R Markdown Code for “Take-Off Engine Particle Emission Indices for In-Service Aircraft at Los Angeles International Airport” Data Descriptor

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Revision:

R00 Final processing code

R01 Updated to reflect summary statistics for R01 test point data

Read in Data Record

```
library(readxl)
LAX_Data <- read_excel("D:/LAX-Ground-Summary_TP_20140518_R01_thru20140525.xlsx",
    sheet = "LAX_Data", na = "NA")
```

Functions to compute geometric mean and geometric standard deviation

```
# Compute geometric mean of a vector
geomean <- function(x, na.rm = FALSE, trim = 0, ...) {
  exp(mean(log(x, ...), na.rm = na.rm, trim = trim, ...))
}

# Compute geometric standard deviation of a vector
geosd <- function(x, na.rm = FALSE, ...) {
  exp(sd(log(x, ...), na.rm = na.rm, ...))
}

# Compute geometric mean for each column in a 2-D matrix
geocolmeans <- function(x, na.rm = FALSE, ...){
  exp(apply(log(x), 2, mean, na.rm = na.rm))
}

# Compute geometric standard deviation for each column in a 2-D matrix
geocolsd <- function(x, na.rm = FALSE, ...){
  exp(apply(log(x), 2, sd, na.rm = na.rm))
}
```

Code to compute geometric mean and standard deviations for different engine types.

Data are used to generate Table 4 in the data descriptor.

```
# Initialize variables
EngineModel <- c()
BC_mu <- c()
Num_Tot_mu <- c()
Num_NV_mu <- c()
CCN_mu <- c()
EEPSn_mu <- c()
EEPSv_mu <- c()

BC_sd <- c()
Num_Tot_sd <- c()
Num_NV_sd <- c()
CCN_sd <- c()
EEPSn_sd <- c()
EEPSv_sd <- c()

BC_N <- c()
Num_Tot_N <- c()
```

```
Num_NV_N <- c()
CCN_N <- c()
EEPSn_N <- c()
EEPSv_N <- c()



MM <- LAX_Data$Engine_Master_Model # Assign shorthand variable



# Loop over all engine master models and compute geometric means and standard deviations
for (StrV in c("CFM56-3B",
               "CFM56-3C",
               "CFM56-5A",
               "CFM56-5B",
               "CFM56-5C",
               "CFM56-7B",
               "CF34-3",
               "CF34-8",
               "CF6-80C2",
               "GE90-94B",
               "GE90-115B",
               "GEnx-2B67",
               "GP7270",
               "JT8D",
               "PT6A",
               "PW118",
               "PW150A",
               "PW2000",
               "PW4000",
               "AE3007",
               "RB211",
               "Trent 556",
               "Trent 772",
               "Trent 892",
               "Trent 970",
               "V2522",
               "V2524",
               "V2527",
               "V2533")){

                        EngineModel <- c(EngineModel, StrV)
                        BC_mu <- c(BC_mu, geomean(LAX_Data$EI_BC[MM==StrV], na.rm=TRUE))
                        BC_sd <- c(BC_sd, geosd(LAX_Data$EI_BC[MM==StrV], na.rm=TRUE))
                        BC_N <- c(BC_N, sum(LAX_Data$EI_BC[MM==StrV]>-1, na.rm=TRUE))

                        Num_Tot_mu <- c(Num_Tot_mu, geomean(LAX_Data$EI_Number_Total[MM==StrV], na.rm=T
RUE))
                        Num_Tot_sd <- c(Num_Tot_sd, geosd(LAX_Data$EI_Number_Total[MM==StrV], na.rm=TRU
E))
                        Num_Tot_N <- c(Num_Tot_N, sum(LAX_Data$EI_Number_Total[MM==StrV]>-1, na.rm=TRUE
))

                        Num_NV_mu <- c(Num_NV_mu, geomean(LAX_Data$EI_Number_Nonvol[MM==StrV], na.rm=TR
UE))
                        Num_NV_sd <- c(Num_NV_sd, geosd(LAX_Data$EI_Number_Nonvol[MM==StrV], na.rm=TRUE
))
                        Num_NV_N <- c(Num_NV_N, sum(LAX_Data$EI_Number_Nonvol[MM==StrV]>-1, na.rm=TRUE)
)

                        CCN_mu <- c(CCN_mu, geomean(LAX_Data$EI_CCN[MM==StrV], na.rm=TRUE))
                        CCN_sd <- c(CCN_sd, geosd(LAX_Data$EI_CCN[MM==StrV], na.rm=TRUE))
                        CCN_N <- c(CCN_N, sum(LAX_Data$EI_CCN[MM==StrV]>-1, na.rm=TRUE))

                        EEPSn_mu <- c(EEPSn_mu, geomean(LAX_Data$EI_Number_EEPS[MM==StrV], na.rm=TRUE))
                        EEPSn_sd <- c(EEPSn_sd, geosd(LAX_Data$EI_Number_EEPS[MM==StrV], na.rm=TRUE))
                        EEPSn_N <- c(EEPSn_N, sum(LAX_Data$EI_Number_EEPS[MM==StrV]>-1, na.rm=TRUE))

                        EEPSv_mu <- c(EEPSv_mu, geomean(LAX_Data$EI_Volume_EEPS[MM==StrV], na.rm=TRUE))
                        EEPSv_sd <- c(EEPSv_sd, geosd(LAX_Data$EI_Volume_EEPS[MM==StrV], na.rm=TRUE))
                        EEPSv_N <- c(EEPSv_N, sum(LAX_Data$EI_Volume_EEPS[MM==StrV]>-1, na.rm=TRUE))
```

```
                        }

# Assemble output data into a data frame
Table1 <- data.frame(EngineModel, BC_mu, BC_sd, Num_Tot_mu, Num_Tot_sd, Num_NV_mu, Num_NV_sd)
Table2 <- data.frame(EngineModel, CCN_mu, CCN_sd, EEPSn_mu, EEPSn_sd, EEPSv_mu, EEPSv_sd)
Table3 <- data.frame(EngineModel, BC_N, Num_Tot_N, Num_NV_N, CCN_N, EEPSn_N, EEPSv_N)

Table1[,-1] <-format(Table1[,-1], digits=4) # Format the precision of the data frame numbers
Table2[,-1] <-format(Table2[,-1], digits=4) # Format the precision of the data frame numbers
```

