CERF's Up!

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Celebrating CERF's 50th Anniversary

A new wave of information from the Coastal and Estuarine Research Federation

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Horseshoe crab at Oyster Bay National Wildlife Refuge, Long Island

Photo: Richard Sack

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Editors' Note:
This issue begins the celebration of CERF's 50th anniversary with an article on the first meeting of CERF in 1971 (when it was known as the Estuarine Research Federation, ERF for short). This is followed by four articles solicited by Bob Christian and Bob Murphy (of the History Committee for the 2021 Conference) on historical developments in estuarine disciplines. Thanks to the USFWS Oyster Bay National Wildlife Refuge (near Plainview, Long Island, site of the first ERF meeting in 1971) for use of their photos.

Front cover: Beach in Oyster Bay National Wildlife Refuge, Long Island, just north of Plainview on Long Island
Photo: Richard Sack

Back cover: Oyster boat in Oyster Bay National Wildlife Refuge
Photo: US Fish & Wildlife Service

Diagnostic Timescales: Old Concepts, New Methods, and the Ageless Power of Simplification

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Don't throw the past away
You might need it some rainy day
Dreams can come true again
When everything old is new again

"Everything Old is New Again"
–Peter Allen and Carole Bayer Sager

The theory underlying the well-known diagnostic timescale "residence time" dates back more than a century to its genesis in chemical engineering.[1,2] Other physical and biological timescales commonly used in the natural sciences and engineering—such as flushing time,[3] water age,[3] turnover time,[4,5] e-folding time,[6] and doubling time[7,8]—were implemented at least as early as the 1920s–1950s. Prior to the era of computational numerical modeling, assessment of such timescales relied upon experimentation, observation, and/or analytical derivation. These timescales were used (1) to characterize or condense experimental or observational data,[3,5] and (2) to convey, in a simple manner, information about the state or functioning of a system.[2,3,8]

Through subsequent decades, diagnostic timescales have helped us distill complexity into intuitively meaningful metrics[9-12] and have aided us in making sense of natural or anthropogenic phenomena.[13-18] For example, a long hydraulic residence time—which encapsulates the overall retentive effect of potentially complex, three-dimensional hydrodynamic processes—might help explain algal biomass build-up or nutrient depletion in an estuary. It can be argued that in the environmental sciences such simplification and distillation power is now needed more than ever, given the daunting volumes of data generated by in situ, vessel-based, and remote observing platforms, as well as by high-resolution, multi-dimensional computer models. Giga-, tera-, and petabytes of data are, after all, not very useful unless meaningful information (such as the identification of key processes or causal relationships) can be extracted from them.[19,20]

Diagnostic timescales—parameters that estimate how long processes take—represent an old tool for tackling this relatively new problem of "too much data."[19-21] They can provide an approximate means of extracting the essence from large, detailed datasets[22] (e.g., the amount of time for which an estuary is exposed to an imported contaminant before it is lost to the sea). A timescale can also convert a primitive variable (e.g., velocity) into a more meaningful number[20] conveying the material effect of the variable in the context of the specific problem under study (e.g., the time for planktonic food subsidies to advect from a productive source region to an unproductive area).[22] In addition, because they all carry the same units (time), timescales describing different biological, geochemical, or physical phenomena can be directly compared to each other, thus bridging disciplinary divides and providing a simple way to identify the fastest, and sometimes dominant, process(es).[18,22,23] Furthermore, diagnostic timescales can prove useful in spatial or temporal system comparisons,[24-26] in the development of simple algebraic "pencil and paper" models,[27,28] and in quantifying connectivity between regions.[12,29,30]

Technological advances leading to our current data boom have thus produced a distillation challenge to which simplification tools like timescales may lend a hand. In parallel, technology and advanced mathematical methods have also led to increasingly powerful approaches for quantifying timescales, with greater temporal and spatial resolution than ever before. For example, high-resolution, multi-dimensional numerical models, in which virtual particles or tracers are transported by computed velocities and diffusivities, are now commonly used to calculate transport timescales such as water age[31,32] (elapsed time since entering[33-35]), exposure time[12,32,36] (time that will be spent in the domain), or residence time[32,37,38] (a variant of the exposure time[22,39]; Fig. 1). Reactions can also be accounted for alongside transport,[40] resulting in timescales that are "holistic", i.e., capturing the influence of a broad collection of processes in a single parameter.[22] Usually, computation-based timescales are obtained via forward schemes,[37,41,42] which involve running a transport model in the usual way: forward in time. Such approaches traditionally have required multiple simulations if one wished to quantify a timescale as a function of time. Advanced methods developed over the last couple of decades, however, provide an antidote to that requirement, allowing for the computation of spatially and temporally variable timescales with a single simulation.[43-45] These approaches include: (1) forward methods for water age that require

