Interreg
EUROPEAN UNION
ADRION
ADRIATIC-IONIAN
European Regional Development Fund - Instrument for Pre-Accession II Fund

HarmoNIA

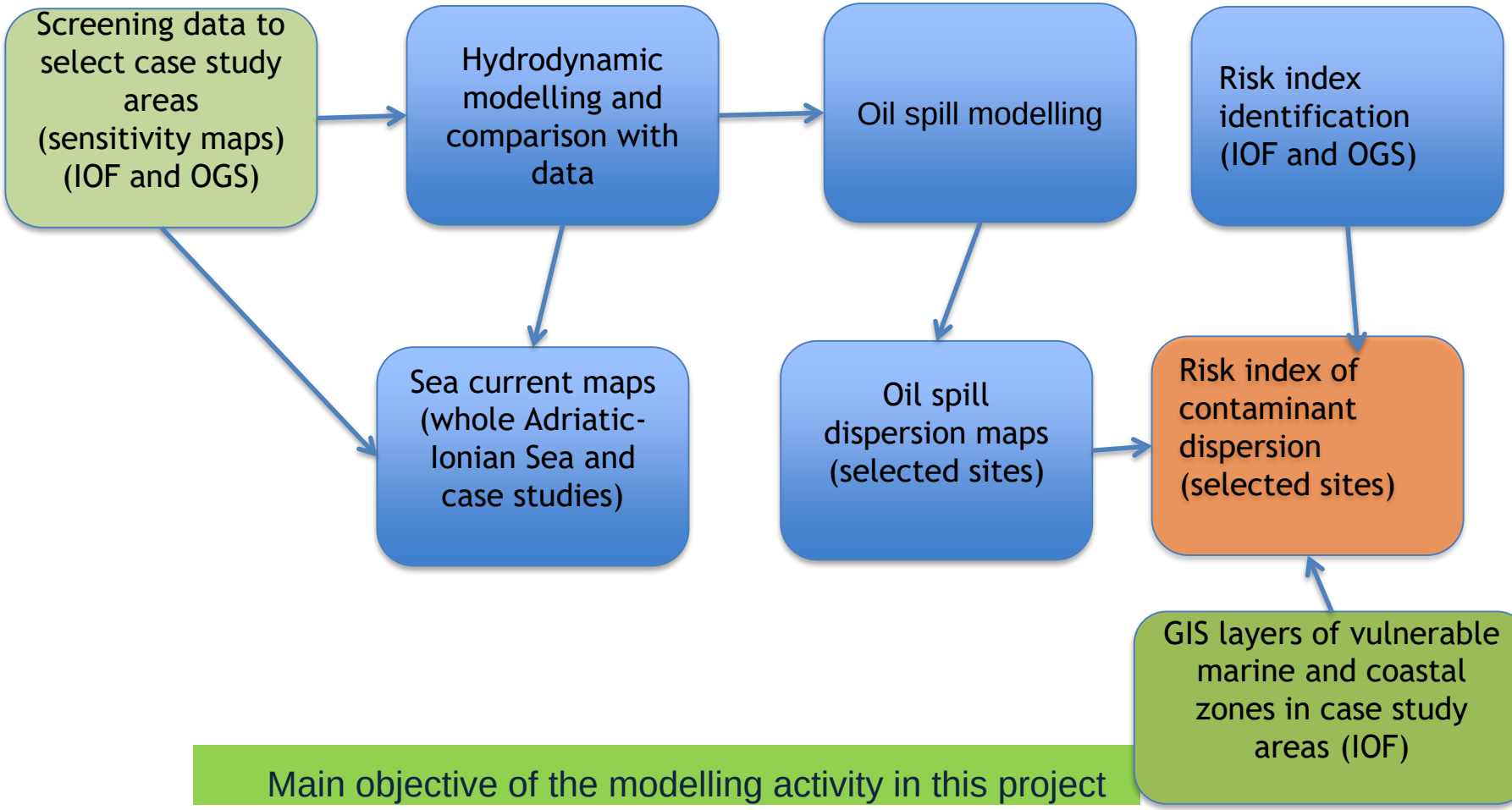
Harmonization and **N**etworking for contaminant assessment in the **I**onian and **A**driatic Seas

Hydrodynamic and oil spill models in oil slick risk assessment

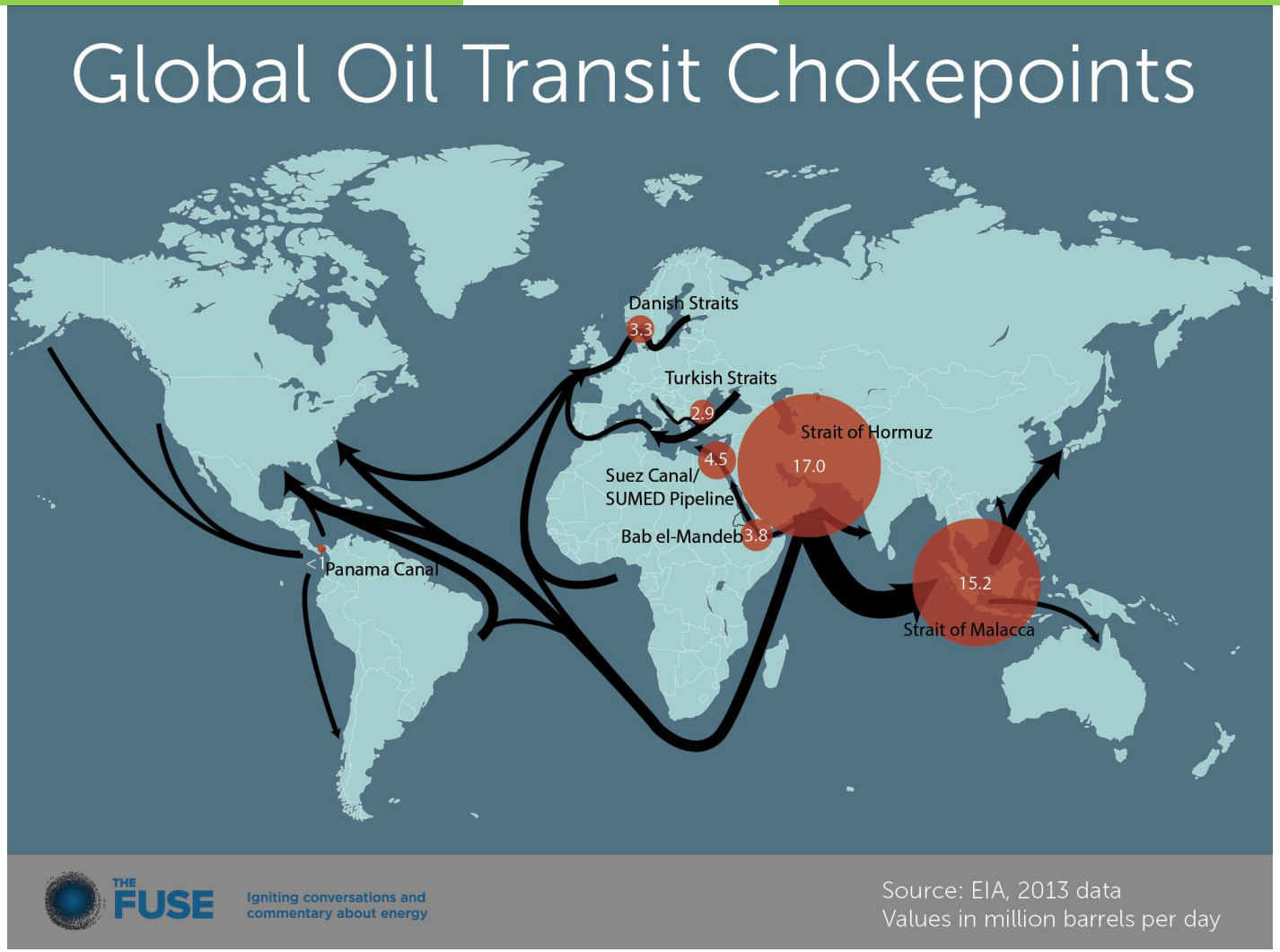
Donata Canu, OGS, Italy

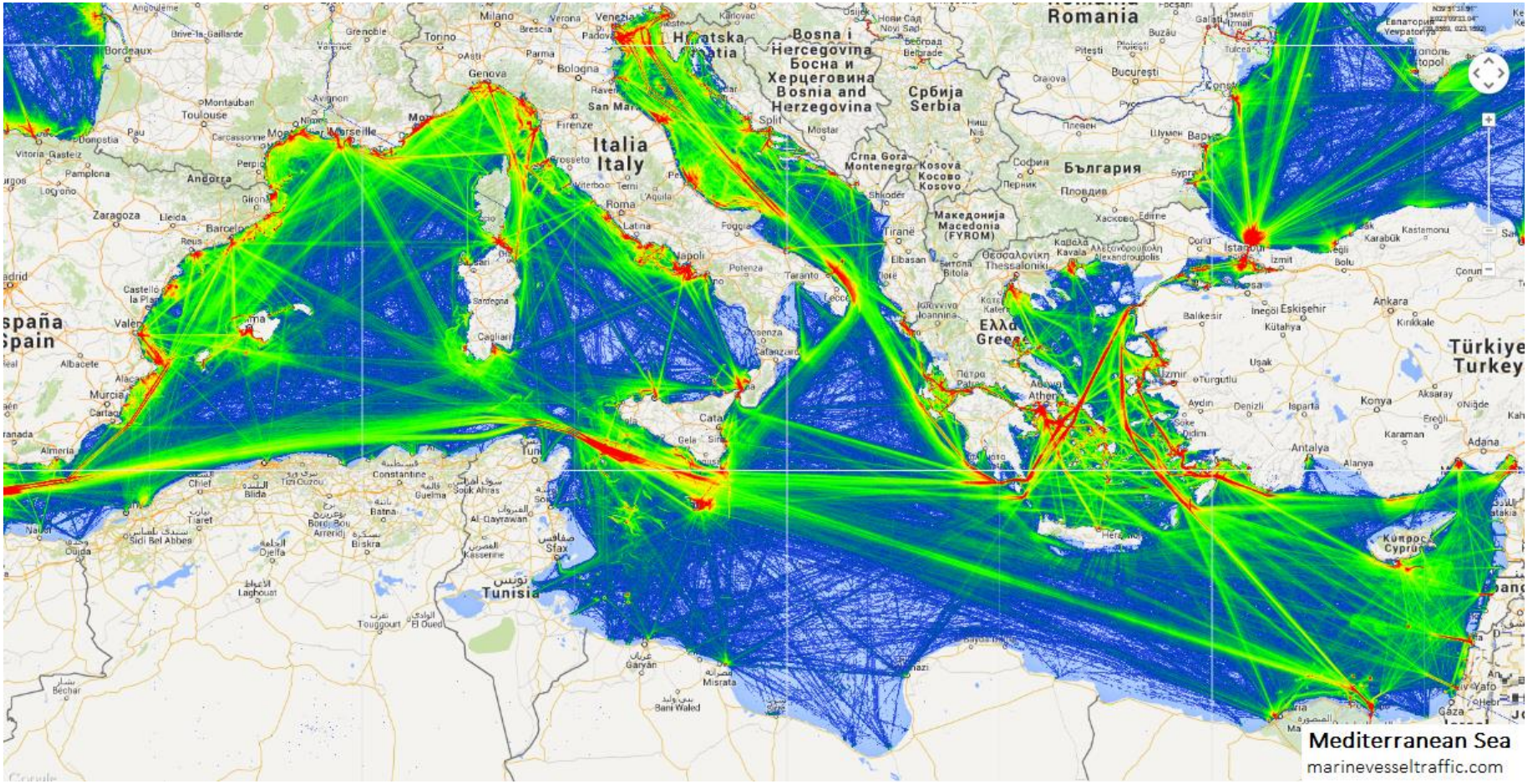
International workshop in the Adriatic Ionian region,
SPLIT, 7/2/2019

