

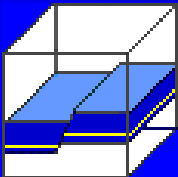
Grid computing for energy exploration and development

Dimitri Bevc, Sergio E. Zarantonello,

Neena Kaushik, Iulian Musat

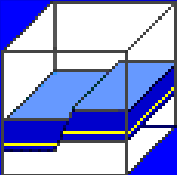
3DGeo Development Inc.

www.3dgeo.com



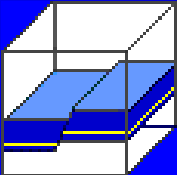
Why Grids for Seismic Imaging ?

- The construction of accurate 3-D images of the subsurface of the Earth is an extremely resource-intensive task. The most advanced technologies are not feasible in traditional environments.
- Harnessing remote resources effectively across different organizational domains is fundamentally important in the oil and gas industry.
- Globus middleware allows the sharing of resources in virtual organizations, enabling compute intensive seismic imaging services on the Grid. This addresses a critical need in a compute and resource intensive industry.



Outline

- Overview of seismic depth imaging
The computational challenge.
- Parallelization Issues
Cluster deployment of PSDM
Grid deployment of PDSM
- Seismic imaging on the Grid
The INSP client-server system.
The Grid-enabled implementation.
- Operational procedures
Scenarios
Issues
Benefits to the oil and gas industry



3-D Depth Imaging Methods

Wave-equation of mathematical physics

Kirchhoff Integral equation

Wave-equation PDE

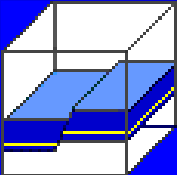
Shot-Gather

Shot-Receiver

Shot profile

Common Azimuth migration

Narrow Azimuth migration



Kirchhoff Migration

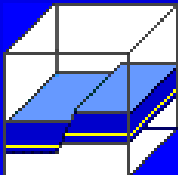
The essence of 3-D prestack *Kirchhoff* migration can be expressed in the following integral equation:

$$\text{Image}(\mathbf{x}) = \int \int_{\mathbf{x}_S} \int_{\mathbf{x}_R} G(\mathbf{x}_S, \mathbf{x}, \omega) G(\mathbf{x}, \mathbf{x}_R, \omega) \text{Data}(\mathbf{x}_S, \mathbf{x}_R, \omega) d\mathbf{x}_R d\mathbf{x}_S d\omega,$$

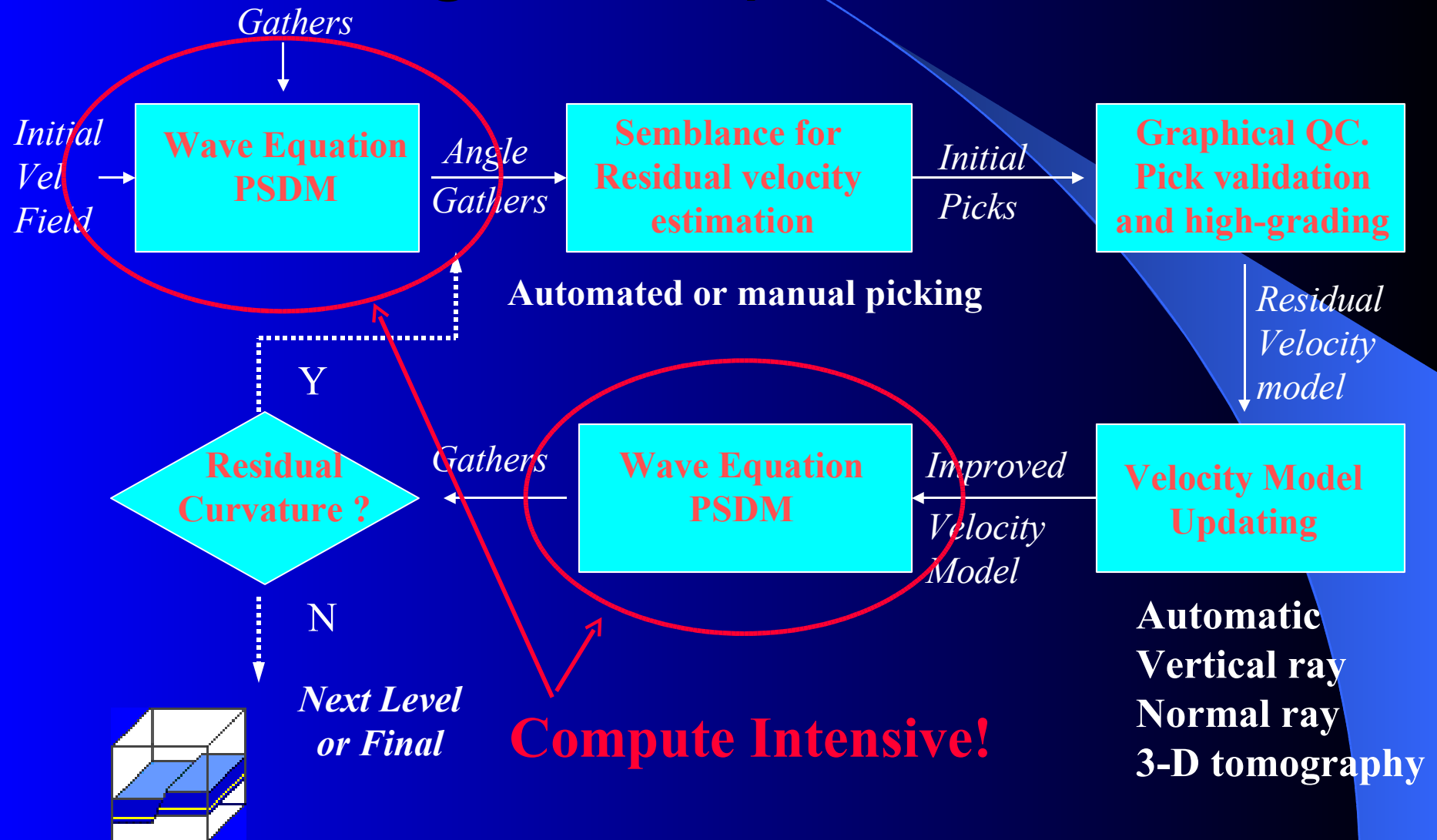
If the Green's functions are completely specified, this solution is as accurate as any “wave-equation” implementation.

