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# Mini-Channel Flow Boiling in 1g and μg

RPI Biological and Chemical Engineering

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# Overview

I. Introduction

II. NASA FBCE Module (Experimental Equipment)

III. Data Acquisition

IV. Experimental Results

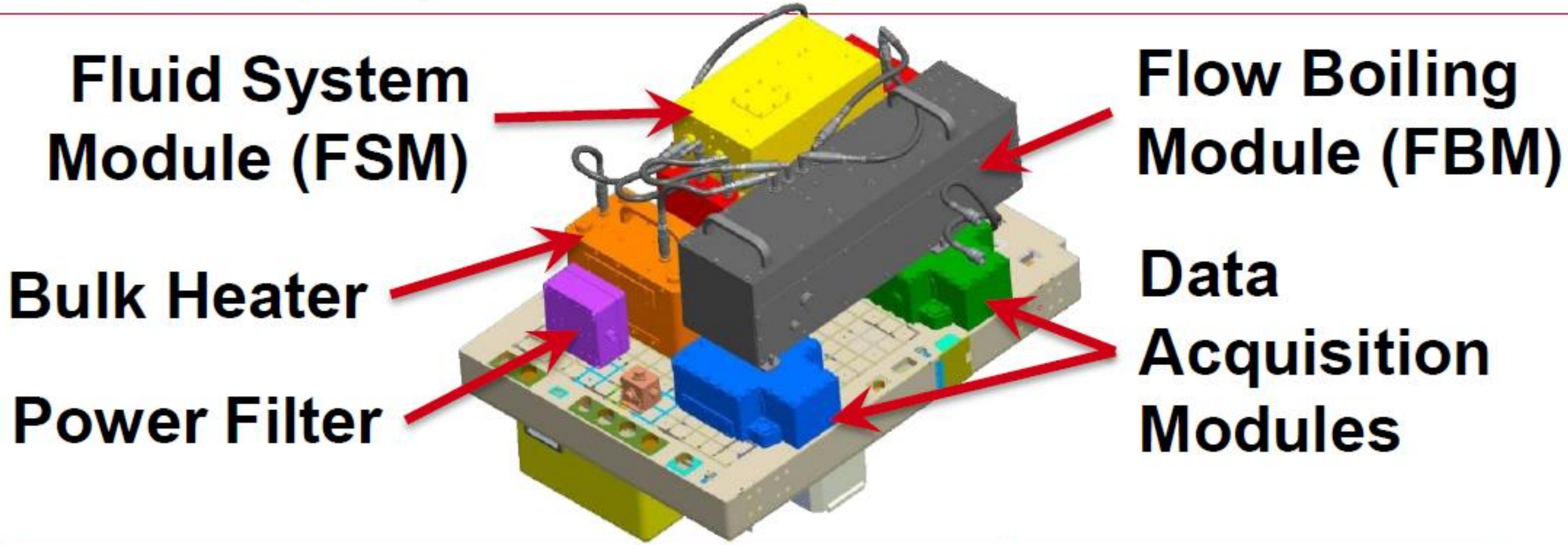
V. Video Processing

VI. Conclusions

# Motivation

- Subcooled flow boiling is one of the most effective cooling mechanisms on Earth.
- The combination of latent and sensible heat contributes to the overall heat transfer.
- Understanding the effect of gravity on subcooled flow boiling systems will allow the technology to be utilized in extraterrestrial exploration.

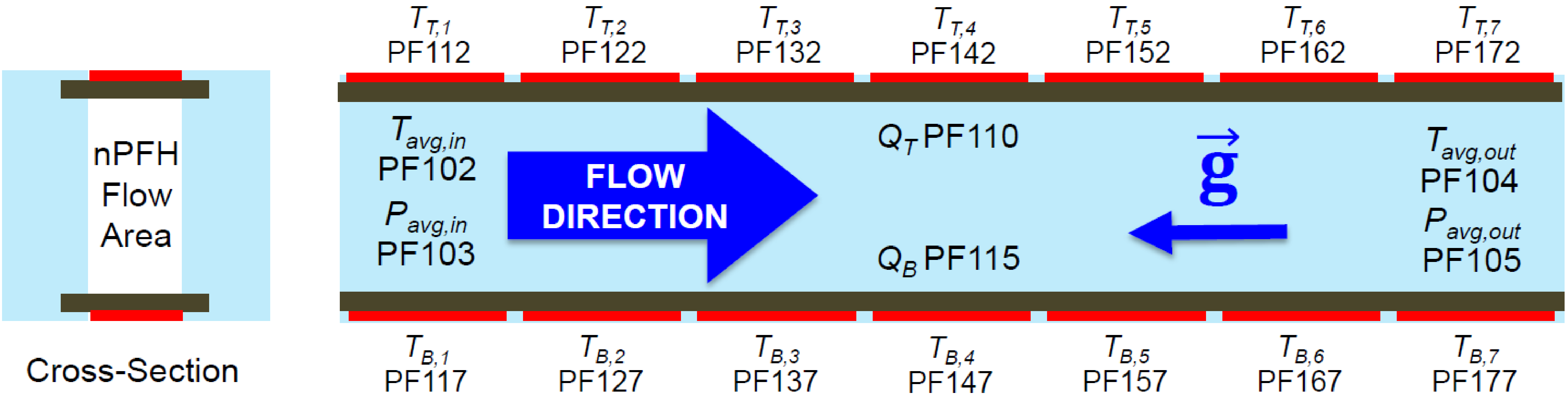
# NASA Fluids Integrated Rack (FIR)




| Parameter | Min | Max |
|---|---|---|
| System Pressure (kPa) | 110 | 160 |
| Flow Rate (g/s) | 4 | 40 |
| Bulk Heater (W) | 0 | 450 × 3 + 180 |
| FBM Heater (W) | 0 | 140 × 2 |
| Frame Rate (fps) | 0 | 2000 |

Adapted from: H. K. Nahra, M. M. Hasan, and M. Guzik, "Flow Boiling and Condensation Experiment (FBCE) Capabilities and System Description," Oct. 2020.

