Unexpected Contributions of Satellite Radar Altimetry to Tsunami Research

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Summary: Satellite altimeters were not initially designed for observing tsunamis because tsunamis were not believed to happen often enough, and it is not always feasible to observe a fast propagating wave from space. Surprisingly, satellite altimeters had observed all the recent mega tsunamis, revealed previously unknown features and revised long-hypothesized theories. For the first time, satellite altimeters unambiguously observed tsunami waves in the open ocean after the 2004 Indonesian earthquake. The observations were close to the epicenter, leading to new development of the tsunami genesis theory [Song et al, 2005; 2008; Song and Han 2011]. In 2010, satellite altimeters observed the Chilean tsunami in the Southern ocean, providing successful testing of using ground GPS networks for early detection and warnings [Song 2007]. Most recently, three satellites observed the 2011 Tohoku-Oki earthquake-induced tsunami, and for the first time, one of them, at the right time and location, recorded a tsunami height about twice as high as that of the other two, confirming the long-hypothesized tsunami merging theory that can double its destructive potential in certain directions [Song et al 2012; Galvan et al. 2012]. These altimetry observations have advanced the understanding of tsunami dynamics as well as provided tests of a new approach to tsunami early detection and warnings. This talk will review these unexpected, but significant and unique contributions from satellite altimetry to tsunami research, their potentials for hazard mitigation, and an outlook for the use of the future swath interferometric altimetry, i.e., NASA's/CNES's Surface Water and Ocean Topography, for improved tsunami observations and research.

