

**Postseismic deformation following the
2010 Haiti earthquake:
Time-dependent surface subsidence induced
by groundwater flow in response to a
sudden uplift**

Shimon Wdowinski¹ and Sang-Hoon Hong^{1,2}

*1. Division of Marine Geology and Geophysics,
University of Miami, Miami, FL*

*2. Korea Aerospace Research Institute, Republic of
Korea*

Presentation content

- The 2010 Haiti earthquake
- Modes of postseismic deformation
- Postseismic deformation following the Haiti earthquake
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- Summary

Magnitude 7.0 HAITI

Tuesday, January 12, 2010 at 21:53:09 UTC

A powerful earthquake hit the impoverished country of Haiti on Jan 12, 2010, collapsing the presidential palace and numerous other critical government buildings and raising fears of substantial casualties in what a witness called “a major, major disaster.”



Before and After Earthquake
Presidential Palace in Port-au-Prince, Haiti



Magnitude 7.0 HAITI

Tuesday, January 12, 2010 at 21:53:09 UTC



Carel Pedre via Twitter



RADIO TELE GINEN

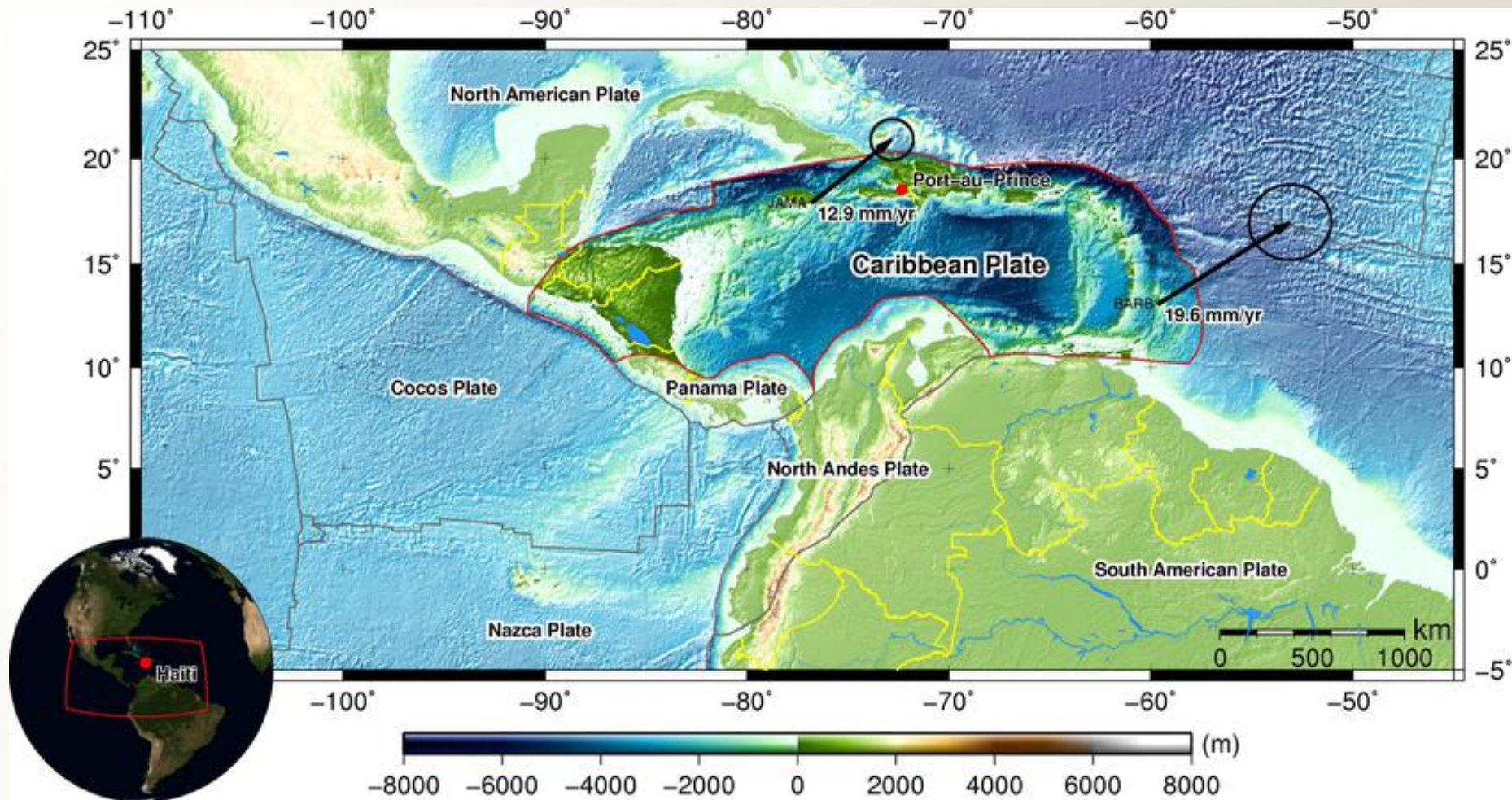
BBC



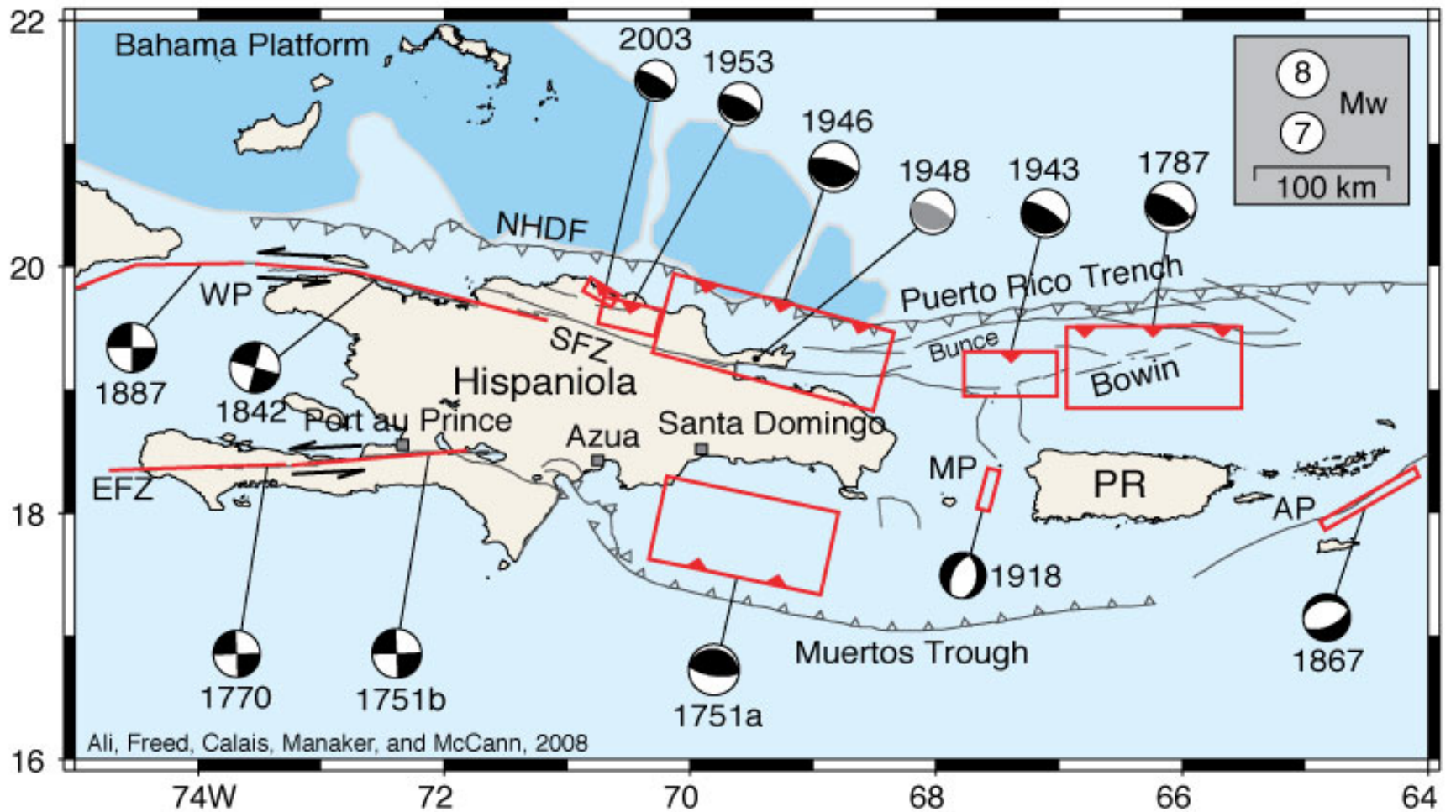
"Thousands of people were feared dead today after a powerful earthquake struck Haiti's capital, leaving tens of thousands homeless and buried beneath rubble....Thousands of people gathered in public squares late into the night, singing hymns and weeping, with many seriously injured people sitting in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

The Gazette, U.K.

