ESiWACE Summerschool
Data Visualization using ParaView

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Deutsches Klimarechenzentrum (DKRZ)

Wednesday, August 26th – Afternoon

Data Visualization – Niklas Röber DKRZ

- 13.30 – 15.00 Data Visualization using ParaVie
  - Introduction + visualization examples
  - Handling large data in visualization
  - Hands-on examples using ParaView

Data Analytics – Donatello Elia CMCC

- 15.15 – 16.45 Introduction to Data Analytics
- 16.45 – 17.15 Lab Tutorial (Ophidia)

Visualization Workshops at DKRZ

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- Hands-on tutorials for ParaView, NCL, VaPOR from 2 and 5 days
- Some online tutorials available at **www.dkrz.de/up/services/analysis**
- Online video tutorials coming soon
- ESiWACE2: dedicated data analytics and visualization workshop

News

- New supercomputer „Mistral" at DKRZ delivers particularly detailed regional climate simulations for Germany
  Oct 05, 2015
- Preview: DKRZ at SC'15
  Sep 30, 2015
- Kick-off for ESiWACE and ESCAPE
  Sep 29, 2015
- Allocations 2016 - request resources

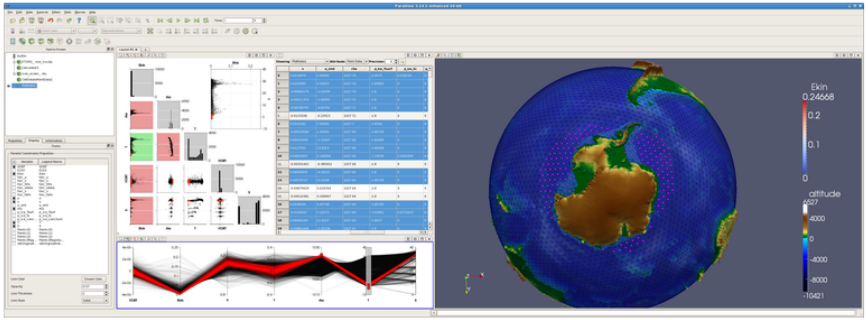
ParaView

Paraview is an open source visualization package that reads a variety of different data formats and lattices and implements the most common visualization techniques. More specifically, Paraview also reads netCDF files and supports different grids, so that it can be used to visualize climate and earth science data sets.

Paraview 4.1 is installed on all visualization nodes of Halo and can be started from the command line via 'paraview'. Older versions of Paraview can be started by appending the version number, such as 'paraview3.98'.

Paraview has come a long way and is used and developed by a very large community from a variety of different sciences. It is installed on DKRZ's Halo nodes since the end of 2012, and we have now prepared a little tutorial that will teach you how to use Paraview for the visualization of your own climate research data.

More general information on Paraview, along with some tutorial data can also be found online on the Paraview website.



The above example shows a complex visualization of an ICON ocean data set using Paraview. The viewport on the right displays the data, the selection made, as well as the Earth's topography. The three viewports on the left hand side are used to specify the selection, based on a scatterplot matrix and parallel coordinates. These techniques are especially well suited for an in-depth data analysis and exploration.

Paraview Tutorial

The final tutorial document will comprise 8 chapters and will be released at the end of the summer in 2014. Alongside, we will provide courses to teach Paraview in a hands-on setting. The first course will already start in December 2013.

Here is a glimpse of the content from the tutorial:

- Chapter 1 "Introduction and Overview" --- The first Chapter starts with an overview of Paraview and briefly explains the underlying visualization toolkit pipeline. The second part of this chapter concentrates on an introduction of the

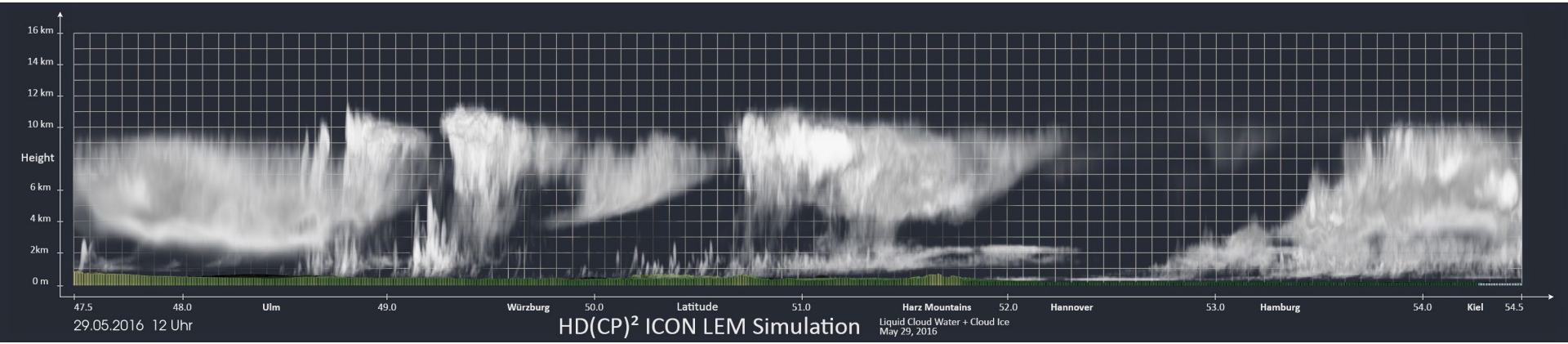
Visualization Work at DKRZ

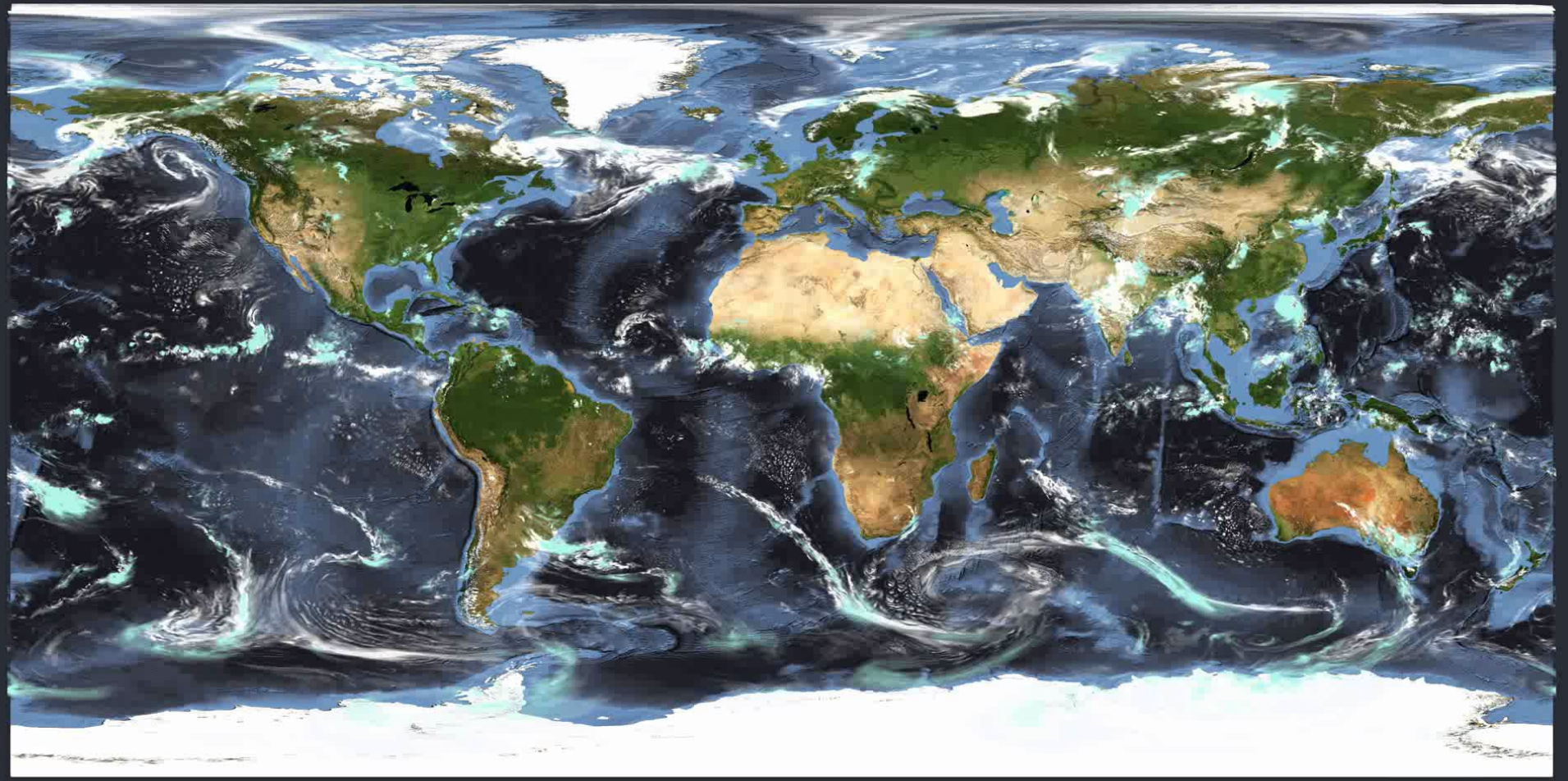
- Looking at ways to work and interact with LARGE data
  - In-situ visualization with ParaView/Catalyst
  - Compression and progressive data visualization using wavelets and Vapor
  - Batch visualization on MISTRAL using ParaView and NCL
- Compression, especially *lossy*, as it has always been done
  (precision, variables, temporal/spatial resolution, model error, GRIB)
- Visualization of uncertainty
- Multivariate data visualization
- Machine learning & online feature tracking

