SPECIAL PROJECT PROGRESS REPORT

Reporting year	2015
Project Title:	Aerodynamic response of precipitation gauges immersed in a turbulent wind field
Computer Project Account:	spitlanz
Principal Investigator(s):	Prof. Luca G. Lanza
Affiliation:	University of Genova (Italy)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….……
Start date of the project:	January 1, 2015
Expected end date:	December 31, 2015

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	0	0	6000000	0
Data storage capacity	(Gbytes)	0	0	750	0

Summary of project objectives

(10 lines max)

The objective of the project is to compute time dependent runs of the 3D airflow field around a common un-shielded precipitation gauge, obtained by imposing a turbulent free-stream airflow (simulating wind with an averaged horizontal speed lower than 10 m/s) and by modelling its aero-dynamic response under a Large Eddies Simulation (LES) turbulence approach.

The simulation of sufficiently refined LES airflows to solve the spatial and temporal scales of the hydrometeors motion near the precipitation gauge represents a fundamental tool for the development of accurate and innovative correction methodologies of the snowfall/rainfall measurements.

Summary of problems encountered (if any)

(20 lines max)

In the first six months, we focused on preparatory activities to set-up the Computational Fluid Dynamics (CFD) model, which is the objective of this special project. The analysis of high-frequency 3D anemometer measurements from the field in order to define the inlet boundary conditions accurately is in course. The spatial discretization of the computational domain is also an ongoing task. The optimization of the mesh has the objective to balance the LES requirement of fine grid spacing with respect to the total amount of cells, which have a direct impact on the number of parallel jobs necessary to run the simulation.

The importance of these activities is crucial considering the large hardware requirements of the Large Eddy Simulation in a complex spatial domain. In fact, all the SBUs allocated to run the turbulent model are dedicated to achieve a fully developed solution of one single simulation run (one mean wind speed). This is the reason why there are no used SBUs/data storage units at this moment.

Summary of results of the current year (from July of previous year to June of current year)

The activity carried out during the first six months was focused on the set-up of a time-dependent finite volume simulation that constitutes the objective of this special project. Given the hardware requirements of the LES model, the goals of this activity will be achieved by performing a single run that will correspond to 20 seconds of physical time.

As a first step of the work, we collected air velocity measurements made at the precipitation gauge level by using a high-frequency 3D anemometer manufactured by Gill. The data sets were then used to obtain information on the turbulence occurring under operational conditions at the gauge collector. Table 1 shows the values of the time averaged wind speed components, the turbulent kinetic energy and the turbulent intensity computed for two 15-min long time series at the Nafferton Farm field site in UK.

Tab. 1: Kinematic characteristics of the high-frequency 3D air velocity measurements performed at the Nafferton Farm (UK) field site

Time series	**Duration** *(min)*	**Sampling Frequency** *(Hz)*	**Average wind speed (Uw_x, Uw_y, Uw_z)** *(m/s)*	**Turbulent Kinetic Energy** *(m^2/s^2)*	**Turbulent Intensity** *(-)*
#1	15	20	(0.05, -2.23, -0.02)	0.39	0.22
#2	15	20	(0.39, -2.74, 0.00)	0.45	0.19

The same time structure of the airflow turbulent fluctuations observed infield would constitute the inlet boundary condition of the CFD simulation. Fig. 1 reports the instantaneous values of the wind speed and the horizontal wind direction for time series #1. By performing the common separation of the velocity terms into the time-averaged and the fluctuating components, it's possible to represent the turbulence of time series #1 as shown in Fig. 2.

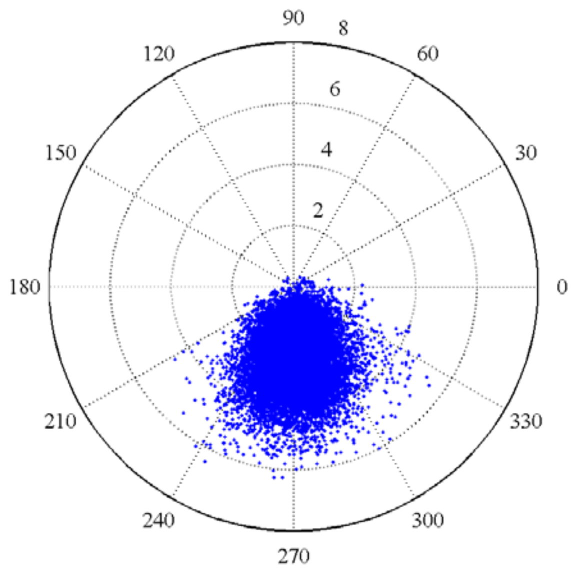

Fig. 1: Polar plot of the high-frequency 3D anemometer measurements on a horizontal plane performed at the Nafferton Farm (UK) field site. The radius represents the wind speed (m/s) while the angle is the wind direction on the horizontal plane.