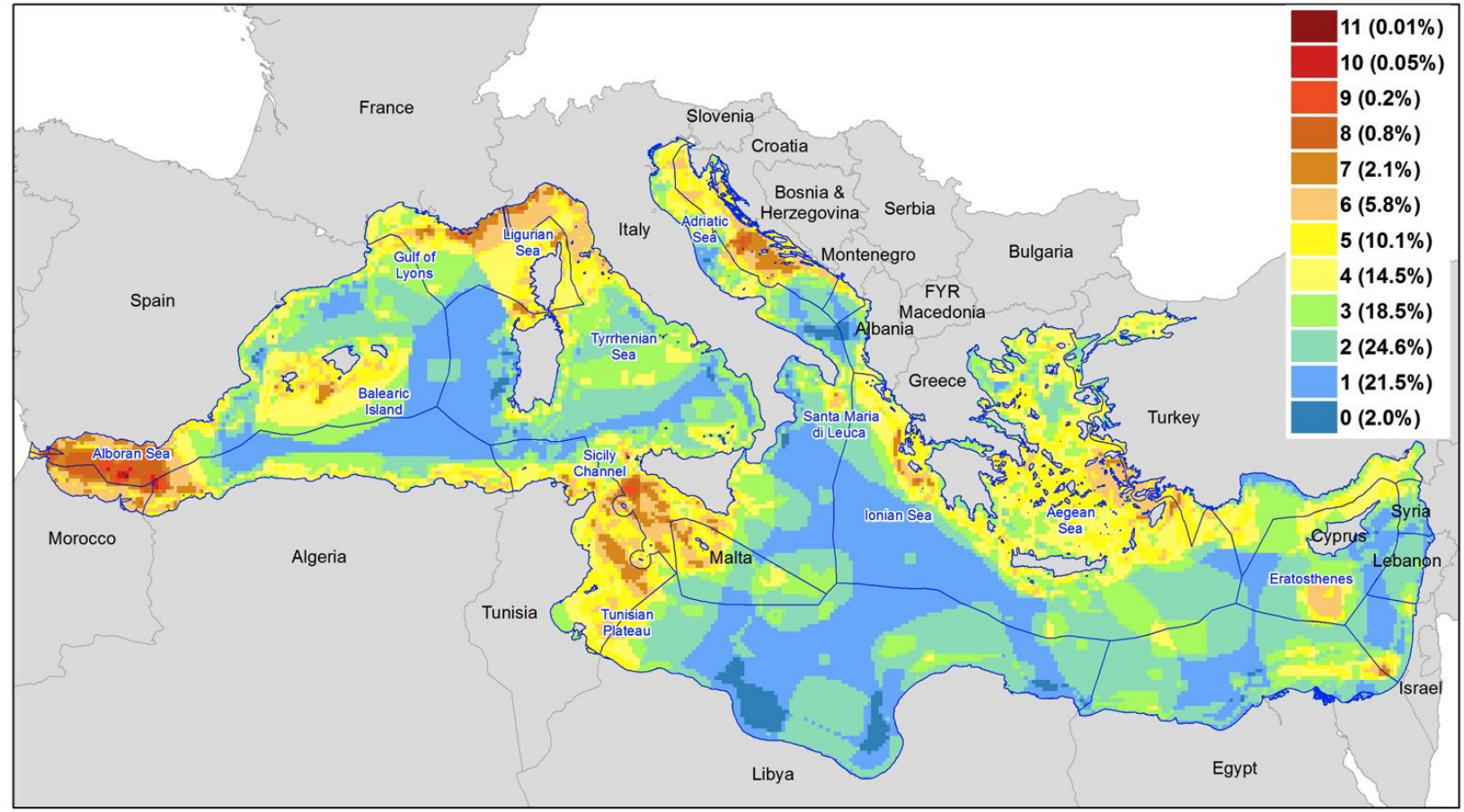
MAIN OBJECTIVE



Main objective of the modelling activity in this project

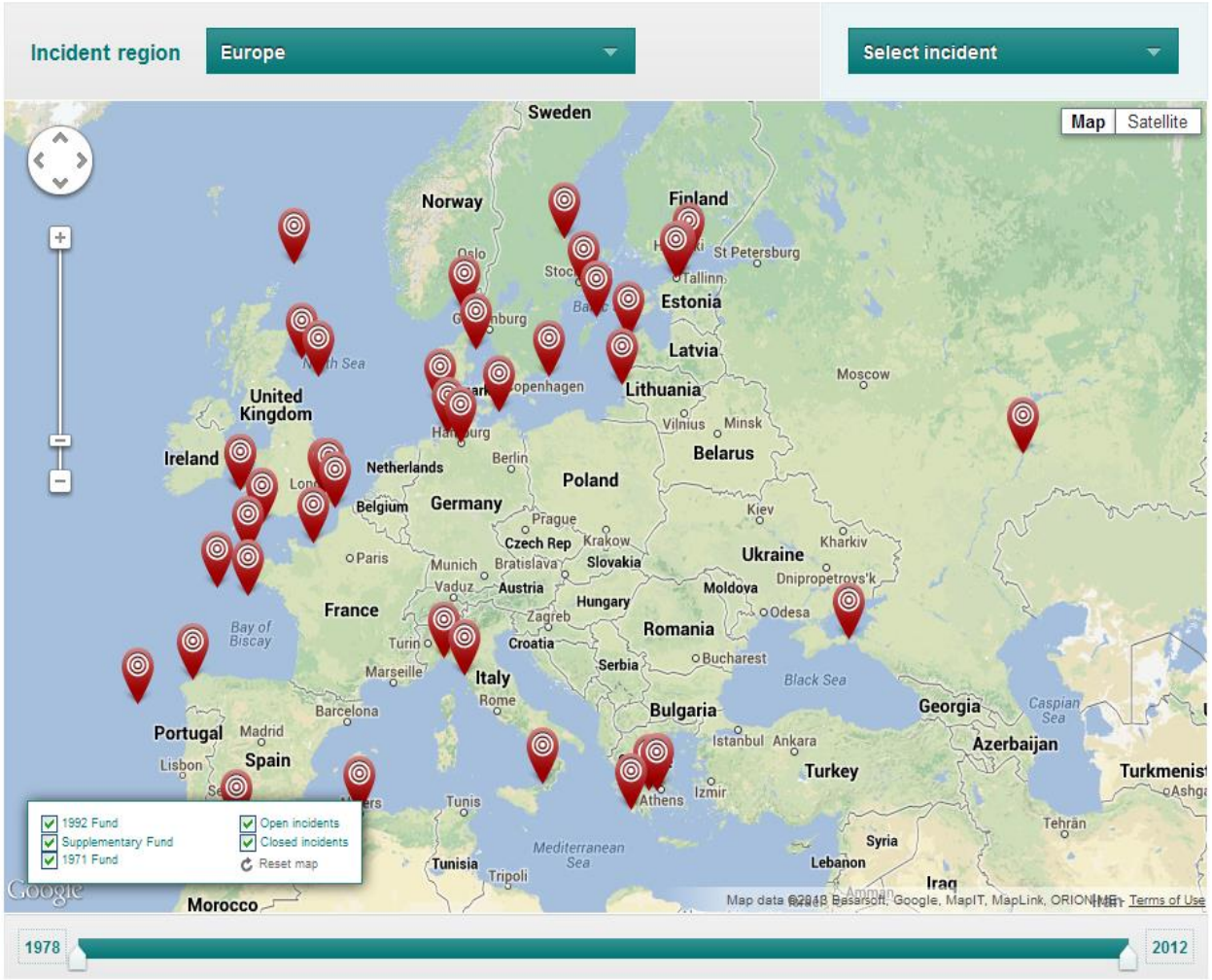

Global Oil Transit Chokepoints
Danish Straits
3.3
Turkish Straits
2.9
Strait of Hormuz
17.0
4.5
Suez Canal/
SUMED Pipeline
Bab el-Mandeb
3.8
<1
Panama Canal
15.2
Strait of Malacca
THE FUSE
Igniting conversations and commentary about energy
Source: EIA, 2013 data
Values in million barrels per day


Mediterranean Sea
marinevesseltraffic.com



Frequency of inclusion by proposed conservation plans

Micheli et al., PLOS ONE. 2013 DOI: 10.1371/journal.pone.0059038



Oil spills (oil tankers)

Including two happened in Italy

- Haven 1991
- Patmos 1985

Oil spilled, respectively: 144000 tons and 700 tons

The International Oil Pollution Compensation Funds (IOPC Funds) 1978-2013
http://www.iopcfunds.org/incidents/

MODEL/DATA

Oil spills hazard: Sicily Channel study site

Marine Pollution Bulletin 94 (2015) 84–95

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Assessment of oil slick hazard and risk at vulnerable coastal sites

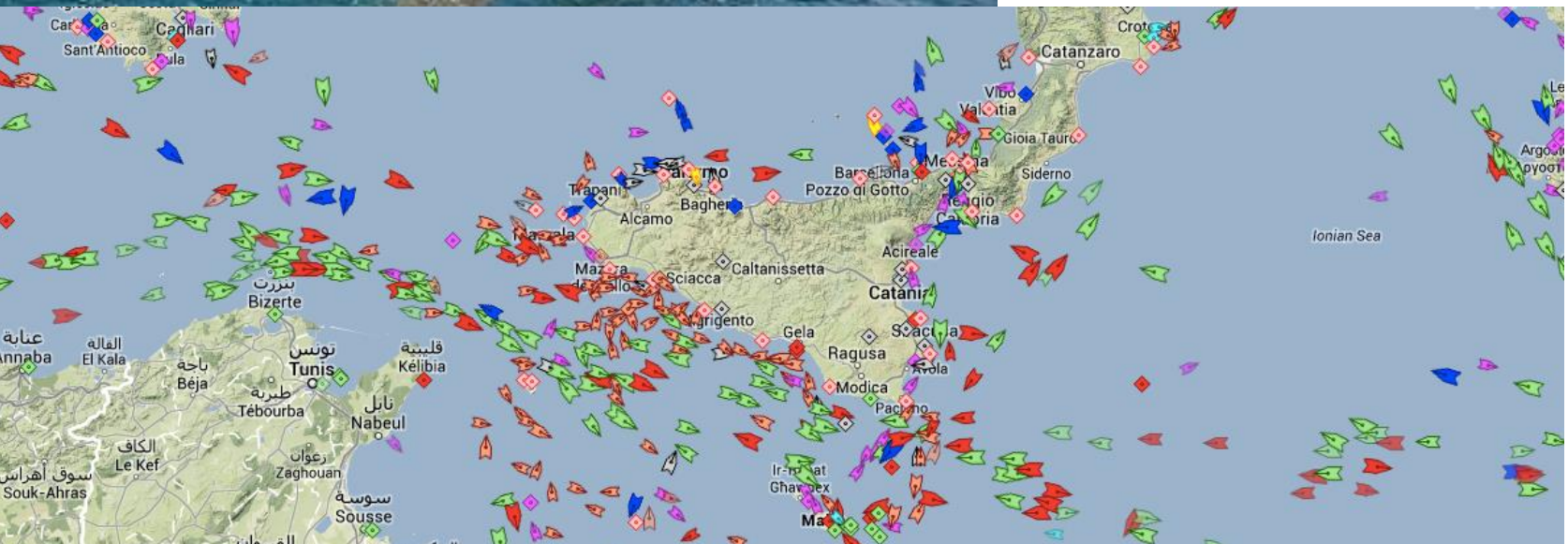
Donata Melaku Canu [a,*], Cosimo Solidoro [a,b], Vinko Bandelj [a], Giovanni Quattrocchi [c], Roberto Sorgente [c], Antonio Olita [c], Leopoldo Fazioli [c], Andrea Cucco [c]

[a] OGS, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Borgo Grotta Gigante 42 c, Sgonico, Trieste, Italy
[b] International Centre for Theoretical Physics, Strada Costiera, 11, Trieste, Italy
[c] CNR-IAMC, Sect. Oristano, c/o International Marine Centre, Loc. Sa Mardini, 09072 Torregrande, Oristano, Italy

Melaku Canu D., Solidoro C., Bandelj V., Quattrocchi G., Sorgente R., Olita A., Fazioli L., Cucco A. 2015. Assessment of oil click hazard and risk at vulnerable coastal sites. Marine pollution bulletin. Vol., 94, issue 1-2, 15 May 2015, Pages 84-95.

A crowded shipping route

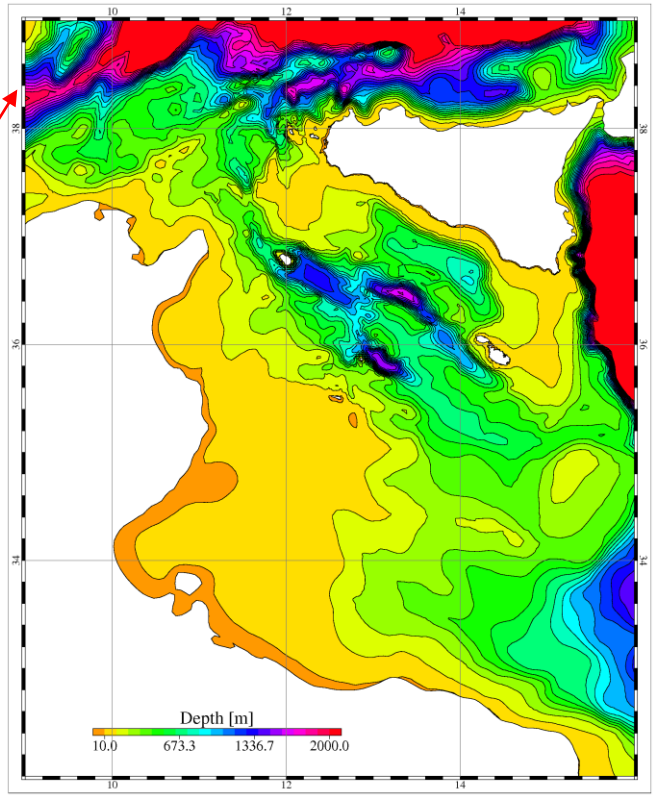
MARINE SHIPPING,
JULY 16th 2014,
10.00 a.m



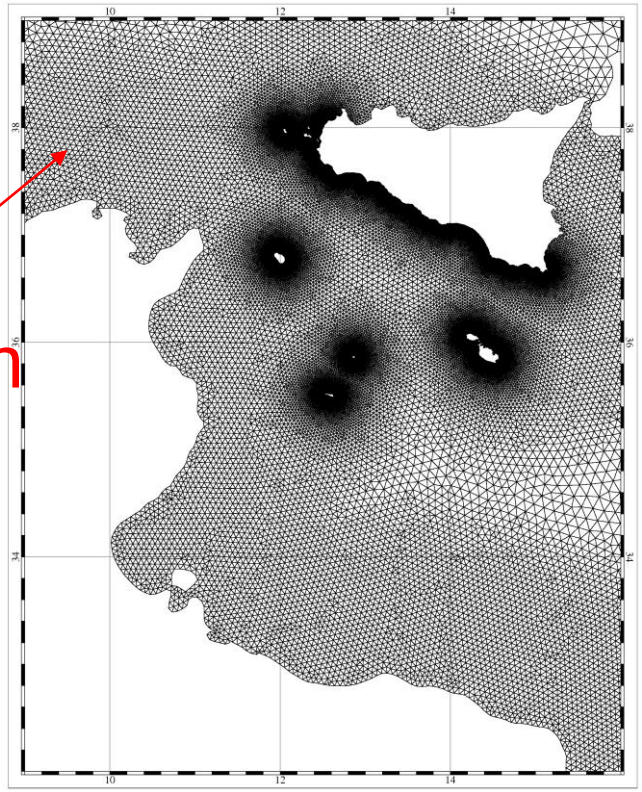
Numerical methods:

- Med Sea Hydrodynamic model (MOON, GNOO)
- Very high resolution Shyfem (3 km – 20 m) nesting for the Sicily Channel
- Lagrangian model for the oil slick simulations, horizontal dispersion
- Simple transformation of oil particles: evaporation and sink (FEMOIL, Cucco et al., 2012)

