Looking into Clouds

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

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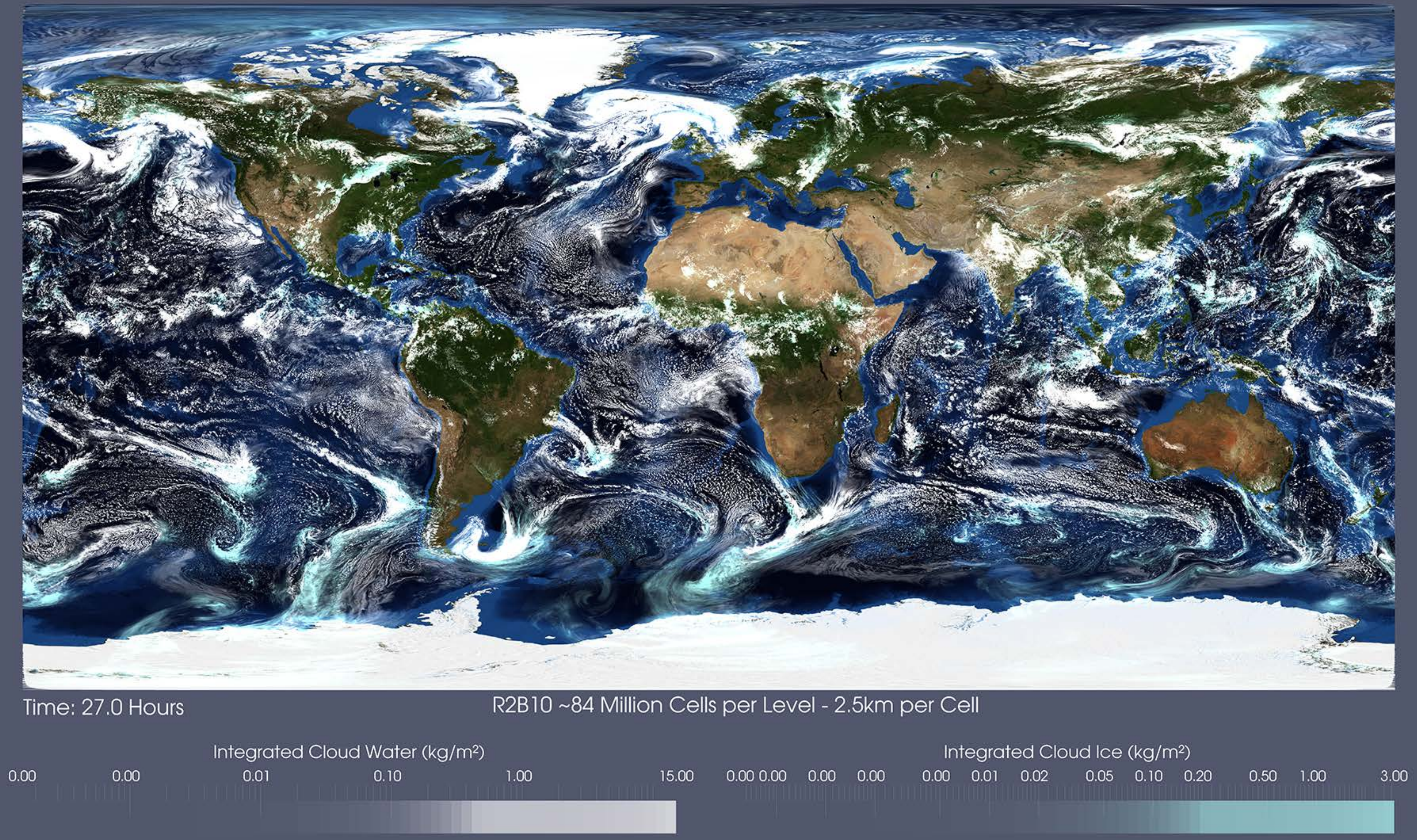
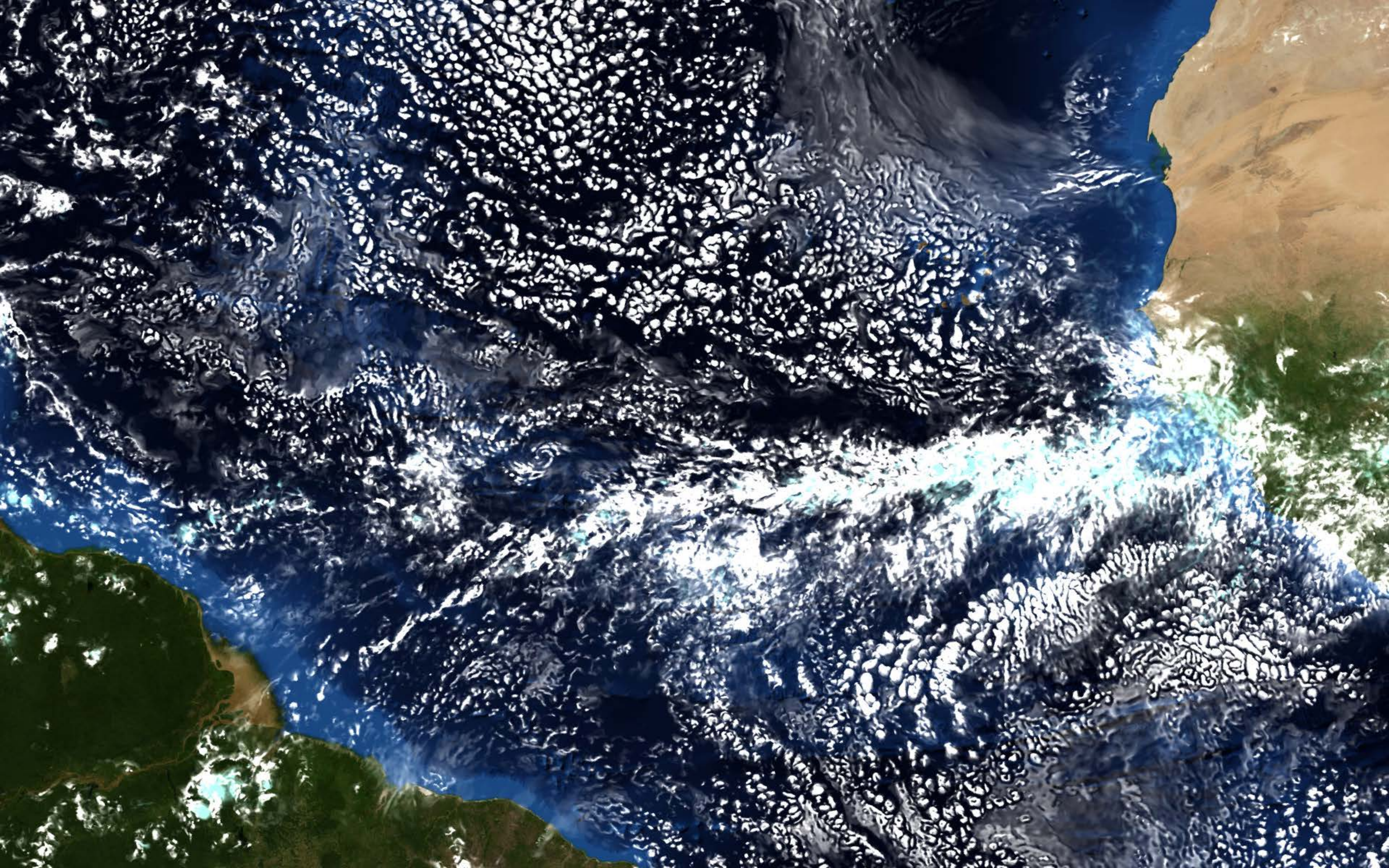
Hamburg, Germany



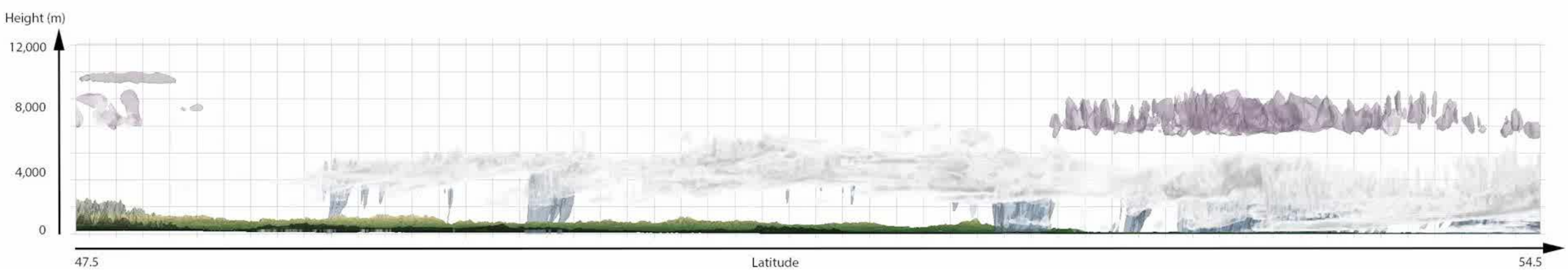
Time: 27.0 Hours
R2B10 ~84 Million Cells per Level - 2.5km per Cell
Integrated Cloud Water (kg/m²)
0.00 0.00 0.01 0.10 1.00 15.00
Integrated Cloud Ice (kg/m²)
0.00 0.00 0.00 0.00 0.00 0.01 0.02 0.05 0.10 0.20 0.50 1.00 3.00



Looking into Clouds …

See, understand, learn, communicate …

- Confirmatory visualization
- Interactive visualization
- Creating animations & stills for communication

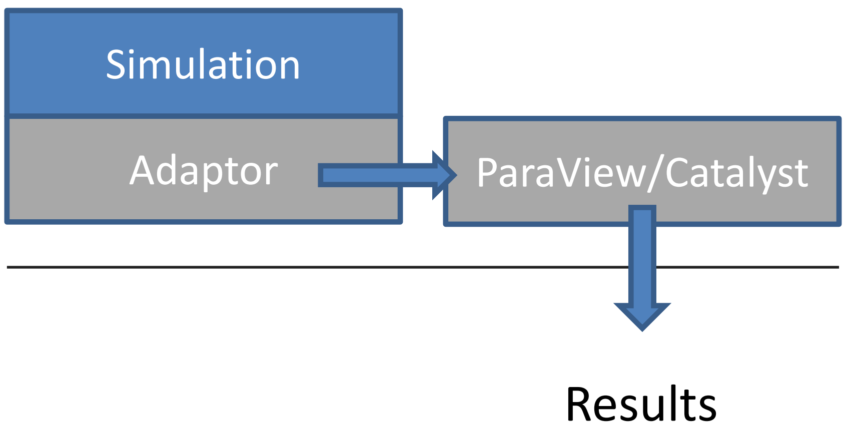


- 21 GPU nodes with dual 12/18 core Haswell/Broadwell CPUs
- 256/512/1024 GB main memory
- 4 GPUs per node (2 dual Kepler/Maxwell)
- VirtualGL/TurboVNC (Remote3D Rendering)
- CDO, ParaView, NCL, VAPOR, (Avizo Green), (SimVis), Matlab, grads …

