A dynamic system theory approach to identify contaminant trapping zones in Vembanad Estuary using Lagrangian Coherent structures

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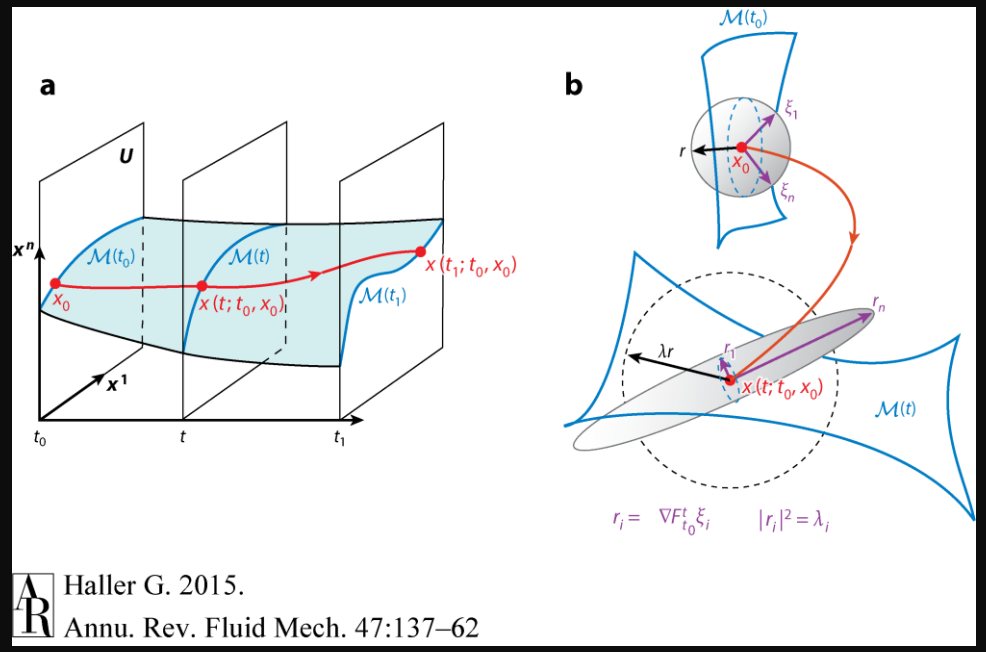
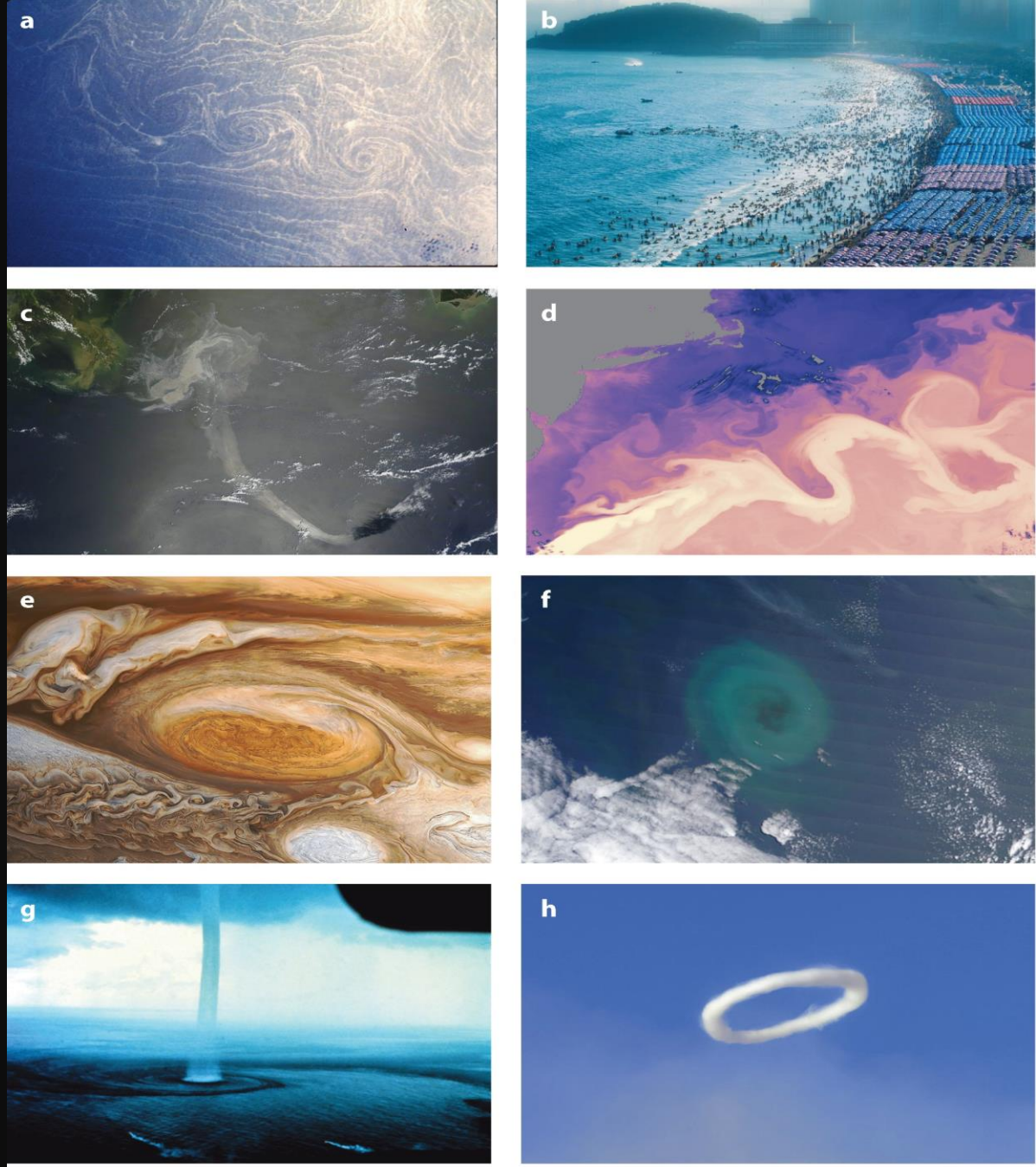
Lagrangian Coherent Structures