Bathymetry



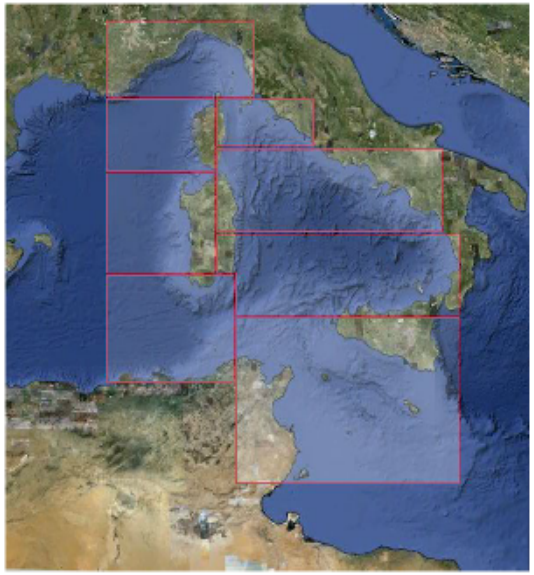
Finite element high resolution grid



Seleziona area

Mediterraneo Occidentale | Canale di Sicilia

Seleziona sotto-area col mouse



Seleziona campo

- Onda
- Corrente
- Temperatura

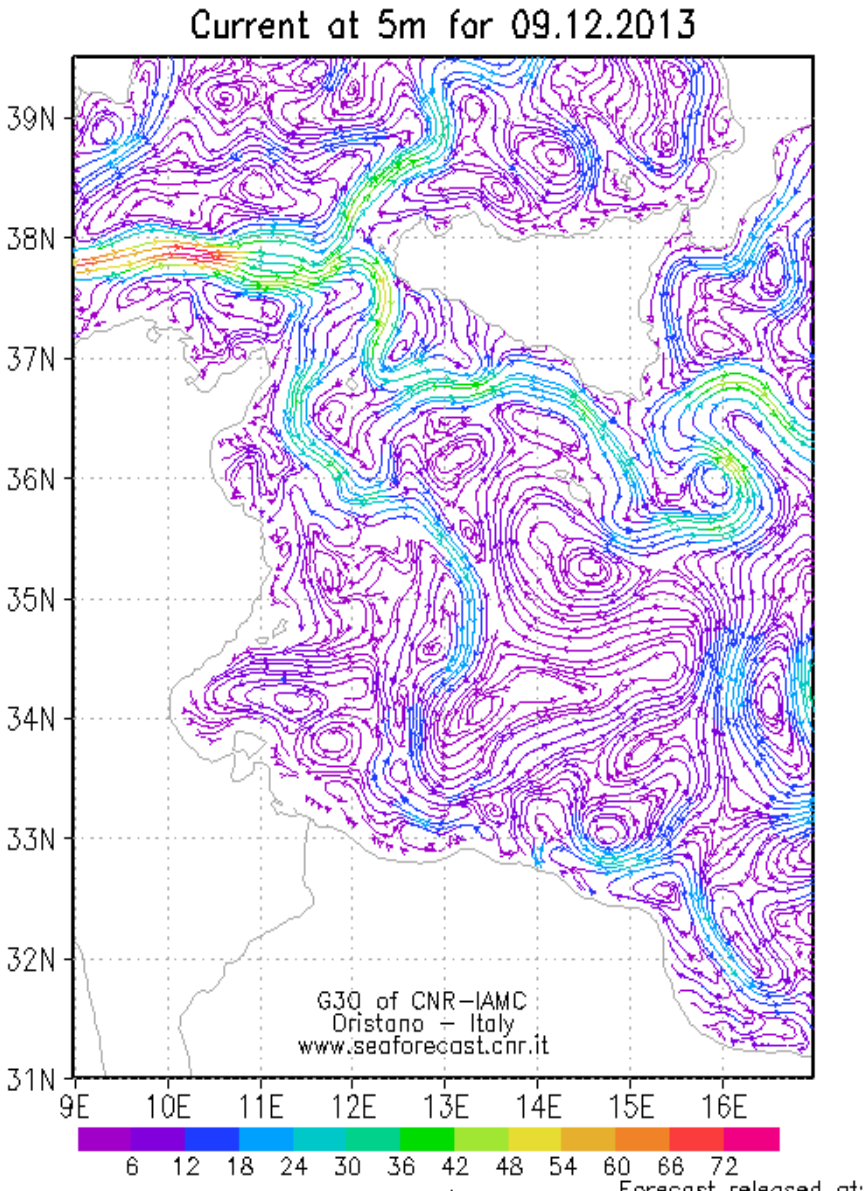
Seleziona giorno

- 10 Dec 2013
- 11 Dec 2013
- 12 Dec 2013

Seleziona profondità

- 5m
- 30m
- 120m

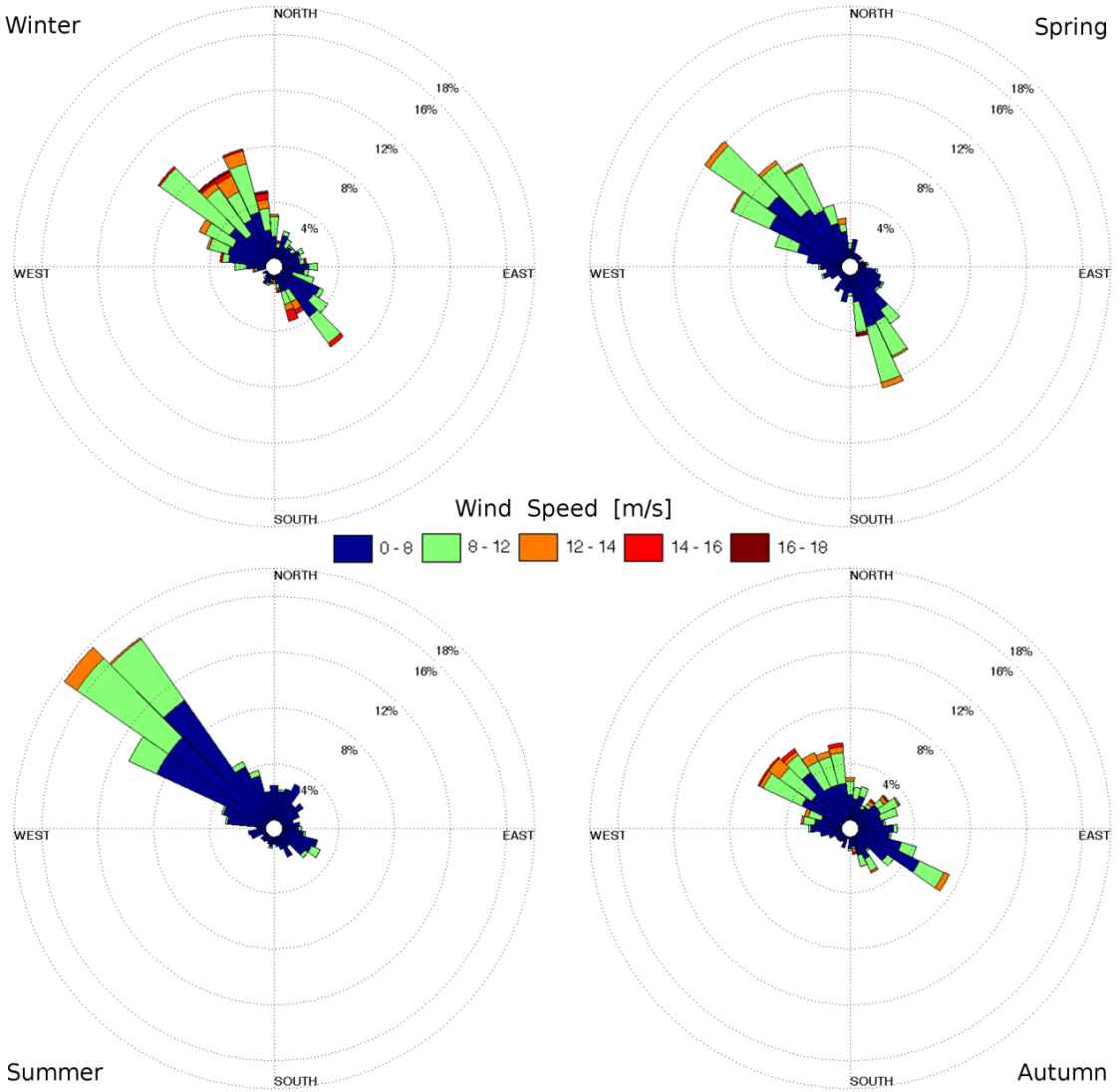
Sezione | Animazione



Operational model:

Hourly data 2010-2011

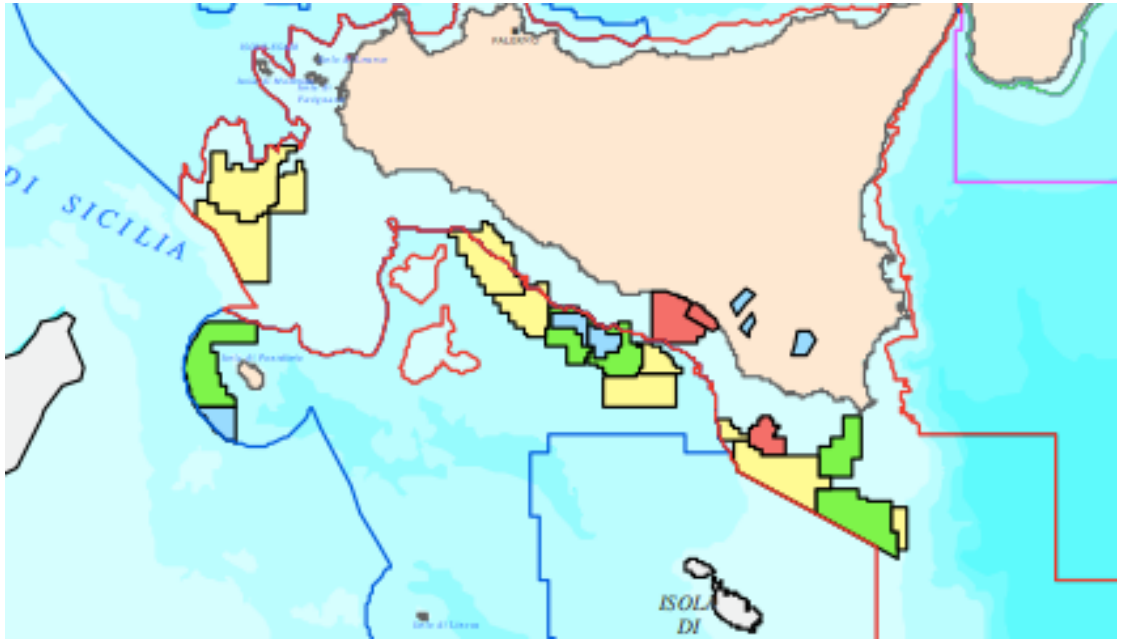
SKIRON high resolution atmospheric numerical model (Kallos et al. 2005)