# 2.5 × 5.0 × 113 mm Mini-Channel




**Resistive Heaters** **Transparent Walls** **Copper Slabs**

Adapted from: H. K. Nahra, M. M. Hasan, and M. Guzik, "Flow Boiling and Condensation Experiment (FBCE) Capabilities and System Description," Oct. 2020.

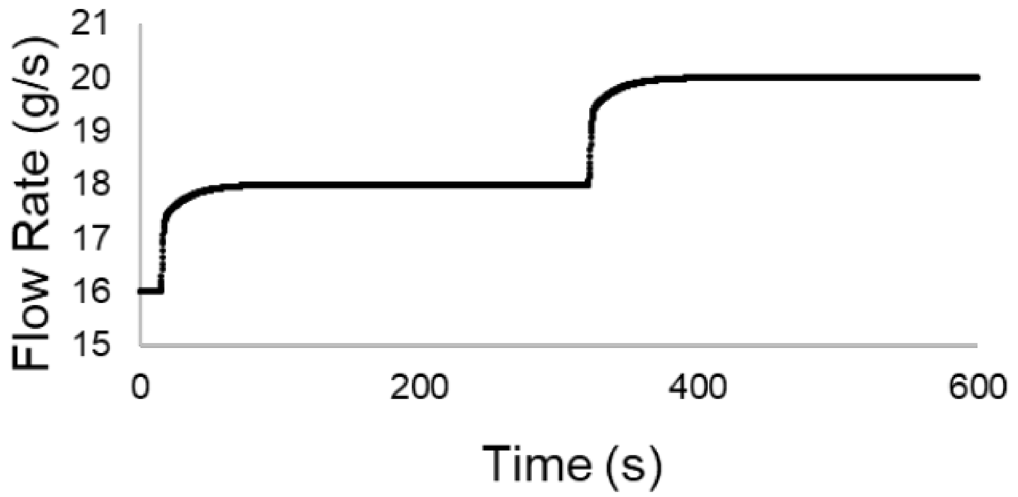
# So far…

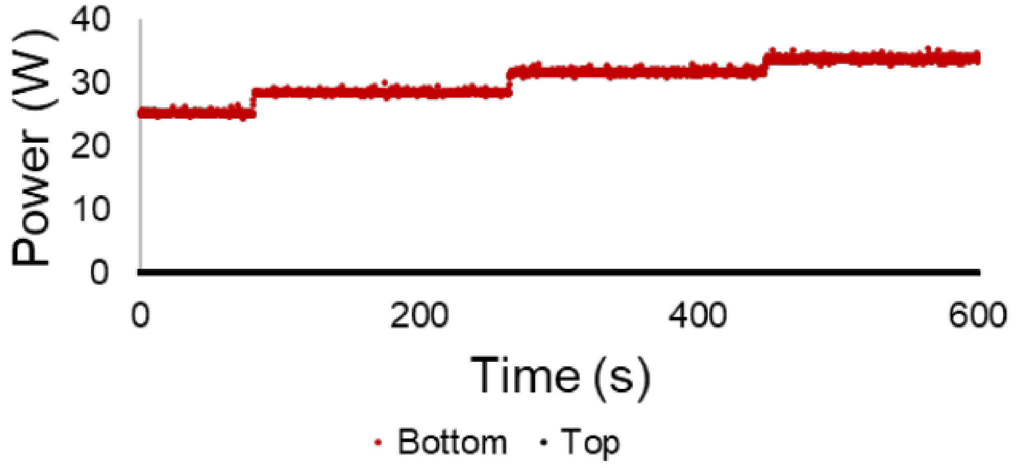
>4 TB

- 253 CSV files from Earth
- 1,941 CSV files from ISS
- ~1,000,000 cells of data per file
- Most data is not pertinent to our research
  - Fault checks, event codes, etc.
- 150,000 cells of relevant data per file
  - Temperature readings, flow rate, pressure readings, heater amperage, and voltage
- 12,000 – 150,000 images per experiment

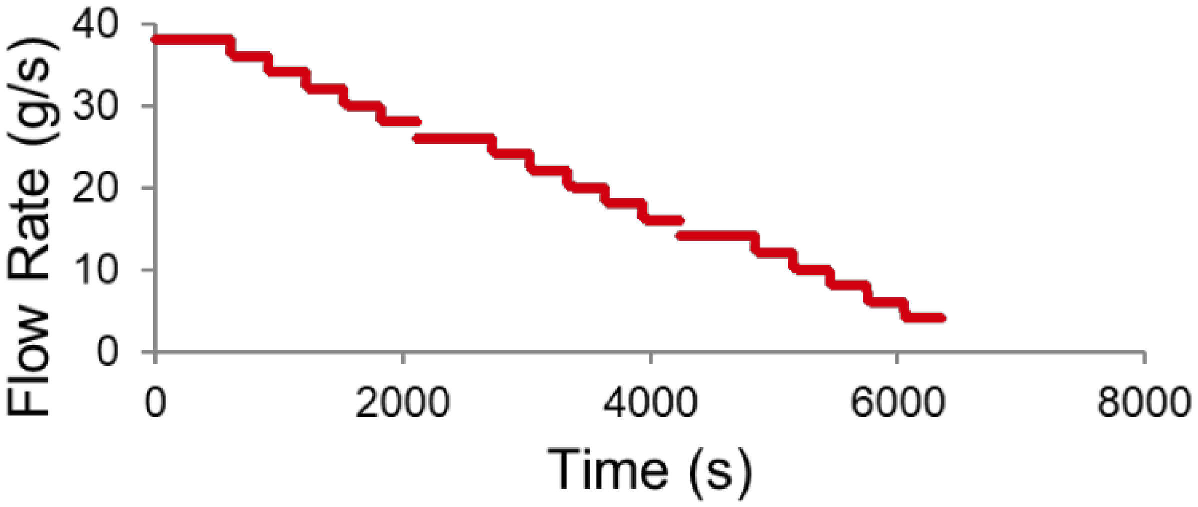
# Processing Flow:

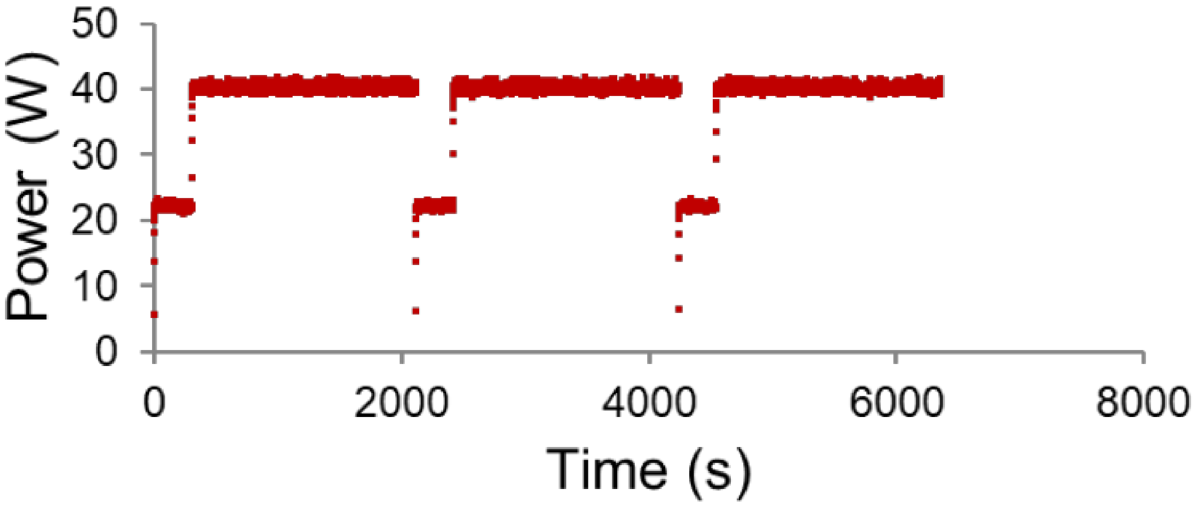
1. Open each CSV file with an Excel “master sheet”.
2. Identify experiment via automated plots.
3. Consolidate experimental data with MatLab script.
4. Run Excel macros to process data.

