## DATA11002 Introduction to Machine Learning 2021

Term Project Final Report

Predicting NPF events

Kai Hartzell

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#### 1. Introduction

In this report, we are studying New Particle Formation (NPF) and predicting NPF events based on training data gathered at the Hyytiälä forestry field station SMEAR II mast on different days in the years 2000-2011 [1, 5].

NPF is an event of particle formation from micro-particles, found in air, to new molecular particles. It is known to affect climate, air quality and thus human and animal health, but the particle formation process is quite complex and not fully known [3, 4].

Therefore, we are using machine learning methods and libraries to help predicting NPF phenomena based on multiple variables found in training data. The interesting question is: When and under which conditions do NPF events occur, and what kind of events could they be? This is also closely related to weather forecasting.

The training data, npf\_train.csv, contained observed NPF data and exactly 100 feature columns presenting physical characteristics. In fact, there were 50 measured variables in total, and for each of the variables, computed mean and std values. A longer description of the variables can be found at [2].

The measurements have been gathered during various days and times between sunrise and sunset. The test data, npf\_test\_hidden.csv, was similar to the training data, but the classes were unknown and thus needed to be predicted.

The class variable class4 (because of 4 different class categories) could be either nonevent or one of the three events: II, Ia or Ib.

The label nonevent meant that no NPF event occurred, otherwise some of the three events occurred.

Event classes were separated into classes II and I, the latter into two additional classes Ia and Ib. Class II meant that the confidence level of NPF growth and formation rates was low. Classes belonging to I had high confidence levels. Class Ia represented strong NPF events, while Ib included other class I events [6].

Eventually, I decided to use Gaussian Naive Bayes NB, (or GNB in separation to Bernoulli BNB) classifier to predict NPF events based on testing data, npf\_test\_hidden.csv. The "hidden" meant that the testing data did not include class labels.

This project was done using R with R Markdown and Git as version control. The computations as well as tables in this report were performed with R, and the text mostly with R Markdown. The used IDE was RStudio. There exist small displayed chunks of code, but the code is mostly not echoed. The whole project can be found from the Git repo [8].

In the following sections, I will present the data pre-processing, machine learning methods used, training of the model, discussing and results of the project.

#### 2. Data analysis and pre-processing

The training data, npf\_train.csv, included 104 columns and 458 observations in total. The test data, npf\_test\_hidden.csv, included 965 unclassified observations. The datasets consisted of columns id, date, class4, partlybad and 100 other feature variables measured. The datasets were quite clean and did not need much pre-processing. This shows how the data looked like. This is the first observation.

```
class4 partlybad CO2168.mean CO2168.std CO2336.mean
## 1
     1 2000-01-01 nonevent
                                FALSE
                                           384.462
                                                     2.284996
                                                                 384.1645
     C02336.std C0242.mean C0242.std C02504.mean C02504.std Glob.mean Glob.std
##
## 1
       2.135062
                  385.2747
                            2.211695
                                        383.8851
                                                    1.955198
                                                             19.24551 11.90955
##
     H20168.mean H20168.std H20336.mean H20336.std H2042.mean
                                                               H2042.std
## 1
        2.278154 0.05150523
                                  2.272 0.05187726
                                                      2.316406 0.05165106
##
     H20504.mean H20504.std H20672.mean H20672.std H2084.mean H2084.std NET.mean
        2.262308 0.05589525
                               2.272769 0.06414115
                                                      2.289062 0.05368097 13.96418
## 1
##
      NET.std NO168.mean NO168.std NO336.mean NO336.std NO42.mean
## 1 11.05117 0.07953846 0.07122655 0.08446154 0.06803103
                                                           0.054375 0.04730432
     NO504.mean NO504.std NO672.mean NO672.std NO84.mean
                                                              NO84.std NOx168.mean
  1 0.08553846 0.07874069 0.06476923 0.05520155
                                                    0.07125 0.06390717
##
     NOx168.std NOx336.mean NOx336.std NOx42.mean NOx42.std NOx504.mean NOx504.std
## 1 0.7728003
                   2.136923
                             0.7141536
                                         2.071875 0.6294565
                                                                2.078769
                                                                          0.6251687
##
     NOx672.mean NOx672.std NOx84.mean NOx84.std O3168.mean O3168.std O342.mean
## 1
                  0.5824053
                              2.085781
                                        0.663547
                                                    20.29892
                                                              2.258243
##
     0342.std 03504.mean 03504.std 03672.mean 03672.std 0384.mean 0384.std
## 1 2.231756
                20.79462
                           1.88802
                                     21.31831 1.976654
                                                          20.11359 2.273609
##
     Pamb0.mean Pamb0.std PAR.mean PAR.std
                                               PTG.mean
                                                             PTG.std RGlob.mean
## 1
       999.8595 0.1664669 20.66235 13.77842 0.003560372 0.005574335
                                                                       7.169164
##
     RGlob.std RHIRGA168.mean RHIRGA168.std RHIRGA336.mean RHIRGA336.std
## 1
     4.595515
                     98.33385
                                   1.127238
                                                   99.06662
                                                                 1.324536
##
     RHIRGA42.mean RHIRGA42.std RHIRGA504.mean RHIRGA504.std RHIRGA672.mean
                                                     1.375835
## 1
          96.47422
                       1.333359
                                      98.88585
                                                                    101.0309
     RHIRGA672.std RHIRGA84.mean RHIRGA84.std RPAR.mean RPAR.std S02168.mean
##
## 1
          1.650608
                        96.99047
                                     1.117522
                                              8.864799 5.279957
                                                                     1.070769
     SO2168.std SWS.mean
                         SWS.std T168.mean T168.std T42.mean
     0.1919416 924.8636 12.33769 -12.66211 0.3762745 -12.20161 0.3752439
##
     T504.mean T504.std T672.mean T672.std T84.mean
                                                          T84.std UV A.mean
## 1 -12.80858 0.4363618 -13.01647 0.5256979 -12.42297 0.3763239
      UV A.std UV B.mean
                            UV_B.std
                                       CS.mean
## 1 0.8569483 0.02643777 0.01461688 0.0033739 0.0007332531
```

I decided to drop out columns id, date and partlybad from both train and test data, because id and date did not have any impact on the results, and the value of partlybad was always FALSE. The class4 column indicated the observed class, and it was one of the classes II, Ia, Ib or nonevent.

The binary classification task was to identify nonevent and event classes, i.e. II, Ia, Ib. The hidden test data was similar to the training data, but did not contain class values. I replaced the NA values with a placeholder nonevent. Then I factored the training data classes as II, Ia, Ib, nonevent.

Next, I constructed a data frame and a table of the class sd and mean values:

