A quantitative management tool reflecting impact of nutrient enrichment from mariculture in the Levantine basin

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Acknowledgments:

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Photo: Dalit Roth-Rosenberg

Background

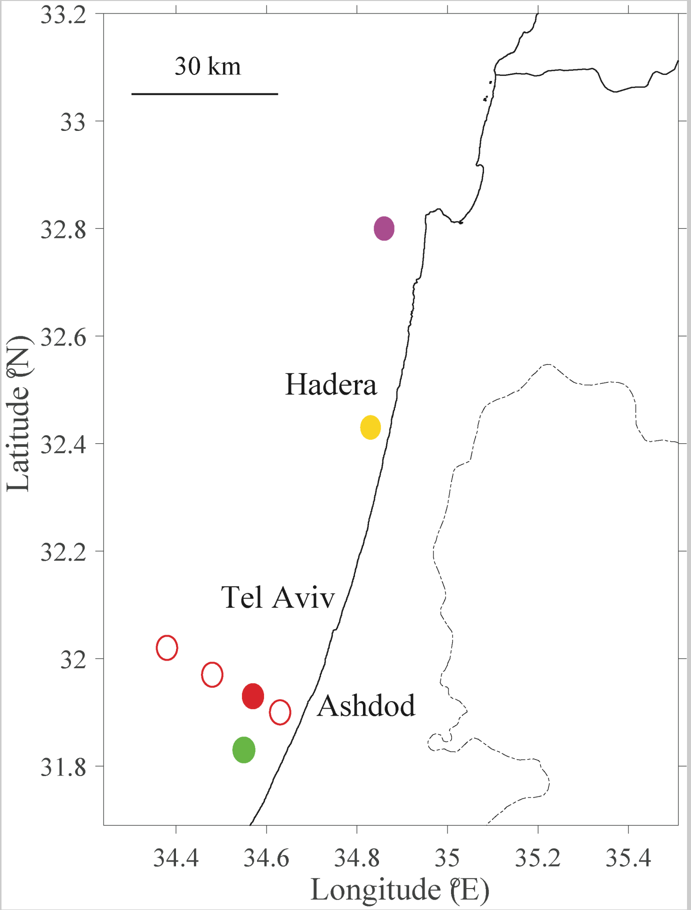
- In Israel, **100,000 tons** of fish are consumed yearly (MOAG, 2015)
- About ¼ is being supplied by the local fishing industry and aquaculture/mariculture facilities and the rest is imported
- Many advantages to mariculture (fresh fishes, jobs, efficient compared with other livestocks, carbon footprint….)

But:
Fish farms are a source of nutrients and antibiotics to the water column, hence, can affect strategically important shoreline areas (such as desalination plants) and the ecosystem

Considerations when planning mariculture farms

- Distance of the farm from shore
- Few small and scattered farms vs. a big one
- Water origin of strategically important coastal areas. Which areas should not be frmed?

We focus on environmental effects, neglecting logistical advantages etc.



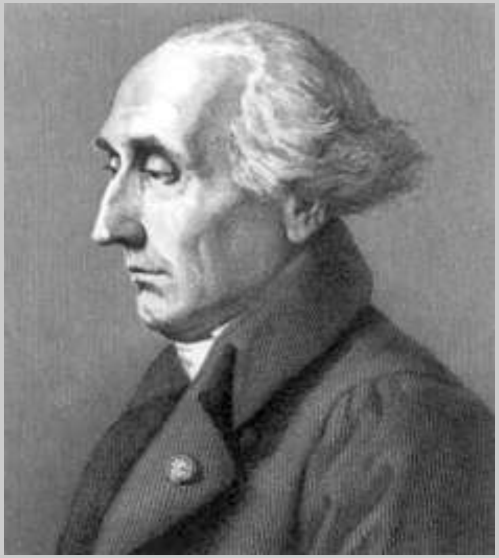
A quick and dirty guide to chaotic mixing and Lagrangian particle tracking

Two methods to observe and analyze fluid flows

Euler

Eulerian viewpoints: observing the velocity and other variables at fixed positions.

Lagrange



Lagrangian viewpoint: observing the trajectories and velocities of specific fluid parcels.

