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ATSC 500 – Boundary Layer Meteorology

Final project report

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TITLE

**Introduction**

Weather models must be fairly accurate to be useful

To simulate the planetary boundary layer (PBL), models need PBL parameterization schemes

Models cannot resolve processes and fluxes at small enough spatial scales

Length scales of eddies are smaller than model grid spacing (1-4km)

Uncertainty and inaccuracies

It’s important for models to be able to simulate the atmosphere fairly accurately for them to be useful to us.

One of the areas they need to be accurate in is forecasting the BL

In order to simulate the boundary layer, models are required to have planetary boundary layer (PBL) schemes in which they parameterize boundary layer processes because they are not able to resolve fluxes at the required spatial scales for the BL.  This is because the length-scales of eddies are smaller than the model grid spacing (which is normally somewhere between 1 and 4 km). Accuracy in PBL schemes is important because uncertainty and inaccuracies in these forecasts can have impacts on larger scale phenomena.  (Conglio et al, 2013)

**Motivation**

I have chosen to

Become familiar with NAEFS data

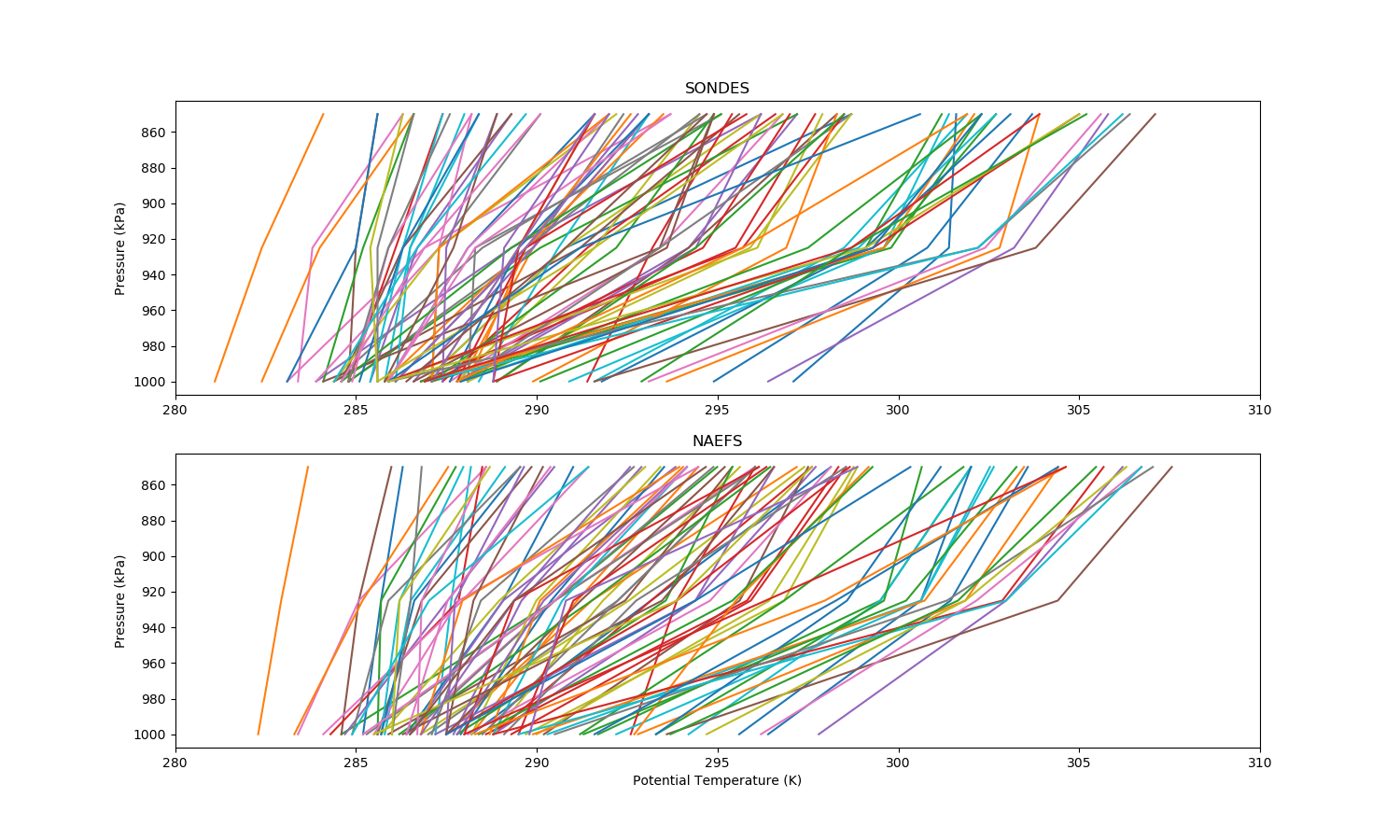
Study PBL scheme of one ensemble member

Assess the ability to forecast the BL

**Study Area**

My area of study is Cape Town, South Africa (33° 55’ 31’’ S, 18° 25’ 26’’ E). I have chosen this location because I am familiar with the area and the weather and thus I am able to have an intuition of the physical processes represented by the data. Cape Town’s time zone is GMT+2. This means that the data at 00z and 12z correspond to 02:00 and 14:00 local time, respectively, and provides examples of soundings both during the day and at night. Although I have specifically chose Cape Town for this project, the methodology could easily be applied to other locations given available data.

**Data**

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**MODEL**

I will be using two different data sets for this project: model data and observational data. The model data is from the North American Ensemble Forecast System (NAEFS). NAEFS is a 42-member ensemble, mad up of 21 Canadian members and 21 American members. Each group of 21 members comprises one control member and 20 perturbed members. The control members are the national weather models for Canada (GEM) and the United States (GFS). Perturbations in the model are in initial conditions and the physics schemes.

