University of Sheffield

Quantifying Cross-sectional concentrations in Accelerating Flows

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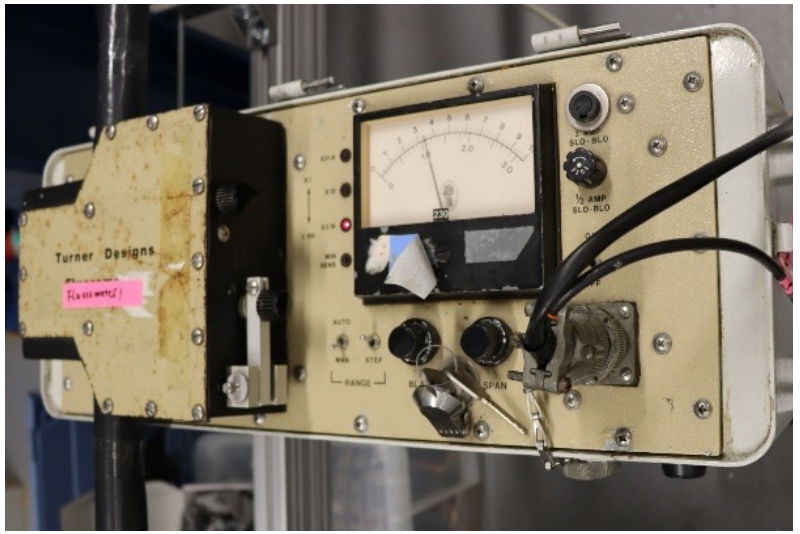
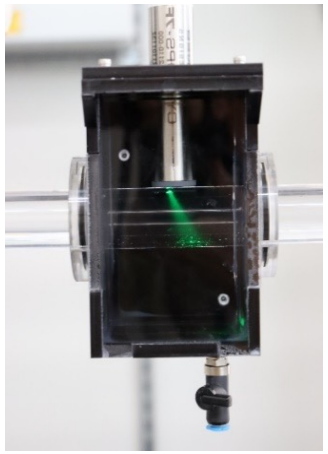
Introduction and Background

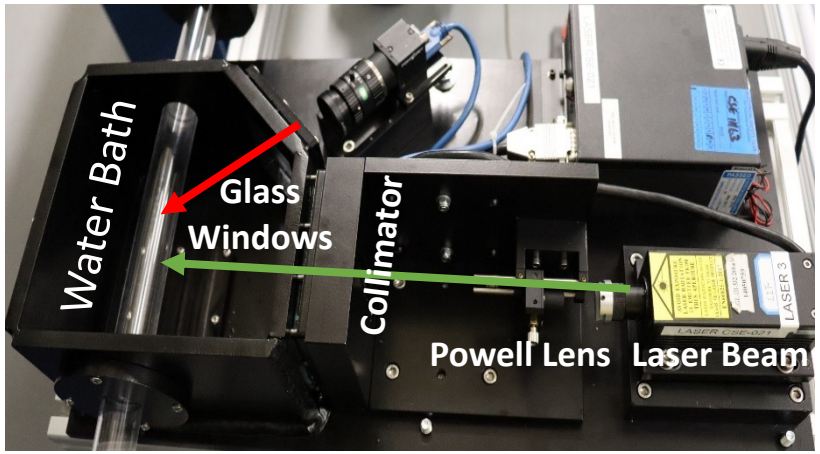
- Steady-state pipe flow
  - Tracer clouds: Gaussian distribution.
  - Longitudinal dispersion obtained from increase in temporal variance of tracer distribution.
- Unsteady pipe flow
  - Acceleration from laminar to turbulent flow, an upstream single peak disaggregated to multiple downstream peaks.
  - Currently not described by models.
- Instruments previously employed:
  - 1980s Turner Design Series 10 fluorometers
  - Low temporal resolution & very sensitive to surrounding light.
  - No information on cross-sectional spatial distribution.
  - New instruments are needed…

