Parallel Implementation of Earth Tomography

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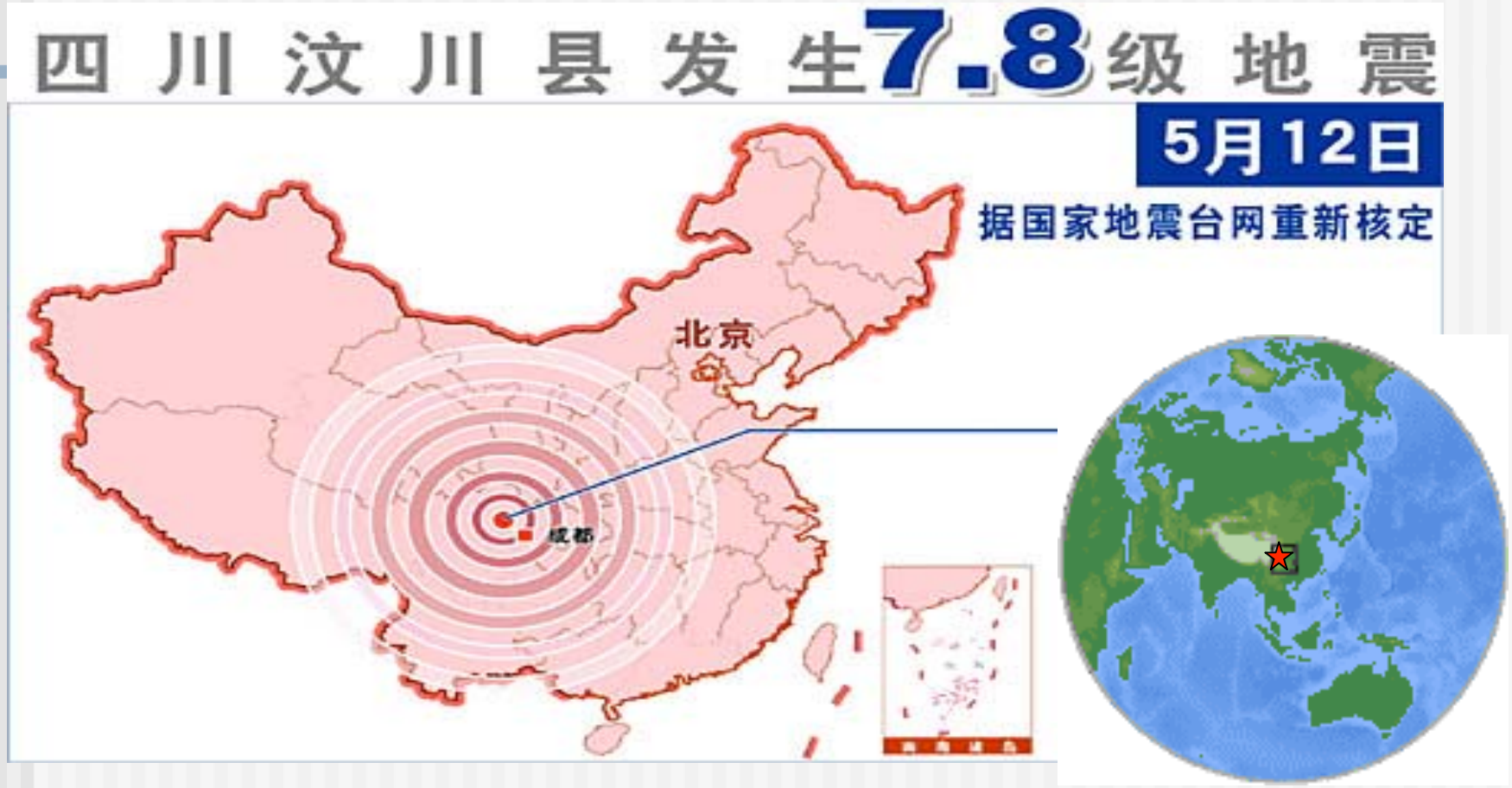
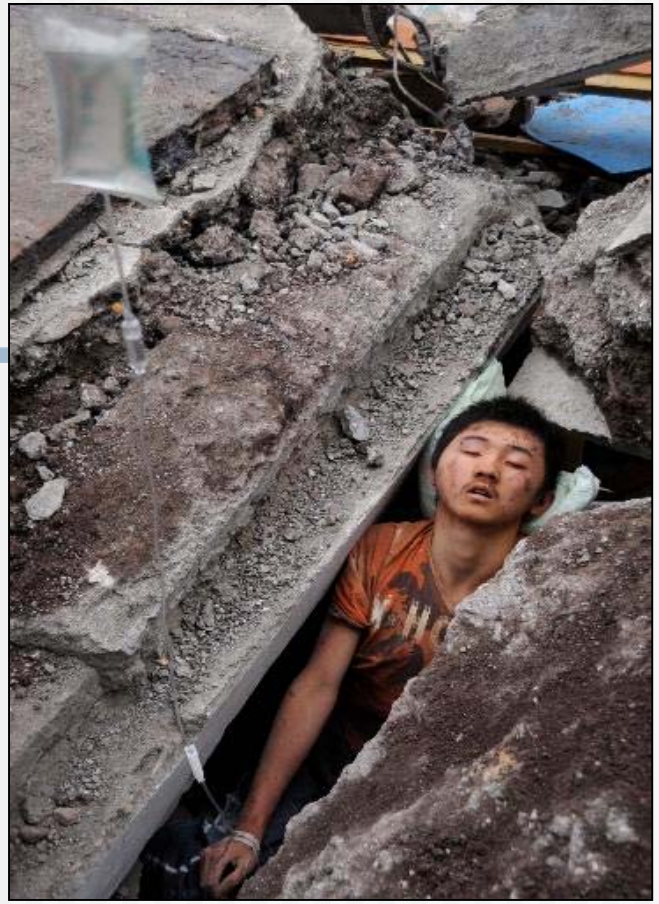
May 15, 2008

