

# ESCENARIO CATASTRÓFICO PARA LIMA Y EL CALLAO ANTE UN SISMO DE GRAN MAGNITUD ( $> M8.0$ )



XXXIV SIMPOSIO NACIONAL DE  
PREVENCIÓN DE DESASTRES

## Análisis de Interferometría Sísmica para la Estimación de Perfiles Profundos en Lima

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INVESTIGACIONES SÍSMICAS Y  
MITIGACIÓN DE DESASTRES

FACULTAD DE  
INGENIERÍA CIVIL

UNIVERSIDAD NACIONAL  
DE INGENIERÍA



# ESTIMACIÓN DE PERFILES SÍSMICOS



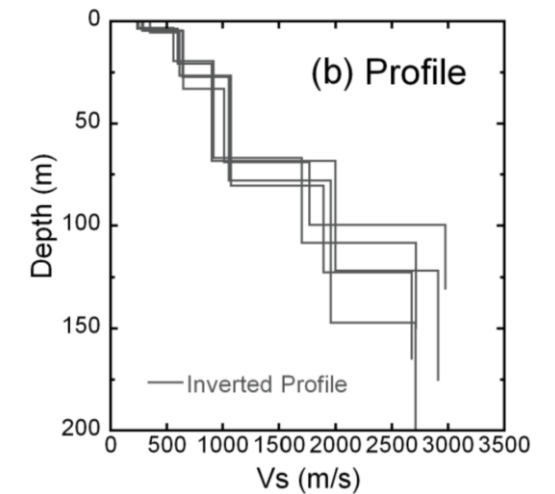
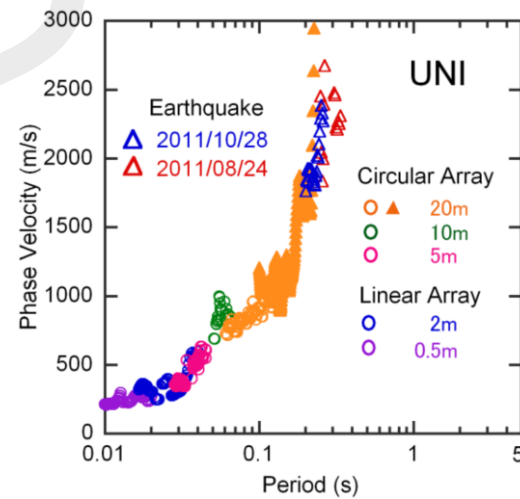
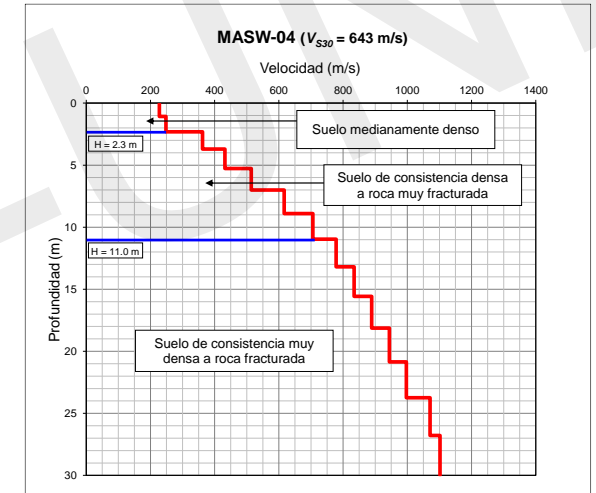
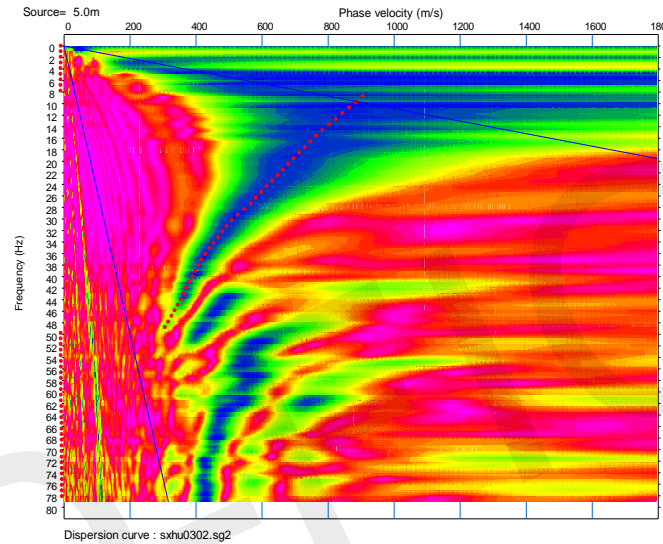
MASW

CISMID (2022). Microzonificación Sísmica de Huaral



ARREGLO DE MICROTREMORES

Calderón (2014)



# Importancia del perfil sísmico $V_s$

- Permite conocer la distribución de los materiales en profundidad. (Impedancia).
- Permite estimar los parámetros dinámicos o proxy ( $V_s$ , profundidad de roca).
- Modelamiento para el análisis de respuesta sísmica (espectros de respuesta, PGA) para el diseño estructural.
- Permite conocer los efectos de sitio (periodo fundamental del suelo).

# Interferometría Sísmica

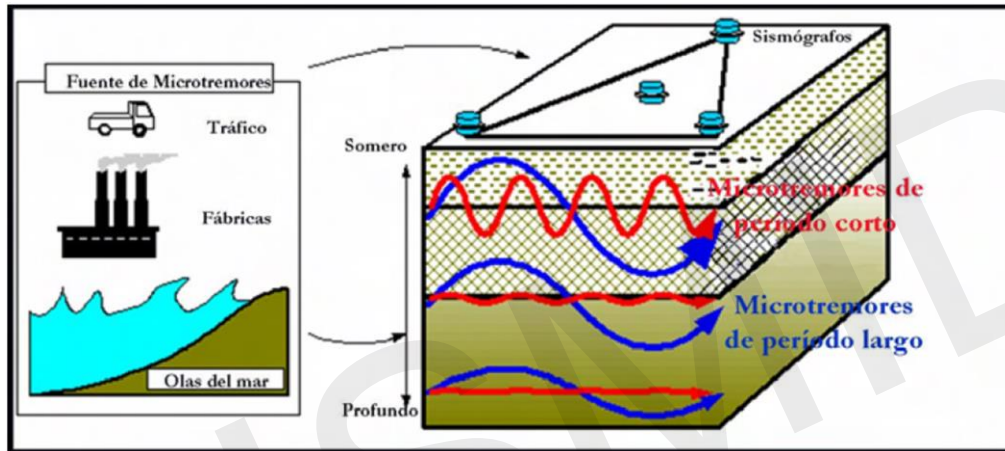
Registros continuos de ruido ambiental

Shapiro (2004)

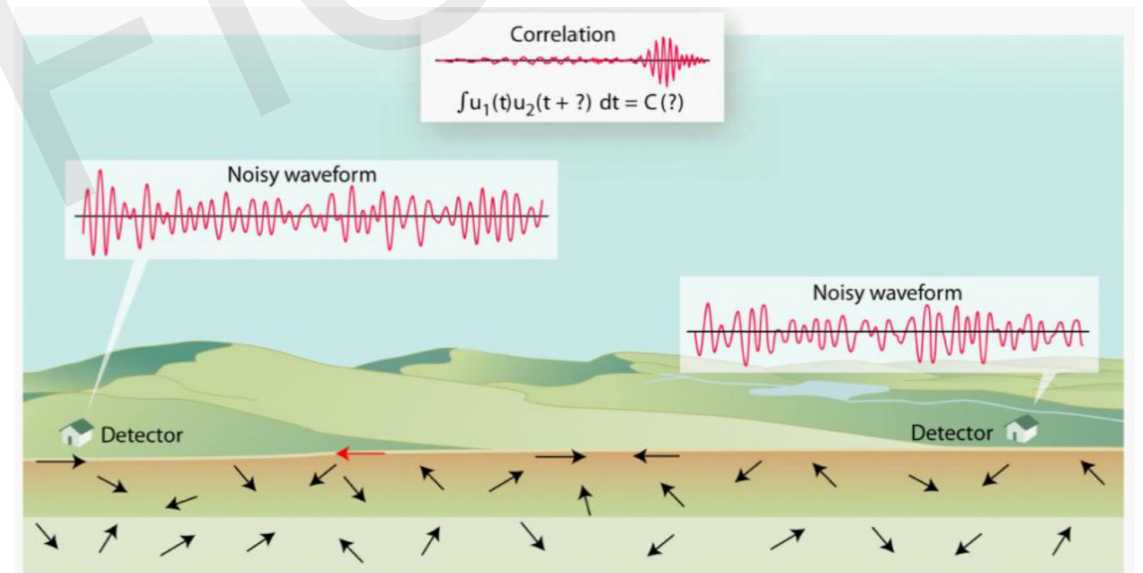
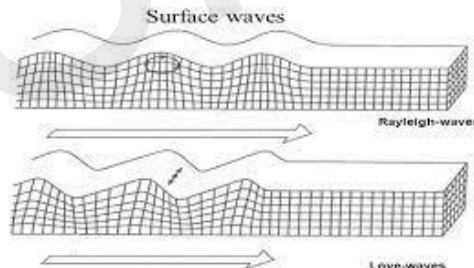
C.C. →

Función de Green

$$C_{fg}(\tau) = \int_{-\infty}^{\infty} f(t)g(t + \tau)dt$$



Linares (2005)



Gaite (2013)

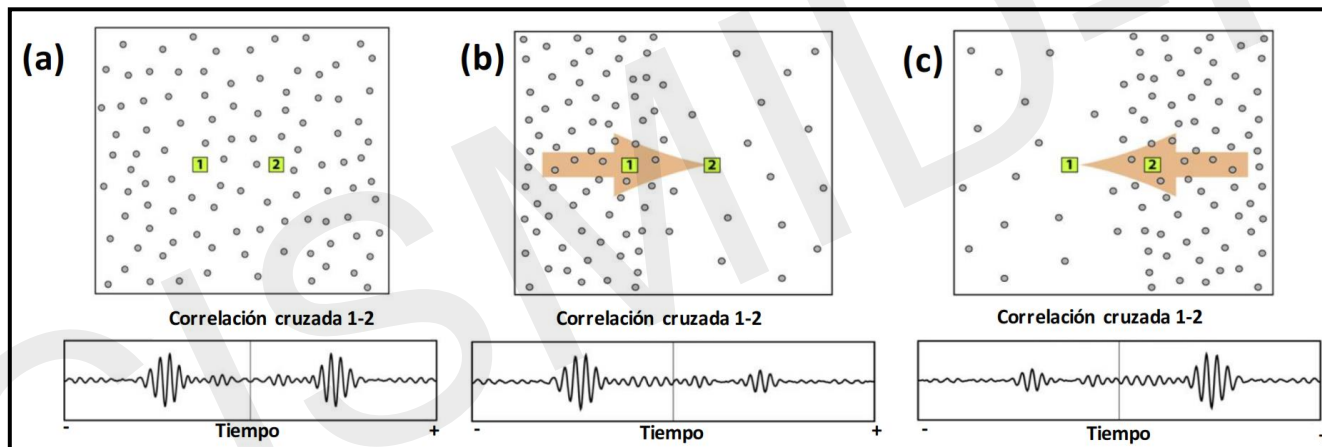
# OBJETIVO

Obtener perfiles sísmicos a partir de las correlaciones cruzadas del medio entre dos estaciones.

INPUT: Registros continuos de ruido ambiental

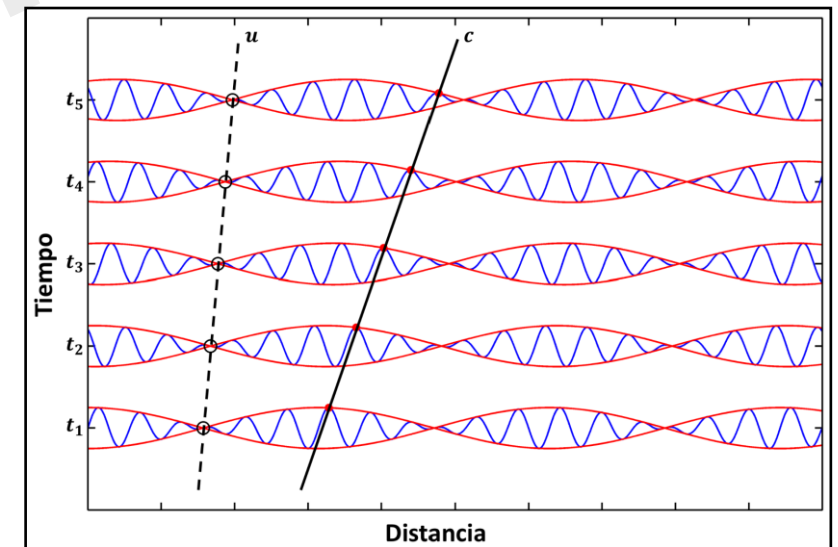


OUTPUT: Perfiles sísmicos



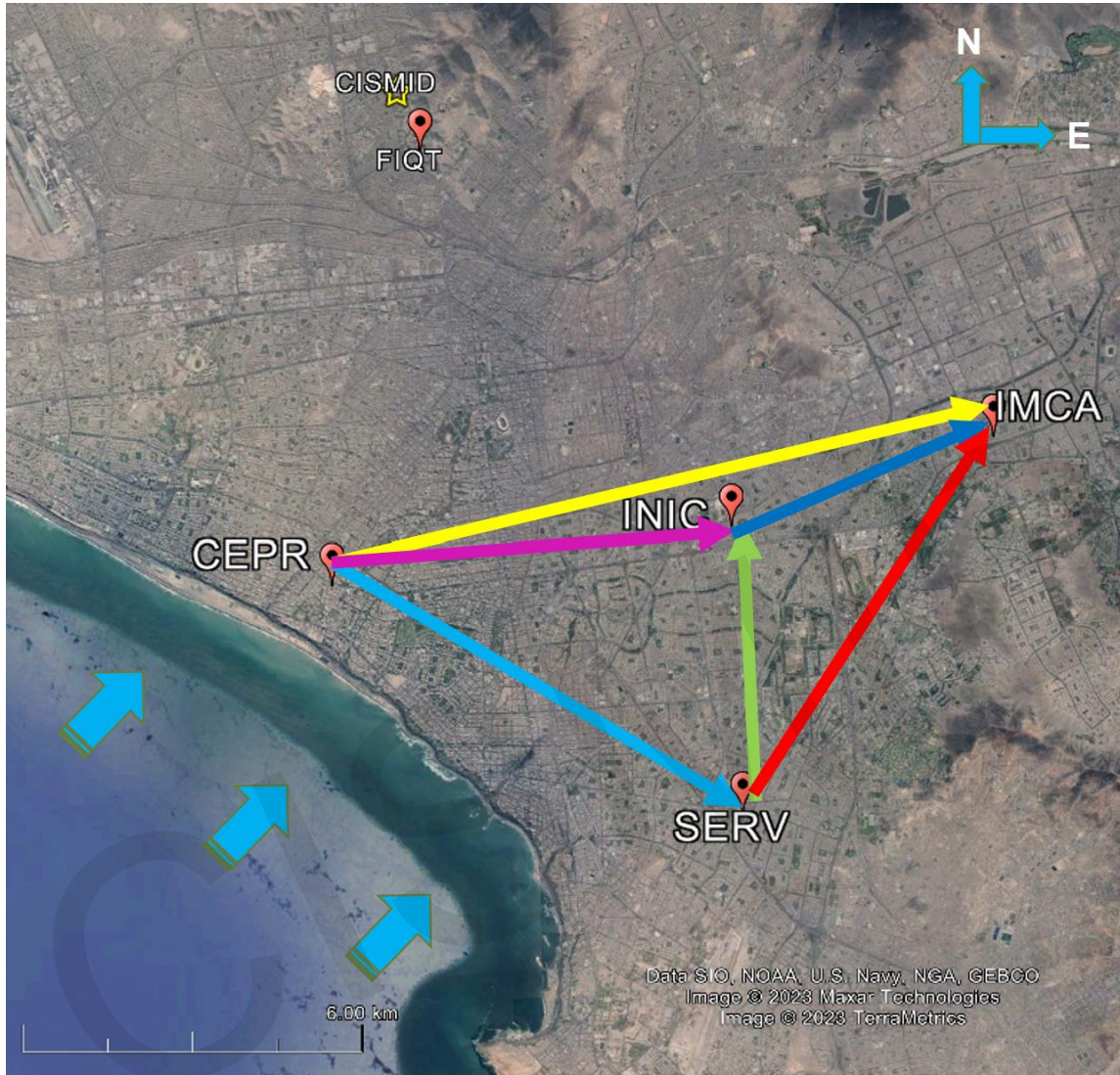
Gaite (2013)

$$\rho_{12}(w) = F(w) \cdot G^*(w)$$



Sáenz (2016)