Haller G. 2015.
Annu. Rev. Fluid Mech. 47:137–62



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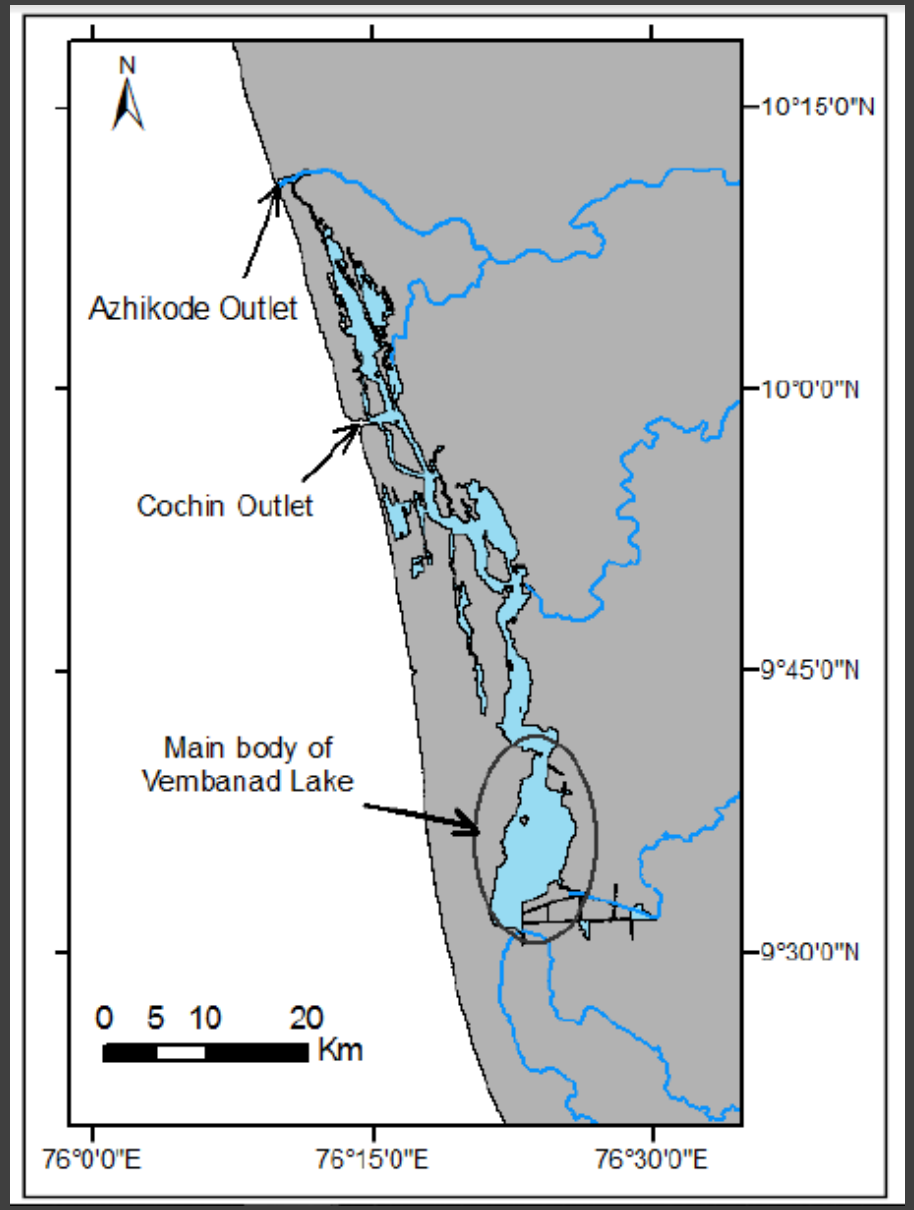
Vembanad Lake

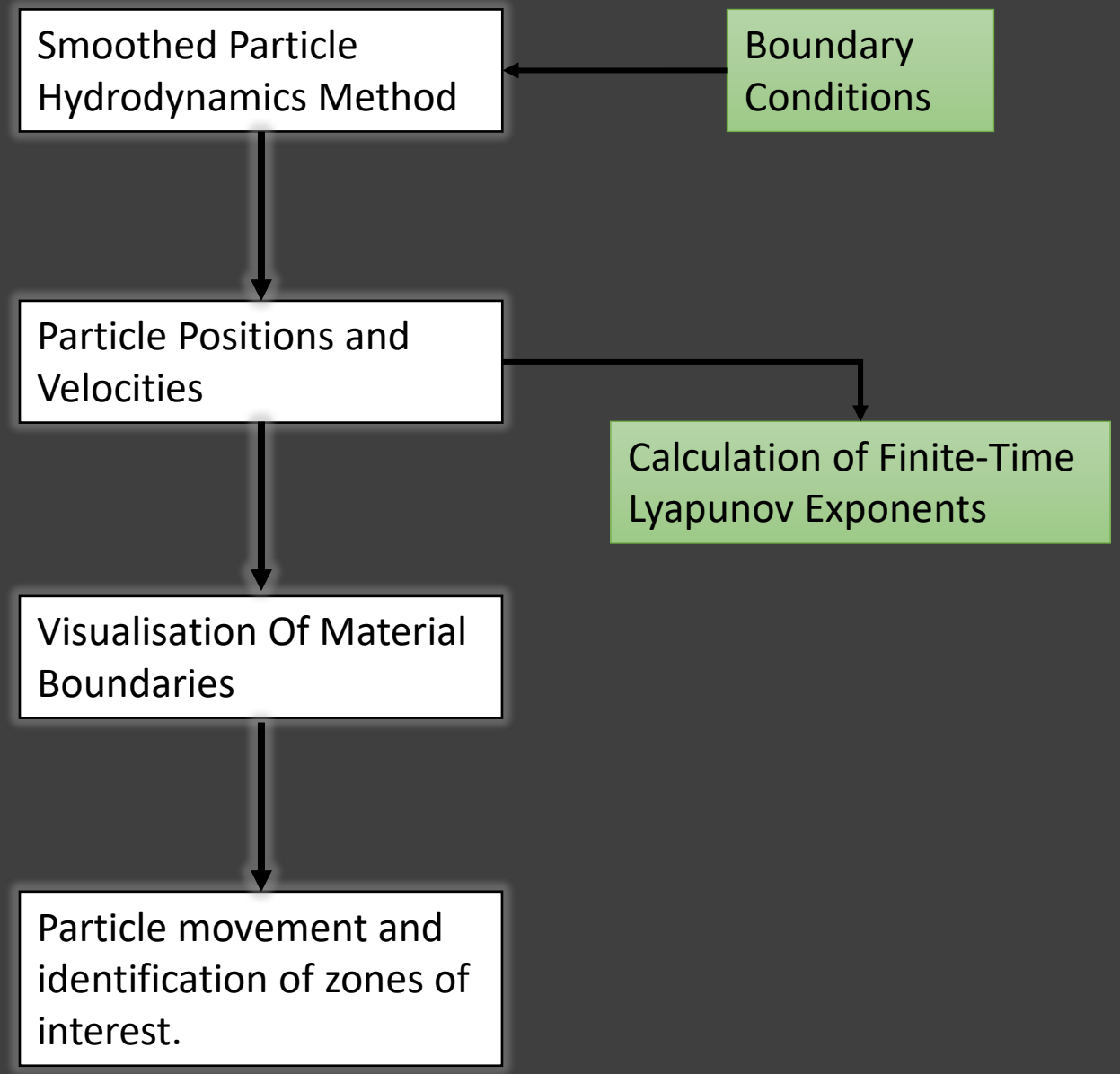
The Vembanad Lake lies in the south of India, in the state of Kerala, The area of the wetland is 1512.5 sq. km.

