the camera used to take the picture of the data being mapped may have a geometric aberration in it. To compensate for this lens distortion during mapping, the `GEOM_CORRECT` keyword is set to `YES`, as follows:

```
GEOM_CORRECT:   YES  # Correct Galileo images.  "NO" is the default.
```

If the `GEOM_CORRECT` keyword is not used, then no geometric aberration correction is performed. Currently, this feature only corrects lens distortions equal to the lens distortion found on the Galileo spacecraft.

2.11.2.11 Emission Angle Cut-off

There are some cases where data on an image is very distorted. For example, data on an image of a planet is very distorted near the edge (limb) of the planet. One method of avoiding data near the limb is to prevent data where emission angles are greater than some given value. Since the emission angle at the limb of a planet is generally 90 degrees (less when close to the planet), choosing an emission angle cut-off of 75 degrees, for example, will prevent any data points with emission angles greater than 75 degrees from being mapped. To use this feature of MaRC, the `EMI_ANG_LIMIT` keyword is needed in the `IMAGE` entry. The `EMI_ANG_LIMIT` keyword accepts degree values greater than zero degrees and less than 90 degrees. The `EMI_ANG_LIMIT` keyword entry is of the form:

```
EMI_ANG_LIMIT:  80  # Cut-off all data points beyond this emission angle
```

2.11.2.12 Avoiding Data Beyond the Terminator

The terminator is the curve on the surface of a body where the illuminated portion of the body meets the dark side of the body. In other words, where day becomes night. Data on the dark side of a body in an image may not be useful or may interfere with the averaging process in regions where images overlap in the map. To force MaRC to avoid data beyond the terminator, the `TERMINATOR` keyword can be used as follows:

```
TERMINATOR:   YES   # Avoid data beyond terminator
```

By default, MaRC will map *all* data, including data beyond the terminator. Remember to set the `TERMINATOR` keyword to `YES` if you do *not* wish to map data beyond the terminator.

2.11.2.13 Image Geometry

The viewing geometry of the body at the time its image was taken is also required by MaRC. The viewing geometry is comprised of the sub-observer point (analogous to the sub-earth point), the position angle, the sub-solar point, the range and the scale. An additional viewing geometry value, the optical axis, may also be set (see Section 2.11.2.7 [Optical Axis], page 18).

Sub-Observer Point

The sub-observer point is the point on the surface of the body which a line connecting the center of the observer (a spacecraft, for example) and the center of the body passes through. The sub-observer point is set by using the `SUB_OBSERV_LAT` and `SUB_OBSERV_LON` keywords as follows:

```
SUB_OBSERV_LAT: 34 N C  # Specifies 34 degrees North bodycentric lat.
SUB_OBSERV_LON: 25.6 W  # Specifies 25.6 degrees West longitude
```

Position Angle

The position angle, sometimes referred to as the north angle is the direction that the projection of the north pole in the *properly oriented (not upside down)* image plane points, measured counter clockwise positive from the vertical (“up”) direction, and is specified by the following keyword entry:

```
POSITION_ANGLE: -14  # 14 degrees clockwise of North (in the projection)
```

Again, by convention, positive values are measured counter-clockwise from the vertical (“up”) direction in the input image, unless the `CW` or the `CCW` tokens are used, as described earlier (see Section 2.3 [Angle & Range], page 3). An equivalent expression for the above example would be:

```
POSITION_ANGLE: 14 CW  # 14 degrees clockwise of North (in projection)
```

Sub-Solar Point

The sub-solar point is the point on the surface of the body which a line connecting the center of the sun and the center of the body passes through. The sub-solar point is set by using the `SUB_SOLAR_LAT` and `SUB_SOLAR_LON` keywords as follows:

```
SUB_SOLAR_LAT:  3.2 S C # Specifies 3.2 degrees South bodycentric lat.
SUB_SOLAR_LON:  15  W   # Specifies 15 degrees West longitude
```

Range

The range is the distance from the observer to the center of the target being observed (line of sight passing through sub-observer point on the surface of the body). The range becomes very important at close distances from the body since perspective effects are no longer negligible at such near distances. Range can be specified either in Kilometers or Astronomical units, as explained earlier, in the *Keywords and Keyword Values* section. The keyword used to enter the range is `RANGE`, as follows:

```
RANGE:     1820266 KM
```

To specify Astronomical Units, use the `AU` keyword token instead.

