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Spatio-temporal variability of lowland river properties and effects on metabolic rate estimates

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Spatio-temporal variability of lowland river properties and effects on metabolic rate estimates

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of the requirements for the degree of

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in

Environmental Systems

by

Sandra Rocio Villamizar Amaya

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August, 2013

To my family, the center of my existence.

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2013	Ph.D. Environmental Systems University of California, Merced
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Scholarly Products

- Gil, Yolanda; Szekely, Pedro; Villamizar, Sandra; Harmon, Thomas; Ratnakar, Varun; Gupta, Shubham; Muslea, Maria; Silva, Fabio; Knoblock, Craig. (2011) Mind Your Metadata: Exploiting Semantics for Configuration, Adaptation, and Provenance in Scientific Workflows. Presented at the 10th International Semantic Web Conference (ISWC2011).
- 2011 Workshop on Aquatic Ecosystem Sustainability (WAES). Coauthor of the Final Report. http://www.isi.edu/~gil/docs/waes11/WAES11-FinalReport.pdf
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September 11-13, 2011	Freshwater Advanced Aquatic Sensor Workshop: Sensors, Platforms, and Data Management. Participant. *http://umbs.lsa.umich.edu/research/aquatic-sensor-workshop*
June 13-14, 2011	2011 Workshop on Aquatic Ecosystem Sustainability (WAES). Participant. *http://water.isi.edu/waes11*
December, 2010	AGU Fall Meeting. Poster presentation. Villamizar, Sandra; Pai, Henry; Butler, Christopher; Barnes, Patrick; Harmon, Thomas C. Temporal variation of stream metabolism in response to disturbance within a managed river system.
December, 2009	AGU Fall Meeting. Poster presentation. Villamizar, Sandra; Pai, Henry; Butler, Christopher; Barnes, Patrick; Harmon, Thomas C. Reach Scale spatial and temporal variations in whole-stream metabolism estimates within the lowland Merced River in California.
December, 2009	AGU Fall Meeting. Poster presentation. Pai, Henry; Fisher, Jason C.; Villamizar, Sandra; Butler, Christopher; Kaiser, William; Harmon, Thomas C. Multi-scale field characterization, data assimilation, and 2-D model development for a complex river confluence.
October, 2009	Global Lake Ecological Observatory Network – GLEON 9 Meeting. Poster presentation. Villamizar, Sandra; Pai, Henry; Butler, Christopher; Barnes, Patrick; Harmon, Thomas C. Reach-scale spatial and temporal variations in whole-stream metabolism estimates within the lowland Merced River in California.

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June, 2009	Fulbright Workshop on the Environment: Creating Regional Partnerships in the Americas. Participant.
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October, 2008	CENS 6th Annual Research Review. Talk. Fisher, Jason C.; Pai, Henry; Villamizar, Sandra; Butler, Christopher; Harmon, Thomas C. Precision flow and salinity mass balance assessments across the Merced-San Joaquin river confluence zone.
April, 2008	IADO-CENS-GLEON Pan-American Sensors for Environmental Observatories PASEO Workshop - Argentine Lake Investigation. Participant *https://eng.ucmerced.edu/paseo/iado-cens-gleon-argentine-lake-investigation*
March, 2008	CENS – NSF Site Visit. Poster presentation. Descriptive analysis of the turbulent velocity profiles for two cross sections in a river confluence zone.
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ABSTRACT

Spatio-temporal variability of lowland river properties and effects on metabolic rate estimates

by

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Ph.D. Environmental Systems
University of California, Merced, 2013

Professor Thomas C. Harmon, Committee Chair

To determine how local features within a river reach may result in discernible transverse gradients of basic water properties and consequently of metabolic rates, we collected high-resolution spatiotemporal data across a transect spanning a lowland river cross-section. The robotically-accessed sampling points facilitated precise estimation of spatial metabolic rates for three diel cycles in April and four in September. We verified the existence of transverse spatial variability for the raw data and the derived metabolic rates, and attribute this to the combined effects of channel hydrogeomorphology and the light/shade patterns produced by the northeast to southwest orientation of the river and the riparian plant community structure along the upstream reach. Light/shade patterns observed on the reach promote gradients of available radiation and water temperature for metabolic processes, and reach hydrogeomorphology creates a transverse velocity gradient resulting in incomplete transverse mixing over timescales associated with metabolic processes. The methods and findings of this study are significant with respect to understanding spatiotemporal variation of lotic ecosystem processes at the reach scale or smaller. Such processes are potentially important in the context of ecohydrologic considerations, including designing and assessing restoration efforts, floodplain–channel dynamics, and groundwater-surface water discharges and hyporheic exchange.

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Nomenclature

CV	Coefficient of variation
CR_{24}	Community respiration (g O_2 m^{-2} d^{-1})
Chl	Chlorophyll-*a* (mg L^{-1})
D	Depth (m)
DO	Dissolved oxygen (mg L^{-1})
GPP	Gross primary productivity (g O_2 m^{-2} d^{-1})
I	Moran's *I* statistic
I_{yz}	Bivariate cross-correlation statistic
NEP	Net ecosystem productivity (g O_2 m^{-2} d^{-1})
PAR	Photosynthetically active radiation (µmol m^{-2} s^{-1})
P/R	Gross primary productivity to Community respiration ratio (-)
RelHum	Relative humidity (%)
SolRad	Solar radiation (W m^{-2})
SpCond	Specific conductivity (µS cm^{-1})
Temp	Temperature (˚C)
Vel	Velocity (m s^{-1})

Chapter 1. Introduction

The importance of aquatic ecosystem metabolism has been increasingly recognized in terms of its role in the storage and cycling of terrestrial carbon [*Cole et al.,* 2007]. Researchers use metrics such as net ecosystem production (*NEP*) or the gross primary productivity to community respiration ratio (*P/R*) to characterize lotic ecosystem biomass production and as trophic structure indicators [*Mulholland et al.,* 2001; *Odum,* 1956]. Lotic energy and mass exchanges occur in the longitudinal, lateral, vertical and temporal dimensions [*Ward,* 1989], and stream ecologists have proposed different models to describe these exchanges and their impact on ecosystem metabolism. Perhaps most prominent among these are the river continuum concept [*Vannote et al.,* 1980] which establishes that metabolic rates within an unaltered stream are expected to vary longitudinally from headwaters to mouth with changing temperature, light availability and nutrient inputs. Departure from the continuum behavior is likely to occur in human-dominated systems, as described by the serial discontinuity concept [*Ward and Stanford,* 1983]. In addition, episodic events like flood pulses contribute to lateral exchanges by importation of riparian resources to the lotic environment and potentially increasing the local productivity of the reach throughout the moving aquatic/terrestrial transition zone [*Junk et al.,* 1989]. Hyporheic zones have also been found to be critical for thermal and mass exchanges between groundwater and surface water, sometimes defining the rates or types of in-stream processes [*Boulton et al.,* 2010]. An attempt to bridge the gap between the different scales at which processes and interactions occur is embodied by the patch dynamics approach [*Pringle et al.,* 1988]. Although the lotic ecosystem carbon cycling is not yet well-understood, the interactions highlighted above lead to observable net metabolism variation on at least four different time scales: daily, episodic, seasonal, and inter-annual [*Roberts et al.,* 2007].

1.1. Factors determining metabolic rates at the reach scale

Whole-stream metabolism is commonly estimated at the reach scale as an integrative property of the aquatic ecosystem [*Hall Jr. and Tank,* 2005; *McCutchan Jr. et al.,* 1998; *McCutchan Jr. et al.,* 2002; *Mulholland et al.,* 2001; *Odum,* 1956]. However, the physicochemical gradients associated with metabolism drivers suggest that estimates may vary at finer spatial scales, and may serve as useful indicators of local habitat quality or gradients therein, as in habitat assessment and restoration undertakings. Water velocity is an important driver, controlling the types of organisms that populate the river [*Angelier,* 2003]. The continuous drift to which benthic communities are subjected by shear forces defines the type of organisms that can establish at a given current speed. In the water column, planktonic communities may proliferate when the transport timescale is large relative to the production rate. At the same time, light availability and the heliophilic degree may also play an important role in defining the distribution of species within narrow and/or shallow river reaches where incident light is aligned with riparian vegetation sun fleck patterns. In deeper, wider waters unaffected by shade, water depth and turbidity are the determinant metabolic factors [*Mulholland et al.,* 2001; *Wiley et al.,* 1990; *Young and Huryn,* 1996]. Elevated concentrations of nutrients (e.g., nitrate and phosphate) associated with human inputs and groundwater seepage can lead to local eutrophication and associated over-production of algae and macrophytes [*Angelier,* 2003; *Mulholland et al.,* 2001; *U.S. Geological Survey,* 2007]. In addition, spatially variable groundwater inputs can lead to local dissolved oxygen and temperature gradients, affecting metabolism [*Hall Jr. and Tank,* 2005; *McCutchan Jr. et al.,* 1998; *McCutchan Jr. et al.,* 2002; *Mulholland et al.,* 2001; *Odum,* 1956]. Respiration rates have also been found to have a direct correlation with water temperature [*Hill et al.,* 2000; *Sinsabaugh,* 1997].

1.2. Mixing effect on transverse variability of metabolic rates

Efforts aimed at quantifying lotic ecosystem structure and function have focused mainly on longitudinal and temporal variability, with comparatively little focus on transverse and vertical variation. Stream *NEP* rates are typically estimated as reach-averaged values using the single or two-station open water method based on diel dissolved oxygen (DO) and water temperature observations [*Odum,* 1956]. Implicit in this approach is the assumption that the stream is well-mixed with respect to mass and energy inputs [*Hall Jr. and Tank,* 2005; *McCutchan Jr. et al.,* 1998; *McCutchan Jr. et al.,* 2002; *Mulholland et al.,* 2001; *Odum,* 1956]. For shallow rivers (width-to-depth ratio > ~15) hydraulic considerations generally support this assumption over a suitable observational scale. For instance, vertical mixing is expected to occur over distances of roughly 50-100 times the river depth [*Yotsukura and Sayre,* 1976], while transverse mixing is roughly 2 to 3 times slower in the same river [*Fisher et al.,* 1979; *Rutherford,* 1994]. River bends tend to increase the rate of cross-sectional mixing due to secondary circulation. In contrast, bank irregularities, submerged obstacles, and aquatic vegetation can create hydraulically isolated zones, reducing transverse mixing rates [*Fisher,* 1973]. More recent studies have examined mixing processes in more complex streams and at sub-reach scales, where lateral exchanges occur between the main flow and transient storage zones located within the stream [*Ensign and Doyle,* 2005; *Gooseff et al.,* 2011] and/or the hyporheic zone [*Bencala,* 2005; *Cardenas et al.,* 2008; *Haggerty et al.,* 2002]. These zones are known to impact stream biogeochemistry non-uniformly [*Ensign and Doyle,* 2005; *Gooseff et al.,* 2011], but have not yet been directly linked to transverse heterogeneity in ecosystem metabolism.

1.3. Impact of light on the transverse metabolic rates

Light availability with respect to primary production in the water column and benthic zones is also a potential driver of in-reach variability in ecosystem metabolism. Available solar radiation varies locally according to changes in riparian zone topography vegetation and channel orientation [*Julian et al.,* 2008a]. In relatively large rivers, water depth is the primary determinant of benthic PAR variation, while riparian vegetation causes most of the variation in small rivers [*Julian et al.,* 2008b]. Beyond direct photosynthetic rate effects, cooling effects of shade [*Gomi et al.,* 2006; *Rutherford et al.,* 2004] and riparian tree evapotranspiration [*Gregory et al.,* 1991] could result in substantial water temperature gradients in streams, which can reduce local metabolic rates. Furthermore, non-uniform solar heating of sediments in shallow streams may also lead to a thermal heterogeneity, hence influencing the distribution of sessile and limited-mobility organisms [*Clark et al.,* 1999].

1.4. Research aim and document outline

Given the variable scales of physicochemical inputs and pathways associated with rivers, and the documented cases of local energy and nutrient gradients, it is reasonable to hypothesize that lotic metabolic rate processes vary within a river reach [*Pringle et al.,* 1988]. If this is the case, then differences in *NEP* and *P/R* estimates must be observable at sub-reach scales, in spite of mixing. In this work, we investigate the transverse variability of stream metabolic rates based on spatiotemporally variable dissolved oxygen measurements, and subject to interpretation based on other water quality parameters (velocity, temperature, specific conductivity, chlorophyll-a) and light conditions. Distributed metabolic rates, and changes in those distributions at this scale, may reflect community structure and its changes, and could serve as useful indicators in habitat assessment and restoration undertakings.

The second chapter of this document presents a description of the study site along with the experimental methods used for the data collection. The third chapter presents the analytical approach namely, the spatial statistics and the description of the whole-stream metabolism calculations. The fourth chapter is dedicated to the presentation of the results and discussion; and the fifth chapter presents the summary, conclusions and recommendations. An appendix is incorporated within the document, presenting a proposed workflow for the development of the metabolism estimates. Using data collected independently by research teams or using readily available government agencies' data, this workflow may be used as a support tool for monitoring in semi-real time river ecosystem structure and function in response to natural or anthropogenic disturbances.

Chapter 2. Experimental Methods

High resolution investigations are often discouraged because the researchers don't count with the adequate technology or the number of sensors required by the objectives of the study. A tethered robotic platform (NIMS AQ) facilitated the data collection process for testing our hypothesis of the existence of transverse spatial variability of metabolic rates within a river reach. In this chapter, I describe the general characteristics of the study site, continue with an overview of the NIMS AQ system, and I finalize by giving a detailed description of the experimental approach.

2.1. Site Description

The study site (Figure 1) is located at river km 26 of the lower Merced River, an agriculturally dominated, impounded river in Central California. Dams are located upstream of the site at river km 84 and 101. Flow and water quality are the product of the management operations for flood control, power generation, and irrigation diversion and drainage practices. At the site, the river is a single-thread meandering system with a narrow corridor ranging between 20 and 40 meters in width. The reach-averaged slope is 0.0003 and the bed sediment is predominantly sand [*Stillwater Sciences,* 2002]. Patches of large woody debris are present in upstream areas of the study reach, creating low velocity zones. Macrophytic vegetation within the reach also impacts flow on the right side (downstream view), and includes native *Ceratophyllum demersum* (Coontail) and *Elodea Canadensis* (Canadian waterweed), and invasive *Egeria densa* (Brazilian waterweed) and *Potamogeton crispus L.* (Curly pondweed). Riprap revetment is in place in some areas of the left bank reach, and riparian vegetation is mostly limited to one tree width on the left bank, followed by a vineyard. The right bank presents a wider swath of native vegetation (10s m) followed by seasonal crops.

2.2. The NIMS AQ system

The rapidly deployable Networked Infomechanical System (NIMS) technology was developed by the Center for Embedded Networked Sensing for the development of high resolution observations in two- and three-dimensional environments [*Harmon et al.,* 2007]. The NIMS AQ system is a mobile aquatic sensing platform that facilitates the characterization of river properties such as flow velocity or water quality parameters. Two anchoring points, one on each bank of the river hold a suspension cable to which the unit is attached. Two pontoons support a rigid sensing tower and a set of batteries used to power the system. The sensing tower hosts the actuators, processor, radio system, and sensor payload. The user of the system from shore connects remotely to the NIMS AQ unit defining the desired sampling strategy. The unit moves side to side according to the pre-programmed schedule defined by the user to explore and characterize the environment of interest by delivering the payload of sensors to the desired positions (See Figure 2).

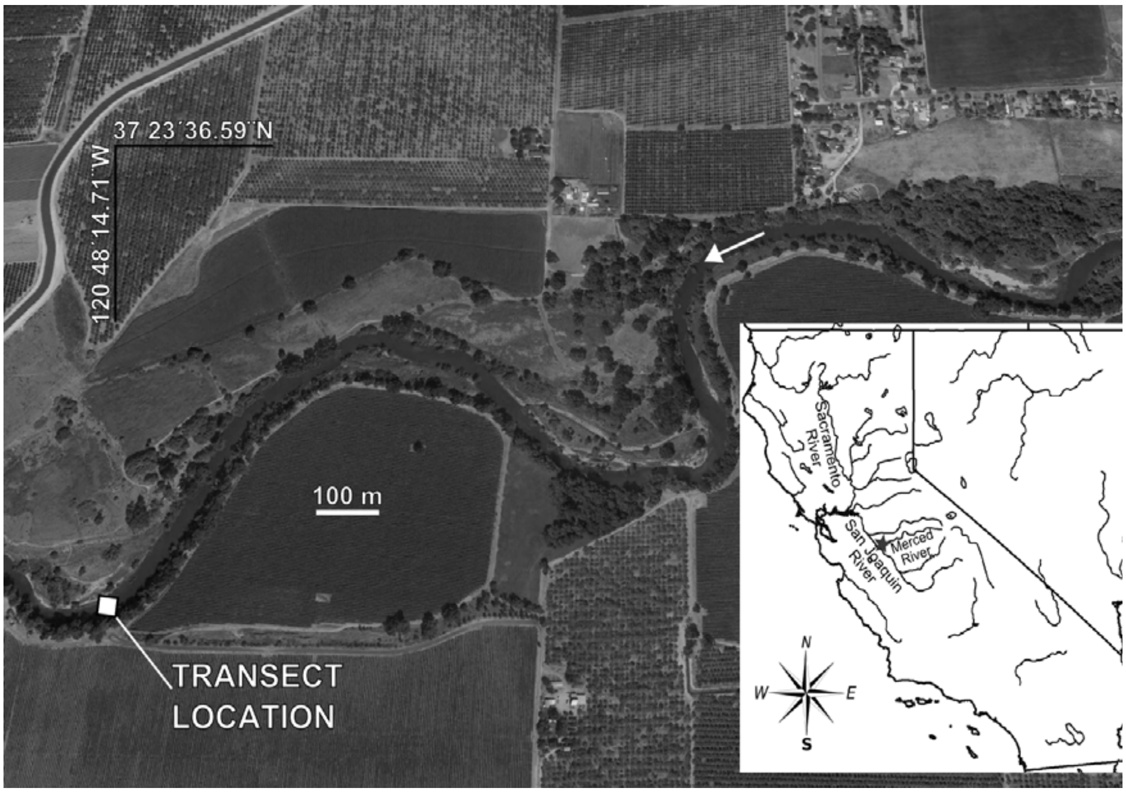

Figure 1. Study site. Satellite image of the Merced River reach under investigation (source: Google Earth) with water flowing from north-east to south-west.

2.3. Experiment description

During spring (April 20-25) and late summer (September 7-12) of 2009 baseflow conditions, two monitoring systems were deployed to study the spatiotemporal variations of water quality parameters within the study reach. A stationary system consisting of a multi-parameter sonde (Hach Hydrolab Model DS5) was attached to an anchored post located 9.5 m from the right bank of the river (Figure 2), and collected data on temperature (Temp, ±0.01 °C), specific conductivity (SpCond, ±0.001 mS cm^{-1}), luminescent dissolved oxygen (DO, ±0.01 mg L^{-1}), and photosynthetically active radiation (PAR, ±1 μmol m^{-2} s^{-1}). Simultaneously, the tethered robotic sensor platform NIMS AQ was used to sample water quality (Hach Hydrolab Model DS5) and velocity (Sontek ADV, Vel, ±0.0001 m s^{-1}) spatial distributions across a transverse river transect located approximately 2 m upstream of the fixed central station. The transect was situated within a bend with a sandy point bar on the right (downstream view) and a cut bank (rock revetment-covered) on the left near the main river channel (Figure 1). The parameters measured with this mobile system were the same as those of the stationary probe with chlorophyll-*a* (Chl, ±0.01 µg L^{-1}) by means of a fluorescence sensor (Turner Designs) instead of the PAR sensor. The robotic system began each raster scan at position x = 1.5 m from the right bank of the river (point 1) where the depth was sufficient to provide adequate probe clearance, and continued along the transect sampling at two-meter intervals, with the exception of the final point, which was only 1 m from the prior location (Figure 2). Dwelling time at each location was 60 s. The data collection strategy for the fixed and mobile systems is summarized in Table 1. While the fixed probe collected data continuously, the mobile probe sampled less frequently at each station following a repetitive raster sampling schedule. Occasional nighttime power depletion resulted in interruptions in the sequential process requiring interpolation to fill data gaps (described further in section 2.3). Metabolism estimates were obtained by integrating DO observations over 24-hour cycles, and the 81 raster scans completed during the spring experiment allowed the evaluation of the spatiotemporal distribution of water quality parameters for three diel cycles (days 2 through 4) while the 114 raster scans developed during the late summer provided data for four diel cycles (days 1 through 4).

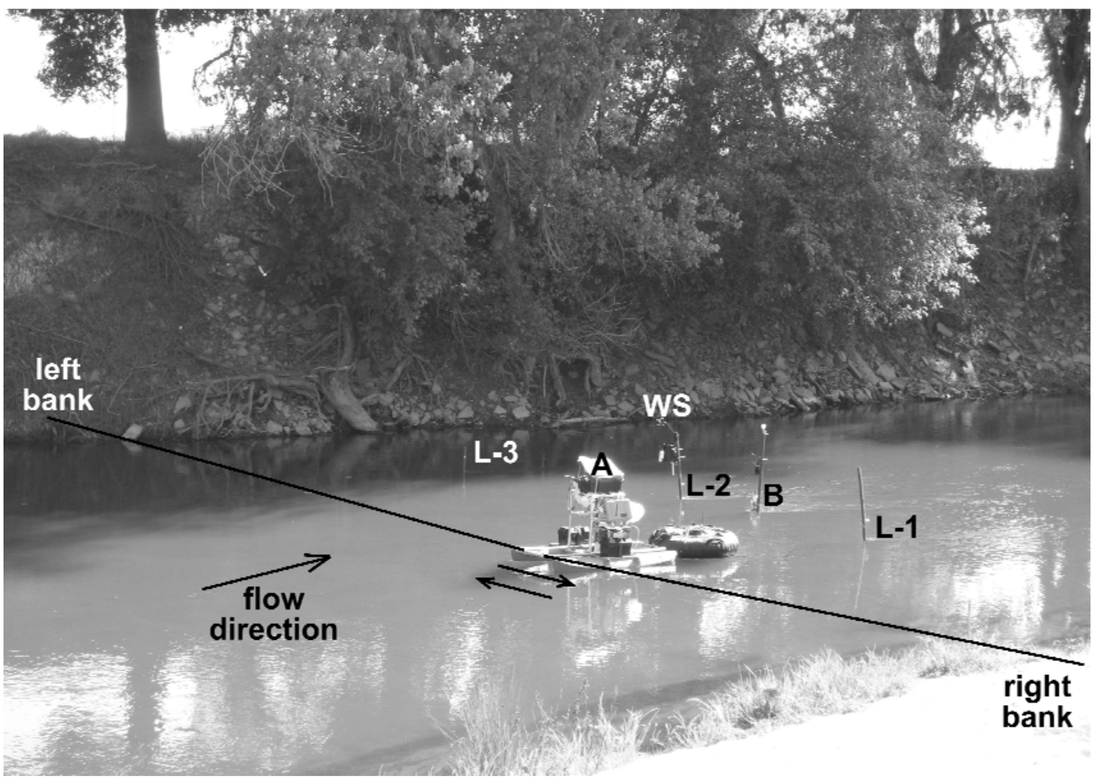

Figure 2. Photograph of the experimental set up. (A) NIMS AQ, the mobile sampling unit (water quality and velocity); (B) fixed sampling unit (water quality and PAR); (WS) weather station; (L-1, L-2, L-3) light intensity sensors. The image captures the predominant shading pattern along the left bank of the river.

Table 1. Summary of the sampling plans for the fixed and mobile systems.

FIXED SYSTEM		
	Spring of 2009	Summer of 2009
Start	20/04/2009 14:11	07/09/2009 12:00
End	25/04/2009 09:58	12/09/2009 01:00
Sampling strategy	Continuous at 5-min intervals	Continuous at 10-min intervals
Data collected	Temp, SpCond, DO, PAR	Temp, SpCond, DO, PAR
Diel cycles	4 (days 1 through 4)	4 (days 1 through 4)
MOBILE SYSTEM		
	Spring of 2009	Summer of 2009
Start	21/04/2009 10:26	07/09/2009 18:31
End	25/04/2009 10:10	12/09/2009 04:56
Sampling strategy	Raster plan, 11 locations, 81 cycles at variable intervals	Raster plan, 10 locations, 114 cycles at variable intervals
Data collected	Temp, SpCond, DO, Chl-a, Vel	Temp, SpCond, DO, Chl-a, Vel
Complete diel cycles	3 (days 2 through 4)	4 (days 1 through 4)

The water quality sensors employed in this study were calibrated per vendor specifications prior to their deployment. Given the importance of comparative DO measurements in the context of estimating metabolic rates, we studied the performance of the two DO sensors more intensively. The previously noted factory-reported precision (± 0.01 mg L^{-1}) was found to be accurate in a controlled laboratory system for either sensor, suggesting that temporal changes in DO levels greater than this amount are significant. The two sensors exhibited absolute differences of 0.03±0.04 (2 SD) mg L^{-1}, and no observable signal drift in comparative lab-based tests spanning days. In longer term river deployments at locations and under conditions similar to those for the present experiments, the same sensors experience no discernible signal drift for two weeks (highly productive summer conditions) or longer (winter conditions). In the context of this investigation, we considered observed DO differences greater than or equal to 0.1 mg L^{-1} to be significant for comparisons between readings from these two sensors (i.e., stationary vs. mobile readings). For comparisons between readings developed with the same sensor, specifically related to the analysis of spatial variability of DO readings for a given raster scan, the threshold is directly related to the precision of that sensor. Here, we use the inverse of the signal-to-noise ratio, the coefficient of variation (CV). Specifically, we distinguish between (1) a standard CV (CV_{std}), defined as the ratio of the sensor's standard deviation under controlled conditions (± 0.01 mg L^{-1}) to the mean sensor reading; and (2) the experimental CV (CV_{exp}), the ratio of the standard deviation to the mean value of the readings for a given raster scan. This approach assumes that the temporal changes in DO and temperature over one spatial sampling cycle is negligible, and is reasonable given that the each cycle lasted about 20 min.

Ancillary measurements made to support the interpretation of the metabolic estimates include three sets of temperature (±0.10 °C) and irradiance (0 to 320,000 lux) sensors logging at a 5-min interval to provide semi-quantitative characterization of cross-sectional light conditions (Hobo Temp/Light Pendants, Onset Computer). Horizontally, the sensors were positioned at three different distances from the right bank such that L-3 (left) was located in a shaded area most of the day, L-2 (center) received direct sunlight for part of the day, and L-1 (right) was fully exposed all day (Figure 2). A total station (Leica Builder R100M) was used to determine the location of all the deployed instruments as well as the river cross sectional geometry. The local meteorological conditions were monitored with a weather station (Davis Wireless Vantage Pro2™) positioned 1 m above the river surface, recording air temperature (±0.1 °C), solar radiation (±1 W m^{-2}), wind speed (±0.1 m s^{-1}), and relative humidity (±1%) at a 5-min interval during April and 10-min interval in September. Regional meteorological conditions were determined using California Irrigation Management Information System (CIMIS) data from a station located 18 km southwest of the experimental site (Station #92).

Chapter 3. Analytical Methods

The spatial distribution of the field data (DO, Temp, SpCond, and Chl) and identification of potential spatial patterns is first verified using the autocorrelation statistic Moran's *I*. For the key variable of the experiment, DO, I develop an analysis of the coefficient of variation as described in section 2.3 of this document, and lastly, the spatial bivariate statistic Moran's I_{yz} is applied to water quality parameters and velocity pairings of individual raster scans to identify the existence of spatial cross-correlation among them. The methodology for the calculation of the single station, whole-stream metabolism is described here. The calculations are used to obtain daily metabolic rates for (1) the fixed station, the typical approach, and (2) each individual sampling point within the raster scan for which a time series of DO and Temp is obtained through a spline interpolation technique based on the data collected with the mobile system. No statistical analysis is developed for the assessment of spatial variability of the daily metabolic rates because of the low number of replicates for each sampling point (only 3 for April and 4 for September) and because metabolic rates between consecutive days are highly autocorrelated.

3.1. Spatial statistics

To test whether the spatial distribution of water quality parameters within this presumed well-mixed system can be attributed to random effects or exhibits a pattern, we calculated the spatial autocorrelation statistic (global Moran's *I*) for each of the monitored water quality parameters [*Moran,* 1950], and the spatial bivariate cross-correlation statistic (Moran's I_{yz}) for all parameter pairings [*Czaplewski and Reich,* 1993]. The *I* statistic is calculated as

$$I = \frac{n}{\sum_{i=1}^{i=n} \sum_{j=1}^{j=n} W_{ij}} \frac{\sum_{i=1}^{i=n} \sum_{j=1}^{j=n} W_{ij} \left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{\sum_{i=1}^{i=n} \left(x_i - \bar{x}\right)^2} \qquad \textbf{(1)}$$

where n is the number of spatially distributed observations, W_{ij} is the spatial weight matrix, x_i and x_j are the values of variable x at positions i and j, and $\bar{x}$ is the mean value of the spatially distributed observations. The inter-locality weights W_{ij} used in the spatial weight matrix are the inverse of the square of the spatial separation between the sampling points [*Wartenberg,* 1985].

