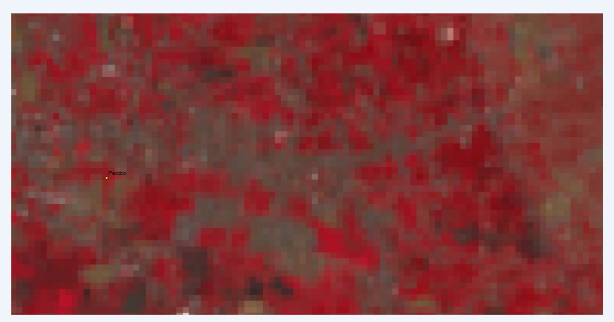
Applications of Remote Sensing to Tsunami and Earthquake Hazards

Damage Assessment

Low altitude or ground imagery as seen here is best for detailed damage assessment after an earthquake and/ or tsunami, but satellite imagery can facilitate a broad assessment of the damage extent and relative severity over a large area.

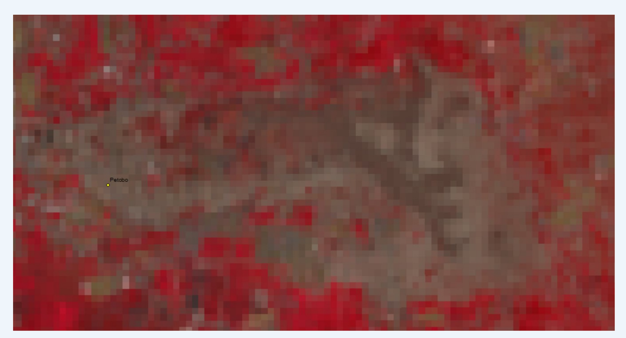
Tsunami damage in Palu—Tatan Syuflana AP

Even with the relatively low resolution of Landsat imagery, major subsidence after the earthquake is apparent in the false color infra red images of Petobo below.



< Before

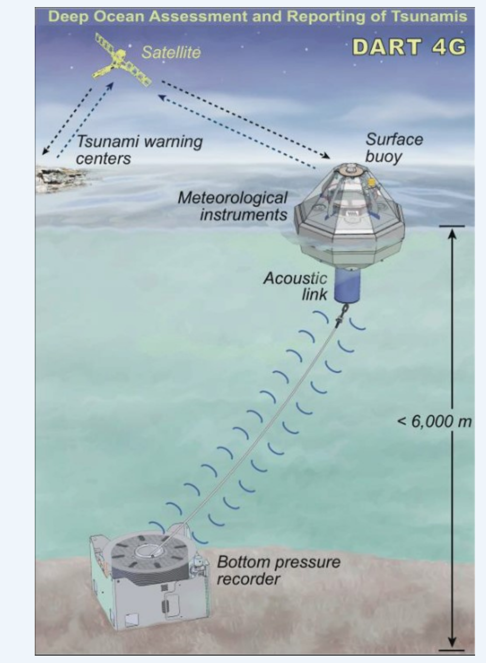
After >



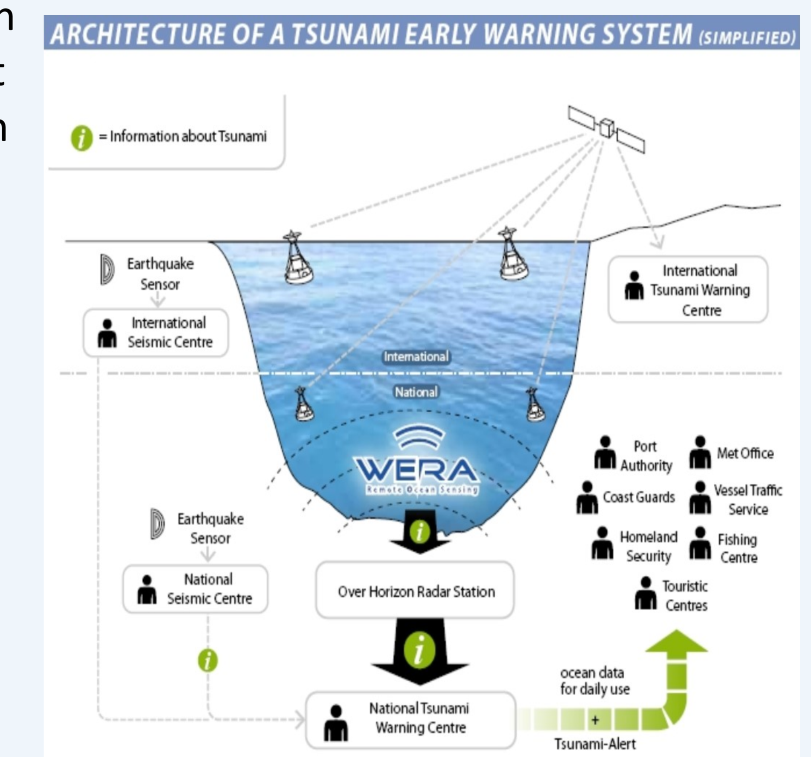
The image below was accessed using Landsat Explorer. It was created by running a change detection process on the Soil Adjusted Vegetation Index derived from Landsat images taken before, and after, the September 2018 earthquake and tsunami in central Sulawesi, Indonesia. This image makes it easy to confirm the areas of tsunami damage along the bay coastline, as well as inland areas where soil liquefaction and landslides occurred. All of these are colored pink. The Petobo district of Palu, also seen in the IR images above, is to the lower right. Petobo suffered some of the worst damage from the earthquake.

