# Subsidence at fish farms in the Yellow River Delta

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## Objective

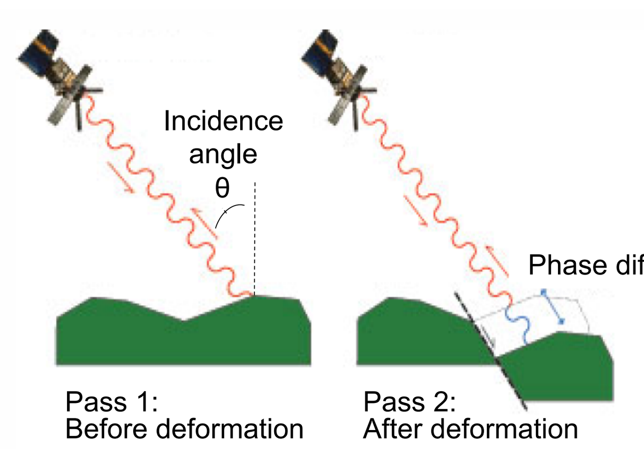
Use InSAR-derived maps of surface deformation to understand why parts of the delta coastline are retreating.

## Abstract

We use Differential Interferometric Synthetic Aperture Radar (D-InSAR) to map surface deformation in the Yellow River delta between 2007 and 2011. We find rapid, localized subsidence of up to 250 mm/y occurring along the coast, apparently related to groundwater extraction at fish farms. This subsidence is severe enough to account for all measured shoreline retreat on the delta. Moreover, similar subsidence may also occur in other deltas, producing relative sea level rise one to two orders of magnitude more quickly than global sea level rise.

## Measuring motion with InSAR

Figure 1: Schematic of differential (two-pass) InSAR. Modified from COMET (2009)




The change in phase between two passes of a satellite-borne Synthetic Aperture Radar (SAR) is a function many factors, which must be subtracted to isolate the displacement signal:

$$\Delta\phi = \Delta\phi_{displacement} + \Delta\phi_{topography} + \Delta\phi_{orbit} + \Delta\phi_{atmosphere} + \Delta\phi_{noise}$$

- ✓ Topography removed with a synthetic interferogram generated from a Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM).
- ✓ Orbit corrected with a best-fit polynomial phase ramp.
- ✓ Atmospheric interference avoided using the MODIS Level-2 water vapor product
- ✓ Noise reduced with averaging and masking

Once these signals are subtracted, phase difference can be converted to vertical displacement *d* using:

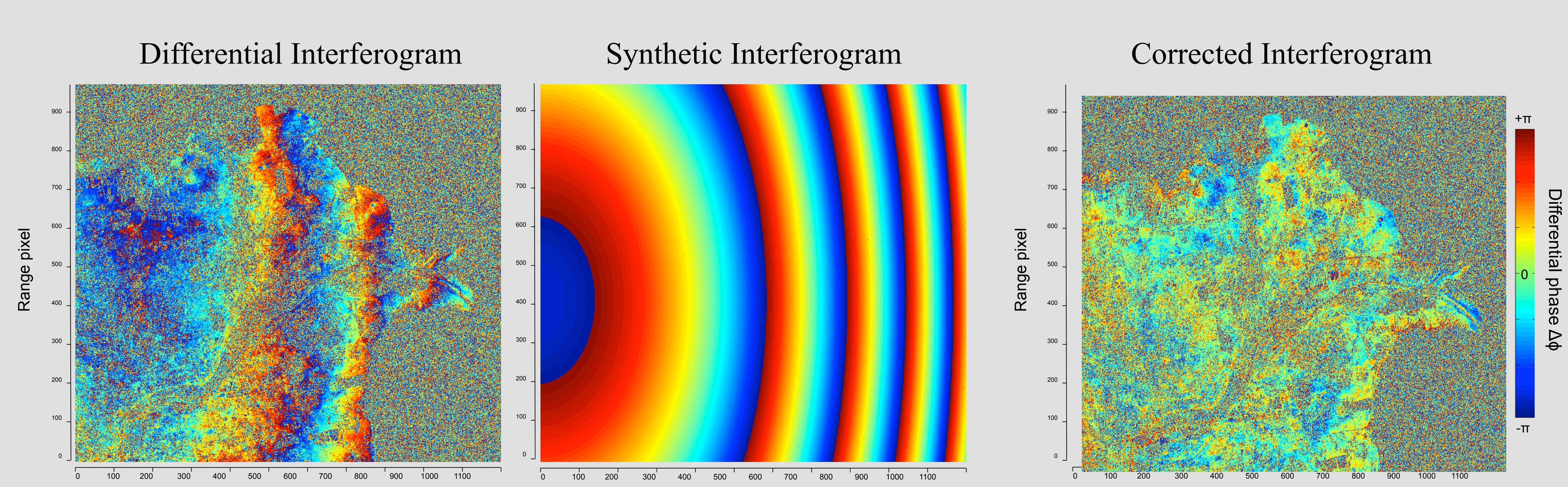
$$\Delta\phi_{displacement} = \frac{4\pi}{\lambda} d \sec\theta$$