# UBICACIÓN DE LOS SENSORES



DATA LOGGER



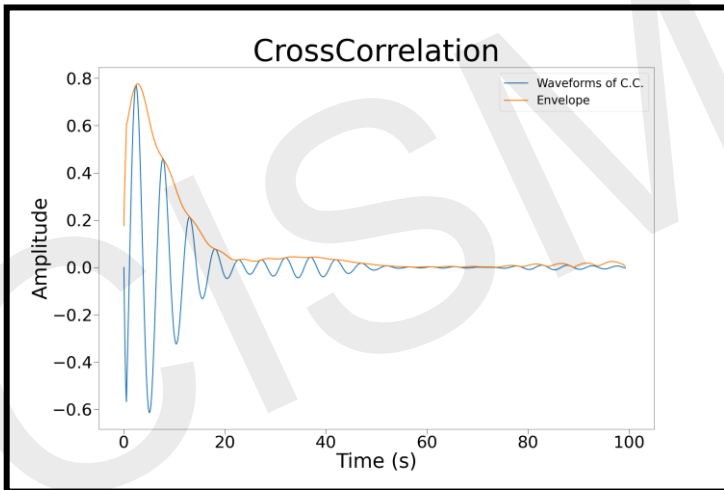
SENSORES

# PROCESAMIENTO

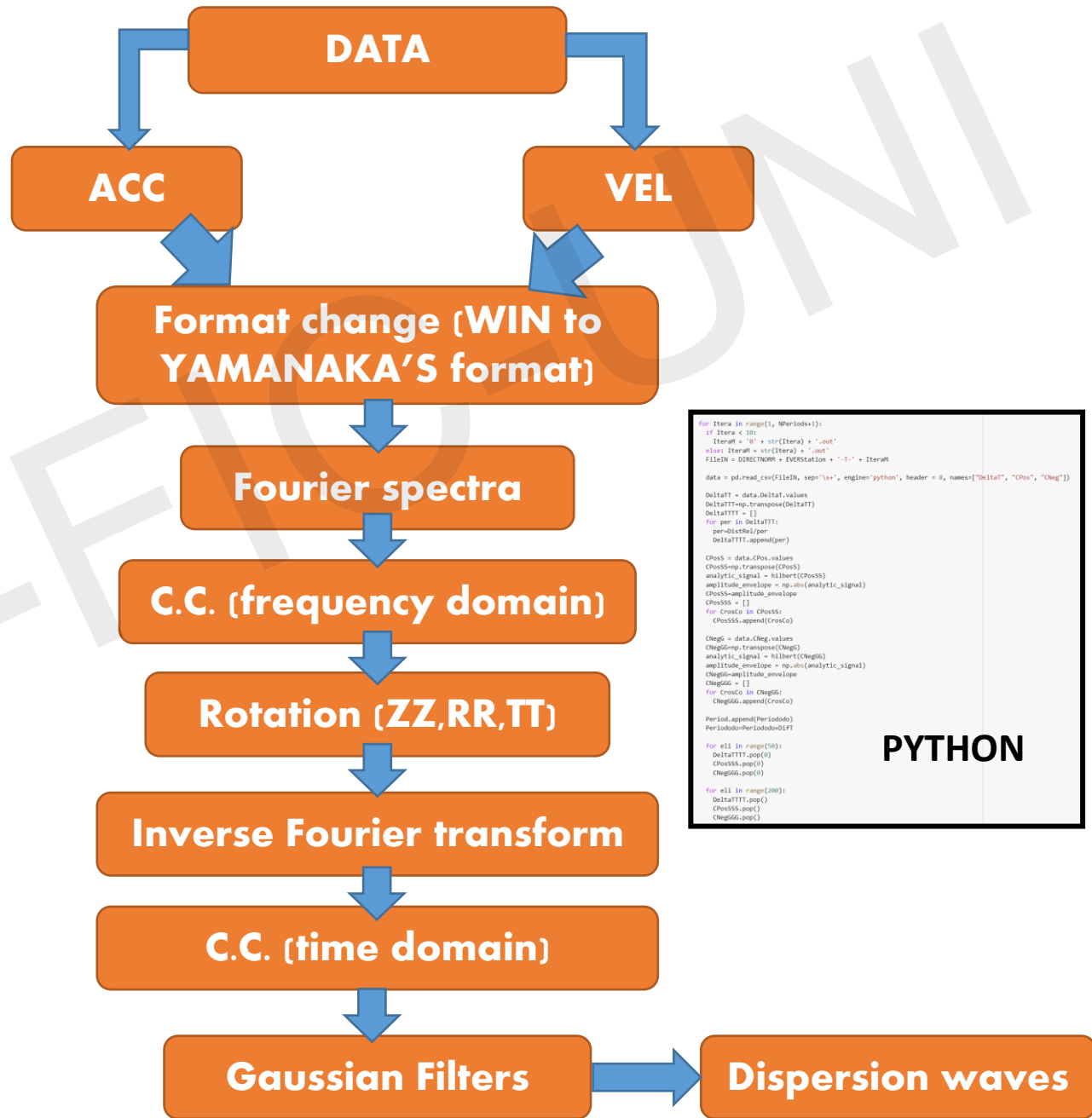
DATA = 77 días (más de 200 GB)

```

03 CEPREUNI /2022/12/25/00
 0.010003600.00000 2.84276566e-03 360000 325758
-3.06170031E-05-5.58491061E-05 1.78470973E-05 2.36935602E-05-5.96954632E-05
-4.13868031E-05-6.30802576E-06 4.03098231E-05-5.47721261E-05 5.55413975E-05
1.24621972E-05-3.18478374E-05 1.10775086E-05 4.07713860E-05 5.84646290E-06
-6.76958862E-06-1.96933487E-05 3.12324202E-05 5.38490004E-06-3.50787774E-05
-4.66178489E-05 2.61552287E-05 2.24627259E-05 3.43095059E-05 3.38479431E-05
-3.55403402E-05-5.52336889E-05-5.63106689E-05 9.30818435E-05 7.95426662E-05
3.36940888E-05-1.84625144E-06 5.80030661E-05 4.13868031E-05-2.80014802E-05
-1.01543829E-05-4.26176374E-05-1.36930315E-05-2.92323145E-05 2.38474144E-05
1.24621972E-05-4.29253460E-05 3.67711745E-05-1.30776144E-05-9.69282006E-06
-5.38490004E-05-5.60029604E-05 3.58480488E-05-4.30792003E-06-1.30776144E-05
1.47700115E-05-2.83091888E-05 7.18499519E-05 5.35412918E-05-7.07729719E-06
9.23125720E-06-7.84656862E-06 9.84667435E-06 4.55408689E-05-4.93872260E-05
3.10785659E-05 2.30781430E-05-1.53854287E-05 1.07698001E-05-5.81569204E-05
-1.53854287E-05 8.21581891E-05-1.73855344E-05 3.06170031E-05 4.61562860E-07
    
```



$$\lambda_{\text{máx}} = R/2$$

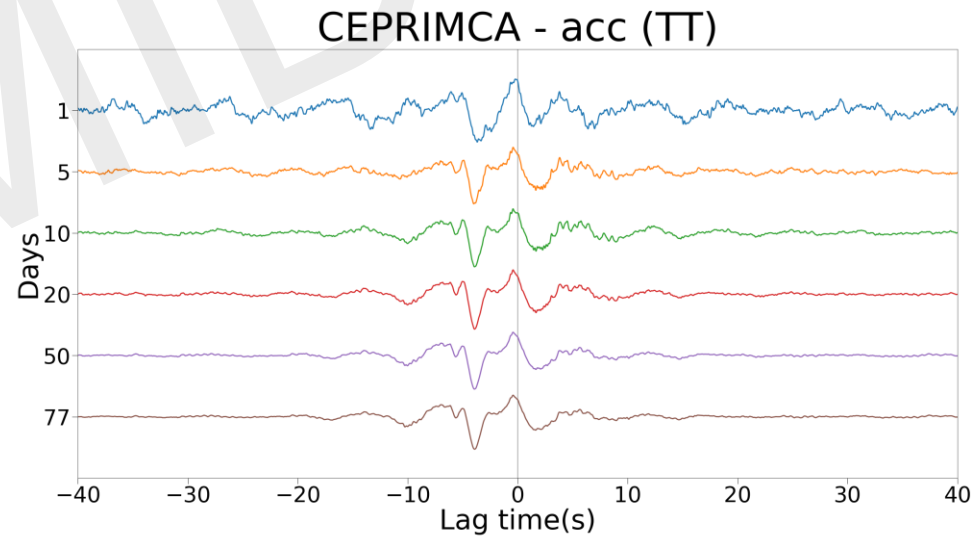
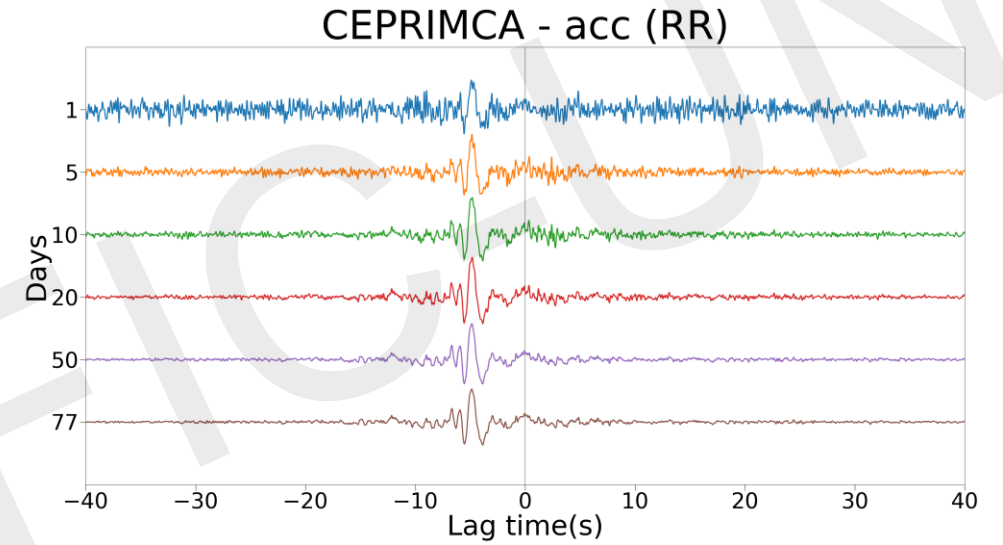
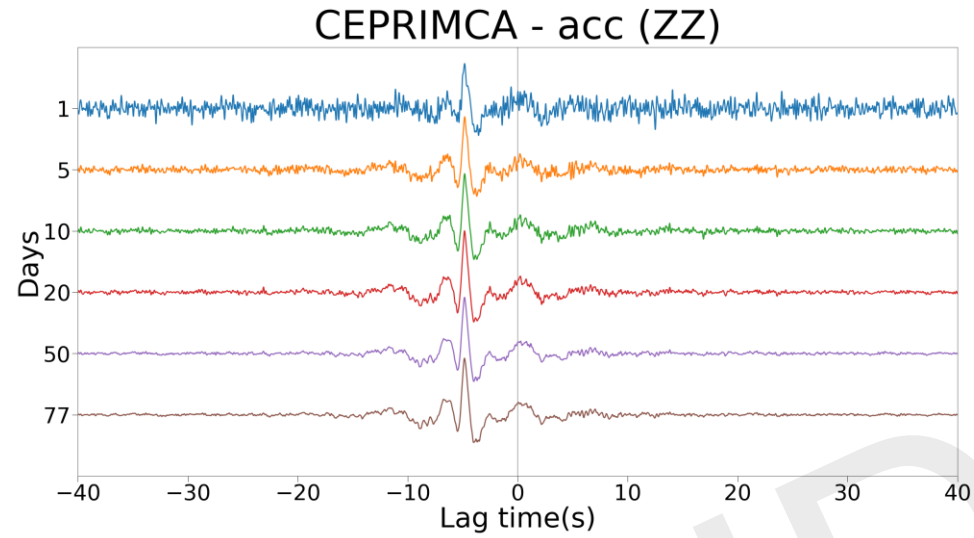


```

for Itera in range(1, NPeriods+1):
    if Itera < 10:
        Itera = '0' + str(Itera) + ".out"
    else:
        Itera = str(Itera) + ".out"
    FileIN = DIRECTORIO + EVERStation + ".T." + Itera
    data = pd.read_csv(FileIN, sep='|', engine='python', header = 0, names=["DeltaT", "CPos", "CNeg"])
    DeltaTT = data.DeltaT.values
    DeltaTTng.transpose(DeltaTT)
    DeltaTTT = []
    for per in DeltaTT:
        per-DeltaT(per)
        DeltaTTT.append(per)
    CPos = data.CPos.values
    CPosng.transpose(CPos)
    analytic_signal = hilbert(CPos)
    amplitude_envelope = np.abs(analytic_signal)
    CPosSS = []
    for CPosCo in CPos:
        CPosSS.append(CPosCo)
    CNeg = data.CNeg.values
    CNegng.transpose(CNeg)
    analytic_signal = hilbert(CNeg)
    amplitude_envelope = np.abs(analytic_signal)
    CNegSS = []
    for CNegCo in CNeg:
        CNegSS.append(CNegCo)
    Period.append(Periodo)
    Periodo=Periodo+1
for e1 in range(50):
    DeltaTTT.pop(0)
    CPosSS.pop(0)
    CNegSS.pop(0)
for e1 in range(200):
    DeltaTTT.pop(0)
    CPosSS.pop(0)
    CNegSS.pop(0)
    
```

PYTHON

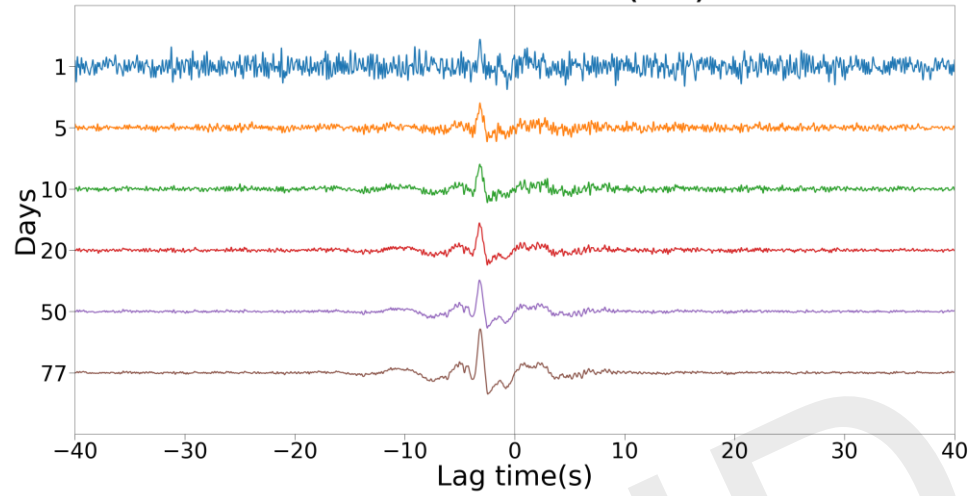
# ANÁLISIS



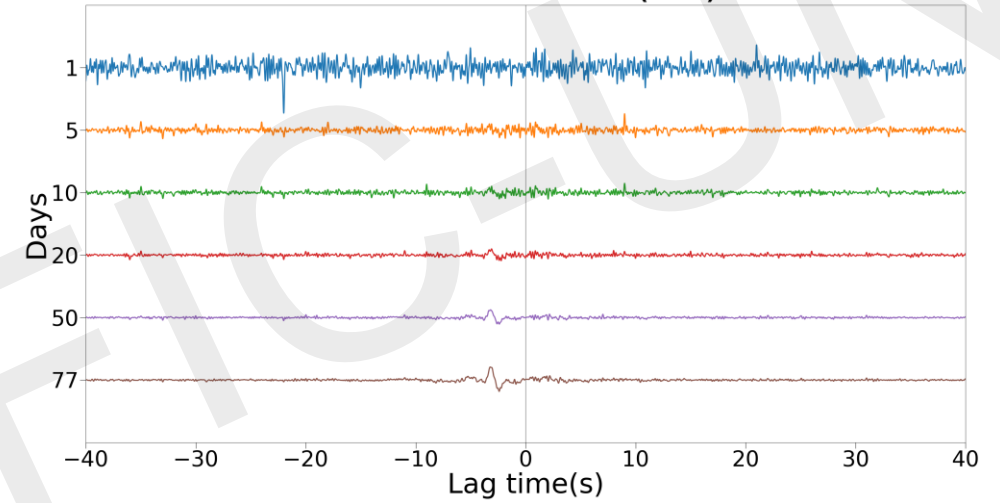


# ANÁLISIS

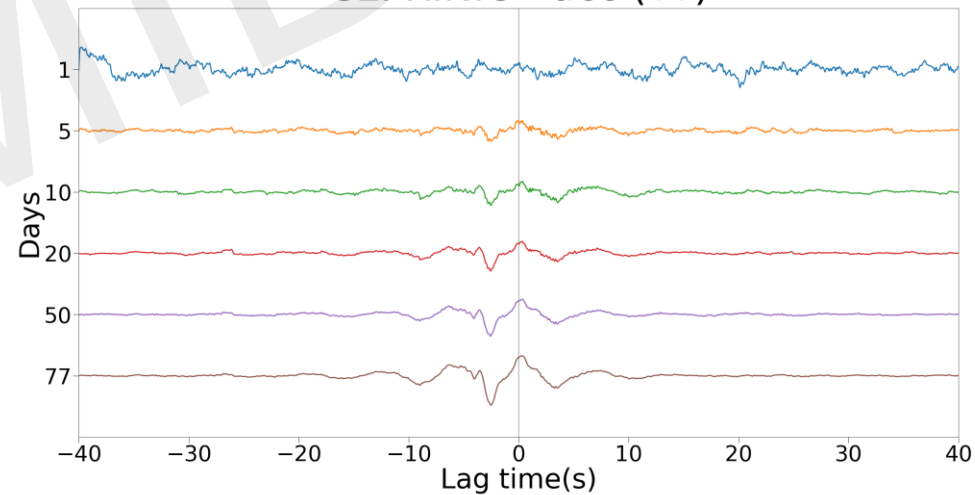
CEPRINIC - acc (ZZ)



