InSAR detected new mode of postseismic deformation following the 2010 M=7.0 Haiti earthquake

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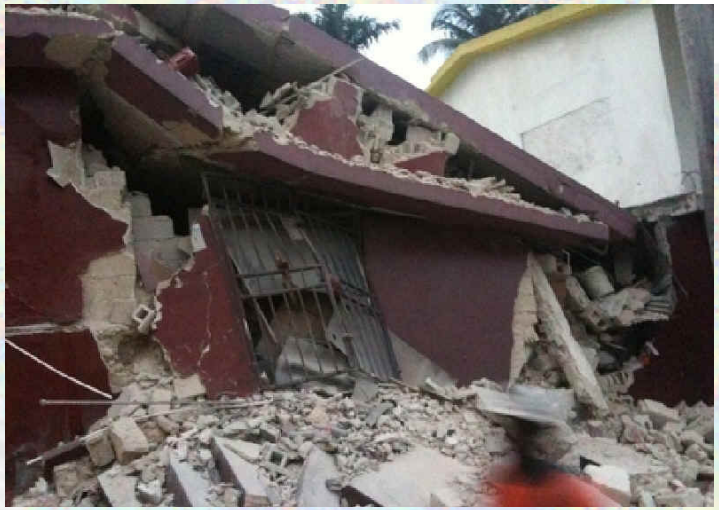
- Modes of postseismic deformation
- Postseismic deformation following the Haiti earthquake
  - Observations
  - Interpretation
  - Model
- Summary
- Acknowledgements

Magnitude 7.0 HAITI
Tuesday, January 12, 2010 at 21:53:09 UTC



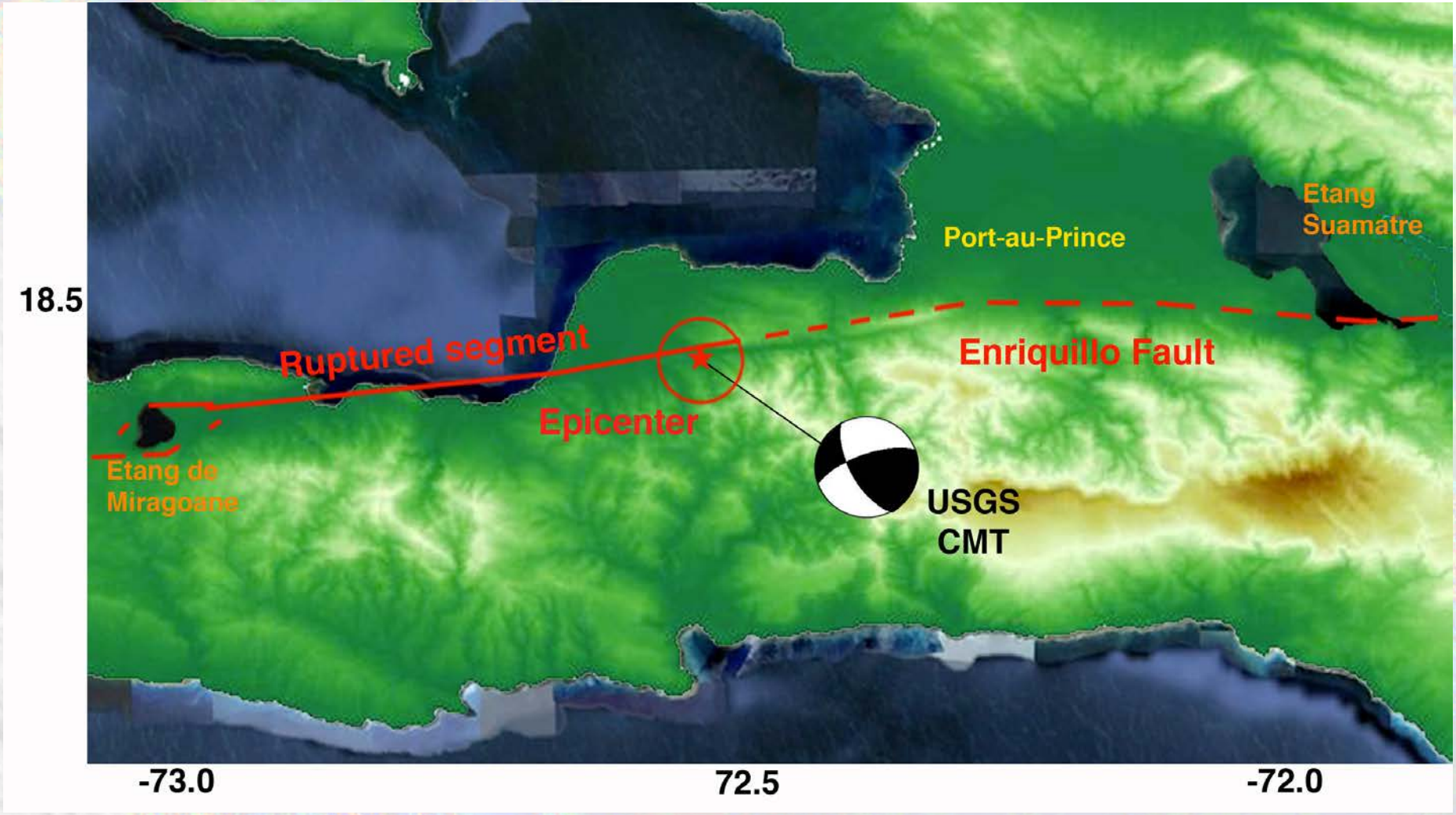
Carel Pedre via Twitter

BBC

"Thousands of people were feared dead today after a powerful earthquake struck Haiti's capital, leaving tens of thousands homeless and buried beneath rubble....Thousands of people gathered in public squares late into the night, singing hymns and weeping, with many seriously injured people sitting in the streets pleading for doctors."

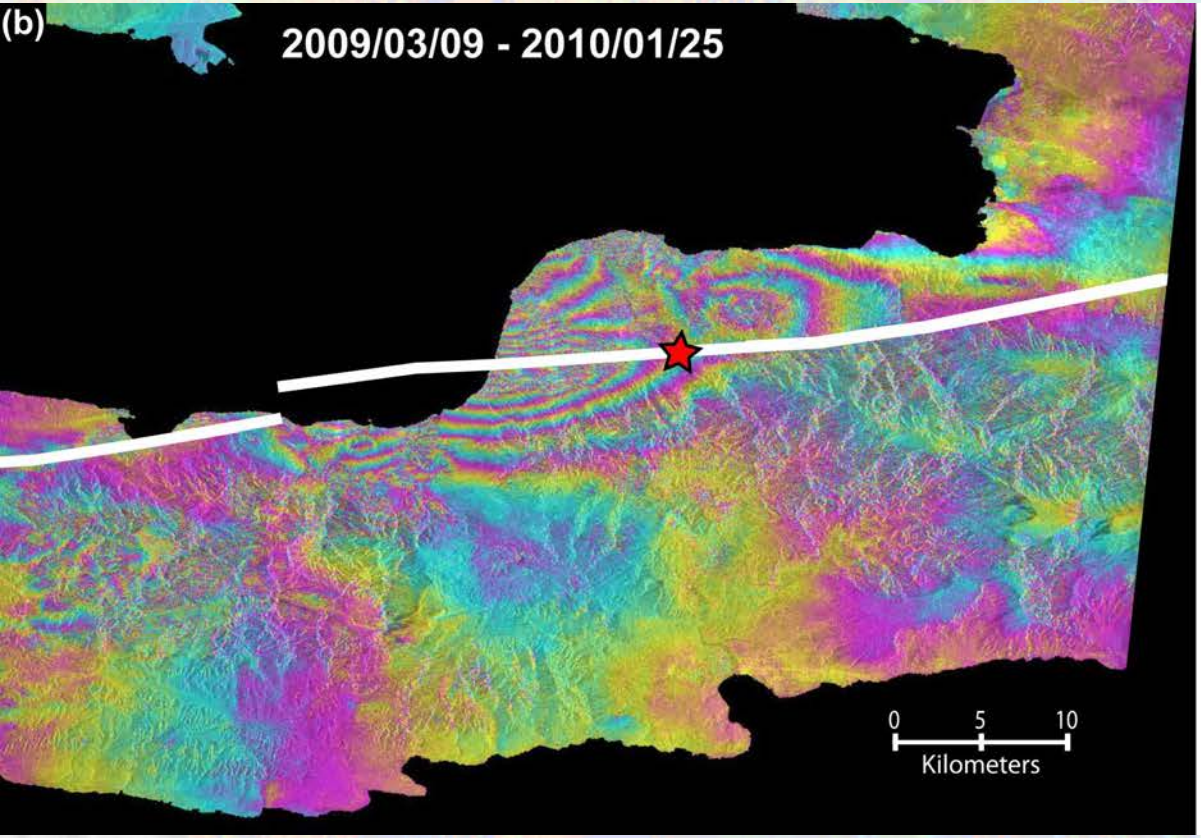
The Gazette, U.K.

