# *Thermal Interactions With Balloon Ascension Rates*

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**Motivation:**

This project was conducted to improve data quality from Tucson's National Weather Service soundings by researching a possible reason for erratic ascension rates. Tucson also has a unique set up in that it lacks an inflation shelter and the balloon is launched from the top of a third story building. The Sippican GPS Mark II samples the atmosphere at a certain rate as the weather balloon lifts it through the atmosphere. Ascension rates that lie outside the recommended rate could lead to erroneous data leading to poor data quality that may get input into Numerical Weather Prediction models.

**Introduction:**

The quality of sonde data is partially based on the one second sampling rate of the Sippican GPS Mark II as the sonde ascends through the atmosphere. If the balloon ascension rate is not within the parameters specified by the sonde manufacturer, inaccurate readings could result. The ideal ascent rate of the Sippican is 300 meters per minute (m/min), with a recommended range between 275 m/min and 350 m/min. What this study attempts to find is a proper helium flow rate and final balloon volume that would best result in proper ascension rates. Also, because we are dealing with an ever changing atmosphere with varying wind flows and stability throughout the entire flight, an attempt was also made to find an atmospheric parameter that helped to predict atmospheric driven irregularity.

Over the course of two months, data was collected to measure changing fill rates and volumes, thermal strength in the lower atmosphere, and current surface conditions. As the study progressed, it was determined that the focus should be on potential problems in the lower atmosphere below 400mb during 00Z flights. Throughout the entire study, 100% of flights between 400mb and termination were within sonde sampling parameters. Secondly, all but one 12Z flight (99.2%) were within the recommended ascent parameters below and above 400mb. Thus, the study pointed toward finding a parameter to help predict ascension rates during the afternoon (00Z) release below 400mb.

The most significant ascent impact in the Desert Southwest relates to heat and the intense thermals that can develop on most afternoons. The ideal gas law would be a good estimate for the behavior of helium under different temperatures and pressures, but our unique filling set up would limit the effectiveness of using the law to calculate the total helium volume (see methodology section for description of Tucson's set up). Thus the focus was to find a correlation between the thermal lift (soaring index) and ascension rates based on our unique set up.

The Soaring Thermal Index is the difference between the environmental temperature and the temperature at a particular level determined by following the dry adiabat through the forecast maximum temperature up to that level. This is a useful index in the desert Southwest as daytime heating creates strong thermal lift on the order of 400 ft/min with a maximum exceeding 750 ft/min. This thermal lift strongly affects ascension rates. The parameter of the Thermal Index that I chose to pay attention to the most was the Maximum Rate of Lift. This parameter is an estimate of the maximum strength of the thermals. It is computed from an empirical formula which combines the expected maximum height of thermals with the difference in the environmental temperatures between the maximum height of the thermals and the temperature four thousand feet above the ground. Additional empirical adjustments are made based on the K-Index and the opacity of middle and high level cloudiness expected during peak thermal hours. The max lift is calculated from the 12:00 UTC sounding, and is available by 15:00 UTC. Weather Forecast Office Tucson runs an internal script to calculate the Soaring Index based on the morning sounding.

## **<u>Methodology:</u>**

First, an overview of the actual launch site is warranted. Unlike most WFO sites that launch weather balloons, Tucson does not have an inflation shelter. The site is located on the University of Arizona campus located in downtown Tucson with many urban features. The launch site is located on the top of a three story building. The balloon is filled in a tub and covered with a cloth material to prevent any movement. Helium then flows into the balloon through a FloCat 16 Series Mass and Volumetric Flow Meter that measures the mass flow and flow volume in Standard Cubic Feet per Minute (SCFM). The gauge also displays the temperature in Celsius and pressure in absolute pounds per square inch of the helium as it passes the gauge. However, there is ten more feet of gray tubing after the gauge that is exposed to the intense heat in the afternoon before reaching the nozzle on the side of the tub. This additional tubing can slightly increase the helium pressure between the flow meter and the balloon itself. Despite this unique launch setup, accurate ascent rates, and thus accurate observations can still be made with some care.

Step by step procedures were established for the continuity between different upper air observers at WFO Tucson. Procedures were changed to limit the amount of "weathering" the balloon would receive being exposed to the elements on the roof. Instead of filling the balloon 30-45 minutes before launch, as recommended by the upper air policy manual. The balloon was filled at a certain rate and to a certain volume, and recorded by each observer. At the conclusion of the flight, thermal parameters, current weather conditions at Tucson International Airport (6 miles due south), ascension rates, and balloon volume were documented on a spreadsheet. After two months of collecting data, the data was used to come up with an experimental chart to estimate balloon rate and volume based on the thermal maximum lift (Figure 1). Also included is the text of the Soaring Index (Figure 2).

