# Reproduce conditional approach

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## Setting up

| | |
|---|---|
| Model 1 (independent Matérns): | $b_o(h) \equiv 0$, |
| Model 2 (pointwise dependence): | $b_o(h) \equiv A\delta(h)$, |
| Model 3 (diffused dependence): | Model 4 with $\Delta = 0$ |
| Model 4 (asymmetric dependence): | $b_o(h) \equiv \begin{cases} A\{1-(\|h-\Delta\|/r)^2\}^2, & \|h-\Delta\| \le r \\ 0, & \text{otherwise,} \end{cases}$ |

where $\Delta = (\Delta_1, \Delta_2)^{\mathrm{T}}$ is a shift-parameter vector that captures asymmetry, $r$ is the aperture parameter, and $A$ is a scaling parameter.

In Models 3 and 4, $b_o(h)$ is a shifted bisquare function defined on $\mathbb{R}^2$.

The covariance functions $C_{11}(\cdot)$ and $C_{2|1}(\cdot)$ are Matérn covariance functions.

For each model we also consider a *reversed* dependence, where we switch $Y_2$ and $Y_1$. This gives us a total of eight models to fit and compare.

```
### Model choice

model_names <- c("independent","pointwise","moving_average_delta0","moving_average")
image_path <- "../paper/art"
show_figs <- 1              ## show figs in document
print_figs <- 0             ## Print figures to file (leave =0)
LK_analysis <- 0            ## log-likelihood analysis
LOO_analysis <- 0           ## LOO analysis
Shifted_Pars_estimation <- 0  ## Fit shifted parimonious Matern
RF_estimation <- 0            ## Carry out LOO with RFields
useMPI <- 0                                ## MPI backend available?
```

## The data

The data were made available through the package `RandomFields`. We first load the data

```
data(weather, package = "RandomFields")
weather <- weather %>% data.frame()
weather %>% head(4) %>% print()
```

```
##   pressure temperature    lon  lat
## 1 200.4844  0.60537720 -131.0 46.0
## 2 384.8516 -0.02233887 -124.4 41.9
## 3 156.8984 -0.26644897 -124.5 46.1
## 4 248.4297 -1.30670166 -124.7 47.3
```

The `weather` table contains four fields, with latitude, longitude, pressure forecasting errors, and temperature forecasting errors for December 13, 2003 at 4 p.m. in the North American Pacific Northwest.

Since pressure and temperature have different units, we find a scaling factor by taking the ratio of the sample variances of the two variates, and computing its square root.

We will use this factor to scale the pressure variable.

```
p_scale <- var(weather$pressure) / var(weather$temperature) %>%
  sqrt() %>%
  as.numeric()
```

From this data frame we extract $Z_1$ and $Z_2$ and concatenate them into one long vector $Z$ through a function `form_Z`.

The vectors $Z_1$ and $Z_2$ are inverted if the model being analysed is greater than 4 (reversed model).

We also define `m1` as the number of observations of $Y_1$, `m2` as the number of observations of $Y_2$ and `m` as the total number of observations.

```
form_z <- function(model_num, scale = T){
  Z1 <- matrix(weather$temperature)
  Z2 <- matrix(weather$pressure)

  if(scale) Z2 <- Z2 / p_scale   # scale pressure

  if(model_num > 4) {
    temp <- Z1   # move temperature values out of Z1 name into temp
    Z1 <- Z2     # pressure values go into name Z1
    Z2 <- temp   # move original temperature values into Z2
  }

  Z <- rbind(Z1, Z2)  # concatenate
}


## Number of observations
m1 <- nrow(weather)
m2 <- nrow(weather)
m = m1 + m2
I_m1 <- Diagonal(m1)
```

## Process Discretisation

We approximate the processes as a sum of elemental basis functions (tent functions) constructed on a triangulation.

The triangulation is formed using the mesher in the `INLA` package, while we provide a tailored function in the package `bicon`, `initFEbasis`

?initFEbasis: initialise a finite element basis which initialises an object of class FEBasis which defines a set of elemental 'tent' basis functions over a pre-specified triangulation in 2-D

which takes information from the `INLA` mesher and casts it into a `Mesh` object

We provide several methods associated with the `Mesh` class which will be useful for plotting later on.