Visualization of LARGE Data Sets

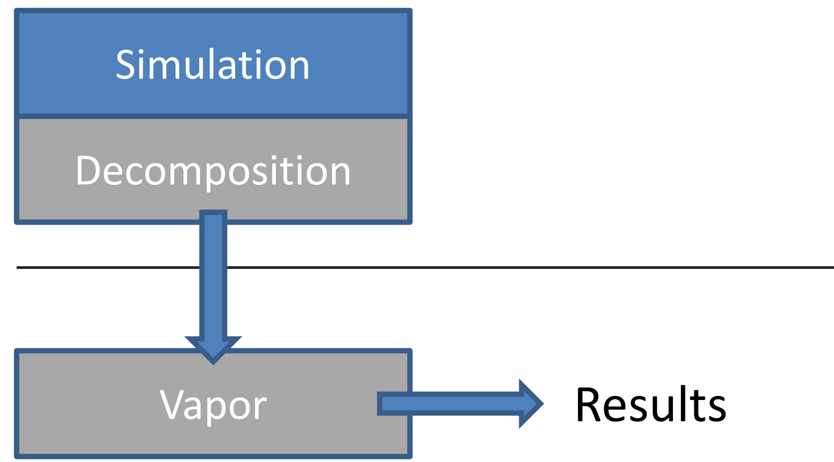
in-situ Visualization

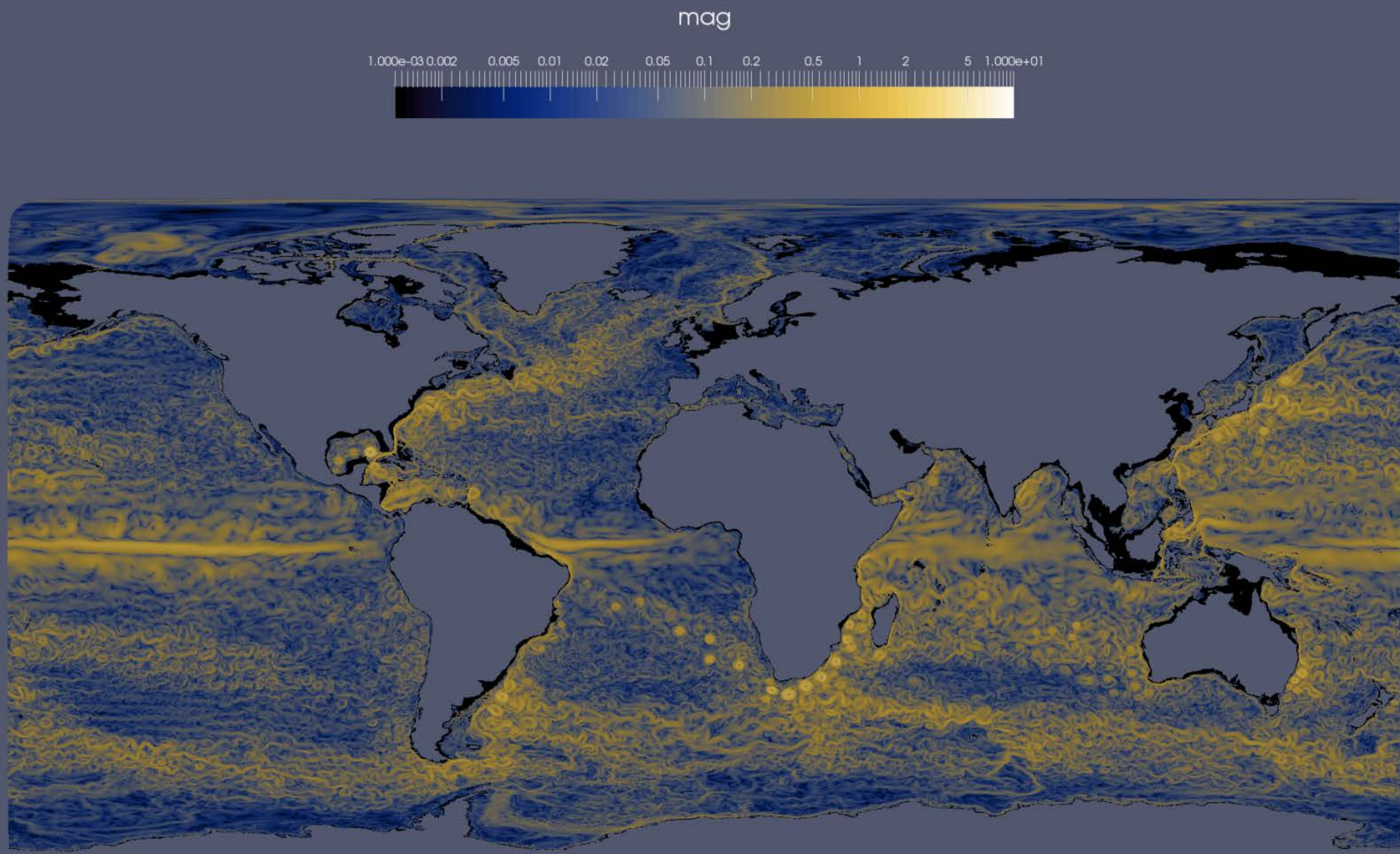
(ParaView/Catalyst)



in-situ Compression

(Vapor)

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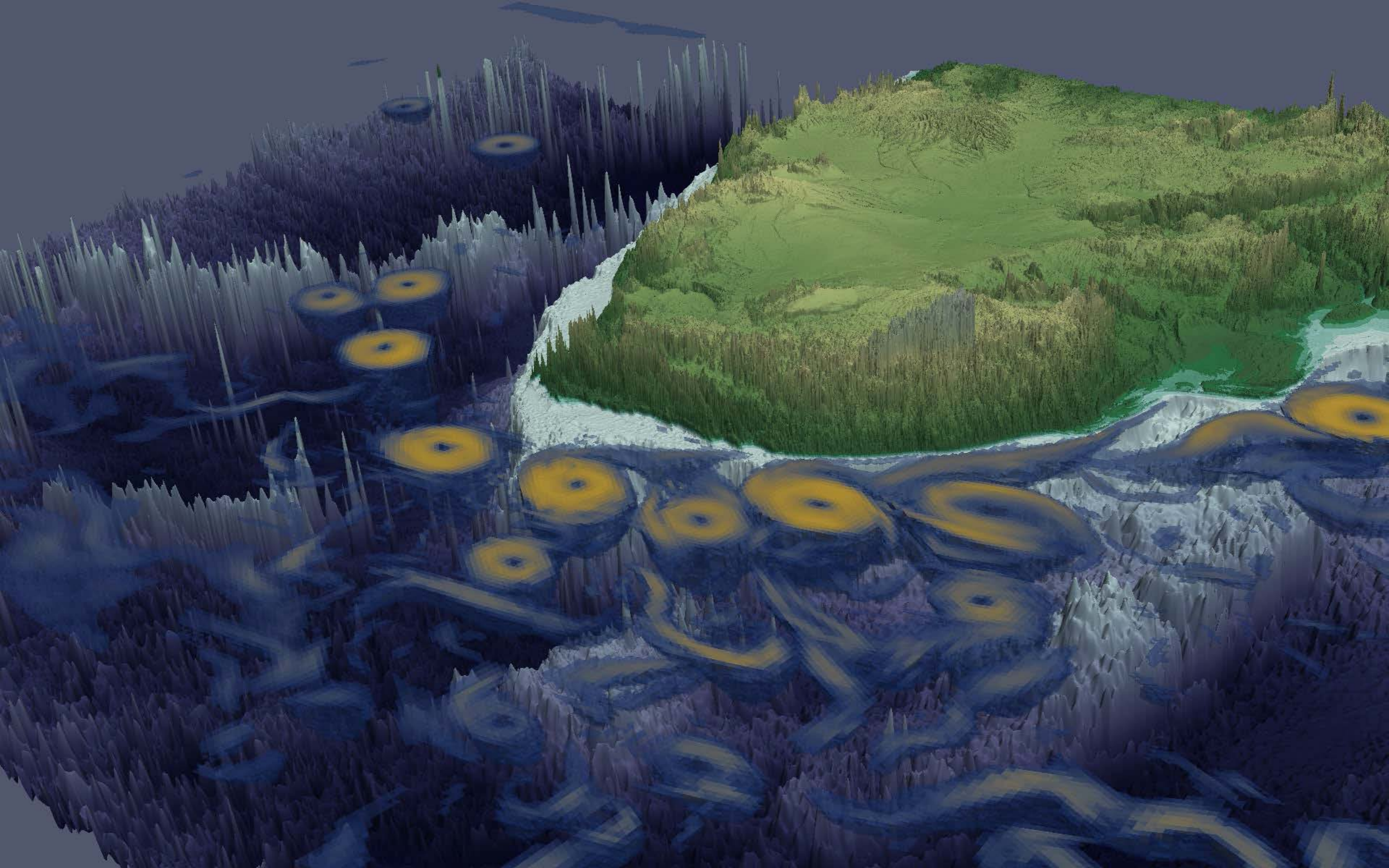


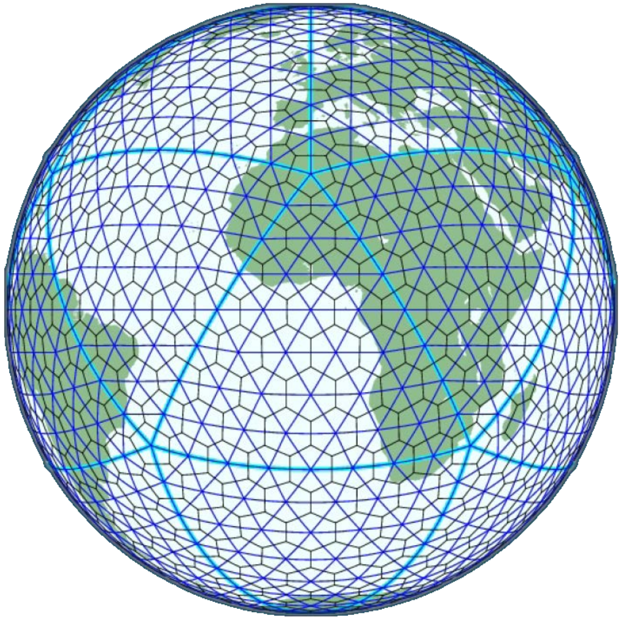
ICON and HD(CP)^2

- **ICO**sahedral **N**on-hydrostatic grid

- Atmosphere and Ocean
- Ocean – 10km resolution

  (3.8 million cells / 64 levels)
- HD(CP)^2 – 120m resolution

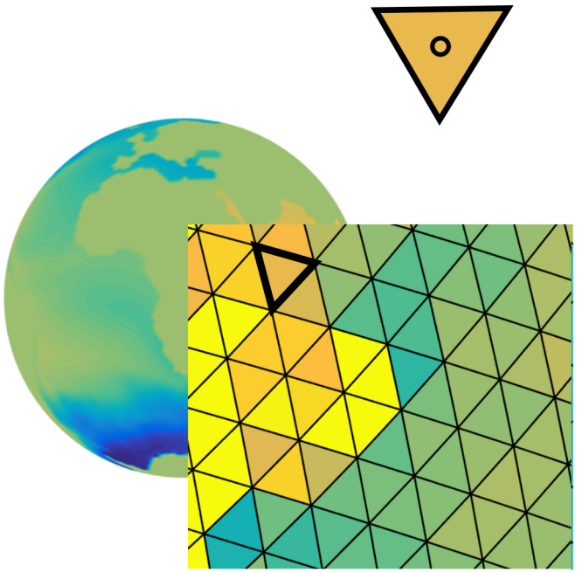
  (22.5 million cells / 150 levels)



