Update: Thermal Imaging

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ISU WEEKLY STAVE QA MEETING

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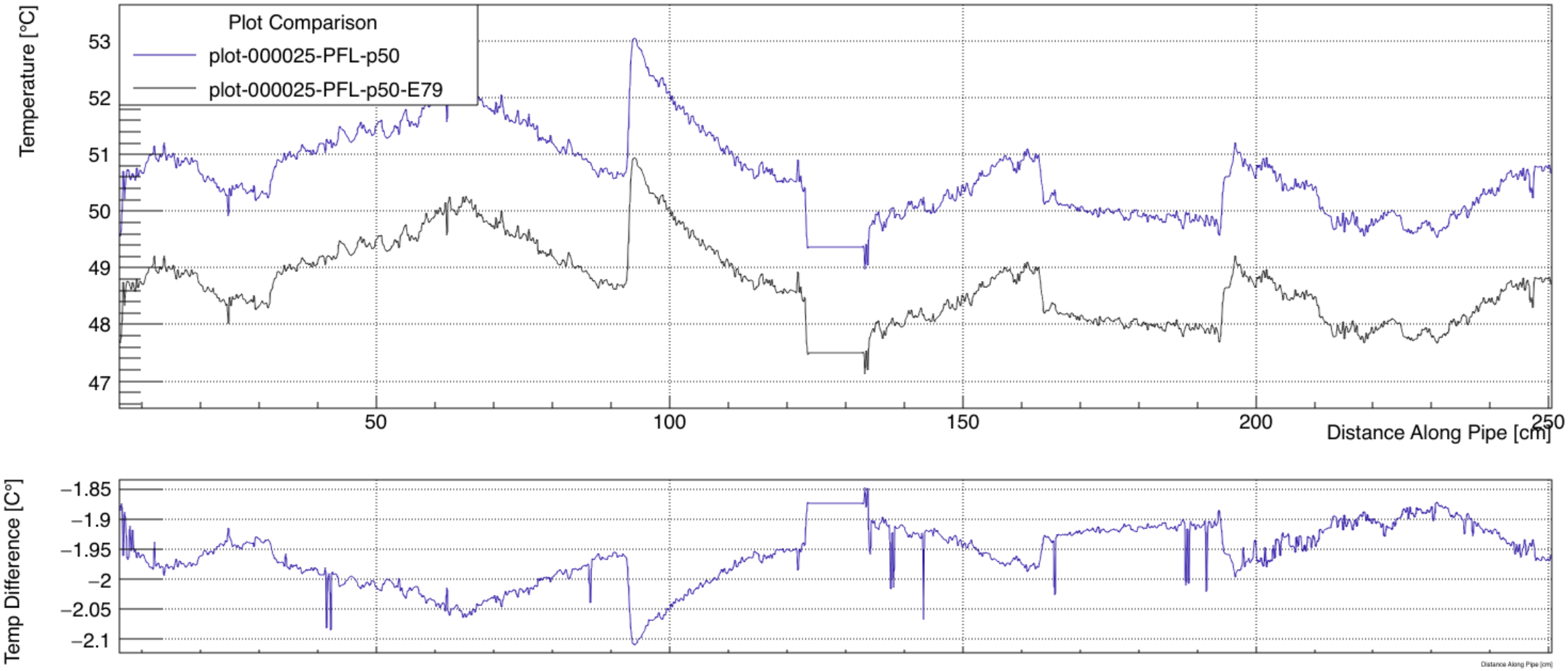
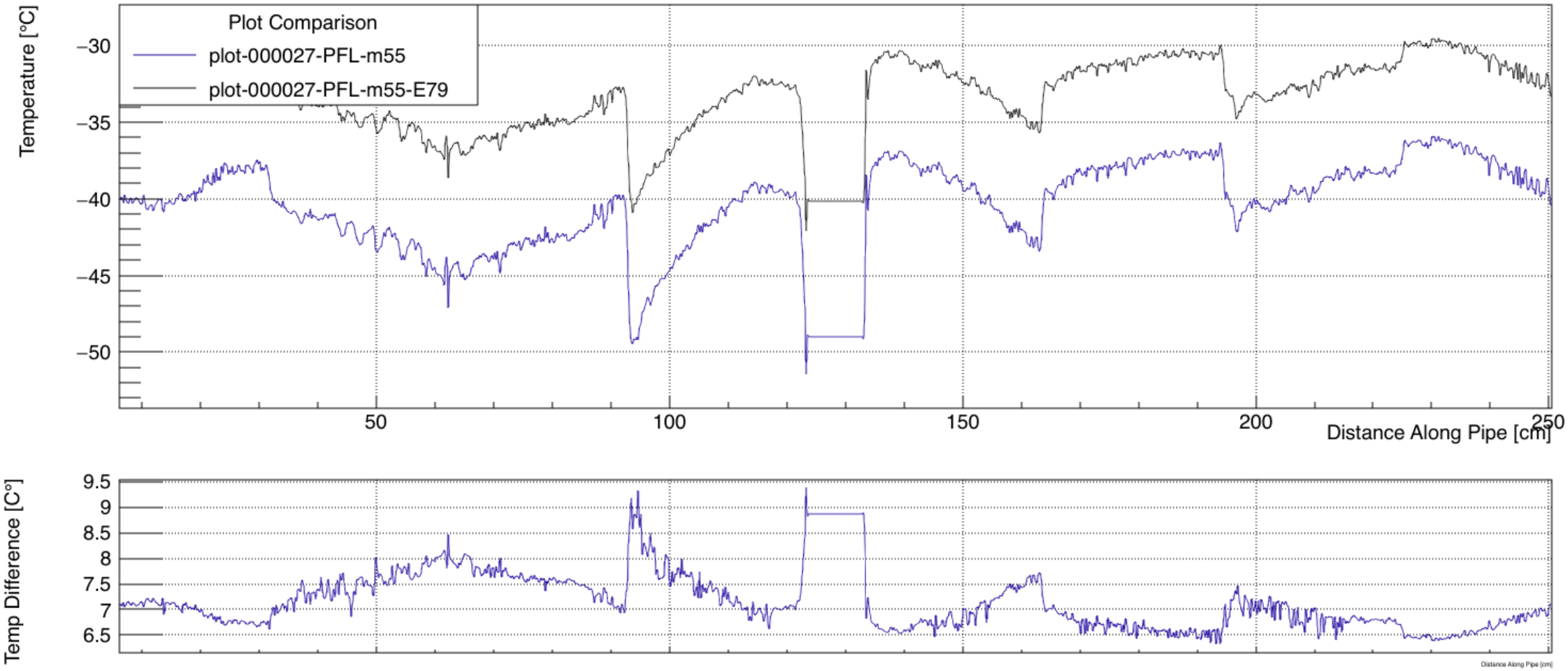
Since Last Time…

