Mapping Delta Subsidence

with Synthetic Aperture Radar Interferometry (InSAR)

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The project goal is to map surface height changes at sinking river deltas.

- Are subsidence rates accelerating, decelerating, or remaining constant? Is subsidence uniform across the deltas?
- How do the small-scale dynamics of subsidence compare between river deltas under different drivers of change, like hydrocarbon extraction, groundwater mining, or reduced aggradation?

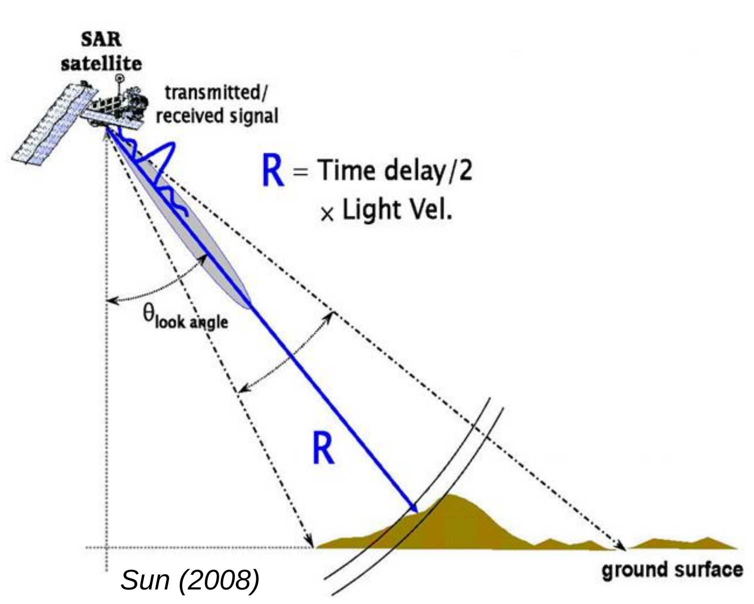
The dynamics and drivers of subsidence are not well understood.

Many of the world's largest river deltas are sinking relative to local sea level, endangering the lives and property of over 300 million people. Most studies cannot accurately assess the distribution of subsidence at these deltas, because they rely on a few discrete measurements (such as GPS or tide gauge readings) to represent extremely large areas. Current studies also struggle to differentiate subsidence caused by different drivers, such hydrocarbon extraction, groundwater mining, sediment distribution, isostacy, sea level rise or tectonics. InSAR is technique that can produce subsidence maps with much higher spatial resolutions than instrument-array techniques (like GPS) can produce, so we expect that InSAR can reveal the small-scale dynamics of subsiding river deltas and illuminate patterns that may be associated with certain drivers of subsidence.

InSAR has many advantages over other subsidence mapping techniques.

InSAR detects surface height changes by exploiting the phase information contained in Synthetic Aperture Radar (SAR) scenes, which are collected by active microwave radars aboard several different satellites. This technique has many advantages over instrument-array techniques like GPS, tide gauges or extensometers:

- High spatial resolution over large areas (20 m horizontal, 1-5 mm vertical, 100km swaths) and adequate temporal resolution (repeat period of ~30 days)
- Near-continuous coverage from 1991-present (C-band), 2006-present (L-band), 2007-present (X-band)
- Inexpensive compared to field measurements (~$200/scene, ~60 scenes per delta)
- Limited political and data-sharing complications
- Measures height independent of sea-level (unlike tide gauges)



Preliminary data processing has been completed over the Ganges Delta (Bangladesh).

