Assessing dry weather flow contribution in TSS and COD storm events loads in combined sewer systems

Estimation des flux d'eau et de polluants de temps sec (MES et DCO) pendant les événements pluvieux en réseau unitaire

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RÉSUMÉ

Une solution reconnue pour l'estimation des flux de Matières en Suspension (MES) et de Demande Chimique en Oxygène (DCO) rejetés par temps de pluie en milieu urbain est le mesurage en continu de la turbidité associée à celle du débit. Sur le site unitaire d'Ecully (Lyon, France) équipé de turbidimètres depuis 2003, plus de 200 événements pluvieux ont été mesurés. Dans cet article, une méthode pour l'estimation de la contribution de temps sec aux flux totaux de MES et de DCO mesurés par temps de pluie est présentée, avec une attention particulière pour la quantification des incertitudes. La méthode prend en compte la dynamique des concentrations en MES et DCO au pas de temps de deux minutes. A partir de l'analyse de 180 jours de temps sec, mesurés sur la période 2007-2008, trois classes de jours de temps sec ont été distinguées. Aucunes tendances au cours de l'année ou interannuelle ni d'influence des saisons n'ont pu être détectées. L'analyse et la quantification des incertitudes ont permis de montrer que la loi de propagation des incertitudes était applicable. La méthode a alors été appliquée à la totalité des événements pluvieux mesurés à Ecully. Cette étude confirme l'intérêt du mesurage en continu à court pas de temps du débit et de la turbidité en réseau d'assainissement, en particulier la modélisation des flux polluants par temps de pluie.

MOTS CLÉS

DCO; contribution de temps sec; charges polluantes; turbidité; MES; incertitudes; modélisation qualité

ABSTRACT

Continuous high resolution long term turbidity measurements along with continuous discharge measurements are now recognised as an appropriate technique for the estimation of in sewer Total Suspended Solids (TSS) and Chemical Oxygen Demand (COD) loads during storm events. In the combined system of the Ecully urban catchment (Lyon, France), this technique is implemented since 2003, with more than 200 storm events monitored. This paper presents a method for the estimation of the dry weather contribution to measured total TSS and COD event loads with special attention devoted to uncertainties assessment. The method accounts for the dynamics of both discharge and turbidity time series at two minutes time step. The study is based on 180 dry weather days monitored in 2007-2008. Three distinct classes of dry weather days were evidenced. Variability analysis and quantification showed that no seasonal effect and no trend over the year were detectable. The law of propagation of uncertainties is applicable for uncertainties estimation. The method has then been applied to all measured storm events. This study confirms the interest of long term continuous discharge and turbidity time series in sewer systems, especially in the perspective of wet weather quality modelling.

KEYWORDS

COD; dry weather contribution; event loads; turbidity; TSS; uncertainties; water quality modelling

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1 INTRODUCTION

As specified in the French transcription (decrees of June 22nd, 2007 and February 15th, 2008) of the European Urban Waste Water Directive of May 21^{st}, 1991, TSS and COD loads at significant discharge points, especially CSOs (Combined Sewer Overflow structures) in sewer systems have to be monitored. Thus, practical and efficient solutions have to be implemented, making particularly challenging the development of economically affordable solutions for a reliable continuous assessment of pollutant loads during storm events. Since a decade, surrogate continuous measurements such as turbidity or UV-visible spectrophotometry are increasingly being recognised as promising techniques for water quality measurement in sewer systems. Several research groups are working on that field worldwide (e.g. Fletcher & Deletic, 2007; Gruber *et al.,* 2005; Muschalla *et al.*, 2008; Ruban *et al.*, 2008; Lacour *et al.*, 2009; Métadier & Bertrand-Krajewski, 2009a). Significant knowledge has been acquired and new methodologies for implementing these techniques were developed with a particular focus on assessing measurement uncertainties (e.g. Bertrand-Krajewski *et al.*, 2008; Fletcher & Deletic, 2007; Ruban & Joannis, 2008; Lacour, 2009). Available continuous turbidity time series can be used for various purposes, including estimation of pollutant loads for regulatory requirements, operation, planning and rehabilitation of sewer systems, real time control and modelling.

