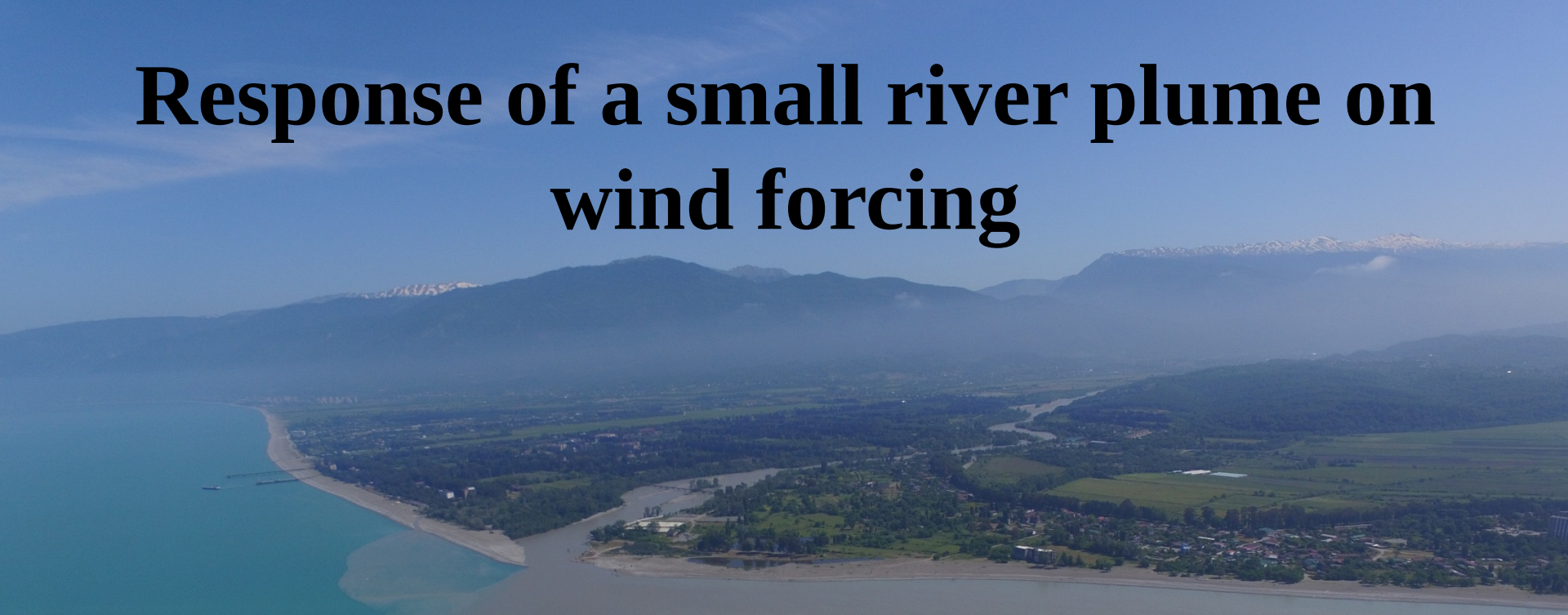
Response of a small river plume on wind forcing



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EGU General Assembly 2022

Motivation

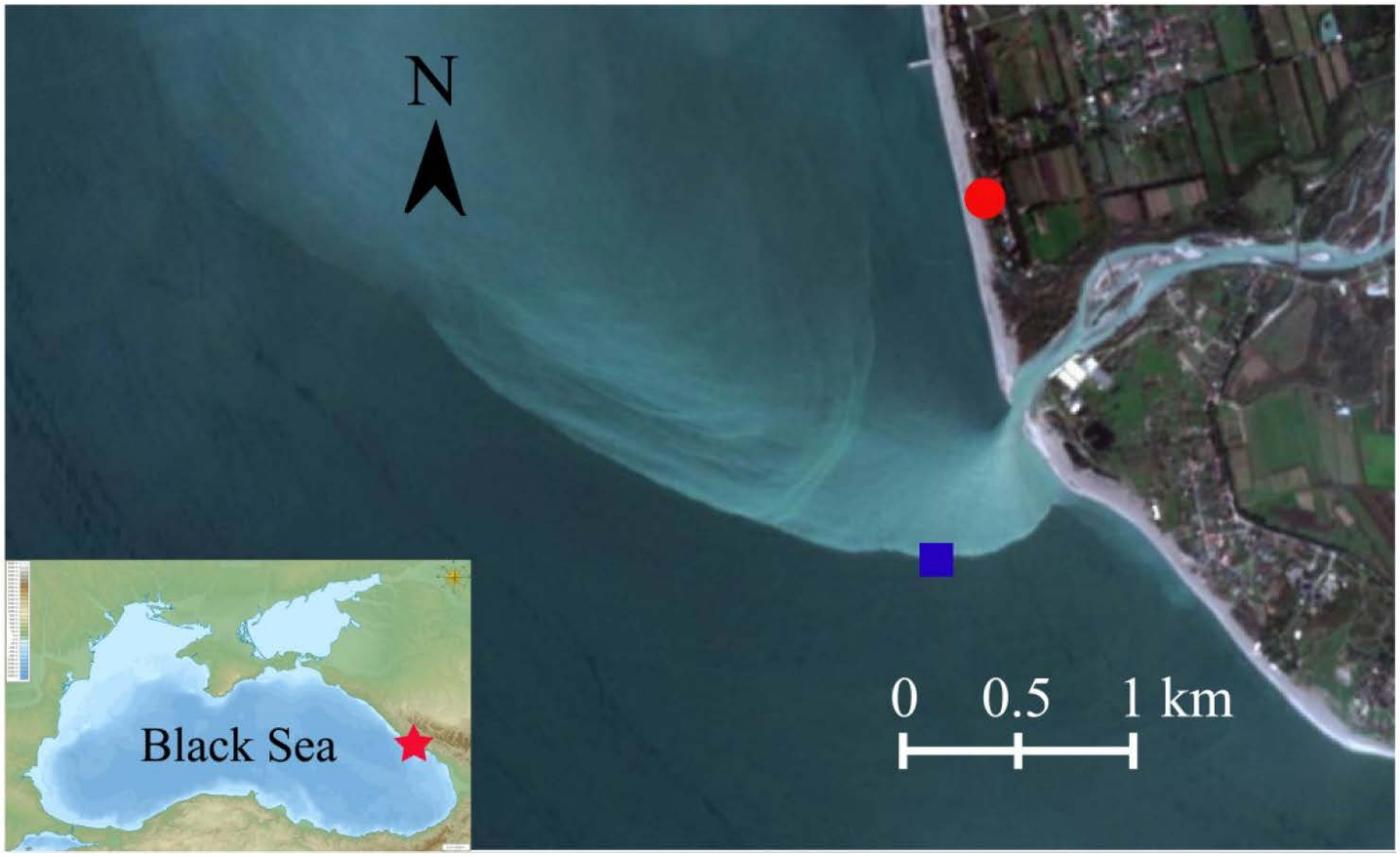
It is of common knowledge that wind forcing is among the main drivers of river plume dynamics. Numerous in situ measurements and numerical simulations address the role of wind forcing on river plume spreading.

However, no one measured (yet) the direct response of a river plume on wind forcing. The main problem is: how to measure the state of a river plume with (1) good spatial coverage and (2) high temporal resolution?

