



MODELACION NUMERICA DE VERTIMIENTOS CON DELFT3D

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Hoja de Vida

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Académico

- Ing. Mecánico de Fluidos
- Mg. Ingeniería Hidráulica

Experiencia profesional

- DIHIDRONAV
- Consultoría ambiental

Experiencia docente

- Docencia
- Asesoría de tesis
- Publicación de artículos
- Participación en proyectos

Línea de investigación

- Hidráulica marítima
- Oceanografía Costera
- Dinámica Litoral
- Transporte de sedimentos

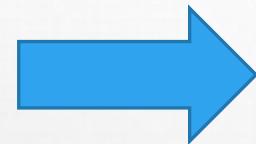
Contacto: ejguzor@gmail.com
eguzmanz@unmsm.edu.pe

Dedicado a
Donny David Guzman Zorrilla



PROCESO

DISPERSION DE
SUSTANCIAS



TIPO DE MODELACION

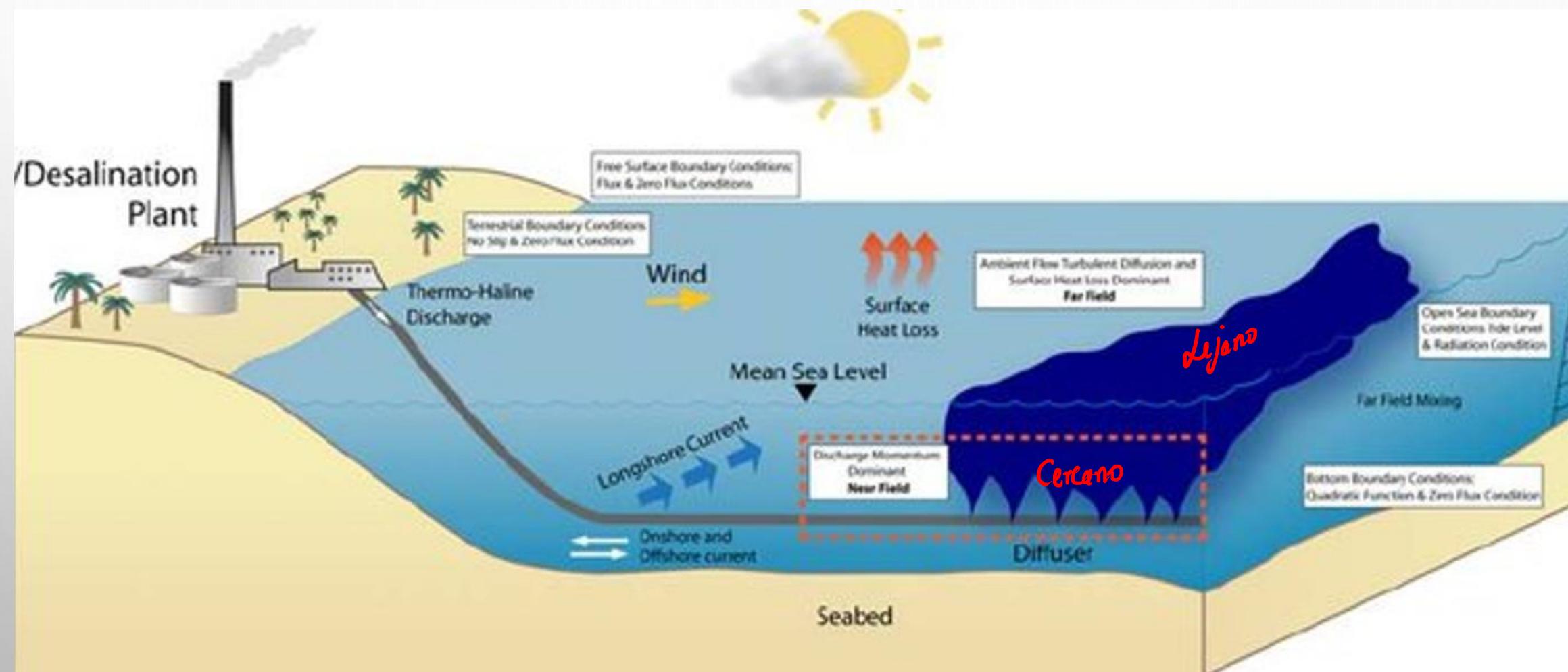
PLUMA DE DISPERSION

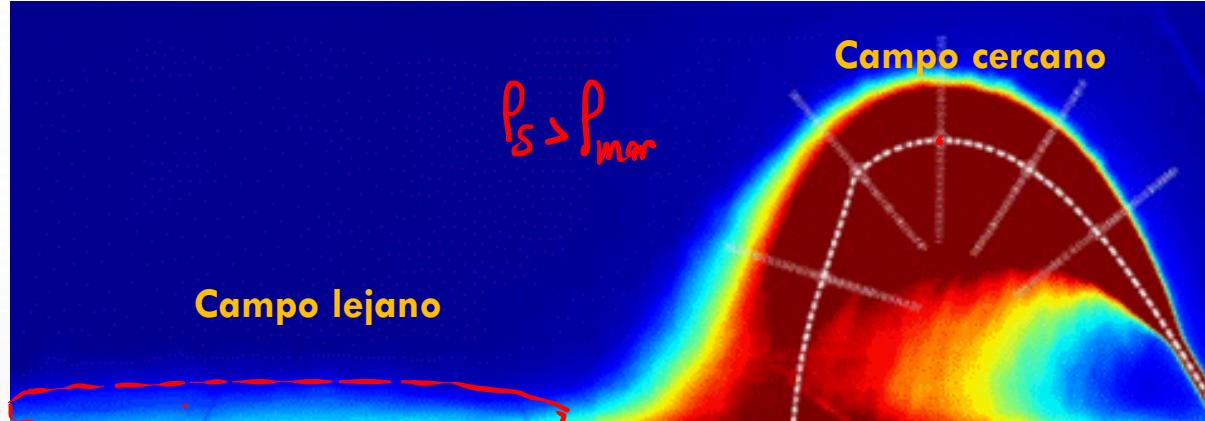
TIPO DE MODELO

Modelos de campo
cercano

Modelos de campo
lejano

ESQUEMA GENERAL DEL PROCESO DE DISPERSION





Fuente: <http://mixzoninc.blogspot.com/2013/05/cormix-mixing-zone-model-training-and.html>

Campo cercano: es el impulso inicial del chorro quien domina el proceso de dispersión

{
CORMIX
VISUAL PLUMES
VISJET

{
DEFLT3D
EFDC
ROMS

Campo lejano: es la velocidad del medio receptor quien domina el proceso de dispersión

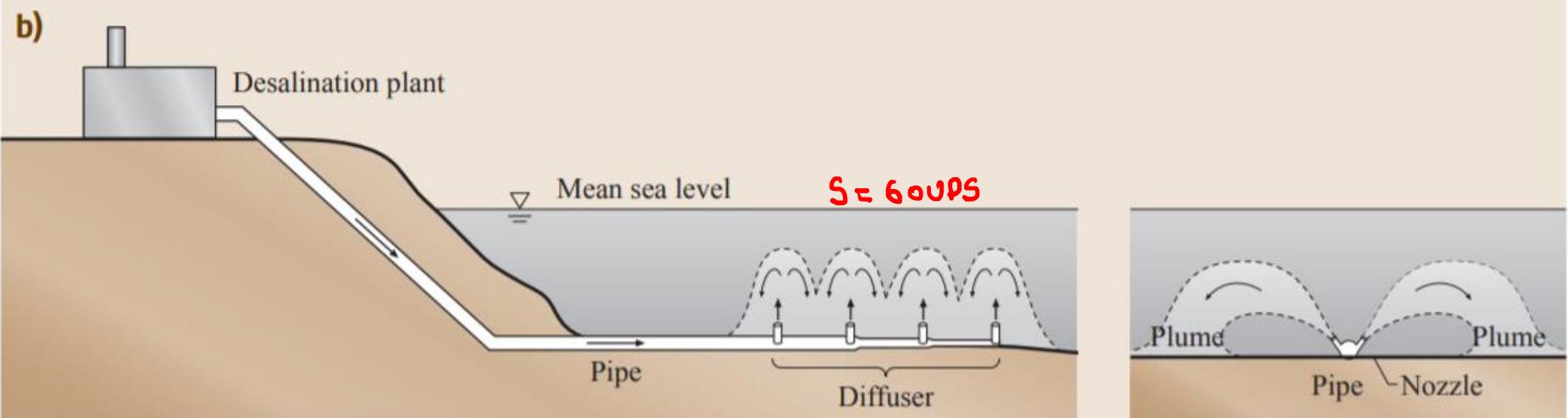
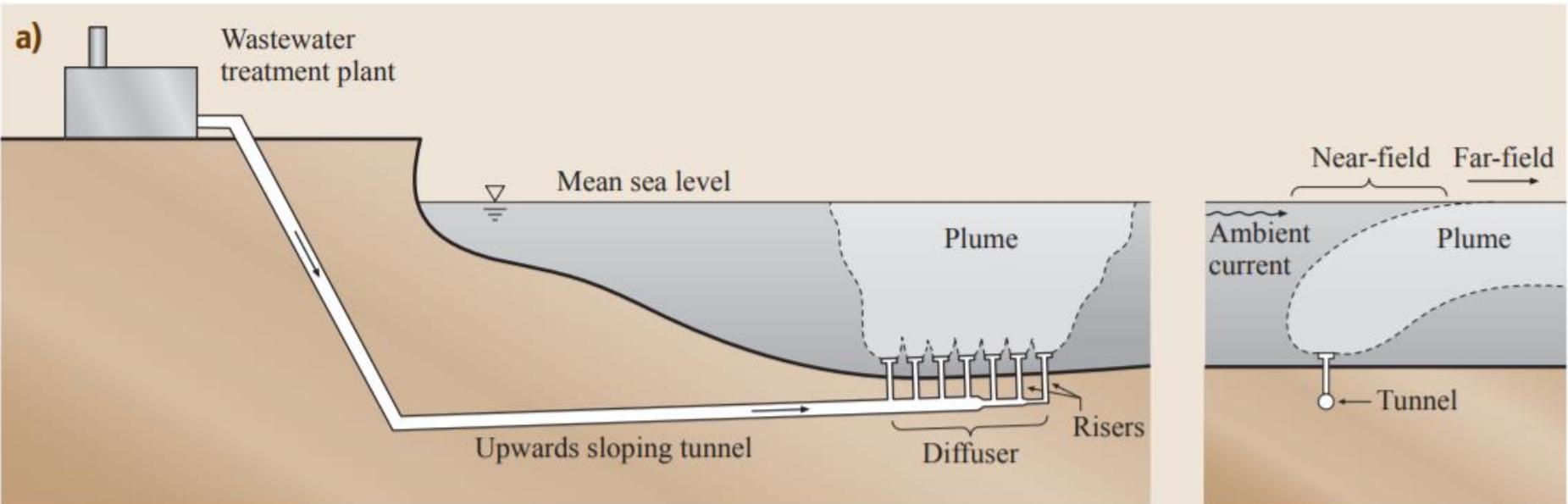


Fig. 32.1a,b Schematics of (a) a wastewater treatment plant outfall, and (b) a desalination plant outfall, showing side views and end views

Febrero 2017



Image Landsat / Copernicus
Image © 2023 Maxar Technologies

Abril 2017



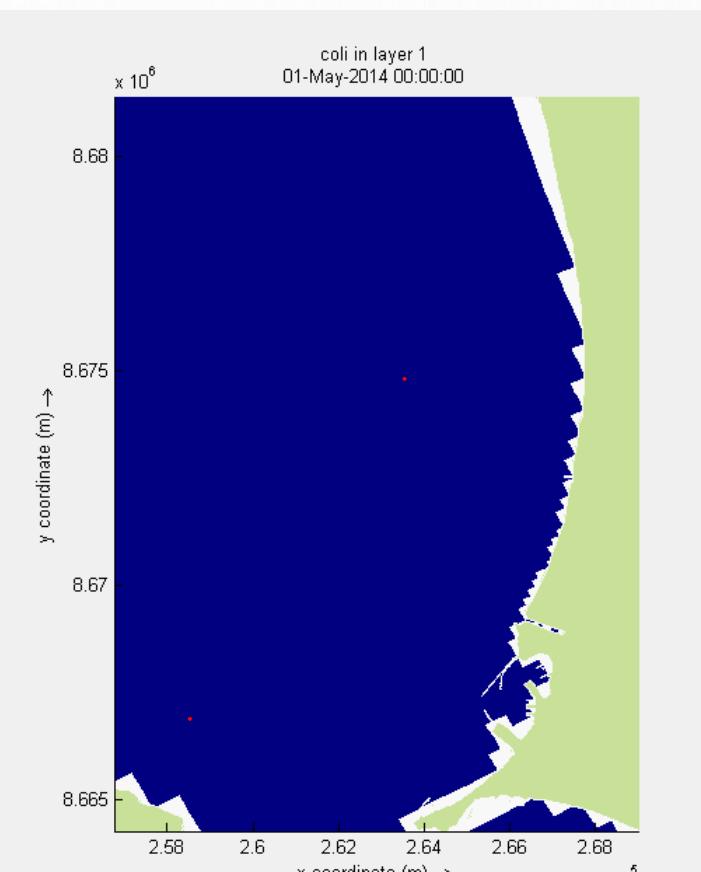
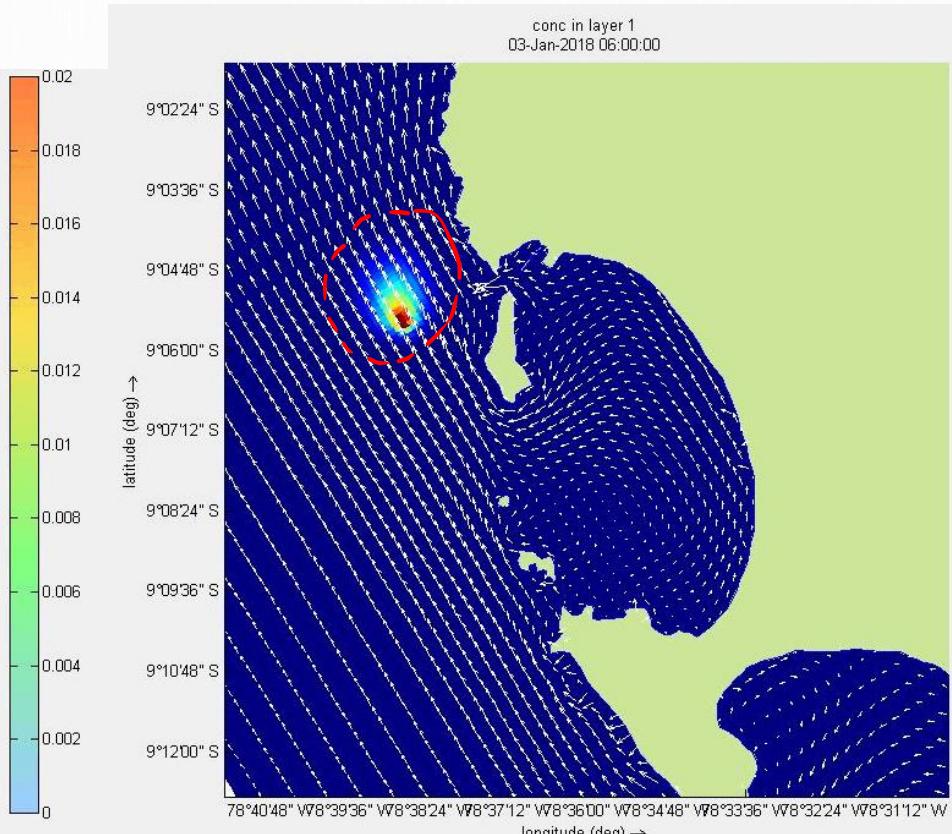
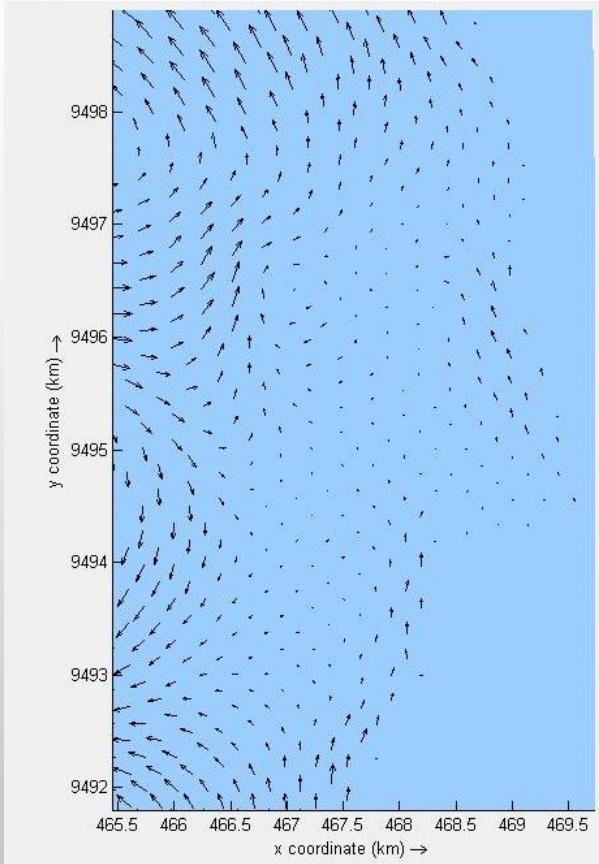
Image Landsat / Copernicus
Image © 2023 CNES / Airbus
Image © 2023 Maxar Technologies

Enero 2020



Image Landsat / Copernicus
Image © 2023 Maxar Technologies

MODELACION DE DISPERSION DE SUSTANCIAS EN CAMPO LEJANO



ASPECTOS GENERALES DE LA ECUACION DE ADVECCION Y DIFUSION

ECUACION GOBERNANTE DEL PROCESO DE DISPERSION DE SUSTANCIAS

$$\frac{\partial c}{\partial t} + \vec{\nabla}(c \cdot \vec{u}) = D \nabla^2 c$$

Ecuación de conservación de escalares

Cuando existe la acción de la turbulencia, la ecuación de dispersión puede escribirse como

The diagram illustrates the dispersion equation with its components:

- Variación temporal:** $\frac{\partial c}{\partial t}$
- Advección:** $u \frac{\partial c}{\partial x} + v \frac{\partial c}{\partial y} + w \frac{\partial c}{\partial z}$
- Fuente contaminante:** $Q_{(x_0, y_0, t)}$
- Decaimiento:** $\frac{2.3}{T_{90}} c$
- Difusión horizontal y vertical:** $\mathcal{E}_h \left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2} \right) + \mathcal{E}_v \frac{\partial^2 c}{\partial z^2}$

Below the diagram, a blue arrow points downwards from the advection term towards the following text:

Existe dependencia de la velocidad de las corrientes → **Se tiene que emplear un modelo hidrodinámico**

*C : Concentración
Sustancia*

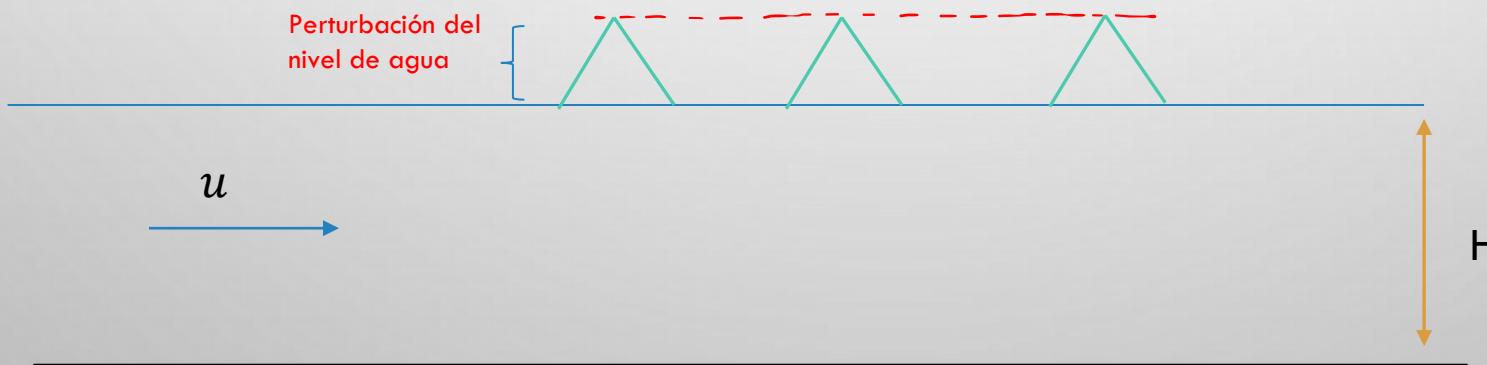
ECUACION DE ADVECCION PURA

Las sustancias se desplazan influenciados sólo por efectos de la velocidad del flujo

$$\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} + v \frac{\partial c}{\partial y} + w \frac{\partial c}{\partial z} = 0$$

