Project[1] Number: [675675]

Project Acronym: [COMPLETE]

Project title: [Cloud-MicroPhysics-Turbulence-Telemetry: An inter-multidisciplinary training network for enhancing the understanding and modelling of atmospheric clouds]

Mid-term report

Part B of the Periodic Report

Period covered by the report: from the project's Kick-Off meeting in Turin 22/06/2016 to the Spring School and Mid-Term meeting in Paris 28/05/2018 – 01/06/2018

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Periodic report: *[*1st*]*

[1] The term 'project' used in this template equates to an 'action' in certain other Horizon 2020 documentation

Contents

1. **Explanation of the work carried out by the beneficiaries and overview of the progress**

- Explain the work carried out during the reporting period in line with the Annex 1 to the Grant Agreement.

ESRs recruitment: The beneficiary partners of the COMPLETE training network have carried out at first, the Marie-Curie fellow recruitment. The recruitment was organised on the basis on the set of announcements in Euraxess (July 2016), Physics Today (July 13, 2016), Nature Jobs (July 13, 2016), ResearchGate (November 2016), Science Careers (July 19, 2016), Academic Positions (November 2016), Met Jobs (January 2017) and SCUDO – PhD School of Politecnico di Torino (December 1, 2016). The recruitment was complicated and delayed due to problems related to the two of the beneficiary partners that have exited the training network. Pentalum was bankrupted (11 April 2017) and Grimm Aesorol was bought by a holding. Due to this problem an Amendment was submitted on 13th April 2017 and it was accepted on 29th May 2017. The recruitment, thus, continued after this date and it heavily influenced the network and reduced its budget. It was reduced from 3,818,522.52 € to 3,555,982.80 € due to the exit of Pentalum and late recruitment. The recruitment started in July 2016 and ended in October 2017 with the recruitment of the last three ESRs (ESR8 Antonio Ibanez Landeta, ESR13 Mina Golshan and ESR14 Tung Bui Duc). During the first Supervisory Board in Turin, 10th March 2017, the decision to reallocate ESR13 to POLITO and ESR8 to MPG was taken. The first recruited ESR was ESR3, Tai Wada, on 20th October 2016 and the last recruited ESR was ESR14, Tung Bui Duc on 12th October 2017.

Network events: The Coordinator organised the first Kick-Off meeting in Turin on 22nd June 2016 and the second Kick-Off meeting and training school from 19 – 22 June 2017, to which all the recruited ESRs by that time participated. This training school was focused on cloud microphysics and entrepreneurship. The second ESR meeting was organised again in Turin, from 14th to 15th February 2018 when all the ESRs were already recruited. See D7.4 ITN Training Programme.

Training organisation: All the ESRs were enrolled to PhD programmes and are attending courses related to their research fields. The description of their first year of the relevant PhD programme has been set out. See tables 1.2b and 1.2c.

Outreach: A website has been constructed with a very innovative part called Wiki, where ESRs and their supervisors can save different material related to their research. In Wiki, ESRs can also create forums in which they can discuss important topics and share their ideas or results. See D6.1 Network website.

Social media management: The network gained an addition, Aleksandra Kardas, who is overseeing the social media profiles of the COMPLETE network. Facebook and Twitter accounts are now active and all the news and interesting facts related to the project are regularly updated and shared with the wider public.

- Include an overview of the project results towards the objective of the action in line with the structure of the Annex 1 to the Grant Agreement including summary of deliverables and milestones, and a summary of exploitable results and an explanation about how they can/will be exploited[2].

COMPLETE network strives towards quality, innovative aspects and credibility of the research programme. The recruited researchers have been enrolled into PhD programmes, they have attended Kick-Off meetings and training schools organised by the network. By being part of such an inter/multidisciplinary training network, the recruited researchers benefit from scientific and industrially oriented skills they have been exposed to. The chosen beneficiaries of the training network have high expertise in turbulence dynamics, cloud physics, weather forecasting and climate modelling, remote sensing, data mining and statistical analysis, instrumentation design, prototyping, test and production, large scale database generation and distribution, as well as commercial and complementary skills. Therefore, the recruited ESRs have the opportunity to build and start testing their abilities in field experiments, laboratory and numerical simulations, designing and developing fast temperature probes, and atmospheric expendable mini radio-sondes. It should be recalled that not all the ESRs have had the same amount of time given for carrying out their research since the first recruited ESR is ESR3, Tai Wada (20 October 2016) and the last recruited ESR is ESR14, Tung Bui Duc (12 October 2017). This results in almost a one year-gap from the first to the last recruited ESR.

Most of the deliverables up to now concern the structure of the training network and its related requirements: D6.1 Network website, D6.2 1st Summer School lecture notes, D7.1 ESRs Recruitment report, D7.2 Code of conduct and quality criteria for the supervision of ESRs, D7.3 ESR's Career Development Plans, D7.4 ITN Training programme, D8.1 Consortium Agreement, D8.2 Ethics, D8.3 Exploitation Plan, D8.4 Supervisory Board, D9.1 NEC – Requirement No.1. Only two deliverables so far are related to scientific achievements: D3.1 Prototyping and testing of a new droplet generator, D5.1 Computation of Lagrangian trajectories from LES.

The milestones that have been reached or are still ongoing are:

- MS1 Kick-Off Meeting: First Supervisory Board meeting carried out.
- MS2 Recruitment assessment: All 14 ESRs are recruited.
- MS5 HPC codes optimization: Codes validated through test runs by groups.
- MS6 Control point: Instrumentation design: Radiosondes and MEMS hot-film sensors design in the making (POLITO, ENV, SIT, MPG, TAU, UW).
- MS7: Access gained to PRACE HPC resources: Application to PRACE Preparatory Access Grant Type C project 2010PA3699 in view of a future submission to PRACE Tier-0 and 1 resources. ISCRA Application Class C Projects code: HP10CA7H4X.
- MS8: Intermediary point: Instrumentation prototyping: Radiosonde, MEMS hot-film sensors prototypes are in the making (POLITO, ENV, SIT, MPG, TAU, UW).
- MS9: Control point: Laboratory experiments: Laboratory experiments in cloud chamber on droplet growth, collision and coalescence rate (TAU and MPG).

[2] Beneficiaries that have received Union funding, and that plan to exploit the results generated with such funding primarily in third countries not associated with Horizon 2020, should indicate how the Union funding will benefit Europe's overall competitiveness (reciprocity principle), as set out in the grant agreement.

All scientific publications related to the COMPLETE training network are published under open access. The “preexisting know-how” which comprises and information and IPR that the partner brings into the project remain the property of the partner who has brought it into the project. The research of the COMPLETE training network is expected to develop patentable results which will increase the strategic competitiveness of the industrial partners because they will be able to propose to the global market new, original and protected products.

1.1 Objectives

List the specific objectives for the project as described in the Description of Action (DoA) and describe the work carried out during the reporting period towards the achievement of each listed objective. Provide clear and measurable details.

- **The characterisation of the direct interactions between cloud dynamics, thermodynamics and microphysics at centimetre and meter scales**

ESRs working on this objective are: ESR 1, 5, 7, 9, 10, 13.

ESR1, Taraprasad Bhowmick (POLITO) is working on three dimensional pseudo-spectral modelling approximation which is used in such DNS codes where fluid velocity and scaler fields are solved using Eulerian frame of reference and evolution of droplets are tracked individually for each particle using Lagrangian reference frame. Spatial dispersion of scalars and velocity fields are computed using Fourier-Galerkin Spectral approximation, whereas, temporal advancement is approximated using Fourth Order Runge-Kutta method. The DNS 14P version of code (conceptualized and written in Politecnico di Torino) uses Message Passing Interface (MPI) libraries for One Dimensional Parallelization. This code will be used by ESR1 for simulating various cloud – clear air interfacial phenomenon. Till date, ESR1 research progress includes detailed review of previous researches, conceptualizing various physical processes involved in evolution of cloud – clear air interfaces, familiarization with the available DNS codes and FORTRAN programming language, and running the DNS code without cloud droplets (only velocity and scalar transient at the interface) to understand the evolution of the flow field around the interface, and formulation of various simulation schemes for his future runs. A grant for PRACE Preparatory Access was obtained and an ISCRA proposal Application Class C has been submitted one week ago. This in the perspective of a future submission to PRACE Tier 0 HPC resources.