We solved this problem using the long-term (~10 hours) and near-continuous (every 15 seconds) observations by quadcopters from a fixed point + wind measurements + in situ salinity measurements

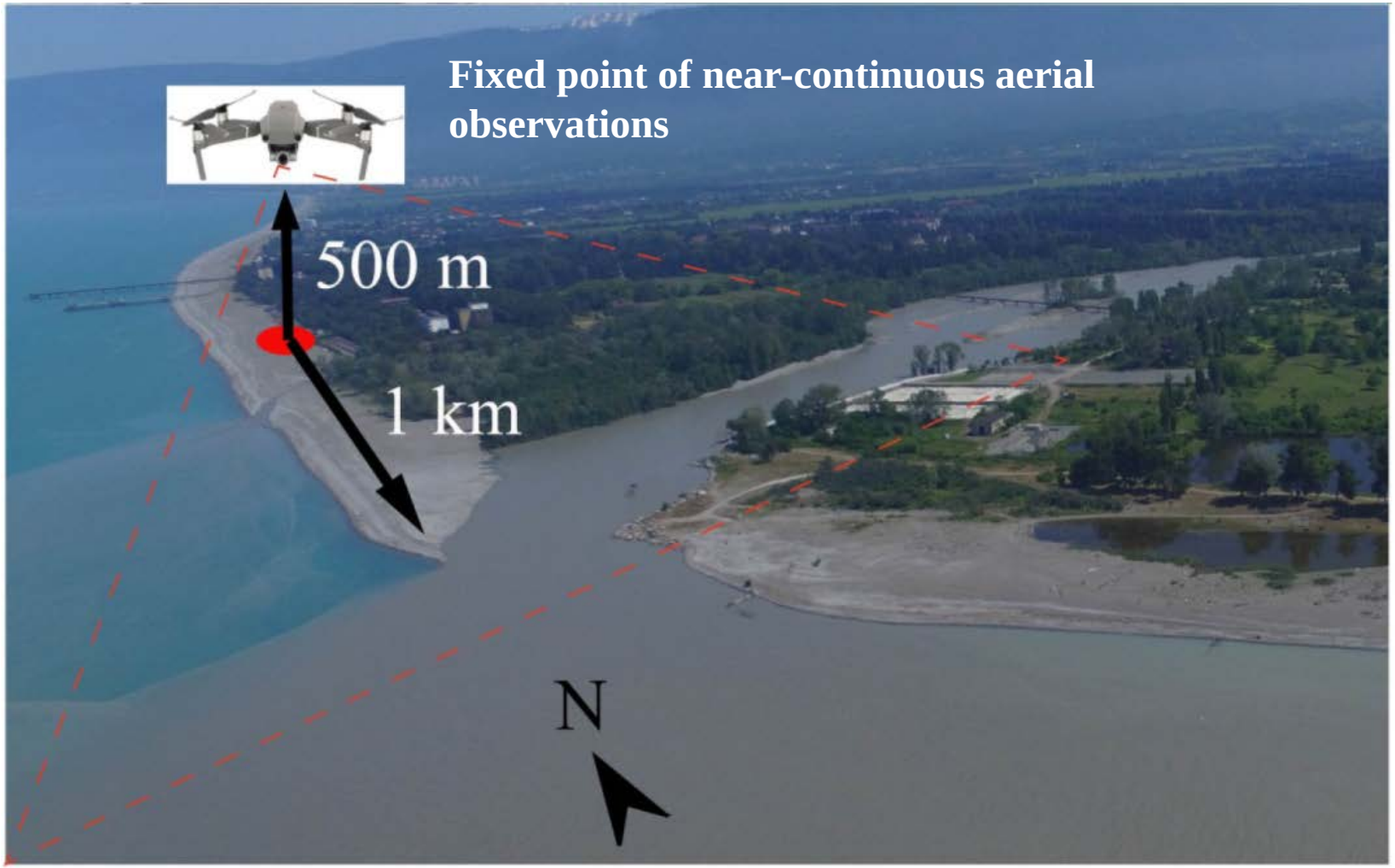
Study area

Study area: the Bzyb plume in the eastern part of the Black Sea.
River discharge ~200 m^3/s, almost no tides, light ambient coastal circulation (< 20 cm/s).
It provided opportunity to assess the effects of light and moderate wind forcing on river plume spreading.



Field measurements

Aerial remote sensing of the Bzyb river plume from the fixed point at the altitude of 500 m using quadcopters on 14–16 April 2021.
These observations provided almost continuous detection of position of the Bzyb plume during daytime of these 3 days with variable wind forcing conditions.



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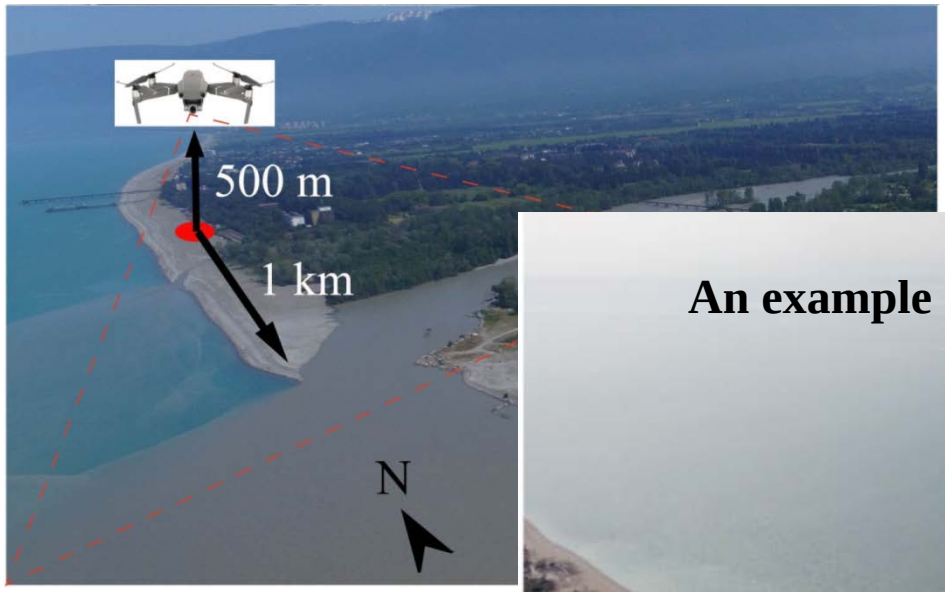
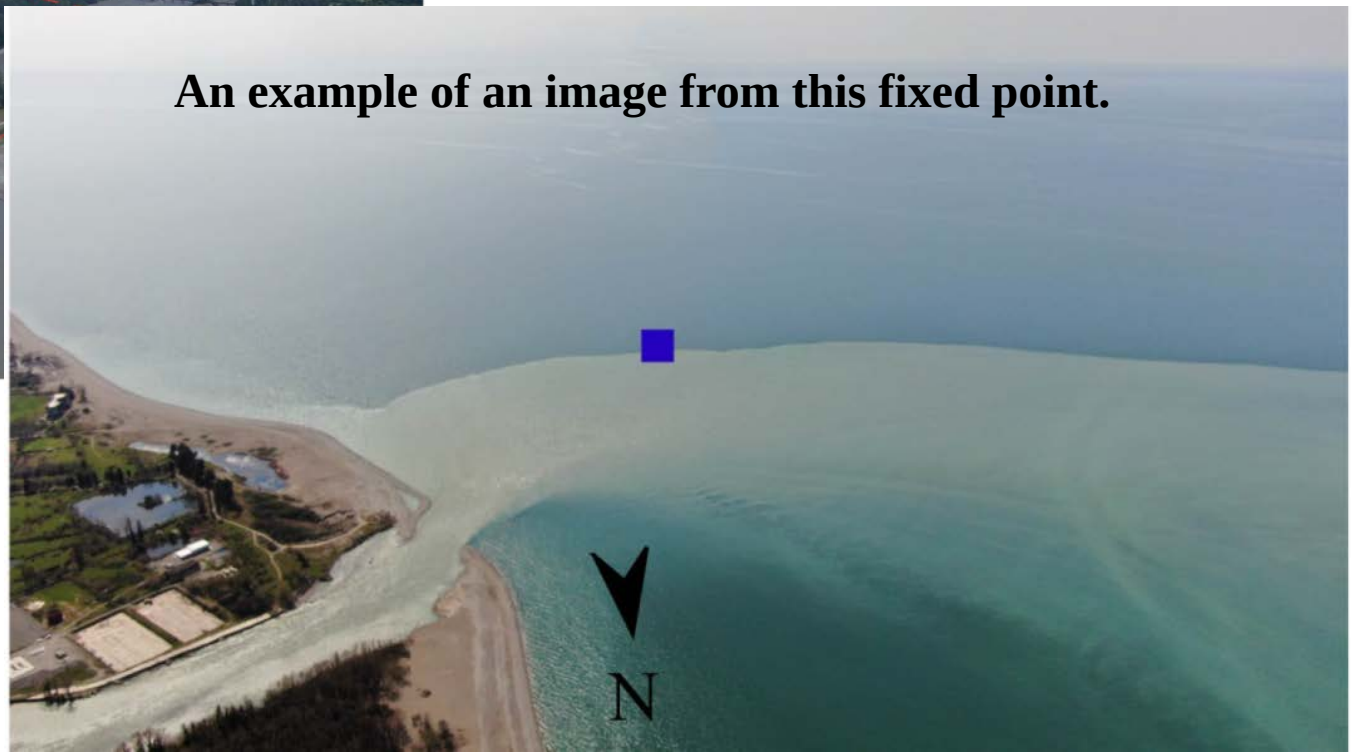


