Numerical ocean models in meteotsunami research and observational systems.

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1.Equations:

Basically, it is shallow water equation with adds in the right part of the momentum

For simplicity, we will use linear approximation and no friction approach

$$\frac{\partial u}{\partial t} = -g\frac{\partial \zeta}{\partial x} - \frac{1}{\rho}\frac{\partial P_a}{\partial x}$$

$$\frac{\partial v}{\partial t} = -g\frac{\partial \zeta}{\partial y} - \frac{1}{\rho}\frac{\partial P_a}{\partial y}$$

$$\frac{\partial \zeta}{\partial t} = -\frac{\partial (hu)}{\partial x} - \frac{\partial (hv)}{\partial y}$$

1.Equations

$$\eta = \zeta + \zeta_a,$$

$$\zeta_a = \frac{P_a}{\rho g}$$

$$\frac{\partial u}{\partial t} = -g\frac{\partial \eta}{\partial x}$$

$$\frac{\partial v}{\partial t} = -g\frac{\partial \eta}{\partial y}$$

$$\frac{\partial \eta}{\partial t} = -\frac{\partial (hu)}{\partial x} - \frac{\partial (hv)}{\partial y} - \frac{\partial \zeta_a}{\partial t}$$

Using a simple transform, we get “tsunami-like” equations

Here $\zeta_a = \frac{P_a}{\rho g}$

The major problem is to define a forcing term, ζ_a (x,y,t). Generally, we need data with temporal step about 1 minute and spatial step about 2 km. on an are ~50 x 50 km or larger (hundreds of stations) It is unrealistic. So, we need some parameterization of the atmospheric pressure field.

2. Wave energy generated by atmospheric pressure forcing

$$\frac{\partial u}{\partial t} = -g\frac{\partial \eta}{\partial x} \qquad \Big| hu$$

$$\frac{\partial v}{\partial t} = -g\frac{\partial \eta}{\partial y} \qquad \Big| hv$$

$$\frac{\partial \eta}{\partial t} = -\frac{\partial (hu)}{\partial x} - \frac{\partial (hv)}{\partial y} - \frac{\partial \zeta_a}{\partial t} \qquad \Big| g\eta$$

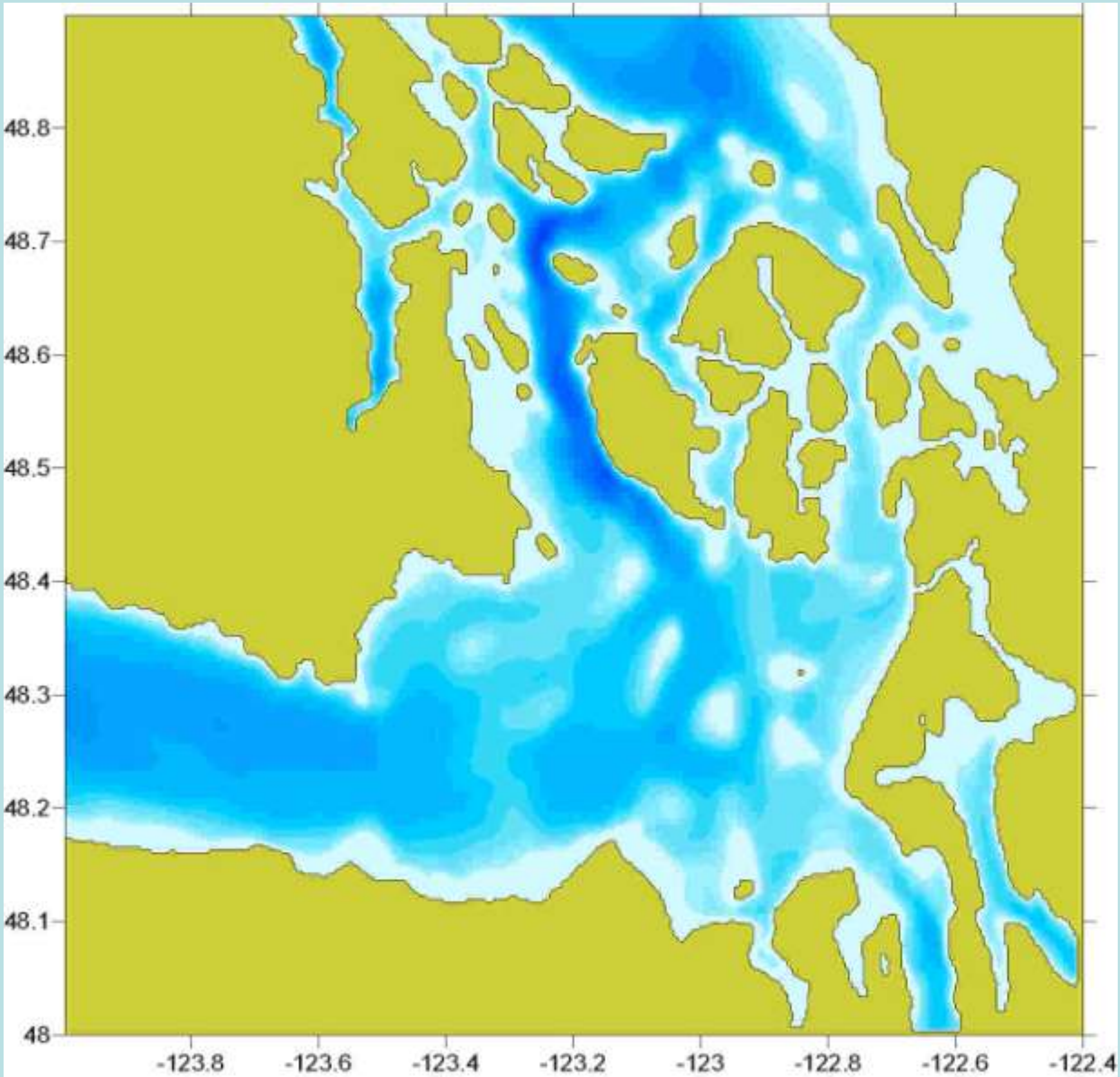
$$\underbrace{\frac{\partial}{\partial t}\frac{1}{2}\iint_\Omega (g\eta^2 + hu + hv)\,dxdy}_{Enegry\ change} = \underbrace{\int_\Gamma g\eta h(u\mathbf{i} + v\mathbf{j})\,d\mathbf{n}}_{Energy\ flux\ trough\ the\ boundary} + \underbrace{\iint_\Omega -g\eta\frac{\partial \zeta_a}{\partial t}\,dxdy}_{Energy\ generation\ rate}$$

