D6.5 Euromech Colloquium proceedings
ETC17 conference in Turin from 3rd to 6th September 2019

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Coordinator and main scientific representative of the project

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In agreement with the Project Officer of the COMPLETE project, this deliverable will not focus on Euromech Colloquium on Turbulence and Microphysics proceedings as it was first planned because the network has decided to substitute the Euromech Colloquium with the organization of the wider, ETC17 conference (17^{th} European Turbulent Conference) that was organized at Politecnico di Torino in collaboration with Università di Torino. This substitution was made because at the moment of the proposal, early 2015, the decision of the Euromech society to hold the ETC17 conference in Turin was not yet known. The chairs of ETC17 were Daniela Tordella, Coordinator of MSCA ITN – ETN COMPLETE, and Guido Boffetta from the University of Turin. The ETC17 was held in Turin, at the premises of Politecnico di Torino, from 3^{rd} to 6^{th} September 2019.

For more information on the conference, please visit its website: http://www.etc17.it/

The purpose was to organise a conference at large related to the topics of the H2020 MSCA ITN – ETN COMPLETE project. By organising the ETC17 instead of the Euromech Colloquium, the participation was vaster and topic sessions many more, thus enriching the scientific programme proposed. Euromech Colloquiums are normally organised for a very limited audience, which is in the order of 50 or 60 people. This was an excellent opportunity of dissemination of scientific content to a much broader audience that what could have been done by organising the Euromech Colloquium. We are happy to say that inside the ETC17 program, we succeeded to include 7 different topic sessions of special interest to the participants of the COMPLETE project. Specifically, there were, in total, 139 presentations, 6 of which presented by our ESRs. The topic sessions to which our ESRs participated were: Boundary Free Turbulence, Turbulent Convection, Multiphase Flows, Geophysical and Astrophysical Turbulence, Vortex Dynamics and Structure Formation, Turbulent Transport, Dispersion and Mixing, Complex and Active Particles.

Two of our ESRs, Mina Golshan (ESR13) and Shahbozbek Abdunabiev (ESR15), also helped with the on-site organisation as the conference was organised with the help of POLITO group. Here bellow all the groups of the COMPLETE project that participated to the organisation of the conference.

The ESRs who participated and/or presented during the ETC17 were:

- Mina Golshan, ESR13
- Shahbozbek Abdunabiev, ESR15 (helped with the organisation)
- Tai Wada, ESR3
- Vishnu Nair, ESR4
- Guus Bertens, ESR5
- Miryam Paredes, ESR12 (participation only)
- Moein Mohammadi, ESR9
- Emmanuel Akinlabi, ESR10

Groups of the H2020 MSCA ITN – ETN COMPLETE that participated to the ETC17 were:

- POLITO (Prof. Daniela Tordella)
- UW (Prof. Szymon Malinowski, Aleksandra Kardas)
- MPG (Prof. Eberhard Bodenschatz)
- TAU (Prof. Alex Liberzon)

- ICL (Prof. Maarten van Reeuwijk)

Teachers of the COMPLETE Training Schools that participated to the ETC17:

- Gholamhossein Bagheri
- Xu Haitao
- Paolo Luchini
- Juan Pedro Mellado
- Alain Pumir
- Jörg Schumacher

Chairs of the ETC17:
Guido Boffetta, *Università di Torino, Italy*
Daniela Tordella, *Politecnico di Torino, Italy*

Scientific secretary of the ETC17:
Miguel Onorato, *Università di Torino, Italy*

The **ETC17 Scientific Committee** was composed of:

Dan Henningson (Chair of the Scientific Committee), *KTH Mechanics, Stockholm, Sweden*

Guido Boffetta, *Dipartimento di Fisica, Università di Torino, Italy*

Colm-Cille Caulfield, *Centre for Mathematical Sciences, Cambridge, UK*

Berengere Dubrulle, *Institut Rayonnement-Matière de Saclay (Iramis), France*

Rich Kerswell, *Bristol University, School of Mathematics, UK*

Patrice Le Gal, *IRPHE-CNRS, Marseille, France*

Szymon Malinowski, *Institute of Geophysics, University of Warsaw, Poland*

Heinz Pitsch, *Institut für Technische Verbrennung, RWTH Aachen University, Germany*

Federico Toschi, *Fluid Dynamics Laboratory, Eindhoven University of Technology, The Netherlands*

Invited Speakers:

Eckart Meiburg, Mechanical Engineering, University of California, Santa Barbara, USA

Olga Shishkina, Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany

Luca Brandt, KTH Mechanics, Stockholm, Sweden

Jerry Westerweel, Technical University, Delft, The Netherlands

Nicholas Hutchins, Department of Mechanical Engineering, University of Melbourne, Australia

Sylvain Joubaud, Laboratoire de Physique, ENS Lyon Dwight Barkley, Mathematics Institute, University of Warwick, UK

Claudia Cenedese, Woods Hole Oceanographic Institution, USA

Paper topics of the ETC17:

- Acoustics of Turbulent Flows
- Instability, Transition and Control of Turbulent Flows
- Intermittency and Scaling
- Boundary Free Turbulence
- Wall Bounded Turbulence
- Fluid-structure Interaction
- Turbulent Convection
- Stratified Flows
- Rotating Flows
- Compressible Flows
- Non-Newtonian Flows
- Multiphase Flows
- Reacting Flows
- Wave Turbulence
- Wave-Turbulence Interactions
- Geophysical and Astrophysical Turbulence
- Two-dimensional Turbulence
- Turbulence, Waves and Instabilities in Plasmas
- Vortex Dynamics and Structure Formation
- Quantum and Superfluid Turbulence
- Turbulent Transport, Dispersion and Mixing
- Complex and Active Particles
- Numerical Methods and Data Analysis

During the ETC17, there were 8 Invited Speakers, more than 450 selected talks and a novelty, a Minisymposium on **"Turbulence in the heliosphere and in the local interstellar medium"**, which was held on Thursday, 5th September 2019. The minisymposium's convenor was Prof. Daniela Tordella, Coordinator of the H2020 MSCA ITN - ETN COMPLETE, and the co-convenor was Post – Doc, Federico Fraternale. First session of the minisymposium was chaired by Prof. Tordella, and the second session was chaired by Prof. Nikolai Pogorelov from the University of Alabama at Hunstville.

Child-care services

Another novelty of the ETC17 was **Child-care services**, a first time the child-care services were offered free of charge to its participants**.**

The service was provided in the afternoon of Tuesday, September 3rd, 2 p.m. – 6 p.m., and in the following days, September 4-5-6, from 8 a.m. to 6 p.m. The service was open for children from a few months to 13 years of age.
The service was provided by stranaidea.it Cooperative, the company that coordinates Policino, the child-care services for the Politecnico di Torino.

Gender, age and nationality of children in child – care services during the conference:

- M, 3 months, Mexico
- M, 16 months, Scandinavia
- F, 11 years, Rome, Italy

- F, 7 years, Rome, Italy
- F, 18 months, Brasil
- F, 2 years, Lecce, Italy
- M, 12 years, Turin, Italy
- M, 12 years, Turin, Italy

Young Scientist Awards

Following the Euromech tradition, there were TWO YOUNG SCIENTIST AWARDS for the two best presentations at ETC17 by researchers under 35 (at the date of the Conference). Each award was of 500 Euros and was paid directly by Euromech after the Conference and the abstracts of the two talks were to be published in the Euromech Newsletter.

Exhibitors

During the ETC17, the following exhibitors had the chance to showcase their latest technologies, products and services: APS physics (Physical Review Journal), Cambridge University Press, Cineca, Dantec Dynamics, Evolution Measurement, Lexma Technology, Photron, Ubertone.

Social programme

The first ice-breaking social event was the **welcome cocktail reception** that was held on Tuesday, 3rd September 2019, at the conference venue. It was a good occasion to meet old and new colleagues in a nice, relaxing atmosphere.

The main social event was the social dinner that was scheduled on Thursday, 5th September 2019 at the Museo Nazionale dell'Automobile (National Car Museum), a fascinating, interactive museum which was recently renovated with a modern, innovative design. The social dinner was included in full-fee registrations.

Attached to this deliverable, please find the abstracts of our ESRs who presented their work during the ETC17.

PARTICLE ENTRAINMENT THROUGH A TURBULENT/NON-TURBULENT INTERFACE.