We made thousands of such images: every 15 seconds, 8-10 hours long, during 3 days

An example of an image from this fixed point.



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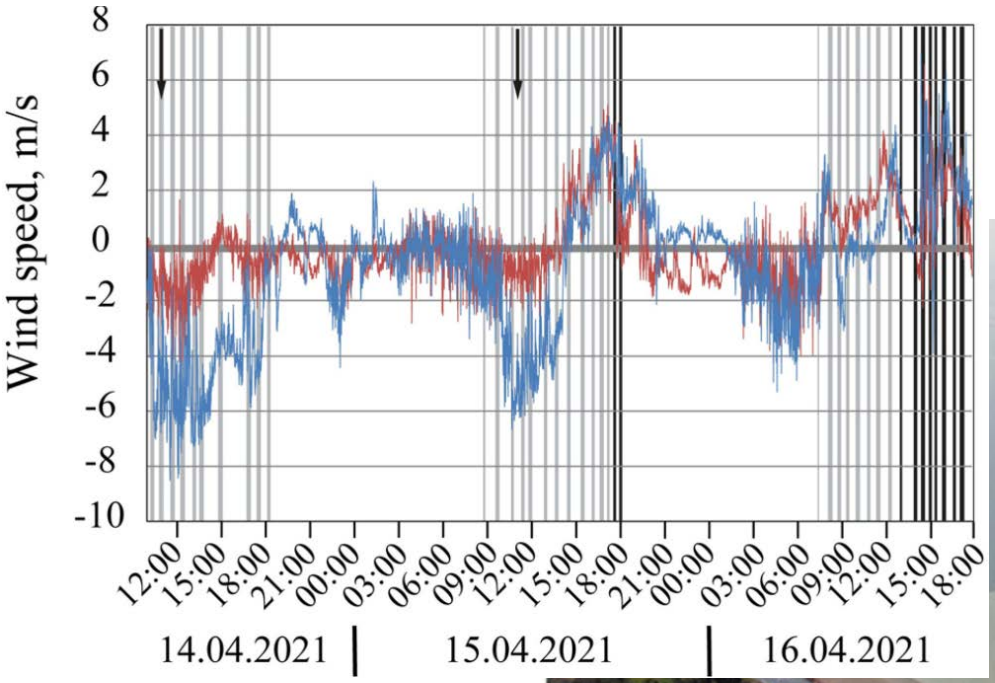
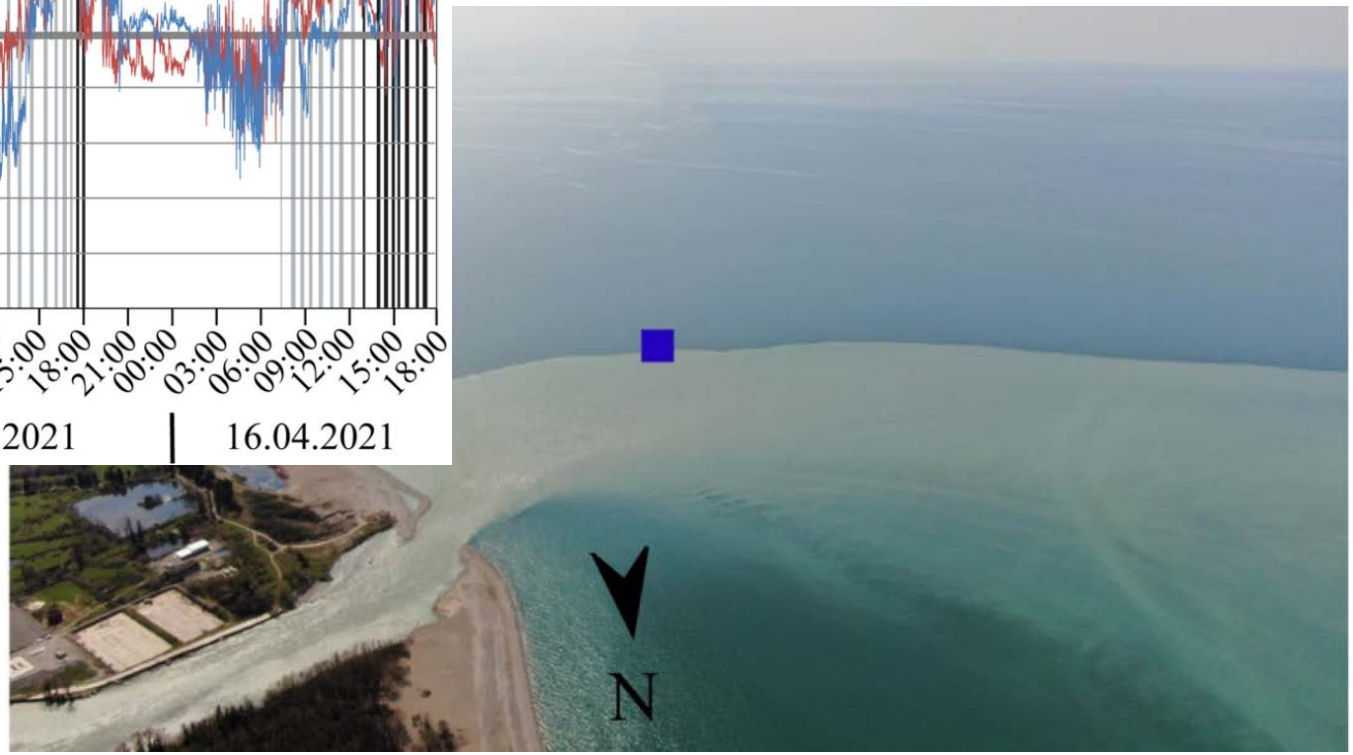


The remote sensing of the plume was accompanied by wind measurements at the study area with temporal resolution of 1 min.