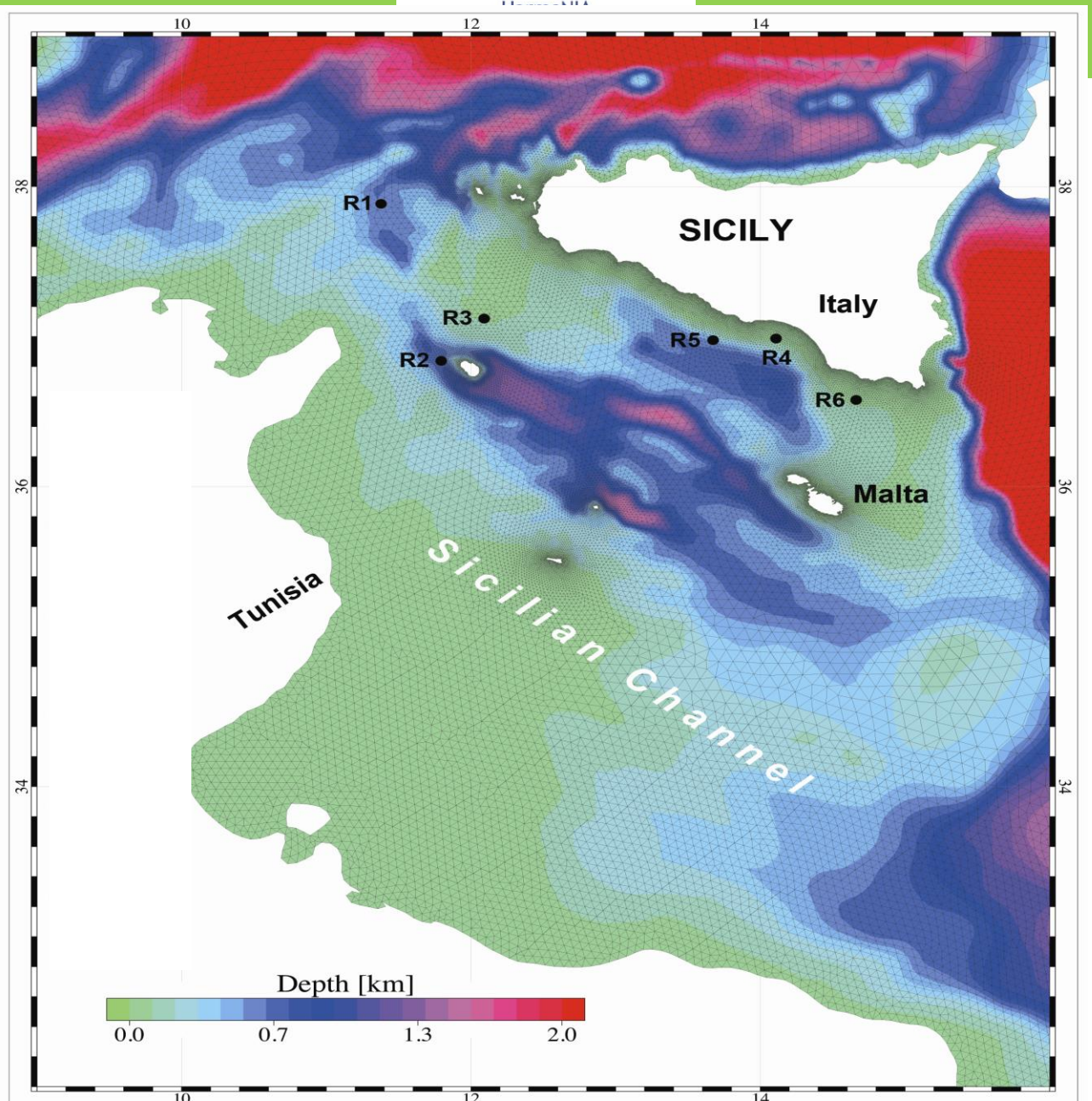


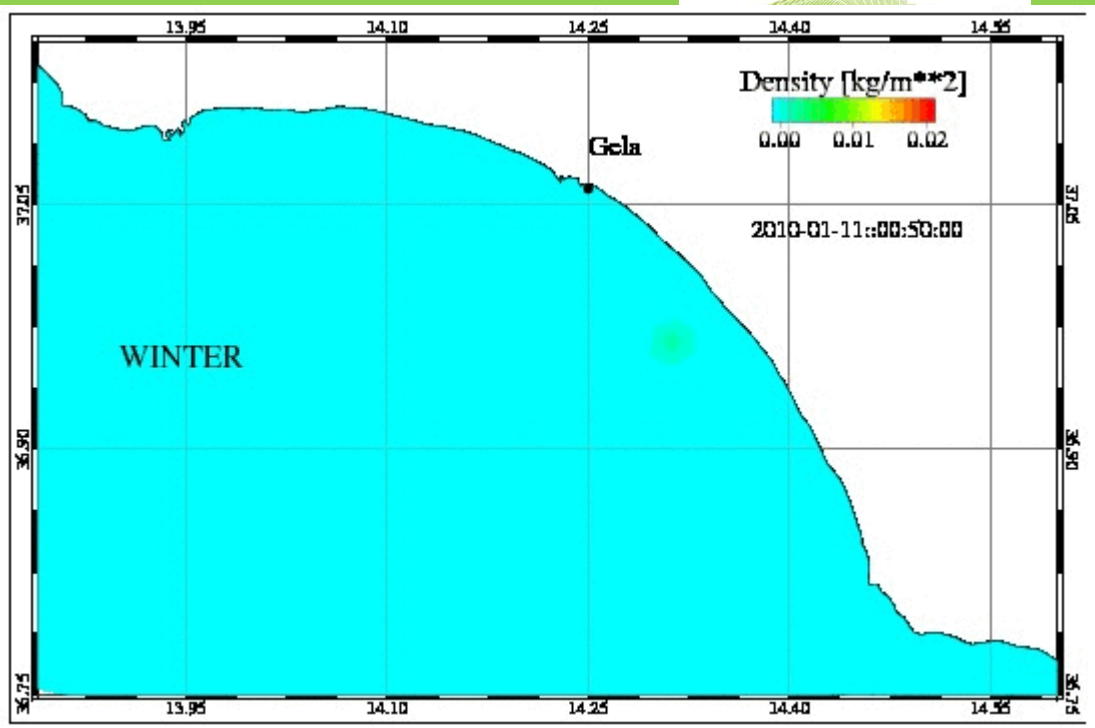
Exploration and production sites, in the Sicily channel

From Italian Ministry of Industry and Economy, 2012 report

Production: red
Exploration: green, yellow




10
12
14
38
36
34
R1
SICILY
Italy
R3
R5
R4
R2
R6
Malta
Tunisia
Sicilian Channel
Depth [km]
0.0
0.7
1.3
2.0

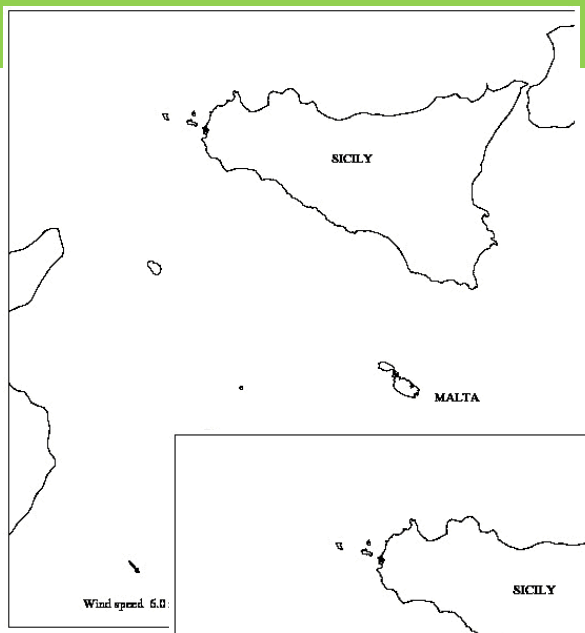


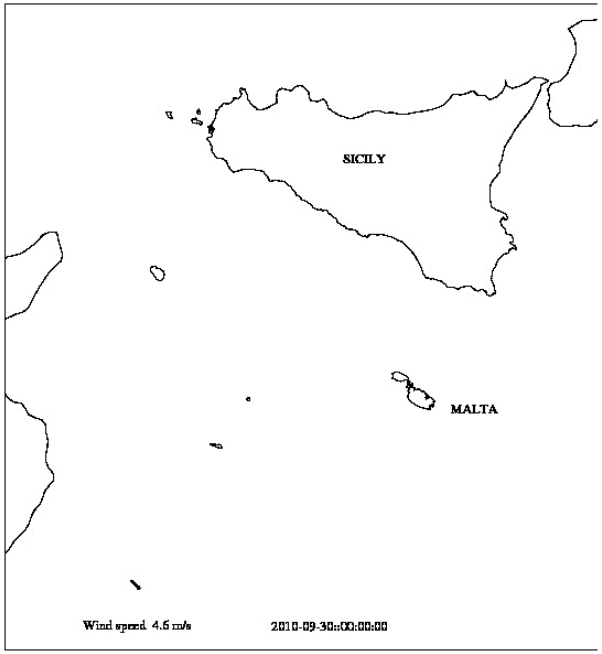
SIMULATIONS:

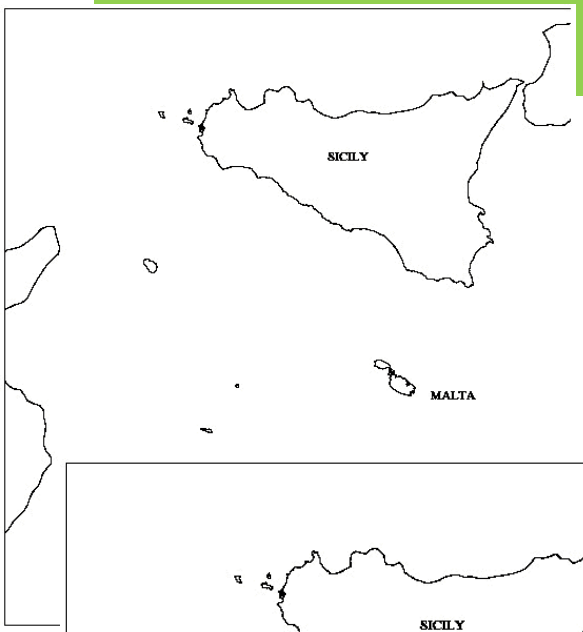
740 spills simulated for 10 days
Under all possible meteorological conditions observed in winter, summer, spring and autumn for 2 years.

ANALYSIS:

Average oil slicks at each season.
At each coastal site.


SICILY
MALTA
Wind speed 5.0


SICILY
MALTA
Wind speed 4.6 m/s
2010-09-30::00:00:00


SICILY
MALTA

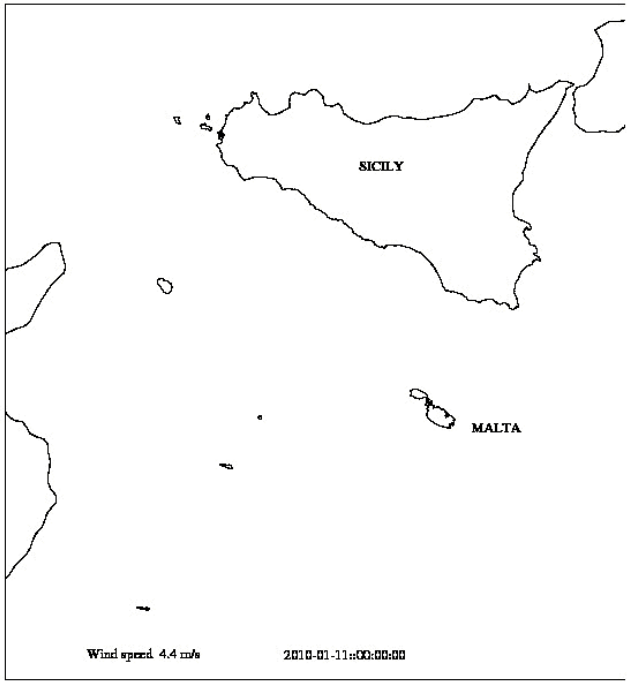
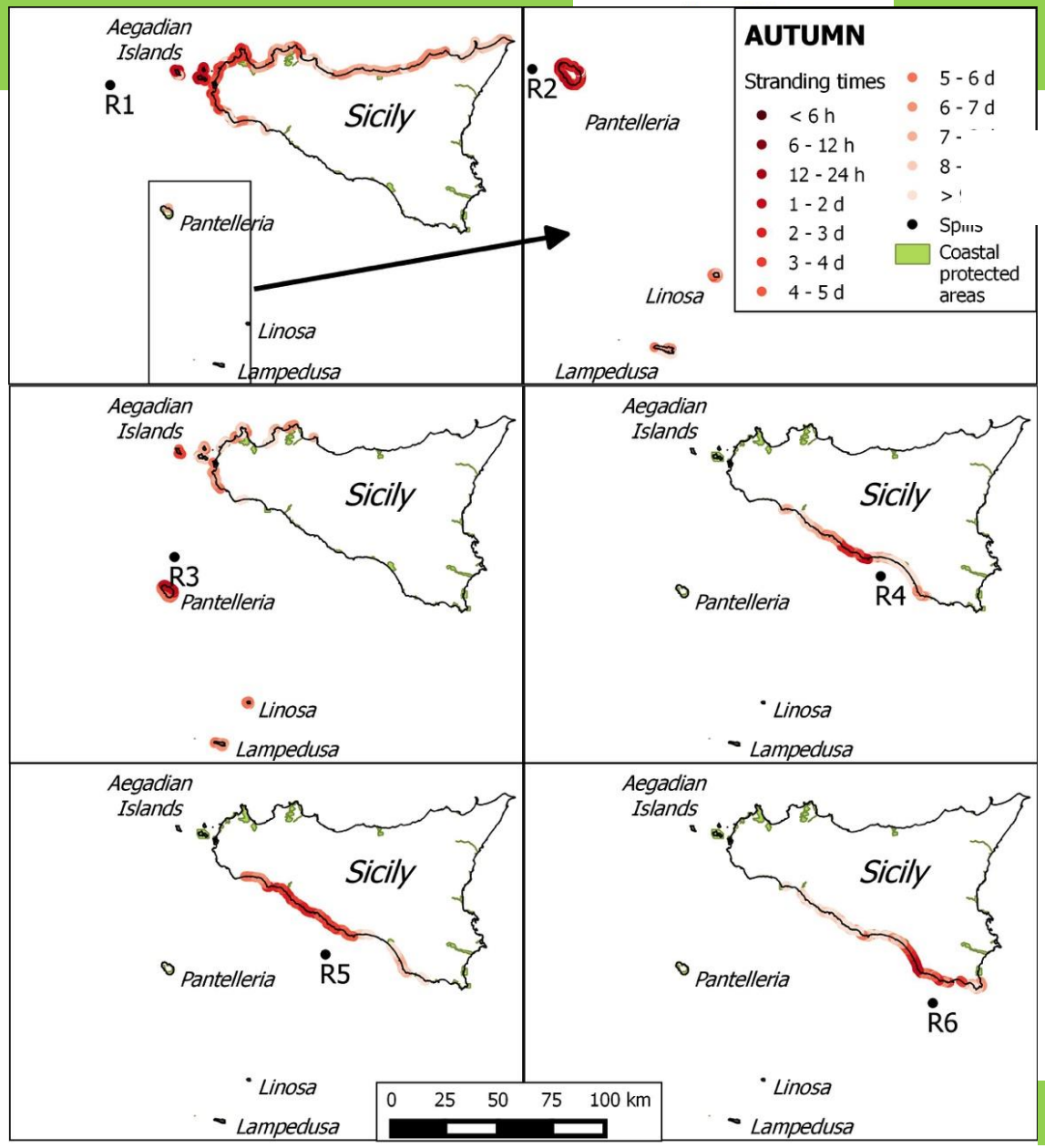

SICILY
MALTA
Wind speed 4.4 m/s
2010-01-11::00:00:00

Table 1. Statistic of the oil spill fate expressed as total released particles (Tot. rel.), % of oil on beached on shore (Onshore) and % of the total amount of particles beached on the same area in relation to the total amount of stranded particles (Maxima).

