Drift bottles in the southern Baltic Sea – an experiment-of-opportunity

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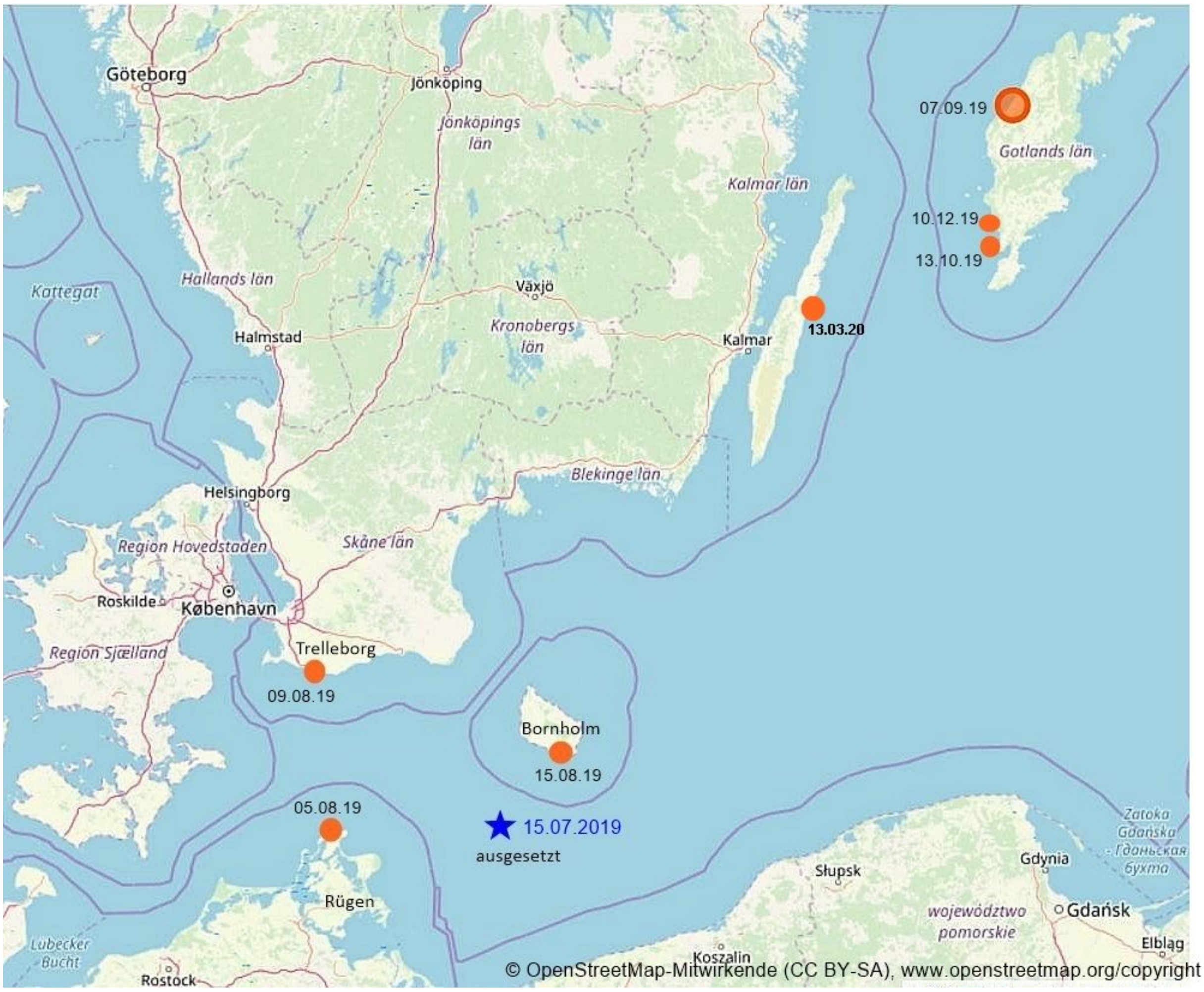
A remarkable story about children preparing drift bottles, seamen dropping several of them simultaneously into the Baltic Sea, and others finding them at beaches far from each other. Thus, a formidable empirical data set, namely of the locations of findings spots, was the result of an "experiment-of-opportunity". Using a transport model, we suggest the mechanism, how this wide spreading happened.

