Magnitude estimate from early energy measurements

G. Festa

In collaboration with A. Zollo e M.F. Lancieri

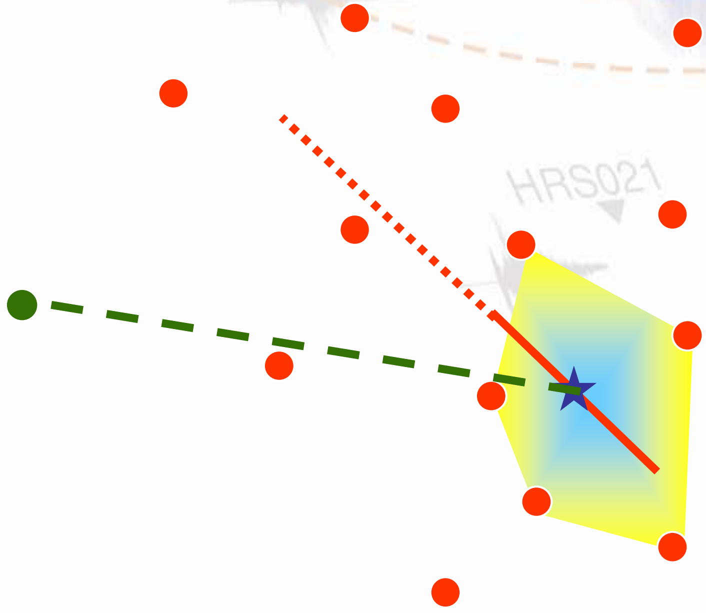
We gratefully acknowledge support from the European Commission's Human Resources and Mobility Programme, Marie Curie Research Training Networks.

EW- DO WE NEED MAGNITUDE?

Objective : Estimate of PGA at a given site, while the rupture is still running on the fault

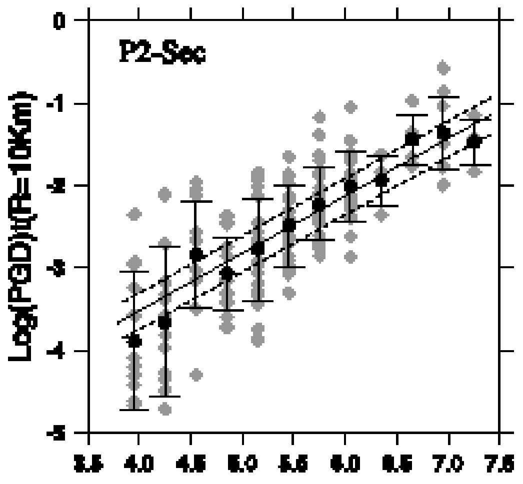
1) PGA can be estimated at the recording sites, then propagated to the target

2) PGA can be evaluated by attenuation relationships



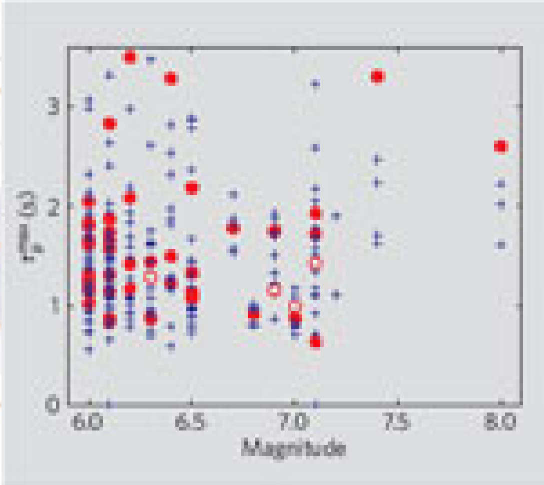
Iervolino et al. (2006) show the weak influence of the magnitude estimate on warning criteria based on present attenuation relationships ***(errors of 0.7 are tolerated).***

Early PGD



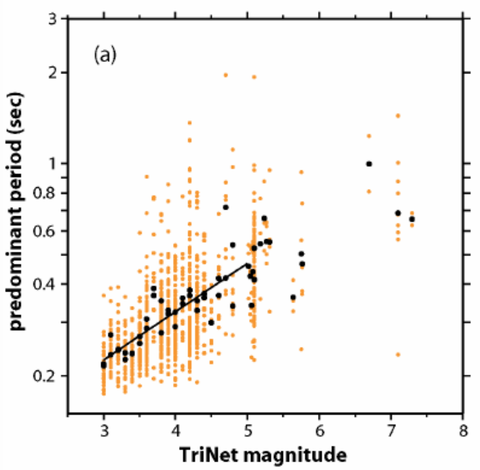
(Zollo et al. 2006; Wu & Zhao, 2006)

Is the rupture deterministic ?

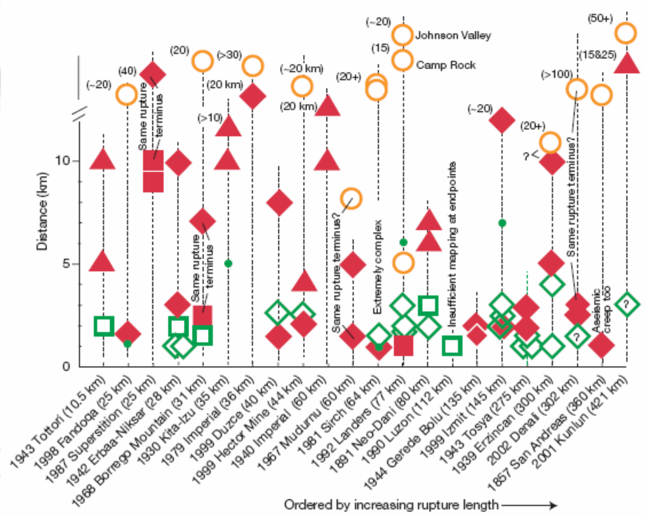


(Rydelek & Oriouchi 2005)

τ



(Allen & Kanamori et al. 2003)



(Wesnousky, 2006)

WHY A NEW PARAMETER ?

Velocity integral: $$I = \int_{T_0}^{T_0+t} v^2(\tau)\,d\tau$$

- more stable than ***peaks*** because it is averaged on the whole duration ;
- ***Baselines and filters*** are less effective for velocities;
- directly linked to the ***radiated energy***

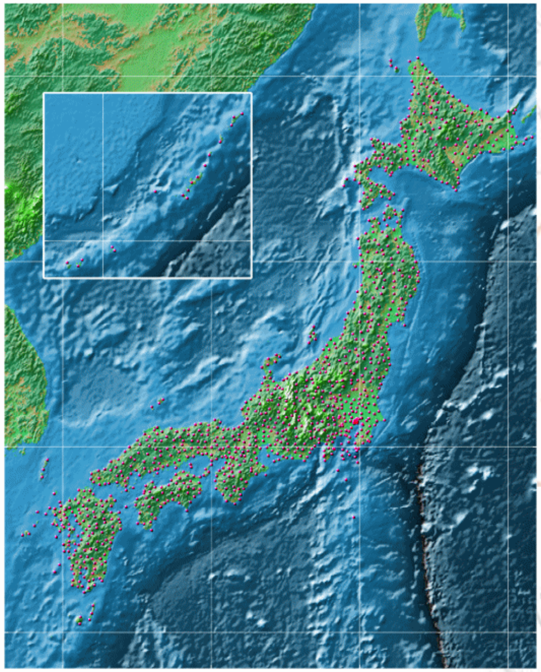
$$E_r = 2\pi f(r)\rho c_s \left\langle R_{\theta\phi} \right\rangle^2 C^{-2} \int_{T_0}^{T_0+T_d} v^2(\tau)\,d\tau$$

