P2.8 INFLUENCE OF THE AIRFLOW DISTORTION ON AIR-SEA FLUX MEASUREMENTS ABOARD RESEARCH VESSEL: RESULTS OF PHYSICAL SIMULATIONS APPLIED TO THE EQUALANT99 EXPERIMENT.

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1. INTRODUCTION

Turbulent fluxes of momentum, heat and moisture intervene in numerous aspects of meteorology and oceanography (climate studies, weather forecasting, mixed layer modelling …). The exchange estimates between ocean and atmosphere are particularly essential to numerical modelling studies which use turbulent fluxes derived from parameterisations and mean meteorological measurements. In recent years, a main focus has been put on the accuracy of these parameterisations in order to reduce the uncertainties of global models of the coupled ocean-atmosphere system.

Since the measurements of turbulent fluxes over the ocean are often performed on huge platforms (research vessels, coastal platforms ...) which modify the upstream air, the improvement of flux parameterisation required to address the issue of flow distortion (Edson et al.,1998). For example, Yelland et al. (1998) revealed that for a given wind speed, the corrections of the stream disturbance reduced the drag coefficient by about 6%.

The main goal of this study is to present the results of momentum and heat fluxes obtained during the EQUALANT99 experiment aboard the R/V La Thalassa and to apply the correction for airflow distortion to various methods of turbulence flux computation and then observe the correction impact.

2. EXPERIMENT AND MEASUREMENTS

The EQUALANT99 experiment took place in the equatorial Atlantic ocean between Salvador de Bahia (Brazil) and Abidjan (Ivory Coast) during the summer months. As large uncertainties remain on the surface energy balance in this region, special emphasis during the EQUALANT99 program was put on the determination of accurate parameterisation of turbulent fluxes.

An instrumented mast was deployed at the bow of the ship and a meteorological package which measured mean and turbulent parameters was implemented at the top of this mast (figure 1).

Two methods were used to derive air-sea fluxes. The inertial-dissipative method (IDM) required the data to be recorded at a high rate in order to capture the whole frequency range; it was also possible to apply the eddy correlation (EC) method since a motion package provided the measurement of ship motions.

figure 1: Picture of the top of the instrumented mast. The meteorological sensors (anemometers, radiation sensors …) and boxes create a lifting and a deceleration of the airflow.

3. PHYSICAL SIMULATIONS OF FLOW DISTORTION

Physical simulations of the air flow distortion caused by the ship and the instrumented mast have been performed in a water channel with a model of the R/V. With the similarity theory, it exists a direct connection between the true atmospheric values (lengths, wind speed and time) and the same values simulated in the water channel.

In the physical simulations, the water flow on the model allowed to reproduce strong wind speeds in neutral atmosphere. A detailed model of the R/V La Thalassa, with the representation of the instrumented mast, was used at 1/60 scale. In the water channel, a standard marine boundary layer was simulated at the same scale with an upstream wind speed corresponding to 15 m/s in real conditions. The three components of the flow speed were measured with laser anemometry which is a non intrusive technique, with an accuracy up to 2%.

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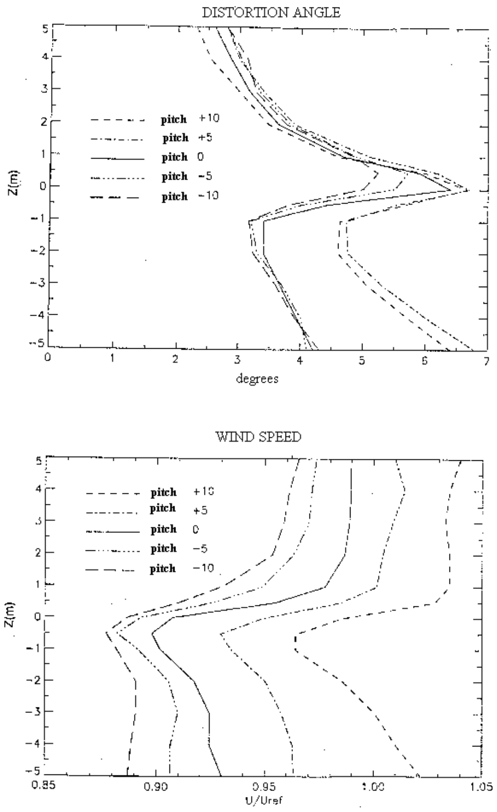

Figure 1: Profile of the airflow disturbance at the sonic anemometer location (corresponding to z)=0) with the pitch angle. Effects on the angle of incidence (above) and on the wind speed (below).

