

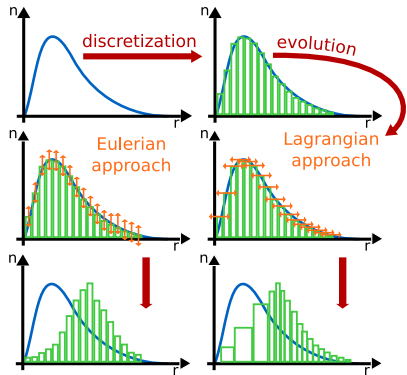
Modelling of Atmospheric Clouds

Sylwester Arabas

Faculty of Mathematics and Computer Science, Jagiellonian University

class 6 (remote)
Mar. 30 2020

previously on ...



plan for today

parcel model project ideas

Smoluchowski equation, PySDM tutorial (jupyter)

SDM Monte-Carlo method, PySDM example (jupyter)

PySDM project ideas

MP(y)DATA project ideas (class 2 + 1 new)

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parcel model idea: Hoppel-gap with Reaktoro

Reaktoro Tutorial **Interactive!**

REAKTORO

a unified framework for modeling chemically reactive systems



Reaktoro is a computational framework developed in C++ and Python that implements numerical methods for modeling chemically reactive processes governed by either chemical equilibrium, chemical kinetics, or a combination of both.

github.com/atmos-cloud-sim-uj/PySDM/wiki/Hoppel-gap

doi:10.1007/s11084-011-9259-9

Development of a Model to Compute the Extension of Life Supporting Zones for Earth-Like Exoplanets

David Neubauer • Aron Vrtala • Johannes J. Leitner •
Maria G. Firneis • Regina Hitzenberger

Received: 24 July 2011 / Accepted: 9 November 2011 /
Published online: 3 December 2011
© Springer Science+Business Media B.V. 2011

Abstract A radiative convective model to calculate the width and the location of the life supporting zone (LSZ) for different, alternative solvents (i.e. other than water) is presented. This model can be applied to the atmospheres of the terrestrial planets in the solar system as well as (hypothetical, Earth-like) terrestrial exoplanets. Cloud droplet formation and growth are investigated using a cloud parcel model. Clouds can be incorporated into the radiative transfer calculations. Test runs for Earth, Mars and Titan show a good agreement of model results with observations.

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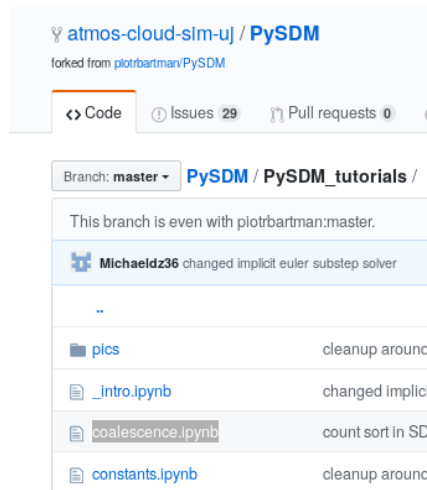
Smoluchowski equation, PySDM tutorial (jupyter)

SDM Monte-Carlo method, PySDM example (jupyter)

PySDM project ideas

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PySDM tutorial



The screenshot shows the GitHub interface for the `atmos-cloud-sim-uj / PySDM` repository, which is a fork of `piotrbartman/PySDM`. At the top, there are tabs for `<> Code`, `Issues 29`, and `Pull requests 0`. Below these, a dropdown menu shows the current branch as `master`, followed by the text `PySDM / PySDM_tutorials /`. A message states: "This branch is even with piotrbartman:master." Below this, a commit by `Michaeldz36` is highlighted, with the message "changed implicit euler substep solver". Underneath the commit message is a double asterisk `**`. A list of files changed in the commit is shown below:

| | |
|--------------------------------|------------------|
| <code>pics</code> | cleanup around |
| <code>_intro.ipynb</code> | changed implic |
| <code>coalescence.ipynb</code> | count sort in SC |
| <code>constants.ipynb</code> | cleanup around |

Acknowledgements: Piotr Bartman, Michael Olesik

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PySDM example





<https://github.com/atmos-cloud-sim-uj/PySDM>

build passing coverage 67%

PySDM

PySDM simulates the dynamics of population of particles immersed in moist air using the particle-based (a.k.a. super-droplet) approach to represent aerosol/cloud/rain microphysics. The package features a Pythonic Implementation of the Super-Droplet Method (SDM) Monte-Carlo algorithm for representing collisional growth (Shima et al. 2009), hence the name.

Demos:

- Shima et al. 2009 Fig. 2  launch binder
- Arabas & Shima 2017 Fig. 5  launch binder
- Yang et al. 2018 Fig. 2:  launch binder
- ICMW 2012 case 1 (work in progress)  launch binder

Tutorials:

- Introduction  launch binder
- Coalescence  launch binder

Acknowledgement: Piotr Bartman

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PySDM project idea: example with Geometric kernel

Berry 1967, Fig. 5

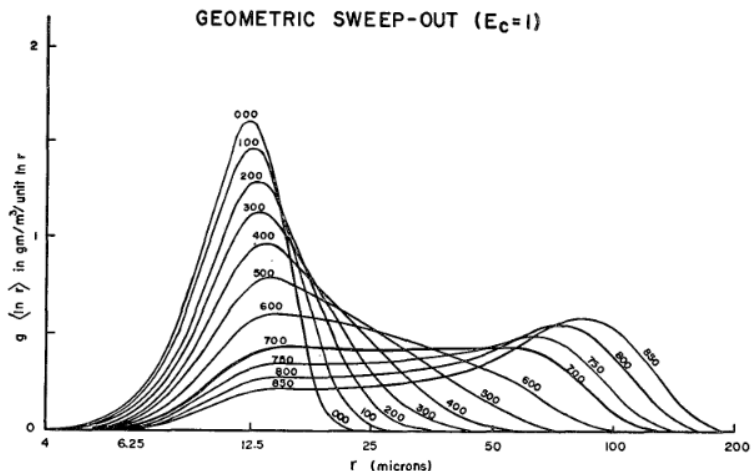


FIG. 5. Computed droplet growth due to geometric sweep-out. The heavy line indicates the appearance of the second maximum.

