Seismic wave Propagation and Imaging in Complex media: a European network

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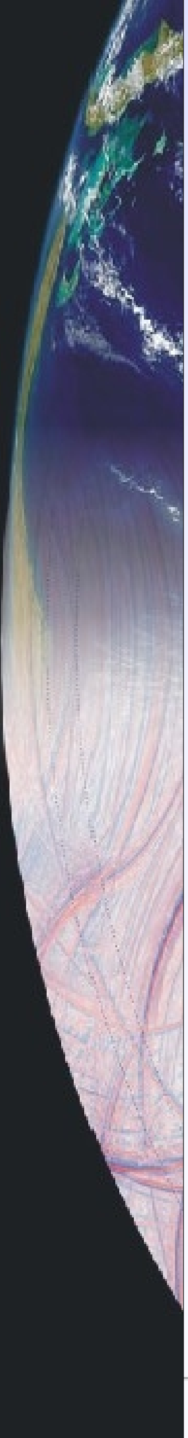
Place of Origin: Milano, Italy
Appointment Time: July 2005

Project: The role of volcanic structure in the generation of Long Period signals.

Task Groups: TG Small Scale

Cooperation: INGV Oss. Sism. Arezzo, CNRS Clermont-Ferrand, OGS Trieste, UCD Dublin



Introduction

The role of volcanic structure in the generation of Long Period signals

Long period signals

Observed at different volcanic areas (wide set of seismic signals)

Long-lasting, low frequency (below 0.5 Hz), monochromatic

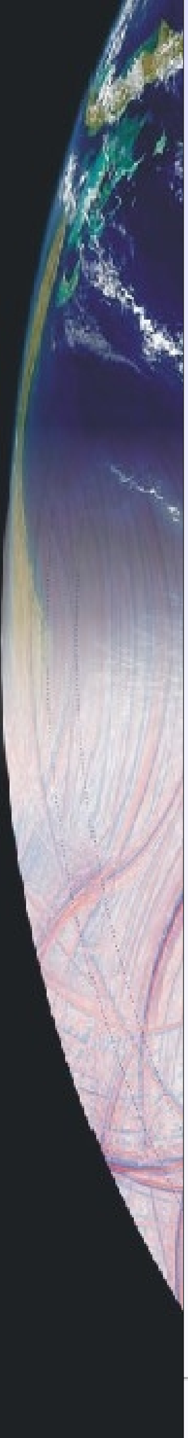
Possible eruption precursors

Source inversions assuming averaged velocity models

Proposed models include resonance of fluid-filled cracks and conduits with different geometries

Complex Source Time Functions

Can LP signals may be explained as combination of source and path effects? Would the retrieved mechanism change, if we consider model accounting for a detailed volcanic structure (e.g. topography, velocity structure)?



Introduction

The role of volcanic structure in the generation of Long Period signals

Long period signals in volcanic areas: source or path effects?

1. Tools:
Generation of GF including topography and heterogeneous velocity structures (Tessmer et al., 1992)
Frequency domain inversion code to retrieve
time-dependent volcanic sources (Cesca & Dahm, 2007)

2. Data:
LP event at Kilauea, 21 May 2001

3. Forward modeling:
Effects of layered structures

4. Inversion for 1D and 3D models:
Effects of topography and heterogeneous velocity structures

5. Conclusions

Method

The role of volcanic structure in the generation of Long Period signals

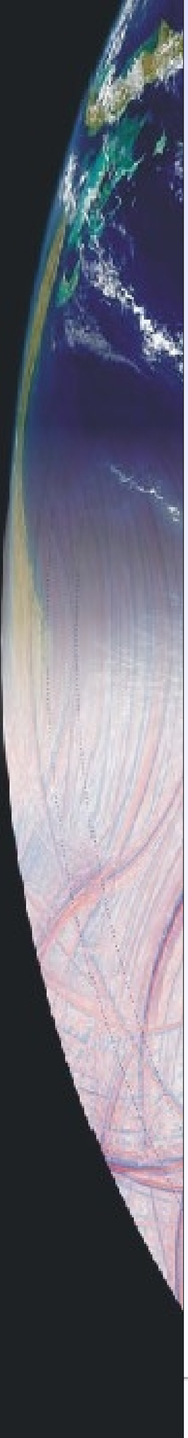
Green´s functions calculation

Wave propagation in 1D models

2) Pseudospectral technique (Heimann, 2005)
3) Reflectivity method (QSEIS, Wang, 1995)

Wave propagation in 3D models

1) Pseudospectral technique (Tessmer et al., 1992)
Topography
Heterogeneous velocity structure



Method

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Frequency domain inversion code

1. *Source: moment tensor and single force, time dependent,* $M_{pq}(t)+F_p(t)$

2. *General formulation for displacement:*

$$U_n(t) = M_{pq}(t) * G_{np,q}(t) + F_p(t)*G_{np}(t)$$

3. *Frequency domain formulation*

$$U_n(w)=m_l(w)\, g_{nl}(w)$$

4. *Inversion process (matrix form, for each frequency value):*

$$U\,[Ntr.x1] = G\,[Ntr.x9]\,M\,[9x1]$$

5. *Constraints on the time-behaviour of source components:*
   by singular value decomposition

This way, we can treat separately the source geometry and the STF

VOLPIS Code, http://www.spice-rtn.org (Cesca and Dahm, 2007, in press)