Modeling of the Vancouver Island response on the atmospheric pressure forcing

Vancouver Island area: Juan de Fuca strait< Haro Strait and Salish Sea

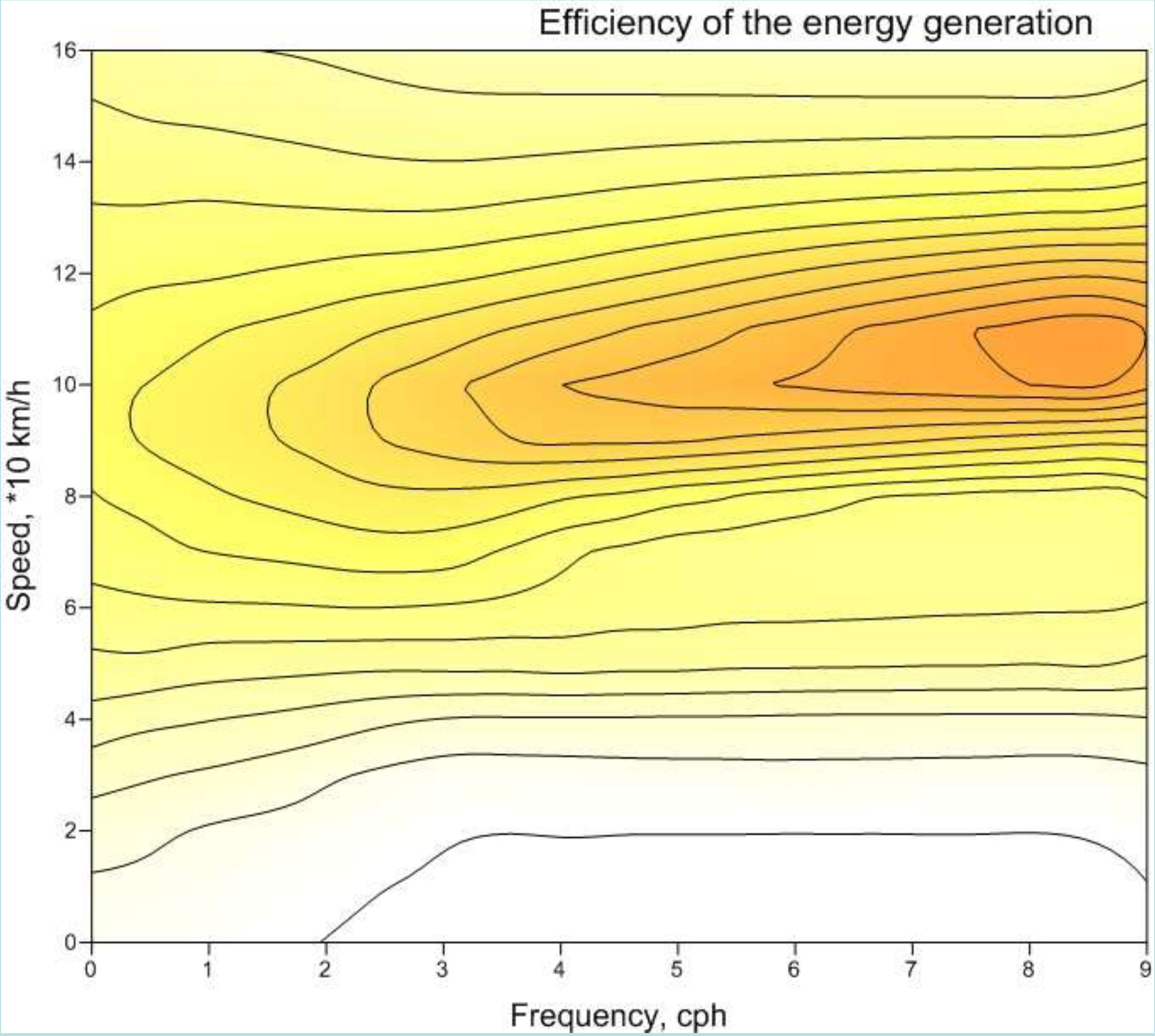
Maximum of the depth is around 350 m.