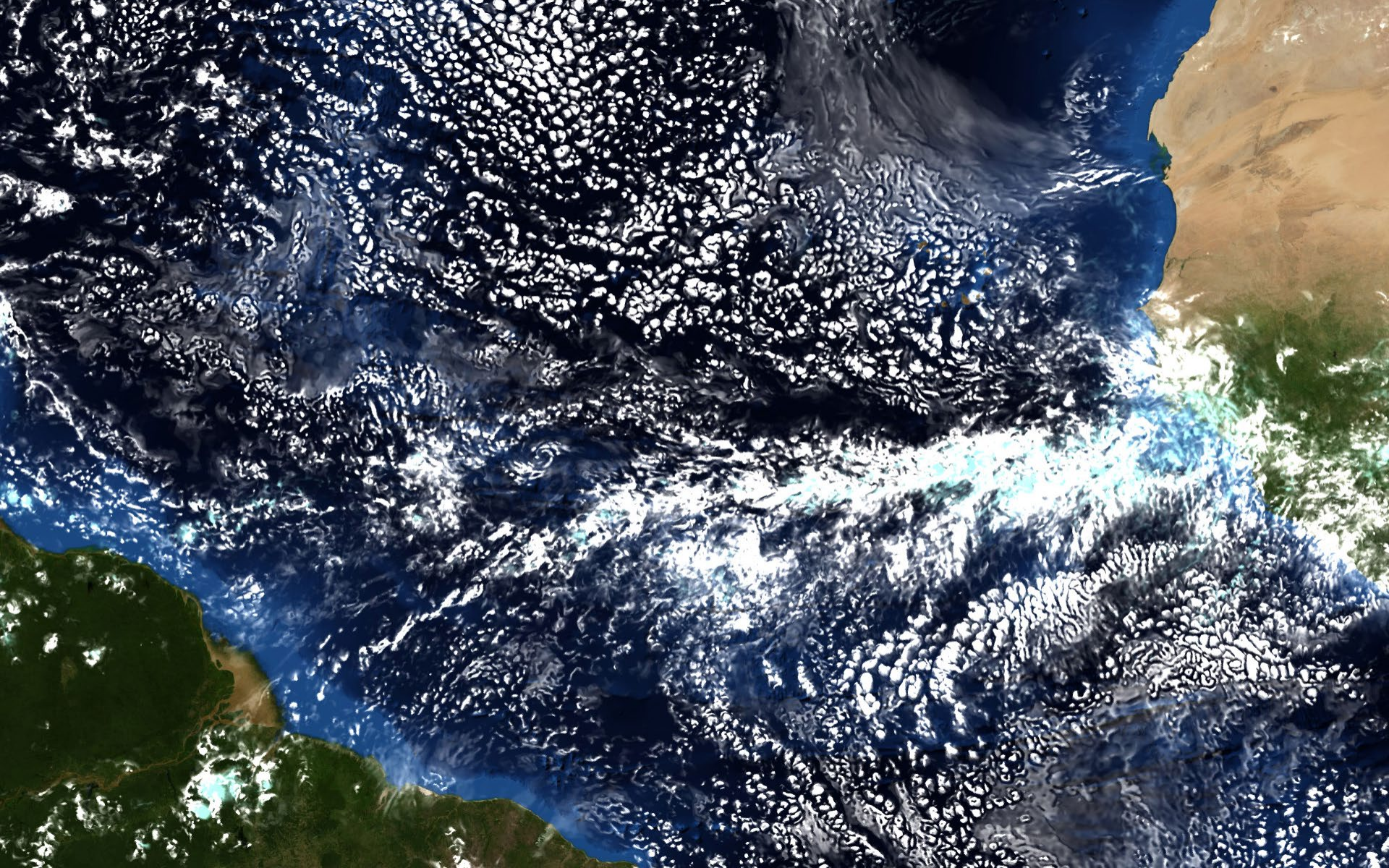
Data Visualization

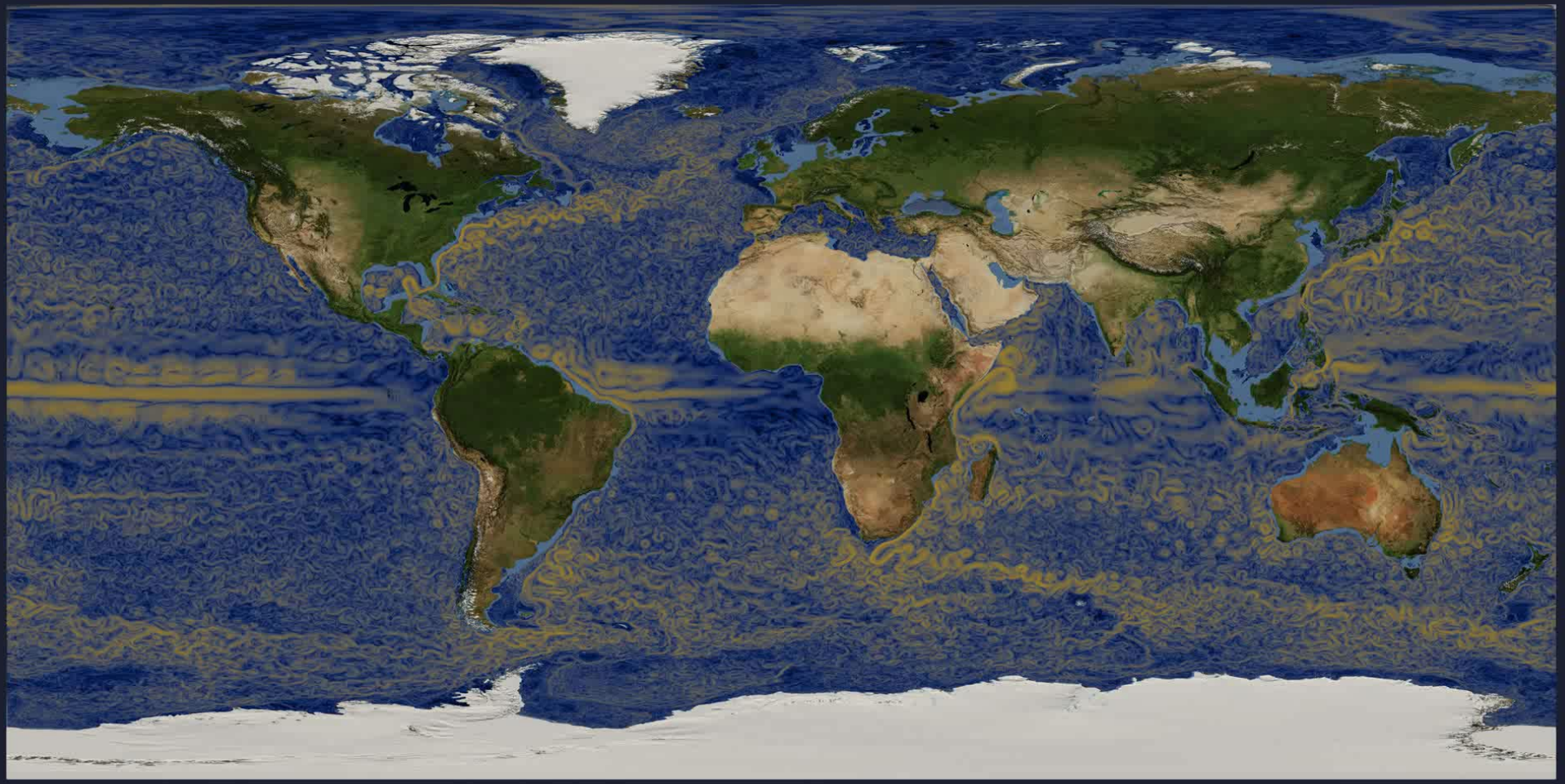
See, understand, learn, communicate …

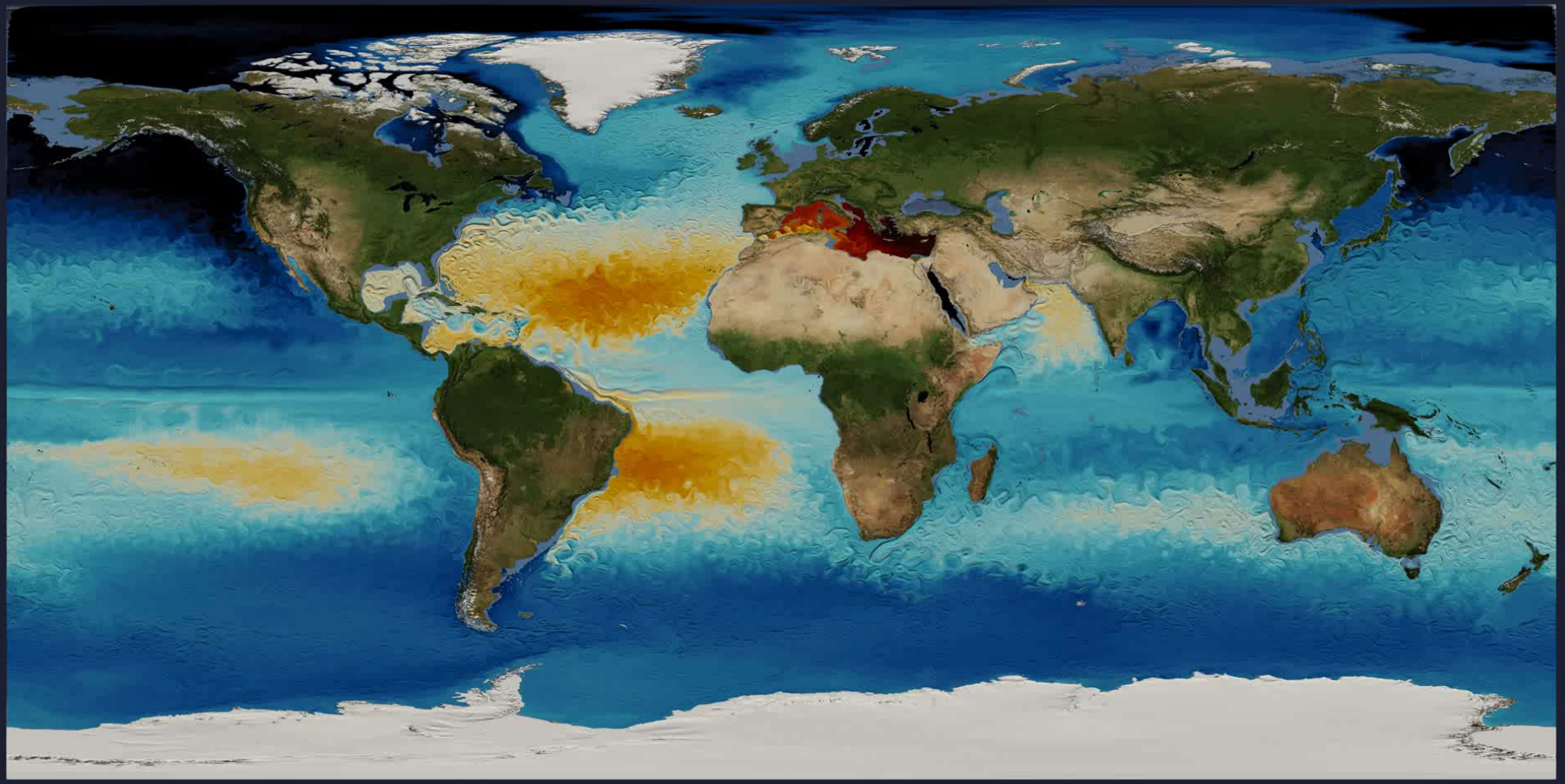
- **Confirmatory** visualization
- **Exploratory** visualization
- Creating animations & stills for **communication**




ICON DYAMOND R2B10 2.5km Resolution
01.08.2016 at 00:00
Vertically Integrated Cloud Water
0.005 0.01 0.02 0.05 0.1 0.2 0.5 1 2 5 10
Vertically Integrated Cloud Ice
0 0.5 1 1.5 2 2.5 3




Horizontal Velocity (m/s)
0.0 0.005 0.01 0.02 0.05 0.1 0.2 0.5 1 2 5 10 20 25.0


Salinity (PSU)
33.0
33.5
34.0
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35.0