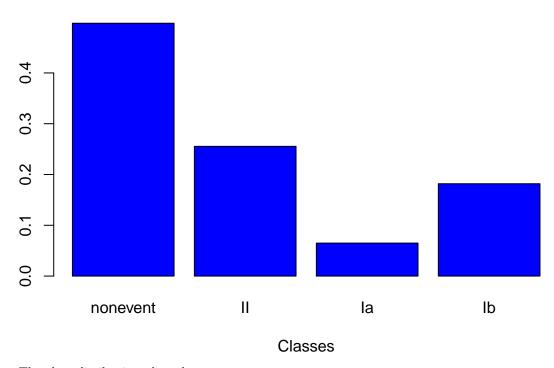
CO2168.mcan383.3267592         12.0163656         379.78165589.6374969         377.39836207.9319611         377.5385938.85728401           CO2168.std         3.8076389         3.7186048         3.4647404         3.0638298         1.8811666         3.132675         3.173907         3.01800199           CO2336.std         3.5531381         3.4511180         3.2415884         2.8516257         1.7707188         3.1835121         3.1055142         2.764834           CO242.mcan         3.453454936         4.4815486         4.2714589         3.2554909         378.05455347.3849728         378.41112688.3496778           CO2504.std         4.5978001         4.4815486         4.2714589         3.255409         377.42363307.5790896         377.52673488.5898615           Glob.std         10.3933153         3.1538781         2.9971388         2.5841776         1.663164         3.015369         3.785781320         3.255490         3.78761743043         3.4514067         3.255490         3.78761743043         3.000043878380525         3.4516070         3.15273         3.4516070         3.2554100         3.2554100         3.775017489.6367019         3.775017489.6367019         3.775017489.6367019         3.775017489.6367019         3.775017489.6367019         3.775017489.6367019         3.775017489.7367019         3.775017489.7367019         3.775017489.73	class non.me	eadass non.s	scelassII.mea	nclassII.sd	classIa.mea	nclassIa.sd	classIb.mea	mlassIb.sd
CO2316.std 3.8976389 3.7156048 3.4647404 3.0638298 1.8811666 3.7126727 3.1736070-98.56020995 CO2336.std 3.5851381 3.4501180 3.2415884 2.8516237 1.7707188 3.1836122 3.7644834 CO242.tmcan 3843.454936 11.4029920 380.56722389.4285409 378.05455347.3849728 378.41112688.3916778 CO2504.mcan.383.1770183 [1.4029920 380.56722389.4285409 378.05455347.3849728 378.41112688.3916778 4.4815486 4.4815486 4.2714589 3.9259490 2.1570477 3.483047 4.2127625 4.3486898 CO2504.mcan.383.1770183 [2.0563130 379.75017480.6367019 377.42363307.8790896 377.52673488.8598615 CO2504.mcan.383.170183 [2.0563130 379.75017480.6367019 377.42363307.8790896 377.52673488.8598615 CO2504.mcan.383.170189 [12.0563130 379.75017480.6367019 377.42363307.8790896 277.52673488.8598615 CO2504.mcan.383.170189 [12.0563130 379.75017480.6367019 377.42363307.8790896 377.52673488.8598615 CO2504.mcan.383.952240 [10.3933135 42.2905246 6.683081 3.193905 47256178 3.0856356 6.1144607 [12.0563130 399.518144 196.397250870.25400491 148.31792847.8803925 197.614956570.4300363 42203366.std 0.5393356 0.4656248 0.6812579 0.4348018 0.3949500 0.3097822 0.6062125 0.3944818 120336.mcan 8.5241607 4.2414113 6.603523 3.187594 4.6750551 3.027596 6.038327 2.7308122 1420336.std 0.5447998 0.46565487 0.6725026 0.4262756 0.3950264 0.3053176 0.6076333 0.3960382 1420542.mcan 8.2524707 4.2441413 6.603523 3.187594 4.678063 2.994583 0.6189676 4.298450 0.465924 0.4505409 0.40730730 0.314933 0.618976 0.399452 0.465945 0.4252746 0.4504093 0.40730730 0.334933 0.618976 0.399450 0.465945 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.378299 0.3075983 0.6089888 0.402542 0.459508 0.459508 0.459508 0.459508 0.459508 0.337329 0.3075983 0.608988 0.402542 0.459508 0.459508 0.459508 0.459508 0.459508 0.337329 0.3075983 0.608988 0.402542 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.459508 0.4		class_non.mexthass_non.scclassII.meanclassII.sd						
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CO242_mean 384_316_3936								
CO242std         4.5978001         4.4815486         4.2714589         3.9259409         2.1576477         3.4830427         4.2127625         4.3486898           CO2504.std         3.4192060         3.1583781         2.9971388         2.5841796         1.6631054         3.0425304         2.8382270         2.4519342           Glob.mean         124,184709         108.2884333         2.5911414         196.397250870.2540049         1.48179284973.836265294         1.281815775           Glob.mean         120,033153         9.5181144         196.397250870.2540049         1.48179284978.830325197.61495657507.430363           H2O168.mean         8.395240         4.2909264         6.6839081         3.2319905         7.7251785         3.0865356         6.1144060         2.7852484           H2O366.std         0.5293356         0.4665487         0.6812579         0.4381018         0.3949500         0.3097822         0.606725         0.6725026         0.4262756         0.3950264         0.303173         0.6076333         0.394818           H2O42.std         0.5417998         0.4852490         0.475903         0.47670073         0.3143933         0.161876         0.3956076         0.2690283         2.880575           H2O54.std         0.5293561         0.4669926         0.425128         0.329329								
CO2504.meanus  S.1770183   12.0503130   379.75017488   6.367010   371.42363307   879.0806   377.52673488   589.8151   CO2504.std   3.4192060   12.41843709   108.2884332265.111477796.6022110   217.4514936136.509043273.8362662294.1315775   Glob.std   100.3933153   89.5181144   196.39725087.02540049   148.317928497.8803925   197.614956570.4300363   RE20168.std   103.393153   89.5181144   196.39725087.02540049   148.317928497.8803925   197.614956570.4300363   RE20168.std   1.5305522   0.4666248   0.6839081   2.319905   4.756178   3.0865356   6.1144096   2.7852484   RE20168.std   0.5239356   0.4665248   0.6635253   0.4348018   0.3949500   0.3097822   0.6062125   0.3944818   RE20336.std   0.5293356   0.4655487   0.6725026   0.4262756   0.3960264   0.303176   0.6076333   0.3960828   0.42627424   0.3090264   0.303176   0.6076333   0.3960828   0.4262744   0.407320   0.331430   0.6196733   0.408049   0.5447998   0.4825240   0.4648605   0.4648605   0.394556   0.3851627   0.466044   0.524781   0.4679204   0.6699668   0.4251228   0.3928798   0.3059966   0.6094654   0.398566   0.426048   0.4453180   0.394556   0.3945856   0.4680479   0.6695066   0.4254028   0.3879299   0.3077983   0.6088883   0.4012817   0.468045   0.5398556   0.4769961   0.695466   0.4254028   0.3879299   0.3077983   0.6088883   0.4012817   0.468045   0.539856   0.4769961   0.695466   0.4254028   0.3879299   0.3077983   0.6088883   0.4012817   0.468045   0.539856   0.4769061   0.4545180   0.3943370   0.3208884   0.618577   0.3918308   0.486045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.448045   0.								
CO2504.std								
Clob.mean   124.1843709   108.2884333265.411477796.6022100.217.4514936_136.5090043273.836265294_1315775   Clob.   Cl								
Clob.std								
H2O168.mean   8.3952240   4.2909264   6.683081   3.2319905   4.7256178   3.066336   6.1144060   2.7852484   H2O108.std   0.5030522   0.4666248   0.6812579   0.4348018   0.3949500   0.3007822   0.6062125   0.3944818   H2O2336.mean   8.3234504   4.2414113   6.6003523   3.1875941   4.6750551   3.0275964   6.0381327   2.7308122   H2O336.std   0.5293356   0.4655487   0.6725026   0.4262756   0.3950264   0.3053176   0.6076353   0.3960382   4.24041413   0.5407908   0.4825249   0.7035039   0.4504993   0.4007320   0.3314933   0.6189761   0.3851627   H2O504.mean   8.2824671   4.2084802   6.5496678   3.1622404   4.6480663   2.945831   5.9924726   2.7011730   4.2084802   0.5499687   3.1622404   4.6480663   2.9945831   5.9924726   2.7011730   4.2084802   0.549688   0.3851607   4.6267247   2.9575198   5.9550852   2.6803969   H2O672.std   0.5299801   0.4680479   0.6695666   0.4254028   0.3873290   0.3077983   0.6088883   0.4012817   4.2084804   0.5398556   0.4769061   0.6954969   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   MET.mean   8.5261547   7.4378550   6.7679388   3.278437   4.7685026   3.3133267   6.1851300   2.8420338   MET.mean   0.0836282   0.1178991   0.0486655   0.0551810   0.0840824   0.1708901   0.0618202   0.0845130   0.0336.std   0.0903346   0.0770128   0.0562562.2764092   133.059102082.5527469   172.493228764.8169662   0.036361   0.0903346   0.0903346   0.0772049   0.080038   0.0558533   0.0763280   0.0787067   0.0865659   0.0772434   0.0563516   0.0903486   0.0952515   0.0372286   0.0466313   0.0748648   0.095503   0.1232974   0.076539   0.058631   0.0786567   0.0786579   0.0966902   0.182580   0.0665548   0.0956318   0.095429   0.0839672   0.0785579   0.096650   0.192800   0.0559156   0.0742345   0.0665548   0.0904848   0.0974910   0.0685648   0.091493   0.0836544   0.091493   0.0836544   0.091493   0.0786579   0.046655   0.036659   0.0786579   0.096669   0.096691   0.0665548   0.0966912   0.0839672   0.076539   0.058631   0.0746649   0.0966912   0.0839672   0.076539   0.056606   0.096606								
H20168.std         0.5305522         0.4666248         0.6812579         0.4348018         0.3049500         0.3097822         0.6062125         0.3944818           H20336.mean         8.2334504         4.2414113         6.605323         1.31575941         4.67505515         3.0275964         6.086125         2.7308122           H2042.mean         8.5241697         4.3895086         6.8414829         3.3113565         4.8100257         3.167060         6.2500283         2.880575           H2042.std         0.5244798         0.4852949         0.7035039         0.4504993         0.4007320         0.3314933         0.6189761         0.3851627           H20504.std         0.5274781         4.04679204         0.669668         0.4251228         0.3928798         0.3059966         0.6094654         0.399690           H20672.mean         8.5207405         4.1830761         0.6695606         0.425402         0.3879890         0.3077983         5.0550585         2.6803969           H20643.std         0.5296147         7.4378508         6.7679388         3.278347         4.7685026         3.133267         0.181300         2.842033           NET.mean         8.0526147         7.4378508         6.7595256         2.764092133,059120         0.3934818         0.393567								
H2O336.mean         8.234504         4.214113         6.003523         3.1875041         4.6750551         3.0275964         0.381327         2.7368122         2.7368122         4.2042.mean         8.5241697         4.3895086         6.814829         3.3113655         4.8102575         3.1670608         6.2500283         2.8805575           H2O42.std         0.5447998         0.4825249         0.7035039         0.4504993         0.4007320         0.3314933         0.6189761         0.3851627           H2O504.std         0.5274781         0.4679204         0.6699628         0.4512249         4.0480603         2.9945831         5.9924726         2.7011730           H2O672.mean         8.2507405         0.4880729         0.6699668         0.4251228         0.3887299         0.3075966         0.6094654         0.399600           H2O672.std         0.5299801         0.4680479         0.6695066         0.4254028         0.3887299         0.3777983         0.608883         0.4012817           H2O84.std         0.539856         0.4769061         0.6954969         0.4453180         0.3943370         0.3208854         0.511877         0.3208854         0.511877         0.3208854         0.6118577         0.3918308           NET.std         8.76830282         78.612603	H2O168.mean 8.3952240		6.6839081		4.7256178	3.0865356	6.1144060	
