Large-Scale Data Visualization Applications on Tianhe-1A

National Supercomputer Center in Tianjin

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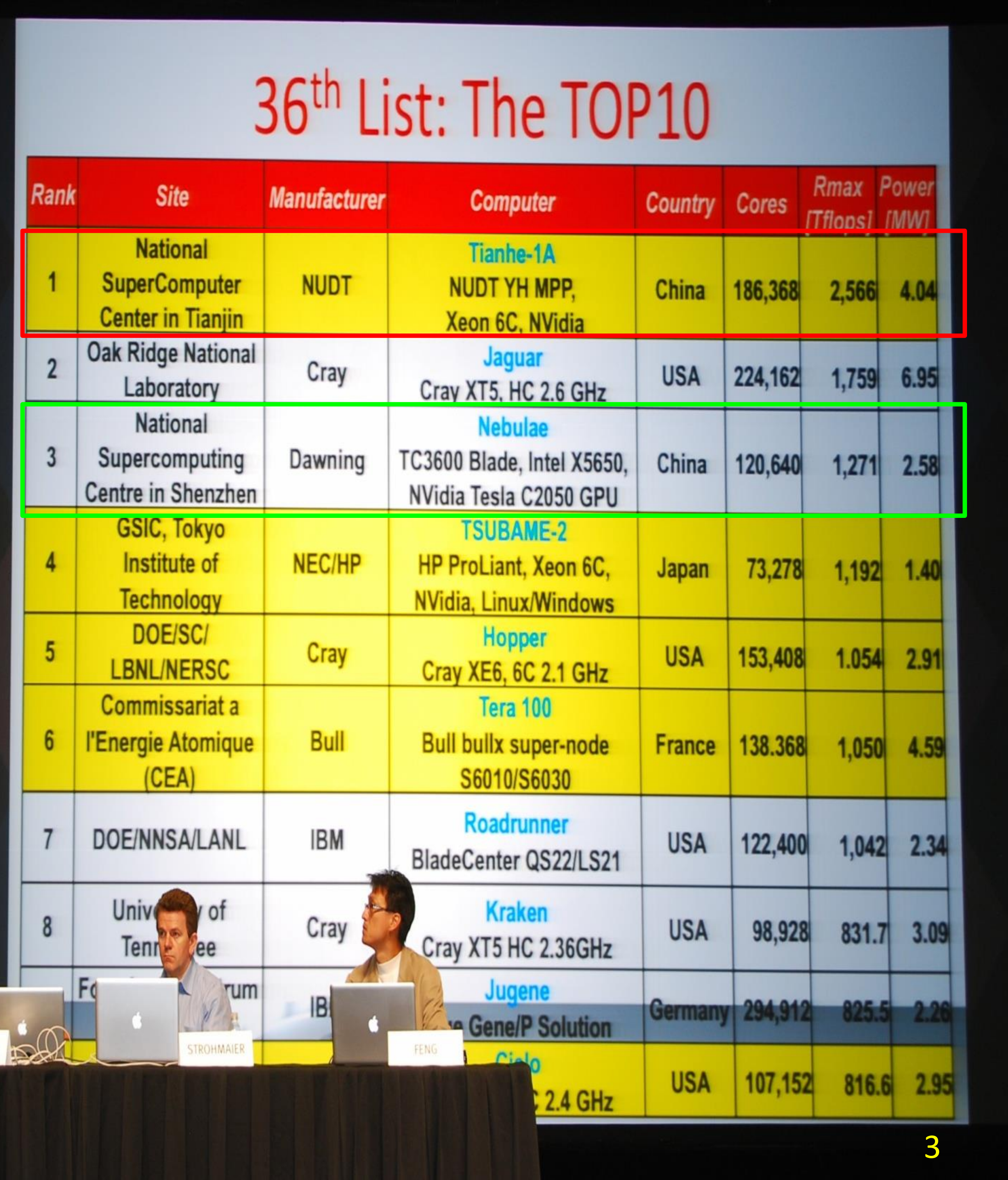
Outline

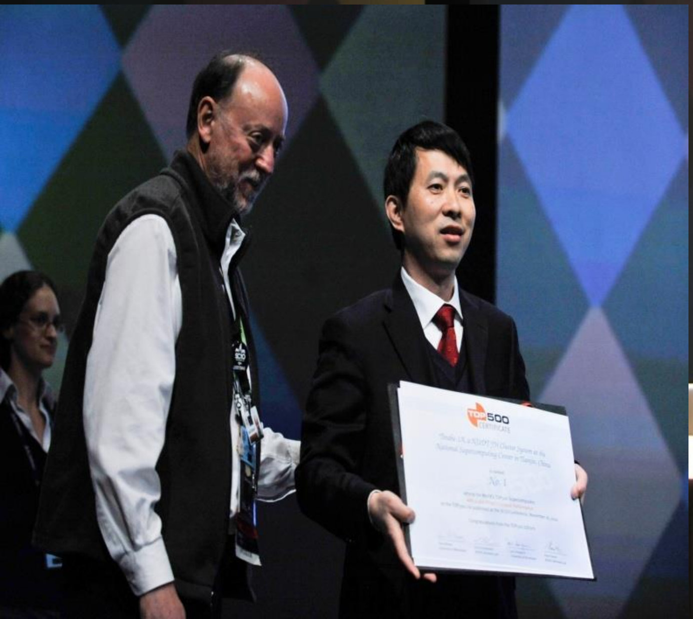
- TH-1A system and its application
- Large-Scale data Visualization
  - Large-Scale Flow Visualization
  - Multi source geological data visualization graphics engine——OpenProbe
- Summary

Tianhe -1A supercomputer got the world's top 500 ranked first at November 16, 2010 .



36th List: The TOP10

Rank	Site	Manufacturer	Computer	Country	Cores	Rmax [Tflops]	Power [MW]
1	National SuperComputer Center in Tianjin	NUDT	Tianhe-1A NUDT YH MPP, Xeon 6C, NVidia	China	186,368	2,566	4.04
2	Oak Ridge National Laboratory	Cray	Jaguar Cray XT5, HC 2.6 GHz	USA	224,162	1,759	6.95
3	National Supercomputing Centre in Shenzhen	Dawning	Nebulae TC3600 Blade, Intel X5650, NVidia Tesla C2050 GPU	China	120,640	1,271	2.58
4	GSIC, Tokyo Institute of Technology	NEC/HP	TSUBAME-2 HP ProLiant, Xeon 6C, NVidia, Linux/Windows	Japan	73,278	1,192	1.40
5	DOE/SC/ LBNL/NERSC	Cray	Hopper Cray XE6, 6C 2.1 GHz	USA	153,408	1.054	2.91
6	Commissariat a l'Energie Atomique (CEA)	Bull	Tera 100 Bull bullx super-node S6010/S6030	France	138.368	1,050	4.59
7	DOE/NNSA/LANL	IBM	Roadrunner BladeCenter QS22/LS21	USA	122,400	1,042	2.34
8	Univ of Tenn ee	Cray	Kraken Cray XT5 HC 2.36GHz	USA	98,928	831.7	3.09
	Fo rum	IB	Jugene e Gene/P Solution	Germany	294,912	825.5	2.26
			Cielo C 2.4 GHz	USA	107,152	816.6	2.95



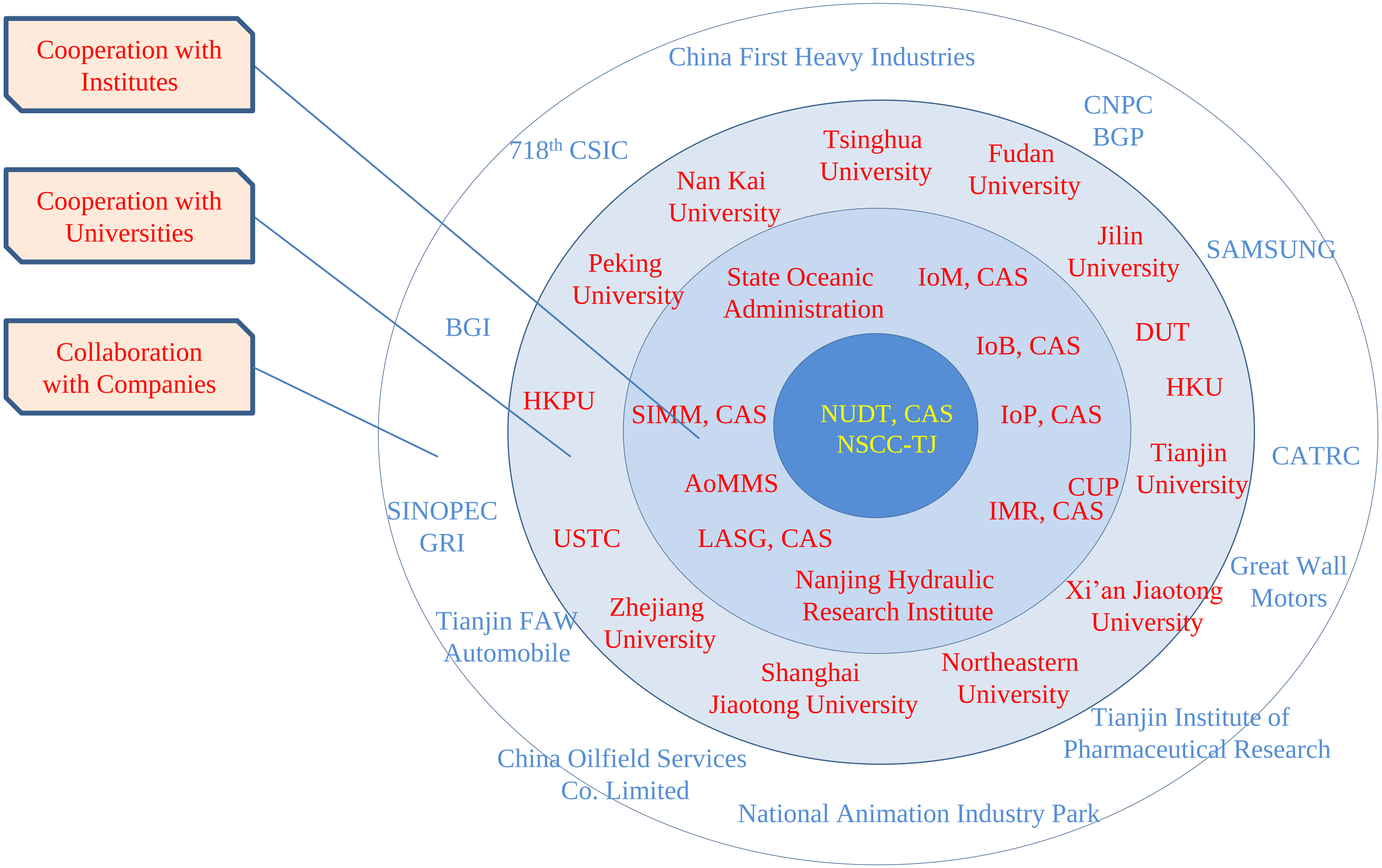
TH-1A system and its application

- TH-1A main hardware parameters :
  - Computation： 4.7 petaflop
    - ✓ Number of computing nodes：7500
    - ✓ Computing node partition：4 computing partitions according to 4 storage partitions
  - Storage：two parts: On line and Near Line
    - ✓ On Line：4 sets Lustre, each set corresponds to a storage partition, the capacity are 430TB, 420TB, 1.3PB, 700TB respectively.
    - ✓ Near Line：dual copy storage，available capacity 4PB
    - ✓ There was one set Lustre before：430 TB

- In addition to the TH-1A, we also constructed
  - TH Cloud Computing Center
  - TH electronic government affairs center
  - TH big data processing environment

HPC Application & Innovation Alliance

NSCC



Cooperation with Institutes

Cooperation with Universities

Collaboration with Companies

NUDT, CAS
NSCC-TJ

State Oceanic Administration

IoM, CAS

IoB, CAS

IoP, CAS

CUP

IMR, CAS

Nanjing Hydraulic Research Institute

LASG, CAS

AoMMS

SIMM, CAS

Tsinghua University

Fudan University

Jilin University

DUT

HKU

Tianjin University

Xi'an Jiaotong University

Northeastern University

Shanghai Jiaotong University

Zhejiang University

USTC

HKPU

Peking University

Nan Kai University

China First Heavy Industries

CNPC BGP

SAMSUNG

CATRC

Great Wall Motors

Tianjin Institute of Pharmaceutical Research

National Animation Industry Park

China Oilfield Services Co. Limited

Tianjin FAW Automobile

SINOPEC GRI

BGI

718th CSIC

中华人民共和国科学技术部
The Ministry of Science and Technology of the People's Republic of China

