Research Workshop
7th August 2018, Brighton

Novel modelling tools in OpenFOAM: FLA with new heating and evaporation models

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Introduction

- Our group in Brighton has been working on applying a Full Lagrangian Approach to spray modelling in conjunction with more elaborate heating and evaporation models.
- This is motivated by the complex dynamics involving gas-vapour-droplet flows
- OpenFOAM is a powerful and open-source CFD code
- BOTH the heating and evaporation models developed here in Brighton and FLA need to be implemented. The FLA is also being developed in its two-way coupling form.
- Some calculations on single drops (using DNS) are also carried out for more physical insight.

Introduction and issues

- FLA and evaporation models necessitate adaptation of basic openFOAM code
- Basic Implementation is a compromise between OO and the need for expediency
- New Evaporation models demand improvement of access to physical properties and numerical tools within OpenFOAM
- FLA is straightforward but difficult to keep 2nd order accuracy

A few equations

Two-way Coupling, what about folds?

$$\frac{\partial \rho Y_i}{\partial t} + \nabla \cdot (\rho U Y_i) - \nabla \cdot \frac{\mu_{eff}}{Sc} \nabla Y_i = S_{evap}$$

$$\frac{\partial \rho U}{\partial t} + \nabla \cdot (\rho U U) - \nabla \cdot \mu_{eff} \nabla U - \nabla \cdot \mu_{eff} \left[(\nabla U)^T - \frac{2}{3} tr\left((\nabla U)^T \right) I \right] = \rho g - \nabla p + S_{mom}$$

$$\dot{q}_{FLA} = \dot{q} n_d$$

$$\dot{m}_{FLA} = \dot{m} n_d$$

$$\frac{\partial \rho h_s}{\partial t} + \nabla \cdot (\rho U h_s) - \nabla \cdot \alpha_{eff} \nabla h_s = \frac{Dp}{Dt} + S_{heat}$$

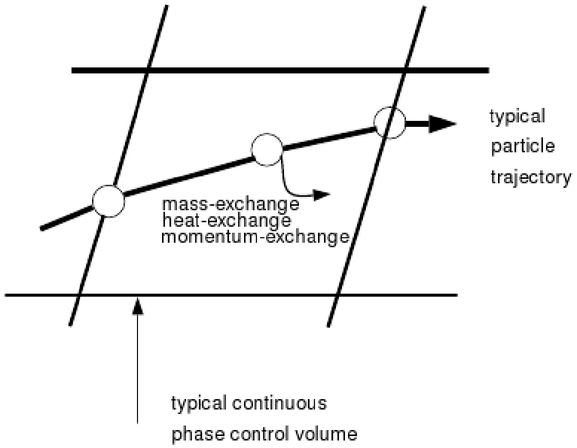
$$m_p \frac{du_p}{dt} = \overrightarrow{F_D}$$

$$\frac{\partial J_{ij}}{\partial t} = \omega_{ij}$$

$$\frac{\partial \omega_{ij}}{\partial t} = \beta \left(\frac{\partial u_i}{\partial x_{j0}} - \omega_{ij} \right)$$

$$\frac{\partial \omega_{ij}}{\partial t} = \beta \left(\sum_k \left(J_{kj} \frac{\partial u_i}{\partial x_k} \right) - \omega_{ij} \right)$$

