error handling; pandas and data analysis

Ben Bolker

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generating errors

- we've already seen the `raise` keyword, in passing
- `raise Exception` is the simplest way to have your program stop when something goes wrong
- in a notebook/console environment, it stops the current cell/function (doesn't crash the session)

```
raise Exception
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
Exception
```

- you have to `raise <something>`
- `Exception` is the most general case ("something happened")
- other possibilities
  - `TypeError`: some variable is the wrong type
  - `ValueError`: some variable is the right type but the wrong value

```
x = -1
if not isinstance(x,str): ## check if x is a str
    raise TypeError
```

```
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
TypeError
```

```
import math
x = -1
if x<0:
    raise ValueError
print(math.sqrt(x))
```

```
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
ValueError
```

error messages

- it's always better to be more specific about the cause of an error:

```
x = -1
if not isinstance(x,str): ## check if x is a str
    errstr = "x is of type "+type(x).__name__+", should be str"
    raise TypeError(errstr)
```

```
TypeError: x is of type int, should be str
```

f-strings are a convenient way to construct error messages: anything inside curly brackets is interpreted as a Python expression. e.g.

```
x=1
print(f"x is of type {type(x).__name__}, should be str")
```

```
## x is of type int, should be str
```

So we could use

```
if not isinstance(x,str): ## check if x is a str
    raise TypeError("x is of type {type(x).__name__}, should be str")
```

```
x = -1
if x<0:
    raise ValueError(f"x should be non-negative, but it equals {x}")
```

```
ValueError: x should be non-negative, but it equals -1
```

warnings

An error means "it's impossible to continue" or "you shouldn't continue without fixing the problem". You might want to issue a *warning* instead. This is not too different from just using `print()` , but it allows advanced users to decide if they want to suppress warnings.

```
import warnings
```

```
warnings.warn("something bad happened")
```

```
## <string>:1: UserWarning: something bad happened
```

handling errors

Now suppose you are getting an error and you don't want your program to stop. "Wrapping" your code in a `try:` clause will allow you to specify what to do in this case. `pass` is a special Python statement called a "null operation" or a "no-op"; it does nothing except keep going.

```
try:
    x= math.sqrt(-1)
except:
    pass
## keep going (but x will not be set)
```

You can specify something you want to do with only a particular set of errors:

```
try:
    x = math.sqrt(-1)
except ValueError:
    print("a ValueError occurred")
except:
    print("some other error occurred")
## keep going (but x will not be set)
```

```
## a ValueError occurred
```

If the error isn't caught because it isn't the right type, it will act like it normally does (without the `try:`)

```
try:
    z += 5  ## not defined yet
except ValueError:
    print("a ValueError occurred")
```

```
NameError: name 'z' is not defined
```

We could catch this with a general-purpose `except:`

```
try:
    z += 5  ## not defined yet
except ValueError:
    print("a ValueError occurred")
except:
    print("some other error occurred")
```

```
## some other error occurred
```

Or add another clause to catch it:

```
try:
    z += 5  ## not defined yet
except ValueError:
    print("a ValueError occurred")
except NameError:
    print("a NameError occurred")
except:
    print("some other error occurred")
```

```
## a NameError occurred
```

general rules

- see if you can change your code to avoid getting errors in the first place
- catch specific errors
- do something sensible with errors (e.g. convert to warnings, return `nan` ...)

```
try:
    x = math.sqrt(-1)
except ValueError:
    x = math.nan
print(x)
```

```
## nan
```

pandas

definition and reference

- `pandas` stands for **pan**el **da**ta **s**ystem. It's a convenient and powerful system for handling large, complicated data sets. (The author pronounces it "pan-duss" (https://twitter.com/wesmckinn/status/706661972431892483?lang=en).)
- pandas cheat sheet (https://github.com/pandas-dev/pandas/blob/master/doc/cheatsheet/Pandas_Cheat_Sheet.pdf)

Data frames

- rectangular data structure, looks a lot like an array.
- each column is a **Series**; each column can be of a different type
- rows and columns act differently
- can index by (column) labels as well as positions
- handles **missing data** (`NaN`)
- convenient plotting
- fast operations with keys
- lots of facilities for input/output

```
import pandas as pd  ## standard abbreviation
# The initial set of baby names and birth rates
names = ['Bob','Jessica','Mary','John','Mel']
births = [968, 155, 77, 578, 973]
## initialize DataFrame with a *dictionary*
p = pd.DataFrame({'Name': names, 'Count': births})
print(p)
```

```
##       Name  Count
## 0      Bob    968
## 1  Jessica    155
## 2     Mary     77
## 3     John    578
## 4      Mel    973
```

What can we do with it?