1. The 2004 Indian Ocean Tsunami: On 26 December of 2004, the Sumatra M9.1 earthquake generated a devastating tsunami.

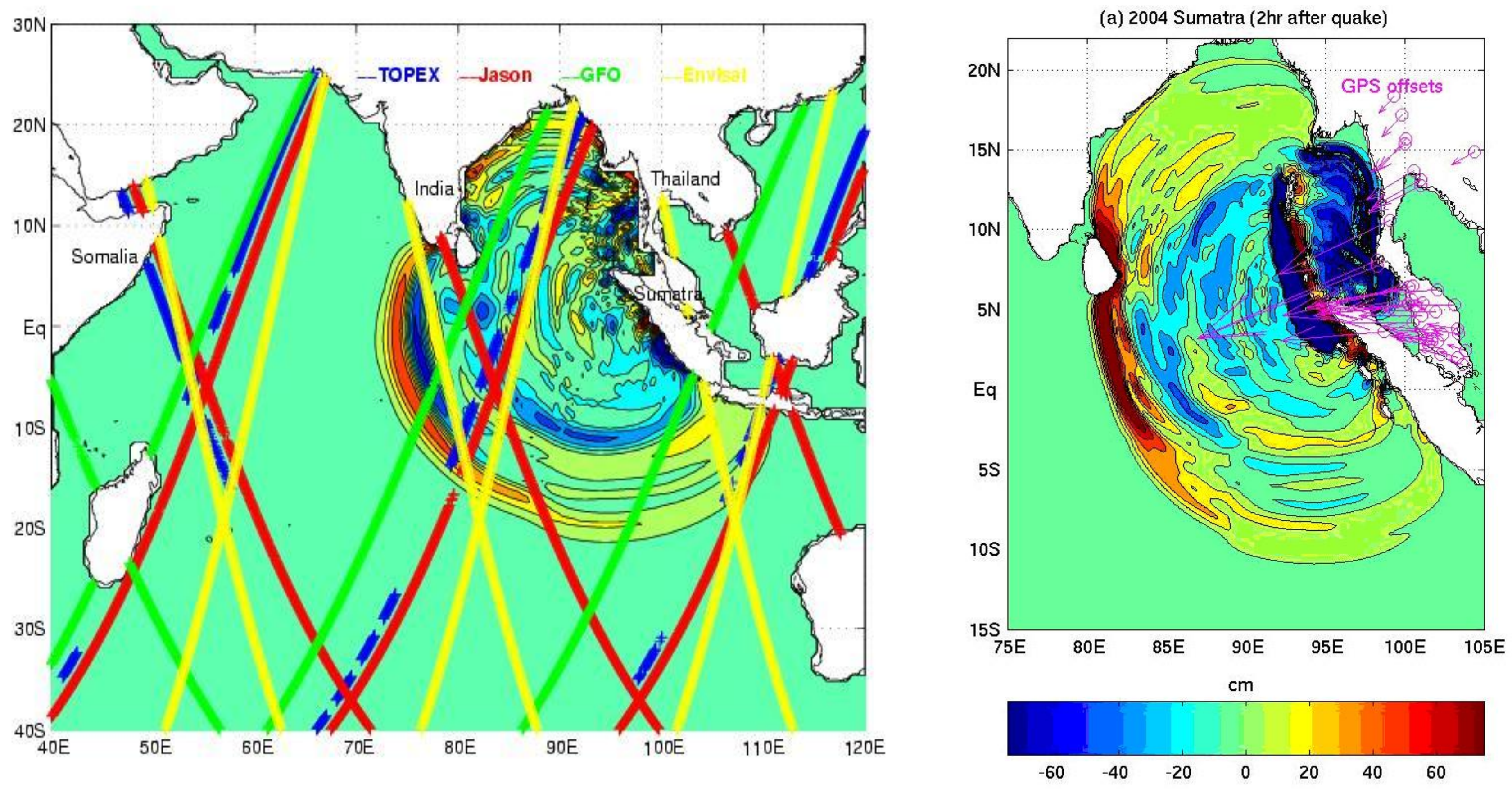

Figure 1: Left panel figure shows several satellites had passed the Indian Ocean during the tsunami period, but only a few of them at the right time and location observed the tsunami. Right panel shows our model tsunami derived from GPS displacement data, which will be used to match the satellite observations.

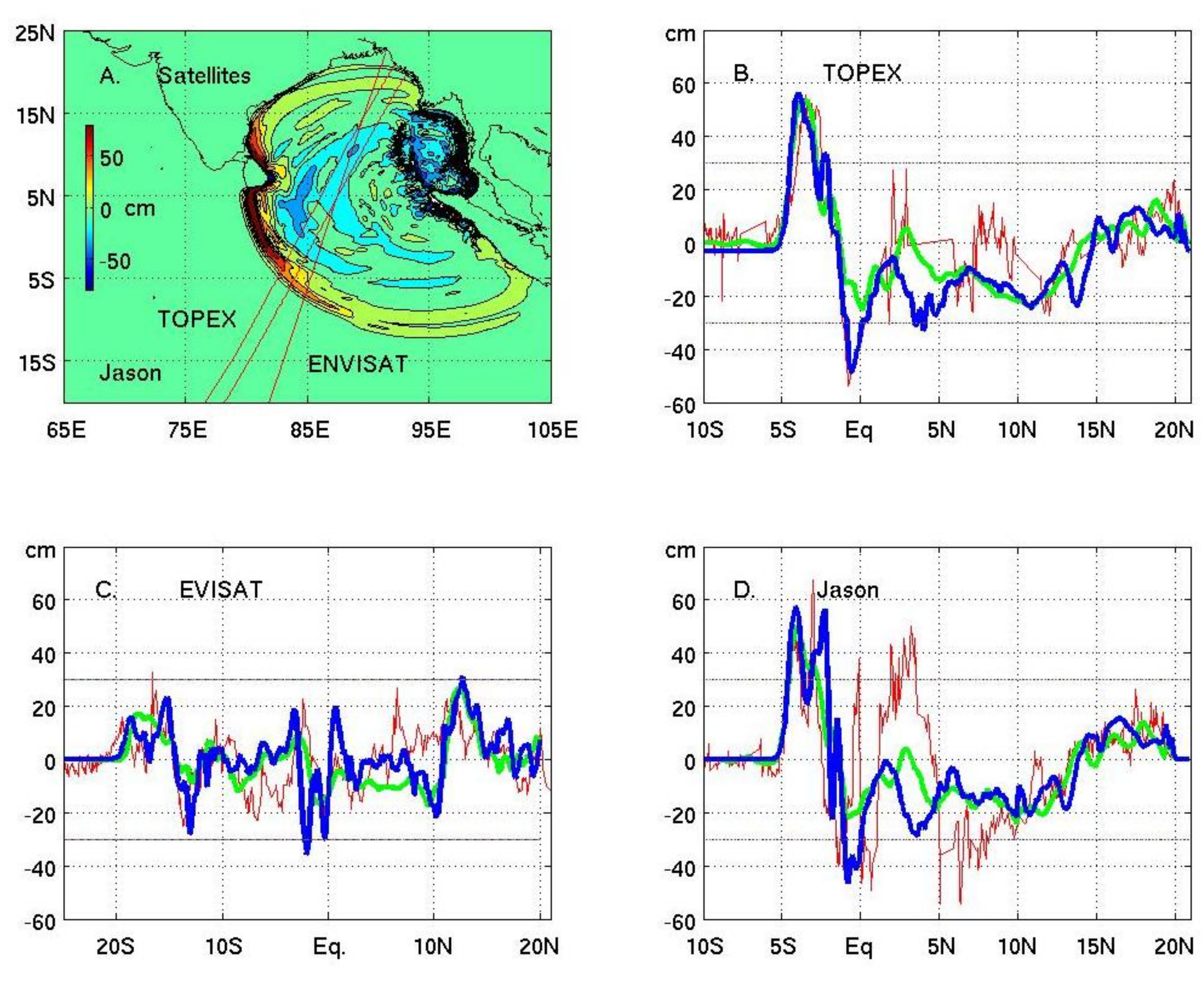

Figure 2: Comparison with satellite observations for the 2004 Indian Ocean tsunami: (a) satellite tracks, (b) TOPEX 1:55 hours after quake, (c) Jason 1:48 hours after, and (d) ENVISAT 3:10 hours after the first quake. Red lines are satellite measurements, green and blue lines are models forced by GPS-derived seafloor motions and by seismic inversion, respectively.

