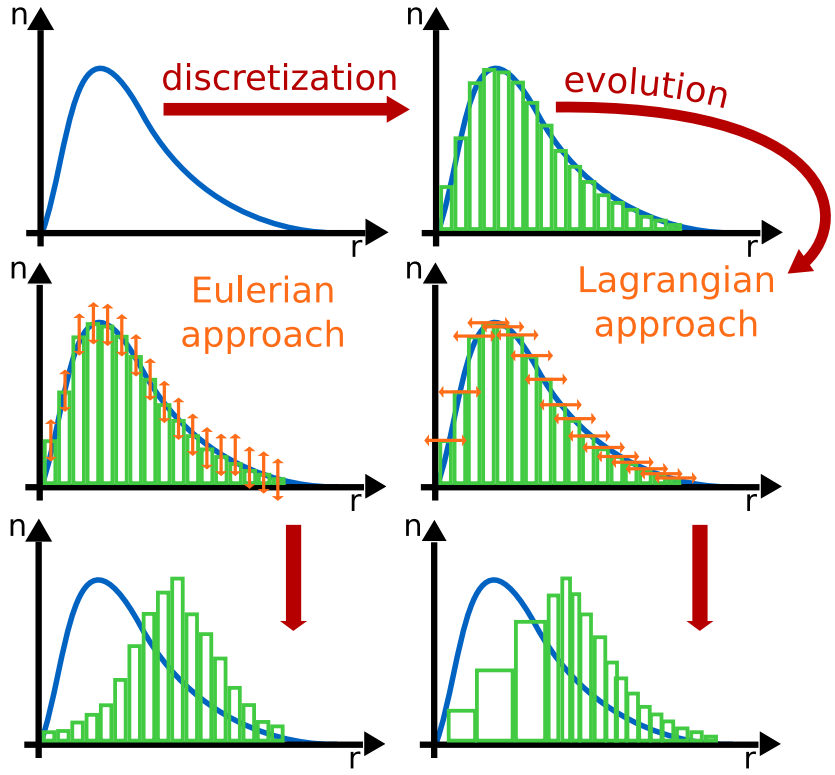
# Modelling of Atmospheric Clouds

**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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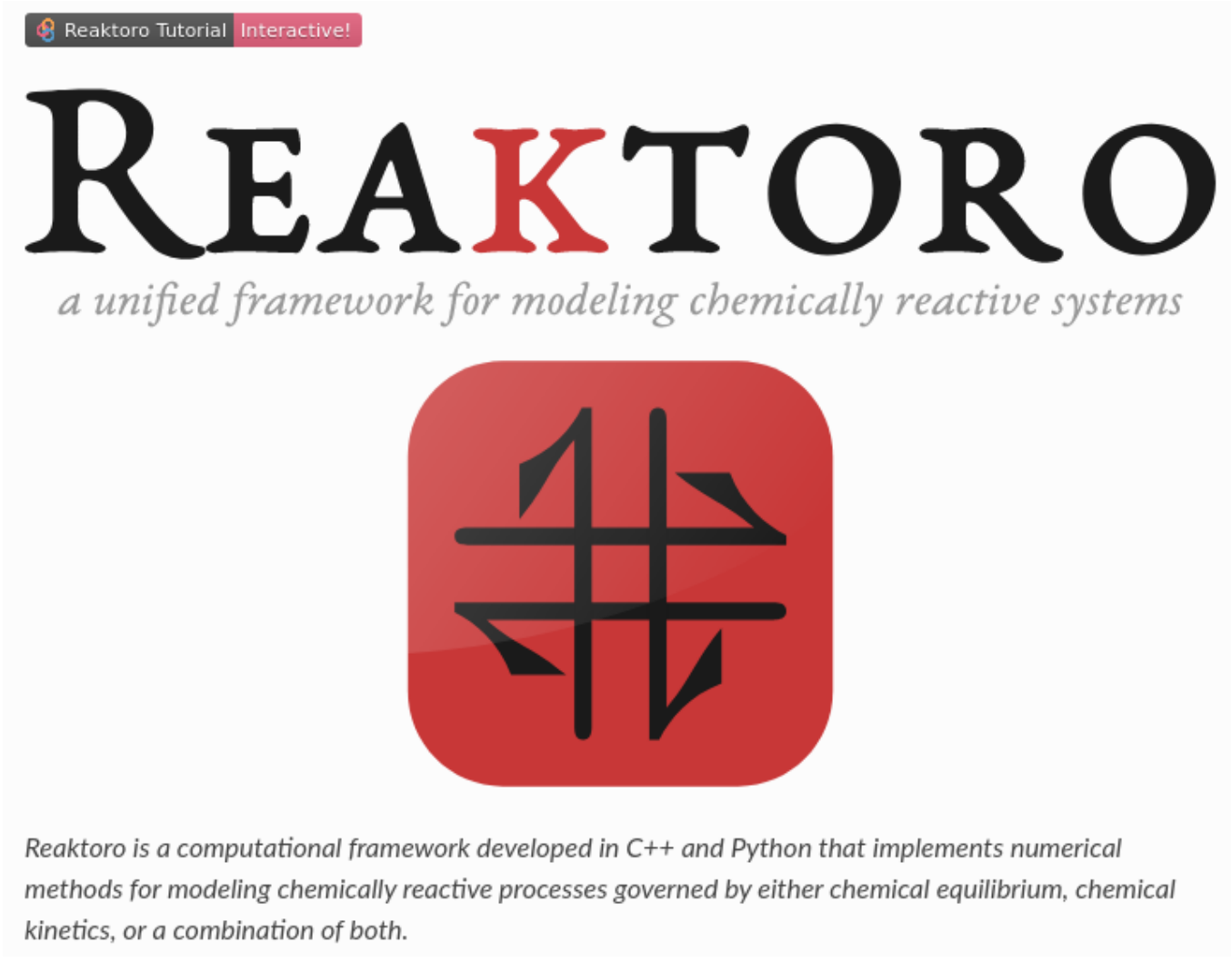
# parcel model idea: Hoppel-gap with Reaktoro




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

# parcel model idea: clouds beyond Earth

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


**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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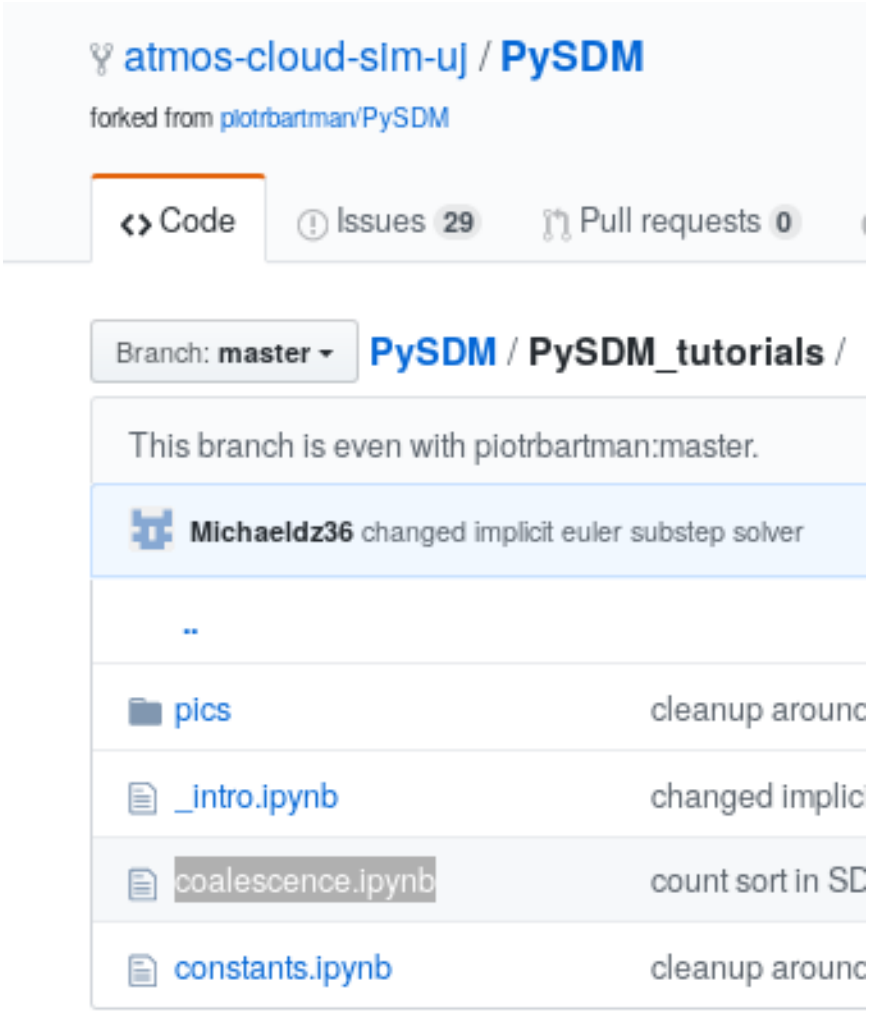
# PySDM tutorial




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 collisinal 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

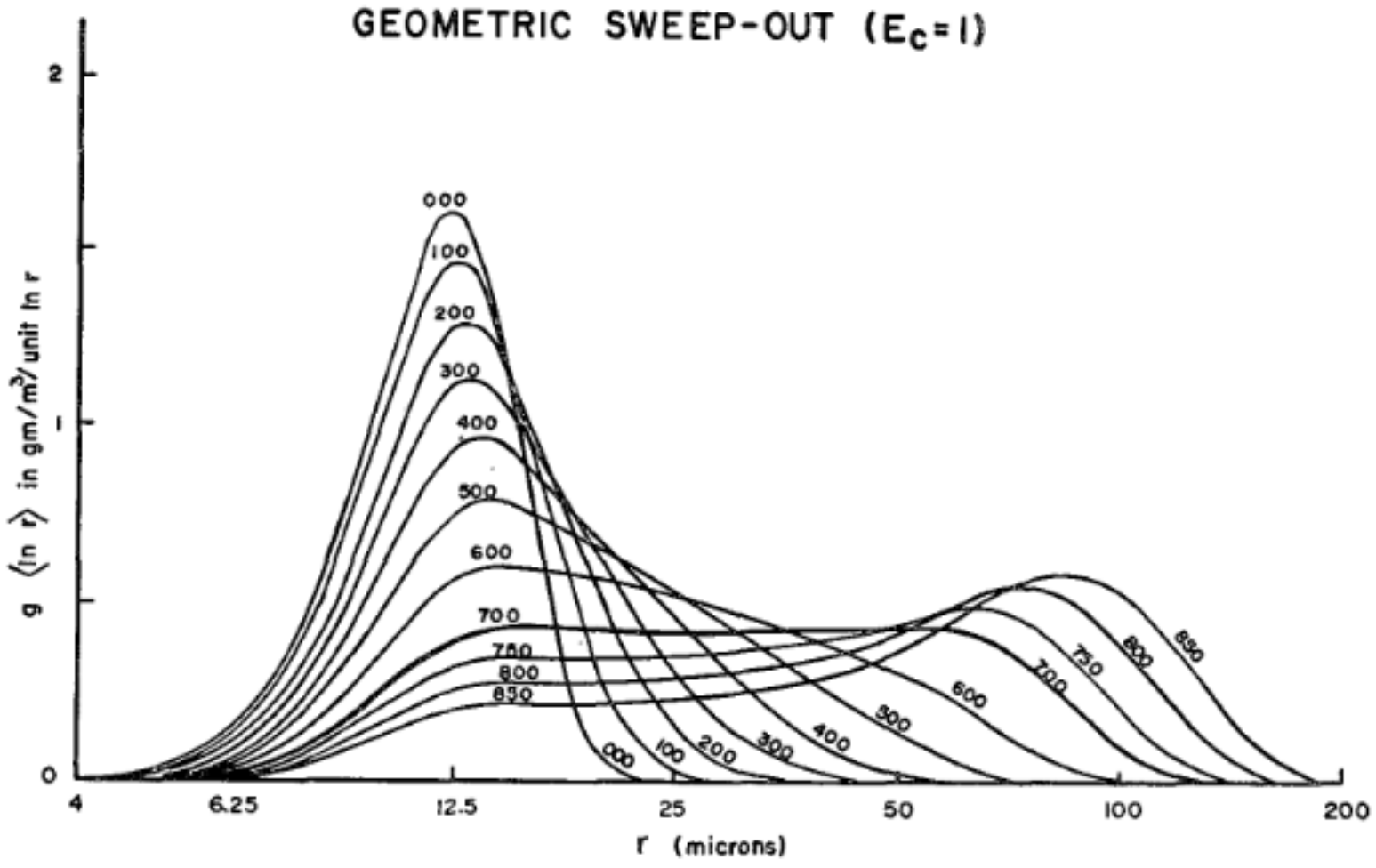
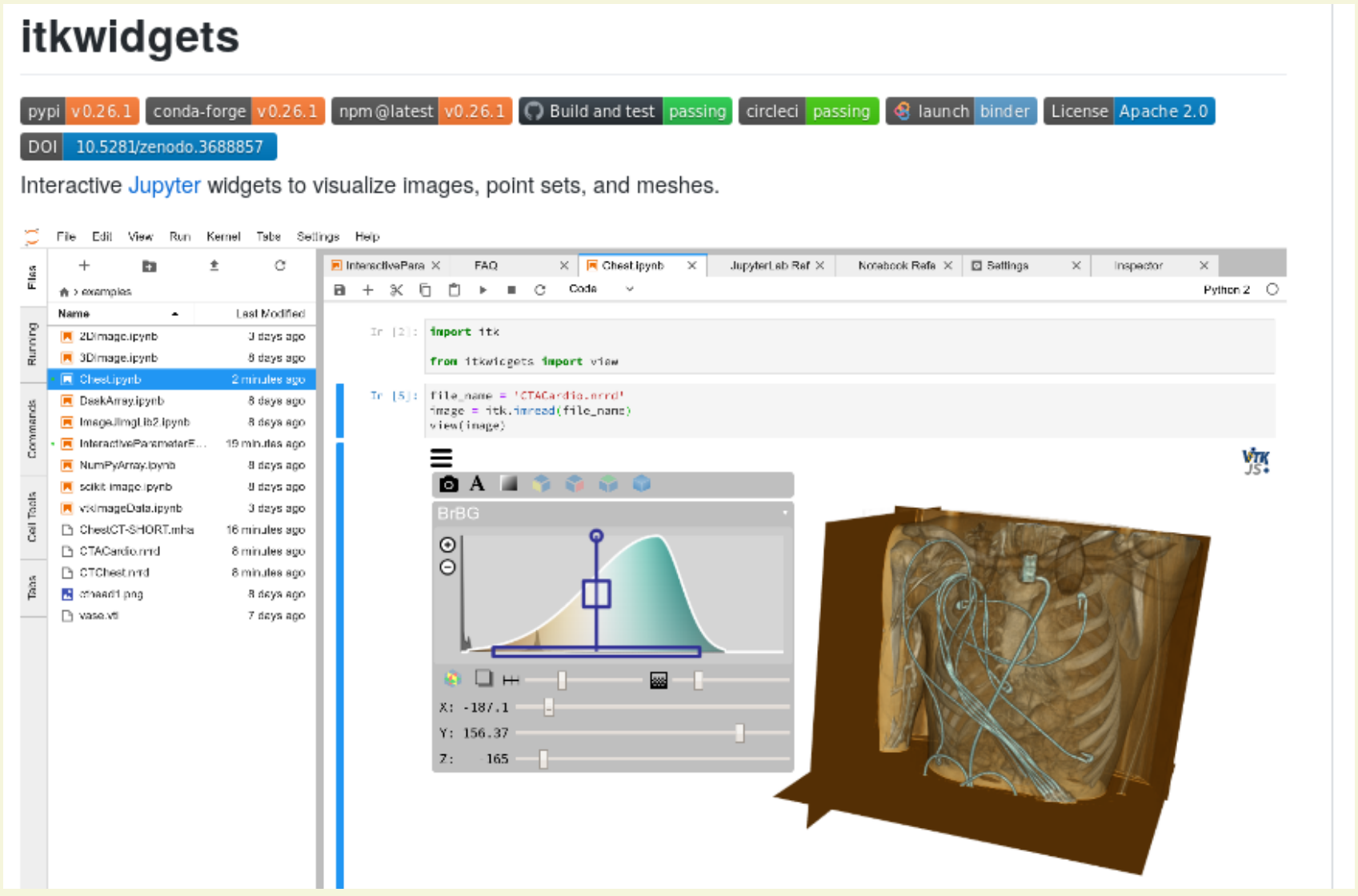



FIG. 5. Computed droplet growth due to geometric sweep-out. The heavy line indicates the appearance of the second maximum.

