

EMPCOV, Program empirical covariance functions.

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The program computes an empirical covariance function of scalar or vector quantities on a spherical surface by taking the mean of product-sums of samples of scalar values or of the along-track (longitudinal) and transversal components of vector quantities. The data must be stored in one or more files which contains as element number 1 and integer, as number two and tree latitude and longitude (or longitude and latitude), followed by one or more data elements.

For scalar quantities f, g , a covariance associated with the distance ψ_j is

$$\text{cov}(\psi_j) = \frac{1}{N_j} \sum_{k,i}^{N_j} f(\varphi_k, \lambda_k) \cdot g(\varphi_i, \lambda_i),$$

$$\psi_j = \sin \varphi_k \sin \varphi_i + \cos \varphi_k \cos \varphi_i \cos(\lambda_i - \lambda_k)$$

where ψ_j is the spherical distance and the products are calculated for all pairs of points, where the distance is in the interval $[\psi_j - \text{dist}, \psi_j + \text{dist}]$, where dist is the sampling interval length. If the left boundary is negative, the value is put equal to zero. An auto-covariance is computed, if f and g are the same kind of quantity. If they are different, both auto-covariances and cross-covariances are computed. The program will not take into account that the two points may not have the same altitude.

The distance "dist" may be difficult to select first time a covariance is computed, the program offers the possibility of using $2 \times \text{dist}$ a number of times, i.e. we get larger and larger sampling intervals, and more data in each interval. This may give a smoother curve than when just using "dist".

The program will for scalar values also compute the variogram, i.e. the summation is formed over all products of the differences between pairs of points.

If f or g are vector quantities (like deflections of the vertical) the quantities are projected on the line connecting the two points and the covariances are calculated for the along-track, the transversal and the cross-covariance between the transversal and the along-track components.

Covariances between maximally 2 sets of scalar or vector quantities may be computed. Each quantity must be identified by an integer between 0 and 16. if a quantity is a scalar, it is identified by for example (1,0).

The following codes may be used, but the program only uses the number to identify whether we deal with scalar or vector quantities, and to identify whether an auto or a cross-covariance is to be computed:

geoid undulations, height anomalies, sea surface heights	1
gravity disturbances	2
gravity anomalies	3
radial derivatives of gravity anomalies	4
radial derivatives of gravity disturbances	5
meridian component of deflection of the vertical	6
prime vertical component of same	7
gravity anomaly gradient, meridian component	8
- - - , prime vertical component	9
- disturbance gradient, meridian component	10

-	-	-	, prime vertical	11
2*	mixed	second	order derivative	12
difference	between	horizontal	2' order derivatives	13

Input description (logical variables have names starting with an "l"):

***** input (0) *****

input of text max. 60 characters describing data. This text is not used by the program but only copied to the output file.

***** input (1) *****

input of interval-length, dist,(minutes), number of intervals, number of times the table can be 'densified', lplot = plot covariance function, lpunch = punch table of covariance function and lsmean = subtract mean value from data.

input: sampling interval (minutes), number of intervals'
number resamplings of table, plot output (t/f)'
table output to separate file (t/f), mean value subtraction ',
(t/f)')

if lplot is false, jump to input 1b.

----- input (1a) -----

input of name of plot-job file, max x-value and min and max y-value.

If lpunch is false, jump to input 2.

----- input (1b) -----

input of name of file to hold covariance function table.

***** input (2) *****

input:

imax = maximal number of observations in current file,

imode = input mode (2) gi standard format for gravity data (1)

output from geocol, scalar data, (3) output from geocol, vector
data, (4) gi standard, pairs of deflections of the vertical, (9) is free-
format

lflat = latitude first,

iang = 1 for angles in degree, min.

and sec., = 2 for deg. and min., = 3 for degrees and 4 for grads,

iobs1 = type of first data element,

iobs2 = type of second data element. if it is equal to zero, a
scalar datatype is input,

scale= binsize for histogram with 21 bins.

larea = true, if data from a limit area must be input, in which
case the boundaries must be input at (2b).

data records are input from unit 8, the name of which must be
input subsequently (input (2a)).

a data record is then supposed to consist of at least latitude,
longitude and one observation. depending on imode a number and
a second observation may be contained, and also lstop, true
for the last data record.

the input from unit 8 will stop, either if imax records have been input, if the value of lstop in the data record is true, or end if file is encountered.

----- input (2x) -----

```
write(*,*)' input number of data and data elements used' (NDAT, NDAT1, NDAT2)
```

This is used to compute compute the components used in the computation. this is so when the for example data are the mixed second order derivative and the difference of the horizontal second order derivatives obtained by torsion balance.

----- input (2a) -----
input of name of file holding data.

----- input (2b) -----

input of latitude and longitude boundaries if larea is true.

