

# Simulating the potential impact of SMS **mining plumes** on deep-sea biodiversity and existing human activities in the Azores

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# Mineral resources

The sea-floor in the Azores may **host mineable mineral** resources

Mostly **Seafloor Massive Sulfides**, iron-manganese crusts<sup>[1]</sup> and manganese nodules

1- Barriga et al., 2009; 2- Nautilus Minerals Inc.; 3- International Seabed Authority GIS Data

# Impacts

**Need for quantifying:**

- (i) impacts on marine ecosystem functioning, goods and services**
- (ii) impacts on other human activities such as bottom and pelagic fishing**

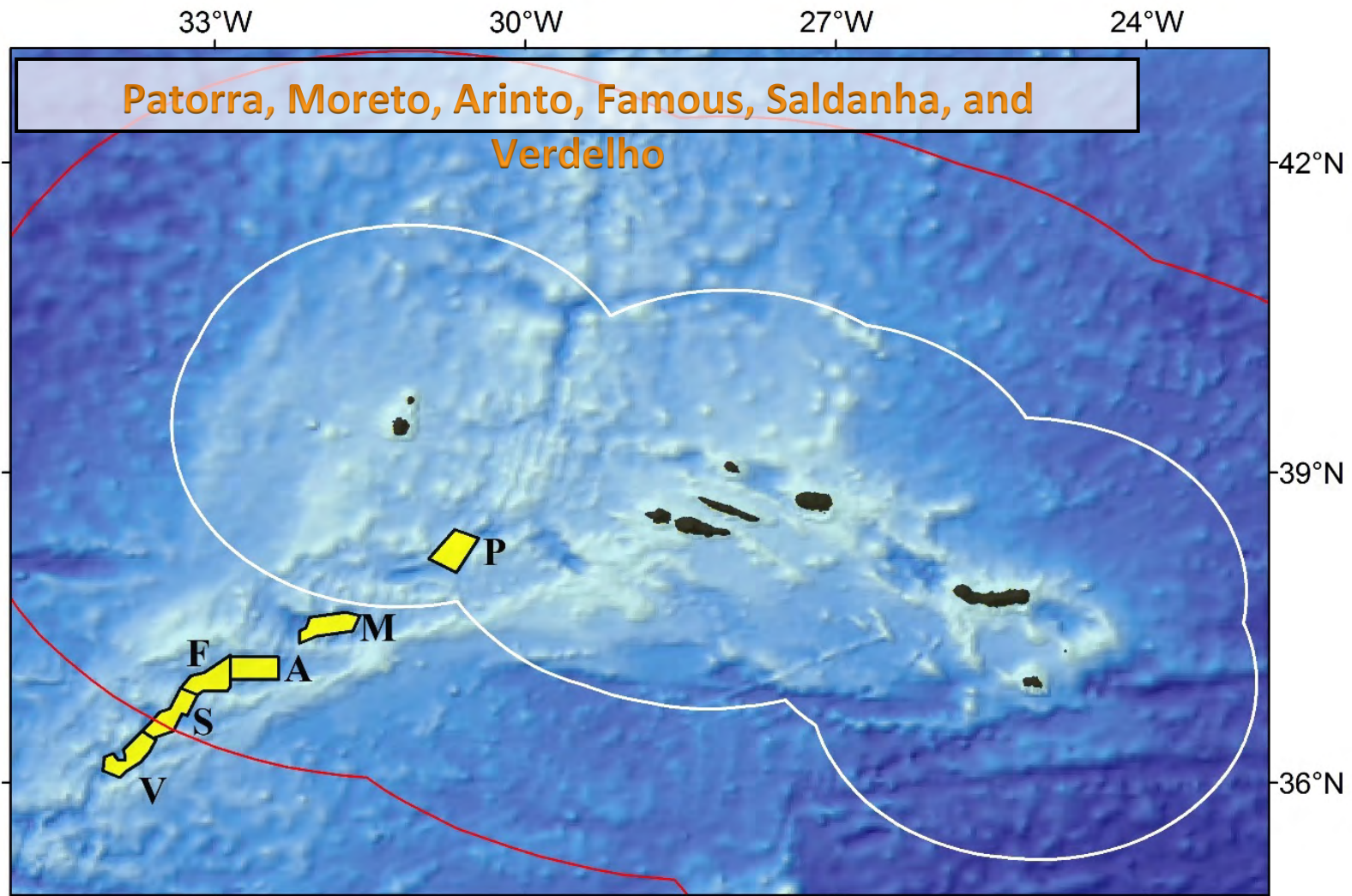
## Question

**What are the scales of potential impacts of deep-sea mining plumes on deep-sea biodiversity and other human activities?**

## Objectives

- (i) Develop **3-D hydrodynamic models** for two different SMS areas
- (ii) Model **plume dispersal** scenarios
- (iii) Create **maps** of the “likelihood” of an area to be impacted by plumes
- (iv) To quantify potential **impacts** due to deep-sea mining plumes

# Study area



# Hydrodynamic modelling

**MOHID<sup>[1]</sup> Lagrangian + MOHID Jet**

**High resolution 3D hydrodynamic models  
developed for 2 areas (Patorras and Moreto)**

**Duration of the simulations is one year**

**Reference year is 2011**

1- <http://www.mohid.com/>

# Plume modelling

**ENVIRONMENTAL IMPACT STATEMENT**

Nautilus Minerals Niugini Limited

**Solwara 1 Project**

Volume B  
Appendices 8 - 15

September 2008  
CR 7008\_9\_v4

IHC Mining B.V.

**Memo**

To  
MIDAS project partners

Copy to

From  
Alicya Ortega  
Wielde Boomsma

Date	Reference	Version	Status
01 May 2014	M13-396	3.0	Final

Subject  
**MIDAS: Mining Research Scenarios**

**The technology innovator.**

# Plume modelling

Studied sediment plumes

Pre-mining terrain preparation



## ENVIRONMENTAL IMPACT STATEMENT

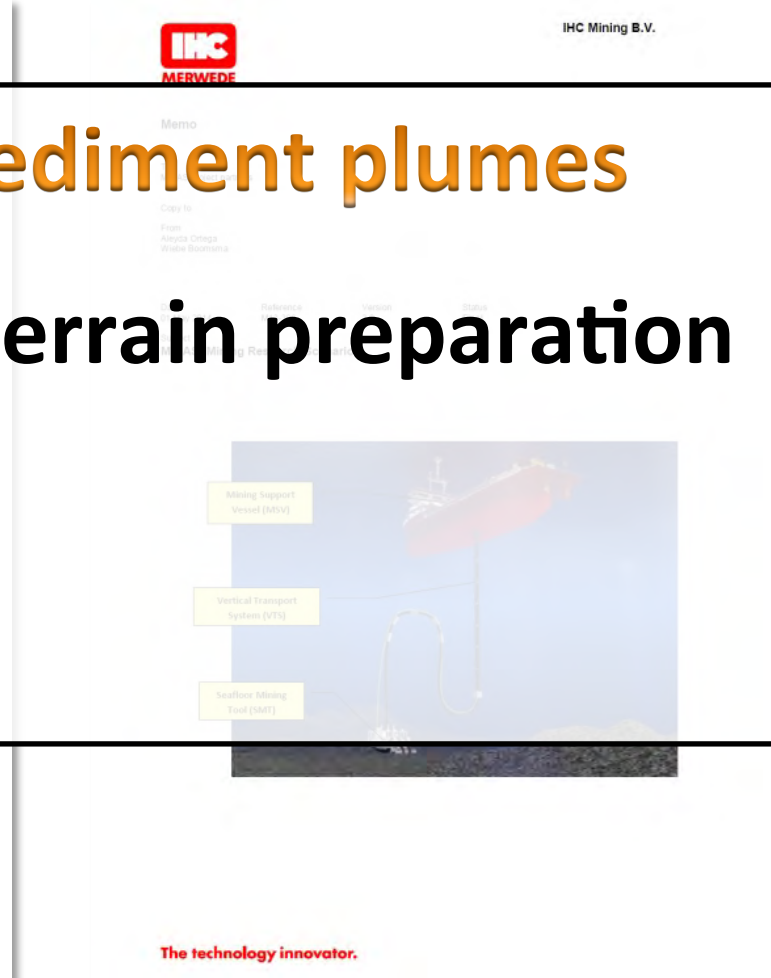
Nautilus Minerals Niugini Limited

Solwara 1 Project

Volume B  
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September 2008  
CR 7008\_9\_v4

coffey natural systems  
SPECIALISTS IN PEOPLE AND PLACE



The technology innovator.

