VESTEC – Interactive Supercomputing for Urgent Decision Making

FETHPC – Transition to Exascale Computing
Supercomputing for Extreme Data and Emerging HPC Use Modes

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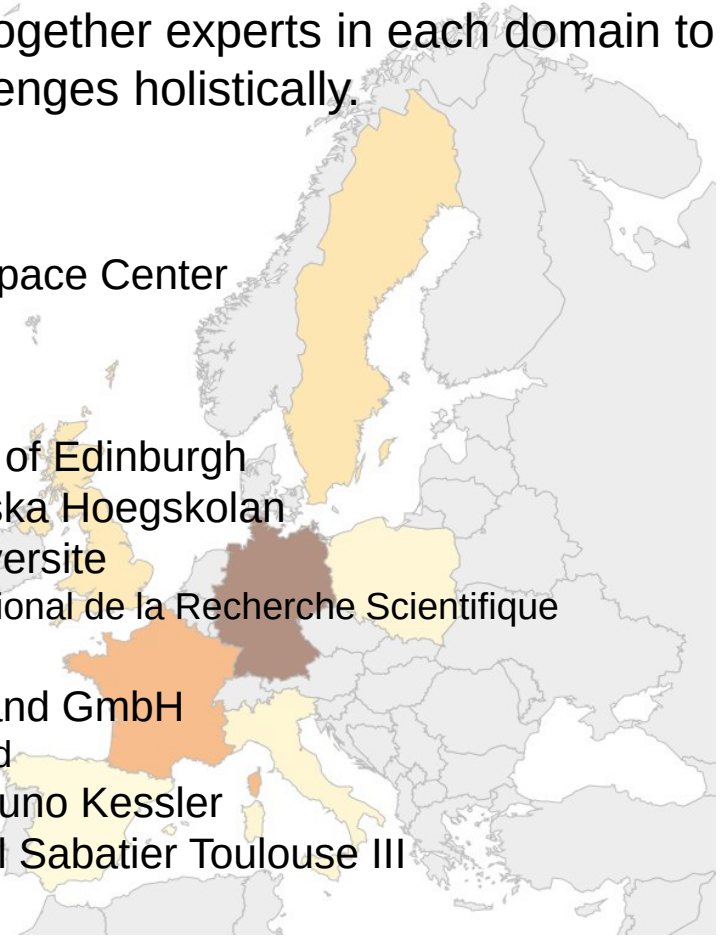
VESTEC – Visual Exploration and Sampling Toolkit for Extreme Computing

Strong Consortium

- VESTEC brings together experts in each domain to address the challenges holistically.

- ***Coordinator:***
  - German Aerospace Center

- ***Partners:***
  - The University of Edinburgh
  - Kunglila Tekniska Hoegskolan
  - Sorbonne Universite
    - Centre National de la Recherche Scientifique
  - Kitware SAS
  - Intel Deutschland GmbH
    - Intel Poland
  - Fondazione Bruno Kessler
  - Universite Paul Sabatier Toulouse III
  - Tecnosylva SL



- High-Performance Computing

- Visualization

- Applications

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The Vision

- ***Objectives***:
  - Urgent decisions to avoid / relief disasters
    - Natural risks (e.g. wild fires, earthquakes, …)
    - Critical clinical diagnostics or spread of diseases
  - Based on high velocity real-time data (e.g. from sensor data networks, Internet of Things)
- ***Available***:
  - Growing opportunities to model and simulate physical, social, or economic phenomena
- ***Goal***:
  - Correlate / enhance simulations with valid sensor data
  - Offer even more precise and reliable predictions

➔ **VESTEC** brings such computational models into complex workflows for **Urgent Decision Making** as emerging HPC use modes!

Fig: Operation room at the Center for Satellite-based Crisis Information (DLR/ZKI).

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Three Use Cases

- Demonstration of the immense benefit for urgent decision making:
  - **Wildfire** monitoring and forecasting
  - **Mosquito-Borne Diseases** risk analysis
  - Effects of **Space Weather** on technical supply chains

