MEDSLIK-II
Open Source Model

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MEDSLIK-II Open Source Oil Spill Model Official Release Meeting,
22 October 2012, Bologna, Italy

OUTLINE

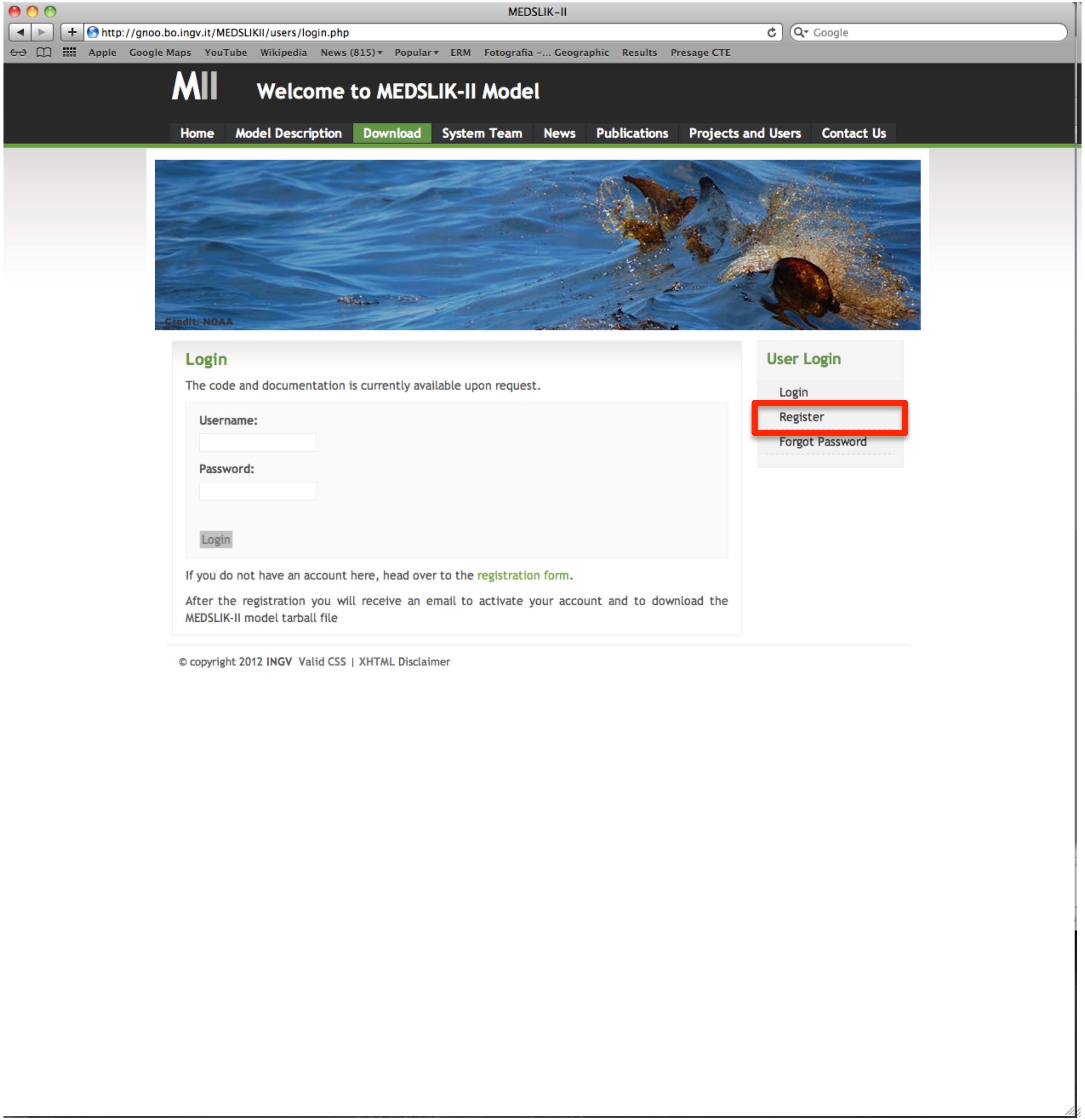
- Introduction
- The theory behind the MEDSLIK-II oil spill model
- Model validation using drifters, satellite observations and in situ data
- Emergency case examples: the Costa Concordia
- How to use the code!

INTRODUCTION

The development of the MEDSLIK-II model is supported by a formal agreement (Memorandum of Agreement for the Operation and Continued Development of MEDSLIK-II) signed by:

The code is now freely available under the GNU Free Software License with the aim of attracting a critical mass of scientists and users:

- **to contribute to the development of the code**
- **to use the model in very different conditions and check its performance**


MEDSLIK-II
http://gnoo.bo.ingv.it/MEDSLIKII/users/login.php
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MII
Welcome to MEDSLIK-II Model
Home
Model Description
Download
System Team
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Login
The code and documentation is currently available upon request.
Username:
Password:
Login
If you do not have an account here, head over to the registration form.
After the registration you will receive an email to activate your account and to download the MEDSLIK-II model tarball file
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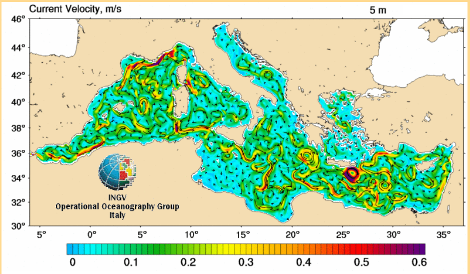
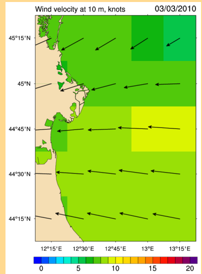
Welcome to MEDSLIK-II Model

OCEANOGRAPHIC EULERIAN MODELS
(Currents, Sea Surface Temperature)



ATMOSPHERIC EULERIAN MODELS
(Winds)



Waves

MEDSLIK-II

ADVECTION-DIFFUSION
+
TRANSFORMATION PROCESSES

Forecast of oil spill transport and transformation

Features of the MEDSLIK-II model

- **MEDSLIK-II is based upon the existing MEDSLIK model, developed by the developed by Lardner and Zodiatis at the Oceanography Center, University of Cyprus (Lardner et al. 2006).**

- **MEDSLIK-II predicts the transport and diffusion and oil transformation processes due to complex physical and chemical processes occurring in the sea-water at the surface**

- **MEDSLIK-II uses a lagrangian representation of the oil slick.**

- **MEDSLIK-II includes a proper representation of high frequency currents, the wave induced currents and wind fields in the advective components of the lagrangian trajectory model.**

- **MEDSLIK-II has been coupled with the remote-sensing data.**

THE MEDSLIK-II MODEL: conceptual basis

$$\frac{\partial C}{\partial t} + \mathbf{U} \cdot \nabla C = \nabla \cdot (\mathbf{K} \nabla C) + \sum_{j=1}^{M} r_j(C)$$

The model splits the active tracer equation into two component equations

ADVECTION - DIFFUSION

$$\frac{\partial C}{\partial t} = -\mathbf{U} \cdot \nabla C_1 + \nabla \cdot (\mathbf{K} \nabla C_1)$$

MEDSLIK-II solves the advection-diffusion equation using particles: the oil slick is discretized by PARTICLES, which are TRANSPORTED by the water currents and the turbulent diffusion.

TRANSFORMATION

$$\frac{\partial C_1}{\partial t} = \sum_{j=1}^{M} r_j(C_1)$$

MEDSLIK-II solves the transformation equation considering the total oil slick volume, which is TRANSFORMED by the physical and chemical processes.

TRANSFORMATION PROCESSES

$$\frac{\partial C_1}{\partial t} = \sum_{j=1}^{M} r_j(C_1)$$

$$\frac{\partial C_S}{\partial t} = \frac{\rho}{\delta x_T \delta y_T} \frac{\partial V_S}{\partial t}$$

$$V_S = V^{TN} + V^{TK}$$

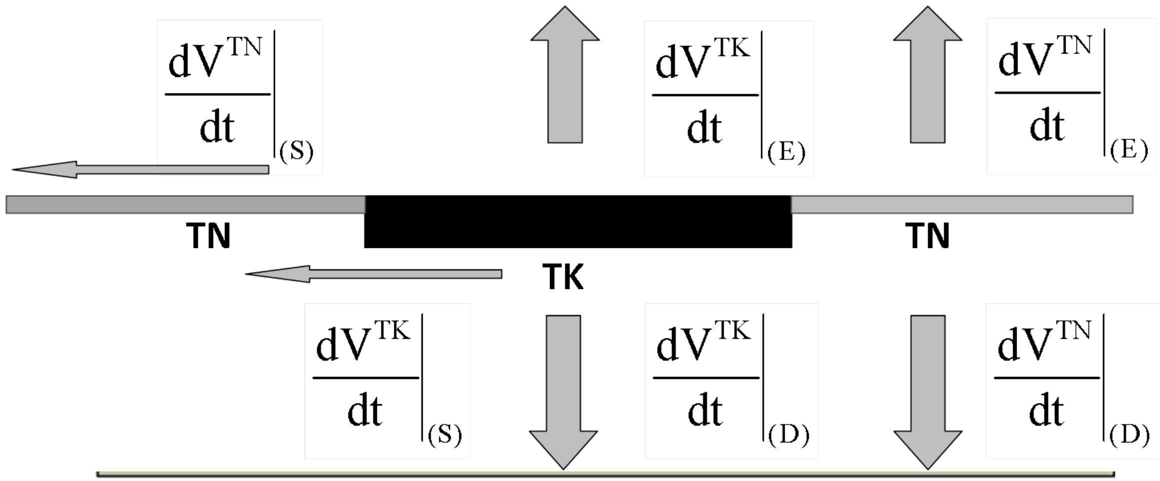
$$\mathrm{V}^{\mathrm{TN}} = \mathrm{A}^{\mathrm{TN}}\mathrm{T}^{\mathrm{TN}} \qquad \mathrm{V}^{\mathrm{TK}} = \mathrm{A}^{\mathrm{TK}}\mathrm{T}^{\mathrm{TK}}$$

(Mackay et al., 1980)

TN: THIN SLICK

TK: THICK SLICK

SLICK variables



$$\frac{dV^{TK}}{dt} = \left.\frac{dV^{TK}}{dt}\right|_{(E)} + \left.\frac{dV^{TK}}{dt}\right|_{(D)} + \left.\frac{dV^{TK}}{dt}\right|_{(S)}$$

$$\frac{dV^{TN}}{dt} = \left.\frac{dV^{TN}}{dt}\right|_{(E)} + \left.\frac{dV^{TN}}{dt}\right|_{(D)} + \left.\frac{dV^{TN}}{dt}\right|_{(S)}$$

TRANSFORMATION PROCESSES solved using empirical formulas

ADVECTION - DIFFUSION

$$\frac{\partial C}{\partial t} = -\mathbf{U} \cdot \nabla C_1 + \nabla \cdot (\mathbf{K} \nabla C_1)$$

- Each particle is 'advected' and 'diffused' by:

$$d\mathbf{x}_k = \underbrace{\mathbf{U}(\mathbf{x}_k, t)dt}_{\text{DETERMINISTIC COMPONENT}} + \underbrace{d\mathbf{x}_k'}_{\text{STOCHASTIC COMPONENT}}$$

ADVECTION-DIFFUSION processes solved using
PARTICLE TRAJECTORY EQUATION

PARTICLE variables

The oil volume is broken into N constituent particles, characterised by:

- **a position vector**

$$\mathbf{x_k}(t) = (x_k(t), y_k(t), z_k(t))$$

→ **CHANGE DUE THE ADVECTION-DIFFUSION PROCESSES**

- **a particle oil volume**

$$\upsilon(n_k, t_0) = \frac{V}{N}$$

$$\upsilon(n_k, t) = \upsilon_E(n_k, t) + \upsilon_{NE}(n_k, t)$$

→ **CHANGE DUE THE TRANSFORMATION PROCESSES**

The particle oil volume is subdivided into 'Evaporative' and 'Non-Evaporative' components.

