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OpenDrift - a generic and modular framework for lagrangian particle tracking

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05/11/16

Outline

- Some reasons do Lagrangian calculations
- OpenDrift framework
- Example case study:
  - NOFO oil-in-water experiment June 2015

National reponsibilities of MET Norway

Provide forecast of the transport and fate of oil in case of a spill/accident

Provide forecast of the transport of objects (person-in-water, life raft, boats, containers...) to support search and rescue operations

NOFO

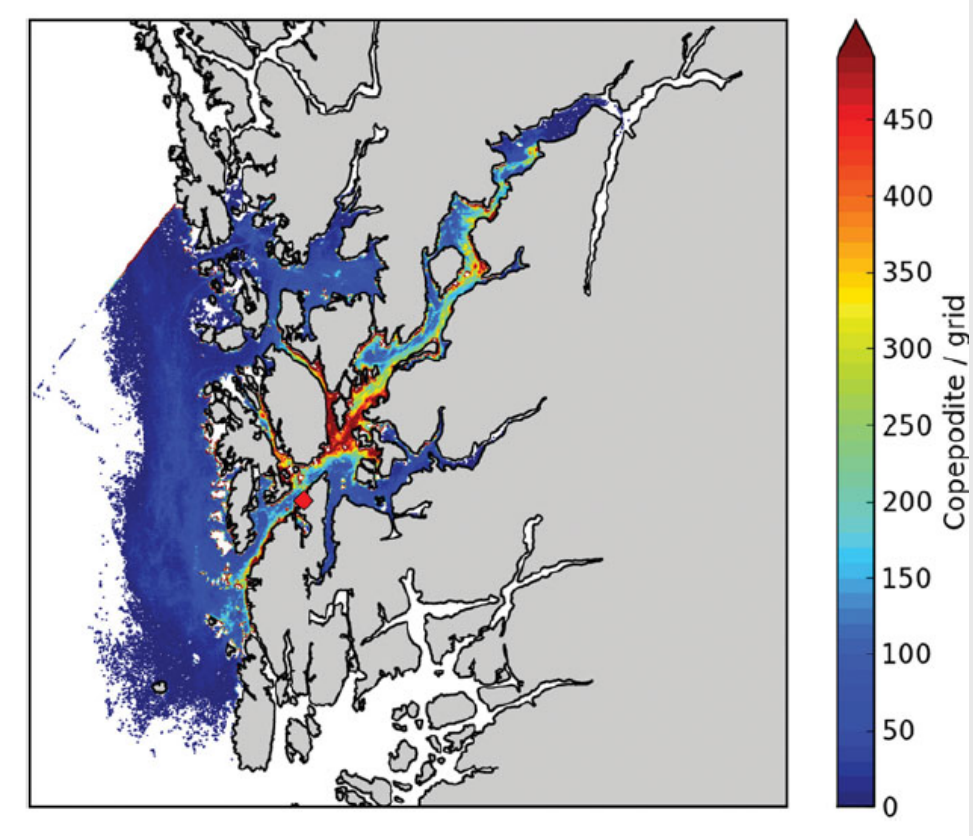
30 minute response time, at any time

- **operated by forecasters on duty**

KYSTVERKET

REDNINGSTJENESTEN

Biological transport model at Norweigan Institute of Marine Research (Ladim)



HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

Ådlandsvik B, Sundby S. 1994. Modelling the transport of cod larvae from the Lofoten area. ICES Marine Science Symposia 198:379–92.

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Other drifting things

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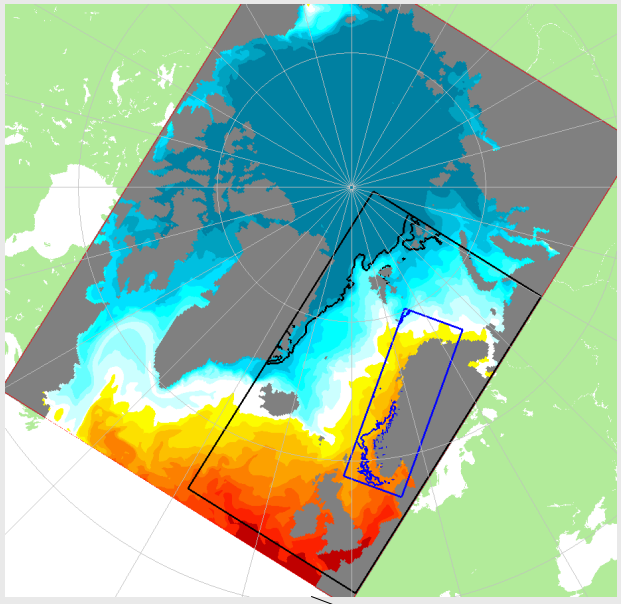
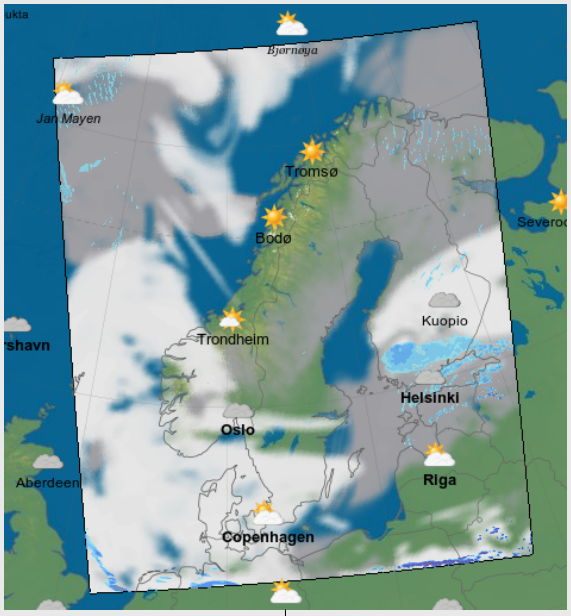
Input from general forecast models

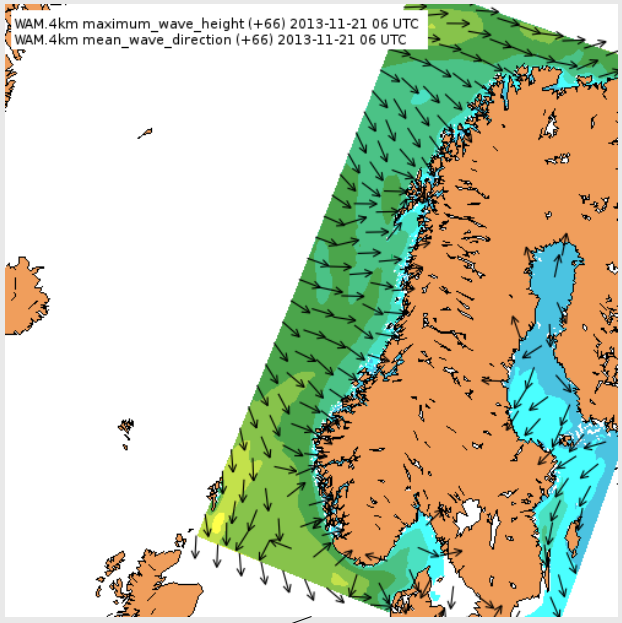
Ocean model (ROMS)



Atmospheric model (Hirlam)



Wave model (WAM)



Trajectory models

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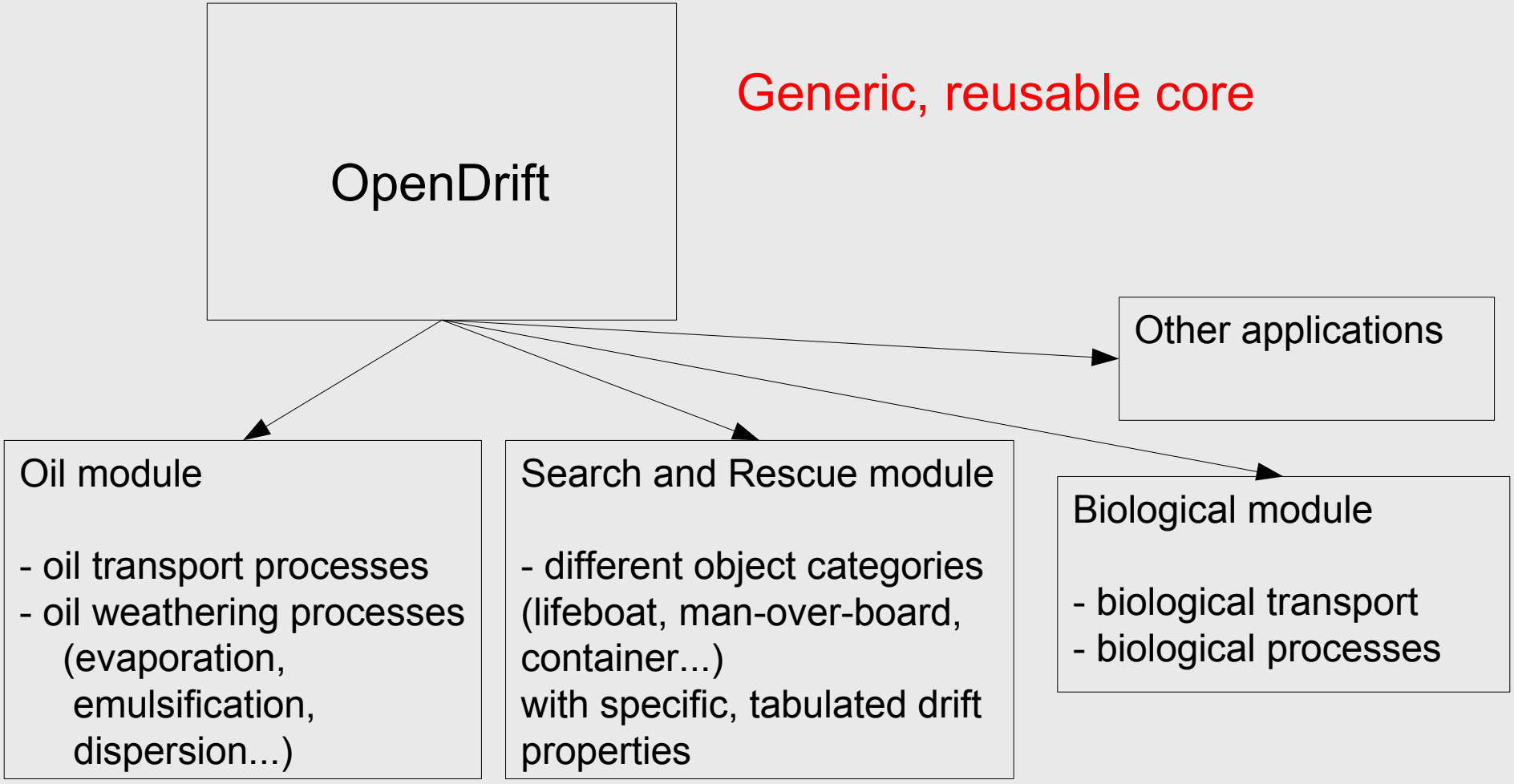
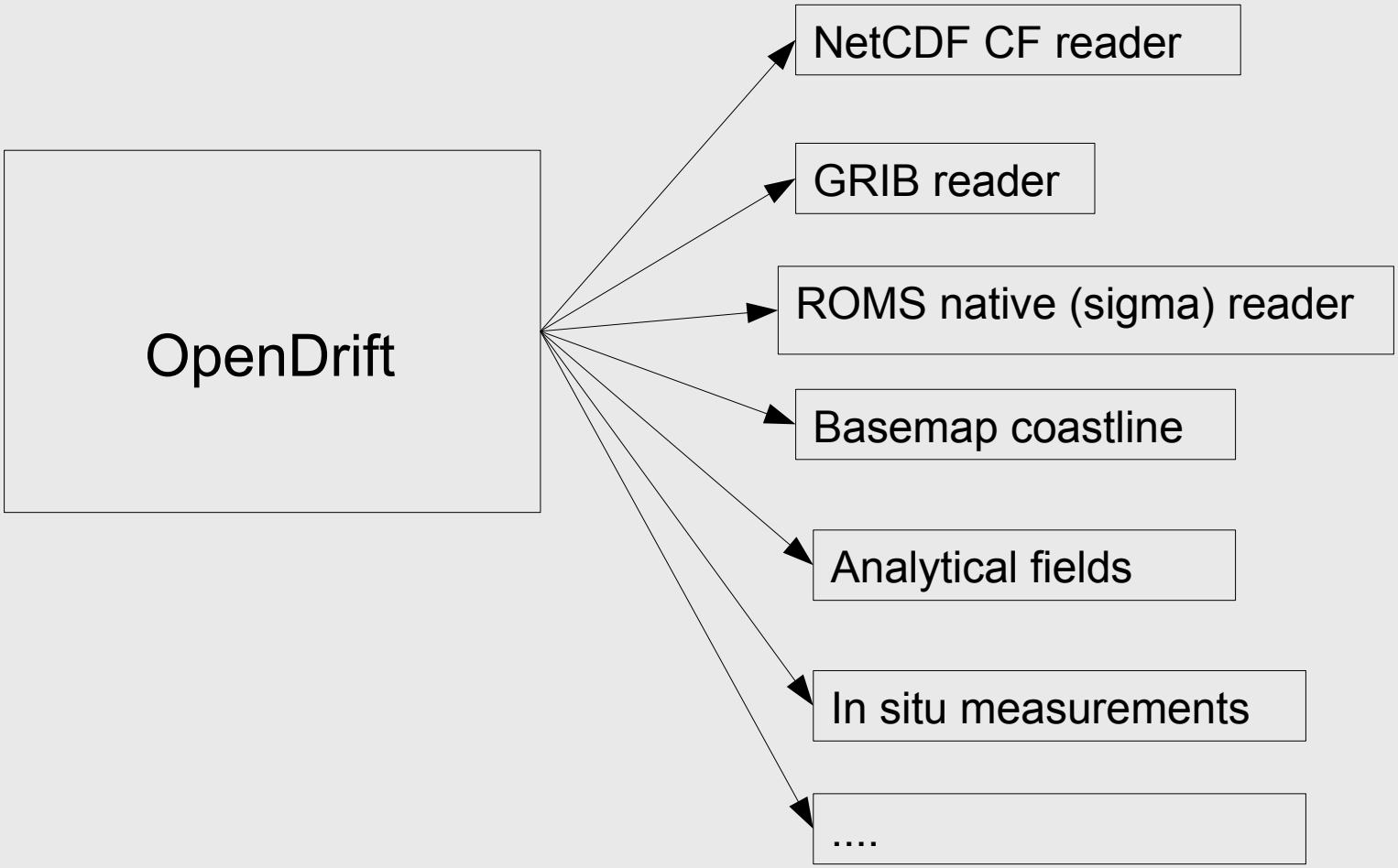
What were the problems?