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36.0
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37.0
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38.5
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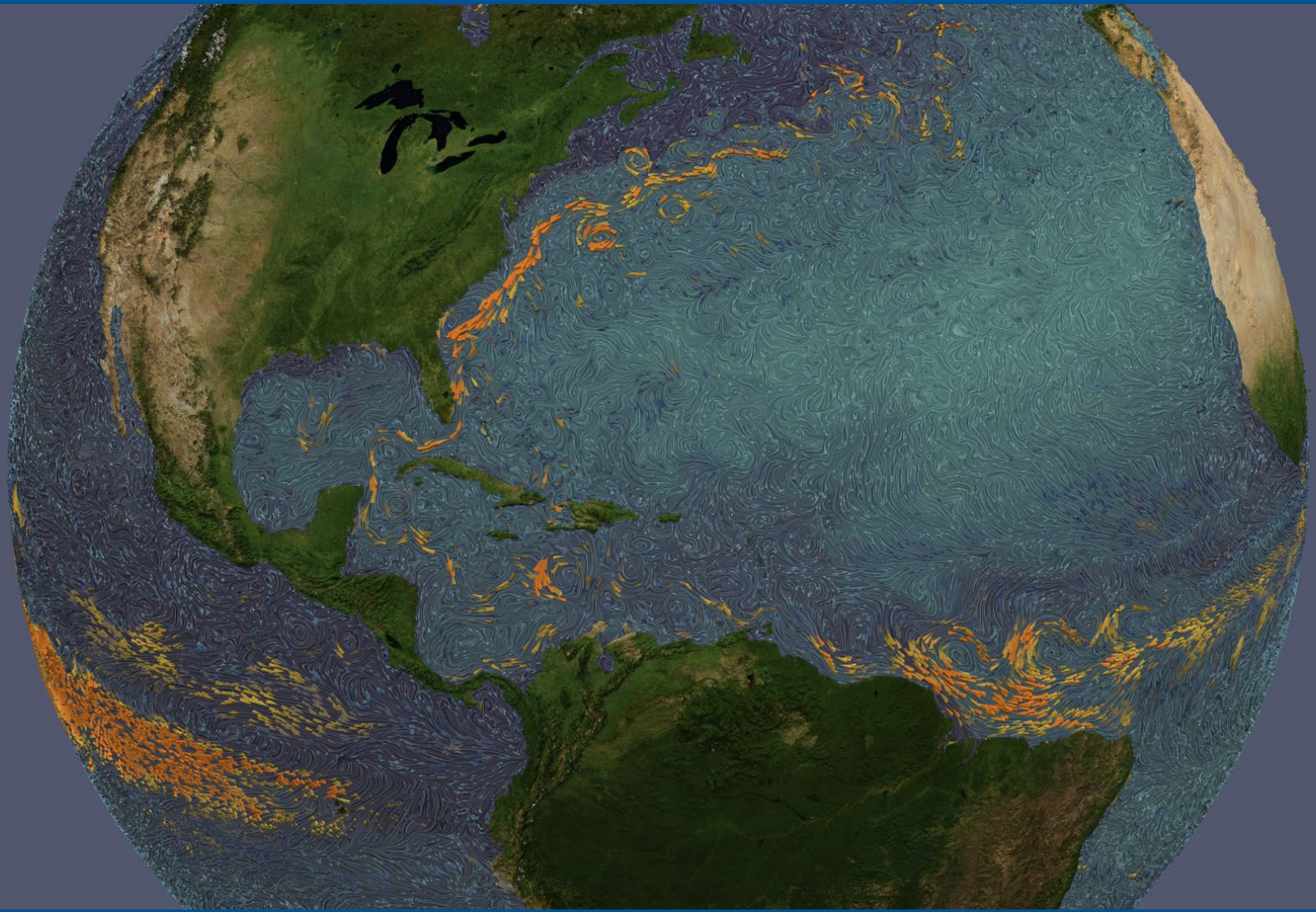
3.9e+01
38.5
38
37.5
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36.5
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34.5
3.4e+01
so
1.0e+00
0.9
0.8
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0.3
0.2
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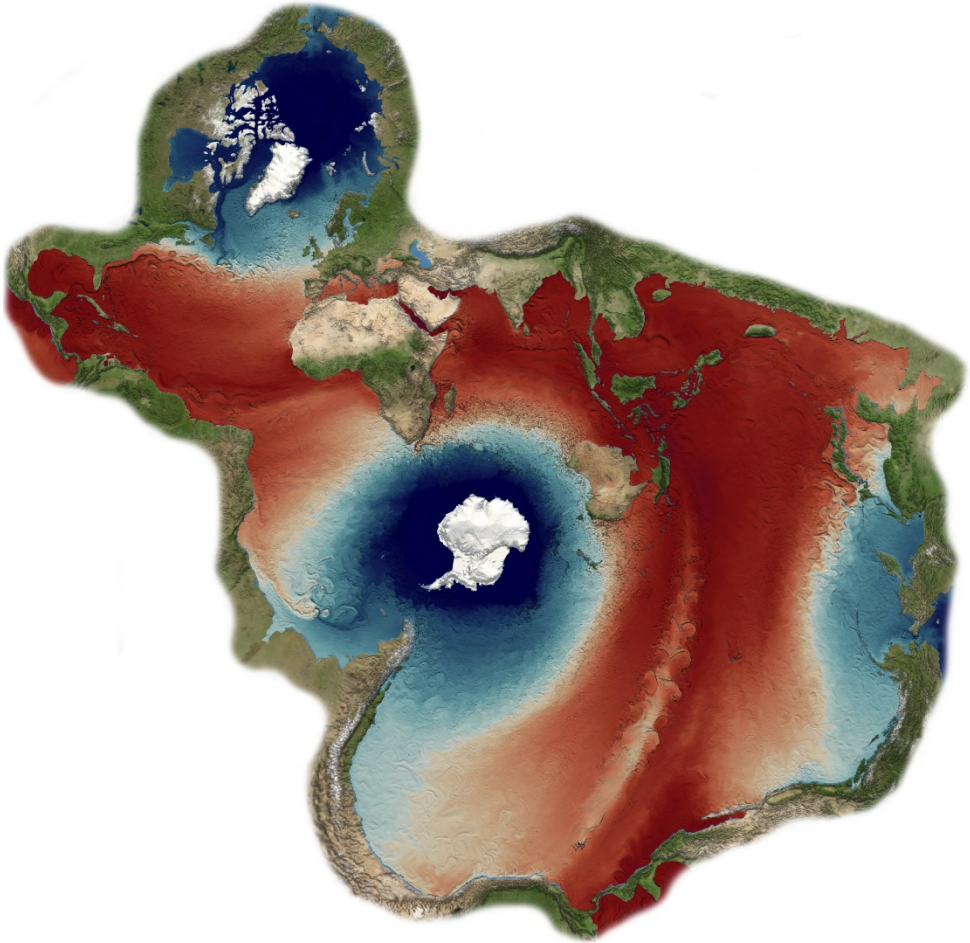
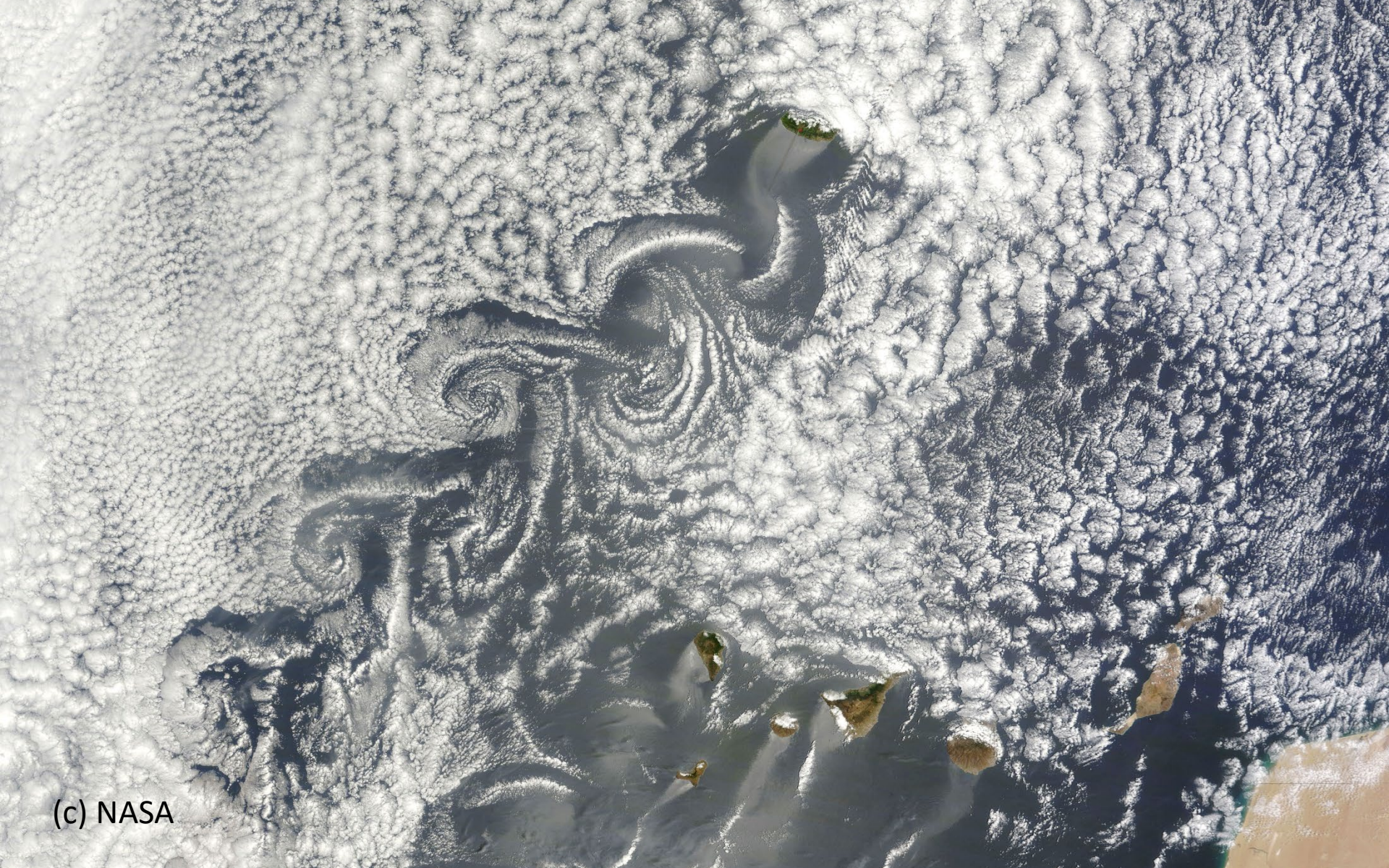
mag

