Towards a turbulent collision kernel for inertial particles in homogeneous isotropic turbulence: measurements of relative particle velocity, cluster statistics, and an effort to find a simplified, measurable kernel

Aliseda, Alberto
(University of Washington, Mechanical Engineering, Seattle. WA, USA)

The hypothesis of enhanced droplet collisions in clouds due to inertial interactions with the ambient turbulence in the cloud core has the potential to close the problem of computing precipitation times and cloud lifetimes in warm rain environments. The fundamental understanding of inertial particle interactions with turbulence strongly support this mechanism for rain formation, but quantifying it with experimental measurements under well-controlled conditions has proven a significant challenge. I will present results from experiments in a wind tunnel that was created to provide conditions that are conducive to reproducing the physics in cumulus clouds, within the limitations of a laboratory. Measurements of the evolution of small inertial (≈5-100 μm) water droplets in homogeneous, isotropic, grid turbulence are collected from high-speed imaging. Light from a thin laser sheet is scattered by the droplets, collected and analyzed via a Particle Tracking algorithm. Droplet trajectories are resolved with high spatial (≈10 μm) and temporal resolution (≈200 μs), over an average of 10-20 consecutive images, yielding high quality statistics of velocity and acceleration over O(107) droplets. To shed light over the turbulence collision kernel for inertial particles, we analyze the preferential concentration and enhanced relative velocities resulting from their inertial interactions with the underlying turbulence. The particle relative velocity, measured from tracks along a streamwise plane, is conditionally analyzed with respect to the distance from the nearest particle. We focus on the non-normality of the statistics for the particle-particle separation velocity: a negative bias in the separation velocity of particles for short separations indicates a tendency of particles to collide more frequently than a random agitation by turbulence would predict. The long positive tail of the velocity distribution shows the high probability of collisions that do not lead to coalescence, where colliding particles do not merge but come out of the collision with an enhanced separation velocity. The effect of gravity on the particle settling velocity and relative velocity is also extracted from the experimental measurements. Finally, we use Voronoi tessellations to track clusters, measure their lifetime statistics, and calculate droplet settling and relative velocities conditioned to the inclusion in clusters.

Dynamic Intermittency in Discrete Erodible Bed Avalanches

Arran, Matthew
(University of Cambridge, DAMTP, Cambridge, United Kingdom)

In a variety of geophysical and industrial contexts, from the slip faces of sand dunes to the filling of grain silos, a slow influx of particles results in discrete avalanching on an erodible bed. Experiments were conducted to investigate the statistics of avalanche events in this regime, in a channel of length 2m, width 5cm, with an erodible bed of depth 10cm developed on a rough base. Dynamic intermittency was found between episodes of quasi-periodic behaviour and episodes of irregular avalanches. Properties of and minimal models for each mode are described, and links are drawn to the theory of phase transitions.

From collisional to turbulent-collisional suspensions

Berzi, Diego
(Politecnico di Milano, Civil and Environmental Engineering, Milano, Italy)

tba

Bewley, Gregory
(Max Planck Institute for Dynamics and Self-Organization, Bodenschatz Abteilung, Göttingen, Germany)

tba

Bodenschatz, Eberhard
(MPI for Dynamics and Self-Organization, Dept. Fluid Dynamics, Pattern Formation and Biocomplexity, Goettingen, Germany)

On the modelling of unsteady debris flow processes using transparent soil

Bowman, Elisabeth
(University of Sheffiled, University of Sheffield, Dept. Civil & Structural Engineering, Mappin St., Sheffield, United Kingdom)

Stability of alternate bars and oblique dunes

Colombini, Marco
(Università di Genova, Dipeartimento di Ingegneria Civile, Chimica e Ambientale - DICC, Genova, Italy)

Weakly nonlinear analysis of river bed forms

Colombini, Marco
(Università di Genova, Dipeartimento di Ingegneria Civile, Chimica e Ambientale - DICC, Genova, Italy)

Two-fluid formulation for turbulent cloud boundaries

de Lozar, Alberto
(Max-Planck-Institut für Meteorologie, Turbulent Mixing Processes in the Earth System, Hamburg, Germany)