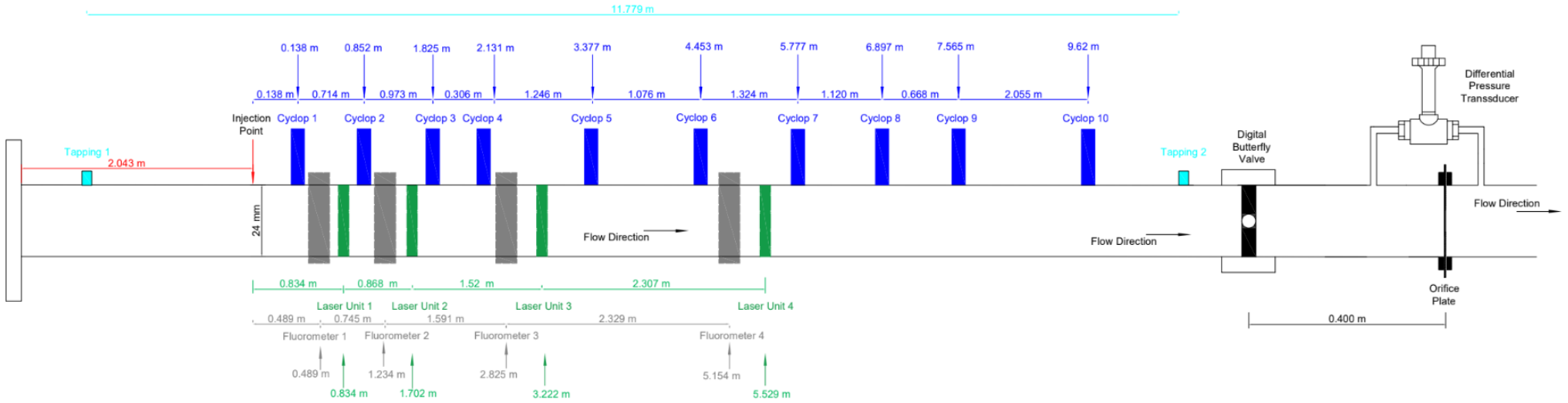


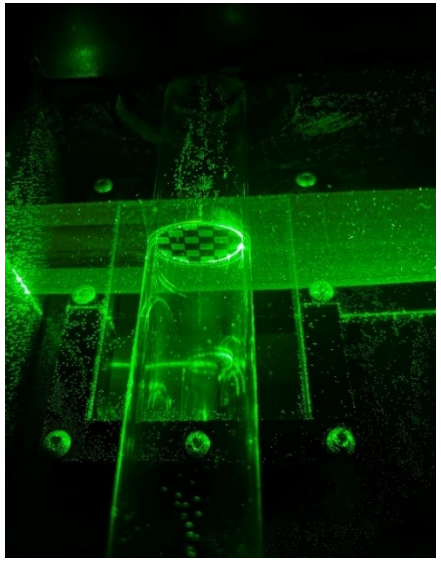
New Measurement Instruments

- Fluorometery:
  - 1980 Turner Design Series 10 Fluorometers (4x)
  - 2000 Turner Design Cyclops (10x)
  - Laser Sheet Generator and Camera – LIF systems (4x)
- A 24 mm diameter and 13 m long pipe:
  - Orifice and Differential Pressure Transducer
  - Computer Control Valve
- Tests programme:
  - Steady @ Re = 700 to 11,000
  - Unsteady (accelerating) flows Re = 1000 to 11,000 various injection times