ESR13, Mina Golshan (POLITO) contribution includes an investigation on the way to consider the heterogeneous and homogeneous nucleation in both classical and non-classical models inside direct numerical simulation (DNS). This, in fact, would require to introduce the specific idea for a possible sub-domain feedback from population balance equation models and proposing some new numerical procedures to implement droplet generation inside the mentioned codes (DNS) which are describing the turbulent mixing and entrainment at the boundary of the cloud. In particular, ESR 13 is thinking to use population balance equations from the nucleation size, about 1nm, to the smallest droplet size that can be simulated, about 20 - 30 μm in radius. The aim is to achieve a local dynamical adjusting of the water particle density by killing or breeding water droplets from the simulation threshold size 2.5 μm up to the maximum droplet size reached in the evolving simulation. The sub-domain volume sought for the feedback is one order of magnitude smaller along each linear dimension than the entire domain of the simulation.

ESR5, Guus Bertens (MPG) contribution involves the experimental setup that is situated on top of the UFS Schneefernerhaus. At its heart the setup consists of a box with three fast cameras, that all look at the same 3x3x3 cm^3 volume. We typically record droplet images at 10 kHz. To prevent the wind from blowing droplets out of measurement volume too quickly, the camera box is mounted on a 6.5 m long rail system, that allows it to move with the mean wind speed. However, due to technical difficulties the rail system hasn't been used for measuring yet. In the summer of 2017 the first measurements were done. We are currently analysing the data, and making improvements to the setup. One of the improvements that is currently being worked on, is the rail system. In particular, the vibrations the rail system introduces in the measurements are trying to be minimised. This improves the accuracy of droplet acceleration measurements. The dynamic properties of droplets depend heavily on their size, but the experimental setup is currently not able to measure droplet sizes. This year, 2018, a method to infer droplet sizes solely from measured intensities will be developed. Next year this method will be deployed at the UFS Schneefernerhaus.

ESR6, Johannes Guettler (MPG) works on the design and prototyping of a new droplet generator, with drop size and drop velocity control. The mechanical design of the droplet generator is complete and the device has been built and assembled. A piezo-electric membrane grants a precise tuning of pressure waves by applying several parameters onto the membrane, such as voltage, frequency and waveform shape. Right now, tests are being performed to find the ideal parameters for each of the two tasks of the droplet generator: 1) Generation of single droplets on demand and 2) generation of a steady stream of droplets, which are split by forcing a Plateau-Rayleigh-instability. In both cases, the diameter of the nozzle orifice has a strong influence on the final droplet size and the pressure needed to create the droplet. Creating droplets in the sizes found in clouds of 10-100 µm diameter requires a nozzle orifice of equal or smaller size. This necessitates the use of new manufacturing techniques such as 2-photon-polymerization (2PP). The Nanoscribe GT, acquired by the MPI DS in April 2017, is a sophisticated 3D-printer capable of creating features down to sizes of one micron. Creating nozzles with the relatively recently developed Nanoscribe GT came with the realization that now is an opportune time to research artificial counterparts of particles such as ice crystals.

ESR8, Antonio Ibanez Landeta (MPG): So far, unsolved questions such as droplet coalescence in the mid range (in between 15-50 µm) need cloud turbulence statistics for a better understanding of what is going on. One of the best available probes for obtaining turbulence statistics (in terms of reliability, spatial and temporal resolution and price) are the NSTAPs (nano scale thermal anemometry probes) hot wires designed in Princeton (Bailey et al., 2010). So far, a 30µm x 3µm prototype was printed with a Nanoscribe printer in a polymer and to be coated with a metal. The wires are straight and reasonably resistant to vibration and movement. However, the production is not optimal yet as the prints are often slightly bent, or the wire's cross-section varies in diameter at different positions along the wire. Tests are underway to find exactly, which of these two constitutes problem, and of course how to avoid it or to use it as an advantage. Wires with a diameter less than 3 µm show a noticeable buckle in the horizontal plane, which we attribute to the internal stresses due to shrinking. Modifications of the production process are being tested to avoid this.

ESR 7, Marco Boetti (TAU): In the first part of his activity, the focus was on the creation of the experimental system dynamics using a DNS code, that is based on SPARKLE. This model has been written at Imperial College London and it proved its reliability and robustness in several studies. It integrates the incompressible Navier-Stokes equations in the Boussinesq approximation on a cuboidal domain. To reproduce the experiment setup, the code is modified in order to create the source of turbulence: it is added an "oscillating grid" (as boundary condition of the fluid) to obtain the fluid stirring. The stratification is made imposing in input an initial discontinuity in the temperature vertical profile at the middle height position of the domain. Several runs were made to evaluate the relevance of physical parameters and initial conditions: the main guideline was to fasten the propagation of the turbulent region toward the temperature interface and to weaken the thermal diffusion that leads to a thickening of the interface. A satisfactory configuration has been made, in which the value of the kinematic viscosity is the main driving parameter.

ESR9, Moein Mohammadi (UW) early results: A frame of light was designed to uniformly illuminate a cloud volume of ~ 50cm x 50cm x 2mm, for visualization of droplets within this volume and quantitative multi-scale measurements of droplet clustering and small scale turbulence. Hence, it was possible to collect images of cloud droplets spatial distribution in a two-dimensional plane enlightened by a laser sheet technique with our digital camera (*Optronis CP80-25-M-72 CoaxPress).* ESR9 also participated to the research campaign at UFS camp along with colleagues from UW. They did some measurements in real clouds there. Then after the campaign, ESR9 worked on analysing the collected data. Although the instrument had been tested in the laboratory successfully before the campaign, the experiments at UFS did not lead to such fruitful results, which could be due to different reasons, such as insufficient laser intensity, high speed winds blowing at field, and smaller drop sizes in real cloud than laboratory. Hence, some improvements on the instrument for the next campaign are planned which would be related to the shape and configuration of the frame as well as laser intensity.

ESR10, Emanuel Akinlabi's (UW) contribution to the project is focused on the correct modelling of collisions and coalescence of Stokes particles in turbulent flows comparing SGS models in true LES with filtered Direct Numerical Simulations (DNS) (a priori LES analysis) as the reference results. The presence of small eddies from the dissipative part of the spectrum enhances the collision rate in turbulent flows. Here, the key quantity which quantifies the enhancement of particle collision kernel is the turbulent kinetic energy (TKE) dissipation rate. The first part of the project was devoted to the problem of TKE dissipation rate retrieval from velocity signal with spectral cut-off, that is a signal where, due to low grid resolution (such as in case of LES) or finite resolution of measuring device (in case of airborne velocity measurements in the atmosphere) high-wavenumber part of the TKE spectrum is missing. For this task, DNS data of velocity field in atmospheric configurations (stratocumulus cloud-top and free convective boundary layer – courtesy of Prof. J. P. Mellado) were first filtered with different spectral cut-off wavenumbers. Next, different methods for TKE dissipation rate retrieval were applied, including standard spectral retrieval methods and new proposals based on a recovery of the missing part of the spectrum. Results of this part of the project have been submitted for publication in New Journal of Physics.

- **The development of new telemetry methods for in-situ measurements of the aerosol and turbulence, as well as temperature, pressure and chemical content**

ESR2 Tessa Basso, ESR12 Miryam Paredes and ESR14 Bui Duc Tung are working on development and implementation of a kind of radiosondes to collect information from the clouds.

The contribution of ESR2, Tessa Basso (POLITO), up to now concerns the first developments for the biodegradable casing of the radio-probe. In particular, she was focusing on the design of the inner skeleton that will hold the electronic circuit at the centre of the balloon, the balloon enclosure making process, and the sealing procedure once the helium has been injected. In the meantime, tests were performed to characterise the materials (bio-degradable or not) in terms of their oxygen/helium and water permeability, mechanical and thermal integrity, hydrophobicity, and attenuation of radio frequencies. The first prototypes of this balloon were made using a thermoplastic known as PET which resulted in a hard outer shell as well as Mylar, a known balloon material. Materials similar to Mylar are also in the characterisation stage but have been unsuccessful in the final balloon making procedure.

ESR12, Miryam Paredes (EnviSens), is working on the transmission protocol to be used by the mini green radio-probe. In order to realize the communication system for the atmospheric probes, some prototypal links and networks have been realized using the Adafruit Feather 32u4 LoRa Radio RFM95 modules, for both: the radio probes and the ground receiver station. The Adafruit Feather 32u4 LoRa Radio RFM95 is an embedded module, which contains a LoRa transceiver RFM95 and an ATmega32u4 microcontroller. The radio module can be powered using 3.3 volts either by using a micro USB or an external battery and it can transmit from +5 dBm to +20 dBm which are theoretically enough to reach the distances required by the probes for atmospheric monitoring as required by the project COMPLETE. The ground receiver is also programmed with a database engine and some graphics software (InfluxDB and Grafana) in order to acquire, store and show in real time the data coming from all the different probes. Some preliminary measurements, both indoor and outdoor environment, have been also performed also considering different configurations (spreading factors, transmitted power, bit rates, antennas, network topology) in order to find the best set of parameters to work in the harsh environment.

