Multi-thermistor activities at NWS

DOC/NOAA/NWS
Sterling Field Support Center (SFSC)
Micheal Hicks, PhD
March 2014

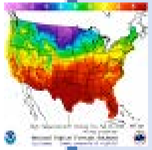
Motivation and Purpose

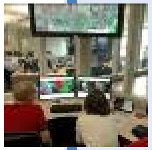
National Weather Service

Protecting Lives and Property

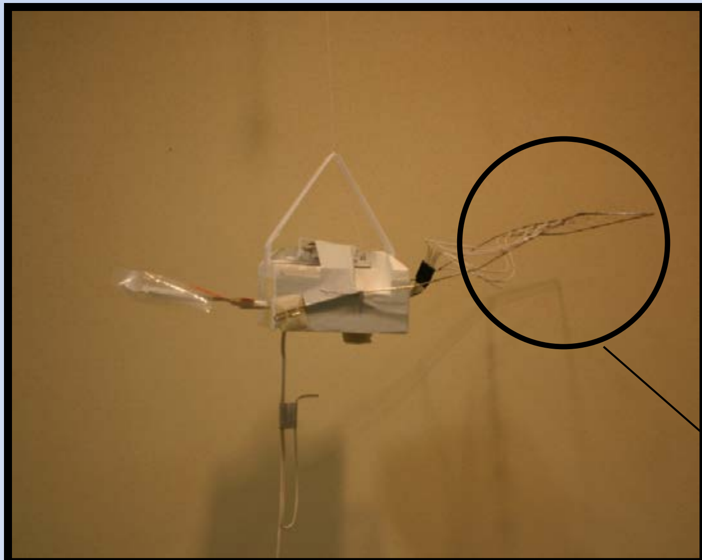
- **Motivation**
  - *The NWS has an upper air network of mix radiosonde types.*
  - *To better understand the climate record impact of this network on Aerological air temperature measurements, NWS is considering the use of the Multi-Thermistor Radiosonde (MTR) as an independent reference.*

- **Purpose**
  - *To assess the precision and repeatability of the MTR 's raw and corrected air temperature measurements.*



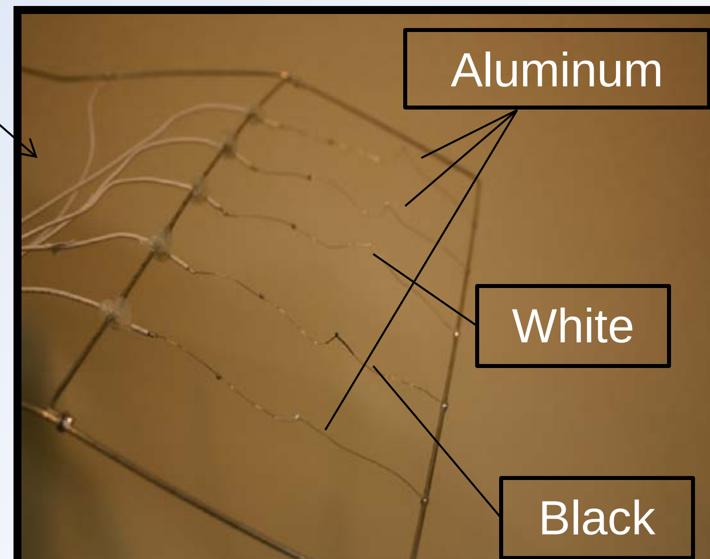


What is the MTR?



The MTR is a radiosonde composed of multiple thermistors.