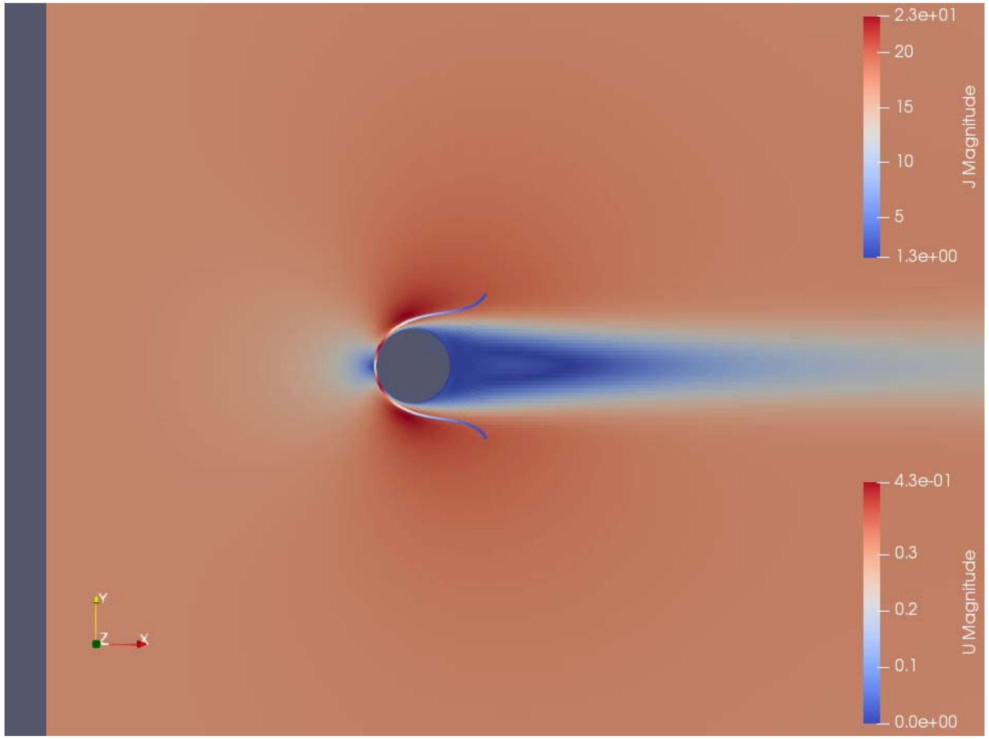
$$J_{ij} = \left(\frac{\partial x_i}{\partial x_{j0}} \right) \quad n_p = \frac{n_0}{|J|}$$