Tectonic background

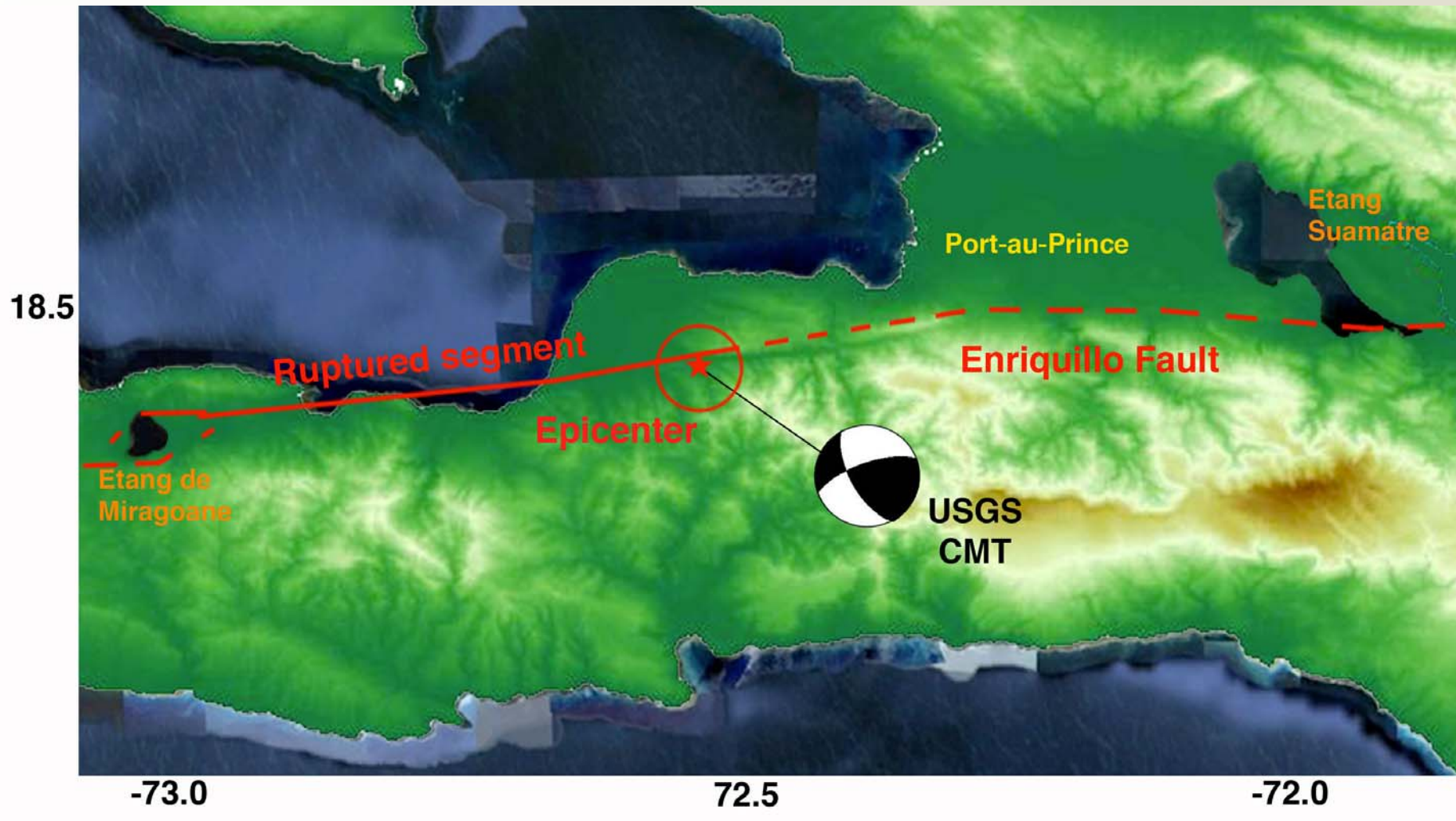


Seismic record

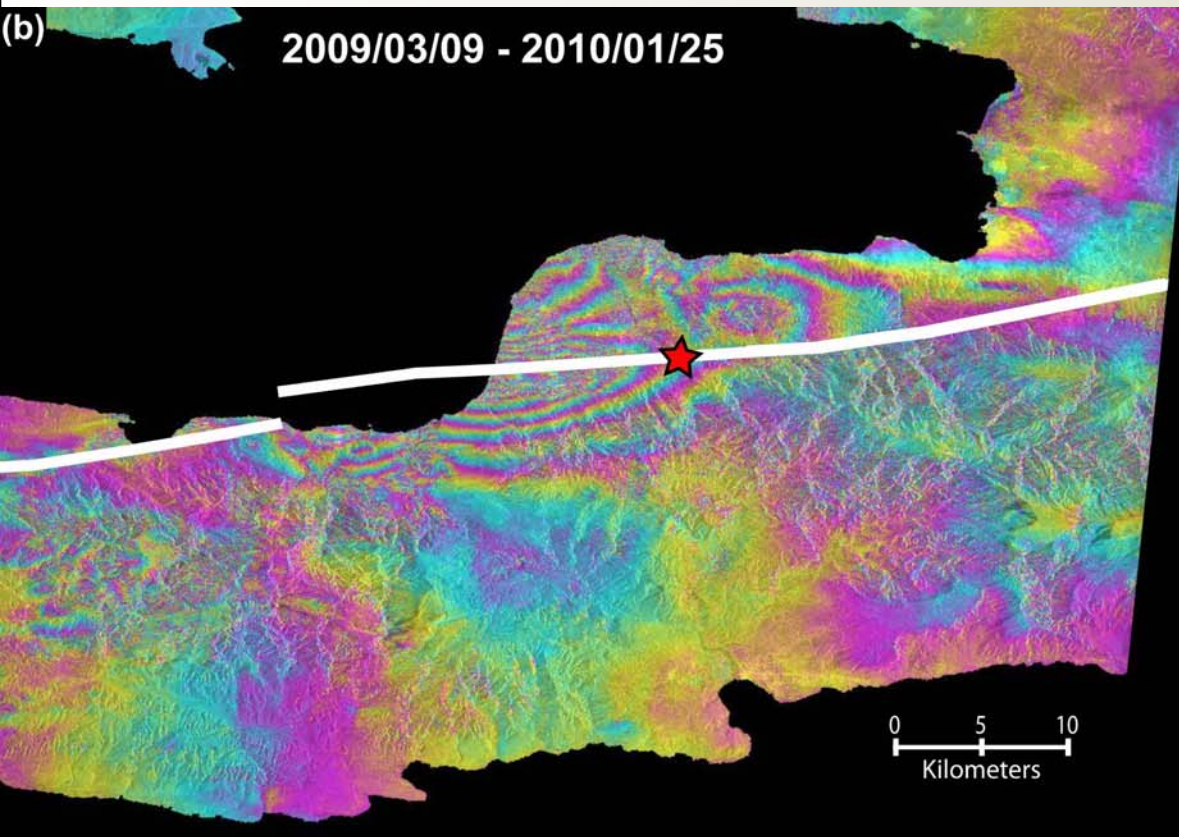


Ali, Freed, Calais, Manaker, and McCann, 2008

The 2010 Haiti earthquake

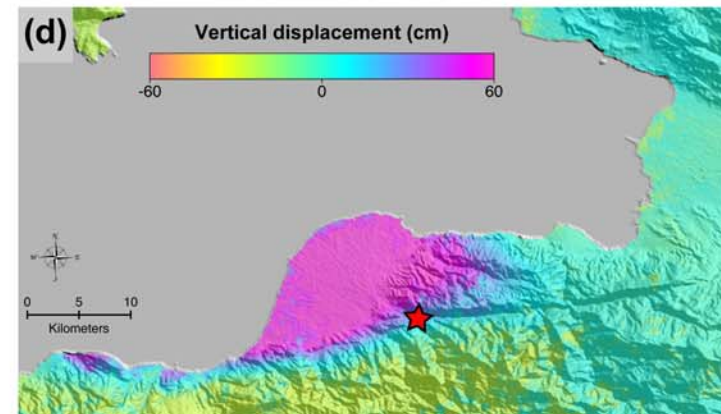
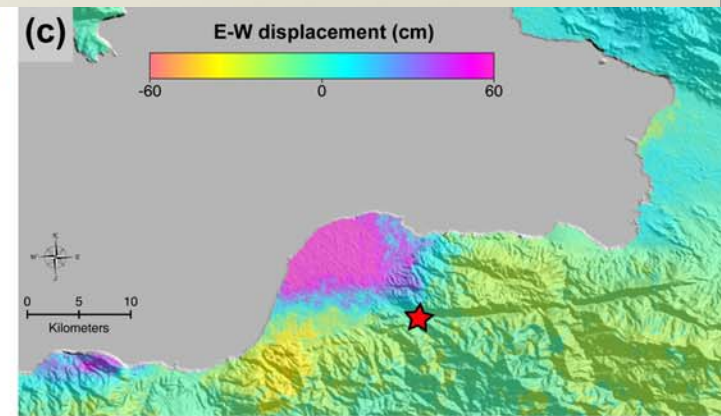