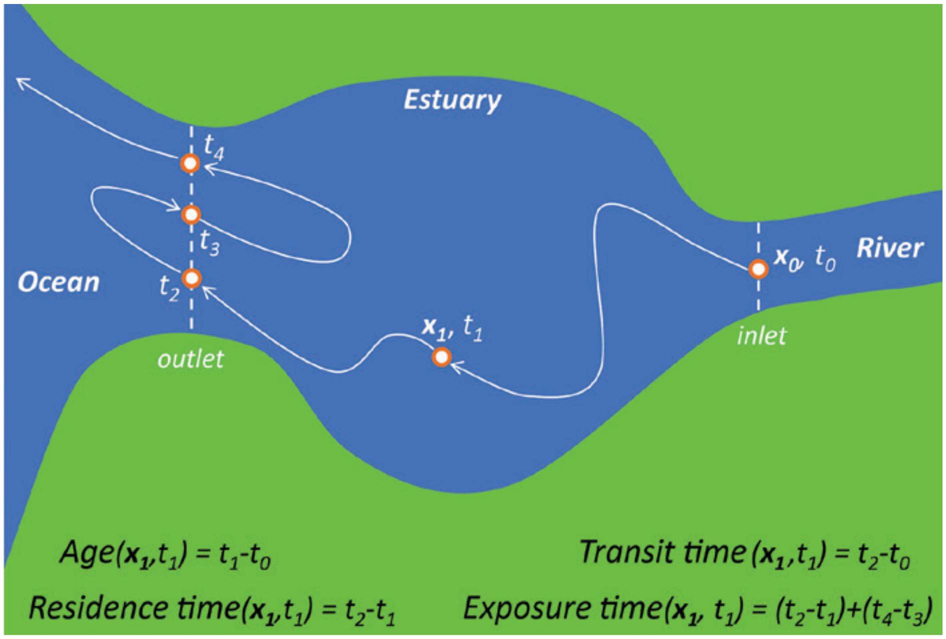

Fig. 1. Schematic describing relationships between core transport timescales: water age, residence time, transit time, and exposure time, following Zimmerman,[35] Delhez,[39] and many others. Reprinted from Lucas and Deleersnijder[22]

solution of an evolution equation for the “age concentration,”[29,43,44] and (2) adjoint methods for residence time and exposure time, which involve running a numerical transport model in reverse.[36,45] These newer approaches can be applied not only to water and tracers, but also to particulate matter and substances adsorbed onto sediment particles.[46-50] Their application is becoming increasingly common for the world’s coastal systems.[51-55]

Similar advances have occurred in field instrumentation, allowing for more detailed assessments of field-based transport timescales than was possible several decades ago. For example, drifters—Lagrangian devices released into a water body to follow water parcels and often used to quantify transport time[56-58]—are now frequently GPS-equipped, eliminating the need to physically follow their trajectories (by vessel) and making it possible to track hundreds of drifters and collect thousands of drifter-days of data in a single study.[59] Methods for conducting field studies with natural or artificial tracers have also improved over time. For example, modern vessel-based instrumentation permits high-frequency measurement of stable isotopes and other water quality parameters along a high-speed boat track, allowing for the spatial mapping of water age and potentially related variables such as chlorophyll a or nutrient concentrations.[60]

Diverse diagnostic timescales—such as those for algal growth, oxygen consumption, nutrient uptake, advective or diffusive transport, or sedimentation of particles—can be compared with each other to discern the fastest process(es) operating in a system or influencing a constituent of interest.[22,28] They can also form the basis of very simple (e.g., box, steady state) mathematical models that, despite their simplicity, can perform well quantitatively.[16,27] In some cases, the timescale comparison (i.e., their ratio) essentially is a model, with that ratio representing the balance between two critical processes and serving as an indicator of likely ecosystem response. (For example, the ratio of an oxygen consumption timescale to a residence time has been shown to be a useful indicator of hypoxia occurrence.)[10] Such simple, timescale-based models offer a useful counterbalance to (and intuitive, back-of-the-envelope check on) more complex numerical models, which (1) tend to be computationally demanding,[22] (2) may be difficult to use, and (3) are not available to every scientist or resource manager desiring a quick, approximate answer to a question.