Out team has historical weather forecasts from NAEFS archived on our servers, which is where I was able to access this data from.

For this project I have chose to use only one ensemble member: the GFS control member. The model is initialised at 00z every day and I use daily forecast runs initialised at this time. The forecasts are available for 6-hourly time intervals: 00z, 06z, 12z and 18z. In order to compare model data with corresponding observations, I use only the data available at only 00z and 12z.

The NAEFS models have forecasts for various pressure levels, three of which may able to capture the boundary layer, depending on boundary layer height: 1000mb, 925mb, and 850mb.

**OBSERVATIONS**

Observations are sounding data, which are available from the University of Wyoming website. Sounding data is generally available at 00z and 12z and sometimes for Cape Town it is available at 09z. Soundings record data at many points within the PBL and the heights or pressure levels at which they are recorded are not consistent. In order to compare the sounding data to model data, I interpolate the soundings to the 850mb, 925mb and 1000mb pressure levels.

**NAEFS PBL SCHEME**

(Han et. al., 2016)

As discussed earlier (in the intro) the PBL scheme of any model will determine its ability to forecast variables in the boundary layer. What follows will be a brief discussion of the PBL scheme used in the Global Forecast System model.

GFS uses a hybrid Eddy Diffusivity Mass Flux (EDMF) BL parameterization scheme. It is hybrid in the sense that different schemes are used under different conditions in order to improve forecast accuracy. This new hybrid scheme was implemented in 2015 in order to improve the simulation of PBL growth in the model. The previous scheme that was used is an Eddy Diffusivity Counter Gradient (EDCG) scheme, which tended to under estimate PBL growth, hence the implementation of the EDMF scheme, which takes into account updraft fluxes. However, the EDMF scheme was shown to overestimate mixing in the tropics where the PBL is seldom strongly unstable, and so the EDCG scheme is still used in these areas as it better represents vertical mixing. The scheme is thus selected depending on the stability of the model. Stability is determined using z/L where L is the Monin-Obukhov stability parameter. The PBL is classified as strongly unstable (convective) for z/L < -0.5, and as weakly and moderately unstable for 0 > z/L > -0.5, after Sorbjan (1989).

