
RADS User Manual

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Chapter 1

Introduction

This document describes the layout and use of the Radar Altimeter Database System (RADS), Version 4. RADS was first developed at Delft University of Technology's Department of Aerospace Engineering, and remains a joint development with NOAA Laboratory for Satellite Altimetry and EUMETSAT.

The Radar Altimeter Database System is composed of three elements:

- A few hundred gigabytes of altimeter data files from missions stretching from Geosat to whatever altimeter data was made available in the last few days;
- A set of software tools (object library and executables);
- Configuration files.

So apart from the actual altimeter data, RADS provides a suite of applications and subroutines that simplify the reading, editing, handling and analysing of data from numerous radar altimeters. Although the actual content and layout of the underlying data products do not have to be identical for all altimeters, the user interface is. Also, the data base is easily expandable with additional data and/or additional corrections without impact to the user interface, or to the software in general. In fact, only in very few cases the core software will need to be adjusted and recompiled, in even fewer cases adjustments to the actual tools will be required. Most changes can be covered by changes in the configuration file.

The data base consists of netCDF files, one for each satellite pass (half a revolution starting and ending close to the poles). Ascending passes have odd numbers, descending passes even numbers. The pass numbering increases consecutively within a repeat cycle.

In case of exact repeat missions the satellite returns to the same ground track every repeat cycle. For Jason-2, for example, this is after 254 passes, when the pass number starts over at 1. Which pass is number 1 is based on the longitude of the equator crossing (ascending node). Thus all passes with the same pass number are collinear.

For non-repeat missions or those with very long repeat cycles (like CryoSat-2 or the Jason-1 Extended Mission), we created "sub-cycles" of a manageable length. There too passes with the same pass number are nearly collinear. Note that the length of the "sub-cycle" may change for cycle to cycle in a kind of dance-step manner.

Each netCDF data file contains the actual (binary) data as well as the meta data that describe the contents (data type, units, creation history, etc.) The naming convention for the files is `SSppPPPPcCCC.nc`, where `SS` is an abbreviation for the satellite (altimeter), `PPPP` is the pass

number, `ccc` is the cycle number, and `nc` is the extension, a standard convention for netCDF data files.

The data files are grouped in one directory for each cycle, named `cCCC`. These cycle directories are then grouped into one directory for each mission phase, which are finally part of one directory per satellite. For example, the data file for pass 801 of cycle 150 in ERS-1's tandem mission is `$RADSDATAROOT/e1/g/c150/e1p0801c150.nc`, where `$RADSDATAROOT` is the root directory of the RADS data base.

To read and manipulate the data, you can use standard netCDF tools, like `ncdump` (that comes with the netCDF package), `GMT` (Generic Mapping Tools), `nco` (NetCDF Operators). But more suitable is the use of the RADS subroutine library and programs. The library is the basis for all data utilities provided with RADS and can also be used to create other programs to the user's convenience. For a description on each of the subroutines in the library and on how to create your own program see Appendix 6. In addition, a number of handy utilities are provided to do some of the most essential jobs (Chapter 5).

Whether you are using the routines, or the provided utilities, you will have to know how the data handling system of RADS works. It is not essential that you understand the intrinsics of the data files, but it is highly recommended that you familiarise yourself with the way the data can be manipulated, selected and edited *on the fly* by the RADS routines. Basically, the RADS routines can take a lot of work out of your hands, provided you have read Chapter 4.

Before going into the details of RADS, the software and the data have to be installed on your computer. Chapter 2 guides you through the process of software installation, and Chapter 3 tells you how to keep the database up to date.

RADS software installation

In order to work efficiently with the RADS data base you are required to install the software (subroutine library, utilities, scripts, and configuration files). This we will tackle in this Chapter. Once you are done with that at least part of the data base needs to be copied onto your hard disk (or another mounted device), which will be described in the next Chapter.

2.1 Prerequisites

In order to install and run the RADS software you need a few things installed on your system:

- A unix platform (for example Linux or Mac OS X).
- The `make` command.
- A Fortran 90 compiler. RADS is known to compile with `gfortran`, `f90`, `f95`, `xlF90`, `xlF95`, `ifort`.
- The netCDF library (version 4.3 or later) and together with the Fortran 90 interface and module file. Of course, netCDF comes with its own dependencies (like HDF5 and `szip`). Please figure out where to find the netCDF module file `netcdf.mod` and the netCDF C library `libnetcdf` and Fortran library `libnetcdf.f` before you continue.
- Optionally, the `git` program.
- For downloading and synchronising the data base, the `rsync` program.

2.2 Download the source code

The source code can be downloaded as a bundle (zip or tarball) from GitHub or can be synchronised directly with the github server with the `git` program. The two methods are described below in Sections 2.2.1 and 2.2.2.

You can put the source code anywhere you like. We will later configure where things will be installed. After downloading the software, continue with the configuration, compilation, and installation steps in Sections 2.3 through 2.5.

It is recommended to regularly check for updates of the RADS source code and recompile if necessary.

2.2.1 Source code download via GitHub

To download the latest bundle of the source code, simply go to <https://github.com/remkos/rads/releases/latest>. There you will find the latest release notes, and links for the downloading of the bundle, either as a zip file, or as a compressed tarball.

You can extract the software in place, or anywhere you want by running:

```
$ tar -xvzf rads-v4.3.6.tar.gz
```

or

```
$ unzip rads-v4.3.6.zip
```

This will create a directory called `rads-v4.3.6`.

2.2.2 Source code synchronisation with git

The version control system `git` helps to administrate software development projects on distributed systems (or at least by distributed users), avoiding problems of accidentally wiping out each other's changes. Also, it is a very practical tool for distributing trees of software to others, who then can make their own changes without running the risk of accidentally overwriting them when a new update is provided. The `git` command can merge those changes, and alerts you of that happening.

You need to have at least the executable `git` installed on your system to connect to the GitHub repository. This program comes installed by default on Mac OS X and most Linux and Unix systems.

First you need to 'clone' the code from the GitHub server onto your machine:

```
$ git clone https://github.com/remkos/rads
```

This downloads all the code and puts it into a directory called `rads`. This needs to be done only once.

Later on you can bring the source on your machine up to date by going into the `rads` directory and executing:

```
$ git pull -t origin master
```

although it is much simpler to just use:

```
$ make update
```

2.3 Software configuration

Now we are going to determine where the software executables, library, and data are going to be stored. For this we run the `configure` in the source directory (`rads-v4.3.6` if you downloaded the tarball, or `rads` if you used `git`). The program `configure` will allow you to specify where you want things installed and also determines which Fortran compiler you have and what special options are needed for your platform.

By default, `configure` will install everything under the directory where it resides itself. It will create directories:

bin for the executables (both binaries and scripts)

include for the Fortran 90 module files to be used with the RADS library

lib for the RADS library

share for the system independent data: the satellite data and configuration files. This one particularly, you might want to put somewhere else, on a dedicated disk, for example.

Normally, you would need to tell `configure` only where you want to install the aforementioned directories. The rest, like where to find your Fortran compiler and the netCDF library, are things that `configure` should be able to figure out by itself, using the `nf-config` script, for example. Therefore, you will only have to specify the root directory for the installation (prefix) and likely the place where you want the RADS altimeter data to reside or where they are already residing (`datadir`). Run, for example:

```
$ configure --prefix=/usr/local --datadir=/rads/data
```

The first argument to `configure` specifies that the `bin`, `include` and `lib` directory are to be put under `/usr/local`. The second argument specifies the directory for the data and configuration file (which could be on a server for more systems to use). Still a directory `share` is created under `/usr/local` to contain the manuals.

If, for whatever reason, `configure` cannot find a Fortran compiler or the netCDF libraries on its own, you need to specify the location of the Fortran compiler and the netCDF library and include files. Here is an example:

```
$ configure FC=/sw/bin/gfortran \
  --with-netcdf-inc=/sw/lib/netcdf-gfortran/include \
  --with-netcdf-lib=/sw/lib:/sw/lib/netcdf-gfortran/lib \
  --prefix=/usr/local --datadir=/rads/data
```

The first argument to `configure` specifies the location of the fortran compiler, while the second identifies the directory where we can find `netcdf.mod`. The third argument specifies the two directories that contain the netCDF C library (`libnetcdf`) and netCDF Fortran library (`libnetcdf.f`), separated by a colon. If these two are merged, or in one directory, you can just use one directory name.

Alternatively, the `nf-config` utility installed with the NetCDF package can provide the correct paths to the netCDF library and include directories. In this option, you can specify the full path to `nf-config`. For example,

```
$ configure FC=/sw/bin/gfortran \
  --with-nf-config=/sw/bin/nf-config
--prefix=/usr/local --datadir=/rads/data
```

The `configure` program also tests if your Fortran compiler is ready for Fortran 90 and can compile with the netCDF library. If you have problems, you may need to review the options you gave to `configure`, and make sure that `configure` picked the same compiler that was used to compile the netCDF library. Finding the `nf-config` command on your system may be pivotal.

Run `configure --help` to get more info.

2.4 Software compilation

Now that your system is configured, it should be easy to compile the software. Just run in the source directory (where you also ran `configure`):

```
$ make
```

It will compile and link the programs in the subdirectory `src`, but not those in `devel`. The latter are only provided to you to get a feel of how the RADS altimeter database was created. You will not be able to compile or link those programs, as essential routines have been left out.

If you have problems compiling, you may need to tweak one of the makefiles, `config.mk`. Please let us know about it, so that we can change the `configure` program accordingly. You can do this at the issue tracker on the RADS GitHub page: <https://github.com/remkos/rads/issues>.

2.5 Installation

To install the software, configuration file, and manuals in the places discussed in Section 2.3, run the following command in the directory where `configure` resides:

```
$ make install
```

Now you can continue with the mirroring of the data files.

Chapter 3

RADS data mirroring

RADS now exceeds 400 GBytes of data. It is virtually impossible to copy all of it in one go, or copy all of it every time that updates have been made. To facilitate the updating, it is recommended to use the `rsync` program. This program will determine by itself which files are updated and will update only those. In fact, it will transfer only those parts of the files that are actually changed. This provides a significant speed benefit when, for example, an extra data field is added.

You need to have at least the executable `rsync` installed on your system to use `rsync`. In case of Linux machines, simply install the `rsync` package available on most distributions. The program `rsync` comes standard with Mac OS X, or can be obtained from <http://rsync.samba.org>.

The `rsync` command will download the data from the `rsync` server at the Delft University of Technology in The Netherlands. This server is setup such that it will allow you to access only the RADS data and software. It will not allow you to log in to the server as a common user. Thus, setting up `ssh` key pairs is not possible.

Let us start, for example, to synchronise the Jason-2 data. The subdirectory for the Jason-2 data is `j2` (See Table 3.1 for all 2-character abbreviations of the altimeter missions). To get all the Jason-2 data, you will type the following commands (still assuming you have your data in `/rads/data`):

```
$ cd /rads/data
$ rsync -avz --del radsuser@rads.tudelft.nl::rads/data/j2 .
```

At the beginning `rsync` will ask you to enter the password for `radsuser`. It will have been provided to you when you registered as a user.

Apart from the satellite specific directories, there is a directory that contains configuration files, that help RADS to read the data files. These files are also installed in the same place, when installing the software, but you can download them from the `rsync` server as well. Be sure to keep these files up to date.

```
$ cd /rads/data
$ rsync -avz --del radsuser@rads.tudelft.nl::rads/data/conf .
```

If you are patient, and want to get all of the data at once, you can perform the following commands:

```
$ cd /rads
$ rsync -avz --del radsuser@rads.tudelft.nl::rads/data .
```

Altimeter	Abbr.	Nr	Alternatives	References
GEOS 3	g3	1	ge3 geos-3 geos3	(not included in RADS)
Seasat	ss	2	sea seasat-a	(not included in RADS)
Geosat	gs	3	geo geosat	
ERS-1	e1	4	er1 ers-1 ers1	[Francis, 1990; Francis et al., 1991]
TOPEX	tx	5	top topex	[Fu et al., 1994]
Poseidon	pn	6	pos poseidon	
ERS-2	e2	7	er2 ers-2 ers2	[Francis et al., 1995]
GFO	g1	8	gfo gfo-1 gfo1	
Jason-1	j1	9	ja1 jason-1 jason1	[Ménard et al., 2003]
Envisat	n1	10	en1 envisat	
Jason-2	j2	11	ja2 jason-2 jason2	[Lambin et al., 2010]
CryoSat-2	c2	12	cs2 cryosat-2 cryosat2	[Wingham et al., 2006]
SARAL	sa	13	sa srl saral altika	
Jason-3	j3	14	ja3 jason-3 jason3	
HY-2A	2a	15	h2a hy-2a hy2a	(not included in RADS)
Sentinel-3A	3a	16	s3a sentinel-3a sentinel3a sntnl-3a	
Sentinel-3B	3b	17	s3b sentinel-3b sentinel3b sntnl-3b	(limited access in RADS)

Table 3.1 Abbreviation and numbers used for the various altimeter missions.

If, for whatever reason, the mirroring is interrupted, you can simply start it again, and it will continue where it left off. If you have a recent version of the `rsync` program, we recommend that you use the option `--del` instead of `--delete`, as it speeds up the process significantly.

There is one more directory that may be of interest, but is not essential. The `/rads/tables` directory contains a number of lists: lists of the time intervals of passes and cycles, and lists of the data available for each satellite.

To mirror these directories use `rsync`:

```
$ cd /rads
$ rsync -avz --del radsuser@rads.tudelft.nl::rads/tables .
```

If you need to use `rsync` regularly to synchronise the RADS data base and you do not want to enter the password every time, you can set up the environment variable `RSYNC_PASSWORD` by one of the following methods (depending on the shell):

```
export RSYNC_PASSWORD=radspasswd      # under sh or bash
setenv RSYNC_PASSWORD radspasswd      # under csh or tcsh
```

If you are using the `bash` or `sh` shell, you can do it all in one line, for example:

```
RSYNC_PASSWORD=radspasswd \
rsync -avz --del radsuser@rads.tudelft.nl::rads/data .
```

Obviously, the password is **not** simply `radspasswd`.

RADS data management

This Chapter describes the basic functionalities of the data management system of RADS. These functionalities are part of the RADS utilities as well as the RADS subroutine library on which the utilities are based.

4.1 Preparations before using the data base

The use of RADS starts with the definition of the environment variable `RADSDATAROOT`, such that it points to the root of the RADS data base. For example (for bash users):

```
$ export RADSDATAROOT=/rads/data
```

If you already specified this directory in the configure step, then you do not have to set the `RADSDATAROOT` directory.

It is also practical to include `/usr/local/bin` (or where ever you installed the binaries) in your executable search path, so that existing executables can be used. However, this is not essential, just practical.