Data, LP event at Kilauea

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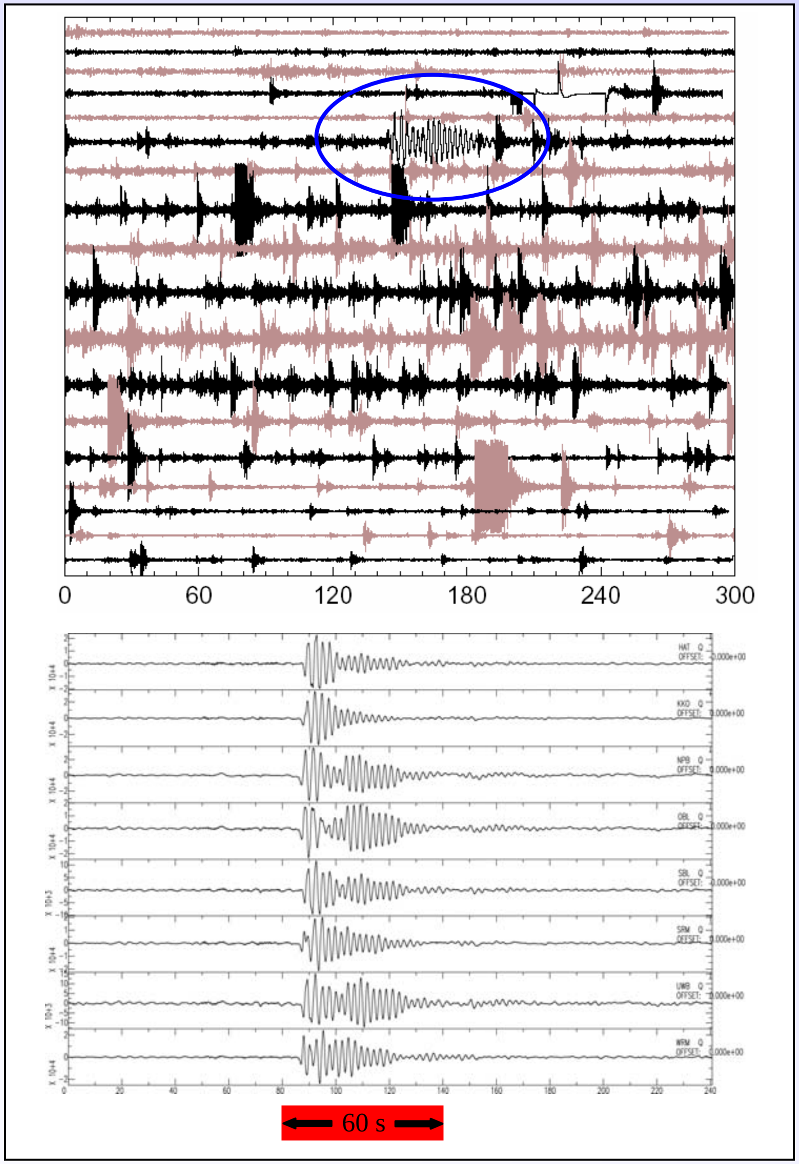

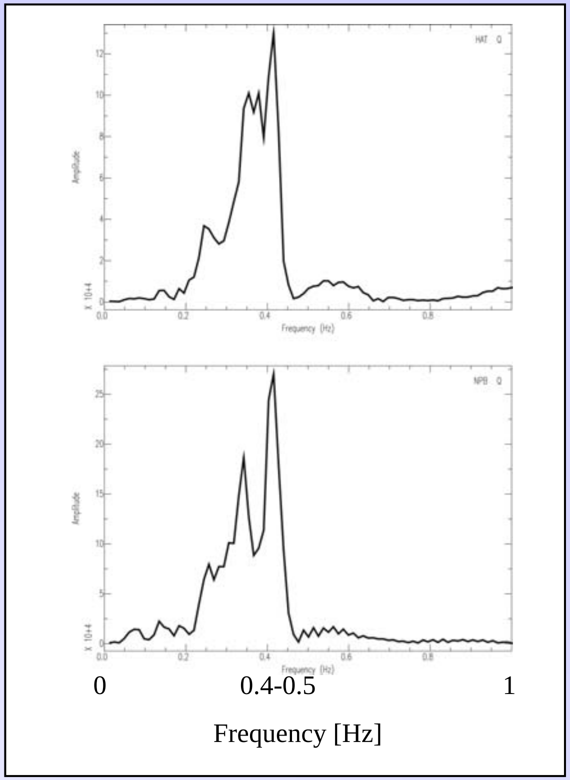

Long-lasting ringing signal

Dominant frequency 0.4-0.5 Hz

Epicentral distances up to 40 km

Data, LP event at Kilauea

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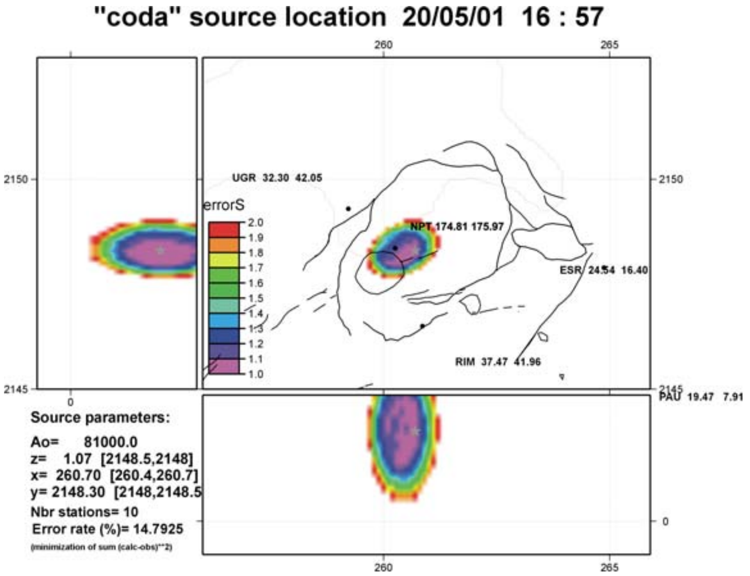
Source location

Inversion of seismic amplitudes corrected by site effects (Battaglia & Aki, 2003)

