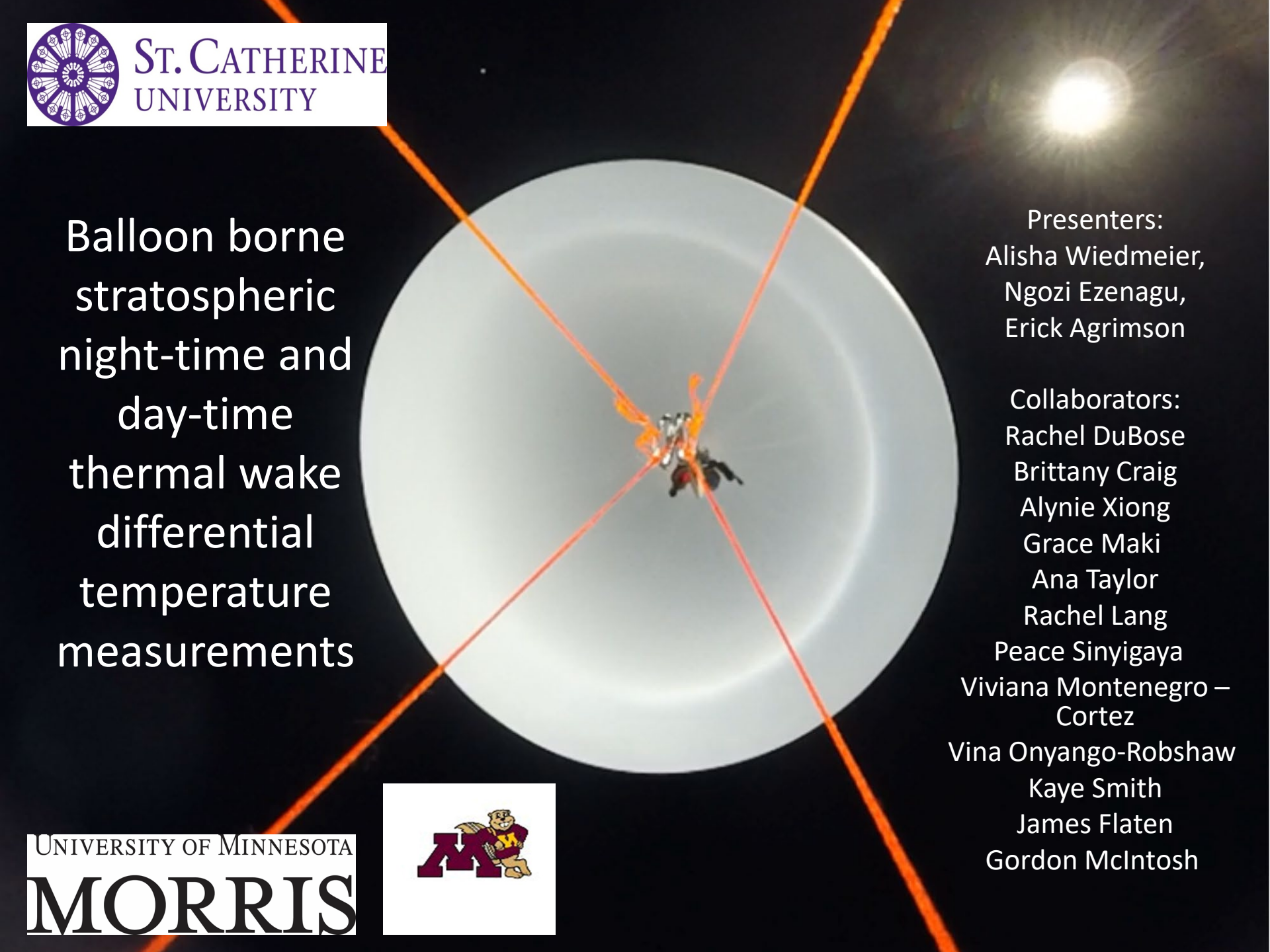

Balloon borne stratospheric night-time and day-time thermal wake differential temperature measurements

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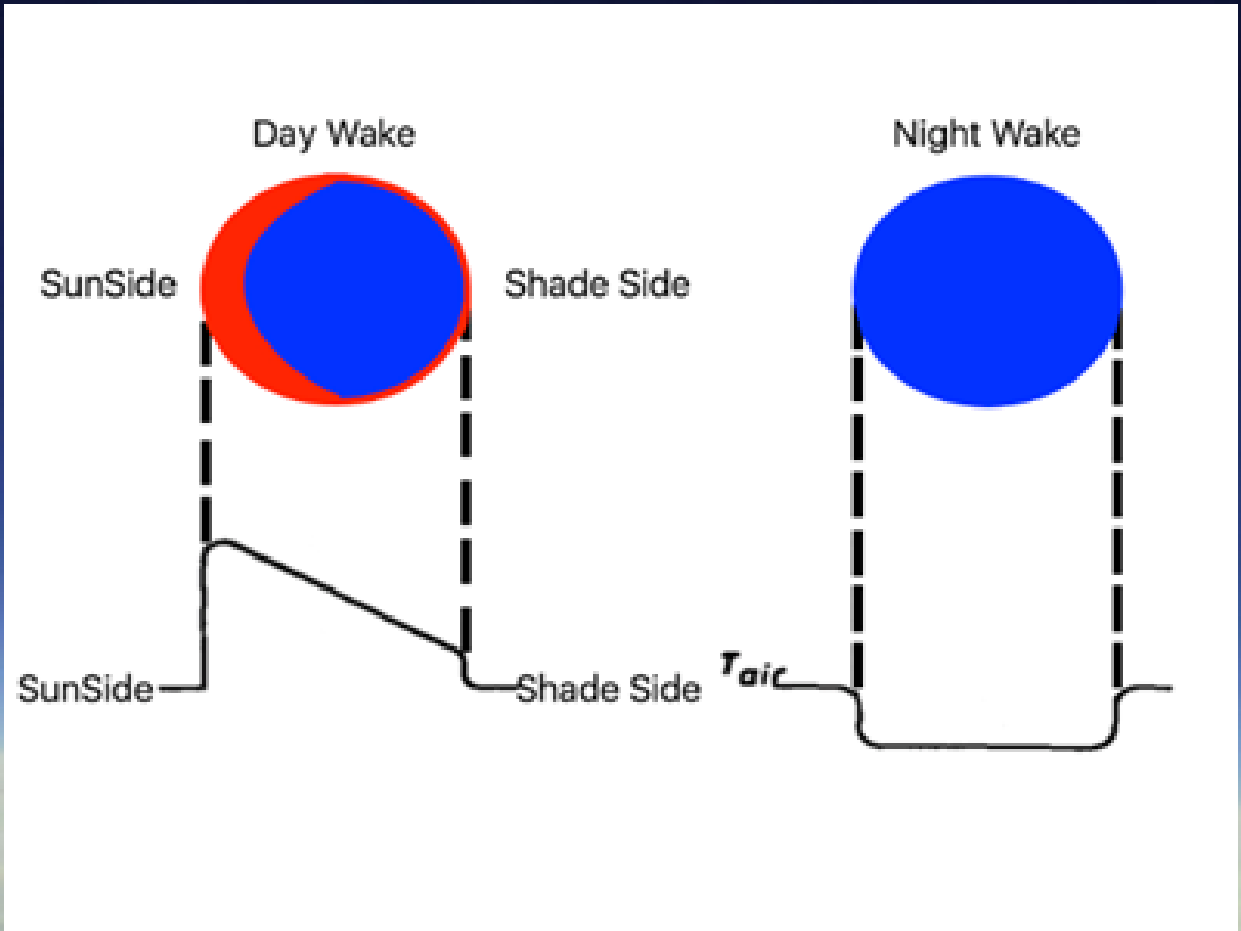
Abstract