The lake is fed by six major rivers of central Kerala namely the Achenkovil, Manimala, Meenachil, Muvattupuzha, Pamba, and Periyar.

Main islands include Vypin, Mulavukad, Vallarpadam, and Willingdon Island.

Kochi Port is built around the Willingdon Island, and the Vallarpadam island.

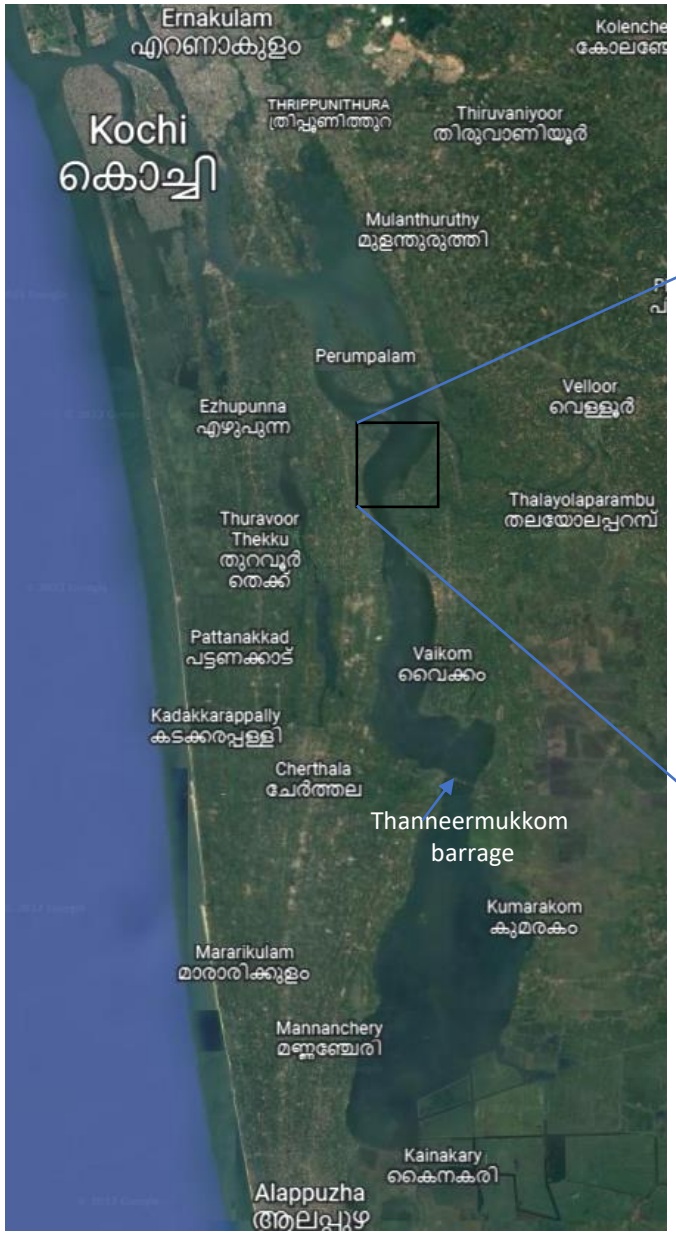


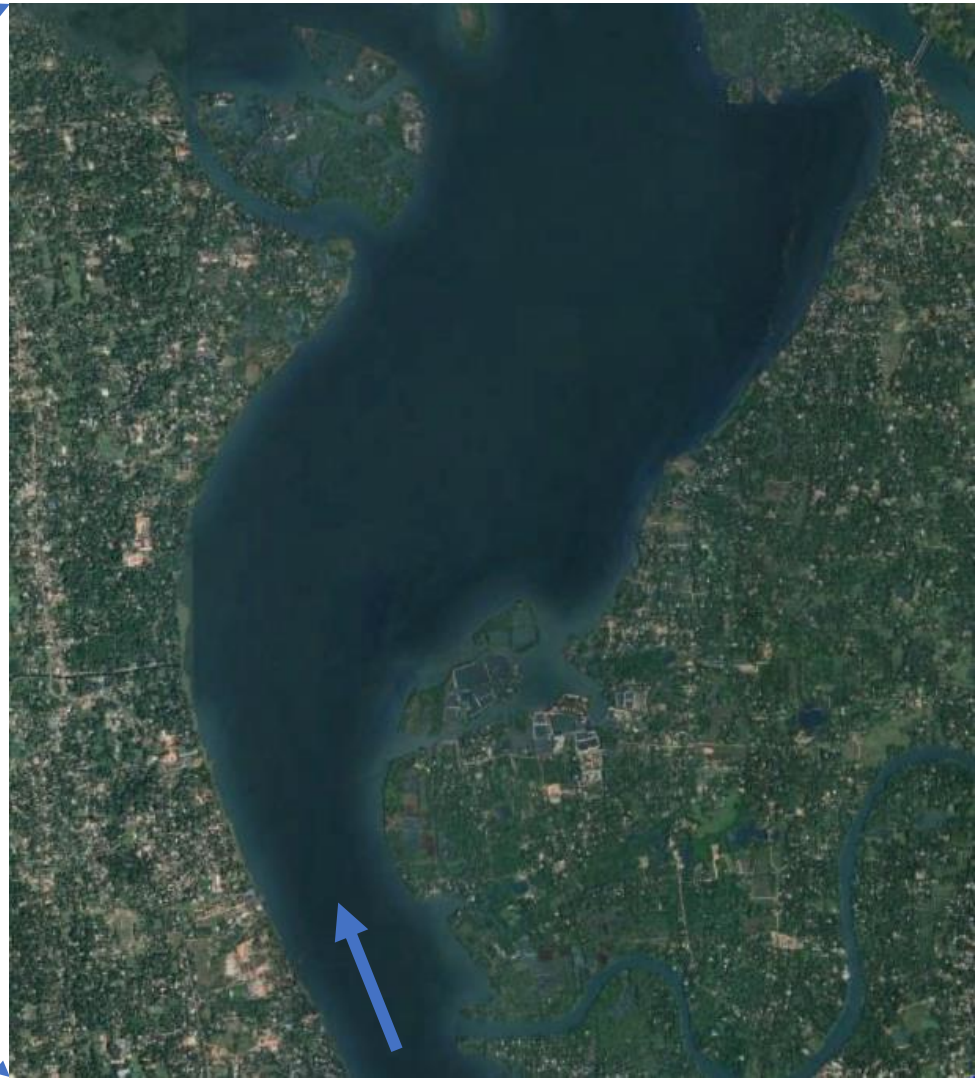


Methodology

Vembanad Lake

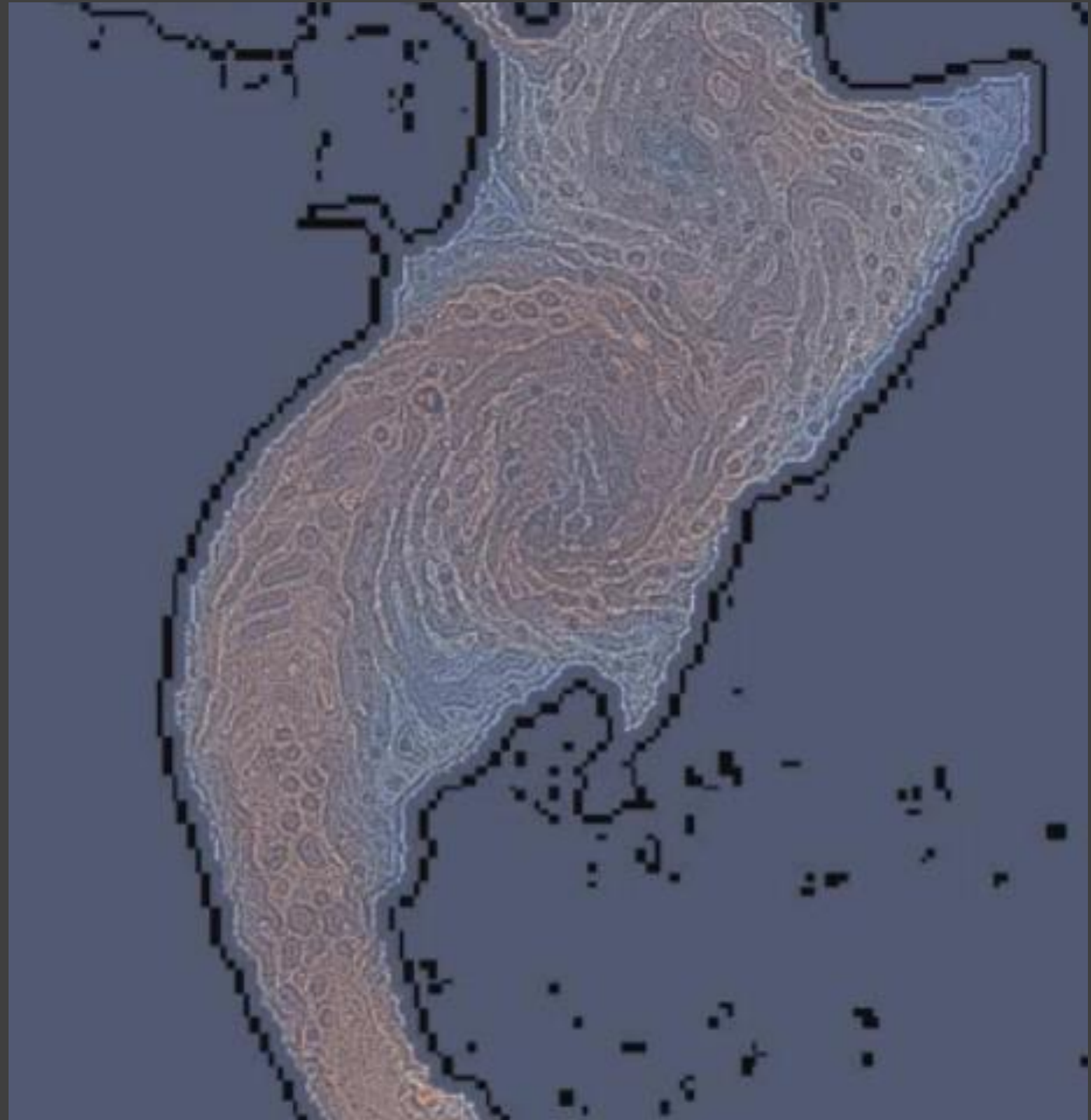
Section under consideration is located north of Vaikom and south of Perumpalam island





