Forecasting Project 1

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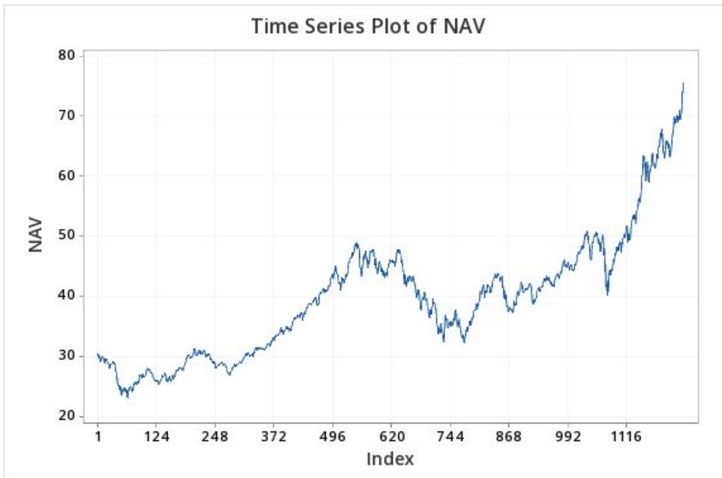
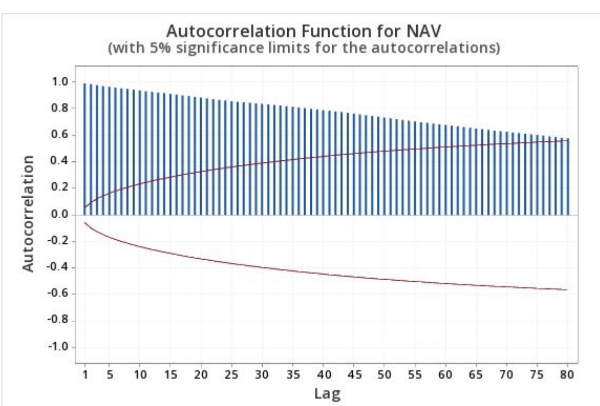
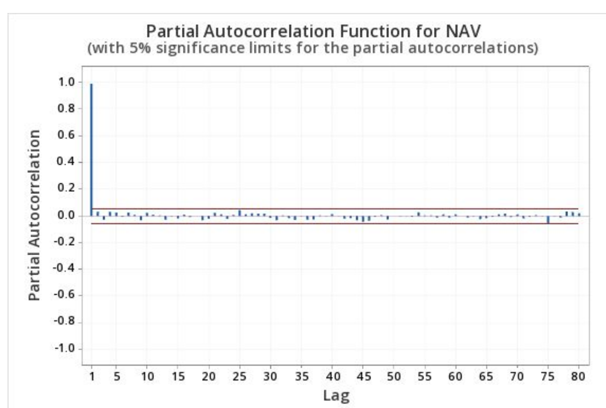
Data Set Used:
JP Morgan (A) China Fund

Data used is a 5 year time span, daily increments of closing NAVs from 11/9/2015 to 11/9/2020, data taken from JP Morgan, amounting to a total of 1236 data points: JPM Asset Management



As shown by this preliminary time series plot, the data is **non-stationary (d=1)**, but also has an **upwards trend** with regional **volatility** that could possibly be better measured in levels. There are also no apparent seasonal or cyclical patterns. Data points towards the end of the time span (Q3 2020) seem to be much higher than normal, which may seem a bit more suited towards an exponential function, but using an ARIMA with a confidence interval should still be better because value-growth is better captured.

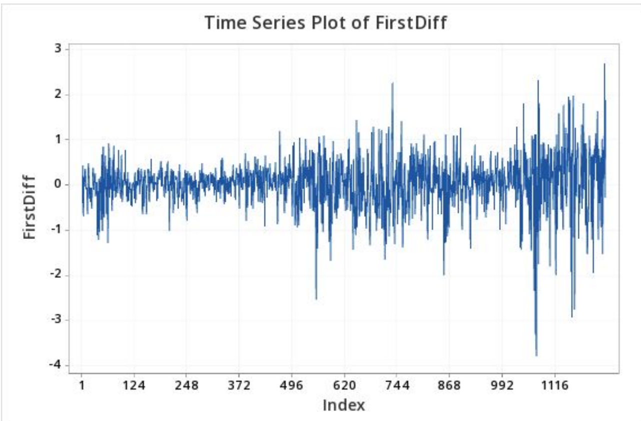




Here, we conduct a preliminary ACF and PACF on prices/NAV to better gauge the solutions towards modeling this data.