For the I statistic, the null hypothesis states that there is no spatial clustering, i.e., there is a random spatial distribution of the parameter values in a given study area ($I \approx 0$); I values approaching 1 suggest a clustered organization of the parameter of interest; and I values approaching -1 describe a perfectly dispersed pattern. To test for the significance of I, we calculate T (based on the Randomization Null Hypothesis computation) as [*Cliff and Ord,* 1973]

$$T = \frac{\left(I - E\left[I\right]\right)}{\sqrt{Var(I)}} \tag{2}$$

where T is the t-score because of our relatively small number of sampling points, $E[I]$ is the expected value of I under the null hypothesis of no spatial autocorrelation

$$E\left[I\right] = \frac{-1}{n-1} \tag{3}$$

and $Var[I]$ is the variance, calculated as

$$Var\left[I\right] = E[I^2] - E[I]^2 \tag{4}$$

The calculation of $E[I^2]$, the second moment of I, follows [*Cliff and Ord,* 1973]:

$$E[I^2] = \frac{A-B}{C} \text{ where,} \tag{5}$$

$$A = n\left[\left(n^2 - 3n + 3\right)S_1 - nS_2 + 3S_0^2\right] \tag{6}$$

$$B = D\left[\left(n^2 - n\right)S_1 - 2nS_2 + 6S_0^2\right]\text{, and} \tag{7}$$

$$C = \left(n-1\right)\left(n-2\right)\left(n-3\right)S_0^2 \tag{8}$$

where the D, S_o, S_1, and S_2 terms are calculated as

$$D = \left[\sum_{i=1}^{i=n}\left(x_i - \bar{x}\right)^4 \Big/ n\right] \Bigg/ \left[\sum_{i=1}^{i=n}\left(x_i - \bar{x}\right)^2 \Big/ n\right]^2 \tag{9}$$

$$S_0 = \sum_{i=1}^{i=n} \sum_{j=1}^{j=n} W_{ij} \tag{10}$$

$$S_1 = \left(1/2\right)\sum_{i=1}^{i=n} \sum_{j=1}^{j=n}\left(W_{ij} + W_{ji}\right)^2\text{, and} \tag{11}$$

$$S_2 = \sum_{i=1}^{i=n}\left(\sum_{j=1}^{j=n} W_{ij} + \sum_{j=1}^{j=n} W_{ji}\right)^2 \quad \textbf{(12)}$$

The bivariate Moran's I_{yz} can be interpreted as a spatially weighted correlation coefficient between variables y and z, under the null hypothesis of no spatial autocorrelation, and without any parametric assumptions regarding the joint distribution of y and z [*Czaplewski and Reich,* 1993]. The statistic is calculated as

$$I_{yz} = \frac{\sum_{i=1}^{i=n}\sum_{\substack{j=1 \\ i \neq j}}^{j=n} W_{ij} y_i z_j}{W\sqrt{Var(y)Var(z)}} \quad \textbf{(13)}$$

where W_{ij} is the spatial weight matrix, n is the number of observation points, y_i and z_j are the observed values of variables y and z at positions i and j, transformed so their means are zero, W is the sum of all the elements of the weight matrix, and $Var(y)$ and $Var(z)$ are the sample variance for y_i and z_j, respectively. The I_{yz} statistic value also ranges between 1 and -1 with large positive values indicating a positive spatial correlation between the two response surfaces, large negative values suggest negative spatial correlation, and I_{yz} values close to zero indicate no spatial correlation. The significance of this test is obtained by calculating the t score as

$$T = \frac{\left(I_{yz} - E\left[I_{yz}\right]\right)}{\sqrt{Var(I_{yz})}} \quad \textbf{(14)}$$

where $E[I_{yz}]$ and $Var[I_{yz}]$ are calculated as

$$E[I_{yz}] = \frac{-\rho_{yz}}{n-1}\text{, and} \quad \textbf{(15)}$$

and,

$$Var\left[I_{yz}\right] = E[I_{yz}^2] - E[I_{yz}]^2 \quad \textbf{(16)}$$

In equation **(15)**, ρ_{yz} is the linear correlation between variables y and z (Pearson product-moment correlation coefficient). The calculation of $Var[I_{yz}]$ follows [*Czaplewski and Reich,* 1993]:

$$Var[I_{yz}] = \left(\frac{ \left(\frac{m_{yz}^2 n}{m_{y^2} m_{z^2}} \right) \left[2\left(W^2 - S_2 + S_1\right) + \left(S_1 - \frac{S_2}{2}\right)(n-3) + S_1(n-2)(n-3) \right] + \left(\frac{-m_{y^2z^2}}{m_{y^2} m_{z^2}} \right) \left[6\left(W^2 - S_2 + S_1\right) + \left(4S_1 - 2S_2\right)(n-3) + S_1(n-2)(n-3) \right] + n\left[\left(W^2 - S_2 + S_1\right) + \left(S_1 - \frac{S_2}{2}\right)(n-3) + S_1(n-2)(n-3) \right] }{(n-1)(n-2)(n-3)W^2} \right) - \left(\frac{m_{yz}^2}{m_{y^2} m_{z^2}} \right) \left(\frac{1}{(n-1)^2} \right) \qquad \textbf{(17)}$$

with terms $m_y^2 = Var(y)$, $m_z^{\ 2} = Var(z)$, $m_{yz} = Cov(yz)$, $m_y^{\ 2}{}_z^{\ 2}$, S_1 and S_2 calculated as follows:

$$m_{yz} = Cov(yz) = \frac{\sum_{p=1}^{n} y_p z_p}{n} = E[y_i z_i] \qquad \textbf{(18)}$$

$$m_{y^2} = Var(y) = \frac{\sum_{p=1}^{n} y_p^2}{n} = E[y_i^2] \qquad \textbf{(19)}$$

$$m_{z^2} = Var(z) = \frac{\sum_{p=1}^{n} z_p^2}{n} = E[z_i^2] \qquad \textbf{(20)}$$

$$m_{y^2z^2} = \frac{\sum_{p=1}^{n} y_p^2 z_p^2}{n} = E[y_i^2 z_i^2] \qquad \textbf{(21)}$$

$$S_1 = \sum_{i=1}^{n} \sum_{\substack{j=1 \\ i \neq j}}^{n} w_{ij}\left(w_{ij} + w_{ji}\right) \qquad \textbf{(22)}$$

$$S_2 = \sum_{i=1}^{n} \left(w_{i\bullet} + w_{\bullet j}\right)^2; \quad w_{i\bullet} = \sum_{j=1}^{n} w_{ij} \quad and \quad w_{\bullet j} = \sum_{i=1}^{n} w_{ij} \qquad \textbf{(23)}$$

By decomposing the spatial cross-correlation matrix I_{yz}, it is possible to examine the relative contribution of each sampling point to the overall statistic [*Reich et al.,* 1994]:

$$I_{yzi} = \frac{\sum_{j=1}^{j=n} W_{ij} y_i z_j}{W\sqrt{Var(y)Var(z)}} \tag{24}$$

3.2. Whole-stream metabolism estimates

Whole-stream metabolism estimates provide an integrated assessment of primary production and respiration rates on a stream and are based of temporal changes in dissolved oxygen (DO) levels. In a river with negligible groundwater inputs and under clear sky conditions DO varies on a diel cycle [*Odum,* 1956] due to (1) primary productivity, or the release of oxygen into the water during photosynthesis by periphyton, phytoplankton, and aquatic macrophytes, (2) community respiration, or the uptake of oxygen from the water as a result of autotrophic and heterotrophic respiration, and (3) reaeration, or the exchange of oxygen between the water and the atmosphere. The instantaneous change of DO can be modeled as

$$\frac{dC}{dt} = p(t) - r + K_2(C_s - C) \tag{25}$$

where C is the DO concentration [ML^{-3}], $p(t)$ is the time-variant rate of primary production [$ML^{-3}T^{-1}$], r is the community respiration rate [$ML^{-3}T^{-1}$], and the last term on the right-hand side describes stream reaeration in terms of K_2, the reaeration rate constant [T^{-1}] and (C_s - C), the DO deficit [ML^{-3}], where C_s [ML^{-3}] is the DO saturation value at the current temperature.

Whole-stream metabolism is estimated by integrating **(25)** over a 24-h period, as described below, to yield a daily DO balance:

$$Q_{24} = GPP - CR_{24} + D \tag{26}$$

where Q_{24}, the 24-*h* net rate of change of DO, is a function of the average daily gross primary production (*GPP*), community respiration (CR_{24}) and stream reaeration rates (*D*) [$ML^{-3}T^{-1}$]. This and similar models have been developed primarily to estimate whole stream metabolism using one- and two-station analysis of DO and temperature time series data [*Mulholland et al.,* 2001; *Roberts et al.,* 2007; *Wilcock et al.,* 1998; *Young and Huryn,* 1999]. In this work, we employ **(25)** with the single-station approach [*Bott,* 2007] to determine whether or not spatial variability of the metabolic estimates is observed. This approach is analogous to that used to compare metabolic rates in pelagic and benthic zones in lentic water bodies [*Van de Bogert et al.,* 2007].

The single-station open-channel *in situ* method for assessing metabolic rates as formulated in equation **(25)** does not address groundwater inputs which are typically characterized by low DO concentrations. While such inputs are known to occur within the study reach, varying spatially and temporally with river stage and groundwater levels [*Butler,* 2009; *Zamora,* 2007], it was estimated that they constituted less than one percent of the overall flow at the time of the studies, suggesting that their effect on metabolism estimates was negligible [*Hall Jr. and Tank,* 2005; *McCutchan Jr. et al.,* 2002].

The general approach to estimating daily *GPP* values involves integrating the observed DO change with time (*dC/dt*) while adjusting for the temperature-corrected photoperiod respiration rate (r_T) and reaeration coefficient ($K_{2,T}$):

$$GPP = \int_{\phi} \left(\frac{dC}{dt} - K_{2,T}\left(C_s - C\right) + r_T \right) dt; \quad \phi = photoperiod \qquad \textbf{(27)}$$

The daily community respiration rate (CR_{24}) is obtained by integrating the instantaneous temperature-corrected respiration rates over the 24-h period:

$$CR_{24} = \int_{24\,h} r_T \; dt \qquad \textbf{(28)}$$

For equations **(27)** and **(28)**, the instantaneous respiration rate (r_T) is obtained as an average of the reaeration-corrected rates of DO change during dark hours [*Marzolf et al.,* 1994], and corrected for the diel temperature variations as [*Erlandsen and Thyssen,* 1983]

$$r_T = r_{20} \; \theta_r^{(T-20)}, \quad \theta_r = 1.07 \qquad \textbf{(29)}$$

Among the various methods for estimating stream reaeration [*Aristegi et al.,* 2009; *Covar,* 1976; *Genereux and Hemond,* 1992; *McBride,* 2002; *Thyssen et al.,* 1987; *Wilcock,* 1982], we selected the energy dissipation model EDM [*Tsivoglou and Neal,* 1976]. This method has been found to be reliable in comparison with results from tracer studies [*Aristegi et al.,* 2009; *Thyssen et al.,* 1987; *Wilcock,* 1988] and is applicable for the river conditions at our study site. The EDM uses the reach-averaged properties to calculate a single value

$$K_{2,20} = K'\, S\, U \qquad \textbf{(30)}$$

where $K_{2,20}$ (d^{-1}) is the reaeration rate constant at 20°C, *K'* is 15300 s m^{-1} d^{-1} for flows above 0.56 m^3 s^{-1} [*Hein,* 2005], *S* is the reach slope (m m^{-1}), and *U* is the mean reach velocity (m s^{-1}). This daily rate ($K_{2,20}$) is applied at both the stationary and the distributed sampling locations throughout the experiment with the appropriate correction for temperature variations [*Elmore and West,* 1961]:

$$K_{2,T} = K_{2,20}\ \theta_K^{(T-20)}, \quad \theta_K = 1.0241 \qquad \textbf{(31)}$$

Lastly, the *GPP* to CR_{24} ratio (*P/R*) and the net ecosystem productivity (*NEP*) metrics are used to evaluate the overall functioning of the system. The former is a dimensionless parameter in which values greater than 1 indicate autotrophic conditions and values lower than one heterotrophic, while the latter is expressed in the same units as *GPP* and CR_{24}:

$$NEP = GPP - CR_{24} \qquad \textbf{(32)}$$

Positive or negative *NEP* values indicate the autotrophic or heterotrophic character of the system, respectively. These rates may be expressed in either areal (g O_2 m^{-2} day^{-1}) or volumetric units (g O_2 m^{-3} day^{-1}).

In regard to the data gaps associated to the distributed sampling strategy, a spline interpolation scheme is used to generate DO and temperature data at a 1-min interval for each of the sampling positions based on the data collected through all the raster scans. The plots in Figure 3 demonstrate the consistency in the temporal trends for the high resolution single-station data and the interpolated data from nearby distributed stations; the interpolation did not significantly bias the latter. An exception is for the latter part of the April time series where a power loss resulted in a lack of data near the minimum of the DO curve and therefore a less reliable interpolation during that period. This portion of the data set was not used as the analysis ends with the data collected at midnight April 25.

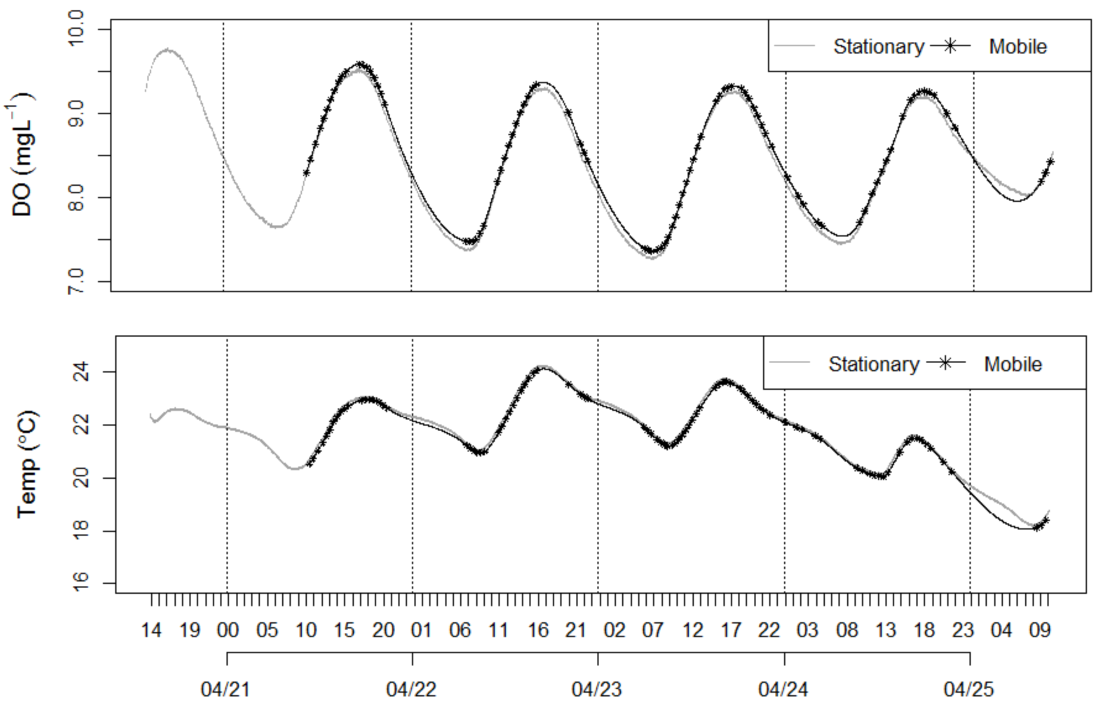

Figure 3. Example of the interpolation scheme for water temperature (top) and dissolved oxygen (bottom) for the April data set. The continuous (grey) line represents the fixed-station data and the symbols and black line represent the observations and 1-min spline-interpolation, respectively, for the nearest sampling point (x = 9.5 m) of the distributed data set.

Chapter 4. Results and Discussion

The results obtained in this study show that, contrary to the typical assumption of a well-mixed system, local processes can produce identifiable transverse gradients across the river transect. This chapter starts by providing an overview of the site conditions during the experiment periods, continues with a description of the temporal trends of metabolic rates obtained at the fixed (central) station informing about the trophic state of the river reach and, based on the site properties, allowing to identify the main drivers of the temporal trends of those rates. The identified spatio-temporal distributions of water quality parameters are described and discussed in terms of the implications that they may have on the observed spatial variability of the metabolic rate estimates.

4.1. Site conditions during experiment periods

The observed flows during the two sampling periods were somewhat similar and can be categorized as base flow conditions. Mean daily flows during the April period were 6 $m^3 s^{-1}$, with mean daily water temperatures of 21 °C. During the September period, the study site's mean daily flow and water temperature were 3.7 $m^3 s^{-1}$ and 23 °C. The observed local velocity values support the assumption of stationary flow conditions for both sampling periods (See Figure 4). The lower flows correspond to slightly lower velocities during September (5 to 50 cm s^{-1}) compared to April (5 to 60 cm s^{-1}). For both experiments, the lowest velocities were observed, as expected, near the river edges. Under the relatively higher flow conditions of April, the minimum velocity was observed on the point bar (right) side of the transect. In September, it was observed on the opposite side. Bed movement during the interceding period is evident from the two transect bed elevation lines, and may have contributed to this result.

The in-river weather station data permits the characterization of local meteorological conditions during the two deployments (Figure 5). In April, two distinct patterns were present, with days 1 and 2 characterized by stable, warm days and cool nights, followed by a change in regional weather with marked effects on day 4, as reflected by the temperature (5a), relative humidity (5b), and solar radiation data (5e). In September, a more stable pattern occurred for all days with warmer temperatures. Times for maximum and minimum air temperatures were similar for both periods (5 pm and 6:30-7:00 am, respectively). Wind above the river occurred mainly during the day, with values below 2 m/s, and was negligible at night. Relative humidity reflected the local semi-arid conditions when wind was present, exhibiting an afternoon minimum, and increasing significantly when the wind abated between midnight and sunrise. No rain occurred during the experiments.

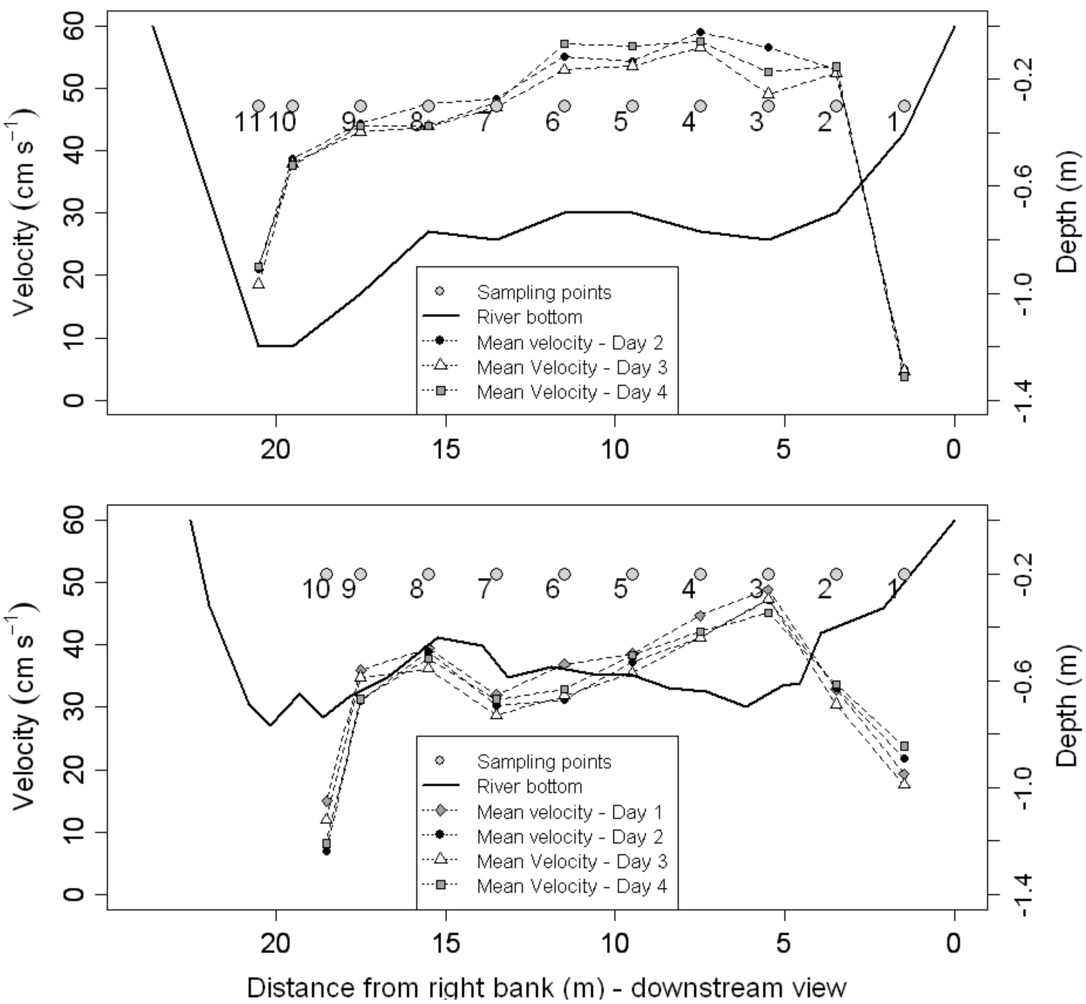

Figure 4. Profiles of daily-average velocities across the river transect during April (top) and September (bottom). Dashed lines with symbols represent velocities for day 1 (grey diamond – September only), day 2 (black circles), day 3 (open triangles), and day 4 (gray squares). The gray circular symbols indicate the position of the sampling points for the distributed system [vertical scale exaggerated].

Incident solar radiation patterns were determined using the local PAR sensor (5f) in conjunction with the regional solar radiation data provided by the CIMIS station (5e). Maximum solar radiation values occurred between noon and 1 pm for both periods reaching 900 W m^{-2} in April and 850 W m^{-2} in September. The influence of cloud cover is evident on days 1 and 4 on April, and on day 4 on September (5e), while sudden temporal variations in the solar radiation data collected just above the water surface (5d) are caused by vegetation shading. Although maximum PAR values (5f) were greater in April (2100-2200 μmol m^{-2} s^{-1}) than in September (1900-2000 μmol m^{-2} s^{-1}), a more consistent distribution along the days was exhibited in the late summer. Based on sunlight/sunset times, the days were 40 to 60 min longer during the April sampling period.

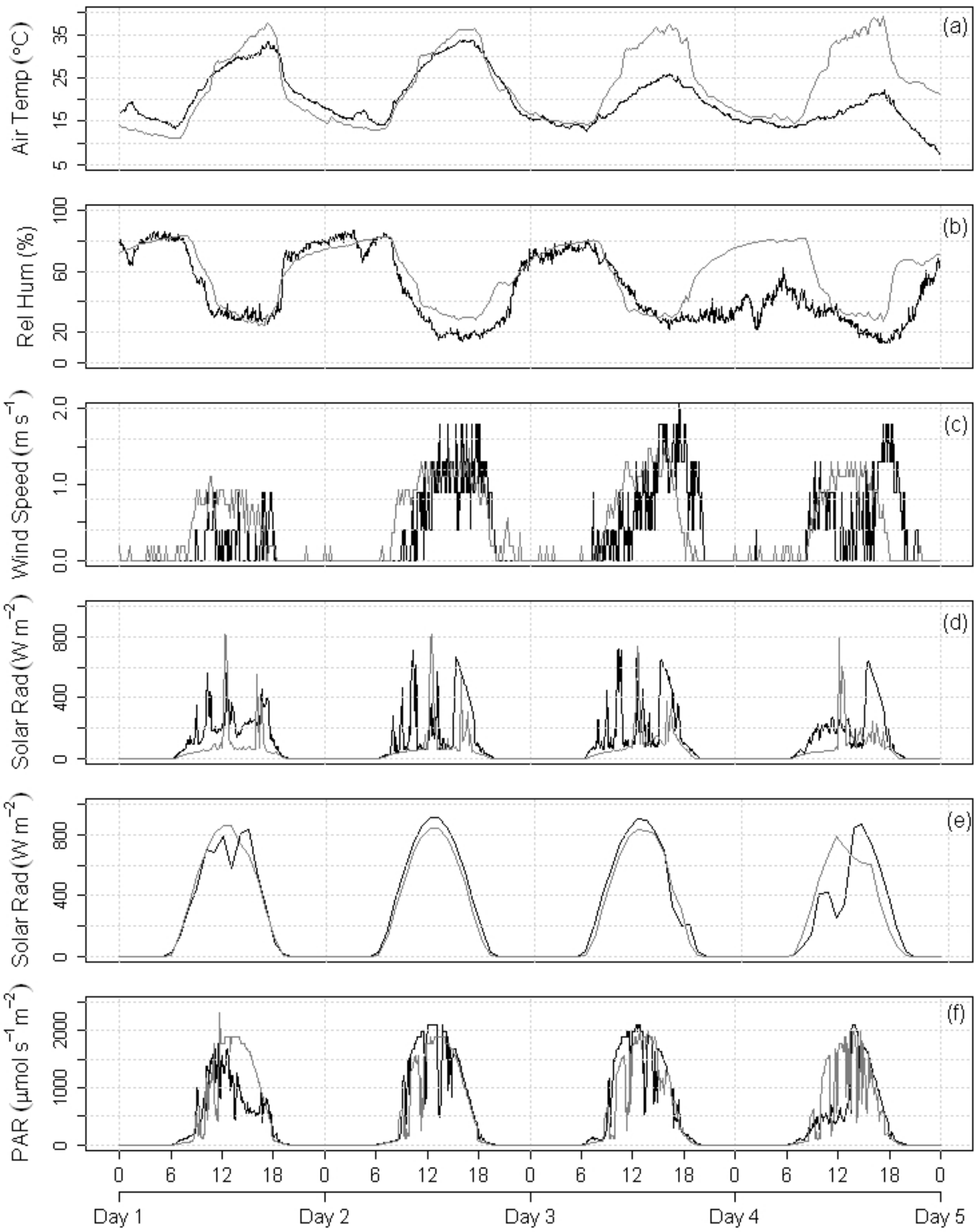

Figure 5. Time series of (a) air temperature, (b) relative humidity, (c) wind speed, (d, e) solar radiation on-site and CIMIS weather station, and (f) PAR at the experimental site (black line: April data; grey line: September data).

The normalized light intensity data from the spatially distributed sensors shows that the left, deeper side of the reach received significantly less light than did the center and right areas (Figure 6). This observation is the result of the northeast to southwest reach orientation and the riparian vegetation structure, which produced a distinct incident light pattern. The exception was the morning of April 24, when the cloudy conditions produced a more diffuse pattern.

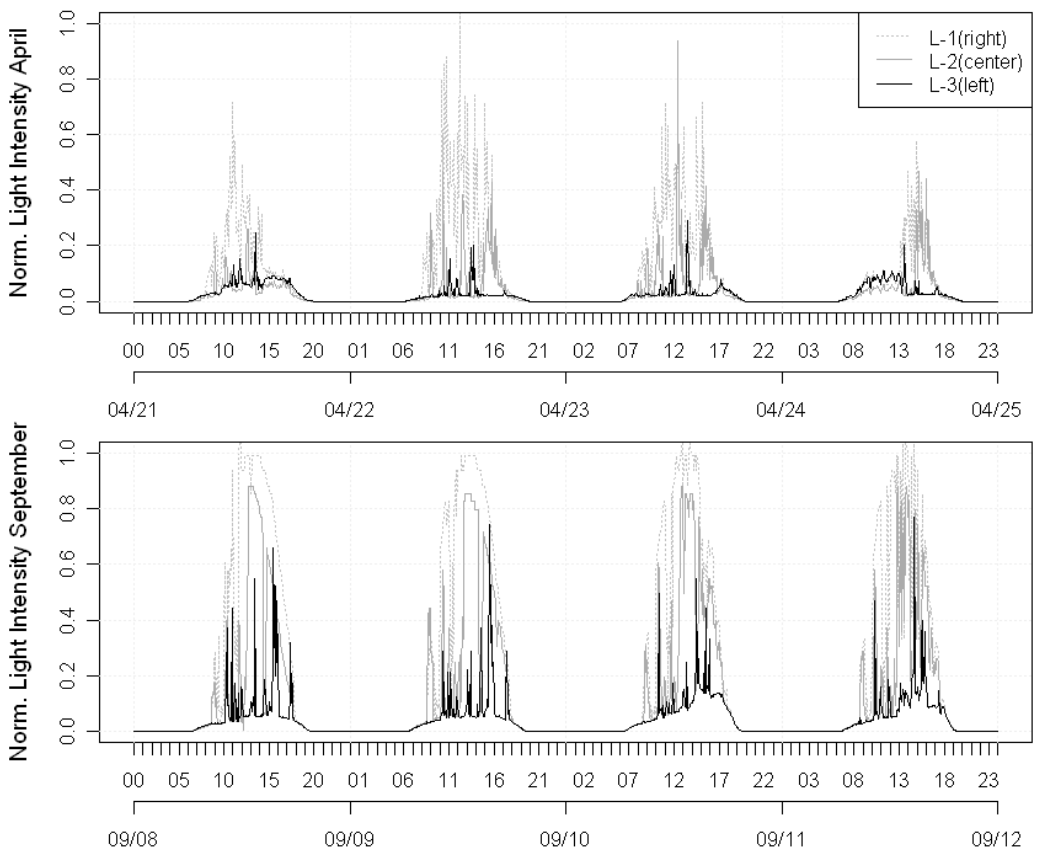

Figure 6. Incident light patterns at the study site represented by the normalized light intensity for three different positions across the river transect. (Top: April 21-24; bottom: September 08-11). The observations (lux) were normalized by the maximum observed value for the two experiments (200,000 lux).

4.2. Temporal trends of metabolic rates.

The range of metabolic rate estimates based on the fixed station observations (Table 2) is consistent with other studies developed for lowland, heterotrophic rivers [*Oliver and Merrick,* 2006; *Wilcock et al.,* 1998]. The temporal variability between the April and September experiments suggests a more productive system during spring time with average *P/R* ratios of 0.85 compared to about 0.78 during late summer. This difference can be explained by the greater light availability during April in terms of the greater number of daylight minutes during that period (approximately, 40 to 60 min). In Addition to the expected seasonal trends, significant short-term variations in metabolic rates can be produced by strong changes in weather patterns. For example, day 4 of the April experiment, registered a decrease of 13% in CR_{24} and 23% in *GPP* with respect to the three previous days. This decrease is attributed to changes in the availability of PAR and variations in water temperature during the experiment [*Kirk,* 1994].

Table 2. Areal metabolic rate estimates based on DO and temperature observations from the stationary setup using average reach velocity and depth (error bars based on propagation of velocity and depth uncertainty through the reaeration and metabolism calculations).

Merced River – Stationary Metabolism Results Areal rates (gr O_2 m^{-2} day^{-1})					
04/2009		CR_{24}	GPP	NEP	P/R
21	day 1	4.16±0.00	3.59±0.02	-0.57±0.02	0.86±0.01
22	day 2	4.29±0.00	3.64±0.02	-0.64±0.02	0.85±0.01
23	day 3	4.06±0.00	3.54±0.03	-0.51±0.03	0.87±0.01
24	day 4	3.61±0.00	2.77±0.02	-0.83±0.02	0.77±0.01
09/2009		CR_{24}	GPP	NEP	P/R
08	day 1	3.18±0.00	2.44±0.01	-0.73±0.01	0.77±0.00
09	day 2	3.23±0.00	2.52±0.01	-0.71±0.01	0.78±0.00
10	day 3	3.30±0.00	2.64±0.01	-0.67±0.01	0.80±0.00
11	day 4	3.21±0.00	2.47±0.01	-0.74±0.01	0.77±0.00

The PAR dependence of productivity is evidenced in Figure 7 which compares the daily *GPP* estimates for the fixed station during April, with total available PAR (mol/m^2) for morning, afternoon, and the entire photoperiod. These results suggest that morning PAR was a limiting factor for photosynthetic activity during day 4, with total morning PAR accounting as only 25% of the total daily radiation compared to 51, 43, and 43% for days 1 through 3. No similar correlation is evident between *GPP* and available afternoon or total daily radiation. This observation is consistent with the notion that maximal photosynthetic rates occur during the morning hours [*Doty and Oguri,* 1957]. Furthermore, from day to day, the strong influence of water temperature on the metabolism estimates appears evident when comparing daily *GPP* values with the number of photoperiod hours in which a temperature increment existed (i.e., the number of daylight hours between minimum and maximum temperature) which varied from 9.0 hours on the first day to 4.3 hours on day 4 despite the fact that the total number of photoperiod hours was identical for all days during this period (13 hours).

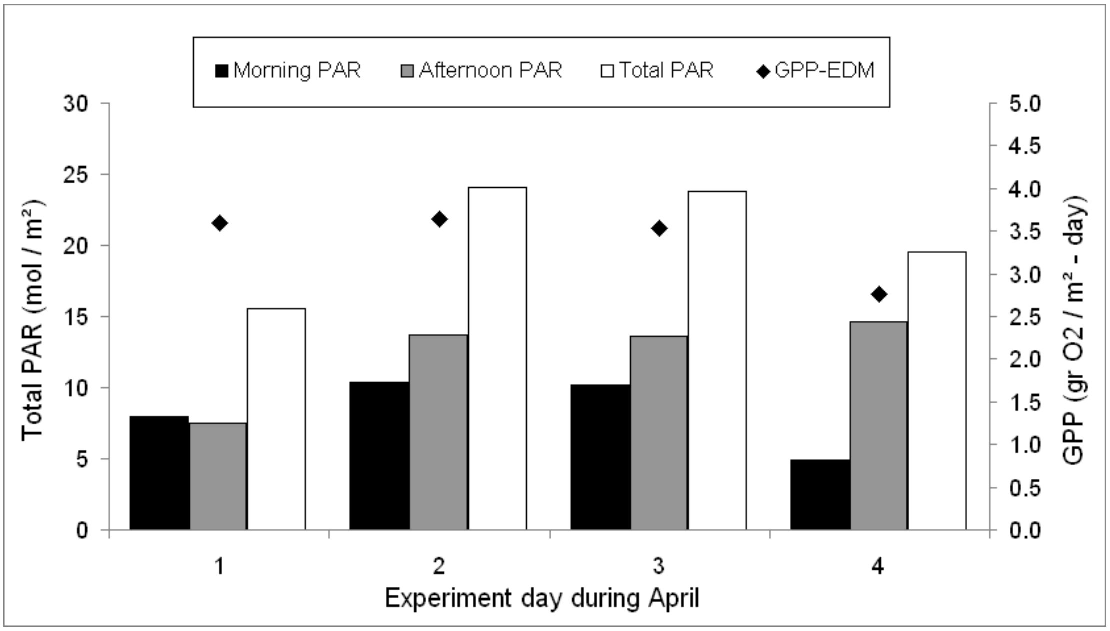

Figure 7. Morning, afternoon, and daily photosynthetically available radiation (PAR) and its effect on ecosystem productivity. Total morning PAR appears to be the limiting factor for productivity.

4.3. Spatio-temporal distributions of water quality parameters

The spatio-temporal distributions of the water quality data collected during the two experiments demonstrate the expected diel cycling of water temperature and DO levels associated with air temperatures and photosynthetic activity (Figure 8). Seasonally, the April conditions are characterized by cooler water with higher DO levels relative to those of September. The specific conductivity data exhibited low values for both periods, with a lower range during September. Furthermore, the warmer and slower water column during September also appeared to support a greater standing phytoplankton biomass, based on the chlorophyll-*a* data.

In support of our hypothesis, the observations in Figure 8 also exhibit transverse gradients in temperature and constituent concentrations that may be important in terms of metabolic rate estimates. To test for the significance of these gradients, we employed the Moran's I statistic. The null hypothesis of random distribution of the observed values is rejected whenever the test is significant ($p<0.05$). The plots in Figure 9 represent the I-values for all of the transect runs, with values approaching 1.0 for more spatially clustered observations than would be expected if the underlying spatial processes were random. This information, combined with the observations of the raw data (see Figure 8), is evidence of significant gradients across the sampling transect. For the case of DO (9a), temperature (9b), and specific conductivity (9c), most of the transect run data exhibit a significant gradient. The results for DO demonstrate a consistent pattern of two peaks of greater *I* values occurring in the morning and afternoon, but with consistently greater values for the September data (i.e., more prominent gradients during September). Temperature gradients are also evident each day, diminishing toward midday and then reestablishing in the afternoon. The observed gradients remained relatively constant for specific conductivity, with the exception of a few late morning September sampling times. Finally, consistent with Figure 8, the *I* values for the Chlorophyll-*a* transect runs (9d) exhibit more distinct gradients for the April period during day time, and more random patterns during the September experiment.