Tai Wada[1], Christos Vassilicos [1]
[1]*Department of Aeronautics, Imperial College London, London, UK*

Turbulent entrainment is an important process closely linked to the dynamics of the Turbulent/Non-Turbulent Interface (TNTI) [1]. In this work we study entrainment in terms of fluid element trajectories at the vicinity of the TNTI which may or may not be crossing it. We run Direct Numerical Simulations (DNS) of turbulent planar jets at inlet Reynolds number $Re = 4000$ and integrate fluid element as well as particle trajectories in the DNS velocity fields with and without gravity. Our results reveal the existence of both detrainment and entrainment events across the TNTI. There are also many fluid elements which stay in the vicinity of the TNTI for significantly long times. Depending on Stokes and Froude numbers, this can also be the case for inertial particles. This barrier effect of the TNTI causes its own clustering and preferential concentration effects.

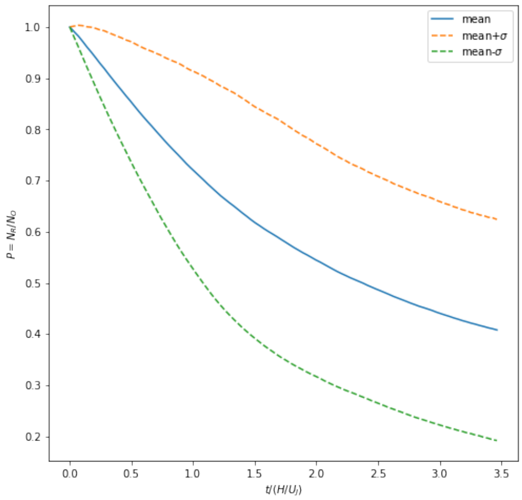

Figure 1: Fluid element persistence plotted against time. Persistence P is defined as $P = N_R/N_O$ where $N_R = N_R(\omega_{th,L}, \omega_{th,H}, t)$ is the number of particles remaining between original thresholds of $\omega^2_{th,L} < \omega^2 < \omega^2_{th,H}$ and $N_O = N_O(\omega_{th,L}, \omega_{th,H}, t_0)$ is the number of particles originally seeded in this threshold range. $\omega^2_{th,L}$ and $\omega^2_{th,H}$ are chosen within the TNTI. Time t is normalized by H/U_J where H is the width of the planar jet opening and U_J is the inlet velocity of the jet.

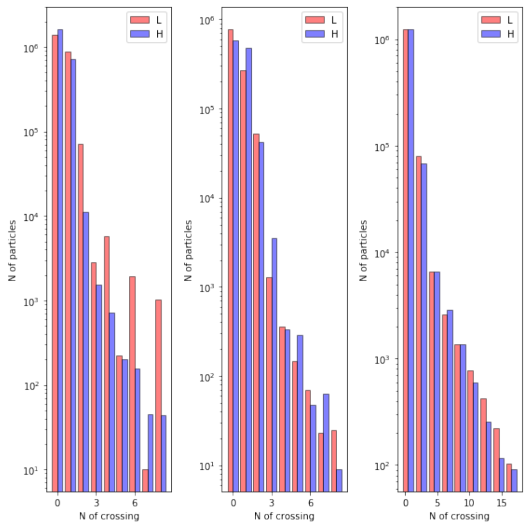

Figure 2: The plots in this figure are histograms of the number of times a particle at the vicinity of the TNTI crosses particular enstrophy thresholds from the range of thresholds which define the TNTI. $\omega^2/\omega^2_{max} = 10^{-8}$ (left), $\omega^2/\omega^2_{max} = 10^{-6}$ (middle) and $\omega^2/\omega^2_{max} = 10^{-4}$ (right). Red: crossings towards the potential side, Blue: crossings towards the turbulent side.

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DYNAMICS OF SUBSIDING SHELLS IN ACTIVELY GROWING CLOUDS WITH VERTICAL UPDRAFTS

Vishnu Nair[1], Thijs Heus[2] & Maarten van Reeuwijk[3]
[1,3]*Department of Civil and Environmental Engineering, Imperial College London, London, UK*
[2]*Department of Physics, Cleveland State University, Cleveland, USA*

The dynamics of a subsiding shell at the edges of actively growing shallow cumulus clouds with updrafts is analysed using direct numerical simulation with grid sizes of up to 3072 x 1536 x 1536. The actively growing clouds have a fixed in-cloud buoyancy and velocity. Turbulent mixing and evaporative cooling at the cloud edges generate a subsiding shell which grows with time [1].

A self-similar regime is observed for first and second order moments when normalized with their respective maximum values. Internal scales derived from integral properties of the flow problem are identified [2]. Self-similarity analysis conducted by normalizing using these scales reveal that contrary to classical self similar flows, the Turbulent Kinetic Energy (TKE) budget terms and the velocity moments scale according to the buoyancy and not with the mean velocity.