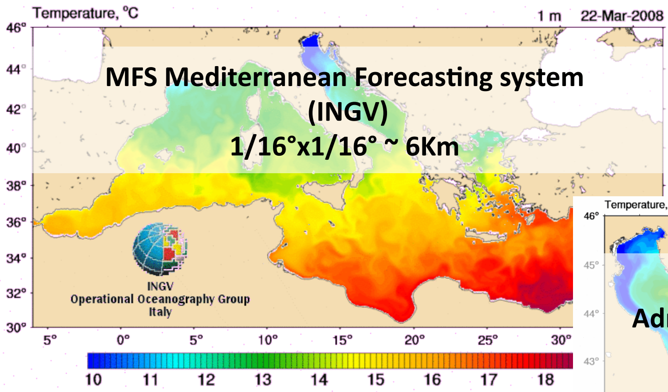
- **a particle status: surface, dispersed, on coast and sedimented**

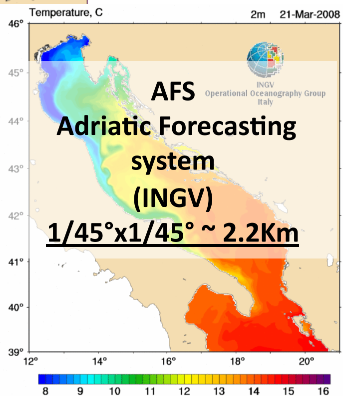
DETERMINISTIC COMPONENT: CURRENTS

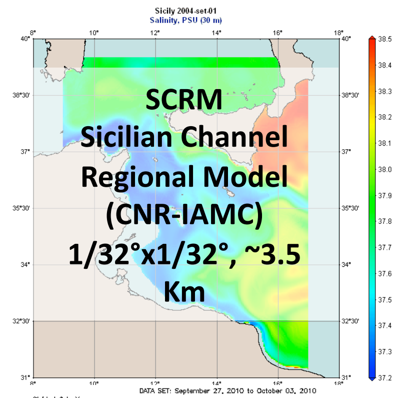
$$d\mathbf{x}(t) = \left[\mathbf{U}_c(\mathbf{x},t) + \mathbf{U}_w(\mathbf{x},t) + \mathbf{U}_s(\mathbf{x},t)\right]dt + d\mathbf{x}'(t)$$

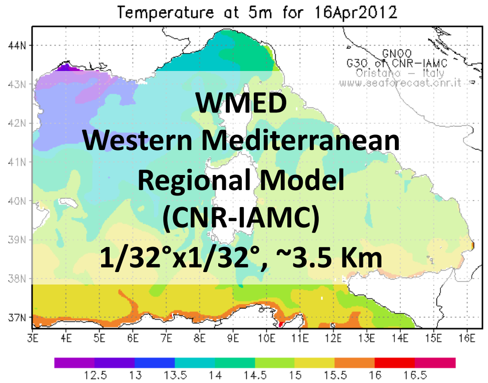
$\mathbf{U}_c(\mathbf{x},t)$ → EULERIAN CURRENTS; $\mathbf{U}_w(\mathbf{x},t)$ → WIND CORRECTION; $\mathbf{U}_s(\mathbf{x},t)$ → WAVE CORRECTION; $d\mathbf{x}'(t)$ → TURBULENCE

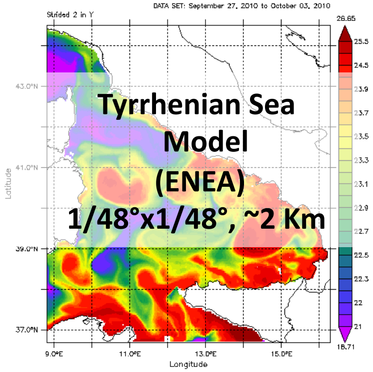
MEDSLIK-II in Italy can use the currents fields provided by:

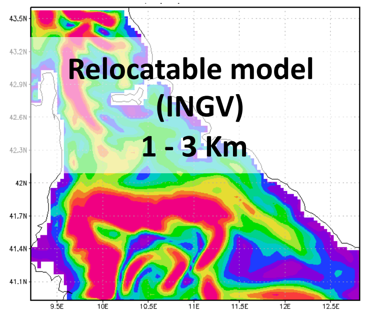












DETERMINISTIC COMPONENT: WINDS

$$d\mathbf{x}(t) = \left[\mathbf{U}_c(\mathbf{x},t) + \mathbf{U}_w(\mathbf{x},t) + \mathbf{U}_s(\mathbf{x},t)\right]dt + d\mathbf{x}'(t)$$

EULERIAN CURRENTS   WIND CORRECTION   WAVE CORRECTION   TURBULENCE

WIND CORRECTION

- **The current velocity field is provided by OPERATIONAL oceanographic models that usually resolve the upper ocean layer dynamics (1-3 m resolution and turbulence closure models)**
- **If necessary a first correction can be applied to consider a 'Ekman wind drift' not well resolved by the oceanographic operational models**

$$U_w = \alpha(W_x \cos\beta + W_y \sin\beta)$$

$$V_w = \alpha(-W_x \sin\beta + W_y \cos\beta)$$

Wx, Wy: wind velocity components;
α: percentage of the wind to be added to the water currents velocity;
β : deviation angle between currents and wind.

DETERMINISTIC COMPONENT: WAVE INDUCED CURRENTS

$$d\mathbf{x}(t) = \left[\mathbf{U}_c(\mathbf{x},t) + \mathbf{U}_w(\mathbf{x},t) + \mathbf{U}_s(\mathbf{x},t)\right]dt + d\mathbf{x}'(t)$$

EULERIAN CURRENTS — WIND CORRECTION — WAVE CORRECTION

WAVE CORRECTION: STOKES drift

$$u_S(\omega, z) \approx a^2 \omega k e^{2kz}$$

$$u_S(z) = \int_0^\infty 2\omega k(\omega) S(\omega) e^{2k(\omega)z} d\omega$$

a: wave amplitude
k: wave number
ω: wave angular frequency
S(ω): wave spectra (JONSWAP Spectrum)

STOCHASTIC COMPONENT: TURBULENT DIFFUSION

$$d\mathbf{x}(t) = \left[\mathbf{U}_c(\mathbf{x}, t) + \mathbf{U}_w(\mathbf{x}, t) + \mathbf{U}_s(\mathbf{x}, t)\right]dt + d\mathbf{x}'(t)$$

EULERIAN CURRENTS WIND CORRECTION WAVE CORRECTION TURBULENCE

TURBULENCE: RANDOM WALK PROCESS

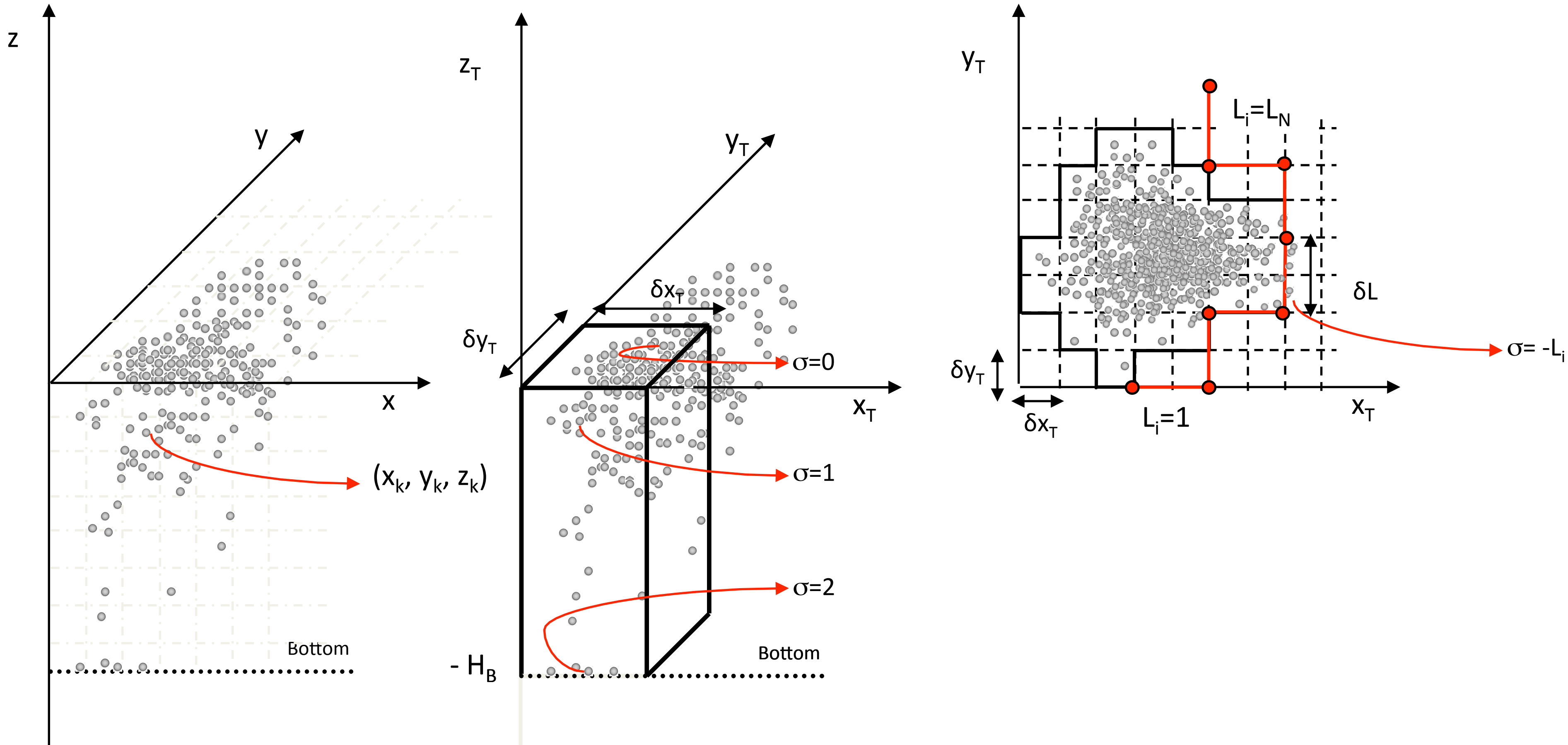
$$dx'(t) = Z_1\sqrt{2K_x dt} = [2n - 1]\sqrt{6K_h dt}$$

$$dy'(t) = Z_2\sqrt{2K_y dt} = [2n - 1]\sqrt{6K_h dt}$$

$$dz'(t) = Z_3\sqrt{2K_z dt} = [2n - 1]\sqrt{6K_v dt}$$

RANDOM INCREMENT **DIFFUSIVITY**

MEDSLIK-II CONCENTRATIONS RECONSTRUCTION



Oil tracer grid for advection-diffusion processes

Oil tracer grid for concentrations reconstruction

MEDSLIK-II CONCENTRATIONS RECONSTRUCTION

MEDSLIK-II computes three different classes of oil concentration:

