COASTAL CIRCULATION RESPONSE TO PHYSICAL FORCING: APPLICATION OF MARS 3D MODEL FOR STUDING DISPERSAL PROCESSES IN THE EASTERN ENGLISH CHANNEL.

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sponsorship:
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Région Nord pas de Calais

Motivation

- Use a high resolution model to characterize coastal circulation in a complex R.O.F.I system (Region Of Freshwater Influence).

- Underline external forcing impacts on coastal circulation.

- Assess the effect of harbor morphological modifications on local hydrodynamics.

- Study the effect of extremes climatic events on transport and dispersion.

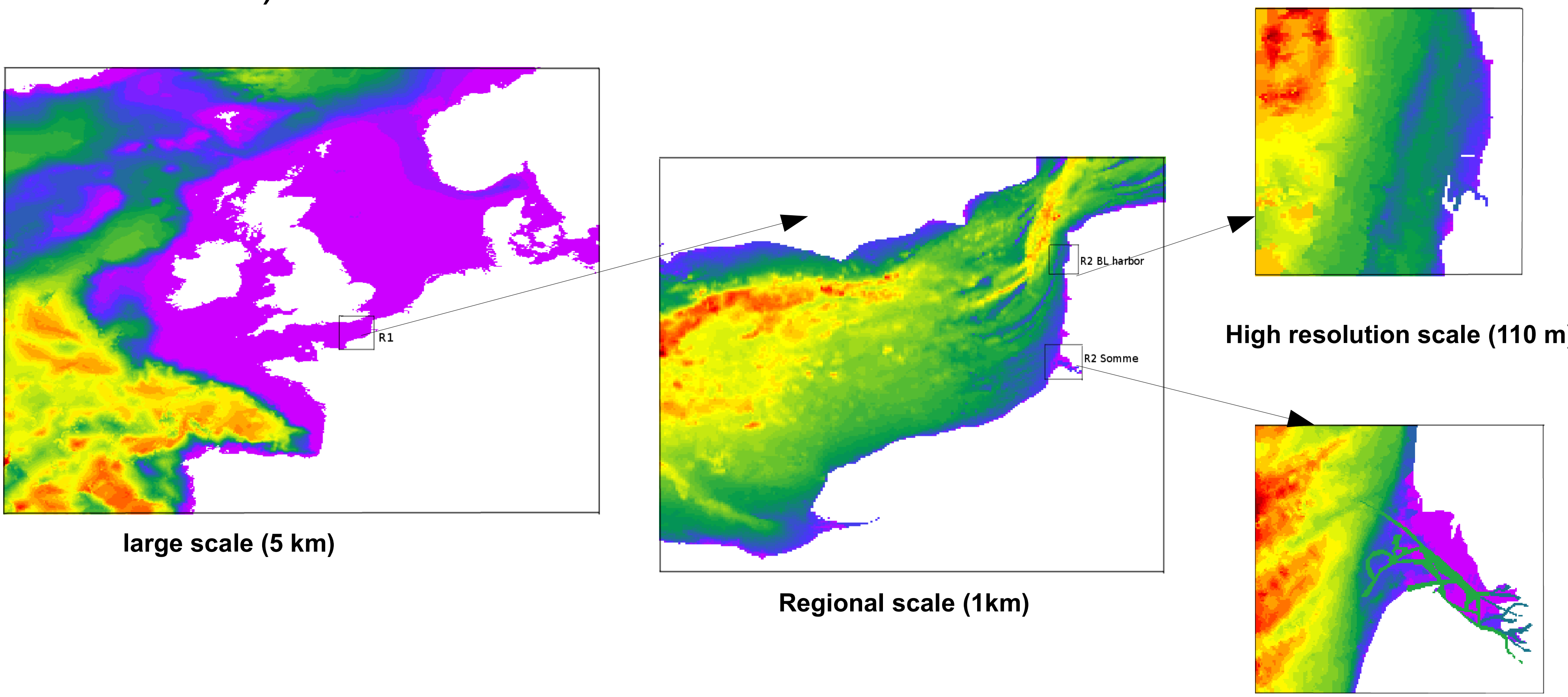
- Apprehend more precisely bacterial contamination and mechanisms of spreading at regional and sub-regional scales

TOOLS

- Hydrodynamic model MARS 3D
- Lagrangian tracking module (ICHTHYOP)
- Physical forcing archives

Hydrodynamic modelling MARS 3D

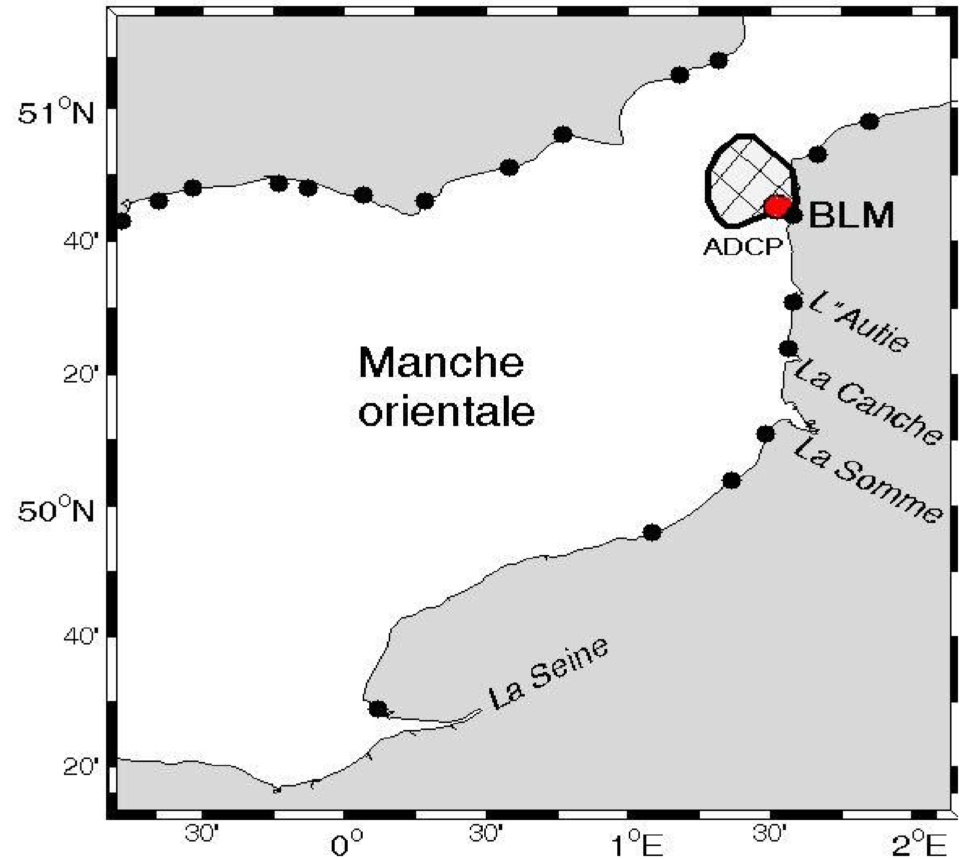
- Nested model approach
- Regional circulation model and high spatial resolution (local model)



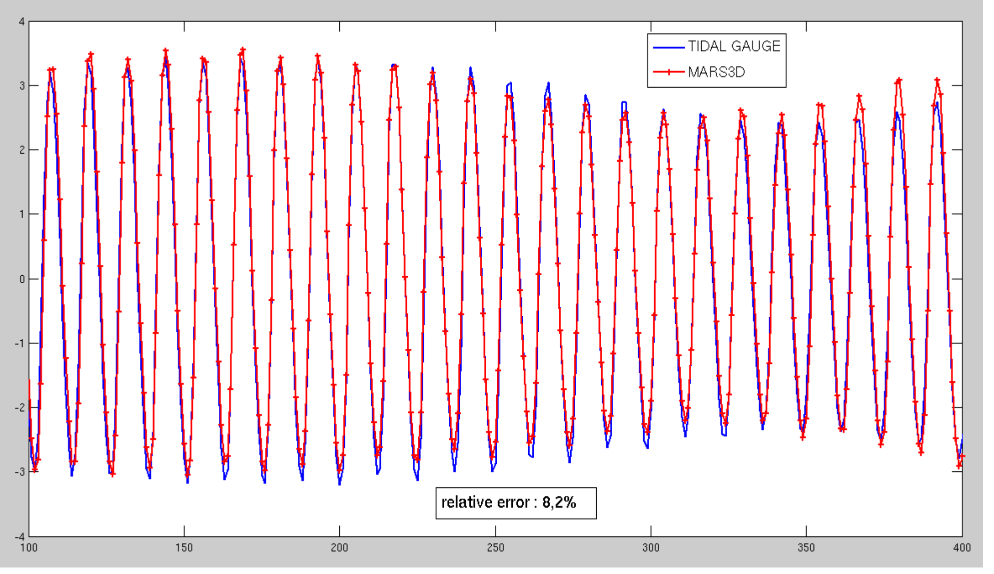
Step 1: Regional model validation

- Tidal gauge database for 20 harbors of the region
- VHF radar measurements (hatched area)
- ADCP measurements (red dot)
- Argos drifters tracking
- Oceanographic measurements

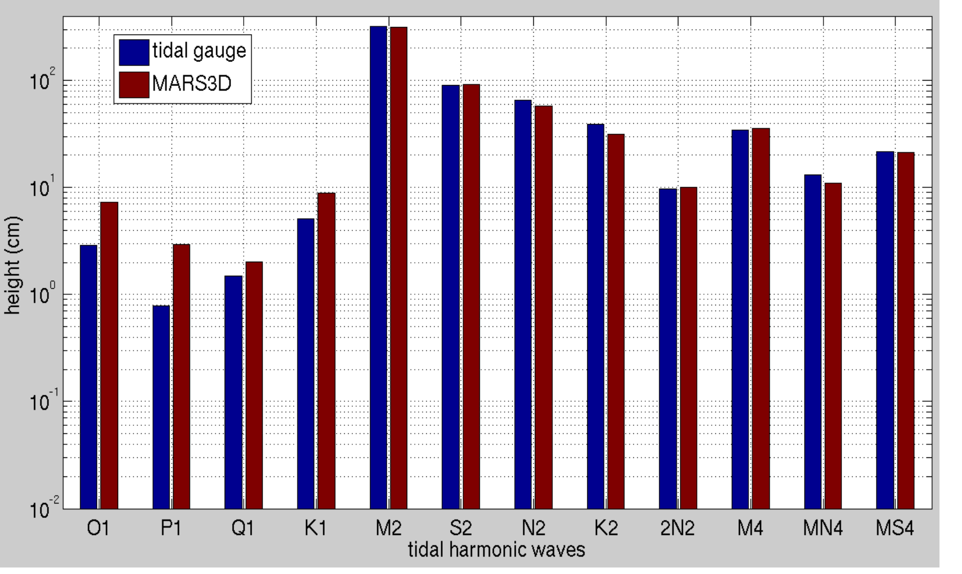
  (T,S, Chl)