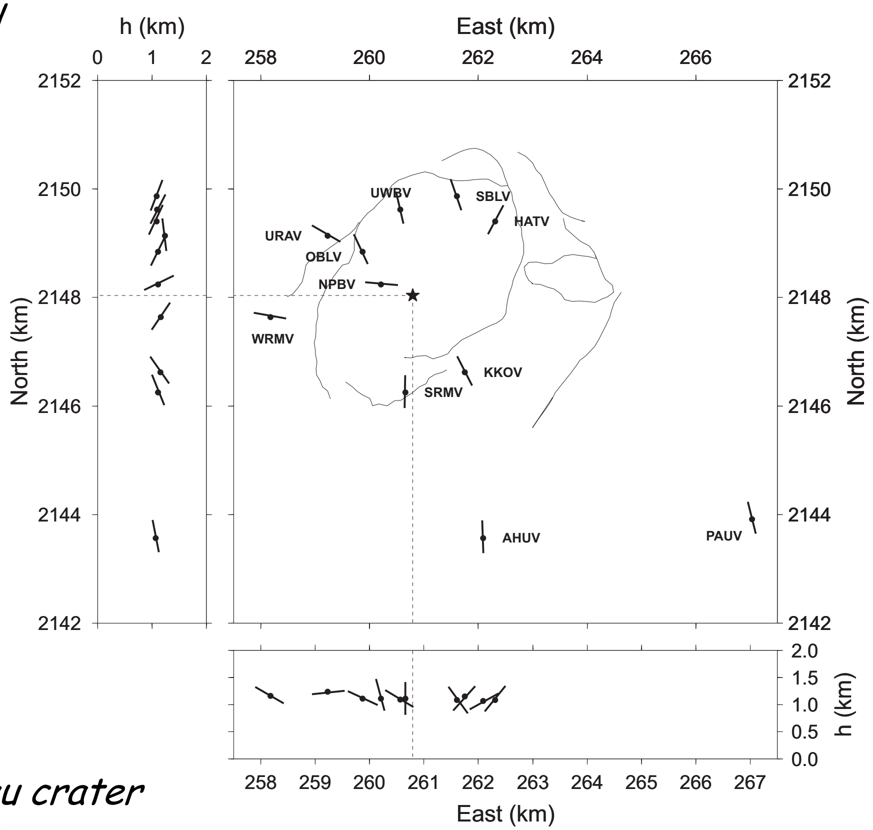


Source parameters:

Ao= 81000.0
z= 1.07 [2148.5,2148]
x= 260.70 [260.4,260.7]
y= 2148.30 [2148,2148.5
Nbr stations= 10
Error rate (%)= 14.7925
(minimization of sum (calc-obs)**2)

Location at the NE rim of the Halemaumau crater
Indications for very shallow source depth

Particle motions



Velocity models

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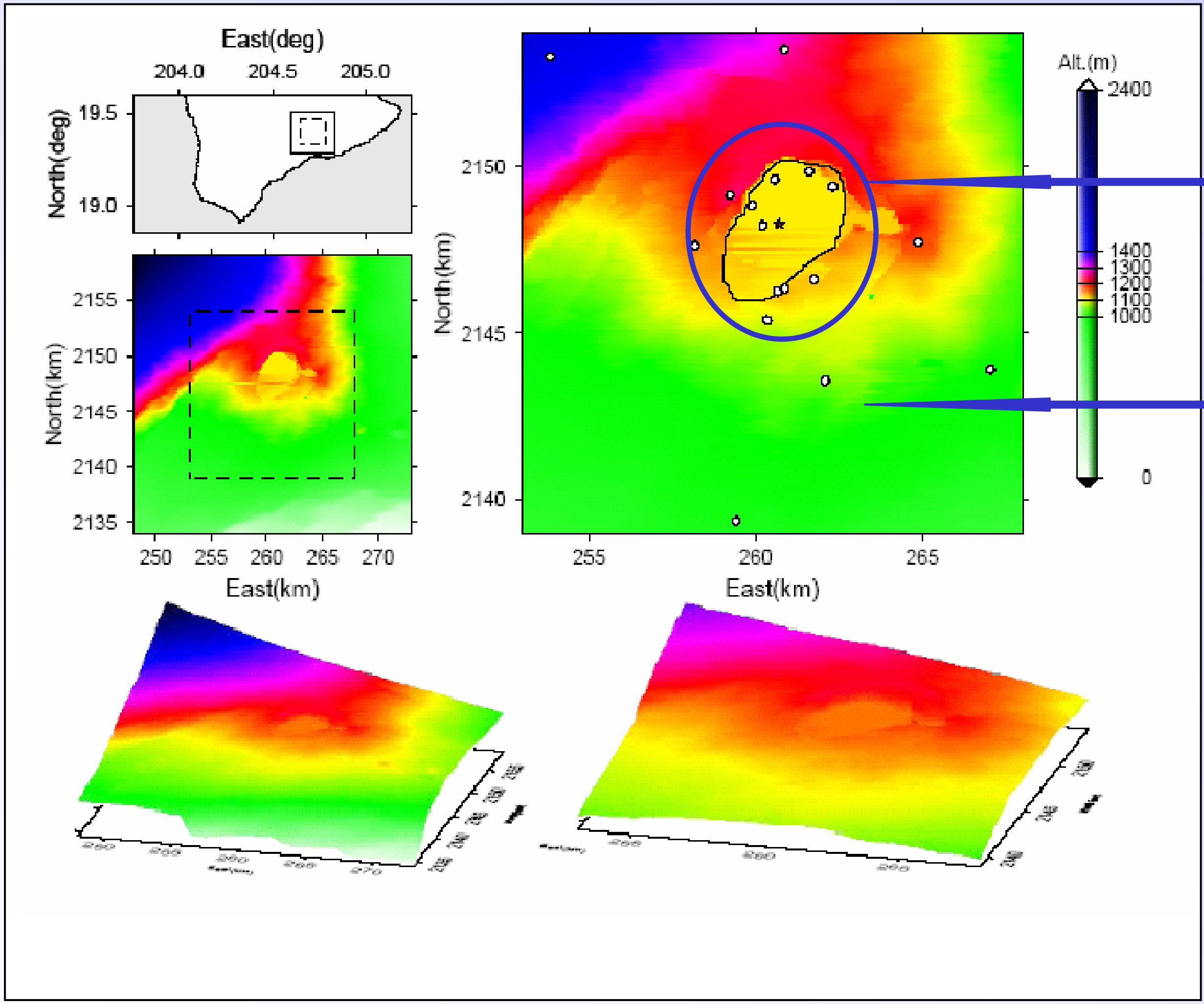

