

# In-situ measurements of temperature, pressure and winds

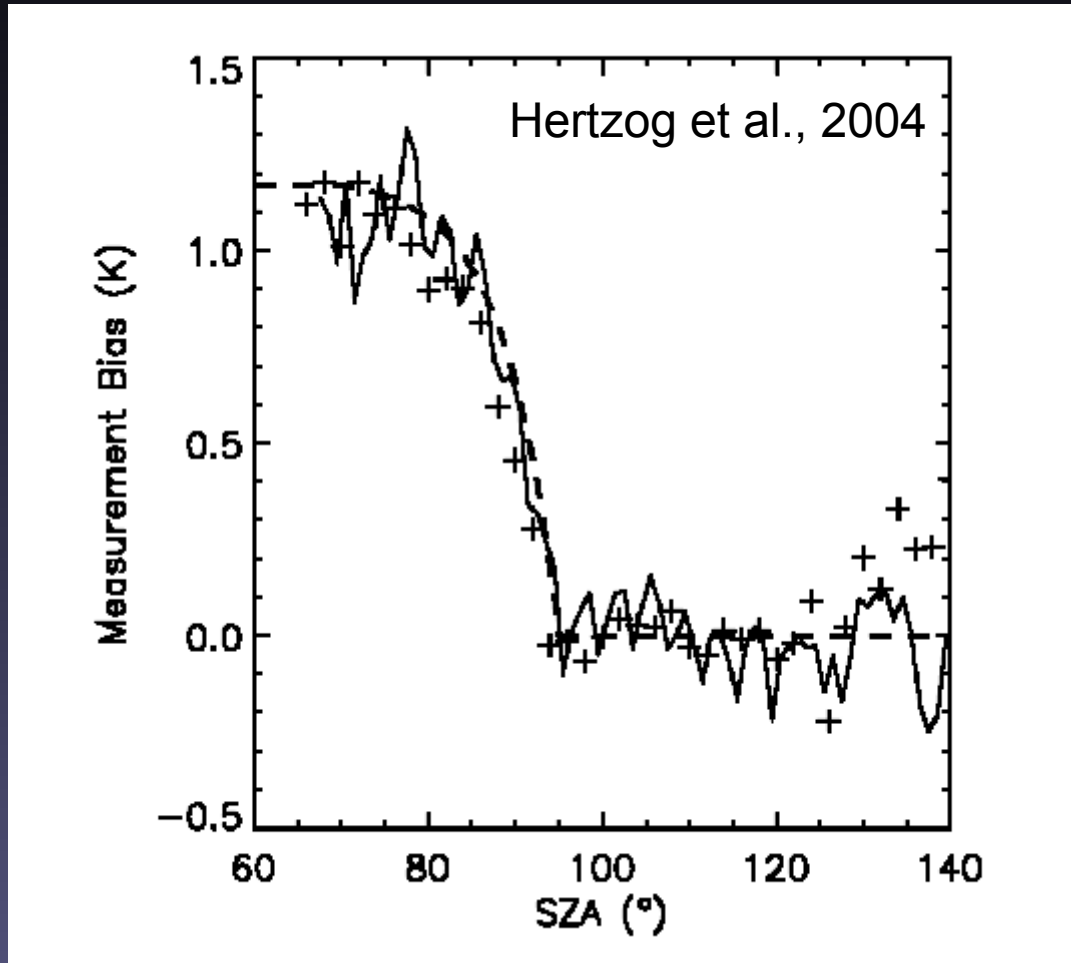
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(and the LMD engineer team)

# Tsen

- Will make measurements of temperature and pressure on board every flight during Strateole 2
- Objectives :
  - P: 1 s, accuracy < 10 Pa, precision < 0.1 Pa (Paroscientific 6000 pressure transducer)
    - Requirements associated with wave and turbulence studies
    - Possibility to further increase the precision (by a factor 1,000) but will have an impact on the power budget (to be studied)
  - T: 30 s, accuracy and precision < 0.2 K (night and day)
- Technology used during Vorcore/Concordiasi:
  - 2 x 120  $\mu\text{m}$ -diameter thermistor
  - Excellent performances at night ( $\sigma < 0.1 \text{ K}$ )...
  - But issues during days :
    - Heating of the thermistor by solar radiations
    - Almost no ventilation of the sensor under a SPB