- Emissivity was measured more accurately.
- Measurements were remade for the pipe-foam stave assembly with fluid reversed. Measurements were not always consistent. Prompting a new study
- Began a new study to see what is necessary for consistency. Over the last few measurements there have been large differences in the mean value of the temperature spectrum.
  - Attempted to hold all user controlled variables constant
  - Recorded values for all of the measured variables
  - Give an estimate of the fluctuation over 2 minutes in which the average frame is taken

Emissivity

- The emissivity of the pipe-foam was measured by comparing a piece of tape on the end of the stave with a known emissivity of 0.95 to a spot directly adjacent. The emissivity was then measured to be 0.73 +/- 0.02.
  - This will give a global change, so all plots are created using emissivity of 0.73. The real temperature may be off by a few degrees C.
  - This could mean that the temperature gradient on each of the foam pieces may be due to small differences in emissivity.
  - On the next two slides we see the difference between 0.79 and 0.73 emissivity values of the same temp profile
    - At High Temp(+50C Fluid) ~2C change
    - At Low Temp (-40C Fluid) ~8C change


Plot Comparison
plot-000025-PFL-p50
plot-000025-PFL-p50-E79
Temperature [°C]
53
52
51
50
49
48
47
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
−1.85
−1.9
−1.95
−2
−2.05
−2.1

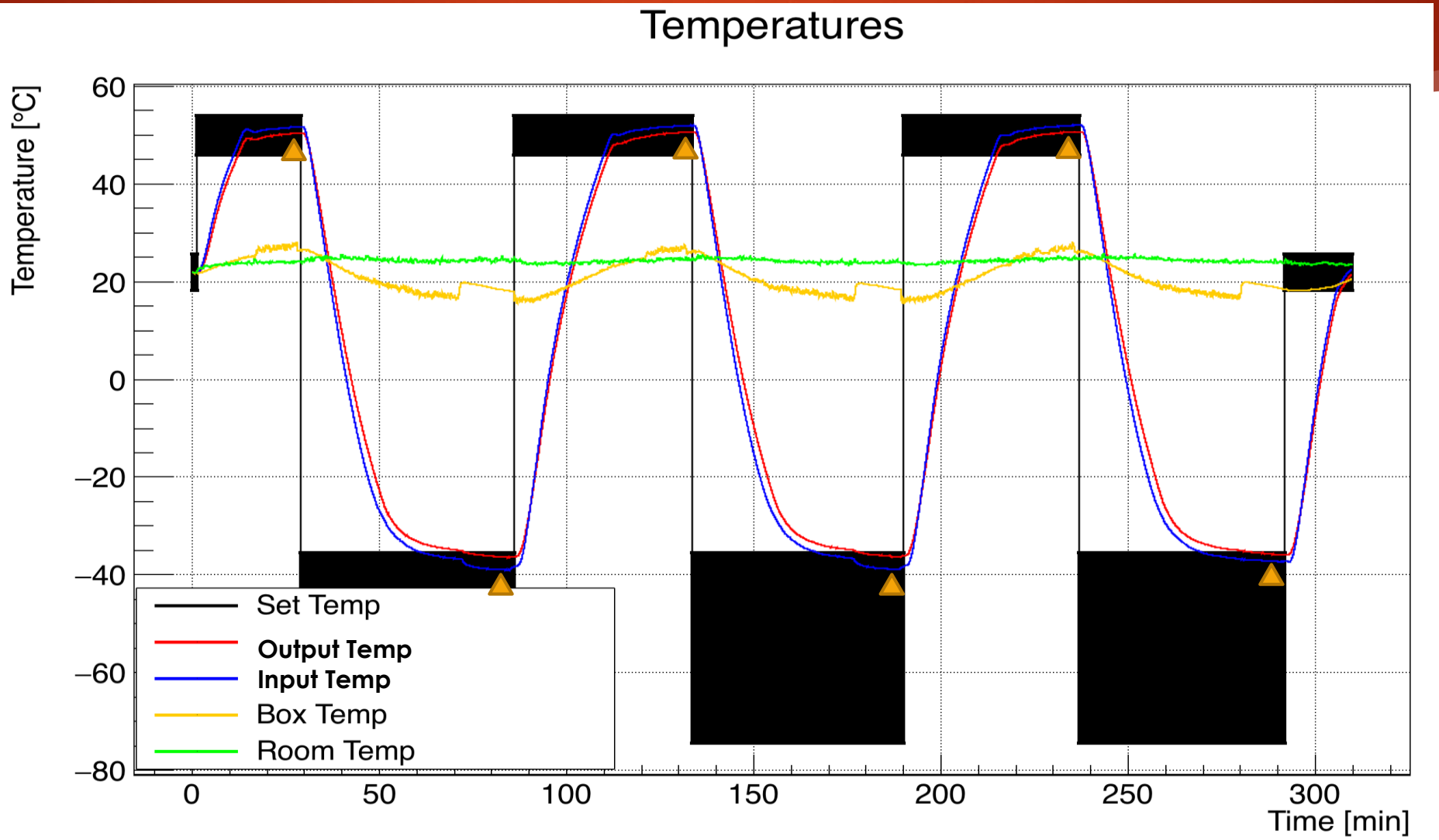

Plot Comparison
plot-000027-PFL-m55
plot-000027-PFL-m55-E79
Temperature [°C]
−30
−35
−40
−45
−50
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
9.5
9
8.5
8
7.5
7
6.5

