NMF Final (Only nndsvd 5 component without ozone)

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2025-01-24

```
# load the packages
library(NMF)
library(tidyverse)
library(gridExtra)
library(readxl)
library(circular)
library(lwgeom)
library(units)
```

Procedure

1. Remove hourly observation with missing observation for any chemical
2. Remove background noise level using min values (except for chemicals with minimum value < 2*LOD and maximum value > 100*LOD)
3. Zero values are converted to a random value between 0 and 0.5*LOD
4. Normalize using min and max
5. Remove Ozone (wouldn't affect # of obs.)

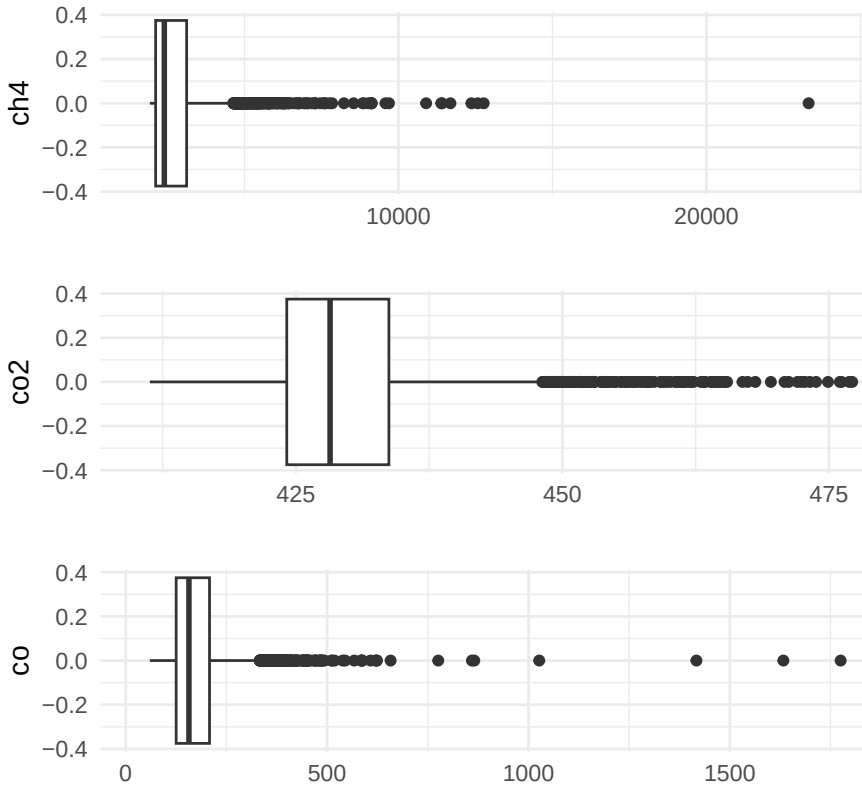
Reading the data

```
hourly_data <- readRDS("../DataProcessing/Trailer_hourly_merge_20240905.rds")
```

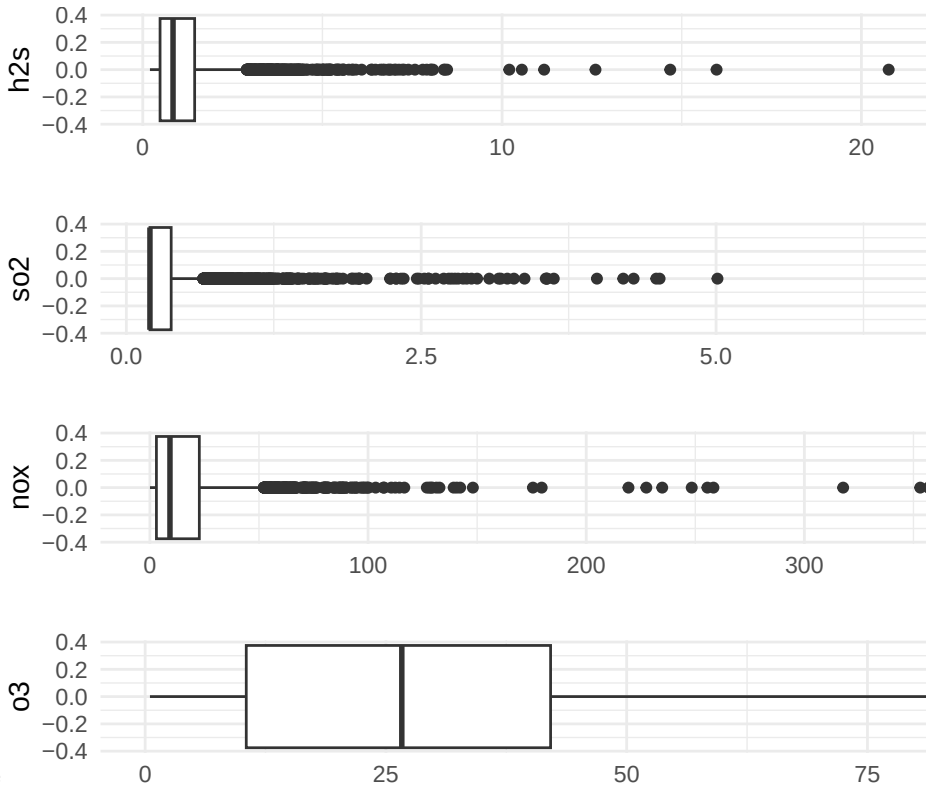
```
# PROCEDURE STEP 1:
hourly_data <- hourly_data %>% rename('co2' = 'co2_ppm')

vocs <- c("ethane", "ethene", "propane", "propene",
                                        "1_3-butadiene", "i-butane", "n-butane",
                                        "acetylene", "cyclopentane", "i-pentane",
                                        "n-pentane", "n-hexane", "isoprene", "n-heptane",
                                        "benzene", "n-octane", "toluene", "ethyl-benzene",
                                        "m&p-xylene", "o-xylene")


non_vocs <- c('ch4', 'co2', 'co', 'h2s', 'so2', 'nox', 'o3')

# remove row with missing obs for any chemical
hourly_nona <- hourly_data %>%
  select(any_of(c('day', 'time_utc', vocs, non_vocs, 'wdr_deg', 'wsp_ms'))) %>%
  na.omit()

# retrieving the vocs, removing everything else except the vocs
```

```r
hourly_vocs <- hourly_nona %>% select(any_of(vocs))

# retrieving the non-vocs: co2_ppm, nox, ch4, h2s, so2, o3
# double check this
hourly_non_vocs <- hourly_nona %>% select(any_of(non_vocs))

hourly_full_nona <- cbind(hourly_non_vocs, hourly_vocs)

# retrive a vector of yearmonth
hourly_dates <- hourly_nona %>%
  mutate(yearmonth = substring(day, 0, 7)) %>%
  pull(yearmonth)
```