As shown by the ACF and PACF, the ACF is too significant and decreases too slowly, towards lag 80, which means that it may not be able to be properly solved. From PACF, the main spike comes from a highly positive lag 1, then instantly falls into the range of insignificance, showing possible signs of AR(1). But all in all, especially as shown by the ACF, **differencing must be used** to create a stationary data set.

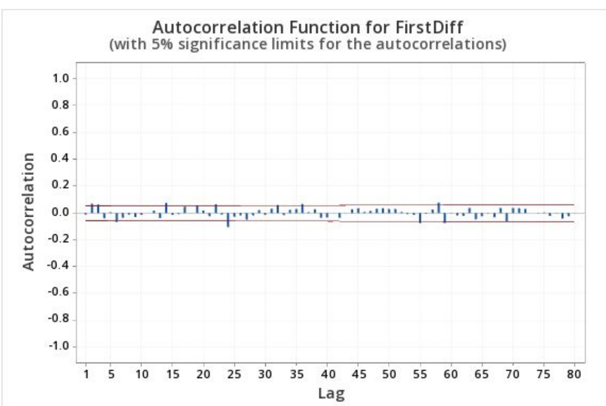
Applying the first difference (lag + difference):

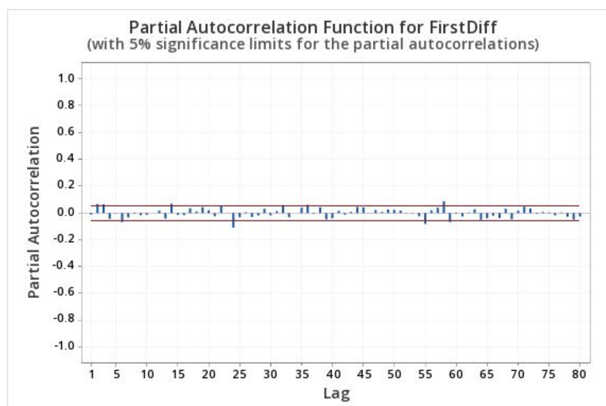


The data is now stationary, where it reverts and oscillates around an arithmetic mean of 0.0367.

Then, to apply the ARIMA (p,d,q) model, we need to find and determine the most suitable parameters.

To do this, run an ACF and PACF to determine the best p, q values (d = 1).





To start off, **overdifferencing is not an issue** as the first lag is basically at 0. This means that, in the most fundamental way, the "first difference" is a sound way to begin looking for AR/MA models. From both the ACF and the PACF, the data generally becomes **less significant after lag 3**, which means that we are going to be exploring the AICcs for all the values of p, q within the range **{0,1,2,3}**.

To begin the process of determining the best fit AICc, we need to set the preface: N= 1236-1 = 1235
And the following equations:

$$AIC_C = N \log\left(\frac{SS}{N}\right) + 2(p+q+1)\,\frac{N}{N-p-q-2}$$ (without constant)

$$AIC_C = N \log\left(\frac{SS}{N}\right) + 2(p+q+2)\,\frac{N}{N-p-q-3}$$ (with constant)

Without Constant					
N	p	d	q	SS	AICc
1235	0	1	3	428.783	-1298.443457
1235	3	1	1	428.249	-1297.966167
1235	3	1	0	429.093	-1297.550904
1235	1	1	3	428.682	-1296.718097
1235	2	1	3	428.058	-1296.497519
1235	2	1	2	428.801	-1296.375314
1235	3	1	2	428.25	-1295.943699
1235	0	1	2	430.975	-1294.159068
1235	2	1	1	430.333	-1293.987128
1235	3	1	3	428.248	-1293.926591
1235	2	1	0	431.239	-1293.402782
1235	0	1	0	433.641	-1290.559175
1235	1	1	0	433.622	-1288.606792
1235	0	1	1	433.625	-1288.598247
1235	1	1	1	432.969	-1288.458248
1235	1	1	2	433.597	-1284.655216