Flow in the section is toward north

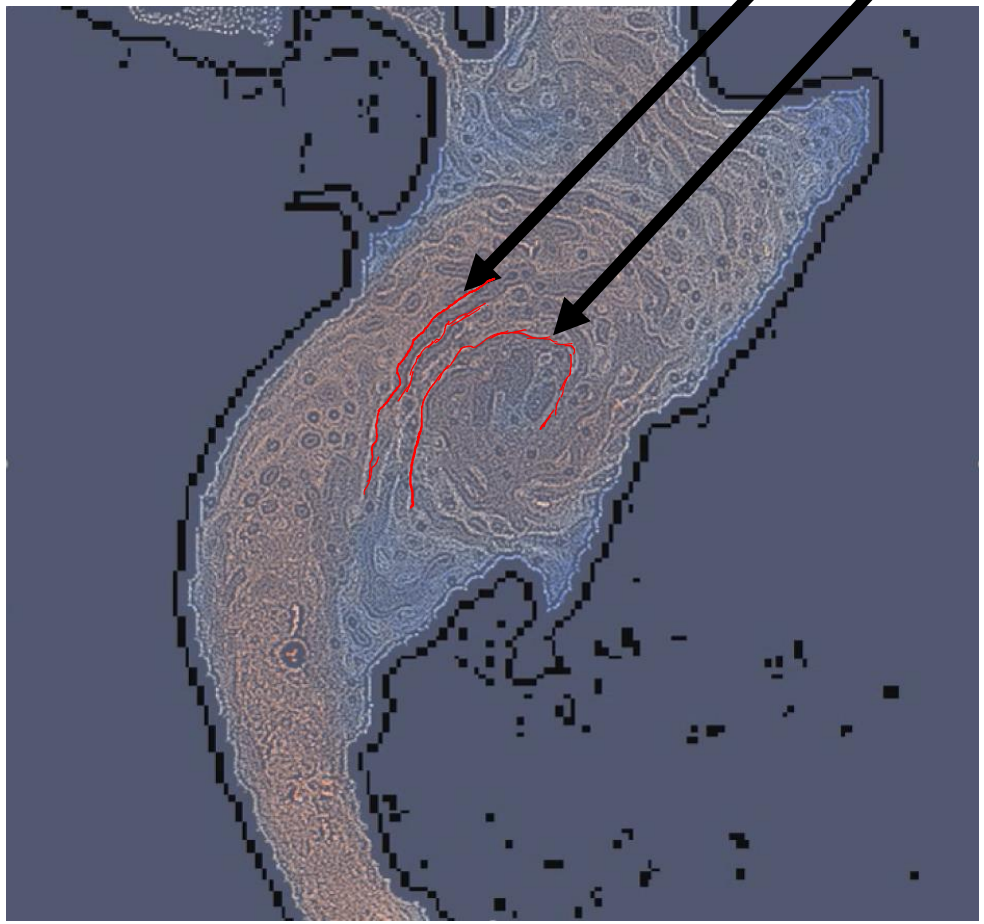
Simulation Results



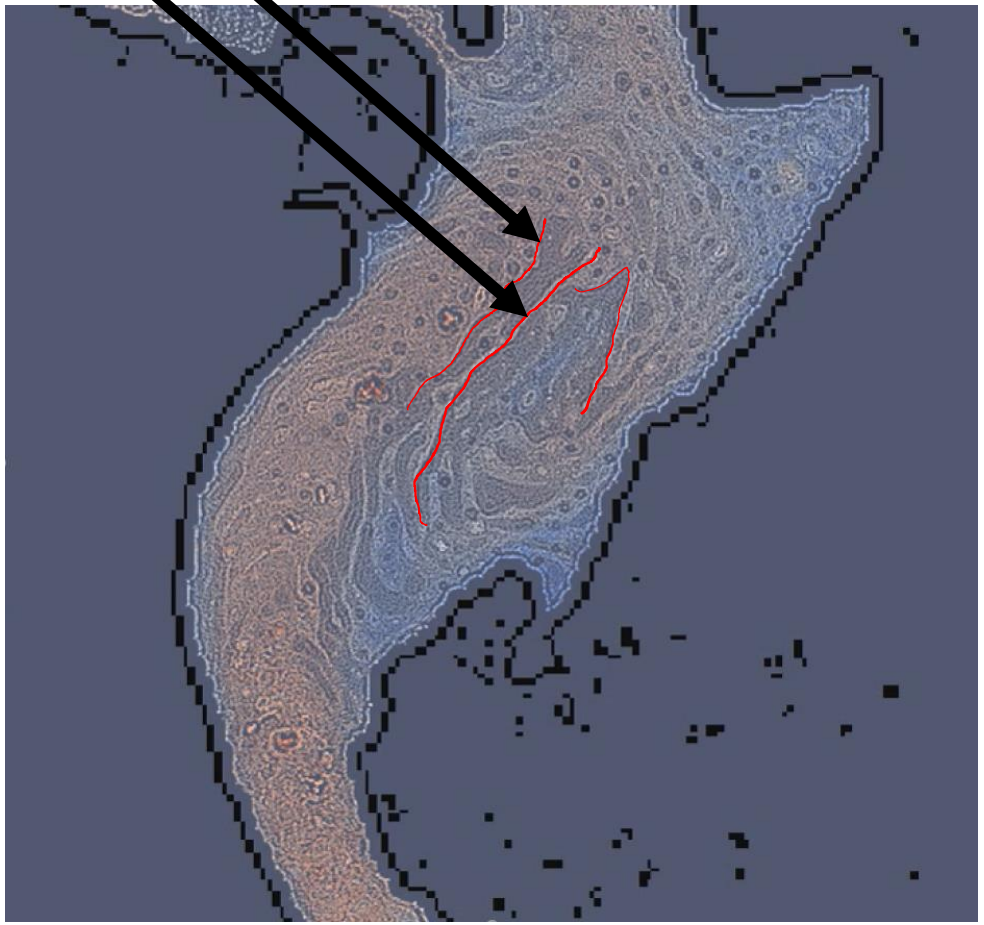
Simulation Results

Material Line present in the system

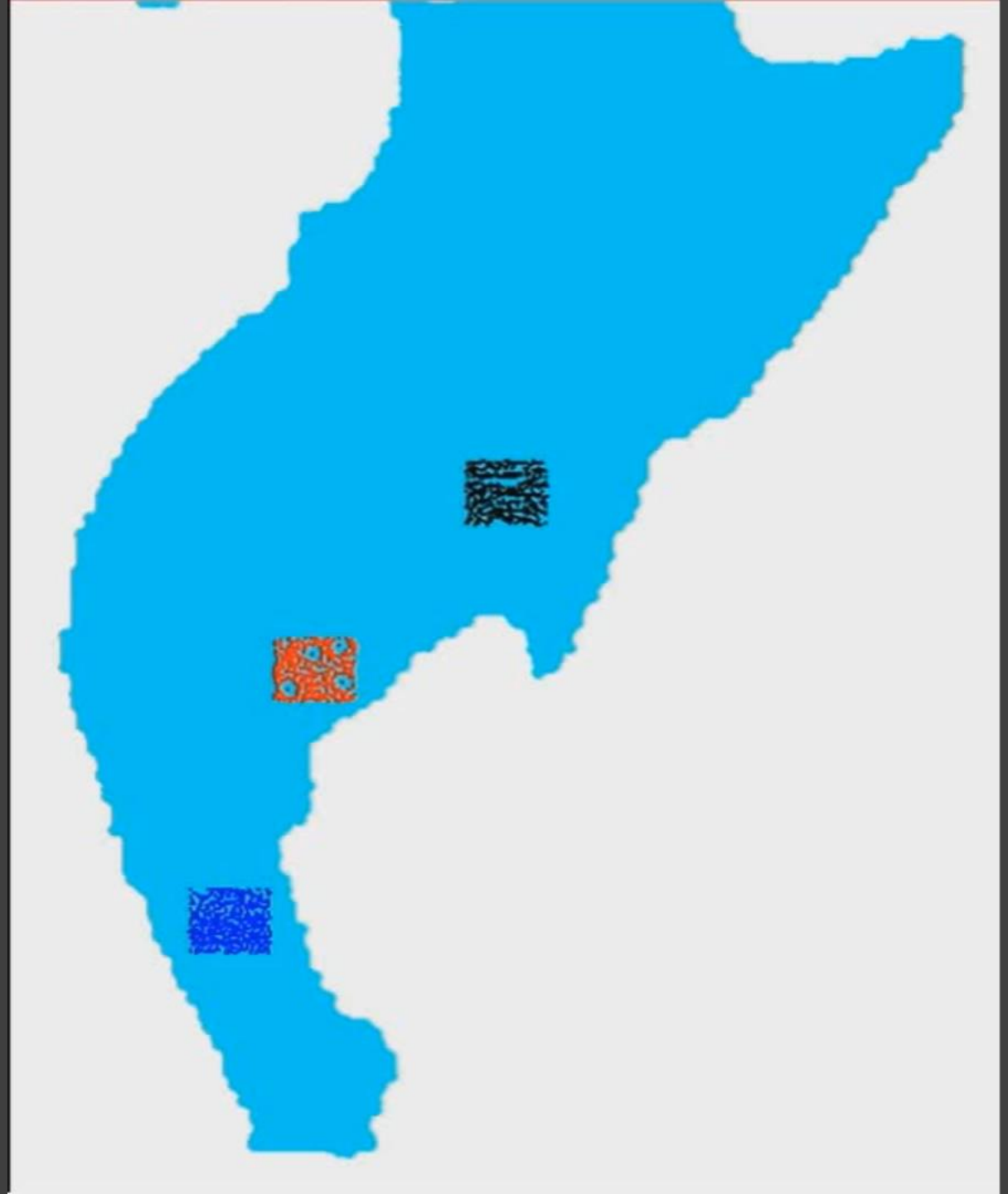
At t = 7.5 sec



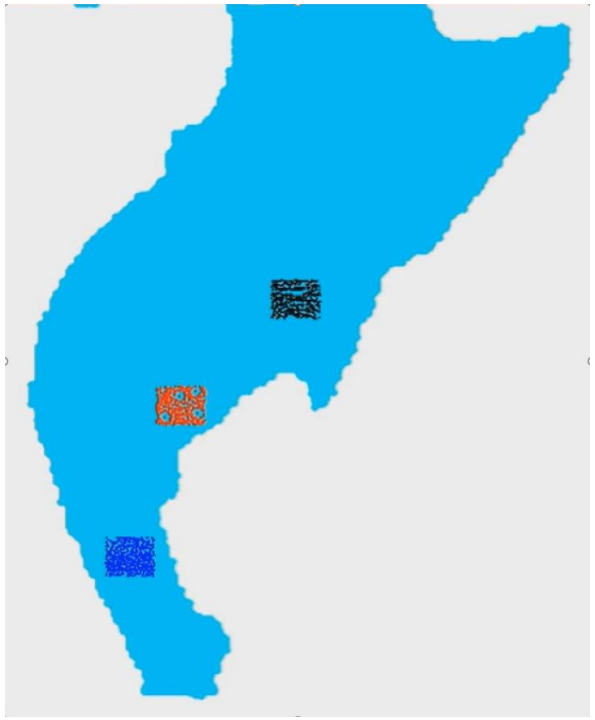
At t = 31.5 sec



Movement of Particle Patches in the Simulated Region

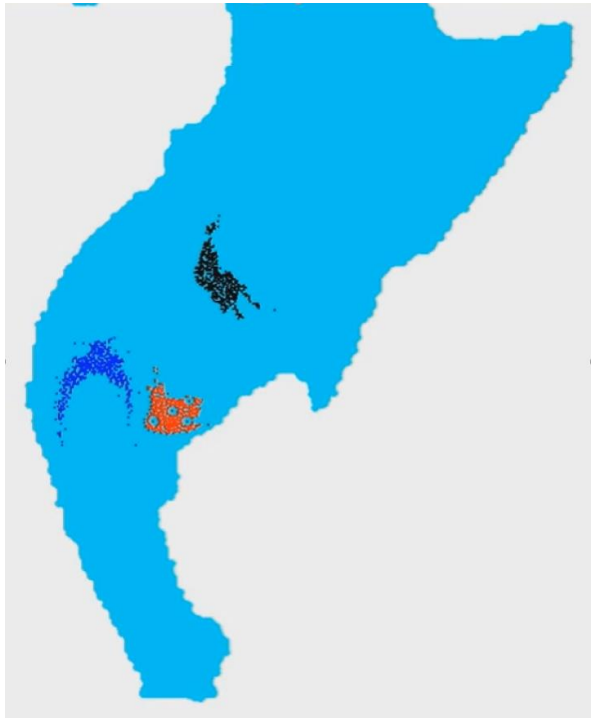


Simulation Results



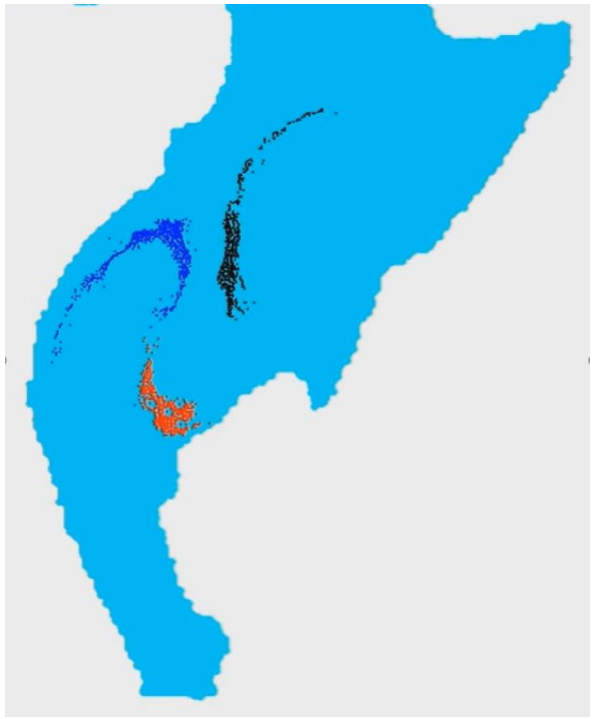
At t = 0 sec

