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Compressibility of the surface currents created by nonlinear waves

Last reviewed: 23/8/2011 10:24

Overview

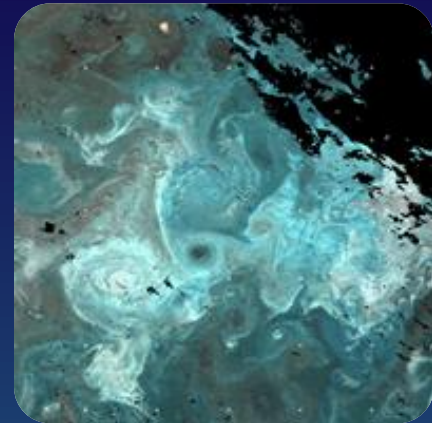
-Knowledge of pollution behaviors and impacts on marine environment is fundamental:

- Better understanding on the environmental responses to pollutants
- Formulate prevention measures

-This knowledge still is sparse and many factors are yet to be taken into account

- We study the effects of compressibility of a two-dimensional velocity field on the transport and mixing of substances floating on the sea surface.

- The most noticeable of these effects is the gathering of floating particles into patches.
- This phenomenon has been studied theoretically and is easily verifiable by direct observation.
- Experimental and numerical evidence about the importance of this phenomenon in marine environment is still scarce.



Compressibility

- Compressibility is defined as the relative weight of the potential component of the velocity field, if the field is decomposed into the solenoidal and potential components (with zero divergence and curl, respectively)
- Compressibility of a velocity field coincides with that of the motion of fluid particles floating in it.
- Compressibility of a fluid is generally nearly 0, hence such fluids are incapable of producing the patchiness of tracers.
- It has been shown that if the compressibility of a velocity field is above the *critical* level of 0.5, passive scalar particles start gathering into patches.
- If we consider only the surface layer though, an exception is due to the capability of particles floating on the surface to 'dive' into the third dimension, raising the average compressibility value of a such defined two-dimensional field.
- This would explain, at least partially the patchiness of floaters in the marine environment.

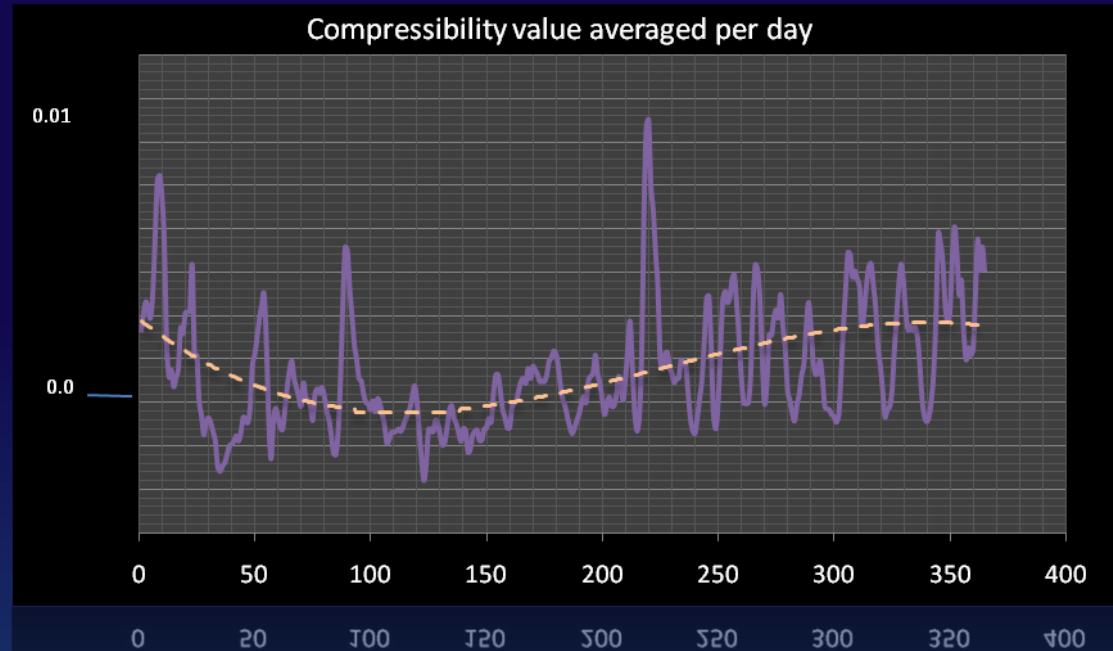
Compressibility

- Since the overall surface area of the sea is constant in time, the average divergence (averaged over the sea surface) is strictly zero.