where is λ the wavelength and Θ is the incidence angle.

## Removing orbital drift

Topography and orbital drift signals (phase ramps) are both removed by generating and subtracting synthetic interferograms

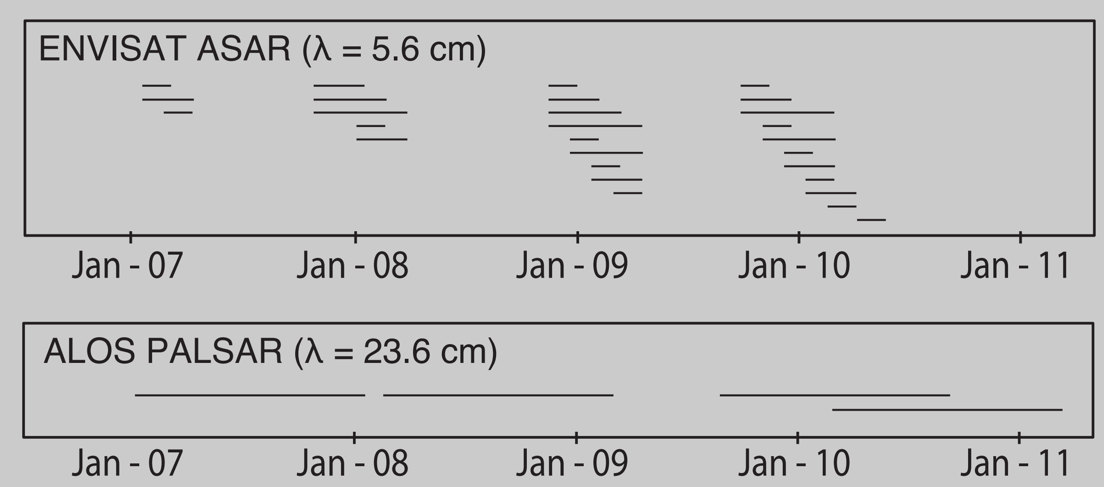
Figure 2: Example of the removal of an orbital drift phase pattern from a differential interferogram. SAR images used in interferogram generation were acquired on Jan 1, 2010 and April 16th, 2010. The corrected interferogram shows deformation between these two dates (it is a one-time measurement of deformation in 105 days). Blue areas in the corrected interferogram rose by 14 mm; red areas sunk by 14 mm.