Caldera area
Layered model
(Saccorotti et al., 2003)

External region
Homogeneous model
(Chouet et al., 1998)

Model KHOM
Homogeneous

Model KLAY
Layered

Model KCAL
Layered at Caldera, homogeneous outside

Forward modeling

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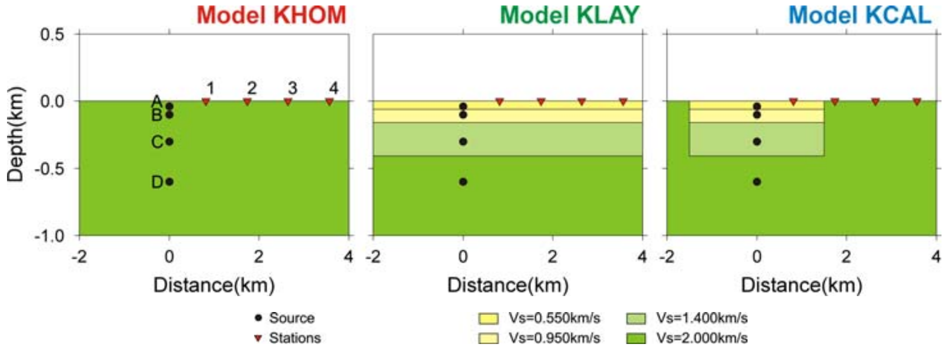
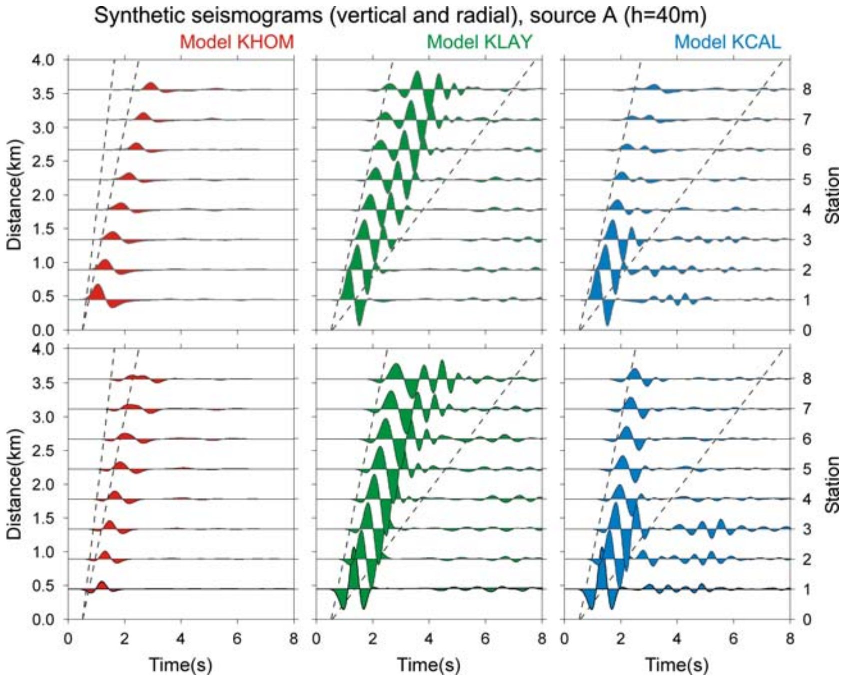
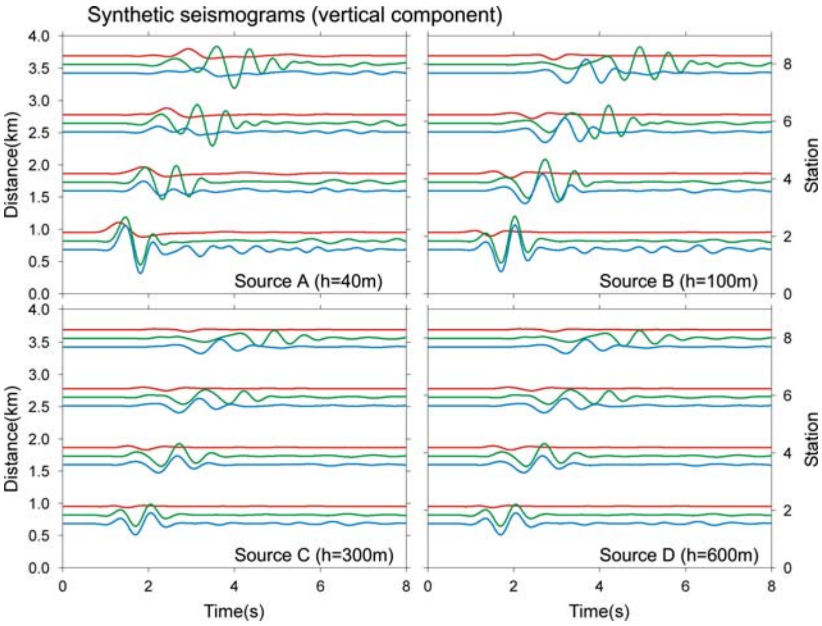