Spilhaus Projection

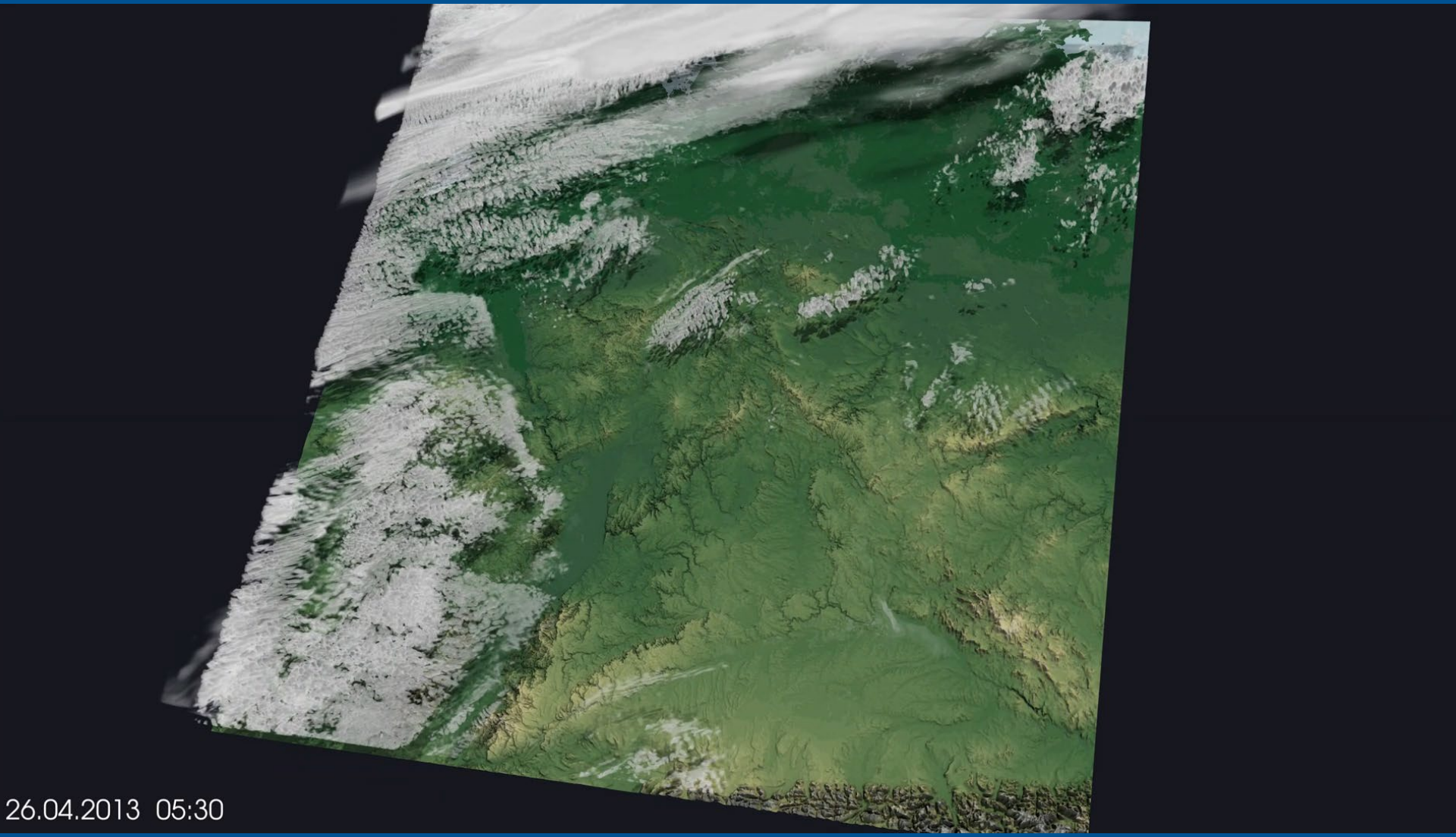



(c) NASA

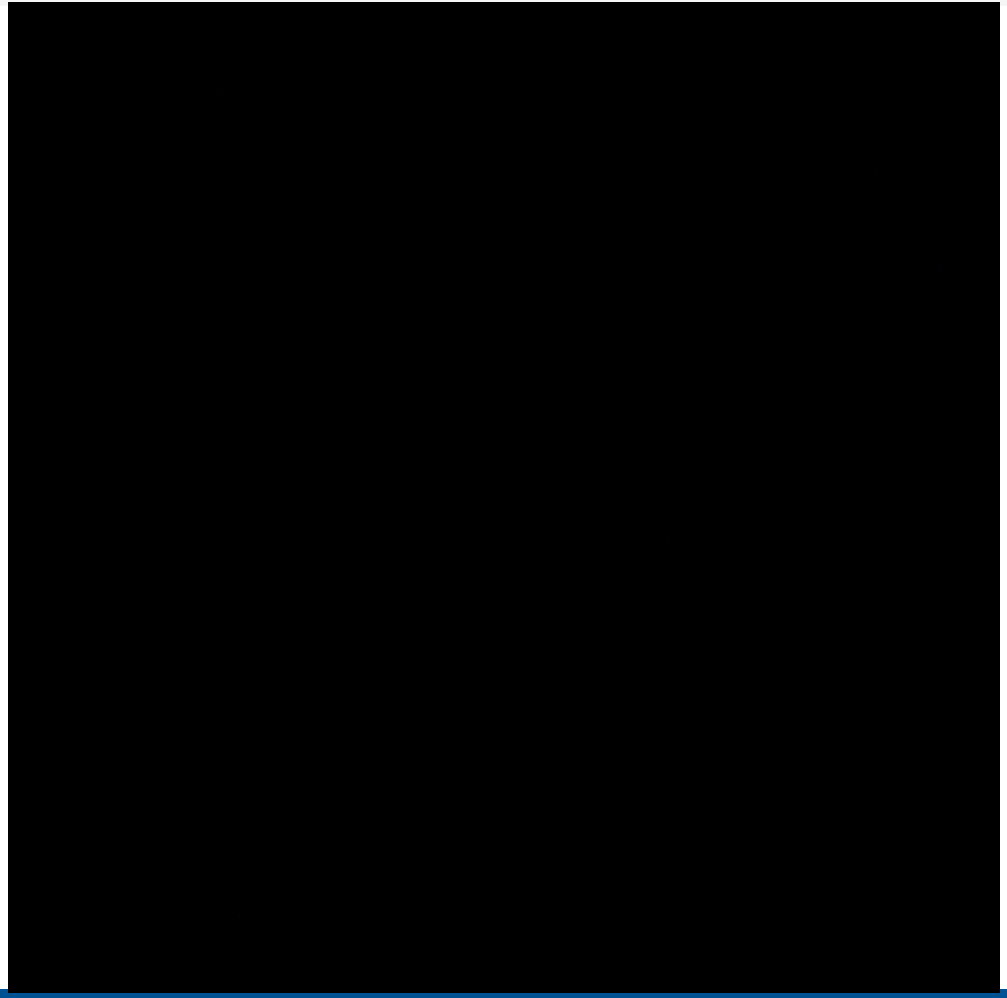
Canary Islands

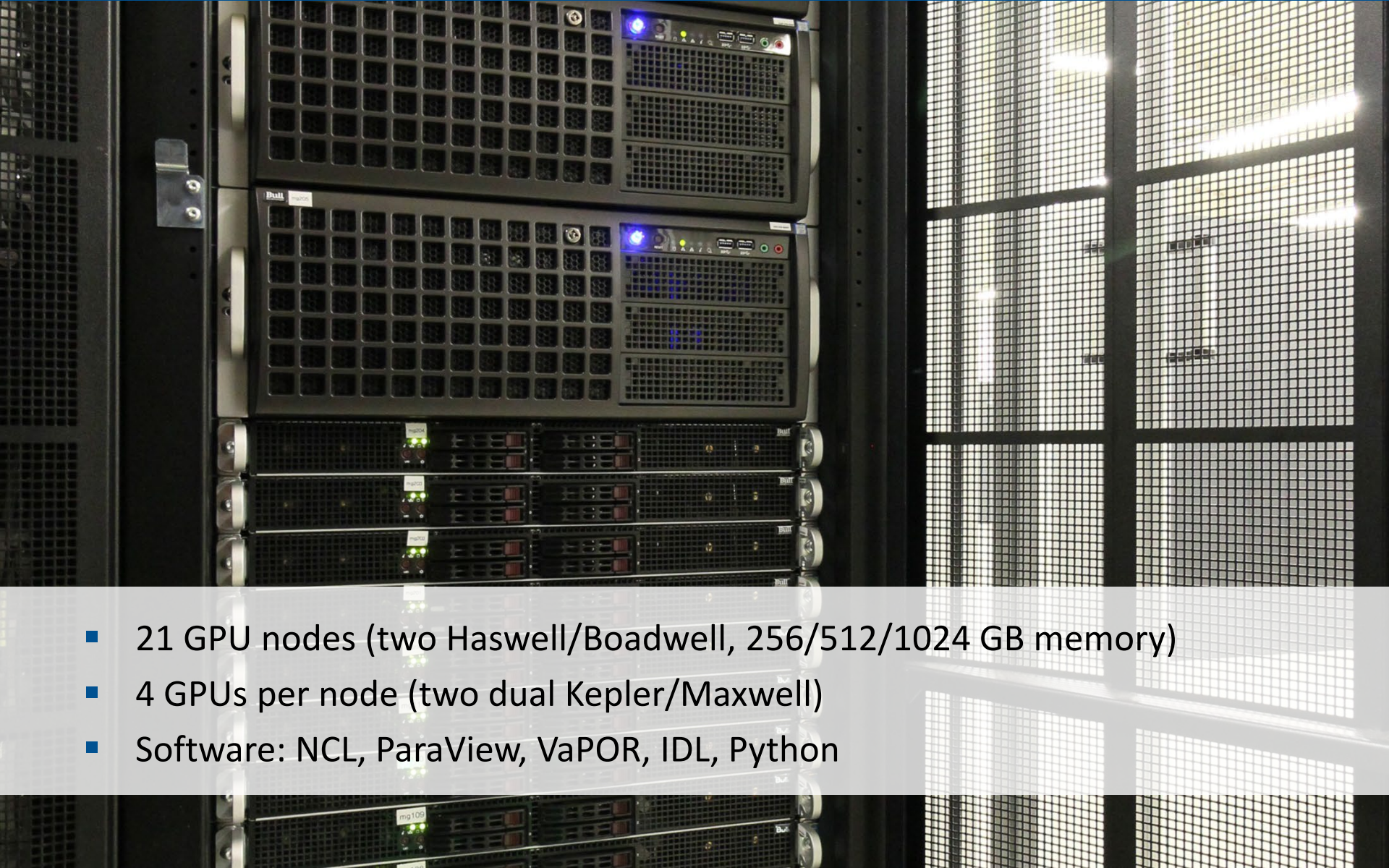
DYAMOND R2B10 - 2D Wind Visualization
(3 Minute Output - 10m Height)


Sea Surface Height (m)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1
Velocity Magnitude (m/s)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5


26.04.2013 05:30

ICON Earth System Model (D++ Setup)





- 21 GPU nodes (two Haswell/Boadwell, 256/512/1024 GB memory)
- 4 GPUs per node (two dual Kepler/Maxwell)
- Software: NCL, ParaView, VaPOR, IDL, Python