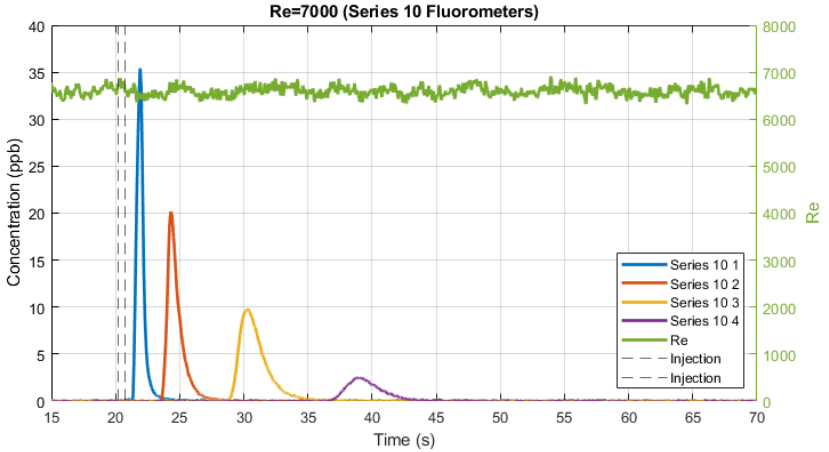


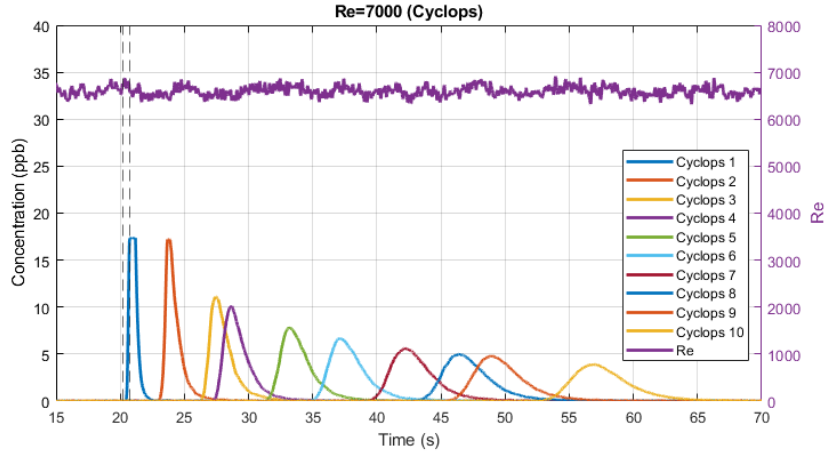
Results: Steady-State

- Temporal concentration profiles and Re.
- In turbulent flow conditions (Re = 7000) both Cyclops and Series 10 fluorometers provide reasonable measurements.

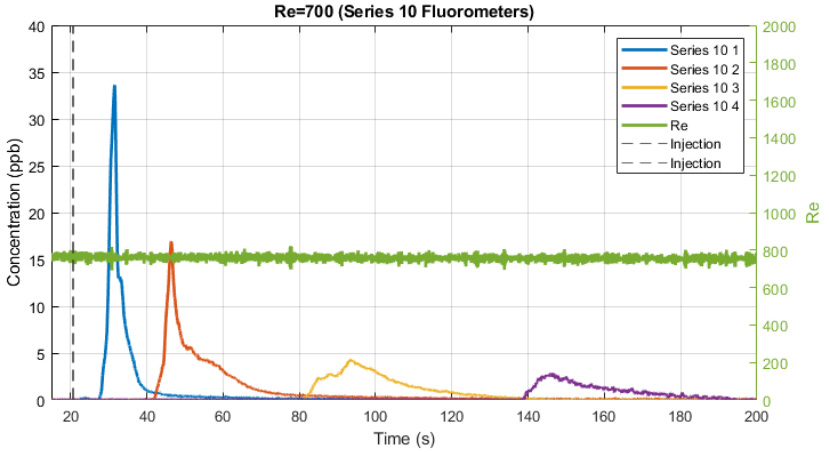
- In laminar flow conditions (Re = 700) the Cyclops didn't provide meaningful cross-sectional mean concentrations.