# PySDM project idea: visualisation with itkwidgets

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



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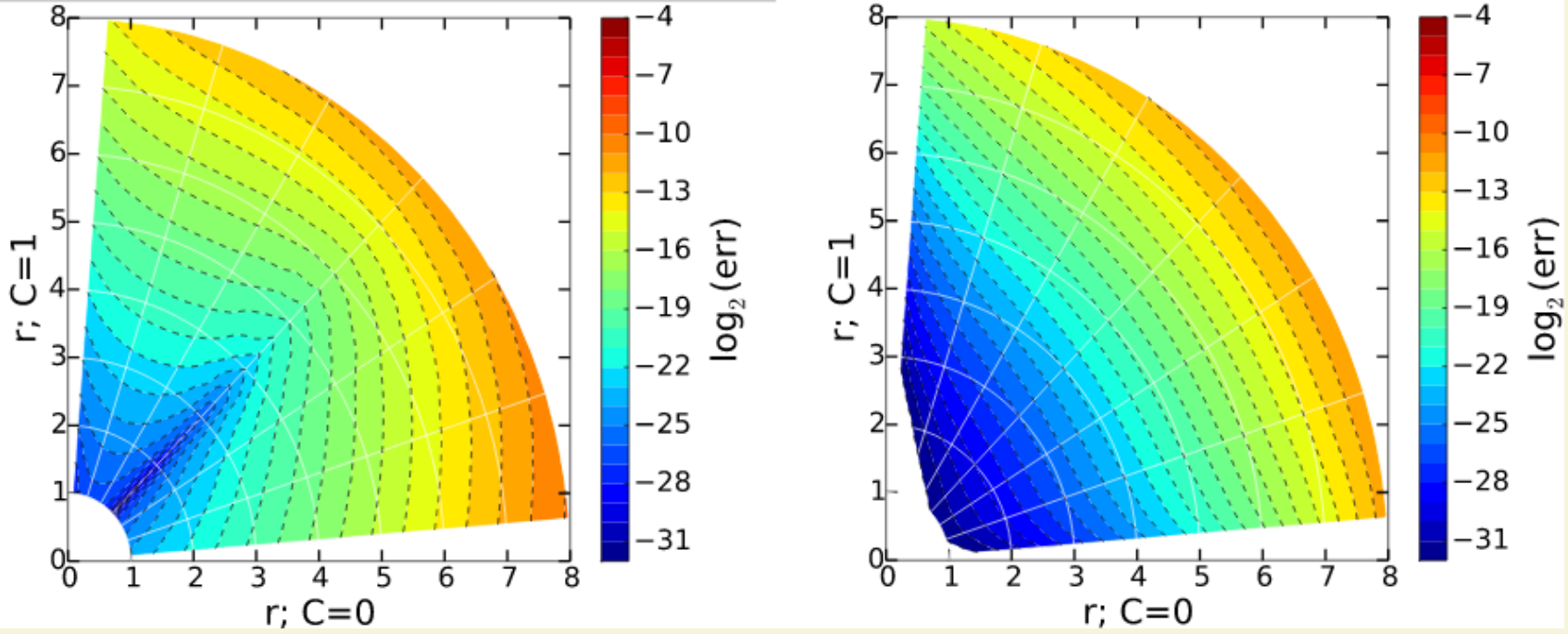
# MPyDATA

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

# MPyDATA project idea: convergence "maps"

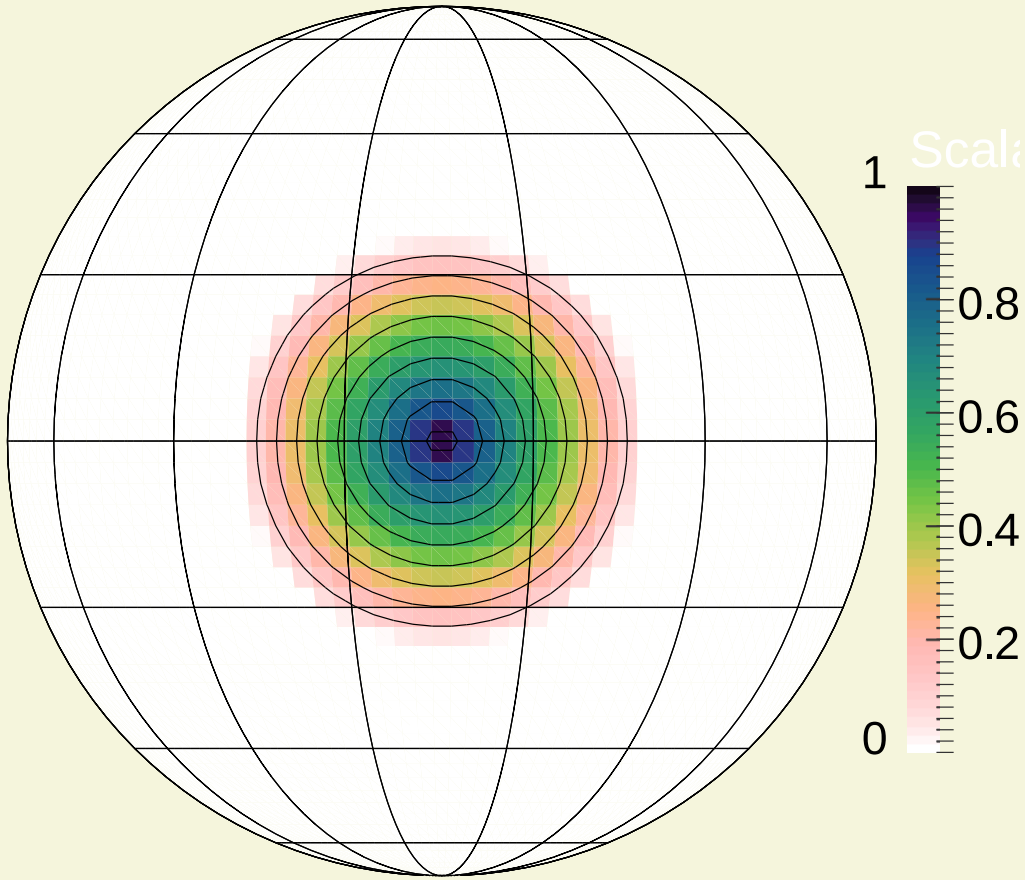
## Jaruga et al. 2015: Figs. 10 & 11




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

# MPyDATA project idea: polar coordinates

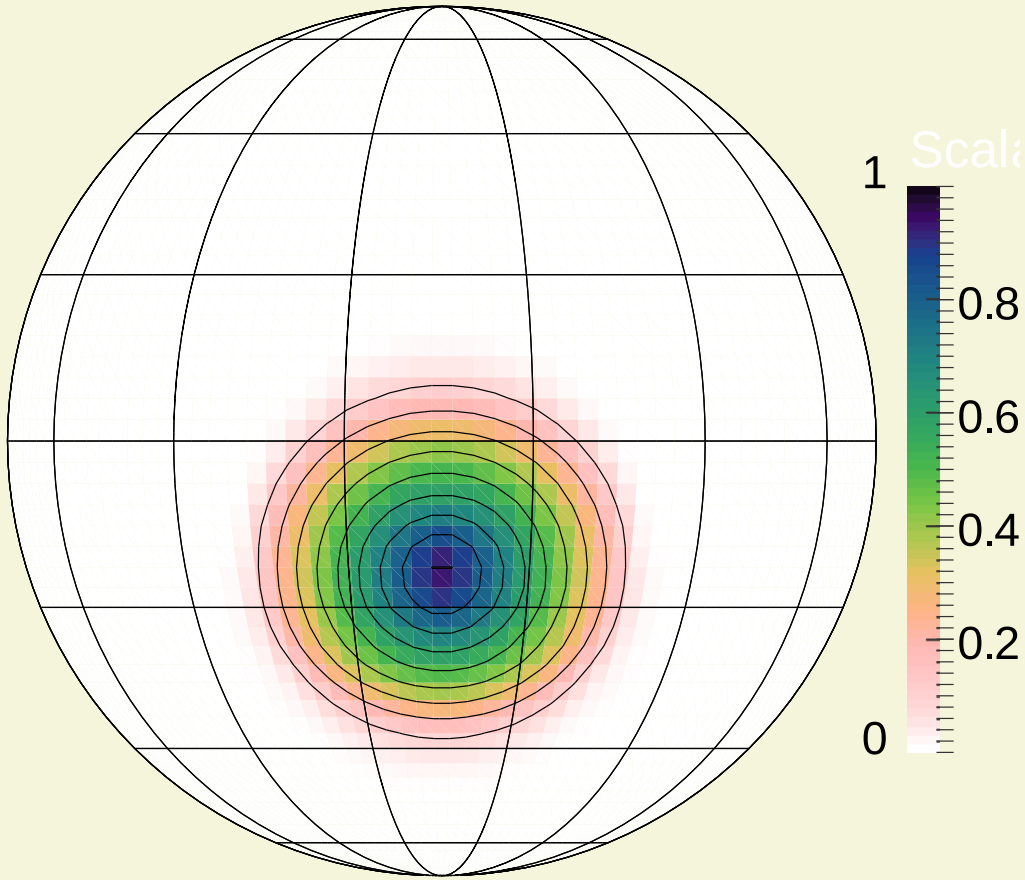
## Jaruga et al. 2015: Fig 14




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

# MPyDATA project idea: polar coordinates

## Jaruga et al. 2015: Fig 14

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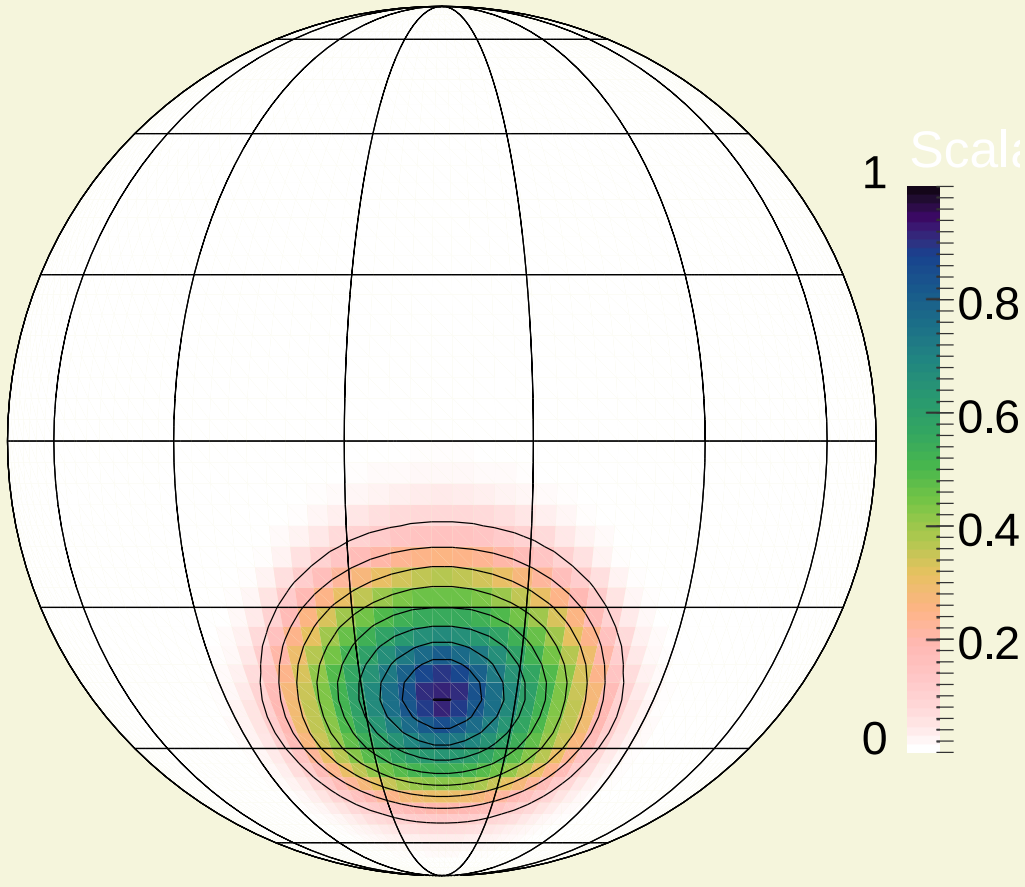


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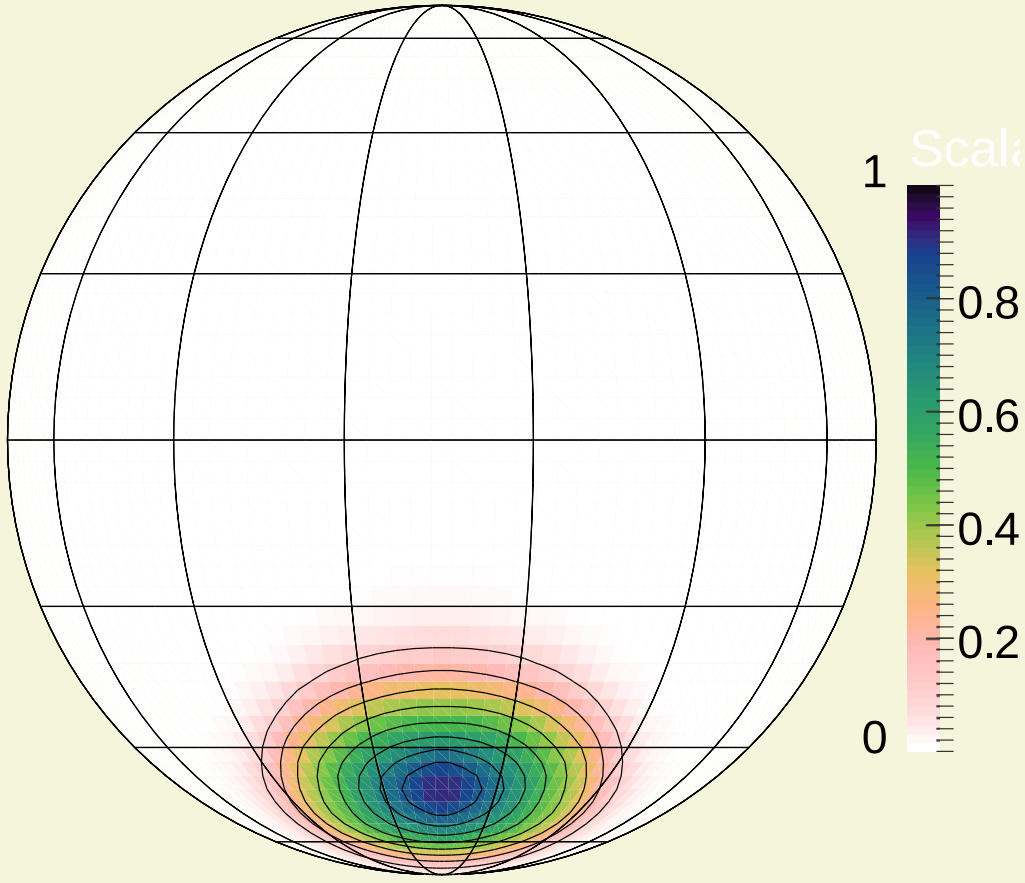


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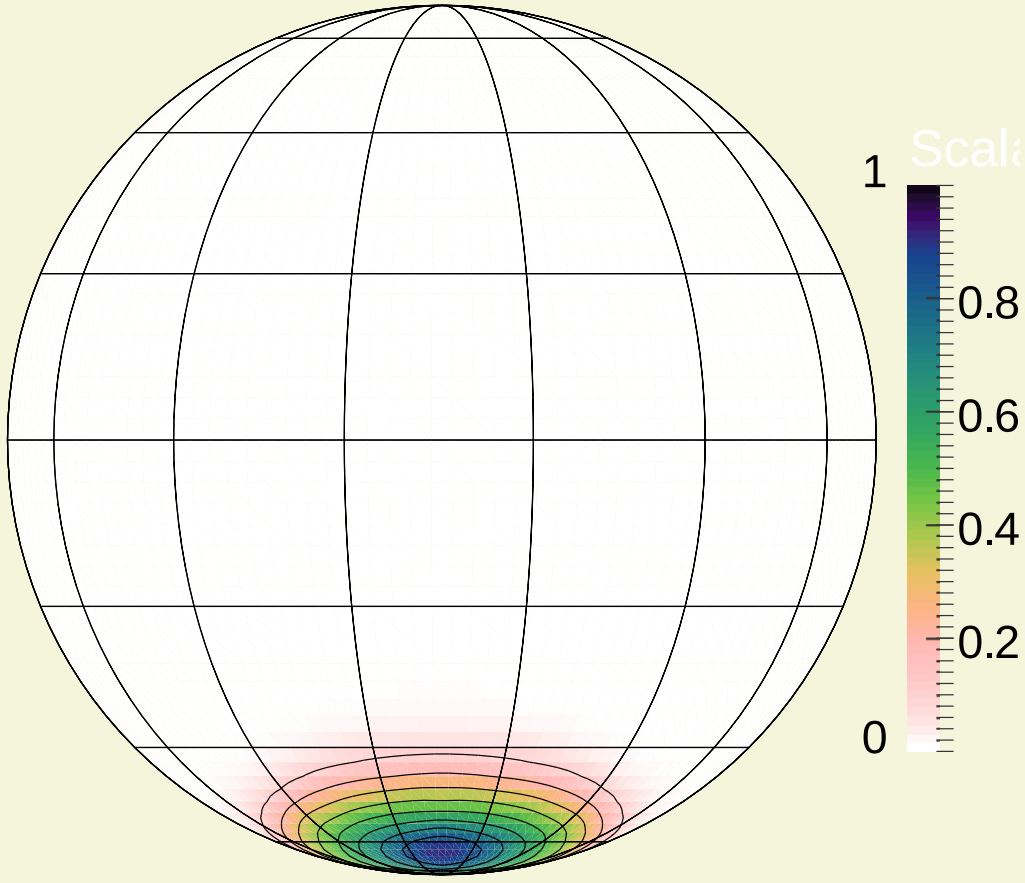