PySDM project idea: visualisation with itkwidgets

<https://pypi.org/project/itkwidgets/>

itkwidgets

pypi v0.26.1 conda-forge v0.26.1 npm@latest v0.26.1 Build and test passing circleci passing launch binder License Apache 2.0

DOI 10.5281/zenodo.3688857

Interactive Jupyter widgets to visualize images, point sets, and meshes.

The screenshot displays a Jupyter Notebook environment. On the left, a file browser sidebar lists various files under categories like 'examples', 'Running', 'Commands', 'Cell Tools', and 'Tools'. The main area shows a Jupyter Notebook with two cells. The first cell contains the following code:

```
In [12]: import itk
          from itkwidgets import view
```

The second cell contains:

```
In [5]: file_name = 'CTACardio.mhd'
         image = itk.imread(file_name)
         view(image)
```

Below the code cells, a widget titled 'BRBG' is visible, showing a 2D histogram plot with a blue square indicating a selected region. To the right of the plot, there are sliders for X, Y, and Z coordinates, with values X: -187.1, Y: 156.37, and Z: 165. On the far right, a 3D visualization of a human torso is shown, with a blue wireframe mesh overlaid on a semi-transparent brown volume, representing a medical scan.

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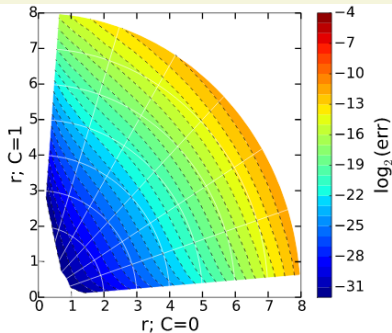
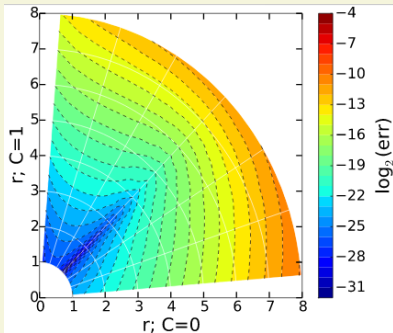
PySDM project ideas

MP(y)DATA project ideas (class 2 + 1 new)

github.com/atmos-cloud-sim-uj/MPyDATA

MPyDATA project idea: convergence “maps”

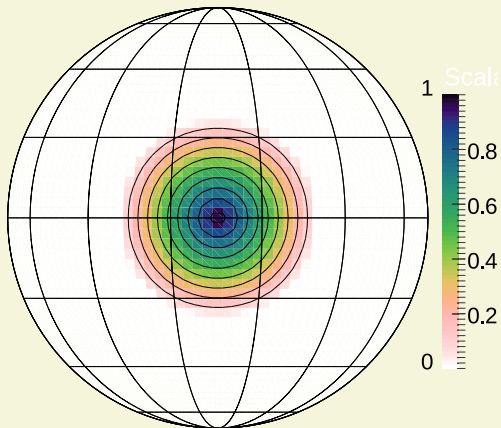
Jaruga et al. 2015: Figs. 10 & 11



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/2_convergence_1d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/2_convergence_1d/plot.py)

MPyDATA project idea: polar coordinates

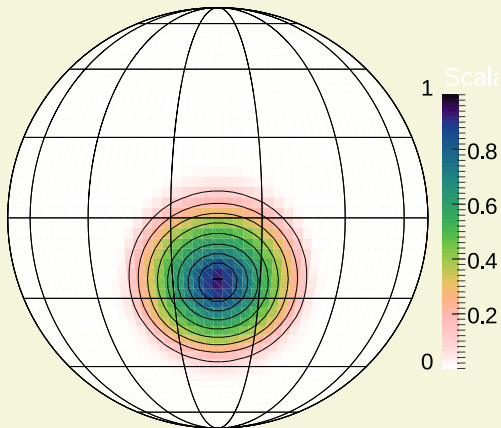
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

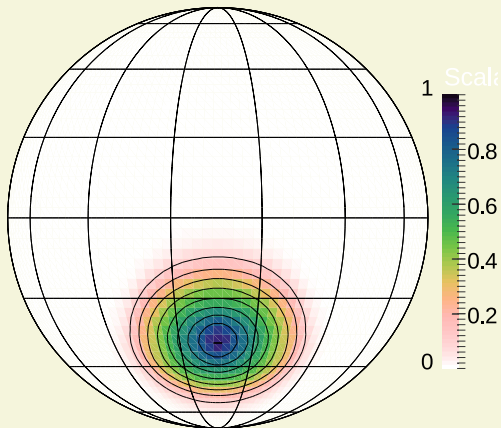
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