4.2 Common functionalities

A subroutine library is created to facilitate the data reading, conversion to SI units, editing and the construction of sea level anomalies. Based on these routines, several programs (utilities) are created to list or manipulate the contents of the data base. Since these programs share the same routines, much of their functionalities are the same, as well as their user interface. In addition, a number of developer tools are available to create the data base. These programs will be of less concern to the users, and are not yet explained in this manual. Their code is only provided for reference, and are not intended to be compiled on your system.

Common to all RADS utilities is the internal data selection, editing, and the ability to construct the sea level anomaly (or any other fields) *on the fly*. The construction of the sea level anomaly includes a number of arithmetic expressions (adding and subtracting), plus applying a number of selection criteria that can flag the sea level anomaly as invalid. Both the ability to do arithmetic (even beyond mere adding and subtracting) and editing are built into the software library, so that they can be shared by the various RADS utilities.

Even when writing their own program, the user does not have to generate code to construct a sea level anomaly or to do editing. At the same time that the sea level anomaly is constructed,

the data is edited based on system-wide, user, or local preferences. These preferences can be specified at several levels, either in XML configuration files, or by command line options. The order in which these preferences are processed is the following:

- System-wide general preferences, found in `$RADSDATAROOT/conf/rads.xml`.
- General user preferences, found in a file `~/.rads/rads.xml`, if available.
- General local preferences, found in a file `rads.xml` in the current working directory.
- Preference files indicated by the `-X` or `--xml` option on the command line.
- Other command line arguments, such as `-L` or `--limits`.

So the command line arguments overrule the local preferences and which overrule the user preferences and eventually the system-wide preferences.

The XML configuration file is “human readable” and is described in the next section.

4.3 RADS4 configuration file

The RADS4 configuration file `rads.xml` controls:

- Information about the various altimeter missions, such as repeat period, number of passes per cycle, etc.
- Information about all the variables available for each mission, including editing criteria, format for writing to ascii, and the complete information needed to store the variable upon creation of the database.
- Optionally, description of variables that can be created *on the fly* from other variables.

The configuration file is a structured XML file, comprised of a number items and blocks, of the following shape:

```
<block>
  <item option="value">....</item>
  <tag>....</tag>
</block>
```

As usual in an XML file, `<tag>` starts an item with name `tag` and `</tag>` ends it. Any content in between is the value, or are the values associated with this tag. Generally, the line can be broken by carriage returns and leading spaces are ignored.

4.3.1 Tags in the configuration file

The various names of the tags used in the configuration file are described below.

if is followed by a condition such as `sat="j1 j2"`, which means that the contents of the block following this `<if>` applies only to the missions `j1` and `j2`. The selection can be negated by starting it with an exclamation point, i.e. `sat="!j1 j2"` means that the following block applies to all missions *except* `j1` and `j2`.

elseif, else can follow an `if`-block. For example:

```
<if sat="j1 j2">
  ... for j1 and j2 ...
```

```

</if>
<elseif sat="e1 e2">
    ... for e1 and e2 ...
</elseif>
<else>
    ... all other missions ...
</else>

```

global_attributes specifies the global attributes that are always to be written to the output file, line by line. The first word on each line is the name of the global attribute, the rest is its value.

satellites specifies, line by line, the 2- and 3-character abbreviations for the altimeter missions. The rest of each line is used to specify alternative names which can be searched for substrings.

var identifies a block of tags that describe a single variable. The tag needs to include an option such as `name="alt_gdre"` to specify the variable name, and optionally (for example) `field=425` which specify the field numbers used in RADS3. A condition like `sat="j1 j2"` can also be added as an option in this tag.

alias specifies an alias (i.e. an alternative name) for a previously specified variable. The tag should at least include an option such as `name="alt"` to specify the name of the alias, and optionally the field number used in RADS3 (e.g. `field=4`). Again, a condition like `sat="j1"` can be added. If more than one value is given, then it means that the alias will point to the first variable, unless it is not available, then it points to the second. For example:

```
<alias name="alt" field="4" sat="j2">alt_gdre alt_gdrd</alias>
```

means that if one uses the variable `alt` for Jason-2, then the variable `alt_gdre` is processed. If determining this variable was unsuccessful, then `alt_gdrd` is used instead.

4.3.2 Tags within a var-block

The following tags can only occur within a `var`-block (with one exception, see below):

long_name specifies the description of the variable, as well as the `long_name` attribute to be written to the netCDF data files.

standard_name, source, comment specify the `standard_name`, `source`, and `comment` attributes to be written to the netCDF data files.

units specifies the units of the variable as used in any output, as well as the `units` attribute in the netCDF data files.

flag_values specifies the meanings of a flag, counting up from 0. For example `yes no` means that 0 is to be interpreted as "yes", 1 as "no".

flag_mask specifies the meanings of a flag word made up of bits. For example `left front up` means that when the LSB is raised "left" is true, and the next bits indicate if "front" and "up" are true.

limits specifies the range of "good" values. Any value less than the lower limit or greater than the upper limit result in the variable to be set to NaN. In case the variable is a `flag_mask`, then the first value indicates the mask of bits that should not be set, the second value the bits that should be set, otherwise the result will yield NaN.

plot_range specifies a suggested range for plotting the variable. It is not used for any processing, except for the `radsvar` program.

parameters is used for the RADS4 database creation and has no impact on any user programs.

data specifies the variable name as used in the input RADS netCDF data files (normally the same as the variable name), but could also be used to specify a mathematical statement that derives the variable from others, or to interpolate values from a grid. More about this in Section 4.3.3.

quality_flag indicates which variables are checked to determine the quality of the current variable. If any of the specified variables lead to NaN (not-a-number), the corresponding value of the current variable is set to NaN as well.

dimension is the dimension of the variable. Default is 1-dimensional. Some variables can be 2-dimensional.

format is the Fortran format specification for ASCII output of the variable.

compress specifies the data type (i.e., `int1`, `int2`, `int4`, `real`, or `db1e`) and optional `scale_factor` and `add_offset` to be used in the output netCDF files. This applies only the output files. Input netCDF files may be different.

Because you may want to overrule just one line in a `var`-block, one can stick the option `var="varname"` in the above tags. For example,

```
<var name="alt_gdre">
  <compress sat="j1 j2 j3 tx">int4 1e-4 1300e3</compress>
</var>
```

is equivalent to

```
<compress var="alt_gdre" sat="j1 j2 j3 tx">int4 1e-4 1300e3</compress>
```

4.3.3 The data-tag

The `data`-tag can be used in a variety of ways, depending on the text (value) between the `<data>` and `</data>` strings, or the optional `source=source` option.

netcdf: The simplest form, explained above, is that the value indicates the name of the netCDF variable in the RADS data files. For example: `<data>alt_gdre</data>`. RADS automatically assumes this type of input if only one value is given. Alternatively use `<data source="nc">` or `<data source="netcdf">`.

It is also possible to read global or variable attributes, which will then be assigned to the variable for all of the given pass. For example, if such attributes exist, `range_ku:add_offset` (the attribute `add_offset` of the variable `range_ku`) or `:range_bias_ku` (the global attribute `range_bias_ku`) could be used to retrieve a possible bias added to the Ku-band range.

math: If more than one value is given (i.e. it contains at least one space), then it will be recognised as a mathematical statement, in "Reverse Polish" notation. A number of mathematical operators are available, as described in Table 4.1. This can be very practical to determine on the fly the difference between two variables, or a combination of many (such as the sea level anomaly). For example `<data>wet_tropo_rad wet_tropo_ecmwf SUB</data>` computes the difference between the radiometer wet tropospheric correction and the

ECWMF wet tropospheric corrections by subtracting the latter from the former. To exercise this mathematical machinery, one can also use `<data source="math">`.

grid: RADS can interpolate in 2-D netCDF grids *on the fly*. This is practical if you have a static model to be interpolated at a certain location (longitude and latitude, or any other two variables). Depending on the argument of the `source=` option, one can select to do bilinear interpolation (`"grid"` or `"grid_l"`), cubic spline interpolation (`"grid_c"` or `"grid_s"`), or nearest neighbour selection (`"grid_q"` or `"grid_n"`). Without any of these options, a file name ending on `".nc"` will automatically be recognised as needing linear interpolation. In addition one can specify the variables to be used as x- and y-coordinated in the interpolation. Default is `x="lon" y="lat"`. Example for interpolating an SSB model:

```
<data source="grid" x="wind_speed_alt" y="swh">my_ssb_model.nc</data>
```

constant: To assign a single constant value use, for example,

```
<data source="constant">0</data>.
```

branch: An additional option allows you to read a variable from a different directory branch. For example, if you have an additional set of data stored in the directory `c2.mydata` next to the normal `c2` branch, then you can add the option `branch=".mydata"` which will indicate that this extension is used to the 2-character mission abbreviation to find files containing the current variable within the `var` block. Currently up to 5 branches (including the standard one) can be used.

4.3.4 Tags for mission definitions

A number of tags are employed to give general information about the various altimeter missions. You find them at the end of the global configuration file `rads.xml`. These tags are:

satellite Name of the satellite (maximum 8 characters).

satid Satellite ID used in the crossover program `radsxogen`.

dt1hz Time step of 1-Hz data.

inclination Orbital inclination in degrees.

frequency Altimeter frequency or frequencies.

xover_params Parameters used in `radsxogen`.

phase A block of tags that apply to a given mission phase.

mission Name of the mission phase.

cycles First and last cycle number in this mission phase.

repeat Length of the repeat cycle (not subcycle) in days, number of passes (half revolutions) per cycle, and (optionally of drifting orbits) the eastward drift of the ground track pattern in degrees per cycle.

ref_pass Date (and time) of a reference equator crossing, longitude of this equator crossing, cycle number (not subcycle number), pass number in this mission phase, and absolute orbit number. If the absolute orbit number is not given, 1 is assumed. This line provides the reference for the cycle and pass numbering.

start_time Start data (and time) of the mission phase.

In the above, date (and time) epochs can be written as `yyyy-mm-ddThh:mm:ss`, where the part from 'T' onward can be omitted in whole or in part.

Operator	Description
x y SUB a	$a = x - y$
x y ADD a	$a = x + y$
x y MUL a	$a = x * y$
PI a	$a = \pi$
E a	$a = \exp(1)$
x POP	remove last item from stack
x NEG a	$a = -x$
x ABS a	$a = x $
x INV a	$a = 1/x$
x SQRT a	$a = \sqrt{x}$
x SQR a	$a = x^2$
x EXP a	$a = \exp(x)$
x LOG a	$a = \ln(x)$
x LOG10 a	$a = \log_{10}(x)$
x SIN a	$a = \sin(x)$
x COS a	$a = \cos(x)$
x TAN a	$a = \tan(x)$
x SIND a	$a = \sin(x)$ [x in degrees]
x COSD a	$a = \cos(x)$ [x in degrees]
x TAND a	$a = \tan(x)$ [x in degrees]
x SINH a	$a = \sinh(x)$
x COSH a	$a = \cosh(x)$
x TANH a	$a = \tanh(x)$
x ASIN a	$a = \arcsin(x)$
x ACOS a	$a = \arccos(x)$
x ATAN a	$a = \arctan(x)$
x ASIND a	$a = \arcsin(x)$ [a in degrees]
x ACOSD a	$a = \arccos(x)$ [a in degrees]
x ATAND a	$a = \arctan(x)$ [a in degrees]
x ASINH a	$a = \operatorname{arcsinh}(x)$
x ACOSH a	$a = \operatorname{arccosh}(x)$
x ATANH a	$a = \operatorname{arctanh}(x)$
x ISNAN a	$a = 1$ if x is NaN; $a = 0$ otherwise
x ISAN a	$a = 0$ if x is NaN; $a = 1$ otherwise
x RINT a	a is nearest integer to x
x NINT a	a is nearest integer to x
x CEIL a	a is nearest integer greater or equal to x
x CEILING a	a is nearest integer greater or equal to x
x FLOOR a	a is nearest integer less or equal to x
x D2R a	convert x from degrees to radian
x R2D a	convert x from radian to degrees
x YMDHMS a	convert seconds of 1985 to format YYYYMMDDHHMMSS
x SUM a	$a(i) = x(1) + \dots + x(i)$ while skipping all NaN
x DIF a	$a(i) = x(i) - x(i-1)$; $a(1) = \text{NaN}$
x DUP a b	duplicate the last item on the stack
x y DIV a	$a = x / y$
x y POW a	$a = x^y$
x y FMOD a	$a = x \text{ modulo } y$
x y MIN a	$a = \text{the lesser of } x \text{ and } y$
x y MAX a	$a = \text{the greater of } x \text{ and } y$
x y ATAN2 a	$a = \arctan(x)$ taking into account the quadrant as determined by y
x y HYPOT a	$a = \sqrt{x^2 + y^2}$
x y R2 a	$a = x^2 + y^2$
x y EQ a	$a = 1$ if $x == y$; $a = 0$ otherwise
x y NE a	$a = 0$ if $x == y$; $a = 1$ otherwise
x y LT a	$a = 1$ if $x < y$; $a = 0$ otherwise
x y LE a	$a = 1$ if $x \leq y$; $a = 0$ otherwise
x y GT a	$a = 1$ if $x > y$; $a = 0$ otherwise
x y GE a	$a = 1$ if $x \geq y$; $a = 0$ otherwise
x y NAN a	$a = \text{NaN}$ if $x == y$; $a = x$ otherwise
x y AND a	$a = y$ if x is NaN; $a = x$ otherwise
x y OR a	$a = \text{NaN}$ if y is NaN; $a = x$ otherwise
x y IAND a	$a = \text{bitwise AND of } x \text{ and } y$
x y IOR a	$a = \text{bitwise OR of } x \text{ and } y$
x y BTEST a	$a = 1$ if bit y of x is set; $a = 0$ otherwise
x y AVG a	$a = 0.5(x+y)$ [when x or y is NaN a returns the other value]
x y DXDY a	$a(i) = (x(i+1) - x(i-1)) / (y(i+1) - y(i-1))$; $a(1) = a(n) = \text{NaN}$
x y EXCH a b	exchange the last two items on the stack (NaNs have no influence)
x y z INRANGE a	$a = 1$ if x is between y and z; $a = 0$ otherwise (also in case of any NaN)
x y z BOXCAR a	$a = \text{filter } x \text{ along monotonic dimension } y \text{ with boxcar of length } z \text{ (NaNs are skipped)}$
x y z GAUSS a	$a = \text{filter } x \text{ along monotonic dimension } y \text{ with Gauss function with sigma } z \text{ (NaNs are skipped)}$

Table 4.1 Math operators that can be used in the data-tag. Left of the operator (in uppercase) are the input value(s); on the right of the operator the output value(s).

Chapter 5

RADS utilities

5.1 Command line interface

The RADS4 commands share a very similar layout of the arguments that can be used on the command line. The common features of the command line interface, are explained in this Section. In later Sections we will explain the syntax and use of each of the RADS4 commands.