2.11.2.18 Image Scale

It is necessary to set how large the body is in the input image. This is the scale. There are three ways of setting the scale of the body in the image. The user can either set the actual number of kilometers per pixel, or set the number of arcseconds per pixel or the instrument optical characteristics. Only one of these three methods of setting the scale can be used in a given image entry.

To set the number of kilometers per pixel, the `KM_PER_PIXEL` keyword is used:

```
KM_PER_PIXEL:   31.45   # This number must be greater than zero.
```

A valid number of kilometers per pixel must be greater than zero.

The number of arcseconds per pixel is an optical characteristic of the instrument used to observe the body. To set the number of arcseconds per pixel, use:

```
ARCSEC_PER_PIX: 0.125   # This number must be greater than zero.
```

A valid number of arcseconds per pixel must be greater than zero.

If the lens geometry is to be specified, the focal length and the pixel scale at the focal plane of the instrument must be set. An example of how to set these values is:

```
FOCAL_LENGTH:   1501.039        # Millimeters
PIXEL_SCALE:    65.6168         # Pixels per millimeter
```

Units are not specified here. However, the distance units used in both entries must be the same. In this example, the unit for focal length was millimeters. As such, the units for the pixel scale **MUST** be pixels per millimeter and **NOT** pixels per centimeter, for example. If a conversion was needed, a mathematical expression could be entered to perform the conversion. Remember that mathematical expressions are valid for any keyword that is expecting a numerical value.

2.11.2.19 Sample Image Entry

An example of a functional image entry may be:

```
IMAGE:          s0349605600.fits
                NIBBLE_LEFT:            10
                NIBBLE_RIGHT:           2
                NIBBLE_TOP:             5
                NIBBLE_BOTTOM:          3
                INVERT:                 VERTICAL
                INTERPOLATE:            NO
                REMOVE_SKY:             NO
                SAMPLE_CENTER:          2756.684
                LINE_CENTER:            1293.4014
                SAMPLE_OA:              400
                LINE_OA:                400
                FLAT_FIELD:             101_410flat.big.fits
                MINNAERT:               TABLE
                GEOM_CORRECT:           YES
                EMI_ANG_LIMIT:          75
                TERMINATOR:             YES
                SUB_OBSERV_LAT:         -3.62
                SUB_OBSERV_LON:         15.20 E
                POSITION_ANGLE:         183.182 CW
                SUB_SOLAR_LAT:          -1.80
                SUB_SOLAR_LON:          65.84 E
                RANGE:                  1820388 KM
                FOCAL_LENGTH:           1501.039
                PIXEL_SCALE:            65.6168
```

Again, if there is more than one image per plane simply place other image entries, such as the above example, immediately after the previous one (see Section 2.12 [Sample Input File], page 24).

2.11.3 Virtual Images

It is often useful to map data that is specific to a given viewing geometry, such as body latitudes and emission angles. A static set of such data is generally not available, or isn't always feasible to create beforehand due to time and space constraints. To avoid these issues, the data in question must be computed "on-the-fly", i.e. at run-time. Since the images do not exist *a priori*, MaRC considers these images to be *virtual* images.

A map of latitudes, longitudes, the cosines of the emission, incidence or phase angle can be created by specifying the following, instead of the `IMAGE` entry:

`LATITUDE` Create a map of latitudes.

`LONGITUDE`
Create a map of longitudes.

`MU` Create a map of the cosines of the emission angles.
`MU0` Create a map of the cosines of the incidence angles.
`PHASE` Create a map of the cosines of the phase angles.

2.11.3.1 Latitude and Longitude Plane Entries

In cases where course-grained map grids (see Section 2.8 [Lat/Lon Grid], page 5) are not suitable, MaRC can create maps of the latitudes and longitudes for each valid pixel on the chosen map projection. Unlike map grids that are considered image extensions, latitude and longitude planes will placed in the primary map itself.

