High resolution modelling with ICON

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

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für Meteorologie

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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Project design

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

Current status

The first datasets are available at DKRZ:

Model	grid [km]	run	data	size	comments
ICON	2.5	✓	✓	25TB	
FV3	3.25	✓	✓	64TB	shallow conv.
NICAM	3.5	✓	ongoing	N/A	
SAM	4	✓	✓	38TB	
ICON	5	✓	✓	6TB	
ICON	5	✓	✓	8TB	fixed clim. SST/sea-ice
ICON	5	✓	✓	28TB	fixed clim. SST/sea-ice, conv.
NICAM	7	✓	✓	6TB	subset of defined output
MPAS	3.75	ongoing		N/A	
MPAS	7.5	ongoing		N/A	
ECMWF	4	ongoing		N/A	

All data are available on the DKRZ production machine's file system.

Technical challenges

Bottlenecks, education, and treasure-hunt

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.

Bottlenecks, Education, and Treasure-hunt

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

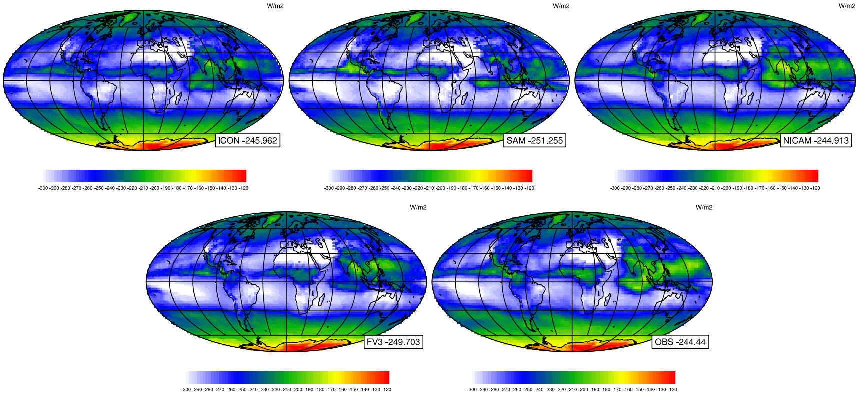
Talk continues after ad

High resolution modeling advertisement

Please, buy a 4k (8k or 16k) beamer - the available equipment does not fit well with high resolution modeling!