To learn the syntax of any of the RADS4 commands, simply use the argument `--help` after the command name. Let us start off with an **excerpt** of the help of the `radsstat4` program obtained when typing:

```
$ radsstat4 --help

radsstat4 (4.3.6): Print RADS statistics per cycle, pass or day(s)

Usage: radsstat4 [required_arguments] [rads_dataselectors] [rads_options] [program_options]

Required argument is:
  -S, --sat SAT[/PHASE]      Specify satellite [and phase] (e.g. e1/g, tx)

Optional [rads_dataselectors] are:
  -C, --cycle C0[,C1[,DC]]   Specify first and last cycle and modulo
  -L, --limits VAR=MIN,MAX   Specify edit data range for variable VAR

Common [rads_options] are:
  -v, --verbose              Increase verbosity level

Program specific [program_options] are:
  -l, --minmax               Output min and max in addition to mean and stddev
  -o, --output [OUTNAME]     Create NetCDF output instead of ASCII (default output
                             filename is "radsstat.nc")
```

The command line for every RADS4 program consists of a few of the following components:

program name always starts the command line.

required arguments need to be part of the command line for proper operation; in the above example it specifies the satellite mission.

data selectors are options (in the Unix parlance those parts that start with one or two hyphens) that select the RADS data of interest.

RADS options are options that are common to most programs.

program options are options can be placed on the command line to provide certain optional functionalities specific to the program.

In this sense, RADS is very much in-line with most Unix commands. RADS also supports both

so-called short options and long options, which each can have required or optional arguments. This you will also find in many other Unix commands, particularly those of the GNU flavour.

In general the order of the arguments is irrelevant, though there are some exceptions that will be explained per program.

5.1.1 Short options

Short options start with a single hyphen and are followed by a single lower case or upper case letter. In RADS a distinction is made between lower case and upper case options in that the upper case options have a common meaning and syntax between most RADS programs whereas lower case options are specific per program; this is done to harmonise the meanings across programs and help the user to easier remember and recognise the distinctive scope of the options.

Short options can have arguments (values attached to them), which can either be required or optional. So there are three possibilities:

no argument: The option flag just switches something on or off, for example `-l` in `radsstat4` adds the printing of minima and maxima to the output. In some cases, like `-v`, the option can be repeated to increase the verbosity level one step each time.

Short options without argument can be combined behind a single hyphen. Thus each of the following are equivalent:

```
-v -l -v
-l -vv
-lvv
-vlv
```

required argument: The option flag assigns some value. For example, `-S j2` selects the satellite altimeter mission `j2`.

The option flag and the value can be separated by whitespace (one or more spaces or tabs), but they can also be pasted together. In addition, the option flag can be preceded by short options without argument under the same hyphen. So again, the following combinations all mean the same thing:

```
-v -S j2
-v -Sj2
-vS j2
-vSj2
```

In this document, for clarity, we leave a single space between the option and the argument.

optional argument: The option flag assigns some value, or switches something on with a default value. In the above example for `radsstat4`, the option `-o` can be used with or without an argument, as identified by the argument `[outname]` between square brackets. As the help explains, when `-o` is omitted, the output is in ASCII format, when `-o` is used without argument, then a netCDF file `radsstat.nc` is created, and when used with an argument (e.g. `-o myfile.nc`) then a netCDF file with that name is created.

Note that the use of these types of options can be tricky, as any value that does not start with a hyphen that follows can be perceived as an argument of this option, which can lead to some unintended consequences. To avoid this problem, the option list can be ended with `--`. All remaining material will then be seen as verbatim arguments (for example input file names), even when they start with a hyphen.

5.1.2 Long options

To make it a bit less hard to understand (or to remember) some of the options, quite often an alternative “long option”, starting with two hyphens is provided. As can be seen in the `radsstat4` help, the short option `-v` can also be written as `--verbose`. But any shorter version of the long option, as long as it is unique, can be used. So `--verb` is allowed as well.

Just like short options, long options can have no argument, a required argument, or an optional argument. But long options cannot be combined into one, while short options can.

There are a few alternative ways of combining a long option with its required or optional argument.

- One can always use whitespace (spaces or tabs) to separate the long option from its argument.
- If the argument contains an equal sign (`'='`) then one can also use a colon to separate the long option and its argument.
- If the argument does not contain an equal sign, then an equal sign can be used to separate the long option and the argument.

For example, either of the following syntaxes can be used:

```
--cycle 10,20 --limits sla=-1,1
--cycle=10/20 --limits:sla=-1/1
--cyc 10-20    --lim sla=-1,1
--cyc=10,20    --lim:sla=-1,1
```

5.2 Common options

As indicated above, the RADS4 commands have a lot of options in common. Most of these use short options in upper case. Long options are always lower case.

5.2.1 Common data selectors

Below, in alphabetical order, are the command line options used to select data from the RADS database.

-A VAR1=VAR2 --alias VAR1=VAR2

Assign `VAR1` as an alias of `VAR2`. This means that when `VAR1` is requested, `VAR2` will be used. For example `--alias wet_tropo=wet_tropo_ecmwf` makes `wet_tropo` (which is used in the construction of the sea level anomaly `sla`) an alias of `wet_tropo_ecmwf`. Hence the model wet tropospheric correction, and not the radiometer wet tropospheric correction will then be used to determine sea level.

-C C0[,C1[,DC]] --cycle C0[,C1[,DC]]

Select data from cycle `C0` to cycle `C1`. If the latter is omitted, only data from cycle `C0` is selected. Adding `DC` will run through the cycles with a step of `DC`, skipping the intermediate ones. The arguments `C0`, `C1` and `DC` can be separated by commas, slashes, or the minus sign. So `-C 1/3` selects cycles 1 through 3. If omitted, data from all cycles (throughout all mission phases) are selected.

-F VAR=FMT --fmt VAR=FMT --format VAR=FMT

For variable *VAR* use the Fortran format *FMT* in ASCII output. E.g., `-F sla=f8.4`. This can also be achieved with the `ctagformat` tag in a RADS4 configuration file.

-L VAR=MIN,MAX --limits VAR=MIN,MAX

Specify the valid range for the selection of a variable. Outside this range the variable will be set to NaN. This is an alternative to using the `limits` tag in a RADS4 configuration file.

--lat LAT0,LAT1

Select data in the latitude range from *LAT0* to *LAT1* in degrees. This is equivalent to using `--limits lat=LAT0,LAT1`. The south to north range has to be specified on the interval from -90° to 90° . Examples:

`--lat -40,-20` Select data between 40°S and 20°S
`--lat 0,90` Selects entire northern hemisphere

When omitted, the default range specified in the RADS4 configuration file is used. By default, this is -90° to $+90^\circ$.

--lon LON0,LON1

Select data in the longitude range from *LON0* to *LON1* in degrees. This is the same as `--limits lon=LON0,LON1`. Note that the output longitudes are influenced by the selection the interval, be it in the range from -180° to 180° or from 0° to 360° . Examples:

`--lon -40,-20` Select data between 40°W and 20°W
`--lon 320,340` Same, but output will have only positive longitudes

The shift by 360° (either way) is automatically made. When omitted, the default range specified in the RADS4 configuration file is used, which is normally -180° to 180° .

-P P0[P1[DP]] --pass P0[P1[DP]]

Select data from pass *P0* to pass *P1* (out of each selected cycle). If the latter is omitted, only data from pass *P0* is selected. Adding *DP* will run through the passes with a step of *DP*, skipping the intermediate ones. The arguments *P0*, *P1* and *DP* can be separated by commas, slashes, or the minus sign. So `-P 1-100` selects passes 1 through 100. If omitted, data from all passes in each of the select cycles is selected.

In addition, one can use `-P a` (or `--pass asc`) to select only ascending passes, whereas `-P d` (or `--pass des`) is used to select only descending passes.

-Q VAR=FLAG --quality-flag VAR=FLAG

Check the variable *FLAG* when validating the variable *VAR*. This means that in any event that the variable *FLAG* is set to NaN (is out of bounds), then *VAR* is also set to NaN as well. This is identical to using the `quality_flag` tag in a RADS4 configuration file.

-R LON0,LON1,LAT0,LAT1 --region LON0,LON1,LAT0,LAT1

Select data within the longitude range from *LON0* to *LON1* and the latitude range of *LAT0* to *LAT1*, both in degrees. This is equivalent to using both the `--lon` and `--lat` options.

-R LON0,LAT0,RADIUS --region LON0,LAT0,RADIUS

Select data within a circular region with a spherical radius *RADIUS* degrees, around the point *LON0,LAT0* (in degrees).

-S SAT[/PHASE] --sat SAT[/PHASE]

Select data from a given satellite *SAT*. Many variants of the satellite name can be used. Either the 2-character code, the 3-character code, or a substring of the satellite name listed in Table 3.1.

This is a required option and needs to be given for all RADS4 programs. Optionally, one can also indicate the mission phase *PHASE*, separated from the satellite by a slash. (For backwards compatibility with RADS3 also a colon can be used, but this is discouraged).

--sla *SLA0,SLA1*

Specify the range of for sea level anomaly in meters (if requested). This is the same as `--limits sla=SLA0,SLA1`.

--time *T0,T1* --ymd *T0,T1* --doy *T0,T1* --sec *T0,T1*

Select data only in the time interval from *T0* to *T1*. RADS4 is generally quite efficient in figuring out the time format when using the generic `--time`, but best is to use instead `--ymd` with time in the format `[YY]YYMMDD[HHMMSS]`, `--doy` for `[YY]YYDDD` (year and day of year), or `--sec` for time in seconds from 1 Jan 1985. Decimal points to indicate fractional days or seconds are also allowed.

The following examples all select data between 1 January 1999, 12:00 UTC and 31 December 2001, 00:00 UTC:

```
--ymd 990101.5,20011231    Note that the century can be omitted
--doy 99001.5,2001365      when using --ymd or --doy.
--mjd 51179.5,52274.0      With --mjd or --doy, use only fractions of day,
--ymd 990101120000,011231  but with --ymd one can also use "HHMMSS".
--sec 441806400,536371200  The old-fashioned seconds since 1985 are still there as well.
```

One will notice that the data selection is very fast. RADS4 will not go through all the data sets to get the right data, but will use its "knowledge" of the repeat cycles and passes to quickly select the appropriate cycles and passes and scan only those.

-V *VAR1,...* --var *VAR1,...*

Select one or more variables from the RADS database. Any number of variables can be selected in one go by adding their names to the list, separated by commas or slashes. Also the old RADS3 numerical field numbers for the variables can be used!

-X *XMLFILE* --xml *XMLFILE*

Load the configuration file *XMLFILE* in addition to the default configuration files (`$RADSDATAROOT/conf/rads.xml`, and—if available—`$HOME/.rads/rads.xml` and `rads.xml` in the current working directory).

-Z *VAR=TYPE[,SCALE[,OFFSET]]* --compress *VAR=TYPE[,SCALE[,OFFSET]]*

Specify how the variable *VAR* is to be stored in a netCDF output file. *TYPE* is one of: `int1`, `int2`, `int4`, `real`, `dble`. *SCALE* and *OFFSET* are optional with a default of 1 and 0. This is identical to using the `compress` tag in a RADS4 configuration file. One can also use `--cmp`.

In all lists, shown as separated by commas above, one can also use slashes, as is done in the GMT program syntax.

5.2.2 Backward compatibility

For backward compatibility with RADS3 a number of options are still allowed, even though their use is deprecated.

-h *H0,H1*

Specify the range from SLA (in meters). This has been replaced by `--sla H0,H1`.

--opt *J*

Use field number *J* when field *J/100* is requested. This is now achieved with `--alias VAR1=VAR2`.

--opt I=J

Make field number *I* (in the range 1 to 99) and alias of field number *J* (in the range 101-9999). This is now achieved with **--alias VAR1=VAR2**.

--sel VAR1,...

Select variables to be read. Same as **--var VAR1,...**, except that using **--sel** signals some additional backward compatible options.

In addition, again to support backward compatibility with RADS3, the user can omit the double hyphen in front of the RADS3 data selectors like **sel=**, **sat=**, **cycle=**, **pass=**, etc. But it is highly recommended to use the new options instead.

5.2.3 Other common options

Additional common options in RADS4 are:

--args FILENAME

Get any of the command line arguments from a file named *FILENAME* with one option per line.

--debug LEVEL

Set debug/verbosity level to *LEVEL*.

--help

Print the syntax of the command and all its arguments.

--log FILENAME

Write statistics and other log information to file *FILENAME* (default is standard output).

-q --quiet

Suppress warning messages (but keeps fatal error messages).

-v --verbose

Increase the verbosity level (warnings and debugging). This option can be used numerous times, increasing verbosity by one level each time.

--version

Print the program version only.

--

Terminates all command line options; all following command-line arguments are considered non-option arguments, even if they begin with a hyphen.

5.3 Order of the options

When processing the data of a single satellite the order of the command line options is irrelevant, with the exception that options that appear later (further to the right) on the command line overrule any similar options that appear earlier. For example **-q -v** will produce verbose output, as **-v** overrules the earlier **-q**.

Yet, there is a more complicated order in which the command line options are processed by the RADS library:

1. Process some input/output options: **--args**, **--debug**, **--help**, **--log**, **-q**, **--quiet**, **-v**, **--verbose**, **--version**.
2. Process the satellite mission selector **-S** or **--sat**.

3. Process possible additional XML files indicated by the `-X` or `--xml` options.
4. Process any alias definitions specified by the `-A` or `--alias` options.
5. Process miscellaneous common options not mentioned elsewhere in this list.
6. Process the variable selection defined by the `-V` or `--var` options.
7. Process program-specific options.

Each of these groups of options are processed left to right. This order is common to all RADS programs discussed later in this Chapter, as they all use the RADS library to scan the command line.

When processing multiple satellites at the time (for example when creating dual-satellite crossovers with `radsxogen`), it matters whether you put common options before or after mission selector (`-S` or `--sat`). The order then determines whether the option is unique to a single mission, or applies to all. The rule is as follows:

- Common options ahead of the first mission selector apply to all missions.
- Common options after the first mission selector apply to the last mission selector to the right of the option.
- Program-specific options can be put anywhere.

This means, for example:

```
$ radsxogen [common options] -S e1 [e1 options] -S e2 [e2 options]
```

5.4 *rads2asc4*

The program `rads2asc4` lists a selection of the RADS4 data base in one ASCII file or in several pass-by-pass ASCII files. These files contain a header per pass with a description of the data content followed by one record for each measurement that passes the selection criteria. The records are built up of columns, separated by white space, listing various data fields. Which data fields are listed (and in which order they are listed) is determined by the command line argument `-V` or `--var`.

In the output, the data that has not passed the editing criteria will be represented by "NaN" (Not-a-Number). If the sea level anomaly field suffers that fate, the record will not be listed in the output file, unless the `-r` option is used (or `-r 0` or `-r none`).