Reproducibility

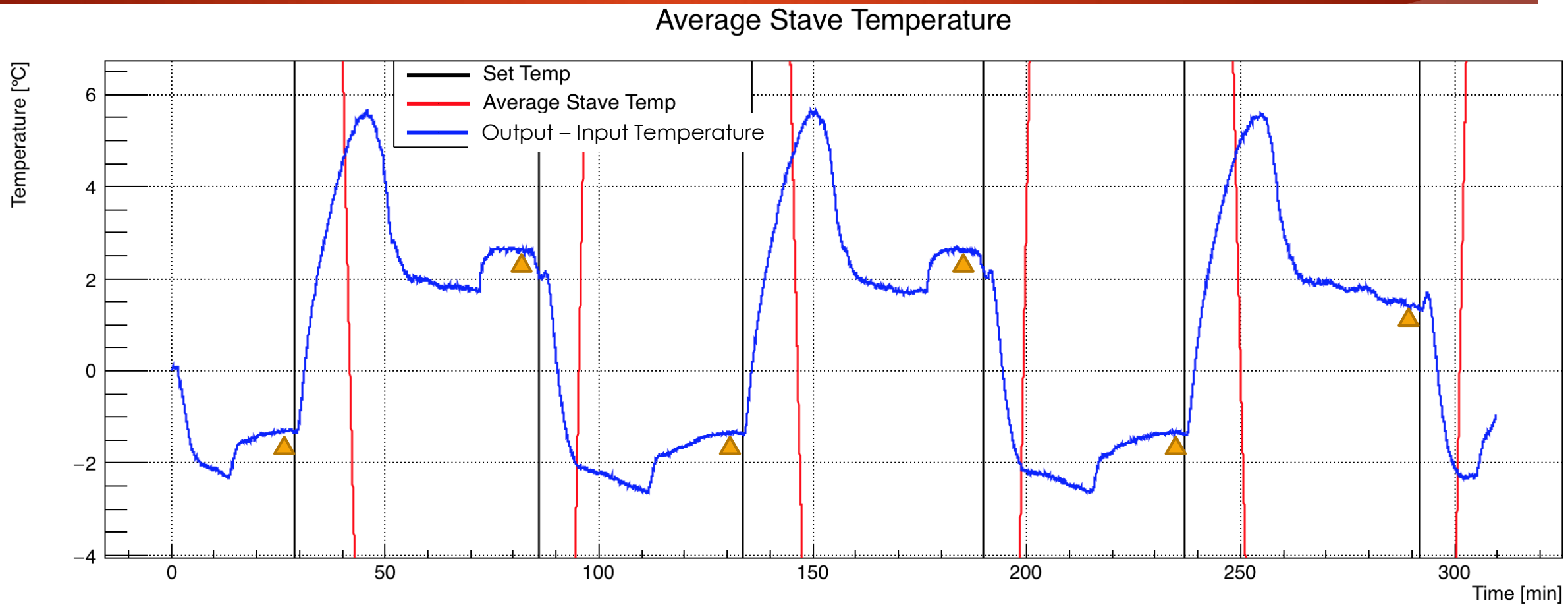
- The PF stave's thermal profile was measured for high(+50C fluid) and low(-40C fluid) input temperatures 3 times.
  - While the chillerctrl program was working toward the set temperature, the airflow was on at ~10psi(40 l/min)
  - Once the fluid reached the trigger temperature and stabilized, the airflow was shut off and the system was left for 10 minutes to restabilize.
  - An image was then taken from an average of 200 frames at a rate of 25 frames/sec
  - The system then looped to the next temperature(high,low,high,low,high,low)
- All variables were measured from the log file to note any differences between the measurements
  - Each measured variable's uncertainty is characterized by its maximum fluctuation over the time in the log file

User Controlled Variables	Variables that we measure
Chiller Set Temperature	Temp In Stave
RPM Booster Pump	Temp Out Stave
Air Flow in Box	Temp in Box
Wait Time	Temp in Room
	Humidity
	Thermal Image

Variables in a Thermal Measurement



More Plots


Average Stave Temperature
Set Temp
Average Stave Temp
Output – Input Temperature
Temperature [°C]
6
4
2
0
−2
−4
0
50
100
150
200
250
300
Time [min]