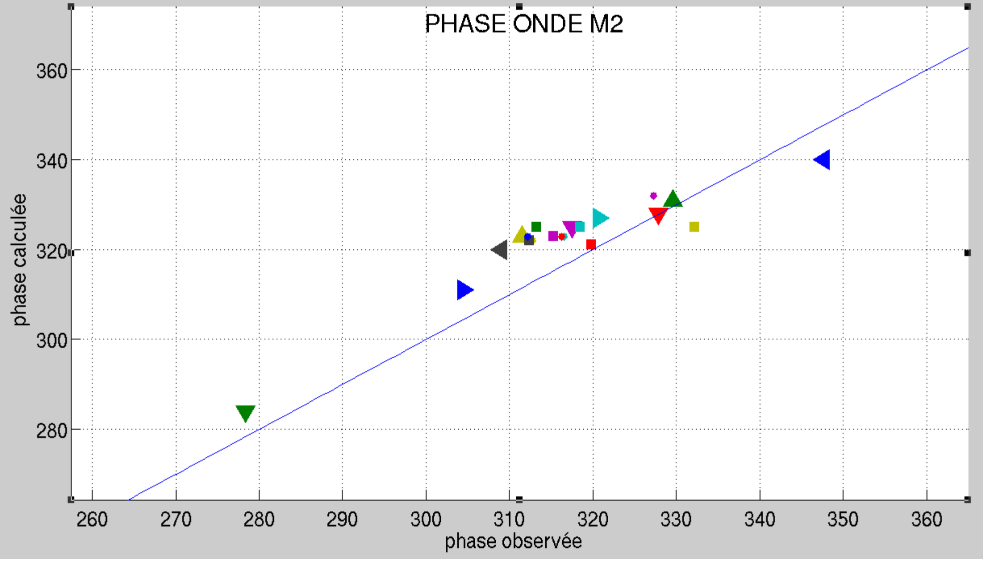
Validation 1 : SSH analysis and tidal harmonics

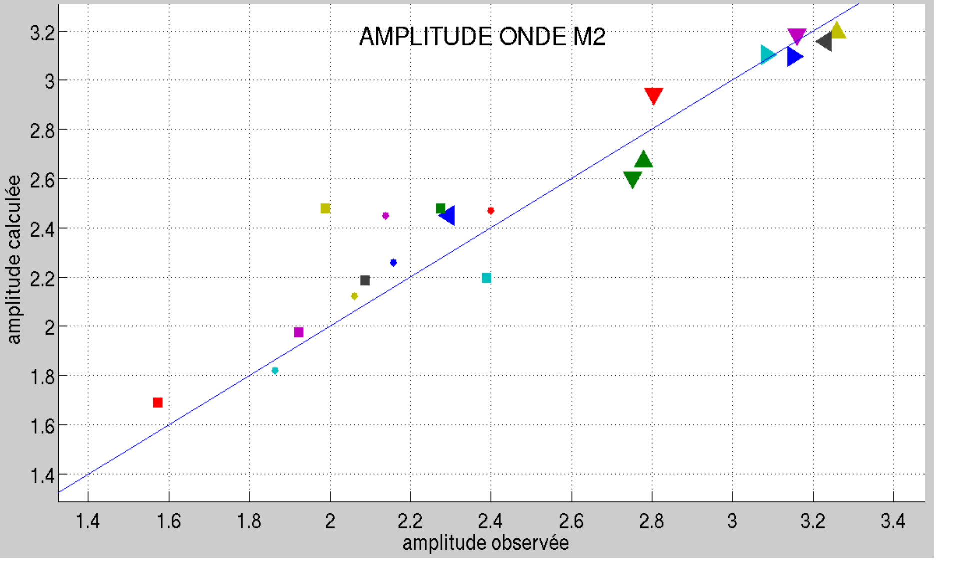


SSH in Boulogne: observations and model results



Amplitude of the major tidal harmonics in Boulogne

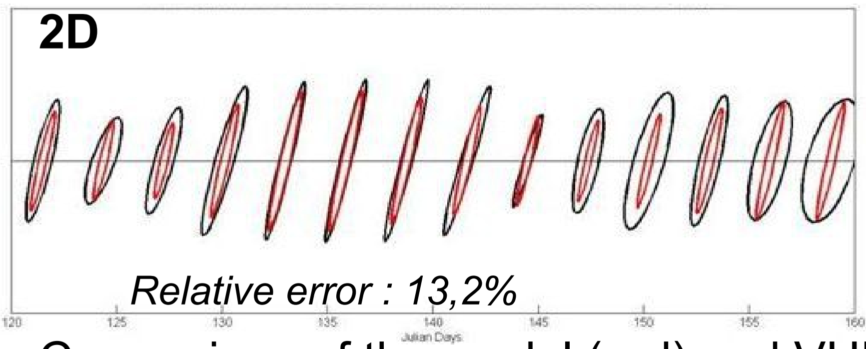




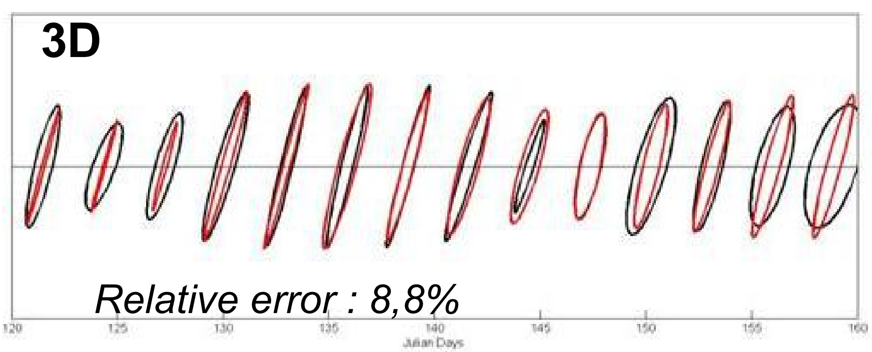
Phase and amplitude of the principal (M2) tidal constituent in the eastern Eng. Channel: observations vs modelling for the 20 harbors of the region

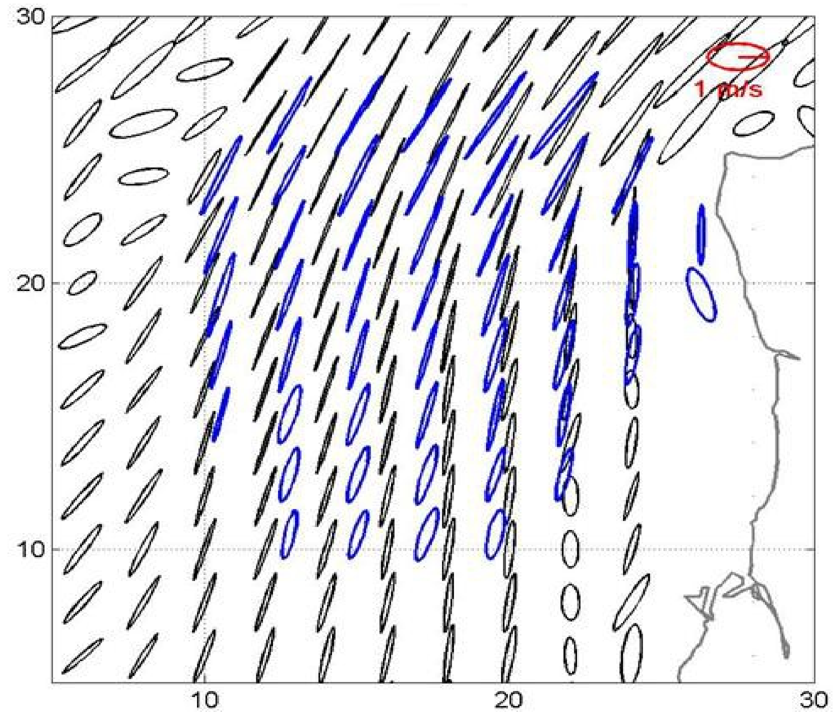
Validation 2:

Comparison of surface tidal ellipsis during a semi-monthly cycle from MAY 2003 the 10th til the 25th: MARS 3D simulation (1km resolution) and VHF radars observations (Sentchev et Yaremchuk,2007).



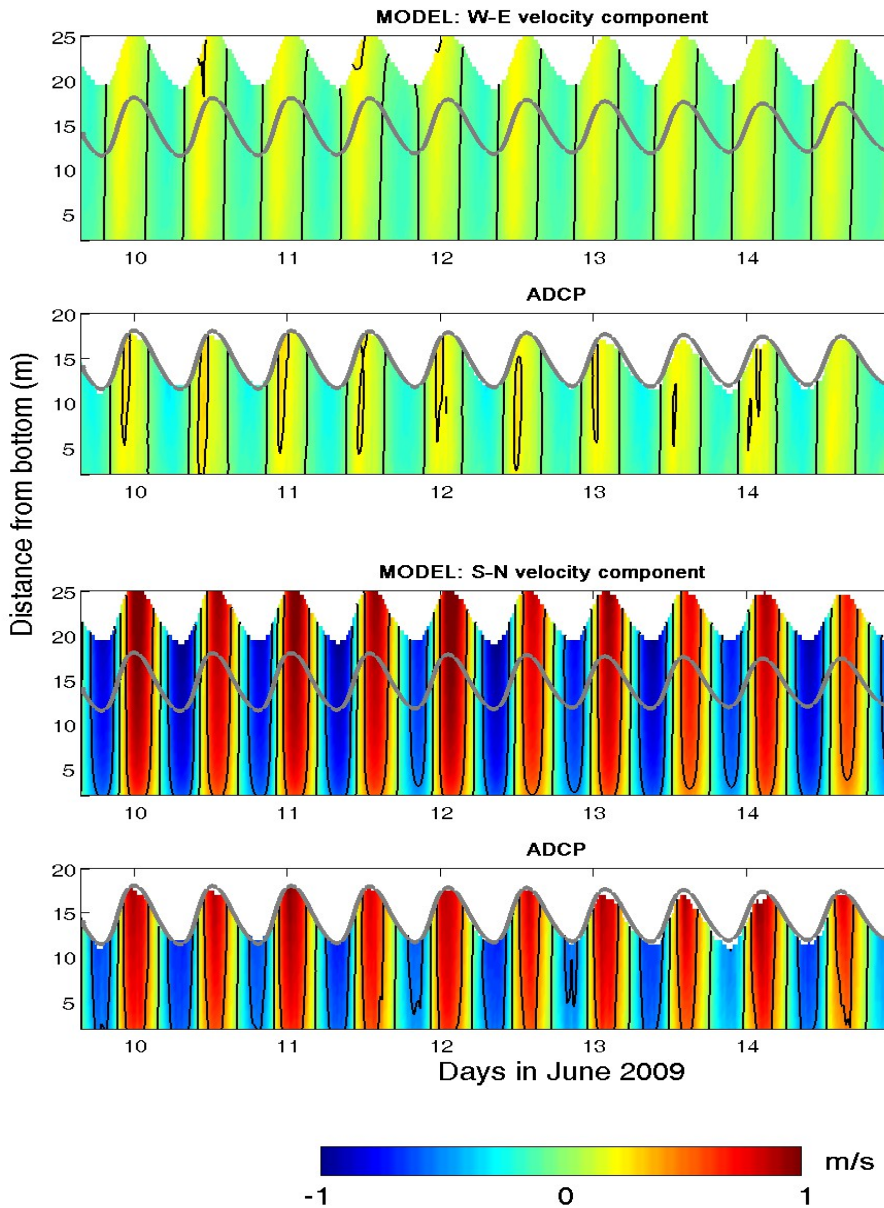
Comparison of the model (red) and VHF radar (black) current ellipsis for 2D and 3D simulations