The system uses its composition of thermistors with unique radiative properties to correct for radiation effects



With the conventional MTR system, the user can not assess the precision of the black and white coated thermistors

MTR's Heat Balance Equation

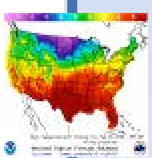
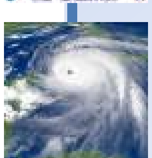
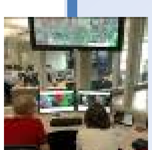
$$H_A \times (T_s - T_A) = S \times A_S + R \times A_R$$

- H_A = Thermal Convectivity Coefficient X Area
- T_s = Sensor Temperature
- T_A = Air Temperature
- S = Solar Radiation
- A_S = Solar Absorptivity Coefficient
- R = Thermal Radiation
- A_r = Thermal Emissivity Coefficient

The NWS developed a process called the Advanced Multi-Thermistor (AMT) solution to determine air temperature and this is what will be evaluated

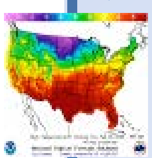
National Weather Service

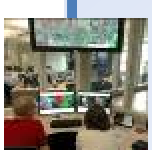
Protecting Lives and Property

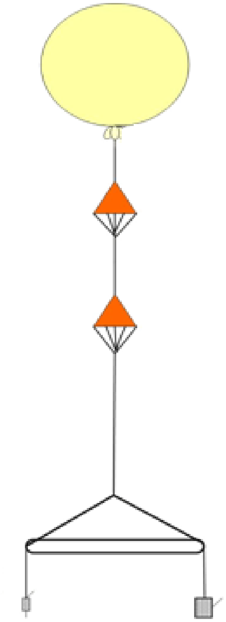
National Weather Service

Protecting Lives and Property

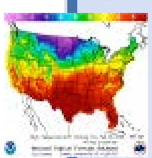


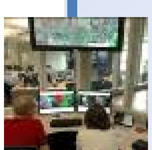


METHODOLOGY



- **Dual Flights**
  - *Conventional MTR radiosondes and Specialty MTR radiosondes*
    - **Specialty MTR radiosonde have either all white or all black coated sensors**
      - *Giving 6 senor temps and 6 air temp profiles per flight*
- **Quality Control**
  - *Record pictures of MTR sensors*
  - *Record any temperature discrepancies during ground check*



