High resolution modelling with ICON

DYnamics of the
Atmospheric general circulation
Modeled
On
Non-hydrostatic
Domains

Luis Kornblueh and Bjorn Stevens
Daniel Klocke, Jürgen Helmert, Florian Prill, Günther Zängl (DWD), Shian-Jiann Lin (NOAA/GFDL), Marat Khairoutdinov (SUNY), Masaki Satoh (CCSR,JAMSTEC), Falko Judt (NCAR), Nils Wedi (ECMWF)
Jan-Frederick Engels, Carsten Beyer, Panos Adamidis, Philipp Neumann, Joachim Biercamp (DKRZ)
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Project Sapphire
Modeling strategy: experiment driven

- As traditional climate modelling is a problem that is somehow not fundamentally progressing, MPIM’s atmospheric department is adding a focus towards explicitly representing physics

- High resolution is, where breakthroughs can be expected

- Design of an ICON physics package around LES and Mesoscale-γ components, which are available from previous projects and high resolution regional weather forecasting

- Start with what we have and decide on the go on further developments, when we encounter problems

- First step is the initiative DYAMOND (by Masaki Satoh, Chris Bretherton, and Bjorn Stevens)
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What is DYAMOND?
Project background

- Create a framework for intercomparison of global high resolution atmospheric circulation models
- Started with four models (but open for more, currently six) contributing results
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Simulations will be performed for a 40 day period with prescribed varying SST and sea-ice and support

1. identifying similarities and differences that emerge at storm resolving scales (1km to 5km) as compared to traditional representations of the atmospheric circulation, and

2. the development of frameworks and protocols for subsequent, and scientifically more ambitious, projects
The first datasets are available at DKRZ:

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All data are available on the DKRZ production machine's file system.
Technical challenges
Input data
Global data sets with sufficient resolution are required. Keep in mind that this resolutions may require changes in Land surface models to represent eg. sealed surfaces or irrigation in the model!

Output
Efficient and highly compressed data formats are necessary for simulations of this kind.

Computing aspects
Do not care too much or you will never start/try . . . 
Observations: network congestion is depending on job mix and can create severe slow-downs, substantial faster HPC production systems are not on the horizon.
Post-processing challenges

This is a major educational problem!

Some aspects one needs to know and understand are:

- bandwidth/per node and total system I/O bandwidth,
- fast and appropriate data remapping,
- minimization of data copies and reduction of data movement,
- management of clever data reduction workflows, and
- use of capable tools:
  - cdo, python matplotlib, paraview, cylc, python dask, …
First DYAMOND results
Please, buy a 4k (8k or 16k) beamer - the available equipment does not fit well with high resolution modeling!
OLR intercomparison

OLR of four different models in Wm$^{-2}$ compare to observations

Courtesy by Daniel Klocke
Hourly mean precipitation intercomparison

Satellite/CMORPH (8km)

Satellite/PERSIANN-CCS (4km)

ICON (5km)

FV3 (3.25km)

Courtesy by Christopher Moseley
Comparison of hourly precipitation PDFs for 6 regions

Courtesy by Christopher Moseley
Comparison of zonal mean precipitation: multi-model

Courtesy by Daniel Klocke and Bjorn Stevens
Comparison of zonal mean precipitation: different physics

Courtesy by Daniel Klocke and Bjorn Stevens
Visibility of differences between 5km and 2.5km resolution?

Total column integrated cloud water (diagnostic) [kg m$^{-2}$]

Can you see the differences shown in the zonal mean in the global 2d view?

Courtesy by Bjorn Stevens
Visualization on original grid: ICON, 2.5km

Courtesy by Monika Esch
Visualization on original grid

Debugging on grid level is possible!
Highres LIC, ICON, 5km
Outlook
Next steps

- Input data in sufficient resolution
- Data analysis and visualization
- NWP validation
- Comparison with satellite observation data in full spatial and high temporal resolution
- Repeat/initiate educational and exploratory hackatons for post-processing
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Coupled 5km resolution Tropical Cyclone path

Courtesy by Marco Giorgetta