- Initial condition
- Three Patches are initialized at different locations to see the behaviour of particles of different regions



At t = 6.89 sec

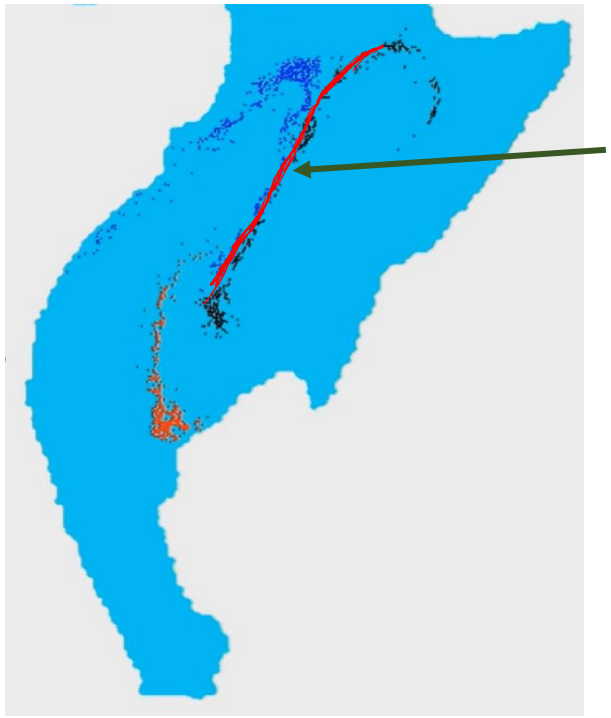
- Initial observation shows that the blue patch is relatively faster than the other patches
- The blue patch also exhibits the behaviour of classical velocity profile in an open channel flow
- Orange patch has very low velocity



At t = 13.41 sec

- Blue patch maintains its velocity profile.