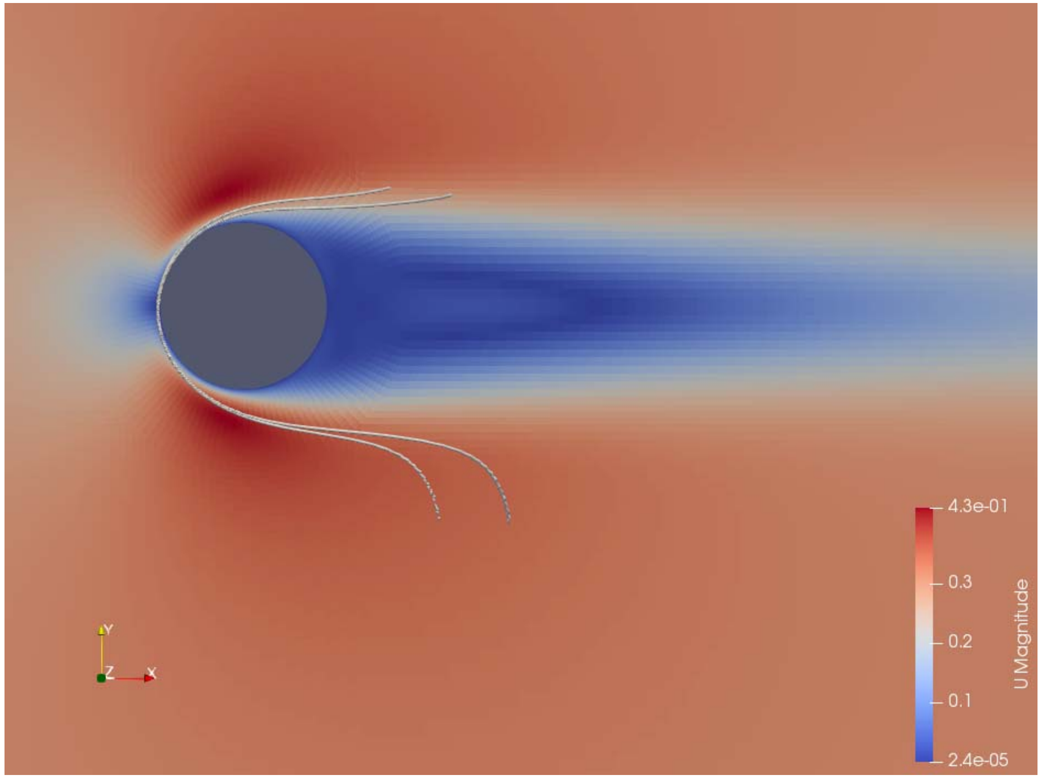


Implementation

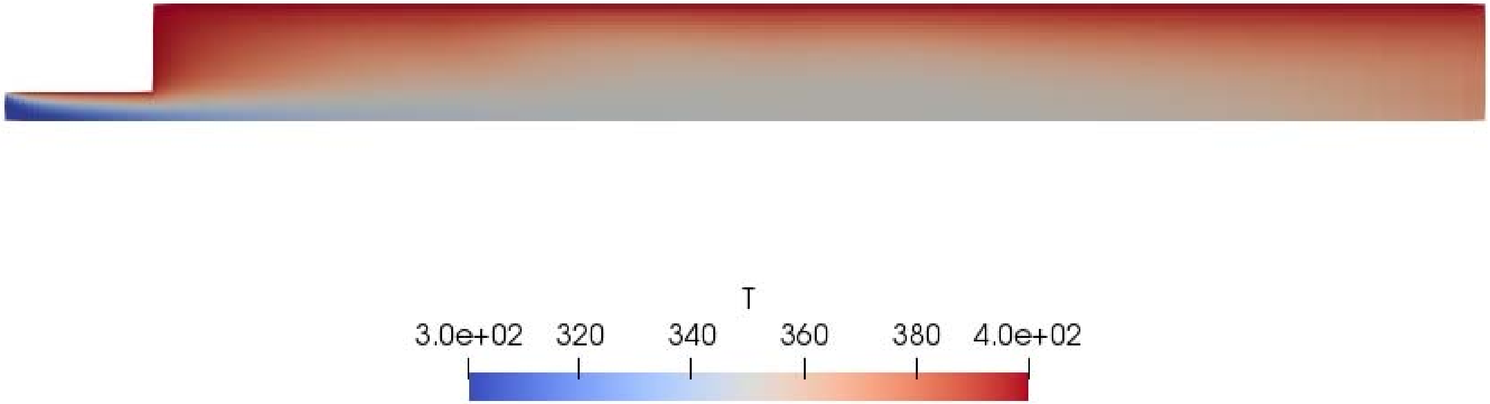
- pierre@moco303-z640:~/OpenFOAM/pierre-v1712/src/lagrangian/intermediate/parcels/Templates/FlaParcel
  - FlaParcel.C FlaParcel.H FlaParcelI.H FlaParcelIO.C FlaParcelTrackingDataI.H
  - That’s it??
  - Not really.