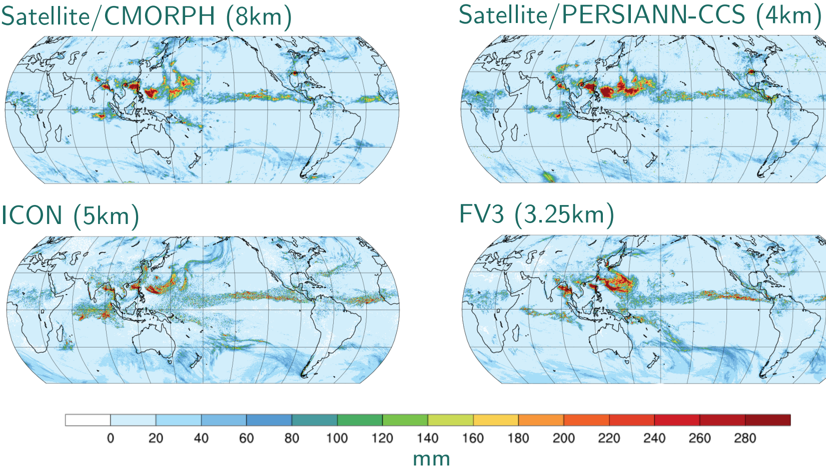
OLR intercomparison

OLR of four different models in Wm−2 compare to observations



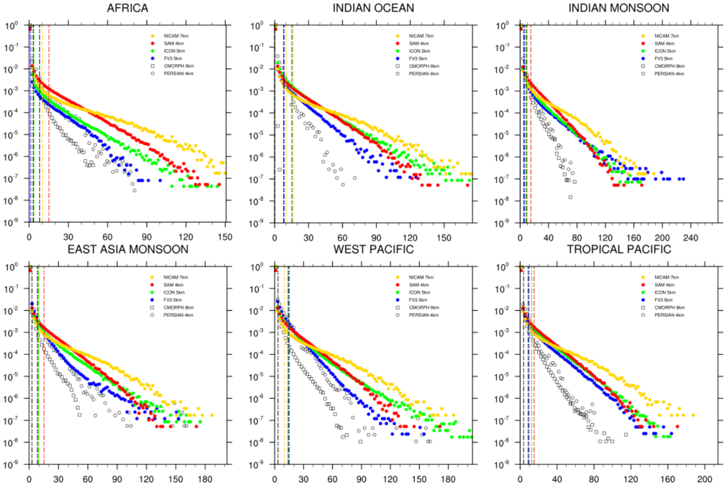
Courtesy by Daniel Klocke

Hourly mean precipitation intercomparison



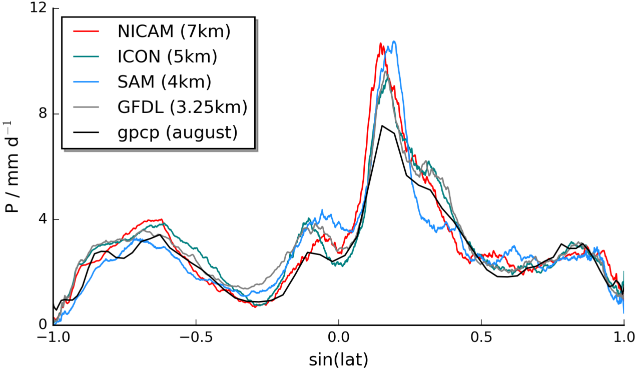
Courtesy by Christopher Moseley

Comparison of hourly precipitation PDFs for 6 regions



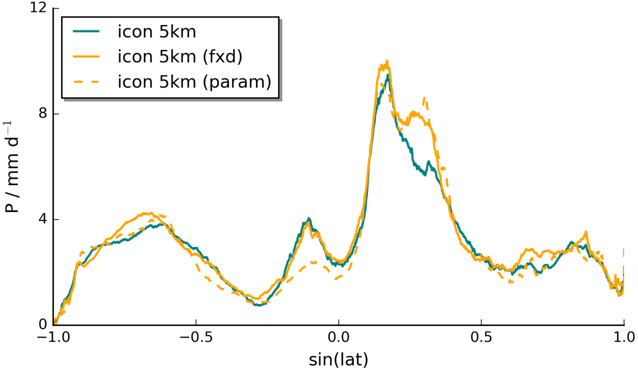
Courtesy by Christopher Moseley

Comparison of zonal mean precipitation: multi-model



Courtesy by Daniel Klocke and Bjorn Stevens

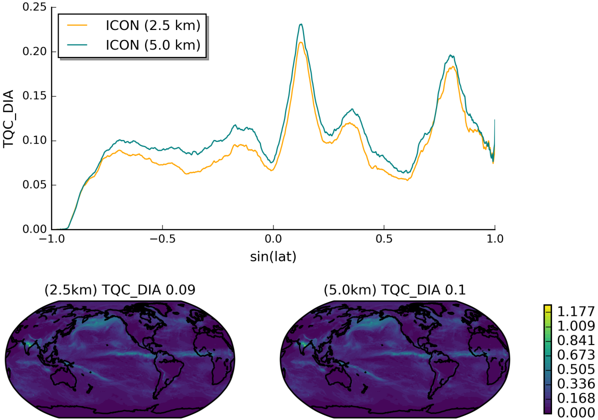
Comparison of zonal mean precipitation: different physics



Courtesy by Daniel Klocke and Bjorn Stevens

Visibility of differences between 5km and 2.5km resolution?

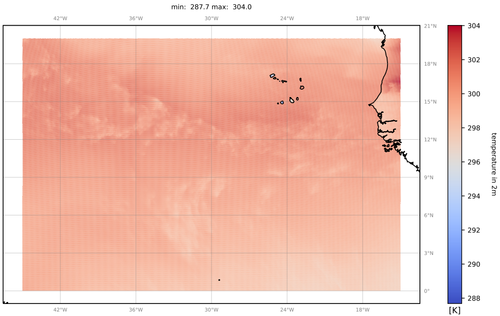
Total column integrated cloud water (diagnostic) [kg m^{-}2]



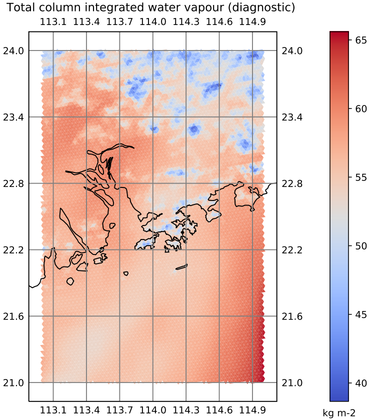
Courtesy by Bjorn Stevens

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

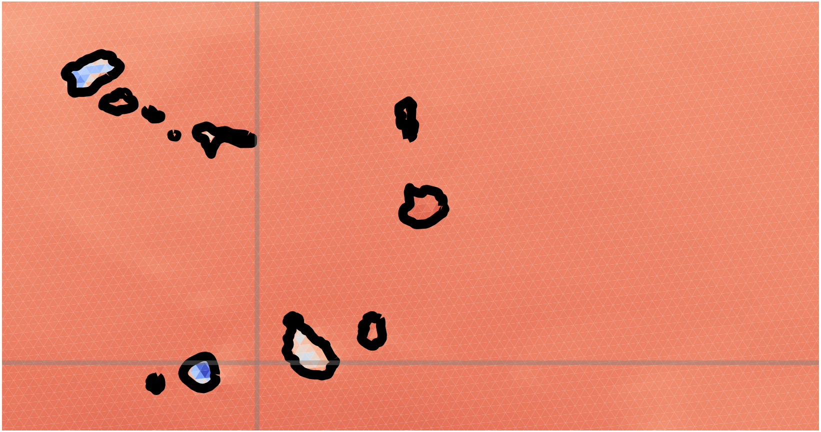
Visualization on original grid: ICON, 2.5km



Courtesy by Monika Esch



Visualization on original grid



Debugging on grid level is possible!

Line Integral Convolution: explore new ways of visualization

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