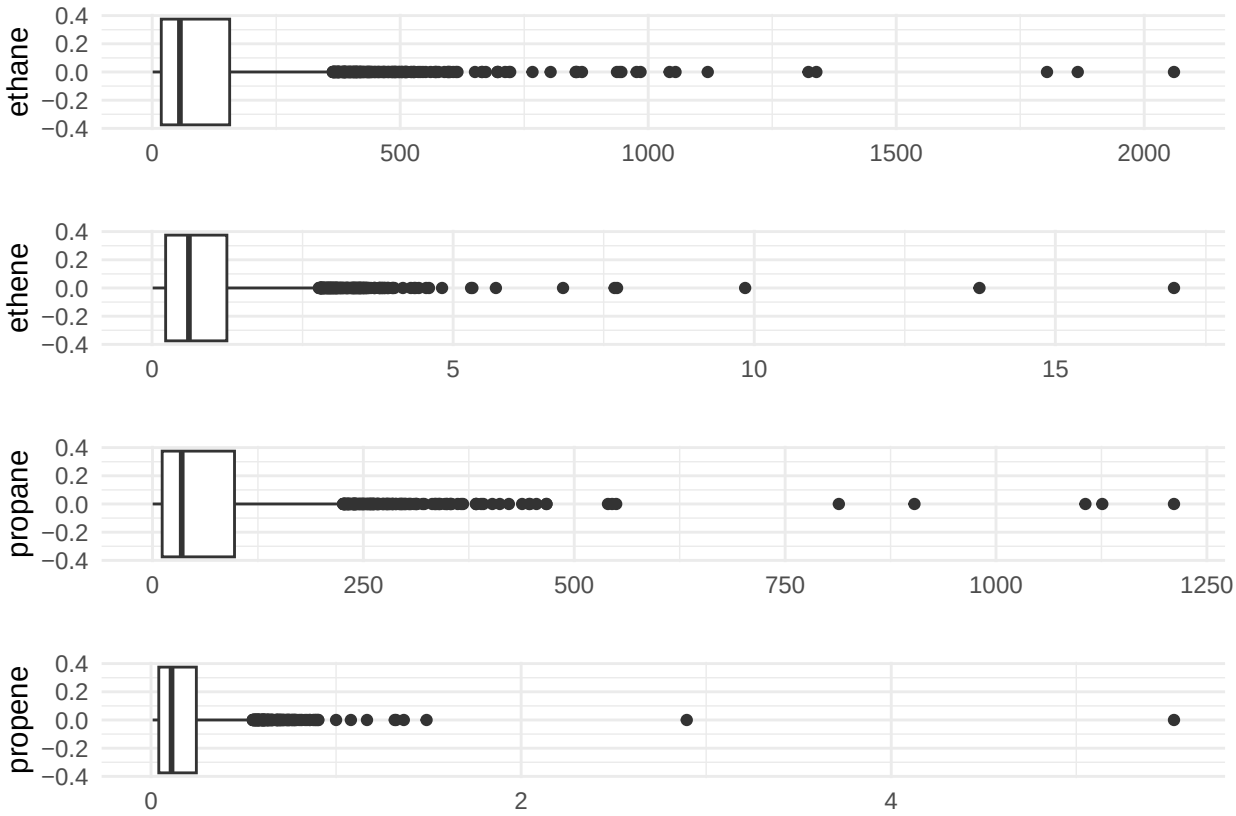
Data visualisation

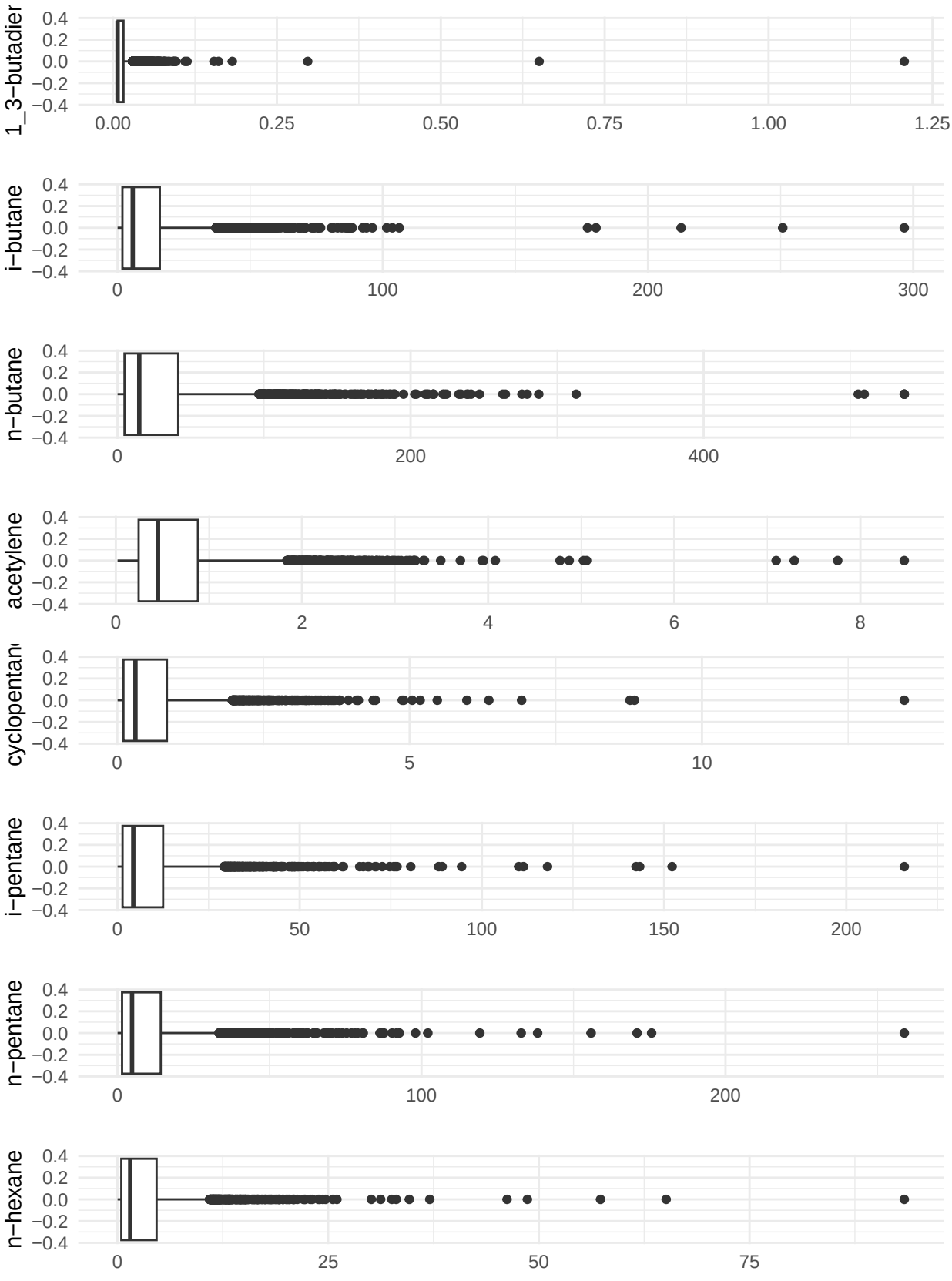


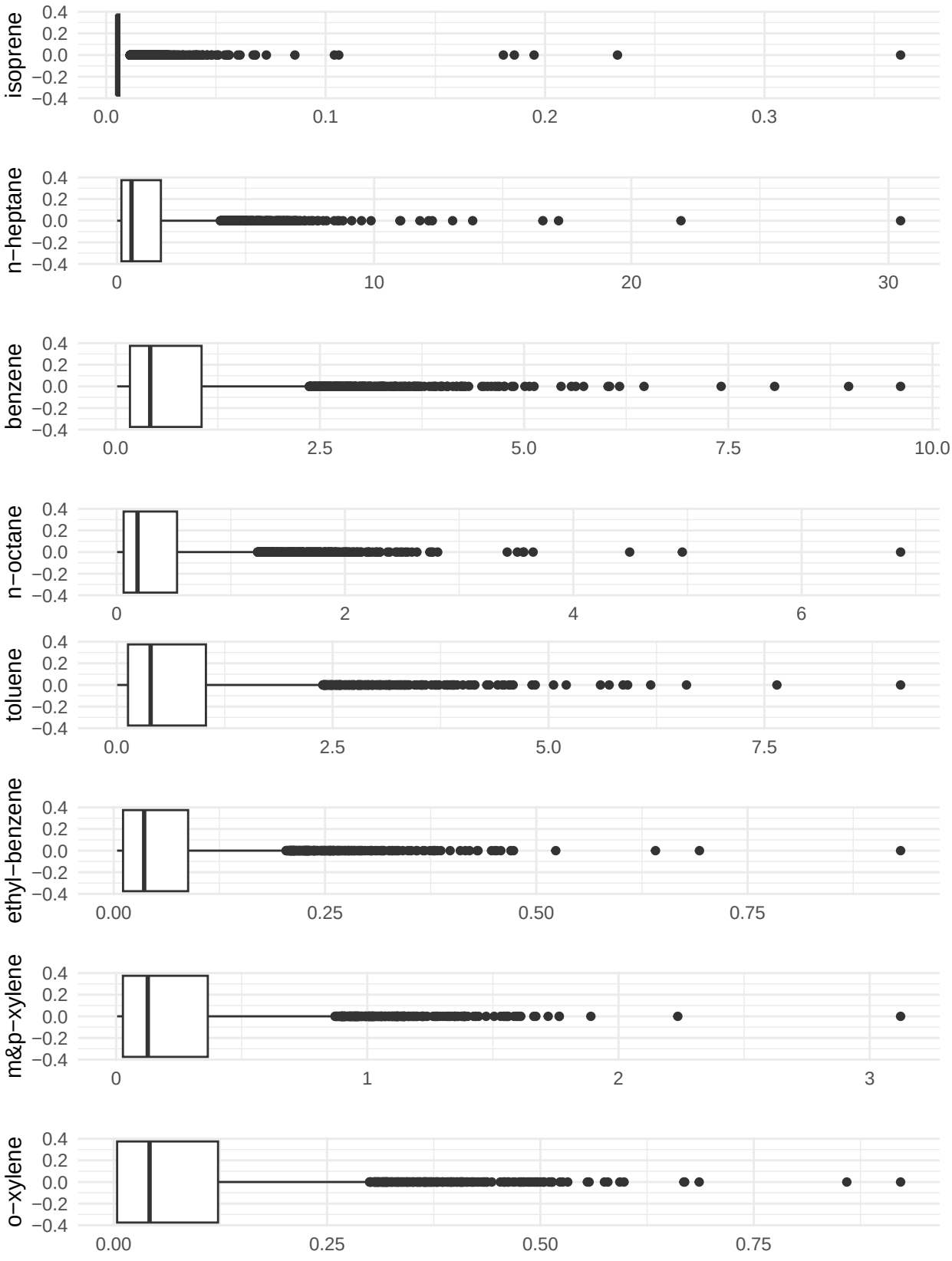
- Boxplots of the hourly concentrations non-voc



- Boxplots sulfur compounds, NOx, ozone
- Boxplots VOCs




1_3−butadier
i−butane
n−butane
acetylene
cyclopentan
i−pentane
n−pentane
n−hexane
0.4
0.2
0.0
−0.2
−0.4
0.00
0.25
0.50
0.75
1.00
1.25
0
100
200
300
400
2
4
6
8
5
10
50
150
25
75


isoprene
0.4
0.2
0.0
−0.2
−0.4
0.0
0.1
0.2
0.3
n−heptane
0
10
20
30
benzene
0.0
2.5
5.0
7.5
10.0
n−octane
0
2
4
6
toluene
0.0
2.5
5.0
7.5
ethyl−benzene
0.00
0.25
0.50
0.75
m&p−xylene
0
1
2
3
o−xylene
0.00
0.25
0.50
0.75