- Three models with very much overlap
  - slows down improvement cycle
  - impractical to use for scientific studies
- Hardcoded with respect to:
  - format of input data (ocean, wind, waves)
    - awkward to use other input models
  - coastline (GSHHS)
- Messy code; technical tasks mixed with physical/chemical processes

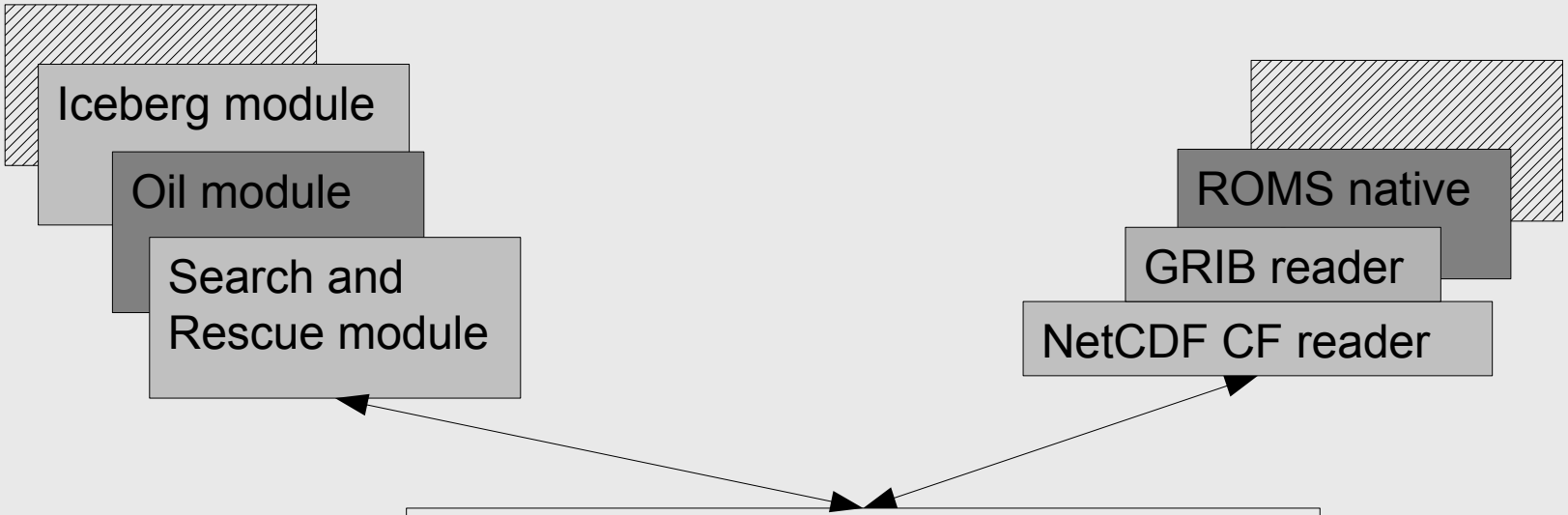
Generic trajectory model



Modularity for driver data: Readers

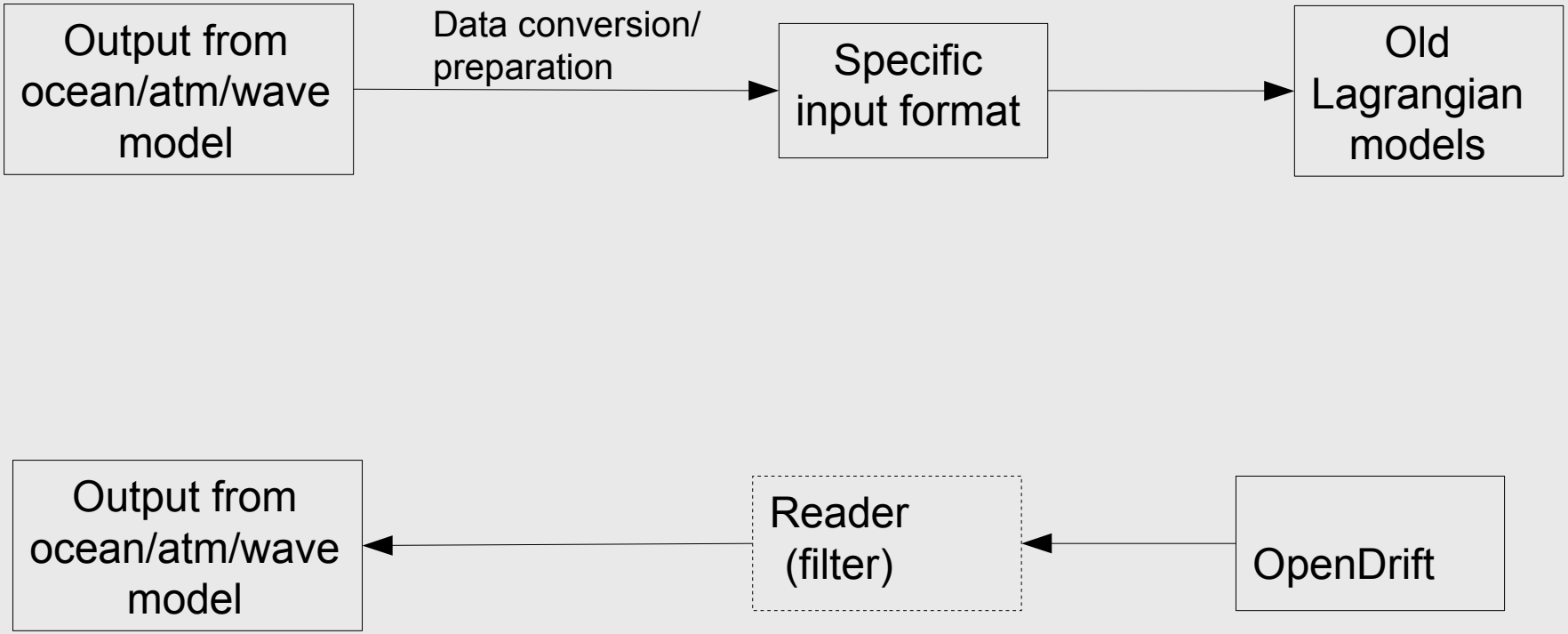


Key to modularity: CF naming convention



x_sea_water_velocity
y_sea_water_velocity
x_wind
y_wind
sea_surface_wave_significant_height
sea_surface_wave_to_direction
sea_surface_wave_stokes_drift_x_velocity
sea_surface_wave_stokes_drift_y_velocity
sea_ice_area_fraction
land_binary_mask
...

Avoid preprocessing of input data

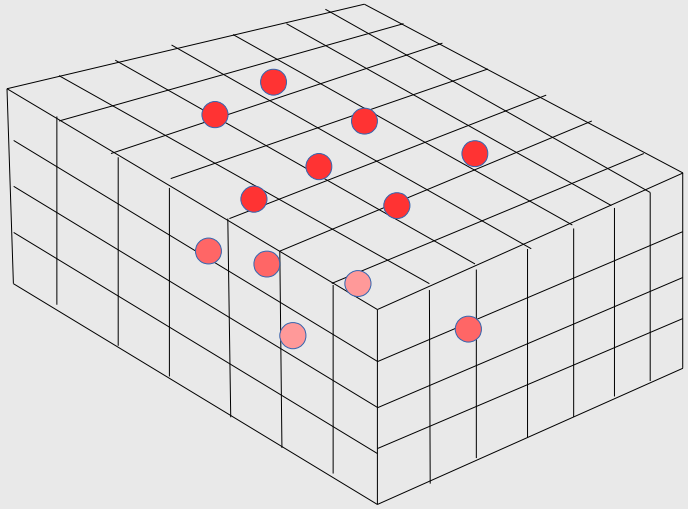


Use of «Readers»

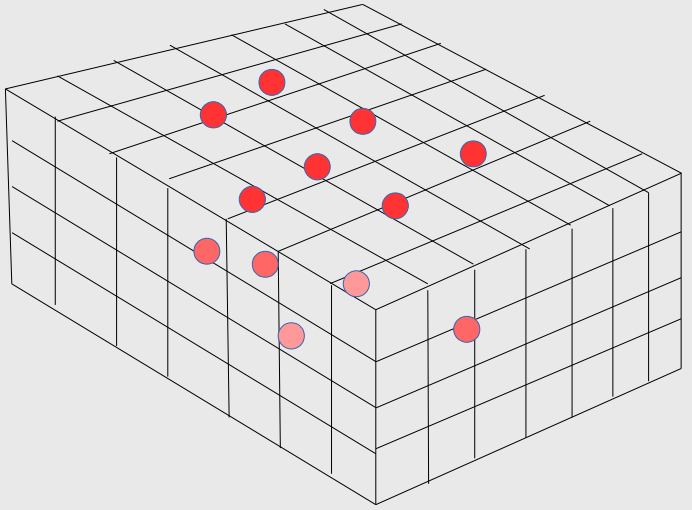
- Data are read in native map projection (SRS)
  - reprojection and vector rotation performed on the fly, using standard proj4 library (pyproj)