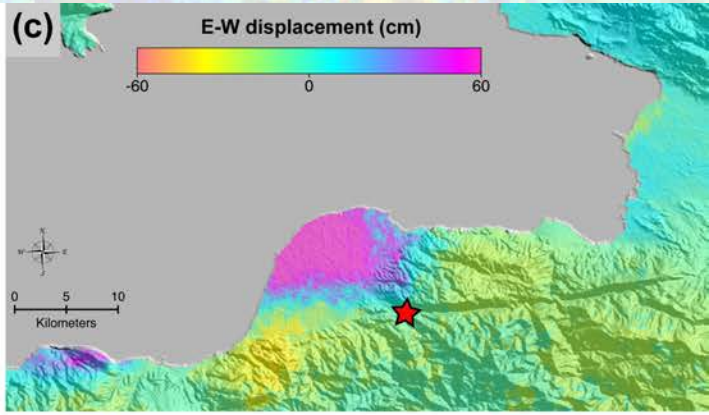
The 2010 Haiti earthquake

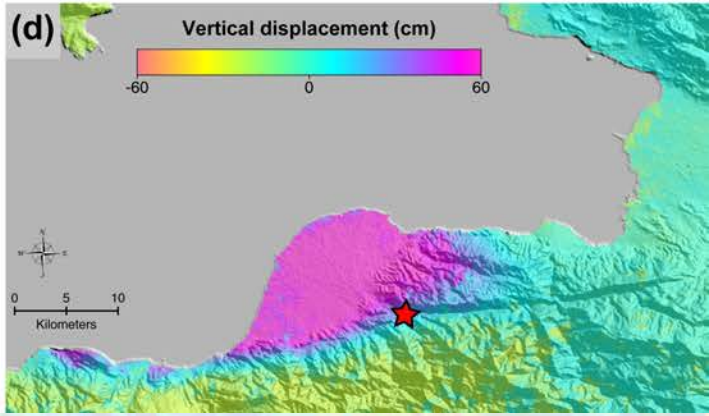


Geodetic observations

E-W component



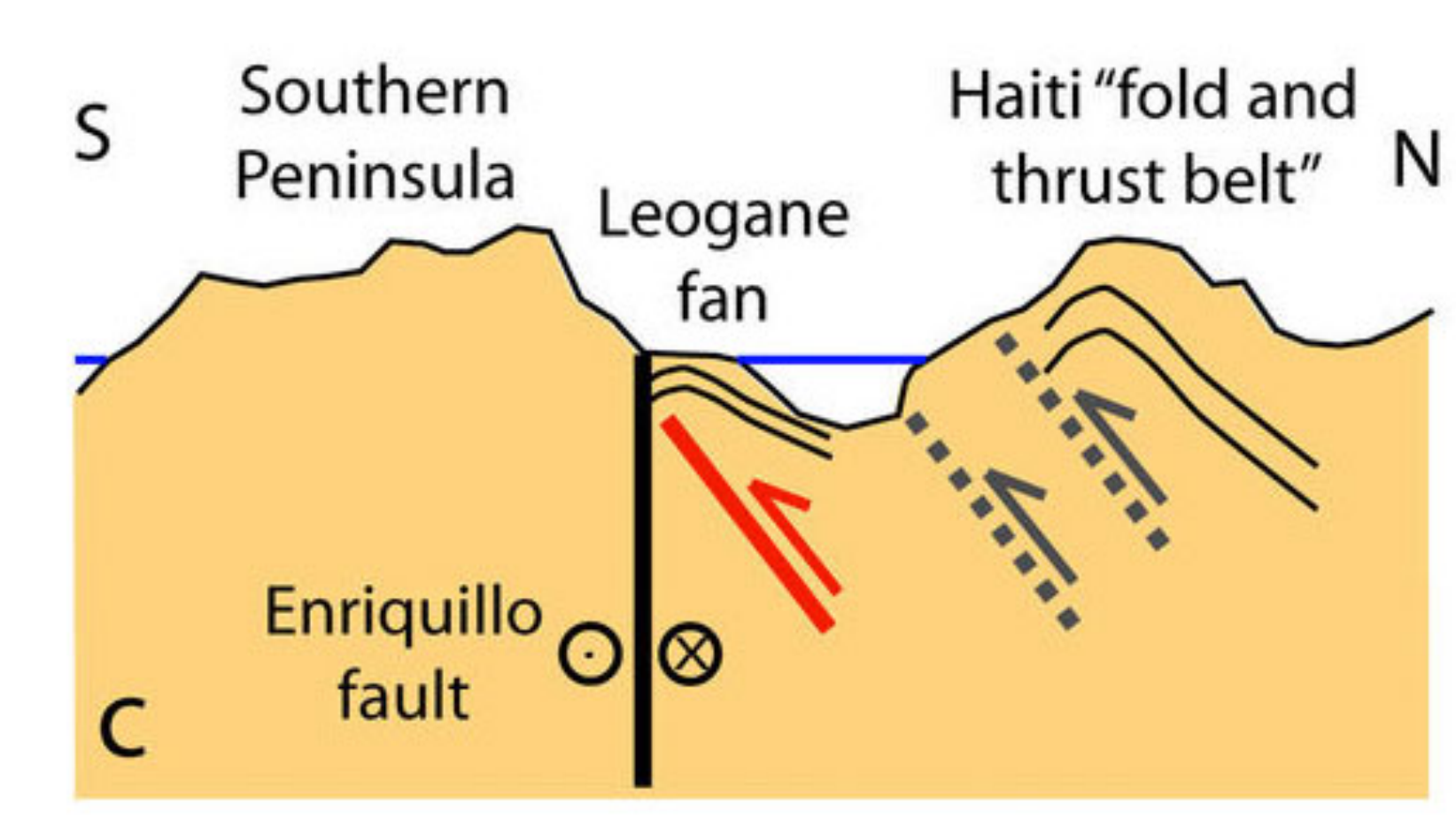




Co-seismic ALOS interferogram

Up component

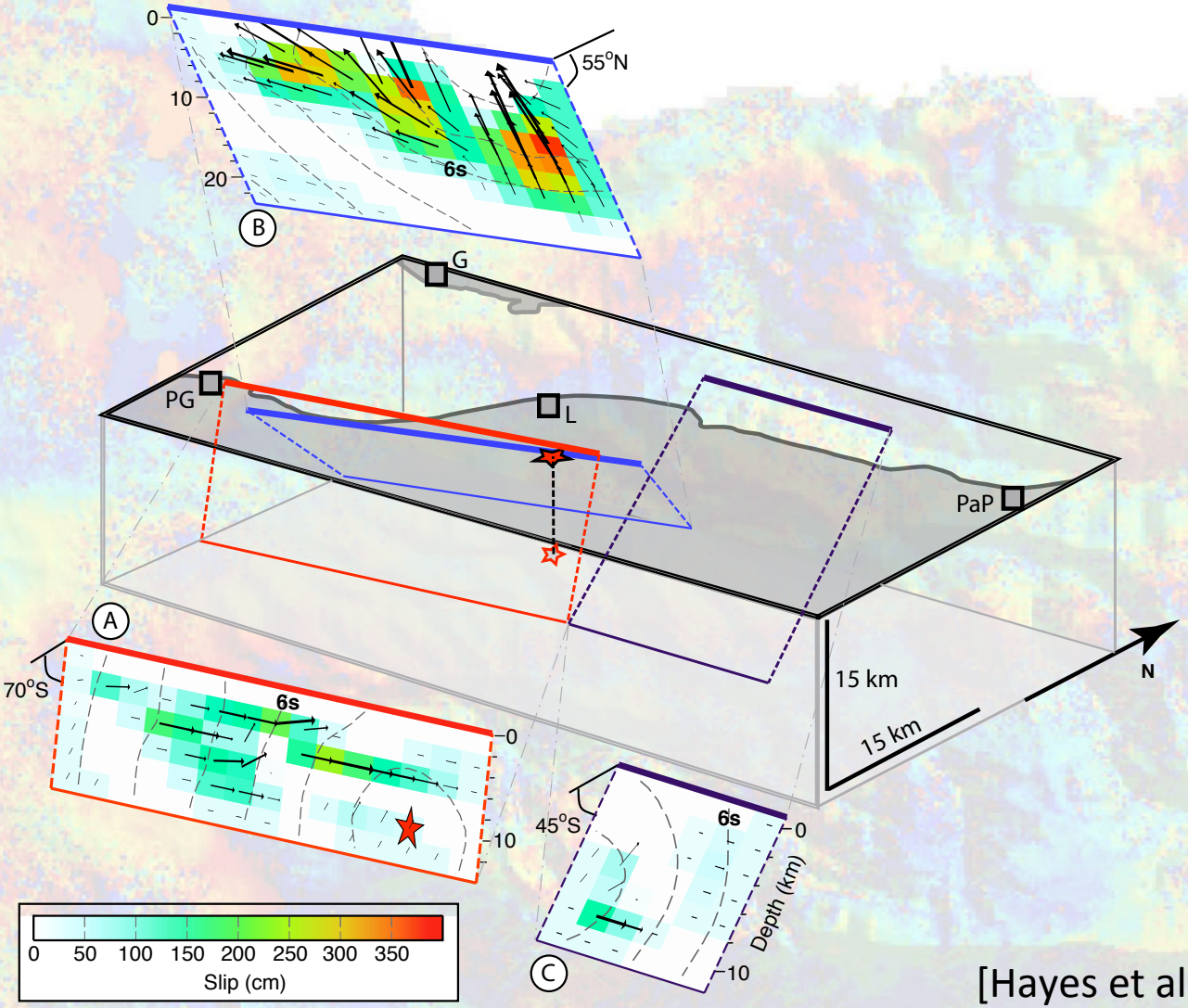
The 2010 Haiti Earthquake



[Calais et al., 2010]