Visualization Software on Mistral

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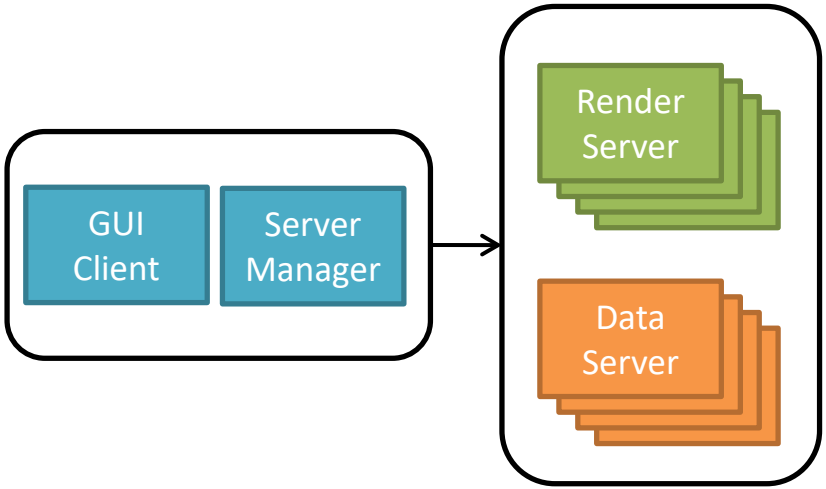
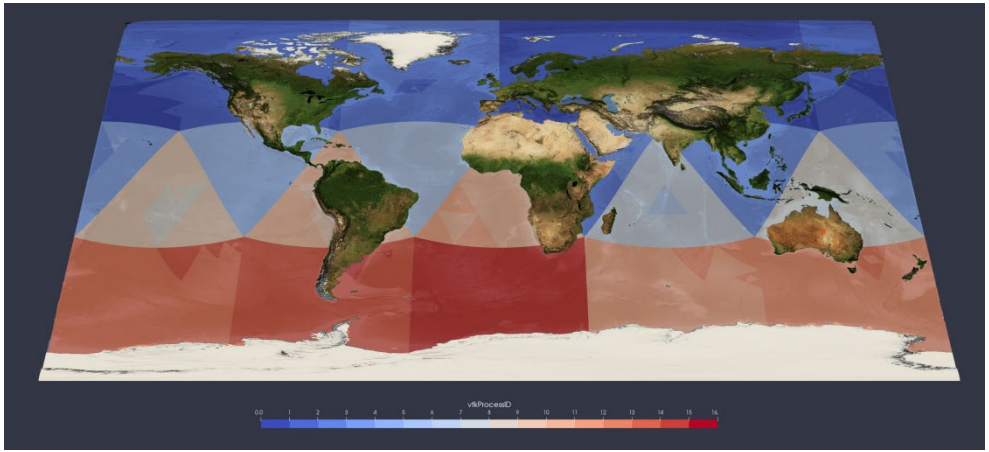
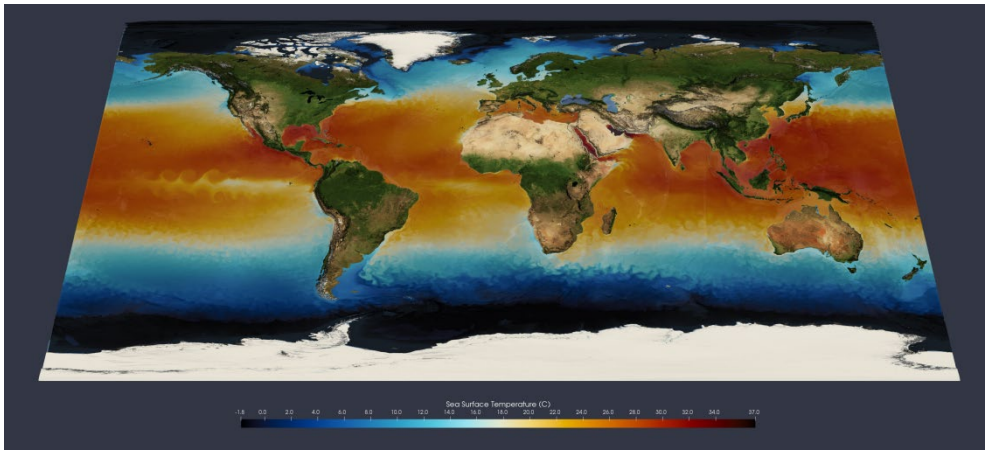
Type	Name	URL	Properties	
Domain-specific	**NCL**	http://www.ncl.ucar.edu/	2D script-based	free
	IDV	http://www.unidata.ucar.edu/software/idv/	2D/3D interactive GUI	free
	Vapor	https://www.vapor.ucar.edu/	3D interactive GUI	free
	UV-CDAT	http://uvcdat.llnl.gov/	Collection: 2D /3D tools	free
	GrADS	http://cola.gmu.edu/grads/	2D script-based	free
	GMT	http://gmt.soest.hawaii.edu/	2D script-based	free
	PyNGL / PyNIO	https://www.pyngl.ucar.edu/Download/	2D script-based	free
General-purpose	**ParaView**	http://www.paraview.org/	3D interactive GUI	free
	Visit	https://visit.llnl.gov/	3D interactive GUI	free
	Avizo	https://www.fei.com/software/avizo3d/	3D interactive GUI	$$
	IDL	http://www.harrisgeospatial.com/	2D script-based	$$
	Python / matplotlib	http://matplotlib.org/	2D script-based	free

Parallel Processing and Visualization



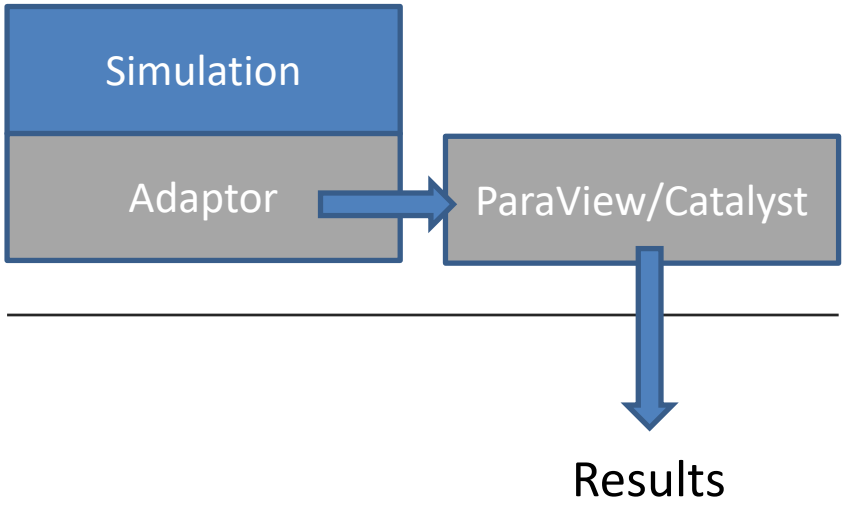




Large Data Visualization

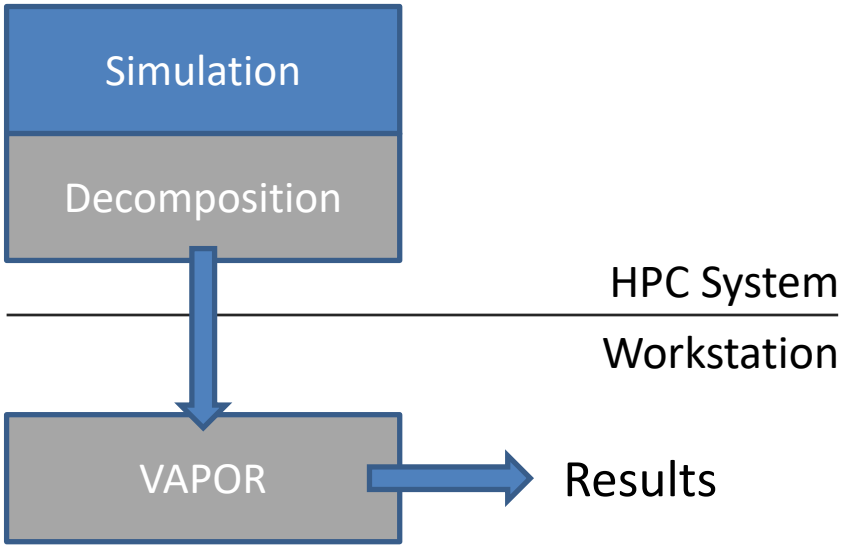
In Situ Visualization

(ParaView/Catalyst)