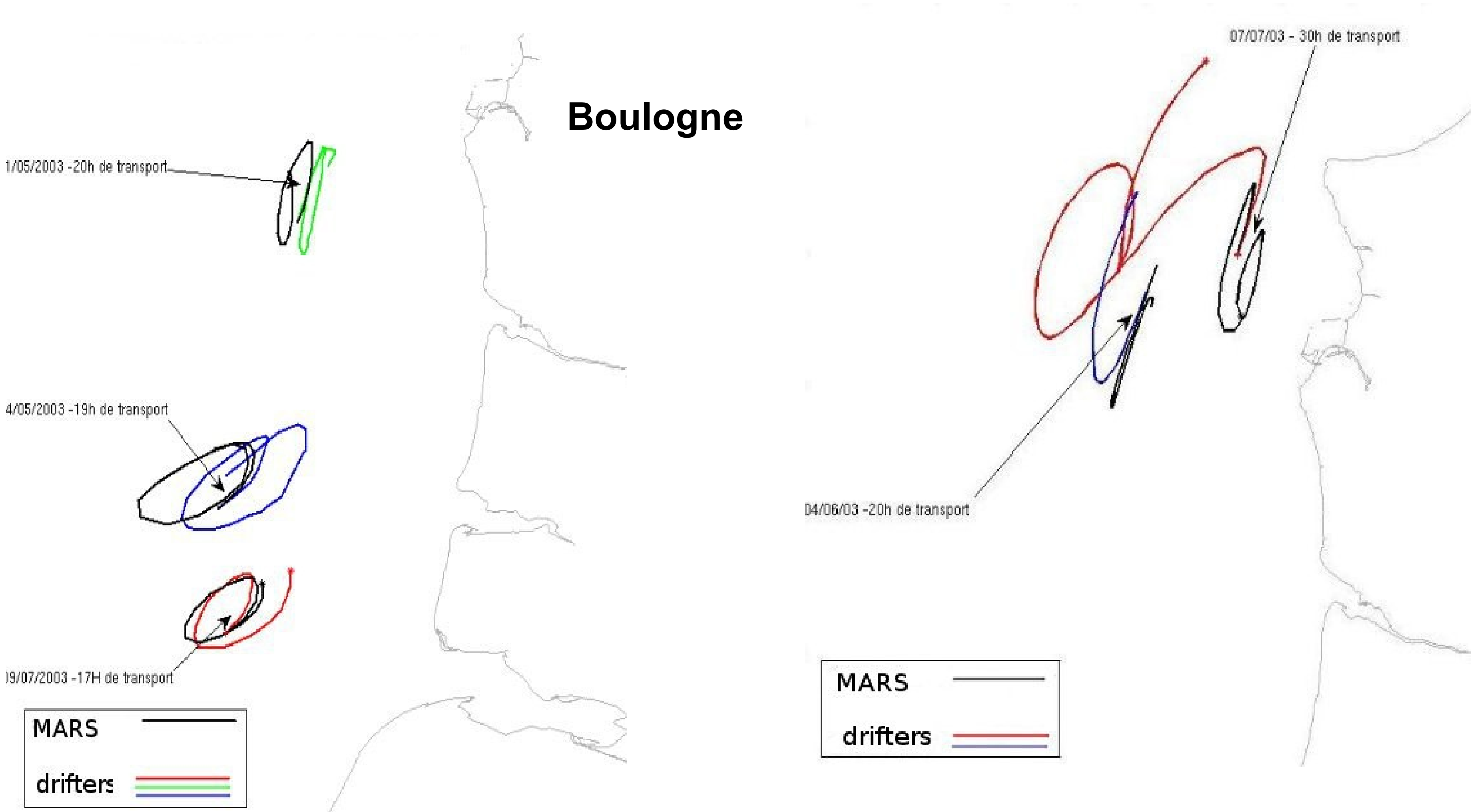
Surface current ellipsis observed (blue) and simulated (black) on 15th of May 2003.

Validation 3: Velocity profiles observed by ADCP and model results in ADCP location



The model under-estimate the zonal velocity component,U (≈12%) but over-estimate the meridional velocity component, V, (≈10%)

Validation 4 :comparison with ARGOS drifters.



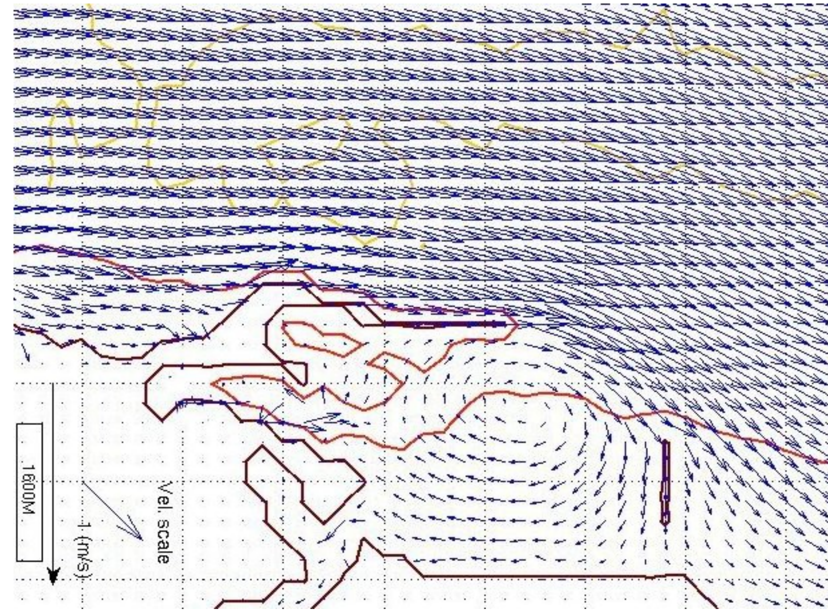
Good agreement in the southern part of the region.

Opposite polarisation of ellipsis in front of BL.

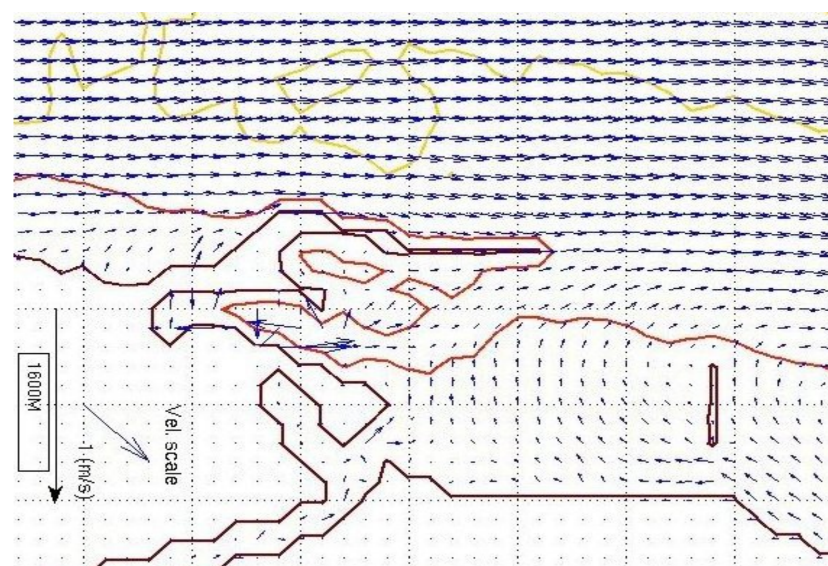
Desagrement in tidal excursion length in the narrowest part of the Eng. Channel.