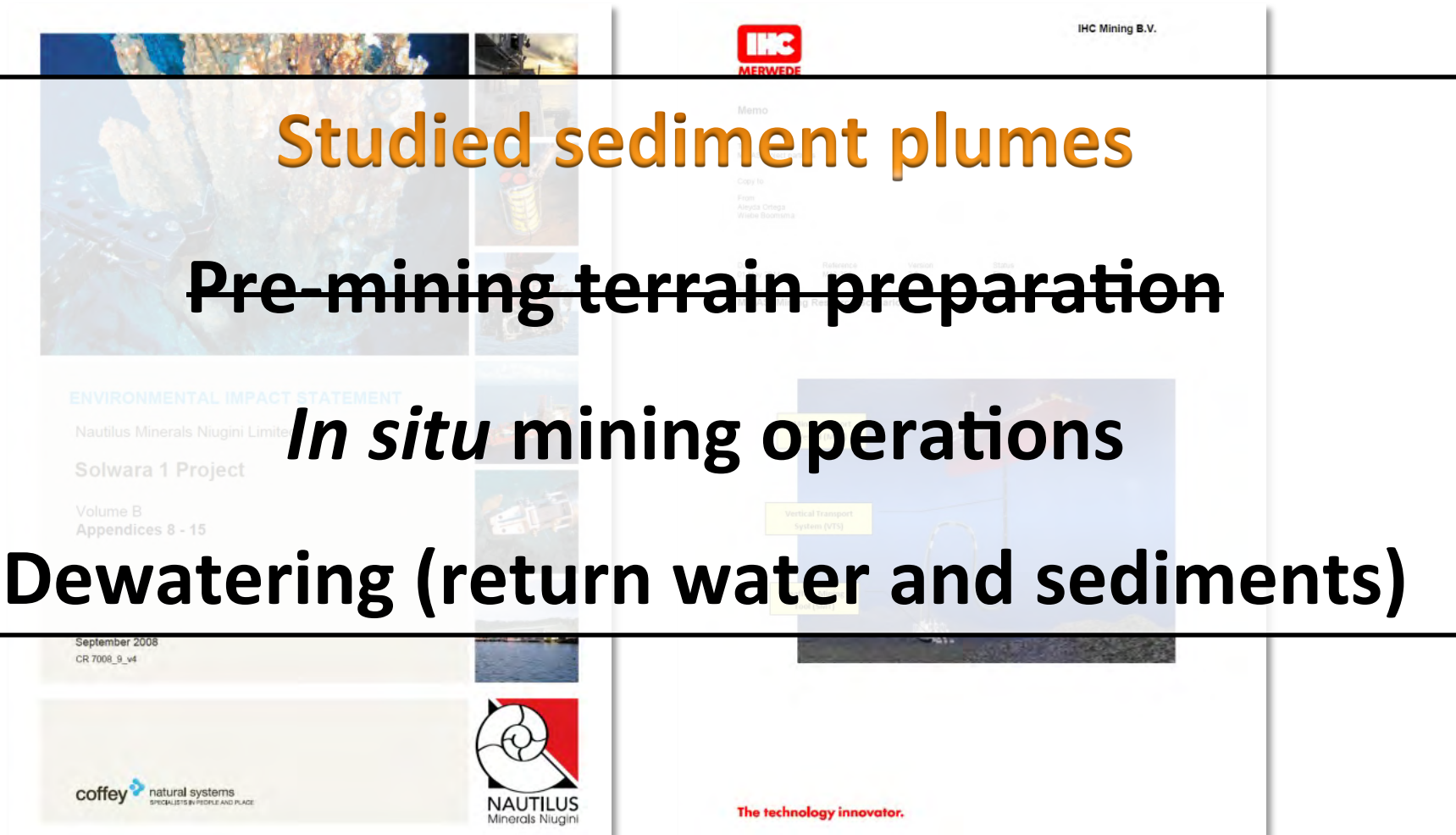
# Plume modelling

**Studied sediment plumes**

~~Pre-mining terrain preparation~~

*In situ* mining operations

**Dewatering (return water and sediments)**



# Plume modelling

Parameter	Adopted values	Units
Hydrodynamic model	MOHID Lagrangean module	
Discharge model	MOHID Jet	
In situ temperature and salinity	MOHID 3D	
Duration of the runs	<u>365</u>	d
Depth of emissions	<u>30m</u> above the bottom depth	
Location (Lat, Long, water depth)		
Moreto	38.274°N, 30.694°W, <u>1060</u>	
Patorras	37.499°N, 31.957°W, <u>2310</u>	
Total mining production days	385	d
Annual production days	250	d y <sup>-1</sup>
Mining hours per day	20	h · d <sup>-1</sup>
Total mining hours	7,700	h
Mining hours per year	5,000	h y <sup>-1</sup>

# Plume modelling

Parameter	Adopted values	Units
Discharge U-shape pipes diameter	170	mm
Discharge orientation	vertically upwards	
Discharge rate <sup>3</sup>	<u>0.253</u>	m <sup>3</sup> · s <sup>-1</sup>
Temperature of discharge Patorras <sup>1</sup>	<u>9.4</u>	°C
Temperature of discharge Moreto <sup>1</sup>	<u>6.5</u>	°C
Salinity of discharge	80% seafloor and 20% surface	
Discharge concentration of solids	6,000	mg · L <sup>-1</sup>
Particle size <sup>2</sup>	<u>&lt;8</u>	µm
Average sediment density	3.3	g · cm <sup>-3</sup>
Settling velocity <sup>4</sup>	0.002	cm · s <sup>-1</sup>

<sup>1</sup> Temperature estimated from local CTD samples using 80% of seafloor and about 20% of surface water. Scenario with 12°C also tried. <sup>2</sup> Average particle size based on samples from Lucky Strike. <sup>3</sup> Residence time assumed to be 8 days. <sup>4</sup> Scenario with increased settling velocity of 0.008 cm · s<sup>-1</sup> also tried.

## Thresholds and targets

Following the ASA/Nautilus report:

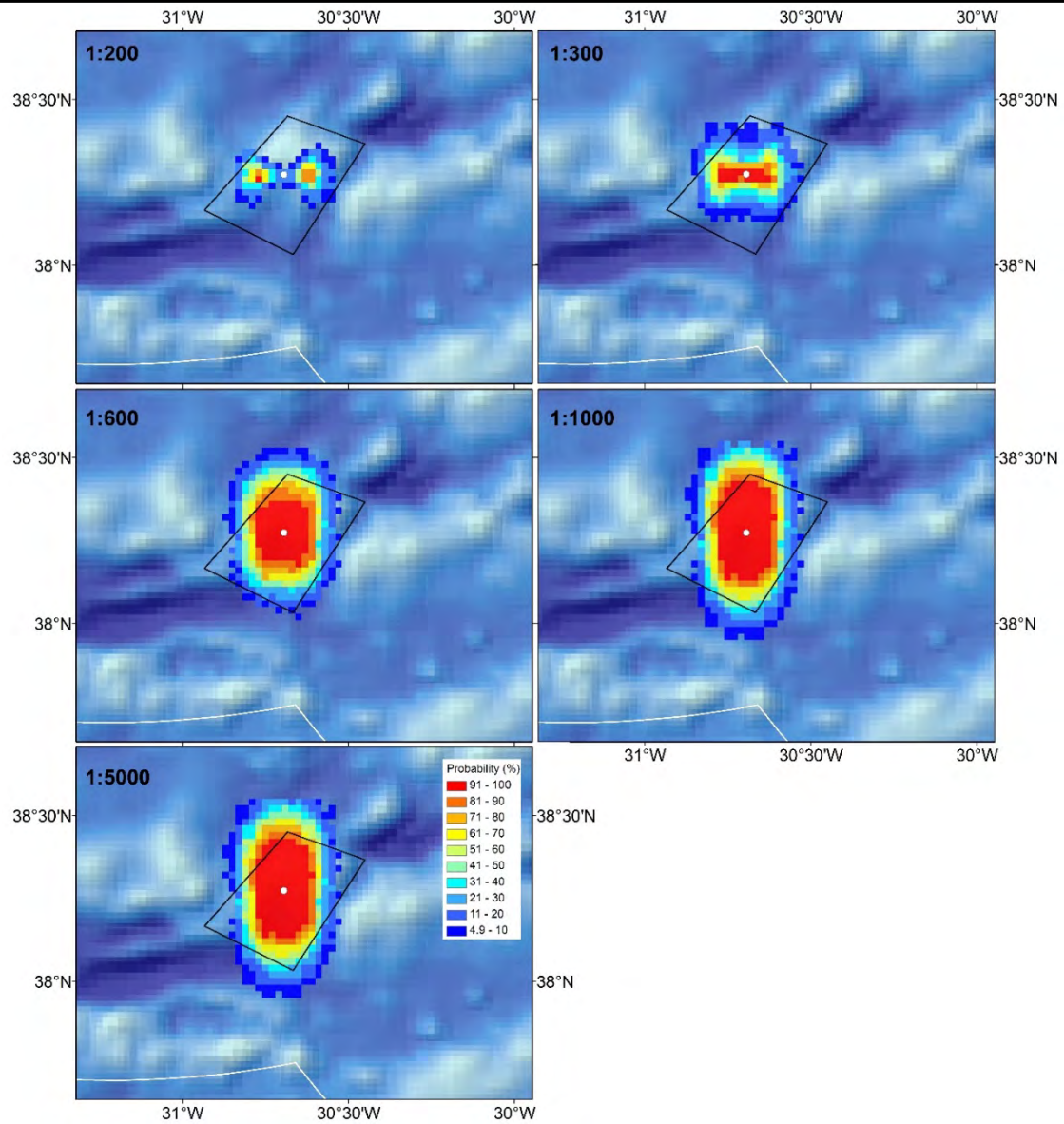
Target for total suspended solids is **1.2 mg·L<sup>-1</sup>**

A dilution of **1/5,000** to meet the guidelines for all contaminants in the return water

