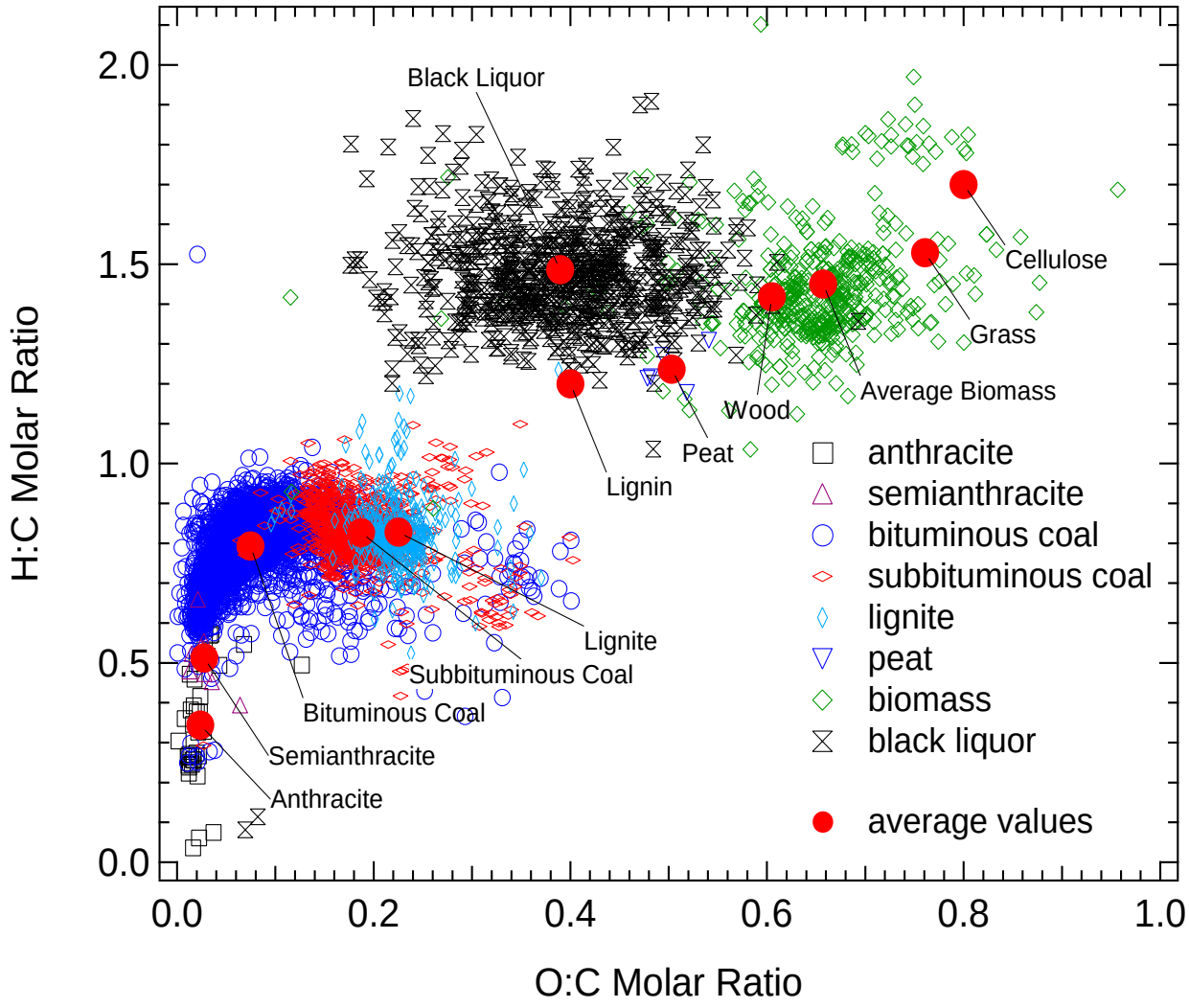
Biomass Particle Reactions: Experimental and Model Results

Larry Baxter
Brigham Young University
Provo, UT 84602

IEA Bioenergy Multi-task Conference
Vancouver, British Columbia, Canada
August 25, 2009

Fuel Diagram

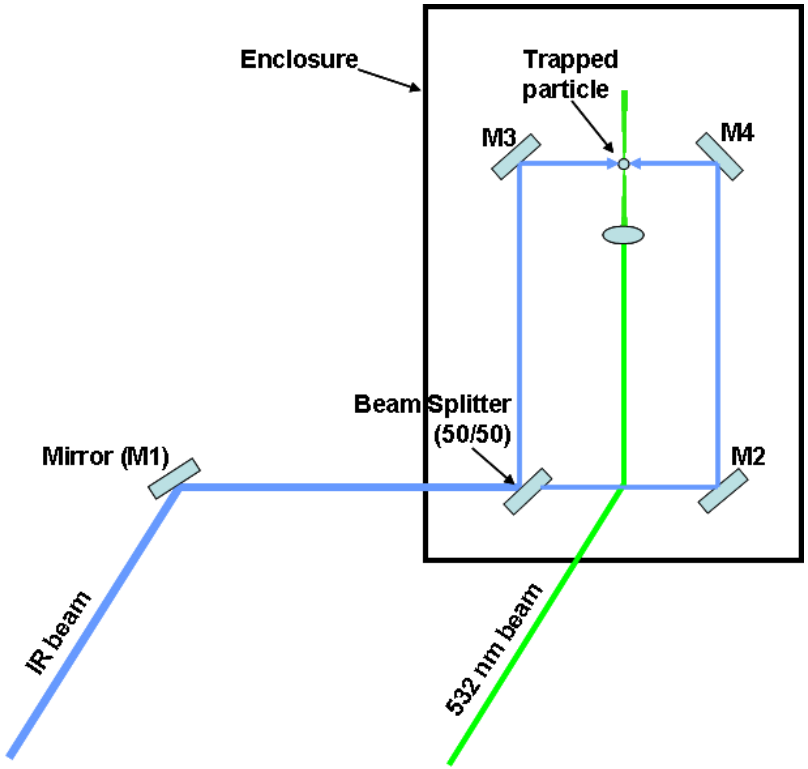


Laser Levitation

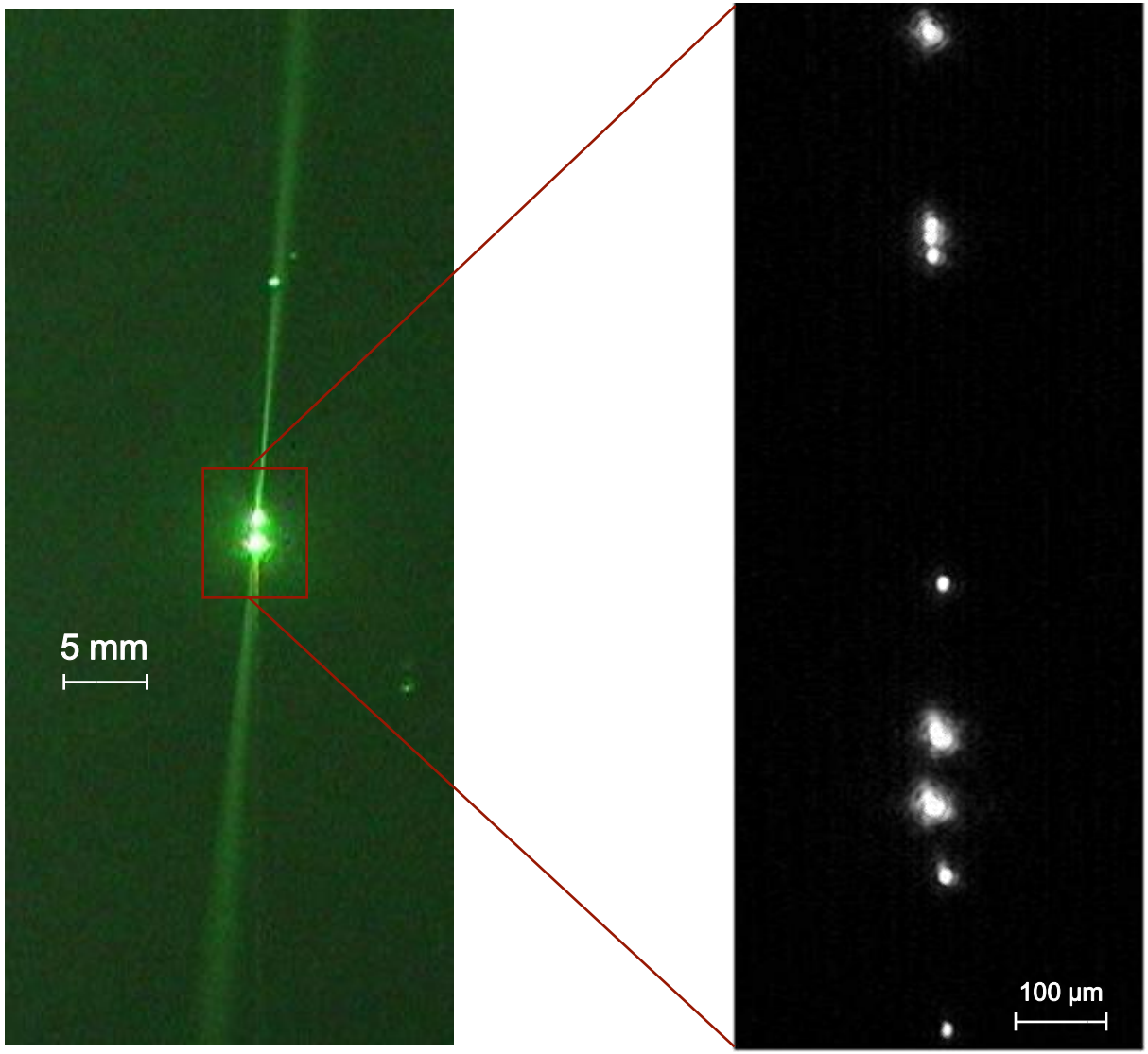
Objectives:

- To enable characterization of drying and devolatilization rates of black liquor droplets under the range of conditions encountered in commercial recovery boilers.
- To observe and model changes in diameter, temperature, mass, and composition of particles as a part of combustion characterization.
- Describe mechanism of optical trapping of absorbing particles.

Arrangement of optics with CO2 beam used to heat suspended particles

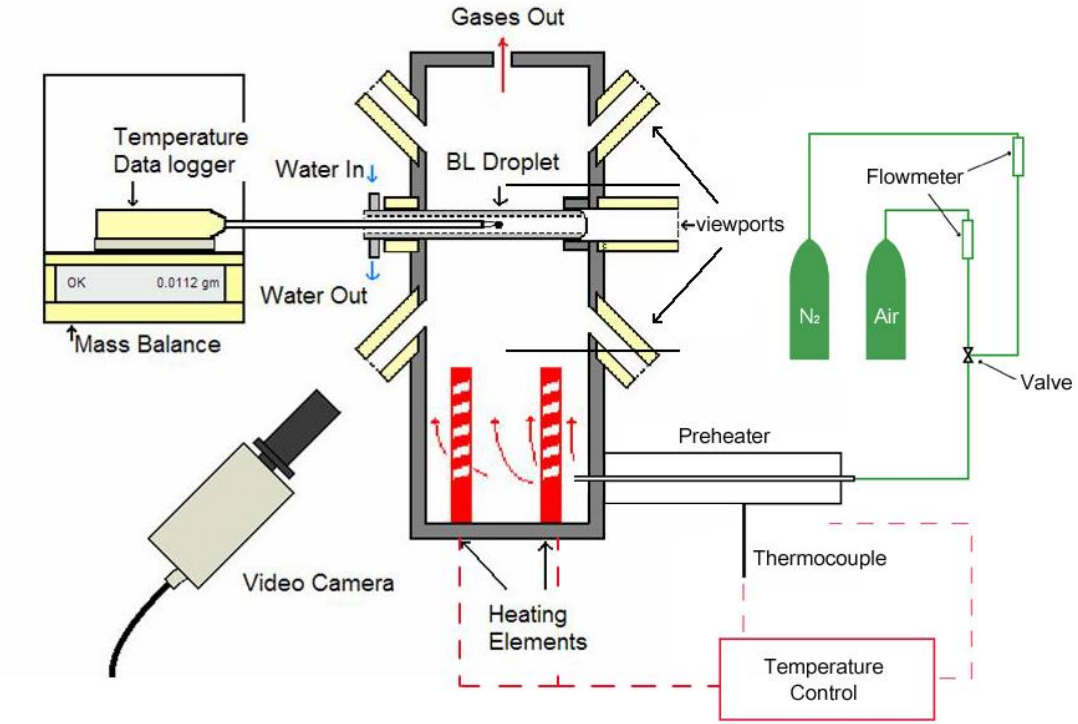


Laser Levitation



- Particles trapped at 2 watts laser power
- All particles shown are optically trapped