H2O336.std         0.5293356         0.4655487         0.6725026         0.4262756         0.3950264         0.3053176         0.6076353         0.3930382           H2O42.mean         8.2541697         3.895086         0.6485249         0.7035039         0.4504993         0.4007320         0.33116068         6.2500283         2.8805575           H2O504.mean         8.2824671         4.2084802         6.5496678         3.1622404         4.6486063         2.9945831         5.9924726         2.7011730           H2O672.mean         8.257491         4.6679204         0.6699668         0.4251228         0.3928798         0.3059960         0.6091654         0.3996900           H2O672.mean         8.257463         4.1830761         6.5114863         3.153607         4.667274         2.9575198         5.958552         2.6803969           H2O641.mean         8.4704343         4.3504865         6.767938         3.2783437         4.7685026         3.1332267         6.1851300         2.842038           NET.std         8.76830282         74.3785508         167.833376873.0851478         128.541307693.46789         171.690150773.6059959           NO168.mean         0.0832628         0.1178991         0.0485625         0.7652256.2764092         0.330.59120382.5527469         172.99228746.816962 <td></td> <td>0.4666248</td> <td>0.6812579</td> <td>0.4348018</td> <td>0.3949500</td> <td>0.3097822</td> <td>0.6062125</td> <td>0.3944818</td>		0.4666248	0.6812579	0.4348018	0.3949500	0.3097822	0.6062125	0.3944818
H2O42.mean8.52416974.38950866.84148293.31135654.81002573.16706086.25002832.8805575H2O42.std0.54479980.48252490.70350390.45049930.40073200.33149330.61897610.3851627H2O504.mean8.28246714.20848026.54966783.16224044.64860362.99458315.99247260.395662H2O504.std0.52747810.46792040.66996280.42512280.39287980.30599660.60946540.3996900H2O672.std0.52998010.46804790.66996680.42540280.38792990.30779835.95508522.6803969H2O84.mean8.47043434.35048656.76793883.27834374.76850263.13326766.18513002.8420338H2O84.std0.53985560.47690610.69549690.44531800.39433700.32088540.61185770.3918308NET.std87.683028278.6126033174.5705225-62.276049213.0359120382.5527469172.4992287-64.8169662NO168.mean0.0883610.07013280.07621560.03859100.07567510.07437350.11036640.1480846NO336.mean0.0891740.12409210.05058790.05858730.075632800.07437350.11036640.1480846NO42.mean0.08862740.12266540.04905830.05585330.07632800.07865800.0681060.068548NO672.mean0.08712720.11833120.04829300.05749970.09056000.08480500.0595950.0765739 </td <td>H2O336.mean 8.3234504</td> <td>4.2414113</td> <td>6.6003523</td> <td>3.1875941</td> <td>4.6750551</td> <td>3.0275964</td> <td>6.0381327</td> <td>2.7308122</td>	H2O336.mean 8.3234504	4.2414113	6.6003523	3.1875941	4.6750551	3.0275964	6.0381327	2.7308122
H2O42.std         0.5447998         0.4825249         0.7035039         0.4504993         0.4007320         0.3314933         0.6189761         0.3851627           H2O504.hmean         8.2824671         0.4679204         0.6699628         0.4251228         0.396803         2.9945831         5.992476         2.7011730           H2O672.mean         8.2507405         4.1830761         6.5114863         3.1356407         4.6267247         2.9575198         5.950852         2.6803969           H2O672.std         0.5299801         0.4680479         0.6695066         0.4254028         0.3879299         0.3077983         0.6088883         0.4012817           H2O84.mean         8.4704343         4.3504865         6.7679388         3.2783437         4.7685026         3.1332267         6.1851300         2.8420338           NET.std         8.5680282         7.68106061         0.695969         0.4453180         0.3943370         0.320854         0.6118577         0.3918308           NO168.mean         0.0832628         0.1178991         0.0486565         0.0551810         0.0840824         0.1708901         0.618202         0.0845130           NO336.std         0.0981754         0.1240921         0.0508787         0.0589467         0.090982         0.182532         0	H2O336.std 0.5293356	0.4655487	0.6725026	0.4262756	0.3950264	0.3053176	0.6076353	0.3960382
H2O504.mean   8.2824671   4.2084802   6.5496678   3.1622404   4.6486063   2.9945831   5.9924726   2.7011730   H2O504.std   0.5274781   0.4679204   0.6699668   0.4251228   0.3928798   0.3059966   0.6094654   0.3996900   0.4680479   0.6695066   0.4254028   0.3879299   0.3077983   0.6088883   0.4012817   H2O84.mean   8.4704343   4.3504865   6.7679388   3.2783437   4.7685026   3.1332267   6.1851300   2.8420338   H2O84.std   0.5398556   0.4769061   0.6954069   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   NET.mean   80.5261547   74.3785508   167.833736873.0851478   128.541307693.6546789   171.490150773.6059595   NET.std   87.6830282   78.6126033   174.570522562.2764092   133.059120382.5527469   172.493228764.8169662   NO168.mean   0.0832628   0.1178991   0.0486565   0.0551810   0.0840824   0.1708901   0.0618202   0.0845130   NO336.mean   0.0891754   0.0170329   0.080398   0.055879   0.0765751   0.0743735   0.1103664   0.480846   0.098346   0.0772049   0.0800398   0.0558533   0.0763280   0.0787067   0.0865659   0.0772434   NO42.mean   0.0886274   0.0985503   0.0322974   0.0735775   0.0413754   0.0679048   0.1414973   0.0495214   0.0668548   0.0905424   0.0905429   0.0839672   0.0763539   0.046231   0.0748648   0.0891513   0.0839574   0.0689388   NO672.mean   0.0871272   0.1183312   0.048293   0.055438   0.0750297   0.0786534   0.089385   0.0764356   0.091403   0.0878955   0.0744356   0.0996601   0.0750297   0.0785534   0.085076   0.0760539   NO84.mean   1.8066764   1.631601   0.6615674   0.0419833   0.0750297   0.0785544   0.089388   NO84.mean   1.8066764   1.631601   0.662568   0.0419833   0.0750297   0.0785544   0.0893828   0.080672   0.0905660   0.0905672   0.063073   0.0726224   0.0419833   0.0750297   0.0785544   0.05259146   0.0693073   0.0760259   0.08336.mean   1.7895067   0.455524   0.4625667   0.700389   0.3706119   0.3411748   0.4621600   0.389016   0.0842844   0.1668948   0.0805113   0.0842824   0.1668948   0.080513   0.366414   0.0842844   0.166494   0.8641324   0.0865244   0.6384147   0.	H2O42.mean 8.5241697	4.3895086	6.8414829	3.3113565	4.8100257	3.1670608	6.2500283	2.8805575
H2O504.std0.52747810.46792040.66996280.42512280.39287980.30599600.60946540.3996900H2O672.mean8.25074054.18307616.51148633.13564074.62672472.95751985.95508522.6863969H2O84.mean8.47043434.35048656.66950660.42540280.38792990.30779830.60888830.4012817H2O84.std0.53985560.47690610.69549690.44531800.39433700.32088540.61185770.3918308NET.mean8.0526154774.3785508167.833736873.0851478128.541307693.6546789 171.690150773.605995NET.std87.683028274.3785508167.833736873.0851478 128.541307693.6546789 171.690150773.6059959NO168.mean0.08326280.1789910.04865650.05518100.08408240.17089010.06182020.0845130NO168.std0.0863610.07013280.07621560.03859100.07567510.07437350.11036640.1480846NO336.std0.09033460.07720490.08003980.0558530.07630800.07437350.11036640.1480846NO42.mean0.08055030.12329740.07357750.04153740.06790480.14149730.04952140.0668548NO672.mean0.08512720.1338120.04829300.05749970.0796500.0840860.11284840.1676579NO54.mean0.0869120.03897520.07635390.0462310.07466480.07905600.01535940.05951460.0389574NOS4.mean1.80	H2O42.std 0.5447998	0.4825249	0.7035039	0.4504993	0.4007320	0.3314933	0.6189761	0.3851627
H20672.mean   8.2507405   4.1830761   6.5114863   3.1356407   4.6267247   2.9575198   5.9550852   2.6803969   H20672.std   0.5299801   0.4680479   0.6695066   0.4254028   0.3879299   0.3077983   0.6088883   0.4012817   0.4680484   0.5398556   0.4769061   0.6954969   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   0.468182   0.5398556   0.4769061   0.6954969   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   0.05886881   0.5398556   0.4769061   0.6954969   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   0.05886861   0.5382628   0.1778991   0.0486565   0.0551810   0.0840824   0.1708901   0.0618202   0.0845130   0.0846565   0.0385910   0.0756751   0.0743735   0.1103664   0.1480846   0.03836.mean   0.0891754   0.1240921   0.0505879   0.0589467   0.0906982   0.1825832   0.0630157   0.0848504   0.042.mean   0.0708654   0.0952515   0.0372286   0.0413754   0.0670948   0.1414973   0.0495214   0.0668548   0.054.std   0.0985203   0.1232974   0.0735775   0.0415377   0.0749556   0.0684068   0.1128484   0.1676579   0.0564.std   0.0905429   0.0839672   0.0762353   0.0413754   0.0748648   0.085013   0.0839574   0.0686518   0.0672.mean   0.0871272   0.1183312   0.0482930   0.0576497   0.09069560   0.1928020   0.0599156   0.0845935   0.064.mean   0.0896912   0.1038470   0.0393163   0.0464958   0.0749010   0.1535954   0.0525418   0.0760259   0.008366   0.0771434   0.069048   0.1414973   0.0495241   0.0668548   0.0046231   0.0746648   0.0791140   0.0603673   0.0744356   0.0396351   0.0750297   0.0788534   0.0850766   0.0845935   0.066836   0.066764   0.630601   0.063073   0.0760259   0.076650   0.1928020   0.0599156   0.0845935   0.0548484   0.079149   0.160699   0.06336   0.0646958   0.066764   0.630601   0.668567   0.0396351   0.0750297   0.0788534   0.0525418   0.0560538   0.054848   0.0570976   0.060363   0.066054   0.0668548   0.0548484   0.05197397   0.6565750   0.3930678   0.3140737   0.3676035   0.336659   0.0446495   0.3506448   0.059066   0.060365   0.066064   0.0668548   0.0548484	H2O504.mean 8.2824671	4.2084802	6.5496678	3.1622404	4.6486063	2.9945831	5.9924726	2.7011730
H20672.mean   8.2507405   4.1830761   6.5114863   3.1356407   4.6267247   2.9575198   5.9550852   2.6803969   H20672.std   0.5299801   0.4680479   0.6695066   0.4254028   0.3879299   0.3077983   0.6088883   0.4012817   0.4680484   0.5398556   0.4769061   0.6954969   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   0.468182   0.5398556   0.4769061   0.6954969   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   0.05886881   0.5398556   0.4769061   0.6954969   0.4453180   0.3943370   0.3208854   0.6118577   0.3918308   0.05886861   0.5382628   0.1778991   0.0486565   0.0551810   0.0840824   0.1708901   0.0618202   0.0845130   0.0846565   0.0385910   0.0756751   0.0743735   0.1103664   0.1480846   0.03836.mean   0.0891754   0.1240921   0.0505879   0.0589467   0.0906982   0.1825832   0.0630157   0.0848504   0.042.mean   0.0708654   0.0952515   0.0372286   0.0413754   0.0670948   0.1414973   0.0495214   0.0668548   0.054.std   0.0985203   0.1232974   0.0735775   0.0415377   0.0749556   0.0684068   0.1128484   0.1676579   0.0564.std   0.0905429   0.0839672   0.0762353   0.0413754   0.0748648   0.085013   0.0839574   0.0686518   0.0672.mean   0.0871272   0.1183312   0.0482930   0.0576497   0.09069560   0.1928020   0.0599156   0.0845935   0.064.mean   0.0896912   0.1038470   0.0393163   0.0464958   0.0749010   0.1535954   0.0525418   0.0760259   0.008366   0.0771434   0.069048   0.1414973   0.0495241   0.0668548   0.0046231   0.0746648   0.0791140   0.0603673   0.0744356   0.0396351   0.0750297   0.0788534   0.0850766   0.0845935   0.066836   0.066764   0.630601   0.063073   0.0760259   0.076650   0.1928020   0.0599156   0.0845935   0.0548484   0.079149   0.160699   0.06336   0.0646958   0.066764   0.630601   0.668567   0.0396351   0.0750297   0.0788534   0.0525418   0.0560538   0.054848   0.0570976   0.060363   0.066054   0.0668548   0.0548484   0.05197397   0.6565750   0.3930678   0.3140737   0.3676035   0.336659   0.0446495   0.3506448   0.059066   0.060365   0.066064   0.0668548   0.0548484	H2O504.std 0.5274781	0.4679204	0.6699628	0.4251228	0.3928798	0.3059966	0.6094654	0.3996900