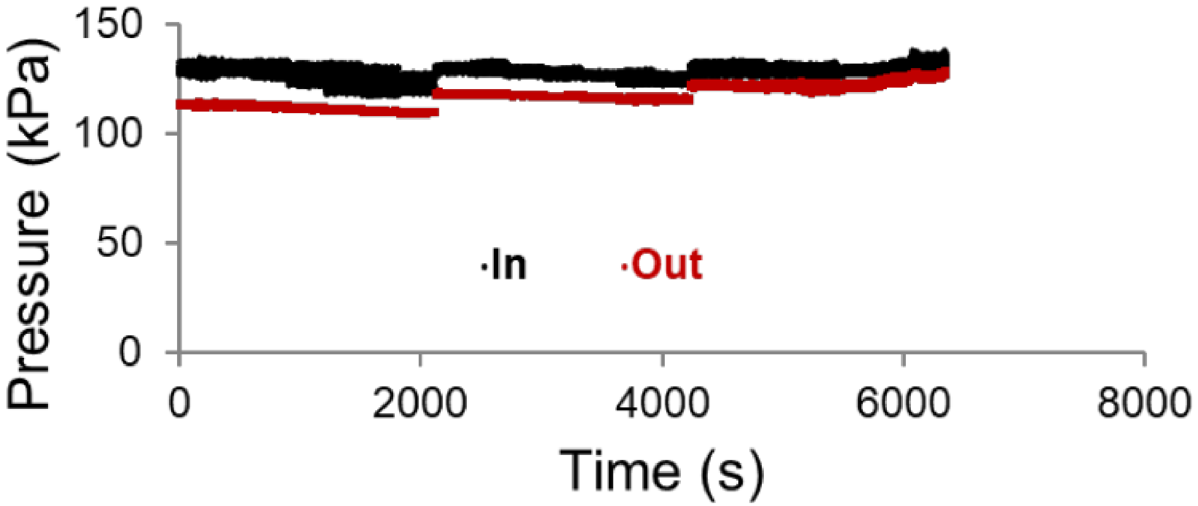


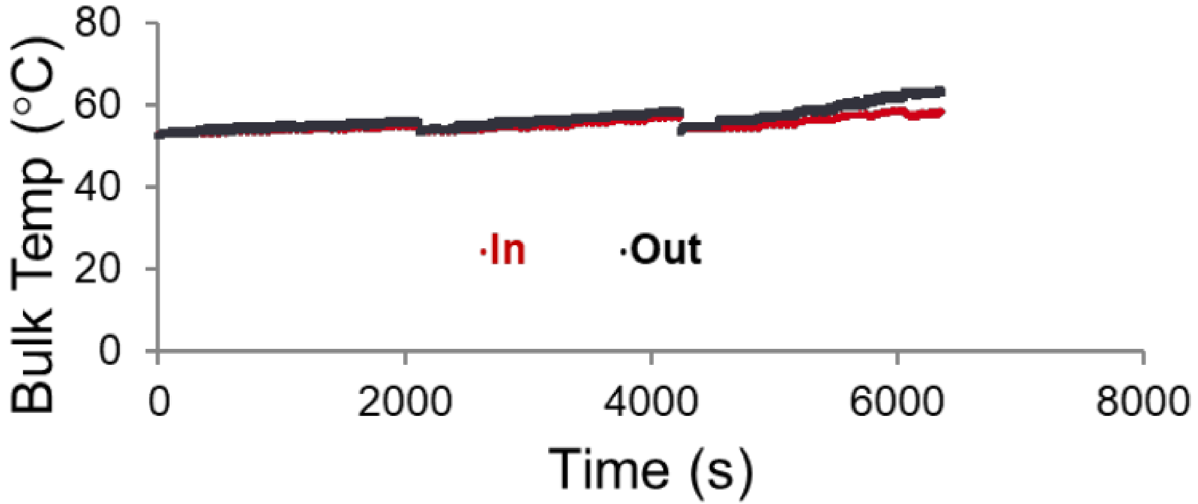



# Experiment 3.0 – 2 g/s Mass Flux Decrement, 40 W, 130 kPa

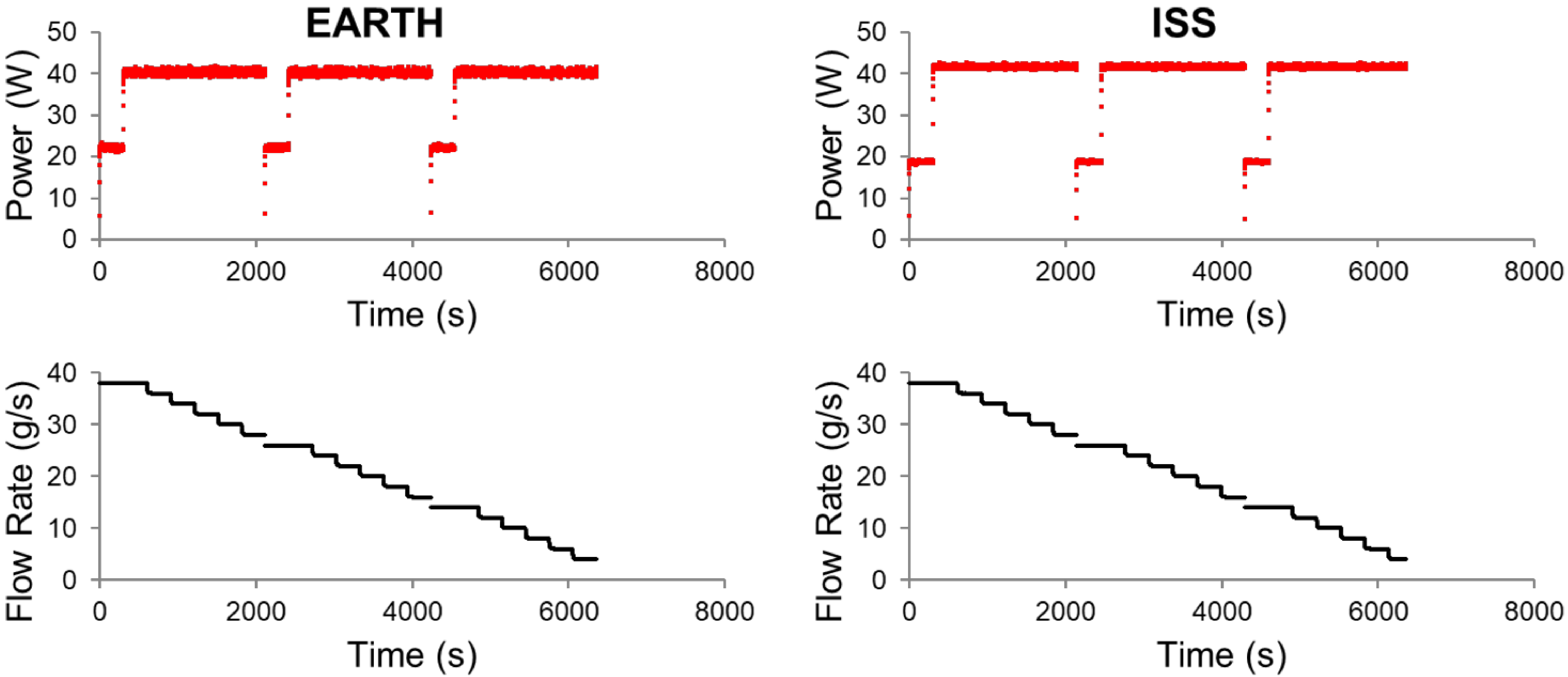


# Comparison of Earth and ISS Data