Single Particle Reactor



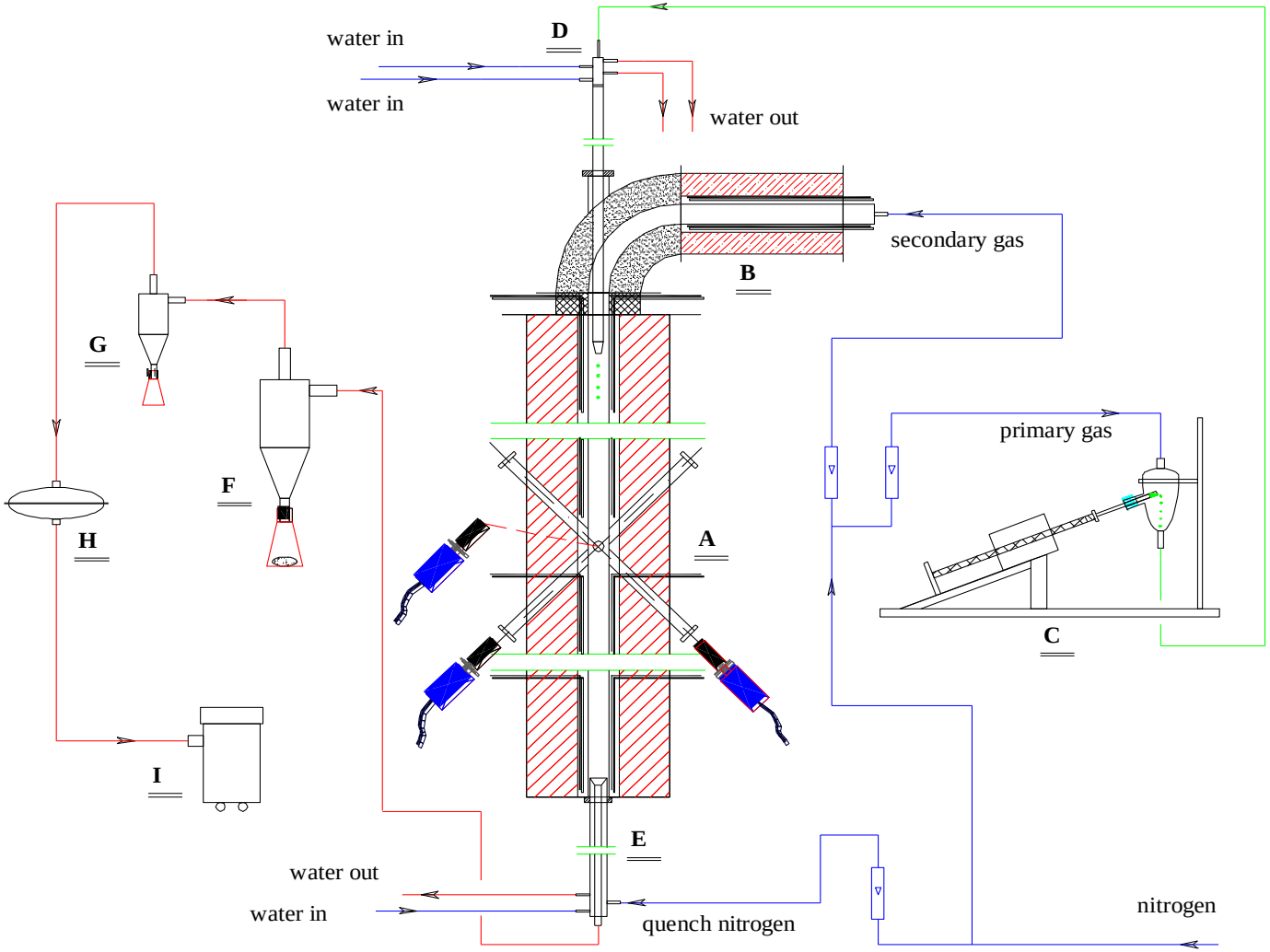
* The three viewports are in three orthogonal direction

Objectives:

Simultaneous Data Collection: (1) Internal Temperature, (2) Mass Loss and (3) Video (size, shape, surface temp), for biomass and/or black liquor single particle combustion.

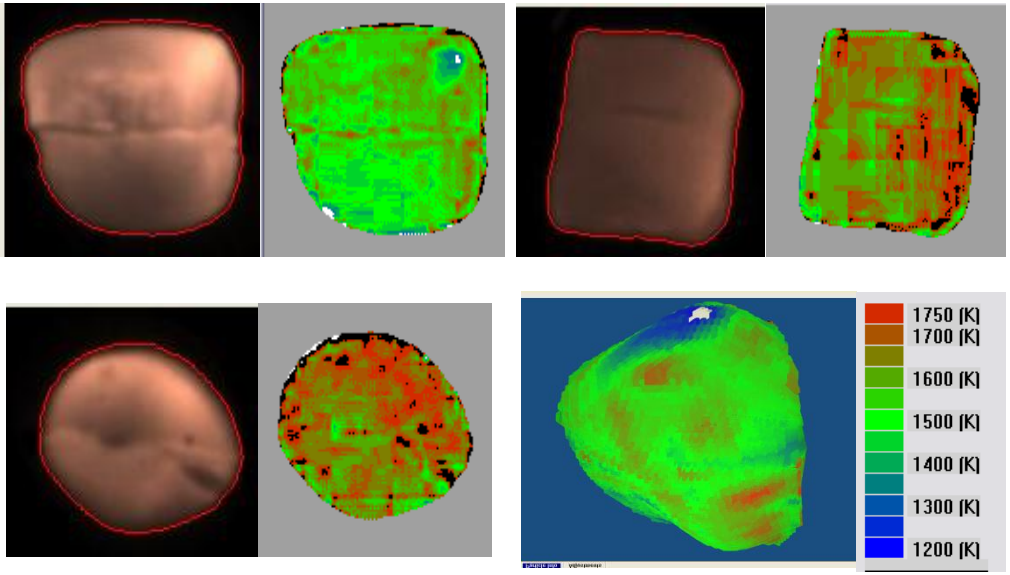
This reactor is equipped with three orthogonal view ports for 3-D reconstruction.

Aspherical Particle Reactor



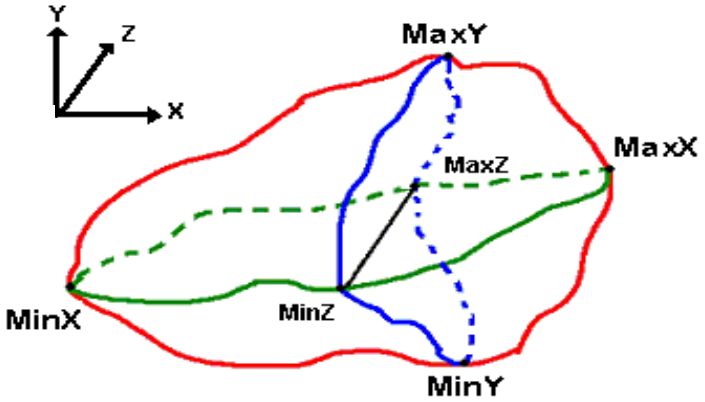
A - entrain flow reactor **B - preheater** **C - syringe feeder** **D - feeding probe** **E - collection probe**
F - 1st cyclone separator **G - 2nd cyclone separator** **H - filter** **I - vacuum**

Particle Combustion – Size & Shape Effects



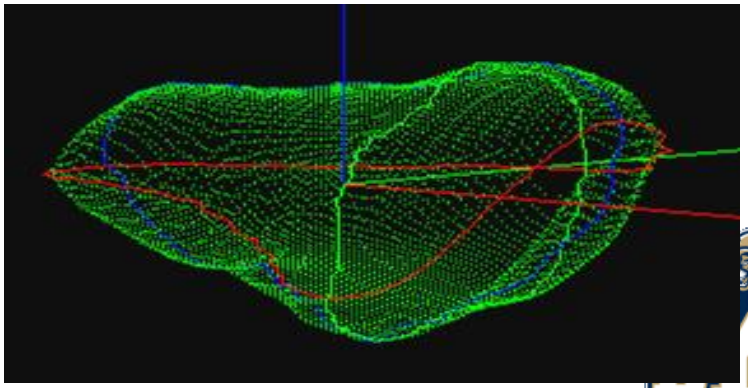
Pixel-by-pixel Temperature Measurement

- Substantial surface temperature differences on biomass particles
- Data indicate leading and trailing edge temperatures and hence reaction rates differ
- Differences decrease with decreasing size