Morphodynamics of a sediment bed under a perturbed oscillating flow inside a cylinder

Duran Matute, Matias
(Eindhoven University of Technology, Department of Applied Physics, Netherlands)

Experimental results on the morphodynamics of a sediment bed under a perturbed oscillating flow inside a cylinder will be presented. The cylinder is filled with a thin layer of translucent plastic granules and water, and it is placed on top of an oscillating/rotating table. The table is set to oscillate with a main sinusoidal signal plus a perturbation (a second sinusoidal signal or background rotation). The bed evolution is measured in real time using a light attenuation technique. The bed remains flat close to the center of the cylinder, and ripples form at outer radii. In general, the bed morphology depends in a complex way on the parameters of the problem. This is explained by analyzing the dependence of the flow itself on the parameters of the problem.

Turbulent suspension capacity of particles near the base of geophysical flows.

Eggenhuisen, Joris
(Universiteit Utrecht, Earth Sciences, Netherlands)

Time-dependent measurements for incipient bed load discharge on shallow open channel flows

Fiorot, Guilherme
(insa de Rennes, LGCGM, Rennes, France)

Among all landscape natural mechanisms, runoff has particular importance. Such phenomenon and the soil erosion that often is related leads to pollutant transport and formation of sediments basins, consequences directly felt by societies. Despite their low discharge, such thin sheet flow of water has high erosional capacity, transporting inert and cohesive materials from up hills to intermediary parts of watersheds and to rivers. These flows and the sediment transport have been largely explored from many mechanical approaches, showing satisfactory predictions when assuming steady and permanent regime. Nevertheless, the non-stationary aspect of the sediment transport, i.e. particles entrainment due to a non-stationary shear stress, is yet to be fully understood. In this work, we present an open channel experiment which was designed for simulating runoff flow over a mobile bed. A measurement system is here presented and used to inspect the solid discharge of particles in time. An horizontal sand trap is used to capture images from eroded sediments which are recorded through high-speed camera and processed afterwards. PTV methodology is followed and sediment discharge is computed. Hydraulic properties of flow are qualitatively and quantitatively studied to determine the flow parameters that should be used to identify fluctuating properties of sediment transport. Results from a series of experiments is showed. Analysis is performed based on fluctuation components at incipient movement conditions (i.e. friction velocity is close to the threshold value).

Snow avalanches - measurement and back calculation

Fischer, Jan-Thomas
(Austrian Research Centre for Forests, Natural Hazards, Innsbruck, Austria)

Entrainment processes

Fraccarollo, Luigi
(Università di Trento, 0, DICAM, Trento, Italy)

Droplet growth aspects: caustics and instabilities

Govindarajan, Rama
(Tata Institute of Fundamental Research, TIFR Centre for Interdisciplinary Sciences (TCIS), Hyderabad, India)

The talk will be in two parts.

In the first part, it will be discussed how droplets which start out within a critical distance of a vortex can participate in sling caustics. Such droplets have a greater opportunity for collisions with other droplets. Using a model vortical flow, and a prescription that all colliding droplets will coalesce, we will estimate how sling caustics contribute to the droplet size distribution. Collaborators: S Ravichandran, P Deepu, Samriddhi Sankar Ray.

In the second part, instabilities/ stabilisation due to the density variations created by condensation/ evaporation will be discussed. Collaborators: S Ravichandran, Harish Dixit, Eckart Meiburg.