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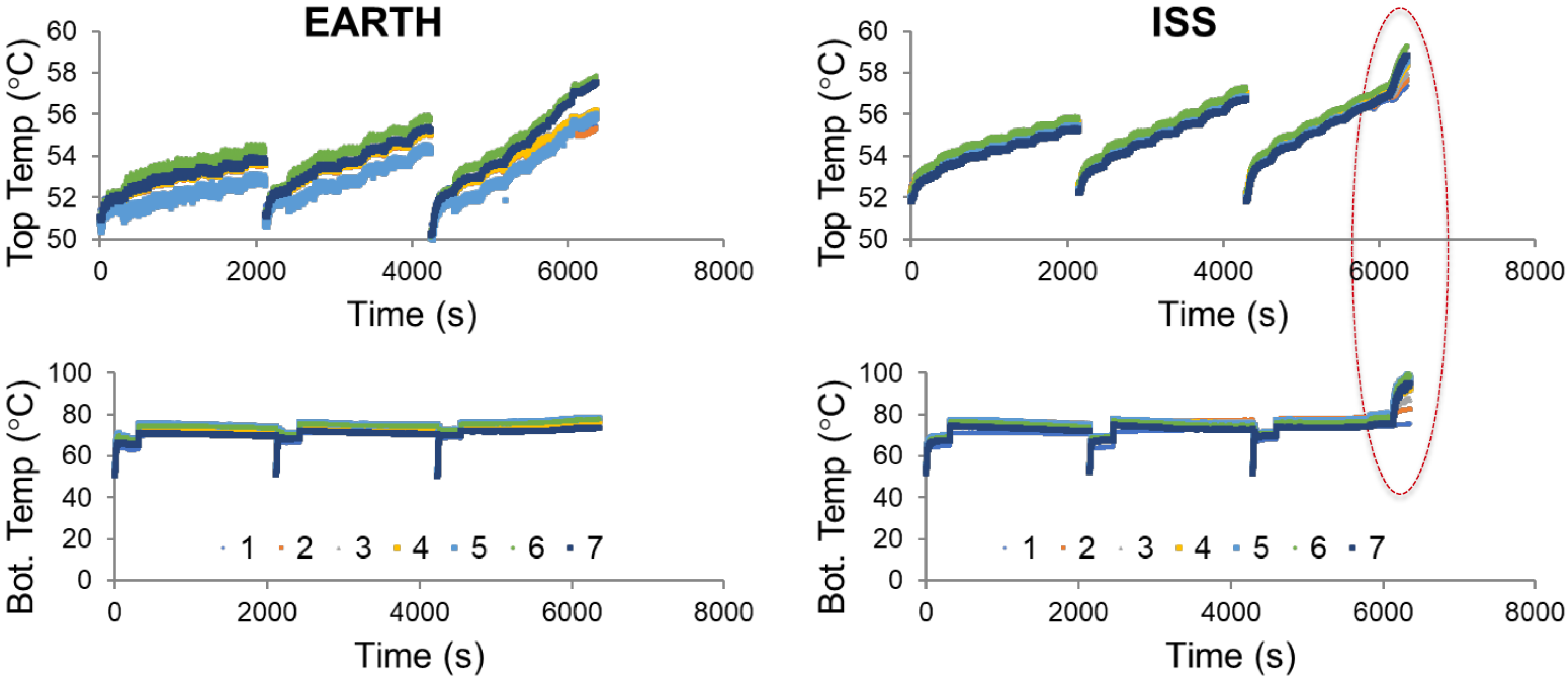

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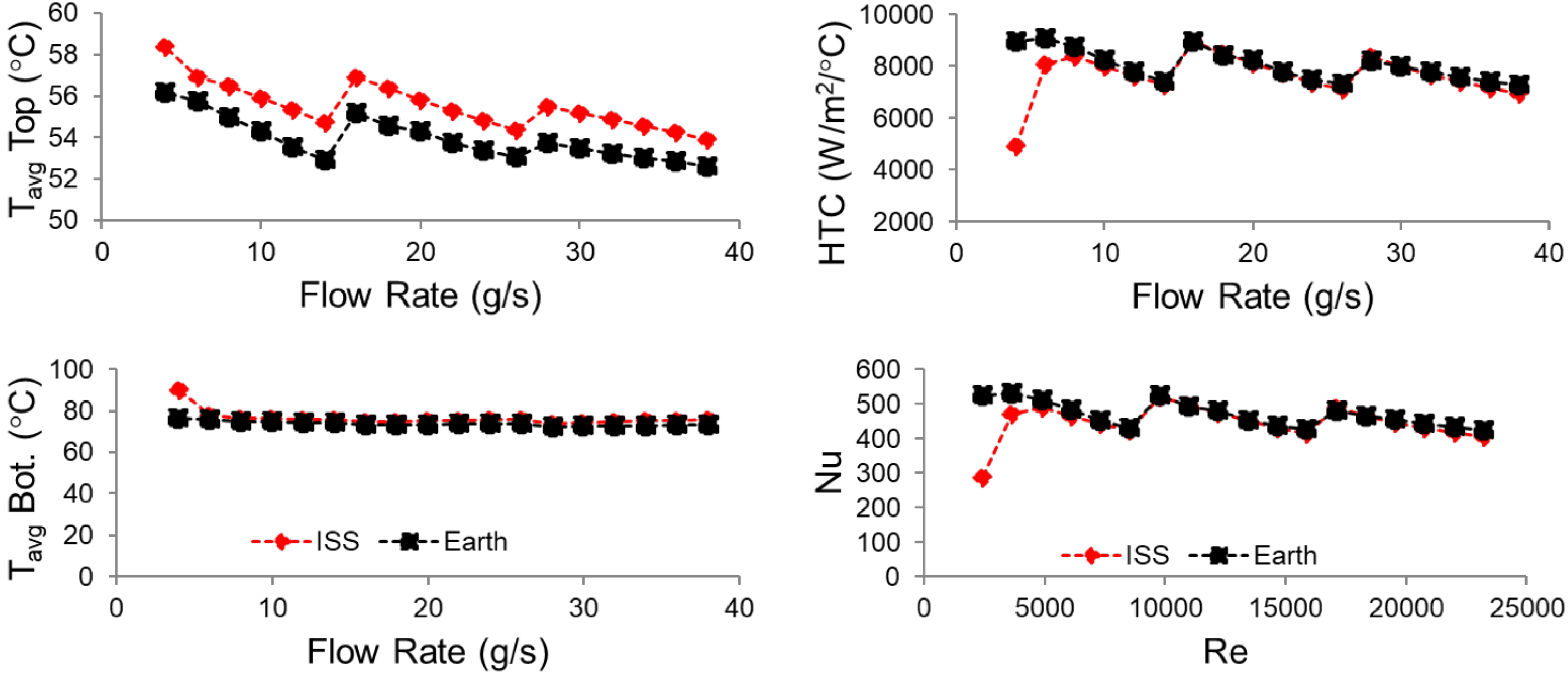
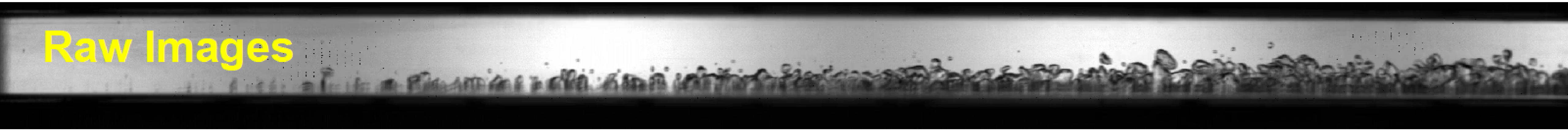