中华人民共和国国家发展和改革委员会
National Development and Reform Commission

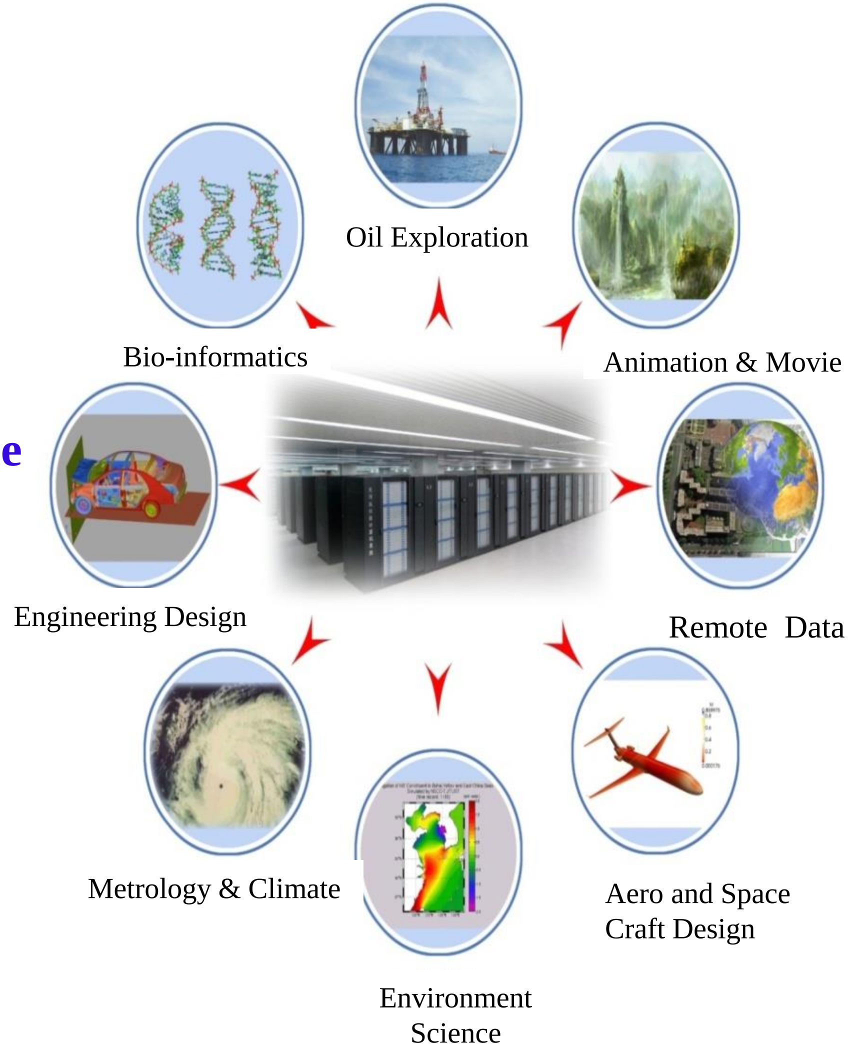
国家自然科学基金委员会
National Natural Science Foundation of China

Application Domains and some typical applications

- Some typical application domains
  - Geophysics：oil exploration
  - Environmental Science： Oceans, weather and climate
  - Aerodynamics： Aircraft

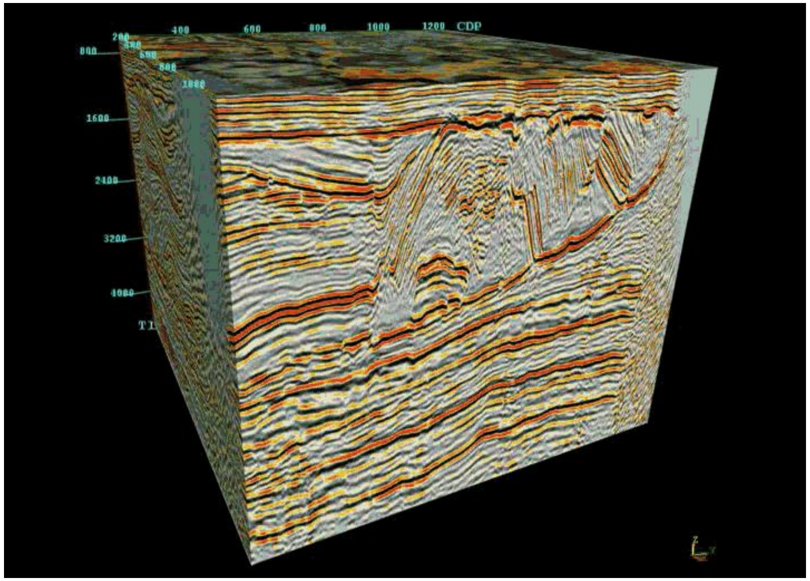
These three types of application can use the whole system of computing resources.

  - Life Sciences：Gene, protein, brain science
  - Engineering simulation

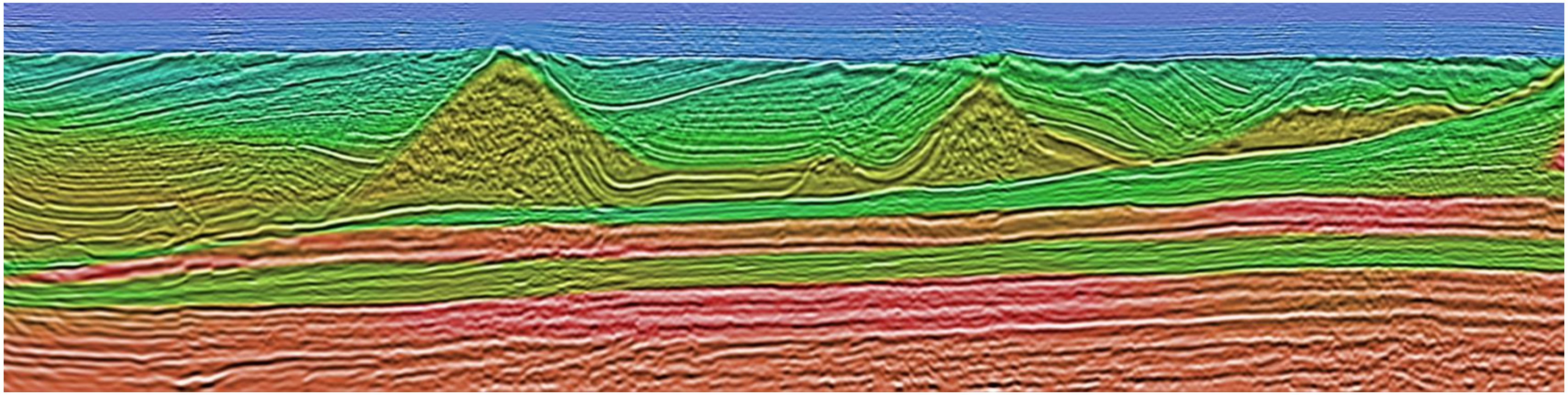


Typical application： oil exploration seismic data processing

- GeoEast：Developed a data processing software for oil seismic exploration with independent intellectual property rights
- Completed a number of data processing tasks, the typical parameters are ：
  - Work area：2,600 Km^2
  - Origin data volume：2.2TB
  - Processing technique ：RTM
  - Imaging data volume ：27GB
  - One of Imaging interpretation technology ：Visualization

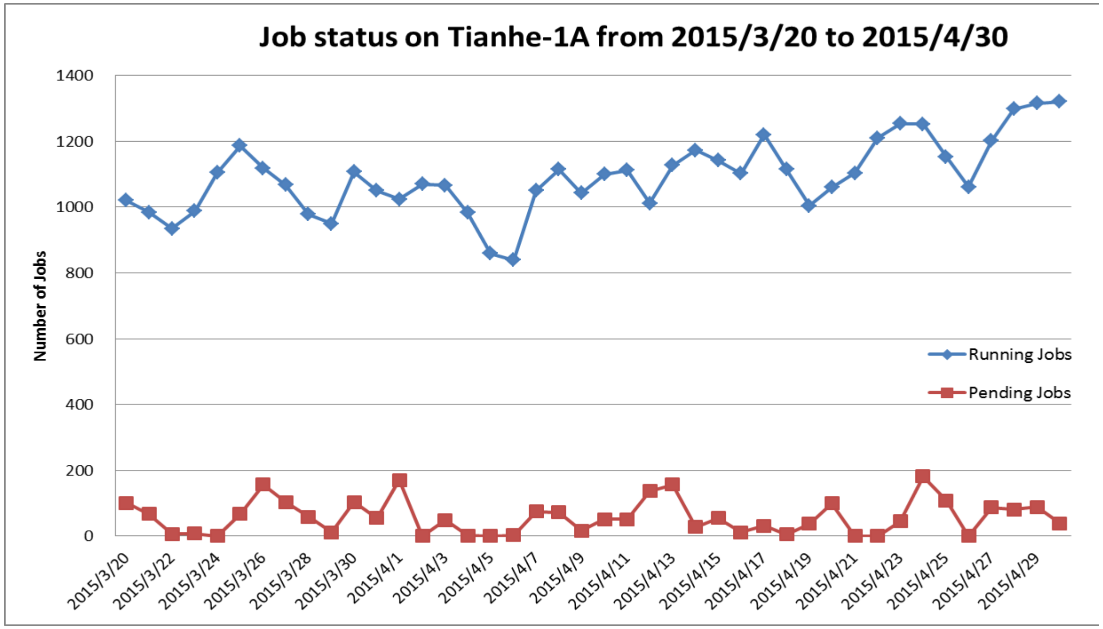


Imaging of underground geological structure



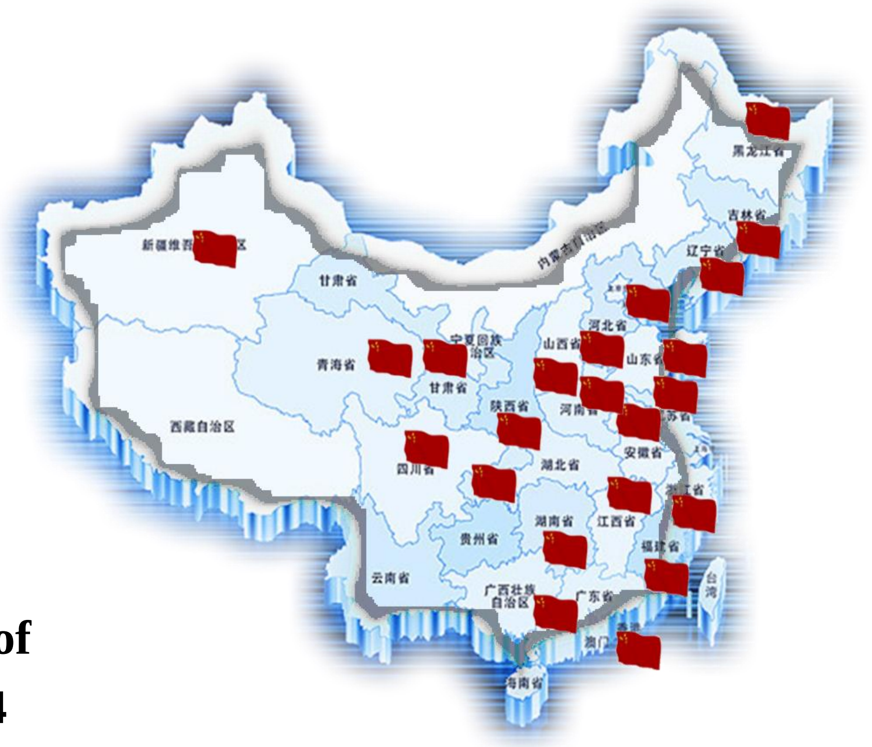
Operation status of Tianhe-1A

- System usage ：> 85%
- Data storaged ：>2.5PB
- Running years：More than 4 years: (2010.12—2015.4)



Projects and users

- TH-1A supports national projects > 800 items
  - NSFC projects > 600 items
  - 863, 973 projects > 100 items
  - Other key project (MIIT, NDRC, CNPC, CNOOC, etc) > 40 items
  - International collaboration projects > 10 items
- Users all over China, and the number of user teams is more than 600 up to 2014
- NSCC-TJ is an open public technology service platform



User distribution graph

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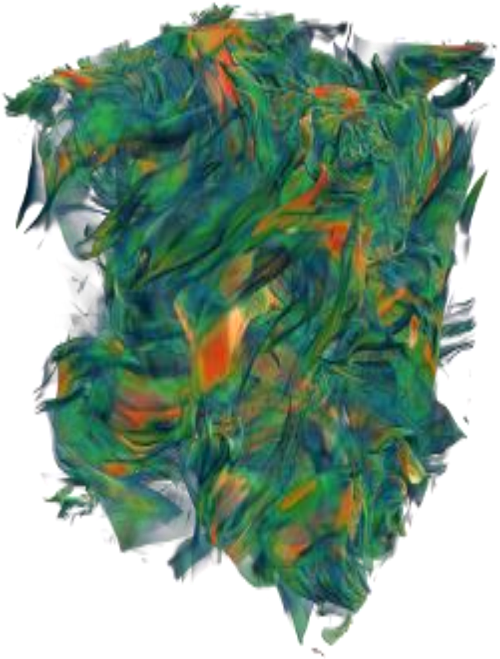
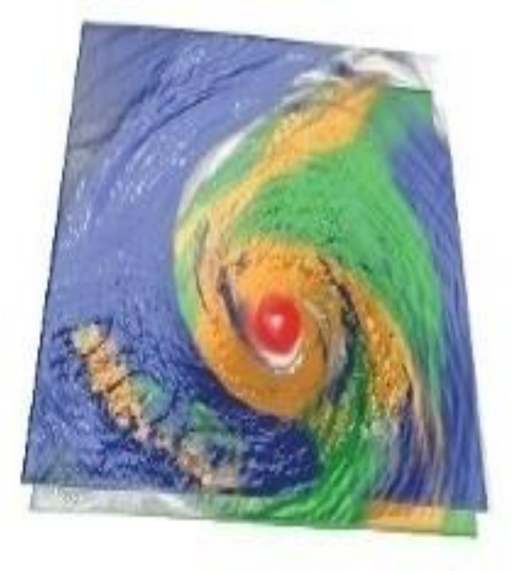
Large-Scale Flow Visualization

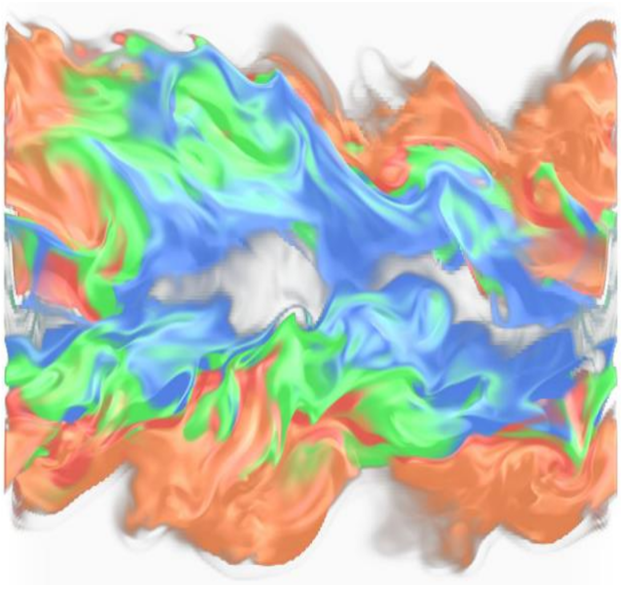
Limitation of Previous Flow Visualization Methods

Flow data usually includes multiple variables, but their corresponding analysis methods are lacking, especially the integrated analysis of vector fields with scalar fields.