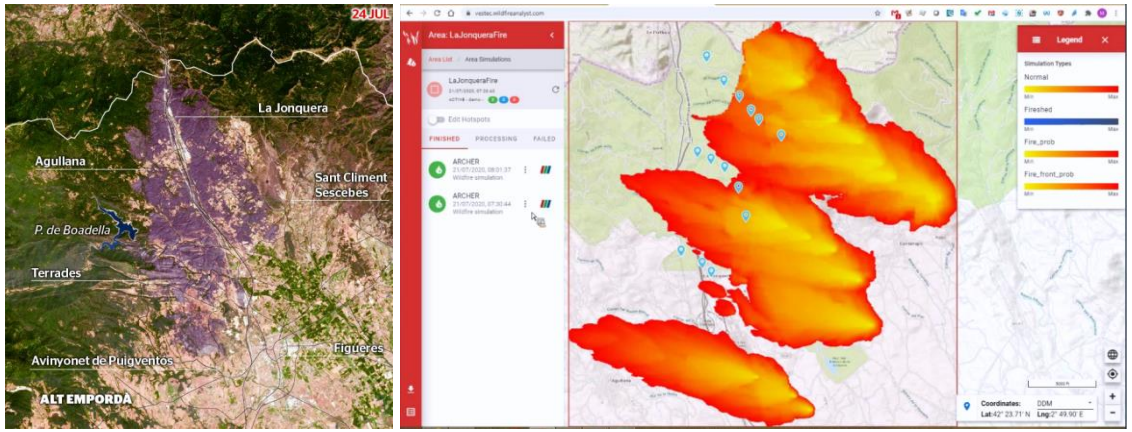

Fig.: "La Jonquera" (Spain, 2012, July 22 – 30)), 10th most destructive forest fire (purple) in Spain (left); Wild Fire Analyst simulation result with manually modified hot spot data (right).

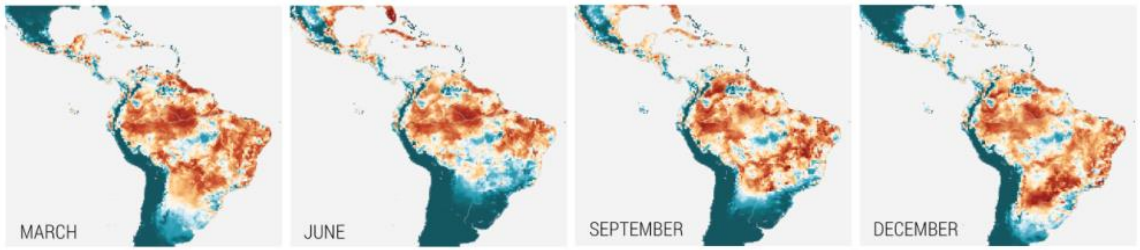

Fig.: Schematic representation of data layers (epidemiological data, temperature, precipitation, population) defining the Mosquito-borne disease.

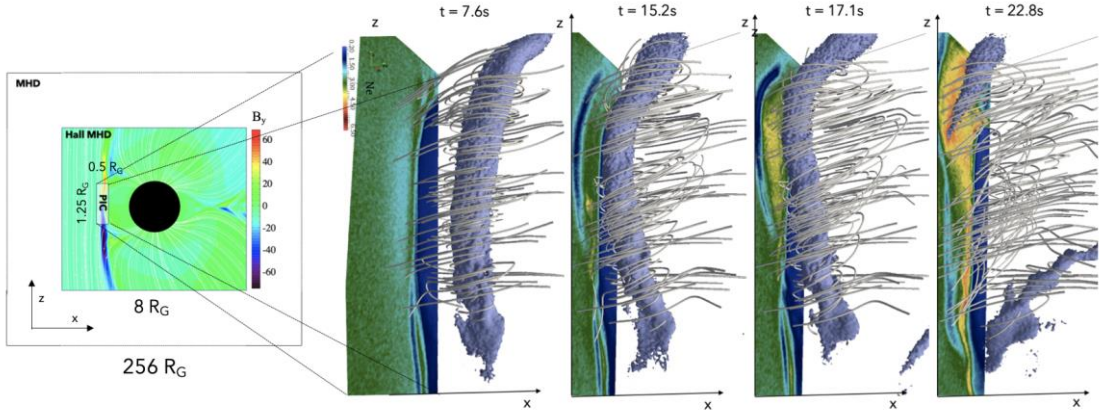

Fig.: Magnetic reconnection is an energetic event that leads to the disruption of the flux rope (structure of high-density plasma (blue) surrounded by magnetic field lines (gray)).

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Urgent Decision Making Workflow

- Detect dangerous or **critical events** from sensor data
- Immediately launch high-precision **forecasts** for monitoring, analyzing, predicting the evolving situation
  - Parametrize simulation models with real-time data
  - Combine simulation models to improve forecasts (e.g. wildfire models with weather simulations)
  - Compute **ensembles** to cover **uncertainties**
  - Use new incoming sensor data
    - To re-initialize simulations or
    - To steer computational models
- Exploit optimized **data analysis** methods and **interactive visualization**
  - Guide the disaster relief forces
  - Offer trends, probabilities, uncertainties
- Integrate **feedback** from crises management center and disaster relief forces to adjust forecast / models