2. The 2010 Chilean Tsunami: On 27 February of 2010, the Chilean Maule M8.8 earthquake generated a moderate tsunami.

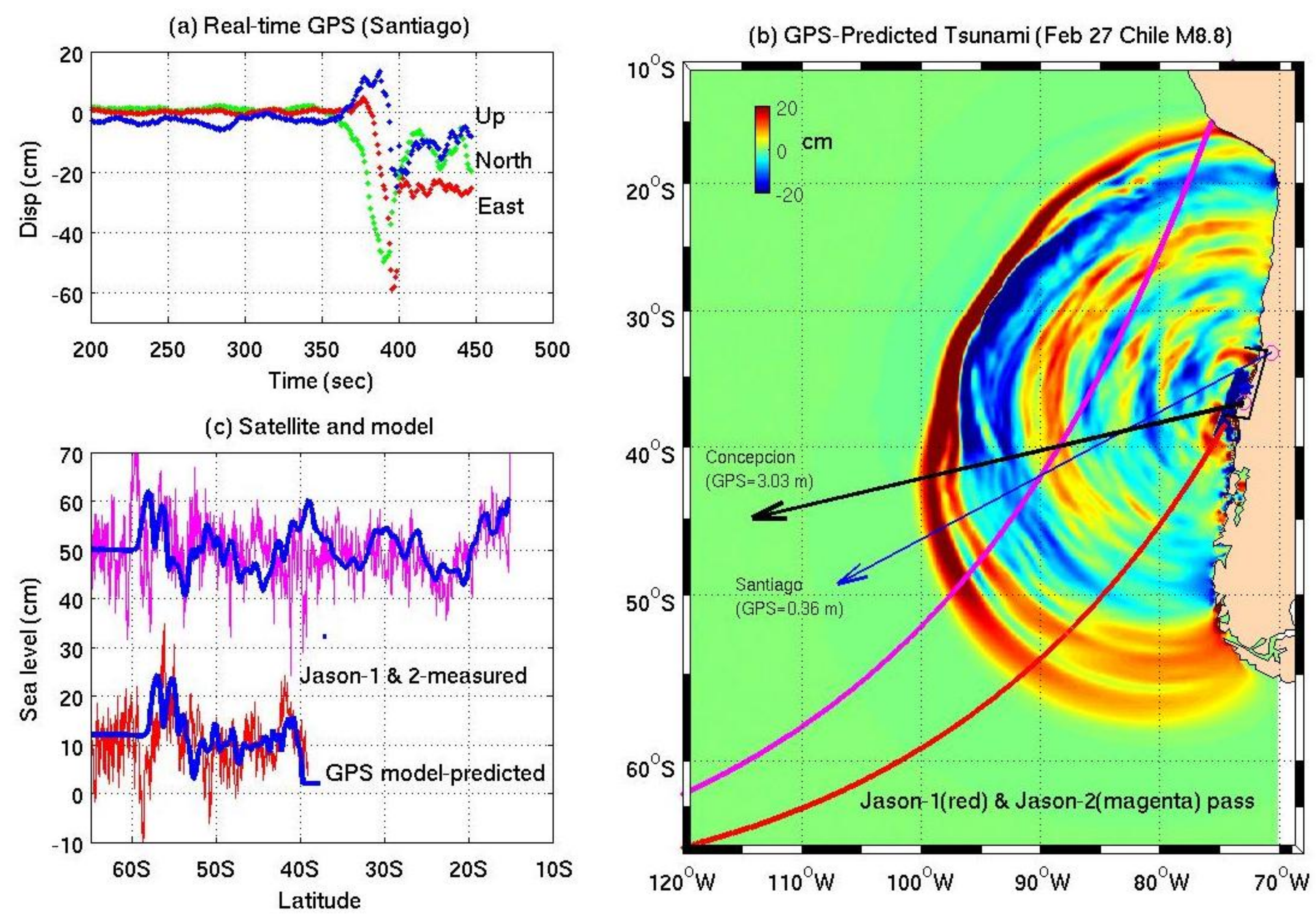

Figure 3: (a) NASA's Global Differential GPS (GDGPS) measures the Chile M8.8 earthquake displacement in real time at Santiago. (b) JPL GREAT alert team predicts a moderate sized tsunami using the real-time GPS and the Song tsunami generation model. (c) NASA/CNES satellites Jason-1 and Jason-2 confirm the tsunami amplitude prediction of the GPS-based model prediction.