# Plume of the return discharge water

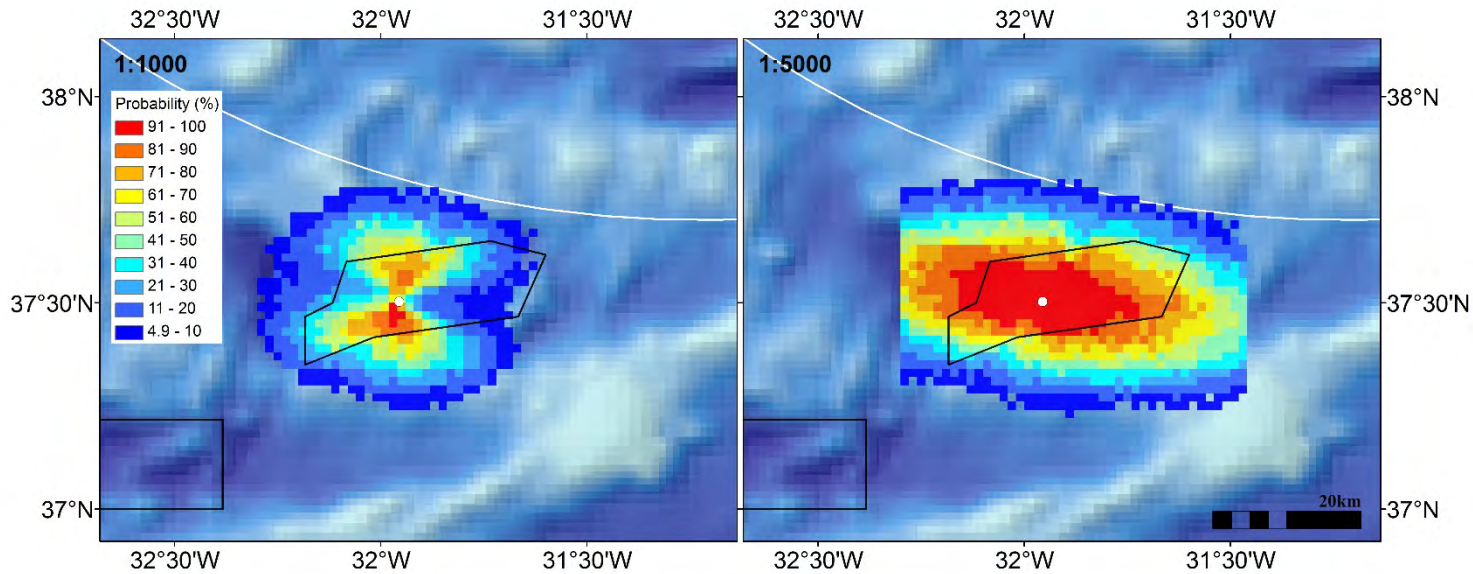
**Results: return discharge water**

**Probability of plumes above a concentration threshold: Patorra**



## Probability of plumes above a concentration threshold: **Moreto**

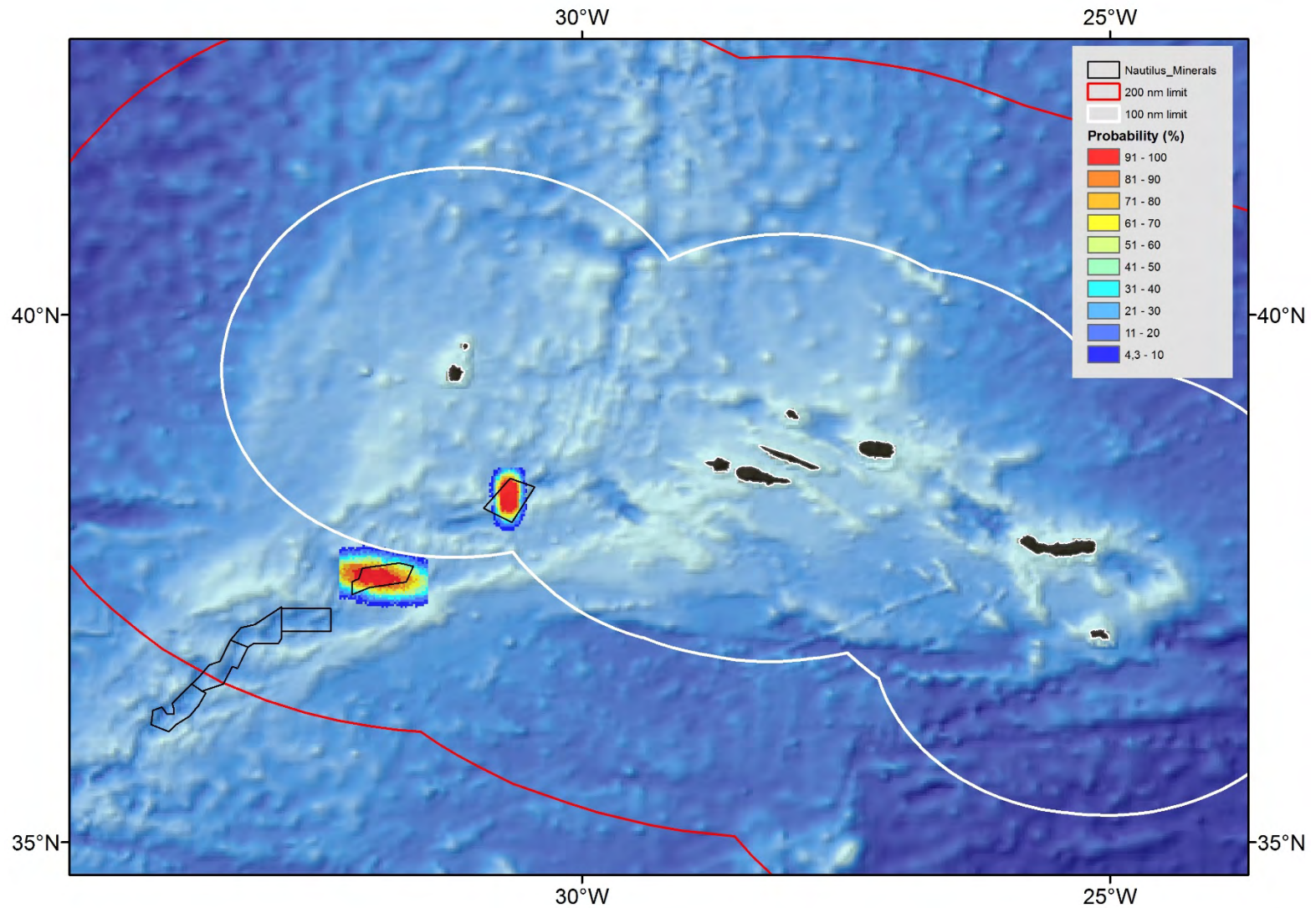
**Results: return discharge water**



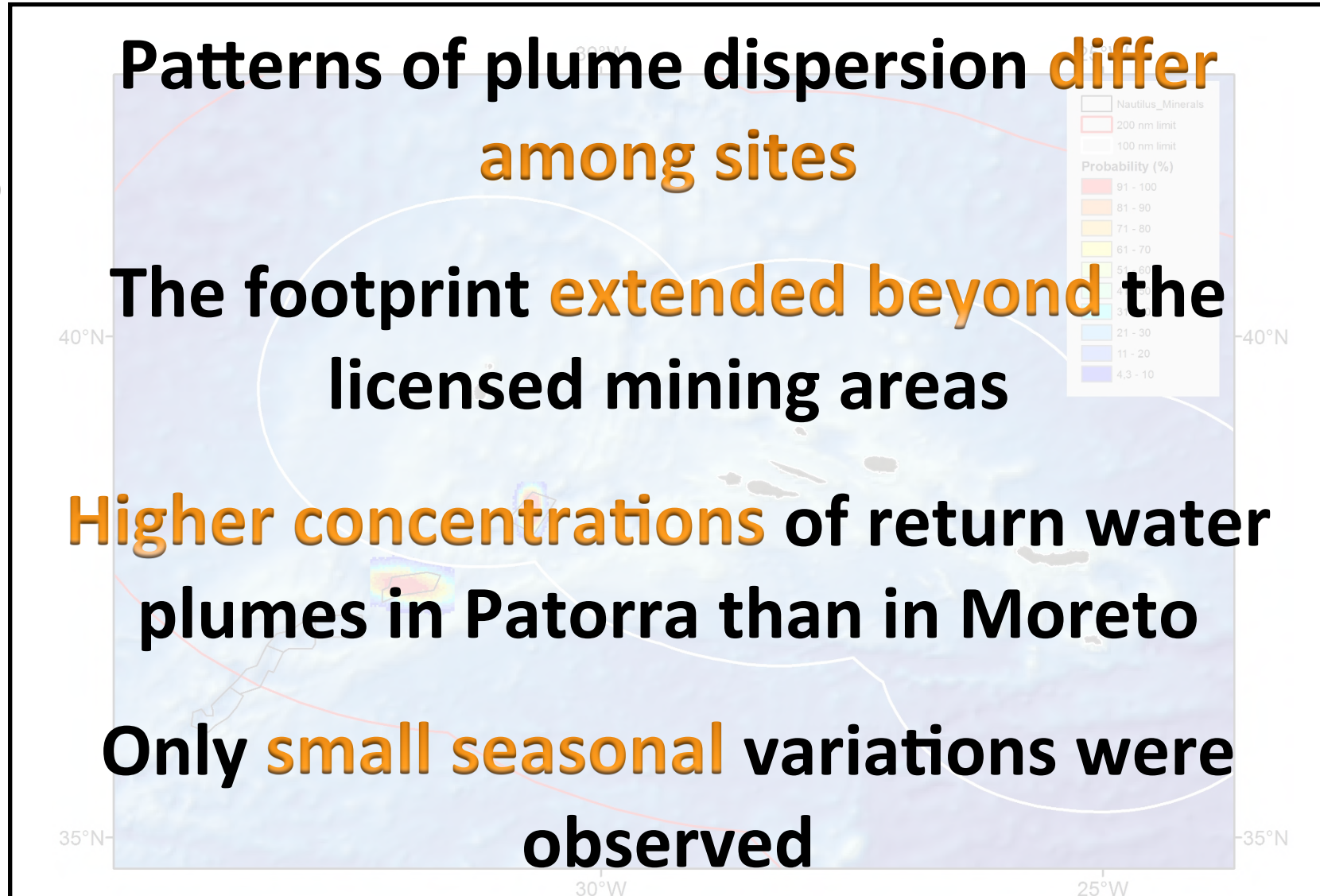
Probabilities above 1:600, 1:300, 1:200 < 5%