Real time Detection

Until recently, the technology used for tsunami detection was limited to a combination of seismographs to detect earthquakes in conjunction with a network of buoys (see diagram on right) which used pressure sensors to detect passing waves. In the United States Pacific Northwest, an array of land based GPS units (called PANGA) can measure major earthquakes (and other crustal deformations) more accurately than seismographs. In 2011, the catastrophic tsunami that struck Tohoku Japan was monitored by high frequency oceanographic radar, which detected the change in water velocities as the tsunami approached the coastline. Further research has led to installation of this kind of radar in several locations in the last five years. Helzel Messtechnik is a German manufacturer of a system called WERA, which uses this radar technology. The radar doesn't measure wave height, but rather senses the changing speed of water currents as a tsunami encounters the continental shelf on its approach to a coastline. The company notes in its product literature that an adequate warning depends on the continental shelf being sufficiently distant from the coastline where the radar is sited.



From DART product brochure at: https://nctr.pmel.noaa.gov/Pdf/brochures/



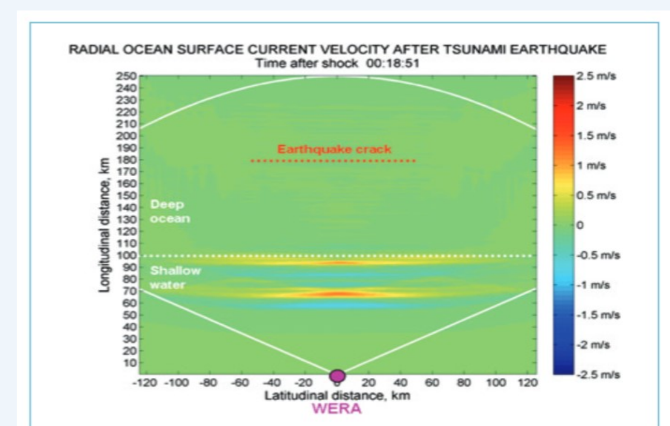


Fig. 3. Simulated radial velocities of tsunami induced currents using HAMSOM.

Fig. 6. Radial ocean surface current velocity map based on the measured HF radar spectra with the simulated tsunami currents shown in Fig. 3.