With Constant					
N	p	d	q	SS	AICc
1235	0	1	3	427.49	-1302.17324
1235	3	1	1	426.916	-1301.816316
1235	2	1	3	426.337	-1301.472824
1235	3	1	0	427.814	-1301.237573
1235	2	1	2	427.444	-1300.28984
1235	3	1	2	426.912	-1299.808303
1235	0	1	2	429.5	-1298.393071
1235	2	1	1	428.997	-1297.827239
1235	3	1	3	426.911	-1297.788321
1235	2	1	0	429.78	-1297.588211
1235	1	1	3	429.464	-1294.467267
1235	1	1	0	431.932	-1293.429489
1235	0	1	1	431.937	-1293.415193
1235	1	1	1	431.745	-1291.954528
1235	1	1	2	431.903	-1289.48963
1235	0	1	0	554.0698	-987.8931941

From these tests, the smallest AICc value comes down to **ARIMA (0,1,3) with a constant.**

Final Estimates of Parameters

Type	Coef	SE Coef	T-Value	P-Value
MA 1	0.0100	0.0285	0.35	0.727
MA 2	-0.0744	0.0284	-2.62	0.009
MA 3	-0.0743	0.0287	-2.59	0.010
Constant	0.0370	0.0191	1.94	0.053

From this model, these are the final parameters:

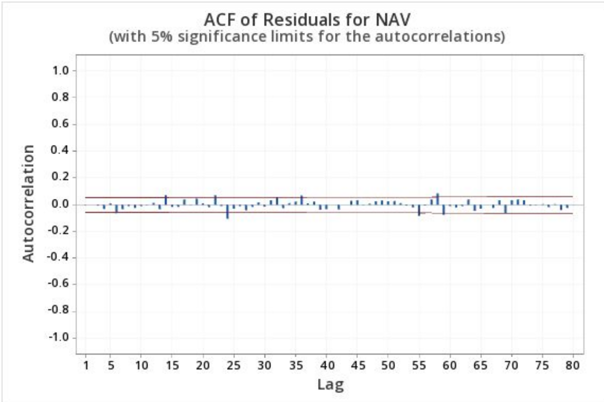
$$x_t - x_{t-1} = \varepsilon_t - 0.01\varepsilon_{t-1} + 0.0744\varepsilon_{t-2} + 0.0743\varepsilon_{t-3} - 0.037$$

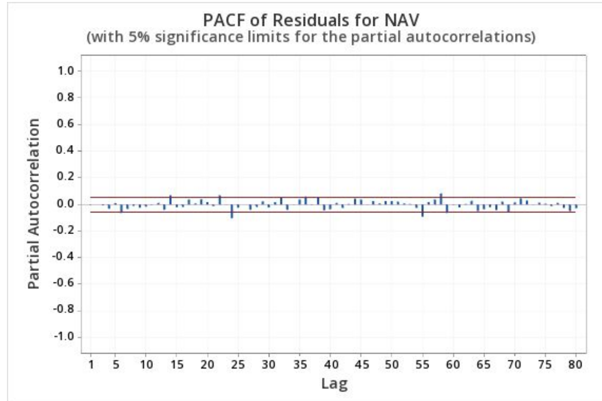
Assuming:
X_t here is the price of the fund at time t.

Modified Box-Pierce (Ljung-Box)

Lag	12	24	36	48
Chi-Square	8.19	42.32	59.94	69.35
DF	8	20	32	44
P-Value	0.416	0.003	0.002	0.009

From the Ljung-Box test, the output P-value is only greater than 0.05 for lag 12, but not 24, 36, or 48. **The model is inadequate and the null is rejected.** This means we should take a look at the ACF/PACF of the residuals to get a better idea of the discrepancies.