- “Simple” indexing
    - *Indexing* (a single value) selects a column by its *key*
    - key could be a number, if column names weren’t given when setting up the data frame
    - *Slicing* selects *rows* by number
    - indexing with a *list* gives multiple columns
    - `.iloc` gives row/column indices (like an array)

```
p["Count"]  ## extract a column = Series (by *name*)
p[2:3]      ## slice one row (3-2 = 1)
p[2:5]      ## slice multiple rows
p[["Name","Count"]]    ## extract multiple columns (data frame)
p.iloc[1,1]     ## index with row/column integers like an array
p.iloc[0:5,:]   ## can also slice
```

Indexing by name

```
p["Name"][4]  ## 5th element of Name
p.Name  ## attribute!
p.loc[1:2,"Name"]  ## index by *label*, _inclusive_
```

Measles data

Download US measles data from Project Tycho (https://www.tycho.pitt.edu/index.php).

- `read_csv` reads a CSV file as a **data frame**; it automatically interprets the first row as headings
- `df.iloc[]` indexes the result as though it were an array
- `df.head()` shows just at the beginning; `df.tail()` shows just the end

Let’s look at the first few rows of a data set on measles in US states:

```
## "Weekly Measles Cases, 1909-2001"
## ...
## "Data provided by Project Tycho, Data Version 1.0.0, released 28 Novem...
## "YEAR","WEEK","ALABAMA","ALASKA","AMERICAN SAMOA","ARIZONA","ARKANSAS"...
## 1909,1,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-...
## 1909,2,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-...
## 1909,3,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-...
```

```
fn = "../data/MEASLES_Cases_1909-2001_20150322001618.csv"
p  = pd.read_csv(fn,skiprows=2,na_values=["-"])  ## read in data
p.head()                     ## look at the first little bit
```

```
##    YEAR  WEEK  ALABAMA  ALASKA  ...  WEST VIRGINIA  WISCONSIN  WYOMING  Unnamed: 61
## 0  1909     1      NaN     NaN  ...            NaN        NaN      NaN          NaN
## 1  1909     2      NaN     NaN  ...            NaN        NaN      NaN          NaN
## 2  1909     3      NaN     NaN  ...            NaN        NaN      NaN          NaN
## 3  1909     4      NaN     NaN  ...            NaN        NaN      NaN          NaN
## 4  1909     5      NaN     NaN  ...            NaN        NaN      NaN          NaN
##
## [5 rows x 62 columns]
```

Mostly `NaN` values at the beginning! (`NaN` = “not a number”: similar to `nan` from `math` or `numpy`)

Selecting

- Like `numpy` array indexing, but a little different …
- Pandas doc, indexing and selecting (http://pandas.pydata.org/pandas-docs/dev/indexing.html)
    - extract by name: `df.loc[:,"MASSACHUSETTS":"NEVADA"]` (index by *label*; **includes endpoint**)
    - extract by integer index: `iloc` method, `df.iloc[:,range]` (index by *integer*; **doesn’t include endpoint**)

```
p.loc[:,"MASSACHUSETTS":"NEVADA"]
```

```
##       MASSACHUSETTS  MICHIGAN  MINNESOTA  ...  MONTANA  NEBRASKA  NEVADA
## 0               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 1               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 2               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 3               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4               NaN       NaN        NaN  ...      NaN       NaN     NaN
## ...             ...       ...        ...  ...      ...       ...     ...
## 4856            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4857            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4858            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4859            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4860            NaN       NaN        NaN  ...      NaN       NaN     NaN
##
## [4861 rows x 8 columns]
```