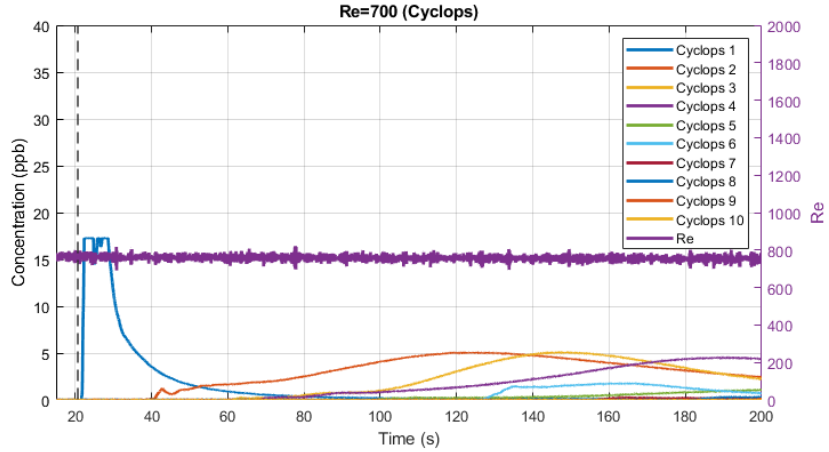
Re=7000





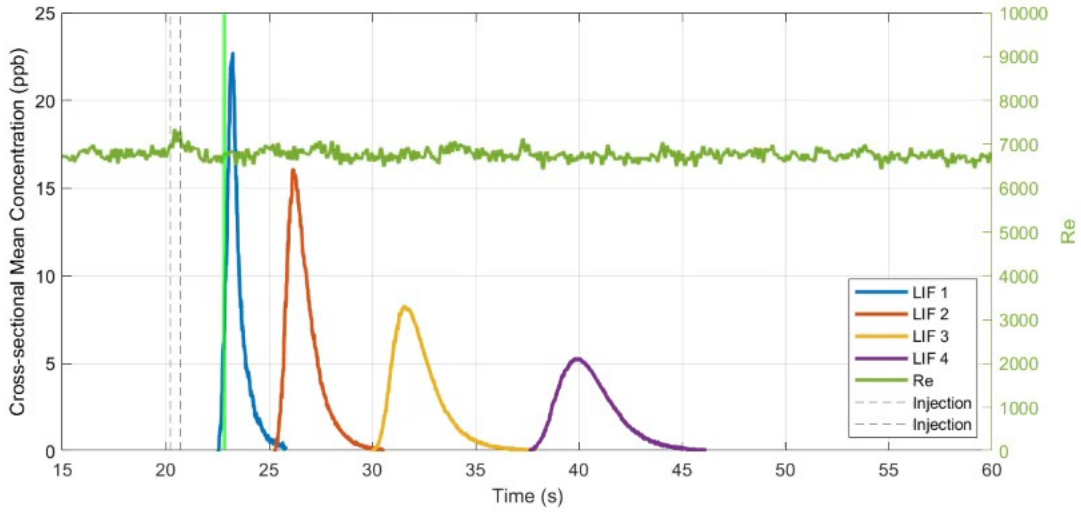
Re=700

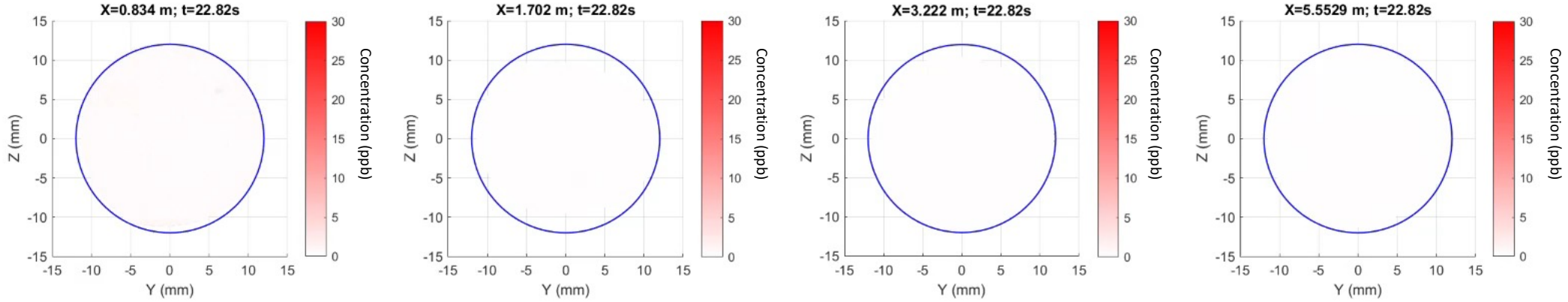




Results: Steady-State @ Re=7000

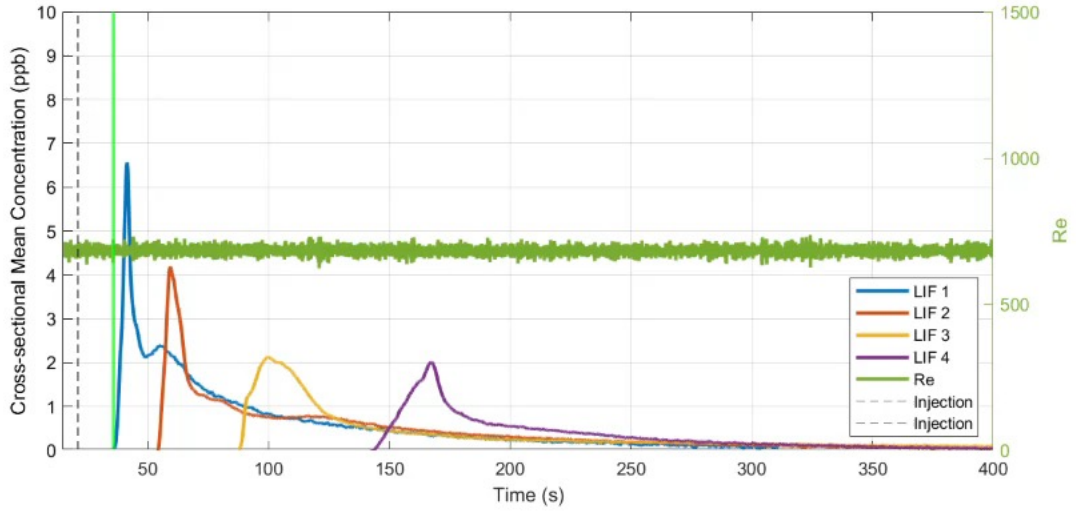
- Top: Temporal profile of pipe cross-sectional averaged concentration.
- Bottom: Pipe cross-section, the shade of red reflects the tracer concentration.
- Tracer was cross-sectionally well-mixed at all locations.
- A single cloud of tracer passes all locations quickly.
- Camera 2 images were not properly de-wrapped.