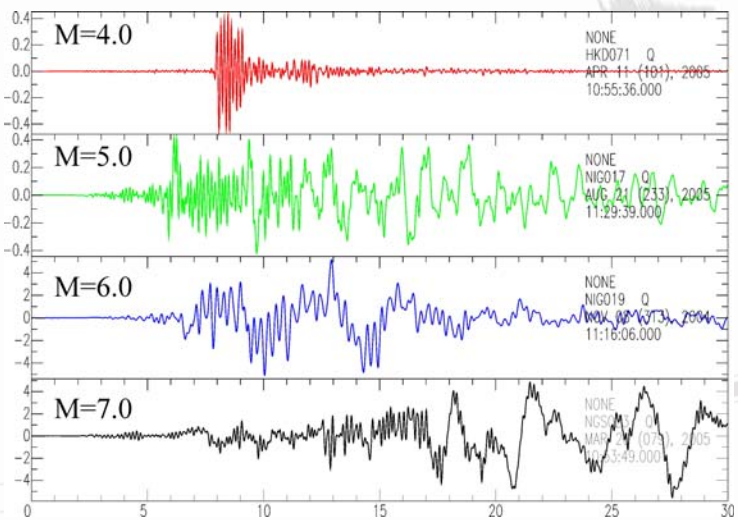
x ***Radiation pattern*** and ***site effects*** difficult to estimate!

$$E_r = \frac{1}{2}\int_\Sigma \Delta\sigma_f \cdot \mathbf{n}\,\Delta\mathbf{u}_f\,d\Sigma + \int_0^\infty dt \int_\Sigma \dot{\sigma}\cdot\mathbf{n}\,\Delta\dot{\mathbf{u}}\,d\Sigma \approx \frac{1}{2}\Delta\sigma \left\langle \Delta u \right\rangle_\Sigma A_\Sigma$$