Probability of plumes above 1/5000 dilution threshold: **Both**

**Results: return discharge water**

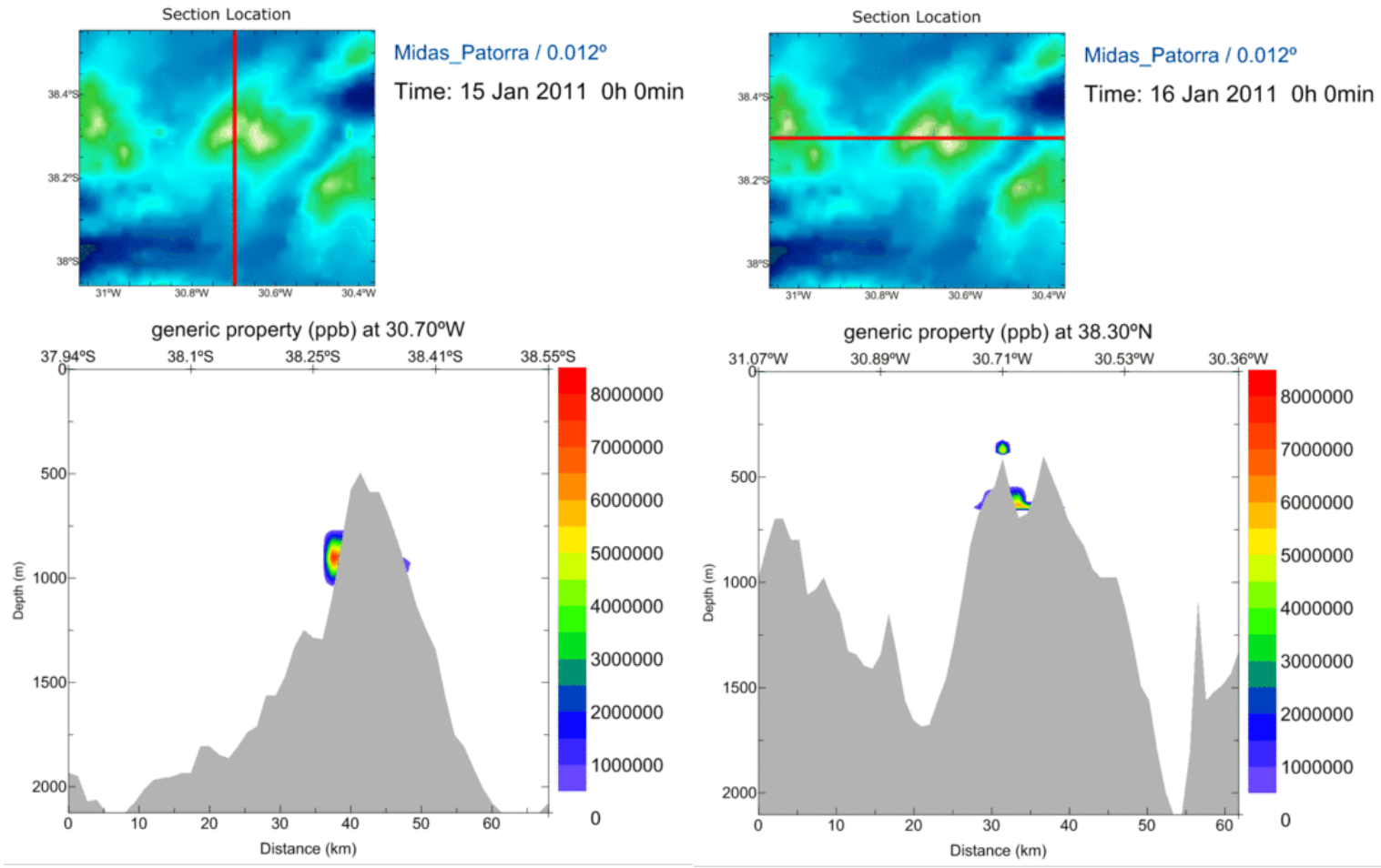


**Results: return discharge water**



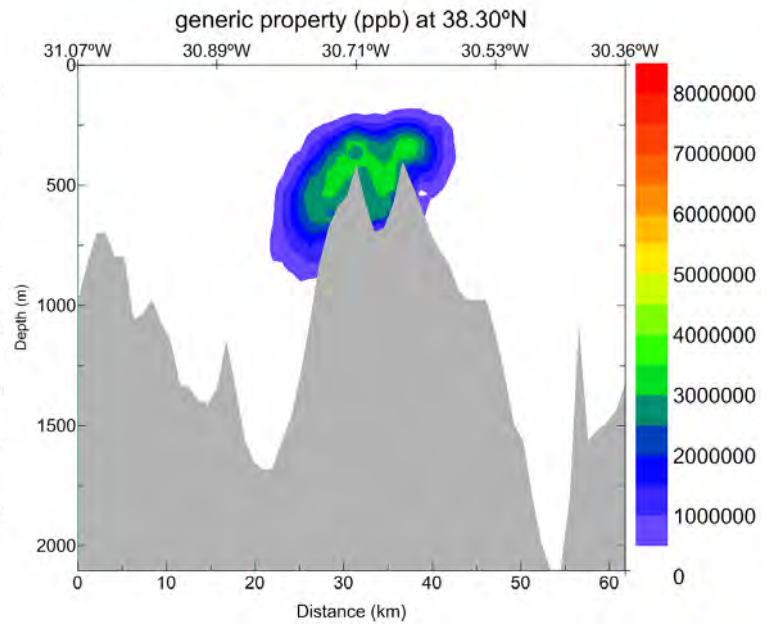
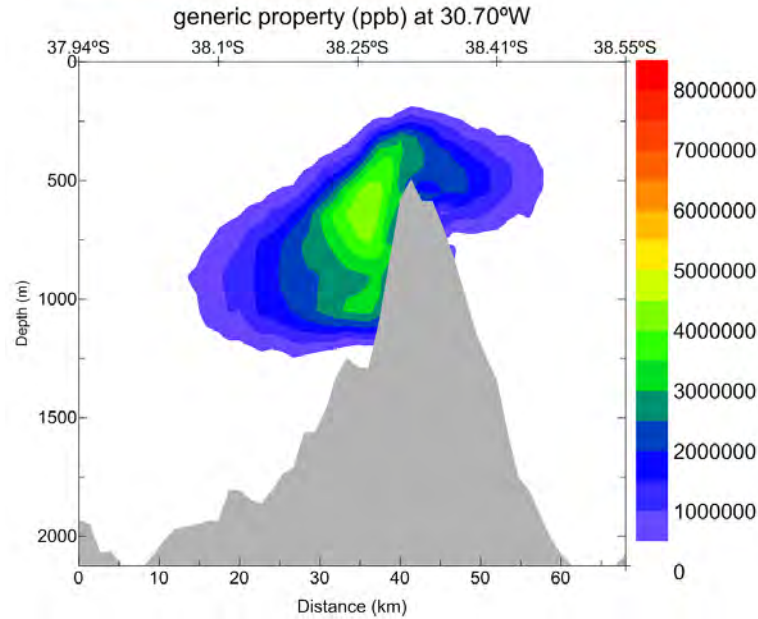
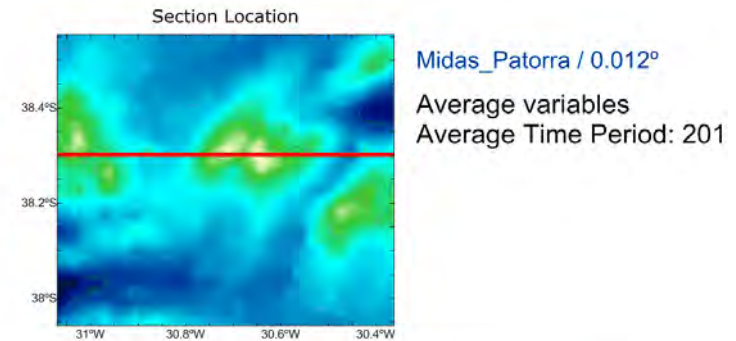
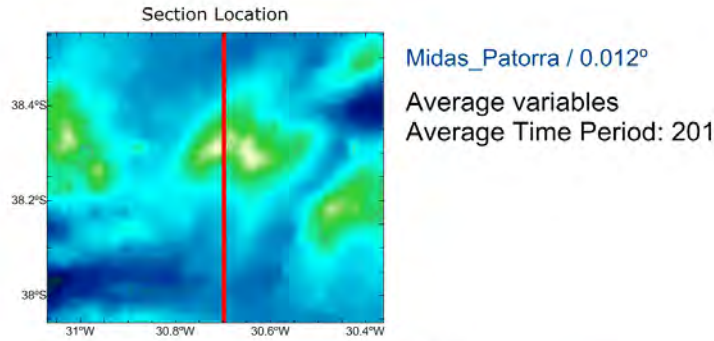
**Results: return discharge water**