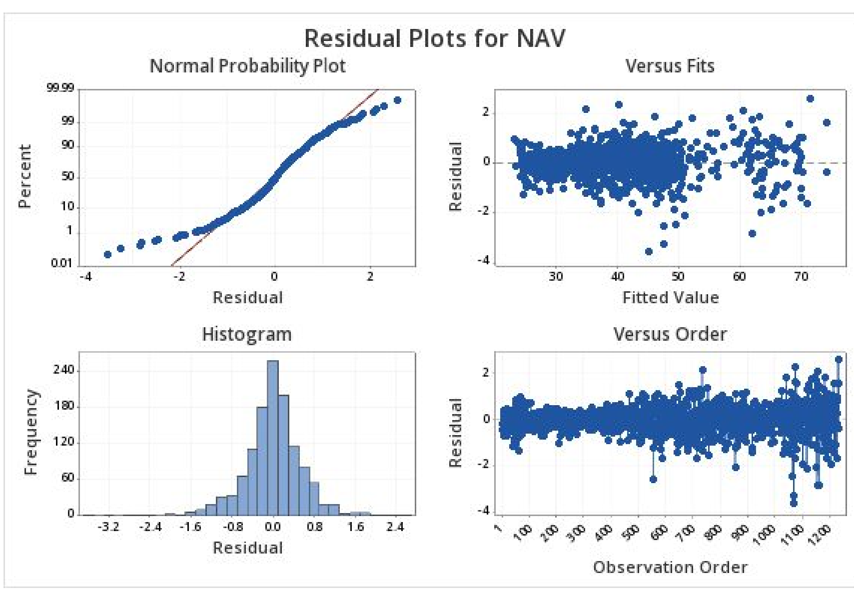




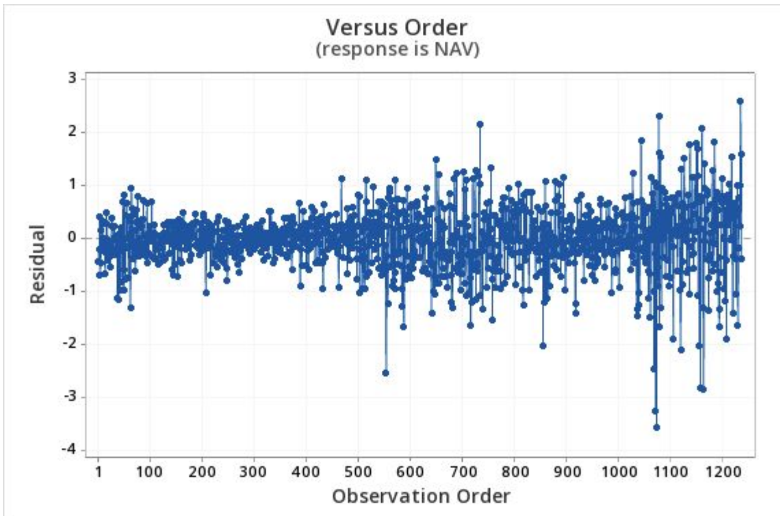
According to the ACF and PACF of the residuals, there are **many significant points after lag 14** in which the residuals are overly autocorrelated or partially autocorrelated, including lags 22, 23, 55, and 58. These are not signs of seasonality, but rather, signs that the data **cannot be properly described** with an ARIMA model, as there is too much volatility and interference in the latter parts of the NAV time series. This up-down "noise" is not a regular trend and only shows up periodically, meaning that there were tangible market impacts/movements during those time periods.

Since data was a daily, five year range, we can approximate the years in which these issues are occurring. In 2016, the Chinese equity market saw a shift from manufacturing into service industries, slowing down. 2018 had high real estate market instability, which saw the performance of global equity markets plummet, especially in China. The reasons for this also carried on to 2019 and Q3 2020: the **US-China relationship/trade-war as well as the tightening of monetary policies in developed markets.** These are all macroeconomic signals that cannot be properly accounted for, and therefore support the Ljung-Box Test that the model is **inadequate**.

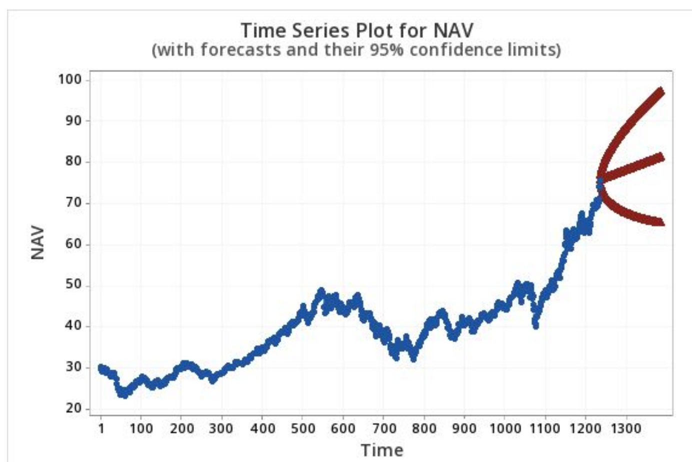
To further explore this idea of data inadequacy, we have plotted the residuals of the NAVs to better visualize the distributions.



From the histogram and the normal probability plot, the distribution looks **approximately normal**, except a possible **skew towards the positive right side**. As seen from the “Versus Fits” graph, there is apparent **heteroscedasticity**, translating to the smaller-than-actual P-values. From the “Versus Order” graph, which is increased in size (see below), there appears to be large (possibly increasing in frequency) up/downward spikes from halfway. The past year from 1000-1250 shows the increase in volatility as a result of the COVID crisis and US election, but overall, it shows **no signs of correlation** as data exhibits almost-normal random white noise by 0.