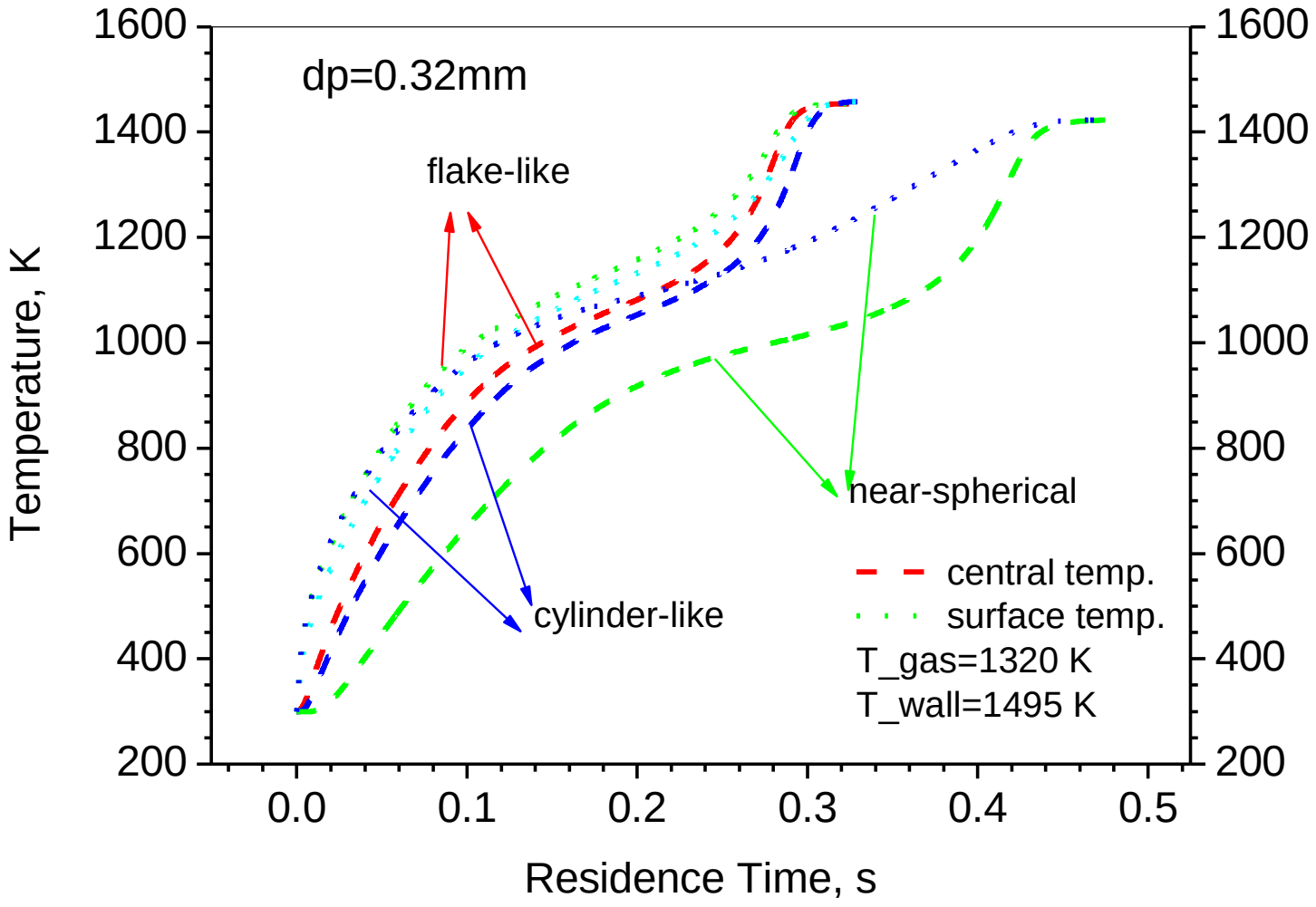


Temporal and Spatial Temperature Resolution

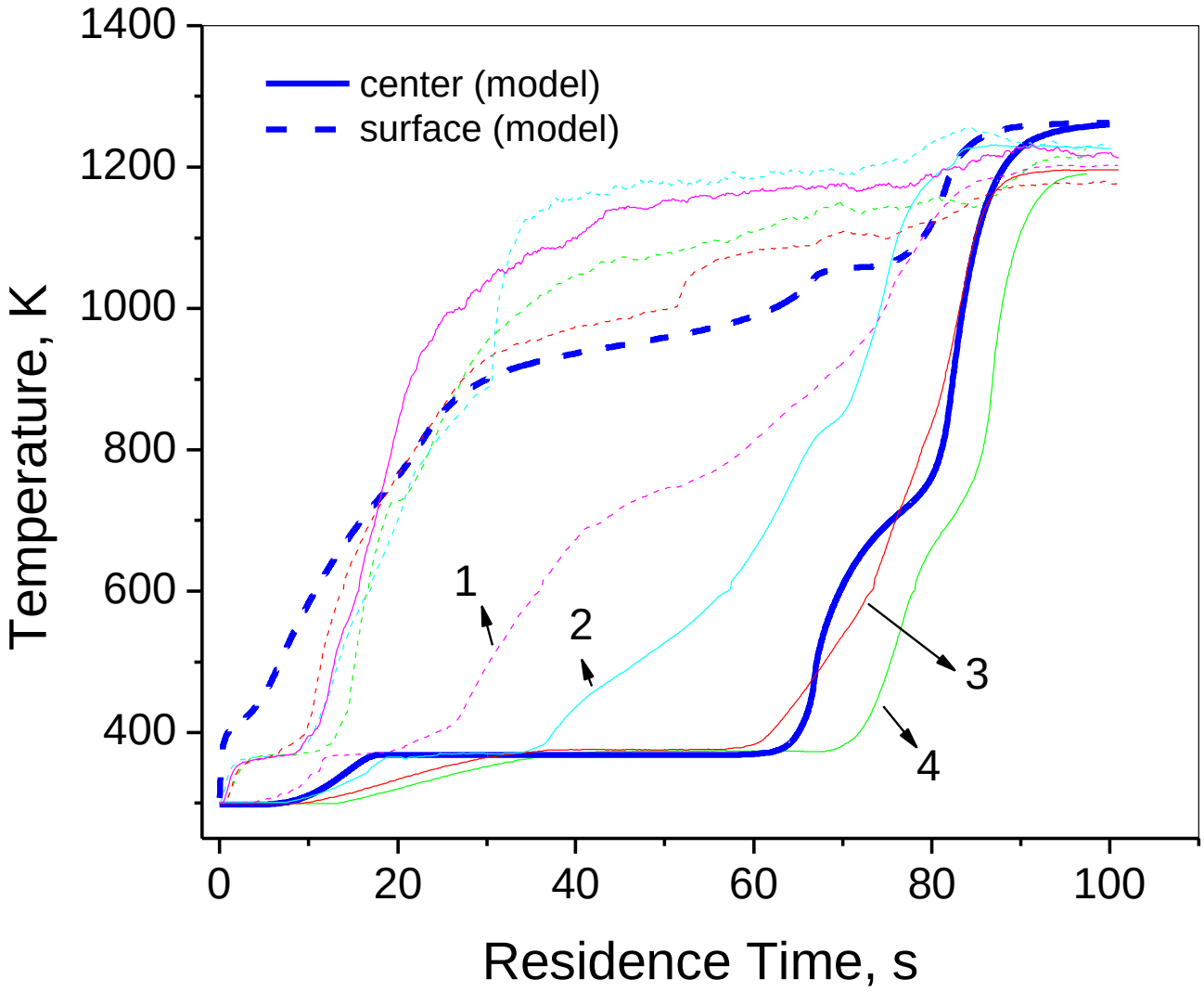
- Large radial temperature gradients measured and predicted in biomass particles
- Substantial surface temperature differences on biomass particles
- Models predict details of radial but not surface temperature differences.