Think of measuring the temperature with a drifter or a mooring

Fluid mixing - kinematics

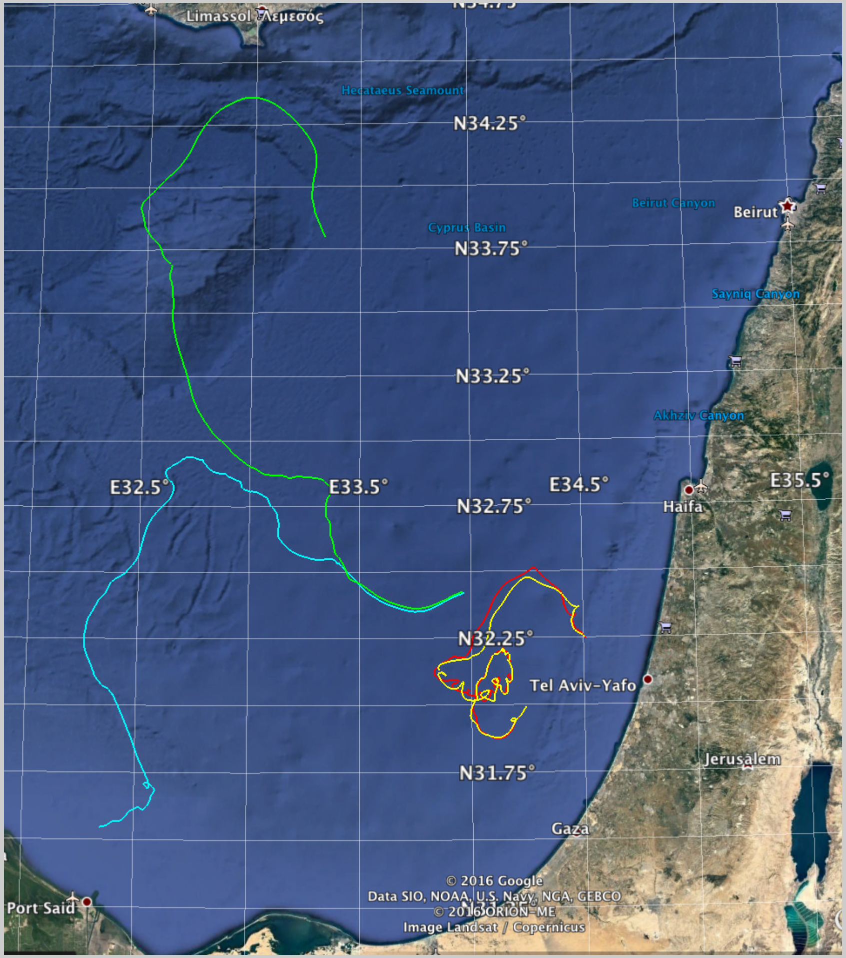
Dealing with the motion of fluids without considering the forces which create the motion.

The Advection diffusion equation for an ocean tracer

$$C_t + U(x,t) \cdot \nabla C = D \Delta C$$

- Advection – "bulk" movement, **stirring**; Diffusion – motion by the molecules.
- Down to small-scales, advection dominant transport.
- There is a coupling between advection and diffusion: advection can increase the gradient of a tracer and this will enhance diffusion.
- Can add biological uptake and other processes.

A quick and dirty guide to chaotic mixing and Lagrangian particle tracking



Sensitivity to initial conditions -> we should average over many particles

Lagrangian particle tracking

- Acquire the velocity field (numerical model, HF radar, satellite altimetry…)
- Seeding an area with many virtual particles
- Choose the particle tracking model:
  - Simple deterministic tracking model (passive tracers); Ignore model/measurement errors, subgrid processes; Inertia-less particles; No interaction.
  - 1^{st} order stochastic model.
  - Individual based model (coupling dynamics and behavior). Swimming, e.g., can have significant effects.
- Typical applications:
  - ❖ Larval dispersion and population connectivity
  - ❖ Oil spill and pollution
  - ❖ Search and rescue
  - ❖ General studies of transport and mixing

Lagrangian particle tracking

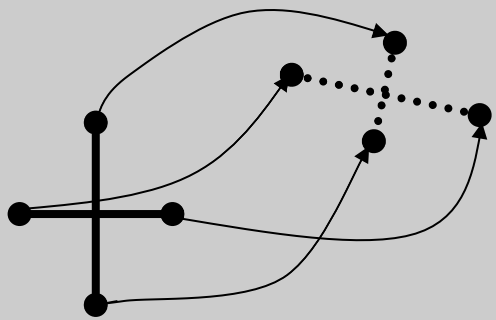
Single particle dispersion: Describes the spreading process

$$A_k^2(t,t_0) = \{\vec{X}_k(t) - \vec{X}_k(t_0)\}^2$$

Multiple particles statistics: Identify LCS such as eddies, barriers to mixing, …..

