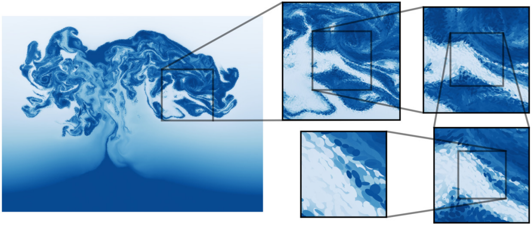
# EPIC workshop

Matthias Frey (St Andrews), David Dritschel (St Andrews), Steven Böing (Leeds)
Rui Apóstolo (EPCC).

July 8, 2024



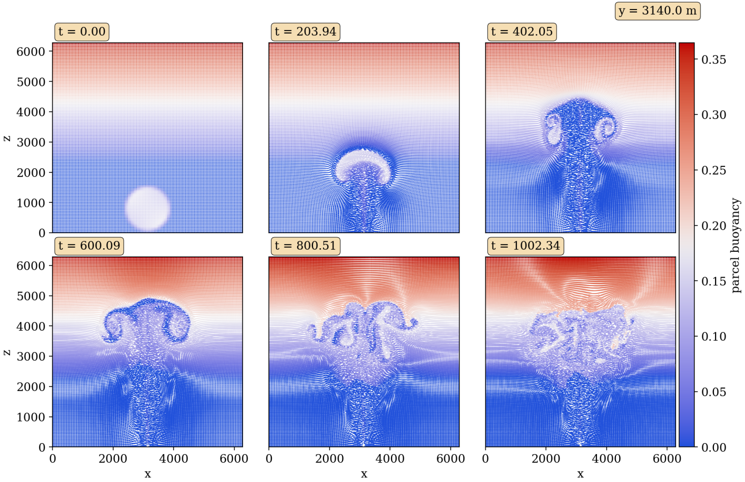
*Dritschel, D. G., Böing, S. J., Parker, D. J. and Blyth, A. M. (2018), The Moist Parcel-in-Cell method for modelling moist convection. Q. J. R. Meteorol. Soc.*
*Böing, S. J., Dritschel, D. G., Parker, D. J. and Blyth, A. M. (2019), Comparison of the Moist Parcel-in-Cell (MPIC) model with large-eddy simulation for an idealized cloud. Q. J. R. Meteorol. Soc.*
*Frey, M., Dritschel, D., and Böing, S. (2022). EPIC: the Elliptical Parcel-in-Cell method. J. Comp. Phys.: X, 14, 100109.*
*Frey, M., Dritschel, D., and Böing, S. (2023). The 3D Elliptical Parcel-in-Cell (EPIC) method. J. Comp. Phys.: X, 100136.*

*Supported by EPSRC grants EP/T025409/1 and EP/M008525/1, NERC grant NE/X018547/1*

EPIC is a model for detailed geophysical fluid modelling (atmosphere, clouds, ocean).

Domantas Dilys, using EPIC's predecessor MPIC

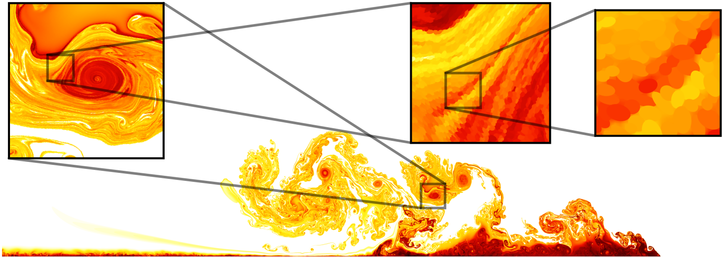
- It is (almost fully) based on parcels. Very different approach!
- Important: these parcels must interact (mix on small scale).
- Clean distinction between resolved dynamics and mixing.



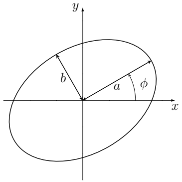

This workshop (Matthias Frey)

# Elliptical Parcel-In-Cell (EPIC)

- We use parcels carrying any number of (conserved) attributes and vorticity (evolved). Monotonic by design and globally conservative.
- Parcels have a volume $V_i$ in order to determine gridded fields needed to construct velocity on the grid.
- Incompressible, Boussinesq, evaporation and condensation but no precipitation yet.
- There are 2D (below) and 3D (today) versions.



# Parcel-based model based on ellipses




Semi-major/-minor axes $a$ and $b$

$$\mathbf{x}^{\mathsf{T}}\mathbf{B}^{-1}\mathbf{x} = 1$$

where $\mathbf{B} = \begin{pmatrix} B_{11} & B_{12} \\ B_{12} & B_{22} \end{pmatrix}$ is symmetric.

