Lagrangian modelling the drift of jellyfish: capabilities and limitations

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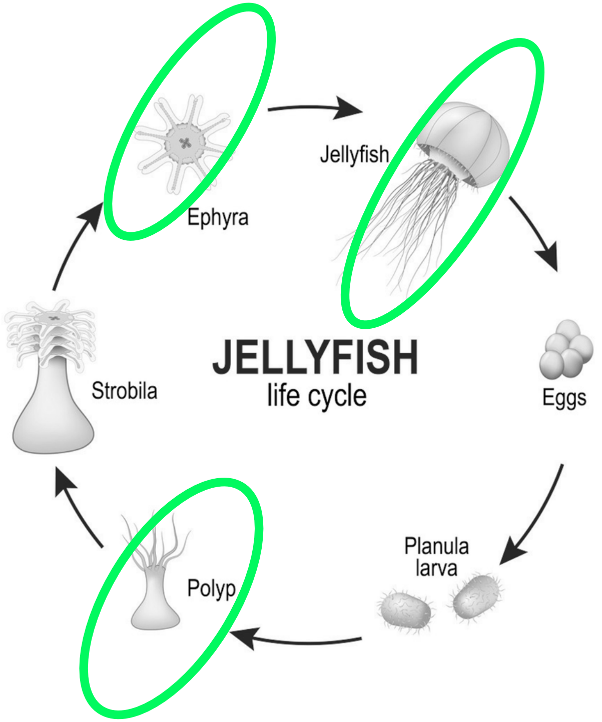
SYSTEMS AND TOOLS FOR LOCATING BLOOM OF JELLYFISH AND PREDICTING THEIR DISPLACEMENT TOWARDS THE COAST

Basics and practices of the jellyfish applications

(1) Coupled physical-biological models: food and growth-related, transport-related and predation-related hypotheses
(2) Lagrangian modelling tracks virtual particles of 0-spatial extend passively driven by ocean hydrodynamics: currents, waves, and wind
(3) Active vertical migrations with a diel cycle
(4) Effect of subgrid scale diffusion: random walk scheme, random fly scheme, etc



Modelled jellyfish life states:

a) Adult jellyfish (most frequent)
b) Ephyra - juvenile medusa
c) Polyp as a source (not to be transported)

Overviewed publications

##	Modelled species	Basin	Reference
1	*Chrysaora quinquecirrha* and *Phyllorhiza punctata*	Mississippi coastal waters (Gulf of Mexico)	Johnson et al., 2001 Johnson et al., 2005
2	*Aurelia aurita* and *Cyanea capillata*	Bornholm Basin (Baltic Sea)	Barz et al., 2006
3	*Nemopilema nomurai*	East China Sea and Japan Sea	Moon et al., 2010
4	*Pelagia noctiluca*	NW Mediterranean	Qiu et al., 2010
5	*Pelagia noctiluca*	Ligurian Sea	Berline et al., 2013

Chrysaora quinquecirrha in the northern Gulf of Mexico (*Johnson et al., 2001*)

Objective: to estimate time and distance scales from probable polyp habitats to areas in which mature medusae are observed

Transport of medusae: horizontal with the OGCM, no active vertical migration, no any subgrid scale dispersion