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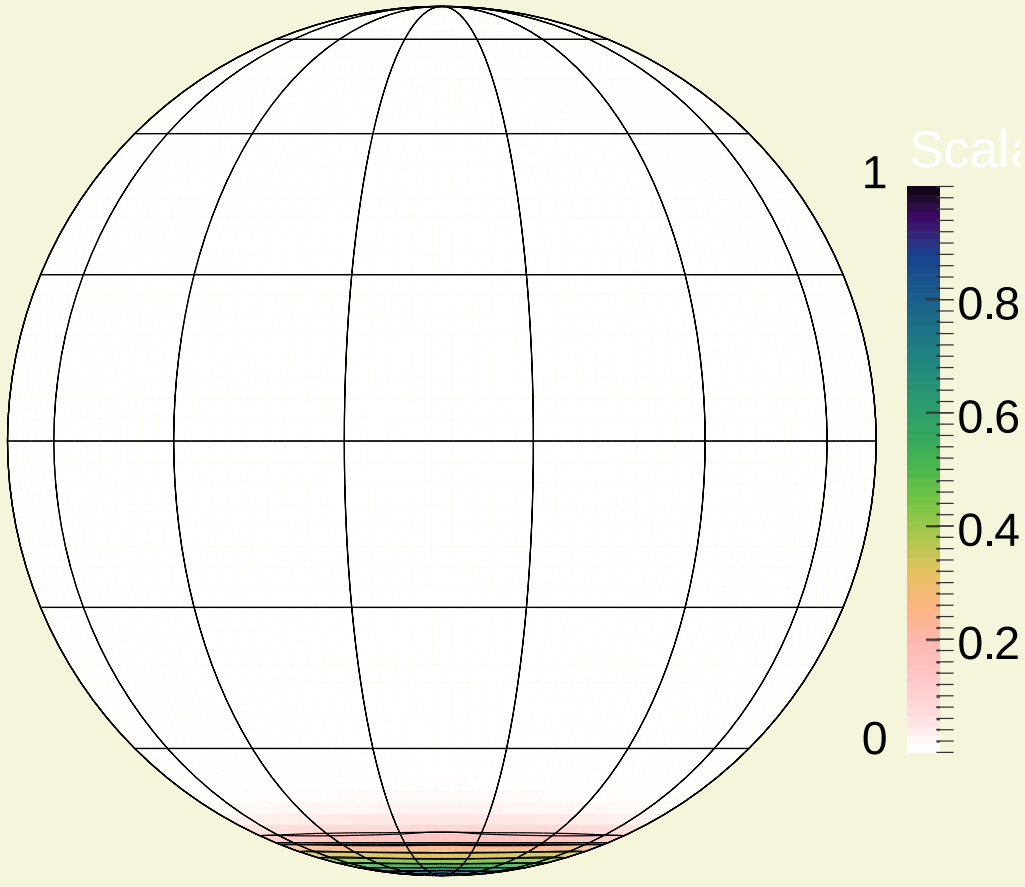


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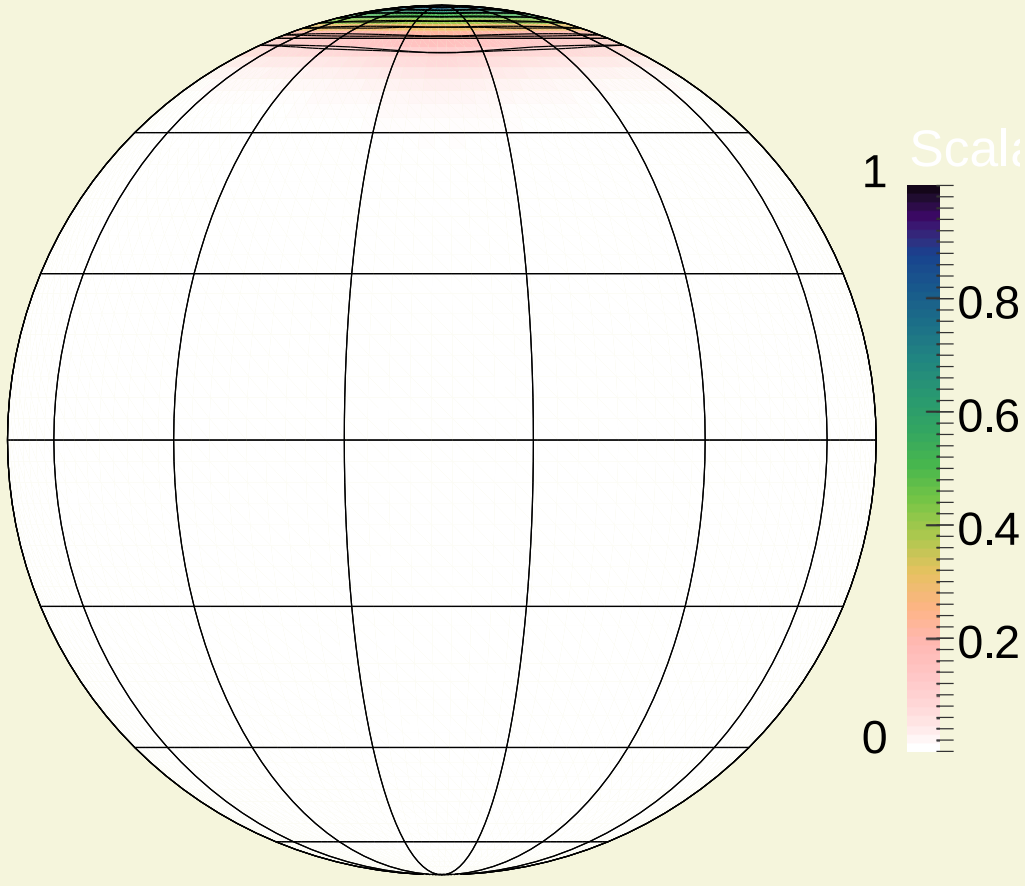


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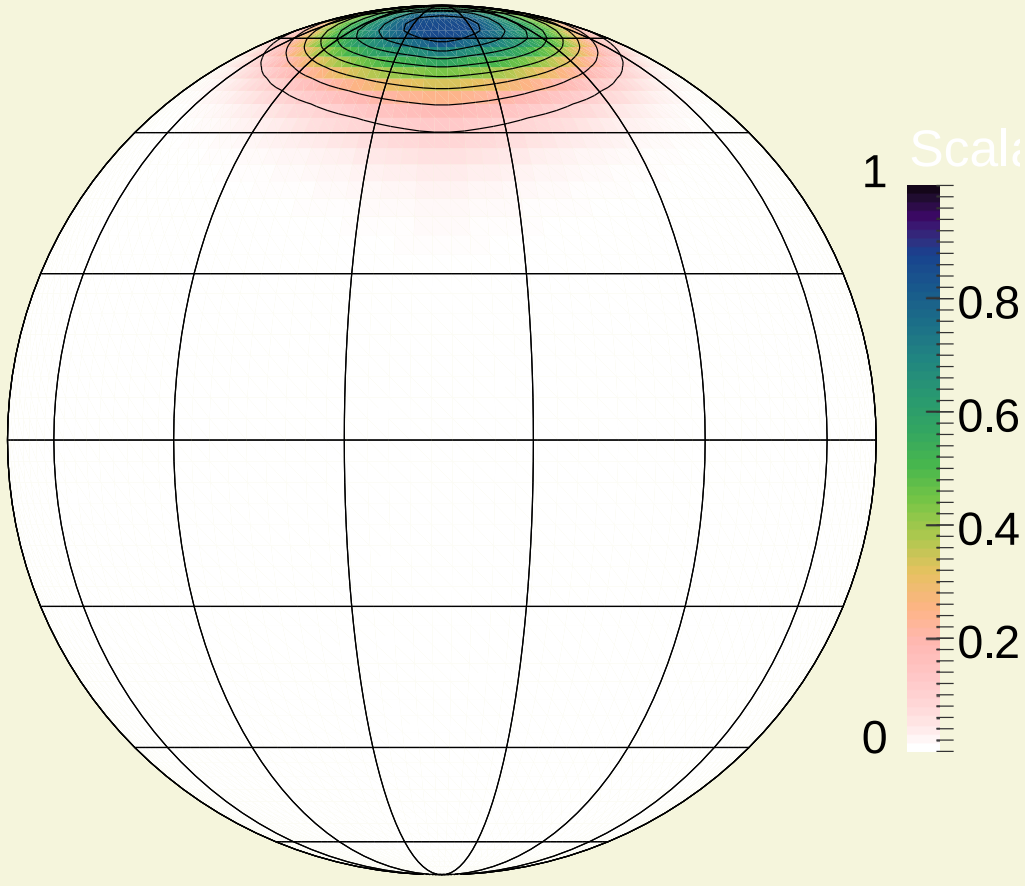


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# MPyDATA project idea: polar coordinates

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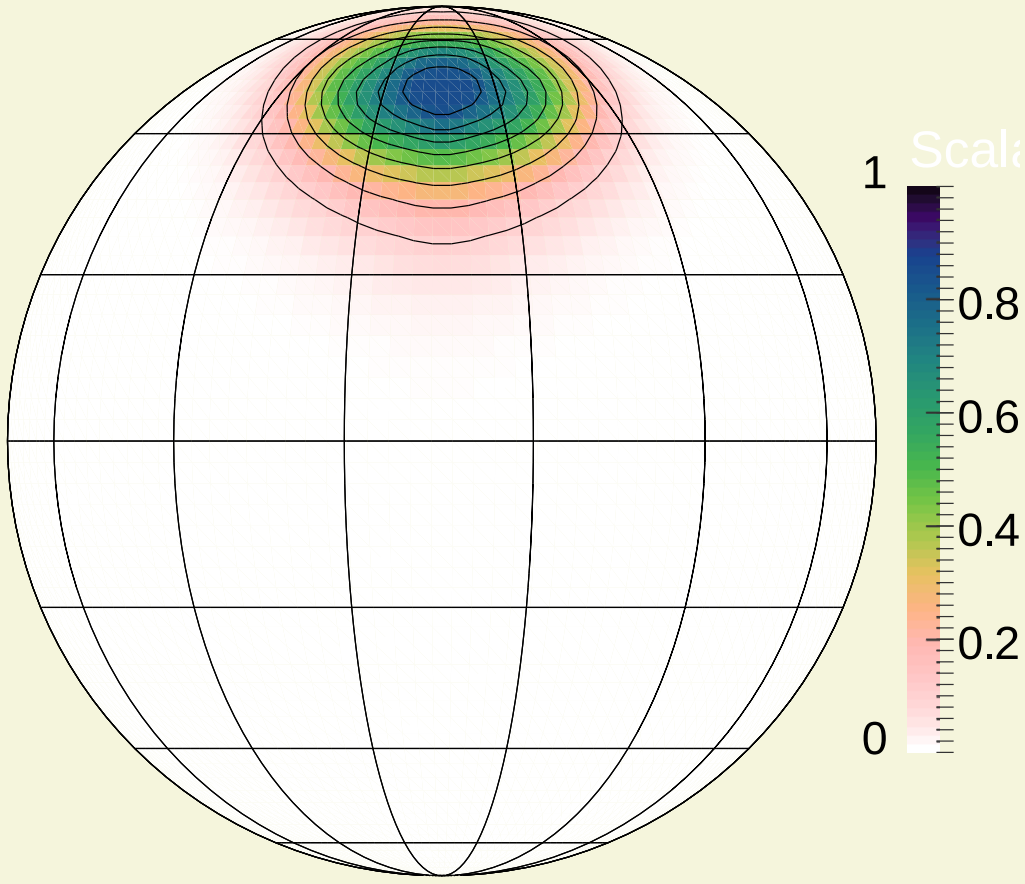


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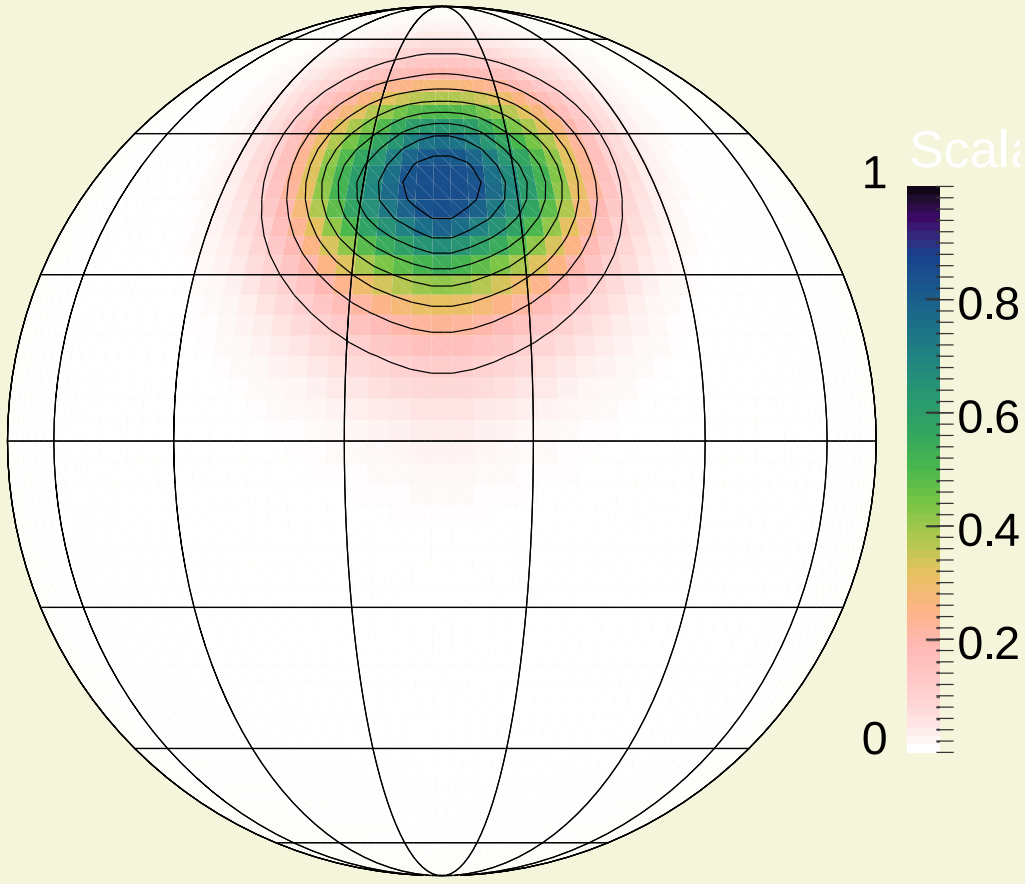


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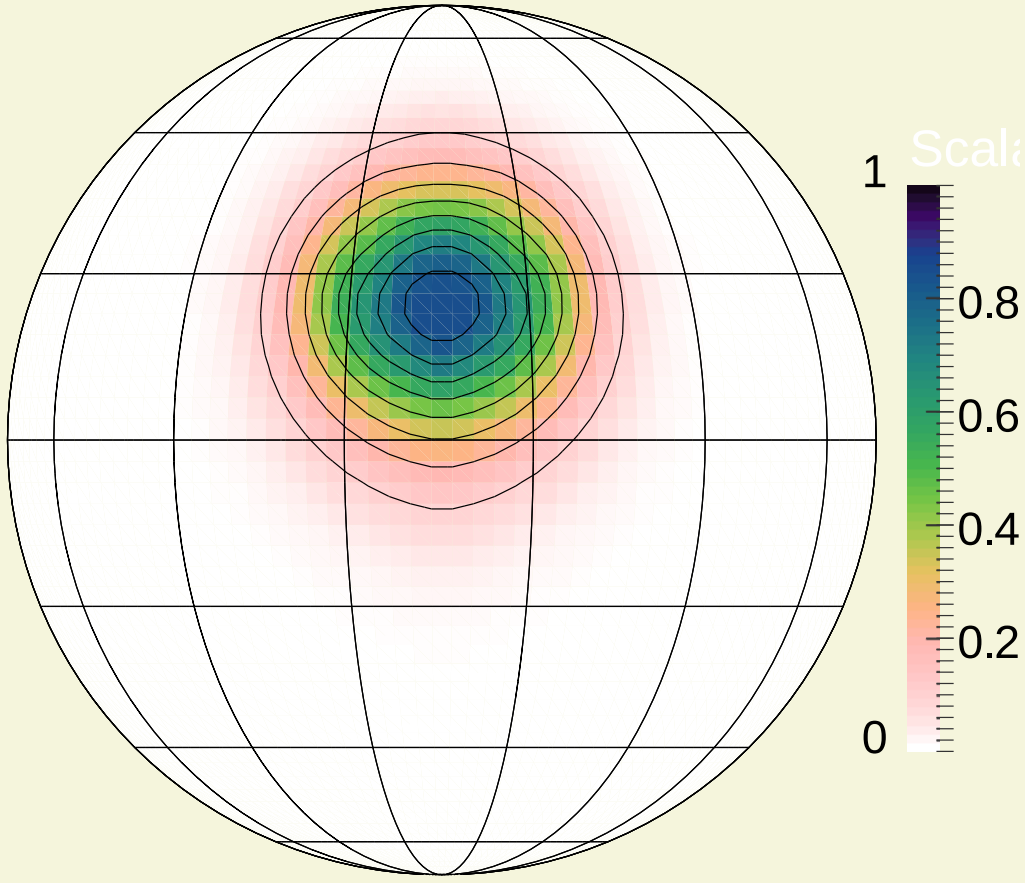