Geodetic observations



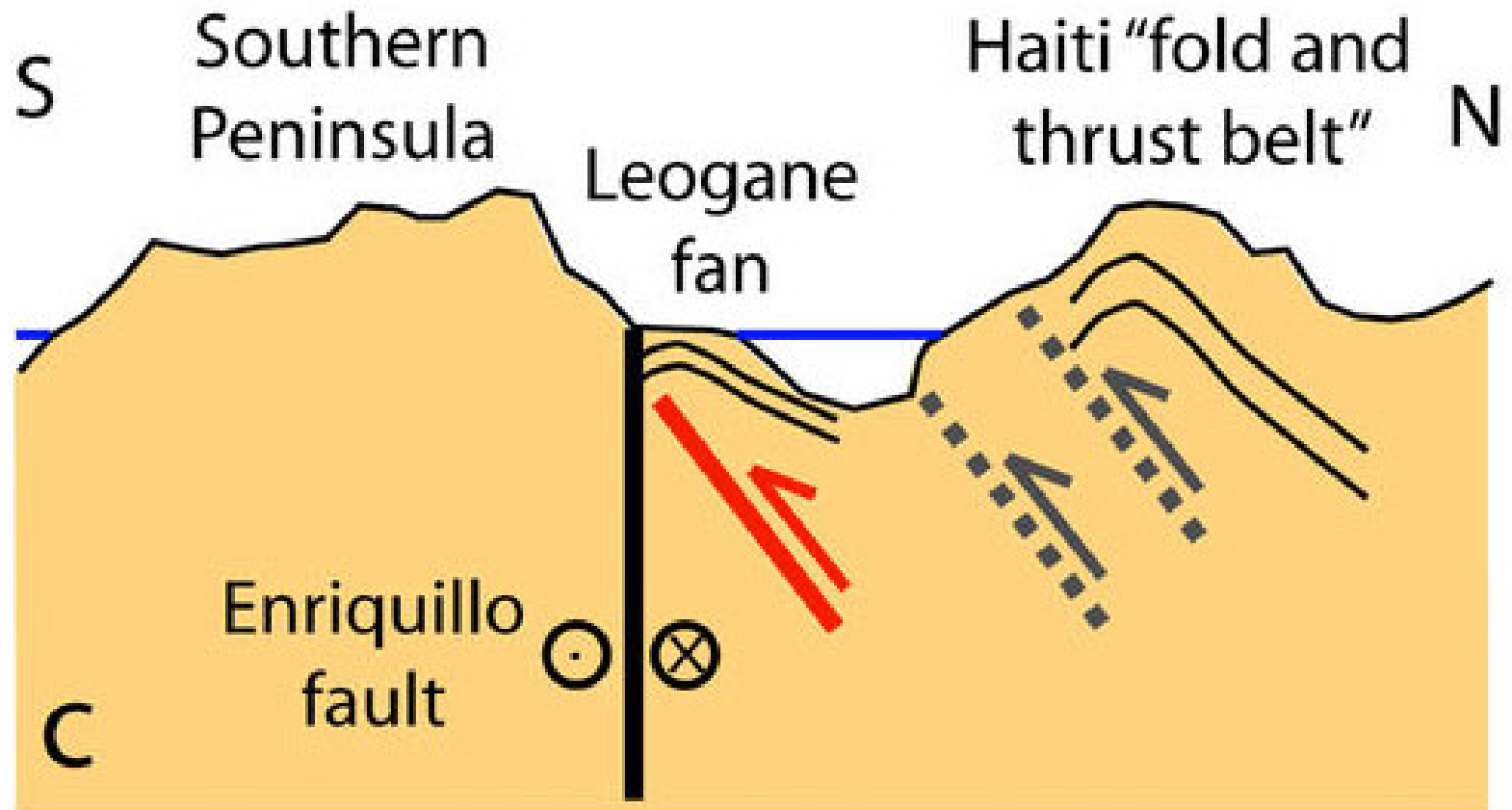
Co-seismic ALOS interferogram

E-W component



Up component

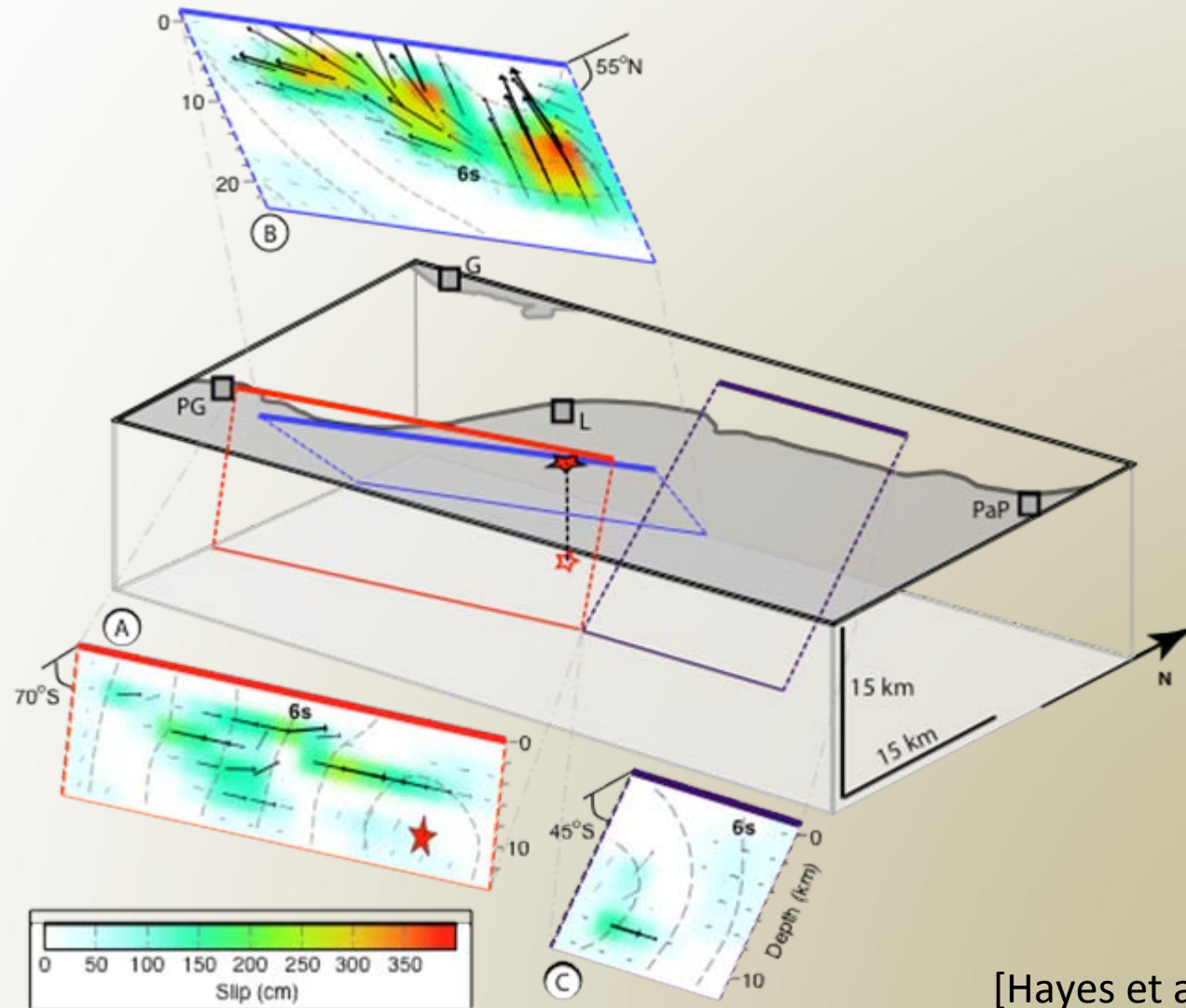
The 2010 Haiti Earthquake



[Calais et al., 2010]

The 2010 Haiti Earthquake

Figure 3



[Hayes et al., 2010]

Field observations

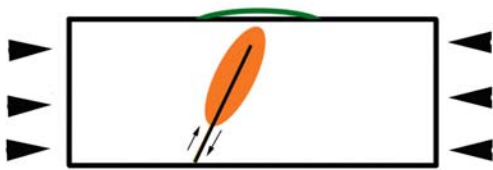


Uplifted corals



Open fractures

The earthquake deformation cycle



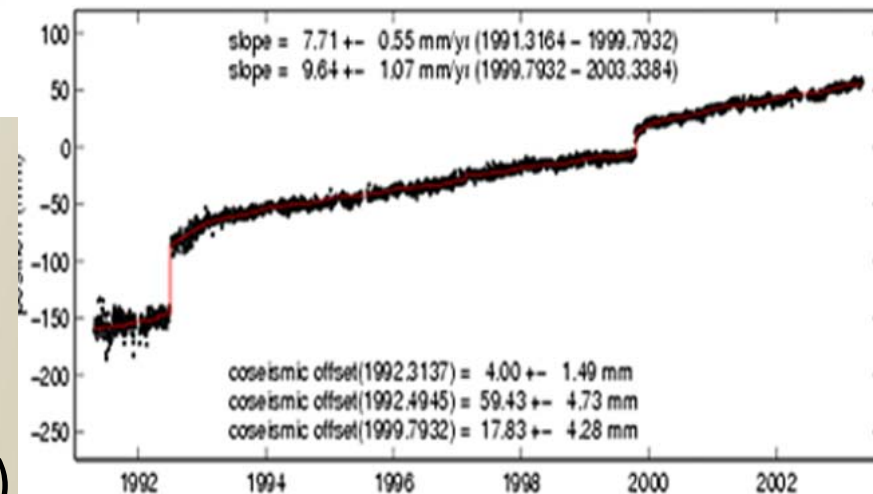
Interseismic deformation
(in between earthquake)
Lower crust is displaced in response to tectonic plate motion
Upper crust accumulates strain resulting in small surface deformation



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

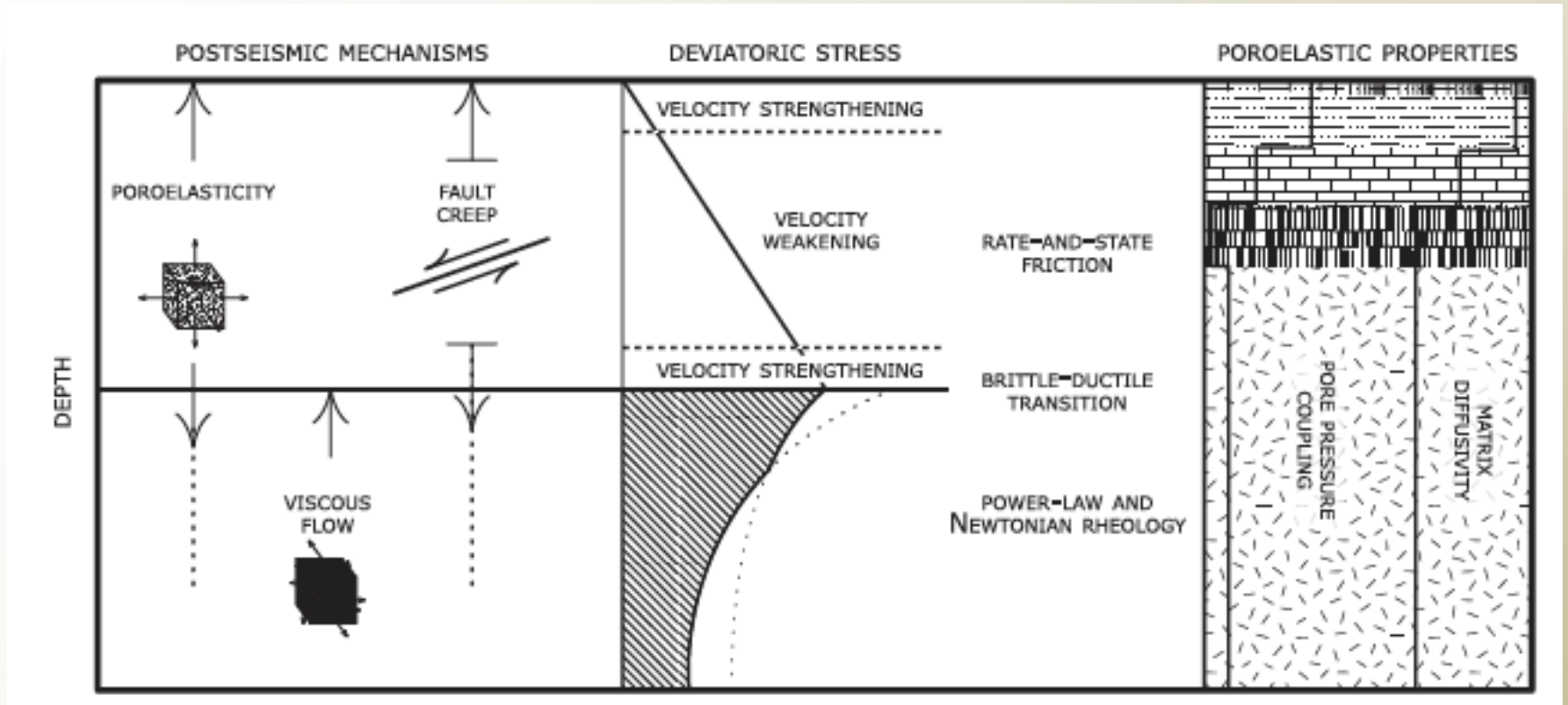


Postseismic deformation
(after large earthquakes)
Time dependent deformation of either Upper or Lower crust; further release of accumulated strain, resulting in small surface deformation. Often postseismic deformation correlates with aftershock activity



