Lagrangian Ocean Ventilation:
Improved Subgrid-Scale Dispersion on Neutral Surfaces

Read in JAMES

edu.nl/b4ky6

Daan Reijnders[1], Eric Deleersnijder[2], Erik van Sebille[1]

[1] *Utrecht University, The Netherlands*
[2] *Université catholique de Louvain, Belgium*

B.J.H.R.Reijnders@uu.nl

abstract

Utrecht University

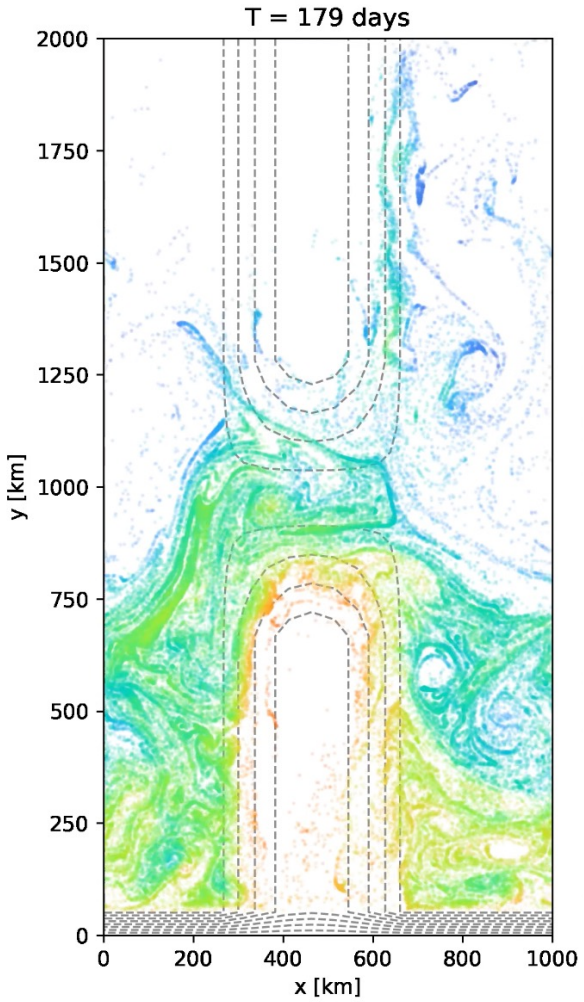
Institute for Marine and Atmospheric research Utrecht