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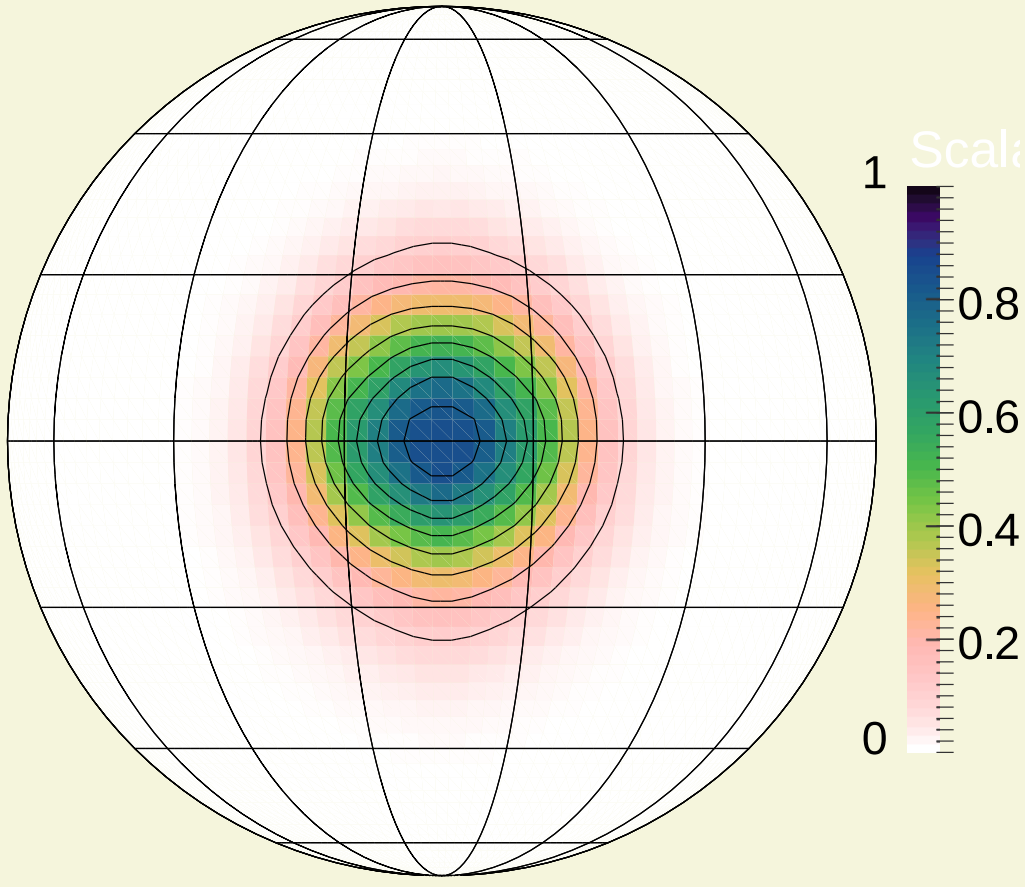



https://github.com/igfuw/libmpdataxx/blob/master/tests/paper_2015_GMD/5_over_the_pole_2d/plot.py

# 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
- Jeffery & Reiser 2006, J. Atmos. Sci. (63(11))
  doi:10.1175/JAS3760.1
- Hoffmann 2016, Mon. Wea. Rev. 144(1)
  doi:10.1175/MWR-D-15-0234.1

## the problem (one of may)

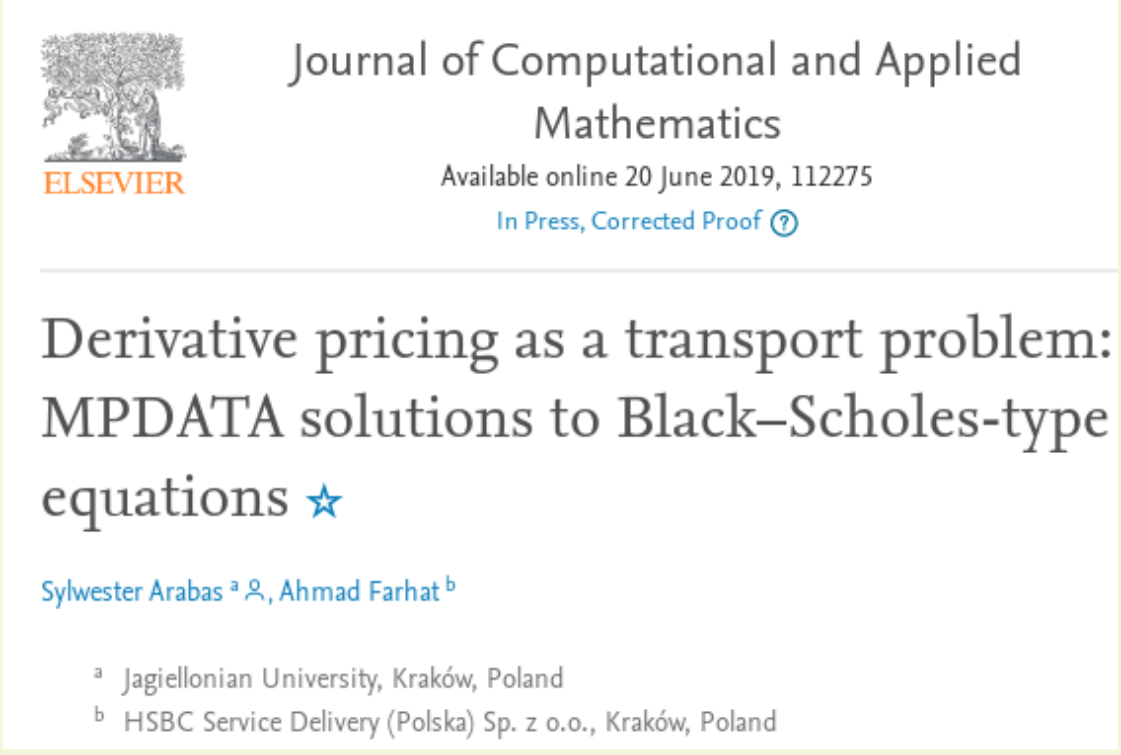
$e_s(T) = e_s(T(q_v, \theta))$ is a non-linear function of the advected (conserved) quantities, good example to showcase applicability of different variants of MPDATA

# 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



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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

# MPyDATA project idea: inhomogeneous system hello world

## Jaruga et al. 2015: Fig. 15

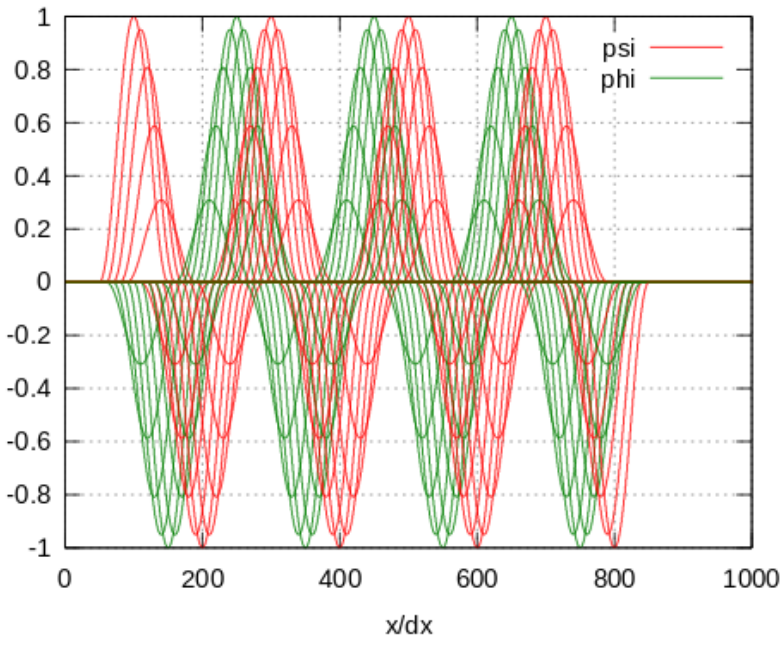


**Figure 15.** Simulation results of the example presented in Sect. 4.3. Abscissa marks the spatial dimension and ordinate represents the oscillator amplitude. The oscillator state is plotted every 20 time steps.

A system of two one-dimensional advection equations,

$$\partial_t \psi + \partial_x (u_o \psi) = \omega \phi ,$$
$$\partial_t \phi + \partial_x (u_o \phi) = -\omega \psi , \qquad (16)$$

represents a harmonic oscillator translating with $u_o =$ constant; see Sect. 4.1 in Smolarkiewicz (2006) for a discussion.[19] Applying the trapezoidal rule to integrate the PDE

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

**www.geosci-model-dev.net/8/1005/2015/**

# MPyDATA project idea: shallow-water equations solver

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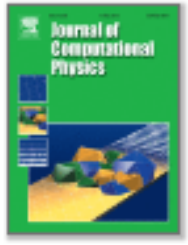
Journal of Computational Physics

Volume 289, 15 May 2015, Pages 53-61



## A spreading drop of shallow water

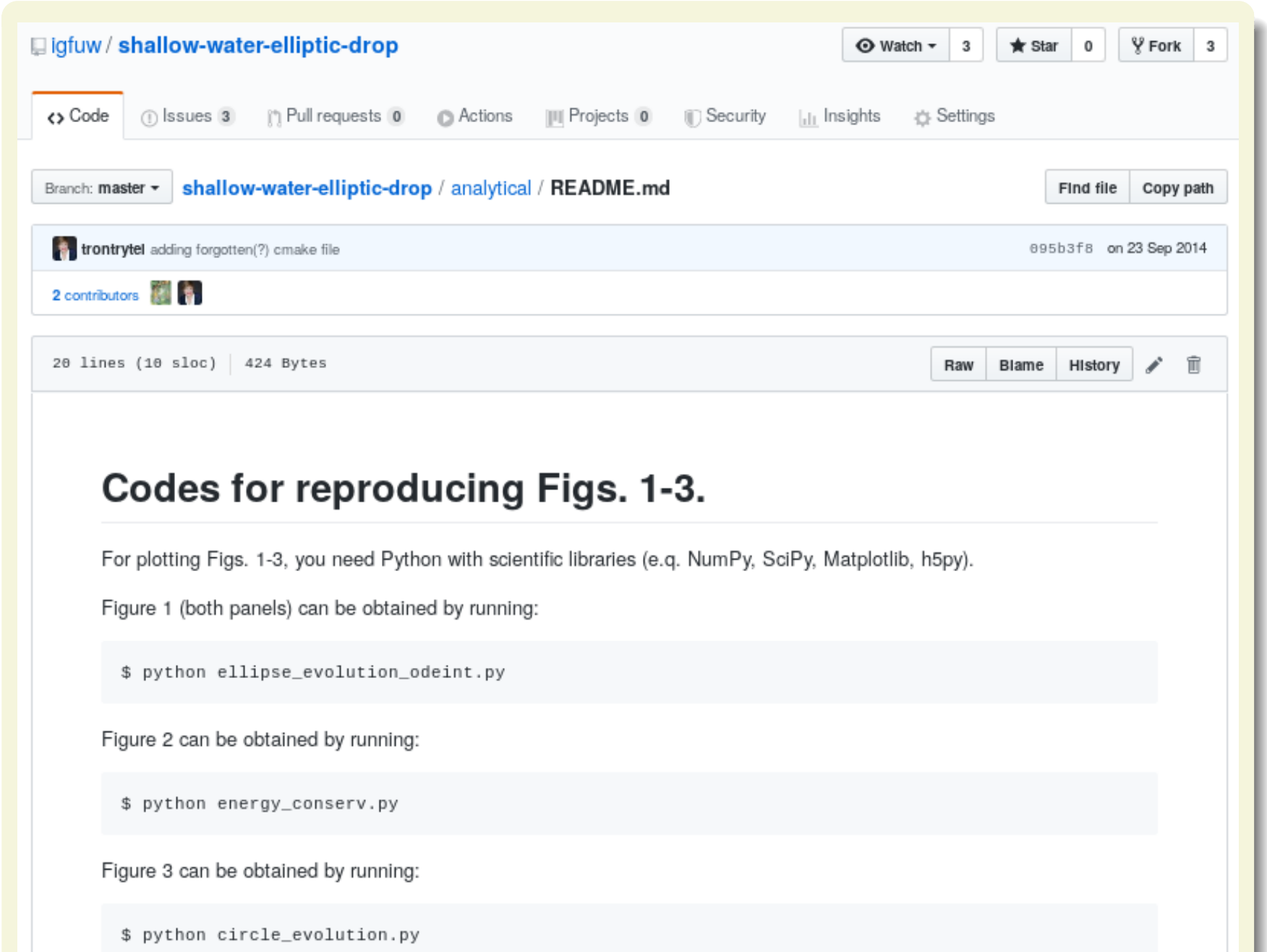
Dorota Jarecka [a, b], Anna Jaruga [a], Piotr K. Smolarkiewicz [c]

[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



igfuw / **shallow-water-elliptic-drop**

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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

20 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.q. NumPy, SciPy, Matplotlib, h5py).

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

```
$ python ellipse_evolution_odeint.py
```

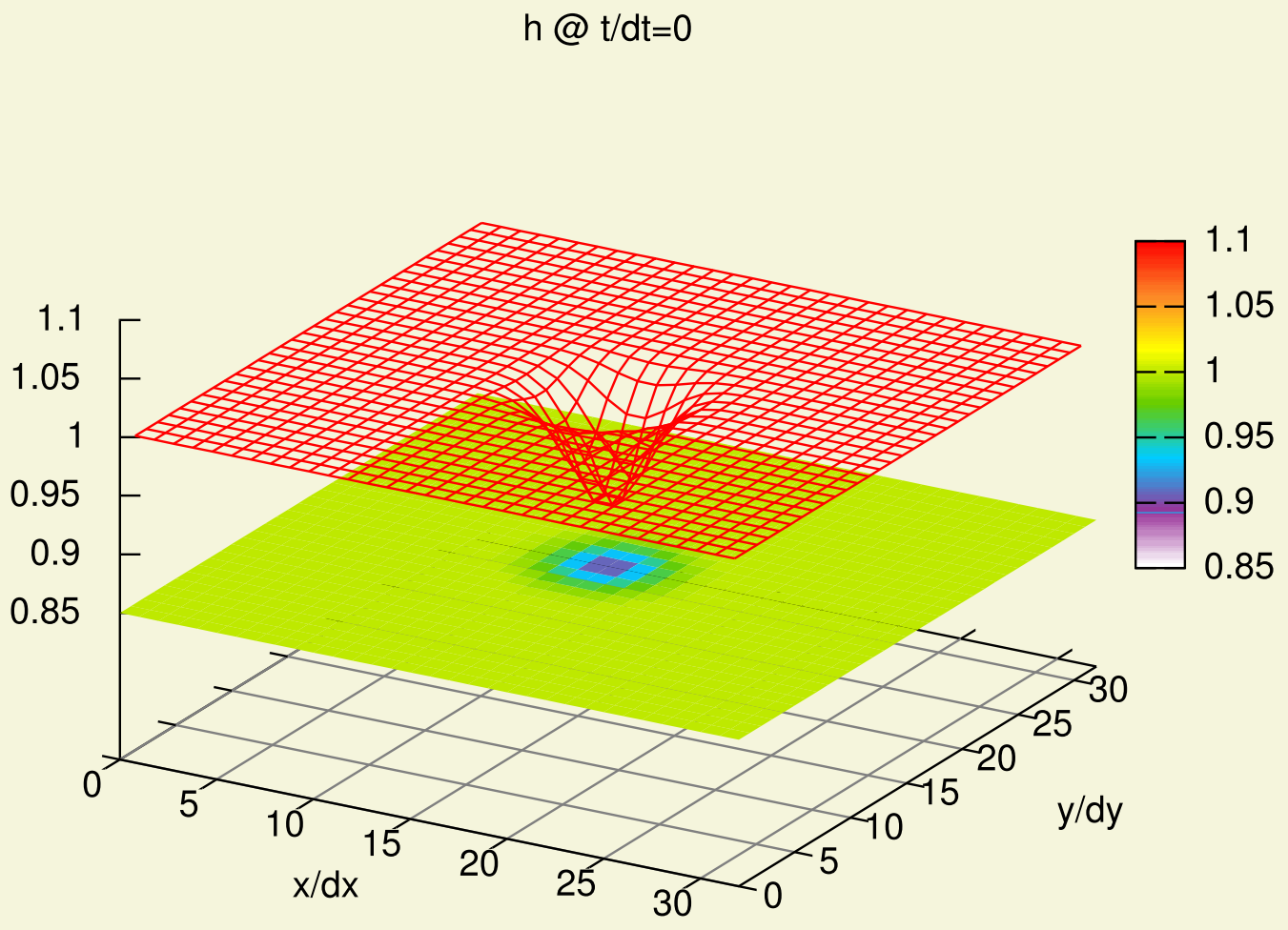
Figure 2 can be obtained by running:

```
$ python energy_conserv.py
```