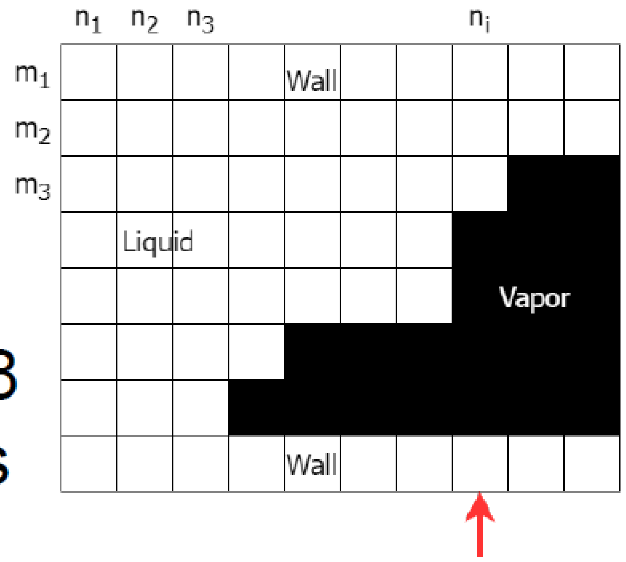
# Video Processing Algorithm – 27 g/s, 40 W, 130 kPa




## Binary Images

2,040 × 164 pixels

10 × 8 pixels




**Subtract Wall Area:**

$$n_{i,total} = 8$$
$$n_{i,wall} = 3$$
$$n_{i,channel} = 5$$

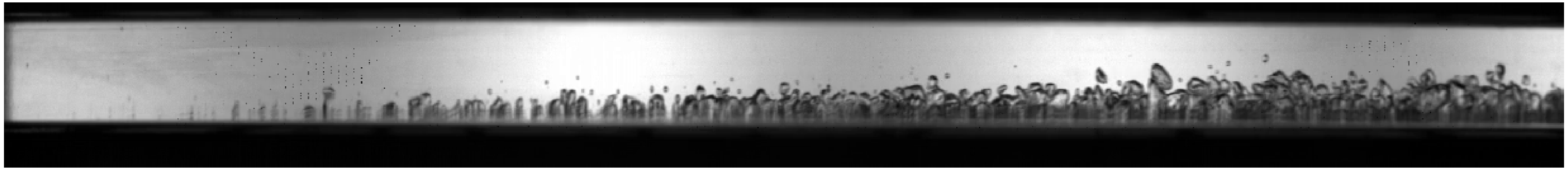
**Calculate Area Void Fraction:**

$$n_{i,black} = n_{i,vap} = 4$$

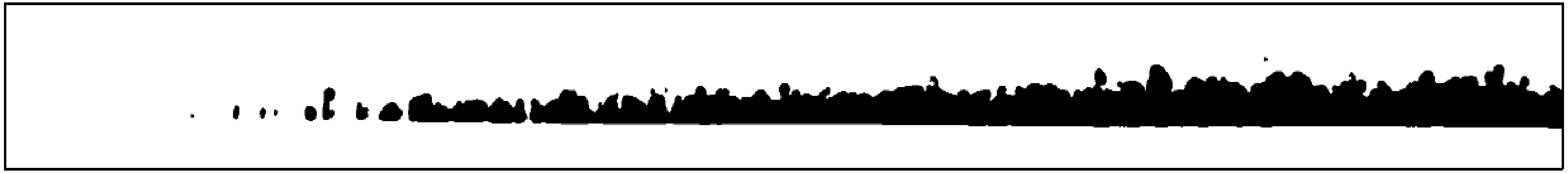
$$\alpha_i = \frac{n_{i,vap}}{n_{i,channel}} = 80\%$$

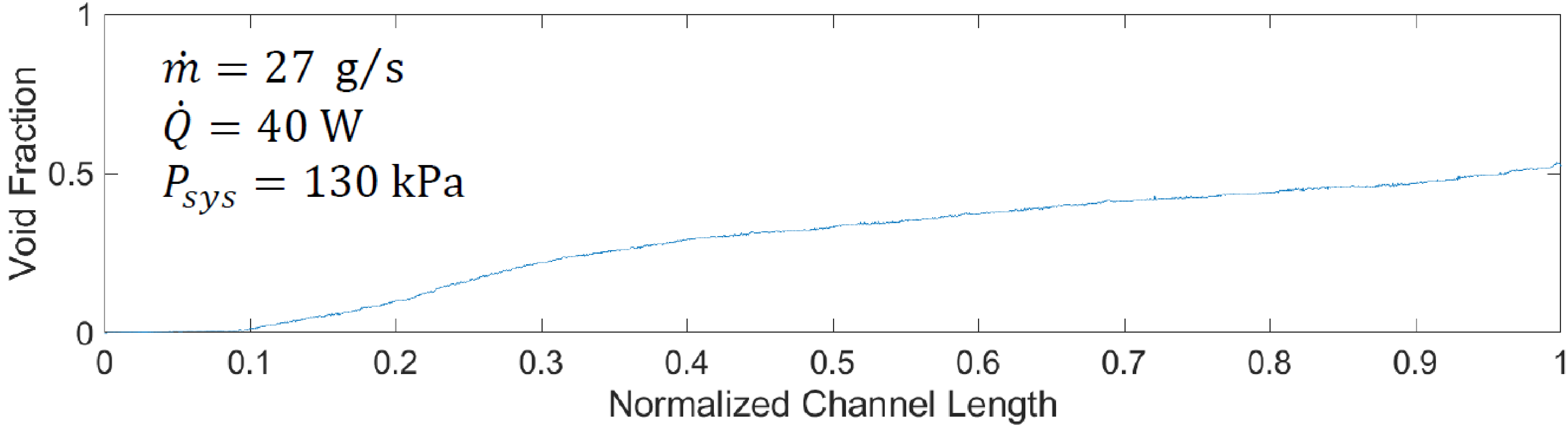
# Video Processing Data – 27 g/s, 40 W, 130 kPa