Two particles Relative Dispersion:

$$RD_k^2(t,t_0) = \frac{1}{4}\sum_{j=1}^{4}\{\vec{X}_j(t) - \vec{X}_k(t_0)\}^2$$



Lyapunov exponents

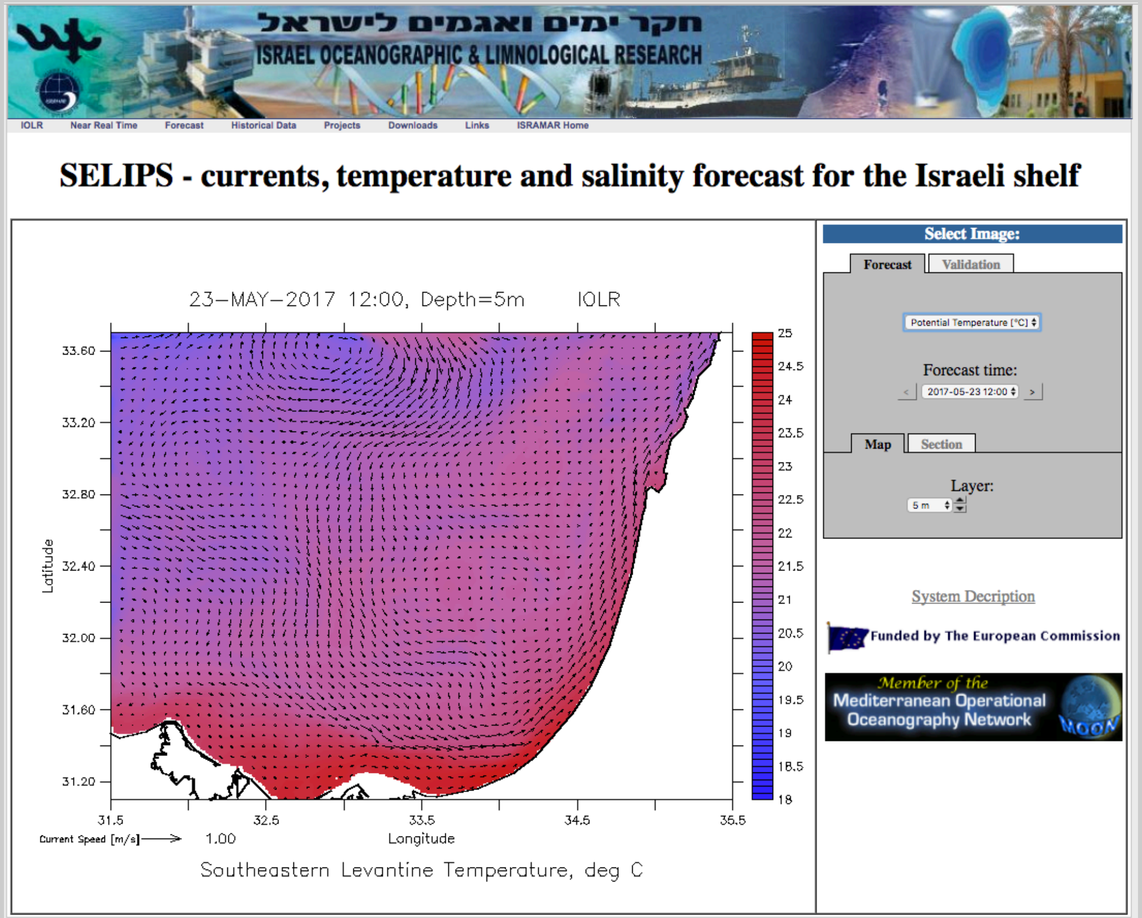
$$r_k(t) \cong r_k(0)e^{\lambda t}$$

Lagrangian particle tracking

