Looking into Clouds
Our approach for the visualization and analysis of large ICON data sets

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Time: 27.0 Hours

R2B10 ~84 Million Cells per Level - 2.5km per Cell

Integrated Cloud Water (kg/m²)

0.00 0.01 0.10 1.00

Integrated Cloud Ice (kg/m²)

0.00 0.01 0.02 0.05 0.10 0.20 0.50 1.00 3.00
Looking into Clouds ...

*See, understand, learn, communicate ...*

- Confirmatory visualization
- Interactive visualization
- Creating animations & stills for communication
- 21 GPU nodes with dual 12/18 core Haswell/Broadwell CPUs
- 256/512/1024 GB main memory
- 4 GPUs per node (2 dual Kepler/Maxwell)
- VirtualGL/TurboVNC (Remote3D Rendering)
- CDO, ParaView, NCL, VAPOR, (Avizo Green), (SimVis), Matlab, grads...
Visualization of LARGE Data Sets

in-situ Visualization
(ParaView/Catalyst)

Simulation
Adaptor
ParaView/Catalyst
Results

in-situ Compression
(Vapor)

Simulation
Decomposition
Vapor
Results

Niklas Röber (DKRZ)
ICON and HD(CP)$^2$

- ICOsahedral Non-hydrostatic grid
- Atmosphere and Ocean
- Ocean – 10km resolution
  (3.8 million cells / 64 levels)
- HD(CP)$^2$ – 120m resolution
  (22.5 million cells / 150 levels)
ICON Grid Layout

Cells | Points | Edges
HD(CP)² Phase II: Hurricane “Gaston”

HD(CP)² Domains
Hurricane “Gaston”

ICON HErZ - NARVAL-II - HD(CP)² Simulations: 20160817 +10.0h

Simulation by Daniel Klocke (DWD) and visualization by Matthias Brueck (MPI-M)
The first part of this contest is based on general visualization tasks to get started and to develop a first understanding - a feel - for the data and the atmospheric processes it describes. Following that are three groups with additional and equally challenging problems. A complete submission would provide answers for the general tasks and for at least one group (A, B or C) of your choice. You may complete as many - or as few - of the visualization tasks as you want, but the more tasks are completed, the greater your chances are of winning this competition. Yet most importantly, have fun with this contest and enjoy exploring our data, while learning new things about clouds and precipitation processes.

The tasks are roughly arranged with an ascending level of difficulty. Some visualization tasks can be completed out-of-the-box using standard visualization software, others require a little more programming and data mining skills. Several references that might be useful are provided at the bottom of this page.

Figure 1. Clouds over southern Europe. (Source: DLR)

**General Tasks**

**Visualization of rain bands**

Visualize the three scalar cloud quantities CLW, CLI and QR and create a short animation showing the progress and the development of various rain bands along with cloud ice and precipitation. Annotate your visualization with topographic information.
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ICON Reader for ParaView

- Reads ICON netCDF data
- 2D/3D cell/point data on all levels (depth, depth_2, ...)
- Spherical, Lon/Lat and Cassini projection
- 3D reconstruction with correct layer thickness
  - Even in 3D with a terrain following model
- Bathymetry masking (wet_c) and earth topography
- Visualization of performance data
NVIDIA IndeX and INTEL OSPRay

- Two different approaches for (volume) rendering of large data
  - Using GPUs and texture based volume rendering
  - Using CPUs and software based ray-tracing
- We (of course) collaborate with both 😊
In-situ Visualization with ParaView

- In-situ (co)processing/visualization using Paraview/Catalyst
- Adaptor required that connects ICON (model) and Catalyst
- Two possibilities for co-processing:
  - Batch-visualization using pre-defined Python scripts
  - Live visualization within a client/server setting
Cinema Science and ParaView

- Image based in-situ visualization of standard variables using predefined views
- Interactive display both online and offline
- Requires ParaView ICON Adaptor
Visualization of LARGE Data Sets

**in-situ Visualization**
(ParaView/Catalyst)

- Simulation
  - Adaptor
  - ParaView/Catalyst

**in-situ Compression**
(Vapor)

- Simulation
  - Decomposition
  - Vapor

Results
**ICON Reader for Vapor**

- Vapor developed at NCAR (open source)
- Supports wavelet compression and LoD rendering for very large (rectilinear) data sets
- Extension for ICON/MPAS data
  - Based on ParaView plugin
  - Very fast on-the-fly resampling of ICON data to regular grid
  - Adjustable under/oversampling
VAPOR and Compression

- Wavelet-based intelligent data storage
- Progressive data access with multiresolution rendering
- Coefficients are sorted and prioritized

Original
275 GBs / 3D field

800:1
0.34 GBs / 3D field

(c) John Clyne
Decompose sphere into 10 diamonds

- Diamond vertices at original base icosahedron vertices
- Each diamond has regular topology

Map centroids of quad, triangles, and hexagons cells into a hexagonal mesh with explicit connectivity

Apply discrete wavelet transform to each regular hexagonal mesh (diamond)

\[ f(x) = \sum_k F[k] \varphi(x - Lk) \]

Multiresolution with Icosahedral Maps

Closing Thoughts

- Looking at ways to work and **interact** with LARGE data
  - In-situ visualization with ParaView/Catalyst
  - In-situ compression and progressive data visualization using wavelets

- *Lossy* compression has always been applied in simulation
  (Float vs. double, variables, temporal/spatial resolution)

- **Next Steps**
  - VAPOR release with ICON/MPAS support (irregular grid)
  - Wavelet evaluation paper (in continuation of [2])
  - In-situ adaptor for Catalyst / Cinema
  - In-situ compression module
  - Machine Learning?