**Raw Images**

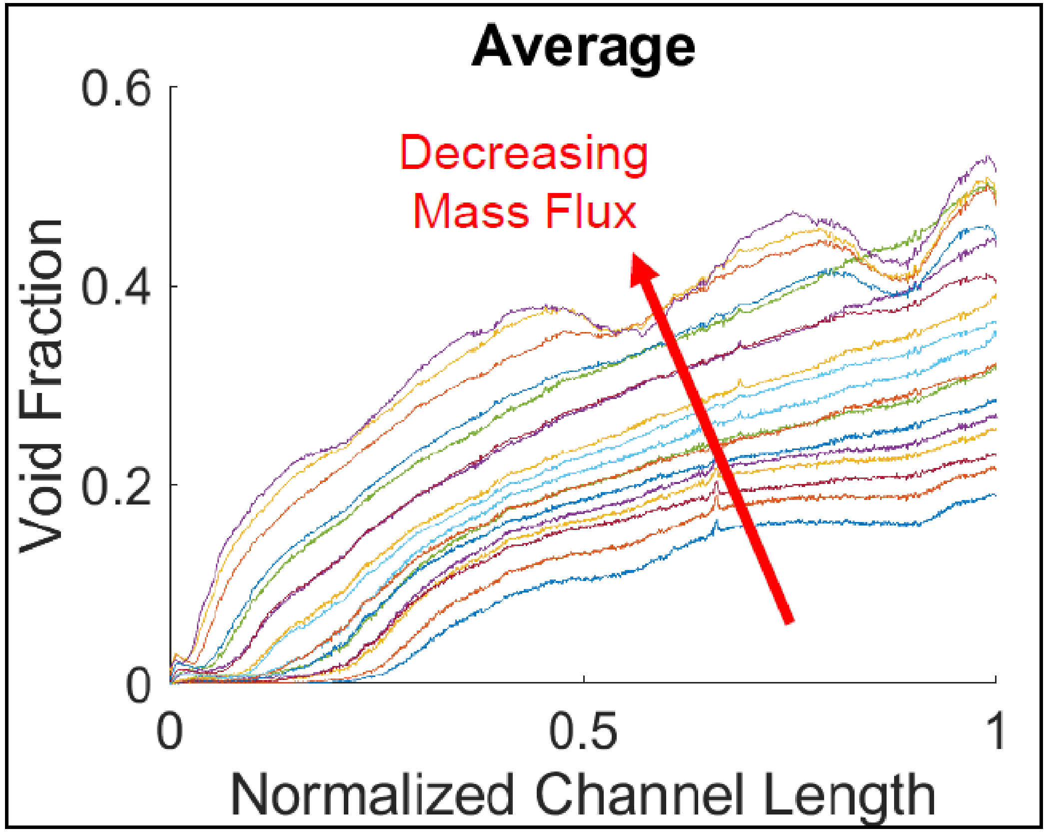


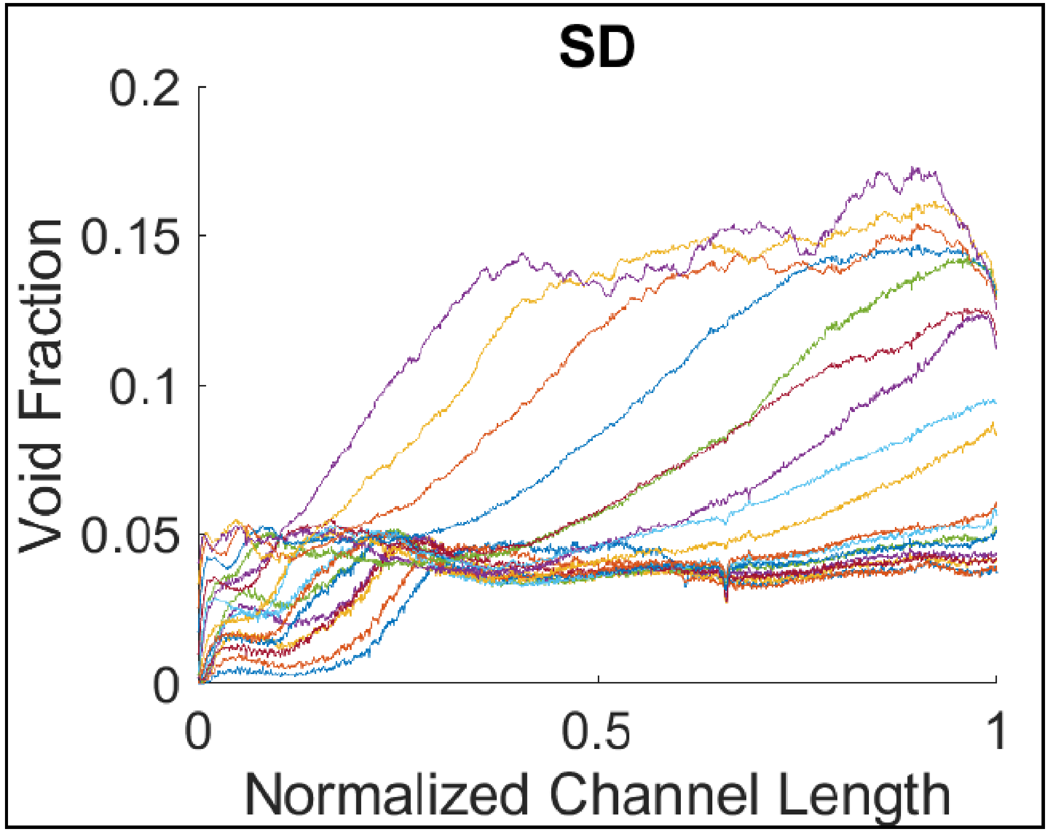
**Processed Images**





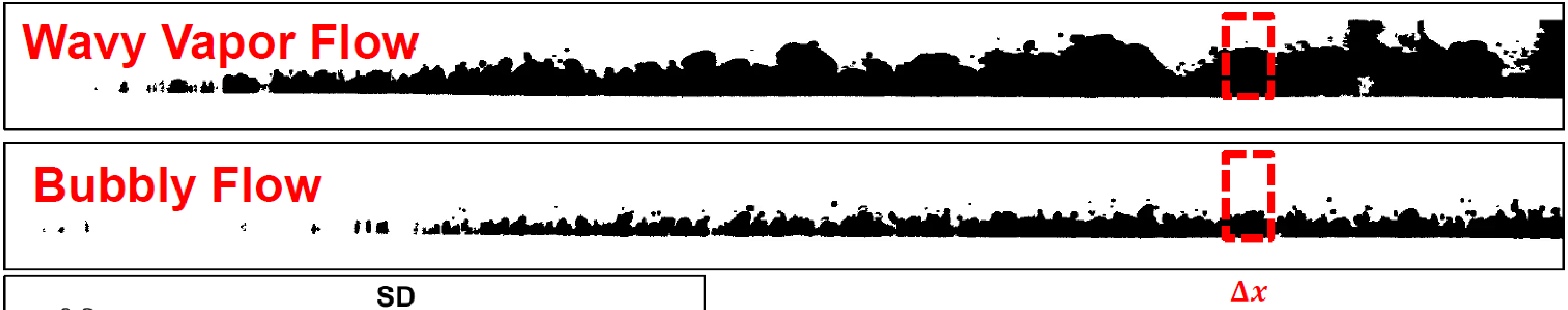
# Video Processing Data

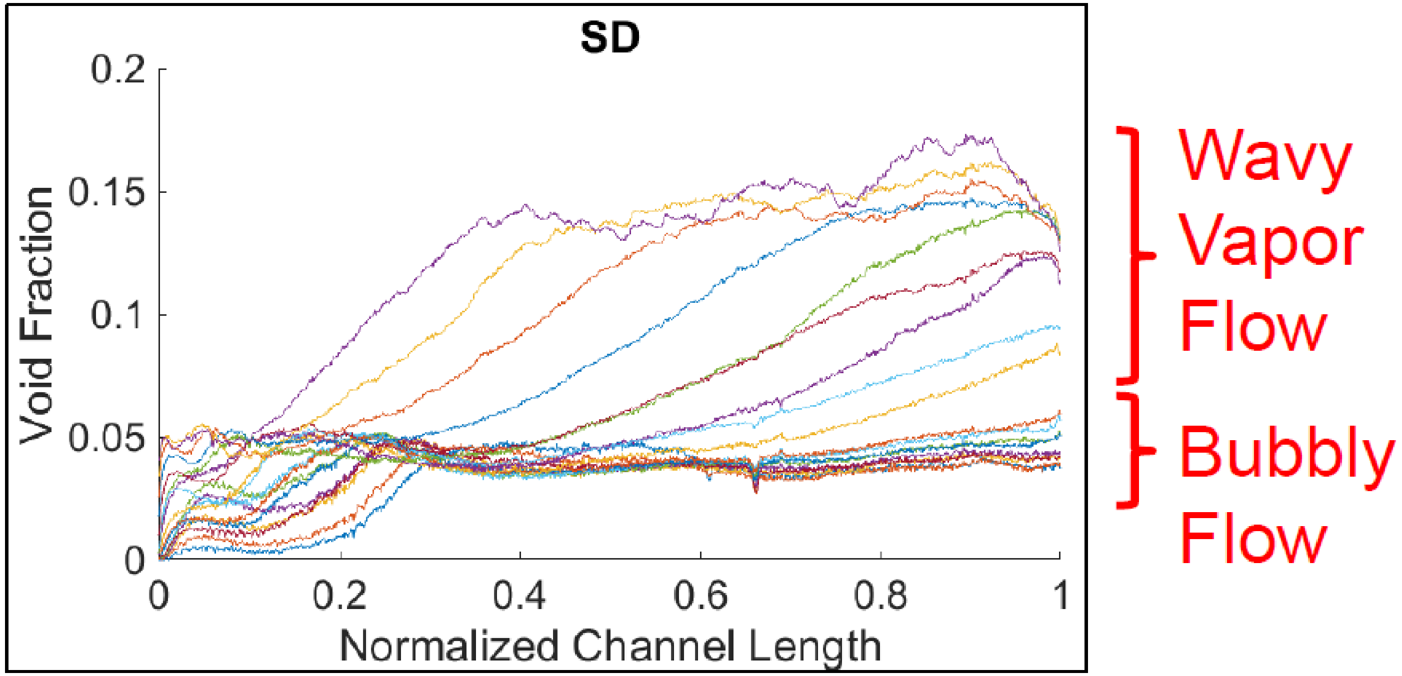



Area average void fraction and deviation along channel length for single-sided heating at 2 g/s flow decrement. Deviation is based on average void fraction.

# Experimental Results




**Variance in area average void fraction can indicate boiling transition.**

**Can temperature readings do the same?**

## Conclusions

- Subcooled flow boiling experiments have been performed on Earth and aboard the ISS using the NASA FBCE.

- Data is being compared to assess how gravity affects the system.

- Fluid inertia may play a key role in effectively utilizing subcooled flow boiling systems for deep space exploration.

- Variance in data may indicate boiling transitions and impending Critical Heat Flux (CHF).

# Acknowledgments

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