Caso simplificado 1D: aplicación a un canal con profundidad constante

$$\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} = 0$$



En forma discreta tenemos:

$$\frac{\Delta c}{\Delta t} = -u \frac{\Delta c}{\Delta x}$$

$$c_i^{k+1} = c_i^k - u \frac{\Delta t}{\Delta x} \Delta c$$

Futuro Presente

Es conocido como numero de Courant

$$CFL = \frac{u}{\Delta x / \Delta t}$$

$$CFL = \frac{u \Delta t}{\Delta x}$$

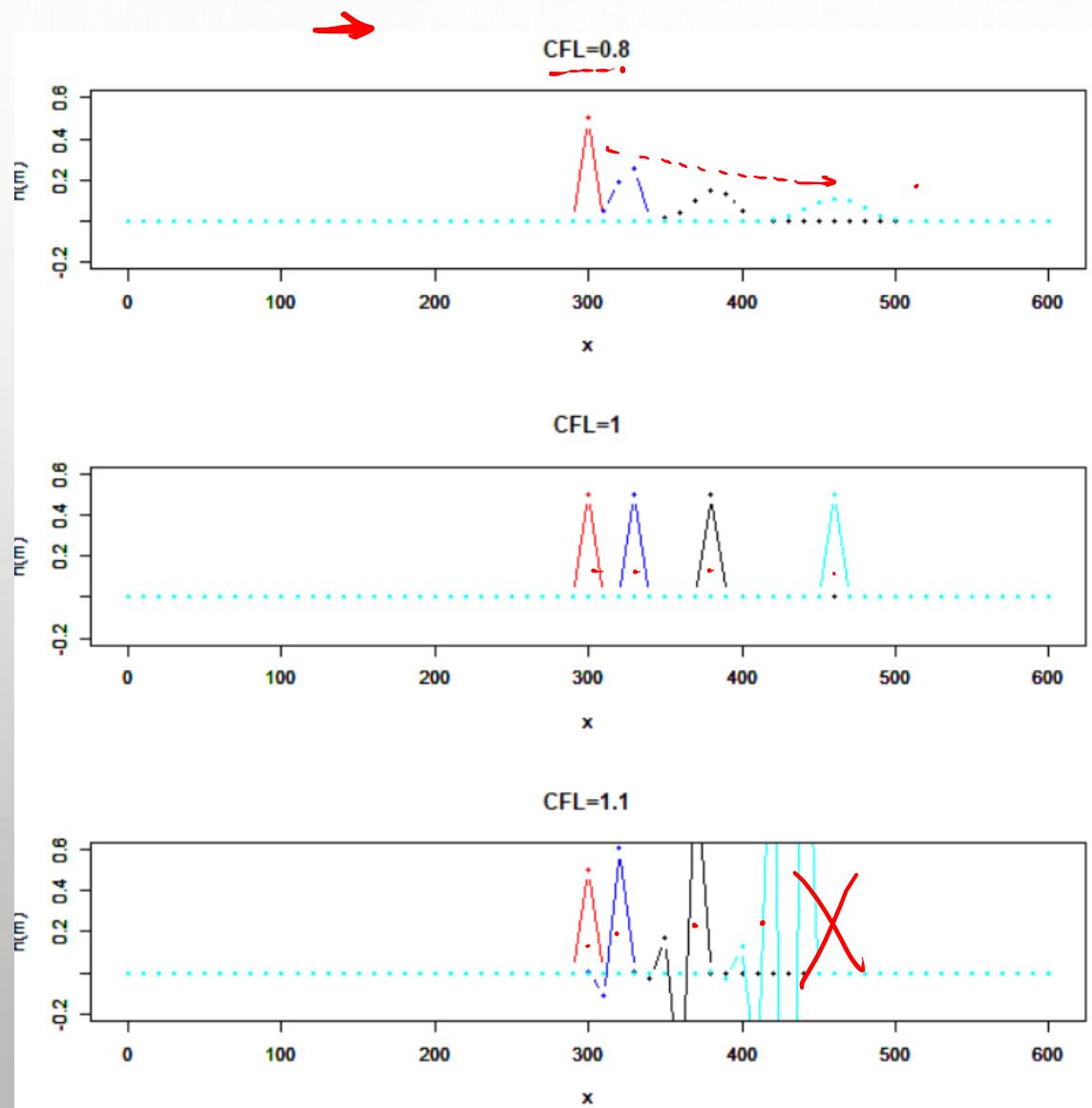
El paso de tiempo se puede calcular en función de CFL

$$\Delta t = CFL \frac{\Delta x}{u}$$

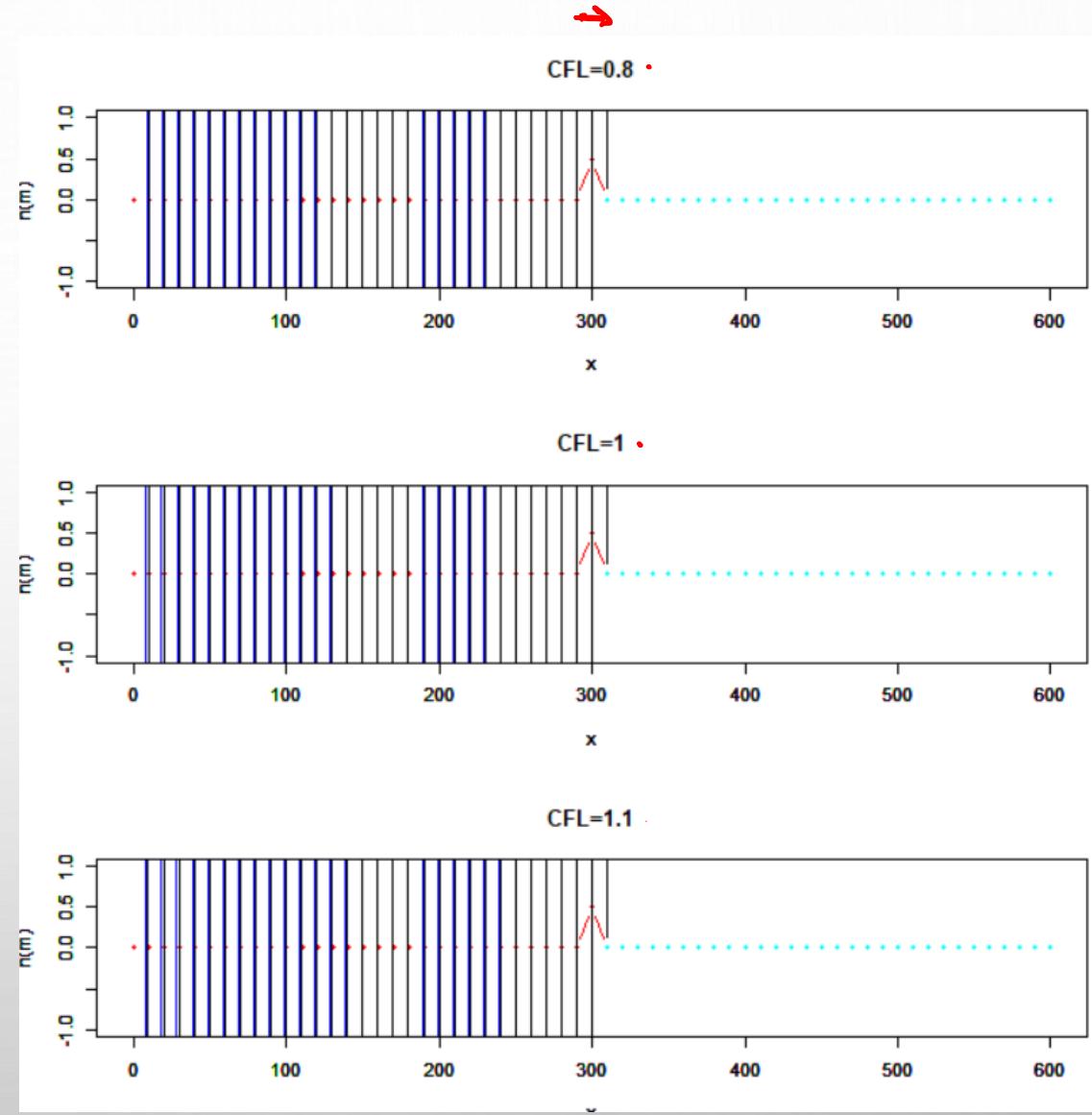
CFL < 1 Explícitos

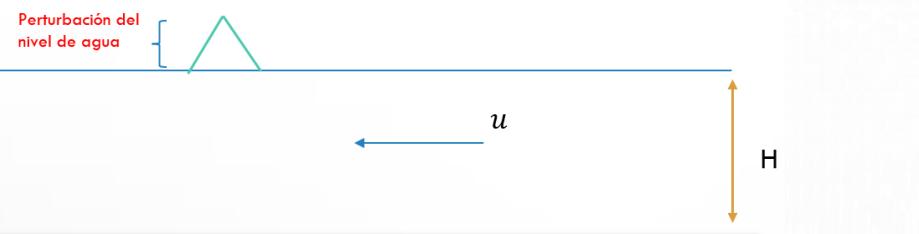
CFL ≤ 10 Implícitos

Esquema FTBS



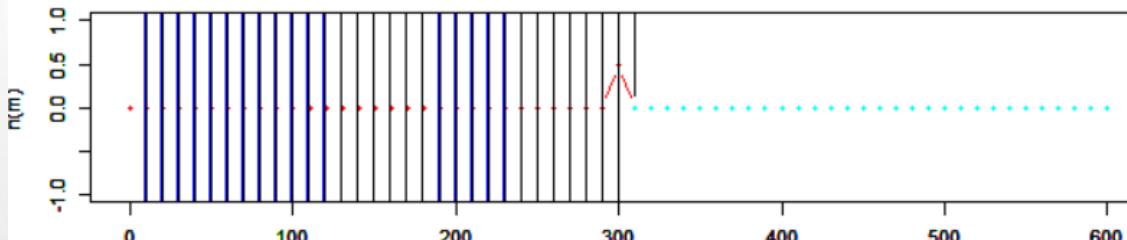
Esquema FTFS



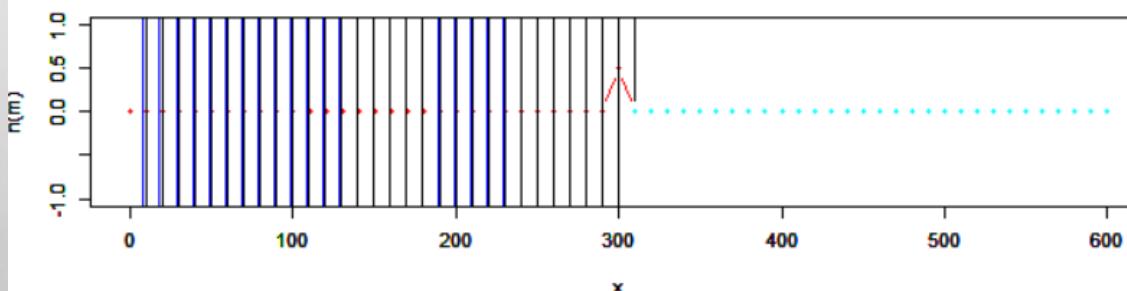


FTBS

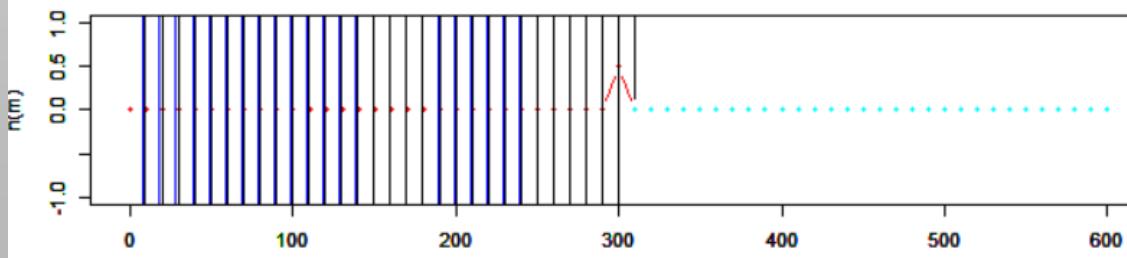
CFL=0.8



CFL=1

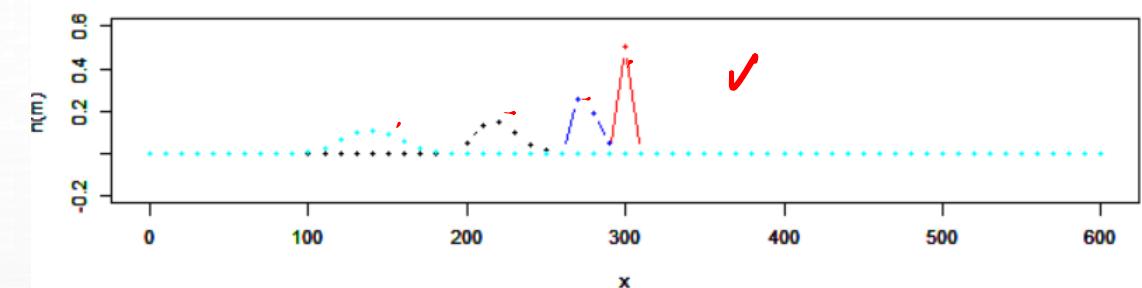


CFL=1.1

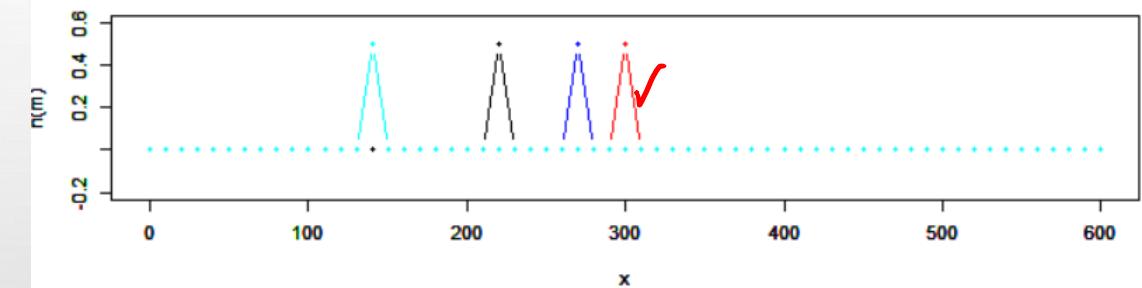


FTFS

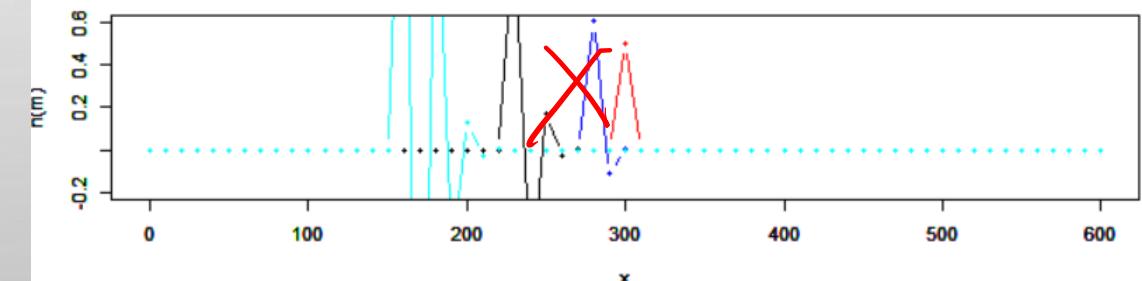
CFL=0.8



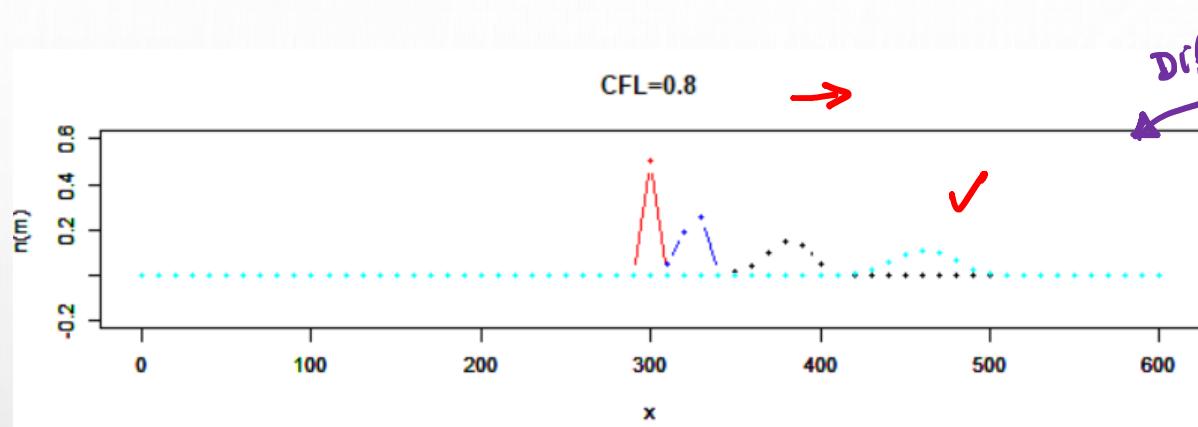
CFL=1



CFL=1.1

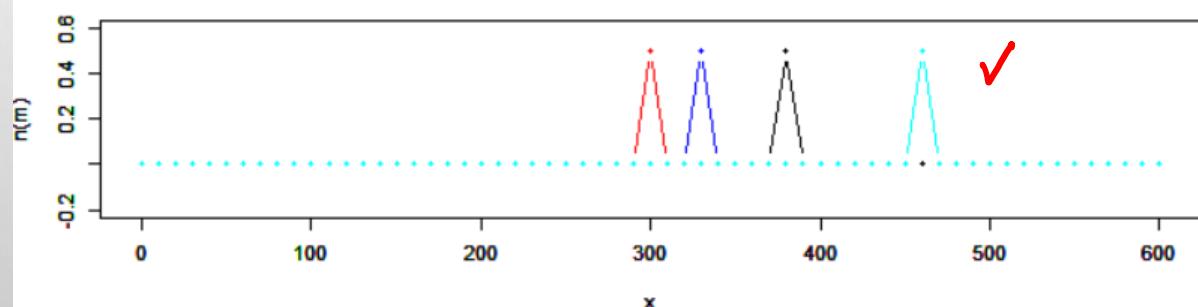


Esquema UPWIND: alterna entre esquemas adelantados o atrasados según el cambio de dirección de flujo

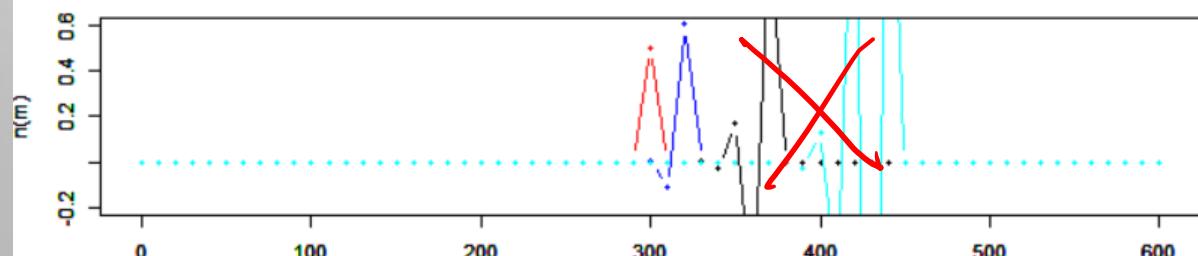


$CFL \leq 1$ Estable !