Existing ensemble visualization methods focus on the scalar fields, while the comparison of vector fields are in need in scientific domain.







Our Approach: Large-Scale Pathlines-Based Flow Field Analysis

New flow field analysis methods equipped with scalable computation

1. **Coupled Ensemble Flow Line Advection and Analysis (eFLAA)**

   vector field + ensemble analysis

2. **Scalable Lagrangian-based Attribute Space Projection (LASP)**

   scalar/vector field + multivariate analysis

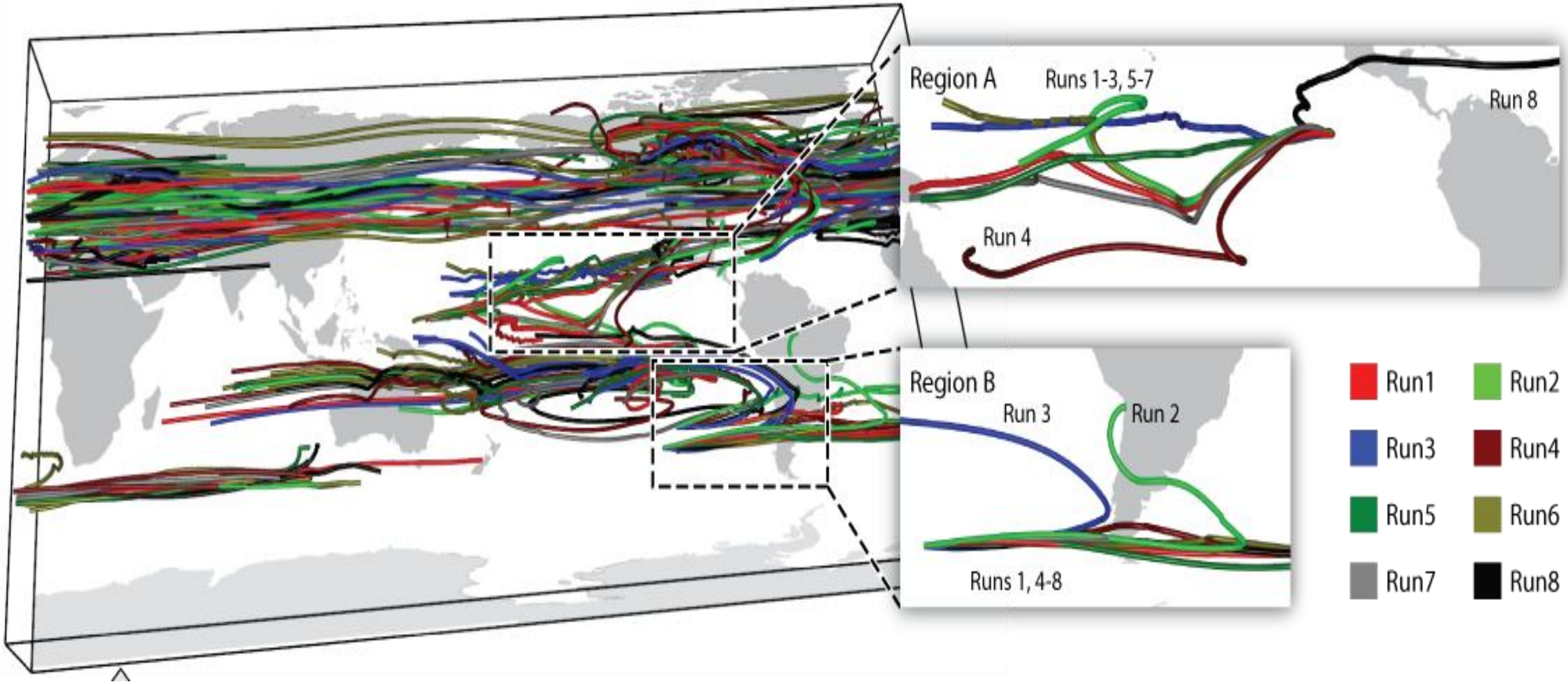
3. **Latent Dirichlet Allocation Based Unsteady Flow Analysis (FLDA)**

   scalar/vector field + multivariate analysis

4. **Advection-Based Sparse Data Management for Visualizing Unsteady Flow**

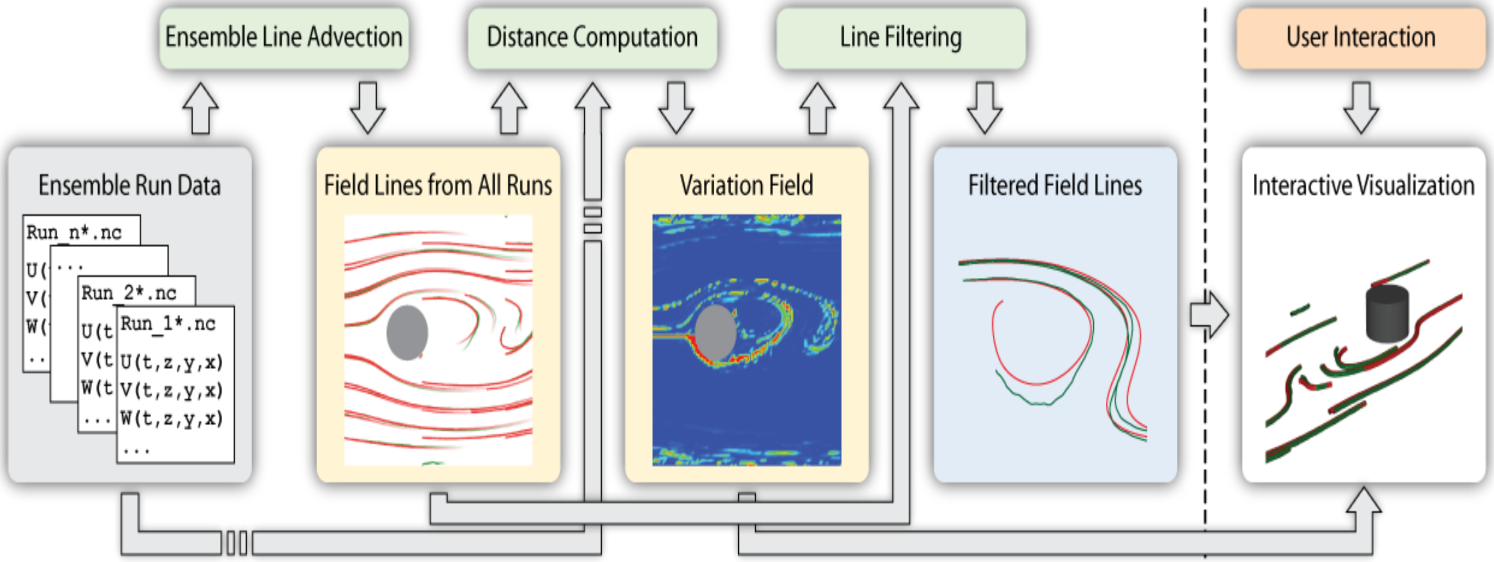
   a fundamental data management to support flow-related analysis

1. eFLAA: Coupled Ensemble Flow Line Advection and Analysis

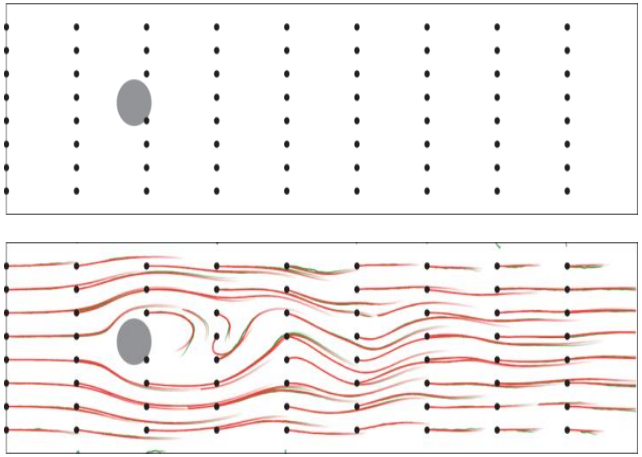


Hanqi Guo, Xiaoru Yuan, Jian Huang, and Xiaomin Zhu, “Coupled Ensemble Flow Line Advection and Analysis.” IEEE Transactions on Visualization and Computer Graphics (Vis ’13), 19(12):2733–2742, 2013.

Pipeline in Concept

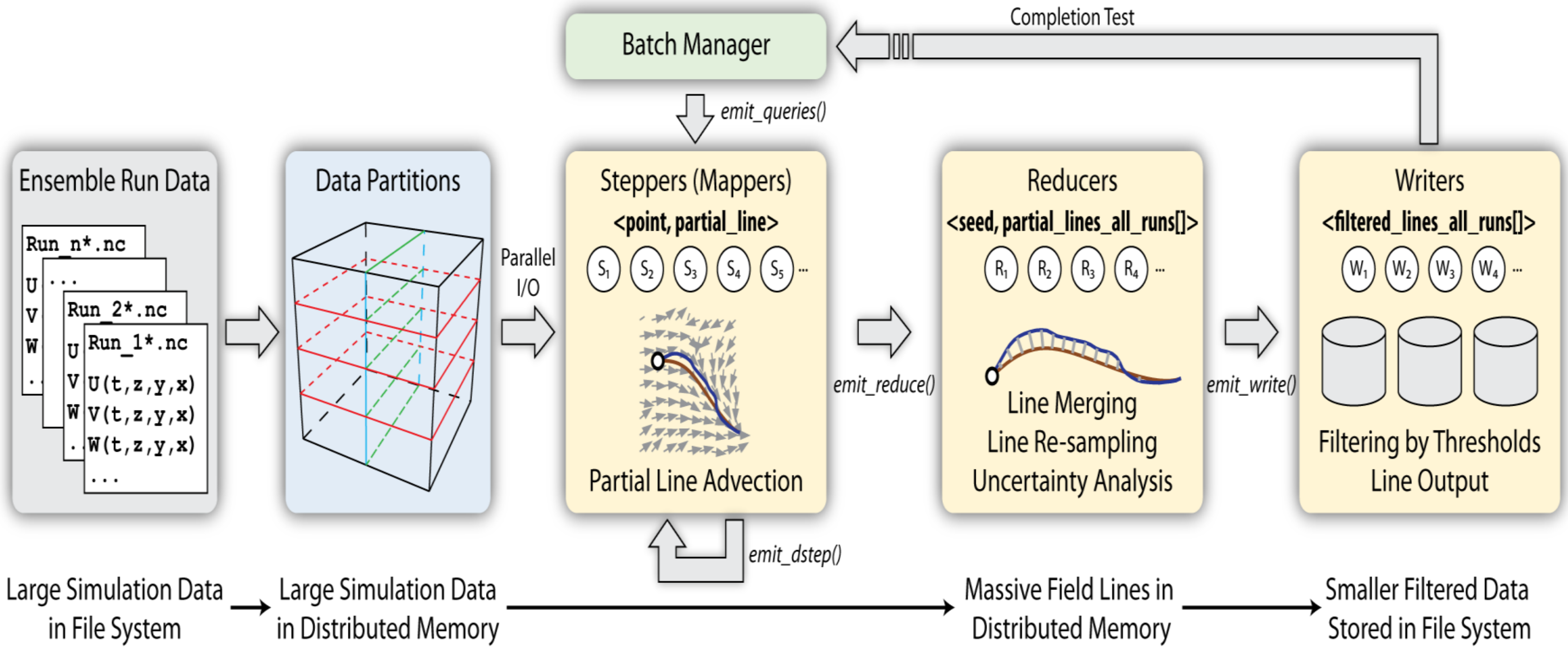


- Ensemble data (large, 76 GB)
- Field line data (much larger than ensemble data, 5.8 TB)
- Variation field (small, less than 1 GB)
- Filtered lines (even smaller)