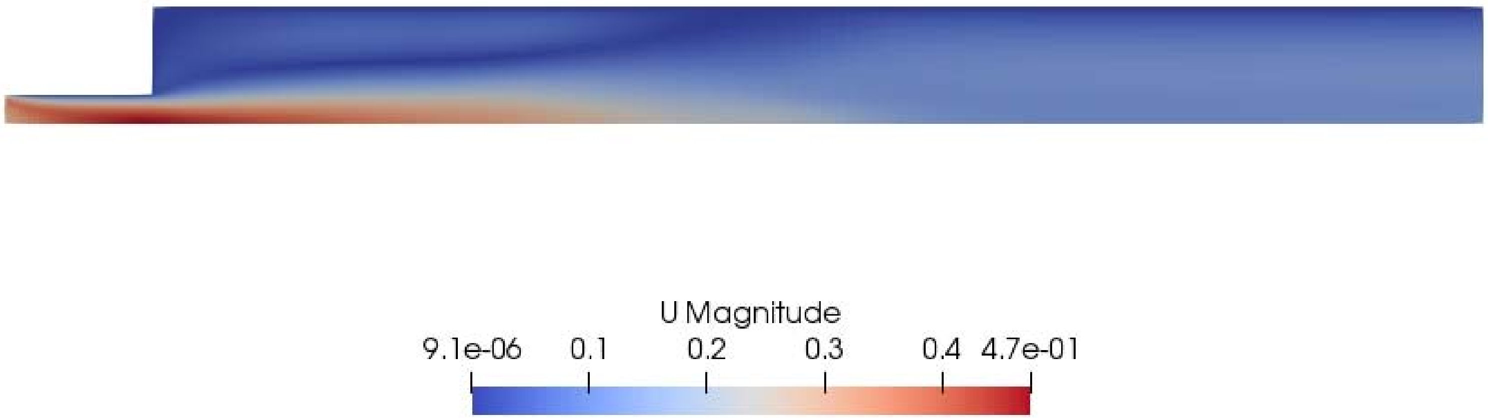
Cylinder case



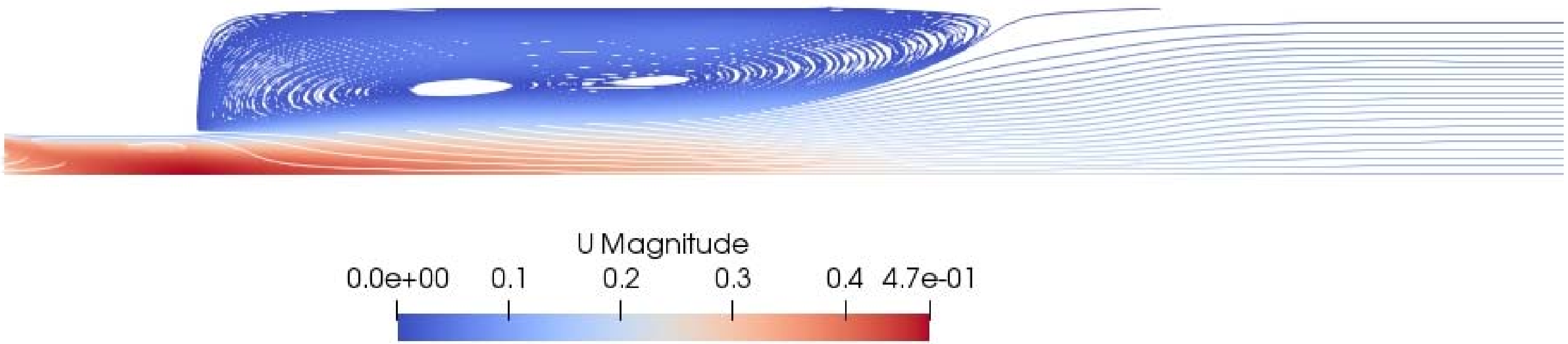


Backstep, work in progress for Evap.