# Daytime thermistor heating



solid:  $T_{\text{obs}} - \langle T_{\text{obs}} \rangle_{\text{night}}$   
cross :  $T_{\text{obs}} - T_{\text{ecmwf}} - \langle T_{\text{obs}} - T_{\text{ecmwf}} \rangle_{\text{night}}$   
dash : empirical correction

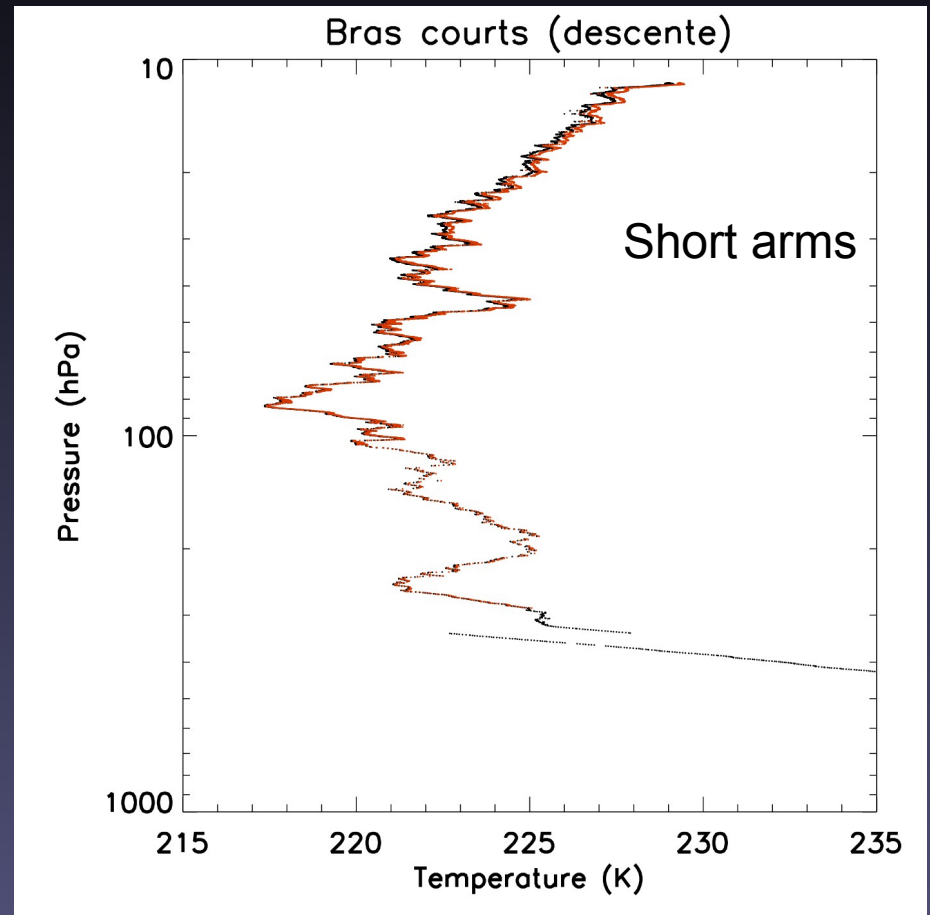
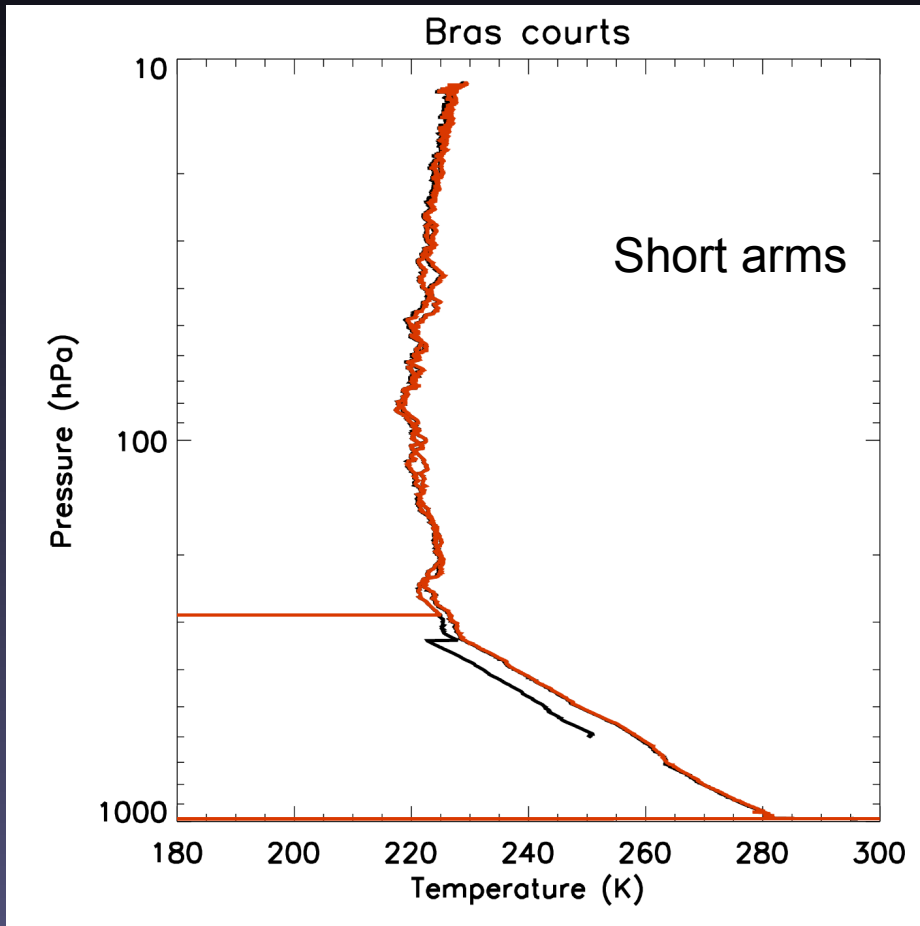
# Daytime thermistor heating