The particle tracking and analysis toolbox (PaTATO) for Matlab

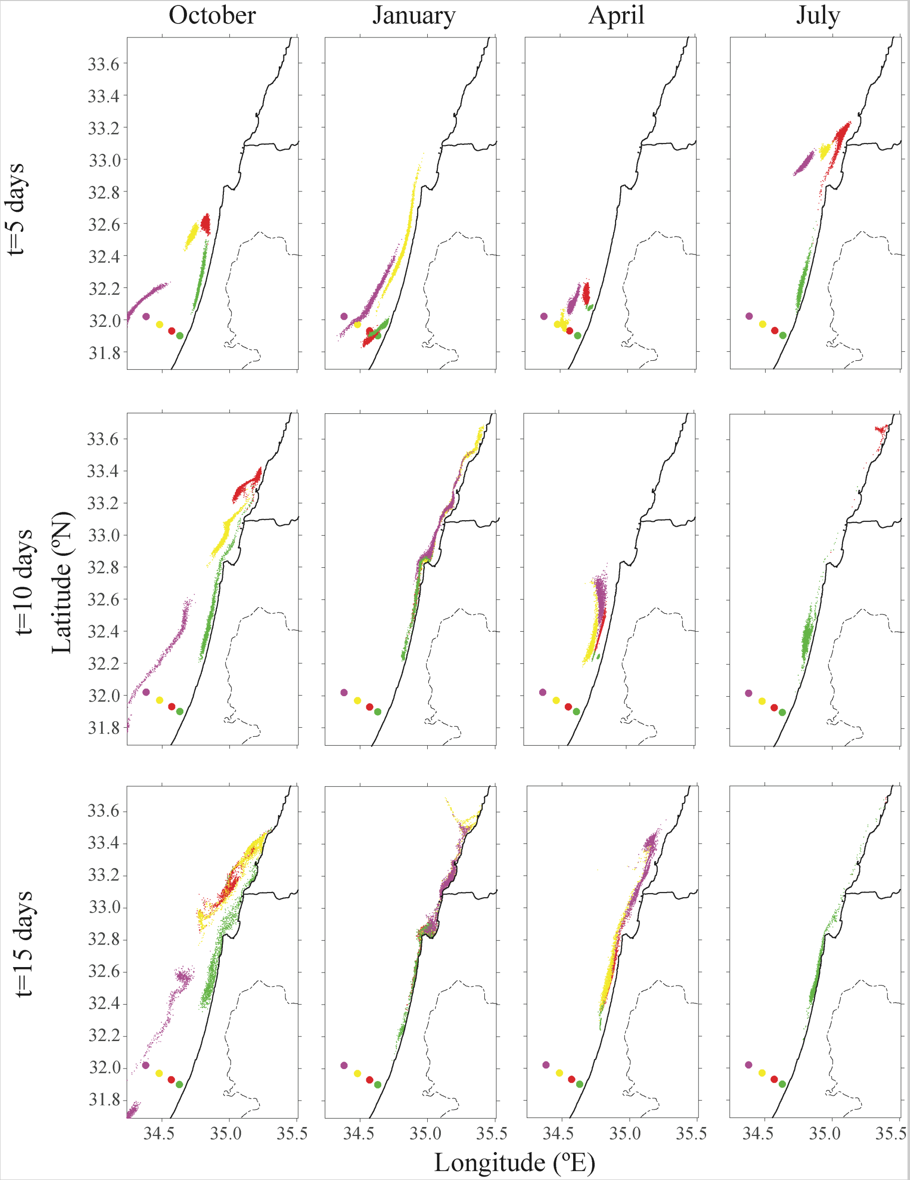
Erick Fredj,*[1] Daniel F. Carlson,†[2] Yael Amitai,[3] Avi Gozolchiani,[4] Hezi Gildor[3]

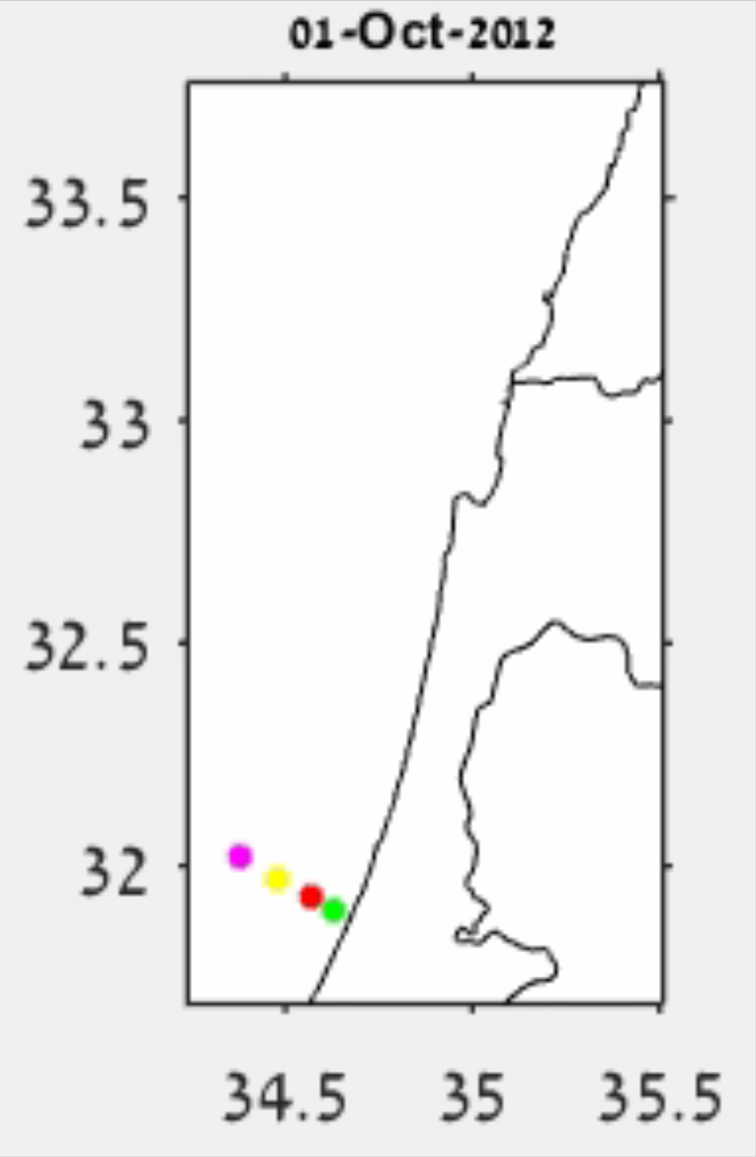
Limnol. Oceanogr. Methods, 14: 586–599, 2016