- We present summer 2018 results related to stratospheric temperature measurements collected using a 3.5m “wake boom” structure, which we have used to characterize the magnitude and extent of the thermal wake below an ascending high altitude balloon. The “wake boom” structure uses over 20 calibrated temperature sensors set at intervals along a horizontal carbon fiber rod. Summer 2018 data confirms thermal wake profile data taken in 2016 during a night flight, as well as daytime temperature profiles collected during the summer of 2017. To present how the thermal wake grows as our balloons ascend through the stratosphere, we compared the average temperature of the ten central temperature sensors to the average of the four outermost sensors on the wake structure. This method clearly shows a daytime wake that warms in the center as the balloon ascends and a night time wake that cools in the center during ascent, as predicted by Tiefenau et al. [(1)] Using this method we also present data from the August 21st , 2017, total solar eclipse, which show a unique wake profile, an “eclipse” thermal wake.

- (1) Tiefenau, H. and Gebbeken, A. *Influence of meteorological balloons on Temperature Measurements with Radiosondes: Nighttime Cooling and Daylight Heating,* J. Atmos. and Oceanic Tech. 6 (36-42), 1989.

Theory – Thermal Wake Effect

Symmetrical and Asymmetrical temperature wake profiles beneath balloons during Day and Night ascents. Blue is representative of the adiabatic cooling of the He gas which is always present but is dwarfed by solar radiation heating during the day.



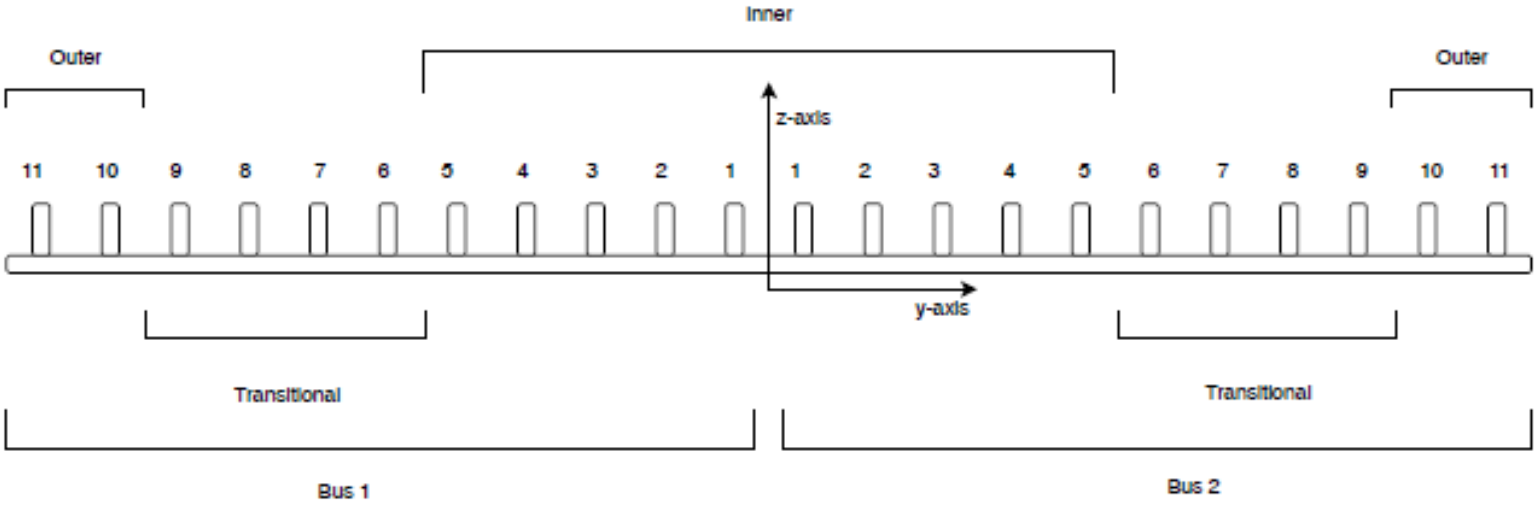
Balloon

Pictures by: Peace Sinyigaya

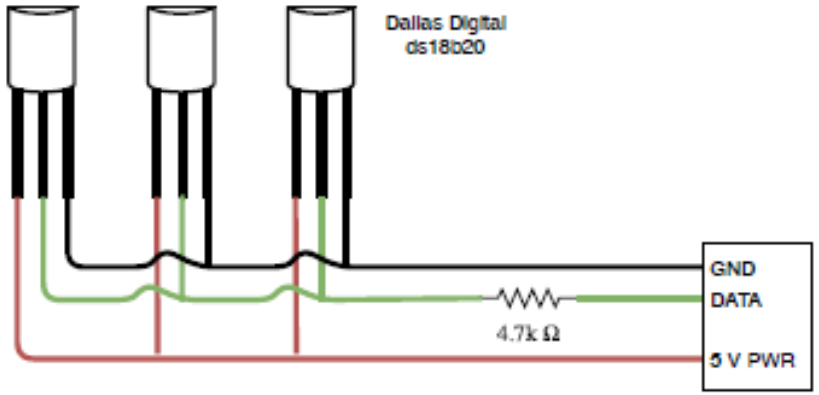
Wake boom

- We measure the spatial temperature effect using a “wake boom.”
- Built from carbon fiber tubing, 3.5m total width.
- 11 digital band-gap sensors mounted from the center to each side of the wake boom for a total of 22 sensors, plus 6 to 8 thermistors.
- Prior to flight, all sensors are calibrated to a NIST certified thermocouple using a low pressure, low temperature chamber. The calibration reduces sensor to sensor variability which becomes more significant at low temperatures and pressures.