Erosion–deposition waves in shallow granular free-surface flows

Gray, Nico
(The University of Manchester, School of Mathematics, Manchester, United Kingdom)

Debris flows can spontaneously develop regular large-amplitude surge waves that are interspersed by periods in which the channel fill is completely stationary. These are important because each individual surge is much more destructive than a steady uniform flow with the same mass flux. In this paper small-scale experiments that exhibit similar behaviour are described. The flow consists of carborundum particles that flow down a rough inclined chute covered with a static erodible layer of the same grains. For inflow conditions close to the minimum depth required for steady uniform flows to exist, small disturbances are unstable, creating waves that rapidly coarsen and grow in size. As the waves become sufficiently large, the troughs between the wave crests drop below a critical thickness and come to rest. A series of steadily travelling waves develop which erode the static layer of particles in front of them and deposit grains behind them, to form a layer that is again stationary. This is, in turn, re-eroded and deposited by the next wave. We term these wa
ves granular erosion–deposition waves. Although erosion and deposition problems are notoriously difficult, a simple model is developed which uses a depth-averaged version of the μ(I)-rheology and Pouliquen and Forterre's extended friction law. The viscous dissipation combines with dynamic, intermediate and static friction regimes to generate finite-length waves with static and mobile regions. The existence of stationary layers fundamentally distinguishes erosion–deposition waves from granular roll waves, which form in slightly deeper flows and are always completely mobilized. Numerical simulations show that the system of equations is able to model both erosion–deposition waves and granular roll waves. Moreover, the computed wave amplitude, wavespeed and coarsening dynamics are in good quantitative agreement with experiments.

The erosion of granular beds under the action of fluid shearing flows

Guazzelli, Elisabeth
(CNRS Aix-Marseille Univ., IUSTI, Marseille, France)

The erosion of granular beds under the action of fluid shearing flows is a problem which has been continuously studied and discussed for over a century. This phenomenon is indeed encountered in a wide range of processes of important relevance in nature or industry such as sediment transport in rivers or oceans and slurry transport in the mining and petroleum industry.

We experimentally investigate the mobile layer of a granular bed composed of spherical particles in a pipe flow. We discuss two fundamental aspects: incipient motion of the bed and sediment transport by focusing on the determination of the particle flux. A two-phase continuum model having a frictional rheology to describe particle-particle interactions can capture most of the experimental observations. Rheological constitutive laws for the dense granular suspension are discussed.

This work has been done in collaboration with P. Aussillous, J. Chauchat, M. Medale, M. Ouriemi, M. Paihla, Y. Peysson

Collisions and relative velocities in turbulent aerosols

Gustafsson, Kristian
(University of Gothenburg, Physics, Gothenburg, Sweden)

Flow induced compaction of deformable porous media

Hewitt, Duncan
(University of Cambridge, Department of Applied Mathematics and Theoretical Physics, Cambridge, United Kingdom)

Bed load transport dynamics near the inset of motion

Heyman, Joris
(Institut de Physique de Rennes, Milieux Divisés, France)

In this talk, we will highlight some of the peculiar characteristics of weak bed load transport in water, both theoretically and experimentally. We will focus on the particular case of flows over steep slopes (>2%) transporting large and heavy particles (Stokes number larger than 1000) close to the incipient motion threshold. 8~km of particle trajectories were recorded in an experimental flume at an high resolution. Among other features, the data reveal that bed load particles deposit according to a trapping mechanism, reminiscent of hysteresis observed in dry granular flows.

Segregation: kinetic theory and a mixture model

Hill, Kimberly
(University of Minnesota, St. Anthony Falls Laboratory, Department of Civil, Environmental, and Geo- Engineering, Minneapolis, USA)

Flows of fluidised particles

Hogg, Andrew
(University of Bristol, School of Mathematics, Bristol, United Kingdom)

A Turbulence-resolving Eulerian Two-Phase Model for Coastal Sediment Transport Applications

Hsu, Tian-Jian
(University of Delaware, University of Delaware, Civil and Environmental Engineering, Newark, USA)

Tentative: Why do some snow avalanches not stop where they should?