**Cross sections of the average plume concentration: Patorra**



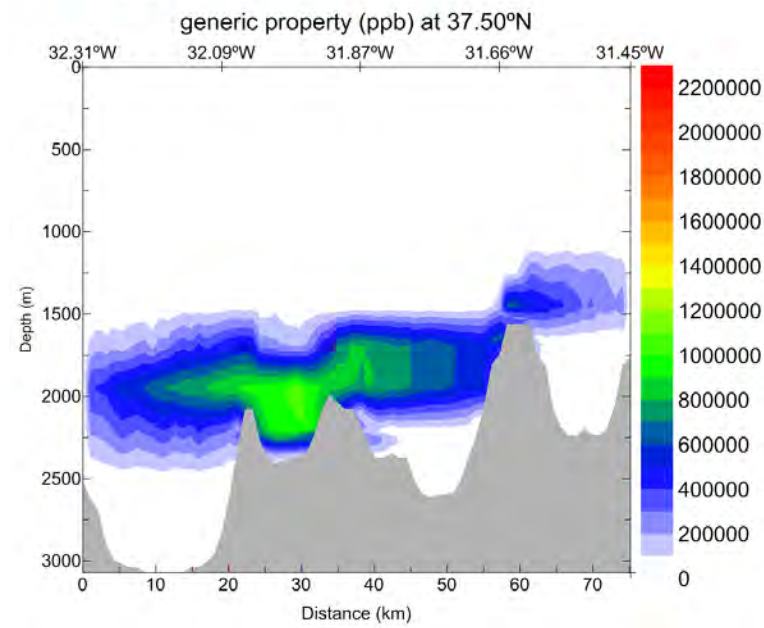
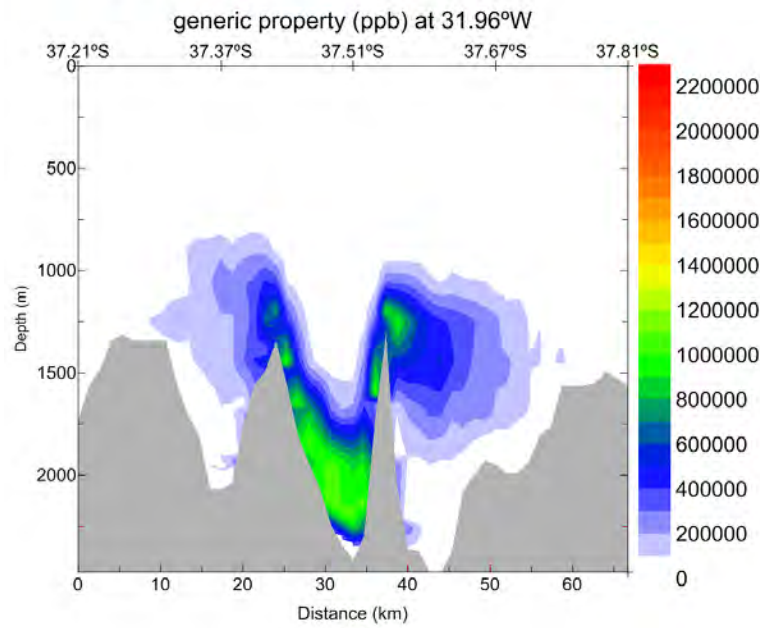
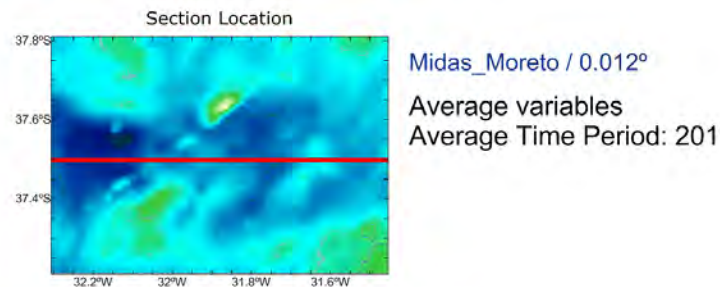
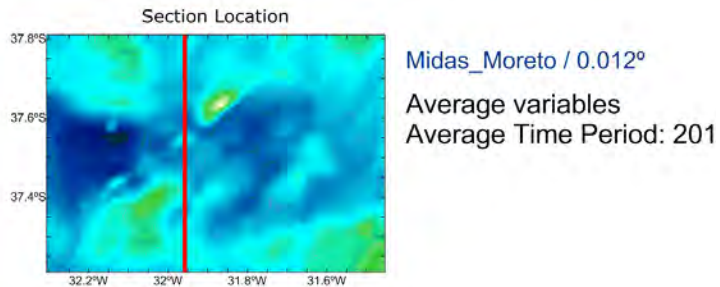
**Results: return discharge water**

**Cross sections of the average plume concentration: Patorra**

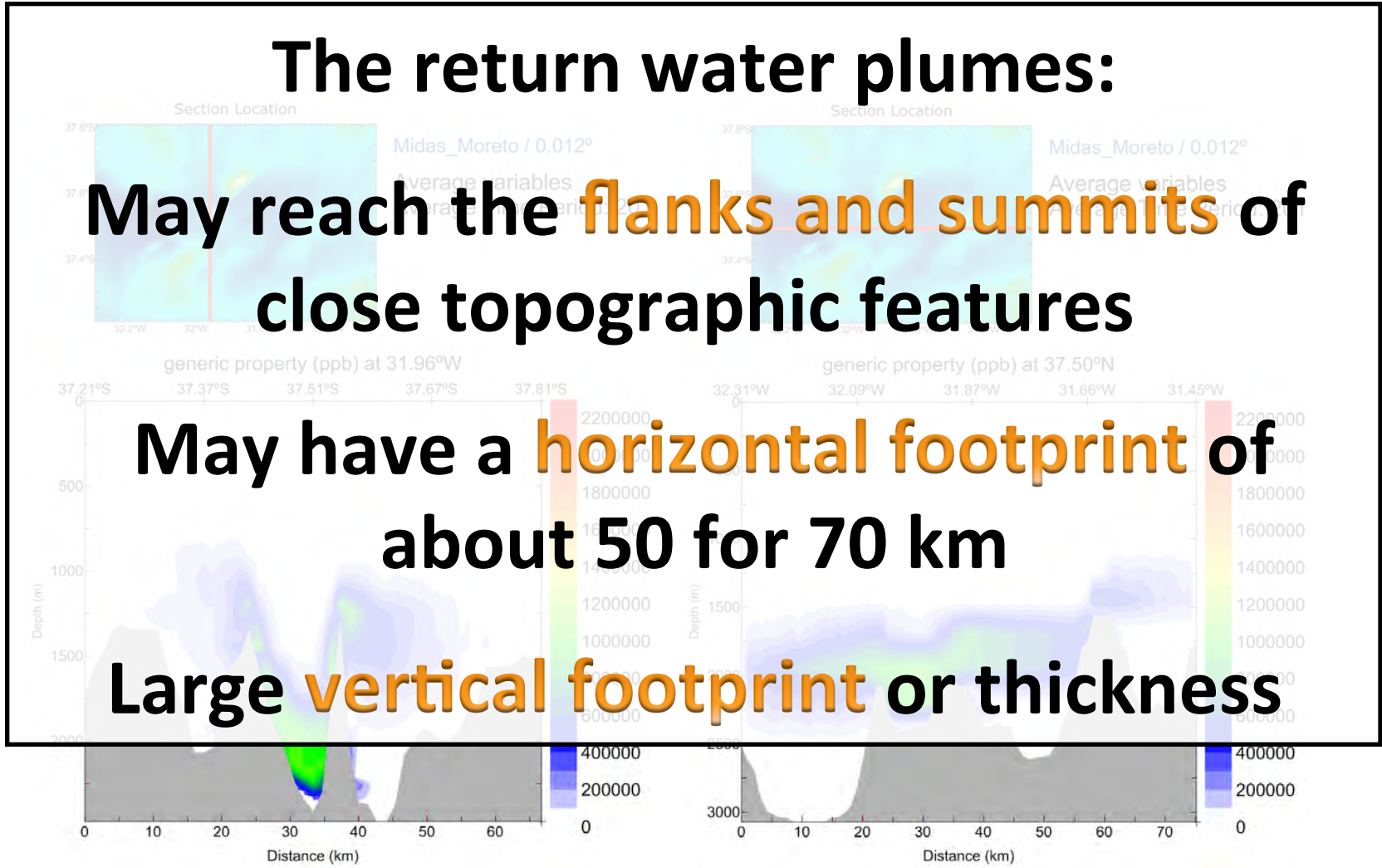


**Results: return discharge water**

**Cross sections of the average plume concentration: Moreto**



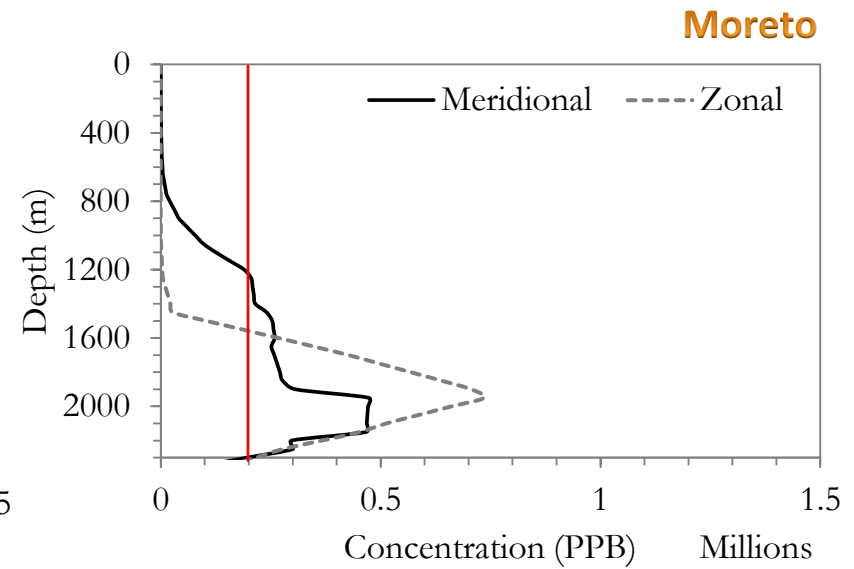
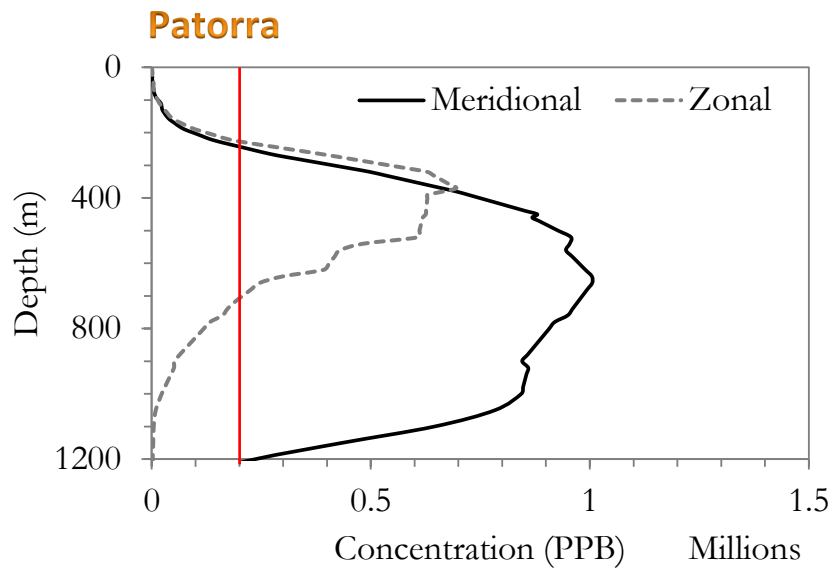
**Results: return discharge water**