In computer implementations, we express the integral as a sum:

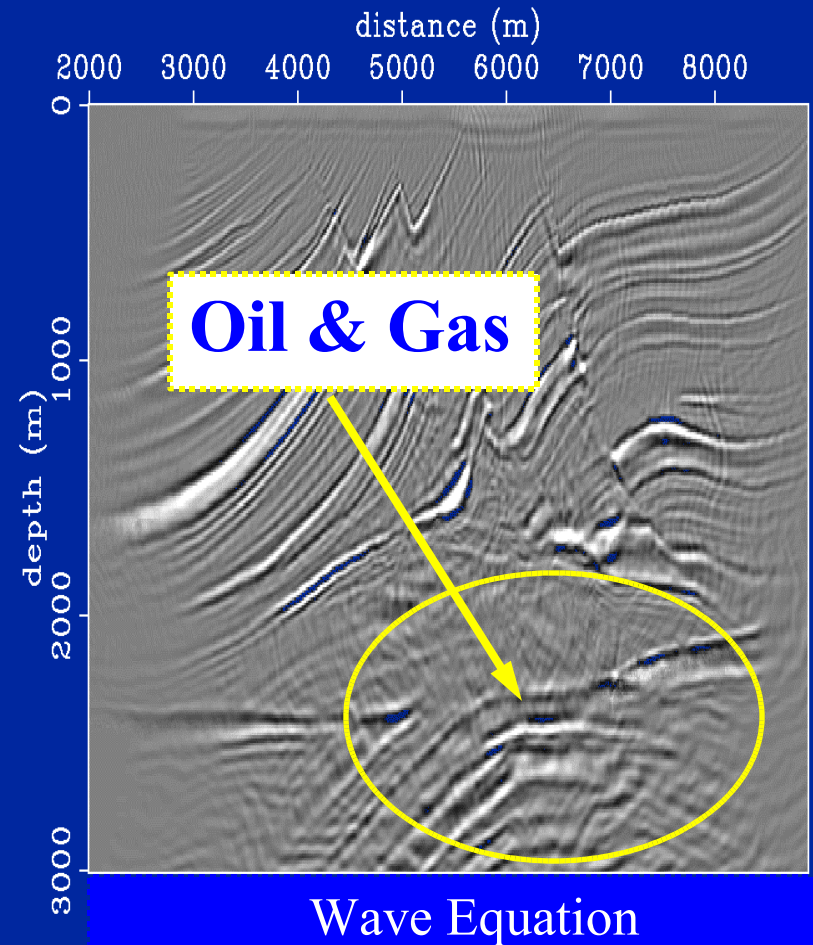
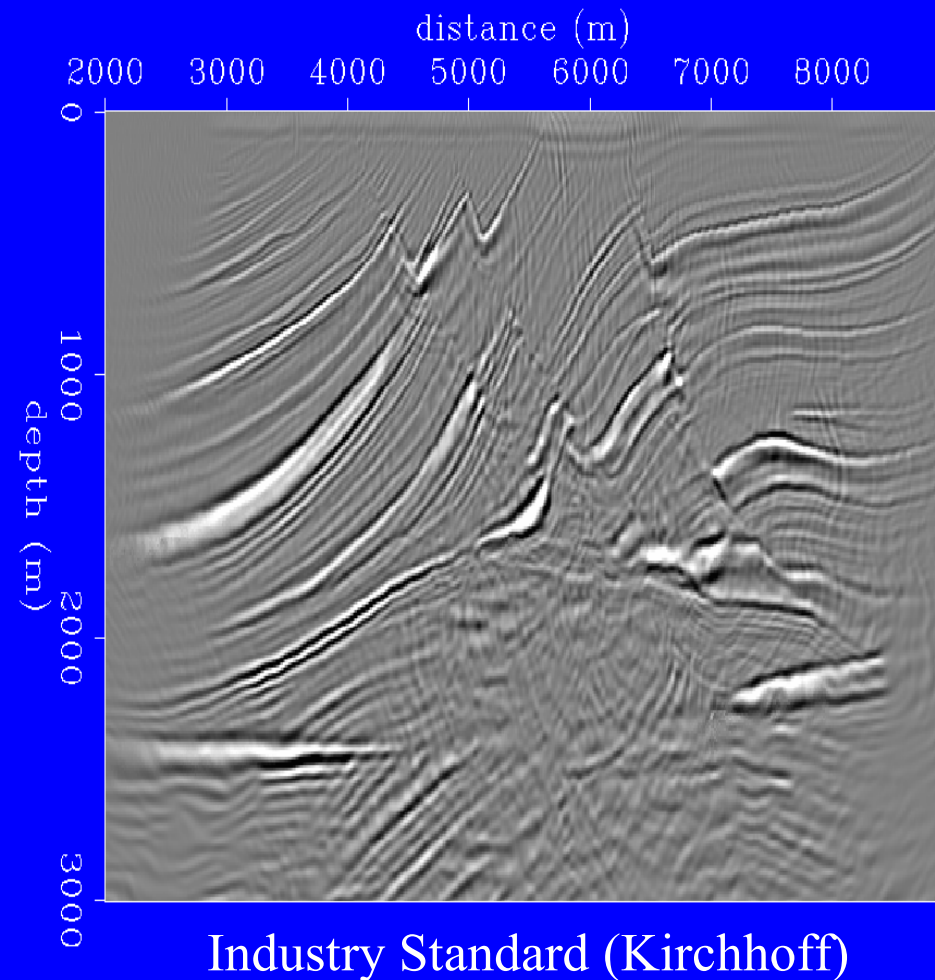
$$\text{Image}(\mathbf{x}) = \sum_{\mathbf{x}_S} \sum_{\mathbf{x}_R} A_S A_R \text{Input}(\mathbf{x}_S, \mathbf{x}_R, t_S + t_R)$$



