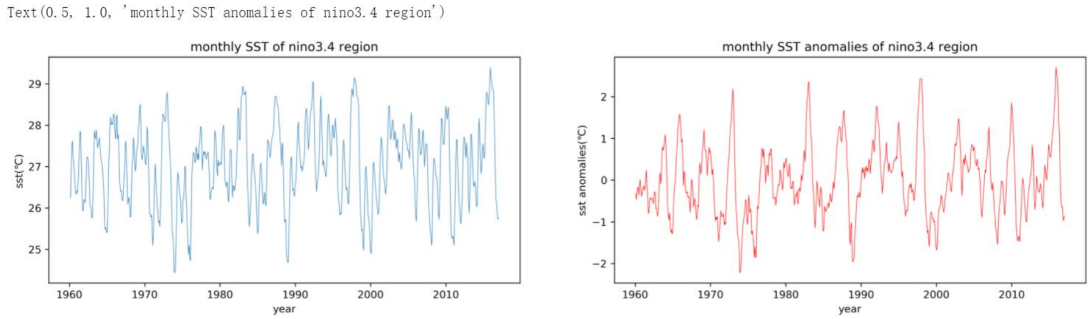
1. Niño 3.4 index

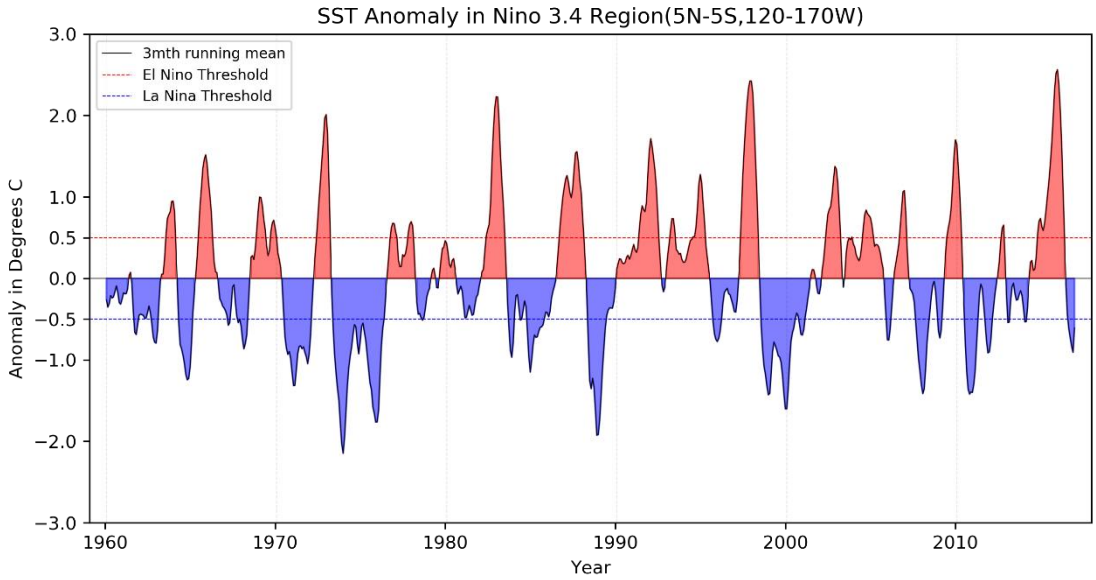
The *Niño 3.4 anomalies* may be thought of as representing the average equatorial sea surface temperatures (SSTs) across the Pacific from about the dateline to the South American coast (`5N-5S, 170W-120W`). The Niño 3.4 index typically uses a 3-month running mean, and El Niño or La Niña events are defined when the Niño 3.4 SSTs exceed `+/- 0.5°C` for a period of `5` months or more. Check Equatorial Pacific Sea Surface Temperatures for more about the Niño 3.4 index.

In this problem set, you will use the sea surface temperature (SST) data from NOAA. Download the `netCDF4` file (`NOAA_NCDC_ERSST_v3b_SST.nc`) here.