- **at the water surface:**

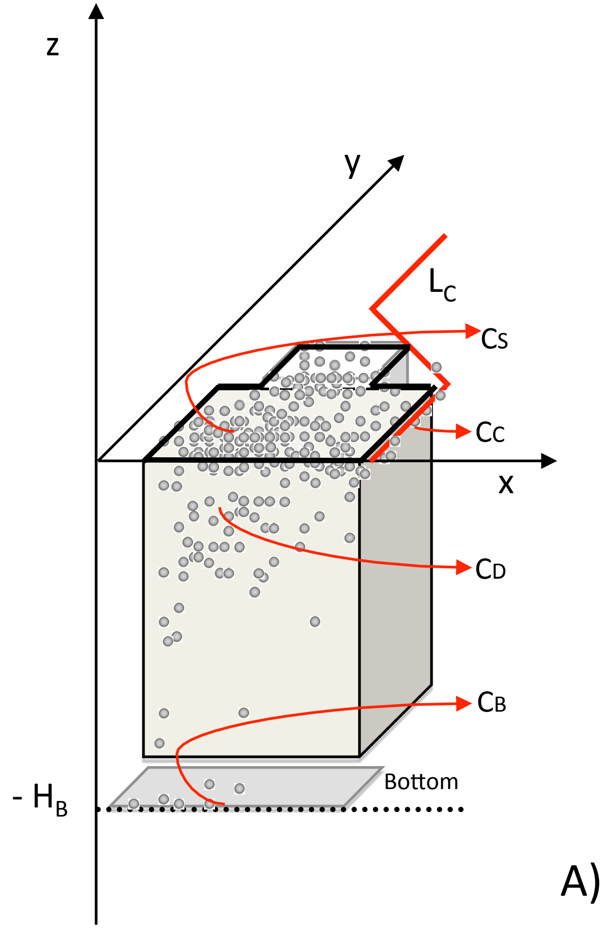
$$C_S(\mathbf{x}_T, t) = \frac{\rho}{\delta x_T \delta y_T} \sum_{n_k \in I_S} \upsilon(n_k, t)$$

- **in the water column:**

$$C_D(\mathbf{x}_T, t) = \frac{\rho}{\delta x_T \delta y_T} \sum_{n_k \in I_D} \upsilon(n_k, t)$$

- **on the coast:**

$$C_C(\delta L_i, t) = \frac{\rho}{\delta L_i} \sum_{n_k \in I_c} \upsilon(n_k, t)$$



AGE of the SLICK

<u>WEATHERING PROCESSES</u> | **<u>ADVECTION + WEATHERING PROCESSES</u>**

Observation time – slick age

Observation time

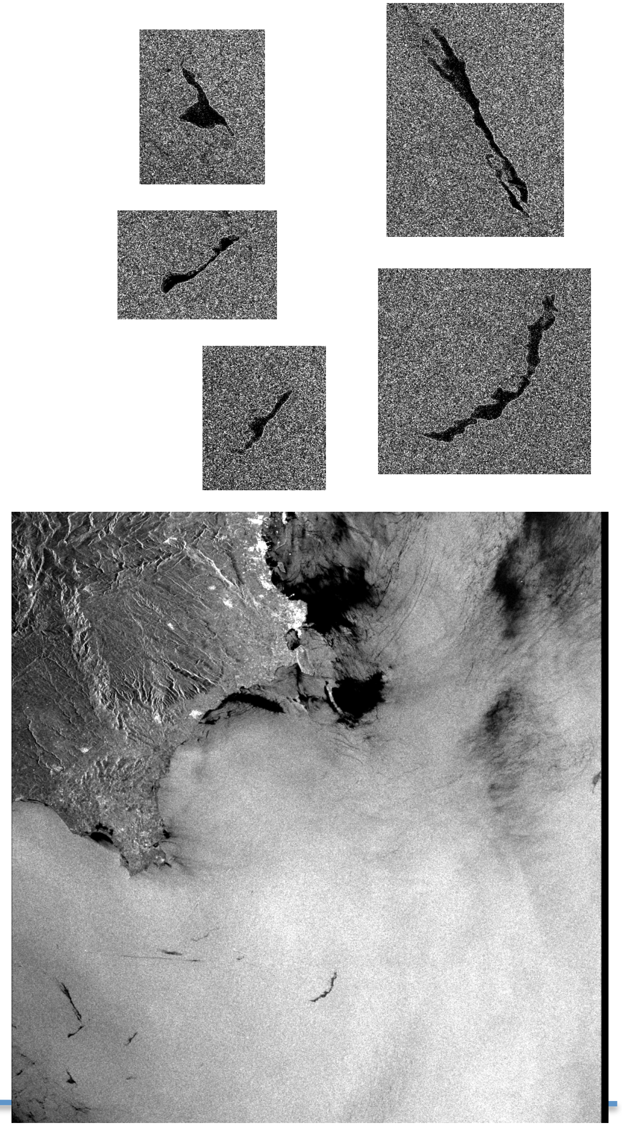
Observation time + Simulation length

WEATHERING PROCESSES INIZIALIZATION:
evaporation, dispersion, emulsification
considering the wind and SST
in the area where the spill is observed.

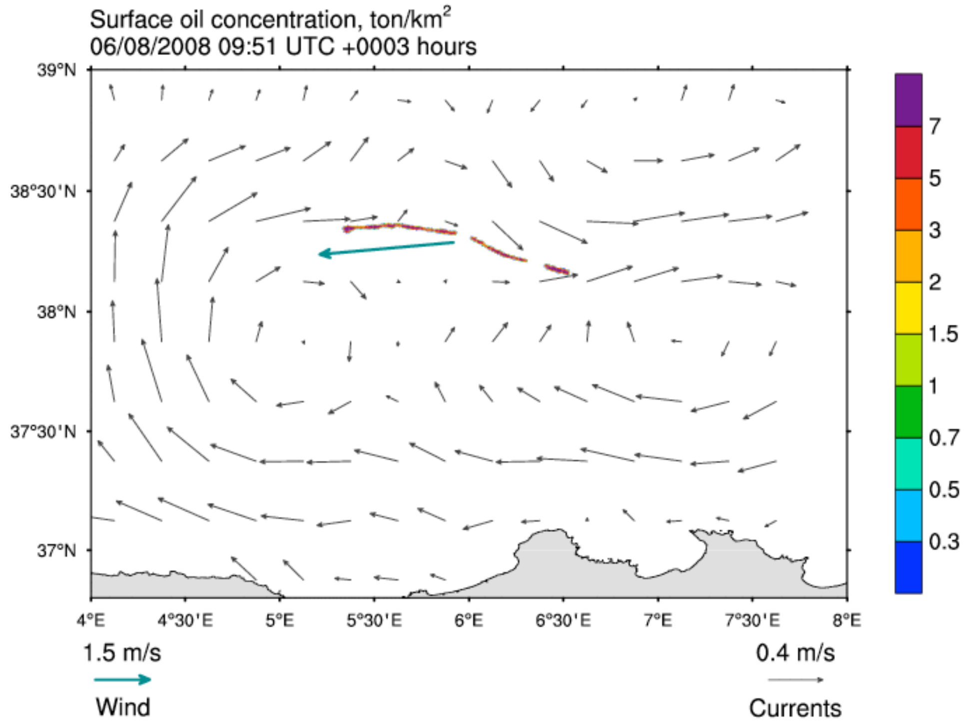
FORECAST

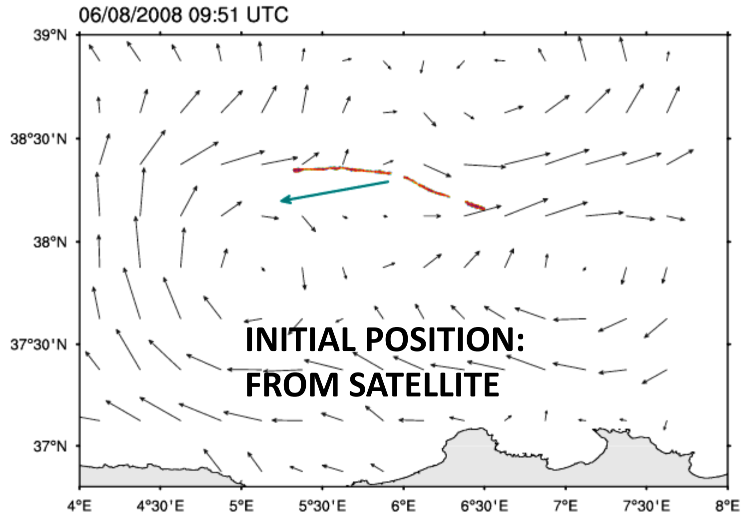
INITIALIZATION: SHAPE OF THE SLICK FROM SATELLITE IMAGES

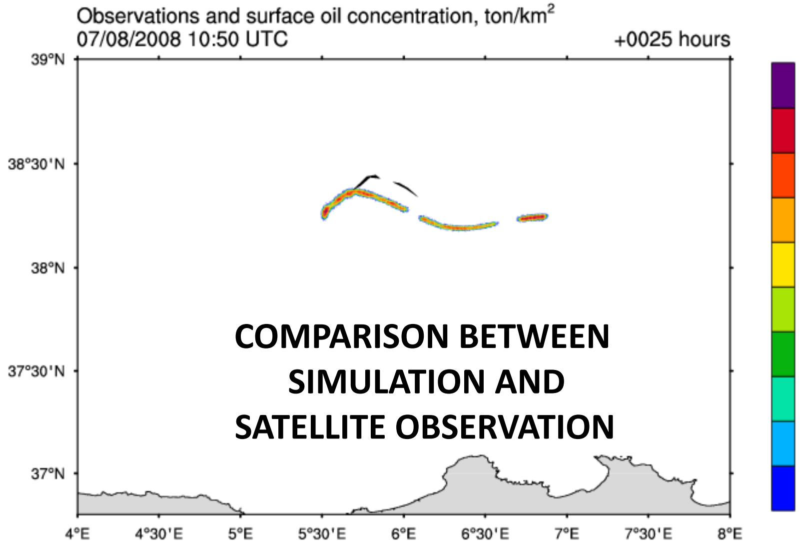
MEDSLIK-II reads the slick polygonal coordinates from satellite data and distributes the spill parcels randomly into the slick area.