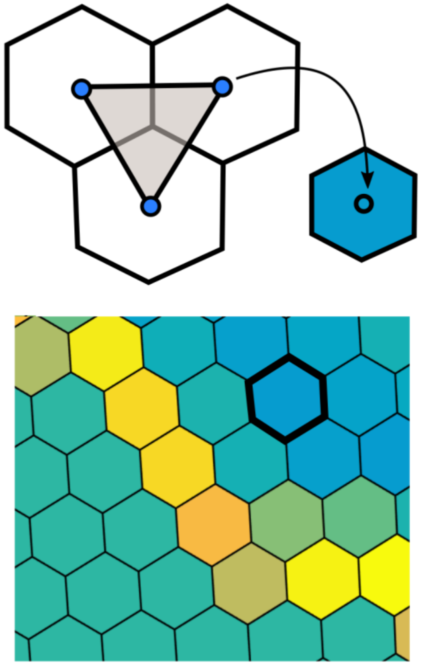
HD(CP)^2

High definition clouds and precipitation for advancing climate prediction

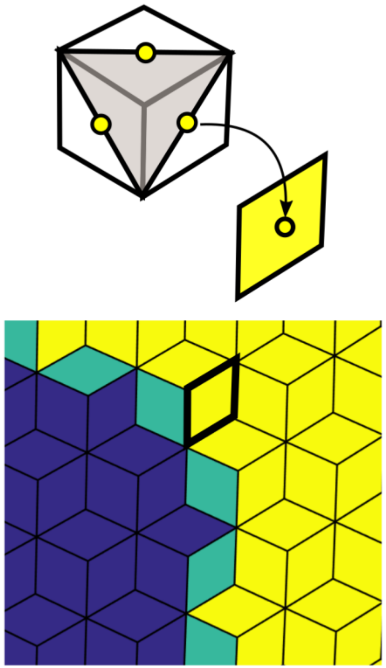
ICON Grid Layout



Cells

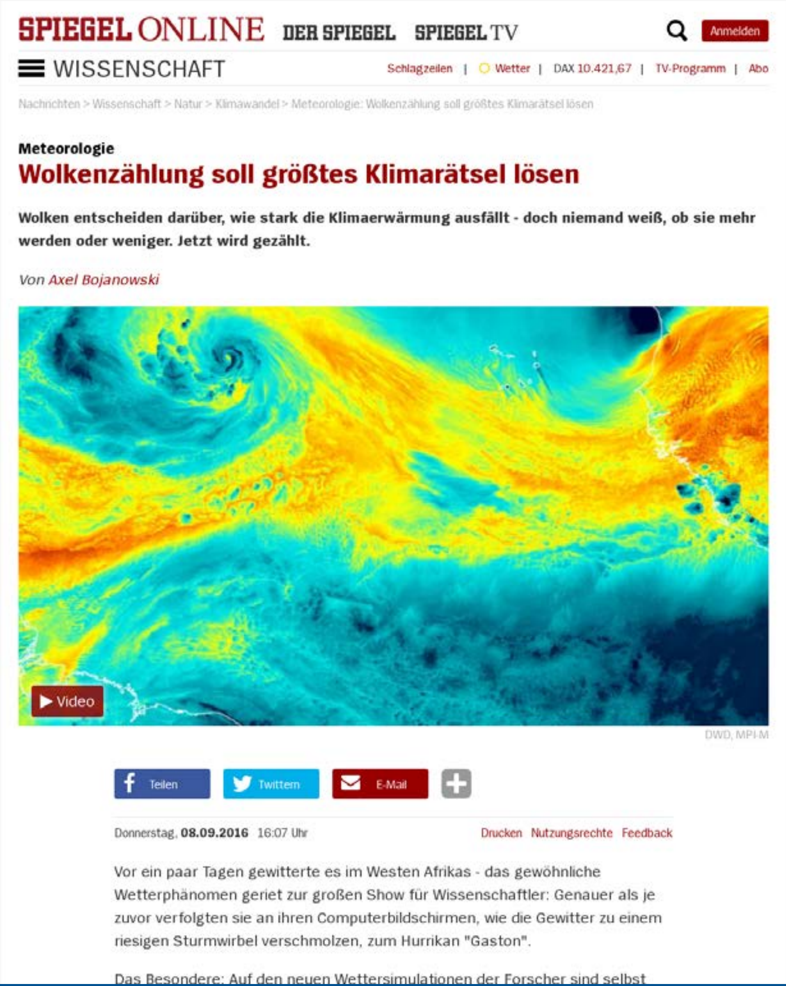


Points



Edges

HD(CP)² Phase II: Hurricane "Gaston"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Nachrichten > Wissenschaft > Natur > Klimawandel > Meteorologie: Wolkenzählung soll größtes Klimarätsel lösen

Meteorologie
Wolkenzählung soll größtes Klimarätsel lösen

Wolken entscheiden darüber, wie stark die Klimaerwärmung ausfällt - doch niemand weiß, ob sie mehr werden oder weniger. Jetzt wird gezählt.

Von Axel Bojanowski

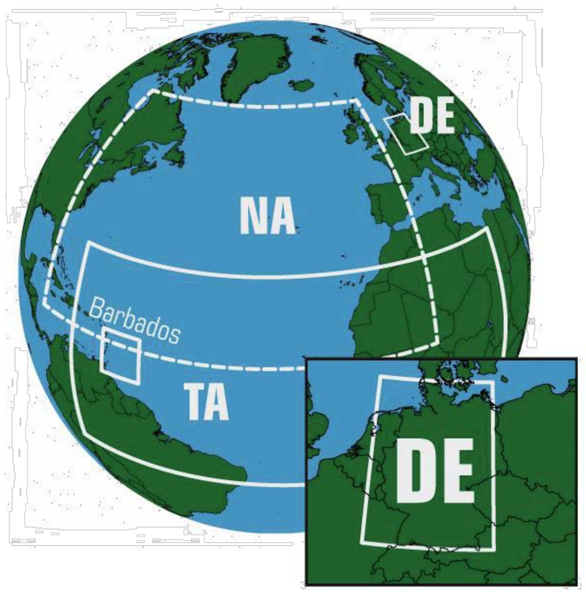
Video
DWD, MPI-M

Teilen Twittern E-Mail

Donnerstag, 08.09.2016 16:07 Uhr
Drucken Nutzungsrechte Feedback

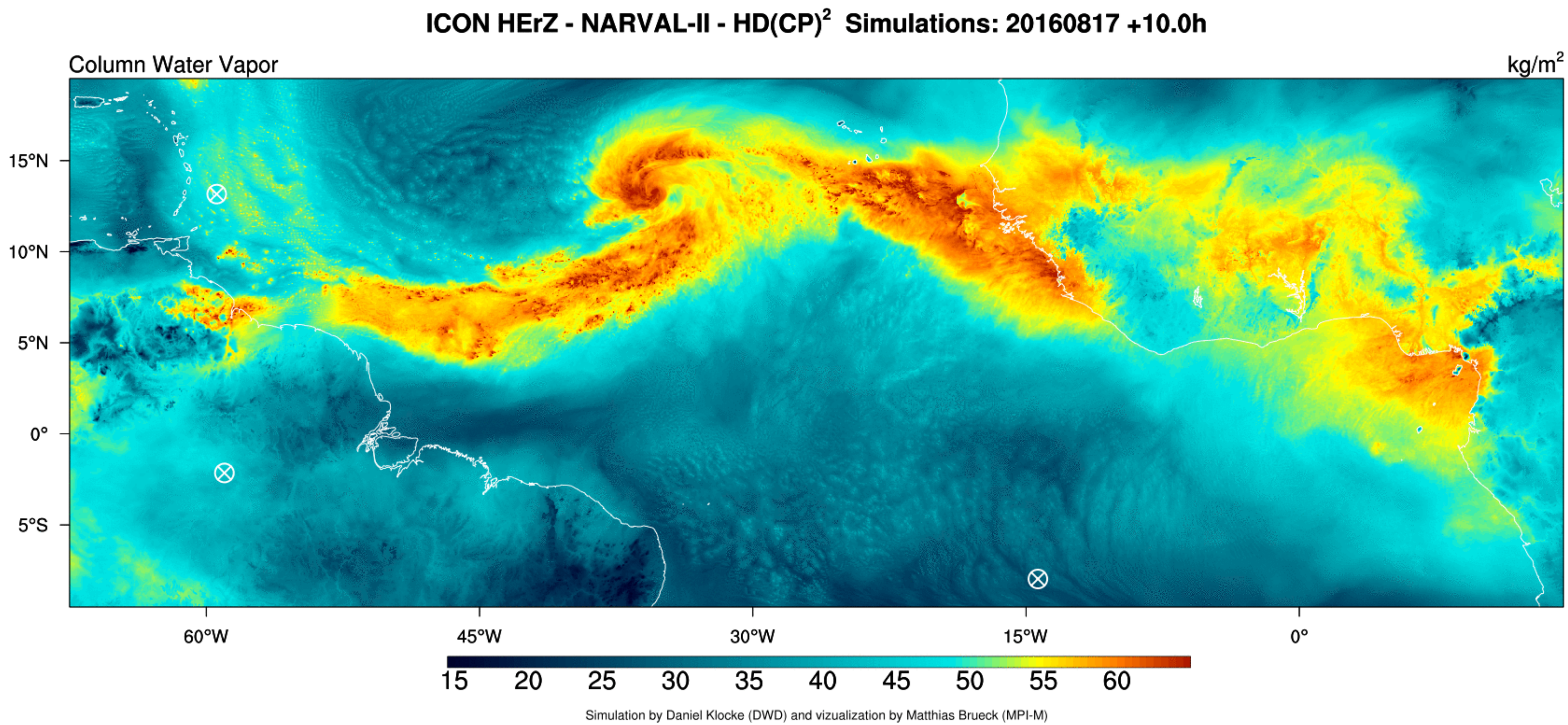
Vor ein paar Tagen gewitterte es im Westen Afrikas - das gewöhnliche Wetterphänomen geriet zur großen Show für Wissenschaftler: Genauer als je zuvor verfolgten sie an ihren Computerbildschirmen, wie die Gewitter zu einem riesigen Sturmwirbel verschmolzen, zum Hurrikan "Gaston".

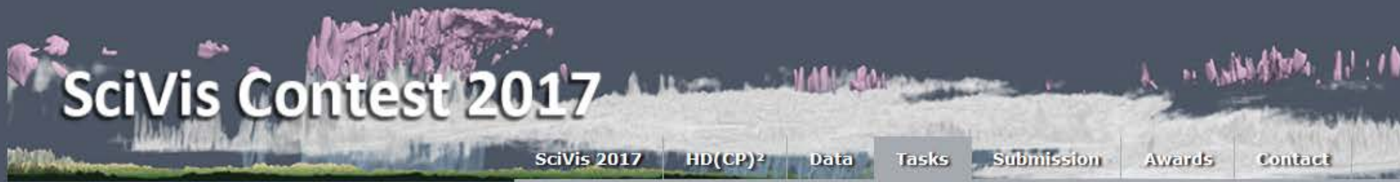
Das Besondere: Auf den neuen Wettersimulationen der Forscher sind selbst



HD(CP)² Domains

Hurricane “Gaston”





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)

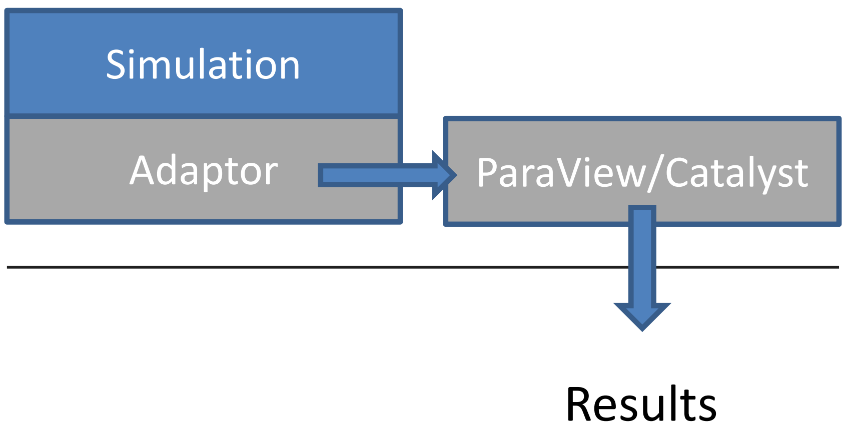
General Tasks

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.