1.1 [5 points] Compute monthly climatology for SST from Niño 3.4 region, and subtract climatology from SST time series to obtain anomalies.



1.2 [5 points] Visualize the computed Niño 3.4. Your plot should look similar to this one.



2. Earth's energy budget

In this problem set, you will analyze top-of-atmosphere (TOA) radiation data from NASA's CERES project. Read this post for more about Earth's energy budget.

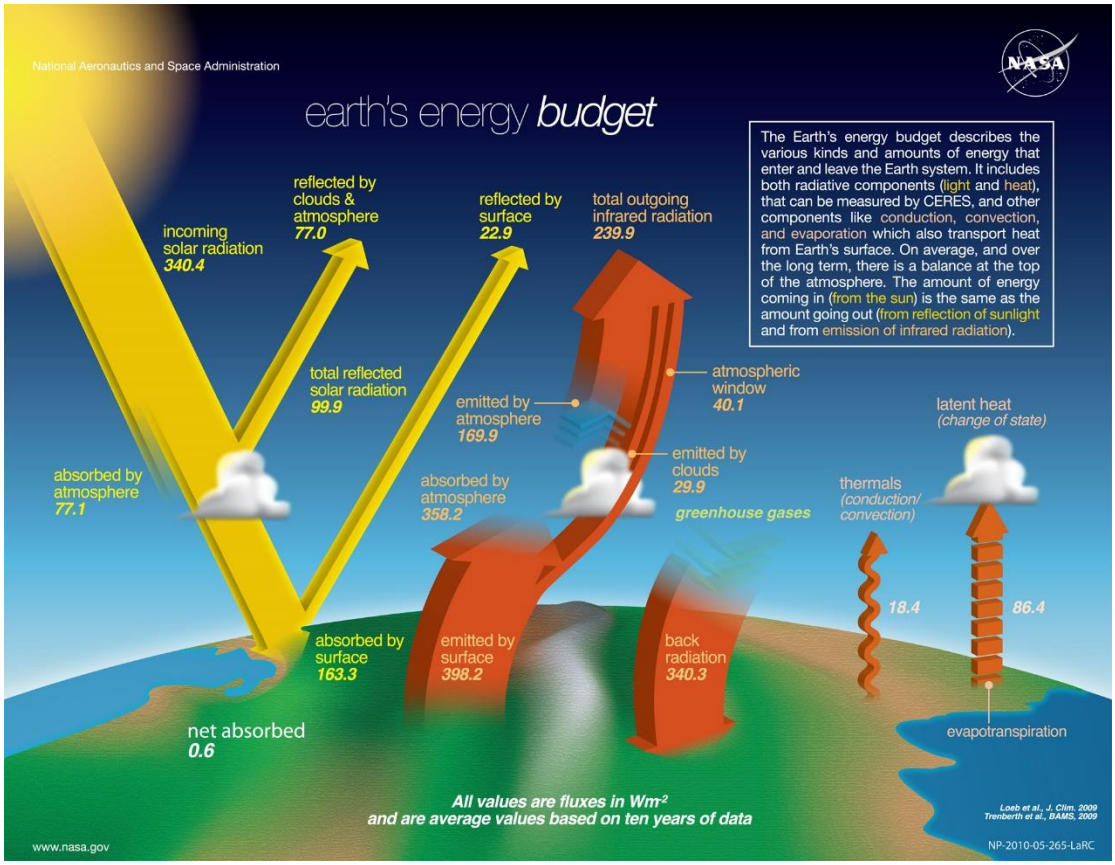
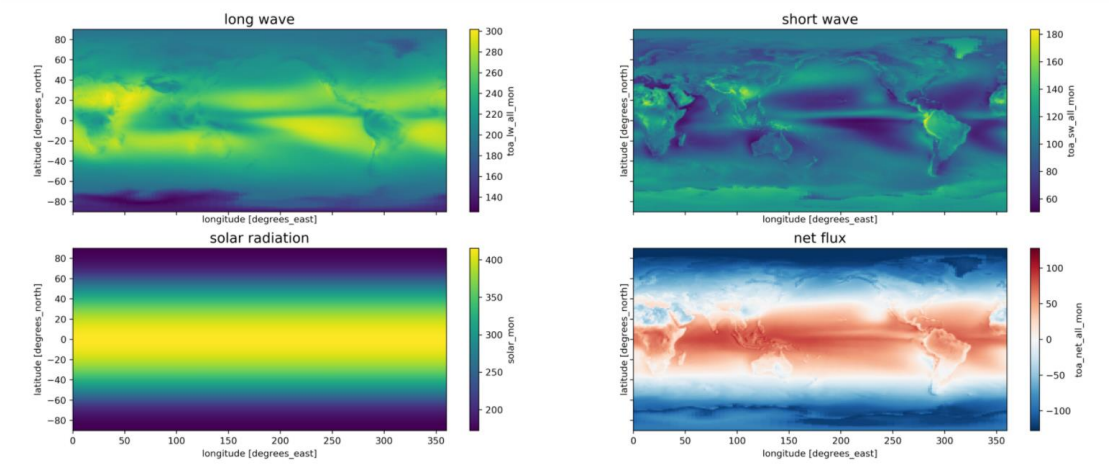


