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A unified model for wind-blown volcanic umbrella clouds

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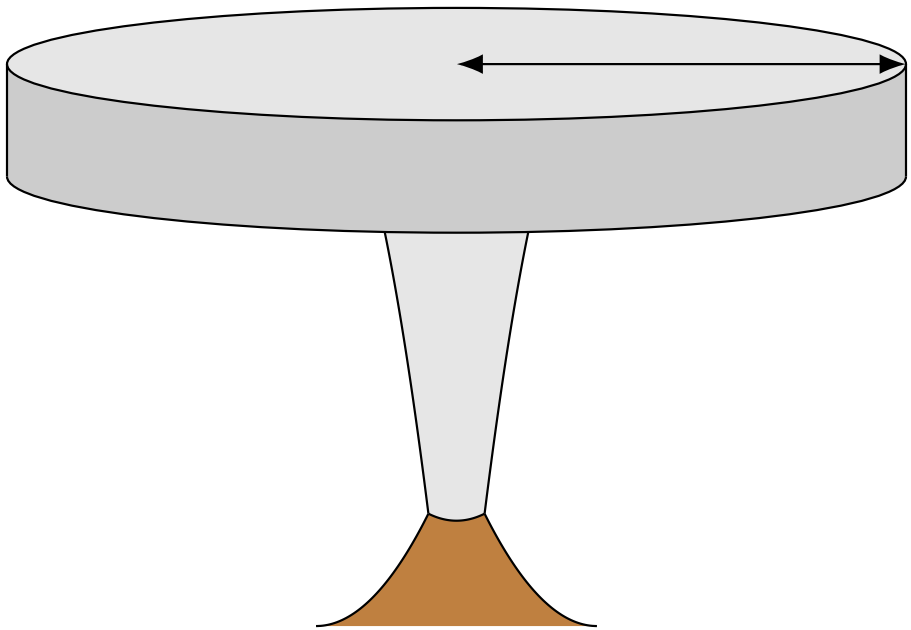
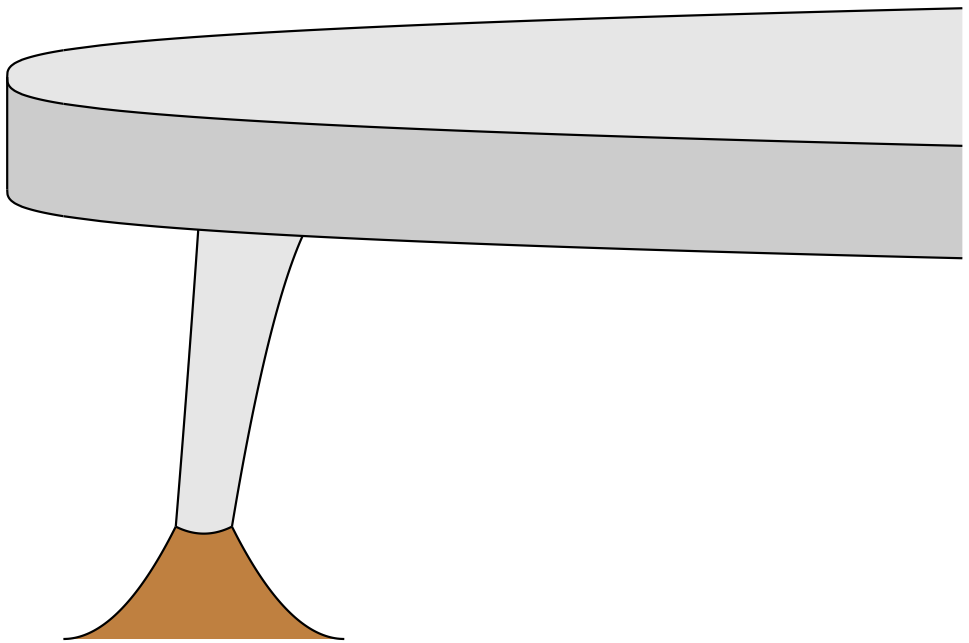
Introduction