This is the same:

```
pc = list(p.columns) ## list of colum names
print(pc[:5])
## find the locations of these two state names
```

```
## ['YEAR', 'WEEK', 'ALABAMA', 'ALASKA', 'AMERICAN SAMOA']
```

```
mass_ind = list(pc).index("MASSACHUSETTS")
neva_ind = list(pc).index("NEVADA")
## index using `.iloc` (with extended range)
p.iloc[:,mass_ind:neva_ind+1]
```

```
##       MASSACHUSETTS  MICHIGAN  MINNESOTA  ...  MONTANA  NEBRASKA  NEVADA
## 0               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 1               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 2               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 3               NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4               NaN       NaN        NaN  ...      NaN       NaN     NaN
## ...             ...       ...        ...  ...      ...       ...     ...
## 4856            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4857            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4858            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4859            NaN       NaN        NaN  ...      NaN       NaN     NaN
## 4860            NaN       NaN        NaN  ...      NaN       NaN     NaN
##
## [4861 rows x 8 columns]
```

More examples

You can also refer to *individual* columns as **attributes** (i.e. just `p.<name>`)

```
p.ARIZONA[:5]
```

```
## 0   NaN
## 1   NaN
## 2   NaN
## 3   NaN
## 4   NaN
## Name: ARIZONA, dtype: float64
```

```
p.ARIZONA.head()
```

```
## 0   NaN
## 1   NaN
## 2   NaN
## 3   NaN
## 4   NaN
## Name: ARIZONA, dtype: float64
```

`.drop()` gets rid of elements

```
pp = p.drop(["YEAR","WEEK"],axis=1)
## equivalent to
pp2 = p.iloc[2:,]
pp3 = p.loc[:,"ARIZONA"]
```

Always use name-indexing whenever you can!

`.index` is a special attribute of data frames that governs searching, plotting, etc.. Here we'll set it to a decimal date value:

```
pp.index = p.YEAR+(p.WEEK-1)/52
```

Filtering

Choosing specific rows of a data frame; `&`, `|`, `~` correspond to `and`, `or`, `not` (individual elements *must* be in parentheses)

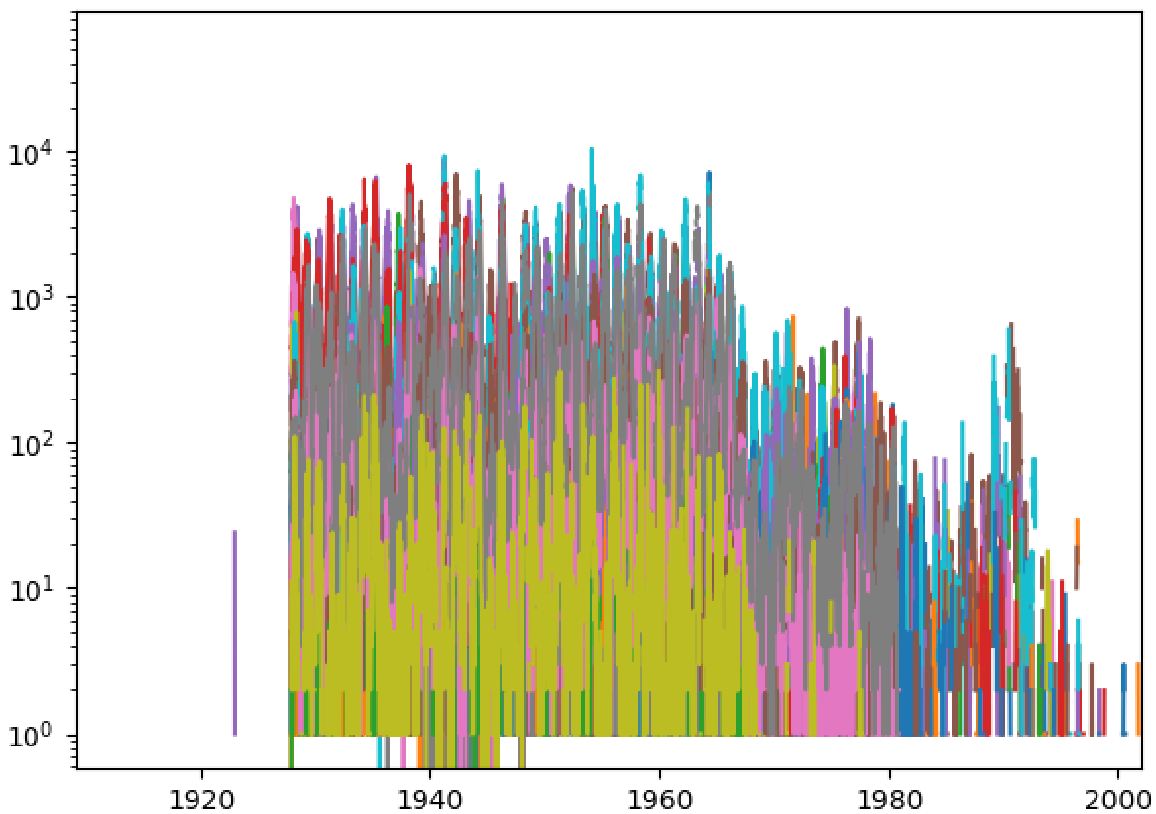
```
ariz = p.ARIZONA                                 ## pull out a column (attribute)
ariz[(p.YEAR==1970) & (ariz>50)]                 ## *must* use parentheses!
```

```
## 3196    69.0
## 3197    57.0
## 3198    62.0
## 3200    56.0
## 3203    73.0
## 3205    54.0
## 3209    55.0
## Name: ARIZONA, dtype: float64
```