@UFollowtheOcean
@daanreij

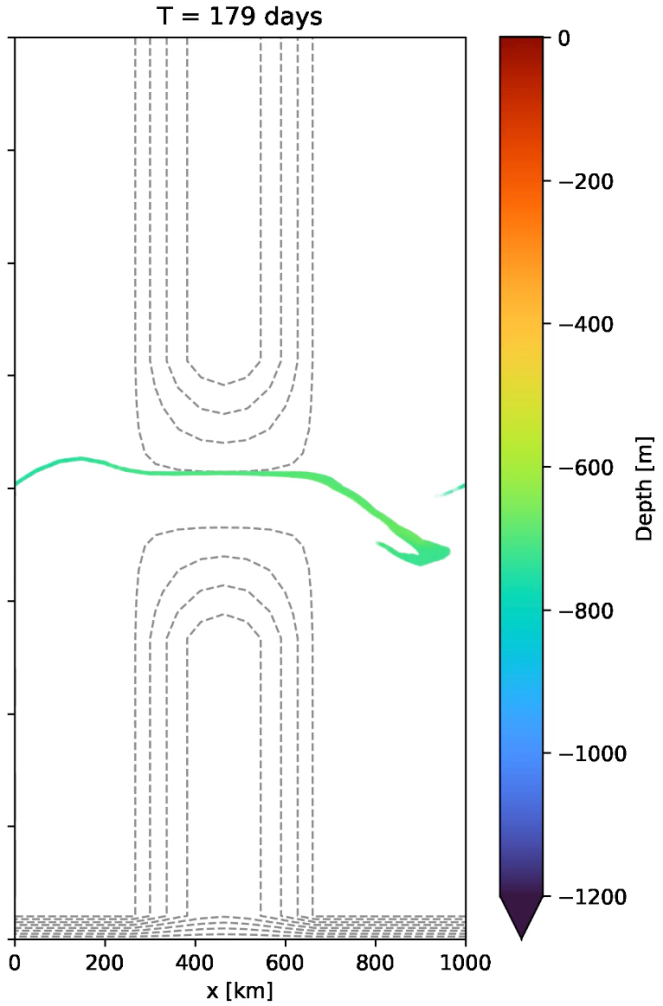
NWO

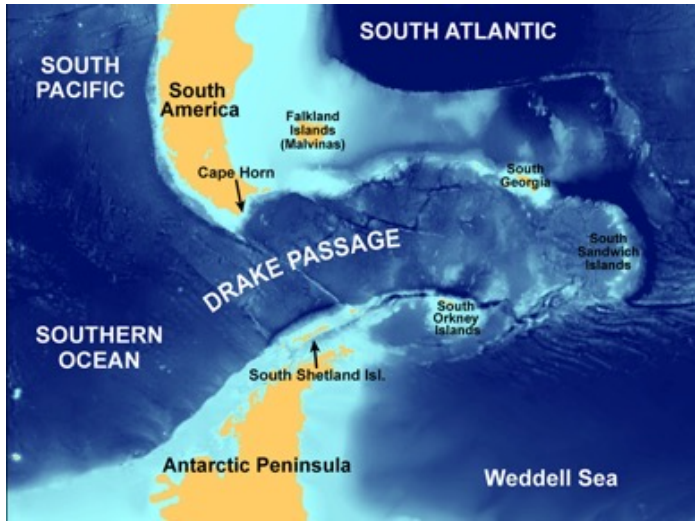
Eddies disperse particles:
Idealized Antarctic Circumpolar Current

$\Delta x = 5$ km → eddy-resolving



$\Delta x = 50$ km → no eddies





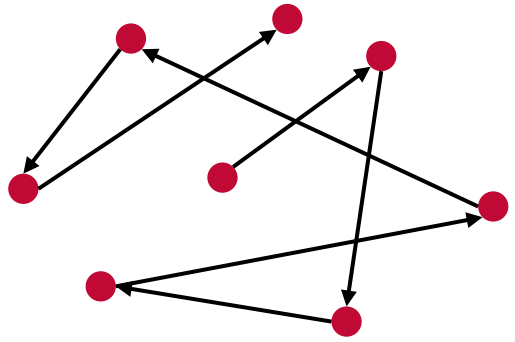
Patch of particles in MITgcm's channel setup: edu.nl/rpyeg

How can we parameterize ***three-dimensional*** *subgrid-scale (eddy) dispersion in Lagrangian simulations?*

+

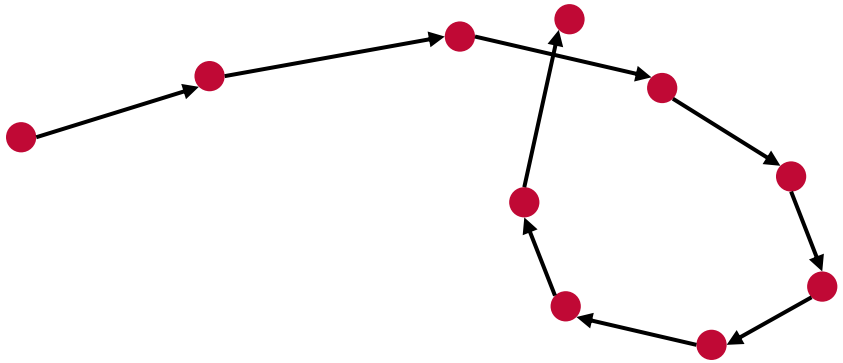
How do we minimize spurious dianeutral diffusivity?

