Spectral Analysis of the 1952 Kamchatka Tsunami Observed at the North East Coast in Japan

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1952年カムチャッカ津波のスペクトル解析

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要　　旨

スペクトル解析は物理学の種々の分野で用いられている分析の方法の1つで，光のスペクトル解析は特によく知られている。これを波の解析に用いるときは，フーリエ解析の手法を用いて，複雑な波形を種々の周波数の正弦波に分解し，それぞれの波（成分波）の振巾を求め，周波数に対する振巾分布（スペクトル）を得る操作を行う。この方法は地震波などの複雑な波形の研究に適用され，成果をあげているが，これを津波の解析に適用する試みは高橋，相田（1959，1963）などによって行われている。それによると同一の津波に対しても，場所によって異なる周期波が卓越し，単純なモデルでは説明しにくい。

1952年のカムチャッカ地震による津波は日本の太平洋岸で 1m の高さで観測されたがこれは初動が60ないし70分という長周期で単一の正弦波に近い形をしていることや，最大振巾波が初動到着後6ないし7時間経過してから観測されたことなどの点で特異な性質をもっている。そこでこれを場所の変化のみならず，時間変化を考えてスペクトル解析した。

方法は験潮記録紙上の津波記録から日常潮位変化を除いて，これを初動から10時間にわたり3分間隔で水位を読み取りフーリエ解析をする。使った記録は北から釧路，宮古，女川，鮎川，小名浜の太平洋岸の5点である。さらにこの10時間を2時間ごとに5つの段階にわけそれぞれについて同様の解析を行いその時間変化をみた。

結果は次のように要約できる。10時間分の水位変化のスペクトル図について包絡線をとって単純化して考える時，北にある観測点程単純なスペクトルが得られた。2図。すなわち釧路では60分にピークをもつ山状構造を示し短周期の成分は減衰が大きい。一方小名浜，鮎川では短周期成分が多く，平担なスペクトルを示す。中でも小名浜の20分の成分波はやや卓越しているがこれは湾や陸棚の共鳴によるものとは考えにくい。釧路の卓越周期は初動の周期，陸棚の共鳴周期に一致し，これによって説明が可能である。一般的にいっ

て南の観測点ほど短周期成分を多く含む。この傾向は高橋，相田（1963）がすでに指適しているが，ここではこれを陸棚の一様傾斜モデルにもとづいた正弦波の透過係数の計算から得た結果をもとにして考察した。初動後２時間の結果によると10分周期に対する振巾比は小名浜では釧路の1.5倍になっている。４図。これにみあう入射角の相異を10分周期に対して求めることから，釧路では80°，小名浜で60°が得られた。これは数値計算の結果からえた屈折図と調和する。３図。

次に60分周期波の時間変化をみると初期の段階で卓越していたものが，第３，４段階でわずかに減衰し，第４，５段階で回復し場合によっては初期のレベルを越すものがみられる。このような時間変化は陸棚の共鳴からは説明しにくく，新しい波の到着を意味すると考えられる。この時間的おくれや振巾からみて陸棚にそって伝わるエツジウェーブと考えらえる。この60分周期波のレベルの回復と一致して原記録上で最大振巾波が記録されていることからみると，エツジウェーブのはたす役割は大きい。

スペクトルの時間変化の特徴として，短周期成分は時間とともに急激に増加し，第３段階で最大になった後急激に減少する。一方長周期成分は最初から卓越し時間変化の巾は短周期のそれにくらべて小さいが，小さいながらも減少した後，回復ないしは最初のレベルを越すという変化がみられる。このことから直達波によるエネルギーの供給が第３段階まで続き，第４，５段階でエッジウェーブによるエネルギーの供給が行われたものとみてよい。

Spectral Analysis of the 1952 Kamchatka Tsunami Observed at the North East Coast in Japan

Abstract

The spectra of the 1952 Kamchatka tsunami were computed for the observational points at the north east coast in Japan. A dependence of the spectra upon the observational point and a time variation of the spectra were investigated. As the result it was found that a small incident angle developed a short-period component and an edge wave caused a long duration of the tsunami. It is considered that the shelf contributed to form the characteristic spectrum of the tsunami observed in Japan.

Introduction

The Kamchatka tsunami of 1952 was observed in Japan with a sinusoidal motion of a long period for the initial wave and a long duration. It was noticed that the maximum amplitude phase arrived 6 or more hours later from the initial arrival. Recently Ishii and Abe (1979) explained that the maximum phase had a character of the edge wave which propagates along the shelf.