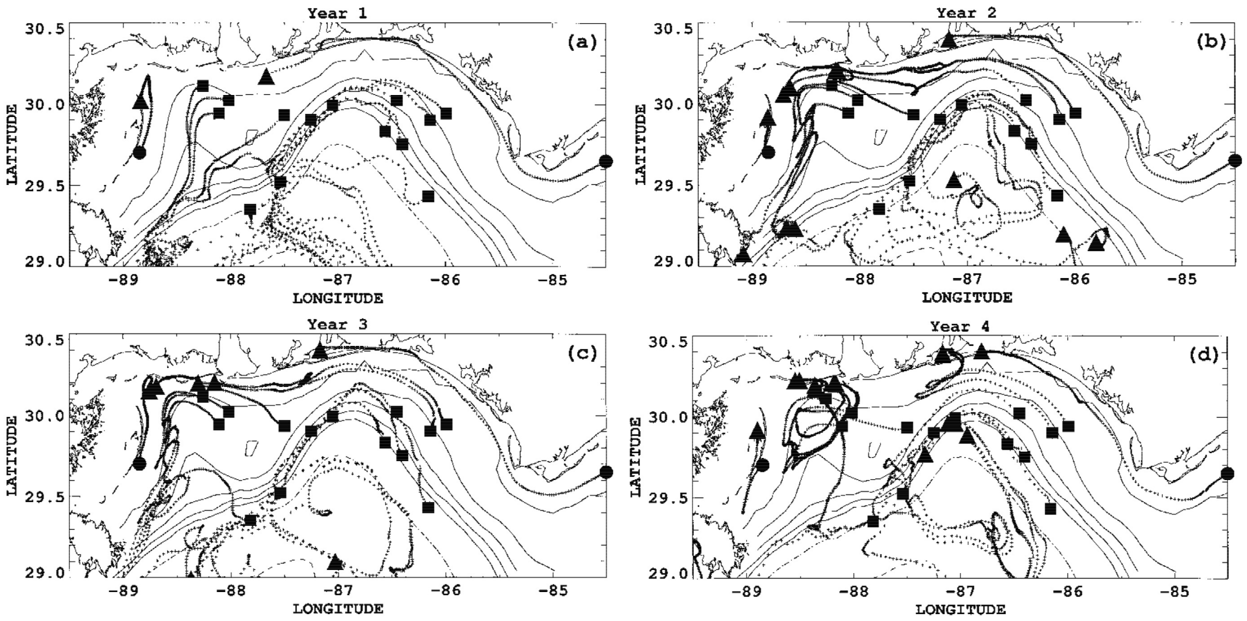
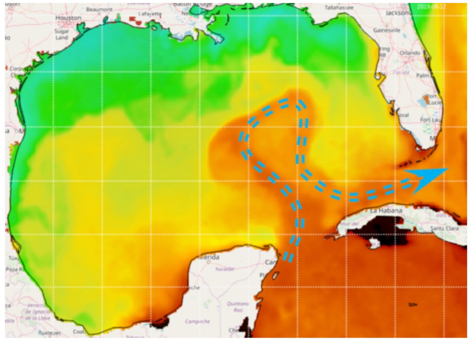


Figure 9. Forward tracing from selected hard bottom locations in the Mississippi Bight (square symbols) for 90 days from June through August. The two circle symbols represent possible locations on the northeast Florida Shelf and along the Chandeleur Islands. Small crosses show track locations every 0.5 days and triangles represent ending locations after 90 days. Ending locations outside the Bight are not shown. Isobaths are shown at 20 m intervals from 20 m to 100 m (solid lines of model year 1). The 200 m isobath is shown by a dot-dash line and the 1000 m isobath by the dashed line. (a) model year 1, (b) model year 2, (c) model year 3, and (d) model year 4.



Loop Current visible on Sea Surface Temperature observed by satellite (source: NOAA/AOML OceanViewer).

Results

Inter-annual differences in distributions of *Chrysaora quinquecirrha* in the Mississippi coastal waters could be explained by Loop Current

Phyllorhiza punctata in the Gulf of Mexico June 2002
(*Johnson et al., 2005)*

Objective: to examine a hypothesis of the jellyfish sudden appearance by advection

Transport of medusae: horizontal with the OGCM (backtracking), no active vertical migration, no any subgrid scale dispersion

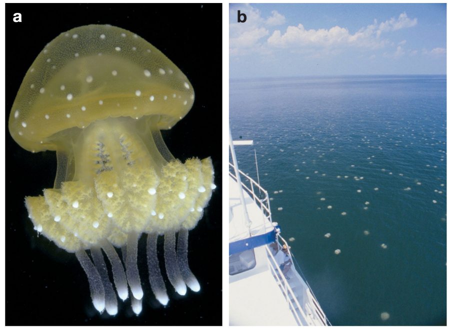


Fig. 1. (a) *Phyllorhiza punctata*, native to the Indo-Pacific. (b) Extensive jellyfish patch in the Mississippi Bight, June 2002