The shell thickness is observed to increase linearly with time. The shell buoyancy scale remains constant as it thickens and is set by the initial thermodynamics of the cloud and environment. The shell accelerates ballistically with a magnitude defined by the saturation value of the buoyancy of the cloud-environment mixture. In this regime, the shell is buoyancy driven and independent of the in-cloud velocity. The shell thickness and the velocity continue to grow indefinitely and could possibly be limited only by the lifetime of the cloud or thermal.

Relations are obtained for predicting the shell thickness and minimum velocities by linking the internal scales with external flow parameters. The values of shell thickness and velocities calculated using these derived relations are consistent with the values of a typical shallow cumulus cloud [3].

The entrainment coefficient, which is predicted by studying the rate of growth of the shell thickness, is observed to be a function only of the initial state of the cloud and the environment. This coefficient is linked to the fractional entrainment rate used in cumulus parameterization schemes for large scale models and is shown to be of the same order of magnitude [4].

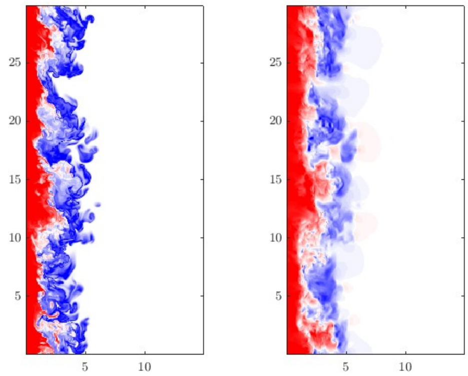

Figure 1. Instantaneous plots of the vertical cross-section of (left) buoyancy and (right) vertical velocity at cloud edge.

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RESULTS FROM THE ZUGSPITZE EXPERIMENT: AN IN-SITU CLOUD-DROPLET PARTICLE-TRACKING EXPERIMENT

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[2]*Tsinghua University, Beijing, China*

It is well-known that rain formation has four phases: nucleation, condensation, turbulent coalescence, and gravitational coalescence. Condensation is effective for droplet sizes of up to $\sim 20\,\mu\mathrm{m}$, whereas gravitational coalescence is effective for droplet sizes larger than $\sim 100\,\mu\mathrm{m}$. Turbulence is responsible for bridging the gap between these two, but how exactly it does this, is not known.

One of the first to study the effect of turbulence on rain formation were Saffman & Turner [6]. While beautiful in its simplicity, their theory has some shortcomings: it doesn't take droplet clustering (e.g. [1]) or the sling effect (e.g. [2]) into account. Many studies have tried to resolve these issues. To keep the problem tractable many theoretical studies assume droplets are monodisperse and/or neglect gravity (e.g. [4, 8]). This makes the results of limited relevance to clouds. Numerical and experimental studies (e.g. [3]) are often limited to low Reynolds numbers, and hence cannot faithfully reproduce cloud conditions. To avoid these issues, one must measure inside clouds.

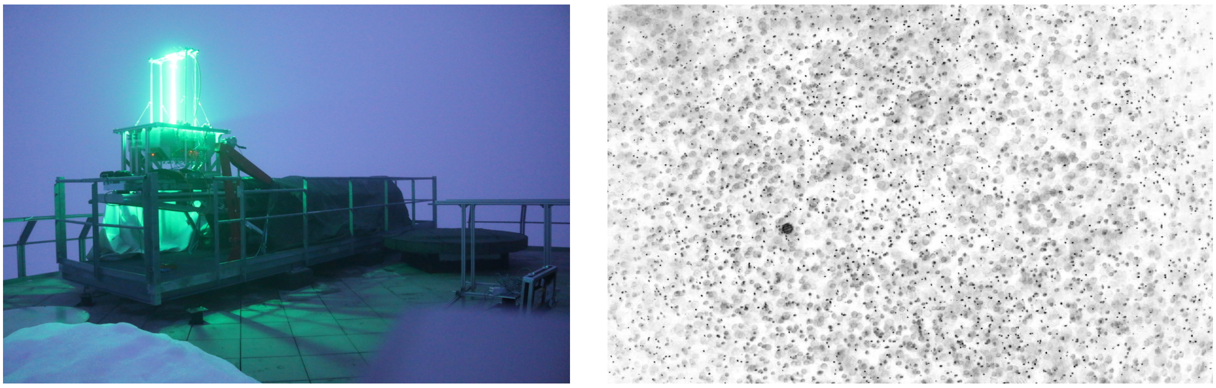

Figure 1. Left: the experimental setup. Most of the rail is covered by a tarp. Right: single camera image; brightness is inverted and enhanced for ease of viewing.