- A module (e.g. oil drift or S&R application) will need input data (currents, wind, waves...) at the positions of the elements

  - OpenDrift will request 3D blocks of the given variables, covering the particles, at the times before/after
  - interpolation in space and time

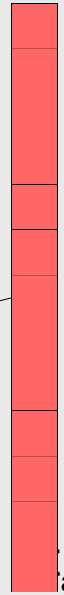


Horisontal and vertical interpolation (bilinear)



Horisontal and vertical interpolation (bilinear)

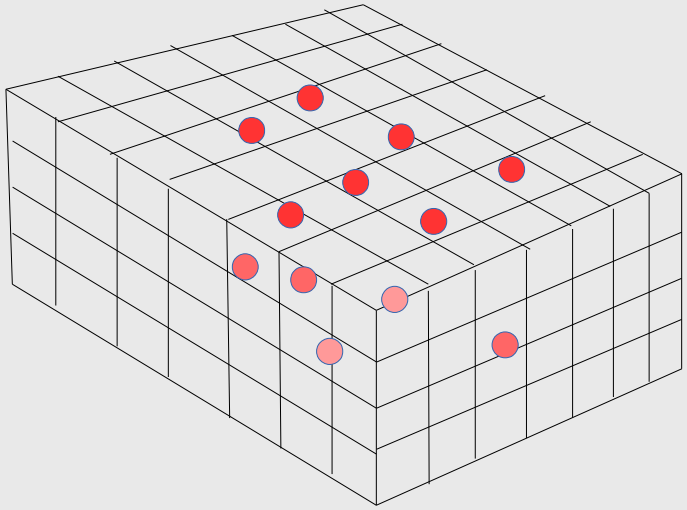
Linear interpolation in time

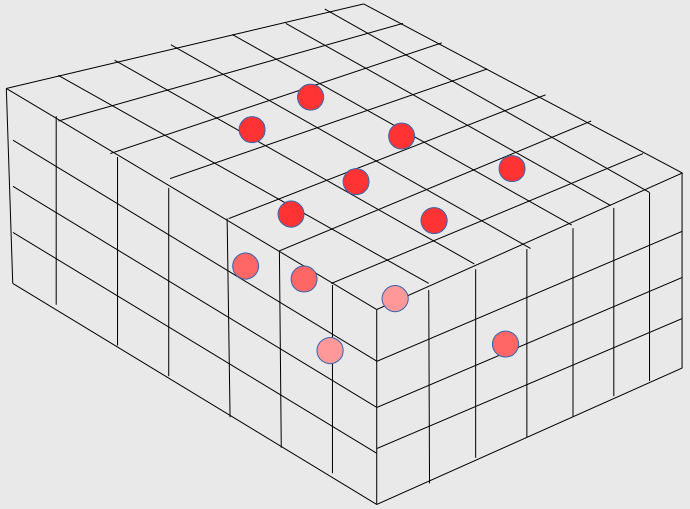


t_{before}

t_1

t_{after}





Horisontal and
vertical interpolation
(bilinear)

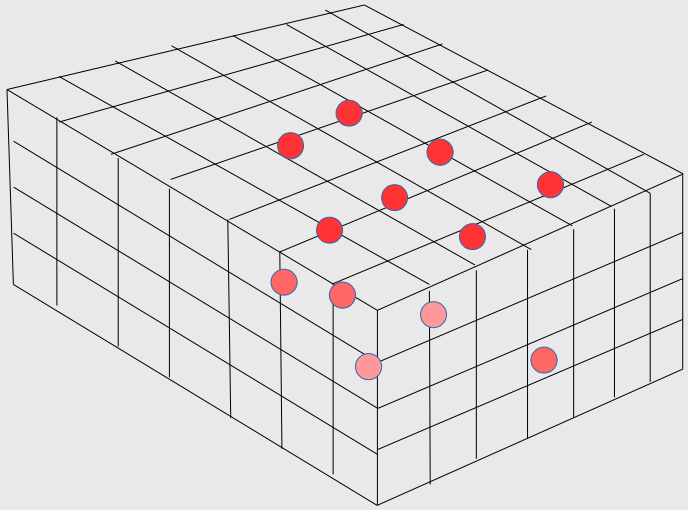
Horisontal and
vertical interpolation
(bilinear)

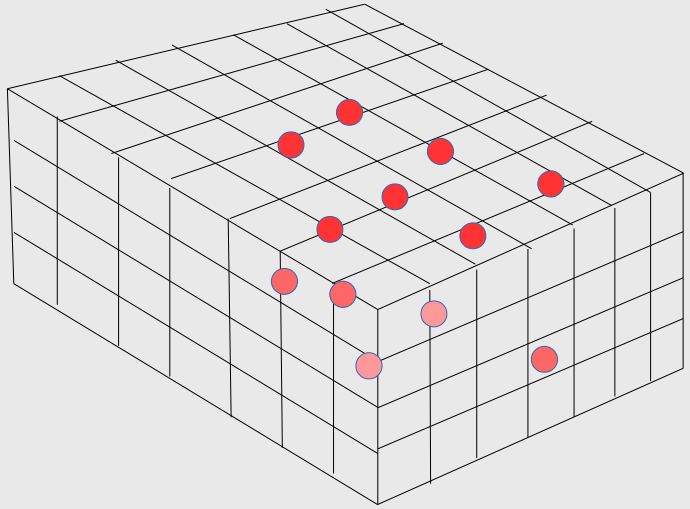
Linear interpolation
in time

t_{before}

t_2

t_{after}





Horisontal and vertical interpolation (bilinear)

Horisontal and vertical interpolation (bilinear)

Linear interpolation in time

t_{before}

t_3

t_{after}

Readers may request remote data

- NetCDF C/F through Thredds data server (OPeNDAP protocol)
- Almost as fast as from local files(!)
- Convenient not having to download large amount to local computer, when only a small part is needed
  - especially the case for third party users (e.g. oil companies)

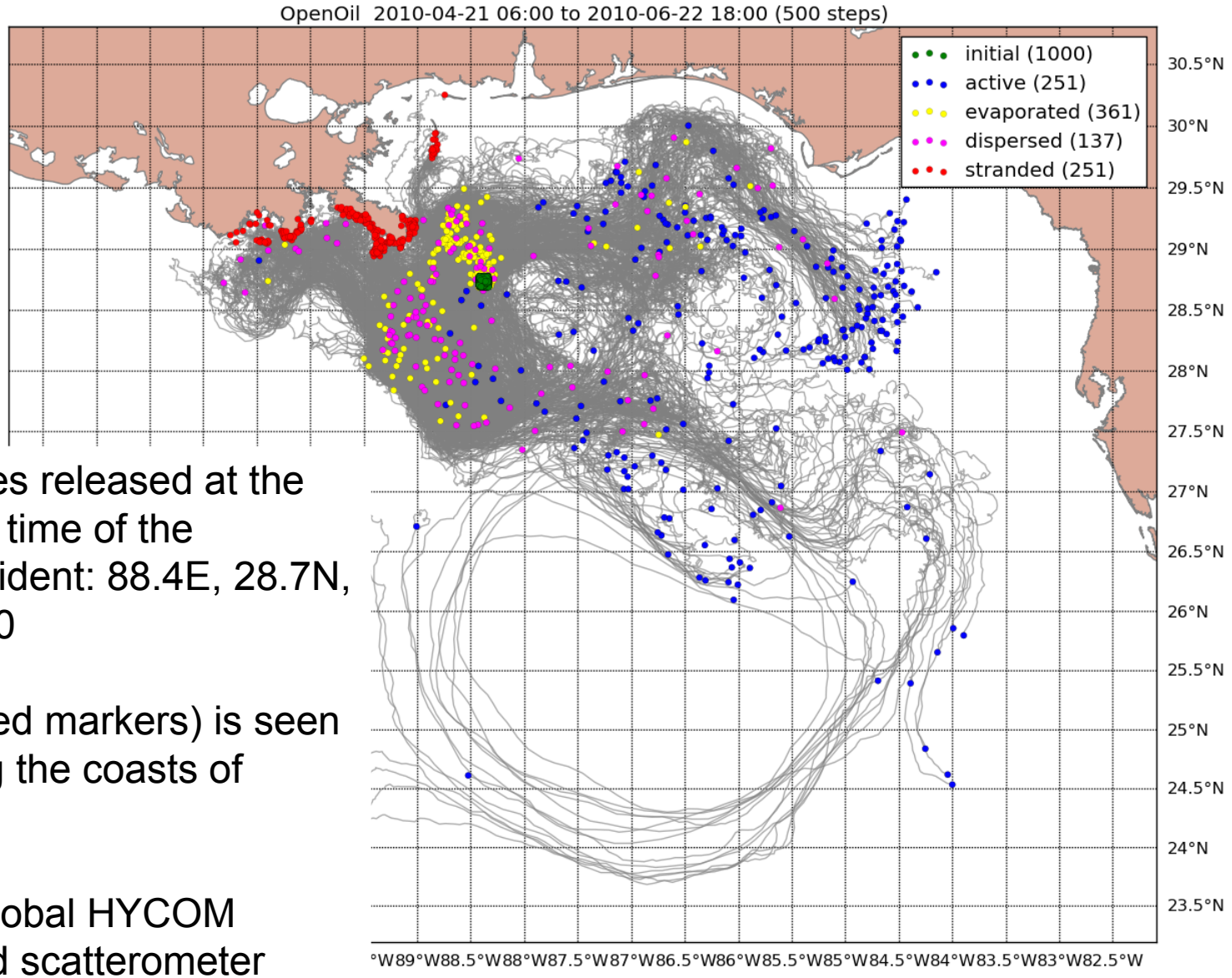
Example of free, online sources of winds, waves and currents:

http://thredds.met.no/thredds/dodsC/sea/norkyst800m/1h/aggregate_be
http://thredds.met.no/thredds/dodsC/arome25/arome_metcoop_default2_5km_latest.nc
http://tds0.ifremer.fr/thredds/dodsC/CLS-L4-CUREUL_HS-ALT_SUM-V01.0_FULL_TIME_SERIE
http://tds.hycom.org/thredds/dodsC/GLBu0.08/expt_19.1/2010/3hrly
http://www.ncdc.noaa.gov/thredds/dodsC/oceanwinds6hr

Priority list of readers

- readers_ocean = ['norkyst800m',
  'nordic4km', 'arctic20km', 'climatology']
- readers_wind = ['arome2.5km', 'ecmwf', 0]

Provides robustness for operational service.

