



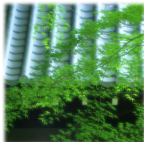
# Using W phase for regional tsunami warning and rapid earthquake hazard assessment

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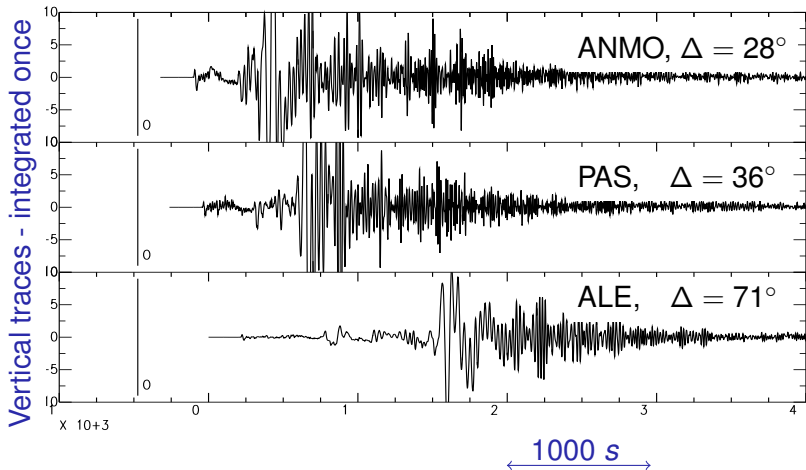
<sup>2</sup>Seismological Laboratory, Caltech

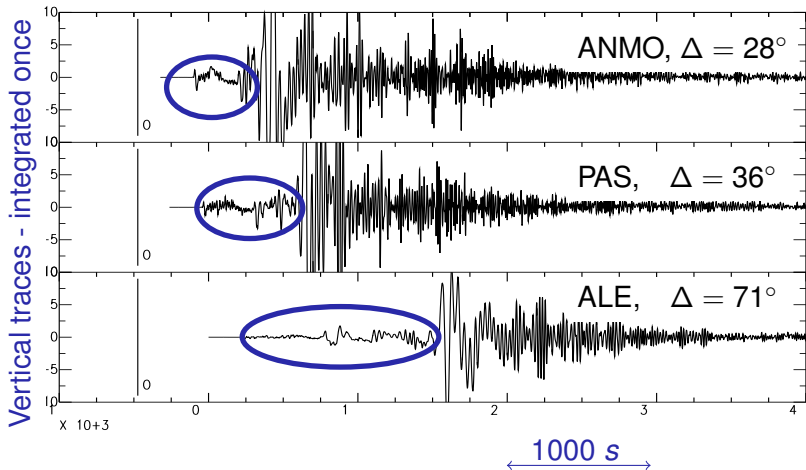
2nd International Workshop on Earthquake Early Warning  
Kyoto, April 21-22, DPRI, Kyoto University



## *Introduction*

- ▶ We have recently developed a source inversion technique based on the waveform modeling of W-phase.
- ▶ W-phase is a very long period (200s-1000s) phase arriving right after the P.
- ▶ It was first recognized after the 1992 Nicaragua earthquake.
- ▶ The inversion technique was originally devised to work for large events ( $M_w > \sim 7.5$ ) with teleseismic data and it provides a VLP characterization of the source (e.g. Tsunami earthquakes).
- ▶ **We explore here the possibility of an application with regional data and with smaller magnitudes.**

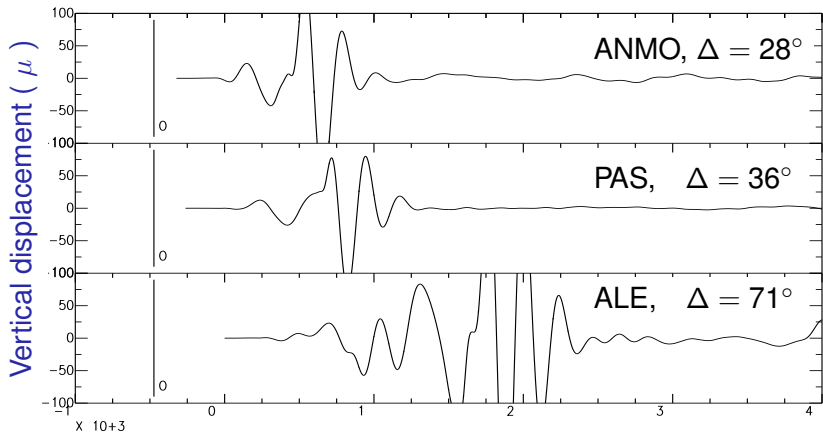




W-phase:

Example: Nicaragua, 1992

Deconvolved + bp 200s-1000s



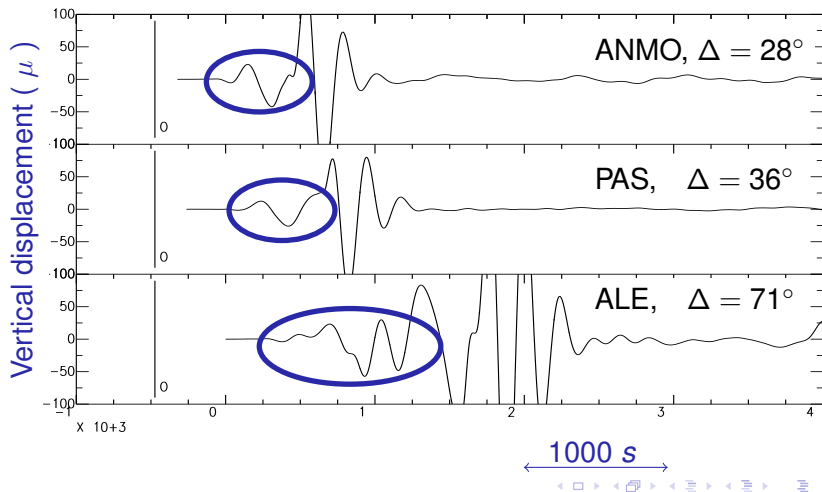
1000 s



W-phase:

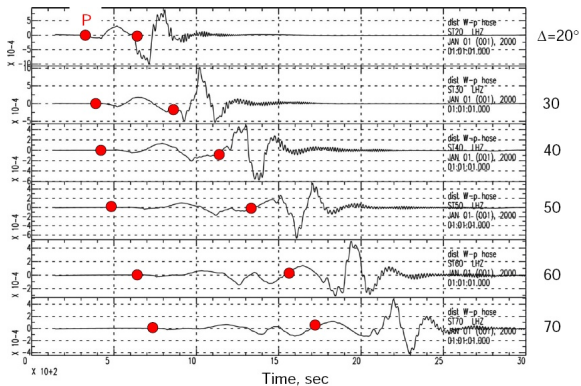
Example: Nicaragua, 1992

Deconvolved + bp 200s-1000s

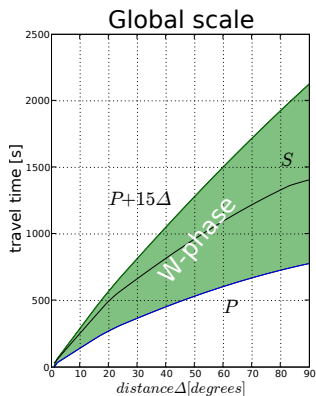


# Time window

*W-phase time-window*  
 $P, P + 15\Delta \text{ s}/\circ$



# W-phase in the global context



## Definition

- ▶ Time window: P, P+15 $\Delta$
- ▶ Bandpass: .001 Hz - .005 Hz

## Properties

- ▶ Fast group velocity: 4.5-9 km/s
- ▶ Fairly insensitive to:
  - ▶ shallow lateral heterogeneities
  - ▶ source second order details
- ▶ Avoid large amplitude surface waves