$$R \sim t^{2/3}$$

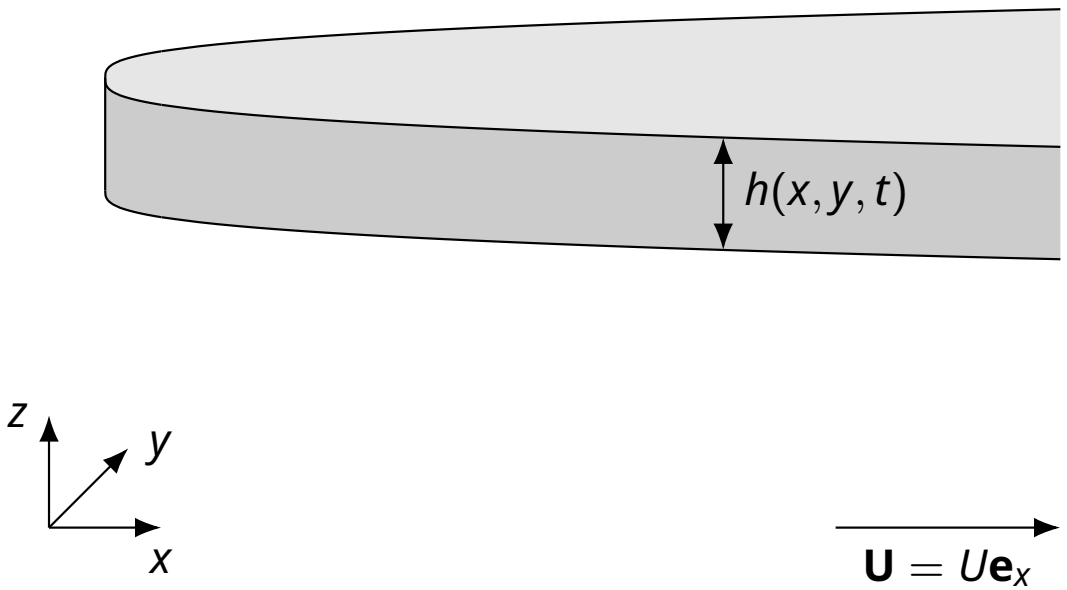


Lemckert and Imberger 1993; Woods and Kienle 1994; Costa, Folch, and Macedonio 2013; Webster et al. 2020; Johnson et al. 2015