Figure 3 can be obtained by running:

```
$ python circle_evolution.py
```

# MPyDATA project idea: shallow-water equations solver



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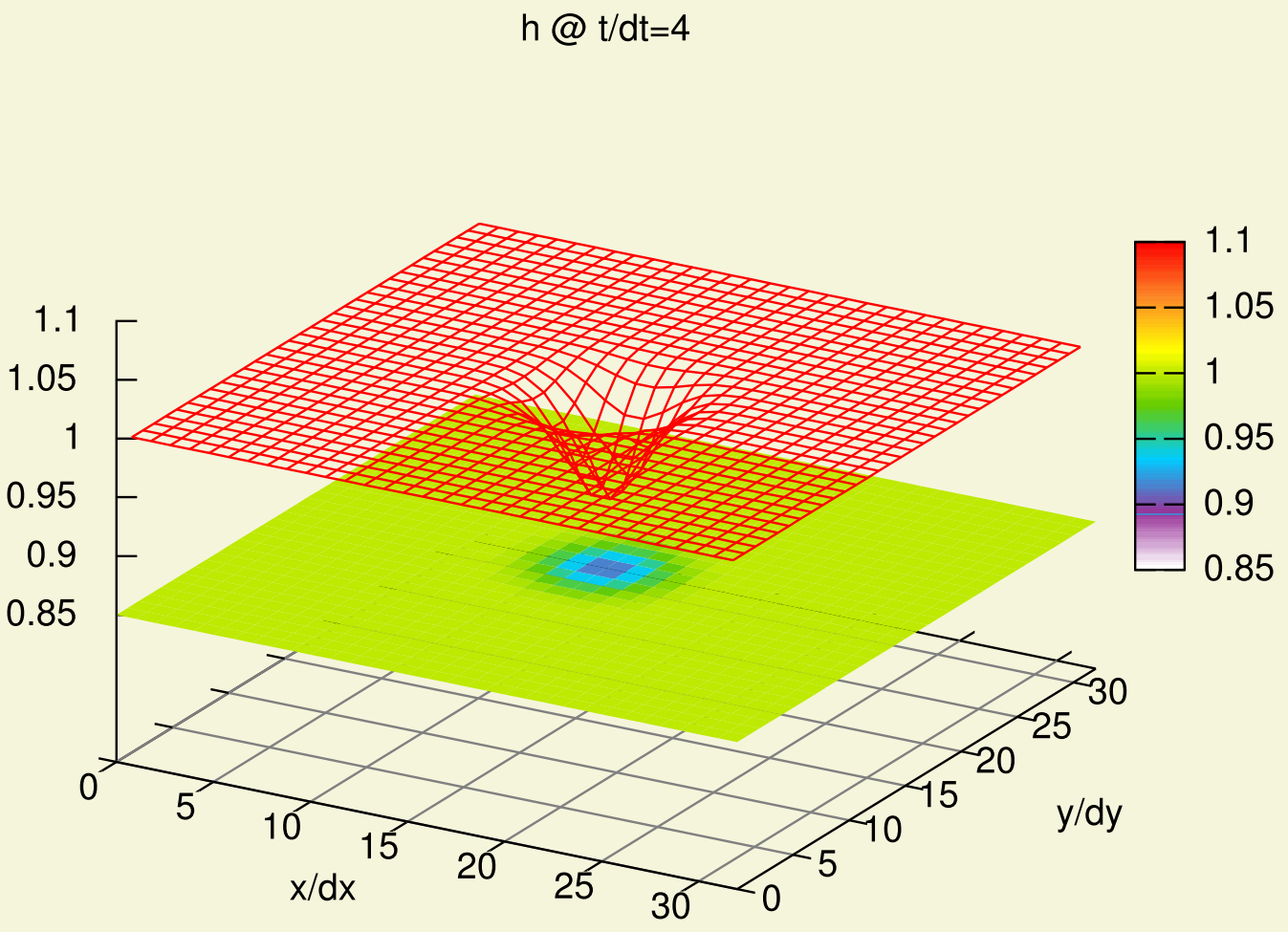
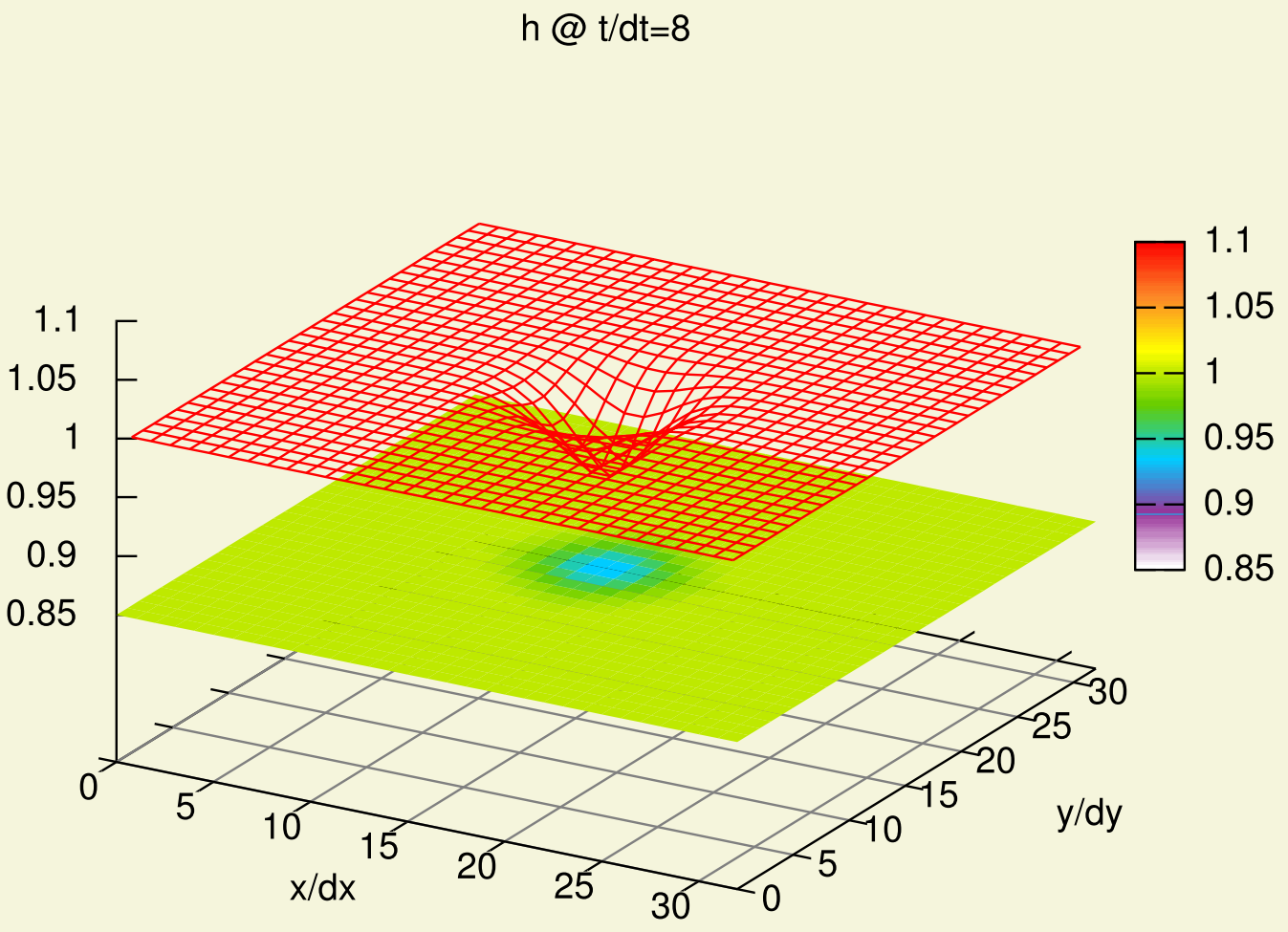
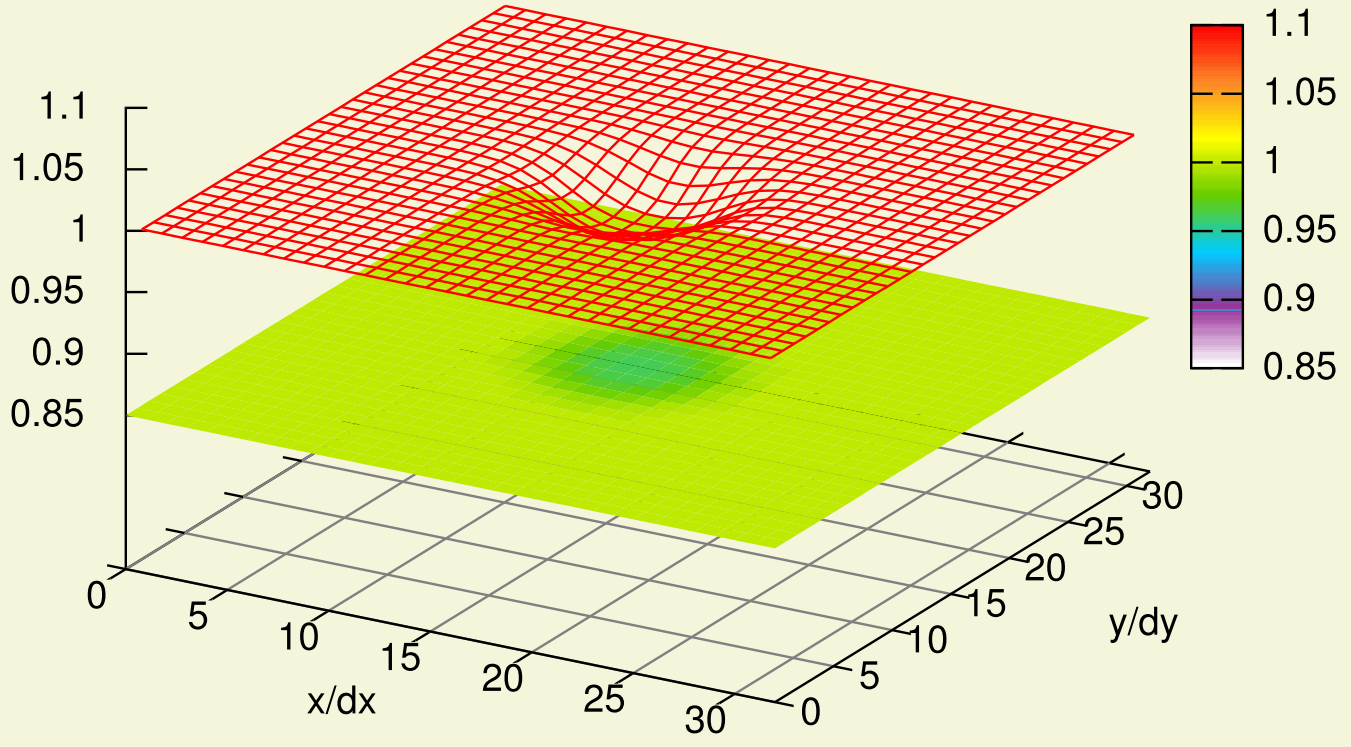


# MPyDATA project idea: shallow-water equations solver



# MPyDATA project idea: shallow-water equations solver



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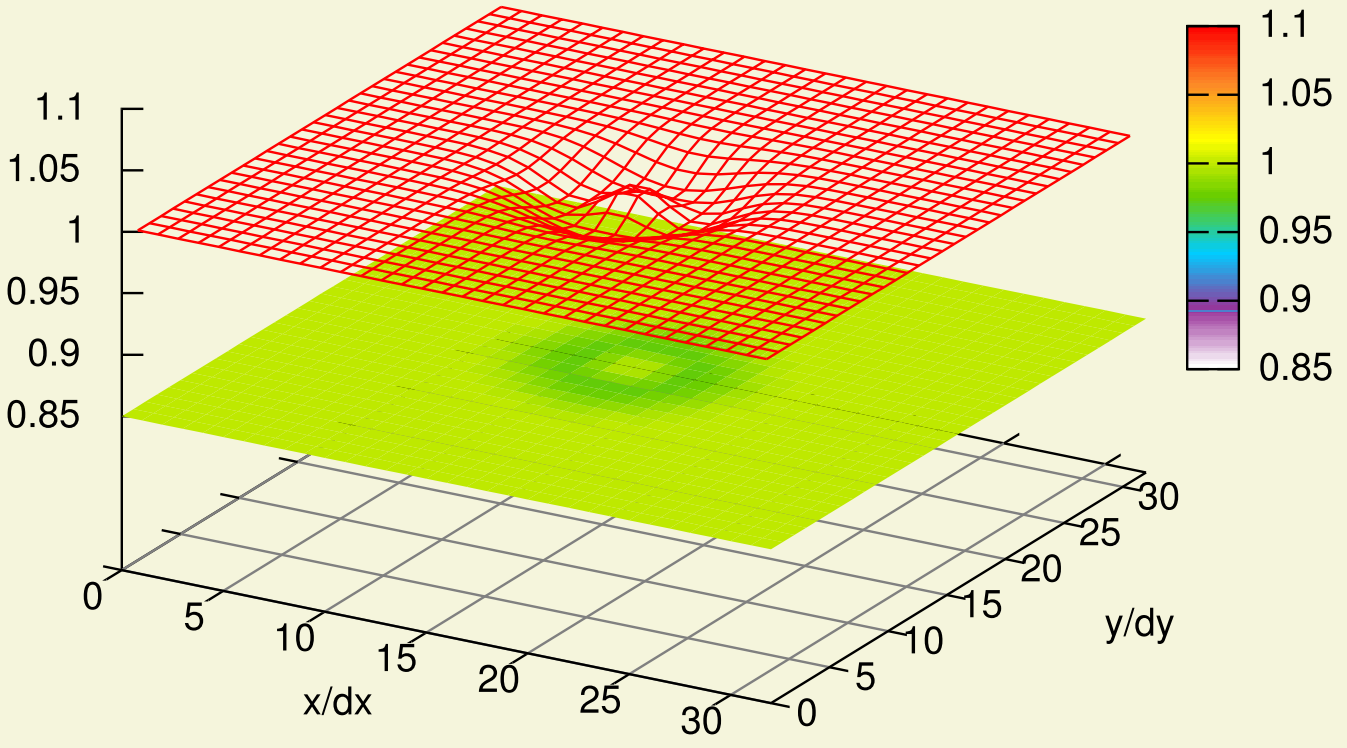

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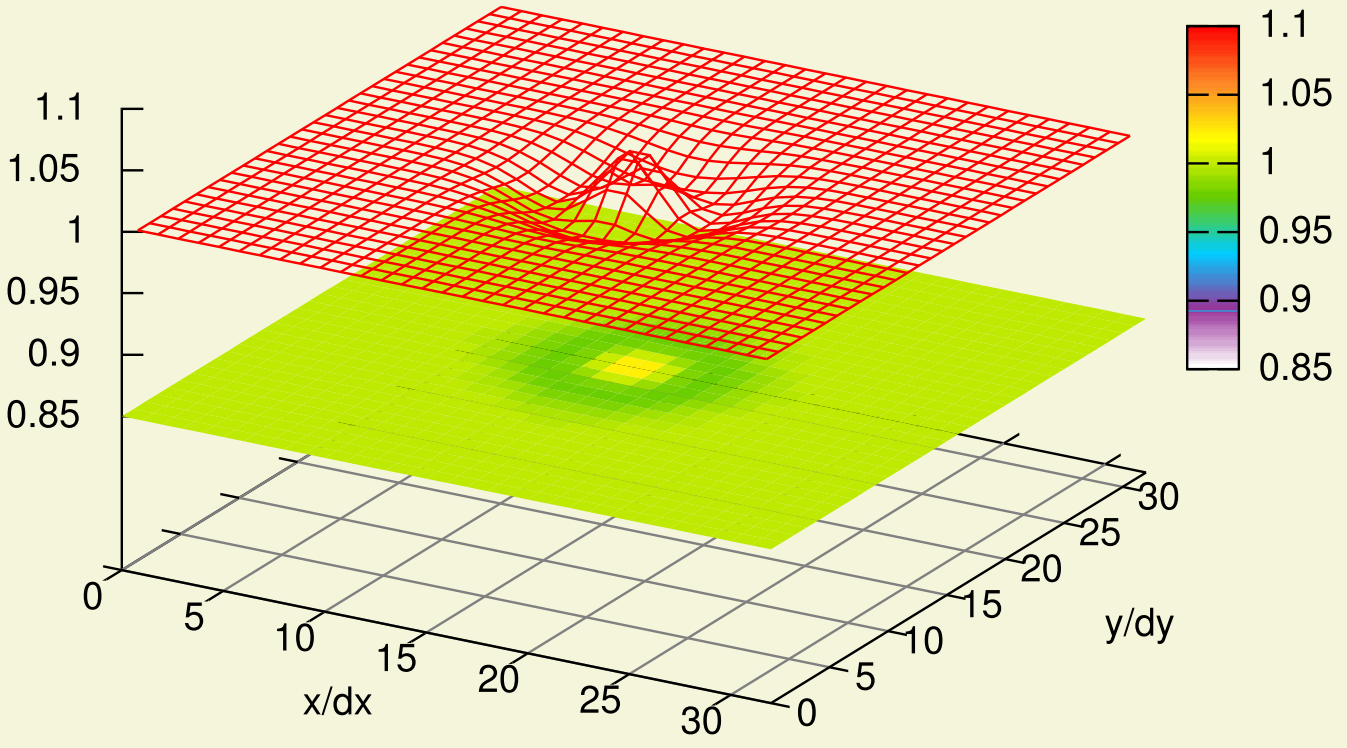