To create a map of latitudes a map plane entry such as the following can be used:

```
LATITUDE:    LATITUDE_TYPE:          CENTRIC
```

The `LATITUDE_TYPE` keyword has the same syntax as the one described in the Simple Cylindrical map projection discussion (see Section 2.9.17 [Simple Cyl], page 14).

To create a map of longitudes a simple map plane entry such as the following can be used:

```
LONGITUDE
```

2.11.3.2 The Emission, Incidence and Phase Angle Plane Entries

The emission angle is the angle between the observer and the normal at a given point on the body. The incidence angle is the angle between the sun and the normal at a given point on the body. The phase angle is the angle between the observer and the sun, where a given point on the surface of the body is the vertex. All computations involving these angles take into account the distance between the observer and the body. The sun is assumed to be an infinite distance away. Here is an example of how to specify the use of the cosines of the incidence angles in the plane entry:

```
MU0:    SUB_OBSERV_LAT:         3.62 S
        SUB_OBSERV_LON:         14.45 E
        RANGE:                  1819712.917 KM
        SUB_SOLAR_LAT:          -1.80
        SUB_SOLAR_LON:          65.07 E
```

To specify one of the other angles, simply replace `MU0` with `MU` or `PHASE`. Note that all three types of angle entries require the sub-observation point, the observer range and the sub-solar point to be specified. This is more for the sake of consistency rather than necessity (e.g. the observer range isn't need to compute incidence angles). These were described in the image entry section (see Section 2.11.2.13 [Image Geometry], page 19). Although the sub-observer point and the observer range are not needed to compute the incidence angles, they are used to force the user to be consistent when entering other angle entries.

2.11.4 A Sample Plane Entry

A functional plane entry would be of the form:

```
PLANE:
        DATA_MIN:       0.1
        DATA_MAX        10000
        IMAGE:          s0349605745.fits
                        INVERT:                 BOTH
                        INTERPOLATE:            NO
                        SAMPLE_CENTER:          2788.453
                        LINE_CENTER:            1295.195
                        SAMPLE_OA:              200
                        LINE_OA:                200
                        FLAT_FIELD:             756flat.big.fits
                        MINNAERT:               1.0
                        GEOM_CORRECT:           YES
                        EMI_ANG_LIMIT:          80
                        TERMINATOR:             NO
                        SUB_OBSERV_LAT:         -3.61
                        SUB_OBSERV_LON:         14.30 E
                        POSITION_ANGLE:         -183.183
                        SUB_SOLAR_LAT:          -1.80
                        SUB_SOLAR_LON:          64.92 E
                        RANGE:                  1819651 KM
                        FOCAL_LENGTH:           1501.039
                        PIXEL_SCALE:            65.6168
        IMAGE:          s0349605768.fits
                        INVERT:                 HORIZONTAL
                        INTERPOLATE:            NO
                        SAMPLE_CENTER:          2117.652
                        LINE_CENTER:            1289.763
                        SAMPLE_OA:              200
                        LINE_OA:                200
                        FLAT_FIELD:             756flat.big.fits
                        MINNAERT:               AUTO
                        GEOM_CORRECT:           YES
                        EMI_ANG_LIMIT:          78
                        TERMINATOR:             YES
                        SUB_OBSERV_LAT:         -3.61
                        SUB_OBSERV_LON:         14.15 E
                        POSITION_ANGLE:         -183.203
                        SUB_SOLAR_LAT:          -1.80
                        SUB_SOLAR_LON:          64.77 E
                        RANGE:                  1819528 KM
                        FOCAL_LENGTH:           1501.039
                        PIXEL_SCALE:            65.6168
```

or:

```
PLANE:
        LATITUDE:       LATITUDE_TYPE:          GRAPHIC_LAT
```

```
        PLANE:
                LONGITUDE
        PLANE:
                PHASE:          SUB_OBSERV_LAT:         3.62 S
                                SUB_OBSERV_LON:         14.45 E
                                RANGE:                  1819712.917 KM
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          65.07 E
```