CEPRINIC - acc (RR)

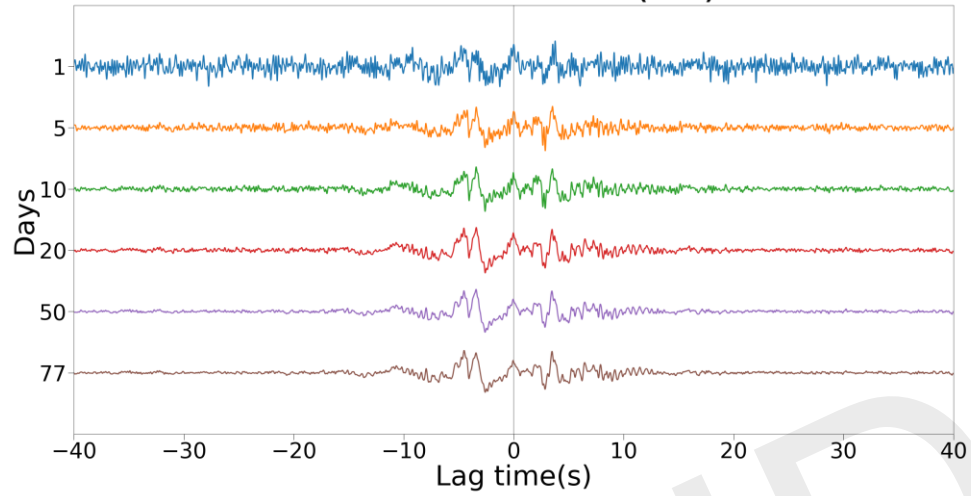


CEPRINIC - acc (TT)

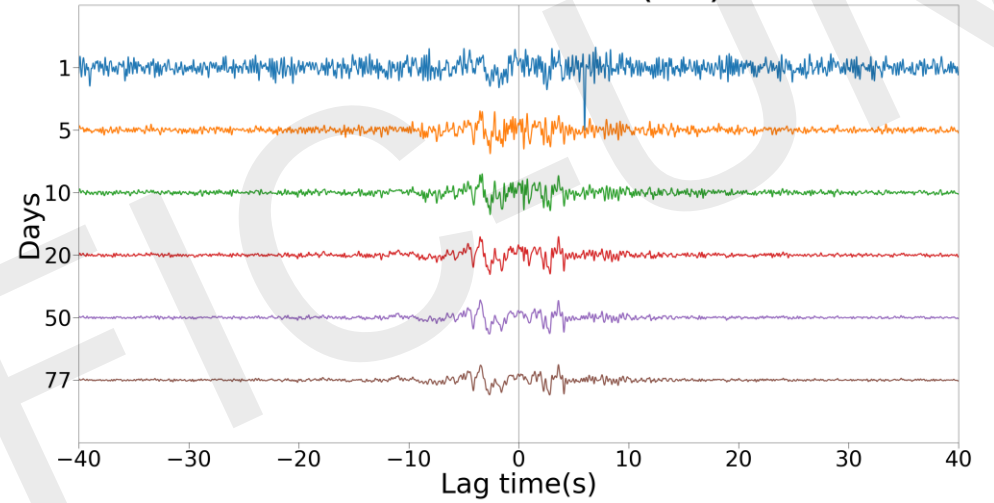


# ANÁLISIS

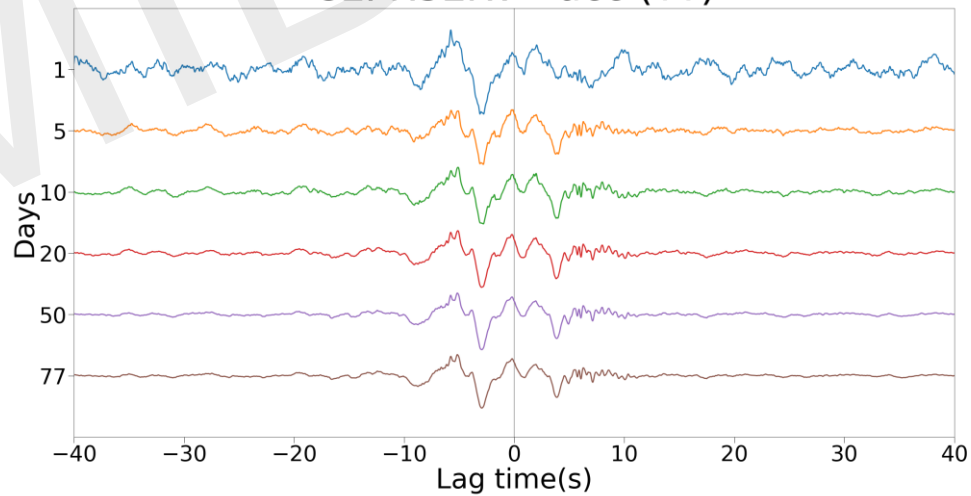
CEPRSERV - acc (ZZ)



CEPRSERV - acc (RR)

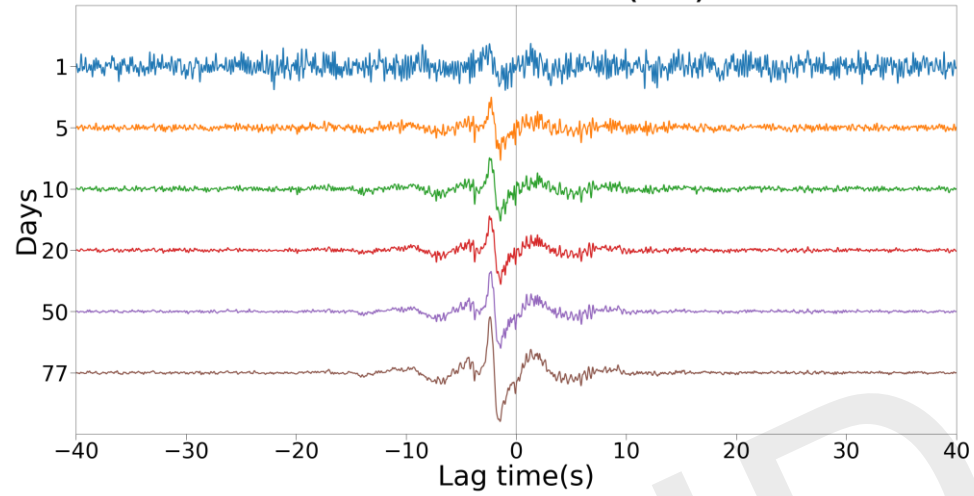


CEPRSERV - acc (TT)

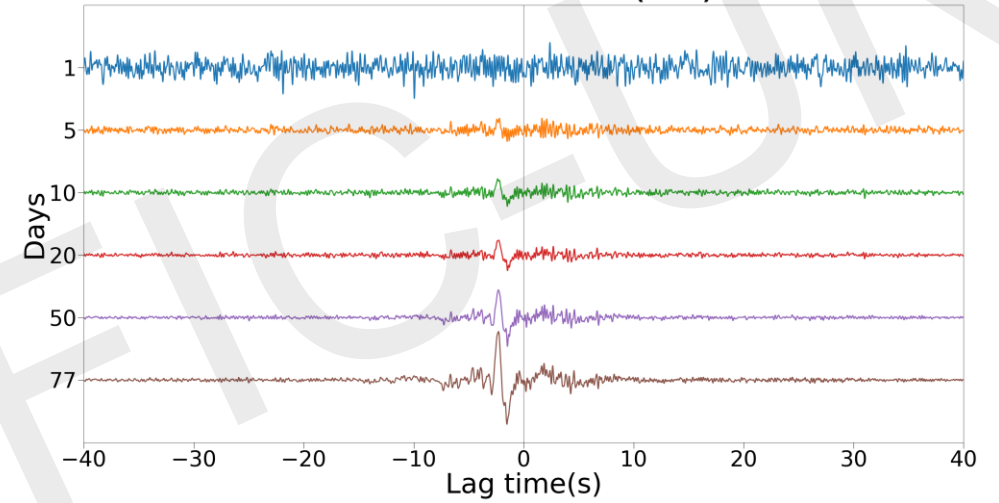


# ANÁLISIS

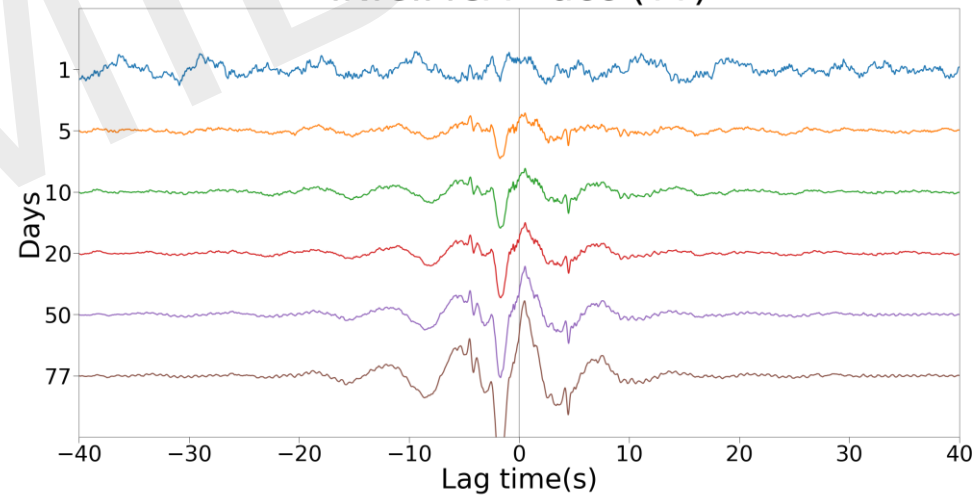
INICIMCA - acc (ZZ)



INICIMCA - acc (RR)

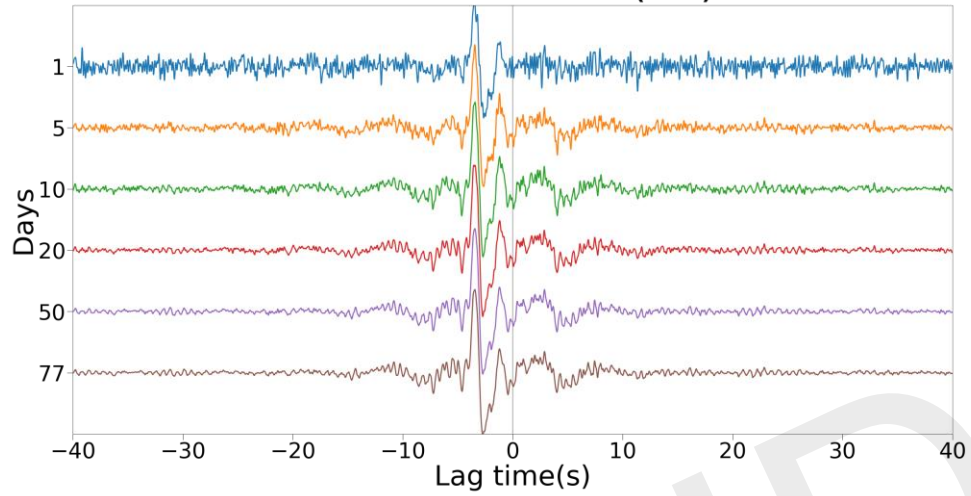


INICIMCA - acc (TT)

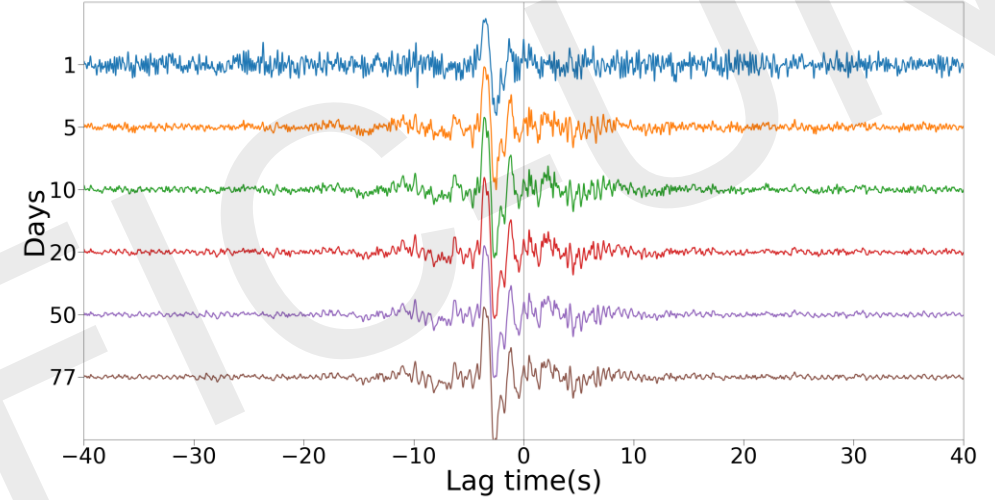


# ANÁLISIS

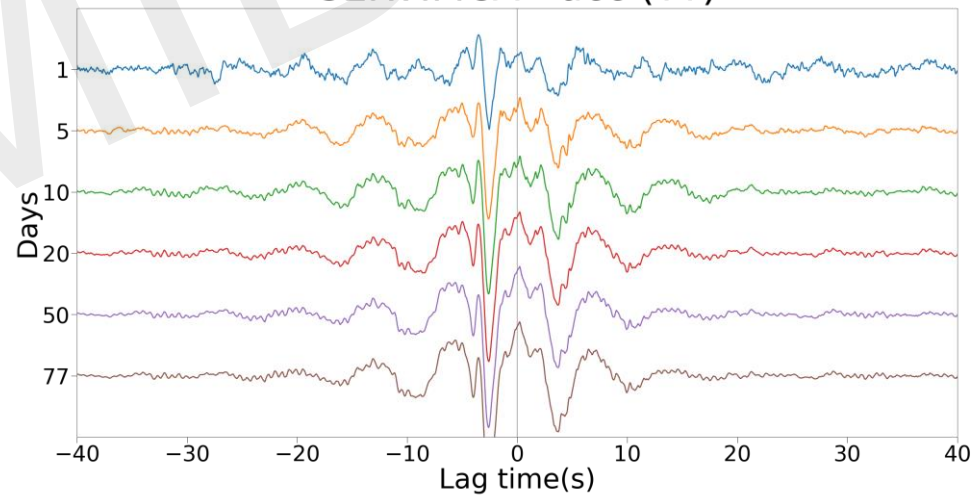
SERVIMCA - acc (ZZ)