The deep part of the Juan De Fuca Strait is about 100 m



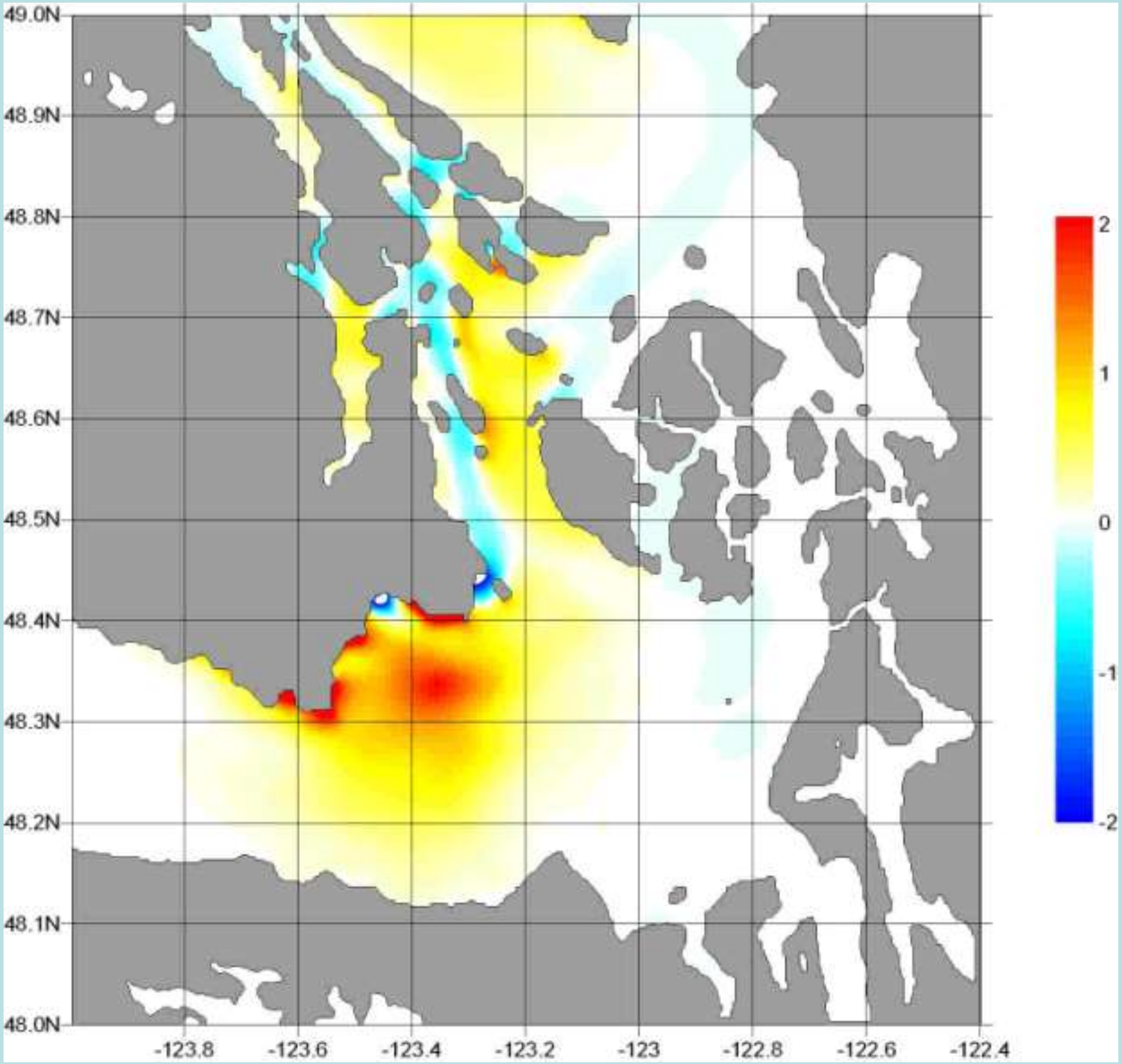
The total energy generated by northward moving atmospheric disturbance

The energy generation efficiency depends on the disturbance speed and on the disturbance frequency. The higher frequency, the sharper Proudman resonance . The “best” speed for such region is about 110 km/h (~30 m/s)



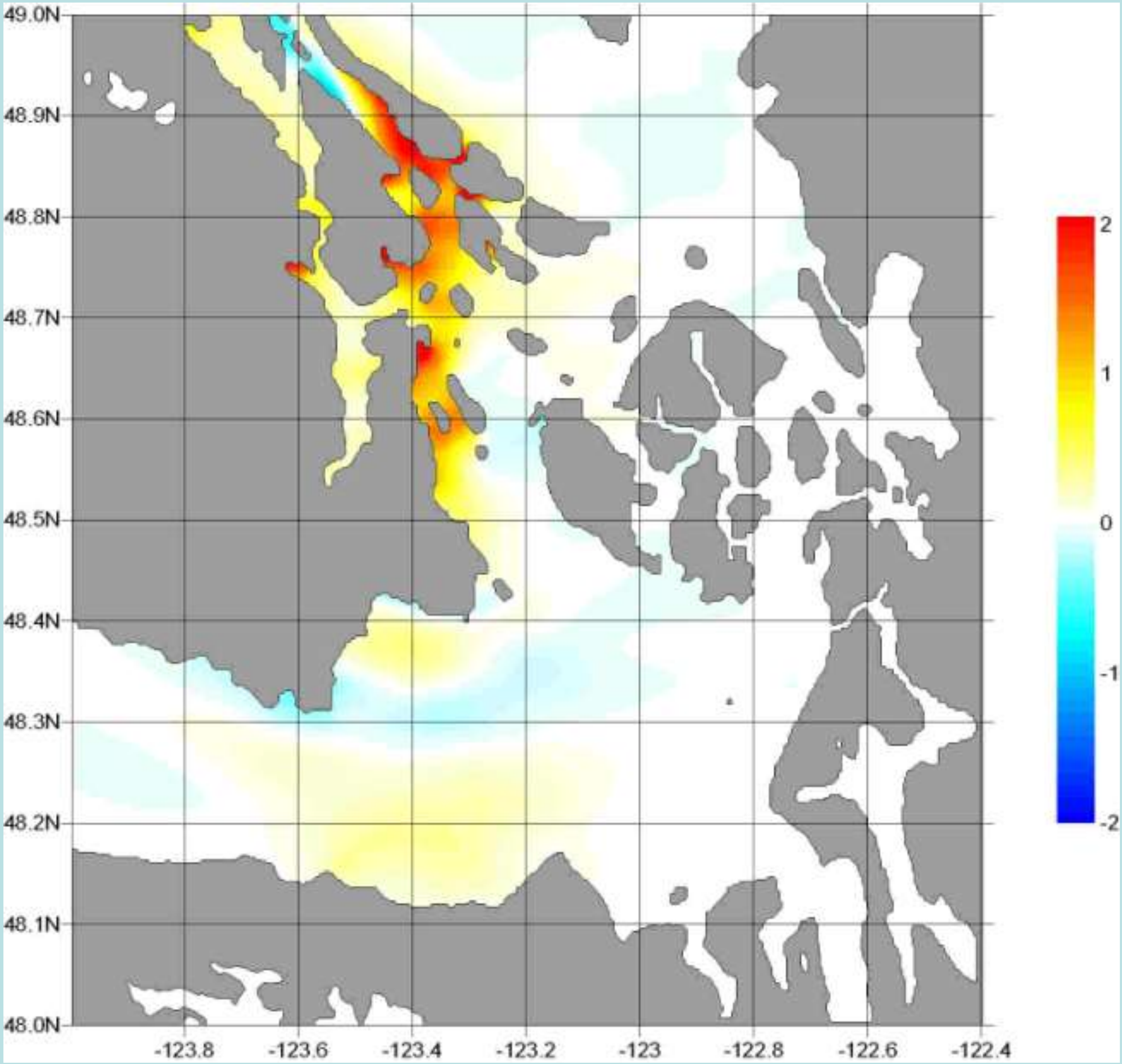
The panel demonstrate the distribution of the generated energy in the area at 120 km/h speed