Application 1: Boulogne Harbor (H.R. 110m)

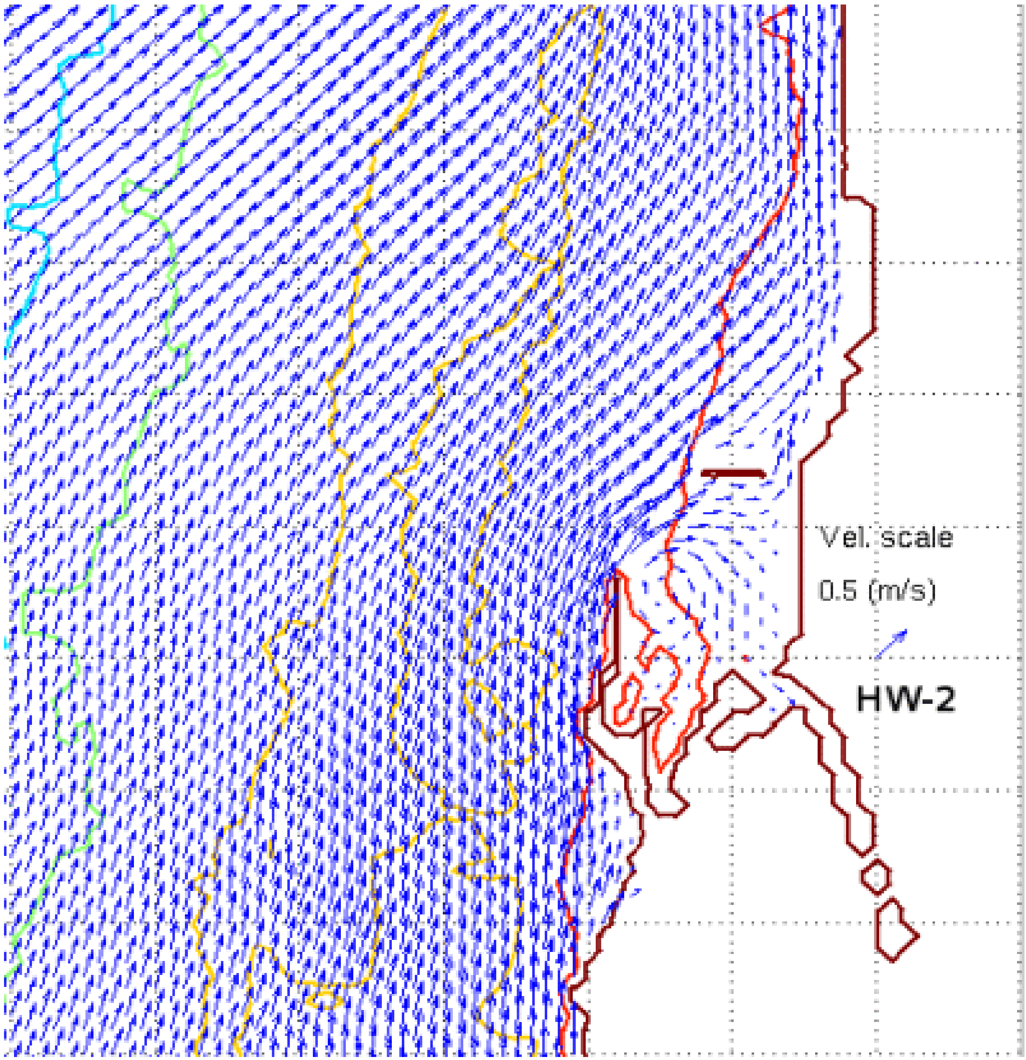
Aerial photography of the anti-cyclonic eddy in BL harbor occurring during the flood at HW -1h (above) and ending at HW +2h (below)



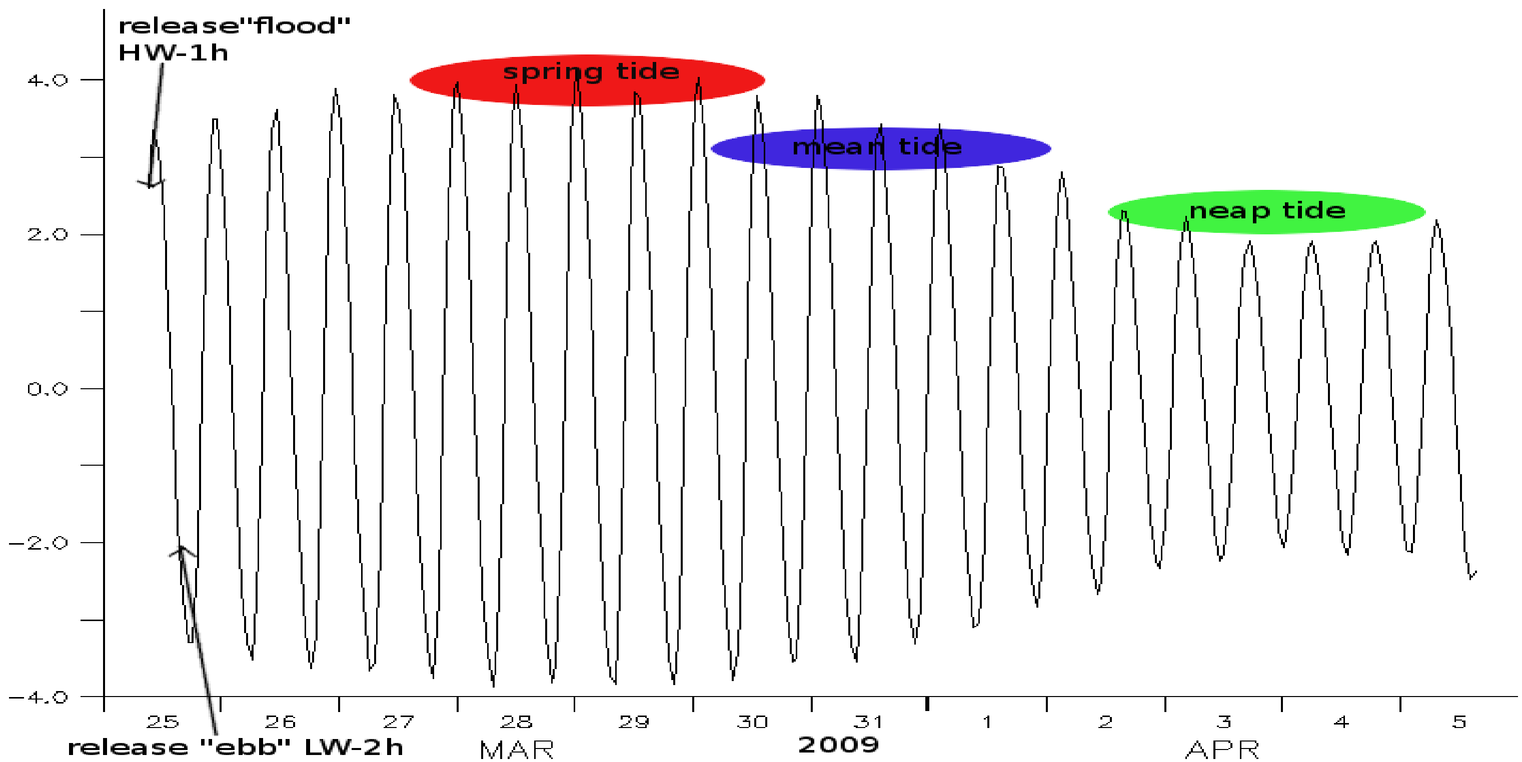
Instantaneous currents given by the model at HW -1h (above) and HW +2h (below)