2.12 An Example of a Complete MaRC Input File

```
MAP:    MAP_101c.fits
COMMENT:Simple cylindrical map of Jupiter.
COMMENT:Generated using MaRC.
XCOMMENT:Latitude/Longitude grid for this map.
        BODY:   Jupiter             # This is an end of line comment.
  #This is a one line comment.
                EQ_RAD:         71492   # Kilometers is a must!!
                POL_RAD:        66854
                ROTATION:       PROGRADE
        DATA_TYPE:              SHORT
        GRID:                   YES
        TYPE:   SIMPLE_C
                OPTIONS:
                                AVERAGING:     UNWEIGHTED
                                LATITUDE_TYPE: GRAPHIC_LAT
                                LO_LAT:        -38 # CENTRIC is default
                                HI_LAT:        -8
                                LO_LON:        282 # West since prograde
                                HI_LON:        337
        SAMPLES:        800
        LINES:          400
        PLANE:
                IMAGE:          s0349605600.fits
                        #       NIBBLE:                 5
        # The above "NIBBLE" has been commented out !!!!
        # The "NIBBLE" keyword sets all of the below NIBBLEs
        # to the same value.
                                NIBBLE_LEFT:            10
                                NIBBLE_RIGHT:           2
                                NIBBLE_TOP:             5
                                NIBBLE_BOTTOM:          3
                                INVERT:                 VERTICAL
                                INTERPOLATE:            NO
                                SAMPLE_CENTER:          2756.684
                                LINE_CENTER:            1293.4014
                                SAMPLE_OA:              200
```

```
                                LINE_OA:                 200
                                FLAT_FIELD:              101_410flat.fits
                                MINNAERT:                TABLE
                                GEOM_CORRECT:            YES
                                EMI_ANG_LIMIT:           83.7556
                                TERMINATOR:              YES
                                SUB_OBSERV_LAT:          -3.62
                                SUB_OBSERV_LON:          15.20 E
                                POSITION_ANGLE:          183.182 CW
                                SUB_SOLAR_LAT:           -1.80
                                SUB_SOLAR_LON:           65.84 E
                                RANGE:                   1820388 KM
                                FOCAL_LENGTH:            1501.039
                                PIXEL_SCALE:             65.6168
                IMAGE:          s0349605622.fits
                                INVERT:                  VERTICAL
                                INTERPOLATE:             NO
                                SAMPLE_CENTER:           2073.767
                                LINE_CENTER:             1284.2759
                                SAMPLE_OA:               200
                                LINE_OA:                 200
                                FLAT_FIELD:              101_410flat.fits
                                MINNAERT:                AUTO
                                GEOM_CORRECT:            YES
                                EMI_ANG_LIMIT:           80
                                TERMINATOR:              YES
                                SUB_OBSERV_LAT:          -3.62
                                SUB_OBSERV_LON:          15.05 E
                                POSITION_ANGLE:          -183.203
                                SUB_SOLAR_LAT:           -1.80
                                SUB_SOLAR_LON:           65.69 E
                                RANGE:                   1820266 KM
                                FOCAL_LENGTH:            1501.039
                                PIXEL_SCALE:             65.6168

        PLANE:
                IMAGE:          s0349605745.fits
                                INVERT:                  VERTICAL
                                INTERPOLATE:             NO
                                SAMPLE_CENTER:           2788.453
                                LINE_CENTER:             1295.195
                                SAMPLE_OA:               200
                                LINE_OA:                 200
                                FLAT_FIELD:              101_756flat.fits
                                MINNAERT:                1.0
                                GEOM_CORRECT:            YES
                                EMI_ANG_LIMIT:           85
```

```
                                TERMINATOR:             NO
                                SUB_OBSERV_LAT:         -3.61
                                SUB_OBSERV_LON:         14.30 E
                                POSITION_ANGLE:         -183.183
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          64.92 E
                                RANGE:                  1819651 KM
                                FOCAL_LENGTH:           1501.039
                                PIXEL_SCALE:            65.6168