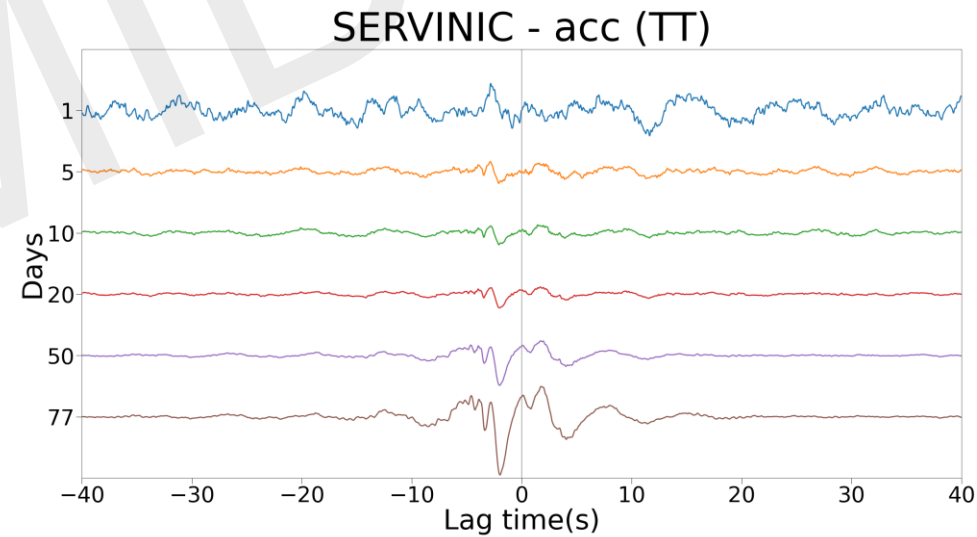
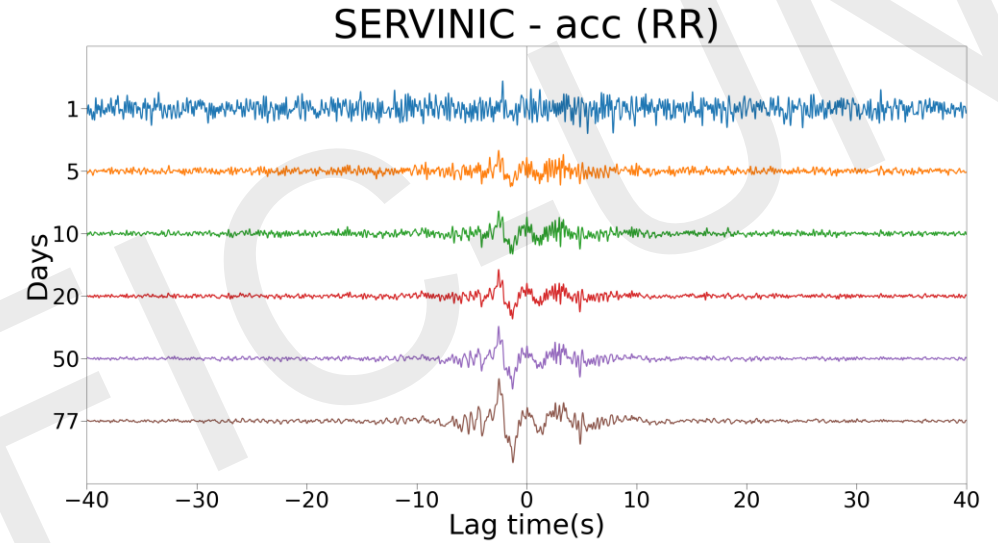
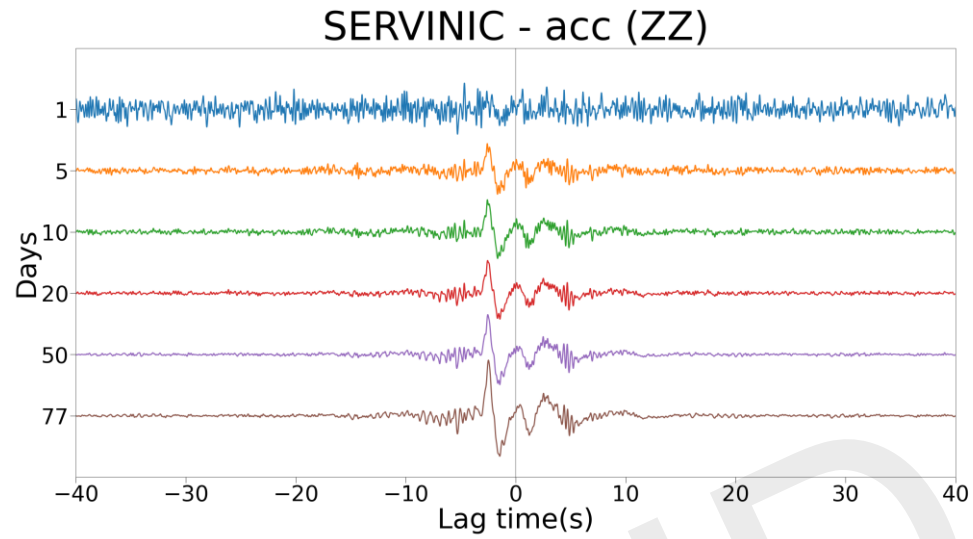
SERVIMCA - acc (RR)



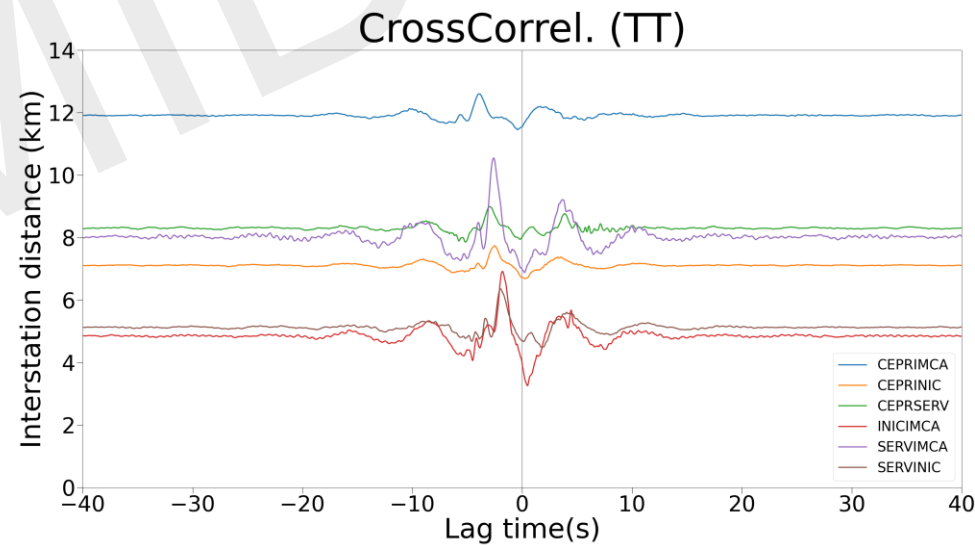
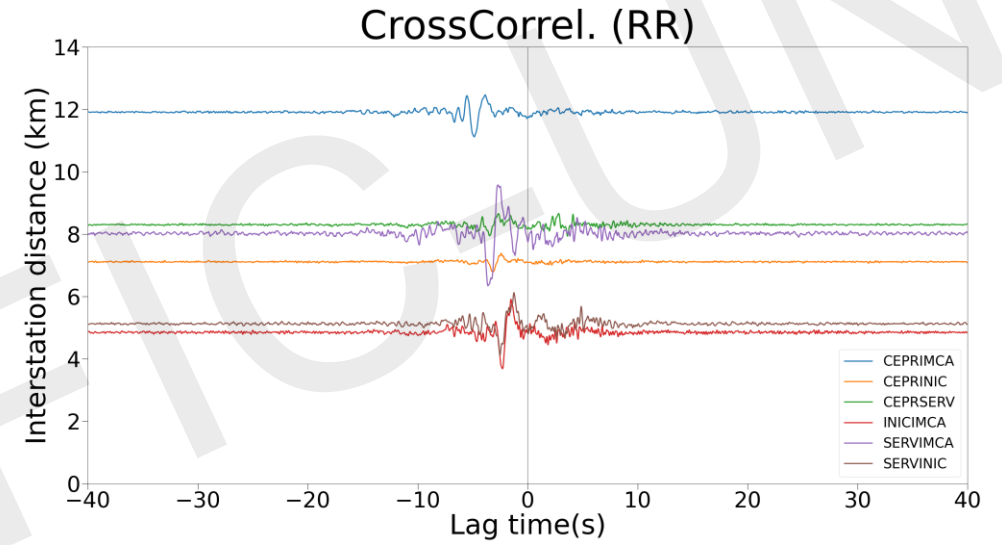
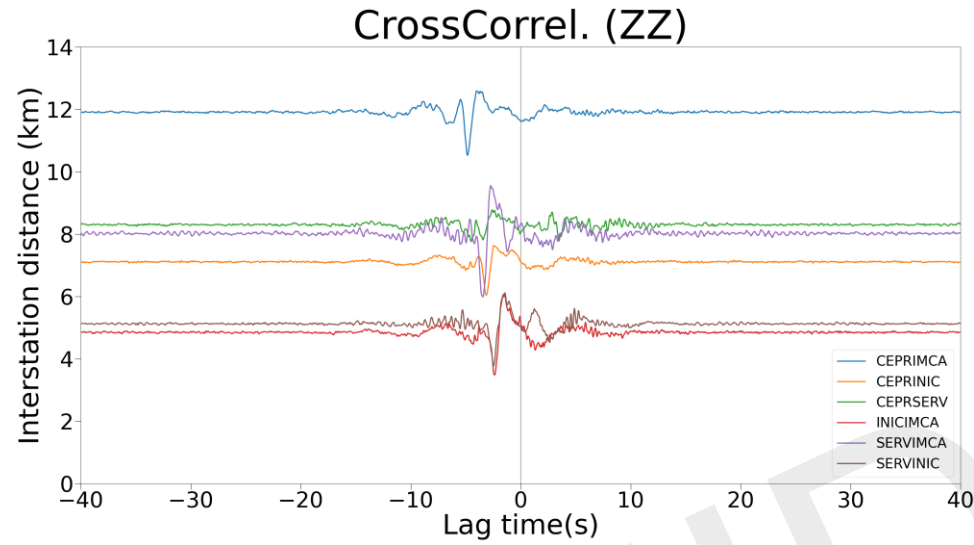
SERVIMCA - acc (TT)



# ANÁLISIS

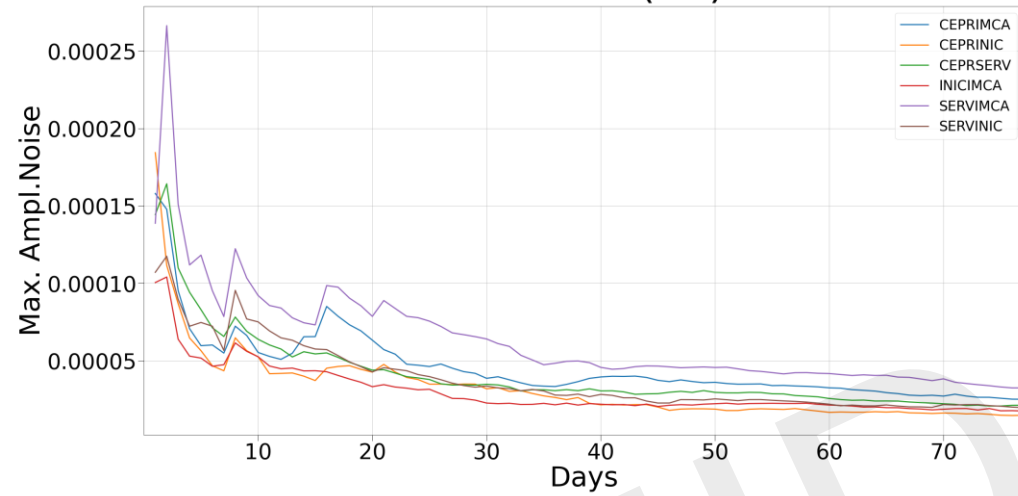


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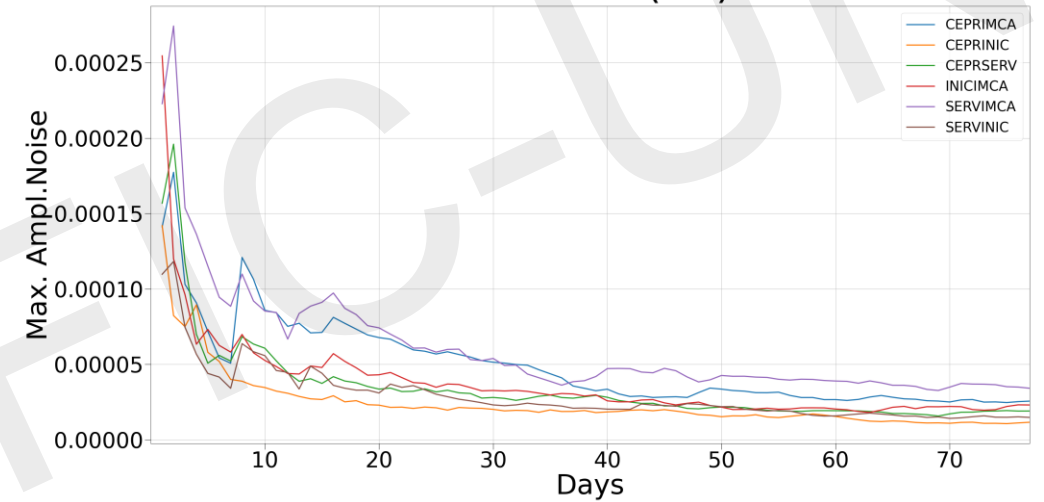


# ANÁLISIS

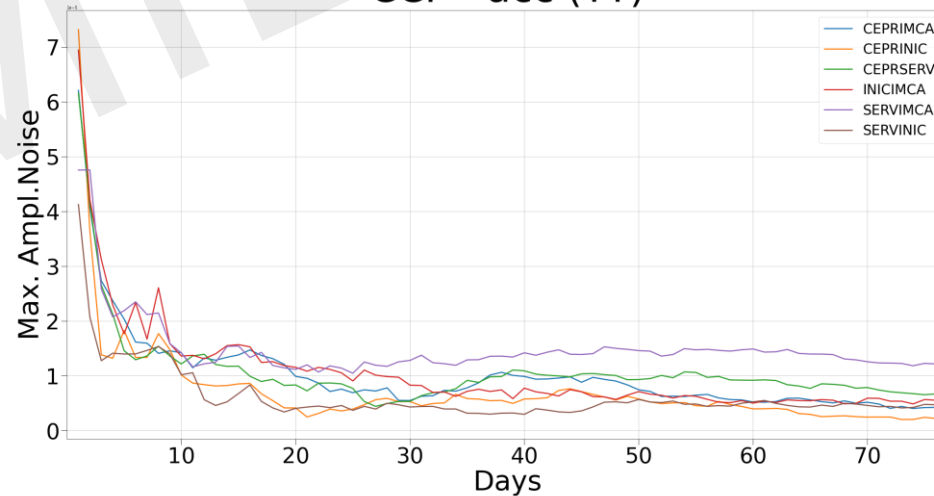
### CCF - acc (ZZ)



### CCF - acc (RR)



### CCF - acc (TT)

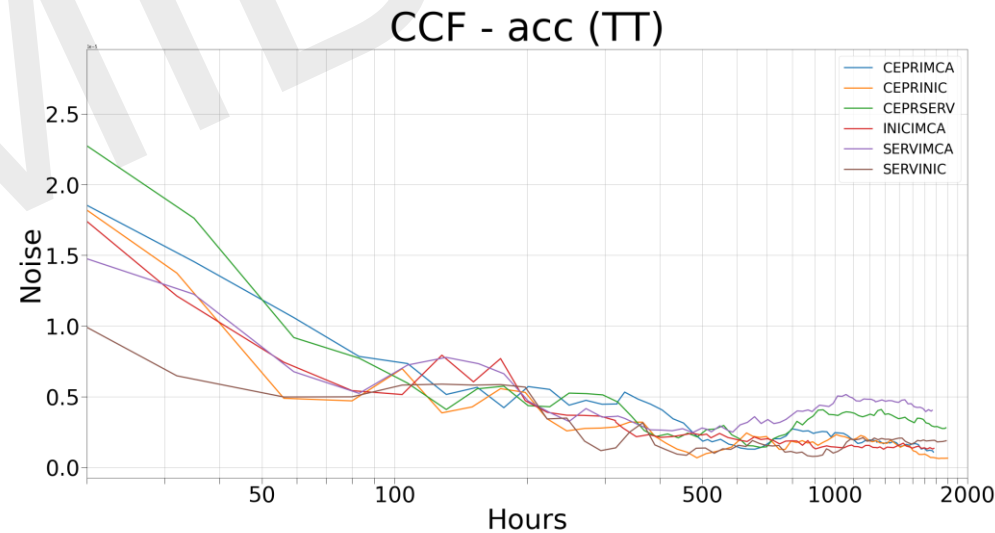
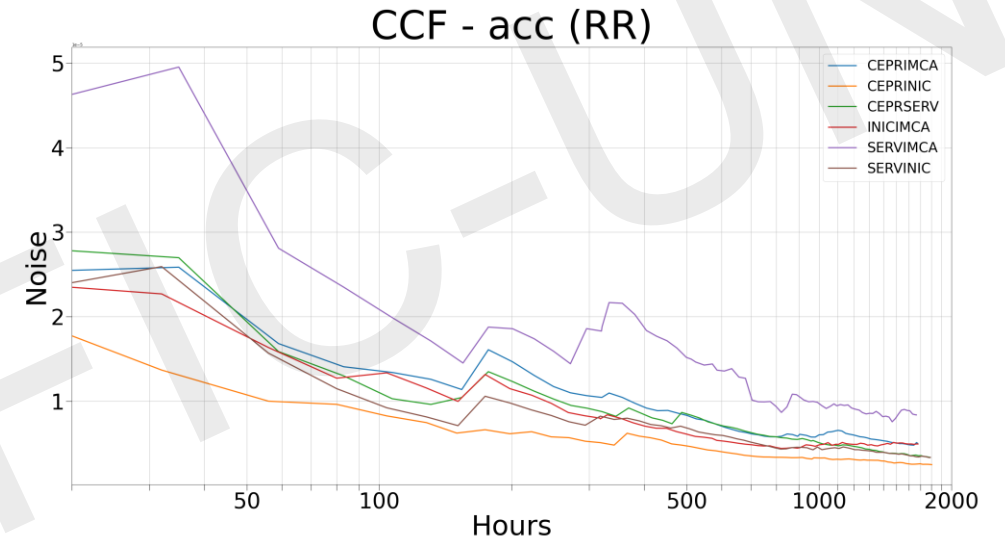
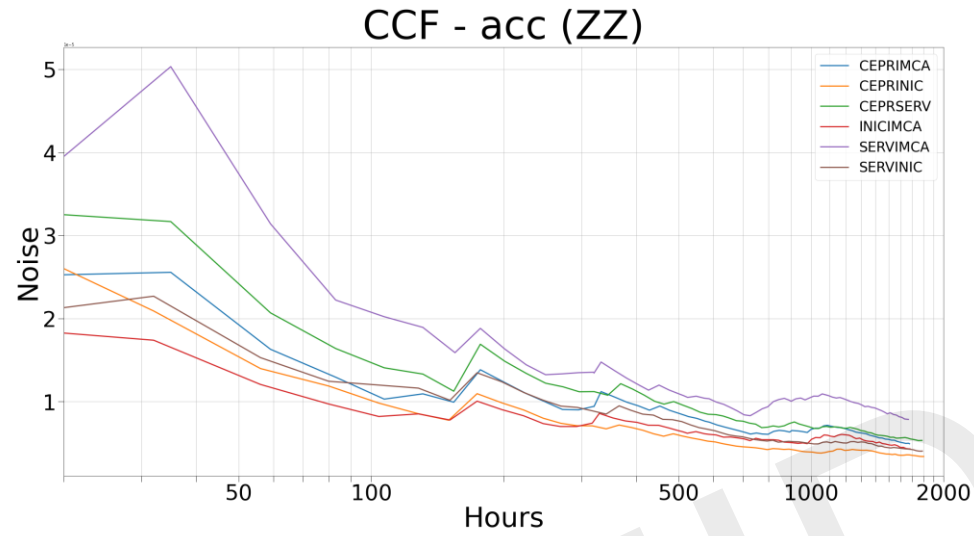