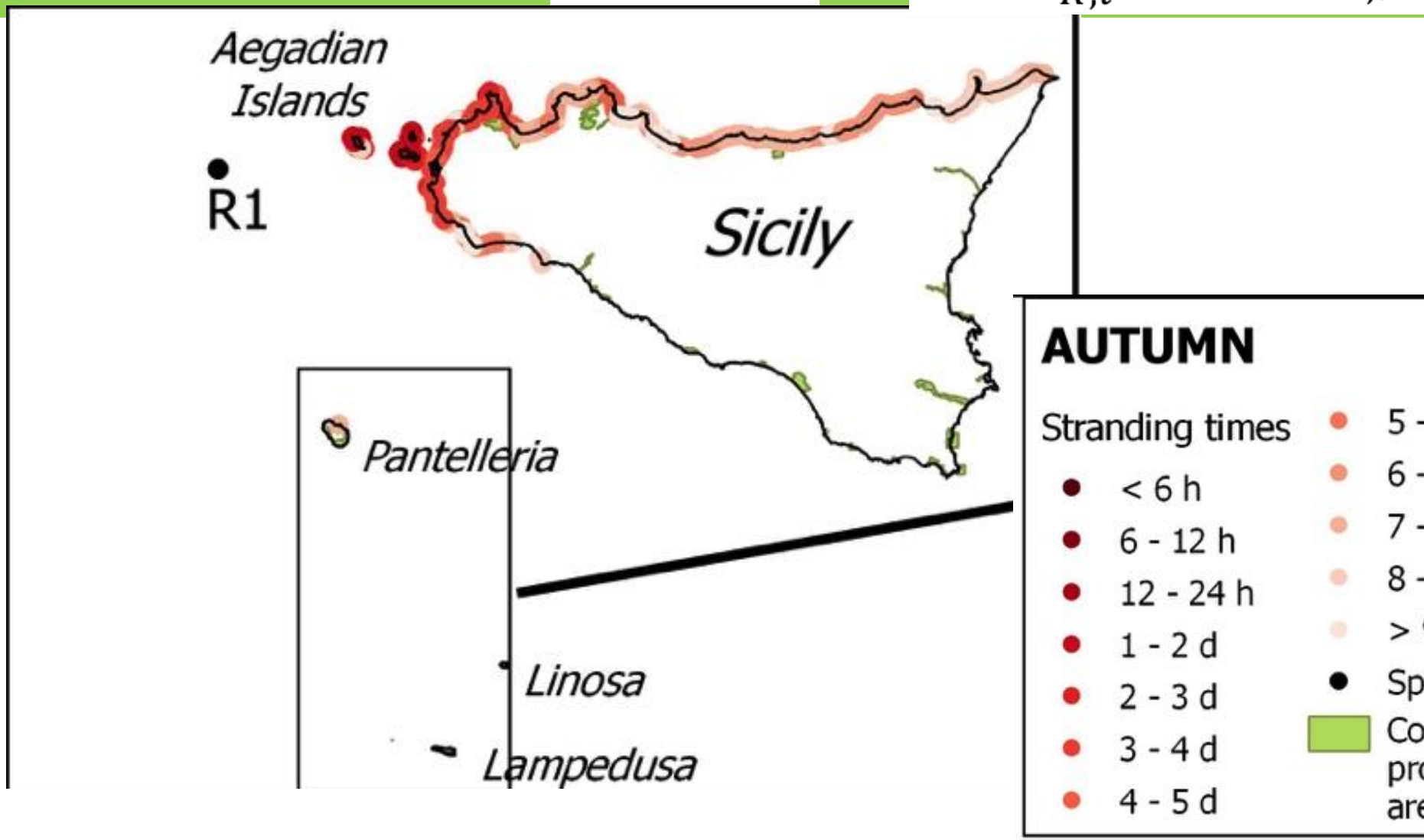
Oil particles	*Tot*	*R1*	*R2*	*R3*	*R4*	*R5*	*R6*
Tot. rel. *10^5	219	36.5	36.5	36.5	36.5	36.5	36.5
Tot. onshore	20%	29%	24%	20%	17%	13%	16%
Winter scenario results							
Onshore	26%	47%	50%	18%	22%	12%	8%
Maxima	7%	6%	19%	12%	8%	8%	14%
Spring scenario results							
Onshore	16%	18%	5%	10%	23%	18%	19%
Maxima	3%	14%	18%	10%	4%	10%	12%
Summer scenario results							
Onshore	13%	14%	7%	39%	6%	5%	5%
Maxima	8%	8%	8%	15%	27%	7%	10%
Autumn scenario results							
Onshore	27%	39%	36%	16%	18%	18%	33%
Maxima	2%	7%	8%	10%	8%	6%	5%

Table 1. Statistic of the oil spill fate expressed as total released particles (Tot. rel.), % of oil on beached



$$H_{R,i}^{st} = minT_{R,i}$$

$$H_{R,i}^{st} = minT_{R,i}$$

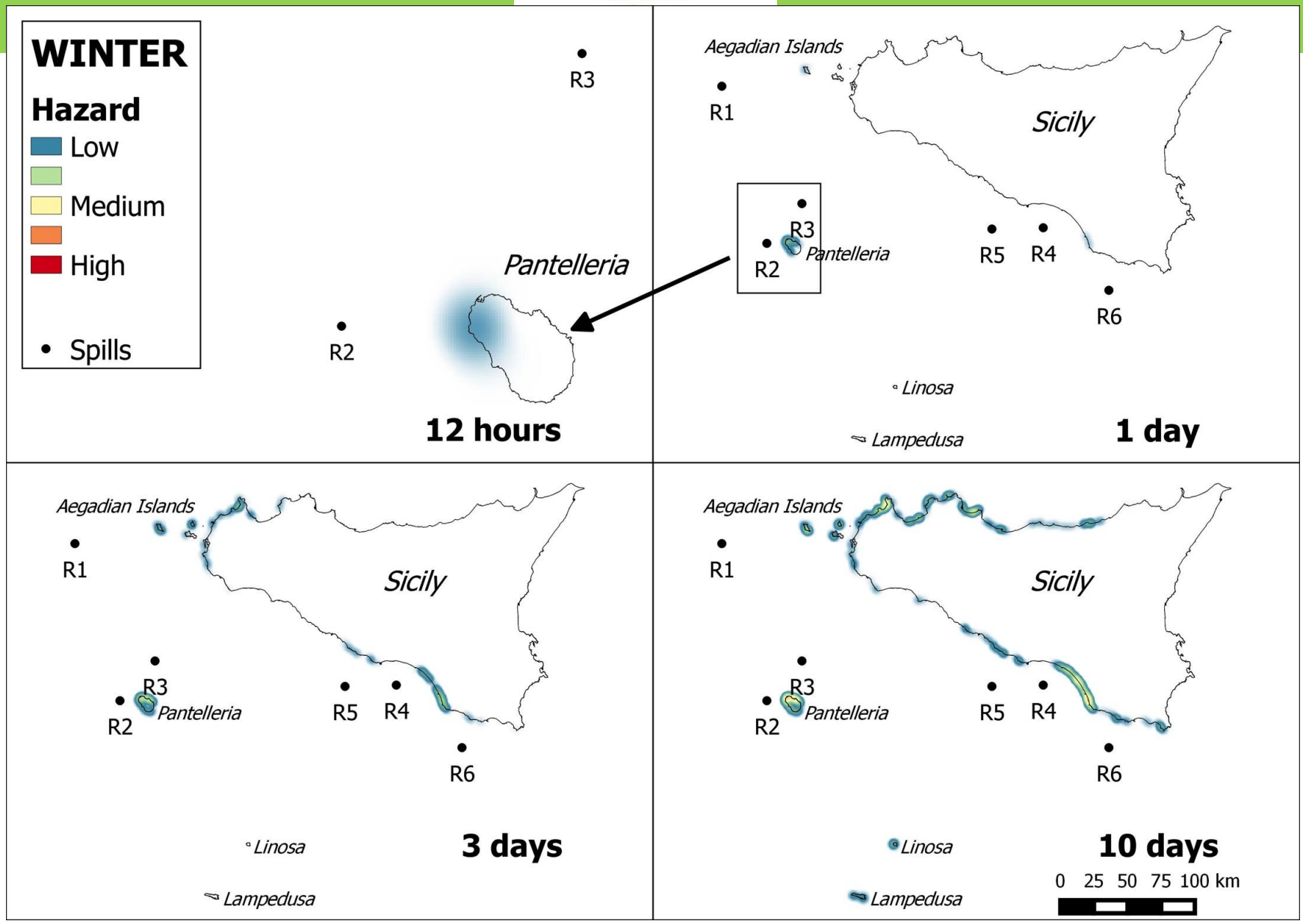


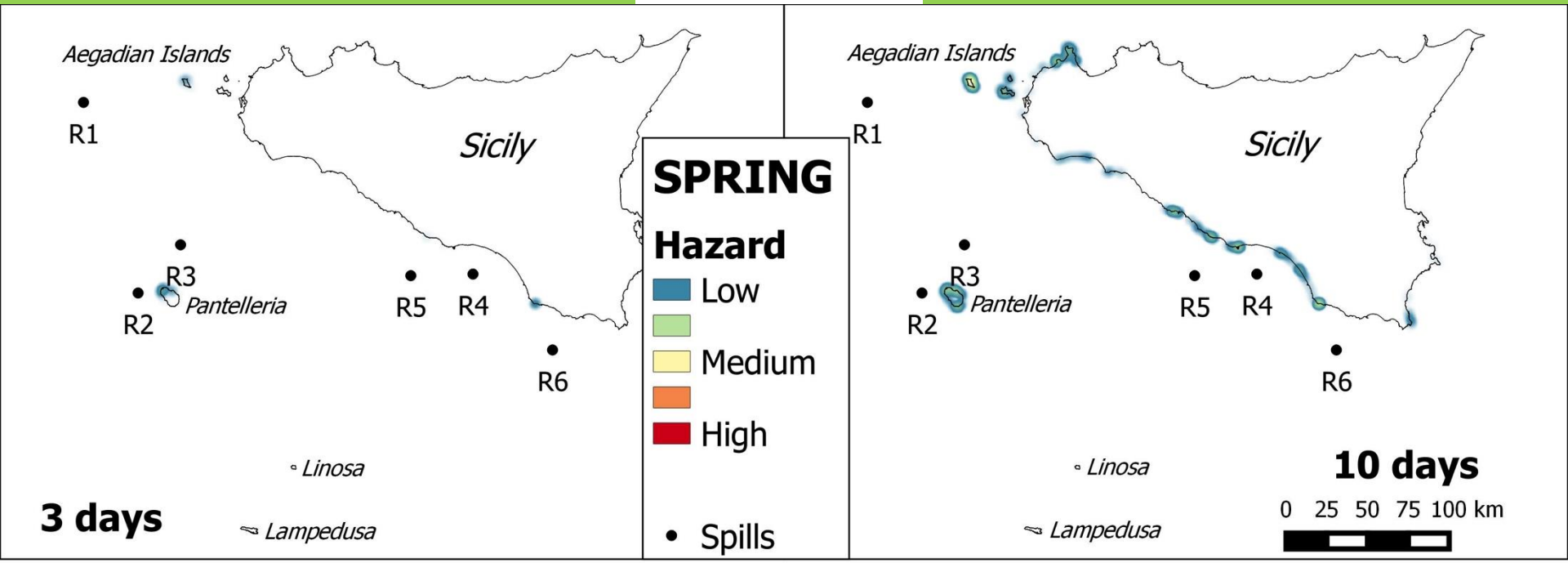
$$HI_{R,\tau,i} = \frac{\sum_{t=0}^{\tau} x_{i,\tau} / \sum_{t=0}^{\tau} x_{R,\tau}}{max\left[\sum_{t=0}^{\tau} x_{i,\tau} / \sum_{t=0}^{\tau} x_{R,\tau}\right]} = \frac{\sum_{t=0}^{\tau} x_{i,\tau}}{max\left[\sum_{t=0}^{\tau} x_{i,\tau}\right]}$$

The % of oil spilled at source *R* that reaches coastal site *i* within the time interval τ, (rescaled over the maximum observed among all sites and all seasons and smoothed using a kernel density estimation with a biweight kernel and a radius of 5000 m), where $x_{i,\tau}$ *is the amount of oil that reaches each coastal site i* within the time interval τ, and $x_{R\,\tau,}$ is the oil released at source R_i within the time interval τ.

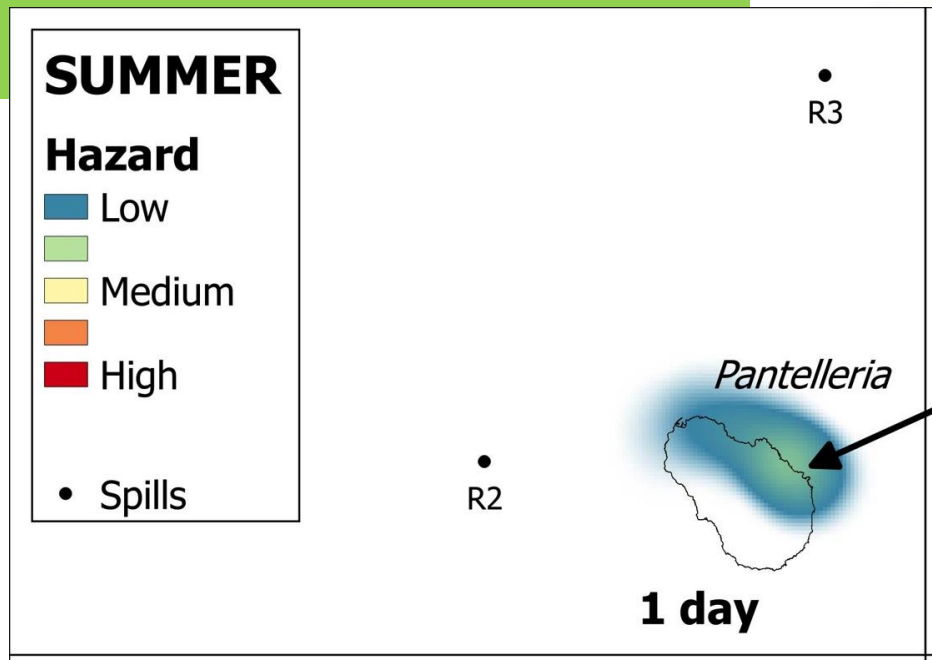
$$HI_{\tau,i} = \sum_R HI_{R,\tau,i} = \frac{\sum_R \sum_{t=0}^{\tau} x_{i,\tau}}{max\left[\sum_{t=0}^{\tau} x_{i,\tau}\right]}$$

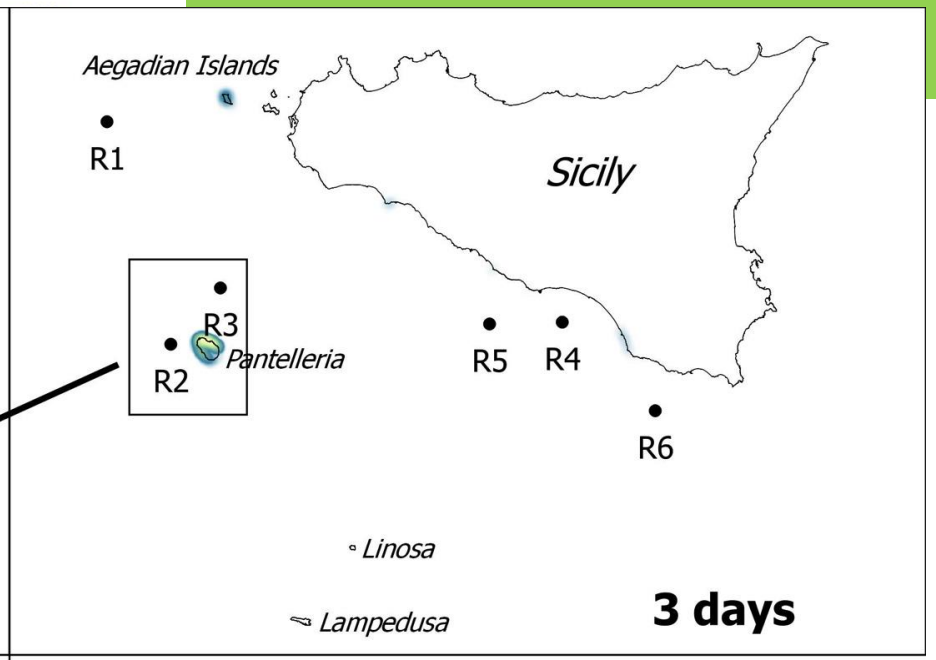
The (cumulative) % of oil spilled from all sources R that reaches costal site i within the time interval τ obtained as the sum of the % referring to each spill source