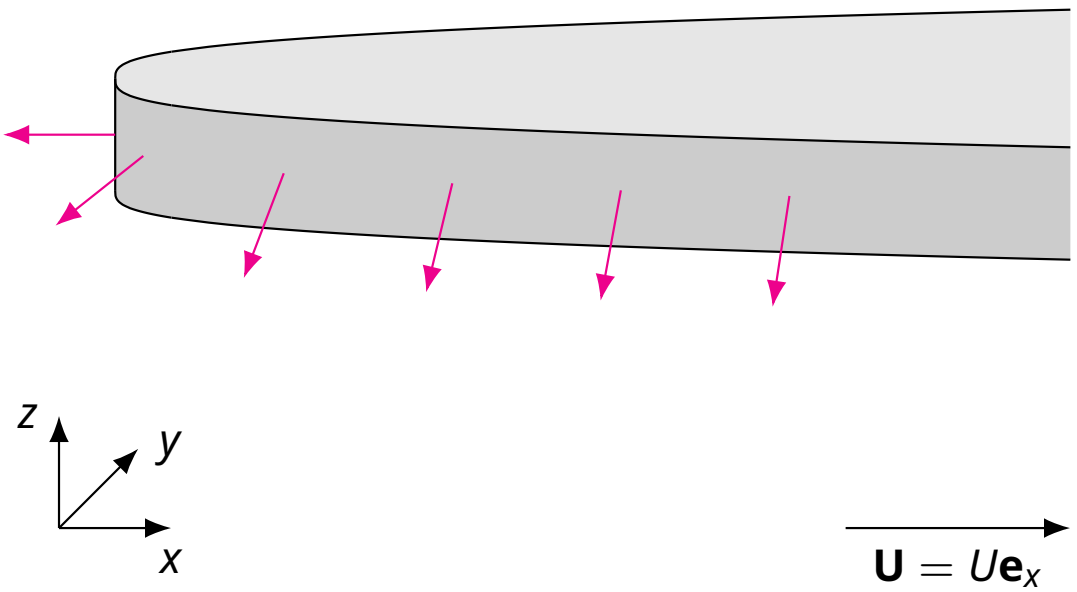
Introduction



Shallow layer theory

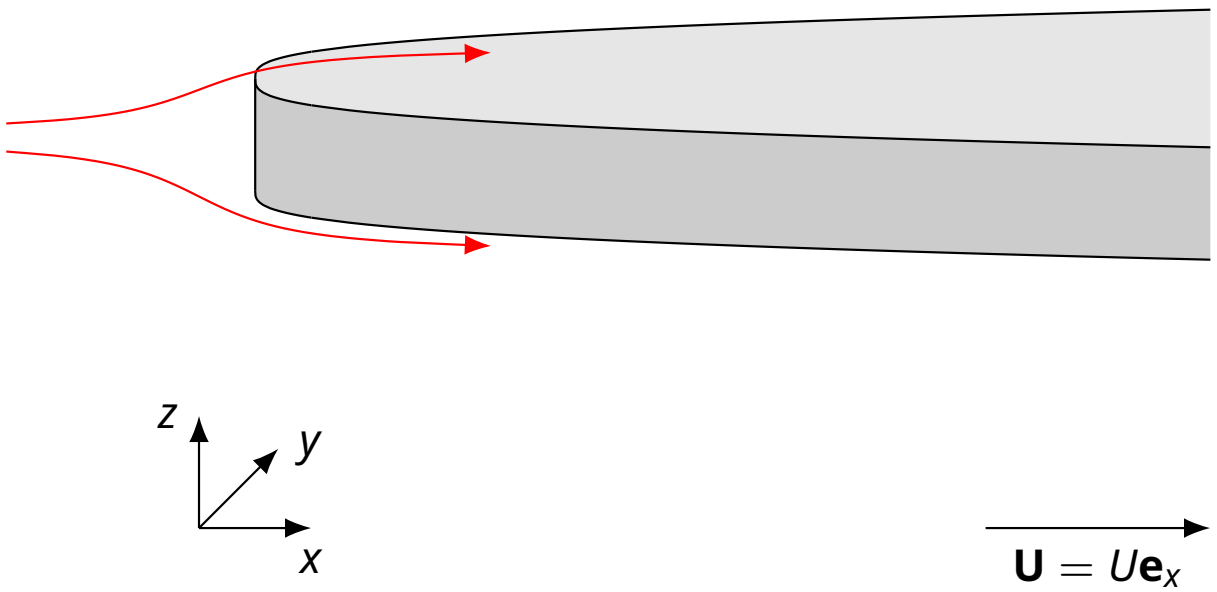


Shallow layer theory



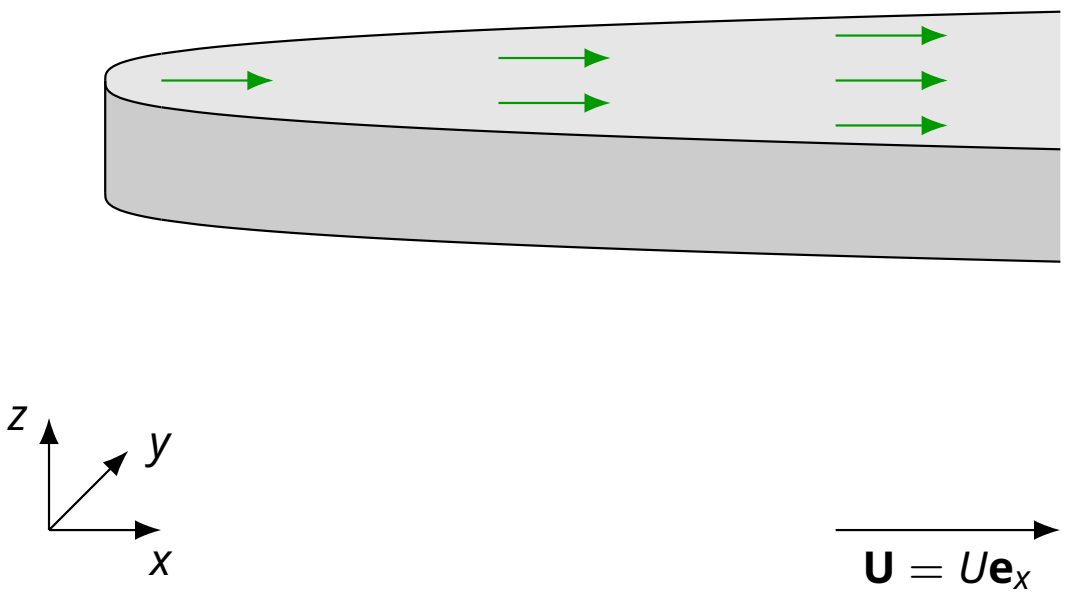
Buoyancy

Shallow layer theory



Inertial Drag

Shallow layer theory



Turbulent Drag

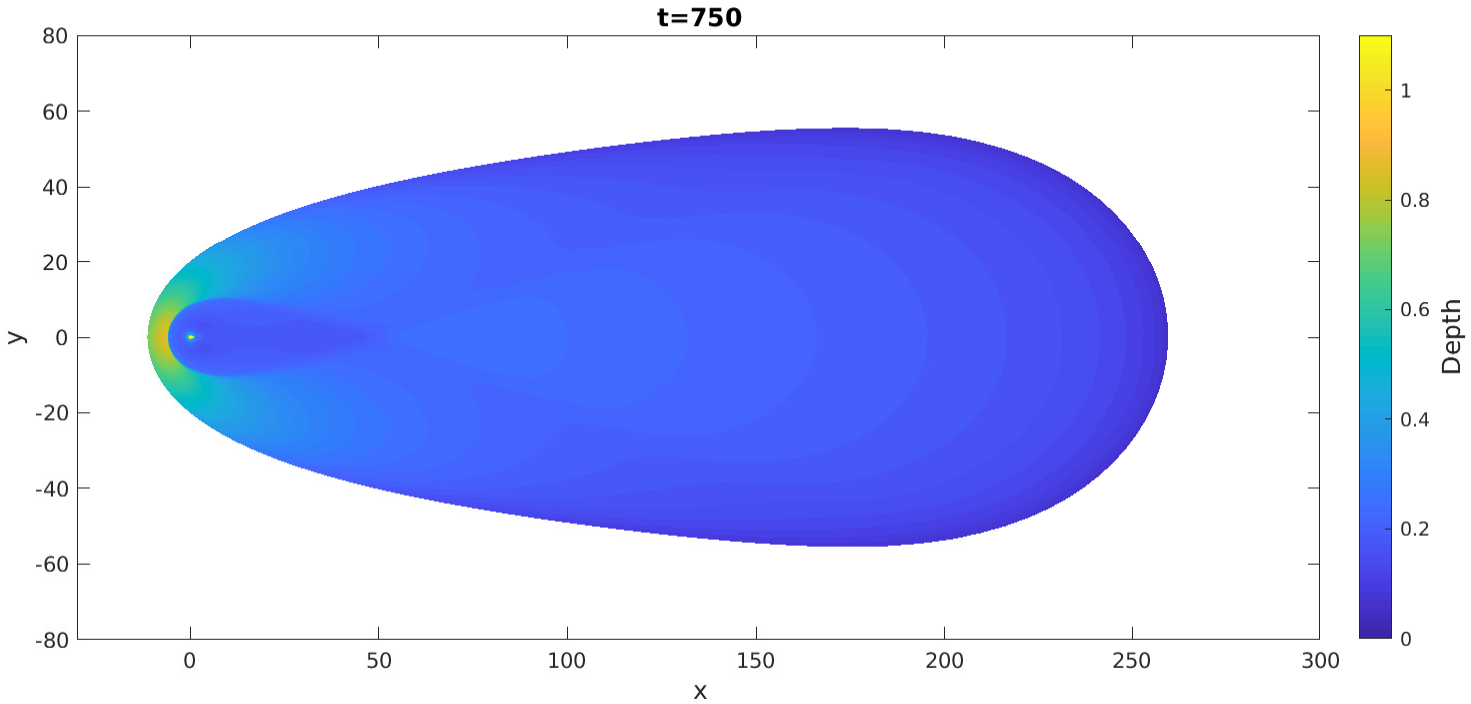
Shallow layer theory

$$\frac{\partial}{\partial t}\begin{bmatrix} h \\ hu \\ hv \end{bmatrix} + \frac{\partial}{\partial x}\begin{bmatrix} hu \\ hu^2 + \frac{h^3}{12} \\ huv \end{bmatrix} + \frac{\partial}{\partial y}\begin{bmatrix} hv \\ huv \\ hv^2 + \frac{h^3}{12} \end{bmatrix} = \begin{bmatrix} 0 \\ C_D\left(U-u\right)\left|\mathbf{U}-\mathbf{u}\right| \\ -C_D v\left|\mathbf{U}-\mathbf{u}\right| + \end{bmatrix},$$