Figure source

Download the data (`CERES_EBAF-TOA_200003-201701.nc`) here. The size of the data file is `702.5 MB`. It will take a minute or two to download. Start by importing `xarray`, `numpy`, and `matplotlib`.

2.1 [5 points] Make a 2D plot of the time-mean TOA longwave, shortwave, and solar radiation for all-sky conditions. Add up the three variables above and verify (visually) that they are equivalent to the TOA net flux.

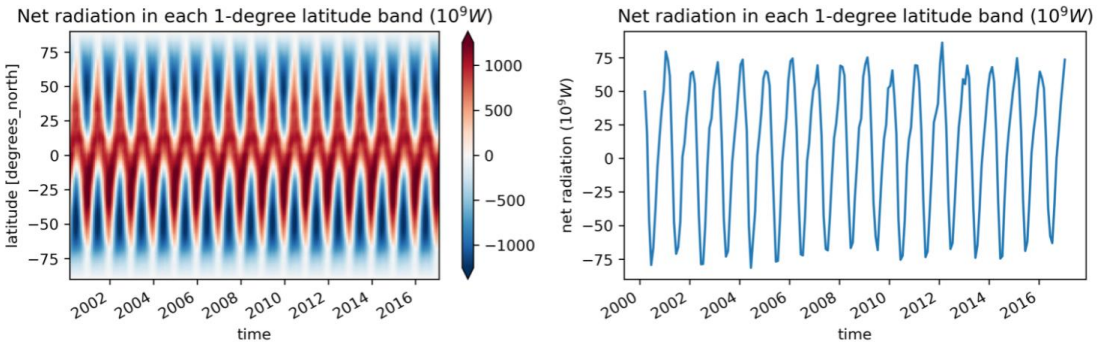


2.2 [10 points] Calculate and verify that the TOA incoming solar, outgoing longwave, and outgoing shortwave approximately match up with the cartoon above.