Issler, Dieter
(Norwegian Geotechnical Institute, Natural Hazards, Snow and Rock Avalanches, Oslo, Norway)

A Two-Phase Continuum Theory for Windblown Sand

Jenkins, James Thomas
(Cornell University, Undergraduate Admissions Office , Civil and Environmental Engineering, Ithaca, USA)

Longitudinal transport in multi-phase particulate flows

Johnson, Chris
(University of Manchester, School of Mathematics, Manchester, United Kingdom)

Large eddy simulation of turbulence and transport processes in riverine and marine systems under flood conditions

Khosronejad, Ali
(University of Minnesota, St. Anthony Falls Laboratory, Minneapolis, USA)

Resilience of in-land and off-shore infrastructures to extreme flood events is one of the most important factors in sustainable design of these structures. Environmental impact of flood events in terms of the contamination and pollution transport in marine and riverine system is another important concern of societies in the current climate change era. During flood events, bed morphology of large rivers and coastal areas particularly demonstrate a complex and highly dynamics response. Such intricate and dynamic responses need to be well understood and predicted in order to have a reliable design. In this study we employed the Virtual Flow simulator (VFS-Rivers) model of St. Anthony Falls Laboratory to carry out fully coupled flow and morphodynamic simulations of flood events in a reach of Mississippi River to investigate the effect of flood flow on the scour depth near and around bridge piers.
In another application, we employ the VFS-Rivers model to simulate the turbulent flow and conservative solute transport in a field-scale stream, which is about 140m long, 3m wide, and 20cm deep. The numerical study was followed by a complete field campaign to measure the flow and solute concentration throughout the channel. The simulation results for the time series of the solute concentration at different locations along the stream are in a good agreement with the field measurements.
We also present herein our coupled flow and morphodynamics simulation results to investigate the underlying mechanisms in the formation and evolution of sand waves under infinite (transverse dunes) and finite (barchans dunes) sand supply.
The simulation strategy we employed in this work illustrates a successful application of high-performance computing and simulation-based engineering science in hydraulic engineering research.

Velocity pulsations in continuous turbidity currents – observations from the field, laboratory experiments and Direct Numerical Simulations

Kostaschuk, Ray
(Simon Fraser University, Geography, Garden Bay, Canada)

Continuous turbidity currents in Lillooet Lake, Canada, and Xiaolangdi Reservoir, China, are sustained by sediment-laden river inflow and characterized by velocity ‘pulsing’. These pulses have been attributed to processes acting along the plunge line where the river enters the receiving water body and to interfacial waves generated at the surface of the continuous flows. Laboratory experiments and two-dimensional Direct Numerical Simulation (DNS) of gravity currents show that K-H instabilities and their amalgamation play an important role in pulsing. In the field, Rayleigh–Taylor instability which, together with the momentum of the flow as it enters the lake, may produce a shift in the position of lobes along the plunge line and hence pulsing underflows. Both Kelvin-Helmholtz and Holmboe waves are also consistent with pulsing in natural flows. The laboratory experiments and DNS generate flows that are similar to field currents proximal to the river outlet, but the much larger inertia of field flows sustains a remarkable distal extent of coherent pulses that is not replicated in the laboratory or in the DNS simulations.

Analytical mesoscale modeling of aeolian sand transport

Kroy, Klaus
(Universität Leipzig, Institut für Theoretische Physik, Fakultät für Physik und Geowissenschaften, Leipzig, Germany)

The mesoscale structure of aeolian sand transport plays a crucial role for the understanding and control of a variety of natural phenomena in planetary and Earth science. We analyze it beyond the mean-field level, based on the conservation laws and kinematics governing the grain-scale physics. Analytical predictions for the height-resolved

sand flux and other important mesoscale characteristics of the aeolian transport layer are derived. Their remarkable agreement with a comprehensive compilation of field and wind tunnel data suggests that the essential mesoscale physics is robustly captured by the coarse-grained analytical model. It also reveals that certain widely accepted experimental procedures are prone to systematic measurement errors, and new ways to avoid them.

Granular hydrodynamics

Kumaran, V.
(Indian Insitute of Science, Department of Chemical Engineering, Bangalore, India)

Particle dynamics and turbulence modification in a turbulent gas-particle flow

Kumaran, V.
(Indian Insitute of Science, Department of Chemical Engineering, Bangalore, India)

An analytical model for dense suspensions

La Ragione, Luigi
(Politenico di Bari, Dipartimento di Ingegneria Civile e Ambientale, Bari, Italy)

We propose an analytical model for the determination of the microstructure and stresses in a sheared suspension that consists of a dense monolayer of identical spheres in a viscous fluid. We calculate the anisotropy in the orientational distribution of spheres, associated with a short-range repulsive force assumed to act between the spheres, and a particle pressure and normal stress difference that result from this anisotropy. The microstructure and stresses are similar to those measured in Stokesian dynamics simulations.