INITIALIZATION: SHAPE OF THE SLICK FROM SATELLITE IMAGES

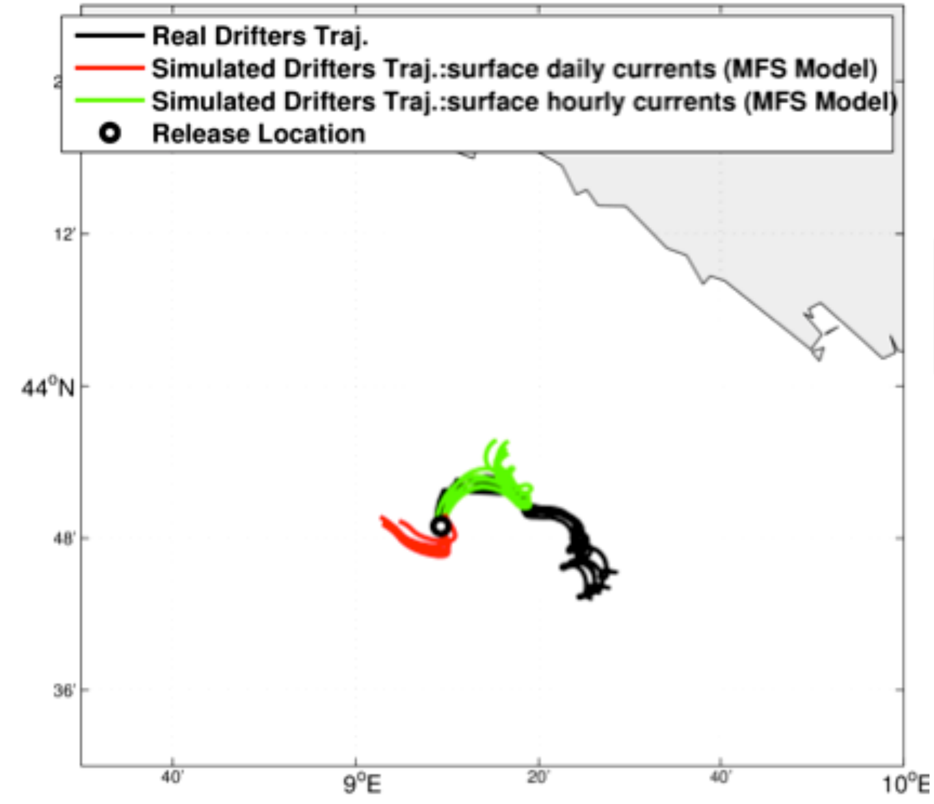


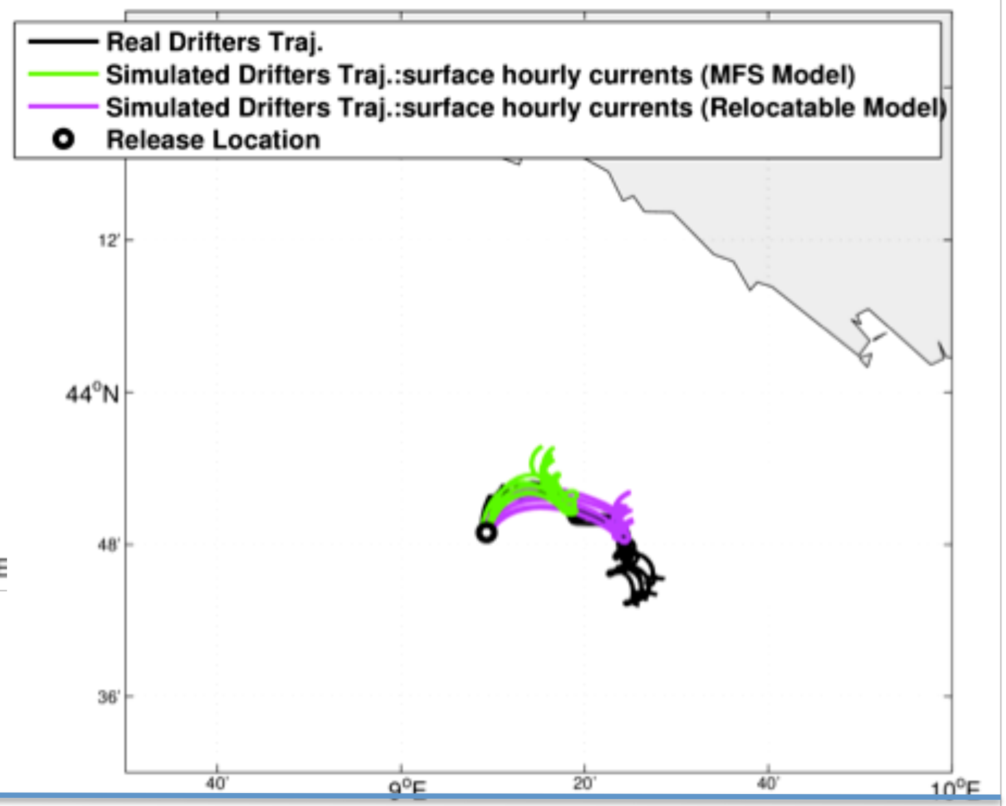




MODEL VALIDATION USING DRIFTERS TRAJECTORIES

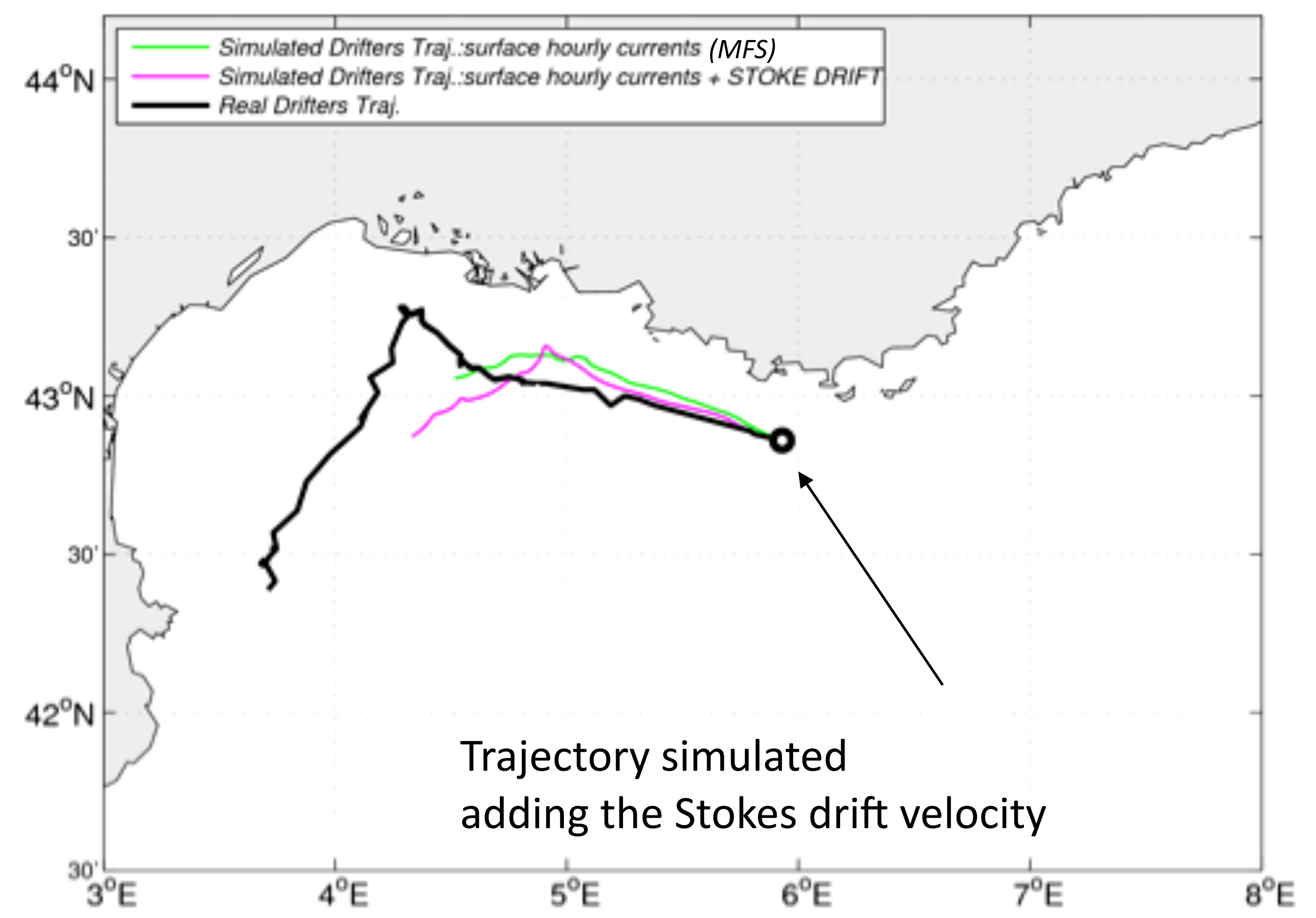
Sensitivity study to the temporal and horizontal spatial resolution of the current field.





MODEL VALIDATION USING DRIFTERS TRAJECTORIES

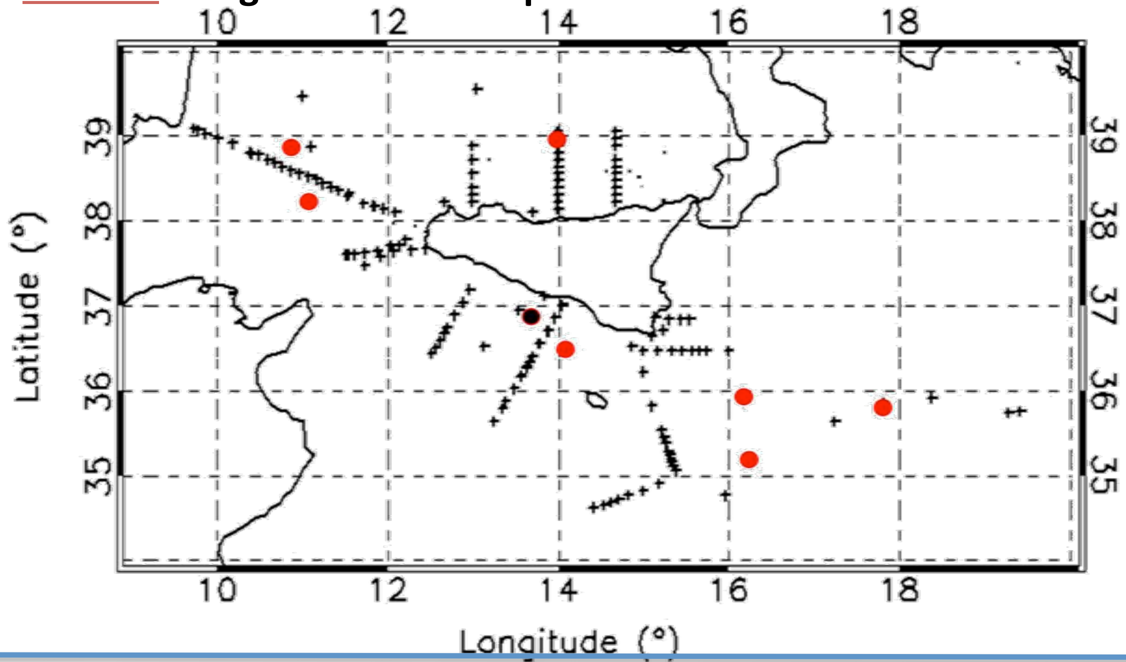
Sensitivity study to the Stokes drift term