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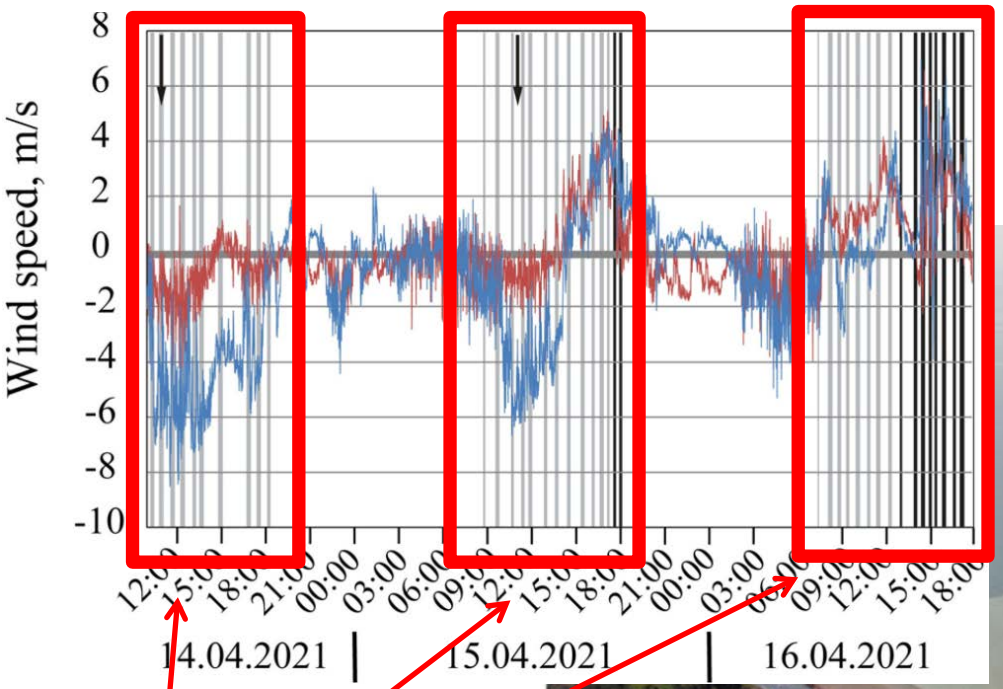

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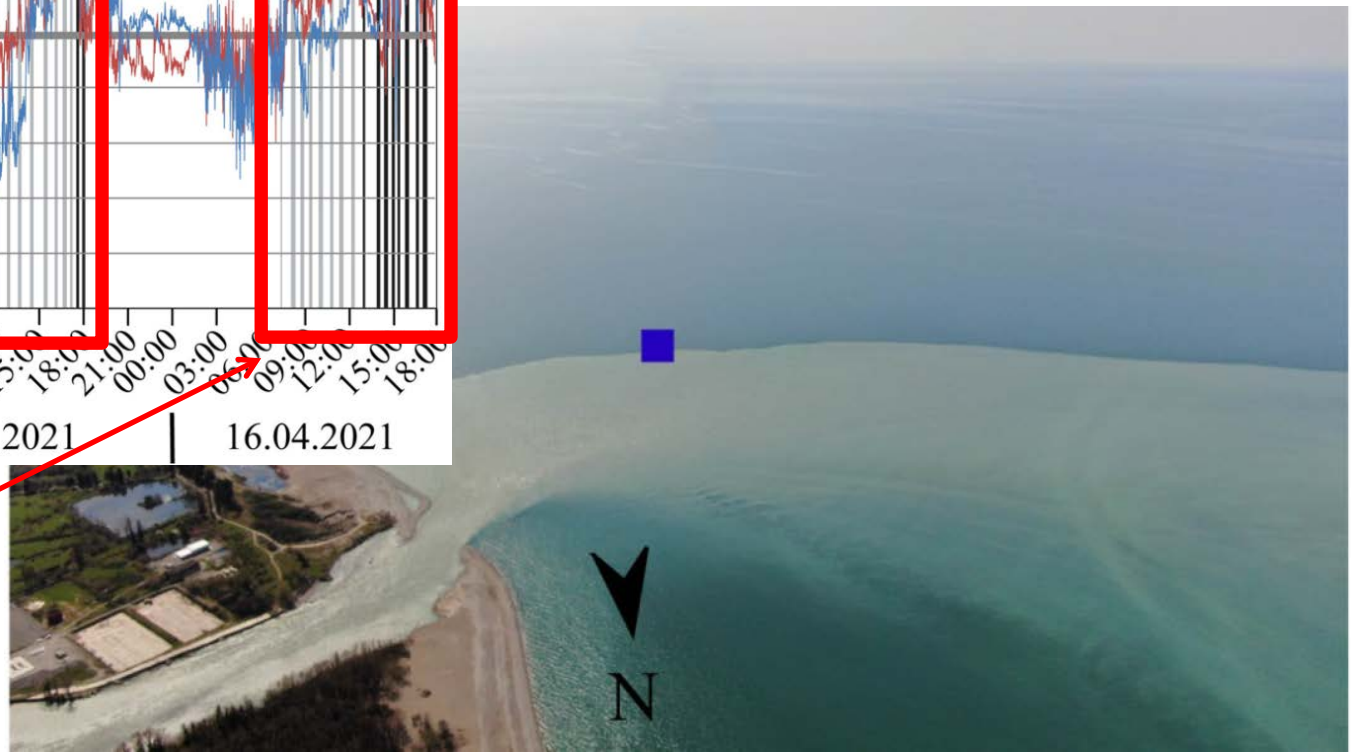
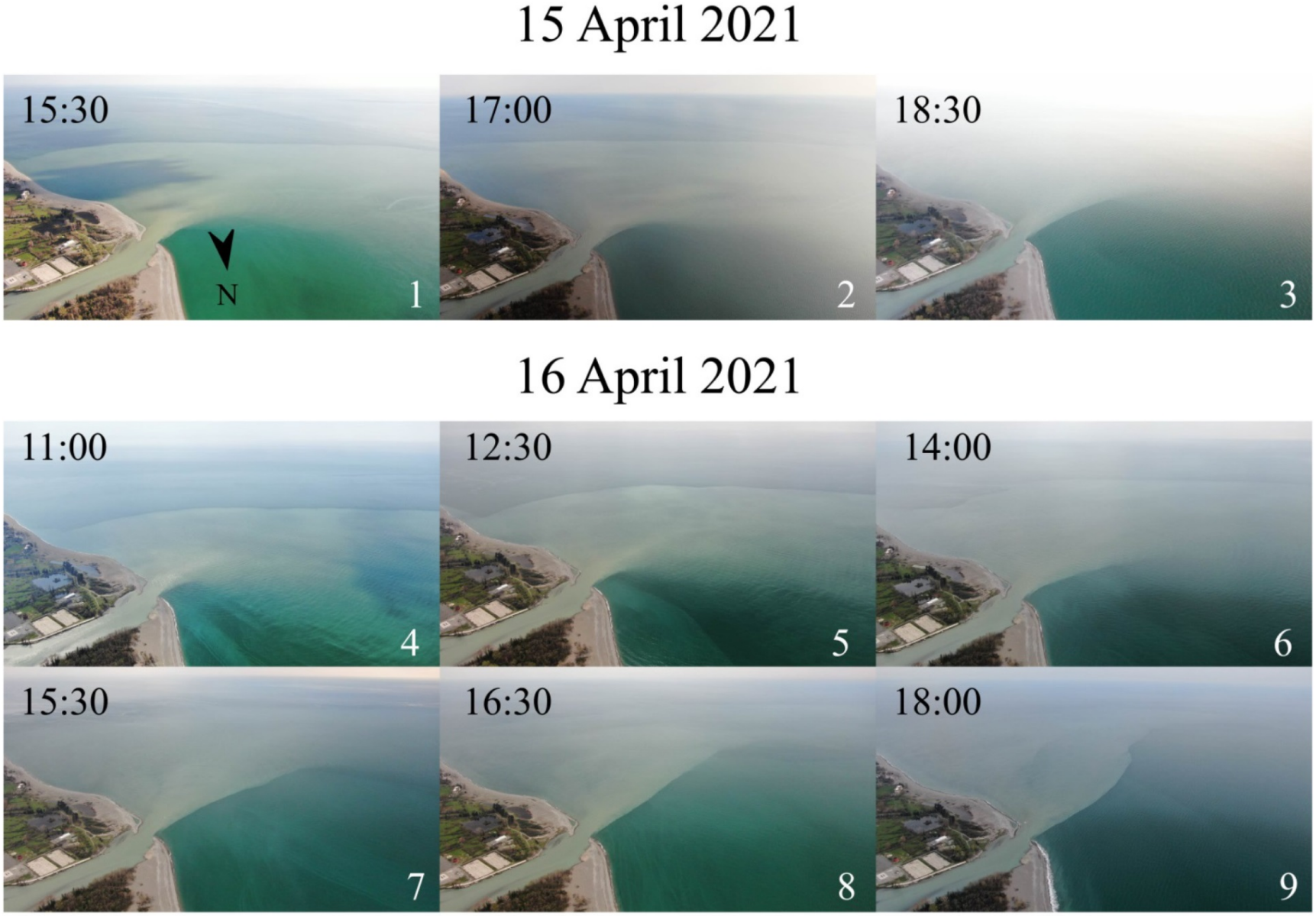