This paper deals with the use of discharge and turbidity time series for pollutant load modelling during storm events in combined sewer systems, with a special attention devoted to the estimation of the dry weather (DW) contribution to total TSS and COD loads measured during storm events. Indeed, most models of storm weather pollutant loads in combined sewer systems are based on the assumption that the total storm event load is the sum of i) the DW contribution that would have been observed during the event duration if no event had occurred and ii) the wet weather contribution including surface runoff + possible erosion of deposits accumulated in the sewers. The DW contribution during a storm event can be estimated by various approaches: mean dry weather days, seasonal or monthly mean dry weather day, etc. usually based on continuous discharge measurements and on traditional sampling and laboratory analyses campaigns for pollutant loads estimation. As sampling and laboratory analyses campaigns are expensive and limited, DW pollutant loads are usually not well estimated during a particular storm event. The idea presented in this paper is to use turbidity continuous time series to improve this estimation. Few studies dealing with TSS and COD DW analysis based on continuous measurements in combined sewer systems are currently available. E.g. Lacour (2009) studied DW flow and turbidity variability for two urban catchments in Paris, with specific attention to measurement uncertainties assessment and focus on potential use of continuous turbidity for sewer water quality based real time control. Schilperoort *et al.* (2009) presented a comparable analysis but focused on WWTP management with definition of performance and design criteria, without evaluation of uncertainties. Regarding water quality modelling, Muschalla *et al.* (2008) used continuous UV-visible spectrophotometry series for estimation of discharge and COD DW patterns.

In the following sections, the proposed methodology is described, discussed and applied.

2 METHODS

2.1 Sources of data

The data set used in this study has been collected in the Ecully 245 ha residential combined urban catchment in Lyon, France. In the frame of the OTHU project (wwww.othu.org), the site was equipped at the catchment outlet with water level, flow velocity and water quality sensors including conductimeters and turbidimeters, recording values with a two minutes time step. A detailed description of the site is available e.g. in Dembélé *et al.* (2009). Five years of continuous data (from 2004 to 2008) have been processed and validated with assessment of standard uncertainties, using a semi-automatic tool especially designed for calculating storm event pollutant loads from continuous raw data (Métadier & Bertrand-Krajewski, 2009a). Discharge along with TSS and COD concentrations and loads with their standard uncertainties were computed using water level, flow velocity and TSS-turbidity and COD-turbidity correlation functions.

Within the period 2004-2008, more than 200 storm events were monitored, excluding those with long time gaps in the turbidity series that can not be simply infilled. 180 dry weather days (DWD) were also monitored within the period 2007-2008 (respectively 103 in 2007 and 73 in 2008) distributed throughout the years. A selected DWD is defined by the following criteria: i) both discharge and turbidity measurements are available, ii*)* it lasts from 00:00 to 24:00 and iii*)* no precipitation has been recorded during the considered day and the previous 4 hours (4 hours is the observed dry duration ensuring that two successive storm events are independent each other for this catchment).

2.2 Event loads calculation

2.2.1 Total loads

The total event mass M_X for the pollutant X (*TSS* or *COD*) is calculated from the continuous pollutant time series measured at each time step i between the starting and the ending times t_d and t_f of the storm event:

$$M_X = \Delta t \cdot \sum_{i=t_d}^{t_f} C_{Xi} \cdot Q_i \qquad \text{(eq. 1)}$$

with Q_i the discharge at time step i, C_{Xi} the concentration of pollutant X estimated from turbidity $Turb_i$ at time step i, and Δt the data acquisition time step (2 minutes).

The pollutant mass standard uncertainty $u(M_X)$ is calculated according to the law of propagation of uncertainties (LPU):

$$u(M_X)^2 = \Delta t^2 \left(\sum_{i=t_d}^{t_f} Q_i^2 \cdot u(C_{Xi})^2 + C_{Xi}{}^2 \cdot u(Q_i)^2 \right) \qquad \text{(eq. 2)}$$

with $u(C_{Qi})$ and $u(C_{Xi})$ the standard uncertainties at time step i respectively for discharge and concentration of pollutant X. Discharge and concentration errors are assumed as normally distributed, these two quantities being derived from water level and turbidity measurements that are themselves considered as normally distributed. Different sources of uncertainties are accounted for in estimating $u(C_{Qi})$ and $u(C_{Xi})$: (i) measurement uncertainties of the water level, the flow velocity and the turbidity values involved in discharge and concentrations calculation and (ii) uncertainties resulting from the methods used for calculating discharge and concentrations, namely water level-velocity-discharge equation and TSS-turbidity and COD-turbidity correlation functions. The detailed method for assessing $u(C_{Qi})$ and $u(C_{Xi})$ is presented in Métadier & Bertrand-Krajewski (2010).

In addition to the above, it is assumed that:

$$M_X = M_{X\_DW} + M_{X\_WW} \qquad \text{(eq. 3)}$$

$$V = V_{DW} + V_{WW} \qquad \text{(eq. 4)}$$

with M_{X_DW} the DW contribution, M_{X_WW} the wet weather contribution to the total mass M_X, V the total event volume, V_{DW} the DW volume during the storm event and V_{WW} the wet weather volume generated by the storm event.

