Fst calculations

Fst is calculated between sets of populations using vcftools. The output is a .txt-like file containing Fst per position.

Import files

First the files are imported and NaN is removed

In [1]:

```
library(dplyr)
library(ggplot2)
```

```
Attaching package: ‘dplyr’


The following objects are masked from ‘package:stats’:

    filter, lag


The following objects are masked from ‘package:base’:

    intersect, setdiff, setequal, union

```

In [2]:

```
YRI_LWK <- read.table("Fst/YRI-LWK.weir.fst", header=TRUE)
YRI_LWK <- na.omit(YRI_LWK)
```

In [3]:

```
YRI_GWD <- read.table("Fst/YRI-GWD.weir.fst", header=TRUE)
YRI_GWD <- na.omit(YRI_GWD)
```

In [4]:

```
YRI_MSL <- read.table("Fst/YRI-MSL.weir.fst", header = TRUE)
YRI_MSL <- na.omit(YRI_MSL)
```

In [5]:

```
YRI_ESN <- read.table("Fst/YRI-ESN.weir.fst", header = TRUE)
YRI_ESN <- na.omit(YRI_ESN)
```

In [6]:

```
LWK_GWD <- read.table("Fst/LWK-GWD.weir.fst", header = TRUE)
LWK_GWD <- na.omit(LWK_GWD)
```

In [7]:

```
LWK_MSL <- read.table("Fst/LWK-MSL.weir.fst", header = TRUE)
LWK_MSL <- na.omit(LWK_MSL)
```

In [8]:

```
LWK_ESN <- read.table("Fst/LWK-ESN.weir.fst", header=TRUE)
LWK_ESN <- na.omit(LWK_ESN)
```

In [9]:

```
GWD_MSL <- read.table("Fst/GWD-MSL.weir.fst", header = TRUE)
GWD_MSL <- na.omit(GWD_MSL)
```

In [10]:

```
GWD_ESN <- read.table("Fst/GWD-ESN.weir.fst", header = TRUE)
GWD_ESN <- na.omit(GWD_ESN)
```

In [11]:

```
MSL_ESN <- read.table("Fst/MSL-ESN.weir.fst", header = TRUE)
MSL_ESN <- na.omit(MSL_ESN)
```

Setup for sliding windows

We define a function that can calculate Fst for sliding windows with a given size and a given step size

In [12]:

```
slide_windows <- function(fst_data, window_size, step_size){
    n_sites <- nrow(fst_data)
    n_windows <- floor((n_sites - window_size)/step_size)+1

    window_start <- seq(1, n_sites - window_size+1, by=step_size)
    window_end <- window_start + window_size - 1

    fst_window <- data.frame(matrix(ncol = 4, nrow = n_windows))
    colnames(fst_window) <- c("CHROM", "WINDOW_START", "WINDOW_END", "MEAN_FST")

    for (i in 1:n_windows) {
        fst_window$CHROM[i] <- fst_data$CHROM[window_start[i]]
        fst_window$WINDOW_START[i] <- fst_data$POS[window_start[i]]
        fst_window$WINDOW_END[i] <- fst_data$POS[window_end[i]]
        fst_window$MEAN_FST[i] <- mean(fst_data$WEIR_AND_COCKERHAM_FST[window_st
    }
    return(fst_window)
}
```