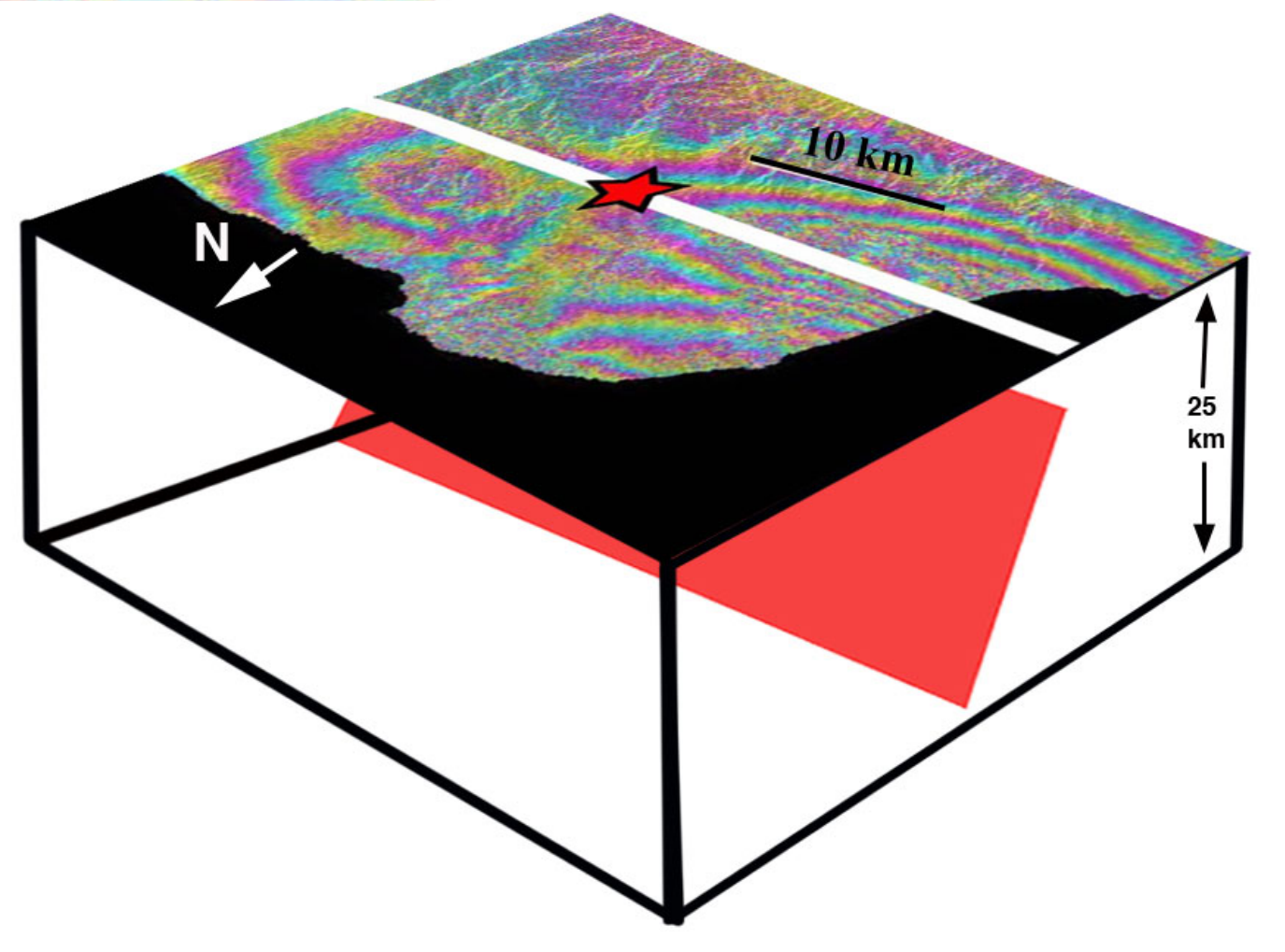
The 2010 Haiti Earthquake

Figure 3



[Hayes et al., 2010]

The 2010 Haiti Earthquake



Geometry of main ruptured segment

Field observations

Uplifted corals

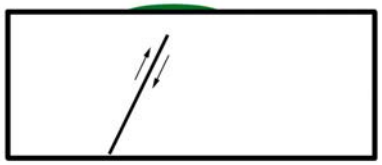
Open fractures

[Hayes et al., 2010]

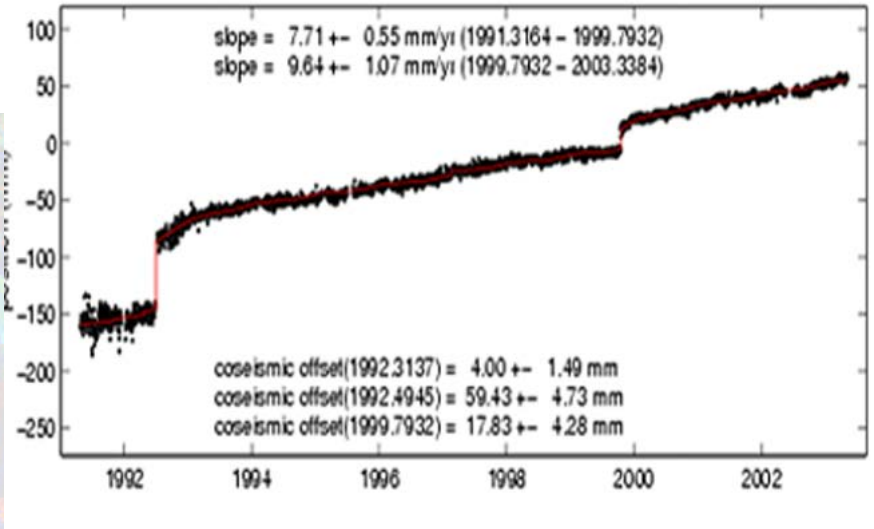
The earthquake deformation cycle

Interseismic deformation
(in between earthquake)
Lower crust is displaced in response to tectonic plate motion
Upper crust accumulates strain resulting in small surface deformation

Coseismic deformation
(large earthquake)
Upper crust is ruptured releasing the accumulated strain as seismic energy and resulting in large surface deformation

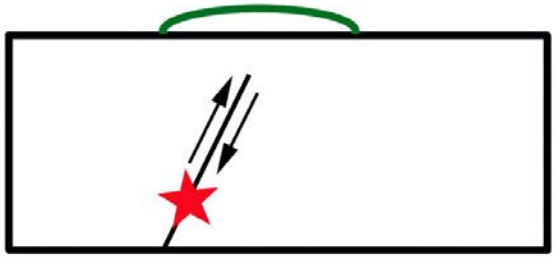


Postseismic deformation
(after large earthquakes)
Time dependent deformation of either Upper or Lower crust; further release of accumulated strain, resulting in small surface deformation. Often postseimic deformation correlates with aftershock activity

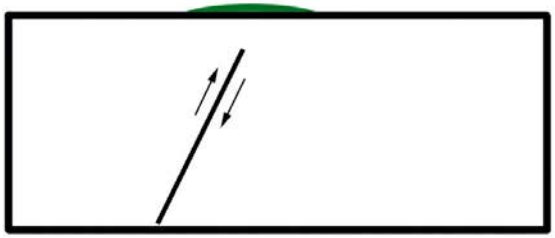


(Nikolaidis , 2002)

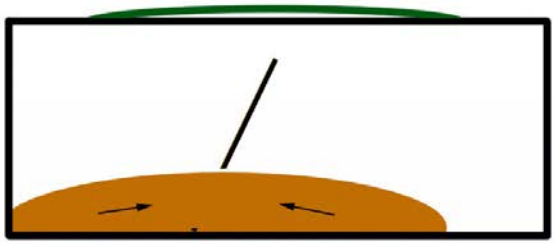
Modes of postseismic deformation



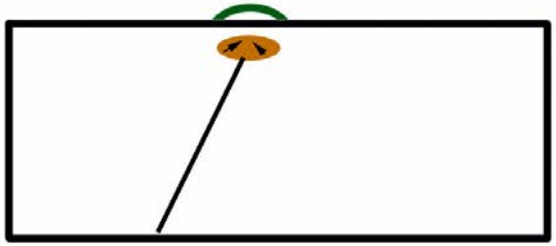
Coseismic deformation



After-slip
Continuous low-magnitude
slip along the ruptured fault
Simiar wavelength as coseismic

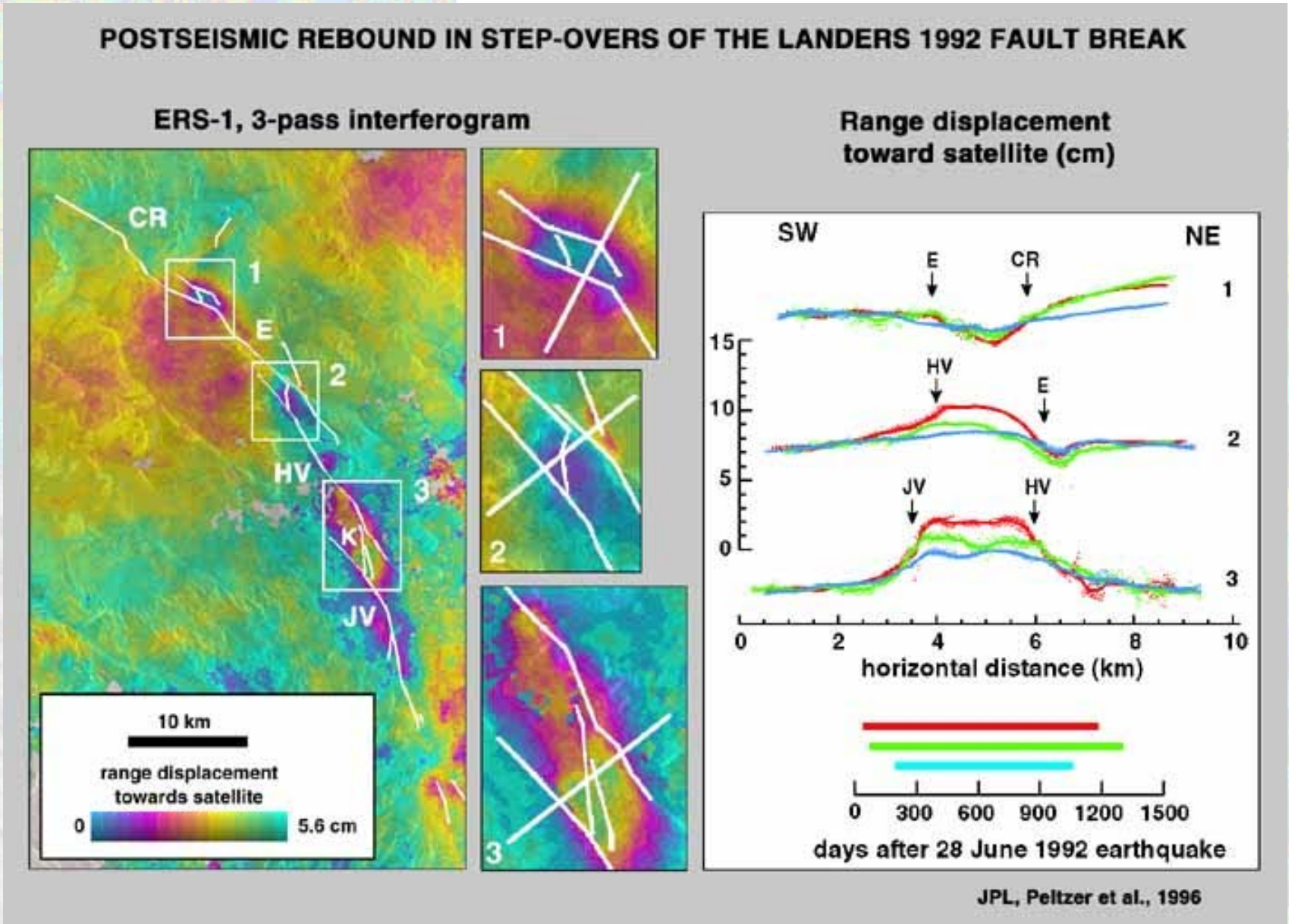


Viscous relaxation
Time dependent viscous
flow of the lower crust
broad wavelength deformation