Visualization of LARGE Data Sets

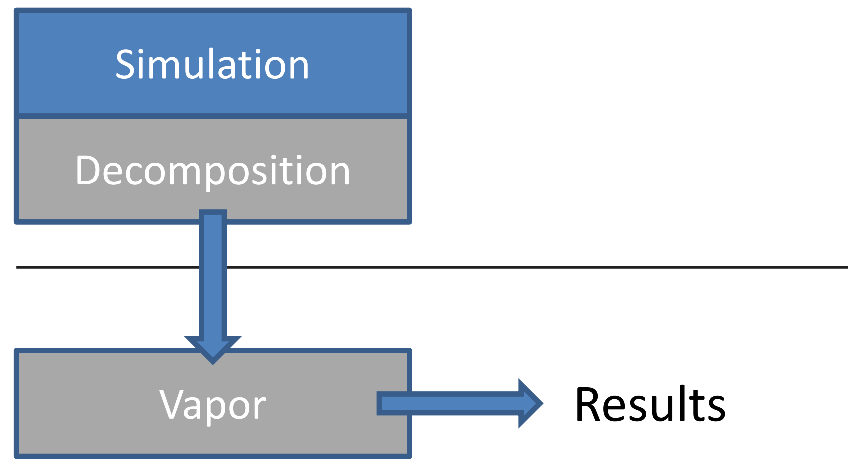
in-situ Visualization

(ParaView/Catalyst)



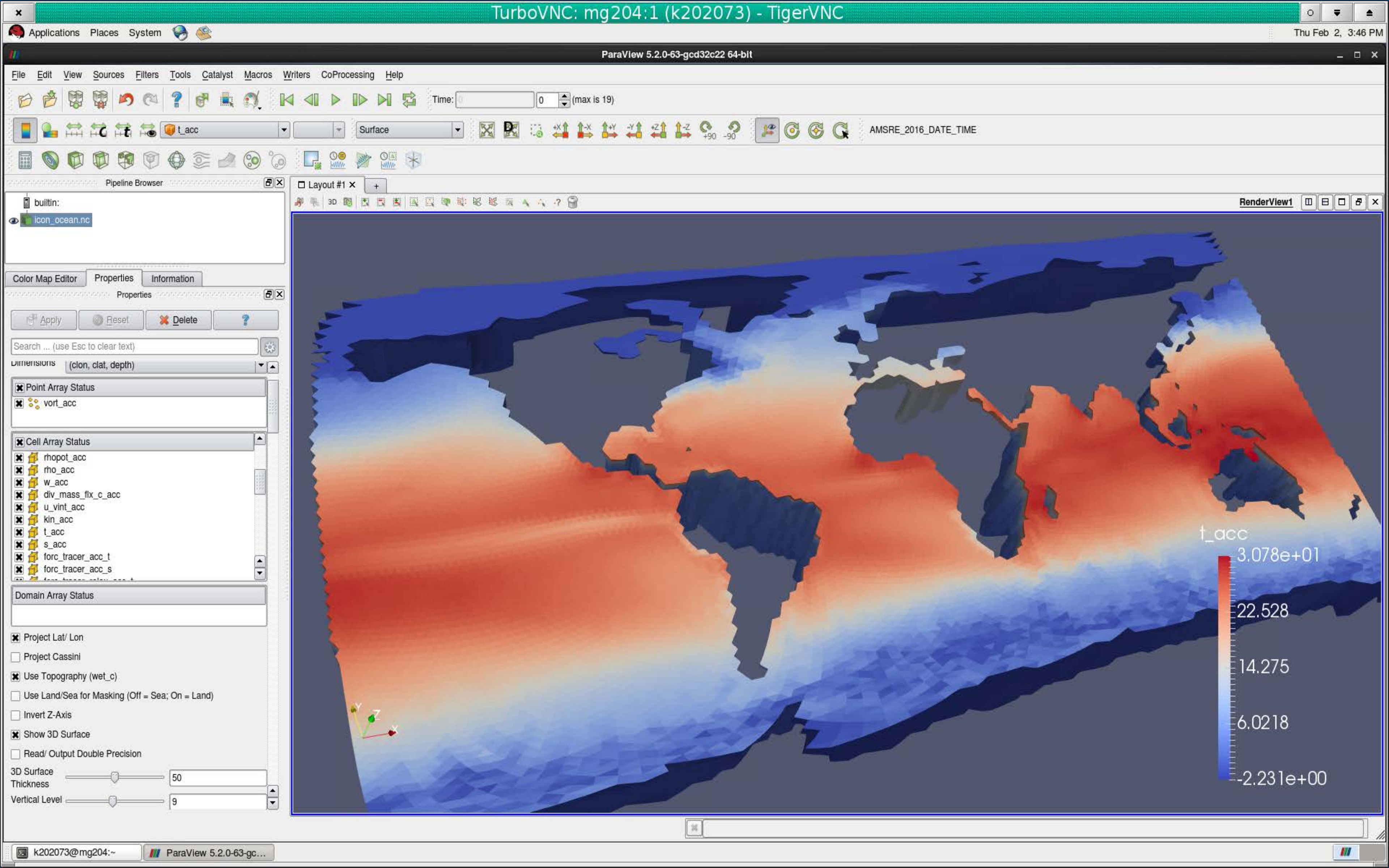
in-situ Compression

(Vapor)



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


TurboVNC: mg204:1 (k202073) - TigerVNC
Applications
Places
System
Thu Feb 2, 3:46 PM
ParaView 5.2.0-63-gcd32c22 64-bit
File
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Dimensions
(clon, clat, depth)
Point Array Status
vort_acc
Cell Array Status
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rho_acc
w_acc
div_mass_flx_c_acc
u_vint_acc
kin_acc
t_acc
s_acc
forc_tracer_acc_t
forc_tracer_acc_s
Domain Array Status
Project Lat/ Lon
Project Cassini
Use Topography (wet_c)
Use Land/Sea for Masking (Off = Sea; On = Land)
Invert Z-Axis
Show 3D Surface
Read/ Output Double Precision
3D Surface Thickness
50
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9
Layout #1
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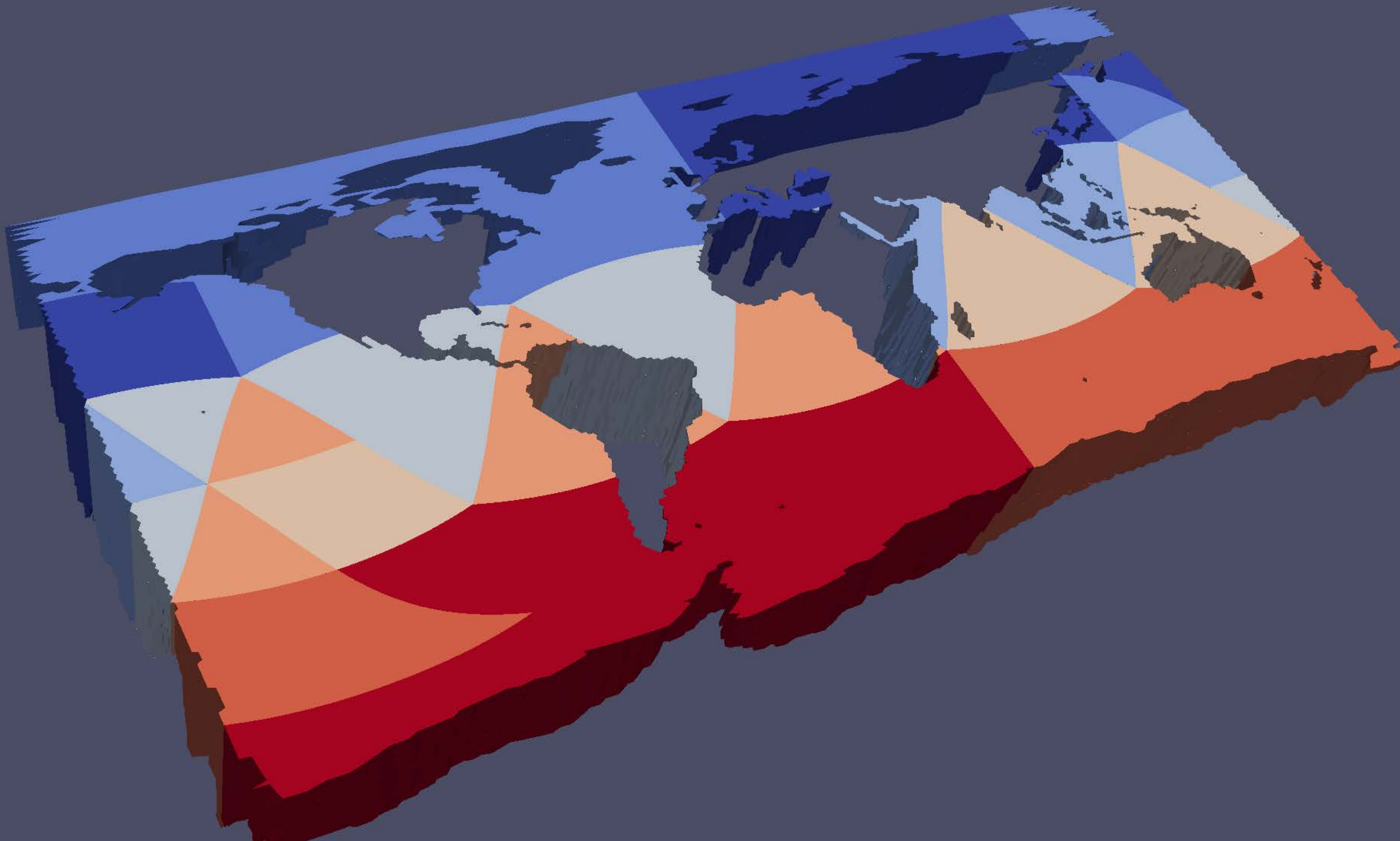
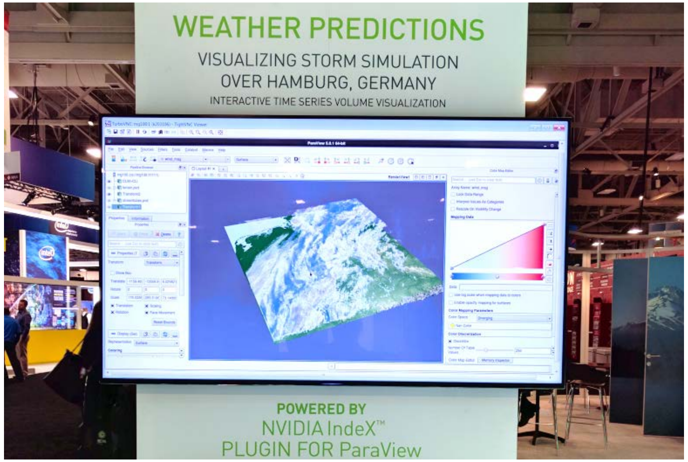
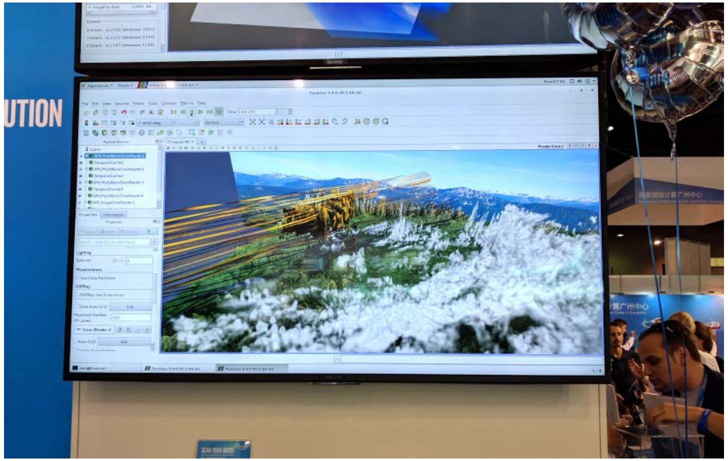