**Ellipse area preserved!**

**Motion of a fluid ellipse in a linear background flow[1]:**

Given a linear background straining flow

$$\mathbf{u}(\mathbf{x}, t) = \mathbf{S}(\mathbf{x}, t)\mathbf{x}(t)$$

where

$$\mathbf{S}(\mathbf{x}, t) = \nabla\mathbf{u}(\mathbf{x}, t) = \begin{pmatrix} u_x(\mathbf{x}, t) & u_y(\mathbf{x}, t) \\ v_x(\mathbf{x}, t) & v_y(\mathbf{x}, t) \end{pmatrix},$$

then reformulating the time derivative of the ellipse equation results in

$$\frac{d\mathbf{B}}{dt} = \mathbf{B}\mathbf{S}^{\mathsf{T}} + \mathbf{S}\mathbf{B}.$$

**Note:** This is also valid in 3D!

[1] McKiver, W. J. & Dritschel, D. G. (2003). The motion of a fluid ellipsoid in a general linear background flow. Journal of Fluid Mechanics, 474, 147-173.

**Splitting and merging conserve**

- total centroid
- total area
- total second moments (approximately)

**Split criterion:**

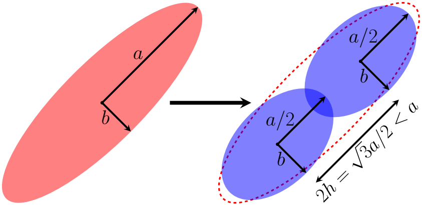
$$\lambda = \frac{a}{b} > \lambda_{\max} \quad [= 4]$$

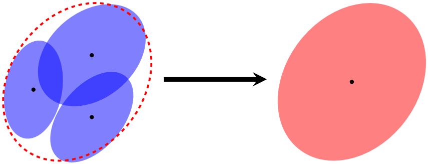
$a_n > a_{\max}$

**Merge criterion:**

$$V_n < V_{\min}$$

Nearest neighbour merging



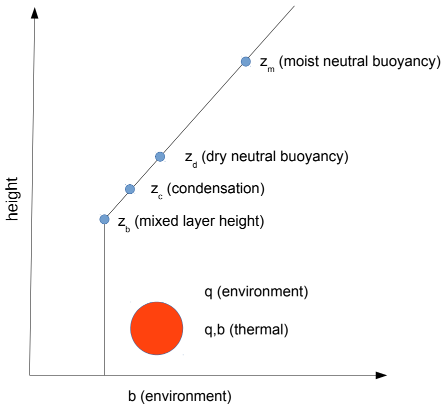



# Moist bubble setup (workshop)

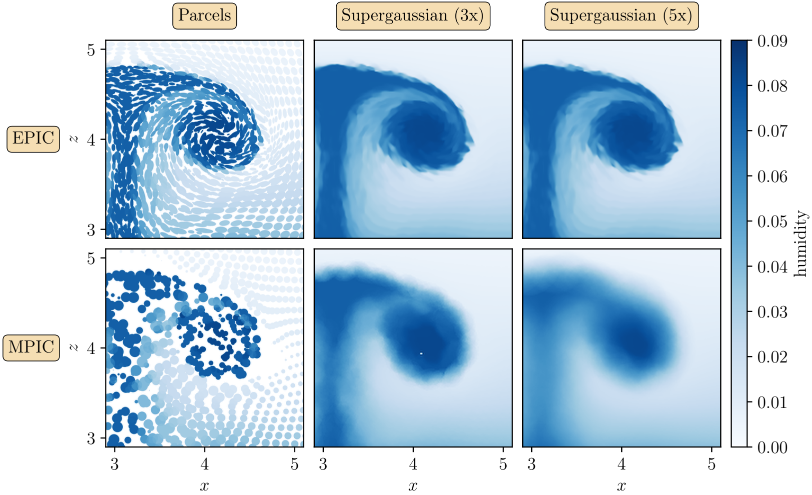
The environment favours condensation (cloud formation) once the thermal rises past the lifting condensation level $z = z_c$.

This releases additional buoyancy, increasing the vertical acceleration, and takes the thermal past its level of dry neutral buoyancy $z = z_d$.

Only when the thermal encounters the level of moist neutral buoyancy $z = z_m$ (the nominal cloud top) is the upward acceleration arrested.