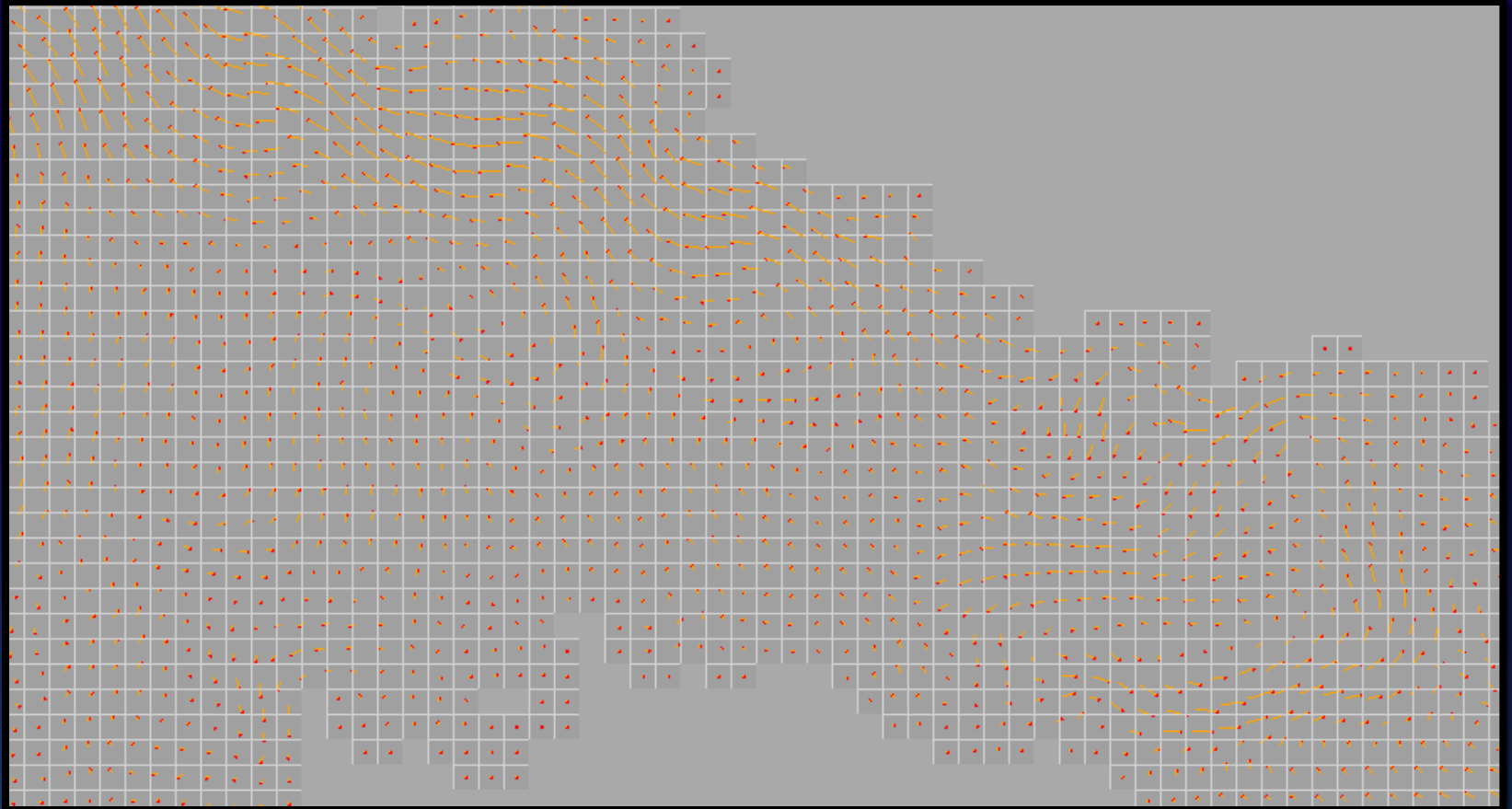
- Floaters though, tend to spend more time in contracting regions than in expanding ones, because the floaters are pushed away from the expanding flows.

- Then, if we show that there exists a non-zero compressibility, particles tend to gather into patches.

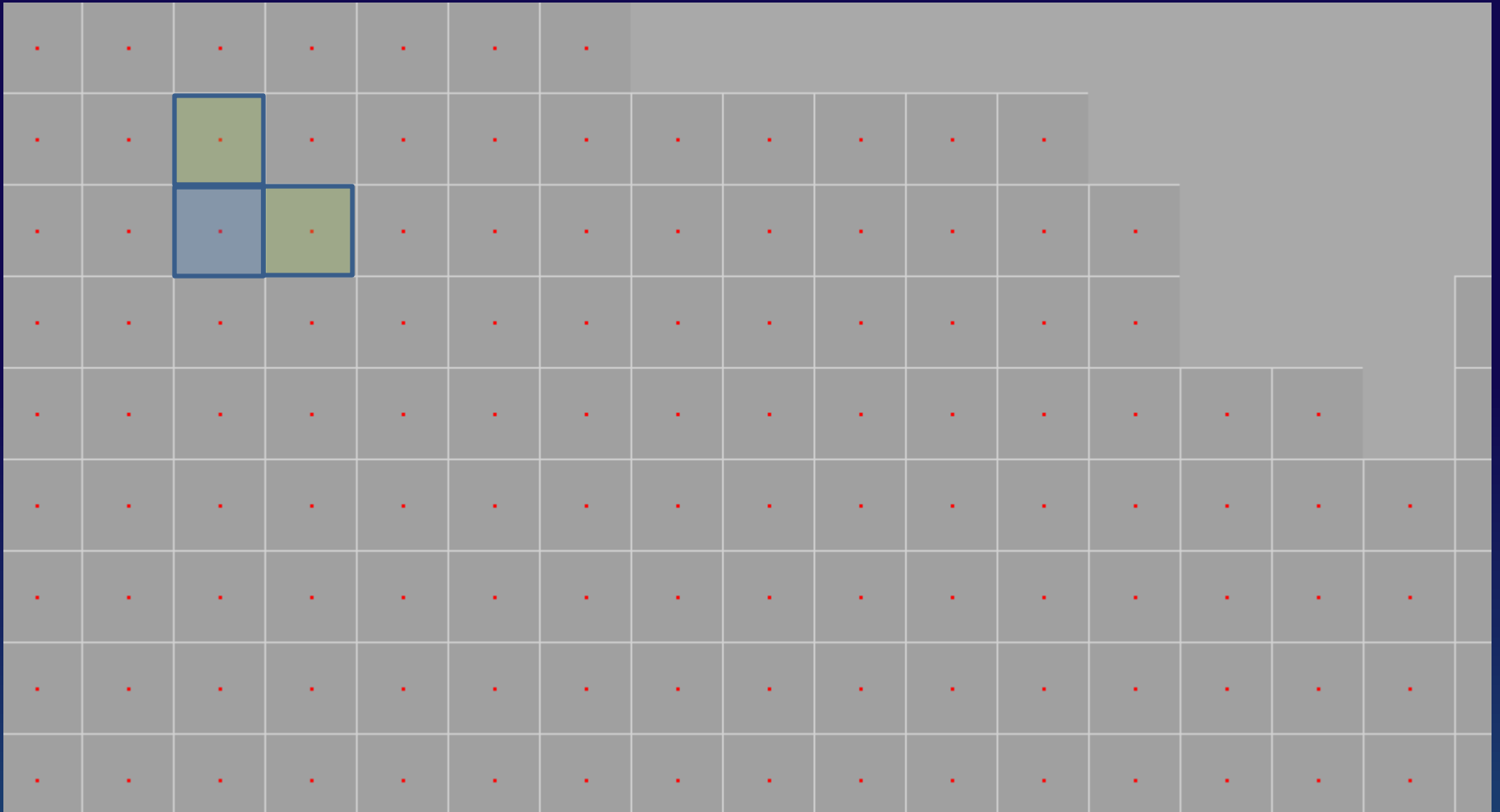
- This compressibility will be shown to exist in the results, and while being not too strong, it should definitely be taken into account.