Poro-elastic deformation
induced by pore-fluid flow
in response to stress changes
Shorth wavelength deformation

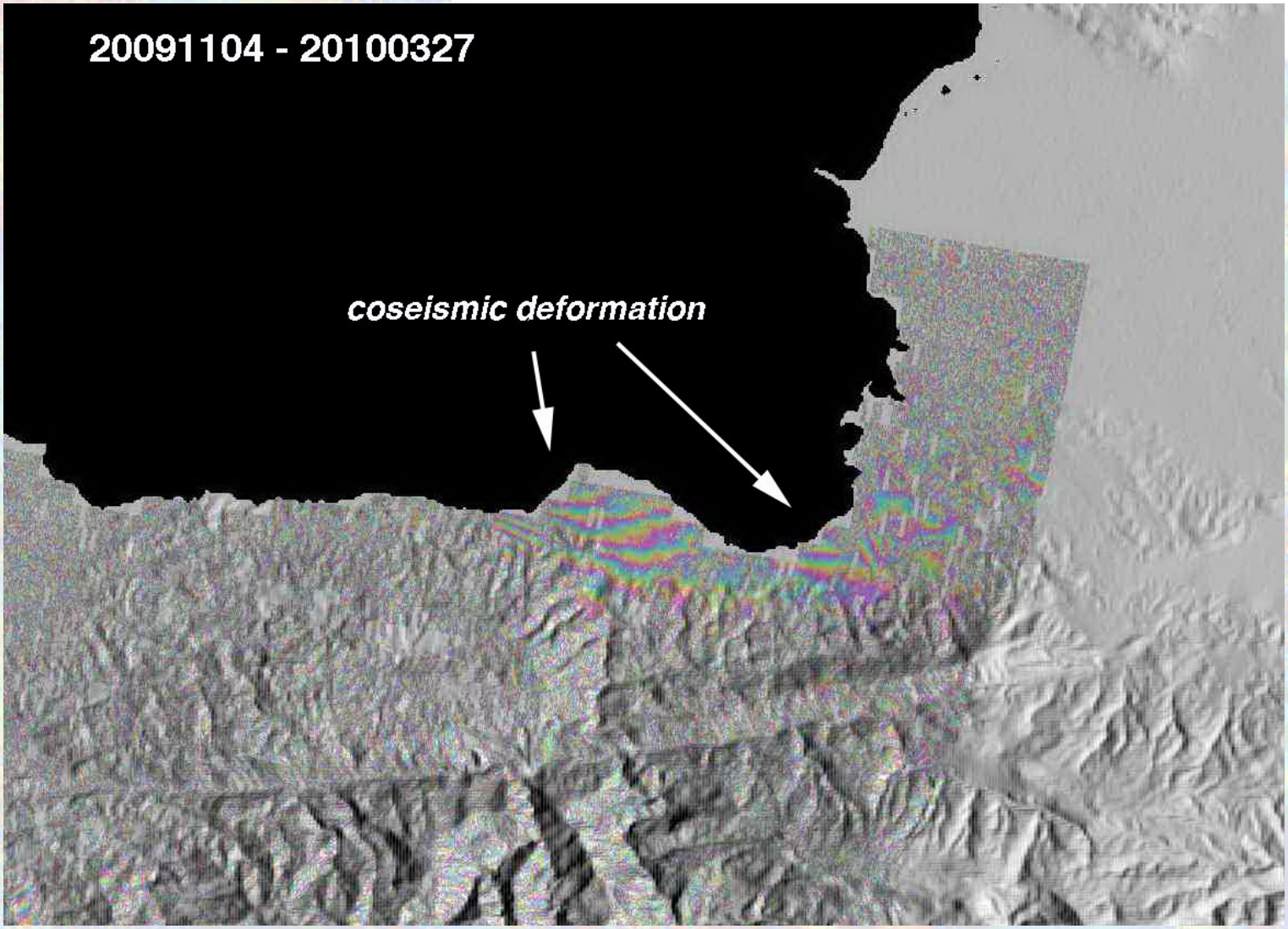
Poro-elastic Postseismic deformation



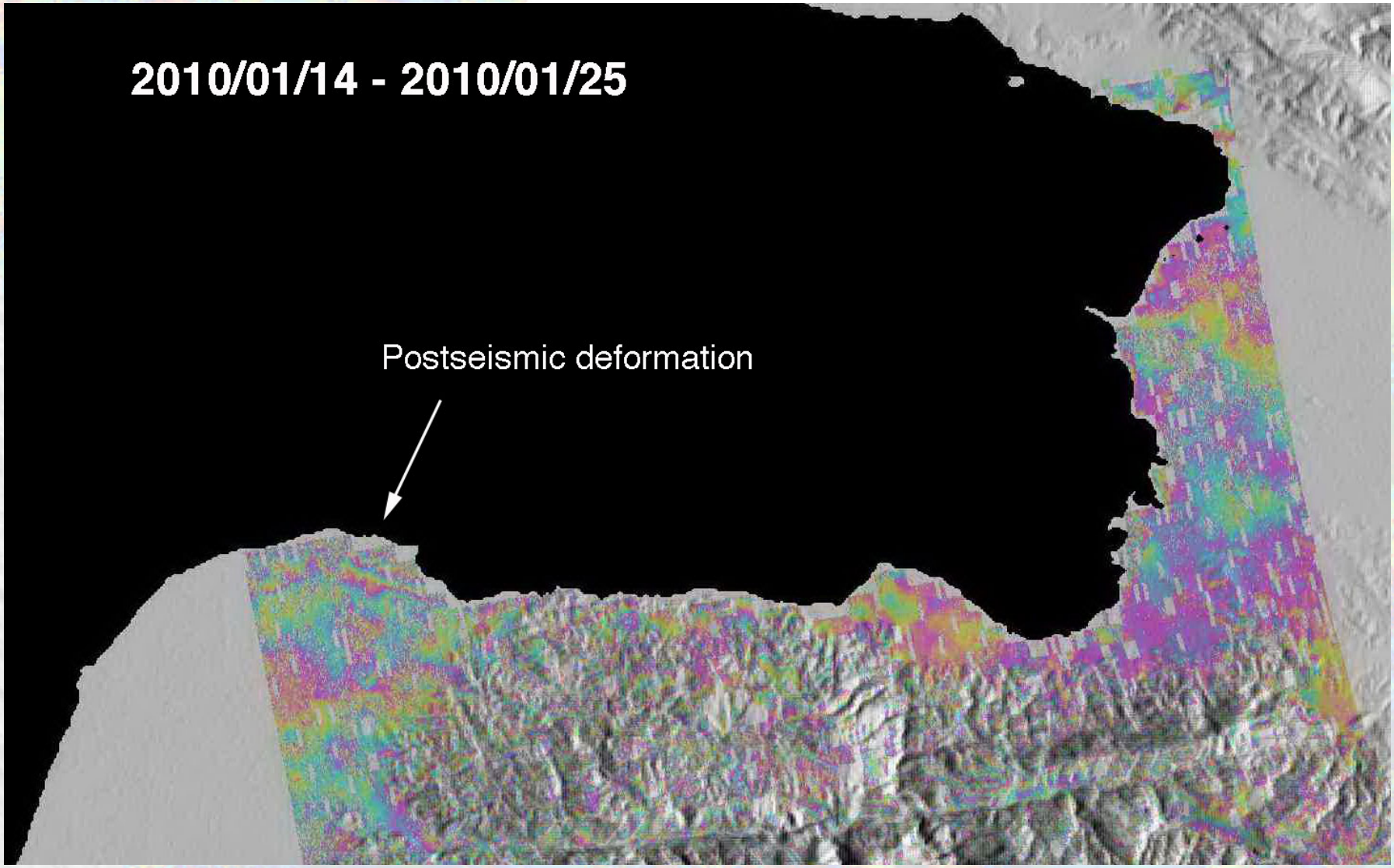
TerraSAR-X acquisitions

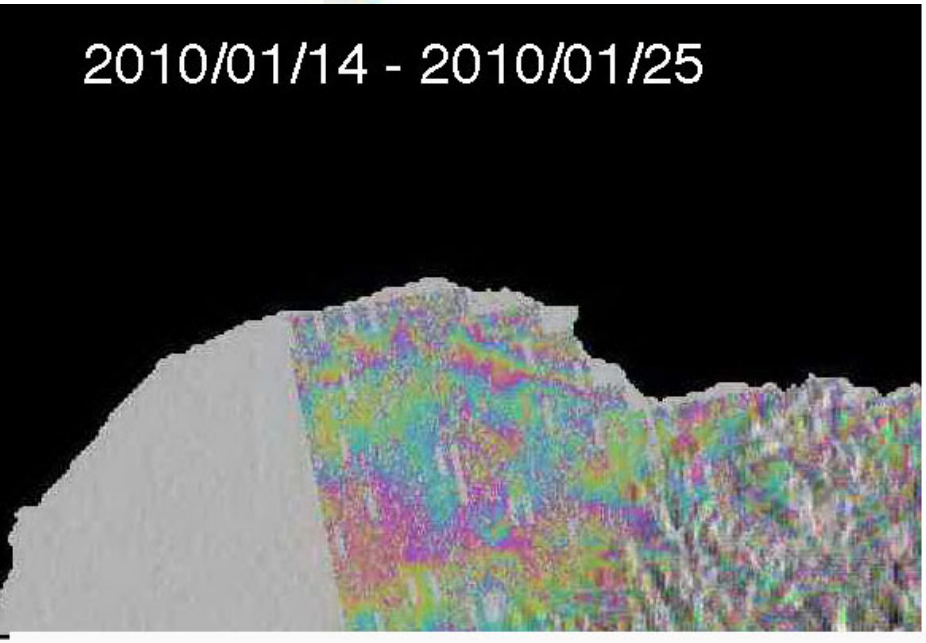
before and after the 2010 Haiti earthquake