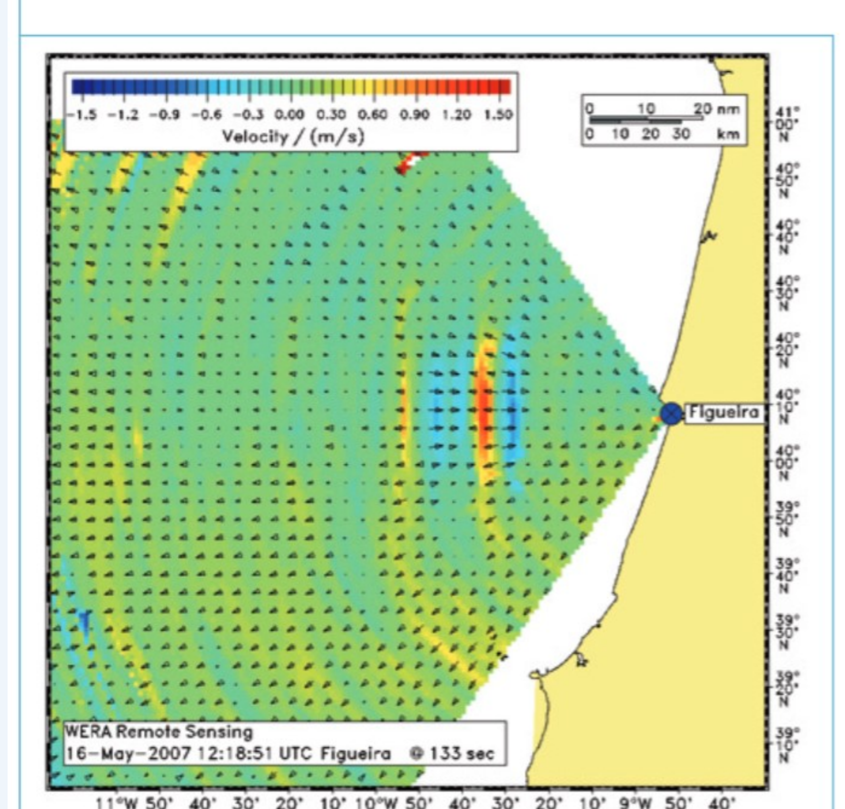
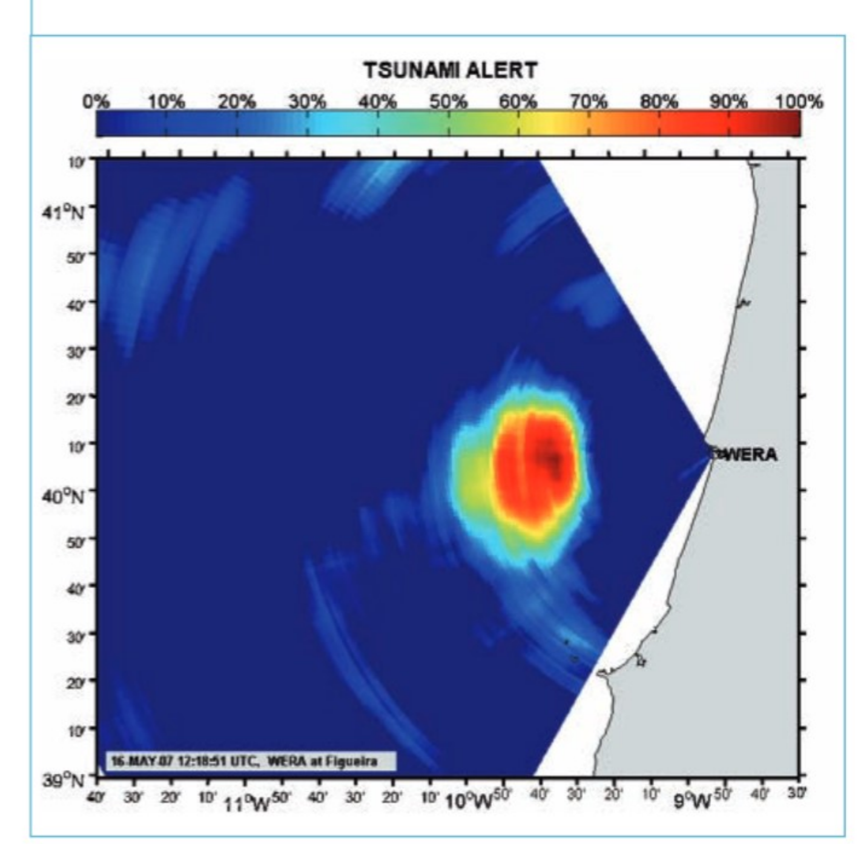


Fig. 7. Tsunami alert map.



Above figures from 'Future Contribution of HF Radar WERA to Tsunami Early Warning Systems' (Dzvonkovskaya/Gurgel)

Risk Assessment

We can look at historic imagery of past flood extents to get some idea of a locations vulnerability to rising water. But if we have detailed elevation data, then we can use inundation modelling software to predict flood extents for a wide range of possible tsunami events. The most comprehensive global elevation data comes from two sources, the Shuttle Radar Topography Mission or SRTM and also the ASTER sensors on the Terra satellite. SRTM used radar specifically designed to collect elevation data. The ASTER sensors didn't measure elevation directly, but a DEM was derived by using the parallax from ASTER images taken from multiple locations. Both SRTM and ASTER elevation data are available for free, and cover most of the world. So this allows for modelling of tsunami on any vulnerable coastline.

