The Formation of Wind

Kacey Clark*,**, Christian Burgoyne***

*Arizona State University, School of Mathematics and Statistical Sciences
**Arizona State University, Department of Physics
***Arizona State University, Ira A. Fulton Schools of Engineering

Abstract

Wind in simple terms is the movement of air. Often, this movement is caused by temperature differences in the atmosphere due to solar heating. In order to model this interaction, parameters such as humidity and pressure were analyzed as were their interferences with themselves over space and time. Large arrays of these values were utilized to simulate the movement of the humidity and pressure levels in three dimensional space. It was successfully demonstrated how slight variations in atmospheric pressure can form wind. Tornadoes are formed when two regions of air, one hot and one cold, meet and create violent funnels of wind. While the objective of simulating this phenomenon was initialized, it was ultimately left for potential future development. Knowing how these initial conditions can lead to large-scale phenomena can aid in the predicting and preparation for natural disasters like tornadoes. The code is written in Python and is freely available at https://github.com/ASU-CompMethodsPhysics-PHY494/final-2018-windformation.

Background

Being able to predict weather is important for the preparation for natural disasters such as tornadoes, but it is also important for daily luxuries, such as estimating how much precipitation will fall in an area on any given day, an ability neccessary for the weather channel to stay in business. These predictions are based on calculations of wind velocity, air pressure, and humidity among other variables.

In the most basic sense, ignoring gravitational effects and the rotation of the Earth, wind is caused by solar heating of the upper atmosphere which creates regions of differing pressures. Air molecules move from higher pressure regions to lower pressure regions, giving the air a net velocity, wind.

"Weather forecasting specifies how fields (temperature, wind, atmospheric moisture) change in time and space." (LaCasce).

Table 1. Preliminary data collected from various sources.

Column1	Colum
Type of Data	value
Energy from the sun	3 kWh/m^2/day
air pressure function	P=101325e^(-0.00012)
Humdidty of clouds	100%
Humdidty of air near clouds	95%
Humdity of air	69%
Density of air	1.225 kg/m^3
Temperature of clouds	329 K
Diffusion coefficient of water in air	0.282 cm^2/s

Methods

The analysis was conducted in Python 3 using the libraries numpy, matplotlib, and mpl_toolkits.30

The effect of solar heating was calculated using a three dimensional numpy array (10 m wide, 10 m long, and 100 m high shown in Fig. 1-2) as the space representing the coordinates of the space, with each point representing a cube of volume (one cubic meter was used as this volume in all calculations). Then the equation for atmospheric pressure as a function of altitude (Table. 1) was used in conjunction with numpy.random.normal() to define the initial conditions with an element of slight random fluctuations. The array was then modified for each time step (1 minute each step for a total of one day in Fig. 1-2), accounting for the added energy from the sun (Table. 1) and the diffusion of air molecules from higher pressure regions to lower pressure regions.

The diffusion of a cloud without wind was simulated using a method similar to that used in the formation of wind. A three dimensional array was again used (20 m wide, 20 m long, and 20 m high shown in Fig. 3-4), this time containing information regarding the moisture levels in each cube of volume with an area of high moisture (100% humidity) being the cloud, a boundary with an intermediate level of moisture (95% humidity), and the rest having a low humidity level (69% humidity). The array was then modified for each time step (1 minute each step for a total of one day in Fig. 3-4) by calculating the diffusion of water in air.

Results

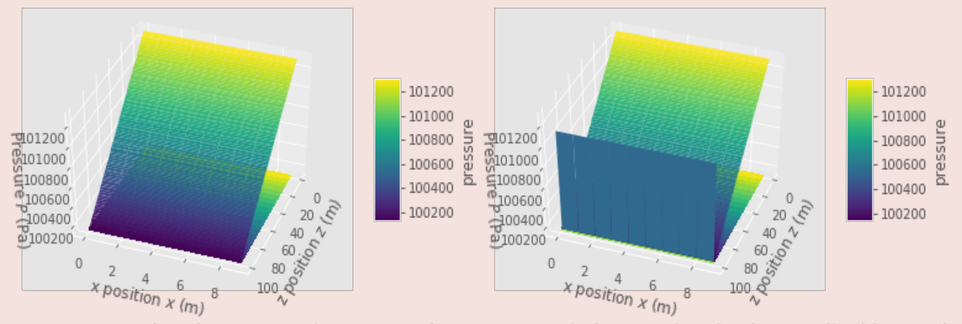

Figure 1. The pressure in the x-z plane at the start of the calculations (left) and at the end of one simulation day (right)