Synthetics for different models



Synthetics for different source depths



Forward modeling

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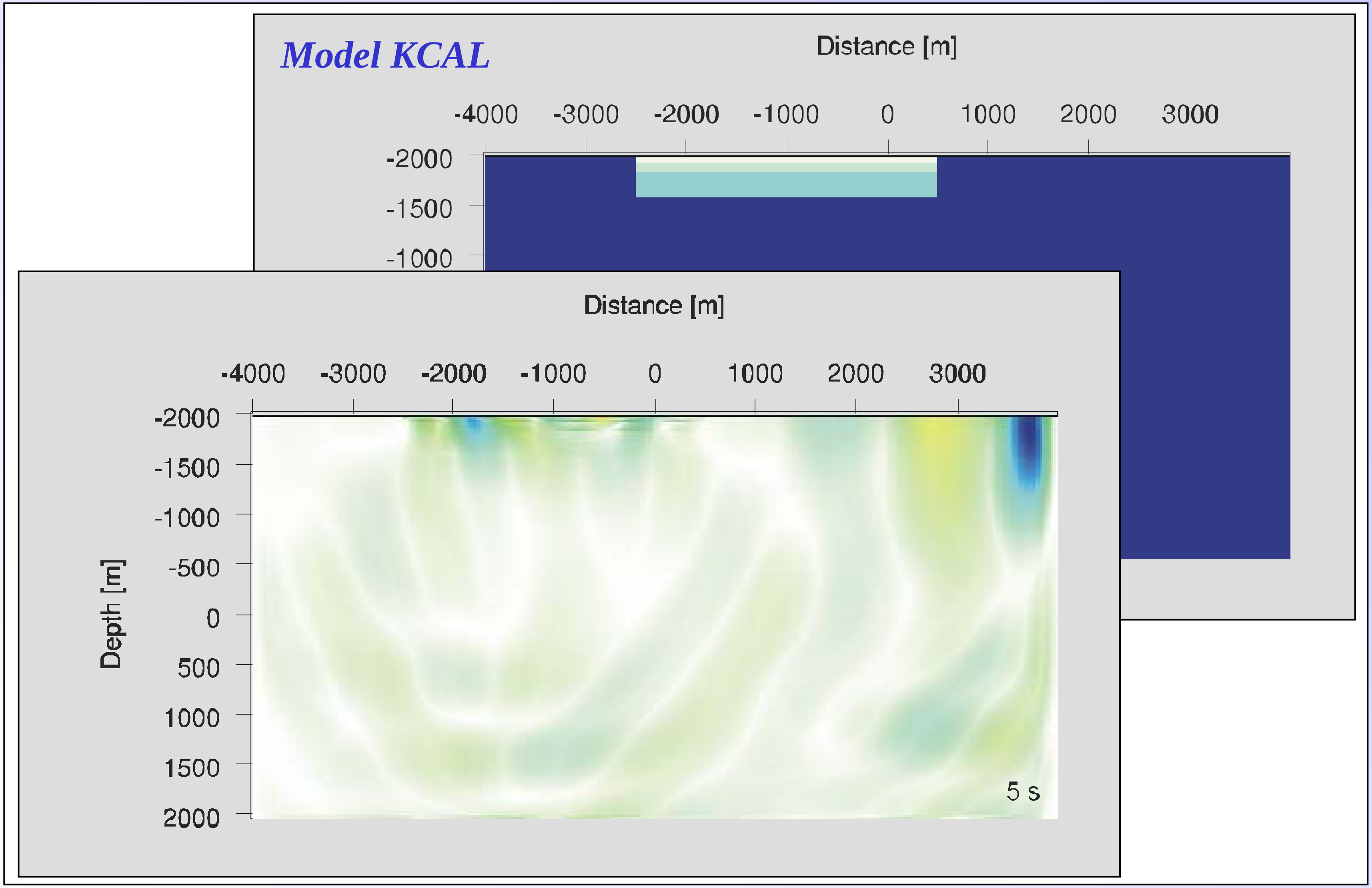