How the two schemes differ:

The difference in the two schemes is of calculating the vertical turbulent flux. In the CG term the vertical turbulent flux is determined as follows:

“K is the turbulent eddy diffusivity, and is the nonlocal CG mixing term due to large nonlocal convective eddies and applied only to the temperature field.”

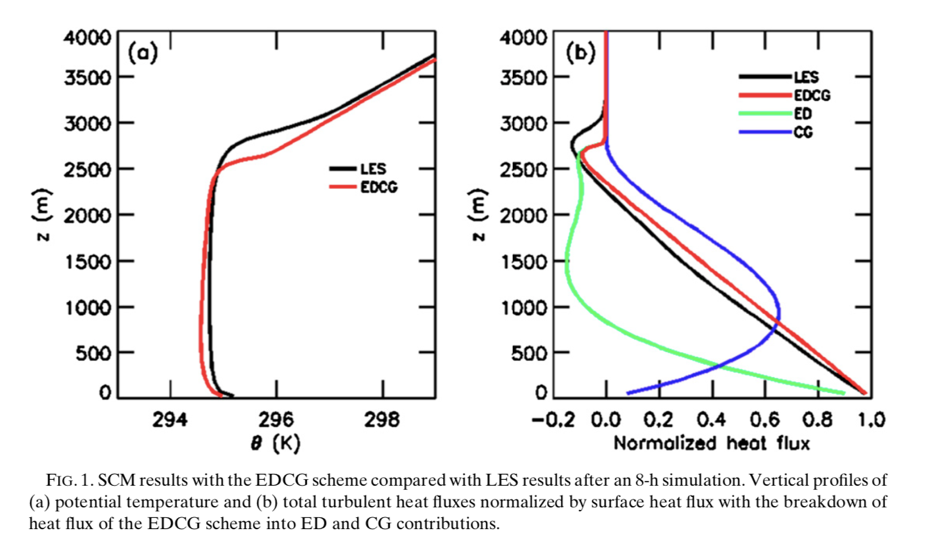
In the MF scheme the nonlocal gradient mixing term, γ, is replaced with a mass flux term as follows:

“where the subscript u refers to the updraft properties and M denotes the updraft mass flux.”

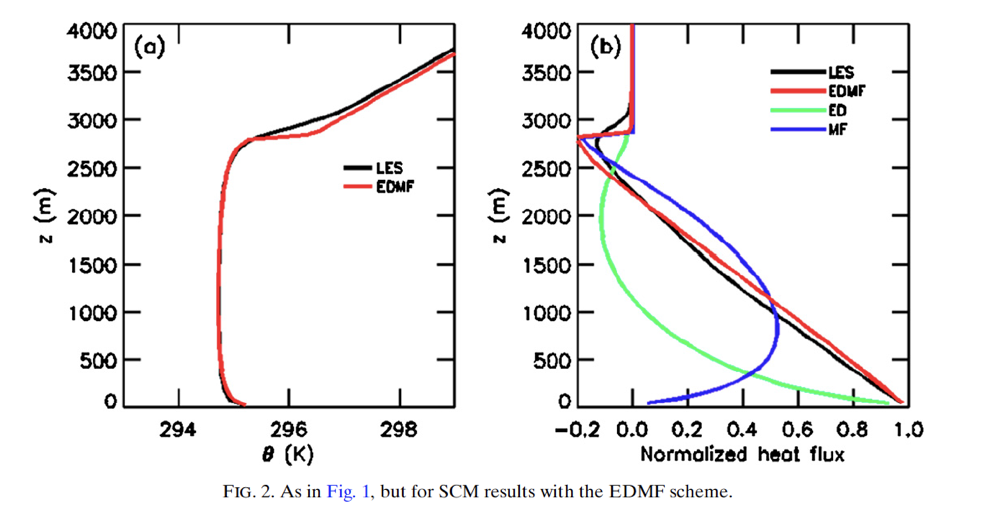
Expand on the above equations

The results of changing this scheme can be seen in Figure ? and figure ?. These figures show the comparison of the GFS single column model with a Large Eddy Simulation (LES) from SAM (the System for Atmospheric Modeling). Plotted are the vertical profiles of potential temperature and turbulent heat flux for both models.