- Radiative heating scales as  $r^2$
- Conductive dissipation in the air scales as  $r$ 
  - => decrease the sensor size to obtain an sensor equilibrium temperature closer to the air temperature
    - As long as the sensor remains larger than the molecular mean free path (~ 0.5  $\mu\text{m}$  at 60 hPa)
- 120  $\mu\text{m}$ -diameter thermistors are no longer manufactured => 240  $\mu\text{m}$  at least...!
- New technology: thermocouple
  - Voltage induced by the temperature difference between 2 junctions of 2 dissimilar alloys
    - One exposed to ambient air (measurement)
    - The other in the gondola (reference), for which temperature is known (measured with a thermistor)
  - Sensor diameter: 30  $\mu\text{m}$

# Stratoscience 2014

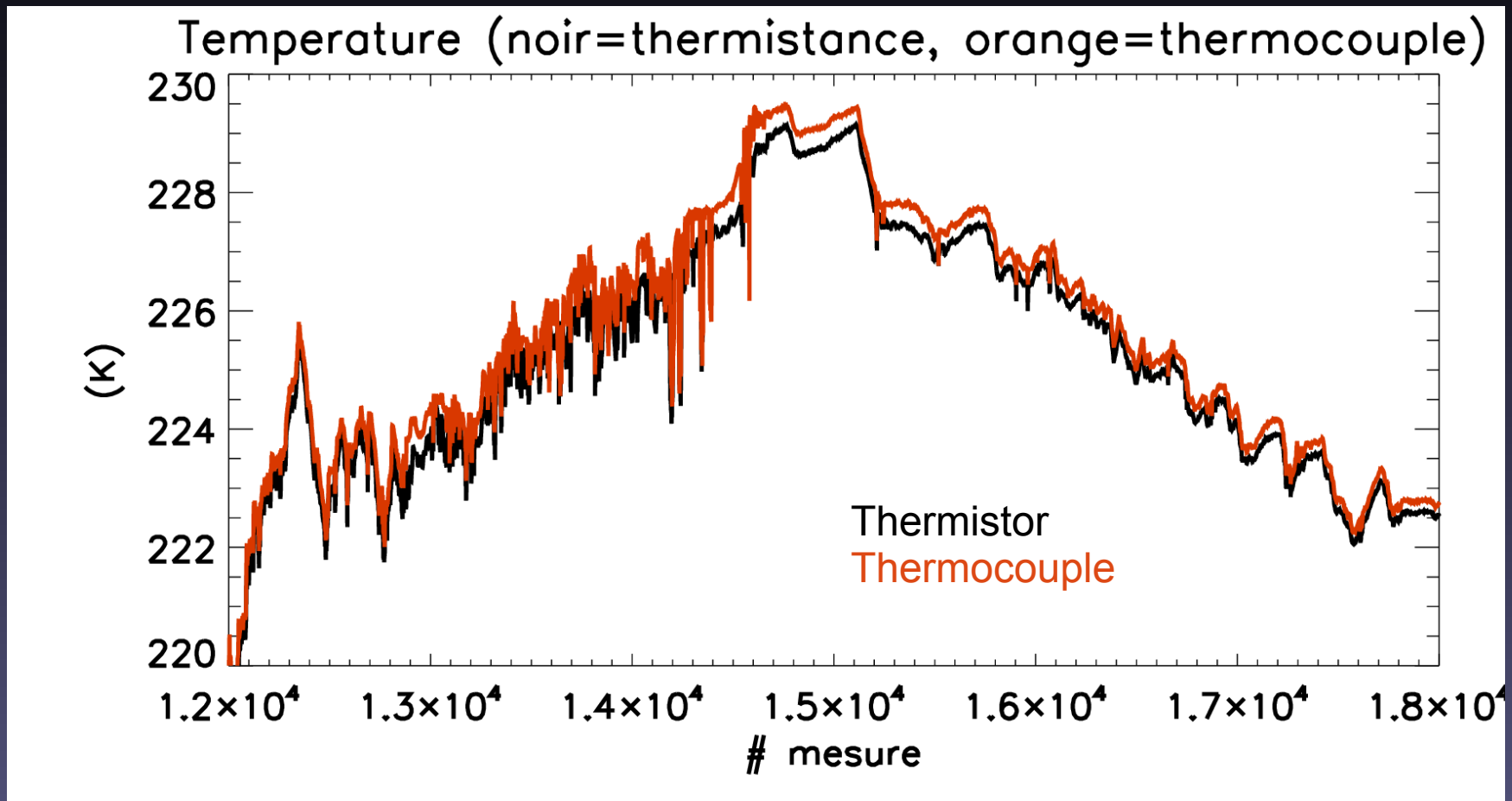
- Technological flights during the recent CNES large balloon campaign in Timmins, ON, 2014
  - Thermistor/thermocouple comparison
- 2 pairs of sensors
  - “short arms”: 50 cm from the main gondola
  - “long arms” : 5 m below the gondola
  - Nighttime flight

# Stratoscience 2014



Same sensitivity of the two technologies  
Good agreement  
Similar noise ( $< 0.1$  K)