M=7.8 Earthquake, Sichuan, China

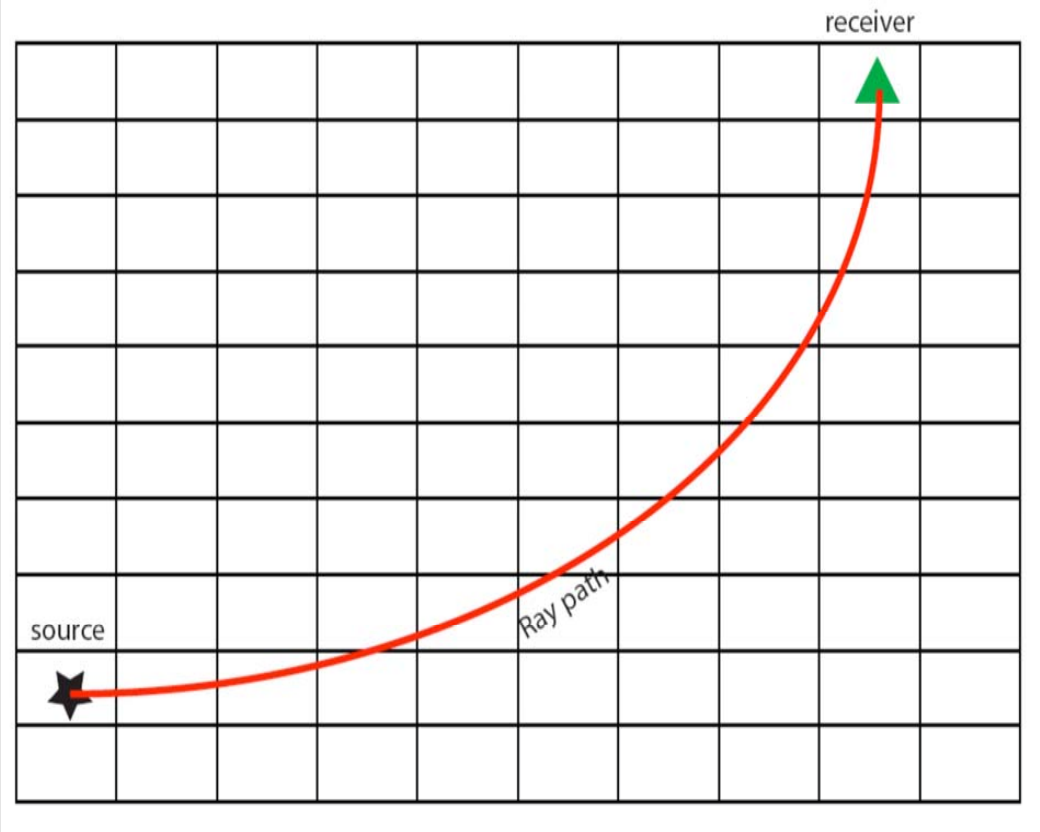


14866 people killed up to May 14, 2008



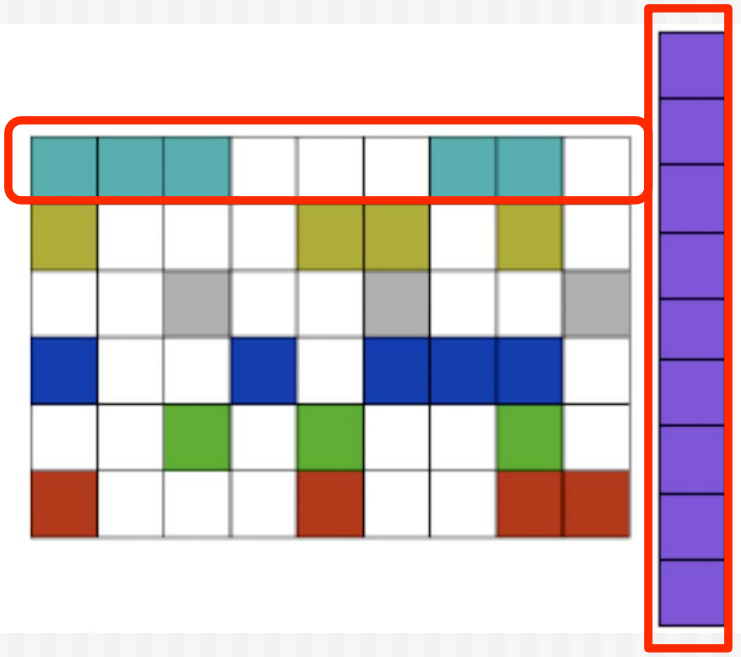

cnsphoto
Nikon 特约

Ray tracing process

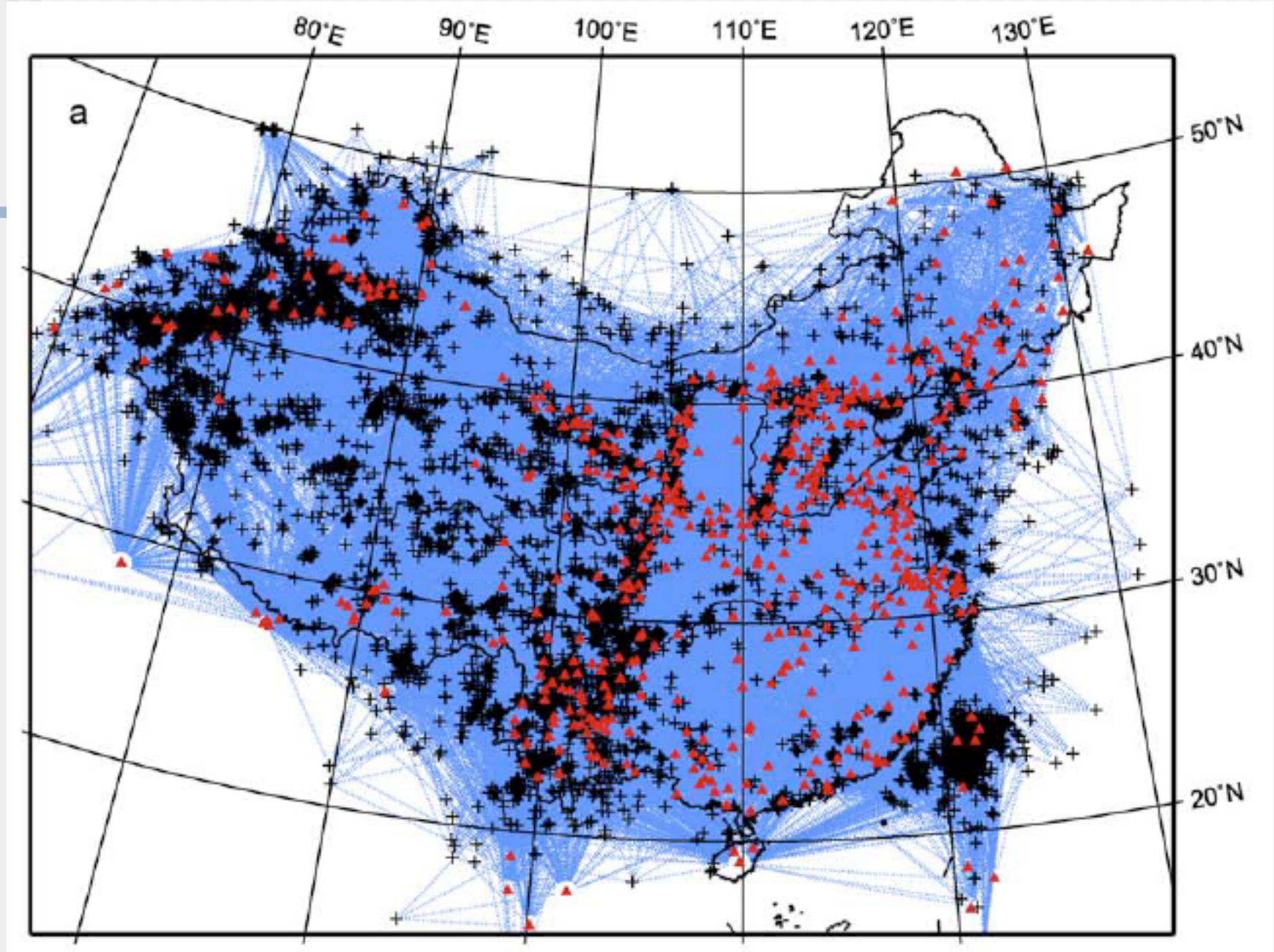


$$t(x,x') = \int_s \frac{ds}{v} \qquad t(x,x') = \sum_j s_j p_j$$

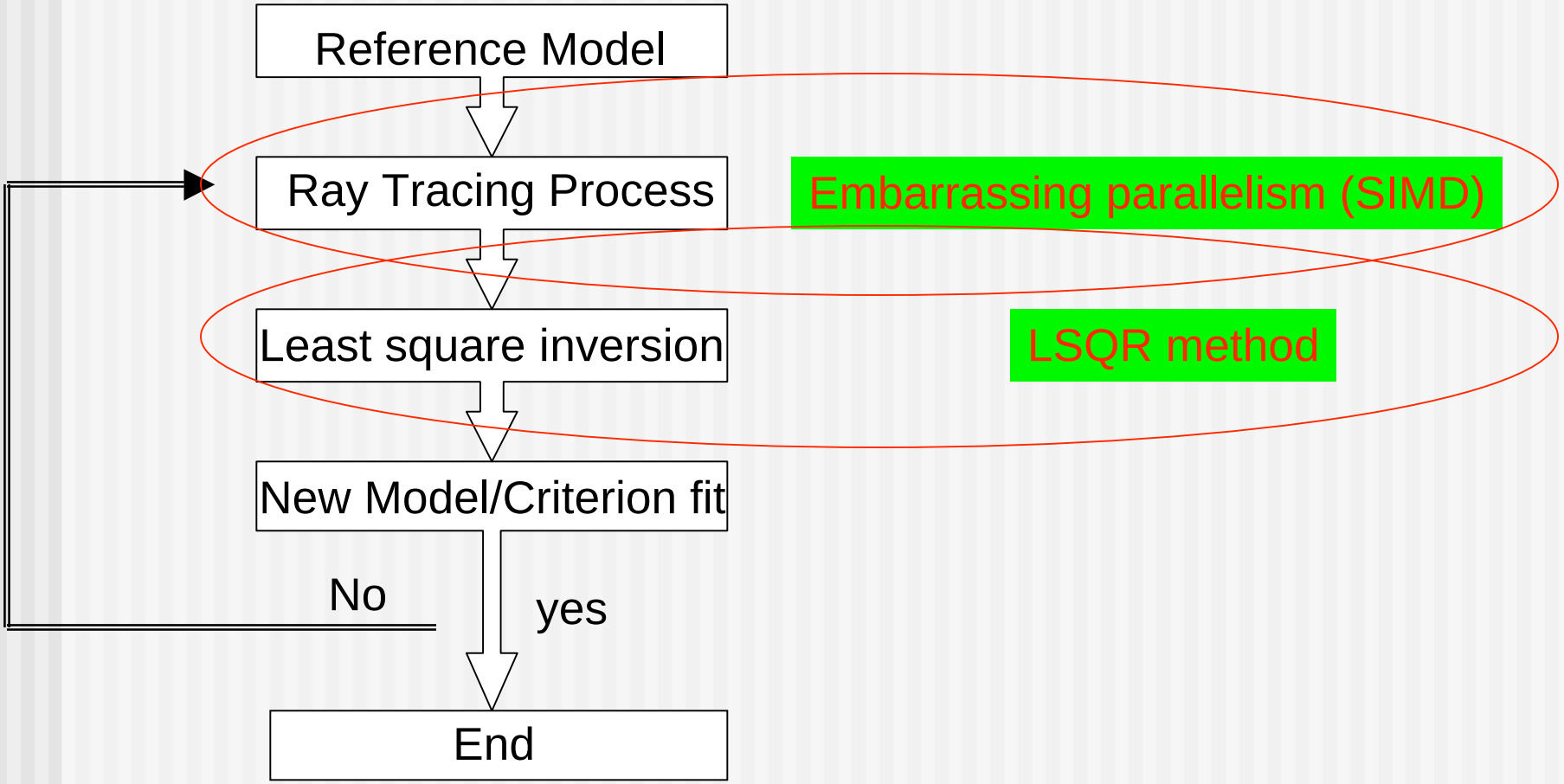
$$Sp = t$$



Fermat's Principle


a
80°E
90°E
100°E
110°E
120°E
130°E
50°N
40°N
30°N
20°N

Tomography workflow



1. Initialize

$\beta_1 u_1 = b, \quad \alpha_1 v_1 = A^T u_1, \quad w_1 = v_1, \quad x_0 = 0$

$\bar{\phi}_1 = \beta_1, \quad \bar{\rho}_1 = \alpha_1$

where $\alpha_i, \beta_i > 0$ and $\|v_i\| = 1, \ \|u_i\| = 1$

2. For i=1, 2, 3, … repeat steps 3-6

3. Continue the bidiagonalization

$\beta_{i+1} u_{i+1} = A v_i - \alpha_i u_i$

$\alpha_{i+1} v_{i+1} = A^T u_{i+1} - \beta_{i+1} v_i$

4. Construct and apply next orthogonal transformation

$\rho_i = (\bar{\rho}_i^2 + \beta_{i+1}^2)^{1/2} \qquad c_i = \bar{\rho}_i / \rho_i$

