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14. ABSTRACT

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a. REPORT	b. ABSTRACT	c. THIS PAGE			David Richter
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as of 26-Aug-2022

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Report Date: 31-Mar-2022   Date Received: 26-Aug-2022
Final Report for Period Beginning 15-Sep-2017 and Ending 31-Dec-2021
Title: Dust, sand, and turbulence: Transport and feedback in the near-surface environment
Begin Performance Period: 15-Sep-2017   **End Performance Period:** 31-Dec-2021
Report Term: 0-Other
Submitted By: David Richter   Email: drichte2@nd.edu
Phone: (574) 631-4839
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STEM Degrees: 4   **STEM Participants:** 4

Major Goals: A key challenge in modeling dust and sand transport throughout the atmosphere lies in the fundamental particle-turbulence interactions which take place in the lower atmospheric boundary layer. The subsequent airborne spatial distributions, lofting and settling mechanisms, and effects on the surface layer winds remain severely understudied and inhibit prediction in Army-relevant regions of the boundary layer. Phenomena such as preferential concentration, where particles dynamically collect in certain regions of the flow, and two-way coupling, where the suspension of the particles modifies the surrounding turbulent motions, can cause sharp deviations of near-surface concentrations and fluxes from those predicted by traditional, similarity-based parameterizations of passive scalars. While these mechanisms have been studied in numerous engineering contexts, these are typically restricted to low Reynolds numbers (i.e., low degrees of scale separation), and therefore much remains unknown about particle transport and feedback in systems with Reynolds numbers relevant to the atmospheric surface layer.

The overarching goal of the project is to achieve a predictive understanding of dust and sand transport in the turbulent boundary layer, in order to start bridging the gap between the existing knowledge on particle-turbulence interactions, which have been traditionally investigated at the micro-scale, and atmospheric dynamics relevant at the macro-scale. The overall strategy is to combine detailed laboratory observations of turbulence/dust interaction with large-scale and high-resolution numerical simulations to inform near-surface transport parameterizations which are crucial for accurately connecting saltation rates and airborne dust/sand concentrations – something which continues to plague surface dust emission models.

Within this overall structure, there are several specific sub-goals of the project: (1) set up and perform particle-laden experiments at the University of Minnesota (UMN), collecting data on particle/fluid velocities, fluxes, and concentration statistics, and carry out corresponding simulations at the University of Notre Dame (UND) to verify and compare; (2) identify the key transport mechanisms which control the airborne lifetime of sand and dust grains, as well as their vertical distribution; (3) quantify the effects of two-way coupling, where the carrying of particles modifies the turbulence which is responsible for its own suspension, and identify the threshold concentration at which this becomes important; (4) measure and predict the influence of suspended dust and sand on surface-air exchange of momentum.

PI Coletti oversees the experimental component of the work, utilizing facilities housed at UMN. A large, temperature-controlled wind tunnel capable of air speeds up to 100 km/h and seeded with size-selected solid particles is being used to measure vertical concentration profiles, clustering characteristics, and other critical quantities associated with turbulent transport, using particle imaging at multiple resolutions. A unique “turbulence chamber" is also being utilized to measure flux-profile relationships in a highly controlled setting. PI Richter is simultaneously guiding the numerical aspects of the work, using the experiments as a source of validation. A series of fundamental, high-resolution direct numerical simulations (DNS) are being performed at unprecedented scales, and will be accompanied by a complimentary suite of large eddy simulations (LES) of the wind tunnel and atmospheric surface layer to probe dust distribution and feedback within high Reynolds number boundary layers. The combined effort will lay the groundwork for more accurate dispersion and transport models for dust of varying size, and linking dust emission models with airborne concentrations and size distributions.

Accomplishments: Over the course of the project, a large number of accomplishments were achieved by the PIs, and have been detailed in previous reports and published manuscripts. Below is only a brief list of highlights:

- Training and multiple postdoctoral researchers (G. Wang, W. Gao, T. Berk) and partial support of 5 undergrad/grad students
- Simulation results have been used to investigate fundamental particle-turbulence interactions in turbulent wall-bounded flows, particularly including multiscale interactions that have direct relevance for modeling this behavior in the dust-laden atmosphere
- A direct comparison between particle-laden channel flow experiments and direct numerical simulations was established as a baseline verification case, which has already garnered international attention
- High-Reynolds number, particle-laden experiments were conducted in the UMN wind tunnel in unprecedented detail, uncovering behavior associated with particle clustering and vertical distribution that is essential for modeling efforts
- Experiments in homogeneous turbulence were conducted to better understand particle settling, where particle and flow velocities were measured simultaneously and where particle clusters could be identified and characterized
- Direct numerical simulations of particle-laden, wall-bounded turbulence were conducted at the highest-ever Reynolds numbers (Re = 5200) to finally achieve regimes which have direct relevance to the atmospheric surface layer. These simulations confirm the hypothesis that particles near the surface can influence turbulent motions throughout the entire atmospheric boundary layer
- Preliminary large eddy simulations have been conducted of particle-laden wall turbulence, highlighting the great difficulties involved when suspended dust influences the background flow
- New machine-learning methodologies were developed for identifying and tracking particle clusters in turbulent flows

Training Opportunities: At UND, two postdoctoral researchers were supported by the project and trained on numerical simulation techniques of dust-laden turbulence (G. Wang and W. Gao). In addition to this, multiple students were partially supported at various stages of the project, with varying degrees of involvement (T. MacMillan, B. Pettingill, K. Soto Rivas, J. Park, A. Gacevic [disrupted due to COVID]).

At UMN, the postdoctoral associate supported by this project, Tim Berk, conducted measurements of particle-laden turbulence both in the zero-mean-flow chamber and in the atmospheric wind tunnel.

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Results Dissemination: A number of publications resulted from the research performed on this project:

Mathematical modeling of inertial particle settling in wall turbulence:
Bragg, A., Richter, D.H., Wang, G., (2021) "Mechanisms governing the settling velocities and spatial distributions of inertial particles in wall-bounded turbulence", Phys Rev Fluids, 6, 064302

Detection of transient clusters in unsteady flow:
MacMillan, T., Ouelette, N., Richter, D.H., (2020) "Detection of evolving Lagrangian coherent structures: A multiple object tracking approach", Phys Rev Fluids, 5, 124401

Lagrangian coherent structures via neural networks:
MacMillan, T., Richter. D.H., (2021) "The most robust representations of flow trajectories are Lagrangian coherent structures", J. Fluid Mech, In press

Defining the limits of when inertia is important in particle settling near the wall:
Bragg, A., Richter, D.H., Wang, G., (2021) "Settling strongly modifies particle concentrations in wall-bounded turbulent flows even when the settling parameter is asymptotically small", Phys Rev Fluids, 6, 124301

The results of the non-time-resolved measurements in the zero-mean-flow chamber were published in:
Berk, T., Coletti F., (2021) "Transport of inertial particles in high-Reynolds number turbulent boundary layers", J. Fluid Mech, 903, A18.

The results of the study in the zero-mean flow turbulence chamber were published in:
Berk T., Coletti F., (2021) "Dynamics of small heavy particles in homogeneous turbulence: a Lagrangian experimental study", J Fluid Mech, 917, A47.

Modeling particle transport in the boundary layer:
Park, H., Sherman, T., Freire, L., Wang, G., Bolster, D., Peng, X., Sorooshian, A., Reid, J., Richter, D.H., (2020) "Predicting vertical concentration profiles in the marine atmospheric boundary layer with a Markov chain random walk model", Journal of Geophysical Research: Atmospheres, 125, e2020JD032731

Effect of domain size on particle-laden turbulence simulations:
Wang, G., Park, H., Richter, D.H., (2020) "Effect of computational domain size on inertial particle one-point statistics in open channel flow", Int J. of Multiphase Flow, 125, 103195

Non-time-resolved measurements in the zero-mean-flow chamber:
Petersen A., Baker L., Coletti F. (2018) "Experimental study of clustering and settling of inertial particles in homogeneous turbulence", J. Fluid Mech., 864: 925-970

Results from high-Reynolds number DNS on multiscale particle-turbulence interaction:
Wang, G. and Richter, D.H. (2019) "Two mechanisms of modulation of very-large-scale motions by inertial particles in open channel flow", J. Fluid Mech., 868, 538-559

Results from high-Reynolds number DNS on spectral filtering and particle transport:
Wang, G. and Richter, D.H., "Transport and two-way coupling effect of inertial particles by large-scale and very-large-scale motions in turbulence", Physical Review Fluids, 5, 44307

Results from the preliminary comparison of DNS with channel flow experiments at UMN:
Wang, G., Fong, K.O., Coletti, F., Capecelatro, J., and Richter, D.H., ("Inertial particle velocity and distribution in vertical turbulent channel flow: a numerical and experimental comparison", Int. J. of Multiphase Flow, 120, 10305

The results of a preliminary study of particle-laden wall-bounded turbulence were published in:
Fong K.O., Amili O., Coletti F. (2019) "Velocity and spatial distribution of inertial particles in a turbulent channel flow", J. Fluid Mech., 872, 367-406.