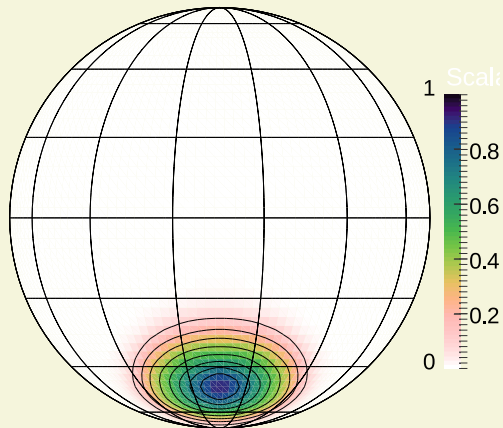
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

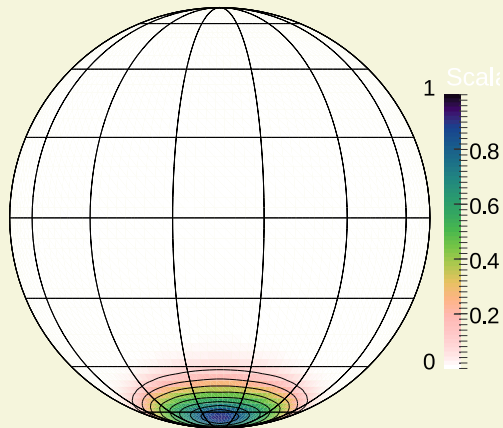
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

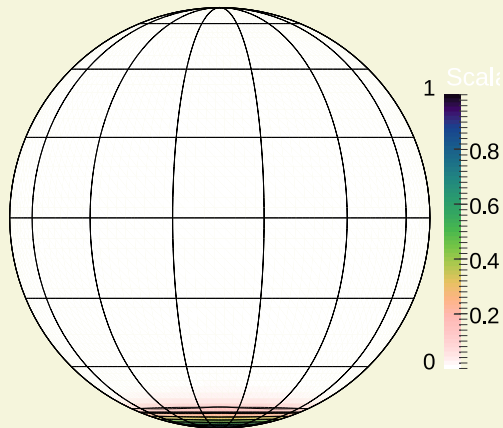
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

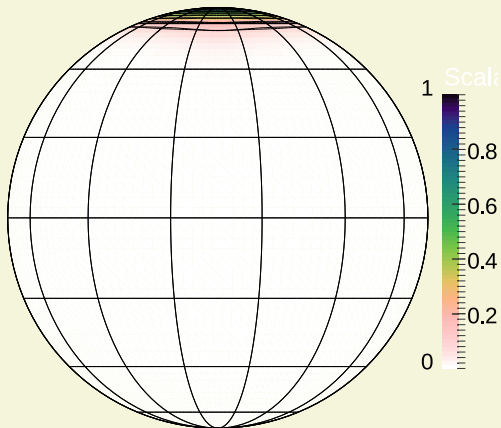
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

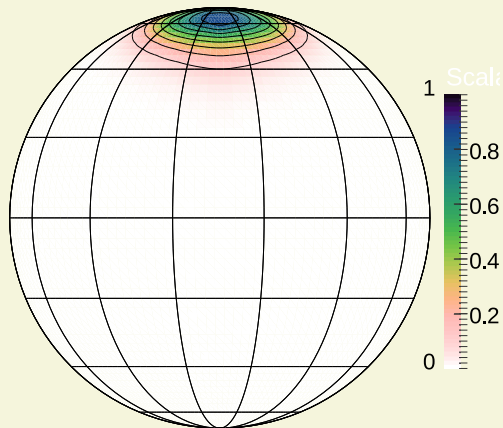
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

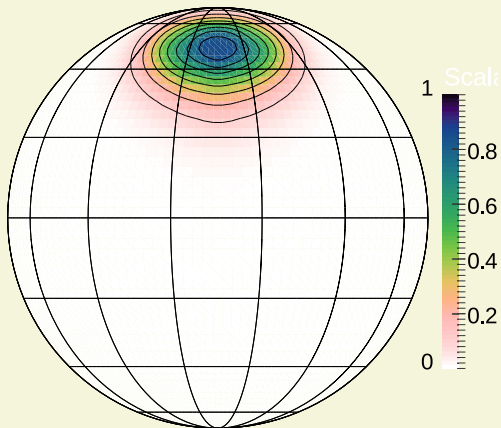
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

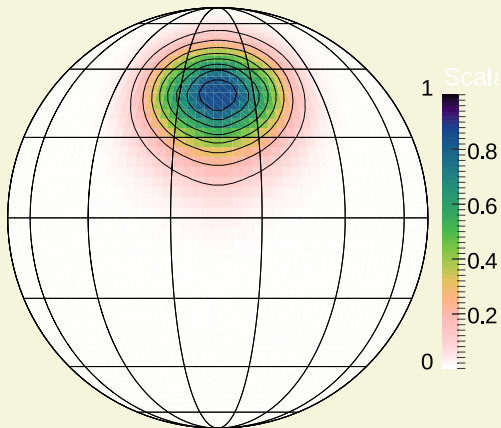
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

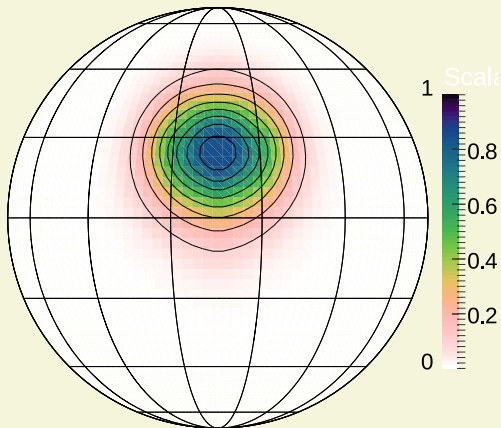
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