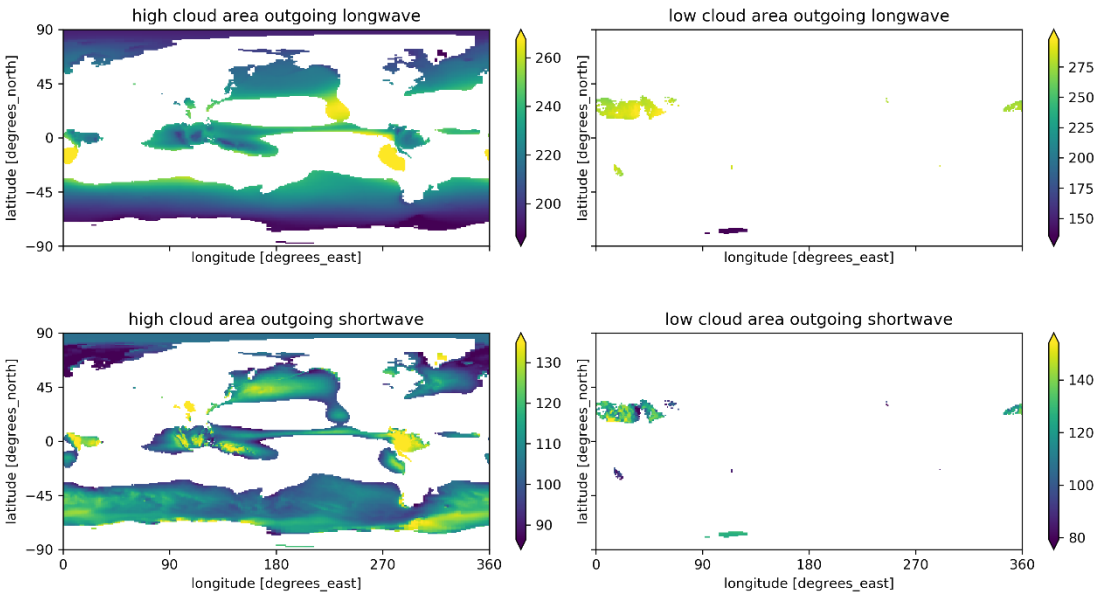
[Hint: Consider calculating the area of each grid]

```
solar radiations (Wm-2): 340.3
long wave outgoing (Wm-2): 240.3
short wave outgoing (Wm-2): 99.1
```

2.3 [5 points] Calculate and plot the total amount of net radiation in each 1-degree latitude band. Label with correct units.



2.4 [5 points] Calculate and plot composites of time-mean outgoing shortwave and longwave radiation for low and high cloud area regions. Here we define low cloud area as $\leq 25\%$ and high cloud area as $\geq 75\%$. Your results should be 2D maps.



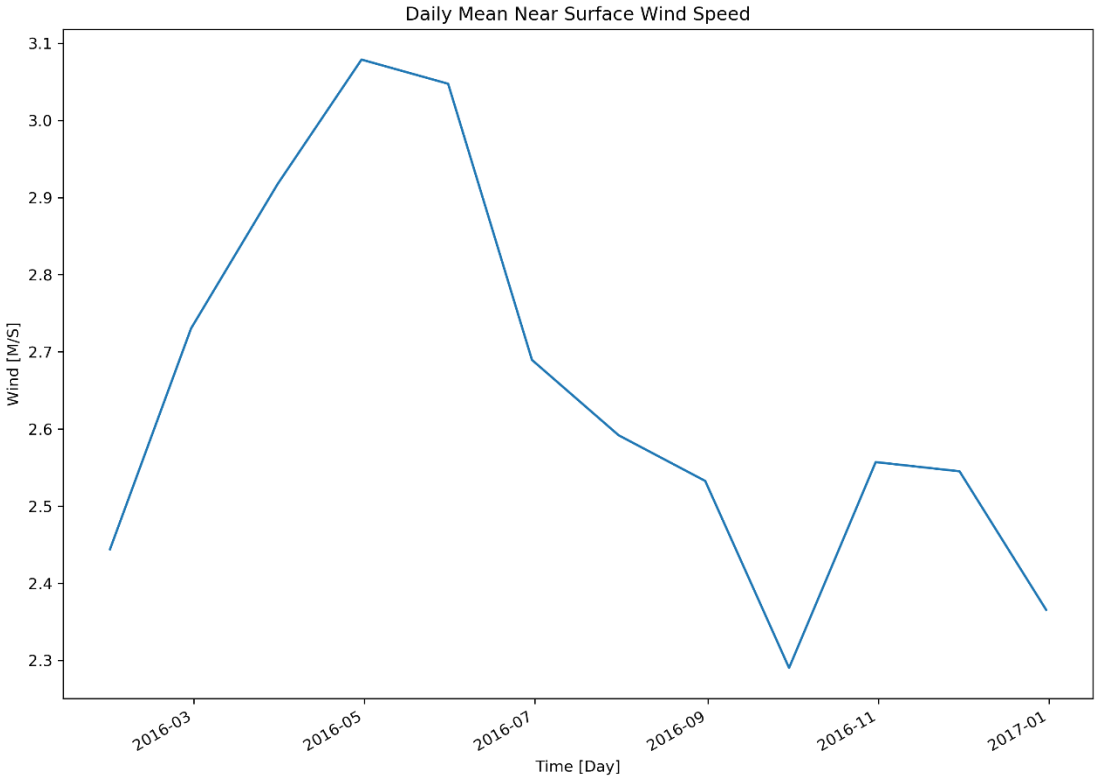
2.5 [5 points] Calculate the global mean values of shortwave and longwave radiation, composited in high and low cloud regions. What is the overall effect of clouds on shortwave and longwave radiation?

```
high cloud, long wave: 216.55675
high cloud, short wave: 108.09777
low cloud, long wave: 270.10367
low cloud, short wave: 122.65546
```