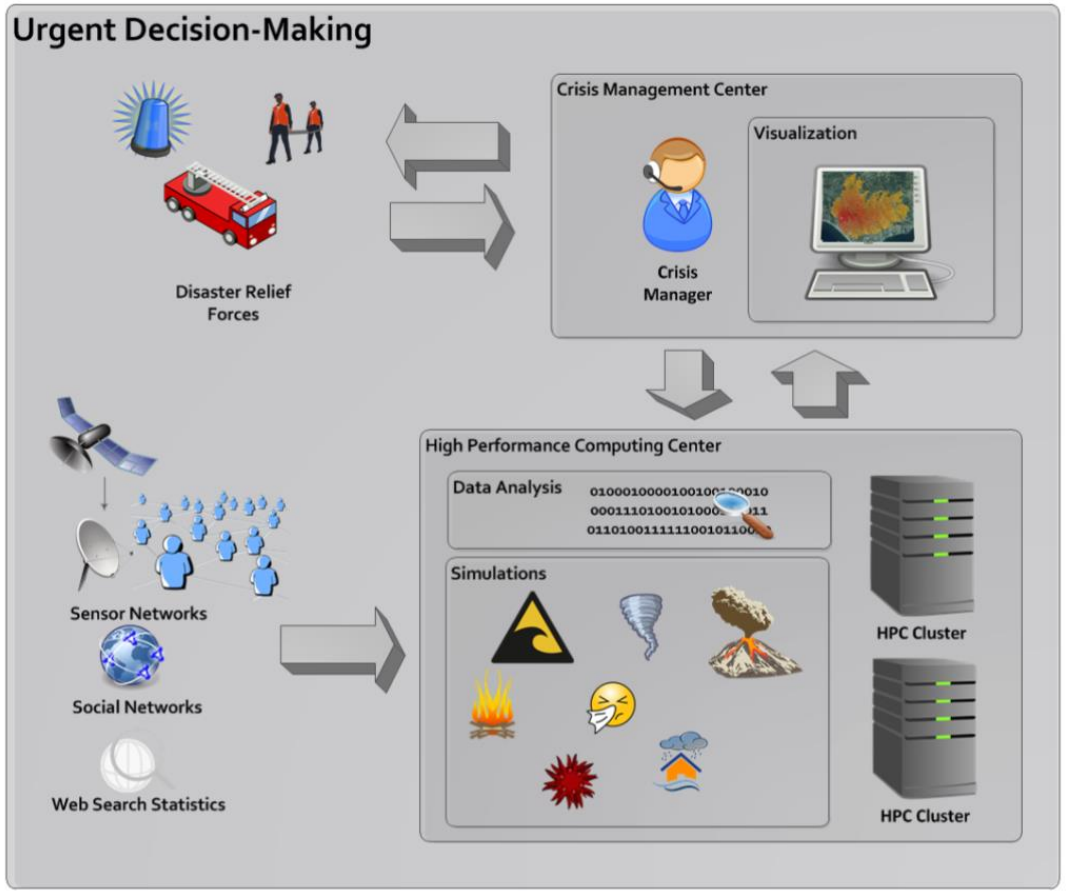

Fig: From sensors to disaster relief force management.

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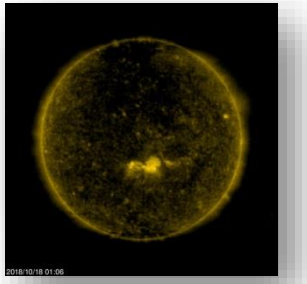
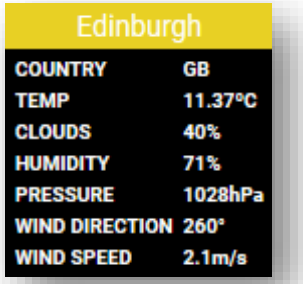
Data Assimilation Process Group

- **Goal**: Integration and processing of high velocity sensor data using HPC environments





- **Challenges**:
  - Streaming data into HPC systems requires new workflow, security, processing and architectural paradigms
    - Cloud techniques
  - Preparation of real-time data for the simulations, e.g.:
    - Classification of land use from satellite imagery (Machine Learning)
    - Impute missing information
    - Quantify uncertainties and noise
    - Adjust temporal and spatial resolution

Fig: ARCHER Cray XC30 cluster at EPCC

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In-Situ Data Processing

- **In-Situ Data Reduction**
  - Compute **topological** relevant **features** from individual simulation steps
  - **Sample** raw **data** from topological proxies (e.g. by computation of pathline snippets)
    - Reduces I/O load for check-pointing
    - Reduces processing and visualization load
  - Transfer reduced data to data analytics group
    - Isolate **most representative** members from **ensembles**
    - Estimate **probabilities** of appearance of new features

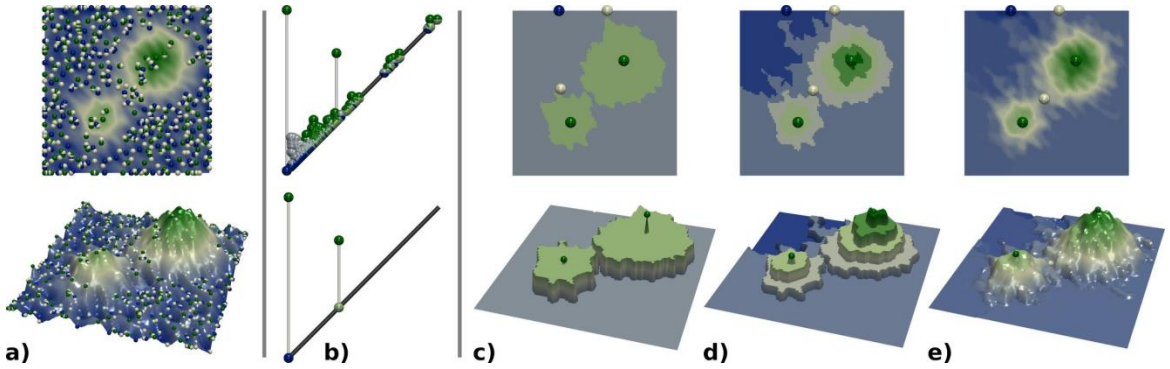

Fig.: Topology-driven data compression of selected ensemble members with topological control (persistence threshold ε of the features to preserve) available in Topology Toolkit (TTK).