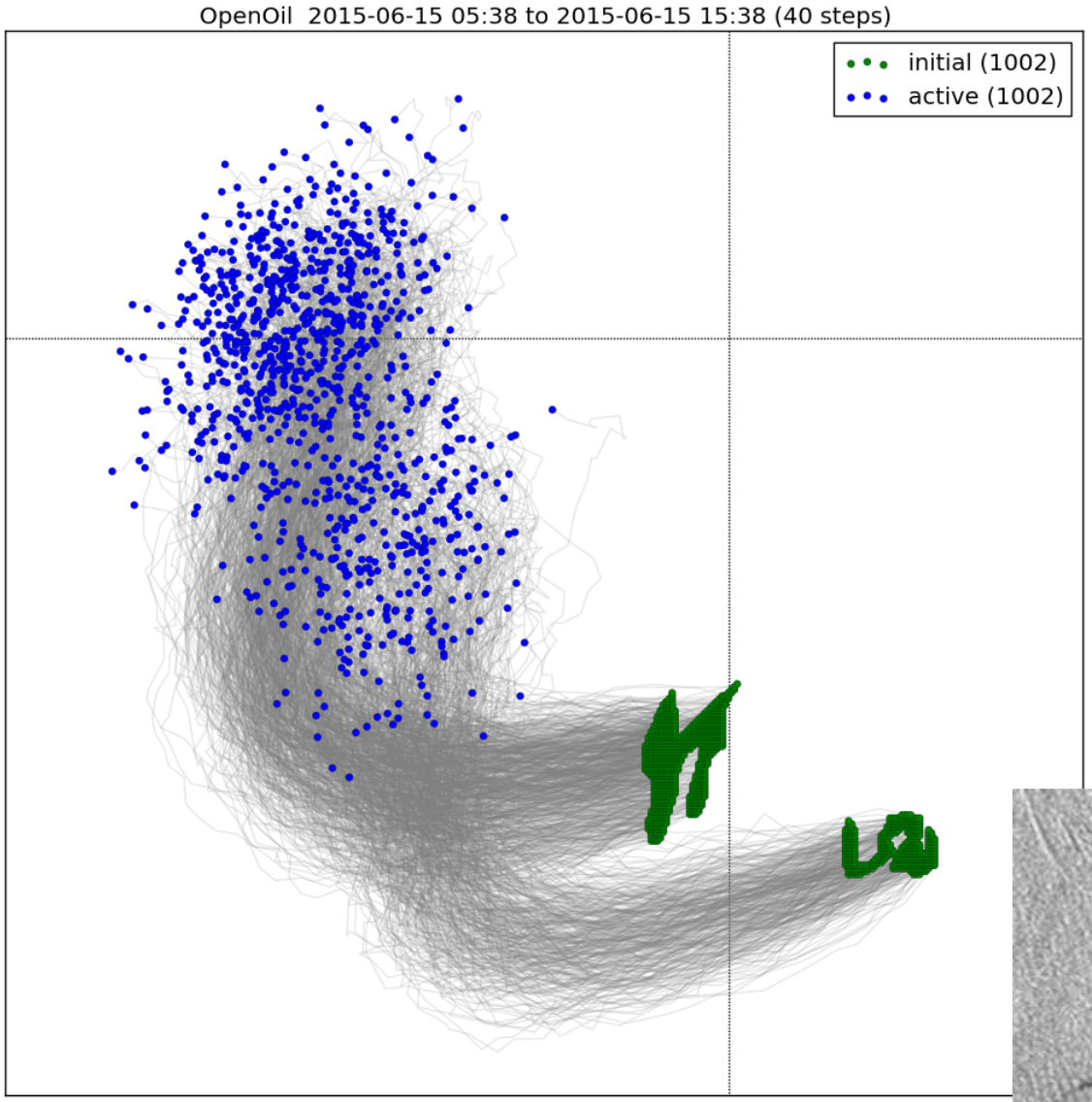


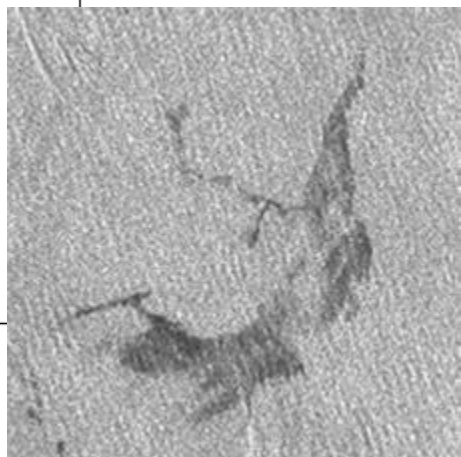
1000 particles released at the position and time of the macondo acident: 88.4E, 28.7N, 21 April 2010

Stranding (red markers) is seen mainly along the coasts of Lousiana.

Forced by global HYCOM (current) and scatterometer (wind) datasets available through remote Thredds servers

Initialisation from satellite images

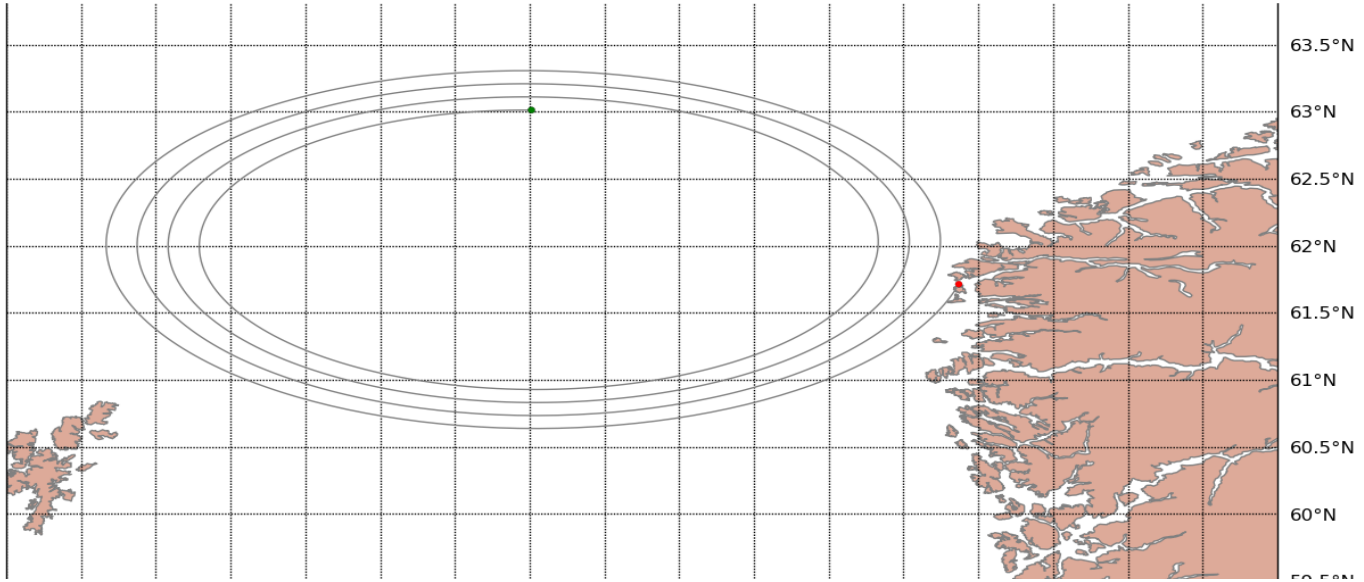




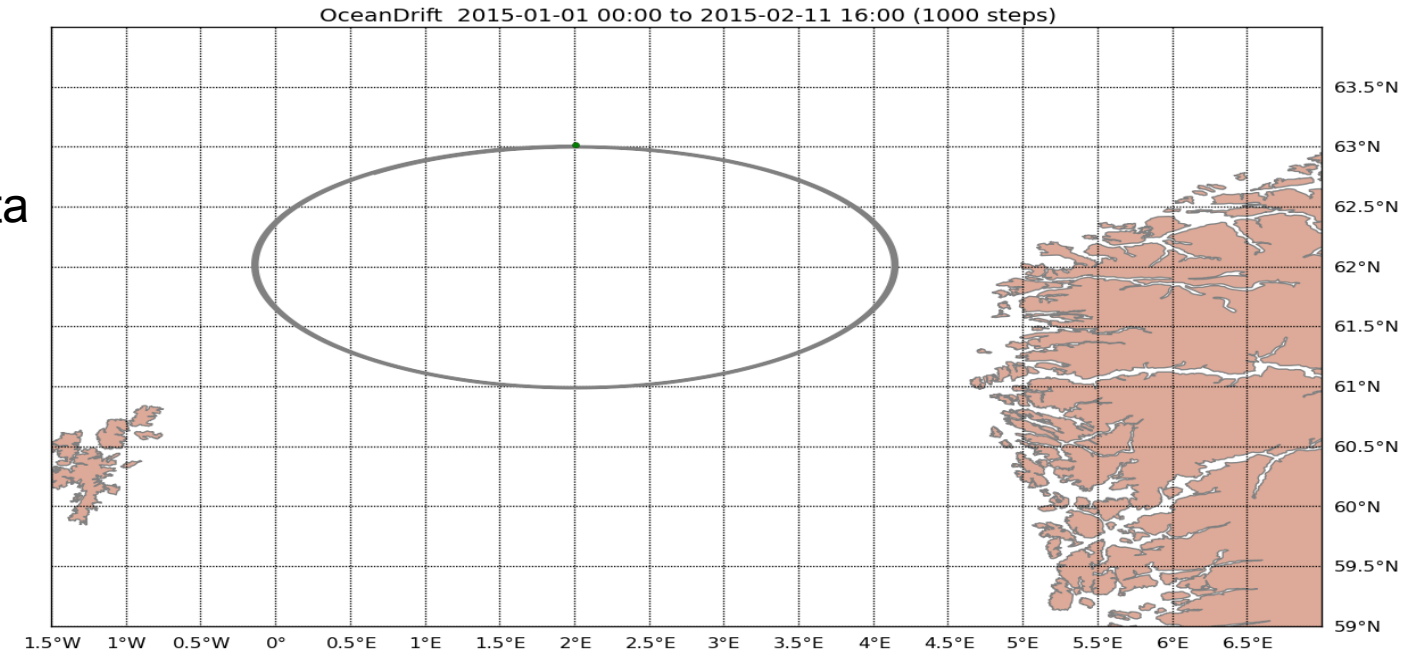
Example of oil slick seen in SAR image

Facilitating theoretical studies, for model development/improvement

Euler scheme



Runge-Kutta scheme



OpenDrift - summary of features

- A new modular open source framework for lagrangian particle tracking
- Written in Python solely, using only standard libraries
  - clean code, following PEP8 style conventions
- No installation necessary, platform independent
- Good performance, due to economical use of disk/network access
- Robust for operational use (priority list of input data)
- Simple to implement and improve models/modules
  - may focus on the physical/chemical/biological processes
- Can use input data (wind/waves/currents...) from any file format (including online/remote), in any map projection
  - no need to preprocess input data
  - users may run model locally without needing to download current/wind/waves
- May run forwards and backwards in time
  - e.g.: «which ship did release the oil?»

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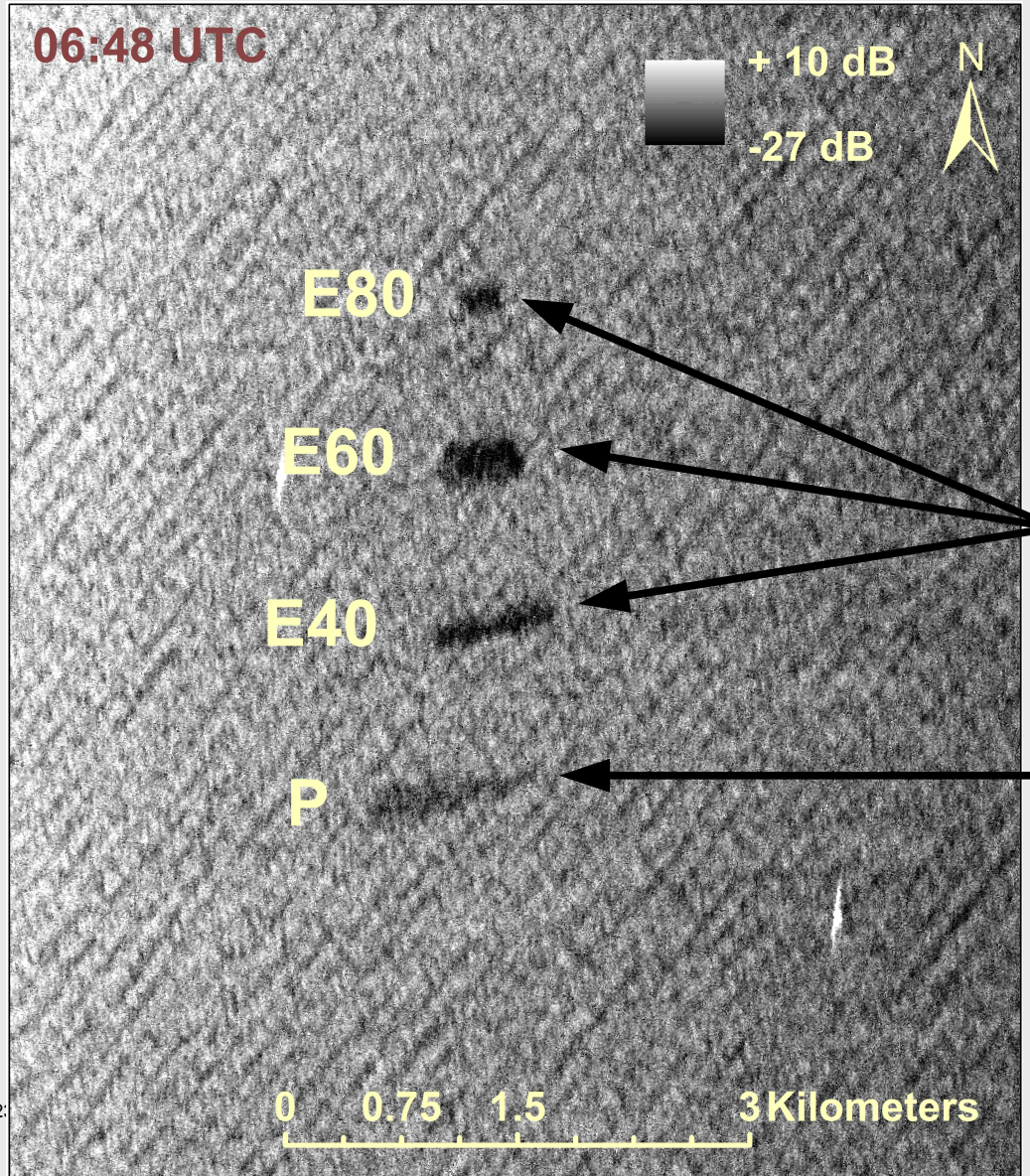
Case study with OpenOil:

NOFO oil-on-water exercise June 2015

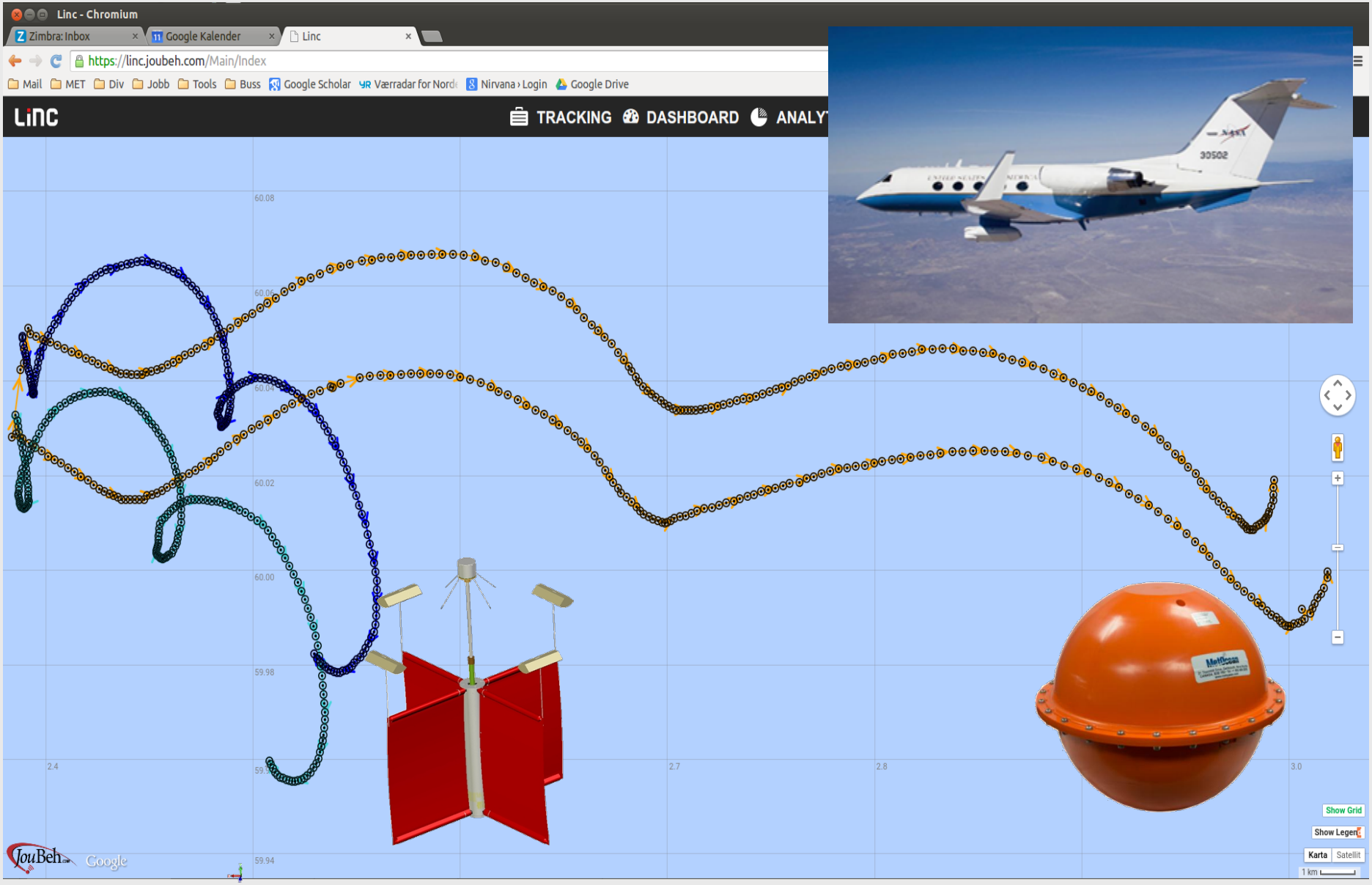
Four concurrent oil slicks



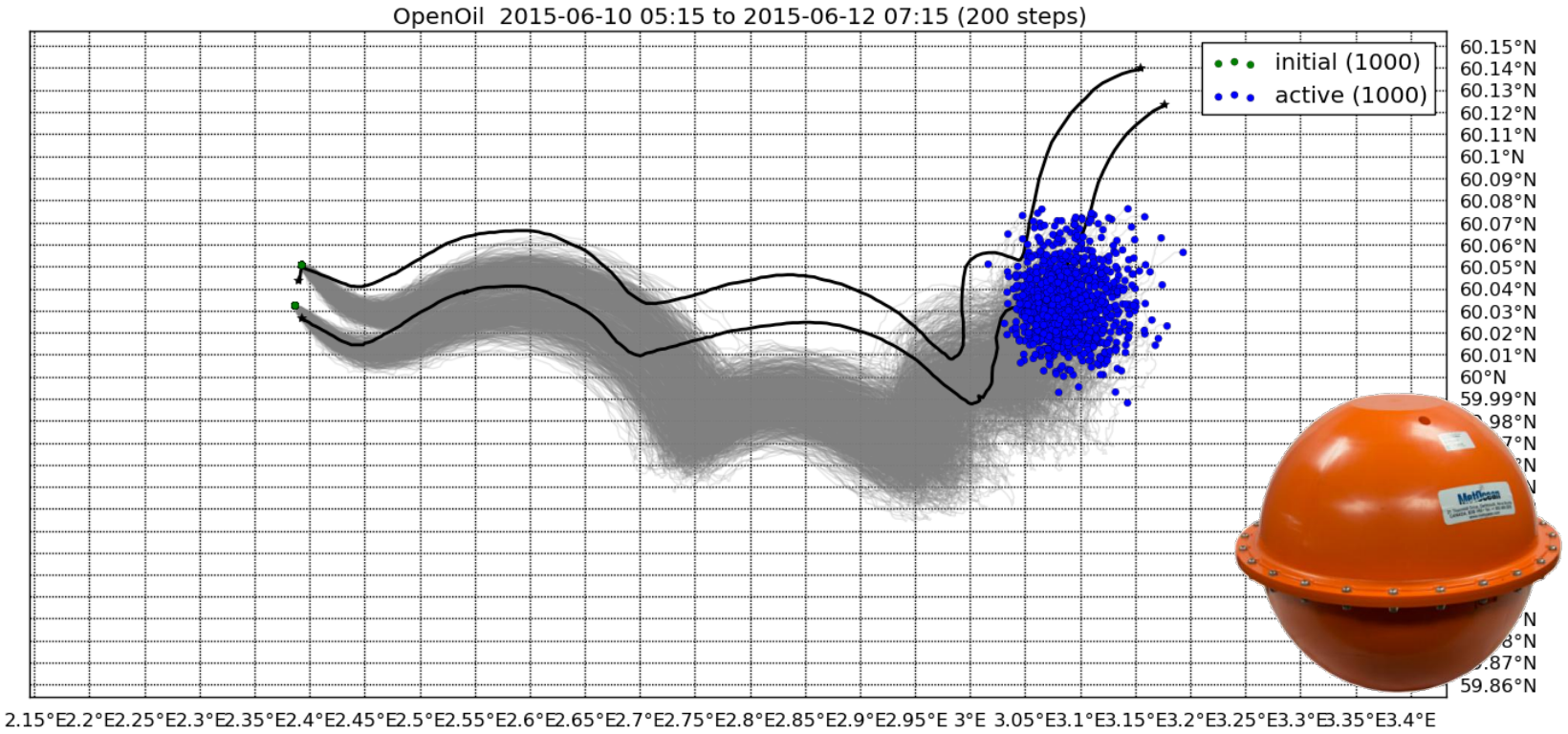
Mineral oil emulsions

Plant oil

NOFO experiment June 2015: drifters

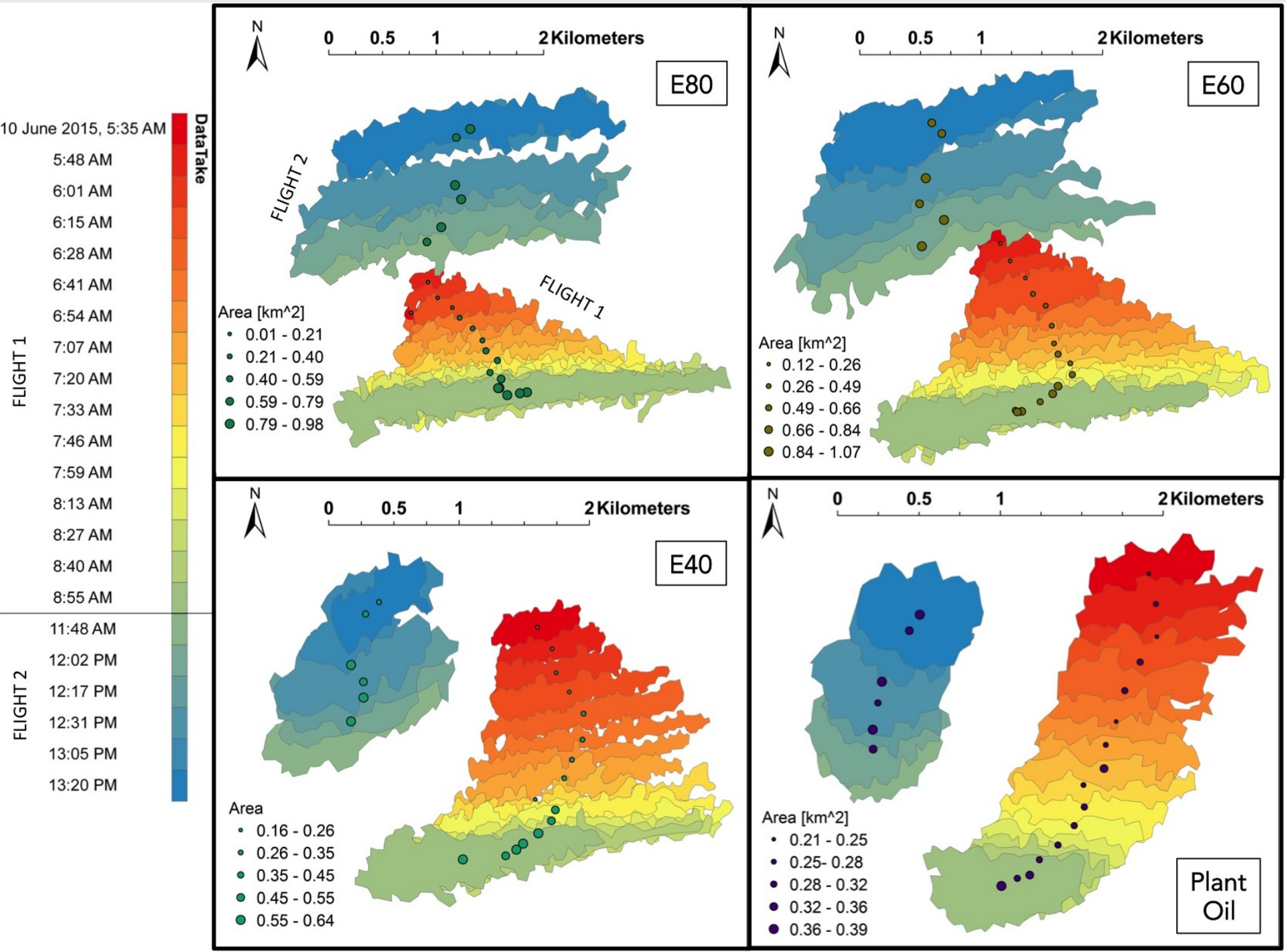


Modelled with currents and wind drift

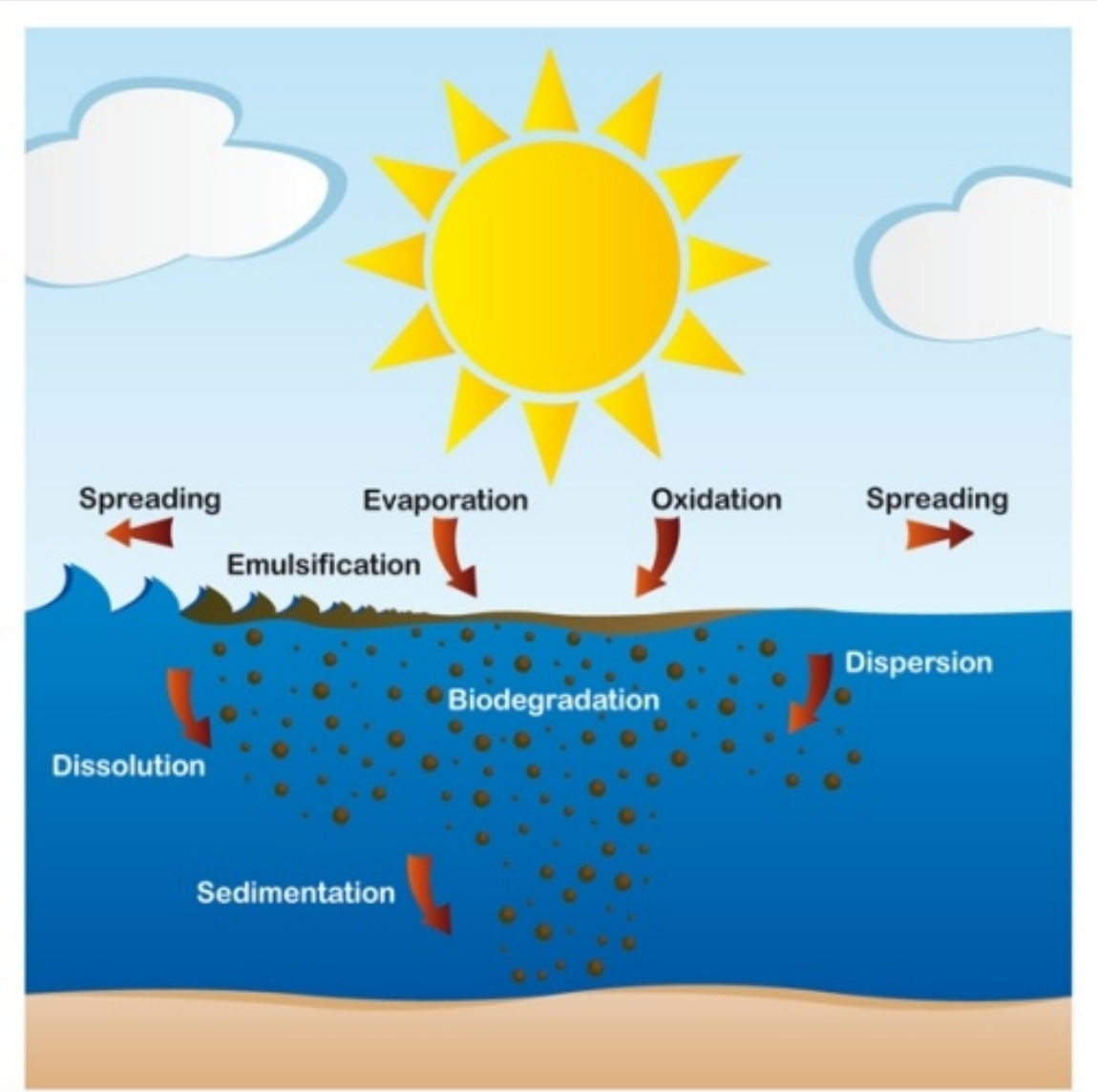


Using NorKyst800 and Arome

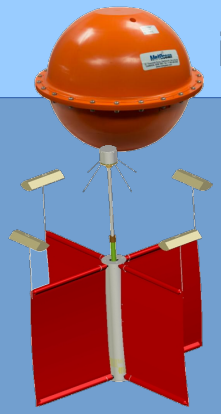
50 hour simulation


DataTake
10 June 2015, 5:35 AM
5:48 AM
6:01 AM
6:15 AM
6:28 AM
6:41 AM
6:54 AM
7:07 AM
7:20 AM
7:33 AM
7:46 AM
7:59 AM
8:13 AM
8:27 AM
8:40 AM
8:55 AM
11:48 AM
12:02 PM
12:17 PM
12:31 PM
13:05 PM
13:20 PM
FLIGHT 1
FLIGHT 2
N
0 0.5 1 2 Kilometers
E80
FLIGHT 2
FLIGHT 1
Area [km^2]
0.01 - 0.21
0.21 - 0.40
0.40 - 0.59
0.59 - 0.79
0.79 - 0.98
E60
Area [km^2]
0.12 - 0.26
0.26 - 0.49
0.49 - 0.66
0.66 - 0.84
0.84 - 1.07
E40
Area
0.16 - 0.26
0.26 - 0.35
0.35 - 0.45
0.45 - 0.55
0.55 - 0.64
Plant Oil
Area [km^2]
0.21 - 0.25
0.25- 0.28
0.28 - 0.32
0.32 - 0.36
0.36 - 0.39