## Implementation:

Since implementation, launchers have been instructed to follow the chart and to note the rate and volume of helium only when flight ascension rates are not within recommended parameters.

A graph of ascension rates from the surface to 400mb from March 1 to April 30 compares the overall inconsistency of ascension rates before the project (Figure 3). Ascension rates were also plotted during the study (Figure 4). Note that while the data was compiled from May through June, and observers wrote down ascension rates each day, better consistency started to appear even before the chart was created. No ascension rate outside the recommended parameters was recorded from June 24 to July 19. This consistency may have been because of overall awareness of observers participating in the research and their ability to adjust helium usage downward. After the chart was implanted, ascension rates were then plotted until September 30 (Figure 5). Finally, an overall look at ascension rates from March 1 to September 30 was included to show improved consistency and lowered ascension rates (Figure 6). Balloon volumes used to be filled to 80 standard cubic feet per minute (SCFM), day or night. However, as the project progressed, volumes did not exceed 78 SCFM at any time, and sometimes volumes were as low as 72 SCFM during strong thermal days. This had the side benefit of lowering helium usage and cutting overall helium costs incurred by the National Weather Service.

## Conclusions:

The goal of this research was to improve consistency in the upper air program at WFO Tucson. Even though WFO Tucson doesn't have the luxury and protection of an inflation shelter and open landscape, quality data based on ascension rates is attainable. The research proves that result.

In addition to improving ascension rate consistency, other areas of improvement were discovered. Helium gas savings have occurred due to using less per flight, which is important due to the expense involved with purchasing helium. Lower ascension rates have also led to higher balloon burst heights, thus allowing more data from the stratosphere. Finally, this research has operational value because it showed the effects of the thermals on helium ascent, and that upper air observers can make adjustments to mitigate these thermal effects.

The additional value of this research for other offices in the desert Southwest is unknown. The methodology could be useful, but the exact effects and strength of the thermals generated at different locations will vary.

**Acknowledgement:**

I would like to acknowledge and thank Jeff Davis (Lead Forecaster WFO Tucson) for his guidance and help with understanding the Soaring Index and for providing additional information to help with my research. I would also like to thank Mic Sherwood (OPL WFO Tucson) for helping with an overview of the equipment and training to launch the weather balloons, and to those on WFO Tucson's staff that helped log data over the past couple of months. Finally, thank you to Glen Sampson (MIC WFO Tucson) and Erik Pytlak (SOO WFO Tucson) for guidance on my first research paper.

**Balloon Fill Rates and Volumes**
*Fill rate should never be more than 12 psi based on balloon specifications

**12Z Flights**

| Range (SCCM) | Midpoint |
|---|---|
| 76 – 80 | 78 |

*99.9% of all flights in this range for 12Z have been within specs

**00Z Flights**

| Thermal Max Lift (ft/min)* | Range (SCCM) | Midpoint |
|---|---|---|
| <400 | 77 – 79 | 78 |
| 401 – 500 | 76 – 77 | 76.5 |
| 501 – 600 | 74 – 76 | 75 |
| 601 – 700 | 73 – 75 | 74 |
| 701 – 800 | 73 – 74 | 73.5 |
| >801 | 72 – 73 | 72.5 |

*Max Lift is based on the Soaring Index and can be found under WRKSRG after 15Z
**Max Lift applies to 00Z Flights only
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Figure 1: Chart created after compiling observed data from research from May and June.

UXUS97 KTWC 091340
WRKSRG

SOARING FORECAST FOR TUS DATE…07/09/09…12Z

THERMAL INDEX….MINUS SIGN INDICATES INSTABILITY
5000 FT ASL……..-6.0
6000 FT ASL……..-5.5
10000 FT ASL……..-2.0
15000 FT ASL……..3.0

HEIGHT OF THE – 3 INDEX…....7500 FT ASL
TOP OF THE LIFT………….........11500 FT ASL
TUS MAX TEMPERATURE.........102 DEGREES F
FIRST USABLE LIFT……….......93 DEGREES F
MAXIMUM LIFT………………...493 FT/MIN ←

UPPER LEVEL WINDS
5000 FT ASL....335 DEGREES AT 03 KNOTS
10000 FT ASL....215 DEGREES AT 07 KNOTS

IT IS EMPHASIZED...THIS SOARING FORECAST INFORMATION IS VALID ONLY FOR THE RAOB SITE AREA AND FREQUENTLY WILL NOT APPLY TO OTHER AREAS IN THE STATE.