Diagnostic timescale estimation, a century-old scientific and engineering approach, has arguably never been more useful than it is today for integrating physical, biological, and geochemical processes and distilling large amounts of data. Timescale evaluation complements the analysis of primitive variables[20] and, in the process, helps shed new light on the functioning of complex systems. Moreover, diagnostic timescales can form the foundation of simple mathematical models[16,27,61] that provide a convenient and accessible alternative—or companion—to computationally demanding expert models.[22] Despite being old in concept, the usefulness of diagnostic timescales has only expanded, and in recent decades their methods of estimation have significantly improved in terms of resolution.[43-45,59,60] Perhaps their most enduring value to estuarine and coastal science, specifically, is their utility in encapsulating the complexity of real ecosystems—helping us identify the essential components of our conceptual models and attaching approximate values to them. Diagnostic timescales demonstrate that the power of simplification never gets old.

Note: References for this article can be found at cerf.science/cerf-s-up--47-1--bulletin---additional-materials. *If the reader wishes to learn more about diagnostic timescale definitions, methods, and applications in the coastal zone, they are encouraged to check out the authors’ recent review paper on the topic at* Lucas and Deleersnijder 2020.

Diagnostic Timescales: Old Concepts, New Methods, and the Ageless Power of Simplification

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References:

1. Nauman EB. 2008. Residence time theory. *Industrial & Engineering Chemistry Research* 47: 3752-3766.
2. Langmuir I. 1908. The velocity of reactions in gases moving through heated vessels and the effect of convection and diffusion. *Journal of the American Chemical Society* 30: 1742-1754.
3. Ketchum BH, Rawn AM. 1951. The flushing of tidal estuaries [with Discussion]. *Sewage and Industrial Wastes* 23: 198-209.
4. McFarlane AS. 1947. Biochemical applications of stable and radioactive isotopes. *The British Medical Journal* 2: 766-768.
5. Popják G. 1948. The use of isotopes in biology. *Science Progress* 36:239-261.
6. Farren WS, Taylor GI. 1925. The heat developed during plastic extension of metals. *Proceedings of the Royal Society of London Series A, Containing Papers of a Mathematical and Physical Character* 107: 422-451.
7. Hoffman JG. 1947. Wright's hypothesis: Its relation to volume growth of tissue cells and mitotic index. *Science* 106: 343-344.
8. Batchelor GK. 1950. On the spontaneous magnetic field in a conducting liquid in turbulent motion. *Proceedings of the Royal Society of London Series A, Mathematical and Physical Sciences* 201: 405-416.
9. Liu X, Dunne JP, Stock CA, Harrison MJ, Adcroft A, Resplandy L. 2019. Simulating Water Residence Time in the Coastal Ocean: A Global Perspective. *Geophysical Research Letters* 46: 13910-13919.
10. Fennel K, Testa JM. 2019. Biogeochemical Controls on Coastal Hypoxia. *Annual Review of Marine Science, Vol 11* 11: 105-130.
11. Tartinville B, Deleersnijder E, Rancher J. 1997. The water residence time in the Mururoa atoll lagoon: Sensitivity analysis of a three-dimensional model. *Coral Reefs* 16: 193-203.
12. de Brauwere A, de Brye B, Blaise S, Deleersnijder E. 2011. Residence time, exposure time, and connectivity in the Scheldt Estuary. *Journal of Marine Systems* 84: 85-95.
13. Monsen NE, Cloern JE, Burau JR. 2007. Effects of flow diversions on water and habitat quality: Examples from California's highly manipulated Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 5: Issue 3, Article 2, 1-16.
14. Qin QB, Shen J. 2019. Physical transport processes affect the origins of harmful algal blooms in estuaries. *Harmful Algae* 84: 210-221.
15. Nixon SW, Ammerman JW, Atkinson LP, et al. 1996. The fate of nitrogen and phosphorus at the land-sea margin of the North Atlantic Ocean. *Biogeochemistry* 35: 141-180.
16. Dettmann EH. 2001. Effect of water residence time on annual export and denitrification of nitrogen in estuaries: A model analysis. *Estuaries* 24: 481-490.
17. Sharples J, Middelburg JJ, Fennel K, Jickells TD. 2017. What proportion of riverine nutrients reaches the open ocean? *Global Biogeochemical Cycles* 31: 39-58.