Inversion for 1D models

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Constrain source detph

KLAY : 50m
KHOM: 300 m

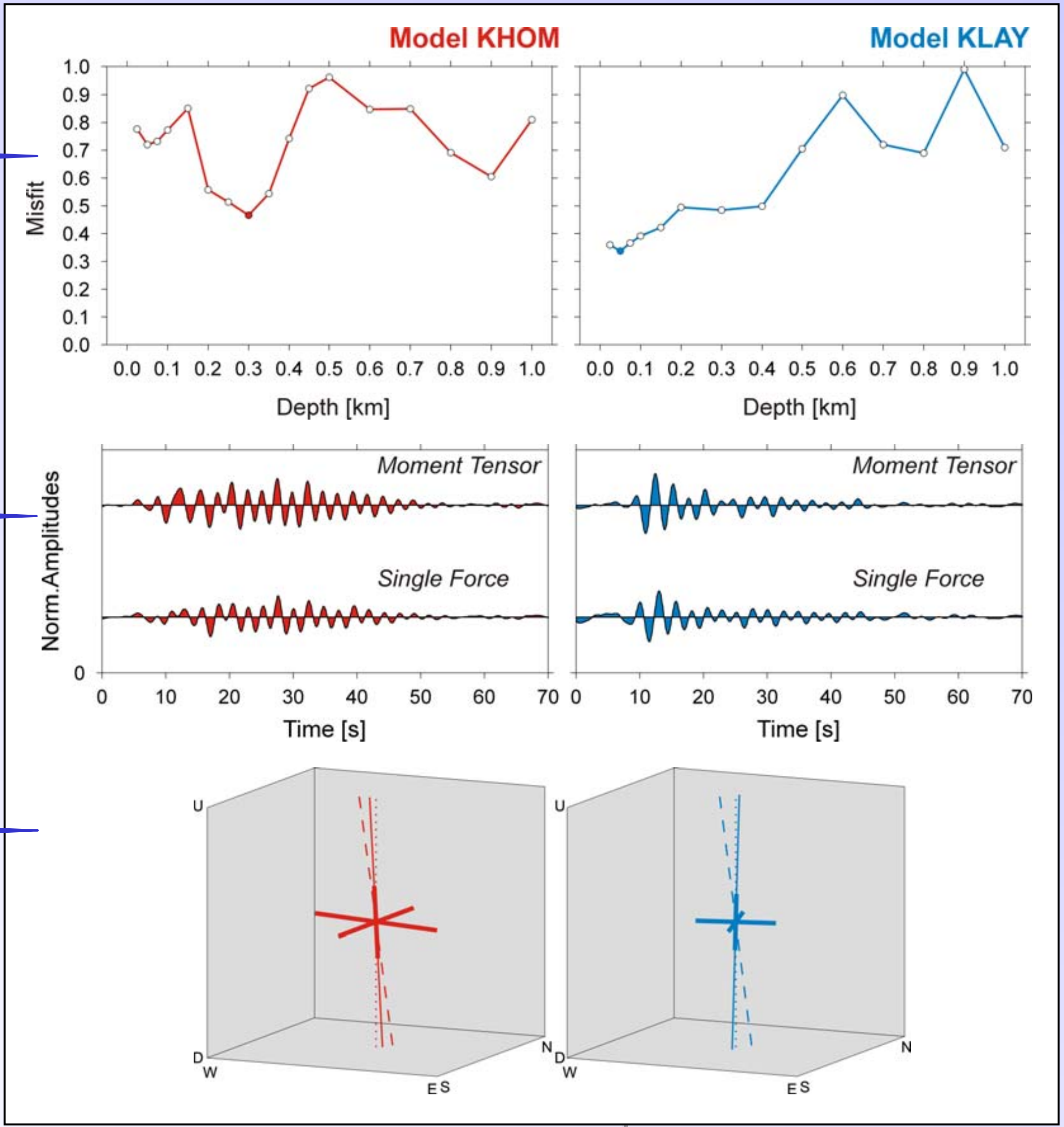
Source Time Function

Simpler time behaviour for model KLAY

Source mechanism

Horizontal crack + Vertical force

Vertical force component may be an artifact



Inversion for 3D models

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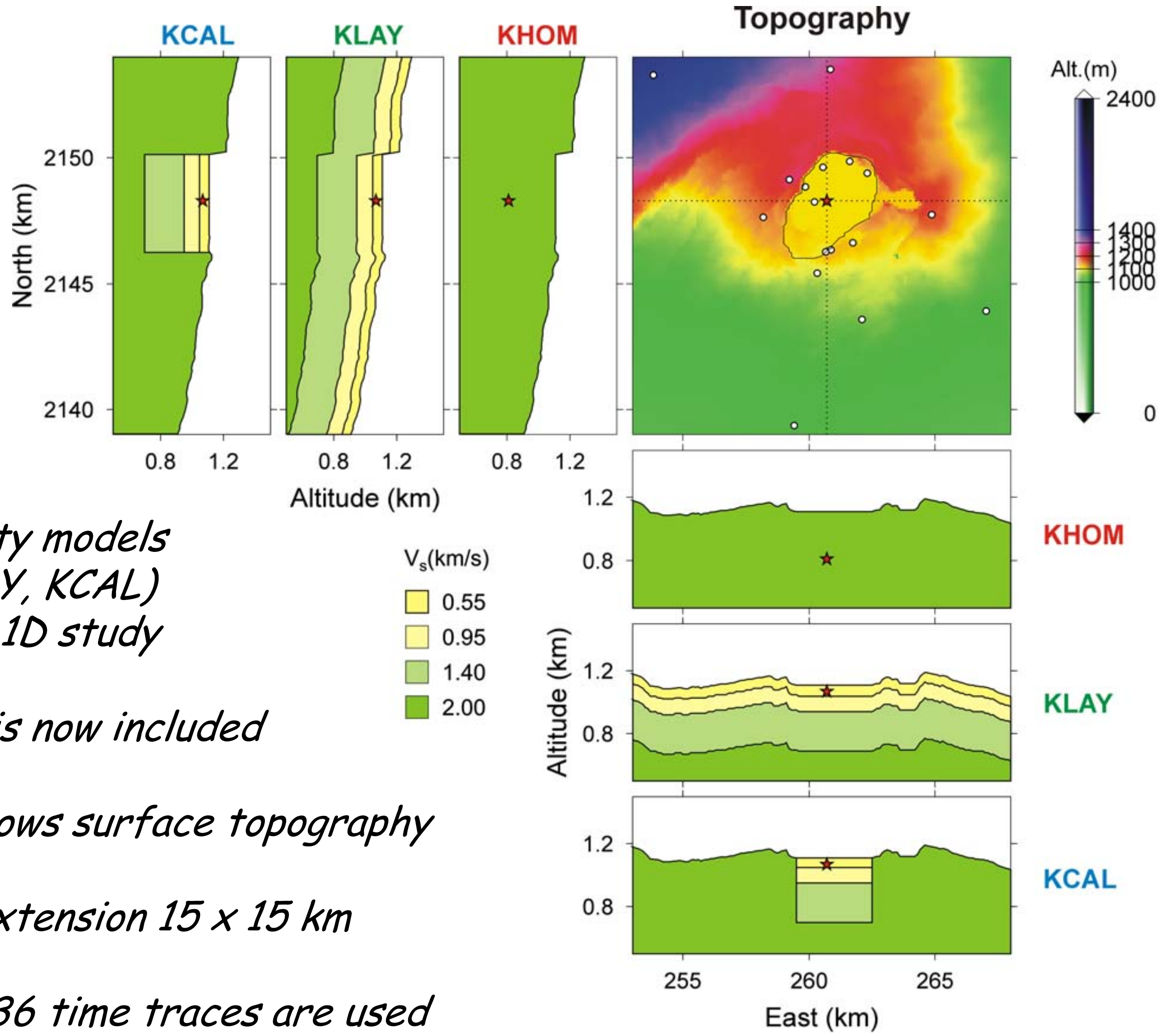