The PRIMI oceanographic survey for oil spill model validation

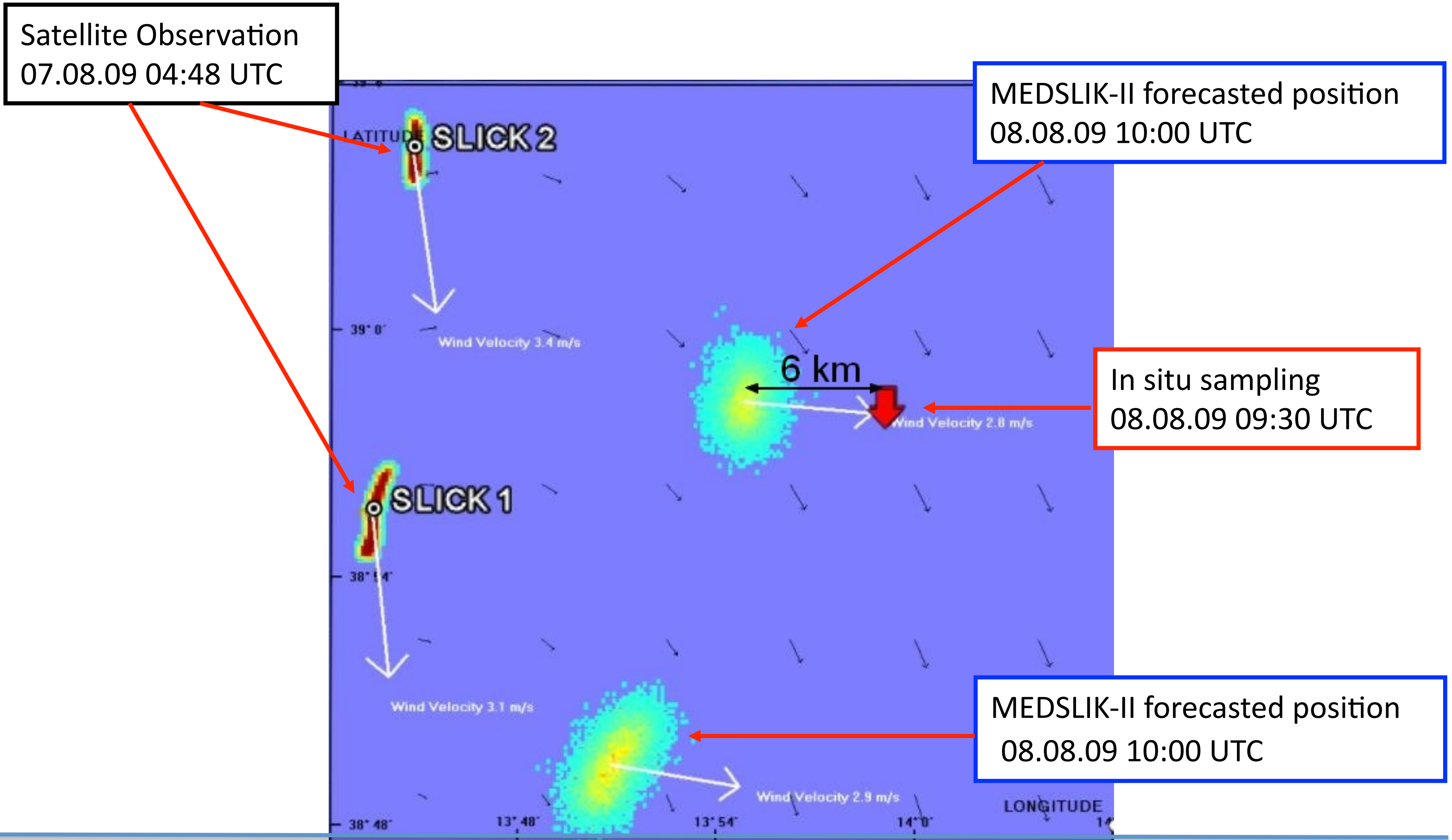
The PRIMI cruise objective was to verify in situ the oil slicks detected by satellite, presumably being the result of illegal tank washing, in order to acquire in situ data for validation of the oil spill model and the satellite detection system.

Period: 6 August 2009 – 6 September 2009

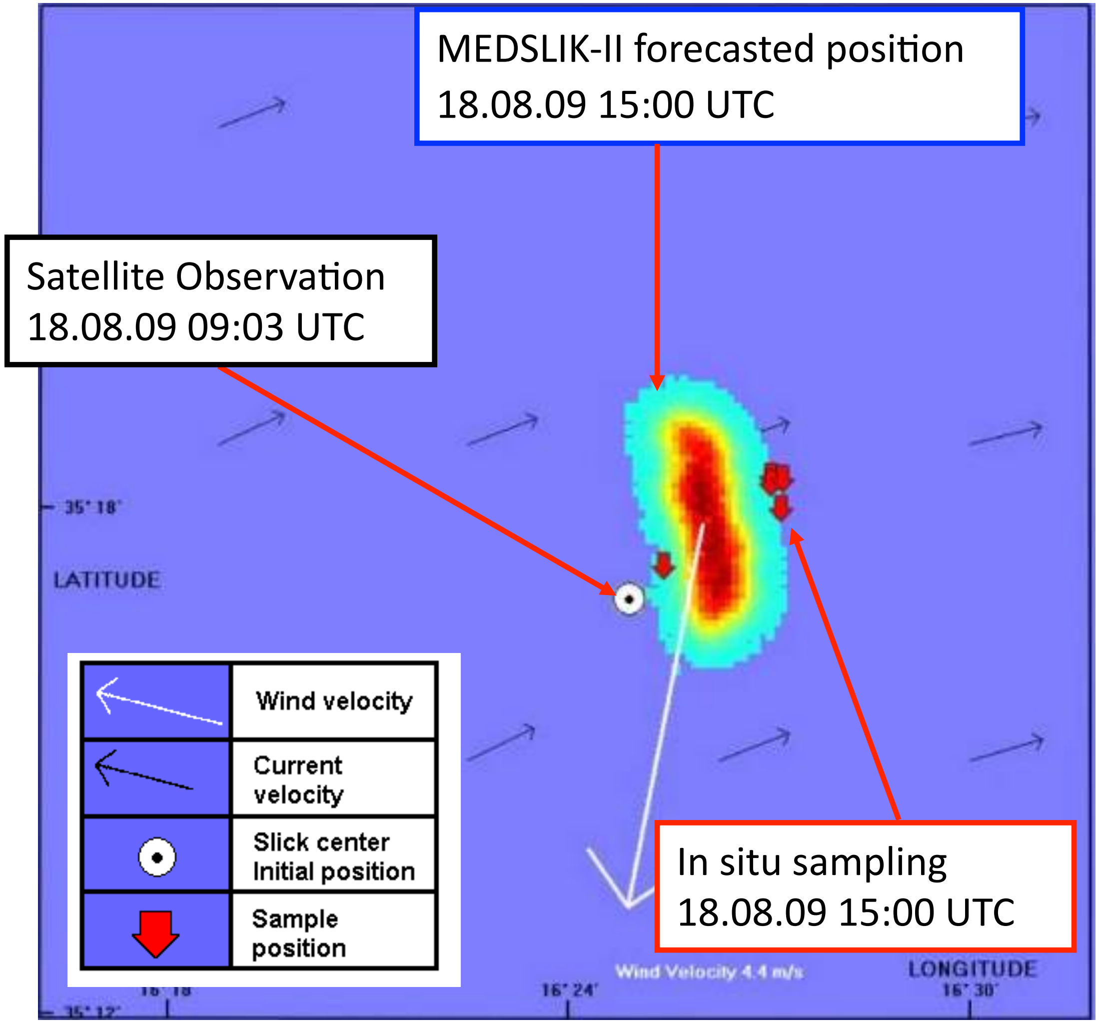


4 oil slicks were found in the position predicted by the oil spill model

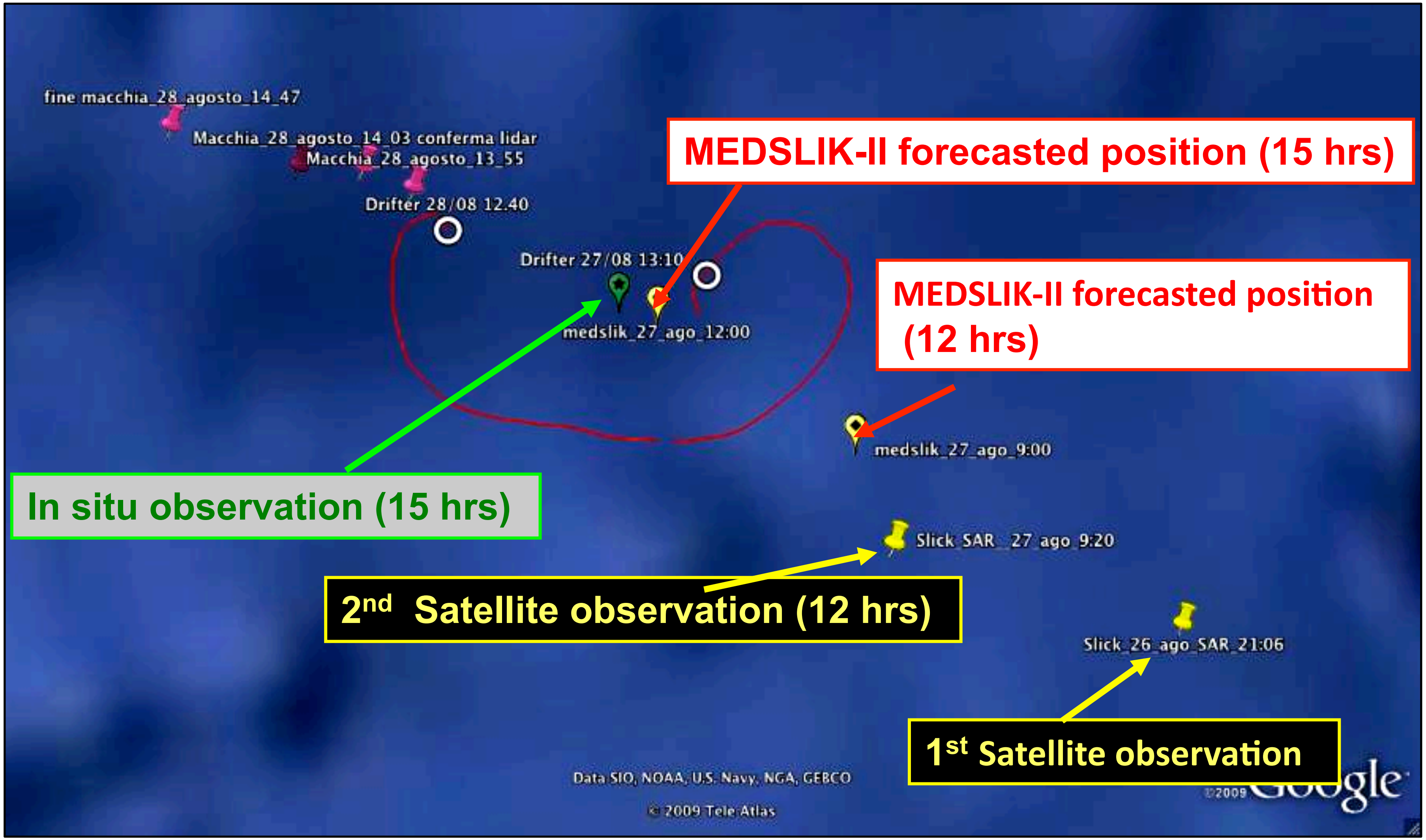
MODEL VALIDATION USING IN SITU DATA:



MODEL VALIDATION USING IN SITU DATA:



MODEL VALIDATION USING IN SITU DATA:



Emergency case examples: the Costa Concordia.