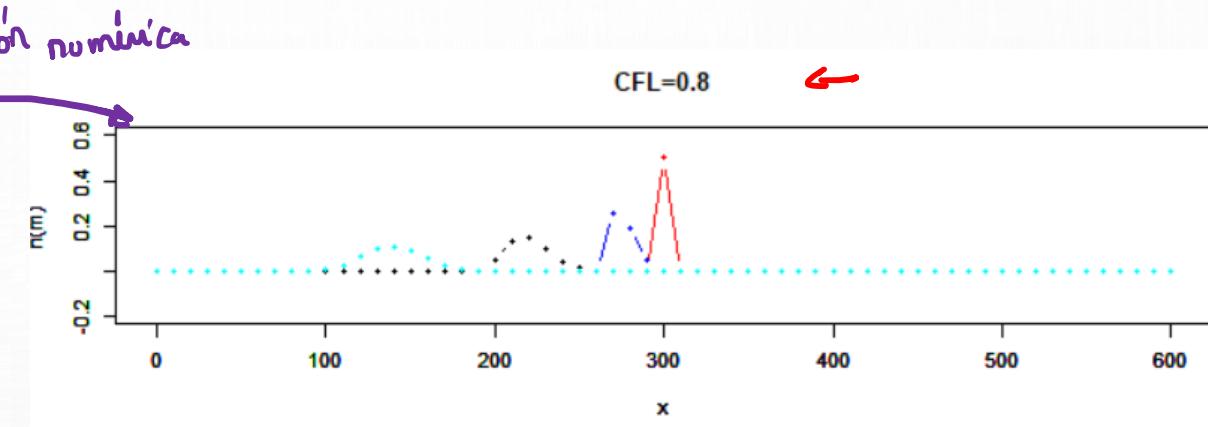
CFL=1



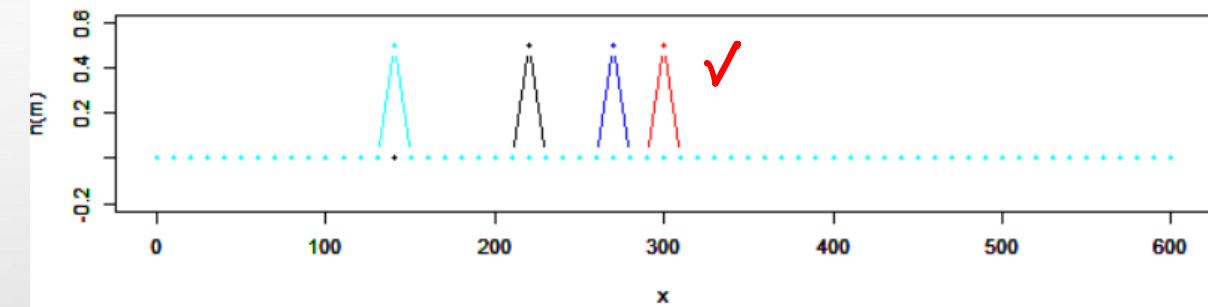
CFL=1.1



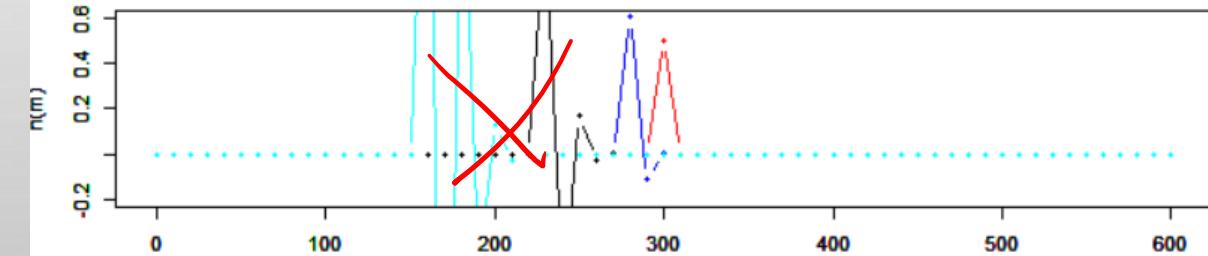
Si $CFL \leq 1$ esquema estable



CFL=1



CFL=1.1



ECUACION DE DIFUSION PURA

Las sustancias se desplazan influenciados sólo por efectos de la velocidad del flujo

$$\frac{\partial c}{\partial t} = \varepsilon_h \left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2} \right) + \varepsilon_v \frac{\partial^2 c}{\partial z^2}$$

Caso simplificado 1D: aplicación a un canal con profundidad constante

$$\frac{\partial c}{\partial t} = \varepsilon_H \frac{\partial^2 c}{\partial x^2}$$



En forma discreta tenemos:

$$\frac{\Delta c}{\Delta t} = E_H \frac{\Delta^2 c}{\Delta x^2}$$

$$c_i^{k+1} = c_i^k + \frac{E_H \Delta t}{\Delta x^2} \Delta^2 c$$

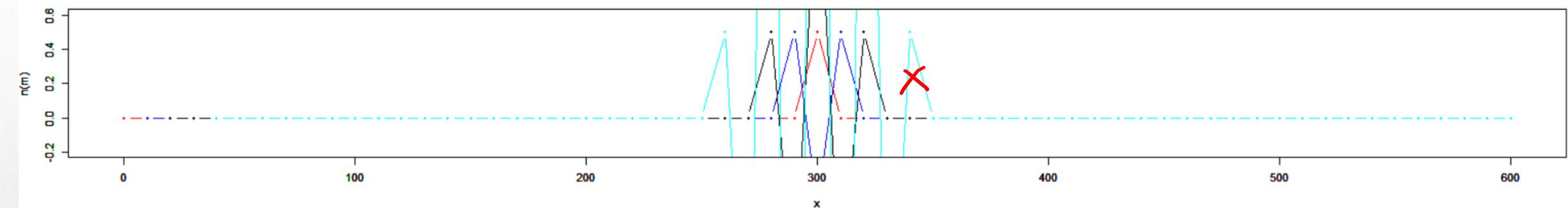
Es conocido como numero de Peclet

$$Pe = \frac{E_H \Delta t}{\Delta x^2}$$

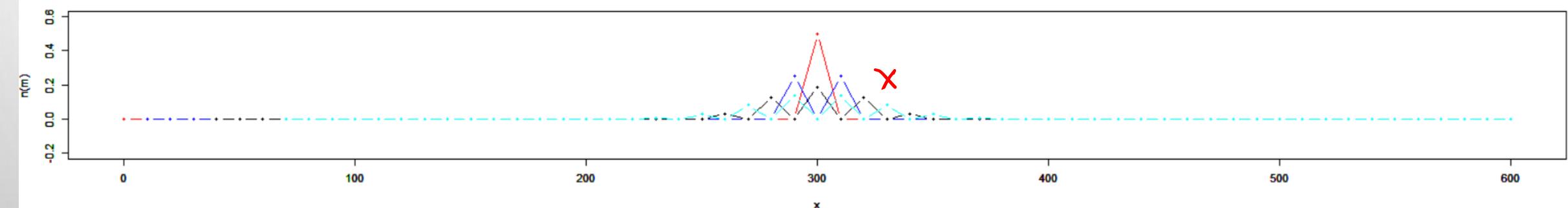
El paso de tiempo se puede calcular en función de ~~CFL~~ Pe

$$\Delta t = Pe \frac{\Delta x^2}{E_H}$$

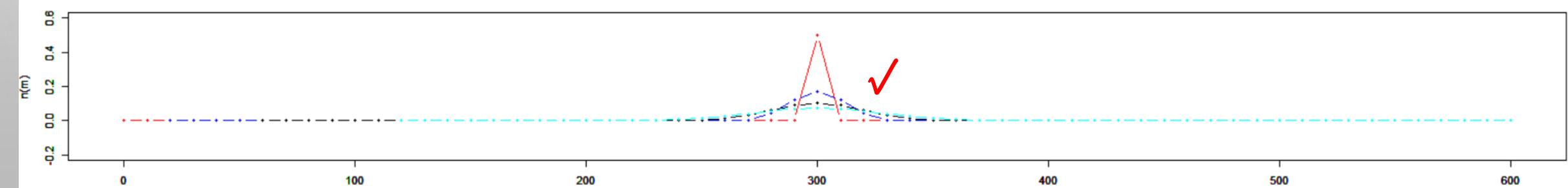
$Pe=1$



$Pe=0.5$



$Pe=0.3$



Si $Pe < 0.5$, el esquema es estable

ECUACION DE ADVECCION – DIFUSION EN 1D

Las sustancias se desplazan influenciados sólo por efectos de la velocidad del flujo

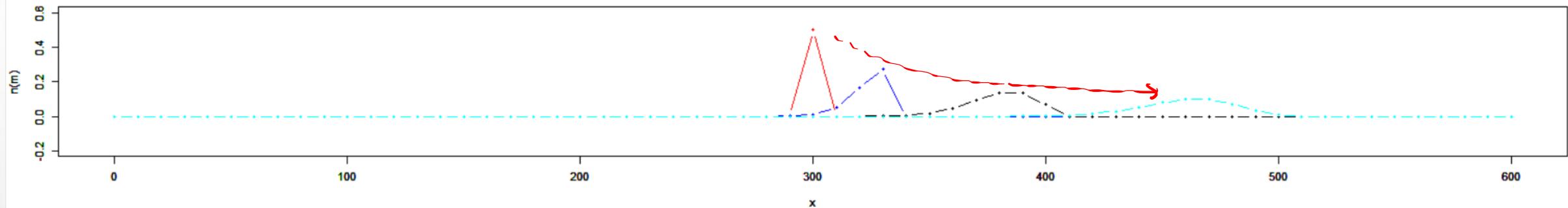
$$\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} = E_h \frac{\partial^2 c}{\partial x^2}$$

Controlado
por CFL Controlado
por Pe

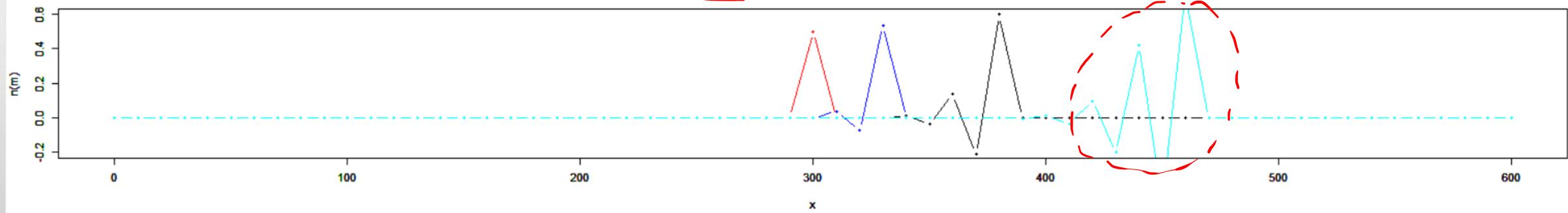


$Pe < 0.5$

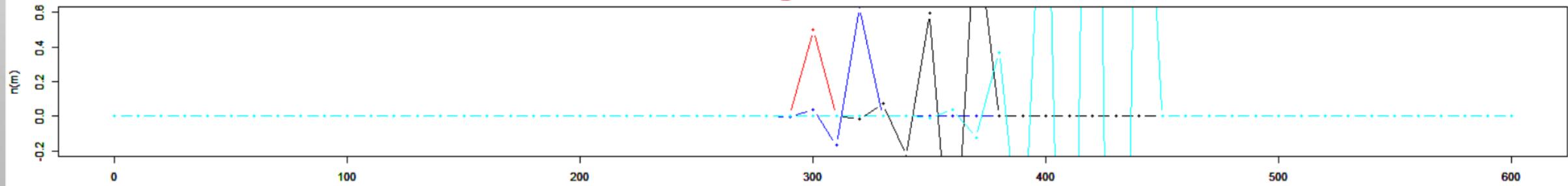
CFL = 0.8, Pe = 0.01, dx = 10, dt = 1.81seg