Fig ? shows the EDCG PBL scheme and one can see that the potential temperature does not mix high enough. On in (b) one can see that the SCM under estimates the heat flux in comparison to the LES.



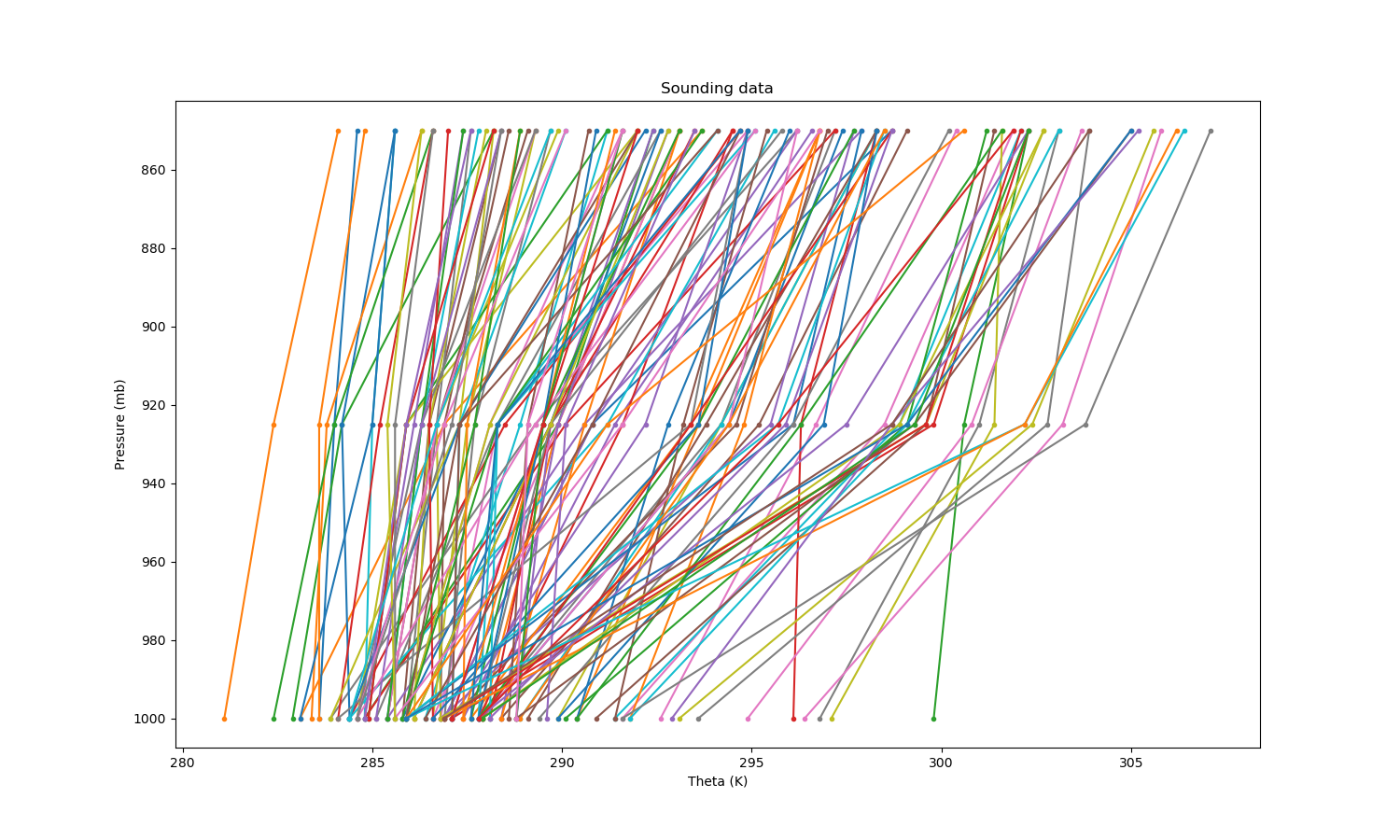
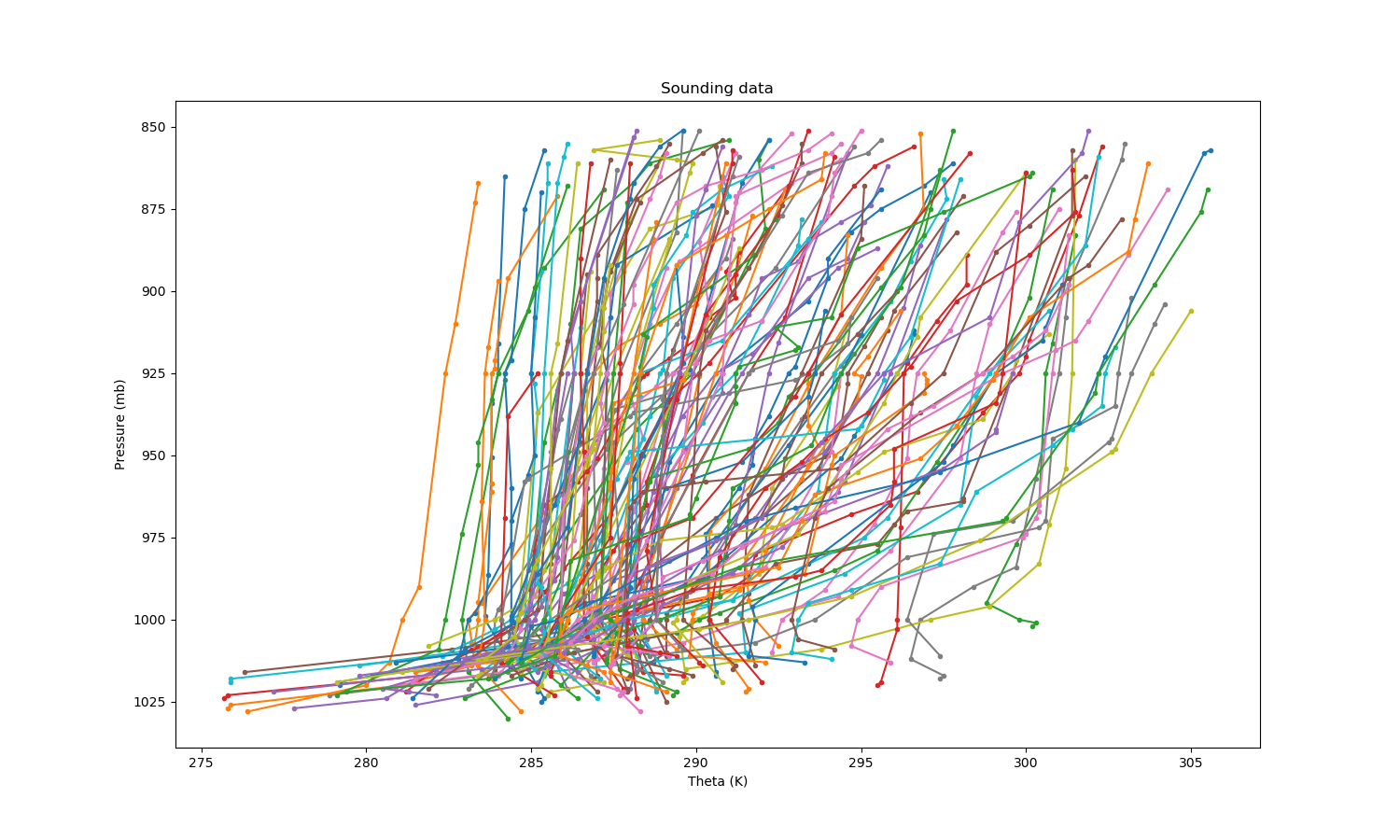
“FIG. 1. SCM results with the EDCG scheme compared with LES results after an 8-h simulation. Vertical profiles of (a) potential temperature and (b) total turbulent heat fluxes normalized by surface heat flux with the breakdown of heat flux of the EDCG scheme into ED and CG contributions.”