- **In-Situ Raytracing**
  - For scalable image generation
  - Fast access to full-resolution simulation data

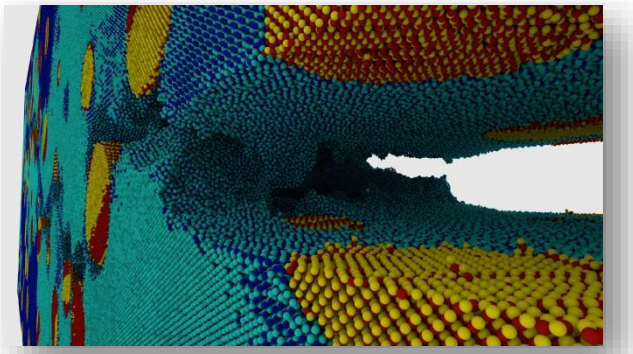

Fig.: Examples of high-fidelity renderings by OSPRay: Several million non-polygonal particles rendered with reflections and ambient occlusion, greatly enhancing depth perception.

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DLR - High-Performance Computing

- **Performance Analysis and Tuning**
  - Investigation of **Use case performance** and **scaling behavior** with state-of-the art measuring tools
  - Identification of **bottlenecks** and possibilities for **performance improvement**
  - Providing direct **feedback** to the use case developers
- **Quality assurance**
  - **integration tests** for all components of the VESTEC system
  - **Automatic monitoring** of workflows**:** Runtimes of **file transfers, local computations and HPC jobs** are automatically stored in the VESTEC data base for **future analysis**

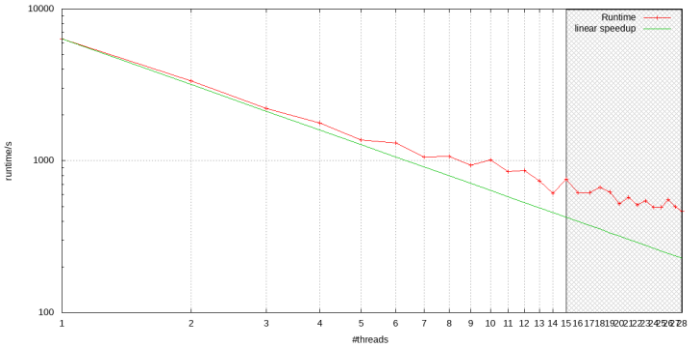

Fig: Single-node scaling of Wildfire simulation

Fig: Output of Likwid performance measurement tool


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__exp1	libm-2.22.so	15%
MTT::MTTClass::ComputeCost(Weather::NetCDFFastValues&, int, int, double)	launcher.exe	12.9%
__cos_avx	libm-2.22.so	4.67%
MTT::MTTClass::MTT_spaceCte(double, int, int, std::vector<Weather::NetC...	launcher.exe	4.57%
void std::__push_heap<__gnu_cxx::__normal_iterator<MTTCte::MTT_reg*, ...	launcher.exe	3.73%
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RotherAddWindSlope(ReturnRothBase&, double, int, int, int)	launcher.exe	1.87%
__sin_avx	libm-2.22.so	1.56%
__tan_avx	libm-2.22.so	1.56%

Fig: Performance of Wildfire simulation by function call

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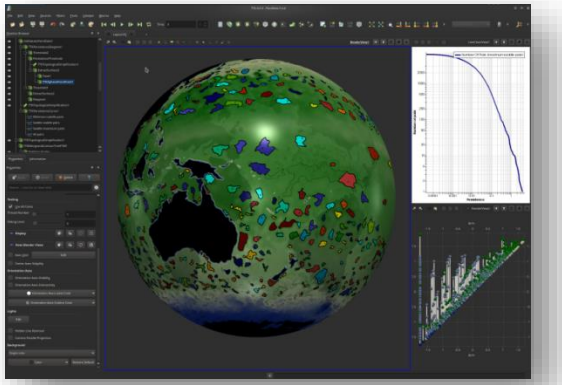
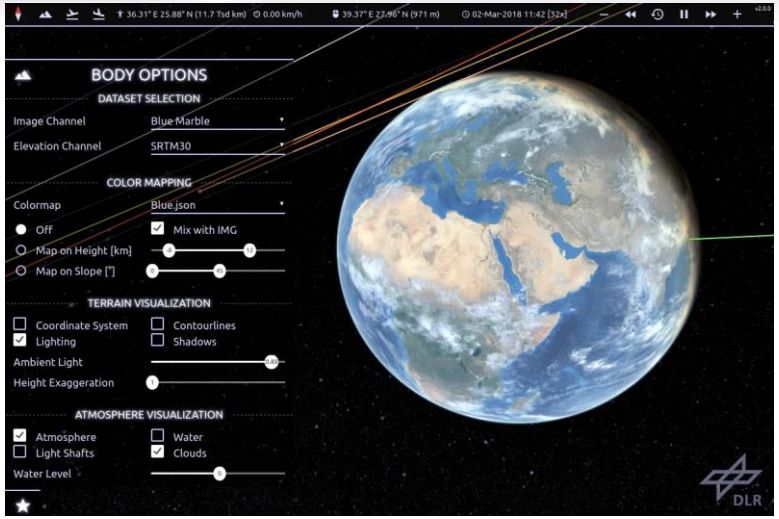
Crisis Management Center