Data pre-processing

- STEP 1: Limits of detection

```
# Define LOD for each chemical
LOD_non_voc <- c('ch4' = 0.9,
             'co2' = 0.0433,
             'co' = 40,
             'h2s' = 0.4,
             'so2' = 0.4,
             'nox' = 0.05,
             'o3' = 1)

# LOD_voc_monthly <- read_csv('../data/LNM_VOC_LOD_Rounded.csv') %>% select(-1)
#
# # extract the yearmonth from date variables
# LOD_voc_monthly <- LOD_voc_monthly %>%
#   mutate(yearmonth = strftime(as.POSIXct(start_date, format = '%Y-%m-%d %H:%M:%S',
#                                          tz = 'UTC'), '%Y-%m'))
#
# LOD_voc_monthly <- LOD_voc_monthly %>%
#   select(-c(start_date, end_date)) %>%
#   select(!any_of(ends_with('half_ldl')))
#
# colnames(LOD_voc_monthly) <- str_replace_all(names(LOD_voc_monthly), '_ldl', '')

LOD_voc_avg <- read_xlsx('../data/LNM_VOC_Uncertainties.xlsx', skip = 1)
LOD_voc_avg <- LOD_voc_avg %>%
  select(1, 4) %>%
  rename('LOD' = 2, 'chemical' = 1) %>%
  head(20)
```

- STEP 2: Background correction

```
##           ch4           co2            co           h2s           so2
##      1928.000       411.300        59.910         0.200         0.200
##           nox            o3        ethane        ethene       propane
##         0.025         0.500         0.916         0.011         0.224
##       propene 1_3-butadiene      i-butane      n-butane     acetylene
##         0.009         0.007         0.035         0.090         0.019
##  cyclopentane     i-pentane     n-pentane      n-hexane      isoprene
##         0.005         0.038         0.042         0.021         0.005
##     n-heptane       benzene      n-octane       toluene ethyl-benzene
##         0.004         0.017         0.004         0.004         0.004
##    m&p-xylene      o-xylene
##         0.004         0.004
```

- Summary statistics of backgrounds and extremes

```
get_info <- function(column) {
  N <- length(column)
  background <- quantile(column, 0)
  quantile1 <- quantile(column, 0.01)
  quantile99 <- quantile(column, 0.99)
  n_background <- sum(column == background)
  max <- max(column)
  return(c(N, quantile1, quantile99, max, background, n_background))
```

```
}

info_table <- hourly_full_nona %>%
  reframe(across(everything(), ~ get_info(.x)))

info_table <- info_table %>%
  mutate(rownames = c('N', '1st percentile', '99th percentile', 'Max',
                      'Background', '# Background')) %>%
  pivot_longer(-rownames) %>%
  pivot_wider(names_from = rownames, values_from = value)

knitr::kable(info_table)
```

name	N	1st percentile	99th percentile	Max	Background	# Background
ch4	4788	1962.98700	6286.12400	34010.900	1928.000	1
co2	4788	416.47870	460.62260	503.990	411.300	1
co	4788	84.23050	442.08860	2513.440	59.910	1
h2s	4788	0.20000	5.20986	27.700	0.200	829
so2	4788	0.20000	1.78686	8.578	0.200	3266
nox	4788	0.22974	89.72371	452.959	0.025	2
o3	4788	0.50000	76.02600	103.100	0.500	259
ethane	4788	1.84422	526.44700	2060.000	0.916	1
ethene	4788	0.01100	3.50826	16.970	0.011	163
propane	4788	0.84674	300.79000	1211.000	0.224	1
propene	4788	0.00900	0.69739	5.528	0.009	411
1_3-butadiene	4788	0.00700	0.05900	1.207	0.007	3357
i-butane	4788	0.15148	60.89400	296.600	0.035	1
n-butane	4788	0.37248	166.52100	536.900	0.090	1
acetylene	4788	0.04900	2.61304	8.471	0.019	2
cyclopentane	4788	0.00500	3.06899	13.460	0.005	96
i-pentane	4788	0.10987	49.60210	215.900	0.038	1
n-pentane	4788	0.10487	55.95980	258.800	0.042	1
n-hexane	4788	0.04300	18.17780	93.360	0.021	2
isoprene	4788	0.00500	0.03313	0.362	0.005	2816
n-heptane	4788	0.01500	6.57669	30.470	0.004	5
benzene	4788	0.02800	3.78693	9.610	0.017	3
n-octane	4788	0.00400	2.00839	6.867	0.004	100
toluene	4788	0.01300	3.52165	9.077	0.004	11
ethyl-benzene	4788	0.00400	0.31613	0.931	0.004	918
m&p-xylene	4788	0.00400	1.29156	3.123	0.004	851
o-xylene	4788	0.00400	0.45700	0.922	0.004	1330

- STEP 2 processing continued: background correction
- adjustments that were made according to paper: Gunnar's paper section 2.2 and Guha 3.3
- Check whether chemical has background noise level that needs to be removed
- NO ADJUSTMENT if minimum value < 2xLOD and maximum value > 100xLOD

```
adjusting_neg_bg_from_lod <- function(chemical, LOD, background, hourly_data){
    # get min and max
    min_value <- min(hourly_data[chemical], na.rm = TRUE)
    max_value <- max(hourly_data[chemical], na.rm = TRUE)
    # if min less than double LOD or max > 100 times LOD
```

```
    # adjust to -100 (for entire column???)
    if (min_value < 2 * LOD & max_value > 100 * LOD ){
      return (0)
    }
  return (background)
}
```

- Check if background is negligible for non voc
- merge background and LOD

```
background_lod_non_voc <- tibble(chemical = non_vocs,
                                 LOD = LOD_non_voc,
                                 background = unname(background_levels[non_vocs]))
adjusted_background_non_voc <- background_lod_non_voc %>%
  rowwise() %>%
  mutate(min = min(hourly_full_nona[chemical], na.rm = TRUE),
         LODx2 = 2 * LOD,
         criterion1 = min(hourly_full_nona[chemical], na.rm = TRUE) < 2 * LOD,
         max = max(hourly_full_nona[chemical], na.rm = TRUE),
         LODx100 = 100 * LOD,
         criterion2 = max(hourly_full_nona[chemical], na.rm = TRUE) > 100 * LOD,
         adjusted_background = adjusting_neg_bg_from_lod(chemical, LOD, background,
                                                         hourly_full_nona))
```

- Check if background is negligible for voc
- merge background and LOD

```
background_lod_voc <- LOD_voc_avg %>%
  left_join(tibble(chemical = setdiff(names(background_levels), non_vocs),
                   background = background_levels[setdiff(names(background_levels),
                                                          non_vocs)]))
adjusted_background_voc <- background_lod_voc %>%
  rowwise() %>%
  mutate(min = min(hourly_full_nona[chemical], na.rm = TRUE),
         LODx2 = 2 * LOD,
         criterion1 = min(hourly_full_nona[chemical], na.rm = TRUE) < 2 * LOD,
         max = max(hourly_full_nona[chemical], na.rm = TRUE),
         LODx100 = 100 * LOD,
         criterion2 = max(hourly_full_nona[chemical], na.rm = TRUE) > 100 * LOD,
         adjusted_background = adjusting_neg_bg_from_lod(chemical, LOD, background,
                                                         hourly_full_nona))
```

- create dataset with background removed

```
# So now we have the adjusted background concentrations
hourly_nona_bgrm <- hourly_full_nona %>%
  mutate(across(adjusted_background_non_voc$chemical,
                ~  .x - adjusted_background_non_voc$adjusted_background[
                    adjusted_background_non_voc$chemical == cur_column()]))
hourly_nona_bgrm <- hourly_nona_bgrm %>%
  mutate(across(adjusted_background_voc$chemical,
                ~  .x - adjusted_background_voc$adjusted_background[
                    adjusted_background_voc$chemical == cur_column()]))
```

- check number of 0 values per compound

```r
# look at zero values
colSums(hourly_nona_bgrm == 0)
```

```
##           ch4           co2            co           h2s           so2
##             1             1             1           829          3266
##           nox            o3        ethane        ethene       propane
##             0             0             1             0             1
##       propene 1_3-butadiene      i-butane      n-butane     acetylene
##             0          3357             1             1             0
##  cyclopentane     i-pentane     n-pentane      n-hexane      isoprene
##             0             1             1             2          2816
##     n-heptane       benzene      n-octane       toluene ethyl-benzene
##             0             0             0             0             0
##    m&p-xylene      o-xylene
##             0             0
```

- STEP 3: replace zero values with random values between 0 and 0.5xLOD

```r
set.seed(123)
replace_zero_with_random <- function(column, name, LOD_df){
  LOD <- LOD_df$LOD[LOD_df$chemical == name]
  column <- if_else(column == 0, round(runif(length(column), 0, 0.5 * LOD), 3), column)
  return (column)
}

hourly_nona_bgrm_zerorepl <- hourly_nona_bgrm %>%
  mutate(across(adjusted_background_non_voc$chemical,
                ~ replace_zero_with_random(.x, cur_column(), adjusted_background_non_voc)))

hourly_nona_bgrm_zerorepl <- hourly_nona_bgrm_zerorepl %>%
  mutate(across(adjusted_background_voc$chemical,
                ~ replace_zero_with_random(.x, cur_column(), adjusted_background_voc)))
```

- STEP 4: Normalize the non-vocs

```r
#normalizing function
normalize_column <- function(column){
  background <- quantile(column, 0)
  max <- quantile(column, 1) # this could be adjusted
  return ((column - background)/(max - background))
}
```