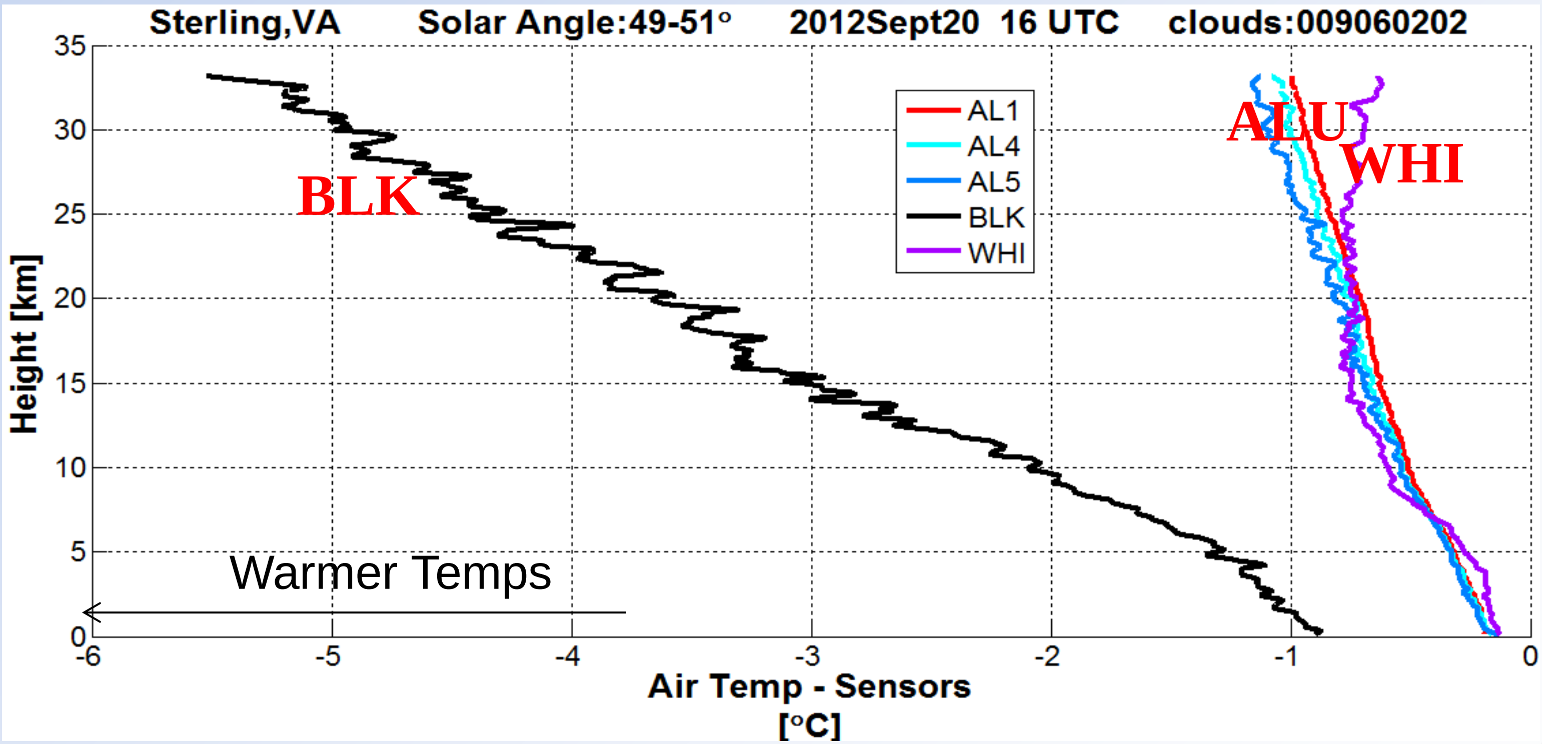


Flight Criteria

- **Conduct flights during various cloud cover conditions**
  - *Clear*
  - *Scattered*
  - *Broken*
  - *Overcast*
- **Solar angles greater than 25°**

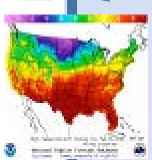
Data Analysis Method

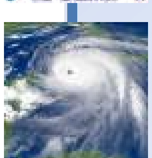
“Temperature Differences”

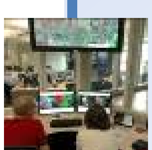


National Weather Service

Protecting Lives and Property







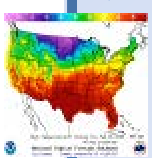
Data Analysis Method

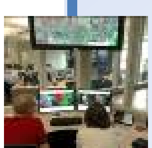
“Data Spread Sheet”

National Weather Service

Protecting Lives and Property

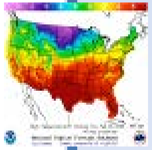
P [hpa]	Heights [km]	Counts	Raw Temp Diff	CI	Air Temp Diff	CI	Correction
20 - 4	27 - 33	954	0.1678	0.4457	0.0205	0.0509	0.9395
50 - 20	21 - 27	1040	0.1657	0.4314	0.0189	0.0486	0.7543
100 - 50	17 - 21	880	0.1605	0.593	0.0217	0.0542	0.608
200 - 100	12 - 17	899	0.1346	0.6546	0.0192	0.0459	0.4725
300 - 200	10 - 12	513	0.1114	0.2764	0.0175	0.04	0.3591
500 - 300	6 - 10	655	0.0817	0.1957	0.0136	0.0295	0.2691
850 - 500	2 - 6	913	0.0594	0.1475	0.0084	0.0191	0.2116
1070 - 850	0 - 2	303	0.0413	0.1107	0.0058	0.0132	0.1589
ALL	0-33	6157	0.1239	0.3435	0.0192	0.0493	0.6009