Particle modulation of near-wall motions:
Wang, G., Richter, D.H., (2019) "Modulation of the turbulence regeneration cycle by inertial particles in planar Couette flow", J. Fluid Mech, 861, 901-929

Between both groups, the results have also been disseminated a multiple conferences, including the annual American Physical Society Division of Fluid Dynamics meetings and the American Geophysical Union's annual meetings. Results gained from this project have also been used in multiple invited talks given by both PIs at institutions across the globe.

Honors and Awards: Over the time period of this project, PI Richter received both the Rev. Edmund P. Joyce, C. S.C. Award for Excellence in Teaching at the University of Notre Dame and the Notre Dame College of Engineering Outstanding Teaching Award in May 2021. He was also promoted to Associate Professor with tenure in July 2019. PI Coletti was also promoted to Associate Professor, and was also awarded the McKnight Land-Grant Professorship (2018-2020), from Office of the Executive Vice President and Provost, University of Minnesota

Protocol Activity Status:

Technology Transfer: The UMN zero-mean flow chamber was used in another DoD-funded project: "Two-way coupling in particle-laden gas turbulence", funded by Army Research Office (Fluid Dynamics Division) for $471,980, PI: Coletti, 08/01/2018 - 07/31/2021. Program Manager: Dr. Matthew Munson, Email: matthew.j.munson6.civ@mail.mil

PI Richter has made multiple connections with the ARL White Sands Missile Range scientists, and will use this research to inform future work on applying it to models and observations of dust transport in the Jornada Experimental range.

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Person Months Worked: 5.00 **Funding Support:**
Project Contribution:
National Academy Member: N

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Person Months Worked: 5.00 **Funding Support:**
Project Contribution:
National Academy Member: N

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Person Months Worked: 12.00 **Funding Support:**
Project Contribution:
National Academy Member: N

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Project Contribution:
National Academy Member: N

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Project Contribution:
National Academy Member: N

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Project Contribution:
National Academy Member: N

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Project Contribution:
National Academy Member: N

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Project Contribution:
National Academy Member: N

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Person Months Worked: 2.00 **Funding Support:**
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ARTICLES:

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Journal: Journal of Fluid Mechanics
Publication Identifier Type: DOI Publication Identifier: 10.1017/jfm.2018.936
Volume: 861 Issue: First Page #:
Date Submitted: 8/9/19 12:00AM Date Published: 8/8/19 6:00AM
Publication Location:
Article Title: Modulation of the regeneration cycle by inertial particles in turbulent Couette flow
Authors: Guiquan Wang, David Richter
Keywords: particles, turbulence
Abstract: Two-way coupling direct numerical simulation is used to investigate the inertial pointwise particles effect on the turbulence modulation of the self-sustained process of coherent structures (so-called the regeneration cycle) in plane Couette flow at low Reynolds number above the onset of transition. The inertial particles show two asymptotic relations in the turbulence modulation: one is destabilized effect reinforced with increasing density ratio and the other is stabilization due to extra dissipation. We mainly focus on particles modulation of the regeneration cycle when inertial particles attenuate the turbulence. During the cycle, the particle spatial distribution relates to a response time scaled by the turnover time of large scale vortices, and the turbulent kinetic energy of particulate phase is highly determined by their presence in different coherent structures (large scale vortices or large scale streaks). The periodic character of whole regenerati
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Volume: 864 Issue: First Page #:
Date Submitted: 8/27/19 12:00AM Date Published:
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Article Title: Experimental study of inertial particles clustering and settling in homogeneous turbulence
Authors: Alec Petersen, Lucia Baker, Filippo Coletti
Keywords: particles, turbulence, settling
Abstract: We study experimentally the spatial distribution, settling, and interaction of sub- Kolmogorov inertial particles with homogeneous turbulence. Utilizing a zero-mean-flow air turbulence chamber, we drop size-selected solid particles and study their dynamics with particle imaging and tracking velocimetry at multiple resolutions. The carrier flow is simultaneously measured by particle image velocimetry of suspended tracers, allowing the characterization of the interplay between both the dispersed and continuous phases. The turbulence Reynolds number based on the Taylor microscale ranges from Re? ? 200 - 500, while the particle Stokes number based on the Kolmogorov scale varies between St? = O(1) and O(10). Clustering is confirmed to be most intense for St? ? 1, but it extends over larger scales for heavier particles.
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Journal: Journal of Fluid Mechanics
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Volume: 868 Issue: First Page #:
Date Submitted: 8/9/19 12:00AM Date Published: 8/8/19 6:00AM
Publication Location:
Article Title: Two mechanisms of modulation of very-large-scale motions by inertial particles in open channel flow
Authors: Guiquan Wang, David Richter
Keywords: particles, turbulence
Abstract: Very-large-scale motions (VLSMs) and large-scale motions (LSMs) coexist at moderate Reynolds numbers in a very long open channel flow. Direct numerical simulations two-way coupled with inertial particles are analysed using spectral information to investigate the modulation of VLSMs. In the wall-normal direction, particle distributions (mean/preferential concentration) exhibit two distinct behaviours in the inner flow and outer flow, corresponding to two highly anisotropic turbulent structures, LSMs and VLSMs. This results in particle inertia's non-monotonic effects on the VLSMs: low inertia (based on the inner scale) and high inertia (based on the outer scale) both strengthen the VLSMs, whereas moderate and very high inertia have little influence. Through conditional tests, low- and high-inertia particles enhance VLSMs following two distinct routes.
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Journal: Journal of Fluid Mechanics
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Volume: 872 Issue: First Page #:
Date Submitted: 8/27/19 12:00AM Date Published: 8/8/19 4:00PM
Publication Location:
Article Title: Velocity and spatial distribution of inertial particles in a turbulent channel flow
Authors: Kee Onn Fong, Omid Amili, Filippo Coletti
Keywords: particles, turbulence, experiments
Abstract: We present experimental observations of the velocity and spatial distribution of inertial particles dispersed in turbulent downward flow through a vertical channel at multiple friction Reynolds numbers. The working fluid is air laden with size-selected glass microspheres. In the more dilute regime, the particle concentration profile shows near-wall and centreline maxima compatible with a turbophoretic drift down the gradient of turbulence intensity; the particles travel at speed similar to that of the unladen flow except in the near-wall region; and their velocity fluctuations generally follow the unladen flow level over the channel core, exceeding it in the near-wall region. The denser regime presents substantial differences in all measured statistics: the near-wall concentration peak is much more pronounced, while the centreline maximum is absent; the mean particle velocity decreases over the logarithmic and buffer layers.
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Volume: 120 Issue: First Page #: 103105
Date Submitted: 9/12/19 12:00AM Date Published:
Publication Location:
Article Title: Inertial particle velocity and distribution in vertical turbulent channel flow: a numerical and experimental comparison
Authors: Guiquan Wang, Kee Onn Fong, Filippo Coletti, Jesse Capecelatro, David Richter
Keywords: particle-laden turbulence, direct numerical simulation, experiment
Abstract: This study is concerned with the statistics of vertical turbulent channel flow laden with inertial particles for two different volume concentrations. Two independent direct numerical simulation models utilizing the point-particle approach are compared to recent experimental measurements, where all relevant nondimensional parameters are directly matched. While both numerical models are built on the same general approach, details of the implementations are different, particularly regarding how two-way coupling is represented. At low volume loading, both numerical models are in general agreement with the experimental measurements, with certain exceptions near the walls for the wall-normal particle velocity fluctuations. At high loading, these discrepancies are increased, and it is found that particle clustering is overpredicted in the simulations as compared to the experimental observations. Potential reasons for the discrepancies are discussed.
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Date Submitted: 7/20/20 12:00AM Date Published: 4/1/20 4:00AM
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Article Title: Multiscale interaction of inertial particles with turbulent motions in open channel flow
Authors: Guiquan Wang, David Richter
Keywords: particles, turbulence
Abstract: Direct numerical simulations two-way coupled with inertial particles are used to investigate the particle distribution and two-way coupling mechanisms in turbulent open channel flow. In particular, the relationship between low- and high-inertia particles and the distinct large-scale motions (LSMs) and very-large-scale motions (VLSMs) which are characteristic of high-Reynolds-number, wall-bounded turbulence are examined. To do this, two methods of spatial filtering are applied to isolate the effects of LSMs versus VLSMs and separately analyze their interactions with inertial particles. One method of filtering the VLSMs from the flow is via artificial domain truncation, which alters the mean particle concentration profile and particle clustering due to the absence of VLSMs. The second method uses on-the-fly low- and high-pass filtering on the velocity field seen by the particles, so that as the simulation progresses the particles can only couple with certain scales of the flow.
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Publication Location:
Article Title: Effect of computational domain size on inertial particle one-point statistics in open channel flow
Authors: Guiquan Wang, Hyungwon John Park, David H. Richter