- **Goal**: Real-time explorative and interactive visualization applications
  - ParaView
  - Wildfire Analyst
  - CosmoScout VR
- **Extension**: Exploit topological proxies and sampled data
  - Level-of-detail rendering and streaming
- **Challenges**:
  - Support the analysis of simulation ensembles
  - Consider uncertainties in the process
  - Human computer interaction:
    - Integrate and evaluate efficient user interfaces
    - Consider Virtual Reality (VR) for exploration

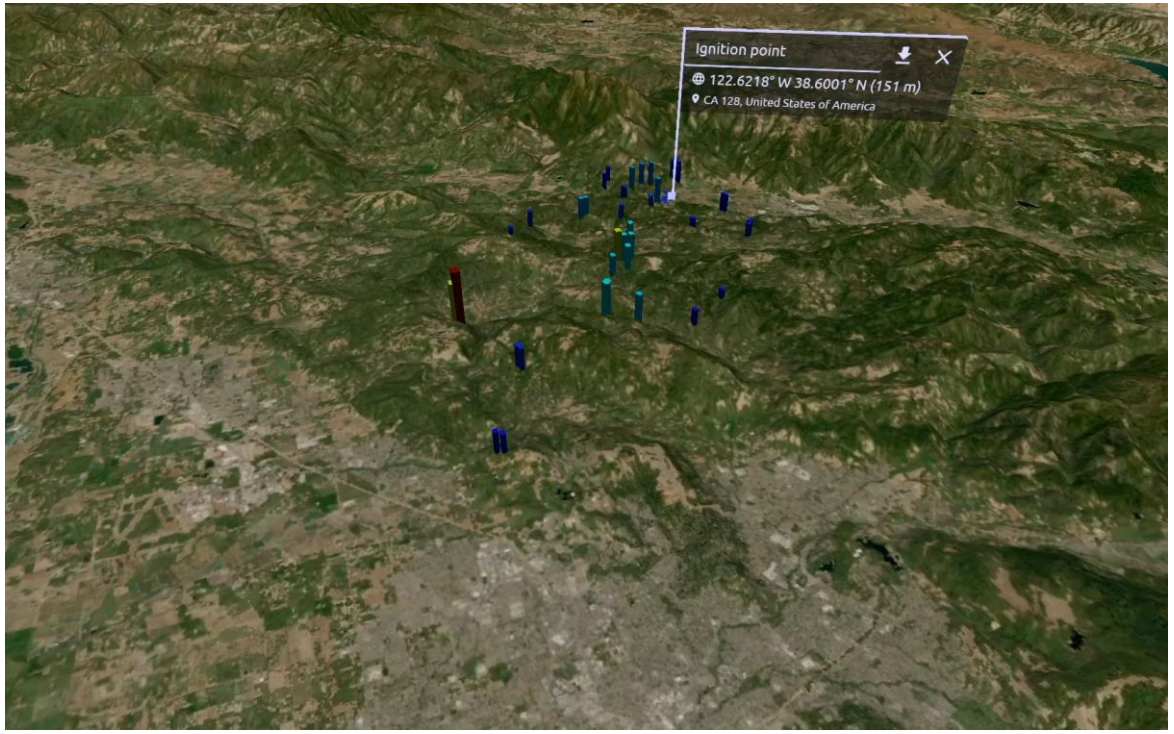




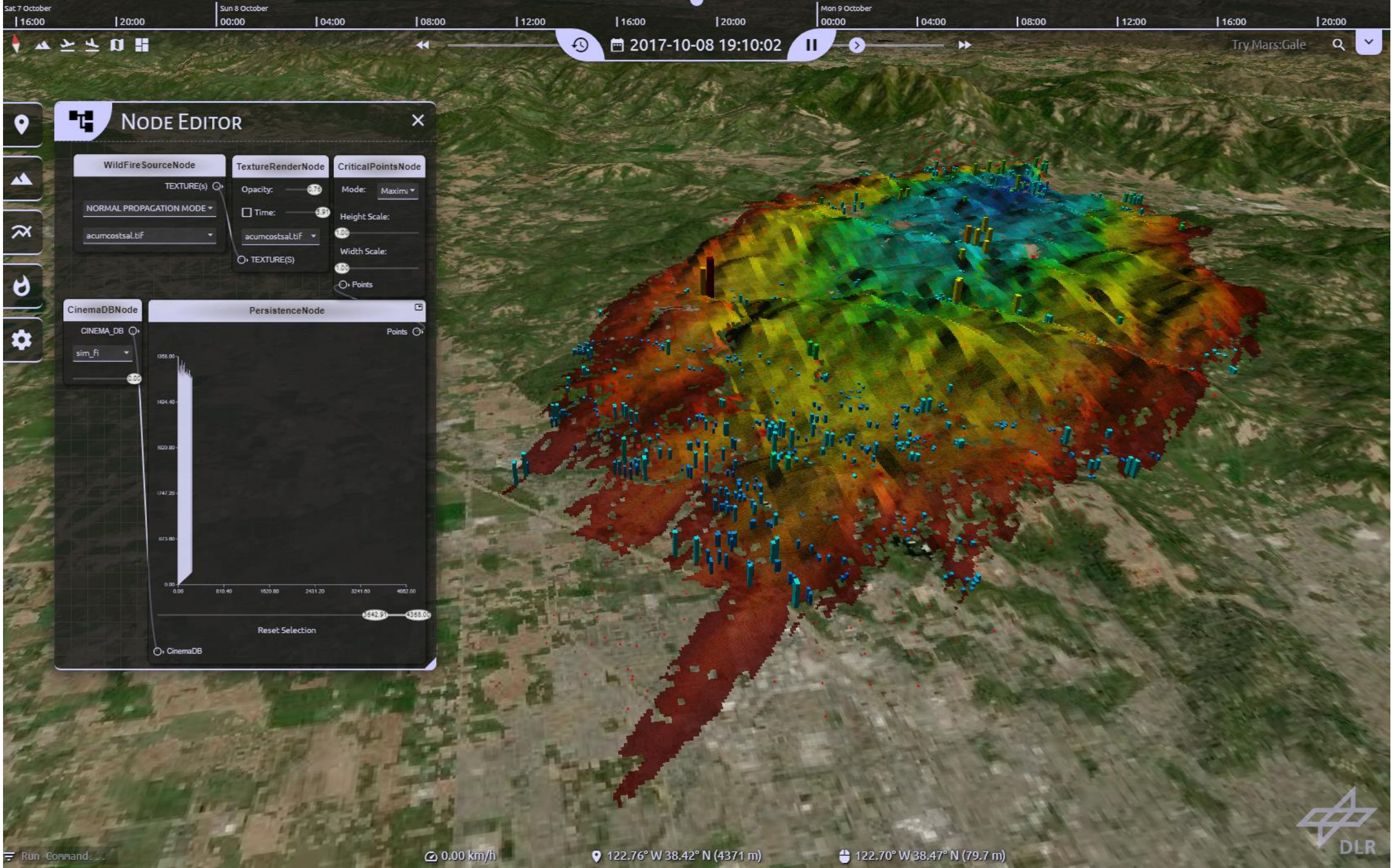
VESTEC Use Case I – Forest Fire

- **Goal**
  - Predict a forest fire to support decision making

- **VESTEC workflow**
  - Select the area of interest
  - Automated analysis of sensor data to get accurate ignition points
    - VIIRS and MODIS satellite information
    - Users can verify and manipulate ignition points
  - Execute a WildFire Analyst based ensemble simulation on the HPC machines
    - Incorporate weather information from MESO-NH
    - Simulate fire propagation, presence probability and fire front probability
    - Augment results by topological information
  - Analyse the results using a graphical user interface
    - Adapt and re-trigger simulation



Video: Analysis of a WildFire Analyst ensemble simulation augmented with topological information. Vertical bars encode the fire intensity at the given locations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Try Mars:Gale
Node Editor
WildFireSourceNode
TEXTURE(s)
NORMAL PROPAGATION MODE
acumcostsal.tif
TextureRenderNode
Opacity:
Time:
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TEXTURE(S)
CriticalPointsNode
Mode:
Maxim
Height Scale:
Width Scale:
Points
CinemaDBNode
CINEMA_DB
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PersistenceNode
Points
Reset Selection
CinemaDB
Run Command...
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122.76° W 38.42° N (4371 m)
122.70° W 38.47° N (79.7 m)
DLR

VESTEC Use Case II – Space weather

- **Goal**
  - Analyse space weather impacts on earth in order to save e.g. power-grids or space infrastructure

- **VESTEC workflow**
  - User defines the initial settings for the simulation
    - Incorporate data from the NASA Magnetospheric Multiscale (MMS) mission
  - The system perturbates the data to create a potentially large number of simulations
  - Execute this ensemble of simulations using iPIC3D
    - In-Situ computation of topological proxies
  - Post-Processing
    - Dimension reduction exploiting the topological proxies
  - Visualize and compare simulation runs using ParaView

