ISOS|2023

Simposio Internacional sobre Sistemas de Emisarios 2023

International Symposium on Outfall Systems 2023

IAHR AIRH International Association for Hydro-Environment Engineering and Research

IWA the international water association

Monitoring of a thermal plume in the coast of the Río de la Plata estuary

LUCÍA PONCE DE LEÓN, FRANCISCO PEDOCCHI, FERNANDA MACIEL

INSTITUTO DE MECÁNICA DE LOS FLUIDOS E INGENIERÍA AMBIENTAL (IMFIA)
FACULTAD DE INGENIERÍA, UNIVERSIDAD DE LA REPÚBLICA (UDELAR), MONTEVIDEO, URUGUAY

aysa Lo bueno del agua llega.

COFES

Ministerio de Obras Públicas Argentina

Introduction

Motivation

The understanding of thermal plumes dispersion is key for the management and preservation of water bodies.

Design of thermal outfalls

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Selection of dispersion coefficients and turbulent viscosity

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Bibliography parameters varies within multiple orders of magnitude.

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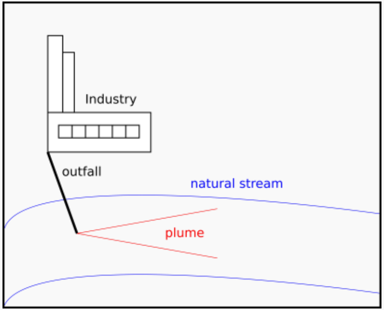
Experimental studies must to be done, such as ink tracers, which are **costly and time expensive**



Introduction

Objective

Determine the horizontal transverse dispersion coefficients (D_T) in the Río de la Plata coast, using velocity profiles obtained with an ADCP, following the **methodology of Fischer (1978)**.

Method evaluation

- Comparison made with a field campaign that provided **spatial information** of the plume
- Comparison made with field data from **yearlong measurements** of temperature around the hot water discharge

Sentinel V model, manufactured by Teledyne RDI, USA

Introduction

Similar approaches in bibliography

- Carr & Rehmann (2007)
- Shen et al. (2010) → Examples of ADCP applications for longitudinal dispersion in rivers
- Jung et al. (2019)

Contribution

- Fischer (1978) methodology applied in the Río de la Plata estuary
- Estimations under **diverse hydrodynamic conditions** of the estuary → specially observing the effect of strong winds

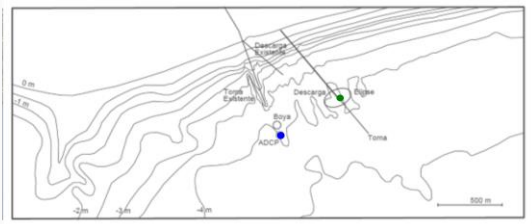
Methods and Preliminary results

Study site

Located in the intermediate zone of the Río de la Plata estuary, at approximately 900 m from the coastline, in San José, Uruguay, where a combined-cycle thermal power plant was constructed.

The power plant:

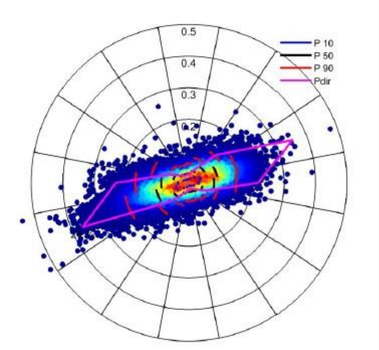
- Produces 530 MW
- Discharges 40,000 m^3/h of hot water
- Temperature jump of maximum 10 °C between the intake and the discharged water



Methods and Preliminary results

Study site

Metoceanic variables	Min	Max	Average
Water temperature (°C)	8,0	29,1	18,8
Depth (m)	2,4	6,1	4,1
Mean vertical current (m/s)	0,008	0,52	0,09
Significant wave height (m)	0,04	1,74	0,39
Wind (m/s)	0,09	19,4	5,9



Mean currents rose

Methods and Preliminary results

Data acquisition and processing - ADCP

The moored uplooking ADCP was configured to measure every hour, averaging measurements taken during 2 minutes with a frequency of 0,5 seconds.