Importantly, the `Mesh` object also contains information on the areas of the elements in the Voronoi tesselation, which will be used to approximate the integrations.

```
## discretizing process Y1,Y2 using triangular grid

## constructing mesh
mesh <- inla.mesh.2d(loc = weather[c("lon", "lat")],
             cutoff = 0,        # minimum allowed dist between pts, two pts further apart at most of th
             max.edge = 0.75,   # the largest allowed tri edge length
             offset = 4)        # automatic extension dist

mesh_locs <- mesh$loc[, 1:2]  # [1:2071, 1:2]


## compute distances as in Gneiting(2010) -- greate-circle distance

### Greate circle distance: shortest distance between two points on the surface of a sphere, measured a

d <- RFearth2dist(as.matrix(mesh_locs)) # transform coods from earth (ellipsoid) to cartesian
```

```
## Angle mode switches to 'degree'.
```

```
D <- as.matrix(d)
Dvec <- as.double(c(D))
```

### understandings 1

```
str(mesh)
```

```
## List of 8
##  $ meta    :List of 5
##   ..$ call        : language inla.mesh.create(loc = loc, boundary = boundary1, interior = interior1,
##   ..$ fmesher.args: chr "--input=input.s --cutoff=0  --boundary=input.segm.bnd.idx  --boundarygrp=inp
##   ..$ time        : num [1:5, 1:5] 0 0 0 0 0 0 0 0 0 0 ...
##   .. ..- attr(*, "dimnames")=List of 2
##   .. .. ..$ : chr [1:5] "pre" "fmesher" "post" "object" ...
##   .. .. ..$ : NULL
##   ..$ prefix      : chr "/var/folders/wq/8wbjn9_s7jv6hzxn1m43d95w0000gn/T//RtmpEWtXIT/fmesher54855e68
##   ..$ is.refined  : logi TRUE
##  $ manifold: chr "R2"
##  $ n       : int 2071
##  $ loc     : num [1:2071, 1:3] -130 -114 -111 -111 -114 ...
##  $ graph   :List of 5
##   ..$ tv : int [1:3982, 1:3] 289 157 162 658 172 1275 336 1613 9 165 ...
##   ..$ vt : int [1:2071, 1] 2619 1734 3559 3375 3629 1738 3413 2356 2165 202 ...
##   ..$ tt : int [1:3982, 1:3] 2967 3869 461 3041 69 2399 3314 208 2705 22 ...
##   ..$ tti: int [1:3982, 1:3] 1 1 1 1 2 2 1 1 1 2 ...
##   ..$ vv :Formal class 'dgTMatrix' [package "Matrix"] with 6 slots
##   .. .. ..@ i       : int [1:12104] 1208 1238 1378 911 1046 1117 847 848 1943 1073 ...
##   .. .. ..@ j       : int [1:12104] 0 0 0 1 1 1 2 2 2 3 ...
##   .. .. ..@ Dim     : int [1:2] 2071 2071
##   .. .. ..@ Dimnames:List of 2
##   .. .. .. ..$ : NULL
##   .. .. .. ..$ : NULL
##   .. .. ..@ x       : num [1:12104] 1 1 1 1 1 1 1 1 1 1 ...
##   .. .. ..@ factors : list()
```

```
##  $ segm    :List of 2
##   ..$ bnd:List of 5
##   .. ..$ loc   : NULL
##   .. ..$ idx   : int [1:158, 1:2] 1 1209 580 1357 439 852 584 1354 219 1352 ...
##   .. ..$ grp   : int [1:158, 1] 0 0 0 0 0 0 0 0 0 0 ...
##   .. ..$ is.bnd: logi TRUE
##   .. ..$ crs   : NULL
##   .. ..- attr(*, "class")= chr "inla.mesh.segment"
##   ..$ int:List of 5
##   .. ..$ loc   : NULL
##   .. ..$ idx   : int[0 , 1:2]
##   .. ..$ grp   : int[0 , 1]
##   .. ..$ is.bnd: logi FALSE
##   .. ..$ crs   : NULL
##   .. ..- attr(*, "class")= chr "inla.mesh.segment"
##  $ idx     :List of 3
##   ..$ loc    : int [1:157] 9 10 11 12 13 14 15 16 17 18 ...
##   ..$ lattice: NULL
##   ..$ segm   : int [1:8] 1 2 3 4 5 6 7 8
##  $ crs     : NULL
##  - attr(*, "class")= chr "inla.mesh"
```

```
head(mesh$loc, 3)
```

```
##           [,1]     [,2] [,3]
## [1,] -129.5832 36.82639    0
## [2,] -114.1306 36.82639    0
## [3,] -110.8833 40.07370    0
```

```
tail(mesh$loc, 3)
```

```
##              [,1]     [,2] [,3]
## [2069,] -134.0416 45.11904    0
## [2070,] -124.3347 50.20053    0
## [2071,] -123.0588 50.49888    0
```

```
d <- RFearth2dist(as.matrix(mesh_locs))
```

```
## Angle mode switches to 'degree'.
```

```
d_matrx <- as.matrix(d)
rm(d_matrx)
rm(d)

dim(D) #2071 2071
```

```
## [1] 2071 2071
```

```
length(Dvec) # 2071 * 2071 = 4289041
```

```
## [1] 4289041
```

```
## obseration locs distance in cartesian

Dobs <- as.matrix(RFearth2dist(as.matrix(weather[c("lon", "lat")])))
```

```
## Angle mode switches to 'degree'.
```

```r
Dobs_vec <- c(Dobs)
```