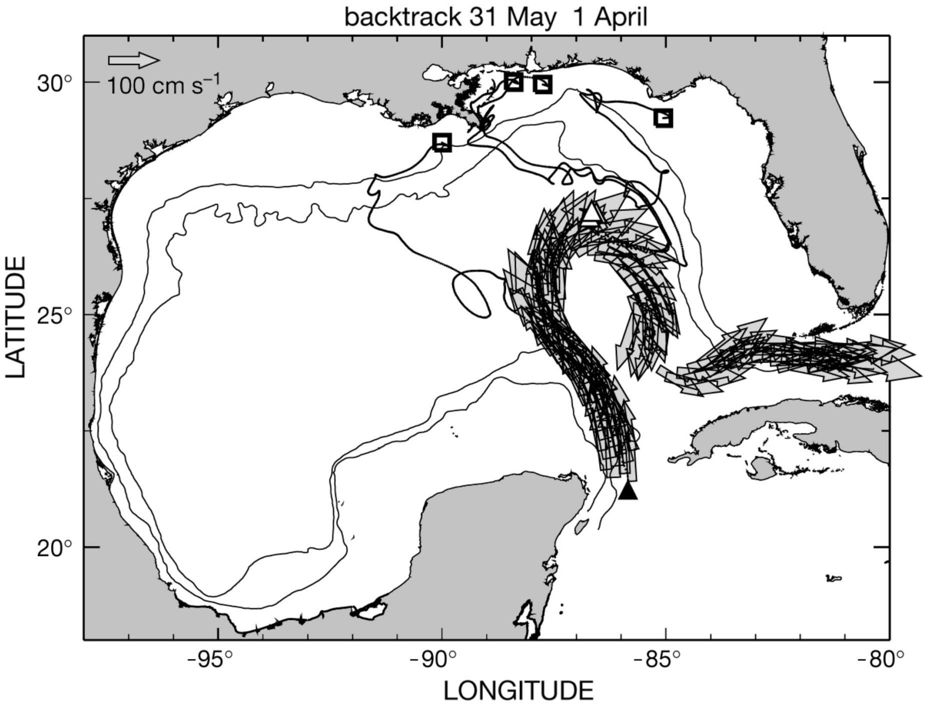


Fig. 6. Back-traced pathways from locations on the shelf starting 31 May (squares) and ending 1 April 2000 (triangles); 200 and 1000 m isobaths are shown; surface current vectors are from the numerical model for 1 April 2000

Result
advection from the Caribbean
in intruding Loop Current and
subsequent flux onto the Mississippi Shelf

Aurelia aurita and Cyanea capillata in the Baltic Sea
(*Barz et al., 2006)*

<u>Objective:</u> model-based study of the growing ephyrae drift from historically known strobilation areas – first appearance and life stage at appearance

<u>Transport of adult medusae:</u> horizontal and vertical transport with the OGCM-based currents, no active migration, no diffusion

<u>Model scenario:</u> ~200 virtual particles released every 10 days over November – April were tracked until August

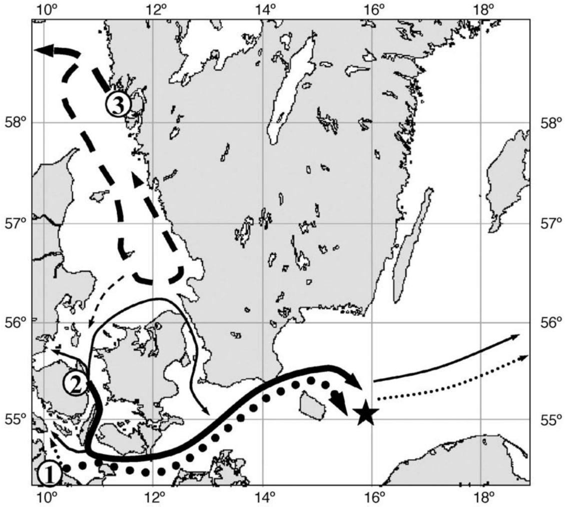
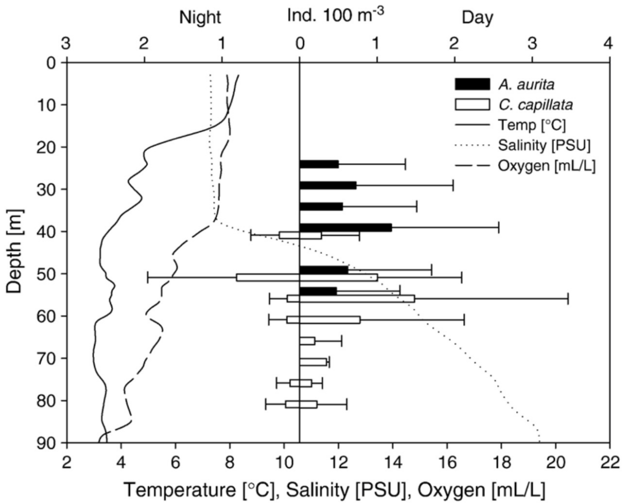


