Atmospheric VOC, Ozone, and Particulate Concentrations In Colorado

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Abstract

There is overwhelming evidence that the concentrations of volatile organic compounds (VOCs), sub-stratospheric ozone, and high particulate counts are important pollutants that can cause or contribute to negative health effects. Further, the levels of these substances can lend insight into the ambient pollution of an area. Relative to their importance, however, there is little data regarding the concentrations of these compounds, especially in Colorado and especially as they relate to altitude and proximity to industries. This information is of particular interest to, among many others, those involved in environmental science education at Front Range Community College. Satisfying this interest is the aim of the Romulus DemoSat, part of the Colorado Space Grant Consortium (COSGC)'s DemoSat Program. To this end, the Romulus DemoSat will utilize the following sensors: a CCS811 VOC sensor, an MQ131 low-concentration ozone sensor, an SPS30 particulate sensor, as well as an MS5803-14BA pressure sensor. We intend to then apply the DemoSat position monitoring offered by the COSGC with wind speed data to compile a comprehensive portrait of these pollutants and their geographical relationships to industries such as fracking and agriculture.

1 Introduction

The EPA has released information regarding the production of ozone as a result of nitrogen oxides and VOCs, which can cause or exacerbate respiratory illnesses such as asthma and other medical conditions [1]. Therefore, the data we collect on both VOCs and ozone can lead us to conclusions regarding the overall pollution levels of the area. According to a number of case studies compiled by Joe Huffman of Carleton College, fracking releases large amounts of methane, along with other pollutants such as ground level ozone, nitrogen oxides, a variety of volatile organic compounds, and particulates [2].

2 Structure

Our designed to manufacture structure is intended to provide streamlined and lightweight packaging for our necessary systems and our sensors. To this effect, we chose a standard polystyrene and isopentane composite foam core board and utilized extensive CAD modeling in SolidWorks to minimize wasted space. Our structure was then laser cut at sufficient speed to prevent burning by a QX-80-1290 laser cutter and assembled with hot glue and aluminum tape. We will also include a layer of mylar shielding for proection from high frequency light and as insulation. For additional stability we 3D printed mounting brackets for our ProtoBoard (we chose a SparkFun Big Red Box) using Acrylonitrile Butadiene Styrene and a FlashForge New Creator Pro Dual Extruder 3D Printer as can be shown in 9. Brass inserts were then created by pouring molten brass into 3D printed cavities to provide us with M3 threads to easily attach our ProtoBoard.
While our total mass is at this point unmeasured, our final DemoSat should be under our previous 700g DemoSat and substatially under the Colorado Space Grant Consortium's mass

limit of 800g.

3 Control System and Life Support

We chose a Teensy 3.5 micro-controller with a real-time clock and an SD card to record our data. We used two CGR18650CF lithium-ion batteries in series for a maximum output of 8.4V, a minimum output of 6V and nominal output of 7.2V. We chose to control the output of these batteries with a COM-00107 5V regulator. This is especially important for COM-11288 resistive heater pads which require 5VDC as well as our sensors. We intend to use mylar insulation as well to reduce the strain on our power supply. Furthermore, we inted to use a PID loop to control the heating system.

4 Code

Our code was written in C/C++ and is available at https://github.com/frcc-bcc-engineering-club/Romulus-WolfSat. Our goal was to create the simplest code for the necessary tasks in order to limit the possibility of malfunction as well as allow all team members the opportunity to contribute code to the project. Therefore, we created an abstract class so we could begin writing the main loop before the sensors arrived and so that no sensor depended on another's code. Our primary loop follows the pattern of (sensors → data storage → life support → sensors → ...). We used the I^2C interface to accomplish this.

5 VOC Sensor

To measure the concentration of volatile organic compounds we decided to use the CCS811 VOC Sensor which is able to measure 0ppb to 32768ppb of total volatile organic compounds. It functions at -40-85C, 10-95% relative humidity and operates at 3.3V. The functional blocks of this sensor can be found in 4.

6 Ozone Sensor

The ozone sensor we used for this project is the MQ131 low-concentration ozone sensor. We intend to calibrate this sensor via co-location with an ozone sensor stationed at the Boulder County Campus of Front Range Community College which has recently been calibrated by the GO_3 Foundation of Boulder County. This sensor is capable of recording ozone concentrations from 10-1000ppb O_3 which is in the range expected. It is self-heating and regulates its temperature at 20C. Regretfully, it requires a 48 hour pre-heat time and requires 65% relative humidity which makes calibration that much more important.