- Black patch shows signs of large stretching which suggest its position close to a Lagrangian Coherent Structure.
- Orange patch still very low movement.

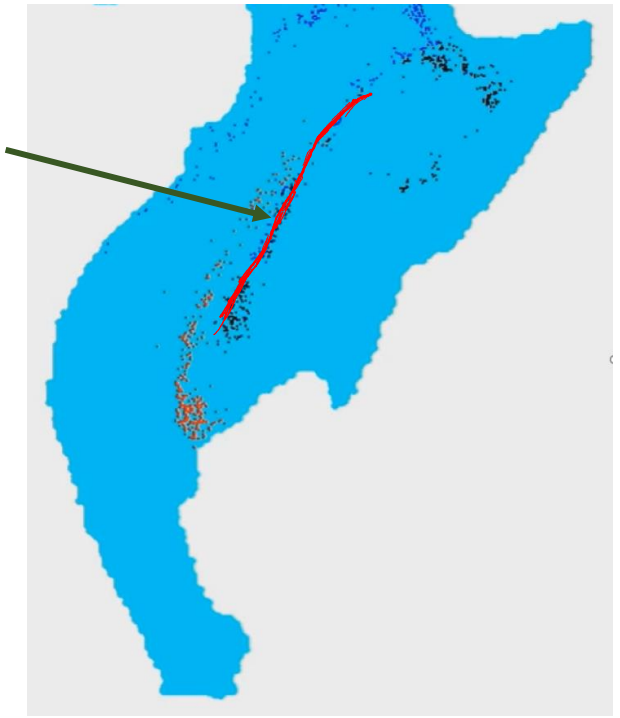
Simulation Results



At t = 22.50 sec

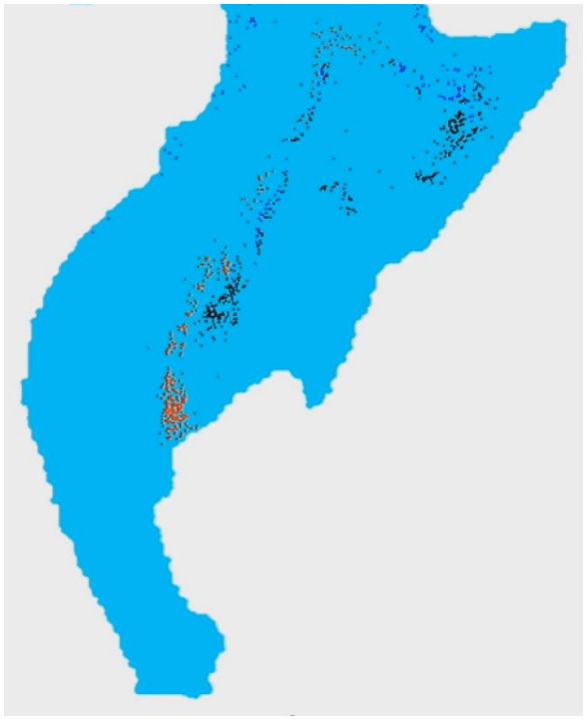
- Part of Blue patch and the black patch is stretched along the same line which confirms the presence of LCS.
- Little Stretching can also be seen in Orange patch which is also moving towards the plotted line.