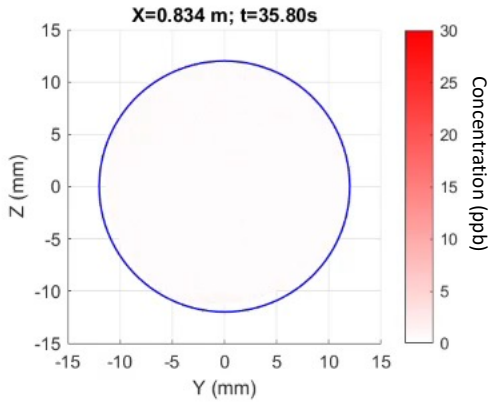


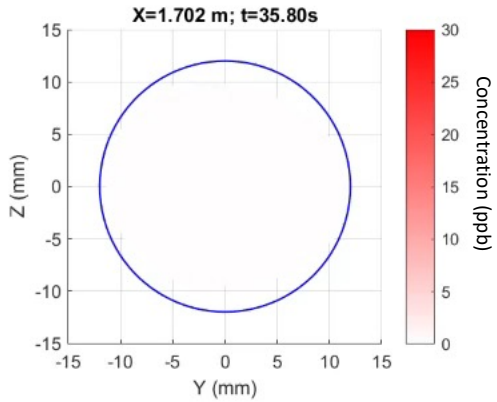


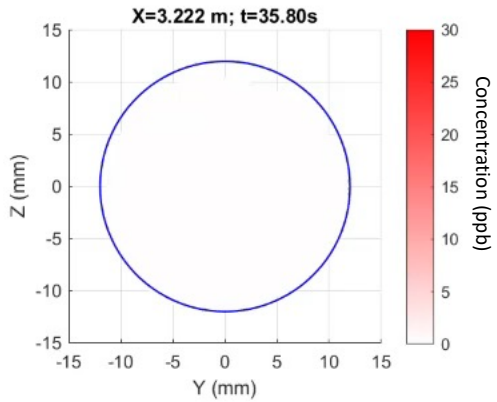
Results: Steady-State @ Re=700

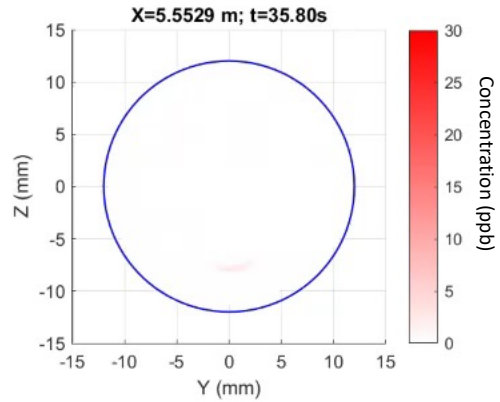
- Tracer at the pipe centre arrives first, and the tracer at the pipe boundary arrived later.
- A single peak at all locations.