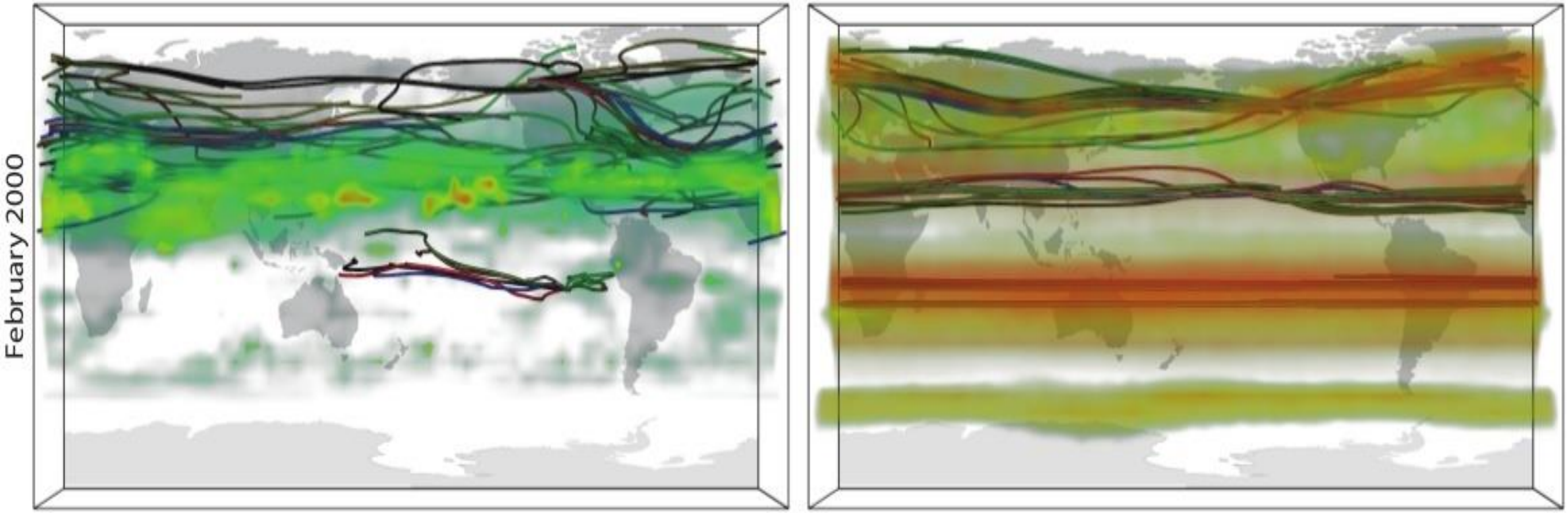
Pipeline of the Parallel System

- Both data scale and problem size are often too large to handle in practice
- A streamed data management mechanism is used to make the system scalable, given the memory limits

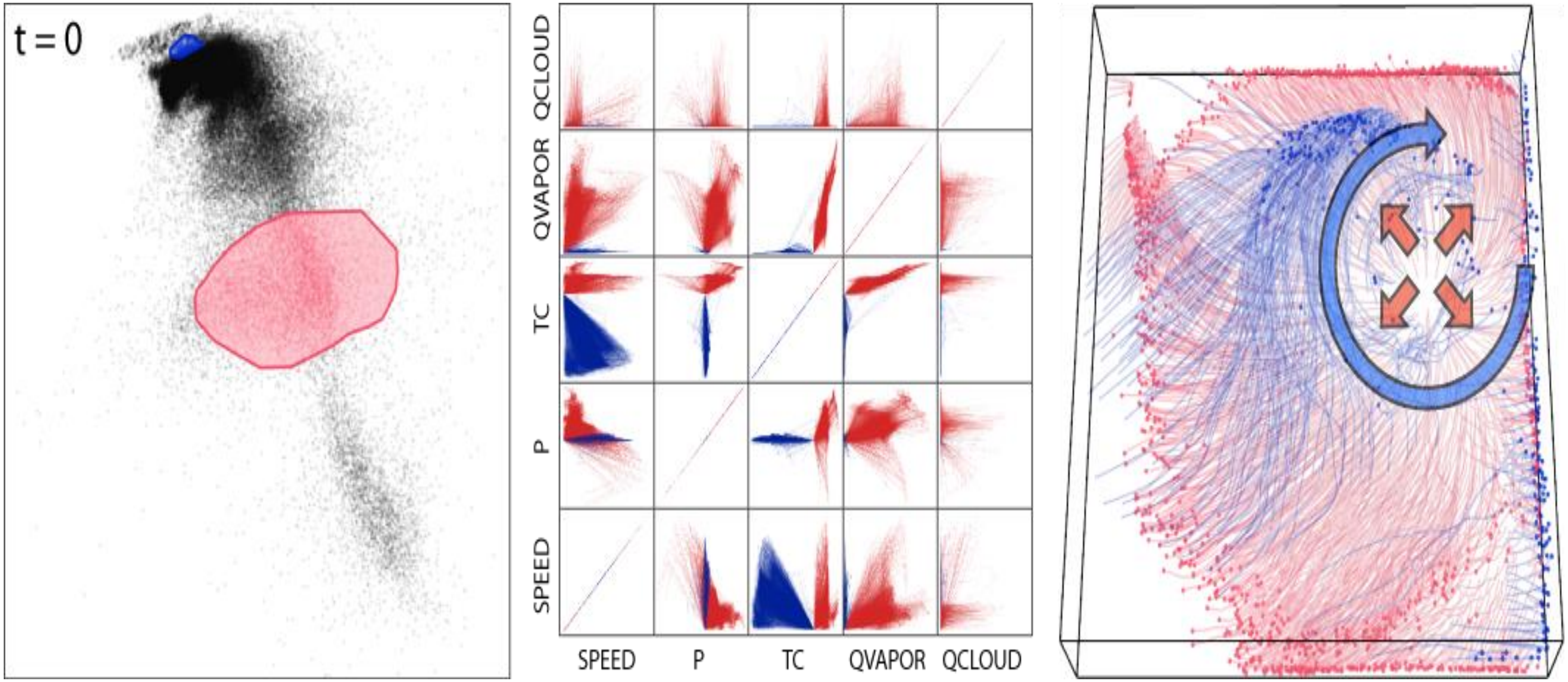


Application – GEOS-5 Simulation

- The metric: the differences of locations / CO_2 concentration along the pathline
- Findings
  - The variation of the wind field is high in the north hemisphere
  - However, The CO_2 difference is higher in south hemisphere and some places in the north
  - CO_2 concentration is not sensitive to wind in above regions



2. LASP : Scalable Lagrangian-based Attribute Space Projection



Hanqi Guo, Fan Hong, Qingya Shu, Jiang Zhang, Jian Huang, and Xiaoru Yuan, “Scalable Lagrangian-based Attribute Space Projection for Multivariate Unsteady Flow Data.” In *Proceedings of IEEE Pacific Visualization Symposium (PacificVis 2014)*, pages 33-40, Yokohama, Japan, Mar. 4–7, 2014.

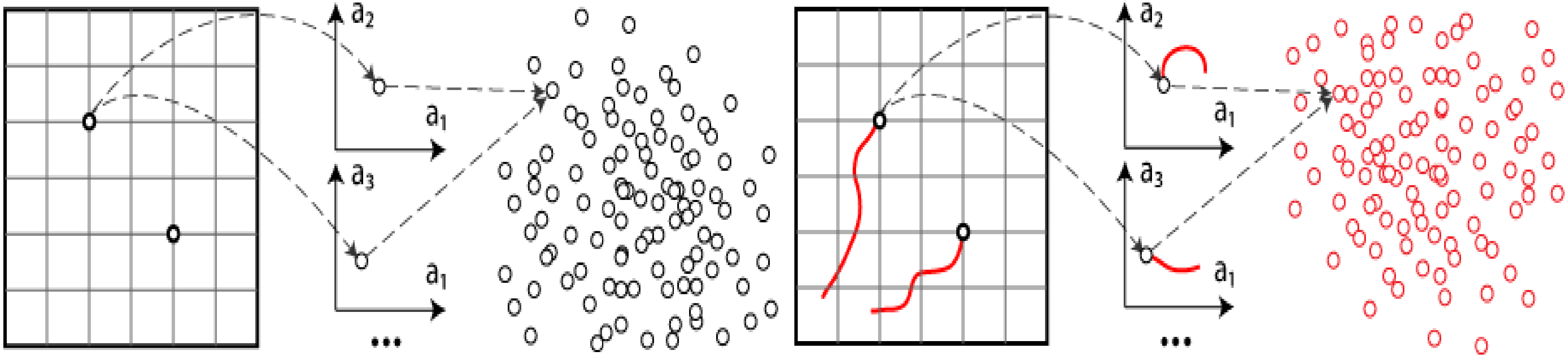
Attribute Space Projection

Eulerian-based Attribute Space Projection

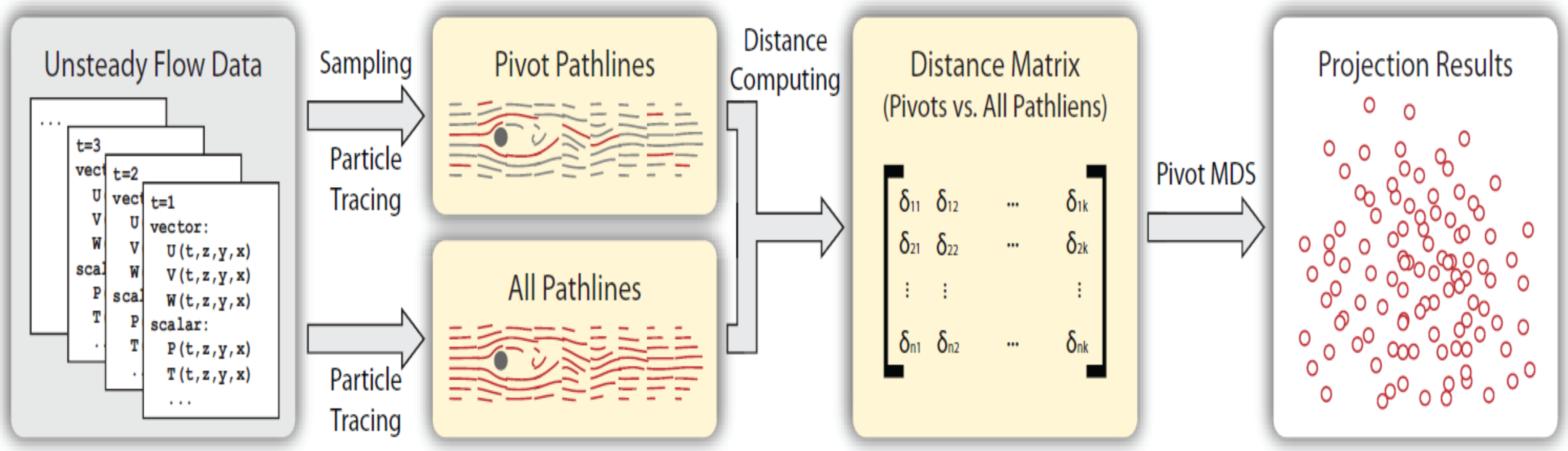
Data samples →
High-dimensional vector in attribute space →
Eulerian-based Attribute Space Projection →
Eulerian-based Attribute Space Projection (EASP)

Lagrangian-based Attribute Space Projection

Pathlines starting from data samples →
Pathlines in attribute space →
Lagrangian-based Attribute Space Projection→
Lagrangian-based Attribute Space Projection (LASP)

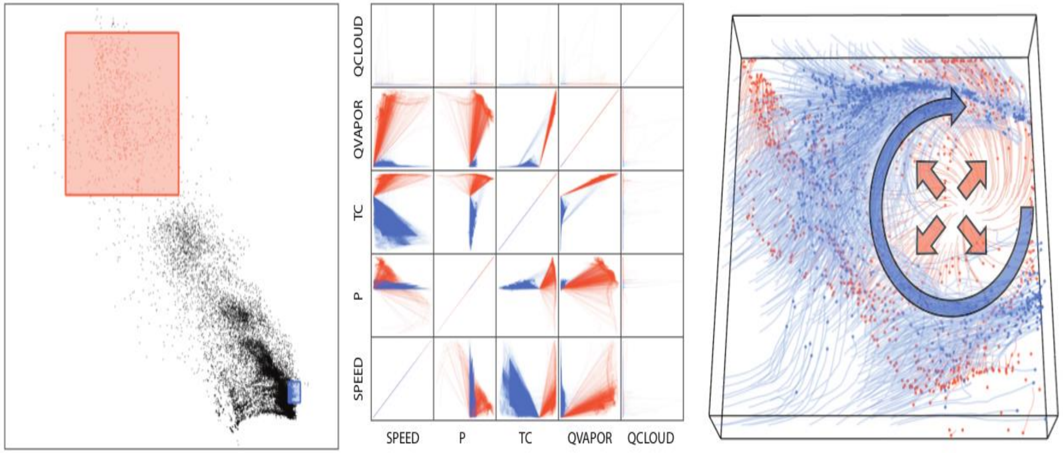


Pipeline

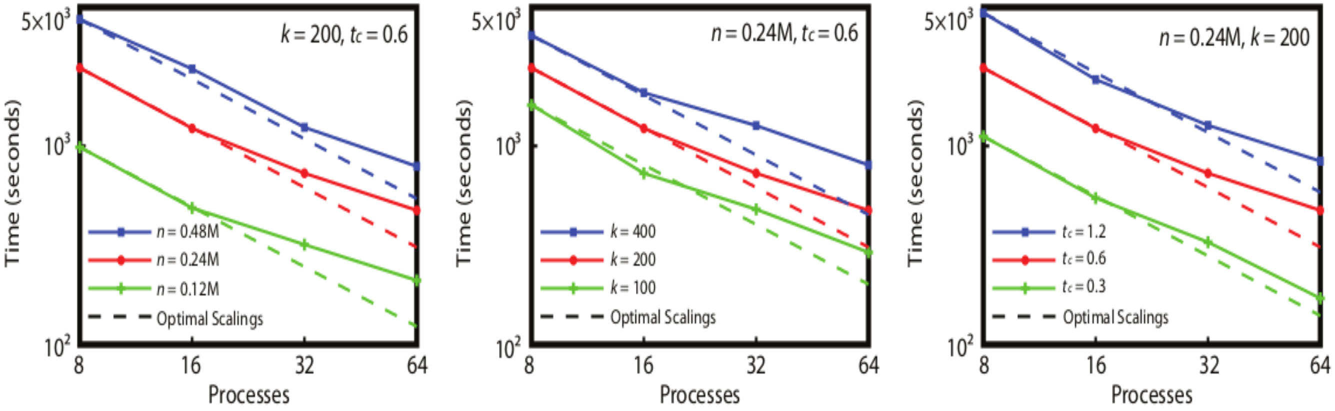


- It is unrealistic to implement LASP with a serial visualization pipeline
  - The complexities of both particle tracing and projection are prohibitive
  - The intermediate data is overwhelmingly large
- The solution: integration of DStep and SPMDS