At the moment, the contribution of ESR14, Tung Bui Duc (Sitael) concerns the selection, design and placing inside the radio-probe electrical circuit of a 3-axis accelerometer, and in order to get the angular rate of the radiosondes, a 3-axis gyroscope. Or in alternative, to keep to a minimum the weight of the probe, a 4-accelerometers combined system is under study.

- **To improve the cloud edges/interface models to better prediction of the mixing efficiency, temperature inversion, clear air entrainment/moist air detrainment**

ESR3, Tai Wada's (ICL) contribution: As part of the COMPLETE project, the final goal is finding interfacial dynamics of aerosols and droplets through Direct Numerical Simulation (DNS). Detailed research project consists of three steps. 1.Study of entrainment in Turbulent / Non-Turbulent Interface (TNTI) in DNS of planar turbulent jet in Eulerian context. Entrainment velocity scaling will be discussed in detail. 2.Study of entrainment in TNTI in Lagrangian context. Same simulation data is used and Lagrangian statistics will be compared with Eulerian statistics. 3. Study of complex interfacial dynamics at TNTI with inertial particles (such as aerosols, droplets). By 2018 April, DNS simulation of a planar jet has been conducted using our in-house Navier-Stokes solver “Incompact3d” and investigated interfacial velocity scaling using theory of Zhou and Vassilicos (JFM, 2017, ZV2017 for later reference). This theory is introducing fractal dimension of the interface and non-equilibrium scaling to estimate interfacial velocity scaling along streamwise direction of the jet/wake (Vassilicos, AR 2017).

ESR4, Vishnu Nair’s (ICL) contribution: The interaction of cloud boundaries with the environment is studied using high fidelity simulations of cloudy turbulent non-turbulent interfaces with a hybrid Eulerian-Lagrangian representation of the water vapor and droplet phase respectively. The in-house numerical code SPARKLE is used to perform Direct Numerical Simulations (DNS) on a cloud-environment model. Initial work focuses on the behaviour of cloud boundaries using bulk wet thermodynamics to describe the flow and processes in the domain under study. The work progresses into a more actual representation of cloud systems, and a study of entrainment on the cloud boundaries is conducted by varying the size and number of droplets to simulate polluted and non-polluted clouds. The main goal of the research can be summarized as the study of the effect of microphysics on cloud boundaries using DNS complemented with a microphysics routine. The following four objectives have been designed to achieve this goal: 1. Perform DNS of turbulent entrainment in shallow cumulus cloud edges using a bulk formulation of wet thermodynamics. 2. Implement and validate a Lagrangian Particle Tracking routine to track individual droplets in SPARKLE. 3. Study the effect of aerosols and microphysics on warm shallow cumulus cloud boundaries by introducing inertial particles capable of collision and coalescence. 4. Study of cloud top entrainment in stratocumulus. Objective 1 has been completed resulting in a journal paper which is currently under preparation. Work is ongoing on objective 2 as on date.

See also Objective 1, and the contributions by ESR1, 7 and 13.

- **The comparison of radiative measurements with data obtained inside warm clouds in a Lagrangian way.**

At this moment, this objective has not been achieved yet because the new mini green radio-sondes are under development. We will start to get some preliminary results as soon as we can do some infield measurements at the UFS. This will hopefully happen at the end of 2018 and at that moment we will start the collaboration with Max Planck Institute for Meteorology in Hamburg, one of the non-beneficiary partners of COMPLETE.

See also preliminary results as described in Objective 1 and the related contribution by ESR2, 12 and 14.

- **Transfer the knowledge acquired by field and laboratory Lagrangian measurements and DNS modelling towards the climate/weather modelling community**

ESR11, Sara Shamekh’s (LMD) contribution: ESR11 studied the tendency of convective clouds to aggregate at a scale larger than the single convective cell. This aggregation is of crucial importance, because it is associated with a dramatic change in the large-scale conditions, including extremely dry and cloudless ones. This drying is a leading-order impact of convection on large scales which is not accounted for in climate models, and more importantly, those very dry conditions imply that the dry atmosphere emits radiation from low levels, with a large climatic effect. ESR11 wants to study how the aggregation is influenced by the details of the surface, such as the presence of ocean or land, and the temperature of the oceans. The physical processes involved are studied by Cloud resolving models or Large Eddy Simulation, and will be verified on Global Climate Models.

1.2 Explanation of the work carried per WP

1.2.1 Work Package 1

Telemetry Instrumentation Sensors

The Radiosondes (ESR2, ESR12 and ESR14):

ESR2 is developing the skeleton and the outer shell, ESR12 is working on the transmission protocol to be used while ESR14 is developing the sensors and together, they perform various measurements. The first tests will be performed in the climate chamber of INRiM (Istituto Nazionale di Ricerca Metrologica) this summer.

ESR2: The radiosondes will allow us to track small scale fluctuations of a variety of properties over a significant distance inside and just outside warm clouds over land and alpine environments. From this we aim to generate a Lagrangian database for various parameters such as temperature, pressure, humidity, aerosol concentration, as well as velocity and acceleration fluctuations. The probes must be as lightweight as possible to float and be transported inside and outside clouds. They must be hydrophobic and impermeable; they must not absorb any moisture, which will change their weight, or allow any water to penetrate as these will have consequences on the results. They aim to be low cost and expendable, which means we need to make them as biodegradable as possible to minimise our environmental impact when releasing several probes at once. They will initially float on an isopycnic (constant density) level at a chosen altitude and will consist of microprocessors (presently the first prototype uses Arduino© Nano and in the close future the Arduino © Pro Mini will be used), controllers and solid state sensors, chosen to measure the fluctuations of the various parameters. The probes collect, store and then send the coded information to a base station located at the ground through a dedicated radio transmission link. For the initial concept, two configurations have been thought of. The first, a simple configuration will contain the electronics inside it. The second, more complex configuration will contain all sensors that need to be in contact with the environment and hence must hang outside of the probe.

The first developments for this probe have been focused on the design of the inner skeleton that will hold the electronic circuit at the centre of the balloon, the balloon enclosure making process, and the sealing procedure once the helium has been injected. In the meantime, tests were performed to characterise the materials (bio-degradable or not) in terms of their oxygen/helium and water permeability, mechanical and thermal integrity, hydrophobicity, and attenuation of radio frequencies. The first prototypes of this balloon were made using a thermoplastic known as PET which resulted in a hard outer shell, as well as Mylar, a known balloon material. Materials similar to Mylar are also in the characterisation stage but a successful way of sealing them is still being developed.

ESR12: Regarding the communication system, a long-range communication link (of about 10 km) should be assured with low power consumption technology: a network based on the Long

range Wide Area Network (LoRaWAN© protocol) to connect and exchange data within the end-modules and the base stations is the potential solution. LoRa uses a proprietary spread spectrum technique called Chirp Spread Spectrum (CSS) to encode information, achieving low power properties and long communication distances, consistent with the probe requirements.
Prototypal links and networks have been realized using the Adafruit Feather 32u4 LoRa Radio RFM95 modules, for both the radio probes and the receiver station. The Adafruit Feather 32u4 LoRa Radio RFM95 is an embedded module, which contains a LoRa transceiver RFM95 and an ATmega32u4 microcontroller. The radio module can be powered using 3.3 volts either by using a micro USB or an external battery and it can transmit from +5 dBm to +20 dBm which is theoretically enough to reach the distances required by the probes for atmospheric monitoring as was foreseen in the Annex 1 to the Grant Agreement of the COMPLETE project. Some preliminary measurements, in both indoor and outdoor environment, considering different configurations (spreading factors, transmitted power, bit rates, antennas) have also been performed to find the best set of parameters to work with in harsh environment.

ESR14: Currently, the PHT (Pressure, Relative Humidity and Temperature) combination sensor is working well in room condition. In the future, further tests in the field need to be done to make sure it will also work in the clouds.
Regarding the positioning and trajectory of the probes, a single 3-axis accelerometer is not enough since it only provides information of linear acceleration. To get the angular rate of radiosondes, a 3-axis gyroscope is required. However, the gyroscopes and IMUs (a device which combines accelerometer and gyroscope) are often heavy and may excess the mass constraint of the system (20g). To solve this problem, 4-accelerometers combined in one system is proposed. In the combined 4-accelerometers, one of them needs to be placed in the center of gravity of the whole system; inside the balloon. The PHT combination sensor must be outside the balloon to collect information from the clouds. This problem needs to be considered after verifying the algorithm and the functions of PHT combination sensor.