In July 2019, a batch of drift bottles was released southwest of Bornholm, as part of the "Flaschenpost" of the annual "Forschung vor Anker" event of the Institute of Coastal Research of the Helmholtz Zentrum Geesthacht. Of the 27 bottles, 8 were found and reported in the coming weeks and months – on a wide range of Baltic Sea coasts, namely two near Trelleborg, one each on Rügen, on Bornholm and on Öland, and three on Gotland (see map).

Found drift-bottle

The story of the drift bottles released during the "Forschung vor Anker" (Coastal research on tour) began some years ago. Children, who visited the research vessel "Ludwig Prandtl" during open-ship arrangements, were asked if they like to write a letter, with their addresses on. These letters were then placed in bottles, and later, when the ship was cruising, released into the sea. These bottles do not immerse very deeply into the water, as they are filled with air. This was done in many years, but in 2019, when the cruise went from Rostock, Stralsund to Lauterbach on Rügen, much more bottles were reported to be found than in earlier years.

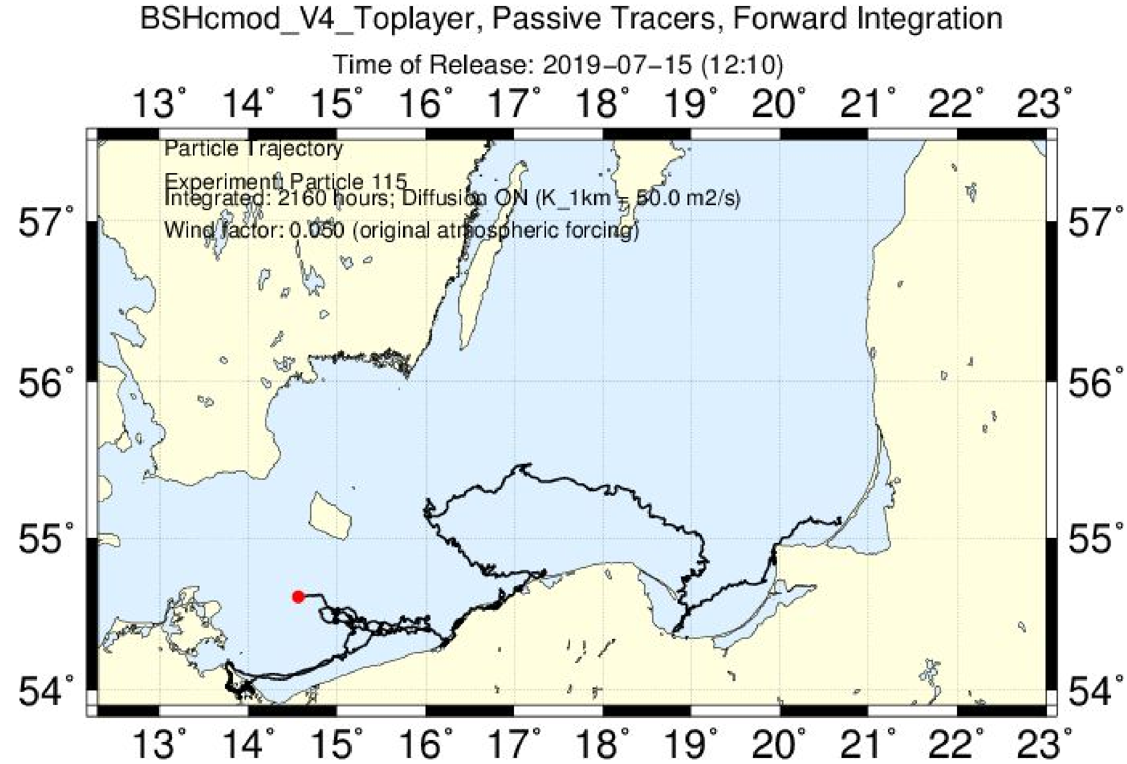
The map shows first the location (as blue star), where the bottles were released on 15. July 2019, and the 7 locations (orange balls), were a bottle was found between August 2019 and March 2020. In August, 2 bottles were found west of the point of departure, namely near Trelleborg and on Rügen. The one on Bornholm was reported slightly later, and the remaining four later or even much later on Öland and Gotland. Of course, it is quite possible, that even more will be reported a found in later times.