Low frequency radiation is related to the seismic moment

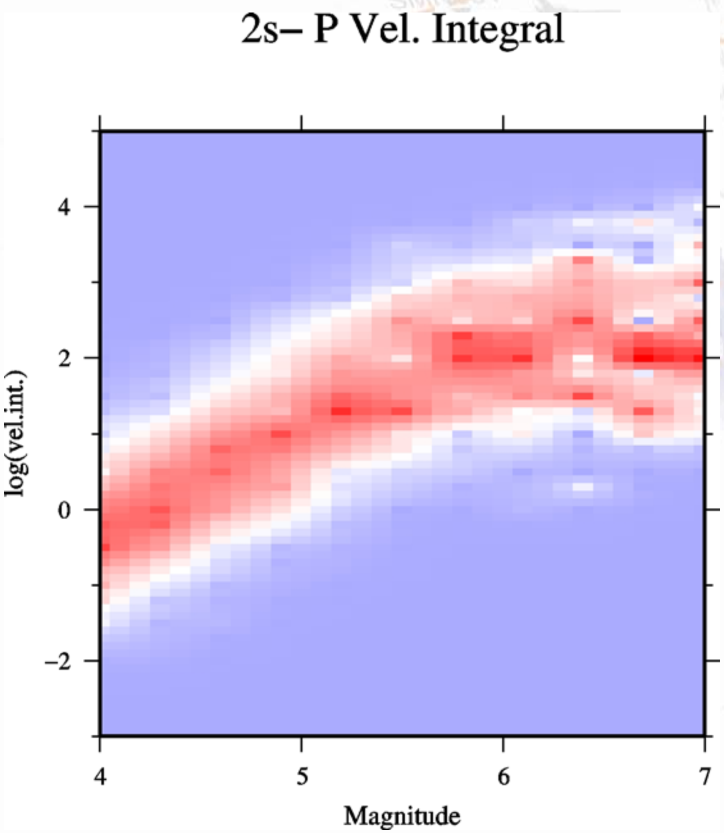
DATA SET

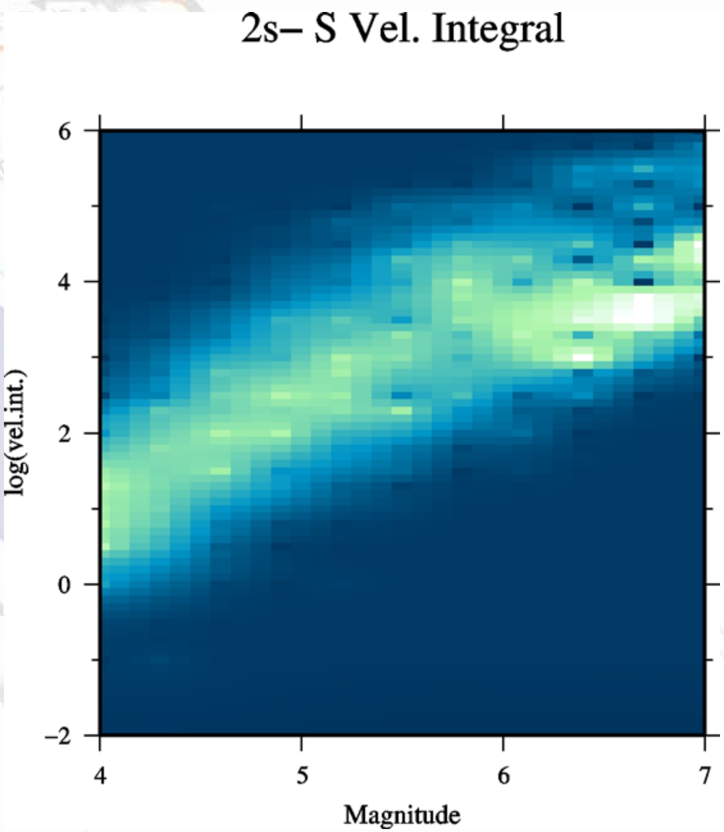




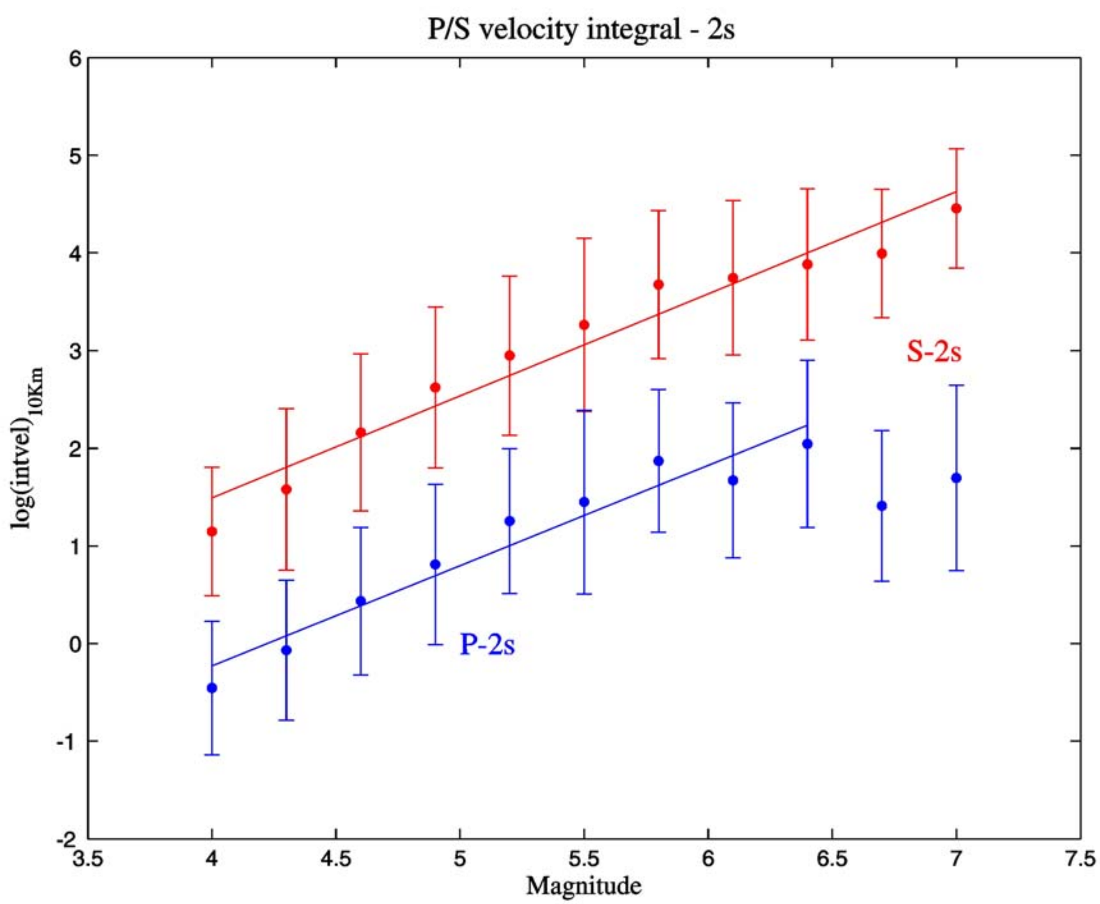
- ***3x1650*** records from K-net and Kik-net (~***300*** earthquakes of magnitude ranging between **4.0 and 7.0**).
- Hypocentral distance < ***60 km***
- Data grouped in magnitude bins of length ***0.3***
- Acceleration records integrated, band –pass filtered ***0.075-10 Hz***
- Correction by distance done analytically (scaling $\boldsymbol{1/R^2}$)

DENSITY PLOTS





RESULTS per BIN

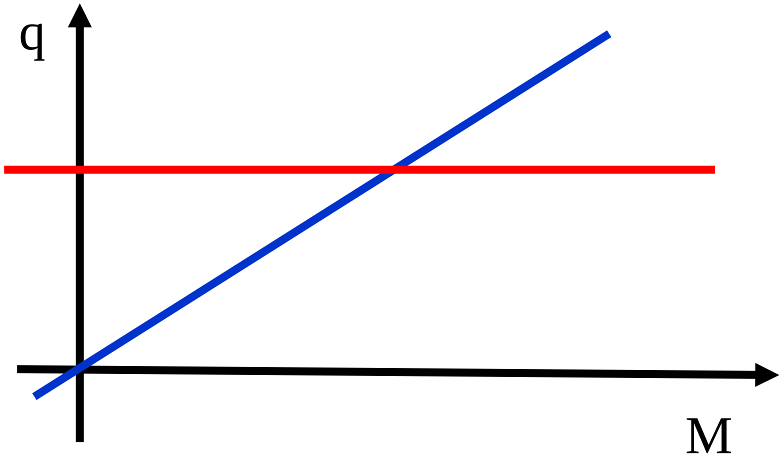


Correlation R-square: r_P=0.94 and r_S=0.96

Does energy in the early seconds determine the final magnitude (area and slip) ?

Yes Completely!

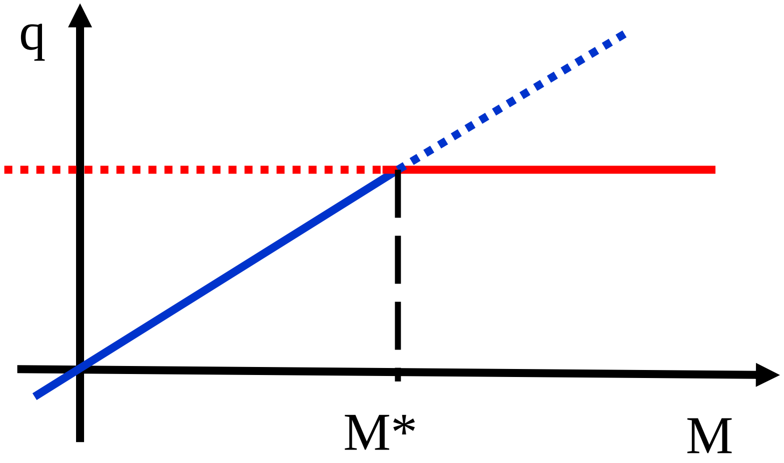
No influence at all



Does energy in the early seconds determine the final magnitude (area and slip) ?

Yes Completely!

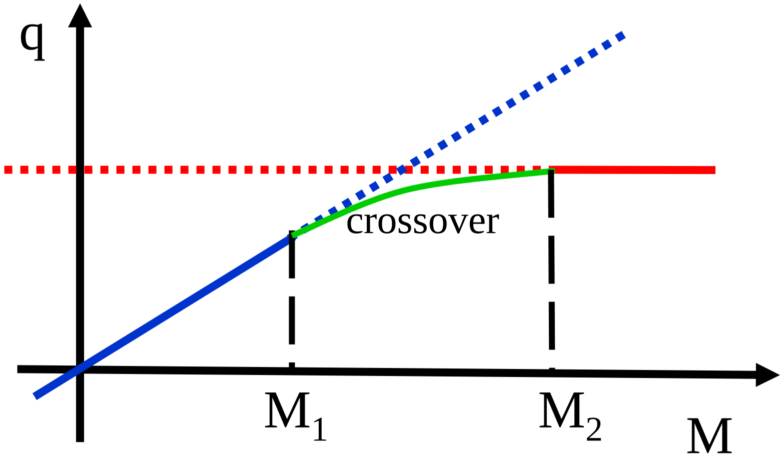
No influence at all



Does energy in the early seconds determine the final magnitude (area and slip) ?