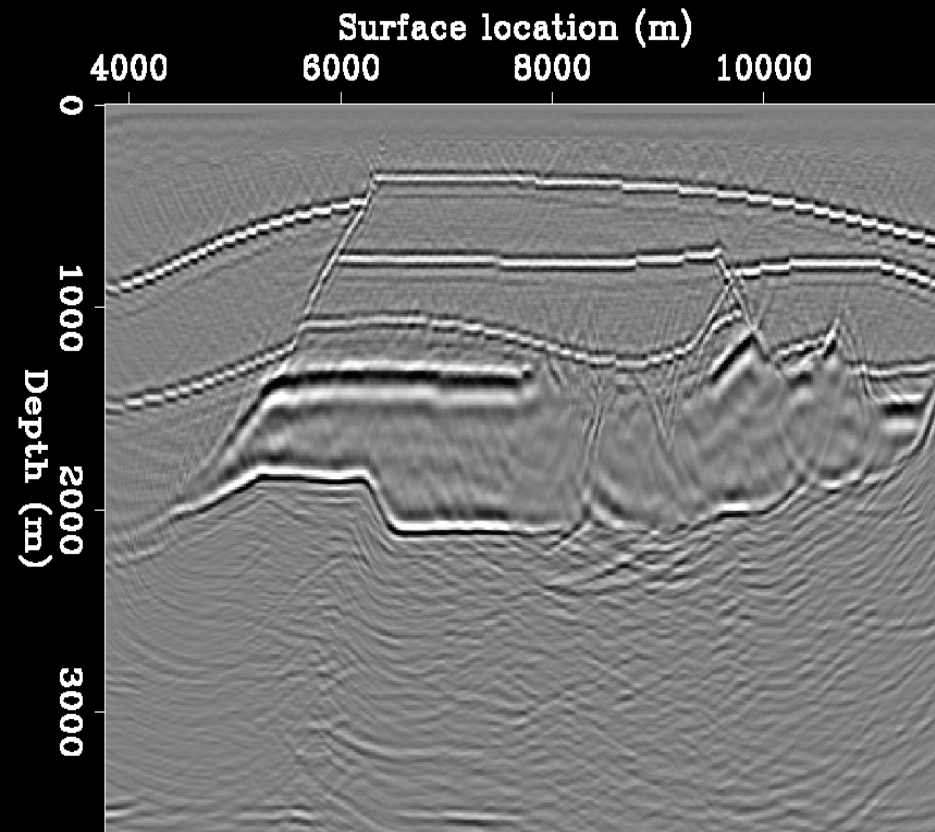
Building a 3D seismic image through multiple iterations



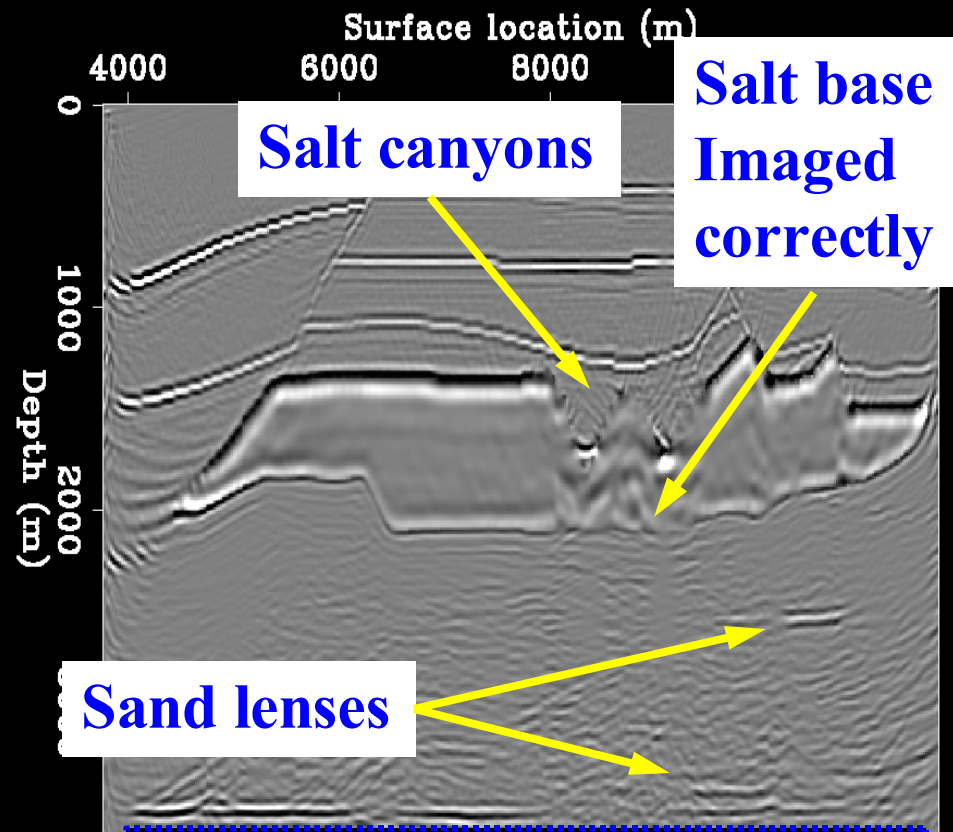
Imaging comparison: Kirchhoff vs. Wave Equation