## Data & software

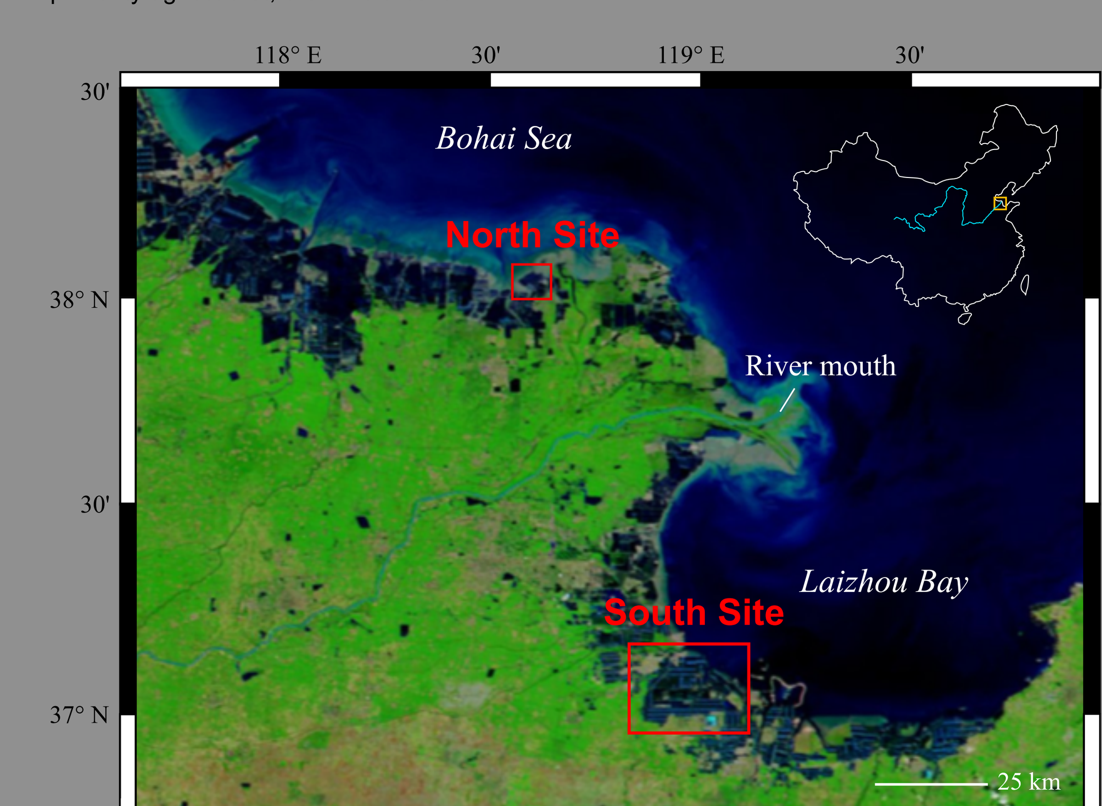
Over the northern part of the delta, we generated 28 interferograms from 19 SAR scenes collected by the ASAR instrument aboard the ENVISAT satellite (European Space Agency). Over the southern part of the delta, we generated 4 interferograms from 8 SAR scenes collected by the PALSAR instrument aboard the ALOS satellite (Japanese Aerospace Exploration Agency). All data processing was performed with the open-source Repeat Orbit Interferometry Package (ROI_PAC) (Rosen et al., 2004).

Figure 3: Date ranges for interferograms generated in this study. Each interferogram is a solid line. Start and end points correspond to the two dates differenced to produce the interferogram.




## Fish farms in the delta

Figure 4: False-color MODIS image of the Yellow River delta in September 2012. Water appears dark blue, highlighting the abundance of aquaculture facilities along the coast. Green land is primarily agricultural; brown is urban.




- Number of fish farmers in the world quadrupled in last 20 years
- Farmed fish was 60 million tonnes in 2010 (FAO, 2010)
- 89% of production is in Asia (FAO, 2010), much in deltas

Figure 5: The north site in this study.