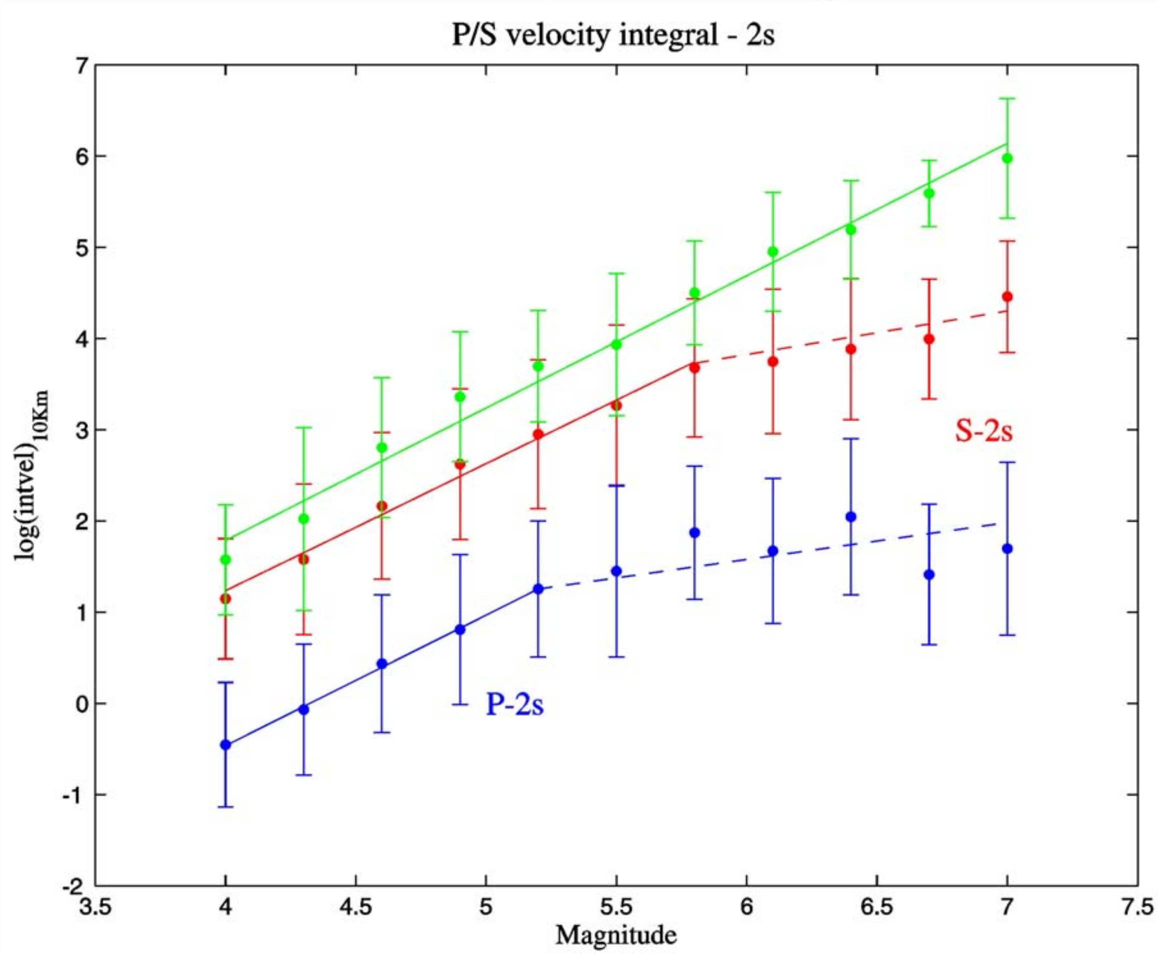
Yes Completely!

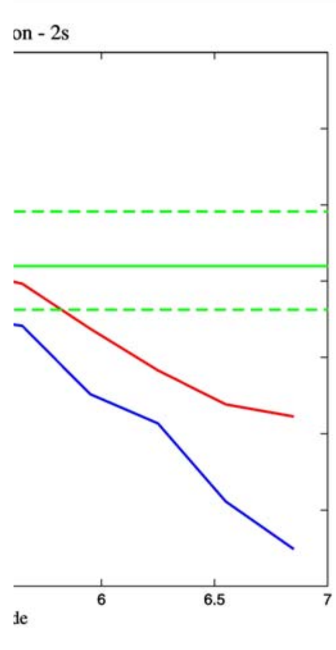
No influence at all

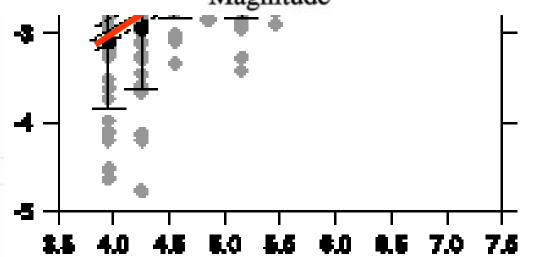


Crossover : Early energy predicts the final magnitude

PREDICTION vs DETERMINISTIC





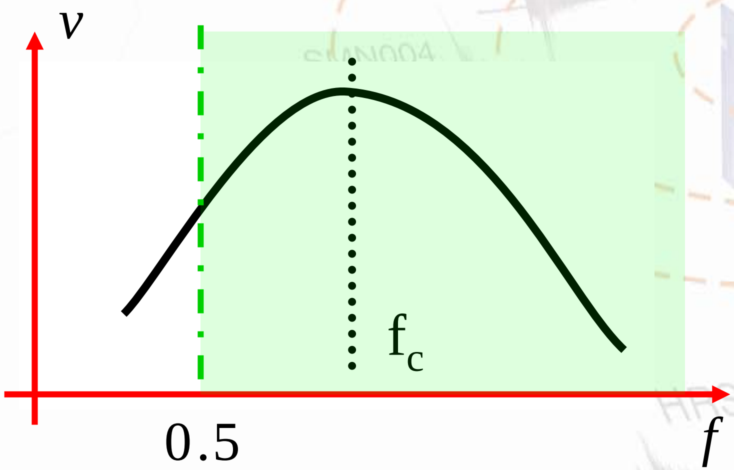


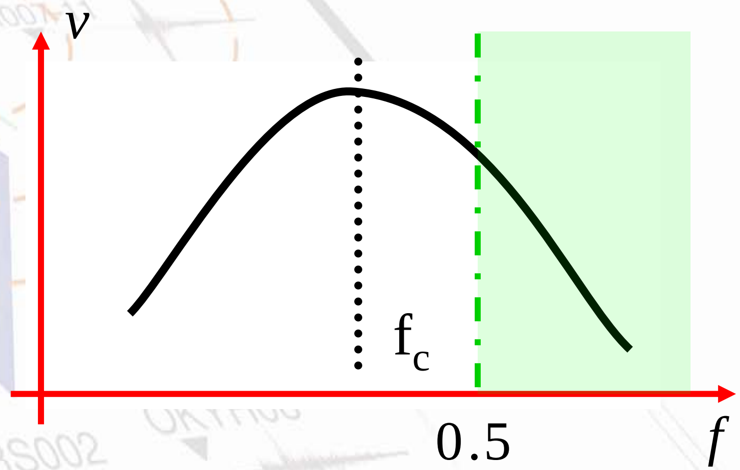
SPECTRA

Parseval theorem : $$I = \int_{T_0}^{T_0+t} v^2(\tau)\,d\tau = \int_{0}^{\omega_t} v^2(\omega')\,d\omega'$$

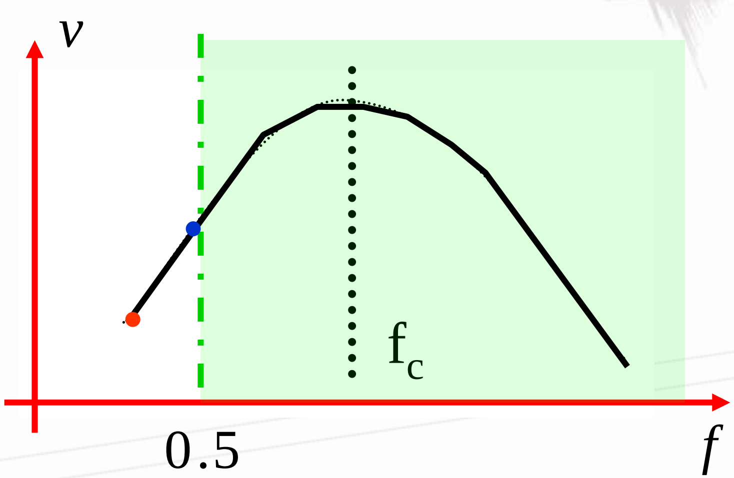
Small earthquakes (M<5)