- STEP 4: Normalize all

```r
# normalize all
hourly_nona_bgrm_zerorepl_norm <- as_tibble(sapply(as.list(hourly_nona_bgrm_zerorepl),
                                                   normalize_column))
#normalize the NON_VOC
summary(hourly_nona_bgrm_zerorepl_norm)
```

```
##       ch4                co2               co                h2s
##  Min.   :0.000000   Min.   :0.0000   Min.   :0.00000   Min.   :0.00000
##  1st Qu.:0.005795   1st Qu.:0.1384   1st Qu.:0.02592   1st Qu.:0.01022
##  Median :0.014603   Median :0.1823   Median :0.03884   Median :0.02335
##  Mean   :0.026837   Mean   :0.2000   Mean   :0.04761   Mean   :0.03500
##  3rd Qu.:0.037200   3rd Qu.:0.2418   3rd Qu.:0.05970   3rd Qu.:0.04525
##  Max.   :1.000000   Max.   :1.0000   Max.   :1.00000   Max.   :1.00000
```

```
##       so2                nox                 o3              ethane
##  Min.   :0.000000   Min.   :0.000000   Min.   :0.00000   Min.   :0.000000
##  1st Qu.:0.007997   1st Qu.:0.006534   1st Qu.:0.09747   1st Qu.:0.008386
##  Median :0.016114   Median :0.020262   Median :0.25487   Median :0.026672
##  Mean   :0.026320   Mean   :0.036440   Mean   :0.26676   Mean   :0.050993
##  3rd Qu.:0.023633   3rd Qu.:0.049978   3rd Qu.:0.40546   3rd Qu.:0.075376
##  Max.   :1.000000   Max.   :1.000000   Max.   :1.00000   Max.   :1.000000
##      ethene            propane            propene         1_3-butadiene
##  Min.   :0.00000   Min.   :0.000000   Min.   :0.000000   Min.   :0.000000
##  1st Qu.:0.01268   1st Qu.:0.009285   1st Qu.:0.005979   1st Qu.:0.001667
##  Median :0.03547   Median :0.028411   Median :0.018482   Median :0.004167
##  Mean   :0.05042   Mean   :0.053805   Mean   :0.028772   Mean   :0.007368
##  3rd Qu.:0.07266   3rd Qu.:0.080132   3rd Qu.:0.042761   3rd Qu.:0.007500
##  Max.   :1.00000   Max.   :1.000000   Max.   :1.000000   Max.   :1.000000
##     i-butane           n-butane          acetylene        cyclopentane
##  Min.   :0.000000   Min.   :0.000000   Min.   :0.00000   Min.   :0.000000
##  1st Qu.:0.006153   1st Qu.:0.008783   1st Qu.:0.02674   1st Qu.:0.007432
##  Median :0.019261   Median :0.027528   Median :0.05135   Median :0.022668
##  Mean   :0.038384   Mean   :0.054906   Mean   :0.07436   Mean   :0.043730
##  3rd Qu.:0.053703   3rd Qu.:0.077047   3rd Qu.:0.10211   3rd Qu.:0.062653
##  Max.   :1.000000   Max.   :1.000000   Max.   :1.00000   Max.   :1.000000
##    i-pentane          n-pentane           n-hexane          isoprene
##  Min.   :0.000000   Min.   :0.000000   Min.   :0.000000   Min.   :0.000000
##  1st Qu.:0.006293   1st Qu.:0.005681   1st Qu.:0.004725   1st Qu.:0.002801
##  Median :0.019932   Median :0.018371   Median :0.016060   Median :0.005602
##  Mean   :0.041085   Mean   :0.038859   Mean   :0.035000   Mean   :0.010304
##  3rd Qu.:0.057848   3rd Qu.:0.054837   3rd Qu.:0.049564   3rd Qu.:0.011204
##  Max.   :1.000000   Max.   :1.000000   Max.   :1.000000   Max.   :1.000000
##    n-heptane           benzene            n-octane           toluene
##  Min.   :0.000000   Min.   :0.00000   Min.   :0.000000   Min.   :0.00000
##  1st Qu.:0.005473   1st Qu.:0.01637   1st Qu.:0.008269   1st Qu.:0.01389
##  Median :0.018348   Median :0.04222   Median :0.026009   Median :0.04276
##  Mean   :0.039328   Mean   :0.07655   Mean   :0.054341   Mean   :0.07825
##  3rd Qu.:0.055866   3rd Qu.:0.10779   3rd Qu.:0.076497   3rd Qu.:0.11333
##  Max.   :1.000000   Max.   :1.00000   Max.   :1.000000   Max.   :1.00000
##  ethyl-benzene        m&p-xylene          o-xylene
##  Min.   :0.000000   Min.   :0.000000   Min.   :0.00000
##  1st Qu.:0.007551   1st Qu.:0.007374   1st Qu.:0.00000
##  Median :0.034520   Median :0.039115   Median :0.04139
##  Mean   :0.062378   Mean   :0.077508   Mean   :0.08650
##  3rd Qu.:0.090615   3rd Qu.:0.115742   3rd Qu.:0.12881
##  Max.   :1.000000   Max.   :1.000000   Max.   :1.00000
```

- FINAL step: create matrix of processed and normalized concentrations for NMF

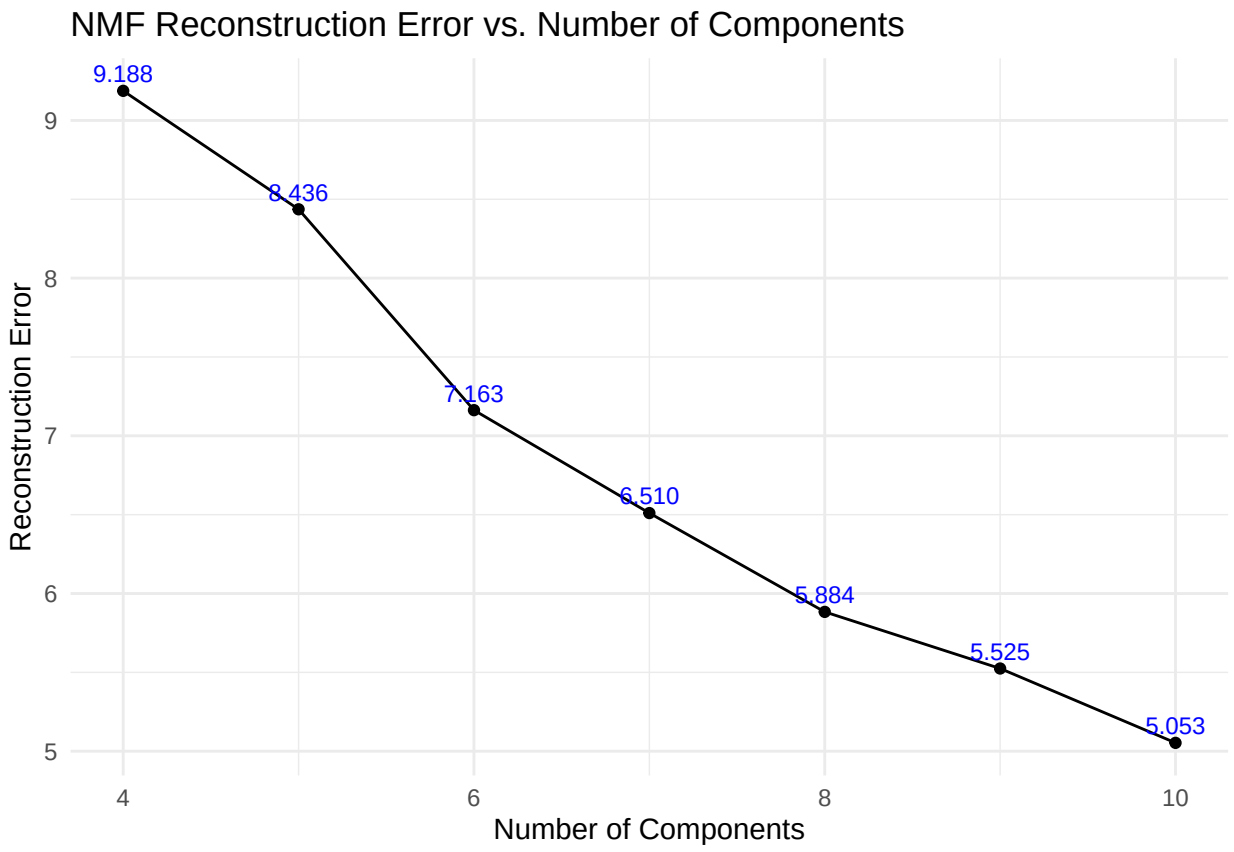
```
normalized_matrix <- as.matrix(hourly_nona_bgrm_zerorepl_norm)
#important: using the normalized VOCs for this file
```

NMF section

Helper for source contributions plots

Apply NMF using 'nndsvd' seed and KL divergence

```
components <- 4:10
errors <- numeric(length(components) - 4)

# Loop over the number of components
# for (n in components) {
#   nmf_result <- nmf(normalized_matrix, rank = n, method = "KL", seed='nndsvd')
#   reconstruction <- basis(nmf_result) %*% coef(nmf_result)
#   error <- norm(normalized_matrix - reconstruction, type = "F")
#   errors[n-3] <- error
#   print(paste0('Completed ', n - 3, ' out of 7'))
# }
#
# saveRDS(errors, 'errors_norm.rds')

errors <- readRDS('errors_norm.rds')
```



NMF with 5 source factors without ozone

- remvove ozone
- use KL divergence loss with svd seed
- Extract W (basis) and H (coefs) matrices
- Calculate variance explained in all 5 factors
- Calculate variance explained by each factor

```
normalized_matrix_less_o3 <-
  normalized_matrix[ ,setdiff(colnames(normalized_matrix), "o3")]
```

```r
nmf_result_5c_less_o3 <- nmf(normalized_matrix_less_o3, rank = 5,
                              method = "KL", seed='nndsvd')
```

```
## Warning in sqrt(S[i] * termn) * uun: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.

## Warning in sqrt(S[i] * termn) * vvn: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.

## Warning in sqrt(S[i] * termn) * uun: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.

## Warning in sqrt(S[i] * termn) * vvn: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.

## Warning in sqrt(S[i] * termn) * uun: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.

## Warning in sqrt(S[i] * termn) * vvn: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.

## Warning in sqrt(S[i] * termp) * uup: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.

## Warning in sqrt(S[i] * termp) * vvp: Recycling array of length 1 in array-vector arithmetic is depre
##   Use c() or as.vector() instead.
```

```r
basis_matrix_5c_less_o3 <- basis(nmf_result_5c_less_o3) #W
coef_matrix_5c_less_o3 <- coef(nmf_result_5c_less_o3) #H

# get variance explained by the factors (total residuals)
reconstruct<-fitted(nmf_result_5c_less_o3)

tss <- sum((normalized_matrix_less_o3 - mean(normalized_matrix_less_o3))^2)
rss <- sum((normalized_matrix_less_o3 - reconstruct)^2)
variance_explained <- 1 - (rss / tss)
variance_explained
```