TRACMASS

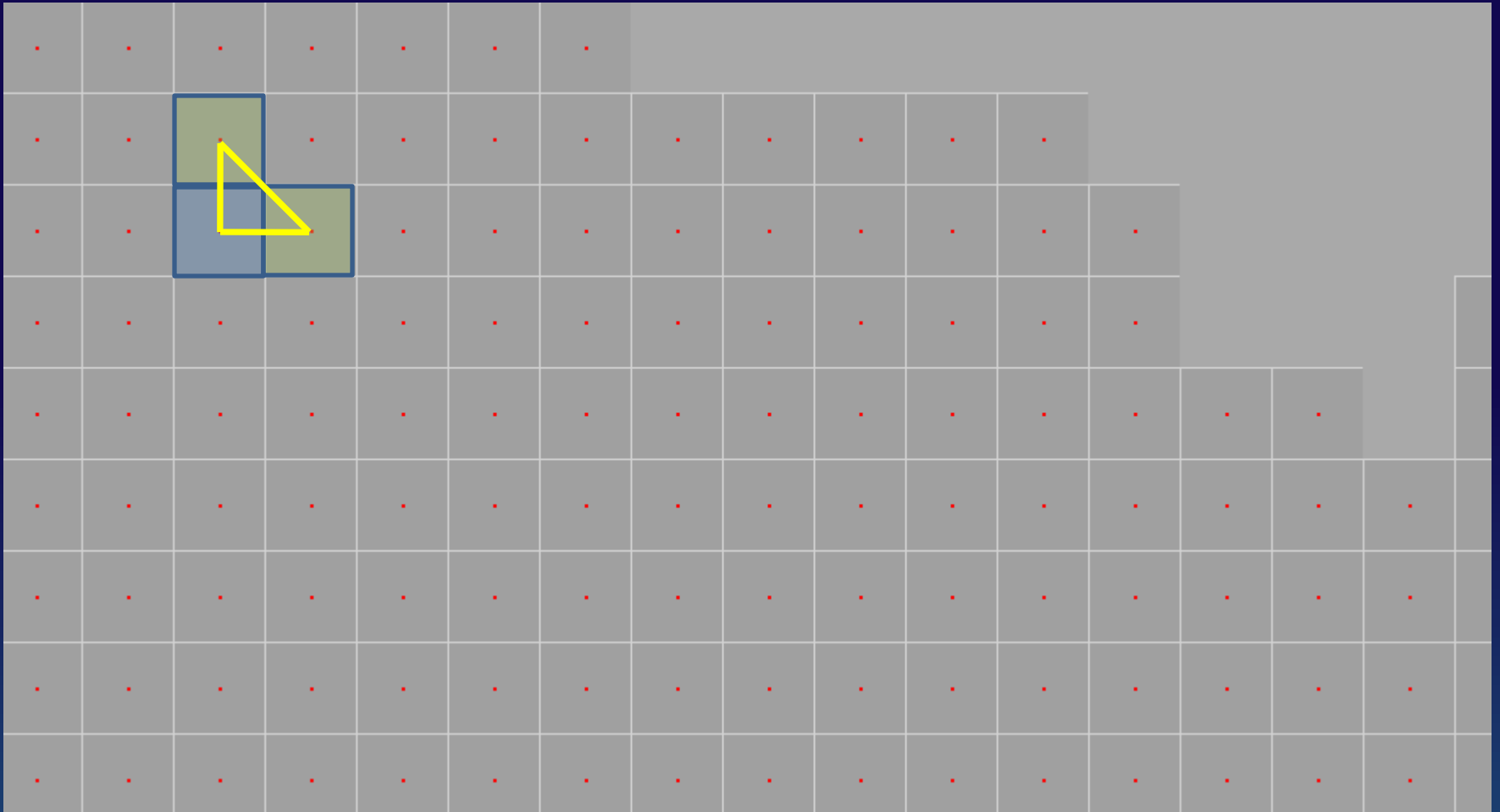


How we did calculations:



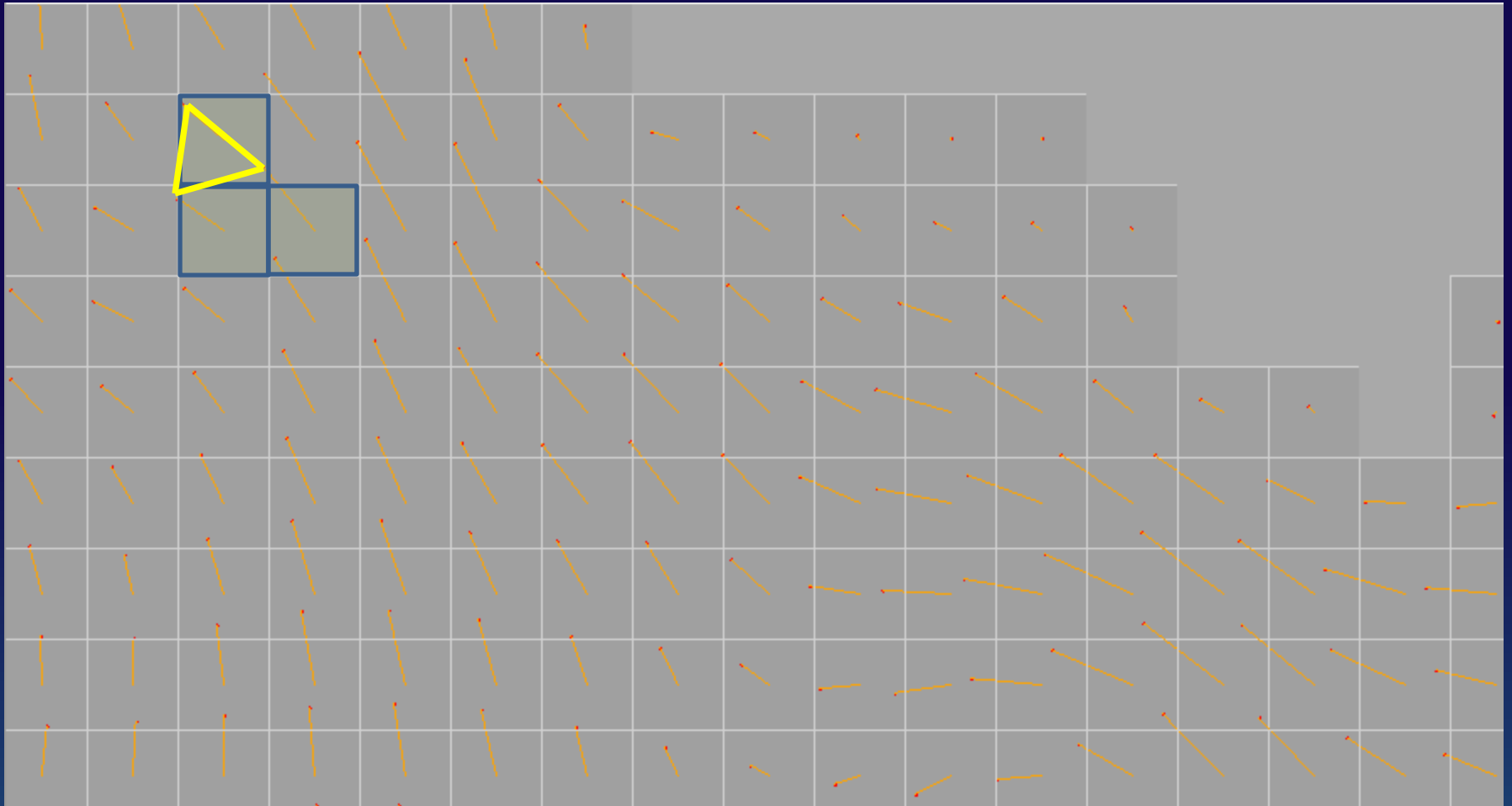
-Let us consider one grid cell, at timestep 0, and find its neighbors, according to some stencil

How we did calculations:



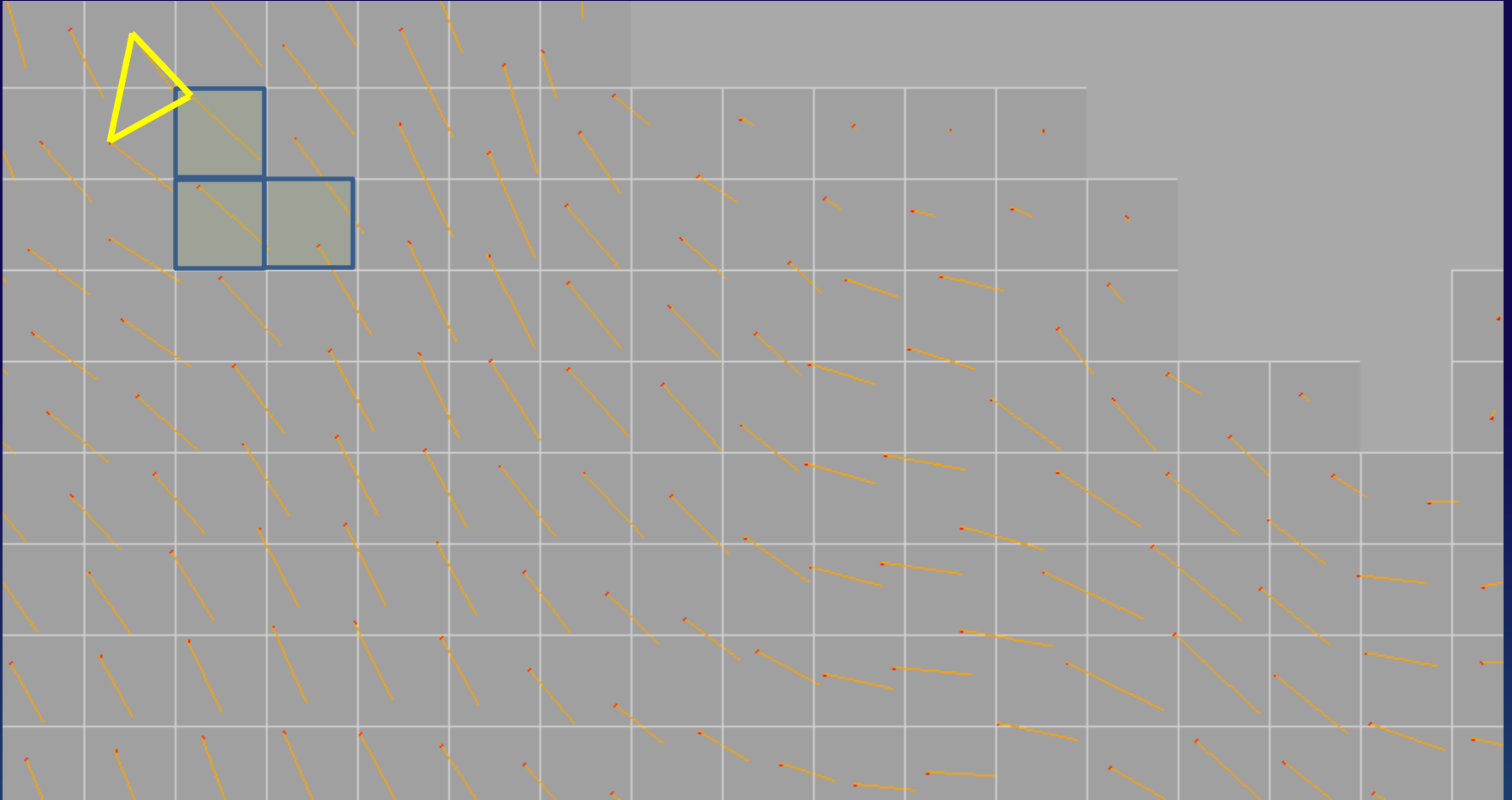
-We define a *Patch* in terms of the properties of triangles.