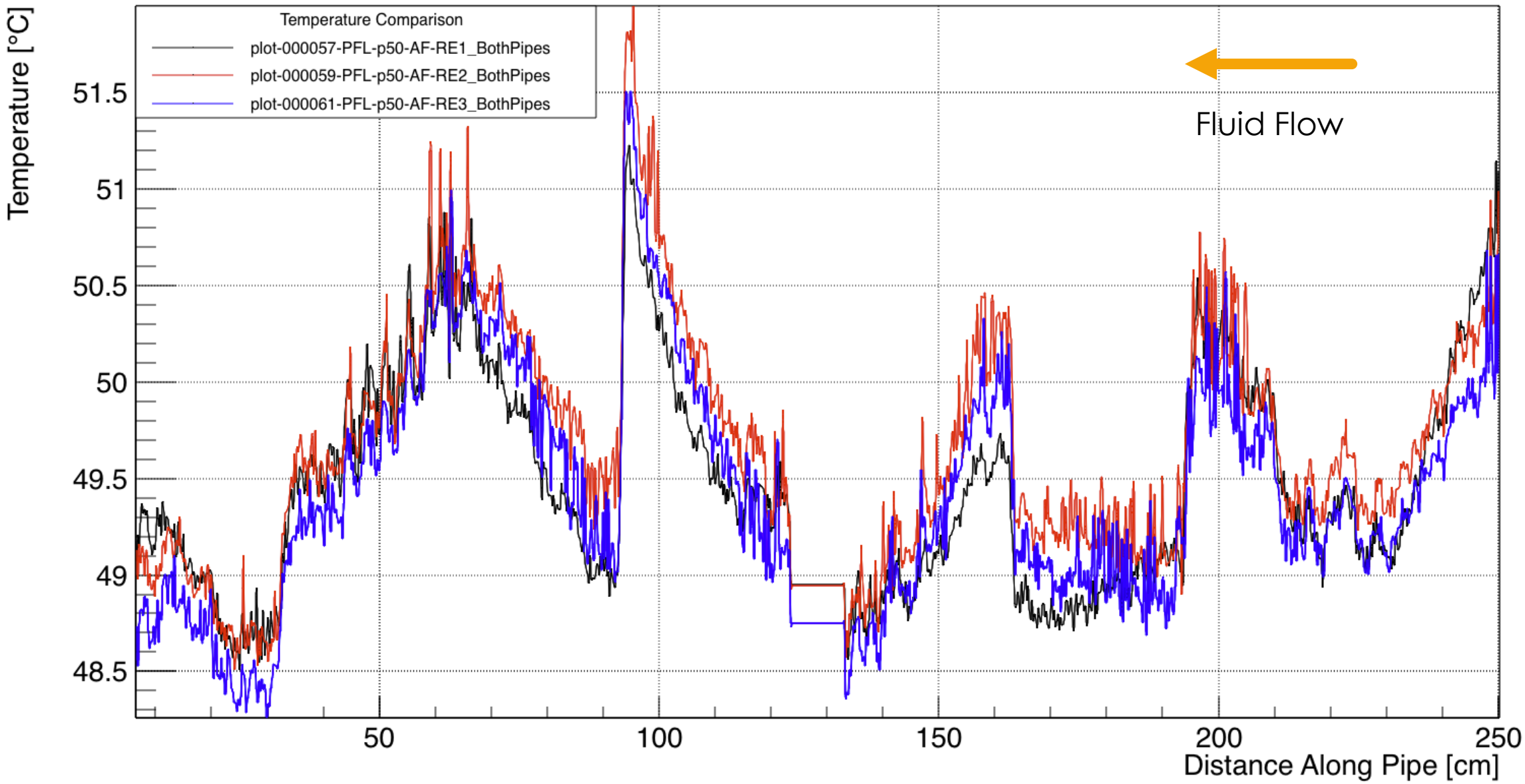
Variables in our Measurement

- These values are for the hot temperature measurement
- During trial 3, the wait time was slightly longer
- Only 2 significant differences in measured variables
  - Input temperature is different on run 1
  - There is about 1% humidity in run 1

Next Slide: A comparison of the hot temperature profile measurements

(Its good…)

Variable	Uncert.	Trial 1	Trial 2	Trial 3
TSet	0.1 [C]	+50	+50	+50
RPM BP	0.1 [rpm]	21.4	21.4	21.4
Air Flow in Box	~0 [l/min]	0	0	0
Wait Time	1 [min]	10	10	15
Abs Time	1 [min]	27	131	234
TIn	**0.1[C]**	**51.6**	**51.9**	**51.9**
TLoss(out-in)	0.1[C]	-1.29	-1.34	-1.34
TBox	1.5[C]	27.4	26.9	27.0
TRoom	1.0[C]	24.1	24.6	24.7
Humidity	**~0.1 [%RH]**	**1.1**	**0**	**0**


Temperature Comparison
plot-000057-PFL-p50-AF-RE1_BothPipes
plot-000059-PFL-p50-AF-RE2_BothPipes
plot-000061-PFL-p50-AF-RE3_BothPipes
Fluid Flow
Temperature [°C]
51.5
51
50.5
50
49.5
49
48.5
50
100
150
200
250
Distance Along Pipe [cm]