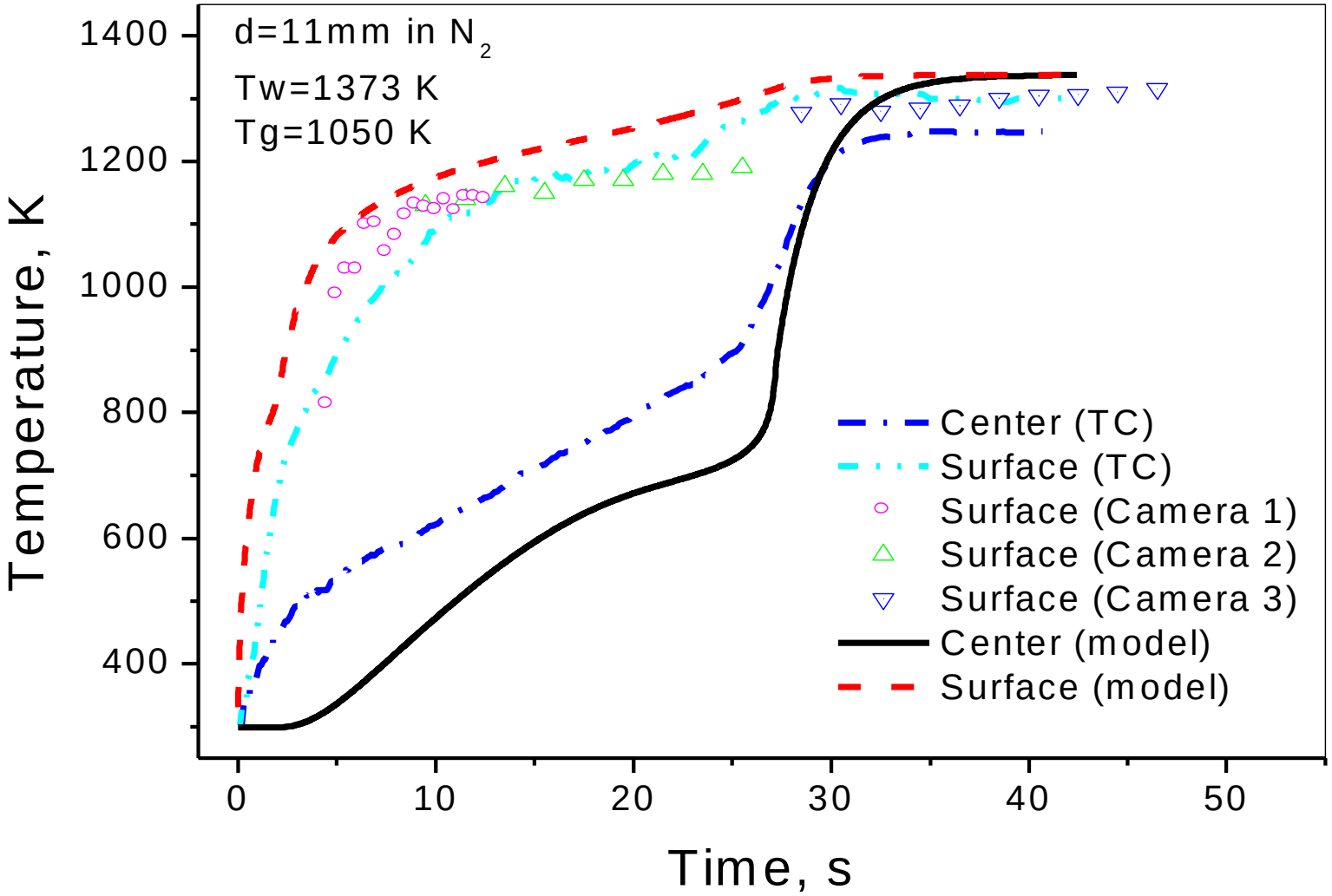
Temperature Transients



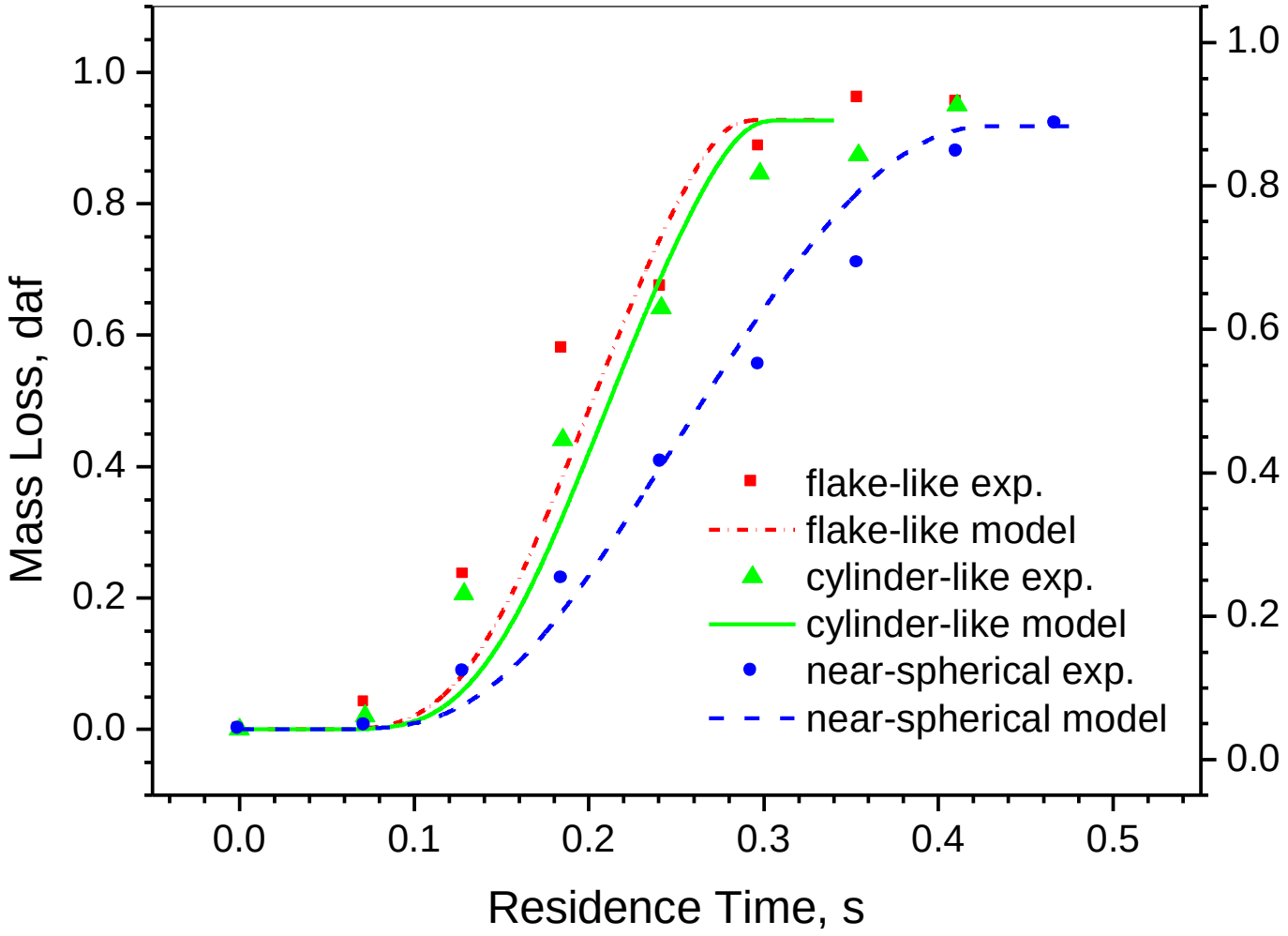
Temperature Data and Model



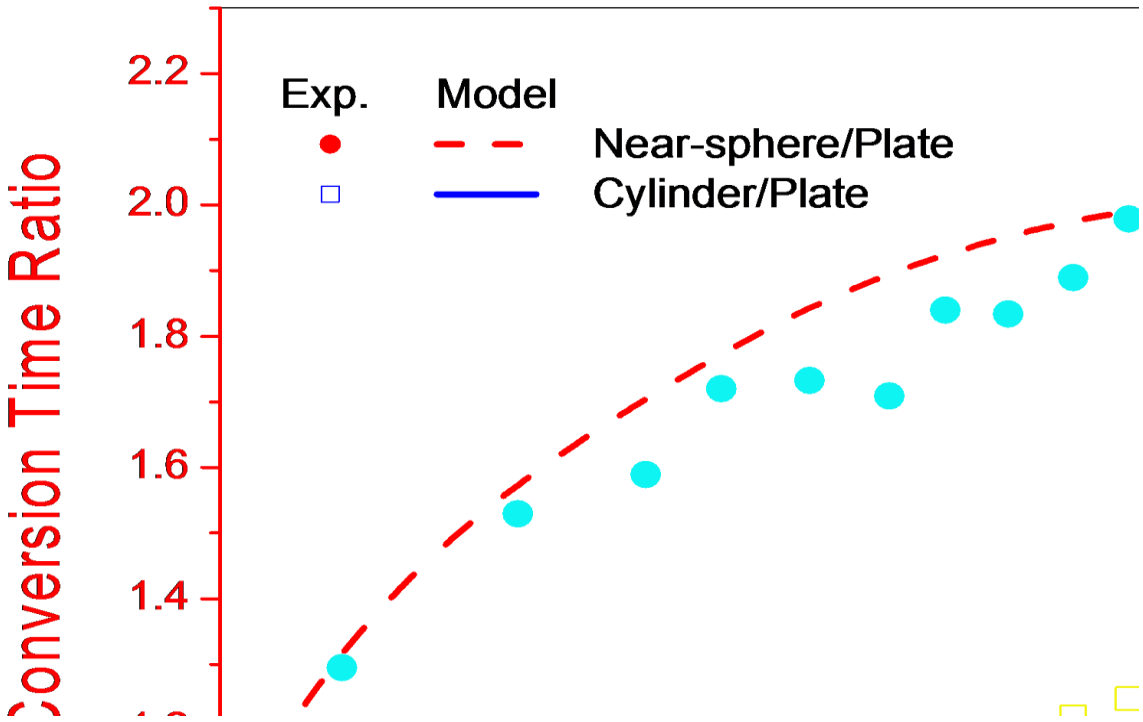
Data and Model: Temperature



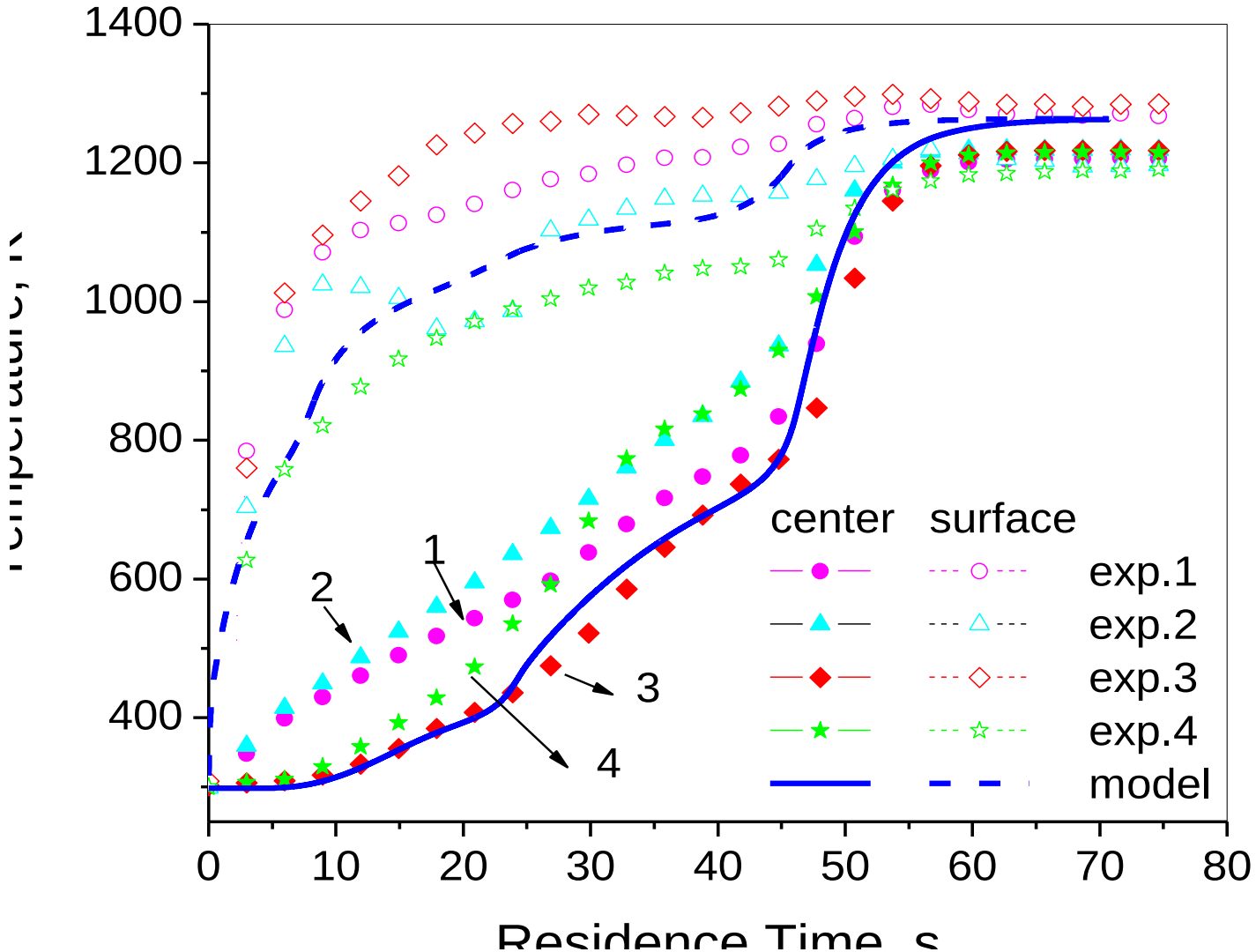
Mass Loss History



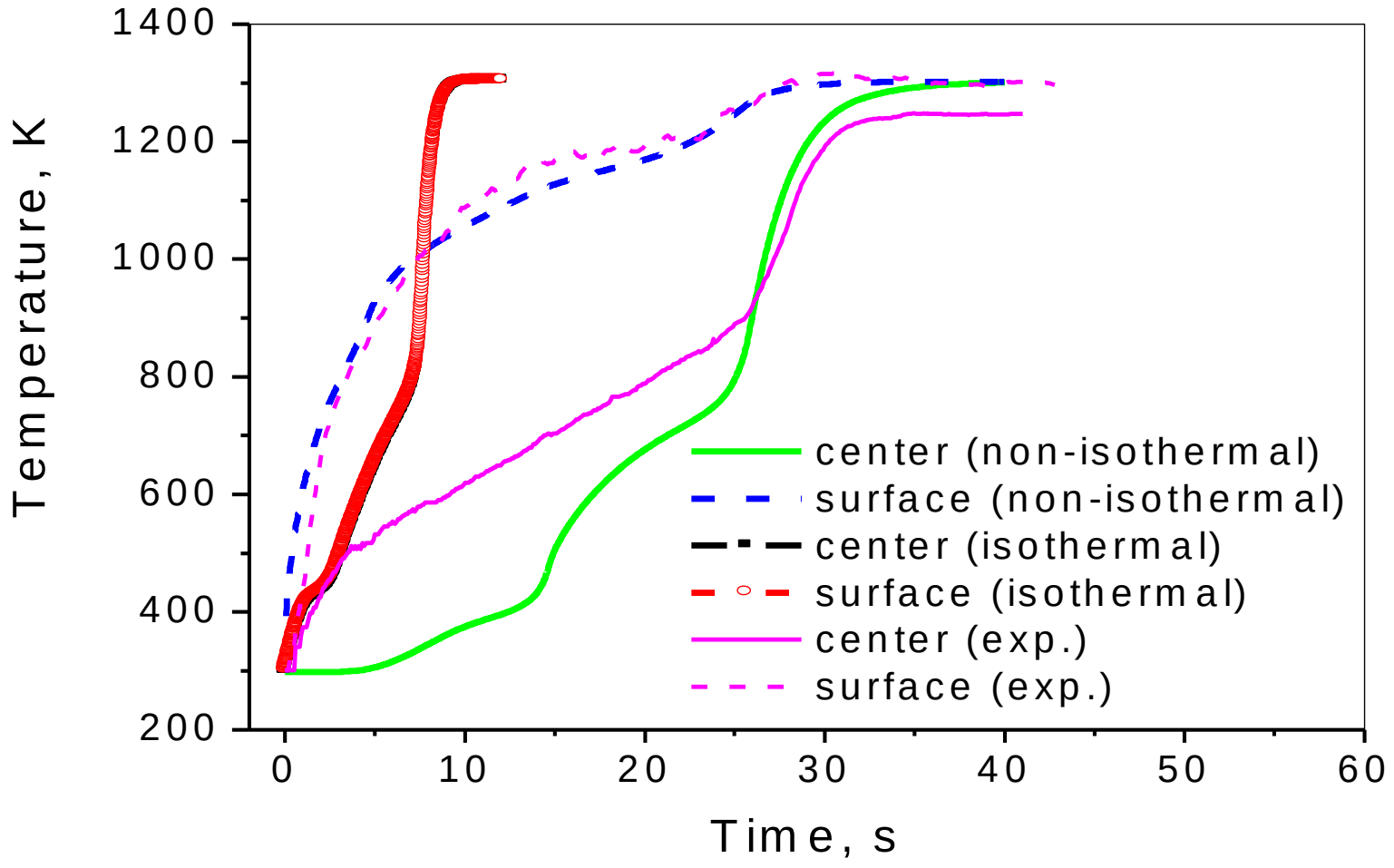
Size Depdenence



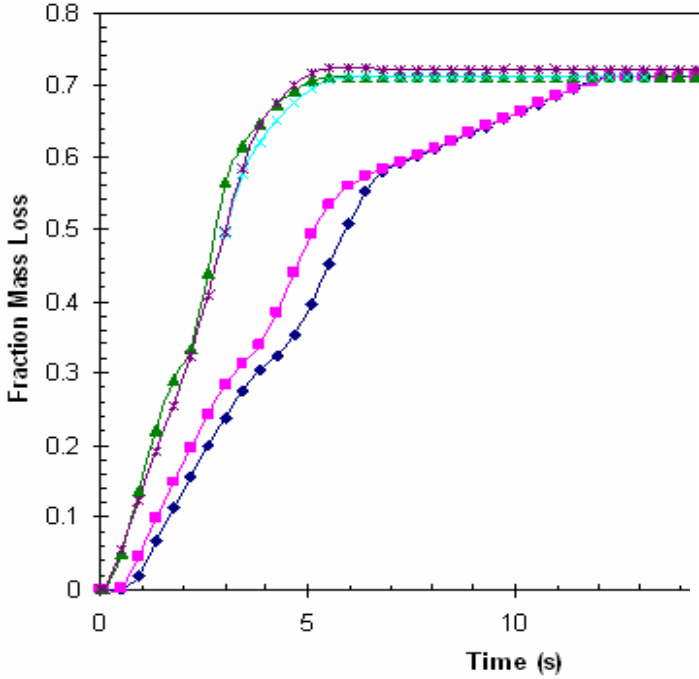