Unto the forecasting portion, a 95% interval was used with a lead time of 150.



From this forecast, the range seems initially reasonable given the rate of growth it has seen in the past 300 data NAV data points; but, given the general decline in Chinese economic growth and large accumulation of forex as per political choices, *this growth rate is unlikely to continue in the long run.* The interval seems **too wide**, as the range of the 150 forecasts is covering approximately 40% of the overall NAV span. On a different note, however, current market overvaluation and inefficiency may contribute towards higher values in the short term 1-2 year span, as the strong Chinese rebound from COVID put strong confidence into its markets. This forecast **captures the general short-term positive outlook.**

Below: See 150 period forecasts for ARIMA (0,1,3) & constant, for the JPM (A) Fund.

Period	Forecast	Lower	Upper
1237	75.94528513	74.79003039	77.10053986
1238	76.07270816	74.44704802	77.69836829
1239	76.22785587	74.18949011	78.26622163
1240	76.2648177	73.83881084	78.69082457
1241	76.30177953	73.54205424	79.06150481
1242	76.33874136	73.28151091	79.3959718
1243	76.37570319	73.04745555	79.70395082
1244	76.41266501	72.8338654	79.99146462
1245	76.44962684	72.63670395	80.26254974
1246	76.48658867	72.45310936	80.52006798
1247	76.5235505	72.28096524	80.76613576
1248	76.56051232	72.11865415	81.0023705
1249	76.59747415	71.96490701	81.2300413
1250	76.63443598	71.81870626	81.4501657
1251	76.67139781	71.67922122	81.66357439
1252	76.70835964	71.54576326	81.87095601
1253	76.74532146	71.41775394	82.07288899
1254	76.78228329	71.29470185	82.26986473
1255	76.81924512	71.17618528	82.46230496
1256	76.85620695	71.0618391	82.65057479
1257	76.89316877	70.95134472	82.83499283
1258	76.9301306	70.84442215	83.01583906
1259	76.96709243	70.74082374	83.19336112
1260	77.00405426	70.64032924	83.36777927
1261	77.04101609	70.54274167	83.5392905
1262	77.07797791	70.44788404	83.70807179
1263	77.11493974	70.35559664	83.87428284
1264	77.15190157	70.26573475	84.03806839
1265	77.1888634	70.17816673	84.19956007
1266	77.22582522	70.09277243	84.35887802
1267	77.26278705	70.00944186	84.51613224
1268	77.29974888	69.92807398	84.67142378
1269	77.33671071	69.84857575	84.82484566
1270	77.37367254	69.77086125	84.97648382
1271	77.41063436	69.69485094	85.12641779
1272	77.44759619	69.62047104	85.27472134
1273	77.48455802	69.54765292	85.42146311
1274	77.52151985	69.47633266	85.56670703
1275	77.55848168	69.40645057	85.71051278
1276	77.5954435	69.33795081	85.85293619
1277	77.63240533	69.2707811	85.99402957
1278	77.66936716	69.20489233	86.13384199
1279	77.70632899	69.14023837	86.27241961
1280	77.74329081	69.07677578	86.40980585
1281	77.78025264	69.01446362	86.54604166
1282	77.81721447	68.95326323	86.68116571
1283	77.8541763	68.89313808	86.81521451
1284	77.89113813	68.83405359	86.94822266
1285	77.92809995	68.775977	87.08022291
1286	77.96506178	68.71887722	87.21124634
1287	78.00202361	68.66272475	87.34132247
1288	78.03898544	68.60749152	87.47047936
1289	78.07594726	68.55315083	87.5987437
1290	78.11290909	68.49967726	87.72614092
1291	78.14987092	68.44704656	87.85269528
1292	78.18683275	68.39523559	87.97842991
1293	78.22379458	68.34422225	88.1033669
1294	78.2607564	68.29398543	88.22752738
1295	78.29771823	68.24450492	88.35093155
1296	78.33468006	68.19576137	88.47359875
1297	78.37164189	68.14773624	88.59554753
1298	78.40860372	68.10041178	88.71679565
1299	78.44556554	68.05377093	88.83736016
1300	78.48252737	68.00779732	88.95725742