## Subsidence at the Northern Site

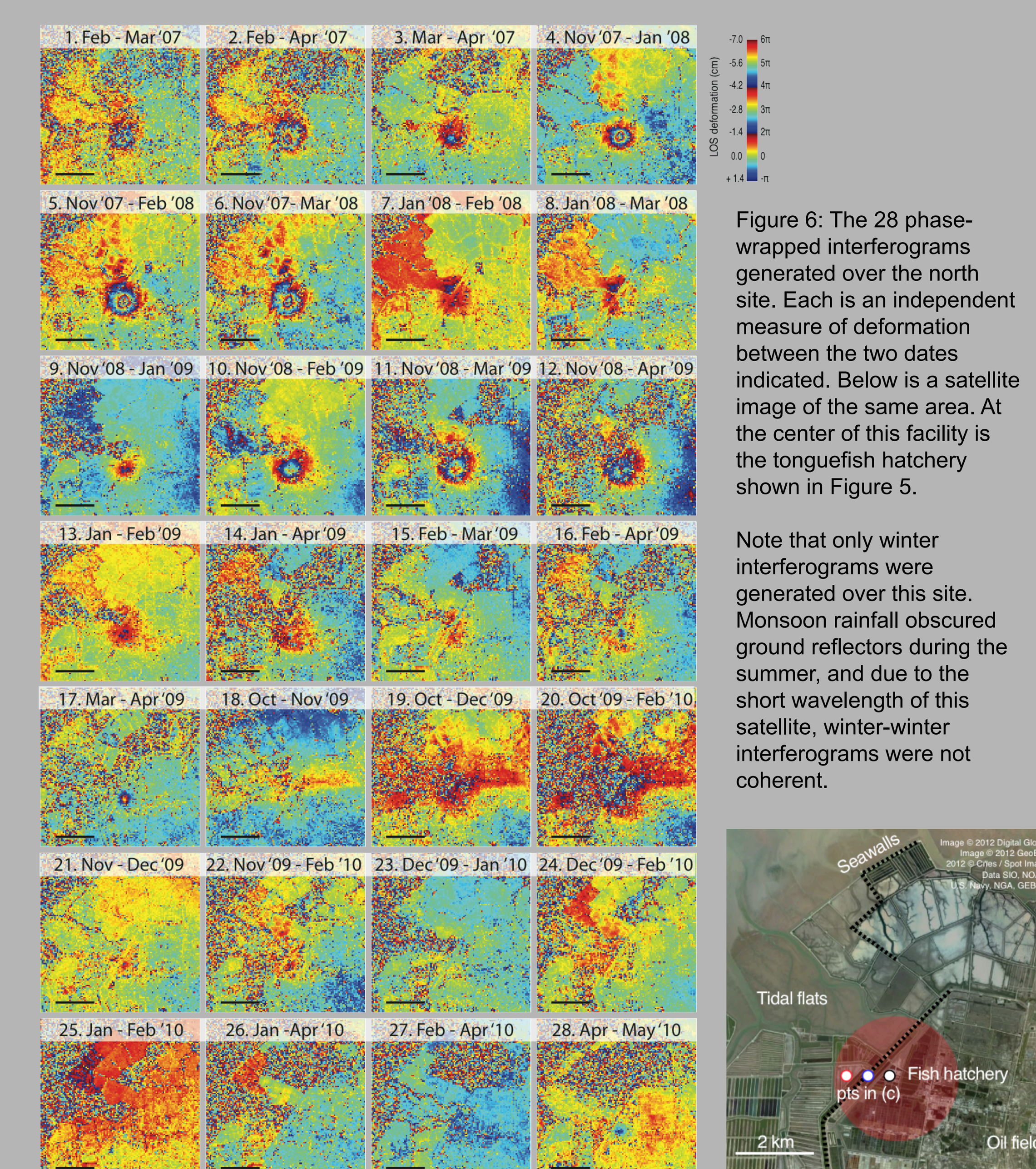
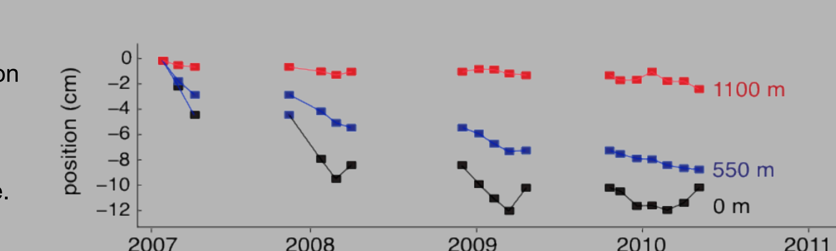



Figure 6: The 28 phase-wrapped interferograms generated over the north site. Each is an independent measure of deformation between the two dates indicated. Below is a satellite image of the same area. At the center of this facility is the tonguefish hatchery shown in Figure 5.