Calculate FST

In [13]:

```
window_size <- 100
window_step <- 50
```

In [14]:

```
fst_YRI_LWK <- slide_windows(YRI_LWK, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
          in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                     (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                     (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                     (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_YRI_GWD <- slide_windows(YRI_GWD, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
          in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                     (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                     (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                     (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_YRI_MSL <- slide_windows(YRI_MSL, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
          in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                     (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                     (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                     (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_YRI_ESN <- slide_windows(YRI_ESN, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
         in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                   (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                   (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                   (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_LWK_GWD <- slide_windows(LWK_GWD, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
         in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                   (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                   (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                   (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_LWK_MSL <- slide_windows(LWK_MSL, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
         in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                   (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                   (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                   (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_LWK_ESN <- slide_windows(LWK_ESN, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
         in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                   (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                   (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                   (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_GWD_MSL <- slide_windows(GWD_MSL, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
         in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                   (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                   (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                   (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_GWD_ESN <- slide_windows(GWD_ESN, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
         in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                   (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                   (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                   (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
fst_MSL_ESN <- slide_windows(MSL_ESN, window_size, window_step) %>%
   mutate(MEAN_FST = ifelse(MEAN_FST < 0, 0, MEAN_FST),
         in_Range = ((WINDOW_START >= 4.6e+07 & WINDOW_START < 4.7e+07)|
                   (WINDOW_START >= 4.8e+07 & WINDOW_START < 4.9e+07)|
                   (WINDOW_START >= 5.0e+07 & WINDOW_START < 5.1e+07)|
                   (WINDOW_START >= 5.2e+07 & WINDOW_START < 5.3e+07)))
```

Find significant using permutations

In [15]:

```
#Make a data frame containing all the Fst values and the positions
Fst <- data.frame(POS = c(YRI_LWK$POS, YRI_GWD$POS, YRI_MSL$POS, YRI_ESN$POS, LW
                               LWK_ESN$POS, GWD_MSL$POS, GWD_ESN$POS, MSL_ESN$PO
                  WEIR_AND_COCKERHAM_FST = c(YRI_LWK$WEIR_AND_COCKERHAM_FST, YRI
                          YRI_ESN$WEIR_AND_COCKERHAM_FST, LWK_GWD$WEIR_AND_COCKE
                          LWK_ESN$WEIR_AND_COCKERHAM_FST, GWD_MSL$WEIR_AND_COCKE
                          MSL_ESN$WEIR_AND_COCKERHAM_FST),
                 CHROM = c(YRI_LWK$CHROM, YRI_GWD$CHROM, YRI_MSL$CHROM, YRI_ESN$
                           LWK_MSL$CHROM, LWK_ESN$CHROM, GWD_MSL$CHROM, GWD_ESN$
arrange(POS)

head(Fst)
```

A data.frame: 6 × 3

	POS	WEIR_AND_COCKERHAM_FST	CHROM
	<int>	<dbl>	<int>
1	46000028	4.42055e-04	3
2	46000028	1.11026e-16	3
3	46000028	6.72933e-04	3
4	46000028	-7.77580e-04	3
5	46000225	-2.01254e-04	3
6	46000225	1.42863e-03	3

In [19]:

```
n = 10000
permuted <- tibble()
sample_Fst <- Fst

window_size <- 100
window_step <- 50

for (i in 1:n){
    sample_Fst$fst <- sample(sample_Fst$fst)
    windows <- slide_windows(sample_Fst, window_size, window_step)
    permuted <- bind_rows(permuted, tibble(fst = windows$MEAN_FST, pos = windows
    if(i%%50==0) {    # Progress tracker
    cat(".")
    flush.console()
  }
}

permuted <- permuted %>%
   arrange(fst)

saveRDS(permuted, "permuted_fst_windows.rds")
```

```
................................................................................
```