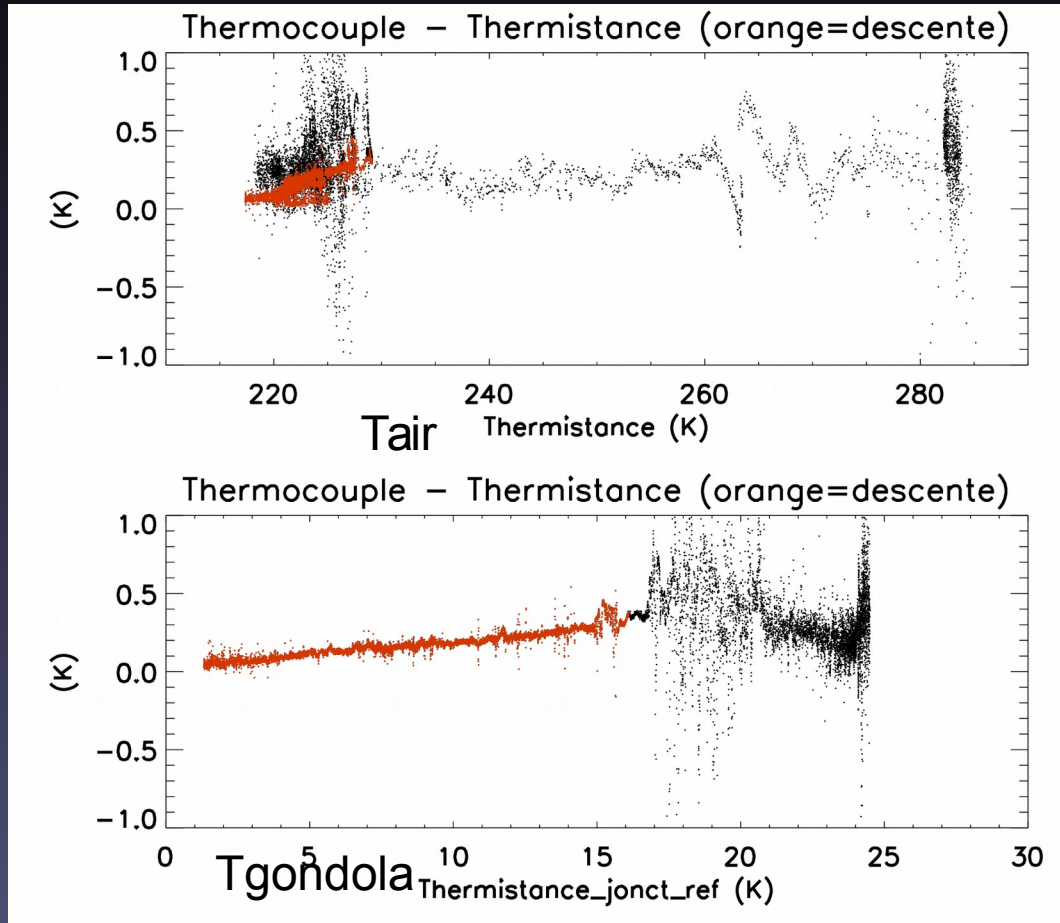
# Stratoscience 2014



Zoom near the flight top

Greater noise during balloon ascent (balloon and gondola wake)  
Bias between the two measurements ~ 0.3 K... but variable