First step…

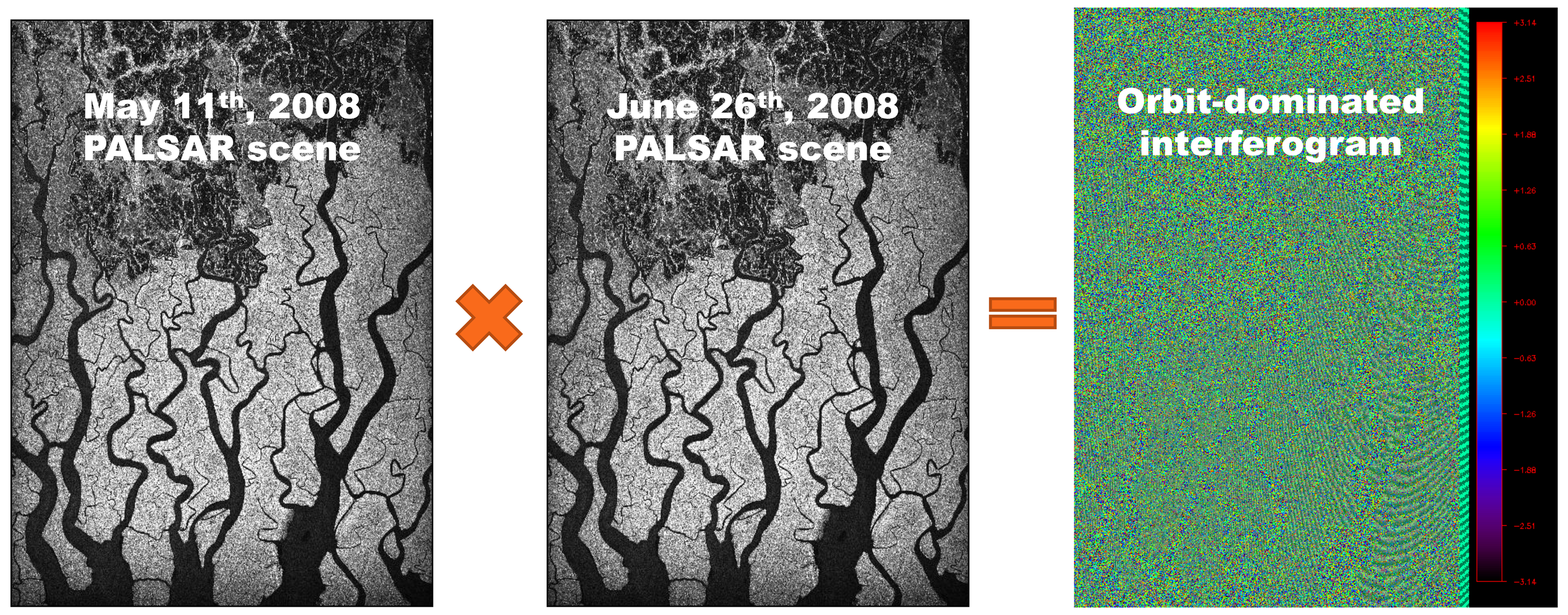
SAR data were collected over the Ganges Delta by the Japanese satellite "ALOS" between 2006 and 2011. ALOS uses an L-band SAR instrument called "PALSAR," with a wavelength of 24 cm. All other satellites use shorter wavelengths, but PALSAR is suitable for the Ganges Delta because the longer wavelength can penetrate the delta's heavy vegetation, rather than becoming incoherent in the presence of changing leaves (Wei & Sandwell, 2010).

The Ganges Delta is the world's largest and most densely populated delta. It is home to over 140 million people and supports another 150 million people through farming and fishing.

Can we provide verification for Mike Steckler's GPS measurements of subsidence?