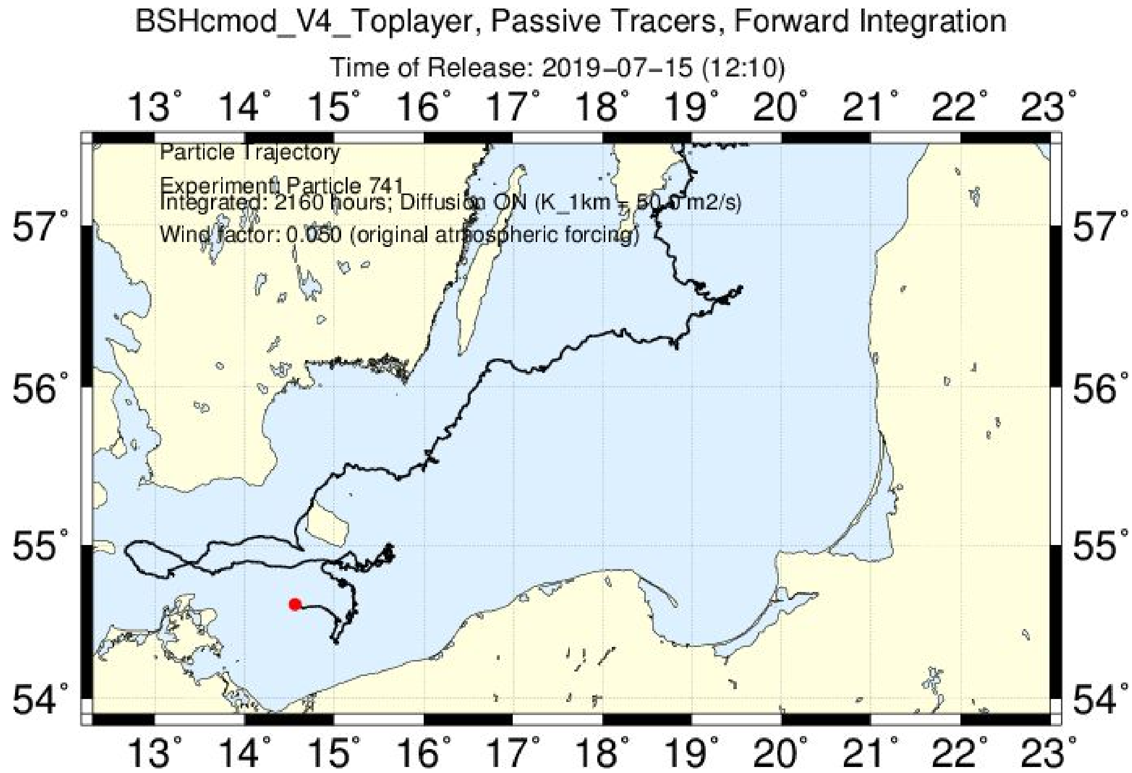


Location of release (blue star) and of reporting findings (orange balls)