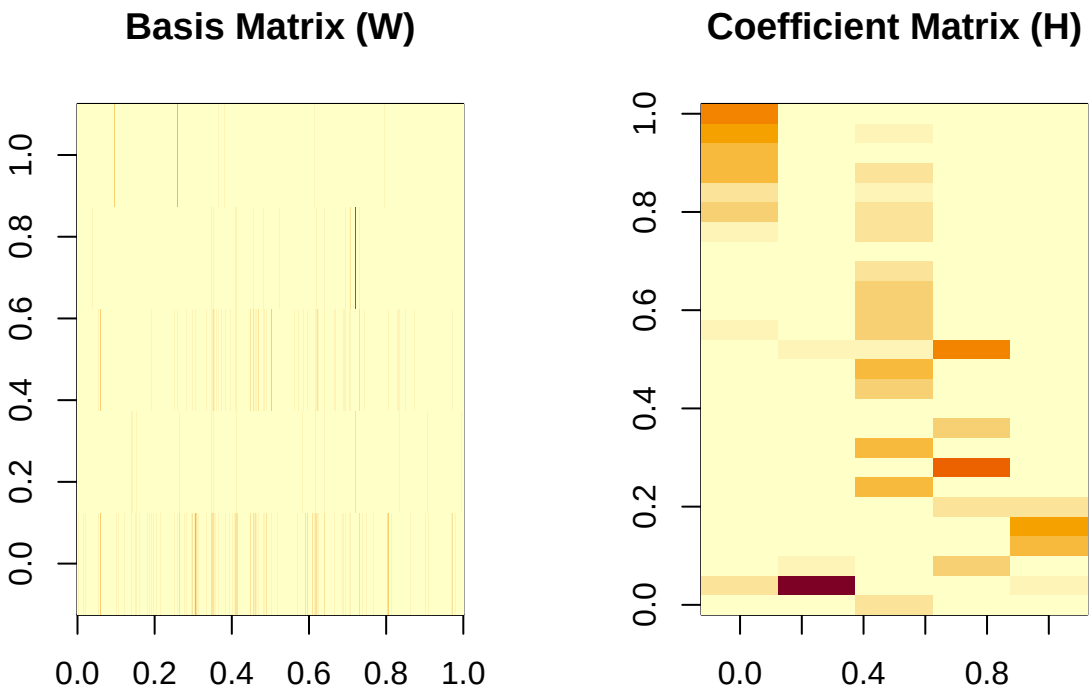
```
## [1] 0.9212817
```

```r
# get variance explained by each factor separately
# Compute variance explained by each factor
# Initialize variance explained tracker
variance_explained_factors <- numeric(5)

# Incrementally add factors and calculate variance explained
reconstruction <- matrix(0, nrow = nrow(basis_matrix_5c_less_o3), ncol = ncol(coef_matrix_5c_less_o3))

for (i in 1:5) {
  # Add the i-th factor to the reconstruction
  reconstruction <- reconstruction + (basis_matrix_5c_less_o3[, i, drop=FALSE] %*% coef_matrix_5c_less_

  # Compute Residual Sum of Squares (RSS)
  rss_f <- sum((normalized_matrix_less_o3 - reconstruction)^2)

  # Compute Variance Explained by adding this factor
  variance_explained_factors[i] <- 1 - (rss_f / tss)
}
```

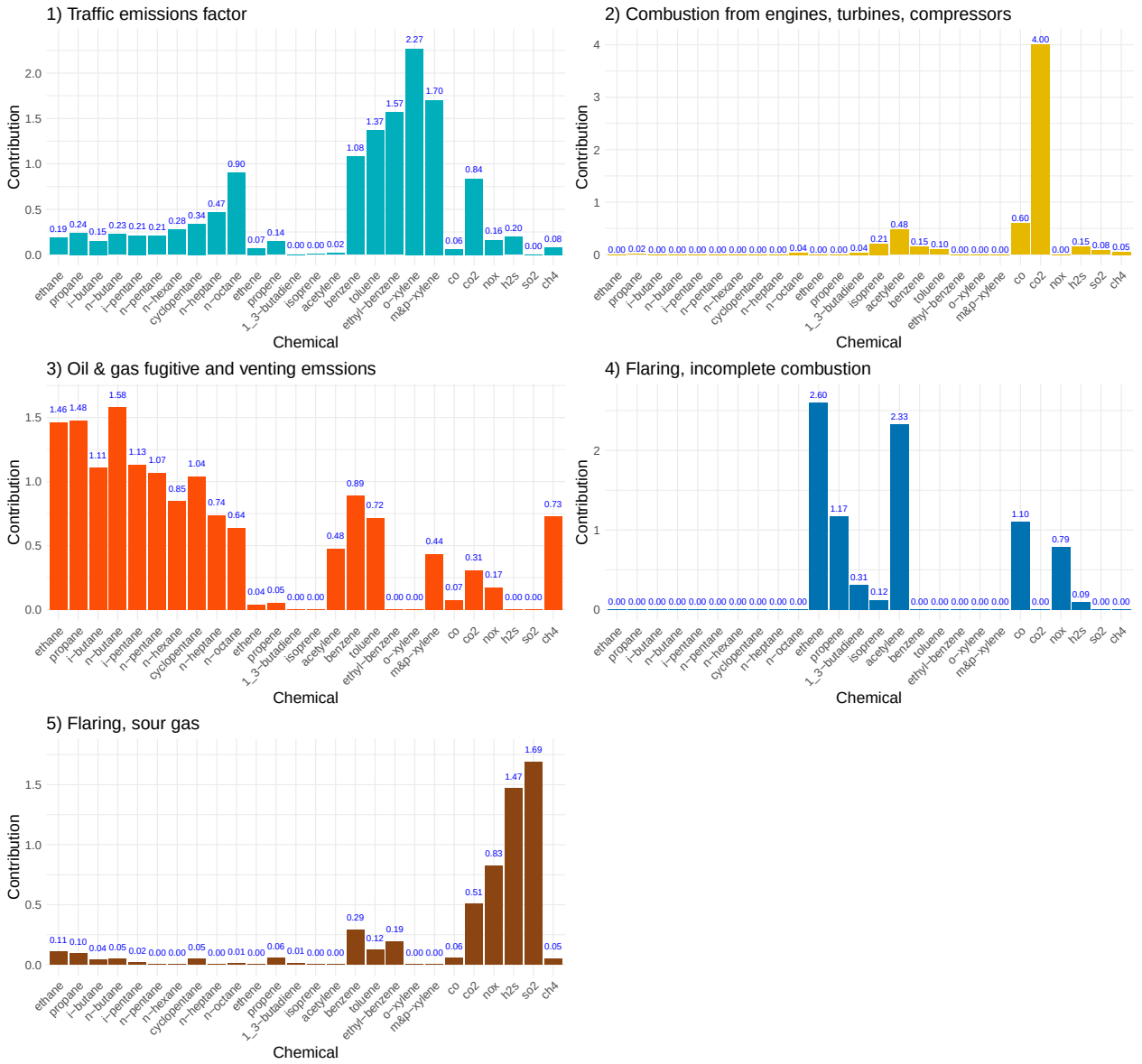
```r
# Print variance explained by each factor cumulatively
variance_explained_factors
```

```
## [1] 0.2409233 0.5113765 0.8112270 0.8924548 0.9212817
```

```r
par(mfrow = c(1, 2))
image(basis_matrix_5c_less_o3, main = "Basis Matrix (W)")
image(coef_matrix_5c_less_o3, main = "Coefficient Matrix (H)")
```