Oil weathering



Horizontal motion of oil



iSphere, 0 m

CODE, 0.7 m

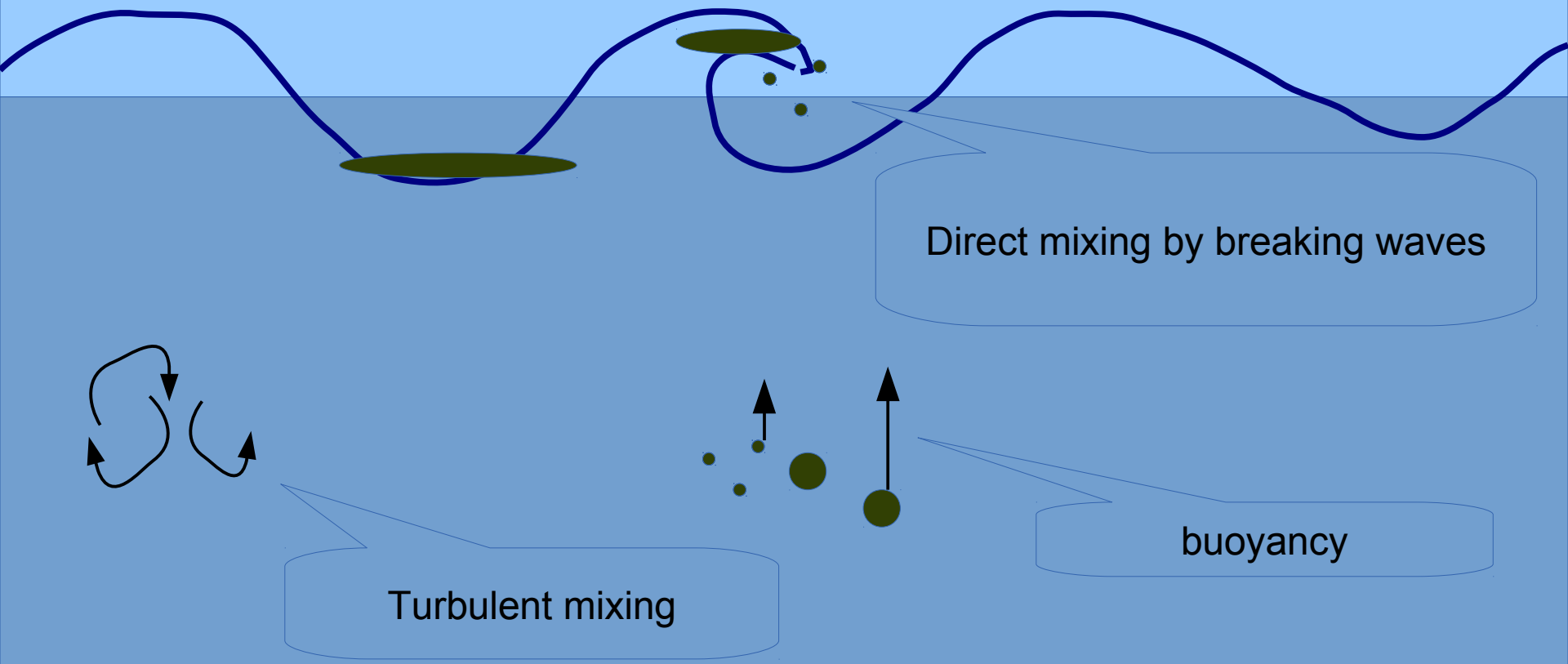
Holey Sock, 15 m

2% of wind

Stokes drift

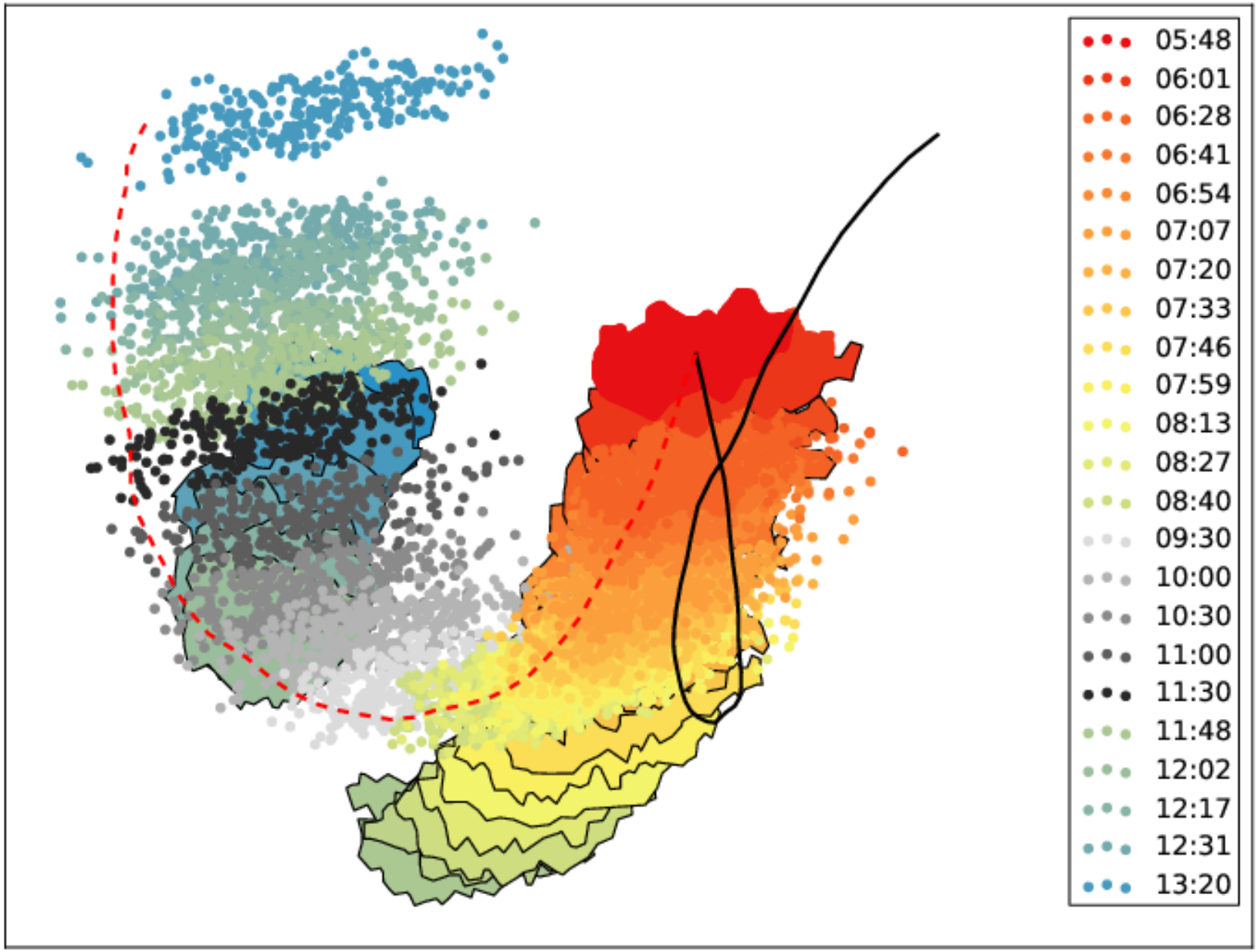
Ambient current

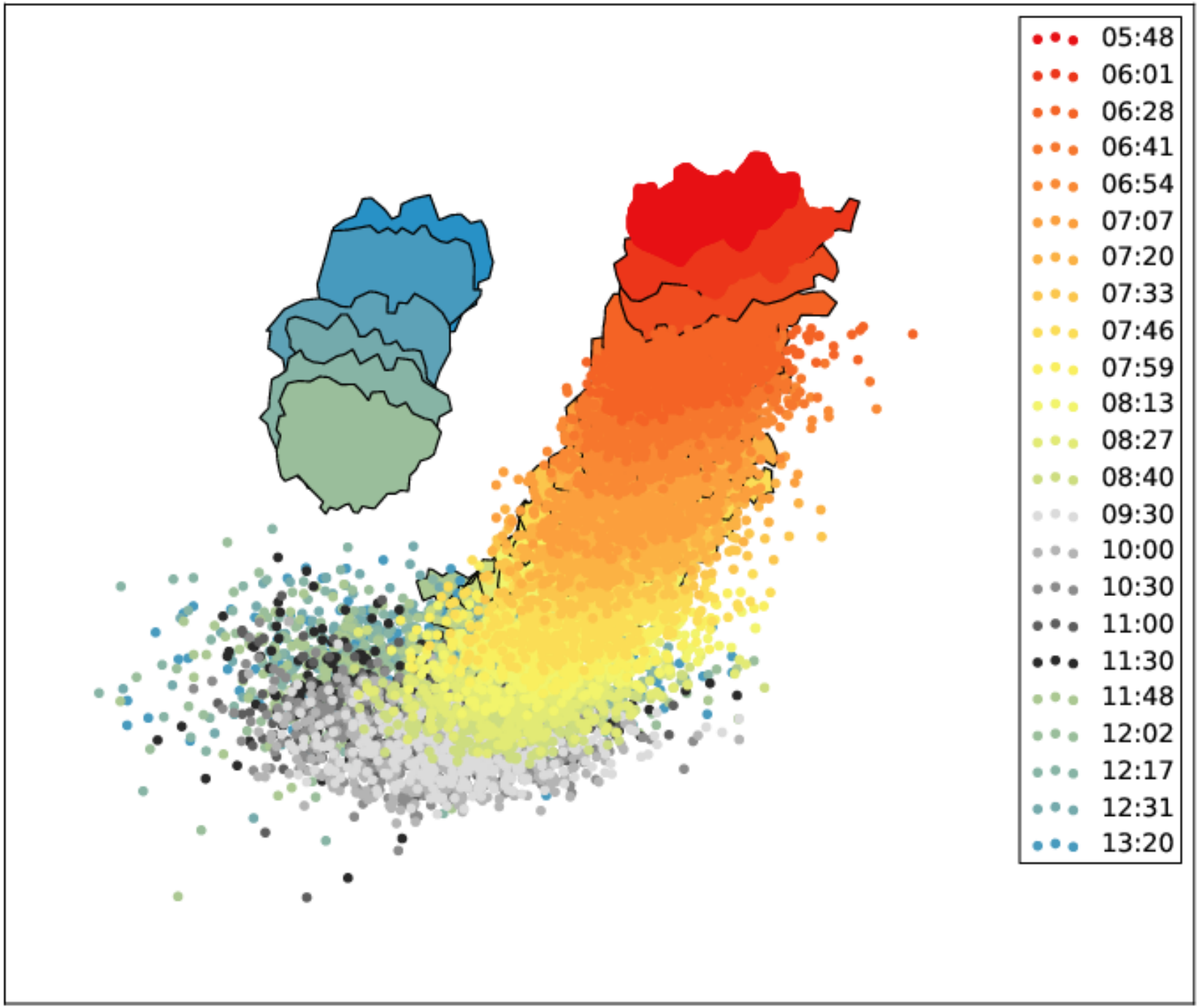
Vertical motion of oil



Thygesen, U. and Ådlandsvik, B. 2007 Simulating vertical turbulent dispersal with finite volumes and binned random walks. Marine Ecology Progress Series 347:145-153-.

Tkalich, P., Chan, E.S. Vertical mixing of oil droplets by breaking waves // Marine Pollution Bulletin. 2002. 44 (11), 1219-1229.


05:48
06:01
06:28
06:41
06:54
07:07
07:20
07:33
07:46
07:59
08:13
08:27
08:40
09:30
10:00
10:30
11:00
11:30
11:48
12:02
12:17
12:31
13:20