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Figure 2: Soaring Forecast for Tucson on July, 09 2009. Maximum lift is highlighted.

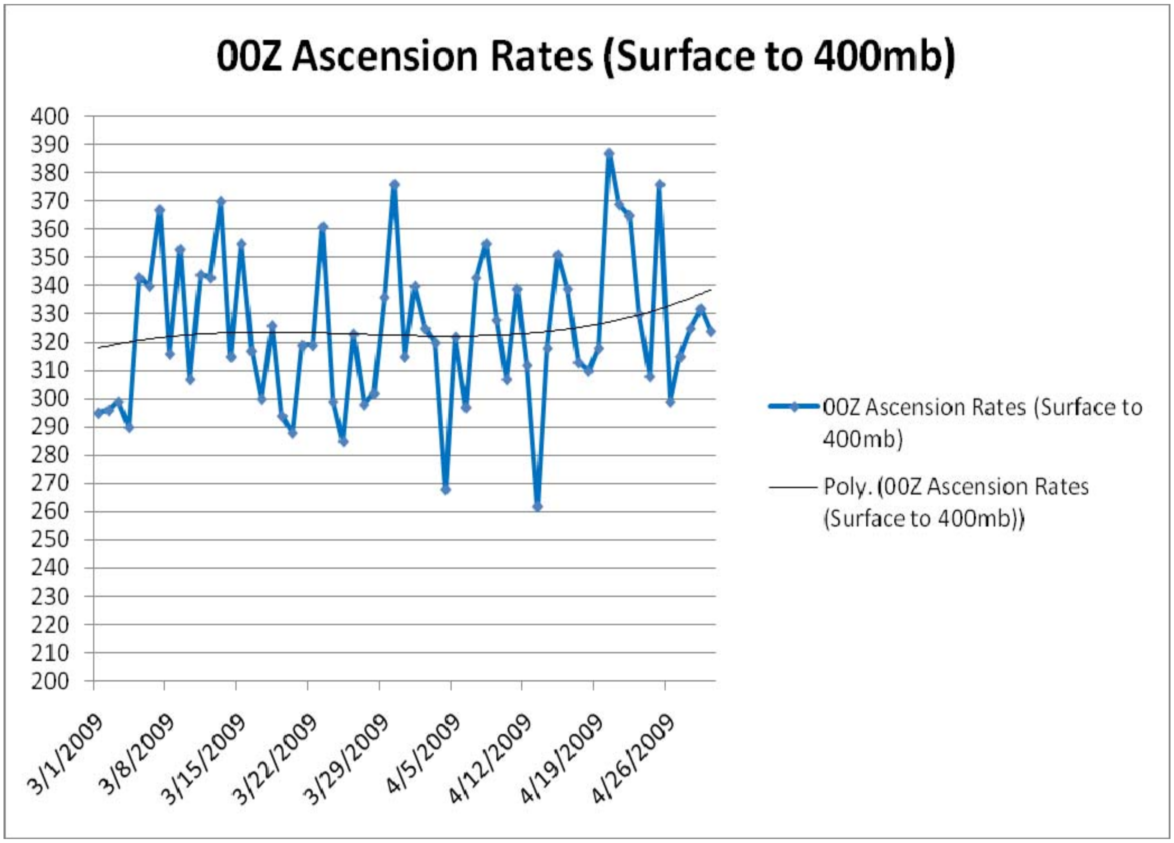


Figure 3: 00Z Flight ascension rates from the surface to 400mb from March 1 to April 30. This is prior to the study.