# Source retrieval from W-phase

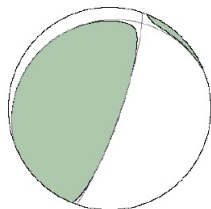
## *Inversion: main features*

- ▶ Time domain
- ▶ Point source (VLP data)
- ▶ Need a preliminary source location: PDE, JMA
- ▶ Library of precomputed Green's functions
- ▶ Linear inversion → Moment tensor components
  - ▶ PDE ( $\Delta < 50^\circ$ ):  $t_0 + 20$  min
  - ▶ Grid search ( $\Delta < 90^\circ$ ):  $t_0 + 35$  min
- ▶ RT implementation:  $\beta$ -test at NEIC-USGS, (Gavin Hayes)

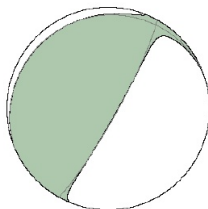
# Example: global data

## *Tokachi-Oki-2003*

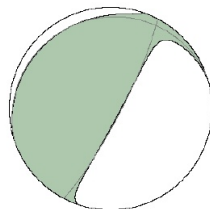
2003 Tokachi-oki WP inversion



PDE location  
 $t_h = 30s, t_d = 30s$   
 $M_w = 8.24$



Optimized centroid  
 $t_h = 30s, t_d = 30s$   
 $M_w = 8.31$



GCMT centroid  
 $t_h = 31.8s, t_d = 33.5s$   
 $M_w = 8.27$



CMT  
 $M_w = 8.3$

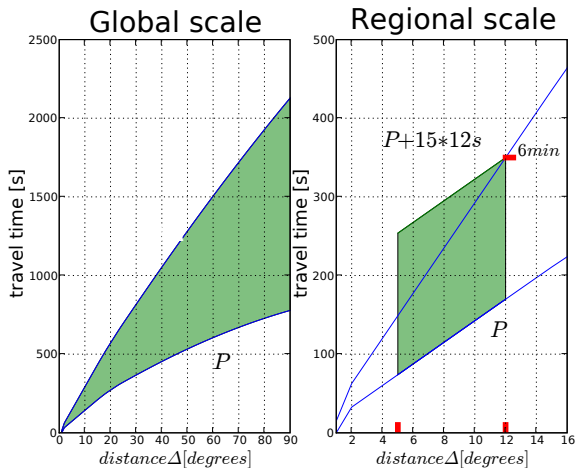
$t_0 + 20$  min

$t_0 + 35$  min

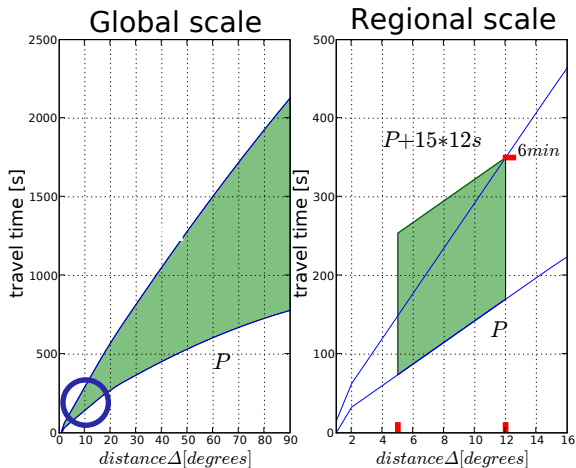
## *Extension to regional data and lower magnitudes*

- ▶ Target:  $M_w > \sim 6.5$
- ▶ Data distribution:
  - ▶  $\Delta < 12^\circ \rightarrow 6 \text{ min.}$
  - ▶  $\Delta > 5^\circ$ : high gain data, nonlinearity.
- ▶ Modifications:
  - ▶ Time window: (P, P+15 $\Delta$ ) inappropriate
  - ▶ Frequency band: signal/noise ratio