Note that only winter interferograms were generated over this site. Monsoon rainfall obscured ground reflectors during the summer, and due to the short wavelength of this satellite, winter-winter interferograms were not coherent.

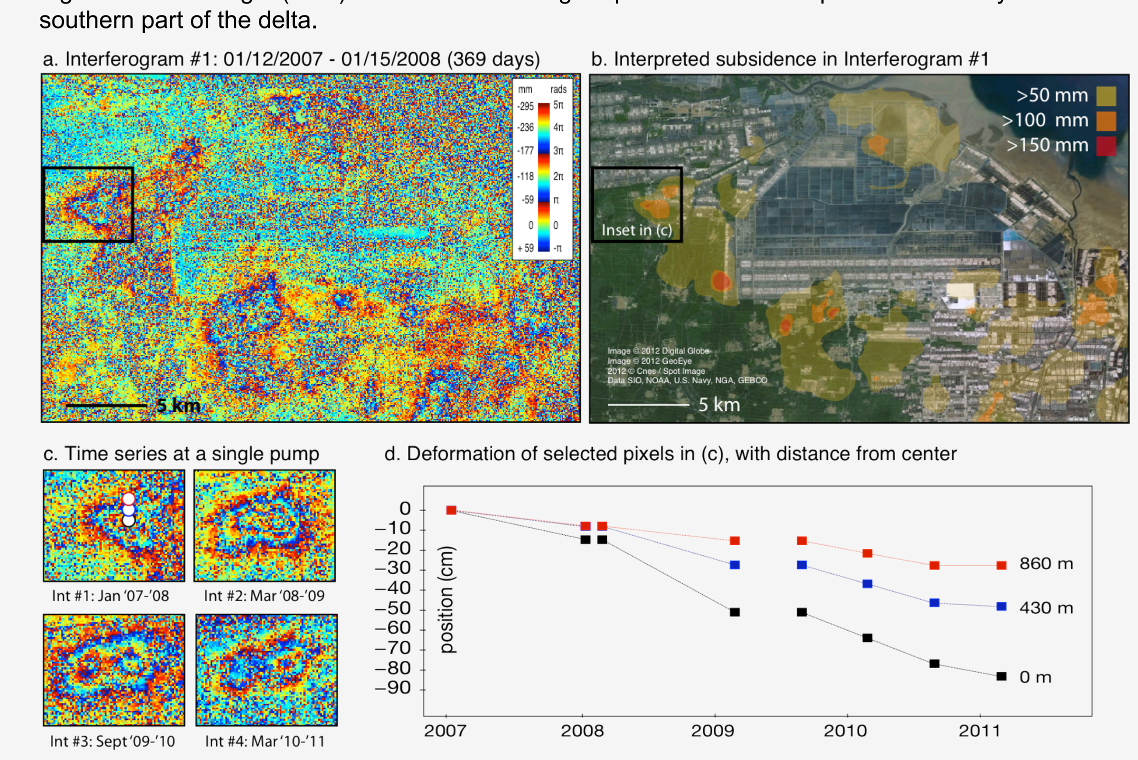
Figure 7: deformation of selected pixels, generated by inverting the time series shown above.




## Subsidence at the Southern Site

*One meter of subsidence at multiple pumps in four years.*

Figure 8. Line of sight (LOS) subsidence at a large aquaculture and salt production facility in the southern part of the delta.




## Conclusions

Deltas are flat, wet landforms where interferometry is difficult and D-InSAR is rarely applied. However, we have obtained good results using C- and L-band radar to image rapid groundwater-related subsidence on the delta. A deltaic aquaculture facility can induce land subsidence and relative sea level rise of one meter in just four years, more than global average sea level rise is expected to produce in a century.

## References

- FAO (2012), The state of world fisheries and aquaculture 2012, Tech. rep., Fisheries and Aquaculture Department, Food and Agriculture Organization (FAO) of the United Nations, Rome.
- Rosen, P. A., Henley, S., Peltzer, G., & Simons, M., (2004), Updated Repeat Orbit Interferometry Package Released. Eos Trans. AGU, 85(5), 47.
- The Centre for the Observation and Modeling of Earthquakes and Tectonics (COMET)

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