Atmospheric Sciences 528: Atmospheric Data Analysis
Dr. Jared Marquis (Fall 2022)
Assignment #1: Function Fitting
Due: 30 September 2022
100 pts

1. Within the course repository, you'll find a jupyter notebook separated into tasks and a RAOBs_201903131200.txt file containing 500-mb observations from 135 rawinsonde stations. The data is comma delimited and formatted:

Station ID	Latitude	Longitude	500-mb Height (m)	500-mb Wind Direction	500-mb Wind Speed (kts)
KBIS	46.77	-100.70	5510.0	240.0	29.0

2. Establish an analysis map, based on a polar stereographic projection with $\varphi_0 = 60°N$, $\lambda_0 = 115°W$, and an Earth's radius value of $R=6371km$, having a map scale of $m=1/15{,}000{,}000$.

3. Establish a 22x28 (# in x-direction × # in y-direction) rectangular grid of points on the above polar stereographic (analysis) map where $\Delta x=\Delta y=1.27cm$, $x_0=18.90cm$, and $y_0=-6.30cm$, where (x_0, y_0) is the northwest corner of your map [i.e., the (0,0) array member].

4. Perform analyses of 500-mb geopotential height values using the two-dimensional, local polynomial fitting technique described in the course notes. Use a second order, two-dimensional polynomial (I.e., M=2), as in Gilchrist and Cressman (1954). Perform your analysis using two different radii of influence:
   a. RoI=10cm
   b. RoI=20cm

   Remember that the general analysis equation for this technique is:

$$\begin{bmatrix} 1 & \overline{x_k} & \overline{y_k} & \overline{x_k^2} & \overline{y_k^2} & \overline{x_k y_k} \\ \overline{x_k} & \overline{x_k^2} & \overline{x_k y_k} & \overline{x_k^3} & \overline{x_k y_k^2} & \overline{x_k^2 y_k} \\ \overline{y_k} & \overline{x_k y_k} & \overline{y_k^2} & \overline{x_k^2 y_k} & \overline{y_k^3} & \overline{x_k y_k^2} \\ \overline{x_k^2} & \overline{x_k^3} & \overline{x_k^2 y_k} & \overline{x_k^4} & \overline{x_k^2 y_k^2} & \overline{x_k^3 y_k} \\ \overline{y_k^2} & \overline{x_k y_k^2} & \overline{y_k^3} & \overline{x_k^2 y_k^2} & \overline{y_k^4} & \overline{x_k y_k^3} \\ \overline{x_k y_k} & \overline{x_k^2 y_k} & \overline{x_k y_k^2} & \overline{x_k^3 y_k} & \overline{x_k y_k^3} & \overline{x_k^2 y_k^2} \end{bmatrix} \begin{bmatrix} c_{00} \\ c_{10} \\ c_{01} \\ c_{20} \\ c_{02} \\ c_{11} \end{bmatrix} = \begin{bmatrix} \overline{f_0(x_k, y_k)} \\ \overline{x_k f_0(x_k, y_k)} \\ \overline{y_k f_0(x_k, y_k)} \\ \overline{x_k^2 f_0(x_k, y_k)} \\ \overline{y_k^2 f_0(x_k, y_k)} \\ \overline{x_k y_k f_0(x_k, y_k)} \end{bmatrix}$$

5. Also, keep track of the number of observations available to the polynomial fitting scheme for each grid point (analysis value) and write these numbers, in addition to the analysis values, to an output fille.

6. Provide contour plots of both the analysis fields and the number of values used in producing the analysis values. Because cartopy's stereographic plotting function doesn't seem to take standard coordinates, you'll need to plot these using the latitude/longitude values of the grid points. The equations to convert from grid x-,y-coordinates to lat-/lon-coordinates are available on the document used for the polar stereographic projection. Otherwise, I have included code within the jupyter notebook that will plot onto a polar stereographic map.

7. You should link your github repository to the course's blackboard site. Within this repository, you should have:
    a. Your code
    b. Text files containing your analyses and number of observations considered during the analysis.
    c. 4 contour plots (2 analyses and 2 indicating the number of obs used at each analysis point for the two different radii of influence).
    d. Answers to the following questions:
        i. Describe the general features that you see in your contoured analyses.
        ii. Describe the differences that you see in your contoured analyses. Does one analysis seem to be smoother than the other? If so, what would cause this?
        iii. Run your program using a radius of influence of 6 cm (do not need to show). Describe the results – do they look realistic? If there are problems, what do you think might be causing them?
        iv. Suppose you ran this program with a small enough radius of influence that only one observation was available for determining a polynomial fit at a grid point. Should you be able to perform the matrix inversion? Why or why not?