$$\mathbf{U} = U\boldsymbol{e}_x, \qquad \left.\frac{2\left|\left(\mathbf{U}-\mathbf{u}\right)\cdot\hat{\mathbf{n}}\right|}{h}\right|_{\delta C} = Fr_f.$$

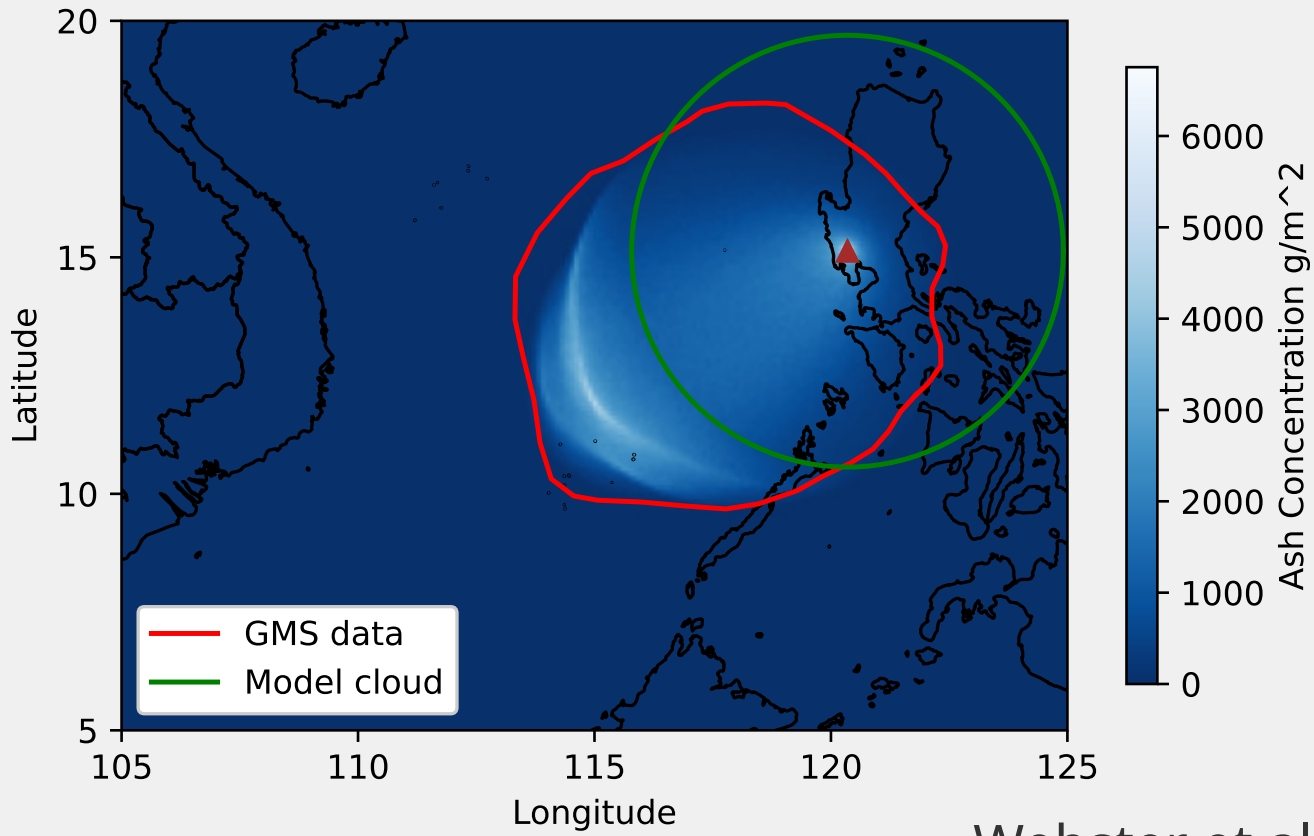
Johnson et al. 2015

Numerical solutions



Applications

Circular umbrella cloud scheme, Pinatubo 1991

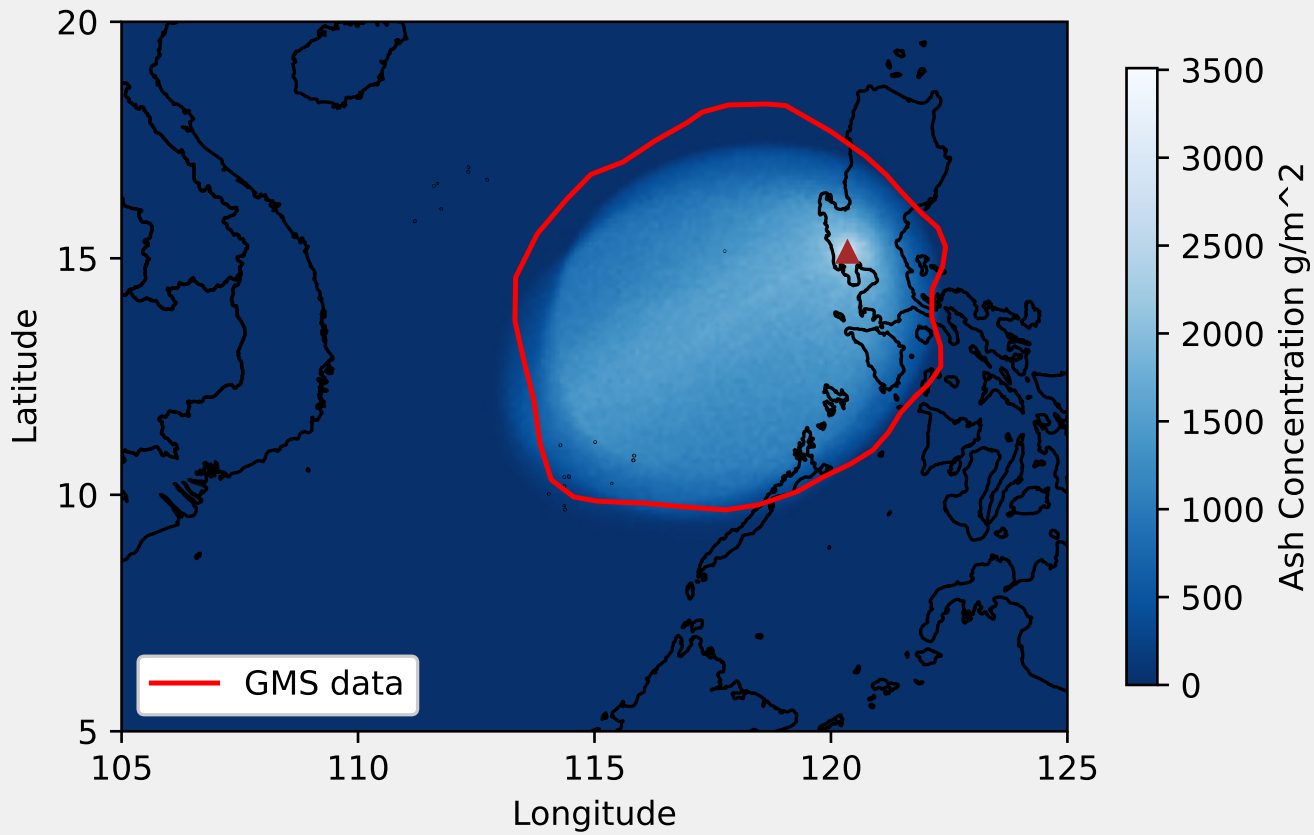


Webster et al. 2020

- Non-physical interior velocities
- Mismatch between cloud shapes leads to accumulation

Applications

Non-axisymmetric wind-blown scheme, Pinatubo 1991



- Interior velocities are solutions to conservation laws
- Reduced cloud mismatch can reduce accumulation

Any Questions?

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References I

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