# Stratoscience 2014

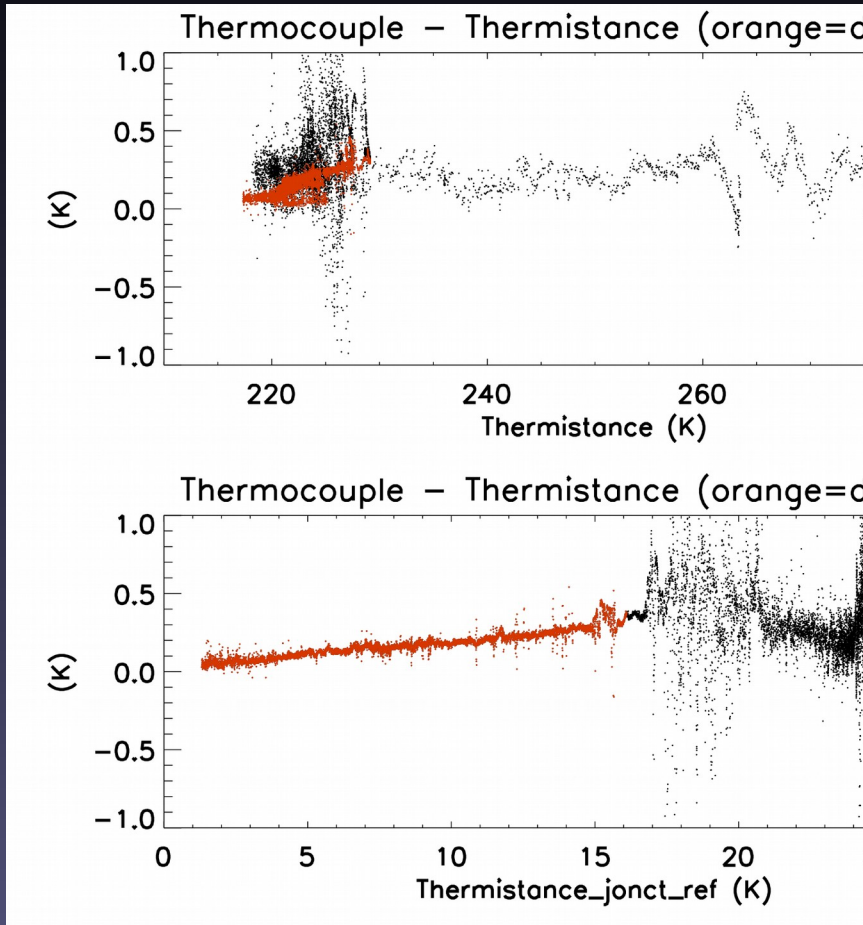


Short arms