## Results: return discharge water

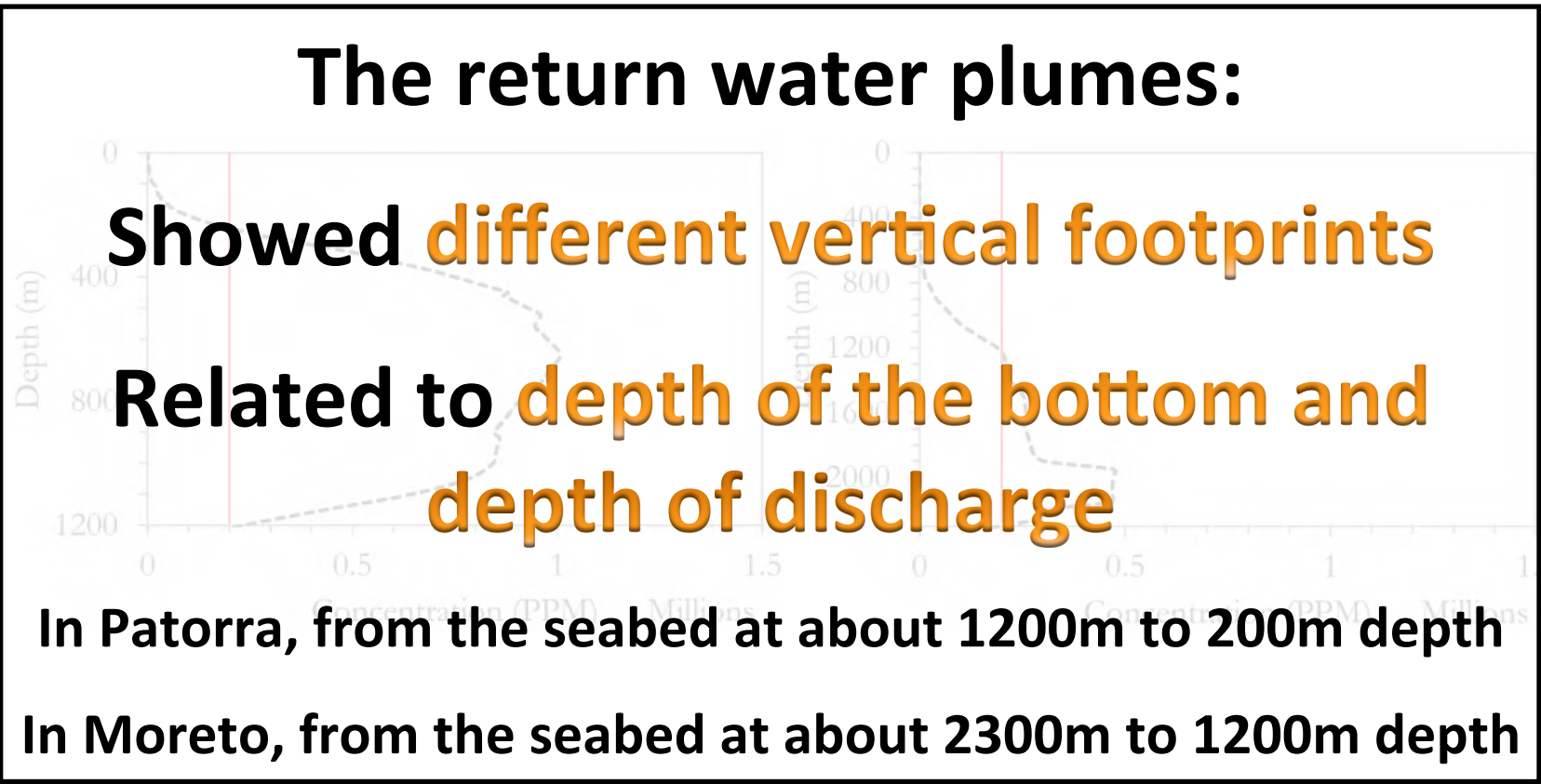
**Plume thickness or vertical footprint**

**Average vertical distribution of the return water discharge plume.**  
**Red line shows the 1/5000 dilution. Duration of the simulation is one year.**



**Results: return discharge water**

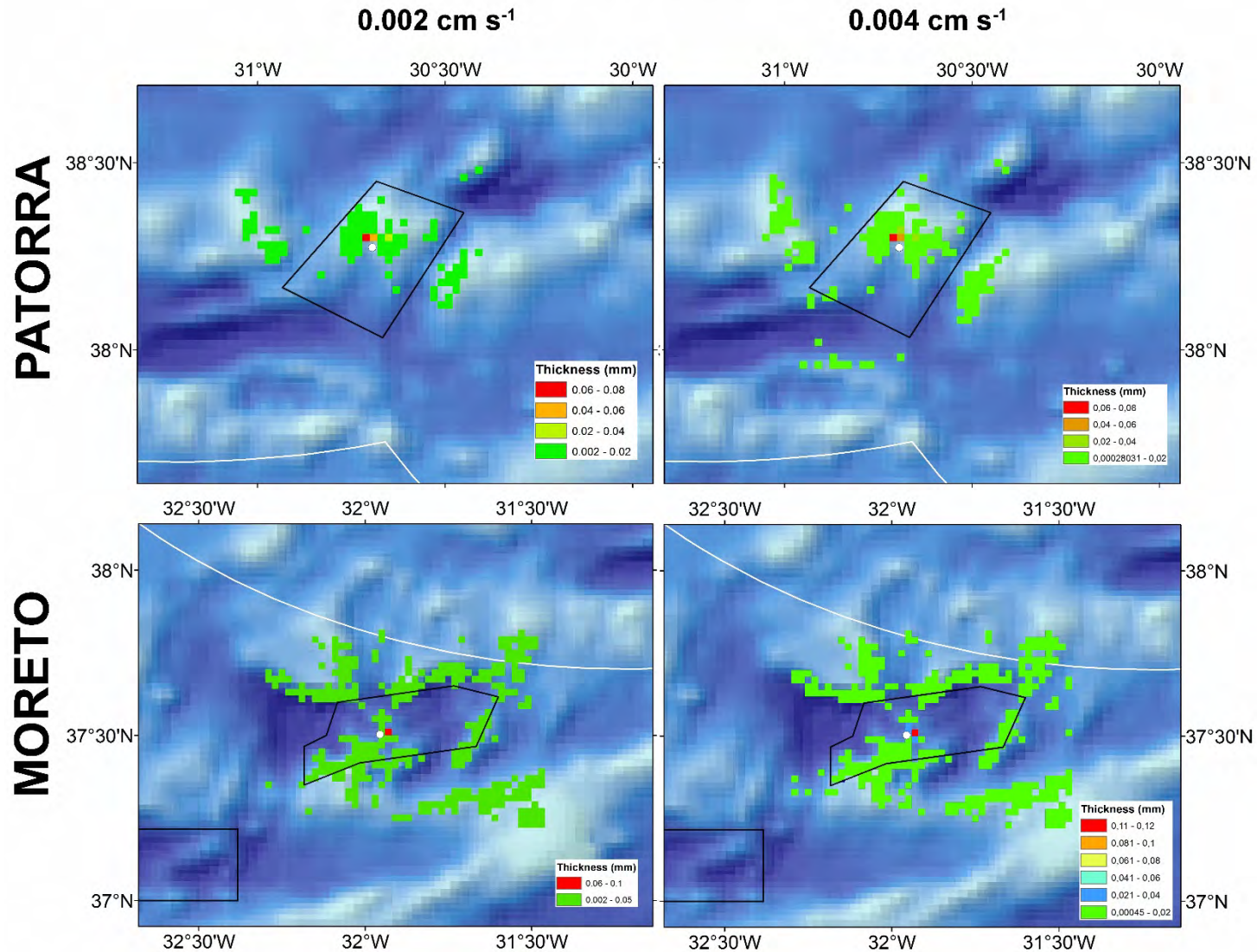
## The return water plumes:



**Bottom thickness of  
settled sediments  
from the return  
water discharge**

**Bottom thickness of settled sediments from the return water modelled with two different settling velocities: **Moreto** and **Patorra****