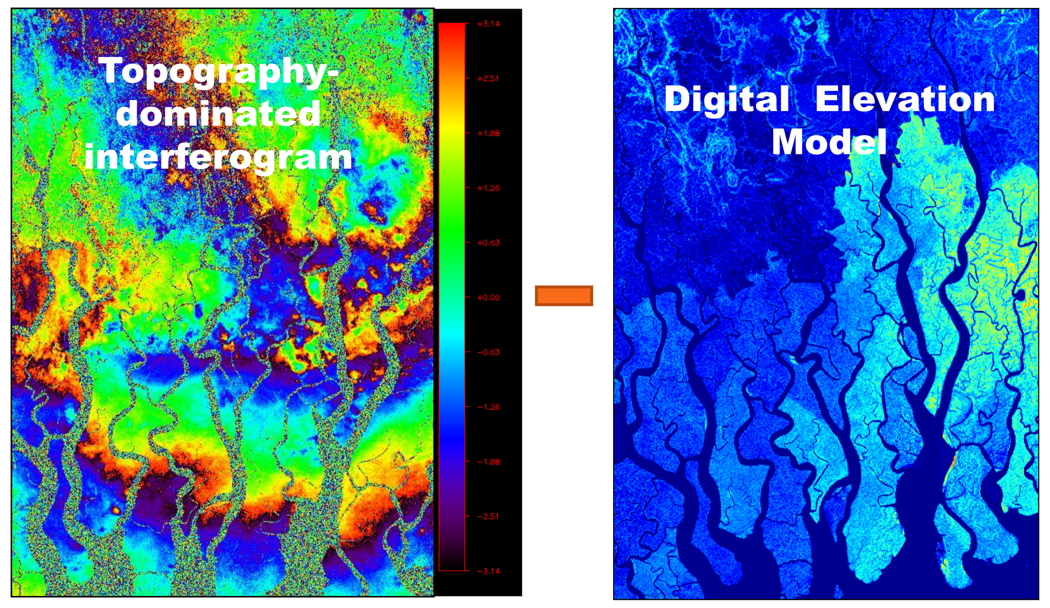
Second step…

Two of the SAR scenes were focused using JPL's "ROI_PAC" routines, then coregistered (aligned) at the sub-pixel level. The complex amplitude of each pixel in the first scene is multiplied by the complex conjugate of each pixel in the second scene to create an interferogram, or a pattern of fringes where each cycle represents a height change of $\lambda/2$ (one half wavelength) in the line of sight of the satellite. The initial result (right) is dominated by a fine pattern caused by the difference in orbital path (baseline) between the two satellite passes.



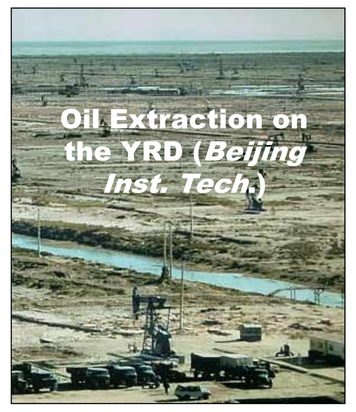
Third step…

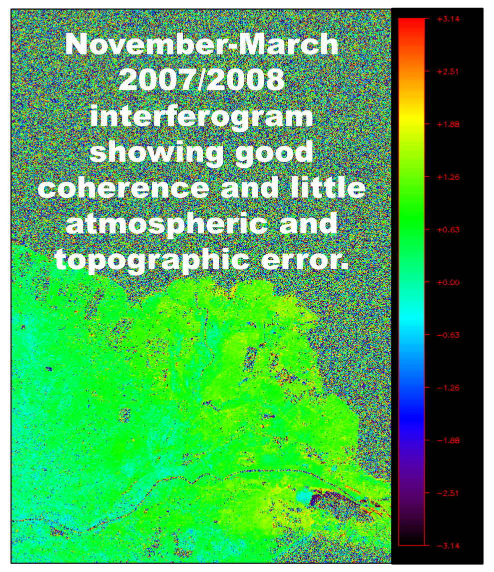
The orbital signal is removed, resulting in an interferogram (left) that is dominated by a signal caused by the local topography. A digital elevation model (middle) can be used in conjunction with orbital information to remove the topographic signal. Water vapor models can also be applied to remove atmospheric error. The last step is to create many interferograms (preferably 15+) over the same location, and use their common features to produce a map of subsidence over time.



Normally, a C-band Digital Elevation Model (DEM) can be subtracted from an interferogram. However, since we produced L-band interferograms rather than the more typical C-band interferograms, the different behaviors of the bands near vegetation makes subtraction problematic. If topography cannot be removed, our Ganges results may still be useful for assessing flood risk – with the topographic signal intact, we have created vegetation-stripped DEMs over the Ganges Delta coastline, which the Shuttle Radar Topography Mission (SRTM) could not obtain.

Promising preliminary results have also been obtained over the Yellow River Delta (China).





33 million tons of crude oil are extracted from the Yellow River Delta each year. A seawall 30 m thick protects land that is already below sea level.

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2. Wei, M. & Sandwell, D. T. 2010 Decorrelation of L-Band and C-Band interferometry over vegetated areas in California. IEEE Transactions on Geoscience and Remote Sensing, 48(7), 2942–2952.