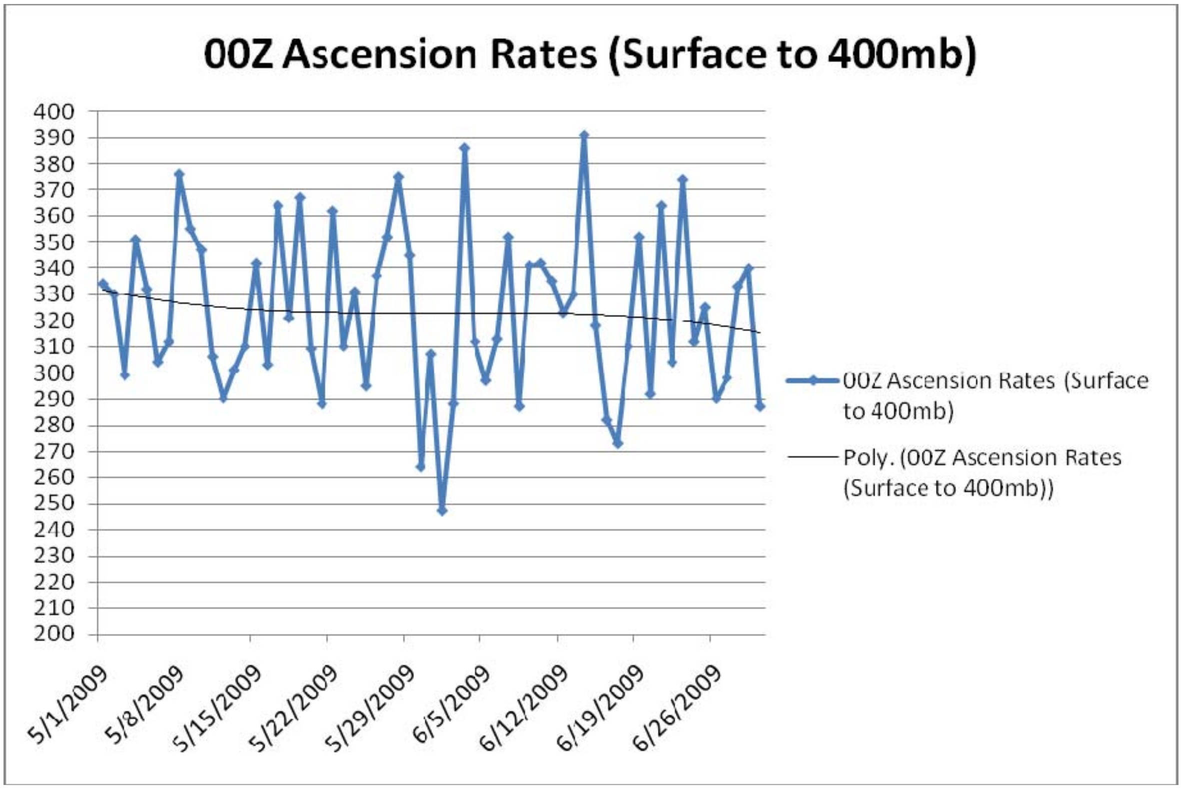


Figure 4: 00Z Flight ascension rates from the surface to 400mb from May 1 to June 30. This is during the study.