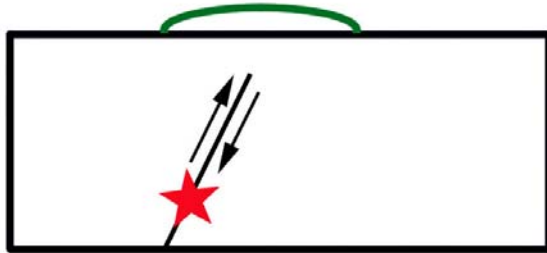
(Nikolaidis , 2002)

Postseismic deformation mechanisms

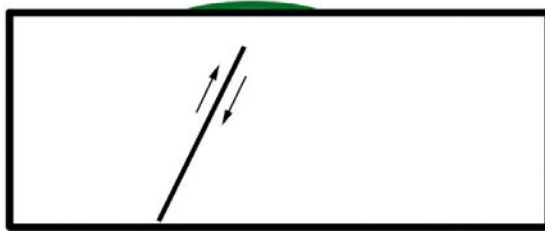


(Barbot&Fialko, 2010)

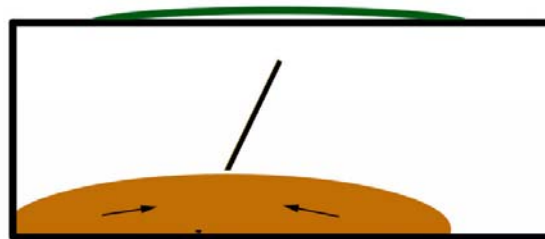
Modes of postseismic deformation



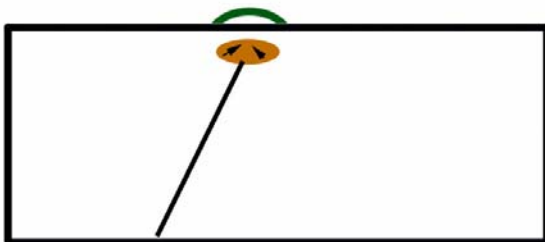
Coseismic deformation



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



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

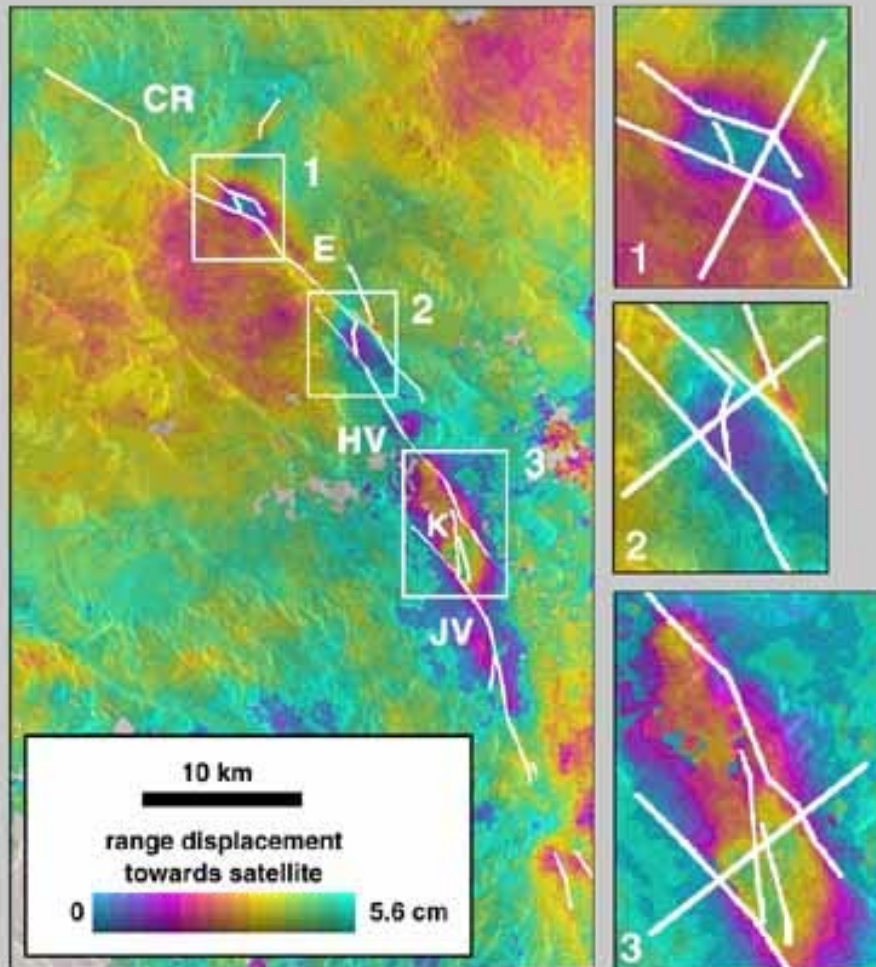


Poro-elastic deformation
induced by pore-fluid flow
in response to stress changes
Short wavelength deformation

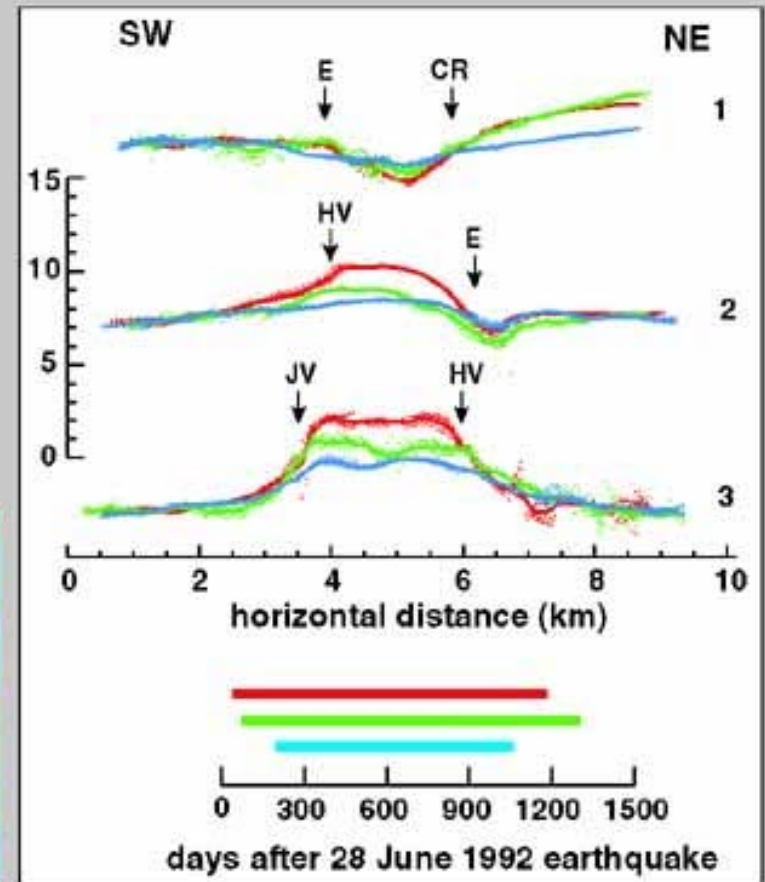
Poro-elastic Postseismic deformation

POSTSEISMIC REBOUND IN STEP-OVERS OF THE LANDERS 1992 FAULT BREAK

ERS-1, 3-pass interferogram



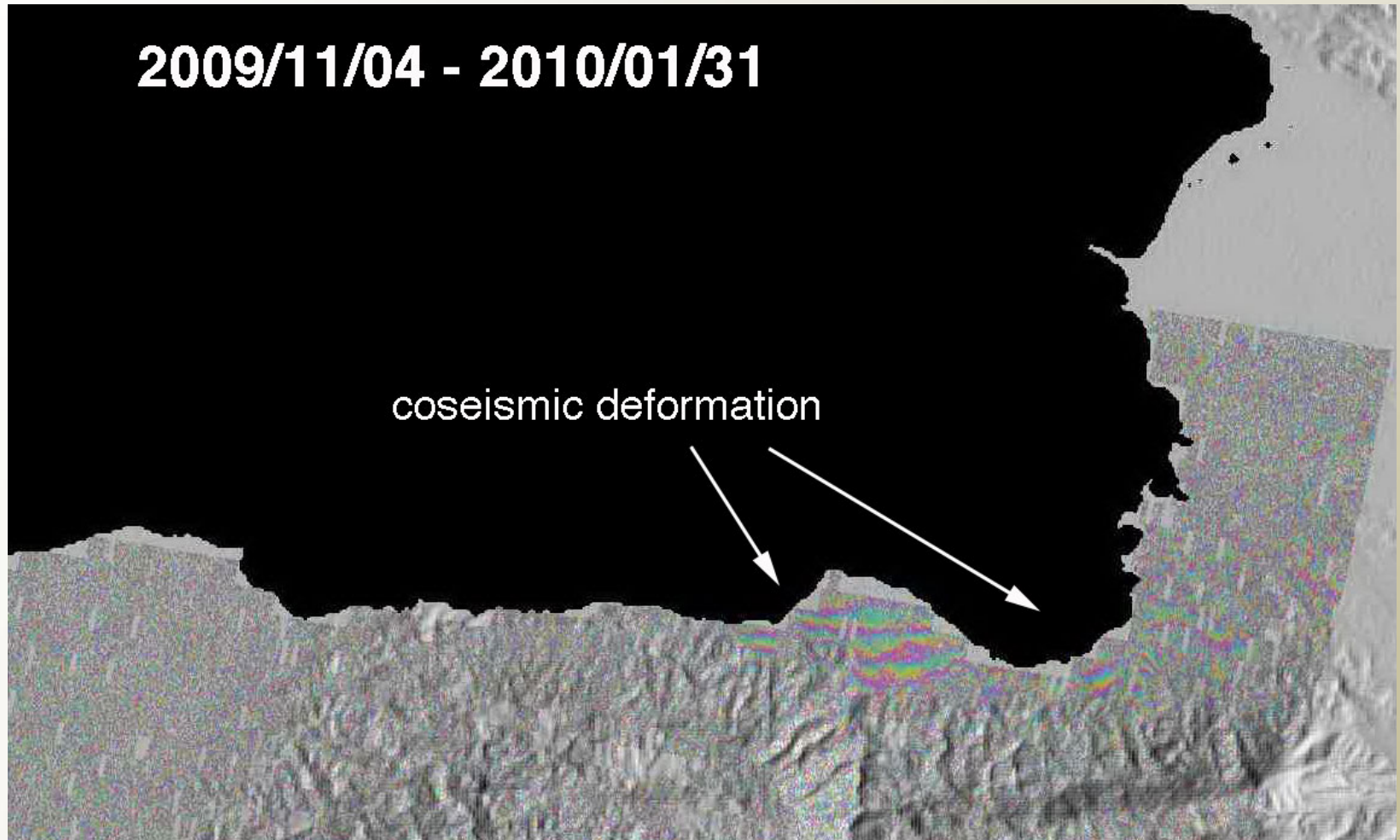
Range displacement toward satellite (cm)