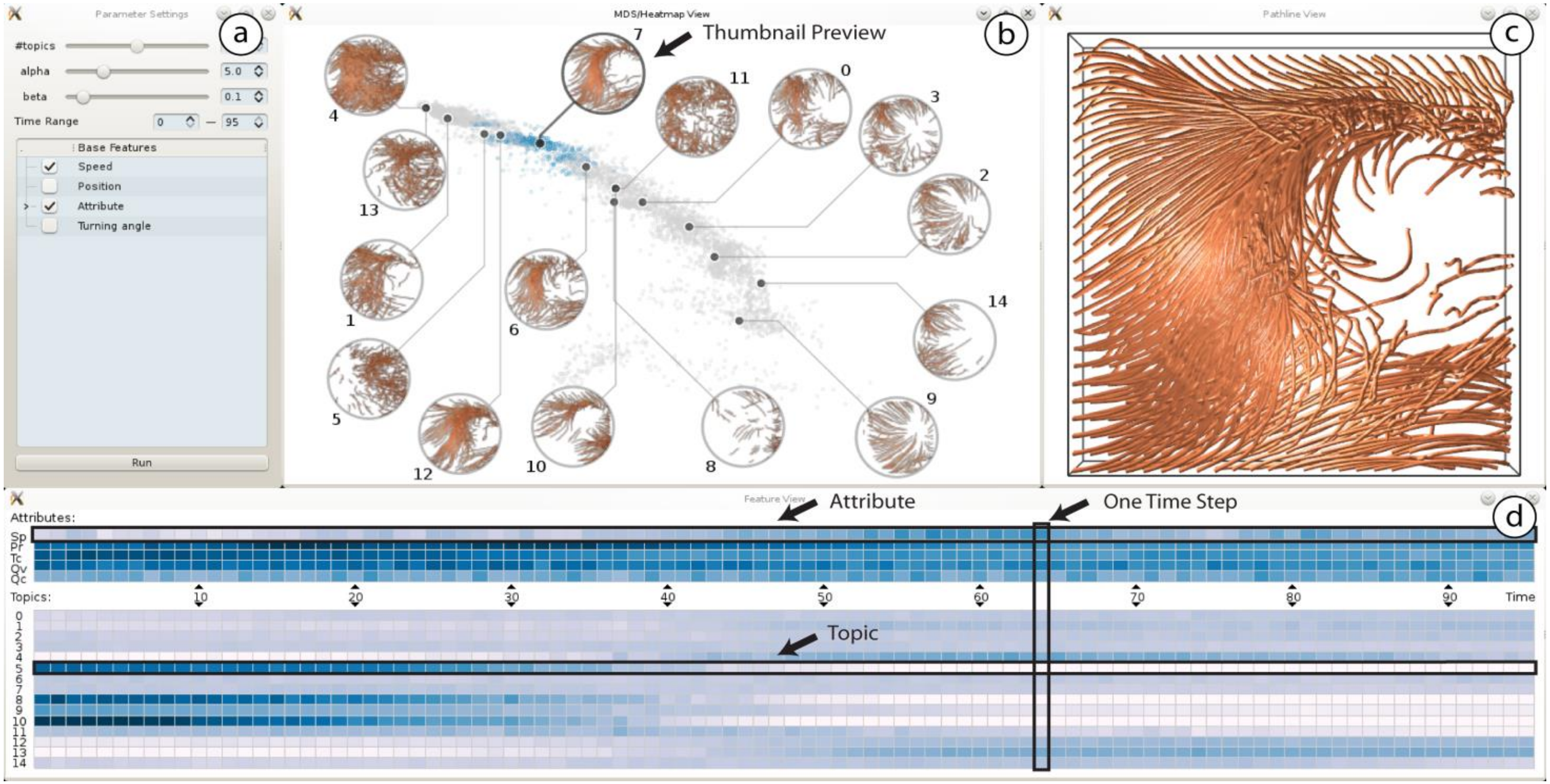
Application: Hurricane Isabel



Attributes along pathlines are significantly different in the two group of selected features



3. FLDA: Latent Dirichlet Allocation Based Unsteady Flow Analysis



Parameter Settings

#topics

alpha 5.0

beta 0.1

Time Range 0 — 95

Base Features

- ☑ Speed
- ☐ Position
- ☑ Attribute
- ☐ Turning angle

Run

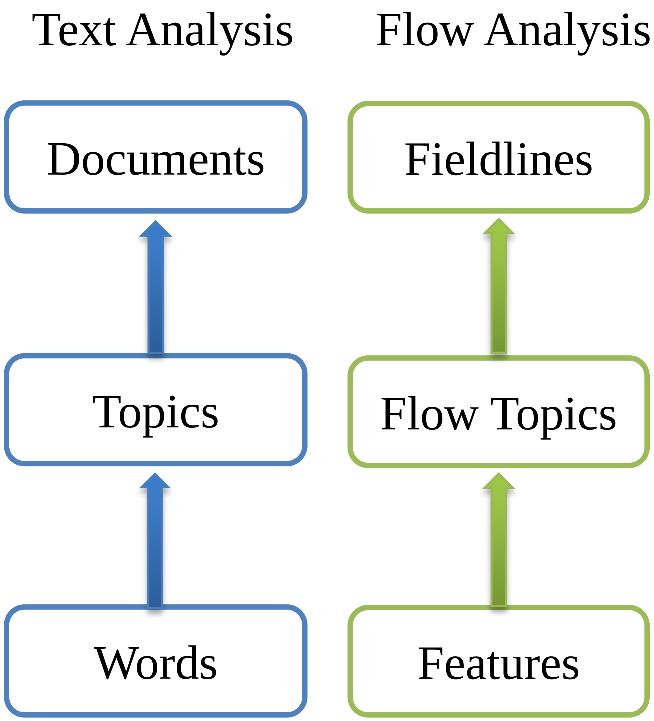
Fan Hong, Chufan Lai, Hanqi Guo, Enya Shen, Xiaoru Yuan, Sikun Li. “FLDA: Latent Dirichlet Allocation Based Unsteady Flow Analysis.” In IEEE VIS 2014.

LDA Topic Model vs Flow LDA Model

LDA (Latent Dirichlet Allocation) is a widely used topic model in text mining.

LDA estimates the similarities between **documents** from the **topic level**.

Topics are extracted based on **document-word** relationships



FLDA clusters **fieldlines** from the **flow topic** level.

Flow topics are extracted based on **fieldline-feature** relationships

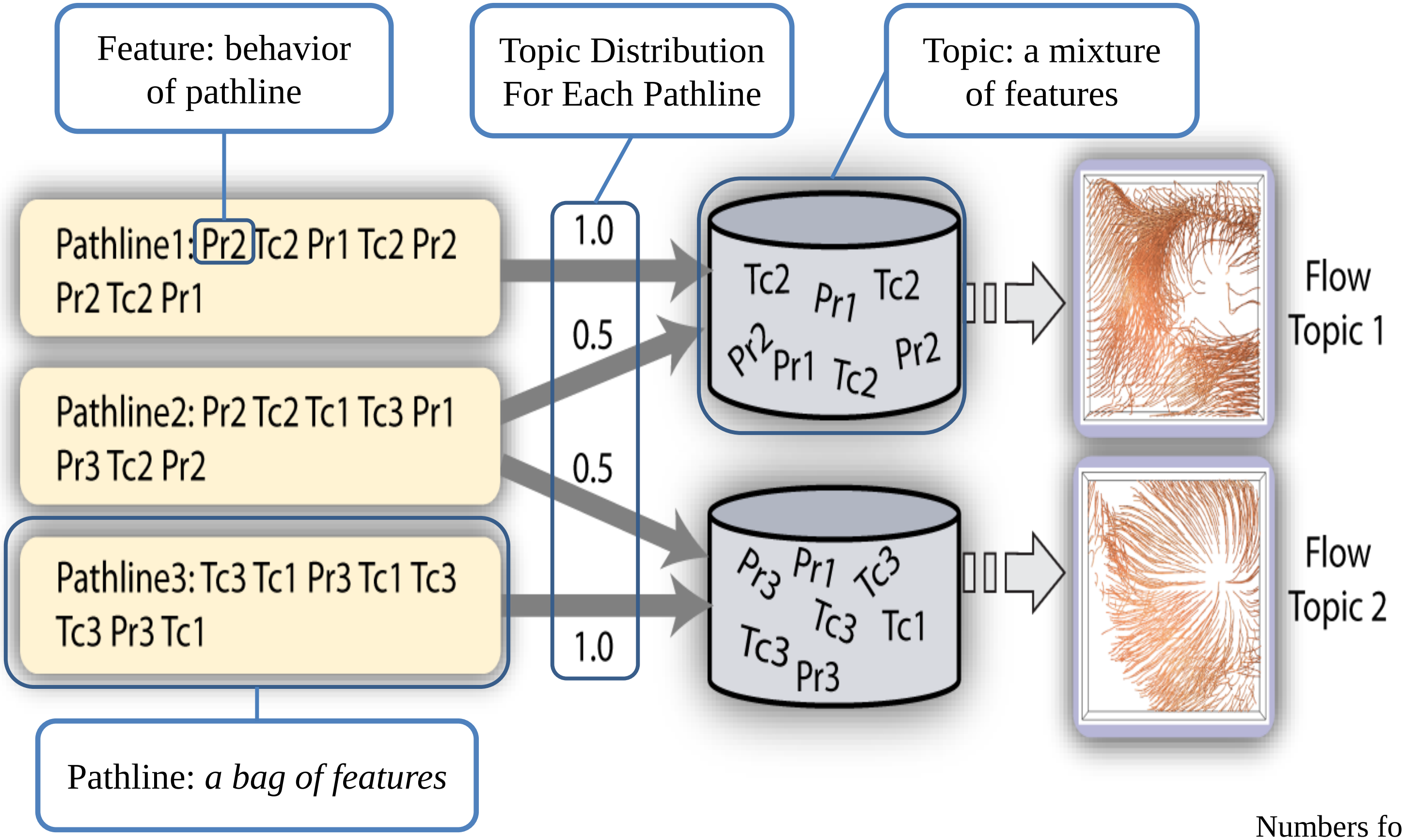
Illustration of FLDA Model

Input:

- Definition of features
- Bags of features for each pathline

Output:

- Topic distribution for each pathline
- Feature distribution for each topic



Feature: behavior of pathline

Topic Distribution For Each Pathline

Topic: a mixture of features

Pathline1: Pr2 Tc2 Pr1 Tc2 Pr2 Pr2 Tc2 Pr1

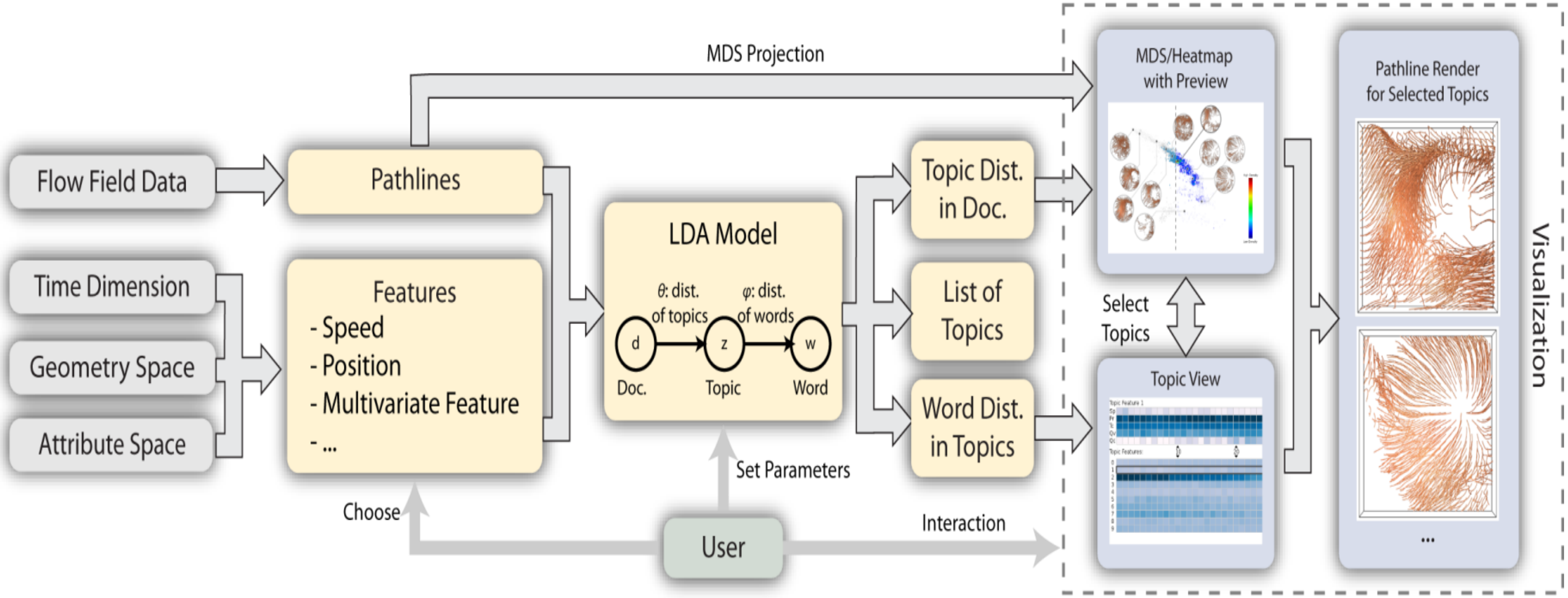
Pathline2: Pr2 Tc2 Tc1 Tc3 Pr1 Pr3 Tc2 Pr2

Pathline3: Tc3 Tc1 Pr3 Tc1 Tc3 Tc3 Pr3 Tc1

Pathline: *a bag of features*

Numbers for illustration only.