Time- & Spatially Resolved Data

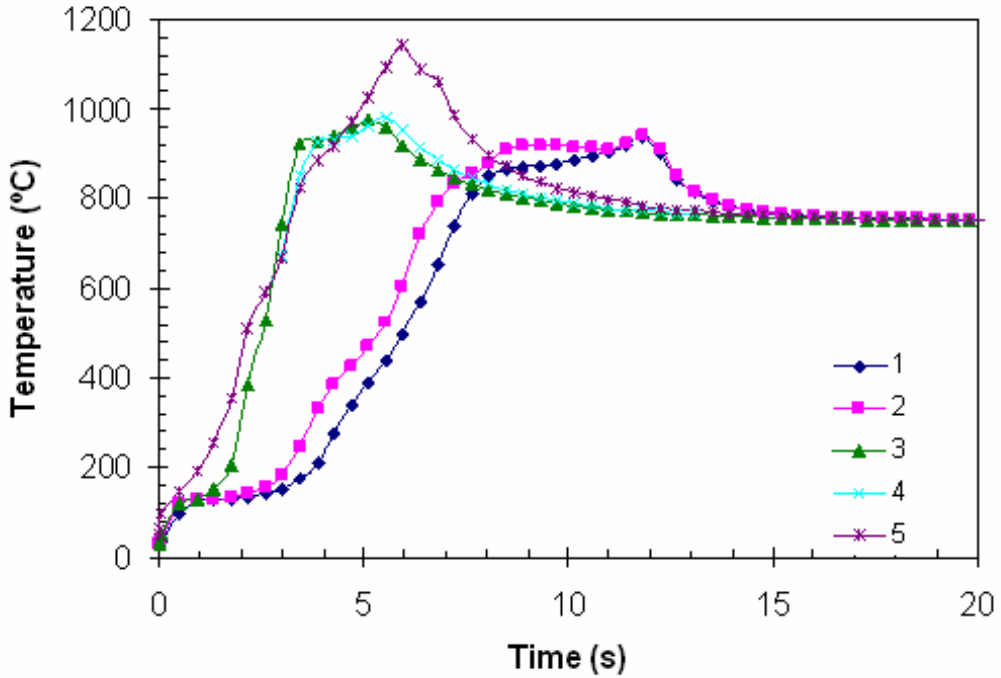


Interparticle Heat Transfer



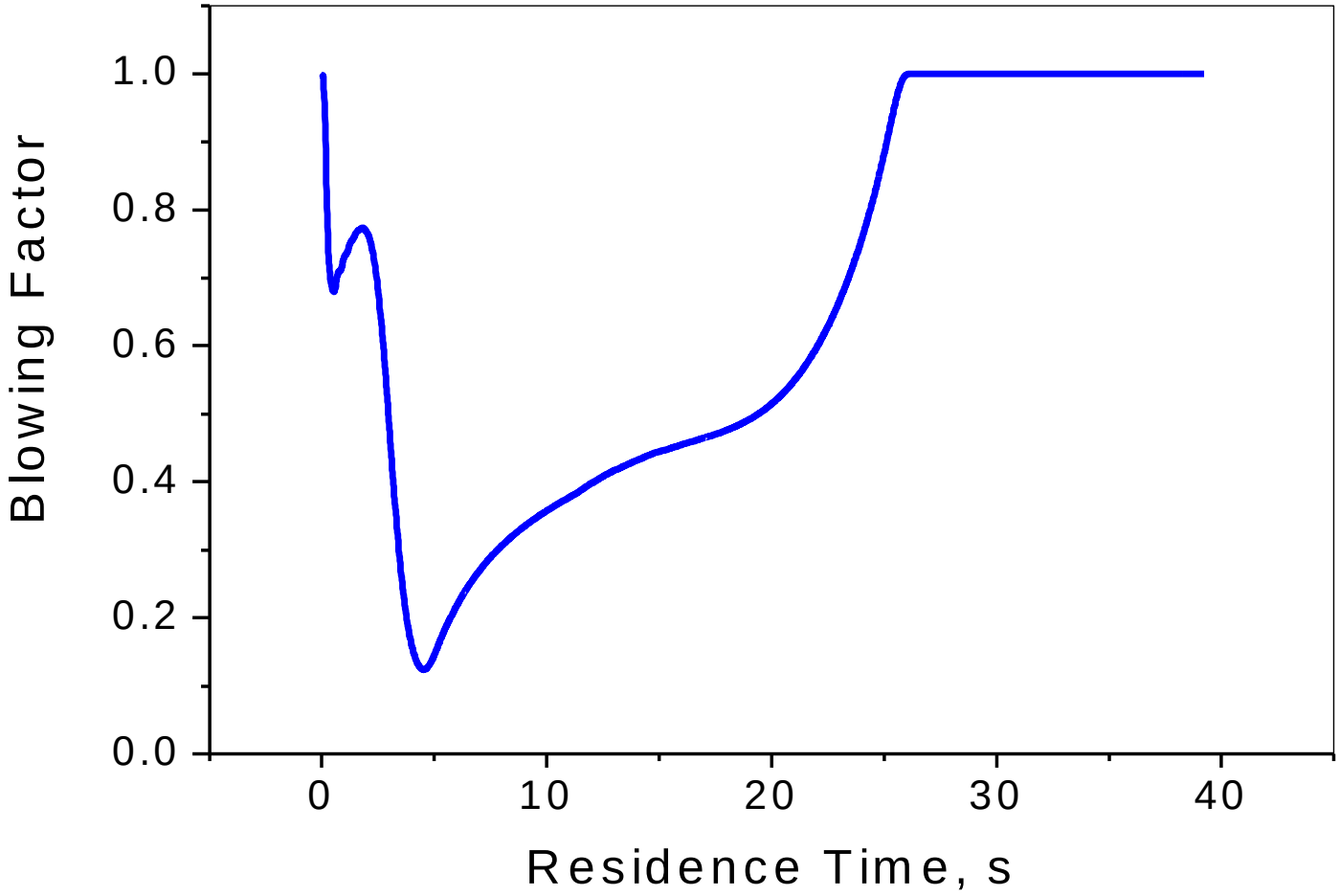
Effects of Model Assumptions



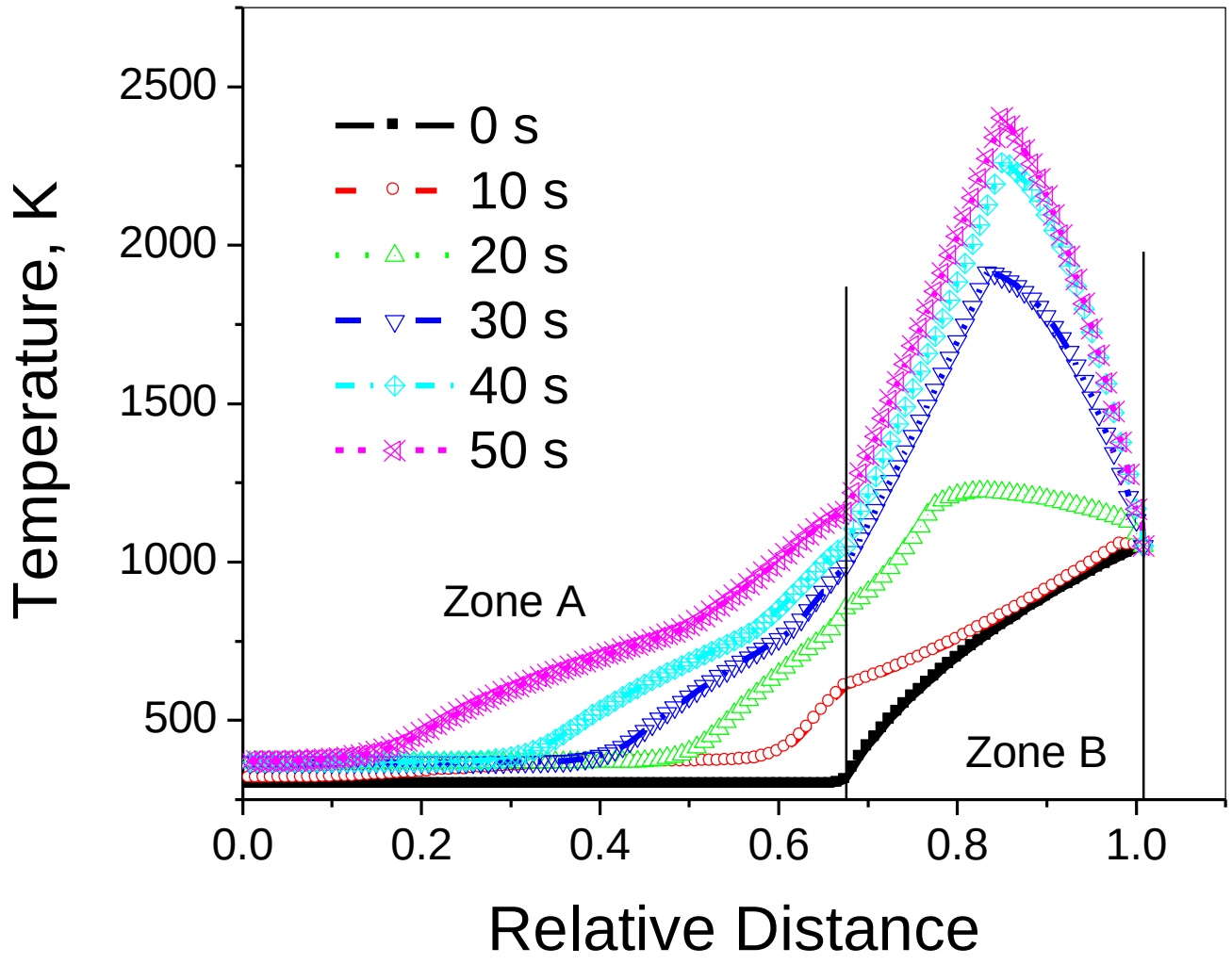


	Prediction Number				
Assumptions	1	2	3	4	5
No Flame	Y	N	N	N	N
No Swelling	Y	Y	N	N	N
Isothermal	Y	Y	Y	N	N
Inert Ash	Y	Y	Y	Y	N