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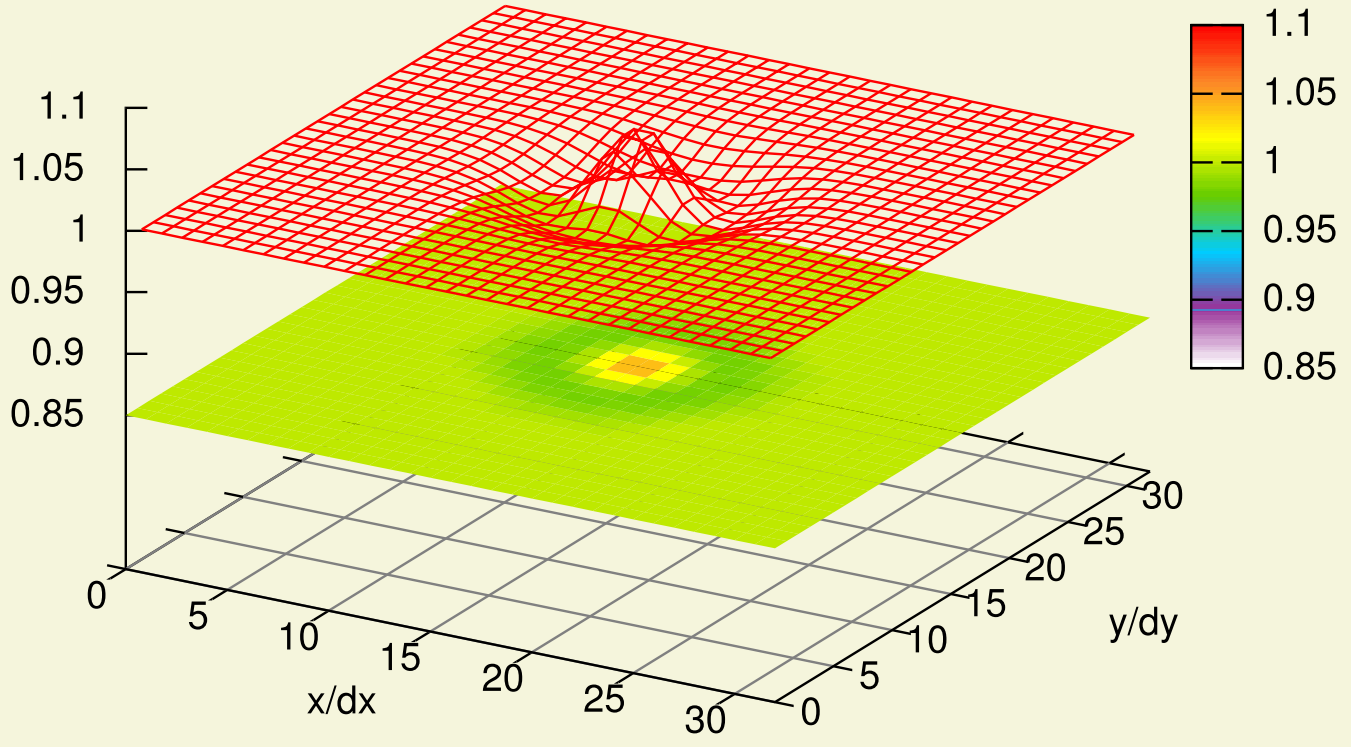

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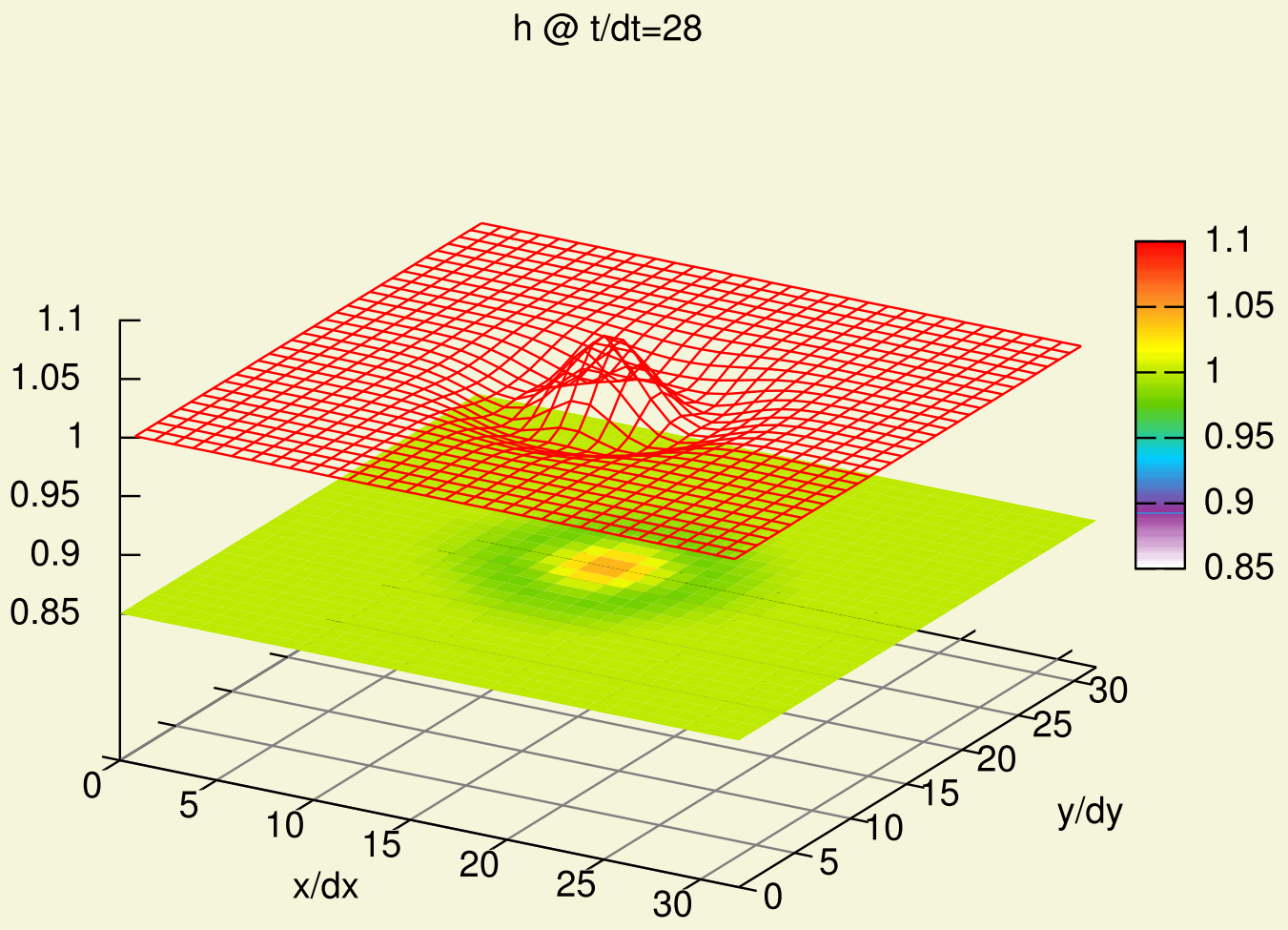

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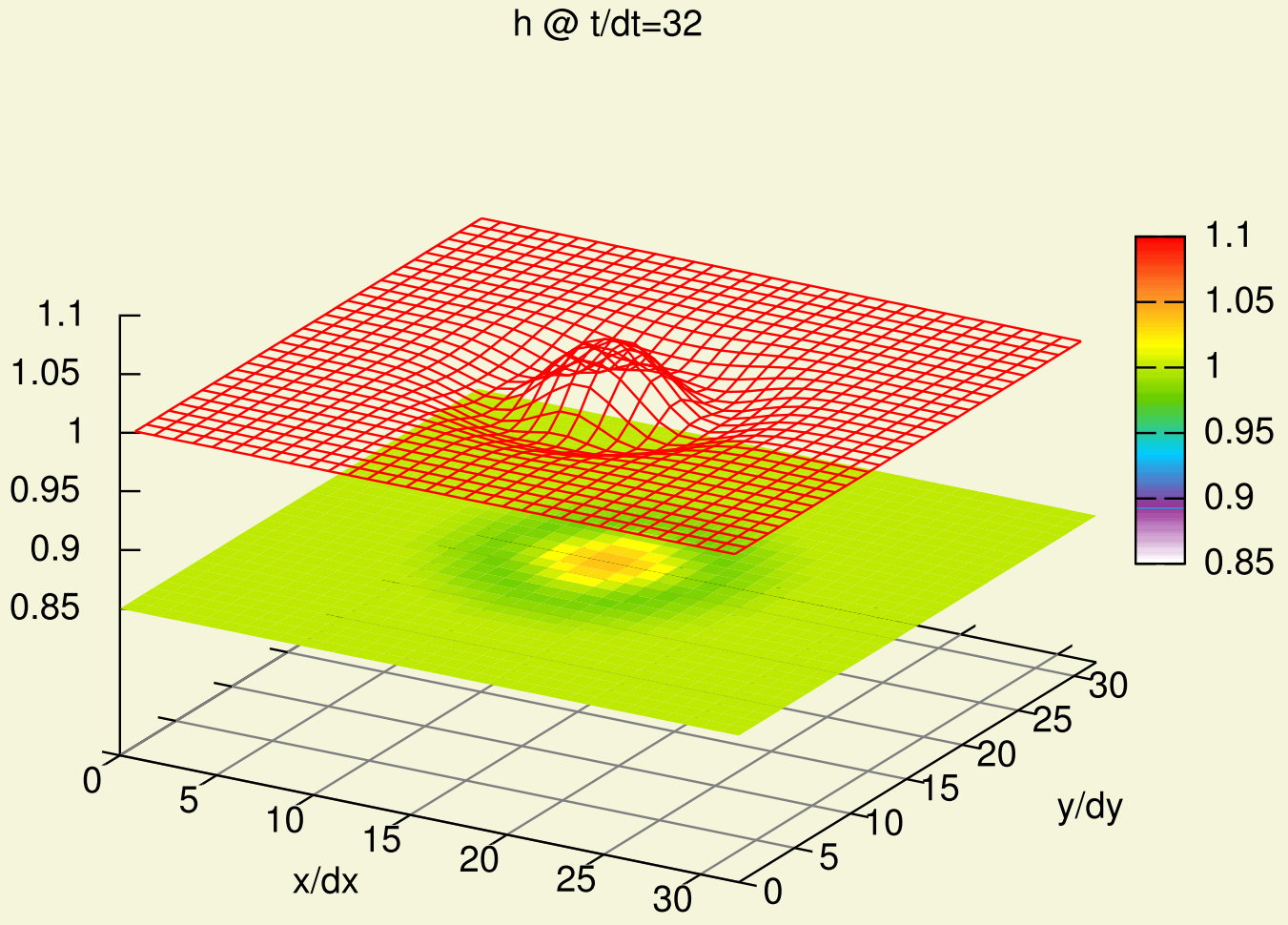

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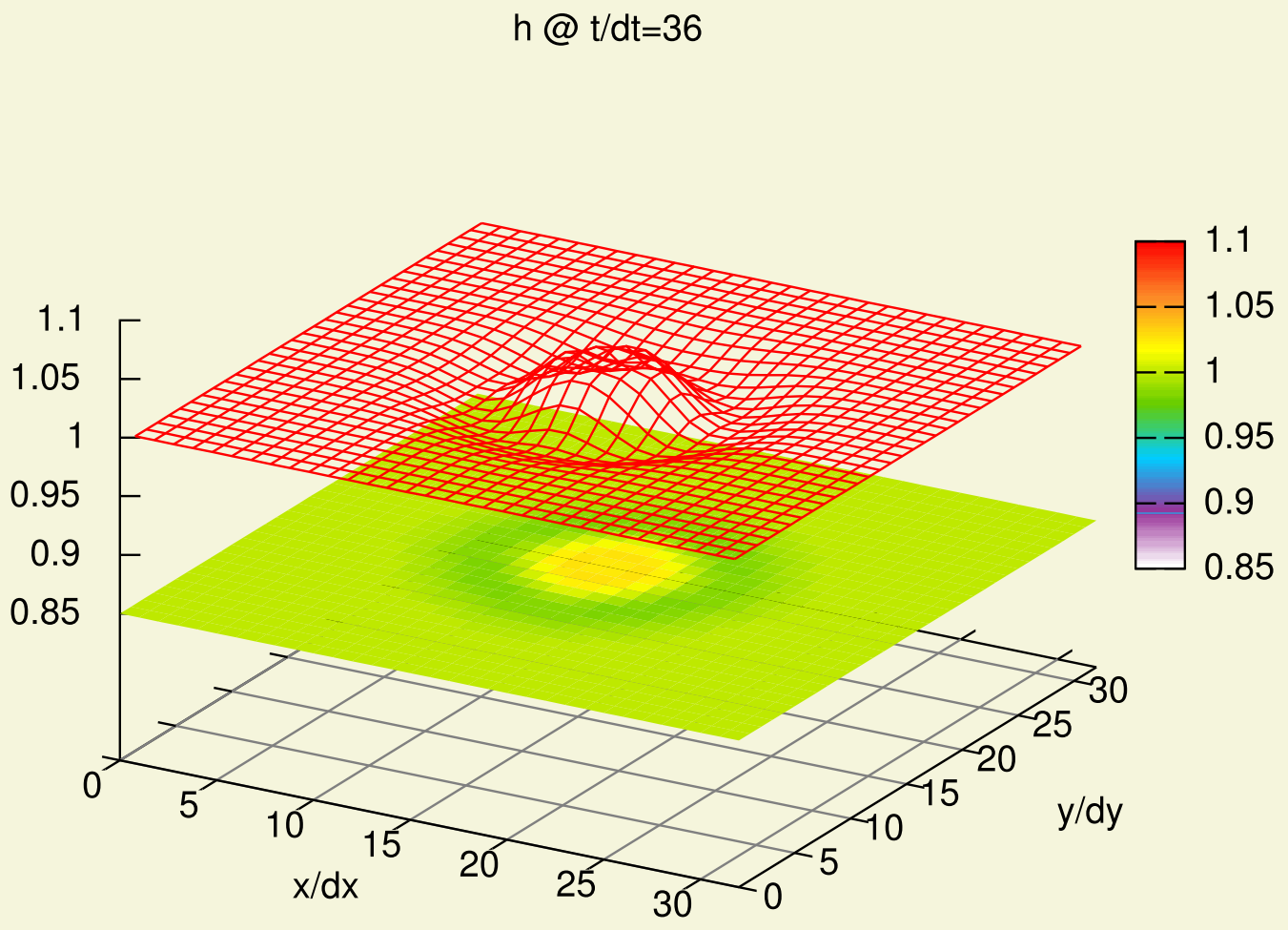

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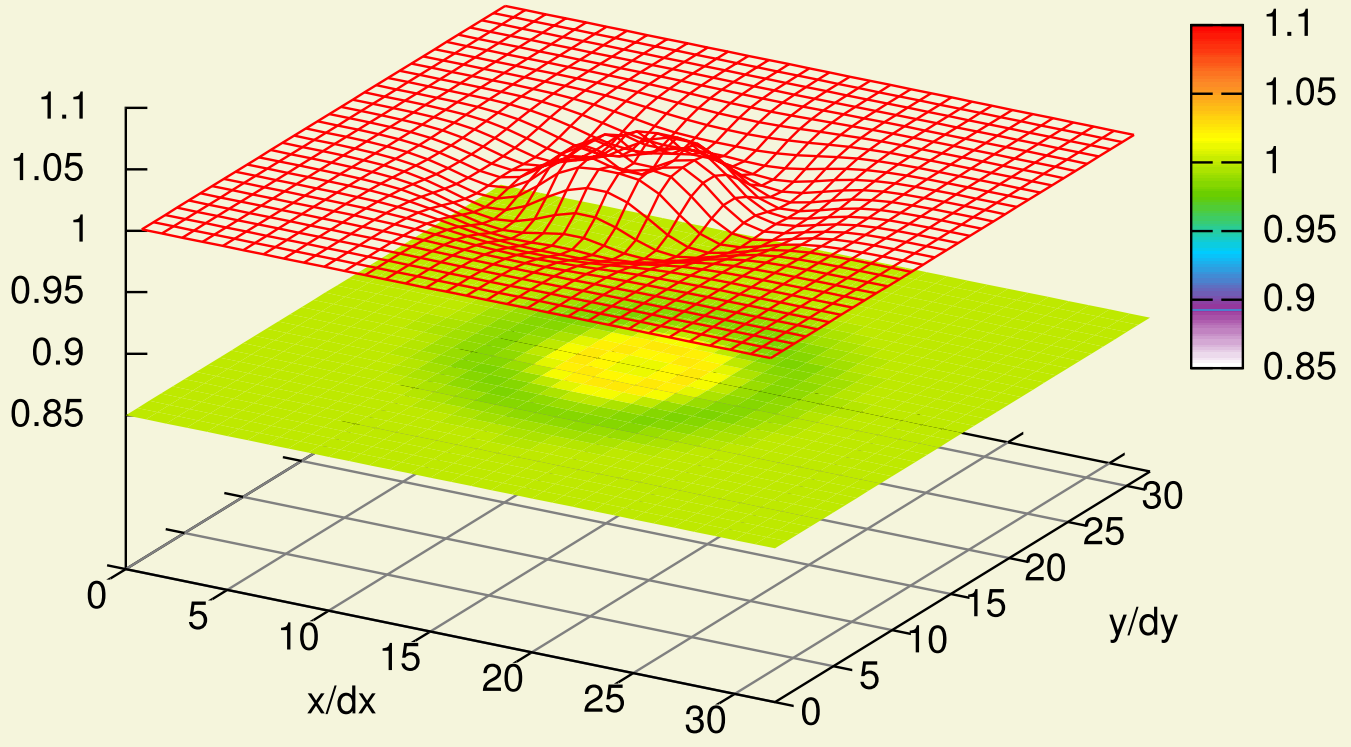