Summary Statistics (Table 1 of 3)

```
print(Table1)
```

```
##    EngineModel  BC_mu BC_sd Num_Tot_mu Num_Tot_sd Num_NV_mu Num_NV_sd
## 1     CFM56-3B 563.96 1.410  3.557e+16      1.411 2.543e+15     2.345
## 2     CFM56-3C 792.14    NA  1.647e+16         NA 2.307e+15        NA
## 3     CFM56-5A 419.17 1.373  4.618e+16      1.248 1.848e+15     2.496
## 4     CFM56-5B 276.12 1.512  5.089e+16      1.387 1.783e+15     2.200
## 5     CFM56-5C 415.59 1.075  5.057e+16      1.024 1.107e+15     1.554
## 6     CFM56-7B 348.07 1.553  5.217e+16      1.312 2.211e+15     2.334
## 7       CF34-3 487.76 1.588  3.618e+16      1.501 4.989e+15     1.339
## 8       CF34-8 435.25 1.486  2.975e+16      1.744 2.668e+15     1.788
## 9     CF6-80C2 189.93 1.485  3.829e+16      1.445 1.062e+15     2.536
## 10    GE90-94B  92.83 1.116  3.952e+16      1.160 5.116e+14     1.132
## 11   GE90-115B 175.24 1.298  3.392e+16      1.198 7.952e+14     1.960
## 12   GEnx-2B67  46.06 1.475  8.727e+16      1.414 1.948e+15     4.070
## 13      GP7270 129.74 1.327  2.855e+16      1.245 1.891e+15     1.178
## 14        JT8D 940.79 1.064  1.727e+16      2.883 2.832e+15     2.526
## 15        PT6A 440.91 2.048  3.769e+16      1.841 6.504e+15     1.793
## 16       PW118 649.34 1.616  5.798e+16      1.329 2.975e+15     1.693
## 17      PW150A 252.18 1.505  5.869e+16      1.255 4.487e+15     3.563
## 18      PW2000 816.96    NA  2.459e+16         NA 2.554e+15        NA
## 19      PW4000 439.41 1.653  8.799e+15      1.055 1.704e+15     1.223
## 20      AE3007 591.66    NA  2.607e+16      3.113 1.447e+15     1.024
## 21       RB211 196.29 1.246  4.115e+16      1.388 1.066e+15     2.079
## 22   Trent 556 319.49 1.487  2.831e+16      1.278 1.061e+15     3.993
## 23   Trent 772 177.42 1.011  2.487e+16      1.322 1.058e+15     1.371
## 24   Trent 892 303.56    NA  3.040e+16         NA 8.087e+14        NA
## 25   Trent 970 355.63 1.231  5.131e+16      1.169 8.439e+14     1.601
## 26       V2522 583.92    NA  2.576e+16         NA 2.861e+15        NA
## 27       V2524 785.64 1.207  1.137e+16      1.152 3.422e+15     2.096
## 28       V2527 413.87 1.331  1.934e+16      1.746 2.363e+15     1.733
## 29       V2533 343.41 1.292  2.091e+16      1.981 1.899e+15     3.147
```