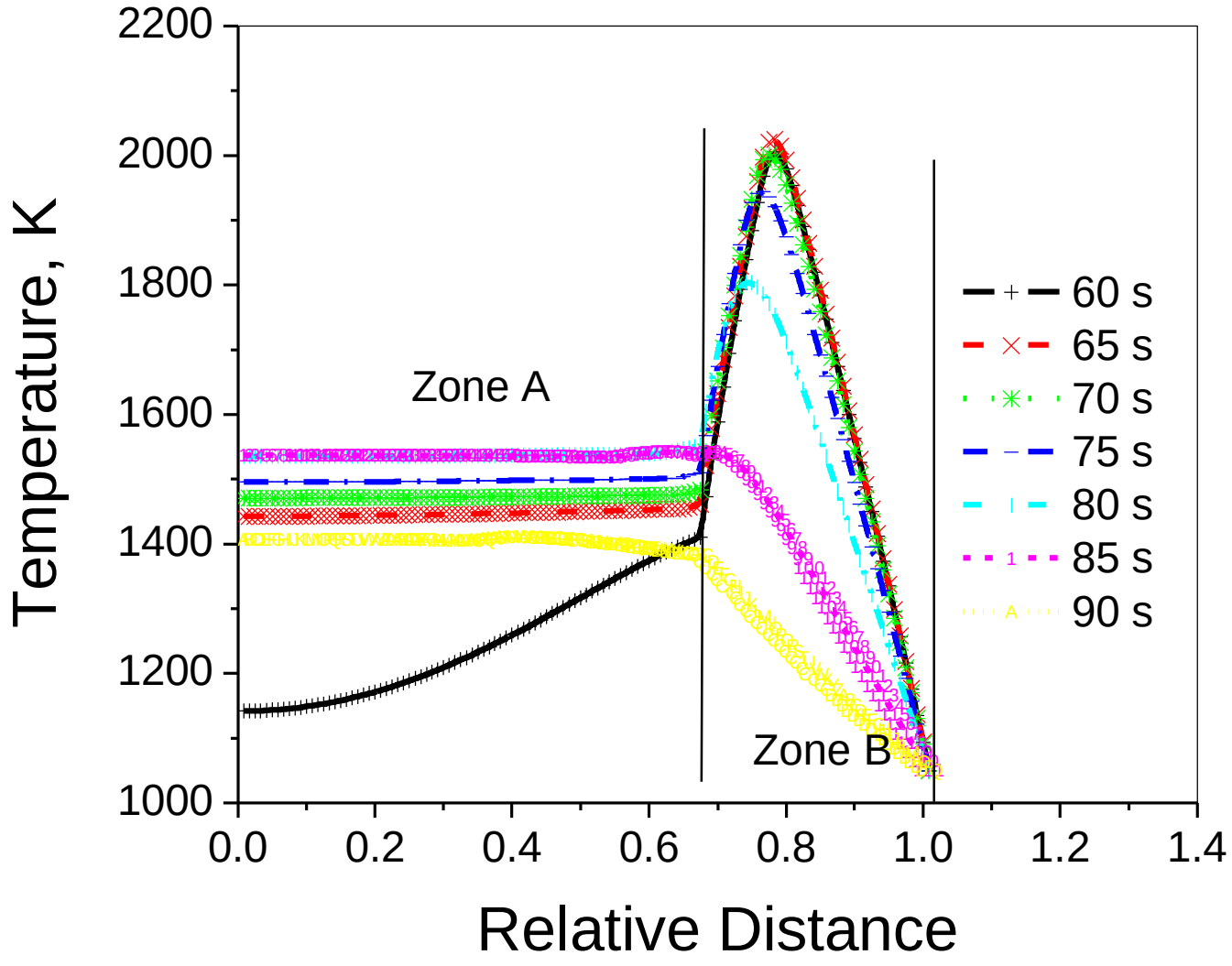
Blowing Factor



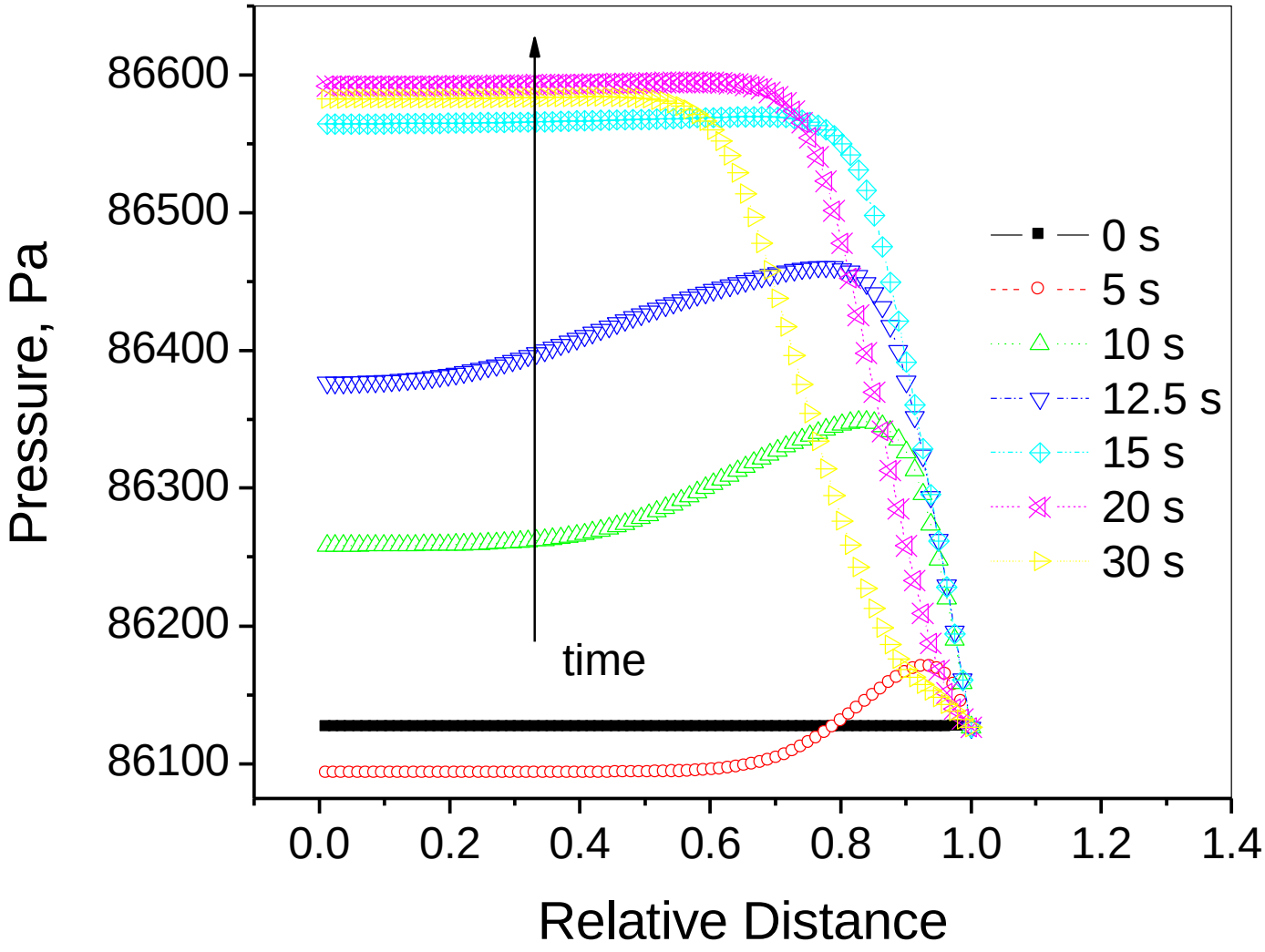
Transient Profiles – Rising T



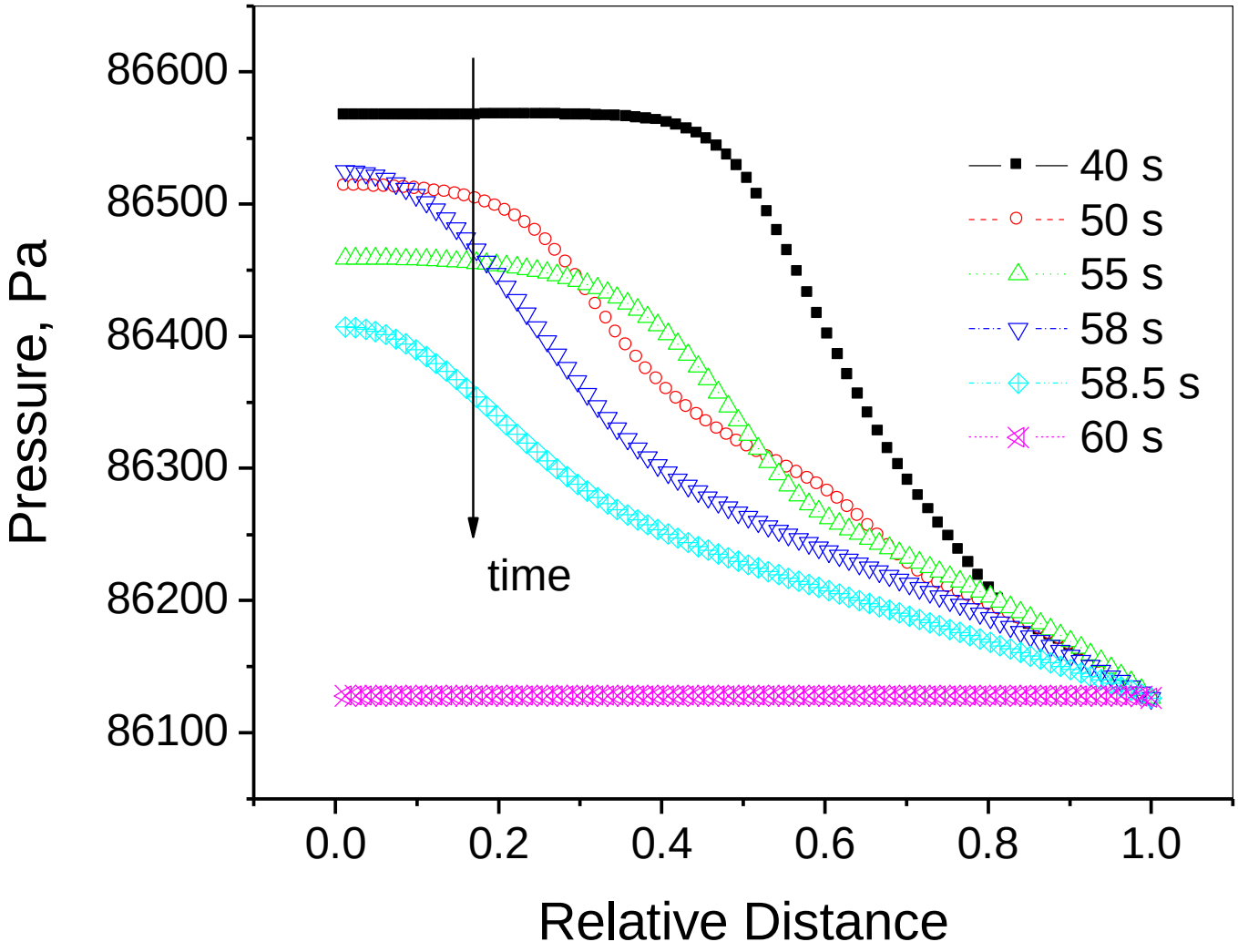
Transient Temperature Profiles



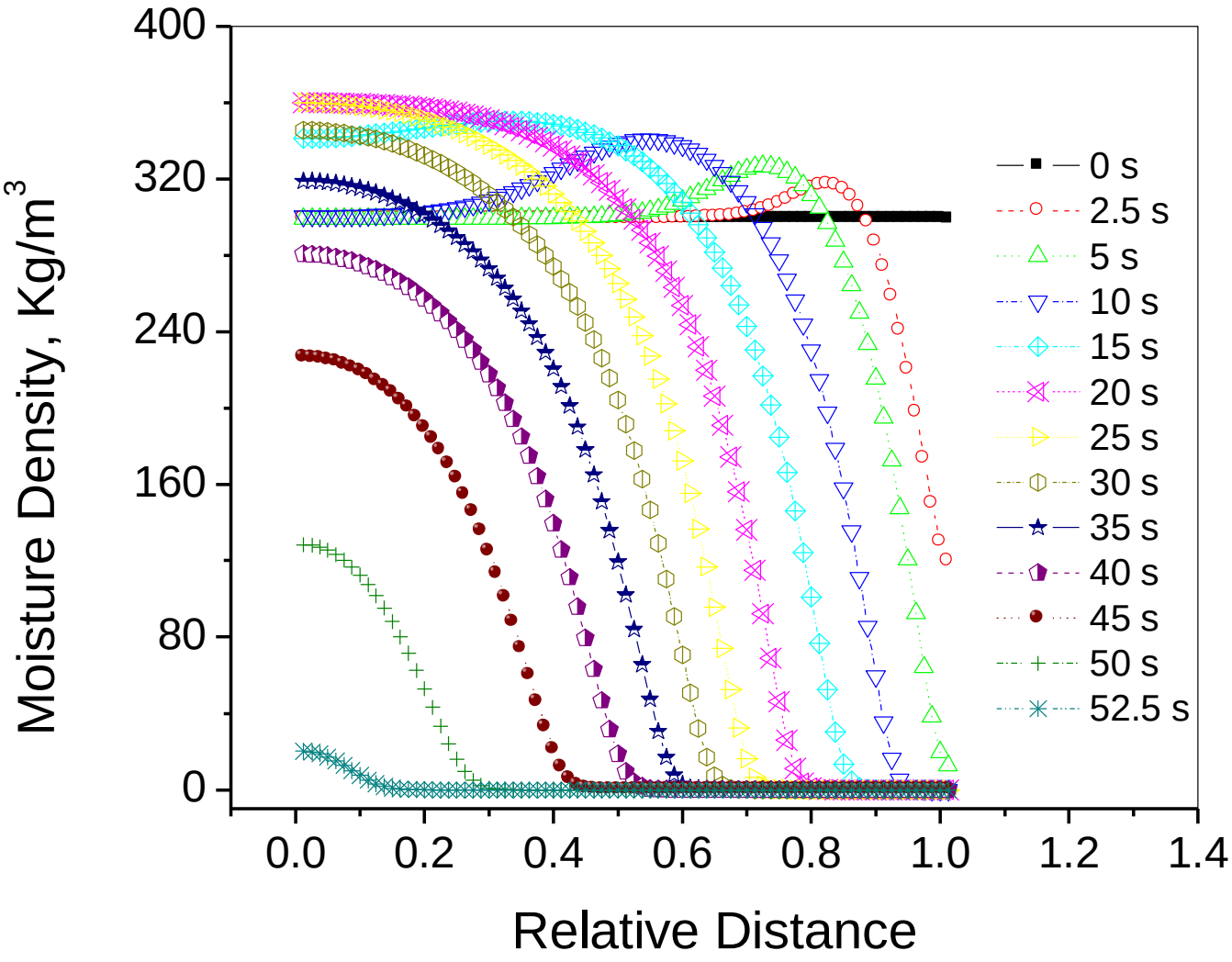
Transient Pressure Profiles



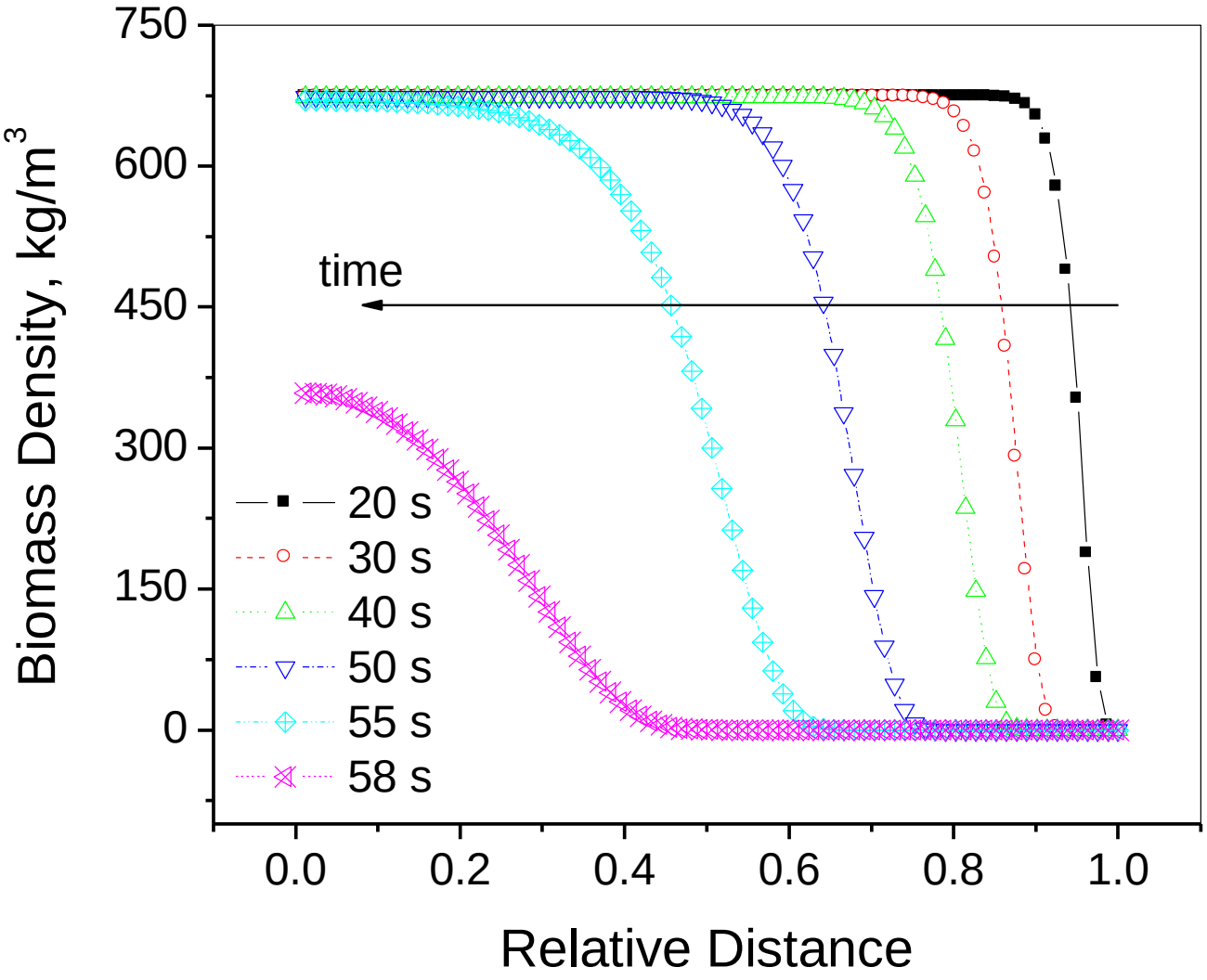
Transient Pressure Profiles



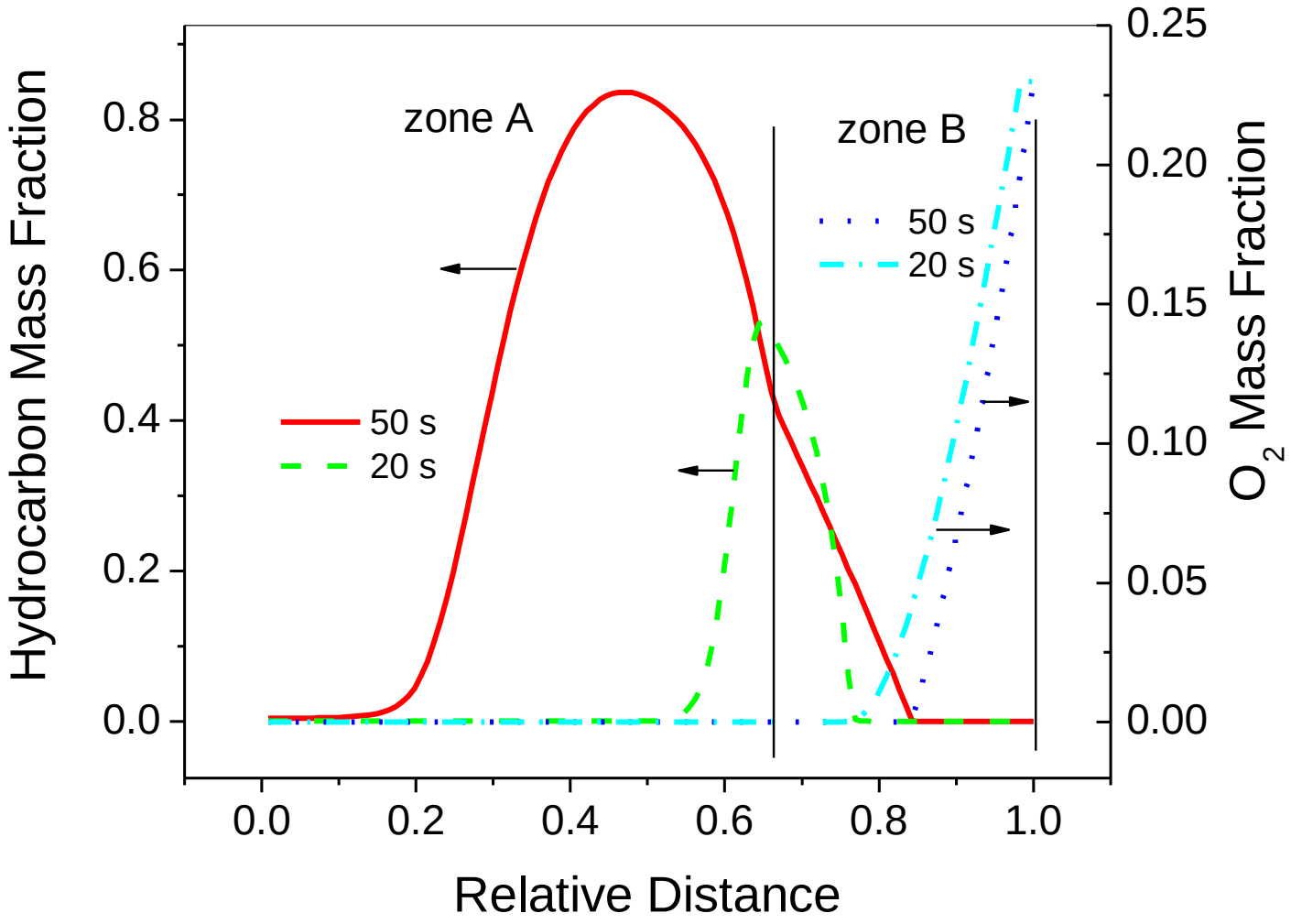
Transient Water (not Steam) Profiles



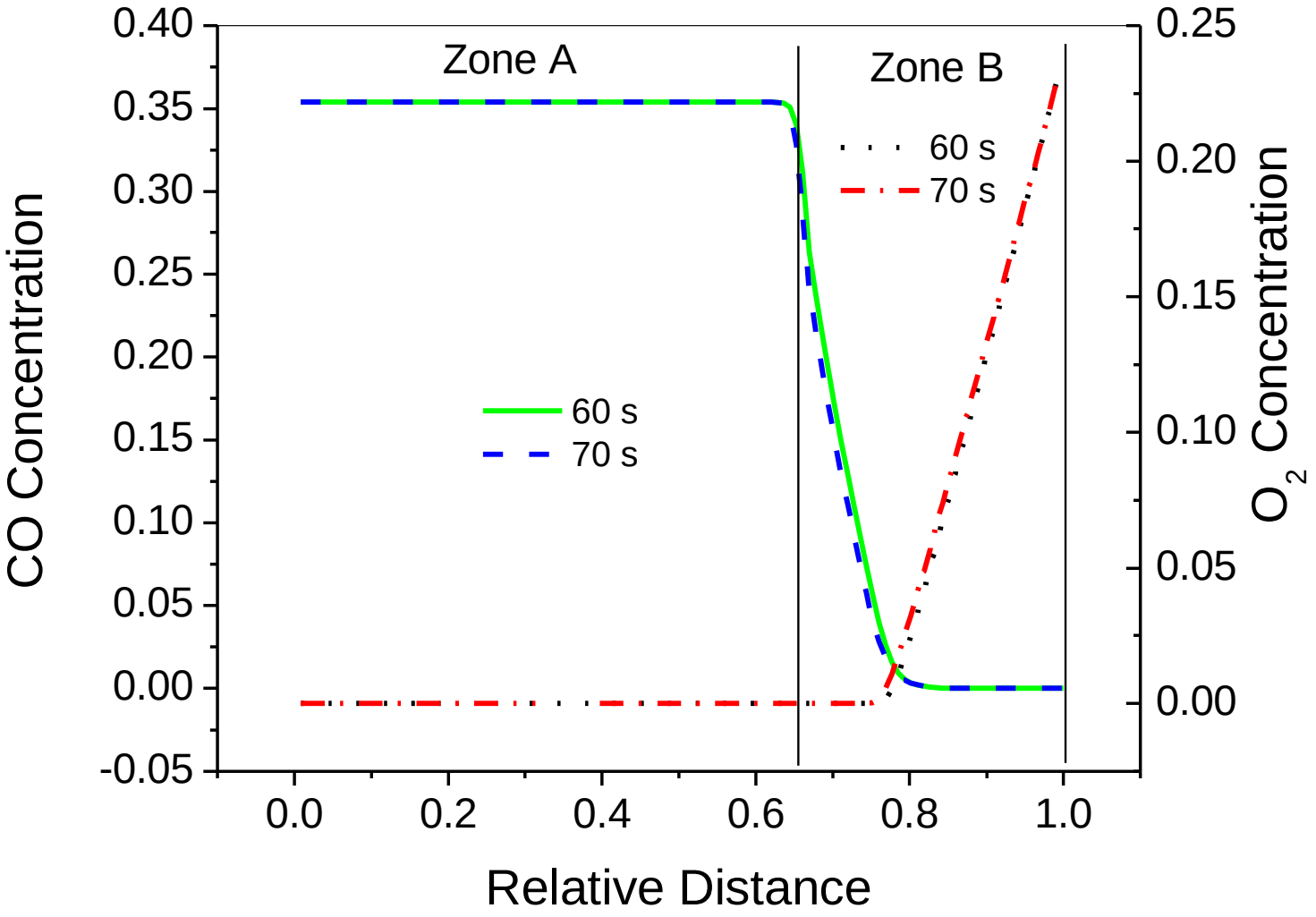