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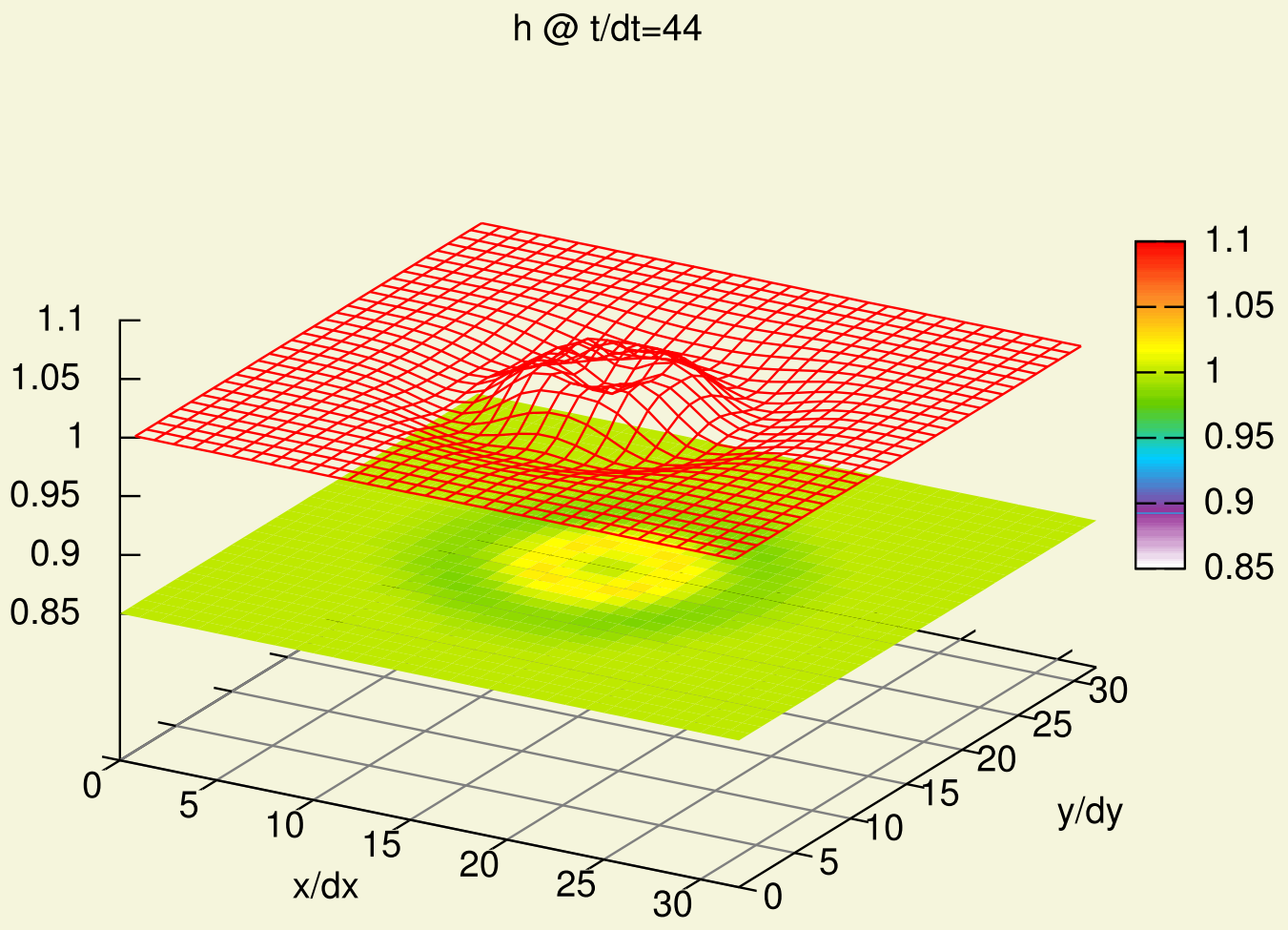

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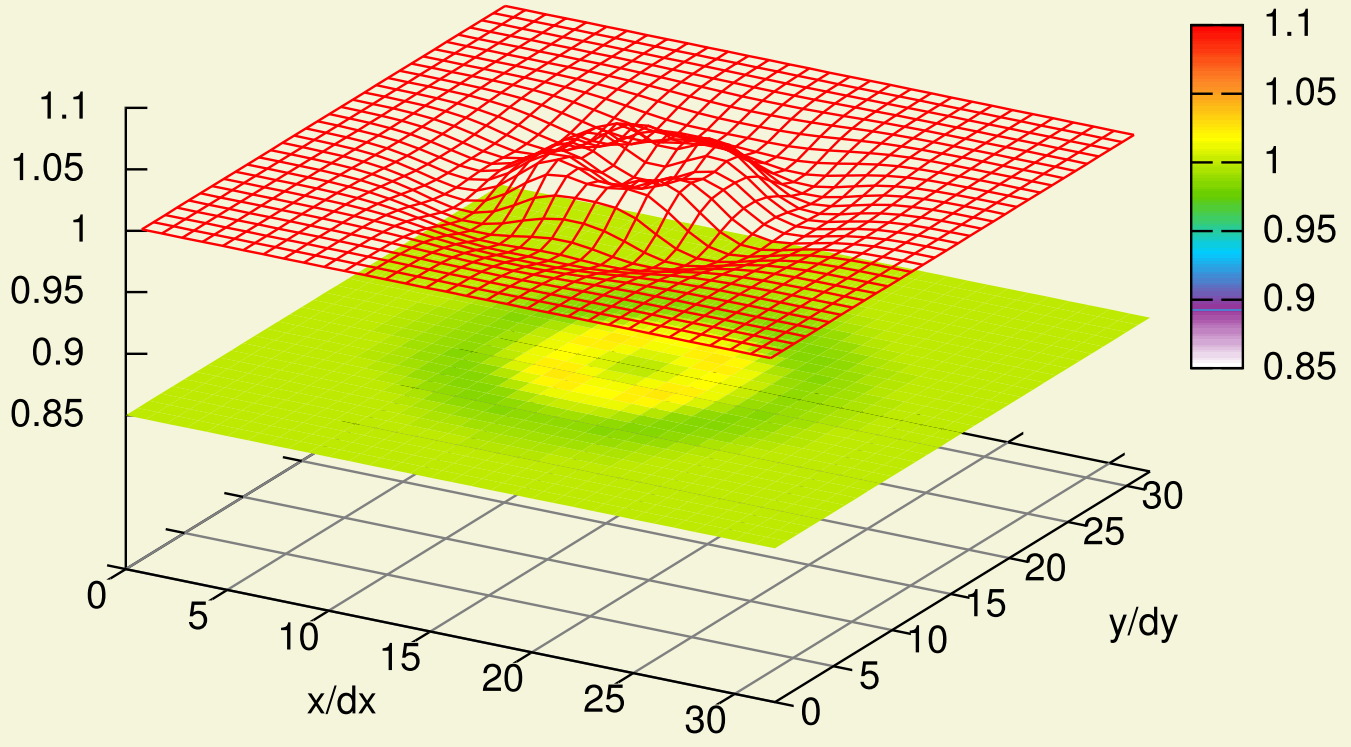
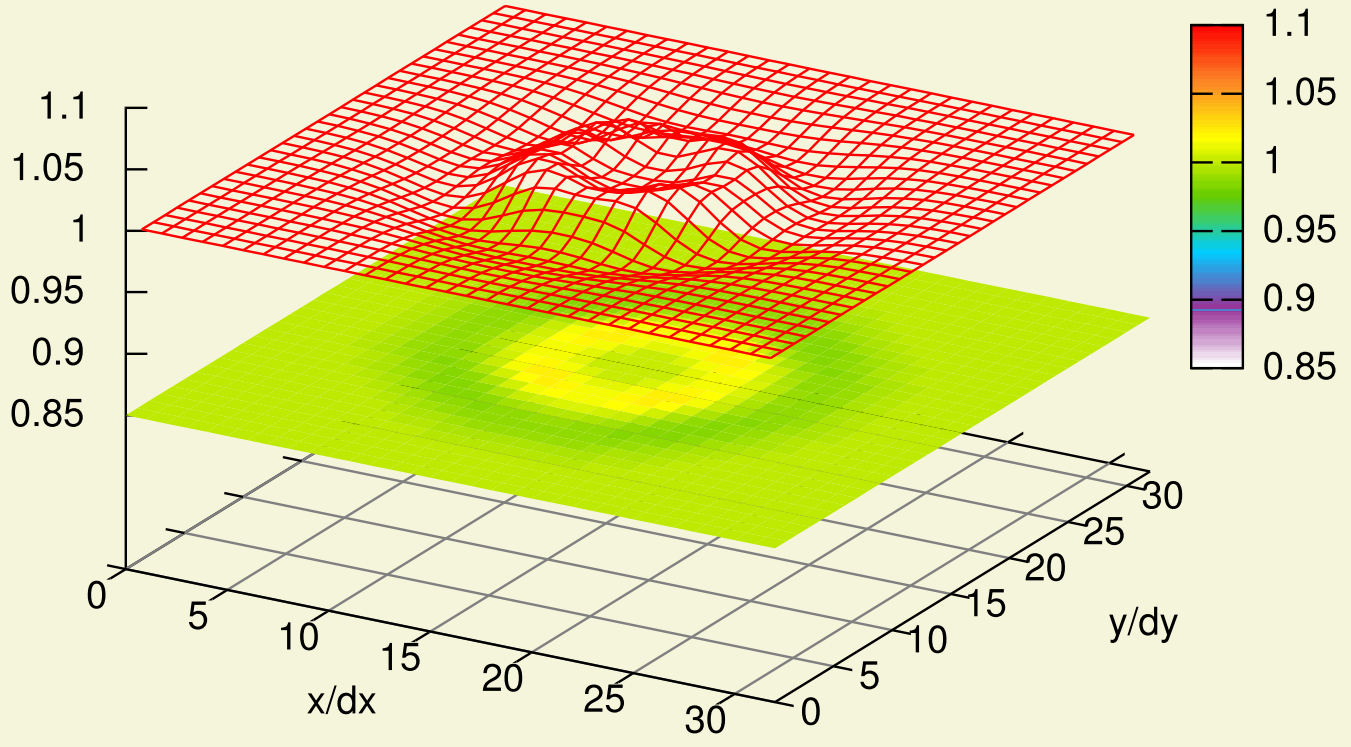
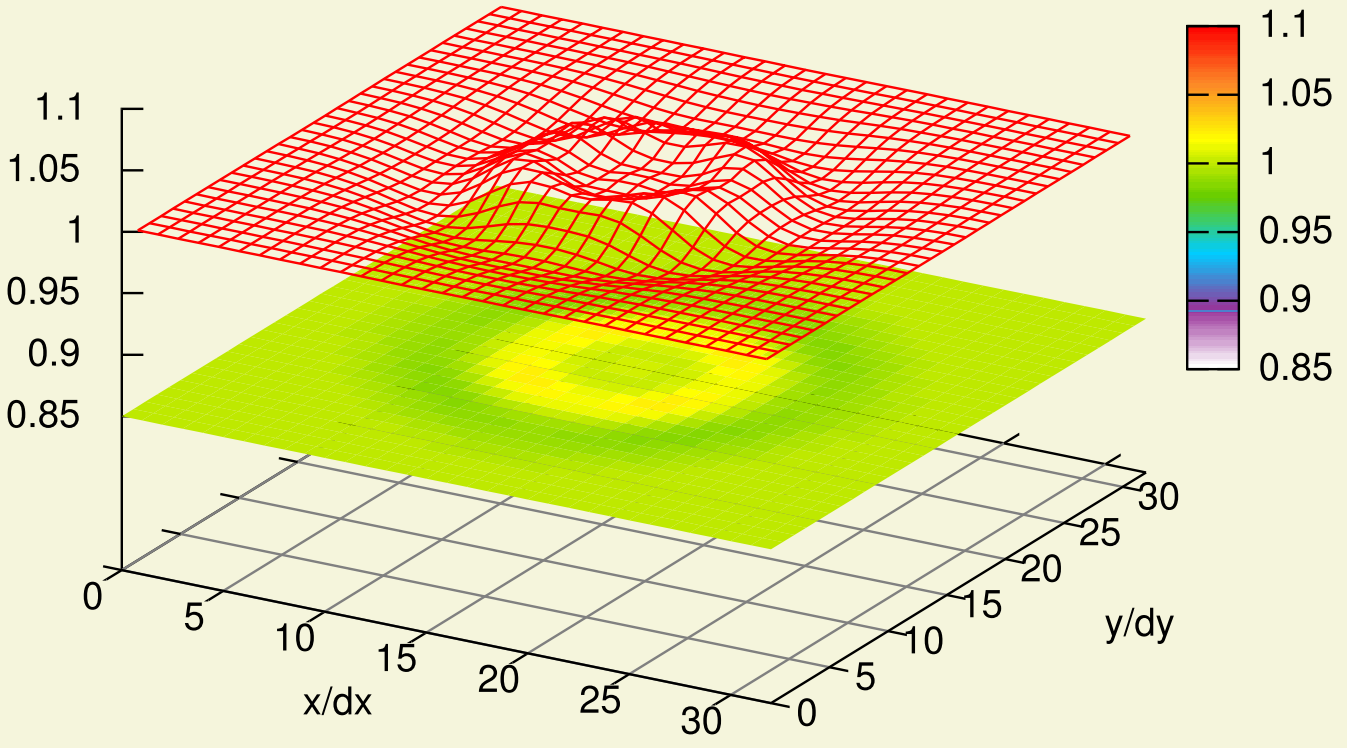


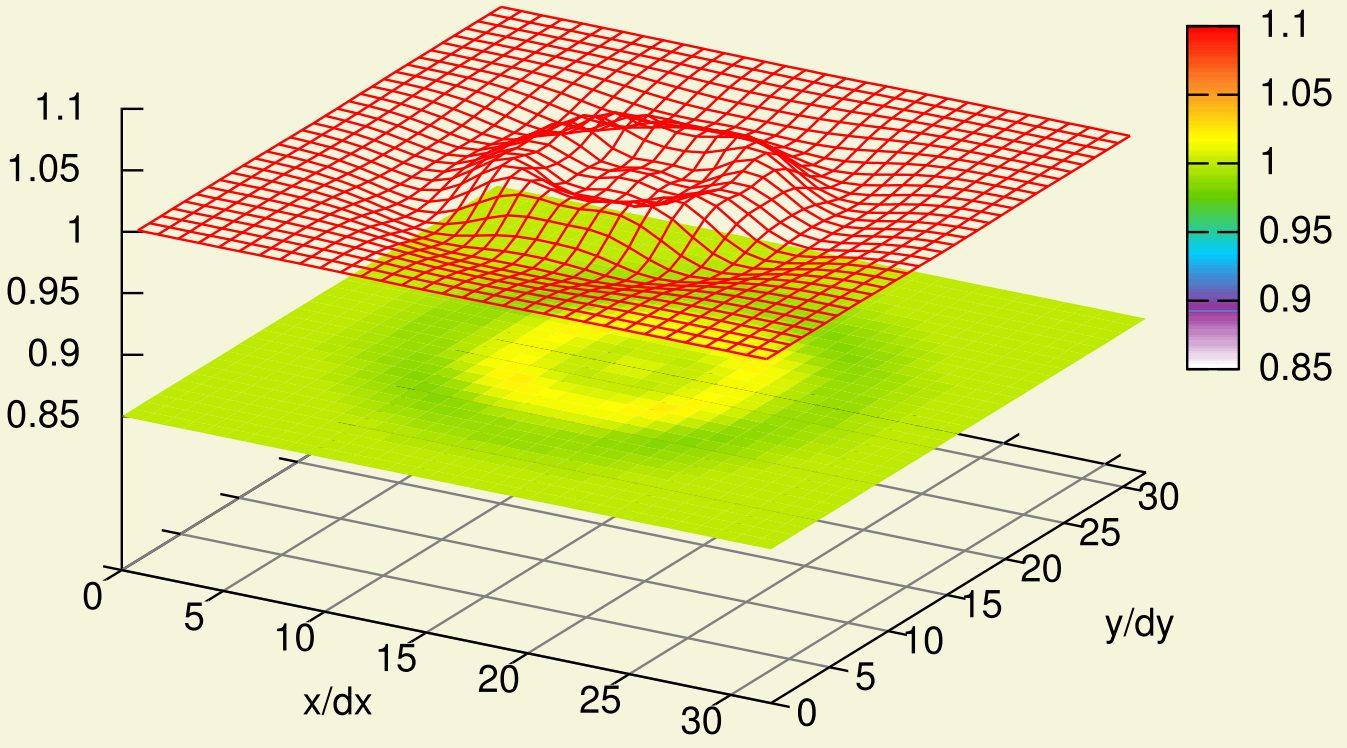
# MPyDATA project idea: shallow-water equations solver