# W-phase time window

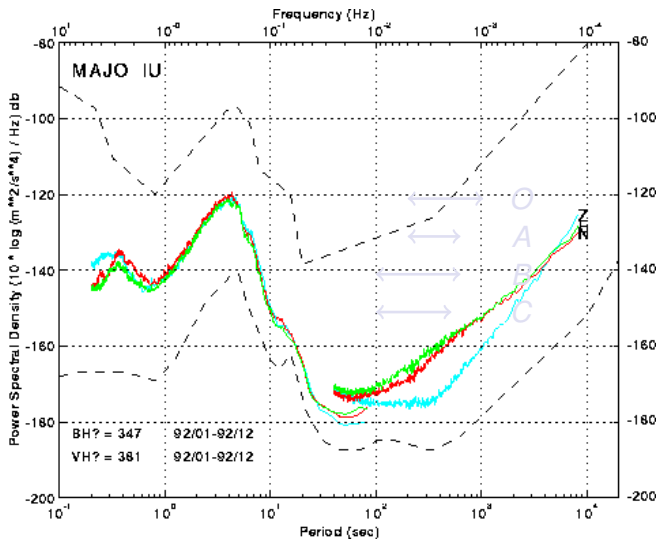


# W-phase time window



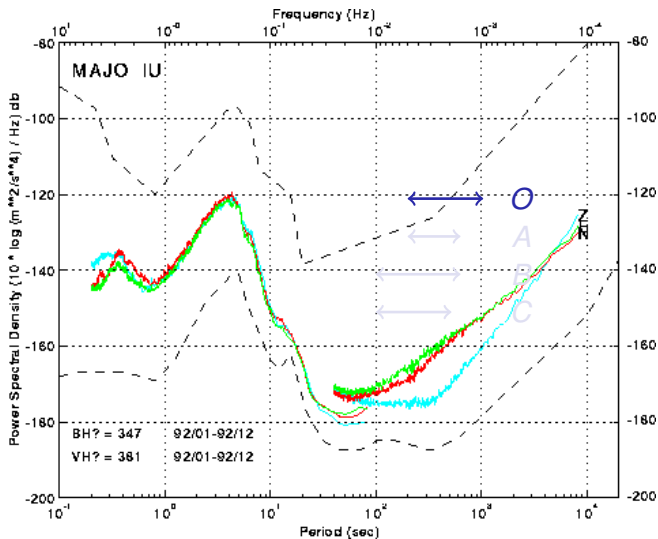
# Extension to lower magnitudes

## *Acceleration noise spectrum at MAJO*



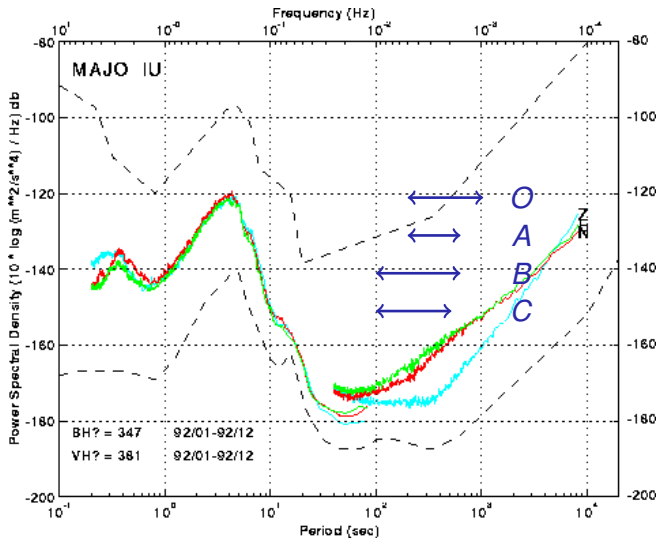
# Extension to lower magnitudes

## Acceleration noise spectrum at MAJO



# Extension to lower magnitudes

## Acceleration noise spectrum at MAJO



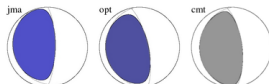




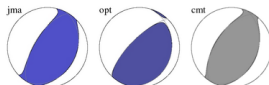
# F-net, 2003-2008, $M_{jma} > 6.7$ (1/4)



200610232117A - 2006\_Torishima Mw 6.37(C)