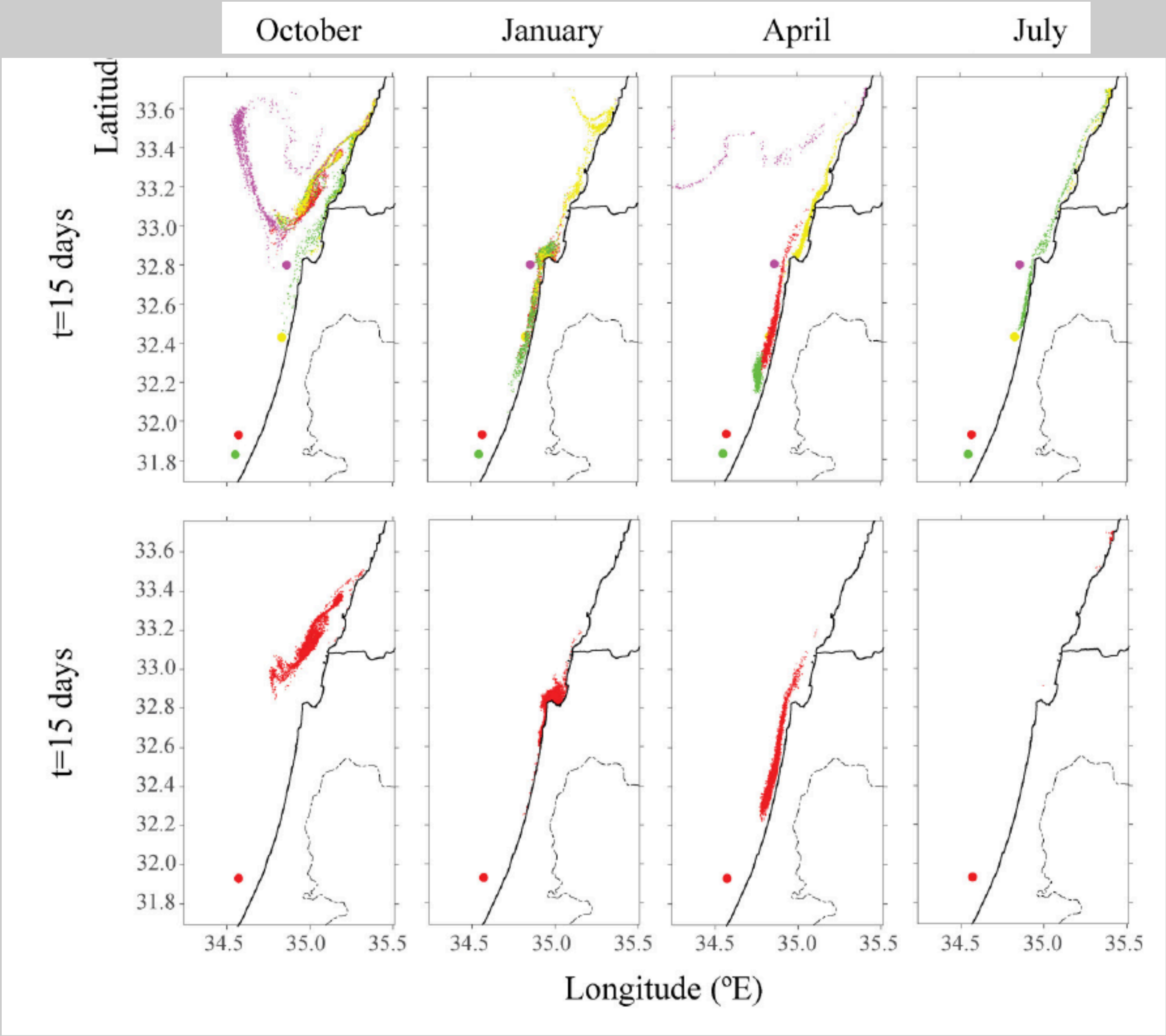
- Model's resolution - 0.01° × 0.00833°
- 10m velocities
- Current data from Sep. 2012 to Sep. 2013 (*Goldman et al.* 2015)
- Agreement between observations during 2015 cruise and the model.