**Methods**

Determine overlapping dates

Interpolate soundings

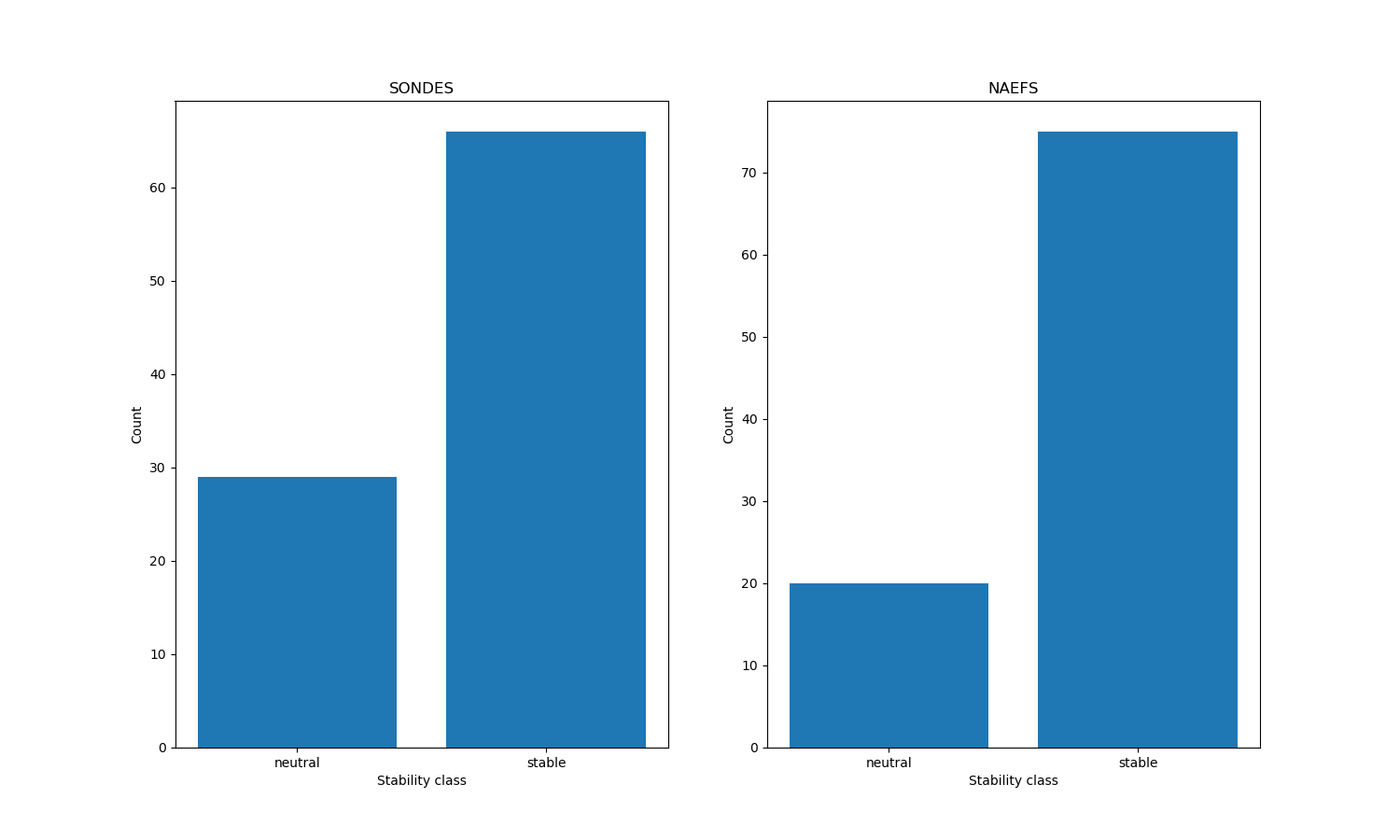


Calculate theta in NAEFS

Calculate gradients (theta)