Summary Statistics (Table 2 of 3)

```
print(Table2)
```

```
##    EngineModel    CCN_mu CCN_sd  EEPSn_mu EEPSn_sd EEPSv_mu EEPSv_sd
## 1     CFM56-3B 7.279e+14  1.385 2.705e+16    1.527    406.4    1.247
## 2     CFM56-3C 6.849e+14     NA 1.252e+16       NA    699.7       NA
## 3     CFM56-5A 5.407e+14  1.443 3.538e+16    1.262    326.9    1.337
## 4     CFM56-5B 4.507e+14  1.525 3.794e+16    1.375    274.1    1.303
## 5     CFM56-5C 4.535e+14  1.068 3.784e+16    1.184    316.7    1.176
## 6     CFM56-7B 4.554e+14  1.908 3.853e+16    1.290    305.5    1.378
## 7       CF34-3 9.129e+14  1.233 2.608e+16    1.423    361.1    1.394
## 8       CF34-8 6.974e+14  1.895 2.591e+16    1.701    295.1    1.496
## 9     CF6-80C2 2.860e+14  1.658 3.509e+16    1.460    203.2    1.571
## 10    GE90-94B 1.802e+14  1.273 2.945e+16    1.310    123.8    1.397
## 11   GE90-115B 3.422e+14  1.582 2.875e+16    1.256    191.0    1.334
## 12   GEnx-2B67 3.772e+14  1.497 4.824e+16    1.049    557.1    1.339
## 13      GP7270 3.228e+14  1.164 3.490e+16    1.419    171.4    1.041
## 14        JT8D 1.266e+15  1.552 1.233e+16    2.890    616.5    1.228
## 15        PT6A 6.454e+14  2.073 2.799e+16    1.564    457.8    2.016
## 16       PW118 8.795e+14  1.301 4.736e+16    1.307    478.4    1.519
## 17      PW150A 5.933e+14  1.020 4.266e+16    1.292    355.9    1.324
## 18      PW2000 1.160e+15     NA 2.730e+16       NA    650.0       NA
## 19      PW4000 5.110e+14  1.478 7.946e+15    1.946    340.8    1.548
## 20      AE3007 1.895e+14  3.270 3.532e+16    1.034    138.0    1.321
## 21       RB211 2.246e+14  1.012 3.029e+16    1.392    241.7    1.697
## 22   Trent 556 3.181e+14  1.313 1.986e+16    1.042    211.8    1.284
## 23   Trent 772 3.092e+14  1.206 2.528e+16    1.373    170.6    1.385
## 24   Trent 892 4.364e+14     NA 3.755e+16       NA    248.6       NA
## 25   Trent 970 3.119e+14  1.232 3.813e+16    1.127    340.0    1.097
## 26       V2522 1.019e+15     NA 2.073e+16       NA    392.3       NA
## 27       V2524 1.435e+15  1.429 1.038e+16    1.399    501.2    1.163
## 28       V2527 8.288e+14  1.506 2.215e+16    1.593    375.7    1.360
## 29       V2533 5.681e+14  1.508 2.565e+16    1.772    288.7    1.495
```

