

Null hypothesis: last 30 years the same temperature as before

Alternative: different temperature

Conclusion: reject null hypothesis

Welch t-test

- wiki: https://en.wikipedia.org/wiki/Welch%27s_t-test
- scipy: https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.ttest_ind.html#scipy.stats.ttest_ind

Data source

- page: <https://www.knmi.nl/nederland-nu/klimatologie/daggegevens/antieke-waarnemingen>
- data: https://cdn.knmi.nl/knmi/map/page/klimatologie/gegevens/daggegevens/antieke_wrn/labrijn_ea.zip

```
In [1]: import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

import scipy
from scipy.stats import t
```

```
In [2]: THRESHOLD = 1990
```

```
In [3]: file_name = 'labrijn_ea.dat'
cols = 'year Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Year Win Spr Sum Aut'.split()
df = (
    pd.read_csv(file_name, sep=r'\s+', skiprows=21, header=0, names=cols)
    .set_index('year')
    .drop('Year Win Spr Sum Aut'.split(), axis=1)
    .dropna() # drop incomplete last year (2021)
)
df['year_avg'] = df.mean(axis=1)
df[f'before_{THRESHOLD}'] = df.index < THRESHOLD
mask = df[f'before_{THRESHOLD}']
df.head()
```

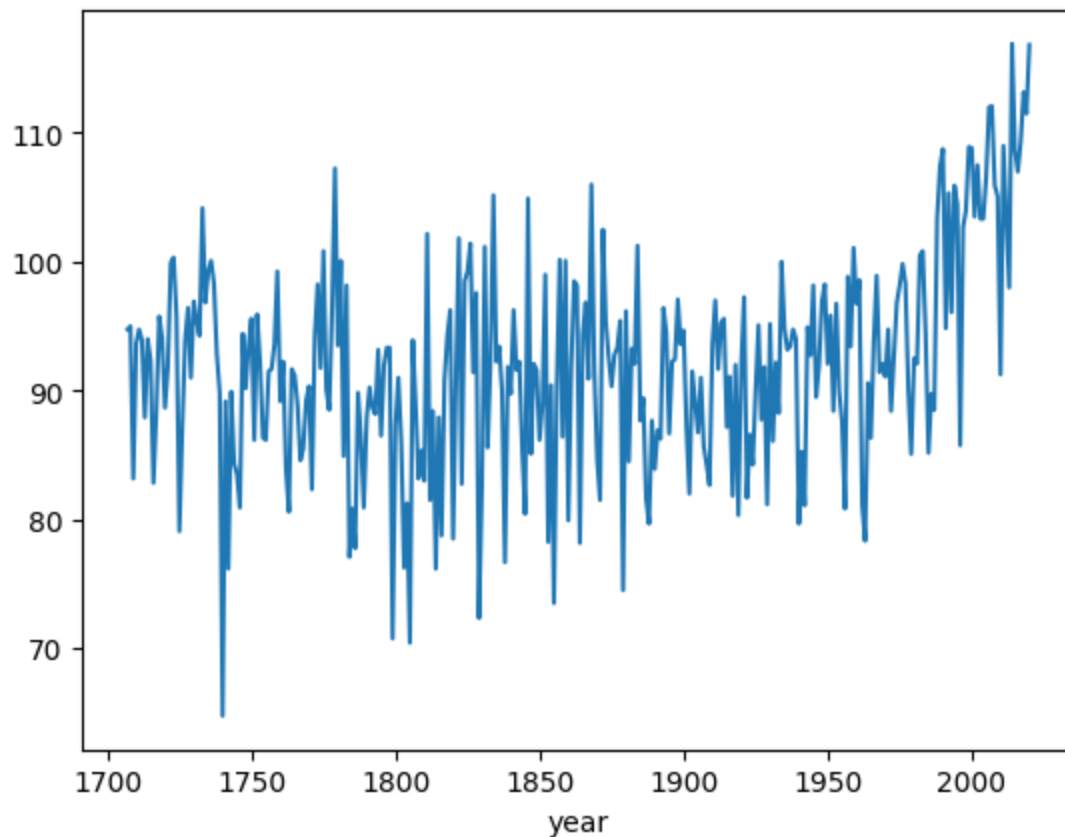
```
Out[3]:
```

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year_avg	before_1990
year														
1707	7	49	47	83	120	168.0	181.0	159.0	149.0	90.0	65.0	19.0	94.750000	True
1708	39	31	59	95	122	146.0	154.0	185.0	159.0	92.0	54.0	4.0	95.000000	True
1709	-51	-3	11	92	116	153.0	161.0	162.0	145.0	109.0	78.0	25.0	83.166667	True
1710	4	18	56	70	133	150.0	152.0	161.0	147.0	108.0	70.0	55.0	93.666667	True
1711	32	6	50	98	127	168.0	160.0	154.0	142.0	106.0	60.0	34.0	94.750000	True