According to Fischer et al. (1979), the **Dispersion Tensor** is

$$D = \begin{pmatrix} D_{xx} & D_{xy} \\ D_{yx} & D_{yy} \end{pmatrix}$$

where D_{ij} is defined as

$$D_{ij} = -\frac{1}{d} \int_0^d u_i' \int_0^z \frac{1}{\varepsilon_V} \int_0^z u_j' \, dz dz dz,$$

d is the depth, ε_V the vertical turbulent viscosity and u_i' the velocity deviation from the vertical average.

Methods and Preliminary results

Data acquisition and processing - ADCP

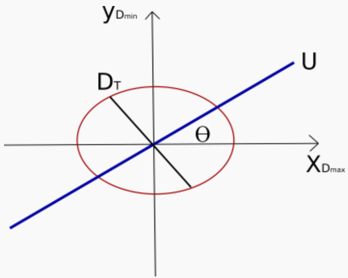
Find the eigenvalues (D_{max} and D_{min}) of the symmetric part of the Dispersion Tensor:

$$D = \begin{pmatrix} D_{xx} & D_{xy} \\ D_{yx} & D_{yy} \end{pmatrix} \Rightarrow S = \begin{pmatrix} D_{xx} & \frac{(D_{xy} + D_{yx})}{2} \\ \frac{(D_{xy} + D_{yx})}{2} & D_{yy} \end{pmatrix} \Rightarrow \begin{pmatrix} D_{max} & 0 \\ 0 & D_{min} \end{pmatrix} \Rightarrow D_{T_{ADCP}}$$

The horizontal transverse dispersion coefficient ($D_{T_{ADCP}}$) can be defined as:

$$D_{T_{ADCP}} = \frac{D_{min} + D_{max}\tan(\theta)^2}{1 + \tan(\theta)^2},$$

where θ is the angle between the mean current direction and the eigenvector of D_{max}.



Methods and Preliminary results

Data acquisition and processing - ADCP

Vertical mixing processes

↓

Vertical turbulent viscosity (ε_V)

↓

Considering the effects of **currents and wind**

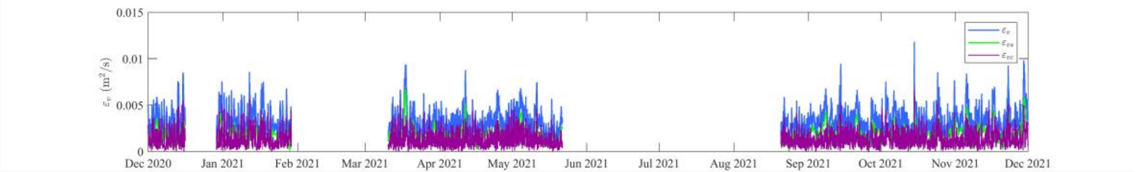
$$\varepsilon_V = \varepsilon_{VC} + \varepsilon_{VS}$$

$$\varepsilon_{VC} = 0.067 u_* d$$ → Using U and n_M (Santoro, 2017)

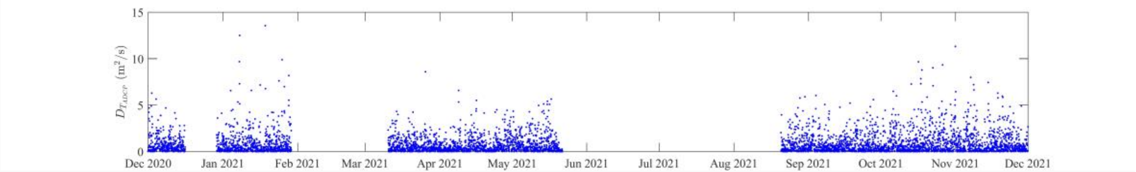
$$\varepsilon_{VS} = 0.0583 u_{*s} d$$ → Using W and C_D (Santoro, 2017)