Imaging comparison: Kirchhoff vs. Wave Equation

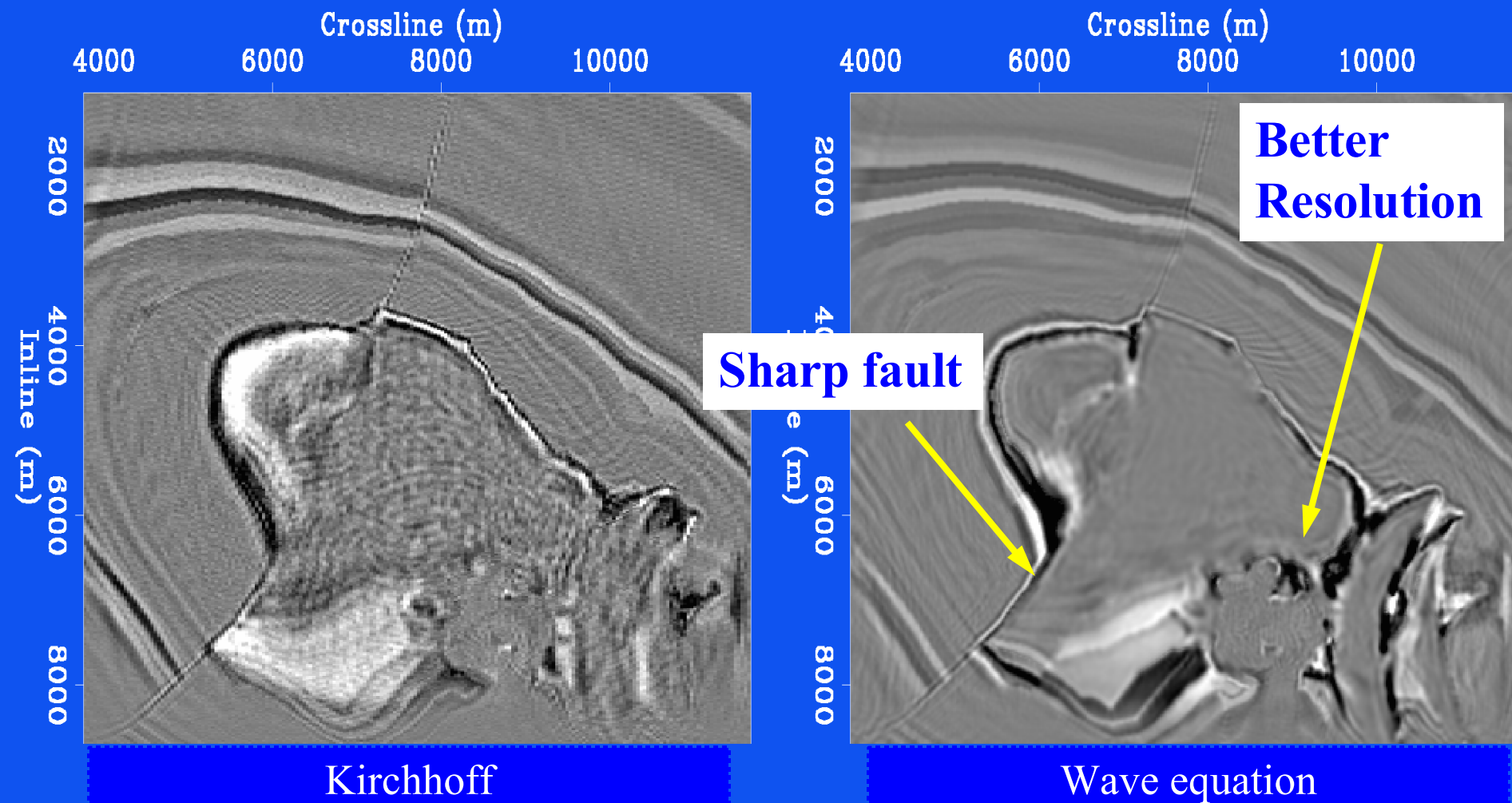


Kirchhoff C3, Xline 376



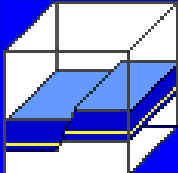
Wave equation

Imaging comparison: Kirchhoff vs. Wave Equation



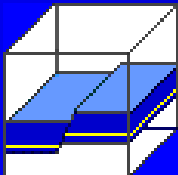
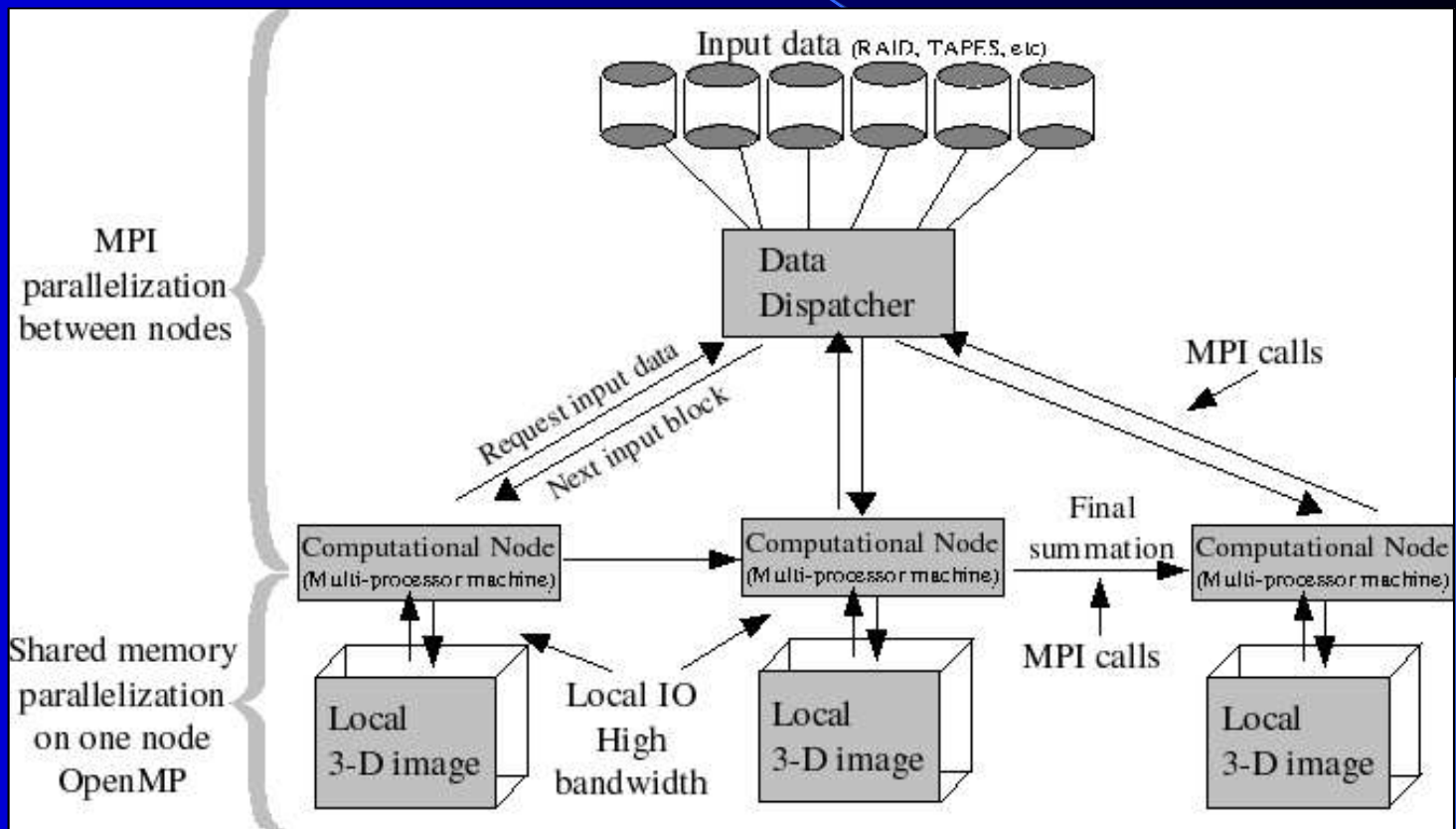
The computational challenge: Gulf of Mexico marine surveys

		Runtime (days)		
Blocks	Gbytes	Kirchhoff & ComAz	Narrow Azim.	Shot Profile
10	620	3	31	184
100	6,200	111	1,100	6,640
500	30,700	996	9,960	59,800 164 yrs!

