MoW & more

DWD

Offenbach, Germany

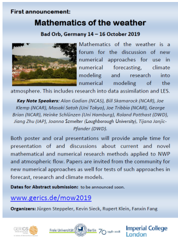
Faster Models by Sparse Grids, Improved Physical Interfaces and Larger Time-steps

J. Steppeler[1], J. Li(李锦熙)[2], F. Fang[3]

1 MoW GmbH: Spessartstr 10, Bad Orb, Germany

2 Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China 中国科学院大气物理研究所，中国北京

3 Applied Mathematics and Computing Group, Imperial College London, London, United Kingdom


First announcement:

Mathematics of the weather

Bad Orb, Germany 14 – 16 October 2019

Mathematics of the weather is a forum for the discussion of new numerical approaches for use in numerical forecasting, climate modeling and research into numerical modeling of the atmosphere. This includes research into data assimilation and LES.

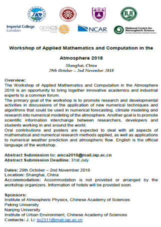
Key Note Speakers: Alan Gadian (NCAS), Bill Skamarock (NCAR), Joe Klemp (NCAR), Masaki Satoh (Uni Tokyo), Joe Tribbia (NCAR), George Brian (NCAR), Heinke Schlünzen (Uni Hamburg), Roland Potthast (DWD), Jiang Zhu (IAP), Joanna Szmelter (Loughborough University), Tijana Janjic-Pfander (DWD).

Both poster and oral presentations will provide ample time for presentation of and discussions about current and novel mathematical and numerical research methods applied to NWP and atmospheric flow. Papers are invited from the community for new numerical approaches as well for tests of such approaches in forecast, research and climate models.

Dates for Abstract submission: to be announced soon.

www.gerics.de/mow2019

Organizers: Jürgen Steppeler, Kevin Sieck, Rupert Klein, Fanxin Fang


Workshop of Applied Mathematics and Computation in the Atmosphere 2018

Shanghai, China

29th October – 2nd November 2018

Overview:

The Workshop of Applied Mathematics and Computation in the Atmosphere 2018 is an opportunity to bring together innovative academics and industrial experts to a common forum.

The primary goal of the workshop is to promote research and developmental activities in discussions of the application of new numerical techniques and algorithms that could be used in numerical forecasting, climate modeling and research into numerical modeling of the atmosphere. Another goal is to promote scientific information interchange between researchers, developers and students working in and around the world.

Oral contributions and posters are expected to deal with all aspects of mathematical and numerical research methods applied, as well as applications to numerical weather prediction and atmospheric flow. English is the official language of the workshop.

Abstract Submission to: amca2018@mail.iap.ac.cn

Abstract Submission Deadline: 31st July

Dates: 29th October – 2nd November 2018

Location: Shanghai, China

Accommodation: Accommodation is not provided or arranged by the workshop organizers. Information of hotels will be provided soon.

Sponsors:

Institute of Atmospheric Physics, Chinese Academy of Sciences

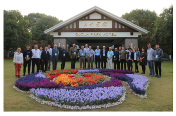
Peking University

Nanjing University

Institute of Urban Environment, Chinese Academy of Sciences

Contacts: J. Li: ljx2311@mail.iap.ac.cn

Announcements of
MOW, Bad Orb, Germany 2019
&
AMCA, Shanghai, China, 2018


Participants of AMCA, China, 2018

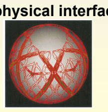

Participants of MoW, France, 2015


The Great Wall with J. LI


Dinner with Mayoress of Erquy, France

Advantages of Spectral Element Method

- Uniform approximated order higher than two under the original icosahedral grid
- o3o3 saves computer time by sparseness and better physical interface
- Mass conservation and without grid imprinting
- Polynomials fit continuously at boundaries
- Easily brought to multiprocessor systems


Grid Imprinting


Lat-Long Grid

Advantages of Polygonal Spline Interpolation

- For computational efficiency: Inhomogenuity of older methods (???) costs efficiency and reduces the allowable time step
- For parallel computing: easily brought to multiprocessor systems and scales well
- For coupling with physics: easily applied to many numerics schemes with uniform-order: FDM, SEM FEM, o3o3

onom method of L-Galerkin Method for Regular Reso

- L-Galerkin methods such as SEM sparse, o3o3 combine high apprixmation order with conservation and suitability for irregular resolution
- 1st o: the fields represented by *n*th-degree polynomials
- 2nd o: the fluxes represented by such of degree *m*
- Grid of o3o3 Method for Regular Resolution:

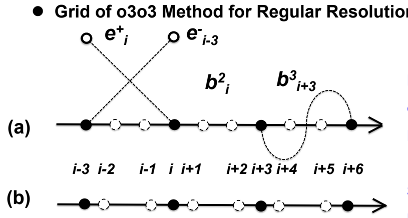


Figure1:
o3o3 computational grid:
Regular points

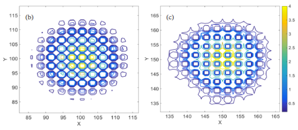
SEM grid:
Irregular Gauss-Lobatto points

