# Effects of oceanic bottom pressure on variations of the tilt and the vertical

# Chuichi Kakuta[1], Tsuneya Tsubokawa[2], Kenzaburou Iwadate[3]

[1] ex-Nihon Univ. Eng., [2] NAO,Mizusawa, [3] NAO.Miz.

http://www.shirakawa.ne.jp/kakuta

During the 1986-1987 El Nino the vertical at Mizusawa and the ground tilt at the Esashi Earth Tides Station show deflection to the west and E-up and a rise of sea level at Chichijima and Oshima is found.To explain these relations, we derive bottom pressure due to the wind stress curl over the western boundary regions of the Pacifc Ocean near the Tohoku District, Japan. The relative vorticity is transferred from the atmosphere to the lower layer in the ocean and contributes to increase the height of the water column .We assume that the Tohoku district, Japan and the western boundary regions of the Pacific consist of a thin elastic plate,which is exerted by a uniform load caused from bottom pressure. Numerical calculations show comparable values of variations.

During the 1986-1987 El Nino the vertical at Mizusawa deflected toward the west about 1 ms and the tilt showed about 50 mas E up, and sea level at Chichijima and Oshima showed a rise of about 5 cm. We try to explain relationship between the tilt and deflection of the vertical based on bottom pressure load near the western boundary regions of the Pacific Ocean on the plate of the Tohoku district, Japan. The atmospheric pressure can not be transferred to the ocean bottom due to the inverted barometer effect. But the atmospheric wind stress can provide the vertical component of vorticity into the ocean.

We adopt the two-layer finite depth model (Hurlburt and Metzger,1998). The mean thickness of each layer is 320 m and from the depth 320 m to the bottom respectively. The upper layer is supplied with the relative vorticity by the wind stress curl, which is the vertical component of the relative voticity. If there is no coupling with the upper layer, the lower layer keeps a constant value of the potential vorticity, ( vertical component of the vorticity of the Earth rotation plus the vertical component of the relative vorticity)divided by(vertical height of the water column). Coupling between two layers at the boundary surface associated with baroclinic motions can transfer the relative vorticity from the upper layer to the lower layer. Increase in the vorticity is compensated by streching the water column in the lower layer. This increases sea level and the pressure at the bottom. In the vicinity of the western boundary regions derivatives in the east-west direction become large compared with derivatives in the north-south direction.The simplified form of the equation is reduced to the steady long wave motion forcing by the wind stress curl for the 5 year period motion. We can estimate bottom pressure. The pressure load on land due to the wind stress is estimated by a balance between the pressure gradient and the wind stress at the surface for a long time variation. By assuming the isothermal atmosphere we can derive the pressure load on land. The pressure load on land is very small compared with bottom pressure over the ocean.

We assume that the plate is a thin elastic plate and that the plate is pushed by the compressional stress from the Japan Trench. Bending of a thin plate exertrd by the horizontal compressional stress and a uniform load is discussed by Timoshenko and Gere (1961). Bending of the plate is solved with the boundary conditions of simply supported edge. The E-W component of the tilt is obtained by the gradient of the displacement upward. Haxby and Turcotte (1978) showed the expression of geoid height for thin mass layer by using asymptotic expansions. We can derive variations of the vertical by taking the gradient of the leading term of their expressions by using the normal displacement of the bending plate.

In numerical calulations, we use the following values for evaluation, the wind stress curl is expressed by 100 nPa per meter in amplitude of the 5 year period, of which wave length is 3000 km, depth of the Pacific Ocean 4280 m, the thin elastic plate to be form of a square 400 km on a side, thickness of the plate to be 30 km, and the center of gravity is located at the coast on the same latitude of the observation stations. We obtain variations of the tilt 190 mas E up, the vertical 240 micro second toward the west, and bottom pressure 11 hPa. The results show that variations of the tilt are mainly due to the normal displacement of the surface.