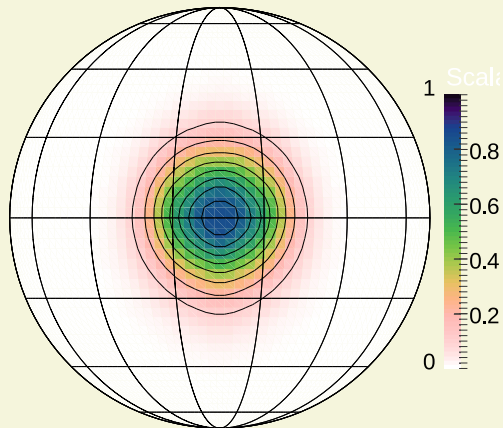
Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: polar coordinates

Jaruga et al. 2015: Fig 14



[https://github.com/igfuw/libmpdataxx/blob/master/
tests/paper_2015_GMD/5_over_the_pole_2d/plot.py](https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py)

MPyDATA project idea: spurious supersaturation study

selected literature

- ▶ Stevens et al. 1996, Mon. Wea. Rev. 124
[doi:10.1175/1520-0493%281996%29124%3C1034:TSPOCE%3E2.0.CO;2](https://doi.org/10.1175/1520-0493%281996%29124%3C1034:TSPOCE%3E2.0.CO;2)
- ▶ Jeffery & Reiser 2006, J. Atmos. Sci. (63(11))
[doi:10.1175/JAS3760.1](https://doi.org/10.1175/JAS3760.1)
- ▶ Hoffmann 2016, Mon. Wea. Rev. 144(1)
[doi:10.1175/MWR-D-15-0234.1](https://doi.org/10.1175/MWR-D-15-0234.1)

the problem (one of many)

$e_s(T) = e_s(T(q_v, \theta))$ is a non-linear function of the advected (conserved) quantities, good example to showcase applicability of different variants of MPDATA

MPyDATA project idea: advection-diffusion equation

Lange 1978 (J. Appl. Meteorol. 17)

$$\frac{\partial \psi}{\partial t} + u \frac{\partial \psi}{\partial x} - \nu \frac{\partial^2 \psi}{\partial x^2} = 0 \quad \rightsquigarrow \quad \frac{\partial \psi}{\partial t} + \frac{\partial}{\partial x} \left[\left(u - \frac{\nu}{\psi} \frac{\partial \psi}{\partial x} \right) \psi \right] = 0$$

quantitative finance example



Journal of Computational and Applied
Mathematics

Available online 20 June 2019, 112275

In Press, Corrected Proof

Derivative pricing as a transport problem:
MPDATA solutions to Black–Scholes-type
equations ☆

Sylwester Arabas ^a, Ahmad Farhat ^b

^a Jagiellonian University, Kraków, Poland

^b HSBC Service Delivery (Polska) Sp. z o.o., Kraków, Poland

https://github.com/atmos-cloud-sim-uj/MPyDATA/tree/master/MPyDATA_examples

Jaruga et al. 2015: Fig. 15

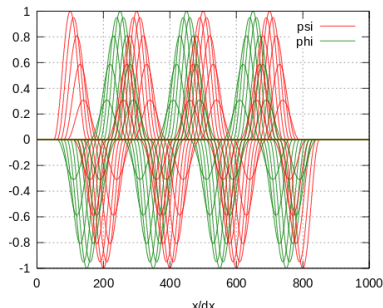


Figure 15. Simulation results of the example presented in Sect. 4.3. Abscissa marks the spatial dimension and ordinate represents the oscillator amplitude. The oscillator state is plotted every 20 time steps.

A system of two one-dimensional advection equations,

$$\begin{aligned}\partial_t \psi + \partial_x(u_0 \psi) &= \omega \phi, \\ \partial_t \phi + \partial_x(u_0 \phi) &= -\omega \psi,\end{aligned}\tag{16}$$

represents a harmonic oscillator translating with $u_0 = \text{constant}$; see Sect. 4.1 in Smolarkiewicz (2006) for a discussion.¹⁹ Applying the trapezoidal rule to integrate the PDE

¹⁹The implicit manner of prescribing forcings, similar to the one presented herein, is an archetype for integrating Coriolis force in Prusa et al. (2008).

MPyDATA project idea: shallow-water equations solver



Journal of Computational Physics

Volume 289, 15 May 2015, Pages 53-61



A spreading drop of shallow water

Dorota Jarecka ^{a, b} ✉, Anna Jaruga ^a, Piotr K. Smolarkiewicz ^c

^a Institute of Geophysics, Faculty of Physics, University of Warsaw, Poland

^b National Center for Atmospheric Research, USA

^c European Centre for Medium-Range Weather Forecasts, UK

MPyDATA project idea: shallow-water equations solver

The screenshot shows a GitHub repository page for 'shallow-water-elliptic-drop' by user 'lgfuv'. The repository has 3 watchers, 0 stars, and 3 forks. The 'Code' tab is selected, showing the 'master' branch with the file path 'shallow-water-elliptic-drop / analytical / README.md'. A commit by 'trontrytel' is visible, dated 23 Sep 2014. The file statistics show 28 lines (10 sloc) and 424 Bytes. The file content includes a section titled 'Codes for reproducing Figs. 1-3.' with instructions on how to run Python scripts to reproduce the figures.

lgfuv / **shallow-water-elliptic-drop** Watch 3 Star 0 Fork 3

Code Issues 3 Pull requests 0 Actions Projects 0 Security Insights Settings

Branch: master shallow-water-elliptic-drop / analytical / README.md Find file Copy path

trontrytel adding forgotten(?) cmake file 095b3f8 on 23 Sep 2014

2 contributors

28 lines (10 sloc) 424 Bytes Raw Blame History

Codes for reproducing Figs. 1-3.