Fig. 1. Study area (Bornholm Basin=★), release areas and main drift routes of medusae derived from the circulation model: 1=Kiel Bight, dotted lines; 2=Kerteminde area, solid lines; 3=Gullmar Fjord area, dashed lines. Width of lines indicates significance of drift route.



<u>Results</u>

- Hydrodynamics matters
- Year to year variability 2003 – 2004

Nemopilema nomuraiin in the the East China Sea and East/Japan Sea (*Moon et al., 2010)*

<u>Objective:</u> to study influence of hydrodynamics on jellyfish transport

<u>Transport of adult medusae:</u> 3D advection with the OGCM + random walk horizontal and vertical diffusion

<u>Model scenario:</u> 50 particles per day were seeded May – June 2005, 30 day tracking

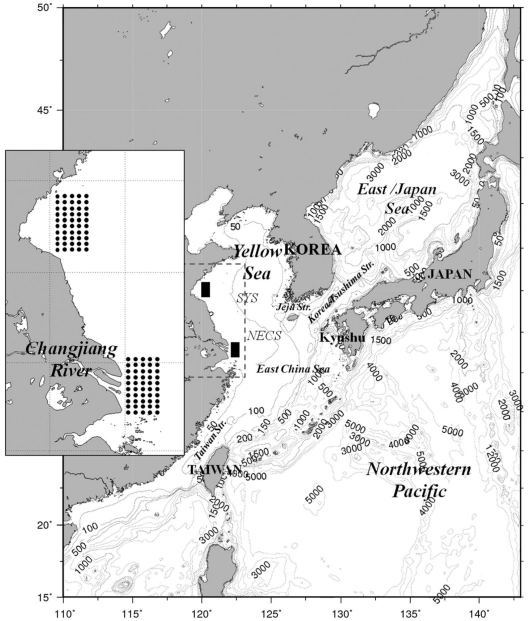
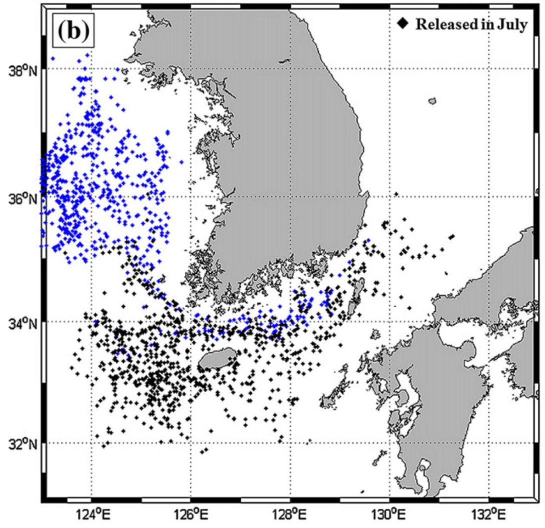


Fig. 1. Model domain and bottom topography (m). Dots in the left figure indicate the positions of the model particles released in the Changjiang River mouth area and the northern Changjiang River area. NECS: northern ECS; SYS: southern YS.