Anatomy of a Wake Boom



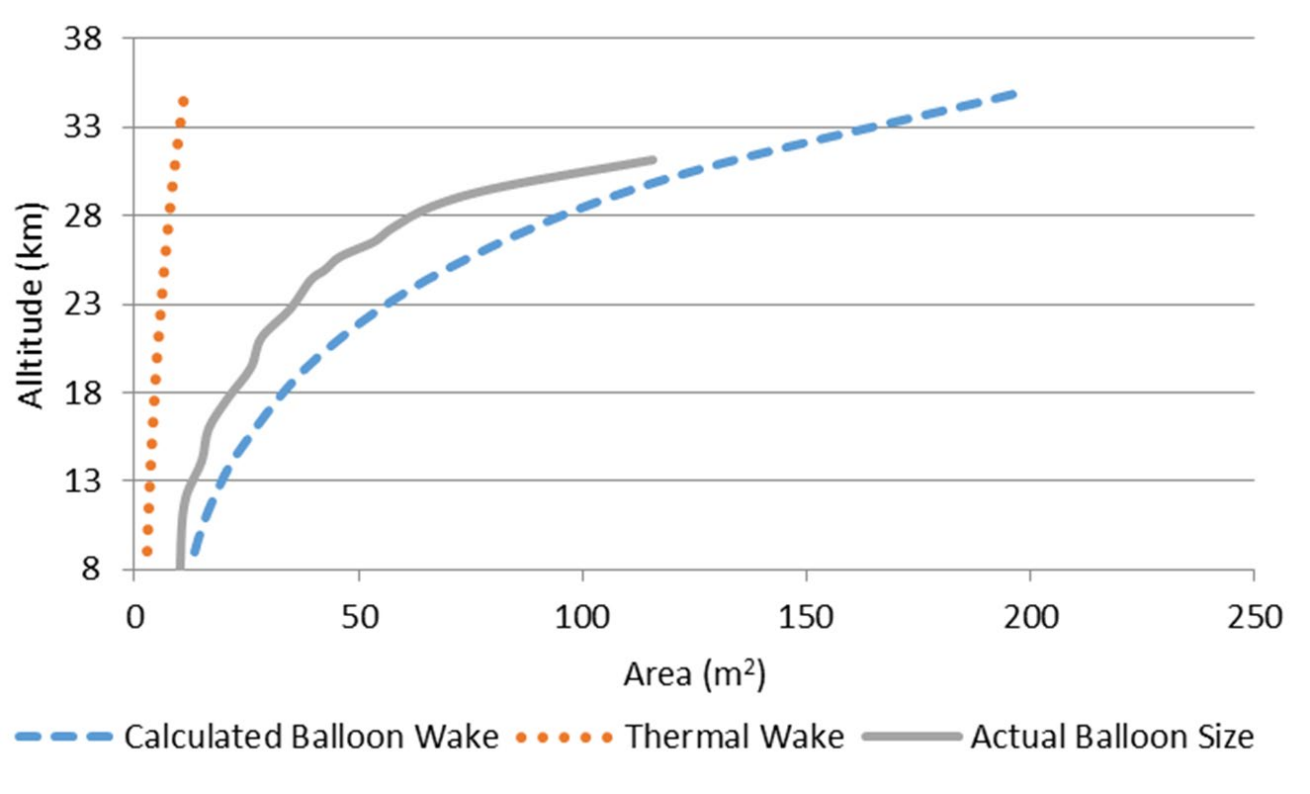
$$\Delta T = \bar{x}_{inner} - \bar{x}_{outer}$$



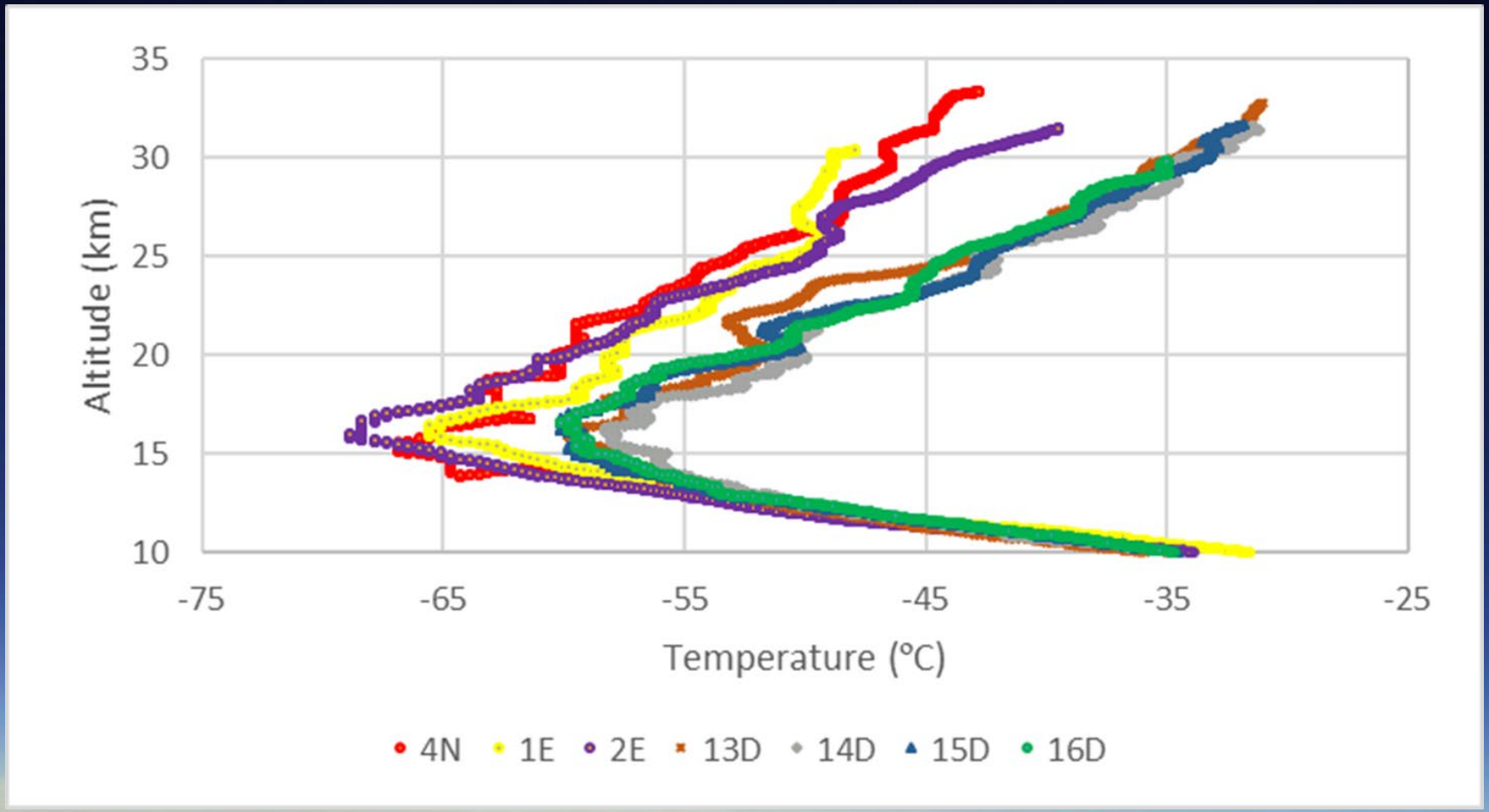
Experiments

- Balloon launched previously to characterize the nighttime wake (8-4-16 and 7-22-18)
- Six balloons carrying wake booms were launched within the 48 hour window leading up to and including the solar eclipse event.
- All flights launched between 11:30 CDT and 12:30 CDT to reduce diurnal temperature effects.
- Follow up daytime launch 6-13-18