The evolution of segregation in dense inclined flows of binary mixtures of spheres

Larcher, Michele
(University of Trento, Civil, Environmental and Mechanical Engineering, Trento, Italy)

We consider the evolution of particle segregation in collisional flows of two types of spheres down rigid bumpy inclines in the absence of sidewalls. We restrict our analysis to dense flows and use an extension of kinetic theory to predict the concentration of the mixture and the profiles of mixture velocity and granular temperature. A kinetic theory for a binary mixture of nearly elastic spheres that do not differ by much in their size or mass is employed to predict the evolution of the concentration fractions of the two types of spheres. We treat situations in which the flow of the mixture is steady and uniform, but the segregation evolves, either in space or in time. Comparisons of the predictions with the results of discrete numerical simulation and with physical experiments are, in general, good.

Particle-induced viscous fingering

Lee, Sungyon
(Texas A&M University, Mechanical Engineering, USA)

A novel fingering instability is experimentally observed when a mixture of particles and viscous oil is injected radially into a Hele-Shaw cell. According to the Saffman-Taylor theory, the equivalent configuration without particles exhibits no fingering. To characterize this particle-induced instability, a series of experiments are conducted with varying particle volume fractions, flow rates, and gap thicknesses. The experimental results show that the onset of finering is most directly affected by the particle volume fraction: the interface is stable when the particle concentration is lower than 10% and becomes unstable with more pronouced fingering patterns with an increasing concentration. In addition, we quantify the strong dependence of fingering behavior on the particle size relative to the gap thickness. Based on the key observations, we discuss the physical mechanism that drives the instablity.

Aeolian sand sorting and megaripple formation

Lämmel, Marc
(University Leipzig, Institute for Theoretical Physics, Leipzig, Germany)

Turbulent flows drive sand along riverbeds or blow it across beaches and deserts. This seemingly chaotic process creates a whole hierarchy of structures ranging from ripple patterns over dunes to vast wavy sand seas. Moreover, by the very same process, grains are constantly being sorted, because smaller grains advance faster while their heavier companions trail behind. Starting from the grain-scale physics, we model the process of erosive sorting and show how it creates the characteristic bimodal grain size distribution that is a prerequisite for the formation of so-called megaripples. Due to the separation into small and big grains, these structures have a lot in common with their bigger relatives, aeolian sand dunes, whose physics is much better understood. This enables us to adapt a well established dune model to predict formation, morphology, and dynamics of the megarippels. Preliminary tests against field data strongly support our approach, which, moreover, provides a roadmap for future systematic field and laboratory measurements.

Granular rheology in turbulent bedload transport

Maurin, Raphael
(IRSTEA Grenoble, Saint Martin d'Hères Cedex, France)

The granular rheology in bedload transport is characteristic of the granular bed response to the fluid shear stress, and is therefore fundamental both in terms of transport rate and for upscaling in the framework of two-phase continuous modelling. Using a validated coupled fluid-Discrete Element Model for bedload transport, the granular rheology is characterized by computing locally the granular stress tensor as a function of the depth for a serie of simulation varying the Shields number, the particle diameter and the specific density. The obtained results are analyzed in the framework of the $\mu(I)$ rheology and show a collapse of the data up to unexpectedly high inertial numbers. These results, on the one hand show the relevancy in modelling the granular phase in bedload transport using the $\mu(I)$ framework, and on the other hand challenge the existing granular rheology. By pragmatically fitting the expression of the $\mu(I)$ rheology with the results obtained, a granular rheology is proposed and tested with a 1D two-phase continuous model. The latter is shown to reproduce accurately the granular depth profiles, and the classical behavior in terms of dimensionless sediment transport rate as a function of the Shields number. The proposed rheology therefore represents an important contribution for upscaling.