2.2.2 Dry weather contribution

The DW contribution M_{X_DW} is defined as "the pollutant load that would have been measured if no storm event had occurred": by definition, it cannot be measured and should be estimated. The proposed method to estimate M_{X_DW} consists to determine the most likely DW discharge and turbidity time series (i.e. DW signals) compatible with the DW time series measured after and before the observed storm event. This most likely DW signal, named hereafter the reference signal, is chosen among available measured DWDs which are close to the day during which the storm event occurs. The two steps are the following ones: i) test of several DW signals by juxtaposing them to the storm event signal and ii*)* comparing the values and the dynamics of the two signals on common DW periods of some hours on both sides (before and after) of the storm event limits: these periods are named the fitting periods. The DW signal having the most similar dynamics over the fitting periods is selected to estimate M_{X_DW}. In other words, it is assumed that if a tested DW signal is similar to the DW signal measured before and after the considered storm event, it is also an appropriate estimation of the non–measurable DW signal during the storm event. The method is illustrated Figure 1. The DW signals to be tested are not chosen randomly but according to a pre-established DWD classification (see Section 3.1). The selected reference signal shall satisfy the following criteria: i) both discharge and turbidity series are available without any gaps, ii) it must be long enough over the fitting periods to ensure a reliable comparison, iii) it is not necessarily an entire DWD as long as the fitting periods are fully covered and iv) it can be composed of several DWDs in case the storm event is occurring over more than one day (*e.g.* weekdays and weekends, see Section 3.1).

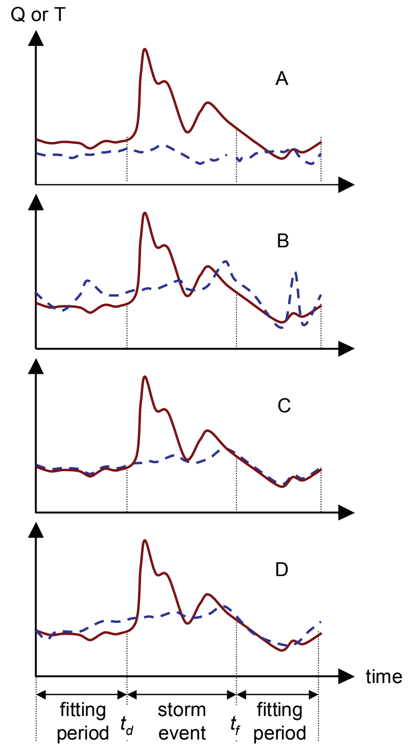

Figure 1. During a storm event, the non measurable DW contribution is estimated by comparing a set of a priori similar signals measured during dry days. In this example, six signals A to F (dotted line) are compared with the dry periods before and after the storm event, named fitting periods. The most similar signal over the fitting periods is signal C. Consequently, signal C is applied to estimate the DW signal during the storm event. The above approach is used for both discharge *Q* and turbidity *T* signals.

In case reference and measured signals are comparable over the fitting periods in terms of dynamics but not in terms of absolute values, the reference signal can be translated by applying a simple mathematical signal fitting, independently for discharge and turbidity. It is based on a least squares minimization of the distance between the two signals, by ignoring extreme distances that correspond to random peaks (especially for turbidity). As for dynamics comparison over the fitting periods, the need for translation is visually evaluated by the operator, with some possible degree of subjectivity. However, based on our experience with long continuous time series, the reference signal translation is rarely required, given measurements from rather close DWDs are usually available. The fitting may be necessary in case of long term gaps in the continuous series or long rain periods, for which no adequate DW periods are available.

M_{X_DW} is then calculated from the reference signal at each time step *i* during the storm event duration:

$$M_{X\_DW} = \Delta t \cdot \sum_{i=t_{d\_DW}}^{t_{f\_DW}} C_{Xi\_DW} \cdot Q_{i\_DW} \qquad \text{(eq. 5)}$$

with Q_{i_DW} the reference signal discharge, C_{Xi_DW} the reference signal concentration of pollutant *X* computed from the signal reference turbidity, $Turb_{i\_DW}$ and t_{d_DW} and t_{f_DW} the reference signal starting and ending times corresponding to the storm event limits t_d and t_f.