**Results: bottom thickness**



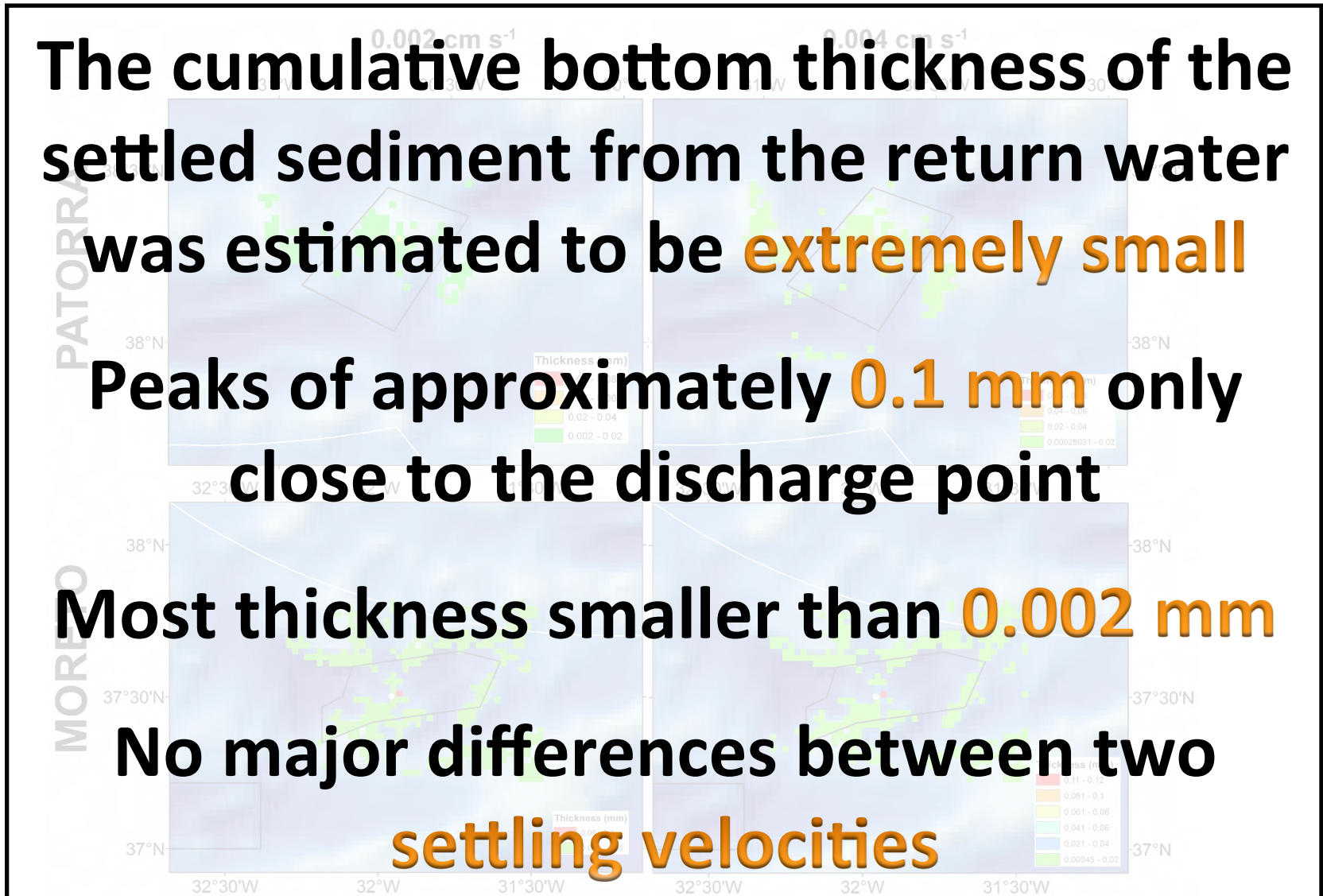
**Results: bottom thickness**

The cumulative bottom thickness of the settled sediment from the return water was estimated to be **extremely small**

Peaks of approximately **0.1 mm** only close to the discharge point

Most thickness smaller than **0.002 mm**

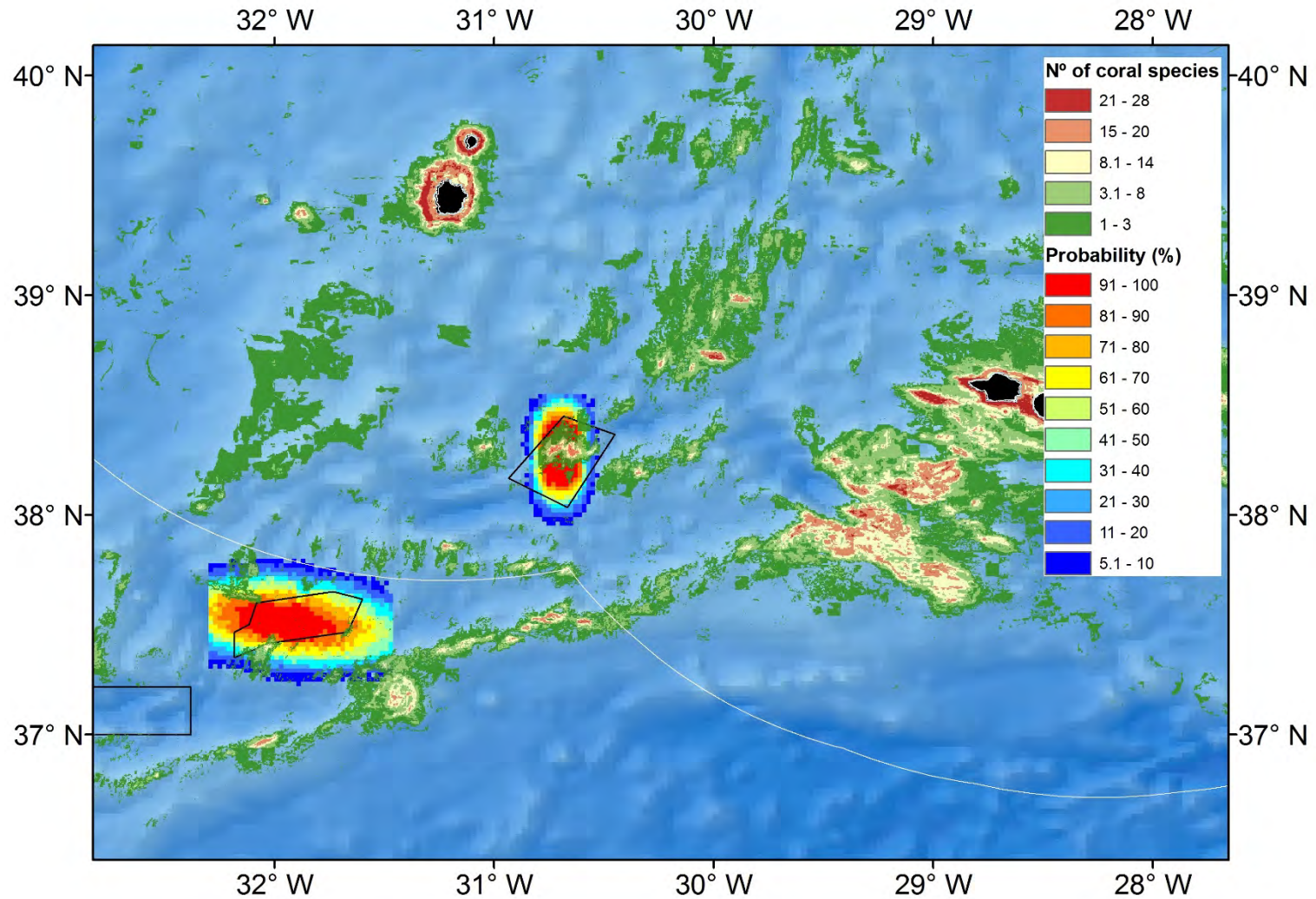
No major differences between two **settling velocities**



# Potential **impacts** of sediment plumes

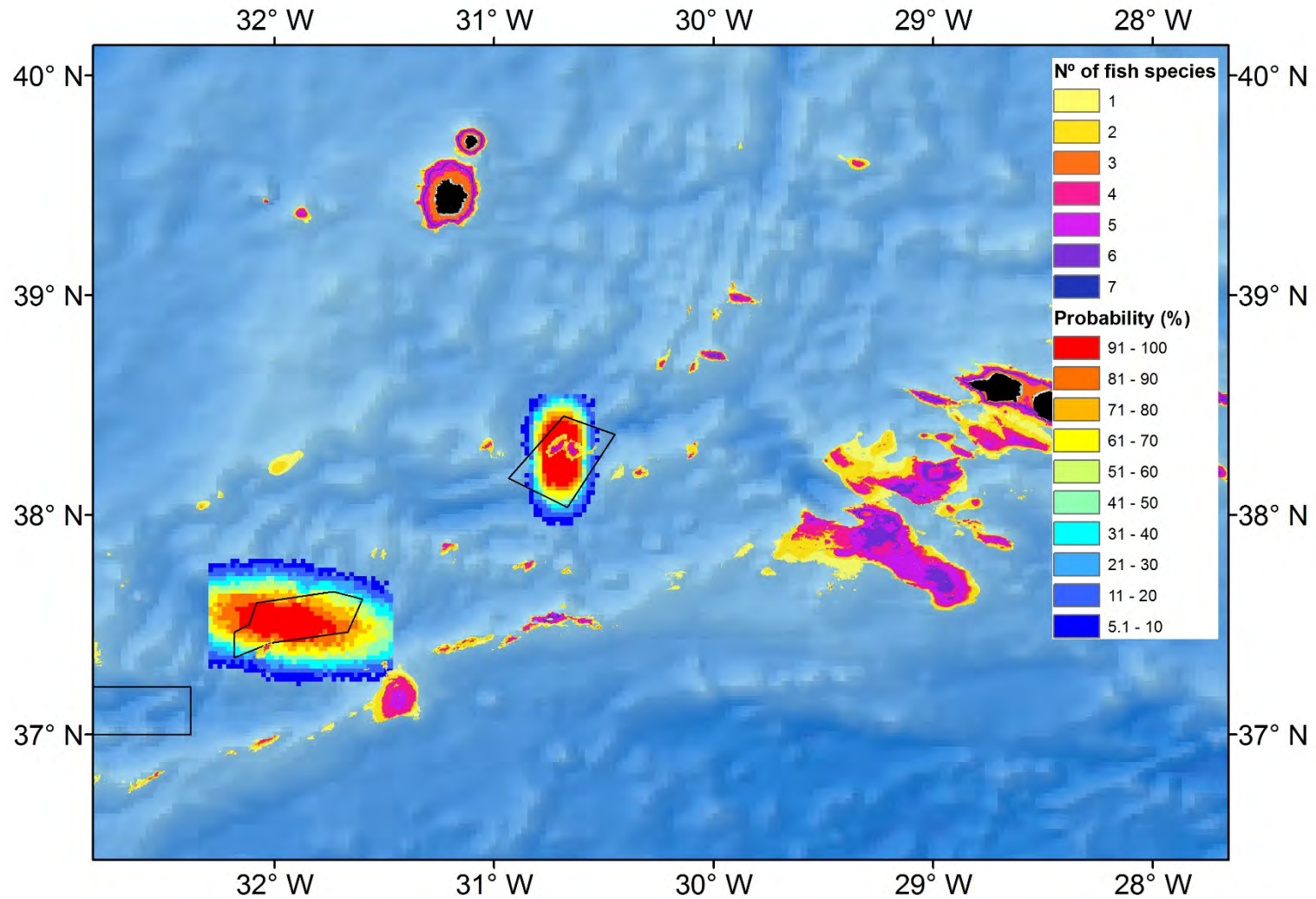
**Overlaying 2D plume simulation outputs with cold-water corals species distribution models**