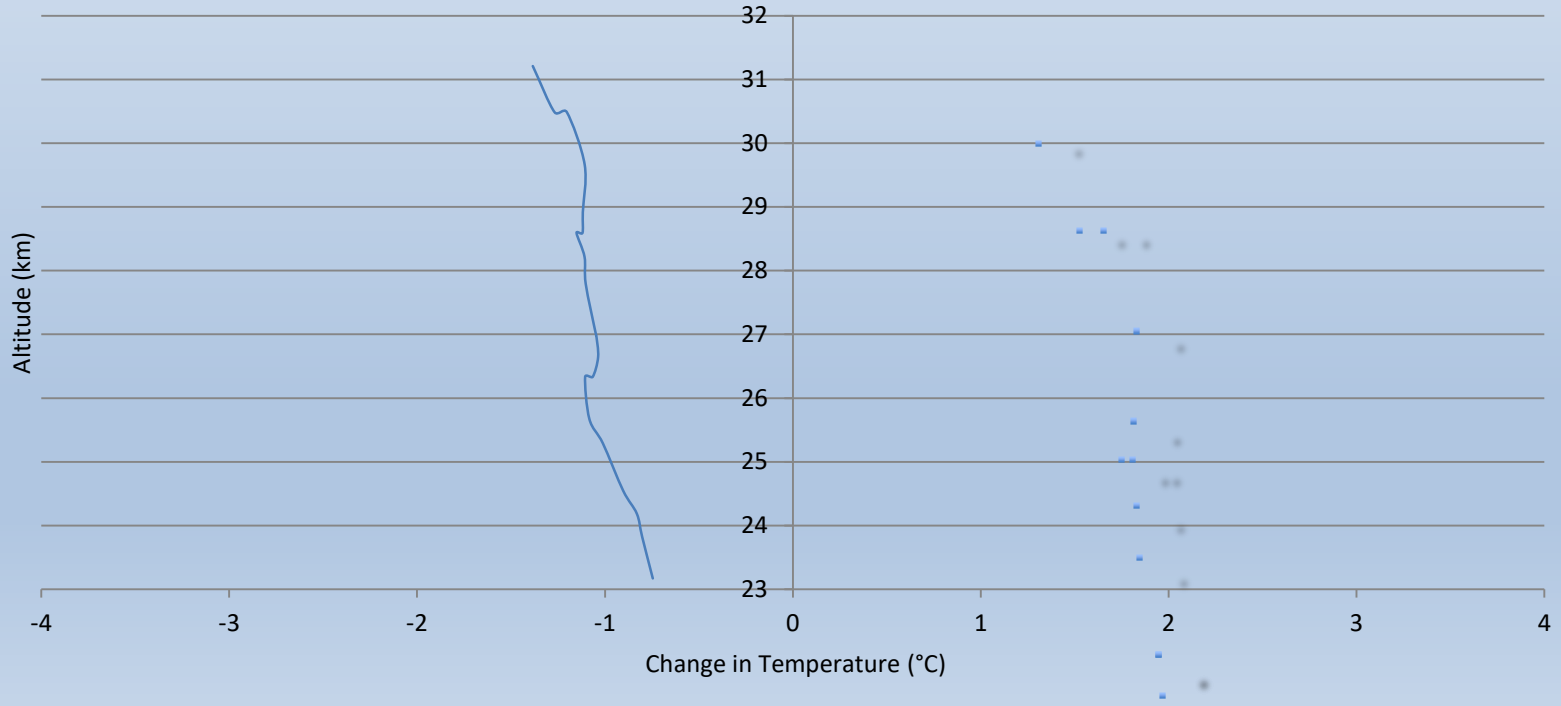
Cross sectional area of the balloon wake and the thermal wake plotted against altitude for an ascending HAB. Calculations are based on standard atmospheric conditions using a 1600 g balloon with helium as the lifting gas. Actual balloon size was measured from video footage taken during an eclipse day ascent using an upward-pointing camera