Dynamics Boundary



At t = 32.23 sec

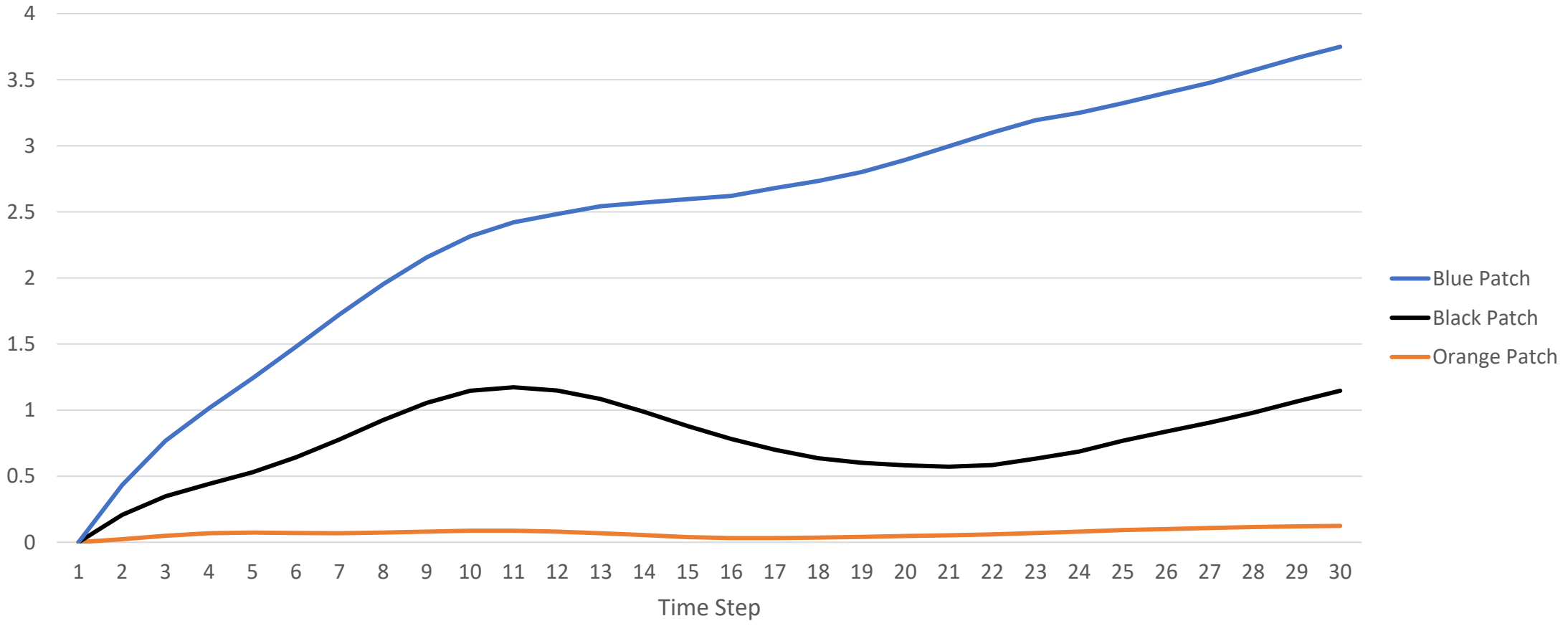
- Most of the particles of Blue patch have left the system.
- Stretching in the orange patch along the same plotted line can be seen.
- Large number of particles of Orange Patch are still at their initial positions.



At t = 40.49 sec

- The simulation shows that the section can be divided into two sections separated by a dynamic boundary.
- The movement of the particle show very different behaviour in both of these regions.

Average Displacements of Patches with respect to time of simulation

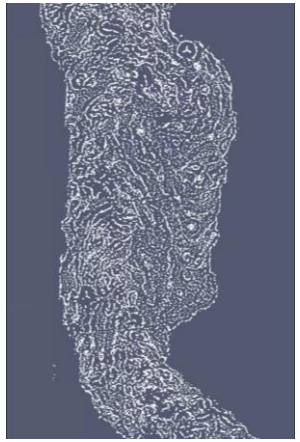


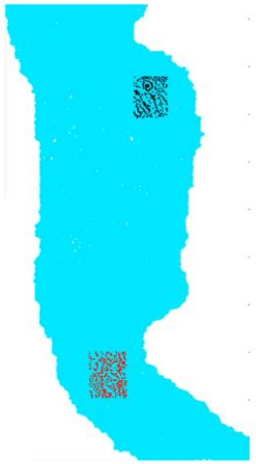
Other Section

Vembanad Lake

The section under consideration is located on the left side of Perumpalam Island

Flow in the section is toward the north

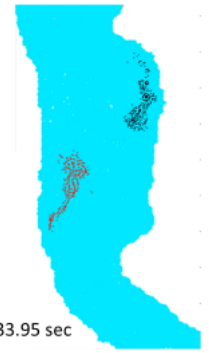




Simulation Results

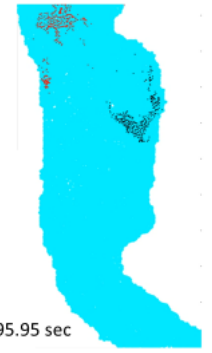
At t = 0 sec

- Initial condition
- Three Patches are initialized at different locations to see the behaviour of particles of different regions



At t = 33.95 sec

- The patch is moving towards north while black is moving towards south
- Stretching in the patches can also be observed



At t = 95.95 sec

- Red patch is about to leave the considered area while the black patch moved relatively away from the end of the considered section
- The velocities around black patch are also very low which can cause sedimentation in that area.

Conclusion

- LCS affects the flow of hydrodynamics in open-channel.
- Particle trapping for non-inertial particles* in a system.
- Correlation between sediment deposition patterns and LCS.
- Effect of LCS on inertial particles^?

*Non-inertial Particles are those whose influence on the movement of water particles can be neglected.
^Inertial Particles are those whose influence on the movement of water particles can not be neglected.

References

1. Haller, G. (2015). Lagrangian coherent structures. *Annual Review of Fluid Mechanics*, 47, 137-162.
2. Monaghan, J. J. (1994). Simulating free surface flows with SPH. *Journal of computational physics*, *110*(2), 399-406.
3. Meron, E., & Procaccia, I. (1986). Theory of chaos in surface waves: The reduction from hydrodynamics to few-dimensional dynamics. *Physical review letters*, *56*(13), 1323.
4. Onu, K., Huhn, F., & Haller, G. (2015). LCS Tool: A computational platform for Lagrangian coherent structures. *Journal of Computational Science*, *7*, 26-36.

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