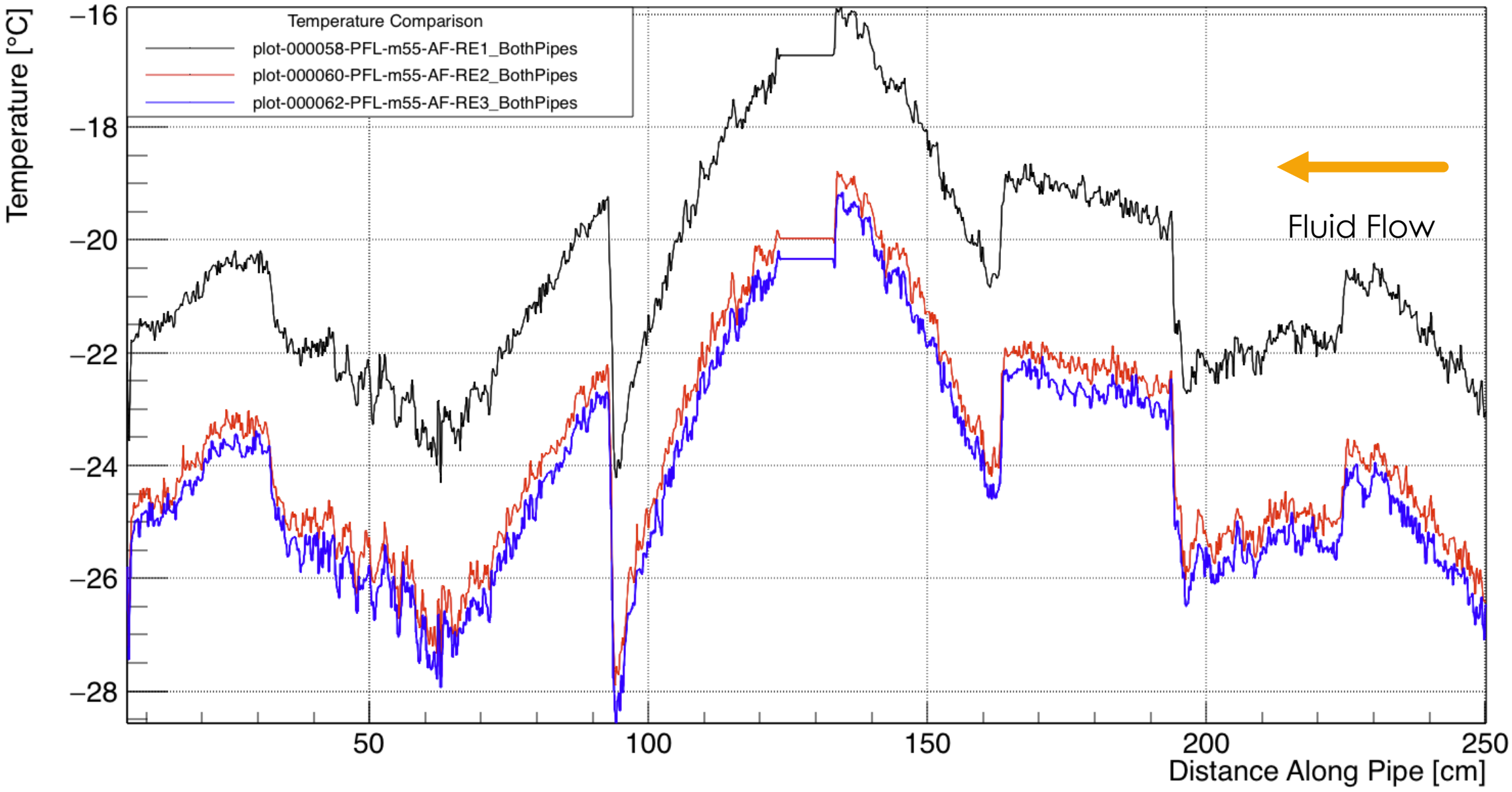
Variables in our Measurement

- These values are for the cold temperature measurement
- During trial 3, the flow rate was not adjusted
- 2 significant differences in variables
  - Input temperature is different on run 3
  - TLoss is much lower on run 3

Next Slide: A comparison of the cold temperature profile measurements

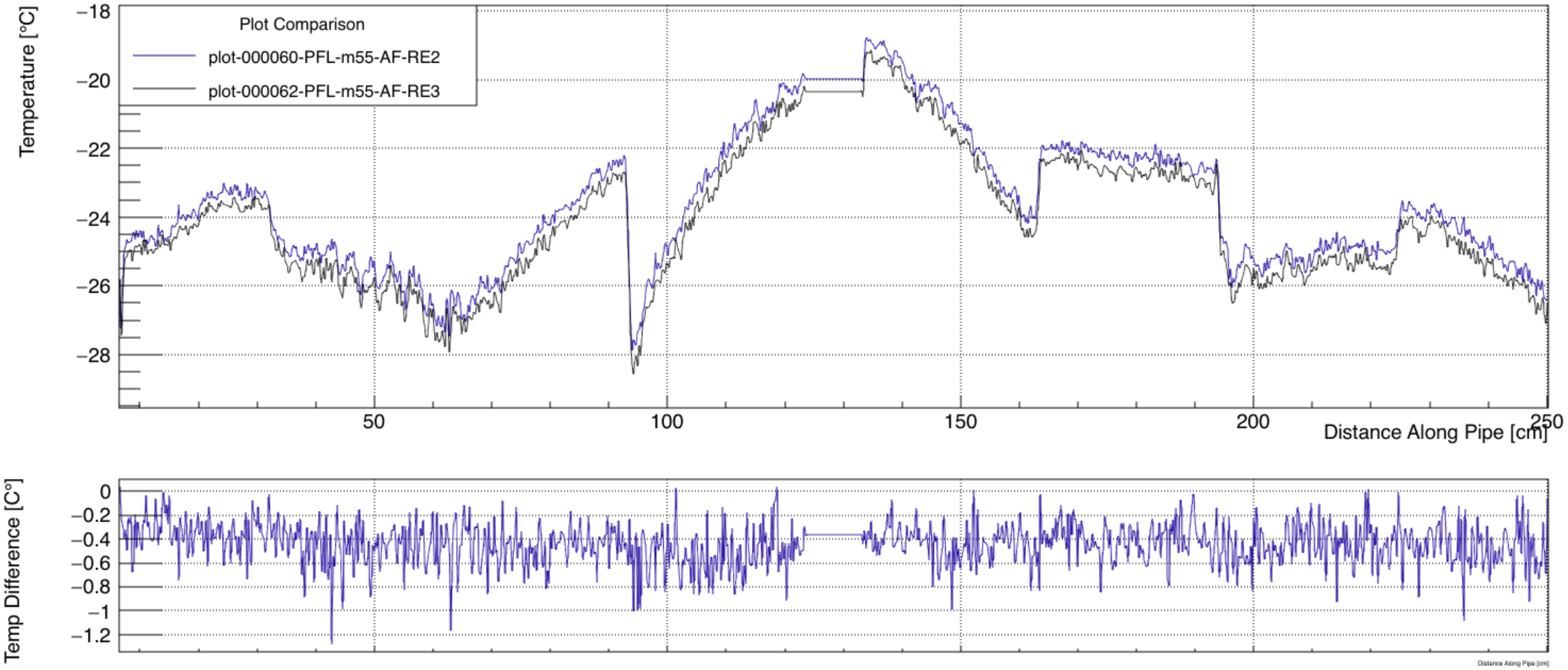
(Less good…)

