Assignment w/Latin Hypercube Sampling (LHS)

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Introduction

For this assignment, we are interested in estimating vegetation or crop water by first estimating atmospheric conductance, which is how easily water diffuses into the air. Atmospheric conductance depends on factors such as windspeed (you get more evaporation in windier conditions), the vegetation itself, and the turbulence it creates.

1. Code a function to compute atmospheric conductance C_{at} (how easily vapor diffuses from vegetation surfaces)

$$C_{at} = \frac{v_m}{6.25 * ln(\frac{z_m - z_d}{z_0})^2}$$

$$z_d = k_d * h$$

$$z_0 = k_0 * h$$

Figure 1: Equation for atmospheric conductance C_{at}, how easily vapor diffuses from vegetation surfaces

Note that:

- ***zm**: height at which windspeed is measured (usually 200cm above the vegetation)*
- ***h**: vegetation height (cm)*
- ***v**: windspeed (cm/sec)*
- ***kd**: 0.7*
- ***ko**: 0.1*

```
#source in atmospheric conductance (cat) function
source(here("functions", "compute_cat.R"))
```

2. Run your model

*You are estimating the atmospheric conductance for a forest that is 10 m high (the accuracy of that measurement is +/- 0.5 m) Windspeeds (**v**) in this region are normally distributed with a mean of 250 cm/s with a standard deviation of 30 cm/sec.*

Come up with a single estimate of atmospheric conductance for this forest.

Set up the C_{at} model parameters:

- number of samples
- `h`: vegetation height (m)
- `v`: windspeed (cm/sec)

```
#parameters
nsamples = 100

#convert m to cm to match the windspeed units
h_default <- 10 * 100
h_deviation = 0.5 * 100

#sample from the uniform distribution of plant heights based on the given forest height accuracy of +/-
h <- runif(min = h_default - h_deviation,
           max = h_default + h_deviation,
           n=nsamples)

v_mean <- 250
v_sd <- 30

#sample the normal distribution of windspeeds based on the given mean and SD values
v <- rnorm(mean = v_mean, sd = v_sd, n = nsamples)

#bind vegetation height (h) and windspeed (v) into a parameters dataframe
parameters <- cbind.data.frame(h, v)
```

Run the model

```
results <- compute_cat(h = parameters$h, v = parameters$v)

mean_cat <- round(mean(results), digits = 2)
#should be 15.44 ?
```

The model estimates that the mean atmospheric conductance for this forest is approximately 15.26 cm/sec.

3. Now do a sensitivity analysis as follows

Consider the sensitivity of your estimate to uncertainty in the following parameters and inputs

- ***h***: vegetation height (cm)
- ***kd***
- ***ko***
- ***v***: windspeed (cm/sec)

*Windspeeds (**v**) are normally distributed with a mean of 250 cm/sec with a standard deviation of 30 cm/sec*

```
#use the same windspeed and nsamples parameters as before
v_mean <- 250
v_sd <- 30
v <- rnorm(mean = v_mean, sd = v_sd, n = nsamples)

nsamples = 100
```

For vegetation height assume that height is somewhere between 9.5 and 10.5 m (but any value in that range is equally likely)

```
#create new vegetation height parameters
h_min = 9.5 * 100
h_max = 10.5 * 100

#sample from new uniform distribution of vegetation heights
h <- runif(min = h_min,
           max = h_max,
           n=nsamples)
```