The spectra of the tsunamis observed in Japan were systematically computed by Takahashi and Aida (1961, 1963). They found that the responses of the bay and shelf show the important roles in any tsunami spectra. It is considered that the total sampling of 20 hours is long enough to develop the seiche of the bay and shelf. Accordingly the part which is occupied with the seiche becomes more important than that occupied with the initial motion. So it is necessary to examine not only a dependence on the obsevational point but also time variation for the 1952 Kamchatka tsunami. It is also expected to understand the characteristic property of a distant tsunami with an oblique incidence.

Method

The observational points are Kushiro, Miyako, Onagawa, Ayukawa and Onahama at the north east coast in Japan which face to the north west Pacific ocean. They are shown in Figure 1. The astronomical tides were removed from the observed ones by the use of the tide table published by Japan Meteorological Agency. The water height above the mean sea level was sampled from the initial arrival for 10 hours with the interval of 3 min. They were disolved into component waves of 6–100 min on the Fourier analysis and the spectra of the tsunami were obtained. Furthermore, the spectra were computed for the interval of each 2 hours. Thus 5 time series of the spectra were obtained and we discuss a time variation for the observational point.

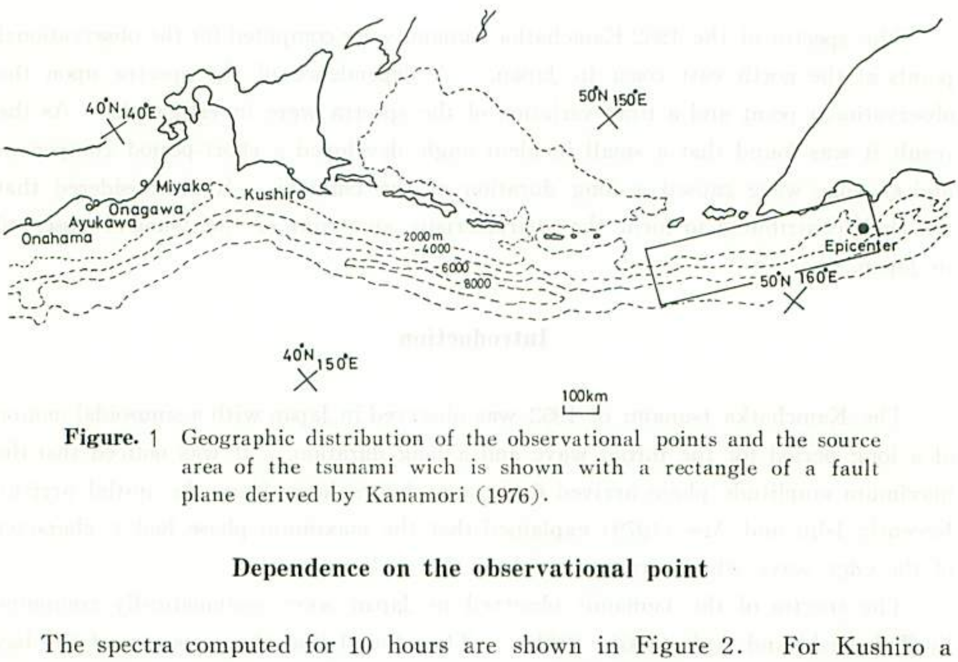

Figure. 1 Geographic distribution of the observational points and the source area of the tsunami wich is shown with a rectangle of a fault plane derived by Kanamori (1976).

Dependence on the observational point

The spectra computed for 10 hours are shown in Figure 2. For Kushiro a simple spectral envelope was obtained with a single peak in the period of 60 min. On the other hand a flat spectral one without any remarkable peak was obtained for Ayukawa and Onahama also shows an almost flat spectrum in envelope. For the latter two the short-period components are predominant to the same extent as the long ones. Takahashi and Aida (1963) obtained the spectra with more short-period components than our ones for these two observational points. Since they took the long sampling time of 20 hours, it is considered that the sheiche predominated. The spectrum of Miyako is similar to that of Kushiro about a peak

