We describe the coseismic rupture of the March 11, 2011 M9.0 Tohoku-Oki megathrust earthquake that occurred offshore NE Honshu, Japan. We begin by using the continuous GPS data of the Japanese GEONET network and deep sea-bottom pressure measurements of the tsunami to invert for the distribution of co-seismic slip. We integrate all this data together using a fully Bayesian probabilistic formalism called CATMIP (Cascaded Adaptive Transitional Monte Carlo In Parallel - S. Minson, 2010). With this approach, we provide a complete description of the inverse problem, without using any type of model regularization. The fault surface is parameterized using a triangulated mesh that attempts to conform to the megathrust interface as imaged by numerous seismic profiles as well as seismicity data available in the area of the earthquake. The family of models which best explains the data indicate that the slip is concentrated in a compact area up-dip of the epicenter with amplitudes locally exceeding 40 m.

As a second step in our analysis, we track the source of the high-frequency (HF) radiations using a back projection technique called MUSIC (Multiple Signal Classification) which allows us to better resolve closely spaced sources while being less sensitive to aliasing. As opposed to the standard assumption that sources of HF radiators are colocated with areas of maximum slip, we find that they instead closely follow the down-dip extent of our slip model. This down-dip limit of our slip model also matches the location of most M7-8 earthquakes recorded in the area over the last century.

We also compare the seismic excitation of the Tohoku-Oki earthquake with the M8.8, 2010, Maule earthquake for the 0.5 to 4Hz range. While the maximum slip of the Tohoku-Oki earthquake is significantly larger than the Maule earthquake, we find that the former radiated less high-frequency energy. We interpret this difference in terms of differences in the depth extent of rupture, the Tohoku-Oki earthquake having an average potency 10-15 km shallower than the Maule earthquake. We propose a synoptic model whereby seismic radiation efficiency, and therefore fracture energy, are controlled by depth.

Finally, from the estimate of secular strain rate accumulation, we argue for the potential of a future large earthquake south of the 2011 event.