Random Walk (Markov-0)



- **Noise** added on particle **positions**
- Mathematically **equivalent** to **diffusion**
- **No** particle **memory**
- **Only** represents **diffusive** limit ($t \gg T_L$) where dispersion linear in time

Random Flight (Markov-1)



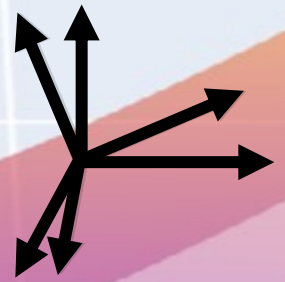
- **Noise** added on turbulent particle **velocity**
- Particle **velocities autocorrelated** in time
- Captures **diffusive** regime **and ballistic** regime ($t \ll T_L$) where dispersion quadratic in time

Markov-1 in 3D

Markov-1 in previous studies only in 2D (surface)

We formulate and test a three-dimensional Markov-1 model:

- assuming eddy dispersion primarily on tilted neutral surfaces
- formulate isotropic Markov-1 in the neutral plane
- use a coordinate rotation to formulate the model in geopotential (‘z-’) coordinates



*"**Markov-1** also captures **ballistic** regime ($t \ll T_L$) where dispersion quadratic in time"*

Why care?

Turbulent displacement in one timestep

Random Walk (Markov-0)

$$\mathrm{E}(||\Delta x||) = \sqrt{2\,\kappa\,\Delta t}$$

isoneutral diffusivity (m^2/s)