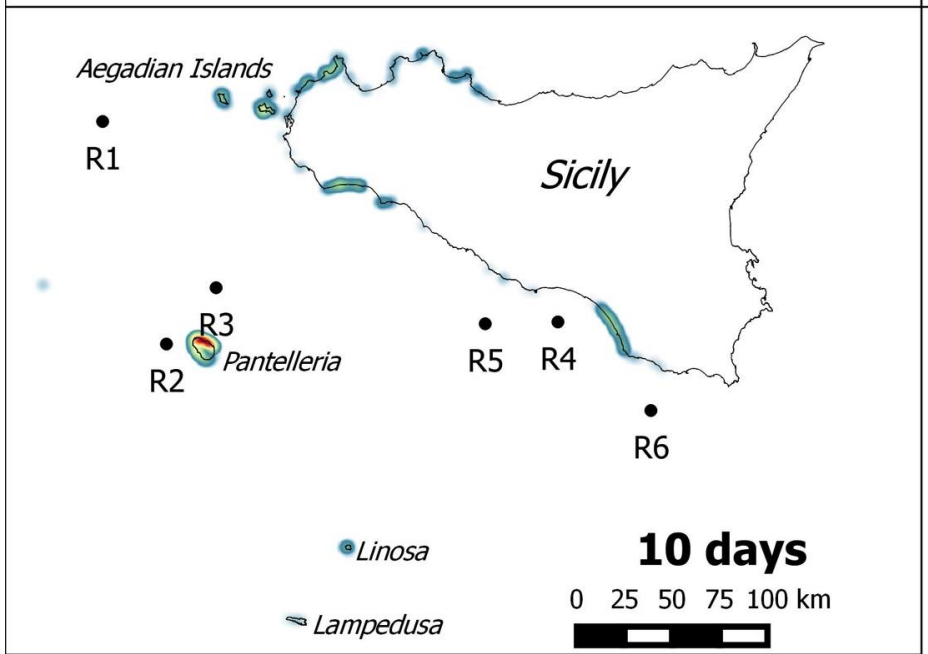

WINTER
Hazard
Low
Medium
High
Spills
R3
R2
Pantelleria
12 hours
Aegadian Islands
R1
Sicily
R3
R2
Pantelleria
R5
R4
R6
Linosa
Lampedusa
1 day
Aegadian Islands
R1
Sicily
R3
R2
Pantelleria
R5
R4
R6
Linosa
Lampedusa
3 days
Aegadian Islands
R1
Sicily
R3
R2
Pantelleria
R5
R4
R6
Linosa
Lampedusa
10 days
0 25 50 75 100 km

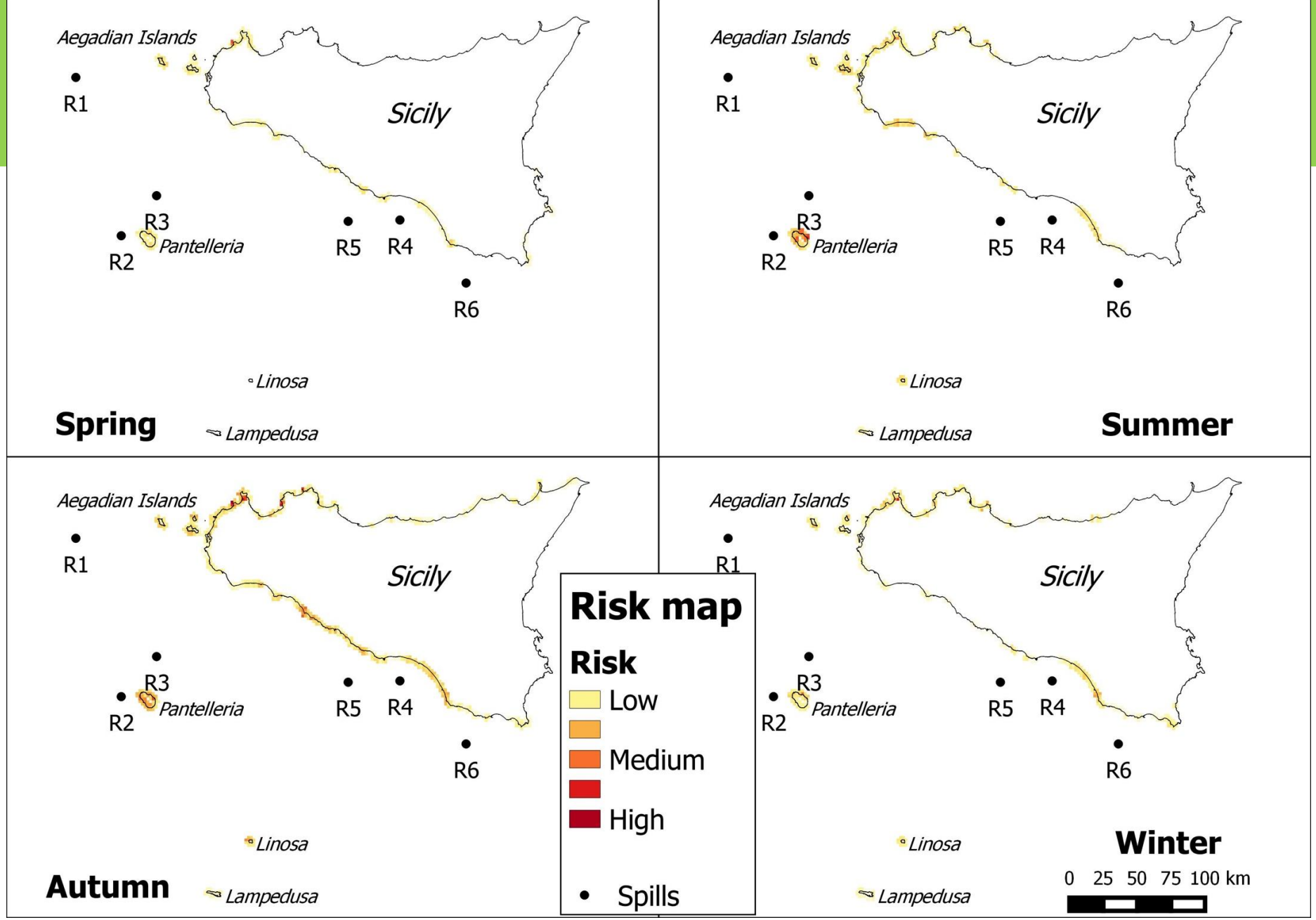

Aegadian Islands
R1
Sicily
R3
R2
Pantelleria
R5
R4
R6
Linosa
Lampedusa
3 days
SPRING
Hazard
Low
Medium
High
Spills
Aegadian Islands
R1
Sicily
R3
R2
Pantelleria
R5
R4
R6
Linosa
Lampedusa
10 days
0 25 50 75 100 km

MODEL/DATA


SUMMER
Hazard
Low
Medium
High
Spills
R3
R2
Pantelleria
1 day


Aegadian Islands
R1
Sicily
R3
R2
Pantelleria
R5
R4
R6
Linosa
Lampedusa
3 days


Aegadian Islands
R1
Sicily
R3
R2
Pantelleria
R5
R4
R6
Linosa
Lampedusa
10 days
0 25 50 75 100 km


Aegadian Islands
R1
Sicily
R3
Pantelleria
R2
R5
R4
R6
Linosa
Lampedusa
Spring
Summer
Autumn
Winter
Risk map
Risk
Low
Medium
High
Spills
0 25 50 75 100 km

MODEL/DATA

Interreg
ADRION
ADRIATIC-IONIAN
EUROPEAN UNION
European Regional Development Fund - Instrument for Pre-Accession II Fund

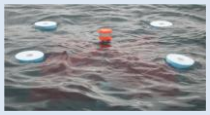
HarmoNIA

Harmonization and **N**etworking for contaminant assessment in the **I**onian and **A**driatic Seas

Hydrodynamic and oil spill modelling in the Adriatic-Ionian Sea

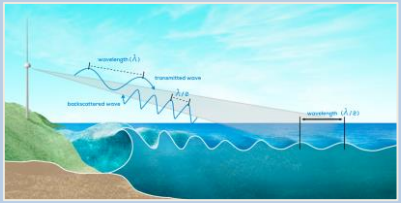
Donata Canu, Stefano Querin, Celia Laurent, Cosimo Solidoro

OGS, Italy



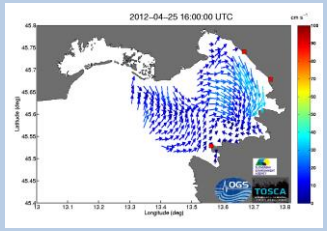
Photos of MAOS group -OGS

Meteorological and oceanographic data are integrated into the hydrodynamic models, both in hindcast and forecast mode (real time assimilation).

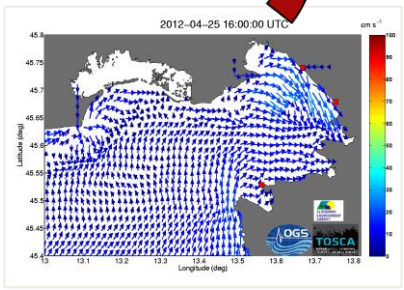


Imagine courtesy of: //www.medclic.es/

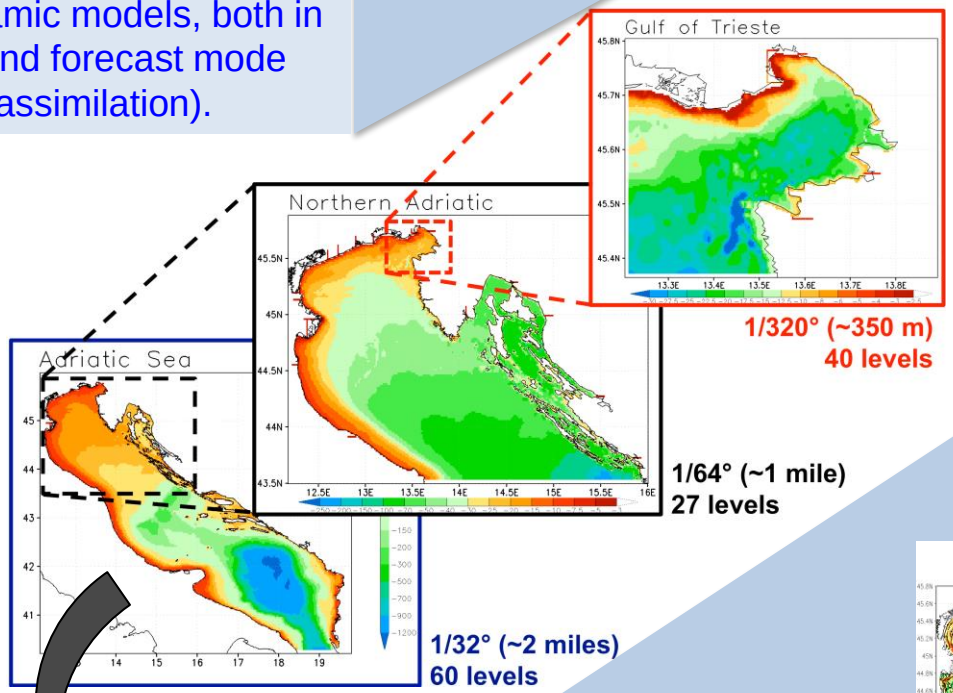
Model-data comparison



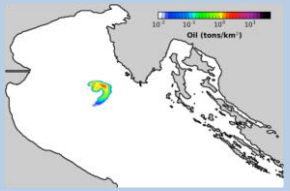
Surface current fields measured by HF radar



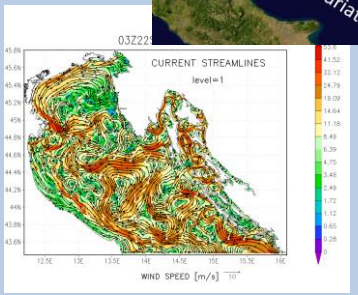
Modelled surface current fields

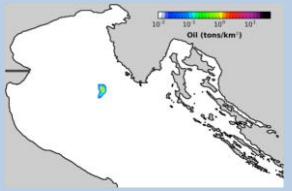


Bathymetry of the Adriatic-Ionian system used for the numerical analysis performed with the MITgcm hydrodynamic model



Oil spill scenario simulated with LTRANS v.Zlev without the weathering module: snapshot of the surface oil slick.