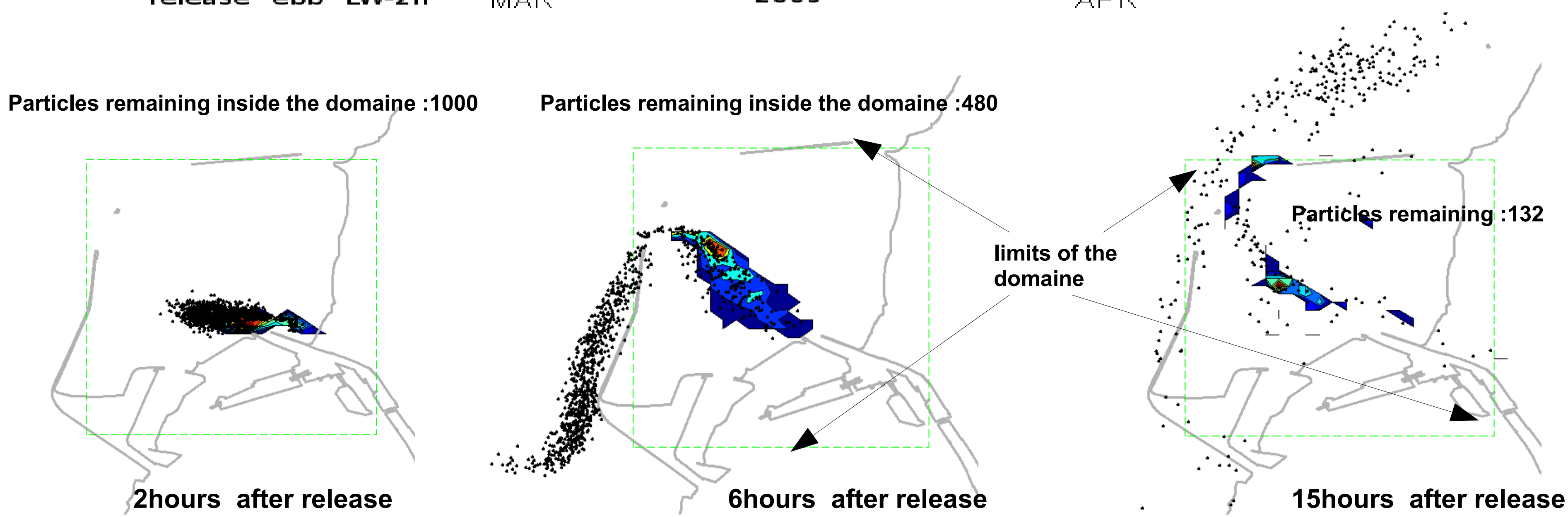


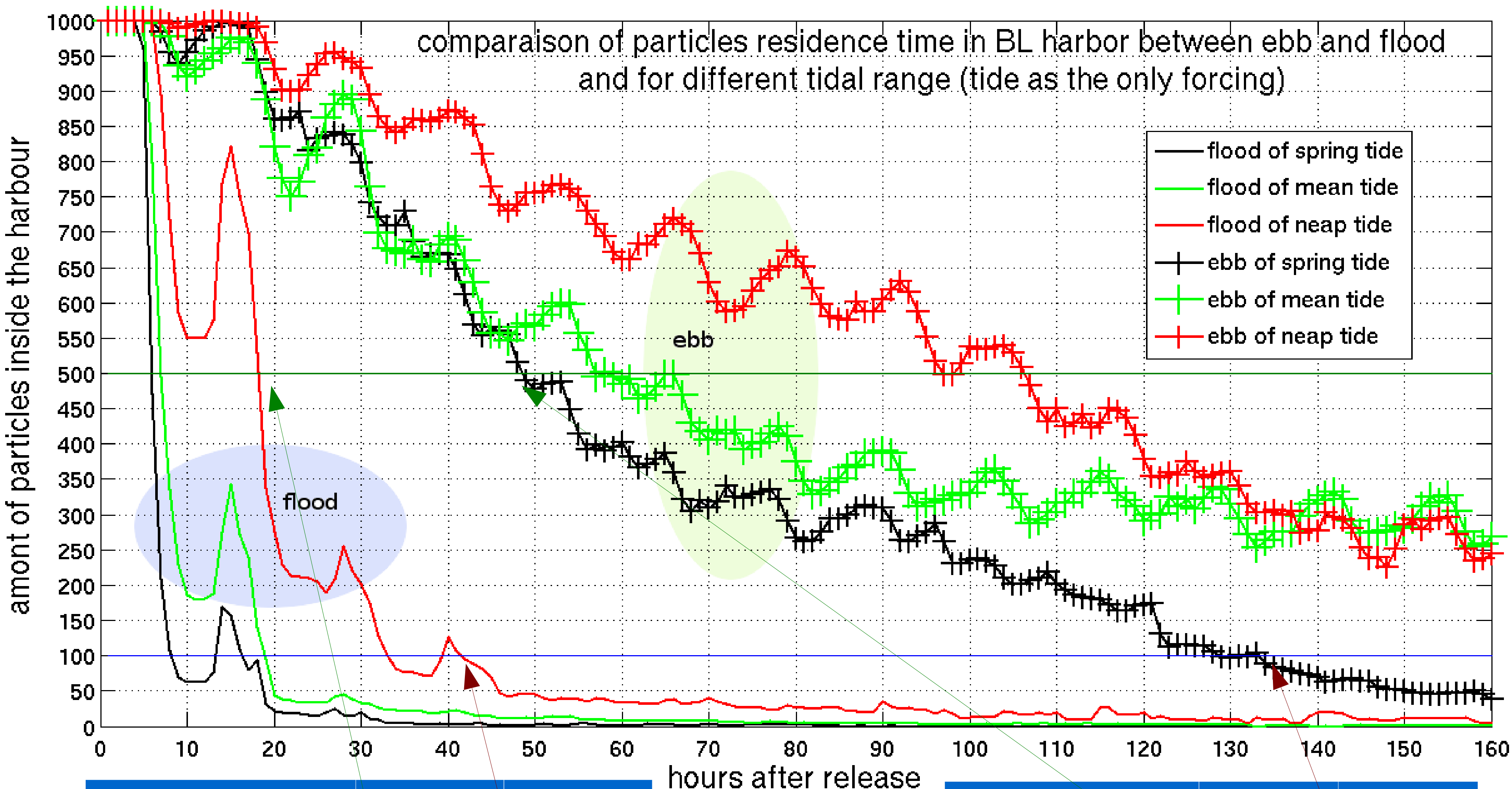
INSTANTANEOUS CURRENTS DURING A TIDAL CYCLE IN BL HARBOR



Method and experimental period







tide only flood	T50	T90
spring tide	6h	17h
mean tide	7h	19h
neap tide	18h	42h

tide only ebb	T50	T90
spring tide	48h	134h
mean tide	65h	+170h
neap tide	108h	+170h

T90= time to evacuate 90% of particles outside the domaine

T50= time to evacuate 50% of particles outside the domaine

Result 1

- When tidal currents increase (from neap to spring tides), the T90 decreases and reciprocally.

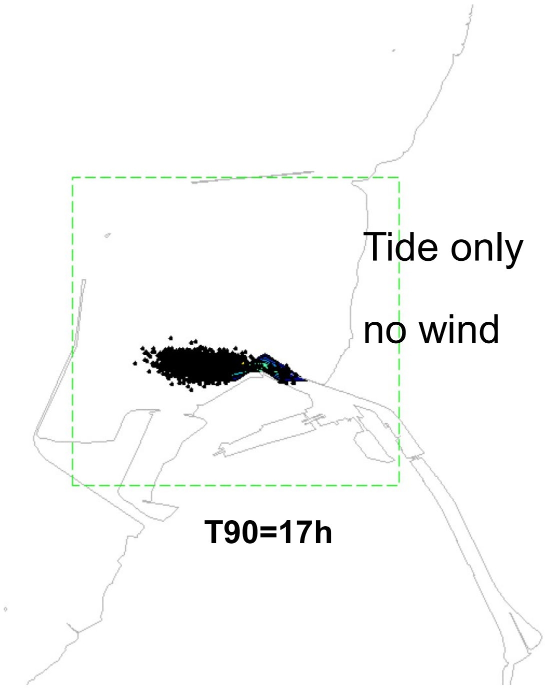
- The ratio, R= $T90_{ebb}$ /$T90_{flood}$ varies from 4 to 9 depending on the tidal range:

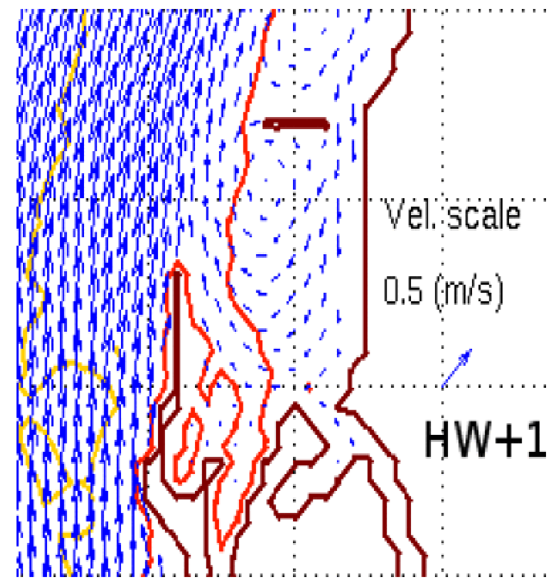
Neap tides : R≈4 (+170h/42h=+4.02)
Mean tides : R≈9 (+170h/19h=+8.94)
Spring tides : R≈8 (134h/17h=7.8)

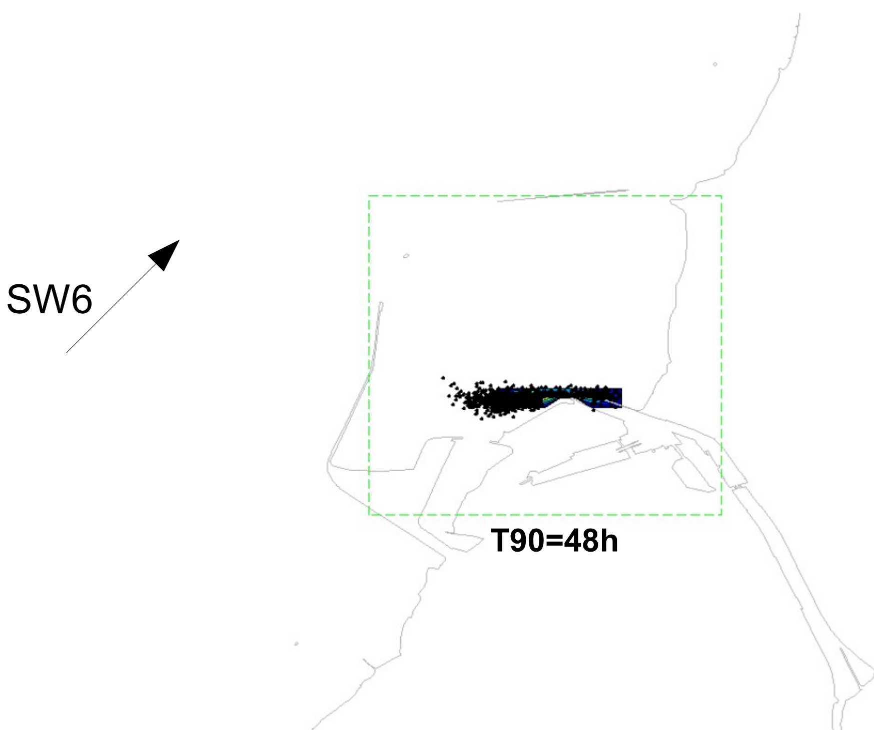
=>the major parameter controlling the particles residence time inside BL harbor is the moment of release :

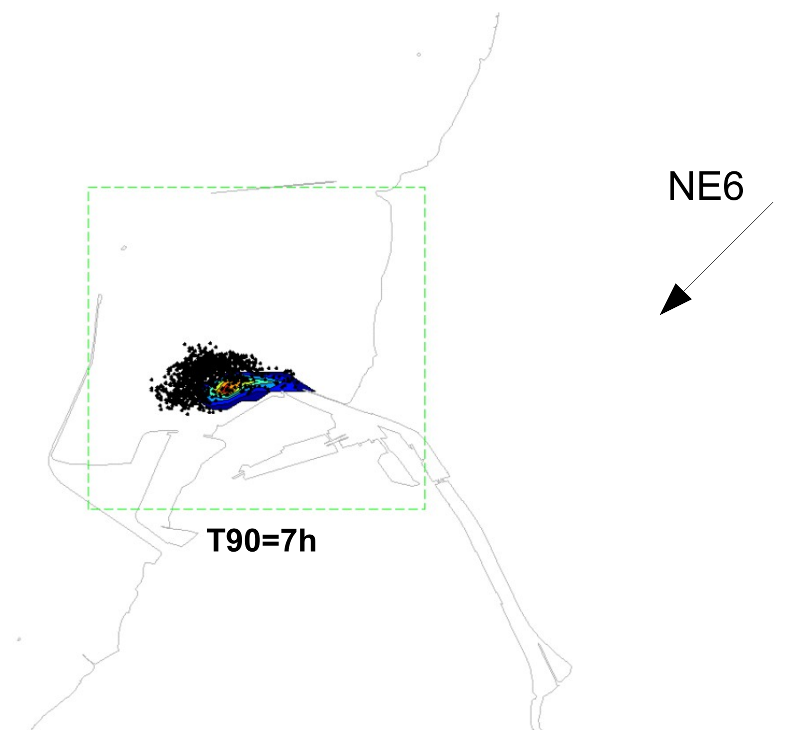
- Maximum flushing occurs for a release on flood
- Maximum trapping occurs for a release on ebb.