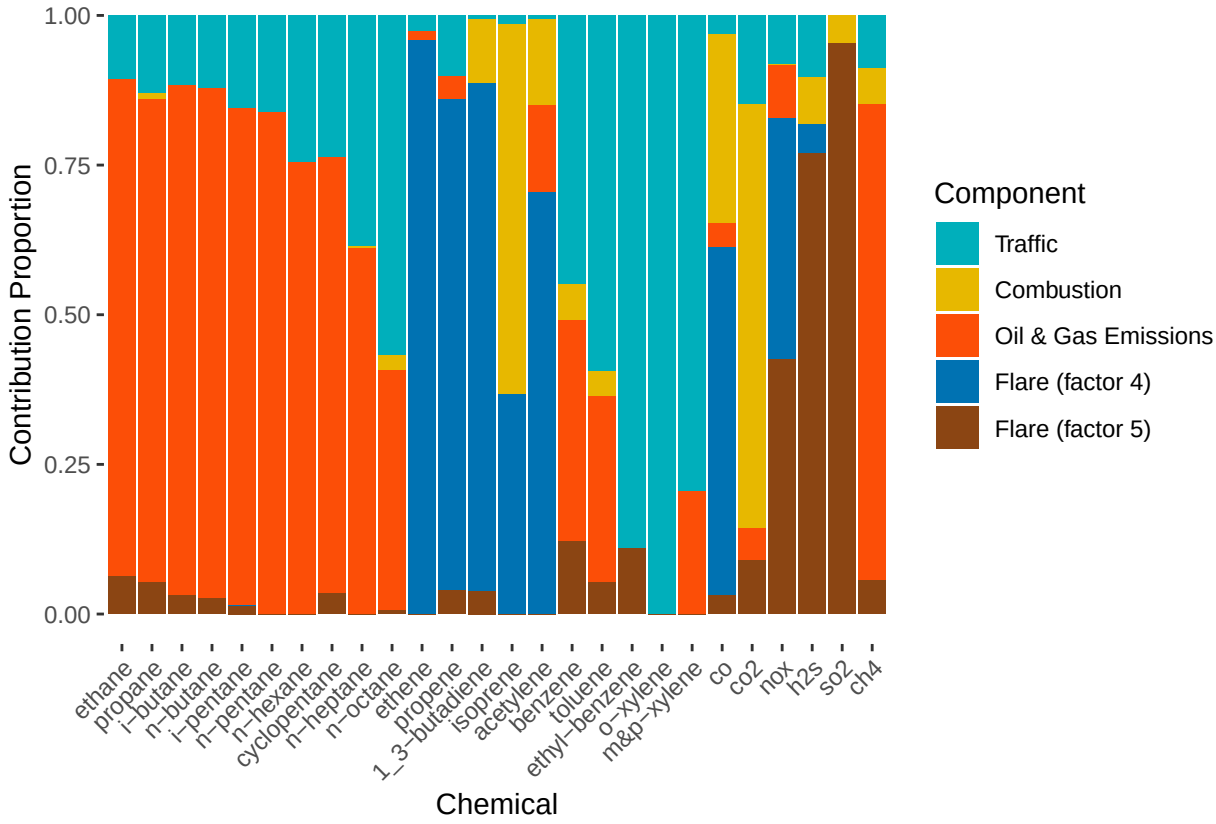

```r
# Convert H to a data frame for ggplot
H_df_5c_less_o3 <- as.data.frame(coef_matrix_5c_less_o3)
# Add a column for chemicals
H_df_5c_less_o3$Component <- rownames(H_df_5c_less_o3)

# Reshape data to long format
H_long_5c_less_o3 <- pivot_longer(H_df_5c_less_o3, cols = -Component,
                                  names_to = "Chemical", values_to = "Contribution")

# Plot
nmfplt_1_svd_5c_less_o3 <- get_component_plot(H_long_5c_less_o3,
                                              '1', '1) Traffic emissions factor')
nmfplt_2_svd_5c_less_o3 <- get_component_plot(H_long_5c_less_o3,
                                              '2', '2) Combustion from engines, turbines, compressors')
nmfplt_3_svd_5c_less_o3 <- get_component_plot(H_long_5c_less_o3,
                                              '3', '3) Oil & gas fugitive and venting emssions')
nmfplt_4_svd_5c_less_o3 <- get_component_plot(H_long_5c_less_o3,
                                              '4', '4) Flaring, incomplete combustion')
nmfplt_5_svd_5c_less_o3 <- get_component_plot(H_long_5c_less_o3,
                                              '5', '5) Flaring, sour gas')
```



Fingerprint plot

```
custom_colors <- c("Traffic" = "#00AFBB",
                   "Combustion" = "#E7B800",
                   "Oil & Gas Emissions" = "#FC4E07",
                   "Flare (factor 4)" = "#0072B2",
                   "Flare (factor 5)" = "#8B4513")

contrib_prop <- apply(H_df_5c_less_o3[,1:(length(H_df_5c_less_o3)-1)], MARGIN = 2,
                      FUN = function(x) {x/sum(x)})

contrib_prop %>%
  as_tibble() %>%
  mutate(Component = c('Traffic', 'Combustion', 'Oil & Gas Emissions', 'Flare (factor 4)', 'Flare (facto
  mutate(Component = factor(Component, levels = c('Traffic', 'Combustion', 'Oil & Gas Emissions', 'Flare
  pivot_longer(cols = -Component, names_to = "Chemical", values_to = "Contribution_prop") %>%
```

```
  mutate(Chemical = factor(Chemical, levels = desired_order)) %>%
  ggplot(aes(fill = Component, y = Contribution_prop, x = Chemical)) +
  geom_bar(position = "fill", stat = "identity") +
  scale_fill_manual(values = custom_colors) +
  theme(axis.text.x = element_text(angle = 45, hjust = 1)) +
  labs(x = "Chemical", y = "Contribution Proportion") +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        panel.background = element_blank())
```



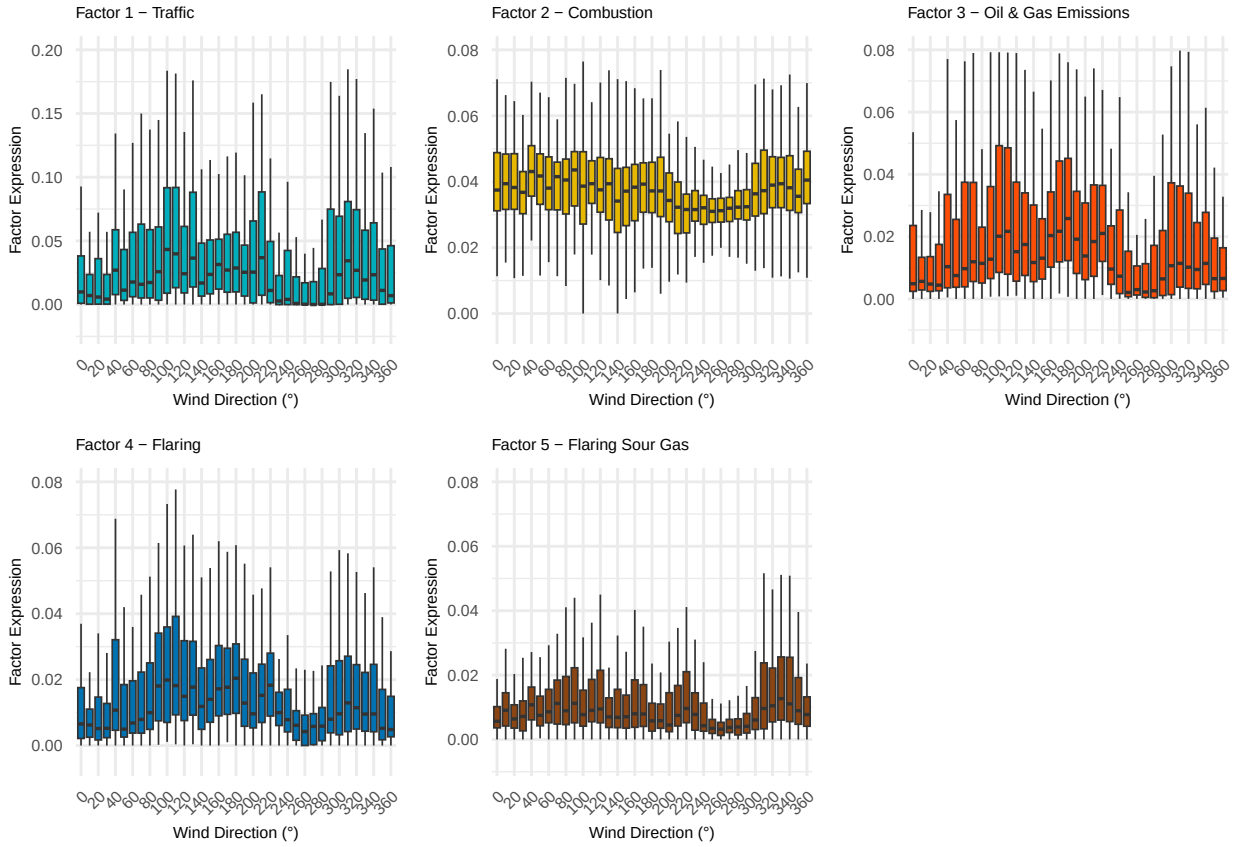

```
#ggsave("fingerprint.png", c)
```

Wind plots

```
hourly_wind_nona <- hourly_nona %>%
  select(wdr_deg, wsp_ms)

data_to_plot <- tibble(
  component1 = basis(nmf_result_5c_less_o3)[,1],
  component2 = basis(nmf_result_5c_less_o3)[,2],
  component3 = basis(nmf_result_5c_less_o3)[,3],
  component4 = basis(nmf_result_5c_less_o3)[,4],
  component5 = basis(nmf_result_5c_less_o3)[,5],
  wd = round(hourly_wind_nona$wdr_deg, -1)
)
```

```r
color_pal <- c("#00AFBB", "#E7B800", "#FC4E07", "#0072B2", "#8B4513")


data_long <- data_to_plot %>%
  pivot_longer(cols = starts_with("component"), names_to = "Factor", values_to = "Expression")


factor_labels <- c(
  "component1" = "Factor 1 - Traffic",
  "component2" = "Factor 2 - Combustion",
  "component3" = "Factor 3 - Oil & Gas Emissions",
  "component4" = "Factor 4 - Flaring",
  "component5" = "Factor 5 - Flaring Sour Gas"
)


data_long <- data_long %>%
  mutate(wd = factor(wd, levels = sort(unique(wd))))

# Select every second wind direction for labeling
every_second_label <- levels(data_long$wd)[seq(1, length(levels(data_long$wd)), by = 2)]


y_axis_limits <- list(
  "component1" = c(-0.02, 0.2),
  "component2" = c(-0.005, 0.08),
  "component3" = c(-0.01, 0.08),
  "component4" = c(-0.005, 0.08),
  "component5" = c(-0.007, 0.08)
)


plots <- lapply(1:5, function(i) {
  factor_name <- paste0("component", i)

  ggplot(data_long %>% filter(Factor == factor_name),
         aes(x = wd, y = Expression, fill = as.factor(wd))) +
    geom_boxplot(outlier.shape = NA, size=0.3) +
    scale_fill_manual(values = rep(color_pal[i], length(unique(data_long$wd)))) +
    scale_x_discrete(breaks = every_second_label) +
    scale_y_continuous(
      limits = y_axis_limits[[factor_name]],
      breaks = seq(0, y_axis_limits[[factor_name]][2], length.out = 5)
    ) +
    labs(title = factor_labels[factor_name],
         x = "Wind Direction (°)",
         y = "Factor Expression") +
    theme_minimal() +
    theme(
      legend.position = "none",
      plot.title = element_text(size = 6),  # Smaller title text
      axis.title = element_text(size = 6),  # Smaller axis labels
      axis.text = element_text(size = 6),  # Smaller x and y tick labels
```

```
      axis.text.x = element_text(angle = 45, hjust = 1)
    )
})


grid.arrange(grobs = plots, ncol = 3)
```




```
#ggsave("factors-wind.png", w)
```