CFL = 1, Pe = 0.01, dx = 10, dt = 2.26seg

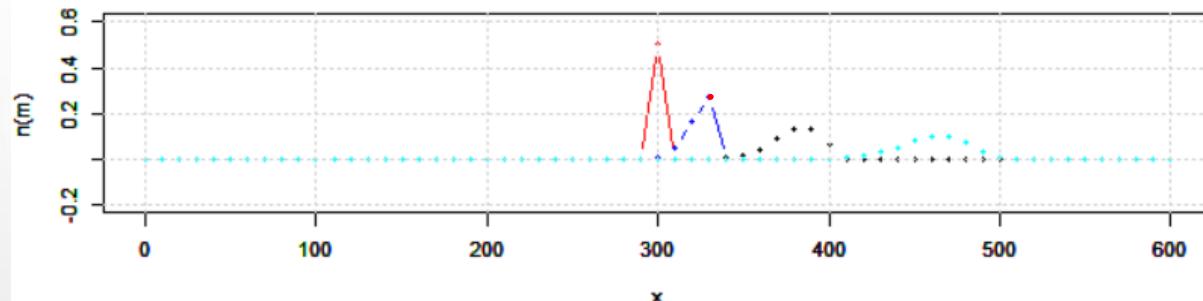


CFL = 1.1, Pe = 0.01, dx = 10, dt = 2.48seg

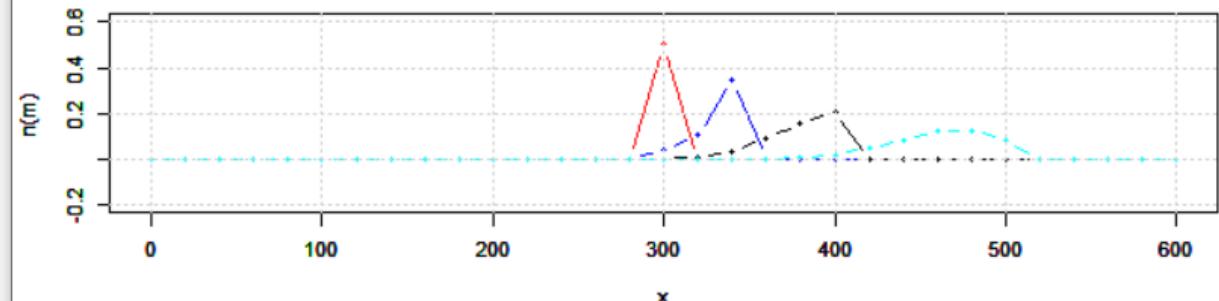


CFL

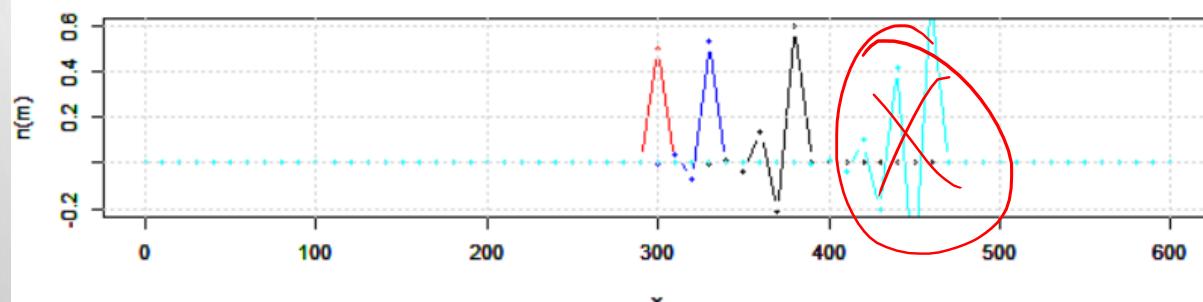
CFL = 0.8,Pe=0.01,dx= 10,dt= 1.81seg



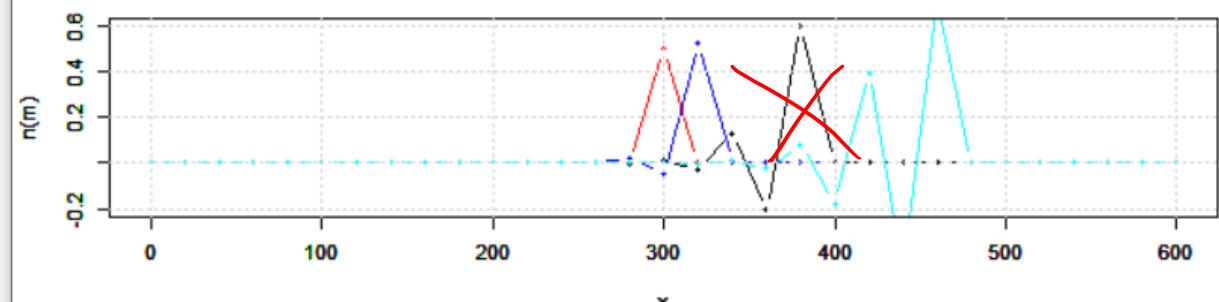
CFL = 0.8,Pe=0.01,dx= 20,dt= 3.61seg



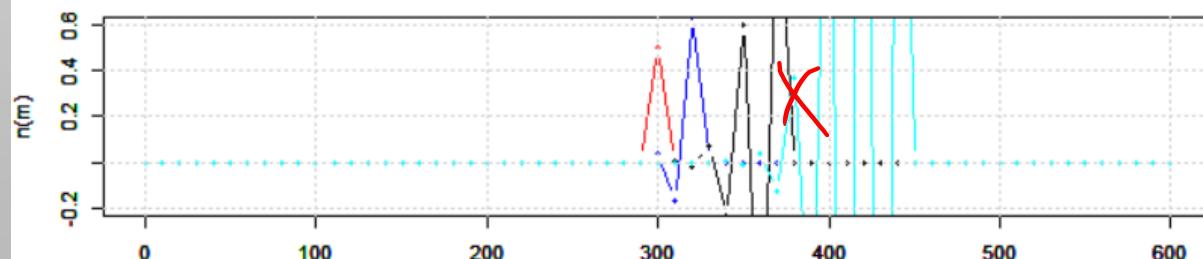
CFL = 1,Pe=0.01,dx= 10,dt= 2.26seg



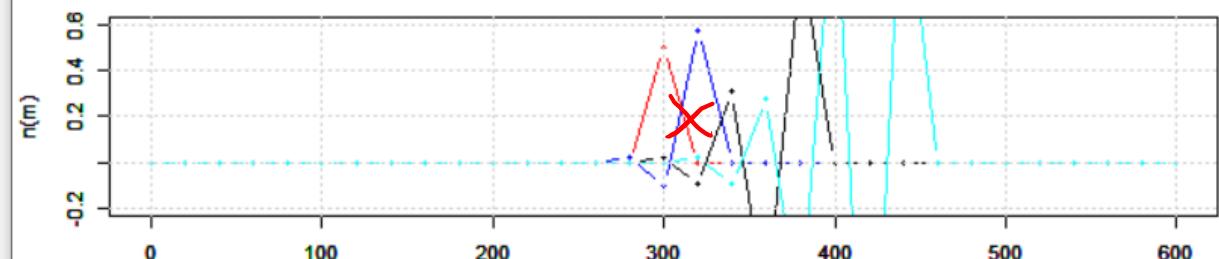
CFL = 1,Pe=0.01,dx= 20,dt= 4.52seg



CFL = 1.1,Pe=0.01,dx= 10,dt= 2.48seg

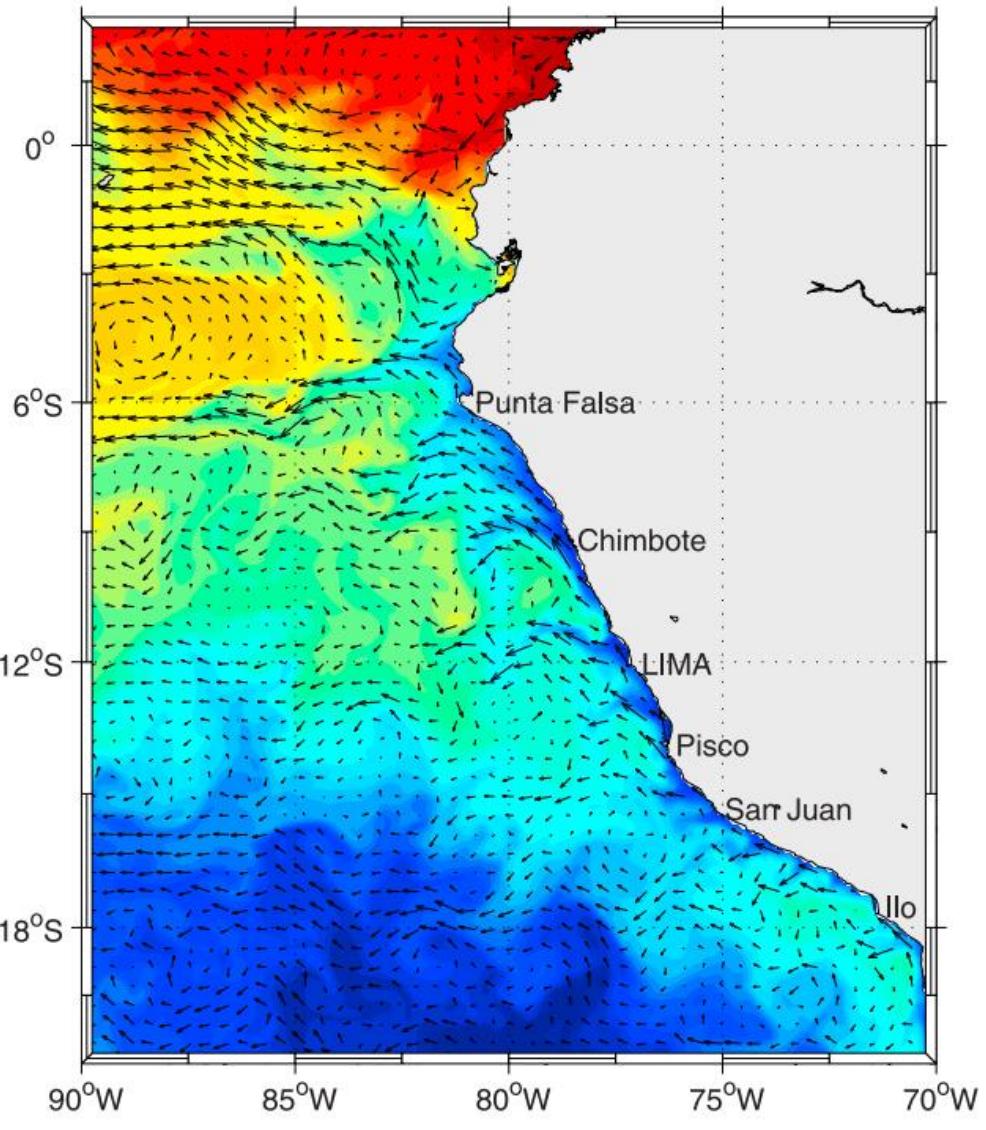


CFL = 1.1,Pe=0.01,dx= 20,dt= 4.97seg

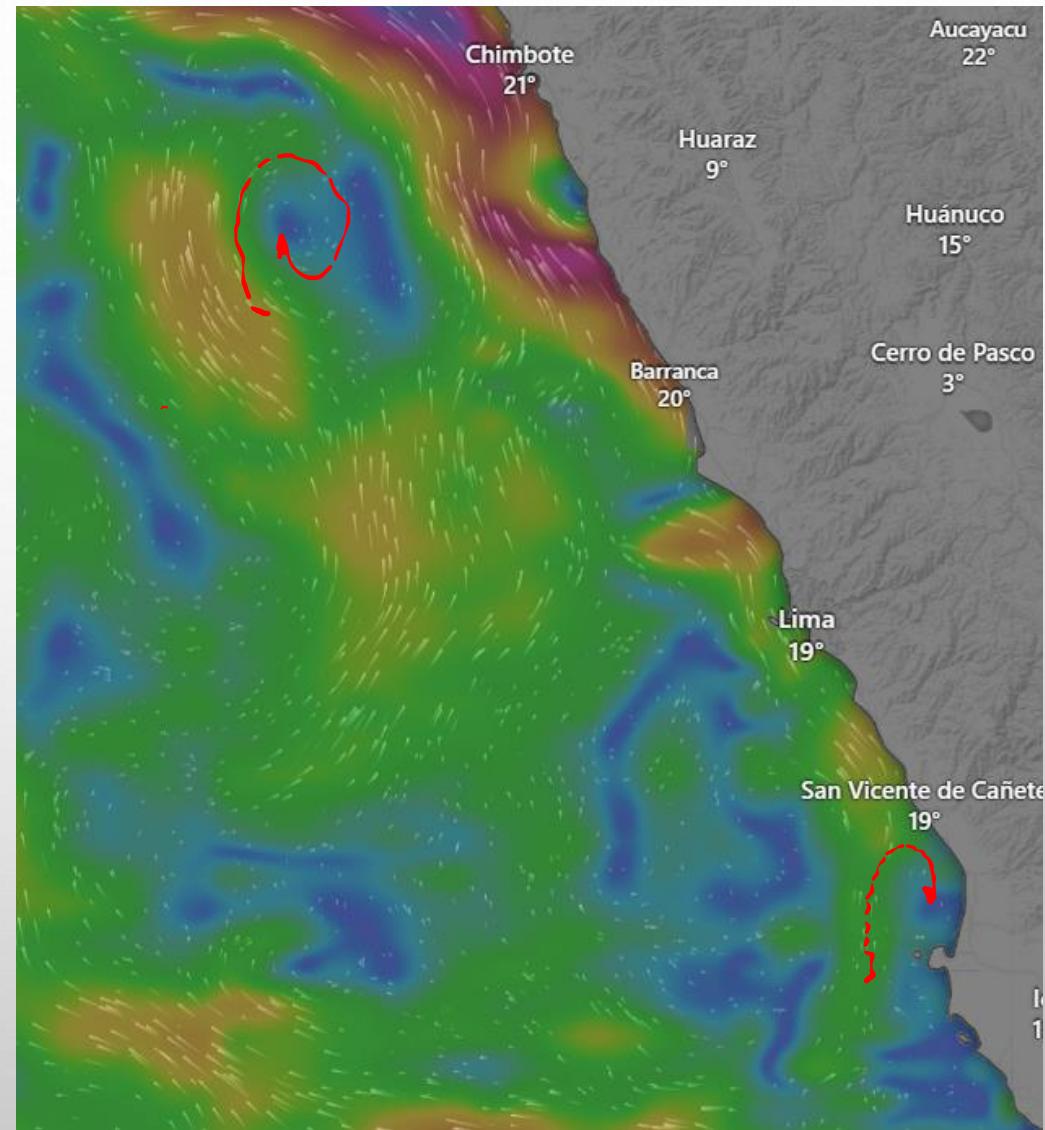


ESQUEMA GENERAL DEL PROCESO DE CIRCULACION

Circulación general frente al litoral peruano

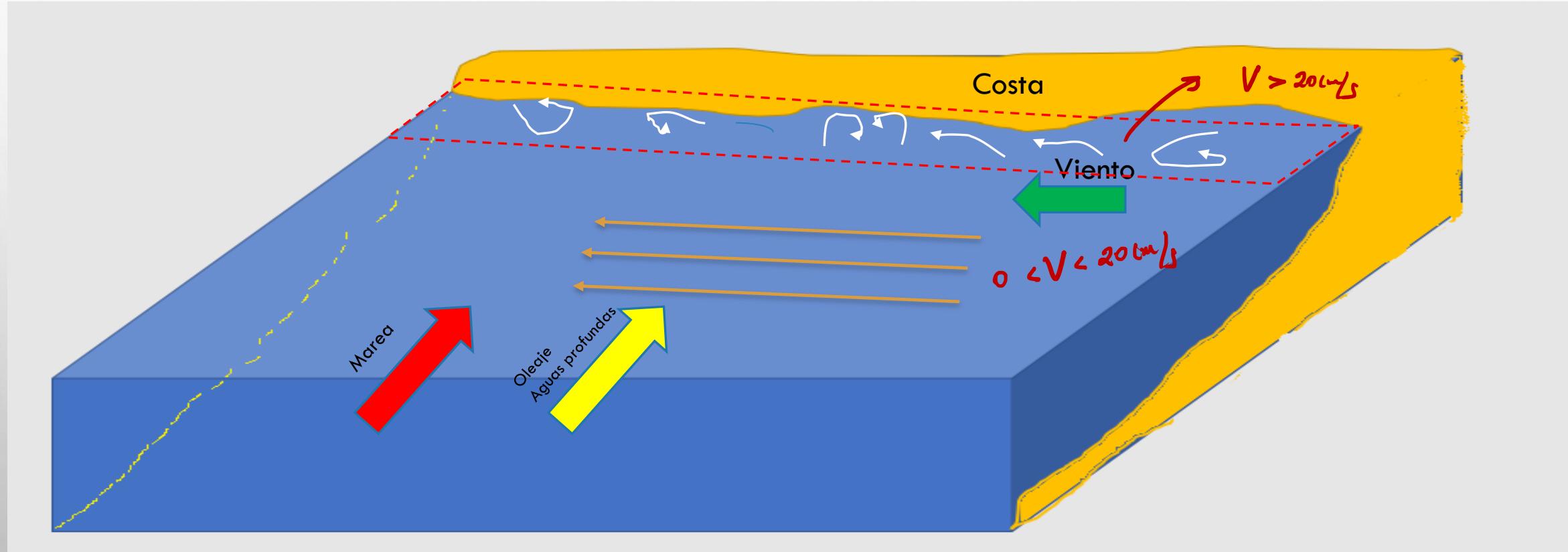


Fuente: Penven et. al 2005

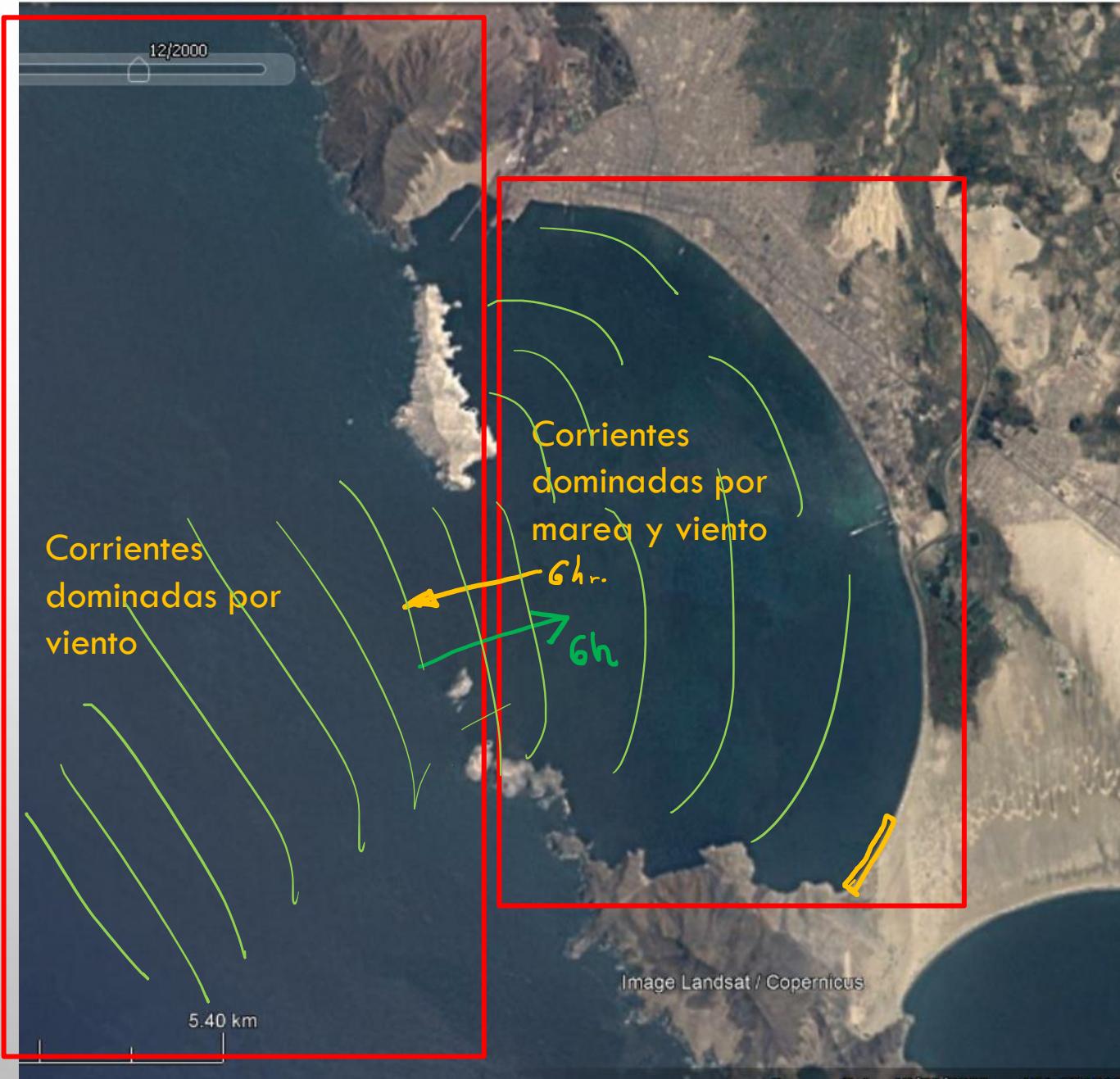
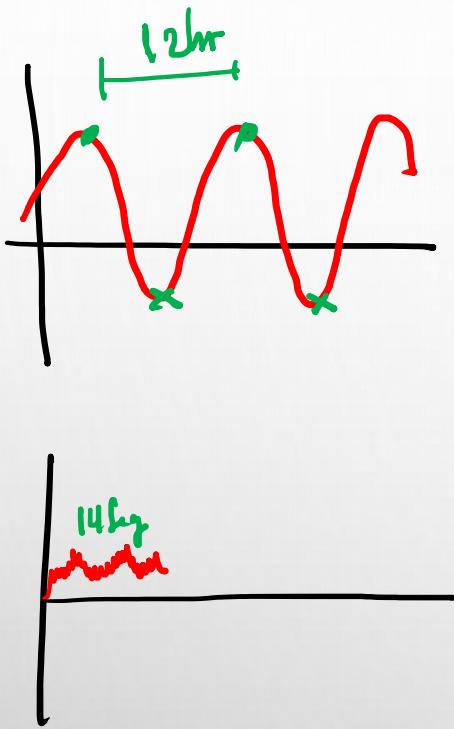


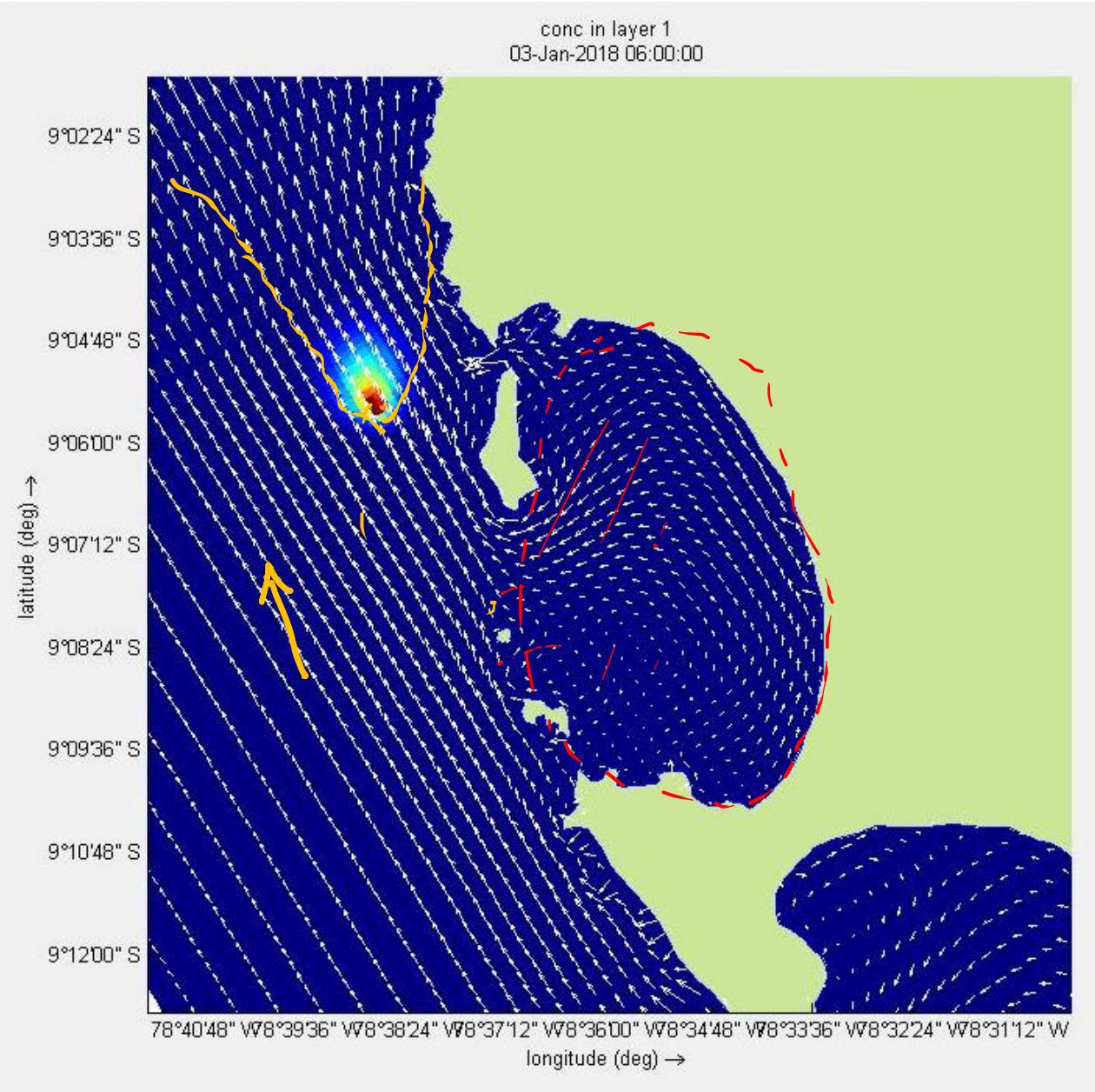
Fuente: Windy

Esquema general del proceso



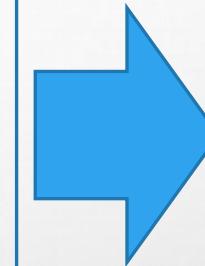






PROCESO DE MODELACIÓN NUMERICA

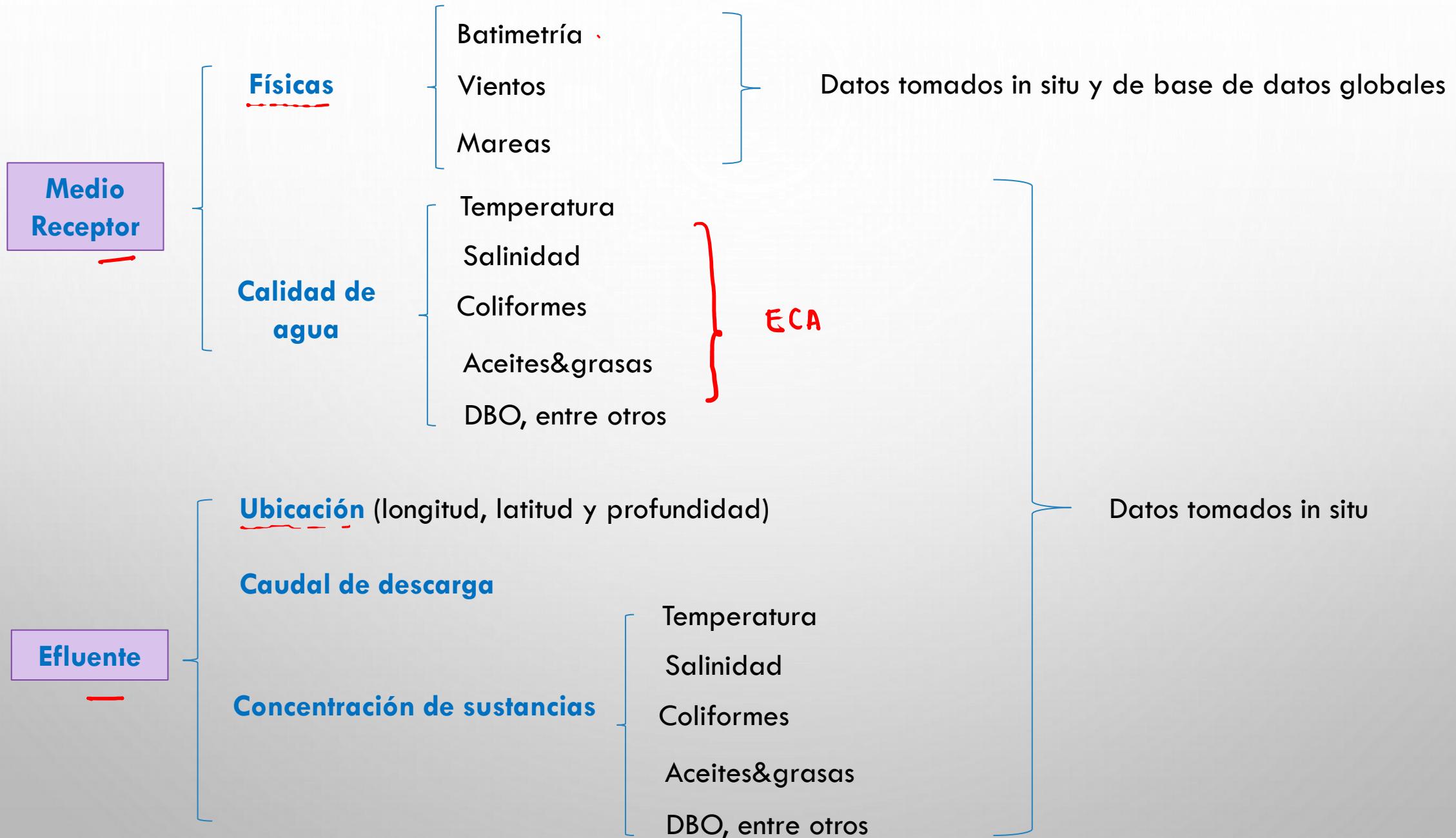
- RECOLECCION DE INFORMACIÓN**
(Toma de datos en campo y de datos históricos)
- ELABORACION DEL MODELO BASE**
(Generación de mallas, entre otros)
- CALIBRACION DE MODELO**
(regulación de parámetros relevantes)
- VALIDACION DE RESULTADOS**
(Se verifica la veracidad del modelo)



MODELO REALISTA
Nunca llega al 100%

DATOS NECESARIOS PARA LA MODELACION DE DISPERSION DE SUSTANCIAS

DATOS NECESARIOS PARA EL MODELAMIENTO DE CAMPO LEJANO



¿DONDE OBTENER DATOS GLOBALES?

BATIMETRIA

GEBCO

Datos de batimetría global con una resolución de 15 segundos (460m)

Data & Products ▾ Seabed 2030 Training News & Media About ▾ Contact

International Hydrographic Organization United Nations Educational, Scientific and Cultural Organization Intergovernmental Oceanographic Commission

General Bathymetric Chart of the Oceans

GEBCO aims to provide the most authoritative, publicly available bathymetry data sets for the world's oceans.

