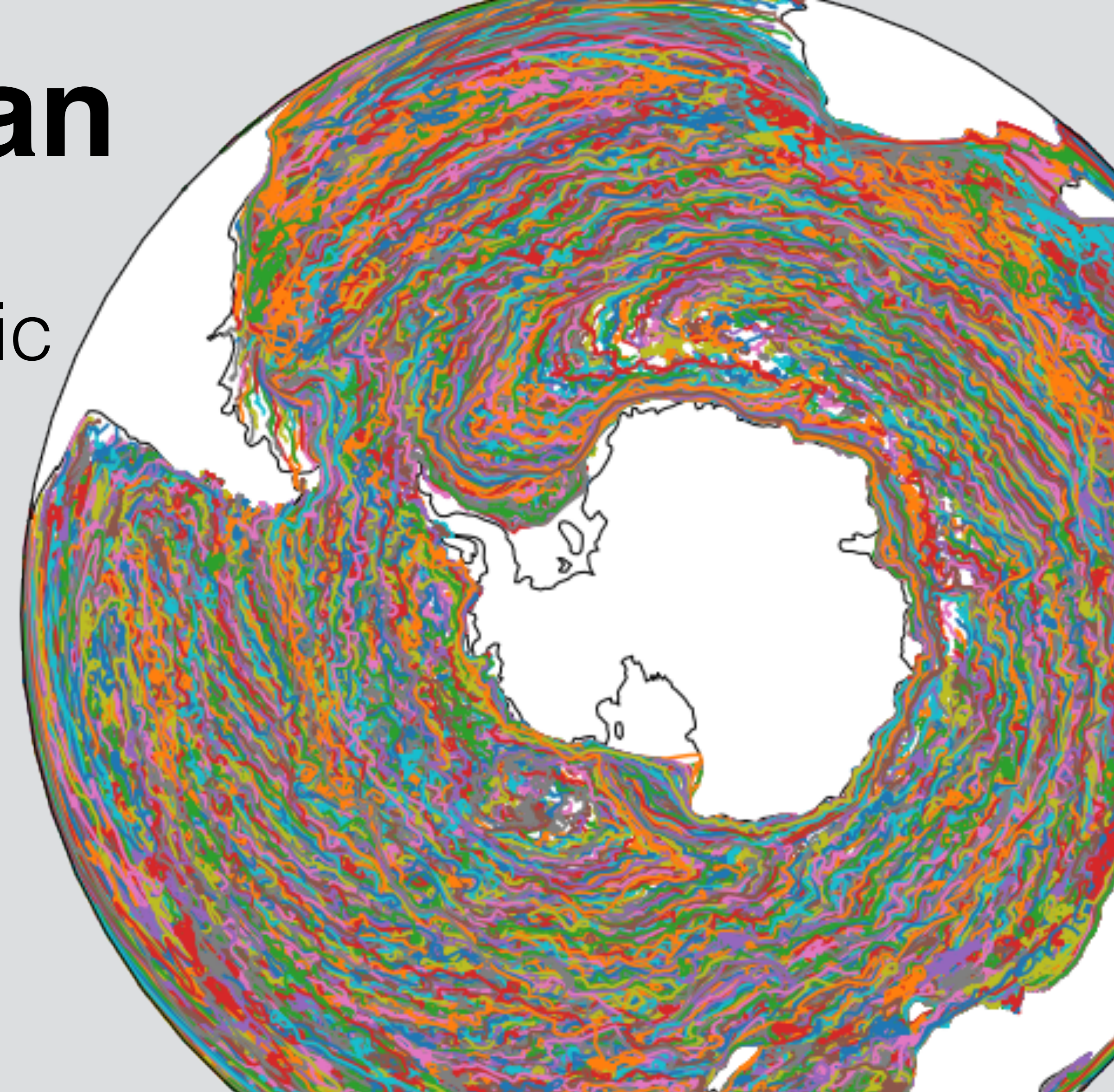# The Connected Ocean

The global-scale transports of
heat, nutrients, plankton and plastic
by ocean currents

Erik van Sebille

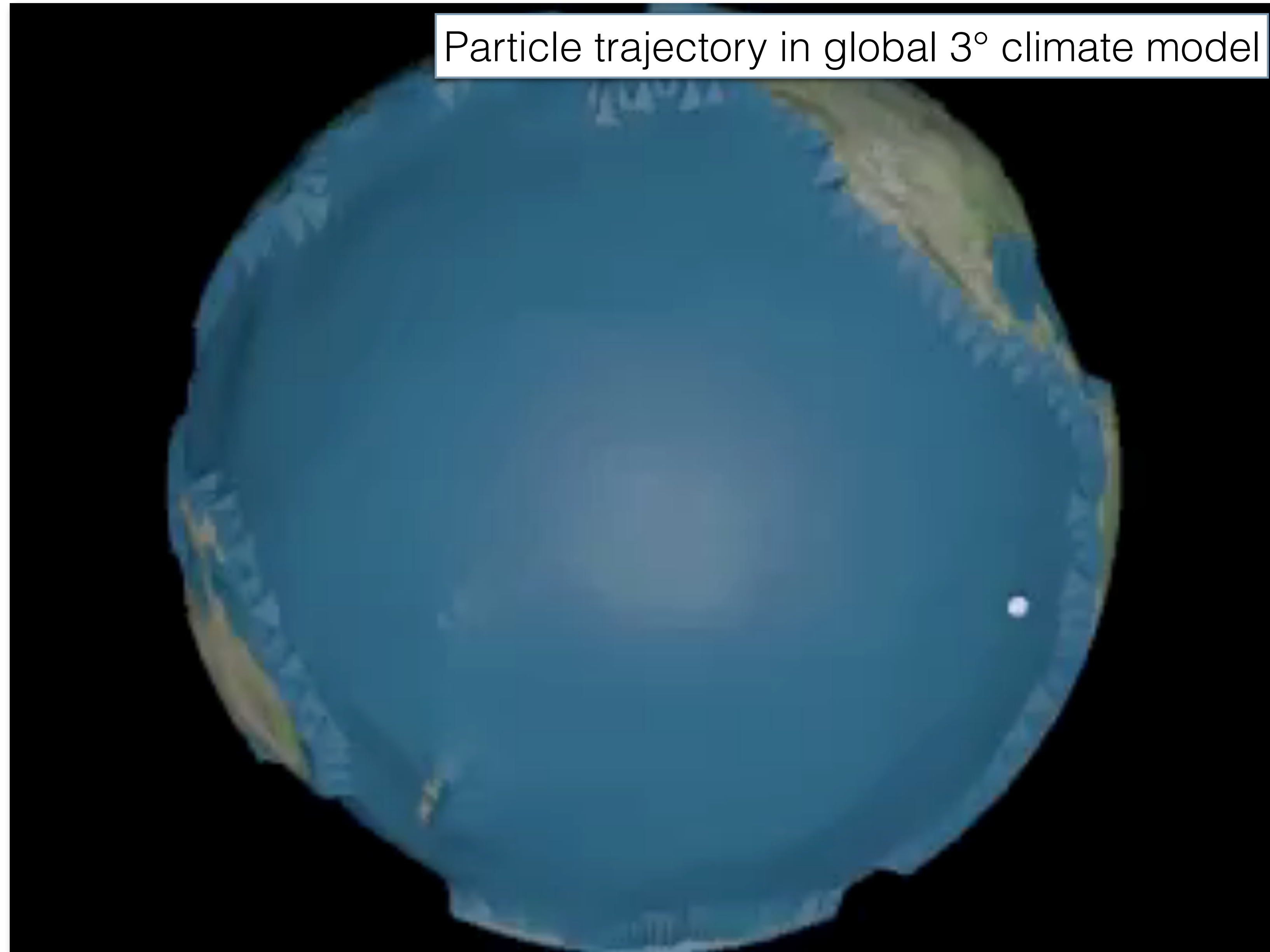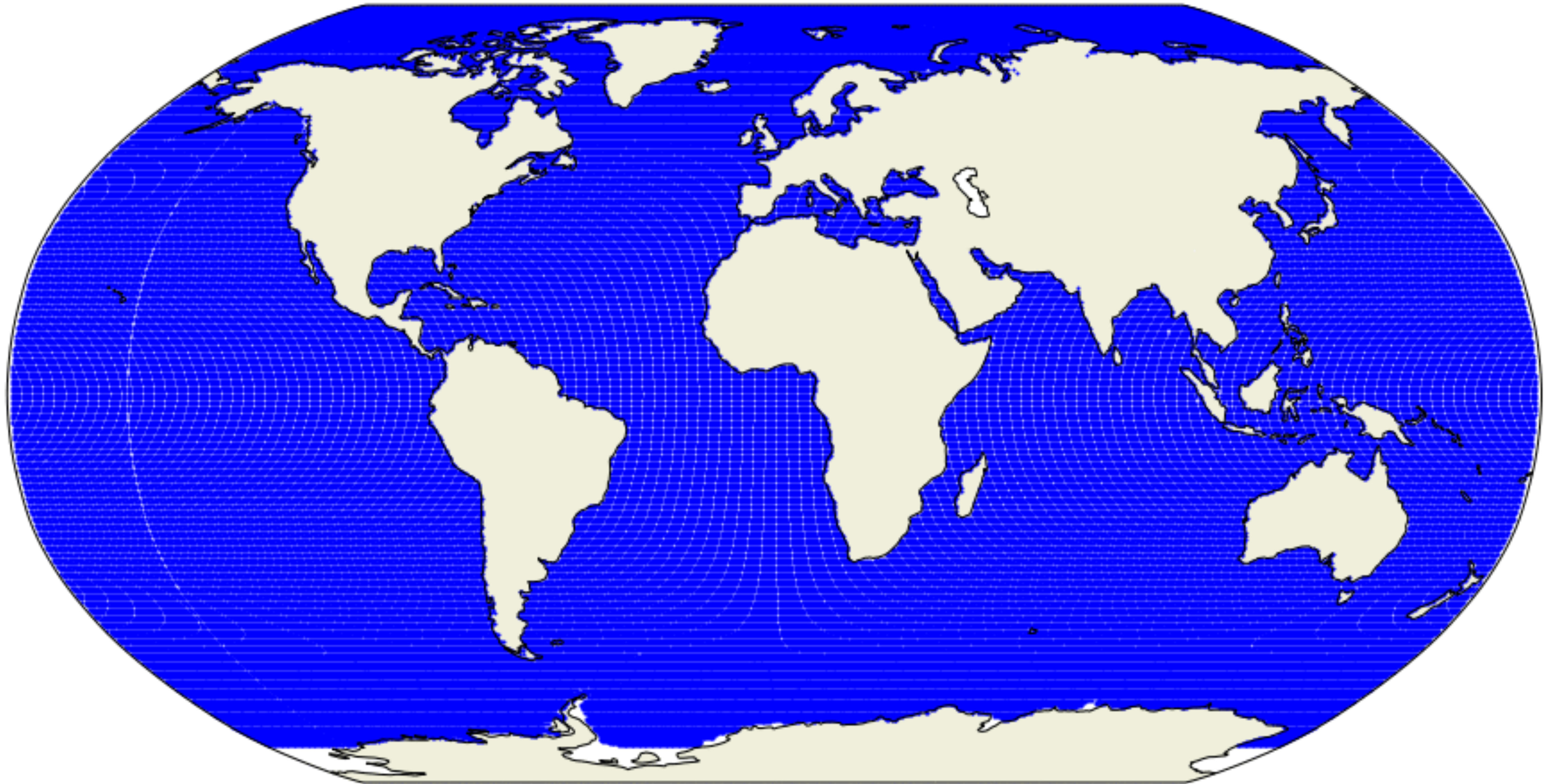and the topios.org and oceanparcels.org teams

Utrecht University

EPSRC
Engineering and Physical Sciences
Research Council

Galapagos
Conservation
Trust

esa

NWO

European Research Council
Established by the European Commission

Simulating virtual particles with computer models (Lagrangian Ocean Analysis)

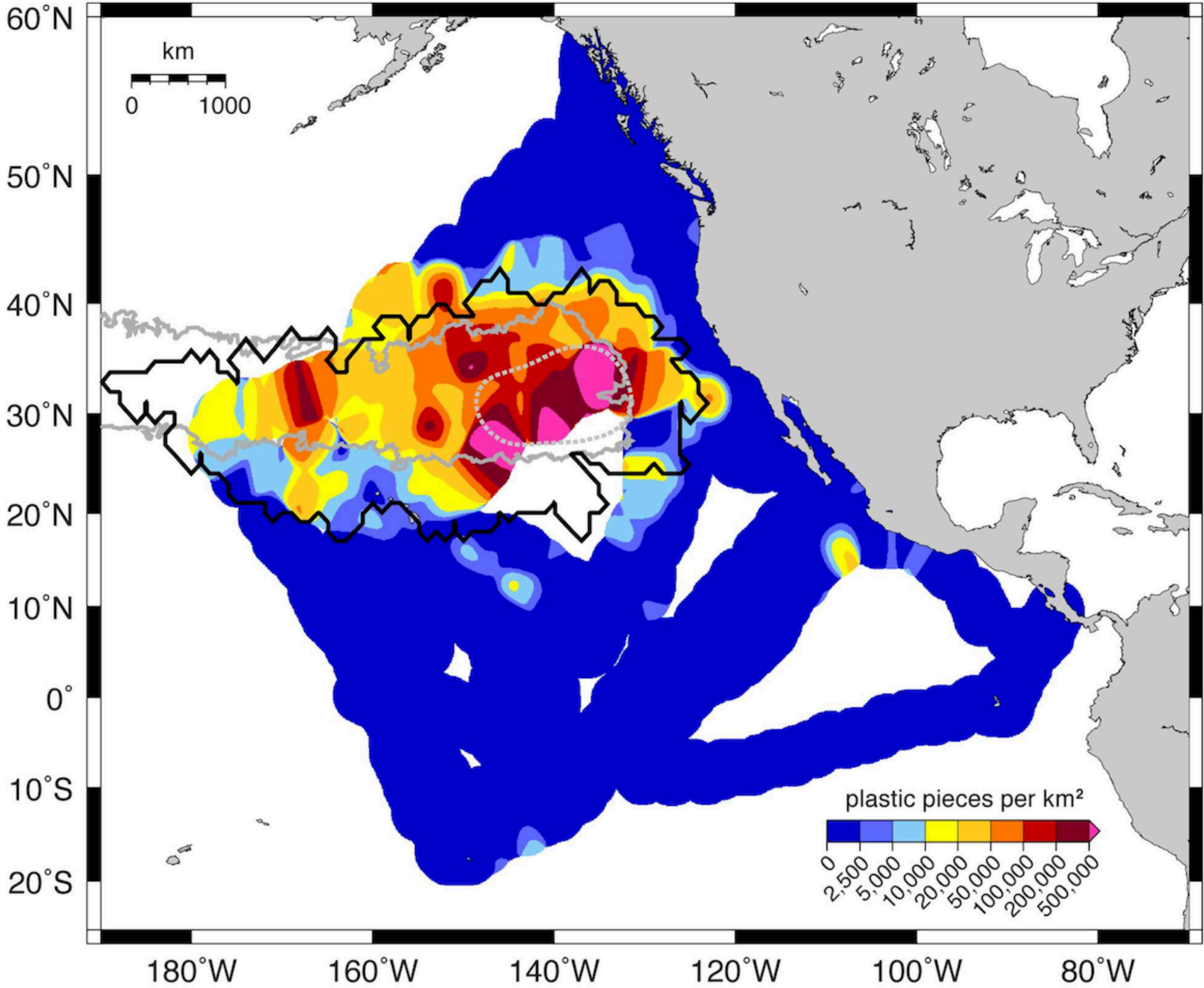Particle trajectory in global 3° climate model