As for total mass, the standard uncertainty $u(M_{X\_DW})$ is calculated with the LPU:

$$u(M_{X\_DW})^2 = \Delta t^2 \left(\sum_{i=t_{d\_DW}}^{t_{f\_DW}} Q_{i\_DW}{}^2 \cdot u(C_{Xi\_DW})^2 + C_{Xi\_DW}{}^2 \cdot u(Q_{i\_DW})^2 \right) \qquad \text{(eq. 6)}$$

with $u(C_{Qi\_DW})$ and $u(C_{Xi\_DW})$ the standard uncertainties at time step *i* for discharge and concentration of pollutant *X* of the reference signal. Compared to total event load uncertainty, the DW contribution uncertainty includes an additional source of uncertainty which is related to the DW contribution estimation method itself, *i.e.* the error due to the fact that the reference signal is substituted to the true but unknown DW signal. Thus, the uncertainty of the substitute discharge and turbidity signals at each time step *i* of the signal reference include both the measurement uncertainty $u(Q_{i\_DW\_m})$ and $u(Turb_{i\_DW\_m})$ and a substitution uncertainty $u(Q_{i\_DW\_subs})$ and $u(Turb_{i\_DW\_subs})$. Under the assumption that substitution uncertainties are normally distributed:

$$u(Q_{i\_DW})^2 = u(Q_{i\_DW\_m})^2 + u(Q_{i\_DW\_subs})^2 \qquad \text{(eq. 7)}$$

$$u(Turb_{i\_DW})^2 = u(Turb_{i\_DW\_m})^2 + u(Turb_{i\_DW\_subs})^2 \qquad \text{(eq. 8)}$$

The evaluation of the substitution uncertainties is presented in Section 2.3.

2.2.3 Wet weather contribution

The wet weather contribution M_{X_WW} and its standard uncertainty are calculated as follows:

$$M_{X\_WW} = M_X - M_{X\_DW} \qquad \text{(eq. 9)}$$

$$u(M_{X\_WW})^2 = u(M_X)^2 + u(M_{X\_DW})^2 \qquad \text{(eq. 10)}$$

2.3 Dry weather substitution uncertainty calculation

The DW substitution uncertainty results from two main sources of uncertainties: i) the random variations of the flow and of the turbidity between similar DWD (each DWD is a unique occurrence) and ii) the criteria used for the choice of the reference signal including the types of tested DWD, the signal fitting method and the operator's subjectivity when comparing the signal dynamics. Systematic uncertainties are considered as negligible by applying the signal reference fitting.

In order to evaluate $u(Q_{i\_DW\_subs})$ and $u(Turb_{i\_DW\_subs})$, the method to select the reference signal has been tested during dry days during which discharge and turbidity signals were available. During a period of time named test period, the available signal was ignored and replaced by a reference signal fitted on two fitting periods before and after the test period which was, in this case, equivalent to a fictive storm event. Once the reference signal has been selected, it was compared to the measured but initially ignored signal during the test period: the difference between the measured signal and the selected reference signal has been analysed in order to evaluate the error created by this substitution. Two test periods have been investigated: i) night test periods (NTP) from 18:00 to 06:00, during which measured discharge and turbidity signals are rather smooth, and ii) day test periods (DTP) from 06:00 to 18:00, during which measured discharge and more significantly turbidity signals have shown stronger fluctuations and random peak values.

3 RESULTS AND DISCUSSION

3.1 Dry weather discharge and turbidity dynamics

Three clearly distinct DW daily pattern classes were identified among the available 180 DWD: i) class 1: weekdays (Monday to Friday) without school holidays, ii) class 2: weekends (Saturday and Sunday) and weekdays with general public holidays and iii) class 3: weekdays (Monday to Friday) with school holidays. The three classes represent respectively 55 %, 22 % and 23 % of the 180 DWD (resp. 99, 40 and 41 DWD). The three classes correspond to calendar percentages over the period 2007-2008 of 41, 32 and 32 %, evidencing a satisfactory representativeness of the available DW data.

In order to analyse the DW pattern variability, mean discharge and turbidity profiles for the period 2007-2008 were computed for each class and for all classes together, with standard deviations and coefficients of variation computed at each time step of the profiles (720 values per day). 5 % - 95 % percentile intervals and distributions of residuals (distances from the each DWD value to the mean profile) were also computed. Results are summarised in Table 1 and illustrated in Figures 1 and 2 for class 2 and for all classes together (named hereafter class 4).

Class	Mean standard deviation		Mean coefficient of variation	
	Discharge (L/s)	Turbidity (FNU)	Discharge (%)	Turbidity (%)
Class 1	7.05	55.23	21.86	31.80
Class 2	6.52	51.31	22.69	29.25
Class 3	9.46	59.33	28.6	36.39
Class 4	7.91	60.18	23.75	34.66

Table 1. Mean standard deviations and mean coefficients of variation of the mean discharge and turbidity along the DW profiles for classes 1 to 4.