H20672.std0.52998010.46804790.66950660.42540280.38792990.30779830.60888830.4012817H2084.mean8.47043434.35048656.76793883.27834374.76850263.13322676.18513002.8420338NET.mean80.526154774.3785508167.833736873.0851478 128.541307693.6546789 171.690150773.6059595NET.std87.683028278.6126033174.570522562.2764092 133.059120382.5527469 172.493228764.8169662NO168.mean0.08326280.11789910.04865650.05518100.08408240.1708010.06182020.0845130NO336.mean0.08917540.12409210.05058790.05894670.09609820.1825320.06301570.0884501NO336.std0.07086540.09525150.037222860.041137540.06790480.14149730.04952140.0668548NO42.std0.09855030.12329740.073757750.04153770.07456480.08051130.08395740.0863361NO504.std0.09054290.08396720.07635390.04062310.07502970.0785340.08591560.0845935NO672.mean0.08712720.11833120.04829300.0574970.09065600.19280200.0591660.0845935NOS4.mean0.0669120.10384700.03931630.04649580.077602970.0785340.05251480.052518NOX168.mean1.8006741.61805260.84850110.7140191.44699601.82472971.09333230.858732NOX336.std0.51973970.4535324	H2O672.mean 8.2507405	4.1830761	6.5114863	3.1356407	4.6267247	2.9575198	5.9550852	
H2O84.mean8.47043434.35048656.76793883.27834374.76850263.13322676.18513002.8420338H2O84.std0.53985560.47690610.69549690.44531800.39433700.32088540.61185770.3918308NET.mean80.526154774.3785508167.833736873.0851478 128.541307693.6546789171.690150773.6059595NET.std87.683028274.6126033174.570522562.2764092 133.059120382.5527469172.493228764.816962NO168.mean0.088326280.11789910.04865650.05518100.08408240.17089010.6182020.0845130NO336.mean0.08917540.12409210.05058790.05894670.0960820.18258320.06301570.0884510NO336.std0.0903460.07720490.08003980.05585330.07632800.07870670.068656590.0772434NO42.mean0.09855030.12329740.07357750.04137540.06790480.14149730.04952140.0668548NO504.mean0.08862740.12266540.04905830.05864380.08932890.19068100.06156470.0689388NO672.mean0.08712720.11833120.04829300.05749970.0760500.19280200.05991560.0845935NOX168.mean1.80067640.090140930.08789550.07443560.039363510.07490100.15359540.05254180.0760259NOX36.mean1.7896071.63016010.86195010.71104970.04649580.07199500.15359540.05254180.0760259	H2O672.std 0.5299801	0.4680479		0.4254028	0.3879299	0.3077983		0.4012817
H2O84.std         0.5398556         0.4769061         0.6954969         0.4453180         0.3943370         0.3208854         0.6118577         0.3918308           NET.mean         80.5261547         74.3785508         167.833736873.0851478 128.541307693.6546789 171.690150773.6059595           NET.std         87.6830282         78.6126033         174.570522562.2764092 133.059120382.5527469 172.493228764.8169662           NO168.mean         0.0883628         0.1178991         0.0486565         0.0551810         0.0840824         0.1708901         0.0618202         0.0845130           NO336.mean         0.0891754         0.1240921         0.0505879         0.059467         0.0906982         0.1825832         0.0630157         0.084501           NO336.std         0.0903346         0.0772049         0.0800398         0.0558533         0.0763280         0.0787067         0.0865659         0.0772434           NO42.mean         0.0708654         0.0952515         0.0372286         0.0415377         0.0749556         0.0684088         0.1128484         0.1676579           NO504.mean         0.0886274         0.1226654         0.0490533         0.058438         0.0893289         0.1906810         0.0615647         0.0683516           NO504.mean         0.0871722         0.1183312         0.				3.2783437	4.7685026	3.1332267		
NET.mean         80.5261547         74.3785508         167.833736873.0851478 128.541307693.6546789 171.690150773.6059595         71.690150773.6059595           NET.std         87.6830282         78.6126033         174.570522562.2764092 133.059120382.5527469 172.493228764.8169662           NO168.mean         0.0832628         0.1178991         0.0486565         0.0551810         0.0840824         0.1708901         0.0618202         0.0845130           NO336.mean         0.0868361         0.0701328         0.0762156         0.0385910         0.0756751         0.0743735         0.1103664         0.1440846           NO336.mean         0.0903346         0.0772049         0.0800398         0.0558530         0.0762050         0.0787067         0.0865659         0.0772434           NO42.mean         0.0708654         0.0952515         0.0372286         0.0413754         0.0679048         0.1414973         0.0495214         0.0668548           NO504.mean         0.0886274         0.1226654         0.0490583         0.0586480         0.0893289         0.1906810         0.0615647         0.0683516           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906500         0.192802         0.0599156         0.0845935           NO672.std         0.0991493								
NET.std         87.6830282         78.6126033         174.570522562.2764092         133.059120382.5527469         172.493228764.8169662           NO168.mean         0.0832628         0.1178991         0.048655         0.0551810         0.0840824         0.1708901         0.0618202         0.0845130           NO336.mean         0.088361         0.0701328         0.0762156         0.0385910         0.0756751         0.0743735         0.1103664         0.1480846           NO336.mean         0.0891754         0.1240921         0.0505879         0.0589467         0.0906982         0.1825832         0.063157         0.0884501           NO336.std         0.0903346         0.0772049         0.0800398         0.0558533         0.0769048         0.1414973         0.0495214         0.0668548           NO42.mean         0.0856274         0.0952515         0.0372286         0.0413754         0.0679048         0.1414973         0.0495214         0.0668548           NO504.mean         0.0886274         0.1226654         0.0490583         0.0586438         0.0893289         0.1906810         0.0615647         0.086316           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906560         0.1928020         0.0599156         0.0845935								
NO168.mean         0.0832628         0.1178991         0.0486565         0.0551810         0.0840824         0.1708901         0.0618202         0.0845130           NO168.std         0.0868361         0.0701328         0.0762156         0.0385910         0.0756751         0.0743735         0.1103664         0.1480846           NO336.mean         0.0891754         0.1240921         0.0505879         0.0589467         0.0906982         0.1825832         0.0630157         0.0884501           NO42.mean         0.0708654         0.0952515         0.0372286         0.0413754         0.0679048         0.1414973         0.0495214         0.0668548           NO42.mean         0.0886274         0.1226654         0.0490583         0.0586438         0.0893289         0.1906810         0.0615647         0.066558           NO504.mean         0.0871272         0.1183312         0.0490583         0.0586438         0.0893289         0.1906810         0.0615647         0.0683516           NO504.mean         0.0871272         0.1183312         0.0448933         0.0574997         0.0906560         0.192802         0.0599156         0.0845935           NO672.std         0.0914093         0.0878955         0.0744356         0.0393163         0.0464958         0.0749010 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>								
NO168.std         0.0868361         0.0701328         0.0762156         0.0385910         0.0756751         0.0743735         0.1103664         0.1480846           NO336.mean         0.0891754         0.1240921         0.0505879         0.0589467         0.0906982         0.1825832         0.0630157         0.0884501           NO336.std         0.0903346         0.0772049         0.0800398         0.0585853         0.0763280         0.0787067         0.0865659         0.0772434           NO42.mean         0.0708654         0.0952515         0.0372286         0.0413754         0.0679048         0.1414973         0.0495214         0.0668548           NO42.std         0.0985503         0.1232974         0.0735775         0.041377         0.0749566         0.0684068         0.1128484         0.1676759           NO504.mean         0.0886274         0.1226654         0.0490583         0.0586438         0.0893289         0.1906810         0.0615647         0.0689388           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906560         0.192802         0.0599156         0.0845935           NO642.mean         0.069912         0.1038470         0.0393163         0.0464958         0.0749010         0.1535954								
NO336.mean         0.0891754         0.1240921         0.0505879         0.0589467         0.0906982         0.1825832         0.0630157         0.0884501           NO336.std         0.0903346         0.0772049         0.0800398         0.0558533         0.0763280         0.0787067         0.0865659         0.0772434           NO42.mean         0.0708654         0.0952515         0.0372286         0.0413754         0.0679048         0.1414973         0.0495214         0.0668548           NO42.std         0.0985503         0.1232974         0.0735775         0.0413757         0.0749556         0.0684068         0.1128484         0.167679           NO504.mean         0.0886274         0.1226654         0.0490583         0.0586438         0.0893289         0.1966810         0.0615647         0.066316           NO504.std         0.0905429         0.0839672         0.0763539         0.046231         0.0748648         0.0805113         0.0839574         0.0689388           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906560         0.1928020         0.0599156         0.0843935           NO642.mean         0.0696912         0.1038470         0.0393163         0.0464958         0.0749010         0.153594         0								