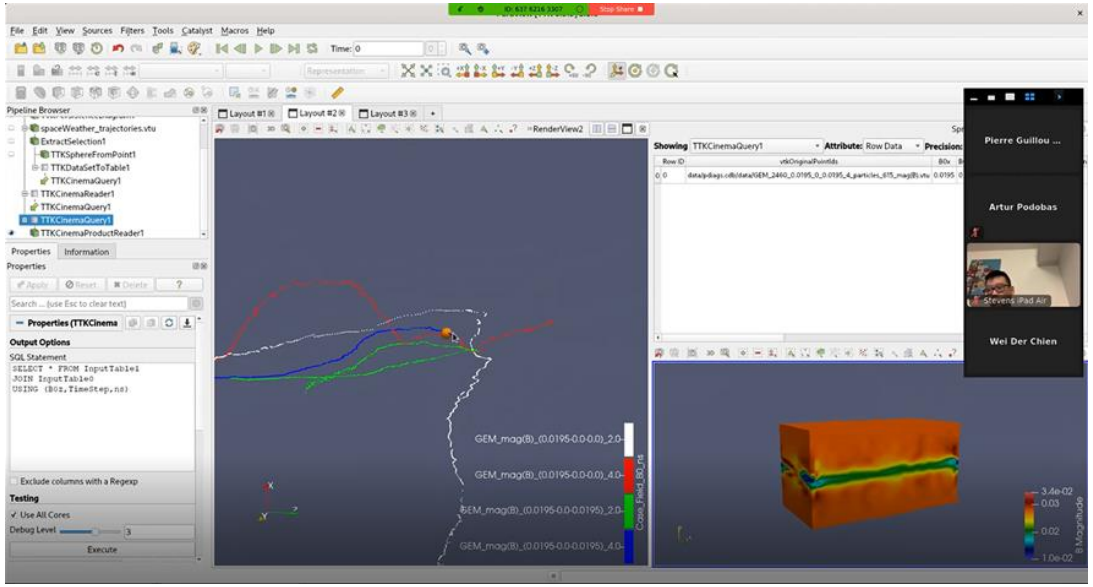
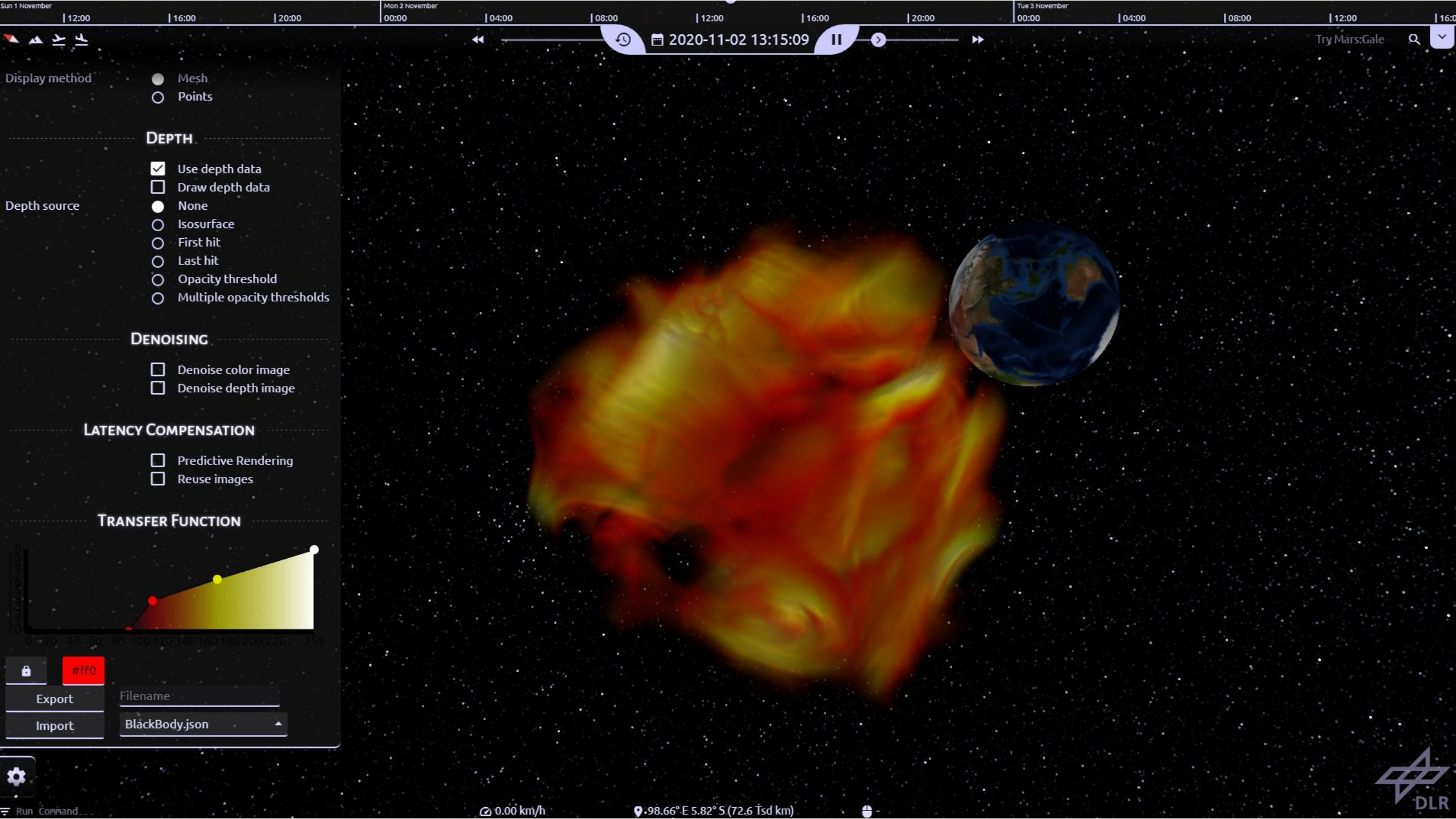