Droplet Generator

ESR6: The main goal of the project is to study droplets and particles as found in clouds. For this, a droplet generator capable of generating liquid droplets of chosen size and velocity is currently under construction. The mechanical design of the droplet generator is complete and the device has been built and assembled. A piezo-electric membrane grants a precise tuning of pressure waves by applying several parameters onto the membrane, such as voltage, frequency and waveform shape.
Right now, tests are being performed to find the ideal parameters for each of the two tasks of the droplet generator:
1) Generation of single droplets on demand;
2) Generation of a steady stream of droplets, split by forcing a Plateau-Rayleigh-instability.
In both cases, the diameter of the nozzle orifice has a strong influence on the final droplet size and the pressure needed to create the droplet. Creating droplets with sizes as those found in clouds of 10-100 μm diameter requires a nozzle orifice of equal or smaller size. This necessitates the use of new manufacturing techniques such as 2-photon-polymerization (2PP). The Nanoscribe GT, acquired by the MPI DS in April 2017, is a sophisticated 3D-printer capable of creating features down to sizes of one micron. Creating nozzles with the relatively recently developed Nanoscribe GT came with the realization that now is an opportune time to research artificial counterparts of particles such as ice crystals. Creating non-spherical particles in a highly reproducible way with exact dimensions and geometries poses a challenge for prior

manufacturing technologies. A wide range of shapes and sizes can be created with 2PP, however. The mechanical workshop of the MPI DS is currently building a new setup, designed by ESR6, which will be used to study the settling behaviour of such non-spherical particles. This study aims to fill a gap in knowledge, especially for non-spherical particles with large density ratios compared to their surrounding media. An estimated density ratio of about 1000 will be reached if the settling particles are studied free falling in air. Both the droplet generator and the artificial particle setup will strengthen the understanding of the microphysical processes that take place inside clouds.

The Ultrafast Hot Wires

ESR8: Knowing the flow properties of a system (i.e. velocity) is important for cloud physics studies. So far, unsolved questions such as droplet coalescence in the mid-range (in between 15-50 μm) need turbulence statistics to better understand the process. One of the best available probes for obtaining turbulence statistics (in terms of reliability, spatial and temporal resolution and price) are the NSTAPs (Nano Scale Thermal Anemometry Probes) hot wires designed at Princeton. However, even these devices need higher environmental stability for turbulence measurements. Hence, the main objectives of this project are:
1. To develop an ultrafast temperature, velocity and humidity probe following the design of the NSTAP family patented by *Hultmark et al*. in 2014 and outlined in *Fan et al., Exp Fluids (2015)*. The superior robustness of the NSTAP probes to cloud-particle impacts, makes them prime candidates for the development of ultrafast probes within multiphase flows such as clouds.
2. To further optimize the design to minimize the expected damage to the probe by particles suspended in the flow and the effect of the particle that strikes the probe, on the data quality.
3. To perform field measurements of cloud microphysics using the probes, either at the research station Schneefernerhaus, or from the research balloon CloudKite owned by MPG during one of their campaigns.

So far, a 30μm x 3μm prototype was printed with a Nanoscribe printer in a polymer and is coated with metal. The wires are straight and reasonably resistant to vibration and movement. However, the production is not yet optimal as the prints are often slightly bent, or the wire's cross-section varies in diameter at different positions along the wire. Tests are underway to find exactly which of these two poses a problem, and how to avoid it or to use it as an advantage. Wires with a diameter less than 3 μm show a noticeable buckle in the horizontal plane, which we attribute to internal stresses due to shrinking. Modifications to the production process are being tested to avoid this. We also follow a second path that is to create a hot wire entirely of metal by printing a hot-wire shaped cast with the 3D-printer, and then electroplating it. Proper printing parameters are being studied for creating the smallest possible cast.

1.2.2 Work package 2

Structure of in-cloud turbulence and interfacial turbulent phenomena

ESR1: The research objectives include DNS of transport of energy, water vapour, temperature and droplet evolution across the warm cloud – clear air interface. A three-dimensional pseudo-spectral modelling approximation is used in DNS codes where fluid velocity and scaler fields are solved using a Eulerian frame of reference. The evolution of droplets is tracked individually

for each particle using a Lagrangian reference frame. Spatial dispersion of scalars and velocity fields are computed using the Fourier – Galerkin Spectral approximation, whereas temporal advancement is approximated using the Fourth Order Runge – Kutta method. The DNS 14P version of code, conceptualized and written at Politecnico di Torino, uses MPI libraries for One Dimensional Parallelization. This code will be used for simulating various cloud – clear air interfacial phenomena.
So far, a detailed review of previous research has been carried out, along with the conceptualizing of various physical processes involved in the evolution of cloud – clear air interfaces. Furthermore, the DNS code was run without cloud droplets (only velocity and scalar transient at the interface) to understand the evolution of the flow field around the interface and various simulation schemes were formulated for future runs. A proposal for PRACE Tier 0 HPC resources for ESR1 simulation runs is also being submitted.

ESR3: The final goal of this project is finding interfacial dynamics of aerosols and droplets through DNS. The research consists of three steps:
1. Study of entrainment in Turbulent/Non-Turbulent Interface in DNS of a planar turbulent jet in Eulerian context.
2. Study of entrainment in TNTI in Lagrangian context. Same simulation data is used and Lagrangian statistics will be compared with Eulerian statistics.
3. Study of complex interfacial dynamics at TNTI with inertial particles (eg. aerosols, droplets).
By April 2018, DNS simulations of a planar jet were conducted using an in-house Navier-Stokes solver "Incompact3d" and investigated interfacial velocity scaling using the theory of Zhou and Vassilicos (JFM, 2017, ZV2017). This theory introduces fractal dimension of the interface and Vassilicos' (AR, 2015) non-equilibrium scaling was used to estimate the interfacial velocity scaling along the stream-wise direction of the jet/wake. Our DNS dataset supports the new scaling law of ZV2017, and its relation to the Kolmogorov velocity scaling and Taylor microscale velocity (which we define as $v_\lambda = \lambda/\nu$) scaling. We're planning to conduct different types of simulations with different non-equilibrium statuses to clarify this relation in different cases. We have also examined fluid elements' behaviour through particle tracking near the interface using our dataset. We found some detrainment peaks in the turbulent sublayer region. We consider this an indication of particles moving along the interface and we plan to conduct further investigation introducing Stokes' drag force to see the effects of inertia. Later this year, passive scalars (temperature and supersaturation) and Lagrangian subroutines (to compute particle displacement and supersaturation) will be added to the code so that we can investigate the full dynamics of the TNTI in the mixing cloud. Applications of this in-house code to more realistic environments will be sought at the end of the project.

ESR4: The main objective of the project is to conduct a numerical study of the interaction between the flow interface and an approximately collocated buoyancy interface. The influence of the non-linear dependency of buoyancy on mixing fraction in clouds, and how these enhance/reduce turbulent exchange, will be studied along with the dynamics of buoyant inertial particles.
The interaction of cloud boundaries with the environment will be studied using high fidelity simulations of cloudy TNTI with a hybrid Eulerian-Lagrangian representation of the water vapour and droplet phase, respectively. The in-house numerical code SPARKLE will be used to perform Direct Numerical Simulations on a cloud-environment model. Initial work will focus on the behaviour of cloud boundaries using bulk wet thermodynamics to describe the flow and processes in the domain under study. The work progresses into a more actual representation of

cloud systems, and a study of entrainment on the cloud boundaries will be conducted by varying the size and number of droplets to simulate polluted and non-polluted clouds. Also, the effect of turbulent entrainment and mixing, on the growth of the cloud droplet size distribution will be investigated. To achieve these objectives, SPARKLE will be complemented with a microphysics routine to conduct simulations which are more representative of actual cloud conditions.

ESR7: The final goal of this project is to study the properties of aerosol parcels at sharp turbulent/non-turbulent interfaces in stratified fluids, setting up numerical simulations coupled with similar experimental configurations providing the particle dispersion and entrainment mechanisms. The project is inspired by a classical experiment consisting of two fluids with different densities in a tank, with stable stratification. Mechanical stirring is produced by an oscillating grid at a certain distance from the fluids interface. The action of the grid generates mixing and consequently the formation of a turbulent region. At the TNTI position, entrainment of fluid from the quiescent layer into the turbulent one initiates. A well-mixed layer is formed and propagates into the quiescent region as the interface moves away from the stirrer.
In the first part of the project, the focus was on the creation of the experimental system dynamics using a DNS code, based on SPARKLE (written at Imperial College London), which integrates the incompressible Navier-Stokes equations in the Boussinesq approximation on a cuboidal domain.
The code is modified to reproduce the experimental set up by adding an "oscillating grid" (as the boundary condition of the fluid), creating a source of turbulence and consequently stirring the fluid. The stratification is made by inputting an initial discontinuity in the temperature vertical profile at the middle height position of the domain.
Several runs were made to evaluate the relevance of physical parameters and initial conditions: the main guideline was to fasten the propagation of the turbulent region toward the temperature interface and to weaken the thermal diffusion that leads to a thicker interface. A satisfactory configuration has been made, in which the value of the kinematic viscosity is the main driving parameter. The next step of the project will be the integration of routines describing particles' dynamics in the code.