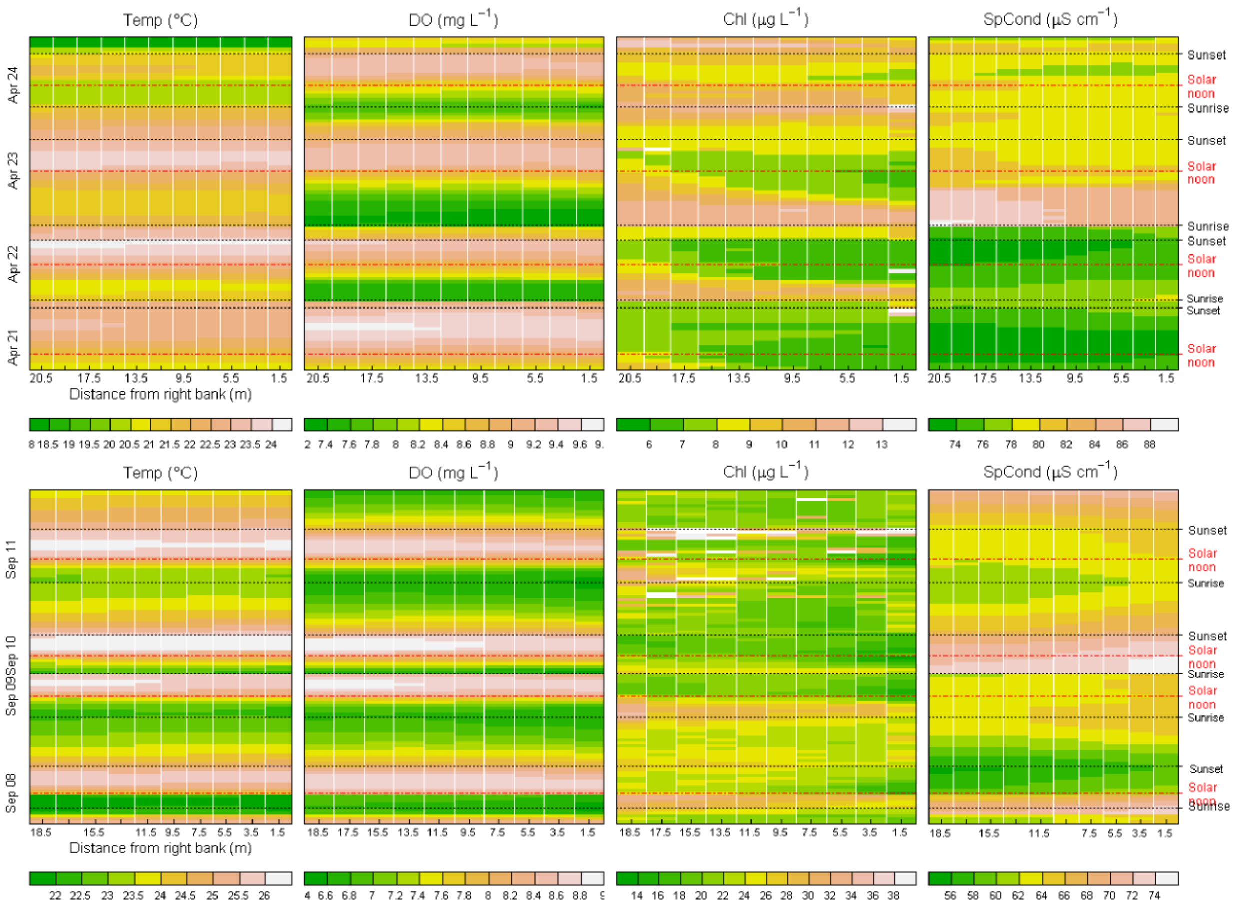

Figure 8. Temperature (Temp), specific conductivity (SpCond), chlorophyll-*a* (Chl), and dissolved oxygen (DO) spatiotemporal behavior observed using the mobile sensor platform (note differences in scale).

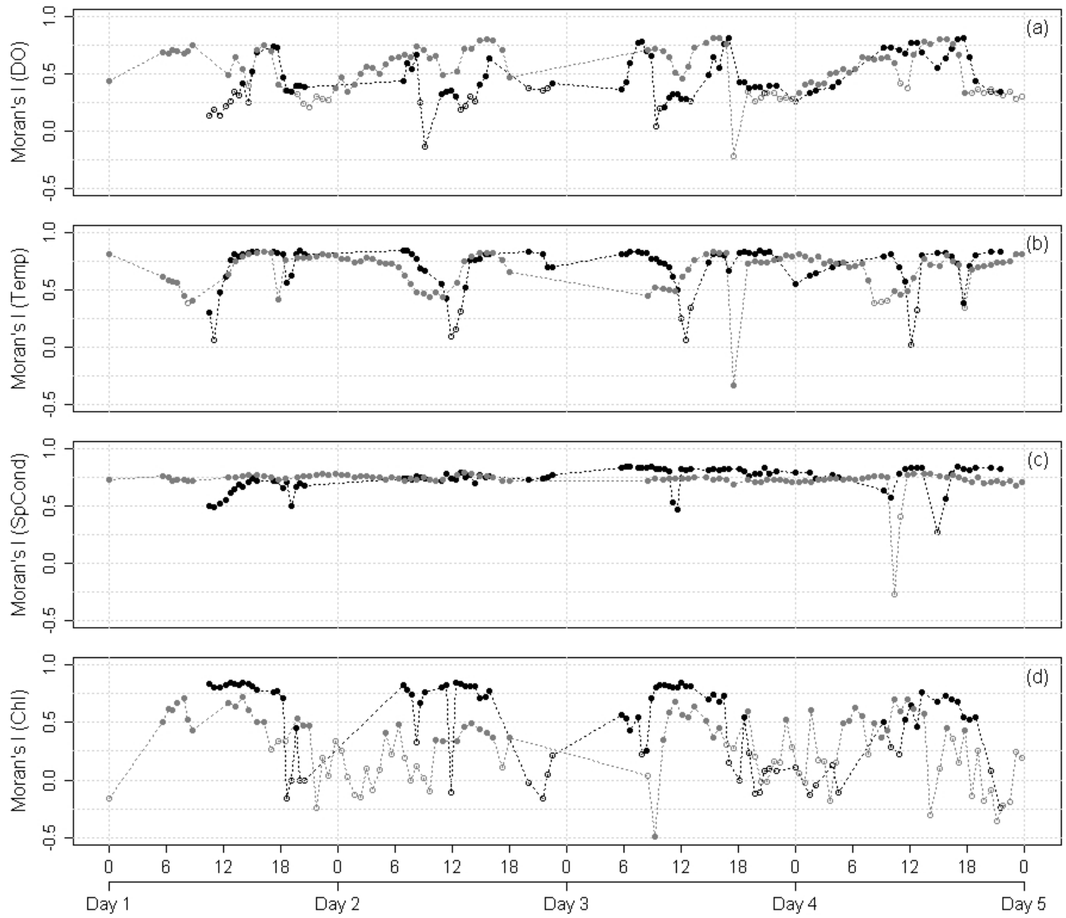

Figure 9. Time series of the calculated Moran's *I* statistic for the two experiment periods. Black symbols refer to the April results and grey symbols to those of September. The filled dots indicate the transect runs for which significant (*p*<0.05) gradients were identified by the Moran's *I* statistic.

The identified spatial gradients lend support to the hypothesis of this study. To test it more directly, we now focus on the key variable of our study, DO. The coefficient of variation ratio (CV_{exp} / CV_{std}) in Figure 10 is used to describe the spatial variability of the transverse DO observations during the April and September experiments. A value of 1 indicates no spatial variability ($CV_{exp} = CV_{std}$), while greater values indicate variability across the raster scan exceeding the DO sensor's "noise" level (see section 2.3). For the April data, the ratios varied between 1.7 and 5.6, with increases in variability over the cross section most prominent between 10:00 and 13:00 and in the evening (from 18:00 to 21:00). This trend is repeated for days 1 through 3 but less noticeable during day 4 due to the different weather conditions of that day which produced a continuous pattern of somewhat higher variability from the 10:00 to 16:00 period. Greater *CV* ratios were obtained for the September sampling period, when the normalized values ranged from 2.1 to 11.9. Variability consistently increased in the morning (between 8:00 and 10:00), then decreased during the early afternoon. One anomalously high CV ratio was observed for unknown reasons around 18:00 on the third day of the September sampling period. Otherwise, a second rise of CV ratios occurred in the afternoon similar in magnitude but earlier relative to the April results. Overall, the *CV* ratio behavior is consistent with the observations made through the Moran's *I* statistic (Figure 9) and appears to be a consequence of the higher rate of local metabolic processes (relative to the transverse mixing rate), due to the combined effects of the observed velocity gradients (Figure 4 bottom) and the solar patterns affecting the reach (Figure 6 bottom).

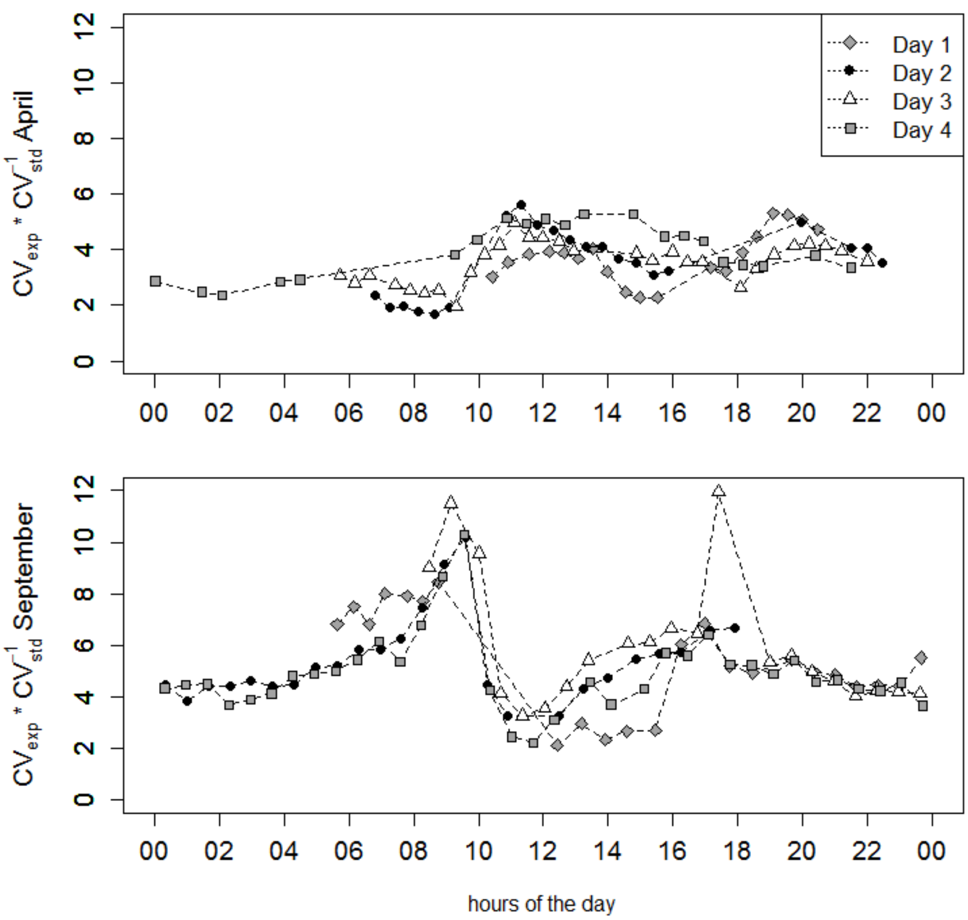

Figure 10. Time series of the normalized distribution of the coefficients of variation (*CV*) of the measured DO concentrations, for the April (top) and September (bottom) raw data. Each symbol represents the variability of one raster scan.

4.4. Implications of the observed transverse gradients on the distributed metabolic rate estimates.

The identification of the transverse variability of the metabolic rate spatial patterns was facilitated by normalizing each of the distributed daily rates by that obtained at the thalweg, point 10 (see Figure 4), for the respective day of analysis. The resulting distributions of the normalized estimates exhibit modest but discernible gradients over the experimental transect (Figure 11). Consistent with the results obtained through the analysis of the *CV* ratios (Figure 10), the normalized estimates for *GPP* in April exhibit minimum spatial variability compared to those for September (Figure 11 a). The April CR_{24} (Figure 11 b, left) exhibited a consistent increasing trend from left (thalweg side) to right (shallow sunny side). In September, the normalized *GPP* and CR_{24} estimates both vary by about 5-10 % over the transect and a trend similar to that observed in April is evident in the September CR_{24} estimates on days 1 and 4. The NEP estimates are simply the difference of *GPP* and CR_{24} **(32)**, and are consistent for the two sampling periods, exhibiting a range of variation of about 20% over the transect, and generally increasing from left to right (more heterotrophic towards the right side). For April, the NEP variation is driven primarily by the respiration rates, while the September NEP variation is more of a function of both the production and respiration estimates. The normalized *P/R* estimates of September (Figure 11 d, right) exhibit a consistent pattern for all days, with lower productivity on the right, an increase toward the center of the channel, and subsequent decrease in productivity toward the left bank. While the April results present a relatively non-discernible gradient for days 2 and 3, the results for day 4 show a similar decrease from the left to right bank due to an enhanced contribution of respiration over productivity in the shallower right-bank area in the absence of the stronger light availability of the prior days (Figure 11 d, left).

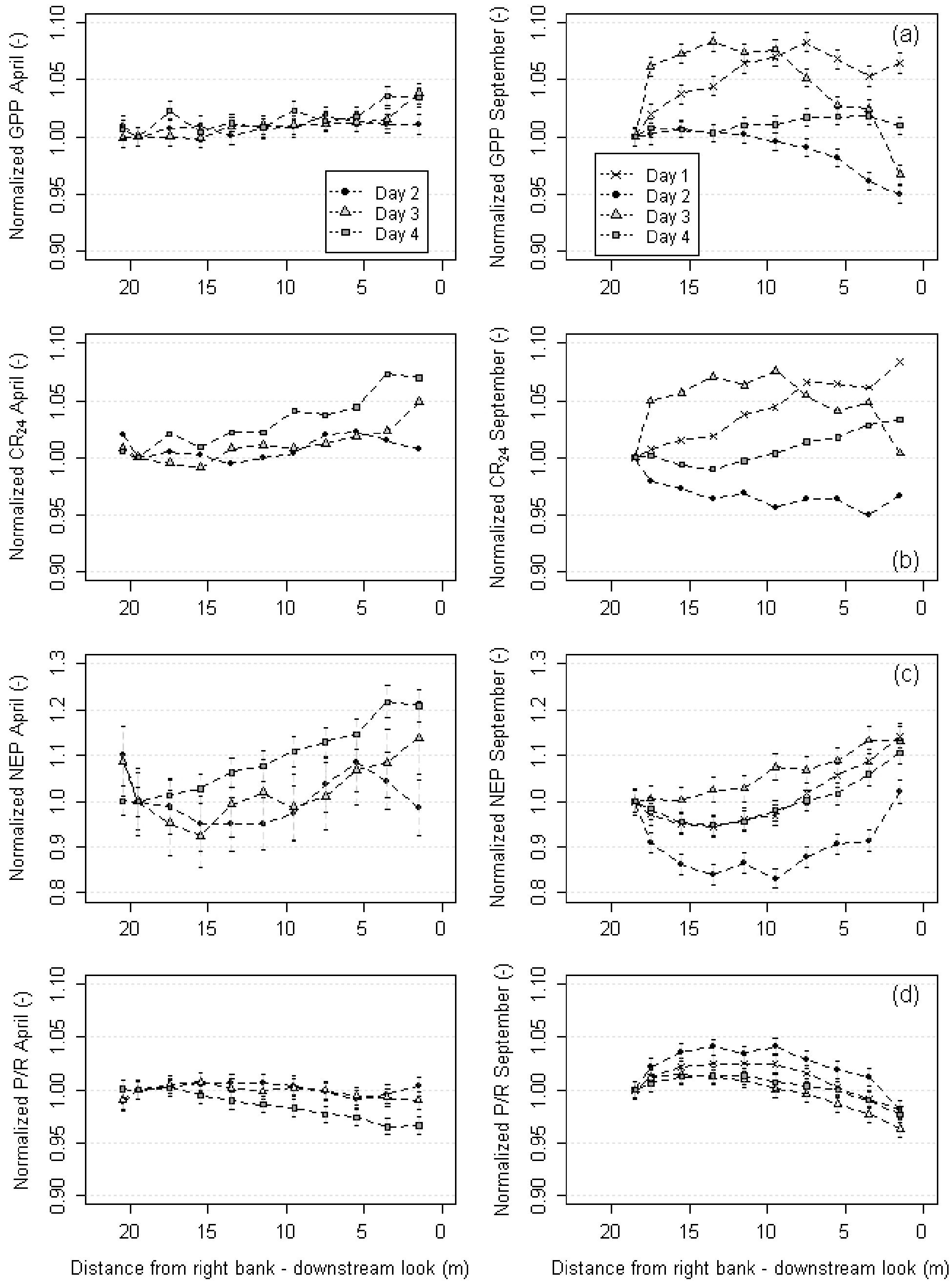

Figure 11. River cross-sectional distributions for (a) *GPP*, (b) CR_{24}, (c) *NEP*, and (d) *P/R* ratios for April (left) and September (right). All results are normalized with respect to the estimates obtained at point 10 (thalweg position) of the sampling transect (The error bars are based on the propagation of velocity and depth uncertainty through the reaeration and metabolism calculations).

The spatiotemporal cross-correlation (I_{yz}) between the observed river properties provides insight with respect to the distributed metabolic estimates. Significant cross correlations (*t*-test, $p<0.05$) were observed between pairings of the water quality parameters and water velocity for some of the transect runs (Figure 12). Positive cross-correlations were identified between noon and sunset during both experimental periods for the DO-Temp pairing, and during the spring experiment for the DO-Chl and Temp-Chl pairings (Figure 12 a-c). These cross-correlations are likely related to the observed variability in the metabolic rate distributions as all of the parameters involved are directly linked to the photosynthetic process. Cross-correlation testing between the same water quality parameters (DO, Temp, Chl) and local water velocity values (Figure 12 d-f) resulted in significant cross-correlations for only a few sampling times, all occurring before noon of each day, and only during the September experiment. Potential trends worth noting are for the negative cross-correlations between noon and sunset for velocity with DO and water temperature (higher DO and Temp values at low velocity areas of the cross section). If valid, these demonstrate a tendency toward diel cycles shifted in phase relative to the water quality pairings discussed above. Furthermore, for the significant velocity and water temperature pairings, decomposing the total cross correlation (I_{yz}) to its local contributions (I_{yzi}) points clearly to the main channel as the dominant contributor to the spatial cross-correlations (Figure 13). Considered together, the cross-correlation results in Figures 12 (d-f) and 13 suggest that the hydraulics of the main channel appear to be more closely associated with the traditional single-station metabolic rates compared to those of the off-channel waters. In the present case, the latter waters are shallower and more strongly influenced by changing light conditions.

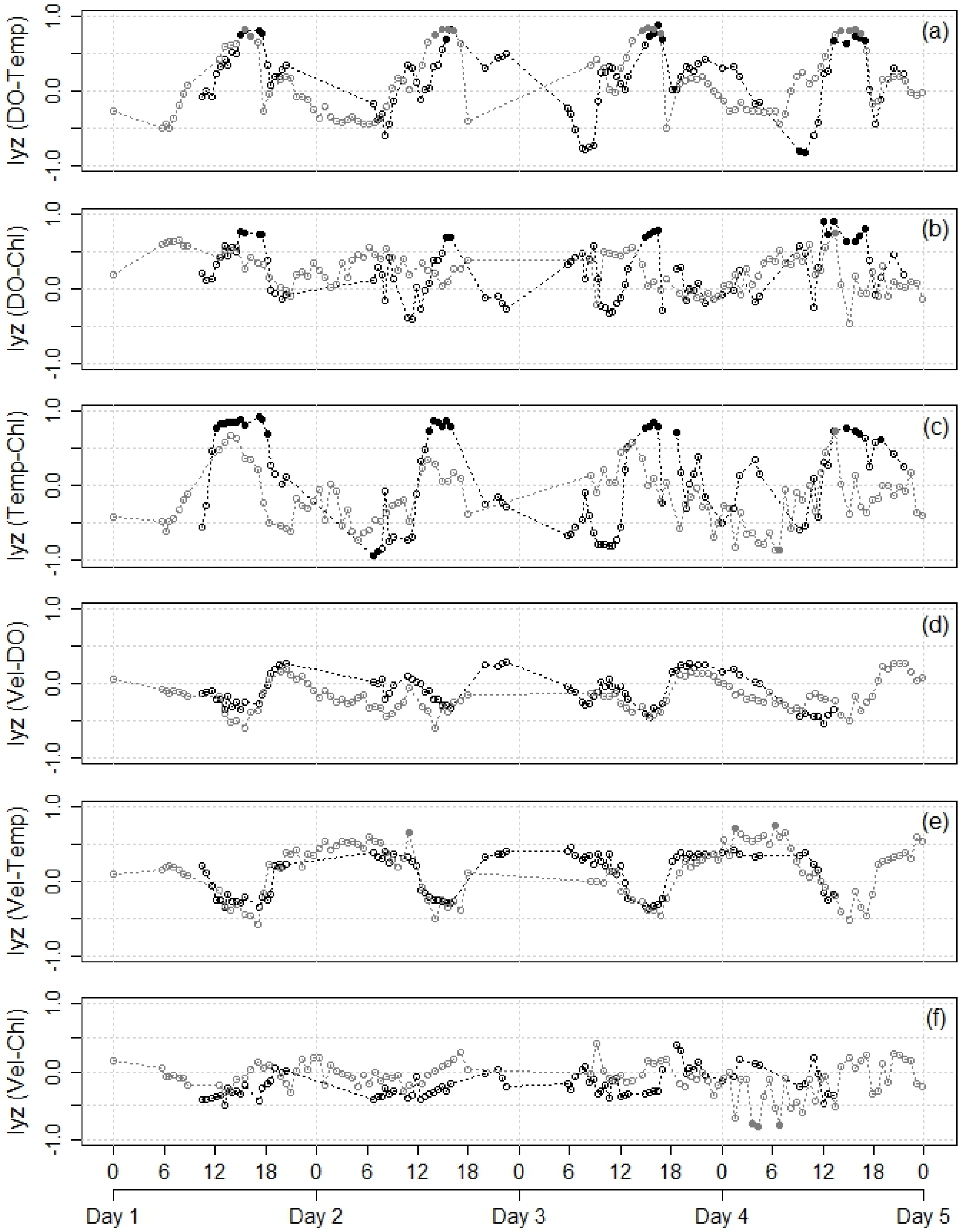

Figure 12. Cross-correlations (I_{yz}) of DO, temperature (Temp), chlorophyll-a (Chl), and velocity (Vel) pairings. Black symbols refer to the April results and grey symbols to those of September. Each dot represents the cross-correlation coefficient between two parameters for a given transect run. The filled dots indicate the transect runs for which significant cross-correlations were identified by the I_{yz} statistic (*t*-test, *p*<0.05).

As noted at the outset, the mixing timescale is presumed to be fast relative to metabolic timescales in the conventional single-station approach. An approximate estimate of the transverse mixing length [*Fisher et al.,* 1979] based on the average properties of the reach during the two experiments suggest mixing time scales on the order of 0.7-2.9 and 1.0-4.0 hours, respectively. Planktonic organisms within a given parcel of water may be subjected to different light intensities due to the light/shade patterns originated by the upstream riparian vegetation and in-stream features, and the pathways taken due to the continuous mixing process [*Reynolds,* 1994]. Because the physiological responses of phytoplankton to changes in light intensity and quality are known to occur at different time scales, ranging from minutes to a few hours [*Falkowski,* 1984; *MacIntyre et al.,* 2000; *Neale and Marra,* 1985; *Pahl-Wostl and Imboden,* 1990], it is feasible that the observed spatial distributions of metabolic rates are, to some degree, a consequence of the combined effects of light and velocity gradients. For instance, during the September experiment the relatively lower velocities increase the opportunity for light and temperature gradients to exert influence on the spatial pattern in productivity and respiration rates across the transect. We propose that these distributions will be prominent in more complex river systems, such as those characterized by more substantial transient storage zones, or those above flood stage where there are channel-floodplain interactions.

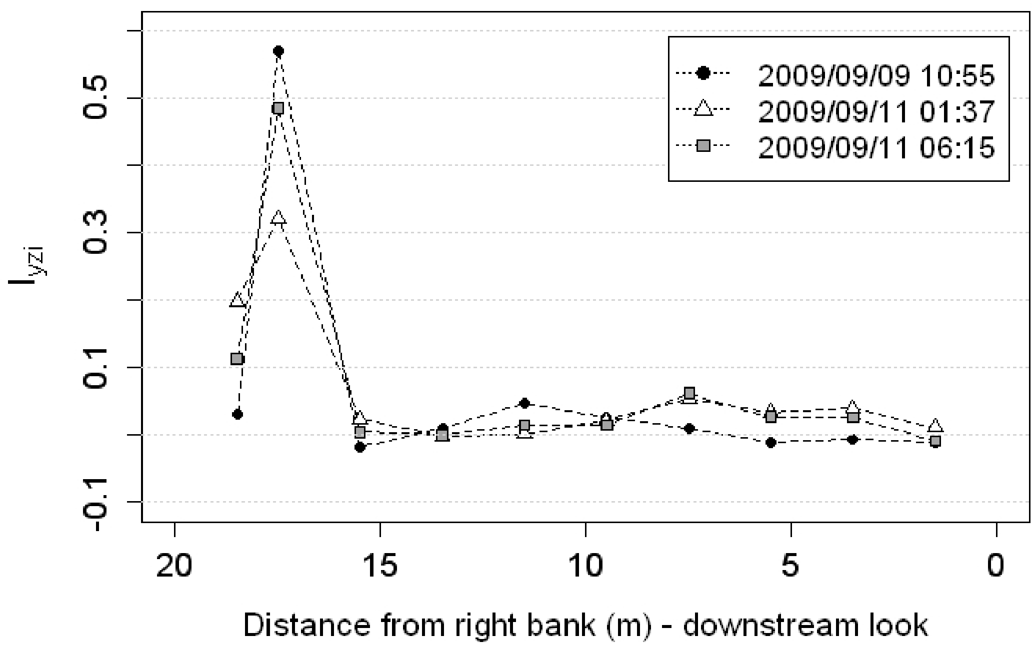

Figure 13. Distribution of the local (I_{yzi}) components of the cross-correlation statistic I_{yz} for the significant cross-correlations between velocity and water temperature data (see Figure 11(e)).

Chapter 5. Concluding Remarks

5.1. Summary

This dissertation document presents the findings of a field experiment aimed at investigating the potential existence of transverse spatial variability of ecosystem processes in a lowland river reach, typically considered well mixed for the purpose of most investigations. We used the single-station whole-stream metabolism method to obtain estimates from (1) a fixed sampling point located near the thalweg of the river, and (2) from a distributed set of sampling points located immediately upstream of the fixed station over a cross-sectional transect using a tethered robotic sensor platform (NIMS AQ). We calculated the stationary and distributed metabolic rates and corroborated the identified spatial variability of these estimates by analyzing the spatial patterns observed in temperature, constituent concentrations (DO, specific conductivity, and chlorophyll-*a*), and light gradients reaching the river.

5.2. Conclusions

Through spatial statistics, we were able to identify spatial patterns in the observed temperature and constituent concentrations. Specifically for DO, the primary parameter for metabolism estimates, we observed gradients in both periods of analysis, with more prominent variability being exhibited during the late summer period. During the diel cycle, the spatial gradients of DO increased during morning hours, in a manner consistent with incident light patterns on the upstream reaches, which were controlled by river orientation and riparian vegetation structure.

Net ecosystem production (*NEP*) estimates derived from the distributed observations varied spatially by approximately 10 to 20% over the transect, with more heterotrophic conditions estimated for the right (shallow, sun-dominated) side (Figure 11(c)). For both experiments, the *NEP* variation was most likely shade-driven as evidenced by a relatively rapid development of spatial *NEP* patterns coinciding with incident light/shade timing (Figure 6). The related pattern manifested by the *P/R* estimates results from greater respiration rate estimates on the sunnier, shallower side. Such an occurrence could be the result of non-uniform sediment heating, although this observation is speculative since subsurface temperatures were not assessed.

The observed gradients of DO and other water parameters and the spatial distributions of metabolic rates support the hypothesis of the existence of transverse heterogeneities of lotic ecosystem metrics. Based on the identified spatial cross-correlations among water quality parameters and between velocity and water quality parameters, we argue that the driving factors for the observed distributions include a combination of upstream hydrogeomorphology, variable solar radiation and resulting water temperature changes driven by the light/shade patterns. For the average reach conditions, the trend towards complete transverse mixing occurs at a timescale of 1 to 4 hours while metabolic processes may operate at significantly shorter timescales (minutes to hours). Although these factors support the identified gradients, additional data such as nutrient concentrations and direct biomass assessments would improve our understanding of the interrelation between hydrodynamic and metabolic processes.

5.3. Recommendations and future work

Should further attempts to develop this kind of high resolution investigation wanted to be pursued, it is recommended that additional ancillary data be collected to better explain the observed gradients and patterns present in the system. Spatially distributed samples of nutrient concentrations and biomass density in surface water and hyporheic zone as well as light and temperature at different locations across the river bed, would greatly benefit the interpretation of results. Furthermore, the uncertainty of the observed gradients can be reduced by developing tracer studies for the calculation of the true reaeration rate, and by replicating the setup at a second transect within the reach of interest.

In a broader context, the results in this investigation serve to open discussion regarding the value of more detailed aquatic ecosystem process and structure inquiries. For a system such the subject reach on the lower Merced River, the reduction of flow and the changing light conditions between the two experimental periods resulted in an increase in spatial variability of the observed water quality parameters and consequently of the estimated metabolic rates. The results for this particular system were relatively minor, and the assumption of a completely mixed cross-section would be reasonable in most contexts. Nevertheless, the presence of defined gradients in metabolic rates in this relatively simple reach implies the existence of substantial gradients in more complex lotic regimes such as reaches with more distinctive transient storage zones. For example, substantial spatial differences in ecosystem metabolism might be expected and important to consider in the context of understanding floodplain-channel nutrient exchange dynamics, restoring aquatic habitat, quantifying the impacts of anthropogenic inputs on a lotic ecosystem, and other efforts.

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Appendix. The workflow for the calculation of whole-stream metabolism

This appendix describes the proposed workflow for the calculation of the metabolic rates (Figure A1). These estimates may be obtained using data collected entirely by the research team, obtained from published data from government agencies or from a combination of the two previous options. The first step of the workflow is to define the basic **Station Information** which includes the station name or code, the location (latitude, longitude, and elevation), and the time zone (to determine whether or not daylight savings time needs to be considered). A **Date** or period of analysis needs to be defined. For the period of analysis **Water Quality** and **Flow** time series are required. The whole-stream metabolism estimates rely on paired, continuous readings of dissolved oxygen (DO), water temperature (Temp) and specific conductivity (SpCond). These time series may be obtained from sensors deployed in the river by the researcher, with logging intervals of less than an hour (ideally, 10 or 15 minutes). If the analysis is to be done with information collected by government agencies (e.g, USGS or California Department of Water Resources), the data is usually obtained through the agencies' websites. For example, in the case of California, CDEC (California Data Exchange Center) provides, in the most general case, 15-min (event) time series of Temp (°F) and SpCond ($\mu S\ cm^{-1}$), and for select stations [1], DO ($mg\ l^{-1}$). The flow time series informs about the key hydraulic parameters surface water slope, mean reach velocity, and mean reach depth (m). The time series can be originated by direct field measurements (for short-term studies), by constructing a rating curve for the research site and monitoring river stage continuously, or if applicable, by downloading the flow data from a government agency website.

Once the data is available, **Data Parsing** verifies for consistency of time zones and develops the required unit conversions to secure that the water quality and flow data are in the same unit system (preferably, metric). **Data Filtering** for outliers is developed on the parsed data at two levels. First, for values outside the expected environmental ranges and second, for outliers within the daily normal distribution of rates of change between consecutive timestamps. Any rate of change with frequency less than 2.5% is considered an outlier and is removed from the time series.