Particulate gravity currents with resuspension

McElwaine, Jim
(Durham University, Department of Earth Sciences, Durham, United Kingdom)

Double-diffusive Sedimentation

Meiburg, Eckart
(University of California at Santa Barbara, Department of Mechanical Engineering, Santa Barbara, USA)

Obtaining insight into turbidity currents via grain-resolving simulations

Meiburg, Eckart
(University of California at Santa Barbara, Department of Mechanical Engineering, Santa Barbara, USA)

Mixing dynamics of turbidity currents interacting with complex seafloor topography

Nasr-Azadani, Mohamad
(University of California Santa Barbara, Mechanical Engineering, Santa Barbara, USA)

Quantifying the influence of grainfall on the avalanche dynamics of an aeolian barchan dune

Nield, Jo
(University of Southampton, Geography and Environment, Southampton, United Kingdom)

details to follow

Model of the saltation transport by Discrete Element Method coupled with wind interaction

Oger, Luc
(University of Rennes 1, UMR CNRS 6251, Institut de Physique de Rennes, Rennes Cedex, France)

The Physical Basis of the Shields Curve

Ouellette, Nicholas
(Stanford University, Civil and Environmental Engineering, Stanford, USA)

Hydrodynamic erosion and sediment transport play a key role in shaping landscapes on both short and long timescales. But erosion is a tremendously complex problem, involving the coupling between turbulent flow, sediment transport, and the mechanics of granular media, and so current models lack predictive capability for all but the simplest situations. Although there is general consensus that better models are needed, there is little agreement as to which features of this high-dimensional problem are essential for making predictions. Here, we focus on the specific question of the nature of the transition from a static granular bed to the bedload transport of grains. I will present the results of a simple numerical model that suggest that the answer to this question depends on the direction of the transition, such that the onset of bed motion is controlled by different physics from the cessation of motion. In particular, I will argue that onset is determined primarily by the structure of the granular bed, while cessation is dominated by the fluid mechanics. I will also present some preliminary results from laboratory experiments aimed at validating these conclusions.

Relaxation Processes in Aeolian Transport

Ould El Moctar, Ahmed
(University of Nantes, Polytech Nantes, Nantes, France)

Two-phase model applied to submerged jet impinging onto a granular bed

Pham-Van-Bang, Damien
(Laboratory for Hydraulics Saint-Venant, c/o EDF R&D, Chatou, France)

This talk deals with dimensions of eroded craters due to the impingment of a submerged and vertical jet onto a granular bed. This flow configuration is used for water injection dredging technology and for in situ evaluation of erodability of soils. Here we investigate both experimentally and numerically the process in 2D XZ. A special development to handle with the solid/liquid transition for the granular phase is presented to improve the two-fluid initial model. Close agreement with 2D data is obtained.

Experimental evidence of an additional momentum flux mechanism induced by the bed variability.

Revil-Baudard, Thibaud
(Karlsruher Institut für Technologie, Institute for hydromechanics, Karlsruhe, Germany)

High resoluted and colocated measurements of velocity and concentration have been collected in intense sediment transport experiments conducted in open channel turbulent flows. This dataset allows to highlight a strong coupling between the large-scale turbulent structures and the bed dynamic. The comparison between the superficial and intrinsic shear stress profiles shows that this coupling induces an additional shear stress in the near bed region as suggested by Nikora et al 2013.
It is also shown that the law of the wall and the Rouse profile hold to describe the velocity and concentration profiles in the suspension layer. However, the von Karman parameter in the mobile bed experiment significantly differs from its clear water value (\kappa=0.4) and the Schmidt number is much lower than 1 (\sigma_s=0.4). An explanation for these features is provided from a statistical analysis of the turbulent velocity fluctuations.
Finally, a qualitative analysis of the measured lag velocities between the fluid and the particles is suggested.