The highest spot at the flat region near Victoria

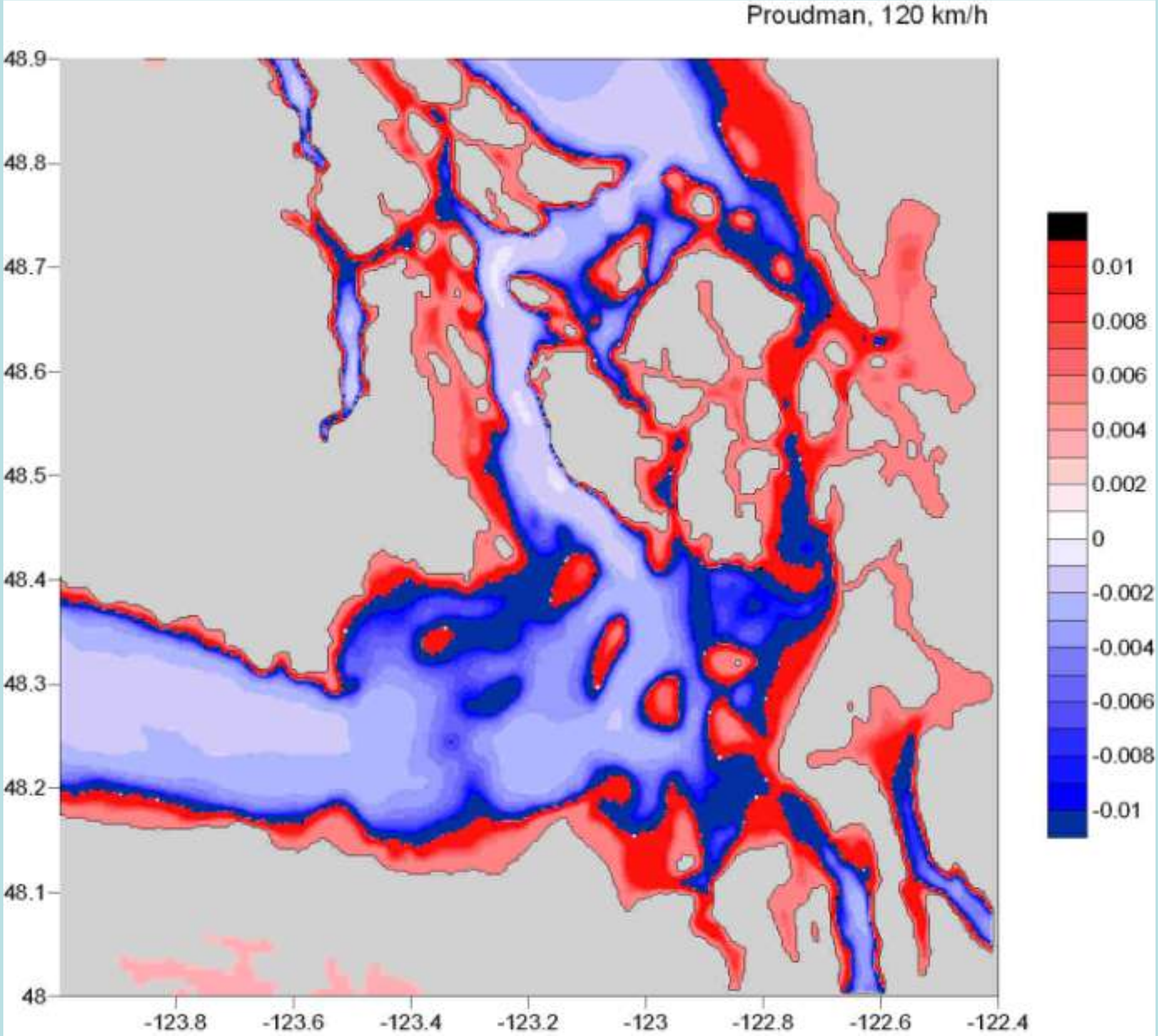


The same as at the previosly slide for the slower movement (60 km/h)