For plotting Figs. 1-3, you need Python with scientific libraries (e.g. NumPy, SciPy, Matplotlib, h5py).

Figure 1 (both panels) can be obtained by running:

```
$ python ellipse_evolution_odeint.py
```

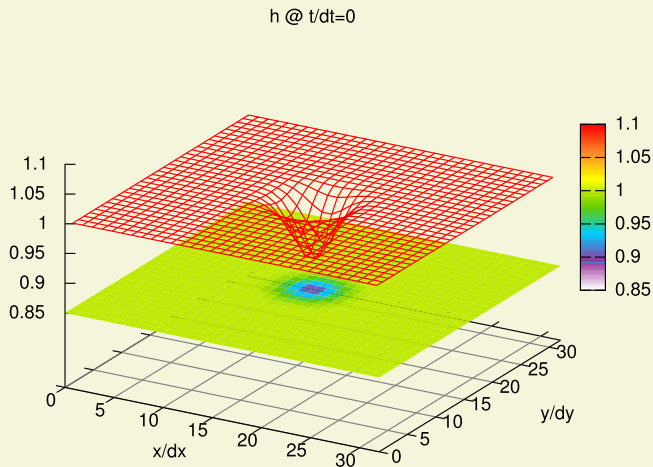
Figure 2 can be obtained by running:

```
$ python energy_conserv.py
```

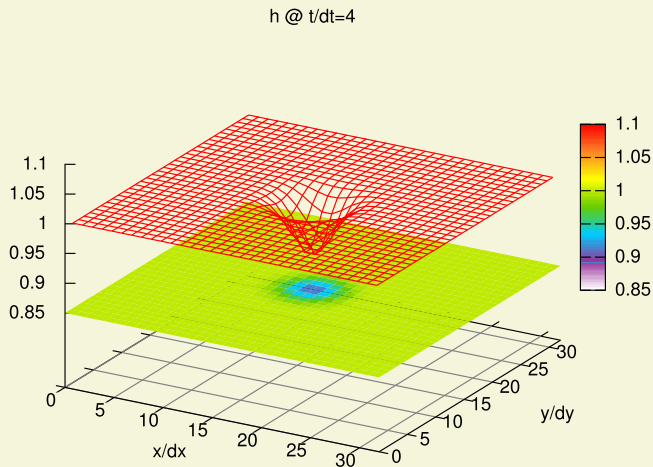
Figure 3 can be obtained by running:

```
$ python circle_evolution.py
```

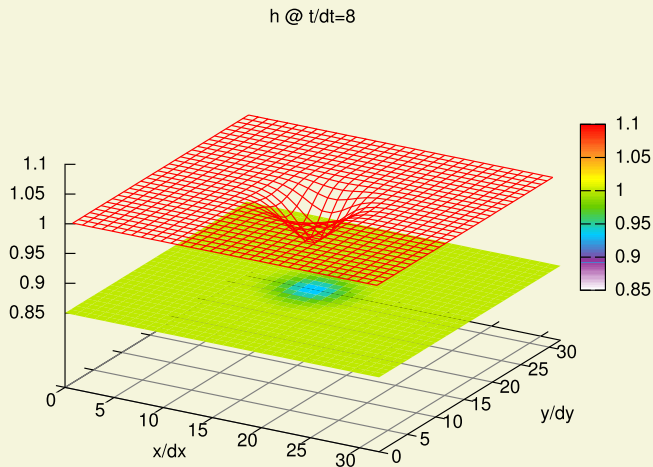
MPyDATA project idea: shallow-water equations solver



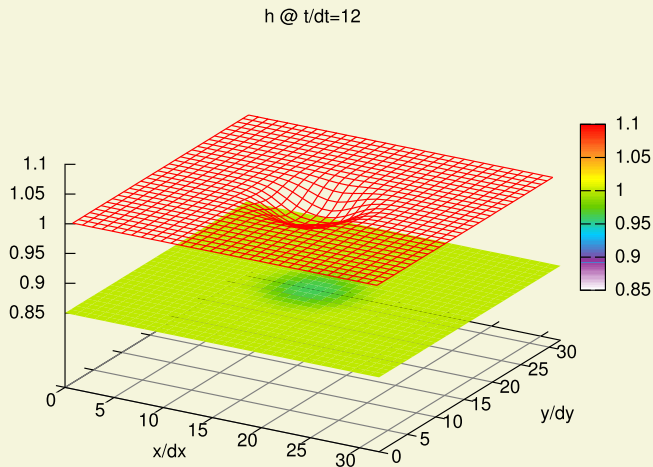
MPyDATA project idea: shallow-water equations solver



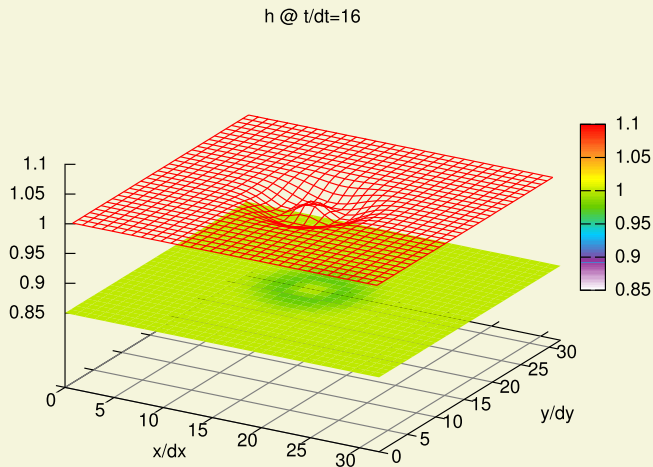
MPyDATA project idea: shallow-water equations solver