Advantages of *onom* method:

- Release time-step restriction in SEM
- Improve computational efficiency by sparseness
- Accelerate physics-dynamics coupling by spline physical interface

Result 1: Time Step in Advection Experiments

- o3o3 advection with a homogeneous velocity field



- The plot gives a blowup of the fields belonging to (b) the initial time and (c) the 50th time step

Schemes	CFL condition
Standard o4	2.0
o3o3 standard	2.5
o3o3 spectral	2.2
3rd SEM	1.0

Table:
CFL condition with RK4 time-stepping

Result 2: Sparseness of Grid by *onom* method

- Sparseness factor being the relation of the points of the full grid to the points of the sparse grid is an indication of potential computer saving

Numerics	o2o3 square	o2o3 hexagon	o3o3 square	o3o3 hexagon
2-D	4:3	12:6	9:5	27:2
3-D	8:4	24:8	27:7	81:8

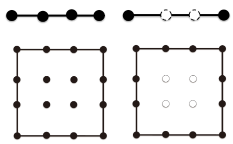


Figure: Computational grid in 2D.
(a) full grid and (b) sparse grid where unused points are indicated in white.

Result 3: Spline Physical Interface

- Why:

Traditional introduction of physical processes into numerical models:

Call the parameterization at every grid point → expensive computing + sampling errors

- How: (An example: a condensation experiment)
- Condensation of Moisture: h(x) = min [2.0, h(x)]

Calling the equation at the boundary points of intervals in o3o3

while applying cubic spline interpolation to the interior points to form sparseness of grids

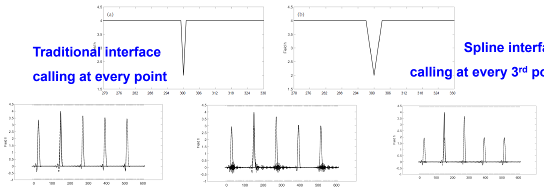


Figure: Advection (c) without condensation, (d) with traditional interface and (e) with spline interface

onom Method for Irregular Resolution

- *onom* is also of uniform order with irregular grids and easily applies to icosahedral or cubed sphere grids without using grid smoothing

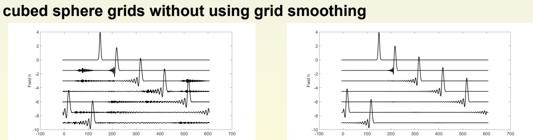
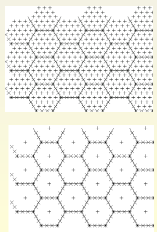


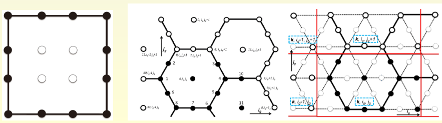
Figure: Advection in irregular resolution (left) control run by standard 4th order scheme, (right) o2o3 method

- 在两到三个月之内，o2o3 局地伽辽金方法能够为几乎任何数值模式提高4倍的计算速度。

Computer Saving from Sparseness and Physical Interface

Sparseness Factor (for saving in 3-D)	Square	Interface	Time step
o3o3 standard	7:27	7:56	7:81
o3o3c1	4:27	4:56	4:81
o3o3c1_Hexagon	6:81	3:81	1.5:81





- The secret of MoW&more is hard work day and night
- 日以继夜的不断努力是MoW获得成功的秘诀

References:

- Steppeler J., J. Li, 2022: Mathematics of the Weather. Springer, Verlag. (In Preparation)
- Steppeler J., J. Li et al., 2019: o3o3, a Variant of Spectral Elements with a Regular Collocation Grid. *Mon. Wea. Rev.* (Under Review)
- Steppeler J., J. Li, F. Fang et al., 2019: Test of a Cubic Spline Interface for Physical Processes with a 1-D Third-Order Spectral Element Model*. Tellus A.* (in print)
- Steppeler J., J. Li, F. Fang et al., 2019: Third-Order Sparse Grid Generalized Spectral Elements on Hexagonal Cells for Homogeneous Advection in a Plane. *Meteorol. Atmos. Phys.* (Under Review)
- Steppeler J., JCP 1974, 22, 295 and Steppeler and Klemp MWR 2017, 1765: spectral elements / L-Galerkin methods
- Li J., F. Fang, Steppeler et al., 2019: Performance of adaptive adaptive unstructured mesh modelling in idealized meteorological modeling with steep terrain, Atmosphere, 2018, 9 , 444.

Email: jsteppeler@t-online.de, ljx2311@mail.iap.ac.cn