The “hot spot” shifted in the shallower area and toward the smaller islands

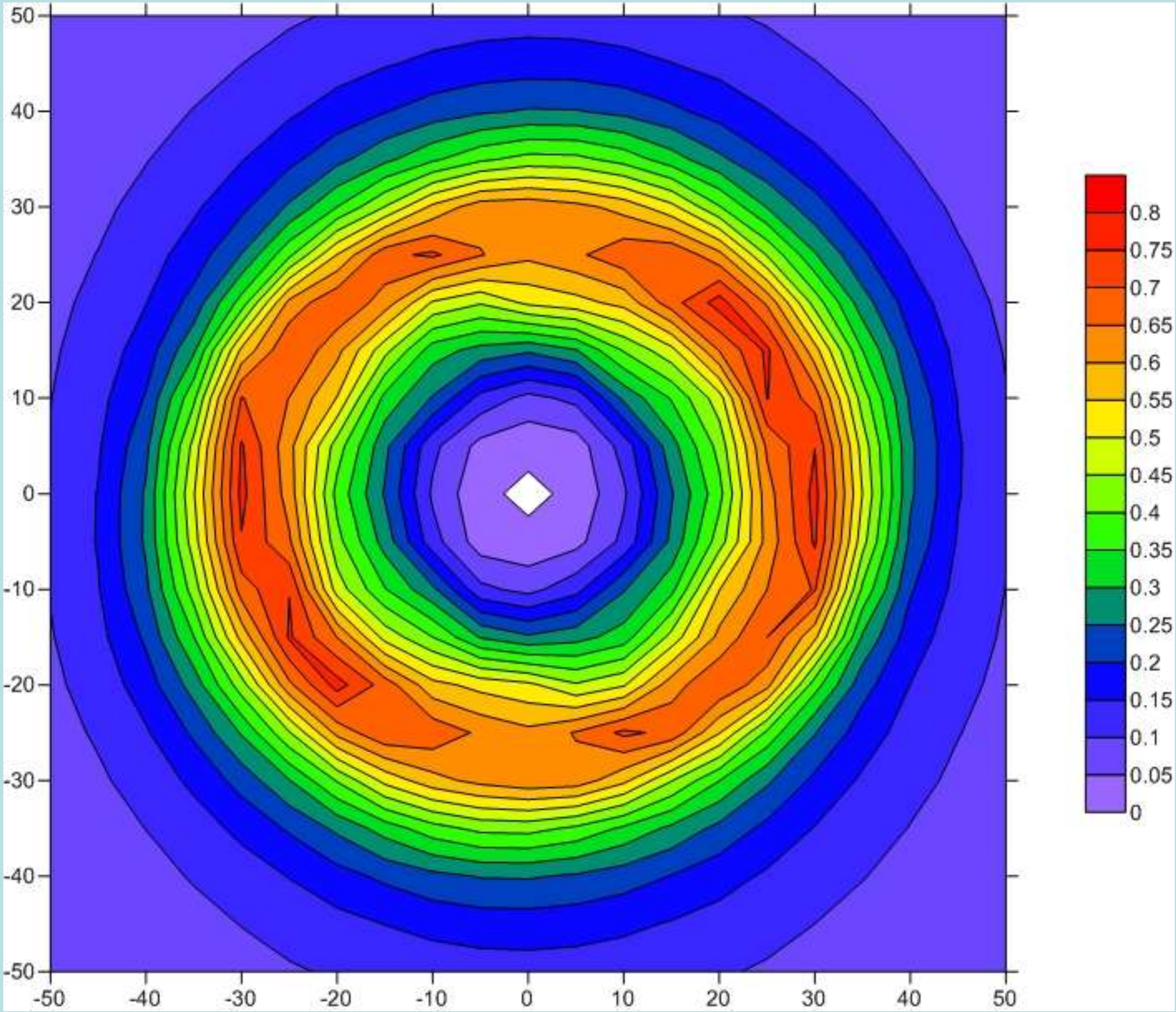


Waves are generated in the areas where the regime of the forcing solution changes from “subsonic” to the ‘supersonic”. The land can be considered as “supersonic” area.