The results appear rather similar for all classes. Residuals are approximately log-normally distributed. The computed 5 % - 95 % percentile intervals are comparable for the four classes, with larger values for high flow periods around 10:00-12:00. Dispersion is significantly higher for turbidity with mean coefficients of variation around 30-35 % compared to 20-25 % for discharge. Moreover 5 % - 95 % percentile intervals are less smoothed for turbidity, which is explained by the random turbidity peaks observed during the day especially during high flow period at the end of morning and evening peaks. This trend is even more pronounced when results are analysed at 2 min time step. Comparable orders of magnitude of the variability for both discharge and turbidity signals have been observed by Lacour (2009) in two urban combined catchments in Paris.

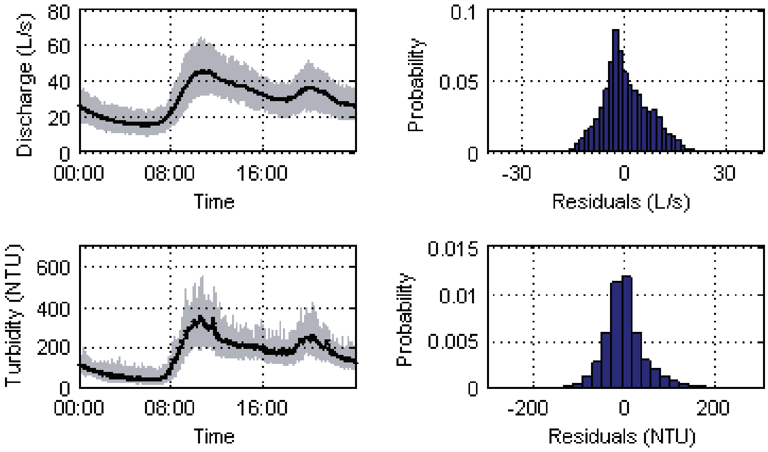

Figure 2. Class 2 mean DW discharge and turbidity patterns,
with 5 % - 95 % percentiles interval (left) and residuals distribution (right).

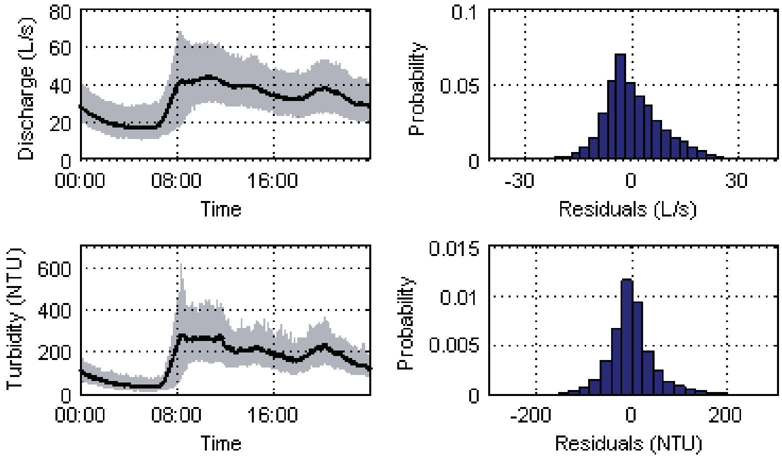

Figure 3. Class 4 mean DW discharge and turbidity patterns,
with 5 % - 95 % percentiles interval (left) and residuals distribution (right).

The above analysis was also carried out separately for 2007 and 2008 (details not shown here). No significant difference with the above results has been observed, except for class 3, with larger 5 % - 95 % percentiles intervals for the mean flow profile. This minor difference can be explained by the variability of the DWD measured for class 3 between the two years, with a majority of DWD during February holidays in 2007 and during Christmas period for 2008.

A specific investigation has been carried out to detect any seasonal variability or any global trend or variation over the 365 days of the year for the discharge and turbidity daily patterns. The results (not shown here) reveal no seasonal effect or annual fluctuation in any of the four classes.

The above results reinforce the conclusion that discharge and turbidity daily profiles vary significantly and that, for modelling purposes, global or annual mean profiles are not accurate enough to be used as reference signals during storm events.

If values at 2 min time step vary very significantly, a clearly non linear correlation between mean discharge values and mean turbidity values has been observed for classes 1 to 4. It is possible to perform an ordinary least squares regression to represent this correlation, as shown in Figure 4 for class 4. This regression could possibly be used to estimate turbidity and its uncertainty as a function of discharge during dry weather for modelling purposes.