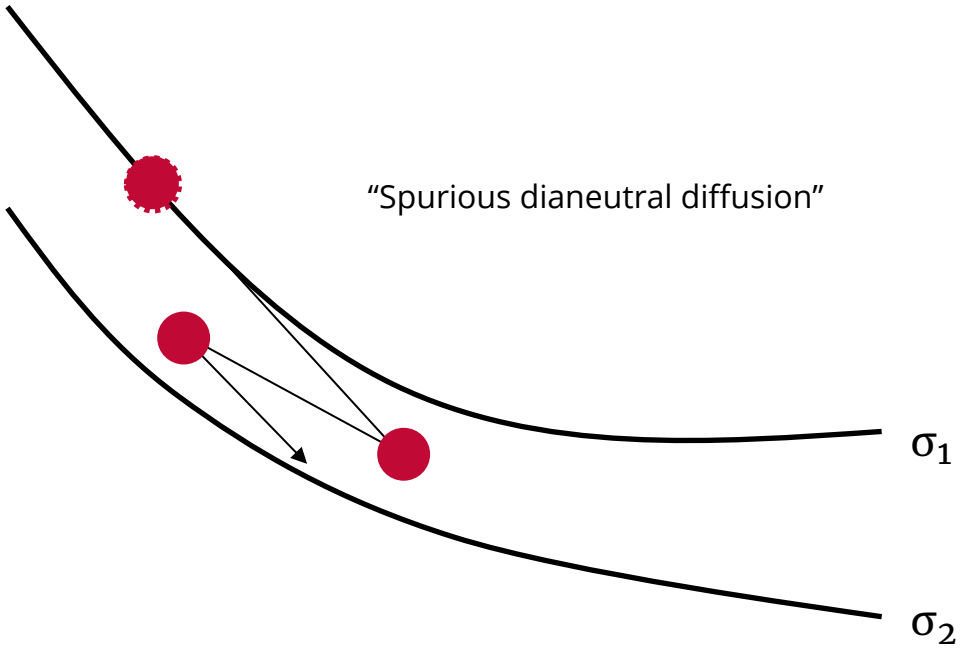
≫

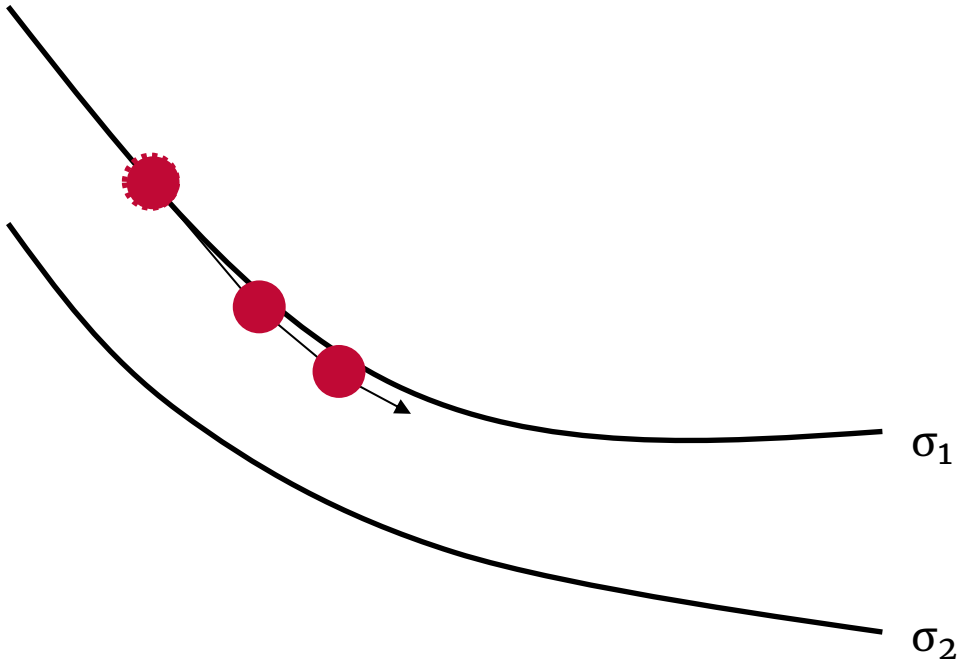
But same statistical behaviour at large times