1.2.3 Work package 3

Microphysics of clouds

ESR5: In order to form rain, small cloud droplets must grow to at least 50 um, at which point they are large enough to start falling. Condensation, which initially forms small cloud droplets, is only effective up to about 15 um, so turbulence must be responsible for bridging the gap between 15 and 50 um. Exactly how turbulence does this, is not known, but several theories exist, notably, preferential concentration and the sling effect. We aim to understand and characterise these mechanisms, by means of an experiment in which we measure Lagrangian droplet trajectories in a cloud on Mt. Zugspitze in Germany.
The experimental setup is situated on top of the UFS Schneefernerhaus. At its heart the setup consists of a box with three fast cameras, all looking at the same 3x3x3 cm^3 volume. They typically record droplet images at 10 kHz. To prevent the wind from blowing droplets out of measurement volume too quickly, the camera box is mounted on a 6.5 m long rail system, that allows it to move with the mean wind speed. However, due to technical difficulties the rail

system hasn't yet been used for measuring.
In the summer of 2017 the first measurements were done. Currently, the data is being analysed and improvements to the setup are underway.
One of the improvements that is currently the focus of this research project is the rail system. It will hopefully be used this year to cancel effects of the mean wind, and thereby extend the lengths of measured droplet trajectories. ESR5 is trying to minimise the vibrations the rail system introduces in the measurements, which improves the accuracy of droplet acceleration measurements.
The dynamic properties of droplets depend heavily on their size, but the experimental setup is currently not able to measure droplet sizes. This year a method will be developed that will infer droplet sizes solely from measured intensities. Next year this method will be deployed at the UFS Schneefernerhaus.

ESR9: Initially, ESR9 thoroughly studied Image processing techniques to analyse archived data from previous experiments. Meanwhile, preparations were underway for the summer campaign at the Environmental Research Station Schneefernerhaus (UFS) in southern Germany by testing their new instrument, named "Frame of light", in the laboratory.
Frame of light was designed to uniformly illuminate a cloud volume of approximately 50cm x 50cm x 2mm, to visualise droplets within this volume and perform quantitative multi-scale measurements of droplet clustering and small scale turbulence. Hence, it is possible to collect images of the cloud droplet spatial distribution in a two-dimensional plane enlightened by a laser sheet technique with our digital camera (*Optronis CP80-25-M-72 CoaxPress).*
Last summer, from 16.08.2017 to 01.09.2017, some measurements in real clouds were made at UFS. After the campaign the data were analysed. Although the instrument was tested in the laboratory successfully prior to the campaign, the experiments at UFS did not produce such fruitful results. This could be attributed to different reasons, such as insufficient laser intensity, high speed winds blowing at the field, and smaller drop sizes in real clouds than in the laboratory. Hence, improvements will be made on the instrument for the next campaign focusing on the shape and configuration of the frame as well as laser intensity.
Furthermore, since last December, tests have been made on a new instrument for the visualization and size/velocity measurements of cloud and fog droplets, as well as precipitation particles with a shadowgraph imaging technique. The method, called "Particle/Droplet Image Analysis" (PDIA), involves illuminating the region of interest from behind with an incoherent, expanded and collimated laser light beam and collecting shadow images of droplets at up to 30 frames or pairs of frames per second with a digital camera. A series of laboratory tests have been performed with small water droplets of ~10 μm diameter, produced by means of an ultrasonic fog generator and advected with forced flow. Recently the setup performance in real condition has been tested, on the roof of a faculty building of UW (Uniwerytet Warszawski); capturing some images of precipitating particles as well as statistical analyses of cloud droplets in foggy weather.
Finally, ESR9 will participate in a summer school at UFS camp next July where he is planning to test both PDIA setup and an improved frame of light in real clouds.

1.2.4 Work package 4

Aerosols and clouds

ESR10: The project is aimed at numerical modelling of transport and interactions of Stokes particles, such as cloud droplets and other aerosols. Large Eddy Simulations are commonly used for the dynamics of high Reynolds number atmospheric flows. In this method, only scales of the order of the grid size are simulated while smaller motions are replaced by a subgridscale (SGS) model. The SGS modelling of Stokes particles in LES is a major theoretical challenge as the SGS flow are complex and multi-scale. The project focuses on accurately modelling collisions and coalescence of Stokes particles in turbulent flows; comparing SGS models in LES with filtered Direct Numerical Simulations (a priori LES analysis) as the reference results. The presence of small eddies from the dissipative part of the spectrum enhances the collision rate in turbulent flows. Here, the key quantity which quantifies the enhancement of the particle collision kernel is the turbulent kinetic energy (TKE) dissipation rate. The first part of the project was devoted to the problem of TKE dissipation rate retrieval from a velocity signal with spectral cut-off. This signal is where, due to low grid resolution (in LES) or finite resolution of measuring devices (for airborne velocity measurements in the atmosphere), the high-wavenumber part of the TKE spectrum is missing. For this task, DNS data of velocity fields in atmospheric configurations (stratocumulus cloud-top and free convective boundary layer – *courtesy of Prof. J. P. Mellado*) were first filtered with different spectral cut-off wavenumbers. Different methods for TKE dissipation rate retrieval were applied, including standard spectral retrieval methods and new proposals based on a recovery of the missing part of the spectrum. Their results were compared with the true TKE dissipation rate retrieved from DNS. Results of this part of the project have been submitted for publication in New Journal of Physics.
Next part of the work, currently in progress, is devoted to the reconstruction of the missing, subfilter turbulent motions using a fractal technique. This method can recover basic statistical properties of the local TKE dissipation rate. The final goal is to model local enhancement of the collision kernel on a grid a few times finer than the LES grid. This will provide am SGS model for the dispersion of cloud droplets.

ESR13: Research objectives include an investigation on how to include heterogeneous and homogeneous nucleation inside direct numerical simulations. This requires the introduction of a new specific numerical procedure to implement cloud droplet nucleation and subsequent generation of new droplets inside numerical codes where droplet growth by condensation/collision is simulated. On a lower level, a sub-domain feed-back on the direct cloud turbulent fluctuation simulation, based on the comparison between the size distribution given by the classical population balance equation and the distribution deduced from the numerical simulation, was introduced. In particular, it was thought to use the population balance equations starting from the nucleation size, about 1nm, to the smallest droplet size we can simulate, about 2.5 µm in radius. The balance equation is parametrized via the initial and boundary conditions, which exploit information from laboratory and in-field measurements. The aim is to achieve a local dynamical adjusting of the water particle density by killing or breeding water droplets from the simulation threshold size of 2.5 µm up to the maximum droplet size reached in the evolving simulation. The sub-domain volume sought for the feedback along each linear dimension is one order of magnitude smaller than the entire domain of the simulation. The spatial structure of clouds is inhomogeneous with continuous changes associated with a large set of coexisting timescales. In our numerical simulation, the cloud interface is modelled through two interacting regions at different turbulent intensities. Different initial conditions reproduce possible local stable or unstable stratifications in density and temperature. Currently, our simulation model includes evaporation, condensation, collision, and coalescence. The governing Navier-Stokes equations are used in Boussinesq's

approximation and are coupled to equations describing the evolution of water drops, seen as inertia particles, transported by background turbulence and gravity.
ESR13 is trying to update the result of this Population Balance Equation model with the DNS 14P version of the code (written in Politecnico di Torino) which uses MPI libraries for one-dimensional parallelization.

1.2.5 Work package 5

Clouds and Weather/Climate Modelling

ESR11: We studied the tendency of convective clouds to aggregate at a scale larger than the single convective cell. This aggregation is of crucial importance because it is associated with a dramatic change in the large-scale conditions, including extremely dry and cloudless ones. This drying is a leading-order impact of convection on large scales which is not accounted for in climate models, and more importantly, those very dry conditions imply that the dry atmosphere emits radiation from low levels, with a large climatic effect. We want to study how the aggregation is influenced by the details of the surface, such as the presence of ocean or land, and the temperature of the oceans. The physical processes involved are studied by Cloud resolving models or Large Eddy Simulation, and will be verified on Global Climate Models.
Ocean hot spot anomalies like ocean eddies or islands largely impact the environment around them and redistribute the wind, cloudiness, and precipitation. For example, the precipitation over the tropical islands is significantly larger than over the ocean surrounding them. Not just precipitation, but also the wind field and temperature profile are affected as well as the large-scale circulation.
In this first year, we have focused on how the ocean hot spot anomaly changes the cloudiness pattern and whether it can enforce aggregation of convective clouds. To do so, we used System of Atmospheric Model (SAM) as a 3D cloud resolving model to simulate hot spot anomaly. The findings show that the hot spot can enforce or accelerate the aggregation of convective clouds. The convections develop mostly over the hot spot, enforcing subsidence in the area far from its centre. The subsidence imports dry air from the upper troposphere to the lower troposphere making the subsiding area dry quickly. The dryness reinforces the subsidence and results in more dryness. This positive feedback in the dry region along with enforced convection over the hot spot develop a large-scale circulation that dictates and maintains the aggregation over the hot spot. The aggregation forms and is maintained even without radiation feedback. The role of the radiative feedbacks has been explored in many studies and the findings suggest that convective clouds do not aggregate without these feedbacks. Moreover, turning off the radiative feedback even after the aggregation is fully established makes it disaggregate. Our findings with hotspot simulations which have homogenized radiation, show that the forcing due to the hot spot and the formation of the large-scale circulation is sufficient for the aggregation of convective clouds to develop.