NO336.std         0.0903346         0.0772049         0.0800398         0.0558533         0.0763280         0.0787067         0.0865659         0.0772434           NO42.mean         0.0708654         0.0952515         0.0372286         0.0413754         0.0679048         0.1414973         0.0495214         0.0668548           NO42.std         0.0985503         0.1232974         0.0735775         0.0415377         0.0749556         0.0684068         0.1128484         0.1676579           NO504.mean         0.0886274         0.1226654         0.0490583         0.0586438         0.0893289         0.1906810         0.0615647         0.0863516           NO504.std         0.0905429         0.0839672         0.0763539         0.0406231         0.0748648         0.0805113         0.0839574         0.0689388           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906560         0.1928020         0.0599156         0.0845935           NO672.std         0.0914093         0.0878955         0.0744356         0.0396351         0.0750297         0.0788534         0.0599156         0.0845935           NO84.mean         1.8006764         1.6301601         0.8619501         0.7170419         1.4469960         1.8247297 <th< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>								
NO42.mean         0.0708654         0.0952515         0.0372286         0.0413754         0.0679048         0.1414973         0.0495214         0.0668548           NO42.std         0.0985503         0.1232974         0.0735775         0.0415377         0.0749556         0.0684068         0.1128484         0.1676579           NO504.mean         0.0886274         0.1226654         0.0490583         0.0586438         0.0893289         0.1906810         0.0615647         0.0863516           NO504.std         0.0905429         0.0839672         0.0763539         0.0406231         0.0748648         0.0805113         0.0839574         0.0689388           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906560         0.1928020         0.0559156         0.0845935           NO672.std         0.0914093         0.0878955         0.0744356         0.0396351         0.0750297         0.0788534         0.0850076         0.0760259           NO84.mean         0.0696912         0.1038470         0.0393163         0.0464958         0.0749010         0.153594         0.0525418         0.0760259           NOx168.mean         1.8006764         1.6301601         0.8619501         0.7170419         1.4469960         1.8247297 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>								
NO42.std         0.0985503         0.1232974         0.0735775         0.0415377         0.0749556         0.0684068         0.1128484         0.1676579           NO504.mean         0.0886274         0.1226654         0.0490583         0.0586438         0.0893289         0.1906810         0.0615647         0.0863516           NO504.std         0.0905429         0.0839672         0.0763539         0.0406231         0.0748648         0.0805113         0.0839574         0.0689388           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906560         0.1928020         0.0599156         0.0845935           NO672.std         0.0914093         0.0878955         0.0744356         0.0396351         0.0750297         0.078534         0.0850076         0.0706539           NO84.mean         0.0696912         0.1038470         0.0393163         0.0464958         0.0749010         0.1535954         0.0525418         0.0706259           NOx168.mean         1.8006764         1.6301601         0.8619501         0.7170419         1.4469960         1.8247297         1.0933323         0.8587882           NOx336.mean         1.7959607         1.6180526         0.8485011         0.7146270         1.4394845         1.8213682								
NO504.mean0.08862740.12266540.04905830.05864380.08932890.19068100.06156470.0863516NO504.std0.09054290.08396720.07635390.04062310.07486480.08051130.08395740.0689388NO672.mean0.08712720.11833120.04829300.05749970.09065600.19280200.05991560.0845935NO672.std0.09140930.08789550.07443560.03963510.07502970.07885340.08500760.0706539NO84.mean0.06969120.10384700.03931630.04649580.07490100.15359540.05254180.0760259NO84.std0.07971400.06030730.07296240.04198330.07519140.07199550.09446490.1160699NOx168.mean1.80067641.63016010.86195010.71704191.44699601.82472971.09333230.8587382NOx168.std0.51973970.45353240.46256670.70038890.37061190.34117480.46216000.3910069NOx336.mean1.79596071.61805260.84850110.71462701.43948451.82136821.08244230.8536414NOx42.mean1.80935221.62241460.86253800.70143391.44011441.79626481.11018870.8502164NOx504.mean1.78117941.59452100.83901830.71909621.41765311.82525141.06484970.8472283NOx504.std0.58978770.65770560.43284580.60360450.33560130.35265930.3316057 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
NO504.std         0.0905429         0.0839672         0.0763539         0.0406231         0.0748648         0.0805113         0.0839574         0.0689388           NO672.mean         0.0871272         0.1183312         0.0482930         0.0574997         0.0906560         0.1928020         0.0599156         0.0845935           NO672.std         0.0914093         0.0878955         0.0744356         0.0396351         0.0750297         0.0788534         0.0850076         0.0706539           NO84.mean         0.0696912         0.1038470         0.0393163         0.0464958         0.0749010         0.1535954         0.0525418         0.0760259           NOX168.mean         1.8006764         1.6301601         0.8619501         0.7170419         1.4469960         1.8247297         1.0933323         0.8587382           NOX168.std         0.5197397         0.4535324         0.4625667         0.7003889         0.3706119         0.3411748         0.4621600         0.3910069           NOX36.mean         1.7959607         1.6180526         0.8485011         0.7146270         1.4394845         1.8213682         1.0824423         0.8536414           NOX42.mean         1.8093522         1.6224146         0.8625380         0.7014339         1.4401144         1.7962648								
NO672.mean0.08712720.11833120.04829300.05749970.09065600.19280200.05991560.0845935NO672.std0.09140930.08789550.07443560.03963510.07502970.07885340.08500760.0706539NO84.mean0.06969120.10384700.03931630.04649580.07490100.15359540.05254180.0760259NO84.std0.07971400.06030730.07296240.04198330.07519140.07199550.09446490.1160699NOx168.mean1.80067641.63016010.86195010.71704191.44699601.82472971.09333230.8587382NOx168.std0.51973970.45353240.46256670.70038890.37061190.34117480.46216000.3910069NOx336.mean1.79596071.61805260.84850110.71462701.43948451.82136821.08244230.8536414NOx336.std0.54994710.56877750.39306780.31407370.36760350.33676590.42168940.3590915NOx42.mean1.80935221.62241460.86253800.70143391.44011441.79626481.11018870.8641324NOx504.mean1.78117941.59452100.83901830.71909621.41765311.82525141.06484970.8472283NOx672.mean1.76314461.57032240.83134920.71641931.40993431.82618451.05941630.8493411NOx672.std0.54879840.53790510.38153420.33560130.35555510.33160570.4136651 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
NO672.std0.09140930.08789550.07443560.03963510.07502970.07885340.08500760.0706539NO84.mean0.06969120.10384700.03931630.04649580.07490100.15359540.05254180.0760259NO84.std0.07971400.06030730.07296240.04198330.07519140.07199550.09446490.1160699NOx168.mean1.80067641.63016010.86195010.71704191.44699601.82472971.09333230.8587382NOx168.std0.51973970.45353240.46256670.70038890.37061190.34117480.46216000.3910069NOx336.mean1.79596071.61805260.84850110.71462701.43948451.82136821.08244230.8536414NOx336.std0.54994710.56877750.39306780.31407370.36760350.33676590.42168940.3590915NOx42.mean1.80935221.62241460.86253800.70143391.44011441.79626481.11018870.8502164NOx504.mean1.78117941.59452100.83901830.71909621.41765311.82525141.06484970.8472283NOx504.std0.58978770.65770560.43284580.60360450.35265930.33126440.41327020.3432988NOx672.std0.54879840.53790510.38153420.33560130.35555510.33160570.41366510.3522673NOx84.mean1.79051421.62965610.86081480.70531001.44113041.81183281.0974465 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
NO84.mean0.06969120.10384700.03931630.04649580.07490100.15359540.05254180.0760259NO84.std0.07971400.06030730.07296240.04198330.07519140.07199550.09446490.1160699NOx168.mean1.80067641.63016010.86195010.71704191.44699601.82472971.09333230.8587382NOx168.std0.51973970.45353240.46256670.70038890.37061190.34117480.46216000.3910069NOx336.mean1.79596071.61805260.84850110.71462701.43948451.82136821.08244230.8536414NOx336.std0.54994710.56877750.39306780.31407370.36760350.33676590.42168940.3590915NOx42.mean1.80935221.62241460.86253800.70143391.44011441.79626481.11018870.8502164NOx504.mean1.78117941.59452100.83901830.71909621.41765311.82525141.06484970.8472283NOx504.std0.58978770.65770560.43284580.60360450.35265930.33126440.41327020.3432988NOx672.mean1.76314461.57032240.83134920.71641931.4093431.82618451.05941630.8493411NOx84.mean1.79051421.62965610.86081480.70531001.44113041.81183281.09744650.8517585NOx84.std0.51279980.44340930.44905620.45471830.37444750.35041280.4846042 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
NO84.std0.07971400.06030730.07296240.04198330.07519140.07199550.09446490.1160699NOx168.mean1.80067641.63016010.86195010.71704191.44699601.82472971.09333230.8587382NOx168.std0.51973970.45353240.46256670.70038890.37061190.34117480.46216000.3910069NOx336.mean1.79596071.61805260.84850110.71462701.43948451.82136821.08244230.8536414NOx336.std0.54994710.56877750.39306780.31407370.36760350.33676590.42168940.3590915NOx42.mean1.80935221.62241460.86253800.70143391.44011441.79626481.11018870.8502164NOx504.mean1.78117941.59452100.83901830.71909621.41765311.82525141.06484970.8472283NOx504.std0.58978770.65770560.43284580.60360450.35265930.33126440.41327020.3432988NOx672.mean1.76314461.57032240.83134920.71641931.40993431.82618451.05941630.8493411NOx672.std0.54879840.53790510.38153420.33560130.35555510.33160570.41366510.3522673NOx84.mean1.79051421.62965610.86081480.70531001.44113041.81183281.09744650.8517585NOx84.std0.51279980.44340930.44905620.45471830.37444750.35041280.4846042<								
NOx168.mean1.80067641.63016010.86195010.71704191.44699601.82472971.09333230.8587382NOx168.std0.51973970.45353240.46256670.70038890.37061190.34117480.46216000.3910069NOx336.mean1.79596071.61805260.84850110.71462701.43948451.82136821.08244230.8536414NOx336.std0.54994710.56877750.39306780.31407370.36760350.33676590.42168940.3590915NOx42.mean1.80935221.62241460.86253800.70143391.44011441.79626481.11018870.8502164NOx42.std0.63841470.77919020.43970160.33269020.38959160.36431030.61641940.8641324NOx504.mean1.78117941.59452100.83901830.71909621.41765311.82525141.06484970.8472283NOx672.mean1.76314461.57032240.83134920.71641931.40993431.82618451.05941630.8493411NOx672.std0.54879840.53790510.38153420.33560130.35555510.33160570.41366510.3522673NOx84.mean1.79051421.62965610.86081480.70531001.44113041.81183281.09744650.8517585NOx84.std0.51279980.44340930.44905620.45471830.37444750.35041280.48460420.4074471O3168.mean28.95639558.701544437.13543057.937559135.58171729.582073938.196								