INGV, CNR-IAMC, ENEA

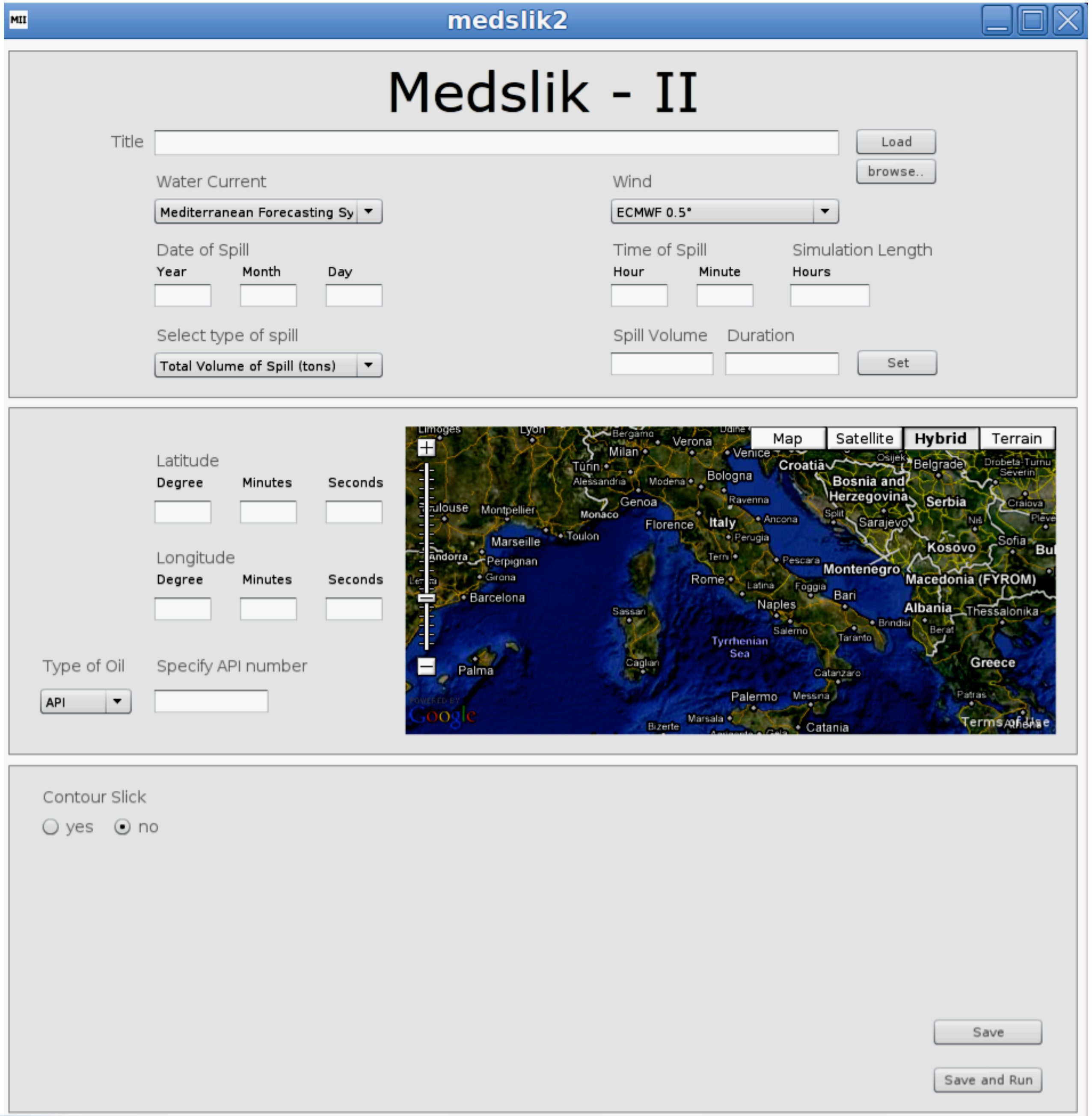
Italian Coast Guard- MEDSLIK-II Oil Spill forecasting system

Meteo-Oceanographic data download

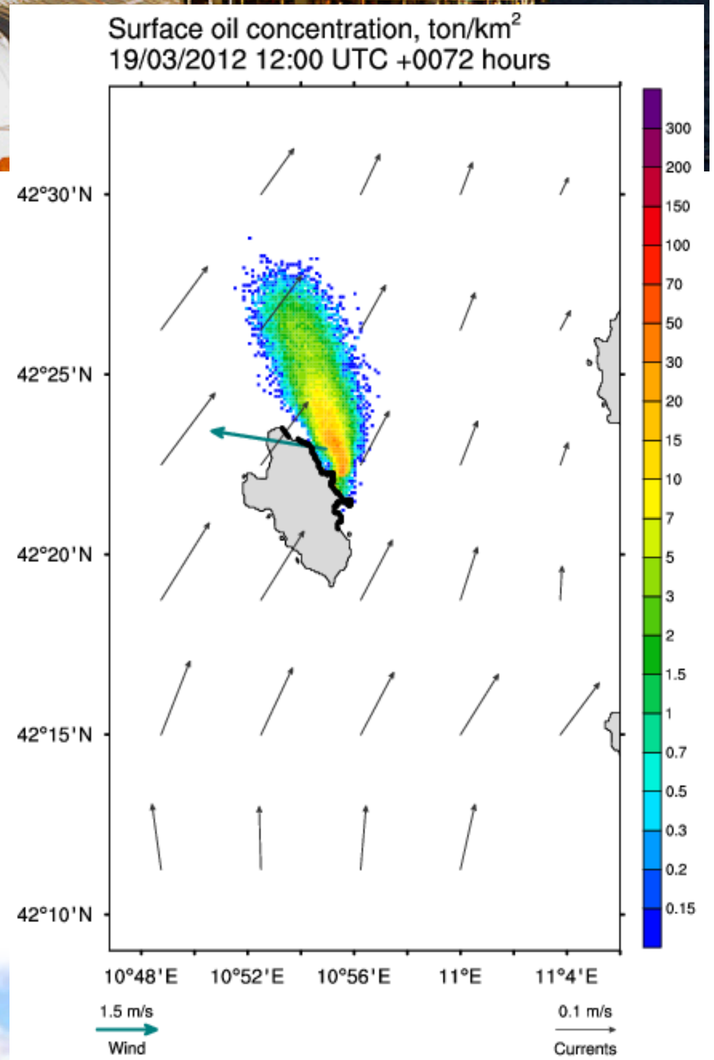
The ITCG oil spill forecasting system downloads every day the Mediterranean Forecasting System and the Adriatic Forecasting System model outputs and ECMWF winds.

↓

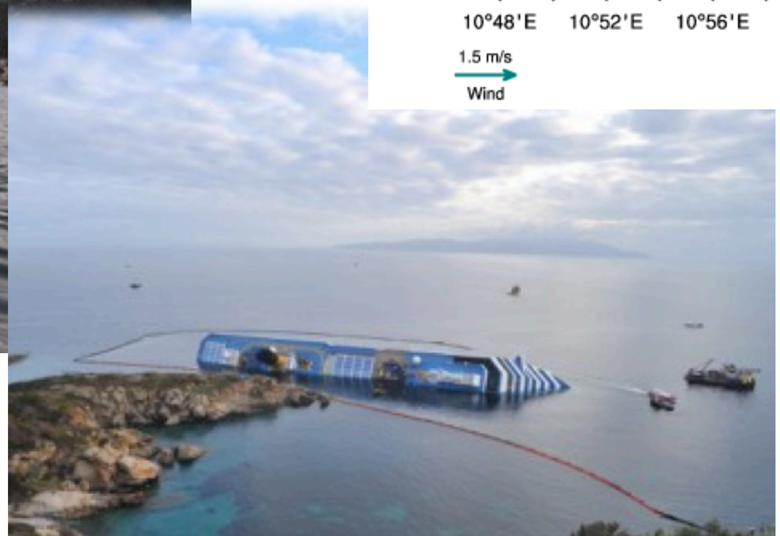
MEDSLIK-II
with Graphical User Interface
for the input and output visualization


medslik2
Medslik - II
Title
Load
browse..
Water Current
Mediterranean Forecasting Sy
Wind
ECMWF 0.5°
Date of Spill
Year
Month
Day
Time of Spill
Hour
Minute
Simulation Length
Hours
Select type of spill
Total Volume of Spill (tons)
Spill Volume
Duration
Set
Latitude
Degree
Minutes
Seconds
Longitude
Degree
Minutes
Seconds
Type of Oil
API
Specify API number
Map
Satellite
Hybrid
Terrain
Contour Slick
yes
no
Save
Save and Run

Simulations of possible oil spill scenarios



Date of accident: 13/01/2012.
The boat contained 2500 tons of oil (API 17).
Every day (since 16/01/2012) a bulletin has been produced with the possible scenario of pollution, the following week the production of the multi-model model bulletin started.
The release of oil has been assumed constant during the 72 hours of simulation.



GNOO supported the Italian Coast Guard in the production of their Bulletin

ITALIAN COAST GUARD HEADQUARTERS

Comando Generale del Corpo delle Capitanerie di Porto

In collaboration with Italian National Group of Operational Oceanography
Istituto Nazionale di Geofisica e Vulcanologia (INGV) – MyOcean Med MFC

Costa Concordia accident: forecast of the possible oil pollution scenario in case of oil spill from the ship.

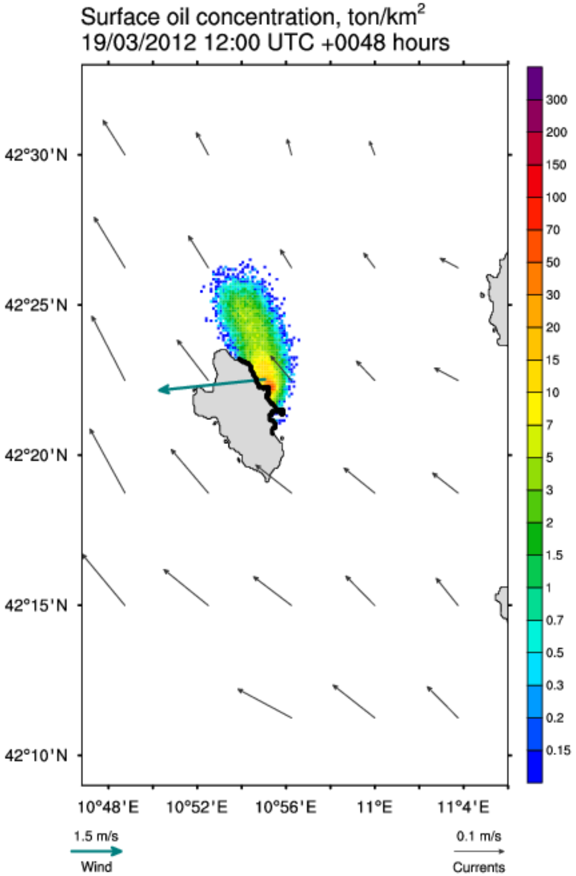
Analysis and forecasting system used by the Italian Coast Guard Operational Centre - I.M.R.C.C. Rome.

Rome 13/02/2012

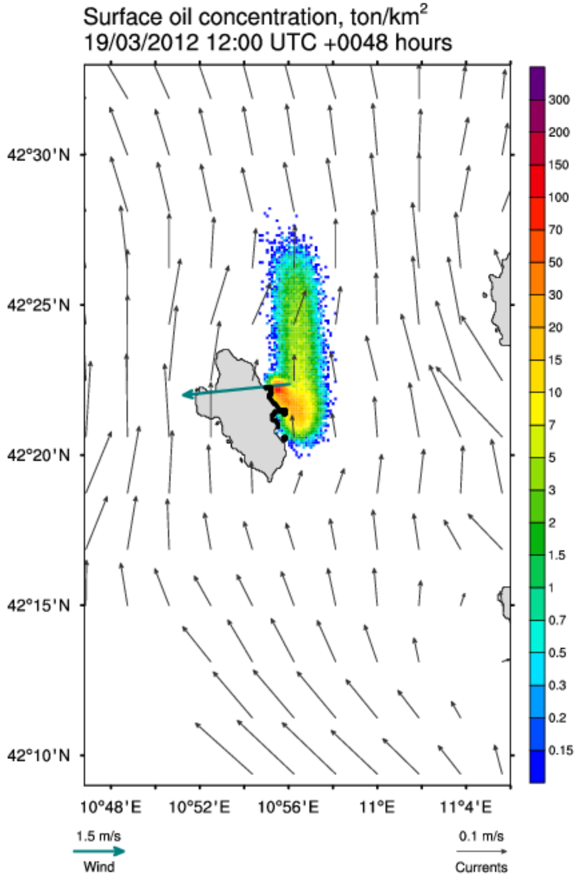
This report is prepared by the Italian Coast Guard Operational Centre - I.M.R.C.C. Rome.

