Long Term Tropospheric and Stratospheric Measurements Using High Altitude Balloons

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Abstract

The Arkansas BalloonSAT program is an educational outreach and research program at Arkansas State University. A variety of instruments including HOB data loggers and Anasode have been flown on flights in the past four years. Measurements using BalloonSAT provide a cost effective option and supplement to satellites and unmanned aerial vehicles. This includes identifying water vapor and temperature profiles over seasons and years. Water vapor trends were observed to vary with seasons with water vapor the lowest in the autumn and greatest in the spring at stratospheric altitudes. Temperature measurements followed a typical atmospheric profile measurement with a lapse rate inversion in the stratosphere.

Introduction

High altitude weather balloons provide a low cost alternative and supplement to unmanned aerial vehicles (UAV) and satellite atmospheric measurements. Weather balloons and UAV are more sensitive to local processes than satellites which are ideal for global studies. Balloon borne measurements in conjunction with satellites can calibrate instruments and identify subtle long-term changes.

Monitoring trends in water vapor content in the stratosphere is important to create accurate climate change detection and prediction. Studies point to the importance of stratospheric water vapor as an indicator of global temperature changes, with 60% contribution to greenhouse effect. Greenhouse gases focus on carbon dioxide as water vapor concentrations are driven by natural processes and not in Higher concentrations of water vapor can absorb more thermal IR energy radiated from the Earth which further warms the atmosphere. This creates a positive feedback loop with warmer temperatures holding more water and greater warming capacities.

Methods

- Anasode-4 (Anasphere) collect temperature, water vapor as relative humidity (RH) and pressure profiles throughout ascent and descent. RH is converted to absolute humidity with known temperatures.
- Typical balloon flights elapse 90-120 minutes reaching up to 26 km (100,000 feet) using 1600 g weather balloons
- Payload boxes secured to balloon and parachute with a 100 pound test polyester line passed through each box.
- HAM radios transmit real time GPS and altitude data to aid in balloon recovery.
- Data was collected across 10 flights over 3 years. On each flight data collected at 15 second intervals. Graphs are made with one minute averages equating to points every 0.55 km.

Figure 1: Inflated balloon with payload boxes before liftoff.

Temperature

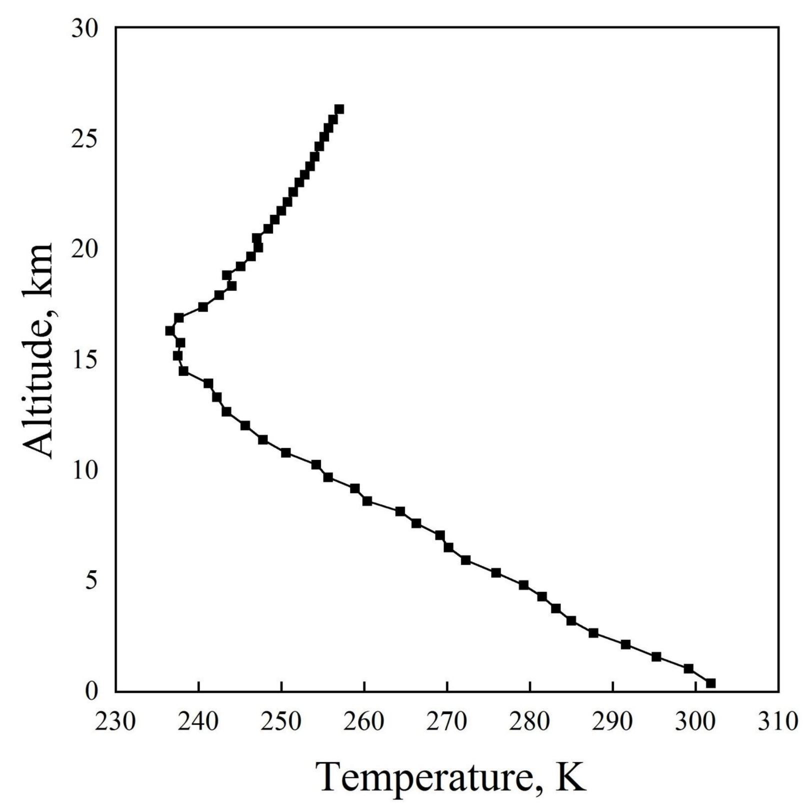

Figure 2: Temperature profile of atmosphere measured with BalloonSAT. (ABS-30)

- Decrease in heat convection as with higher altitudes (0-15km) results in negative temperature lapse rate in the troposphere.
- Tropospheric lapse rate measurements (-4.2 °C/km) compare to the U.S. standard lapse rate (-6.5 °C/km).
- Positive lapse rate in the stratosphere (15-30 km) is due to ozone reactions to form oxygen and heat.
- Similar trends observed on descent.