*For the **kd** and **ko** parameters you can assume that they are normally distributed with standard deviation of 1% of their default values*

```
#create kd and k0 parameters
kd_default = 0.7
k0_default = 0.1

kd_sd = 0.01 * kd_default
k0_sd = 0.01 * k0_default

#sample from normal distributions of kd and k0
kd <- rnorm(mean = kd_default, sd = kd_sd, n = nsamples)
k0 <- rnorm(mean = k0_default, sd = k0_sd, n = nsamples)
```

a) *use LHS to generate parameter values for the 4 parameters*

1. v - normally distributed
2. h - uniform distribution
3. k0 - normally distributed
4. kd - normally distributed

```
# considering 4 parameters
factors = c("v", "h", "k0", "kd")

# Decide how many parameter sets to generate
nsets=100

q = c("qnorm", "qunif", "qnorm", "qnorm")

q.arg = list(list(mean = 250, sd = 30), #v
             list(min = 9.5 * 100, max = 10.5 * 100), #h
             list(mean = k0_default, sd = k0_sd), #k0
             list(mean = kd_default, sd = kd_sd)) #kd

# generate samples from LHS
sens_cat = LHS(NULL, factors, nsets, q, q.arg)
sens_parameters = get.data(sens_cat) #we want to know what parameters we want to run
head(sens_parameters) #we can look at all the parameter values we want to run - we will have 100 parame
```

```
##          v      h         k0        kd
## 1 275.7885  976.5 0.10115035 0.7029830
## 2 308.7989  967.5 0.09946116 0.7068188
## 3 235.5482  992.5 0.09937199 0.7065421
## 4 272.6625 1034.5 0.10085962 0.7074069
## 5 224.2115  978.5 0.09996239 0.7057673
## 6 226.3243  952.5 0.09924458 0.7126834
```

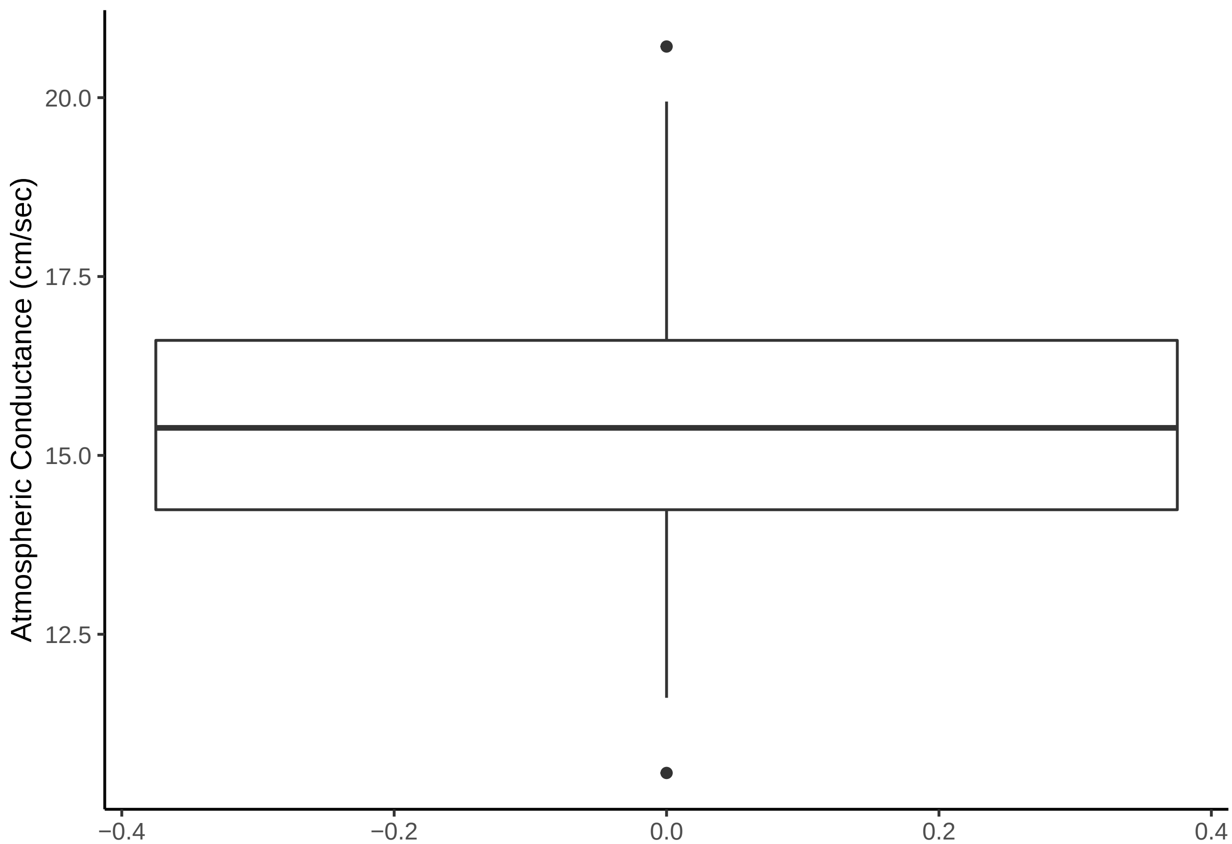
b) run you atmospheric conductance model for these parameters and return aerodynamic conductances

```
conductances <- sens_parameters %>% pmap(compute_cat)
conductances_test <- as.data.frame(unlist(conductances))

#yieldsd = conductances %>% map_dfr(`[`)

sens_cat = pse::tell(sens_cat, t(as.matrix(conductances_test)),
                        res.names=c("conductance"))
```