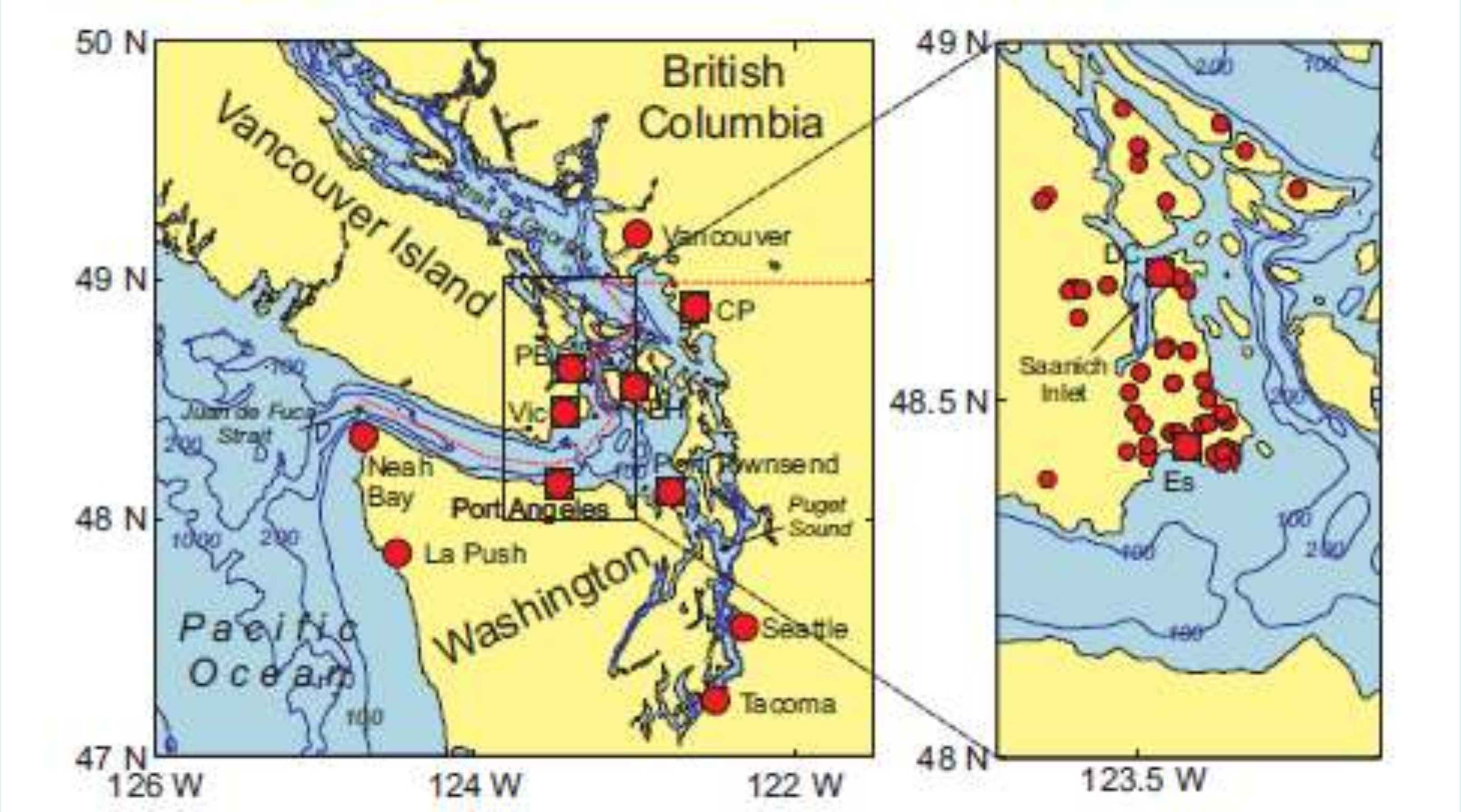


Isotropy and anisotropy of the response

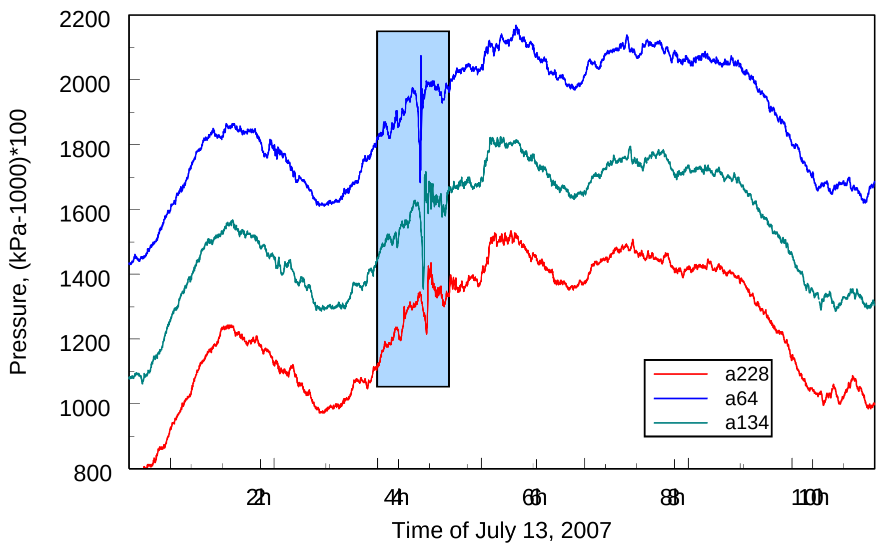
In the energy term, the wqave generation almost independent to the direction of the atmospheric disturbances . Not the same to the response in the specific place.

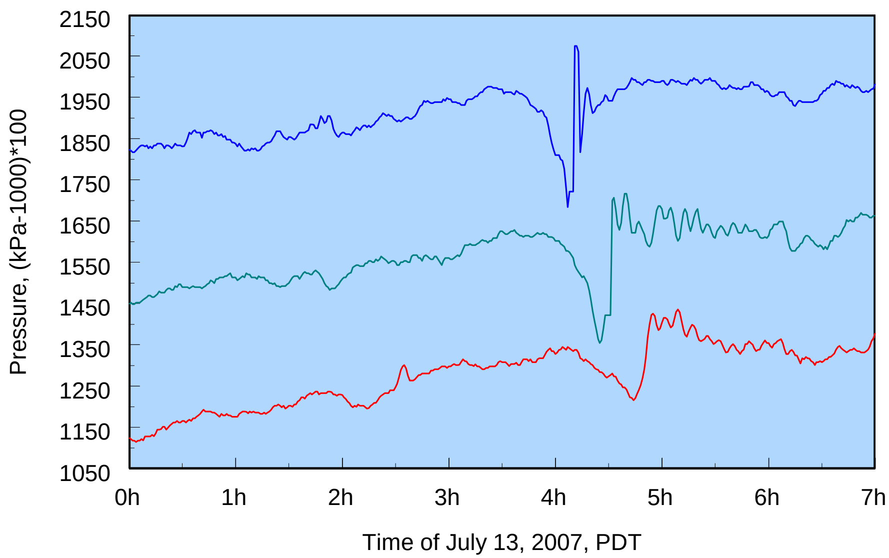


6 How get the forcing field: Vancouver island example

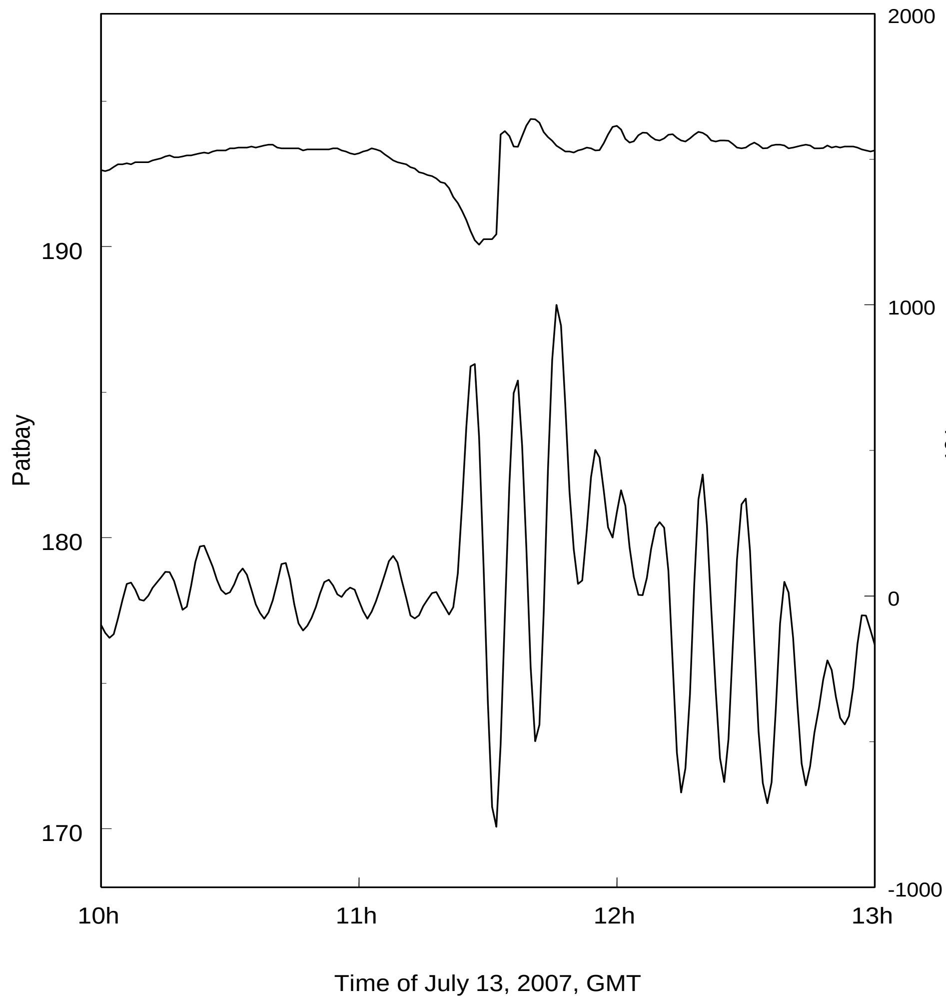


Examples of the records of the 2007 event: 3 out of 30 records.