1.2.6 Work package 6

Dissemination and communication

To raise the profile of the project and the level of scientific awareness in Europe overall, results of COMPLETE were planned to be communicated in a targeted and tailored manner to the public at large. WP 6 is specifically addressed toward the popularization to non-specialists and to the interaction with the society. WP6 is led by the UW group that has got an established experience through the management of the popular science webpage: http://naukaoklimacie.pl/. Outreach work includes a focus on traditional as well as new kinds of methods: (1) working with schools (8-18 year olds) and presentations at science fairs such as the British Science Festival, Open University Days, Researchers Night and Science Cafés, to showcase our research, where ESRs have a chance to enthuse and inspire the future generation. ESR9, for example, has participated to the 21st Festival of Science at UW on 29-30th of September 2017 in which they, as "Cloud Dynamics & Atmospheric Turbulence" group of Institute of Geophysics (IGF) of UW under the direction of Prof. Malinowski, have performed some lectures and experiments for public visitors at "Hydrodynamics laboratory" of IGF. ESR9 and ESR10 also participated to the Open Day at Uniwersytet Warszawski's Ochota Campus on April 14th, 2018. Public was invited to visit multiple research facilities, and Fluid Dynamics Laboratory of Instytut Geofizyki - Wydział Fizyki UW was one of them. Prof. Szymon Malinowski together with the two ESRs presented to the public the secrets of cloud chamber and cloud research in general; (2) workshops and presentations organized in collaboration with regional agencies for environmental protection and monitoring (UFS, Regione Piemonte, ARPA) which, in turn, will contribute in diffusing the network results in the environmental monitoring community and in addressing their exploitation; (3) publication of articles in popular science column in regional and national newspapers, (4) a project website which will inform the wider public and scientific audience alike and the website of COMPLETE is up and running: https://www.complete-h2020network.eu/. All beneficiaries communicate results of COMPLETE to the wider public also through their websites. (5) all ESR are encouraged to open accounts on social platforms (as Facebook and LinkedIn) and use them to discuss and present the topics of their research, with the aim to increase the visibility to the external society. After the Supervisory Board meeting on 19 June 2017 where it was decided that the network will dedicate up to 8000 € from the network management costs to the dissemination activities associated to the Social Platform (Facebook, Twitter). COMPLETE now has its own Twitter account and Facebook page, which is very active and all the partners have been sending material to be published and shared with the wider public. It should be noticed that presentations in primary and high schools is a customary practice at ICL, POLITO, TAU, UW, MPG, LMD, and MPIM whose Media Relations Unit will also raise awareness of the project through press releases and press conferences with the participation of local, national and international journalists. Direct engagement with the public is encouraged since this benefits researchers, helping them understand public interest and concern about science and technology. This recognizes the obligation expected in the "European Charter for Researchers" to ensure their activities are made known to society to improve the public understanding of science. Results from the project are distributed to the general public through YouTube videos (Alex Liberzon has quite some YouTube videos, for example). An innovative form of dissemination and outreach within COMPLETE is that the ESRs use Wiki space of the COMPLETE website that explains the research in general terms and also acts as a repository for significant results.

Each ESR will establish a publication record that is vital to demonstrate at the international level the quality of their work with potential employers or collaborators. On average, working with supervisors, each ESR is expected to be author of 1-2 papers in international, peer-reviewed journals, like J.Atm.Sci, J. Geophys. Res., Quart. J. Roy. Meteor. Soc., J.Fluid Mech., Phys.Fluids, Phys.Rev.Lett., Physica D, J. of Turbulence, IEEE Transactions, Comp. Phys, Comm.. International conferences and colloquia are important means to communicate excellence in research, and to train soft skills of the ESR such as presentation skills, debating, logics and building a professional network. Most of the ESRs have already participated to international conferences such as EGU2018 (ESRs 2, 9, 10, 12, 13, and 14 participated) APS, EFMC, and Euromech colloquia. ESRs endeavour to publish under the Open Access model to ensure the widest possible dissemination of results and access by a much larger audience. The consortium ensures open access (free of charge, online access for any user) to all peer-reviewed scientific publications relating to its results (according to article 29.2 of the Horizon 2020 GA). The partners of the consortium will organize one EUROMECH Colloquium dedicated to the COMPLETE research areas (prior experience in organizing an EUROMECH Colloquium has already been acquired in 2009 by POLITO). Moreover, the network activity is published on the project website through periodic updates.

1.2.7 Work package 7

Recruitment and training

As described at the beginning of this report, the results of the advertisements of online magazines were fruitful as in total, there were 147 applications for the 14 ESR positions in the COMPLETE network. Applicants came from 40 different countries, of which 78,2 % were male candidates and only 21,8 % were female candidates. The number of applicants from European countries is much lower than the number of applicants coming from the rest of the world. The majority of applicants, however, were from India (24%) and Iran (22%).
Out of 14 ESR positions, 10 (71,4%) were assigned to male and 4 (28,6%) to female applicants. The final recruited candidates of the COMPLETE network represent 11 different countries, making the participation in the project very international. 4 out of 14 ESRs already have families and the majority of the ESRs have concluded a part of their studies abroad.
The deadline by the MSCA rules for the recruitment of all the ESRs was 31st May 2017 but due to problems related to the difficulties of recruitment met by Tel Aviv University, Pentalum’s default and position renouncements by candidates that were already chosen, the recruitment was finalized in October 2017. The ESRs recruited after May 31st 2017 were Mina Golshan, Miryam Paredes, Antonio Ibanez Landeta and Tung Bui Duc. For the first two delay reasons, an Amendment to the Grant Agreement was submitted to the Research Executive Agency to reallocate ESR13 to POLITO and ESR8 to MPG, following a collective decision by the Supervisory Board summoned on March 10, 2017. The Amendment was accepted by REA on May 29th, 2017.
Below is a table with the principal information on the 14 recruited ESRs.

Name	Surname	E-mail address	Nationality	Gender
Taraprasad	Bhowmick	taraprasad.bhowmick@polito.it	India	M
Tessa Chiara	Basso	tessa.basso@polito.it	Australia - Italy	F
Tai	Wada	t.wada@imperial.ac.uk	Japan	M
Vishnu	Nair	v.satheesh-kumar-nair16@imperial.ac.uk	India	M
Guus	Bertens	guus.bertens@ds.mpg.de	Netherlands	M
Johannes	Guettler	johannes.guettler@ds.mpg.de	Germany	M
Marco	Boetti	marcoboetti@mail.tau.ac.il	Italy	M
Antonio	Ibanez Landeta	antonio.ibanez@ds.mpg.de	Chile	M

Moein	Mohammadi	moein.mohammadi@fuw.edu.pl	Iran	M
Emmanuel	Akinlabi	emmanuel.akinlabi@fuw.edu.pl	Nigeria	M
Sara	Shamekh	shamekh@lmd.ens.fr	Iran	F
Miryam Elizabeth	Paredes Quintanilla	miryam.paredes@envisens.com	Ecuador	F
Mina	Golshan Koviji	mina.golshan@polito.it	Iran	F
Tung	Bui Duc	tungbd@vnu.edu.vn	Vietnam	M

Apart from attending PhD courses, some of the ESRs have already undergone secondment periods and others have been collaborating (local training) with different institutions regarding their projects, such as IIT, INRiM, and UFS. ESRs have not only participated to schools organised by the consortium but also to courses organised by different institutions, such as a courses on computing codes, LoRa Enabled Radiation and Environmental Monitoring Sensors and others.