Download GEBCO's global grid Download polar grids Contribute data

ETOPO

Datos de batimetría global con una resolución de 1 minuto (1840m)

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NOAA > NESDIS > NCEI (formerly NGDC) > Marine Geology and Geophysics > Bathymetry & Relief

All Bathy/Relief Coastal DEMs Fishing Global Lakes Multibeam

ETOPO1 Global Relief Model

ETOPO1 is a 1 arc-minute global relief model of Earth's surface that integrates land topography and ocean bathymetry. Built from global and regional data sets, it is available in "Ice Surface" (top of Antarctic and Greenland ice sheets) and "Bedrock" (base of the ice sheets).

ETOPO1 Global Relief Model is used to calculate the Volumes of the World's Oceans and to derive a Hypsographic Curve of Earth's Surface.

Cite ETOPO1: doi:10.7289/N6C8276M

Grid Versions

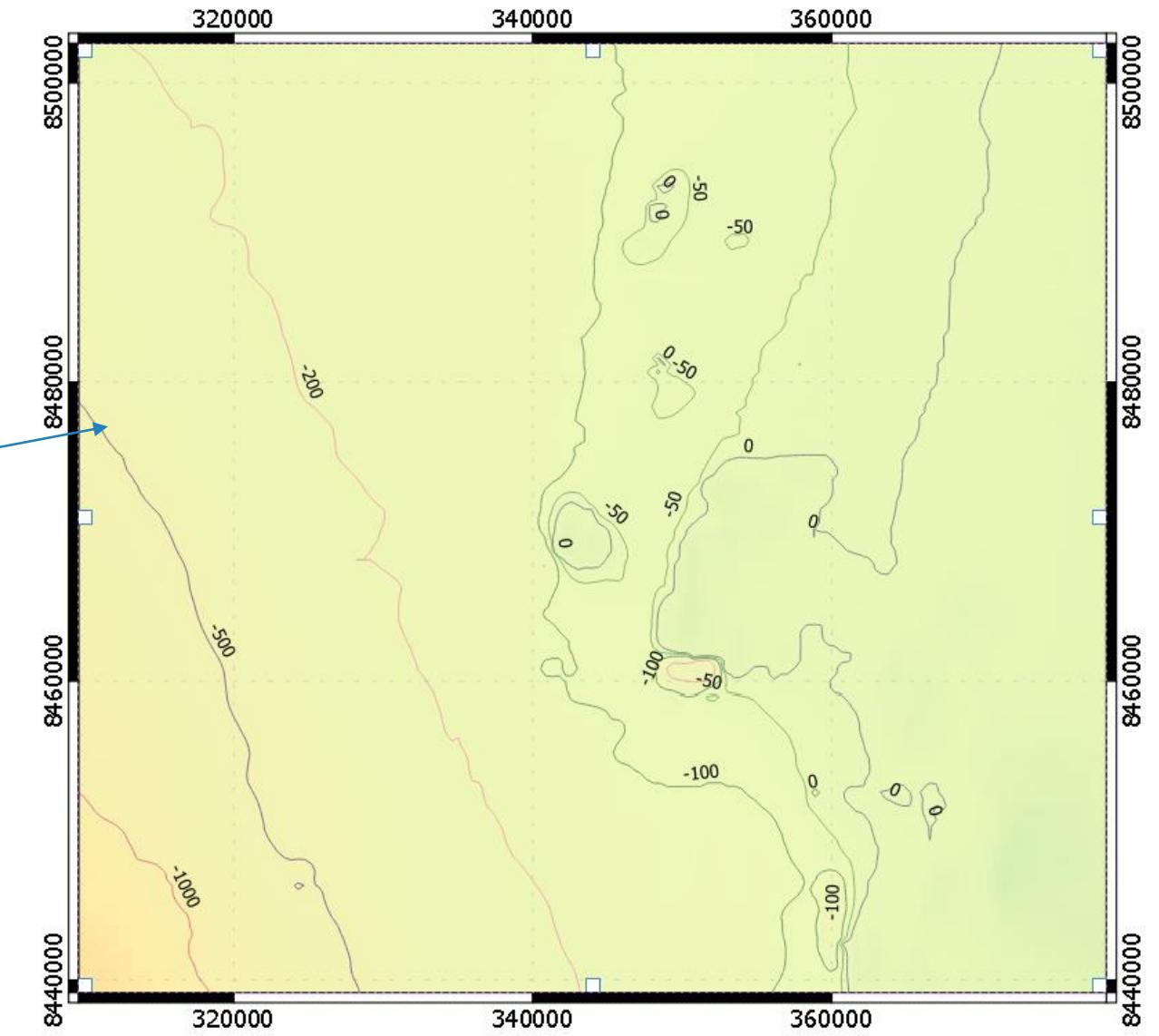
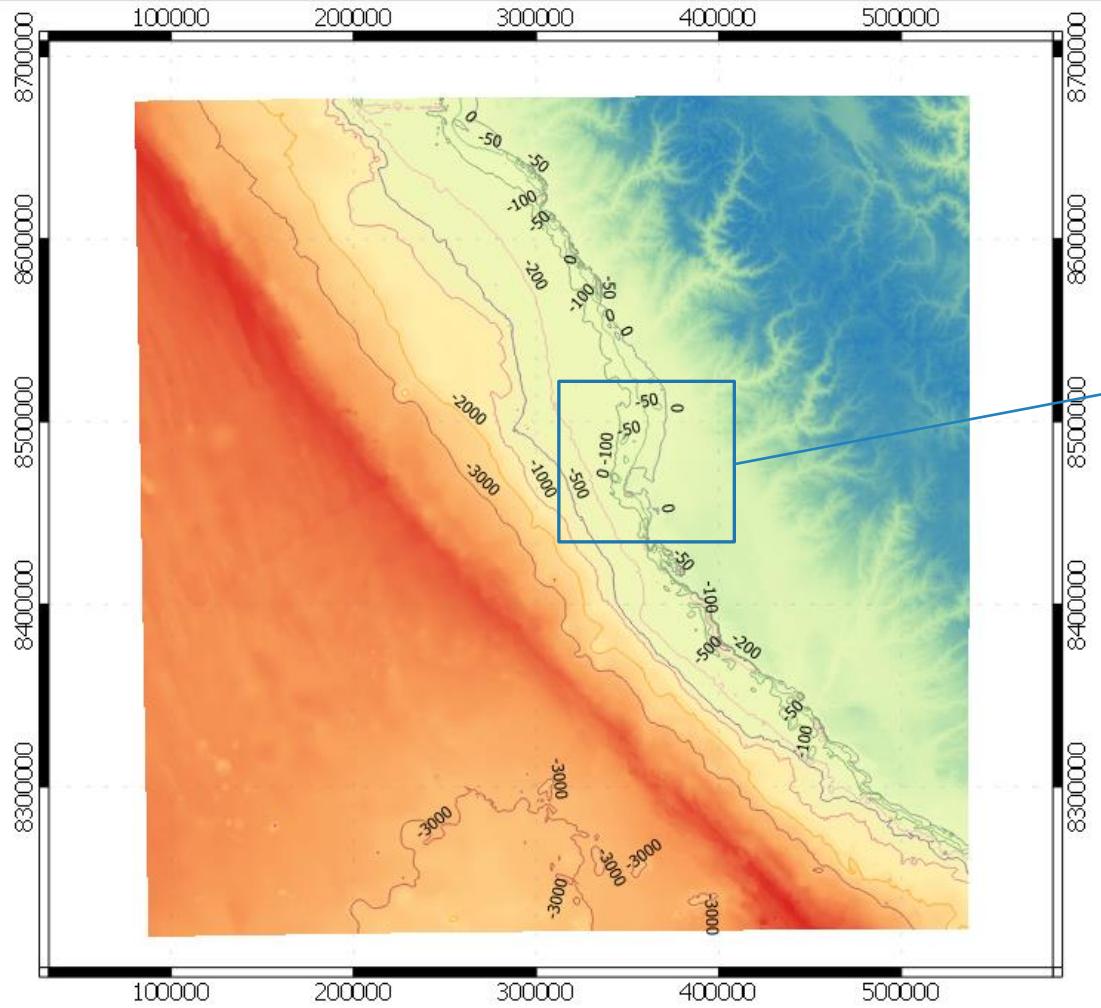
- ETOPO1 Ice Surface: Grid of Earth's surface depicting the top of the Antarctic and Greenland ice sheets.
 - grid-registered: netCDF, georeferenced tif
 - cell-registered: netCDF, georeferenced tif
- ETOPO1 Bedrock: Grid of Earth's surface depicting the bedrock underneath the ice sheets.
 - grid-registered: netCDF, georeferenced tif
 - cell-registered: netCDF, georeferenced tif

View Metadata. Relief for the rest of the world is the same in both versions.

Registrations

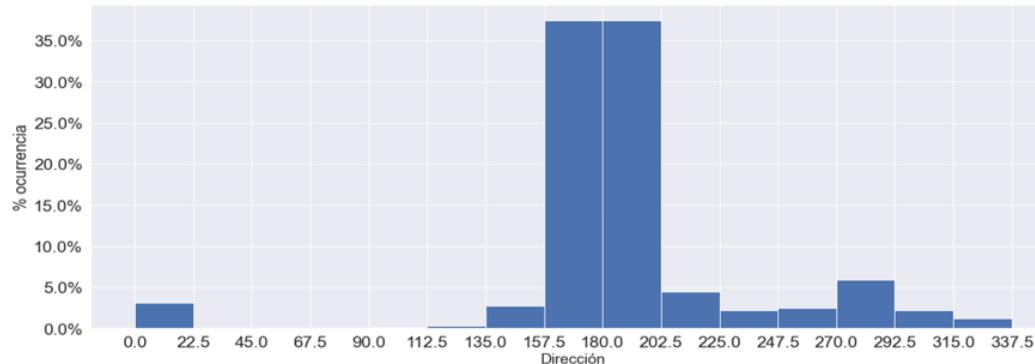
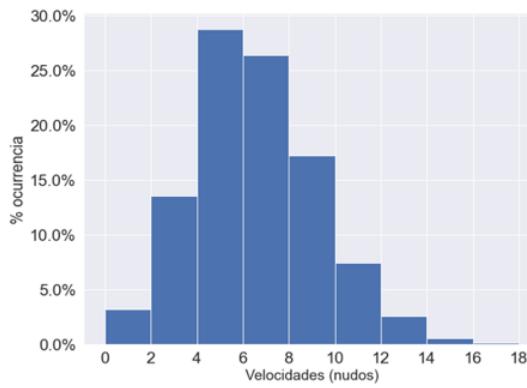
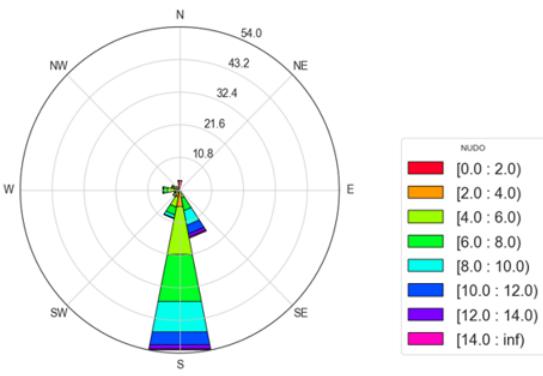
- Grid/node-registered: cells are centered on lines of latitude and longitude (21601 by 10801 cells).

Ejemplo de batimetría obtenida de GEBCO

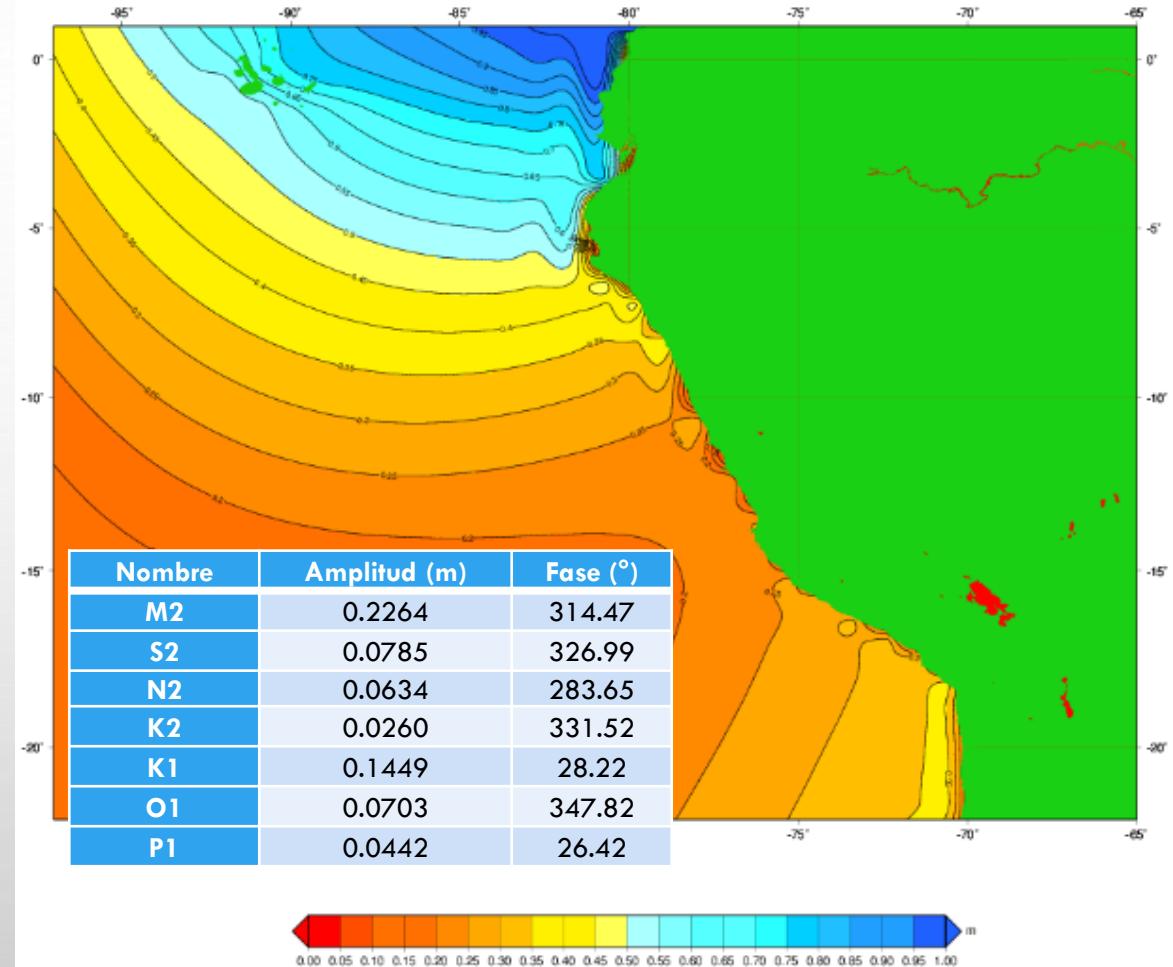


Forzantes del modelo de corrientes

Vientos



Mareas



```

wind-NOV-DEC2019
wind-OCT-DEC2019_old
dataERA_wind_-81.5_-5
windERA.nc
windERA5_oct-dec.nc
R lee
.Rhistory
dataERA_wind_-80.5_-4.5
dataERA_wind_-80.5_-4.75
dataERA_wind_-80.5_-5
dataERA_wind_-80.75_-4.5
dataERA_wind_-80.75_-4.75
dataERA_wind_-80.75_-5
dataERA_wind_-81.5_-4.5
dataERA_wind_-81.5_-4.75
dataERA_wind_-81.5_-5
dataERA_wind_-81.25_-4.5
dataERA_wind_-81.25_-4.75
dataERA_wind_-81.25_-5
dataERA_wind_-81.75_-4.5
dataERA_wind_-81.75_-4.75
dataERA_wind_-81.75_-5
dataERA_wind_-81_-4.5
dataERA_wind_-81_-4.75
dataERA_wind_-81_-5

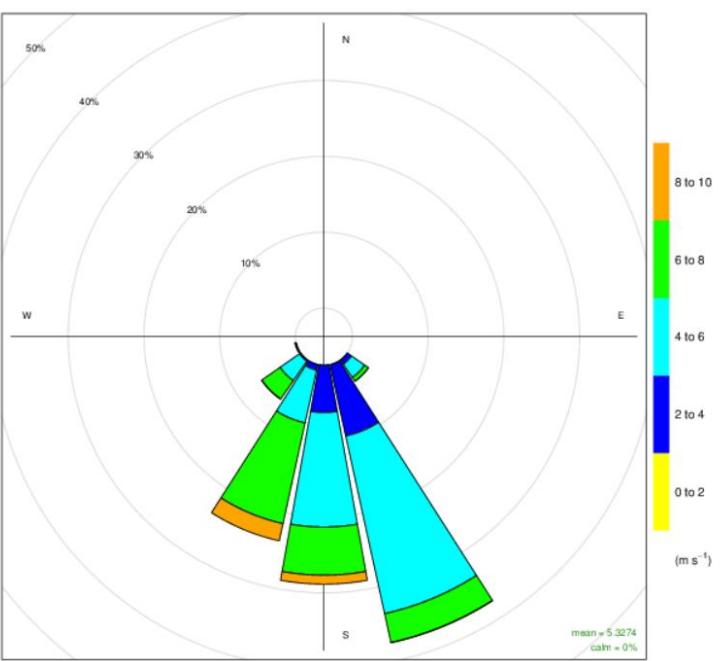
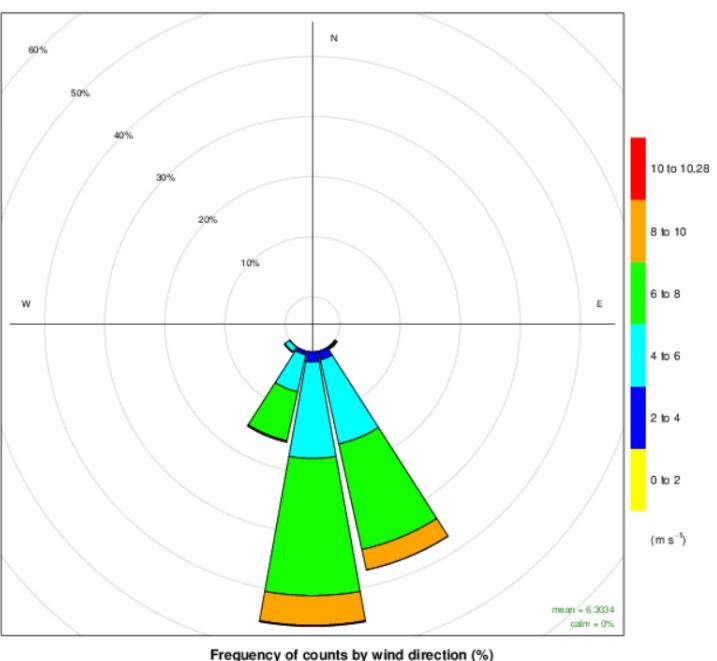
```

```

rm(list = ls())
library(ncdf4)
library(graphics)
library(plotly)
library(openair)
AA=nc_open("windERA5_oct-dec.nc")
UW=ncvar_get(AA,"u10")
VW=ncvar_get(AA,"v10")
XW=ncvar_get(AA,"longitude")
YW=ncvar_get(AA,"latitude")
time=ncvar_get(AA,"time")
tim2=as.POSIXct(time*3600,origin='1900-01-01 05:00'); tim2[1]

#ii=7;jj=3
for (jj in 1:3) {
  for (ii in 1:7){
    WM=(UW[ii,jj,]^2+VW[ii,jj,]^2)^0.5
    BB=atan2(VW[ii,jj,],UW[ii,jj,])*180/pi
    im=length(BB)
    plot(BB)
    BB2=NULL
    for (i in 1:im) {
      BB2=c(BB2,bb[i])
    }
    plot(BB2)
  }
}