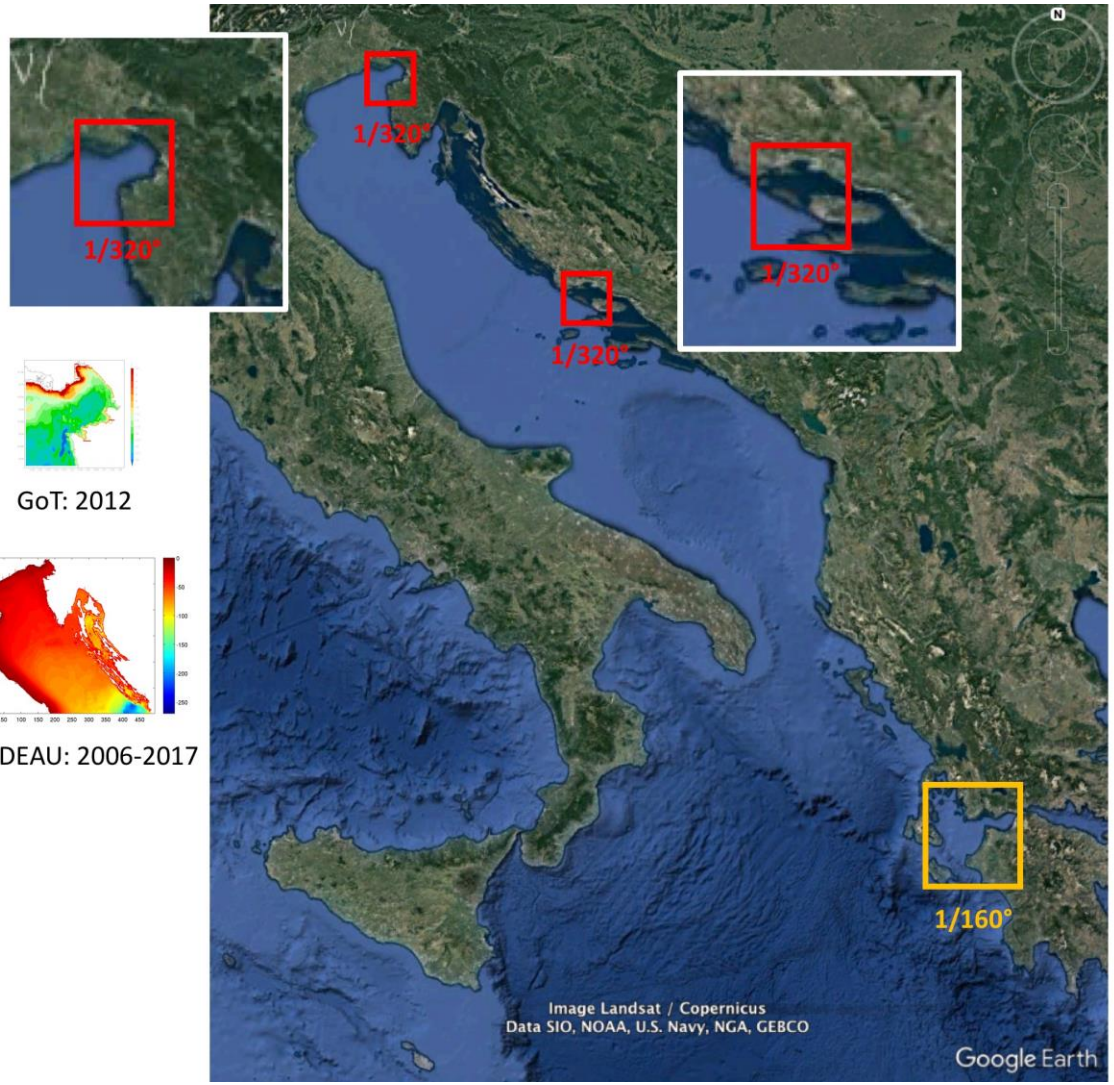


Oil spill scenario simulated with OILTRANS v.Zlev with the weathering module: snapshot of the surface oil slick.

Oil spill models are run using hydrodynamic model output fields

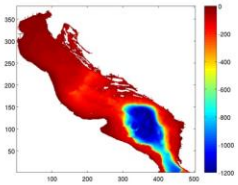
Gulf of Trieste, Italy

Kaštela Bay, Croatia



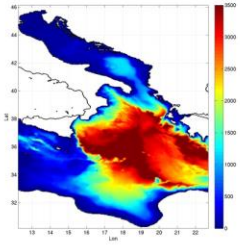
GoT: 2012

CADEAU: 2006-2017



MANTIS: 2006-2012

Gulf of Patras, Greece



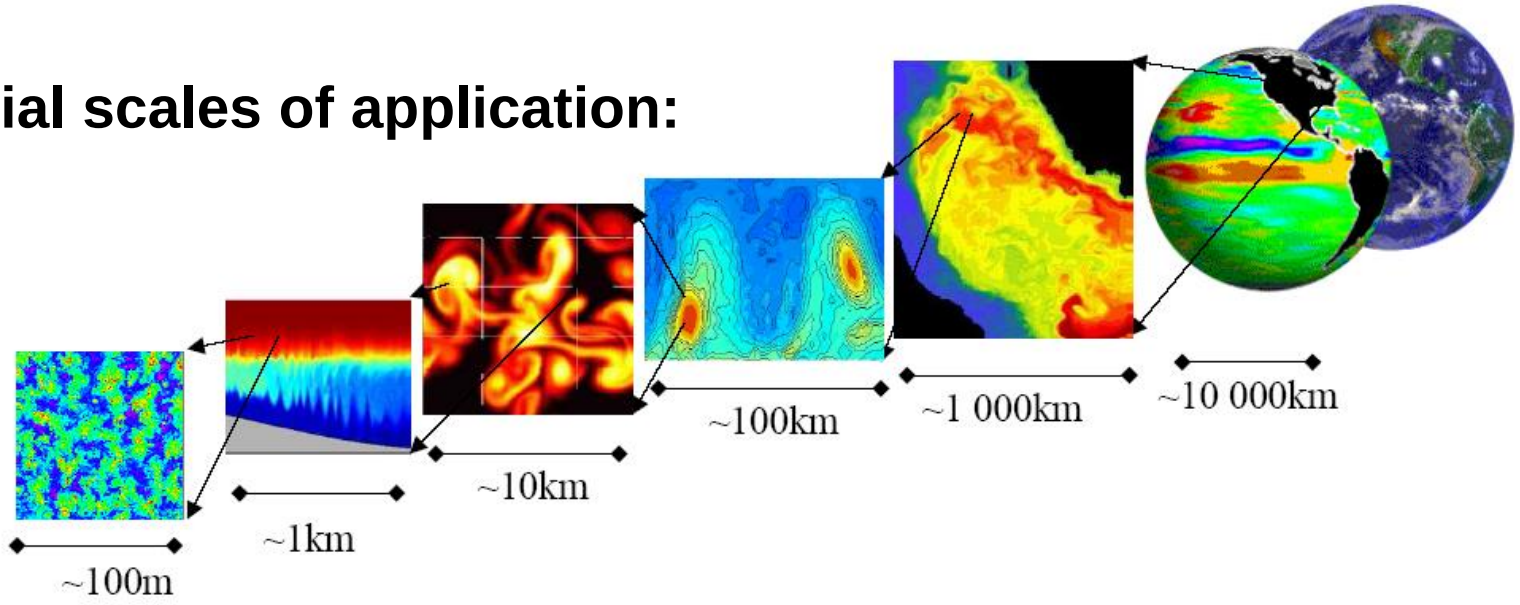
ADIOS: 2006-2012

Identification of modelling **domain** and **resolution** for 3 study sites

MITgcm Ocean General Circulation Model [*Marshall et al.*, 1997]

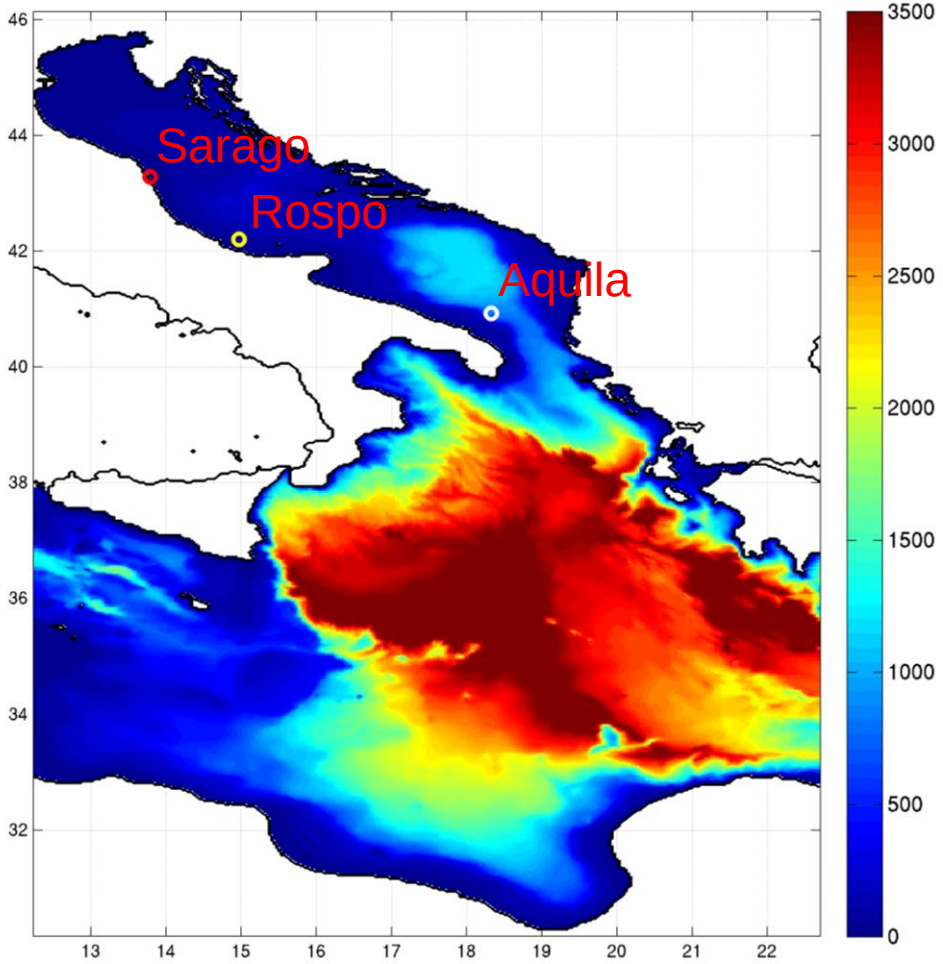
- non hydrostatic
- finite volumes
- open source

Spatial scales of application:



MITgcm hydrodynamic model

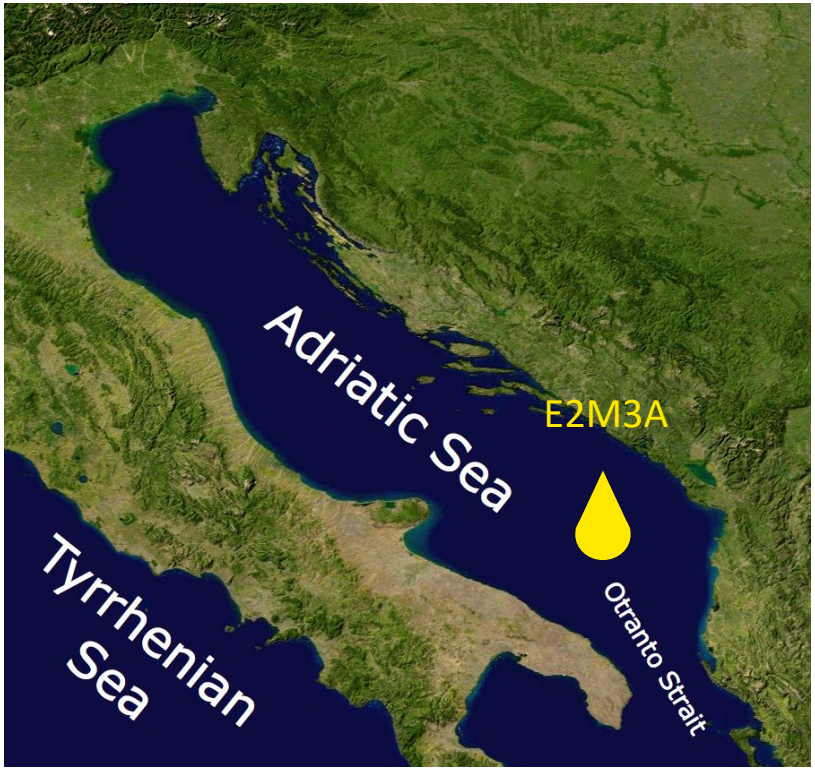
- Adriatic-Ionian
- Spatial resolution 1/32° (~2 nm)
- *Study sites Nesting at higher resolution*
- Long term simulation 2006-2012
- Time step 200 s
- *spin-up* (45 days)



Domain of the MITgcm model (1/32°)
Adriatic-Ionian system [*Querin et al*., 2013; *Querin et al*., 2016]

MITgcm hydrodynamic model

experimental-numerical study of the thermohaline properties of the southern Adriatic Sea, with focus on the bottom layer (below 1000 m)



E2M3A

ADCP ~300m

CTD ~315m

CT ~515m

CTD ~720m

CT ~980m

CT ~1160m
RCM11 ~1170m

Releasers ~1200m

<u>experimental data</u>

E2M3A mooring

- hourly data
- quality checked
- filtered (low pass)

***Bensi et al.*, JGR, 2013**

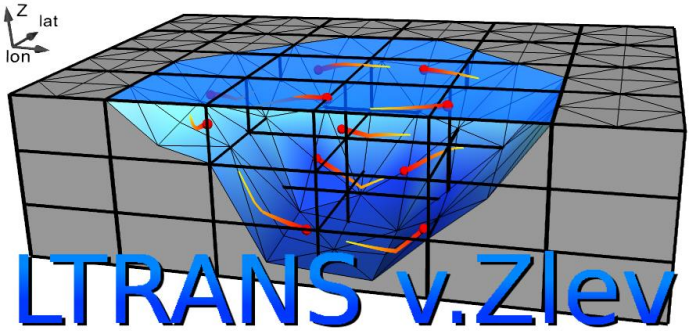
MODEL/DATA

Processes presently modeled by examples of referenced oil or inert drift modeling systems

	ADIOS	GNOME	OILMAP / SARMAP / OILMAPWEB	OSCAR	MOTHY	POSEIDON OSM	MEDSLIK	MEDSLIK II	SEATRACK WEB	OILTRANS	BSHmod.L	SLROSM	OD3D + LEEWAY	GulfSpill	MOHID	OILTRANS mod
Advection	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Diffusion	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Wind drift	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stokes drift	-	-	-	+	+	+	-	+	+	+	+	-	+	-	+	+
Floating objects	-	-	+	-	+	-	+	+	+	-	+	-	+	-	+	-
Backtracking	-	-	+	-	+	-	+	-	+	-	-	-	-	-	+	+
Stranding	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Spreading	+	-	+	+	+	+	-	-	+	+	+	+	-	+	+	+
Evaporation	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Emulsification	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Natural Dispersion	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Vertical Movement	-	-	+	+	+	+	-	-	+	-	+		+	-	+	-
Dissolution	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-
Sedimentation	-	-	-	+	+	+	+	+	+	-	+	-	-	-	+	-
	ADIOS	GNOME	OILMAP / SARMAP / OILMAPWEB	OSCAR	MOTHY	POSEIDON OSM	MEDSLIK	MEDSLIK II	SEATRACK WEB	OILTRANS	BSHmod.L	SLROSM	OD3D + LEEWAY	GulfSpill	MOHID	OILTRANS mod

(Note: the information sources for this table were mainly obtained from the references and bibliography cited in this paper; MOHID already includes developed processes described in this paper)