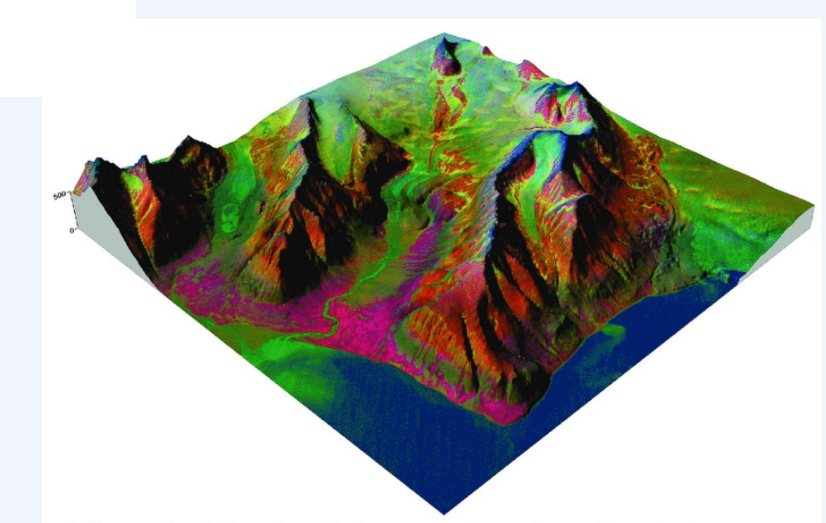
	ASTER GDEM	SRTM3*	GTOPO30**	10 m mesh digital elevation data
Data source	ASTER	Space shuttle radar	From organizations around the world that have DEM data	1:25,000 topographic map
Generation and distribution	METI/NASA	NASA/USGS	USGS	GSI
Release year	2009 ~	2003 ~	1996 ~	2008~
Data acquisition period	2000 ~ ongoing	11 days (in 2000)		
Posting interval	30m	90m	1000m	about 10m
DEM accuracy (stdev.)	7~14m	10m	30m	5m
DEM coverage	83 degrees north ~ 83 degrees south	60 degrees north ~ 56 degrees south	Global	Japan only
Area of missing data	Areas with no ASTER data due to constant cloud cover (supplied by other DEM)	Topographically steep area (due to radar characteristics)	None	None

Other examples of available DEMs
- NED: with a resolution of 30 m, covering the entire U.S.A., provided by USGS

*SRTM3: Shuttle Radar Topography Mission Data at 3 Arc-Seconds
**GTOPO30: Global 30 Arc-Second Elevation Data Set

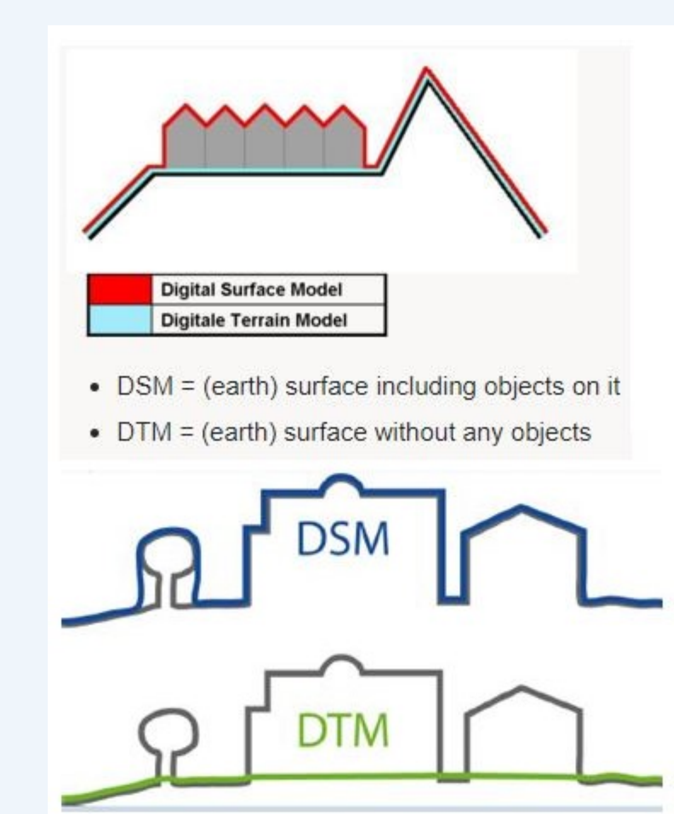
Shaded relief map of Sulawesi island, Indonesia Derived from SRTM elevation data.

As shown in the above chart, the different characteristics of the imaging sensors and algorithms used by SRTM vs ASTER result in different gaps in the data sets. SRTM doesn't provide accurate elevation data for extremely mountainous areas, while ASTER data is more constrained by atmospheric conditions.



Orthophotomap of Petuniabukta region-satellite (TERRA/ASTER, taken on July 13, 2002) image draped on DEM (elaborated by A. Stach)

When using elevation data for inundation modelling, we need to be aware of the difference between a 'digital surface model' (DSM) and 'digital terrain model'. The 'raw' elevation data from satellite/ shuttle imagery may need further processing or correlation with data from other sources in order to give the ground elevation (DTM) at a given location, rather than the elevation at the top of built structures or vegetation (DSM).



Poster by Dave Magill, March 2019