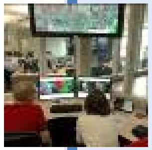




National Weather Service

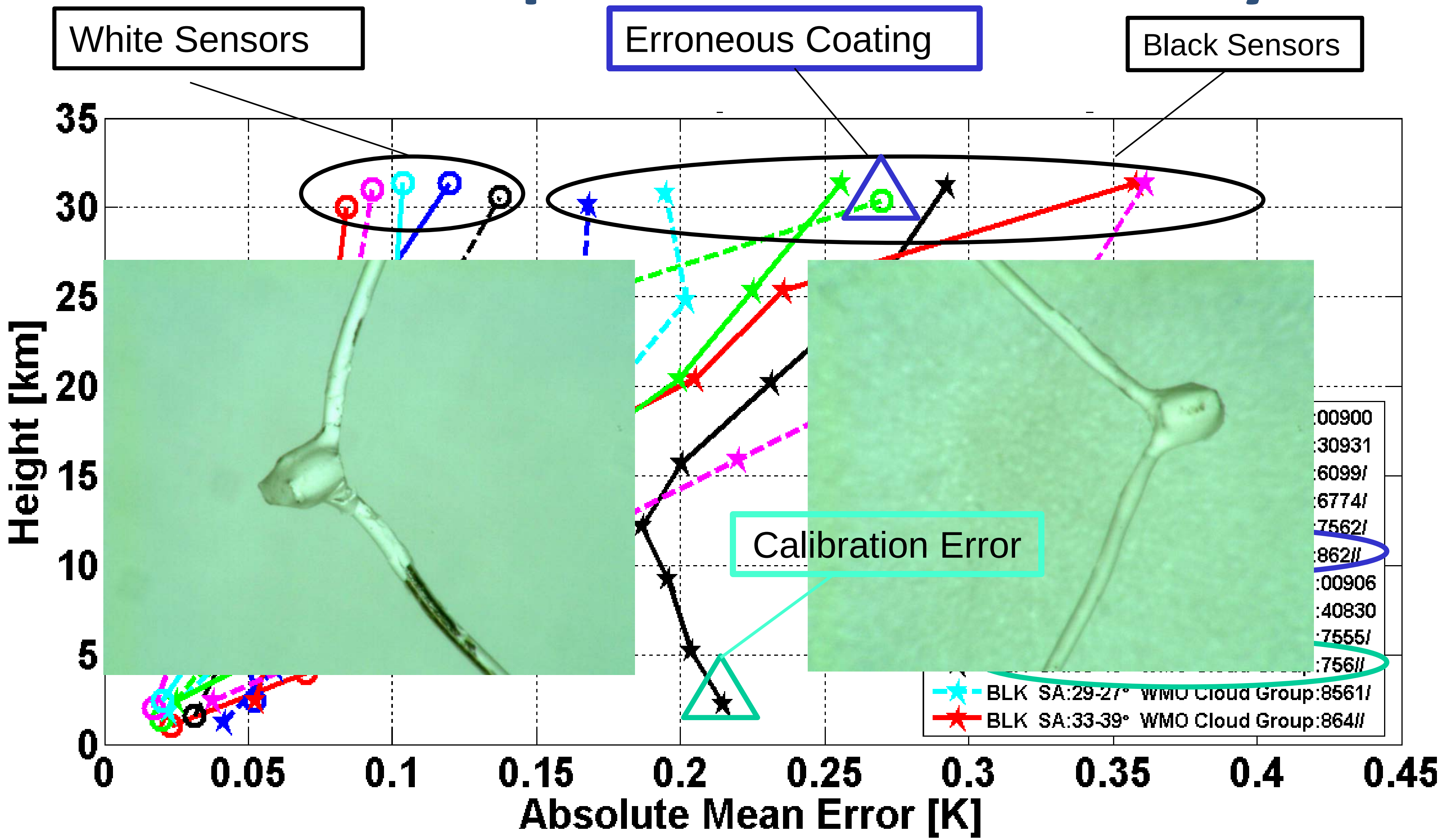
Protecting Lives and Property





Results

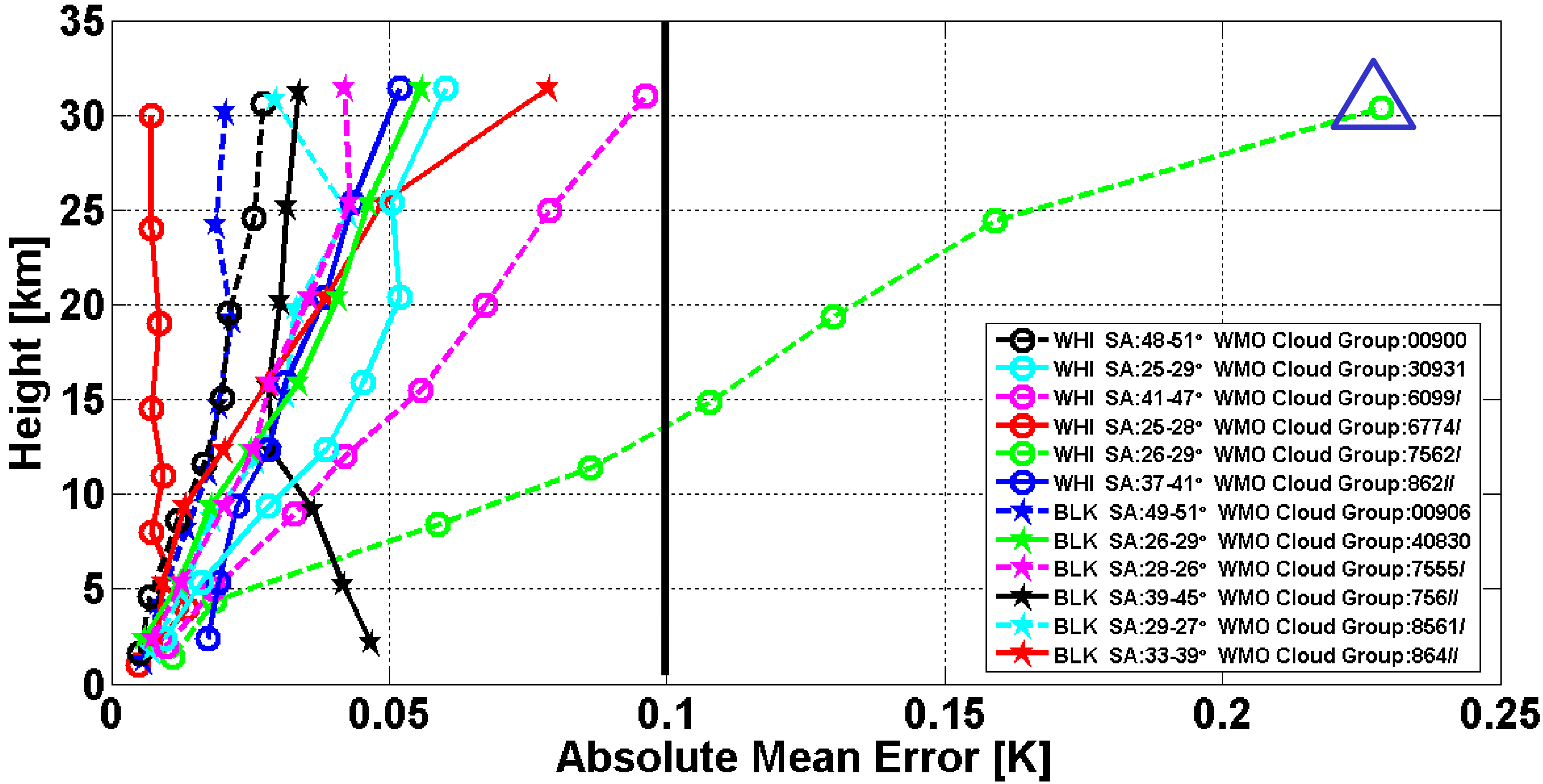
Raw Temperature Uncertainty



TOP OF FLIGHT AVERAGES