# Application to three-dimensional clouds



# EPIC workshop

Work in pairs. Use EPCC cirrus machine short queue.

workshop-trieste
/ README.md

RuiApostolo Links from readme to new files 28ff07c · yesterday History

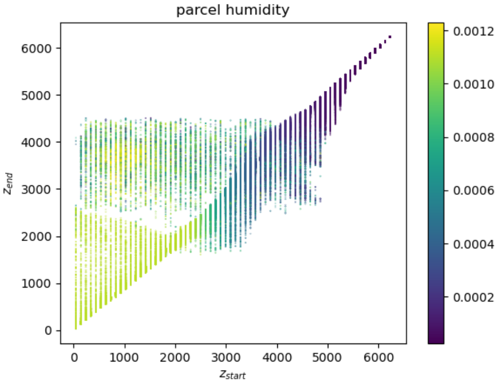
Preview Code Blame 299 lines (246 loc) · 12.5 KB Raw

## Welcome to the EPIC workshop in Trieste!

This repository serves as a tutorial to show you how to prepare, run and analyse a moist bubble simulation using the Elliptical Parcel-In-Cell (EPIC) method. During the course of this workshop (July 8th 2024), we provide you temporary access to the Cirrus cluster, a Tier-2 system of the EPSRC. All information how to access Cirrus is provided below. If you would like to work on your own laptop, feel free to do so. However, we might not be able to help you in case you face any issues regarding code compilation (not necessarily EPIC!).

### Table of Contents

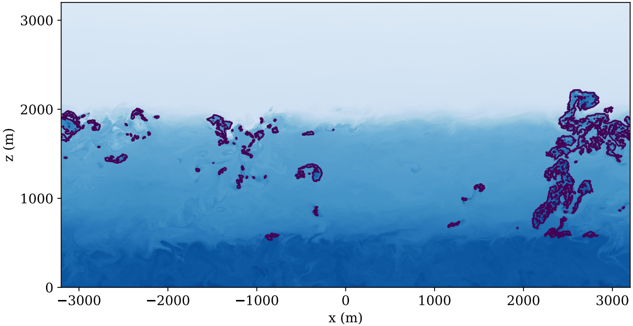
- Analysis of parcel data
- Parcel history (following e.g Heus et al., JAS, 2008).



# Link to cloud organisation

# Prototype BOMEX simulations

- Realistic thermodynamics: potential temperature, liquid water and water vapour.
- Includes large-scale forcings and surface fluxes of heat and moisture.
- EPIC involving into LES alternative.

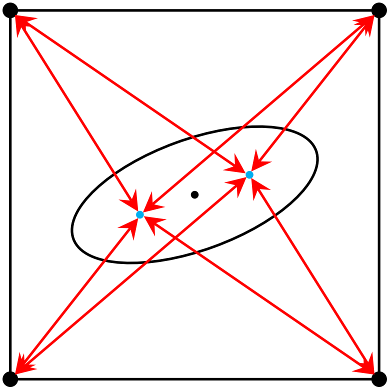


# How do we interpolate from/to the grid (needed to get velocity)

## Optimal points at foci of ellipses:

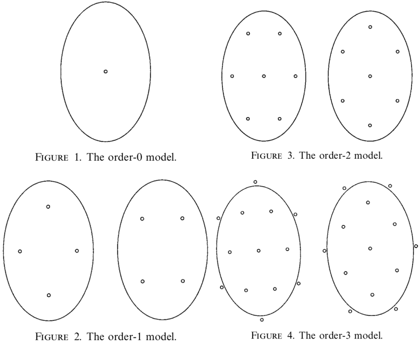
Legras, B. & Dritschel, D. G. (1991). The elliptical model of twodimensional vortex dynamics. I: The basic state. Physics of Fluids A: Fluid Dynamics, 3, 845–854.

$\mathbf{x} \pm \frac{1}{2}\sqrt{a^2 - b^2}\hat{\mathbf{a}}$ with ellipse centre at $\mathbf{x}$ ($\hat{\mathbf{a}}$ eigenvector)

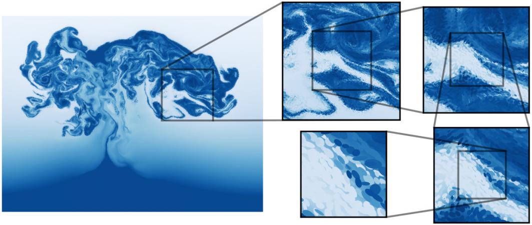


## Optimal points for ellipsoids:

Dritschel, D. G., Reinaud, J. N. & McKiver, W. J. (2004). The quasi-geostrophic ellipsoidal vortex model. Journal of Fluid Mechanics, 505, 201–223.




**Quadrature points to accurately approximate the volume integral!**



2D paper

3D paper

github