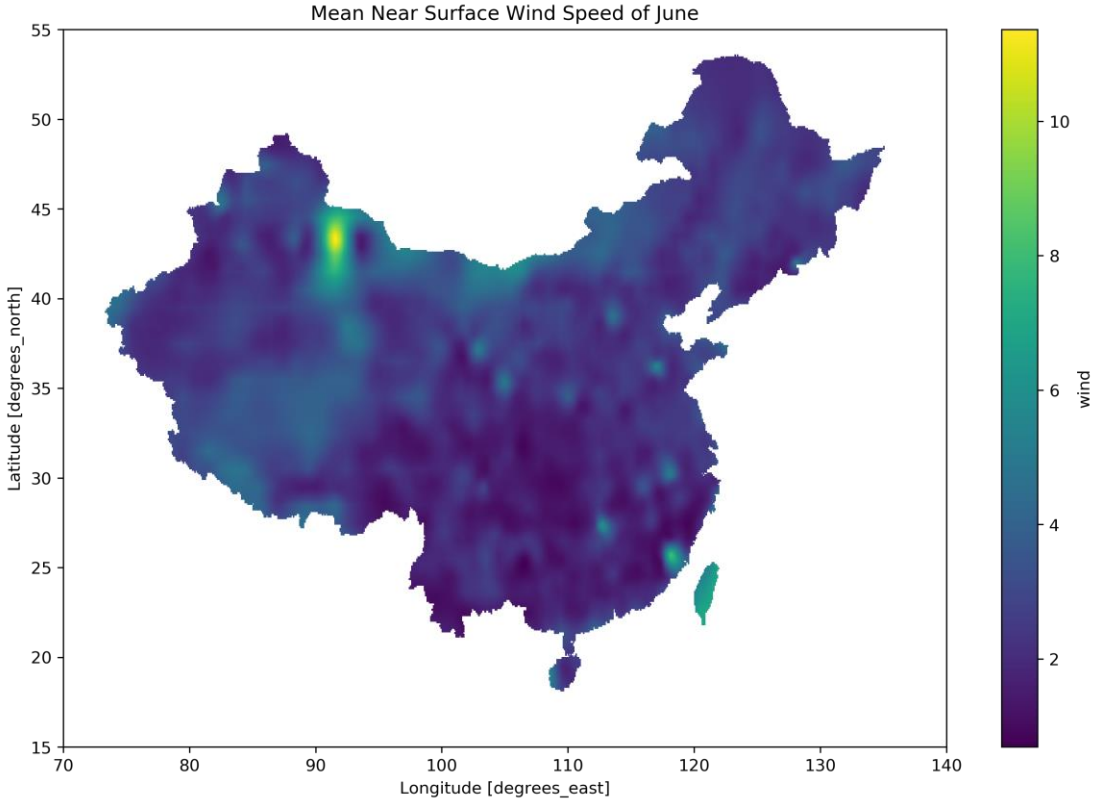
3. Explore a `netCDF` dataset

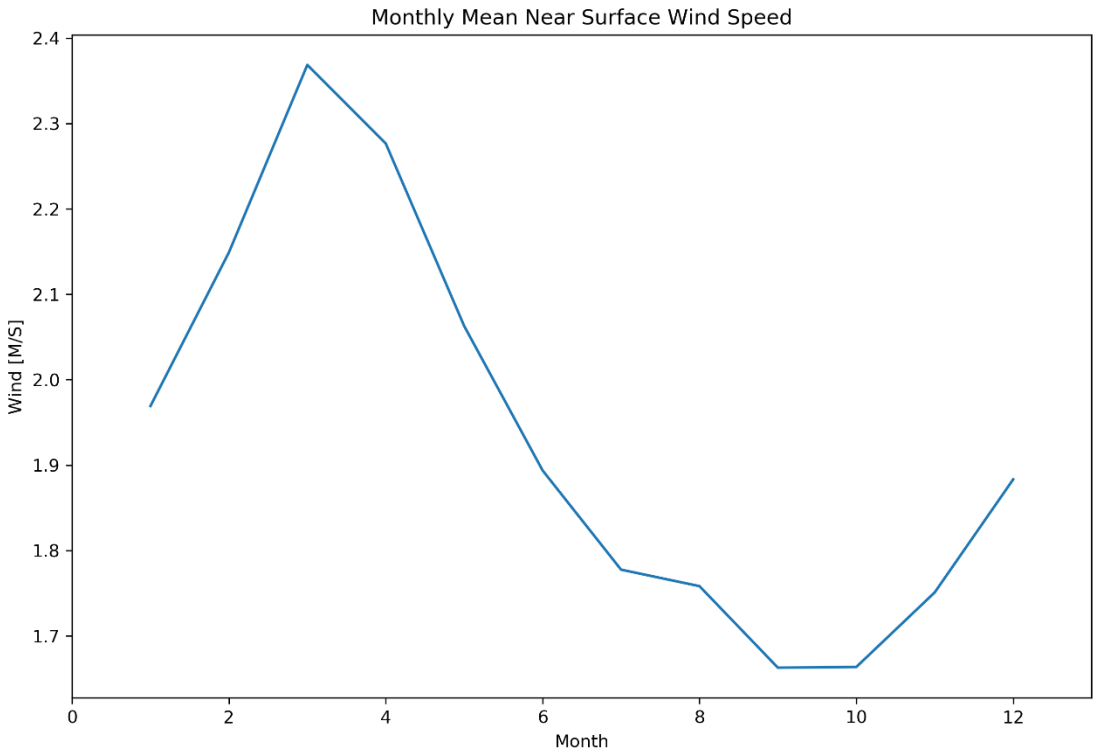
Browse the NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC) website. Search and download a dataset you are interested in. You are also welcome to use data from your group in this problem set. But the dataset should be in `netCDF` format, and have temporal information.