Keywords: particles, turbulence
Abstract: Effects of the computational domain size on inertial particle one-point statistics are presented for direct numerical simulations of turbulent open channel flow at a moderate Reynolds number, which are seeded with two-way coupled particles at low volume concentration (less than 1 . 5 × 10 ?3 , for such particle load the one-way coupled particles scheme is also valid). Particle one-point statistics across a wide range of Stokes numbers for a small domain (which captures only one or two large-scale motions (LSMs) in the inner layer) and a medium domain (which captures only one or two very large-scale motions (VLSMs) in the outer layer), are compared with those from a reference large domain. Although in single-phase flow the medium domain size simulation reproduces the same fluid one-point statistics as those in a large domain size, in particle-laden flow, comparisons show certain discrepancies in the particle one- point statistics.
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Article Title: Transport of inertial particles in high-Reynolds number turbulent boundary layers
Authors: Tim Berk, Filippo Coletti
Keywords: turbulence, particles, wind tunnel experiments
Abstract: We investigate the transport of size-selected particles suspended in turbulent boundary layers at friction Reynolds numbers up to 19000. We use microscopic glass spheres in air, spanning a wide range of viscous Stokes numbers, St = 18–870. These are imaged simultaneously with the flow tracers, and particle image and tracking velocimetry are used to measure the two-phase flow along a wall-normal plane in the logarithmic region. The air flow statistics are not altered by the particles at the present mass loading. In comparison to the classic equilibrium solution, the particle concentration profiles display weaker wall-normal gradients. This is shown to be an effect of particle inertia: this manifests itself through different mechanisms in different strata of the flow, and the effects on the concentration are captured by a three-layer parameterization of the profile. The present findings highlight how high-Reynolds number features of turbulent boundary layers impact the transport of dust.
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Publication Location:
Article Title: Dynamics of small heavy particles in homogeneous turbulence: a Lagrangian experimental study
Authors: Tim Berk, Filippo Coletti
Keywords: particles, settling
Abstract: We investigate the behaviour of microscopic heavy particles settling in homogeneous air turbulence. The regimes are relevant to the airborne transport of dust and droplets: the Taylor-microscale Reynolds number is, the Kolmogorov-scale Stokes number is and the Kolmogorov acceleration is comparable to the gravitational acceleration (i.e. the Froude number). We use high-speed laser imaging to track the particles and simultaneously characterize the air velocity field, resolving all relevant spatiooral scales. The role of the flow sampled by the particles is spotlighted. In the present range of parameters, the particle settling velocity is enhanced proportionally to the velocity scale of the turbulence. Both gravity and inertia reduce the velocity fluctuations of the particles compared to the fluid; while they have competing effect on the particle acceleration, through the crossing trajectories and inertial filtering mechanisms, respectively.
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Publication Location:
Article Title: Mechanisms governing the settling velocities and spatial distributions of inertial particles in wall-bounded turbulence
Authors: A. D. Bragg, D. H. Richter, G. Wang
Keywords: particle settling, pdf methods
Abstract: We use theory and direct numerical simulations (DNSs) coupled with point particles to explore the average vertical velocities and spatial distributions of inertial particles settling in a wall-bounded turbulent flow. The theory is based on the exact phase-space equation for the probability density function describing particle positions and velocities. This allows us to identify the distinct physical mechanisms governing the particle transport, which we then examine using the DNS data and relate them to the well-known preferential sweeping mechanism in homogeneous isotropic turbulence. When the average vertical particle mass flux is zero, the averaged vertical particle velocity is zero away from the wall due to the particles preferentially sampling regions where the fluid velocity is positive, which balances with the downward Stokes settling velocity.
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Publication Location:
Article Title: Detection of evolving Lagrangian coherent structures: A multiple object tracking approach
Authors: Theodore MacMillan, Nicholas T. Ouellette, David H. Richter
Keywords: Lagrangian coherent structures, object tracking
Abstract: Recently, advances in techniques for the detection of Lagrangian coherent structures (LCSs) have driven forward understanding of kinematics and particle transport in a variety of flows. One major shortcoming of these techniques, however, is the lack of an objective procedure for identifying time scales of interest, or an ability to characterize the lives, deaths, or age of coherent structures, especially when relevant flow time scales are larger than the time scales associated with coherence. Here, we address these issues by proposing a multiple object tracking framework frequently used in video analysis to extend the use of existing LCS detection algorithms, allowing coherence time scales to be considered independently of the overall flow evolution time scale and revealing dynamics of the LCSs. Our approach enables the detection of evolving Lagrangian coherent structures, which are created and destroyed throughout the larger time scales of analysis of complex flows
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Article Title: The most robust representations of flow trajectories are Lagrangian coherent structures
Authors: MacMillan Theodore, Richter David
Keywords: Lagrangian coherent structures, particle trajectories
Abstract: What is the most robust way to communicate flow trajectories? To answer thisquestion, we employ two neural networks to respectively deconstruct (the encoder) andreconstruct (the decoder) trajectories, where information is passed between the twonetworks through a low dimensional latent space in a setup known as an autoencoder.To ensure that their communications are robust, we add noise to the coded informationpassed through this latent space. In the low-noise limit, the latent space structuresare nonspatial in nature, resembling modes of a principle component analysis (PCA).However, as the signal-to-noise ratio is decreased, we uncover Lagrangian coherentstructures as the most compact representations which still allow the decoder to accuratelyreconstruct trajectories. This relationship offers increased interpretability to both PCAand LCS analysis, and helps to bridge the gap between two methods of flow analysis
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Article Title: Settling strongly modifies particle concentrations in wall-bounded turbulent flows even when the settling parameter is asymptotically small
Authors: A. D. Bragg, D. H. Richter, G. Wang
Keywords: Settling
Abstract: We explore the role of gravitational settling on inertial particle concentrations in a wall-bounded turbulent flow. While it may be thought that settling can be ignored when the settling parameter Sv ? vs/u? is small (vs is Stokes settling velocity, u? is fluid friction velocity), we show that even in this regime the settling may make a leading order contribution to the concentration profiles. This is because the importance of settling is determined, not by the size of vs compared with u? or any other fluid velocity scale, but by the size of vs relative to the other mechanisms that control the vertical particle velocity and concentration profile. We explain this in the context of the particle mean-momentum equation, and show that in general, there always exists a region in the boundary layer where settling cannot be neglected, no matter how small Sv is (provided it is finite).
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support: **Y**