```

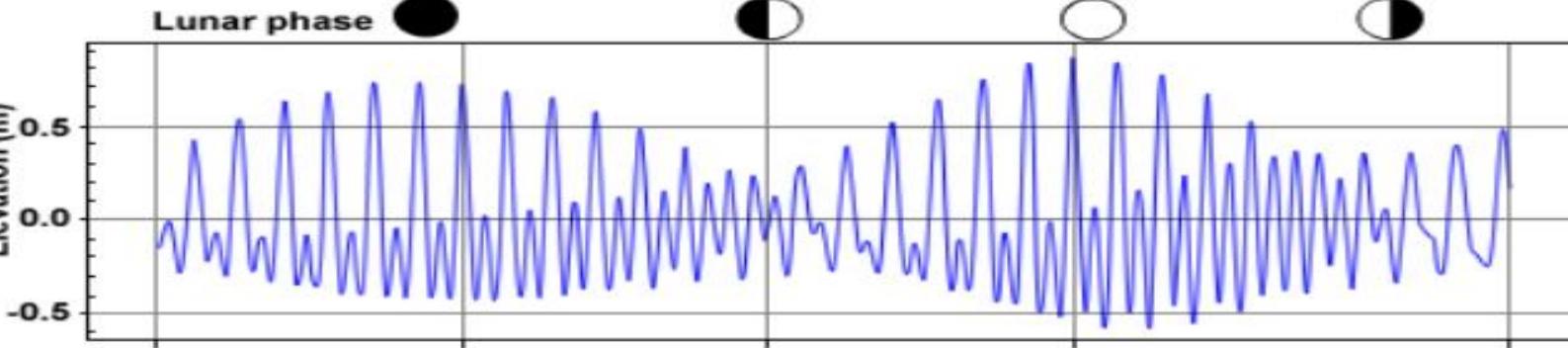


date	ws	wd
2019-10-01	00:00:00	4.6, 211.3
2019-10-01	01:00:00	4.64, 209.6
2019-10-01	02:00:00	4.21, 206.6
2019-10-01	03:00:00	3.73, 203.4
2019-10-01	04:00:00	3.21, 198.8
2019-10-01	05:00:00	2.75, 199.7
2019-10-01	06:00:00	2.28, 201.8
2019-10-01	07:00:00	2.01, 201.3
2019-10-01	08:00:00	1.8, 201.8
2019-10-01	09:00:00	1.58, 204.3
2019-10-01	10:00:00	1.57, 200.9
2019-10-01	11:00:00	1.57, 218.8
2019-10-01	12:00:00	1.34, 211
2019-10-01	13:00:00	1.27, 195
2019-10-01	14:00:00	1.38, 189.5
2019-10-01	15:00:00	1.73, 190.2
2019-10-01	16:00:00	2.46, 189.7
2019-10-01	17:00:00	3.36, 190.7
2019-10-01	18:00:00	3.99, 187.9
2019-10-01	19:00:00	4.32, 182.8
2019-10-01	20:00:00	4.63, 179.8
2019-10-01	21:00:00	4.9, 181.8
2019-10-01	22:00:00	4.8, 186.8
2019-10-01	23:00:00	4.5, 188.5
2019-10-01	24:00:00	4.11, 193.2

MAREA

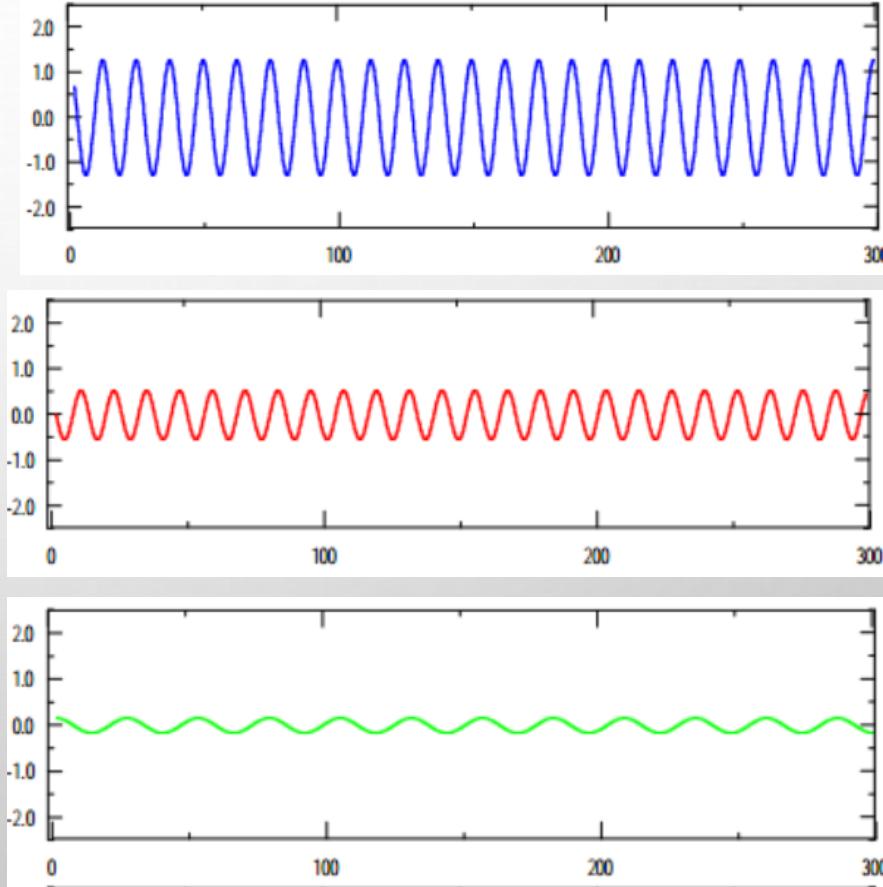
Una serie de niveles del mar en el tiempo puede descomponerse en varias ondas que son llamado componentes armónicos de marea

Tide Time Series in the Philippines Showing Neap and Spring Tide Cycle



Name	Symbol	Period, solar hr
Principal lunar	M_2	12.42
Principal solar	S_2	12.00
Larger lunar elliptic	N_2	12.66
Luni-solar semidiurnal	K_2	11.97
Larger solar elliptic	T_2	12.01
Smaller solar elliptic	L_2	12.19
Lunar elliptic second order	$2N_2$	12.91
Larger lunar evctional	v_2	12.63
Smaller lunar evctional	λ_2	12.22
Variational	μ_2	12.87
Luni-solar diurnal	K_1	23.93
Principal lunar diurnal	O_1	25.82
Principal solar diurnal	P_1	24.07
Larger lunar elliptic	Q_1	26.87
Smaller lunar elliptic	M_1	24.84
Small lunar elliptic	J_1	23.10
Lunar fortnightly	Mf	327.86
Lunar monthly	Mm	661.30
Solar semiannual	Ssa	2191.43

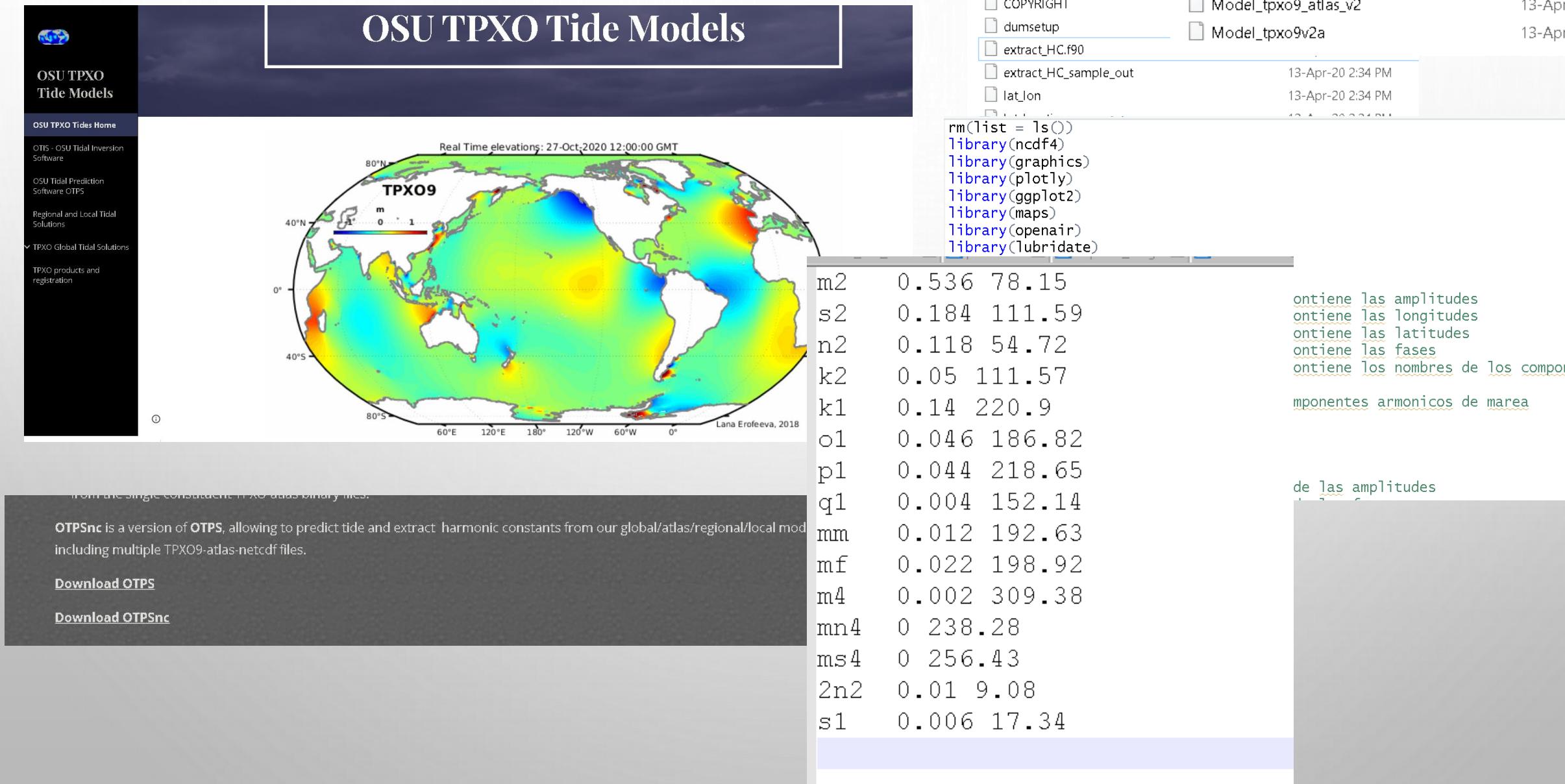
M_2
+
 S_2
+
 O_1



Componentes
armónicos

Se puede emplear los valores de los armónicos de marea del modelo TPXO

Modelo TPXO: <https://www.tpxo.net/home>



VIENTOS

Base de datos ERA5:

<https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=form>

ERA5 hourly data on single levels from 1979 to present

Overview Download data Quality assessment Documentation View

Clear all

Year

1979	1980	1981	1982	1983	1984
1985	1986	1987	1988	1989	1990
1991	1992	1993	1994	1995	1996
1997	1998	1999	2000	2001	2002
2003	2004	2005	2006	2007	2008
2009	2010	2011	2012	2013	2014
2015	2016	2017	2018	2019	2020

Clear all

Month

January	February	March	April	May	June
July	August	September	October	November	December

Clear all

Day

01	02	03	04	05	06
07	08	09	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31					

Clear all

Time ⓘ

00:00	01:00	02:00	03:00	04:00	05:00
06:00	07:00	08:00	09:00	10:00	11:00
12:00	13:00	14:00	15:00	16:00	17:00
18:00	19:00	20:00	21:00	22:00	23:00

Select all Clear all

Geographical area ⓘ

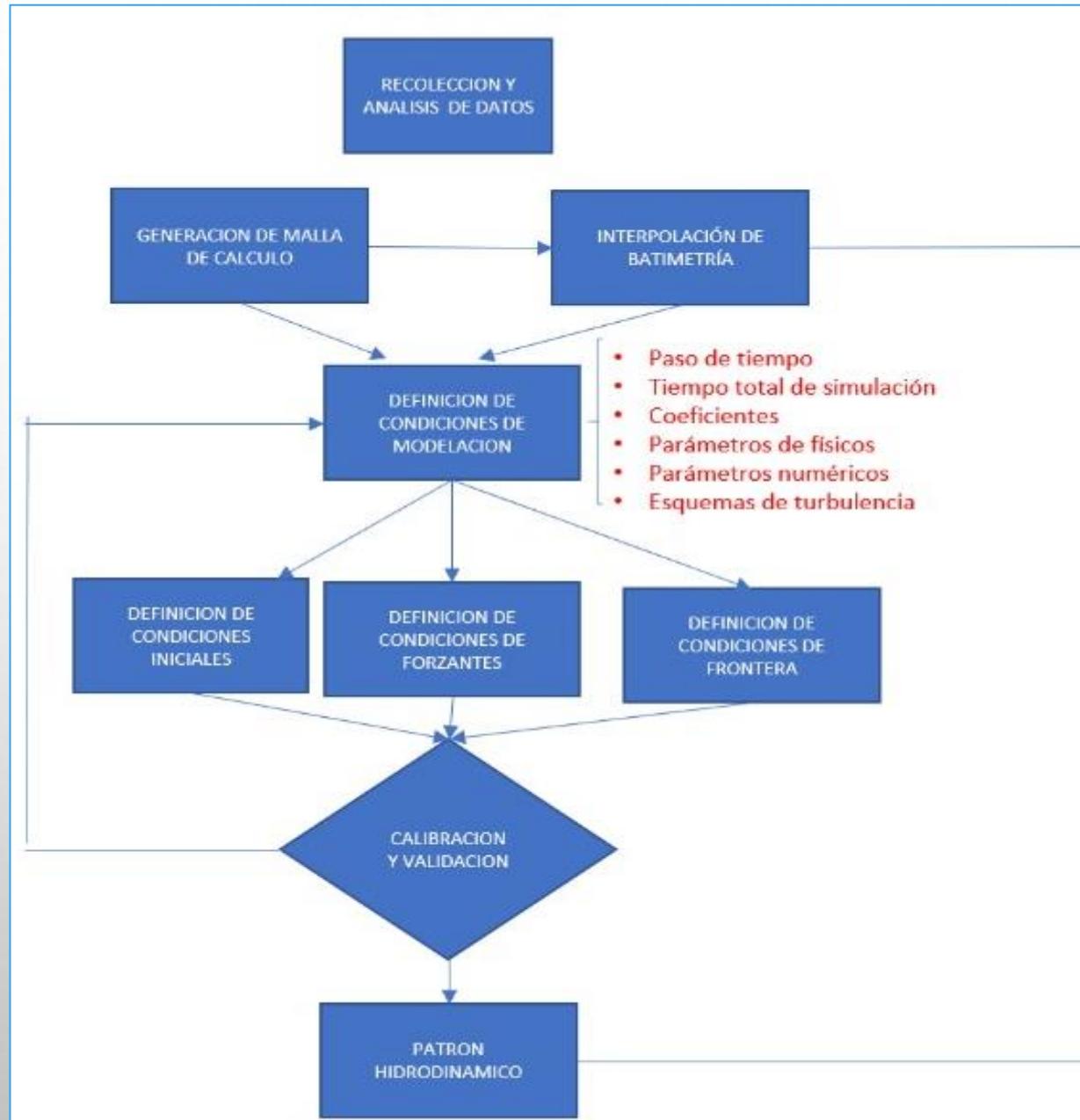
Whole available region
With this option selected the entire available area will be provided

Sub-region extraction ⓘ

North	5
West	-100
East	-70
South	-20

Select all Clear all

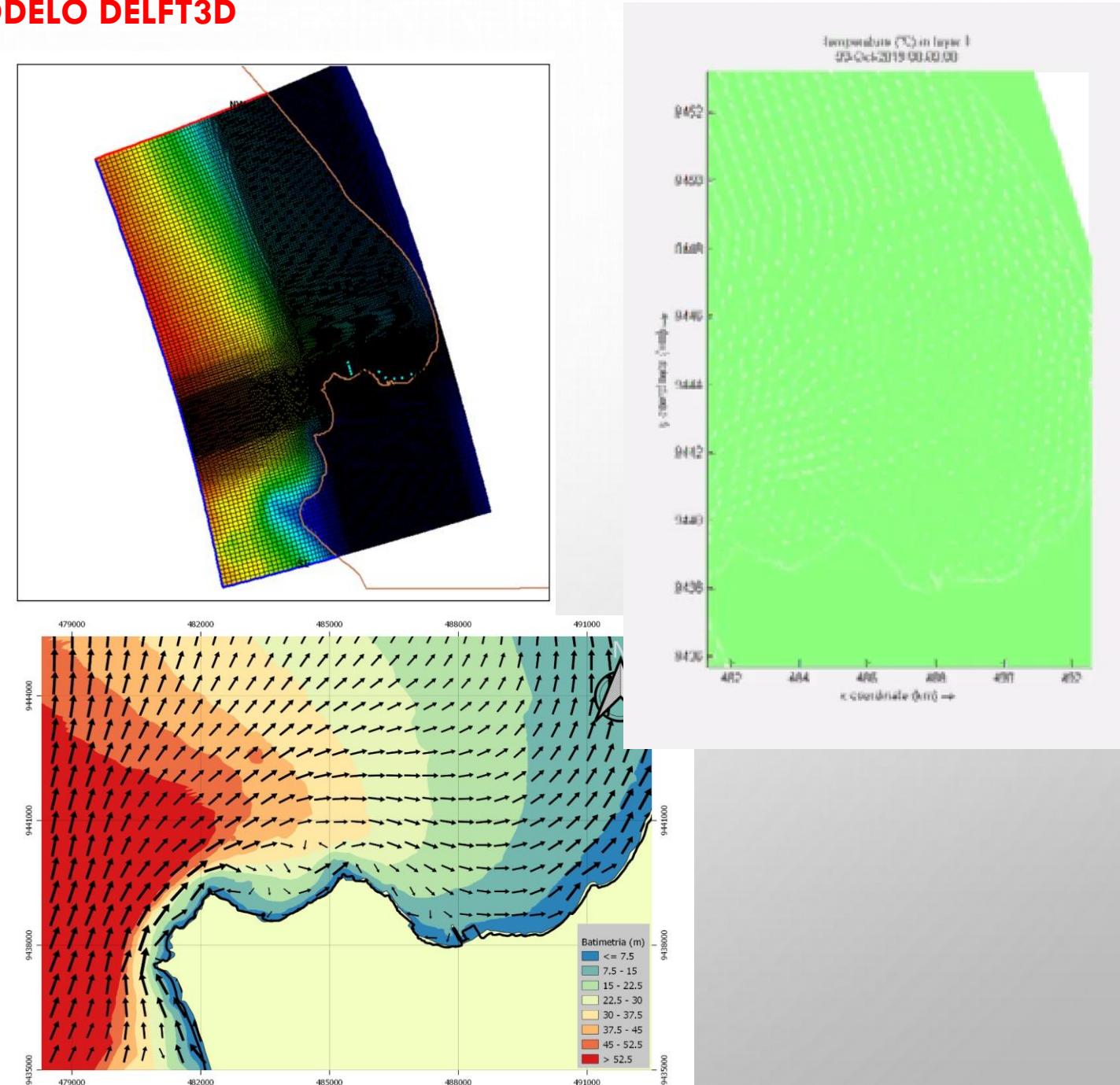
Diagrama de flujo de la modelación de corrientes