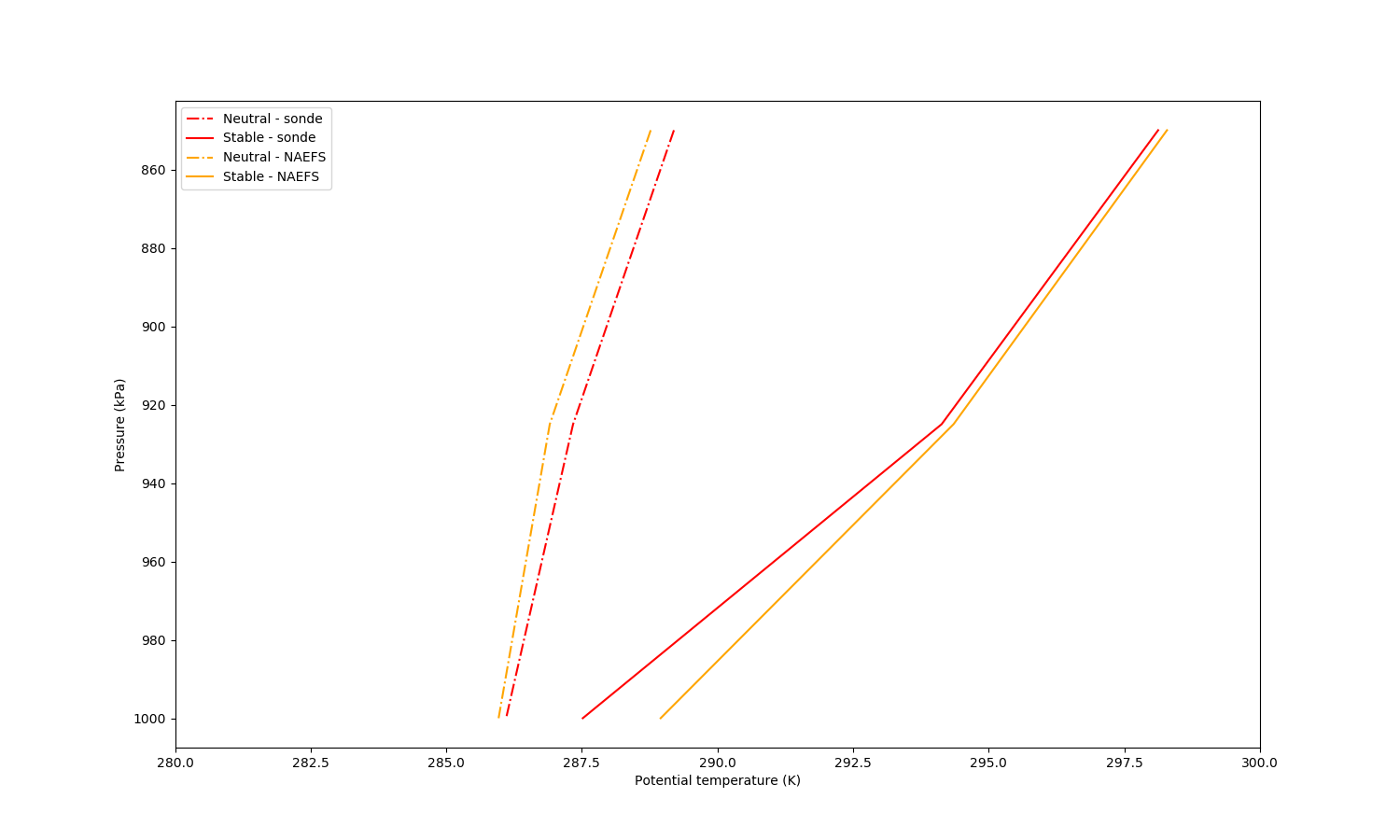
Identify stability classes

-- how did I do this?



Compare data across stability classes

**Results**



**Discussion**

**Conclusion**

**References**

Han, J., Witek, M.L., Teixeira, J., Sun, R., Pan, H.L., Fletcher, J.K. and Bretherton, C.S., 2016. Implementation in the NCEP GFS of a hybrid eddy-diffusivity mass-flux (EDMF) boundary layer parameterization with dissipative heating and modified stable boundary layer mixing. *Weather and Forecasting*, *31*(1), pp.341-352.

**NOTES**