Factor analysis

- merge in factors 1-5 to dataset (hourly)

```
# First look at how well this approximates
fitted_5c_less_o3 <- fitted(nmf_result_5c_less_o3)
sum(abs(normalized_matrix_less_o3-fitted_5c_less_o3))
```

```
## [1] 1060.414
```

```
# NMF factorizes V = WH
# Store Basis matrix (W) and Coef Matrix (H)
saveRDS(basis_matrix_5c_less_o3, 'result_rfiles/nmf_norm_5c_less_o3_basis.rds')
saveRDS(coef_matrix_5c_less_o3, 'result_rfiles/nmf_norm_5c_less_o3_coef.rds')

# Merge basis matrix into hourly observations
basis_matrix_5c_less_o3 <- as_tibble(basis_matrix_5c_less_o3) %>%
  setNames(c('Factor1', 'Factor2', 'Factor3', 'Factor4', 'Factor5'))
```

```
## Warning: The `x` argument of `as_tibble.matrix()` must have unique column names if
## `.name_repair` is omitted as of tibble 2.0.0.
## i Using compatibility `.name_repair`.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

```
normalized_hourly_data_5c_less_o3 <- hourly_nona[,c('day', 'time_utc')] %>%
  cbind(normalized_matrix_less_o3) %>%
  cbind(basis_matrix_5c_less_o3) %>%
  right_join(hourly_data %>% select(-'day'), join_by(time_utc), suffix = c('_norm', ''))

# saveRDS(normalized_hourly_data_5c_less_o3,
#  'result_rfiles/normalized_hourly_data_5c_less_o3.rds')
```

- make daily dataset for VNF analysis
- compute wind directions from plots

```
# Also compute a daily dataset
normalized_daily_data_5c_less_o3 <- normalized_hourly_data_5c_less_o3 %>%
  group_by(day) %>%
  summarise(across(where(is.numeric) & !any_of('wdr_deg'), ~ mean(.x, na.rm = T)),
            wdr_deg = as.numeric(mean(circular(wdr_deg, units = "degrees"), na.rm = T))) %>%
  mutate(wdr_deg = if_else(wdr_deg < 0, wdr_deg+360, wdr_deg)) %>%
  mutate(wind_45_135 = wdr_deg >= 45 & wdr_deg < 135,
         wind_135_180 = wdr_deg >= 135 & wdr_deg < 180,
         wind_180_270 = wdr_deg >= 180 & wdr_deg < 270,
         wind_270_45 = wdr_deg >= 270 & wdr_deg < 45)

# saveRDS(normalized_daily_data_5c_less_o3,
#  'result_rfiles/normalized_daily_data_5c_less_o3.rds')

normalized_daily_data_5c_less_o3 <-
  readRDS('result_rfiles/normalized_daily_data_5c_less_o3.rds')
```

- 1) number of flares in 100km of trailer associated with NMF
- 2) weighted count based on distance to trailer

```
# Check if relationship between # flares and flare factor (4 & 5)
# Linear model
flare_factor <- lm(n_flare_100 ~ Factor1 + Factor2 + Factor3 + Factor4 + Factor5,
                   data = normalized_daily_data_5c_less_o3)
summary(flare_factor)
```

```
##
## Call:
## lm(formula = n_flare_100 ~ Factor1 + Factor2 + Factor3 + Factor4 +
##     Factor5, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.7635 -3.0378 -0.4893  2.3031 16.8406
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)    3.351      1.014   3.305  0.00108 **
```

```
## Factor1      -10.434     14.475  -0.721  0.47163
## Factor2        7.936     26.825   0.296  0.76756
## Factor3       36.265     20.638   1.757  0.08001 .
## Factor4      -28.511     33.444  -0.852  0.39469
## Factor5       37.042     28.700   1.291  0.19791
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.785 on 273 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.02441,    Adjusted R-squared:  0.006544
## F-statistic: 1.366 on 5 and 273 DF,  p-value: 0.2372
```

```
flare_factor45 <- lm(n_flare_100 ~ Factor4 + Factor5, data = normalized_daily_data_5c_less_o3)
summary(flare_factor45)
```

```
##
## Call:
## lm(formula = n_flare_100 ~ Factor4 + Factor5, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.4658 -3.0946 -0.3795  2.2016 17.1266
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)    3.592      0.456   7.878 7.71e-14 ***
## Factor4        6.625     20.357   0.325    0.745
## Factor5       42.500     27.706   1.534    0.126
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.787 on 276 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.01269,    Adjusted R-squared:  0.005536
## F-statistic: 1.774 on 2 and 276 DF,  p-value: 0.1716
```

```
flare_factor_weighted <- lm(weighted.count ~ Factor1 + Factor2 + Factor3 + Factor4 + Factor5,
                            data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted)
```

```
##
## Call:
## lm(formula = weighted.count ~ Factor1 + Factor2 + Factor3 + Factor4 +
##     Factor5, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.369  -3.477  -0.572   2.114 117.655
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)    9.165      2.232   4.107  5.3e-05 ***
## Factor1      -29.660     31.861  -0.931  0.35272
## Factor2     -121.718     59.043  -2.062  0.04020 *
```

```
## Factor3       20.457     45.425   0.450  0.65283
## Factor4      -43.619     73.613  -0.593  0.55398
## Factor5      188.812     63.171   2.989  0.00305 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.332 on 273 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.05585,    Adjusted R-squared:  0.03856
## F-statistic:  3.23 on 5 and 273 DF,  p-value: 0.007515
```

```
flare_factor_weighted45 <- lm(weighted.count ~ Factor4 + Factor5,
                              data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted45)
```

```
##
## Call:
## lm(formula = weighted.count ~ Factor4 + Factor5, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.209  -3.167  -0.377   1.832 120.250
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)    5.030      1.007   4.996 1.04e-06 ***
## Factor4     -103.752     44.944  -2.308  0.02171 *
## Factor5      193.540     61.168   3.164  0.00173 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.361 on 276 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.03869,    Adjusted R-squared:  0.03173
## F-statistic: 5.554 on 2 and 276 DF,  p-value: 0.004316
```

```
# All factors + wind speed + wind direction + factor5:sw wind.
# Wind direction from 270 to 45 is left as reference group.
flare_factor_weighted_2 <- lm(weighted.count ~ Factor1 + Factor2 + Factor3 +
                                Factor4 + Factor5 + wsp_ms + wind_45_135 +
                                wind_135_180 + Factor5*wind_180_270,
                              data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_2)
```

```
##
## Call:
## lm(formula = weighted.count ~ Factor1 + Factor2 + Factor3 + Factor4 +
##     Factor5 + wsp_ms + wind_45_135 + wind_135_180 + Factor5 *
##     wind_180_270, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.444  -3.183  -0.521   2.261 114.568
##
## Coefficients:
```

```
##                             Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  10.3777     3.2634   3.180  0.00165 **
## Factor1                     -28.7880    32.8916  -0.875  0.38223
## Factor2                    -135.7806    60.7431  -2.235  0.02622 *
## Factor3                       7.8931    47.1800   0.167  0.86726
## Factor4                     -32.2435    77.0050  -0.419  0.67576
## Factor5                     201.1532    73.2026   2.748  0.00641 **
## wsp_ms                       -0.2740     0.4426  -0.619  0.53646
## wind_45_135TRUE               2.5387     1.7368   1.462  0.14498
## wind_135_180TRUE             -0.5723     1.2991  -0.441  0.65993
## wind_180_270TRUE              1.4875     2.1999   0.676  0.49953
## Factor5:wind_180_270TRUE    -82.7076   126.3094  -0.655  0.51316
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.342 on 268 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.07083,    Adjusted R-squared:  0.03616
## F-statistic: 2.043 on 10 and 268 DF,  p-value: 0.02944
```

```
# Same as above but only factor 4 and 5
flare_factor_weighted_3 <- lm(weighted.count ~ Factor4 + Factor5 + wsp_ms +
                                Factor5*wind_180_270,
                              data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_3)
```

```
##
## Call:
## lm(formula = weighted.count ~ Factor4 + Factor5 + wsp_ms + Factor5 *
##     wind_180_270, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.181  -3.098  -0.366   1.876 119.987
##
## Coefficients:
##                             Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   5.5004     2.1788   2.524  0.01216 *
## Factor4                    -115.1950    50.6660  -2.274  0.02377 *
## Factor5                     204.1482    71.2016   2.867  0.00446 **
## wsp_ms                       -0.1641     0.4010  -0.409  0.68264
## wind_180_270TRUE              1.2950     2.0985   0.617  0.53769
## Factor5:wind_180_270TRUE    -48.4824   124.5886  -0.389  0.69748
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.398 on 273 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.04064,    Adjusted R-squared:  0.02307
## F-statistic: 2.313 on 5 and 273 DF,  p-value: 0.04421
```