18. Middelburg JJ, Nieuwenhuize J. 2000. Uptake of dissolved inorganic nitrogen in turbid, tidal estuaries. *Marine Ecology Progress Series* 192: 79-88.
19. Deleersnijder E, Delhez EJM. 2007. Timescale- and tracer-based methods for understanding the results of complex marine models. *Estuarine Coastal and Shelf Science* 74: V-Vii.
20. Deleersnijder E, Draoui I, Lambrechts J, Legat V, Mouchet A. 2020. Consistent boundary conditions for age calculations. *Water* 12: 1-29.
21. Viero DP, Defina A. 2016. Renewal time scales in tidal basins: Climbing the Tower of Babel. In: Erpicum S, Dewals B, Archambeau P, Pirotton M, eds. Sustainable hydraulics in the era of global change: advances in water engineering and research. First ed. London: CRC Press:338-345.
22. Lucas LV, Deleersnijder E. 2020. Timescale Methods for Simplifying, Understanding and Modeling Biophysical and Water Quality Processes in Coastal Aquatic Ecosystems: A Review. *Water* 12.
23. Crump BC, Hopkinson CS, Sogin ML, Hobbie JE. 2004. Microbial biogeography along an estuarine salinity gradient: Combined influences of bacterial growth and residence time. *Applied and Environmental Microbiology* 70: 1494-1505.
24. Hall NS, Paerl HW, Peierls BL, Whipple AC, Rossignol KL. 2013. Effects of climatic variability on phytoplankton community structure and bloom development in the eutrophic, microtidal, New River Estuary, North Carolina, USA. *Estuarine Coastal and Shelf Science* 117: 70-82.
25. Peierls BL, Hall NS, Paerl HW. 2012. Non-monotonic Responses of Phytoplankton Biomass Accumulation to Hydrologic Variability: A Comparison of Two Coastal Plain North Carolina Estuaries. *Estuaries and Coasts* 35: 1376-1392.
26. Strayer DL, Caraco NF, Cole JJ, Findlay S, Pace ML. 1999. Transformation of freshwater ecosystem by bivalves. *Bioscience* 49: 19-27.
27. Shen J, Hong B, Kuo AY. 2013. Using timescales to interpret dissolved oxygen distributions in the bottom waters of Chesapeake Bay. *Limnology and Oceanography* 58: 2237-2248.
28. Lucas LV, Thompson JK, Brown LR. 2009. Why are diverse relationships observed between phytoplankton biomass and transport time? *Limnology and Oceanography* 54: 381-390.
29. Mouchet A, Cornaton F, Deleersnijder E, Delhez EJM. 2016. Partial ages: diagnosing transport processes by means of multiple clocks. *Ocean Dynamics* 66: 367-386.
30. Delpeche-Ellmann N, Torsvik T, Soomere T. 2015. Tracks of surface drifters from a major fairway to marine protected areas in the Gulf of Finland. *Proceedings of the Estonian Academy of Sciences* 64: 226-233.
31. Du J, Park K, Shen J, Dzwonkowski B, Yu X, Yoon BI. 2018. Role of Baroclinic Processes on Flushing Characteristics in a Highly Stratified Estuarine System, Mobile Bay, Alabama. *Journal of Geophysical Research: Oceans* 123: 4518-4537.
32. Monsen NE, Cloern JE, Lucas LV, Monismith SG. 2002. A comment on the use of flushing time, residence time, and age as transport time scales. *Limnology and Oceanography* 47: 1545-1553.
33. Bolin B, Rodhe H. 1973. A note on the concepts of age distribution and transit time in natural reservoirs. *Tellus* 25: 58-62.
34. Takeoka H. 1984. Fundamental concepts of exchange and transport time scales in a coastal sea. *Continental Shelf Research* 3: 311-326.
35. Zimmerman JTF. 1976. Mixing and flushing of tidal embayments in the western Dutch Wadden Sea. Part I: Distribution of salinity and calculation of mixing time scales. *Netherlands Journal of Sea Research* 10: 149-191.