Pipeline

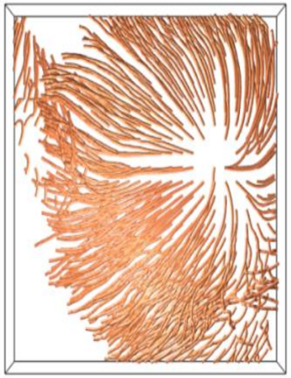


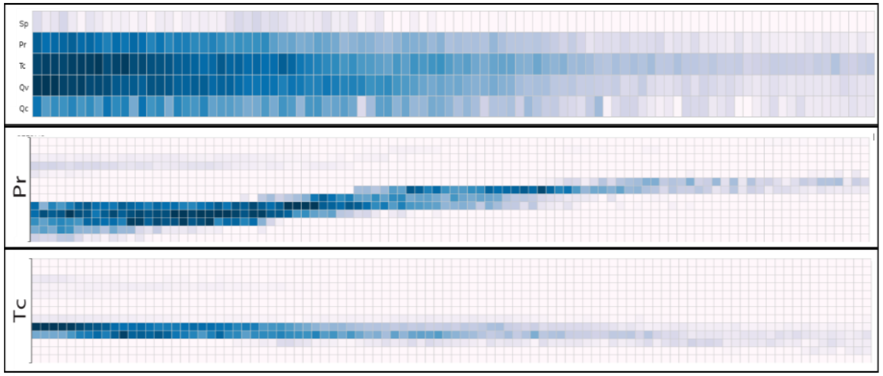
Steps:

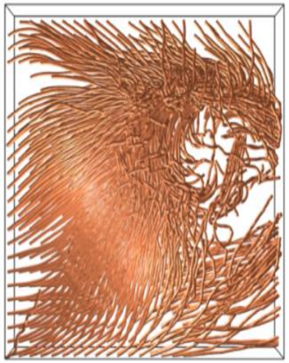
1. Define features to represent behaviors of interest.
2. Generate pathlines, and construct bags of features.
3. Feed feature bags into classical LDA model.
4. Visualize and analyze output topics and distributions.

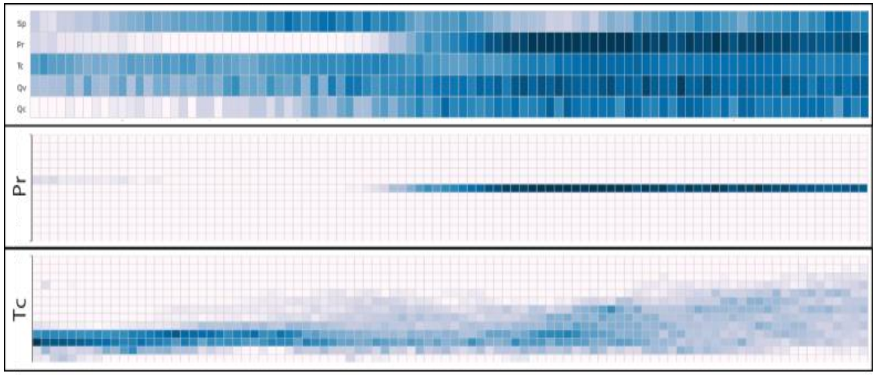
Application – Isabel Case

- Pathlines advect from hurricane eye to the periphery.
- Pathlines are similar in attributes pressure and temperature, in the first half of advection.
- Pathlines have an increasing pressure, and stable temperature.





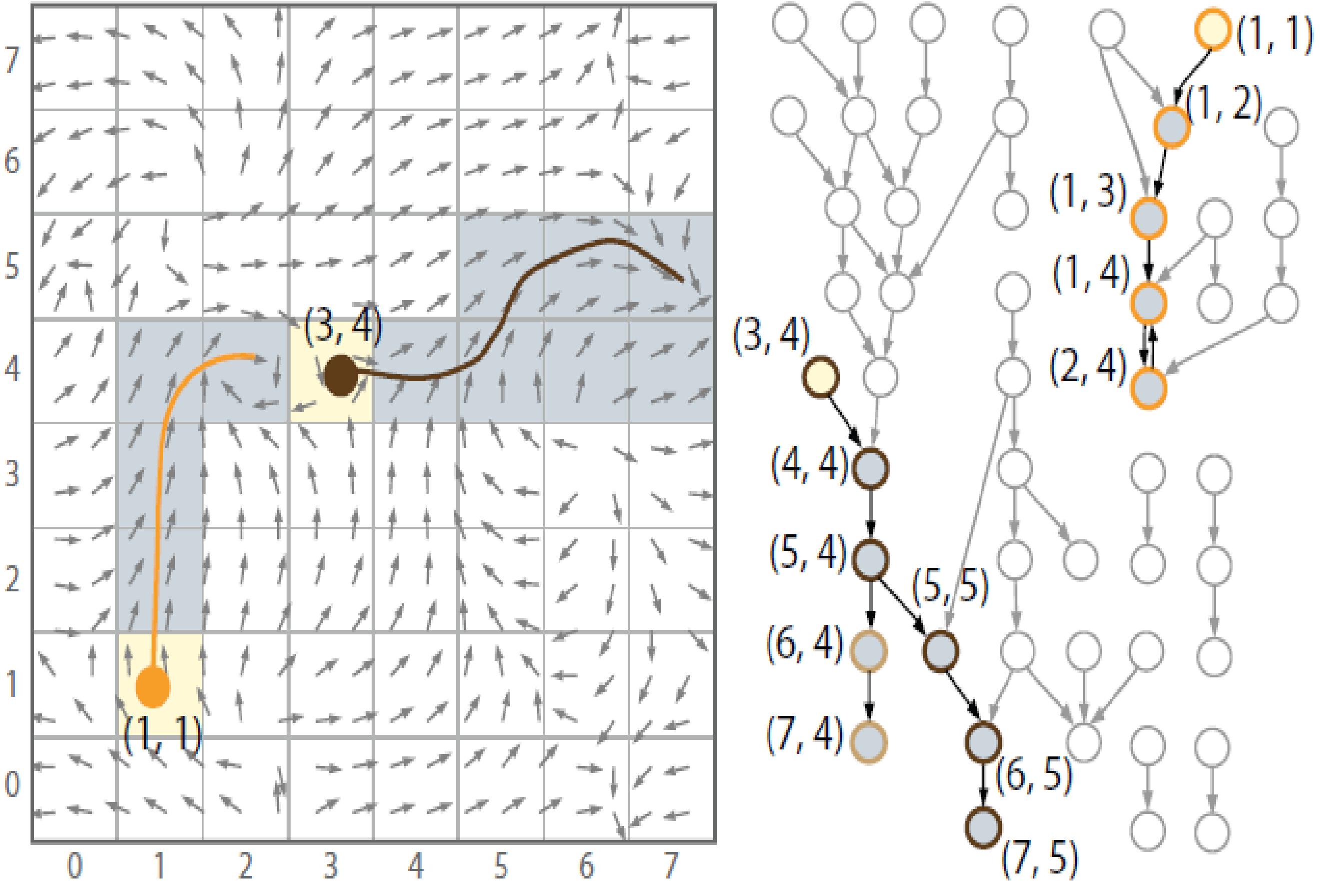




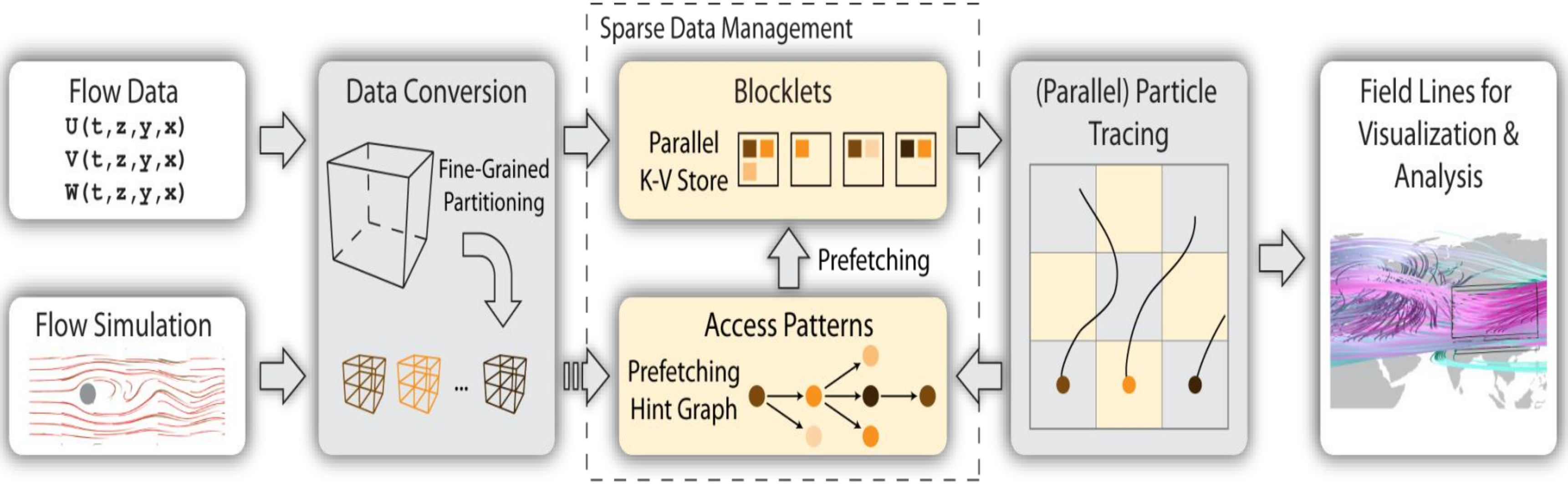
- Pathlines form a clockwise circulation around hurricane eye.
- Pathlines have focused pressure values in the last half of time.
- The pressure of pathlines are changing for focuses values to dispersed one.

4. Advection-Based Sparse Data Management for Visualizing Unsteady Flow

Hanqi Guo, Jiang Zhang, Richen Liu, Lu Liu, Xiaoru Yuan, Jian Huang, Xiangfei Meng, and Jingshan Pan. “Advection-based Sparse Data Management for Visualizing Unsteady Flow.” In IEEE VIS 2014.