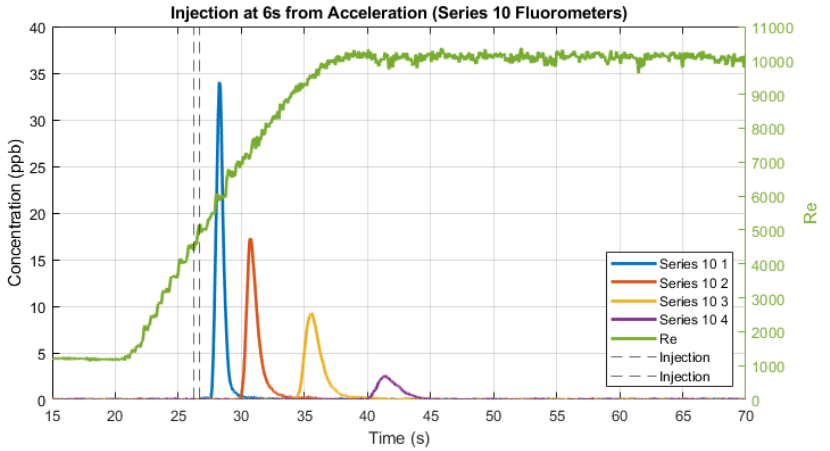


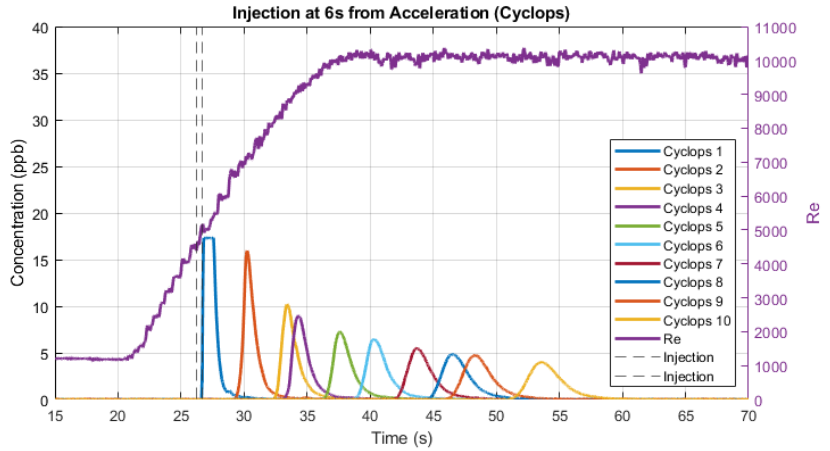


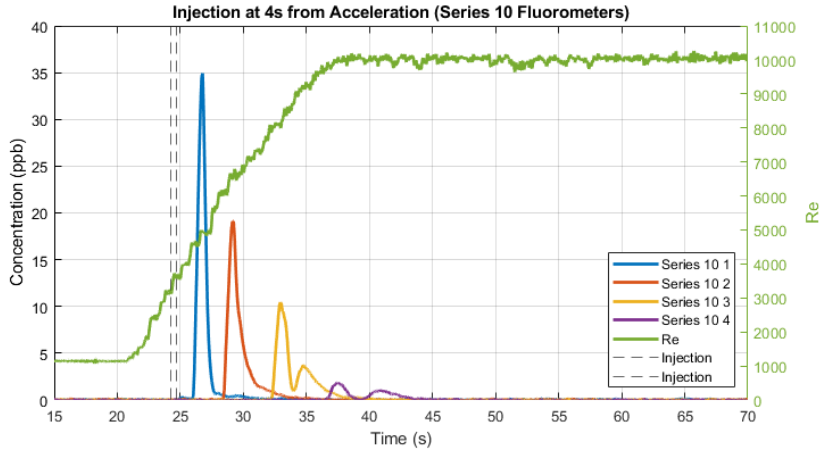


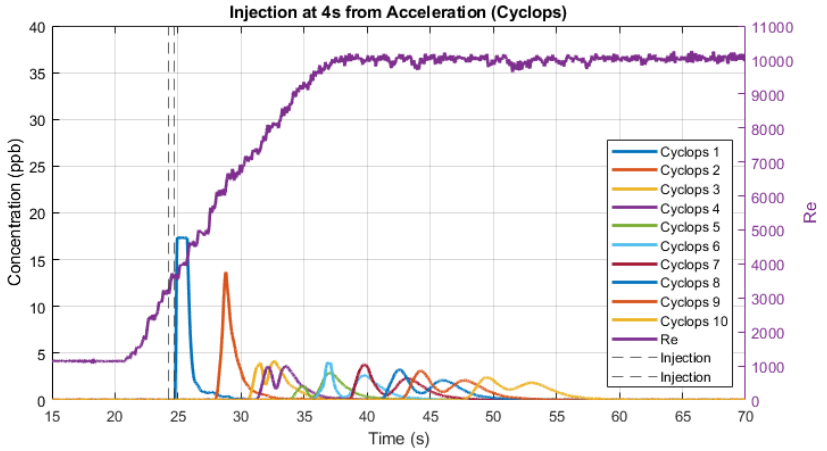
Results: Unsteady-State (Acceleration)

- Acceleration started at 20 s, acceleration from Re=1000 to 10,000 over 18 s, 0.5 s injection.
- Injection at 6s:
  - Injection @ Re=5000.
  - Single peak at all the measurement locations.
- Injection at 4s:
  - Injection @ Re=3500.
  - Single peak at the first measurement location.
  - Clear disaggregation at all the other downstream locations with first peak > second.
- Both Series 10 and Cyclops fluorometers gave good measurements.