Random Flight (Markov-1)

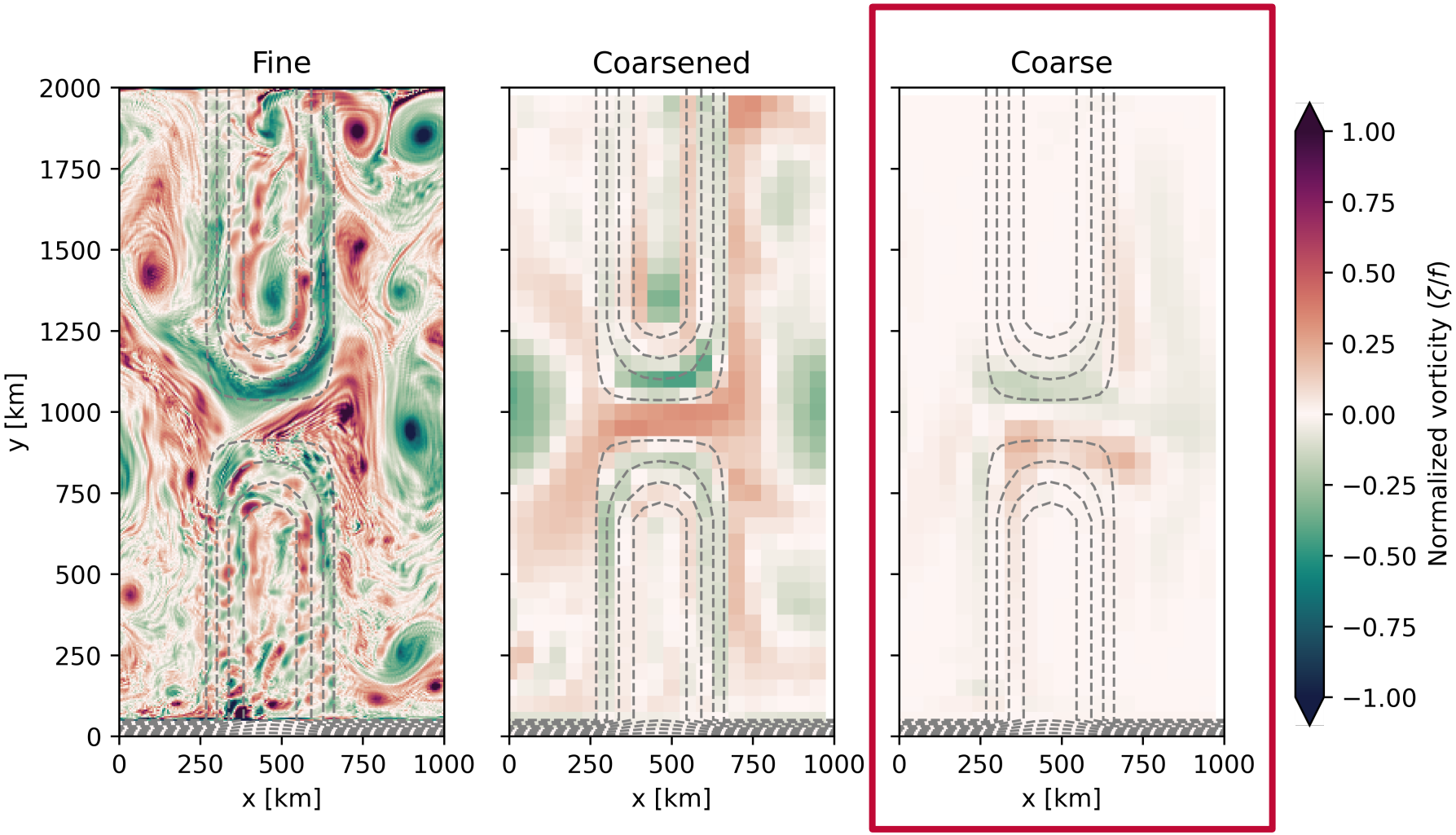
$$\mathrm{E}(||\Delta x||) = \nu\,\Delta t$$