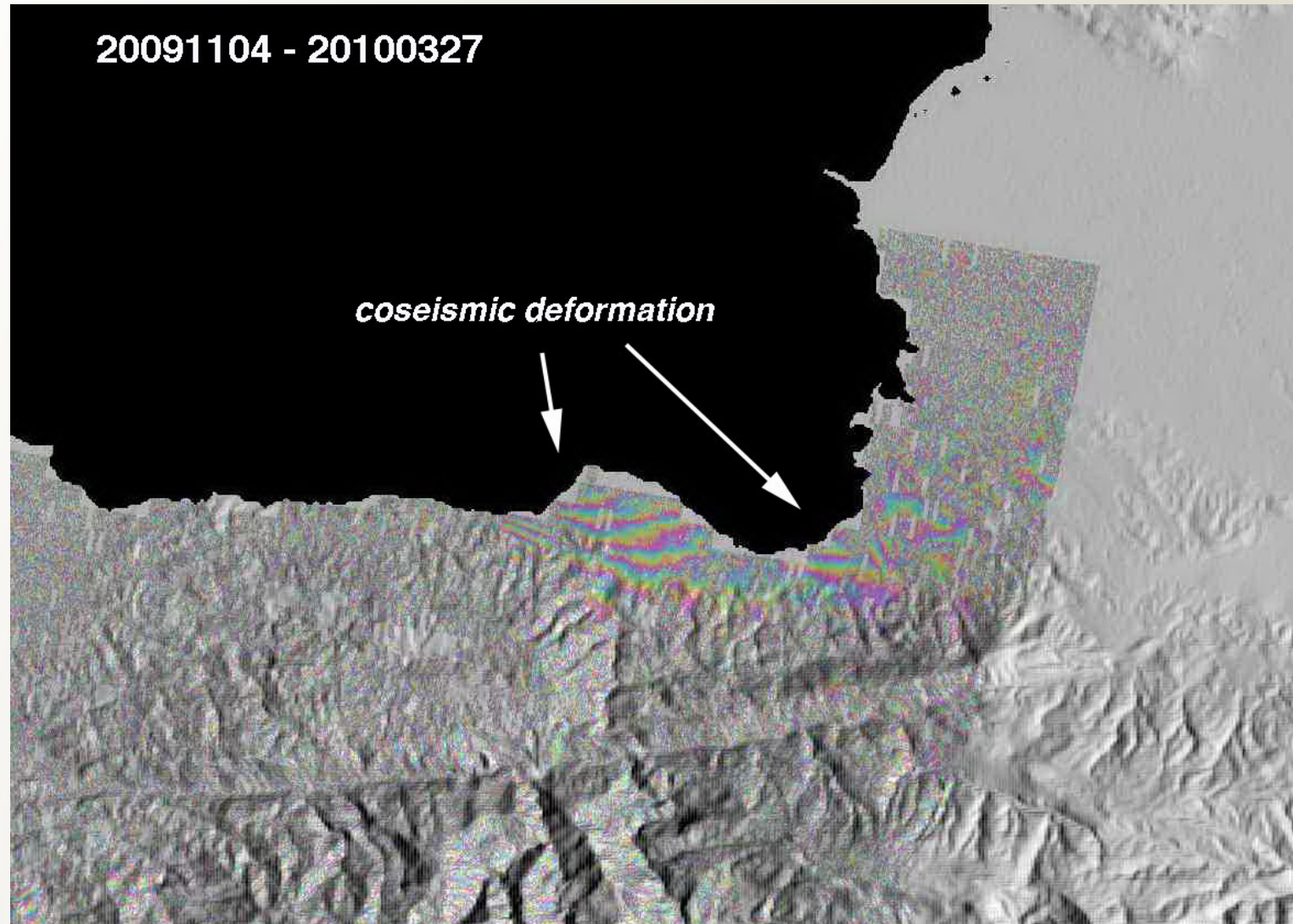
TerraSAR-X acquisitions before and after the 2010 Haiti earthquake