Publication Type: Journal Article Peer Reviewed: Y **Publication Status:** 1-Published
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Date Submitted: 8/26/22 12:00AM Date Published: 10/1/20 4:00AM
Publication Location:
Article Title: Predicting Vertical Concentration Profiles in the Marine Atmospheric Boundary Layer With a Markov Chain Random Walk Model
Authors: Hyungwon John Park, Thomas Sherman, Livia S. Freire, Guiquan Wang, Diogo Bolster, Peng Xian, Arm
Keywords: atmospheric boundary layer
Abstract: In an effort to better represent aerosol transport in mesoscale and global-scale models, large eddy simulations (LES) from the National Center for Atmospheric Research (NCAR) Turbulence with Particles (NTLP) code are used to develop a Markov chain random walk model that predicts aerosol particle profiles in a cloud-free marine atmospheric boundary layer (MABL). The evolution of vertical concentration profiles are simulated for a range of aerosol particle sizes and in a neutral and an unstable boundary layer. For the neutral boundary layer we find, based on the LES statistics and a specific model time step, that there exist significant correlation for particle positions, meaning that particles near the bottom of the boundary are more likely to remain near the bottom of the boundary layer than being abruptly transported to the top, and vice versa.
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support: **Y**

CONFERENCE PAPERS:

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Conference Name: 11th International Symposium on Turbulence and Shear Flow Phenomena
Date Received: 09-Aug-2019 Conference Date: 02-Aug-2019 Date Published: 02-Aug-2019
Conference Location: Southampton, UK
Paper Title: Transport of inertial particles in high-Re turbulent boundary layer
Authors: Tim Berk, Filippo Coletti
Acknowledged Federal Support: **Y**

RPPR Final Report
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Publication Type: Conference Paper or Presentation **Publication Status:** 4-Under Review
Conference Name: IUTAM Symposium on Turbulent Structure and Particles-Turbulence Interaction
Date Received: 20-Jul-2020 Conference Date: 26-Jun-2020 Date Published:
Conference Location: Lanzhou, China
Paper Title: Particle settling and distribution in wall-bounded turbulence
Authors: David Richter, Andrew Bragg, Guiquan Wang
Acknowledged Federal Support: **Y**

Partners

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I certify that the information in the report is complete and accurate:
Signature: David Richter
Signature Date: 8/26/22 2:34PM

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