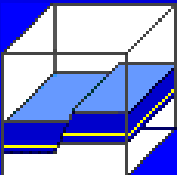
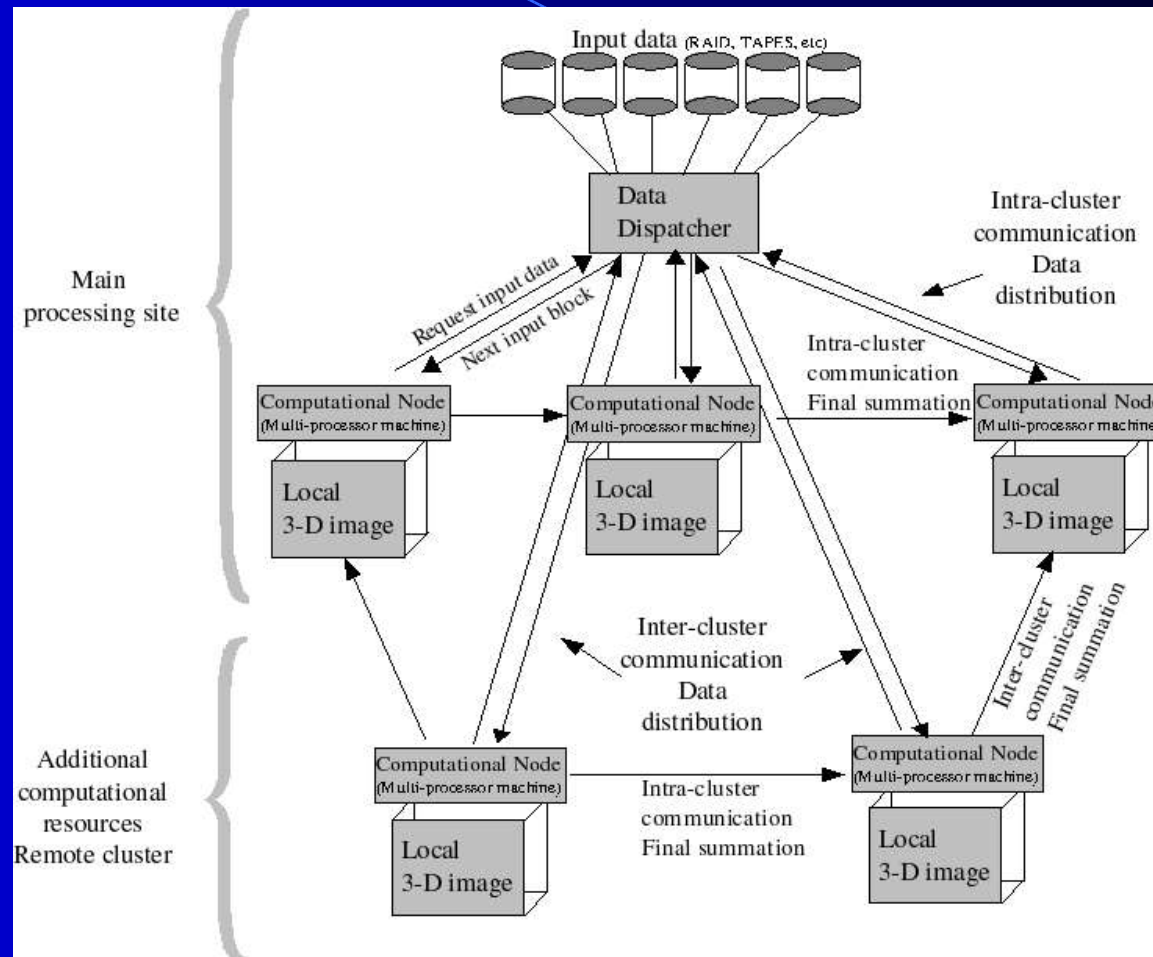


128 CPU Pentium 4 Cluster
(2.4 Ghz – 900 Mflops/cpu sustained)

PSDM cluster deployment



PSDM for Grid deployment



Distribute to additional compute resources:

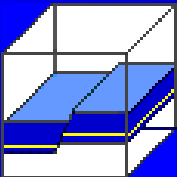
- support distributed heterogeneous computing environments
- through Web Service Resource Framework (WSRF)

What is INSP?



Internet Seismic Processing – started in '97

- 3DGeo's graphical interface to our processing system.
- Job Setup and Progress Monitoring.
- Remote Quality Control.
- Interpretation and Velocity Model Building.
- Network Collaboration.



The Grid is a natural evolutionary step for INSP

INSP user interface

The screenshot displays the INSP 3.1 user interface with several windows open:

- INSP 3.1**: The main application window with a menu bar (File, Edit, View, Build, Tools, Window) and a toolbar.
- Split_1 [Filesystems]**: A tree view showing the file structure, including folders like /home/lup/data01/julian/data, 3DGeo Houston Processing Center, and subfolders like BR, Fugro, Modules, Processes (Temporary), POC2, Pemex, Tutorial, and 2D. The 2D folder is expanded, showing subfolders like Data, MVA, PSDM, and PreProc.
- Machines**: A table listing available machines for processing.
- Workflow Builder**: A diagram showing the processing workflow, including steps like TT file, Data Viewer, PSDM, Gathers, Stack, Data Viewer Gathers, Bandpass, AGC, Velocity OK?, and Velocity import wizard.
- PSDM_iter1 - PSDM**: A dialog box for configuring the PSDM process, with tabs for Required, Typical, and All. It includes sections for Output Parameters, Migration Parameters, and Velocity.
- 3DGeo Houston Processing Center**: A window showing a 3D visualization of seismic data, with a color scale ranging from 0 to 18000.
- MVA/vint.0.sm.H**: A window showing a 2D visualization of seismic data, with a color scale ranging from 0 to 18000.