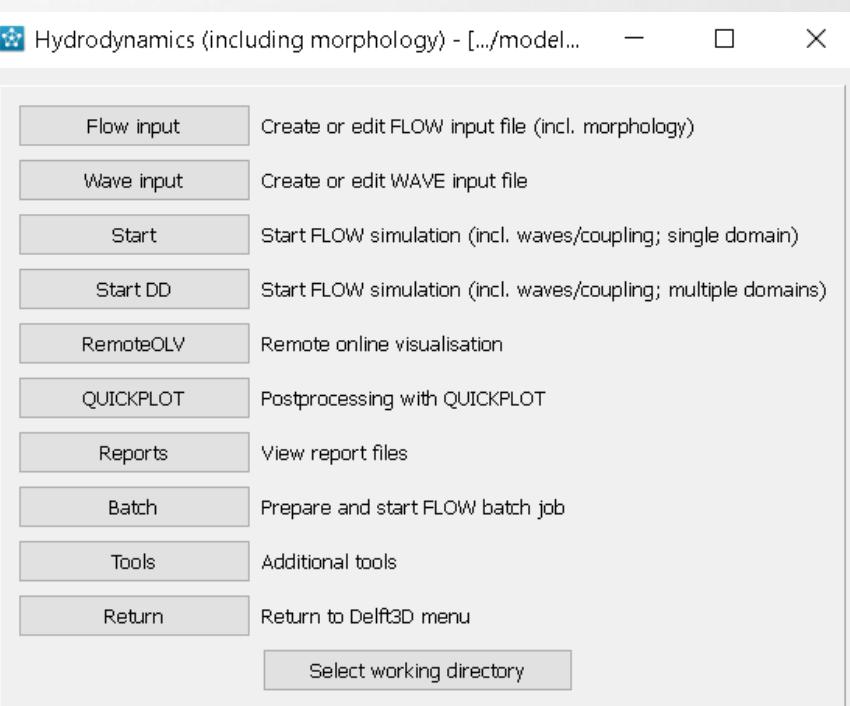
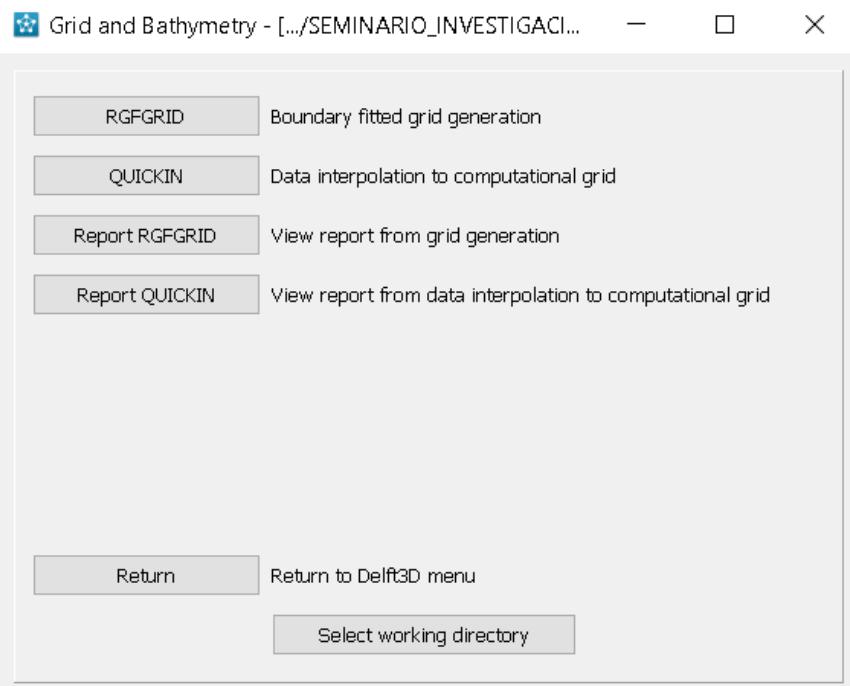
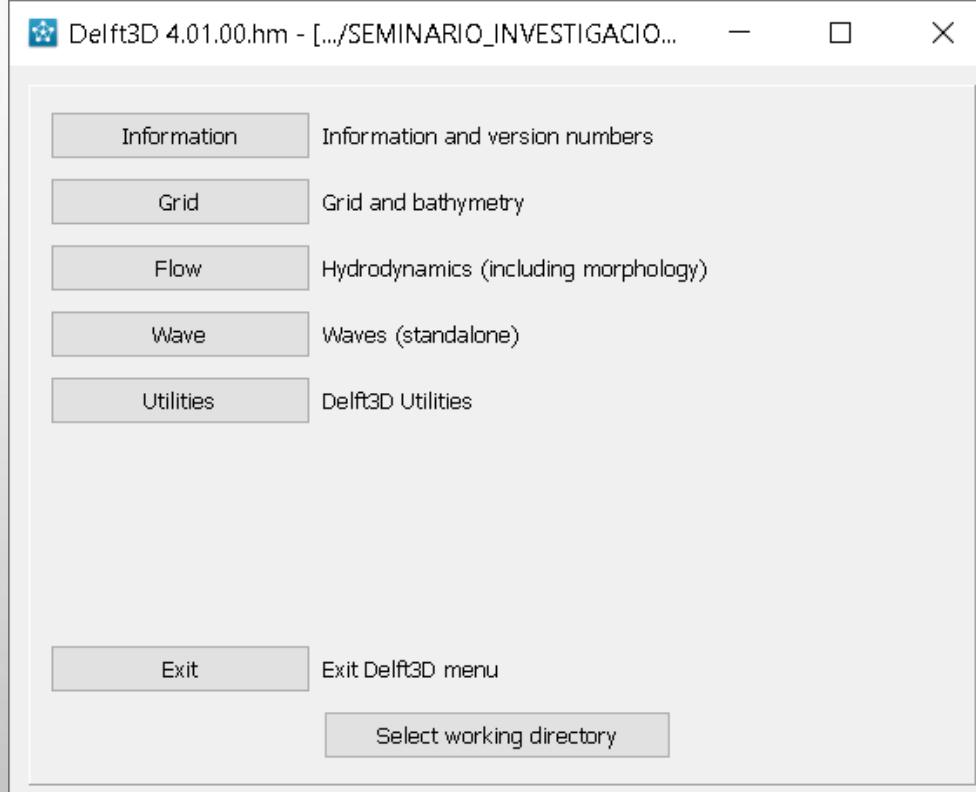
MODELO DELFT3D

Una de las características del modelo es la capacidad de poder generar mallas con resolución variable, lo que permite dar mayor detalle la zona a modelar, y sobre esta malla, se procedió a interpolar la batimetría. El modelo es de aplicable a los siguientes casos:

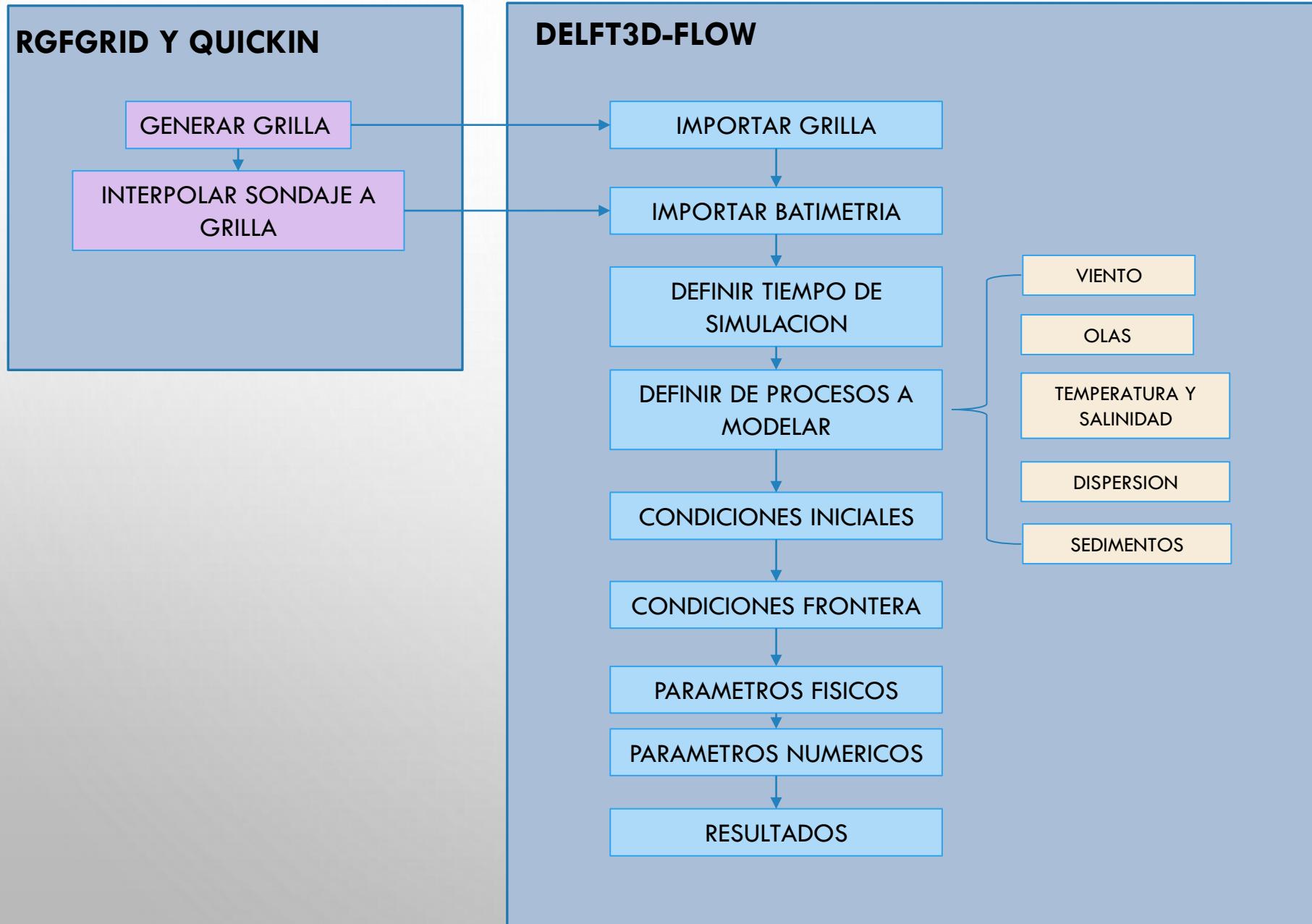
- Flujos forzados por viento y marea
- Flujos estratificados asociados a cambios de densidad
- Simulación en ríos, lagos y reservorios
- Simulación de tsunamis
- Descarga de agua dulce en bahías e intrusión salina
- Estratificación térmica en lagos, mareas y reservorios
- Captación de agua de enfriamiento y descarga de aguas residuales
- Transporte de material disuelto y contaminantes
- Transporte de sedimentos y morfología



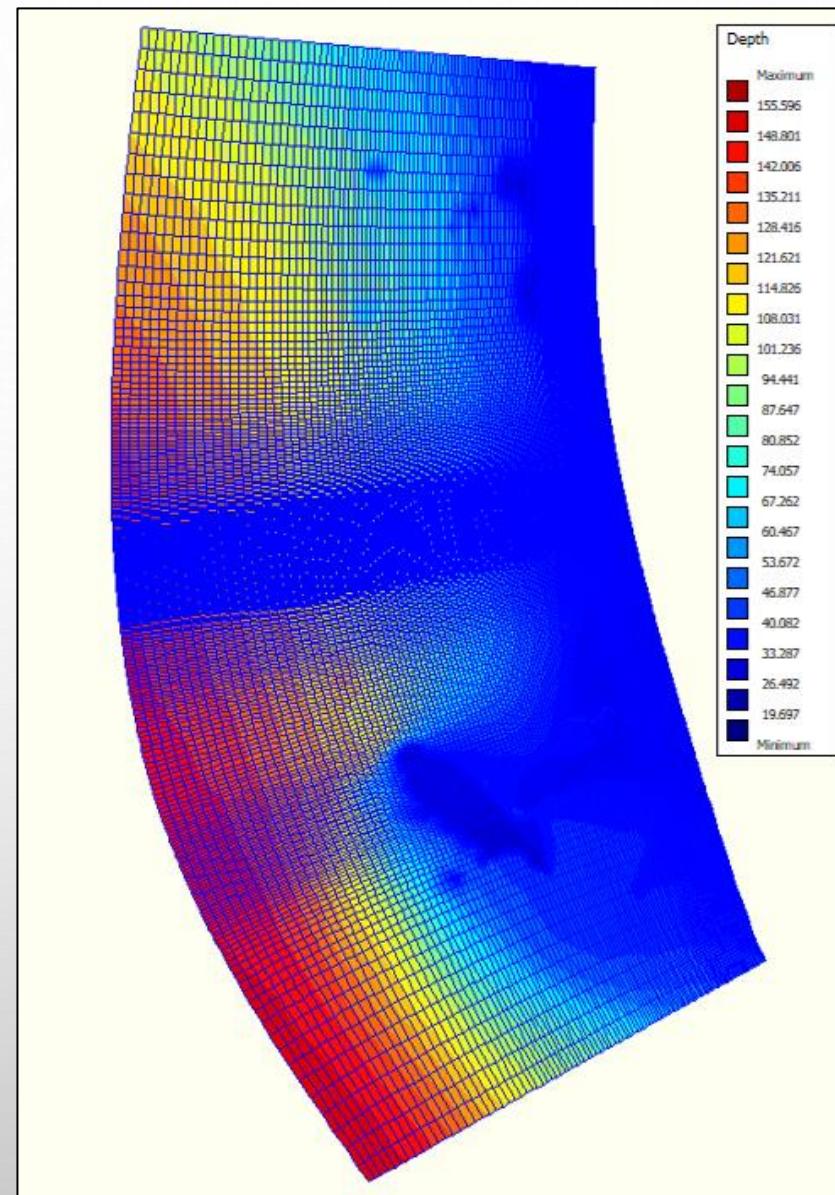
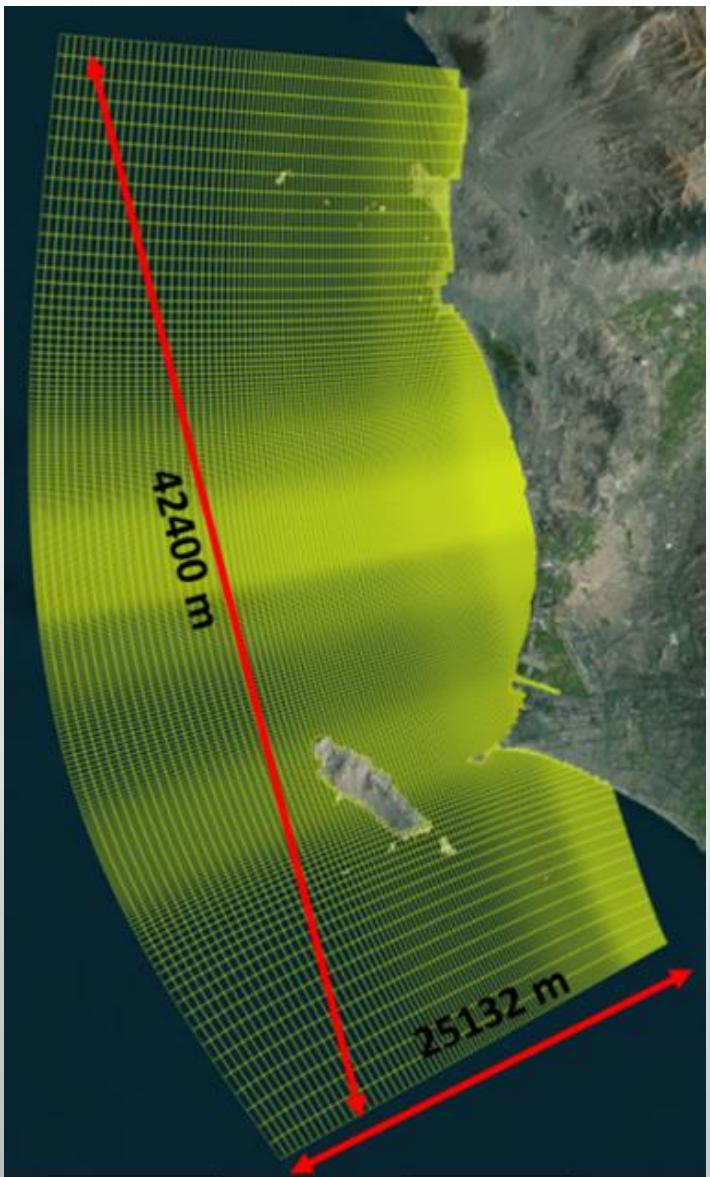
INTERFAZ GRAFICA



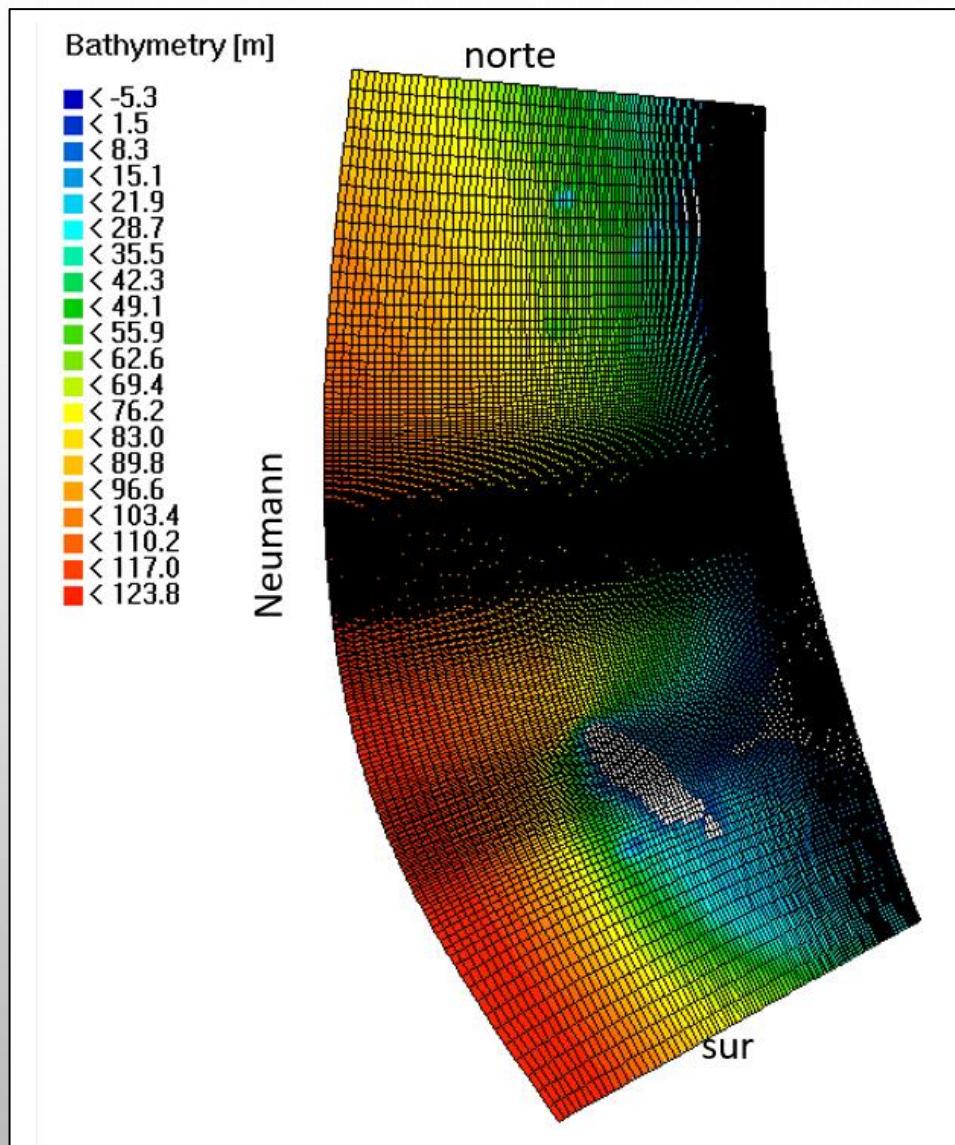
ESQUEMA DE FUNCIONAMIENTO



Mallado y generación de batimetría



Configuración del modelo de corrientes



File Table View Help

Description
Domain
Time frame
Processes
Initial conditions
Boundaries
Physical parameters
Numerical parameters
Operations
Monitoring
Additional parameters
Output

Boundaries

Sea
Norte
Sur

Add Open / Save
Delete

Section name
Sea
M1 1 N1 258
M2 1 N2 2

Flow conditions

Type of open boundary (quantity) : Water level
Reflection parameter alpha: 1000 [s²]
Forcing type: Astronomic