How we did calculations:



-If we have a look at next timesteps, we observe how this *Patch's* surface changes with time.

How we did calculations:



-If we have a look at next timesteps, we observe how this *Patch's* surface changes with time.

- Compressibility is calculated in this way:

Let us consider the quantity

$$S_t = |(x_1^t - x_2^t) \cdot (y_1^t - y_3^t) - (y_1^t - y_2^t) \cdot (x_1^t - x_3^t)|$$

That's twice the surface of a triangle shown in the previous slide.

The relative change over time of this area is:

$$dS_t = \frac{S_t - S_{t-1}}{S_{t-1}}$$

Let then us consider the squared lengths of two edges of one of the triangles:

$$A_t = (x_1 - x_2)^2 + (y_1 - y_2)^2$$

$$B_t = (x_1 - x_3)^2 + (y_1 - y_3)^2$$

And their respective changes over time:

$$dA_t = \frac{A_t - A_{t-1}}{A_t}, dB_t = \frac{B_t - B_{t-1}}{B_t}$$

Let's then consider the root mean square of these three quantities:

$$dS_{rms} = \sqrt{\frac{\sum_i^n dS_i^2}{n}}$$

$$dA_{rms} = \sqrt{\frac{\sum_i^n A_i^2}{n}}$$

$$dB_{rms} = \sqrt{\frac{\sum_i^n B_i^2}{n}}$$

- We calculate Compressibility as:

$$C = \frac{2 \cdot dS_{rms}}{dA_{rms} + dB_{rms}}$$

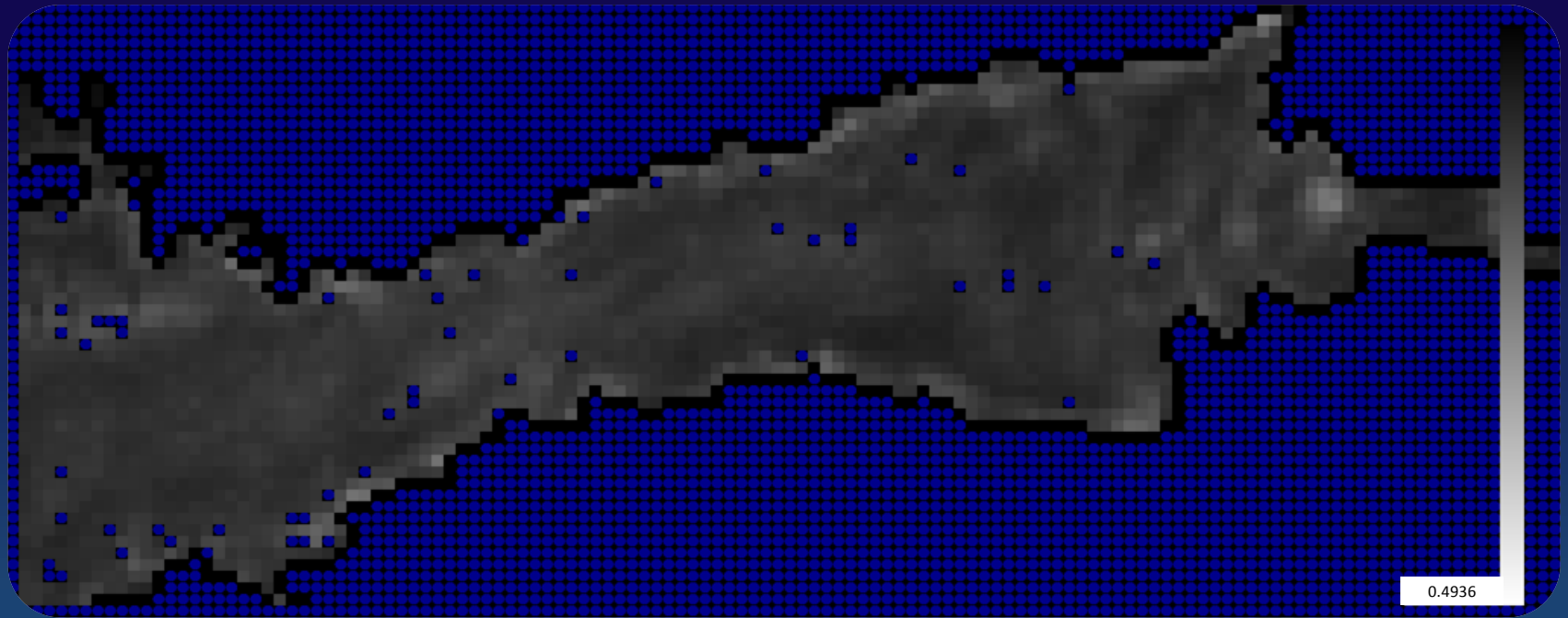
Therefore:

- If the flow is purely incompressible, $dS_{rms} = 0$, and hence $C = 0$
- If the flow is purely contractive or expanding, A or B would change it with the same relative rate as S, so that we would have $C = 1$.
- We would obtain results in the range from 0 to 1, with 1 implying a purely compressible flow.
- The importance of such defined C is that we can use it to predict to which degree the tracer particle will gather into patches.