36. Delhez EJM. 2006. Transient residence and exposure times. *Ocean Science* 2: 1-9.
37. Defne Z, Ganju NK. 2015. Quantifying the Residence Time and Flushing Characteristics of a Shallow, Back-Barrier Estuary: Application of Hydrodynamic and Particle Tracking Models. *Estuaries and Coasts* 38: 1719-1734.
38. Rayson MD, Gross ES, Hetland RD, Fringer OB. 2016. Time scales in Galveston Bay: An unsteady estuary. *Journal of Geophysical Research-Oceans* 121: 2268-2285.
39. Delhez EJM. 2013. On the concept of exposure time. *Continental Shelf Research* 71: 27-36.
40. Delhez EJM, Lacroix G, Deleersnijder E. 2004. The age as a diagnostic of the dynamics of marine ecosystem models. *Ocean Dynamics* 54: 221-231.
41. Du JB, Park K, Yu X, Zhang YLJ, Ye F. 2020. Massive pollutants released to Galveston Bay during Hurricane Harvey: Understanding their retention and pathway using Lagrangian numerical simulations. *Science of the Total Environment* 704.
42. Jouon A, Douillet P, Ouillon S, Fraunie P. 2006. Calculations of hydrodynamic time parameters in a semi-opened coastal zone using a 3D hydrodynamic model. *Continental Shelf Research* 26: 1395-1415.
43. Delhez EJM, Campin JM, Hirst AC, Deleersnijder E. 1999. Toward a general theory of the age in ocean modelling. *Ocean Modelling* 1: 17-27.
44. Deleersnijder E, Campin JM, Delhez EJM. 2001. The concept of age in marine modelling I. Theory and preliminary model results. *Journal of Marine Systems* 28: 229-267.
45. Delhez EJM, Heemink AW, Deleersnijder E. 2004. Residence time in a semi-enclosed domain from the solution of an adjoint problem. *Estuarine Coastal and Shelf Science* 61: 691-702.
46. Gong WP, Shen J. 2010. A model diagnostic study of age of river-borne sediment transport in the tidal York River Estuary. *Environmental Fluid Mechanics* 10: 177-196.
47. Mercier C, Delhez EJM. 2007. Diagnosis of the sediment transport in the Belgian Coastal Zone. *Estuarine Coastal and Shelf Science* 74: 670-683.
48. Delhez EJM, Wolk F. 2013. Diagnosis of the transport of adsorbed material in the Scheldt estuary: A proof of concept. *Journal of Marine Systems* 128: 17-26.
49. Ralston DK, Geyer WR. 2017. Sediment Transport Time Scales and Trapping Efficiency in a Tidal River. *Journal of Geophysical Research-Earth Surface* 122: 2042-2063.
50. Zhu L, Gong W, Zhang H, Huang W, Zhang R. 2020. Numerical study of sediment transport time scales in an ebb-dominated waterway. *Journal of Hydrology* 591: 125299, 125291-125213.
51. Gross E, Andrews S, Bergamaschi B, et al. 2019. The Use of Stable Isotope-Based Water Age to Evaluate a Hydrodynamic Model. *Water* 11.
52. Shen J, Haas L. 2004. Calculating age and residence time in the tidal York River using three-dimensional model experiments. *Estuarine Coastal and Shelf Science* 61: 449-461.
53. Rutherford K, Fennel K. 2018. Diagnosing transit times on the northwestern North Atlantic continental shelf. *Ocean Science* 14.
54. Lin L, Liu Z. 2019. Partial residence times: determining residence time composition in different subregions. *Ocean Dynamics* 69: 1023-1036.
55. Du JB, Shen J. 2016. Water residence time in Chesapeake Bay for 1980-2012. *Journal of Marine Systems* 164: 101-111.
56. Storlazzi CD, Cheriton OM, Messina AM, Biggs TW. 2018. Meteorologic, oceanographic, and geomorphic controls on circulation and residence time in a coral reef-lined embayment: Faga'alu Bay, American Samoa. *Coral Reefs* 37: 457-469.
57. Manning JP, McGillicuddy DJ, Pettigrew NR, Churchill JH, Incze LS. 2009. Drifter Observations of the Gulf of Maine Coastal Current. *Continental Shelf Research* 29: 835-845.

58. Falco P, Griffa A, Poulain P-M, Zambianchi E. 2000. Transport Properties in the Adriatic Sea as Deduced from Drifter Data. *Journal of Physical Oceanography* 30: 2055-2071.
59. Pawlowicz R, Hannah C, Rosenberger A. 2019. Lagrangian observations of estuarine residence times, dispersion, and trapping in the Salish Sea. *Estuarine Coastal and Shelf Science* 225: 1-16.
60. Downing BD, Bergamaschi BA, Kendall C, et al. 2016. Using Continuous Underway Isotope Measurements To Map Water Residence Time in Hydrodynamically Complex Tidal Environments. *Environmental Science & Technology* 50: 13387-13396.
61. Lucas LV, Thompson JK. 2012. Changing restoration rules: exotic bivalves interact with residence time and depth to control phytoplankton productivity. *Ecosphere* 3: art 117.