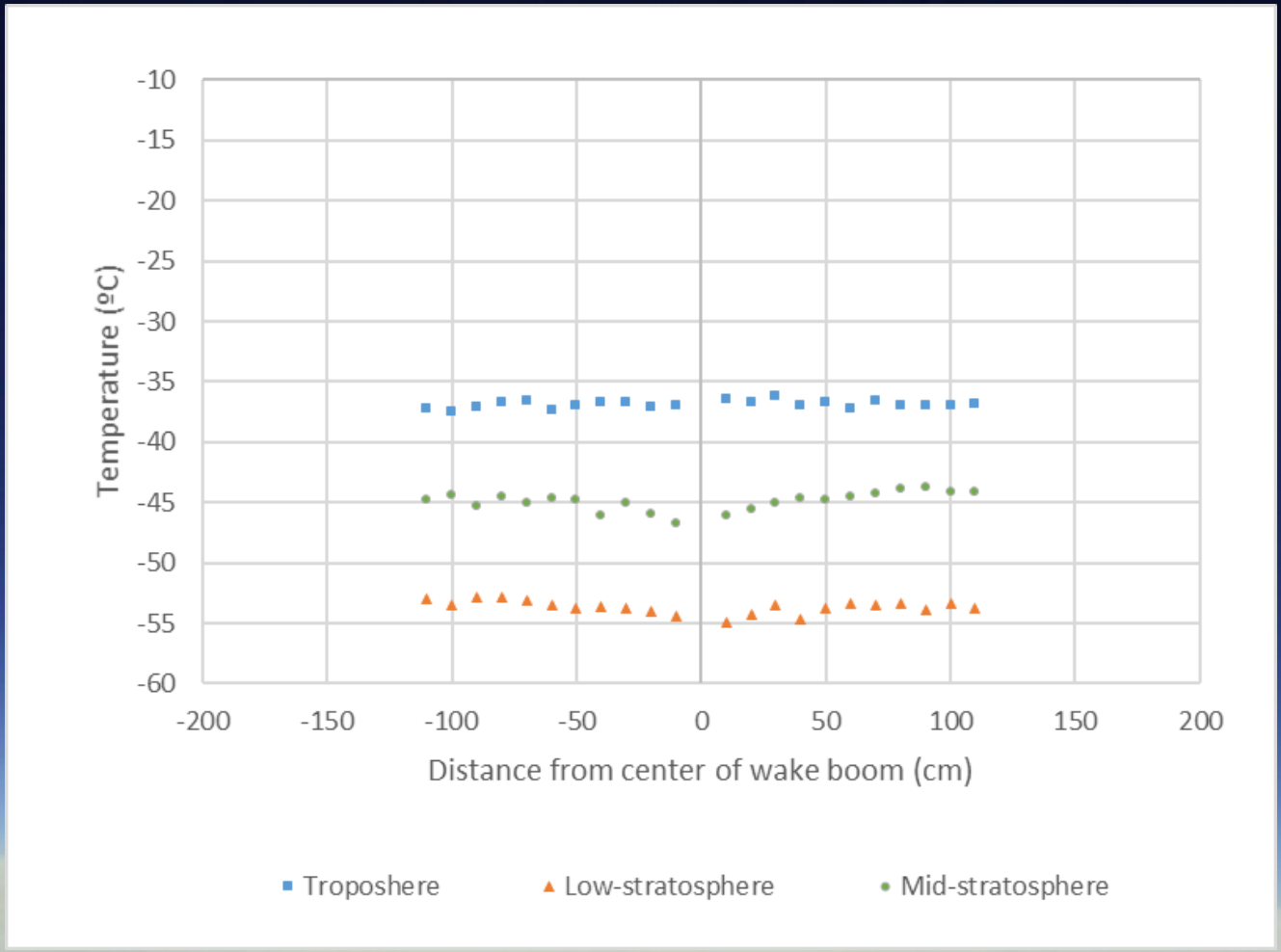
Eclipse Flights



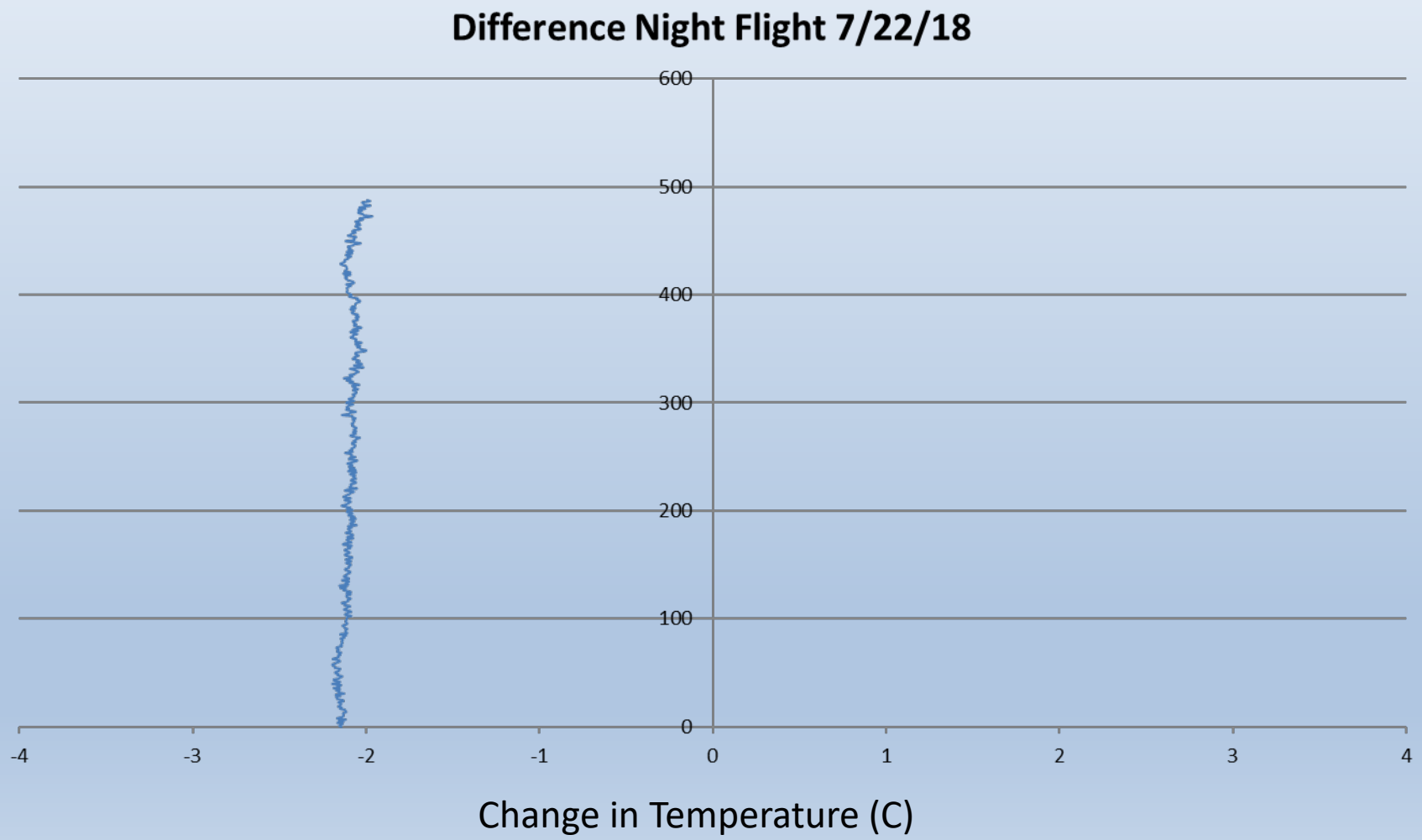
4N showing a negative temperature difference between the average temperature measured across the central 100 cm of the wake boom and the average temperature measured by the outermost sensors. The negative difference indicates that it is cooler within the thermal wake directly beneath the balloon.



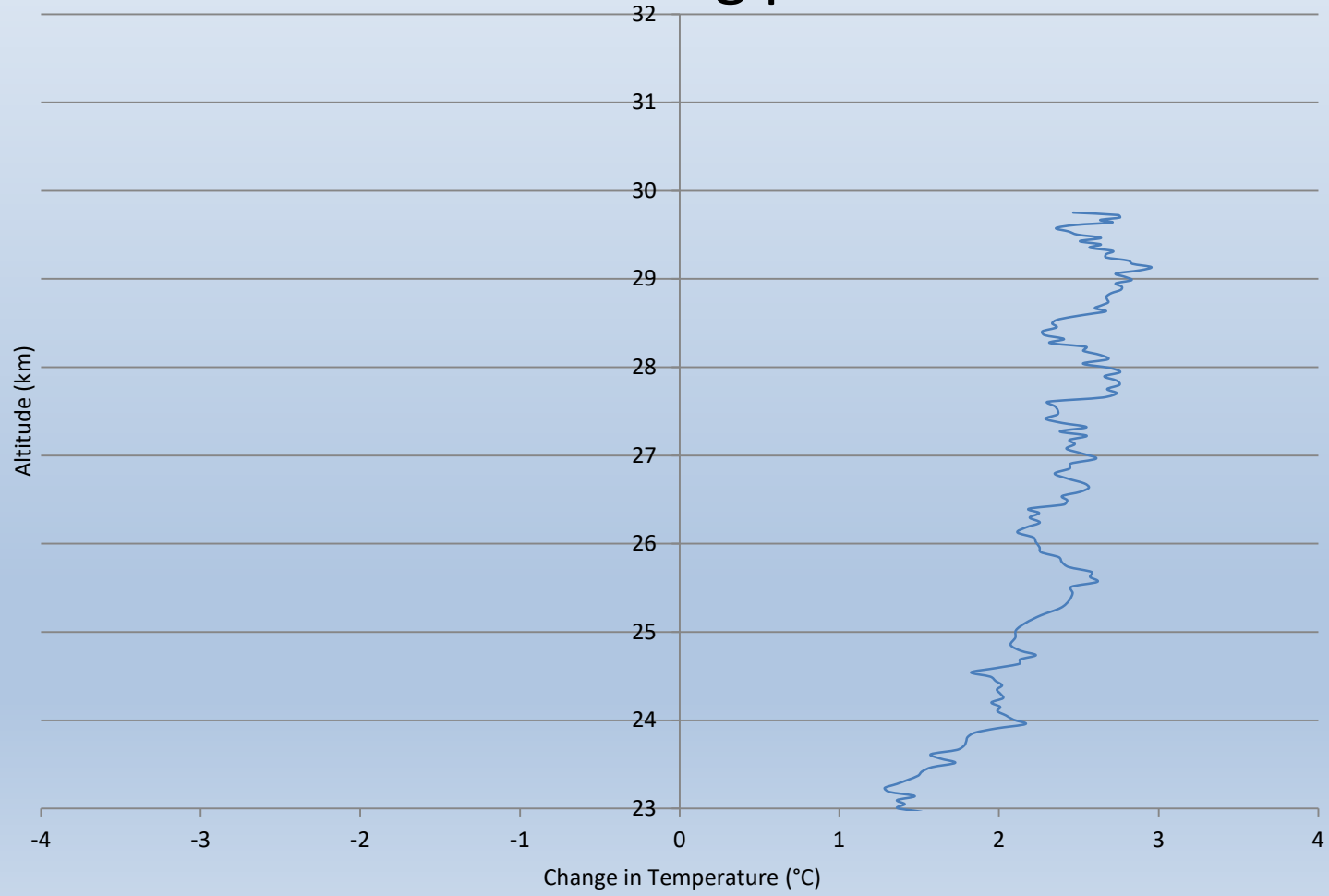
Old way 4N “Slices”