Methods and Preliminary results

Results - ADCP



Vertical turbulent viscosity



Transverse horizontal dispersion coeffcient

Methods and Preliminary Results

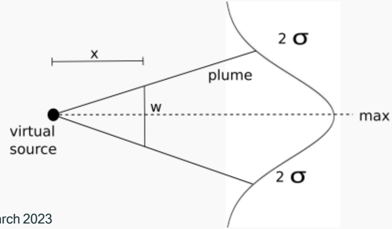
Data acquisition and processing - River Ray

A field campaign was done using a RiverRay, which provided a dispersion coefficient ($D_{T_{RR}}$) calculated using the equation of Socolofsky & Jirka (2005) for point source:

$$D_{T_{RR}} = \frac{w^2 U}{32x}$$

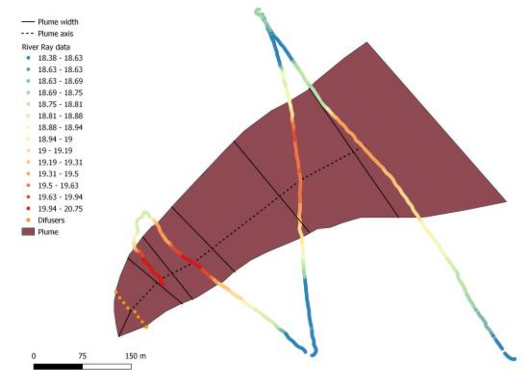
where w the plume width and x the distance from the virtual outfall.

ADCP RiverRay model, manufactured by Teledyne RDI, USA

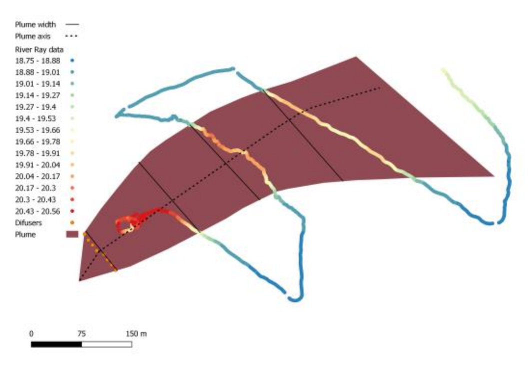


Methods and Preliminary Results

Data acquisition and processing - River Ray



First set of measurements - $D_{T_{RR}}$ = 0.27 m^2/s

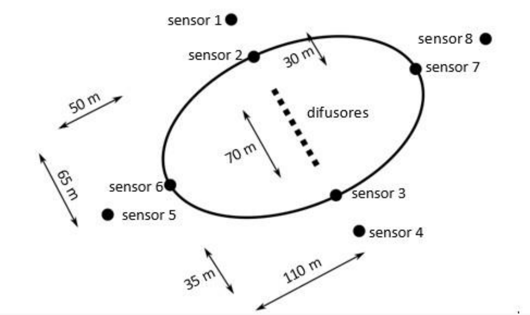


Second set of measurements - $D_{T_{RR}}$ = 0.40 m^2/s

Methods and Preliminary results

Data acquisition and processing - STAR

Starmon Mini HiRes, manufactured by Star Oddi, Iceland



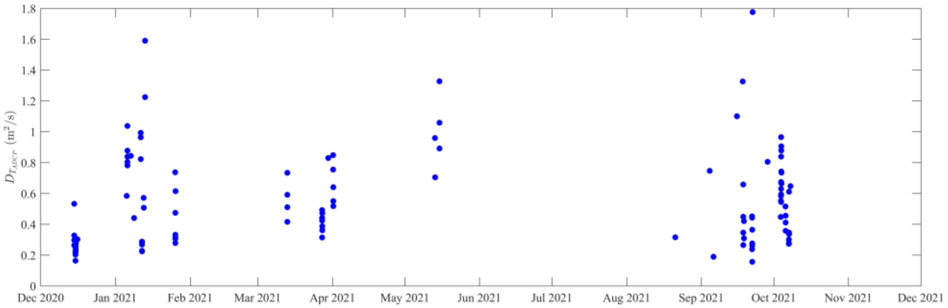
Estimation of the dispersion coefficient using the equation of Rutherford (1981) for continuous vertical lineal source:

$$D_{T_{STAR}} = \left(\frac{q_w T'_w}{dT'} \right)^2 \frac{1}{4\pi x U},$$

- $T' = T - T_0$
- T_0 the water body temperature
- T the temperature of the sensor
- T_w the discharge temperature
- q_w the discharge rate
- x the distance from the sensor to the virtual discharge origin

Methods and Preliminary results

Results - STAR



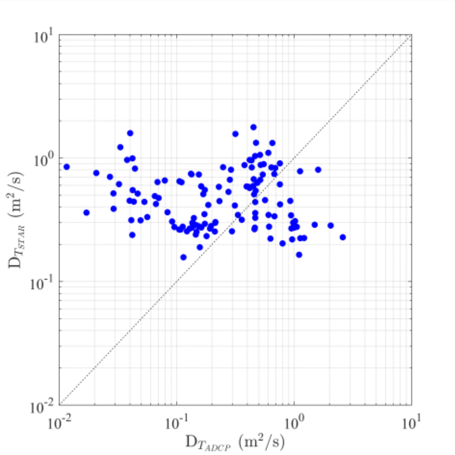
Transverse horizontal dispersion coefficient

Results and Discussion

Comparison

- River Ray and ADCP:

	1st set	2nd set
$D_{T_{RR}}$	0.27	0.40
$D_{T_{ADCP}}$	0.20	0.15



- Temperature sensors and ADCP:

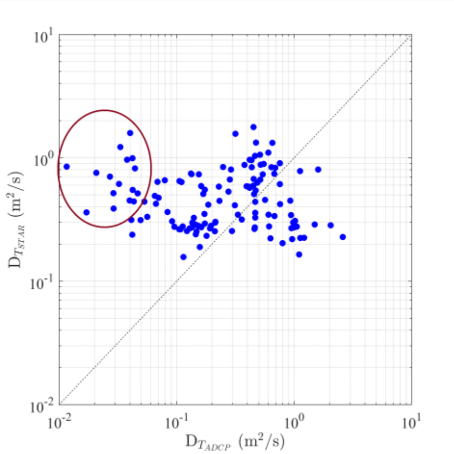
The majority of the calculations are of the same order of magnitude, from 10^{-1} to 10^{2} m^2/s.
A small cloud of data points seem to underestimate the dispersion.

Results and Discussion

Comparison

The data was analyzed considering waves, and sensitivity analysis to constants, such as the Manning and drag coefficient, was done.

Hypothesis ➜ initial mixing due to the difusers.



Conclusions

Conclusions

- The comparison with measurements results in similar values with a slight underestimation in some cases, when considering the other methodology as a reference.
- Results are in the same order of magnitude of bibliography for estuaries: 0.3 m^2/s (Rutherford, 1981).
- Extensive tracer campaigns are rare and extremely expensive, while ADCP measurements are widely used, thus the advantages of the velocity profile calculations to estimate dispersion coefficients are large.
- It allows to estimate the dispersion coefficient during diverse hydrodynamic conditions, including strong winds and storms.
- No specific considerations must be taken previous to the deployment regarding the ADCP configuration, therefore, already available data could be used.

Conclusions

Future work

- Apply the methodology to a longer timeseries.
- Consider the initial mixing due to the difusers.
- Finish my thesis by May/June 2023.
- Include the effect of waves on the turbulent mixing in the Río de la Plata estuary would improve the results.

Thank you!
Questions and comments?
lponce@fing.edu.uy

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