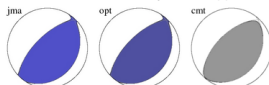
200501190611A - 2005\_off\_Honshu Mw 6.54(C)



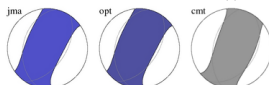
102304D - 2004\_mid\_Nigata Mw 6.56(C)



200503200153A - 2005\_Kyushu Mw 6.58(C)



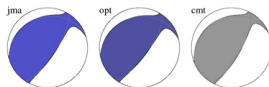
200707160113A - 2007\_Chuetsu-oki Mw 6.62(C)



200703250041A - 2007\_Noto-oki Mw 6.68(C)



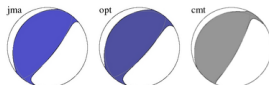
# F-net, 2003-2008, $M_{jma} > 6.7$ (2/4)



120604A - 2004\_Nemuro\_2 Mw 6.74(C)



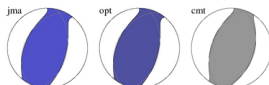
200807231526A - 2008\_Miyagi-Iwate Mw 6.80(C)



200809110020A - 2008\_Koshiro-oki Mw 6.77(C)



200805071645A - 2008\_Ibaraki Mw 6.85(C)



200806132343A - 2008\_Iwate Mw 6.88(C)



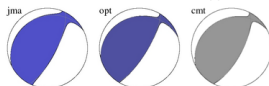
200807190239A - 2008\_Fukushima Mw 6.91(C)



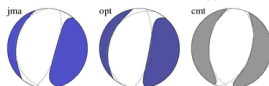
# F-net, 2003-2008, $M_{jma} > 6.7$ (3/4)



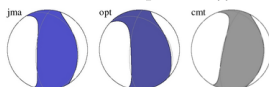
103103A - 2003\_Fukushima Mw 6.97(C)



1128041 - 2004\_Nemuro\_1 Mw 6.98(C)



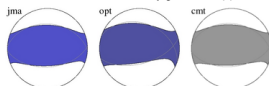
200511142138A - 2005\_Sanriku Mw 6.98(C)



052603A - 2003\_Miyagi-oki Mw 6.99(C)



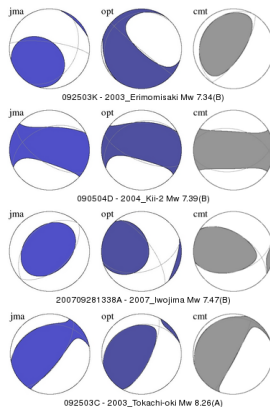
200508160246A - 2005\_Miyagi-oki Mw 7.19(B)



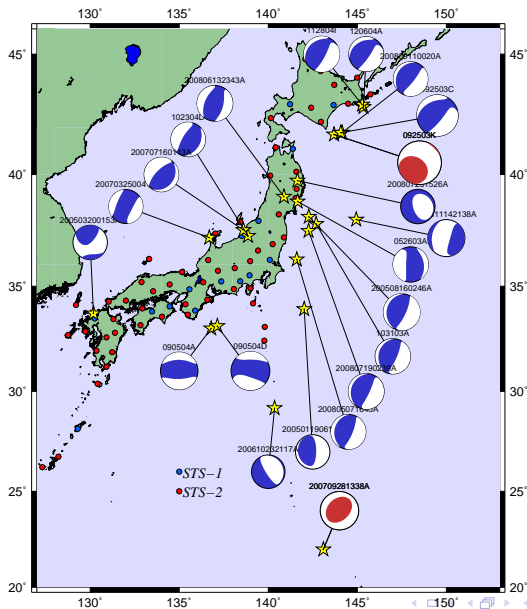
090504A - 2004\_Kii-1 Mw 7.20(B)