Joint effect of wind on the particles transport for a spring tide with a release on flood

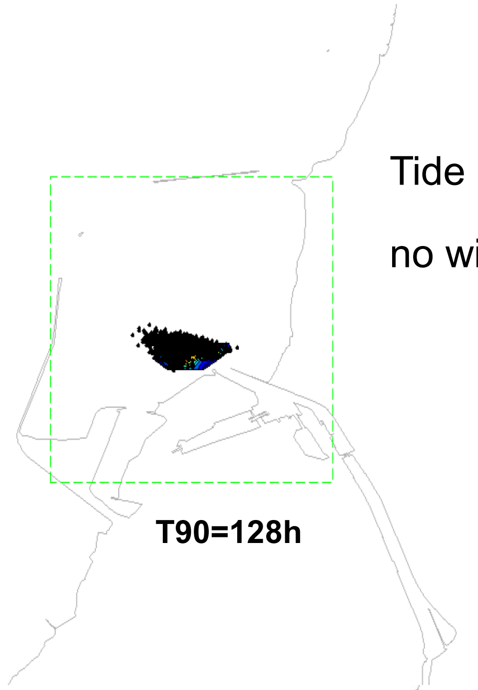








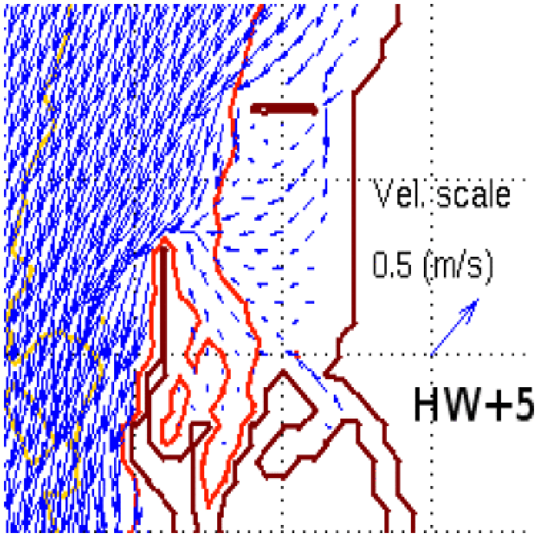
Joint effect of wind on the particles transport for a spring tide with a release on ebb



