# Lab Part of Homework 5

## S+SpatialStatsProblem (Tutorial)

We will use the `aquifer` dataset to demonstrate *kriging*. The dataset is included in the S+SpatialStats module in S-Plus and has the following description (see the help-file on `aquifer`):

```
SUMMARY:
The aquifer data frame is a spatial data set with 85 rows and 3
columns: easting, northing and head. The data are from the Wolfcamp
Aquifer in West Texas/New Mexico, U.S.A.

DATA DESCRIPTION:
This data frame contains the following columns:
easting: relative longitude position.
northing: relative latitude position.
head: piezometric-head in feet above sea level.

SOURCE:
Cressie (1989) lists the data and uses it to illustrate kriging. The
original data are from Harper and Furr (1986).
```

At the beginning of your S-Plus session, type:

```
> module(spatial)  ## don't wory about the message
License Warning : spatial license expires Mon Jul 31 23:59:59 2000
> attach(aquifer)
```

Now, do the following:

(a) The data. Interpolate the raw data (`head`) and make a contour map by using the following commands:

```
> int.aq <- interp(easting,northing,head)
> scaled.plot(easting,northing,type='n')  ## scales axis identical
> contour(int.aq,add=T)
> points(easting,northing)
> mtext(side=3,line=1,"Interpolated Data",cex=1.5)
```

Note the trend. Print out the plot[1].

[1] To create a postscript file including the graph, do the following before plotting: `trellis.device(postscript,file='data.ps',horizontal=F)`. When you have finished with all the plotting commands, type: `dev.off()`. The postscript file can be converted to a pdf-file by the UNIX command `ps2pdf data.ps data.pdf` (see notes from S-Plus lab-2).

(b) TREND. Use the `loess` function to estimate the trend:

```
trend <- loess(head ~ easting*northing,family='symmetric')
```

The argument `family='symmetric'` specifies the use of 'robust' regression (not as sensitive to outliers).

To plot the trend, we need first to create a *grid* to work with:

```
> east.g <- seq(min(easting),max(easting),by=5)
> north.g <- seq(min(northing),max(northing),by=5)
> aq.grid <- expand.grid(easting=east.g,northing=north.g)
```

Next, specify the *area-of-interest* (AOI) — use the convex hull surrounding the sites:

```
> def.hull <- chull(easting,northing)
> my.hull <- list(x=easting[def.hull],y=northing[def.hull])
> in.hull <- points.in.poly(aq.grid$e,aq.grid$n,my.hull)
```

Finally, plot the trend surface:

```
> pred.trend <- predict(trend,aq.grid)
> pred.trend[!in.hull] <- NA  ## outside of AOI
> levelplot(pred.trend ~ easting*northing,data=aq.grid,
+           contour=T,pretty=T,aspect=0.68,
+           main=list("loess trend surface",cex=1.5))
```

Print out the plot.

(c) VARIOGRAM. Subtract the fitted trend from `head` and plot the empirical variogram (actually, the semivariogram):

```
> res <- head - predict(trend)
> v.use <- variogram(res ~ loc(easting,northing),method='r')
> plot(v.use)
```

Add the following, fitted, spherical semivariogram to the plot:

```
> x <- v.use$distance
> lines(x,spher.vgram(x,range=48.555,sill=13318,nugget=13157))
> mtext(side=3,line=1,
+       'robust empirical, and fitted spherical, variogram',cex=1.5)
```

Print out the plot.

(d) KRIGING. Do a kriging prediction on the `aq.grid`:

```
> k.fit <- krige(res ~ loc(easting,northing),
+                covfun=spher.cov,
+                range=48.555,sill=13318,nugget=13157)
> k.pred <- predict(k.fit,aq.grid)
```

Plot the fitted values:

```
> k.pred$fit[!in.hull] <- NA
> levelplot(fit ~ easting*northing,data=k.pred,
+           contour=T,pretty=T,aspect=0.68,
+           main=list('Fitted values',cex=1.5))
```

Print out the plot.

Plot the predicted `head` values:

```
> k.pred$pred <- k.pred$fit + predict(trend,aq.grid)  ## add trend
> k.pred$pred[!in.hull] <- NA
> levelplot(pred ~ easting*northing,data=k.pred,
+           contour=T,pretty=T,aspect=0.68,
+           main=list('Predicted head',cex=1.5))
```

Print out the plot.

Plot the kriging standard errors:

```
> k.pred$se.fit[!in.hull] <- NA
> levelplot(se.fit ~ easting*northing,data=k.pred,
+           contour=T,pretty=T,aspect=0.68,
+           main=list('Standard errors',cex=1.5))
```

Print out the plot.

(e) BONUS: CROSS-VALIDATION. Use the kriging cross-validation function in `/home/gardar/pub/.Data` to cross-validate your model:

```
> attach('/home/gardar/pub/.Data')
> fit.data <- data.frame(res=res,easting=easting,northing=northing)
> k.cv <- cv.krige(k.fit,fit.data)
> k.cv.qq <- qqnorm(k.cv$res,plot.it=F)
> plot(k.cv.qq,type='n',xlab='Gaussian quantiles',ylab='CV residuals')
> text(k.cv.qq$x,k.cv.qq$y,1:nrow(fit.data),cex=0.8)
> qqline(k.cv$res)
```

Do you see any outliers?

Turn in the plots that were printed.