# F-net, 2003-2008, $M_{jma} > 6.7$ (4/4)

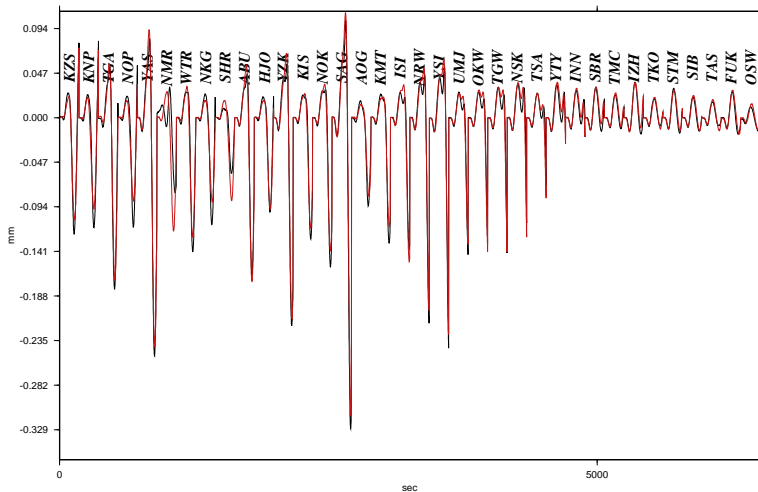


# Regional W phase focal mechanisms ( $t_0 + 6min$ )

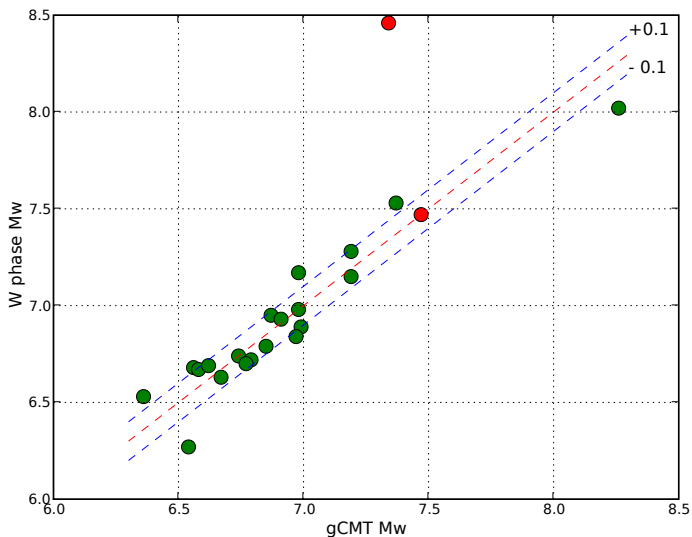


# Regional W-phase, example of fit: 2008 Iwate

200806132343A ( 0.002 Hz - 0.010 Hz,  $n = 4$ , W )

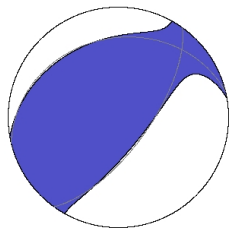


# Moment Magnitude: gCMT - W-phase





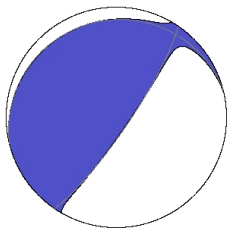
## 2003 Tokachi-oki: depth effect



$H = 45\text{km}$

$\delta = 29^\circ$

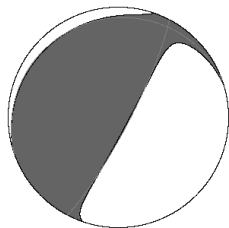
$M_w = 8.02$



$H = 28\text{km}$

$\delta = 14^\circ$

$M_w = 8.15$



$HVD(H = 28\text{km})$

$\delta = 11^\circ$

$M_w = 8.26$

## Conclusions

- ▶ We use F-net data in the range ( $5^\circ < \Delta < 12^\circ$ )
- ▶ Time window:  $t_P, t_P + 180s$
- ▶ Variable frequency band:  
(.00167Hz – .005Hz)  $\rightarrow$  (.005Hz.010Hz)
- ▶ Moment tensor solution available at  $t_0 + 6min$
- ▶ Can be done completely automatic and
- ▶ Provide a solution 6 min after the origin time.