***** input (3) *****

```
imode=1
  read(8,98)no,rla,rlo,g
imode=2
  read(8,97)idla,rla,idlo,rlo,g,lstop
  97 format(1x,i2,f5.2,1x,i4,f5.2,25x,f6.1,30x,11)
imode=3
  2003 read(8,96)idla,rla,idlo,rlo,g,g1
  96 format(i6,2(i4,f6.2),16x,2f8.2)
imode=4
  read(8,95)no,idla,m1a,rla,idlo,m1o,rlo,g,g1
  95 format(i5,2(i4,i3,f6.2),16x,f8.2,8x,f8.2)
imode=5
  read(8,94)no,idla,rla,idlo,rlo,g
  94 format(i10,2(i4,f5.1,3x),11x,/,34x,f8.2)
imode=6
  read(8,93)no,idla,rla,idlo,rlo,g,gpot,g1
  93 format(3x,i7,2(i4,f5.1,3x),11x,/,2x,f8.2,16x,2f8.2)
  g=g-gpot
imode=7
  read(8,92)no,rla,rlo,g
  92 format(i11,f9.4,3x,f9.4,25x,f8.2)
imode=8
  read(8,91)no,rla,rlo,g2,g1,g
  91 format(i8,f11.6,f10.6,10x,f7.3,2f9.3)
  prepared for density data from g.hein, hswb, 1987.
  if (iobs1.eq.16) g=(g2-2.67)*10
imode=9
  if (iang.eq.3) read(8,*,end=2013)no,rla,rlo,h,
  *(datai(kn),kn=1,ndata)
  if (iang.eq.2) read(8,*,end=2013)no,idla,rla,idlo,rlo,h,
  *(datai(kn),kn=1,ndata)
  if (iang.eq.1) read(8,*,end=2013)no,idla,m1a,rla,idlo,m1o,rlo,
  *h,(datai(kn),kn=1,ndata)
  g=datai(ndat1)
  if (ndat2.gt.0) g1=datai(ndat2)
  if (iobs1.eq.17) then
```

```
if (h.ge.0.0d0) g1=g1-h*0.1119
if (h.lt.0.0d0) g1=g1-h*0.03
```

```
***** input (3) *****
```

input of logical variable lstop, true when last gravity file has been input. Otherwise jump back to input (2).

Output

Number of data, mean and standard-deviation of data in each input file.
Primitive histogram, with binsize="scale".

Table of covariances:

psi for all values where the number of products in positive, covariance, Standard deviation of cov., number of products and variogram value. psi in minutes, covariance in units of the input data.

If output to file, the value of psi is in decimal degrees.

Example.

This example illustrates the computation of a covariance function of gravity anomalies.

```
MN GRAVITY DATA - OSU91A -TC . Text to be reproduced in output
  5.0 96 2 Bin-size dist, number of bins, 2 compressions
F T F no plot output, table output, mean not subtrac.
nm91.covt Name of covariance table output file
4800 9 T Max. Number of points, imode, latitude first,
  3 2 0 5.0 f iang, ions1, iobs2,scale, larea
  3 3 0 NDATA, NDA1, NDA2 (shows scalar data)
nmfa.rd Input data file
T No more files (lstop)
```

This input produced the following output:

EMPIRICAL COVARIANCE FUNCTIONS, VERS. FEB. 1991.

```
INPUT TEXT DESCRIBING DATA (MAX 60 CHAR):
MN GRAVITY DATA - OSU91A -TC .
INPUT: SAMPLING INTERVAL (MINUTES), NUMBER OF INTERVALS
NUMBER RESAMPLINGS OF TABLE, PLOT OUTPUT (T/F)
TABLE OUTPUT TO SEPARATE FILE (T/F), MEAN VALUE SUBTRACTION (T/F)
INPUT NAME OF FILE HOLDING COV TABLE
COVARIANCE FUNCTION TABLE OUTPUT TO FILE nm91.covt
INPUT: MAX NUMBER OF VALUES, INPUT MODE (WHERE 9 IS FREE FORMAT)
LATITUDE FIRST IN RECORD (T/F), ANGULAR TYPE: 1, DDMSS.S
2: DMM.M, 3: DD.D, OBSERVATION TYPE 1 (INTEGER) AND
TYPE 2 (INTEGER, 0 IF NOT PRESENT), SCALE OF HISTOGRAM
AND DATA TO BE SELECTED WITHIN GIVEN AREA (T/F)
INPUT NUMBER OF DATA AND DATA ELEMENTS USED
INPUT NAME OF FILE HOLDING DATA
LAST DATA FILE (T/F) ?
2920 VALUES INPUT FROM FILE nmfa.rd
NUMBER OF OBS 2= 2920 MEAN = .86 VAR. = 190.7
```

HISTOGRAM, USING BIN SIZE= 5.0

0 0 1 1 6 14 32 95101213305851412355205166 79 33 21 18 12 0 0
OUT-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9' 10OUT

PSI COVA(2, 2) PROD. STDV OF COV..
O M (UNIT)**2 NUMB (UNIT)**2

0	.00	177.80	6076	3.6	8.05
0	5.00	113.67	29370	1.4	66.04
0	10.00	58.99	54216	.9	122.83
0	15.00	23.16	75303	.8	159.98
***** lines removed *****					
3	45.00	-24.26	10	14.8	99.01

PSI COVA(2, 2) PROD. STDV OF COV..
O M (UNIT)**2 NUMB (UNIT)**2

0	.00	177.80	6076	3.6	8.05
0	7.50	78.20	83586	.8	102.88
0	17.50	10.70	168278	.5	175.20
***** lines removed *****					
3	27.50	48.15	3062	1.9	105.56
3	37.50	28.21	484	4.2	106.06
3	47.50	-24.26	10	14.8	99.01

Stop - Program terminated.