Transient Biomass Profiles



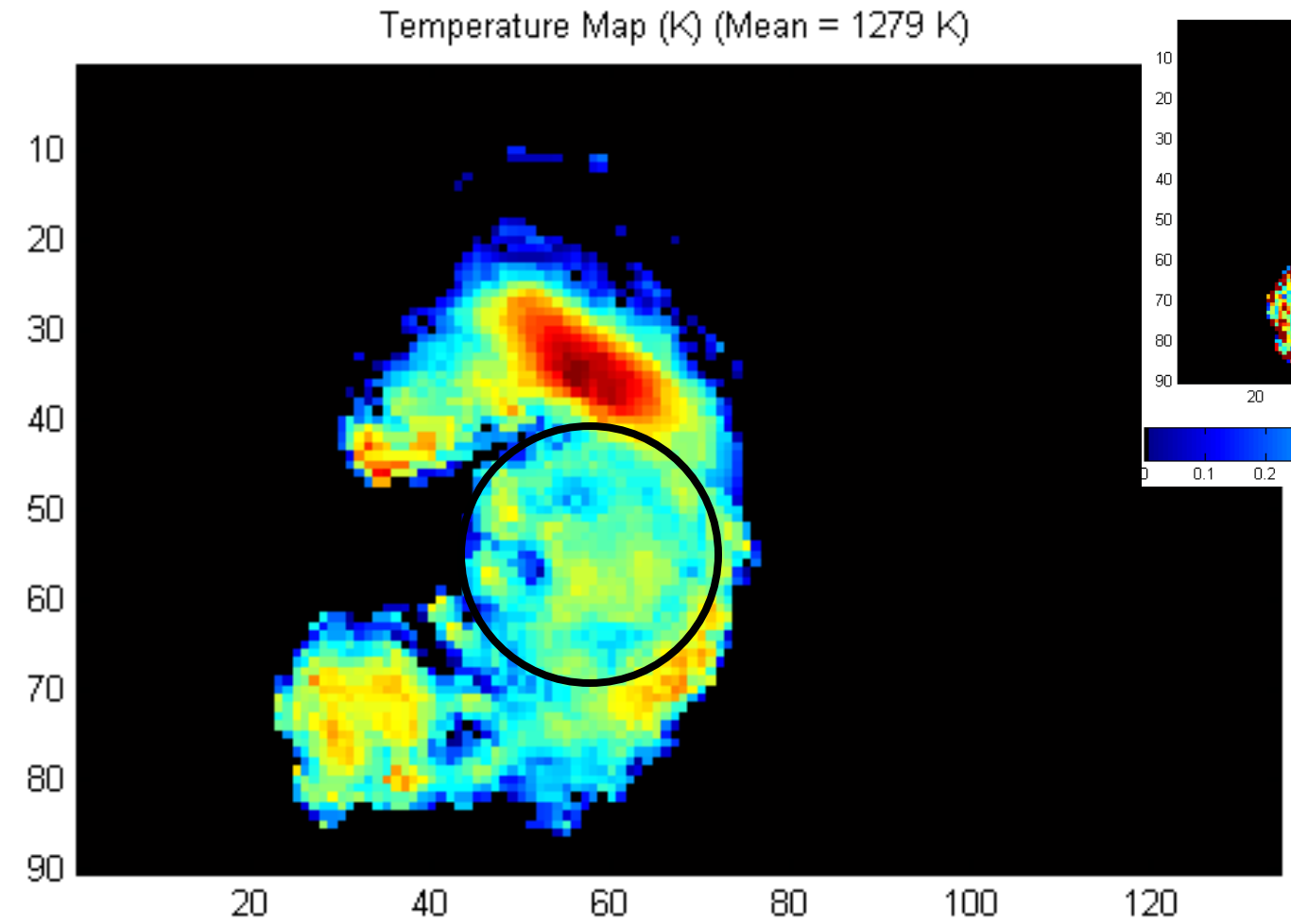
Transient Gas Species Profiles

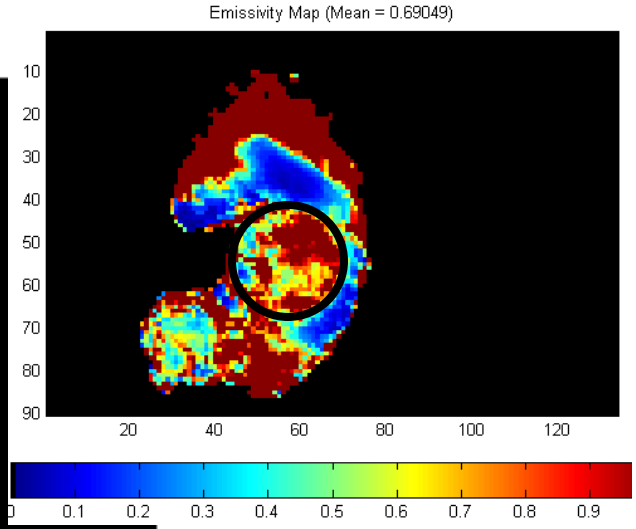


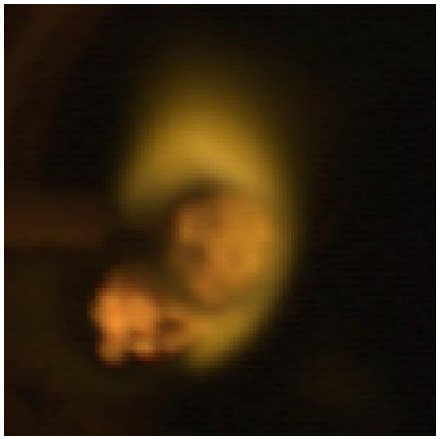
Transient Gas Species Profiles



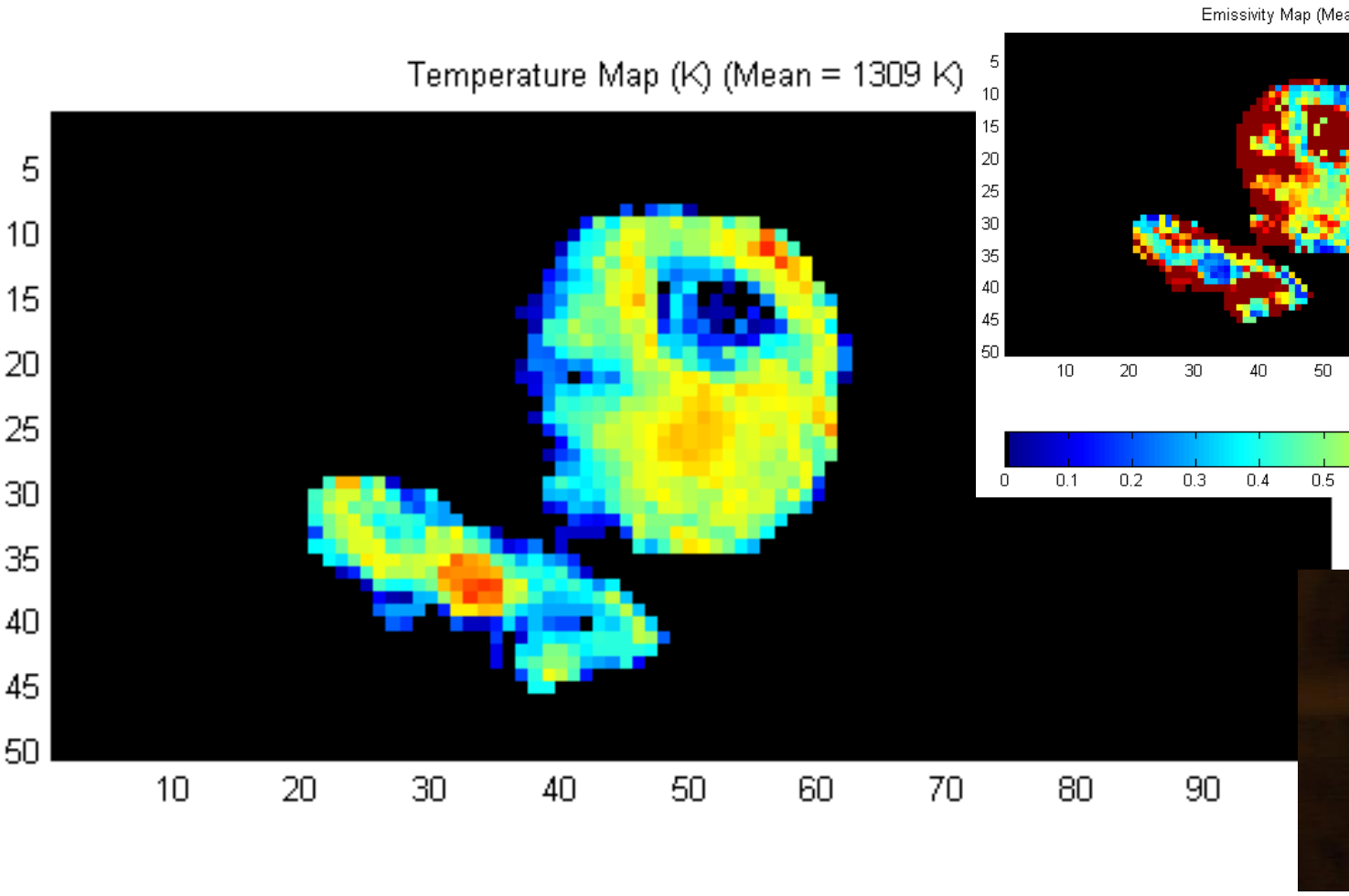
Surface Temperature Map

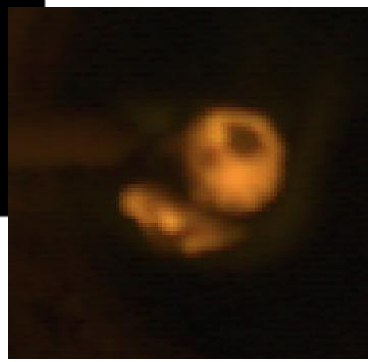






Surface Temperature Map





Conclusions

- **Traditional, isothermal, spherical particle descriptions have been experimentally and theoretically shown to be poor representations of biomass combustion.**
- **Particle size and shape influence internal profiles, with spherical particles being an extreme case of surface-area-to-volume ratio and therefore a poor model for aspherical shapes.**
- **Multidimensional aspects of particle combusiton include dominant radial and temporal transients and possibly significant azimuthal gradients, even in steady state.**