*Root mean square (rms)*

$\langle -500, -400 \rangle \text{ sec}$



# ANÁLISIS

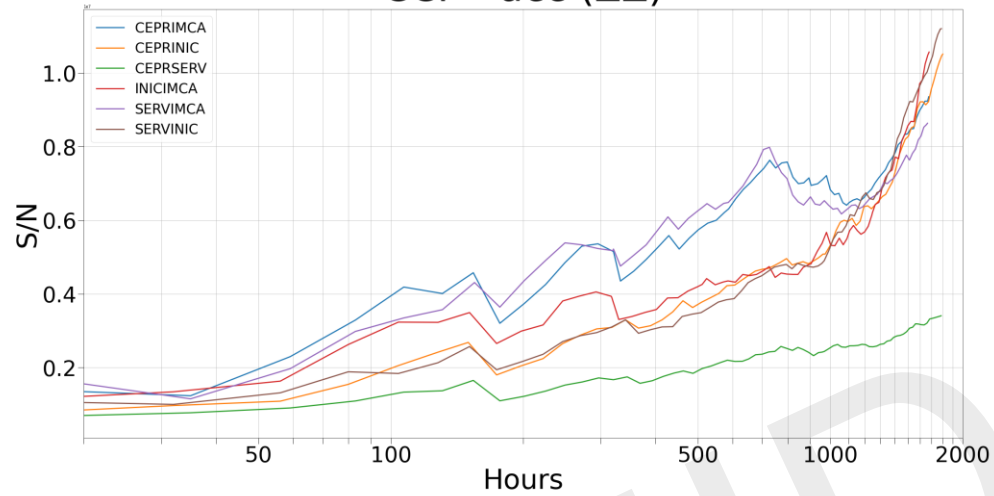


*Root mean square (rms)*  
 $< -500, -400 > \text{ sec}$

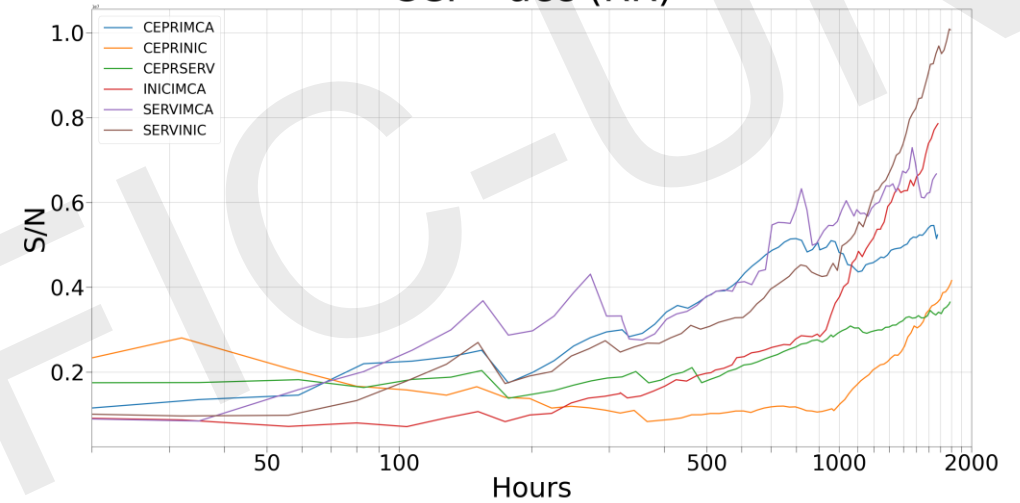


# ANÁLISIS

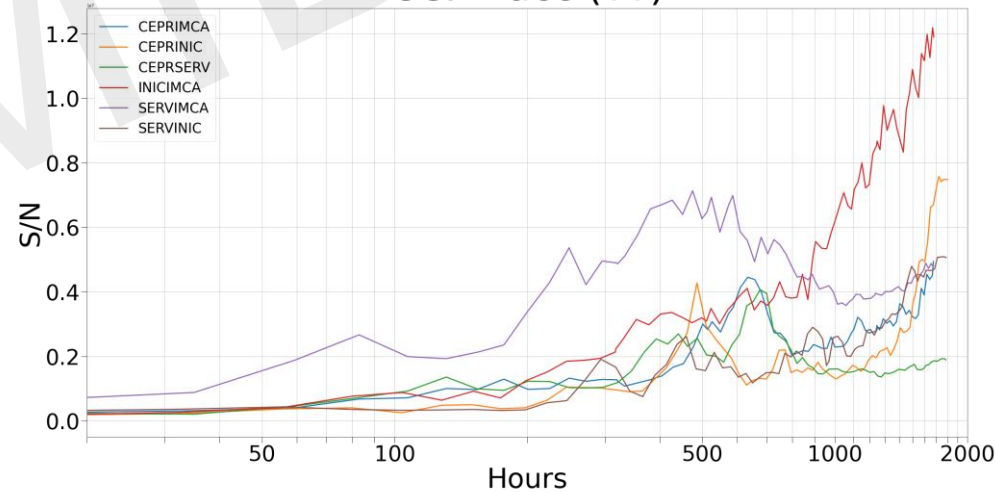
CCF - acc (ZZ)



CCF - acc (RR)



CCF - acc (TT)



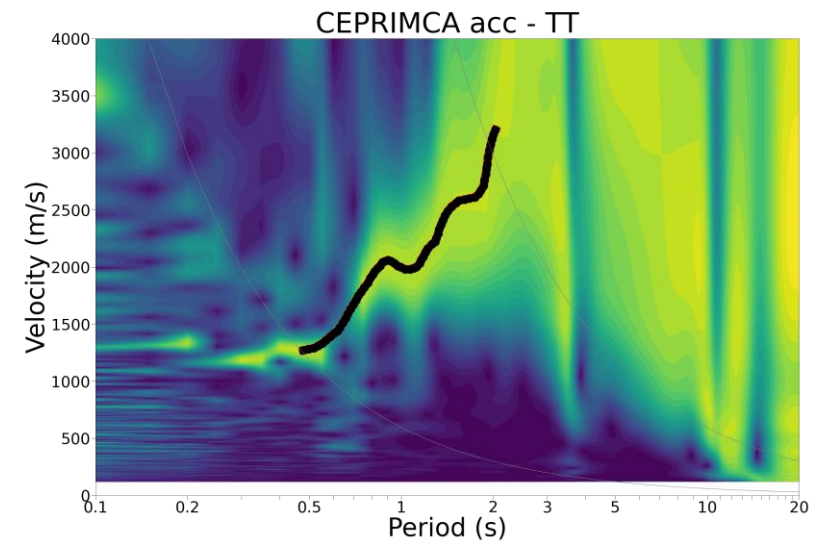
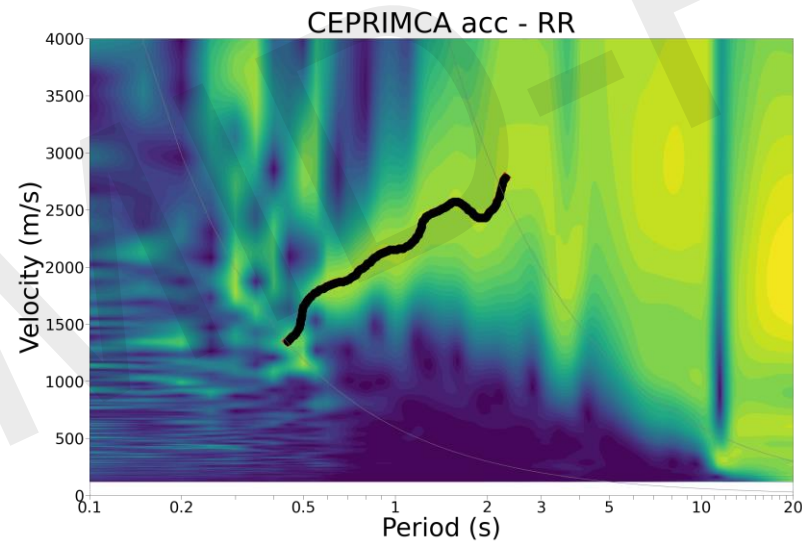
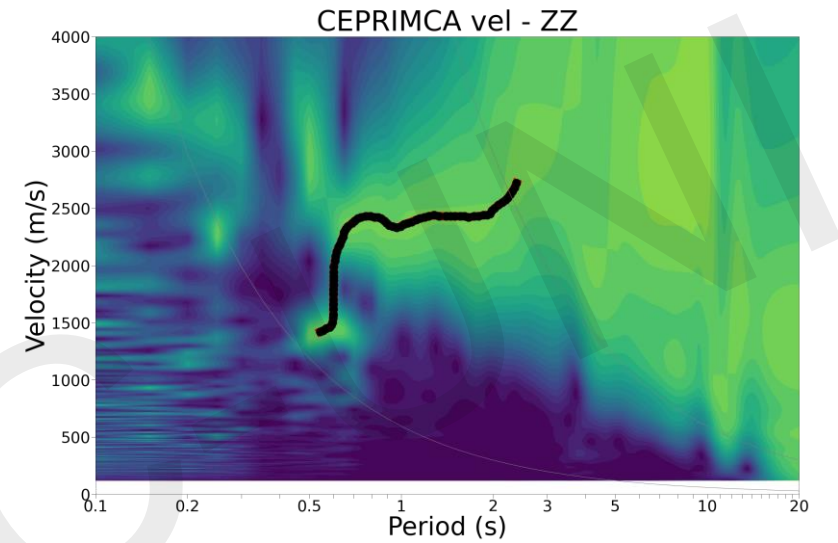
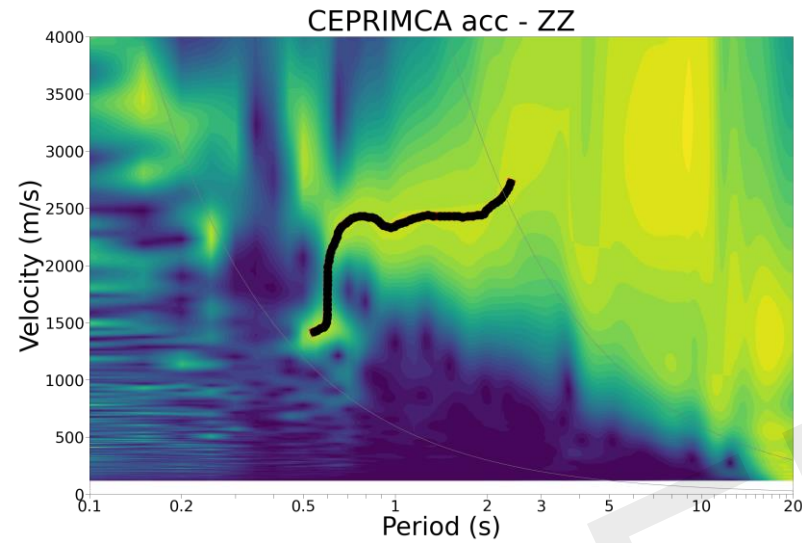
$$S/N = \frac{\text{Maximum Amplitude}}{\text{Root mean square (rms)}}$$