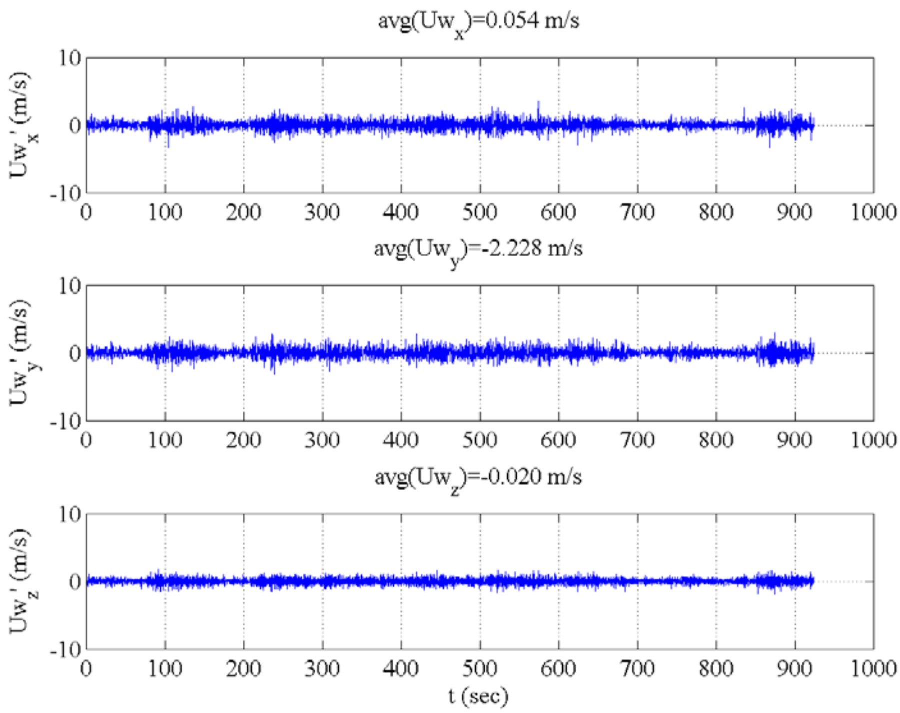

Fig. 2: Time series of the fluctuating wind velocity component U_w'(m/s) measured by an high-frequency 3D anemometer at the Nafferton Farm (UK) field site.

The field data showed that a free-stream airflow characterized by an average speed between 2 and 3 *m/s* and measured at the level of the precipitation gauge collector has a turbulent kinetic energy value *TKE* ≈ 0.4 m^2/s^2 corresponding to a turbulent intensity approximated to 0.2. These are the main kinematic characteristics of the airflow at the inlet of the simulation environmental box. The synthetic reconstruction of the time and spatial structure of the velocity field on the inlet boundary according to the previous parameters is currently ongoing.

Simultaneously to the analysis of high frequency airflow observations, the previous months have been dedicated to the realization of the simulation spatial grid.