White Sensor: 0.14 $\pm$ 0.41 **Black Sensor: 0.27 $\pm$ 0.69**

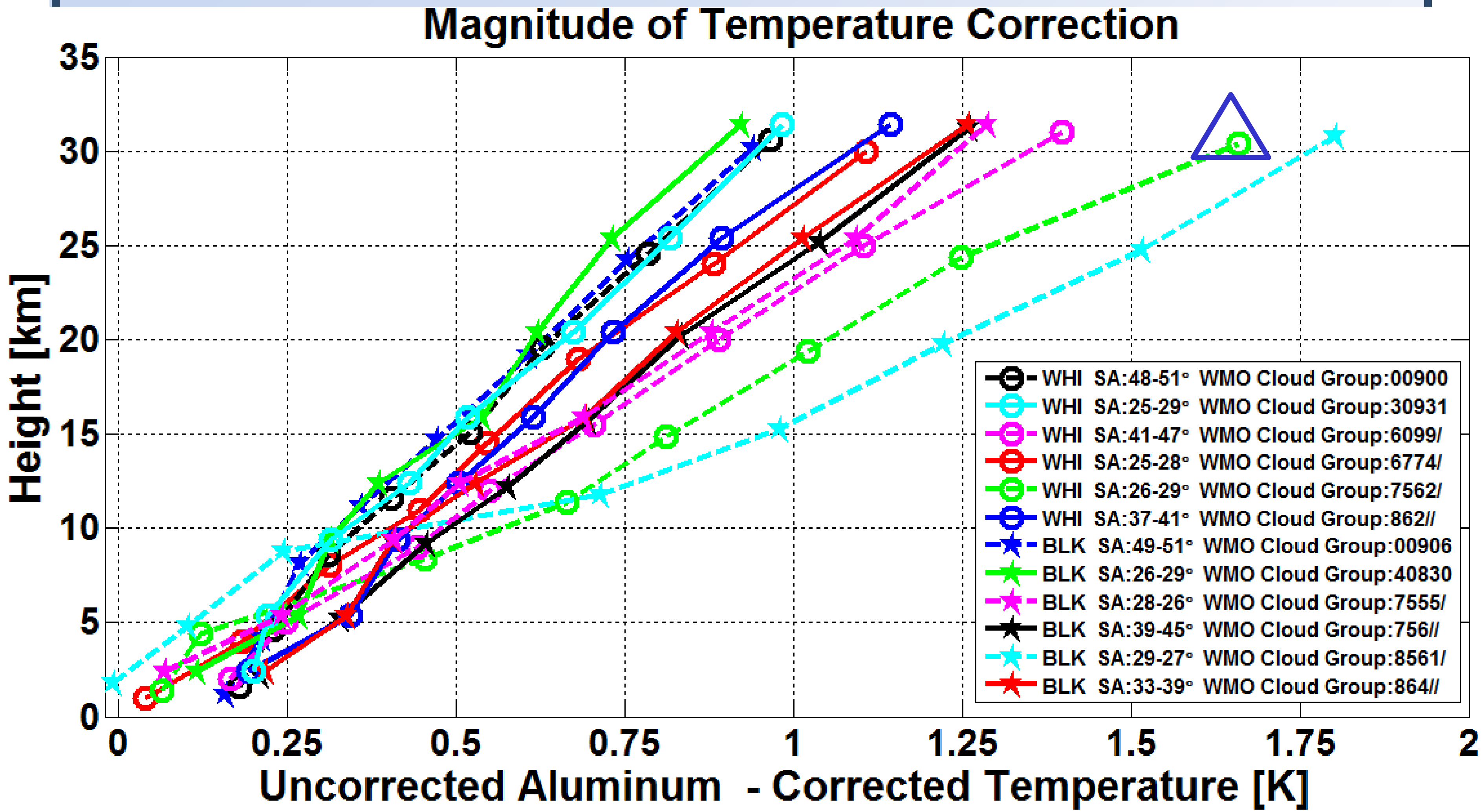
AMT Solution Uncertainty



TOP OF FLIGHT AVERAGES

White Flights: 0.06 ± 0.14 **Black Flights: 0.04 ± 0.10**

Magnitude of Temperature Correction



Sensitivity Analysis: Cooling and Warming of Sensors and Resulting T_{air} Mean Error

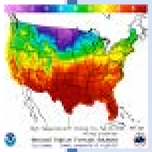
ΔT_{sensor}	-0.00001	-0.0001	-0.001
WHI	0.008	-0.94	-10.008
BLK	-0.917	-0.562	3.979
ALU	-0.021	-2.01	-19.85