Periods of plume observations + wind measurements

Plume frontal motion



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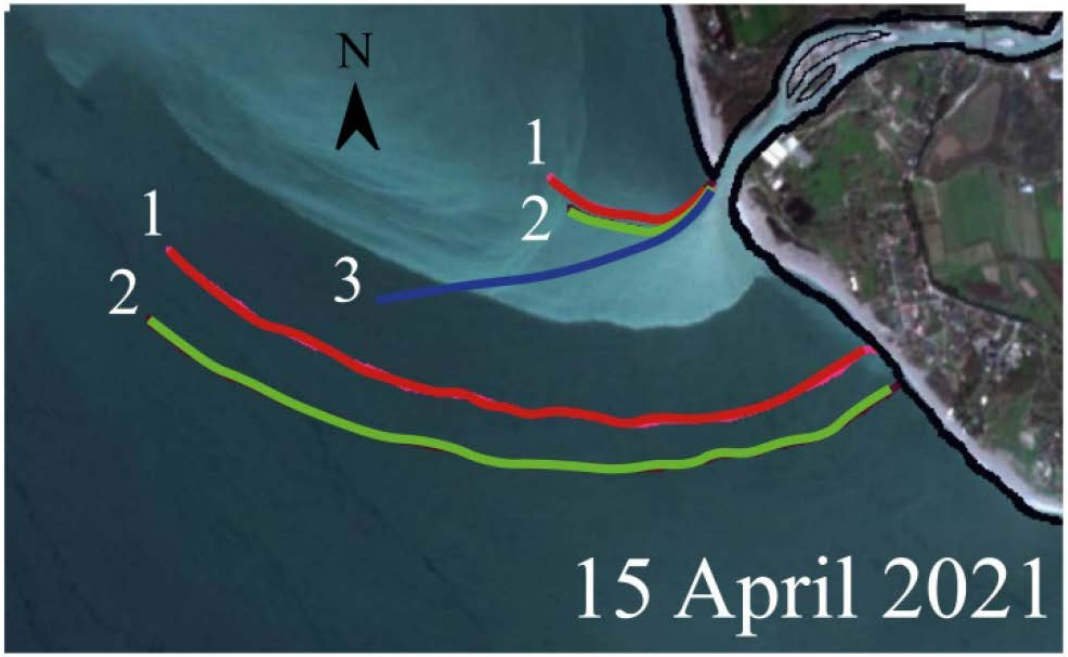
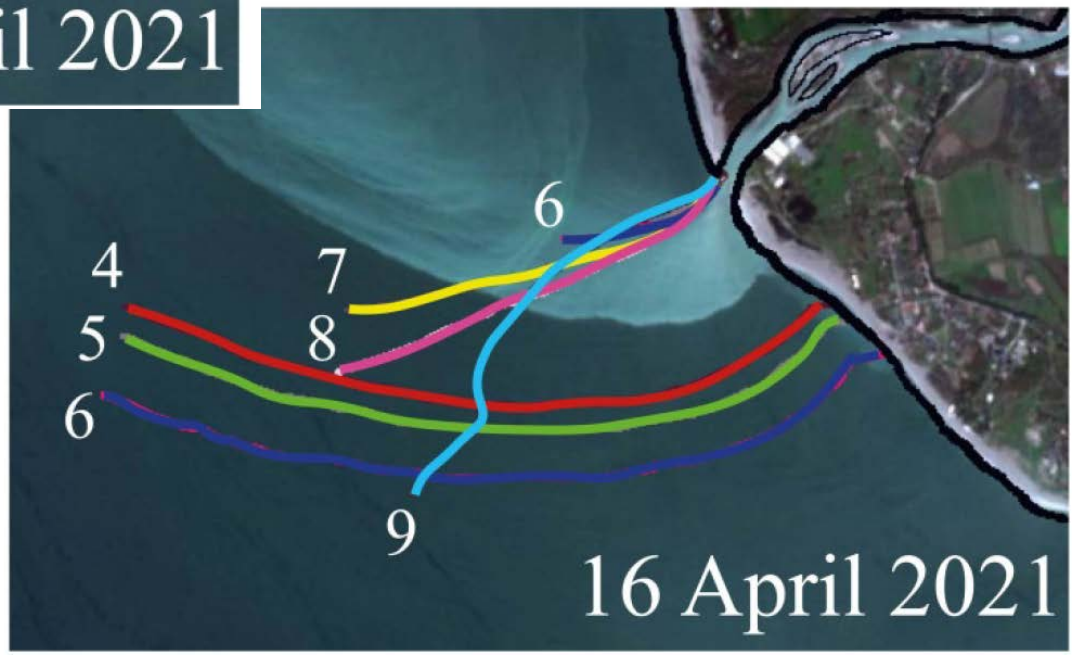


We process the aerial imagery and reconstruct location of the plume border.

