Advanced marine oil spill modelling for short term forecasting and applications to the Mediterranean Sea

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OUTLINE

- MEDSLIK-II oil spill model:
  - Transport processes & weathering processes
  - Coupling with meteo-oceanographic forcings and remote sensing data
- Validation
- Applications
- Conclusions

FEATURES of the MEDSLIK-II MODEL

- MEDSLIK-II is based upon the existing MEDSLIK model, developed by Prof. R. Lardner and G. 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.

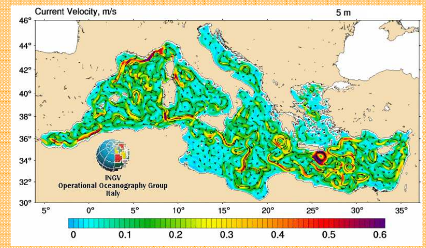
- MEDSLIK-II includes a proper representation of high frequency currents, the wave induced currents and wind fields in the advective components of the lagrangian trajectory model.

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

SCHEMATIC OF THE OIL SPILL MODEL INPUTS AND OUTPUTS

EULERIAN OCEANOGRAPHIC MODEL

(current velocities and SST analyses and forecast)



EULERIAN METEOROLOGICAL MODEL

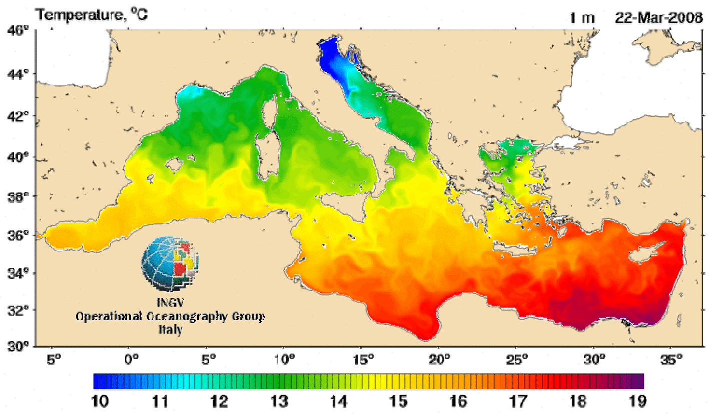
(wind velocity forecast)

MEDSLIK-II: LAGRANGIAN MODEL

DETERMINISTIC COMPONENT
(advection)
+
STOCHASTIC COMPONENT
(turbulent diffusion)
+
TRASFORMATION PROCESSES

Forecast of oil transport, dispersion and transformation

DETERMINISTIC COMPONENT: CURRENTS AND WINDS

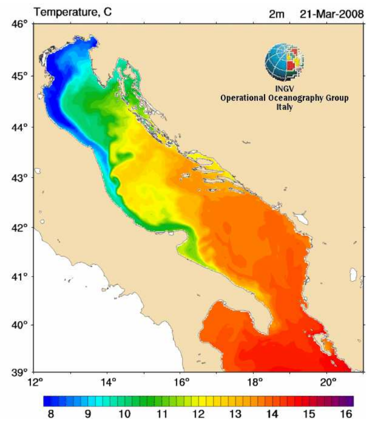


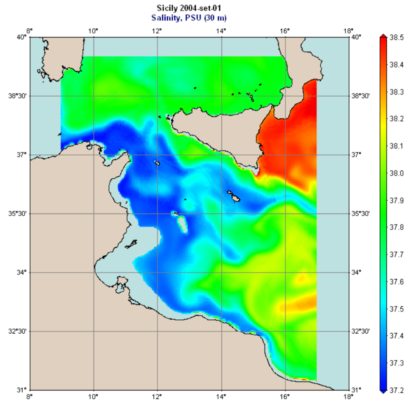
MEDSLIK-II can use the currents fields provided by:

1) MyO-Med-MFC (Mediterranean Sea) (INGV)
- 1/16°x1/16° ~ 6Km

NESTED SYSTEMS in MyO-Med-MFC:

2) AFS (Adriatic Forecasting system) (INGV)
- 1/45°x1/45° ~ 2.2Km

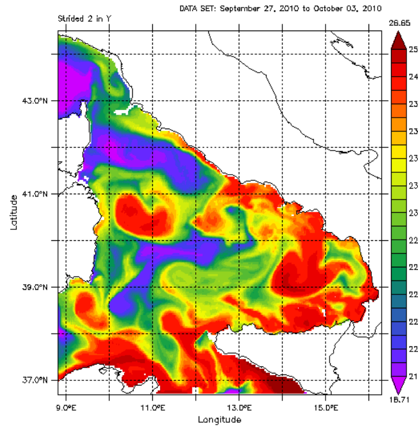




3) SCRM (Sicilian Channel Region
1/32°x1/32°, ~3.5 Km

4) Tyrrhenian Sea Model: (ENEA)
- 1/48°x1/48°, ~2 Km

5) Relocatable model: (INGV)
- 1 - 3 Km



DETERMINISTIC COMPONENT: CURRENTS AND WINDS

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

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

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

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

W_x, W_y: 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

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

$$U_S(z) = \int_0^\infty 2S(f)\omega(f)k(f)e^{2k(f)z}\,df$$

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

STOCHASTIC COMPONENT: TURBULENT DIFFUSION

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

EULERIAN CURRENTS — WIND CORRECTION — WAVE CORRECTION — TURBULENCE

TURBULENCE: RANDOM WALK PROCESS

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

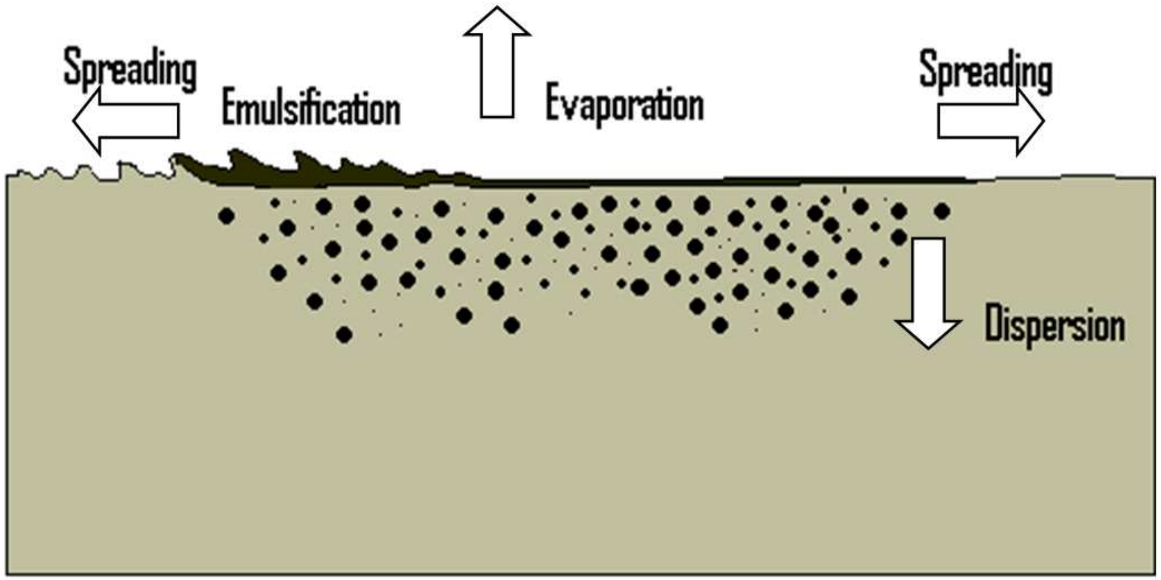
$$dy'(t) = Z_2\sqrt{2K_y dt} = [2n-1]\sqrt{2K_h dt}$$