Wave-Induced Pressure Under an Internal Solitary Wave and Its Impact at the Bed

Rivera, Gustavo
(Cornell University, Ithaca, Civil and Environmental Engineering, Ithaca, USA)

The bottom boundary layer (BBL) under a mode-1 internal solitary wave (ISW) of depression propagating against an oncoming model barotropic current is examined using 2-D direct numerical simulation based on a spectral multidomain penalty method model. Particular emphasis is placed on the diffusion into the bed of the pressure field driven by the wake and any near-bed instabilities produced under specific conditions. To this end, a spectral nodal Galerkin approach is used for solving the diffusion equation for the wave-induced pressure. At sufficiently high ISW amplitude, the BBL undergoes a global instability which produces intermittent vortex shedding from within the separation bubble in the lee of the wave. The potential for bed failure upon the passage of the ISW trough and implications for resuspension of bottom particulate matter are both discussed in the context of specific sediment transport models.

Particles breaking out of liquids

Turnbull, Barbara
(University of Nottingham, Faculty of Engineering, Nottingham, United Kingdom)

Debris flows are mixtures of water with sediments, small stones and large boulders that can flow down hillsides with high speeds. Just as there is a rich diversity in their component parts, there is a rich diversity in their dynamics. In this talk, some simplistic chute experiments of debris flows, deigned to achieve Froude number and particle Reynolds number similarity with field scale events, are introduced. In these, mono- and polydispere mixtures of glass marbles in water or glycerol were released from behind a lock down a 27 incline, with glass marbles fixed to the surface. By oversampling high speed imaging of the flows, it was possible to delineate areas of the flow with different character - i.e. a shearing quasi-steady core of the flow and an intermittent and collisional cloud around it. Pore pressure measurements at the base show that the fronts of the flows are dry, even in mono-disperse cases. Thus, these experimental flows exhibit a 'snout-body architecture' reminiscent of more complex field scale debris flows, but with no obvious segregation mechanism to achieve it.
From these observations, we asked ourselves how the quasi-steady core and the intermittent collisional regions are connected - in particular, what effect does a fluid surface have on the inertial particles within the flow? To start understanding this, we carried out simple experiments on a single ball-bearing, winched out of a bath of water. For order 10mm particles winched at speeds in the range 0.2-0.7 m/s the particles remained connected with the fluid over several particle diameters from passing through the free surface. A scaling analysis indicated that the timescale of this connection was determined by the flow of the think film draining from the ball.

Saltation on Earth and extraterrestrial atmospheres

Valance, Alexandre
(Université de Rennes 1, Campus Beaulieu, Bat 11A, Rennes Cedex, France)

Growth of rain droplets in exotic environments: diffusion, sedimentation, and droplet collection

Vollmer, Jürgen
(Georg-August-Universität Göttingen, Mathematisches Institut, Göttingen,)

The fine-grained structure of avalanches and sand dunes

Vriend, Nathalie
(University of Cambridge, Centre for Mathematical Sciences, Department of Applied Mathematics and Theoretical Physics (DAMTP), Cambridge, United Kingdom)

Understanding rainfall: the role of turbulence and large deviation theory

Wilkinson, Michael
(The Open University, Mathematics and Statistics, Milton Keynes, United Kingdom)

Understanding the mechanism of rainfall from ice-free cumulus clouds is a challenging problem, because of the low rate of collisions between microscopic water droplets settling under gravity.
It has been proposed that turbulence may facilitate collisions between droplets. I shall describe the mechanisms for enhancement of collision rates due to turbulence, and the latest DNS results quantifying this mechanism. It appears to be insufficient to explain rainfall.

An alternative approach is required. Recently, I showed that large deviation theory can explain how raindrops result from a succession of unusually rapid collisions. The onset of rain showers can be surprisingly rapid, much faster than the mean time required for a single collision.

The work on turbulent enhancement of collision rates involved various collaborations, primarily with Alain Pumir, Bernhard Mehlig, Vlad Bezuglyy, and Michel Vosskuhle.
The talk is based upon a review article, Collisional Aggregation due to Turbulence, A. Pumir and Michael Wilkinson, Ann. Rev. Cond. Matter Phys., in press, and a paper Large Deviation Analysis of Rapid Onset of Rain Showers, M. Wilkinson, Phys. Rv. Lett. 116, 018501, (2016).