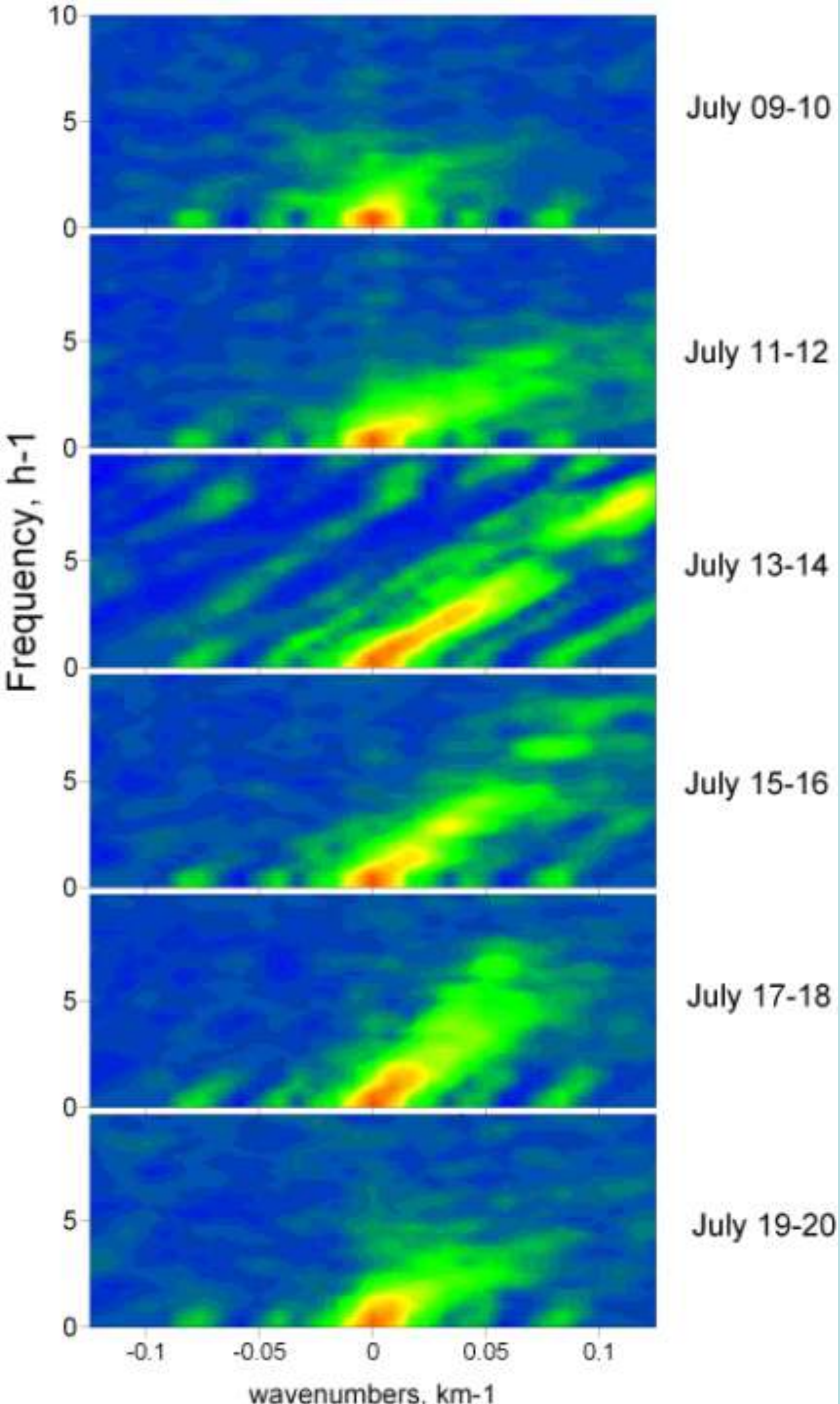




Saahich Inlet and Pat Bay atmospheric pressure and response: No visual forcing wave in the water. Almost simultaneous start of the event in the air and the water.