c) Plot conductance estimates in a way that accounts for parameter uncertainty

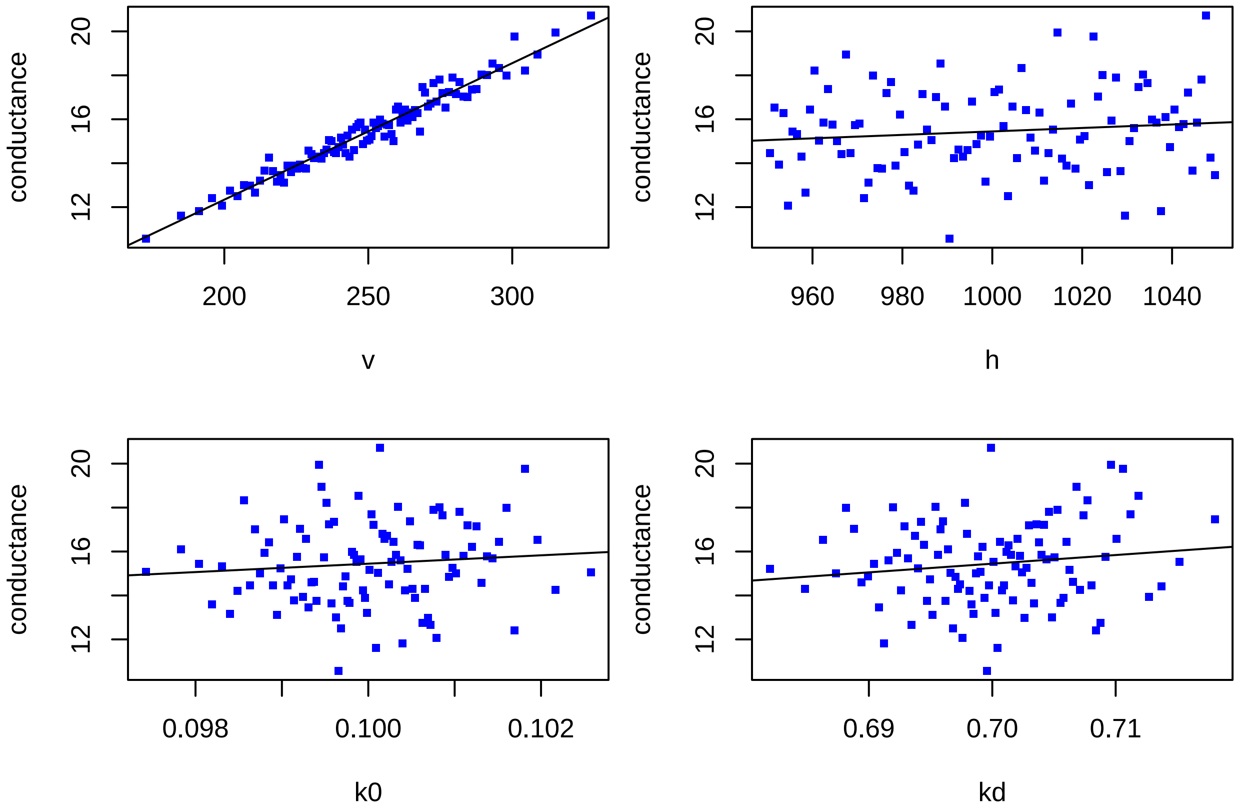
```
tmp = conductances_test %>% gather(value="value", key="yield")

ggplot(tmp, aes(y = value)) +
```

```
  geom_boxplot() +
  labs(y="Atmospheric Conductance (cm/sec)") +
  theme_classic()
```



