Turbulence Mixing and the study of Clouds

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Venturefest 2012, Oxford
William Turner, “Study of Clouds”, about 1830
(Tate Gallery, London)
Motivation: Cloud entrainment

*Isolated cumulus:* Entrainment throughout the cloud depth: from above, sides and at the base.
Effects of gravity vary

*Stratocumulus:* Entrainment mainly from the top
All turbulence measurements in a stratocumulus are consistent with laboratory experiments (data from Siebert et al., 2009)
Field Data
Small Cumulous

Settling parameter vs. Stokes number

Upward diagonals: dissipation rate [m²/s³]
Downward diagonals: droplet diameters [µm]

N.B: these are averaged values

\[ Sv = \frac{\nu_t}{\nu_\eta} = \frac{St}{Fr}, \quad St \approx d^2 \varepsilon^{1/2} \quad \text{and} \quad Sv \approx \frac{d^2}{\varepsilon^{1/4}} \]
Laboratory experiments

Settling particle velocity enhancement/reduction in turbulence with gravity

Alesida et al, JFM 468 (2002)
Davila - Hunt, JFM 440 (2001)
Murray JGR 75 (1970)
Nielsen, J.Sed.Petr. 35 (1993)
Tooby et al, JGR 82 (1977)
Wang - Maxey JFM 256 (1993)
...

Acceleration of inertial particles: Bodenschatz, Xu, Mordant, Ayyalasomayajula, Qureshi, ...

Clustering: Shaw, collins, Bec, Vassilicos, Hunt
Particle diameter effect

Red : g+
Blue : g₀
Black : g⁻

Squares: TT interface,
Circles: TN interface

Inset: particle size distribution

No gravity ⇒ small & large particles transported the same way
Real clouds: sharp interfaces and shear

Shear is important!

from Shaw, ARFM 35 (2003)
What can simulations tell

http://www.polito.it/philofluid

Entrainment
Entrainment - Interface

PHILOFLUID
Entrainment

Energy/velocity field:
John Constable, “Study of Clouds”, about 1820
(University of Oxford, Ashmolean museum)
Conclusions

- gravity is very important in droplet distribution
- mixing is affected by large scales
- we are beginning to understand the mechanics of entrainment, but need to know more about:
  - evaporation
  - shear
  - convection
- rain making must understand droplet distribution and how it changes with time
- global warming ⇔ droplet size distribution (absorption/reflection of light)

Interdisciplinary holistic approach is necessary!