Simulating surface transport on a global scale

Particles in 1/12° NEMO surface fields at time 2000-01-03
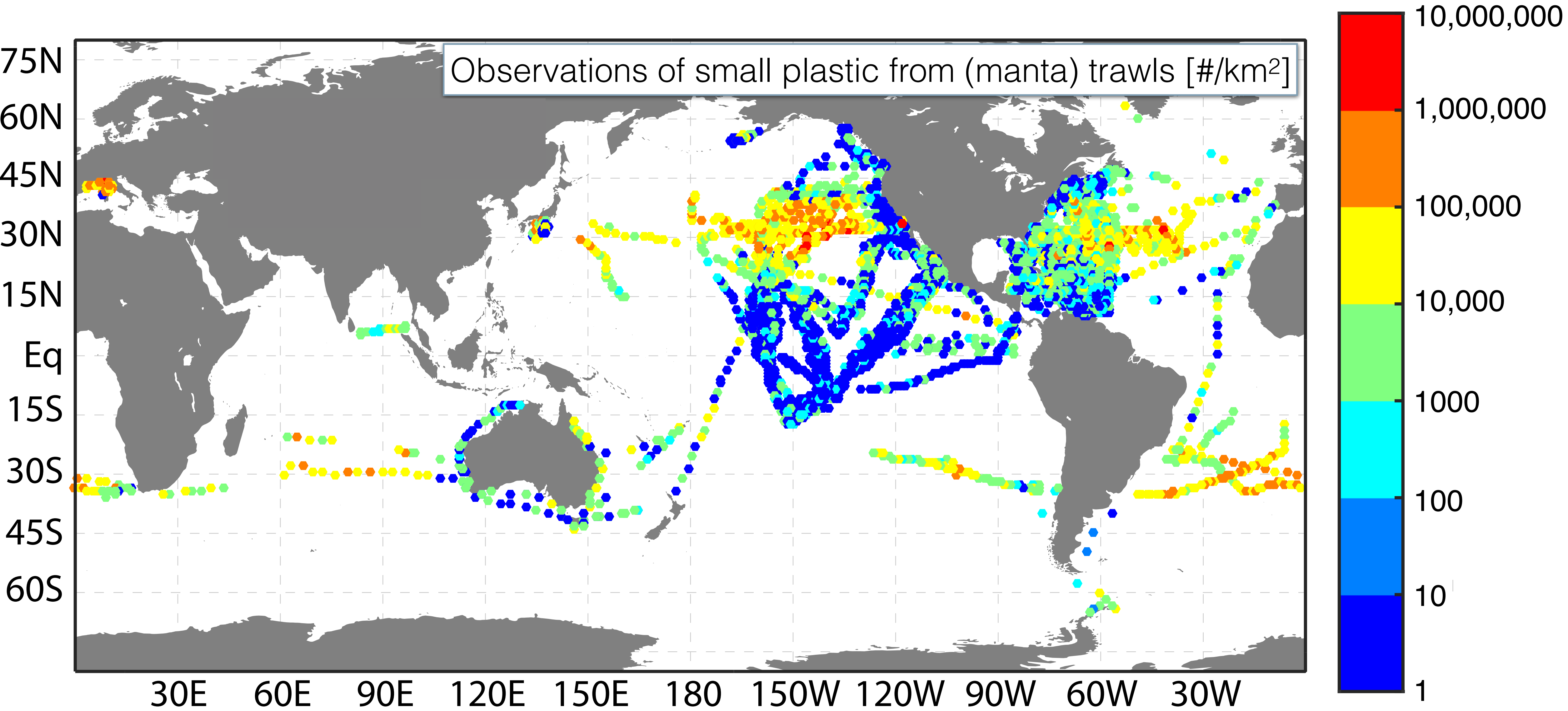
Observational evidence for the garbage patches

Photo: Philippe Delandmeter

plastic pieces per km²

0 2,500 5,000 10,000 20,000 50,000 100,000 200,000 500,000

Law, Morét-Ferguson, Goodwin, Zettler, DeForce, Kukulka & Proskurowski (2014) *Environmental Science & Technology*

The 'plastic soup'

1 mile Zooplankton Trawl Gyre

Moore (2008) *Environmental Research*

Combining 11,000 trawl data points

Observations of small plastic from (manta) trawls [#/km²]

Sebille, Wilcox, Lebreton, Maximenko, Hardesty, van Franeker, Eriksen, Siegel, Galgani & Law (2015) *Environmental Research Letters*

Estimating the amount of small floating plastic

Modelled small plastic concentration [#/km²]

Total amount of 'small' plastic floating on the ocean:
15 - 51 trillion particles
weighing 93 - 236 thousand metric tonnes

Van Sebille, Wilcox, Lebreton, Maximenko, Hardesty, van Franeker, Eriksen, Siegel, Galgani & Law (2015) *Environmental Research Letters*
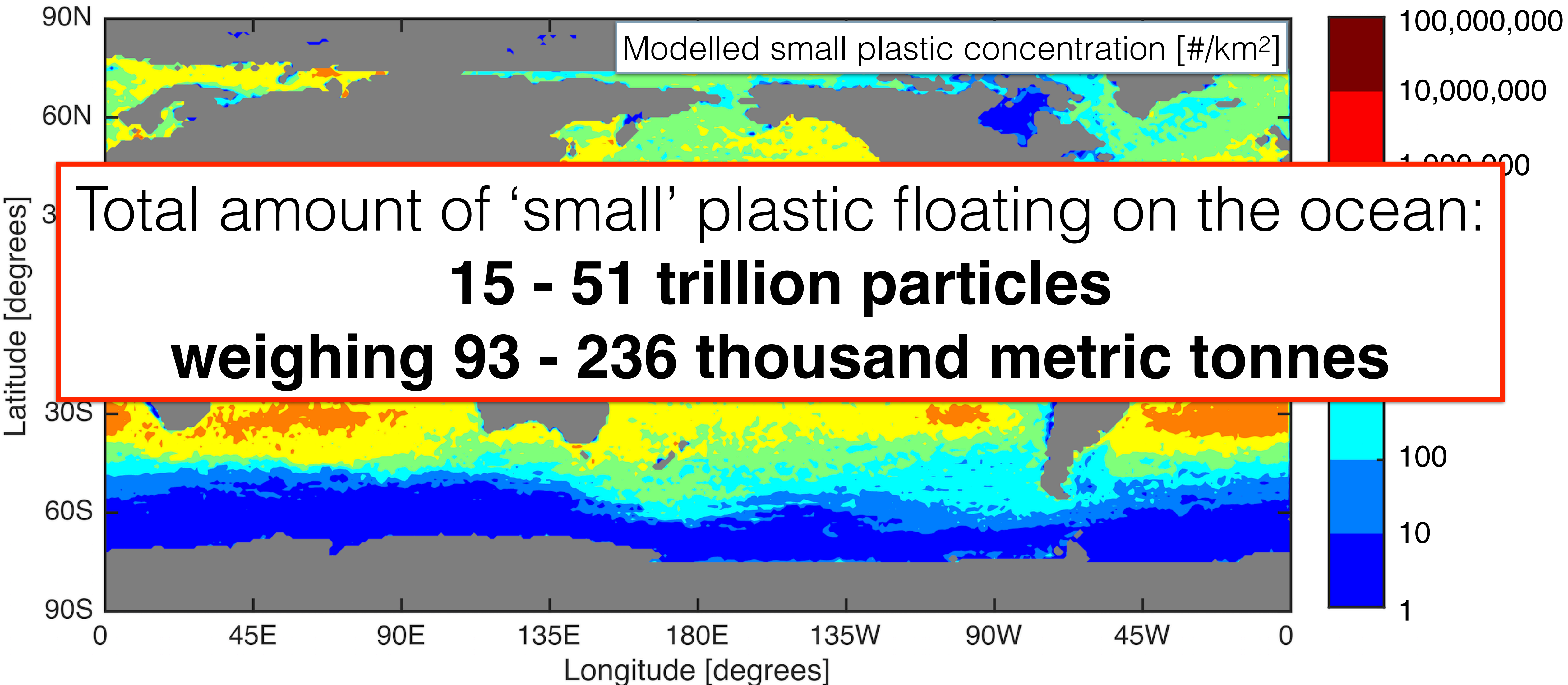
The case of our 99% missing plastic
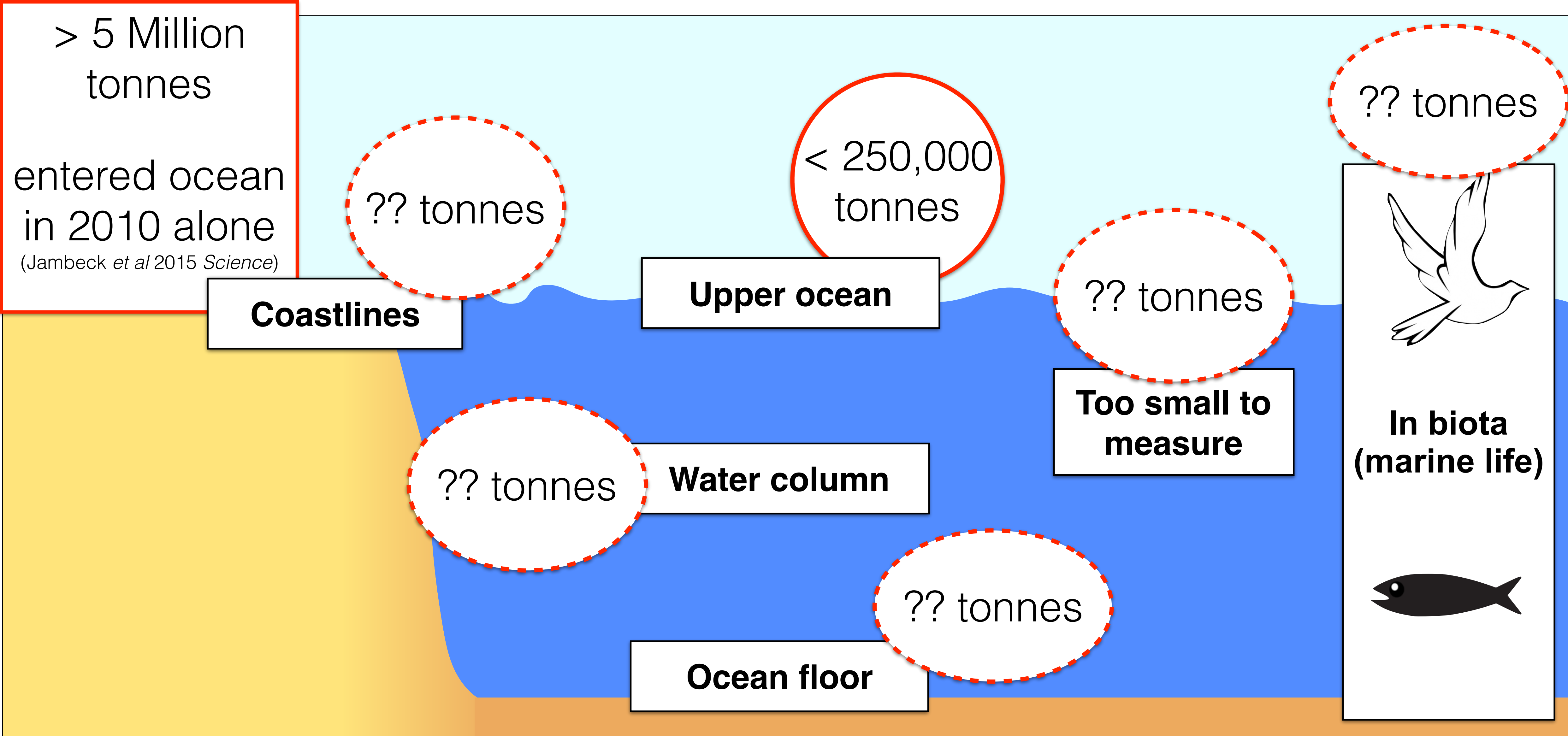
Simulating the pathways of plastic

Winds

Waves

Currents

Phytoplankton

Land input

Fragmentation

Beaching

Biofouling

Ingestion

Sinking
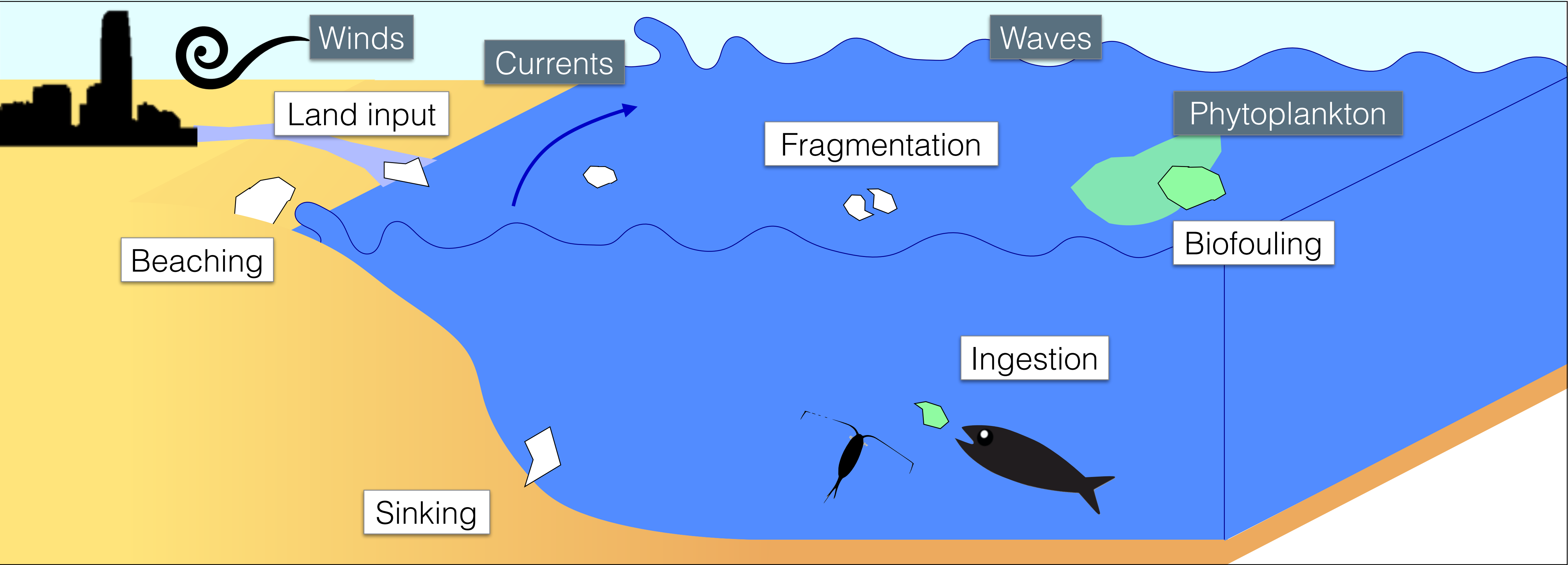
European Research Council
Established by the European Commission