The large spread of the bottles, southwesterly and northwesterly plus northeasterly of the location of release, was at first a bit of a surprise, since in a laminar flow, this would be highly unlikely. But the bottles do move under the influence of both, the wind and the currents, which are both turbulent. Such turbulent flows may enlarge an initial very small difference in location to a very large one, possibly transferring drifting bottles from one to another eddy-like structure. Depending on their spatial scale, such eddies may or may not be resolved by the hydrodynamic model. The currents and winds are strongly dependent on bottom and land topography, both aspects that are complex in the Baltic Sea region. As the bottles all are observed as landed on the shore the wind, current and wave interaction close to the coast are fundamental and not properly resolved by most numerical atmospheric or Baltic Sea models. Still Baltic Sea numerical models are capable to reproduce relevant aspects of the currents at scales they resolve and the interesting question here is whether or not they can give information also on bottle drifting in the Baltic Sea?

To find out, if the concept of turbulent wind and current pattern will generate an ensemble of pathways of our bottles, or trajectories, consistent with the locations of finding, we simulated 1000 trajectories of imaginary “things”. The trajectories would not end, i.e., the “things” would not run abeach but continue to flow through the regions. We have examined the first 90 days of the trajectories.





Two simulated trajectories, emanating from the red dot, extending across 90 days. A random displacement, accounting or the lack of sufficient small-scale turbulent movement, is added, and responsible for the wiggly development. Note that this trajectory is not passing any of the findings spots. – 2nd diagram for alternative trajectory needed

How a “thing” will move under the influence of wind and current, depends on how deep the “thing” is immersing. The larger its part above the water surface is, the more important is the extra wind drag. Using a transport model (PELETS-2D, see Callies et al. 2011), forced with analysed winds and currents, 1000 trajectories were calculated assuming a relative strong wind induced drift component (5% of 10 m winds). Operational analyses of winds and marine currents were obtained from the Deutscher Wetterdienst (DWD) and the Bundesamt für Seeschifffahrt und Hydrographie (BSH), the latter using the BSHcmod_V4 model. These marine currents are available with roughly 900 m grid resolution to the west of Bornholm and a roughly 5 km grid resolution to the east of Bornholm. The overall model setup (with less wind drag, however) was successfully run during a drifter experiment in the North Sea (Callies et al. 2017).

To represent small-scale turbulent movements not resolved by the model, we added an artificial random walk component, which would move a “thing” irregularly at every time step. Particle displacements were drawn from a normal distribution in agreement with an assumed diffusivity adjusted to the grid resolution of the underlying numerical model (Callies et al., 2011). The figures show two such trajectories that were selected to illustrate the large differences that may occur.