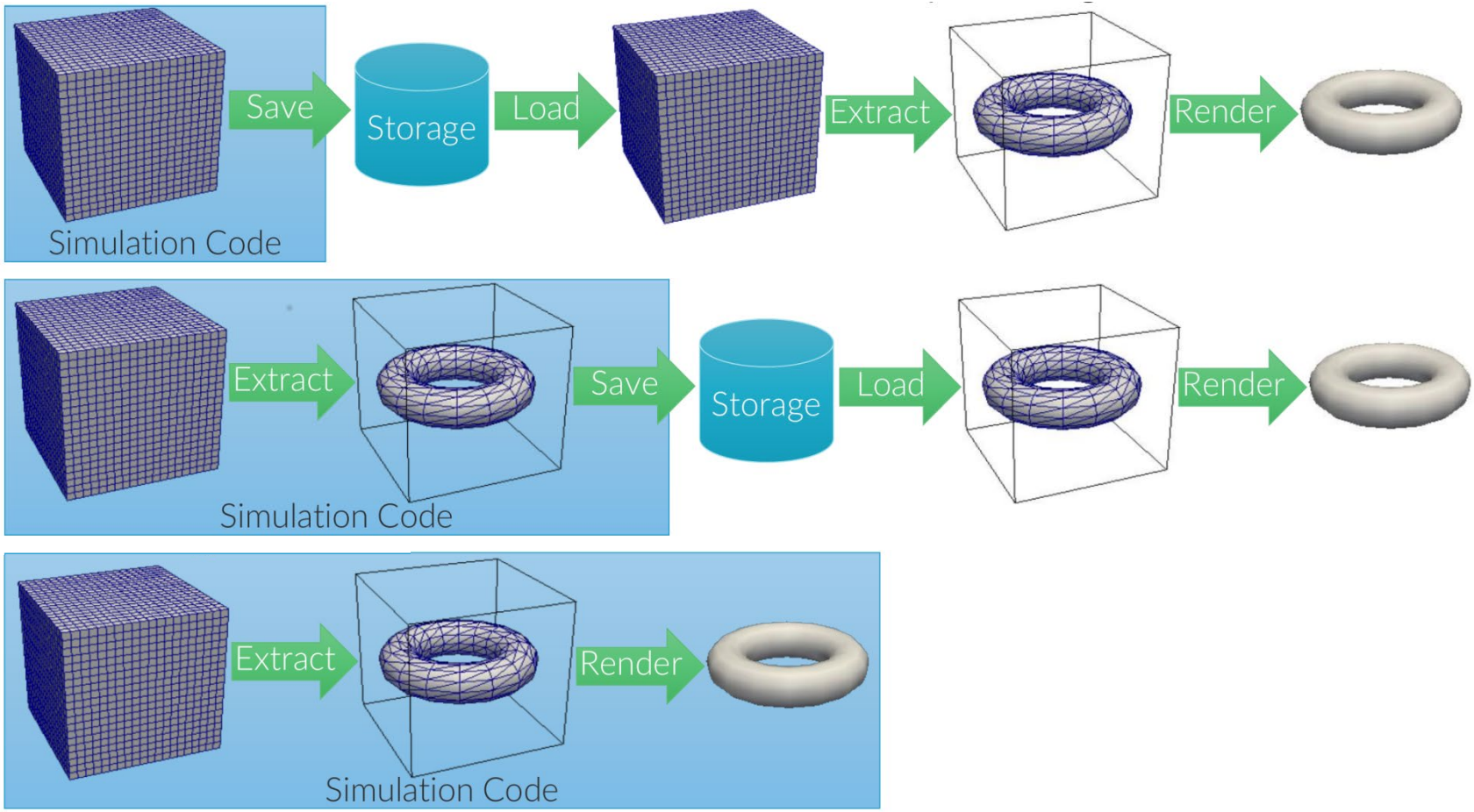


Progressive Visualization

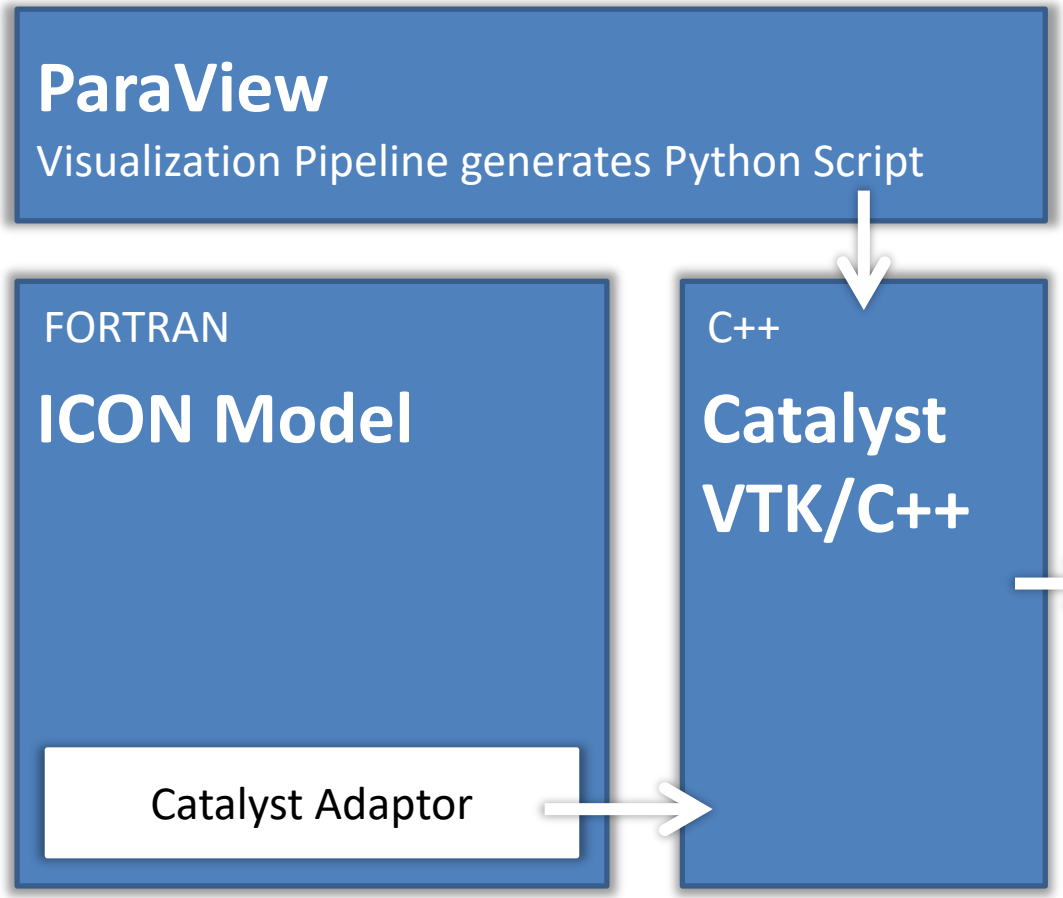
(VAPOR)



From Post Visualization to In-Situ



ICON and Catalyst Adaptor



- Rendered images
- Cinema database
- Data reduction (par. I/O)
- Feature det./tracking
  (e.g. cloud classification)
- Live visualization
- Data decomp./comp.

Advantages

- Much less I/O
  -> Simulation faster / less disk
- Preview of data