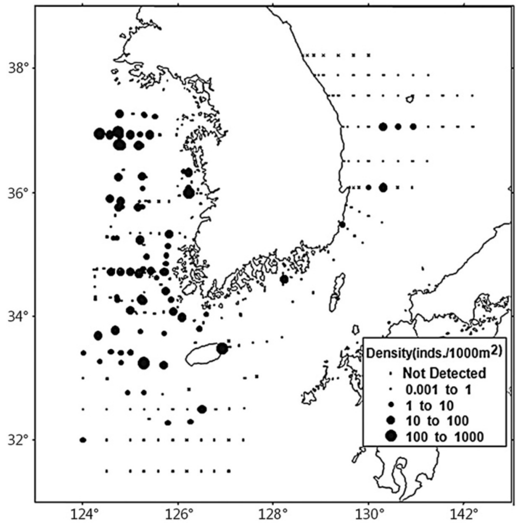


Fig. 12. Distributions of the giant jellyfish observed by NFRDI in August 2005.

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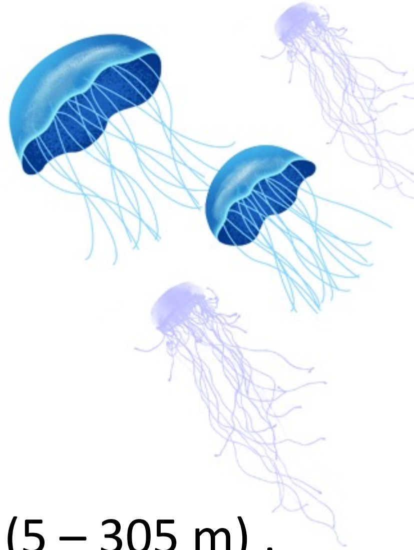

Pelagia noctiluca in the NW Mediterranean

(*Qiu et al., 2010)*

<u>Objective:</u> to study influence of hydrodynamics on jellyfish transport

<u>Transport of adult medusae:</u> horizontal with the OGCM + active vertical migration with a diel cycle (5 – 305 m) , no any subgrid scale dispersion

<u>Model scenario:</u> 40 day tracking the 400 virtual particles released on monthly basis (March – August)

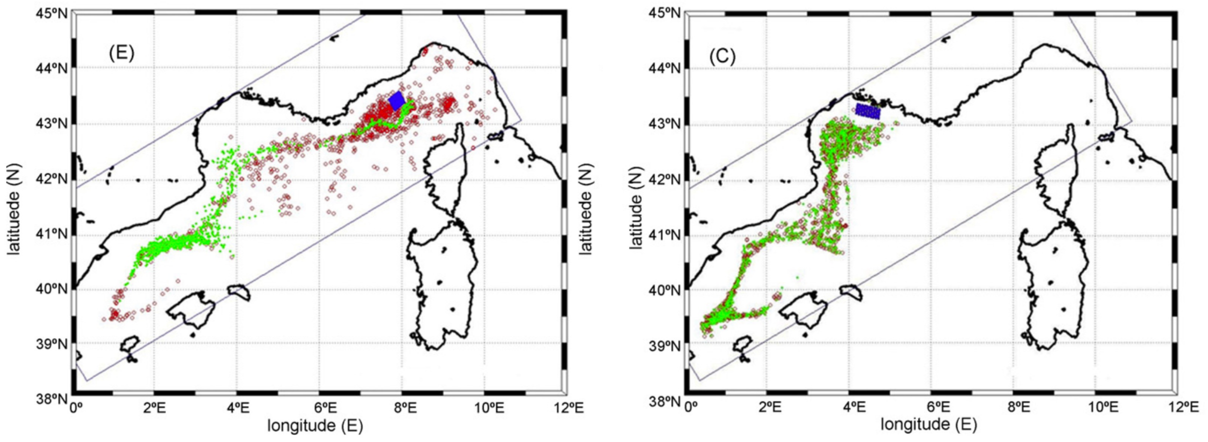

Fig. 6. Final distribution patterns of particles released around the DYFAMED station (blue square) in simulations with DVM in 3 months: (A) March, (B) June and (C) August. Empty red circles represent final positions of particles released at 5 m; full green lozenges represent final positions of particles released at 100 m. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