If the argument `-o OUTNAME` or `--output OUTNAME` is used, the output will go into one file (named `OUTNAME`). Otherwise, pass files are created with the names `SSpPPPPcCCC.asc`, similar to what is described in Chapter 1.

This program can be called as `rads2asc`, or as `rads2asc4` to avoid conflicts with an already installed `RADS3`.

For more details, see the description of the command line options in the next Sections.

5.4.1 Syntax

```
rads2asc4 (4.3.6): Select RADS altimeter data and output to ASCII
```

```
Usage: rads2asc4 [required_arguments] [rads_dataselectors] [rads_options] [program_options]
```

```
Required argument is:
```

-S, --sat SAT[/PHASE] Specify satellite [and phase] (e.g. e1/g, tx)

Optional [rads_dataselectors] are:

-A, --alias VAR1=VAR2 Use variable VAR2 when VAR1 is requested
 -C, --cycle C0[,C1[,DC]] Specify first and last cycle and modulo
 -F, --fmt, --format VAR=FMT Specify Fortran format used to print VAR (for ASCII output only)
 -L, --limits VAR=MIN,MAX Specify edit data range for variable VAR
 --lon LON0,LON1 Specify longitude boundaries (deg)
 --lat LAT0,LAT1 Specify latitude boundaries (deg)
 -P, --pass P0[,P1[,DP]] Specify first and last pass and modulo; alternatively use -Pa
 (--pass asc) or -Pd (--pass des) to restrict selection to
 ascending or descending passes only
 -Q, --quality-flag VAR=FLAG Check variable FLAG when validating variable VAR
 -R, --region LON0,LON1,LAT0,LAT1 Specify rectangular region (deg)
 -R, --region LON0,LAT0,RADIUS Specify circular region (deg)
 --sla SLA0,SLA1 Specify range for SLA (m)
 --time T0,T1 Specify time selection (optionally use --ymd, --doy,
 or --sec for [YY]YYMMDD[HHMMSS], [YY]YYDDD, or SEC85)
 -V, --var VAR1,... Select variables to be read
 -X, --xml XMLFILE Load configuration file XMLFILE in addition to the defaults
 -Z, --cmp, --compress VAR=TYPE[,SCALE[,OFFSET]] Specify binary output format for variable VAR (NetCDF only); TYPE
 is one of: int1, int2, int4, real, dble; SCALE and OFFSET are
 optional (def: 1,0)

Still working for backward compatibility with RADS3 are options:

--h H0,H1 Specify range for SLA (m) (now --sla H0,H1)
 --opt J Use field number J when J/100 requested (now -A VAR1=VAR2)
 --opt I=J Make field I (range 1-99) and alias for field J (now -A VAR1=VAR2)
 --sel VAR1,... Select variables to read

Common [rads_options] are:

--args FILENAME Get all command line arguments from FILENAME (1 argument per line)
 --debug LEVEL Set debug/verbosity level
 --help Print this syntax message
 --log FILENAME Send statistics to FILENAME (default is standard output)
 -q, --quiet Suppress warning messages (but keeps fatal error messages)
 -v, --verbose Increase verbosity level
 --version Print version info only
 -- Terminates all options; all following command-line arguments are
 considered non-option arguments, even if they begin with a hyphen

Program specific [program_options] are:

-r, --reject-on-nan VAR Reject records if variable VAR on -V specifier is NaN
 -r NR Reject records if data item number NR on -V specifier is NaN
 -r 0, -r none, -r Do not reject records with NaN values
 -r n, -r any Reject records if any value is NaN
 Note: If no -r option is given -r sla is assumed
 -f Do not start with time,lat,lon in output (only with --sel)
 -s, --stat a|c|p Include statistics for all data (a), per cycle (c), or per pass (p)
 --step N Step through records with stride N (default = 1)
 --list FILENAME Specify file name in which to write list of output files
 --maxrec NREC Specify maximum number of output records (default = unlimited)
 -o, --output OUTNAME Specify name of a single output file or - for standard output or
 (when ending in /) directory name for pass files; by default pass
 files are created in the current directory

5.4.2 Common options

For a full explanation of the command line options that are common to most RADS4 programs, see Section 5.2.

5.4.3 Program specific options

The command line options that are specific to rads2asc4 are listed here.

-r VAR --reject-on-nan VAR

Do not output records when the value of variable VAR, given as an argument to the -V

or `--VAR` option, is set to NaN. By default records for which the sea level anomaly (if requested) is set to NaN are rejected.

-r NR --reject-on-nan NR

For backward compatibility with RADS3, this will eliminate records when the value of item number *NR* on the `-V` option is NaN.

-r 0 -r none -r

When either of these is used, no records are eliminated and all NaN values are kept.

-r n -r any

Indicates that a line should not be printed when a value in any of the data columns is NaN.

-f This only counts when using `--sel` instead of `--var`, in order to be backward compatible with RADS3. When using `--sel` normally time, latitude and longitude are automatically added as output columns. With `-f` those columns are not automatically added, i.e., you will have to add them to the list of variables.

-s c|p

Include statistics per cycle (c) or pass (p). Those will be included in the output with lines starting with `'# min :', '# max :', '# mean:',` and `'# std :'` followed by the cycle number, the number of valid passes in the cycle (c) or the pass number itself (p), the number of valid records in that cycle (c) or pass (p), and then the statistics (minimum, maximum, mean, and standard deviation) of each column.

--step N

Print only one out of *N* records.

--list FILENAME

Specify the name of a file to which to write a list of the created output files.

--maxrec NREC

Specify the maximum number of output records. The default is unlimited.

-o OUTNAME --output OUTNAME

By default (without this option) files are created per pass with a name similar to the ones in the data base, i.e., `SSpPPPPcCCC.asc`, where *SS* is the satellite abbreviation, *PPPP* is the pass number, and *CCC* is the cycle number. This option will send the output to a single named file, or to standard output when using `-o -`. Alternatively, when *OUTNAME* ends in a slash, then it indicates the directory in which to store the pass files `SSpPPPPcCCC.asc`.

5.4.4 Example

Assuming a default configuration, we issue the following command:

```
$ rads2asc4 -S e2 -C 0 -P 901,1000,2 -R -8,42,28,48 \
  -V time_ymdhms,lat,lon,sla,sw,h,wind_speed -o rads2asc4.asc -v
```

The program will print to standard output information on which passes are available and have valid data points in the requested area (Mediterranean Sea), how many records were read and how many remained in the particular area, how many records were rejected based on the selection criteria on the corrections, and finally some statistics on the columns that were requested.

```
*****
```

```
Data selection for satellite ERS-2 phase a
```

```
x = pass has no data in period and area
```

```
- = pass file does not exist
o = pass file has no valid data
# = pass file has valid data
```

```
Cycle Pass .....1.....2.....3.....4.....5.....6.....7.....8.....9.....
0 901 x x x x x o # # x x x x x x x x x x x # # x x x x x x x x x x x # # x x x x x x x x x x x
#####
# Editing statistics for ERS-2 (e2)
# Created: 2020-07-20 08:46:02 UTC: rads2asc4 -S e2 -C 0 -P 901,1000,2 -V time_ymdhms,lat,lon,sla,swh,wind_spe
#
# PASSES QUERIED 50
#
# REJECTED SELECTED LOWER UPPER STEP
# Cycle number limits 0 50 0 0 1
# Pass number limits 0 50 901 1000 2
# Time limits 0 50 NaN NaN
# Equator longitude limits (asc) 42 8 -3.440 57.004
# Equator longitude limits (des) 0 0 -23.004 37.440
#
# PASSES AND MEASUREMENTS READ 8 11517
#
# REJECTED SELECTED LOWER UPPER MIN MAX
# time [seconds since 1985-01-01 00:00:00] 0 11517 NaN NaN 950512/1843 950515/1932
# latitude [degrees_north] 10533 984 28.000 48.000 30.185 47.953
# longitude [degrees_east] 5435 6082 -8.000 42.000 -7.996 41.983
#
# MEASUREMENTS IN REQUESTED PERIOD AND REGION 851
#
# REJECTED SELECTED LOWER UPPER MIN MAX
# sea level anomaly [m] 293 558 -3.000 3.000 -0.262 0.118
# REAPER/COMBI orbital altitude [m] 0 851 NaN NaN 787721.981 791023.403
# Ku-band range corrected for instr. effec 0 851 750000.000 850000.000 787647.826 791005.014
# ECMWF dry tropospheric correction [m] 0 851 -2.400 -2.100 -2.331 -2.266
# radiometer wet tropospheric correction [ 11 840 -0.600 0.000 -0.598 -0.033
# NIC09 ionospheric correction [m] 0 851 -0.400 0.040 -0.025 -0.018
# MOG2D dynamic atmospheric correction (ER 0 851 -1.000 1.000 -0.143 0.234
# solid earth tide [m] 0 851 -1.000 1.000 -0.108 0.084
# FES2014b ocean tide [m] 0 851 -5.000 5.000 -1.590 0.764
# FES2014a load tide [m] 0 851 -0.500 0.500 -0.018 0.044
# pole tide [m] 0 851 -0.100 0.100 -0.010 0.003
# BM3 sea state bias [m] 6 845 -1.000 1.000 -0.857 0.473
# DTU15 mean sea surface height [m] 0 851 NaN NaN 3.573 53.228
# Ku-band significant wave height [m] 16 835 0.000 8.000 0.000 7.960
# Ku-band backscatter coefficient [dB] 8 843 6.000 27.000 6.460 26.410
# altimeter wind speed [m/s] 2 849 -1.000 30.000 0.000 24.944
# std dev of Ku-band range [m] 66 785 0.000 0.400 0.022 0.398
# number of valid Ku-band measurements [1] 64 787 16.500 20.500 17.000 20.000
# flag word [count] 286 565 65512.000 0.000 0.000 0.000
# std dev of Ku-band significant wave heig 63 788 0.000 2.100 0.290 2.100
# off-nadir angle squared from waveform (s 0 851 -0.050 0.050 0.000 0.000
# reference frame offset [m] 0 851 NaN NaN 0.062 0.062
#####
```

The resulting ASCII output file rads2asc4.asc will look like this:

```
# RADS_ASC
# Created: 2020-07-20 08:46:02 UTC: rads2asc4 -S e2 -C 0 -P 901,1000,2 -V time_ymdhms,lat,lon,sla,swh,wind_spe
# Satellite = ERS-2
# Phase = a
# Cycle = 000
# Pass = 0915
# Equ_time = 326925796.651424 (1995-05-12 20:43:16.651424)
# Equ_lon = 26.724487
# Original = OPR V6 (0603) data of 1997-175T18:26:46 (ver.1)
# Col 1 = time [yymmddhhmmss]
# Col 2 = latitude [degrees_north]
# Col 3 = longitude [degrees_east]
# Col 4 = sea level anomaly [m]
# Col 5 = Ku-band significant wave height [m]
# Col 6 = altimeter wind speed [m/s]
950512205154.226807 30.661485 19.480321 -0.0916 0.120 1.737
950512205155.207275 30.719321 19.464490 -0.0562 0.000 1.815
950512205156.187500 30.777142 19.448650 -0.1665 0.330 1.616
950512205157.167969 30.834975 19.432791 -0.1600 0.560 1.858
..... lines removed .....
950515192036.179321 43.127032 39.342061 0.0097 1.260 4.894
950515192037.159790 43.184400 39.321693 0.0279 1.140 4.576
```

```
950515192038.140259 43.241765 39.301295 0.0488 0.930 5.521
950515192039.120483 43.299112 39.280871 0.0415 0.870 5.821
```

5.5 rads2grd4

The program `rads2grd4` is a quick-and-dirty gridding program for RADS data. No smoothing or interpolation is performed. The data are simply collected in cells of predefined size, after which the mean and standard deviation in each cell is computed.

The boundaries of the grid are specified by the limits set in the RADS4 configuration files, or by the appropriate common command line arguments `--limits`, `loptlat`, or `--lon`. The cell size is determined by the option `--res`. Alternatively, the options `--x` and `--y` can be used to set both the range and interval along both coordinate axis of the grid. The use of grid-node oriented or cell oriented boundaries is controlled by the `--c` option. The required minimum number of measurements per cell can be specified with the `--min` option. Cells with a number of points less than the required number will not be part of the output.

The grid program not only grids sea level anomaly in longitude-latitude space, but any data field in any other space specified by the `-V` (or `--var`) option. For example, a non-parametric sea state bias model can be created by gridding the sea level anomalies in wind-wave space, in which case `-wind.speed,swh,sla` is used.

Multiple variables can be gridded simultaneously on the same space. When gridding several variables at once, only records (measurements) for which every variable is valid (not NaN) will be included in the gridding process.

There are two ways to produce output:

ASCII: Without the `-o` or `--output` option the program will write to standard output a file with an ASCII header explaining the content, followed by one record for each grid cell with a valid solution. Those records contain the *x*- and *y*-coordinate of the centre of the cell, and a pair of mean and standard deviation for each *z*-variable. The right-most column contains the number of points in the cell. This output can be used directly in GMT's `xyz2grd`.

netCDF: With the `-o` or `--output` option a netCDF grid file is produced. This contains a grid for the mean and standard deviation of each variable as well as a grid with the number of points.

The output is a list of ASCII records per cell: *x* and *y* of the centre of the cell, mean of *z*, standard deviation of *z*, number of points. Cells with a number of points less than the required number are not listed. This output can be used directly in GMT.

This program can be called as `rads2grd`, or as `rads2grd4` to avoid conflicts with an already installed RADS3.