- No seasonal variation in temperature was observed at 10 km.
- Tropospheric temperature was lower in autumn 2013, but higher in 2014 compared to spring and summer 2014.
- BalloonSAT measurements indicate a 0.0013 K increase per year at 10 km, matching satellite measurements (+0.004 K), considering error in satellite and balloon-borne measurements.

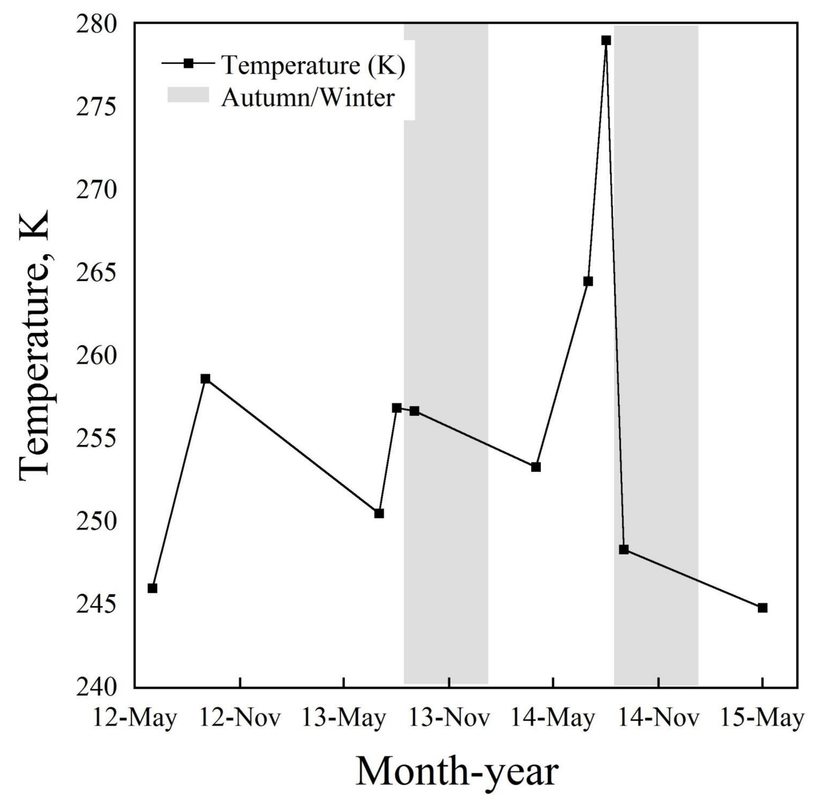

Figure 3: Seasonal temperature variation at 10 km.