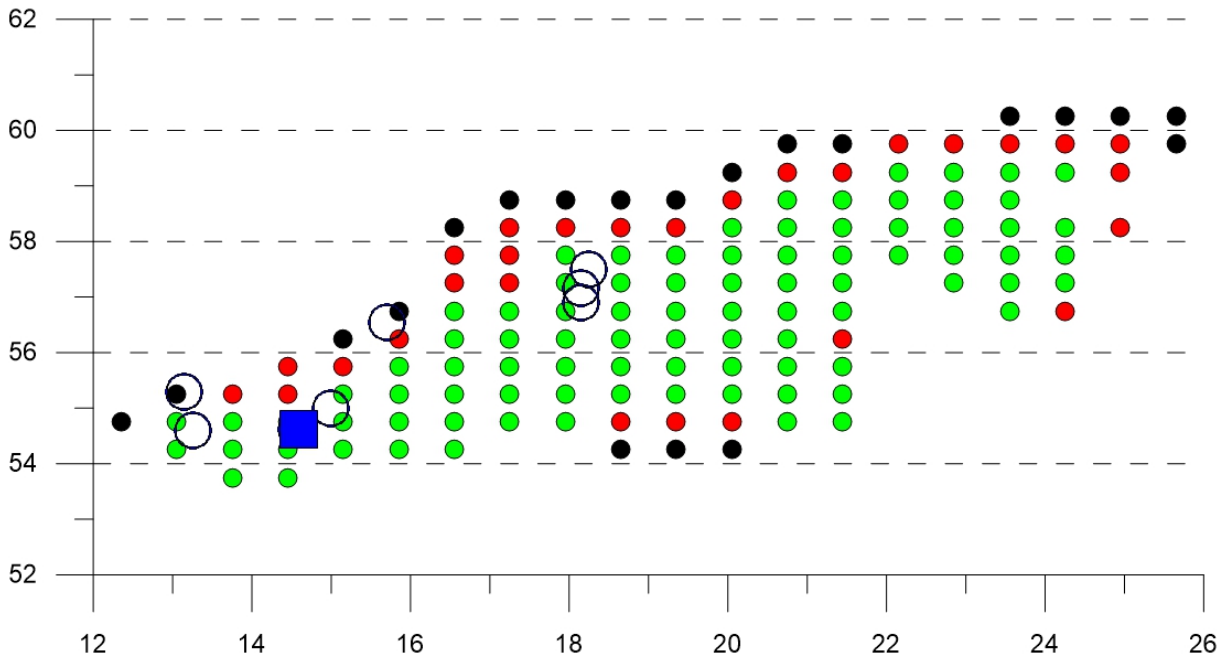
For assessing which points may be reached by a trajectory emanating from the point of release, or boxes of about 0.5° latitudes and 0.7° longitudes covering the southern Baltic Sea, it was counted how often a trajectory would pass through. In green are those points, where this happens often, in red, when it happens sometimes, and in black, where this is a rare event. The point of releases is given by a blue block, and the locations of finding are given as open blue circles.

The entire Southern Baltic Sea east of Trelleborg is covered, also the Bay of Riga and the Finnish Bight. Obviously, all finding spots are within the cloud of filled boxes. Trelleborg and Öland are met only by a few trajectories, but Rügen, Bornholm and Öland by many. Indeed, the lumping of three findings on Gotland, indicates that many trajectories have passed by, which is confirmed by the green color of the dots near Gotland.

Interestingly, even if the coasts of Poland and the Baltic countries are marked as “frequent”, there were no findings reported. We can only speculate why this is. First, when we reduce the random displacements from XX m to xx m, we find essentially the same pattern (not shown). Thus, it is not an artifact of possibly too large displacements. However, from the original 27 bottles, already 8 are taken out; more may have beached before the trajectories led to Poland and the Baltic countries, but were not reported or destroyed. And finally, some may still be underway.

Another simulation (not shown) with a less intense extra forcing by the wind, results in a considerably smaller cloud of boxes, which are all south of 58°N and west of 22°E. Also, in this case, all finding spots are classified as possible, but chances are much reduced - In particular the Gotland findings are rare events.

We conclude that the small entertainment project for children during the open-ship of “Ludwig Prandtl” became an “experiment of opportunity” for testing our modelling capability and an assessment of the relative role of wind compared to that of currents. The data to compare the model results with, namely the locations of finding spots, are completely independent of the modelling effort – and we could show that the model suggests a cloud of movement, which is fully consistent with this empirical evidence. This could be achieved, when a dominant influence of the wind is assumed, with the currents being of comparable importance for moving the bottles.



Frequency of a trajectory passing though the boxes of 0.7°x0.5° size – green: often, red: sometimes, and black: rarely. Point of release. Blue box, points of finding: open blue circles. Horizontal axis: degrees longitude vertical axis: degrees latitude.

Apart of the significance of the wind, is the random displacement, reflecting unresolved or insufficiently resolved small scale features such as eddies or inertial oscillations, another critical factor, which will need more detailed study.

However, for the time being, we suggest that Baltic Sea numerical models and available wind forcing fields provide an explanation for the wide spreading of drifting bottles as observed even though most processes at the shores are not resolved. This is also in agreement with Kjellsson and Döös (2012).

References:

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