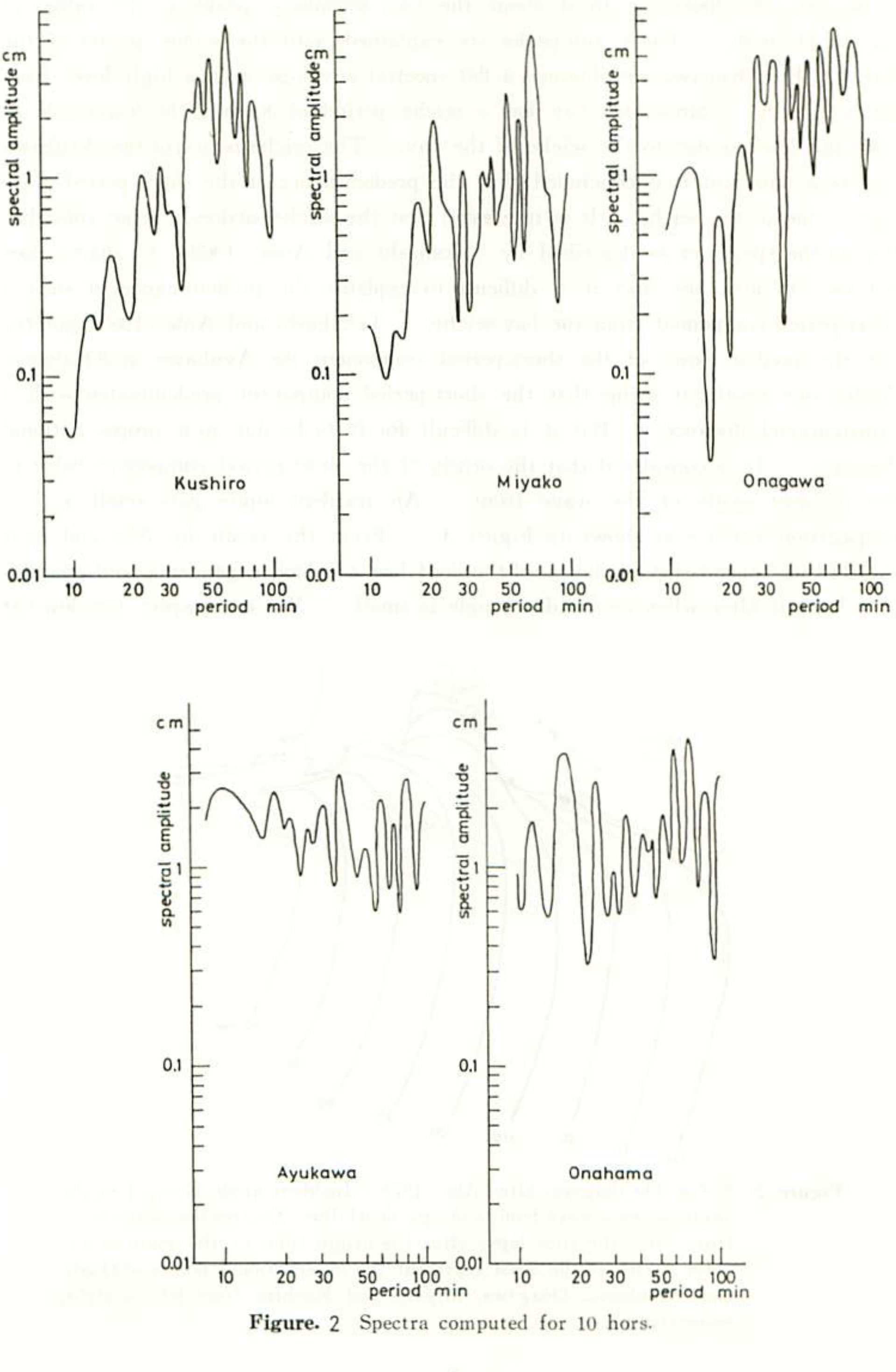

Figure. 2 Spectra computed for 10 hors.

of 60 min and dissimilar to it about the two secondary peaks at the values of 22 and 50 min. These sub-peaks are explained with the seiche period of the bay. For Onagawa we obtained a flat spectral envelope with a high level from 30 to 90 min. Since this bay has a seiche period of 30 min, the lower side of the high level is due to the seiche of the bay. The seiche period of the Ayukawa bay is 8 min and it is concluded that the predominance of the short period of 10 min is due to the seiche. It is interested that the seiche makes a large contribution to the spectrum as described by Takahashi and Aida (1963). Onahama does not face to any bay and it is difficult to explaine the predominance of such a short-period component from the bay seiche. Takahashi and Aida (1963) pointed out the predominance of the short-period component for Ayukawa andOnahama. As for our results it seems that the short-period component predominates with a propagational distance. But it is difficult for it to be due to a propa- gational distance. It is considered that the origin of the short-period component isdue to the incident angle of the wave front. An incident angle gets small with a propagation distance as shown in Figure 3. From the result by Abe and Ishii (1979) the transmission coefficient of the shelf has a period dependence and operates as a low-cut filter when an incident angle is small. We can expect the low-cut