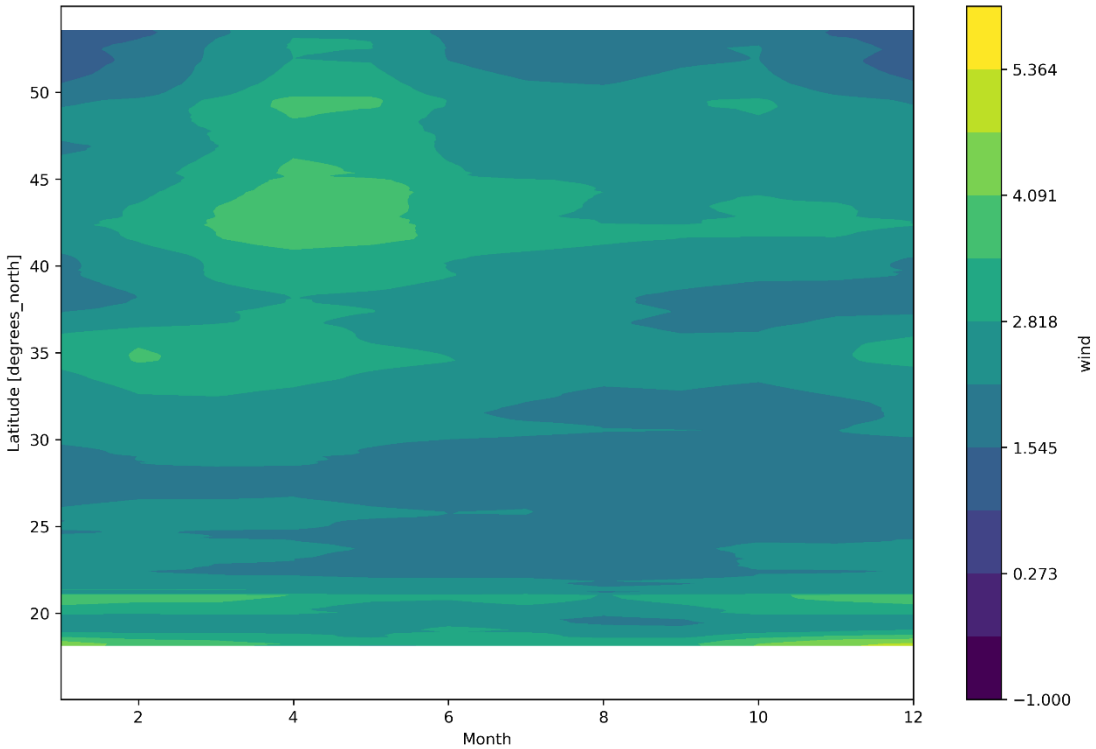
3.1 [5 points] Plot a time series of a certain variable with monthly seasonal cycle removed.