Coseismic deformation



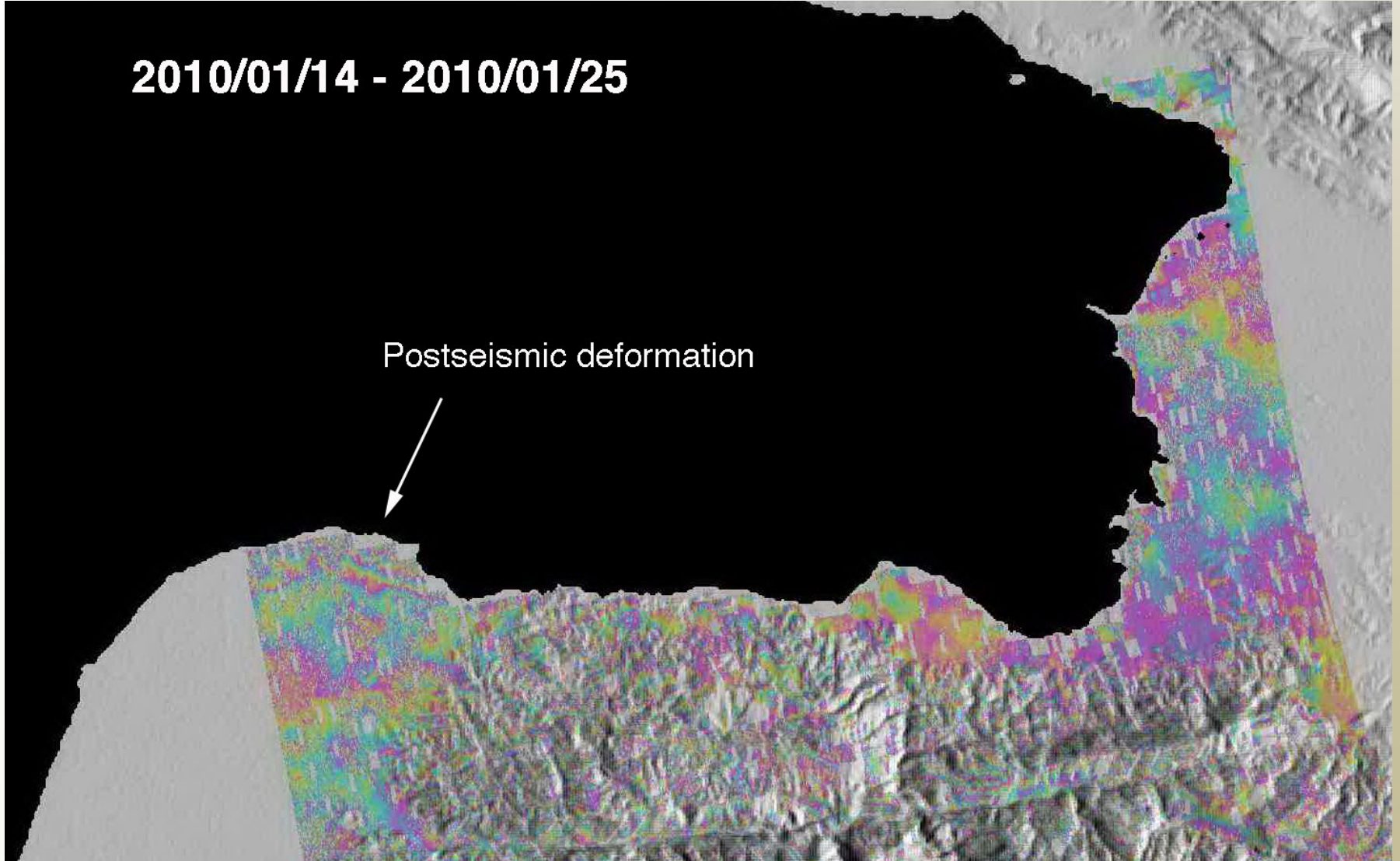
Coseismic deformation



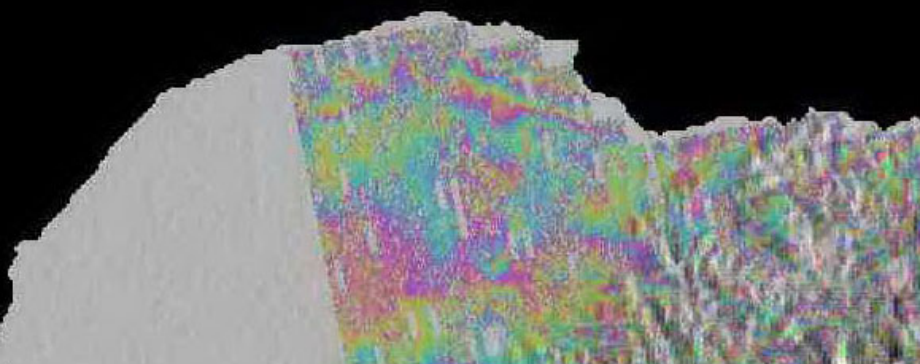
Postseismic deformation

2010/01/14 - 2010/01/25

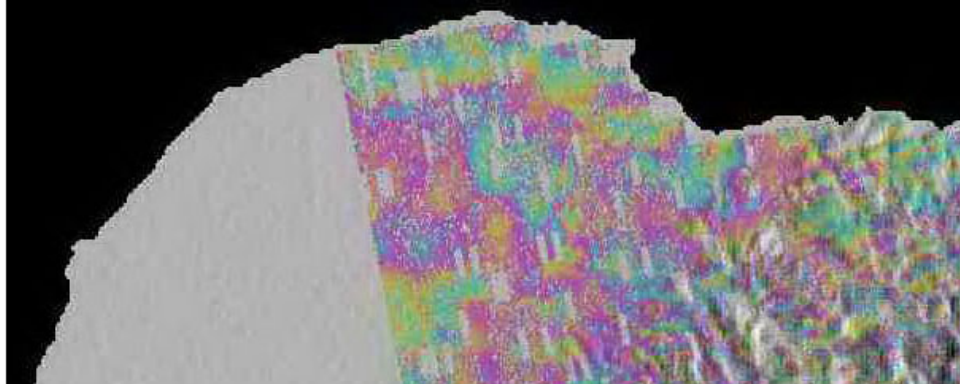
Postseismic deformation



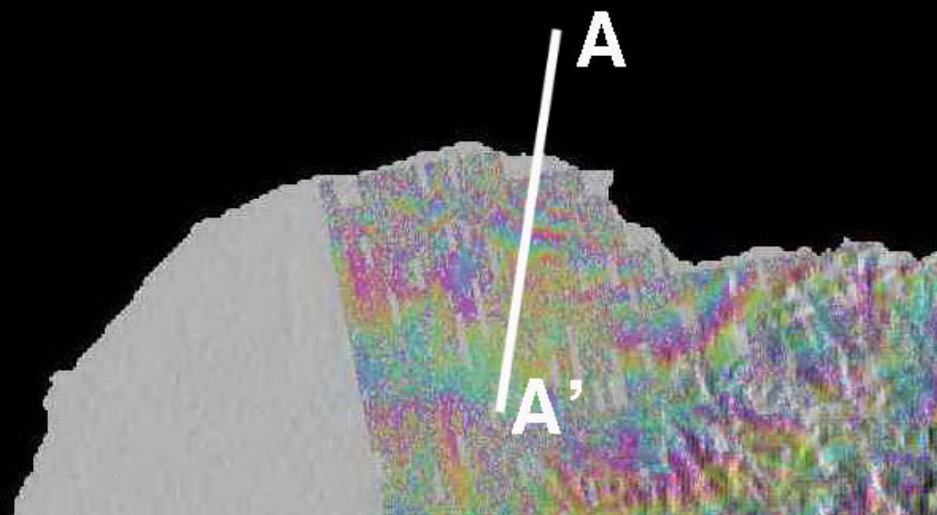
2010/01/14 - 2010/01/25



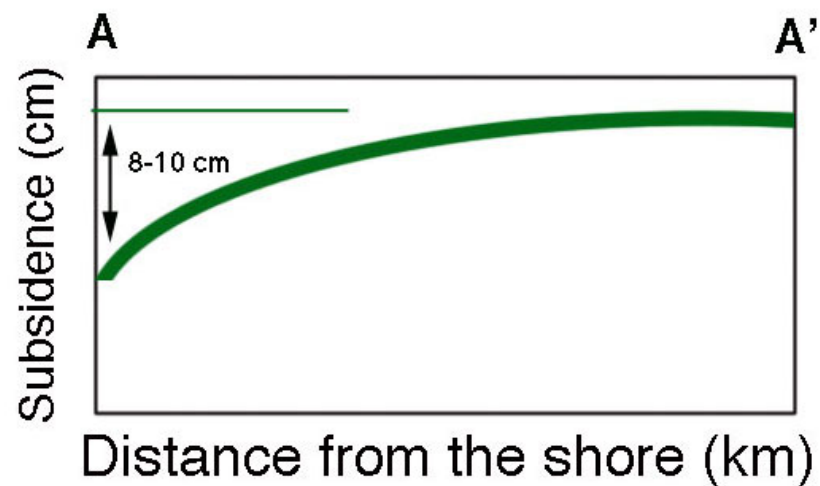
2010/01/25 - 2010/02/05



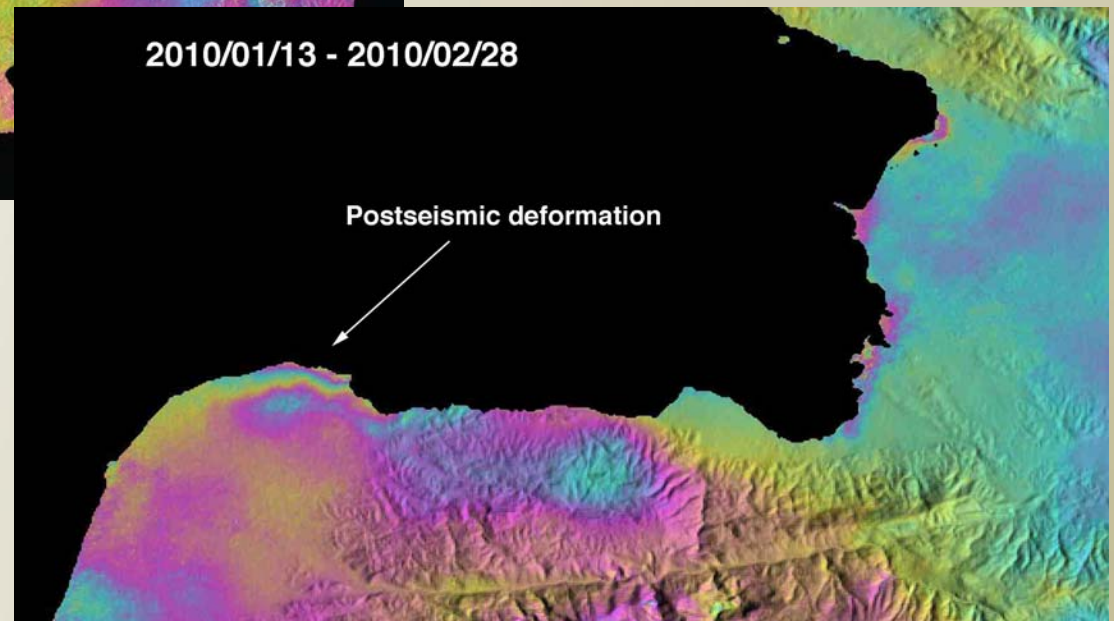
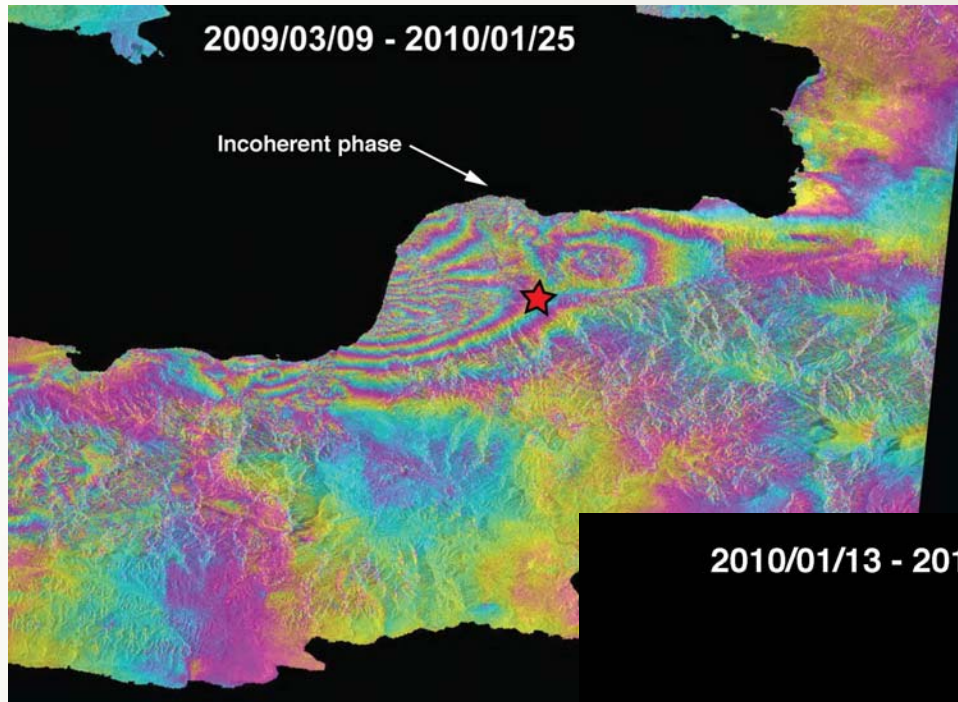
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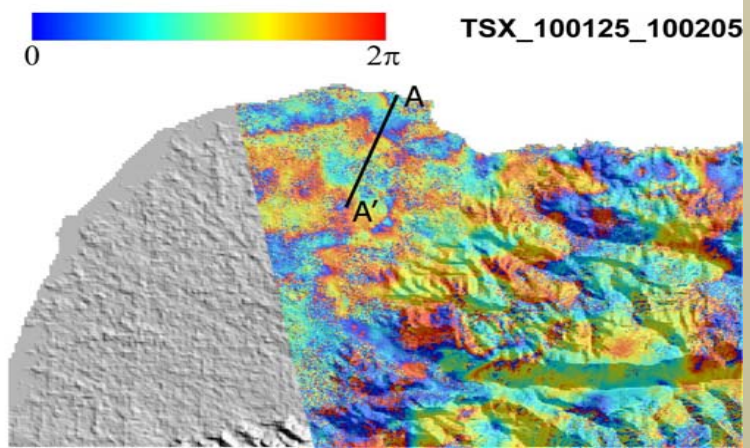
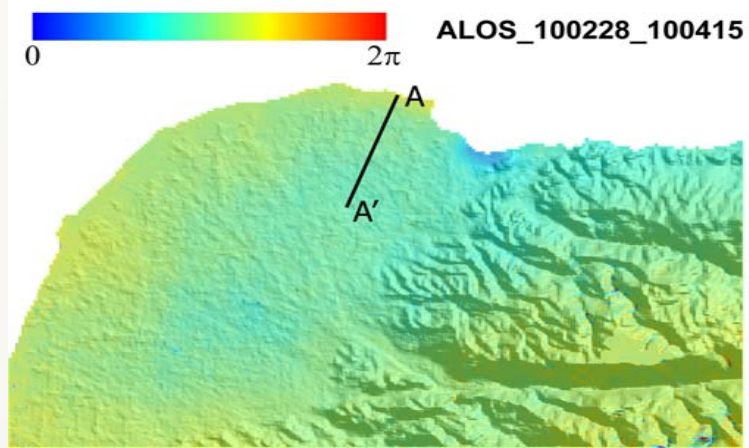
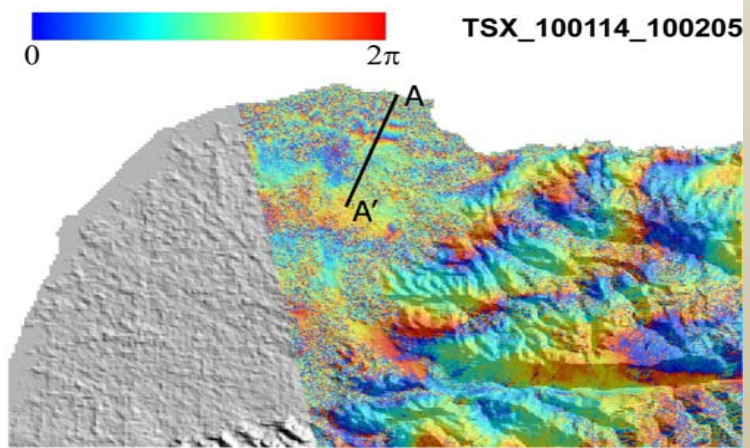
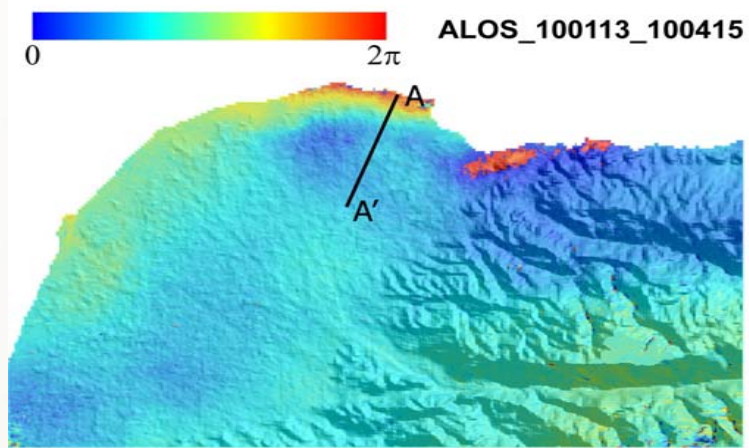
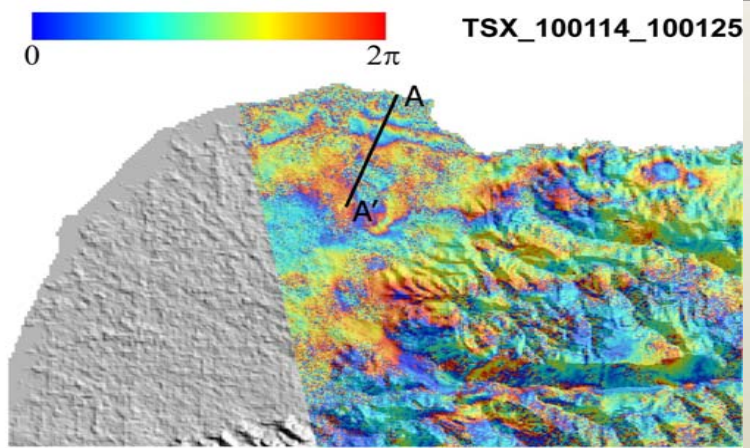
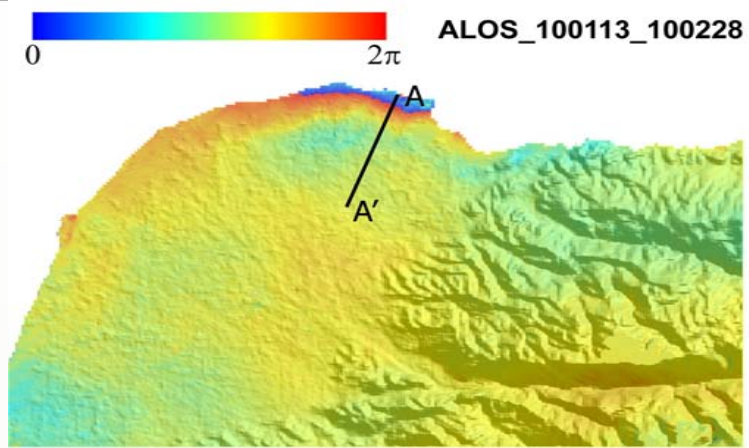