5.5.1 Syntax

`rads2grd4` (4.3.6): Quickly grid RADS data to xyz or NetCDF grid

Usage: `rads2grd4` [required_arguments] [rads_dataselectors] [rads_options] [program_options]

Required argument is:

`-S, --sat SAT[/PHASE]` Specify satellite [and phase] (e.g. e1/g, tx)

Optional [rads_dataselectors] are:

`-A, --alias VAR1=VAR2` Use variable VAR2 when VAR1 is requested

`-C, --cycle C0[,C1[,DC]]` Specify first and last cycle and modulo

```

-F, --fmt, --format VAR=FMT          Specify Fortran format used to print VAR (for ASCII output only)
-L, --limits VAR=MIN,MAX             Specify edit data range for variable VAR
--lon LON0,LON1                     Specify longitude boundaries (deg)
--lat LAT0,LAT1                     Specify latitude boundaries (deg)
-P, --pass P0[,P1[,DP]]             Specify first and last pass and modulo; alternatively use -Pa
                                     (--pass asc) or -Pd (--pass des) to restrict selection to
                                     ascending or descending passes only
-Q, --quality-flag VAR=FLAG          Check variable FLAG when validating variable VAR
-R, --region LON0,LON1,LAT0,LAT1     Specify rectangular region (deg)
-R, --region LON0,LAT0,RADIUS        Specify circular region (deg)
--sla SLA0,SLA1                     Specify range for SLA (m)
--time T0,T1                         Specify time selection (optionally use --ymd, --doy,
                                     or --sec for [YY]YYMMDD[HHMMSS], [YY]YYDDD, or SEC85)
-V, --var VAR1,...                   Select variables to be read
-X, --xml XMLFILE                   Load configuration file XMLFILE in addition to the defaults
-Z, --cmp, --compress VAR=TYPE[,SCALE[,OFFSET]]
                                     Specify binary output format for variable VAR (NetCDF only); TYPE
                                     is one of: int1, int2, int4, real, dble; SCALE and OFFSET are
                                     optional (def: 1,0)

Still working for backward compatibility with RADS3 are options:
--h H0,H1                           Specify range for SLA (m) (now --sla H0,H1)
--opt J                             Use field number J when J/100 requested (now -A VAR1=VAR2)
--opt I=J                           Make field I (range 1-99) and alias for field J (now -A VAR1=VAR2)
--sel VAR1,...                       Select variables to read

Common [rads_options] are:
--args FILENAME                     Get all command line arguments from FILENAME (1 argument per line)
--debug LEVEL                       Set debug/verbosity level
--help                             Print this syntax message
--log FILENAME                      Send statistics to FILENAME (default is standard output)
-q, --quiet                         Suppress warning messages (but keeps fatal error messages)
-v, --verbose                       Increase verbosity level
--version                           Print version info only
--                                  Terminates all options; all following command-line arguments are
                                  considered non-option arguments, even if they begin with a hyphen

Program specific [program_options] are:
-V, --var X,Y,Z[,...]              Variables for x, y and z (default: lon,lat,sla); multiple z's may be specified
--x X0,X1[,DX]                     Set x-range and interval (default: as set by default limits and --res)
--y Y0,Y1[,DY]                     Set y-range and interval (default: as set by default limits and --res)
--res DX[,DY]                      Set resolution in x and y (default: 1)
--min MINNR                        Minimum number of points per grid cell (default: 2)
-o, --output, --grd GRIDNAME       Create NetCDF grid (suppresses ASCII)
--line-format FORMAT               Format to be used for ASCII output (default is determined by variables)
-c                                 Boundaries are cell oriented
-c[x|y]                            Only [x|y]-boundaries are cell oriented

```

5.5.2 Common options

For a full explanation of the command line options that are common to most RADS4 programs, see Section 5.2. Note that the -V and --var options have a slightly different meaning in this program (see below) than in most others.

5.5.3 Program specific options

The command line options that are specific to rads2grd4 are listed here.

-V X,Y,Z[,...] --var X,Y,Z[,...]

Specify the variables for the ordinates X and Y, and the variable to be gridded (Z). One can specify one or more variables for Z; each will be part of the output.

--x X0,X1[,DX]

Set the x-range and optional interval. The default range is determined by the limits set in the RADS4 configuration file. The interval can also be set with the `--res` option.

--x *X0,X1[,DX]*

Set the y-range and optional interval. The default range is determined by the limits set in the RADS4 configuration file. The interval can also be set with the `--res` option.

--res *DX[,DY]*

Set the resolution of the x- and y-coordinate. If only one number is given the same number is used for both coordinates. The default resolution is 1×1.

--min *MINNR*

Specify the minimum number of points in the grid cell. The default is 2.

-o *GRIDNAME* --output *GRIDNAME*

Create a netCDF file with the name *GRIDNAME* containing the output grids. This suppresses the ASCII output. For backward compatibility with RADS3, one can also use `--grd`.

--line-format *FORMAT*

Format to be used for ASCII output. The default is determined by the specific Fortran formats for each variable specified in the RADS4 configuration file.

-c [*x|y*] Determines that the boundaries of the x-y space are cell-oriented, instead of grid-oriented. When using `-c x` this applies only to the x-coordinate, when using `-c y` it applies only to the y-coordinate. When using `-c` without argument, it applies to both coordinates.

5.5.4 Examples

Assuming a default configuration, we issue the following command:

```
$ rads2grd4 -S e2 -C 0 -P 901,1000,2 -R -8,42,28,48 -V wind_speed,swh,sla -c
```

This command creates the following results to print to standard output:

```
# Grid of RADS variables
# Created: 2020-07-20 08:46:02 UTC: rads2grd4 -S e2 -C 0 -P 901,1000,2 -V wind_speed,swh,sla -c
#
# Satellite : e2/a
# Cycles    : 0 - 0
# Passes    : 901 - 1000
#
# Output columns per grid cell:
# ( 1) altimeter wind speed [m/s]
# ( 2) Ku-band significant wave height [m]
# ( 3- 4) mean and stddev of sea level anomaly [m]
# ( 5) nr of measurements
0.500 0.500 -0.0194 0.1099 463
1.500 0.500 -0.0404 0.1090 766
2.500 0.500 -0.0513 0.1100 938
3.500 0.500 -0.0472 0.0966 925
..... lines removed .....
15.500 7.500 -0.0270 0.1109 24
16.500 7.500 -0.0302 0.0917 47
17.500 7.500 0.0035 0.0817 73
18.500 7.500 -0.0320 0.0778 42
```

When we want to create a netCDF file as output, we use the `-o` option:

```
$ rads2grd4 -S e2 -C 0 -P 901,1000,2 -R -8,42,28,48 -V wind_speed,swh,sla -c \
-o rads2grd4.nc
```

To list its contents, use the `ncdump` command. The result will look like the following:

```
netcdf rads2grd4-o {
dimensions:
```



```

    wind_speed = 31 ;
    swh = 8 ;
variables:
    double wind_speed(wind_speed) ;
        wind_speed:long_name = "altimeter wind speed" ;
        wind_speed:units = "m/s" ;
        wind_speed:standard_name = "wind_speed" ;
        wind_speed:axis = "X" ;
        wind_speed:valid_min = -0.5 ;
        wind_speed:valid_max = 29.5 ;
        wind_speed:grid_step = 1. ;
    double swh(swh) ;
        swh:long_name = "Ku-band significant wave height" ;
        swh:units = "m" ;
        swh:standard_name = "sea_surface_wave_significant_height" ;
        swh:axis = "Y" ;
        swh:valid_min = 0.5 ;
        swh:valid_max = 7.5 ;
        swh:grid_step = 1. ;
    float sla_mean(swh, wind_speed) ;
        sla_mean:long_name = "mean of sea level anomaly" ;
        sla_mean:units = "m" ;
        sla_mean:_FillValue = NaNf ;
    float sla_stddev(swh, wind_speed) ;
        sla_stddev:long_name = "std dev of sea level anomaly" ;
        sla_stddev:units = "m" ;
        sla_stddev:_FillValue = NaNf ;
    int nr(swh, wind_speed) ;
        nr:long_name = "number of points per cell" ;

// global attributes:
    :Conventions = "CF-1.7" ;
    :title = "rads2grd4-o.out" ;
    :history = "2020-07-20 08:46:09 UTC: rads2grd4 -S e2 -C 0 -P 901,1000,2 -V wind_speed,swh,sla -c -o ra
    :node_offset = 1 ;
data:

    wind_speed = -0.5, 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, 6.5, 7.5, 8.5, 9.5, 10.5,
        11.5, 12.5, 13.5, 14.5, 15.5, 16.5, 17.5, 18.5, 19.5, 20.5, 21.5, 22.5,
        23.5, 24.5, 25.5, 26.5, 27.5, 28.5, 29.5 ;
    ..... lines removed .....
    0, 0, 0, 0, 0, 0, 4, 9, 4, 24, 22, 16, 22, 53, 75, 112, 75, 143, 100, 38,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4, 1, 2, 9, 17, 20, 28, 24, 47, 73, 42, 1, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0 ;
}

```

5.6 rads2nc

The RADS4 program `rads2nc` works similar to `rads2asc4` (Section 5.4). Instead of writing output to one or more ASCII files, it creates one or more netCDF files. This significantly reduces the output size, and can be convenient for reading into third-party programs.

By default, `rads2nc` will create pass-by-pass netCDF files, named `SSpPPPPcCCC.nc`, with only the information of the netCDF variables given on the command line using the `-V` or `--var` options. The variables are edited given the selection criteria in the RADS4 configurations files or elsewhere on the command line. Values regarded 'invalid' will be set to the `_FillValue` in the netCDF files (or NaN in case of floating numbers). They will show up as an underscore (`_`) in the output of `ncdump`.

The output can also be captured in a single netCDF file or in a different directory than the current working directory. See the description of the option `-o` or `--output` below.

For more details, see the description of the command line options in the next Sections.

5.6.1 Syntax

rads2nc (4.3.6): Select RADS altimeter data and output to NetCDF

Usage: rads2nc [required_arguments] [rads_dataselectors] [rads_options] [program_options]

Required argument is:

-S, --sat SAT[/PHASE] Specify satellite [and phase] (e.g. el/g, tx)

Optional [rads_dataselectors] are:

-A, --alias VAR1=VAR2 Use variable VAR2 when VAR1 is requested
 -C, --cycle C0[,C1[,DC]] Specify first and last cycle and modulo
 -F, --fmt, --format VAR=FMT Specify Fortran format used to print VAR (for ASCII output only)
 -L, --limits VAR=MIN,MAX Specify edit data range for variable VAR
 --lon LON0,LON1 Specify longitude boundaries (deg)
 --lat LAT0,LAT1 Specify latitude boundaries (deg)
 -P, --pass P0[,P1[,DP]] Specify first and last pass and modulo; alternatively use -Pa
 (--pass asc) or -Pd (--pass des) to restrict selection to
 ascending or descending passes only
 -Q, --quality-flag VAR=FLAG Check variable FLAG when validating variable VAR
 -R, --region LON0,LON1,LAT0,LAT1 Specify rectangular region (deg)
 -R, --region LON0,LAT0,RADIUS Specify circular region (deg)
 --sla SLA0,SLA1 Specify range for SLA (m)
 --time T0,T1 Specify time selection (optionally use --ymd, --doy,
 or --sec for [YY]YYMMDD[HHMMSS], [YY]YYDDD, or SEC85)
 -V, --var VAR1,... Select variables to be read
 -X, --xml XMLFILE Load configuration file XMLFILE in addition to the defaults
 -Z, --cmp, --compress VAR=TYPE[,SCALE[,OFFSET]] Specify binary output format for variable VAR (NetCDF only); TYPE
 is one of: int1, int2, int4, real, dble; SCALE and OFFSET are
 optional (def: 1,0)

Still working for backward compatibility with RADS3 are options:

--h H0,H1 Specify range for SLA (m) (now --sla H0,H1)
 --opt J Use field number J when J/100 requested (now -A VAR1=VAR2)
 --opt I=J Make field I (range 1-99) and alias for field J (now -A VAR1=VAR2)
 --sel VAR1,... Select variables to read

Common [rads_options] are:

--args FILENAME Get all command line arguments from FILENAME (1 argument per line)
 --debug LEVEL Set debug/verbosity level
 --help Print this syntax message
 --log FILENAME Send statistics to FILENAME (default is standard output)
 -q, --quiet Suppress warning messages (but keeps fatal error messages)
 -v, --verbose Increase verbosity level
 --version Print version info only
 -- Terminates all options; all following command-line arguments are
 considered non-option arguments, even if they begin with a hyphen

Program specific [program_options] are:

-r, --reject-on-nan VAR Reject records if variable VAR on -V specifier is NaN
 -r NR Reject records if data item number NR on -V specifier is NaN
 -r 0, -r none, -r Do not reject records with NaN values
 -r n, -r any Reject records if any value is NaN
 Note: If no -r option is given -r sla is assumed
 --step N Step through records with stride n (default: 1)
 --maxrec NREC Specify maximum number of output records (default: unlimited)
 -o, --output OUTNAME Specify name of a single output file or (when ending in /) directory
 name for pass files; default is pass files in current directory

5.6.2 Common options

For a full explanation of the command line options that are common to most RADS4 programs, see Section 5.2.

5.6.3 Program specific options

The command line options that are specific to `rads2nc` are listed here. Notice that they have some in common with `rads2asc4` (Section 5.4).

-r VAR --reject-on-nan VAR

Do not output records when the value of variable *VAR*, given as an argument to the `-V` or `--VAR` option, is set to NaN. By default records for which the sea level anomaly (if requested) is set to NaN are rejected.

-r NR --reject-on-nan NR

For backward compatibility with RADS3, this will eliminate records when the value of item number *NR* on the `-V` option is NaN.

-r 0 -r none -r

When either of these is used, no records are eliminated and all NaN values are kept.

-r n -r any

Indicates that a line should not be printed when any of the selected variables is NaN.

--step N

Print only one out of *N* records.

--maxrec NREC

Specify the maximum number of output records. The default is unlimited.

-o OUTNAME --output OUTNAME

By default (without this option) files are created per pass with a name similar to the ones in the data base, i.e., `SSpPPPPcCCC.asc`, where *SS* is the satellite abbreviation, *PPPP* is the pass number, and *CCC* is the cycle number. This option will send the output to a single named file. Alternatively, when *OUTNAME* ends in a slash, then it indicates the directory in which to store the pass files `SSpPPPPcCCC.nc`.