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

RANDOM INCREMENT — DIFFUSIVITY

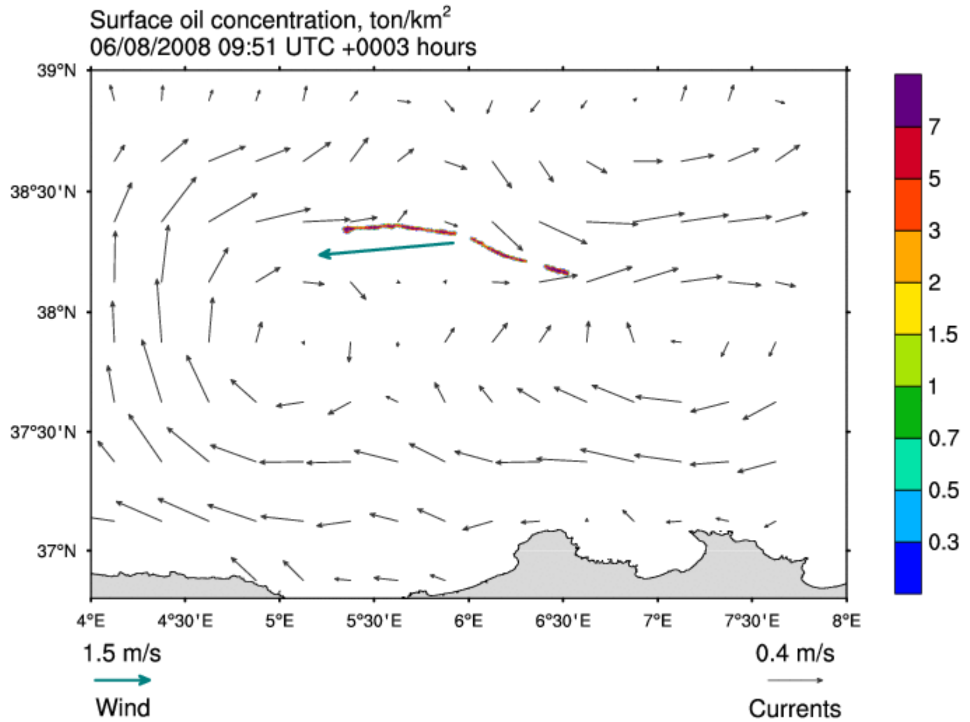
WEATHERING PROCESSES

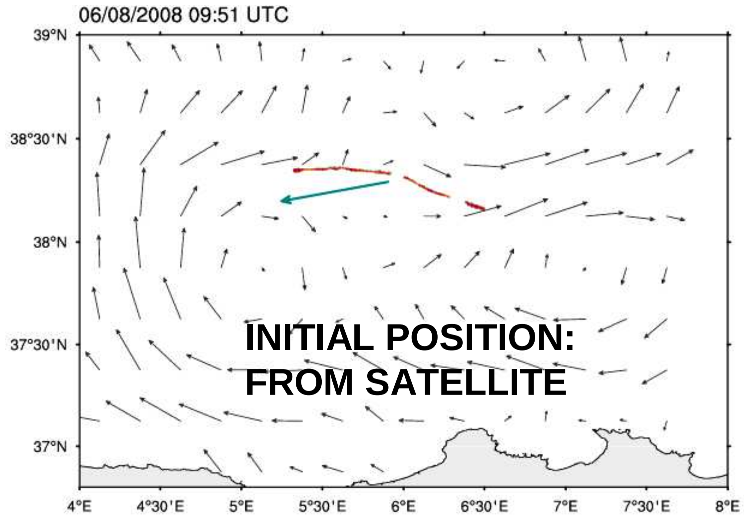
1. Evaporation
2. Dispersion
3. Spreading
4. Emulsification
5. Beaching

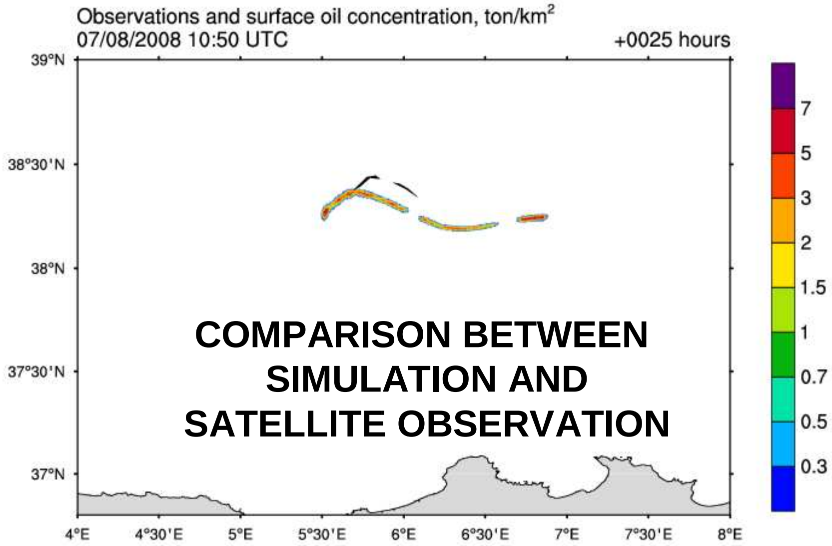


INITIALIZATION:
SHAPE OF THE SLICK FROM SATELLITE IMAGES

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







INITIALIZATION: WEATHERING PROCESSES

WEATHERING PROCESSES	ADVECTION + WEATHERING PROCESSES

Observation time – Slick age *Observation time* *Observation time + Simulation length*