$s_i = \beta_{i+1} / \rho_i \qquad \theta_{i+1} = s_i \alpha_{i+1}$

$\bar{\rho}_{i+1} = -c_i \alpha_{i+1} \qquad \phi_i = c_i \bar{\phi}_i$

$\bar{\phi}_{i+1} = s_i \bar{\phi}_i$

5. Update x,w

$x_i = x_{i-1} + (\phi_i / \rho_i) w_i$

$w_{i+1} = v_{i+1} - (\theta_{i+1} / \rho_i) w_i$

6. Test for convergence

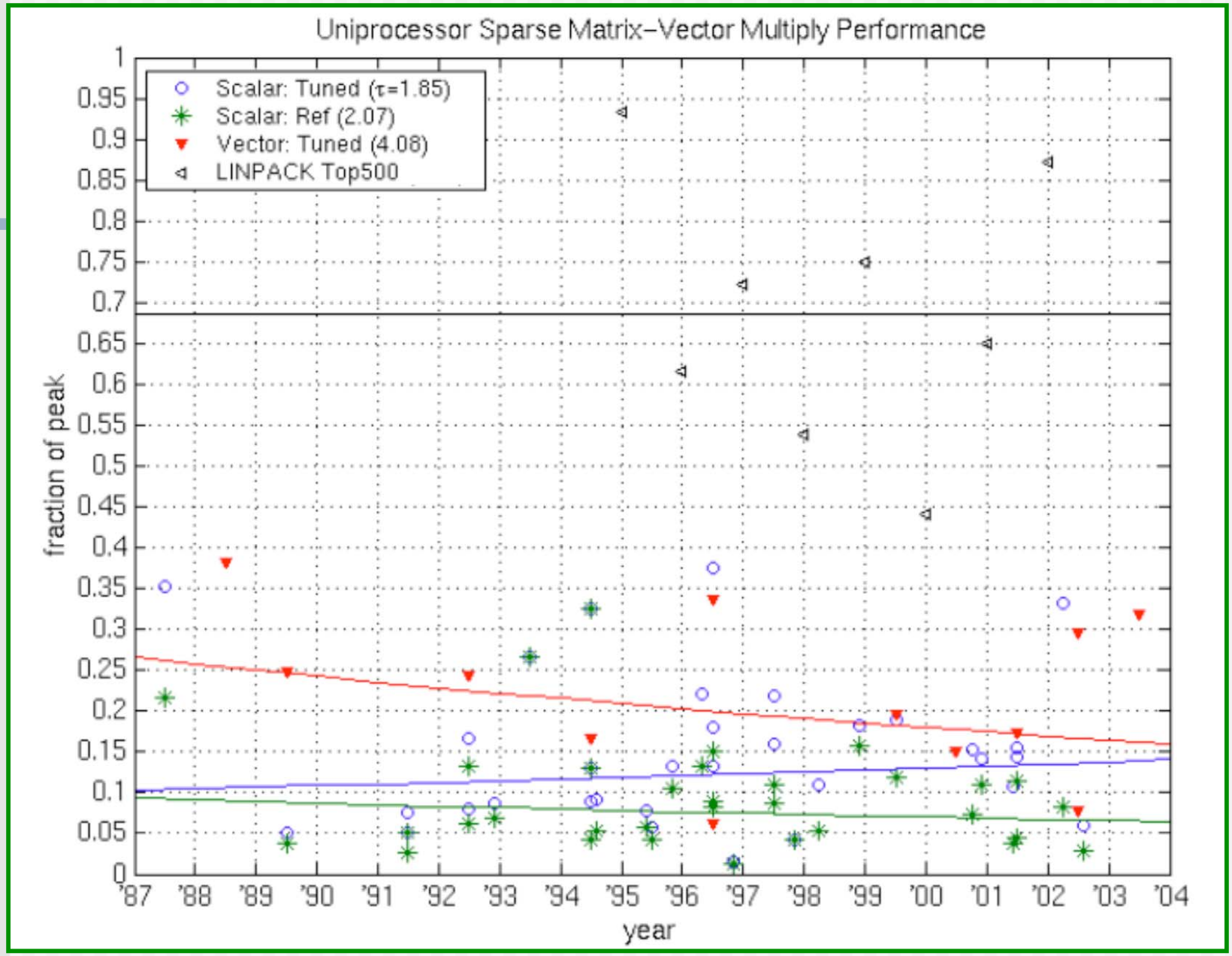
LSQR method

$Ax = b$

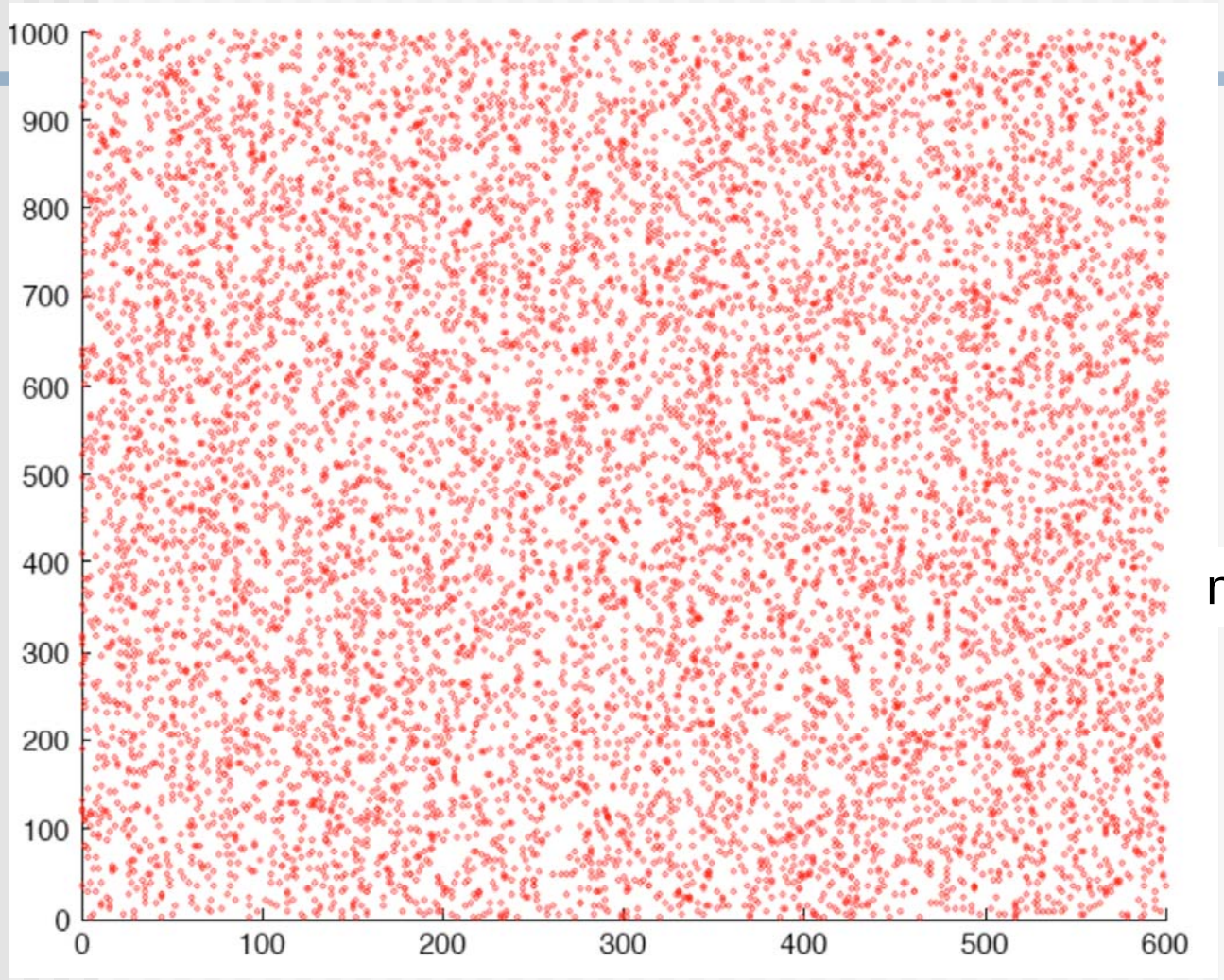
The most time consuming part:

Sparse Matrix-Vector Multiply

Locality and load balance


Uniprocessor Sparse Matrix–Vector Multiply Performance
Scalar: Tuned (τ=1.85)
Scalar: Ref (2.07)
Vector: Tuned (4.08)
LINPACK Top500
fraction of peak
year
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
'87
'88
'89
'90
'91
'92
'93
'94
'95
'96
'97
'98
'99
'00
'01
'02
'03
'04

A practical example of the matrix

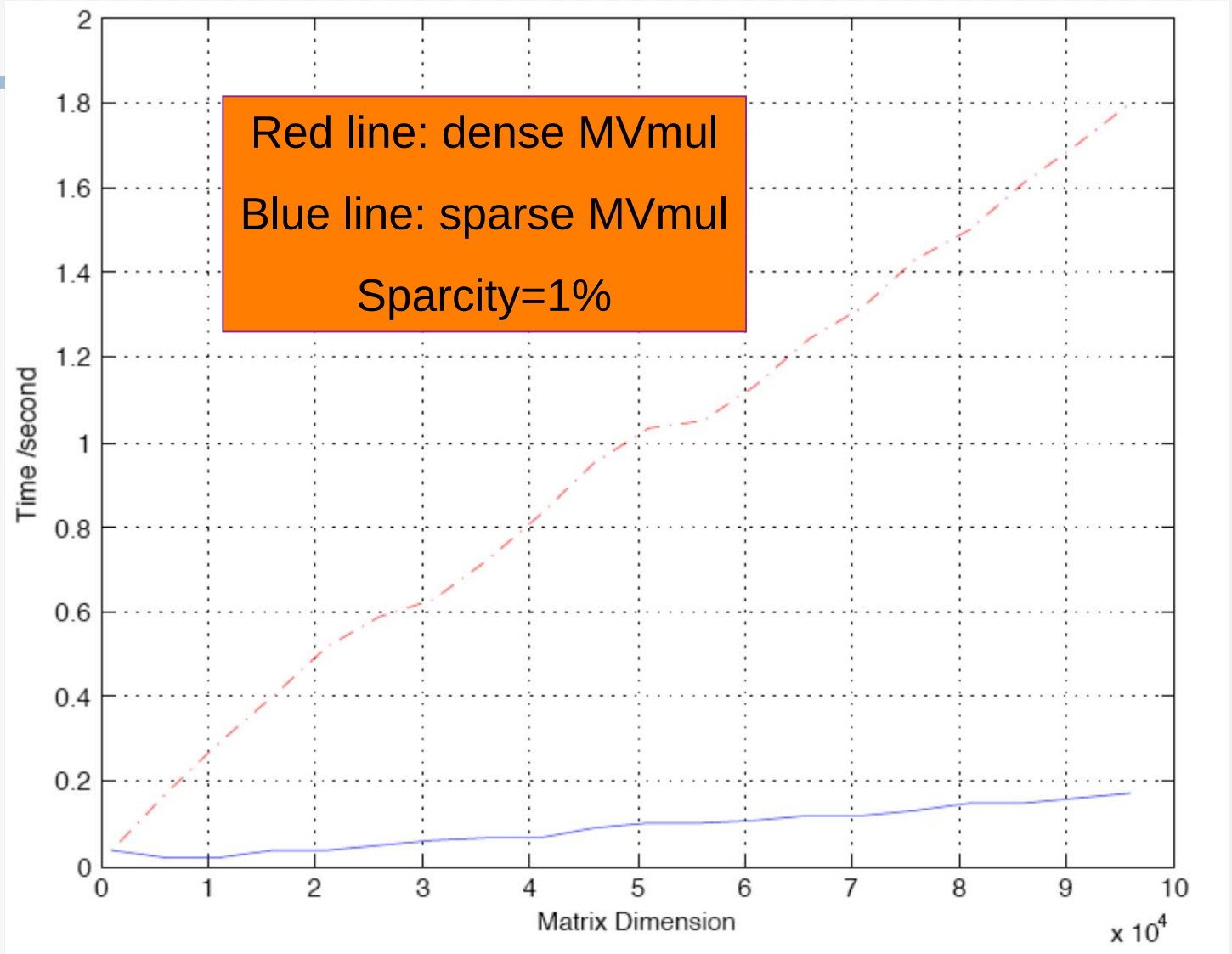


NNZ=10020

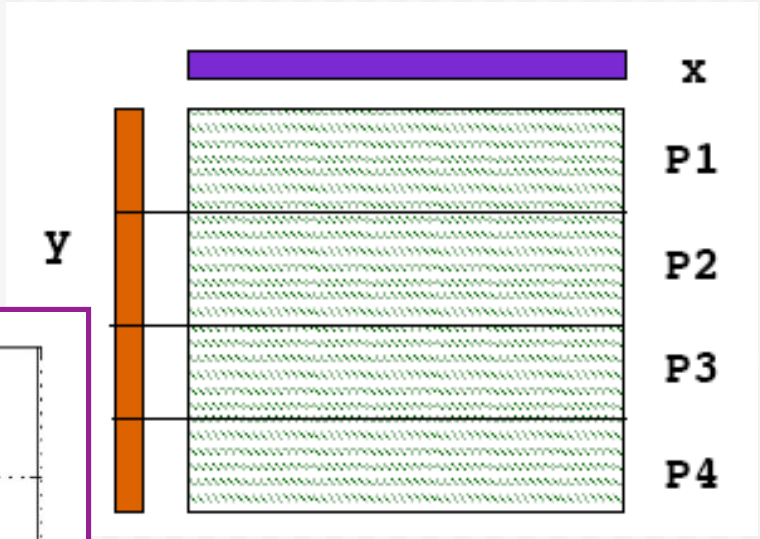
Sparsity=0.0167