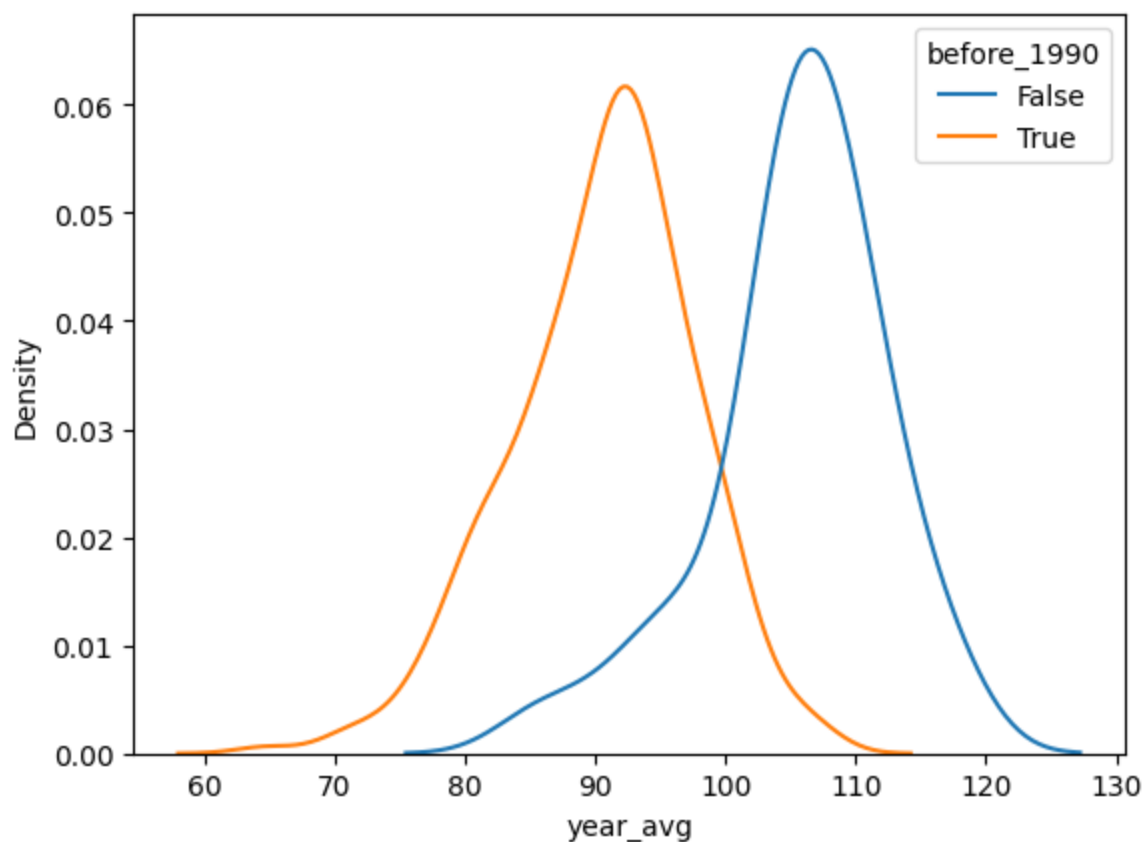
```
In [4]: assert 2020-1707+1 == df.shape[0]
```

```
In [5]: df['year_avg'].plot()
```

```
Out[5]: <AxesSubplot:xlabel='year'>
```



```
In [6]: sns.kdeplot(data=df, x='year_avg', hue=f'before_{THRESHOLD}', common_norm=False)  
plt.show()
```



```
In [7]: before_1990 = df.loc[mask, 'year_avg']  
from_1990 = df.loc[~mask, 'year_avg']
```

```
In [8]: def std(x, dof):  
        return (((x - x.mean()) ** 2).sum() / (x.shape[0] - dof)) ** 0.5
```

```
In [9]: std(before_1990, dof=1), before_1990.std(ddof=1)
```

```
Out[9]: (7.004986535824251, 7.004986535824251)
```

```
In [10]: # own implementation  
mu1 = before_1990.mean()  
mu2 = from_1990.mean()  
sigma1 = before_1990.std(ddof=1)  
sigma2 = from_1990.std(ddof=1)  
n1 = before_1990.shape[0]  
n2 = from_1990.shape[0]  
std_error1 = sigma1 / np.sqrt(n1)  
std_error2 = sigma2 / np.sqrt(n2)  
  
test_stat = (mu1 - mu2) / (np.sqrt(std_error1 ** 2 + std_error2 ** 2))  
dof = (std_error1 ** 2 + std_error2 ** 2) ** 2 / (std_error1 ** 4 / (n1 - 1) + std_error2 ** 4 /  
pval = t.cdf(test_stat, df=dof) * 2  
  
test_stat, dof, pval
```

```
Out[10]: (-11.510212643389224, 37.26574563278072, 7.840663626690791e-14)
```

```
In [11]: # scipy implementation  
scipy.stats.ttest_ind(before_1990, from_1990, equal_var=False)
```

```
Out[11]: Ttest_indResult(statistic=-11.510212643389224, pvalue=7.840663626690791e-14)
```

2nd null hypothesis: last 30 years are warmer than before

Cannot be rejected

```
In [12]: scipy.stats.ttest_ind(before_1990, from_1990, equal_var=False, alternative='greater')
```

```
Out[12]: Ttest_indResult(statistic=-11.510212643389224, pvalue=0.99999999999999608)
```