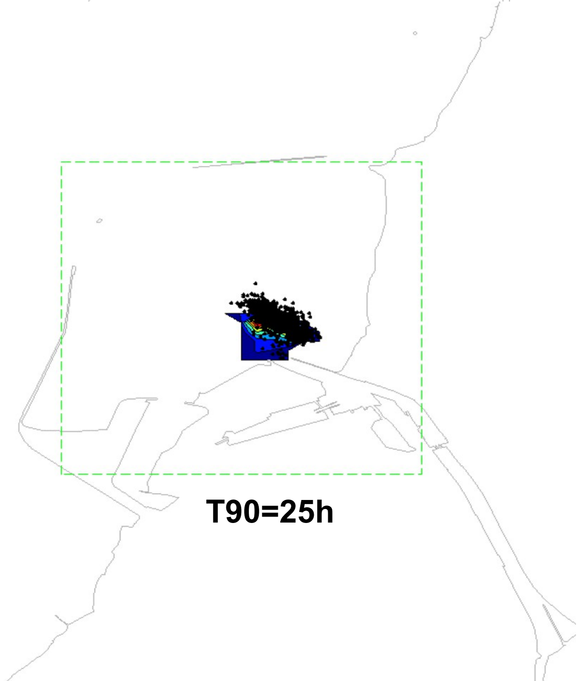
Tide only

no wind

T90=128h

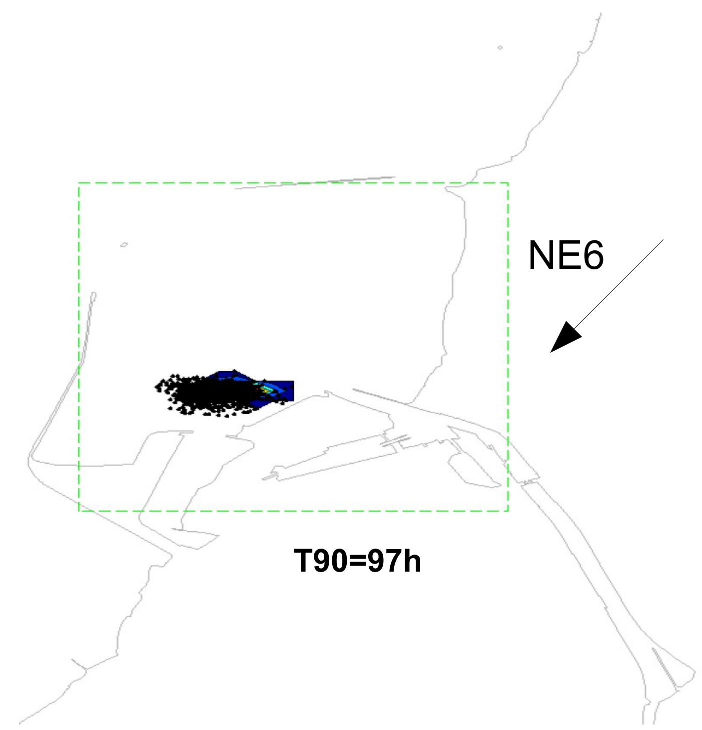


SW6



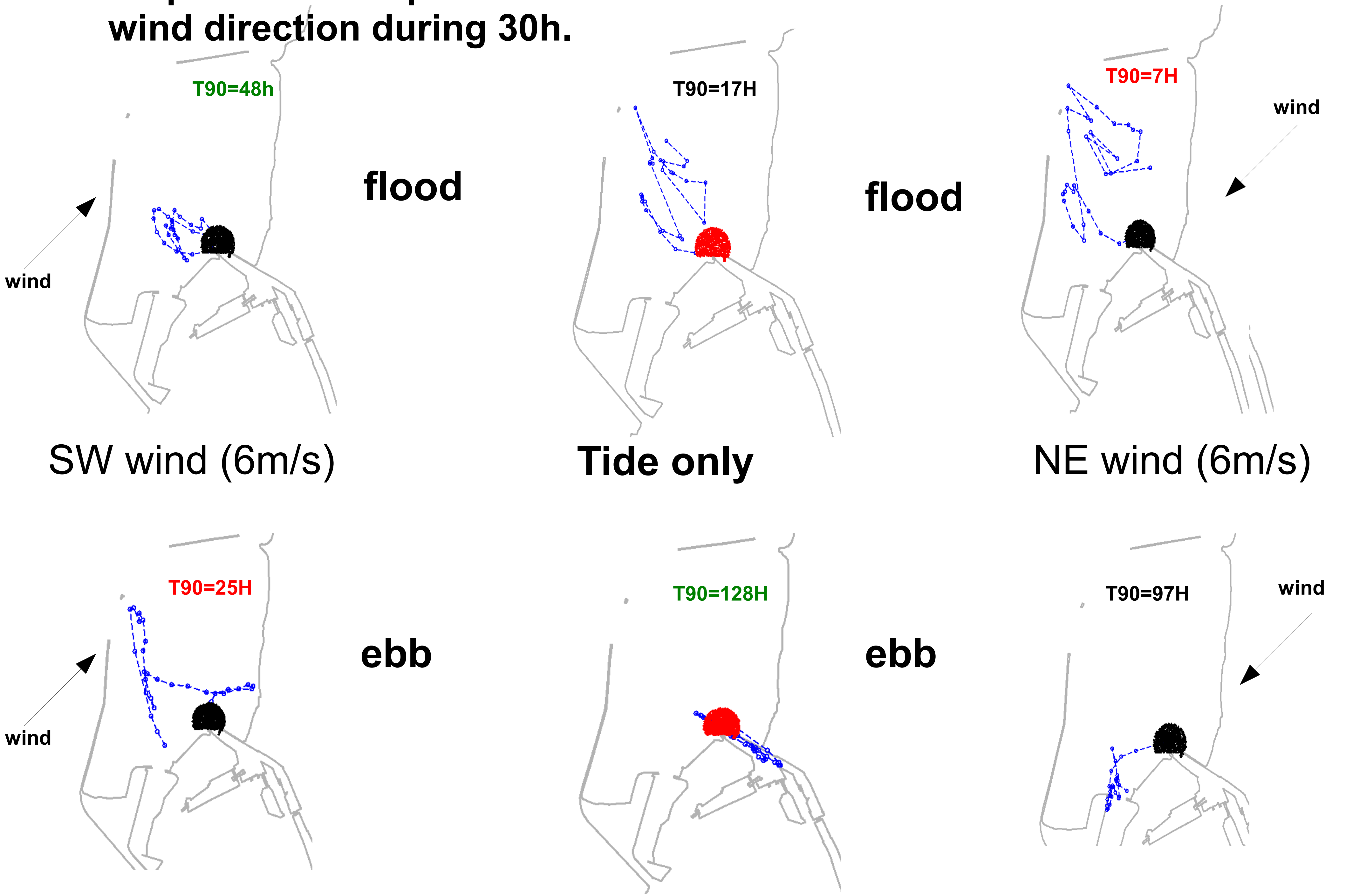
T90=25h

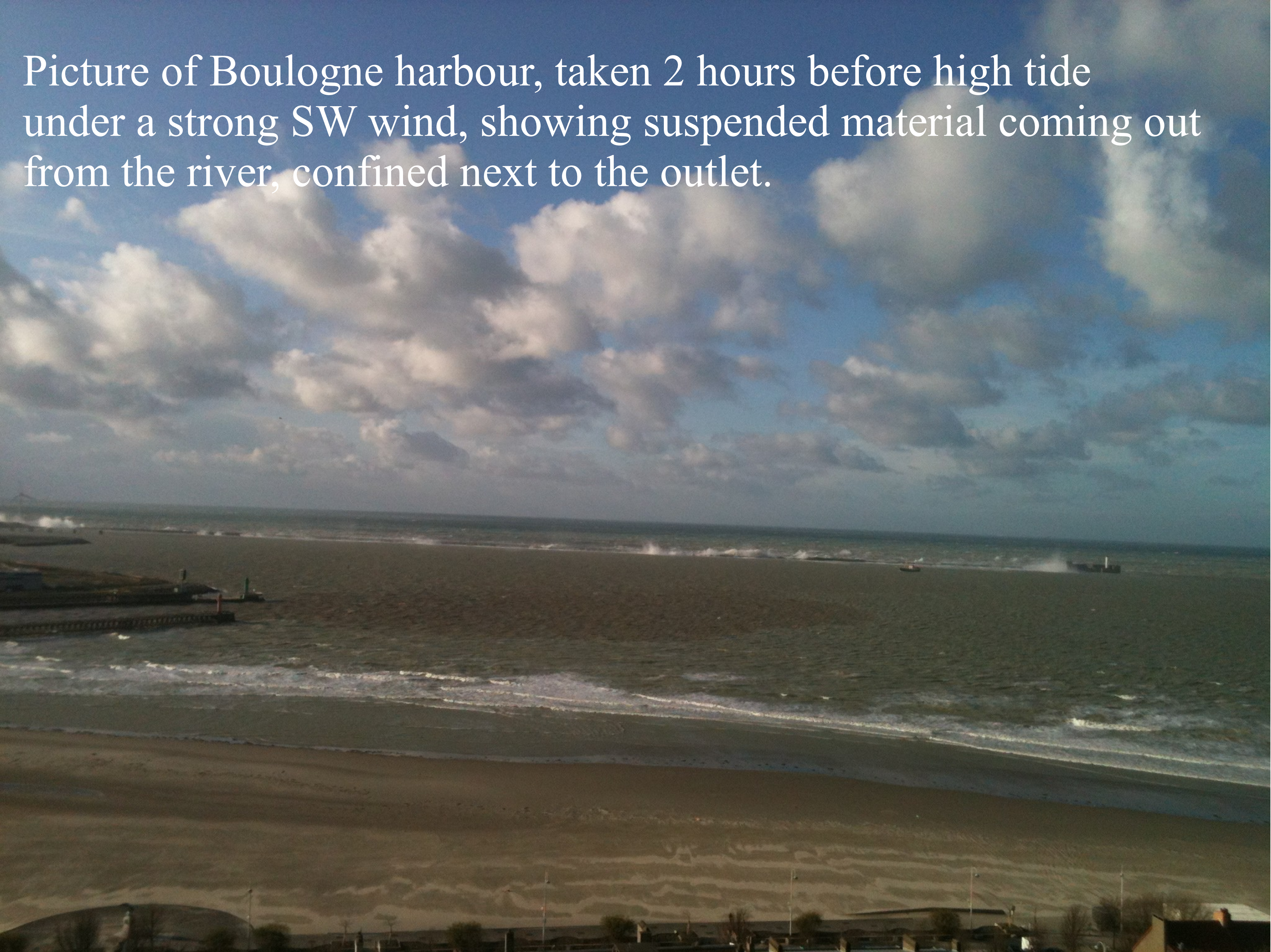
NE6



T90=97h

Displacement of particles centre of mass under different wind direction during 30h.




Picture of Boulogne harbour, taken 2 hours before high tide under a strong SW wind, showing suspended material coming out from the river, confined next to the outlet.

Result 2

FLOOD

- maximum trapping: SW wind (6m/s)
  (T90=116h under neap tides)
- maximum flushing : NE winds
  (T90=7h under spring tides)

- T90 SW wind > T90 NE wind

EBB

- maximum trapping: NE wind (12m/s)
  (T90=178h under neap tides)
- maximum flushing : SW wind (6m/s)
  (T90=25h under spring tides)

- T90 SW wind < T90 NE wind

Results for spring and neap tides for all forcings

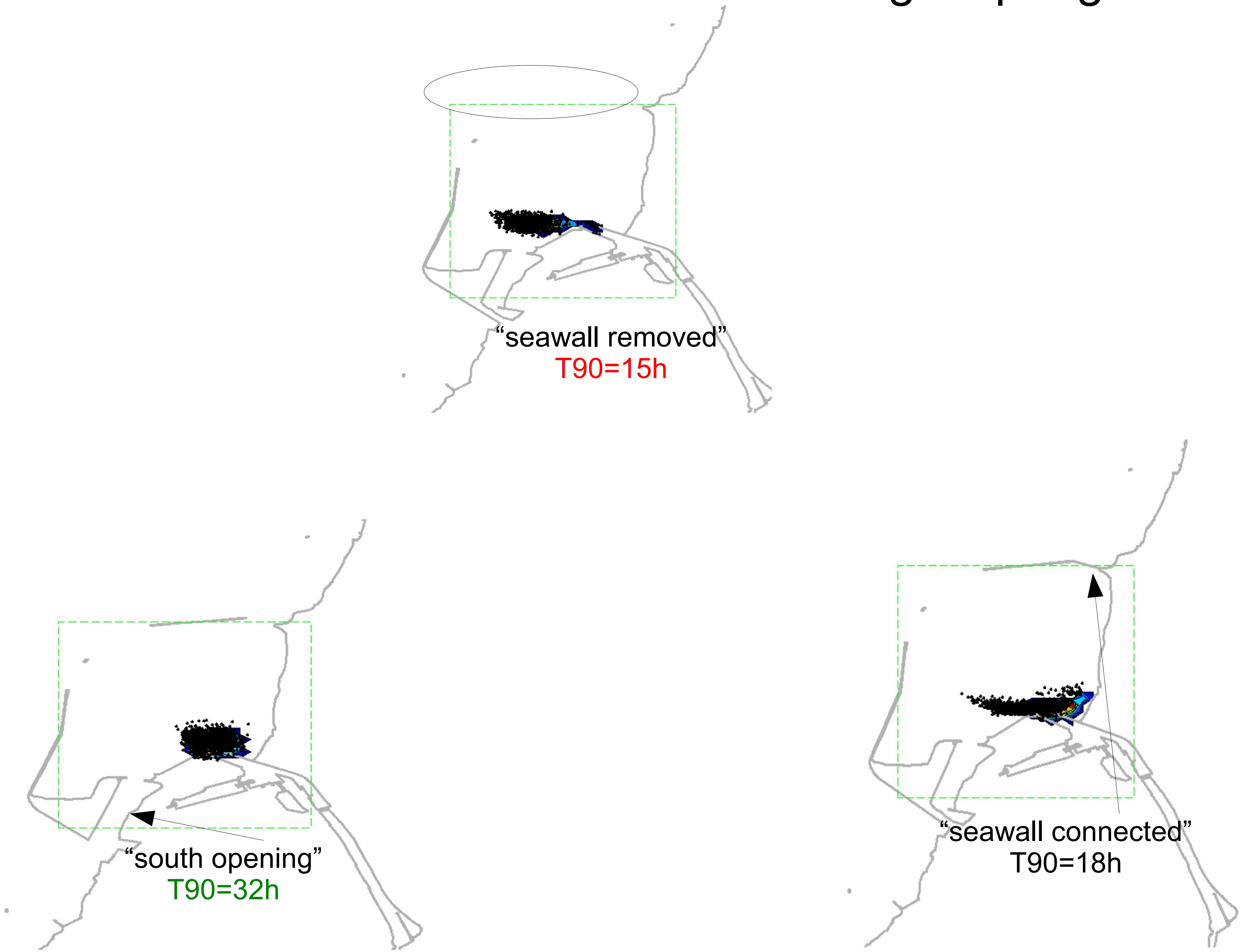
spring tide -flood-	T50	T90
TIDE ONLY	6h	17h
TIDE+NE6	6h	7h
TIDE+NE12	4h	7h
TIDE+SW6	18h	48h
TIDE+SW12	12h	40h
TIDE+DEB2	6h	19h
TIDE+DEB10	6h	15h

spring tide -ebb-	T50	T90
TIDE ONLY	48h	128h
TIDE+NE6	25h	97h
TIDE+NE12	39h	162h
TIDE+SW6	22h	25h
TIDE+SW12	18h	35h
TIDE+DEB2	38h	125h
TIDE+DEB10	10h	35h

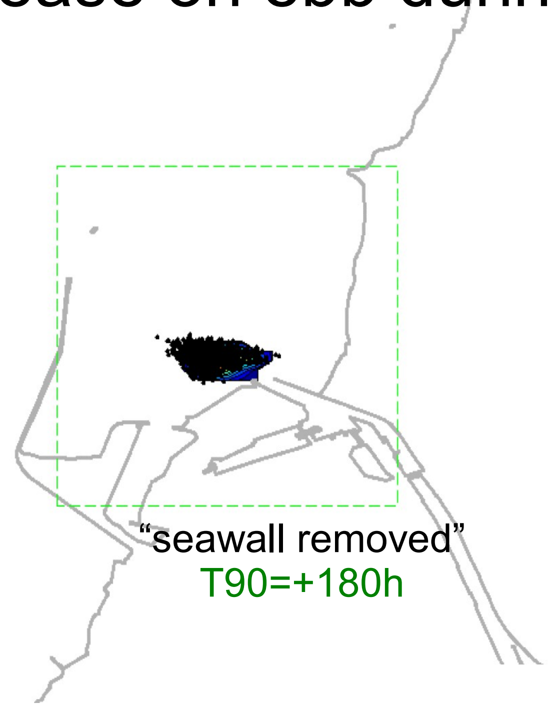
neap tide -flood-	T50	T90
TIDE ONLY	18H	42H
TIDE+NE6	6h	8h
TIDE+NE12	6h	18h
TIDE+SW6	21h	116h
TIDE+SW12	25h	72h
TIDE+DEB2	8h	34h
TIDE+DEB10	8h	28h

neap tide -ebb-	T50	T90
TIDE ONLY	108h	+180h
TIDE+NE6	38h	115h
TIDE+NE12	38h	178h
TIDE+SW6	27h	115h
TIDE+SW12	19h	48h
TIDE+DEB2	15h	140h
TIDE+DEB10	12h	34h

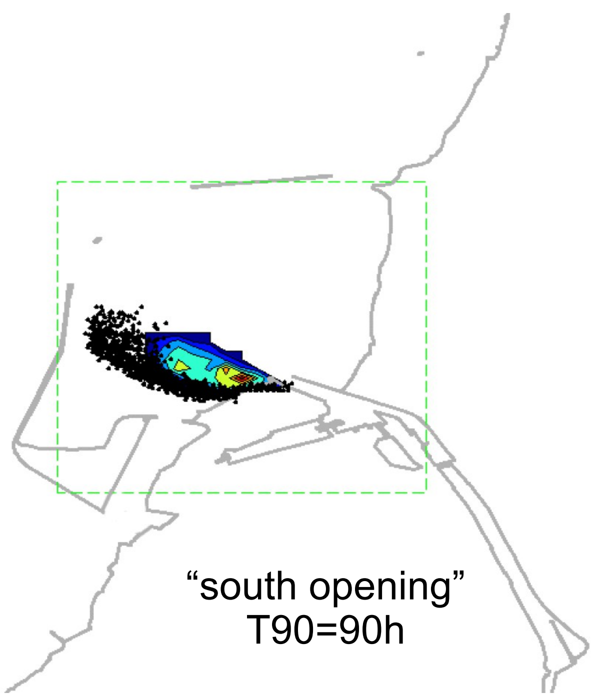
Effects of harbor morphological changes on particles residence time for a release on flood during a spring tide