- In situ feature tracking
- Analyze extremely large simulation “output”
- Time to knowledge shorter

Drawbacks

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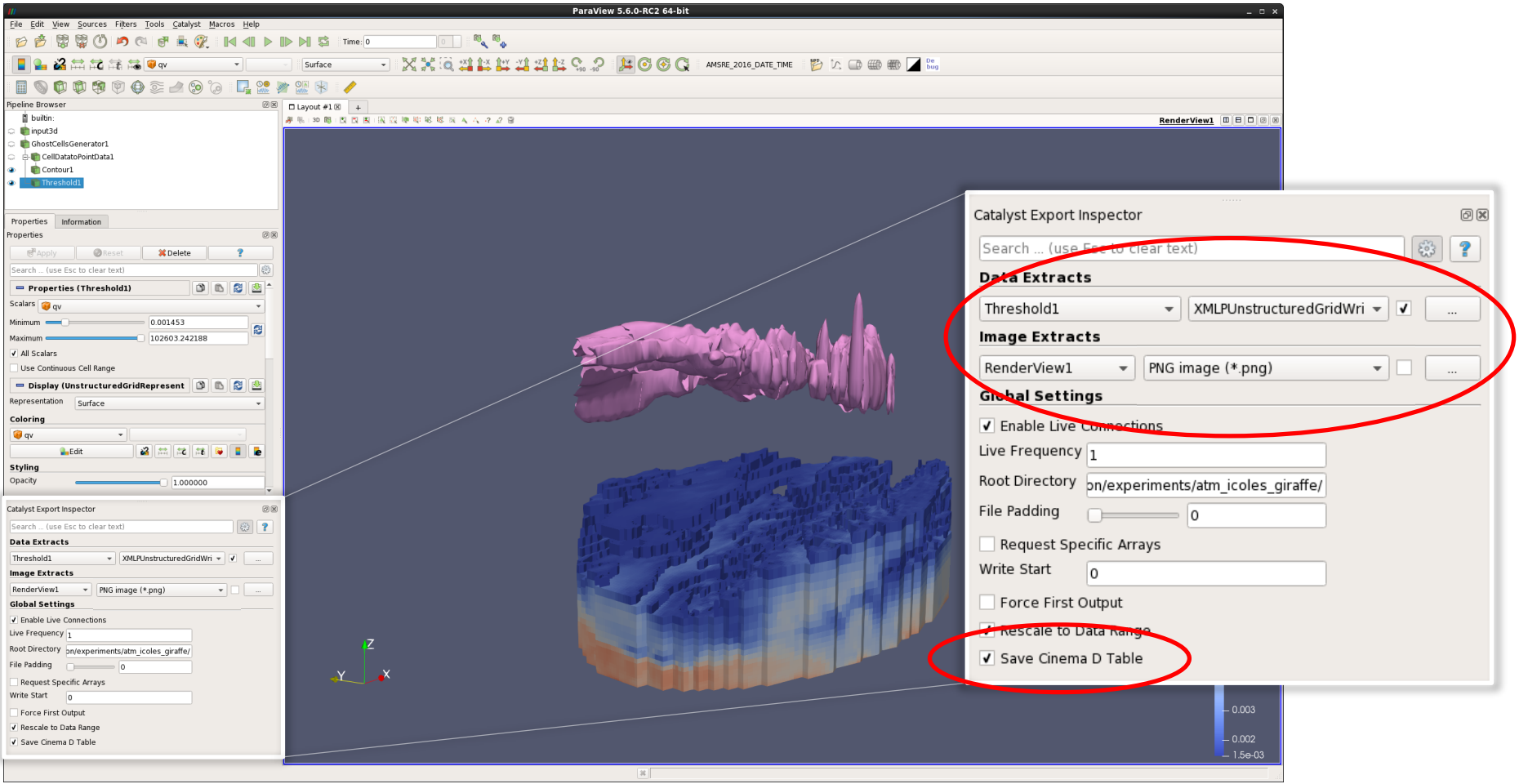
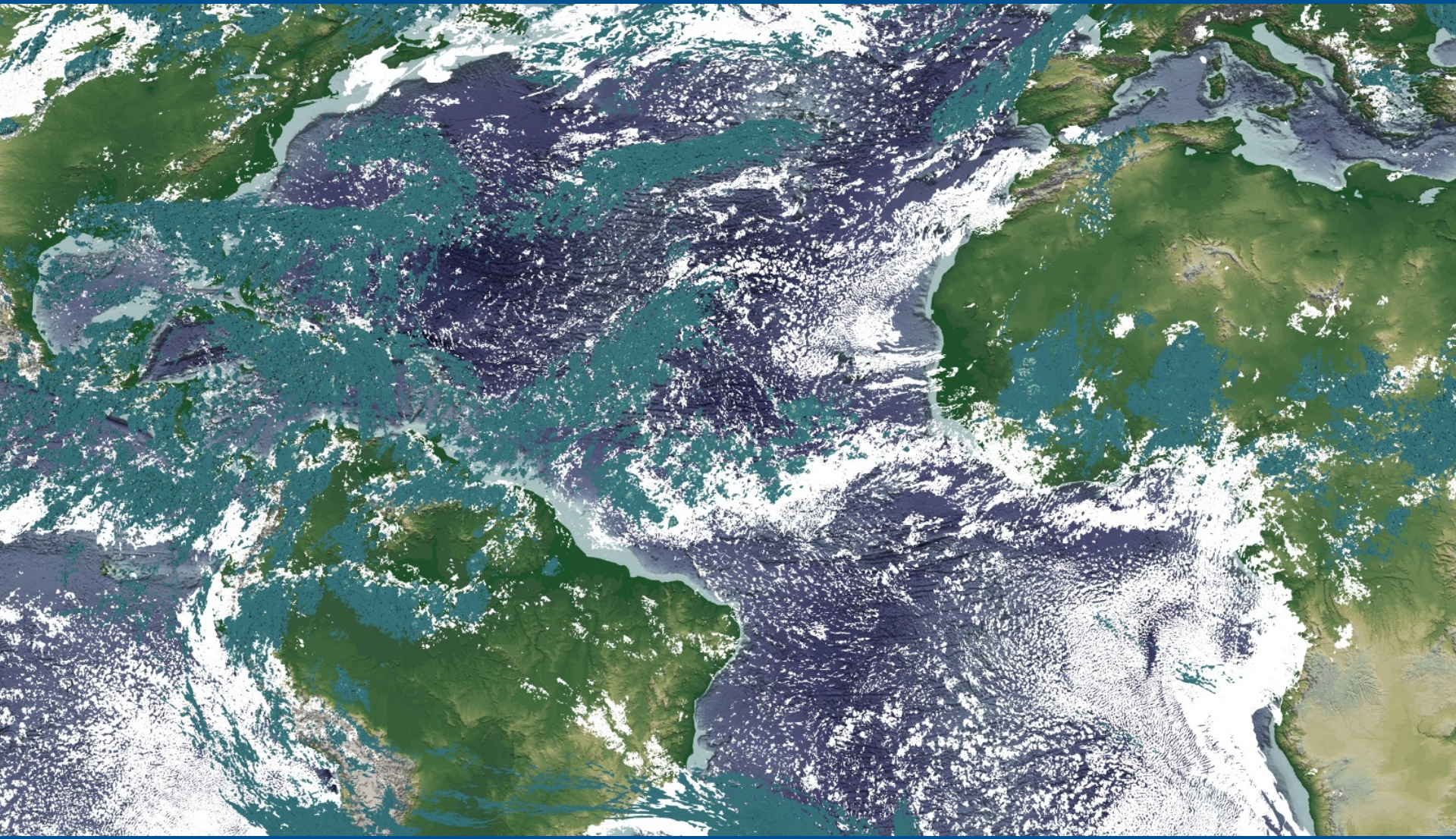
- Additional resources required
- A priori knowledge needed
- Need to run sim/vis again for new analysis/visualization
- Workflow complexity increases
- Statistical analysis more complex