Results

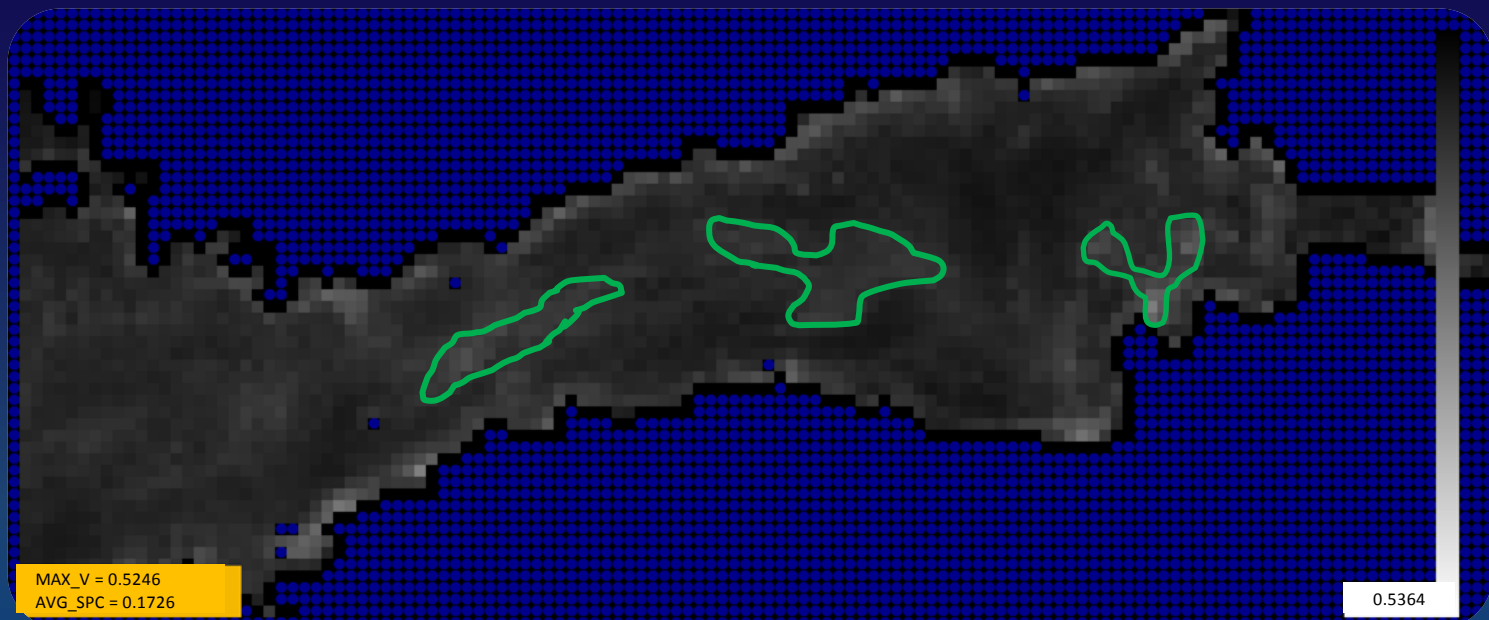
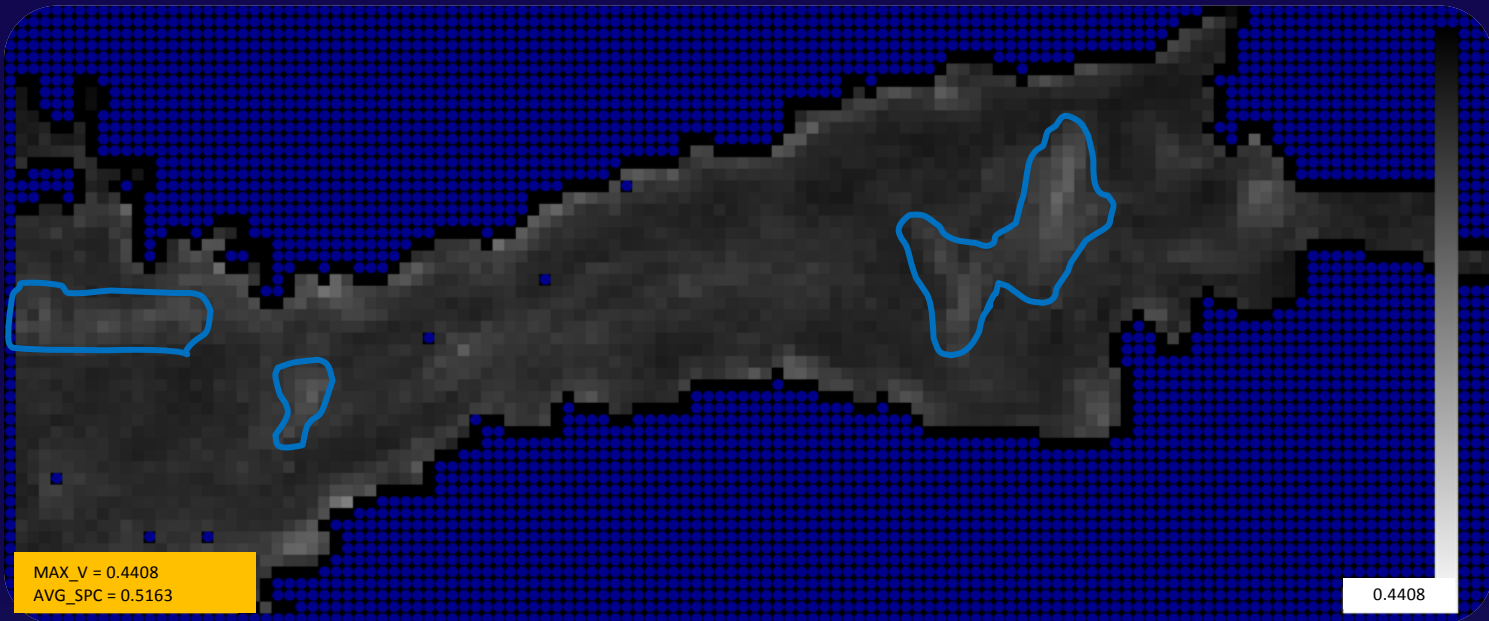
- We use these ideas to produce *Compressibility maps* of the areas of our interest (Gulf of Finland), showing a predictive estimate of the likelihood of tracers inserted into various grid cells to gather patches of floaters
- We averaged these results on a daily, monthly, seasonal, and yearly base.