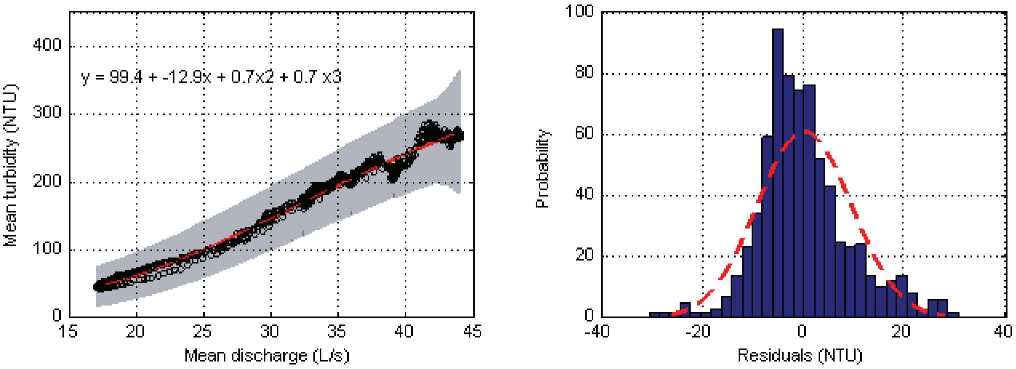

Figure 4. Class 4 regression between mean discharge and mean turbidity with 95 % confidence interval (left) and corresponding residuals distribution with best fitted normal distribution (dotted line) (right). All uncertainties in discharge, turbidity and regression coefficients have been accounted for in the 95 % confidence interval.

3.2 Dry weather substitution uncertainty

DW discharge and turbidity substitution uncertainties were calculated for the 2007-2008 period and for classes 1 to 4. In each case, they were estimated for both night and day test periods separately (resp. NTP and DTP) and globally (GTP), thus leading to 12 different results for both discharge and turbidity signals. For classes 1 to 3, the method was repeated respectively 20, 8 and 8 times by randomly selecting DWDs among the 99, 40 and 41 available DWD in the database, the number of repetitions corresponding for each class 1 to 3 to 20 % of the total number of the available DWD in each class. For the 12 different cases, residuals distributions were analysed and mean values and standard deviations were computed. Results are presented in Table 2.

	Mean residual						Standard deviation					
	Flow (L/s)			Turbidity (FNU)			Flow (L/s)			Turbidity (FNU)		
	NTP	DTP	GTP	NTP	DTP	GTP	NTP	DTP	GTP	NTP	DTP	GTP
Class 1	0.33	-0.03	0.15	2.33	-7.56	-2.62	2	4.58	3.93	48.76	91.66	73.58
Class 2	-0.92	0.55	-0.19	1.39	-0.36	0.51	3.14	4.98	4.84	53.01	82.50	69.34
Class 3	0.18	-0.63	-0.23	3.04	11.04	7.04	4.58	5.16	5.25	60.90	119.02	94.61
Class 4	0.02	-0.03	-0.01	2.28	-1.83	0.22	5.32	4.82	4.47	52.62	96.86	77.97

Table 2. Mean residuals and standard deviation of mean discharge and turbidity profiles for classes 1 to 4.

Results show larger standard deviations for day test periods, especially for turbidity with 96.86 FNU compared to 52.62 for night test period for class 4. For a given test period (Night, Day or Global), standard deviations are significantly higher for class 3, pointing out the higher variability for that class already revealed in the DWD variability analysis (section 3.1). Results also indicate that residuals distribution could be approximated by centred normal distributions for all cases, as illustrated by Figure 5 for the most global case (class 4 and GTP). This confirms that the LPU is applicable to propagate substitution uncertainties. However, standard deviation was computed by ignoring extreme values of the distribution (values beyond +/- twice observed standard deviations), in order not to over estimate the substitution uncertainties due to random peak values. In the most global case, final computed standard deviations taking into account this exclusion rule are respectively equal to 3.33 L/s and 47.0 FNU for discharge and turbidity. Substitution uncertainties are comparable to measurement uncertainties for which mean values are respectively approximately 6 L/s and 30 FNU in 2007-2008: consequently, it is necessary to account for both measurement and substitution uncertainties in estimating DW contributions during storm events.