ERC Starting Grant: Tracking Of Plastic In Our Seas (TOPIOS)

Wed 09:00-09:15 (room 15B): Cleo Jongedijk - Beaching
Wed 15:15-15:30 (room 15B): Mikael Kaandorp - Mediterranean plastic budget
Wed 16:00-18:00 (poster 2986): Delphine Lobelle - Biofouling

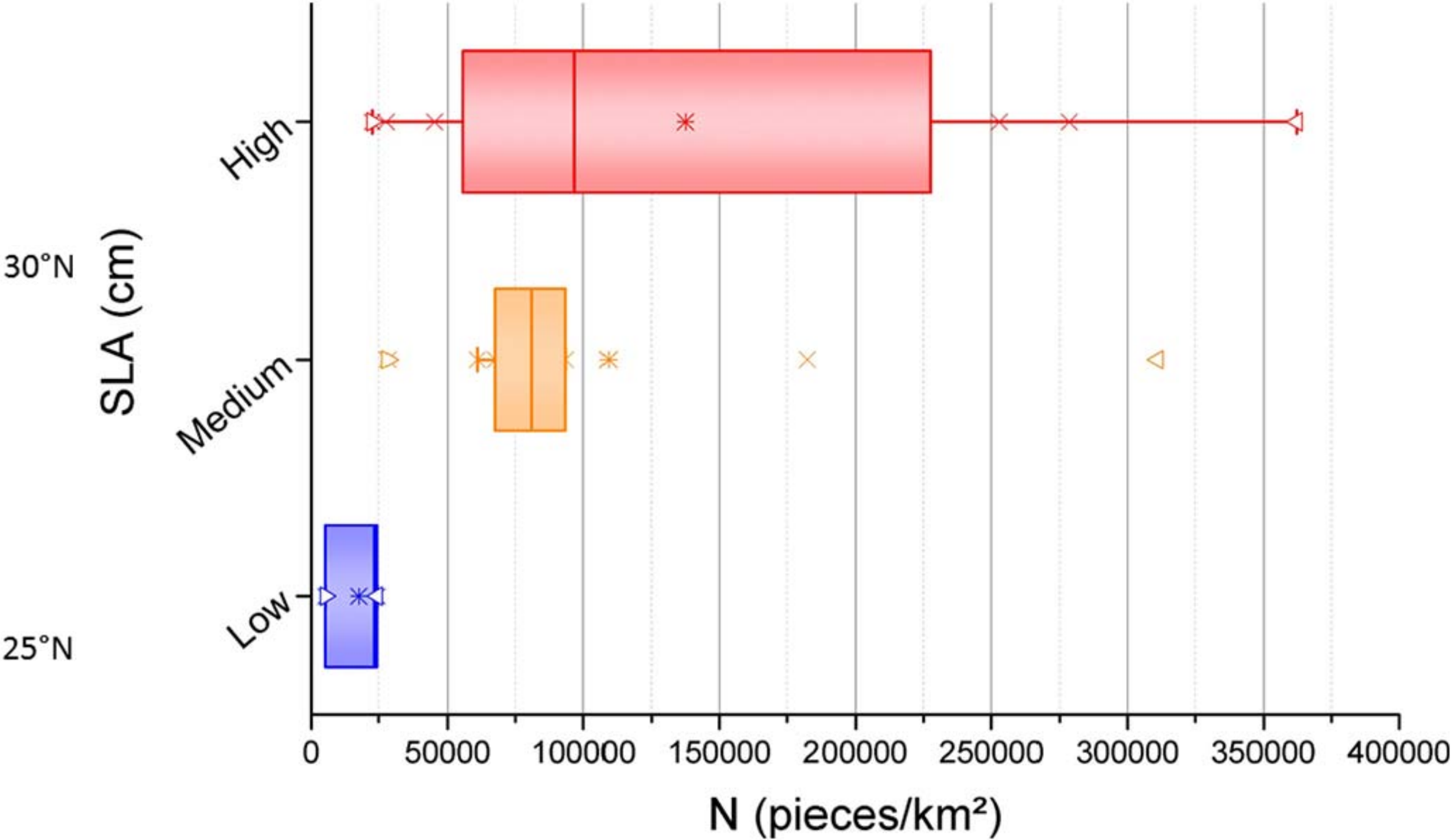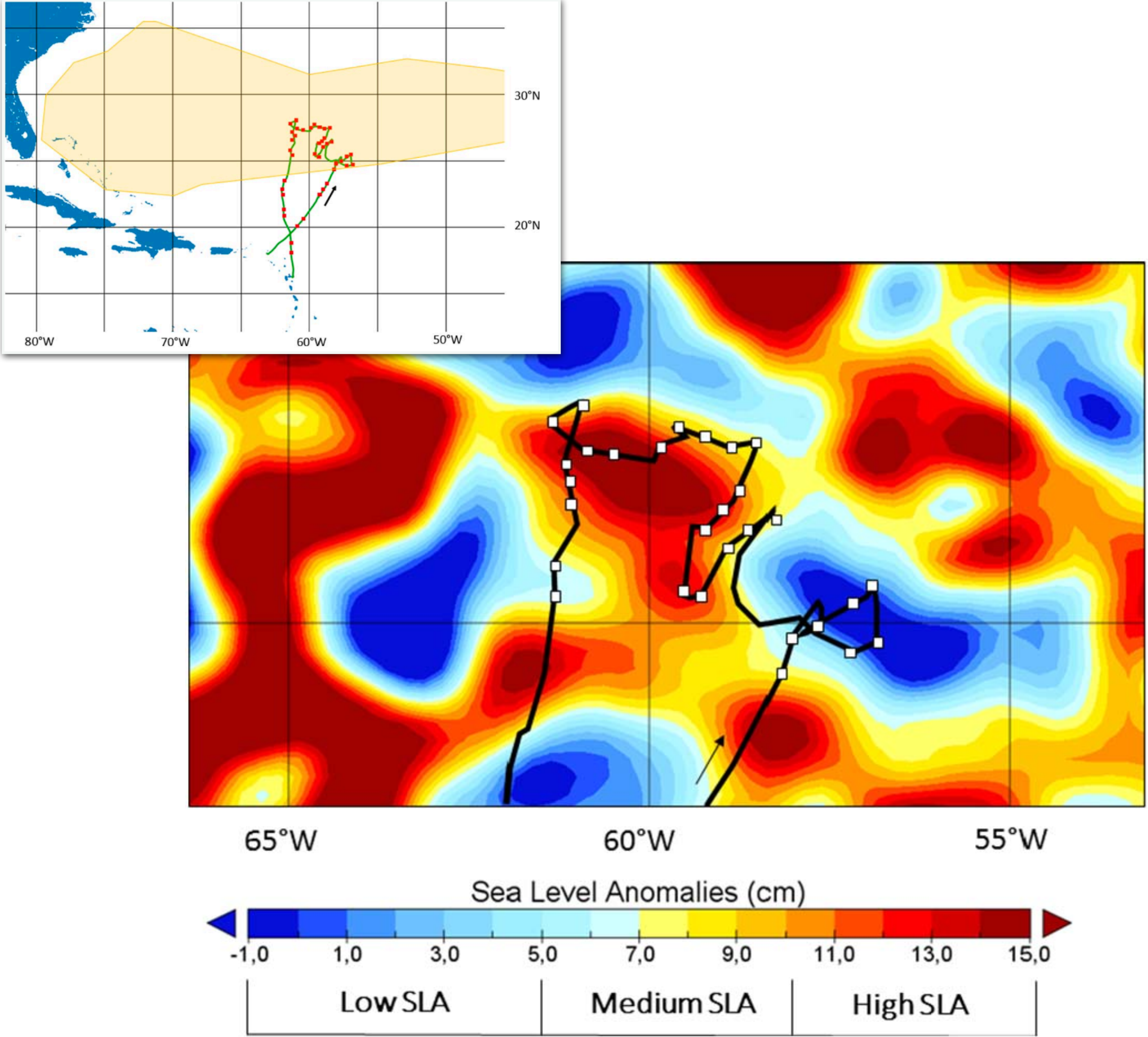# The physical oceanography of the transport of floating marine debris
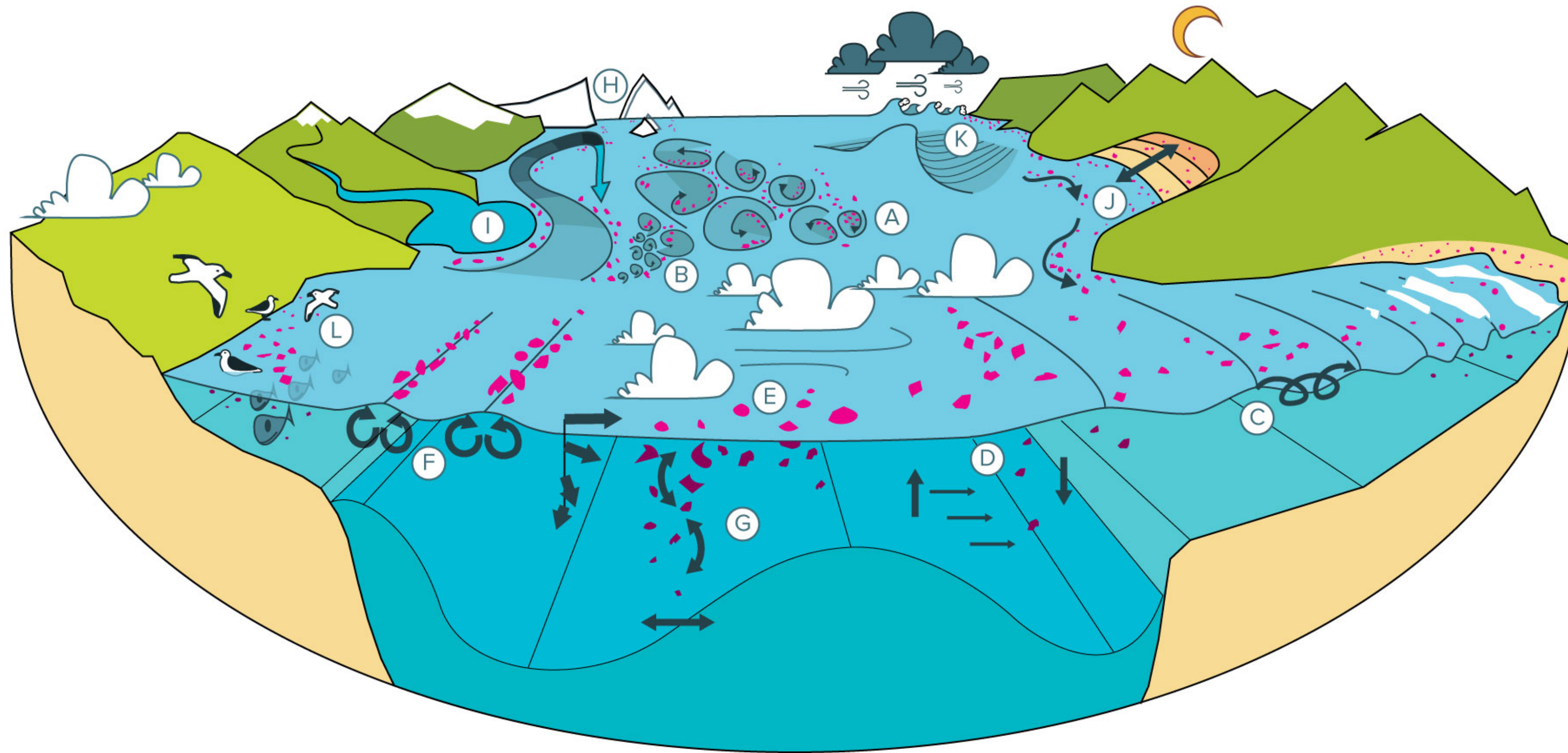
PHYSICAL PROCESSES

A   Large-scale open ocean processes

B   Submesoscale open ocean processes

C   Open ocean Stokes drift

D   Internal tides

E   Direct wind transport (windage)