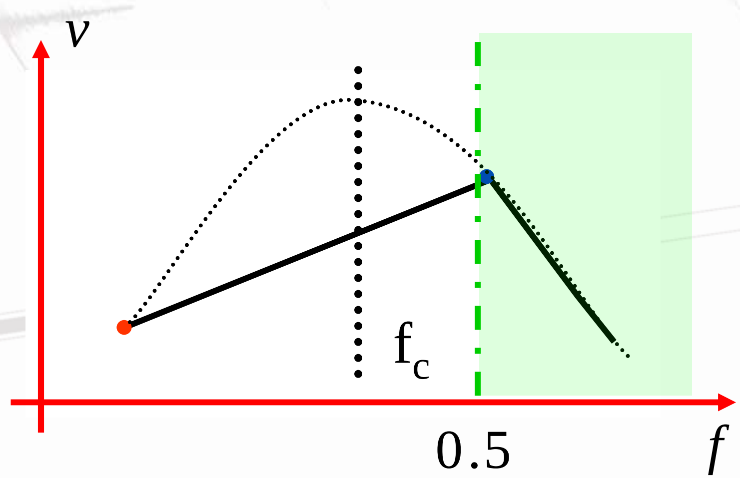
Large earthquakes (M>6)



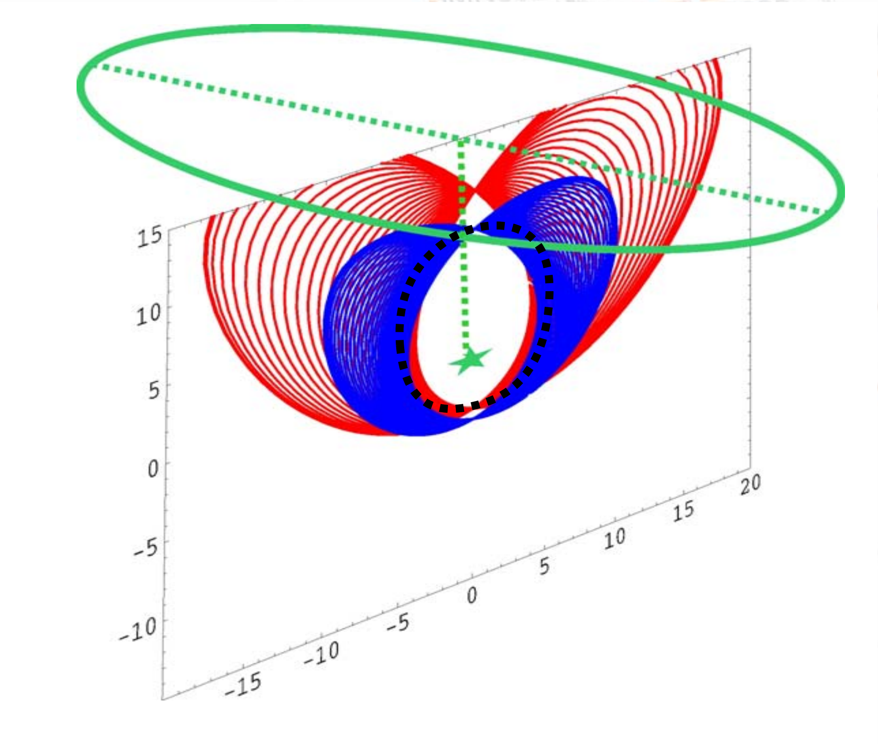


Discrete

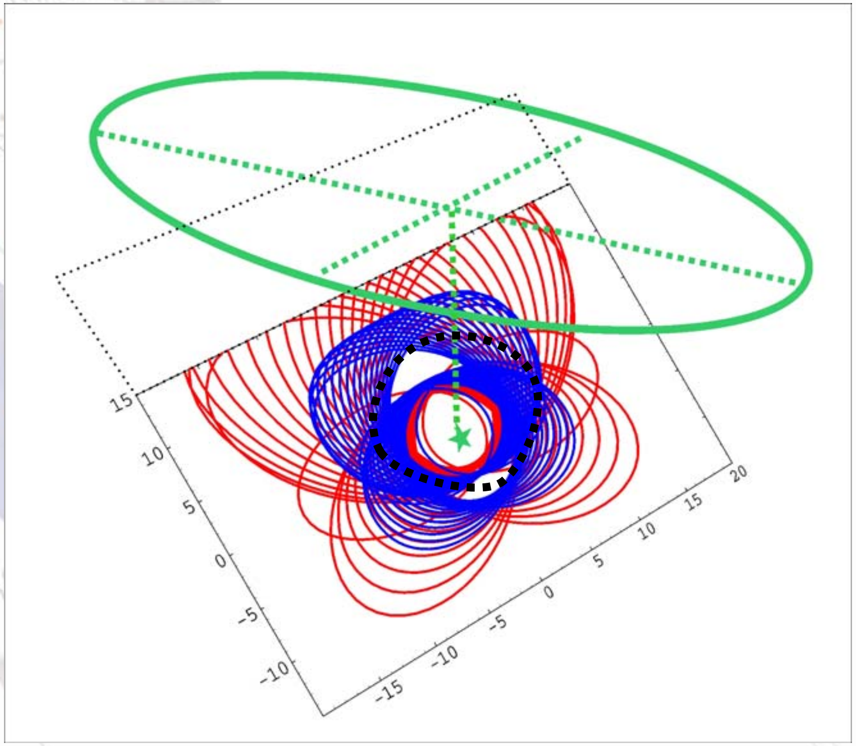




Strike-slip fault (dip 90)