### understandings 2

```r
obs_locs <- weather[c("lon", "lat")] ## df 157 obs, 2 vars
str(obs_locs)
```

```
## 'data.frame':    157 obs. of  2 variables:
##  $ lon: num  -131 -124 -124 -125 -124 ...
##  $ lat: num  46 41.9 46.1 47.3 44.6 ...
```

```r
obs_locs <- as.matrix(weather[c("lon", "lat")]) # [1:157, 1:2]

length(Dobs_vec)  # 24649
```

```
## [1] 24649
```

```r
## Cast into custom Mesh object
## define a set of tent basis functions over a prespecified triangulation in 2D
Mesh <- initFEbasis(p = mesh_locs,
            t = mesh$graph$tv,
            K = mesh$graph$vv)

str(Mesh)
```

```
## Formal class 'FEBasis' [package "bicon"] with 3 slots
##   ..@ pars:List of 5
##   .. ..$ p   : num [1:2071, 1:2] -130 -114 -111 -111 -114 ...
##   .. ..$ t   : int [1:3982, 1:3] 289 157 162 658 172 1275 336 1613 9 165 ...
##   .. ..$ K   :Formal class 'dgTMatrix' [package "Matrix"] with 6 slots
##   .. .. .. ..@ i       : int [1:12104] 1208 1238 1378 911 1046 1117 847 848 1943 1073 ...
##   .. .. .. ..@ j       : int [1:12104] 0 0 0 1 1 1 2 2 2 3 ...
##   .. .. .. ..@ Dim     : int [1:2] 2071 2071
##   .. .. .. ..@ Dimnames:List of 2
##   .. .. .. .. ..$ : NULL
##   .. .. .. .. ..$ : NULL
##   .. .. .. ..@ x       : num [1:12104] 1 1 1 1 1 1 1 1 1 1 ...
##   .. .. .. ..@ factors : list()
##   .. ..$ vars:'data.frame':  2071 obs. of  4 variables:
##   .. .. ..$ x        : num [1:2071] -130 -114 -111 -111 -114 ...
##   .. .. ..$ y        : num [1:2071] 36.8 36.8 40.1 52.6 55.7 ...
##   .. .. ..$ n        : int [1:2071] 1 2 3 4 5 6 7 8 9 10 ...
##   .. .. ..$ area_tess: num [1:2071] 0.112 0.137 0.146 0.128 0.111 ...
##   .. ..$ pol :List of 2071
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -129 -130 -130 -129
##   .. .. .. .. .. .. ..$ y   : num [1:4] 36.8 36.8 37.1 37
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -114 -114 -114 -114
##   .. .. .. .. .. .. ..$ y   : num [1:4] 36.8 36.8 37.1 37.1
```

```
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -111 -111 -111 -111
##   .. .. .. .. .. .. ..$ y   : num [1:4] 39.7 40 40.3 40.3
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -111 -111 -111 -111
##   .. .. .. .. .. .. ..$ y   : num [1:4] 52.4 52.4 52.6 52.9
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -114 -114 -114 -114
##   .. .. .. .. .. .. ..$ y   : num [1:4] 55.4 55.5 55.7 55.7
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -131 -131 -131 -131 -131
##   .. .. .. .. .. .. ..$ y   : num [1:5] 55.5 55.3 55.3 55.7 55.7
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -135 -135 -135 -135
##   .. .. .. .. .. .. ..$ y   : num [1:4] 51.2 51.2 51.7 51.4
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -135 -135 -135 -135
##   .. .. .. .. .. .. ..$ y   : num [1:4] 42.2 41.9 42.5 42.5
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -131 -131 -131 -131 -131 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 45.9 45.7 45.7 46.2 46.2 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -124 -124 -125 -125 -125 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 41.9 41.7 41.8 42.1 42.1 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -124 -124 -125 -125 -125 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 46.1 45.8 45.9 46.4 46.5 ...
```

```
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -124 -125 -125 -125 -125 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 47.2 47 47 47.4 47.6 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -124 -125 -125 -125 -124 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 44.4 44.3 44.5 44.7 44.9 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -125 -125 -125 -125 -125
##   .. .. .. .. .. .. ..$ y   : num [1:5] 49.9 49.9 49.9 49.9 49.9
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:4] -125 -125 -125 -125
##   .. .. .. .. .. .. ..$ y   : num [1:4] 49.9 49.8 49.9 49.9
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -128 -128 -128 -128 -128
##   .. .. .. .. .. .. ..$ y   : num [1:5] 49.7 49.7 49.7 49.8 49.8
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -128 -128 -128 -128 -128
##   .. .. .. .. .. .. ..$ y   : num [1:5] 49.6 49.6 49.7 49.7 49.7
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -123 -124 -124 -124 -124
##   .. .. .. .. .. .. ..$ y   : num [1:5] 49.3 49.1 49.4 49.6 49.5
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -129 -129 -129 -129 -129 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 51.3 51.1 51.1 51.5 51.7 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -126 -126 -126 -126 -126
##   .. .. .. .. .. .. ..$ y   : num [1:5] 48.8 48.8 48.9 49 48.9
```

```
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -126 -126 -126 -126 -126
##   .. .. .. .. .. .. ..$ y   : num [1:5] 48.7 48.7 48.8 48.8 48.8
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -130 -130 -130 -130 -130
##   .. .. .. .. .. .. ..$ y   : num [1:5] 50.8 50.7 50.7 50.9 50.9
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -130 -130 -130 -130 -130
##   .. .. .. .. .. .. ..$ y   : num [1:5] 50.9 50.9 51.1 51.1 51
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -124 -124 -125 -125 -124
##   .. .. .. .. .. .. ..$ y   : num [1:5] 43.2 43.1 43.1 43.4 43.5
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -123 -123 -124 -124 -124 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 48.3 48.2 48.2 48.4 48.4 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:7] -123 -123 -123 -123 -123 ...
##   .. .. .. .. .. .. ..$ y   : num [1:7] 50 49.9 49.8 49.9 50 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -123 -123 -123 -124 -123 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 49.4 49.2 49.3 49.5 49.9 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -121 -121 -122 -122 -122 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 51 50.9 51 51.4 51.4 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:7] -126 -126 -126 -127 -127 ...
##   .. .. .. .. .. .. ..$ y   : num [1:7] 49.4 49.4 49.2 49.1 49.4 ...
```

```
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -124 -124 -124 -124 -124
##   .. .. .. .. .. .. ..$ y   : num [1:5] 49.1 49.1 49.2 49.3 49.4
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -123 -123 -123 -123 -123 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 48.8 48.7 48.6 48.8 49 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. .. ..$ y   : num [1:6] 50.2 50.1 50.2 50.4 50.5 ...
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. .. ..$ hole: logi FALSE
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. .. ..$ y   : num [1:5] 50.6 50.5 50.5 50.9 51
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. .. ..$ y   : num [1:5] 46.7 46.7 46.7 46.8 46.8
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. .. ..$ y   : num [1:6] 46.3 46.3 46.5 46.5 46.5 ...
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. ..$ :List of 3
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##   .. .. .. .. .. .. ..$ y   : num [1:6] 46.6 46.5 46.5 46.7 46.8 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -120 -121 -121 -121 -120
##   .. .. .. .. .. .. ..$ y   : num [1:5] 41.4 41.2 41.4 41.8 41.7
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -124 -124 -124 -124 -124
##   .. .. .. .. .. .. ..$ y   : num [1:5] 40.7 40.8 41.2 41.2 41
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:7] -118 -119 -119 -119 -119 ...
##   .. .. .. .. .. .. ..$ y   : num [1:7] 45.8 45.8 46 46.1 46.2 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:7] -124 -124 -124 -124 -124 ...
##   .. .. .. .. .. .. ..$ y   : num [1:7] 46.1 46 45.9 46.1 46.2 ...
```