Three velocity models (KHOM, KLAY, KCAL) analogous to 1D study

Topography is now included

Layering follows surface topography

Horizontal extension 15 x 15 km

17 stations, 36 time traces are used

Inversion for 3D models

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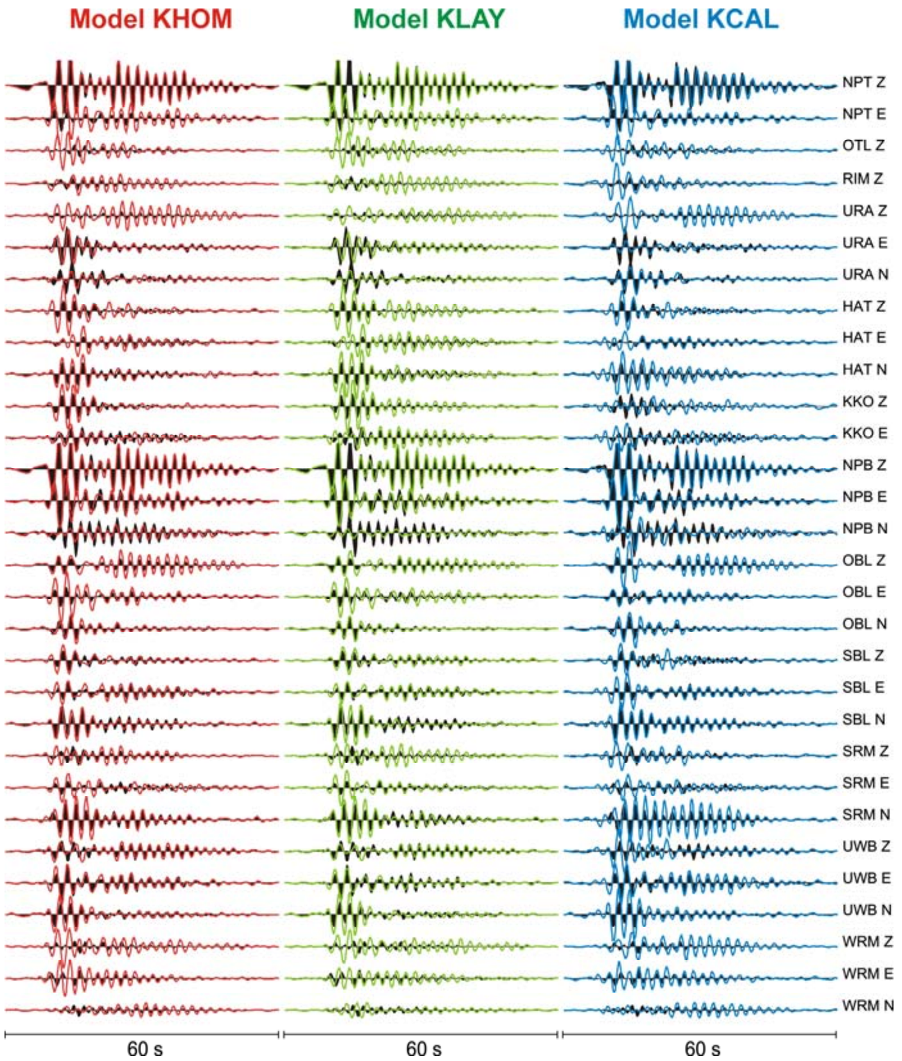
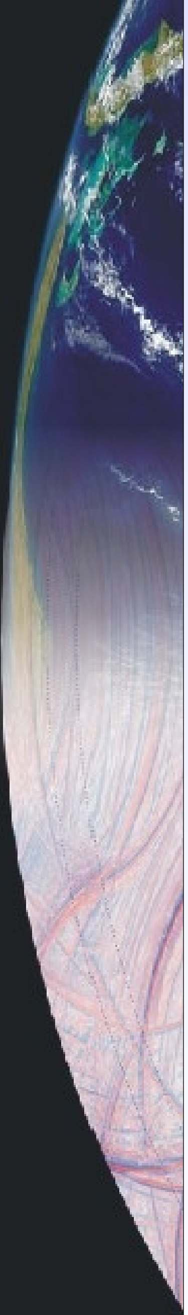
Fit of displacements

A better fit is found for models KHOM (h=300 m) and KCAL (h=50 m)

Worse fit for model KLAY (h=50 m), indicating that the chosen layered structure is not correctly reproducing the Velocity structure outside the Caldera

The inverted sources for all models can be well-reproduced by a common STF for Moment Tensor and a second one for Single Force





Inversion for 3D models

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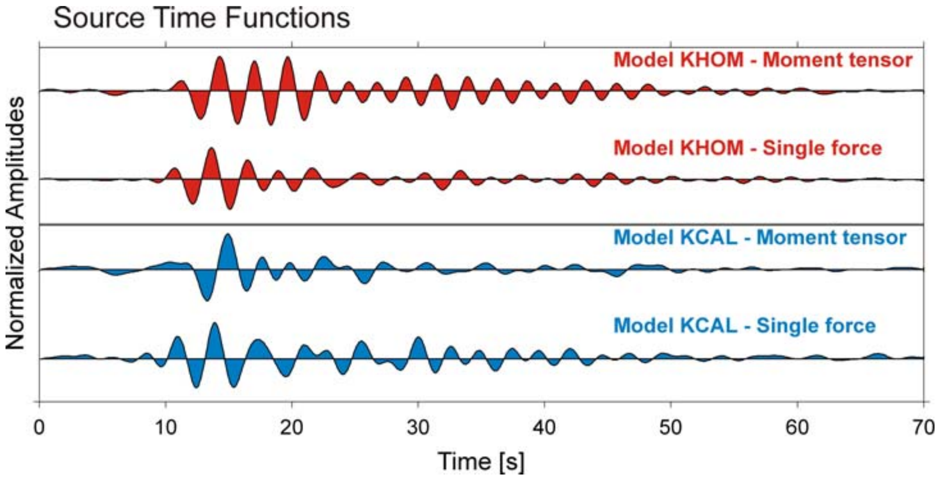
Source mechanism

Source Time Function

Effects of velocity structure:
Simpler time behaviour
for model KLAY and KCAL

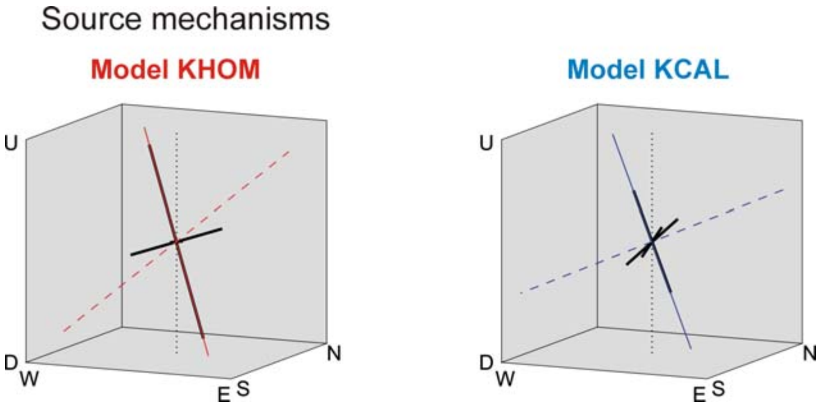
STF for Moment Tensor and
Single Force are different