F   Langmuir circulation

G   Vertical mixing

H   Ice formation, melting and drift

I   River plumes and coastal fronts

J   Coastal currents, surface waves and beaching
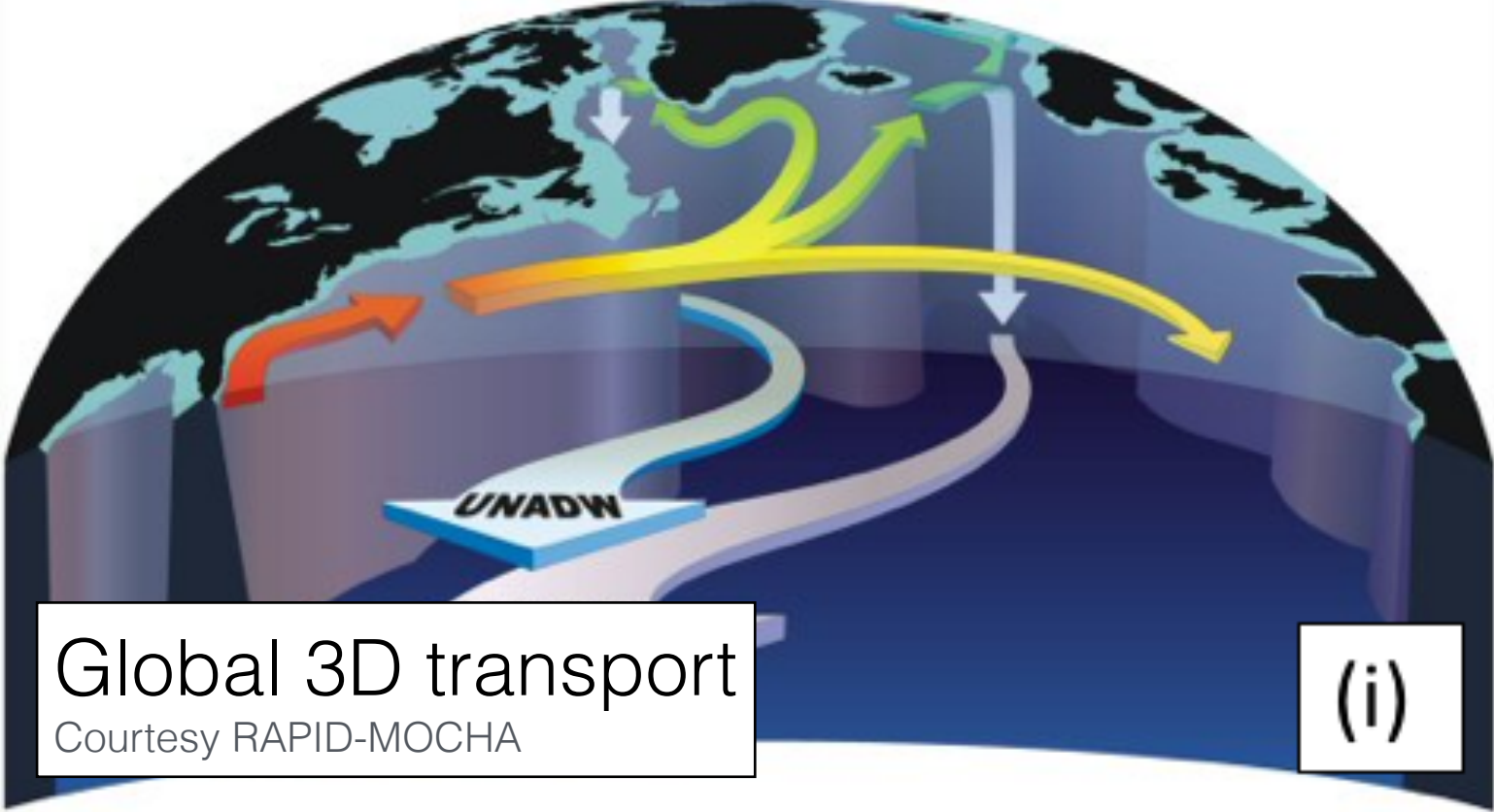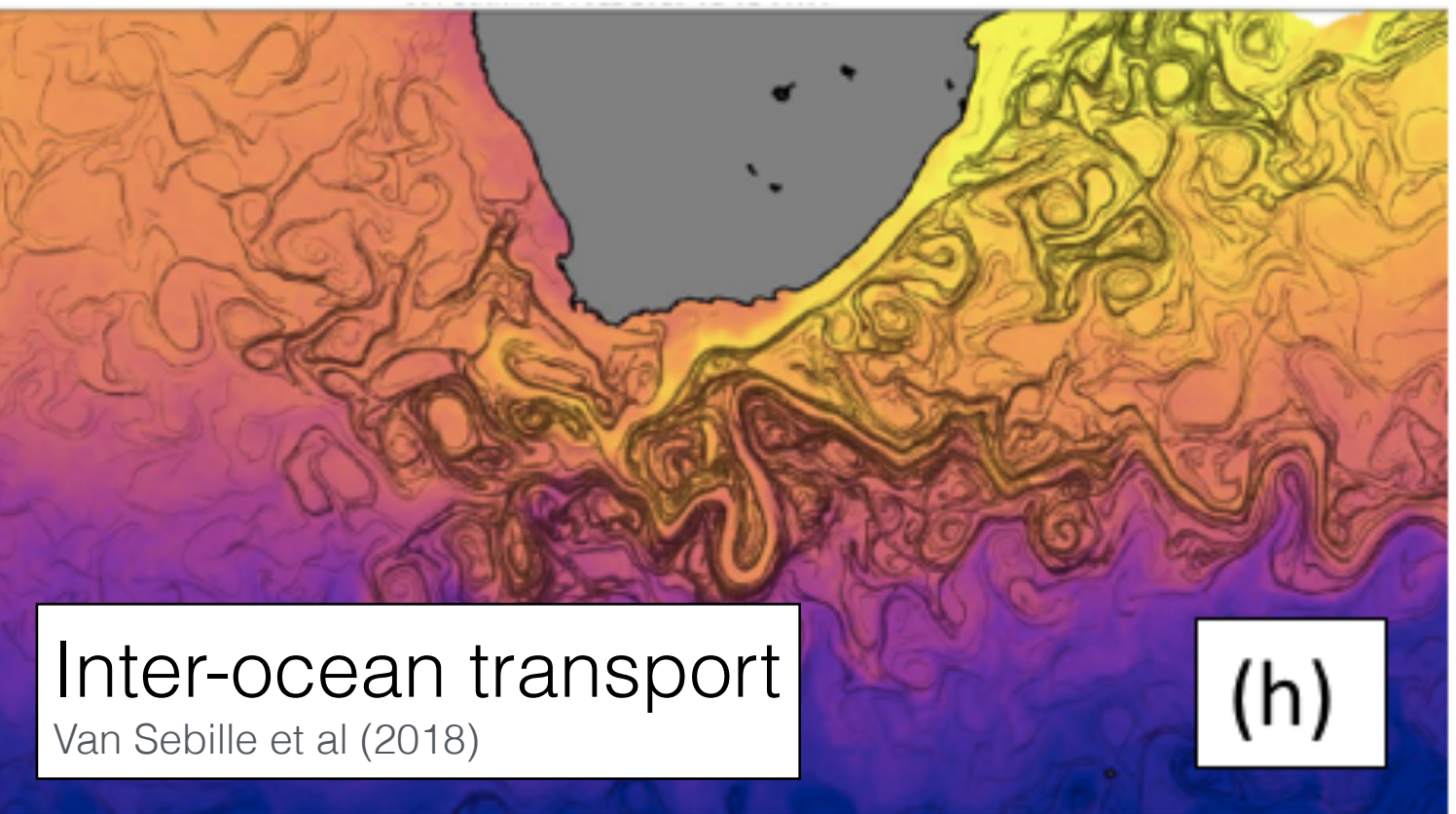
K   Extreme events

L   *Transport by biology*
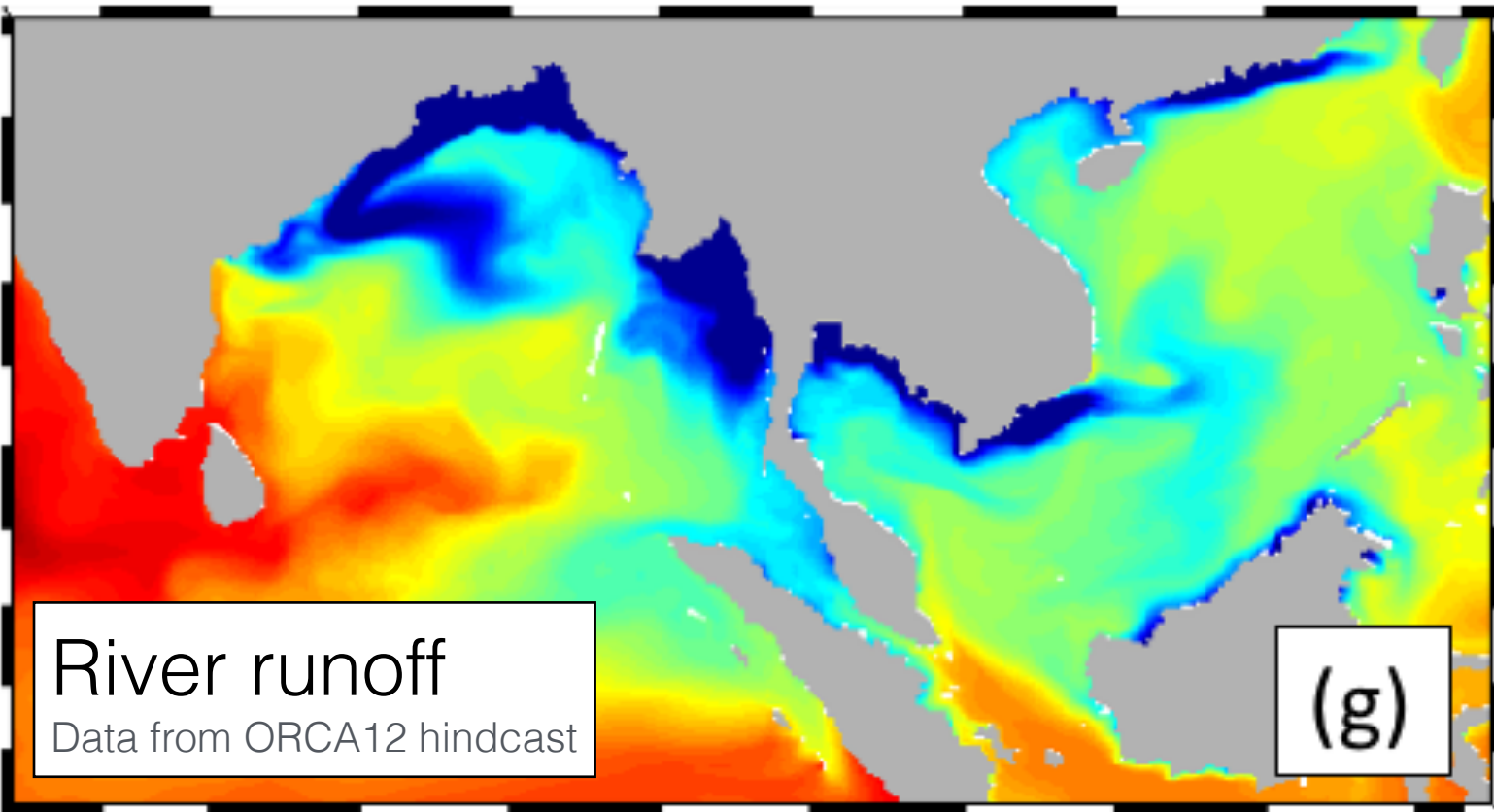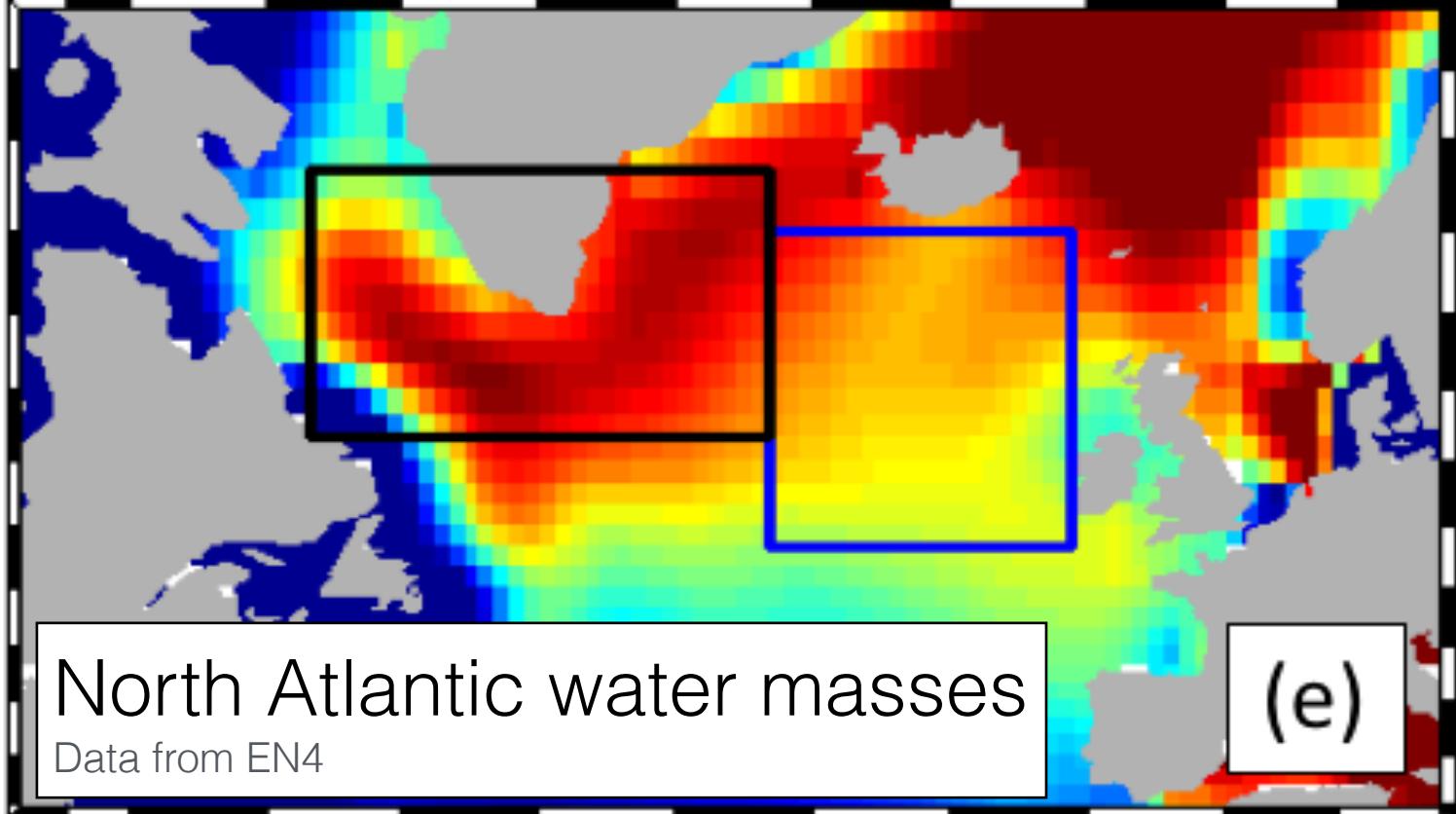
More plastic in anticyclonic eddies than in cyclonic

Brach, Deixonne, Bernard, Durand, Desjean, Perez, Van Sebille & Ter Halle (2018) *Marine Pollution Bulletin*

Lagrangian oceanography - An undergrad textbook w/ Bob Marsh (U Southampton)

(a) Marine plastic
Van Sebille et al (2015)

(b) (Planktonic) organisms
Scott et al (2014)

(c) Shelf exchanges
Marsh et al (2017)

(d) Tropical heat transport
Data from GODAS and NCEP

(e) North Atlantic water masses
Data from EN4

(f) Ice transport
Photo Erik van Sebille

(g) River runoff
Data from ORCA12 hindcast

(h) Inter-ocean transport
Van Sebille et al (2018)

(i) Global 3D transport
Courtesy RAPID-MOCHA

Interocean exchanges with virtual particles

- Using virtual particles to map 3D pathways of water around Australia and measure mixing

- **Conditional pathways**: Northern Hemisphere ITF | Southern Hemisphere ITF | Tasman leakage

Van Sebille, Sprintall, Schwarzkopf, Sen Gupta, Santoso, England, Biastoch & Böning (2014) *Journal of Geophysical Research*

Particles as plankton

Temperature of particles on 01-Jan-1990 [degC]

color = temperature | size = age
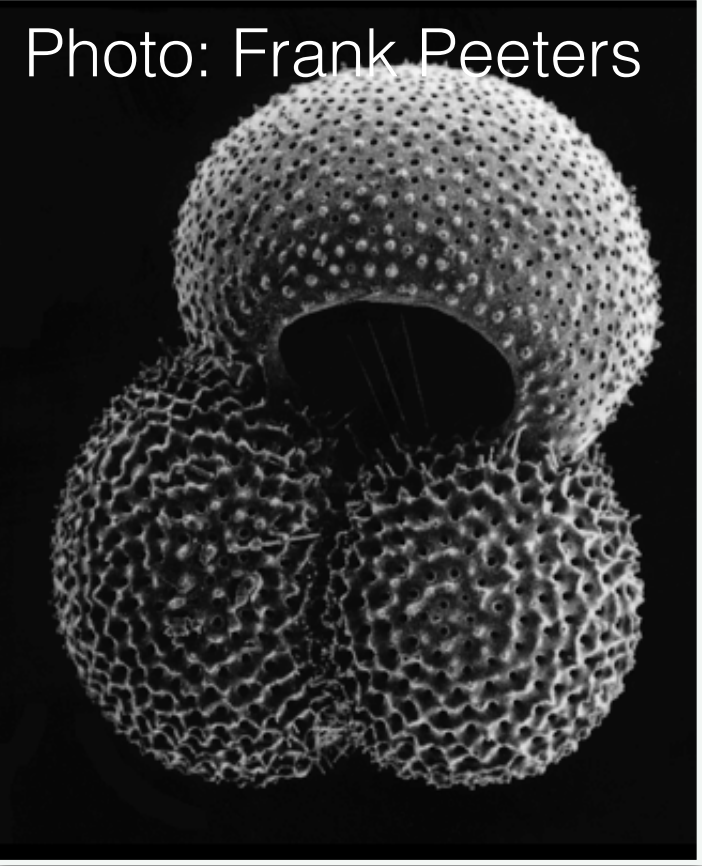
longitude [degrees]