NVIDIA IndeX and INTEL OSPRay

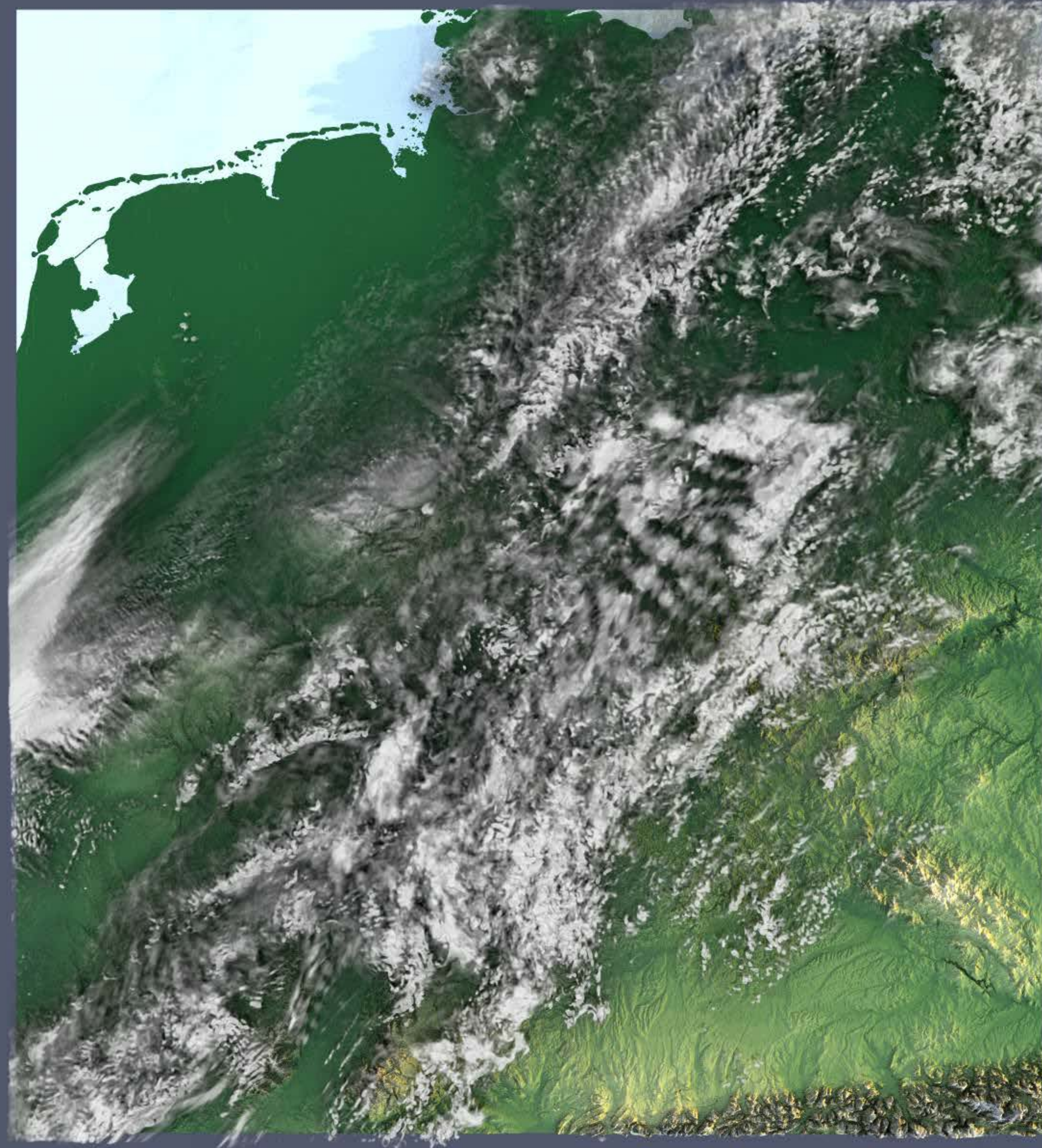
- Two different approaches for (volume) rendering of large data
  - Using GPUs and texture based volume rendering
  - Using CPUs and software based ray-tracing
- We (of course) collaborate with both ☺