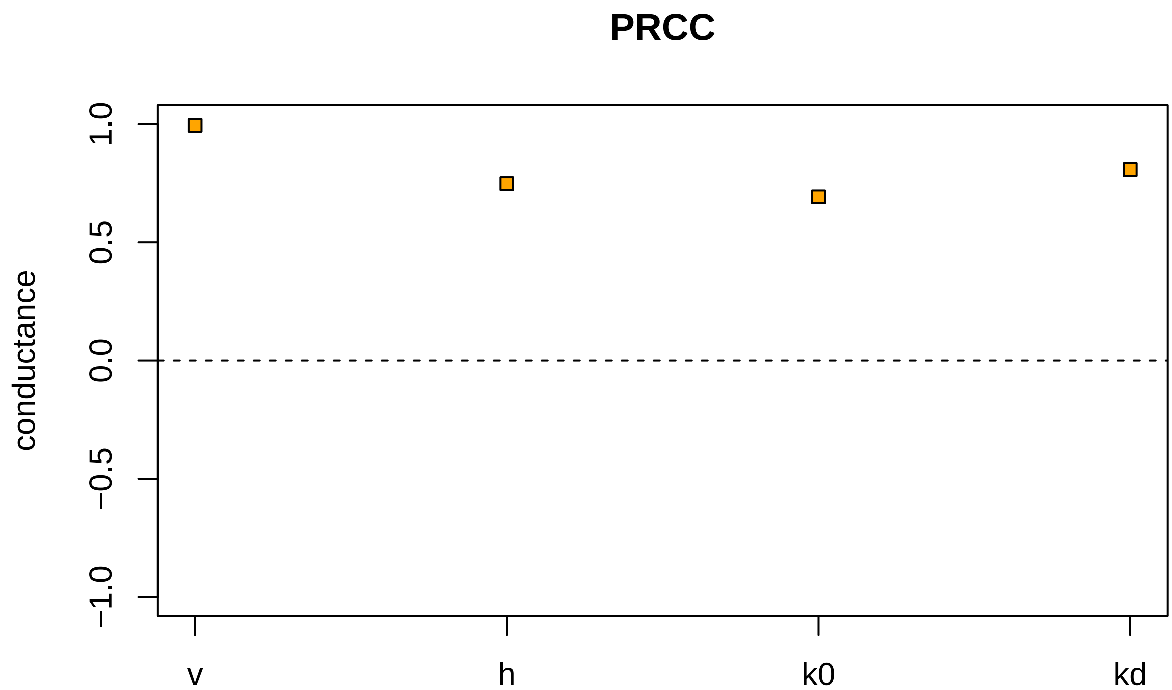
d) Plot conductance estimates against each of your parameters

```
pse::plotscatter(sens_cat, col="blue", cex=5)
```



e) Estimate the Partial Rank Correlation Coefficients

```
pse::plotprcc(sens_cat)
```



f) Discuss what your results tell you about how aerodynamic conductance? What does it suggest about what you should focus on if you want to reduce uncertainty in aerodymaic conductance estimates? Does this tell you anything about the sensitivity of plant water use to climate change?