Photo: IODP Expedition 320 crew

Photo: Frank Peeters

Van Sebille, Scussolini, Peeters, Durgadoo, Biastoch, Weijer, Turney, Paris & Zahn (2015) *Nature Communications*
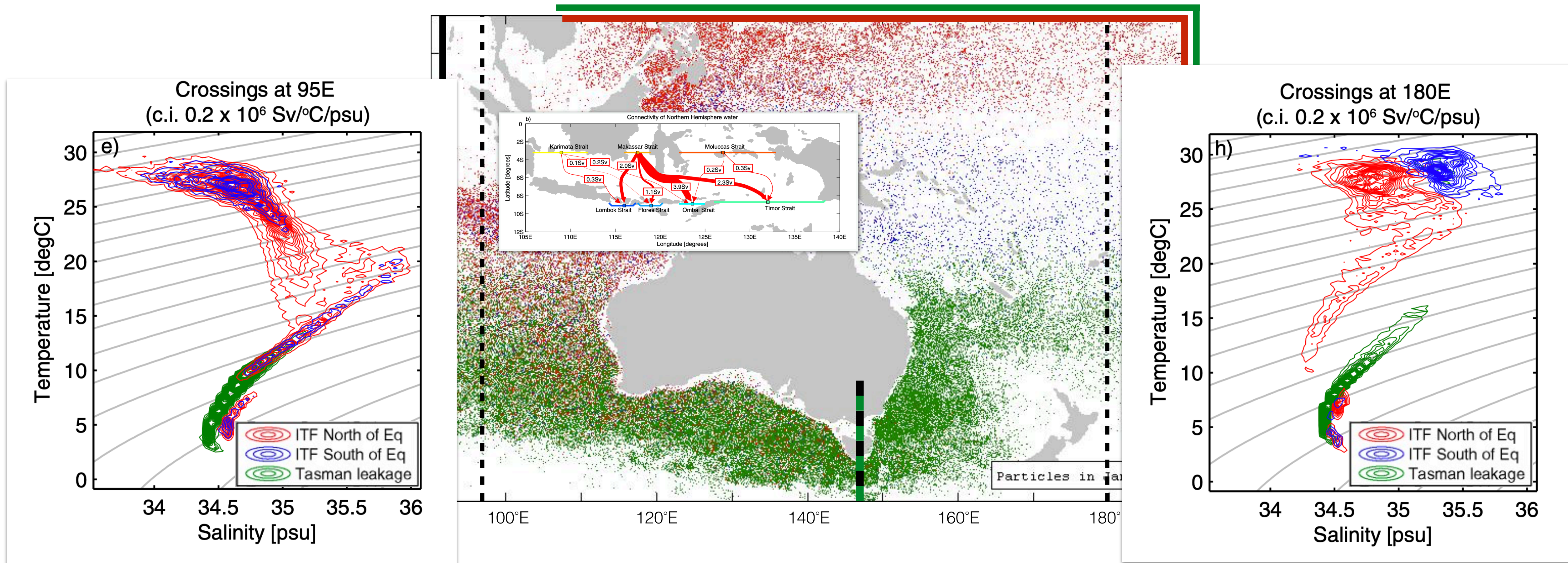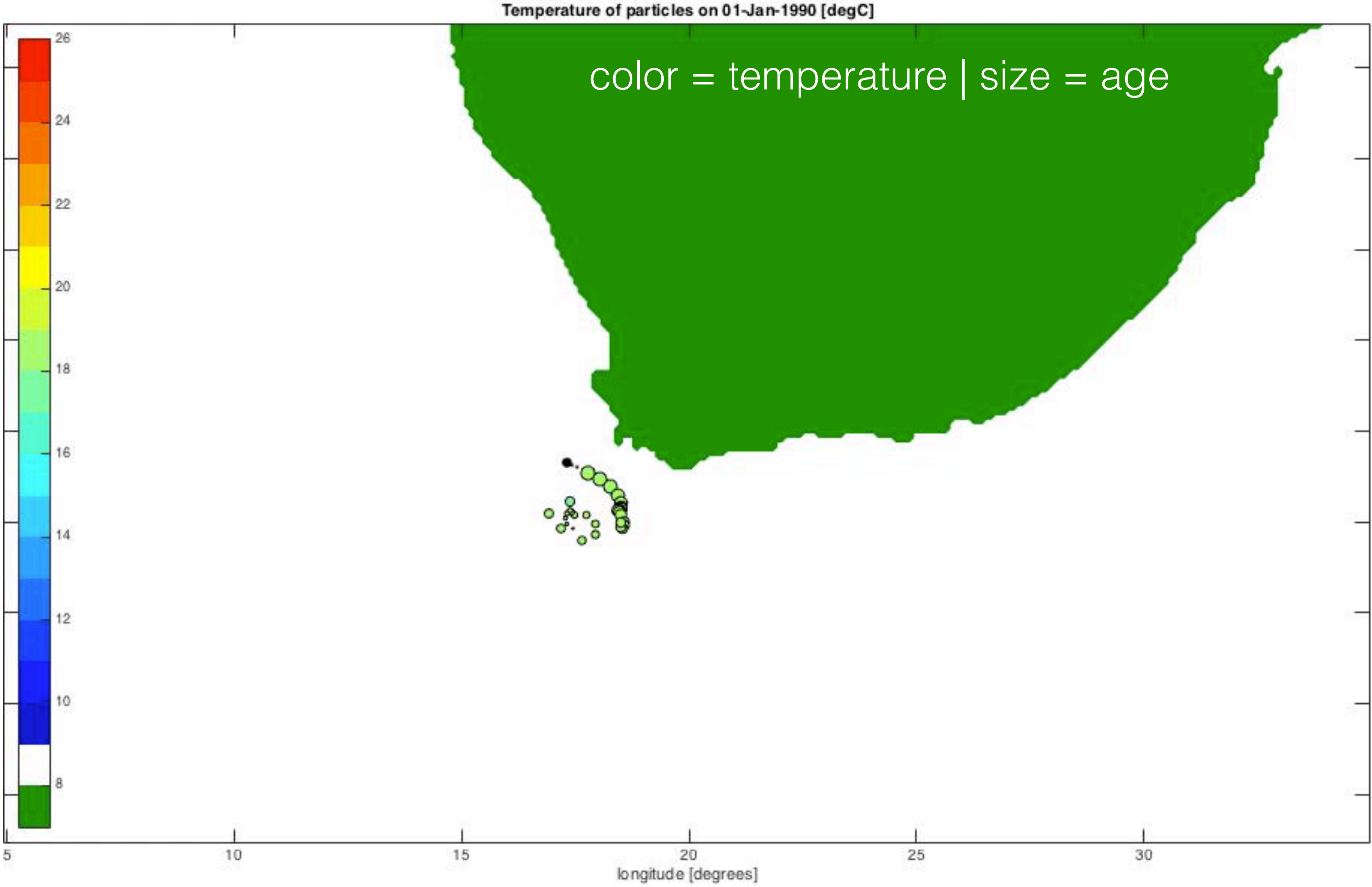
Going global
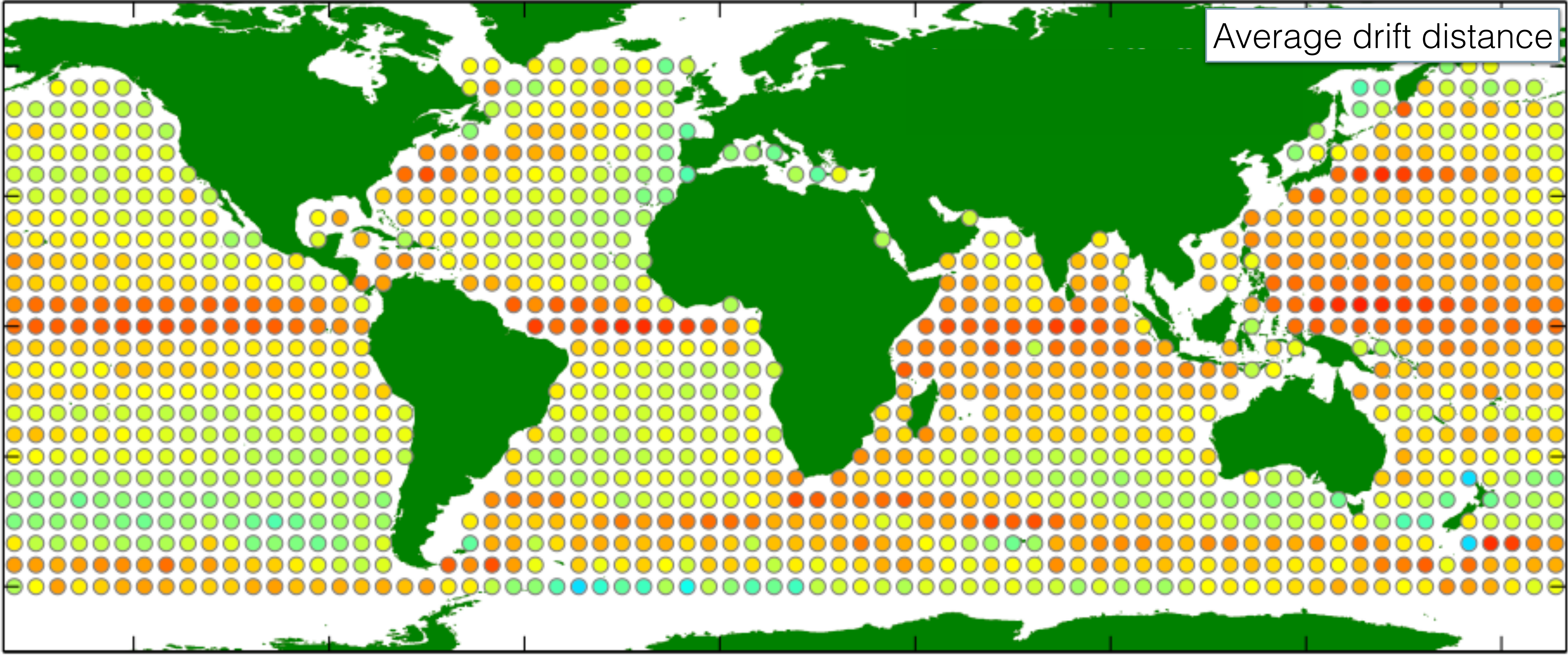
Average drift distance

[km]

3   10   30   100   300   1000   3000

The effect of drift on temperature proxies

Average temperature bias

[°C]

Virtual Microbes: Intergenerational temperature exposure

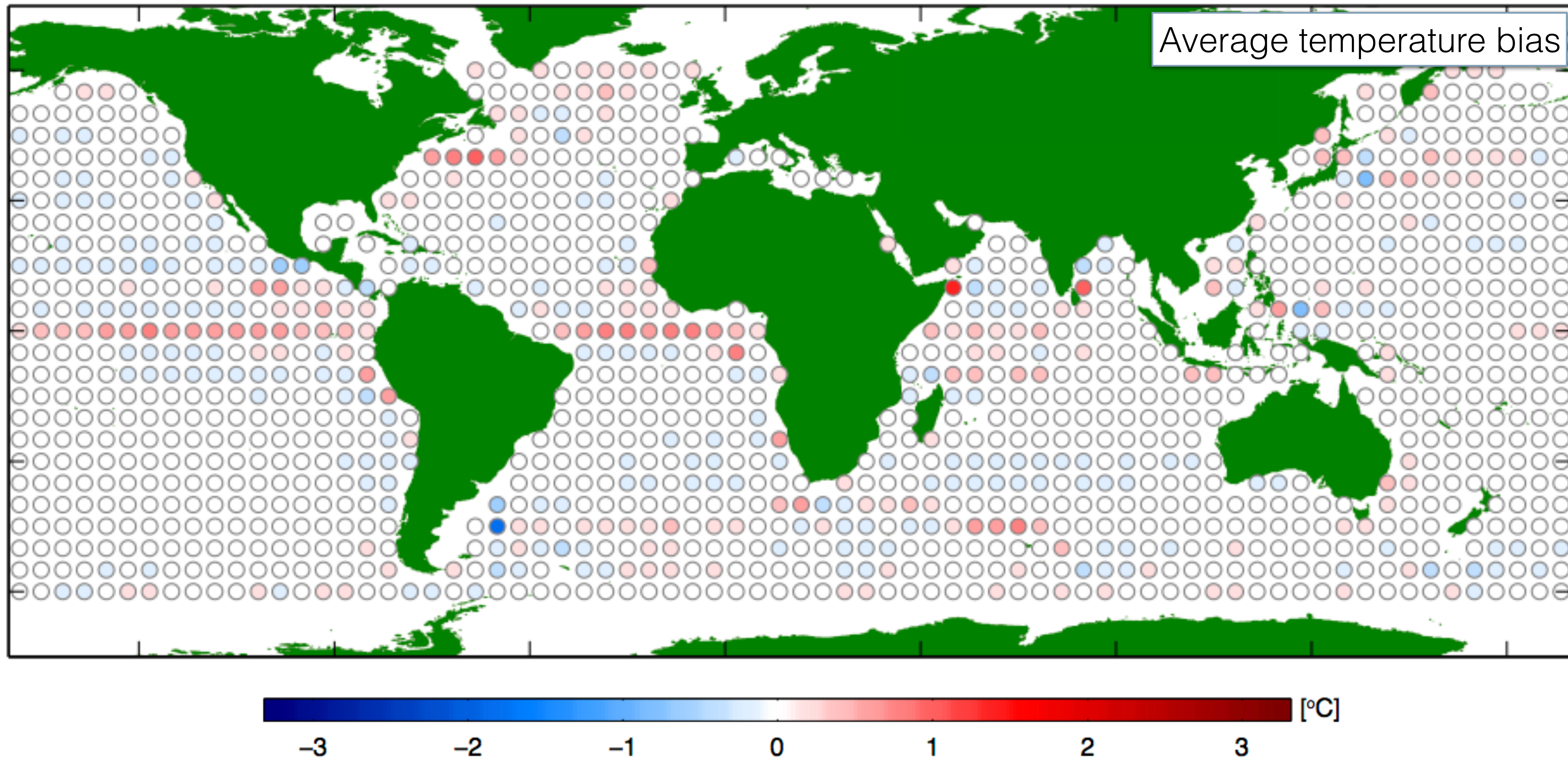Lagrangian minus Eulerian mean temperature [°C]