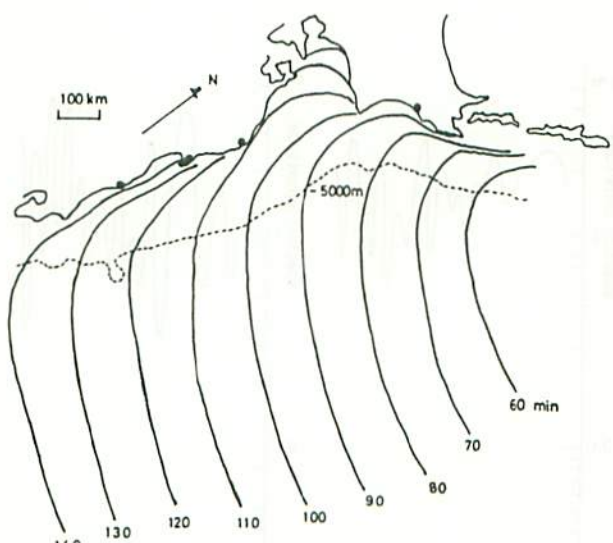

Figure. 3 Refraction diagram after Abe (1979). Incident angle is equal to the angle between wave front and equi-depth line. Figures beside the wave front show the time lapse after the origin time of the main shock. Solid circles at the coast represent the observational points of Onahama, Ayukawa, Onagawa, Miyako and Kushiro from left to right, respectively.

spectra in Onahama and Ayukawa from their result. This result is quantitatively harmoneous with their result.

Time variation of the spectra

The spectra were computed for every 2 hours from the initial arrival and the time variations for 10 hours were obtained for the periods of 10, 20, 30 and 60 min. It is shown in Figure 4. From the result it is generally found that a short-period component shows a large variation. The steep increaces in amplitude are commonly found for the periods of 10 and 20 min in the initial stages of all the observational points and they stop at the lapse of 6 hours except for Ayukawa. This fact shows that a supply of the new wave stopped when it took 6 hours after the initial arrival. The long-period component of 60 min keeps a large amplitude from the initial stage of each station and it shows a recovery after a small decreace. Particularly it is found that the level to be recovered exceeds the initial one at

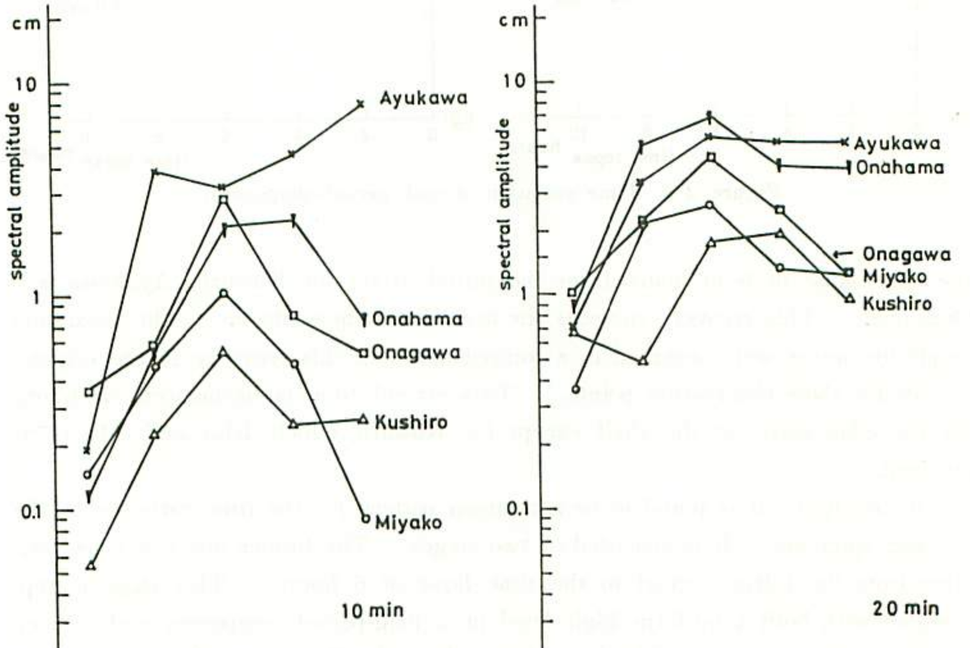

Figure. 4-1 Time variation of each period-component.