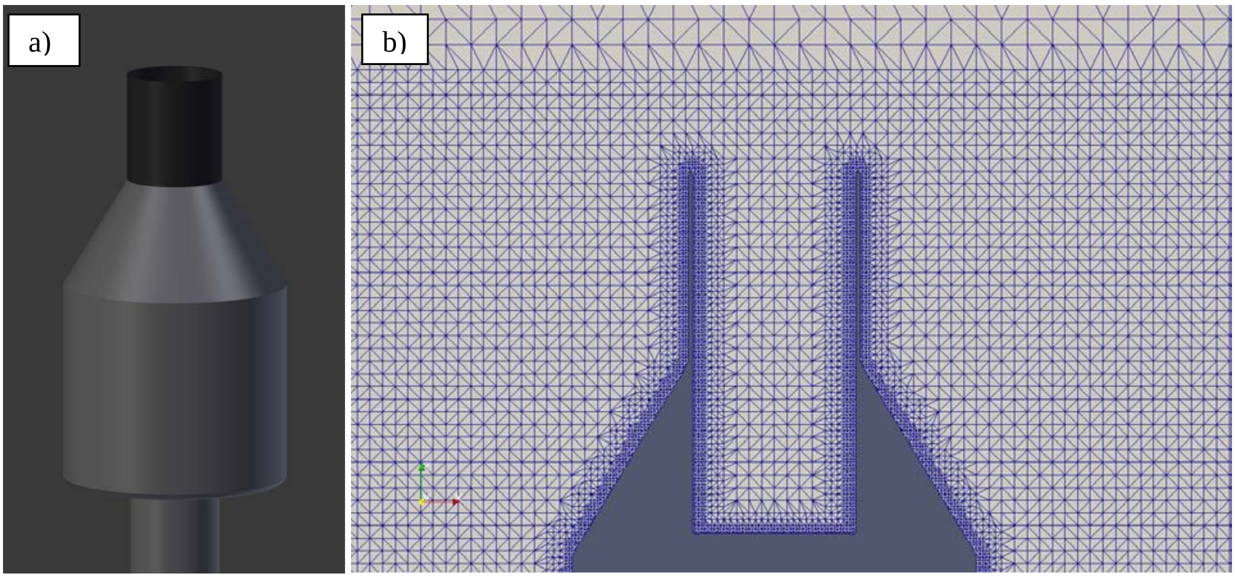

Fig. 3: 3D model of a common unshielded precipitation gauge geometry (panel a). Spatial discretization grid based on polyhedral cells (panel b) on a vertical plane passing through the gauge center.

Panel *a* of Figure 3 reports a three-dimensional representation of the axial-symmetric precipitation gauge geometry. The gauge surfaces are surrounded by the finite volumes cells that compose the spatial grid of the computational domain. Increasing refinement levels of the mesh have been imposed by getting closer to the gauge surfaces (no slip wall conditions) as shown in panel *b*. The illustration focuses on a vertical plane passing through the gauge center.

Two different meshing techniques were compared: hybrid tetrahedral/prism mesh and hexahedral mesh. The computation of the spatial grid has been performed by using algorithms optimized for the execution in 32 parallel threads.

Tab. 2: Geometric characteristics and quality factors of different tested grids

Mesh	*N. elements*				*Max values*		
	tetrahedral	*prims*	*hexahedral*	*polyhedral*	*skewness*	*non-orthog.*	*aspect ratio*
#1 RANS	$1.5\ 10^{6}$	$4.7\ 10^{6}$	0	0	2.7	67.4	84.5
#2 LES	$5.5\ 10^{6}$	$22.0\ 10^{6}$	0	0	2.7	67.3	161.3
#3 LES	0	$7.2\ 10^{4}$	$6.9\ 10^{6}$	$0.5\ 10^{6}$	1.2	31.3	3.5

Table 2 shows the number of elements resulting from the different spatial gridding and the associated geometric quality factors of the finite volumes constituting the mesh. The result of this step of the project is a hexahedral mesh constituted by 7.5 million cells characterized by low maximum values of skewness, non-orthogonality and aspect ratios. In particular, the three quality factors of mesh #3 (Table 2) show always lower values than those resulting by adopting hybrid tetrahedral/prism grids under the same level of refinements around the surfaces of the precipitation gauge.

The next step of the activity plan is to transfer the simulation set-up (mainly composed of the boundary condition algorithms and the three dimensional spatial grid) on the ECMWF computing system and to execute the LES simulation.

List of publications/reports from the project with complete references

Since the simulations are in a preparatory/set-up stage, no publication has been submitted during the first 6 months of activity. The results of the simulation will be exploited to produce a minimum of two articles to be submitted to international scientific journals following the post-processing (e.g. EGU Atmospheric Measurement Techniques, Journal of Hydrology. Atmospheric Research, etc.).

Summary of plans for the continuation of the project

(10 lines max)

The plan for the continuation of this project is summarized as follows:

- Development of a time dependent inlet condition for the turbulent airflow
- Execution of the simulation with a time dependent LES turbulence model (with an averaged horizontal speed lower than 10 m/s)
- Post-processing of the simulation results for data analysis, comparison with field observations and graphical representations.

All the previous tasks will be performed during the current year (2015) within the present special project. Future projects will aim at extending the methodology to simulate a wider range of mean wind speeds between 1 and 20 m/s and to consider different gauge shapes (e.g. disdrometers).