Here we present an in-situ cloud-droplet tracking experiment. The experiment (Fig. 1, left) is located on top of the environmental research station Schneefernerhaus, at $2650\,\mathrm{m}$ altitude, just below the peak of Mt. Zugspitze in the German Alps. At this location clouds occur close to the ground [5], which obviates the need for planes or helicopters.

At the heart of the experiment are three high speed cameras, capable of recording $1\,\mathrm{Mpx}$ at $10\,\mathrm{kHz}$. They are pointed at a small volume, approximately $(2.5\,\mathrm{cm})^3$ in size, illuminated by a $75\,\mathrm{W}$ green laser. The cameras are mounted on rails and can be moved by a linear motor, in order compensate for the mean wind. Images are processed with an in-house particle tracking code, that is remniscent of the Shake-The-Box algorithm [7]. The code is particularly suitable for processing low light imagery (Fig. 1, right), in which many droplet images are out of focus.

We report measurements of the radial distribution function (RDF) for separations of $0.1\,\mathrm{mm}$ to $20\,\mathrm{mm}$. Furthermore we can estimate relative radial velocities (RRV), and condition both quantities on approximate droplet size.

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TURBULENCE IN MARINE BOUNDARY LAYER CLOUDS: A META-ANALYSIS OF AIRBORNE MEASUREMENTS

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Moein Mohammadi[1] & Jesper Pedersen[1]

1 Institute of Geophysics, Faculty of Physics, University of Warsaw, Warsaw, Poland

Turbulence is a key transport mechanism responsible for many cloud processes. As a primary mechanism of cloud evolution, it drives entrainment and mixing, influences cloud microphysics. However, experimental information on turbulence within, between and below clouds, based on in situ airborne measurements is scarce and incomplete. The present study is aimed to fill this gap. We perform meta-analysis of airborne turbulence measurements collected in the course of research campaigns: POST [1], DYCOMS-II [2], ASTEX [3], RICO [4] and EPIC [5] in order to provide a comprehensive experimental description of turbulence in marine boundary layer with clouds.

The measurements, performed at various locations around the globe allow to obtain some universal statistical characteristics of turbulence in marine stratocumulus (Sc) and cumulus (Cu) boundary layers. We use freely available data on three components of velocity, temperature, humidity and liquid water content as well as about aircraft position and velocity recorded in the course of measurements, stored in open scientific database [6]. These data allow to provide a wide variety of statistics of turbulence properties.

In Fig. 1 example conditional statistics of velocity autocorrelations is shown. In the presentation we will discuss many other statistics, including those characterizing turbulence kinetic energy and its dissipation rate. We will provide comprehensive information on turbulence properties in marine convective clouds. We will also demonstrate capabilities of novel dissipation rate retrievals from under resolving measurements introduced in [7].

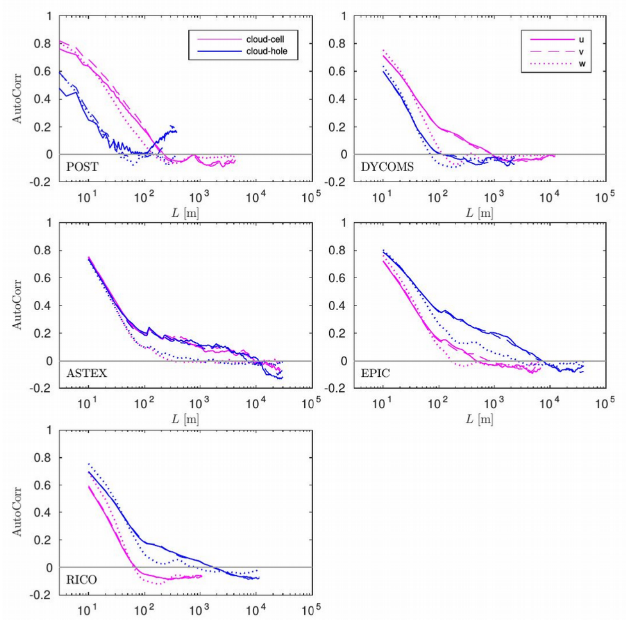

Figure 1. Autocorrelations of velocity fluctuations in clouds (magenta) and out of clouds (blue) on horizontal flight segments within cloud layers in 5 experimental campaigns. Solid, dashed and dotted lines correspond to u,v,w velocity components (w - vertical). POST and DYCOMS data are from Sc, ASTEX from mixed Sc and Cu conditions, EPIC and RICO from Cu layers.