As a result, we detected plume frontal motion with very high spatial (10 m) and temporal (1 min) resolution



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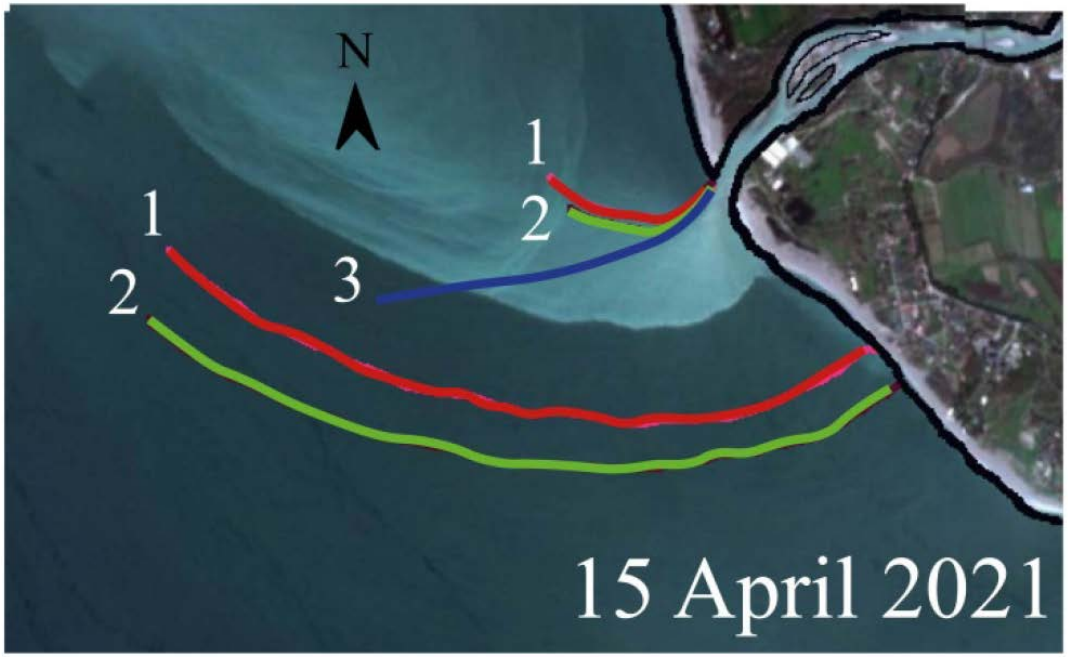
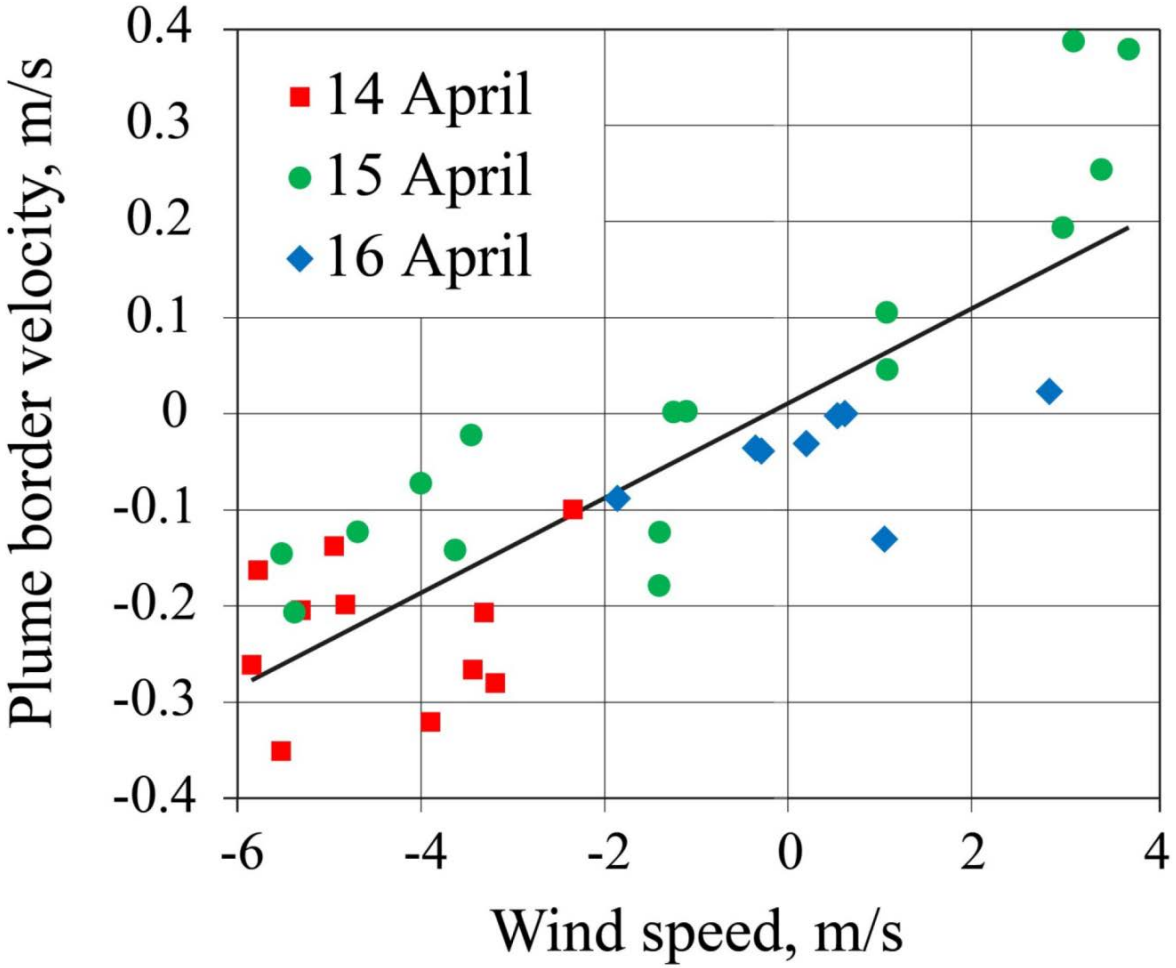


1. The cross-shore wind component determined position of the plume due to large Ekman angle ~60-80°
2. The response time of the plume border motion on changes in wind direction is 10-20 minutes
3. The plume reversal between upstream/downstream spreading direction occurs during 1-3 hours even under low (< 5 m/s) wind forcing conditions.