Several experimental conditions were used to characterize the distortion, three inlet azimuth angles (0, 15 and 30 degrees) and five pitch angles (-10, -5, 0, 5, 10 degrees). In fact, as no varying angle of the wind flow can be simulated in a water channel (the flow is always flat), the varying pitch angle in the water channel corresponds to the angle of wind incidence at the top of the mast, in real conditions. If I_m is the measured angle of incidence at the sonic anemometer, θ the pitch angle and δI the angle of distortion, we have:

$$I_m = \text{Arctan}\,(w_m / U_m) + \theta + \delta i, \quad [1]$$

w_m and U_m are respectively the measured vertical component of the wind velocity and its horizontal component. So what is called the pitch angle in the water channel represents the angle of the wind incidence in true measurement conditions.

The data reveal that the flow is distorted by both the ship body and the mast, but this latter has the dominant effect because of all the sensors and boxes settled on it which disrupt the flow and cause an air compression. The aerodynamic envelope of the ship induces a wind speed decrease up to 2% above the deck and the mast amplifies this perturbation up to 10% at the location of the sonic anemometer. Similarly, the attack angle of the wind reaches 7° in front of the anemometer (figure 1).

Besides, the figure 1 also shows that the distortion is very sensitive to the angle of wind stream at the sonic anemometer location I_m. The effect of incidence can reach 12% on the wind velocity for an angle of –10° (when the ship bow leans forward). The distortion also varies with the azimuth angles. In fact, the wind speed decreases when the relative wind azimuth angle increases (see figure 2).

The mast and more especially the sensors installed at its top induce a disrupt of the flow and force the stream to lift up at the wind measurement place. This air rising is also estimated with the physical simulations, its value is about 1 meter.

3. RESULTS

The physical simulations provide discrete correction coefficients for the wind speed varying with the angles of wind stream incidence and relative wind direction (azimuth). In order to approximate continuously the corrections for flow distortion, a polynomial surface was deduced from the experimental coefficients but this corrective function $\alpha(I_m,\varphi)$ is only applied to the horizontal wind velocity U in the range of angles used for simulations and it expresses as:

$$\alpha(I_m, \varphi) = - 8.127\text{x}10^{-5}\,\varphi^2 - 2.53\text{x}10^{-4}\,I_m^2 - 2.38\text{x}10^{-3}\,i_m + 1.113, \quad [2]$$

$$U_{corrected} = U_{measured} \times \alpha, \quad [3]$$

where i_m and φ are respectively the angle of incidence and the angle of wind azimuth .

Figure 2 shows the comparison of the uncorrected versus corrected relative wind speed for mean azimuth angles of the wind with respect to the ship axis lower than 30°. The impact of the correction is stronger for azimuth angles between 15° and 30°. But generally, the correction increases the wind velocity by about 5 to 10%.

The analysis of the neutral exchange coefficients allows to assess the consistency of the wind speed correction for the flow distortion. In this paper, only preliminary results of neutral coefficients derived from the inertial-dissipative method are presented but it is planned to apply the same kind of corrections to the eddy covariance (EC) fluxes since turbulent air-sea exchanges for the EQUALANT99 experiment are also computed by this method.

Concerning the inertial-dissipation method (Dupuis et al., 1997), it is assumed that the turbulence in the inertial sub-range is not affected by the air stream disturbance. Thus, the dissipation rates are calculated from uncorrected data but the wind speed averaged over 30 minutes is corrected with the equations 2-3, and the measurement height is corrected for vertical displacement which is a fixed value of 0.9 m.