Key Factors in the modeling system



1. Hydrodynamic model

- **modeling assumptions**
- **grid resolution**
- **temporal resolution**
- **atmospheric forcing**

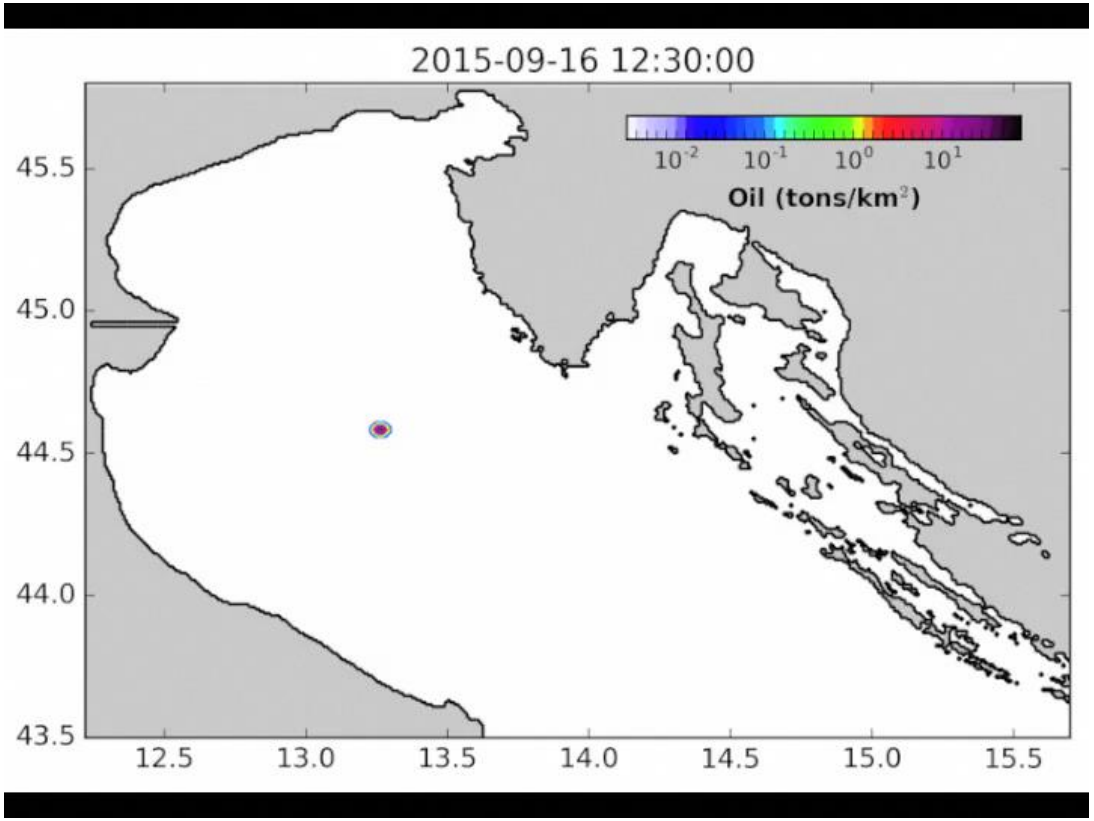
2. Lagrangian particles tracking model

- **wind drift**
- Intensity of the random displacement representing sub-grid scale horizontal **turbulent diffusion**

3. Process related factors

- **temporal dependency** for larval applications
- **critical survival conditions** for larval applications
- **weathering formulations** for oil spill applications

Filmato: scenario #1 simulato con OILTRANS



OILTRANS +MITgcm

OILTRANS: API 33.0 Dispersion (Berry, 2011)

Evaporation Fingas

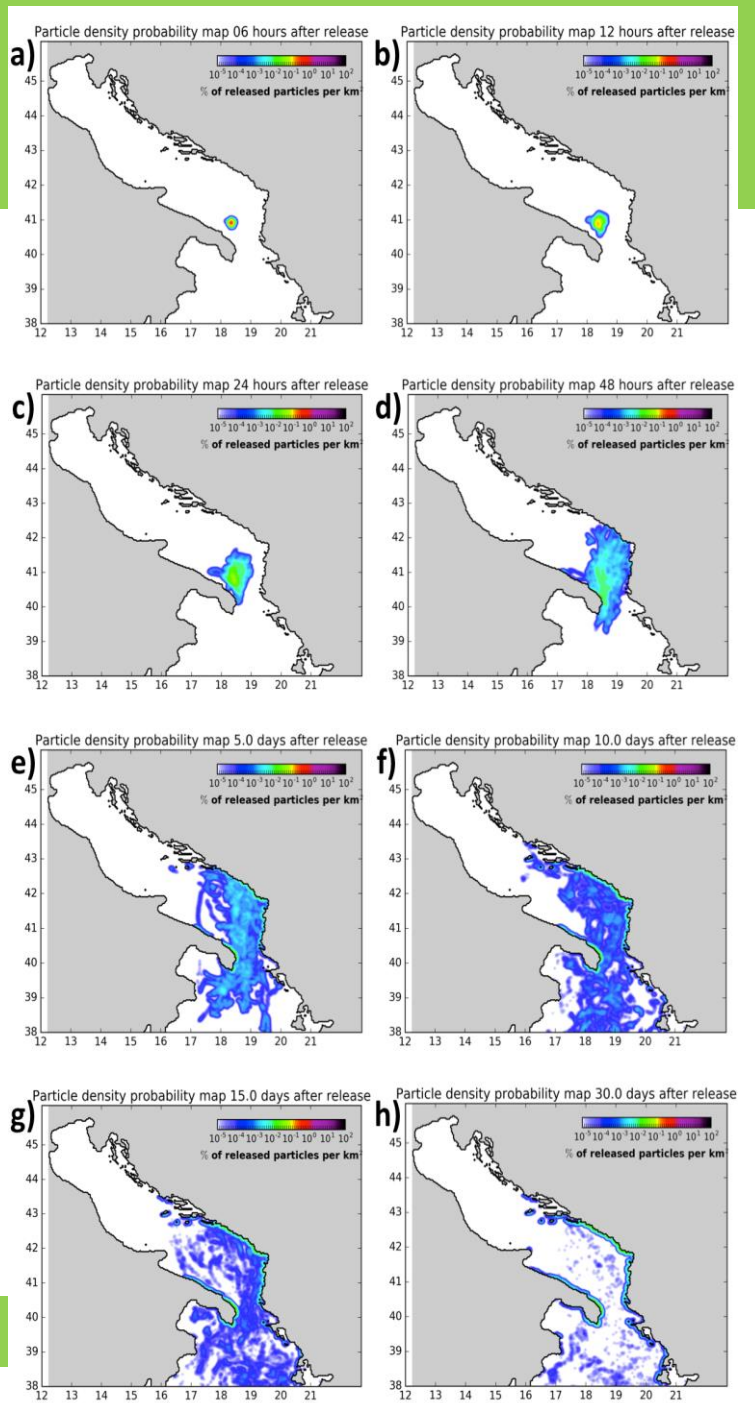
oil spill in the southern Adriatic

- release coordinates

42°43’ 15’’ N

15°08’ 37” E

- passive tracer (NO weathering)
- continuous release
- 1 year simulation



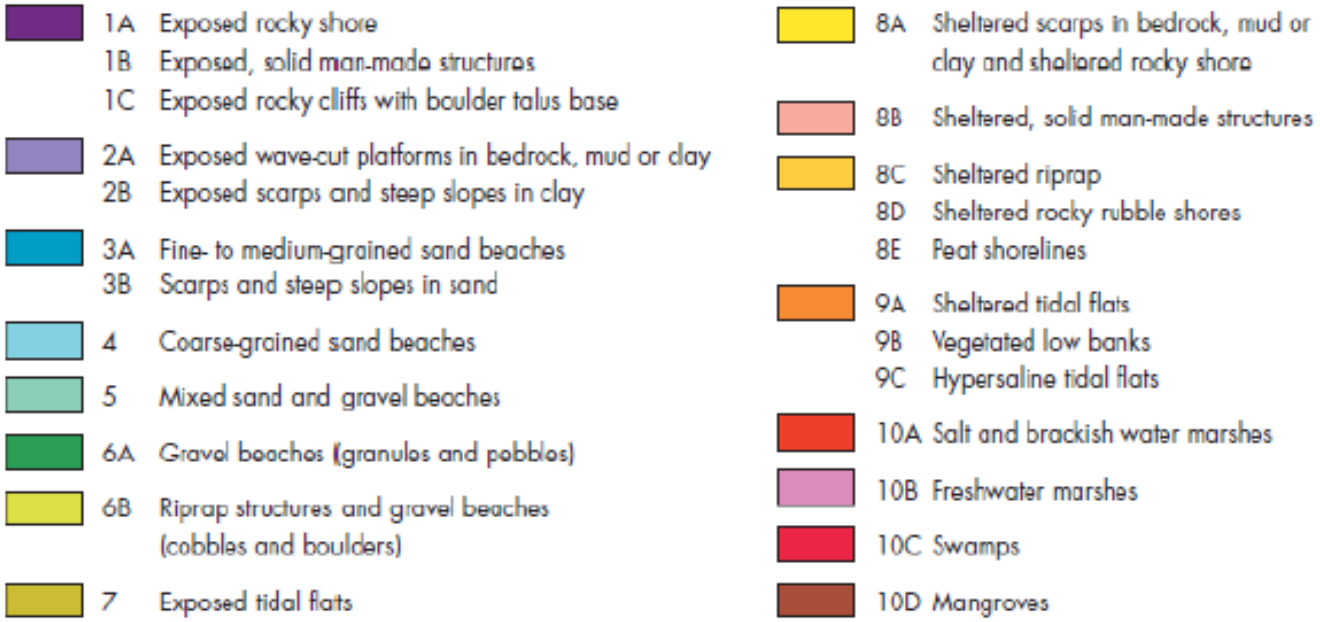


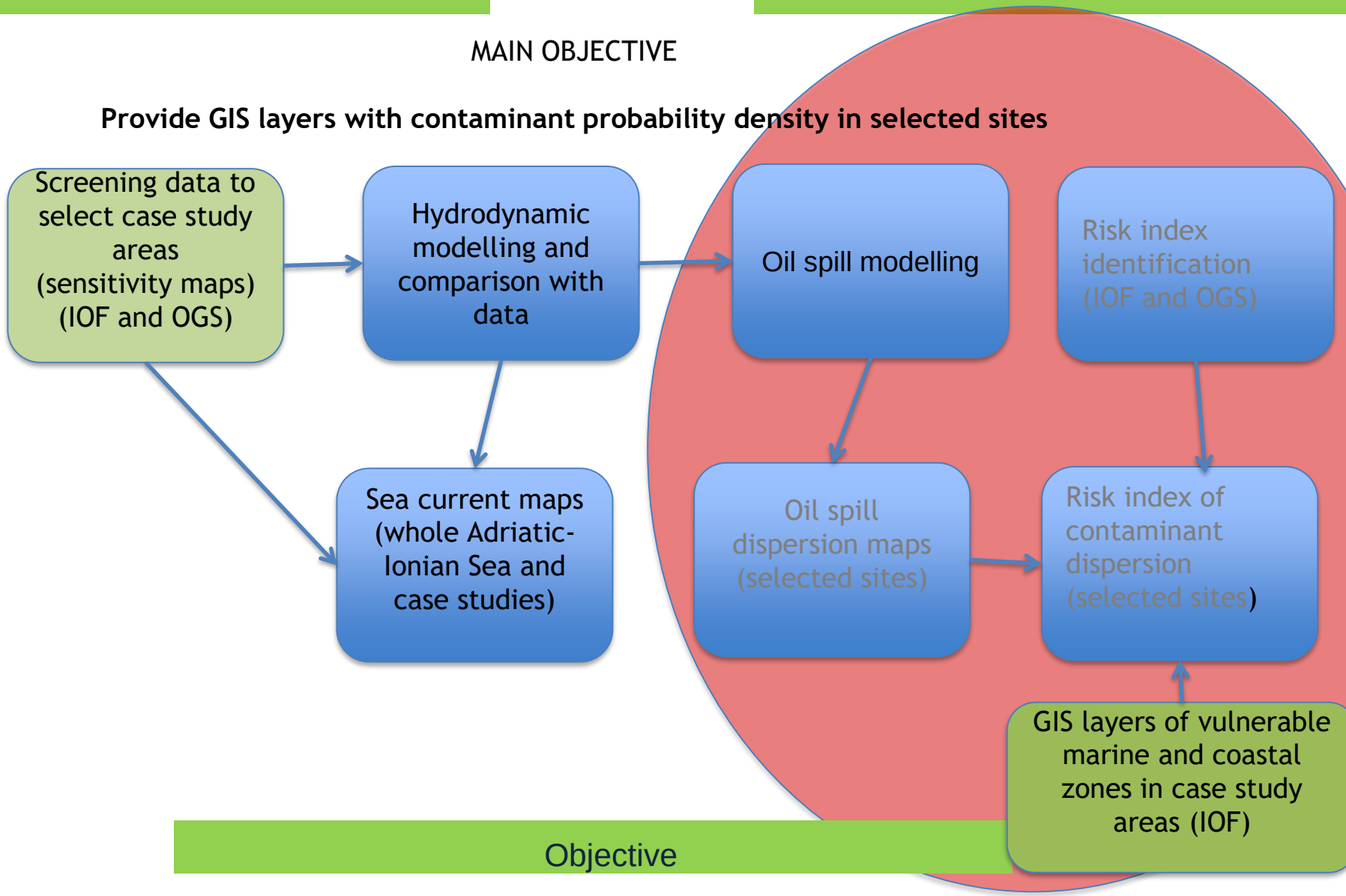
Figura 17. Scala ESI [6]

ESI (from 1 to 10)		Simplified ESI	Mapping of simplified ESI
Index 1 and 2	→	1 (very low)	Not represented
Indexes 3, 4, 5 and 6	→	2 (low)	Not represented
Index 7	→	3 (medium)	Not represented
Index 8	→	4 (high)	**4 (high)**
Index 9 and 10	→	5 (very high)	**5 (very high)**

Figura 18. Semplificazione Scala ESI

MAIN OBJECTIVE

Provide GIS layers with contaminant probability density in selected sites



OIL SPILL SCENARIO for RISK ASSESSMENT

Provide the information needed for the oil spill simulation at the study sites