Along-trajectory temperature bias over 500 days

Doblin & Van Sebille (2016) *Proceedings of the National Academies of Sciences*
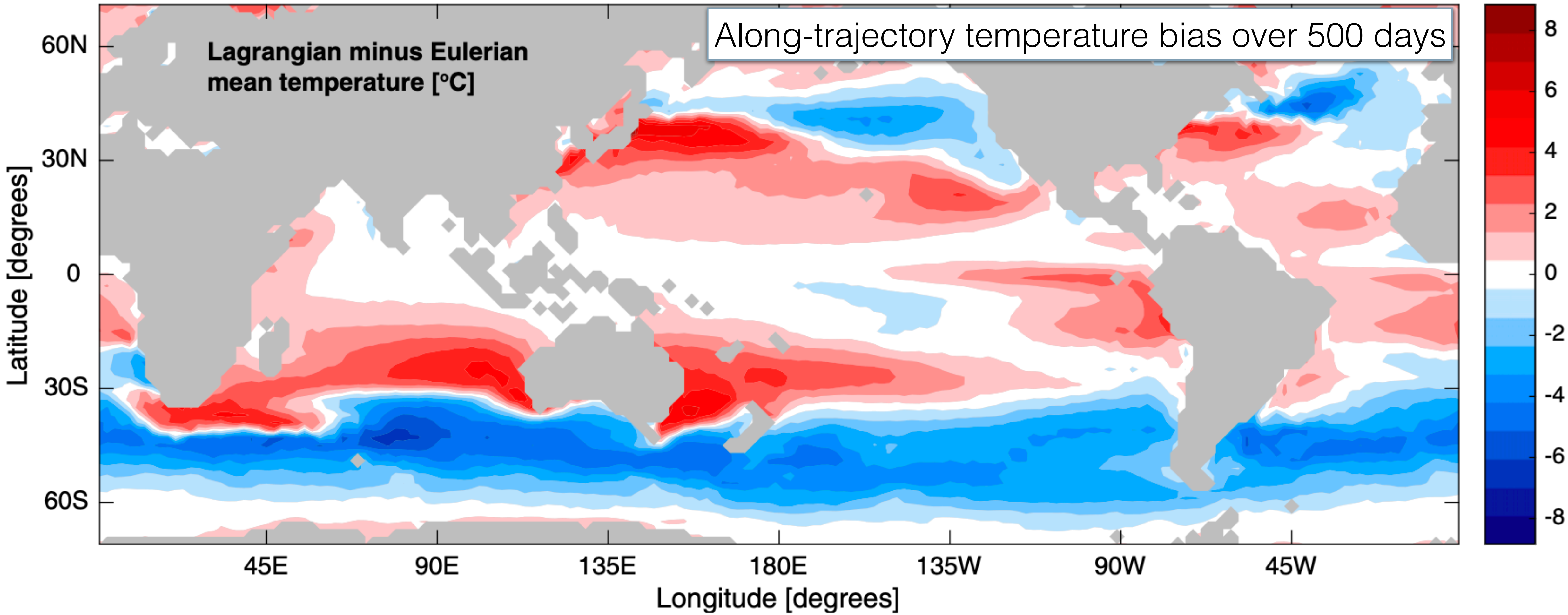
Towards particles that behave like fish

Unfavourable habitat   Better habitat
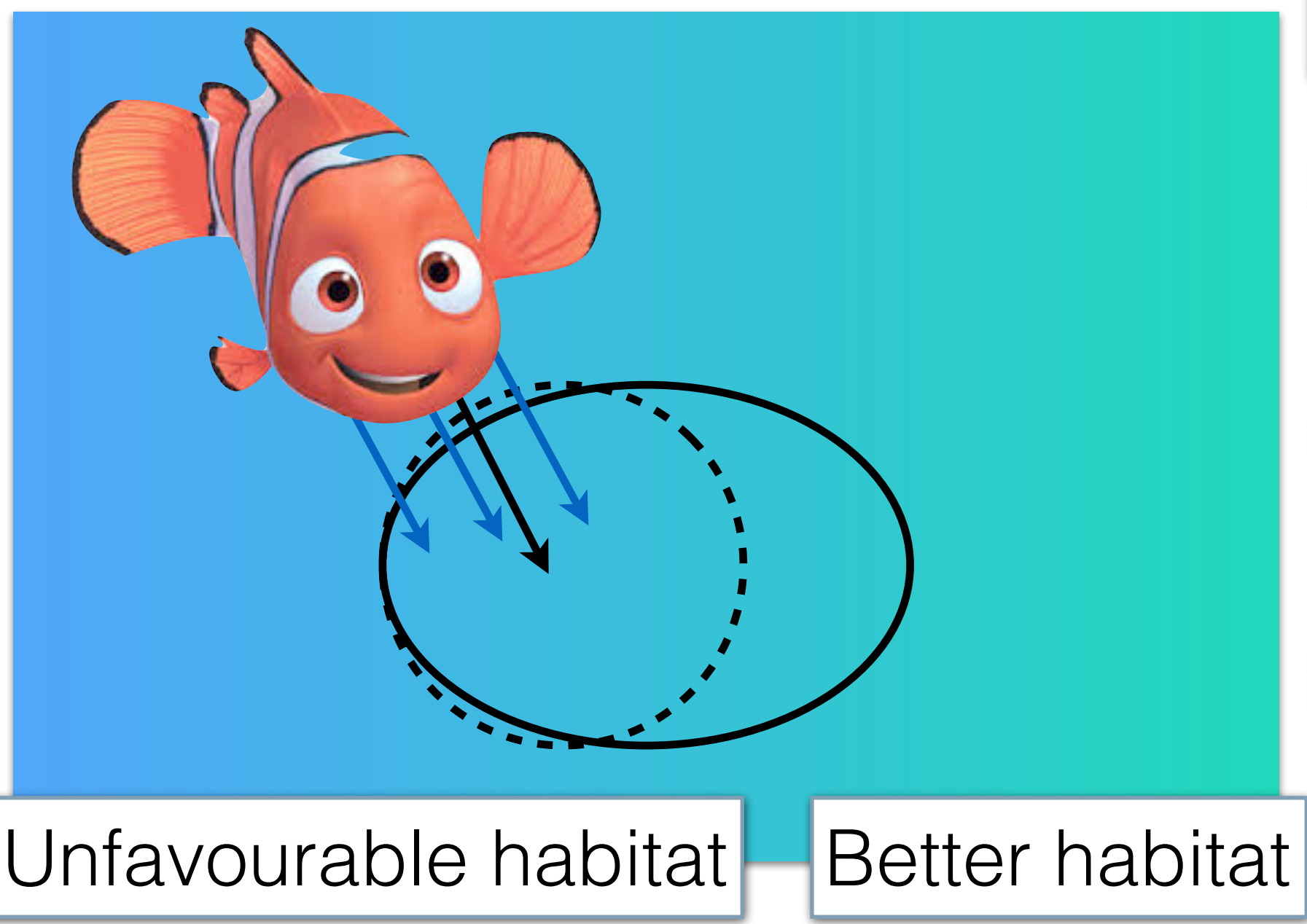
Reaching reef without swimming
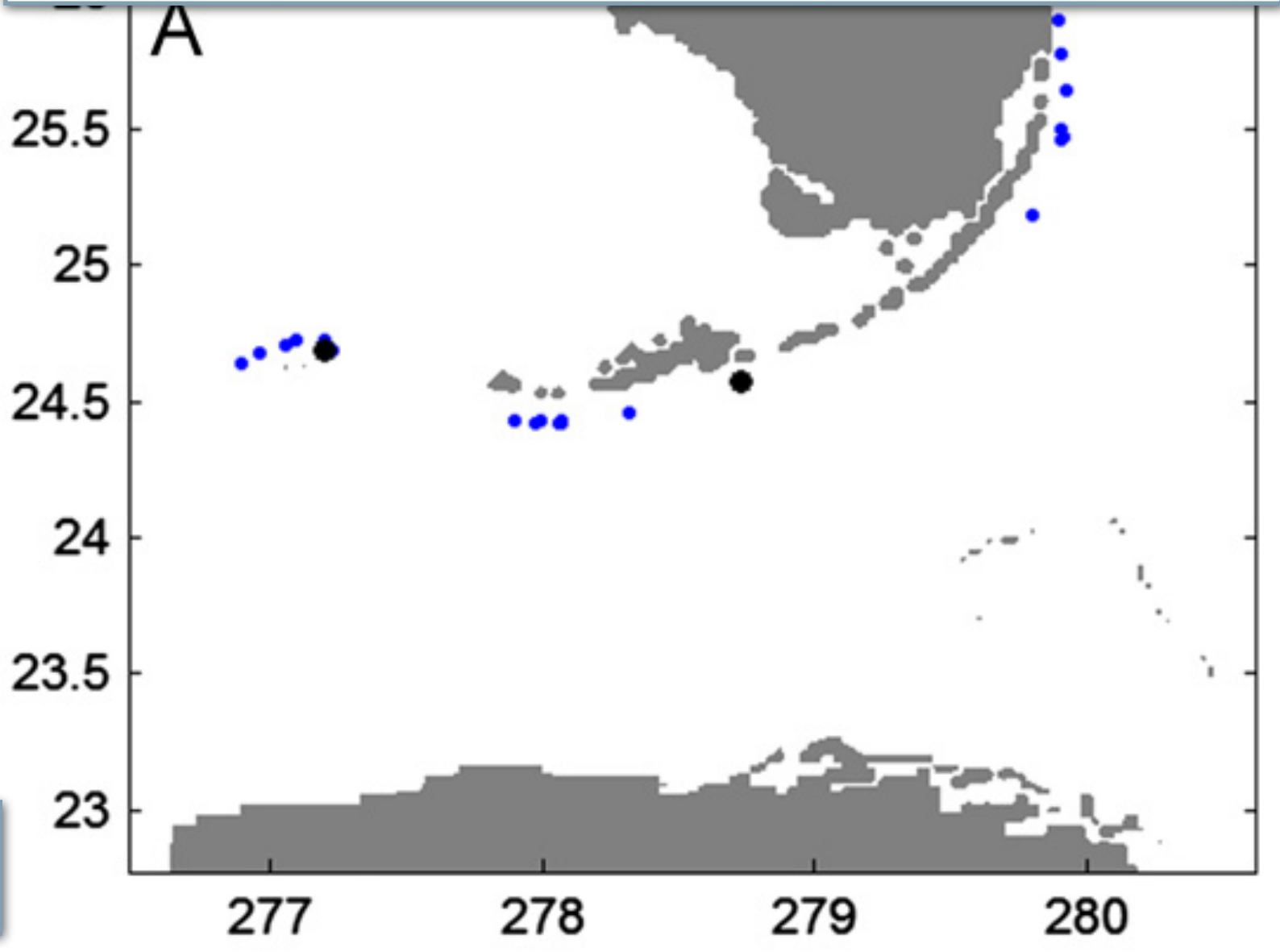
Reaching reef with swimming

Staaterman, Paris & Helgers (2013) *Journal of Theoretical Biology*
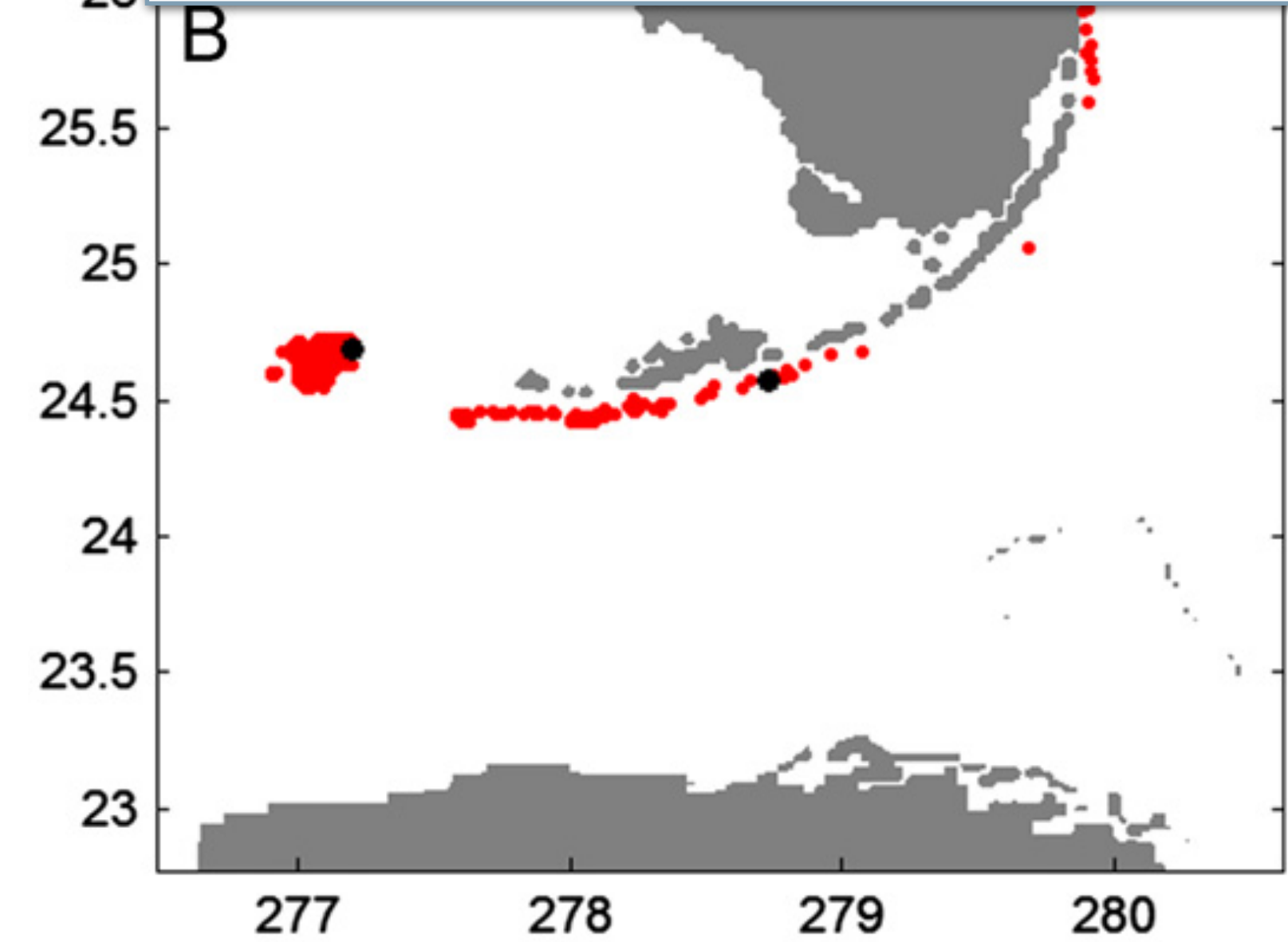
The Parcels framework for Lagrangian Ocean Analysis

▸ Parcels: "Probably A Really Computationally Efficient Lagrangian Simulator"[1]

   ▸ A set of **python classes and methods** for building Lagrangian particle models

▸ Kernel-driven computation: a "kernel" encodes a particular action

   ▸ Pre-built kernels: advection, diffusion

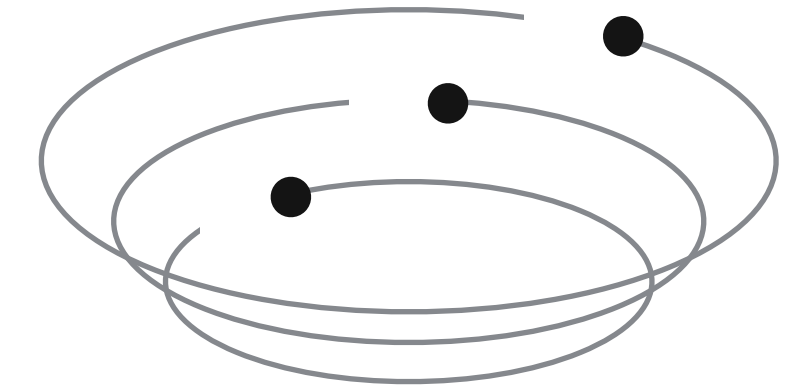   ▸ Customised: Encode anything you need

      ▸ Sinking, swimming, fragmenting, …

   ▸ Concatenate kernels to create particle behaviour

Ocean**Parcels**.org

Search or jump to...