Fig.: Analysis of an iPIC3D ensemble simulation. The lines (middle) enable comparing different simulation runs by using dimension reduction of topological input data.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Try Mars:Gale
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Mesh
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Depth
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Depth source
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First hit
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Opacity threshold
Multiple opacity thresholds
Denoising
Denoise color image
Denoise depth image
Latency Compensation
Predictive Rendering
Reuse images
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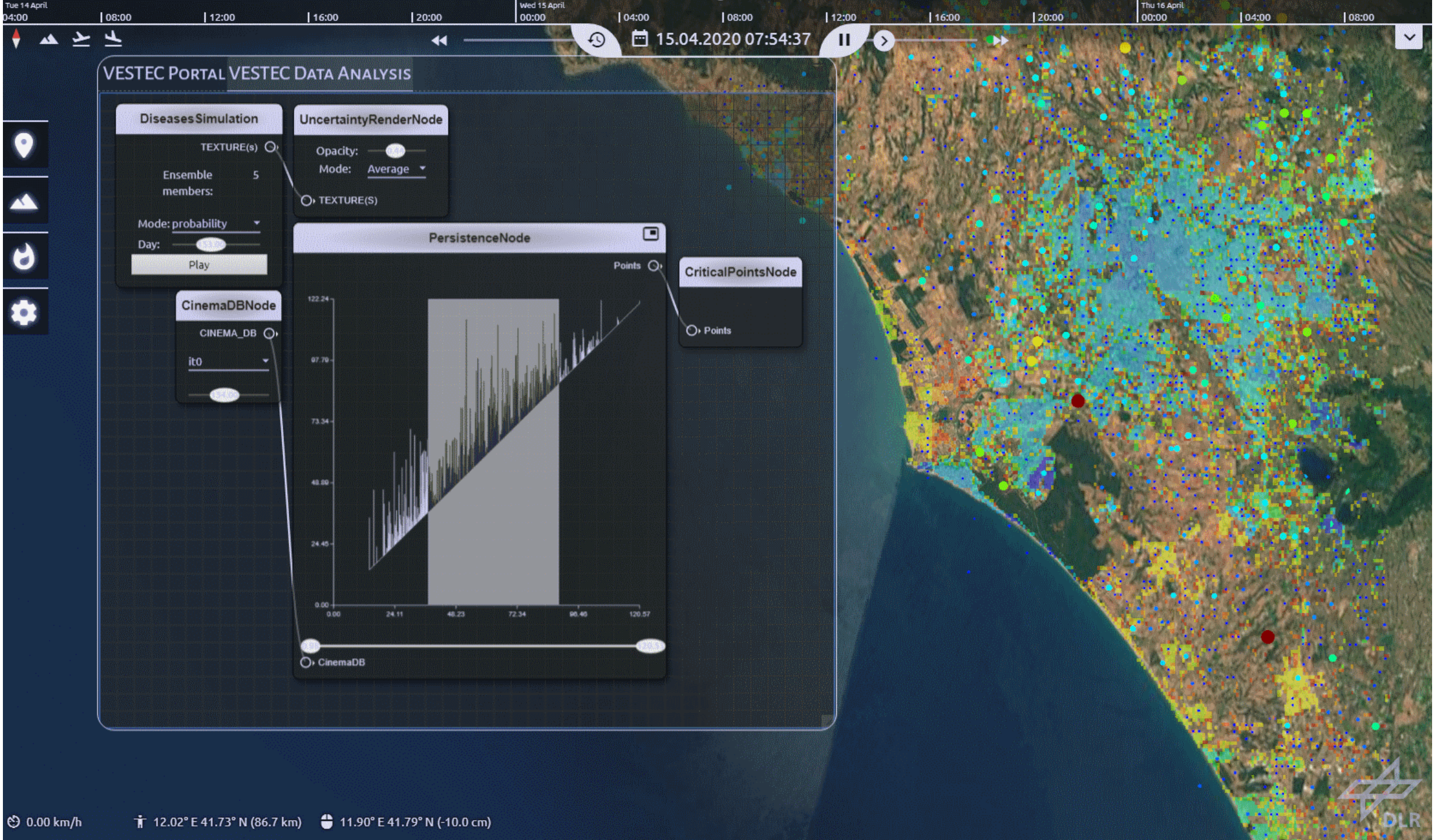
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VESTEC Portal VESTEC Data Analysis
DiseasesSimulation
TEXTURE(s)
Ensemble members:
5
Mode: probability
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UncertaintyRenderNode
Opacity:
Mode:
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TEXTURE(S)
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Points
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11.90° E 41.79° N (-10.0 cm)
DLR

Many thanks for your attention!

Questions?

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