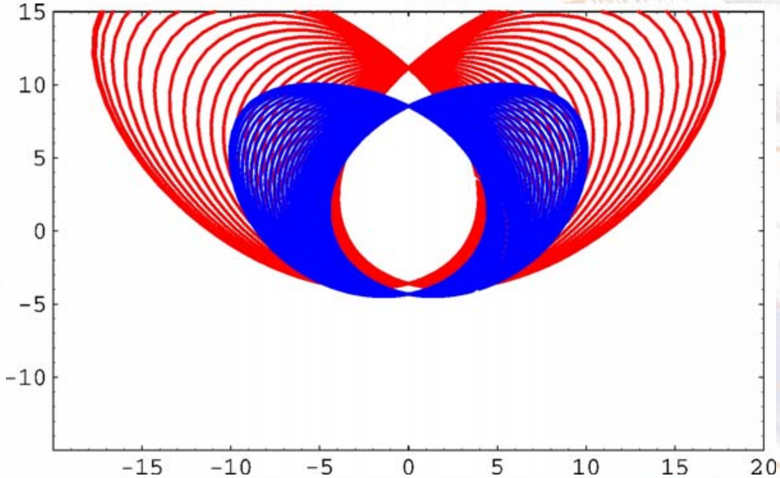
Fault dipping at 60

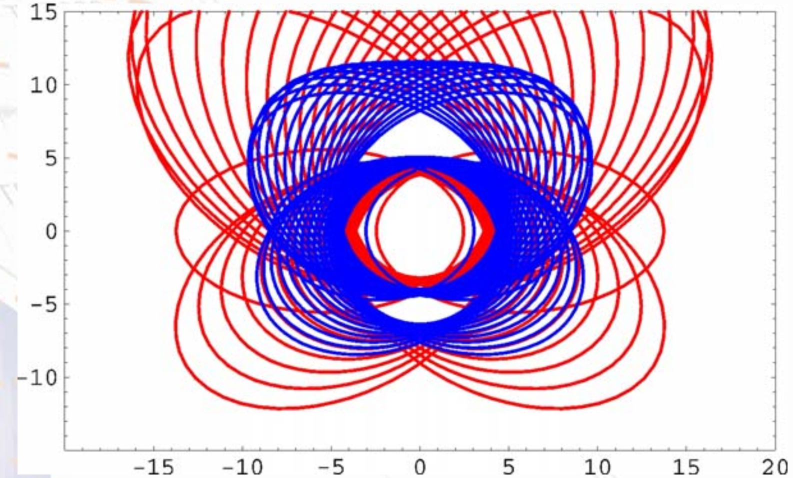


Near-source **2s of P/S records** can be very different from **2s of rupture**

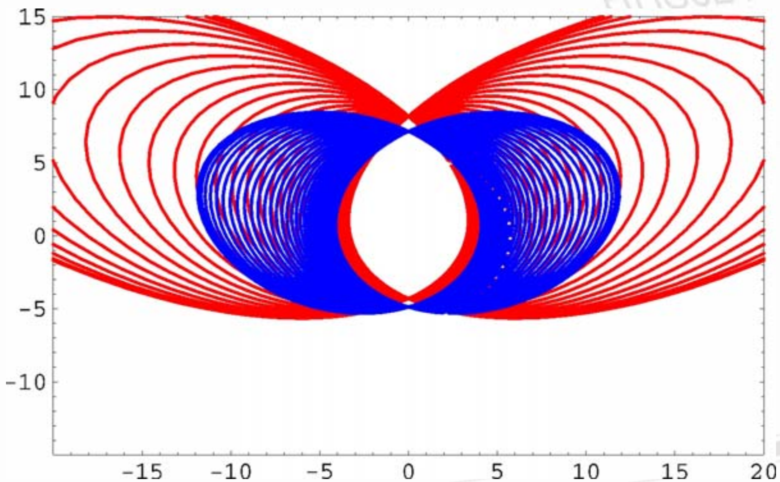
ISOCHRONES

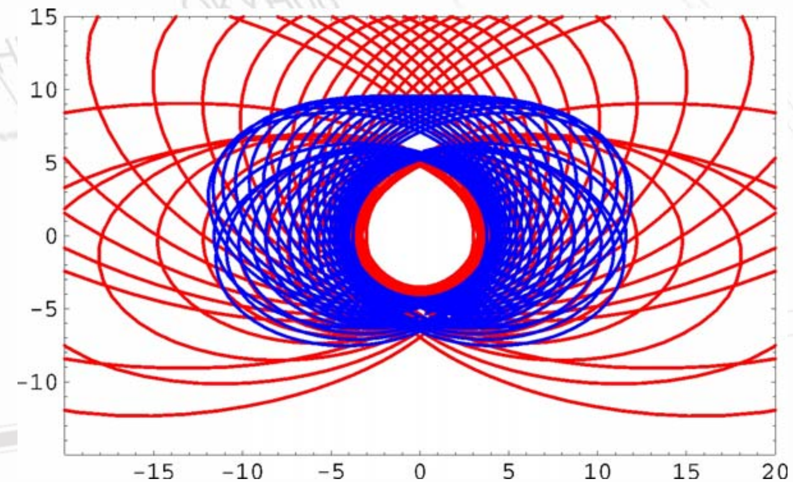
Strike-slip fault (dip 90) | Fault dipping 60





r_{Epi}=15 km, z_{Hypo} = 15km



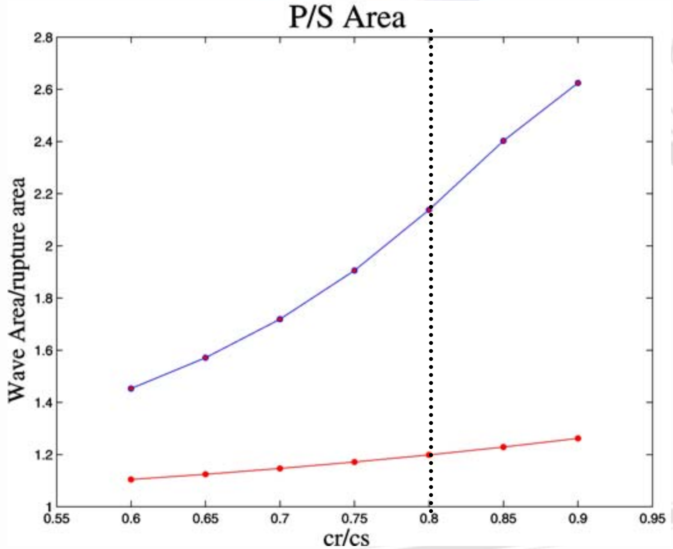


r_{Epi}=40 km, z_{Hypo} = 15km

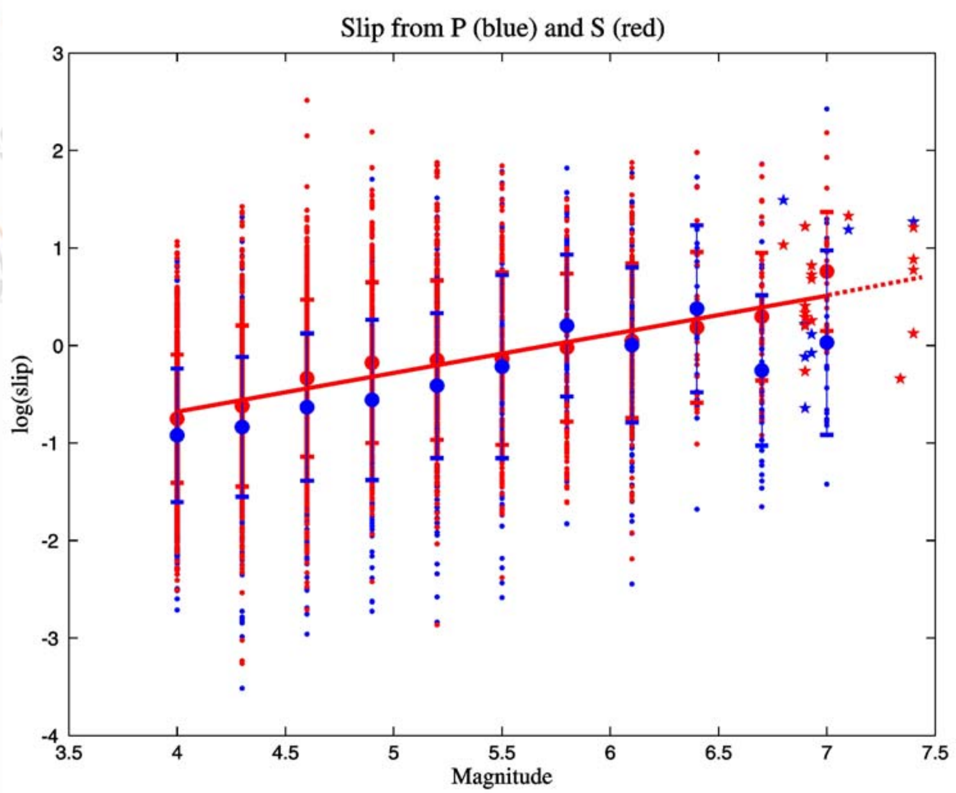
We analytically evaluate the average area spanned by 2s P/S waves (for r_{Epi} =30 km, c_s=3.3 km/s, c_p=5.4 km/s):

- The average area is not influenced by the hypocenter location
- For c_r/c_s=0.8, we found A_P=120 km^2, A_S=220 km^2

  For a Brune model we have M_P=6 and M_S=6.3



Velocity integral → Radiated Energy → ($\Delta\sigma$=10 MPa) Slip



Best fit : log(slip) = a M + b

a= 0.39 ± 0.04

b= -2.27 ± 0.25

CONCLUSIONS

Early velocity integral (radiation) can be used as an indicator for magnitude

Japanese data are interpreted by a two-slopes model with crossover low limit at M=5.2 for P waves and M=5.8 for S waves.