Edit flow conditions

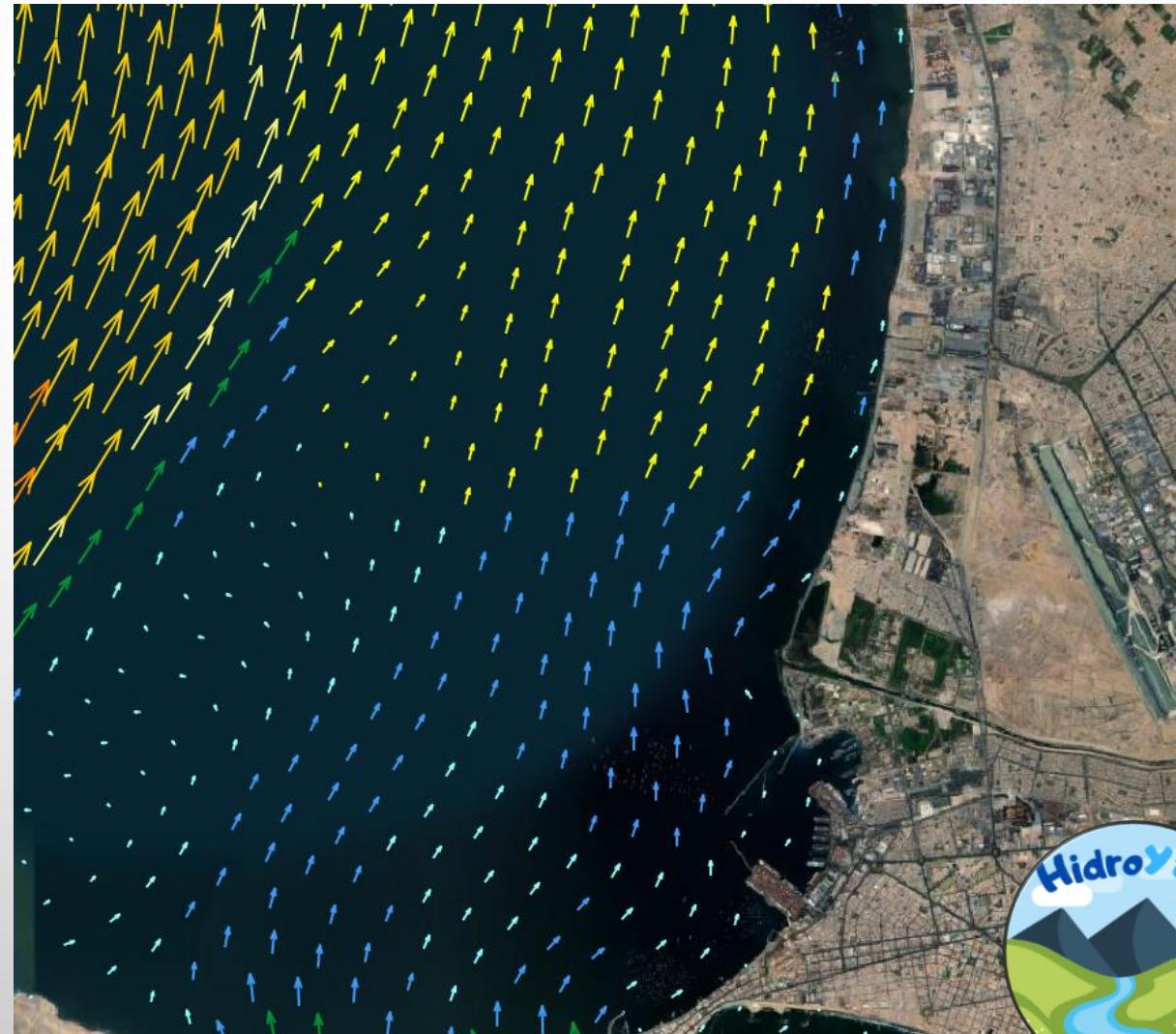
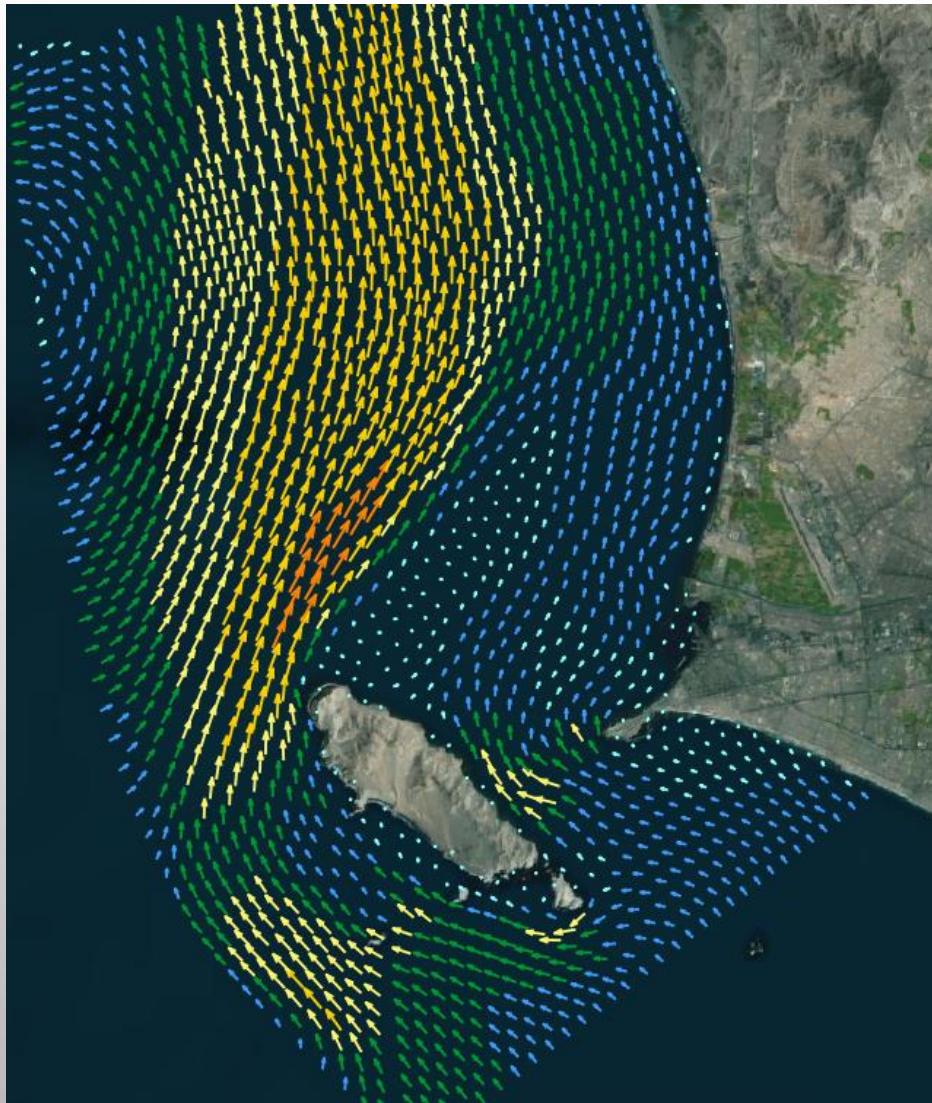
Transport conditions

Thatcher-Harleman time lag: 1000 [min]

Edit transport conditions



Resultados de la modelación de corrientes



Parámetros de calibración

Constants Roughness Viscosity Heat flux model Wind

Hydrodynamic constants

Gravity	9.81	[m/s ²]
Water density	1025	[kg/m ³]
Air density	1.17	[kg/m ³]

Wind drag coefficients

Breakpoints	Coefficient	Wind speed
A	0.01863	[·] 4 [m/s]
B	0.01923	[·] 100 [m/s]
C	0.01923	[·] 100 [m/s]

Constants Roughness Viscosity Heat flux model Wind

Bottom roughness

Roughness formula: Manning

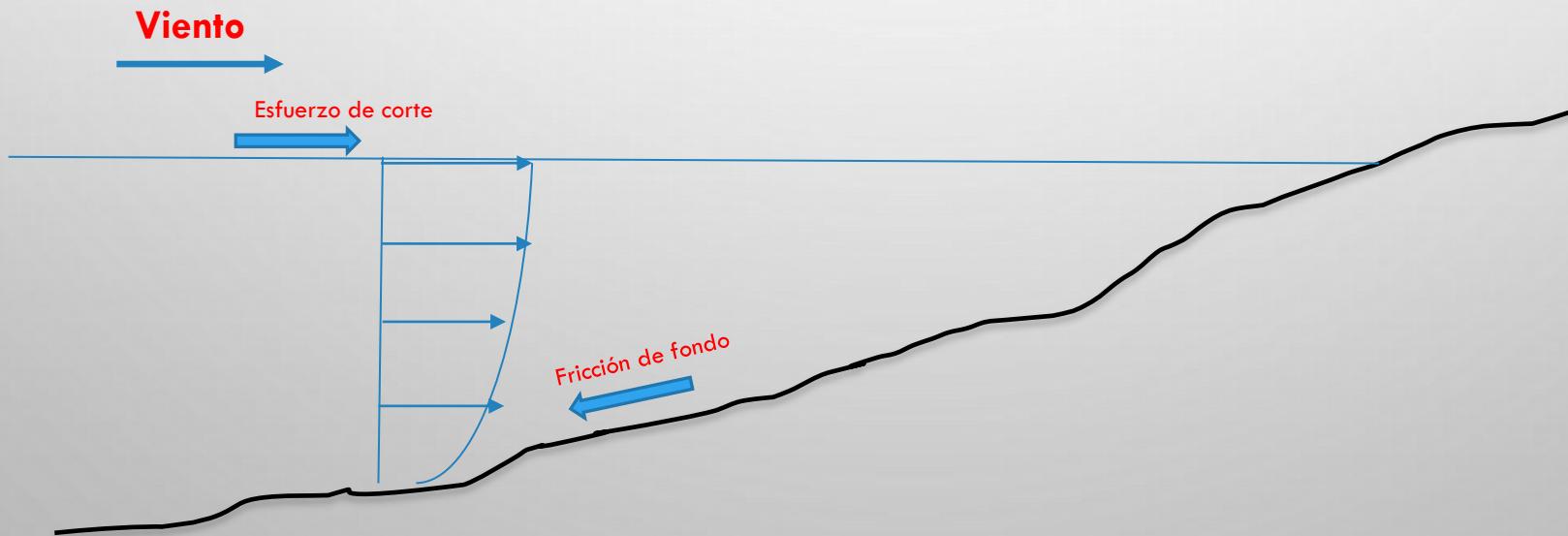
Uniform U: 0.025 v: 0.025

File Select file
File: Filename unknown

Wall roughness

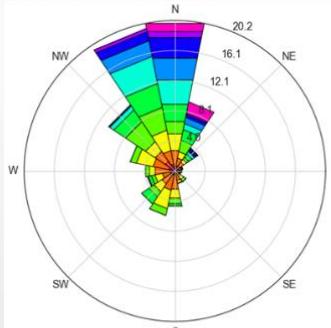
Slip condition: Free

Roughness length: 0 [m]



Validación de la modelación de corrientes

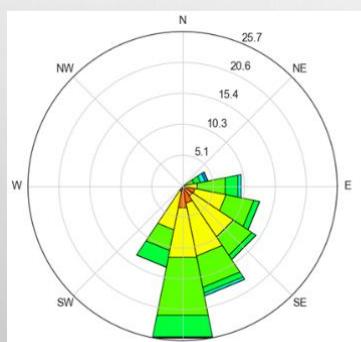
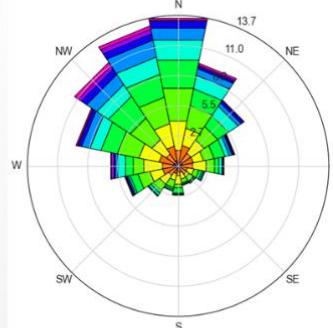
Modelado



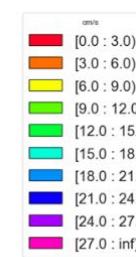
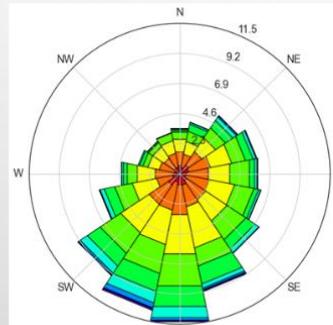
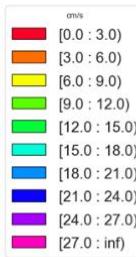
Capa Superficial



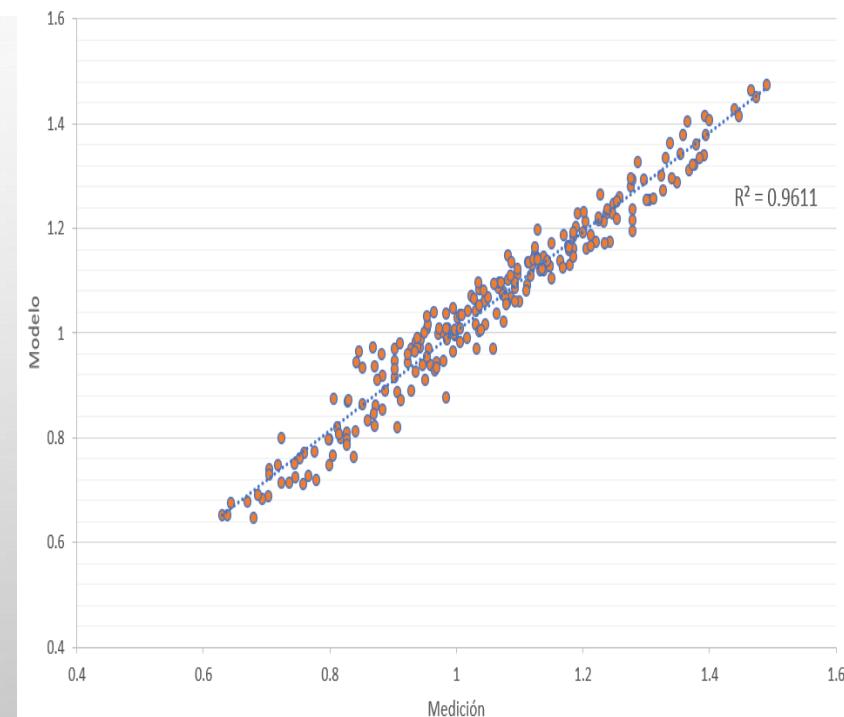
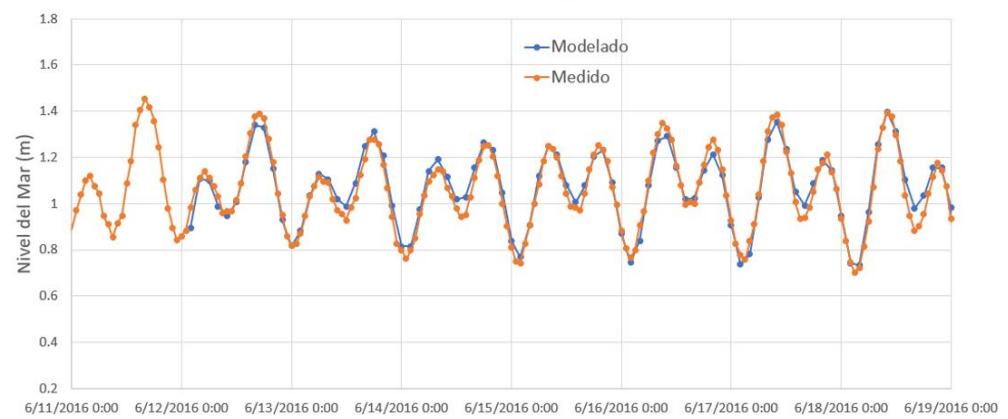
Observado



Capa de fondo



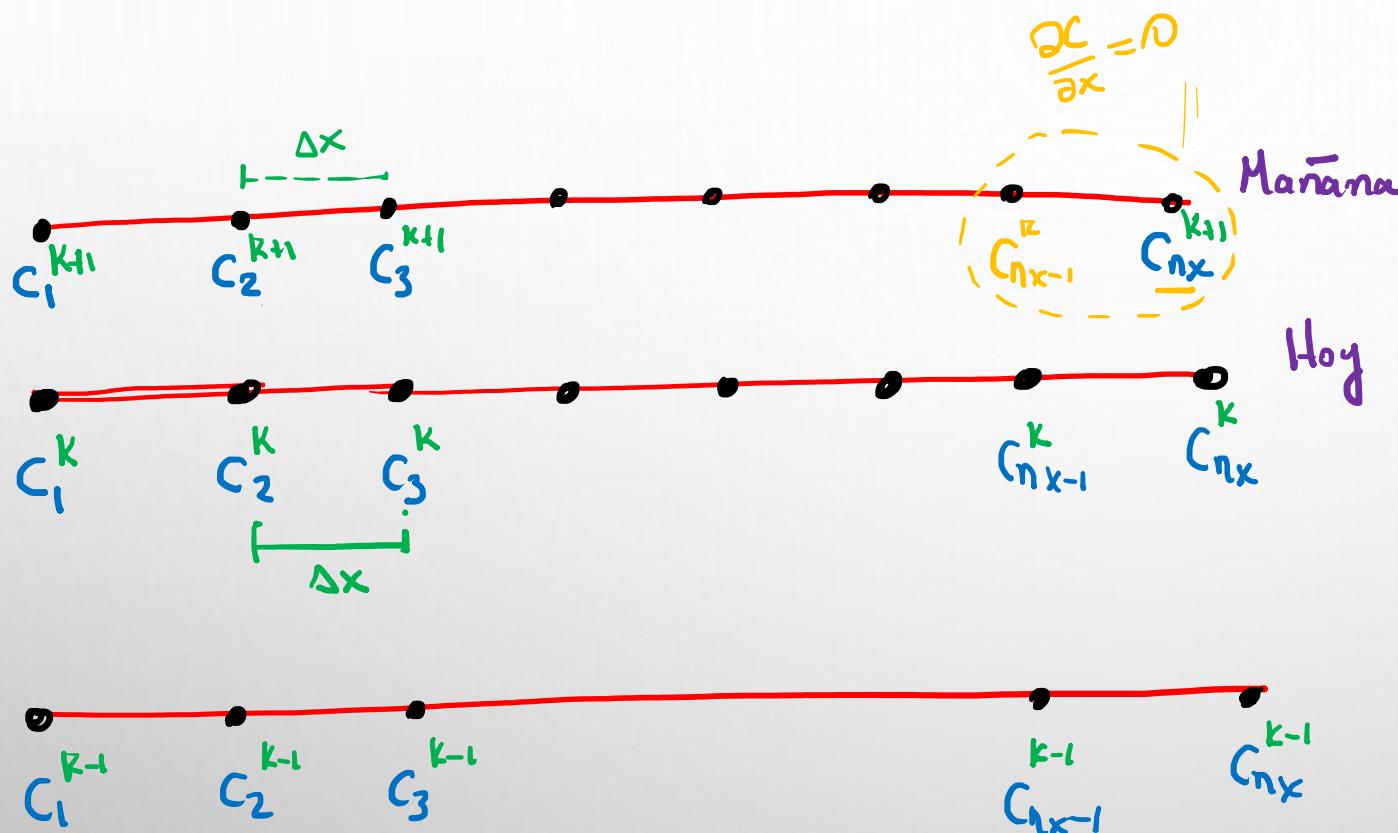
Nivel



$$\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} = 0$$

Implícito }
Explícito } Derivadas
espaciales

$$\frac{\partial c}{\partial x} = \frac{\Delta c}{\Delta x} = \frac{c_3 - c_2}{\Delta x} \rightarrow \text{Explícito}$$



$$\frac{\Delta c}{\Delta x} = \frac{c_3 - c_2}{\Delta x} \rightarrow \text{Implícito}$$

mañana

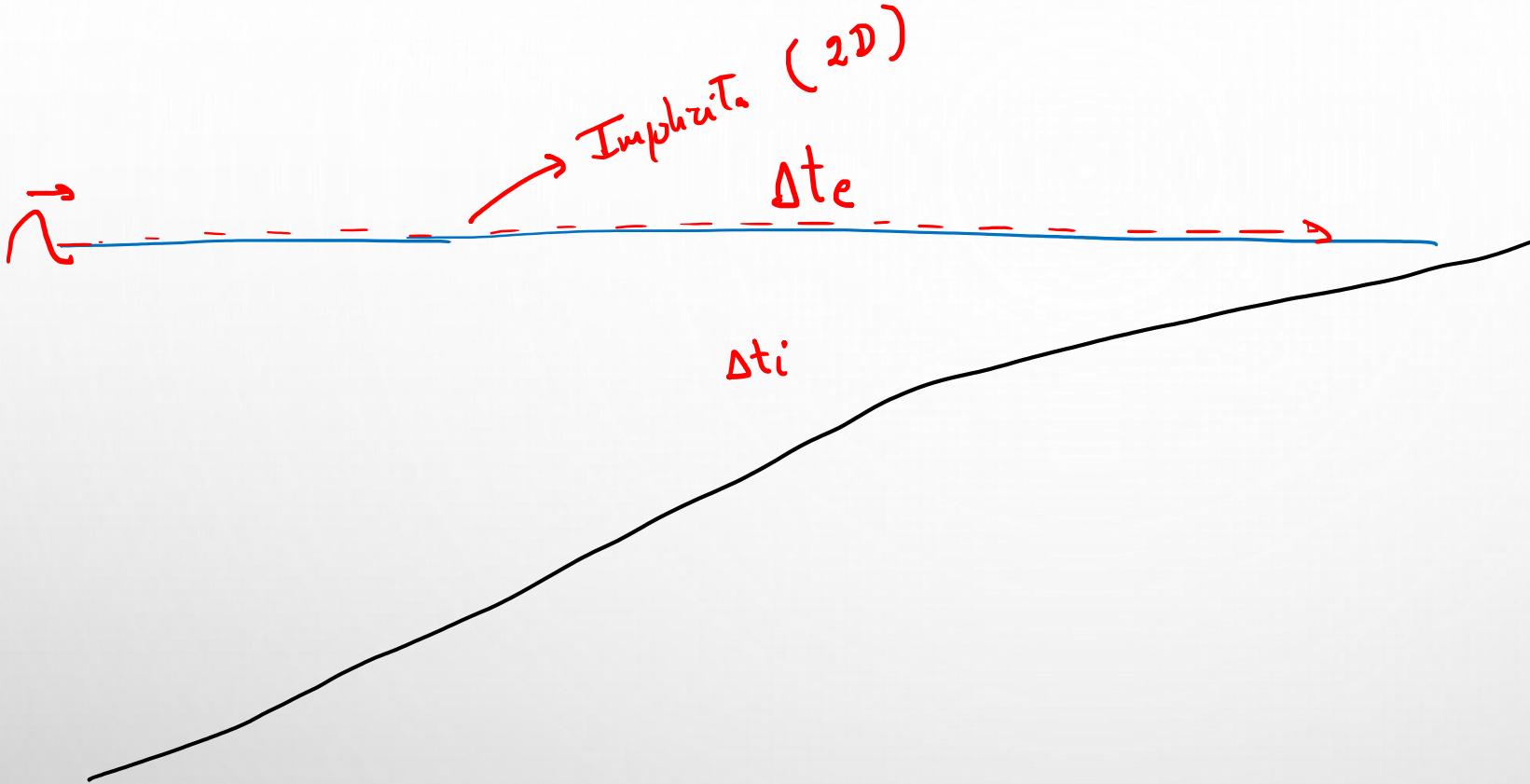
$$c_i^K = c_i^{K+1} + u \Delta t \left(\frac{c_i^K - c_{i-1}^K}{\Delta x} \right)$$

mañana Hoy mañana

$$c_i^K = c_i^{K+1} + u \Delta t \left(\frac{c_i^{K+1} - c_{i-1}^{K+1}}{\Delta x} \right)$$

$\alpha_1 c_{n-1}^{K+1} + c_i^{K+1} + \beta_1 c_{i+1}^{K+1} = \tilde{c}_i^K$

mañana



Ec. Cons. Masa

Ec. Cant. Mov.

MUCHAS GRACIAS

Dedicado a
Donny David Guzman Zorrilla