                IMAGE:          s0349605768.fits
                                INVERT:                 VERTICAL
                                INTERPOLATE:            NO
                                SAMPLE_CENTER:          2117.652
                                LINE_CENTER:            1289.763
                                SAMPLE_OA:              200
                                LINE_OA:                200
                                FLAT_FIELD:             101_756flat.fits
                                MINNAERT:               TABLE
                                GEOM_CORRECT:           YES
                                EMI_ANG_LIMIT:          70
                                TERMINATOR:             NO
                                SUB_OBSERV_LAT:         -3.61
                                SUB_OBSERV_LON:         14.15 E
                                POSITION_ANGLE:         183.203 CW
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          64.77 E
                                RANGE:                  1819528 KM
                                FOCAL_LENGTH:           1501.039
                                PIXEL_SCALE:            65.6168

        PLANE:
                MU:             SUB_OBSERV_LAT:         -3.62
                                SUB_OBSERV_LON:         14.45 E
                # RANGE defaults to units of Kilometers
                                RANGE:                  1819712.917
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          65.07 E

        PLANE:
                MU0:            SUB_OBSERV_LAT:         3.62 S
                                SUB_OBSERV_LON:         14.45 E
                                RANGE:                  1819712.917 KM
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          65.07 E

# The next map in the input file follows.
MAP:    mumu0.TEST2.fits
```

```
COMMENT:This is just a sample input file for a Mu/Mu0/cos(Phase) map
XCOMMENT:Latitude / Longitude grid for primary array (the cube)
        BODY:   Jupiter
                EQ_RAD:         71492
                POL_RAD:        66854
                ROTATION:       PROGRADE

        DATA_TYPE:              SHORT
        GRID:                   YES
        GRID_INTERVAL:          10
        TYPE:   ORTHO
        OPTIONS:
                                SUB_OBSERV_LAT:         3.73 S G
                                SUB_OBSERV_LON:         303.54 W
                                POSITION_ANGLE:         34.56 CCW
                                KM_PER_PIXEL:           300
                                SAMPLE_CENTER:          250
                                LINE_CENTER:            250
        SAMPLES:        400
        LINES:          500
        PLANE:
                MU:             SUB_OBSERV_LAT:         -2.83
                                SUB_OBSERV_LON:         56.46 E
                                RANGE:                  1555114.417 KM
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          65.07 E
        PLANE:
                MU0:            SUB_OBSERV_LAT:         -2.83
                                SUB_OBSERV_LON:         56.46 E
                                RANGE:                  1555114.417
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          65.07 E
        PLANE:
                PHASE:          SUB_OBSERV_LAT:         -2.83
                                SUB_OBSERV_LON:         56.46E
                                RANGE:                  1555114.417
                                SUB_SOLAR_LAT:          -1.80
                                SUB_SOLAR_LON:          65.07E
        PLANE:
                LONGITUDE
```

3 User Defaults Files

Sometimes all maps in a given input file have the same options. Setting the same option for each map or image can be tedious. Instead, the user can define default values for all maps and input images. At startup, MaRC searches for a file called '.marc' in the users home directory. This file contains user defined defaults for the grid interval size, the valid data range for each plane and the nibbling values for all input images. If set, than these values will be applied to all maps and input images. However, it is possible to override these values by entering a different value in the input file where appropriate, as explained the MaRC Input File section. Any map, plane or image entry that does not override the values in the user defaults file will use the values found in the user defaults file. If a value is not set in the user defaults file, then the MaRC internal defaults will be used. All entries in the user defaults file are optional, but must follow a specific order if used:

```
GRID_INTERVAL:  10      # Must be before the data range and nibbling.
DATA_MIN:       0.001   # Both before the nibbling entries.
DATA_MAX:       10000
NIBBLE_LEFT:    6       # These must used in the shown order.
NIBBLE_RIGHT:   20
NIBBLE_TOP:     8
NIBBLE_BOTTOM:  8
```

If it is not necessary, for example, to set DATA_MIN and NIBBLE_RIGHT, then simply remove them from the user defaults file, since all of these entries are optional.

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