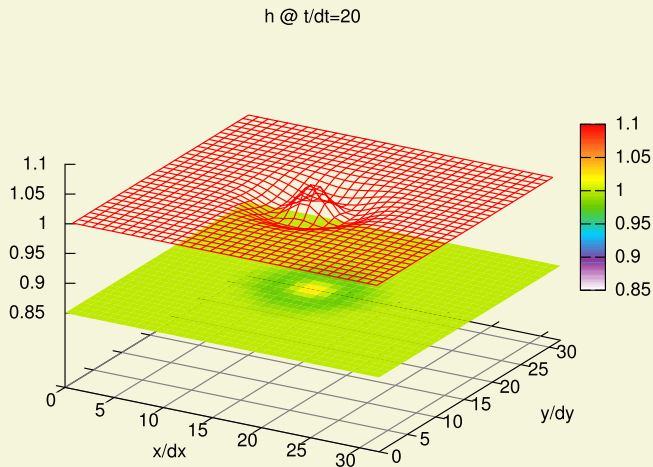
MPyDATA project idea: shallow-water equations solver



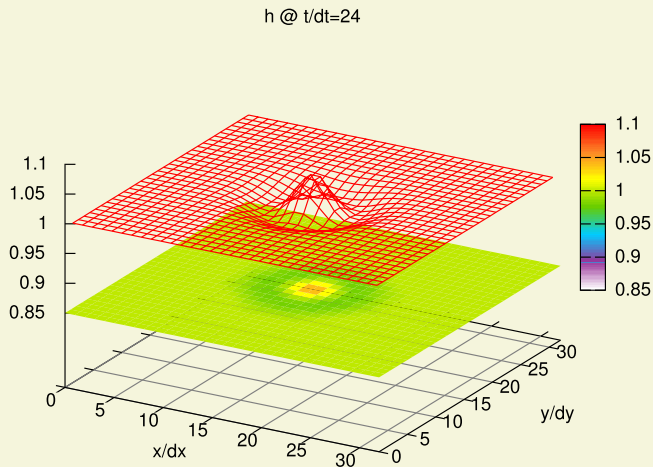
MPyDATA project idea: shallow-water equations solver



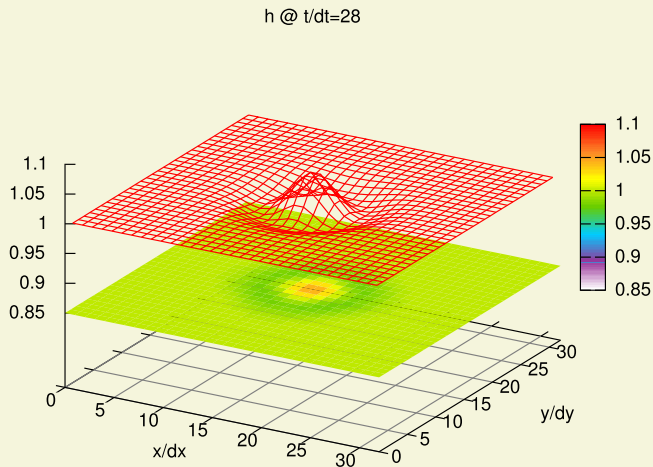
MPyDATA project idea: shallow-water equations solver



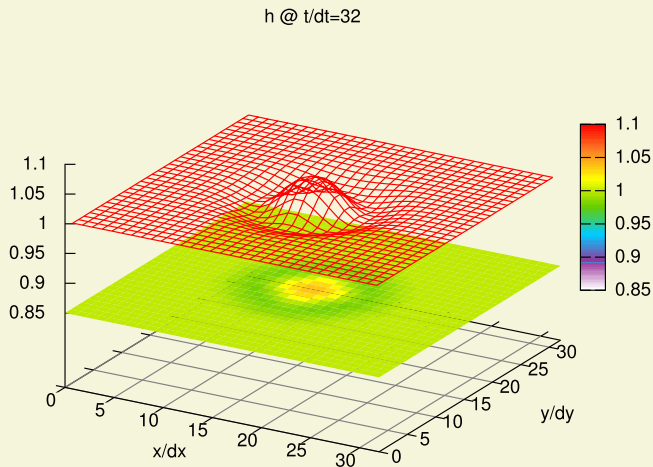
MPyDATA project idea: shallow-water equations solver



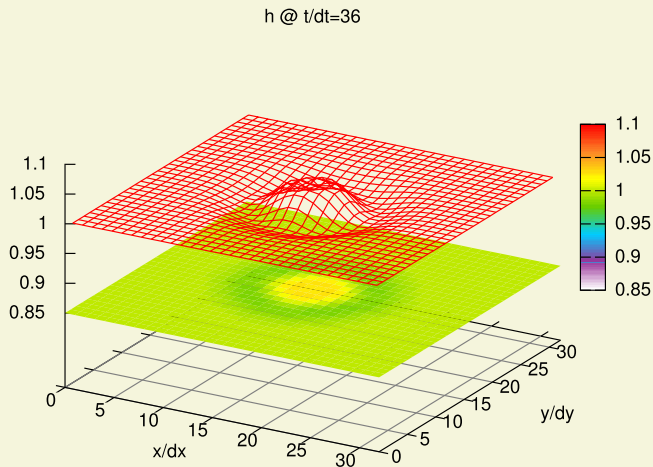
MPyDATA project idea: shallow-water equations solver