Italian multi-model bullettin (INGV, CNR-IAMC e ENEA)

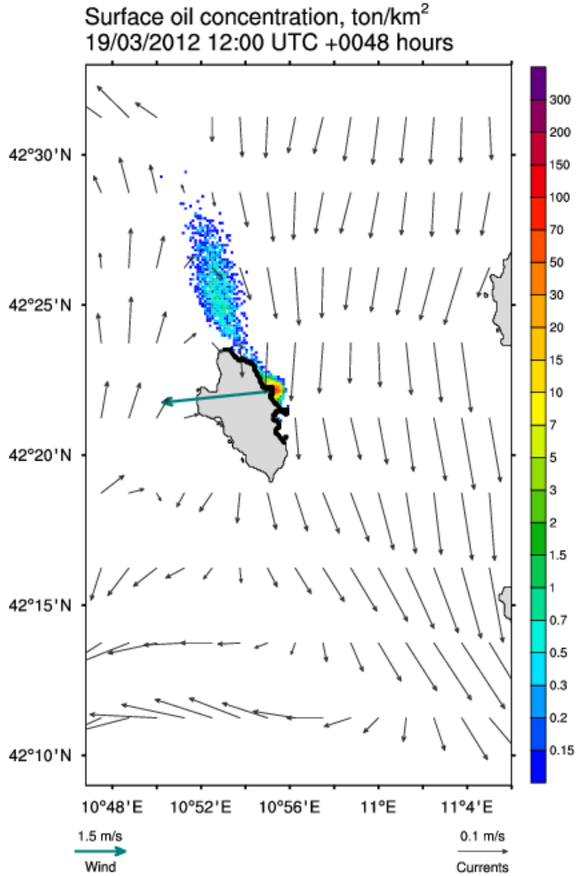
MFS (INGV)
6.5 km



WMED (CNR-IAMC)
3.5 km

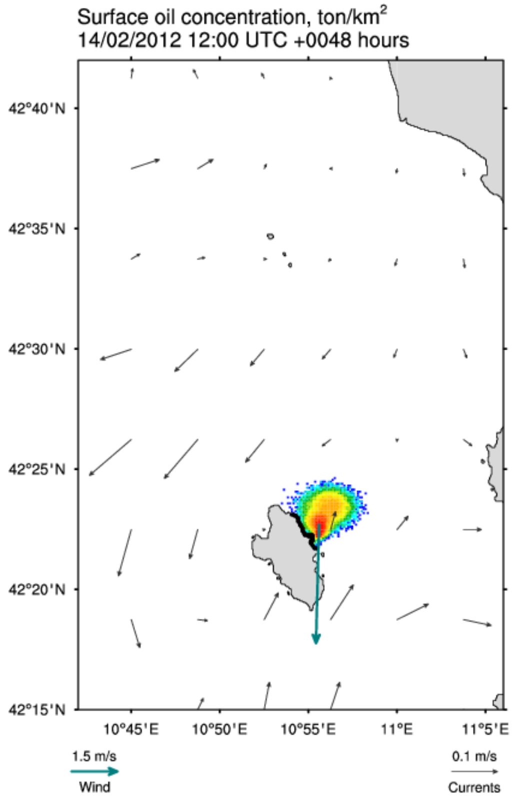


TYRR (ENEA)
2km

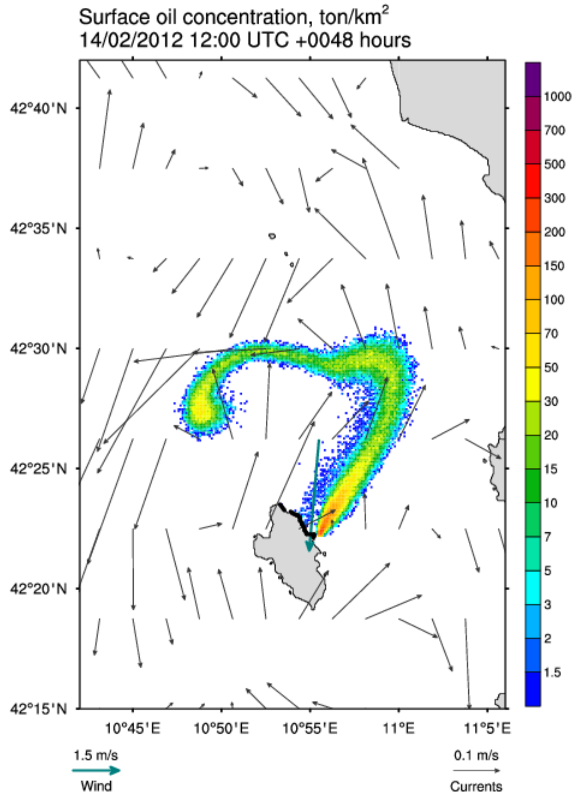


Italian multi-model bullettin (INGV, CNR-IAMC e ENEA)

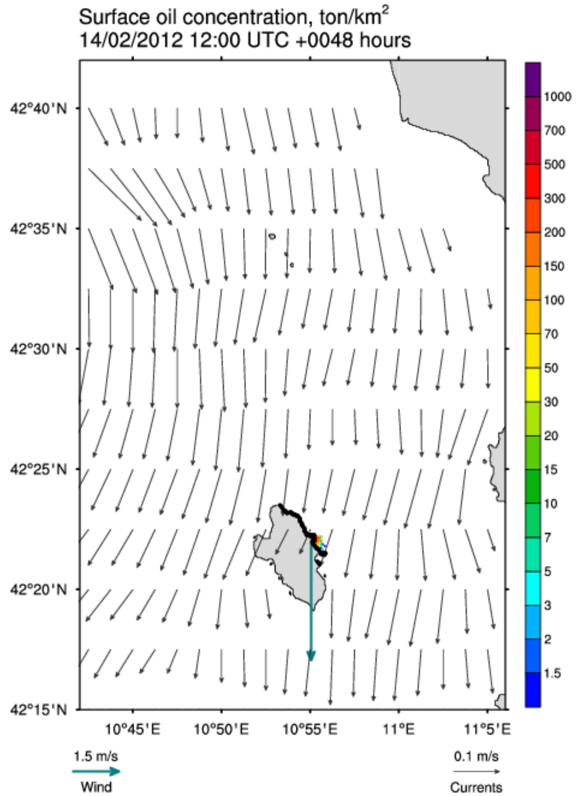
MFS (INGV) 6.5 km



WMED (CNR-IAMC) 3.5 km



TYRR (ENEA) 2km



Drifters release experiment

1

4

3

2

4 drifters (SPHERE) released the 14 of February 2012 (ARGOMARINE project)

The real drifters trajectories have been simulated using the MEDSLIK-II model coupled with MFS, TYRR, WMED and the relocatable model.

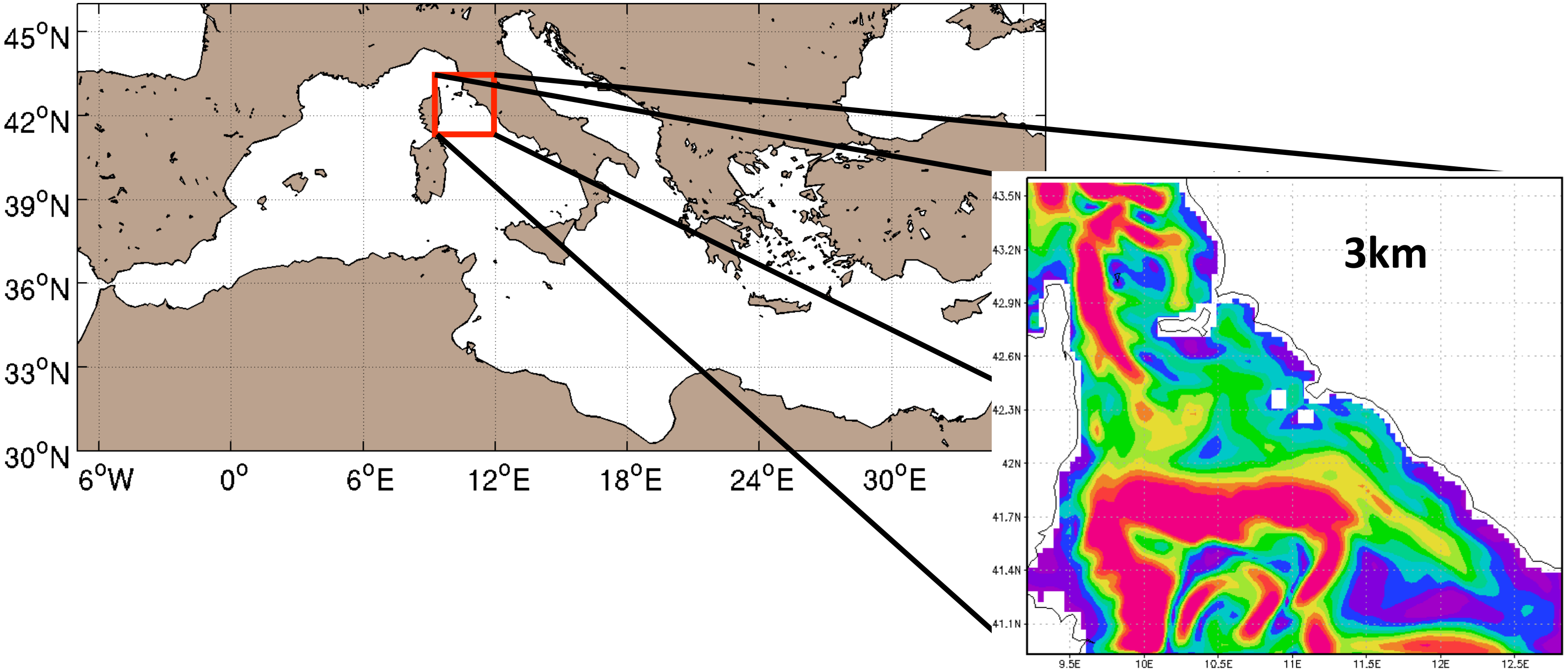
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 GeoEye
Image © 2012 European Space Imaging

42°15'02.31" N 11°01'02.65" E elev -141 m Eye alt 38.59 km

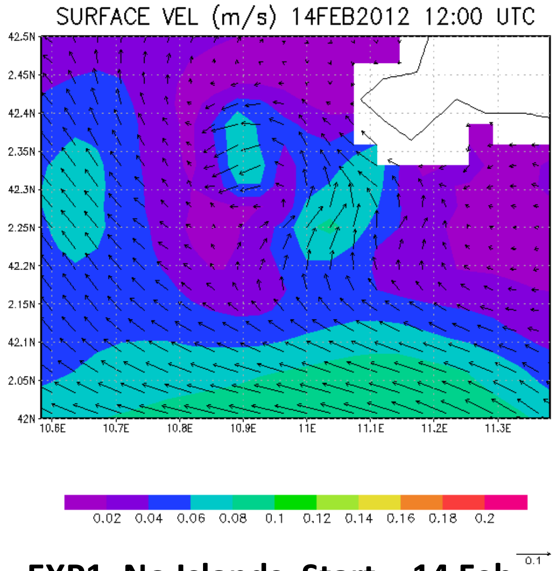
Relocatable model Nesting

The relocatable model produces high horizontal resolution currents and can be nested in any area of the Mediterranean Sea.