---

[1] The GRF station is an example of the select stations in which DO is being monitored due to the ongoing San Joaquin River Restoration Program.
http://cdec.water.ca.gov/cgi-progs/stationInfo?station_id=GRF

Because the metabolic rates are calculated on a daily basis, the particular properties of the day of analysis are stored in the **Parameters File**. The inputs required by the **Daily Parameters** function include the station name or code and station location (from Station Information), the parsed and filtered time series of water quality and flow; hydraulic parameters including mean water velocity, mean reach depth and water surface slope (for the case of long time series, this input can be in the way of regression equations for the calculation of mean water velocity and depth based on mean daily flow, and water surface slopes for the expected ranges of flow during the period of analysis). The final inputs to Daily Parameters are atmospheric data in the form of time series of solar radiation (SolRad), barometric pressure (BarPress), and PAR. These can be originated from on-site measurements or from data provided by government agencies from nearby stations. For example, hourly time series of SolRad can be downloaded from the California Irrigation Management Information System – CIMIS[2] and the BarPress data can be obtained from the University of Utah MesoWest data base[3]. Neither the PAR data nor the SolRad are required for the actual metabolism calculations however, they serve as useful tools for data interpretation. When PAR data is not available, a conversion factor can be used to approximately transform SolRad into PAR. The **Daily Parameters** function calculates mean daily values of flow, SpCond, Temp, BarPress, SolRad, the times of sunrise and sunset, the mean water velocity and reach depth, the water surface slope, and the total PAR available for the day.

The **DO Saturated** function uses the parsed and filtered time series of DO and Temp from **Water Quality_1** and the mean daily values of BarPress and SpCond from the **Parameters File** to calculate the saturated concentration of DO for each time stamp correcting for barometric pressure and salinity.

The **Reaeration** function uses the mean water velocity and water surface slope from the **Parameters File** to calculate the reaeration rate ($K_{2,20}$) through the Energy Dissipation Model (EDM), an empirical method. This function can be modified to incorporate a different method, or to include true reaeration rates obtained from tracer studies

The calculation of the daily metabolic rates is developed by the **Calculate Metabolism** function using the water quality time series (**Water Quality_2)** and the daily properties of the site (**Parameters File_1)**, according to the methodology presented in section 3.2 of this manuscript. The final results of this workflow include the daily rates of *GPP*, *CR24*, *NEP*, *P/R* together with the daily properties of the site (**Results**).

This workflow presents the basic steps for the calculation of daily metabolic rates. Minor variations may occur depending on the available inputs and specific methods that the researcher desires to apply. The functions are developed using the R language and are included within this Appendix.

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[2]http://wwwcimis.water.ca.gov/cimis/myCimis.jsp
[3] http://mesowest.utah.edu/

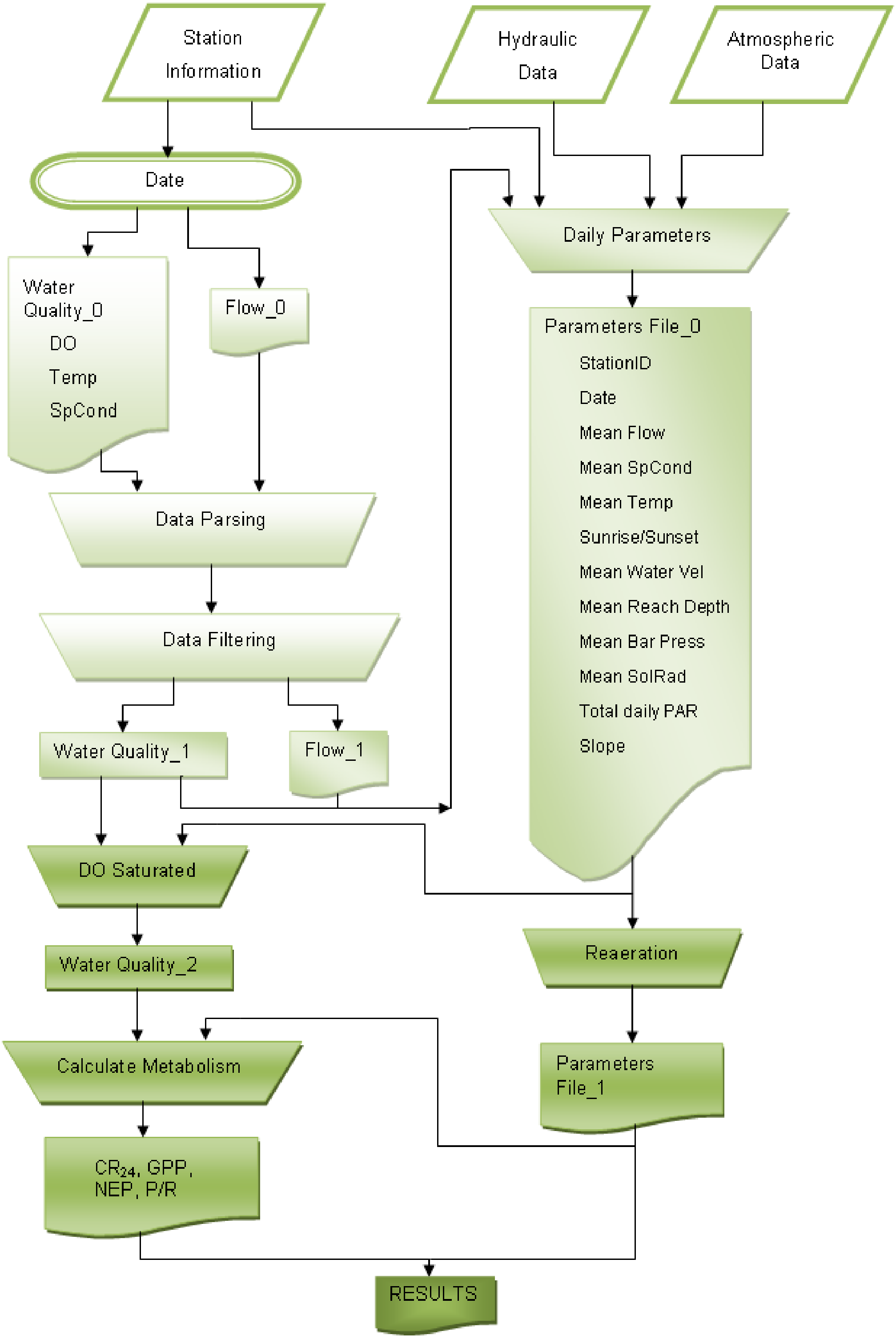

Figure A. Workflow for the calculation of whole-stream metabolism.

```
################# 2013 Main function of the Metabolism workflow ################

# 1. Setting up working directory and defining destination paths

setwd("E:/Appendix_Scripts_Metabolism")
DL_DESTINATION = "E:/Appendix_Scripts_Metabolism/"
PLOT_DESTINATION = "E:/Appendix_Scripts_Metabolism/"

# 2. Installing required packages package
  install.packages('chron', repos="http://cran.r-project.org")
  install.packages('zoo', repos="http://cran.r-project.org")
  install.packages('maptools', repos="http://cran.r-project.org")
  require(chron)
  require(zoo)
  require(maptools)
  require(tcltk)

# 3. Running R scripts: data.down, plot.filter1, check.normality, filter2.outlier,
     # daily.param1, doxy.cs, reaeration.empirical,
     # metabolism.empirical.uncertainty
     # http://127.0.0.1:10494/library/base/html/source.html
  sourceDir <- function(path, trace = TRUE, ...) {
    for (nm in list.files(path, pattern = "\\.[RrSsQq]$")) {
      if(trace) cat(nm,":")
        source(file.path(path, nm), ...)
      if(trace) cat("\n")
    }
  }
  wd = paste(getwd(), "/Rscripts", sep = "")
  sourceDir(wd)

# 4. Reading weather station data
  # KMAE_Weather_final.csv (for SMN and SJB) or  KFAT_Weather_final.csv (for GRF)
  # Required fields are:
  fileName<- tclvalue(tkgetOpenFile())
  ws<- read.csv(file=fileName, header=TRUE)
  # CIMIS-105_daily.csv(for GRF) or CIMIS-92_daily.csv (for SMN and SJB)
  fileName<- tclvalue(tkgetOpenFile())
  SolarRad<- read.csv(file=fileName, header=TRUE)


# 5. creating the headers of the results table
  type_label = c("Date", "Flow", "FlowPoints", "SpCon", "SpConPoints", "Vel", "dV",
            "depth", "dH", "slope", "BarPress", "SolarRad", "MeanTemp",
            "tempPoints", "doxyPoints",
            "SunsetPrev", "Sunrise", "Sunset",
            "K2.edm", "dK2edm", "CR24", "d.CR24", "PhotoResp", "d.Photo.Resp",
            "dcdtday", "d.dcdtday", "GPP", "d.GPP",  "NDM", "d.NDM",  "P/R",
"d.P/R")
  units_label = c("%m/%d/%Y", "m3/s", "%", "uS/cm", "%", "m/s", "m/s",
            "m", "m", "-", "mmHg", "W_sqm", "degC", "%", "%",
            "%Y-%m-%d %H:%M:%S", "%Y-%m-%d %H:%M:%S", "%Y-%m-%d %H:%M:%S",
            "1/min", "1/min", "g/m2-day", "g/m2-day", "g/m2", "g/m2",
            "g/m2", "g/m2", "g/m2-day", "g/m2-day", "g/m2-day", "g/m2-day", "-", "-
")
  new_headers = rbind(type_label, units_label)
```

```
  write.table(new_headers, file = "MetResults_GRF.txt", append = T, quote = F,
              sep = "\t", na = "NA", dec = ".", row.names = F, col.names = F )

################################################################################
##############################  START HERE!  ###################################
# Removing everything but the following objects
  rm(list=setdiff(ls(), c("data.down", "plot.filter1", "filter2.outlier",
  "check.normality", "daily.param1", "doxy.cs", "reaeration.empirical",
  "metabolism.empirical.uncertainty", "ws", "SolarRad", "sourceDir", "wd",
  "new_headers", "DL_DESTINATION", "PLOT_DESTINATION")))
################################################################################
###########################   MODIFY HERE!! ####################################
station = "GRF"              # Enter Station ID
station.flow = "GRF"         # Flow data used from FFB instead of SMN
DATE = "10/06/2011"            # Enter date of interest in format "mm/dd/yyyy"
DATE1 = "10-06-2011"
################################################################################
################################################################################
day = chron(dates = DATE); day
day.start = day - 1; day.start
day.end = day + 1; day.end
################################################################################
# Downloading data from CDEC repository - all in PST time zone (-8 hours)
# INPUTS: station, sampling rate, sensor ID, current day, previous day,
# following day, lower limit, upper limit (for first filetering round)
flow = data.down(station.flow, "E", "20", DATE1, day.start, day.end, 0.1, 50 )
#cms
doxy = data.down(station, "E", "61", DATE1, day.start, day.end, 6, 18.5) #mg/l
temp = data.down(station, "E", "25", DATE1, day.start, day.end, -6.5, 32) #C
spcon = data.down(station, "E", "100", DATE1, day.start, day.end, 20, 65) #uS/cm
################################################################################
# plotting 4 datasets in 1
start.date = as.character(day.start);start.date
end.date = as.character(day); end.date
  rows<- 4
  cols<- 1
  op<- par(mfrow=c(rows, cols))
  plot.filter1("flow", day.start, day.end)
  plot.filter1("doxy", day.start, day.end)
  plot.filter1("temp", day.start, day.end)
  plot.filter1("spcon", day.start, day.end)
  par(op)
  title(main = paste(station, " data from ", start.date, " to ", end.date, sep =
""))
plot_file = paste(DATE1, "_", station, sep = "")
f.name = paste(PLOT_DESTINATION, plot_file, sep = "")
savePlot(filename = f.name, type = "png")
################################################################################
# Running the function "filter2.outlier" for second filtering round
flow1 = filter2.outlier("flow")
#  cat("points number is=", length(flow1$ord.y))
doxy1 = filter2.outlier("doxy")
#  cat("points number is=", length(doxy1$ord.y))
temp1 = filter2.outlier("temp")
#  cat("points number is=", length(temp1$ord.y))
spcon1 = filter2.outlier("spcon")
```

```
#  cat("points number is=", length(spcon1$ord.y))
################################################################################
# Creating a new table with timestamps, oxygen and temperature event data (table2)
table1 = merge(doxy1, temp1, by = "ab.x", all.x = FALSE, all.y = FALSE)
table2 = subset(table1, select = c("ab.x", "ord.y.x", "ord.y.y"))
colnames(table2) = c("DTseconds", "doxy2", "temp2")
################################################################################
# Running the function "daily.param1" to obtain the daily parameters - Part1:
# Flow, velocity, depth, slope, barpress, sunsetprevious, sunrise, sunset.
diel.parameters = list()
diel.parameters = daily.param1(station, DATE, day.start, flow1, doxy1,
                                temp1, spcon1, ws, SolarRad)
################################################################################
# Calculating the saturated concentration of oxygen for each time stamp
cs = doxy.cs(table2, diel.parameters[["spcon.uScm"]], diel.parameters[["bp.mmHg"]])
table2$temp.K = cs$temp.K
table2$do.sat = cs$do.sat.corr
################################################################################
# Calculating K2 through the Energy Dissipation Model (empirical)
# K2.edm at temperature of 20 Celcius in units of min^-1
edm = reaeration.empirical(diel.parameters[["flow.cms"]],
       diel.parameters[["vel.mps"]],diel.parameters[["dV"]],
       diel.parameters[["slope"]])
diel.parameters$K2.edm = edm[[1]]
diel.parameters$d.K2edm = edm[[2]]#uncertainty
################################################################################
# The actual metabolism calculations
metabolism = metabolism.empirical.uncertainty(table2, diel.parameters )

diel.parameters$CR24 = metabolism[[1,1]]
diel.parameters$d.CR24 = metabolism[[1,2]]
diel.parameters$photo.resp = metabolism[[1,3]]
diel.parameters$d.photo.resp = metabolism[[1,4]]
diel.parameters$dcdtarea.daytime = metabolism[[1,5]]
diel.parameters$d.dcdtarea.daytime = metabolism[[1,6]]
diel.parameters$GPP = metabolism[[1,7]]
diel.parameters$d.GPP = metabolism[[1,8]]
diel.parameters$NDM = metabolism[[1,9]]
diel.parameters$d.NDM = metabolism[[1,10]]
diel.parameters$P.R = metabolism[[1,11]]
diel.parameters$d.P.R = metabolism[[1,12]]
diel.parameters

write.table(diel.parameters, file = "MetResults_GRF.txt", append = T, quote = F,
            sep = "\t", na = "NA", dec = ".", row.names = F, col.names = F )
#############################################################################END
```

```
############################    data.down    ####################################
# Function to download data from CDEC and clean data on a first level
# based on predetermined environmental ranges.
#################################################################"data.down" STARTS
data.down<- function(STATION_ID, DUR_CODE, SENSOR_NUM, DATE1, START_DATE,
                      END_DATE, low.lim, up.lim){
A = list()
# some plotting parameters
if(SENSOR_NUM == 20) {y_type = "flow"; y_units = "cfs"}
if(SENSOR_NUM == 61) {y_type = "dissolved oxygen"; y_units = "mg/l"}
if(SENSOR_NUM == 25) {y_type = "water temperature"; y_units = "degrees F"}
if(SENSOR_NUM == 146) {y_type = "water temperature"; y_units = "degrees C"}
if(SENSOR_NUM == 100){y_type = "EC"; y_units = "uS/cm"}

# putting together url of cdec file
URL_PART1 = "http://cdec.water.ca.gov/cgi-progs/queryCSV?station_id="
URL_PART2 = "&sensor_num="
URL_PART3 = "&dur_code="
URL_PART4 = "&start_date="
URL_PART4a = "+01%3A00" #because the -1 hour shift of the PST time
URL_PART5 = "&end_date="
URL_PART5a = "+00%3A59" #because the -1 hour shift of the PST time
URL_PART6 = "&data_wish=View+CSV+Data"

user_url = paste( URL_PART1, STATION_ID,
                  URL_PART2, SENSOR_NUM,
                  URL_PART3, DUR_CODE,
                  URL_PART4, START_DATE,
                  URL_PART4a,
                  URL_PART5, END_DATE,
                  URL_PART5a,
                  URL_PART6,
                  sep = "")

dest_file = paste(STATION_ID, "_", DATE1, "_", y_type, ".csv", sep = "")
dest = paste(DL_DESTINATION, dest_file, sep = "")

# downloading the data from CDEC website
url_open = url(user_url, open = "r")
url_dat = read.table(url_open, fill = T, sep = ",", colClasses = "character")
close(url_open)

# removing headers in rows 1 and 2
url_dat = url_dat[3:nrow(url_dat), ]

# Combining date and time from CDEC file
url_date = url_dat[, 1]
url_time = url_dat[, 2]
url_dateTimeString = paste(url_date, url_time, sep = "_")
url_dateTime = strptime(url_dateTimeString, format = "%Y%m%d_%H%M")

#Re-assigning variables
x = url_dateTime
y = as.numeric(url_dat[,3])

if(y_units == "ft")         {y = as.numeric(y) * 0.3048; y_units = "m"}
```

```
if(y_units == "cfs")        {y = as.numeric(y) * 0.0283168466; y_units = "cms"}
if(y_units == "degrees F")  {y = (as.numeric(y) - 32) * 5 / 9; y_units = "degC"}

POSIXlt_dateTime = as.POSIXlt(x)
string_dateTime = strftime(POSIXlt_dateTime, "%Y-%m-%d %H:%M:%S")

# Removing outliers and generating cleaner file
id_new = c(which(y > low.lim & y < up.lim))
y_new<- y[id_new]
x_new<- string_dateTime[id_new]

type_label = c("date_time", y_type)
units_label = c("%Y-%m-%d_%H:%M:%S", y_units)

new_headers = rbind(type_label, units_label)
new_dat2 = cbind(x_new, y_new)

write.table(new_headers, dest, sep = ",", quote = F,
            row.names = F, col.names = F)
write.table(new_dat2, dest, append = T, sep = ",", quote = F,
            row.names = F, col.names = F)

max_y = max(as.numeric(new_dat2[, 2]))
avg_y = mean(as.numeric(new_dat2[, 2]))
min_y = min(as.numeric(new_dat2[, 2]))
npoints = length(new_dat2[,1])
stats = c(max_y, avg_y, min_y, npoints)

#filling the list
A[[1]] = new_dat2
A[[2]] = stats
A
}
################################################################ data.down ENDS
```

```
##############################  plot.filter1   ################################
# Function to plot any of the downloaded water quality data from CDEC
############################################################ plot.filter  STARTS
plot.filter1<- function(variable, day.start, day.end){ #flow, doxy, temp, spcon

# plotting parameters
if(variable == "flow") {sensor = flow; color = "black"; label.Y = "Flow (m3/s)"}
if(variable == "doxy") {sensor = doxy; color = "blue"; label.Y = "DO (mg/l)"}
if(variable == "temp") {sensor = temp; color = "red";
                        label.Y = "Temperature (C)"}
if(variable == "spcon") {sensor = spcon; color = "green";
                        label.Y = "Sp Conductiviy (uS/cm)"}

X = sensor[[1]][1:nrow(sensor[[1]]),1]
ab.X<- strptime(X, "%Y-%m-%d %H:%M:%S", tz="Pacific/Pitcairn")
ord.Y = sensor[[1]][1:nrow(sensor[[1]]),2]
lowlim = min(sensor[[2]][1:3])
uplim = max(sensor[[2]][1:3])
#start.date = day.start
#end.date = day.end

start.date = min(ab.X)
end.date = max(ab.X)

  plot(ab.X, ord.Y, type='p', col=color, xaxt="n", ylim=c(lowlim,uplim),
      ylab=label.Y, cex.lab=1.2, cex.axis=1.0, cex.main=2.0)
  #label the x axis by days
  axis.POSIXct(1, at=seq(start.date, end.date, by="day"), format="%d")
  horizontal = seq(lowlim, uplim, by = ((uplim - lowlim)/4))
  abline(h = horizontal, col = 1, lty = 3)
}
############################################################## plot.filter1 ENDS
```

```
############################# check.normality    #################################
# Script to test for normality - back of the envelope
##################################################################################
# Author: SV
# Input: table1 (within filter2.outlier function)
# Output: TRUE or FALSE for the test of normality (TRUE = normal distribution)
# Comments: Works within the filter2.outlier function
# checks whether or not values above or below 3*SD exist within the distribution
# if TRUE then, stop the filtering process.
# if FALSE, continue filtering.
########################################################"check.normality" STARTS

check.normality = function(table1){
mean.yactual = mean(abs(table1$y.actual))
sd.yactual = sd(abs(table1$y.actual))
AA = 3*sd.yactual
min.range = mean.yactual - AA
max.range = mean.yactual + AA
check1 = which(abs(table1$y.actual)< min.range)
check2 = which(abs(table1$y.actual)> max.range)

if (length(check1) == 0 & length(check2) == 0){
    check.norm = "TRUE"} else
    check.norm = "FALSE"

check.norm
}

##########################################################"check.normality" ENDS
```

```
###############################   filter2.outlier   ############################
# Function to filter second round
######################################################### filter2.outlier STARTS
#variable = flow, doxy, temp, spcon
filter2.outlier<- function(variable){

# the available data sets
  if(variable == "flow") {sensor = flow}
  if(variable == "doxy") {sensor = doxy}
  if(variable == "temp") {sensor = temp}
  if(variable == "spcon") {sensor = spcon}

  x.0 = sensor[[1]][1:nrow(sensor[[1]]),1]
  x.1 = strptime(x.0, "%Y-%m-%d %H:%M:%S", tz="Pacific/Pitcairn")
# ab.x is time in seconds
  ab.x = as.numeric(unclass(as.POSIXct(x.1)))

# ord.y is the response variable
  ord.y = as.numeric(sensor[[1]][1:nrow(sensor[[1]]),2])

  table1 = cbind(ab.x, ord.y)
  colnames(table1) = c("ab.x", "ord.y") # at this point table1 is a matrix
  table1 = as.data.frame(table1); #fix(table1)

# calculate differences for each time stamp
  table1$x.diff[1] = 0
  table1$y.diff[1] = 0
  table1$y.actual[1] = 0
  for (i in 1:((length(table1$ab.x))-1)){
    table1$x.diff[i+1] = table1$ab.x[i+1] - table1$ab.x[i]
    table1$y.diff[i+1] = table1$ord.y[i+1] - table1$ord.y[i]
    table1$y.actual[i+1] = table1$y.diff[i+1] / (table1$x.diff[i+1]/900)
  }

check.norm = check.normality(table1)
  if (check.norm == TRUE) {
    table2 = table1} else {# if true, stop filtering

    # histogram to learn about the data
      a = hist(abs(table1$y.actual), plot = F) #"histogram" class
      # x axis of the histogram
      values = as.vector(a[[1]])
      # y axis of the histogram "frequency"
      counts = as.vector(a[[2]])
      # the total number of data points
      m = sum(counts)
      #frequencies less than 2.5% of total counts
      b = which((counts < (0.025*m)) & (counts != 0))

    if (length(b) == 0){
    table2 = table1} else {#nothing to clean

        # vector of values with frequencies less than 2.5% of total counts
        off.values = values[b]
        # now to erase the outliers based on the off.values
        table1$check.off[1] = 0
```

```r
        for (i in 1:((length(table1$ab.x))-1)){
          if (abs(table1$y.actual[i]) >  min(off.values)){
              if (abs(table1$y.actual[i+1]) > min(off.values)){
                  table1$check.off[i] = 1} else
                  table1$check.off[i] = 0
              }
        }

        ff = unique(table1$check.off)
        if (length(ff) == 1) {table2 = table1}
        if (length(ff) == 2) {
        f = which(table1$check.off == 1)#rows with identified outliers
        table2 = table1[-f,]
        }
     }
  }

# saving table
  dest_file = paste(station, "_", DATE1, "_", variable, "_",
                    "filter2.csv", sep = "")
  dest = paste(DL_DESTINATION, dest_file, sep = "")
  write.table(table2, dest, sep = ",", row.names = F, col.names = T)


# plotting new filtered data
  ab.X = as.POSIXlt(table2$ab.x, origin="1970-01-01", tz="Pacific/Pitcairn")
  ord.Y = table2$ord.y
  lowlim = min(table2$ord.y)
  uplim = max(table2$ord.y)
  start.date = min(ab.X)
  end.date = max(ab.X)
    plot(ab.X, ord.Y, type='p', col= "black", xaxt="n", ylim=c(lowlim,uplim),
        ylab=variable, cex.lab=1.2, cex.axis=1.0, cex.main=2.0)
    title(main = paste(station, "_", DATE1, "_", variable, sep = ""))
    #label the x axis by days
    axis.POSIXct(1, at=seq(start.date, end.date, by="day"), format="%d")
    horizontal = ((uplim + lowlim)/2)
    abline(h = horizontal, col = 1, lty = 3)
table2
}
############################################################ filter2.outlier ENDS
```

```
######################### daily.param1 #########################################
# Script to create the daily parameters
################################################################################
# Author: SV
# Input: flow from "flow1" (filter2.oulier)
#        barometric pressure "ws" from weather station data
#        Lat, long, and slope as attributes of the stations
#        velocity and depth regression equations (as attributes of the stations)
# Output: date, mean.flow, mean.velocity, mean.depth, slope, mean.spconductivity
#         mean.barPress, sunrise and sunset information
# Comments: Regression parameters for velocity and depth need to be predefined

##########################################################"daily.param1" STARTS

daily.param1 = function(station, DATE, day.start, flow1, doxy1,
                        temp1, spcon1, ws, SolarRad){

  if(station == "FWQ") {(num.points = 24)}
  if(station == "GRF") {(num.points = 96)}
  if(station == "SMN") {(num.points = 96)}

  ##############   PART A - MEAN FLOW    ########################
  day.param<- strptime(DATE, "%m/%d/%Y", tz="Pacific/Pitcairn")
  DTseconds<-  as.numeric(unclass(as.POSIXct(day.param)))
  # anything larger than this number corresponds to the date of analysis
  flow2 = subset(flow1, flow1$ab.x >= DTseconds, c(ab.x,ord.y) )
  mean.flow = mean(flow2$ord.y) # in m3/s - cms
  #% of points available for the day of analysis
  p.flow = (length(flow2$ord.y)/num.points)*100

  ##############   PART B - MEAN SPCOND    ########################

  spcon2 = subset(spcon1, spcon1$ab.x >= DTseconds, c(ab.x,ord.y) )
  mean.spcon = mean(spcon2$ord.y) # in uS/cm
  #% of points available for the day of analysis
  p.spcon = (length(spcon2$ord.y)/num.points)*100

  ############   PART C - ASSIGNING SLOPES    ######################

  if(station == "FWQ") {if (mean.flow <= 5){slope = 0.000005} else if
                        (mean.flow >= 30){slope = 0.0005}
                         else (slope = 0.00005)}
  if(station == "GRF") {if (mean.flow < 5){slope = 0.00005} else if
                     (mean.flow >= 5 && mean.flow < 20){slope = 0.0002} else if
                     (mean.flow >= 20 && mean.flow < 30){slope = 0.0004} else if
                     (mean.flow >= 30 && mean.flow < 80){slope = 0.0007} else if
                     (mean.flow >= 80 && mean.flow < 150){slope = 0.0006} else
                     (slope = 0.0004)} #based on model of the river
  if(station == "SMN") {if (mean.flow <= 5){slope = 0.000001} else if
                        (mean.flow >= 30){slope = 0.0001}
                         else (slope = 0.00001)}
```

```
###########   PART D - ASSIGNING SPECIFIC PARAMETERS   ##############

if(station == "FWQ") {lat = 36.999300; long = -119.706100;
                      V.a = -3e-5; V.b = 1.13e-2; V.c = 1.477e-1; V.ci = 0.1494;
                      H.a = 0; H.b = 3.198e-1; H.c = 2.188e-1; H.ci = 0.2211;
                      ws.column = 11} #column number of the ws file
if(station == "GRF") {lat = 36.798000; long = -120.160000;
                      V.a = 0; V.b = 2.5e-3; V.c = 5.399e-1; V.ci = 0.2588;
                      H.a = 0; H.b = 3.837e-1; H.c = 6.58e-2; H.ci = 0.5000;
                      ws.column = 12} #column number of the ws file
if(station == "SMN") {lat = 37.347214; long = -120.976181;
                  V.a = -1.415e-4; V.b = 1.55e-2; V.c = 1.997e-1; V.ci = 0.1783;
                  H.a = -4e-4; H.b = 5.53e-2; H.c = 3.184e-1; H.ci = 0.4857;
                  ws.column = 11} #column number of the ws file

  ##############   PART E - Average velocity and depth    ######################
# velocity in m/s
# depth in m

if(station == "FWQ")   {vel.mps = (V.a * mean.flow^2)+ (V.b * mean.flow) + V.c;
                        d.V = V.ci; #error in m/s (95%)
                        depth.m = (H.b * log(mean.flow)) + H.c;
                        d.H = H.ci} #error in m/s (95%)}
if(station == "GRF")  {vel.mps = (V.b * mean.flow) + V.c;
                        d.V = V.ci; #error in m/s (95%)
                        depth.m = (H.b * log(mean.flow)) + H.c;
                        d.H = H.ci} #error in m/s (95%)}
if(station == "SMN")  {vel.mps = (V.a * mean.flow^2)+ (V.b * mean.flow) + V.c;
                        d.V = V.ci; #error in m/s (95%)
                        depth.m = (H.a * mean.flow^2)+ (H.b * mean.flow) + H.c;
                        d.H = H.ci} #error in m/s (95%)}

  ##############   PART F - Sunrise and sunset    ########################
  # function taken from StreamMetabolism (Stephen A Sefick Jr.)

  sunrise.set.1 = function (lat, long, date.1,
                             timezone = "Pacific/Pitcairn", num.days = 1)
  {
    lat.long <- matrix(c(long, lat), nrow = 1)
    date.2<- strptime(date.1, "%m/%d/%y", tz = timezone)
    day.2 <- as.POSIXct(date.2, tz = timezone)
    sequence <- seq(from = day.2, length.out = num.days, by = "days")
    sunrise <- sunriset(lat.long, sequence, direction = "sunrise",
        POSIXct = TRUE)
    sunset <- sunriset(lat.long, sequence, direction = "sunset",
        POSIXct = TRUE)
    ss <- data.frame(sunrise, sunset)
    ss <- ss[, -c(1, 3)]
    colnames(ss) <- c("sunrise", "sunset")
    return(ss)
  }
    sunriset.1<- sunrise.set.1(lat, long, day.start,
                                 timezone = "Pacific/Pitcairn", num.days = 2)
    sun.rise.prev = sunriset.1[[1]][[1]]
    sun.rise      = sunriset.1[[1]][[2]]
```

```
    sun.set.prev  = sunriset.1[[2]][[1]]
    sun.set       = sunriset.1[[2]][[2]]

  ##############   PART G - Barometric pressure    ########################

  ws$DATE = substr(ws$dtime.pst, 1, 10)
  id.DATE = grep(DATE, ws$DATE, ignore.case = FALSE, value = FALSE,
               fixed = TRUE, useBytes = FALSE)
  ws.bp = as.list(ws[ws.column])
  mean.bp = mean(ws.bp[[1]][id.DATE])

  ##############   PART H - Solar radiation    ########################

  id.DATE1 = grep(DATE, SolarRad$Date, ignore.case = FALSE, value = FALSE,
               fixed = TRUE, useBytes = FALSE)
  mean.SolarRad = SolarRad$SolRad_W.sq.m[[id.DATE1]]

  ##############   PART I - Temperature #####################

  temp2 = subset(temp1, temp1$ab.x >= DTseconds, c(ab.x,ord.y) )
  mean.temp = mean(temp2$ord.y)
  #% of points available for the day of analysis
  p.temp = (length(temp2$ord.y)/num.points)*100

  ##############   PART J - Number of DO points #####################

  doxy2 = subset(doxy1, doxy1$ab.x >= DTseconds, c(ab.x,ord.y) )
  #% of points available for the day of analysis
  p.doxy = (length(doxy2$ord.y)/num.points)*100

  ##############   PART K - Putting results together    ########################
  diel.param = list()
  diel.param$Date = DATE
  diel.param$flow.cms = mean.flow
  diel.param$p.flow = p.flow
  diel.param$spcon.uScm = mean.spcon
  diel.param$p.spcon = p.spcon
  diel.param$vel.mps = vel.mps
  diel.param$dV = d.V
  diel.param$depth.m = depth.m
  diel.param$dH = d.H
  diel.param$slope = slope
  diel.param$bp.mmHg = mean.bp
  diel.param$solRad.Wpsqm = mean.SolarRad
  diel.param$temp = mean.temp
  diel.param$p.temp = p.temp
  diel.param$p.DO = p.doxy
  diel.param$sunset.prev = sun.set.prev
  diel.param$sunrise = sun.rise
  diel.param$sunset = sun.set

diel.param

}
##############################################################"daily.param1" ENDS
```

```
################################## doxy.cs  ######################################
# Calculating saturated concentration of DO
##################################################################################
# Author: SV
# Input: table2["DTseconds", "doxy2", "temp2"],
# Output: cs table with DO corrected saturated concentrations
# Comments: uses the Benson and Krause (1980) method
################################################################### doxy.cs STARTS

doxy.cs = function(table2, spcon.mean, bp.mean){
  # to obtain salinity in 0/00
    sal = (5.572E-4 * spcon.mean) + (2.02E-9 * spcon.mean^2)
  #barometric pressure in atmospheres
    bp.atm = bp.mean / 760

  cs =  table2

  # salinity correction factor
    cs$temp.K = cs$temp2 + 273.15
    cs$Fs = exp(-sal*(0.017674-(10.754/cs$temp.K)+(2140.7/(cs$temp.K^2))))

  # pressure correction factor
    cs$teta = 0.000975 - (1.426E-5 * cs$temp2) + (6.436E-8 * cs$temp2^2)
    cs$u = exp(11.8571 - (3840.70/cs$temp.K) - (216961/cs$temp.K^2))
    cs$Fp = ((bp.atm-cs$u)*(1-(cs$teta*bp.atm)))/((1-cs$u)*(1-cs$teta))

  # DOsat
cs$do.sat = exp(-139.34411 + (1.575701E5/cs$temp.K) - (6.642308E7/(cs$temp.K^2))
            + (1.243800E10/(cs$temp.K^3)) - (8.621949E11/(cs$temp.K^4)) )

cs$do.sat.corr = cs$do.sat * cs$Fs * cs$Fp

cs

}
##################################################################### doxy.cs ENDS
```

```
###################### reaeration.empirical #####################################
# Calculating reaeration through Energy Dissipation Model (EDM)
################################################################################
# Author: SV
# Input: diel.parameters
# Output: K2.edm(20C) and units min^-1
#################################################### reaeration.empirical STARTS

reaeration.empirical = function(flow.mean, velocity.mean, dV, slope.mean){
  # looking for the right K' parameter to use according to flow
  if (flow.mean >= 0.028 && flow.mean < 0.28) {
  Kprime = 28300} else {
  if (flow.mean > 0.28 && flow.mean <= 0.56) {
  Kprime = 21300} else {Kprime = 15300}
  }
  edm = list()
  # K2(at temperature of 20 Celcius in units of min^-1)
  edm[["K2"]] = (velocity.mean * slope.mean * Kprime) / (24*60)
  edm[["dK2"]] = dV*(slope.mean*Kprime/1440)
  edm
}
############################################################################ ENDS
```

```
################### metabolism.empirical.uncertainty ###########################
# Script to obtain metabolism estimates
################################################################################
# Author: SV
# Input: table2; diel.parameters
# Output: Metabolism Estimates - K2 from empirical methods
# Comment: Respiration rates are calculated from an average of the night data
########################################## metabolism.empirical.uncertainty STARTS

metabolism.empirical.uncertainty = function(table2, diel.parameters ){

table3 = table2

# Obtaining a temperature-corrected K2 for each time interval
  table3$interval[1] = 15 #interval of 15 min by default of this dataset
  table3$interval[2:length(table3$DTseconds)]= (diff(table3$DTseconds))/60

  table3$K2.int = diel.parameters$K2.edm * table3$interval
  table3$dK2.int = diel.parameters$d.K2edm * table3$interval #uncertainty

  table3$K2.temp = table3$K2.int*1.024^(table3$temp2 - 20) #interval^-1
  table3$dK2.temp = table3$dK2.int *  1.024^(table3$temp2 - 20) #uncertainty

# raw dC/dt
  table3$dc.dt[1] = 0
  table3$dc.dt[2:length(table3$DTseconds)]= diff(table3$doxy2) #g/m3 per interval

# Correcting for reaeration
# If the number is positive, there is surplus of DO.
# If negative, there is deficit of DO in the water.
  table3$def.sur = table3$doxy2 - table3$do.sat # mg/l or g/m3
  table3$exchange = table3$def.sur * table3$K2.temp # g/m3-per interval
  table3$d.exch = abs(table3$dK2.temp * table3$def.sur) #uncertainty

# mean exchange between two consecutive time intervals
#(negative means oxygen into the water)
  table3$exchange.ave[1] = 0; table3$d.exch.ave[1] = 0
  for (i in 1:(length(table3$DTseconds)-1)){
    #g/m3-per interval
    table3$exchange.ave[i+1]= mean(c(table3$exchange[i],table3$exchange[i+1]))
    #uncertainty
    table3$d.exch.ave[i+1]= sqrt((table3$d.exch[i]/2)^2 + (table3$d.exch[i+1]/2)^2)
  }

#Reaeration-corrected rates of change of DO per unit volume and area:
  table3$dcdt.vol = table3$dc.dt + table3$exchange.ave #g/m3-per interval
  table3$d.dcdt.vol = table3$d.exch.ave #uncertainty
  #g/m2-per interval
  table3$dcdt.area = table3$dcdt.vol * diel.parameters$depth.m
  #uncertainty
  table3$d.dcdt.area = sqrt((table3$d.dcdt.vol * diel.parameters$depth.m)^2 +
                             (diel.parameters$dH * table3$dcdt.vol)^2)
```

```r
# day of analysis in DTseconds
  day.3<- strptime(day, "%m/%d/%y", tz = "Pacific/Pitcairn")#; day.3
  # day in seconds
  date.3 = as.numeric(unclass(as.POSIXct(day.3)))

# subset of table 3 with only data for day of analysis
  table4 = subset(table3, table3$DTseconds >= date.3)

# Calculating temp-corrected respiration rates
  sunrise = as.numeric(unclass(as.POSIXct(diel.parameters$sunrise)))
  sunset = as.numeric(unclass(as.POSIXct(diel.parameters$sunset)))
  # subset of the night-time reaeration-corrected rate of change
    night.id = c(which(table4$DTseconds < sunrise),
                 which(table4$DTseconds >= sunset))
    # remove the rates that have intervals > 15 min to get the average
      sub.night = table4[night.id, ]
      intDiff.15 = which(sub.night$interval != 15)
      if (length(intDiff.15) == 0){
        sub.night.1 = sub.night
        } else {
          sub.night.1 = subset(sub.night[-intDiff.15,])
          }

    # the mean respiration rate for the night time
      CR.night = mean(sub.night.1$dcdt.area)
    # now the uncertainty
      partial = vector()
      for (i in 1:length(sub.night.1$DTseconds)){
        partial[i] = ((1/length(sub.night.1$DTseconds))*
                      sub.night.1$d.dcdt.area[i])^2
      }
      d.CR.night = sqrt(sum(partial))

    # the mean temperature of the night time
      temp.night = mean(sub.night.1$temp2)

  # correcting CR.night for daily temperature variations
    table4$CR.temp = CR.night*1.072^(table4$temp2 - temp.night)
    #uncertainty
    table4$d.CR.temp = abs(d.CR.night * 1.072^(table4$temp2 - temp.night))

# The results I'm looking for:
# ==> Calculating CR24: the sum of the temp-corrected rates of CR (all day)
      CR24 = sum(table4$CR.temp) #g/m2-day
      #uncertainty
      d.CR24 = sqrt(sum((table4$d.CR.temp)^2))

# subset of table4 corresponding to daytime (between sunrise and sunset)
  day.id = which(table4$DTseconds >= sunrise & table4$DTseconds < sunset)

# total photoperiod respiration rate (g/m2-photoperiod)
  photo.resp = sum(table4$CR.temp[day.id])
  #uncertainty
  d.photo.resp = sqrt(sum((table4$d.CR.temp[day.id])^2))
```

```
# sum of the photoperiod rates of DO change (g/m2-photoperiod)
  dcdtarea.daytime = sum(table4$dcdt.area[day.id])
  #uncertainty
  d.dcdtarea.daytime = sqrt(sum((table4$d.dcdt.area[day.id])^2))

# ==> Calculating GPP in g/m2-day
      GPP = dcdtarea.daytime + abs(photo.resp)
      #uncertainty
      d.GPP = sqrt((d.dcdtarea.daytime)^2 + (d.photo.resp)^2)

# ==> Calculating NDM in g/m2-day
      NDM = GPP + CR24
      #uncertainty
      d.NDM = sqrt((d.GPP)^2 + (d.CR24)^2)

# ==> Calculating the P/R ratio
      P.R = GPP / abs(CR24)
      #uncertainty
      d.P.R = sqrt((d.GPP / CR24)^2 + (d.CR24*(GPP/(CR24)^2))^2)

# ==> Putting everything together in a matrix:
      metabolism = cbind(CR24, d.CR24, photo.resp, d.photo.resp,
      dcdtarea.daytime, d.dcdtarea.daytime, GPP, d.GPP, NDM, d.NDM, P.R, d.P.R)

metabolism

}
########################################################################## ENDS
```