Basic plotting

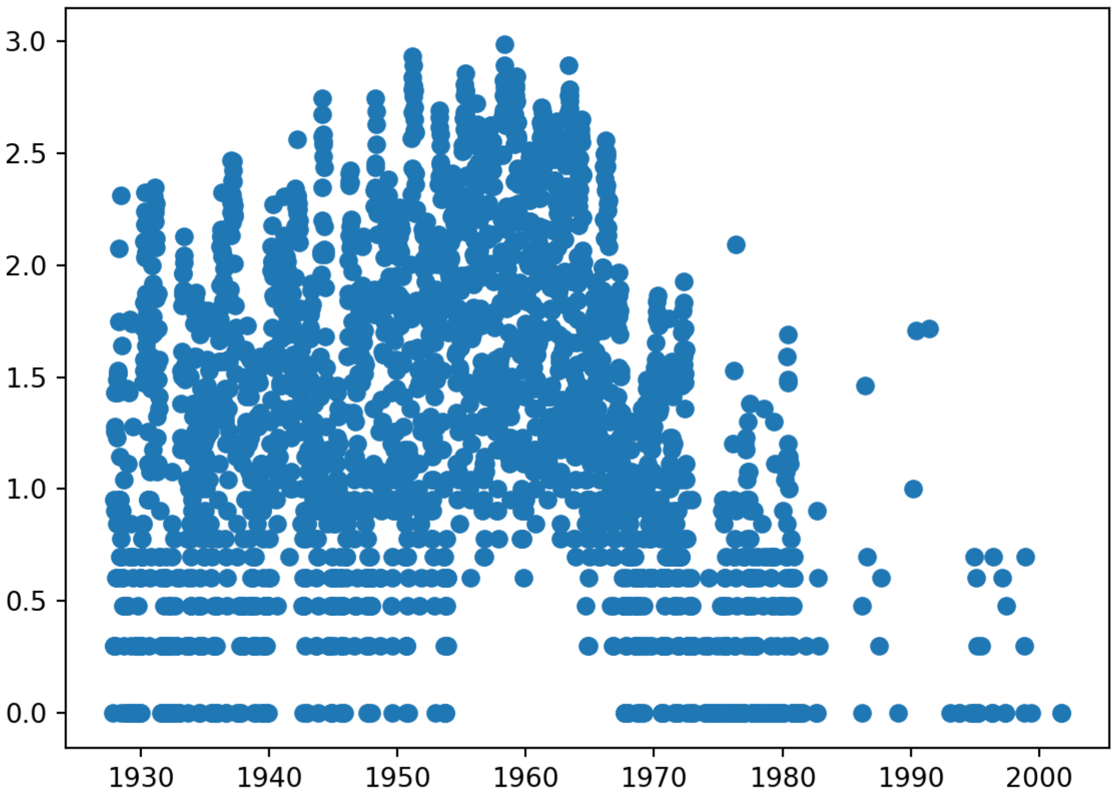
`pandas` will automatically plot data frames in a (reasonably) sensible way

```
import matplotlib.pyplot as plt
fig, ax = plt.subplots()
## pp.plot()
pp.plot(legend=False,logy=True)                  ## plot method (non-Pythonic)
plt.savefig("pix/measles1.png")
```