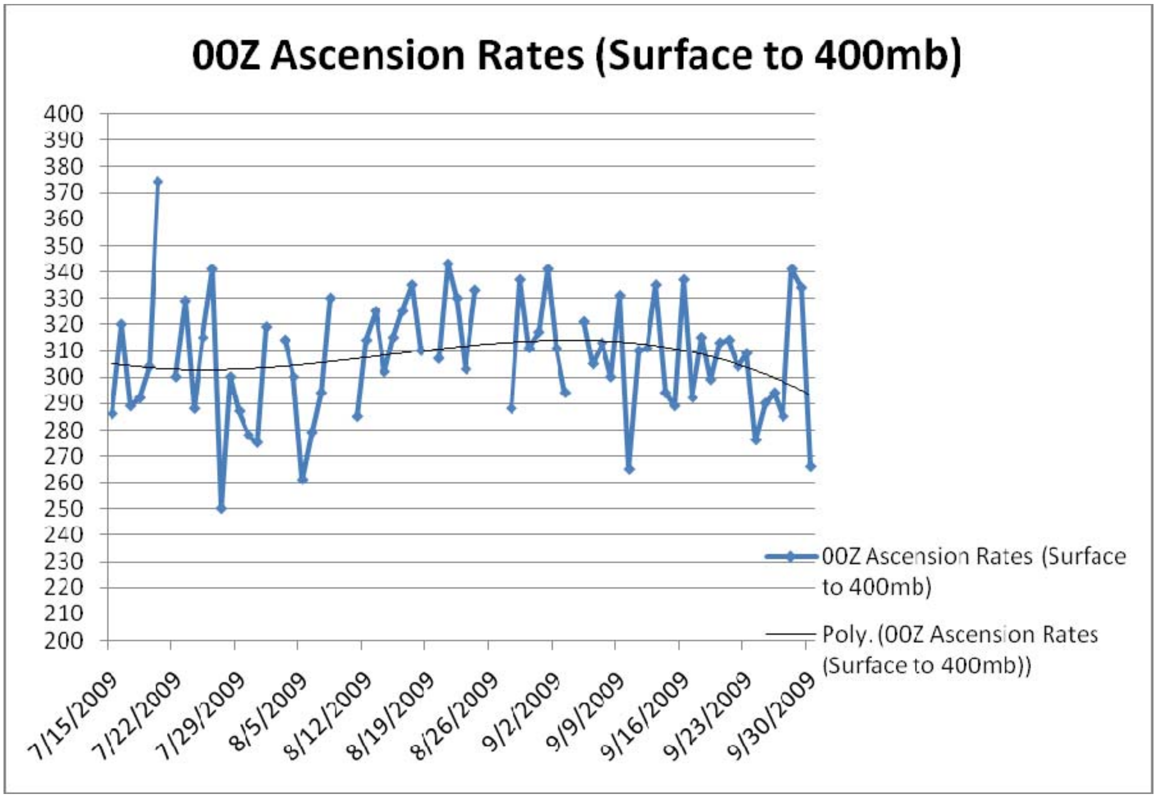


Figure 5: 00Z Flight ascension rates from the surface to 400mb from July 15 to September 30. This is post study with observers using the chart.

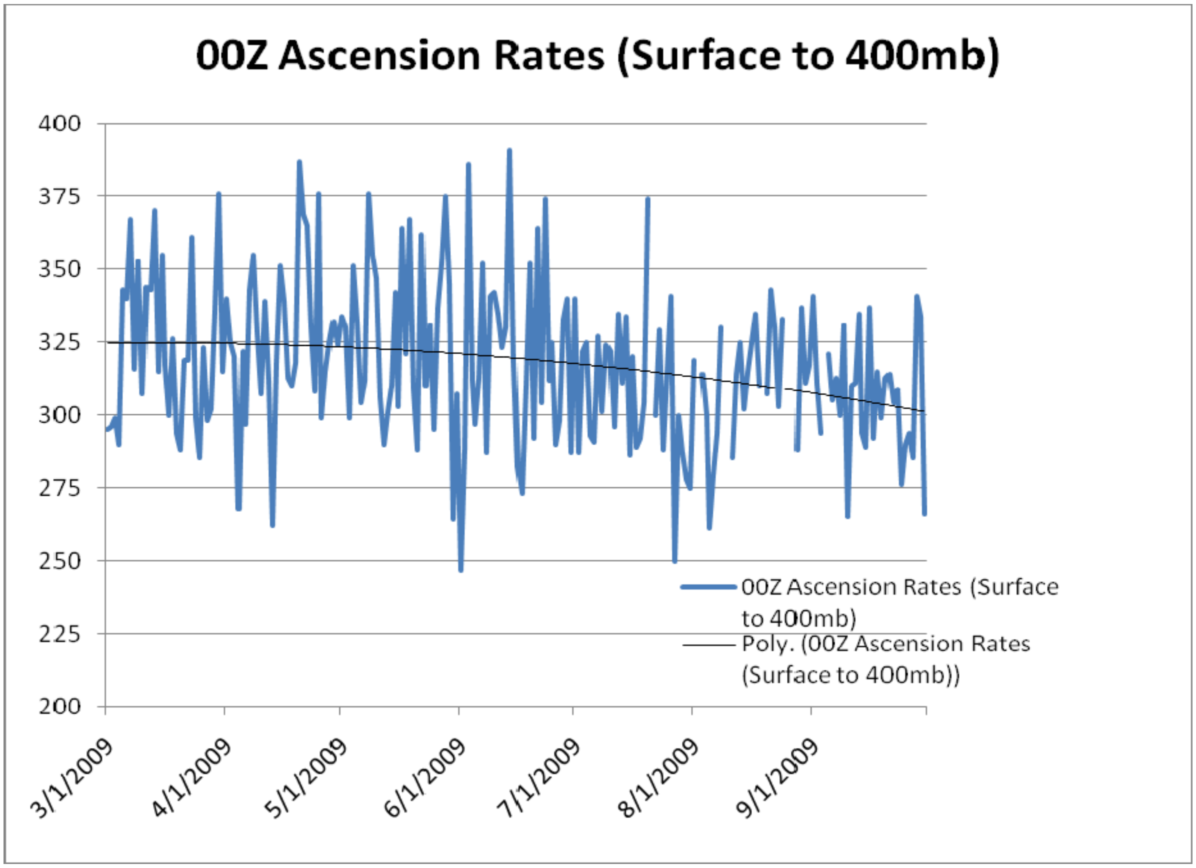


Figure 6: 00Z Flight ascension rates from the surface to 400mb from March 1 to September 30.