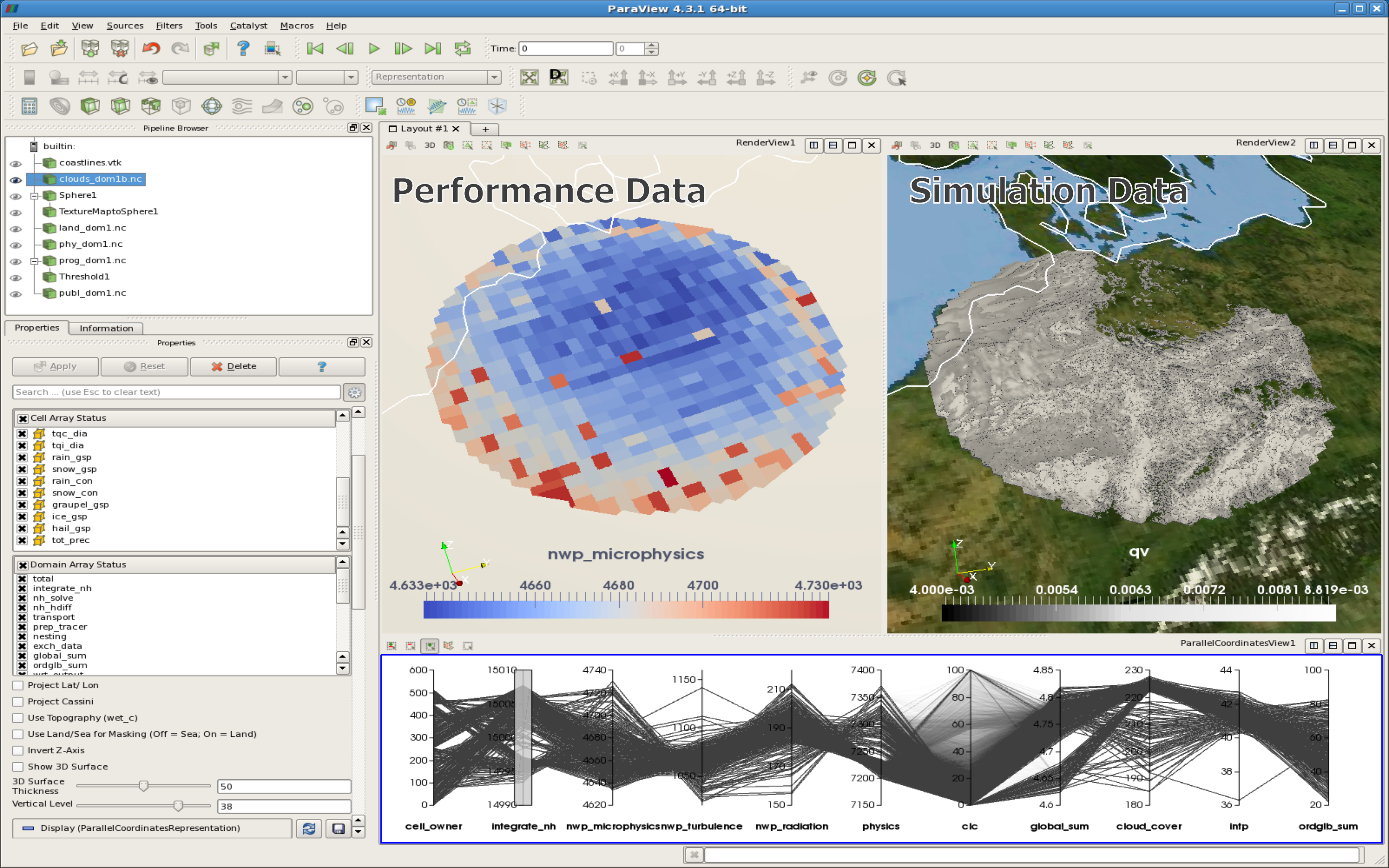


SC 16



ISC 17





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land_dom1.nc
phy_dom1.nc
prog_dom1.nc
Threshold1
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Reset
Delete
Search ... (use Esc to clear text)
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snow_gsp
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ice_gsp
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nh_solve
nh_hdiff
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exch_data
global_sum
ordglb_sum
Project Lat/ Lon
Project Cassini
Use Topography (wet_c)
Use Land/Sea for Masking (Off = Sea; On = Land)
Invert Z-Axis
Show 3D Surface
3D Surface Thickness
50
Vertical Level
38
Display (ParallelCoordinatesRepresentation)
Layout #1
RenderView1
Performance Data
nwp_microphysics
4.633e+03 4660 4680 4700 4.730e+03
RenderView2
Simulation Data
qv
4.000e-03 0.0054 0.0063 0.0072 0.0081 8.819e-03
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cell_owner
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nwp_radiation
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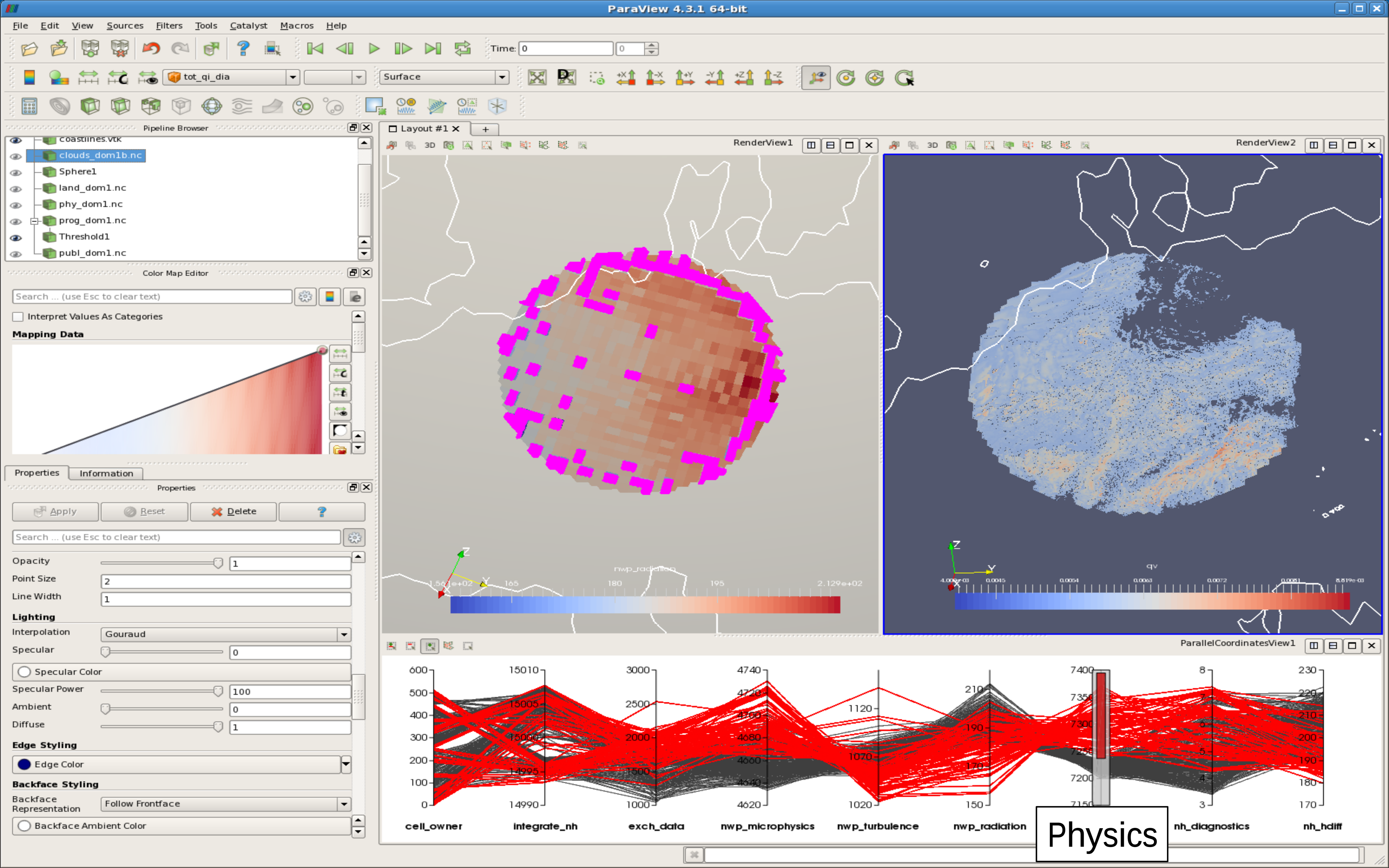
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Reset
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Opacity
Point Size
Line Width
Lighting
Interpolation
Gouraud
Specular
Specular Color
Specular Power
Ambient
Diffuse
Edge Styling
Edge Color
Backface Styling
Backface Representation
Follow Frontface
Backface Ambient Color
Layout #1
RenderView1
RenderView2
nwp_radiation
qv
ParallelCoordinatesView1
cell_owner
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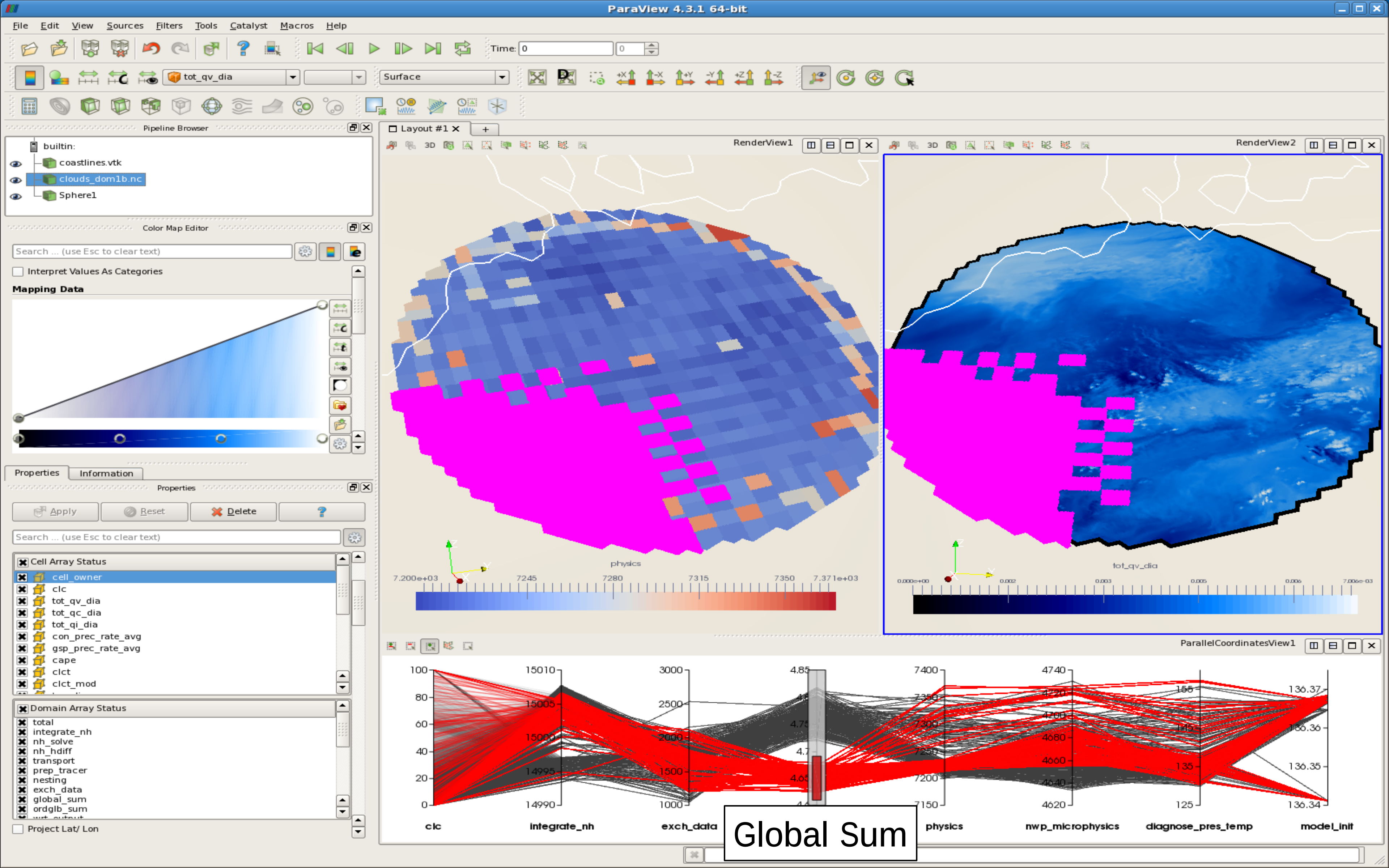
exch_data
nwp_microphysics
nwp_turbulence
nwp_radiation
nh_diagnostics
nh_hdiff
Physics


ParaView 4.3.1 64-bit
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clouds_dom1b.nc
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Interpret Values As Categories
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gsp_prec_rate_avg
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clct_mod
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total
integrate_nh
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nh_hdiff
transport
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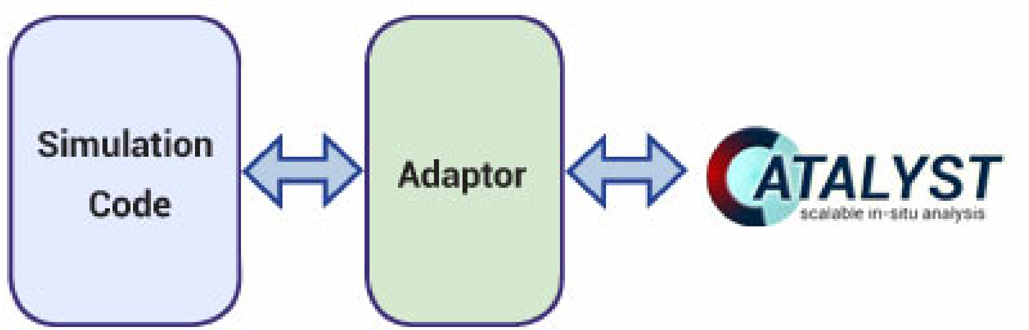
exch_data
global_sum
ordglb_sum
Project Lat/ Lon
Layout #1
RenderView1
RenderView2
physics
7.200e+03
7245
7280
7315
7350
7.371e+03
tot_qv_dia
ParallelCoordinatesView1
clc
integrate_nh
exch_data
physics
nwp_microphysics
diagnose_pres_temp
model_init
Global Sum

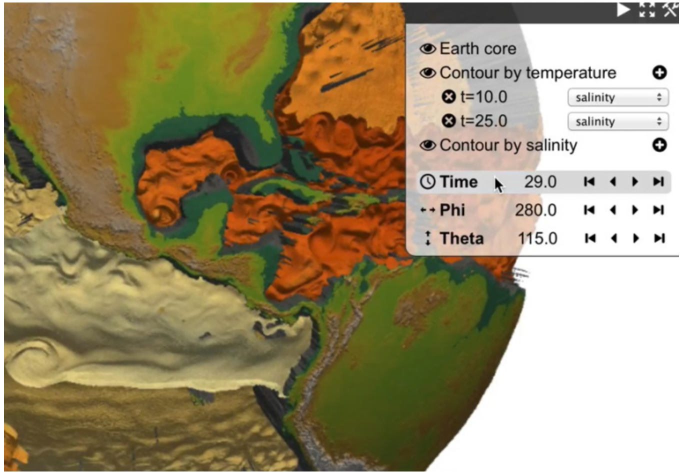
In-situ Visualization with ParaView

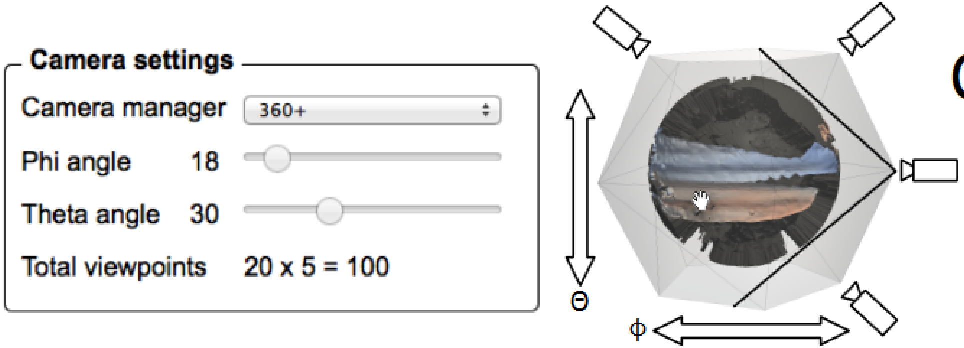
- In-situ (co)processing/visualization using Paraview/Catalyst
- Adaptor required that connects ICON (model) and Catalyst
- Two possibilities for co-processing:
  - Batch-visualization using pre-defined Python scripts
  - Live visualization within a client/server setting



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



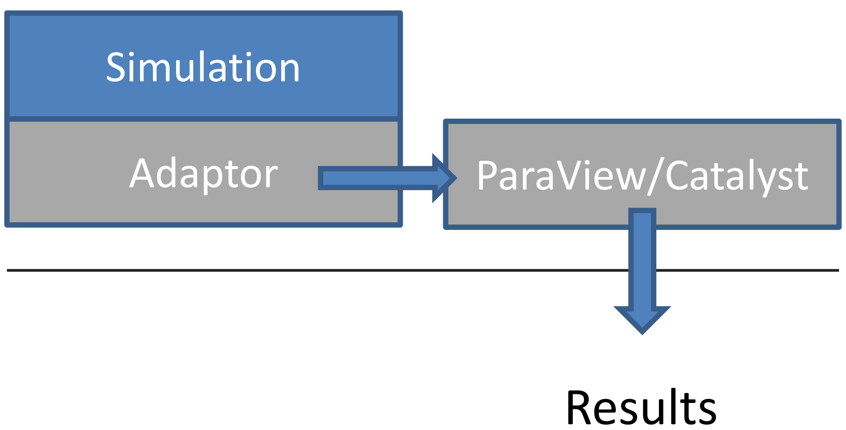


Camera

Visualization of LARGE Data Sets

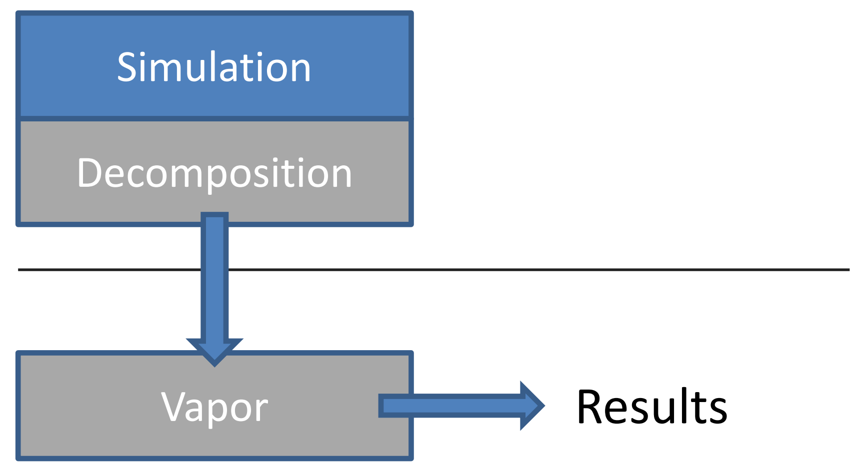
in-situ Visualization

(ParaView/Catalyst)