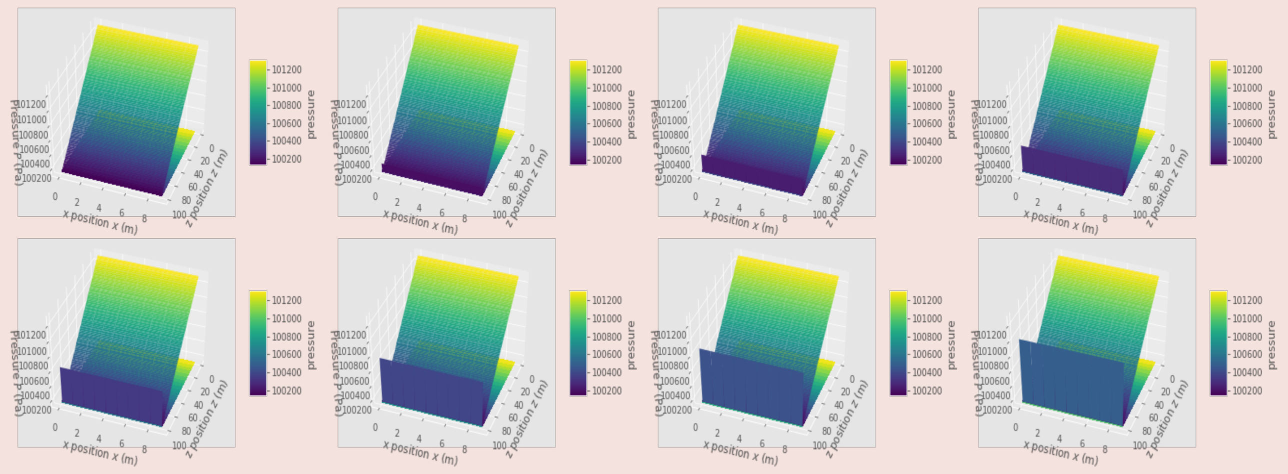

Figure 2. The pressure in the x-z plane (from top left to bottom right) at the start of the calculations, after 200 minutes, after 400 minutes, after 600 minutes, after 800 minutes, after 1000 minutes, after 1200 minutes, and after 1400 minutes.

Results

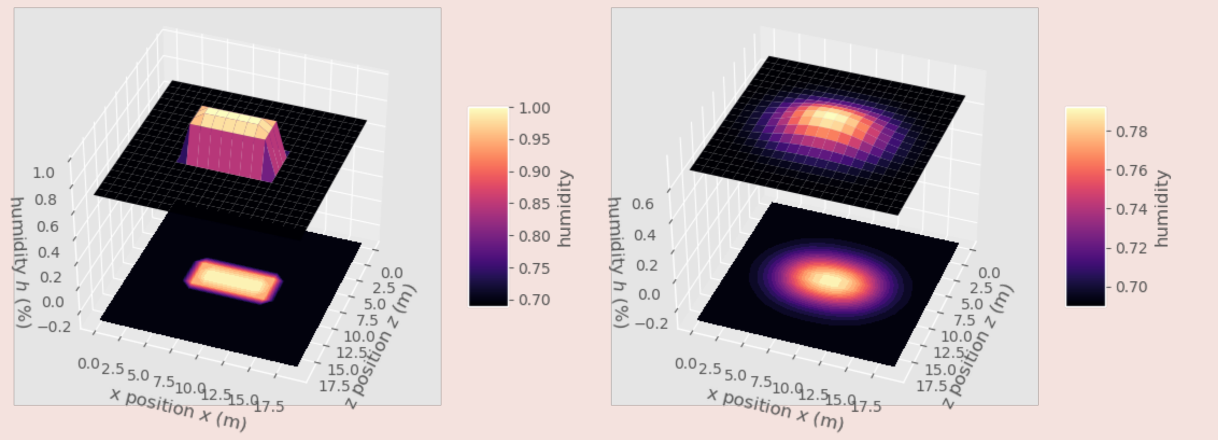

Figure 3. The humidity in the x-z plane at the start of the calculations (left) and at the end of one simulation day (right)