1301	78.5194892	67.96247523	89.07650317
1302	78.55645103	67.91778954	89.19511252
1303	78.59341285	67.8737257	89.31310001
1304	78.63037468	67.83026973	89.43047963
1305	78.66733651	67.78740814	89.54726488
1306	78.70429834	67.74512795	89.66346873
1307	78.74126017	67.70341663	89.7791037
1308	78.77822199	67.6622621	89.89418189
1309	78.81518382	67.62165271	90.00871493
1310	78.85214565	67.58157721	90.12271409
1311	78.88910748	67.54202471	90.23619025
1312	78.9260693	67.50298471	90.3491539
1313	78.96303113	67.46444704	90.46161522
1314	78.99999296	67.42640189	90.57358404
1315	79.03695479	67.38883972	90.68506986
1316	79.07391662	67.35175133	90.7960819
1317	79.11087844	67.31512779	90.90662909
1318	79.14784027	67.27896047	91.01672007
1319	79.1848021	67.24324098	91.12636322
1320	79.22176393	67.20796118	91.23556667
1321	79.25872575	67.1731132	91.34433831
1322	79.29568758	67.13868939	91.45268578
1323	79.33264941	67.10468231	91.56061651
1324	79.36961124	67.07108475	91.66813773
1325	79.40657307	67.0378897	91.77525643
1326	79.44353489	67.00509036	91.88197943
1327	79.48049672	66.9726801	91.98831335
1328	79.51745855	66.94065247	92.09426463
1329	79.55442038	66.90900123	92.19983953
1330	79.59138221	66.87772027	92.30504414
1331	79.62834403	66.84680367	92.4098844
1332	79.66530586	66.81624564	92.51436608
1333	79.70226769	66.78604058	92.6184948
1334	79.73922952	66.75618299	92.72227604
1335	79.77619134	66.72666754	92.82571515
1336	79.81315317	66.69748903	92.92881731
1337	79.850115	66.66864239	93.03158761
1338	79.88707683	66.64012267	93.13403099
1339	79.92403866	66.61192504	93.23615227
1340	79.96100048	66.58404481	93.33795616
1341	79.99796231	66.55647737	93.43944726
1342	80.03492414	66.52921824	93.54063004
1343	80.07188597	66.50226305	93.64150889
1344	80.10884779	66.47560752	93.74208807
1345	80.14580962	66.44924747	93.84237178
1346	80.18277145	66.42317883	93.94236408
1347	80.21973328	66.3973976	94.04206895
1348	80.25669511	66.3718999	94.14149031
1349	80.29365693	66.34668191	94.24063195
1350	80.33061876	66.32173991	94.33949761
1351	80.36758059	66.29707026	94.43809092
1352	80.40454242	66.27266939	94.53641544
1353	80.44150425	66.24853382	94.63447467
1354	80.47846607	66.22466013	94.73227202
1355	80.5154279	66.20104499	94.82981082
1356	80.55238973	66.17768512	94.92709434
1357	80.58935156	66.15457733	95.02412578
1358	80.62631338	66.13171849	95.12090828
1359	80.66327521	66.10910551	95.21744491
1360	80.70023704	66.08673541	95.31373867
1361	80.73719887	66.06460522	95.40979251
1362	80.7741607	66.04271207	95.50560932
1363	80.81112252	66.02105312	95.60119193
1364	80.84808435	65.9996256	95.6965431
1365	80.88504618	65.97842679	95.79166557
1366	80.92200801	65.95745402	95.88656199
1367	80.95896983	65.93670468	95.98123499
1368	80.99593166	65.91617621	96.07568712
1369	81.03289349	65.89586607	96.16992091
1370	81.06985532	65.87577182	96.26393882
1371	81.10681715	65.85589102	96.35774327
1372	81.14377897	65.8362213	96.45133665
1373	81.1807408	65.81676032	96.54472129
1374	81.21770263	65.79750579	96.63789947
1375	81.25466446	65.77845546	96.73087346
1376	81.29162629	65.75960712	96.82364545
1377	81.32858811	65.7409586	96.91621762
1378	81.36554994	65.72250778	97.0085921
1379	81.40251177	65.70425255	97.10077098
1380	81.4394736	65.68619087	97.19275632
1381	81.47643542	65.6683207	97.28455015
1382	81.51339725	65.65064007	97.37615443
1383	81.55035908	65.63314702	97.46757114
1384	81.58732091	65.61583963	97.55880218
1385	81.62428274	65.59871602	97.64984945
1386	81.66124456	65.58177434	97.74071479