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i. **Basics: accessing SAC functionality and data from external programs**
ii. Automating SAC processing with shell scripts
iii. Accessing SAC data from Fortran with the sacio library
iv. Accessing SAC data from MATLAB

SAC from external programs

- Even with macros, SAC inevitably will not be able (nor is designed) to implement every possible function or methodology one might wish to apply to seismic data

- SACs macro language has limits, and many things are not possible which are trivial in scripts or compiled languages

- External access to SAC is in two main ways; (a) running SAC itself from some sort of control environment, and (b) loading, modifying and writing SAC data in external programs unconnected to SAC

- We will look at each of these in turn.

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Calling SAC from shell scripts

- Shell scripts (similarly, batch files in Windows systems) are sets of commands interpreted by the operating system
- They can run both system commands and executable codes (like SAC)
- Shell scripts also enable basic programming constructs like conditionals and loops
- They can be used to provide a higher level of SAC automation than is possible from within SAC using macros

SAC default macro

- SAC automation is made possible by the ability for the user to specify a macro which SAC will execute when it starts:

```
$ sac mymacro
```

starts SAC, which then runs the command(s) in the macro mymacro

- A shell script can construct these macros on the fly, so each time SAC is executed (say in a loop) a new macro can be used

Example SAC automation script

```
#!/bin/csh
# Script to demonstrate automated running of SAC.
#
unalias sac # prevent any aliases colliding

# set loop length
set n = 5

# run loop
@ i = 1
while ($i <= $n) # start of loop

# build up a SAC macro
echo "funcgen seismogram" > /tmp/mymacro
echo "mul " $i >> /tmp/mymacro
echo "w myfile."$i >> /tmp/mymacro
echo "quit" >> /tmp/mymacro

# run SAC with the macro
sac /tmp/mymacro

@ i = $i + 1
end # end of loop

# end of script
```

SAC automation

- Automation in this fashion is a handy way of accessing SAC functionality from other programs
- Set up large SAC batch jobs; possible to use for parallel processing in SAC
- Not very efficient – requires a lot of extra processing effort starting and quitting SAC. Shell scripts are much (much!) slower than compiled code, and only provided fairly limited programming functionality
- For a lot of applications this does not matter!

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Externally processing SAC data

- Other model is to process SAC data inside an external compiled program
- This enables the addition of processing not available in SAC – obviously in research seismology this is not an uncommon occurrence!
- (Probably) the most commonly used programming language in Science is Fortran. Also, a huge amount of ‘legacy’ code exists.
- A library of data access functions for Fortran (and C) are distributed with SAC
- Enables easy reading and writing of SAC files, allows access to headers

Linking FORTRAN to the sacio library

- Fortran codes using the sacio library routines must be linked to the sacio.a library, e.g.:

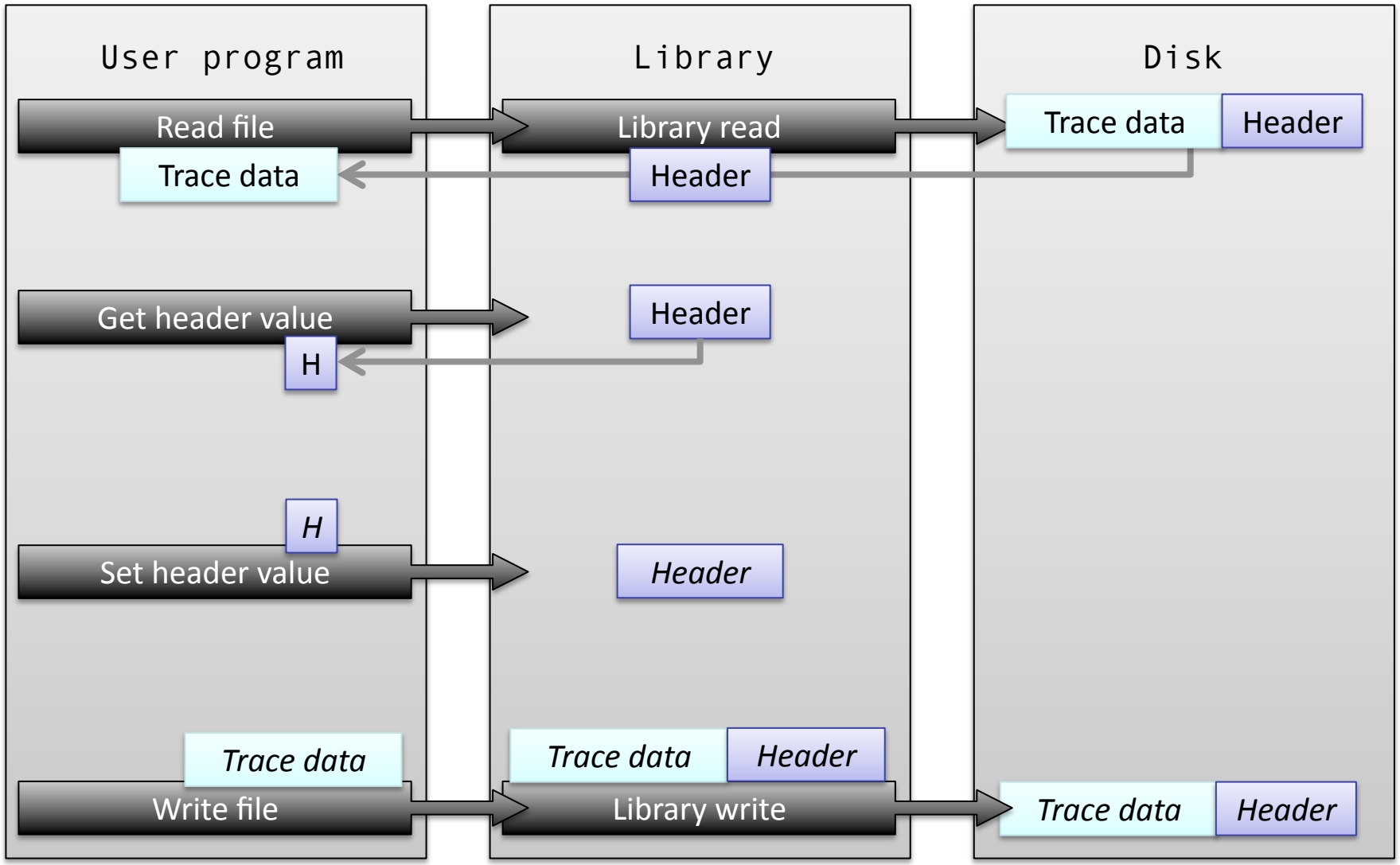
```
$ gfortran -o myprog myprog.f90 /usr/local/lib/sacio.a
```

- Problems can arise when trying to link 64-bit programs to a 32-bit library (for example, that distributed with MacSAC)

- To circumvent this, compile your program as 32-bit:

```
$ gfortran -m32 -o myprog myprog.f90 /usr/local/lib/sacio.a
```

sacio library interaction model



Reading SAC files

- Subroutine rsac1 reads SAC time-series files:

```
*=====================================================================
      subroutine rsac1(kname,yarray,nlen,beg,del,max,nerr)
*=====================================================================
* PURPOSE: To read an evenly spaced SAC file.
*=====================================================================
* INPUT ARGUMENTS:
*    KNAME:   Name of disk file to read. [c]
*             The name should be blank filled.
*    MAX:     Size of YARRAY. [i]
*=====================================================================
* OUTPUT ARGUMENTS:
*    YARRAY:  Contains the data from the file. [fa]
*    NLEN:    Number of data points read. [i]
*             Will be less than or equal to MAX.
*    BEG:     Beginning value of independent variable. [f]
*    DEL:     Sampling interval of the independent variable. [f]
*    NERR:    Error return flag 0 if no error occurred. [i]
*             Possible values for this subroutine are:
*             =  801 if file is not evenly spaced.
*             = -803 if number of points in file is greater than MAX.
*             In this case, the first MAX points are read.
```

- Only minimal header information is returned – header of the last trace read is stored in the library

Getting headers

- Subroutine getfhv fetches (floating point) header values for the last trace read by the library

```
*=====================================================================
      subroutine getfhv(kname,fvalue,nerr)
*=====================================================================
* PURPOSE: To get a floating point header value from the current SAC
file.
*=====================================================================
* INPUT ARGUMENTS:
*    KNAME:   Name of header field to get. [c]
*=====================================================================
* OUTPUT ARGUMENTS:
*    FVALUE:  Value of header field from current SAC data file. [f]
*    NERR:    Error flag. Set to 0 if no error occurred. [i]
*             = 1336 Header variable is undefined.
*             = 1337 Header variable does not exist.
*=====================================================================
```

- Equivalent routines fetch integer (getihv), character (getkhv) and logical (getlhv) headers.