Inizialization of the spill fate parameters

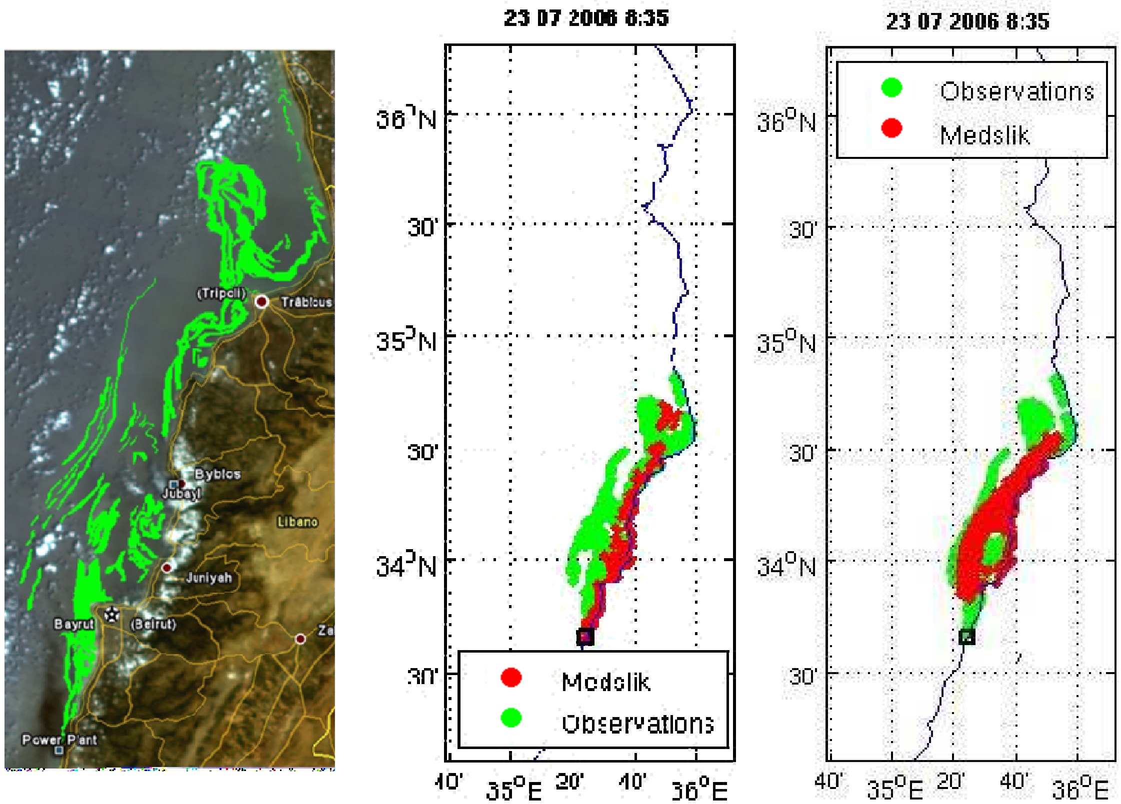
WEATHERING PROCESSES calculation (evaporation, dispersion, emulsification) considering the wind and SST in the area where the spill is observed.

Simulation of the spill evolution

WEATHERING PROCESSES calculation (evaporation, dispersion, emulsification, spreading) and ADVECTION calculation.