Or we can create our own (less complex) plots

```
import numpy as np
fig = plt.figure()
ax = fig.add_subplot(1,1,1)
ax.scatter(pp.index,np.log10(pp.ARIZONA))
```

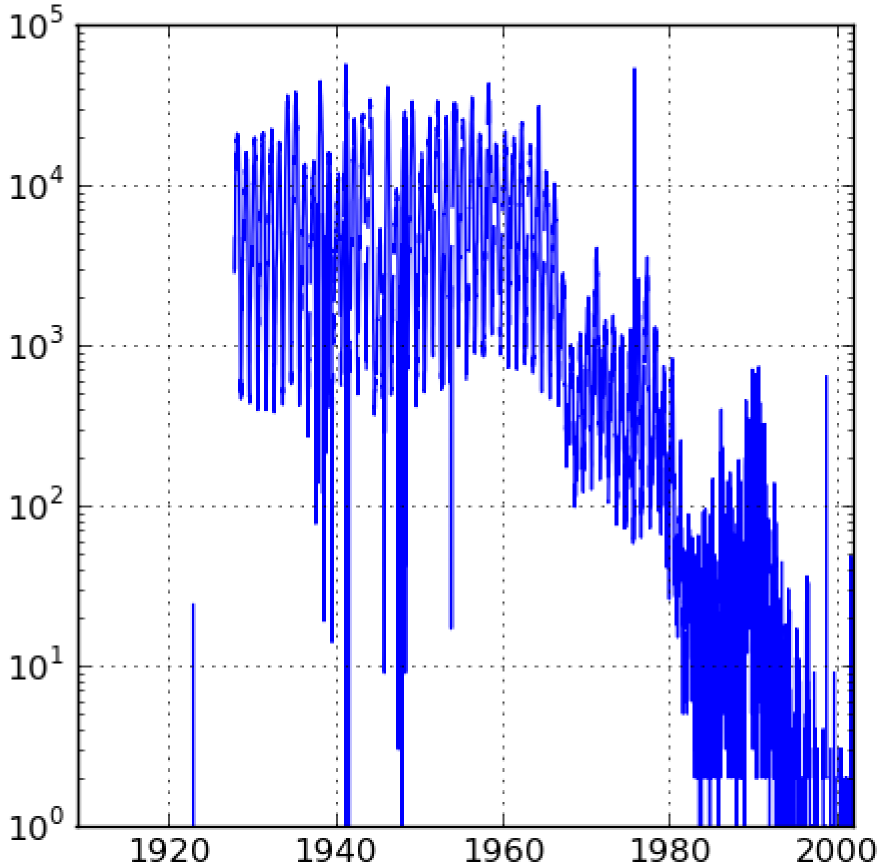


Column and row manipulations

- totals by week

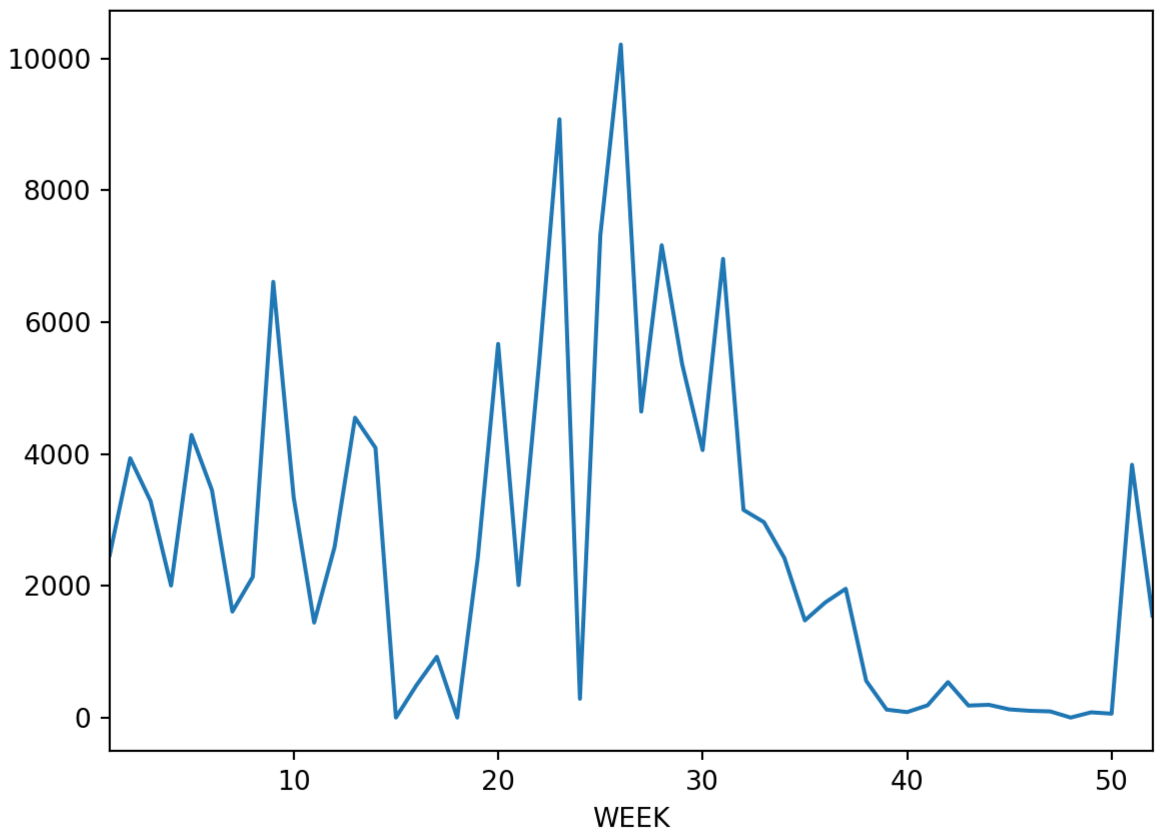
```
ptot = pp.sum(axis=1)
```

- `df.min` , `df.max` , `df.mean` all work too …

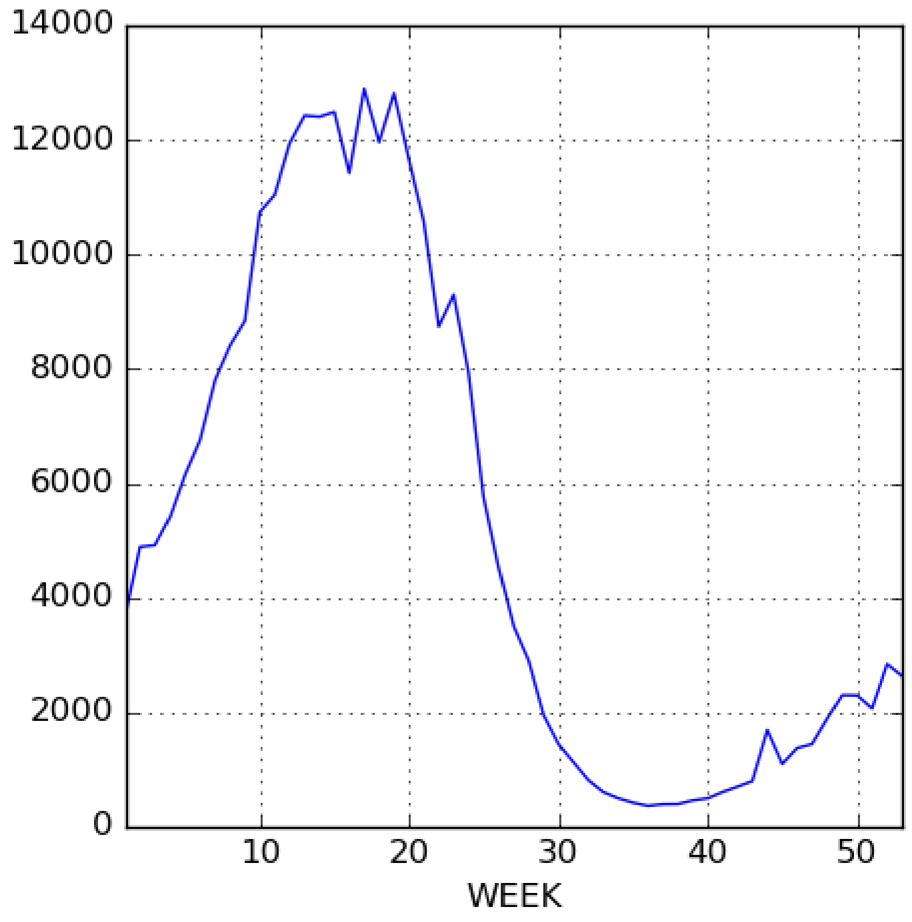


Aggregation

```
ptotweek = ptot.groupby(p.WEEK)
ptotweekmean = ptotweek.aggregate(np.mean)
ptotweekmean.plot()
```



10000
8000
6000
4000
2000
0
10
20
30
40
50
WEEK



14000
12000
10000
8000
6000
4000
2000
0
10
20
30
40
50
WEEK

Dates and times

reference (https://docs.python.org/3.0/library/datetime.html)

- (Another) complex subject.
- Lots of possible date formats (https://xkcd.com/1179/)
- Basic idea: something like `%Y-%m-%d` ; separators just match whatever's in your data (usually "/" or "-"). Results need to be unambiguous, and ambiguity is dangerous (how is day of month specified? lower case, capital? etc.)
- `pandas` tries to guess, but you shouldn't let it.

```
print(pd.to_datetime("05-01-2004"))
```

```
## 2004-05-01 00:00:00
```

```
print(pd.to_datetime("05-01-2004",format="%m-%d-%Y"))
```

```
## 2004-05-01 00:00:00
```

- Time zones and daylight savings time can be a nightmare
- May need to have the right number of digits, especially in the absence of separators:

```
import pandas as pd
print(pd.to_datetime("1212004",format="%m%d%Y"))
```

```
## 2004-12-01 00:00:00
```

```
print(pd.to_datetime("12012004",format="%m%d%Y"))
```

```
## 2004-12-01 00:00:00
```