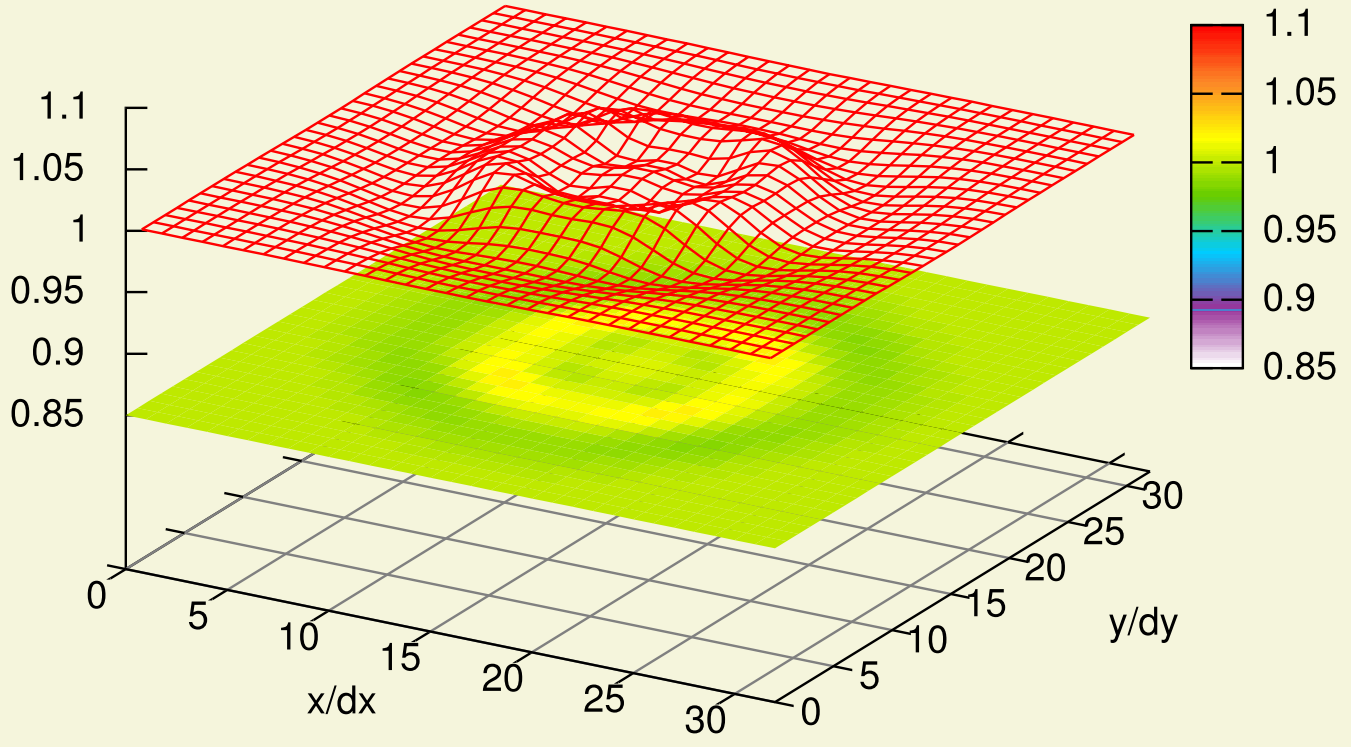
# MPyDATA project idea: shallow-water equations solver



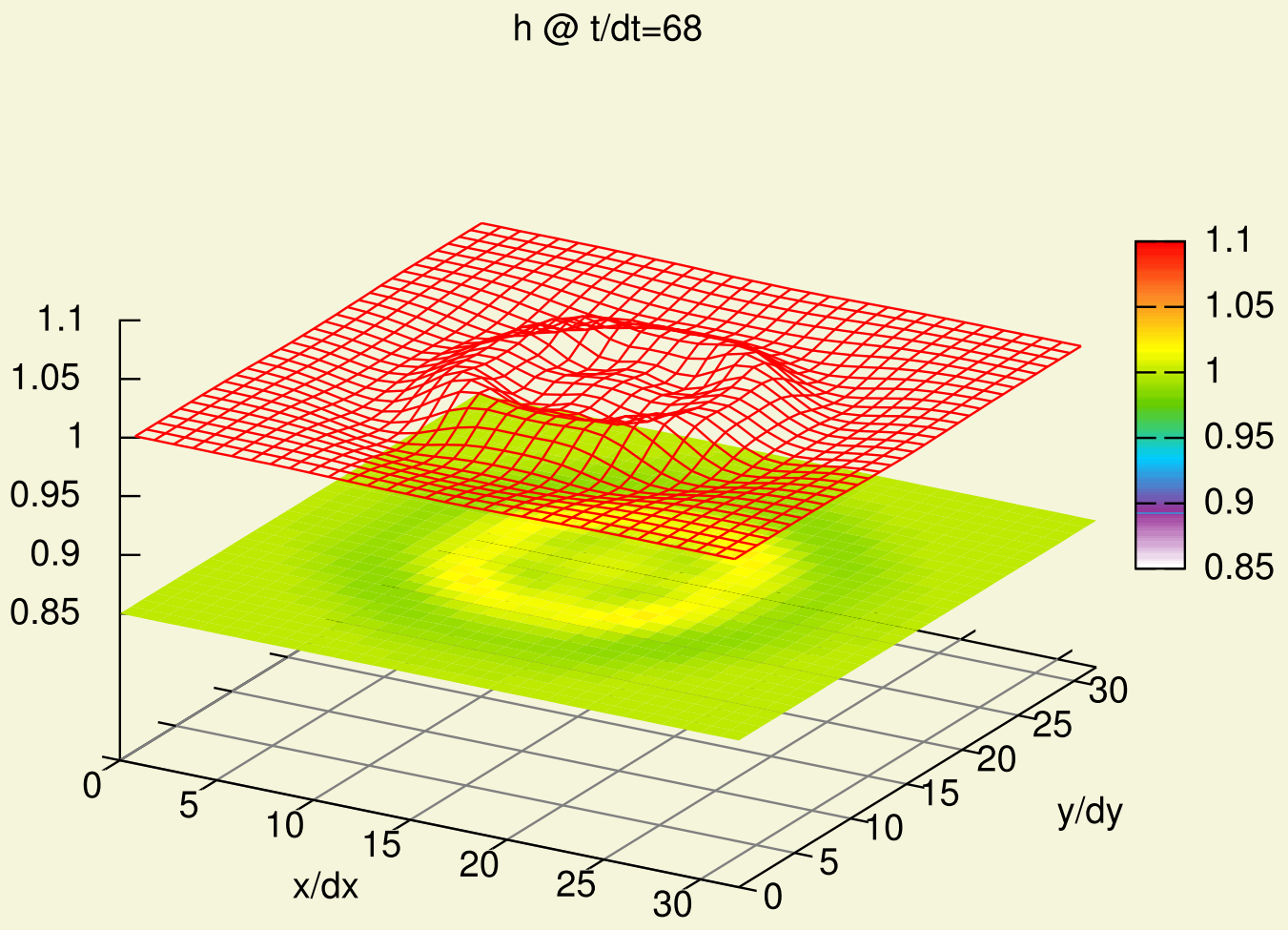
# MPyDATA project idea: shallow-water equations solver



# MPyDATA project idea: shallow-water equations solver



# MPyDATA project idea: shallow-water equations solver



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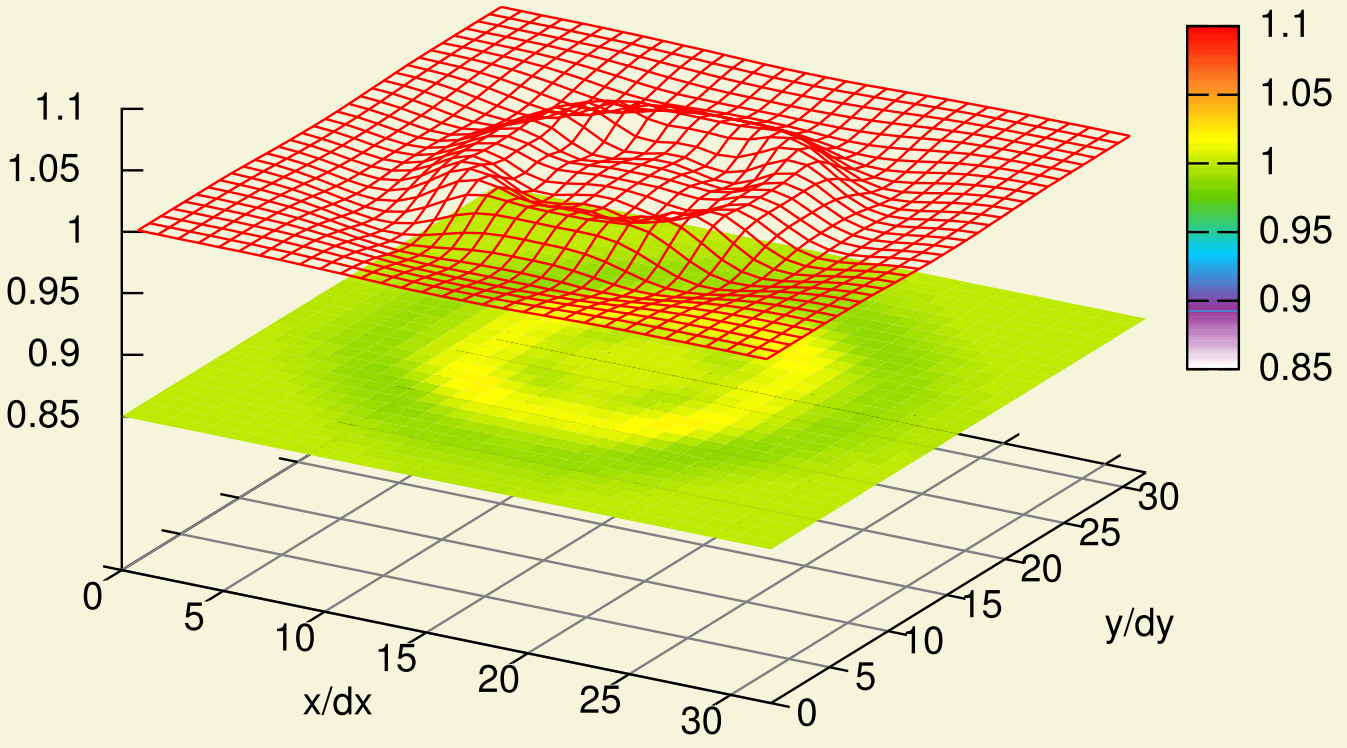
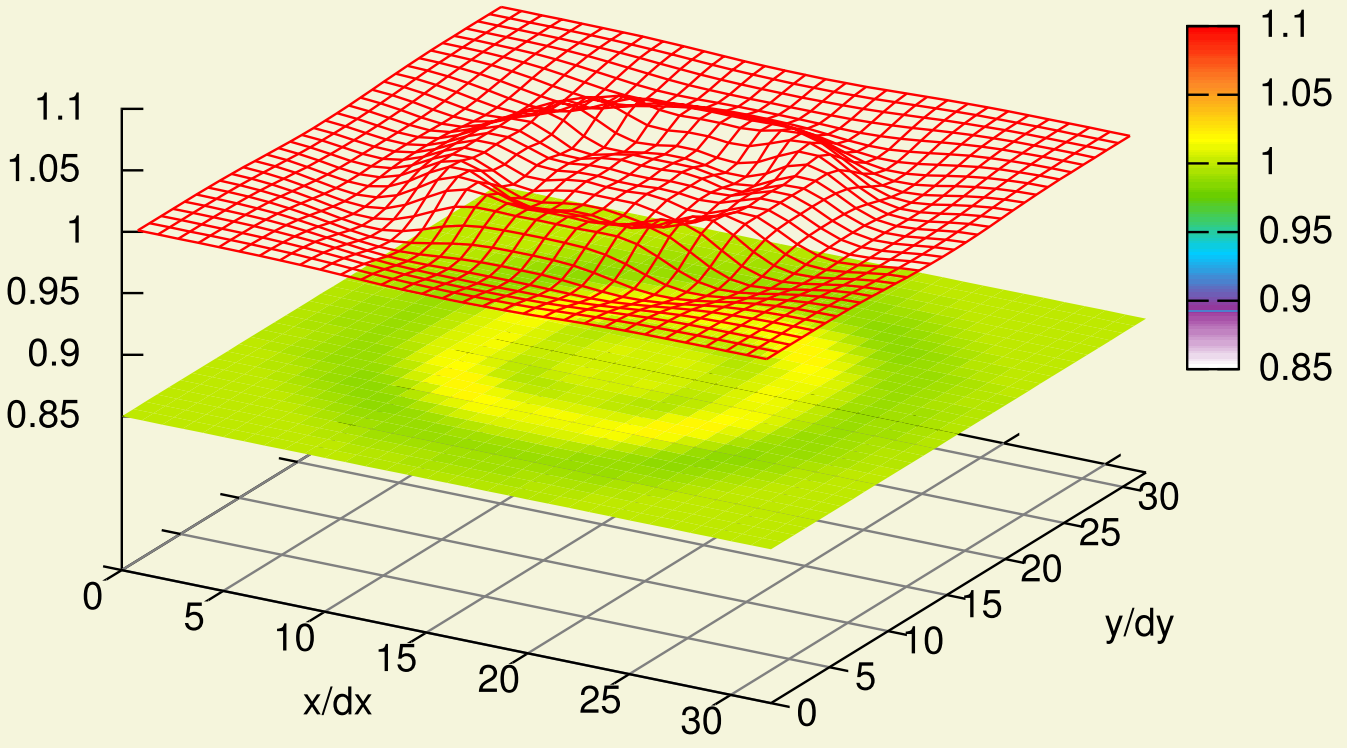


# MPyDATA project idea: shallow-water equations solver



# MPyDATA project idea: DPDC variant of MPDATA

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

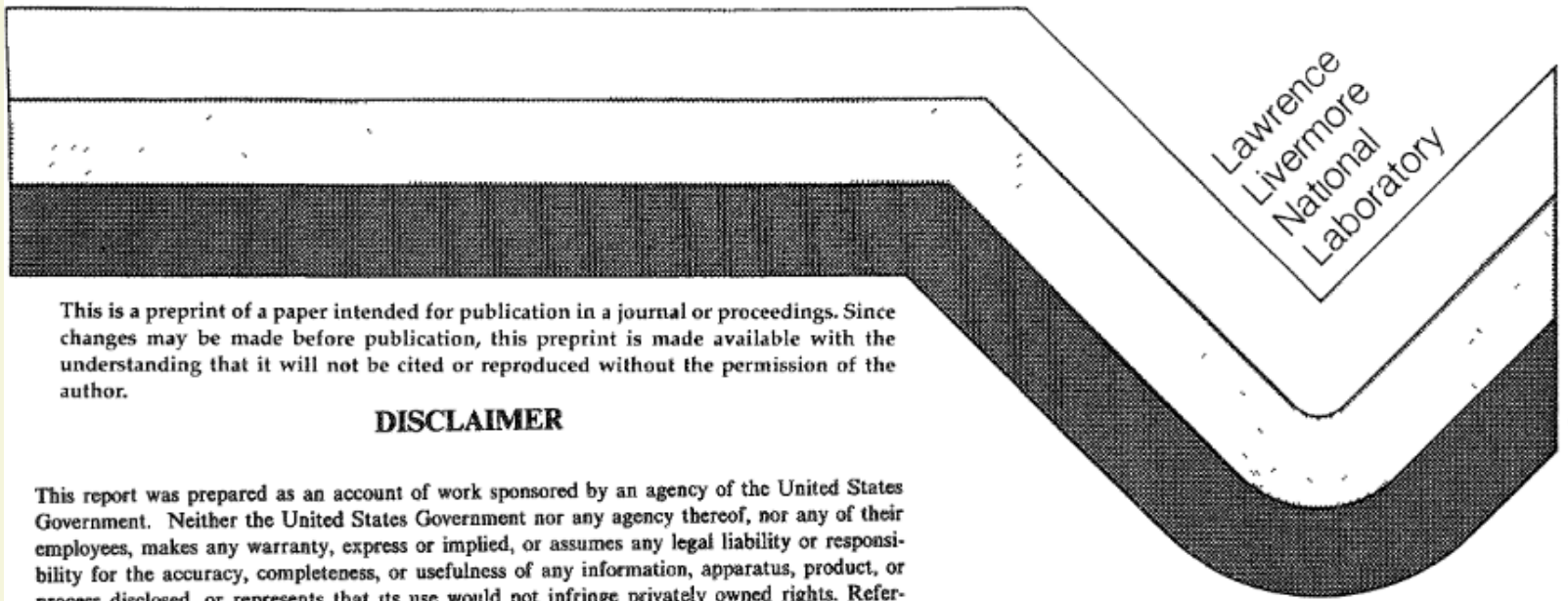
DPDC: A SECOND-ORDER MONOTONE SCHEME FOR ADVECTION

C. W. Beason

L. G. Margolin

This paper was prepared for submittal to
Fifth Nuclear Code Developers' Conference
October 11-14, 1988, Boulder, CO

September 26, 1988



# MPyDATA project idea: Kuo et al. 1999 variant

https://doi.org/10.1016/S0045-7930(98)00036-X

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## A study on the high-order Smolarkiewicz methods

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Thank you for your attention!