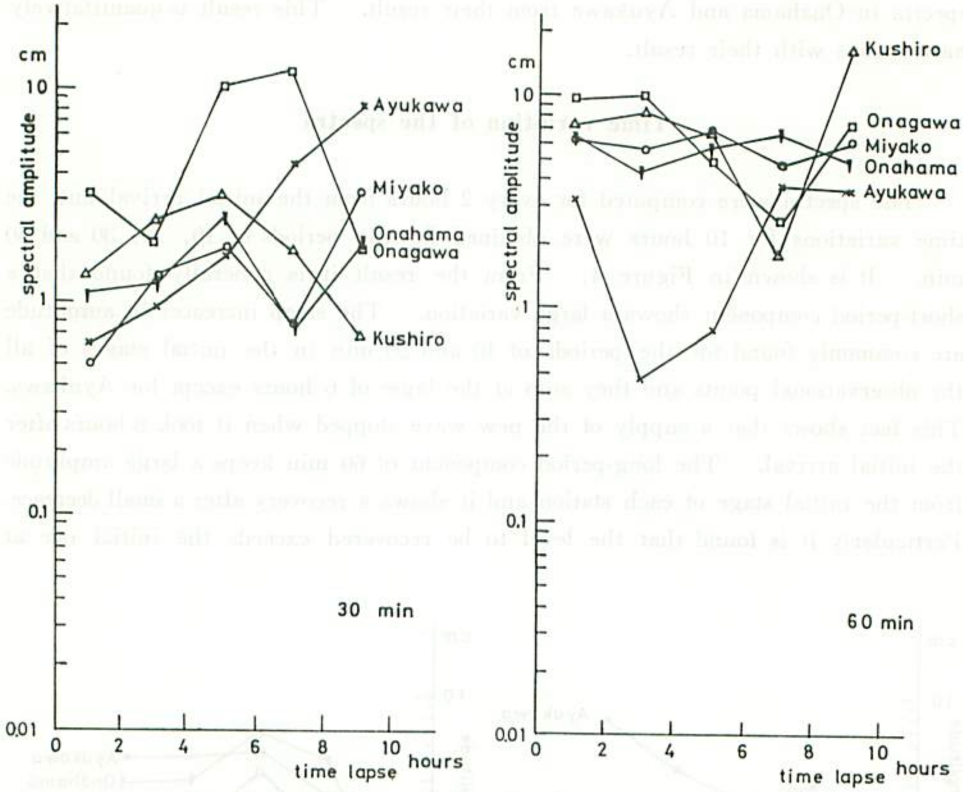

Figure. 4-2 Time variation of each period-component.

the time lapse of 8-10 hours from the initial arival for Kushiro, Ayukawa and Onahama. This recovery suggests the arrival of a new phase. The maximum amplitude waves were observed in a coincedence with this recovery in the original records for those observation points. This arrival time is harmoneous with one for the edge wave on the shelf except for Kushiro, which Ishii and Abe (179) obtained.

In conclusion it is found to be a common pattern for the time variation of the tsunami spectrum. It is consisted of two stages. The former one is a time variation from the initial arrival to the time lapse of 6 hours. This stage is represented with both a uniform high level of a long-period component and a steep increace of a short one. The latter is one from the time lapse of 8 hours, exceptionally 6 hours, to that of 10 hours. This one is represented with both a decreace of a short-period componnt and a recovery of the initial level after a small decreace of a long one.

It is important that the small decreace were observed before the maximum arrival in the long-period component. The seich period of the shelf is 60 min from the computation with a simple shelf model by Abe and Ishii (1979). Since the period is equal to one of the newly arrival, it is possible to identify the high level with the seiche to be excited. But this small decreace and the recovery is unfavorable to the excitation of the shelf seiche and favorable to the arrival of the new phase from this recovery phase.

This analysis is restricted within 10 hours after the initial arrival. This restriction is considered to be the minimum interval for the spectrum analysis like this because the maximum amplitude phase appeared 6-8 hours later from the initial arrival. It is believed that a general aspect of this tsunami is described in this analysis in spite of the restriction.

It is possible to estimate the relative incident angle into the shelf from the difference of the spectral amplitude of 10 min in the use of the result by Abe and Ishii (1979). One of Onahama is 1.5 times of that of Kushiro in the intial stage. It is estimated to be 60 degrees for Onahama by assuming 80 degrees for Kushiro from the amplitude dependence on the incident angle for the transmitted sinusoidal wave. This result is consistent with the refraction diagram shown in Figure 3.

Conclusion

It was found in the spectral analysis that the shelf contributed to the spectra of the 1952 Kamchatka tsunami observed in Japan. One contribution is the predominance of the short-period component with the smaller incident angle and another is the long duration of the tsunami due to the generation of the edge wave.

Acknowledgement.

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