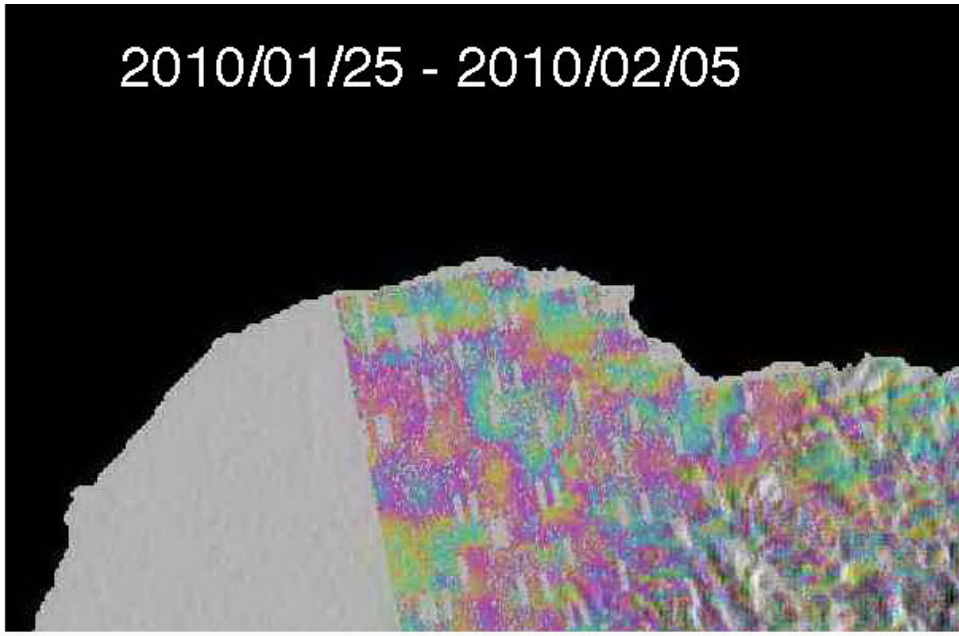
Coseismic deformation

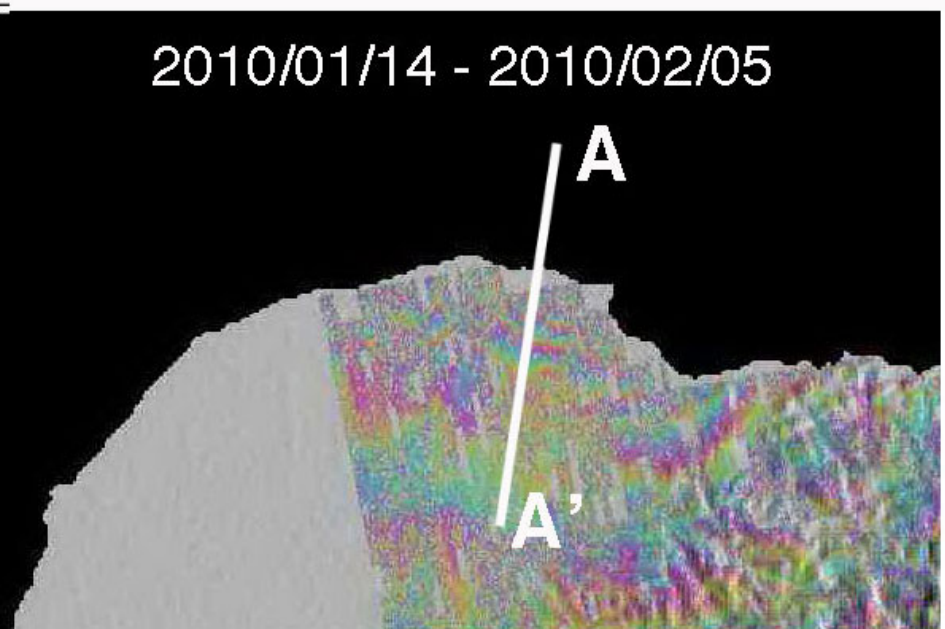


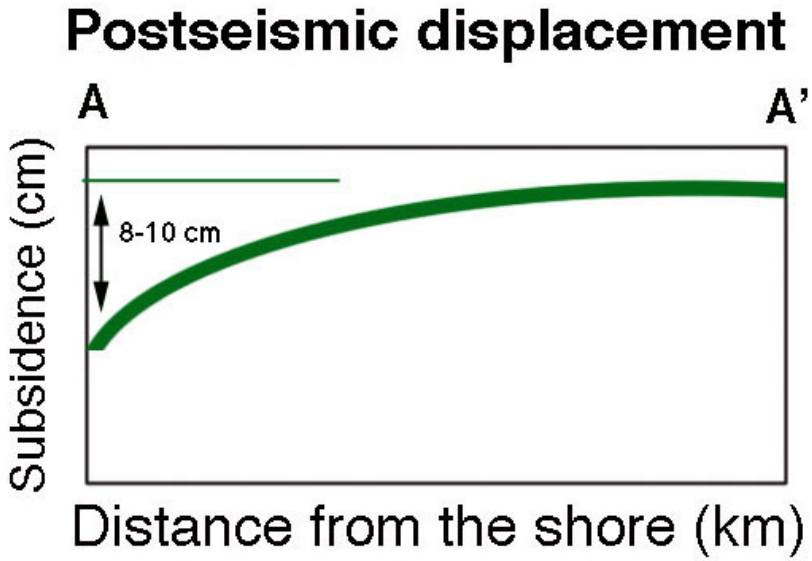
Postseismic deformation



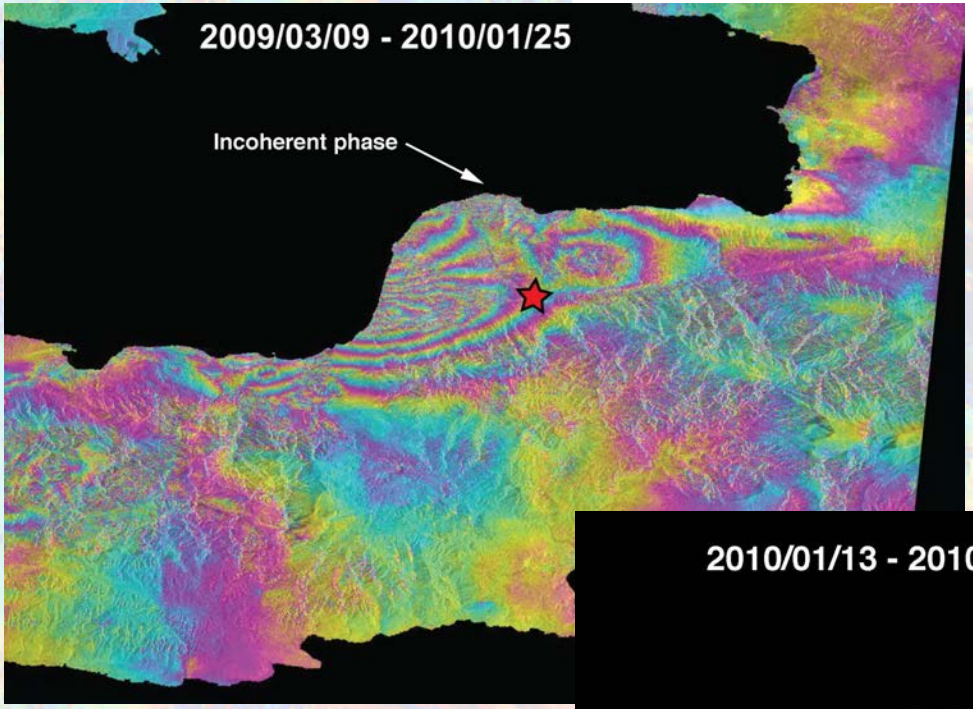

2010/01/14 - 2010/01/25

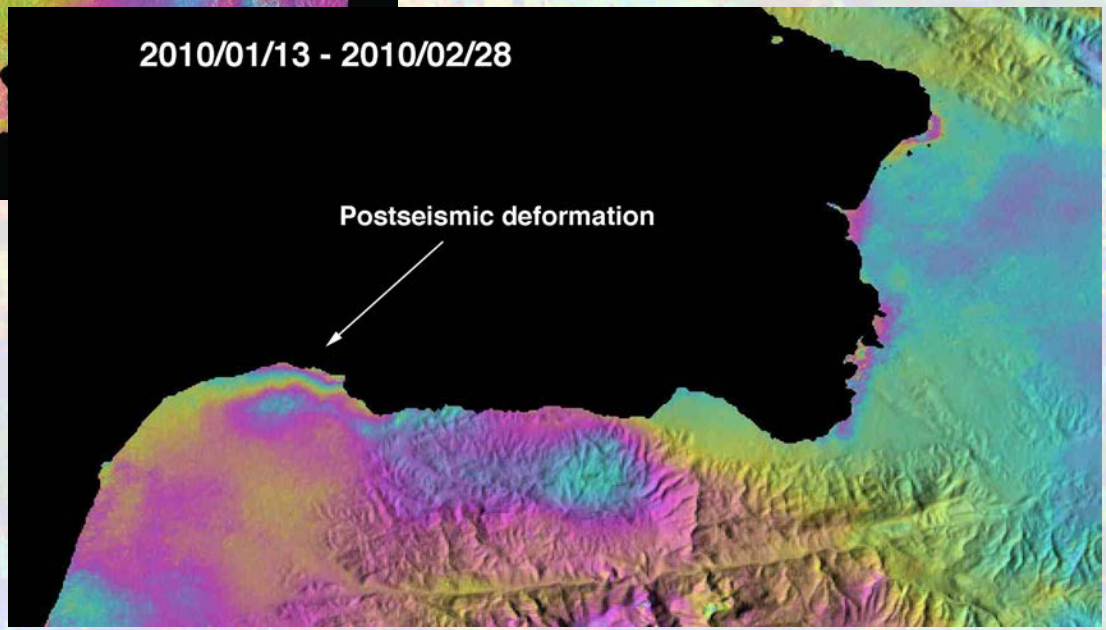

2010/01/25 - 2010/02/05

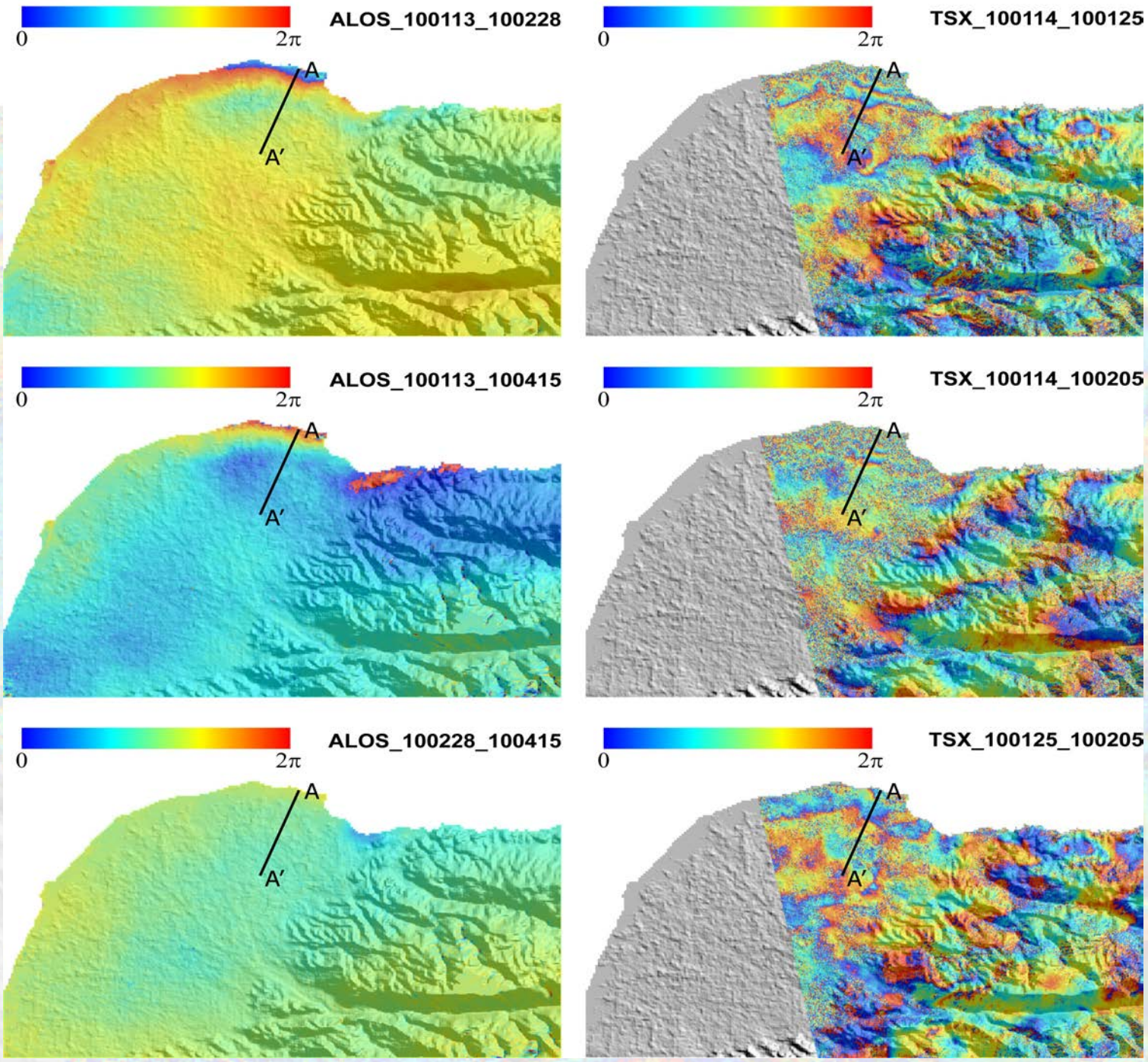

2010/01/14 - 2010/02/05
A
A’


Postseismic displacement
A
A’
8-10 cm
Subsidence (cm)
Distance from the shore (km)