MODEL VALIDATION USING SATELLITE DATA

Lebanon Accident

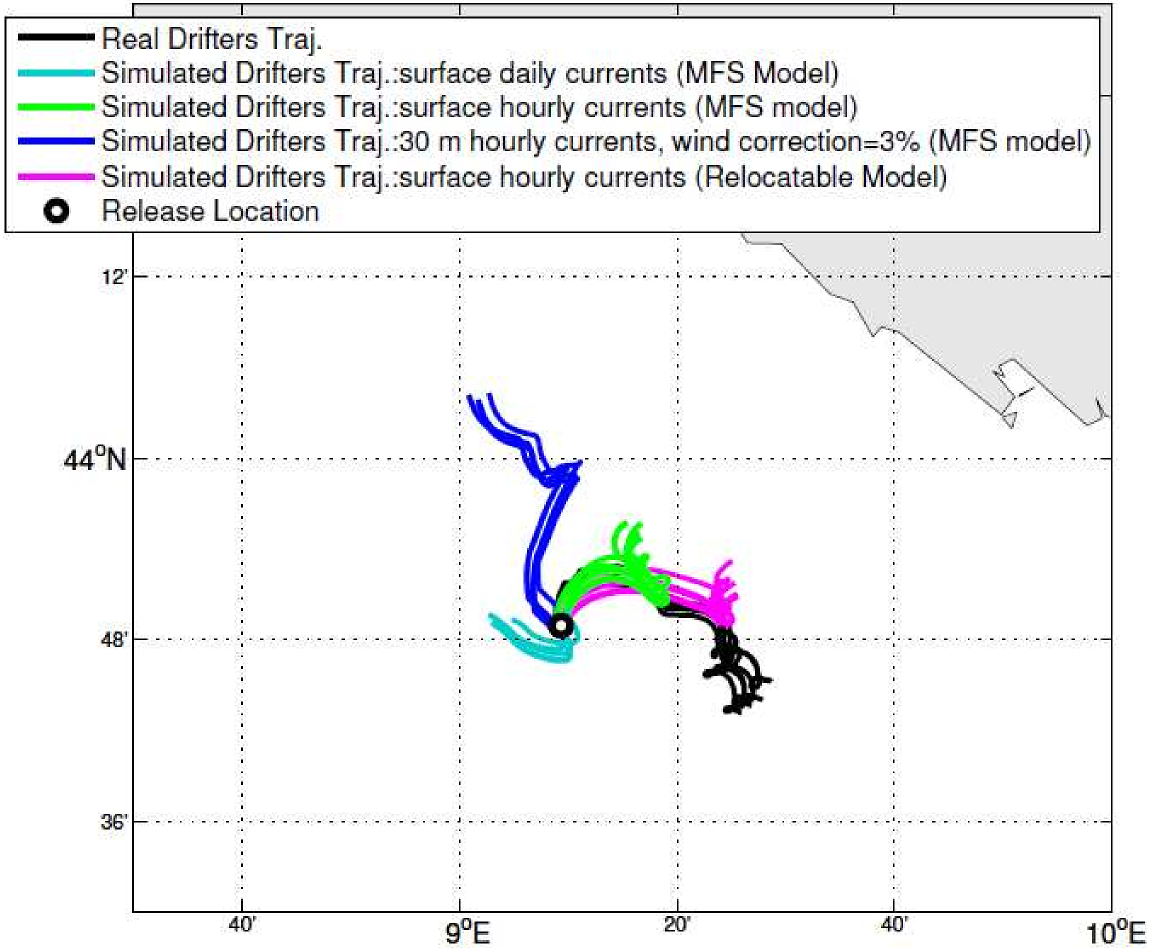


Input data	
Spill Date	13/07/2006
Observation Time	08:00
Latitude	35° 10' E
Longitude	33° 41' N
Volume	18770 tons
Spill Duration	144 hrs
Current velocities	MFS 1 hourly Analysis
Wind forcing	ECMWF 6 hourly Analysis

The position of the oil slicks predicted by B) **CYCOFOS-MEDSLIK** C) **MFS-MEDSLIK**, corresponding to July 23 8:00 GMT compared with A) the slick observed by MODIS ACQUA (green)

MODEL VALIDATION USING DRIFTERS TRAJECTORIES

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



CONCLUSIONS

- An advanced oil spill transport and transformation model has been upgraded to contain different current corrections and initialization procedures

- 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 and with satellite data.

- MEDSLIK-II has been used to provide timely information on the oil spill evolution forecasting during several emergency cases in the Mediterranean Sea

- Future developments include: improvement of particle time integration algorithms, backtracking, different lagrangian turbulence parameterizations, extension to a fully three dimensional lagrangian framework