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Fractal reconstruction of sub-grid scales for particle dispersion in large eddy simulation

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ABSTRACT

Particle dispersion in turbulent flows have attracted the attention of researchers in recent times due to its wide range of application such as pollutant dispersion, spray dynamics, cloud dynamics etc. Direct numerical simulation (DNS) is the most detailed research tool, used to accurately predict particle trajectories in turbulent flows. For high-Reynolds number flow, this tool requires unrealistic computational resources and as a compromise, Large eddy simulation (LES) is used. LES provides a better representation of large-scale features of the flow while sub-grid (unresolved) scales are modelled. Sub-grid scale model errors can lead to the progressive divergence of particle trajectories when compared with those obtained in experiment or DNS [2]. As a result, particle statistics are either over- or under-estimated [1, 4].

The present work addresses the reconstruction of sub-grid scales in large eddy simulation (LES) of turbulent dispersed flows. We focus on fractal sub-grid model, which is based on the fractality assumption of turbulent velocity field. The fractal model reconstructs sub-grid velocity field from known filtered values on LES grid, by means of fractal interpolation, proposed by Scotti and Meneveau [6]. The characteristics of the reconstructed signal depend on the (free) stretching parameter d, which is related to the fractal dimension of the signal. In [6], the stretching parameter was assumed to be constant in space and time and are obtained from experimental data of homogeneous and isotropic turbulence. However, turbulence at moderate or high-Reynolds' number possesses intermittency at small scales, which lead to strong variability in its local stretching parameter. To account for the stretching parameter variability, we calculate the probability distribution function of the local stretching parameter from DNS data of stratocumulus top boundary layer (STBL) [5] using an algorithm proposed by Mazel and Hayes [3]. We observe self-similarity in the PDFs of d when the velocity fields are filtered to wave-numbers within the inertial range (see figure 1). By randomly selecting d from its self-similar PDF, we perform a 1D a priori test and compare statistics of the constructed velocity increments with statistics of DNS velocity increments (see figure 2). This idea was applied to Physics of stratocumulus top (POST) airborne data and 3-D LES velocity fields. We observed that the constructed sub-grid scale velocity fields with the random values of d are able to reproduce most of the sub-grid scales and give smaller error in mass conservation when compared to the use of constant values of d.

References

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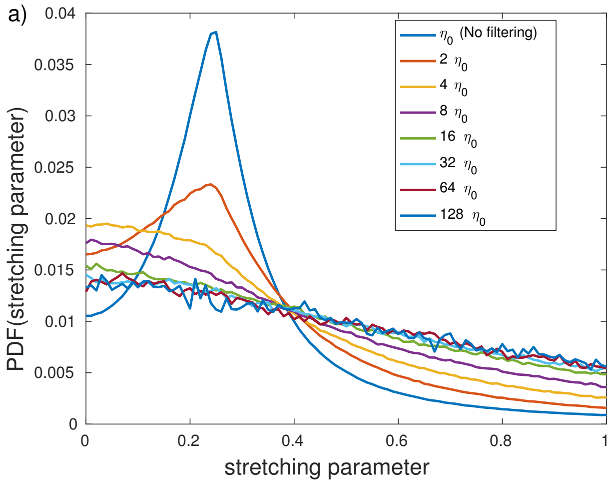