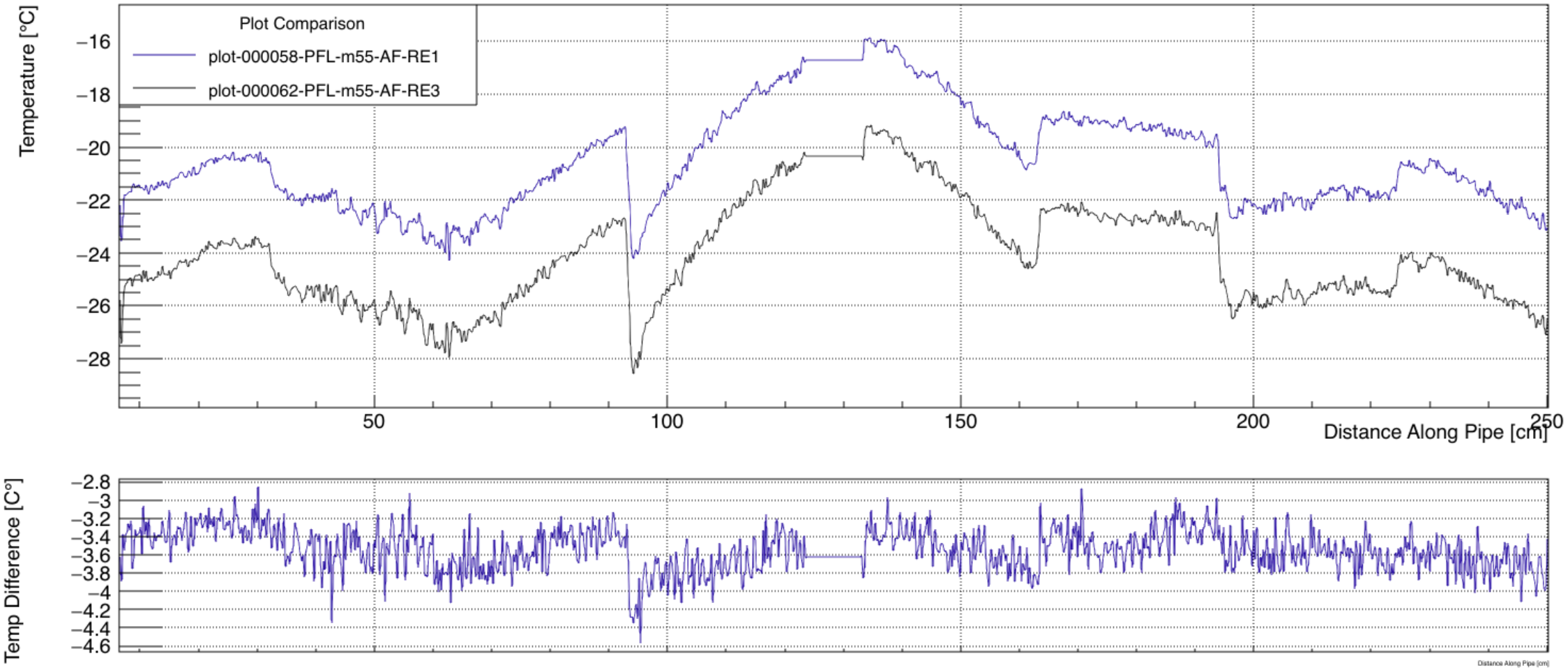
Variable	Uncert.	Trial 1	Trial 2	Trial 3
TSet	0.5 [C]	-55	-55	-55
RPM BP	0.1 [rpm]	26.7	26.7	21.4
Air Flow in Box	~0 [l/min]	0	0	0
Wait Time	1 [min]	10	10	10
Abs Time	1 [min]	83	188	290
TIn	**0.1[C]**	**-38.9**	**-38.8**	**-37.2**
TLoss(out-in)	**0.1[C]**	**+2.61**	**+2.58**	**+1.41**
TBox	0.5[C]	18.3	18.5	18.8
TRoom	1.0[C]	24.6	24.1	24.1
Humidity	~0.1 [%RH]	0	0	0

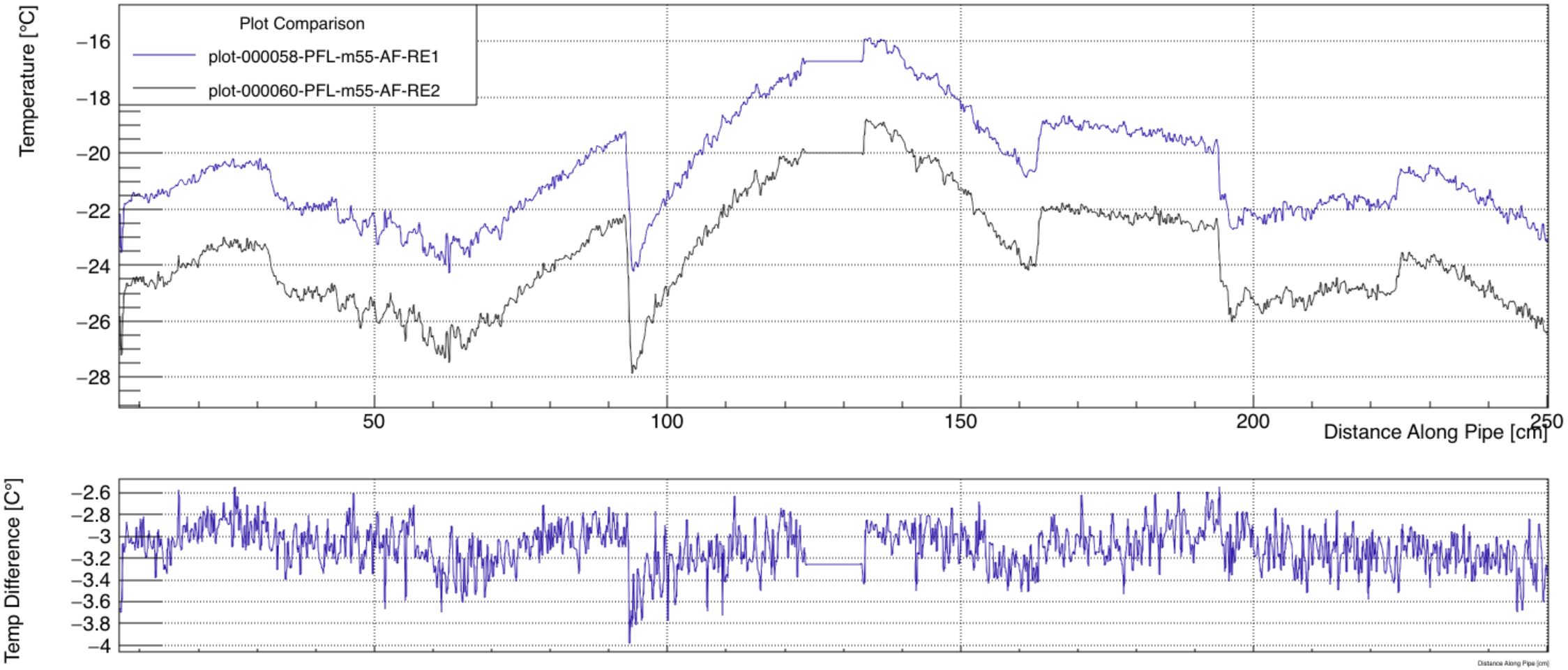

Temperature Comparison
plot-000058-PFL-m55-AF-RE1_BothPipes
plot-000060-PFL-m55-AF-RE2_BothPipes
plot-000062-PFL-m55-AF-RE3_BothPipes
Temperature [°C]
−16
−18
−20
−22
−24
−26
−28
50
100
150
200
250
Distance Along Pipe [cm]
Fluid Flow