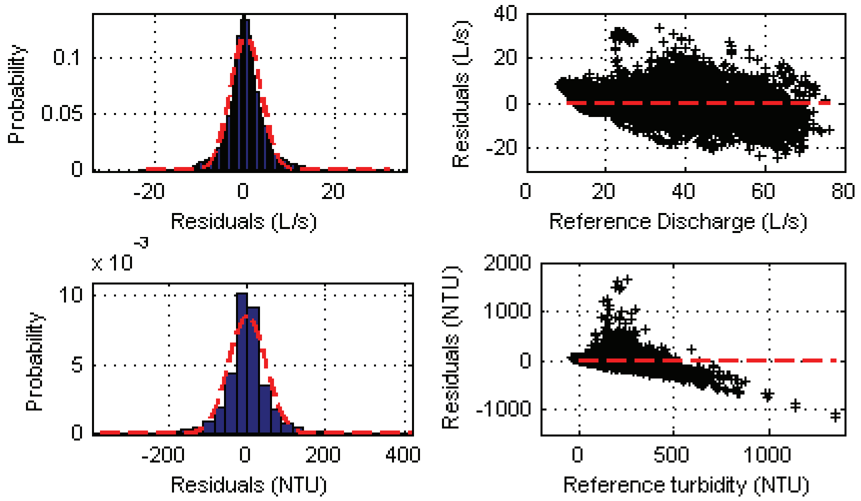

Figure 5. Residuals distribution for class 4 and Global (night+day) Test Periods (left) with fitted normal distribution (dotted lines), and evolution of the residuals with the reference signal respectively for discharge and turbidity (right) with residual mean values (dotted lines).

The method is illustrated in Figure 6 for class 1 and DTP (06:00-18:00) for Tuesday, 29 January 2008, with reference signals and measured signals shown for fitting periods (noted a) and the test period (noted b). In this example, the reference signals have been selected from Monday 28 January 2008 without signal fitting.

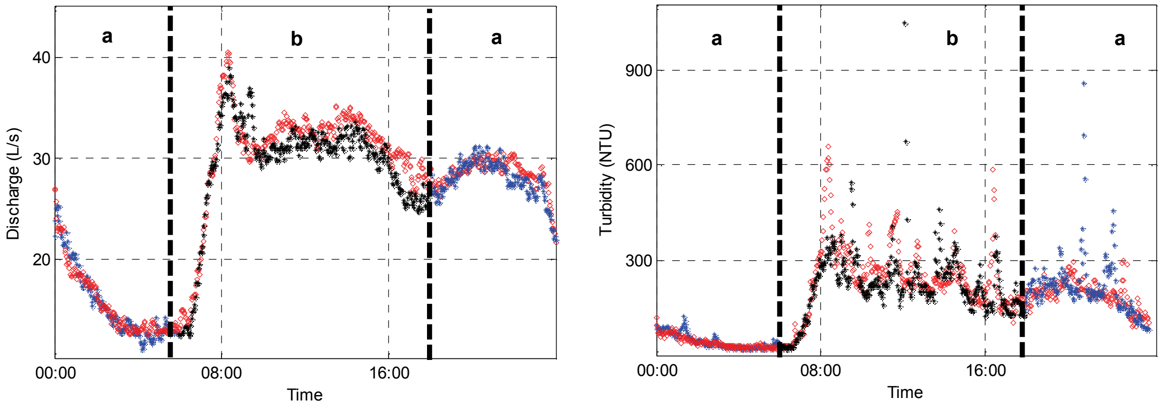

Figure 6. Illustration of the method applied to estimate discharge and turbidity during the DTP (06:00-18:00) on Tuesday 29 January 2008: reference signals (o) and measured signals (*), a and b refer respectively to fitting periods and test period.

The analysis of the evolution of the residuals with the reference signal value shows that residuals are not homoscedastic along the measurement ranges, i.e. non constant, especially for turbidity with significantly higher residuals above 500 FNU. Nevertheless, no obvious trend can be observed and high turbidity residuals are mostly explained by the random turbidity peaks observed during the high flow period, as illustrated in Figure 5. Thus, it seems reasonable to consider a constant substitution uncertainty along DW discharge and turbidity ranges. In addition, coefficients of variation for turbidity are higher than for discharge, with mean values ranging from 25-30 % for discharge and 35-40 % for turbidity.

3.3 Event load calculation: example of results

The proposed method has been applied to TSS and COD event loads calculation for the 239 storm events measured in Ecully in 2007-2008. Constant substitution uncertainties were applied, respectively 3.33 L/s and 47.0 FNU for discharge and turbidity. As an example, Figure 7 illustrates the storm event dated Friday 31 October 2008, which is a class 3 DWD. The rainfall depth is 10.7 mm, event starting and ending times are respectively 12:28 and 20:28. The reference signal has been selected on Tuesday 4 December 2008. The left graphs represent, from top to bottom, the rainfall intensity, the conductivity, the discharge and turbidity reference signals measured on Tuesday 4 December 2008) and the measured discharge and turbidity signals measured on Friday 31 October 2008. The right graphs represent, from bottom to top, COD and TSS mass fluxes (in kg/s) computed from the TSS-turbidity and COD-turbidity correlations, and event pollutant loads (in kg). For discharge, turbidity, fluxes and event loads, 95 % confidence intervals are computed with the LPU. Event runoff volume, TSS and COD loads with WW and DW contributions and their 95 % confidence intervals are summarized in Table 3.