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##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -122 -122 -122 -122 -122
##   .. .. .. .. .. .. ..$ y   : num [1:5] 47.5 47.5 47.6 47.6 47.6
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -118 -118 -118 -118 -118 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 44.6 44.5 44.7 45.1 45.1 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -122 -123 -123 -123 -123 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 48.5 48.6 48.7 48.8 49 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -119 -119 -119 -119 -119 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 43.5 43.3 43.4 43.8 43.8 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -116 -116 -116 -117 -116 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 43.5 43.2 43.2 43.6 43.9 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:5] -124 -124 -124 -124 -124
##   .. .. .. .. .. .. ..$ y   : num [1:5] 41.6 41.6 41.7 41.9 41.9
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. ..$ :Formal class 'gpc.poly' [package "gpclib"] with 1 slot
##   .. .. .. .. ..@ pts:List of 1
##   .. .. .. .. .. ..$ :List of 3
##   .. .. .. .. .. .. ..$ x   : num [1:6] -123 -124 -124 -124 -123 ...
##   .. .. .. .. .. .. ..$ y   : num [1:6] 47.8 47.8 48.1 48.2 48.2 ...
##   .. .. .. .. .. .. ..$ hole: logi FALSE
##   .. .. .. [list output truncated]
##   ..@ n   : int 2071
##   ..@ fn  : list()
```