ALOS co- and post-seismic deformation






ALOS_100113_100228
0
2π
A
A′
TSX_100114_100125
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2π
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A′
ALOS_100113_100415
0
2π
A
A′
TSX_100114_100205
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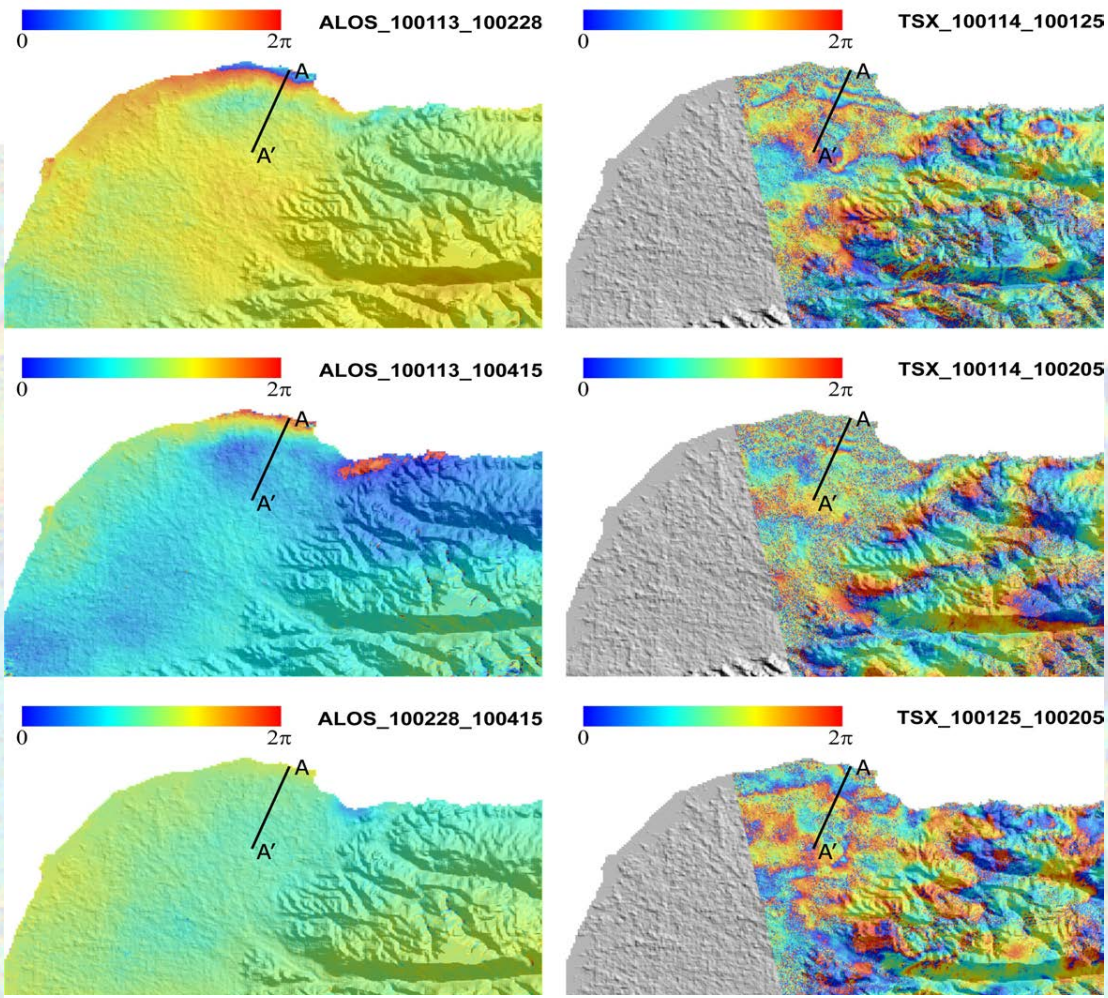
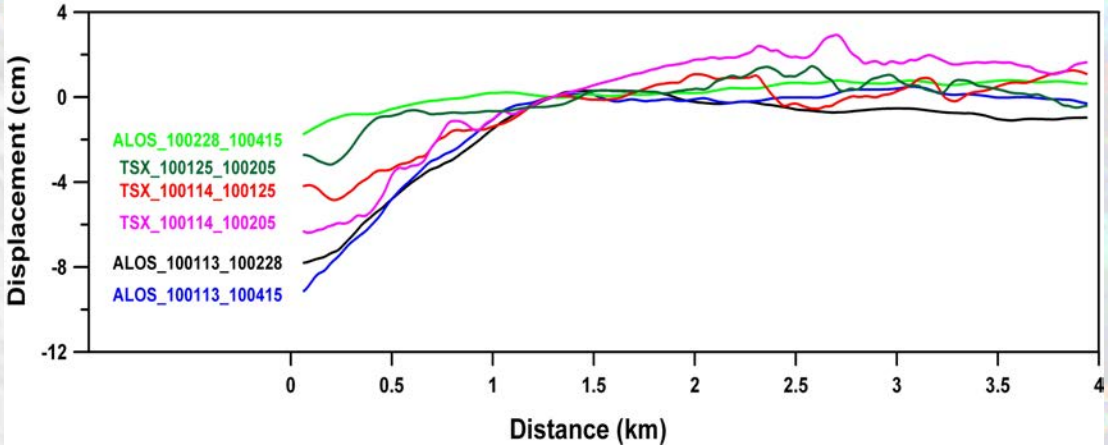
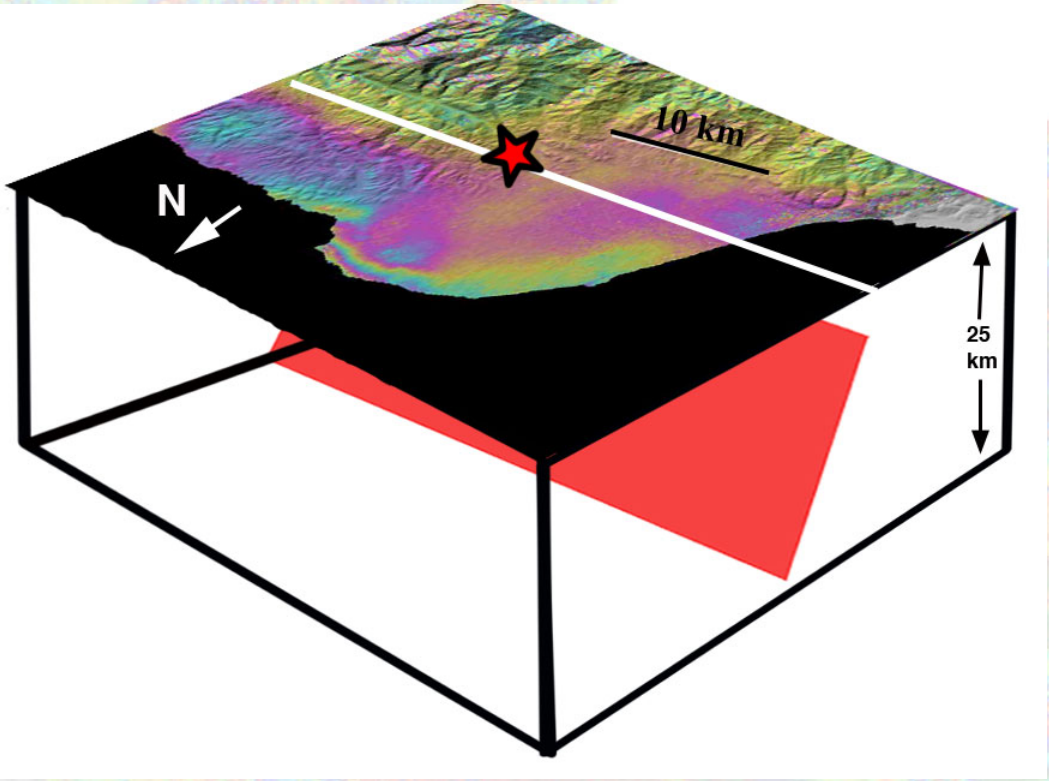
A′
TSX_100125_100205
0
2π
A
A′