Results -1: Distance of the farm from shore

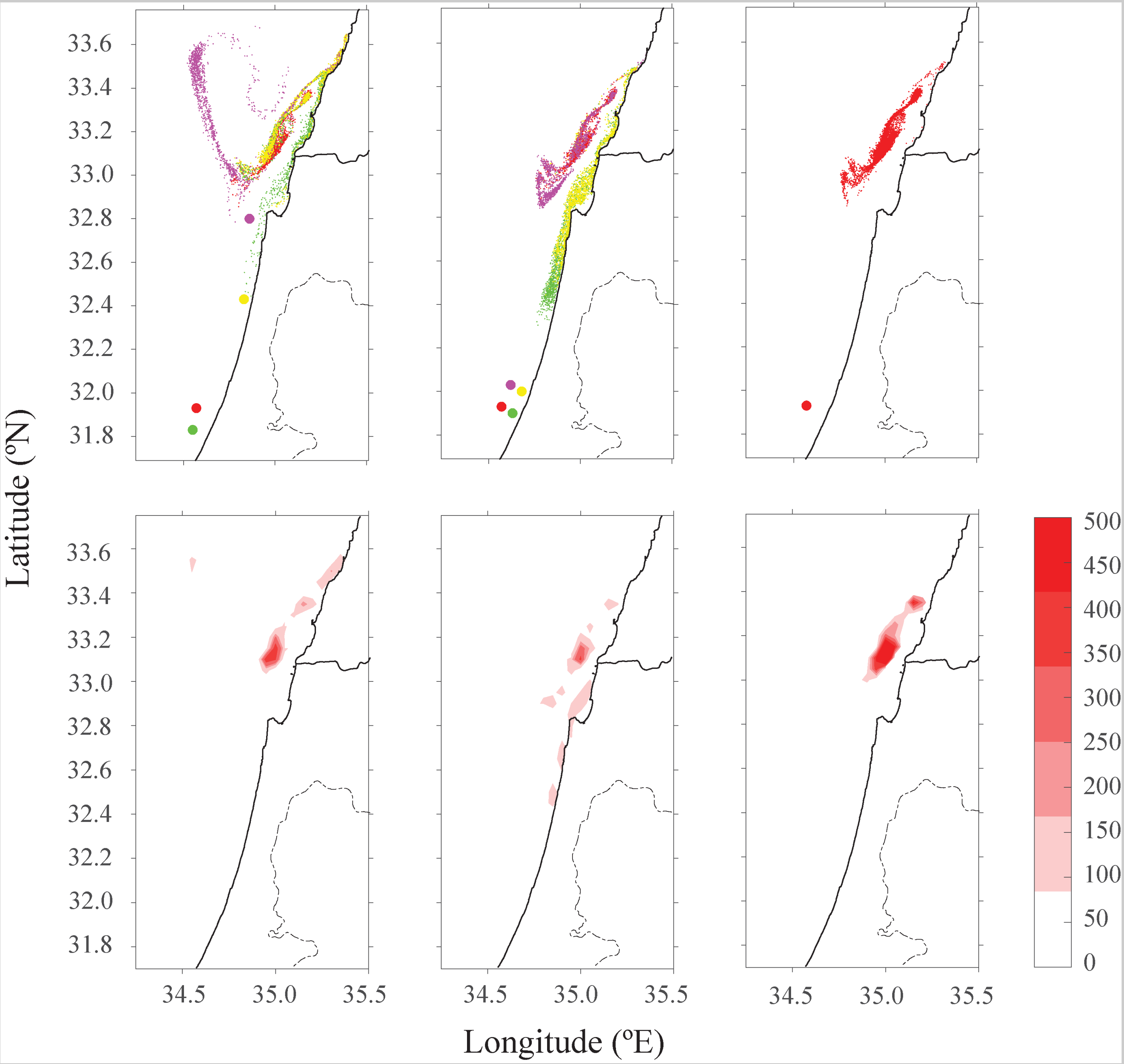


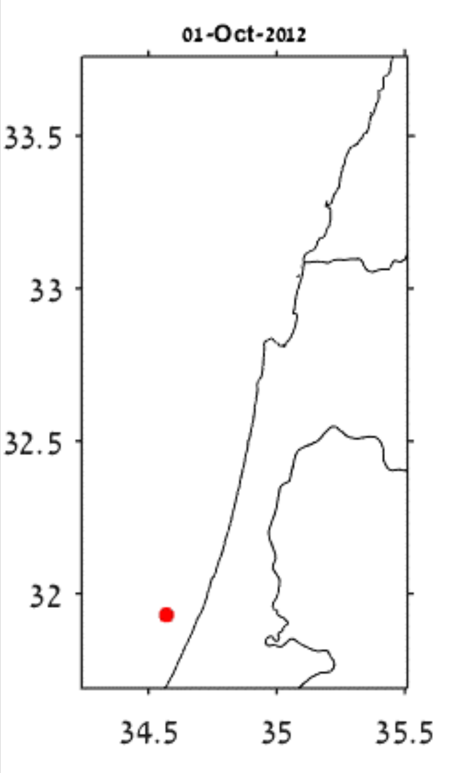


Results -2: Few scattered vs. big farm



Results -2: Few scattered vs. big farm





Half-life reduction calculation

In reality, the concentration of nutrients is reduced, taken up by phytoplankton or via sinking particles …

number of particles after time *t* (days)

$$N(t) = N(0) \cdot e^{-\frac{t}{H}}$$

half-life constant

number of particles at the beginning of the simulation

H?