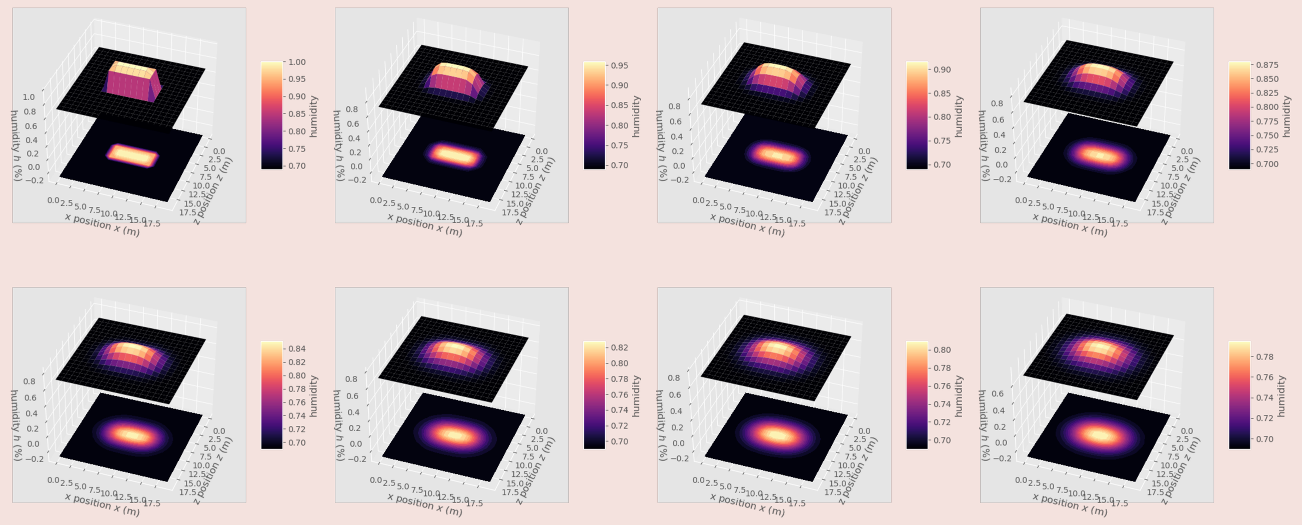

Figure 4. The humidity in the x-z plane (from top left to bottom right) at the start of the calculations, after 200 minutes, after 400 minutes, after 600 minutes, after 800 minutes, after 1000 minutes, after 1200 minutes, and after 1400 minutes.

Conclusion

The goal of these simulations was to model how wind is formed by solar heating and how clouds diffuse in the absence of wind. While a movement of air was simulated, the approach was naive in its neglect to consider gravitational effects. The aim of modeling the diffusion of a cloud was far more successful in that the model looked like the expected outcome, which can be directly observed. The benefit of using this simulation over observing an actual event is that the simulation gives an overview of the motion in a shorter, more observable timeframe.

References

http://www.uio.no/studier/emner/matnat/geofag/GEF4500/h08/unisdyn1.pdf

http://www.cgd.ucar.edu/staff/islas/teaching/2_Equations.pdf

http://www.need.org/files/curriculum/guides/energyfromthesunstudentguide.pdf

https://en.wikipedia.org/wiki/Barometric_formula

https://github.com/ASU-CompMethodsPhysics-PHY494/PHY494-resources/blob/master/16_PDEs_waves/16_PDEs_waves.ipynb

https://www.atmos-chem-phys.net/4/639/2004acp-4-639-2004.pdf

https://www.currentresults.com/Weather/Illinois/humidity-july.php

https://en.wikipedia.org/wiki/Density_of_air

https://www.cwb.gov.tw/V7e/knowledge/encyclopedia/