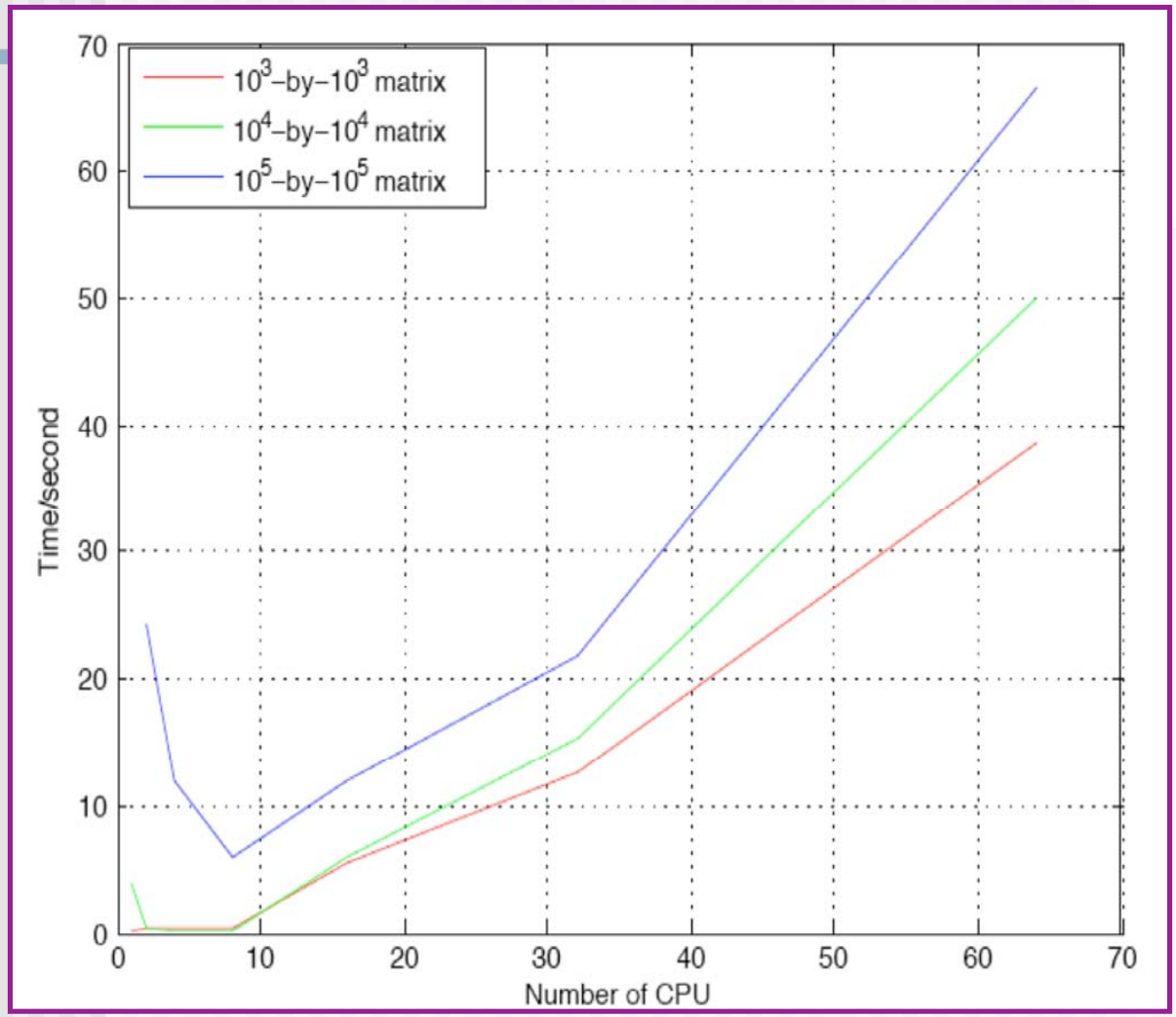
not easy to localize nnzs

Not as sparse as band diagonal matrices, BUT …



1D row partition by Star-P





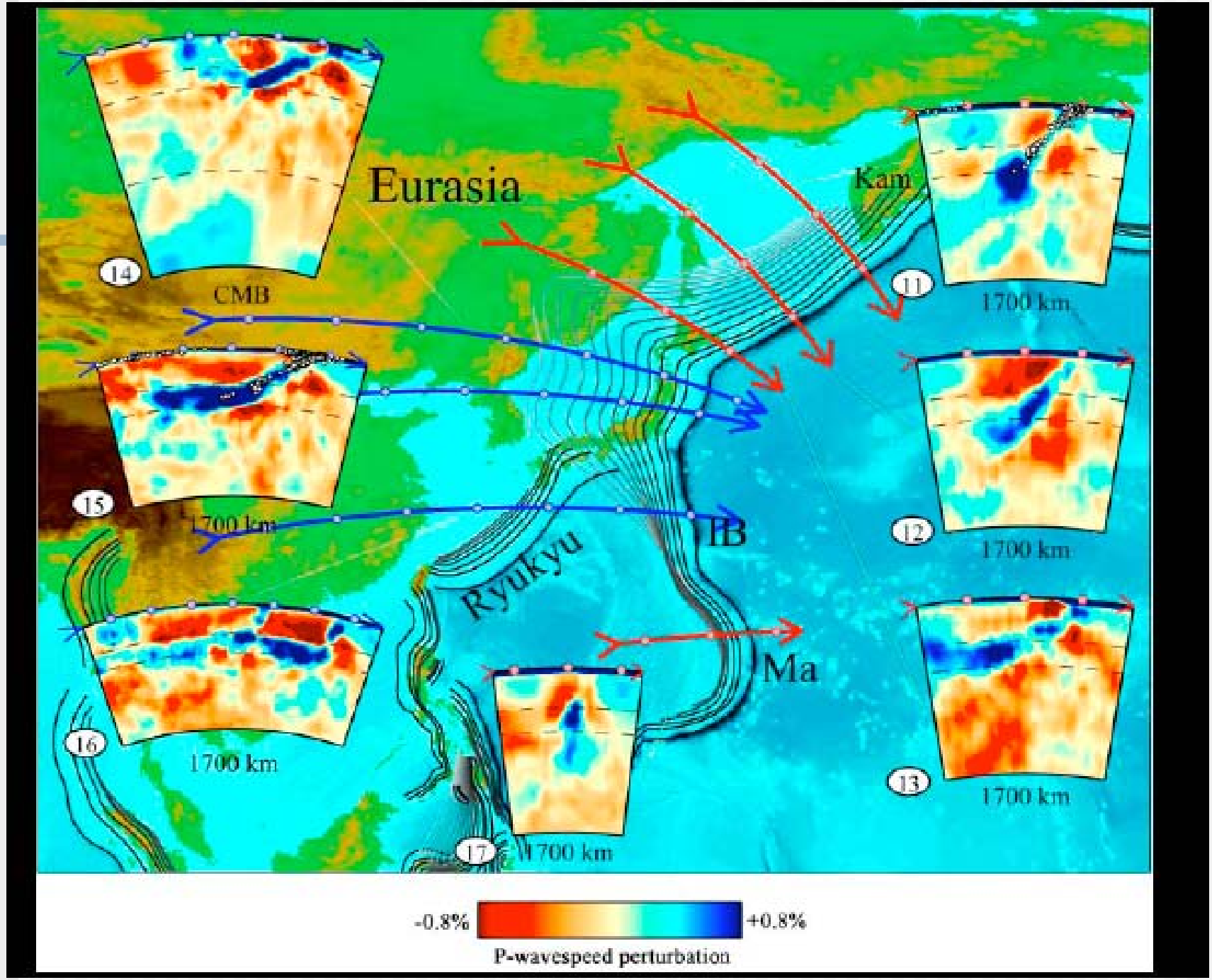
Communication cost

$$O(N/n_p) + O(2\rho MN/n_p)$$

Computing cost

$$O(2\rho MN/n_p)$$

Latency dominate ??


Eurasia
Kam
CMB
14
11
1700 km
15
1700 km
IB
12
1700 km
Ryukyu
Ma
16
1700 km
17
1700 km
13
1700 km
-0.8%
+0.8%
P-wavespeed perturbation

Conclusion

- Parallelize the tomography code
- Different parts, different strategies
- SpMV is case by case.
- Compare with direct method?
- How to find the balance between communication and computation?

Call for donation for China Earthquake!

So far, **14,866** people died, **7,841** people are missing and **25,788** people are still buried. Please, donate through:

MercyCorps

http://www.mercycorps.org/chinaearthquake/

American Red Cross

http://www.redcross.org/news/in/profiles/Intl_profile_ChinaEarthquake.html

Canada Red Cross

https://www.paypaq.com/redcross/new/