For our measles data we have week of year, so things get a little complicated

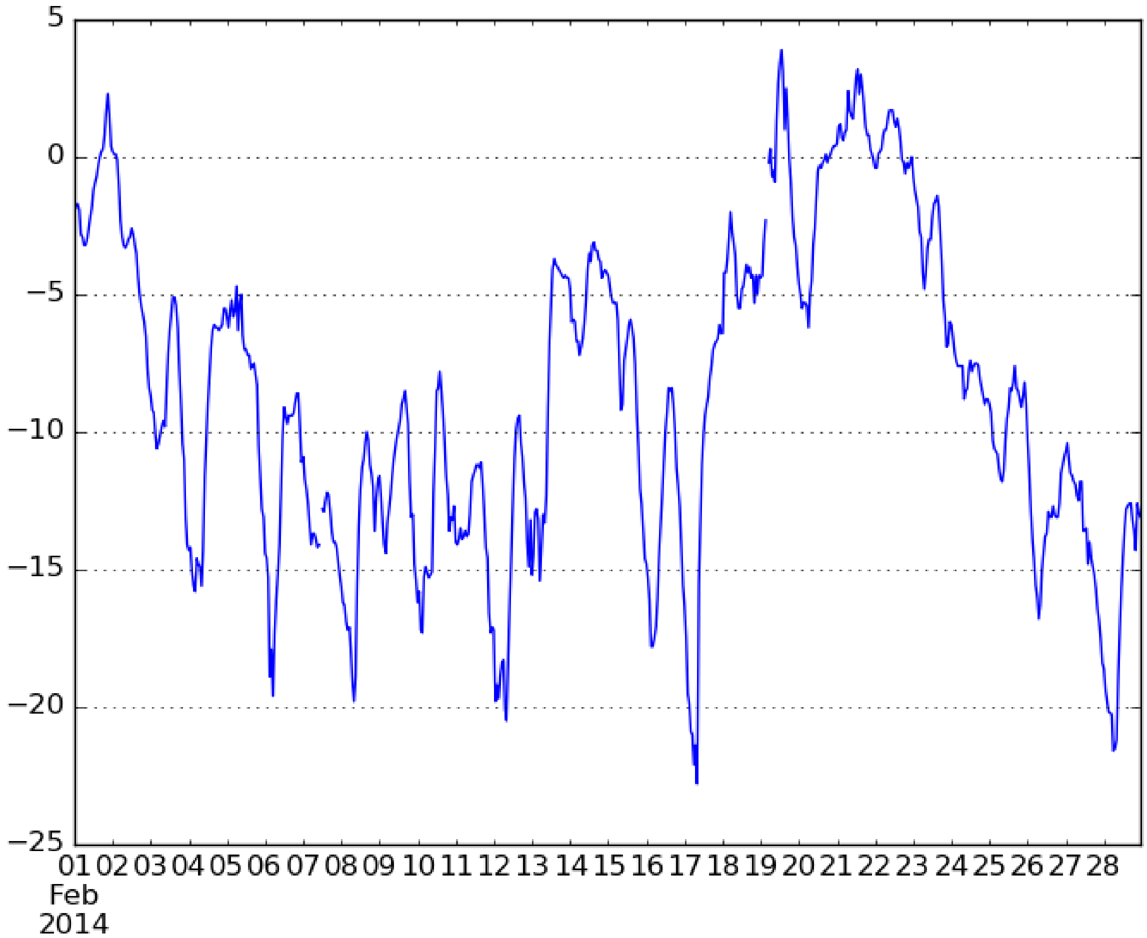
```
yearstr = p.YEAR.apply(format)
weekstr = p.WEEK.apply(format,args=["02"])
datestr = p.YEAR.astype(str)+"-"+weekstr+"-0"
dateindex = pd.to_datetime(datestr,format="%Y-%U-%w")
```

Binning results

- turn a quantitative variable into categories
- `pd.cut(x,bins=...)` ; decide on bins
- `pd.qcut(x,n)` ; decide on number of bins (equal occupancy)

Weather data

```
## fancy stuff: automatically look for index and convert it to a date/time
p = pd.read_csv("../data/eng2.csv",skiprows=14,encoding="latin1",index_col="Date/Time",parse_
dates=True)
## rename columns
p.columns = [
    'Year', 'Month', 'Day', 'Time', 'Data Quality', 'Temp (C)',
    'Temp Flag', 'Dew Point Temp (C)', 'Dew Point Temp Flag',
    'Rel Hum (%)', 'Rel Hum Flag', 'Wind Dir (10s deg)', 'Wind Dir Flag',
    'Wind Spd (km/h)', 'Wind Spd Flag', 'Visibility (km)', 'Visibility Flag',
    'Stn Press (kPa)', 'Stn Press Flag', 'Hmdx', 'Hmdx Flag', 'Wind Chill',
    'Wind Chill Flag', 'Weather']
## drop columns that are *all* NA
p = p.dropna(axis=1,how='all')
p["Temp (C)"].plot()
## get rid of columns (axis=1) we don't want
p = p.drop(['Year', 'Month', 'Day', 'Time', 'Data Quality'], axis=1)
```



Now pull out the temperature and take the median by hour:

```
temp = p[['Temp (C)']]
temp["Hour"] = temp.index.hour
```

```
## <string>:1: SettingWithCopyWarning:
## A value is trying to be set on a copy of a slice from a DataFrame.
## Try using .loc[row_indexer,col_indexer] = value instead
##
## See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/stable/user_gui
de/indexing.html#returning-a-view-versus-a-copy
```

```
temphr = temp.groupby('Hour')
medtmp = temphr.aggregate(np.median)
maxtmp = temphr.aggregate(np.max)
mintmp = temphr.aggregate(np.min)
```

Now plot these …