5.6.4 Example

Assuming a default configuration, we issue the following command:

```
$ rads2nc -S e2 -C 0 -P 901,1000,2 -R -8,42,28,48 \
  -V time,lat,lon,sla,swh,wind_speed -o rads2nc.nc -v
```

Just as `rads2asc4` the program `rads2nc` will now print to standard output information on which passes are available and have valid data points in the requested area (Mediterranean Sea), how many records were read and how many remained in the particular area, how many records were rejected based on the selection criteria on the corrections, and finally some statistics on the columns that were requested. At the same time a netCDF file `rads2nc.nc` will be created. To list its contents, use the `ncdump` command. The result will look like the following:

```
netcdf rads2nc {
dimensions:
    time = UNLIMITED ; // (558 currently)
variables:
    double time(time) ;
        time:long_name = "time" ;
        time:standard_name = "time" ;
        time:units = "seconds since 1985-01-01 00:00:00 UTC" ;
        time:field = 101s ;
        time:comment = "UTC time of measurement. Attribute leap_second gives time of leap second if any occurs" ;
    int lat(time) ;
        lat:_FillValue = 2147483647 ;
        lat:long_name = "latitude" ;
        lat:standard_name = "latitude" ;
```

```

        lat:units = "degrees_north" ;
        lat:scale_factor = 1.e-06 ;
        lat:field = 201s ;
        lat:comment = "Positive latitude is North latitude, negative latitude is South latitude" ;
int lon(time) ;
    lon:_FillValue = 2147483647 ;
    lon:long_name = "longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
    lon:scale_factor = 1.e-06 ;
    lon:field = 301s ;
    lon:comment = "East longitude relative to Greenwich meridian" ;
short sla(time) ;
    sla:_FillValue = 32767s ;
    sla:long_name = "sea level anomaly" ;
    sla:standard_name = "sea_surface_height_above_sea_level" ;
    sla:units = "m" ;
    sla:quality_flag = "swh sig0 range_rms range_numval flags swh_rms attitude" ;
    sla:scale_factor = 0.0001 ;
    sla:coordinates = "lon lat" ;
    sla:field = 0s ;
    sla:comment = "Sea level determined from satellite altitude - range - all altimetric corrections" ;
short swh(time) ;
    swh:_FillValue = 32767s ;
    swh:long_name = "Ku-band significant wave height" ;
    swh:standard_name = "sea_surface_wave_significant_height" ;
    swh:units = "m" ;
    swh:scale_factor = 0.001 ;
    swh:coordinates = "lon lat" ;
    swh:field = 17s ;
short wind_speed(time) ;
    wind_speed:_FillValue = 32767s ;
    wind_speed:long_name = "altimeter wind speed" ;
    wind_speed:standard_name = "wind_speed" ;
    wind_speed:source = "altimeter" ;
    wind_speed:units = "m/s" ;
    wind_speed:scale_factor = 0.01 ;
    wind_speed:coordinates = "lon lat" ;
    wind_speed:field = 19s ;

// global attributes:
:Conventions = "CF-1.7" ;
:title = "RADS 4 pass file" ;
:institution = "EUMETSAT / NOAA / TU Delft" ;
:source = "radar altimeter" ;
:references = "RADS Data Manual, Version 4.2 or later" ;
:featureType = "trajectory" ;
:ellipsoid = "TOPEX" ;
:ellipsoid_axis = 6378136.3 ;
:ellipsoid_flattening = 0.00335281317789691 ;
:filename = "rads2nc.out" ;
:mission_name = "ERS-2" ;
:mission_phase = "a" ;
:log01 = "2020-07-20 | rads2nc -S e2 -C 0 -P 901,1000,2 -V time,lat,lon,sla,swh,wind_speed -R -8,42,20" ;
:history = "2020-07-20 08:46:02 : rads2nc -S e2 -C 0 -P 901,1000,2 -V time,lat,lon,sla,swh,wind_speed" ;

data:

    time = 326926314.226853, 326926315.207322, 326926316.187547,
           326926317.168015, 326926318.148484, 326926319.128953, 326926320.109178,
    ..... lines removed .....
           1129, 1169, 1147, 1155, 1158, 1180, 1162, 1133, 1066, 1043, 1028,
           987, 957, 546, 555, 526, 529, 564, 565, 574, 611, 615, 634, 618, 644,
           634, 614, 595, 605, 595, 624, 621, 604, 611, 634, 637, 633, 610, 643,
           647, 624, 585, 579, 558, 489, 458, 552, 582 ;
}

```

5.7 radscolin4

The program `radscolin4` creates collinear tracks (in a rather straightforward way). No smoothing or interpolation is performed. The data are “gridded” based on their time with respect to the equator passages. The measurements are simply collected in bins of predefined length. By default this is the 1-Hz sampling rate of the specific mission), but it can be altered with the `--dt`

option. Then the data falling in those bins for each specified pass are output in a way similar to `rads2asc4` (Section 5.4) or `rads2nc` (Section 5.6). No averaging or differencing is performed.

This program can also be used to compute differences between two different altimeter missions (with `--diff`, `--diff-no-coord`, or `--diff1`), as long as they are collinear. Some variance to the strict collinearity is allowed when using the `-f` or `--force` option. See Section 5.3 for more info on using the command line when multiple missions are involved.

The program will output only those bins in which valid sea level anomalies can be found for all specified repeat cycles, unless the `-r` option is used. This behaviour of `-r` is significantly different from `rads2asc4` and `rads2nc`. See the syntax description below.

The output is one record for each bin, containing the variables selected by the `-V` or `--var` option, for each of the specified cycles. The output can be either ASCII (the default) or netCDF (with the `-o` or `--output`) option. In the case of ASCII, normally only the passes with some valid data are output. Using the option `-k` or `--keep` keeps all passes, irrespectively.

This program can be called as `radscolin`, or as `rads2colin4` to avoid conflicts with an already installed RADS3.

5.7.1 Syntax

`radscolin4` (4.3.6): Make collinear data sets from RADS

Usage: `radscolin4` [required_arguments] [rads_dataselectors] [rads_options] [program_options]

Required argument is:

`-S, --sat SAT[/PHASE]` Specify satellite [and phase] (e.g. e1/g, tx)

Optional [rads_dataselectors] are:

`-A, --alias VAR1=VAR2` Use variable VAR2 when VAR1 is requested
`-C, --cycle C0[,C1[,DC]]` Specify first and last cycle and modulo
`-F, --fmt, --format VAR=FMT` Specify Fortran format used to print VAR (for ASCII output only)
`-L, --limits VAR=MIN,MAX` Specify edit data range for variable VAR
`--lon LON0,LON1` Specify longitude boundaries (deg)
`--lat LAT0,LAT1` Specify latitude boundaries (deg)
`-P, --pass P0[,P1[,DP]]` Specify first and last pass and modulo; alternatively use `-Pa` (`--pass asc`) or `-Pd` (`--pass des`) to restrict selection to ascending or descending passes only
`-Q, --quality-flag VAR=FLAG` Check variable FLAG when validating variable VAR
`-R, --region LON0,LON1,LAT0,LAT1` Specify rectangular region (deg)
`-R, --region LON0,LAT0,RADIUS` Specify circular region (deg)
`--sla SLA0,SLA1` Specify range for SLA (m)
`--time T0,T1` Specify time selection (optionally use `--ymd`, `--doy`, or `--sec` for [YY]YYMMDD[HHMMSS], [YY]YYDDD, or SEC85)
`-V, --var VAR1,...` Select variables to be read
`-X, --xml XMLFILE` Load configuration file XMLFILE in addition to the defaults
`-Z, --cmp, --compress VAR=TYPE[,SCALE[,OFFSET]]` Specify binary output format for variable VAR (NetCDF only); TYPE is one of: `int1`, `int2`, `int4`, `real`, `dble`; SCALE and OFFSET are optional (def: 1,0)

Still working for backward compatibility with RADS3 are options:

`--h H0,H1` Specify range for SLA (m) (now `--sla H0,H1`)
`--opt J` Use field number J when J/100 requested (now `-A VAR1=VAR2`)
`--opt I=J` Make field I (range 1-99) and alias for field J (now `-A VAR1=VAR2`)
`--sel VAR1,...` Select variables to read

Common [rads_options] are:

`--args FILENAME` Get all command line arguments from FILENAME (1 argument per line)
`--debug LEVEL` Set debug/verbosity level
`--help` Print this syntax message
`--log FILENAME` Send statistics to FILENAME (default is standard output)
`-q, --quiet` Suppress warning messages (but keeps fatal error messages)
`-v, --verbose` Increase verbosity level
`--version` Print version info only

```

--                               Terminates all options; all following command-line arguments are
                               considered non-option arguments, even if they begin with a hyphen

Program specific [program_options] are:
--dt DT                         Set minimum bin size in seconds (default is determined by satellite)
--step N                       Write out only one out of N bins along track
-r, --reject-on-nan VAR        Base rejection criteria (below) on VAR
-r all                         Base rejection criteria (below) on all selected variables
                               Note: By default rejection of data is based on 'sla' (if selected) or 1st on -V
                               Note: The two options above can be combined with any of the three below
-r NR                         Reject stacked data when fewer than NR tracks with valid values
-r 0, -r none, -r             Keep all stacked data points, even NaN
-r n, -r any                  Reject stacked data when data on any track is NaN (default)
                               Note: If no -r option is given, -r any is assumed
-k, --keep                    Keep all passes, even those that do not have data in the selected area
-a, --mean                    Output mean in addition to pass data
-s, --stddev                  Output standard deviation in addition to pass data
-l, --minmax                  Output minimum and maximum in addition to pass data
-d, --no-pass                 Do not output pass data
-t, --no-track                Do not print along-track data (ascii output only)
-c, --cumul                   Output cumulative statistics (ascii output only) (implies --keep)
    --diff                    Compute difference between first and second half of selected passes
                               (implies --keep)
    --diff-no-coord            Same as --diff, but excluding coordinates from computing difference
    --diff1                    Same as --diff-no-coord, writing one cycle at a time, chronologically
                               (cannot be combined with -o, -a, -s, or -l)
-f, --force                   Force comparison, even when missions are not considered collinear
-o, --output [FILENAME]       Create NetCDF output by pass (default is ascii output to stdout).
                               Optionally specify FILENAME including "#", to be replaced by the pass
                               number. Default is "radscolin_p#.nc"

```

5.7.2 Common options

For a full explanation of the command line options that are common to most RADS4 programs, see Section 5.2.

5.7.3 Program specific options

The command line options that are specific to *radscolin4* are listed here. Notice that the *-r* option is somewhat different than that of *rads2asc4* (Section 5.4) and *rads2nc* (Section 5.6).

--dt *DT* Set the minimum bin size in seconds. The default is the maximum 1-Hz sampling rate of the missions selected.

--step *N* Write out only one out of *N* bins along track.

-r *VAR* --reject-on-nan *VAR*

Base the count of “valid passes” on variable whether *VAR* is not NaN. By default *radscolin4* looks for the validity of the variable *sla*, if used in the list of variables on the *-V* option. If *sla* is not used, the first variable is checked for validity.

-r *all* --reject-on-nan *all*

Base the count of “valid passes” on whether all variables on the *-V* option are not NaN.

-r *NR*

Reject stacked data when there are fewer than *NR* tracks with valid values. Which variable is used to determine “valid” is explained above.

-r 0 -r none -r

When either of these is used, keep the stacked data in the output, even when they are NaN.

-r n -r any

Reject stacked data when data on any track is NaN. This is the default behaviour.

-k --keep

Keep all the passes in the output, even those that do not have any valid data in the selected area. By default, passes without any valid values are removed from the output.

-a --mean

Output the mean value in each stacked bin in addition to the values in each collinear pass.

-s --stddev

Output the standard deviation in each stacked bin in addition to the values in each collinear pass.

-l --minmax

Output the minimum and maximum in each stacked bin in addition to the values in each collinear pass.

-d --no-pass

Do not output the values in each individual collinear pass.

-t --no-track

Do not print the along-track data (applies to ASCII output only).

-c --cumul

Print cumulative statistics (applies to ASCII output only).

--diff

Compute the difference between the first and the second half of the selected passes. This is practical when computing the difference between two missions. It implies **--keep**.

--diff-no-coord

This is the same as **--diff**, except that the coordinates (time, latitude and longitude) are not differenced, instead the first value is produced.

--diff1

This is the same as **--diff-no-coord**, except that in ascii printouts passes are printed chronologically, one cycle at a time, instead of the usual multiple columns for passes. This cannot be used in combination with statistics options (**-a**, **-s**, or **-l**)

-f --force

Force collinear track comparison, even when missions are not strictly considered collinear.

-o [FILENAME] --output [FILENAME]

Create netCDF output files per pass. The default is ASCII output to standard output. Optionally specify a *FILENAME* including the hash character ('#'), which will be replaced by the pass number. The default netCDF output file name is `radscolin_p#.nc`.

5.7.4 Examples

Assuming a default configuration, we issue the following command:

```
$ radscolin -S e2 -C 0,2 -P 915,1000,2 -R -8,42,28,48 -V lat,sla,swh
```

This command creates the following results to print to standard output:

```
# RADS collinear track file
# Created: 2020-07-20 08:46:02 UTC: radscolin4 -S e2 -C 0,2 -P 915,1000,2 -R -8,42,28,48 -V lat,sla,swh
#
# Pass          = 0915
# Satellite    =      e2      e2      e2
# Cycles       =      000      001      002
#
# Column ranges for each variable:
#   1 -   3 : latitude [degrees_north]
```

```
# 4 - 6 : sea level anomaly [m]
# 7 - 9 : Ku-band significant wave height [m]
# 10 : number of measurements
# 11 : record number
#
30.661485 30.649574 30.691639 -0.0916 -0.0201 -0.0127 0.120 0.640 0.840 3 528
30.719321 30.707412 30.749460 -0.0562 -0.0840 -0.0171 0.000 0.880 0.760 3 529
30.777142 30.765233 30.807295 -0.1665 -0.0813 -0.0544 0.330 0.760 0.890 3 530
30.834975 30.823067 30.865128 -0.1600 -0.0550 -0.0619 0.560 0.560 0.960 3 531
..... lines removed .....
43.299112 43.263665 43.286058 0.0415 0.0760 -0.0004 0.870 0.520 0.410 3 747
# 42.368730 42.333236 42.355645 -0.0130 0.0414 -0.0176 1.022 0.362 0.840 0 999 # avg
# 0.572197 0.572222 0.572209 0.0494 0.0385 0.0713 0.264 0.192 0.505 0 999 # std
# 33 33 33 33 33 33 33 33 33 0 999 # nr
```

To illustrate the impact of the `-r` option, we also present here the result of the following command:

```
$ radscolin -S e2 -C 0,2 -P 915,1000,2 -R -8,42,28,48 -V lat,sla,swh -r

# RADS collinear track file
# Created: 2020-07-20 08:46:09 UTC: radscolin4 -S e2 -C 0,2 -P 915,1000,2 -R -8,42,28,48 -V lat,sla,swh -r
#
# Pass = 0915
# Satellite = e2 e2 e2
# Cycles = 000 001 002
#
# Column ranges for each variable:
# 1 - 3 : latitude [degrees_north]
# 4 - 6 : sea level anomaly [m]
# 7 - 9 : Ku-band significant wave height [m]
# 10 : number of measurements
# 11 : record number
#
30.185412 NaN 30.215553 NaN NaN NaN 3.740 NaN 6.140 2 520
NaN 30.418223 30.459773 NaN NaN NaN NaN NaN 1.680 2 524
30.487462 30.476067 30.518135 NaN NaN NaN 0.770 0.480 0.960 3 525
30.545822 30.533894 30.575961 NaN NaN NaN 0.700 0.770 1.060 3 526
..... lines removed .....
NaN 47.161520 NaN NaN NaN NaN NaN 0.250 NaN 1 815
# 42.323495 42.345405 42.355645 -0.0143 0.0431 -0.0176 1.026 0.368 0.840 0 999 # avg
# 0.588227 0.588225 0.572209 0.0487 0.0381 0.0713 0.271 0.198 0.505 0 999 # std
# 35 35 33 35 35 33 35 35 33 0 999 # nr
```

5.8 radspassesindex

The RADS4 program `radspassesindex` works the same as the program by the same name in RADS3. It provides a quick index of the information of pass files. It can be used either in predictive mode (not reading any files) or actually reading the meta data in RADS files. Output is in ASCII format. The information printed is:

- Phase name
- Cycle number
- Pass number
- Start time
- End time
- Equator crossing time
- Equator crossing longitude
- Number of points

For more details, see the description of the command line options in the next Sections.