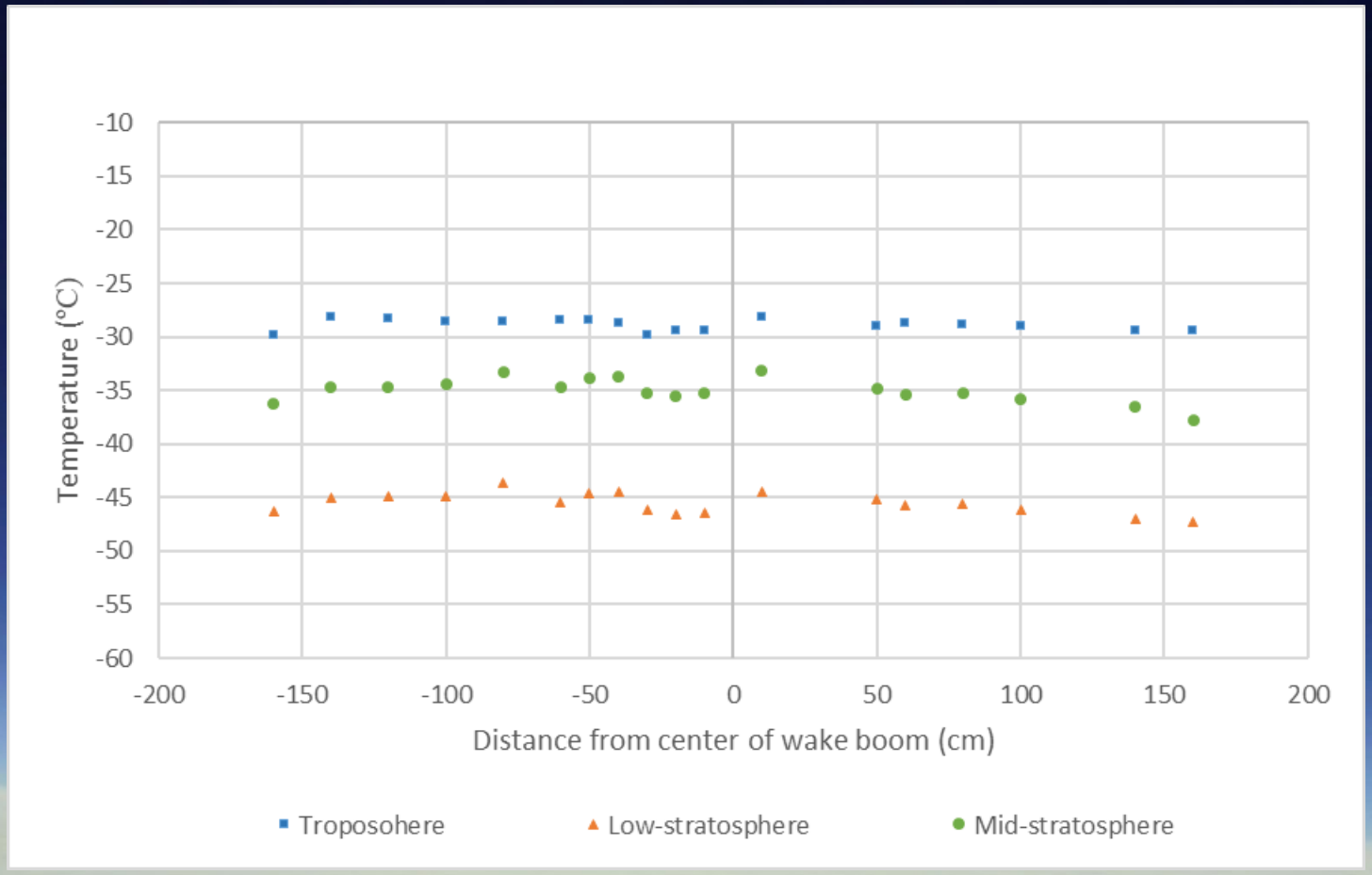
Night Flight 5N



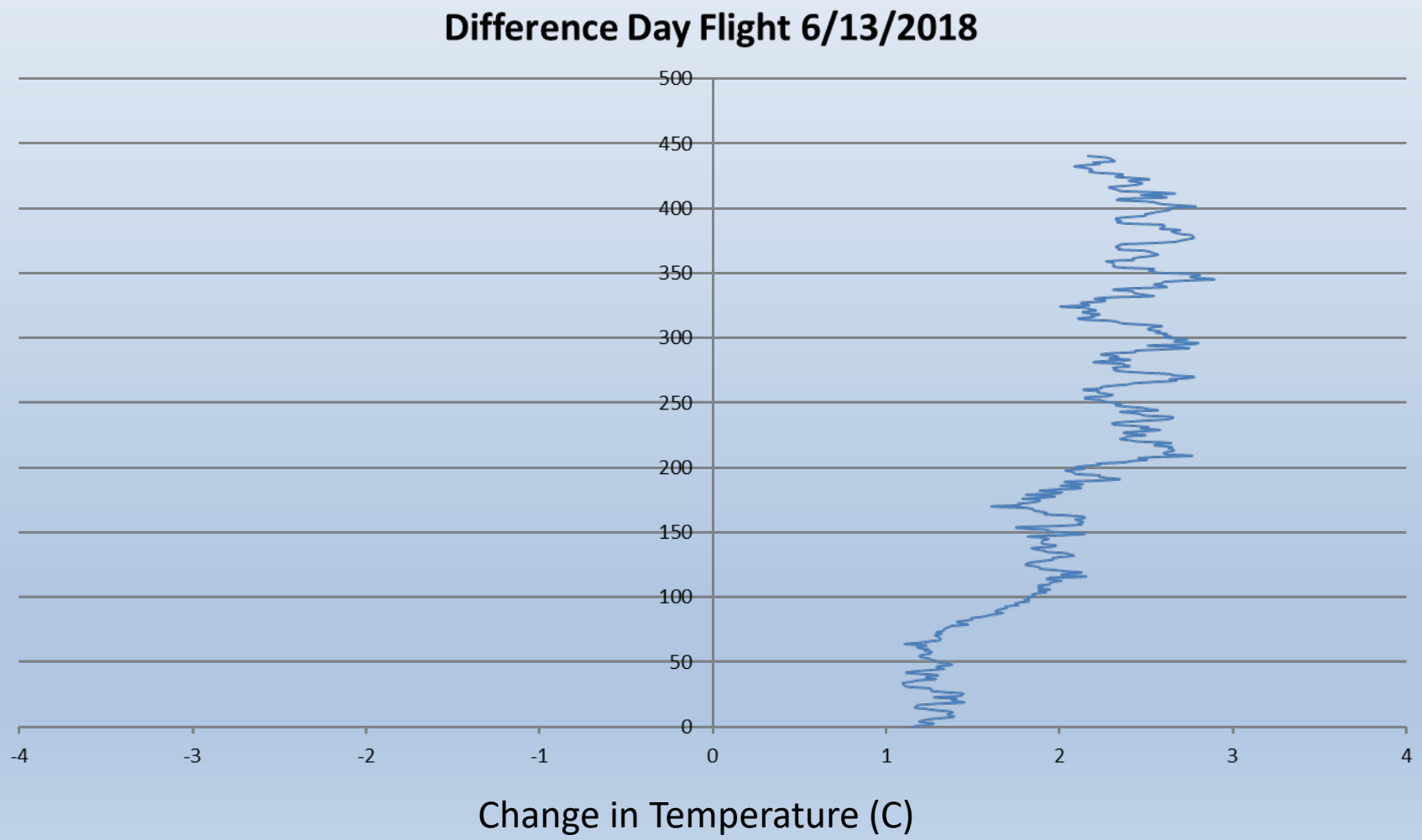
16D The positive difference indicates that it is warmer beneath the balloon. This increasing positive result agrees with Tiefenau [2], that warm wake effects increase as the heat exchange layer thickness grows with decreasing pressure.