Root mean square (rms)  
 $< -500, -400 > \text{ sec}$

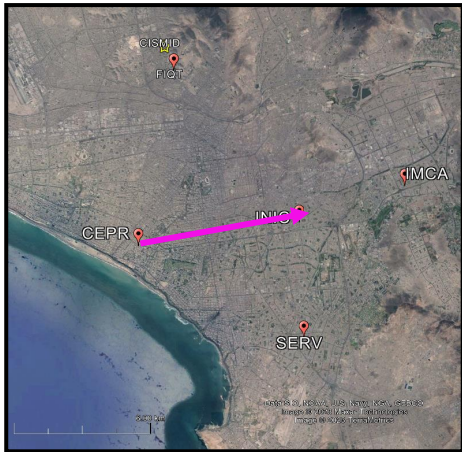
# DISPERSIÓN DE ONDAS CEPRIMCA



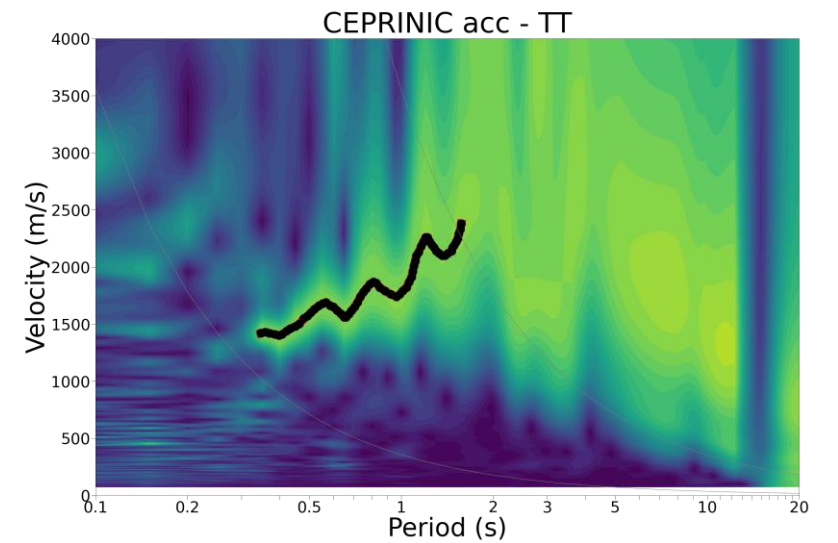
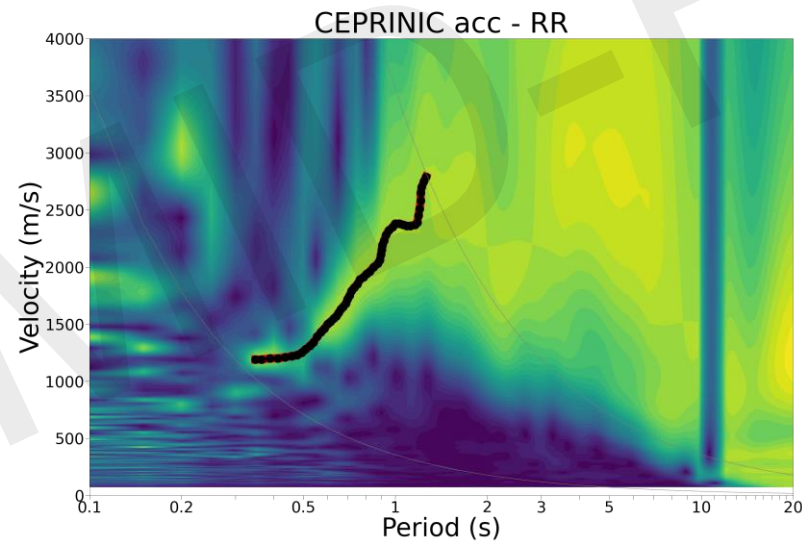
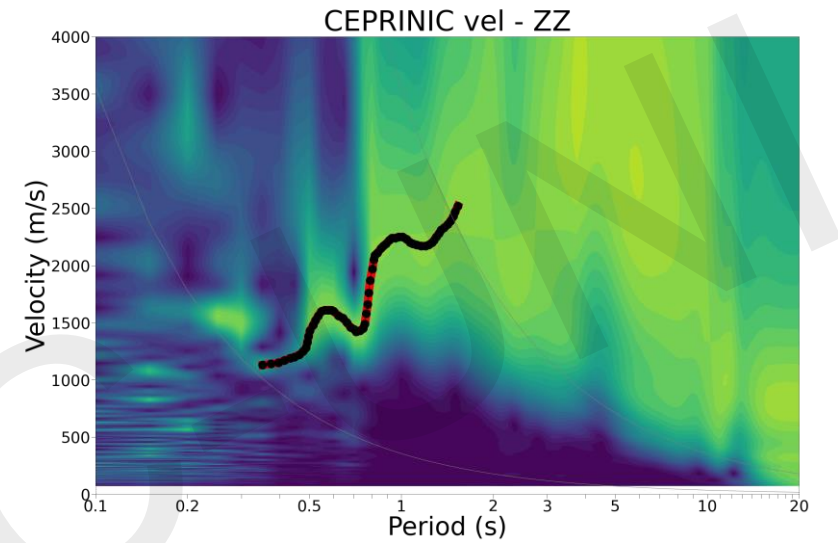
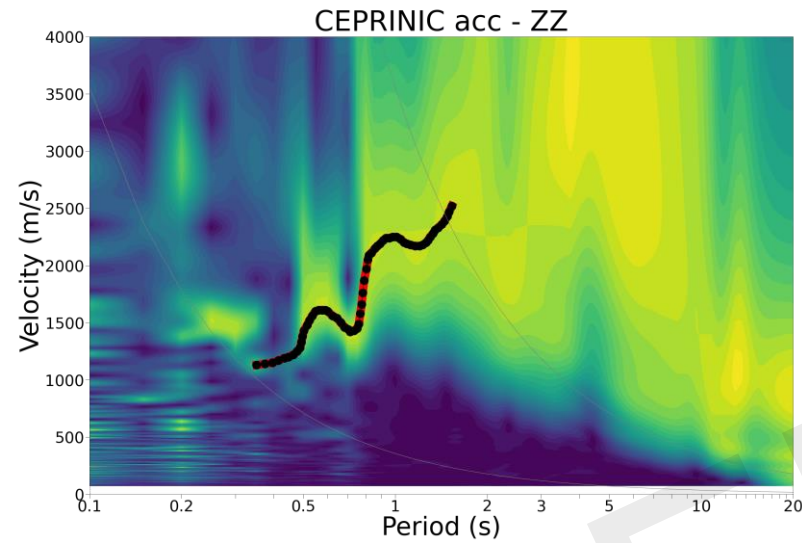
STATIONS	Dist. (km)	Azim.(°)
CEPRIMCA	11.9	77.2
CEPRINIC	7.1	81.6
CEPRSERV	8.3	119.7
INICIMCA	4.9	70.7
SERVIMCA	8.0	33.0
SERVINIC	5.1	357.9



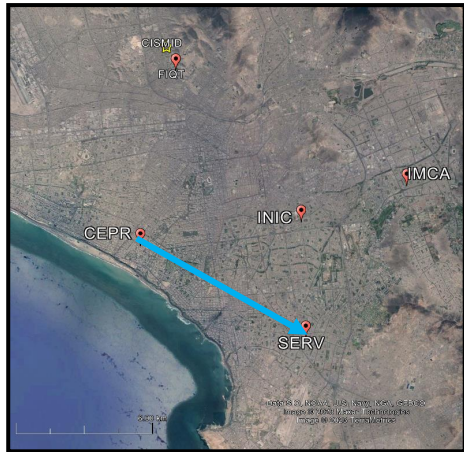
# DISPERSIÓN DE ONDAS CEPRINIC



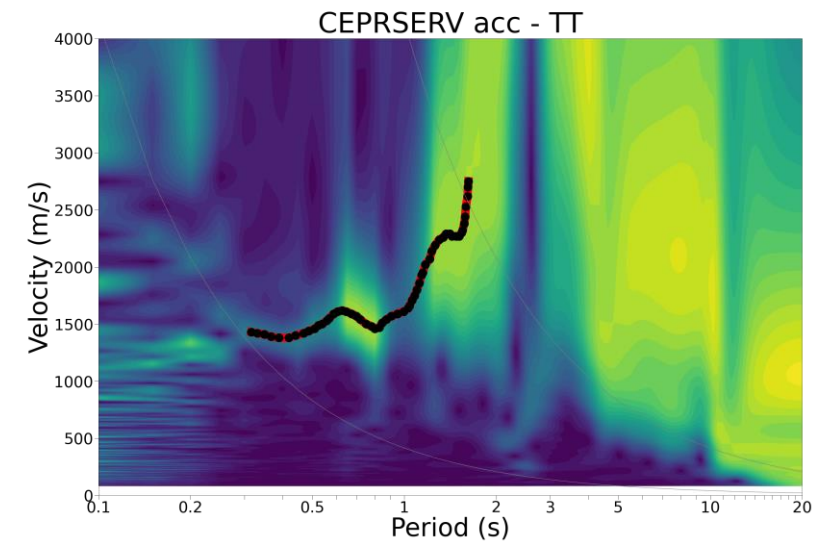
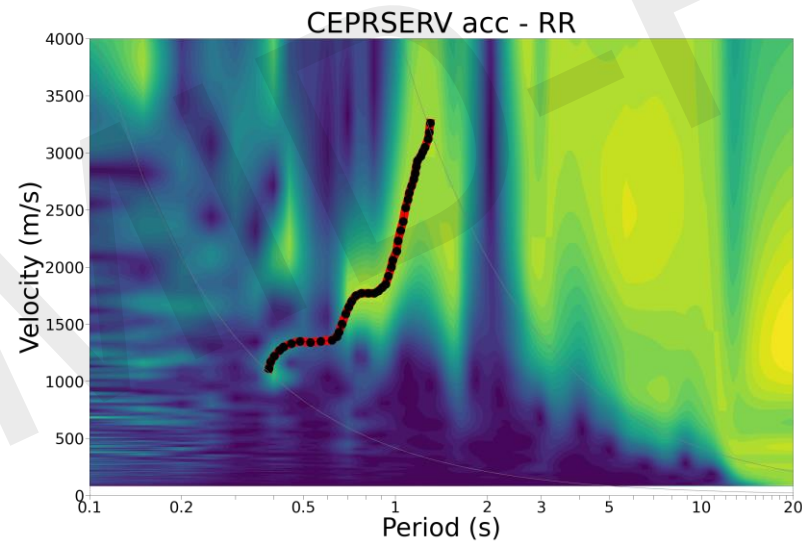
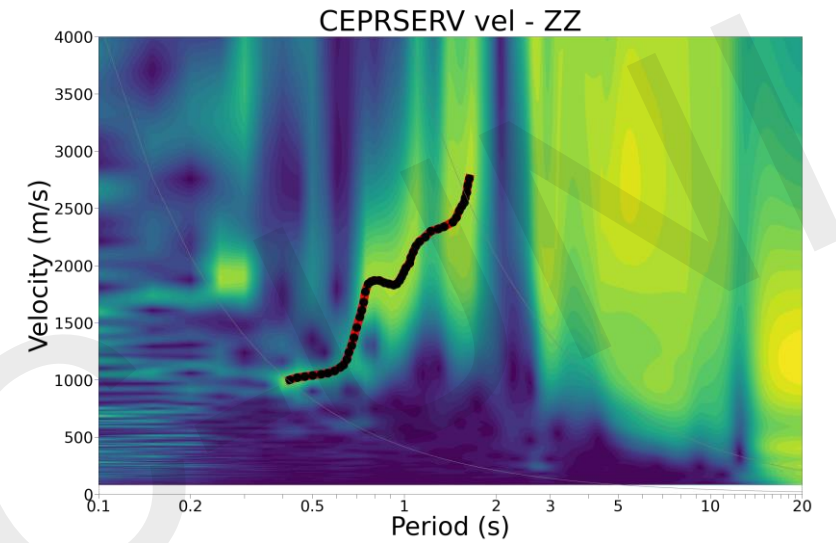
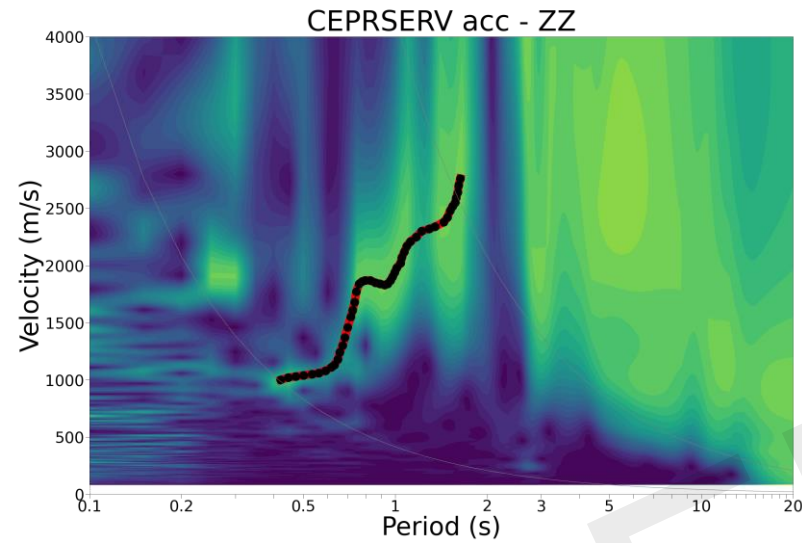
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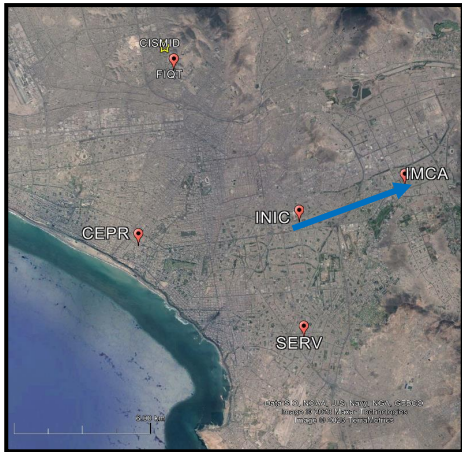
# DISPERSIÓN DE ONDAS CEPRSERV



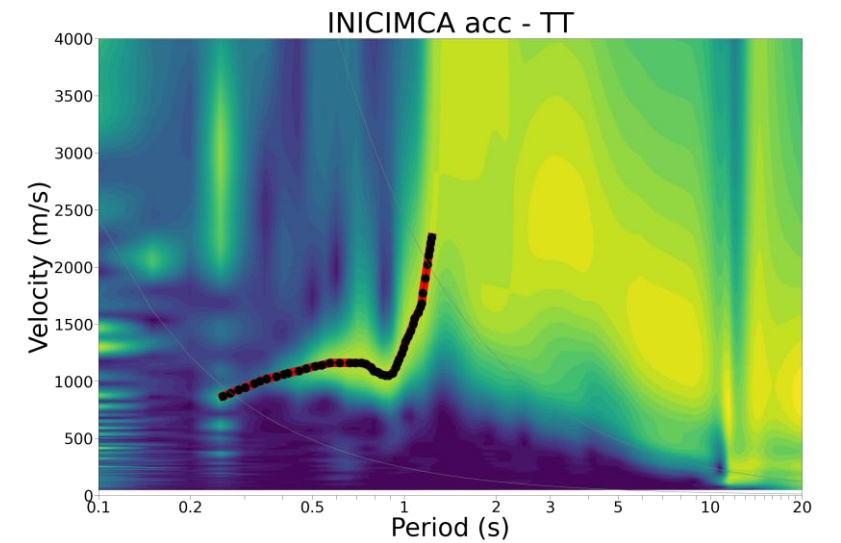
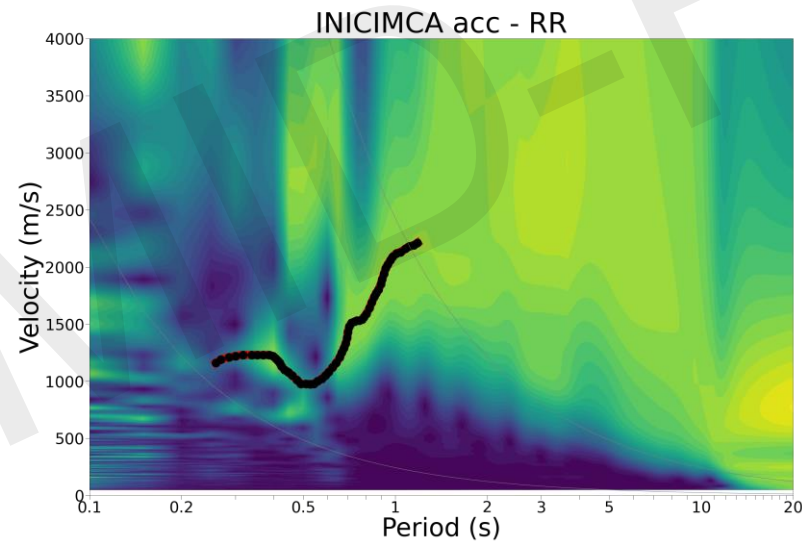
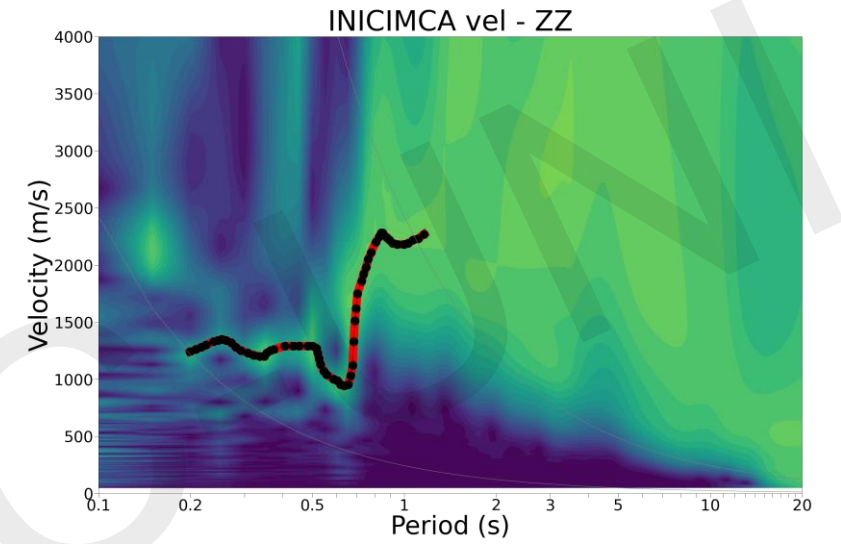
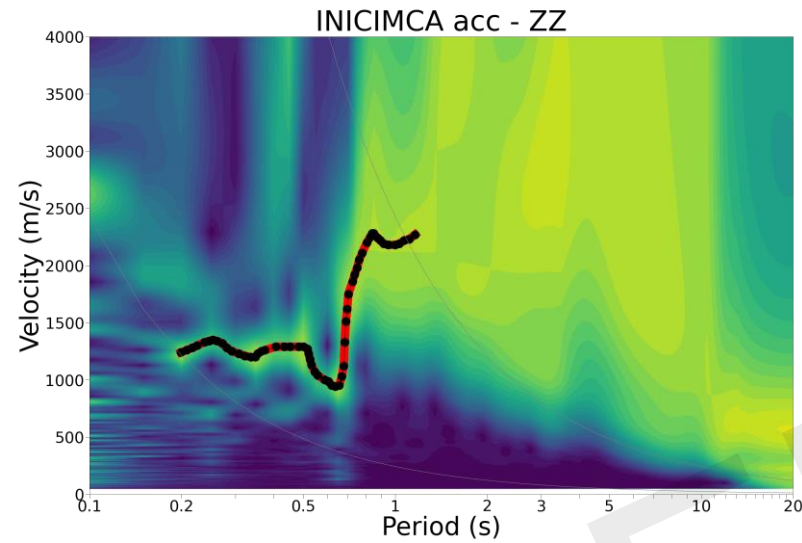
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SERVIMCA	8.0	33.0
SERVINIC	5.1	357.9