7 Particulate Sensor

Our team has worked with the SPS30 particulate sensor on our previous DemoSat and we are familiar with its workings. It is able to detect both number of particles (from 0-3,000 particles/cm^3) and particle mass concentrations from .3 $\mu\cdot$ m up to 10 $\mu\cdot$ m.

8 Plans for Analysis

We intend to compare the data we receive to prior DemoSat flights, Colorado Oil and Gas Conservation Commission (COGCC) data such as 5 as well as wind speed and direction data from the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS), such as 6 along with DemoSat positioning provided the Colorado Space Grant Consortium (COSGC). Combining information from these three resources and our payload will hopefully lead to usable data regarding the pollution levels of Colorado and lead to inferences on the impact that industries, particularly oil and gas operations, can have in Colorado.

9 Figures

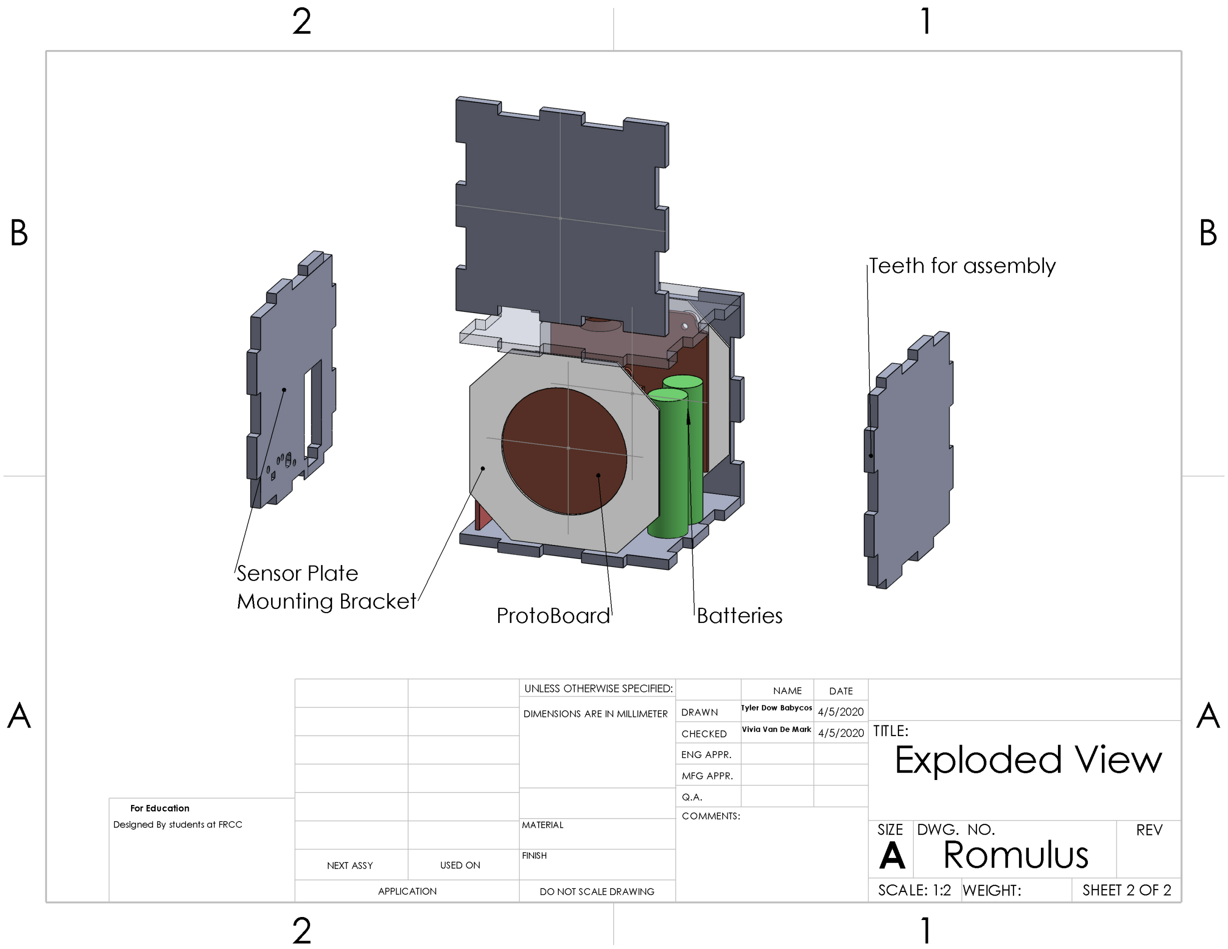

Figure 1: Exploded View of Romulus DemoSat

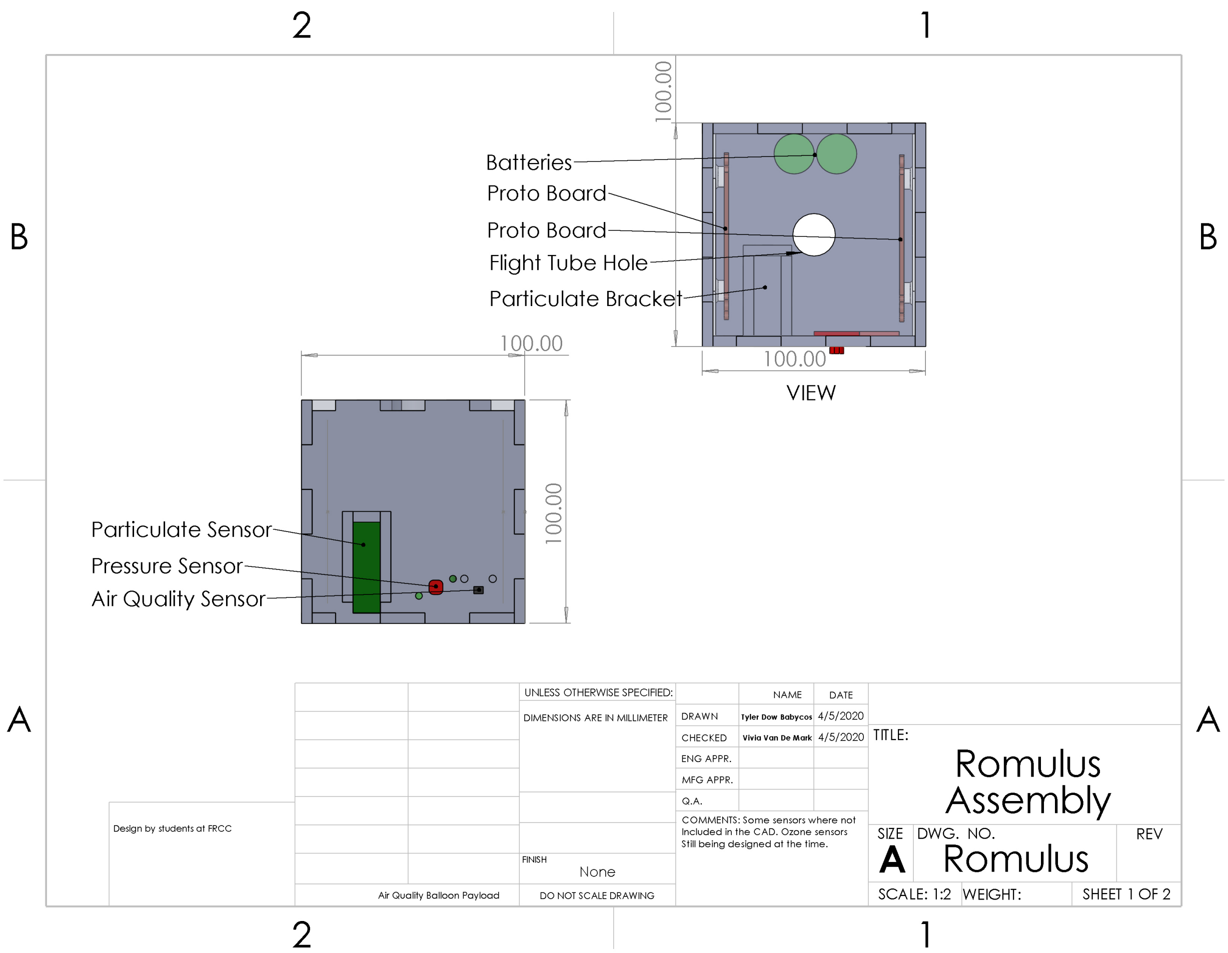

Figure 2: Closed View of Romulus DemoSat