Postseismic deformation

Postseismic deformation



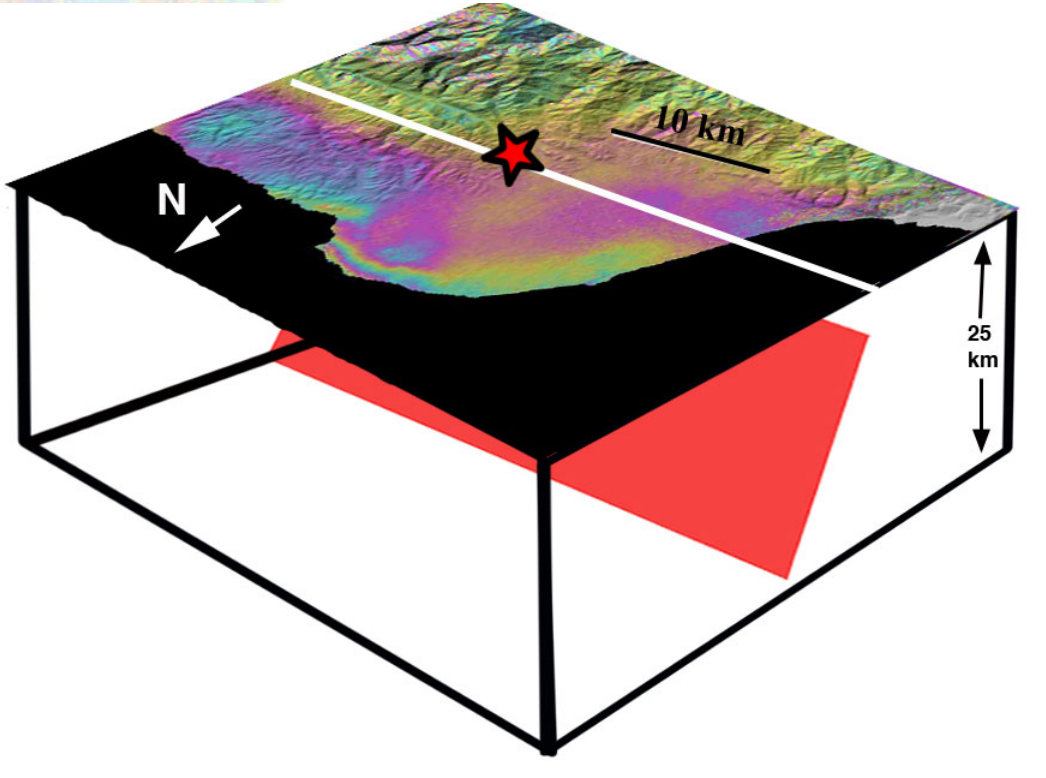
Spatial characteristics

- Narrow (1 km wide)
- Located above the deepest part of the ruptured fault
- Show no relations to the fault geometry

Can it be explained by the known deformation mechanisms?

- Afterslip
- Poro-elastic
- Viscous relaxation

Postseismic deformation

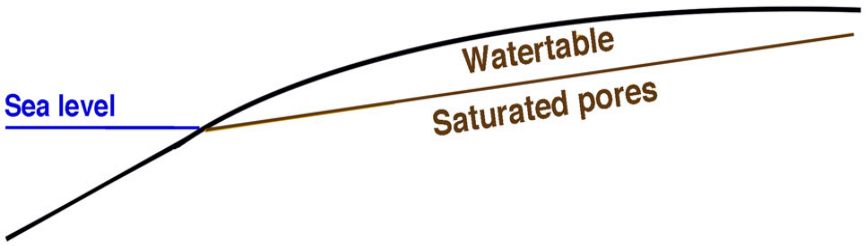


The spatial extent of the deformation:

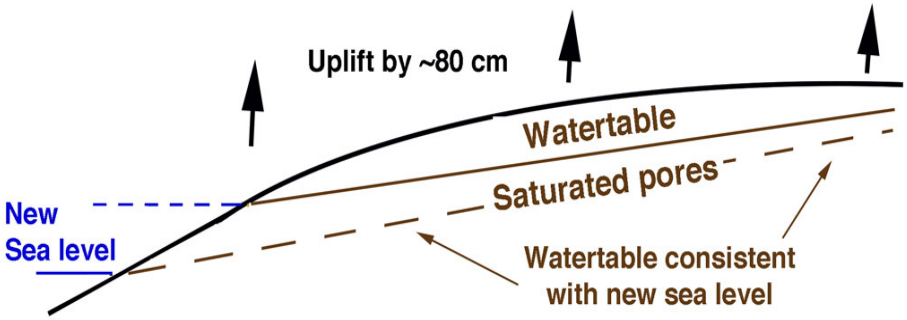
- **Follows the shoreline**
- **Sub-parallel to the shore**

=> The deformation is governed by coastal processes

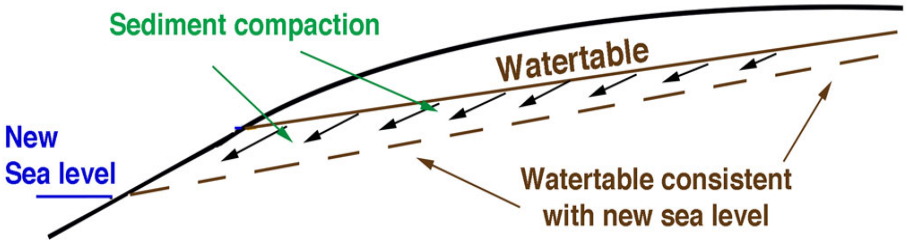
Postseismic deformation: Sediment compaction in response to Groundwater table adjustment to the new sea level



Before the earthquake
Watertable is in equilibrium with sea level



During the earthquke
(within ~20 seconds)
Uplift of the delta by ~80 cm disturbed the watertable equilibrium.



After the earthquake
Groundwater flow downward toward the sea in order to reach an equilibrium with the new sea level.
Water withdrawal from pores results in sediment compaction and surface subsidence.