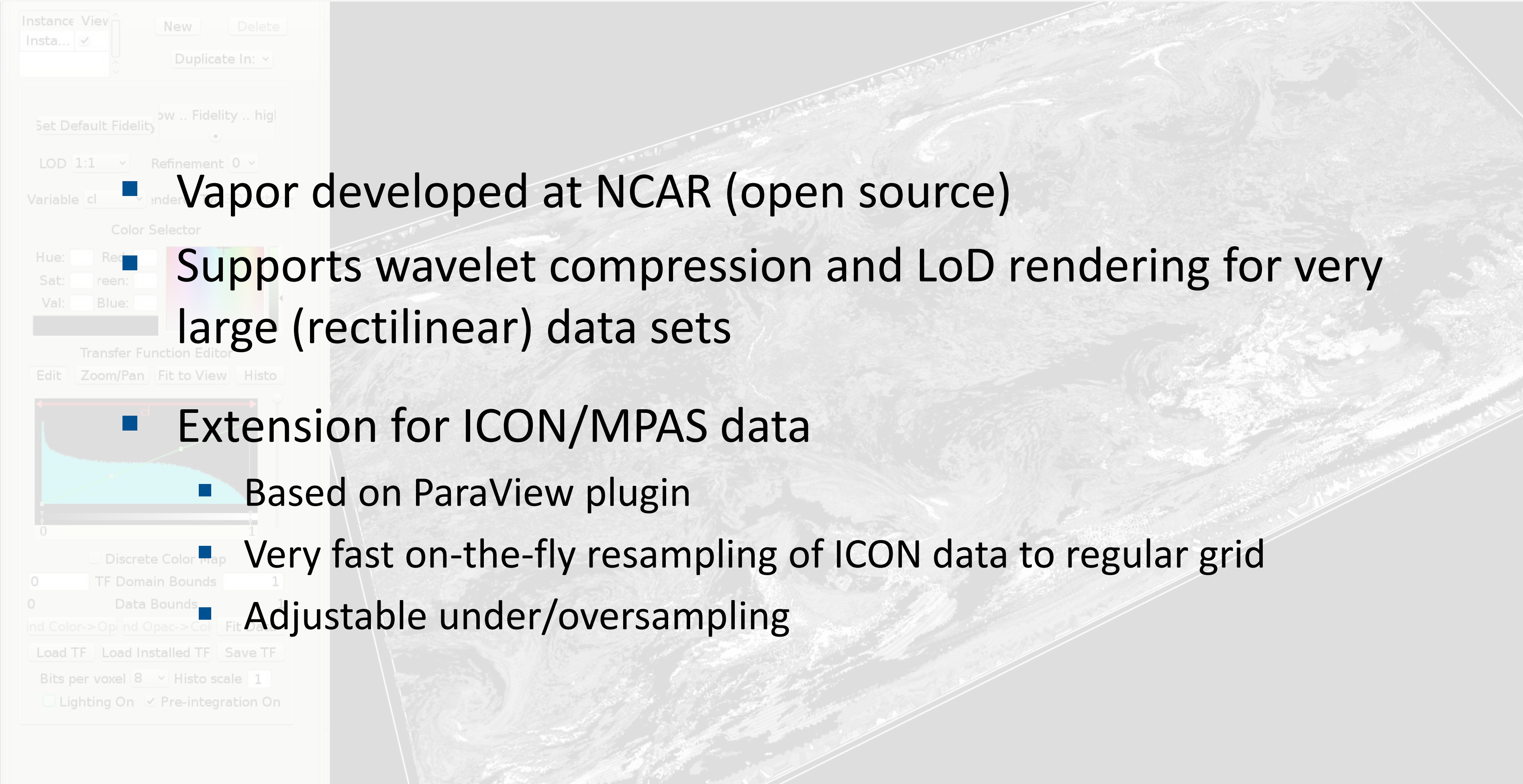


in-situ Compression

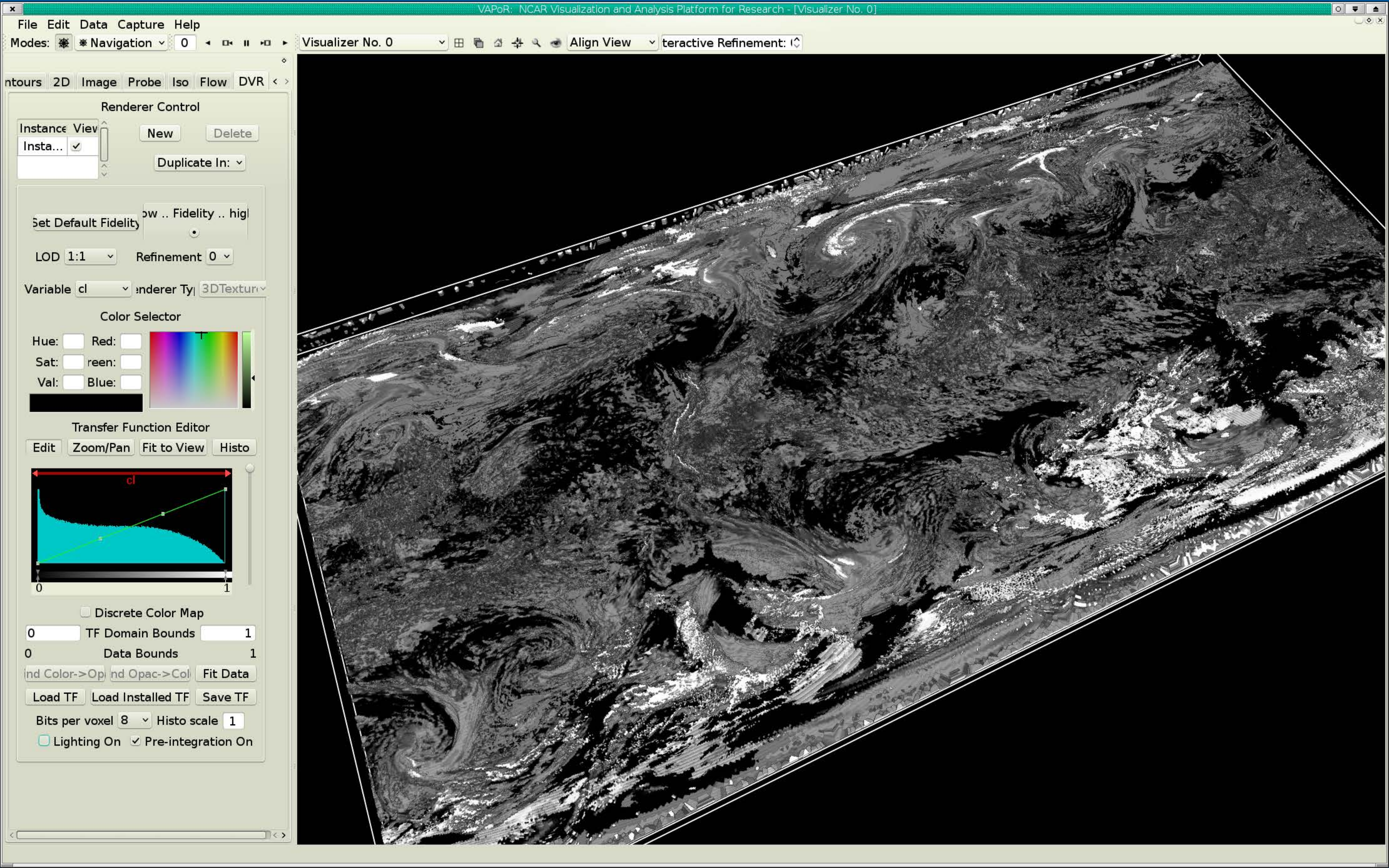
(Vapor)



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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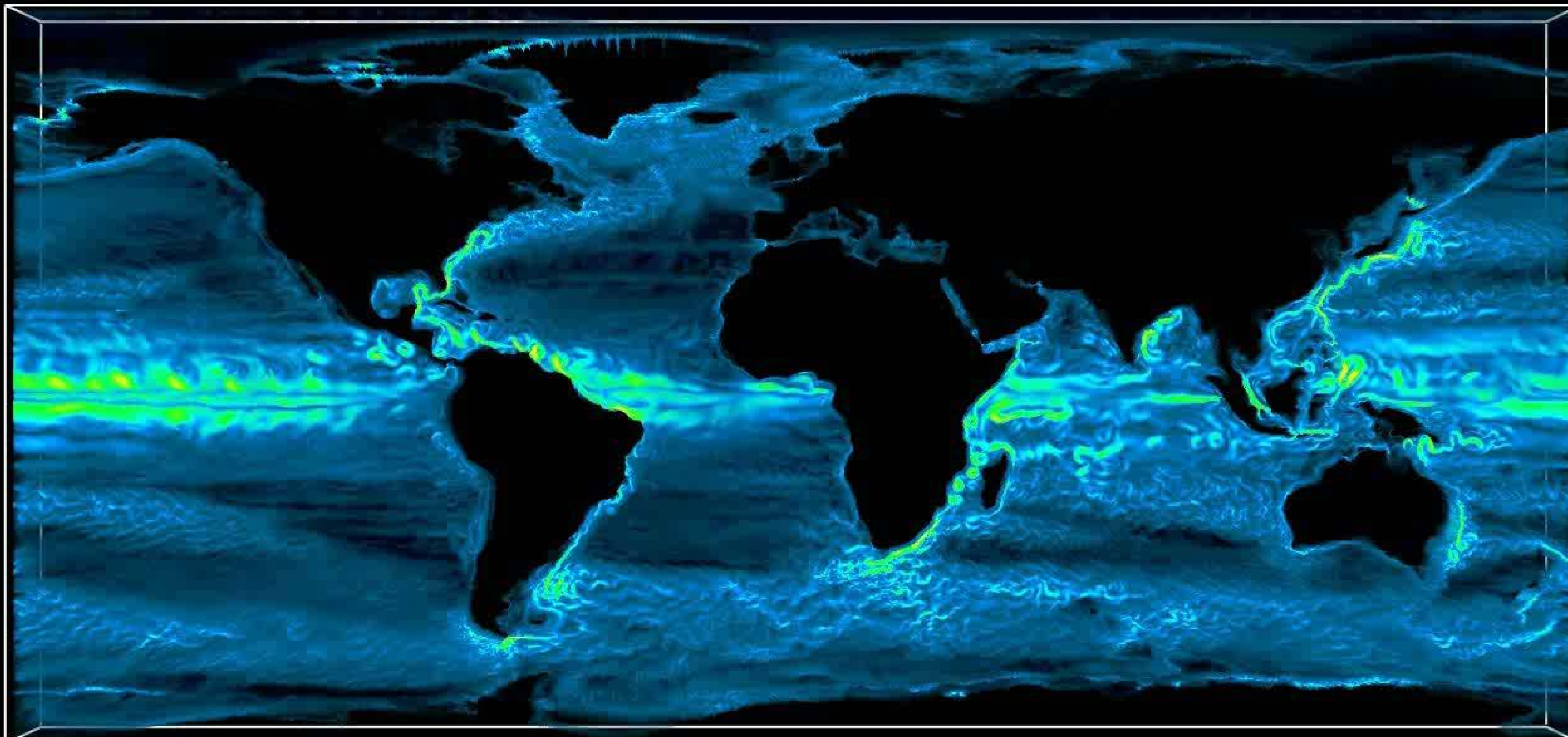
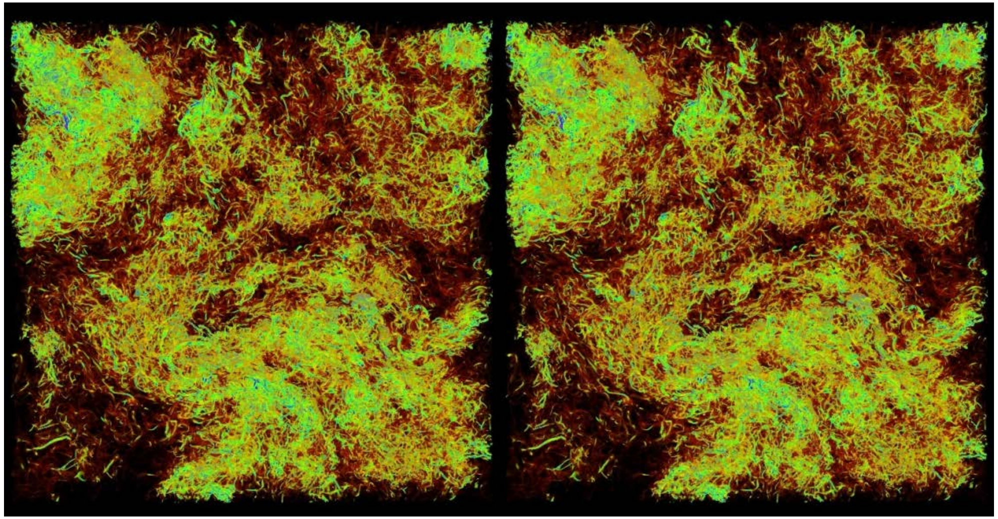