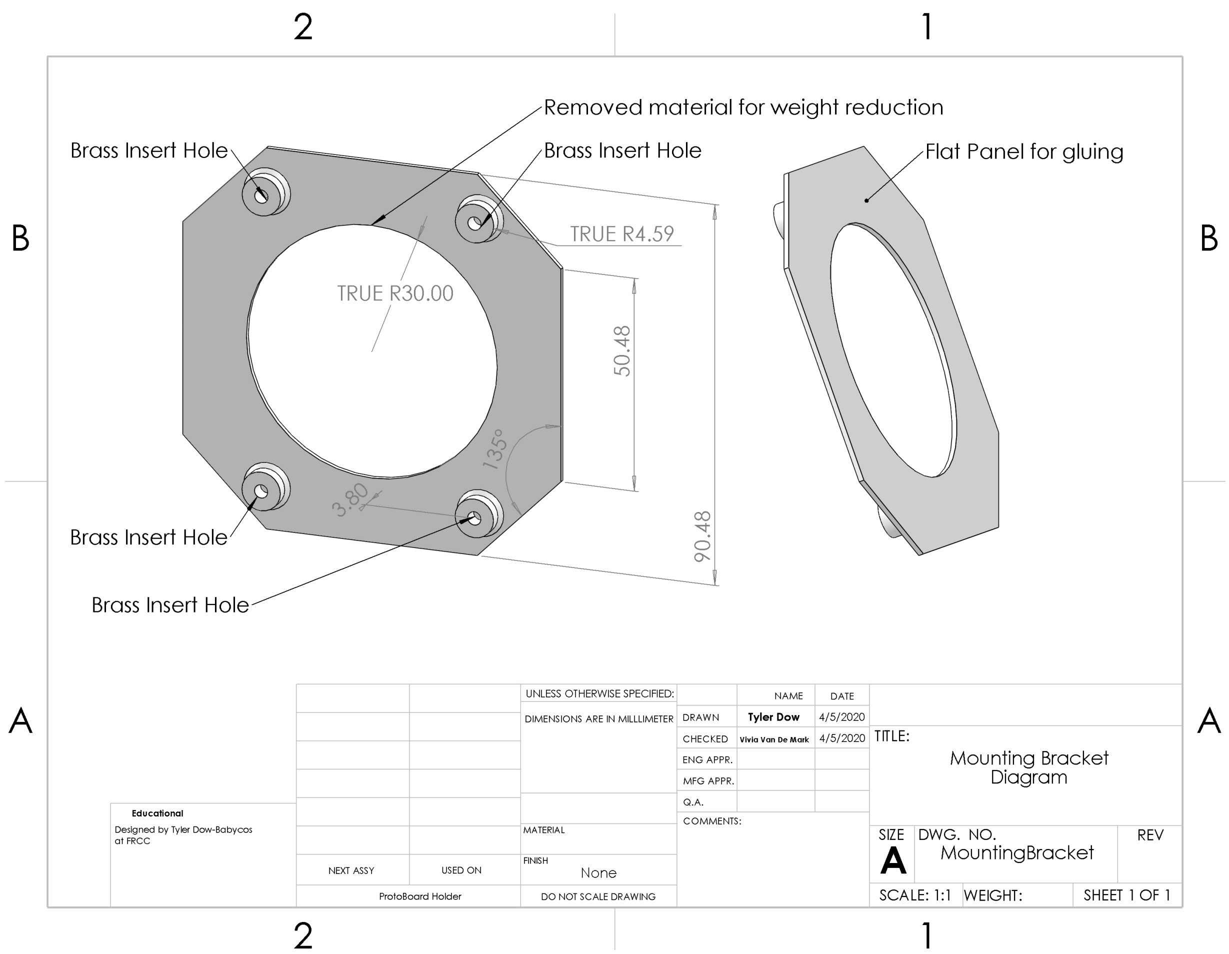

Figure 3: ProtoBoard Mounting Bracket Diagram

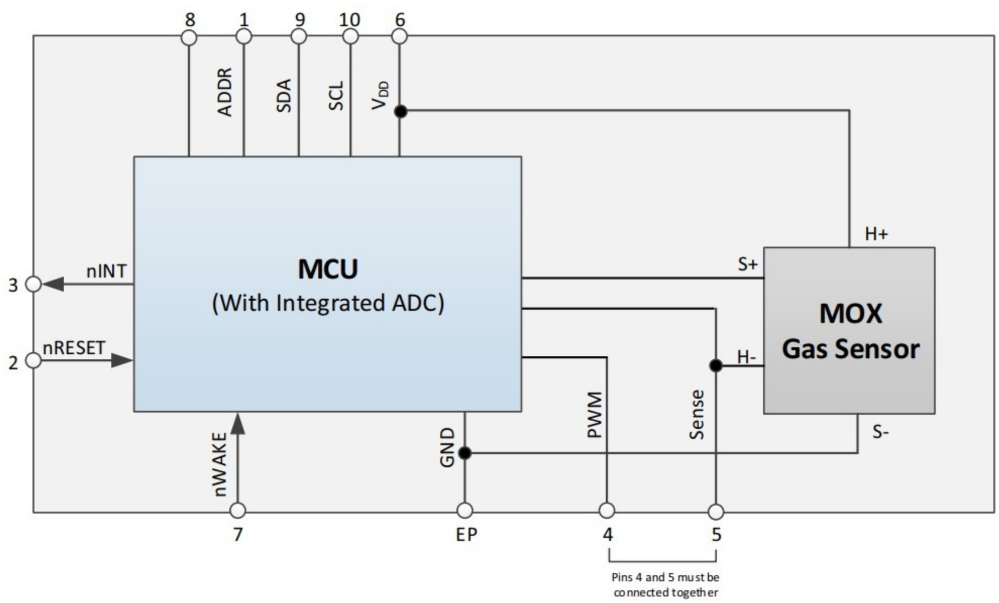

Figure 4: CCS811 VOC Sensor Block Diagram

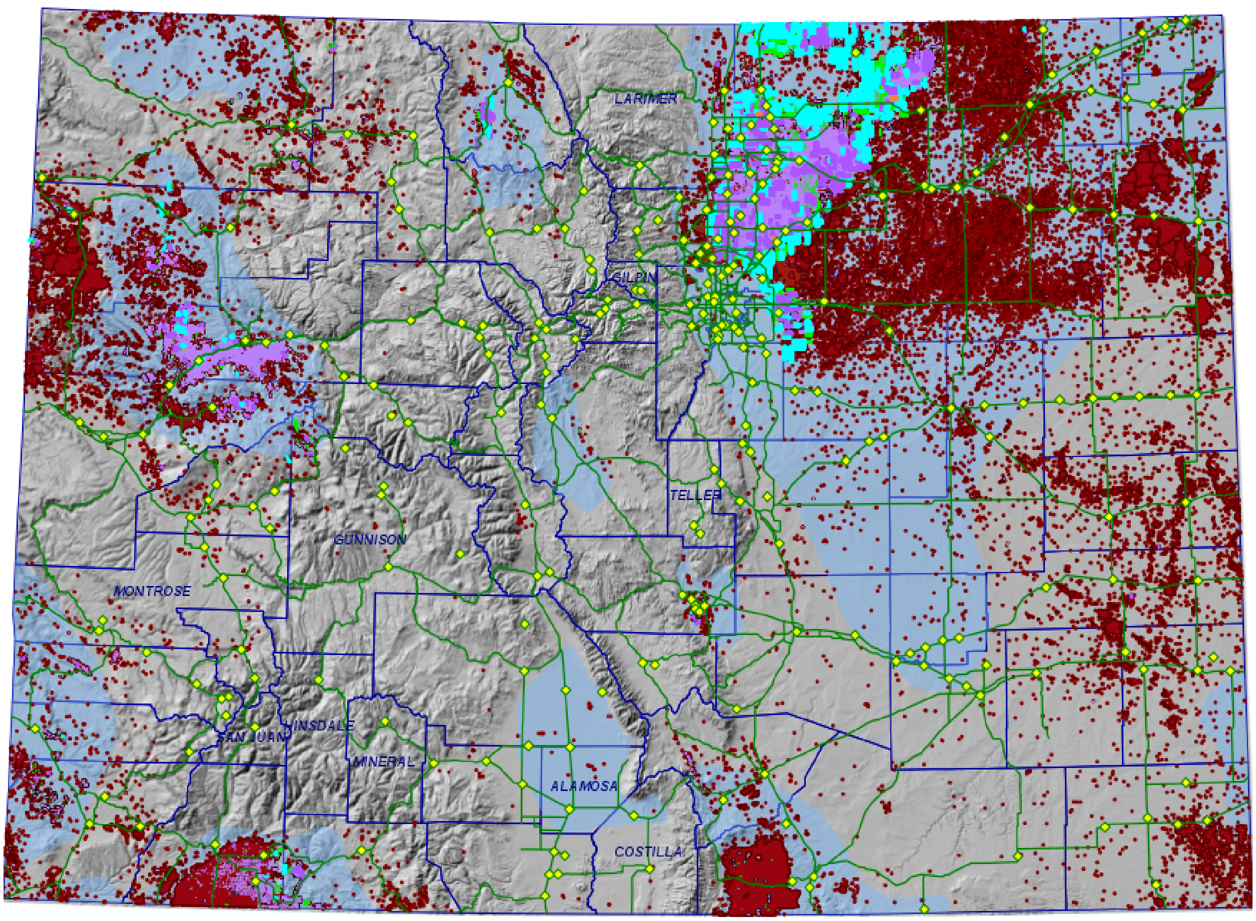

Figure 5: COGCC Oil and Gas Wells and Facilities

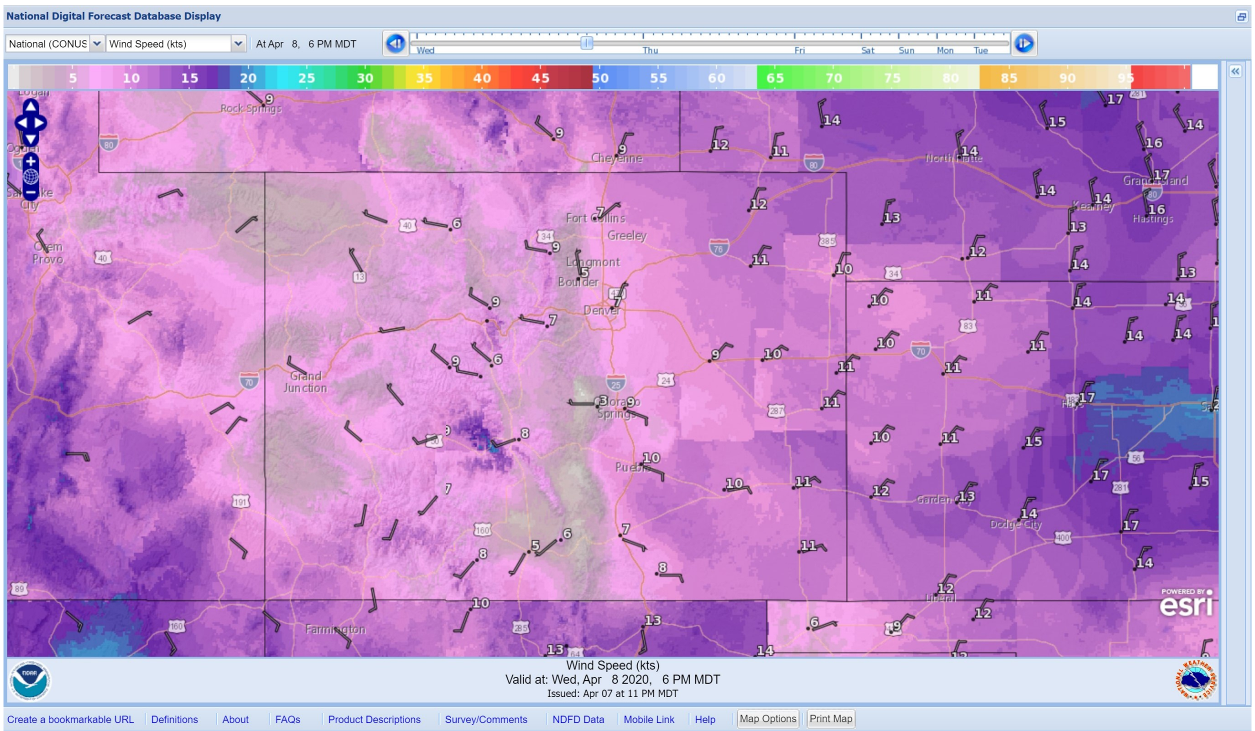

Figure 6: NOAA/NWS Wind Speed and Direction Data

References

[1] "Ground-Level Ozone Basics." *EPA*, Environmental Protection Agency, 31 Oct. 2018, www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics

[2] Huffman, J. (2019, February 15). Potential Health and Environmental Effects of Hydrofracking in the Williston Basin, Montana. Retrieved January 30, 2020, from https://serc.carleton.edu/NAGTWorkshops/health/ casestudies/hydrofrackingw.html