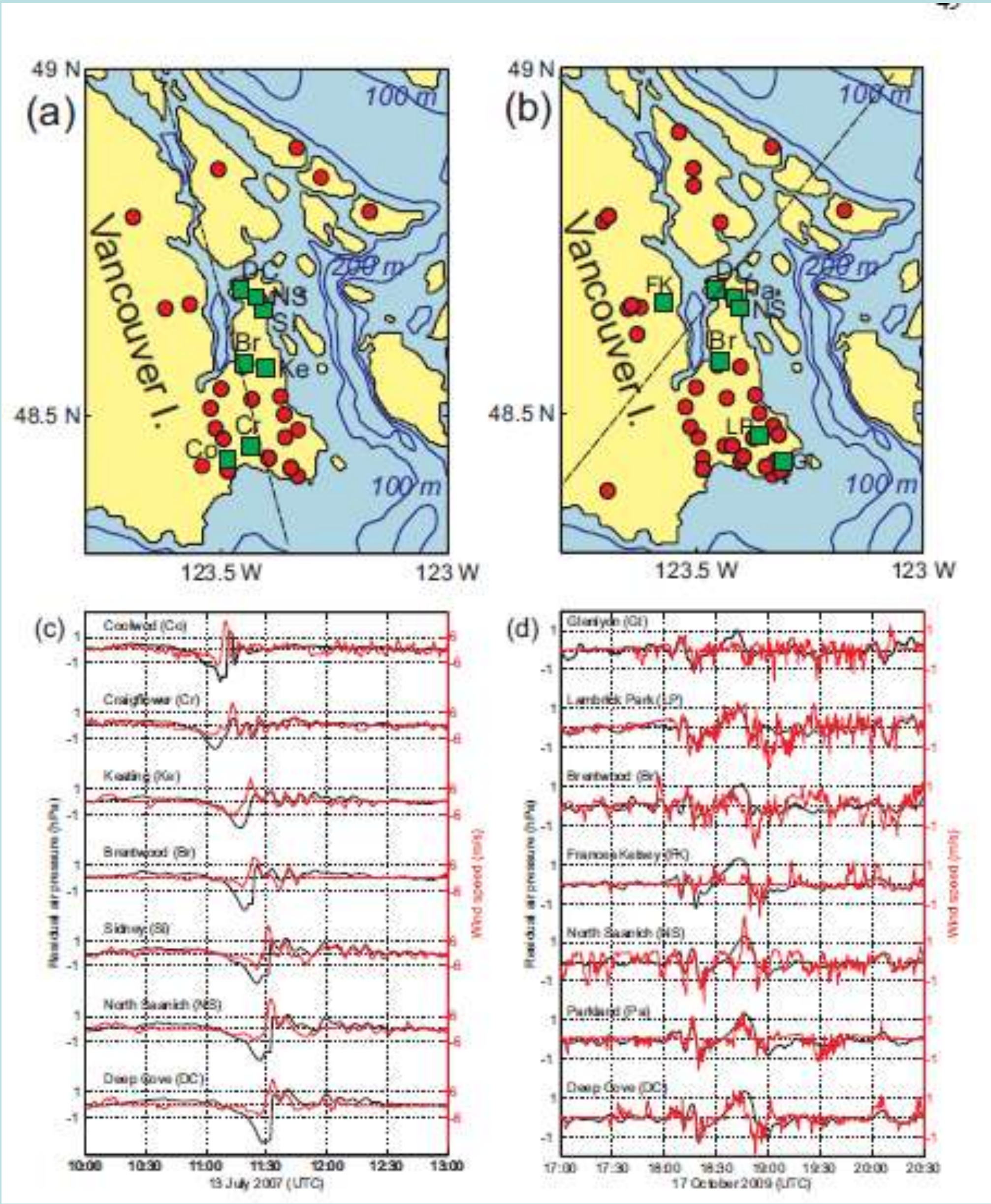
Spatial-temporal spectra of the 2007 event, prepared by 30 station cross-spectra analysis. During the event period, the high-frequency part of the spectrum are higher and waves are almost non-dispersive.



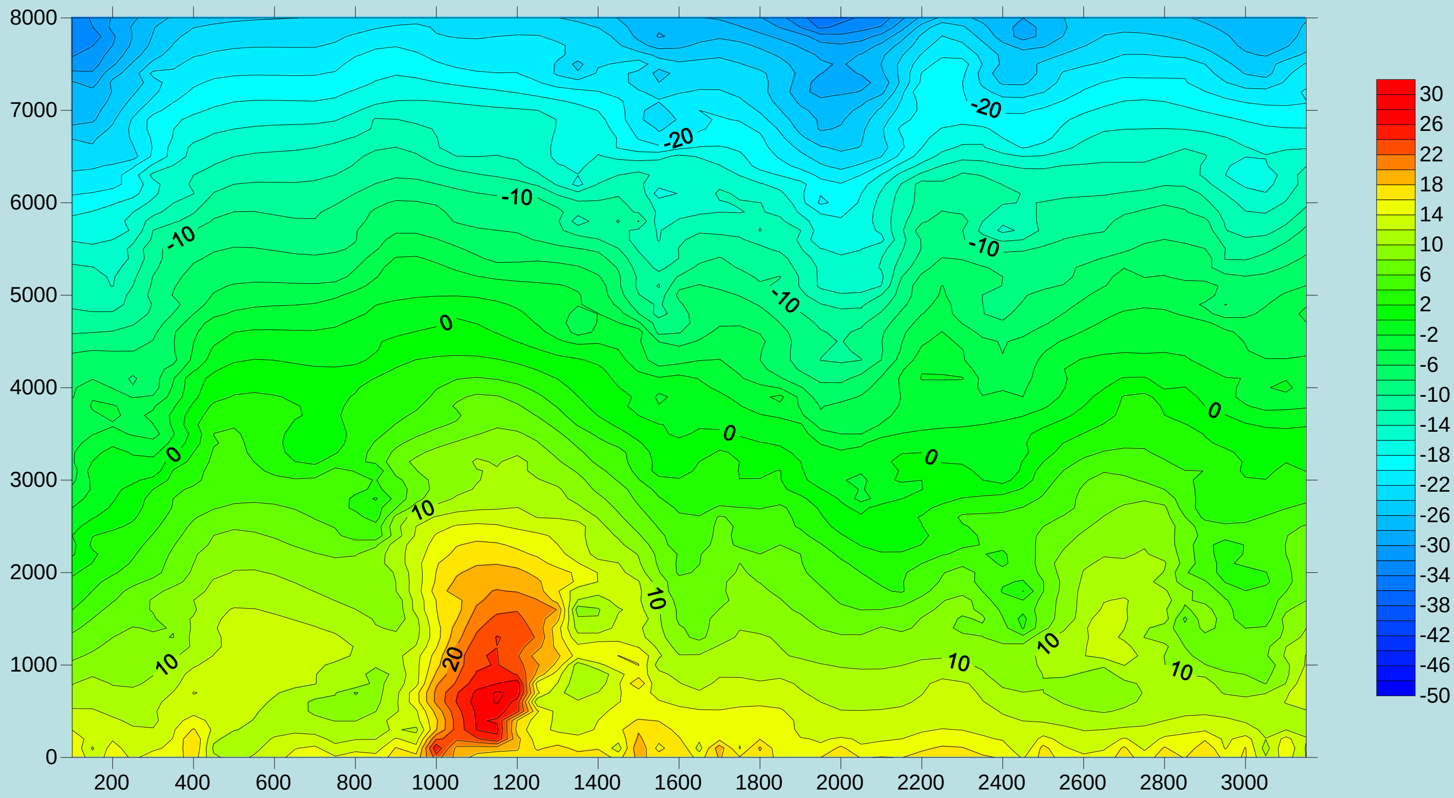
Addition option: use the wind data to determine the disturbance direction and propagation speed by a single station

$$\mathbf{w} = \mathbf{n}\frac{P}{\rho}$$

Where w is wind vector and n is “slowness” vector (with direction toward disturbance moving and value of inverse speed0



Preconditions.



The end