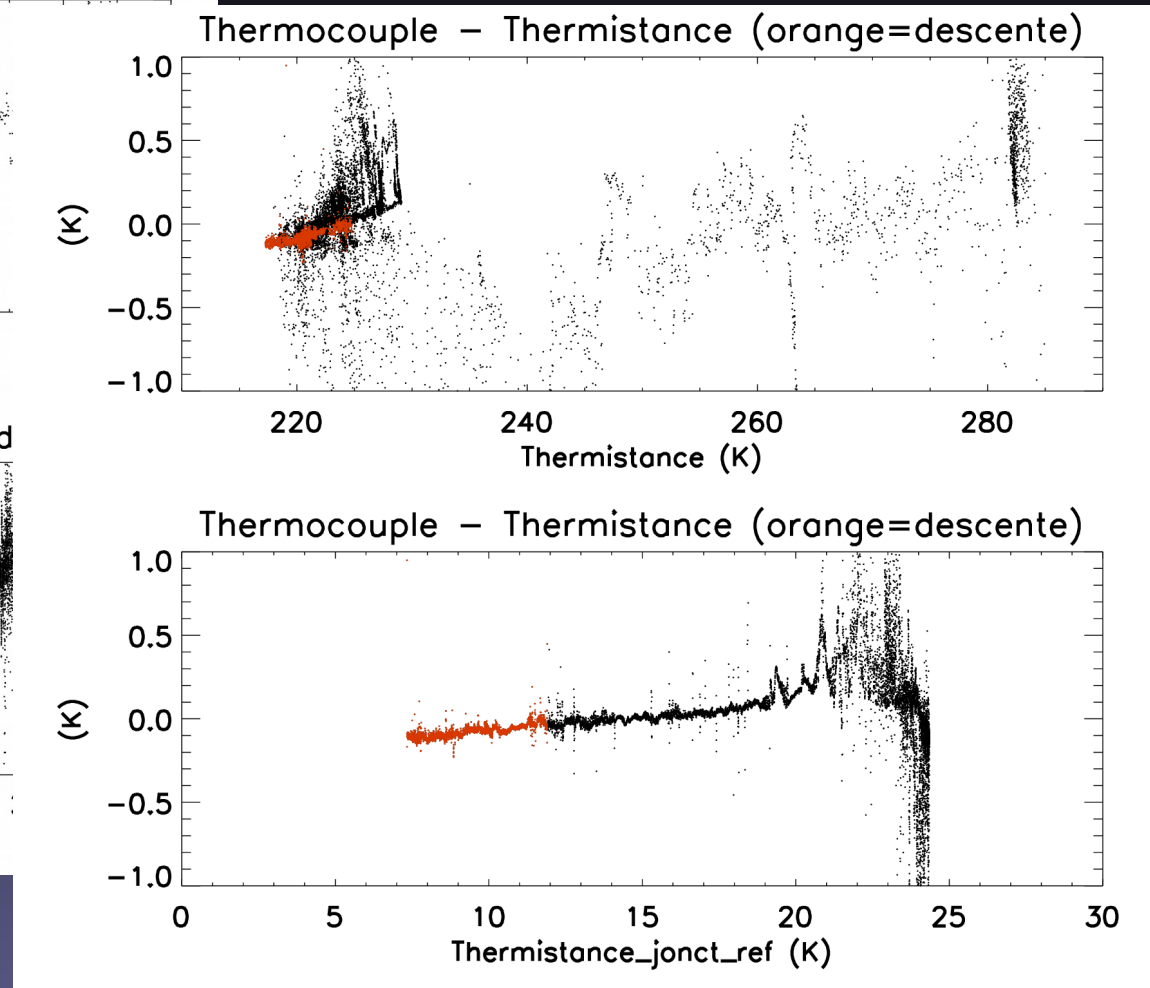
Error likely due to a poor compensation of the reference junction