Source Time Functions

Focal Mechanism

Sub-horizontal crack (dipping SW)
+ Single Force (almost coplanar)

For model KCAL, SF component
is coplanar to crack orientation
and striking as surface fissures


Source mechanisms

Conclusions

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LP waveform consequence of both source and path effects

Shallow sources embedded in low velocity layers generate long lasting signals

Inversion results confirm effects of velocity structure also for 1D models: long lasting ringing STF are retrieved for homogeneous models

Topography effects highlighted by different solutions, assuming 1D and 3D models. Artificial retrieval of single forces for 1D models (radiation patterns).

Application to LP event at Kilauea:
1. Source as a sub-horizontal crack, dipping toward SW.
2. Additional single force, coplanar to crack geometry and striking toward ENE, consistent with fissure orientation.
3. LP source is likely to be associated to hydrothermal systems.

This work has been funded by the SPICE R&T Programme of the European Union.

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Effects of topography

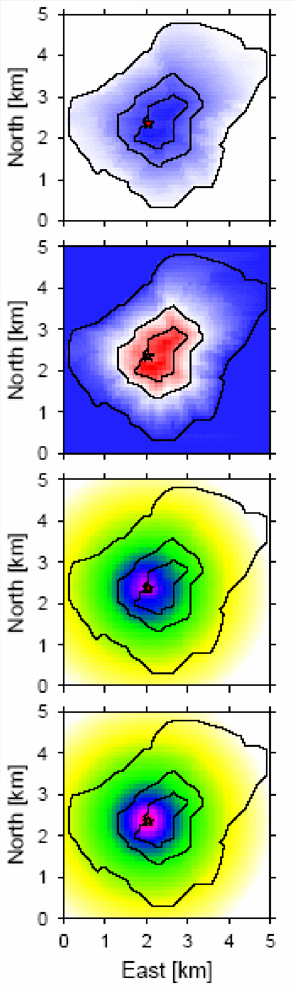
Explosion at 500 m altitude

Altitude

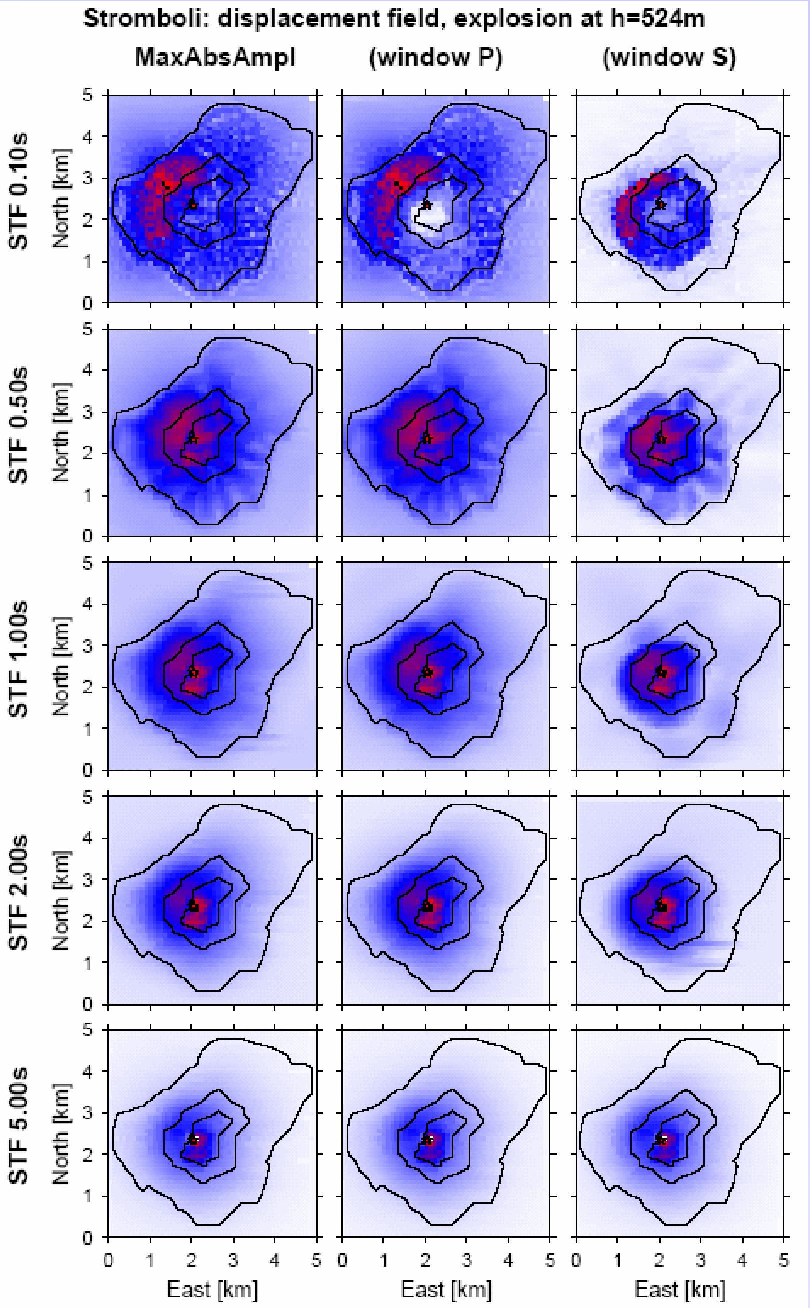
Relative altitude

Distance

Epicentral distance



Maximal displacements due to isotropic sources ($M_{11}=M_{22}=M_{33}=1$, $M_{12}=M_{13}=M_{23}=0$) with different durations (0.1-5s)



Isotropic source, GFs