Generating a Catalyst Script





Cinema:Explorer

cinema.dkrz.de/explore/

Suchen

Cinema:Explorer

Select Database: amip Load

Smooth Lines

timestep producer Contour1 theta phi

4992 out of 4992 results selected

Image Spread | Scatter Plot | Line Chart

Results Per Page: 25 Sort By: timestep Reverse Sort Order: Group equal values:

Image Size: 150px

Index: 5
timestep: 0.000000e+00
producer: view_0
Contour1: undefined
theta: 35
phi: -180
FILE: cinema/R2B10/0.000000e+00/-180/35.png

1 11 > >|
1 / 200

Implementation & Status

- Started refactoring other in-situ code -> too complex
- Started fresh -> few hundred lines in FORTRAN and C++ with minimal changes to ICON
- Zero copy arrays FORTRAN -> C++
- Tightly coupled (in line) w/ even number of sim/vis processes

- Prototype available on Mistral for ICON
- Development of workflows

Timings R2B10 – 2.5km global / 540 nodes

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name	# calls	t_min	min r	t_avg	t_max	max r	total min (s)	total min r	total max (s)	total max rank
total	4305	06m48s	[6	**06m48s**	48s	[3919]	408.010	[6	**408.027**	[3919]
L wrt_output	8610	0.00778s	[17		090s	[3239]	23.707	[14		[2838]
L integrate_nh	344400	3.9458s	[34		784s	[256]	347.016	[34		[0]
L nh_solve	1722000	0.29028s			131s	[216]	156.504	[20		[47]
L nh_hdiff	344400	0.09548s	[13		944s	[420]	8.426	[21		[1852]
L physics	344400	0.53099s	[4	**0.02430s**	728s	[2598]	57.132	[4	**2.037**	[2831]
....										
L insitu_set_var	344400	0.01999s		**0.06853s**	760s	[221]	1.663		**10.067**	[126]
L insitu_do_work	340095	0.00014s	[10	**1.6174s**	341s	[0]	5.312	[23	**2.033**	[0]
L insitu_do_work1st	4305	1.5387s	[22		325s	[0]	1.539	[22		[0]
....										
model_init	12915	1.5042s	[17	**01m11s**	001s	[1672]	214.388	[19	**215.458**	[885]
L insitu_init	4305	4.9177s	[19	**6.1077s**	381s	[4164]	4.918	[19	**6.388**	[4164]

Hands-on Examples with ParaView

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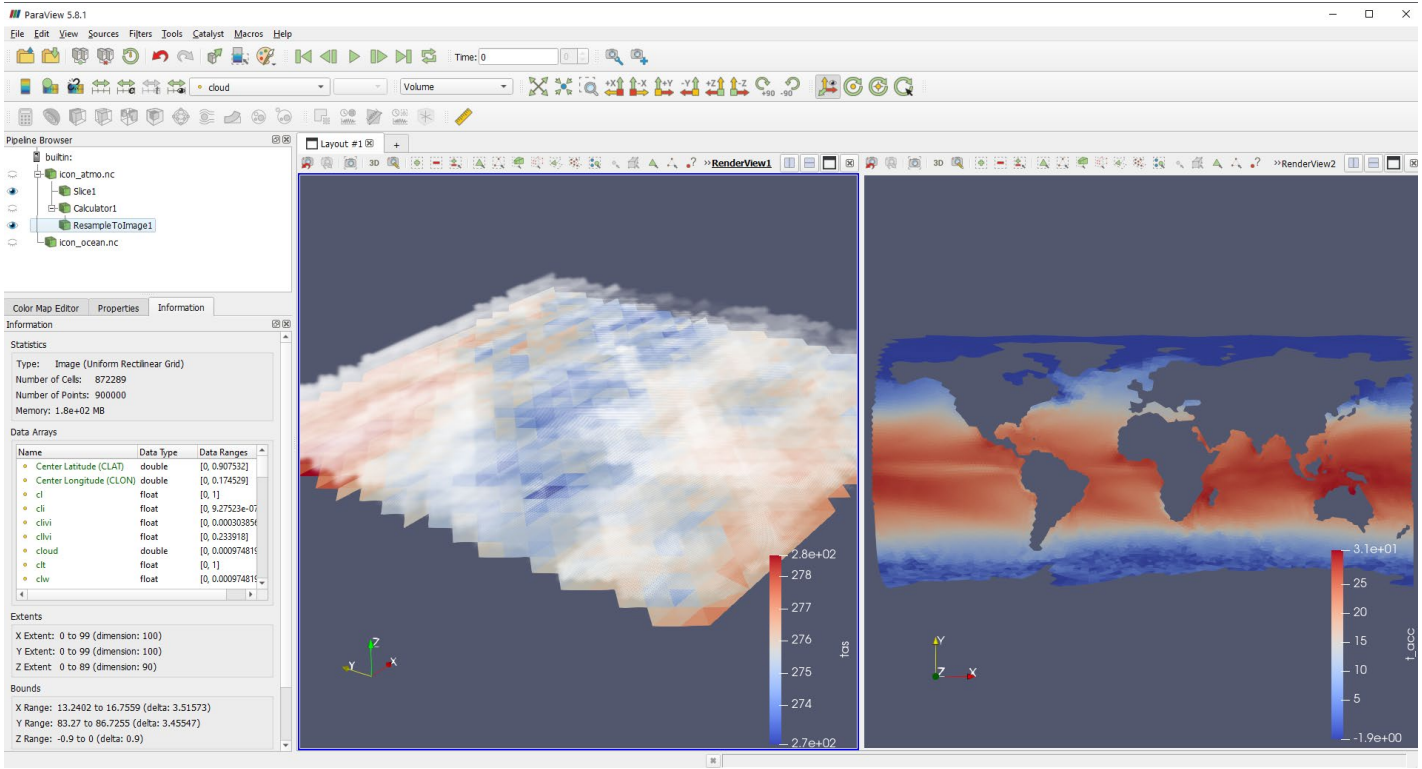

https://nextcloud.dkrz.de/s/LqDFNxyaLBMcyXc

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The projects ESiWACE and ESiWACE2 have received funding from the European Union's Horizon 2020 research and innovation program under grant agreements No 675191 and No 823988.

www.esiwace.eu