Summary Statistics (Table 3 of 3)

```
print(Table3)
```

```
##    EngineModel BC_N Num_Tot_N Num_NV_N CCN_N EEPSn_N EEPSv_N
## 1     CFM56-3B   20        20       20    18      17      17
## 2     CFM56-3C    1         1        1     1       1       1
## 3     CFM56-5A   11        11       11    10      10      10
## 4     CFM56-5B   40        40       40    36      37      37
## 5     CFM56-5C    2         2        2     2       2       2
## 6     CFM56-7B   83        86       86    76      80      80
## 7       CF34-3    6         6        6     6       6       6
## 8       CF34-8   21        23       23    21      21      21
## 9     CF6-80C2    6         6        6     6       5       5
## 10    GE90-94B    2         2        2     2       2       2
## 11   GE90-115B    6         6        6     6       5       5
## 12   GEnx-2B67    2         2        2     2       2       2
## 13      GP7270    3         3        3     3       3       3
## 14        JT8D    2         2        2     2       2       2
## 15        PT6A    7         7        7     5       5       5
## 16       PW118   10        10       10    10      10      10
## 17      PW150A    3         3        3     2       2       2
## 18      PW2000    1         1        1     1       1       1
## 19      PW4000    2         2        2     2       2       2
## 20      AE3007    1         2        2     2       2       2
## 21       RB211    2         2        2     2       2       2
## 22   Trent 556    2         2        2     2       2       2
## 23   Trent 772    2         2        2     2       2       2
## 24   Trent 892    1         1        1     1       1       1
## 25   Trent 970    3         3        3     3       3       3
## 26       V2522    1         1        1     1       1       1
## 27       V2524    2         2        2     2       2       2
## 28       V2527   17        17       17    17      16      16
## 29       V2533   10        10       10     9       9       9
```

Code to compute geometric mean and standard deviation size distributions for different engine types.

Data are fit to log-normal functions to generate Table 5 in the data descriptor.

```
SizeDistrData <- as.matrix(LAX_Data[,38:69])


# Initialize Variables
EngineModel <- c()
SizeDistr_mu <- data.frame()
SizeDistr_sd <- data.frame()
N <- data.frame()

# Loop over all engine master models and compute column geometric means and standard deviations
for (StrV in c("CFM56-3B",
               "CFM56-3C",
               "CFM56-5A",
               "CFM56-5B",
               "CFM56-5C",
               "CFM56-7B",
               "CF34-3",
               "CF34-8",
               "CF6-80C2",
               "GE90-94B",
               "GE90-115B",
               "GEnx-2B67",
               "GP7270",
               "JT8D",
               "PT6A",
               "PW118",
               "PW150A",
               "PW2000",
               "PW4000",
               "AE3007",
               "RB211",
               "Trent 556",
               "Trent 772",
               "Trent 892",
               "Trent 970",
               "V2522",
               "V2524",
               "V2527",
               "V2533")){

                        EngineModel <- c(EngineModel, StrV)

                        SubsetData <- subset(SizeDistrData, LAX_Data$Engine_Master_Model==StrV)

                        SizeDistr_mu <- rbind(SizeDistr_mu, t(geocolmeans(SubsetData, na.rm=TRUE)))
                        SizeDistr_sd <- rbind(SizeDistr_sd, t(geocolsd(SubsetData, na.rm=TRUE)))
                        N <- rbind(N, (NROW(SubsetData)))
                      }


row.names(SizeDistr_mu) <- EngineModel
row.names(SizeDistr_sd) <- EngineModel
row.names(N) <- EngineModel
```

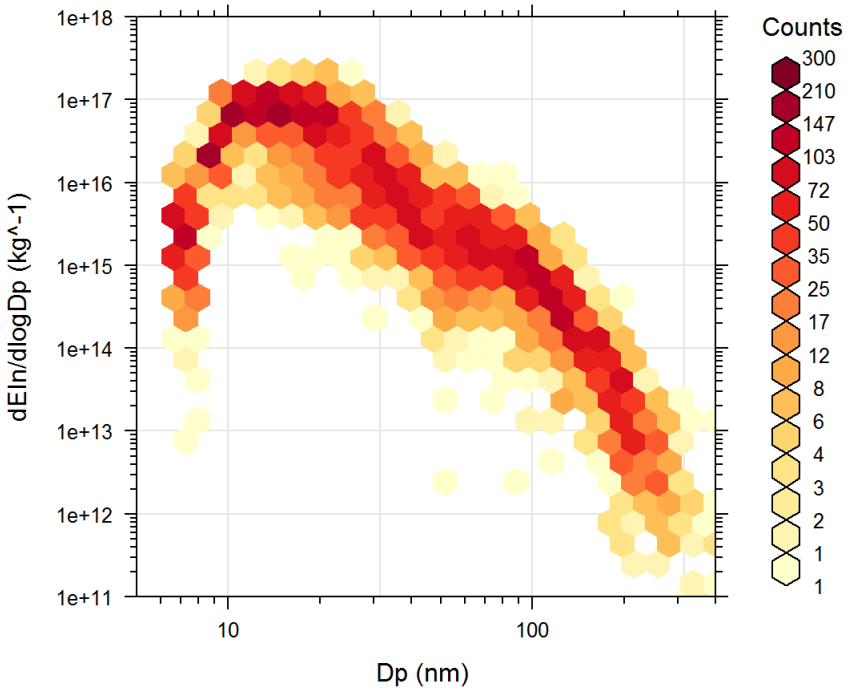
Code to generate size distribution density plots.