The **Machines** window contains the following table:

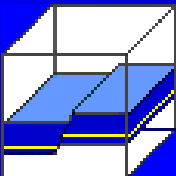
Use	Host Name	Platform	Available
<input checked="" type="checkbox"/>	2.toro20	LINUX	2
<input checked="" type="checkbox"/>	2.toro21	LINUX	2
<input checked="" type="checkbox"/>	2.toro22	LINUX	2
<input checked="" type="checkbox"/>	2.toro23	LINUX	2
<input checked="" type="checkbox"/>	2.toro24	LINUX	2
<input checked="" type="checkbox"/>	2.toro25	LINUX	2
<input checked="" type="checkbox"/>	2.toro26	LINUX	2
<input checked="" type="checkbox"/>	2.toro27	LINUX	2
<input checked="" type="checkbox"/>	2.toro28	LINUX	2
<input checked="" type="checkbox"/>	2.toro29	LINUX	2
<input checked="" type="checkbox"/>	2.toro30	LINUX	2
<input type="checkbox"/>	2.cerdo01	LINUX	2
<input type="checkbox"/>	2.cerdo02	LINUX	2
<input type="checkbox"/>	2.cerdo03	LINUX	2
<input type="checkbox"/>	2.cerdo04	LINUX	2
<input type="checkbox"/>	2.cerdo05	LINUX	2

The **PSDM_iter1 - PSDM** dialog box shows the following parameters:

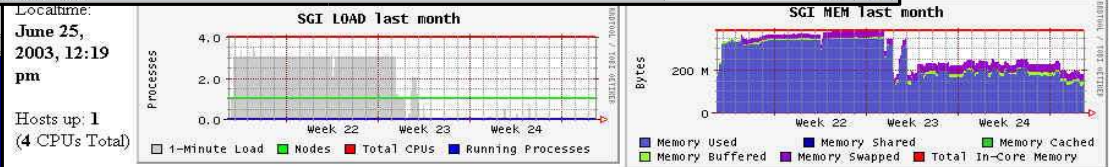
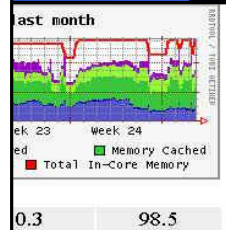
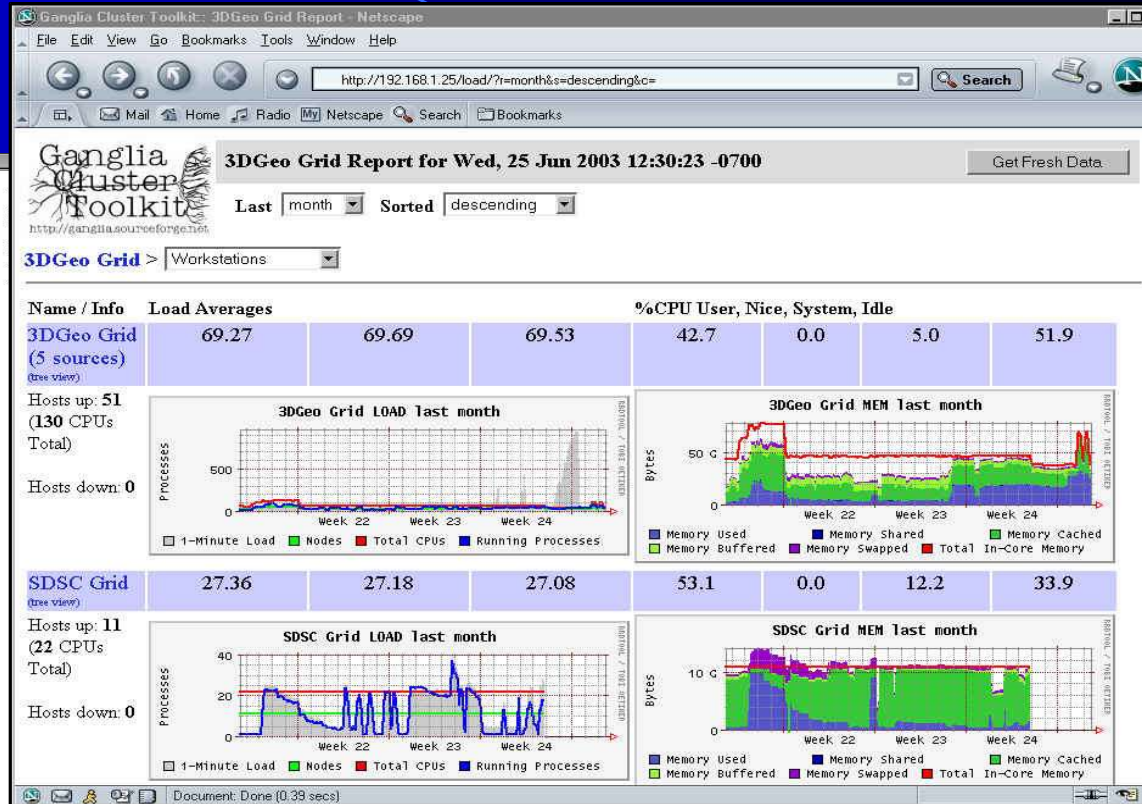
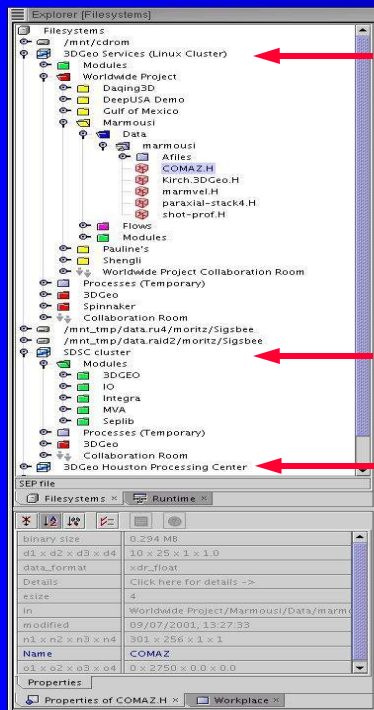
- Output Parameters**:
 - prestack_output_file: /Tutorial/2D/Data/mpi_local/psdm.1
 - PSDM_parameter_file: /Tutorial/2D/Data/mpi_local/psdm.1
 - output_data_format: binary_disk
- Migration Parameters**:
 - top_aperture_angle: 60.0 degrees
 - aperture_angle: 60.0 degrees
- Velocity**:
 - velocity_file: /Tutorial/2D/Data/Vel/v.1.H
 - velocity_parameter_file: /Tutorial/2D/Data/Vel/v.1.H
 - n_z_vel: 800
 - d_z_vel: 10.0
 - o_z_vel: 0.0
 - n_iline_vel: 731
 - d_iline_vel: 25.0

The **Workflow Builder** diagram shows the following flow:

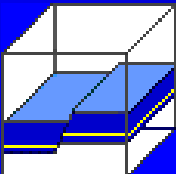
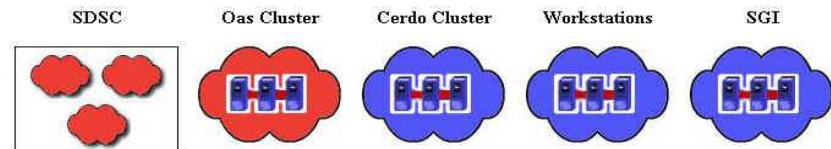
```
graph TD
    TT[TT file] --> DV1[Data Viewer]
    DV1 --> Stop1[Stop? yes/no]
    Stop1 -- yes --> PSDM[PSDM]
    Stop1 -- no --> Gathers[Gathers]
    PSDM --> Gathers
    Gathers --> Stack[Stack]
    Gathers --> DV2[Data Viewer Gathers]
    Gathers --> Bandpass[Bandpass]
    Bandpass --> AGC[AGC]
    AGC --> VelocityOK[Velocity OK? YES/NO]
    VelocityOK -- no --> Interp[Interp]
    Interp --> Smooth[Smooth]
    Smooth --> VelocityOK
    VelocityOK -- yes --> Increment[Increment Iteration Number and start]
    Increment --> PSDM
    VelocityOK -- yes --> DV3[Data Viewer VELOCITY]
    DV3 --> Velconvert[Velconvert]
    Velconvert --> Velimport[Vel import wizard]
    Velimport --> Veltxt[Vel.txt]
```



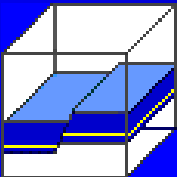
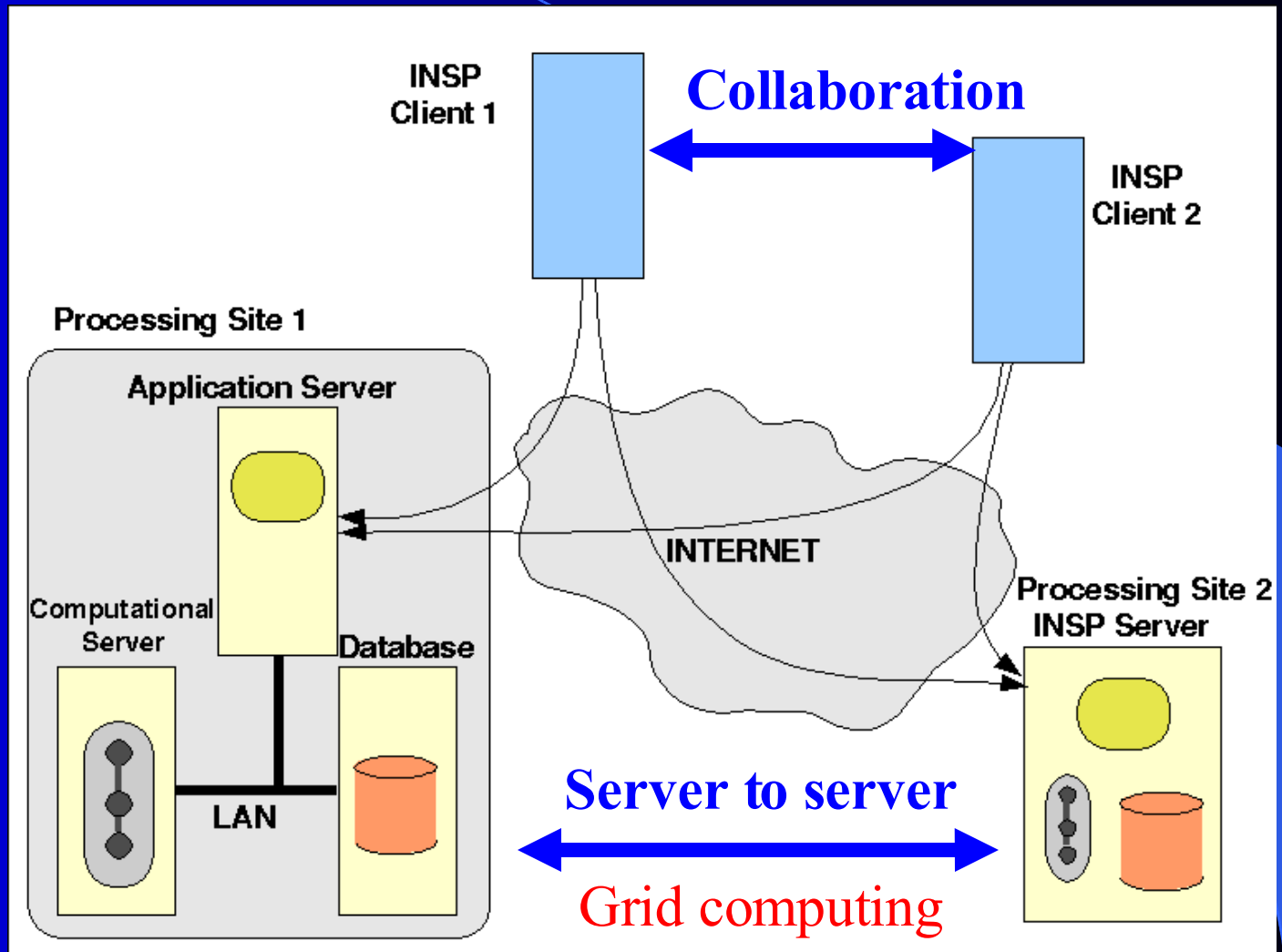
Grid status, resource monitoring