DateTime	temp.c	RelHum	sknt	drct	qflg	alti.mb	dwp.c	alti.mmhg	bp.sjb	bp.smn	bp.grf	dtime.pst
10-1-2011 0:53 GMT	31.1	34	5.1	300	OK	1010.16	13.3	757.68	753.44	756.19	753.44	09/30/11 04:53 PM
10-1-2011 1:53 GMT	28.3	38	4.6	280	OK	1010.5	12.8	757.94	753.69	756.44	753.69	09/30/11 05:53 PM
10-1-2011 2:53 GMT	26.7	44	2.1	290	OK	1010.84	13.3	758.19	753.95	756.7	753.95	09/30/11 06:53 PM
10-1-2011 3:53 GMT	25.6	47	2.6	330	OK	1011.51	13.3	758.7	754.45	757.2	754.45	09/30/11 07:53 PM
10-1-2011 4:53 GMT	23.9	52	6.2	310	OK	1011.85	13.3	758.95	754.7	757.45	754.7	09/30/11 08:53 PM
10-1-2011 5:53 GMT	21.7	57	4.6	310	OK	1012.19	12.8	759.21	754.96	757.71	754.96	09/30/11 09:53 PM
10-1-2011 6:53 GMT	20.6	61	3.6	320	OK	1012.53	12.8	759.46	755.21	757.96	755.21	09/30/11 10:53 PM
10-1-2011 7:53 GMT	19.4	66	4.6	320	OK	1012.87	12.8	759.72	755.47	758.22	755.47	09/30/11 11:53 PM
10-1-2011 8:53 GMT	18.3	70	3.1	320	OK	1013.21	12.8	759.97	755.72	758.47	755.72	10/01/11 12:53 AM
10-1-2011 9:53 GMT	17.8	70	3.6	320	OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/01/11 01:53 AM
10-1-2011 10:53 GMT	17.2	70	3.6	320	OK	1014.22	11.7	760.73	756.48	759.23	756.48	10/01/11 02:53 AM
10-1-2011 11:53 GMT	16.7	72	4.1	320	OK	1014.56	11.7	760.98	756.74	759.49	756.74	10/01/11 03:53 AM
10-1-2011 12:53 GMT	15.6	78	4.6	310	OK	1015.24	11.7	761.49	757.25	760	757.25	10/01/11 04:53 AM
10-1-2011 13:53 GMT	15.6	78	4.1	310	OK	1015.92	11.7	762	757.76	760.51	757.76	10/01/11 05:53 AM
10-1-2011 14:53 GMT	16.7	72	4.6	320	OK	1016.59	11.7	762.51	758.26	761.01	758.26	10/01/11 06:53 AM
10-1-2011 15:53 GMT	18.9	63	4.1	320	OK	1016.93	11.7	762.76	758.51	761.26	758.51	10/01/11 07:53 AM
10-1-2011 16:53 GMT	21.1	53	3.6	320	OK	1016.93	11.1	762.76	758.51	761.26	758.51	10/01/11 08:53 AM
10-1-2011 17:53 GMT	22.8	48	0		OK	1016.93	11.1	762.76	758.51	761.26	758.51	10/01/11 09:53 AM
10-1-2011 18:53 GMT	25	41	2.1	180	OK	1016.25	11	762.25	758	760.75	758	10/01/11 10:53 AM
10-1-2011 19:53 GMT	26.7	35	1.5	230	OK	1015.58	10	761.75	757.5	760.25	757.5	10/01/11 11:53 AM
10-1-2011 20:53 GMT	27.8	33	2.1		OK	1014.9	10	761.24	756.99	759.74	756.99	10/01/11 12:53 PM
10-1-2011 21:53 GMT	28.9	30	2.1		OK	1014.22	9.4	760.73	756.48	759.23	756.48	10/01/11 01:53 PM
10-1-2011 22:53 GMT	30	27	3.1	250	OK	1013.88	9	760.47	756.23	758.98	756.23	10/01/11 02:53 PM
10-1-2011 23:53 GMT	30	27	1.5		OK	1012.87	9	759.72	755.47	758.22	755.47	10/01/11 03:53 PM
10-2-2011 0:53 GMT	28.9	28	2.1	310	OK	1012.87	8.3	759.72	755.47	758.22	755.47	10/01/11 04:53 PM
10-2-2011 1:53 GMT	26.7	35	3.6	300	OK	1012.87	10	759.72	755.47	758.22	755.47	10/01/11 05:53 PM
10-2-2011 2:53 GMT	25.6	40	4.1	310	OK	1013.21	11.1	759.97	755.72	758.47	755.72	10/01/11 06:53 PM
10-2-2011 3:53 GMT	23.9	45	4.6	300	OK	1013.88	11.1	760.47	756.23	758.98	756.23	10/01/11 07:53 PM
10-2-2011 4:53 GMT	23.3	45	6.7	320	OK	1014.56	10.6	760.98	756.74	759.49	756.74	10/01/11 08:53 PM
10-2-2011 5:53 GMT	21.7	53	4.6	310	OK	1015.24	11.7	761.49	757.25	760	757.25	10/01/11 09:53 PM
10-2-2011 6:53 GMT	20.6	57	6.2	300	OK	1015.58	11.7	761.75	757.5	760.25	757.5	10/01/11 10:53 PM
10-2-2011 7:53 GMT	19.4	61	5.1	300	OK	1015.58	11.7	761.75	757.5	760.25	757.5	10/01/11 11:53 PM
10-2-2011 8:53 GMT	18.9	61	4.6	310	OK	1015.92	11.1	762	757.76	760.51	757.76	10/02/11 12:53 AM
10-2-2011 9:53 GMT	17.8	65	5.7	310	OK	1015.92	11.1	762	757.76	760.51	757.76	10/02/11 01:53 AM

10-2-2011 10:53 GMT	17.2	70	2.6	330	OK	1015.58	11.7	761.75	757.5	760.25	757.5	10/02/11 02:53 AM
10-2-2011 11:53 GMT	16.7	75	5.1	310	OK	1015.92	12.2	762	757.76	760.51	757.76	10/02/11 03:53 AM
10-2-2011 12:53 GMT	16.7	75	3.1	310	OK	1016.25	12.2	762.25	758	760.75	758	10/02/11 04:53 AM
10-2-2011 13:53 GMT	16.1	78	2.6	310	OK	1016.59	12.2	762.51	758.26	761.01	758.26	10/02/11 05:53 AM
10-2-2011 14:53 GMT	16.1	78	2.6	280	OK	1017.27	12.2	763.02	758.77	761.52	758.77	10/02/11 06:53 AM
10-2-2011 15:53 GMT	17.8	73	0		OK	1017.61	12.8	763.27	759.02	761.77	759.02	10/02/11 07:53 AM
10-2-2011 16:53 GMT	19.4	63	0		OK	1017.95	12.2	763.53	759.28	762.03	759.28	10/02/11 08:53 AM
10-2-2011 17:53 GMT	21.7	55	0		OK	1017.95	12.2	763.53	759.28	762.03	759.28	10/02/11 09:53 AM
10-2-2011 18:53 GMT	23.9	46	3.1	310	OK	1017.61	11.7	763.27	759.02	761.77	759.02	10/02/11 10:53 AM
10-2-2011 19:53 GMT	25.6	42	2.1		OK	1016.93	11.7	762.76	758.51	761.26	758.51	10/02/11 11:53 AM
10-2-2011 20:53 GMT	27.2	38	1.5		OK	1015.92	11.7	762	757.76	760.51	757.76	10/02/11 12:53 PM
10-2-2011 21:53 GMT	27.8	37	2.6	350	OK	1015.24	11.7	761.49	757.25	760	757.25	10/02/11 01:53 PM
10-2-2011 22:53 GMT	27.8	37	0		OK	1014.56	11.7	760.98	756.74	759.49	756.74	10/02/11 02:53 PM
10-2-2011 23:53 GMT	28.9	33	0		OK	1013.88	11.1	760.47	756.23	758.98	756.23	10/02/11 03:53 PM
10-3-2011 0:53 GMT	28.3	34	0		OK	1013.55	11.1	760.23	755.98	758.73	755.98	10/02/11 04:53 PM
10-3-2011 1:53 GMT	27.2	37	2.1	220	OK	1013.55	11.1	760.23	755.98	758.73	755.98	10/02/11 05:53 PM
10-3-2011 2:53 GMT	25	44	4.6	300	OK	1013.88	12	760.47	756.23	758.98	756.23	10/02/11 06:53 PM
10-3-2011 3:53 GMT	23.9	45	3.6	310	OK	1014.22	11.1	760.73	756.48	759.23	756.48	10/02/11 07:53 PM
10-3-2011 4:53 GMT	22.8	48	3.6	310	OK	1014.22	11.1	760.73	756.48	759.23	756.48	10/02/11 08:53 PM
10-3-2011 5:53 GMT	21.1	53	5.1	300	OK	1014.22	11.1	760.73	756.48	759.23	756.48	10/02/11 09:53 PM
10-3-2011 6:53 GMT	19.4	55	4.1	310	OK	1013.88	10	760.47	756.23	758.98	756.23	10/02/11 10:53 PM
10-3-2011 7:53 GMT	18.3	54	5.1	310	OK	1013.88	8.9	760.47	756.23	758.98	756.23	10/02/11 11:53 PM
10-3-2011 8:53 GMT	17.8	58	5.1	310	OK	1013.88	9.4	760.47	756.23	758.98	756.23	10/03/11 12:53 AM
10-3-2011 9:53 GMT	16.7	65	4.1	310	OK	1013.55	10	760.23	755.98	758.73	755.98	10/03/11 01:53 AM
10-3-2011 10:53 GMT	15.6	69	5.1	300	OK	1013.55	10	760.23	755.98	758.73	755.98	10/03/11 02:53 AM
10-3-2011 11:53 GMT	15	72	4.6	300	OK	1013.88	10	760.47	756.23	758.98	756.23	10/03/11 03:53 AM
10-3-2011 12:53 GMT	15	72	3.1	320	OK	1013.88	10	760.47	756.23	758.98	756.23	10/03/11 04:53 AM
10-3-2011 13:53 GMT	14.4	72	2.6	320	OK	1014.22	9.4	760.73	756.48	759.23	756.48	10/03/11 05:53 AM
10-3-2011 14:53 GMT	15	67	2.1	330	OK	1014.56	9	760.98	756.74	759.49	756.74	10/03/11 06:53 AM
10-3-2011 15:53 GMT	16.7	60	2.1	330	OK	1014.56	8.9	760.98	756.74	759.49	756.74	10/03/11 07:53 AM
10-3-2011 16:53 GMT	18.3	52	1.5		OK	1014.56	8.3	760.98	756.74	759.49	756.74	10/03/11 08:53 AM
10-3-2011 17:53 GMT	20.6	45	2.1	330	OK	1014.22	8.3	760.73	756.48	759.23	756.48	10/03/11 09:53 AM
10-3-2011 18:53 GMT	22.8	40	0		OK	1013.55	8.3	760.23	755.98	758.73	755.98	10/03/11 10:53 AM
10-3-2011 19:53 GMT	23.9	37	2.1	180	OK	1012.53	8.3	759.46	755.21	757.96	755.21	10/03/11 11:53 AM
10-3-2011 20:53 GMT	25.6	33	2.6	170	OK	1011.51	8.3	758.7	754.45	757.2	754.45	10/03/11 12:53 PM

10-3-2011 21:53 GMT	26.7	29	3.6	200	OK	1010.84	7.2	758.19	753.95	756.7	753.95	10/03/11 01:53 PM
10-3-2011 22:53 GMT	26.1	29	3.1	240	OK	1010.84	6.7	758.19	753.95	756.7	753.95	10/03/11 02:53 PM
10-3-2011 23:53 GMT	23.9	37	5.1	310	OK	1010.5	8.3	757.94	753.69	756.44	753.69	10/03/11 03:53 PM
10-4-2011 0:53 GMT	23.3	40	5.7	320	OK	1010.84	8.9	758.19	753.95	756.7	753.95	10/03/11 04:53 PM
10-4-2011 1:53 GMT	21.1	31	5.7	310	OK	1011.18	3.3	758.45	754.2	756.95	754.2	10/03/11 05:53 PM
10-4-2011 2:53 GMT	20	35	4.6	320	OK	1011.18	4	758.45	754.2	756.95	754.2	10/03/11 06:53 PM
10-4-2011 3:53 GMT	19.4	40	5.1	320	OK	1011.18	5.6	758.45	754.2	756.95	754.2	10/03/11 07:53 PM
10-4-2011 4:53 GMT	18.9	47	4.6	300	OK	1011.18	7.2	758.45	754.2	756.95	754.2	10/03/11 08:53 PM
10-4-2011 5:53 GMT	18.3	54	4.1	310	OK	1011.18	8.9	758.45	754.2	756.95	754.2	10/03/11 09:53 PM
10-4-2011 6:53 GMT	17.8	56	3.1	300	OK	1011.51	8.9	758.7	754.45	757.2	754.45	10/03/11 10:53 PM
10-4-2011 7:53 GMT	17.8	56	3.6	280	OK	1011.85	8.9	758.95	754.7	757.45	754.7	10/03/11 11:53 PM
10-4-2011 8:53 GMT	17.2	60	2.1	230	OK	1012.19	9.4	759.21	754.96	757.71	754.96	10/04/11 12:53 AM
10-4-2011 9:53 GMT	16.7	65	2.1	280	OK	1011.51	10	758.7	754.45	757.2	754.45	10/04/11 01:53 AM
10-4-2011 10:53 GMT	17.2	63	0		OK	1011.85	10	758.95	754.7	757.45	754.7	10/04/11 02:53 AM
10-4-2011 11:53 GMT	16.1	70	2.6	270	OK	1012.19	10.6	759.21	754.96	757.71	754.96	10/04/11 03:53 AM
10-4-2011 12:53 GMT	16.1	75	0		OK	1012.87	11.7	759.72	755.47	758.22	755.47	10/04/11 04:53 AM
10-4-2011 13:53 GMT	16.1	75	0		OK	1013.21	11.7	759.97	755.72	758.47	755.72	10/04/11 05:53 AM
10-4-2011 14:53 GMT	16.1	78	0		OK	1013.55	12.2	760.23	755.98	758.73	755.98	10/04/11 06:53 AM
10-4-2011 15:53 GMT	17.2	70	0		OK	1013.55	11.7	760.23	755.98	758.73	755.98	10/04/11 07:53 AM
10-4-2011 16:53 GMT	17.8	65	1.5	90	OK	1013.88	11.1	760.47	756.23	758.98	756.23	10/04/11 08:53 AM
10-4-2011 17:53 GMT	18.9	59	0		OK	1013.55	10.6	760.23	755.98	758.73	755.98	10/04/11 09:53 AM
10-4-2011 18:53 GMT	22.2	44	1.5	40	OK	1013.21	9.4	759.97	755.72	758.47	755.72	10/04/11 10:53 AM
10-4-2011 19:53 GMT	21.1	51	1.5		OK	1013.55	10.6	760.23	755.98	758.73	755.98	10/04/11 11:53 AM
10-4-2011 20:53 GMT	21.1	47	2.1	270	OK	1013.21	9.4	759.97	755.72	758.47	755.72	10/04/11 12:53 PM
10-4-2011 21:53 GMT	21.7	45	0		OK	1012.53	9.4	759.46	755.21	757.96	755.21	10/04/11 01:53 PM
10-4-2011 22:53 GMT	22.2	43	1.5	220	OK	1011.51	8.9	758.7	754.45	757.2	754.45	10/04/11 02:53 PM
10-4-2011 23:53 GMT	22.8	40	2.1	210	OK	1011.51	8.3	758.7	754.45	757.2	754.45	10/04/11 03:53 PM
10-5-2011 0:53 GMT	22.2	40	1.5	260	OK	1011.51	7.8	758.7	754.45	757.2	754.45	10/04/11 04:53 PM
10-5-2011 1:53 GMT	21.7	44	2.6	170	OK	1010.84	8.9	758.19	753.95	756.7	753.95	10/04/11 05:53 PM
10-5-2011 2:53 GMT	21.1	47	1.5	130	OK	1010.84	9.4	758.19	753.95	756.7	753.95	10/04/11 06:53 PM
10-5-2011 3:53 GMT	20	53	2.1	130	OK	1011.18	10	758.45	754.2	756.95	754.2	10/04/11 07:53 PM
10-5-2011 4:53 GMT	20	53	3.6	120	OK	1010.5	10	757.94	753.69	756.44	753.69	10/04/11 08:53 PM
10-5-2011 5:53 GMT	19.4	55	4.1	160	OK	1010.16	10	757.68	753.44	756.19	753.44	10/04/11 09:53 PM
10-5-2011 6:53 GMT	18.3	56	4.1	160	OK	1010.16	9.4	757.68	753.44	756.19	753.44	10/04/11 10:53 PM
10-5-2011 7:53 GMT	16.7	72	6.2	130	OK	1009.48	11.7	757.17	752.93	755.68	752.93	10/04/11 11:53 PM

10-5-2011 8:53 GMT	15.6	75	7.2	140	OK	1009.82	11.1	757.43	753.18	755.93	753.18	10/05/11 12:53 AM
10-5-2011 9:53 GMT	13.9	83	6.2	130	OK	1009.14	11.1	756.92	752.67	755.42	752.67	10/05/11 01:53 AM
10-5-2011 10:53 GMT	12.8	89	5.1	110	OK	1008.13	11.1	756.16	751.91	754.66	751.91	10/05/11 02:53 AM
10-5-2011 11:53 GMT	12.8	89	5.1	110	OK	1007.11	11.1	755.4	751.15	753.9	751.15	10/05/11 03:53 AM
10-5-2011 12:53 GMT	12.2	93	5.7	110	OK	1006.43	11.1	754.89	750.64	753.39	750.64	10/05/11 04:53 AM
10-5-2011 13:43 GMT	13	94	5.7	120	OK	1006.1	12	754.64	750.39	753.14	750.39	10/05/11 05:43 AM
10-5-2011 13:53 GMT	13.3	90	5.7	130	OK	1006.1	11.7	754.64	750.39	753.14	750.39	10/05/11 05:53 AM
10-5-2011 14:32 GMT	14	94	4.1	160	OK	1006.43	13	754.89	750.64	753.39	750.64	10/05/11 06:32 AM
10-5-2011 14:53 GMT	13.9	87	3.1	280	OK	1007.45	11.7	755.65	751.4	754.15	751.4	10/05/11 06:53 AM
10-5-2011 14:56 GMT	14	88	4.1	290	OK	1007.79	12	755.91	751.66	754.41	751.66	10/05/11 06:56 AM
10-5-2011 14:59 GMT	14	88	2.6	280	OK	1007.79	12	755.91	751.66	754.41	751.66	10/05/11 06:59 AM
10-5-2011 15:15 GMT	14	94	0		OK	1007.79	13	755.91	751.66	754.41	751.66	10/05/11 07:15 AM
10-5-2011 15:53 GMT	13.9	93	0		OK	1007.45	12.8	755.65	751.4	754.15	751.4	10/05/11 07:53 AM
10-5-2011 16:53 GMT	14.4	87	2.1	260	OK	1008.47	12.2	756.42	752.17	754.92	752.17	10/05/11 08:53 AM
10-5-2011 17:53 GMT	16.1	78	4.6	280	OK	1009.48	12.2	757.17	752.93	755.68	752.93	10/05/11 09:53 AM
10-5-2011 18:00 GMT	17	72	3.1	280	OK	1009.48	12	757.17	752.93	755.68	752.93	10/05/11 10:00 AM
10-5-2011 18:23 GMT	17	72	3.1	310	OK	1009.48	12	757.17	752.93	755.68	752.93	10/05/11 10:23 AM
10-5-2011 18:53 GMT	17.2	67	4.1	300	OK	1009.48	11.1	757.17	752.93	755.68	752.93	10/05/11 10:53 AM
10-5-2011 19:53 GMT	14.4	70	9.8	300	OK	1009.82	8.9	757.43	753.18	755.93	753.18	10/05/11 11:53 AM
10-5-2011 20:53 GMT	17.8	52	5.1	310	OK	1009.48	7.8	757.17	752.93	755.68	752.93	10/05/11 12:53 PM
10-5-2011 21:53 GMT	18.3	43	3.1	310	OK	1009.14	5.6	756.92	752.67	755.42	752.67	10/05/11 01:53 PM
10-5-2011 22:53 GMT	18.9	45	2.6	290	OK	1009.14	6.7	756.92	752.67	755.42	752.67	10/05/11 02:53 PM
10-5-2011 23:53 GMT	17.2	52	6.2	310	OK	1008.8	7.2	756.66	752.42	755.17	752.42	10/05/11 03:53 PM
10-6-2011 0:53 GMT	16.1	50	5.7	310	OK	1009.14	5.6	756.92	752.67	755.42	752.67	10/05/11 04:53 PM
10-6-2011 1:53 GMT	15	55	3.1	350	OK	1009.82	6	757.43	753.18	755.93	753.18	10/05/11 05:53 PM
10-6-2011 2:53 GMT	14.4	60	6.2	330	OK	1010.5	6.7	757.94	753.69	756.44	753.69	10/05/11 06:53 PM
10-6-2011 3:53 GMT	13.3	72	4.6	350	OK	1011.51	8.3	758.7	754.45	757.2	754.45	10/05/11 07:53 PM
10-6-2011 4:53 GMT	13.3	75	2.1	10	OK	1011.51	8.9	758.7	754.45	757.2	754.45	10/05/11 08:53 PM
10-6-2011 5:53 GMT	13.3	75	0		OK	1011.85	8.9	758.95	754.7	757.45	754.7	10/05/11 09:53 PM
10-6-2011 6:53 GMT	13.3	72	0		OK	1012.19	8.3	759.21	754.96	757.71	754.96	10/05/11 10:53 PM
10-6-2011 7:53 GMT	12.2	80	0		OK	1012.19	8.9	759.21	754.96	757.71	754.96	10/05/11 11:53 PM
10-6-2011 8:53 GMT	11.7	83	1.5	240	OK	1012.53	8.9	759.46	755.21	757.96	755.21	10/06/11 12:53 AM
10-6-2011 9:53 GMT	11.1	86	0		OK	1012.53	8.9	759.46	755.21	757.96	755.21	10/06/11 01:53 AM
10-6-2011 10:53 GMT	11.7	83	0		OK	1012.87	8.9	759.72	755.47	758.22	755.47	10/06/11 02:53 AM
10-6-2011 11:53 GMT	11.1	83	1.5	320	OK	1013.21	8.3	759.97	755.72	758.47	755.72	10/06/11 03:53 AM