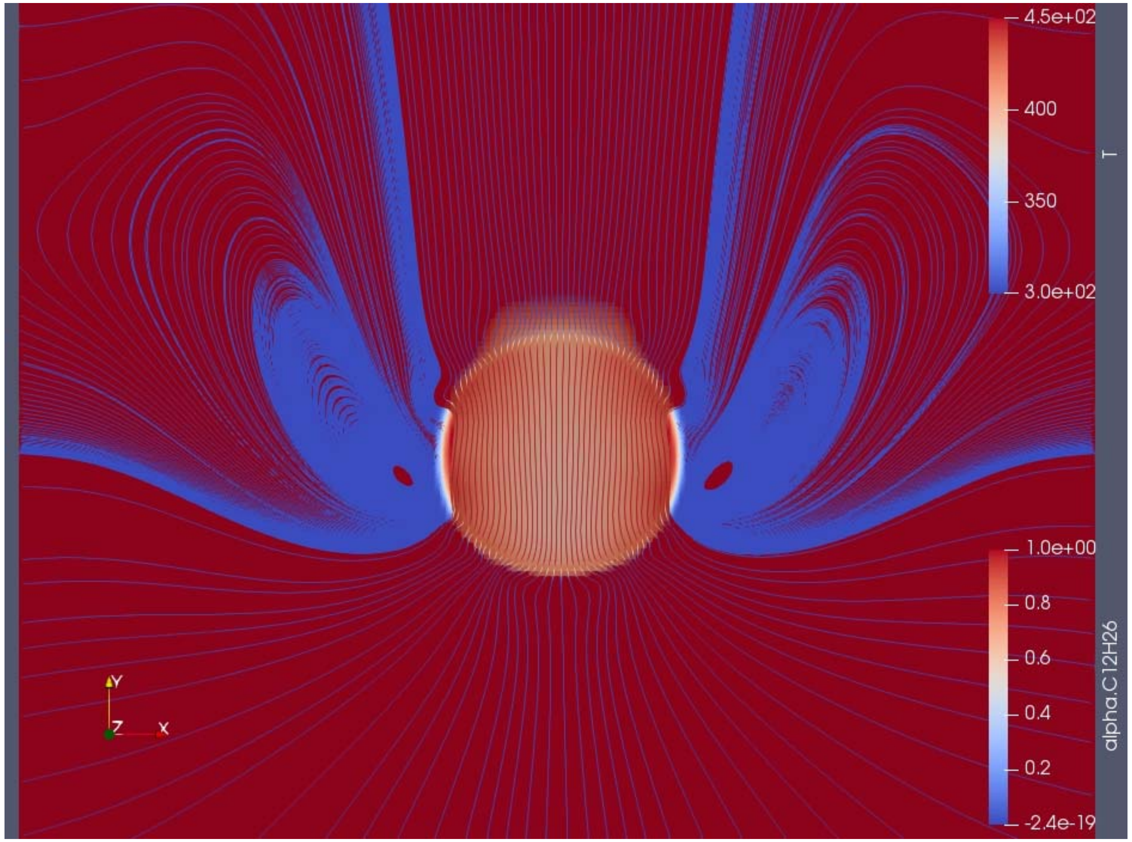


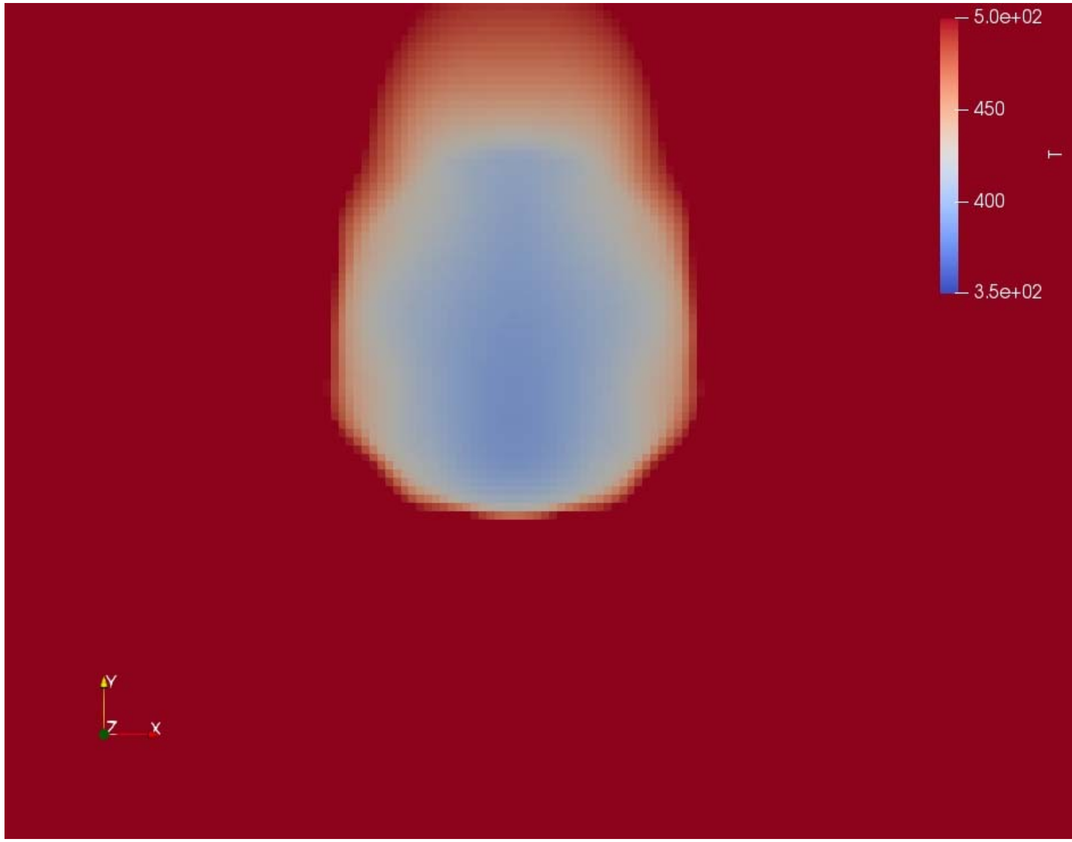


Streamlines, any folds?



Single Drop calculations





Conclusion

- It’s all coming along nicely.
- By end of the month, implementation complete.
- Still in progress
  - Effect of interpolation should be studied, to validate the whole implementation.
  - Need to simplify handling of energy transfer and liquid properties libraries.
  - Test the evaporation model