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Simplified motion model and simulation of oblique plate-slab subduction (1): Method and application to Japanese islands

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1. Introduction

Complex phenomena occur when oceanic plate-slab subducts obliquely under island arc system (trench-arc-backarc). Simplified mathematical model and numerical simulator for the situation (geometry and movement) have been developed. And, the results obtained by applying the method to Japanese islands have been compared to the distributions of deep hypocenters (deeper than ca 30 km) roughly corresponding to the distributions of low-temperature slabs (Shigeno, 2008a).

2. Method

This simplified modeling and simulation method calculates the trace of temporal movement of points distributed on oceanic plate-slab. The relations between the points (e.g. strain) are not calculated.

Let's think a moving oceanic plate A and its slab A1 subducting under an island arc as a basic model (using 3-D orthogonal coordinates system, and horizontal counter-clock-wise angle starting from the top). VA (cm/year) and qA (deg) are relative speed and angle of the moving plate A, and qp (deg) and qd (deg) are apparent horizontal direction angle of subduction (perpendicular to the trench alignment) and apparent dip angle for the moving slab A1, respectively. And, the initial coordinates of the moving point P on the trench are X0, Y0, Z0.

With proceeding a time step Dt (year), the changing location of the point P (Xi, Yi, Zi; km) at time i is shown by a series of difference equations (Y is the horizontal base direction (of observation), X is horizontal -90 deg direction to Y, and Z is vertical up direction) as follows:

$DX = VA * Dt * \cos(qA - qp) * \cos(qd)$

$DY = VA * Dt * \sin(qA - qp)$

$DZ = VA * Dt * \cos(qA - qp) * \sin(qd)$

$X_i = X_{i-1} + (- DX * \sin(qp) - DY * \cos(qp)) * 10^{-5}$ (km)

$Y_i = Y_{i-1} + (DX * \cos(qp) - DY * \sin(qp)) * 10^{-5}$ (km)

$Z_i = Z_{i-1} - DZ * 10^{-5}$ (km)

Based on the above model, a simple numerical simulator (SSSS) has been developed. The simulator is essentially for calculating the changing P positions using assumed parameter values (acceptable for their temporal changes), and has been extended according to the necessity.

3. Application to Japanese islands

The above method has been applied to the Pacific plate-East Japan arc system (16 points), and the Philippine Sea plate-West Japan arc system (17 points) for 12 million years (maximum). The parameter values have been adjusted through repeating the simulation by matching the calculated slab distribution to the reported hypocenter distribution. The results are fairly concordant to the phenomena caused by collision of the slabs at the arc junctions, and diversion of the segmented slabs around the areas between central and end parts of the arcs.

Recent advances are prominent in publications of various kinds of electronic earth sciences information (high quality) for Japanese islands and their adjacent areas, and distributions of processing and presentation software for these data (e.g. Geol. Surv. Japan, 2007). By using these data and software, and by combining modeling and simulation methods as shown in this abstract, various kinds of analyses, from diverse, integrating and evolutional points of view, are going to be easily possible for various kinds of subjects in earth sciences (e.g. Shigeno, 2008b, 2008c).

References

Shigeno, H. (2008a) Study on high-temperature hot-springs in the Kinki district, Japan, based on integrated analysis of electronic earth-sciences information (1): Simplified mathematical model and numerical simulation of oblique oceanic-plate-slab subduction. Chishitsu Nyusu (Geology News, edited by GSJ) (in Japanese; submitted-in press).