📖 OceanParcels / **parcels**

| 📦 Used by ▾ | 3 | 👁 Unwatch ▾ | 21 | ★ Unstar | 98 | ⑂ Fork | 57 |

Sep 27, 2015 – Jan 16, 2020

Contributions: Commits ▾

Contributions to master, excluding merge commits
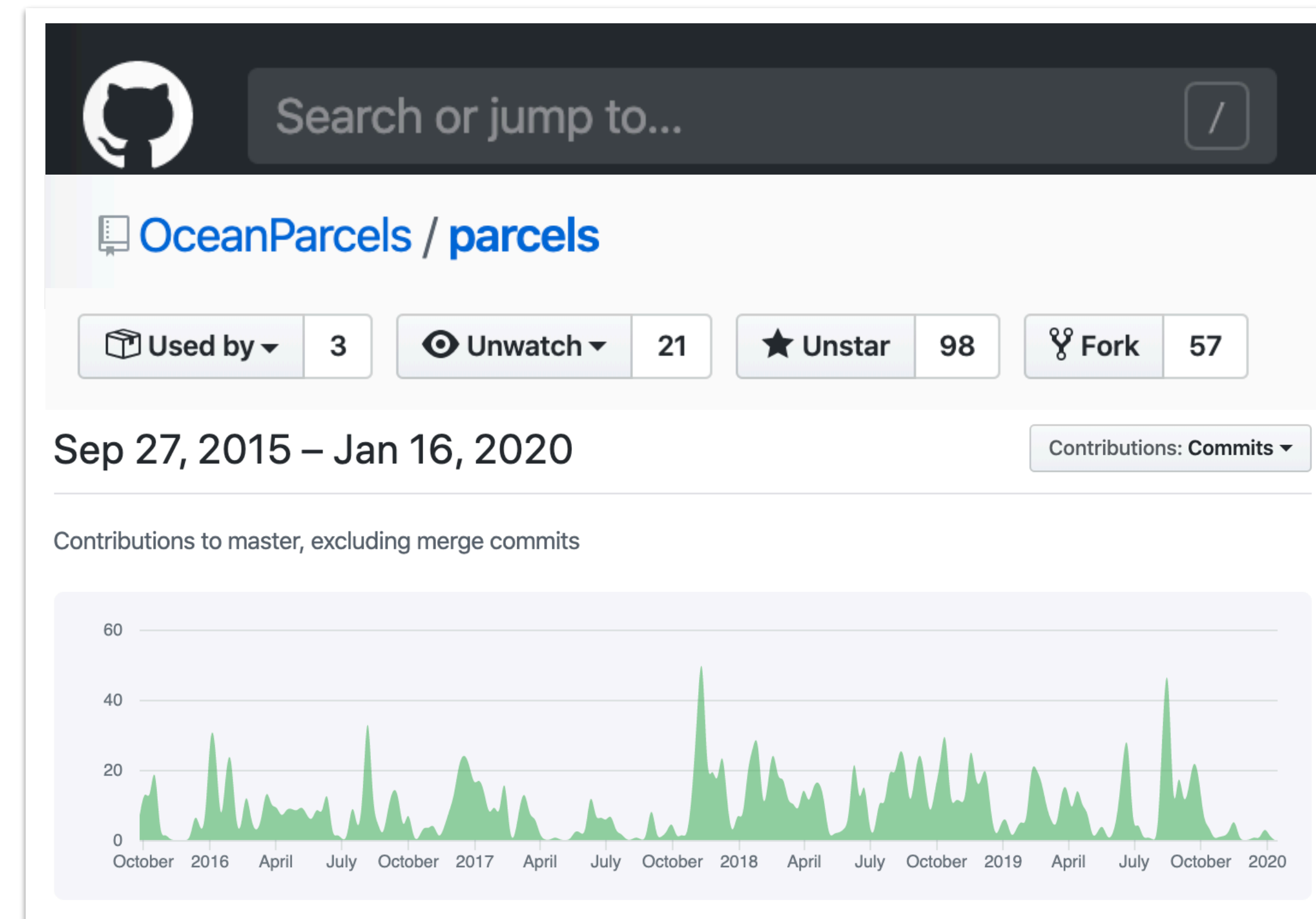
[1] Thanks to Joakim Kjellsson for the backronym!

The Big Ocean Data challenge

Total storage of 3D flow for 50-year simulation &100 vertical levels
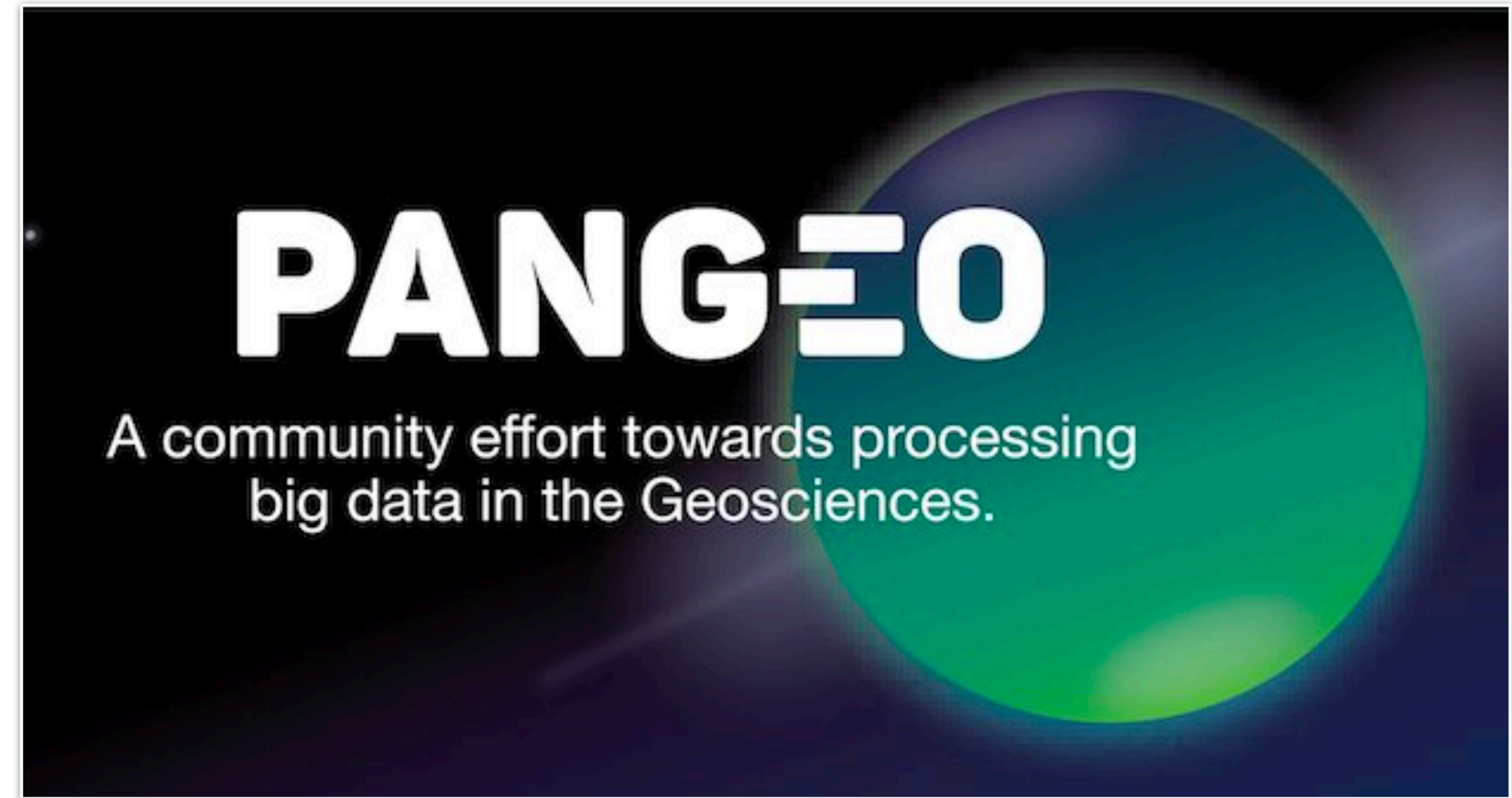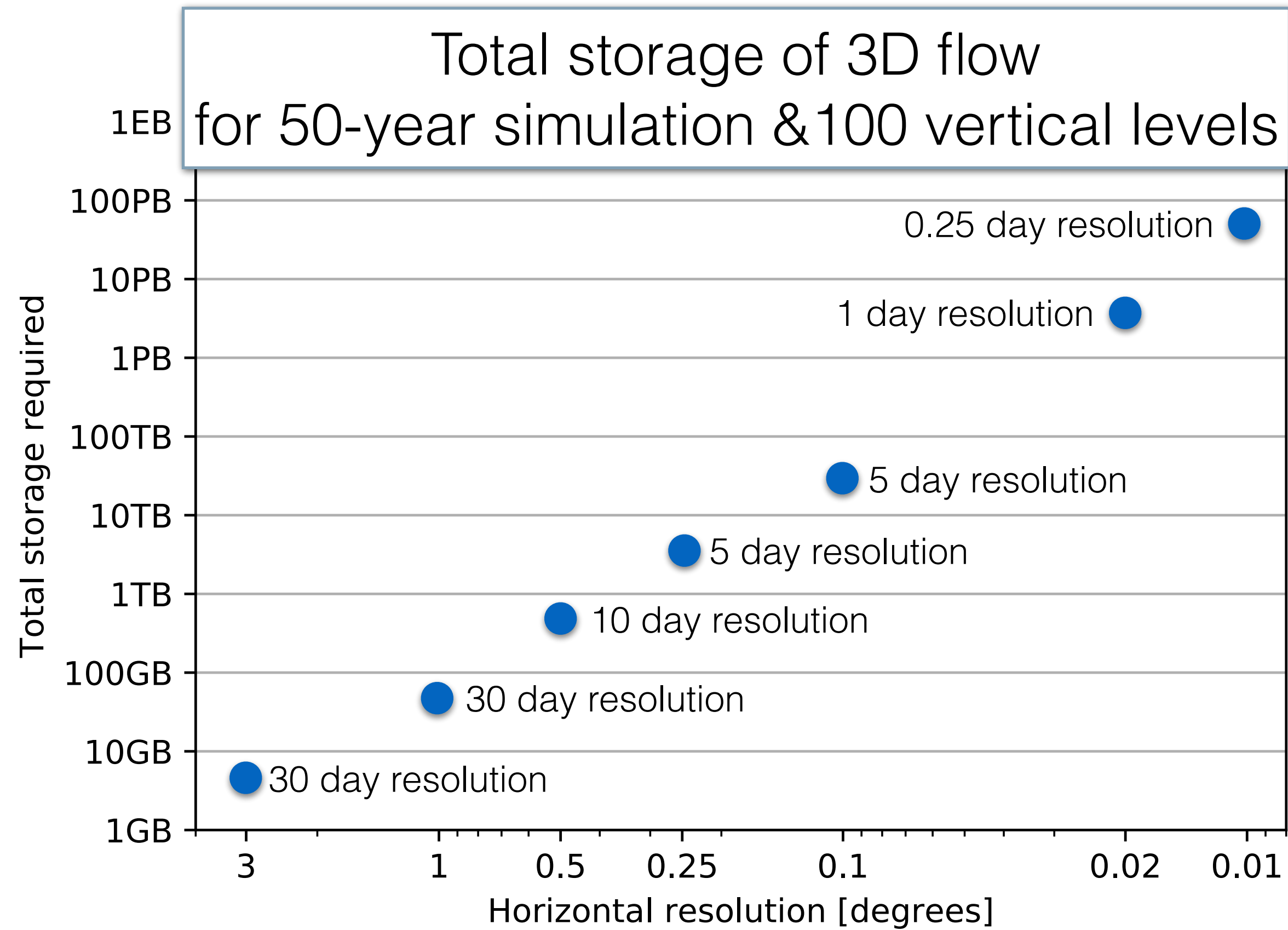

▸ How do we make sure our tools and infrastructure are ready for the **petascale age**?

▸ How do we make sure our codes are **sharable** and results are **reproducible**?

Towards a radically open science

Planning our research through co-creation | **Conducting** our research transparently and inclusively