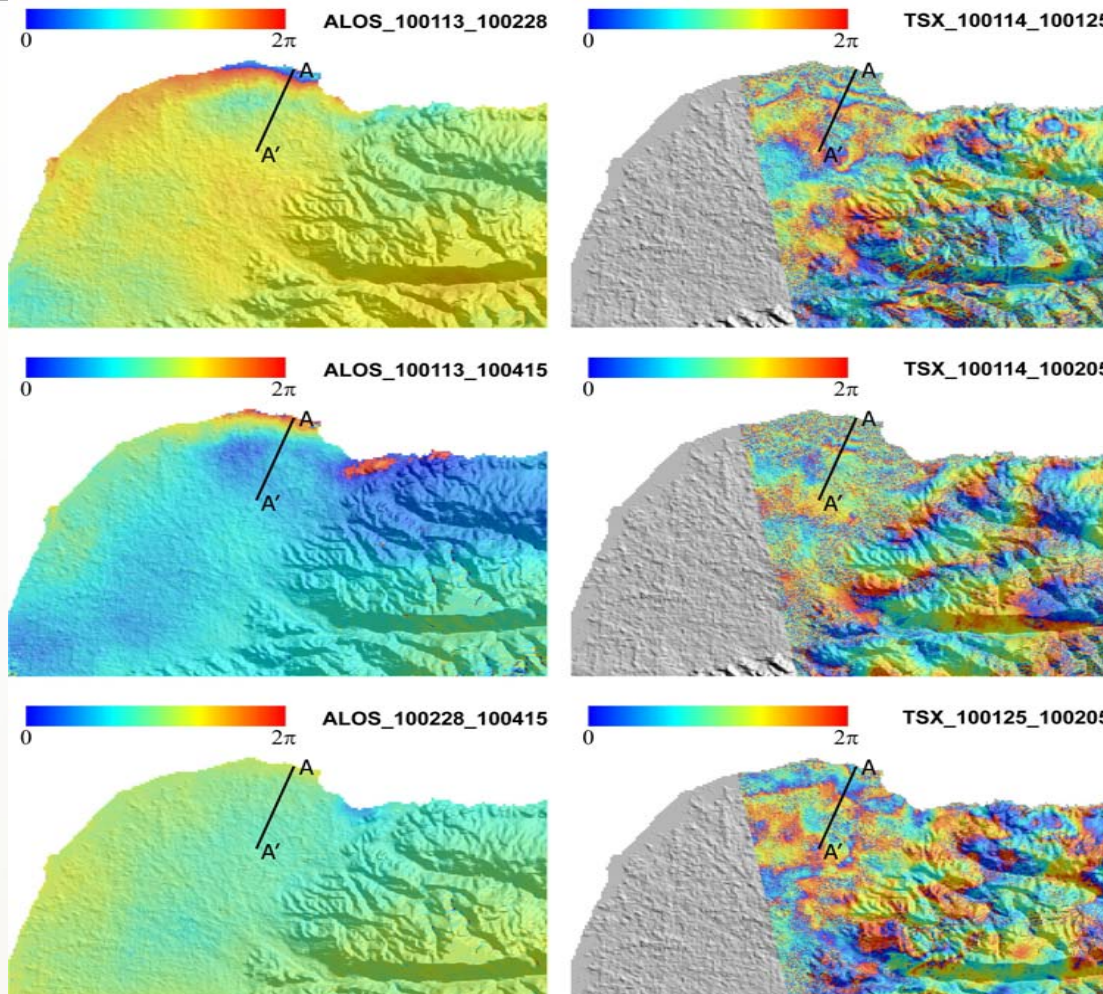
Postseismic displacement



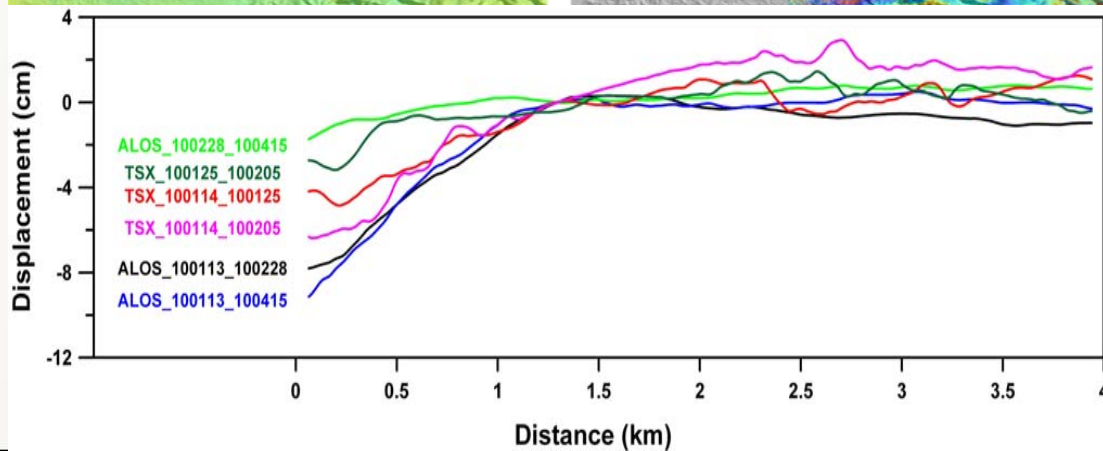
ALOS co- and post-seismic deformation



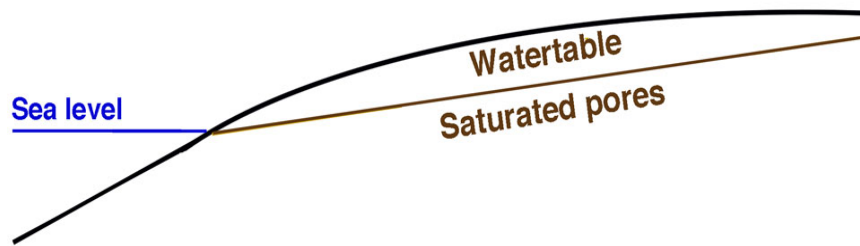




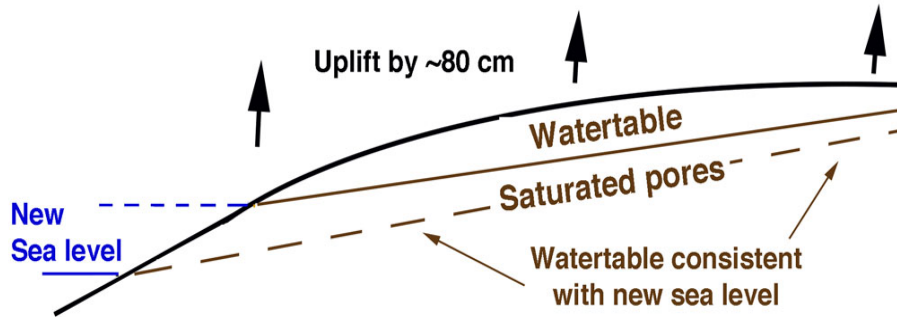
Postseismic deformation



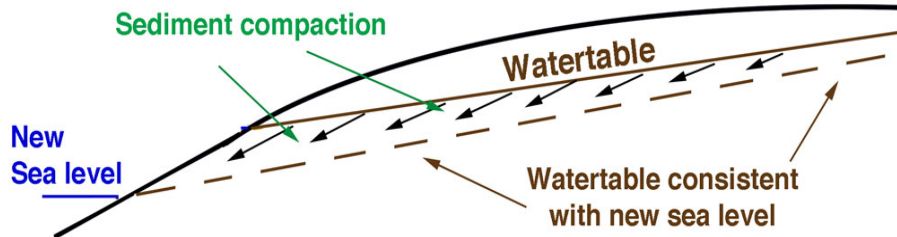
Postseismic deformation: Sediment compaction in response to Groundwater table adjustment to the new sea level