2-s slip correlates with magnitude between 4 and 7 (7.5).
Errors indicate that we can individuate the scale of the rupture but not details.

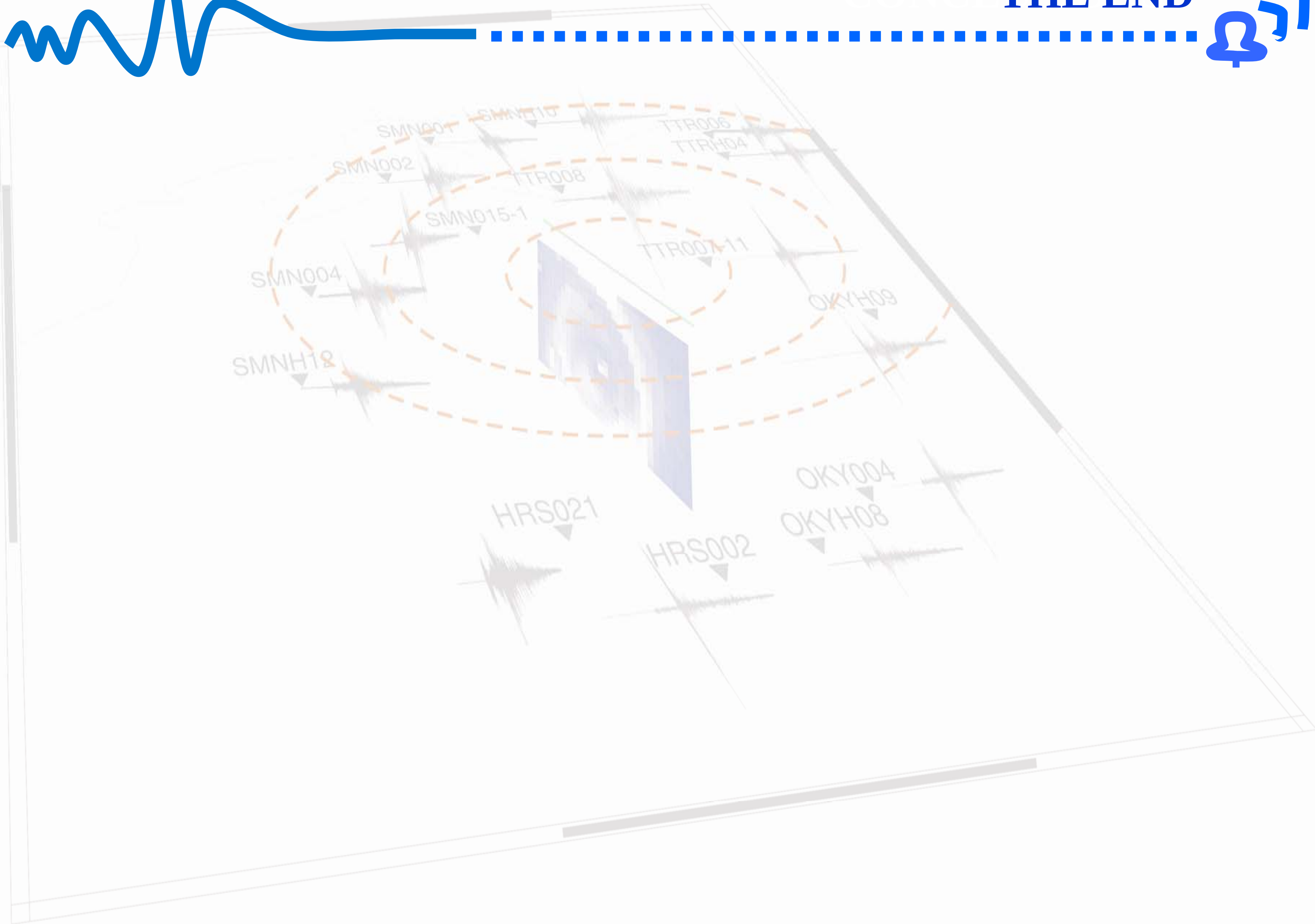
For Japanese dataset, P waves saturate at M=6.5, whilst S waves do not.
Limited database ? Absorption of P waves more effective than S waves ?
Surface slip ?

Perspectives :

Extend the analysis to events whose magnitude is larger than 7.

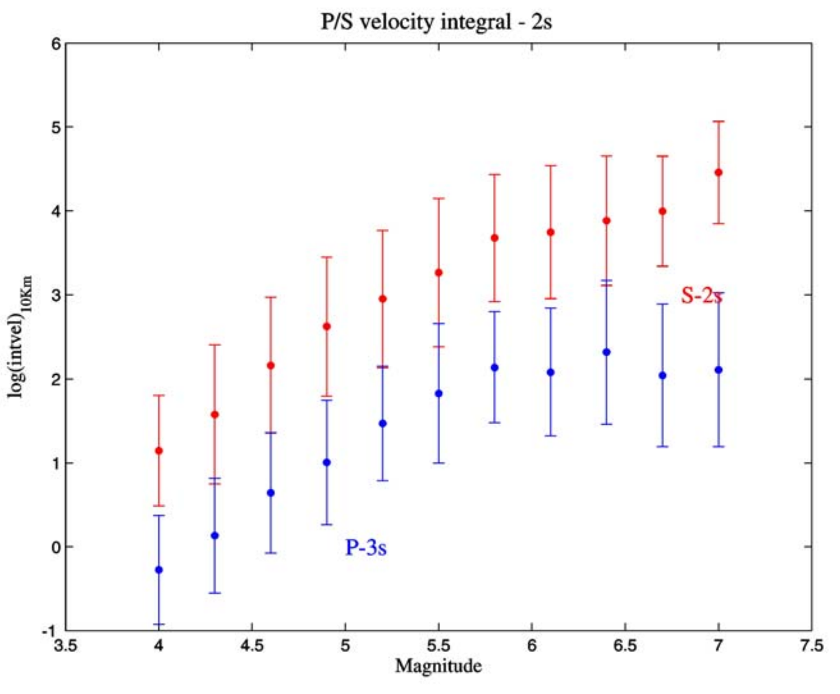
We can use this approach in a bayesian estimate of the missed/false alarm probabilities for warning threshold.