```
# Same as above but interaction between factor 4 and SW wind
flare_factor_weighted_3b <- lm(weighted.count ~ Factor4 + Factor5 + wsp_ms +
                                 Factor4*wind_180_270,
                               data = normalized_daily_data_5c_less_o3)
```

```r
summary(flare_factor_weighted_3b)
```

```
##
## Call:
## lm(formula = weighted.count ~ Factor4 + Factor5 + wsp_ms + Factor4 *
##     wind_180_270, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
##  -9.978  -3.171  -0.290   1.841 120.163
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  5.7763     2.1217   2.723  0.00690 **
## Factor4                   -120.3790    55.0563  -2.186  0.02963 *
## Factor5                    190.5754    62.1541   3.066  0.00239 **
## wsp_ms                      -0.1648     0.4021  -0.410  0.68227
## wind_180_270TRUE             0.2192     2.2108   0.099  0.92108
## Factor4:wind_180_270TRUE    21.2282    94.6402   0.224  0.82269
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.4 on 273 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.04028,    Adjusted R-squared:  0.0227
## F-statistic: 2.292 on 5 and 273 DF,  p-value: 0.046
```

```r
# Same as above but with East wind
flare_factor_weighted_3c <- lm(weighted.count ~ Factor4 + Factor5 + wsp_ms +
                                 Factor5*wind_45_135,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_3c)
```

```
##
## Call:
## lm(formula = weighted.count ~ Factor4 + Factor5 + wsp_ms + Factor5 *
##     wind_45_135, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -22.708  -2.847   0.007   2.101  94.801
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  7.2565     1.9884   3.649 0.000315 ***
## Factor4                   -115.8172    46.1765  -2.508 0.012717 *
## Factor5                     88.8289    58.7340   1.512 0.131591
## wsp_ms                      -0.2622     0.3680  -0.713 0.476627
## wind_45_135TRUE            -18.2763     3.3450  -5.464 1.05e-07 ***
## Factor5:wind_45_135TRUE   1441.5995   206.5522   6.979 2.25e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.704 on 273 degrees of freedom
```

```
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.1928, Adjusted R-squared:  0.178
## F-statistic: 13.04 on 5 and 273 DF,  p-value: 2.174e-11
```

```
flare_factor_weighted_3d <- lm(weighted.count ~ Factor4 + Factor5 + wsp_ms +
                                 Factor4*wind_45_135,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_3d)
```

```
##
## Call:
## lm(formula = weighted.count ~ Factor4 + Factor5 + wsp_ms + Factor4 *
##     wind_45_135, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.959  -3.123  -0.101   1.978 114.048
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 4.36016    2.12027   2.056  0.04069 *
## Factor4                   -62.16866   51.90733  -1.198  0.23208
## Factor5                   176.93325   61.20495   2.891  0.00415 **
## wsp_ms                     -0.04398    0.39320  -0.112  0.91102
## wind_45_135TRUE             8.71066    2.74477   3.174  0.00168 **
## Factor4:wind_45_135TRUE -348.14280  128.95859  -2.700  0.00737 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.254 on 273 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.07347,    Adjusted R-squared:  0.0565
## F-statistic:  4.33 on 5 and 273 DF,  p-value: 0.0008292
```

```
# Wind speed + factor 4 and interaction with East wind
flare_factor_weighted_4a <- lm(weighted.count ~ wsp_ms + Factor4*wind_45_135,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_4a)
```

```
##
## Call:
## lm(formula = weighted.count ~ wsp_ms + Factor4 * wind_45_135,
##     data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.378  -2.800  -0.039   1.756 117.438
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 6.4368     2.0215   3.184 0.001619 **
## wsp_ms                     -0.2062     0.3944  -0.523 0.601521
## Factor4                   -13.6951    49.7795  -0.275 0.783435
## wind_45_135TRUE             9.2438     2.7751   3.331 0.000984 ***
## Factor4:wind_45_135TRUE -371.1890   130.4285  -2.846 0.004763 **
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.364 on 274 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.04511,    Adjusted R-squared:  0.03117
## F-statistic: 3.236 on 4 and 274 DF,  p-value: 0.01288
```

```
# Wind speed + factor 4 and interaction with SE wind
flare_factor_weighted_4b <- lm(weighted.count ~ wsp_ms + Factor4*wind_135_180,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_4b)
```

```
##
## Call:
## lm(formula = weighted.count ~ wsp_ms + Factor4 * wind_135_180,
##     data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
##  -7.276  -2.666  -0.108   1.507 123.726
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 8.4605     2.0284   4.171 4.07e-05 ***
## wsp_ms                     -0.2906     0.3993  -0.728    0.467
## Factor4                   -75.7741    55.0513  -1.376    0.170
## wind_135_180TRUE           -3.2162     2.2939  -1.402    0.162
## Factor4:wind_135_180TRUE   97.7109    97.3642   1.004    0.316
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.499 on 274 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.01397,    Adjusted R-squared:  -0.0004239
## F-statistic: 0.9705 on 4 and 274 DF,  p-value: 0.424
```

```
# Wind speed + factor 4 and interaction with SW wind
flare_factor_weighted_4c <- lm(weighted.count ~ wsp_ms + Factor4*wind_180_270,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_4c)
```

```
##
## Call:
## lm(formula = weighted.count ~ wsp_ms + Factor4 * wind_180_270,
##     data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
##  -7.001  -2.990  -0.227   1.583 124.220
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 8.1106     2.0105   4.034 7.11e-05 ***
## wsp_ms                     -0.3435     0.4039  -0.850    0.396
## Factor4                   -71.2477    53.4743  -1.332    0.184
```

```
## wind_180_270TRUE           0.1415     2.2443   0.063    0.950
## Factor4:wind_180_270TRUE  22.2221    96.0796   0.231    0.817
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.528 on 274 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.007232,   Adjusted R-squared:  -0.007261
## F-statistic: 0.499 on 4 and 274 DF,  p-value: 0.7365
```

```
# Wind speed + factor 5 and interaction with East wind
flare_factor_weighted_5a <- lm(weighted.count ~ wsp_ms + Factor5*wind_45_135,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_5a)
```

```
##
## Call:
## lm(formula = weighted.count ~ wsp_ms + Factor5 * wind_45_135,
##     data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -23.857  -2.640   0.193   1.842  97.377
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)                4.3974     1.6449   2.673  0.00796 **
## wsp_ms                     0.1450     0.3334   0.435  0.66396
## Factor5                   44.2960    56.5239   0.784  0.43391
## wind_45_135TRUE          -17.7090     3.3694  -5.256 2.97e-07 ***
## Factor5:wind_45_135TRUE 1423.9509   208.4158   6.832 5.40e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.778 on 274 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.1742, Adjusted R-squared:  0.1621
## F-statistic: 14.45 on 4 and 274 DF,  p-value: 1.022e-10
```

```
# Wind speed + factor 5 and interaction with SE wind
flare_factor_weighted_5b <- lm(weighted.count ~ wsp_ms + Factor5*wind_135_180,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_5b)
```

```
##
## Call:
## lm(formula = weighted.count ~ wsp_ms + Factor5 * wind_135_180,
##     data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -11.230  -3.033  -0.247   1.607 121.106
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 2.6160     1.8517   1.413  0.15887
```

```
## wsp_ms                       0.2543     0.3583   0.710  0.47835
## Factor5                    205.6894    70.6049   2.913  0.00387 **
## wind_135_180TRUE             0.9276     1.9887   0.466  0.64128
## Factor5:wind_135_180TRUE -178.3060   119.1866  -1.496  0.13580
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.402 on 274 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.03637,    Adjusted R-squared:  0.0223
## F-statistic: 2.585 on 4 and 274 DF,  p-value: 0.03737
```

```
# Wind speed + factor 5 and interaction with SW wind
flare_factor_weighted_5c <- lm(weighted.count ~ wsp_ms + Factor5*wind_180_270,
                               data = normalized_daily_data_5c_less_o3)
summary(flare_factor_weighted_5c)
```

```
##
## Call:
## lm(formula = weighted.count ~ wsp_ms + Factor5 * wind_180_270,
##     data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
##  -9.586  -2.920  -0.146   1.662 122.420
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 2.7653     1.8304   1.511   0.1320
## wsp_ms                      0.2419     0.3618   0.669   0.5043
## Factor5                   160.6788    69.1065   2.325   0.0208 *
## wind_180_270TRUE            0.9646     2.1094   0.457   0.6478
## Factor5:wind_180_270TRUE -53.5432   125.5129  -0.427   0.6700
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.462 on 274 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.02247,    Adjusted R-squared:  0.008201
## F-statistic: 1.575 on 4 and 274 DF,  p-value: 0.1812
```

```
# Check relationship between avg flare distance and flare factor (4 & 5)
# Linear model
flare_factor_dist <- lm(distToLovi ~ Factor4 + Factor5, data = normalized_daily_data_5c_less_o3)
summary(flare_factor_dist)
```

```
##
## Call:
## lm(formula = distToLovi ~ Factor4 + Factor5, data = normalized_daily_data_5c_less_o3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -17.8872  -4.0924  -0.6397   3.1281  15.8871
##
## Coefficients:
```

```
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  20.3055     0.8902  22.809   <2e-16 ***
## Factor4      78.3034    40.2421   1.946    0.053 .
## Factor5     -61.7593    51.8998  -1.190    0.235
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.536 on 218 degrees of freedom
##   (59 observations deleted due to missingness)
## Multiple R-squared:  0.01769,    Adjusted R-squared:  0.008681
## F-statistic: 1.963 on 2 and 218 DF,  p-value: 0.1429
```