10-6-2011 12:53 GMT	11.1	83	0		OK	1013.55	8.3	760.23	755.98	758.73	755.98	10/06/11 04:53 AM
10-6-2011 13:53 GMT	10.6	83	0		OK	1013.88	7.8	760.47	756.23	758.98	756.23	10/06/11 05:53 AM
10-6-2011 14:53 GMT	11.1	86	0		OK	1014.22	8.9	760.73	756.48	759.23	756.48	10/06/11 06:53 AM
10-6-2011 15:53 GMT	13.9	67	1.5	10	OK	1014.9	7.8	761.24	756.99	759.74	756.99	10/06/11 07:53 AM
10-6-2011 16:53 GMT	15	59	0		OK	1014.9	7	761.24	756.99	759.74	756.99	10/06/11 08:53 AM
10-6-2011 17:53 GMT	16.1	52	1.5	170	OK	1015.24	6.1	761.49	757.25	760	757.25	10/06/11 09:53 AM
10-6-2011 18:53 GMT	16.1	54	0		OK	1014.9	6.7	761.24	756.99	759.74	756.99	10/06/11 10:53 AM
10-6-2011 19:53 GMT	17.2	43	2.6	190	OK	1014.56	4.4	760.98	756.74	759.49	756.74	10/06/11 11:53 AM
10-6-2011 20:53 GMT	17.2	43	3.6	290	OK	1014.22	4.4	760.73	756.48	759.23	756.48	10/06/11 12:53 PM
10-6-2011 21:53 GMT	18.3	38	1.5	240	OK	1013.88	3.9	760.47	756.23	758.98	756.23	10/06/11 01:53 PM
10-6-2011 22:53 GMT	17.2	45	3.6	360	OK	1013.88	5	760.47	756.23	758.98	756.23	10/06/11 02:53 PM
10-6-2011 23:53 GMT	17.8	45	2.6	10	OK	1013.88	5.6	760.47	756.23	758.98	756.23	10/06/11 03:53 PM
10-7-2011 0:53 GMT	17.2	46	2.1	350	OK	1014.22	5.6	760.73	756.48	759.23	756.48	10/06/11 04:53 PM
10-7-2011 1:53 GMT	16.1	50	3.6	310	OK	1015.24	5.6	761.49	757.25	760	757.25	10/06/11 05:53 PM
10-7-2011 2:53 GMT	15	58	3.1	320	OK	1015.58	6.7	761.75	757.5	760.25	757.5	10/06/11 06:53 PM
10-7-2011 3:53 GMT	14.4	60	3.1	330	OK	1016.25	6.7	762.25	758	760.75	758	10/06/11 07:53 PM
10-7-2011 4:53 GMT	13.3	64	3.1	330	OK	1016.59	6.7	762.51	758.26	761.01	758.26	10/06/11 08:53 PM
10-7-2011 5:53 GMT	12.8	66	0		OK	1016.93	6.7	762.76	758.51	761.26	758.51	10/06/11 09:53 PM
10-7-2011 6:53 GMT	11.7	77	3.1	290	OK	1017.61	7.8	763.27	759.02	761.77	759.02	10/06/11 10:53 PM
10-7-2011 7:53 GMT	11.1	80	1.5	280	OK	1017.95	7.8	763.53	759.28	762.03	759.28	10/06/11 11:53 PM
10-7-2011 8:53 GMT	10.6	86	2.1	340	OK	1018.63	8.3	764.04	759.79	762.54	759.79	10/07/11 12:53 AM
10-7-2011 9:53 GMT	10.6	83	1.5	40	OK	1018.96	7.8	764.28	760.04	762.79	760.04	10/07/11 01:53 AM
10-7-2011 10:53 GMT	10	86	1.5	310	OK	1019.3	7.8	764.54	760.29	763.04	760.29	10/07/11 02:53 AM
10-7-2011 11:53 GMT	10	89	0		OK	1019.64	8.3	764.8	760.55	763.3	760.55	10/07/11 03:53 AM
10-7-2011 12:11 GMT	10	87	0		OK	1019.64	8	764.8	760.55	763.3	760.55	10/07/11 04:11 AM
10-7-2011 12:53 GMT	9.4	93	0		OK	1020.32	8.3	765.31	761.06	763.81	761.06	10/07/11 04:53 AM
10-7-2011 13:13 GMT	10	87	1.5	50	OK	1020.66	8	765.56	761.31	764.06	761.31	10/07/11 05:13 AM
10-7-2011 13:53 GMT	10	94	0		OK	1020.66	9	765.56	761.31	764.06	761.31	10/07/11 05:53 AM
10-7-2011 14:53 GMT	10	89	1.5	90	OK	1021.33	8.3	766.06	761.82	764.56	761.82	10/07/11 06:53 AM
10-7-2011 15:53 GMT	10.6	92	1.5	160	OK	1022.01	9.4	766.57	762.33	765.07	762.33	10/07/11 07:53 AM
10-7-2011 16:53 GMT	11.1	89	1.5	160	OK	1022.01	9.4	766.57	762.33	765.07	762.33	10/07/11 08:53 AM
10-7-2011 17:34 GMT	12	82	2.1	220	OK	1022.35	9	766.83	762.58	765.33	762.58	10/07/11 09:34 AM
10-7-2011 17:53 GMT	13.3	77	2.1	210	OK	1022.35	9.4	766.83	762.58	765.33	762.58	10/07/11 09:53 AM
10-7-2011 18:19 GMT	14	72	3.1	150	OK	1021.67	9	766.32	762.07	764.82	762.07	10/07/11 10:19 AM
10-7-2011 18:53 GMT	15	67	2.1	160	OK	1021.33	9	766.06	761.82	764.56	761.82	10/07/11 10:53 AM

10-7-2011 19:53 GMT	16.7	56	1.5		OK	1021.33	7.8	766.06	761.82	764.56	761.82	10/07/11 11:53 AM
10-7-2011 20:53 GMT	18.3	50	0		OK	1020.32	7.8	765.31	761.06	763.81	761.06	10/07/11 12:53 PM
10-7-2011 21:53 GMT	18.9	47	2.1	80	OK	1019.98	7.2	765.05	760.8	763.55	760.8	10/07/11 01:53 PM
10-7-2011 22:53 GMT	18.9	45	0		OK	1019.98	6.7	765.05	760.8	763.55	760.8	10/07/11 02:53 PM
10-7-2011 23:53 GMT	19.4	40	1.5	320	OK	1019.64	5.6	764.8	760.55	763.3	760.55	10/07/11 03:53 PM
10-8-2011 0:53 GMT	19.4	37	0		OK	1019.64	4.4	764.8	760.55	763.3	760.55	10/07/11 04:53 PM
10-8-2011 1:53 GMT	18.3	45	1.5	90	OK	1019.64	6.1	764.8	760.55	763.3	760.55	10/07/11 05:53 PM
10-8-2011 2:53 GMT	17.2	50	0		OK	1019.64	6.7	764.8	760.55	763.3	760.55	10/07/11 06:53 PM
10-8-2011 3:53 GMT	17.2	52	0		OK	1019.98	7.2	765.05	760.8	763.55	760.8	10/07/11 07:53 PM
10-8-2011 4:53 GMT	16.1	58	0		OK	1019.98	7.8	765.05	760.8	763.55	760.8	10/07/11 08:53 PM
10-8-2011 5:53 GMT	15.6	64	0		OK	1019.98	8.9	765.05	760.8	763.55	760.8	10/07/11 09:53 PM
10-8-2011 6:53 GMT	14.4	70	0		OK	1019.98	8.9	765.05	760.8	763.55	760.8	10/07/11 10:53 PM
10-8-2011 7:53 GMT	15	67	0		OK	1020.32	9	765.31	761.06	763.81	761.06	10/07/11 11:53 PM
10-8-2011 8:53 GMT	15.6	69	0		OK	1020.32	10	765.31	761.06	763.81	761.06	10/08/11 12:53 AM
10-8-2011 9:53 GMT	14.4	72	0		OK	1019.98	9.4	765.05	760.8	763.55	760.8	10/08/11 01:53 AM
10-8-2011 10:53 GMT	13.3	77	1.5	130	OK	1019.64	9.4	764.8	760.55	763.3	760.55	10/08/11 02:53 AM
10-8-2011 11:53 GMT	13.3	77	0		OK	1019.64	9.4	764.8	760.55	763.3	760.55	10/08/11 03:53 AM
10-8-2011 12:53 GMT	12.2	80	2.1	80	OK	1019.64	8.9	764.8	760.55	763.3	760.55	10/08/11 04:53 AM
10-8-2011 13:53 GMT	11.7	83	0		OK	1019.64	8.9	764.8	760.55	763.3	760.55	10/08/11 05:53 AM
10-8-2011 14:53 GMT	12.2	83	2.1	120	OK	1019.98	9.4	765.05	760.8	763.55	760.8	10/08/11 06:53 AM
10-8-2011 15:53 GMT	14.4	72	2.1	150	OK	1020.32	9.4	765.31	761.06	763.81	761.06	10/08/11 07:53 AM
10-8-2011 16:53 GMT	16.1	62	1.5	150	OK	1020.66	8.9	765.56	761.31	764.06	761.31	10/08/11 08:53 AM
10-8-2011 17:53 GMT	18.9	50	0		OK	1020.66	8.3	765.56	761.31	764.06	761.31	10/08/11 09:53 AM
10-8-2011 18:53 GMT	20	43	2.1		OK	1019.98	7	765.05	760.8	763.55	760.8	10/08/11 10:53 AM
10-8-2011 19:53 GMT	21.7	41	3.1	280	OK	1019.3	7.8	764.54	760.29	763.04	760.29	10/08/11 11:53 AM
10-8-2011 20:53 GMT	21.7	39	0		OK	1018.29	7.2	763.78	759.53	762.28	759.53	10/08/11 12:53 PM
10-8-2011 21:53 GMT	22.8	37	2.6	300	OK	1017.61	7.2	763.27	759.02	761.77	759.02	10/08/11 01:53 PM
10-8-2011 22:53 GMT	23.3	36	2.1	320	OK	1016.59	7.2	762.51	758.26	761.01	758.26	10/08/11 02:53 PM
10-8-2011 23:53 GMT	23.3	37	2.6	280	OK	1016.25	7.8	762.25	758	760.75	758	10/08/11 03:53 PM
10-9-2011 0:53 GMT	22.2	40	2.6	300	OK	1016.25	7.8	762.25	758	760.75	758	10/08/11 04:53 PM
10-9-2011 1:53 GMT	21.1	46	2.1	320	OK	1016.25	8.9	762.25	758	760.75	758	10/08/11 05:53 PM
10-9-2011 2:53 GMT	19.4	52	1.5	290	OK	1016.25	9.4	762.25	758	760.75	758	10/08/11 06:53 PM
10-9-2011 3:53 GMT	18.3	58	0		OK	1016.59	10	762.51	758.26	761.01	758.26	10/08/11 07:53 PM
10-9-2011 4:53 GMT	17.2	65	0		OK	1016.93	10.6	762.76	758.51	761.26	758.51	10/08/11 08:53 PM
10-9-2011 5:53 GMT	16.7	67	0		OK	1017.27	10.6	763.02	758.77	761.52	758.77	10/08/11 09:53 PM

10-9-2011 6:53 GMT	16.1	72	0		OK	1017.27	11.1	763.02	758.77	761.52	758.77	10/08/11 10:53 PM
10-9-2011 7:53 GMT	15	77	1.5	120	OK	1017.27	11	763.02	758.77	761.52	758.77	10/08/11 11:53 PM
10-9-2011 8:53 GMT	13.9	81	0		OK	1017.61	10.6	763.27	759.02	761.77	759.02	10/09/11 12:53 AM
10-9-2011 9:53 GMT	13.9	81	0		OK	1017.27	10.6	763.02	758.77	761.52	758.77	10/09/11 01:53 AM
10-9-2011 10:53 GMT	13.3	84	0		OK	1016.59	10.6	762.51	758.26	761.01	758.26	10/09/11 02:53 AM
10-9-2011 11:53 GMT	12.8	86	1.5	30	OK	1016.59	10.6	762.51	758.26	761.01	758.26	10/09/11 03:53 AM
10-9-2011 12:53 GMT	12.8	83	2.1	60	OK	1016.59	10	762.51	758.26	761.01	758.26	10/09/11 04:53 AM
10-9-2011 13:53 GMT	12.8	83	0		OK	1016.93	10	762.76	758.51	761.26	758.51	10/09/11 05:53 AM
10-9-2011 14:53 GMT	13.3	80	2.1	60	OK	1016.93	10	762.76	758.51	761.26	758.51	10/09/11 06:53 AM
10-9-2011 15:53 GMT	16.7	67	0		OK	1016.93	10.6	762.76	758.51	761.26	758.51	10/09/11 07:53 AM
10-9-2011 16:53 GMT	18.9	56	1.5	150	OK	1017.27	10	763.02	758.77	761.52	758.77	10/09/11 08:53 AM
10-9-2011 17:53 GMT	20.6	49	0		OK	1016.93	9.4	762.76	758.51	761.26	758.51	10/09/11 09:53 AM
10-9-2011 18:53 GMT	21.7	42	0		OK	1015.92	8.3	762	757.76	760.51	757.76	10/09/11 10:53 AM
10-9-2011 19:53 GMT	23.3	40	1.5		OK	1015.24	8.9	761.49	757.25	760	757.25	10/09/11 11:53 AM
10-9-2011 20:53 GMT	24.4	39	3.1	280	OK	1013.88	9.4	760.47	756.23	758.98	756.23	10/09/11 12:53 PM
10-9-2011 21:53 GMT	25.6	35	0		OK	1013.21	8.9	759.97	755.72	758.47	755.72	10/09/11 01:53 PM
10-9-2011 22:53 GMT	25.6	33	2.6	300	OK	1012.87	8.3	759.72	755.47	758.22	755.47	10/09/11 02:53 PM
10-9-2011 23:53 GMT	25.6	33	3.1	320	OK	1012.53	8.3	759.46	755.21	757.96	755.21	10/09/11 03:53 PM
10-10-2011 0:53 GMT	25	33	2.6	340	OK	1012.53	7.8	759.46	755.21	757.96	755.21	10/09/11 04:53 PM
10-10-2011 1:53 GMT	22.8	41	2.1	290	OK	1012.87	8.9	759.72	755.47	758.22	755.47	10/09/11 05:53 PM
10-10-2011 2:53 GMT	20.6	53	2.6	310	OK	1013.21	10.6	759.97	755.72	758.47	755.72	10/09/11 06:53 PM
10-10-2011 3:53 GMT	19.4	59	2.6	310	OK	1013.55	11.1	760.23	755.98	758.73	755.98	10/09/11 07:53 PM
10-10-2011 4:53 GMT	19.4	59	0		OK	1013.55	11.1	760.23	755.98	758.73	755.98	10/09/11 08:53 PM
10-10-2011 5:53 GMT	18.3	63	0		OK	1013.88	11.1	760.47	756.23	758.98	756.23	10/09/11 09:53 PM
10-10-2011 6:53 GMT	17.2	70	0		OK	1013.88	11.7	760.47	756.23	758.98	756.23	10/09/11 10:53 PM
10-10-2011 7:53 GMT	16.1	75	1.5	280	OK	1013.88	11.7	760.47	756.23	758.98	756.23	10/09/11 11:53 PM
10-10-2011 8:53 GMT	15.6	78	0		OK	1013.88	11.7	760.47	756.23	758.98	756.23	10/10/11 12:53 AM
10-10-2011 9:53 GMT	15	82	0		OK	1014.22	12	760.73	756.48	759.23	756.48	10/10/11 01:53 AM
10-10-2011 10:53 GMT	13.9	83	0		OK	1013.88	11.1	760.47	756.23	758.98	756.23	10/10/11 02:53 AM
10-10-2011 11:53 GMT	13.9	83	0		OK	1014.56	11.1	760.98	756.74	759.49	756.74	10/10/11 03:53 AM
10-10-2011 12:53 GMT	13.9	81	1.5	90	OK	1014.56	10.6	760.98	756.74	759.49	756.74	10/10/11 04:53 AM
10-10-2011 13:53 GMT	12.8	86	2.1	140	OK	1014.56	10.6	760.98	756.74	759.49	756.74	10/10/11 05:53 AM
10-10-2011 14:53 GMT	13.3	87	2.1	170	OK	1014.9	11.1	761.24	756.99	759.74	756.99	10/10/11 06:53 AM
10-10-2011 15:39 GMT	14	88	0		OK	1015.58	12	761.75	757.5	760.25	757.5	10/10/11 07:39 AM
10-10-2011 15:53 GMT	15	82	1.5	80	OK	1015.58	12	761.75	757.5	760.25	757.5	10/10/11 07:53 AM

10-10-2011 16:22 GMT	16	77	0		OK	1015.92	12	762	757.76	760.51	757.76	10/10/11 08:22 AM
10-10-2011 16:31 GMT	16	77	0		OK	1016.25	12	762.25	758	760.75	758	10/10/11 08:31 AM
10-10-2011 16:53 GMT	17.2	75	1.5	120	OK	1015.92	12.8	762	757.76	760.51	757.76	10/10/11 08:53 AM
10-10-2011 17:53 GMT	20	61	1.5	110	OK	1015.92	12.2	762	757.76	760.51	757.76	10/10/11 09:53 AM
10-10-2011 18:53 GMT	22.2	51	1.5		OK	1015.92	11.7	762	757.76	760.51	757.76	10/10/11 10:53 AM
10-10-2011 19:53 GMT	23.9	45	0		OK	1015.24	11.1	761.49	757.25	760	757.25	10/10/11 11:53 AM
10-10-2011 20:53 GMT	24.4	42	0		OK	1014.22	10.6	760.73	756.48	759.23	756.48	10/10/11 12:53 PM
10-10-2011 21:53 GMT	25.6	36	1.5		OK	1013.88	9.4	760.47	756.23	758.98	756.23	10/10/11 01:53 PM
10-10-2011 22:53 GMT	26.1	35	2.1		OK	1013.55	9.4	760.23	755.98	758.73	755.98	10/10/11 02:53 PM
10-10-2011 23:53 GMT	25	36	3.6	300	OK	1013.55	9	760.23	755.98	758.73	755.98	10/10/11 03:53 PM
10-11-2011 0:53 GMT	25	36	3.6	320	OK	1013.55	9	760.23	755.98	758.73	755.98	10/10/11 04:53 PM
10-11-2011 1:53 GMT	23.9	41	3.1	320	OK	1013.88	10	760.47	756.23	758.98	756.23	10/10/11 05:53 PM
10-11-2011 2:53 GMT	23.3	46	2.6	330	OK	1014.56	11.1	760.98	756.74	759.49	756.74	10/10/11 06:53 PM
10-11-2011 3:53 GMT	22.8	50	2.6	330	OK	1014.9	11.7	761.24	756.99	759.74	756.99	10/10/11 07:53 PM
10-11-2011 4:53 GMT	21.7	53	2.1	340	OK	1015.24	11.7	761.49	757.25	760	757.25	10/10/11 08:53 PM
10-11-2011 5:53 GMT	20.6	57	3.6	290	OK	1015.24	11.7	761.49	757.25	760	757.25	10/10/11 09:53 PM
10-11-2011 6:53 GMT	19.4	66	2.1	300	OK	1015.24	12.8	761.49	757.25	760	757.25	10/10/11 10:53 PM
10-11-2011 7:53 GMT	18.9	78	2.1	330	OK	1015.58	15	761.75	757.5	760.25	757.5	10/10/11 11:53 PM
10-11-2011 8:53 GMT	18.3	84	3.1	320	OK	1015.92	15.6	762	757.76	760.51	757.76	10/11/11 12:53 AM
10-11-2011 9:53 GMT	17.8	87	2.6	280	OK	1015.92	15.6	762	757.76	760.51	757.76	10/11/11 01:53 AM
10-11-2011 10:53 GMT	17.2	87	1.5	340	OK	1015.58	15	761.75	757.5	760.25	757.5	10/11/11 02:53 AM
10-11-2011 11:53 GMT	16.7	86	1.5	350	OK	1015.58	14.4	761.75	757.5	760.25	757.5	10/11/11 03:53 AM
10-11-2011 12:53 GMT	16.1	90	2.6	300	OK	1015.92	14.4	762	757.76	760.51	757.76	10/11/11 04:53 AM
10-11-2011 13:53 GMT	16.7	86	2.1	320	OK	1016.25	14.4	762.25	758	760.75	758	10/11/11 05:53 AM
10-11-2011 14:53 GMT	17.2	84	2.1	320	OK	1016.59	14.4	762.51	758.26	761.01	758.26	10/11/11 06:53 AM
10-11-2011 15:53 GMT	19.4	76	1.5	320	OK	1017.27	15	763.02	758.77	761.52	758.77	10/11/11 07:53 AM
10-11-2011 16:53 GMT	21.7	68	3.6	310	OK	1017.27	15.6	763.02	758.77	761.52	758.77	10/11/11 08:53 AM
10-11-2011 17:53 GMT	24.4	60	5.7	290	OK	1017.27	16.1	763.02	758.77	761.52	758.77	10/11/11 09:53 AM
10-11-2011 18:53 GMT	25	57	5.1	300	OK	1016.93	16	762.76	758.51	761.26	758.51	10/11/11 10:53 AM
10-11-2011 19:53 GMT	27.2	49	3.6	300	OK	1016.25	15.6	762.25	758	760.75	758	10/11/11 11:53 AM
10-11-2011 20:53 GMT	27.8	47	5.7	300	OK	1015.58	15.6	761.75	757.5	760.25	757.5	10/11/11 12:53 PM
10-11-2011 21:53 GMT	27.8	44	6.7	300	OK	1014.9	14.4	761.24	756.99	759.74	756.99	10/11/11 01:53 PM
10-11-2011 22:53 GMT	28.3	44	6.7	310	OK	1014.56	15	760.98	756.74	759.49	756.74	10/11/11 02:53 PM
10-11-2011 23:53 GMT	27.2	44	8.2	300	OK	1014.56	13.9	760.98	756.74	759.49	756.74	10/11/11 03:53 PM
10-12-2011 0:53 GMT	26.1	47	6.2	310	OK	1014.56	13.9	760.98	756.74	759.49	756.74	10/11/11 04:53 PM

10-12-2011 1:53 GMT	23.9	54	5.1	310	OK	1014.9	13.9	761.24	756.99	759.74	756.99	10/11/11 05:53 PM
10-12-2011 2:53 GMT	22.8	57	3.6	310	OK	1015.58	13.9	761.75	757.5	760.25	757.5	10/11/11 06:53 PM
10-12-2011 3:53 GMT	21.7	61	4.6	310	OK	1015.92	13.9	762	757.76	760.51	757.76	10/11/11 07:53 PM
10-12-2011 4:53 GMT	21.1	64	3.1	310	OK	1016.25	13.9	762.25	758	760.75	758	10/11/11 08:53 PM
10-12-2011 5:53 GMT	20	68	3.1	330	OK	1016.59	14	762.51	758.26	761.01	758.26	10/11/11 09:53 PM
10-12-2011 6:53 GMT	19.4	71	3.6	310	OK	1016.93	13.9	762.76	758.51	761.26	758.51	10/11/11 10:53 PM
10-12-2011 7:53 GMT	18.3	76	2.6	310	OK	1016.93	13.9	762.76	758.51	761.26	758.51	10/11/11 11:53 PM
10-12-2011 8:53 GMT	17.2	81	2.1	290	OK	1017.61	13.9	763.27	759.02	761.77	759.02	10/12/11 12:53 AM
10-12-2011 9:53 GMT	16.7	84	3.1	310	OK	1017.27	13.9	763.02	758.77	761.52	758.77	10/12/11 01:53 AM
10-12-2011 10:53 GMT	16.1	87	2.1	310	OK	1017.27	13.9	763.02	758.77	761.52	758.77	10/12/11 02:53 AM
10-12-2011 11:53 GMT	15.6	90	1.5	300	OK	1017.27	13.9	763.02	758.77	761.52	758.77	10/12/11 03:53 AM
10-12-2011 12:53 GMT	15	94	1.5	310	OK	1017.61	14	763.27	759.02	761.77	759.02	10/12/11 04:53 AM
10-12-2011 13:53 GMT	15	94	0		OK	1017.61	14	763.27	759.02	761.77	759.02	10/12/11 05:53 AM
10-12-2011 14:53 GMT	15.6	90	0		OK	1018.29	13.9	763.78	759.53	762.28	759.53	10/12/11 06:53 AM
10-12-2011 15:53 GMT	16.7	90	0		OK	1018.96	15	764.28	760.04	762.79	760.04	10/12/11 07:53 AM
10-12-2011 16:53 GMT	20	73	2.1	100	OK	1018.96	15	764.28	760.04	762.79	760.04	10/12/11 08:53 AM
10-12-2011 17:53 GMT	21.1	68	1.5	130	OK	1018.63	15	764.04	759.79	762.54	759.79	10/12/11 09:53 AM
10-12-2011 18:53 GMT	23.3	60	2.6	150	OK	1018.29	15	763.78	759.53	762.28	759.53	10/12/11 10:53 AM
10-12-2011 19:53 GMT	24.4	56	1.5		OK	1017.61	15	763.27	759.02	761.77	759.02	10/12/11 11:53 AM
10-12-2011 20:53 GMT	25.6	52	0		OK	1016.59	15	762.51	758.26	761.01	758.26	10/12/11 12:53 PM
10-12-2011 21:53 GMT	27.2	46	0		OK	1015.92	14.4	762	757.76	760.51	757.76	10/12/11 01:53 PM
10-12-2011 22:53 GMT	27.2	46	0		OK	1015.24	14.4	761.49	757.25	760	757.25	10/12/11 02:53 PM
10-12-2011 23:53 GMT	27.2	46	0		OK	1014.9	14.4	761.24	756.99	759.74	756.99	10/12/11 03:53 PM
10-13-2011 0:53 GMT	27.2	44	2.6	330	OK	1014.56	13.9	760.98	756.74	759.49	756.74	10/12/11 04:53 PM
10-13-2011 1:53 GMT	25	51	2.1	280	OK	1014.56	14	760.98	756.74	759.49	756.74	10/12/11 05:53 PM
10-13-2011 2:53 GMT	23.9	55	2.1	270	OK	1014.9	14.4	761.24	756.99	759.74	756.99	10/12/11 06:53 PM
10-13-2011 3:53 GMT	22.8	61	2.1	310	OK	1015.24	15	761.49	757.25	760	757.25	10/12/11 07:53 PM
10-13-2011 4:53 GMT	22.2	59	1.5	330	OK	1015.58	13.9	761.75	757.5	760.25	757.5	10/12/11 08:53 PM
10-13-2011 5:53 GMT	21.7	61	0		OK	1015.58	13.9	761.75	757.5	760.25	757.5	10/12/11 09:53 PM
10-13-2011 6:53 GMT	20.6	65	0		OK	1015.58	13.9	761.75	757.5	760.25	757.5	10/12/11 10:53 PM
10-13-2011 7:53 GMT	20	73	0		OK	1015.58	15	761.75	757.5	760.25	757.5	10/12/11 11:53 PM
10-13-2011 8:53 GMT	18.3	84	0		OK	1015.58	15.6	761.75	757.5	760.25	757.5	10/13/11 12:53 AM
10-13-2011 9:53 GMT	18.3	81	0		OK	1015.58	15	761.75	757.5	760.25	757.5	10/13/11 01:53 AM
10-13-2011 10:53 GMT	17.8	84	1.5	360	OK	1015.24	15	761.49	757.25	760	757.25	10/13/11 02:53 AM
10-13-2011 11:53 GMT	17.2	87	0		OK	1014.9	15	761.24	756.99	759.74	756.99	10/13/11 03:53 AM

10-13-2011 12:53 GMT	16.7	90	0		OK	1014.9	15	761.24	756.99	759.74	756.99	10/13/11 04:53 AM
10-13-2011 13:53 GMT	16.7	86	1.5	60	OK	1014.9	14.4	761.24	756.99	759.74	756.99	10/13/11 05:53 AM
10-13-2011 14:53 GMT	17.2	87	0		OK	1015.24	15	761.49	757.25	760	757.25	10/13/11 06:53 AM
10-13-2011 15:53 GMT	19.4	79	1.5	110	OK	1015.58	15.6	761.75	757.5	760.25	757.5	10/13/11 07:53 AM
10-13-2011 16:53 GMT	21.1	76	2.1	110	OK	1015.58	16.7	761.75	757.5	760.25	757.5	10/13/11 08:53 AM
10-13-2011 17:53 GMT	23.3	64	0		OK	1014.9	16.1	761.24	756.99	759.74	756.99	10/13/11 09:53 AM
10-13-2011 18:53 GMT	25.6	54	0		OK	1014.22	15.6	760.73	756.48	759.23	756.48	10/13/11 10:53 AM
10-13-2011 19:53 GMT	26.7	47	0		OK	1013.21	14.4	759.97	755.72	758.47	755.72	10/13/11 11:53 AM
10-13-2011 20:53 GMT	28.9	43	2.6		OK	1012.19	15	759.21	754.96	757.71	754.96	10/13/11 12:53 PM
10-13-2011 21:53 GMT	28.9	43	0		OK	1011.51	15	758.7	754.45	757.2	754.45	10/13/11 01:53 PM
10-13-2011 22:53 GMT	29.4	40	1.5		OK	1010.84	14.4	758.19	753.95	756.7	753.95	10/13/11 02:53 PM
10-13-2011 23:53 GMT	29.4	40	3.1	310	OK	1010.5	14.4	757.94	753.69	756.44	753.69	10/13/11 03:53 PM
10-14-2011 0:53 GMT	28.3	41	3.1	280	OK	1009.82	13.9	757.43	753.18	755.93	753.18	10/13/11 04:53 PM
10-14-2011 1:53 GMT	26.1	49	2.1	310	OK	1010.16	14.4	757.68	753.44	756.19	753.44	10/13/11 05:53 PM
10-14-2011 2:53 GMT	25	54	1.5	300	OK	1010.5	15	757.94	753.69	756.44	753.69	10/13/11 06:53 PM
10-14-2011 3:53 GMT	24.4	54	0		OK	1010.84	14.4	758.19	753.95	756.7	753.95	10/13/11 07:53 PM
10-14-2011 4:53 GMT	22.8	61	0		OK	1011.18	15	758.45	754.2	756.95	754.2	10/13/11 08:53 PM
10-14-2011 5:53 GMT	21.7	66	0		OK	1011.18	15	758.45	754.2	756.95	754.2	10/13/11 09:53 PM
10-14-2011 6:53 GMT	20.6	73	1.5	80	OK	1011.18	15.6	758.45	754.2	756.95	754.2	10/13/11 10:53 PM
10-14-2011 7:53 GMT	20	78	0		OK	1011.18	16	758.45	754.2	756.95	754.2	10/13/11 11:53 PM
10-14-2011 8:53 GMT	19.4	79	0		OK	1011.18	15.6	758.45	754.2	756.95	754.2	10/14/11 12:53 AM
10-14-2011 9:53 GMT	18.9	81	0		OK	1010.84	15.6	758.19	753.95	756.7	753.95	10/14/11 01:53 AM
10-14-2011 10:53 GMT	18.3	81	0		OK	1010.5	15	757.94	753.69	756.44	753.69	10/14/11 02:53 AM
10-14-2011 11:53 GMT	17.8	84	0		OK	1010.5	15	757.94	753.69	756.44	753.69	10/14/11 03:53 AM
10-14-2011 12:53 GMT	17.2	87	1.5	80	OK	1010.84	15	758.19	753.95	756.7	753.95	10/14/11 04:53 AM
10-14-2011 13:53 GMT	17.8	81	1.5	80	OK	1010.84	14.4	758.19	753.95	756.7	753.95	10/14/11 05:53 AM
10-14-2011 14:53 GMT	17.8	84	0		OK	1011.18	15	758.45	754.2	756.95	754.2	10/14/11 06:53 AM
10-14-2011 15:53 GMT	20	78	2.6	120	OK	1011.85	16	758.95	754.7	757.45	754.7	10/14/11 07:53 AM
10-14-2011 16:53 GMT	22.2	71	0		OK	1012.19	16.7	759.21	754.96	757.71	754.96	10/14/11 08:53 AM
10-14-2011 17:53 GMT	25	57	2.1	110	OK	1011.85	16	758.95	754.7	757.45	754.7	10/14/11 09:53 AM
10-14-2011 18:53 GMT	27.2	51	1.5	190	OK	1011.51	16.1	758.7	754.45	757.2	754.45	10/14/11 10:53 AM
10-14-2011 19:53 GMT	28.3	46	0		OK	1010.5	15.6	757.94	753.69	756.44	753.69	10/14/11 11:53 AM
10-14-2011 20:53 GMT	28.9	43	2.1	120	OK	1009.82	15	757.43	753.18	755.93	753.18	10/14/11 12:53 PM
10-14-2011 21:53 GMT	30.6	39	1.5		OK	1009.48	15	757.17	752.93	755.68	752.93	10/14/11 01:53 PM
10-14-2011 22:53 GMT	31.1	36	0		OK	1009.14	14.4	756.92	752.67	755.42	752.67	10/14/11 02:53 PM