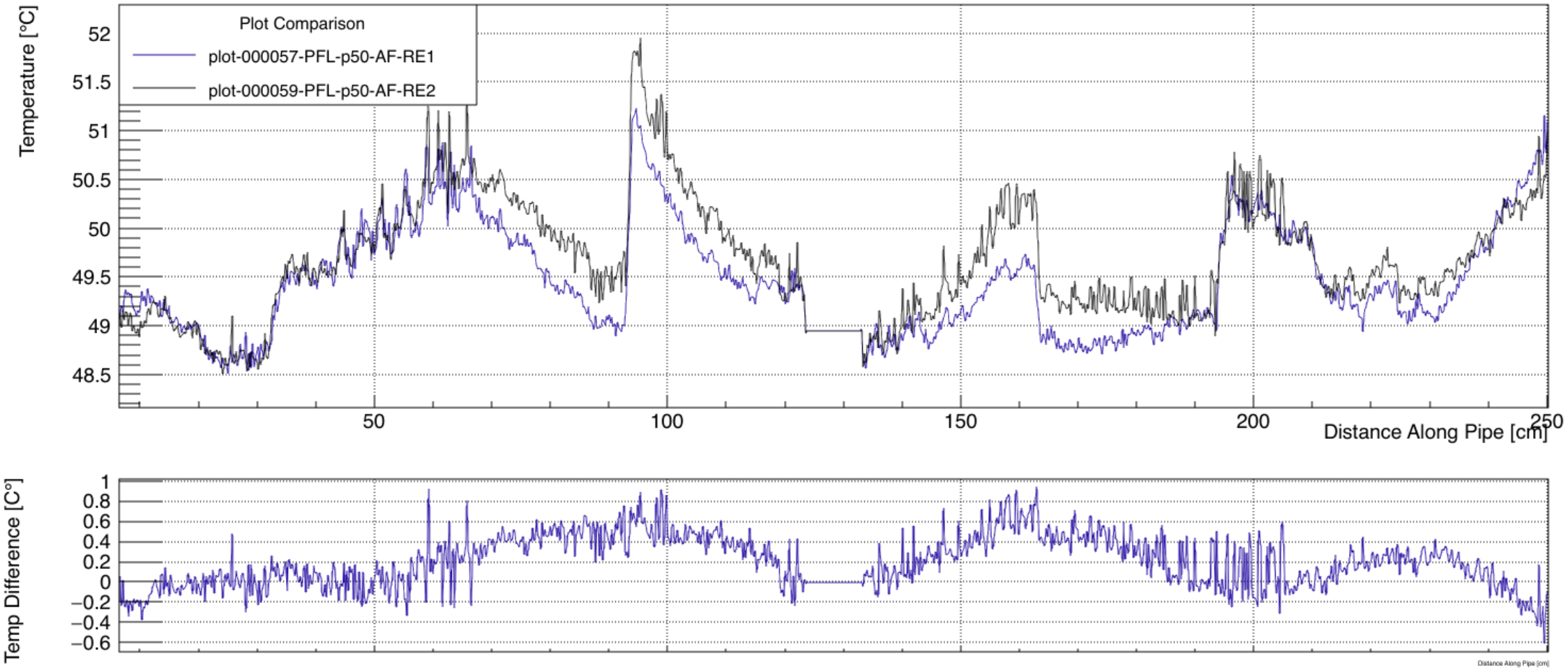
Conclusions?

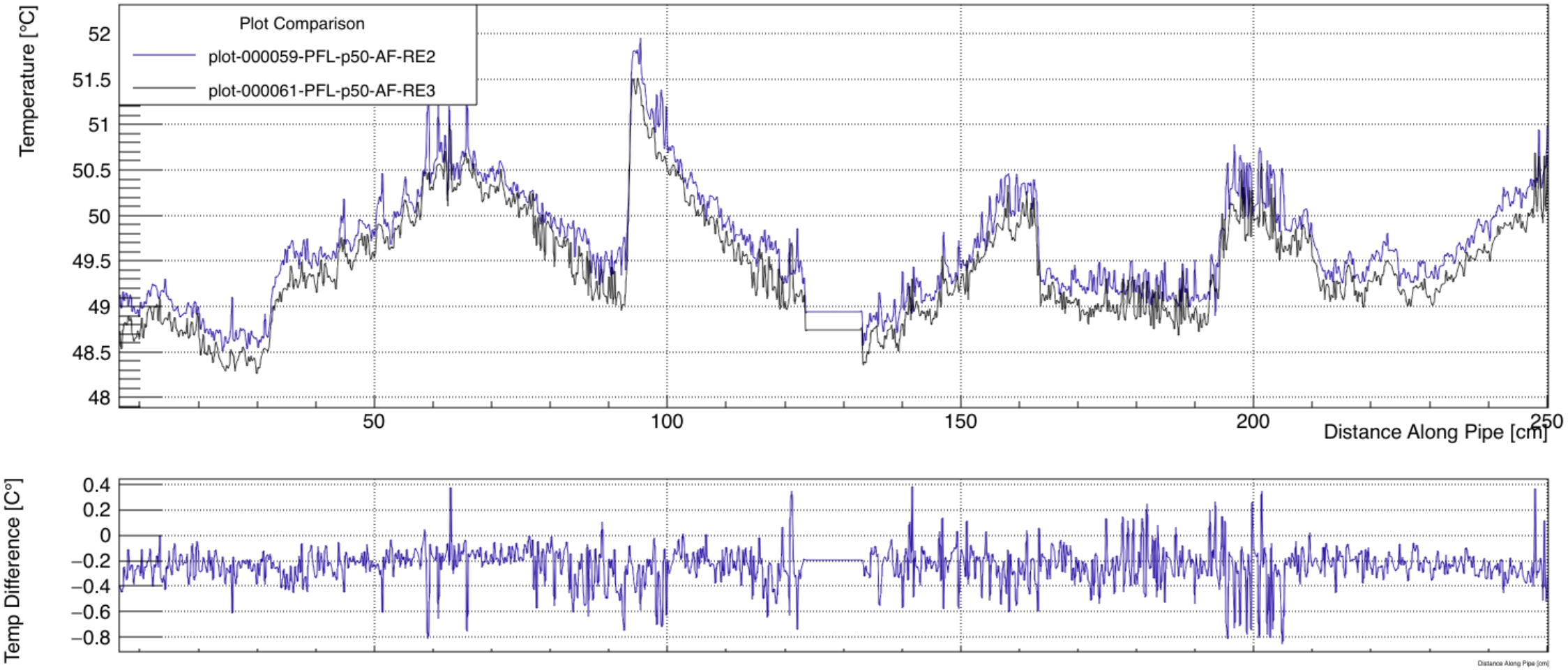
- Something happened at low temperature…
- When things don't happen, we see a difference of max 0.2 C between each spectrum