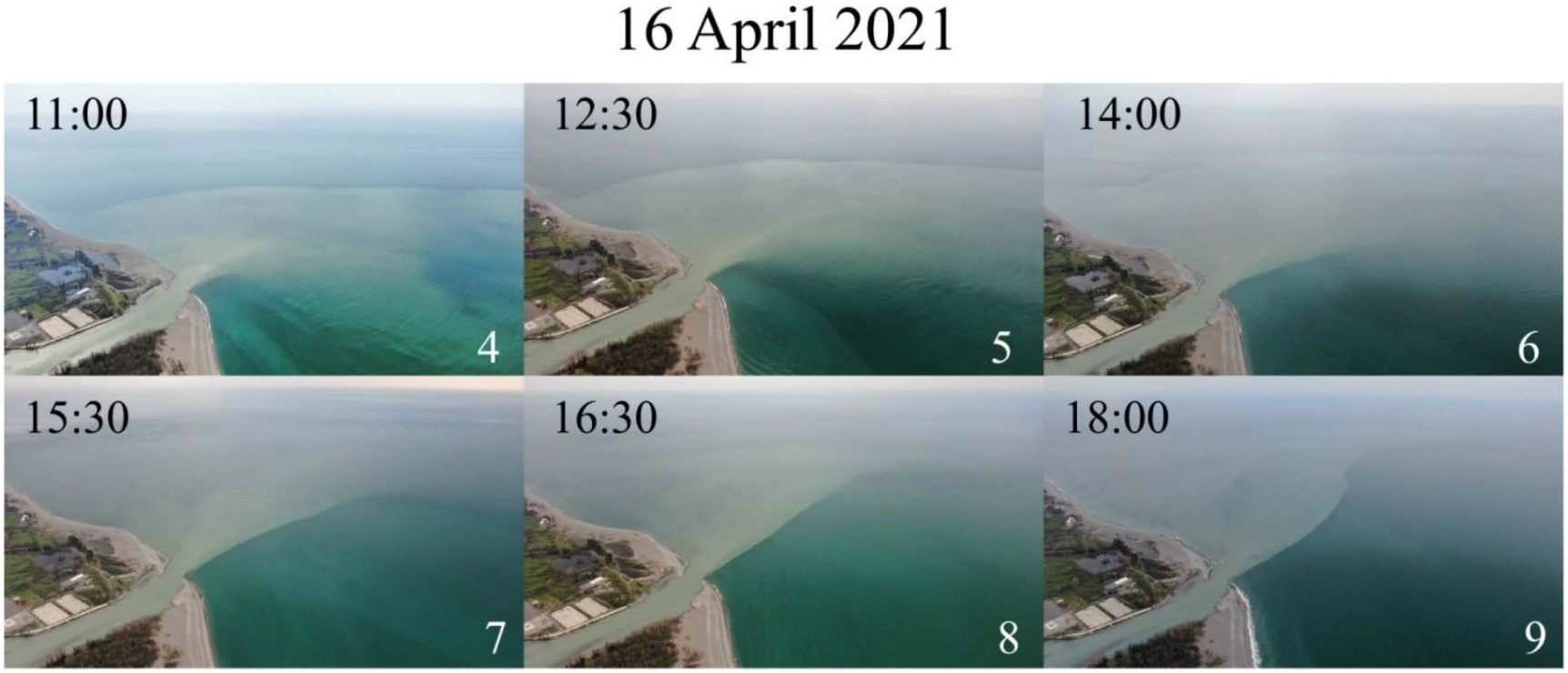
Plume frontal motion



$$V_{plume} = V_{wind} / 20$$

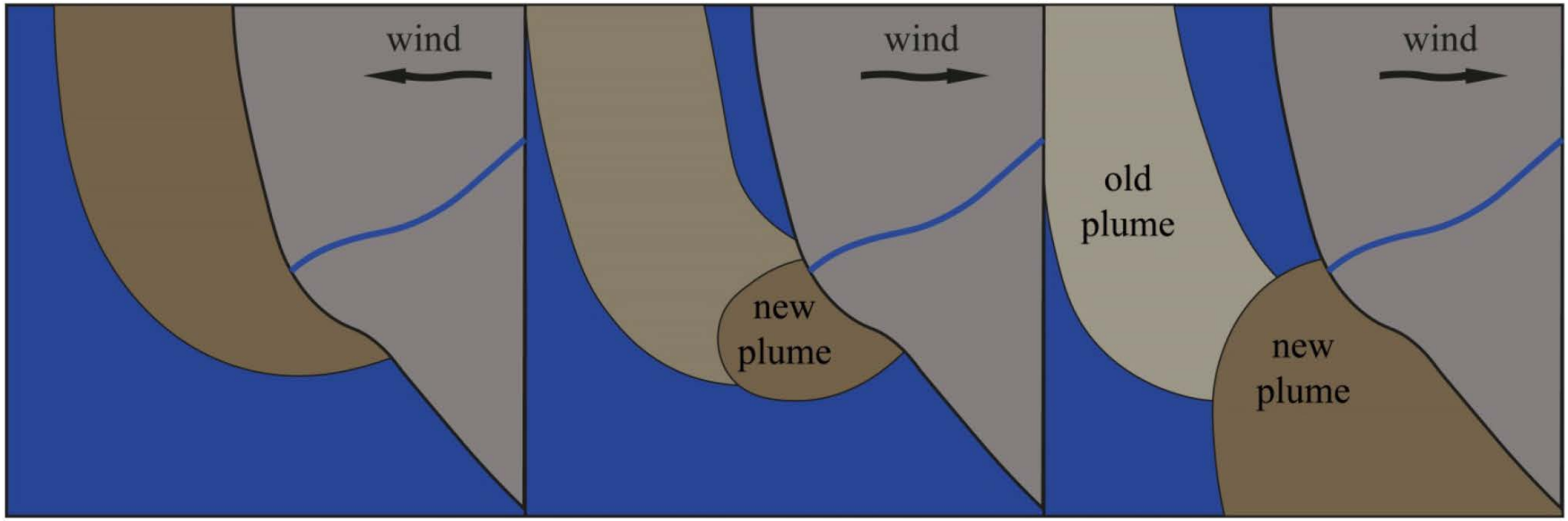
The quick response of the Bzyb plume on wind forcing results in stable linear relation between advection velocity of the plume border and magnitude of zonal wind speed

Plume reversals



Plume reversals were limited to the relatively small near-field area of the plume and did not involve the majority of the far-field part of the plume.
The wind-induced quick plume reversal induces formation of a new plume adjacent to the river mouth rather than changes position of the existing plume.
In particular, the observed area of the Bzyb plume shortly after the northward-southward reversals reduced from 10 to 2.5 km^2.

Plume reversals



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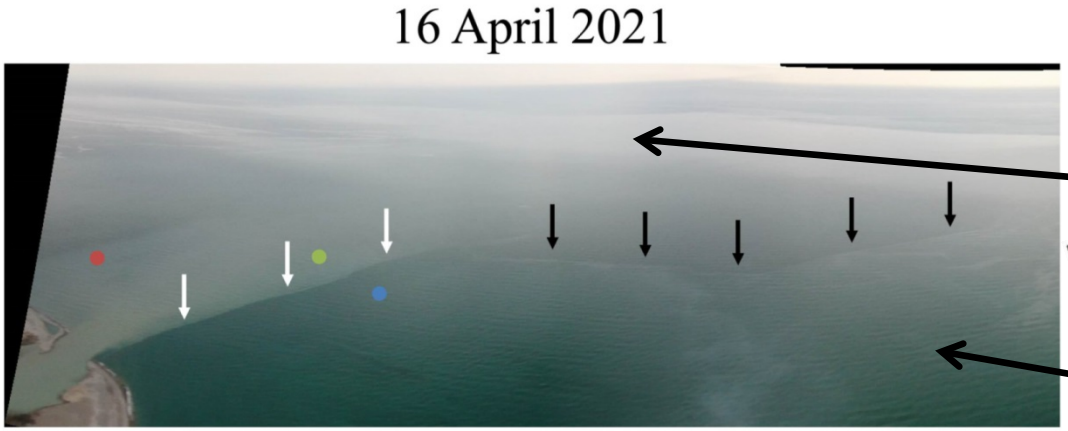