NOx168.std         0.5197397         0.4535324         0.4625667         0.7003889         0.3706119         0.3411748         0.4621600         0.3910069           NOx336.mean         1.7959607         1.6180526         0.8485011         0.7146270         1.4394845         1.8213682         1.0824423         0.8536414           NOx336.std         0.5499471         0.5687775         0.3930678         0.3140737         0.3676035         0.3367659         0.4216894         0.3590915           NOx42.mean         1.8093522         1.6224146         0.8625380         0.7014339         1.4401144         1.7962648         1.1101887         0.8502164           NOx42.std         0.6384147         0.7791902         0.4397016         0.3326902         0.3895916         0.3643103         0.6164194         0.8641324           NOx504.mean         1.7811794         1.5945210         0.8390183         0.7190962         1.4176531         1.8252514         1.0648497         0.8472283           NOx672.mean         1.7631446         1.5703224         0.8313492         0.7164193         1.4099343         1.8261845         1.0594163         0.8493411           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328								
NOx336.mean         1.7959607         1.6180526         0.8485011         0.7146270         1.4394845         1.8213682         1.0824423         0.8536414           NOx336.std         0.5499471         0.5687775         0.3930678         0.3140737         0.3676035         0.3367659         0.4216894         0.3590915           NOx42.mean         1.8093522         1.6224146         0.8625380         0.7014339         1.4401144         1.7962648         1.1101887         0.8502164           NOx42.std         0.6384147         0.7791902         0.4397016         0.3326902         0.3895916         0.3643103         0.6164194         0.8641324           NOx504.mean         1.7811794         1.5945210         0.8390183         0.7190962         1.4176531         1.8252514         1.0648497         0.8472283           NOx504.std         0.5897877         0.6577056         0.4328458         0.6036045         0.3526593         0.3312644         0.4132702         0.3432988           NOx672.mean         1.7631446         1.5703224         0.8313492         0.7164193         1.4099343         1.8261845         1.0594163         0.8493411           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328								
NOx336.std         0.5499471         0.5687775         0.3930678         0.3140737         0.3676035         0.3367659         0.4216894         0.3590915           NOx42.mean         1.8093522         1.6224146         0.8625380         0.7014339         1.4401144         1.7962648         1.1101887         0.8502164           NOx42.std         0.6384147         0.7791902         0.4397016         0.3326902         0.3895916         0.3643103         0.6164194         0.8641324           NOx504.mean         1.7811794         1.5945210         0.8390183         0.7190962         1.4176531         1.8252514         1.0648497         0.8472283           NOx504.std         0.5897877         0.6577056         0.4328458         0.6036045         0.3526593         0.3312644         0.4132702         0.3432988           NOx672.mean         1.7631446         1.5703224         0.8313492         0.7164193         1.4099343         1.8261845         1.0594163         0.8493411           NOx672.std         0.5487984         0.5379051         0.3815342         0.3356013         0.3555551         0.3316057         0.4136651         0.3522673           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328								
NOx42.mean         1.8093522         1.6224146         0.8625380         0.7014339         1.4401144         1.7962648         1.1101887         0.8502164           NOx42.std         0.6384147         0.7791902         0.4397016         0.3326902         0.3895916         0.3643103         0.6164194         0.8641324           NOx504.mean         1.7811794         1.5945210         0.8390183         0.7190962         1.4176531         1.8252514         1.0648497         0.8472283           NOx504.std         0.5897877         0.6577056         0.4328458         0.6036045         0.3526593         0.3312644         0.4132702         0.3432988           NOx672.mean         1.7631446         1.5703224         0.8313492         0.7164193         1.4099343         1.8261845         1.0594163         0.8493411           NOx672.std         0.5487984         0.5379051         0.3815342         0.3356013         0.3555551         0.3316057         0.4136651         0.3522673           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328         1.0974465         0.8517585           NOx84.std         0.5127998         0.4434093         0.4490562         0.4547183         0.3744475         0.3504128								
NOx42.std         0.6384147         0.7791902         0.4397016         0.3326902         0.3895916         0.3643103         0.6164194         0.8641324           NOx504.mean         1.7811794         1.5945210         0.8390183         0.7190962         1.4176531         1.8252514         1.0648497         0.8472283           NOx504.std         0.5897877         0.6577056         0.4328458         0.6036045         0.3526593         0.3312644         0.4132702         0.3432988           NOx672.mean         1.7631446         1.5703224         0.8313492         0.7164193         1.4099343         1.8261845         1.0594163         0.8493411           NOx672.std         0.5487984         0.5379051         0.3815342         0.3356013         0.3555551         0.3316057         0.4136651         0.3522673           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328         1.0974465         0.8517585           NOx84.std         0.5127998         0.4434093         0.4490562         0.4547183         0.3744475         0.3504128         0.4846042         0.4074471           O3168.mean         28.9563955         8.7015444         37.1354305         7.9375591         35.5817172         9.5820739								
NOx504.mean       1.7811794       1.5945210       0.8390183       0.7190962       1.4176531       1.8252514       1.0648497       0.8472283         NOx504.std       0.5897877       0.6577056       0.4328458       0.6036045       0.3526593       0.3312644       0.4132702       0.3432988         NOx672.mean       1.7631446       1.5703224       0.8313492       0.7164193       1.4099343       1.8261845       1.0594163       0.8493411         NOx672.std       0.5487984       0.5379051       0.3815342       0.3356013       0.3555551       0.3316057       0.4136651       0.3522673         NOx84.mean       1.7905142       1.6296561       0.8608148       0.7053100       1.4411304       1.8118328       1.0974465       0.8517585         NOx84.std       0.5127998       0.4434093       0.4490562       0.4547183       0.3744475       0.3504128       0.4846042       0.4074471         O3168.mean       28.9563955       8.7015444       37.1354305       7.9375591       35.5817172       9.5820739       38.1966494       7.6531242								
NOx504.std         0.5897877         0.6577056         0.4328458         0.6036045         0.3526593         0.3312644         0.4132702         0.3432988           NOx672.mean         1.7631446         1.5703224         0.8313492         0.7164193         1.4099343         1.8261845         1.0594163         0.8493411           NOx672.std         0.5487984         0.5379051         0.3815342         0.3356013         0.3555551         0.3316057         0.4136651         0.3522673           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328         1.0974465         0.8517585           NOx84.std         0.5127998         0.4434093         0.4490562         0.4547183         0.3744475         0.3504128         0.4846042         0.4074471           O3168.mean         28.9563955         8.7015444         37.1354305         7.9375591         35.5817172         9.5820739         38.1966494         7.6531242								
NOx672.mean         1.7631446         1.5703224         0.8313492         0.7164193         1.4099343         1.8261845         1.0594163         0.8493411           NOx672.std         0.5487984         0.5379051         0.3815342         0.3356013         0.3555551         0.3316057         0.4136651         0.3522673           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328         1.0974465         0.8517585           NOx84.std         0.5127998         0.4434093         0.4490562         0.4547183         0.3744475         0.3504128         0.4846042         0.4074471           O3168.mean         28.9563955         8.7015444         37.1354305         7.9375591         35.5817172         9.5820739         38.1966494         7.6531242								
NOx672.std         0.5487984         0.5379051         0.3815342         0.3356013         0.3555551         0.3316057         0.4136651         0.3522673           NOx84.mean         1.7905142         1.6296561         0.8608148         0.7053100         1.4411304         1.8118328         1.0974465         0.8517585           NOx84.std         0.5127998         0.4434093         0.4490562         0.4547183         0.3744475         0.3504128         0.4846042         0.4074471           O3168.mean         28.9563955         8.7015444         37.1354305         7.9375591         35.5817172         9.5820739         38.1966494         7.6531242								
NOx84.mean       1.7905142       1.6296561       0.8608148       0.7053100       1.4411304       1.8118328       1.0974465       0.8517585         NOx84.std       0.5127998       0.4434093       0.4490562       0.4547183       0.3744475       0.3504128       0.4846042       0.4074471         O3168.mean       28.9563955       8.7015444       37.1354305       7.9375591       35.5817172       9.5820739       38.1966494       7.6531242	NOx672.mean 1.7631446							
NOx84.std 0.5127998 0.4434093 0.4490562 0.4547183 0.3744475 0.3504128 0.4846042 0.4074471 O3168.mean 28.9563955 8.7015444 37.1354305 7.9375591 35.5817172 9.5820739 38.1966494 7.6531242		0.5379051						
O3168.mean 28.9563955 8.7015444 37.1354305 7.9375591 35.5817172 9.5820739 38.1966494 7.6531242		1.6296561	0.8608148			1.8118328	1.0974465	0.8517585
	NOx84.std 0.5127998	0.4434093	0.4490562	0.4547183	0.3744475	0.3504128	0.4846042	0.4074471
O3168.std 3.5209114 2.3207539 4.0125807 2.2471876 3.1157460 2.1628869 4.0468967 2.3752102	O3168.mean 28.9563955	8.7015444	37.1354305	7.9375591	35.5817172	9.5820739	38.1966494	7.6531242
	O3168.std 3.5209114	2.3207539	4.0125807	2.2471876	3.1157460	2.1628869	4.0468967	2.3752102
		8.5799124	35.9105184	8.1806544	34.7646199	9.6125137	37.1545134	8.0531688