Estimating H:

H was set to be H=1 day as the minimum boundary, and H=5 days as the maximum.

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Deep-Sea Research II 52 (2005) 3054–3073

DEEP-SEA RESEARCH PART II

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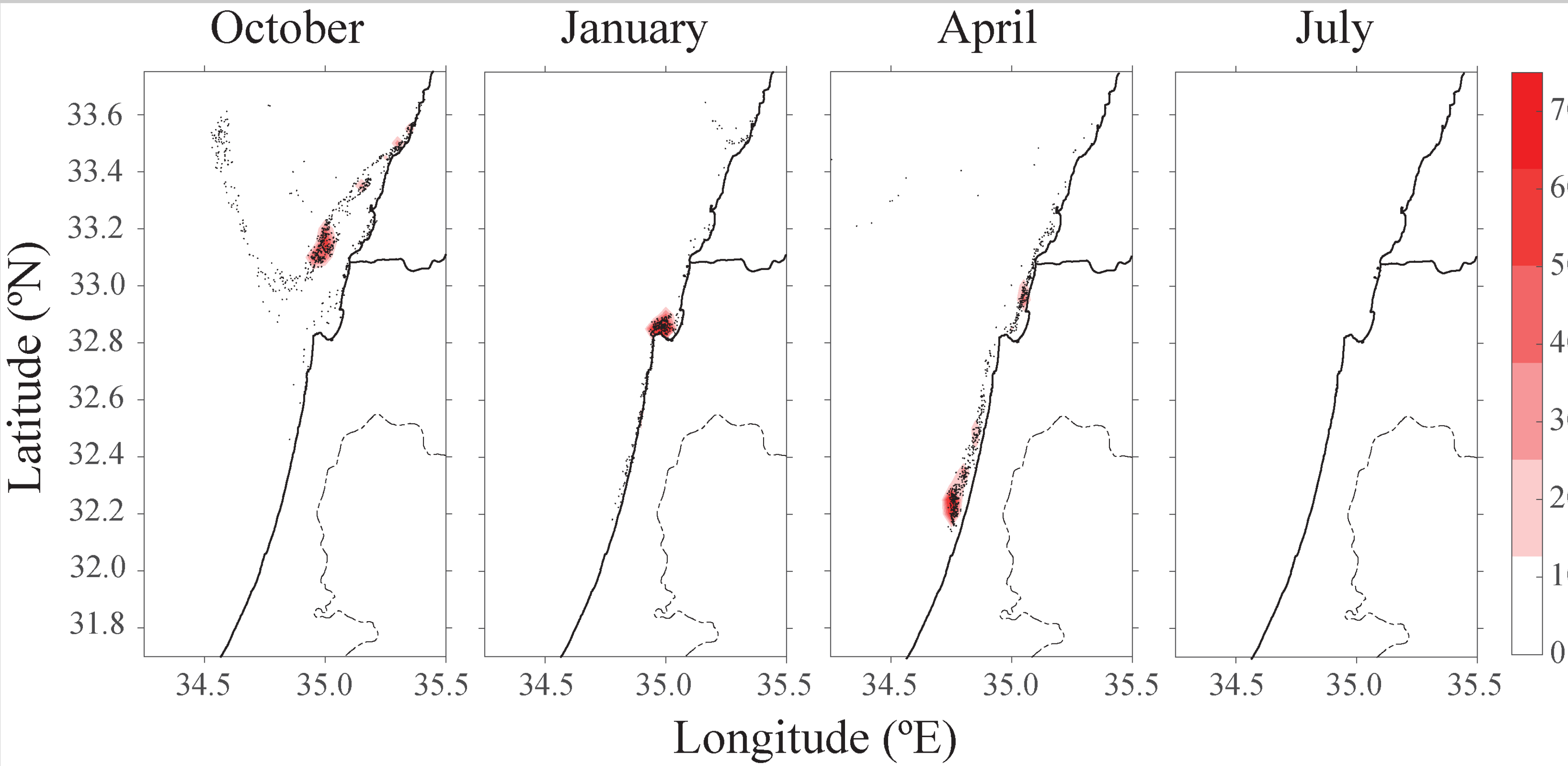
Effect of P and N addition to oligotrophic Eastern Mediterranean waters influenced by near-shore waters: A microcosm experiment

