Tides and topographic waves in the vicinity of the Svalbard islands in the Barents Sea

by

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The main purpose of this review is to provide a background perspective for the presentation by Støylen and Weber (2008) on tide generated internal Kelvin waves in the VanMijen fjord on Spitzbergen.

Spitzbergen is the main island in the Svalbard archipelago located between 76° and 80° North in the Barents Sea. The barotropic tides in the regions around the Svalbard islands display interesting dynamical features due to the topography of the surrounding shelf. In particular the shelf slope along the western edges of the Barents Sea, extending from Norway towards the Fram Straight at the entrance of the Arctic Ocean, has a profound effect.

The tides in this area have been simulated by various numerical models which cover the Norwegian, Greenland, Barents Seas and the Arctic Ocean (Gjevik and Straume 1989, Gjevik et al. 1990, 1994, Kowalik and Proshutinsky 1995 and Lyard 1997). The simulations are based on numerical solutions of Laplace tidal equations with prescribed input along the boundary towards the North Atlantic and the tide generating force on the water masses within the model domain included. It has been shown (Gjevik and Straume 1989) that the incoming tidal waves from the North Atlantic is the most important factor for the semi-diurnal tides in the Norwegian and the Barents Seas and that the direct effect of the tide generating force within the basin is of less importance. The \(M_2\) chart (fig. 1) display a well formed amphidromic center southeast of Svalbard. Three other smaller amphidromic points are also visible. One in the Kara Sea east of Novaja Zemlja, another at the southwestern side of Novaja Zemlja, and the third west of Franz Josef Land. The main amphidrome south-east of Svalbard controls the dynamics of the tide in the central parts of the Barents Sea.

The tidal wave is progressing into the Barents Sea with high amplitudes along the coast of Finnmark, northern Norway, and increasing amplitude eastwards along the coasts of Kola, in Russia. At the same time a tidal wave crest is progressing northward in the deep Norwegian Sea through the Fram Strait and into the Arctic Ocean north of Svalbard. This wave is partly diffracted around Svalbard and re-enters the Barents Sea in the straight between Nordaustlandet and Franz Josef Land. The wave leads to a westward propagating wave south of the Edge Island and over Svalbardbanken between Svalbard and Bear Island as seen from the structure of the amphidromic point. The tidal charts for the semi-diurnal components \(S_2\) and \(N_2\) show a similar structure of contour lines as for \(M_2\), implying that these semi-diurnal tidal waves have nearly the same dynamic features as \(M_2\). An animation of the propagating \(M_2\) tide in the Norwegian and Barents Seas can be found on the internet site: http://www.math.uio.no/tidepred/

The tidal chart for the diurnal component \(K_1\) shows a very different structure, with
Figure 1: Tidal chart for the dominant semidiurnal component $M_2$ in the Barents Sea. Full drawn lines are sea level amplitude in centimeter, dotted lines are phase angle relative to Greenwich (Gjevik et al. 1994).

A large amphidromic point in the Fram Strait between Svalbard and Greenland. Also the amphidromic structures south of Svalbard are more complex than for the semidiurnal components, with several local amplitude maxima near the shelf edge. This is a manifestation that the diurnal tide is resonating with shelf wave modes with nearly the same period as $K_1$ (Gjevik et al. 1990, 1994, Kowalik and Proshutinsky 1995, and Kasajima and Marchenko 2001). Although the sea level amplitude of the diurnal components is small compared to the main semidiurnal component, the diurnal current oscillations dominates in some locations over the semidiurnal oscillations. Current oscillations and eddies due to topographic waves are observed in the West-Spitzbergen Current (WSC) (Nilsen et al. 2006).

Strong tidal currents occur east of Spitsbergen in the Freeman Sound between the Barents Island and Edge Island, in Heleysundet between the Barents Island and Nordaustlandet, and also in the Hinlopen Strait between Spitsbergen and Nordaustlandet. This is a result of the almost 180 degree phase difference for the semidiurnal tide between Storfjorden and the area east of the Barents Island and Edge Island.

Tidal currents are particularly strong over the shallow banks around and northeast of Bear Island. The current ellipses are nearly circular with a clockwise rotation of the current vector. Maximum current speed is up to 1.0 m/s which is an exceptional large current in open ocean.

Near the critical latitude, were the period of the tide coincides with the inertial period, turbulence and stratification will have a dominant effect on the profile of the tidal current. The critical latitude for the $M_2$ component is 75° 2.8‘ which passes through the Barents Sea north of Bear Island. Nøst (1994) found that recorded current data from this area show the expected influence on the tidal current profile in good
agreement model predictions.

The tide leads to a tidal induced clockwise circulation around Bear Island where particles will circumvent the island in 6-8 days. This has been documented both from observations (Vinje et al. 1989) and model studies (Gjevik et al. 1994, Kowalik and Proshutinsky 1995).

Internal waves are frequently generated due to tidal forcing both in situations with shallow density stratification due to fresh water in the melting season and along more permanent deep density interfaces along the shelf slope. An example to the latter is the interface between the relatively warm water in the WSC and the cold bottom water.

References