Snapshot of the 3DGeo Grid | Legend

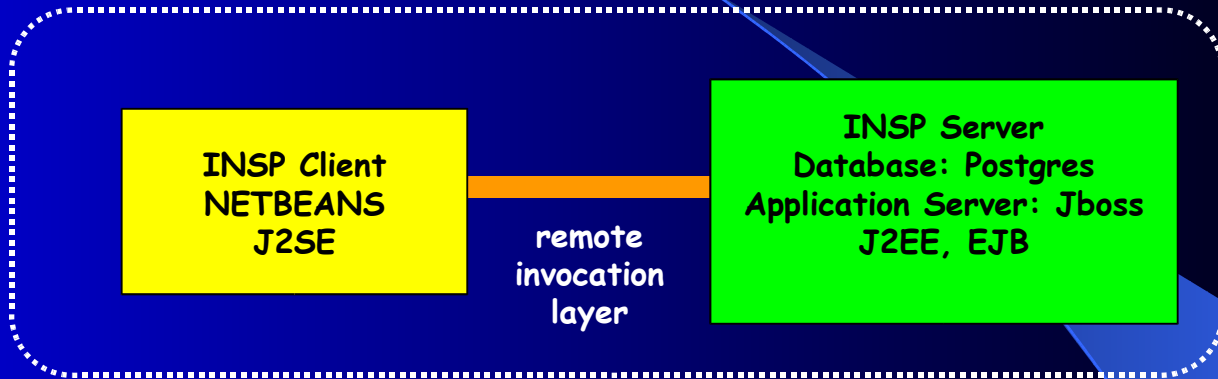


INSP architecture

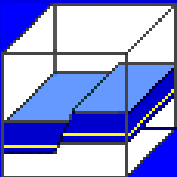
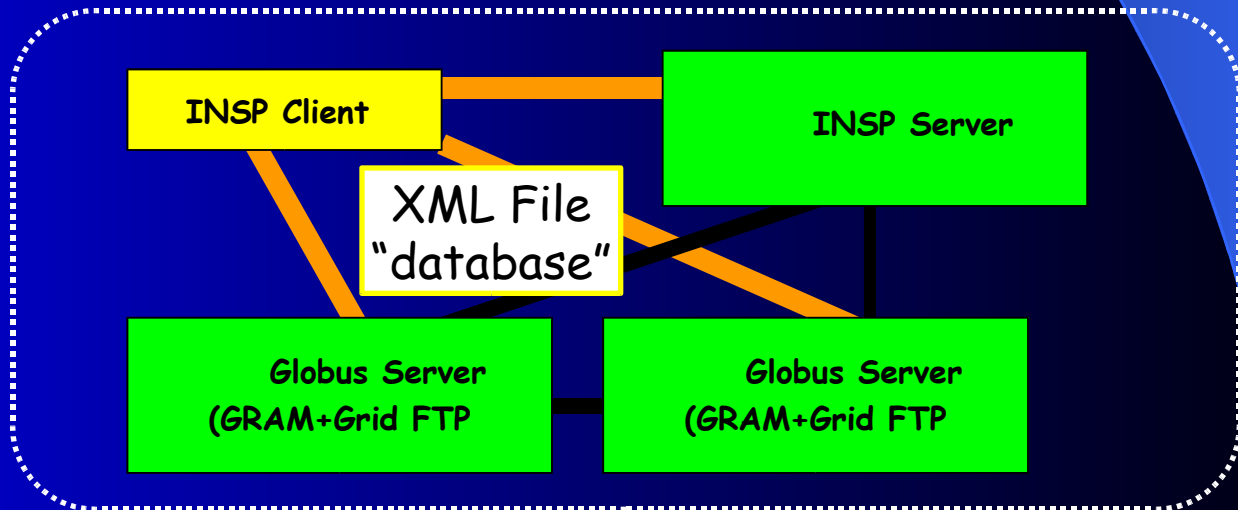


Grid-enabling INSP

current
design



target
design



Today's operational scenario

Data acquisition



Preprocessing



Data bank



100's of TBytes

Drilling decision



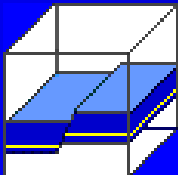
Oil Company



Data analysis & Interpretation

1–2 yr process

Depth Imaging



INSP operational scenario

Data acquisition



Preprocessing



Data bank



100's of TBytes

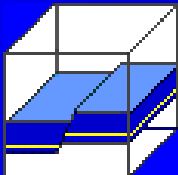
Drilling decision



Oil Company



Site a platform



Data analysis
& Interpretation

1 yr process

Depth Imaging



Grid Operational scenario

Data acquisition



Preprocessing



Data bank



100's of TBytes

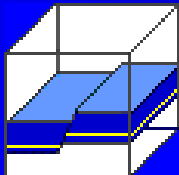
Drilling decision



Oil Company



Site a platform



Data analysis
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1 yr process

Depth Imaging



Grid operational scenario

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Preprocessing



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100's of TBytes

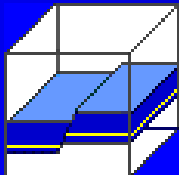
Drilling decision



Oil Company



Site a platform



Data analysis
& Interpretation

1/2 yr process

Depth Imaging

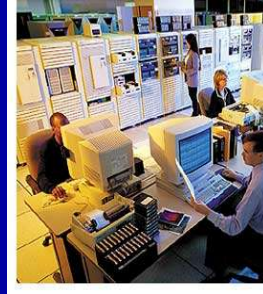


Grid operational scenario

Data acquisition



Preprocessing



Data banks



100's of TBytes

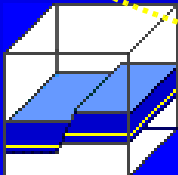
Drilling decision



Oil Company



Site a platform



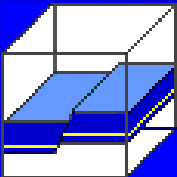
Data analysis & Interpretation

Depth Imaging

1/2 yr process

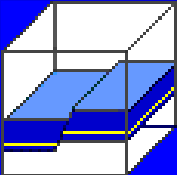
Algorithmic issues

- Dynamic optimization of workload
- Data partitioning
 - Kirchhoff: distribute input, velocity model, Green's functions, image volumes.
 - Wave-equation migration: frequency slices, distribute input, velocity model, image volumes
- Scaling across heterogeneous resources
- Modeling the application



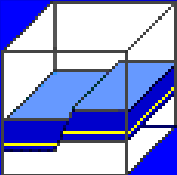
Practical issues

- Proprietary data – security
- Data volumes – transfer rates, compression
- Data distributed in data banks – access, & data transfer
- Authority delegation across organizational boundaries – change of business culture
- Computationally intense – months of runtime
- Peak loads – access to on-demand computing



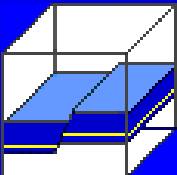
What we're doing today

- INSP used today: client-server Internet app.
- Collaboration between 3DGeo's Houston and Santa Clara offices, and oil company client sites.
 - use facilities & personnel more efficiently.
- Access computers at SDSC for remote jobs.
- Outsource excess compute needs.
- Moving toward GT 4.0.



The future

- Seamless access to resources over the web
- Utility computing:
 - Companies based on IP shouldn't have to worry about buying computers or maintaining, and administrating computer hardware
- Ultimate goal is to tie in all stages from acquisition, to interpretation, to drilling decision into a “real time” process.



Benefits to the oil & gas industry

- Better results sooner – shorten the time to making a drilling decision
- More flexible way of processing and interpreting data – increased productivity
- Process and interpret data as it is acquired – the instrumented oil field
- Utility computing – outsourcing model allows access to the latest hardware
- The *IntraGrid* within Oil Companies