5.8.1 Syntax

radspassesindex4 (4.3.6): Print information about passes

Usage: radspassesindex4 [required_arguments] [rads_dataselectors] [rads_options] [program_options]

Required argument is:

-S, --sat SAT[/PHASE] Specify satellite [and phase] (e.g. e1/g, tx)

Optional [rads_dataselectors] are:

-A, --alias VAR1=VAR2 Use variable VAR2 when VAR1 is requested
 -C, --cycle C0[,C1[,DC]] Specify first and last cycle and modulo
 -F, --fmt, --format VAR=FMT Specify Fortran format used to print VAR (for ASCII output only)
 -L, --limits VAR=MIN,MAX Specify edit data range for variable VAR
 --lon LON0,LON1 Specify longitude boundaries (deg)
 --lat LAT0,LAT1 Specify latitude boundaries (deg)
 -P, --pass P0[,P1[,DP]] Specify first and last pass and modulo; alternatively use -Pa
 (--pass asc) or -Pd (--pass des) to restrict selection to
 ascending or descending passes only
 -Q, --quality-flag VAR=FLAG Check variable FLAG when validating variable VAR
 -R, --region LON0,LON1,LAT0,LAT1 Specify rectangular region (deg)
 -R, --region LON0,LAT0,RADIUS Specify circular region (deg)
 --sla SLA0,SLA1 Specify range for SLA (m)
 --time T0,T1 Specify time selection (optionally use --ymd, --doy,
 or --sec for [YY]YYMMDD[HHMMSS], [YY]YYDDD, or SEC85)
 -V, --var VAR1,... Select variables to be read
 -X, --xml XMLFILE Load configuration file XMLFILE in addition to the defaults
 -Z, --cmp, --compress VAR=TYPE[,SCALE[,OFFSET]] Specify binary output format for variable VAR (NetCDF only); TYPE
 is one of: int1, int2, int4, real, dble; SCALE and OFFSET are
 optional (def: 1,0)

Still working for backward compatibility with RADS3 are options:

--h H0,H1 Specify range for SLA (m) (now --sla H0,H1)
 --opt J Use field number J when J/100 requested (now -A VAR1=VAR2)
 --opt I=J Make field I (range 1-99) and alias for field J (now -A VAR1=VAR2)
 --sel VAR1,... Select variables to read

Common [rads_options] are:

--args FILENAME Get all command line arguments from FILENAME (1 argument per line)
 --debug LEVEL Set debug/verbosity level
 --help Print this syntax message
 --log FILENAME Send statistics to FILENAME (default is standard output)
 -q, --quiet Suppress warning messages (but keeps fatal error messages)
 -v, --verbose Increase verbosity level
 --version Print version info only
 -- Terminates all options; all following command-line arguments are
 considered non-option arguments, even if they begin with a hyphen

Program specific [program_options] are:

-h Add header
 -p Predict the pass information rather than opening files
 -y Print out dates as YYYY-MM-DDTHH:MM:SS.SSSSSS

5.8.2 Common options

For a full explanation of the command line options that are common to most RADS4 programs, see Section 5.2.

5.8.3 Program specific options

The command line options that are specific to radspassesindex are listed here.

-h Add header at the top of the output

-p Predict the start and stop times and equator time and longitude. The number of points is estimated based on full coverage.

-y Print times in the format YYYY-MM-DDTHH-MM-SS.SSSSSS instead of seconds since 1985.

5.8.4 Example

Assuming a default configuration, we issue the following command:

```
$ radspassesindex -S e2 -C 0 -P 901,910 -h -y -p
```

The result will look like the following:

#	cyc	pass	start_time	end_time	equator_time	equator_lon	nr
a	000	0901	1995-05-12T08:33:48.682635	1995-05-12T09:24:06.646707	1995-05-12T08:58:57.664671	202.764731	3079
a	000	0902	1995-05-12T09:24:06.646707	1995-05-12T10:14:24.610778	1995-05-12T09:49:15.628743	10.189880	3079
a	000	0903	1995-05-12T10:14:24.610778	1995-05-12T11:04:42.574850	1995-05-12T10:39:33.592814	177.615030	3079
a	000	0904	1995-05-12T11:04:42.574850	1995-05-12T11:55:00.538922	1995-05-12T11:29:51.556886	345.040180	3079
a	000	0905	1995-05-12T11:55:00.538922	1995-05-12T12:45:18.502994	1995-05-12T12:20:09.520958	152.465329	3079
a	000	0906	1995-05-12T12:45:18.502994	1995-05-12T13:35:36.467066	1995-05-12T13:10:27.485030	319.890479	3079
a	000	0907	1995-05-12T13:35:36.467066	1995-05-12T14:25:54.431138	1995-05-12T14:00:45.449102	127.315629	3079
a	000	0908	1995-05-12T14:25:54.431138	1995-05-12T15:16:12.395210	1995-05-12T14:51:03.413174	294.740778	3079
a	000	0909	1995-05-12T15:16:12.395210	1995-05-12T16:06:30.359281	1995-05-12T15:41:21.377245	102.165928	3079
a	000	0910	1995-05-12T16:06:30.359281	1995-05-12T16:56:48.323353	1995-05-12T16:31:39.341317	269.591078	3079

Chapter 6

RADS library

6.1 Module rads

6.1.1 module/rads

SUMMARY:

RADS main module

SYNOPSIS:

```
module rads
use typesizes
use rads_grid, only: grid

! * Parameters
! Dimensions
integer(fourbyteint), parameter :: rads_var_chunk = 100, rads_varl = 40, &
    rads_naml = 160, rads_cmdl = 320, rads_strl = 1600, rads_hstl = 3200, &
    rads_cyclistl = 50, rads_optl = 50, rads_max_branches = 5
! RADS4 data types
integer(fourbyteint), parameter :: rads_type_other = 0, rads_type_sla = 1, &
    rads_type_flagmasks = 2, rads_type_flagvalues = 3, rads_type_time = 11, &
    rads_type_lat = 12, rads_type_lon = 13, rads_type_dim = 14
! RADS4 data sources
integer(fourbyteint), parameter :: rads_src_none = 0, rads_src_nc_var = 10, &
    rads_src_nc_att = 11, rads_src_math = 20, rads_src_grid_lininter = 30, &
    rads_src_grid_splinter = 31, rads_src_grid_query = 32, &
    rads_src_constant = 40, rads_src_flags = 50, rads_src_tpj = 60
! RADS4 warnings
integer(fourbyteint), parameter :: rads_warn_nc_file = -3
! RADS4 errors
integer(fourbyteint), parameter :: rads_noerr = 0, &
    rads_err_nc_file = 1, rads_err_nc_parse = 2, rads_err_nc_close = 3, rads_err_memory = 4, &
    rads_err_var = 5, rads_err_source = 6, rads_err_nc_var = 7, rads_err_nc_get = 8, &
    rads_err_xml_parse = 9, rads_err_xml_file = 10, rads_err_alias = 11, rads_err_math = 12, &
    rads_err_cycle = 13, rads_err_nc_create = 14, rads_err_nc_put = 15, rads_err_nophase = 16
! Additional RADS4 helpers
character(len=1), parameter :: rads_linefeed = char(10), rads_tab = char(9), rads_noedit = '_'
! RADS3 errors or incompatibilities
integer(fourbyteint), parameter :: rads_err_incompat = 101, rads_err_noinit = 102
integer(twobyteint), parameter :: rads_nofield = -1
! Math constants
real(eightbytereal), parameter :: pi = 3.1415926535897932d0, rad = pi/180d0
! I/O parameters
integer, parameter :: stderr = 0, stdin = 5, stdout = 6

! * Variables
! I/O variables
integer(fourbyteint), save :: rads_verbose = 0          ! Verbosity level
integer(fourbyteint), save :: rads_log_unit = stdout ! Unit number for statistics logging

! * RADS4 variable structures
type :: rads_varinfo                                ! Information on variable used by RADS
```

```

character(len=rads_varl) :: name
character(len=rads_naml) :: long_name
character(len=rads_naml) :: standard_name
character(len=rads_naml) :: source
character(len=rads_naml) :: parameters
character(len=rads_strl) :: dataname
character(len=rads_cmdl) :: flag_meanings
character(len=rads_cmdl) :: quality_flag
character(len=rads_cmdl) :: comment
character(len=rads_varl) :: units
character(len=rads_varl) :: format
character(len=rads_varl) :: gridx, gridy
type(grid), pointer :: grid
real(eightbytereal) :: default
real(eightbytereal) :: limits(2)
real(eightbytereal) :: plot_range(2)
real(eightbytereal) :: add_offset, scale_factor
real(eightbytereal) :: xmin, xmax, mean, sum2
logical :: boz_format
integer(fourbyteint) :: ndims
integer(fourbyteint) :: brid
integer(fourbyteint) :: nctype, varid
integer(fourbyteint) :: datatype
integer(fourbyteint) :: datasrc
integer(fourbyteint) :: cycle, pass
integer(fourbyteint) :: selected, rejected
endtype

type :: rads_var
character(len=rads_varl), pointer :: name
character(len=rads_naml), pointer :: long_name
type(rads_varinfo), pointer :: info, infl, inf2
logical(twobyteint) :: noedit
integer(twobyteint) :: field(2)
endtype

type :: rads_cyclist
integer(fourbyteint) :: n, i
integer(fourbyteint) :: list(rads_cyclistl)
endtype

type :: rads_phase
character(len=rads_varl) :: name, mission
integer(fourbyteint) :: cycles(2), passes
real(eightbytereal) :: start_time, end_time
real(eightbytereal) :: ref_time, ref_lon
integer(fourbyteint) :: ref_cycle, ref_pass
integer(fourbyteint) :: ref_orbit
real(eightbytereal) :: pass_seconds
real(eightbytereal) :: repeat_days
real(eightbytereal) :: repeat_shift
integer(fourbyteint) :: repeat_nodal
integer(fourbyteint) :: repeat_passes
type(rads_cyclist), pointer :: subcycles
endtype

type :: rads_sat
character(len=rads_naml) :: userroot
character(len=rads_naml) :: dataroot
character(len=rads_varl) :: branch(rads_max_branches)
character(len=rads_varl) :: spec
character(len=rads_cmdl) :: command
character(len=rads_naml), pointer :: glob_att(:)
character(len=8) :: satellite
real(eightbytereal) :: dtlhz
real(eightbytereal) :: frequency(2)
real(eightbytereal) :: inclination
real(eightbytereal) :: eqlonlim(0:1,2)
real(eightbytereal) :: centroid(3)
real(eightbytereal) :: xover_params(2)
integer(fourbyteint) :: cycles(3), passes(3)
integer(fourbyteint) :: error
integer(fourbyteint) :: pass_stat(7)
integer(fourbyteint) :: total_read, total_inside
integer(fourbyteint) :: nvar, nsel
logical :: n_hz_output
character(len=2) :: sat
integer(twobyteint) :: satid

! Short name of variable used by RADS
! Long name (description) of variable
! Optional CF 'standard' name ('' if none)
! Optional data source ('' if none)
! Optional link to model parameters ('' if none)
! Name associated with data (e.g. NetCDF var name)
! Optional meaning of flag values ('' if none)
! Quality flag(s) associated with var ('' if none)
! Optional comment ('' if none)
! Optional units of variable ('' if none)
! Fortran format for output
! RADS variable names of the grid x and y coords
! Pointer to grid (if data source is grid)
! Optional default value (Inf if not set)
! Lower and upper limit for editing
! Suggested range for plotting
! Offset and scale factor in case of NetCDF
! Minimum, maximum, mean, sum squared deviation
! Format starts with B, O or Z.
! Number of dimensions of variable
! Branch ID (default 1)
! NetCDF data type (nf90_int, etc.) and input var ID
! Type of data (one of rads_type_*)
! Retrieval source (one of rads_src_*)
! Last processed cycle and pass
! Number of selected or rejected measurements

! Information on variable or alias
! Pointer to short name of variable (or alias)
! Pointer to long name (description) of variable
! Links to structs of type(rads_varinfo)
! .true. if editing is suspended
! RADS3 field numbers (rads_nofield = none)

! List of cycles
! Number of elements in list, additional value
! List of values

! Information about altimeter mission phase
! Name (1-letter), and mission description
! Cycle range and maximum number of passes
! Start time and end time of this phase
! Time and lon of equator crossing of "ref. pass"
! Cycle and pass number of "reference pass"
! Absolute orbit nr of "reference pass" (at eq.)
! Length of pass in seconds
! Length of repeat period in days
! Eastward shift of track pattern per cycle for near repeat
! Length of repeat period in nodal days
! Number of passes per repeat period
! Subcycle definition (if requested)

! Information on altimeter mission
! Root directory of current user (i.e. $HOME)
! Root directory of RADS data (i.e. $RADSDATAROOT)
! Name of optional branches
! Temporary holding space for satellite specs
! Command line
! Global attributes
! Satellite name
! "1 Hz" sampling interval
! Frequency (GHz) of primary and secondary channel
! Satellite inclination (deg)
! Equator lon limits for asc. and desc. passes
! Lon, lat, distance (in rad) selection criteria
! Crossover parameters used in radsxoconv
! Cycle and pass limits and steps
! Error code (positive = fatal, negative = warning)
! Stats of rejection at start of rads_open_pass
! Total nr of measurements read and inside region
! Nr of available and selected vars and aliases
! Produce multi-Hz output
! 2-Letter satellite abbreviation
! Numerical satellite identifier

```

```

    type(rads_cyclist), pointer :: excl_cycles      ! Excluded cycles (if requested)
    type(rads_var), pointer :: var(:)             ! List of available variables and aliases
    type(rads_var), pointer :: sel(:)             ! List of selected variables and aliases
    type(rads_var), pointer :: time, lat, lon      ! Pointers to time, lat, lon variables
    type(rads_phase), pointer :: phases(:)        ! Definitions of all mission phases
    type(rads_phase), pointer :: phase            ! Pointer to current phase
endtype

type :: rads_file                                ! Information on RADS data file
    integer(fourbyteint) :: ncid                 ! NetCDF ID of pass file
    character(len=rads_cmdl) :: name              ! Name of the NetCDF pass file
endtype

type :: rads_pass                                ! Pass structure
    character(len=rads_strl) :: original          ! Name of the original (GDR) pass file(s)
    character(len=rads_hstl), pointer :: history  ! File creation history
    real(eightbytereal) :: equator_time, equator_lon ! Equator time and longitude
    real(eightbytereal) :: start_time, end_time  ! Start and end time of pass
    real(eightbytereal), pointer :: tll(:, :)    ! Time, lat, lon matrix
    integer(twobyteint), pointer :: flags(:)      ! Array of engineering flags
    logical :: rw                                ! NetCDF file opened for read/write
    integer(fourbyteint) :: cycle, pass          ! Cycle and pass number
    integer(fourbyteint) :: nlogs                ! Number of RADS3 log entries
    integer(fourbyteint) :: ndata                ! Number of data points (1-Hz)
    integer(fourbyteint) :: n_hz, n_wvf         ! Size second/third dimension (0=none)
    integer(fourbyteint) :: first_meas, last_meas ! Index of first and last point in region
    integer(fourbyteint) :: time_dims            ! Dimensions of time/lat/lon stored
    integer(fourbyteint) :: trkid                ! Numerical track identifiers
    type (rads_file) :: fileinfo(rads_max_branches) ! File information for pass files
    type (rads_sat), pointer :: S                ! Pointer to satellite/mission structure
    type (rads_pass), pointer :: next            ! Pointer to next pass in linked list
endtype

type :: rads_option                                ! Information on command line options
    character(len=rads_varl) :: opt              ! Option (without the - or --)
    character(len=rads_cmdl) :: arg              ! Option argument
    integer :: id                                  ! Identifier in form 10*nsat + i
endtype

! These command line options can be accessed by RADS programs
type(rads_option), allocatable, target, save :: &
    rads_opt(:)                                     ! List of command line options
integer(fourbyteint), save :: rads_nopt = 0        ! Number of command line options saved

```

PURPOSE:

This module provides the main functionalities for the RADS4 software.
 To use any of the following subroutines and functions, add the following line in your Fortran 90 (or later) code:

```
use rads
```

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6.1.2 rads/rads.init

SUMMARY:

Initialize RADS4

SYNTAX:

```

subroutine rads_init (S, sat, xml)
  type(rads_sat), intent(inout) :: S <or> S(:)
  character(len=*), intent(in), optional :: sat <or> sat(:)
  character(len=*), intent(in), optional :: xml(:)

```

PURPOSE:

This routine initializes the <S> struct with the information pertaining to given satellite/mission phase <sat>, which is to be formed as 'el', or 'elg', or 'el/g'. If no phase is specified, all mission phases will be queried.