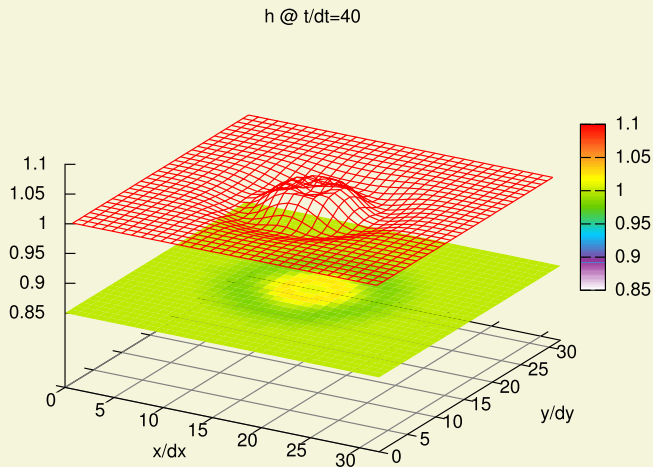
MPyDATA project idea: shallow-water equations solver



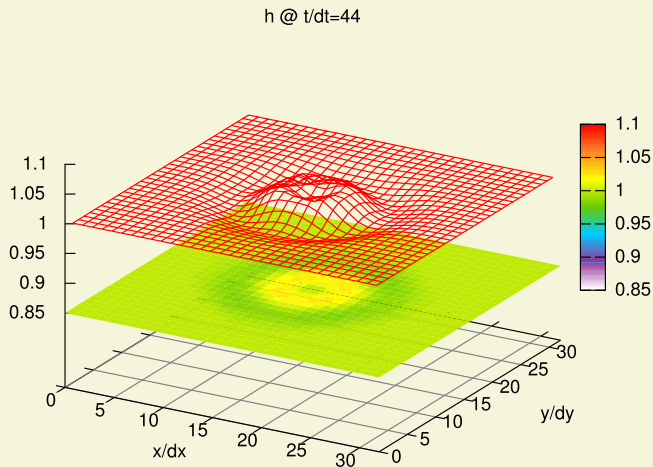
MPyDATA project idea: shallow-water equations solver



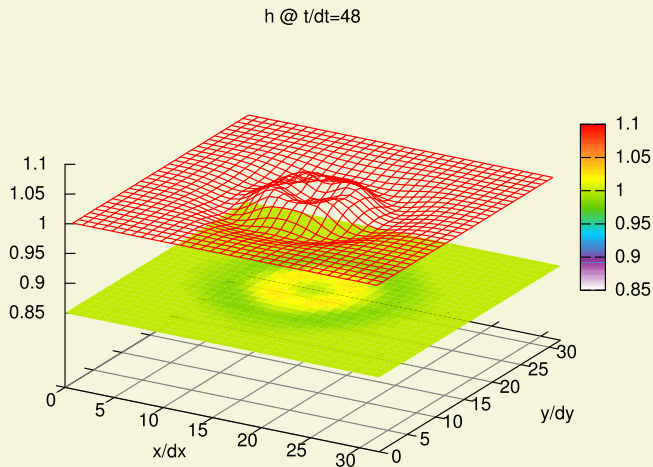
MPyDATA project idea: shallow-water equations solver



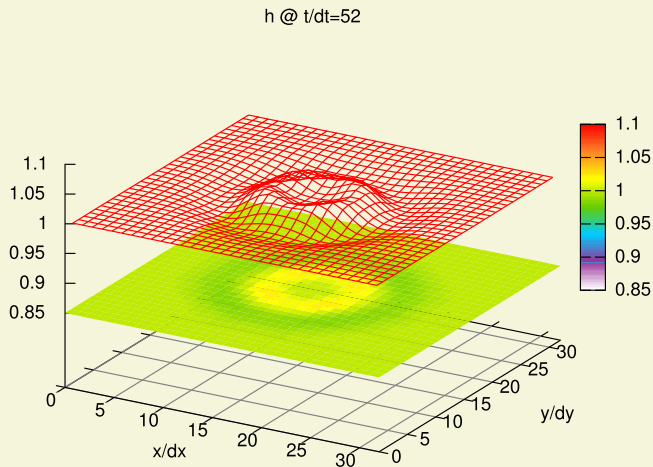
MPyDATA project idea: shallow-water equations solver



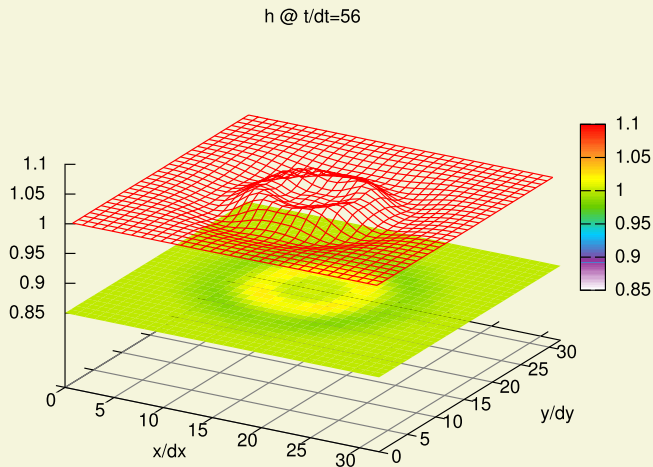
MPyDATA project idea: shallow-water equations solver