05:48
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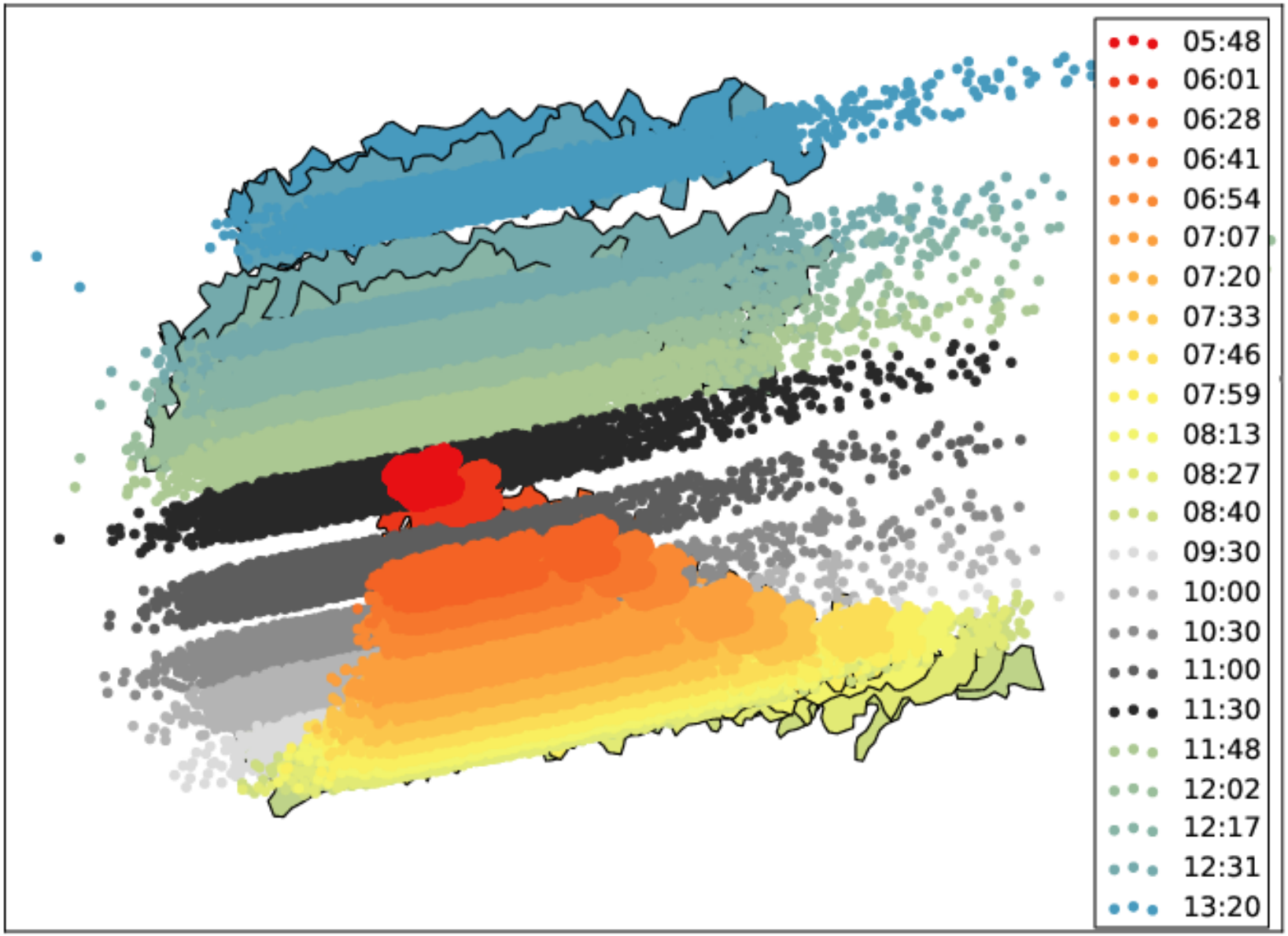
05:48
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08:13
08:27
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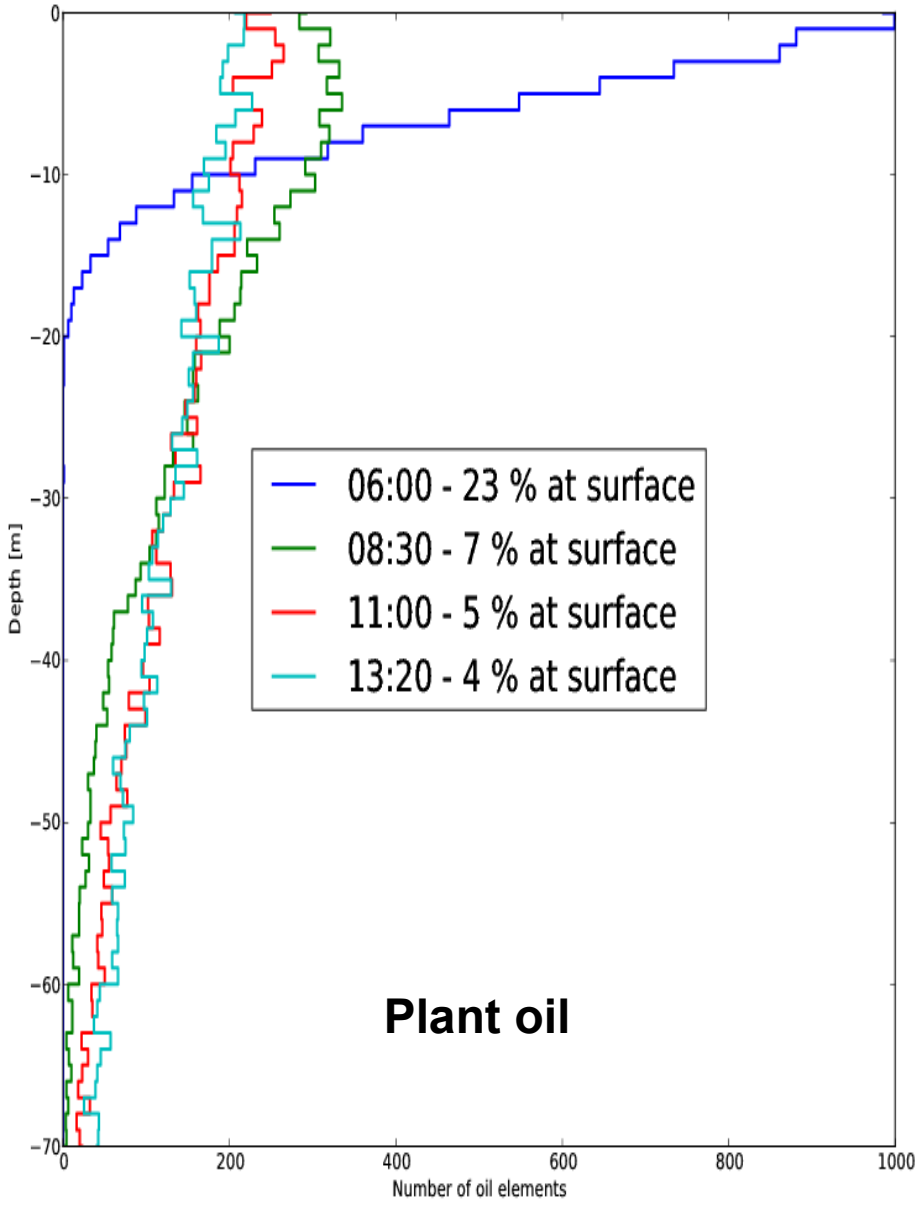
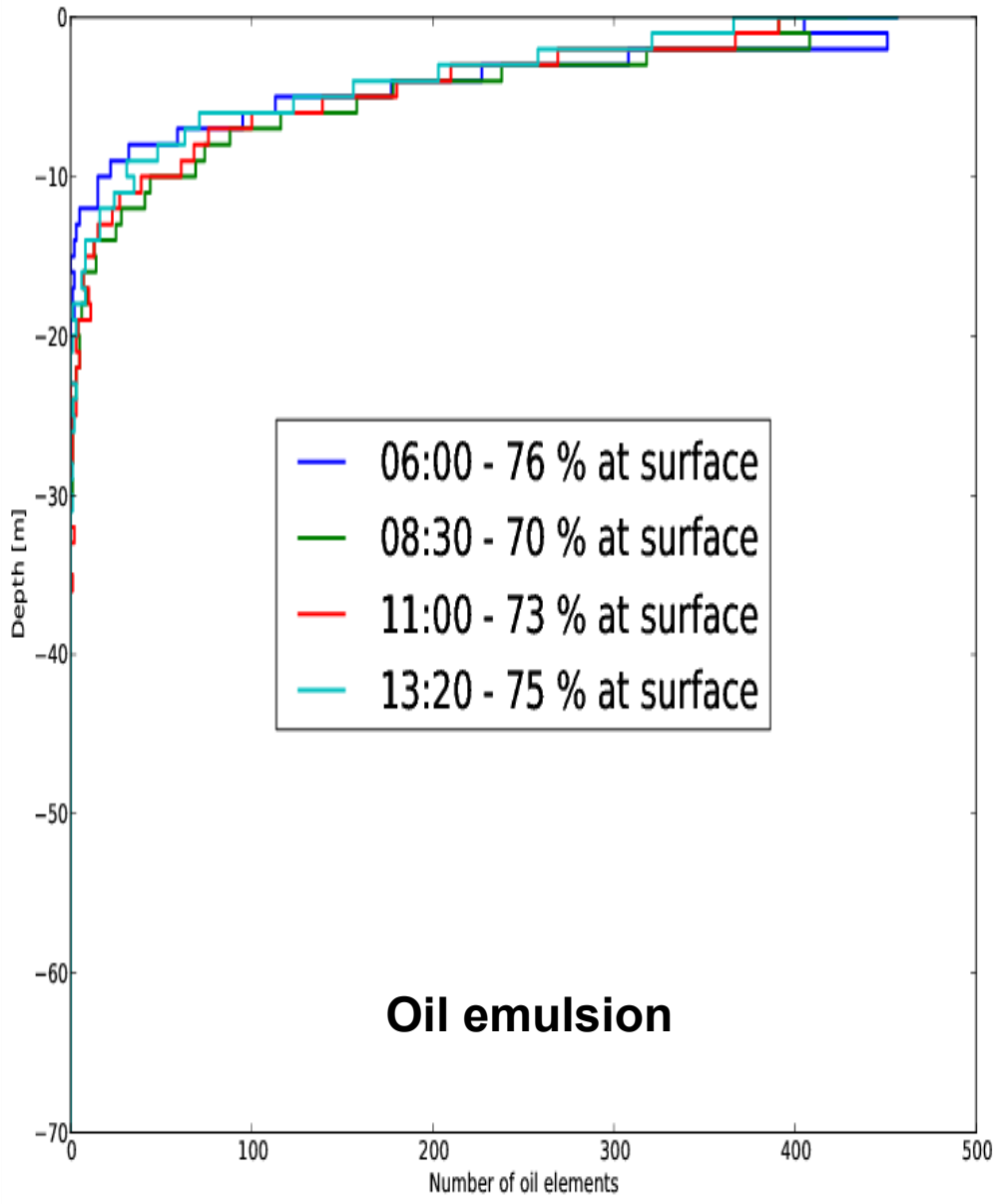
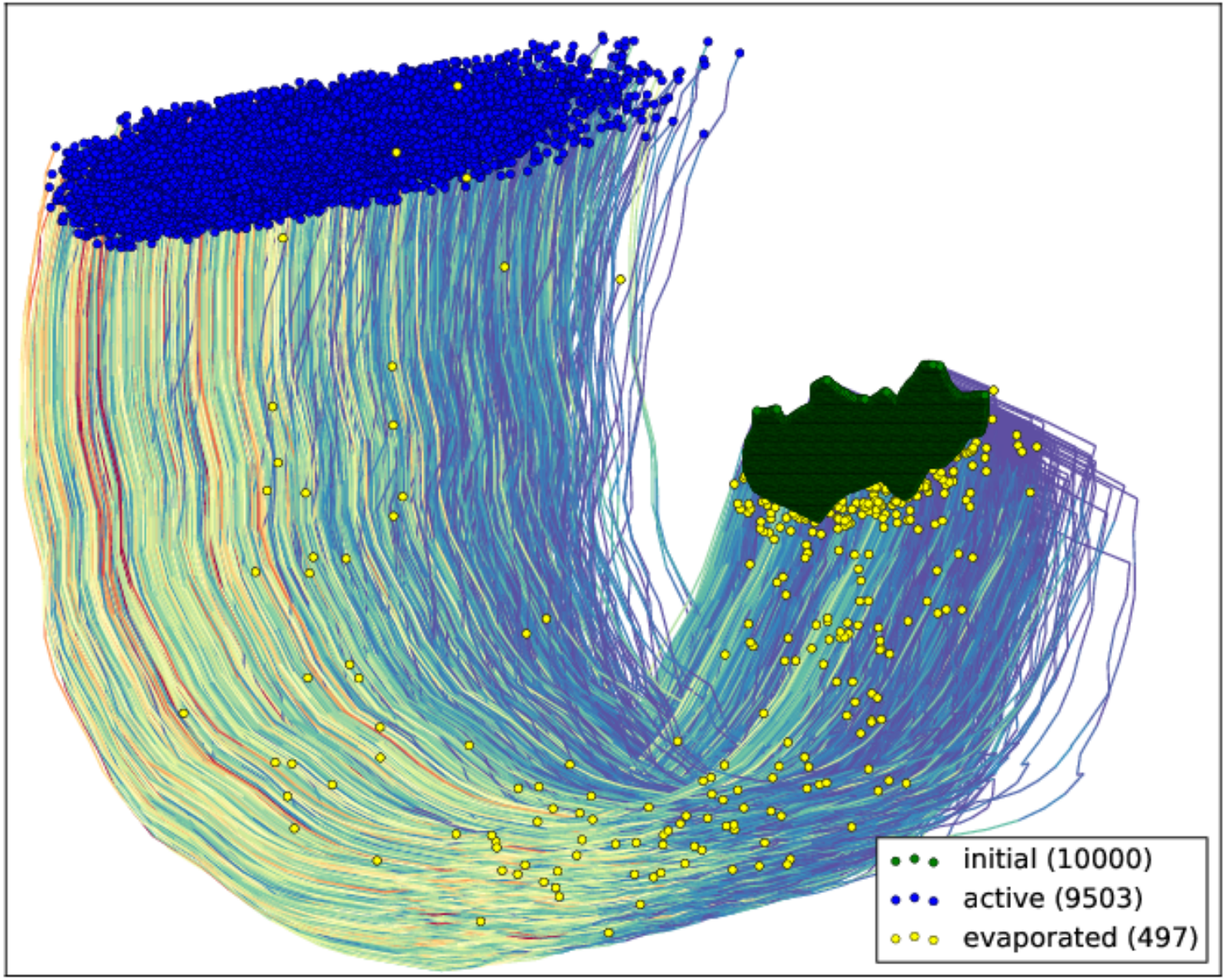
11:48
12:02
12:17
12:31
13:20

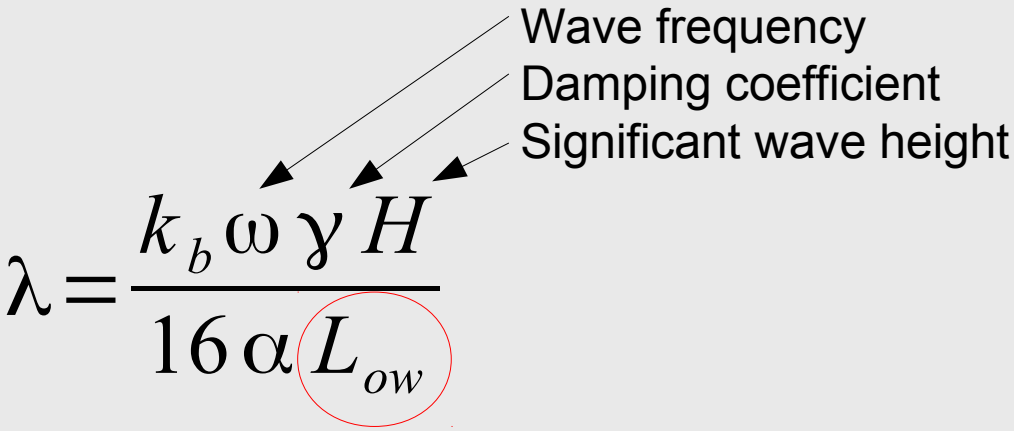
Vertical distribution






initial (10000)
active (9503)
evaporated (497)
−105
−90
−75
−60
−45
−30
−15
0
z [m]

Tuning of wave entrainment rate



	L_{ow} (length scale)	λ (rate)	droplet radius
Plant oil	1 cm	0.024 s^{-1}	10 micrometers
Emulsion	10 cm	0.0024 s^{-1}	100 micrometers

Tkalich, P., Chan, E.S. Vertical mixing of oil droplets by breaking waves, Marine Pollution Bulletin. 2002. 44 (11), 1219-1229.

Conclusion

OpenDrift is a new, open source, modular ocean trajectory framework written in Python

Conclusion from case study

Vertical mixing and wave entrainment is critical to reproduce observed motion of oil slicks of 2015 NOFO exercise

- entrained oil is «sheltered» from surface wind drift and Stokes drift
- more so for low-viscous oils than high-viscous oils