	1	1	11 TT	1 77 1	1 T	1 7 1	1 T1	
	class_non.m	ieachass_non.	sœlassII.mea	nclassII.sd	classla.mea	nclassla.sd	class1b.mea	mlass1b.sd
O342.std	3.9320093	2.5715429	4.5629995		3.4300530	2.2983362	4.5916329	2.6110586
O3504.mean	29.9223688	8.7826482	38.1124111	7.6215776	36.1765368	9.4885172	38.9206969	7.4458559
O3504.std	3.3379269	2.1808745	3.6198586	2.0168362	2.9581700	2.1895254	3.6856651	2.1572885
O3672.mean	30.2570159	8.8153168	38.4638542	7.5423407	36.4179137	9.4671344	39.1708386	7.4083422
O3672.std	3.2974286	2.1320519	3.4793625	1.8999729	2.8855798	2.2111996	3.5270694	2.0859228
O384.mean	28.2950117	8.6449395	36.4847757	8.0918533	35.2079586	9.5844538	37.6702692	7.8834566
O384.std	3.6818176	2.4325495	4.2321932	2.3653424	3.1852934	2.1710969	4.2537071	2.4787015
${\bf Pamb 0. mean}$	989.5739182	10.4595733	992.434422	17.5447690	993.083107	512.7955733	3993.8398014	49.2653530
Pamb0.std	0.9036629	0.7414164	1.1832659	0.8141691	1.0277771	0.6889135	1.1659888	0.8041929
PAR.mean	252.1034293	219.836291	0521.825264	7189.138226	3 <b>2</b> 15.749190	2262.77427	3 <b>6</b> 33.1584717	7184.637852
PAR.std	201.6516309	180.623172	4387.977789	5139.014894	4 <b>0</b> 286.6517870	0191.622924	<b>18</b> 86.993314	4139.2281508
PTG.mean	0.0013185	0.0072903	_	0.0047814	-	0.0053309	-	0.0031918
			0.0005988		0.0007118		0.0016611	
PTG.std	0.0067485	0.0064188	0.0120327	0.0058381		0.0069848	0.0115483	0.0054228
RGlob.mean		14.4447614	36.2972617					11.9587230
RGlob.std	13.7137875		23.9939113					
RHIRGA168.			57.2879848					
RHIRGA168.		4.7117565	11.6976471				12.1942132	
RHIRGA336.			57.4444120					
RHIRGA336.		4.6981200	11.4247132				11.9648446	
RHIRGA42.n			58.4772003				956.8580399	
RHIRGA42.s		5.0783234	12.4831364				13.0917220	
RHIRGA504.			57.3573156				15.0317220	
RHIRGA504.		4.6848747	11.1521853				11.5776651	
RHIRGA672.			57.8459091					
RHIRGA672.		4.6333869	10.9344953				11.2599693	
RHIRGA84.n			57.6708747					
RHIRGA84.s			12.1984752				12.7443155	
RPAR.mean		4.9777942	22.5765995				24.4094019	
	10.5616485							
RPAR.std		8.7993333					16.9022109	
SO2168.mean		0.4872757	0.1926844		0.1695263		0.2362119	0.3058720
SO2168.std	0.1529806	0.1386084	0.1577387	0.1276472			0.1684688	0.1246219
SWS.mean	901.2928793		915.222233					
SWS.std	28.9825589		16.4777475				5 12.6442312	
T168.mean	6.0779466		8.5962921		2.8687104		7.6928053	8.0038911
	1.3599286	0.9772331					2.4789441	
T42.mean	6.1653770		8.6499311		2.9865494		7.7541718	8.0064785
T42.std	1.4646568	1.1112941	2.6472802		2.1859501		2.7393903	1.0755007
T504.mean	5.8160029		8.2703335		2.5531536		7.3368535	8.0393041
T504.std	1.2650820	0.9053966	2.1760562		1.8472449		2.2836336	0.9179909
T672.mean	5.6329681		8.0609689		2.3391703		7.1069544	8.0400739
T672.std	1.2171312	0.8754616	2.0874301		1.7835714		2.1963858	0.8942363
T84.mean	6.1500669		8.6976018		2.9538699		7.8076448	8.0135334
T84.std	1.4406672	1.0637270	2.5498165		2.1481955		2.6451795	1.0221479
$UV\_A.mean$	7.6842886	6.1089685					14.7907621	
UV A.std	5.6597847	4.8468768	10.3911167	3.9771654	7.5590838	5.1088458	10.3899427	3.9910193
	0.2050000	0.3044106	0.6028462	0.2732618	0.4214711	0.2929315	0.5940769	0.2781953
UV_B.mean	0.3258228	0.3044100						
	0.3238228 $0.2887586$	0.3044100 $0.2824756$	0.5214276		0.3465650	0.2574466	0.5066760	0.2556018
$UV\_B.mean$				0.2522659			$\begin{array}{c} 0.5066760 \\ 0.0024524 \end{array}$	$\begin{array}{c} 0.2556018 \\ 0.0016285 \end{array}$