Communicating with peers and the public | Getting **recognised** and rewarded in an unbiased way
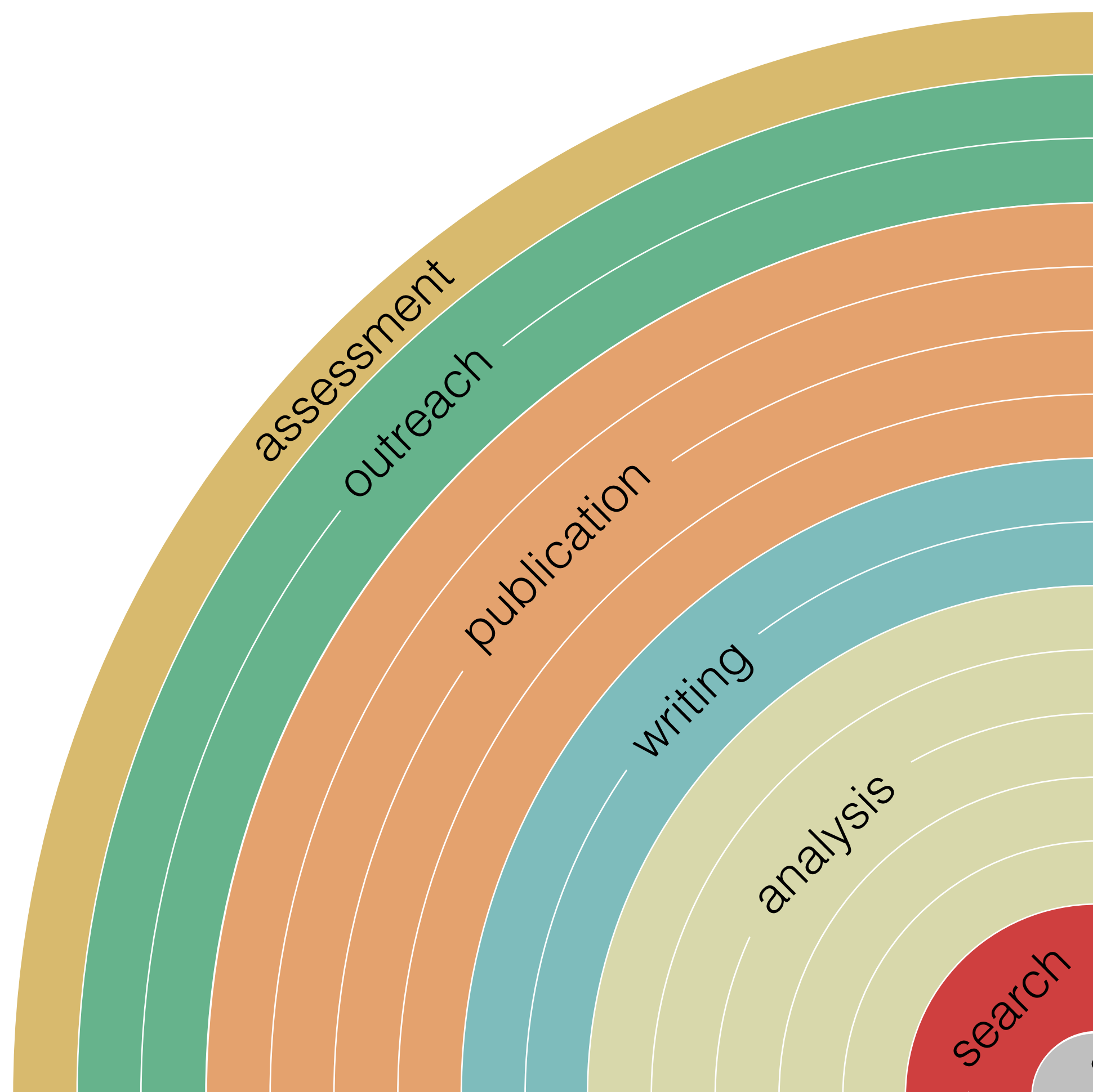
- adding alternative evaluation
- communicating via social media
- sharing posters and presentations
- using open licenses
- publishing open access
- using open peer review
- sharing preprints
- using actionable formats
- open XML-drafting
- sharing protocols and workflow
- sharing notebooks
- sharing code
- sharing data
- pre-registering
- commenting openly
- using shared reference libraries
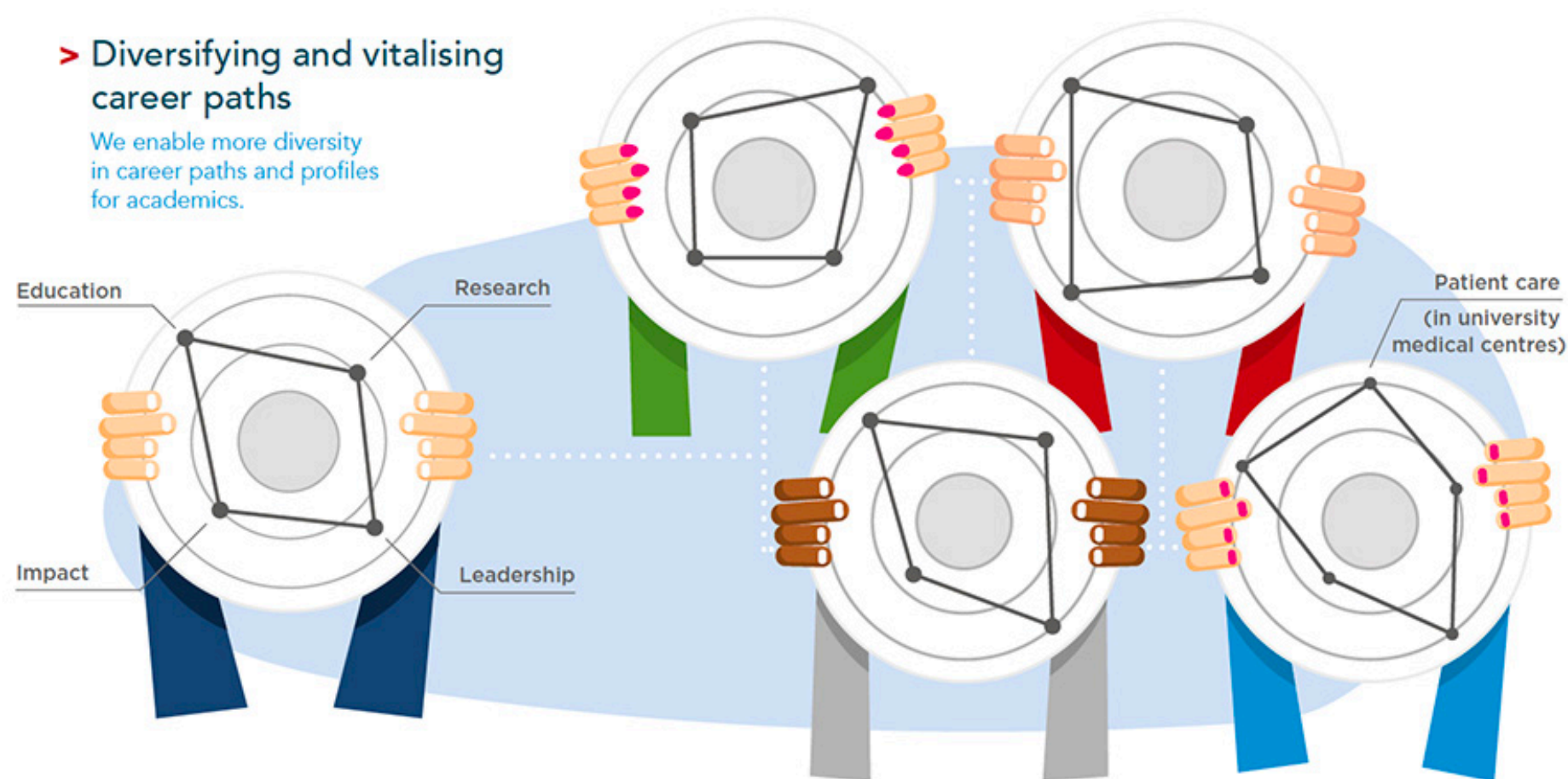- sharing (grant) proposals

Room for everyone's talent

towards a new balance in recognising and rewarding academics

> **Diversifying and vitalising career paths**
We enable more diversity in career paths and profiles for academics.

Education
Research
Patient care (in university medical centres)
Impact
Leadership

Stimulating academic leadership

We stimulate good academic leadership at all levels.

Achieving balance between individuals and the collective

We assess academics based on both their individual and their team performance.

Focusing on quality

In our assessments of academic performance, we increasingly focus on quality, content and creativity.

Great idea!

well thought-out methodology
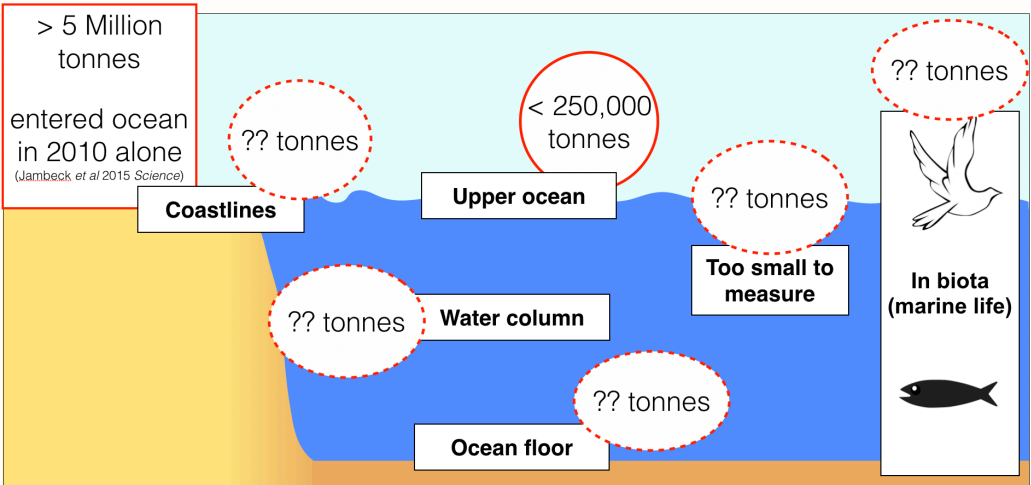
vsnu
NFU
KNAW
NWO
ZonMw

Conclusions

The ocean is no bathtub; it is in constant motion and full of small-scale eddies, which have a crucial role in the transport of heat, nutrients, plankton and plastic.
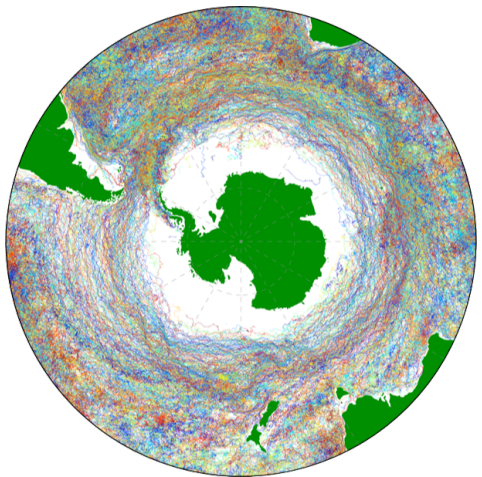
Most of the plastic in the ocean is 'missing'. Mapping this plastic is an exciting challenge for oceanographers. Plastic is a unique tracer.

Lagrangian Ocean Analysis provides interpretation of oceanic flow through conditional pathways and connectivity, for both passive and active virtual particles.
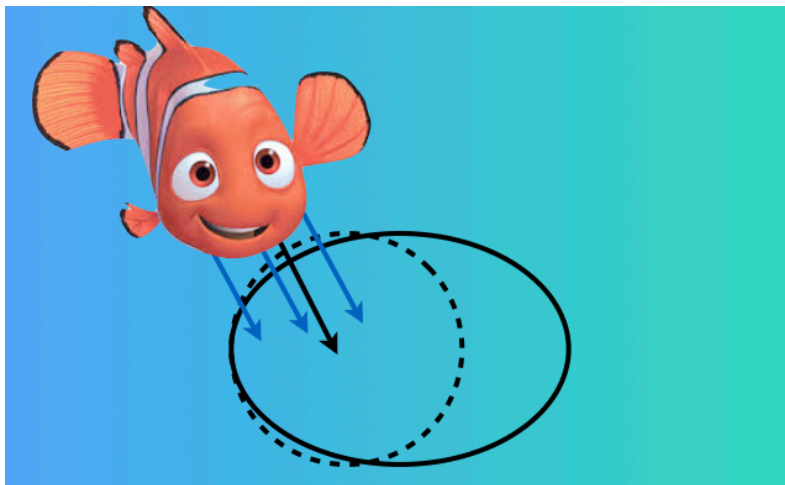
To cope with the petascale-age of ocean data, we need to reward radically open science!

Thanks to the topios.org and oceanparcels.org teams

Erik van Sebille
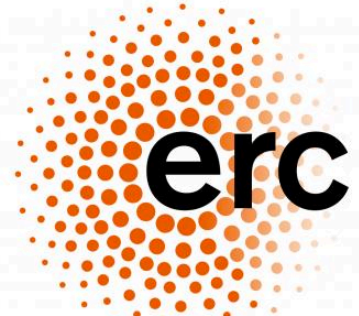Associate Professor
@ Utrecht University
Erik leads and coordinates the TOPIOS project. He is an expert in Lagrangian Ocean Analysis.

Philippe Delandmeter
Postdoc
@ Utrecht University
Philippe improves and optimises the Parcels code used in TOPIOS to simulate plastic transport.

Delphine Lobelle
Postdoc
@ Utrecht University
Delphine investigates how 3D ocean circulation impacts plastic transport.

Christian Kehl
Postdoc
@ Utrecht University
Christian develops and improves the Parcels code used in TOPIOS to simulate plastic transport.

David Wichmann
PhD student
@ Utrecht University
David investigates how ocean currents and waves transport plastic litter around.

Mikael Kaandorp
PhD student
@ Utrecht University
Mikael investigates how to use machine learning to incorporate plastic distribution data into models.

Daan Reijnders
PhD student
@ Utrecht University
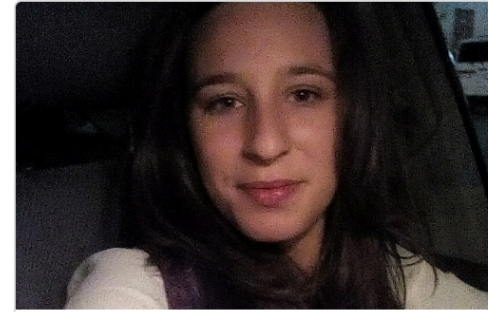Daan investigates how turbulent flow transports nutrients

Peter Nooteboom
PhD student
@ Utrecht University
Peter investigates how sinking plankton can be used to reconstruct paleoclimates

Cleo Jongedijk
PhD student
@ Imperial Collge London
Cleo investigates how plastic litter ends up on beaches.

Rebeca de la Fuente
PhD student @ IFISC
Rebeca investigates how plastic litter sinks to the ocean floor.

Anneke Vries
MSc student
@ Utrecht University
Anneke investigates the role of sea ice in transporting plastic through the Arctic.

Maarten Muller
MSc student
@ Utrecht University
Maarten investigates how plastic crosses the Southern Ocean near Antarctica.

Arianna Olivelli
MSc student
@ Utrecht University
Arianna tracks the origin of micro- and nanoplastic in the South Atlantic gyre.

Reint Fischer
MSc student
@ Utrecht University
Reint investigates the flow around corals

Victor Onink
MSc student
@ Utrecht University
Victor investigates why floating plastic litter ends up in the infamous garbage patches.

Aike Vonk
MSc student
@ Utrecht University
Aike investigates how best to incorporate marine plastic research into school curriculums.
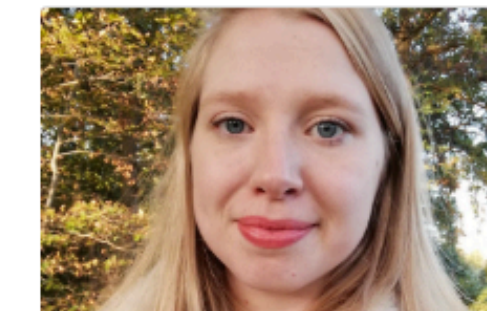
Judith Ewald
MSc student
@ Utrecht University
Judith investigates how SKIM flow fields can be used to track microplastic.

Laura Chow
MSc student
@ Utrecht University
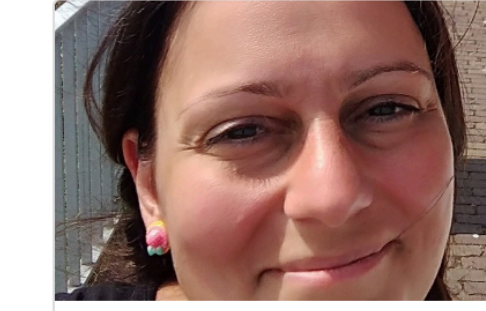Laura creates puzzle boxes for high school students about marine plastic litter.

Michal Janssen
BSc student
@ Utrecht University
Michal simulates how debris from the MSC Zoe disperses through the North Sea.

Miriam Sterl
BSc student
@ Utrecht University
Miriam investigates how global tides impact the transport of plastic litter.

Nicoleta Tsakali
BSc student
@ Utrecht University
Nicoleta investigates how ocean currents transport plastic to the Galapagos Islands.

Jose M Alsina
Lecturer in Fluid Mechanics
@ Universitat Politècnica de Catalunya
Jose is an expert in wave flume experiments, and investigates how plastic ends up on beaches.

United Nations Decade of Ocean Science for Sustainable Development
2021 2030

SUSTAINABLE DEVELOPMENT GOALS

Utrecht University · SCOR International Council for Science Scientific Committee on Oceanic Research · SURF SARA · EPSRC Engineering and Physical Sciences Research Council · Galapagos Conservation Trust · esa · NWO · European Research Council Established by the European Commission · erc