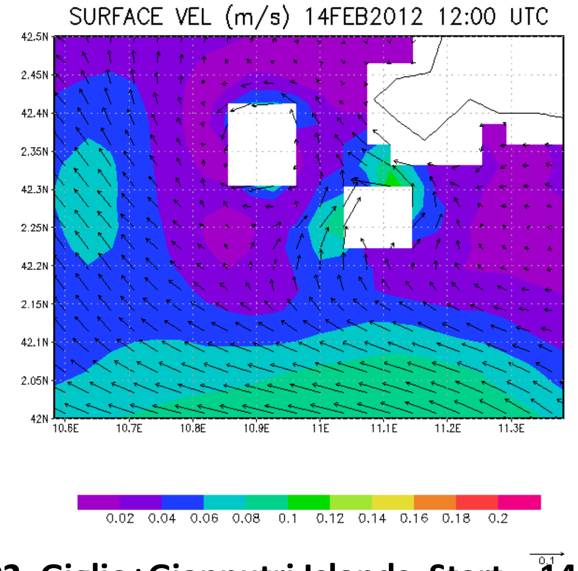
3 km model implementation,
nested in the Mediterranean Forecasting System (MFS)



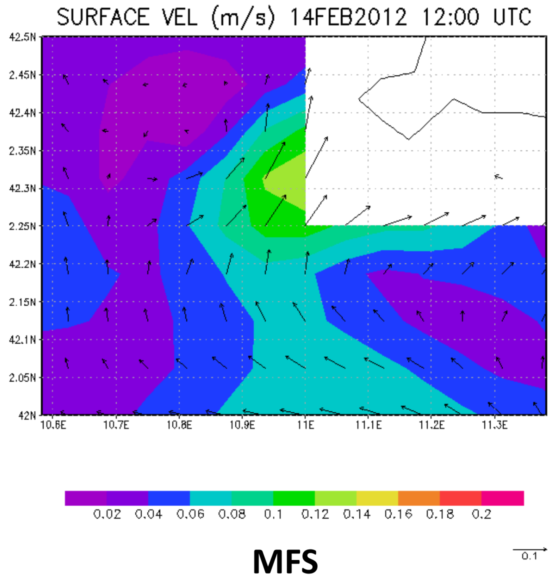
Relocatable model Nesting



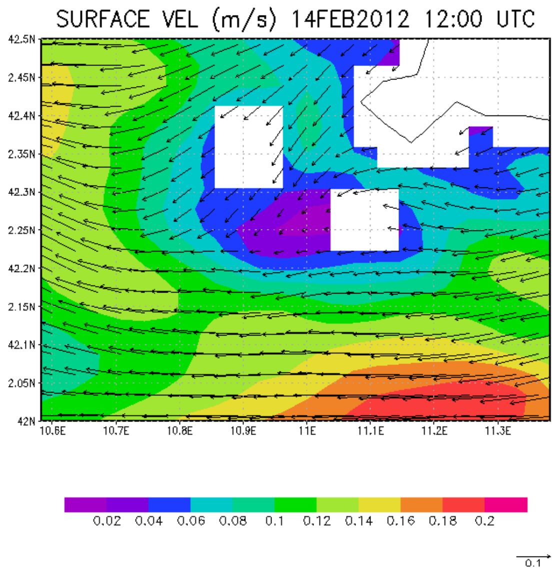
EXP1: No Islands, Start = 14 Feb



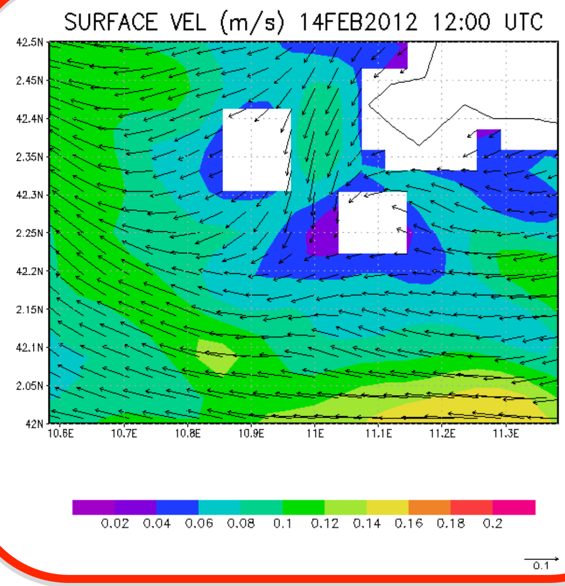
EXP2: Giglio+Giannutri Islands, Start = 14 Feb



MFS

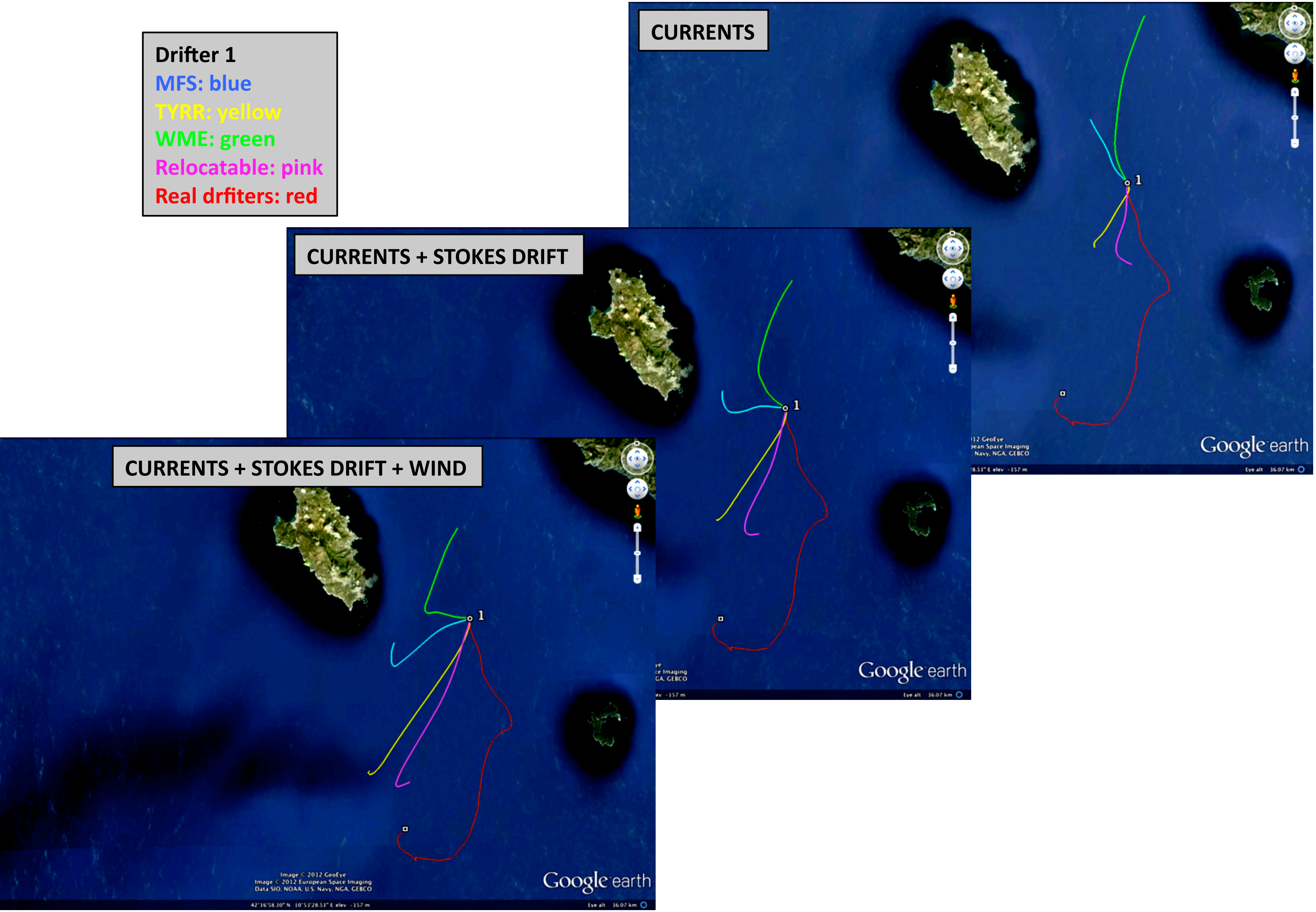


EXP3: Giglio+Giannutri Islands, Start = 13 Feb



EXP4: Giglio+Giannutri Islands, Start = 12 Feb

Drifter 1
MFS: blue
TYRR: yellow
WME: green
Relocatable: pink
Real drfiters: red



MII

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Download Model Code and Quick Start Guide

At the following links you can find:

- Test case output example (Algeria)
- Reference paper (work in progress)
- User manual

Model Code

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MEDSLIK-II Version 1.01
User Manual
M. De Dominicis

October 2012

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animation
observation_1
initial
0006
0012
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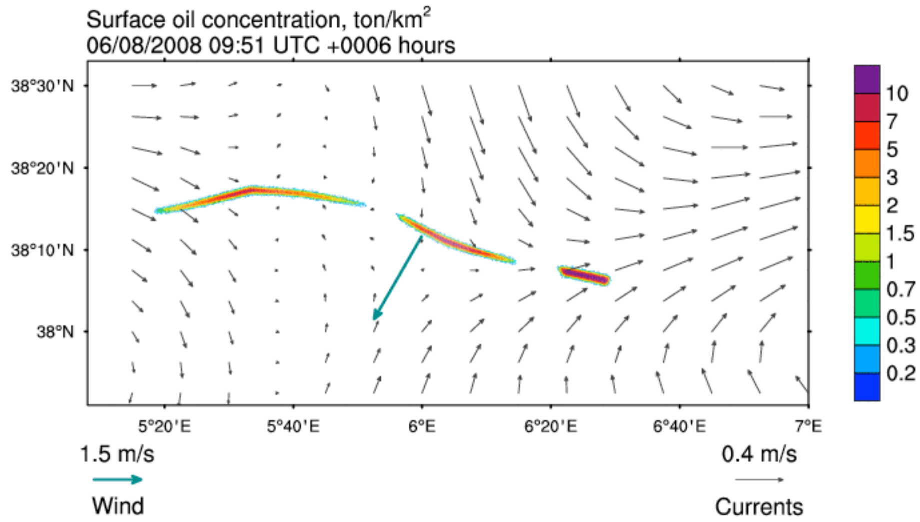
0036

MEDSLIK-II visualisation



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Model Code

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CONCLUSIONS

MEDSLIK-II is now available as an open source code!

- A surface oil spill model equations have been written in a modern formal framework to facilitate the understanding the modelling assumptions and to improve the model in the future

- MEDSLIK-II has been upgraded to include a proper representation of high frequency currents, wave-induced currents and wind fields corrections.

- The oil spill forecast accuracy usually increases with high frequency and high resolution eulerian currents (hourly values are recommended).

- Oil spill model predictions are in good agreement with drifter trajectories, with in situ data and with satellite data.

- MEDSLIK-II is today available at basin scale allowing a possible support to oil spill emergencies in the entire Mediterranean basin.

POSSIBLE FUTURE DEVELOPMENTS

- Improvement of particle numerical integration scheme
- Development of 3-D trajectories
- Deep source of spill
- Back-tracking
- Coupling with high resolution wind forcing
- Coupling with finite element eulerian models
- Coupling with wave models
- Langrangian turbulent diffusion parametrization