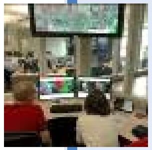
ΔT_{sensor}	0.00001	0.0001	0.001
WHI	0.196	1.105	7.804
BLK	-0.99	-1.333	-5.45
ALU	0.0328	1.987	17.64

- This analysis indicates that the aluminum sensor is the most critical for accurate air temperature measurements for the AMT solution and then next the white sensor and lastly the black sensor.
- The results for the black sensor indicates that at minimum an error in its measurement can propagate an air temperature error of about -1°, which is not consistent with the earlier precision results
  - This result was unexpected and its validity is still under review.

National Weather Service

Protecting Lives and Property



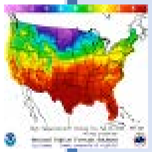


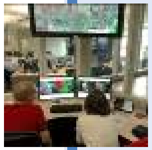
Conclusion and Further Work

- **The black coated thermistor produced more uncertainty than the white coated thermistor**
  - ***Black Sensor: 0.27 $\pm$ 0.69***
  - ***White Sensor: 0.14 $\pm$ 0.41***
  - ***Aluminum Sensor: 0.17 $\pm$ 0.50***
- **The AMT's air temperature uncertainty is negligible relative to the sensor measurements uncertainties**
  - ***Black Specialty Flights AMT solution: 0.04 $\pm$ 0.10***
  - ***White Specialty Flights AMT solution: 0.06 $\pm$ 0.14***
- **Sensitivity analysis indicated the AMT solution was the most sensitivity to errors of the Aluminum sensors**
- **Future work includes assessing the uncertainty of the MTR system in SFSC's environmental altitude chamber and at other climate regime locations**

National Weather Service

Protecting Lives and Property

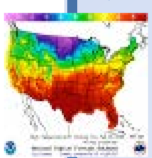


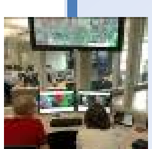


Back Up Slides

National Weather Service

Protecting Lives and Property





Sources of Radiosonde Temperature Error

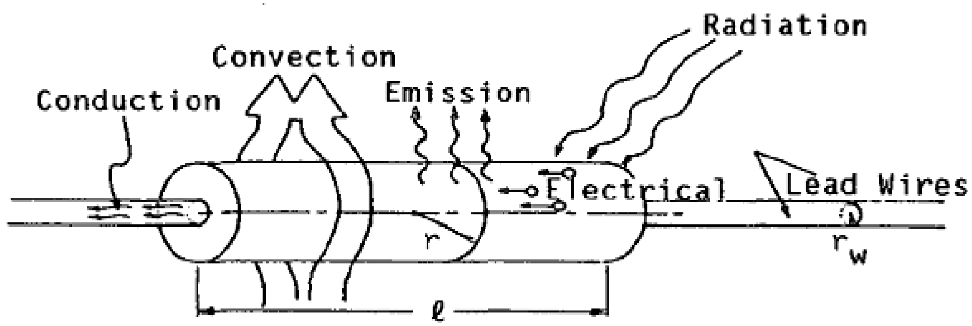


FIG. 1. Thermistor geometry and heat transfer processes.

$$mC(dT/dt) = q_{abs} - q_{emit} + q_{conv} + q_{elec} + q_{cond}$$

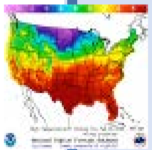
- q_{abs} heat transfer from absorbed radiation
- q_{emit} emitted radiation
- q_{conv} convection
- q_{elec} resistance heating
- q_{cond} thermal conduction

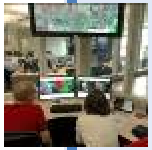
System of Equations

$$H_A \times (\overline{T_{AL}} - T_A) = S \times A_s(AL) + R \times A_r\,(AL)$$

$$H_A \times (T_W - T_A) = S \times A_s(W) + R \times A_r\,(W)$$

$$H_A \times (T_B - T_A) = S \times A_s(B) + R \times A_r\,(B)$$





National Weather Service

Protecting Lives and Property