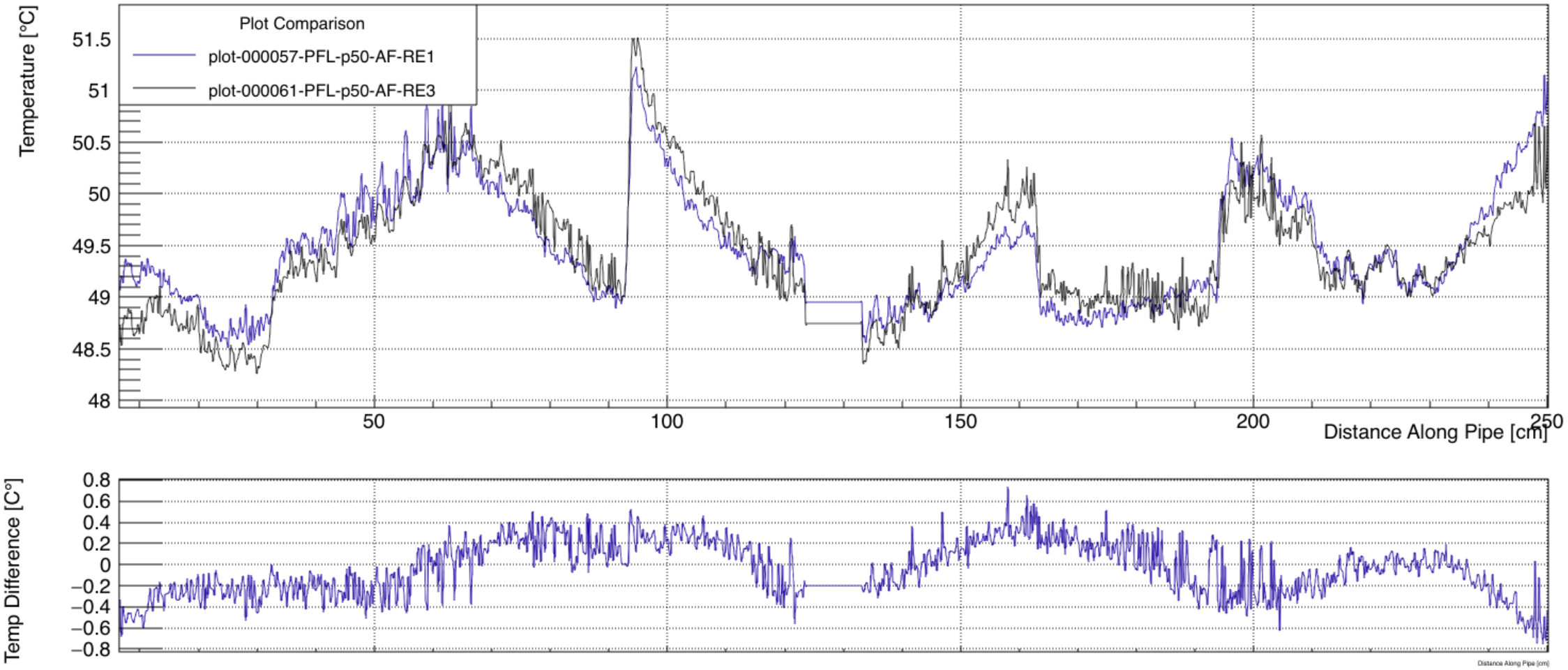

Plot Comparison
plot-000060-PFL-m55-AF-RE2
plot-000062-PFL-m55-AF-RE3
Temperature [°C]
−18
−20
−22
−24
−26
−28
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2


Plot Comparison
plot-000058-PFL-m55-AF-RE1
plot-000062-PFL-m55-AF-RE3
Temperature [°C]
−16
−18
−20
−22
−24
−26
−28
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
−2.8
−3
−3.2
−3.4
−3.6
−3.8
−4
−4.2
−4.4
−4.6


Plot Comparison
plot-000058-PFL-m55-AF-RE1
plot-000060-PFL-m55-AF-RE2
Temperature [°C]
−16
−18
−20
−22
−24
−26
−28
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
−2.6
−2.8
−3
−3.2
−3.4
−3.6
−3.8
−4


Plot Comparison
plot-000057-PFL-p50-AF-RE1
plot-000059-PFL-p50-AF-RE2
Temperature [°C]
52
51.5
51
50.5
50
49.5
49
48.5
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6


Plot Comparison
plot-000059-PFL-p50-AF-RE2
plot-000061-PFL-p50-AF-RE3
Temperature [°C]
52
51.5
51
50.5
50
49.5
49
48.5
48
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8


Plot Comparison
plot-000057-PFL-p50-AF-RE1
plot-000061-PFL-p50-AF-RE3
Temperature [°C]
51.5
51
50.5
50
49.5
49
48.5
48
50
100
150
200
250
Distance Along Pipe [cm]
Temp Difference [C°]
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8

Backup Slides