1.2.8 Work package 8

Project Management

Project management has overseen the administrative part of the project, carried out by the project manager of COMPLETE, Anja Visocnik. Her main tasks are mainly reviewing the overall progress of the project which includes the delivery of milestones, deliverables planned and its reporting. Regular communication with REA/European Commission has been present throughout the project. Writing reports, deliverables and other administrative documents is one of the main duties of the project manager. On a daily basis, information is collected from other beneficiary partners and ESRs. Preparation of Kick-Off meetings and training schools is among the principal activities, along with the preparation of all the necessary related documents such as minutes, schedules, programmes, notes, and the required administrative documentation by the Politecnico of Torino for proper advancement of the project.

1.3 Impact

Include in this section whether the information in the DoA (how your project will contribute to the expected impacts) is still relevant or needs to be updated. Include further details in the latter case.

It is confirmed that the information in the DoA is still relevant and does not need to be updated. The modifications are explained in the “Deviations from Annex 1” section of this report.

2. **Update of the plan for exploitation and dissemination of result (if applicable)**

Include in this section whether the plan for exploitation and dissemination of results as described in the DoA needs to be updated and give details.

It is confirmed that the plan for exploitation and dissemination of results as described in the DoA is still relevant and does not need to be updated.

3. **Update of the data management plan (if applicable)**

Include in this section whether the data management plan as described in the DoA needs to be updated and give details.

At the moment we do not have any updates on the data management plan.

4. **Deviations from Annex 1 (if applicable)**

Explain the reasons for deviations from the DoA, the consequences and the proposed corrective actions.

The main reason for deviations from the DoA was Pentalum's default and its exit (April 11, 2017) from the consortium which caused delay in recruitment. Also Grimm Aerosol (as beneficiary partner) and Aerosol Akademie (non-beneficiary partner) left the consortium on 29 September 2016, which caused the modification of some tasks, especially the modification of WP4. Both of these partners were supposed to work on aerosol data acquisition and elaboration. For the above mentioned reasons some deliverables were postponed so that the leading beneficiaries had enough time to write them with the appropriate information and results. The ESRs programme needed to be redefined and reassigned to other beneficiary partners (MPG Goettingen and POLITO).

4.1 Tasks

Include explanations for tasks not fully implemented, critical objectives not fully achieved and/or not being on schedule. Explain also the impact on other tasks on the available resources and the planning.

Below is a list of adjustments following the decisions taken during the Supervisory Board meeting on 1st December 2017, regarding the entrance of Istituto Italiano di Tecnologia (IIT) and Istituto Nazionale di Ricerca Metrologica (INRiM). During this Supervisory Board meeting the entrance of both institutes has been officially approved. On 30th January 2018 we have also made a formal notification regarding the inclusion of IIT and INRiM to the network, including minor changes to the tasks and deliverables.

- **Task 1.1:** TAU removed from Task 1.1
- **Task 1.2:** TAU, UW removed from Task 1.2, POLITO, IIT and INRiM added to Task 1.2
- **Task 1.3:** IIT added to Task 1.3
- **Task 1.6:** TAU removed from Task 1.6
- **Task 4.1:** ICL changed deliverable title of D4.1
- **Task 4.2:** ICL changed deliverable title of D4.2, TAU added to Task 4.2
- **Task 4.4:** TAU and ICL removed from Task 4.4

The Department of Aeronautics of Imperial College London has moved building and premises during the summer and autumn of 2017. In this process, wind tunnels have been decommissioned in the old premises and rebuilt in the new ones. Major delays have occurred and wind tunnels are not in a state where they can be used as their flow quality has not even been documented yet and further delays are expected as well as not fully predictable given subcontracting dependencies. It has therefore been decided to replace current D4.1 with a similar deliverable on another laboratory experiment, equally if not in fact even more relevant to COMPLETE given its complementarity to other projects within COMPLETE and its direct import and impact on COMPLETE's aims: "Laboratory experiments of interfaces in a turbulent shear flow" for which our turbulent jet facility will be used which is independent from our wind tunnels. Interfaces are central to cloud physics and to COMPLETE.

Objectives of the WP4 have been slightly changed in respect to the proposal for the motives described above and due to the exit of Pentalum and Grimm Aerosol

Predictive methods of cloud particle formation and growth (O4.1), new methods to characterize particle size distributions in clouds (O4.2).

Description

WP4 is concerned with how initial droplet distributions – which are strongly depended on aerosol concentration -- affect cloud evolution. Of particular interest is how particle/droplet distributions evolve in the proximity of sheared, buoyant and cloudy interfaces.

The behaviour of droplets near interfaces may significantly influenced by their inertia. WP4 studies interfaces, in particular their effect on inertial particles, including effects of shear and buoyancy. (ICL, TAU) using Direct Numerical Simulation.

New models for droplet growth immediately after nucleation, including the minimum droplet diameters yielded by nucleation, will be developed and incorporated in Navier-Stokes solvers. The droplet population dynamics is inferred from Population Balance Equations with accessory condition deduced from infield measurements (POLITO).

WP4 will develop improved or new methods (T4.3) to characterize the effect of aerosols on particle droplet size distributions near for cloud edges. The effect of the initial droplet distribution on the evolution of cloud interfaces will be studied using Direct numerical simulation by resolving millions of interacting and coalescing droplets (ICL). Models will be developed for the interaction between droplets and interfaces (UW).

Deliverables

D4.1 ICL: Laboratory experiments of interfaces in turbulent shear flow
D4.2 ICL: Simulation of aerosol/droplets
D4.3 UW: New model conception (LES/RANS) on interface/droplets interaction
D4.4 MPG: Data deposit – aerosol and clouds - in an OpenAccess Lagrangian database
D4.5 ICL: Technical and scientific report

5. **List of publications**

1. E. O. Akinlabi, M Waclawczyk, J. P. Mellado, and S. P. Malinowski, Estimating turbulent kinetic energy dissipation rate and external intermittency from DNS of atmospheric stratified flows, Geophysical Research Abstracts Vol. 20, EGU2018-6958, EGU General Assembly 2018.

2. E. O. Akinlabi, M. Wacławczyk, J. P. Mellado, S. P. Malinowski, "Estimating turbulent kinetic energy dissipation rate in atmospheric flows: a priori study" manuscript submitted *to New Journal of Physics*, 2018.

3. T. C. Basso, M. Iovieno, S. Bertoldo, G. Perotto, A. Athanassiou, F. Canavero, G. Perona, D. Tordella, Design for green, disposable, mini radiosondes to track fluctuations along isopycnic surfaces in cloud environments, 70th Annual Meeting of the APS Division of Fluid Dynamics, November 19 – 21, 2017, Denver, CO. Bulletin of the American Physical Society, Volume 62, Number 14, page 323.

4. T. C. Basso, M. Iovieno, S. Bertoldo, G. Perotto, A. Athanassiou, F. Canavero, G. Perona, D. Tordella, Disposable radiosondes for tracking Lagrangian fluctuations inside warm clouds, International Conference on Electromagnetics in Advanced Applications, September 11 – 15, 2017, Verona, Italy.

5. T.C. Basso, M. Iovieno, S. Bertoldo, Disposable radiosondes for tracking Lagrangian fluctuations inside warm clouds, PROCEEDINGS OF THE 2017 IEEE-APS TOPICAL CONFERENCE ON ANTENNAS AND PROPAGATION IN WIRELESS COMMUNICATIONS (APWC), pages 189 – 192, 2017.

6. T. C. Basso, S. Bertoldo, G. Perona, G. Perotto, A. Athanassiou, and D. Tordella, Innovative, green, floating radiosondes to track small-scale fluctuations along isopycnic surfaces in and around warm clouds, Geophysical Research Abstracts, Vol. 20, EGU2018-17660, EGU General Assembly 2018.

7. S. Bertoldo, M. Paredes, L. Carosso, C. Lucianaz, M. Allegretti, F. Canavero, G.Perona, Progress on the realization of a LoRa® based communication system for atmospheric monitoring probes, XXII Riunione Nazionale di Elettromagnetismo, XXII RiNEm, 3-6 September 2018, Cagliari, Italy, ABSTRACT ACCEPTED.

8. T. Bhowmick, D. Codoni, V. Ruggiero and D. Tordella, Transient evolution of warm cloud – clear air interface and its impact on cloud droplet evolution, EFMC – 12th European Fluid Mechanics Conference, 9 – 13 September 2018, Vienna, Austria.

9. D. Codoni, M. Golshan, V. Ruggiero, M. Iovieno, M. Vanni, and D. Tordella, Water droplets simulation in a warm cloud like ambient, Geophysical Research Abstracts, Vol. 20, EGU2018-17910, EGU General Assembly 2018.

10. D. Codoni, M. Golshan, V. Ruggiero, M. Iovieno, M. Vanni, D. Tordella, Water droplets simulation in a warm cloud-like ambient, EUROMECH Colloquium 596, 9 – 11 May 2018, Venice, Italy.