Field observations

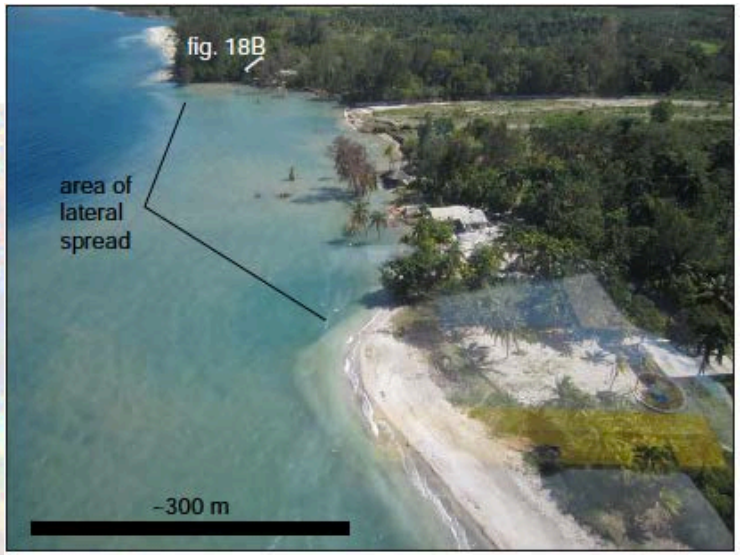
Uplifted corals

Open fractures

[Hayes et al., 2010]

Lateral spreading at river outlets

GEER report (2010)



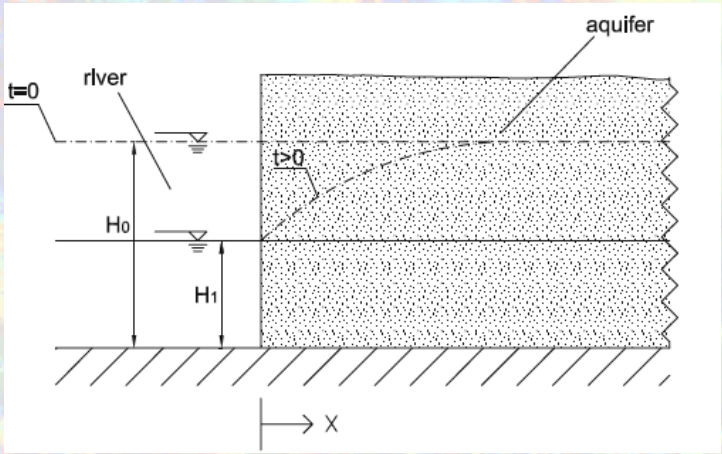
Koehler and Mann (2011)

Flow model *(analytical solution)*

Response of a water table to a sudden drawdown

Governing equation:

$$\frac{\partial h}{\partial t} = \frac{K}{S}\frac{\partial}{\partial x}\left(h\frac{\partial h}{\partial x}\right)$$



Boundary conditions:

$$h(0, t) = 0 \qquad t > 0$$

$$h(\infty, t) = h_0 \qquad t > 0$$

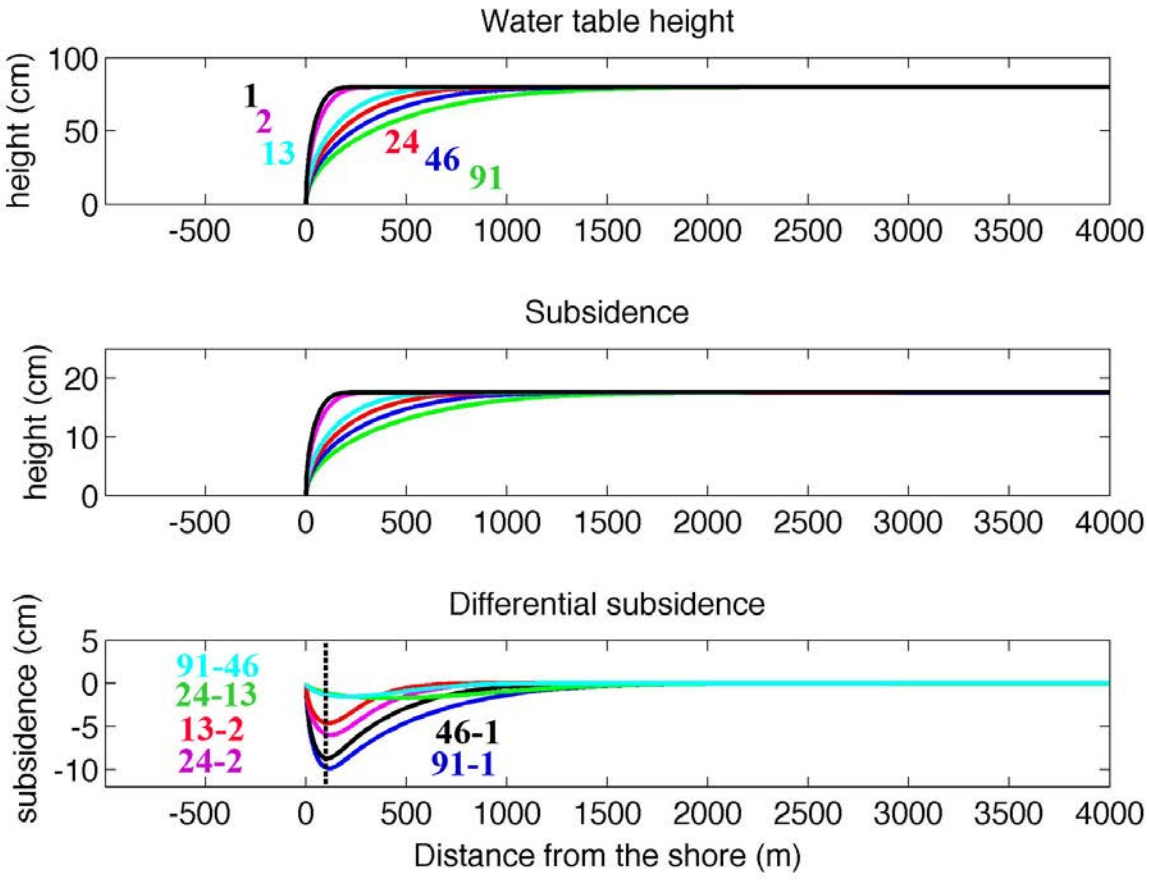
Initial condition:

$$h(x, 0) = h_0 \qquad x > 0$$

(Hogarth and Parlnage, 1999)

Flow model *(analytical solution)*

Response of a water table to a sudden drawdown



<u>Model parameters</u>

Δh – 0.8 m
(sudden drop)

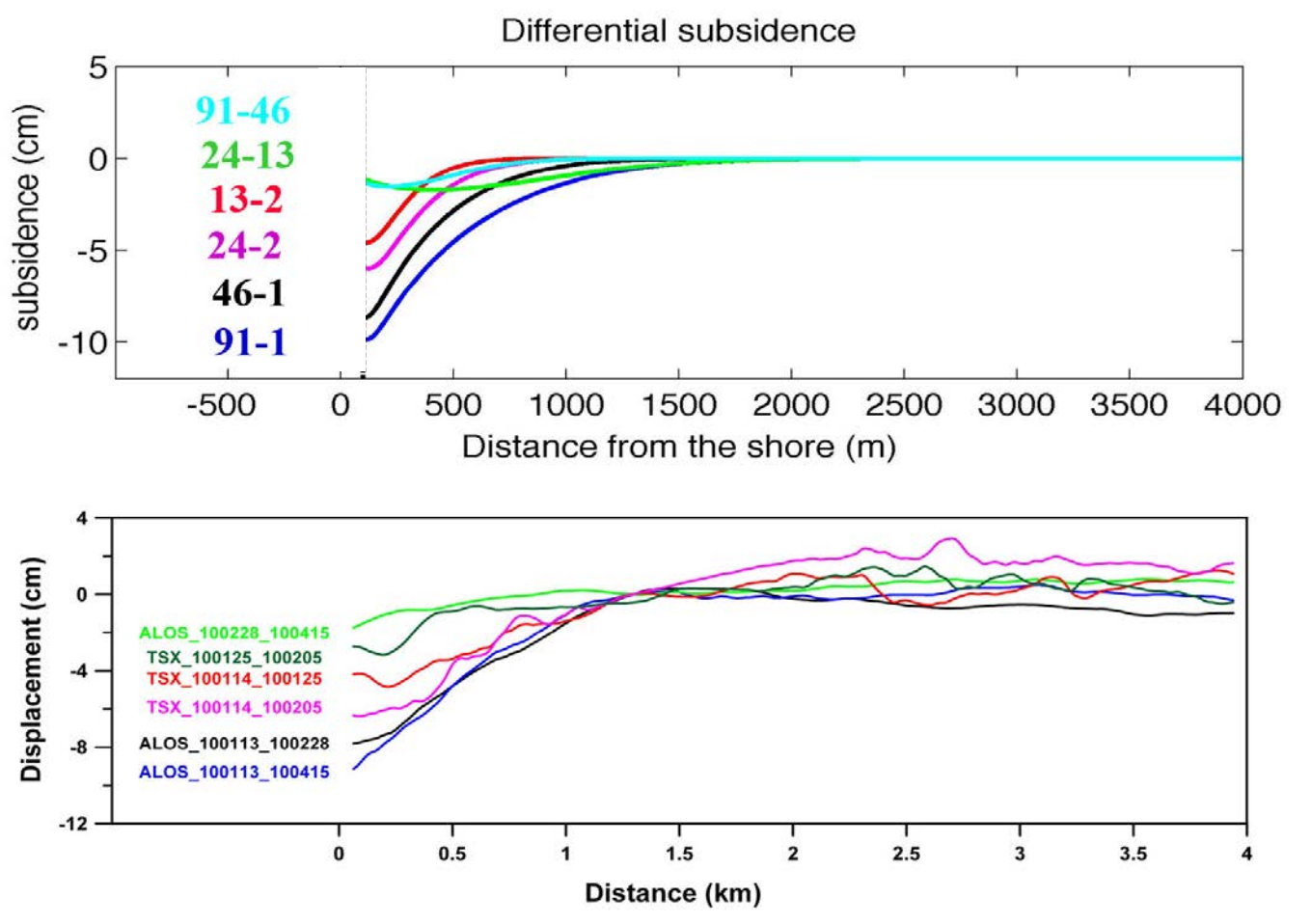
K – 1000 m/day
(hydraulic conductivity)

S – 0.27
(Specific yield)

C – 0.22
(Compaction)

Flow model *(analytical solution)*

Response of a water table to a sudden drawdown



Conclusions

- TerraSAR-X (TSX) and ALOS observations detected postseismic deformation that occurred along the northern part of the Leogane delta during 90 days after the earthquake.
- The TSX observations led to a discovery of a new mode of postseismic deformation, caused by sediment compaction due to groundwater table adjustment to a new sea level.
- It is very important to task SAR satellites to monitor surface deformation right after a large earthquake. Fast response of space agencies will allow the acquisition of the time-dependent postseismic deformation.

Acknowledgements

NSF – RAPID grant

German Space Agency (DLR) – TerraSAR-X data

Japanese Space Agency (JAXA) – ALOS data