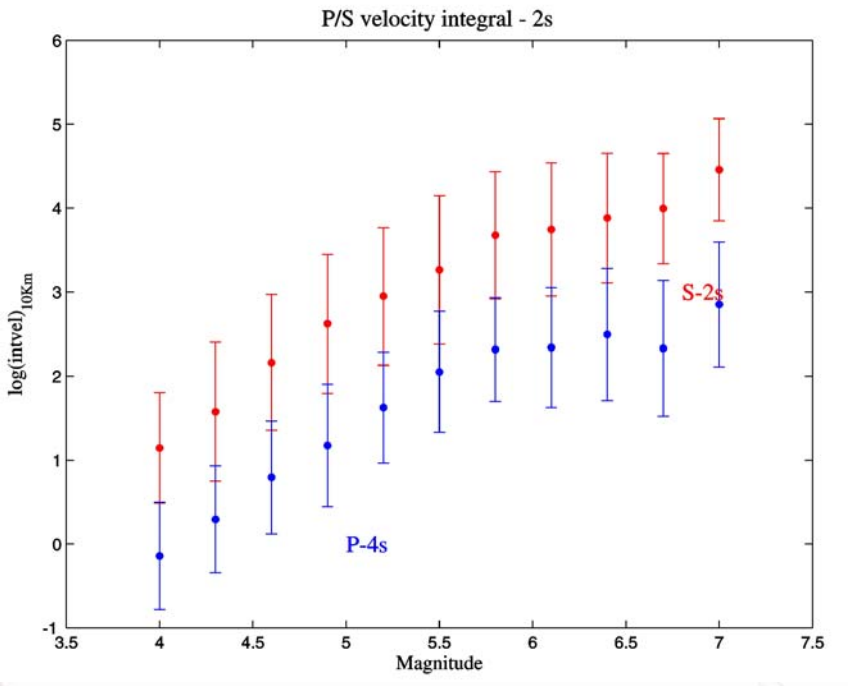
THE END



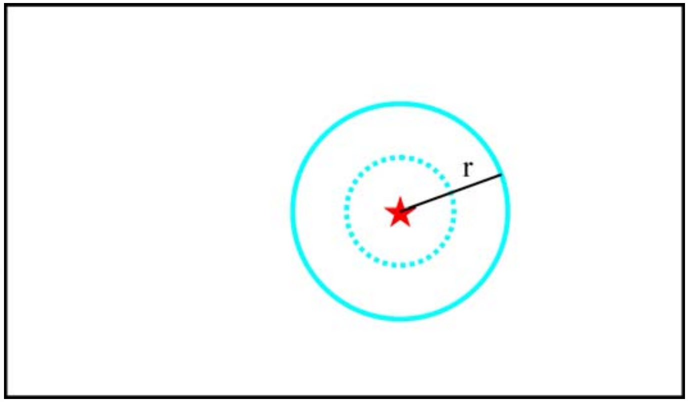
SMN002
TTR008
SMN015-1
TTR007-11
SMN004
OKYH09
SMNH12
OKY004
HRS021
OKYH08
HRS002

3P/4P/2S

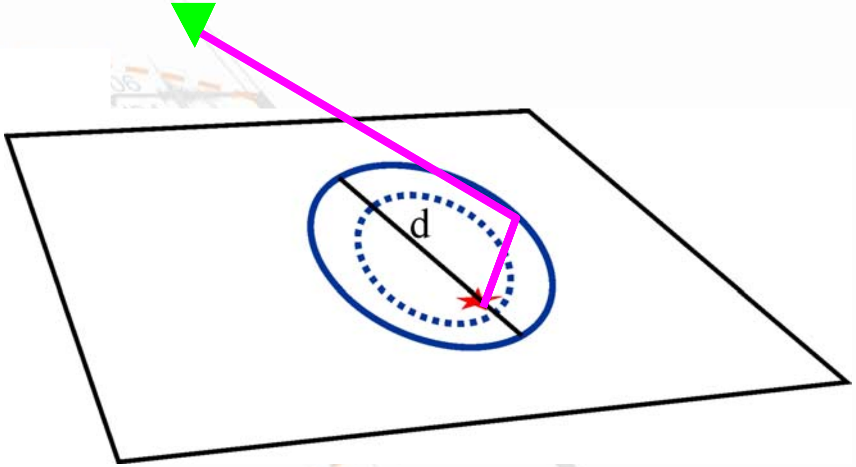

P/S velocity integral - 2s
log(intvel)10Km
Magnitude
S-2s
P-3s


P/S velocity integral - 2s
log(intvel)10Km
Magnitude
S-2s
P-4s

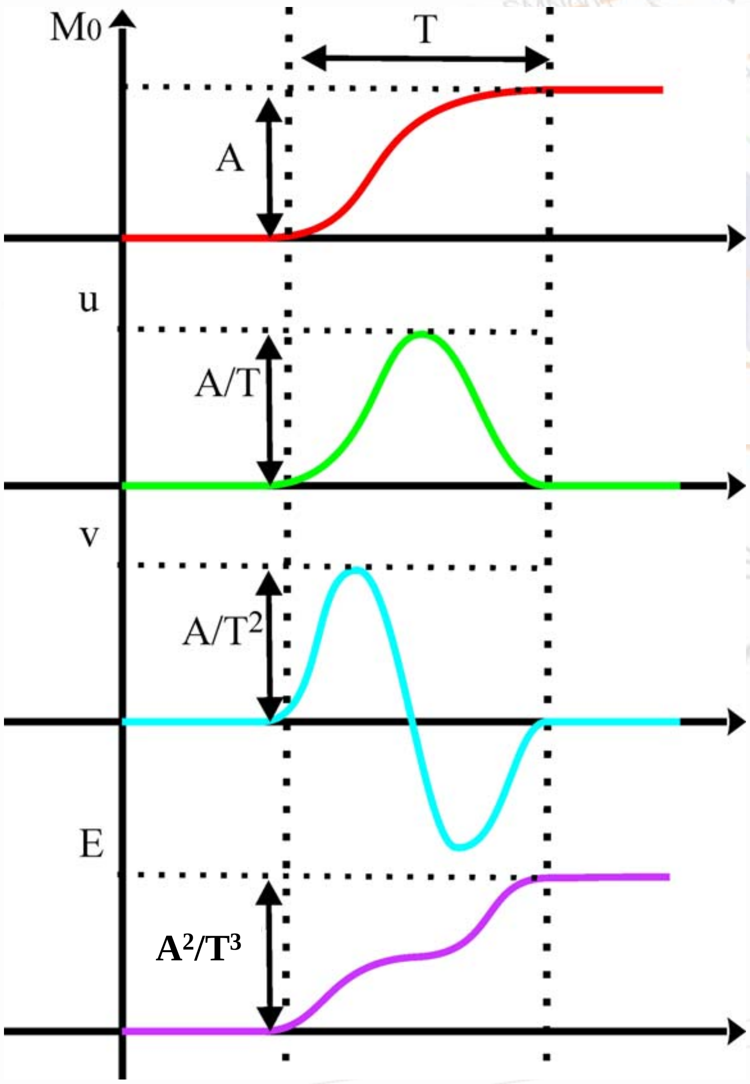
ISOCHRONES

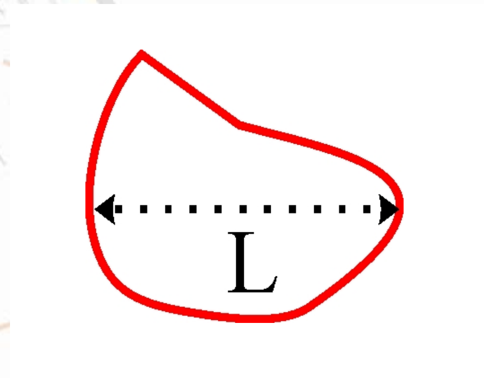


$$2 = t_r = r / v_r$$



$$T = 2 + t_{hypo} = t_r + t_p$$





$$A : L^2$$

$$\Delta u : \frac{\Delta\sigma}{\mu} L$$

$$M_0 : \Delta\sigma L^3$$

$$T : L$$

$$u_{max} : \Delta\sigma L^2 : M_0^{2/3}$$

$$E_R : \Delta\sigma^2 L^3 : \Delta\sigma M_0$$