11. M. Golshan, M. Vanni, D. Tordella, A proposal to obtain and introduce a feedback from water droplet population balance model to direct numerical simulation of lukewarm clouds, EFMC – 12th European Fluid Mechanics Conference, 9 – 13 September 2018, Vienna, Austria.

12. M. Mohammadi, J. L. Nowak, and S. P. Malinowski, Laboratory measurements of cloud droplets size/velocity distributions with shadowgraph imaging technique, Geophysical Research Abstracts, Vol. 20, EGU2018-15164-1, EGU General Assembly 2018.

13. M. Paredes, S. Bertoldo, C. Lucianaz, and M. Allegretti, Ultra-light disposable radio probes for atmospheric monitoring, Geophysical Research Abstracts, Vol. 20, EGU2018-1389, EGU General Assembly 2018.

14. M. Paredes, S. Bertoldo, C. Lucianaz, L. Carosso, F. Canavero, G.Perona, M. Allegretti, On the realization of a communication system for atmospheric probes based on LoRa technologies: preliminary measurements and results, ICEAA 2018, 10-14 September 2018, Cartagena de Indias, Colombia, ABSTRACT ACCEPTED.

15. V. Ruggiero, D. Codoni and D. Tordella, A Numerical Code for The Study of Water Droplets Growth, Collision, Coalescence and Clustering Inside Turbulent Warm Cloud-Clear Air Interfaces, PRACE, white paper, PRACE Preparatory Access Grant Type C project 2010PA3699.

16. J. Molacek, G. Bagheri, A. Bertens, E. Bodenschatz, Field measurements of cloud droplet dynamics, 70th Annual Meeting of the APS Division of Fluid Dynamics, November 19 – 21, 2017, Denver, CO. Bulletin of the American Physical Society, Volume 62, Number 14, page 322.

6. **Reference documentation in relation to REA and COMPLETE project to be consulted for further details.**

1. Grant Agreement, Number – 675675 – COMPLETE
2. Annex 1 to the Grant Agreement (Description of the Action), Part A
3. Annex 1 to the Grant Agreement (Description of the Action), Part B
4. Proposal COMPLETE 675675
5. Consortium Agreement, version 2.0, 2016-9-29
6. Consortium Agreement Amendment n.1, version 2017-07-06

These documents can be found on the Participant Portal.

7. **Appendix (tables of training schools, network-wide training events and conferences, and ESR reports)**

Table 1.2 b (enumeration according to the proposal) Main Network-Wide Training Events, Conferences and Contribution of Beneficiaries (see Annex 1, part B to the Grant Agreement, page 13)

N.	Main Training Events & Conferences	ECTS (*if any*)	Lead Institution	Project Month (*estimated*)
1	1st Workshop and 1st Training School/Kick-Off meeting	2	POLITO	4
2	1st Summer School	6	MPG	10
3	2nd Network workshop and 2nd training school	2	TAU	12
4	2nd Spring School	6	LMD	18
5	3rd Workshop	6	UW	24
6	3rd Spring School	6	ICL	30
7	4th workshop	2	ICL	36
8	Euromech	2	POLITO	40

Table 1.2 c Detailed description of Main Network-Wide Training Events and Conferences

No.	Location	Event Type	Schedule	Topics	Audience
1. M13 (19-22 June 2017)	Location: Torino Organizer: POLITO	Student's Kick-Off Meeting 1st Workshop	Day 1	1. ESR students Board kick-off meeting 2. Introduction to COMPLETE project (ESRs)	ETN
			Day 1, afternoon	3. Beneficiaries present their research activities 4. Dissemination Board and Scientific Board meeting	Open
	Organizer: UW	1st Training School	Day 2	Atmospheric turbulence, convection and clouds	Open
	Organizer: I3P		Day 3-4	Entrepreneurship and business planning, Application of the Business Canvas Model	Open
19 June 2017	Torino	1st Annual Meeting			
2. Early 2018 (15-16 Feb 2018)	Location: Torino Organizer: POLITO	ESRs presentations meeting	Day 1 Day 2	1. ESRs 1 – 10 presentations *** FORMER TRAINING AT TAU*** 2. ESRs 11 – 14 presentations	ETN
3. M24 (28 May – 1 June 2018)	Location: Paris Organizer: LMD, ISAC	1st Spring School on Cloud Parametrization in Climate Models Invited speaker: A Lanotte (CNR-ISAC)	Day 1	Fundamental elements of dynamics and physics of climate. The role of clouds in the climate system. Afternoon: ESR presentations.	Open
			Day 2	Modelling climate: Structure of current models of the atmosphere, ocean and of the climate system. Weather prediction, climate simulations. Dynamics and physical parameterization	Open
			Day 3	The physics of convection and its parameterizatoin in climate models. Observing systems. Afternoon: ESR presentations.	Open
			Day 4	The physics of clouds. Radiation, dynamics, microphysics. Physical parameteriation of clouds. Observing systems	Open
			Day 5	The frontier: errors in climate models, incertitude in observing systems. Afternoon: ESR presentations.	Open
May 2018	Paris	2nd Annual Meeting Mid Term Report Meeting			
4. M26 (July 2018)	Location: Zugspitze (UFS) Organizer: MPG,MPIM Organizer: ENV	2nd Summer School on Microphysics and dynamics of clouds Invited speaker : A.Pumir (ENS,Lyon)	Day 1	Inertial particles. Droplet collision models. Afternoon: ESR presentations.	Open
			Day 2	Cloud Microphysics and meso-scale dynamic.	Open
			Day 3	Applied Boundary Layer Meteorology. Afternoon: ESR presentations.	Open
			Day 4	Application to Meteorology and Climatology	Open
			Day 5	Remote sensing of atmospheric data. Satellite navigation. Afternoon: ESR presentations.	Open
	Organizer: BAYFOR		Day 6	1. Project Management 2. EU bid writing	ETN
5. M33 (Feb 2019)	Location: Warsaw Organizer: UW Organizer: MPG	3rd Workshop /Training School	Day 1	1. ESR presentations 2. Outreach and public engagement.	ETN
			Day 2	Cloud microphysivs	ETN
			Day 3	Aerosol and cloud chemistry (aerosol processing by clouds)	ETN
			Day 4	Langrangian experimental measurements in turbulence	ETN
			Day 5	1. Control sensor engineering. 2. Atmospheric radiosondes and LiDAR technology *** FORMER TRAINING AT TAU***	ETN
6. M36 (Summer 2019)	Location: (Göttingen) or Valsavarenche Organizer: MPG,POLITO ***NOTE: Valsavarenche http://www.to.isac.cnr.it/aosta/ ***	3rd Spring School on Small-scale Turbulence in clouds Invited speaker: Z.Warhaft (Cornell)	Day 1	Eddy structures and intermittency in fine-scale turbulence. Afternoon: ESR presentations.	Open
			Day 2	Strongly anisotropic turbulence structure and cascade: stably stratified and rotating flows	Open
			Day 3	Correlation between small-scale velocity, temperature, vapor and liquid water concentration fluctuations. Afternoon: ESR presentations.	Open
			Day 4	Physical models for small–scale structures.	Open
			Day 5	Active versus passive scalar turbulence. Afternoon: ESR presentations.	Open
May 2019	Göttingen	3rd Annual Meeting			
7. M40 (Sept 2019)	Location: London Organizer: ICL	4th Workshop	Day 1	1. ESR presentations 2. All participants meeting	ETN
			Day 2	Big Data Analysis and high performance computing	ETN
			Day 3	1. Data mining and Data Sharing 2. Exchange between numeric and experimental data	ETN
	Organizer: TAU		Day 5	1. MEMS technology, 2. Micro hot/cold wire/film probes for small scale turbulence *** FORMER TRAINING AT TAU***	
	Organizer: RAMOT		Day 4	Intellectual property rights in the technology transfer *** FORMER TRAINING AT TAU***	
8. M48 (May 2020)	Location: Torino Organizer: POLITO	Euromech Colloquium on Cloud Dynamics	Day 1	Session1. Warm boundary layer clouds. Session 2: Physics of stratocumulus top: turbulence, mixing, entrainment	Public
			Day 2	Session 3: Numerical models for moist convection, Session 4: Aerosol-Cloud interaction.	Public
			Day 3	Session 5: Session 5: Cloud droplets and precipitation.	Public
	Organizer: UW	Final meeting	Day 4	1. ESR Presentations, 2.Student Board, 3. All participants meeting	ETN
May 2020	Torino	4th Annual Meeting (final report)			

Table 1.2 c (enumeration according to the proposal) Detailed description of Main Network-Wide Training Events and Conferences (see Annex 1, part B to the Grant Agreement, page 15)

Attached to this document is a sequence of the reports written by all the ESRs of the COMPLETE project.