10-14-2011 23:53 GMT	30.6	36	1.5	190	OK	1008.8	13.9	756.66	752.42	755.17	752.42	10/14/11 03:53 PM
10-15-2011 0:53 GMT	29.4	40	1.5	300	OK	1008.8	14.4	756.66	752.42	755.17	752.42	10/14/11 04:53 PM
10-15-2011 1:53 GMT	26.7	52	2.1	280	OK	1008.8	16.1	756.66	752.42	755.17	752.42	10/14/11 05:53 PM
10-15-2011 2:53 GMT	25.6	56	0		OK	1009.48	16.1	757.17	752.93	755.68	752.93	10/14/11 06:53 PM
10-15-2011 3:53 GMT	25	61	0		OK	1009.82	17	757.43	753.18	755.93	753.18	10/14/11 07:53 PM
10-15-2011 4:53 GMT	22.8	71	2.1	30	OK	1010.16	17.2	757.68	753.44	756.19	753.44	10/14/11 08:53 PM
10-15-2011 5:53 GMT	22.8	71	0		OK	1010.5	17.2	757.94	753.69	756.44	753.69	10/14/11 09:53 PM
10-15-2011 6:53 GMT	21.1	76	1.5	60	OK	1010.5	16.7	757.94	753.69	756.44	753.69	10/14/11 10:53 PM
10-15-2011 7:53 GMT	21.1	73	0		OK	1010.16	16.1	757.68	753.44	756.19	753.44	10/14/11 11:53 PM
10-15-2011 8:53 GMT	20.6	75	0		OK	1010.5	16.1	757.94	753.69	756.44	753.69	10/15/11 12:53 AM
10-15-2011 9:53 GMT	19.4	81	0		OK	1010.16	16.1	757.68	753.44	756.19	753.44	10/15/11 01:53 AM
10-15-2011 10:53 GMT	18.9	84	0		OK	1010.16	16.1	757.68	753.44	756.19	753.44	10/15/11 02:53 AM
10-15-2011 11:53 GMT	18.3	87	0		OK	1010.16	16.1	757.68	753.44	756.19	753.44	10/15/11 03:53 AM
10-15-2011 12:53 GMT	18.3	87	0		OK	1010.5	16.1	757.94	753.69	756.44	753.69	10/15/11 04:53 AM
10-15-2011 13:53 GMT	17.2	87	1.5	70	OK	1010.84	15	758.19	753.95	756.7	753.95	10/15/11 05:53 AM
10-15-2011 14:53 GMT	17.8	78	0		OK	1011.51	13.9	758.7	754.45	757.2	754.45	10/15/11 06:53 AM
10-15-2011 15:53 GMT	21.1	66	2.1	150	OK	1011.85	14.4	758.95	754.7	757.45	754.7	10/15/11 07:53 AM
10-15-2011 16:53 GMT	23.3	62	1.5	130	OK	1012.53	15.6	759.46	755.21	757.96	755.21	10/15/11 08:53 AM
10-15-2011 17:53 GMT	25	57	1.5	140	OK	1012.53	16	759.46	755.21	757.96	755.21	10/15/11 09:53 AM
10-15-2011 18:53 GMT	27.2	51	2.1	190	OK	1012.53	16.1	759.46	755.21	757.96	755.21	10/15/11 10:53 AM
10-15-2011 19:53 GMT	27.8	47	1.5	130	OK	1011.85	15.6	758.95	754.7	757.45	754.7	10/15/11 11:53 AM
10-15-2011 20:53 GMT	28.3	48	0		OK	1011.18	16.1	758.45	754.2	756.95	754.2	10/15/11 12:53 PM
10-15-2011 21:53 GMT	30	40	0		OK	1010.5	15	757.94	753.69	756.44	753.69	10/15/11 01:53 PM
10-15-2011 22:53 GMT	30.6	36	1.5	310	OK	1010.16	13.9	757.68	753.44	756.19	753.44	10/15/11 02:53 PM
10-15-2011 23:53 GMT	30.6	36	1.5	250	OK	1009.82	13.9	757.43	753.18	755.93	753.18	10/15/11 03:53 PM
10-16-2011 0:53 GMT	29.4	42	0		OK	1009.82	15	757.43	753.18	755.93	753.18	10/15/11 04:53 PM
10-16-2011 1:53 GMT	27.8	47	1.5	340	OK	1010.5	15.6	757.94	753.69	756.44	753.69	10/15/11 05:53 PM
10-16-2011 2:53 GMT	25.6	56	0		OK	1011.18	16.1	758.45	754.2	756.95	754.2	10/15/11 06:53 PM
10-16-2011 3:53 GMT	25	57	0		OK	1011.51	16	758.7	754.45	757.2	754.45	10/15/11 07:53 PM
10-16-2011 4:53 GMT	22.8	66	0		OK	1012.19	16.1	759.21	754.96	757.71	754.96	10/15/11 08:53 PM
10-16-2011 5:53 GMT	22.2	66	0		OK	1012.53	15.6	759.46	755.21	757.96	755.21	10/15/11 09:53 PM
10-16-2011 6:53 GMT	20.6	75	2.1	70	OK	1012.53	16.1	759.46	755.21	757.96	755.21	10/15/11 10:53 PM
10-16-2011 7:53 GMT	20.6	75	1.5	240	OK	1012.53	16.1	759.46	755.21	757.96	755.21	10/15/11 11:53 PM
10-16-2011 8:53 GMT	18.9	84	2.6	290	OK	1013.21	16.1	759.97	755.72	758.47	755.72	10/16/11 12:53 AM
10-16-2011 9:53 GMT	18.3	84	3.1	320	OK	1013.21	15.6	759.97	755.72	758.47	755.72	10/16/11 01:53 AM

10-16-2011 10:53 GMT	17.2	84	3.1	320	OK	1013.55	14.4	760.23	755.98	758.73	755.98	10/16/11 02:53 AM
10-16-2011 11:53 GMT	16.7	84	2.1	330	OK	1014.22	13.9	760.73	756.48	759.23	756.48	10/16/11 03:53 AM
10-16-2011 12:53 GMT	16.1	83	3.1	310	OK	1014.9	13.3	761.24	756.99	759.74	756.99	10/16/11 04:53 AM
10-16-2011 13:53 GMT	15.6	86	1.5	340	OK	1014.9	13.3	761.24	756.99	759.74	756.99	10/16/11 05:53 AM
10-16-2011 14:53 GMT	16.1	83	1.5	290	OK	1015.92	13.3	762	757.76	760.51	757.76	10/16/11 06:53 AM
10-16-2011 15:53 GMT	17.8	78	2.1	300	OK	1016.59	13.9	762.51	758.26	761.01	758.26	10/16/11 07:53 AM
10-16-2011 16:53 GMT	20.6	65	0		OK	1016.93	13.9	762.76	758.51	761.26	758.51	10/16/11 08:53 AM
10-16-2011 17:53 GMT	23.3	52	2.1	130	OK	1016.93	12.8	762.76	758.51	761.26	758.51	10/16/11 09:53 AM
10-16-2011 18:53 GMT	25	44	2.6	180	OK	1016.59	12	762.51	758.26	761.01	758.26	10/16/11 10:53 AM
10-16-2011 19:53 GMT	26.1	44	0		OK	1016.59	12.8	762.51	758.26	761.01	758.26	10/16/11 11:53 AM
10-16-2011 20:53 GMT	27.2	41	0		OK	1015.58	12.8	761.75	757.5	760.25	757.5	10/16/11 12:53 PM
10-16-2011 21:53 GMT	28.9	37	2.1	330	OK	1015.24	12.8	761.49	757.25	760	757.25	10/16/11 01:53 PM
10-16-2011 22:53 GMT	28.9	36	2.1	290	OK	1015.24	12.2	761.49	757.25	760	757.25	10/16/11 02:53 PM
10-16-2011 23:53 GMT	28.9	37	3.6	310	OK	1014.9	12.8	761.24	756.99	759.74	756.99	10/16/11 03:53 PM
10-17-2011 0:53 GMT	27.8	41	4.1	320	OK	1014.9	13.3	761.24	756.99	759.74	756.99	10/16/11 04:53 PM
10-17-2011 1:53 GMT	25.6	48	3.6	310	OK	1015.58	13.9	761.75	757.5	760.25	757.5	10/16/11 05:53 PM
10-17-2011 2:53 GMT	24.4	52	4.6	320	OK	1015.92	13.9	762	757.76	760.51	757.76	10/16/11 06:53 PM
10-17-2011 3:53 GMT	22.2	59	4.1	300	OK	1016.59	13.9	762.51	758.26	761.01	758.26	10/16/11 07:53 PM
10-17-2011 4:53 GMT	21.1	64	3.6	300	OK	1017.27	13.9	763.02	758.77	761.52	758.77	10/16/11 08:53 PM
10-17-2011 5:53 GMT	20	68	2.1	290	OK	1017.61	14	763.27	759.02	761.77	759.02	10/16/11 09:53 PM
10-17-2011 6:53 GMT	18.9	75	2.1	290	OK	1017.95	14.4	763.53	759.28	762.03	759.28	10/16/11 10:53 PM
10-17-2011 7:53 GMT	18.9	75	0		OK	1017.61	14.4	763.27	759.02	761.77	759.02	10/16/11 11:53 PM
10-17-2011 8:53 GMT	17.2	81	1.5	300	OK	1017.61	13.9	763.27	759.02	761.77	759.02	10/17/11 12:53 AM
10-17-2011 9:53 GMT	16.7	86	2.1	280	OK	1017.61	14.4	763.27	759.02	761.77	759.02	10/17/11 01:53 AM
10-17-2011 10:53 GMT	16.7	84	2.1	330	OK	1017.61	13.9	763.27	759.02	761.77	759.02	10/17/11 02:53 AM
10-17-2011 11:53 GMT	16.1	87	0		OK	1018.29	13.9	763.78	759.53	762.28	759.53	10/17/11 03:53 AM
10-17-2011 12:53 GMT	15.6	90	0		OK	1018.29	13.9	763.78	759.53	762.28	759.53	10/17/11 04:53 AM
10-17-2011 13:53 GMT	15	88	1.5	280	OK	1018.96	13	764.28	760.04	762.79	760.04	10/17/11 05:53 AM
10-17-2011 14:53 GMT	15.6	86	0		OK	1019.3	13.3	764.54	760.29	763.04	760.29	10/17/11 06:53 AM
10-17-2011 15:53 GMT	17.2	84	0		OK	1019.98	14.4	765.05	760.8	763.55	760.8	10/17/11 07:53 AM
10-17-2011 16:53 GMT	19.4	73	0		OK	1020.32	14.4	765.31	761.06	763.81	761.06	10/17/11 08:53 AM
10-17-2011 17:53 GMT	22.2	59	0		OK	1019.98	13.9	765.05	760.8	763.55	760.8	10/17/11 09:53 AM
10-17-2011 18:53 GMT	23.3	57	2.1		OK	1019.64	14.4	764.8	760.55	763.3	760.55	10/17/11 10:53 AM
10-17-2011 19:53 GMT	24.4	54	0		OK	1018.63	14.4	764.04	759.79	762.54	759.79	10/17/11 11:53 AM
10-17-2011 20:53 GMT	26.7	47	0		OK	1017.95	14.4	763.53	759.28	762.03	759.28	10/17/11 12:53 PM

10-17-2011 21:53 GMT	27.8	43	0		OK	1016.93	13.9	762.76	758.51	761.26	758.51	10/17/11 01:53 PM
10-17-2011 22:53 GMT	28.9	37	0		OK	1016.59	12.8	762.51	758.26	761.01	758.26	10/17/11 02:53 PM
10-17-2011 23:53 GMT	28.9	36	0		OK	1015.92	12.2	762	757.76	760.51	757.76	10/17/11 03:53 PM
10-18-2011 0:53 GMT	27.8	40	1.5	300	OK	1015.92	12.8	762	757.76	760.51	757.76	10/17/11 04:53 PM
10-18-2011 1:53 GMT	26.1	49	1.5	310	OK	1015.92	14.4	762	757.76	760.51	757.76	10/17/11 05:53 PM
10-18-2011 2:53 GMT	24.4	54	0		OK	1016.25	14.4	762.25	758	760.75	758	10/17/11 06:53 PM
10-18-2011 3:53 GMT	22.8	59	0		OK	1016.59	14.4	762.51	758.26	761.01	758.26	10/17/11 07:53 PM
10-18-2011 4:53 GMT	22.2	61	0		OK	1016.93	14.4	762.76	758.51	761.26	758.51	10/17/11 08:53 PM
10-18-2011 5:53 GMT	20.6	68	0		OK	1017.27	14.4	763.02	758.77	761.52	758.77	10/17/11 09:53 PM
10-18-2011 6:53 GMT	19.4	76	0		OK	1017.27	15	763.02	758.77	761.52	758.77	10/17/11 10:53 PM
10-18-2011 7:53 GMT	19.4	73	0		OK	1017.27	14.4	763.02	758.77	761.52	758.77	10/17/11 11:53 PM
10-18-2011 8:53 GMT	18.9	75	0		OK	1017.27	14.4	763.02	758.77	761.52	758.77	10/18/11 12:53 AM
10-18-2011 9:53 GMT	17.8	78	0		OK	1017.27	13.9	763.02	758.77	761.52	758.77	10/18/11 01:53 AM
10-18-2011 10:53 GMT	17.2	81	0		OK	1016.93	13.9	762.76	758.51	761.26	758.51	10/18/11 02:53 AM
10-18-2011 11:53 GMT	16.7	84	0		OK	1016.93	13.9	762.76	758.51	761.26	758.51	10/18/11 03:53 AM
10-18-2011 12:53 GMT	17.2	81	0		OK	1017.27	13.9	763.02	758.77	761.52	758.77	10/18/11 04:53 AM
10-18-2011 13:53 GMT	16.1	83	0		OK	1017.27	13.3	763.02	758.77	761.52	758.77	10/18/11 05:53 AM
10-18-2011 14:53 GMT	16.7	80	0		OK	1017.61	13.3	763.27	759.02	761.77	759.02	10/18/11 06:53 AM
10-18-2011 15:53 GMT	18.9	75	1.5	120	OK	1017.95	14.4	763.53	759.28	762.03	759.28	10/18/11 07:53 AM
10-18-2011 16:53 GMT	21.7	63	1.5	110	OK	1017.61	14.4	763.27	759.02	761.77	759.02	10/18/11 08:53 AM
10-18-2011 17:53 GMT	23.9	58	1.5	210	OK	1017.27	15	763.02	758.77	761.52	758.77	10/18/11 09:53 AM
10-18-2011 18:53 GMT	26.7	47	2.1	180	N/A	1016.93	14.4	762.76	758.51	761.26	758.51	10/18/11 10:53 AM
10-18-2011 19:53 GMT	27.8	41	1.5	170	OK	1015.92	13.3	762	757.76	760.51	757.76	10/18/11 11:53 AM
10-18-2011 20:53 GMT	28.9	38	0		OK	1014.9	13.3	761.24	756.99	759.74	756.99	10/18/11 12:53 PM
10-18-2011 21:53 GMT	30.6	35	2.1	350	OK	1014.22	13.3	760.73	756.48	759.23	756.48	10/18/11 01:53 PM
10-18-2011 22:53 GMT	30.6	35	1.5	230	OK	1013.88	13.3	760.47	756.23	758.98	756.23	10/18/11 02:53 PM
10-18-2011 23:53 GMT	30.6	31	0		OK	1013.21	11.7	759.97	755.72	758.47	755.72	10/18/11 03:53 PM
10-19-2011 0:53 GMT	30.6	34	1.5	40	OK	1012.53	12.8	759.46	755.21	757.96	755.21	10/18/11 04:53 PM
10-19-2011 1:53 GMT	27.8	43	0		OK	1012.19	13.9	759.21	754.96	757.71	754.96	10/18/11 05:53 PM
10-19-2011 2:53 GMT	25.6	50	2.6	260	OK	1012.53	14.4	759.46	755.21	757.96	755.21	10/18/11 06:53 PM
10-19-2011 3:53 GMT	23.9	58	2.6	300	OK	1013.21	15	759.97	755.72	758.47	755.72	10/18/11 07:53 PM
10-19-2011 4:53 GMT	23.3	57	2.6	10	OK	1013.55	14.4	760.23	755.98	758.73	755.98	10/18/11 08:53 PM
10-19-2011 5:53 GMT	21.1	68	2.6	290	OK	1013.88	15	760.47	756.23	758.98	756.23	10/18/11 09:53 PM
10-19-2011 6:53 GMT	20.6	70	3.6	310	OK	1013.55	15	760.23	755.98	758.73	755.98	10/18/11 10:53 PM
10-19-2011 7:53 GMT	19.4	73	3.6	320	OK	1013.55	14.4	760.23	755.98	758.73	755.98	10/18/11 11:53 PM

10-19-2011 8:53 GMT	18.9	73	3.6	310	OK	1013.55	13.9	760.23	755.98	758.73	755.98	10/19/11 12:53 AM
10-19-2011 9:53 GMT	17.2	81	5.1	300	OK	1013.88	13.9	760.47	756.23	758.98	756.23	10/19/11 01:53 AM
10-19-2011 10:53 GMT	16.7	80	4.1	310	OK	1013.55	13.3	760.23	755.98	758.73	755.98	10/19/11 02:53 AM
10-19-2011 11:53 GMT	16.1	83	5.7	310	OK	1013.88	13.3	760.47	756.23	758.98	756.23	10/19/11 03:53 AM
10-19-2011 12:53 GMT	15.6	83	5.1	320	OK	1014.22	12.8	760.73	756.48	759.23	756.48	10/19/11 04:53 AM
10-19-2011 13:53 GMT	15.6	83	4.6	320	OK	1014.56	12.8	760.98	756.74	759.49	756.74	10/19/11 05:53 AM
10-19-2011 14:53 GMT	15.6	83	4.6	310	OK	1014.9	12.8	761.24	756.99	759.74	756.99	10/19/11 06:53 AM
10-19-2011 15:53 GMT	17.2	75	4.6	320	OK	1015.24	12.8	761.49	757.25	760	757.25	10/19/11 07:53 AM
10-19-2011 16:53 GMT	18.9	68	4.1	290	OK	1015.58	12.8	761.75	757.5	760.25	757.5	10/19/11 08:53 AM
10-19-2011 17:53 GMT	21.1	59	4.1	320	OK	1015.58	12.8	761.75	757.5	760.25	757.5	10/19/11 09:53 AM
10-19-2011 18:53 GMT	22.8	53	2.6	330	OK	1015.24	12.8	761.49	757.25	760	757.25	10/19/11 10:53 AM
10-19-2011 19:53 GMT	24.4	47	4.6	330	OK	1014.56	12.2	760.98	756.74	759.49	756.74	10/19/11 11:53 AM
10-19-2011 20:53 GMT	25.6	45	3.6	310	OK	1013.88	12.8	760.47	756.23	758.98	756.23	10/19/11 12:53 PM
10-19-2011 21:53 GMT	25.6	43	3.1	290	OK	1013.55	12.2	760.23	755.98	758.73	755.98	10/19/11 01:53 PM
10-19-2011 22:53 GMT	26.7	39	4.1	320	OK	1013.21	11.7	759.97	755.72	758.47	755.72	10/19/11 02:53 PM
10-19-2011 23:53 GMT	26.1	41	4.1	300	OK	1012.87	11.7	759.72	755.47	758.22	755.47	10/19/11 03:53 PM
10-20-2011 0:53 GMT	24.4	47	4.1	320	OK	1012.87	12.2	759.72	755.47	758.22	755.47	10/19/11 04:53 PM
10-20-2011 1:53 GMT	22.8	51	3.1	330	OK	1012.87	12.2	759.72	755.47	758.22	755.47	10/19/11 05:53 PM
10-20-2011 2:53 GMT	21.7	55	1.5	320	OK	1013.21	12.2	759.97	755.72	758.47	755.72	10/19/11 06:53 PM
10-20-2011 3:53 GMT	20.6	59	3.6	300	OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/19/11 07:53 PM
10-20-2011 4:53 GMT	19.4	63	2.6	300	OK	1014.22	12.2	760.73	756.48	759.23	756.48	10/19/11 08:53 PM
10-20-2011 5:53 GMT	18.3	70	2.1	290	OK	1014.56	12.8	760.98	756.74	759.49	756.74	10/19/11 09:53 PM
10-20-2011 6:53 GMT	18.3	73	0		OK	1014.9	13.3	761.24	756.99	759.74	756.99	10/19/11 10:53 PM
10-20-2011 7:53 GMT	16.7	78	0		OK	1014.9	12.8	761.24	756.99	759.74	756.99	10/19/11 11:53 PM
10-20-2011 8:53 GMT	17.2	78	0		OK	1014.9	13.3	761.24	756.99	759.74	756.99	10/20/11 12:53 AM
10-20-2011 9:53 GMT	15.6	83	1.5	300	OK	1014.56	12.8	760.98	756.74	759.49	756.74	10/20/11 01:53 AM
10-20-2011 10:53 GMT	15.6	83	0		OK	1014.56	12.8	760.98	756.74	759.49	756.74	10/20/11 02:53 AM
10-20-2011 11:53 GMT	15	88	1.5	330	OK	1014.56	13	760.98	756.74	759.49	756.74	10/20/11 03:53 AM
10-20-2011 12:53 GMT	15	88	0		OK	1014.9	13	761.24	756.99	759.74	756.99	10/20/11 04:53 AM
10-20-2011 13:53 GMT	13.9	89	1.5	290	OK	1015.24	12.2	761.49	757.25	760	757.25	10/20/11 05:53 AM
10-20-2011 14:53 GMT	14.4	90	0		OK	1015.58	12.8	761.75	757.5	760.25	757.5	10/20/11 06:53 AM
10-20-2011 15:53 GMT	16.7	80	0		OK	1016.25	13.3	762.25	758	760.75	758	10/20/11 07:53 AM
10-20-2011 16:53 GMT	18.9	68	0		OK	1016.59	12.8	762.51	758.26	761.01	758.26	10/20/11 08:53 AM
10-20-2011 17:53 GMT	20.6	63	1.5	160	OK	1016.59	13.3	762.51	758.26	761.01	758.26	10/20/11 09:53 AM
10-20-2011 18:53 GMT	23.3	53	0		OK	1016.25	13.3	762.25	758	760.75	758	10/20/11 10:53 AM

10-20-2011 19:53 GMT	24.4	50	0		OK	1015.24	13.3	761.49	757.25	760	757.25	10/20/11 11:53 AM
10-20-2011 20:53 GMT	26.1	44	1.5		OK	1014.56	12.8	760.98	756.74	759.49	756.74	10/20/11 12:53 PM
10-20-2011 21:53 GMT	26.1	42	0		OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/20/11 01:53 PM
10-20-2011 22:53 GMT	27.2	38	3.1	310	OK	1013.88	11.7	760.47	756.23	758.98	756.23	10/20/11 02:53 PM
10-20-2011 23:53 GMT	27.2	39	3.1	300	OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/20/11 03:53 PM
10-21-2011 0:53 GMT	25.6	43	3.1	300	OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/20/11 04:53 PM
10-21-2011 1:53 GMT	23.9	52	2.1	270	OK	1014.56	13.3	760.98	756.74	759.49	756.74	10/20/11 05:53 PM
10-21-2011 2:53 GMT	22.8	55	2.1	290	OK	1015.24	13.3	761.49	757.25	760	757.25	10/20/11 06:53 PM
10-21-2011 3:53 GMT	22.2	59	1.5	290	OK	1015.58	13.9	761.75	757.5	760.25	757.5	10/20/11 07:53 PM
10-21-2011 4:53 GMT	21.1	64	2.1	320	OK	1016.25	13.9	762.25	758	760.75	758	10/20/11 08:53 PM
10-21-2011 5:53 GMT	20.6	65	0		OK	1016.93	13.9	762.76	758.51	761.26	758.51	10/20/11 09:53 PM
10-21-2011 6:53 GMT	20	68	0		OK	1017.27	14	763.02	758.77	761.52	758.77	10/20/11 10:53 PM
10-21-2011 7:53 GMT	17.8	81	0		OK	1017.27	14.4	763.02	758.77	761.52	758.77	10/20/11 11:53 PM
10-21-2011 8:53 GMT	17.2	81	0		OK	1017.27	13.9	763.02	758.77	761.52	758.77	10/21/11 12:53 AM
10-21-2011 9:53 GMT	16.7	84	0		OK	1017.61	13.9	763.27	759.02	761.77	759.02	10/21/11 01:53 AM
10-21-2011 10:53 GMT	16.1	87	0		OK	1017.61	13.9	763.27	759.02	761.77	759.02	10/21/11 02:53 AM
10-21-2011 11:53 GMT	16.1	87	0		OK	1017.95	13.9	763.53	759.28	762.03	759.28	10/21/11 03:53 AM
10-21-2011 12:53 GMT	15.6	86	0		OK	1018.29	13.3	763.78	759.53	762.28	759.53	10/21/11 04:53 AM
10-21-2011 13:53 GMT	15	88	0		OK	1018.96	13	764.28	760.04	762.79	760.04	10/21/11 05:53 AM
10-21-2011 14:53 GMT	15	88	1.5	330	OK	1019.64	13	764.8	760.55	763.3	760.55	10/21/11 06:53 AM
10-21-2011 15:53 GMT	16.1	83	0		OK	1020.32	13.3	765.31	761.06	763.81	761.06	10/21/11 07:53 AM
10-21-2011 16:53 GMT	19.4	68	0		OK	1020.66	13.3	765.56	761.31	764.06	761.31	10/21/11 08:53 AM
10-21-2011 17:53 GMT	21.7	61	2.1	150	OK	1020.32	13.9	765.31	761.06	763.81	761.06	10/21/11 09:53 AM
10-21-2011 18:53 GMT	23.9	55	2.6	180	OK	1020.32	14.4	765.31	761.06	763.81	761.06	10/21/11 10:53 AM
10-21-2011 19:53 GMT	25	52	3.1	230	OK	1019.98	14.4	765.05	760.8	763.55	760.8	10/21/11 11:53 AM
10-21-2011 20:53 GMT	26.1	47	2.6	310	OK	1019.3	13.9	764.54	760.29	763.04	760.29	10/21/11 12:53 PM
10-21-2011 21:53 GMT	25.6	47	2.1		OK	1018.96	13.3	764.28	760.04	762.79	760.04	10/21/11 01:53 PM
10-21-2011 22:53 GMT	26.7	44	2.6	310	OK	1018.29	13.3	763.78	759.53	762.28	759.53	10/21/11 02:53 PM
10-21-2011 23:53 GMT	26.7	42	3.1	300	OK	1018.29	12.8	763.78	759.53	762.28	759.53	10/21/11 03:53 PM
10-22-2011 0:53 GMT	25	47	2.6	300	OK	1017.95	13	763.53	759.28	762.03	759.28	10/21/11 04:53 PM
10-22-2011 1:53 GMT	23.9	54	2.1	300	OK	1018.29	13.9	763.78	759.53	762.28	759.53	10/21/11 05:53 PM
10-22-2011 2:53 GMT	22.2	59	2.6	300	OK	1018.63	13.9	764.04	759.79	762.54	759.79	10/21/11 06:53 PM
10-22-2011 3:53 GMT	22.2	57	2.1	320	OK	1018.96	13.3	764.28	760.04	762.79	760.04	10/21/11 07:53 PM
10-22-2011 4:53 GMT	20.6	63	1.5	300	OK	1019.3	13.3	764.54	760.29	763.04	760.29	10/21/11 08:53 PM
10-22-2011 5:53 GMT	20	64	1.5	290	OK	1019.3	13	764.54	760.29	763.04	760.29	10/21/11 09:53 PM

10-22-2011 6:53 GMT	18.9	70	0		OK	1019.3	13.3	764.54	760.29	763.04	760.29	10/21/11 10:53 PM
10-22-2011 7:53 GMT	18.3	73	0		OK	1019.64	13.3	764.8	760.55	763.3	760.55	10/21/11 11:53 PM
10-22-2011 8:53 GMT	17.8	78	0		OK	1019.64	13.9	764.8	760.55	763.3	760.55	10/22/11 12:53 AM
10-22-2011 9:53 GMT	17.2	81	0		OK	1019.64	13.9	764.8	760.55	763.3	760.55	10/22/11 01:53 AM
10-22-2011 10:53 GMT	16.1	87	0		OK	1019.3	13.9	764.54	760.29	763.04	760.29	10/22/11 02:53 AM
10-22-2011 11:53 GMT	15.6	86	0		OK	1019.3	13.3	764.54	760.29	763.04	760.29	10/22/11 03:53 AM
10-22-2011 12:53 GMT	15.6	86	0		OK	1019.3	13.3	764.54	760.29	763.04	760.29	10/22/11 04:53 AM
10-22-2011 13:53 GMT	15	88	0		OK	1019.3	13	764.54	760.29	763.04	760.29	10/22/11 05:53 AM
10-22-2011 14:53 GMT	15.6	86	0		OK	1019.64	13.3	764.8	760.55	763.3	760.55	10/22/11 06:53 AM
10-22-2011 15:53 GMT	17.8	73	0		OK	1020.32	12.8	765.31	761.06	763.81	761.06	10/22/11 07:53 AM
10-22-2011 16:53 GMT	21.1	61	3.1	150	OK	1020.32	13.3	765.31	761.06	763.81	761.06	10/22/11 08:53 AM
10-22-2011 17:53 GMT	22.2	59	2.1	200	OK	1020.32	13.9	765.31	761.06	763.81	761.06	10/22/11 09:53 AM
10-22-2011 18:53 GMT	23.9	54	2.1	200	OK	1019.64	13.9	764.8	760.55	763.3	760.55	10/22/11 10:53 AM
10-22-2011 19:53 GMT	26.1	47	0		OK	1018.96	13.9	764.28	760.04	762.79	760.04	10/22/11 11:53 AM
10-22-2011 20:53 GMT	27.2	39	0		OK	1017.61	12.2	763.27	759.02	761.77	759.02	10/22/11 12:53 PM
10-22-2011 21:53 GMT	28.3	38	0		OK	1017.27	12.8	763.02	758.77	761.52	758.77	10/22/11 01:53 PM
10-22-2011 22:53 GMT	28.3	37	0		OK	1016.59	12.2	762.51	758.26	761.01	758.26	10/22/11 02:53 PM
10-22-2011 23:53 GMT	28.3	36	0		OK	1015.92	11.7	762	757.76	760.51	757.76	10/22/11 03:53 PM
10-23-2011 0:53 GMT	26.7	42	2.1	290	OK	1015.58	12.8	761.75	757.5	760.25	757.5	10/22/11 04:53 PM
10-23-2011 1:53 GMT	25	47	1.5	320	OK	1015.92	13	762	757.76	760.51	757.76	10/22/11 05:53 PM
10-23-2011 2:53 GMT	23.3	53	0		OK	1015.92	13.3	762	757.76	760.51	757.76	10/22/11 06:53 PM
10-23-2011 3:53 GMT	22.8	55	0		OK	1016.25	13.3	762.25	758	760.75	758	10/22/11 07:53 PM
10-23-2011 4:53 GMT	21.1	64	0		OK	1016.59	13.9	762.51	758.26	761.01	758.26	10/22/11 08:53 PM
10-23-2011 5:53 GMT	18.9	75	0		OK	1016.59	14.4	762.51	758.26	761.01	758.26	10/22/11 09:53 PM
10-23-2011 6:53 GMT	18.3	76	1.5	60	OK	1016.59	13.9	762.51	758.26	761.01	758.26	10/22/11 10:53 PM
10-23-2011 7:53 GMT	17.2	78	0		OK	1016.59	13.3	762.51	758.26	761.01	758.26	10/22/11 11:53 PM
10-23-2011 8:53 GMT	17.2	78	0		OK	1016.59	13.3	762.51	758.26	761.01	758.26	10/23/11 12:53 AM
10-23-2011 9:53 GMT	15.6	83	0		OK	1016.25	12.8	762.25	758	760.75	758	10/23/11 01:53 AM
10-23-2011 10:53 GMT	16.1	78	0		OK	1015.92	12.2	762	757.76	760.51	757.76	10/23/11 02:53 AM
10-23-2011 11:53 GMT	15.6	80	0		OK	1015.58	12.2	761.75	757.5	760.25	757.5	10/23/11 03:53 AM
10-23-2011 12:53 GMT	15	82	1.5	80	OK	1015.92	12	762	757.76	760.51	757.76	10/23/11 04:53 AM
10-23-2011 13:53 GMT	15	82	1.5	80	OK	1015.92	12	762	757.76	760.51	757.76	10/23/11 05:53 AM
10-23-2011 14:53 GMT	15	82	1.5	80	OK	1016.25	12	762.25	758	760.75	758	10/23/11 06:53 AM
10-23-2011 15:53 GMT	17.8	68	1.5	80	OK	1016.59	11.7	762.51	758.26	761.01	758.26	10/23/11 07:53 AM
10-23-2011 16:53 GMT	20.6	61	2.1	130	OK	1016.59	12.8	762.51	758.26	761.01	758.26	10/23/11 08:53 AM