VAPOR and Compression

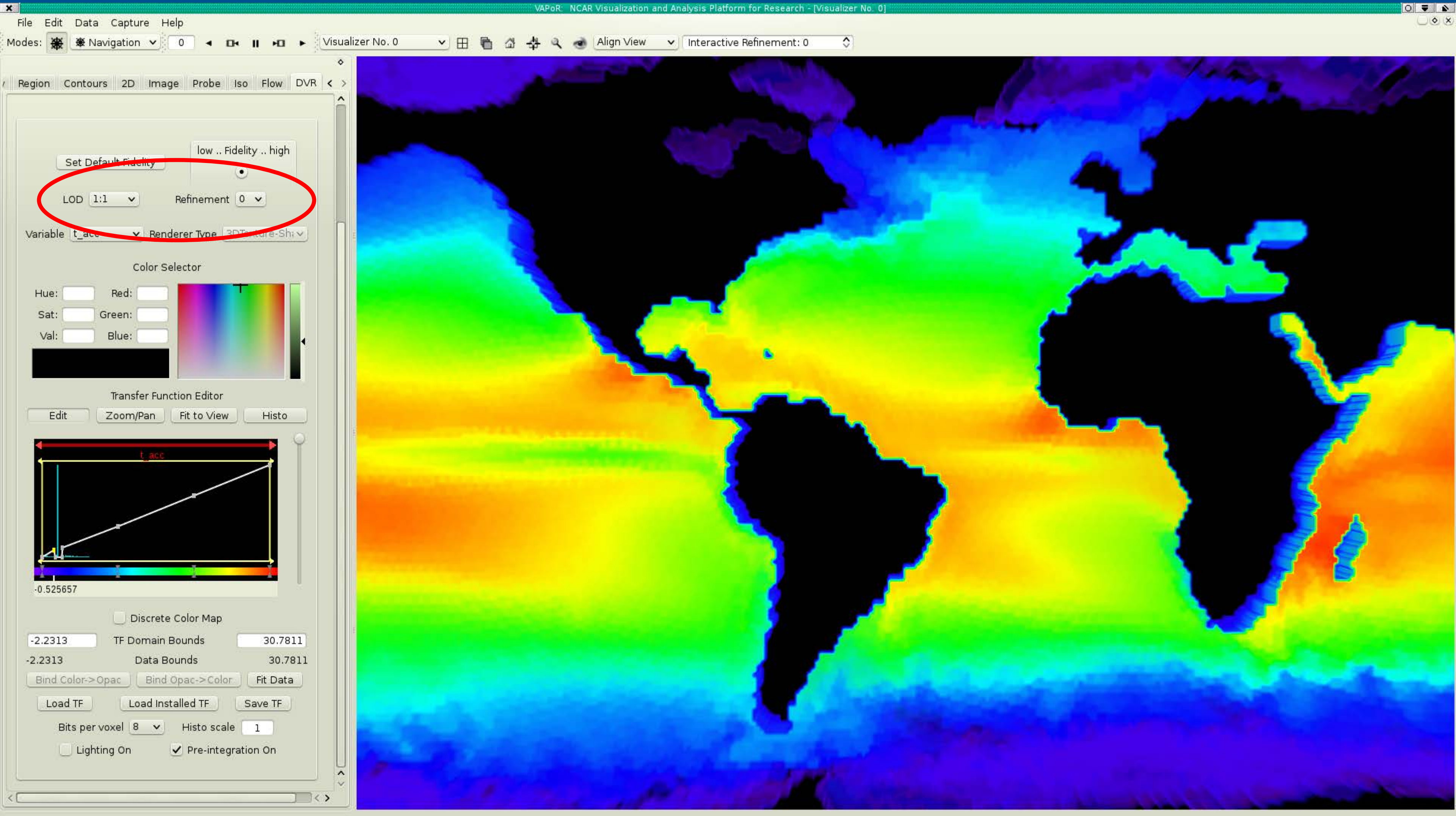
- Wavelet-based intelligent data storage
- Progressive data access with multiresolution rendering
- Coefficients are sorted and prioritized

Original
275 GBs / 3D field



800:1
0.34 GBs / 3D field

(c) John Clyne


VAPoR: NCAR Visualization and Analysis Platform for Research - [Visualizer No. 0]
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Align View
Interactive Refinement: 0
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t_acc
Renderer Type
Color Selector
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Val:
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Transfer Function Editor
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Discrete Color Map
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TF Domain Bounds
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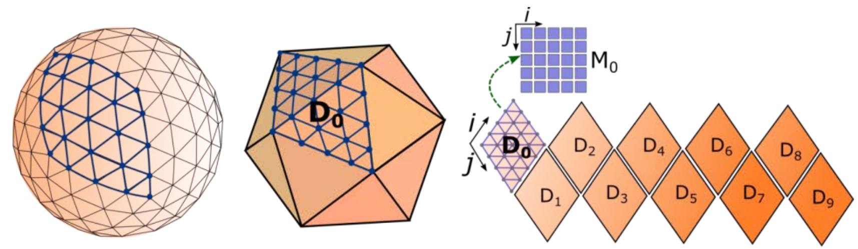
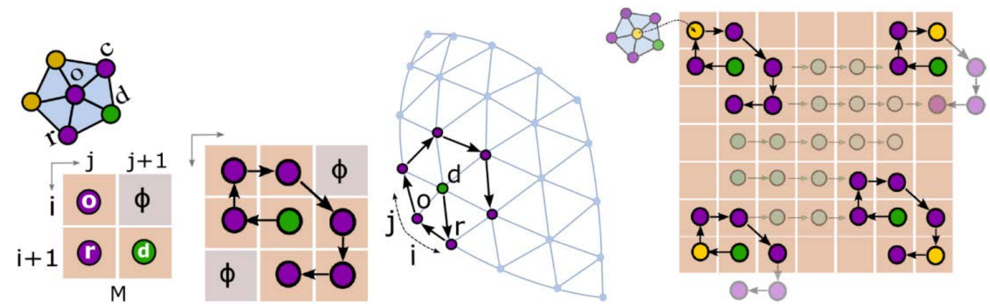
Discrete Hexagonal Wavelet Transform for ICON/MPAS

Decompose sphere into 10 diamonds

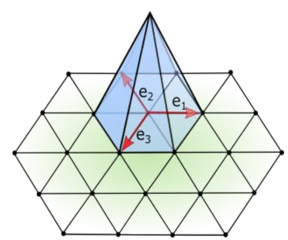
- Diamond vertices at original base icosahedron vertices
- Each diamond has regular topology



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



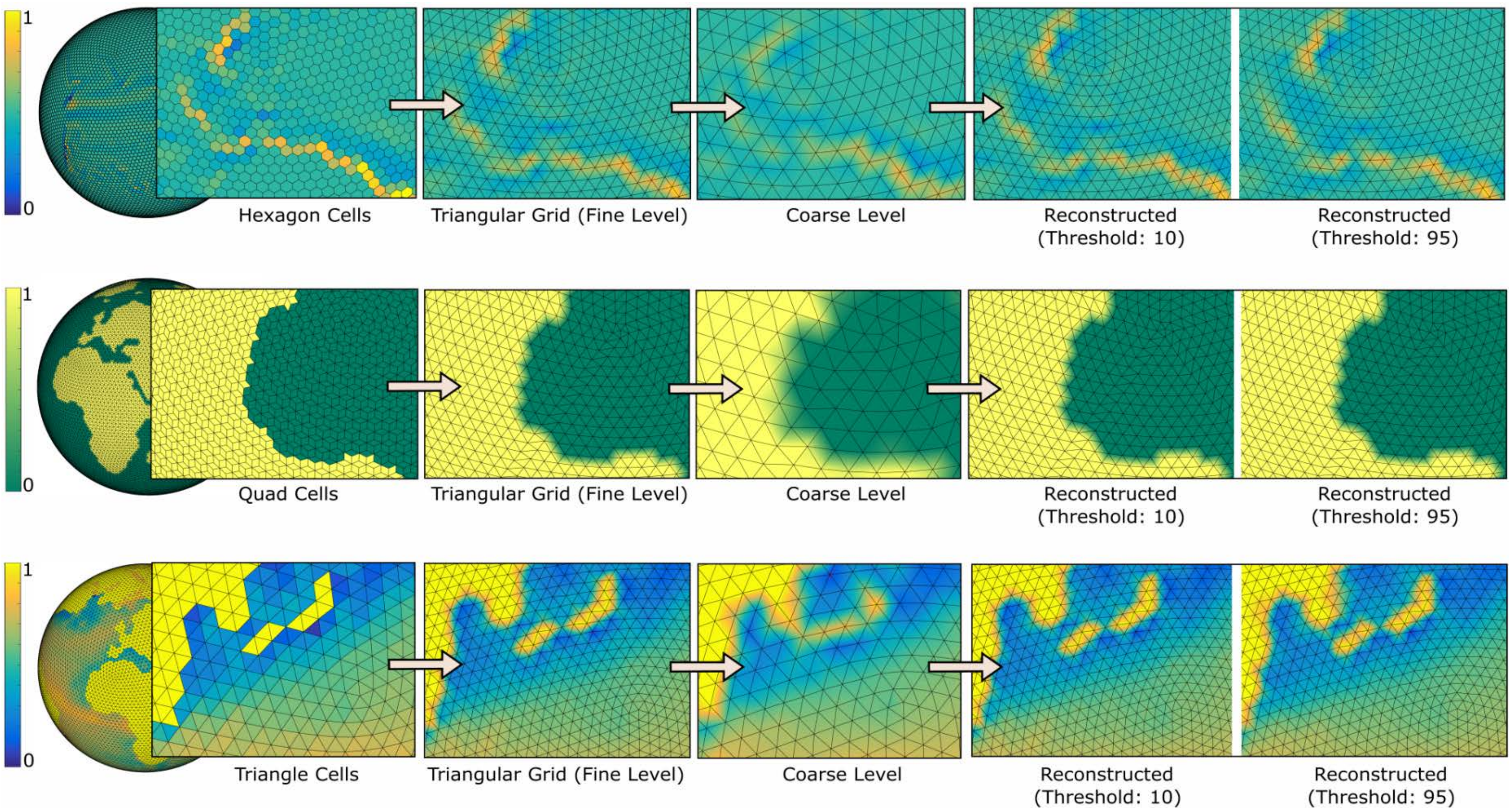
Apply discrete wavelet transform to each regular hexagonal mesh (diamond)



$$f(\mathbf{x}) = \sum_{\mathbf{k}} \overbrace{F[\mathbf{k}]}^{\textit{data}}\,\overbrace{\varphi(\mathbf{x}-\mathbf{L}\mathbf{k})}^{\textit{box spline}}$$

[1] Jubair et.al. *“Icosahedral Maps for a Multiresolution Representation of Earth Data”*, VMV 2016

Multiresolution with Icosahedral Maps



[1] Jubair et.al. *"Icosahedral Maps for a Multiresolution Representation of Earth Data"*, VMV 2016

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?

[2] Baker et.al. "A Methodology for Evaluating the Impact of Data Compression on Climate Simulation Data", HPDC 2014