**Results: potential impacts**



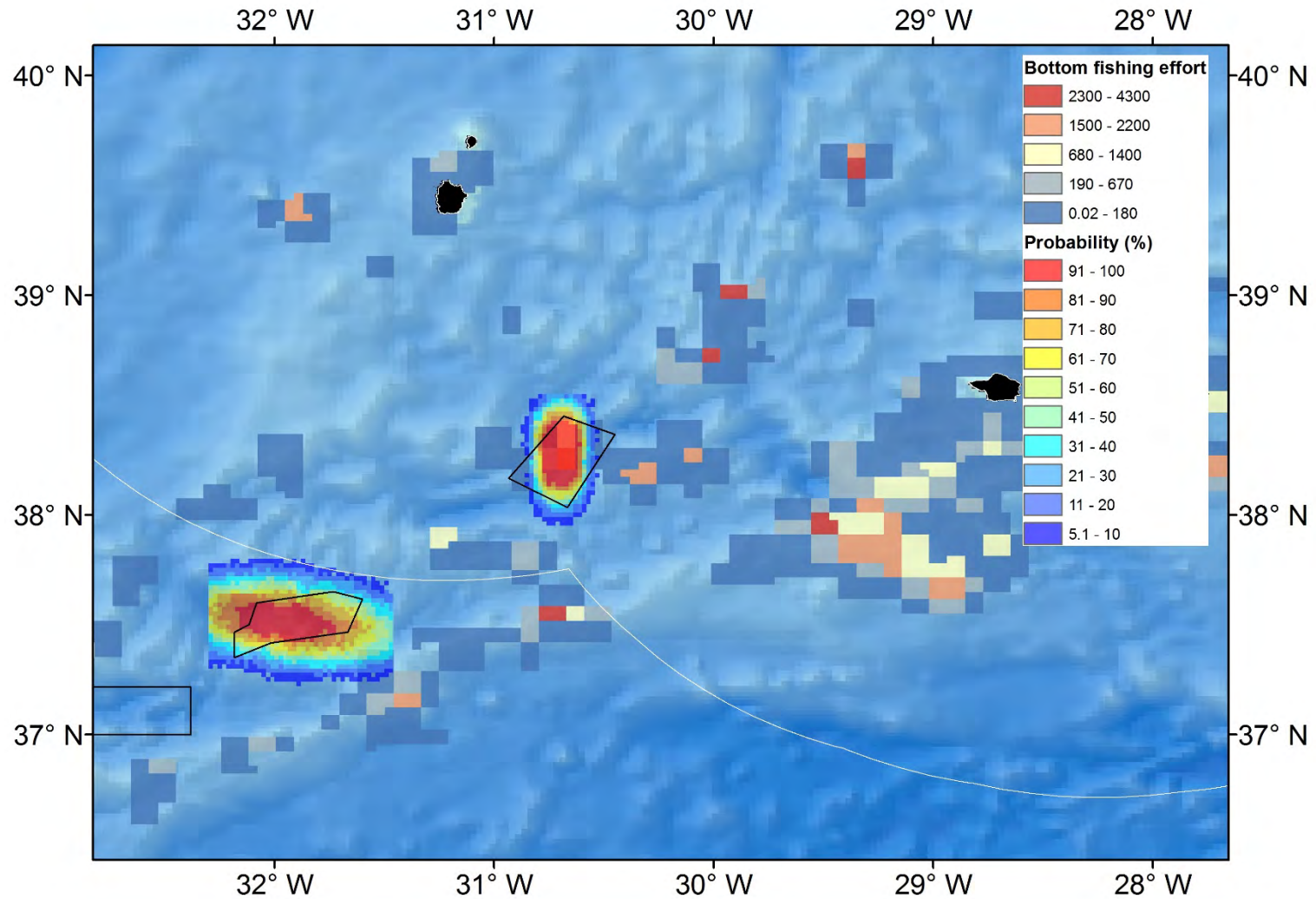
**Overlaying 2D plume simulation outputs with commercial fish species distribution models**

**Results: potential impacts**



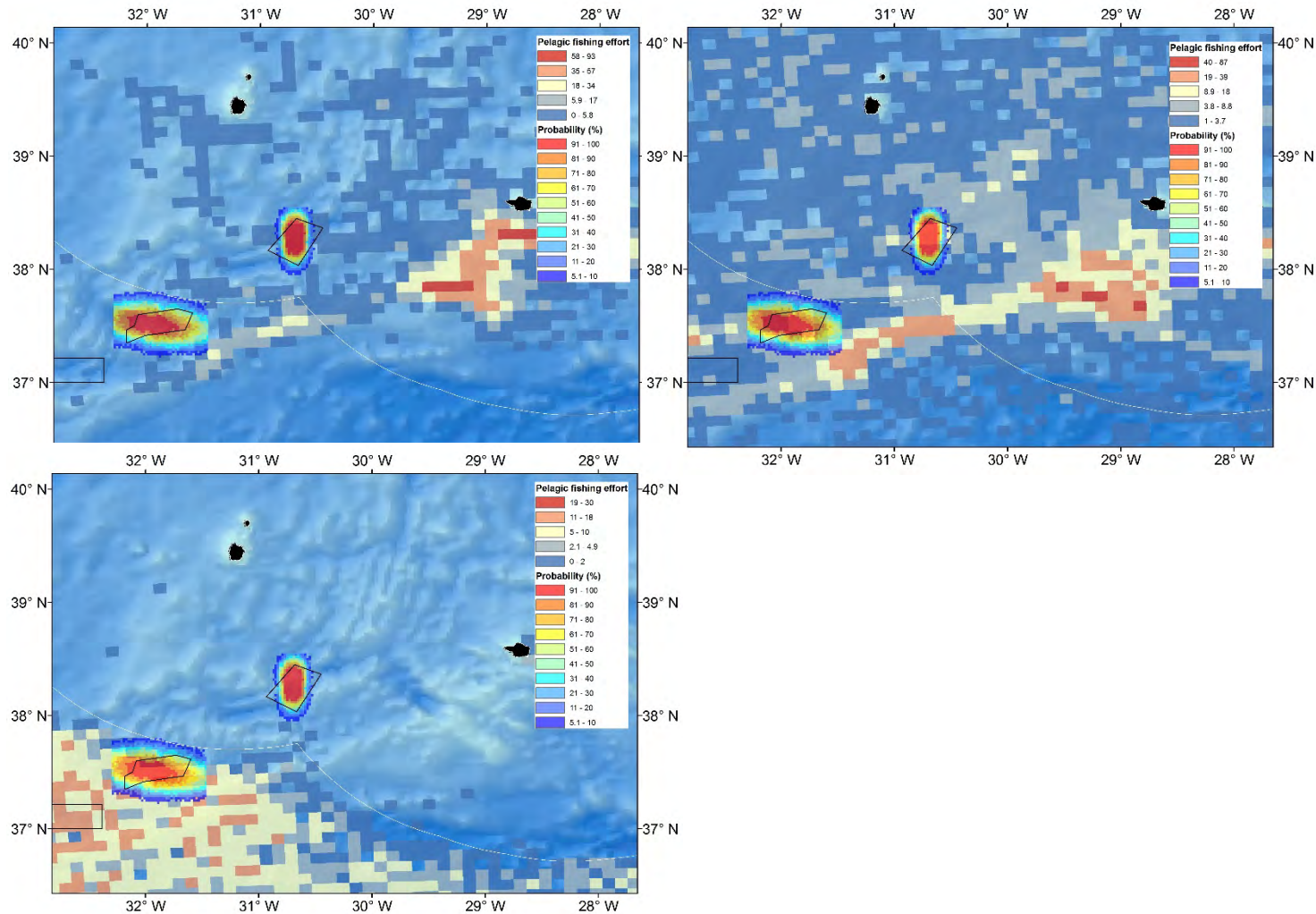
**Overlaying 2D plume simulation outputs with bottom longline fishing effort maps from VMS data**

**Results: potential impacts**



## Overlaying 2D plume simulation outputs with pelagic longline fishing effort maps from VMS data

Results: potential impacts



## Conclusions

Simulations of plume dispersal **vary significantly** between sites, making generalizations hard to adopt

The **mesopelagic environment** will likely receive most of the deep-sea mining plumes

Simulations suggest potential **overlap with pelagic fishing** activities

# Acknowledgments

**Special thanks** to the co-workers on this project



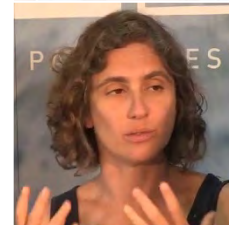
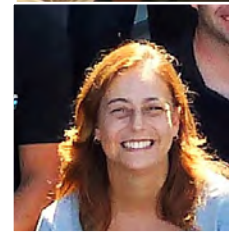
**Manuela Juliano**

**Christopher K. Pham**

**Ana Colaço**

**Marina Carreiro-Silva**

**Inês Martins**



And to people involved in SDM and spatial analyses, namely Hugo Parra,  
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