turbulent velocity (m/s)

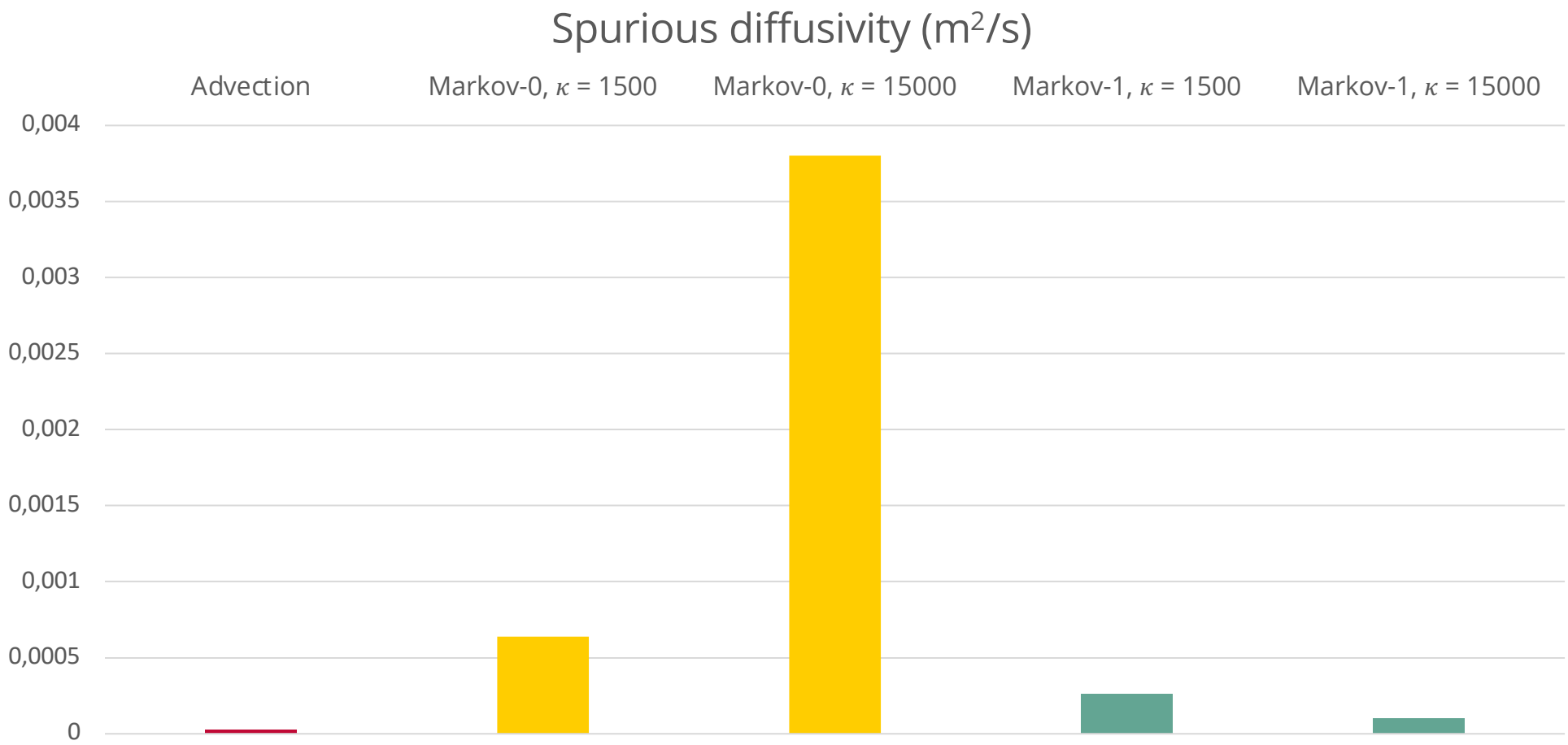




Results: idealized Antarctic Circumpolar Current at 50 km resolution

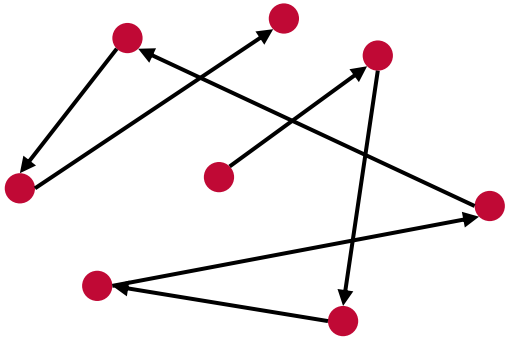


Results: idealized Antarctic Circumpolar Current at 50 km resolution

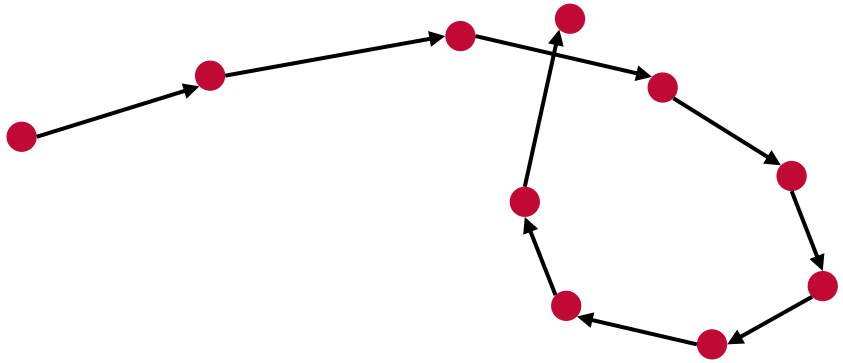


Simulating Lagrangian Subgrid-Scale Dispersion on Neutral Surfaces

Random Walk (Markov-0)



Random Flight (Markov-1)



- Markov-1:
  - produces more realistic trajectories
  - reproduces Lagrangian autocorrelation
  - **has smaller spurious dianeutral diffusivity than Markov-0**
    → staying on neutral surfaces important for ventilation studies

Read in JAMES

edu.nl/b4ky6

Utrecht University

Institute for Marine and Atmospheric research Utrecht

@UFollowtheOcean
@daanreij

B.J.H.R.Reijnders@uu.nl