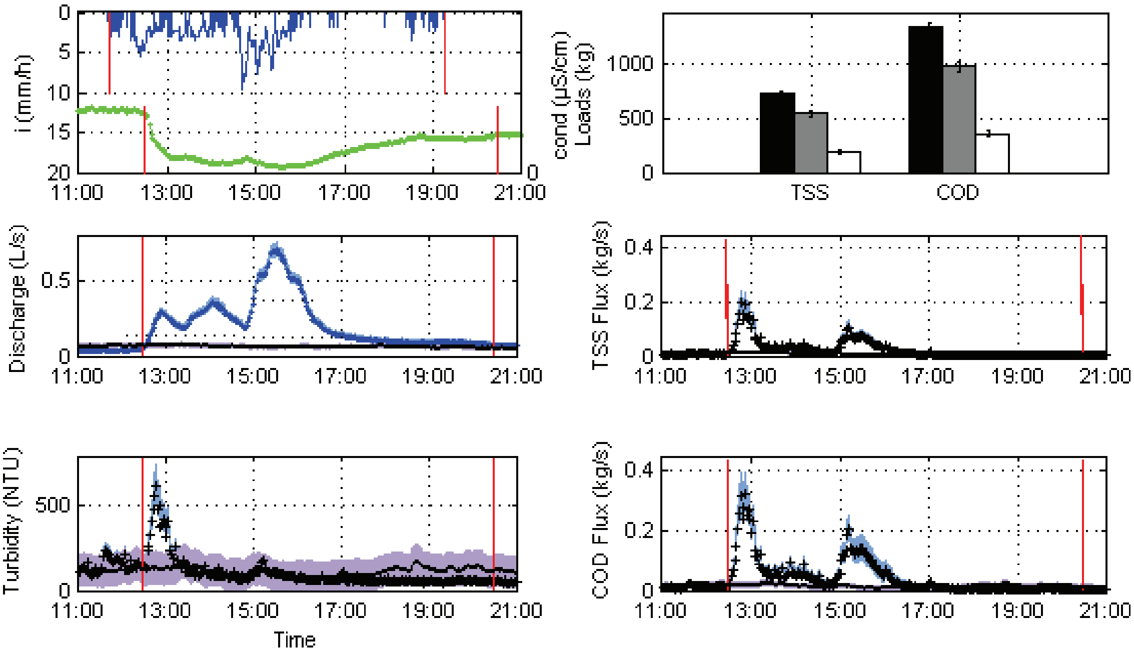

Figure 7. Illustration of the proposed methodology for the storm event dated 31 October 2008.

Friday 31 October 2008	Total	WW contribution	DW contribution
Runoff	6323 +/- 26 m^3	4645 +/- 62 m^3	1718 +/- 32 m^3
TSS load	729 +/- 22 kg	540 +/- 26 kg	189 +/- 13 kg
COD load	1324 +/- 42 kg	967 +/- 46 kg	356 +/- 20 kg

Table 3. Results for the storm event dated Friday 31 October 2008.

4 CONCLUSION

This work confirms the great interest and potential of long term continuous discharge and turbidity time series measured in sewer systems. Based on the analysis of 180 dry weather days and 239 storm events monitored in a combined sewer system, respectively in period 2007-2008 and period 2004-2008, the main conclusions are the following ones:

- Three distinct classes of dry weather days have been established, each one with specific daily discharge and turbidity profiles.
- The variability within each class has been analysed and quantified.
- No seasonal effect and no trend over the year have been detectable.
- A method has been proposed to estimate the dry weather contributions to total storm event volumes and TSS and COD loads, accounting for the dynamics of both discharge and turbidity time

series at short time step (2 minutes). The method is based on the identification of the most likely dry weather signals among a set of tested dry weather signals taken from the appropriate DWD class. It has to be highlighted that despite the very rich and reliable data set from Ecully catchment used in this study, the results of the analysis might be different in different catchments and with different gauges.

- The selected signal is named the reference signal and its total uncertainty, including both measurement uncertainty and substitution uncertainty, is evaluated. The substitution uncertainty is estimated based on simulations of the method applied to measured dry weather days.
- Analyses of time series, mean values and residuals indicate that the LPU is applicable to evaluate uncertainties.
- For any storm event, the method allows calculating the total event TSS and COD loads, the contributions of dry weather and wet weather, and all associated uncertainties and 95 % confidence intervals.
- The method will be used to calibrate storm weather quality models.

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