We notice that there are some undefined measurements, but they do not have a large impact. Laplace smoothing of 1 was used for the data. The estimated class probabilities for the training data:

#### nb\_class

# **Class Distribution**



The class distibution plotted.

#### 3. Machine learning methods and steps

I applied Gaussian NB classifier [7] to compute the class probabilities for all rows of testing data. The variables were considered as conditionally independent (because of that is the pre-assumption), even though some of them might have a relationship, i.e. smaller or larger correlation.

The variables were studied and only a subset of the variables were used. There were some challenges choosing the variables. The classifier predicted the probabilities of each class for each row. The row was identified as nonevent, if the probability was higher than the nb\_class probability for that class.

The formula of NB Gaussian density was

$$\frac{e^{(-(x-\mu)^2/(2*\sigma^2))}}{\sqrt{2*\pi*\sigma^2}}\tag{1}$$

I used some small coefficient adjustments and modifications for the multiclass classification problem. The multiclass problem was, of course, more challenging than the binary classification problem because of more events to be predicted.

The predicted probabilities were compared step by step, with different coefficients. The target was to produce reasonable prediction probabilities for the classes.

After having identified the class as **nonevent** or **event**, the event class had to be predicted, if it was not **nonevent**. I compared the probabilities of different predicted events with NB classifier and chose suitable coefficients for predicting the event classes. I guessed that the accuracy of the binary classification could be 0.73.

Regarding the different classification sub-tasks, the main target was to build a reasonably performing binary classifier. Building a more accurate event class classifier was not as important, although the higher accuracy, the better.

The first 15 estimated classes and probabilities were:

#### head(df, 15)

```
##
## 1
          0.73
## 2
        class4
                   0.727504450479219
## 3
            Ιa
                   0.080463843559317
      nonevent
## 5
            Ib
                   0.990897111743513
## 6
            II
                   0.991238939899939
## 7
                   0.120253990842419
      nonevent
## 8
                   0.978951849227886
            II
      nonevent 0.000677548460571997
## 9
## 10 nonevent
                0.00245307701477748
## 11
            TT
                   0.926588565138545
## 12
            II
                   0.539002979107427
## 13 nonevent
                0.00085019262958641
## 14 nonevent
                   0.497539389391826
## 15
                   0.790420964630693
```

In the above table, the first row contains the guessed accuracy, and the second row labels for the classes and probabilities: class4 and p.

After that, each row contained the predicted class and prediction probability for the class being an event class, for each data row in the test data. So if the probability p was 0.3, the probability of a non-event would have then been 0.7.

This whole data frame was exported as a csv file answers.csv. That file contains all the predicted results.

#### 4. Summary and discussing

The predicted class distributions for testing data for classes nonevent, II, Ia, Ib:

```
## [1] 0.4611399
```

## [1] 0.2683938

## [1] 0.09948187

## [1] 0.1709845

These probabilities were quite close to the probabilities in the training data.

It turned out that my binary accuracy (predicting event vs. nonevent) was about 0.795, actually higher than the guessed value 0.73. The margin of error was quite small: about 0.065. In addition, the multiaccuracy (predicting the correct class) was around 0.585, meaning that the model could have performed better, but at least it predicted almost 3 out of 5 classes correctly. As expected, it was more difficult to predict event classes than to predict binary classes (i.e. event vs. non-event).

The perplexity value turned out to be 1.65, meaning that it was placed between 1 and 2, the perplexities of "perfect" and dummy random classifiers. The perfect classifier would predict the class always correct, and dummy classifier would assign probability 0.5 to both binary classes.

Regarding the methods, I also considered using cross-validation, Random Forest, logistic regression, kNN and SVM. I ended up in using NB, because of the pros of it. The model is highly scalable and simple generative classifier, it can usually be trained efficiently in supervised learning, and it often requires only a small number of training data. In addition, it is not much affected by random noise and rarely leads to overfitting.

The downsides of using NB in this project were that all the variables were not independent and normally distributed. Those are the assumptions, but by leaving the correlated and not normally distributed variables out, the assumption is still kind of holding, and the classifier performed reasonably. The model can still be biased in some situations.

One of the features of NB is that it can be making strong assumptions based on the data, because it is a "naive" model. However, that can also be advantageous, but not every time. Moreover, the model requires information about the distributions and the probabilities, which need to be estimated.

As a hindsight, different subset of the feature variables could have been used. One option would have been to use e.g. only mean values instead of std values, or other variables based on correlations.

There were initially some problems with the class distributions, but after making some tweaks, I got the NB classifier to predict reasonable results. I learned a lot about the effectiviness and usability of the NB classifier. Hopefully this research is helpful in some way and makes opportunities for future work.

#### 5. Self-grading

"At the end of the course, you will be asked to give your project deliverables (final report, presentation, and challenge submission) an integer grade on a scale from 0 (fail) to 5 (excellent)".

I am giving these grades to my deliverables:

- Challenge submission: 3. This looked as it should, and was returned in time. The accuracy could have been a bit better, but there are no large problems with it. This showed understanding of the topic and was suitable for the problem. The challenge was based on the model, and overall, the level was average.
- Presentation: 0. Unfortunately, I didn't have time with this.
- Final report: 3. The level of this final report was also average as in challenge submission. Nothing relevant was missing, and this showed some deeper understanding of the topic as well as critical analyzing. The readability should be ok, and there are some visualisations. However, the report could have been a bit more comprehensive, and more machine learning methods could have been used. All in all, the topics and research questions were answered in sufficient manner.

The average grade of these deliverables is 2, so I will give myself a grade 2 of this project in total. The minimal requirements are satisfied; the presentation was not defined as a minimal requirement anywhere. But unfortunately, that drops the grade with a number. Otherwise the grade could have been at least 3. The work mostly follows the instructions given.

## List of references

## References

- [1] https://www2.helsinki.fi/en/research-stations/hyytiala
- [2] https://wiki.helsinki.fi/pages/viewpage.action?pageId=243959901
- $[3] \ https://iopscience.iop.org/article/10.1088/1748-9326/aadf3c$
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- [6] https://acp.copernicus.org/articles/18/9597/2018/
- [7] https://iq.opengenus.org/gaussian-naive-bayes/
- [8] Git repo: https://github.com/hartzka/iml21