Before the earthquake
Watertable is in equilibrium
with sea level



During the earthquake
(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

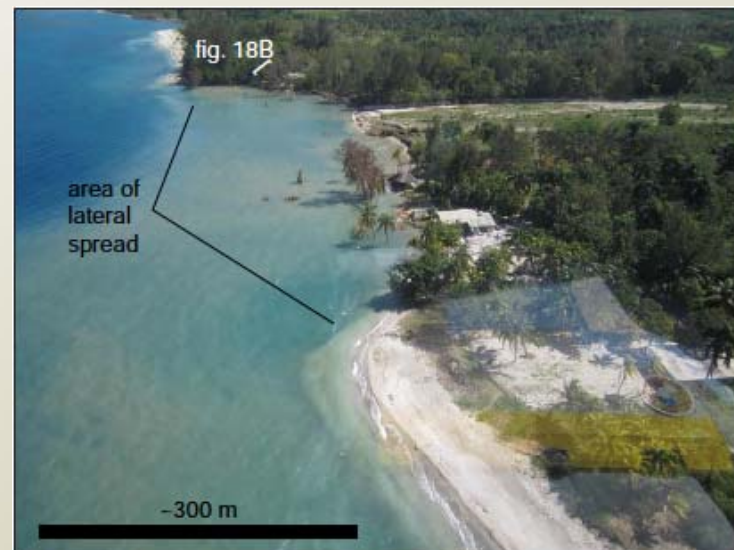


Open fractures

Lateral spreading at river outlets



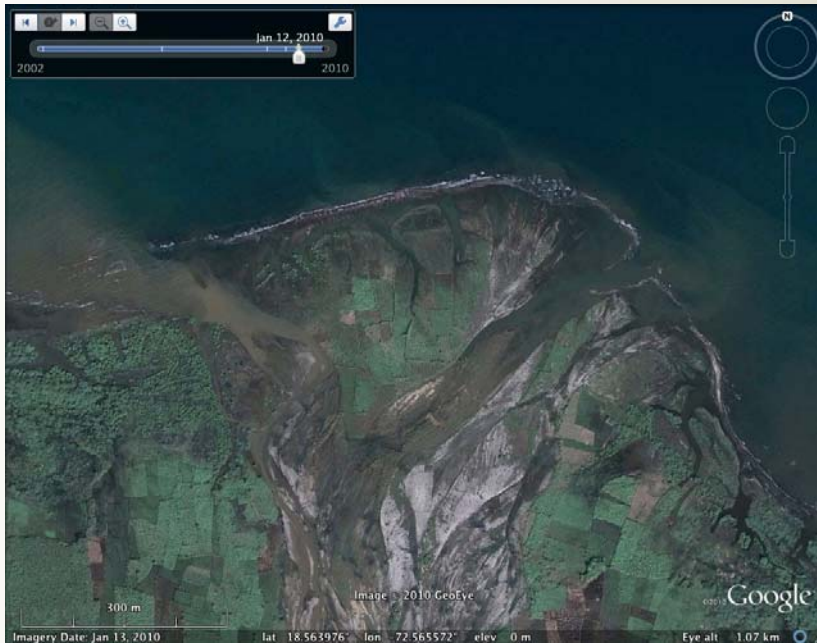
GEER report (2010)



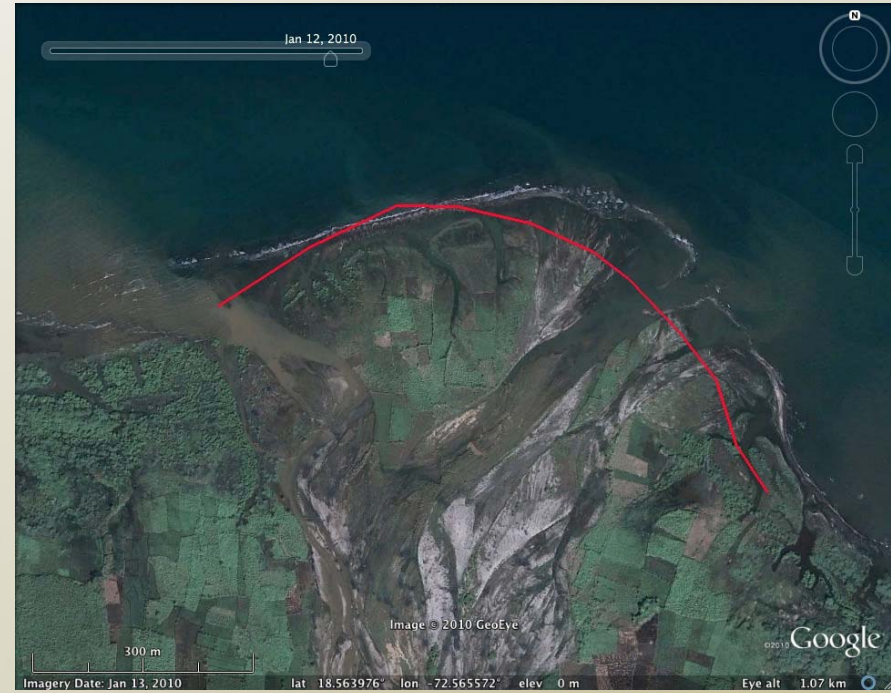
Koehler and Mann (2011)



2005-12-05



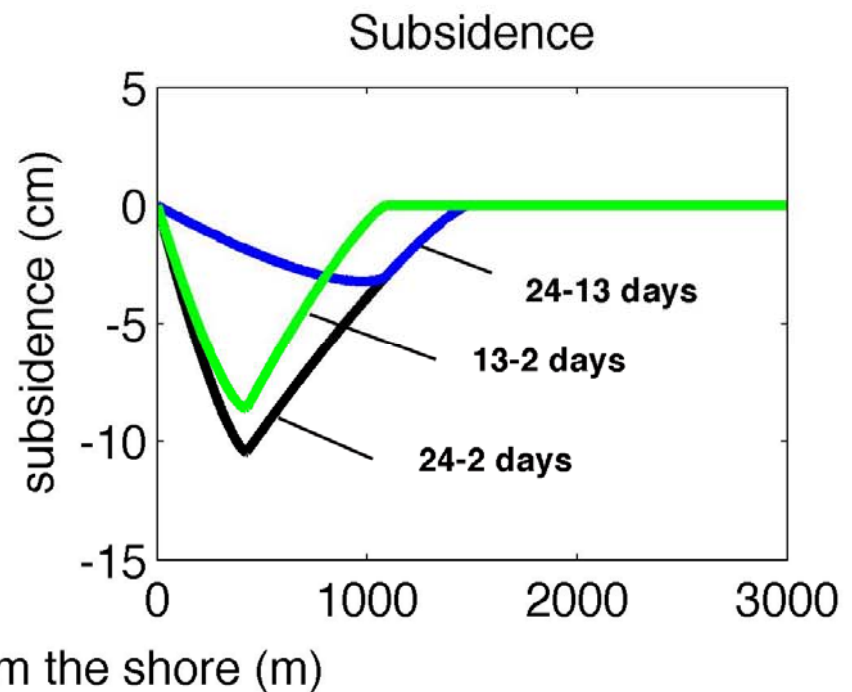
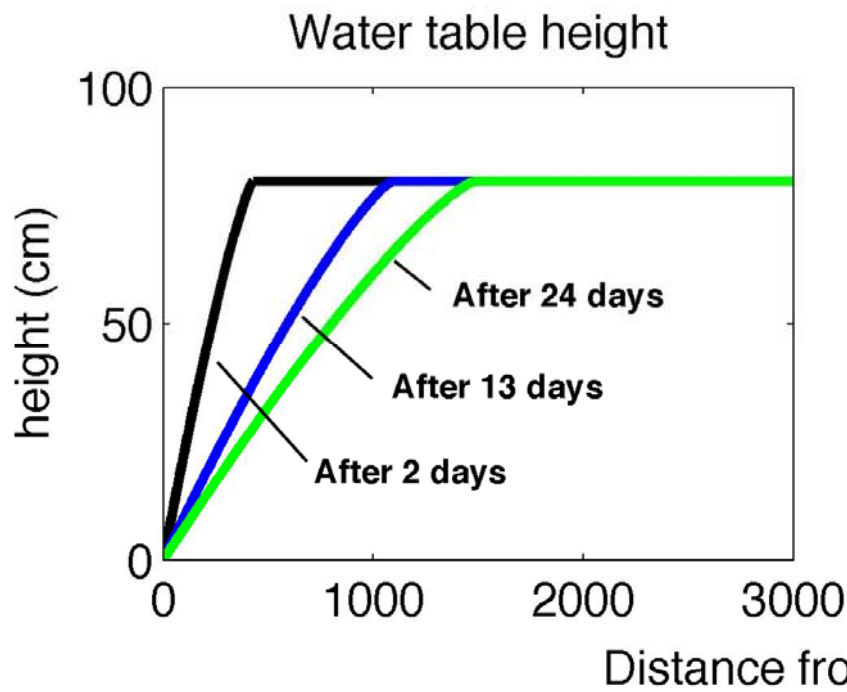
2010-01-13



Difference

Flow model (*analytical solution*)

Response of unconfined aquifer to sudden change in boundary head



Conclusions

- TerraSAR-X (TSX) observations detected postseismic deformation that occurred along the northern part of the Leogane delta during 24 days after the earthquake.
- The coseismic (main earthquake) deformation of the 2010 Haiti earthquake has been under-estimated (by $\sim 5\%$), because the coseismic deformation analysis is based on interferograms that include both coseismic and postseismic deformation.
- 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. It is important to start acquiring data immediately after the earthquake, when the postseismic signal is the largest.

Acknowledgements

NSF – RAPID grant

German Space Agency (DLR) – TerraSAR-X data

Japanese Space Agency (JAXA) – ALOS data