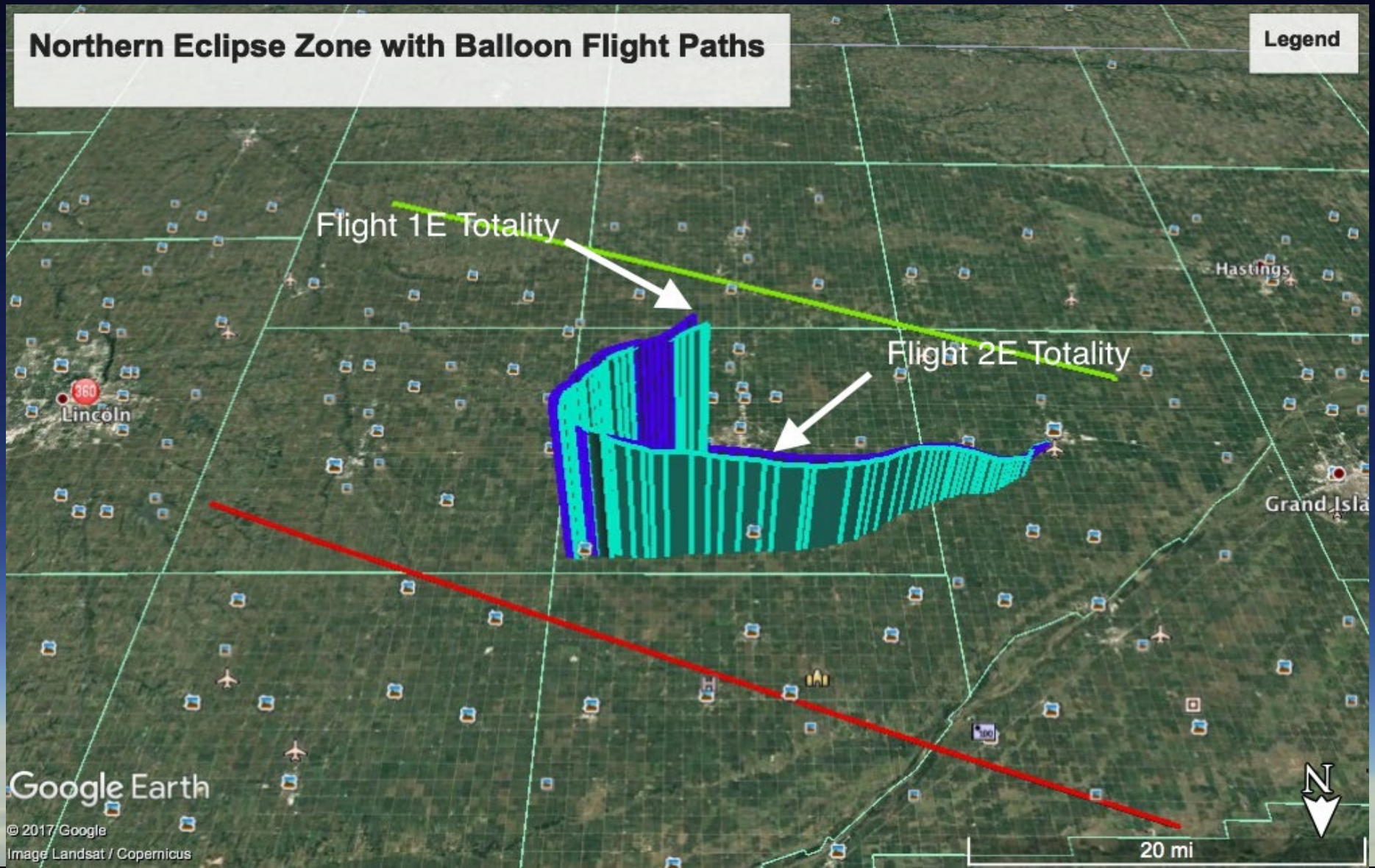
Old Way 16 D “Slices”