# DISPERSIÓN DE ONDAS INICIMCA



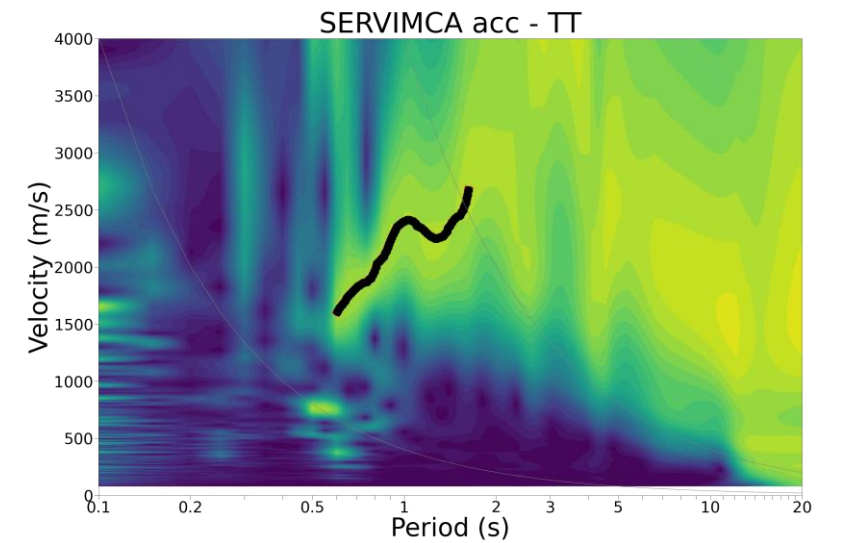
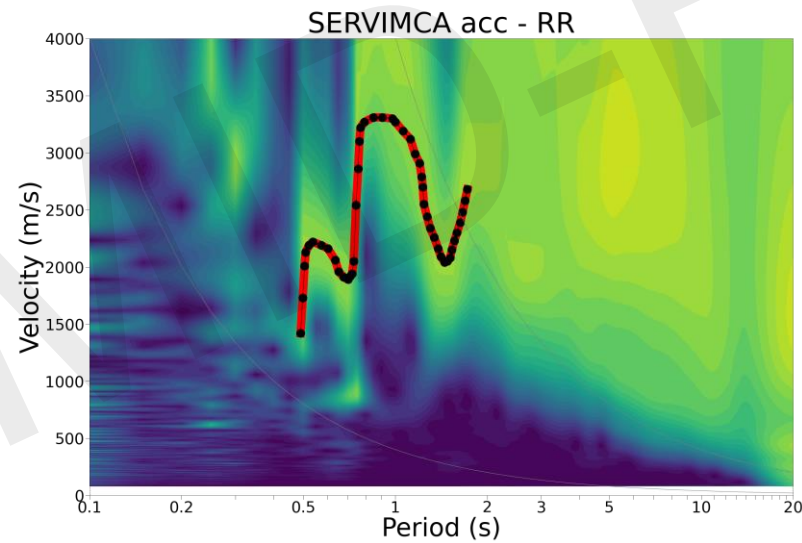
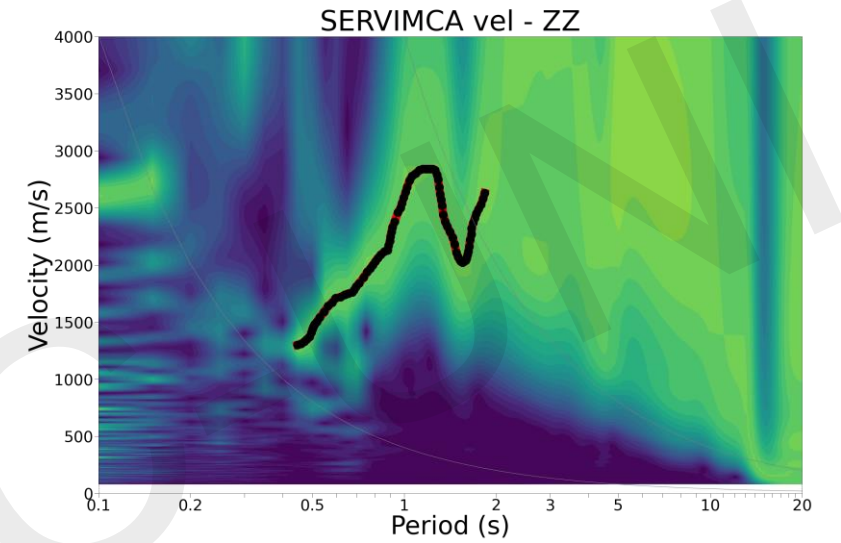
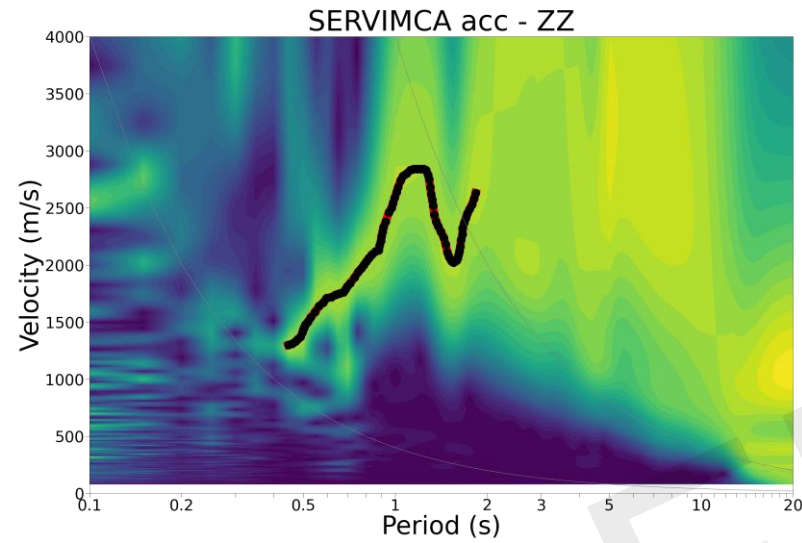
STATIONS	Dist. (km)	Azim.(°)
CEPRIMCA	11.9	77.2
CEPRINIC	7.1	81.6
CEPRSERV	8.3	119.7
INICIMCA	4.9	70.7
SERVIMCA	8.0	33.0
SERVINIC	5.1	357.9



# DISPERSIÓN DE ONDAS SERVIMCA



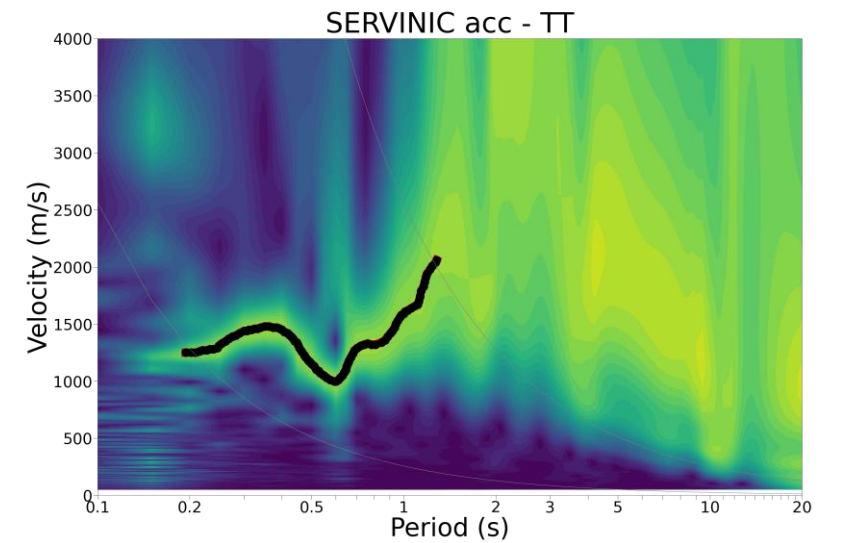
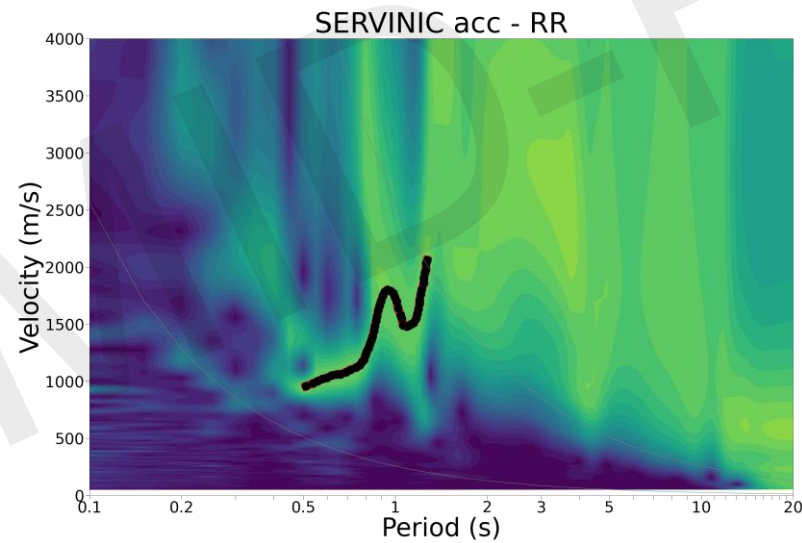
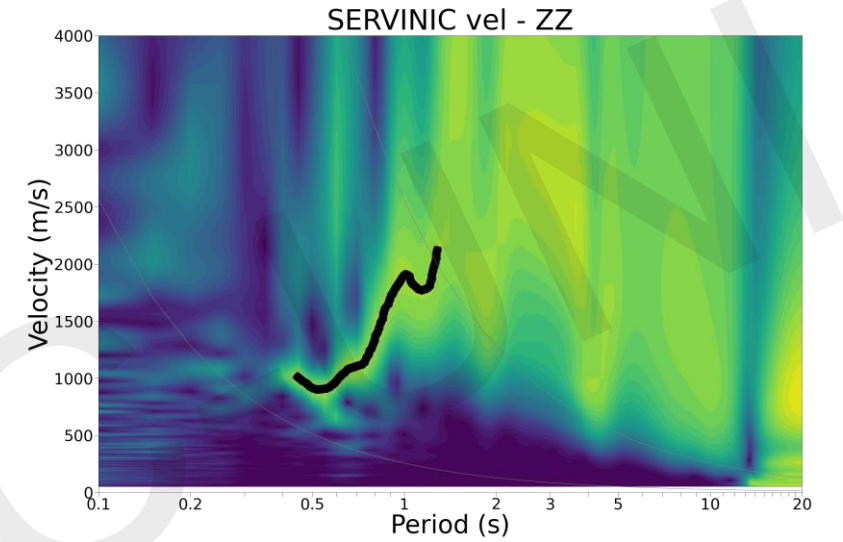
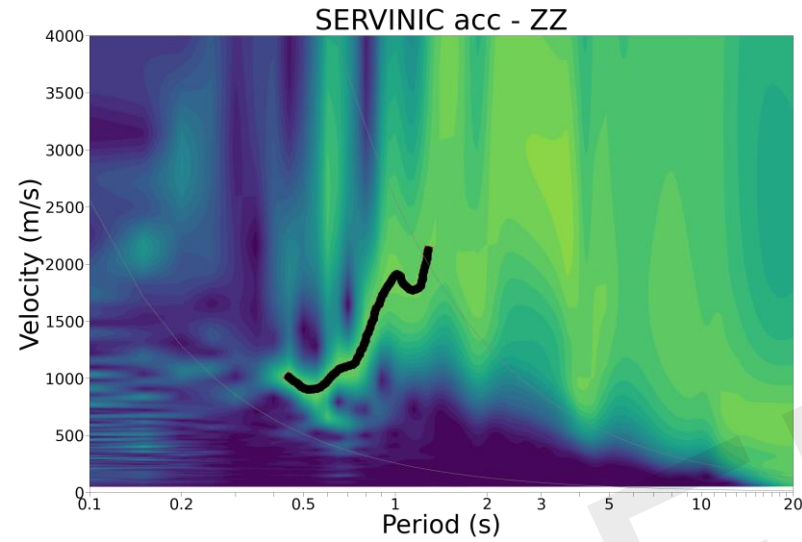
STATIONS	Dist. (km)	Azim.(°)
CEPRIMCA	11.9	77.2
CEPRINIC	7.1	81.6
CEPRSERV	8.3	119.7
INICIMCA	4.9	70.7
SERVIMCA	8.0	33.0
SERVINIC	5.1	357.9



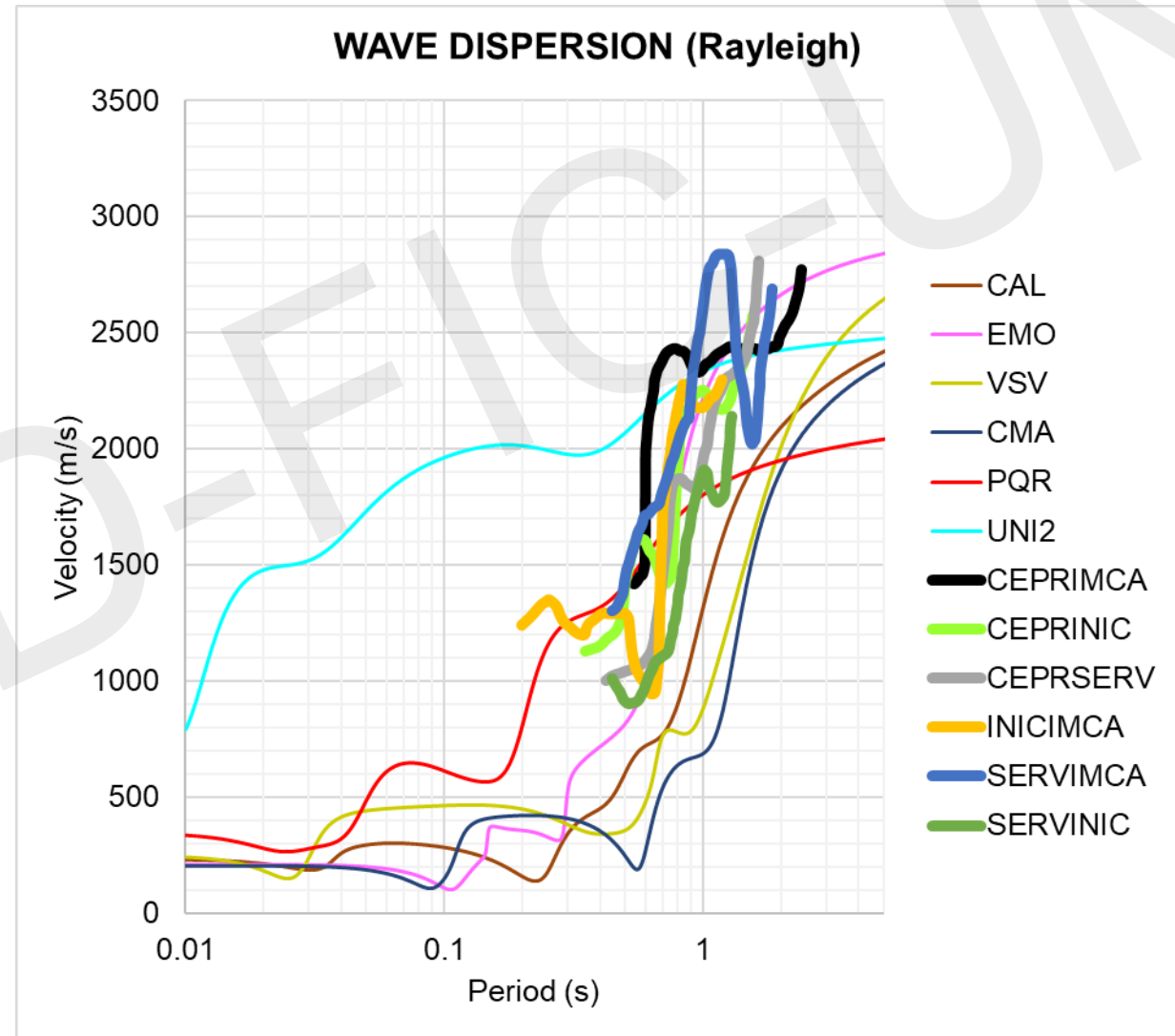
# DISPERSIÓN DE ONDAS SERVINIC



STATIONS	Dist. (km)	Azim.(°)
CEPRIMCA	11.9	77.2
CEPRINIC	7.1	81.6
CEPRSERV	8.3	119.7
INICIMCA	4.9	70.7
SERVIMCA	8.0	33.0
SERVINIC	5.1	357.9