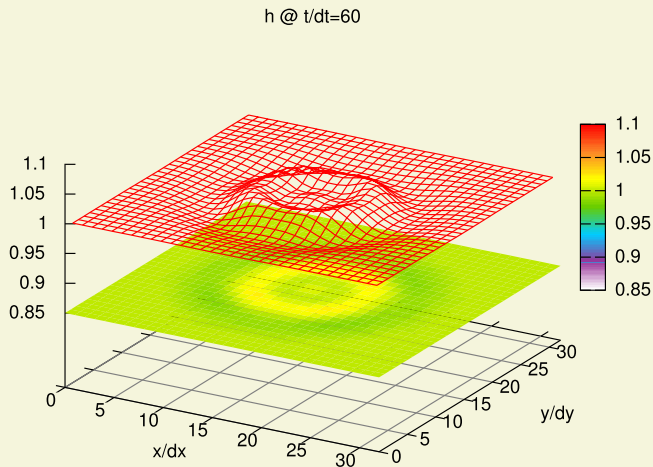
MPyDATA project idea: shallow-water equations solver



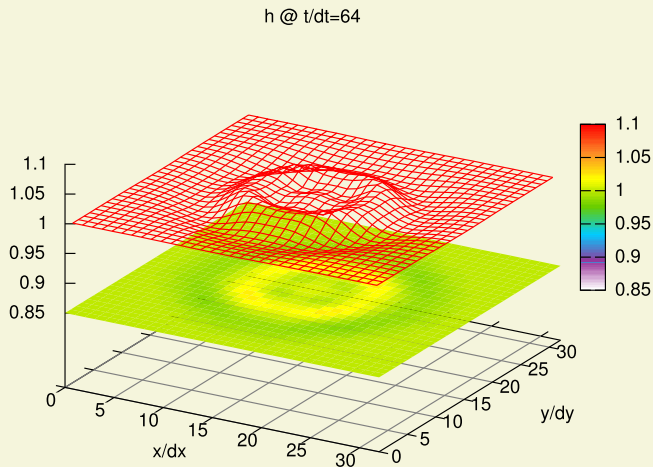
MPyDATA project idea: shallow-water equations solver



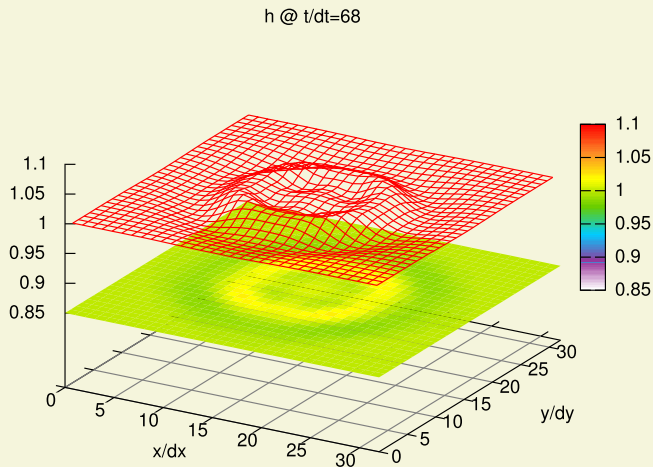
MPyDATA project idea: shallow-water equations solver



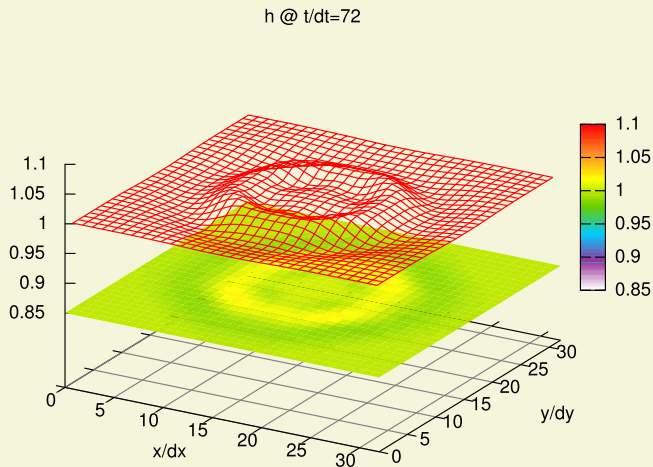
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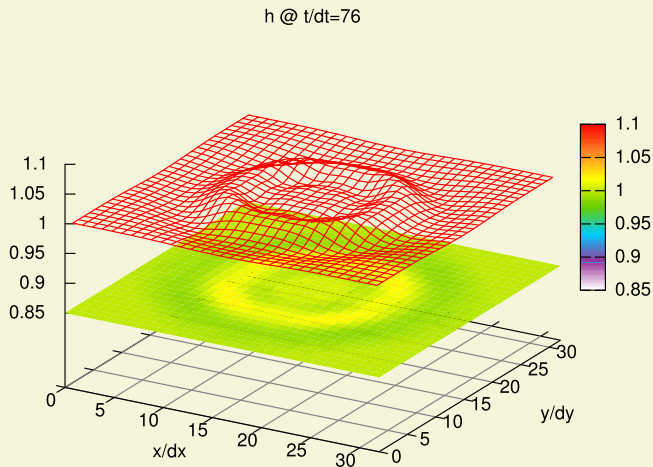
MPyDATA project idea: shallow-water equations solver



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MPyDATA project idea: DPDC variant of MPDATA

<https://www.osti.gov/servlets/purl/7049237>

DPDC: A SECOND-ORDER MONOTONE SCHEME FOR ADVECTION

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A study on the high-order Smolarkiewicz methods

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Thank you for your attention!