# Stratoscience 2014



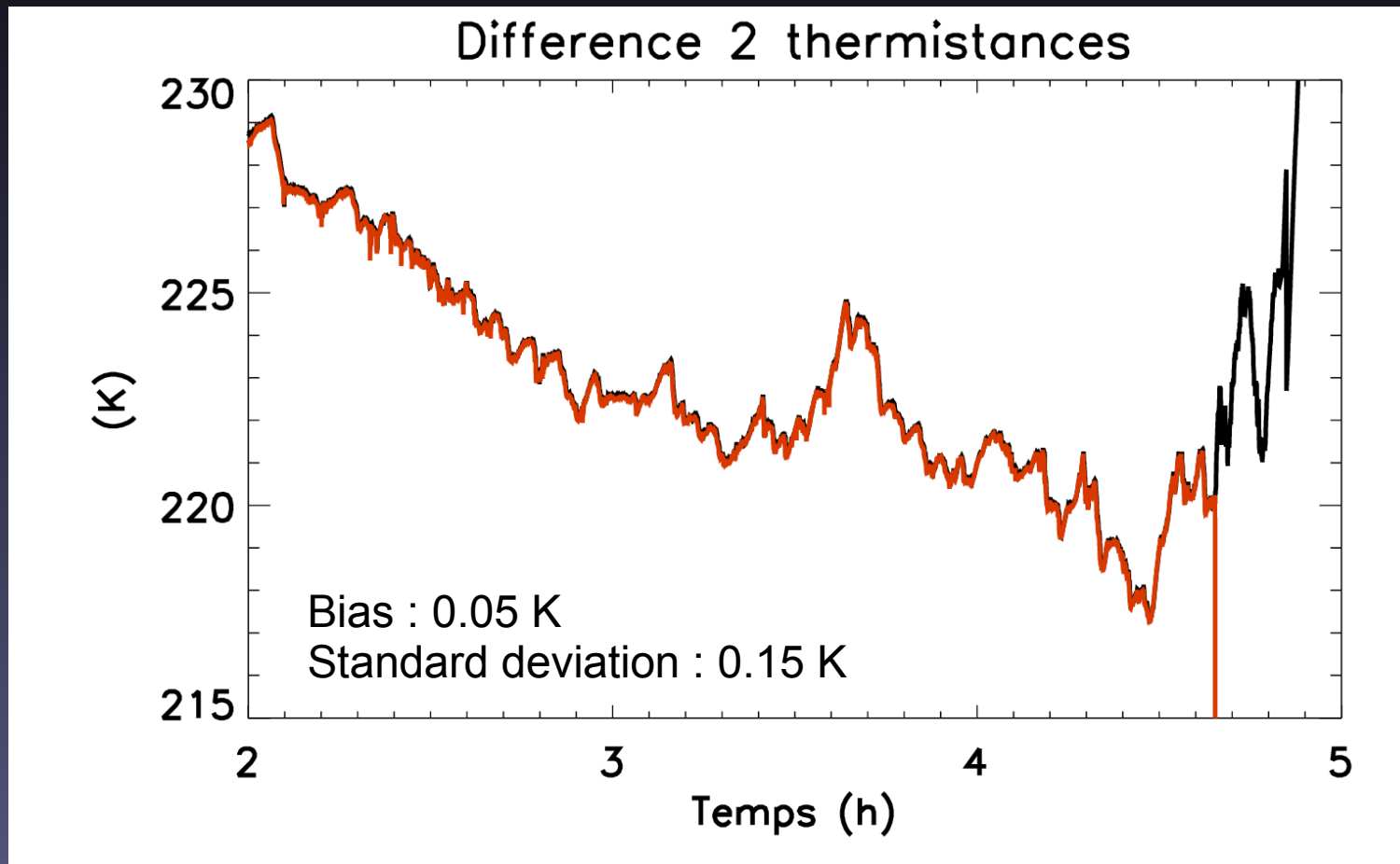
Short arms



Long arms

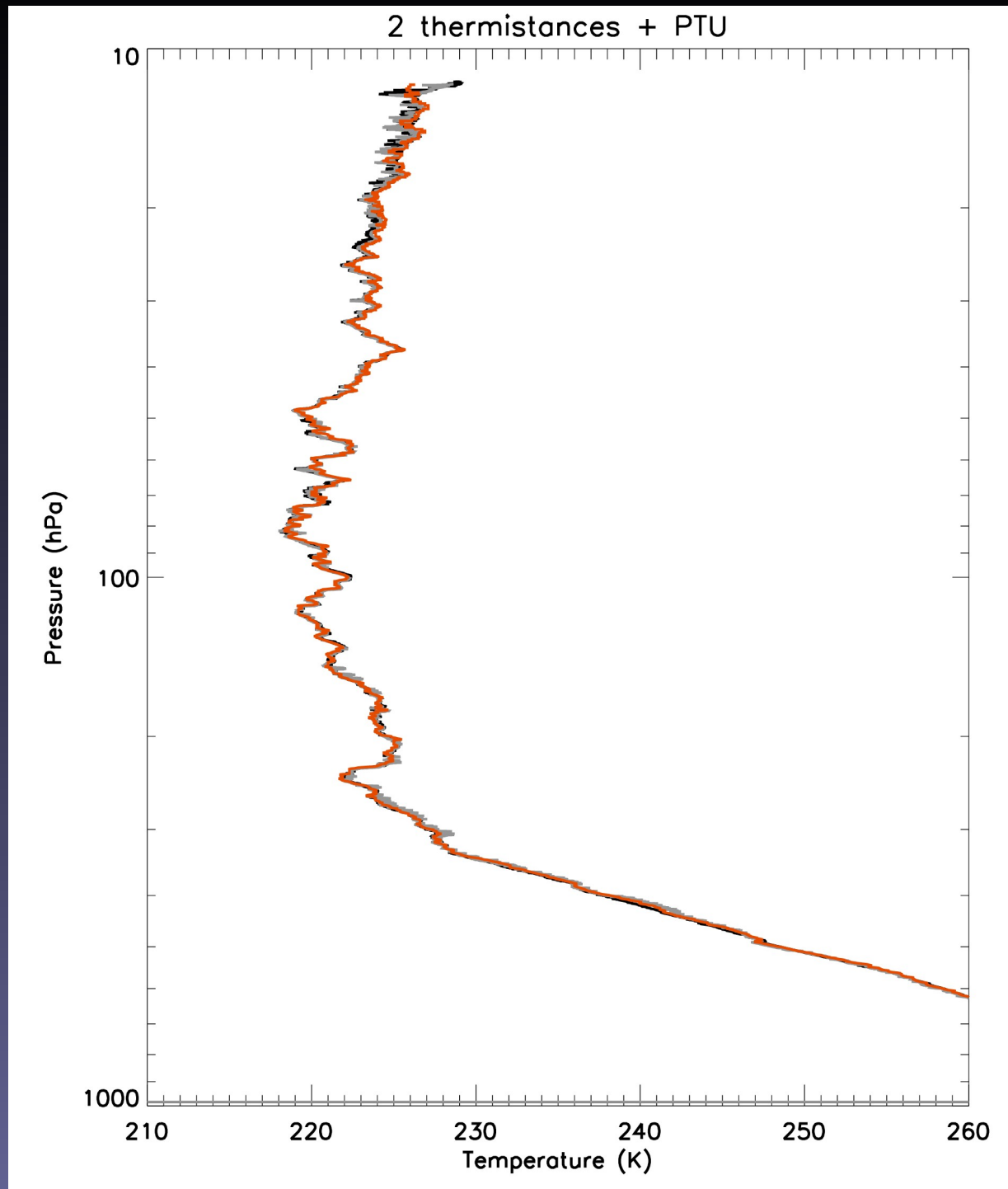
Error likely due to a poor compensation of the reference junction

# Comparison btw 2 thermistors



End of the flight

# Comparison 2 thermistors + PTU sonde



# Temperature

- Demonstrate that thermocouple can be used to measure air temperature on SPBs
  - Lab work to improve compensation of the reference junction
- Daytime flight to check thermocouple performance with solar radiation
  - Fly 4 Tsen instrument under Google Loon balloons
- Planned configuration during Stratéole 2 :
  - 1 thermistor (nighttime reference)
  - 1 thermocouple (daytime measurements)

# Winds

- Horizontal component of the winds are derived from successive balloon positions
  - Measurements every 30 s
  - Planned standard GPS receiver within Zephyr: u-blox neo-7p
    - 1-m precision on the horizontal positions (< 2 m on the vertical)
    - Winds precision ~ 0.05 m/s with measurements every 30 s
    - GPS time & positions will be supplied to every instrument onboard Zephyr
  - Another GPS receiver in Euros
    - With similar performances
  - Jennifer's hi-precision GPS receivers on 4 flights/campaign
    - 10 cm horizontal position, 20 cm vertical