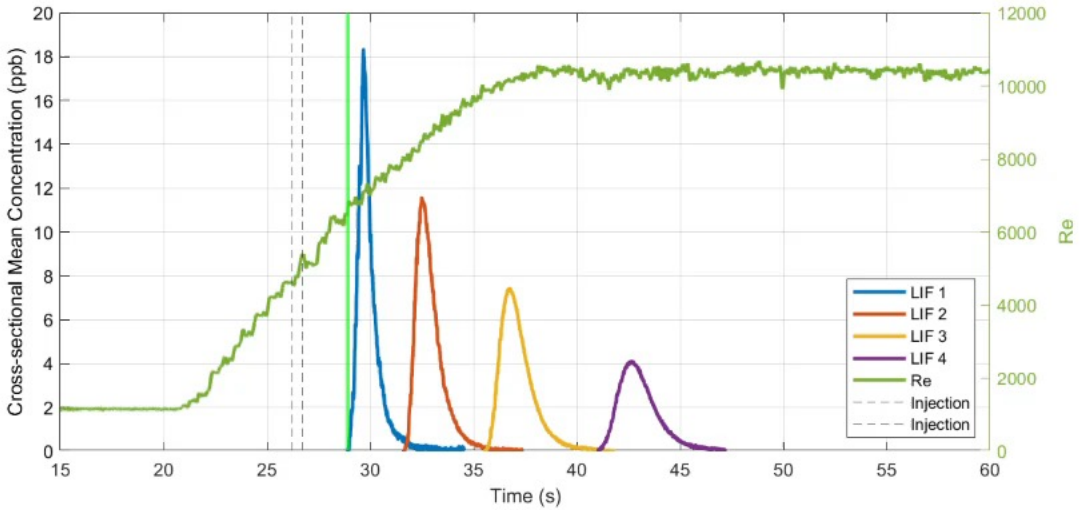


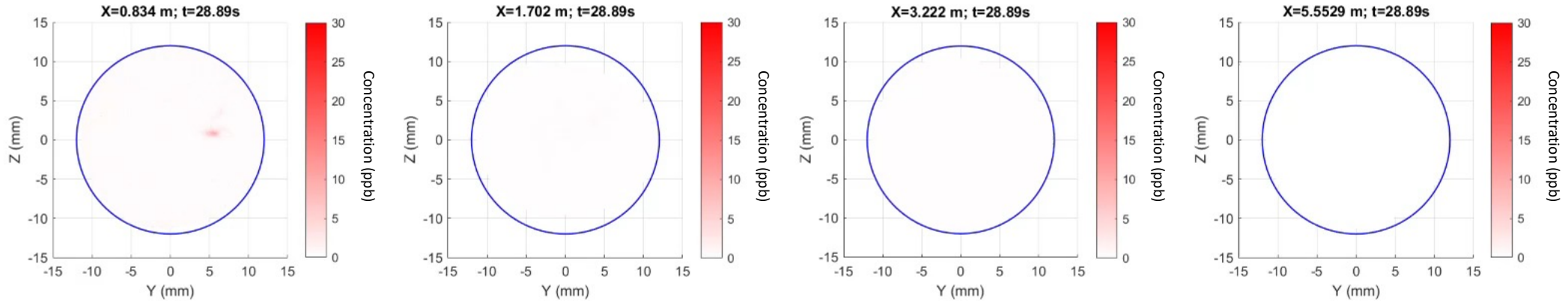




Results: Unsteady-State @ injection at 6s

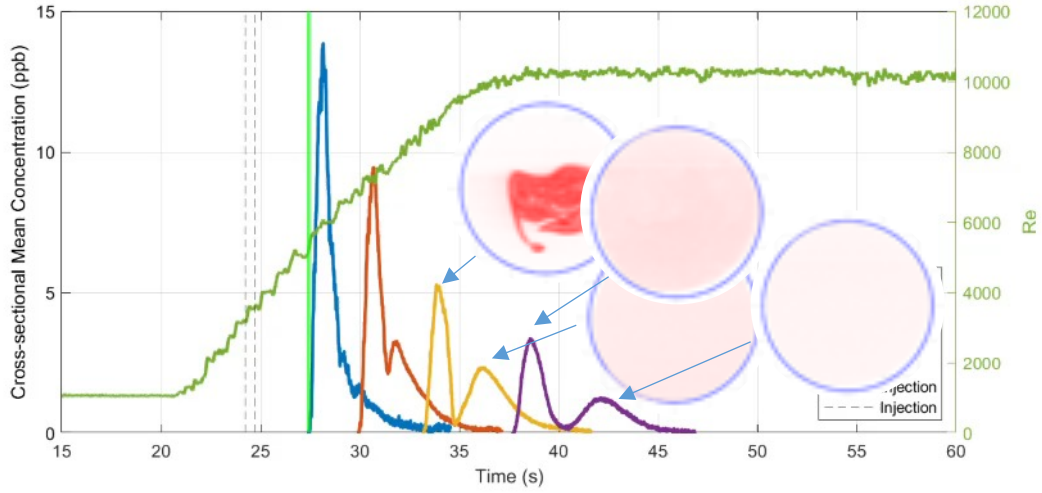
- Injection was made at Re=5000.
- Single peak at all the measurement locations with tracer cross-sectional well mixed.

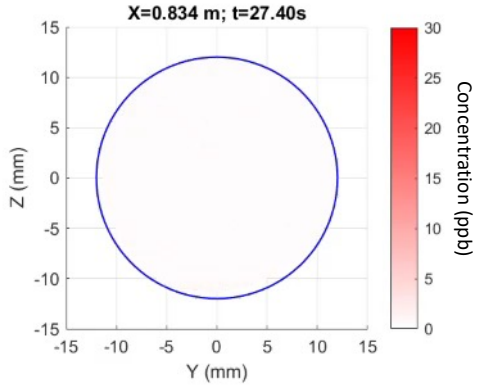


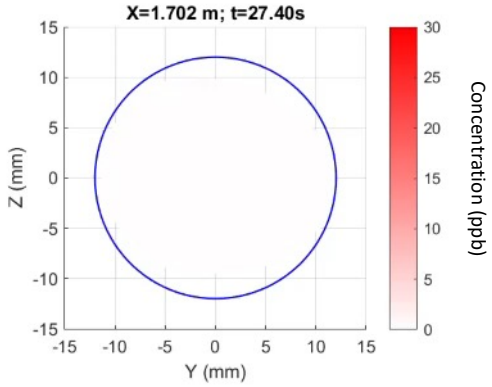


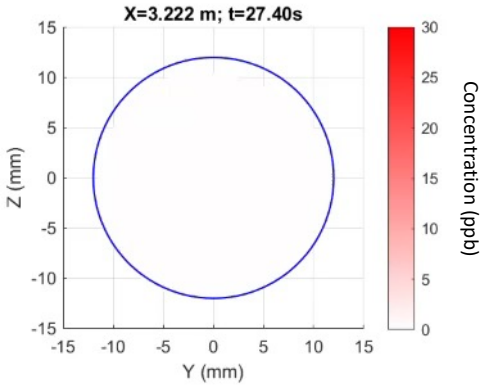
Results: Unsteady-State @ injection at 4s

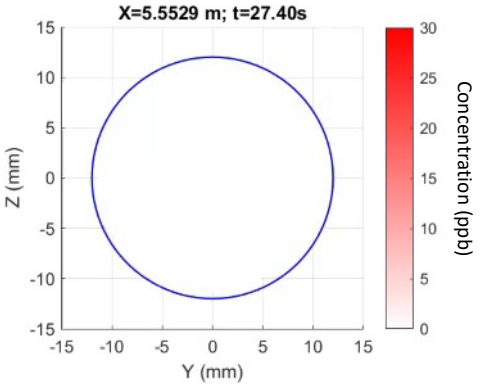
- Two peaks at all the downstream locations.
- First peak occurs at the pipe centre.
- Second peak was well mixed over the whole pipe cross-section.
- Downstream location (camera 4) two well-mixed peaks.
- First peak > second peak.











Conclusions and Future Work

- **Conclusions to-date:**
  - Series 10 Fluorometers: low temporal resolution, good cross-sectional mean concentration.
  - All the instruments provide good measurements in turbulent flows.
  - The innovative LIF system provides detailed information on the pipe cross-sectional concentration distribution.
- **Future work:**
  - Interpret creation of two peak distributions, using UVP velocity & head losses measurements.