<u>Results</u>

- Strong seasonality of the patterns
- In some months (March, June, July, August) "the Northern Current can work as a barrier for particles entering the the Gulf of Lions from the offshore sea"

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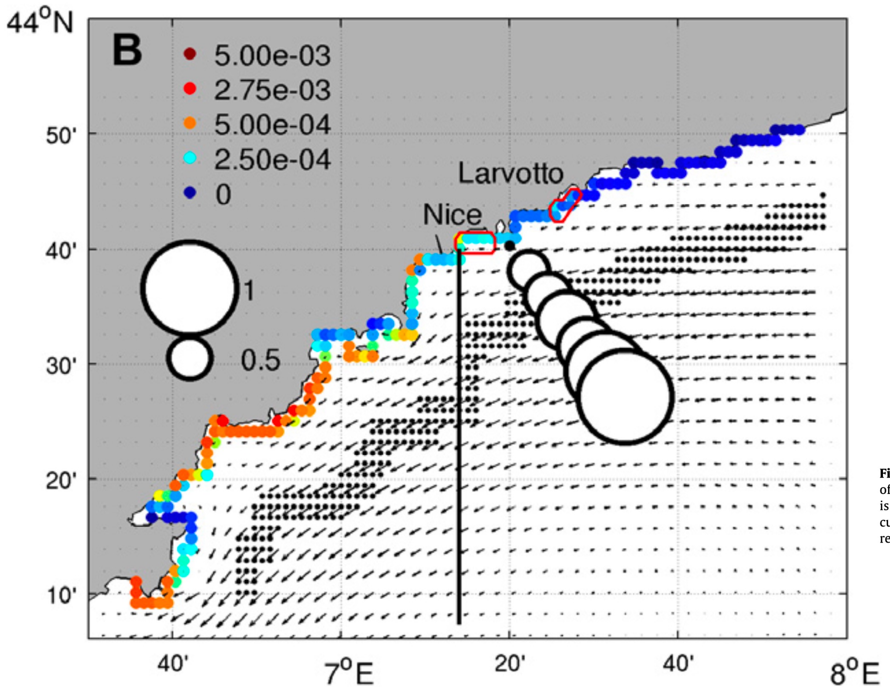
Pelagia noctiluca in the Ligurian Sea

(*Berline et al., 2013*)

Objective: to study the time and space variability of stranding of the jellyfish and the main drivers of transport

Transport of adult medusae: horizontal with the OGCM + active vertical migration with a diel cycle, no any subgrid scale dispersion

Model scenario: tracking the 328 virtual particles during 10 days



Results

"… abundance can reach maxima in bays and in the lee of capes. Two factors impact jellyfish arrivals at the coast: the position of the Northern Current and the wind."

Fig. 1. (A) Map of the studied area showing the initial positions (black dots) and the littoral zone (colored dots). Colored dots show upstream connectivity for each grid point of the littoral zone during year 2001. (B) Colored dots show the average abundance of particles computed in the same way as upstream connectivity. Note that the color scale is double-linear. White circles: average index of abundance of jellyfish *Pelagia* from the in situ observations of Ferraris et al. (2012). Black vectors: model annual average current at 5 m. The vertical line is the position of the section used in Figs. 2, 4 and 5. The Nice and Larvotto beach zones are circled with red lines.(For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Conclusion

- Following Miller (2007), Lagrangian models for jellyfish can be:
  Explanatory that provide an explanation of an observed empirical patterns (Barz et al., 2006)
  Inferential that quantify the relative contribution of different processes to producing the observed patterns (Dawson et al., 2001, Jae-Hong Moon et al., 2010, Qiu et al., 2010, Berline et al., 2013)
  Hypothesis-generating that is lead by hypotheses that could be tested (Dawson et al., 2005)

- As a rule, Lagrangian models for jellyfish are at early stages of the development (passive tracers moving deterministically with the diel migration cycle)

- Level of complexity of models should correspond the quantity and quality of field datasets available

- Development of models is driven by social needs

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