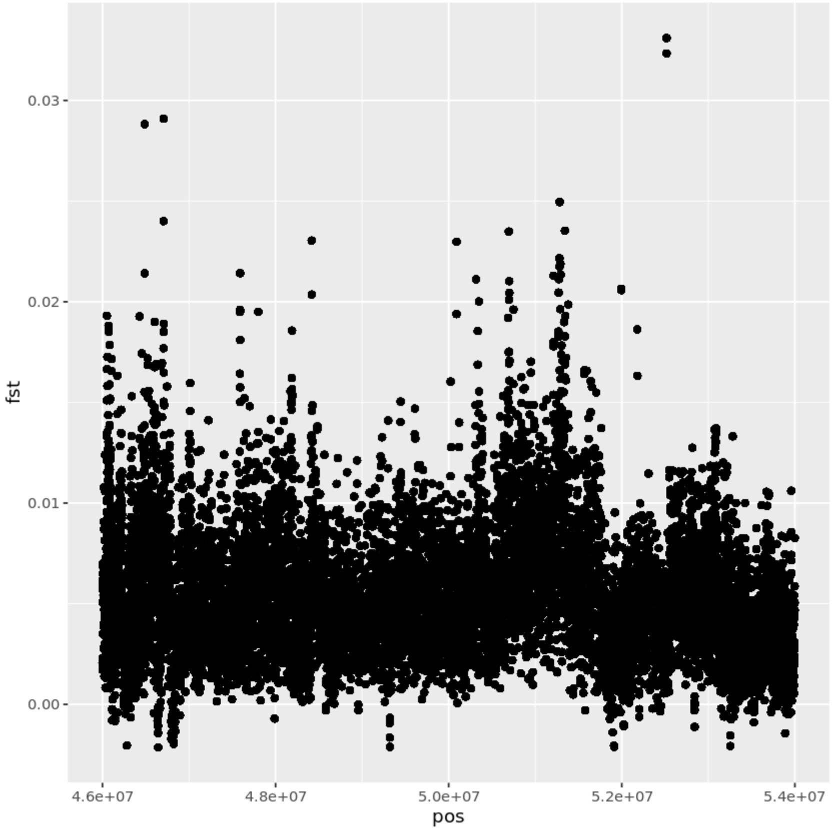
In [16]:

```
permuted <- readRDS("permuted_fst_windows.rds")
```

Plots of the permuted data are based on 1000 permutations instead of 10,000

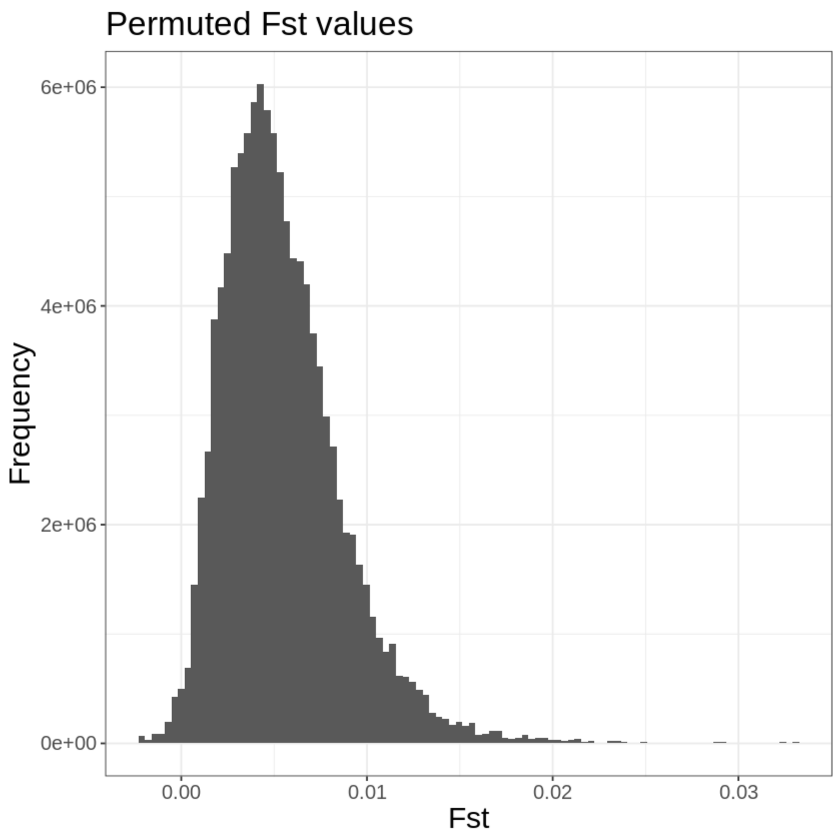
In [20]:

```
ggplot(permuted_plot) +
geom_point(aes(x=pos, y=fst))
```