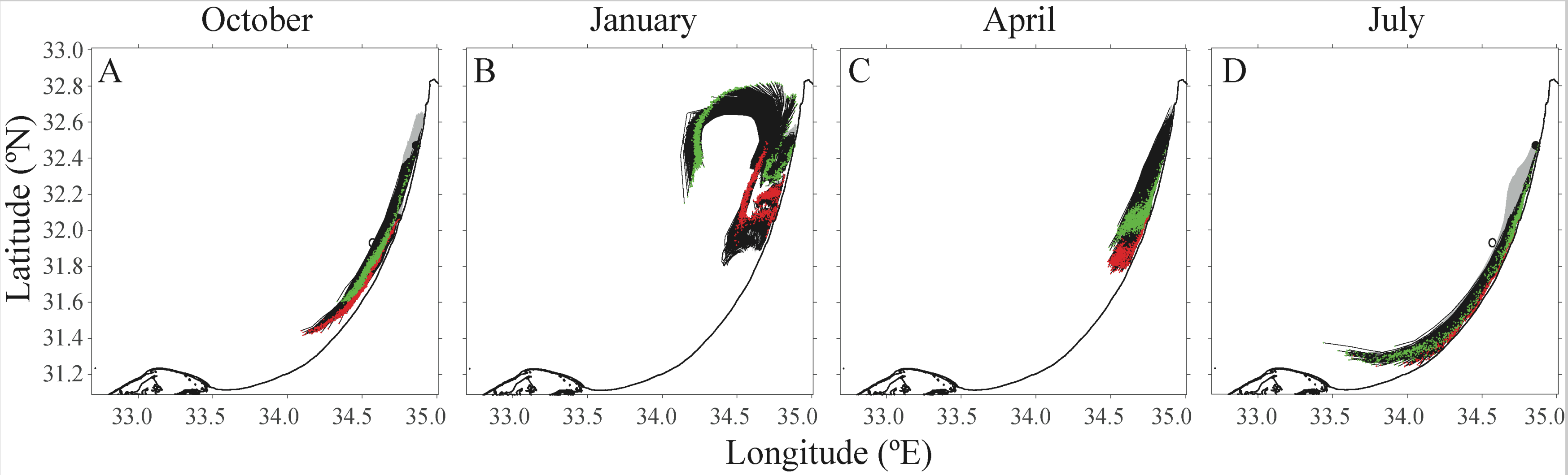
Nurit Kress[a,*], T. Frede Thingstad[b], Paraskevi Pitta[c], Stella Psarra[c], Tsuneo Tanaka[b], Tamar Zohary[d], Stephen Groom[e], Barak Herut[a], R. Fauzi C. Mantoura[f], Thalia Polychronaki[c], Fereidoun Rassoulzadegan[g], Georgina Spyres[h]

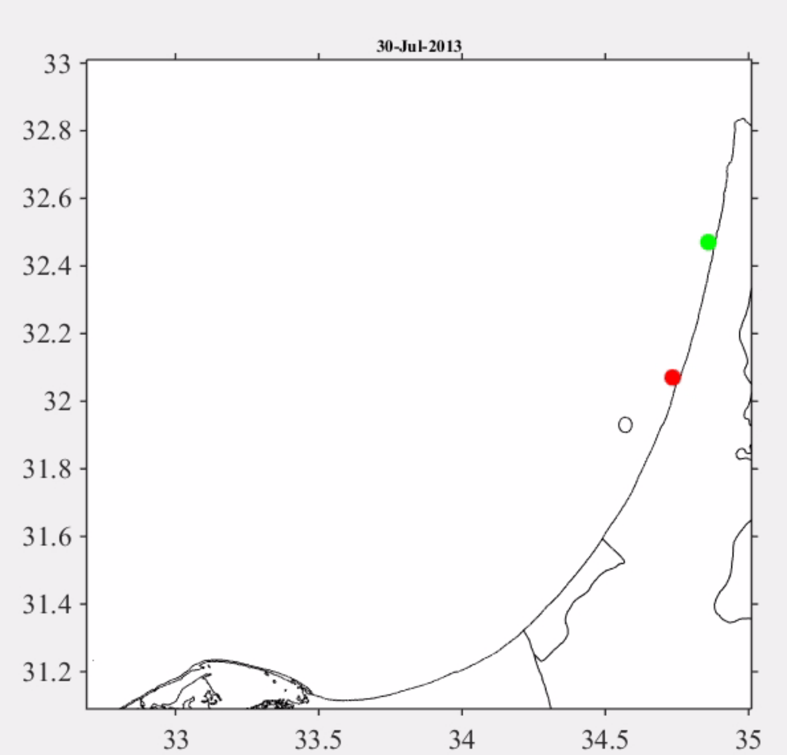
Results -3: Half-time reduction



Results for *H*=5 days

Results -3: Water origin by back trajectory





Conclusions

- A remote location of the farm from shore is preferred
- Scattered small farms are less contaminating than one big farm or many adjacent farms
- Back trajectories may be used to identify potentially harmful locations
- This tool can help decision-makers in planning future farms by determining size and location
- The goal was to demonstrate this tool, rather than produce realistic simulations