Water Vapor

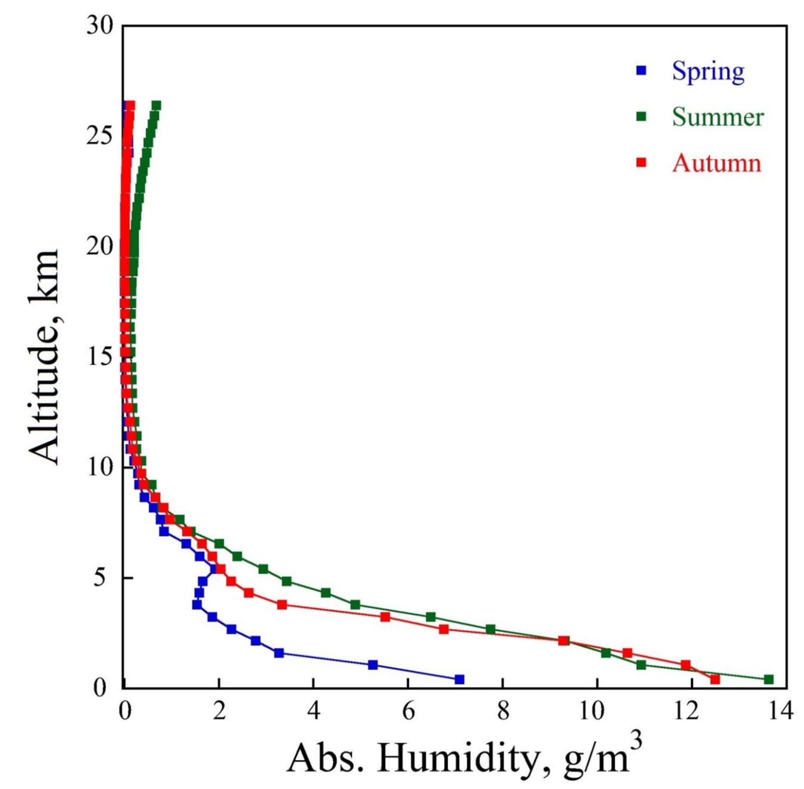

Figure 4: Seasonal water vapor profiles observed over NE Arkansas.

- Water vapor concentration decreases in troposphere as the saturation vapor pressure and temperature are proportional.
- Most seasonal changes occur below 12 km within the troposphere.
- Opposing processes , extinction of upwelling from troposphere verses methane oxidation may explain small variation in stratospheric water vapor observed.
- Same trends observed on descent.

- Higher amounts of water vapor were found to occur in the summer months, with minima occurring in autumn months.
- Maxima correlate with North America monsoon seasons which transport moist tropospheric air into stratosphere via monsoonal circulations.
- Winter water vapor is lower as water vapor freezes into ice crystals which fall out of stratosphere.

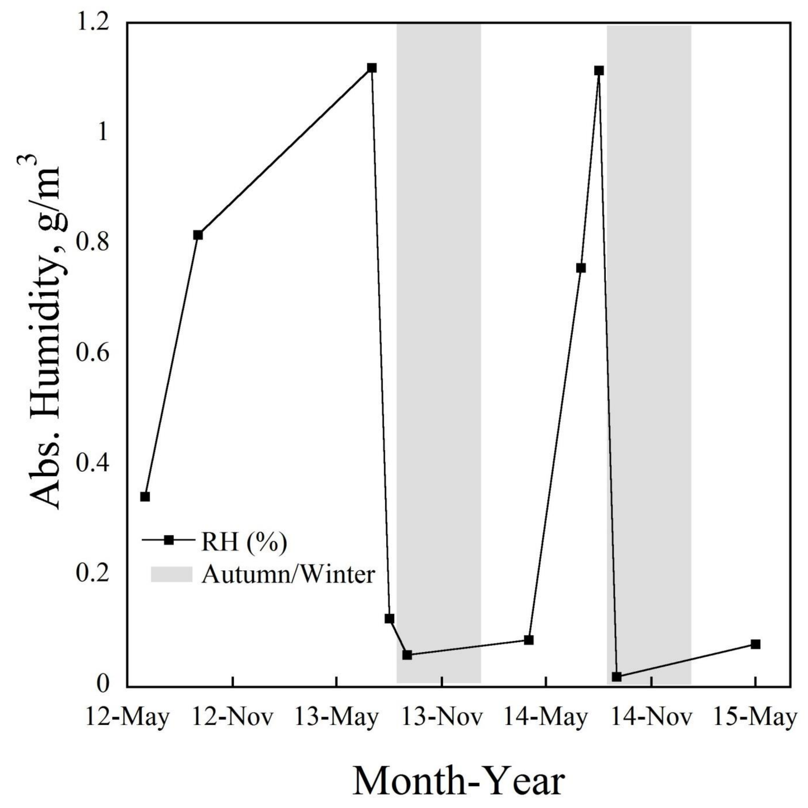

Figure 5: Seasonal water vapor measurements observed at 27 km .

Summary

- Arkansas BalloonSAT measurements using Anasode instruments prove to be effective research instruments that match other high altitude balloon and satellite studies
- Temperature profile measurements show a negative lapse rate in the troposphere and positive lapse rate in the stratosphere, which correlates with understood atmospheric models and other measurement techniques.
- Temperatures are lower with higher tropospheric altitudes due to greater distance from surface convection currents, while higher with increasing stratospheric altitudes due to reactions of ozone and UV which releases heat as a product.
- Water vapor measured as absolute humidity shows high variability across seasons at altitudes below 12 km, and small variations at higher altitudes.
- Stratospheric water vapor measurements show higher concentrations in summer than autumn which correlate with North America monsoon seasons.

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