Sparse Data Management



Solution

- Data partition on granularity of blocklets
- Parallel key-value store based data management
- High-efficient data prefetching

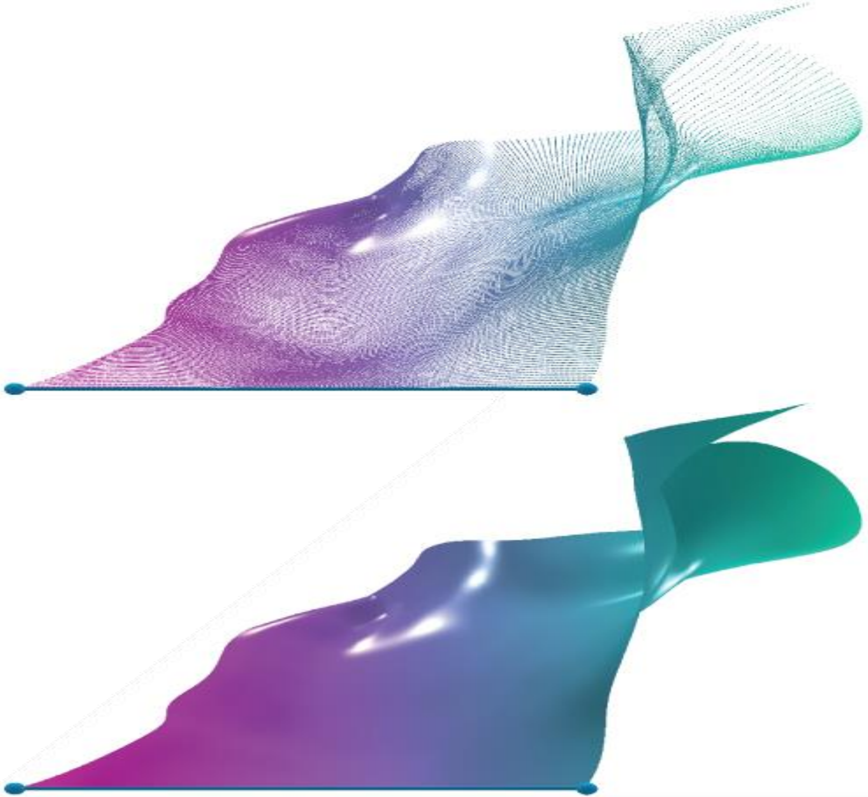
Benefits

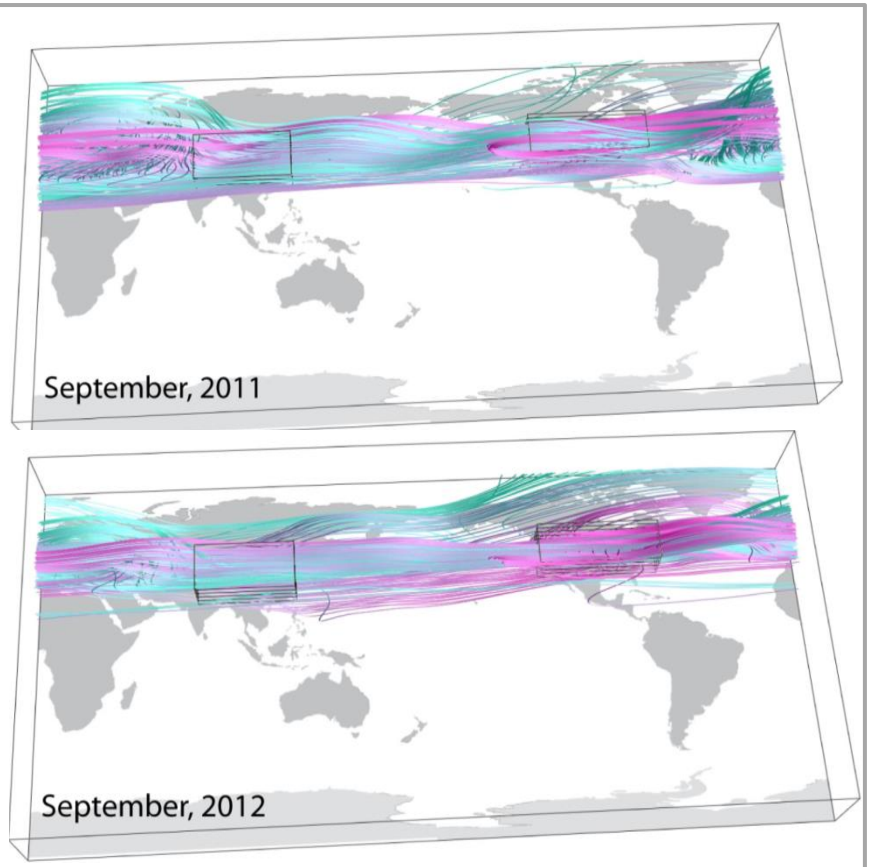
- Enable large-scale unsteady flow analysis while requiring a very limited amount of hardware resources.
- Improve both performance and scalability of the naive task-parallel particle tracing

Applications

Streak Surface Computation

- Streak surfaces dipicts the flow field over the entire lifetime by continuously releasing particles from given seed curves.
- Data: TB-scale turbulence simulation data
  - curvilinear grid, with spatial resolution 1024x1024x720
  - 100 time steps





Origin-Destination Query

- Study advection of massless particles (such as pullutants, etc.) in flow fields.
- Data: GEOS-5, global climate simulation data

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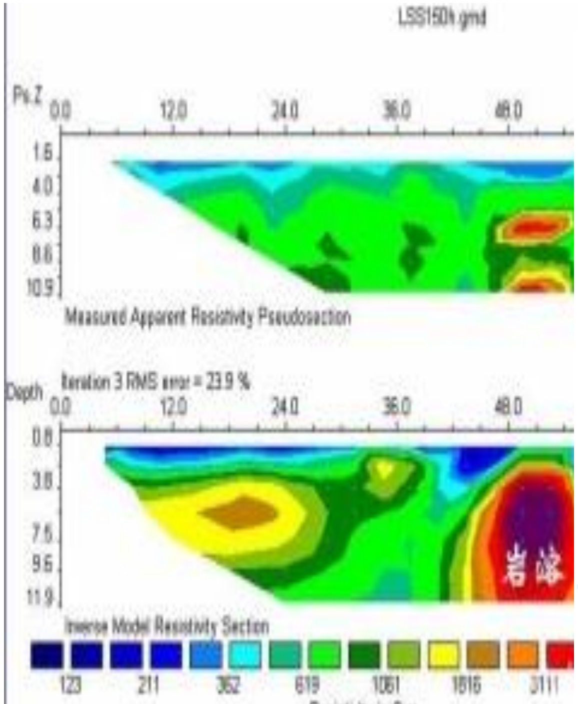
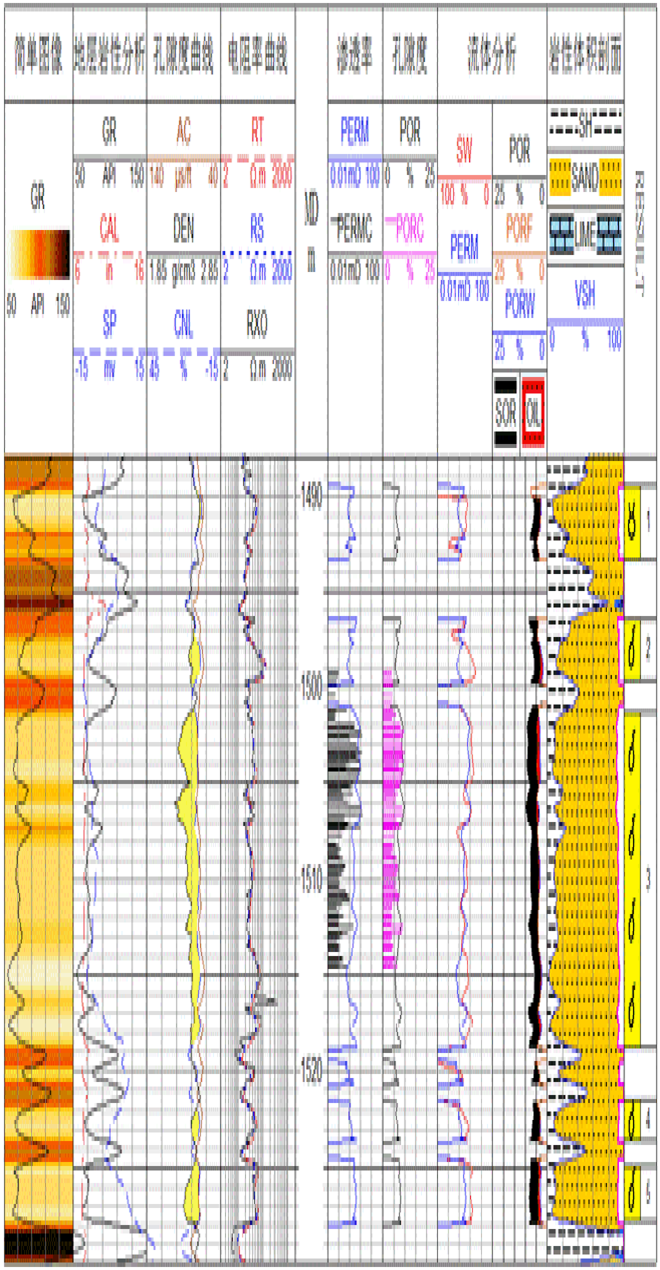
Multi-source geologic data visualization graphics engine—OpenProbe

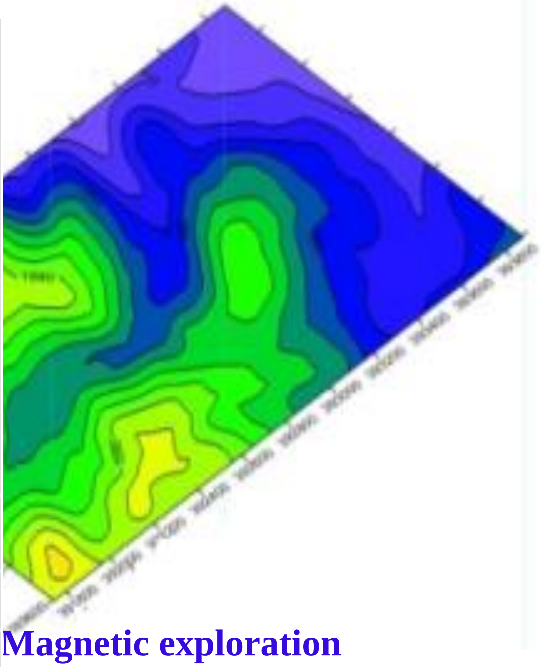
- Supports seismic, logging, gravity , magnetic, electric and other data
- Supports Windows, Linux and other operating systems
- Supports multi-touch interactive operation mode
- Supports plug-in type secondary development
- Supports large-scale data 3D stereoscopic visualization