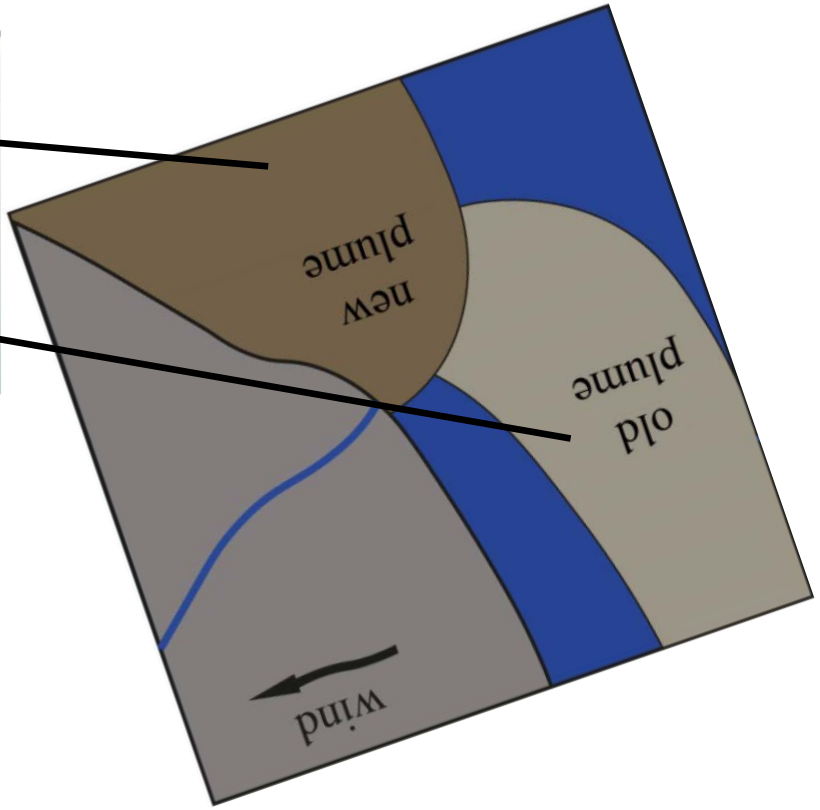

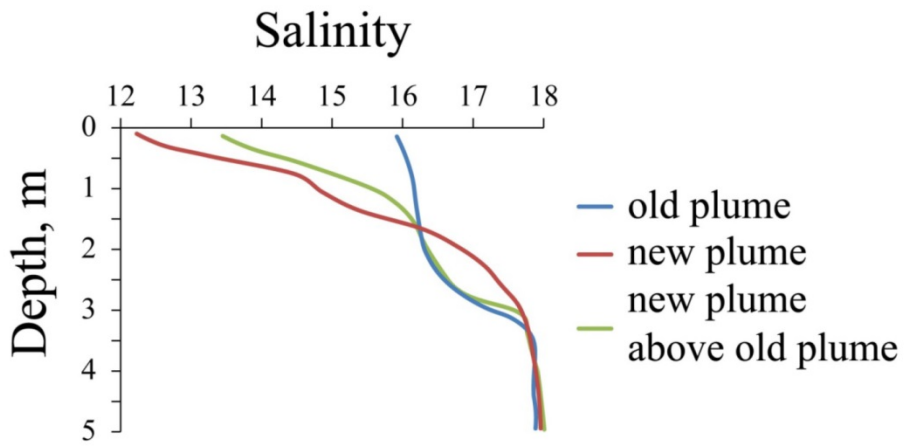

CTD measurements showed dramatic difference in vertical stratification at the old and new plumes that determines difference in their response to wind forcing. The new plume spreading above the old plume forms a three-layered stratification.

Conclusions

1. Very small response time of the small plume spreading dynamics on wind forcing variability: 10-20 minutes

2. Stable linear relation between advection velocity of the plume border and magnitude of zonal wind speed: $V_{plume} = V_{wind} / 20$

3. Variability of wind direction is an important mechanism of detachment of the far-field plume from the river mouth. It strongly intensifies plume mixing

Conclusions

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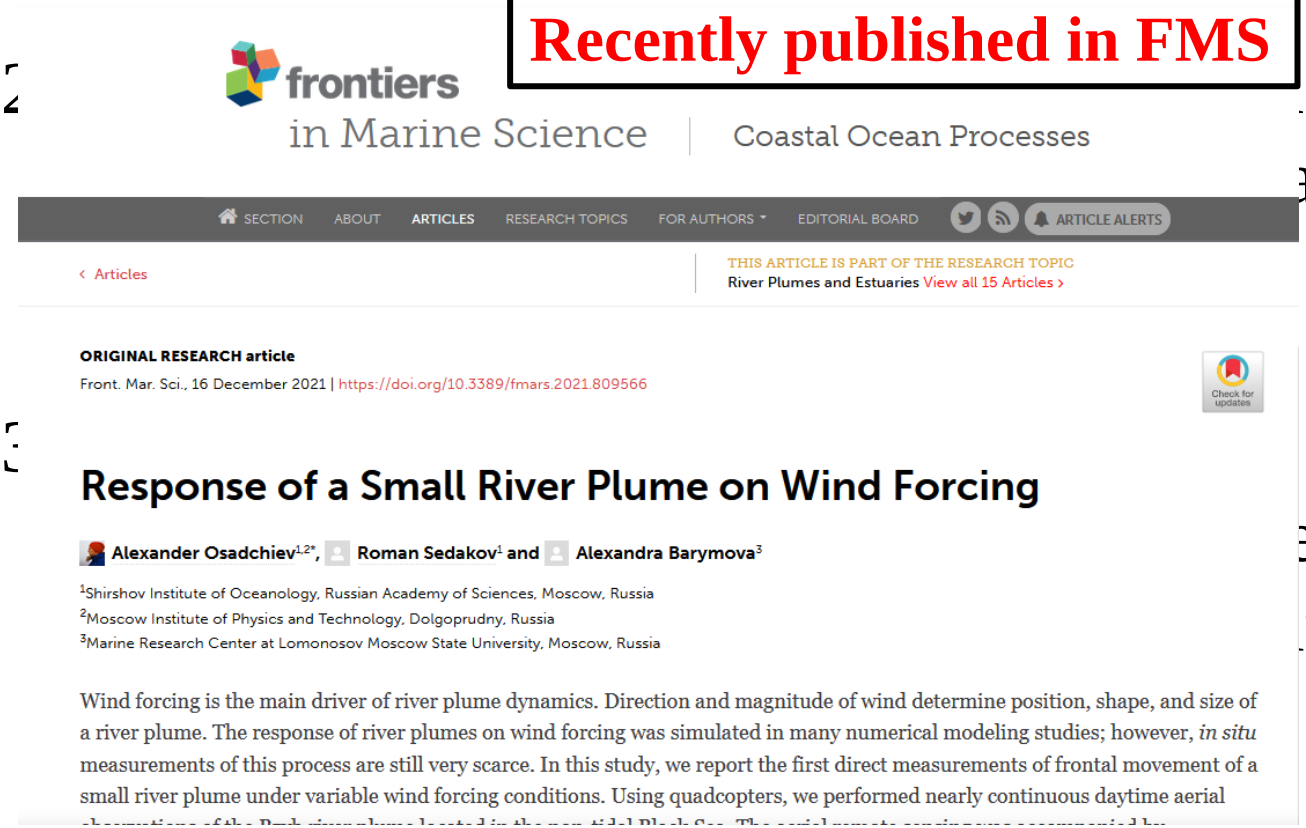

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Response of a Small River Plume on Wind Forcing

Alexander Osadchiev[1,2]*, Roman Sedakov[1] and Alexandra Barymova[3]

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[2]Moscow Institute of Physics and Technology, Dolgoprudny, Russia
[3]Marine Research Center at Lomonosov Moscow State University, Moscow, Russia

Wind forcing is the main driver of river plume dynamics. Direction and magnitude of wind determine position, shape, and size of a river plume. The response of river plumes on wind forcing was simulated in many numerical modeling studies; however, *in situ* measurements of this process are still very scarce. In this study, we report the first direct measurements of frontal movement of a small river plume under variable wind forcing conditions. Using quadcopters, we performed nearly continuous daytime aerial

velocity of the

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Thank you for your attention!