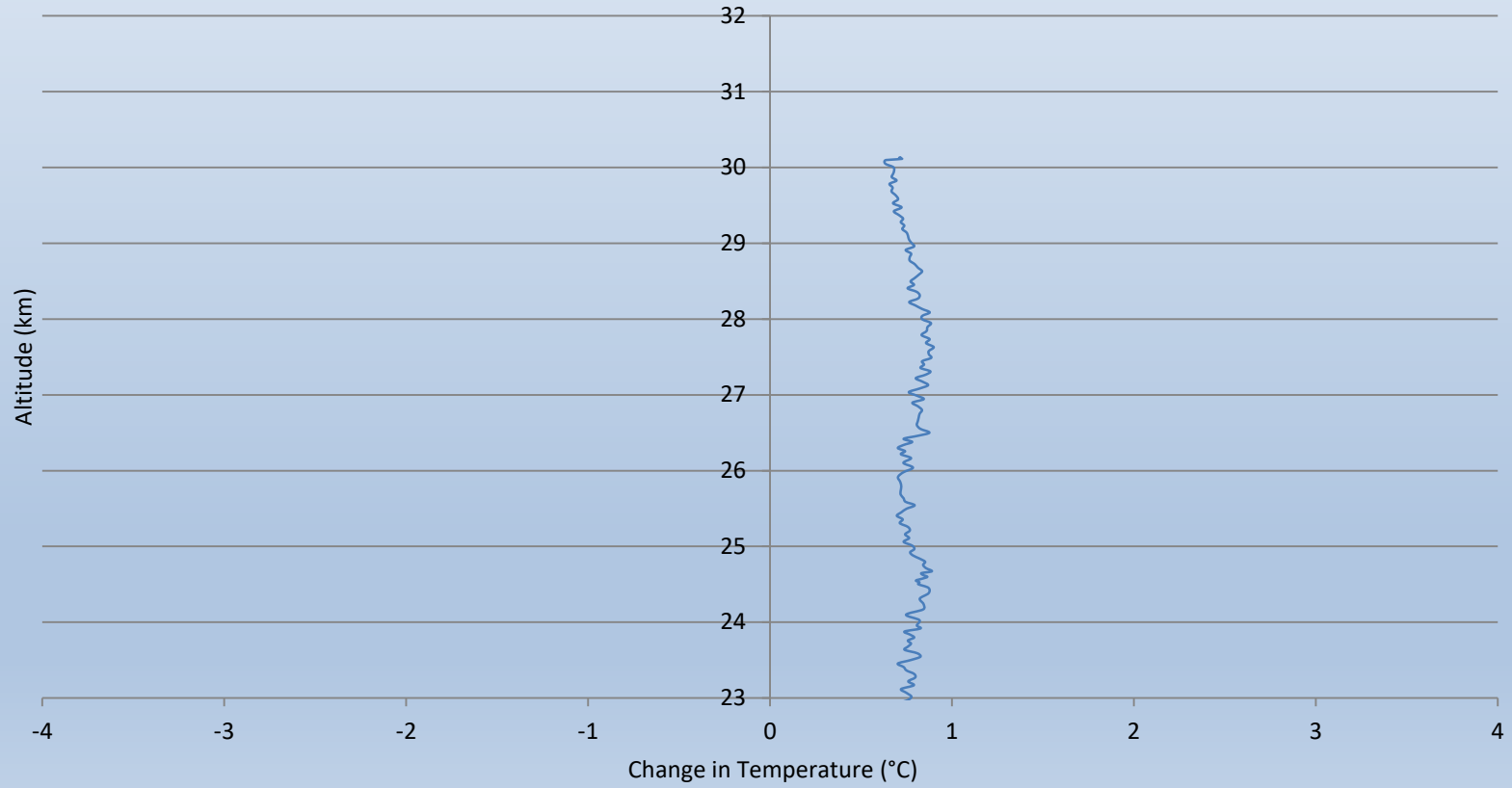
Day Flight D17



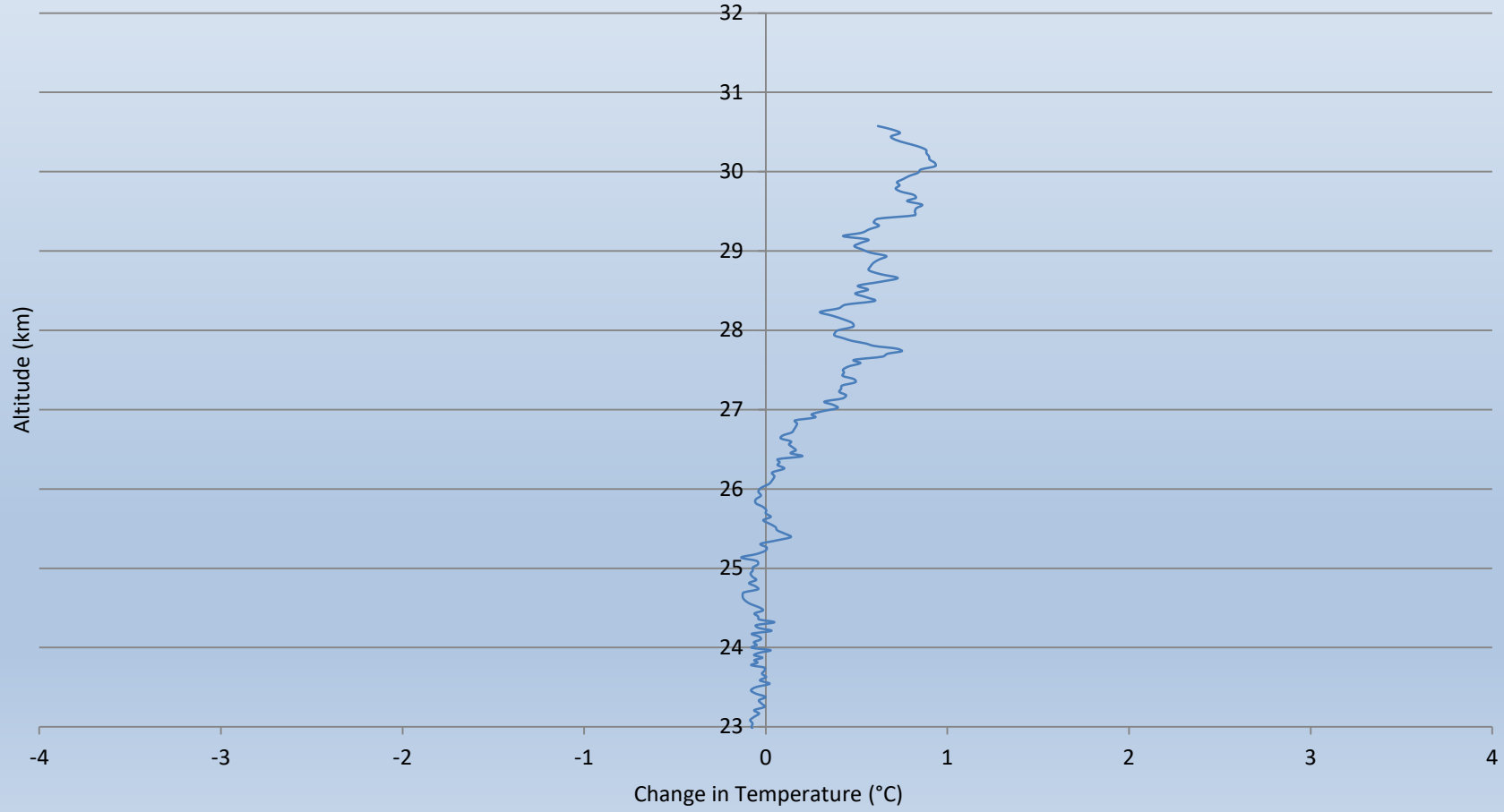
Eclipse flights in relation to path of totality (12:59 pm start)



1E Compared to the night and day flights, the temperature difference across the wake boom is nearly constant, indicating no significant positive or negative temperature difference across the thermal wake profile.



2E stratospheric temperature difference showing that wake boom profiles were essentially zero well past totality. A slight warming begins at 26 km altitude, approximately 25 minutes after totality.



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  - Ana Taylor
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- 2. Tiefenau, H. and Gebbeken, A. Influence of meteorological balloons on Temperature Measurements with Radiosondes: Nighttime Cooling and Daylight Heating, J. Atmos. and Oceanic Tech. 6 (36-42), 1989.

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Questions?