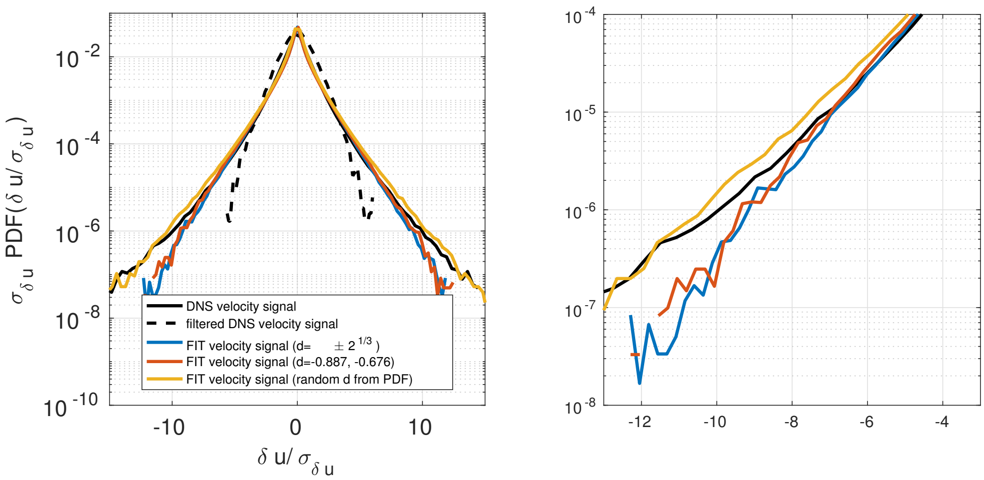

Figure 2: PDFs of DNS, filtered and FIT velocity increments (δu) signal for u velocity component at $|\mathbf{r}| = 2\eta_0$ with constant stretching parameter $d = \pm 2^{-1/3}$, $d = -0.887, -0.676$ and random stretching parameters from DNS calculated PDF

Cloud-clear air interfaces: Population Balance Equation solutions by considering nucleation information from in-situ measurements, and by modeling the droplet growth on super-saturation fluctuation data from numerical simulation.

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[1]*Dept. of Applied Science and Technology, Politecnico di Torino, Torino, Italy*

In this study we will present a preliminary analysis of the droplet population as hosted by a turbulent shear-less mixing air flow which is mimicking a cloud/clear-air interface. The interface is subject to density stratification and vapor density fluctuation under super-saturation conditions. We use the Population Balance Equation (PBE) as a tool to represent a few aspects of the droplet size dynamics by taking into consideration both turbulence results coming from in-situ and laboratory measurements and from numerical simulations. In particular, we use the PBE formulation proposed by Park and Rogak in 2004 [1]

$$\frac{\partial n(v,t)}{\partial t} + \frac{\partial (n(v,t)G(v))}{\partial v} = \frac{1}{2}\int_0^v \beta(v-\bar{v}\,,\bar{v})n(v-\bar{v}\,,t)n(\bar{v}\,,t)d\bar{v}\,,$$

where $n(v,t)$ is the numerical density of drops with volume v at the time t, $G(v) = dv/dt$ is the droplet growth/fallout and $\beta(v-\bar{v}\,,\bar{v})$ is the kernel describing the aggregation/coalescence interaction between drops of different size. Although, at the state of the art, fragmentation can be included in an approximate way in the global process of aggregation–breakage [2], we consider here the aggregation process alone because nowadays cloud simulations can take into consideration only aggregation (by single or multiple coalescence). The kernel $\beta(v-\bar{v}\,,\bar{v})$ depends on the size of colliding particles and the local turbulent dissipation rate according to the classical relationship by Saffman & Turner [3]. However, in the future we foresee to better this representation by exploiting the statistics on the collisions that can be directly deduced from the simulations.

We aim at observing the population distribution evolution by exploiting information both from numerical simulation of a turbulent cloud interface and in-situ/laboratory measurements. The first aim is reached: i) by using as initial condition for the PBE particle size distributions obtained from direct numerical simulations of cloud-clear air interfaces [4, 5] and ii) by introducing inside the growth/fallout rate, which is directly proportional to supersaturation variability, statistical information on the fluctuation of the supersaturation field at the various transient stages of the turbulence in the system portion we are actually simulating (a volume of 0.25 m x 0.25 m x 0.5 m across the cloud/clear-air interface, 512x512x1024 grid points). The model is based on a series expansion up to the fourth-order moment of the fluctuation. The second aim is reached by introducing via the boundary condition, always placed at the droplet nucleation size, information from the time derivative of the numerical density $n(v,t)$ observed in the in-situ experiment by Ovadnevaite et al., 2016 [6], and in CERN CLOUD laboratory experiment [7], http://cloud.web.cern.ch and http://www.goethe-university-frankfurt.de/65418923/The_CLOUD_Experiment.
Starting from three different monodisperse distributions of 6, 18 and 25 microns in radius, the time broadening of the drop size distribution and the position and value of the peak of the distribution are characterized in terms of the supersaturation variability [8] and are contrasted with the available in-situ observations and numerical simulations.

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