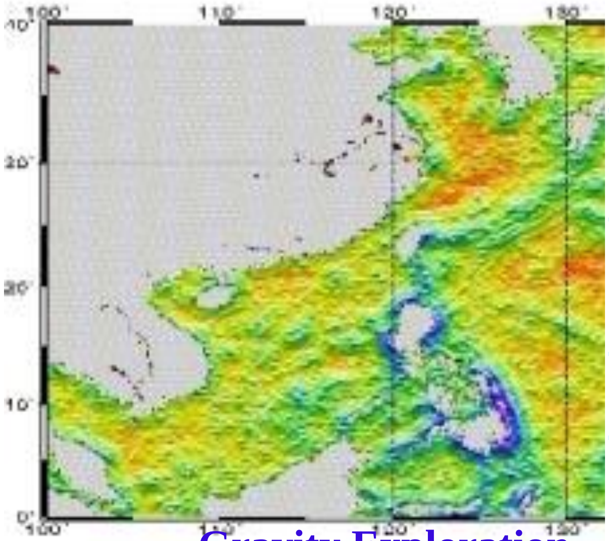
Electrical exploratio



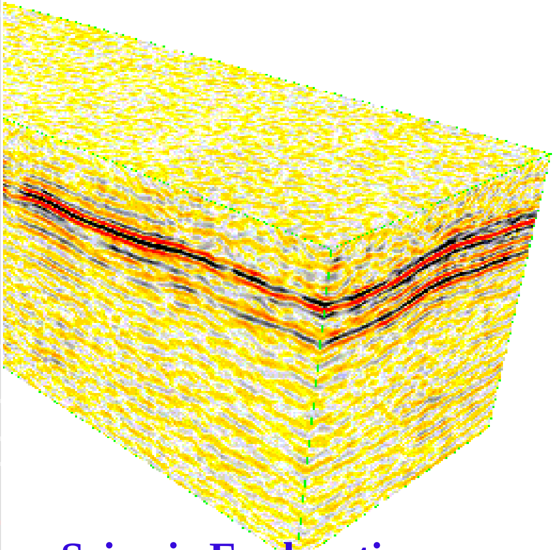
Well logging



Magnetic exploration

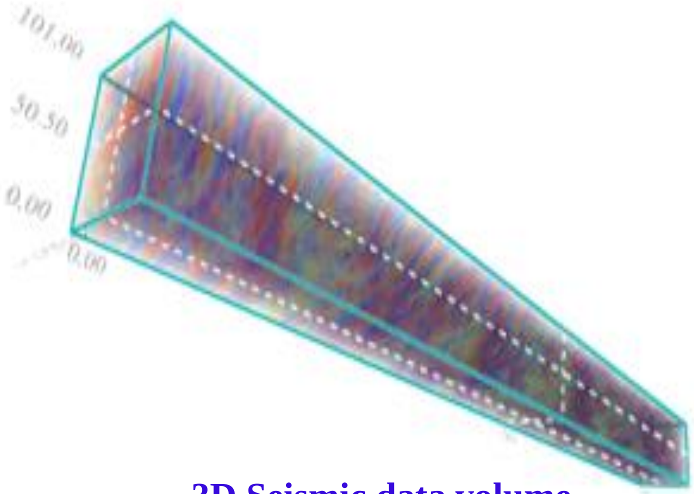


Gravity Exploration

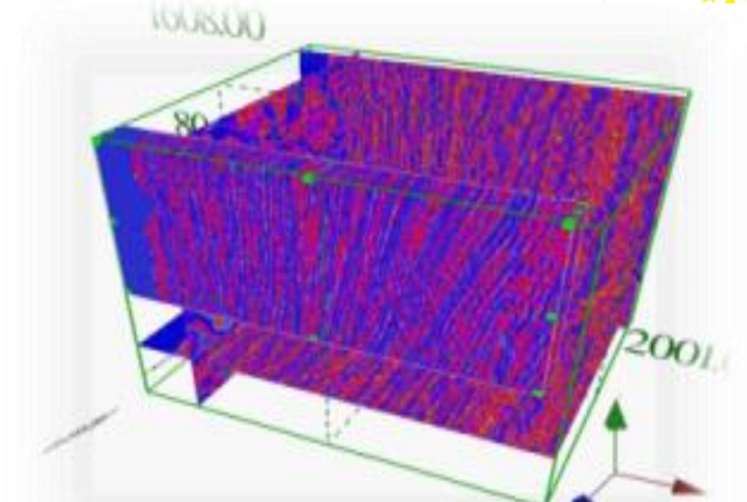


Seismic Exploration

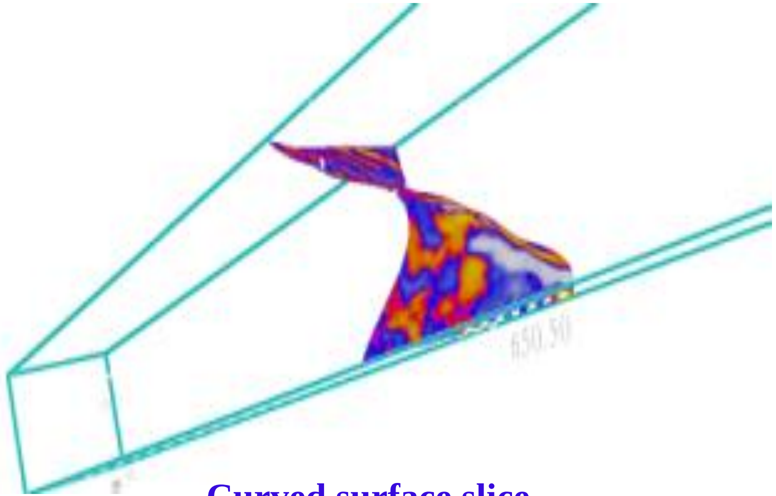
VolumeViz Module



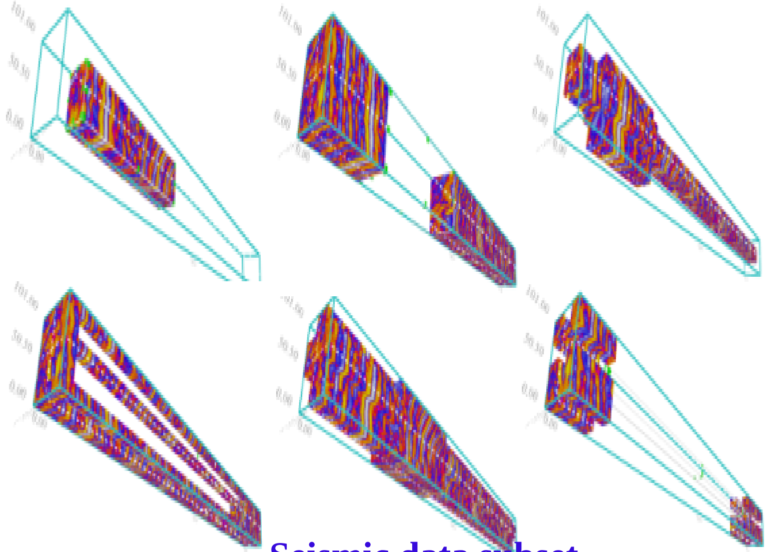
3D Seismic data volume



Orthogonal slices

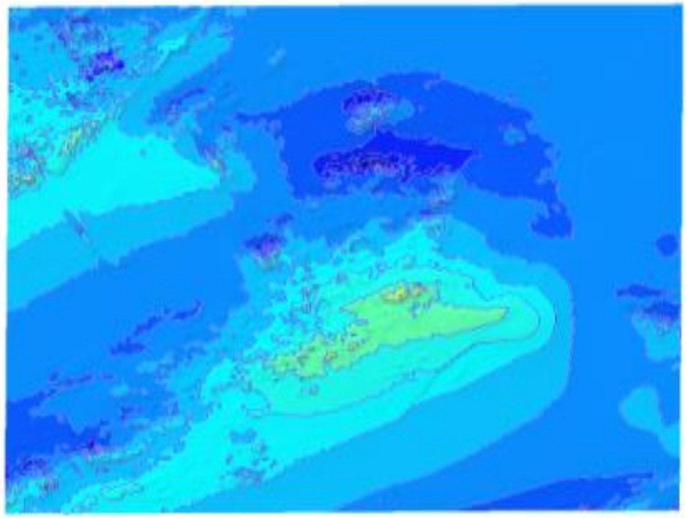


Curved surface slice

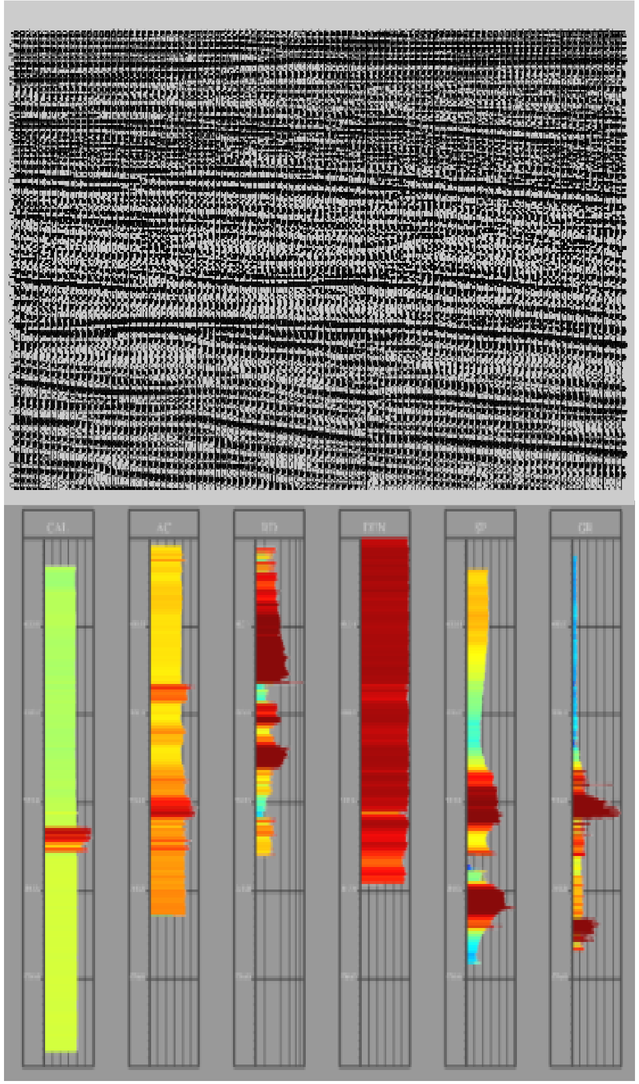


Seismic data subset

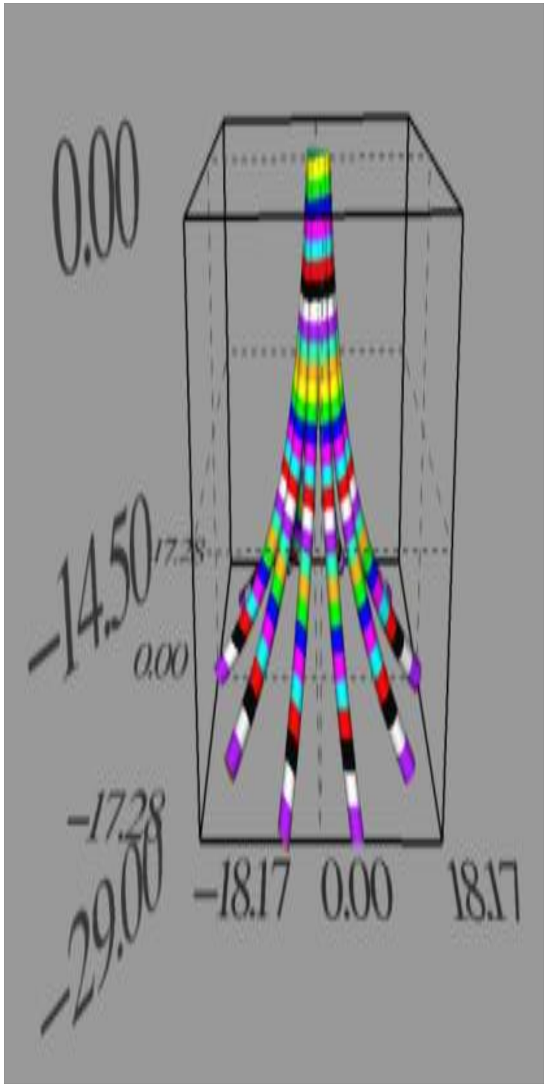
MeshViz Module



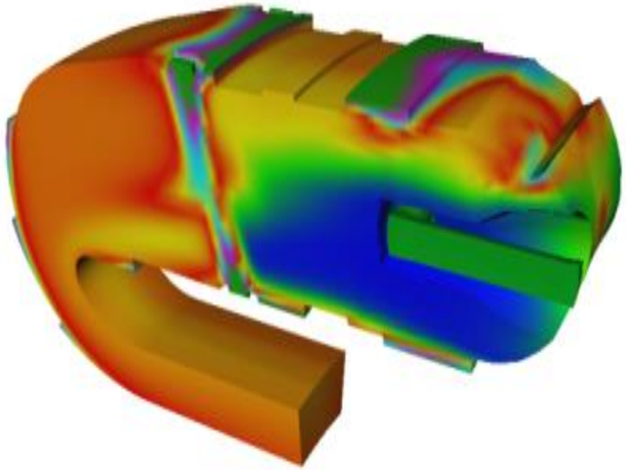
2D Grid



2D curve (seismic & logging)



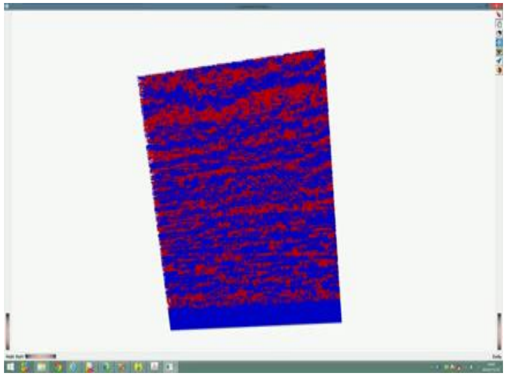
Curve hose (logging tracks)



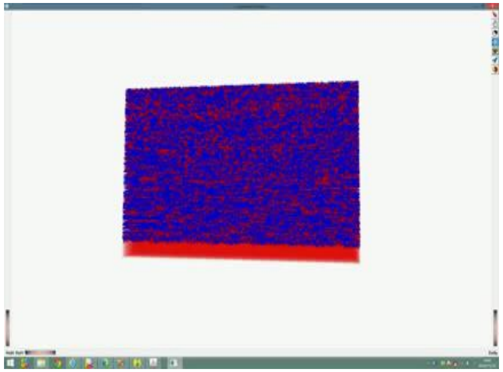
3D Grid

LDM: High efficiency management module of large scale seismic data

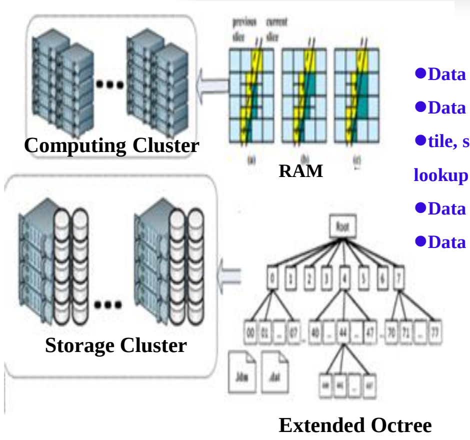
- Able to handle ultra-large-scale data, the data size unlimited.
- Real-time rendering of massive data.
- Supports multi-resolution seismic data rendering.



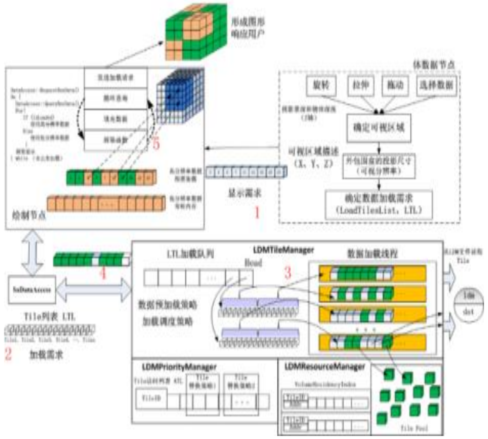
Data size：26Gb



Data size： 100Gb



- Data mapping algorithm
- Data Fast Load
- tile, surface domain lookup
- Data Logic Coding
- Data storage organization



LDM Core technology architecture diagram

Outline

- TH-1A system and its application
- Large-Scale data Visualization
  - Large-Scale Flow Visualization
  - Multi source geological data visualization graphics engine——OpenProbe
- Summary

Summary

- Propose novel approaches to integrate flow field analysis with multivariate and ensemble analysis.
- Propose a parallel sparse data management to support advection-based flow analysis.
- Develop a set of common, object oriented 3D graphics toolkit, supporting geoscience application software secondary development.
- OpenProbe offers a range of application modules for geoscience data features, and uses LDM to achieve massive geoscience data 3D stereoscopic dynamic visualization.

Thanks