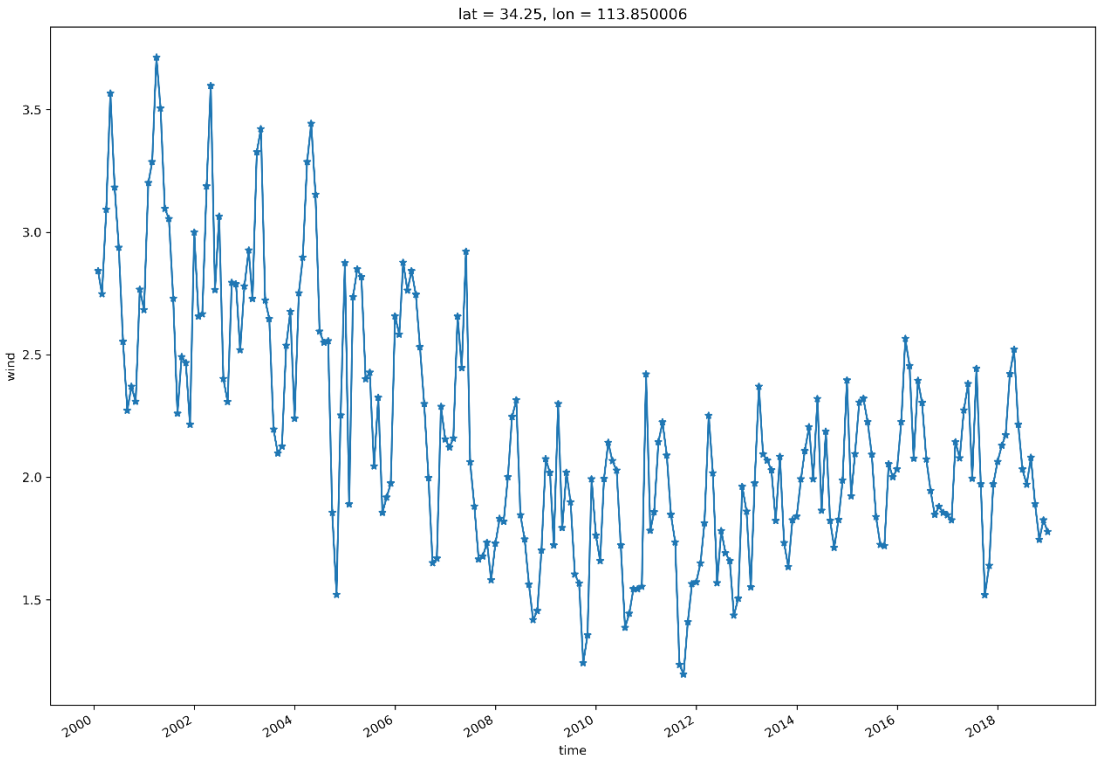


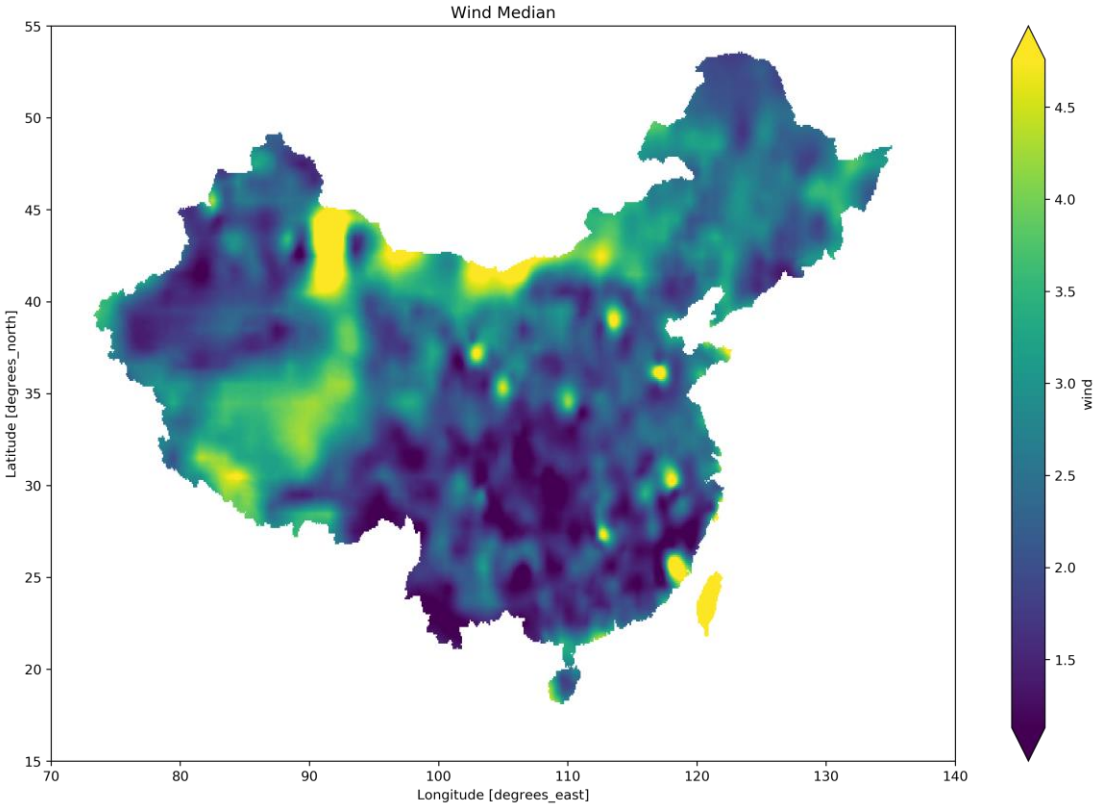
3.2 [5 points] Make at least 5 different plots using the dataset.




Monthly Mean Near Surface Wind Speed
Wind [M/S]
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
0
2
4
6
8
10
12
Month


Latitude [degrees_north]
50
45
40
35
30
25
20
2
4
6
8
10
12
Month
5.364
4.091
2.818
1.545
0.273
−1.000
wind


lat = 34.25, lon = 113.850006
wind
time
3.5
3.0
2.5
2.0
1.5
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018


Wind Median
Latitude [degrees_north]
Longitude [degrees_east]
wind
55
50
45
40
35
30
25
20
15
70
80
90
100
110
120
130
140
4.5
4.0
3.5
3.0
2.5
2.0
1.5