1991



0.4936174

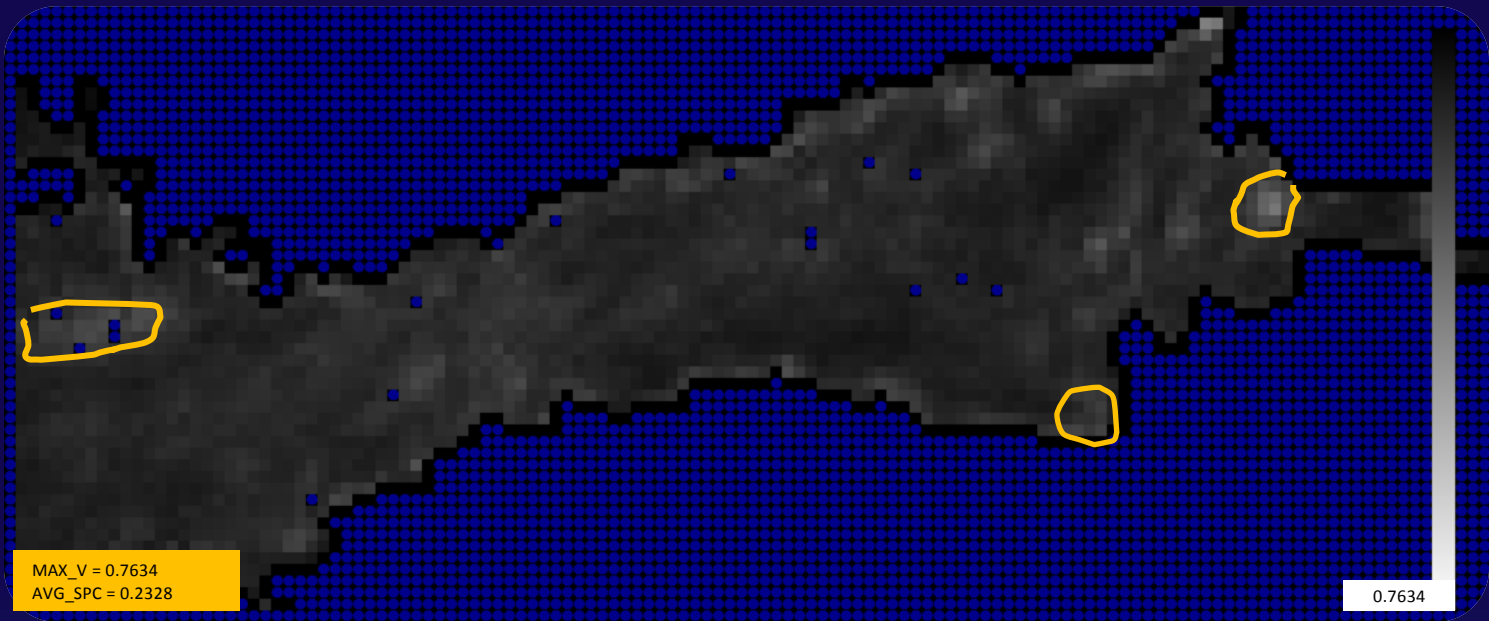
Results



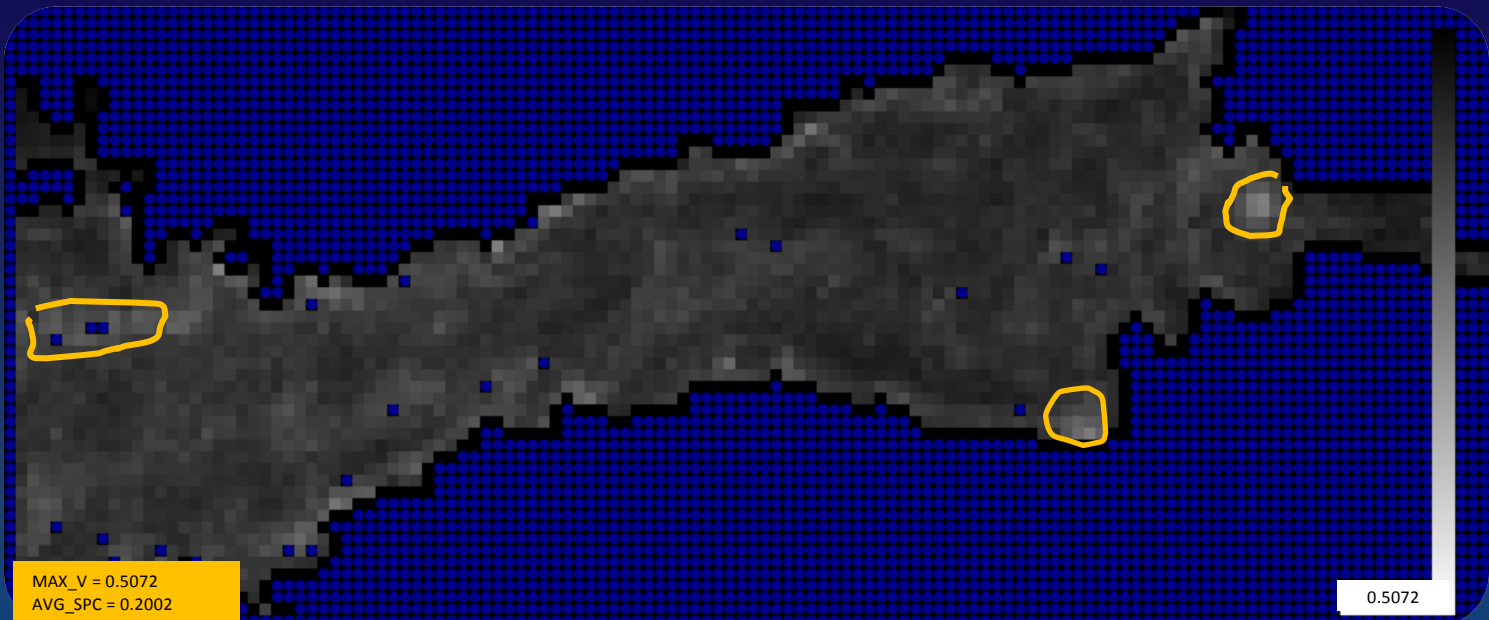
SPACE_AVG 0.1726093
MAX_VALUE 0.5246589

0.5246589

Results



Autumn

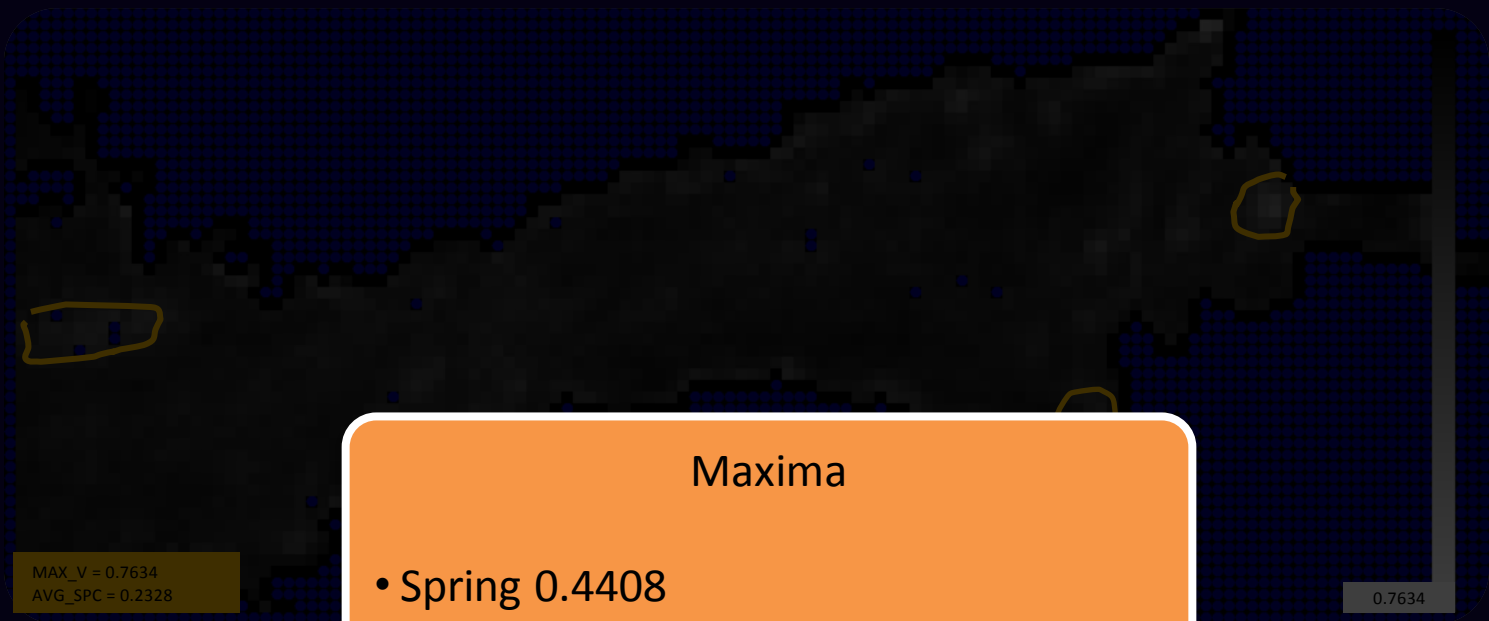


Winter

SPACE_AVG 0.2002441
MAX_VALUE 0.5072833

0.5072833

Results



Maxima

- Spring 0.4408
- Summer 0.5246
- Autumn 0.7634
- Winter 0.5072



Autumn

Winter

Conclusions

- To the best of our knowledge, this is the first study where a compressibility map of a marine region has been calculated.
- Hereby we showed how the spatial variations of the compressibility are fairly strong.
- Typically, regions characterized by significant compressibility (and thus capable of producing tracers patchiness) form stripe shaped patterns close to the shore. This could be either the effect of coastal currents or regular up/downwelling events.
- This study does not cover compressibility of small-scale structures ($<2\text{nm}$), which can greatly enhance the effect of patchiness and will be the subject of further studies.



Thank you



Спасибо



Aitäh



Grazie



Kiitos