Figure 5 in the data descriptor.

```
# Load external packages
library(openair)
library(hexbin)

# Input vector containing EEPS bin midpint diameters (as corrected, see data descriptor)
Dp = c(6.64, 7.68, 8.87, 10.2, 11.9, 13.6, 15.7, 18.2, 21.0, 24.3, 28.1,
       32.3, 37.4, 43.1, 49.8, 57.5, 66.4, 76.8, 88.7, 102.4, 118.3, 136.5,
       157.6, 182.1, 210.2, 242.8, 280.3, 323.7, 373.8, 431.6, 498.5, 575.6)

dEIn_dlogDp_Vector <- as.vector(t(SizeDistrData)) # Unwrap number EI size distribution matrix into a vect
or

Dp_Vector <- as.vector(t(matrix(rep(Dp,275), nrow = 275, ncol = length(Dp), byrow=T))) # Create a vector
corresponding to size distribution data

dEIv_dlogDp_Vector <- dEIn_dlogDp_Vector*pi/6*(Dp_Vector*1e-6)^3 # Compute volume EI size distribution vec
tor

mydata = data.frame(Dp_Vector, dEIn_dlogDp_Vector, dEIv_dlogDp_Vector) # Combine vectors into a data fram
e.
```

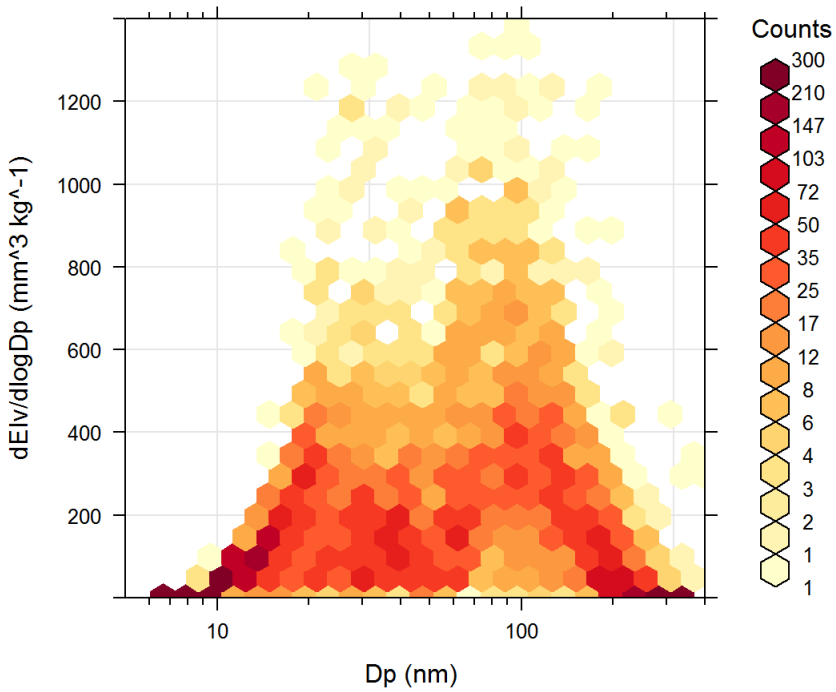
Aerosol number size distribution density plot.

```
plt <- scatterPlot(mydata, x="Dp_Vector", y="dEIn_dlogDp_Vector", method="hexbin", log.x=TRUE, log.y=TRUE
, mincnt=1, maxcnt=300, col="heat", xlim=c(5,400), ylim=c(1e11,1e18), xbin=25, xlab="Dp (nm)", ylab="dEIn
/dlogDp (kg^-1)")
```



Aerosol volume size distribution density plot.

```
pltv <- scatterPlot(mydata, x="Dp_Vector", y="dEIv_dlogDp_Vector", method="hexbin", log.x=TRUE, mincnt=1,
maxcnt=300, col="heat", xlim=c(5,400), ylim=c(0,1400), xbin=25, xlab="Dp (nm)", ylab="dEIv/dlogDp (mm^3 k
g^-1)")
```


dElv/dlogDp (mm^3 kg^-1)
1200
1000
800
600
400
200
10
100
Dp (nm)
Counts
300
210
147
103
72
50
35
25
17
12
8
6
4
3
2
1
1