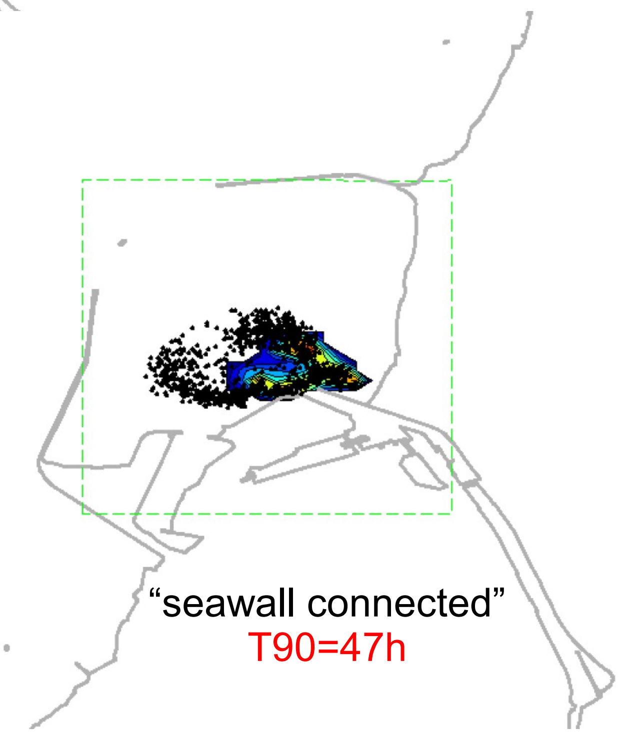
Effects of harbor morphological changes on particles residence time for a release on ebb during a neap tide



"seawall removed"
T90=+180h

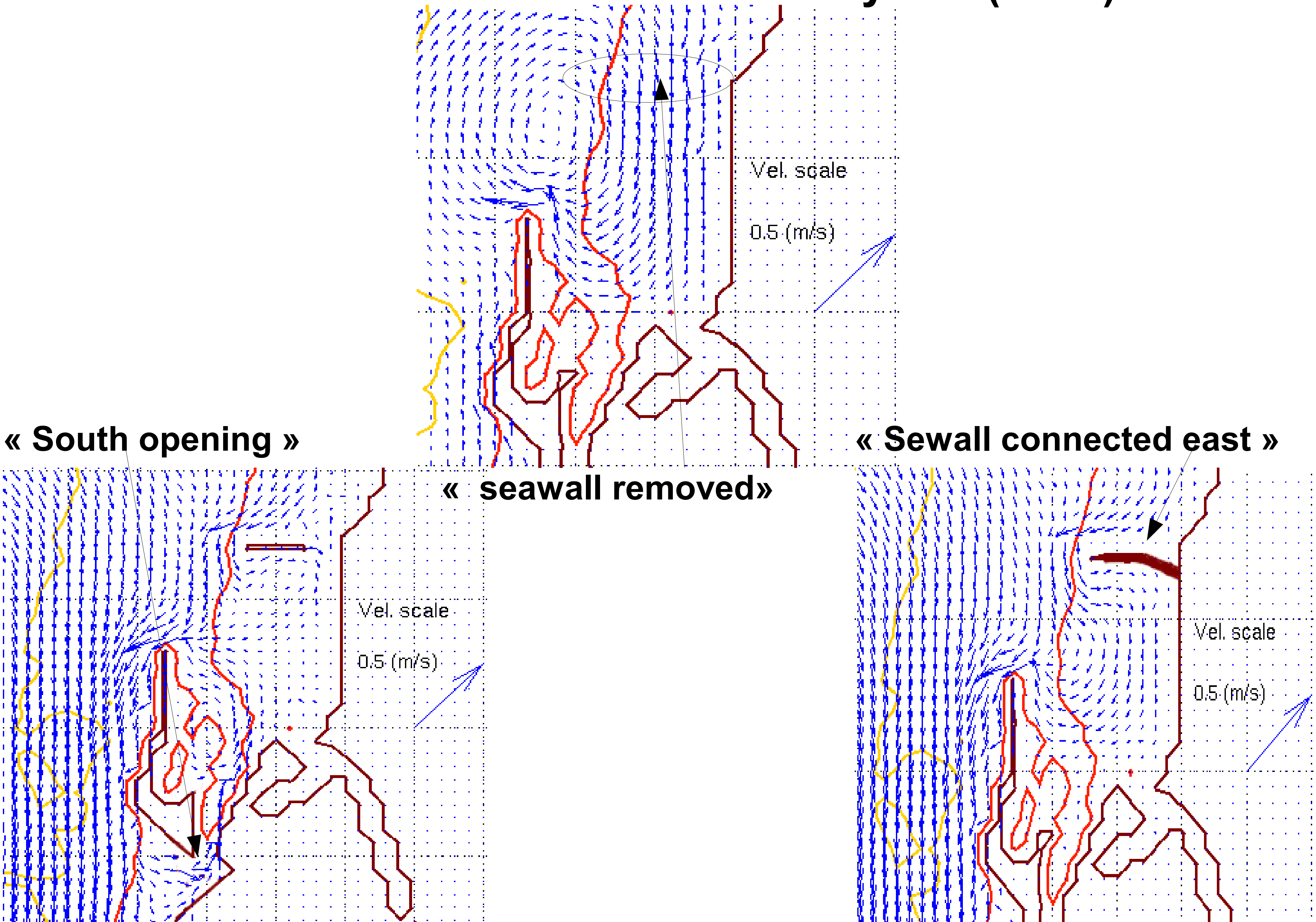


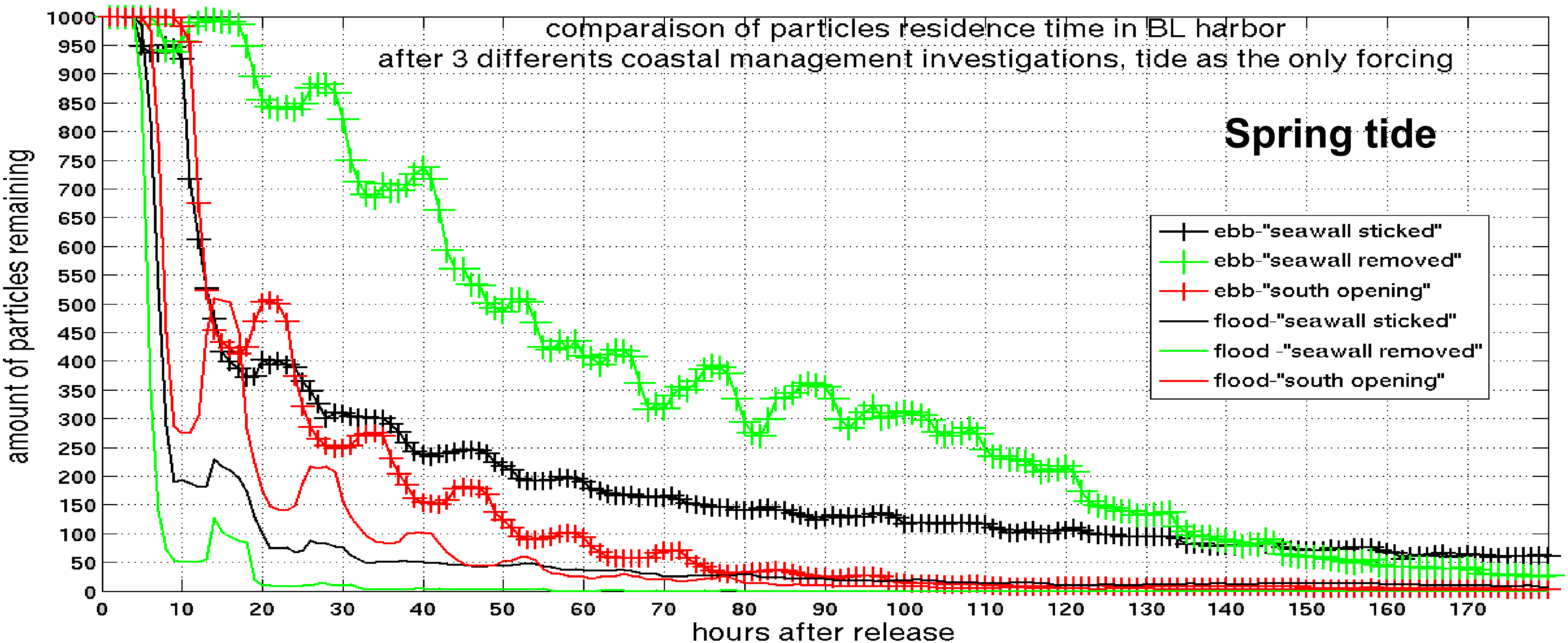
"south opening"
T90=90h



"seawall connected"
T90=47h

Residual currents over 10 tidal cycles (125h)





spring tide -flood-	T50	T90
TIDE ONLY	6h	17h
« removed »	7h	15h
«connected »	8h	20h
« opened »	9h	32h

spring tide -ebb-	T50	T90
TIDE ONLY	48h	128h
« removed »	53h	136h
«connected »	14h	125h
« opened »	22h	60h

neap tide -flood-	T50	T90
TIDE ONLY	18H	42H
« removed »	6h	16h
« connected »	8h	18h
« opened »	16h	45h

neap tide -ebb-	T50	T90
TIDE ONLY	108h	+180h
« removed »	110h	+180h
«connected »	13h	47h
« opened »	25h	90h

Result 3

FLOOD

- maximum trapping: « south opening »
  (T90=45h under neap tides)

- maximum flushing : « seawall removed »
  (T90=15h spring tides)

EBB

- maximum trapping: « seawall removed »
  (T90 >180h under neap tides)

- maximum flushing : « seawall connected east »
  (T90=47h under neap tides)

Conclusions

The morphology of BL harbor induces a complex circulation which controls particles residence time, transport and dispersion processes of passive tracers.

The moment of release is the major parameter controlling the residence time inside the harbor for any tidal ranges :
- fast evacuation for release occurring on flood.
- slow evacuation for release occurring on ebb.

-On flood, a SW wind increases the T90 (compare to tide only) , but a NE wind decreases it.
- on ebb, a SW wind decreases the T90 but a NE increases it.
If the magnitude of a NE wind increases (from 6 to 12m/s) it strengthens the trapping enhancing the southward drift. Besides, a strong SW wind (12m/s) traps less particles than a moderate one (6m/s) reducing the southward drift.

Tide is the major forcing controlling the circulation pattern in the harbor but additional forcings such as wind or morphological changes play an important role on particles residence time.
If the combined effect of tide and the considered forcing increases the southward drift, it traps particles in the lowest hydrodynamic area of the harbor, where an important sedimentation is observed in-situ.