3. The 2011 Japanese Tsunami: On 11 March of 2011, the Tohoku-Oki M9.0 earthquake generated another devastating tsunami.

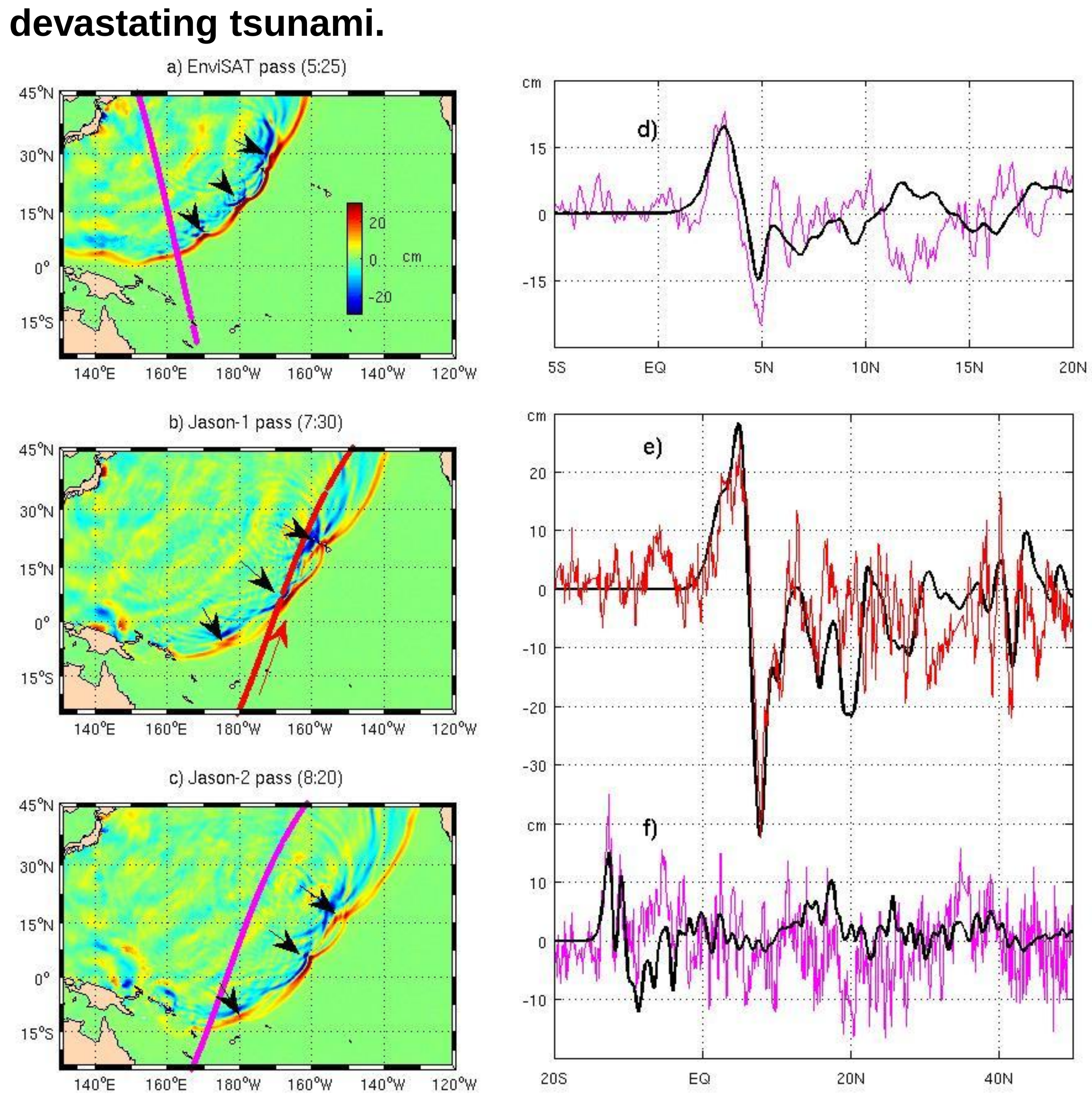

Figure 4: (a) ENVISAT pass at 5:25 hours after the quake, (b) Jason-1 pass at 7:30 hours after the quake, (c) Jason-2 pass at 8:20 hours after the quake, and (d-f) comparing model tsunami (black) with the satellite altimetry data along the passes, respectively. Black arrows indicate locations of merging tsunamis. Only the Jason-1 satellite, indicated by the red arrow, was at the right location and right time to catch the tsunami merge phenomenon.

Reference:

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