10-23-2011 17:53 GMT	22.8	59	1.5	160	OK	1016.25	14.4	762.25	758	760.75	758	10/23/11 09:53 AM
10-23-2011 18:53 GMT	25	51	0		OK	1015.92	14	762	757.76	760.51	757.76	10/23/11 10:53 AM
10-23-2011 19:53 GMT	27.2	41	2.1	260	OK	1014.9	12.8	761.24	756.99	759.74	756.99	10/23/11 11:53 AM
10-23-2011 20:53 GMT	27.8	37	0		OK	1013.88	11.7	760.47	756.23	758.98	756.23	10/23/11 12:53 PM
10-23-2011 21:53 GMT	29.4	32	1.5		OK	1013.21	11.1	759.97	755.72	758.47	755.72	10/23/11 01:53 PM
10-23-2011 22:53 GMT	29.4	31	1.5	350	OK	1012.53	10.6	759.46	755.21	757.96	755.21	10/23/11 02:53 PM
10-23-2011 23:53 GMT	30	31	1.5	360	OK	1012.53	11	759.46	755.21	757.96	755.21	10/23/11 03:53 PM
10-24-2011 0:53 GMT	27.8	34	1.5	300	OK	1012.53	10.6	759.46	755.21	757.96	755.21	10/23/11 04:53 PM
10-24-2011 1:53 GMT	25.6	42	1.5	320	OK	1012.53	11.7	759.46	755.21	757.96	755.21	10/23/11 05:53 PM
10-24-2011 2:53 GMT	23.3	50	2.1	320	OK	1012.87	12.2	759.72	755.47	758.22	755.47	10/23/11 06:53 PM
10-24-2011 3:53 GMT	22.8	53	1.5	330	OK	1013.21	12.8	759.97	755.72	758.47	755.72	10/23/11 07:53 PM
10-24-2011 4:53 GMT	21.1	59	2.1	330	OK	1013.55	12.8	760.23	755.98	758.73	755.98	10/23/11 08:53 PM
10-24-2011 5:53 GMT	20.6	61	1.5	320	OK	1013.88	12.8	760.47	756.23	758.98	756.23	10/23/11 09:53 PM
10-24-2011 6:53 GMT	19.4	63	0		OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/23/11 10:53 PM
10-24-2011 7:53 GMT	18.3	68	1.5	80	OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/23/11 11:53 PM
10-24-2011 8:53 GMT	17.2	72	1.5	150	OK	1014.22	12.2	760.73	756.48	759.23	756.48	10/24/11 12:53 AM
10-24-2011 9:53 GMT	16.7	78	0		OK	1014.22	12.8	760.73	756.48	759.23	756.48	10/24/11 01:53 AM
10-24-2011 10:53 GMT	15.6	80	1.5	60	OK	1013.88	12.2	760.47	756.23	758.98	756.23	10/24/11 02:53 AM
10-24-2011 11:53 GMT	15.6	83	1.5	60	OK	1013.88	12.8	760.47	756.23	758.98	756.23	10/24/11 03:53 AM
10-24-2011 12:53 GMT	14.4	84	0		OK	1014.22	11.7	760.73	756.48	759.23	756.48	10/24/11 04:53 AM
10-24-2011 13:53 GMT	15	77	0		OK	1014.56	11	760.98	756.74	759.49	756.74	10/24/11 05:53 AM
10-24-2011 14:53 GMT	15.6	72	0		OK	1014.9	10.6	761.24	756.99	759.74	756.99	10/24/11 06:53 AM
10-24-2011 15:53 GMT	18.3	65	0		OK	1015.58	11.7	761.75	757.5	760.25	757.5	10/24/11 07:53 AM
10-24-2011 16:53 GMT	20.6	55	0		OK	1015.58	11.1	761.75	757.5	760.25	757.5	10/24/11 08:53 AM
10-24-2011 17:53 GMT	23.3	46	1.5	170	OK	1015.58	11.1	761.75	757.5	760.25	757.5	10/24/11 09:53 AM
10-24-2011 18:53 GMT	24.4	50	1.5	160	OK	1015.24	13.3	761.49	757.25	760	757.25	10/24/11 10:53 AM
10-24-2011 19:53 GMT	26.7	42	0		OK	1014.56	12.8	760.98	756.74	759.49	756.74	10/24/11 11:53 AM
10-24-2011 20:53 GMT	27.8	37	1.5	270	OK	1013.88	11.7	760.47	756.23	758.98	756.23	10/24/11 12:53 PM
10-24-2011 21:53 GMT	28.3	34	1.5	260	OK	1013.21	11.1	759.97	755.72	758.47	755.72	10/24/11 01:53 PM
10-24-2011 22:53 GMT	28.3	32	0		OK	1012.87	10	759.72	755.47	758.22	755.47	10/24/11 02:53 PM
10-24-2011 23:53 GMT	28.3	34	1.5	220	OK	1012.53	11.1	759.46	755.21	757.96	755.21	10/24/11 03:53 PM
10-25-2011 0:53 GMT	26.7	39	2.1	230	OK	1012.87	11.7	759.72	755.47	758.22	755.47	10/24/11 04:53 PM
10-25-2011 1:53 GMT	25	44	1.5	240	OK	1013.21	12	759.97	755.72	758.47	755.72	10/24/11 05:53 PM
10-25-2011 2:53 GMT	23.9	50	0		OK	1013.55	12.8	760.23	755.98	758.73	755.98	10/24/11 06:53 PM
10-25-2011 3:53 GMT	22.2	55	0		OK	1013.55	12.8	760.23	755.98	758.73	755.98	10/24/11 07:53 PM

10-25-2011 4:53 GMT	21.1	59	2.1	290	OK	1014.22	12.8	760.73	756.48	759.23	756.48	10/24/11 08:53 PM
10-25-2011 5:53 GMT	19.4	63	3.1	330	OK	1014.9	12.2	761.24	756.99	759.74	756.99	10/24/11 09:53 PM
10-25-2011 6:53 GMT	17.8	70	2.6	310	OK	1015.24	12.2	761.49	757.25	760	757.25	10/24/11 10:53 PM
10-25-2011 7:53 GMT	17.2	72	3.1	310	OK	1015.24	12.2	761.49	757.25	760	757.25	10/24/11 11:53 PM
10-25-2011 8:53 GMT	16.7	72	2.1	320	OK	1015.24	11.7	761.49	757.25	760	757.25	10/25/11 12:53 AM
10-25-2011 9:53 GMT	16.1	75	3.1	320	OK	1015.24	11.7	761.49	757.25	760	757.25	10/25/11 01:53 AM
10-25-2011 10:53 GMT	15	81	1.5	330	OK	1014.9	11.7	761.24	756.99	759.74	756.99	10/25/11 02:53 AM
10-25-2011 11:53 GMT	14.4	81	4.1	320	OK	1014.9	11.1	761.24	756.99	759.74	756.99	10/25/11 03:53 AM
10-25-2011 12:53 GMT	13.9	83	3.6	310	OK	1015.24	11.1	761.49	757.25	760	757.25	10/25/11 04:53 AM
10-25-2011 13:53 GMT	13.3	84	3.6	320	OK	1015.58	10.6	761.75	757.5	760.25	757.5	10/25/11 05:53 AM
10-25-2011 14:53 GMT	13.9	81	3.1	310	OK	1015.92	10.6	762	757.76	760.51	757.76	10/25/11 06:53 AM
10-25-2011 15:53 GMT	15	77	2.6	310	OK	1016.59	11	762.51	758.26	761.01	758.26	10/25/11 07:53 AM
10-25-2011 16:53 GMT	16.7	65	4.1	330	OK	1016.93	10	762.76	758.51	761.26	758.51	10/25/11 08:53 AM
10-25-2011 17:53 GMT	19.4	52	4.6	300	OK	1017.27	9.4	763.02	758.77	761.52	758.77	10/25/11 09:53 AM
10-25-2011 18:53 GMT	20.6	51	3.1		OK	1017.27	10	763.02	758.77	761.52	758.77	10/25/11 10:53 AM
10-25-2011 19:53 GMT	21.7	45	3.6	350	OK	1016.59	9.4	762.51	758.26	761.01	758.26	10/25/11 11:53 AM
10-25-2011 20:53 GMT	21.7	44	2.6		OK	1015.92	8.9	762	757.76	760.51	757.76	10/25/11 12:53 PM
10-25-2011 21:53 GMT	22.8	37	1.5		OK	1015.24	7.2	761.49	757.25	760	757.25	10/25/11 01:53 PM
10-25-2011 22:53 GMT	23.3	33	2.1	300	OK	1014.9	6.1	761.24	756.99	759.74	756.99	10/25/11 02:53 PM
10-25-2011 23:53 GMT	22.8	31	3.1	310	OK	1014.9	5	761.24	756.99	759.74	756.99	10/25/11 03:53 PM
10-26-2011 0:53 GMT	21.1	33	2.6	300	OK	1014.9	4.4	761.24	756.99	759.74	756.99	10/25/11 04:53 PM
10-26-2011 1:53 GMT	19.4	47	3.1	280	OK	1014.9	7.8	761.24	756.99	759.74	756.99	10/25/11 05:53 PM
10-26-2011 2:53 GMT	18.9	56	3.6	320	OK	1015.24	10	761.49	757.25	760	757.25	10/25/11 06:53 PM
10-26-2011 3:53 GMT	18.3	61	2.6	320	OK	1015.24	10.6	761.49	757.25	760	757.25	10/25/11 07:53 PM
10-26-2011 4:53 GMT	16.7	67	3.6	290	OK	1015.58	10.6	761.75	757.5	760.25	757.5	10/25/11 08:53 PM
10-26-2011 5:53 GMT	15.6	67	3.6	280	OK	1015.92	9.4	762	757.76	760.51	757.76	10/25/11 09:53 PM
10-26-2011 6:53 GMT	15	59	3.6	310	OK	1015.92	7	762	757.76	760.51	757.76	10/25/11 10:53 PM
10-26-2011 7:53 GMT	13.9	64	3.1	300	OK	1016.25	7.2	762.25	758	760.75	758	10/25/11 11:53 PM
10-26-2011 8:53 GMT	13.3	69	2.6	330	OK	1016.59	7.8	762.51	758.26	761.01	758.26	10/26/11 12:53 AM
10-26-2011 9:53 GMT	12.2	77	1.5	320	OK	1016.59	8.3	762.51	758.26	761.01	758.26	10/26/11 01:53 AM
10-26-2011 10:53 GMT	12.2	80	2.1	330	OK	1016.59	8.9	762.51	758.26	761.01	758.26	10/26/11 02:53 AM
10-26-2011 11:53 GMT	11.7	83	2.1	270	OK	1016.93	8.9	762.76	758.51	761.26	758.51	10/26/11 03:53 AM
10-26-2011 12:53 GMT	12.2	75	1.5	360	OK	1017.27	7.8	763.02	758.77	761.52	758.77	10/26/11 04:53 AM
10-26-2011 13:53 GMT	11.1	74	2.1	280	OK	1017.95	6.7	763.53	759.28	762.03	759.28	10/26/11 05:53 AM
10-26-2011 14:53 GMT	11.1	71	1.5	340	OK	1018.29	6.1	763.78	759.53	762.28	759.53	10/26/11 06:53 AM

10-26-2011 15:53 GMT	12.2	64	1.5	300	OK	1019.3	5.6	764.54	760.29	763.04	760.29	10/26/11 07:53 AM
10-26-2011 16:53 GMT	13.3	57	0		OK	1019.98	5	765.05	760.8	763.55	760.8	10/26/11 08:53 AM
10-26-2011 17:53 GMT	15	55	1.5	130	OK	1019.98	6	765.05	760.8	763.55	760.8	10/26/11 09:53 AM
10-26-2011 18:53 GMT	16.7	52	1.5	160	OK	1019.98	6.7	765.05	760.8	763.55	760.8	10/26/11 10:53 AM
10-26-2011 19:53 GMT	18.3	43	1.5		OK	1019.3	5.6	764.54	760.29	763.04	760.29	10/26/11 11:53 AM
10-26-2011 20:53 GMT	20	35	2.1	140	OK	1017.95	4	763.53	759.28	762.03	759.28	10/26/11 12:53 PM
10-26-2011 21:53 GMT	20	40	0		OK	1017.95	6	763.53	759.28	762.03	759.28	10/26/11 01:53 PM
10-26-2011 22:53 GMT	20.6	36	0		OK	1017.95	5	763.53	759.28	762.03	759.28	10/26/11 02:53 PM
10-26-2011 23:53 GMT	20.6	35	1.5	200	OK	1017.61	4.4	763.27	759.02	761.77	759.02	10/26/11 03:53 PM
10-27-2011 0:53 GMT	20	35	0		OK	1017.27	4	763.02	758.77	761.52	758.77	10/26/11 04:53 PM
10-27-2011 1:53 GMT	19.4	39	0		OK	1017.61	5	763.27	759.02	761.77	759.02	10/26/11 05:53 PM
10-27-2011 2:53 GMT	17.8	45	0		OK	1017.61	5.6	763.27	759.02	761.77	759.02	10/26/11 06:53 PM
10-27-2011 3:53 GMT	16.1	56	0		OK	1017.61	7.2	763.27	759.02	761.77	759.02	10/26/11 07:53 PM
10-27-2011 4:53 GMT	15.6	57	0		OK	1017.95	7.2	763.53	759.28	762.03	759.28	10/26/11 08:53 PM
10-27-2011 5:53 GMT	15	63	0		OK	1017.95	8	763.53	759.28	762.03	759.28	10/26/11 09:53 PM
10-27-2011 6:53 GMT	13.9	67	1.5	90	OK	1018.29	7.8	763.78	759.53	762.28	759.53	10/26/11 10:53 PM
10-27-2011 7:53 GMT	12.8	72	1.5	90	OK	1018.63	7.8	764.04	759.79	762.54	759.79	10/26/11 11:53 PM
10-27-2011 8:53 GMT	11.7	77	2.1	130	OK	1018.29	7.8	763.78	759.53	762.28	759.53	10/27/11 12:53 AM
10-27-2011 9:53 GMT	11.7	74	2.6	110	OK	1018.29	7.2	763.78	759.53	762.28	759.53	10/27/11 01:53 AM
10-27-2011 10:53 GMT	11.7	71	0		OK	1018.29	6.7	763.78	759.53	762.28	759.53	10/27/11 02:53 AM
10-27-2011 11:53 GMT	11.1	71	0		OK	1018.29	6.1	763.78	759.53	762.28	759.53	10/27/11 03:53 AM
10-27-2011 12:53 GMT	10.6	77	0		OK	1018.63	6.7	764.04	759.79	762.54	759.79	10/27/11 04:53 AM
10-27-2011 13:53 GMT	10.6	79	0		OK	1018.63	7.2	764.04	759.79	762.54	759.79	10/27/11 05:53 AM
10-27-2011 14:53 GMT	10.6	83	0		OK	1018.63	7.8	764.04	759.79	762.54	759.79	10/27/11 06:53 AM
10-27-2011 15:53 GMT	12.8	74	1.5	130	OK	1018.96	8.3	764.28	760.04	762.79	760.04	10/27/11 07:53 AM
10-27-2011 16:53 GMT	15.6	60	1.5		OK	1018.96	7.8	764.28	760.04	762.79	760.04	10/27/11 08:53 AM
10-27-2011 17:53 GMT	17.8	45	1.5		OK	1019.3	5.6	764.54	760.29	763.04	760.29	10/27/11 09:53 AM
10-27-2011 18:53 GMT	20	35	2.1	170	OK	1018.63	4	764.04	759.79	762.54	759.79	10/27/11 10:53 AM
10-27-2011 19:53 GMT	21.7	30	3.1	200	OK	1017.61	3.3	763.27	759.02	761.77	759.02	10/27/11 11:53 AM
10-27-2011 20:53 GMT	22.8	25	2.6	170	OK	1016.93	1.7	762.76	758.51	761.26	758.51	10/27/11 12:53 PM
10-27-2011 21:53 GMT	23.3	20	0		OK	1016.59	-1.1	762.51	758.26	761.01	758.26	10/27/11 01:53 PM
10-27-2011 22:53 GMT	23.9	18	0		OK	1015.92	-1.7	762	757.76	760.51	757.76	10/27/11 02:53 PM
10-27-2011 23:53 GMT	23.3	17	0		OK	1015.92	-2.8	762	757.76	760.51	757.76	10/27/11 03:53 PM
10-28-2011 0:53 GMT	22.8	19	0		OK	1015.92	-2.2	762	757.76	760.51	757.76	10/27/11 04:53 PM
10-28-2011 1:53 GMT	20	28	1.5	290	OK	1016.25	1	762.25	758	760.75	758	10/27/11 05:53 PM

10-28-2011 2:53 GMT	18.3	34	0		OK	1016.59	2.2	762.51	758.26	761.01	758.26	10/27/11 06:53 PM
10-28-2011 3:53 GMT	16.1	44	1.5	40	OK	1016.93	3.9	762.76	758.51	761.26	758.51	10/27/11 07:53 PM
10-28-2011 4:53 GMT	15	48	0		OK	1017.27	4	763.02	758.77	761.52	758.77	10/27/11 08:53 PM
10-28-2011 5:53 GMT	13.9	49	0		OK	1017.61	3.3	763.27	759.02	761.77	759.02	10/27/11 09:53 PM
10-28-2011 6:53 GMT	13.3	49	0		OK	1017.95	2.8	763.53	759.28	762.03	759.28	10/27/11 10:53 PM
10-28-2011 7:53 GMT	12.2	49	0		OK	1018.29	1.7	763.78	759.53	762.28	759.53	10/27/11 11:53 PM
10-28-2011 8:53 GMT	11.7	52	0		OK	1018.63	2.2	764.04	759.79	762.54	759.79	10/28/11 12:53 AM
10-28-2011 9:53 GMT	11.7	56	0		OK	1018.63	3.3	764.04	759.79	762.54	759.79	10/28/11 01:53 AM
10-28-2011 10:53 GMT	10.6	56	0		OK	1018.29	2.2	763.78	759.53	762.28	759.53	10/28/11 02:53 AM
10-28-2011 11:53 GMT	10	62	0		OK	1018.29	3	763.78	759.53	762.28	759.53	10/28/11 03:53 AM
10-28-2011 12:53 GMT	9.4	69	0		OK	1018.63	3.9	764.04	759.79	762.54	759.79	10/28/11 04:53 AM
10-28-2011 13:53 GMT	9.4	69	0		OK	1019.3	3.9	764.54	760.29	763.04	760.29	10/28/11 05:53 AM
10-28-2011 14:53 GMT	10	66	0		OK	1019.98	4	765.05	760.8	763.55	760.8	10/28/11 06:53 AM
10-28-2011 15:53 GMT	12.2	59	0		OK	1020.32	4.4	765.31	761.06	763.81	761.06	10/28/11 07:53 AM
10-28-2011 16:53 GMT	16.1	39	0		OK	1020.66	2.2	765.56	761.31	764.06	761.31	10/28/11 08:53 AM
10-28-2011 17:53 GMT	18.3	34	0		OK	1020.66	2.2	765.56	761.31	764.06	761.31	10/28/11 09:53 AM
10-28-2011 18:53 GMT	20.6	31	0		OK	1020.66	2.8	765.56	761.31	764.06	761.31	10/28/11 10:53 AM
10-28-2011 19:53 GMT	21.7	30	0		OK	1019.98	3.3	765.05	760.8	763.55	760.8	10/28/11 11:53 AM
10-28-2011 20:53 GMT	23.9	26	2.1		OK	1018.96	3.3	764.28	760.04	762.79	760.04	10/28/11 12:53 PM
10-28-2011 21:53 GMT	25	24	0		OK	1018.29	3	763.78	759.53	762.28	759.53	10/28/11 01:53 PM
10-28-2011 22:53 GMT	25	26	1.5	320	OK	1018.29	4	763.78	759.53	762.28	759.53	10/28/11 02:53 PM
10-28-2011 23:53 GMT	25	26	2.6	300	OK	1017.61	4	763.27	759.02	761.77	759.02	10/28/11 03:53 PM
10-29-2011 0:53 GMT	22.2	33	3.1	280	OK	1017.95	5	763.53	759.28	762.03	759.28	10/28/11 04:53 PM
10-29-2011 1:53 GMT	21.1	36	1.5	310	OK	1018.29	5.6	763.78	759.53	762.28	759.53	10/28/11 05:53 PM
10-29-2011 2:53 GMT	18.9	43	2.1	320	OK	1018.29	6.1	763.78	759.53	762.28	759.53	10/28/11 06:53 PM
10-29-2011 3:53 GMT	17.8	46	0		OK	1018.96	6.1	764.28	760.04	762.79	760.04	10/28/11 07:53 PM
10-29-2011 4:53 GMT	16.7	52	0		OK	1019.3	6.7	764.54	760.29	763.04	760.29	10/28/11 08:53 PM
10-29-2011 5:53 GMT	15	59	0		OK	1019.64	7	764.8	760.55	763.3	760.55	10/28/11 09:53 PM
10-29-2011 6:53 GMT	13.9	64	0		OK	1019.98	7.2	765.05	760.8	763.55	760.8	10/28/11 10:53 PM
10-29-2011 7:53 GMT	12.8	69	0		OK	1019.98	7.2	765.05	760.8	763.55	760.8	10/28/11 11:53 PM
10-29-2011 8:53 GMT	11.7	71	0		OK	1019.98	6.7	765.05	760.8	763.55	760.8	10/29/11 12:53 AM
10-29-2011 9:53 GMT	11.1	71	0		OK	1019.98	6.1	765.05	760.8	763.55	760.8	10/29/11 01:53 AM
10-29-2011 10:53 GMT	10.6	71	0		OK	1019.98	5.6	765.05	760.8	763.55	760.8	10/29/11 02:53 AM
10-29-2011 11:53 GMT	10	76	0		OK	1019.98	6	765.05	760.8	763.55	760.8	10/29/11 03:53 AM
10-29-2011 12:53 GMT	10	74	0		OK	1020.32	5.6	765.31	761.06	763.81	761.06	10/29/11 04:53 AM

10-29-2011 13:53 GMT	9.4	71	2.1	70	OK	1020.32	4.4	765.31	761.06	763.81	761.06	10/29/11 05:53 AM
10-29-2011 14:53 GMT	9.4	74	0		OK	1020.66	5	765.56	761.31	764.06	761.31	10/29/11 06:53 AM
10-29-2011 15:53 GMT	11.1	71	1.5	130	OK	1021.33	6.1	766.06	761.82	764.56	761.82	10/29/11 07:53 AM
10-29-2011 16:53 GMT	15	51	3.6	140	OK	1021.33	5	766.06	761.82	764.56	761.82	10/29/11 08:53 AM
10-29-2011 17:53 GMT	17.2	46	2.1	140	OK	1021.33	5.6	766.06	761.82	764.56	761.82	10/29/11 09:53 AM
10-29-2011 18:53 GMT	19.4	44	1.5	130	OK	1021	6.7	765.82	761.57	764.32	761.57	10/29/11 10:53 AM
10-29-2011 19:53 GMT	21.1	39	0		OK	1020.32	6.7	765.31	761.06	763.81	761.06	10/29/11 11:53 AM
10-29-2011 20:53 GMT	22.8	35	0		OK	1018.96	6.7	764.28	760.04	762.79	760.04	10/29/11 12:53 PM
10-29-2011 21:53 GMT	23.3	34	0		OK	1018.63	6.7	764.04	759.79	762.54	759.79	10/29/11 01:53 PM
10-29-2011 22:53 GMT	23.9	32	2.1	240	OK	1018.29	6.1	763.78	759.53	762.28	759.53	10/29/11 02:53 PM
10-29-2011 23:53 GMT	23.3	33	0		OK	1017.95	6.1	763.53	759.28	762.03	759.28	10/29/11 03:53 PM
10-30-2011 0:53 GMT	22.2	37	1.5	270	OK	1017.95	6.7	763.53	759.28	762.03	759.28	10/29/11 04:53 PM
10-30-2011 1:53 GMT	21.1	41	0		OK	1018.29	7.2	763.78	759.53	762.28	759.53	10/29/11 05:53 PM
10-30-2011 2:53 GMT	18.3	52	0		OK	1018.29	8.3	763.78	759.53	762.28	759.53	10/29/11 06:53 PM
10-30-2011 3:53 GMT	16.1	60	0		OK	1018.63	8.3	764.04	759.79	762.54	759.79	10/29/11 07:53 PM
10-30-2011 4:53 GMT	16.1	58	0		OK	1018.63	7.8	764.04	759.79	762.54	759.79	10/29/11 08:53 PM
10-30-2011 5:53 GMT	15	62	0		OK	1018.96	7.8	764.28	760.04	762.79	760.04	10/29/11 09:53 PM
10-30-2011 6:53 GMT	13.9	62	1.5	190	OK	1019.3	6.7	764.54	760.29	763.04	760.29	10/29/11 10:53 PM
10-30-2011 7:53 GMT	12.8	64	0		OK	1019.3	6.1	764.54	760.29	763.04	760.29	10/29/11 11:53 PM
10-30-2011 8:53 GMT	12.2	66	0		OK	1019.3	6.1	764.54	760.29	763.04	760.29	10/30/11 12:53 AM
10-30-2011 9:53 GMT	11.7	69	0		OK	1019.3	6.1	764.54	760.29	763.04	760.29	10/30/11 01:53 AM
10-30-2011 10:53 GMT	11.1	74	1.5	70	OK	1018.96	6.7	764.28	760.04	762.79	760.04	10/30/11 02:53 AM
10-30-2011 11:53 GMT	10.6	77	0		OK	1018.96	6.7	764.28	760.04	762.79	760.04	10/30/11 03:53 AM
10-30-2011 12:53 GMT	10.6	77	2.1	80	OK	1019.3	6.7	764.54	760.29	763.04	760.29	10/30/11 04:53 AM
10-30-2011 13:53 GMT	10.6	74	0		OK	1019.64	6.1	764.8	760.55	763.3	760.55	10/30/11 05:53 AM
10-30-2011 14:53 GMT	10.6	74	0		OK	1019.98	6.1	765.05	760.8	763.55	760.8	10/30/11 06:53 AM
10-30-2011 15:53 GMT	13.9	62	1.5	80	OK	1020.32	6.7	765.31	761.06	763.81	761.06	10/30/11 07:53 AM
10-30-2011 16:53 GMT	17.2	50	0		OK	1020.32	6.7	765.31	761.06	763.81	761.06	10/30/11 08:53 AM
10-30-2011 17:53 GMT	20	43	0		OK	1020.32	7	765.31	761.06	763.81	761.06	10/30/11 09:53 AM
10-30-2011 18:53 GMT	22.2	37	0		OK	1019.98	6.7	765.05	760.8	763.55	760.8	10/30/11 10:53 AM
10-30-2011 19:53 GMT	23.3	33	1.5	170	OK	1018.96	6.1	764.28	760.04	762.79	760.04	10/30/11 11:53 AM
10-30-2011 20:53 GMT	25	29	0		OK	1017.95	5.6	763.53	759.28	762.03	759.28	10/30/11 12:53 PM
10-30-2011 21:53 GMT	25.6	27	2.1	310	OK	1017.27	5	763.02	758.77	761.52	758.77	10/30/11 01:53 PM
10-30-2011 22:53 GMT	26.1	26	0		OK	1016.93	5	762.76	758.51	761.26	758.51	10/30/11 02:53 PM
10-30-2011 23:53 GMT	26.1	25	2.1	320	OK	1016.59	4.4	762.51	758.26	761.01	758.26	10/30/11 03:53 PM

10-31-2011 0:53 GMT	23.9	31	1.5	280	OK	1016.59	5.6	762.51	758.26	761.01	758.26	10/30/11 04:53 PM
10-31-2011 1:53 GMT	21.1	41	1.5	290	OK	1017.27	7.2	763.02	758.77	761.52	758.77	10/30/11 05:53 PM
10-31-2011 2:53 GMT	19.4	47	0		OK	1017.61	7.8	763.27	759.02	761.77	759.02	10/30/11 06:53 PM
10-31-2011 3:53 GMT	17.2	54	0		OK	1017.95	7.8	763.53	759.28	762.03	759.28	10/30/11 07:53 PM
10-31-2011 4:53 GMT	16.1	60	0		OK	1017.95	8.3	763.53	759.28	762.03	759.28	10/30/11 08:53 PM
10-31-2011 5:53 GMT	15.6	62	0		OK	1018.29	8.3	763.78	759.53	762.28	759.53	10/30/11 09:53 PM
10-31-2011 6:53 GMT	14.4	67	0		OK	1018.29	8.3	763.78	759.53	762.28	759.53	10/30/11 10:53 PM
10-31-2011 7:53 GMT	12.2	72	0		OK	1018.63	7.2	764.04	759.79	762.54	759.79	10/30/11 11:53 PM
10-31-2011 8:53 GMT	12.8	69	0		OK	1018.29	7.2	763.78	759.53	762.28	759.53	10/31/11 12:53 AM
10-31-2011 9:53 GMT	12.2	72	2.6	80	OK	1017.95	7.2	763.53	759.28	762.03	759.28	10/31/11 01:53 AM
10-31-2011 10:53 GMT	11.7	74	1.5	80	OK	1017.95	7.2	763.53	759.28	762.03	759.28	10/31/11 02:53 AM
10-31-2011 11:53 GMT	11.7	74	0		OK	1017.61	7.2	763.27	759.02	761.77	759.02	10/31/11 03:53 AM
10-31-2011 12:53 GMT	11.1	74	0		OK	1017.95	6.7	763.53	759.28	762.03	759.28	10/31/11 04:53 AM
10-31-2011 13:53 GMT	11.1	74	0		OK	1017.61	6.7	763.27	759.02	761.77	759.02	10/31/11 05:53 AM
10-31-2011 14:53 GMT	11.1	74	0		OK	1017.95	6.7	763.53	759.28	762.03	759.28	10/31/11 06:53 AM
10-31-2011 15:53 GMT	13.3	62	2.1	130	OK	1018.63	6.1	764.04	759.79	762.54	759.79	10/31/11 07:53 AM
10-31-2011 16:53 GMT	16.7	52	2.6	150	OK	1018.29	6.7	763.78	759.53	762.28	759.53	10/31/11 08:53 AM
10-31-2011 17:53 GMT	18.9	47	1.5	100	OK	1018.29	7.2	763.78	759.53	762.28	759.53	10/31/11 09:53 AM
10-31-2011 18:53 GMT	21.1	42	0		OK	1017.95	7.8	763.53	759.28	762.03	759.28	10/31/11 10:53 AM
10-31-2011 19:53 GMT	23.3	37	0		OK	1016.93	7.8	762.76	758.51	761.26	758.51	10/31/11 11:53 AM
10-31-2011 20:53 GMT	24.4	33	0		OK	1015.92	7.2	762	757.76	760.51	757.76	10/31/11 12:53 PM
10-31-2011 21:53 GMT	25.6	30	0		OK	1014.9	6.7	761.24	756.99	759.74	756.99	10/31/11 01:53 PM
10-31-2011 22:53 GMT	26.1	30	3.1	320	OK	1014.56	7.2	760.98	756.74	759.49	756.74	10/31/11 02:53 PM
10-31-2011 23:53 GMT	26	30	2.6	310	OK	1014.22	7	760.73	756.48	759.23	756.48	10/31/11 03:53 PM

CIMIS_105_daily_2011-Oct

Stn Id	Date	Jul	qc	SolRad_W.sq.m	qc	AvgAirTemp_DegC	qc	AvgVap_kPa	qc
105	10/01/11	274	*	226	*	20	*	1.4	*
105	10/02/11	275	*	222	*	20	*	1.4	*
105	10/03/11	276	*	178	*	17.6	*	1.2	*
105	10/04/11	277	*	125	*	18.6	*	1.4	*
105	10/05/11	278	*	168	*	14.7	*	1.3	*
105	10/06/11	279	*	148	*	12.7	*	1.1	*
105	10/07/11	280	*	218	*	13.7	*	1.1	*
105	10/08/11	281	*	213	*	15.2	*	1.1	*
105	10/09/11	282	*	205	*	16.7	*	1.2	*
105	10/10/11	283	*	179	*	19.4	*	1.4	*
105	10/11/11	284	*	203	*	21.2	Y	1.8	Y
105	10/12/11	285	*	205	*	19.9	*	1.4	*
105	10/13/11	286	*	201	*	20.2	*	1.2	*
105	10/14/11	287	*	167	*	21.4	*	1.5	*
105	10/15/11	288	*	174	*	22.4	*	1.5	*
105	10/16/11	289	*	190	*	20.4	Y	1.5	*
105	10/17/11	290	*	194	*	20.3	*	1.5	*
105	10/18/11	291	*	188	*	21.1	*	1.4	*
105	10/19/11	292	*	190	*	18.4	*	1.4	*
105	10/20/11	293	*	186	*	18.5	*	1.3	*
105	10/21/11	294	*	188	*	18.4	*	1.3	*
105	10/22/11	295	*	183	*	19.4	*	1.3	*
105	10/23/11	296	*	180	*	19.5	*	1.3	*
105	10/24/11	297	*	157	*	19.9	*	1.3	*
105	10/25/11	298	*	129	*	17.5	*	0.9	*
105	10/26/11	299	R	187	*	13.5	*	0.5	*
105	10/27/11	300	*	177	*	13.4	*	0.5	*
105	10/28/11	301	*	173	*	14.9	*	0.7	*
105	10/29/11	302	*	175	*	14.9	*	0.7	*
105	10/30/11	303	*	173	*	15	*	0.7	*
105	10/31/11	304	*	168	*	16.5	*	0.9	*

AvgWdSpd_mps	qc	Precip_mm	qc	AvgRelHum_per	qc	DewPt_DegC	qc	WndRun_Km
2.6	*	0	*	59	*	11.7	*	223.5
2.7	*	0	*	60	*	11.9	*	229.4
2.9	*	0	*	62	*	10.2	*	253.4
1.8	*	0.2	*	64	*	11.6	*	154.1
3.5	*	9.2	*	76	*	10.5	*	306.2
1.8	*	0.3	*	75	*	8.4	*	158.5
2	*	0	*	69	*	8.2	*	169.9
1.4	*	0	*	65	*	8.7	*	121.1
1.4	*	0	*	64	*	9.8	*	120.8
1.8	*	0	*	63	*	12.2	*	158.9
3.7	*	0	Y	70	Y	15.6	Y	321.8
3.3	*	0	*	60	*	11.9	*	281.5
1.4	*	0	*	50	*	9.3	*	123.3
1.3	*	0	*	59	*	12.9	*	108
1.3	*	0	*	55	*	13	*	115.9
2.6	*	0	Y	65	Y	13.5	*	226
2.1	*	0	*	62	*	12.8	*	177.8
1.3	*	0	*	55	*	11.8	*	115.7
2.9	*	0	*	65	*	11.6	*	251.3
2	*	0	*	62	*	11.2	*	169.8
2.6	*	0	*	62	*	10.9	*	225.3
1.4	*	0	*	56	*	10.5	*	119.2
1.3	*	0	*	58	*	11	*	108.3
1.5	*	0	*	54	*	10.3	*	129.3
3.3	*	0	*	46	*	5.7	*	289
3.2	*	0	*	34	*	-1.8	*	274.1
1.3	*	0	*	36	*	-1.5	*	110.2
1.6	*	0	*	42	*	2	*	137.6
2.2	*	0	*	42	*	2	*	188.6
1.4	*	0	*	44	*	2.8	*	120.4
1.5	*	0	*	47	*	5.3	*	128.3