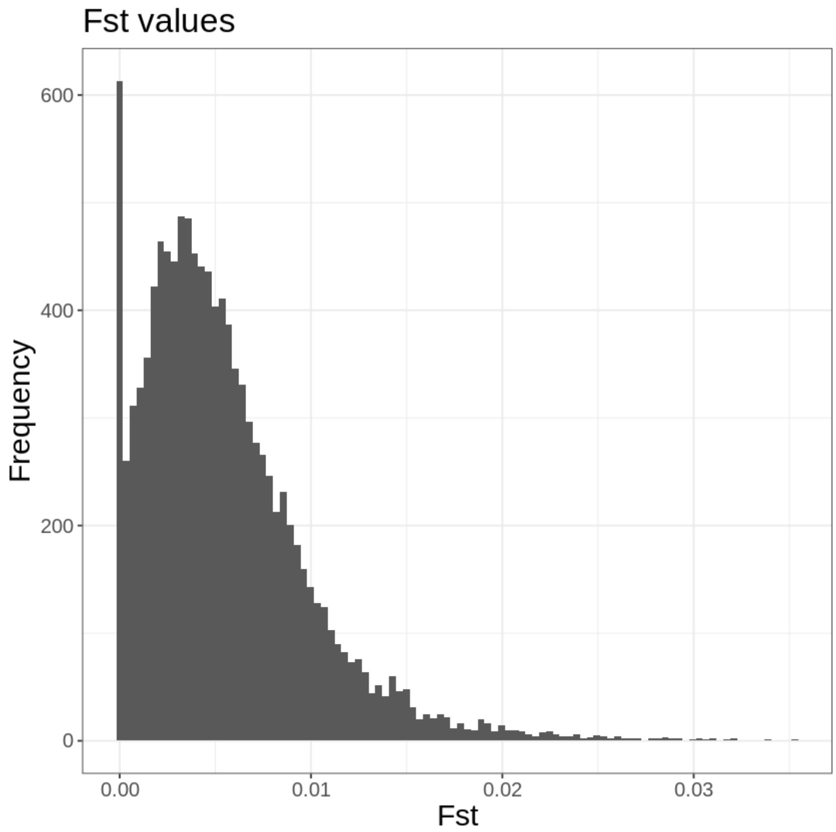


In [18]:
```
#Gives the null distribution
#pdf(file="plots/permutedFst.pdf", width = 8, height = 8)
ggplot(permuted) +
   geom_histogram(aes(fst), bins = 100) +
   theme_bw() +
   labs(title = "Permuted Fst values", x = "Fst", y="Frequency") +
   theme(axis.title = element_text(size=18), axis.text = element_text(size=12),
#dev.off()
```

null device: 1



```
In [22]: ggplot(fst_long) +
            geom_histogram(aes(fst), bins = 100) +
            theme_bw() +
            labs(title = "Fst values", x = "Fst", y="Frequency") +
            theme(axis.title = element_text(size=18), axis.text = element_text(size=12),
```



```
In [23]: critical_value <- quantile(permuted$fst, 0.99)
```

```
critical_value
```

99%: 0.01555081222

In [29]:

```
pdf(file="plots/Fstall.pdf", width = 8, height = 8)
#library(repr)
#options(repr.plot.width = 8, repr.plot.height = 8)
ggplot() +
   geom_point(data = fst_YRI_LWK, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_YRI_GWD, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_YRI_MSL, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_YRI_ESN, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_LWK_GWD, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_LWK_MSL, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_LWK_ESN, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_GWD_MSL, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_GWD_ESN, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_point(data = fst_MSL_ESN, aes(x=WINDOW_START, y=MEAN_FST), color = ifels
   geom_hline(yintercept = critical_value, color = "red", linetype = "longdash",
   labs(x="Position", y="Fst", title = "Fst for all comparisons") +
   theme_bw() +
   theme(axis.title = element_text(size=18), axis.text = element_text(size=12),
dev.off()
```