The <S> and <sat> arguments can either a single element or an array. In the latter case, one <S> struct will be initialized for each <sat>. To parse command line options after this, use rads_parse_cmd.

Only if the <sat> argument is omitted, then the routine will parse the command line for arguments in the form:
 --sat=<sat> --cycle=<lo>,<hi>,<step> --pass=<lo>,<hi>,<step>
 --lim:<var>=<lo>,<hi> --lat=<lo>,<hi> --lon=<lo>,<hi> --alias:<var>=<var>
 --opt:<value>=<value> --opt=<value>,... --fmt:<var>=<value>
 or their equivalents without the = or : separators after the long name,
 or their equivalents without the initial --, or the short options -S, -C,
 -P, -L, -F

The routine will read the satellite/mission specific setup XML files and store all the information in the struct <S>. The XML files polled are:

```

$RADSDATAROOT/conf/rads.xml
~/.rads/rads.xml
rads.xml
<xml> (from the optional array of file names)

```

If more than one -S option is given, then all further options following this argument until the next -S option, plus all options prior to the first -S option will pertain to this mission.

Execution will be halted when the dimension of <S> is insufficient to store information of multiple missions, or when required XML files are missing.

The verbosity level can be controlled by setting rads_verbose before calling this routine (default = 0). The output unit for log info can be controlled by setting rads_log_unit up front (default = stdout).

ARGUMENTS:

```

S          : Satellite/mission dependent structure
sat         : (optional) Satellite/mission abbreviation
xml         : (optional) Array of names of additional XML files to be loaded

```

6.1.3 rads/rads_end

SUMMARY:

End RADS4

SYNTAX:

```

subroutine rads_end (S)
  type(rads_sat), intent(inout) :: S <or> S(:)

```

PURPOSE:

This routine ends RADS by freeing up all <S> space and other allocated global arrays.

ARGUMENT:

```

S          : Satellite/mission dependent struct or array of structs

```

6.1.4 rads/rads_get_var

SUMMARY:

Read variable (data) from RADS4 file

SYNTAX:

```
recursive subroutine rads_get_var (S, P, var, data, noedit)
  type(rads_sat), intent(inout) :: S
  type(rads_pass), intent(inout) :: P
  character(len=*) :: var
  <or> integer(fourbyteint) :: var
  <or> type(rads_var), intent(in) :: var
  real(eightbytereal), intent(out) :: data(:)
  logical, intent(in), optional :: noedit
```

PURPOSE:

This routine loads the data from a single variable <var> into the buffer <data>. This command must be preceded by <rads_open_pass>. The variable <var> can be addressed as a variable name, a RADS3-type field number or a varlist item.

The array <data> must be at the correct size to contain the entire pass of data, i.e., it must have the dimension P%ndata. If no data are available and no default value and no secondary aliases then NaN is returned in the array <data>.

ARGUMENTS:

```
S      : Satellite/mission dependent structure
P      : Pass dependent structure
var    : (string) Name of the variable to be read.
          If <var> ends with % editing is skipped.
          (integer) Field number.
          (type(rads_var)) Variable struct (e.g. S%sel(i))
data   : Data returned by this routine
noedit : (optional) Set to .true. to skip editing on limits and/or
          quality flags; set to .false. to allow editing (default)
```

ERROR CODE:

```
S%error : rads_noerr, rads_err_var, rads_err_memory, rads_err_source
```

6.1.5 rads/rads_stat

SUMMARY:

Print the RADS statistics for a given satellite

SYNTAX:

```
subroutine rads_stat (S)
  type(rads_sat), intent(in) :: S <or> S(:)
  integer(fourbyteint), intent(in), optional :: unit
```

PURPOSE:

This routine prints out the statistics of all variables that were processed per mission (indicated by scalar or array <S>), to the output on unit <rads_log_unit>.

ARGUMENTS:

```
S      : Satellite/mission dependent structure
```

6.1.6 rads/rads_init_sat_struct

SUMMARY:

Initialize empty rads_sat struct

SYNOPSIS:

```
subroutine rads_init_sat_struct (S)
  type(rads_sat), intent(inout) :: S
```

PURPOSE:

This routine initializes the <S> struct with the bare minimum. It is later updated in rads_init_sat_0d.

ARGUMENTS:

S : Satellite/mission dependent structure

6.1.7 rads/rads_init_pass_struct

SUMMARY:

Initialize empty rads_pass struct

SYNOPSIS:

```
subroutine rads_init_pass_struct (S, P)
  type(rads_sat), target, intent(in) :: S
  type(rads_pass), intent(inout) :: P
```

PURPOSE:

This routine initializes the <P> struct with the bare minimum. This is only really necessary prior to calling rads_create_pass.

ARGUMENTS:

S : Satellite/mission dependent structure
P : Pass dependent structure

6.1.8 rads/rads_set_options

SUMMARY:

Specify the list of command specific options

SYNOPSIS

PURPOSE:

Add the command specific options to the list of common RADS options. The argument <optlist> needs to have the same format as in the routine <getopt> in the <rads_misc> module. The short options will be placed before the common ones, the long options will be placed after them.

ARGUMENT:

optlist : (optional) list of command specific short and long options

6.1.9 rads/rads_open_pass

SUMMARY:

Open RADS pass file

SYNOPSIS:

```
subroutine rads_open_pass (S, P, cycle, pass, rw, echofilepaths)
use netcdf
use rads_netcdf
use rads_time
use rads_misc
use rads_geo
type(rads_sat), intent(inout) :: S
type(rads_pass), intent(inout) :: P
integer(fourbyteint), intent(in) :: cycle, pass
logical, intent(in), optional :: rw
logical, intent(in), optional :: echofilepaths
```

PURPOSE:

This routine opens a NetCDF file for access to the RADS machinery. However, prior to opening the file, three tests are performed to speed up data selection:

- (1) All passes outside the preset cycle and pass limits are rejected.
- (2) Based on the time of the reference pass, the length of the repeat cycle and the number of passes per cycle, a rough estimate is made of the temporal extent of the pass. If this is outside the selected time window, then the pass is rejected.
- (3) Based on the equator longitude and the pass number of the reference pass, the length of the repeat cycle and the number of passes in the repeat cycle, an estimate is made of the equator longitude of the current pass. If this is outside the limits set in S%eqlonlim then the pass is rejected.

If the pass is rejected based on the above criteria or when no NetCDF file exists, S%error returns the warning value rads_warn_nc_file. If the file cannot be read properly, rads_err_nc_parse is returned. Also, in both cases, P%ndata will be set to zero.

By default the file is opened for reading only. Specify perm=nf90_write to open for reading and writing.
The file opened with this routine should be closed by using rads_close_pass.

ARGUMENTS:

```
S          : Satellite/mission dependent structure
P          : Pass structure
cycle      : Cycle number
pass       : Pass number
rw         : (optional) Set read/write permission (def: read only)
echofilepaths : (optional) Print to standard output the file path before
                  it is being checked for existence.
```

ERROR CODE:

```
S%error : rads_noerr, rads_warn_nc_file, rads_err_nc_parse
```

6.1.10 rads/rads_close_pass

SUMMARY:

Close RADS pass file

SYNOPSIS:

```
subroutine rads_close_pass (S, P, keep)
use netcdf
use rads_netcdf
```

```

type(rads_sat), intent(inout) :: S
type(rads_pass), intent(inout) :: P
logical, intent(in), optional :: keep

```

PURPOSE:

This routine closes a NetCDF file previously opened by `rads_open_pass`. The routine will reset the `ncid` element of the `<P>` structure to indicate that the passfile is closed. If `<keep>` is set to `.true.`, then the history, flags, time, lat, and lon elements the `<P>` structure are kept. I.e., they are not deallocated but only their links are removed. Otherwise, they are deallocated along with the log entries. A second call to `rads_close_pass` without the `keep` argument can subsequently deallocate the time, lat and lon elements of the `<P>` structure.

ARGUMENTS:

```

S      : Satellite/mission dependent structure
P      : Pass structure
keep   : Keep the P%tll matrix (destroy by default)

```

ERROR CODE:

```

S%error : rads_noerr, rads_err_nc_close

```

6.1.11 rads/rads_read_xml**SUMMARY:**

Read RADS4 XML file

SYNOPSIS:

```

subroutine rads_read_xml (S, filename)
use netcdf
use xmlparse
use rads_time
use rads_misc
type(rads_sat), intent(inout) :: S
character(len=*), intent(in) :: filename

```

PURPOSE:

This routine parses a RADS4 XML file and fills the `<S>` struct with information pertaining to the given satellite and all variable info encountered in that file.

The execution terminates on any error, and also on any warning if `fatal = .true.`

ARGUMENTS:

```

S      : Satellite/mission dependent structure
filename : XML file name
fatal   : If .true., then all warnings are fatal.

```

ERROR CODE:

```

S%error : rads_noerr, rads_err_xml_parse, rads_err_xml_file

```

6.1.12 rads/rads_set_alias**SUMMARY:**

Set alias to an already defined variable

SYNOPSIS:

```
subroutine rads_set_alias (S, alias, varname, field)
use rads_misc
type(rads_sat), intent(inout) :: S
character(len=*), intent(in) :: alias, varname
integer(twobyteint), intent(in), optional :: field(2)
```

PURPOSE:

This routine defines an alias to an existing variable, or up to three variables. When more than one variable is given as target, they will be addressed one after the other.
 If alias is already defined as an alias or variable, it will be overruled.
 The alias will need to point to an already existing variable or alias.
 Up to three variables can be specified, separated by spaces or commas.

ARGUMENTS:

```
S          : Satellite/mission dependent structure
alias      : New alias for (an) existing variable(s)
varname    : Existing variable name(s)
field      : (optional) new field numbers to associate with alias
```

ERROR CODE:

```
S$error    : rads_noerr, rads_err_alias, rads_err_var
```

6.1.13 rads/rads_set_limits**SUMMARY:**

Set limits on given variable

SYNOPSIS:

```
subroutine rads_set_limits (S, varname, lo, hi, string, iostat)
use rads_misc
type(rads_sat), intent(inout) :: S
character(len=*), intent(in) :: varname
real(eightbytereal), intent(in), optional :: lo, hi
character(len=*), intent(in), optional :: string
integer(fourbyteint), intent(out), optional :: iostat
```

PURPOSE:

This routine set the lower and upper limits for a given variable in RADS.
 The limits can either be set by giving the lower and upper limits as double floats <lo> and <hi> or as a character string <string> which contains the two numbers separated by whitespace, a comma or a slash.
 In case only one number is given, only the lower or higher bound (following the separator) is set, the other value is left unchanged.

ARGUMENTS:

```
S          : Satellite/mission dependent structure
varname    : Variable name
lo, hi     : Lower and upper limit
string     : String of up to two values, with separating whitespace
            : or comma or slash.
iostat     : (optional) iostat code from reading string
```

ERROR CODE:

```
S$error    : rads_noerr, rads_err_var
```

6.1.14 rads/rads_set_region

SUMMARY:

Set latitude/longitude limits or distance to point

SYNOPSIS:

```
subroutine rads_set_region (S, string)
  use rads_misc
  type(rads_sat), intent(inout) :: S
  character(len=*), intent(in) :: string
```

PURPOSE:

This routine set the region for data selection (after the -R option). The region can either be specified as a box by four values "W/E/S/N", or as a circular region by three values "E/N/radius". Separators can be commas, slashes, or whitespace.

In case of a circular region, longitude and latitude limits are set accordingly for a rectangular box surrounding the circle. However, when reading pass data, the distance to the centroid is used as well to edit out data.

ARGUMENTS:

S : Satellite/mission dependent structure
 string : String of three or four values with separating whitespace.
 For rectangular region: W/E/S/N.
 For circular region: E/N/radius (radius in degrees).

ERROR CODE:

S%error : rads_noerr, rads_err_var

6.1.15 rads/rads_set_format

SUMMARY:

Set print format for ASCII output of given variable

SYNOPSIS:

```
subroutine rads_set_format (S, varname, format)
  type(rads_sat), intent(inout) :: S
  character(len=*), intent(in) :: varname, format
```

PURPOSE:

This routine set the FORTRAN format specifier of output of a given variable in RADS.

ARGUMENTS:

S : Satellite/mission dependent structure
 varname : Variable name
 format : FORTRAN format specifier (e.g. 'f10.3')

ERROR CODE:

S%error : rads_noerr, rads_err_var

6.1.16 rads/rads_predict_equator

SUMMARY:

Predict equator crossing time and longitude

SYNOPSIS:

```
subroutine rads_predict_equator (S, P, cycle, pass)
type(rads_sat), intent(inout) :: S
type(rads_pass), intent(inout) :: P
integer(fourbyteint), intent(in) :: cycle, pass
```

PURPOSE:

This routine estimates the equator time and longitude, as well as the start and end time of a given <cycle> and <pass>.

The routine works for exact repeat orbits as well as drifting orbits.

The estimated variables (equator_time, equator_lon, start_time, end_time) are returned in the pass struct <P>.

ARGUMENTS:

S	: Satellite/mission dependent structure
P	: Pass structure
cycle	: Cycle number
pass	: Pass number

ERROR CODE:

S%error : rads_noerr, rads_err_nophase

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