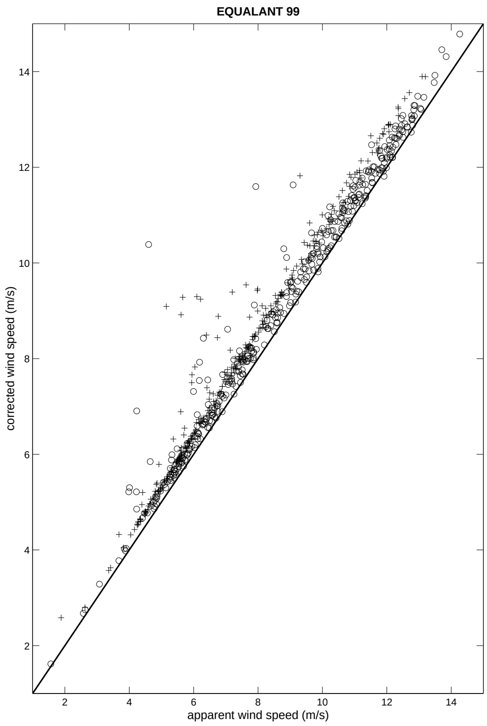

Figure 2: uncorrected versus corrected relative wind speed. Crosses represent samples when the mean azimuth angle is between 15° to 30°, and circles represent samples when the mean azimuth angle is lower than 15°.

Figure 3 compares exchange coefficients C_{D10n} and C_{E10n} as a function of u_{10n} for uncorrected and corrected samples (crosses and dots respectively), using only relative wind azimuth angles within +/-30° to the bow axis. Mean values and the standard deviation computed over 1 $m.s^{-1}$ bins are represented as well as usual bulk parameterization (Smith 1980 for the drag coefficient C_{D10n} and Large & Pond 1982 for C_{E10n}).

It appears that the neutral exchange coefficients are decreased when the correction is applied. Besides, it can be noted that for both the C_{D10n} and the C_{E10n}, the standard deviations are smaller after corrections for flow distortion, which means that the correction reduces the scatter of neutral coefficients as a function of u_{10n}. The curve for the mean corrected drag coefficients is close to that of the Smith parameterization (1980).

Figure 3 also shows that the C_{E10n} values present a dependence on the neutral wind speed u_{10n} contrary to the Large and Pond parameterization.

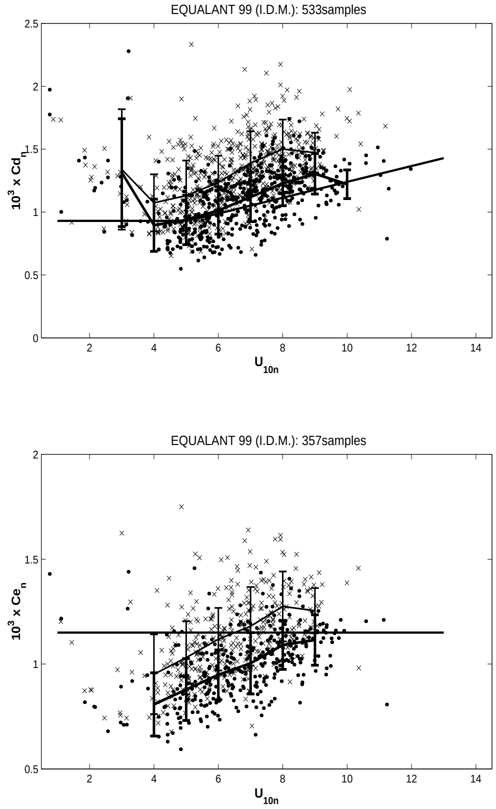

Figure 3: (Top) C_{D10n} values versus u_{10n} obtained from the R/V La Thalassa measurements with the inertial dissipation method. Crosses are uncorrected C_{D10n} values and dots are values corrected for airflow distortion. Solid lines join the mean values of C_{D10n} calculated in classes of 1 ms^{-1}bins. Error bars indicate the standard deviation with respect to the mean for each bin. The parameterization of Smith (1980) is also plotted. (Bottom) The same representation is used for C_{E10n} versus u_{10n}. The solid line stands for the parameterization of Large and Pond (1982).

4. CONCLUSION

Only preliminary results are presented here since the impact of flow distortion on EC flux measurement is still at study. But it can already can be noticed that the correction for flow distortion seems consistent since it reduces the scatter of neutral coefficients with the neutral wind speed. It can be assumed that a systematic correction for airflow distortion applied to data obtained from huge platforms at sea, will lead to more consensual parameterisations of turbulent air-sea fluxes.

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