png: 2

In [21]:

```
fst_long <- data.frame(fst = c(fst_YRI_LWK$MEAN_FST, fst_YRI_GWD$MEAN_FST, fst_Y
                               fst_LWK_GWD$MEAN_FST, fst_LWK_MSL$MEAN_FST, fst_L
                               fst_GWD_ESN$MEAN_FST, fst_MSL_ESN$MEAN_FST),
                       pos = c(fst_YRI_LWK$WINDOW_START, fst_YRI_GWD$WINDOW_STAR
                               fst_LWK_GWD$WINDOW_START, fst_LWK_MSL$WINDOW_STAR
                               fst_GWD_ESN$WINDOW_START, fst_MSL_ESN$WINDOW_STAR
                       in_Range = c(fst_YRI_LWK$in_Range, fst_YRI_GWD$in_Range,
                               fst_LWK_GWD$in_Range, fst_LWK_MSL$in_Range, fst_L
                               fst_GWD_ESN$in_Range, fst_MSL_ESN$in_Range),
                       compare = c(rep("YRI/LWK", nrow(fst_YRI_LWK)), rep("YRI/G
                                   rep("YRI/ESN", nrow(fst_YRI_ESN)), rep("LWK/G
                                   rep("LWK/ESN", nrow(fst_LWK_ESN)), rep("GWD/M
                                   rep("MSL/ESN", nrow(fst_MSL_ESN))))
```

In [33]:

```
pdf(file="plots/Fstpop.pdf", width = 8, height = 6.5)
#library(repr)
#options(repr.plot.width = 8, repr.plot.height = 6.5)
ggplot(fst_long) +
   geom_point(aes(x=pos, y=fst), color = ifelse(fst_long$in_Range, "navyblue", '
   geom_hline(yintercept = critical_value, color = "red", linetype = "longdash")
   theme_bw() +
   facet_wrap(~compare, ncol = 5) +
   labs(x = "Position", y="Fst", title = "Fst for comparisons between populatior
   theme(axis.text.x = element_text(angle = 90)) +
   theme(axis.title = element_text(size=18), axis.text = element_text(size=12),
dev.off()
```

png: 2

We now calculate how many windows has mean Fst higher than the critical value, and find the percentage in that tail.

In [29]:

```
n_significant <- sum(fst_long$fst >= critical_value)
```

```
In [31]: n_significant/nrow(fst_long)
```

```
0.0301152234636872
```

The critical value was found from the permuted null distribution as the highest 1 %. In the data we observe 3% in the tail, which indicates more high Fst values than expected by chance.

```
In [35]: YRI_LWK <- sum(fst_YRI_LWK$MEAN_FST >= critical_value)/nrow(fst_YRI_LWK)
         YRI_GWD <- sum(fst_YRI_GWD$MEAN_FST >= critical_value)/nrow(fst_YRI_GWD)
         YRI_MSL <- sum(fst_YRI_MSL$MEAN_FST >= critical_value)/nrow(fst_YRI_MSL)
         YRI_ESN <- sum(fst_YRI_ESN$MEAN_FST >= critical_value)/nrow(fst_YRI_ESN)
         LWK_GWD <- sum(fst_LWK_GWD$MEAN_FST >= critical_value)/nrow(fst_LWK_GWD)
         LWK_MSL <- sum(fst_LWK_MSL$MEAN_FST >= critical_value)/nrow(fst_LWK_MSL)
         LWK_ESN <- sum(fst_LWK_ESN$MEAN_FST >= critical_value)/nrow(fst_LWK_ESN)
         GWD_MSL <- sum(fst_GWD_MSL$MEAN_FST >= critical_value)/nrow(fst_GWD_MSL)
         GWD_ESN <- sum(fst_GWD_ESN$MEAN_FST >= critical_value)/nrow(fst_GWD_ESN)
         MSL_ESN <- sum(fst_MSL_ESN$MEAN_FST >= critical_value)/nrow(fst_MSL_ESN)
```

```
In [40]: tails <- data.frame(Comparison = c("YRI-LWK", "YRI-GWD", "YRI-MSL", "YRI-ESN", "
                             "Percent in tail" = c(YRI_LWK, YRI_GWD, YRI_MSL, YRI_ESN, LW


         tails
```

A data.frame: 10 × 2

Comparison	Percent.in.tail
<chr>	<dbl>
YRI-LWK	0.0197594502
YRI-GWD	0.0405172414
YRI-MSL	0.0055813953
YRI-ESN	0.0000000000
LWK-GWD	0.0881889764
LWK-MSL	0.0571428571
LWK-ESN	0.0233766234
GWD-MSL	0.0000000000
GWD-ESN	0.0522260274
MSL-ESN	0.0009191176