Setting headers

- Subroutine setfhv sets (floating point) header values for the current header stored in the library

```
*=====================================================================
      subroutine setfhv(kname,fvalue,nerr)
*=====================================================================
* PURPOSE: To set a floating point header value in the current SAC file.
*=====================================================================
* INPUT ARGUMENTS:
*    KNAME:   Name of header field to set. [c]
*    FVALUE:  New value of header field. [f]
*=====================================================================
* OUTPUT ARGUMENTS:
*    NERR:    Error flag. Set to 0 if no error occurred. [i]
*             = 1337 Header field does not exist.
*=====================================================================
```

- Equivalent routines set integer (setihv), character (setkhv) and logical (setlhv) headers.

Writing SAC files

- Two different approaches to writing files:
  1. Output a file with minimal header information
     - Requires no set up
     - Any previous trace information is lost
     - Useful for temporary or QC files, files to which the header information no longer applies
  2. Output a file with a complete header
     - Need to either set up header, or have one from a previously read trace
     - Useful for when program is a processing step

Writing SAC files: method 1

- Command wsac1 writes out a file with a minimal header:

```
*=====================================================================
      subroutine wsac1(kname,yarray,nlen,beg,del,nerr)
*=====================================================================
* PURPOSE: To write an evenly spaced SAC file.
*=====================================================================
* INPUT ARGUMENTS:
*     KNAME:  Name of disk file to write. [c]
*             The name should be blank filled.
*    YARRAY:  Array containing the dependent variable. [fa]
*      NLEN:  Length of YARRAY. [i]
*       BEG:  Beginning value of the independent variable. [f]
*       DEL:  Sampling interval of the independent variable. [f]
*=====================================================================
* OUTPUT ARGUMENTS:
*      NERR:  Error return flag, 0 if no error occurred. [i]
*=====================================================================
```

Writing SAC files: method 2

- Command wsac0 writes out a file with *the current* header:

```
*=====================================================================
      subroutine wsac0(kname,xarray,yarray,nerr)
*=====================================================================
* PURPOSE: To write a SAC file to disk using current header values.
*=====================================================================
* INPUT ARGUMENTS:
*     KNAME:  Name of disk file to write. [c]
*             The name should be blank filled.
*    XARRAY:  Array containing independent variable. [fa]
*             This is not used if the data is evenly spaced.
*    YARRAY:  Array containing dependent variable. [fa]
*=====================================================================
* OUTPUT ARGUMENTS:
*      NERR:  Error return flag 0 if no error occurred. [i]
*=====================================================================
```

- If there is no current header (for example, if the trace is being generated by the program) then a new (empty) header must be generated with a call to newhdr, and the required variables set with set*hv calls

Example

```
!  program to double amplitudes in files recorded before 2005
   program correct_pre2005
      implicit none
      integer, parameter :: nmax = 10000
      real data(nmax),beg,dt
      integer nzyear,npts,nerr,ip

      character fn*80,stnm*8

!     read trace
      fn = 'SWAV.BHN'
      call rsac1(fn,data,npts,beg,dt,nmax,nerr)

!     if seismogram is pre-2005, double amplitudes
      call getnhv('NZYEAR',nzyear,nerr)
      if (nzyear < 2005) then
         do ip=1,npts
            data(ip) = data(ip) * 2.0
         enddo
      endif

!     flag fixed in a header
      call setkhv('KUSER0','FIXED   ',nerr)

!     write back the file, using the header currently in memory
      call wsac0(fn,data,data,nerr)
      stop
   end program correct_pre2005
```

FOTRAN90 alternative

- The F90sac library is an alternative to the standard sacio library which uses FORTRAN90 constructs to provide a more object-oriented approach to handling SAC files
- Traces are treated as structures, with header and trace being fields
- This makes multiple traces much easier to handle

```
program simplef90
use f90sac  ! use the f90sac module
implicit none
type (SACTrace) :: tr

fname = 'SWAV.BHE'
call f90sac_readtrace(fname,tr)

tr % t0 = 275. ;
tr % kt0 = 'NewPick' ;
tr % trace(:) = 0.0

call f90sac_writetrace(fname,tr)

end program simple
```

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Using SAC data in other languages

- Read and write routines also exist in other languages
- MATLAB and Python routines are included in the API subdirectory in the software distribution
- Enables the use of, e.g., graphical/processing capabilities:

```
% read traces
tr = msac_mread('*.BHE') ;
A = [tr(:).trace] ;
T = [tr(:).time] ;
for itr = 1:length(tr), D(:,itr) = tr(itr).gcarc; , end

% sort matrices by epicentral distance
[d,ind] = sort([tr(:).gcarc]) ;
AS = A(:,ind) ;
TS = T(:,ind) ;
DS = D(:,ind) ;

% plot surface
h=surf(DS,TS,AS,'LineStyle','none');
```

Using SAC data in other languages