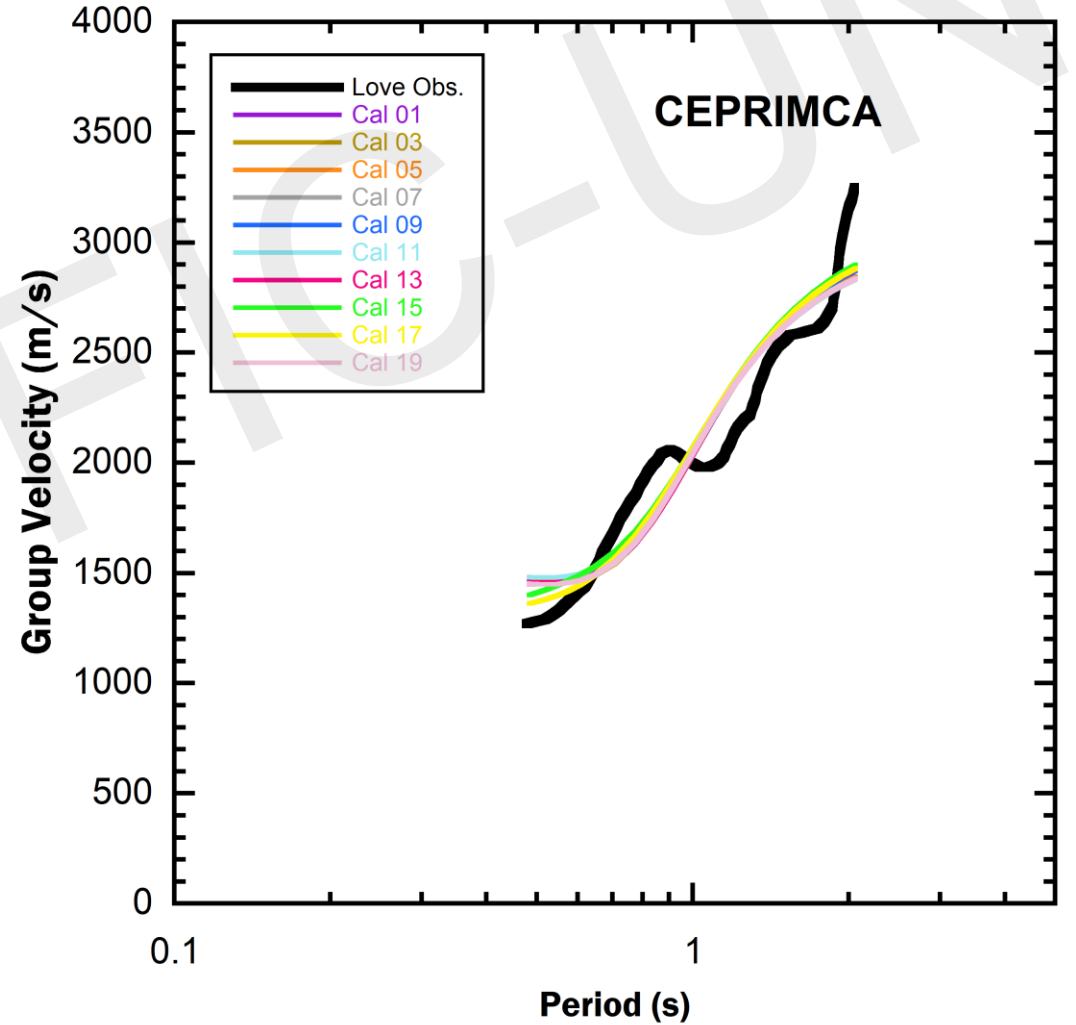
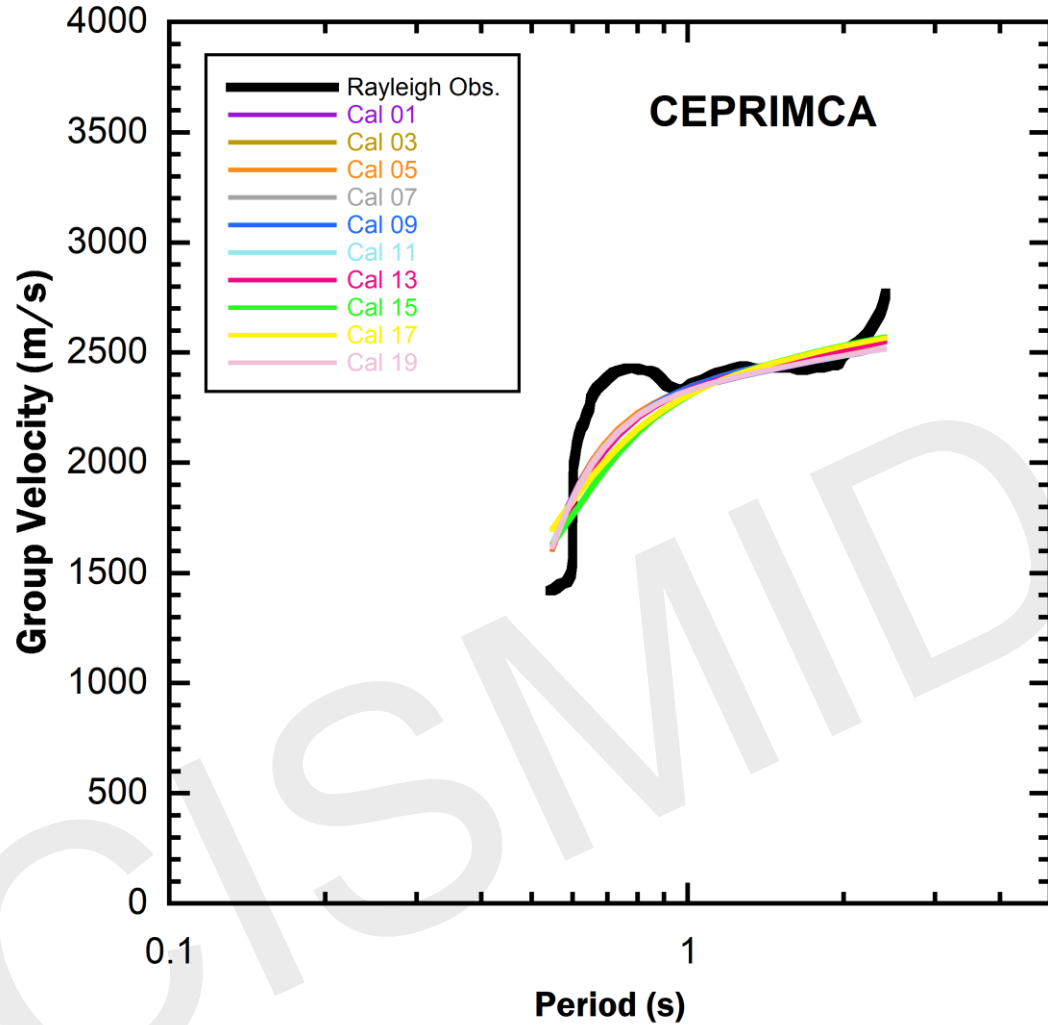


# COMPARACIÓN CON ESTUDIOS ANTERIORES

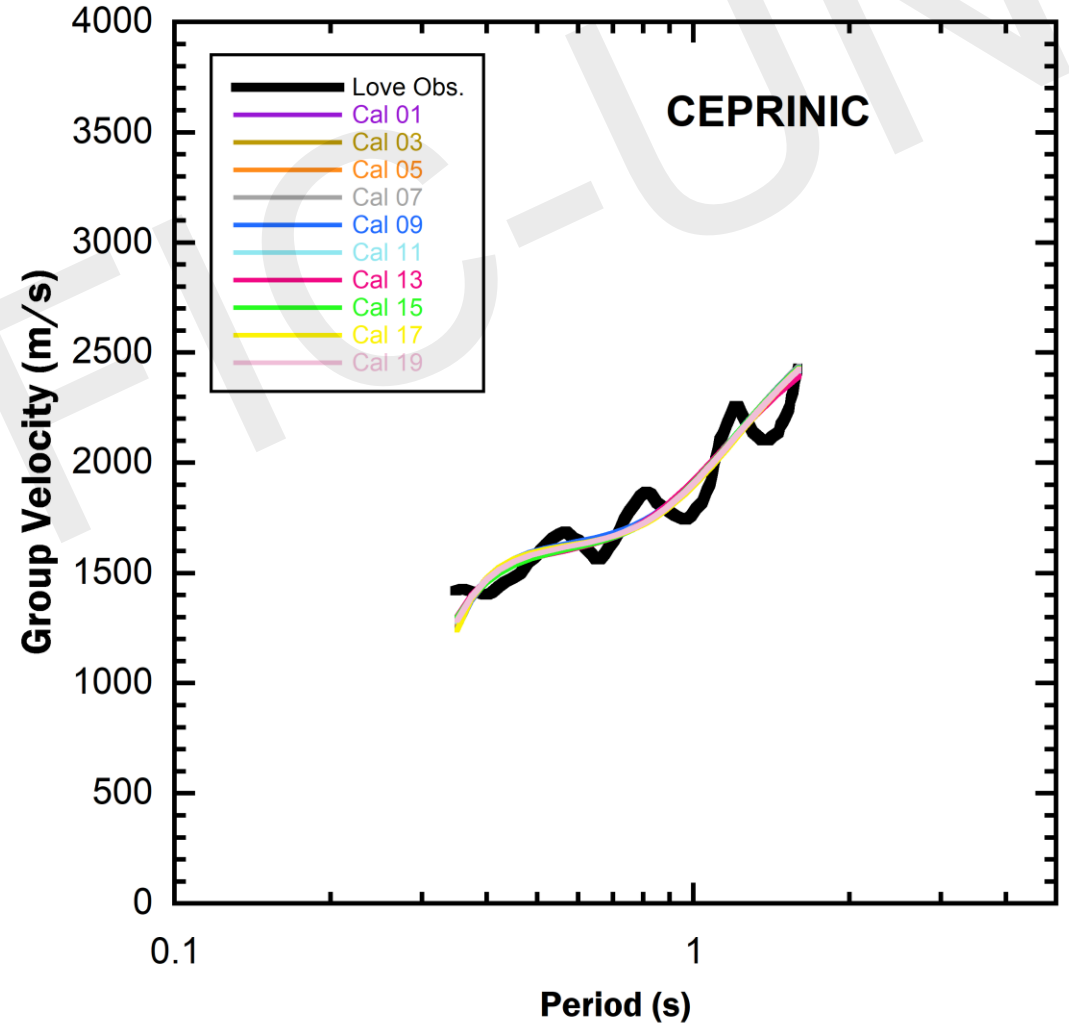
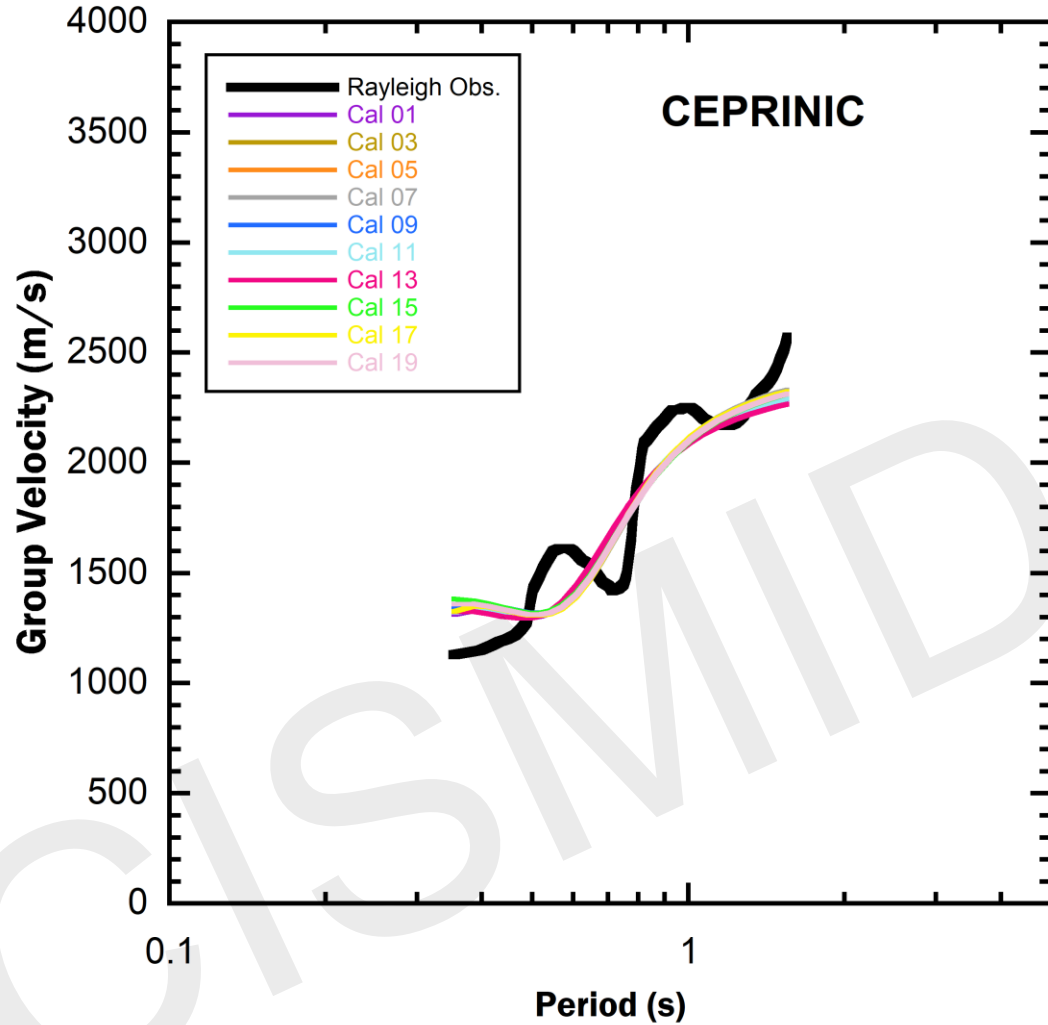




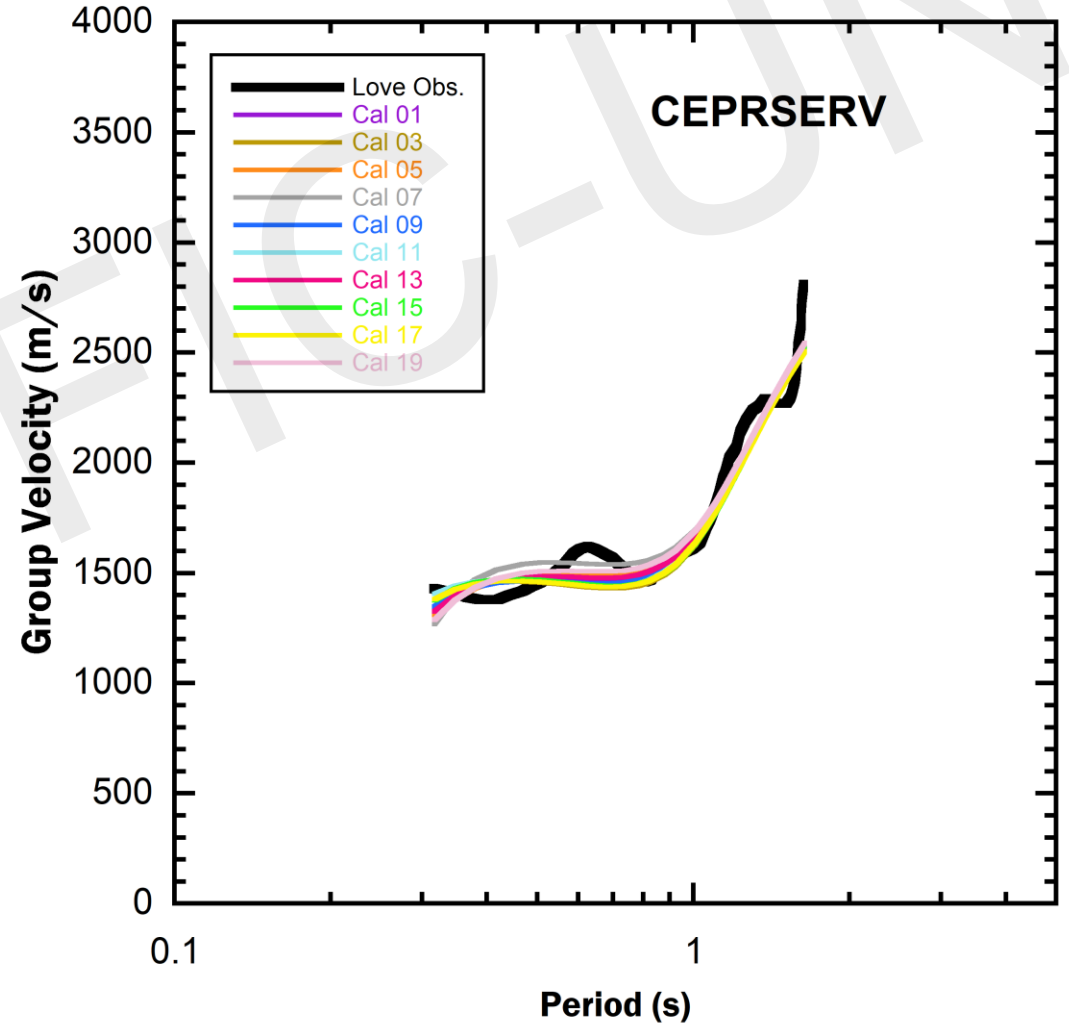
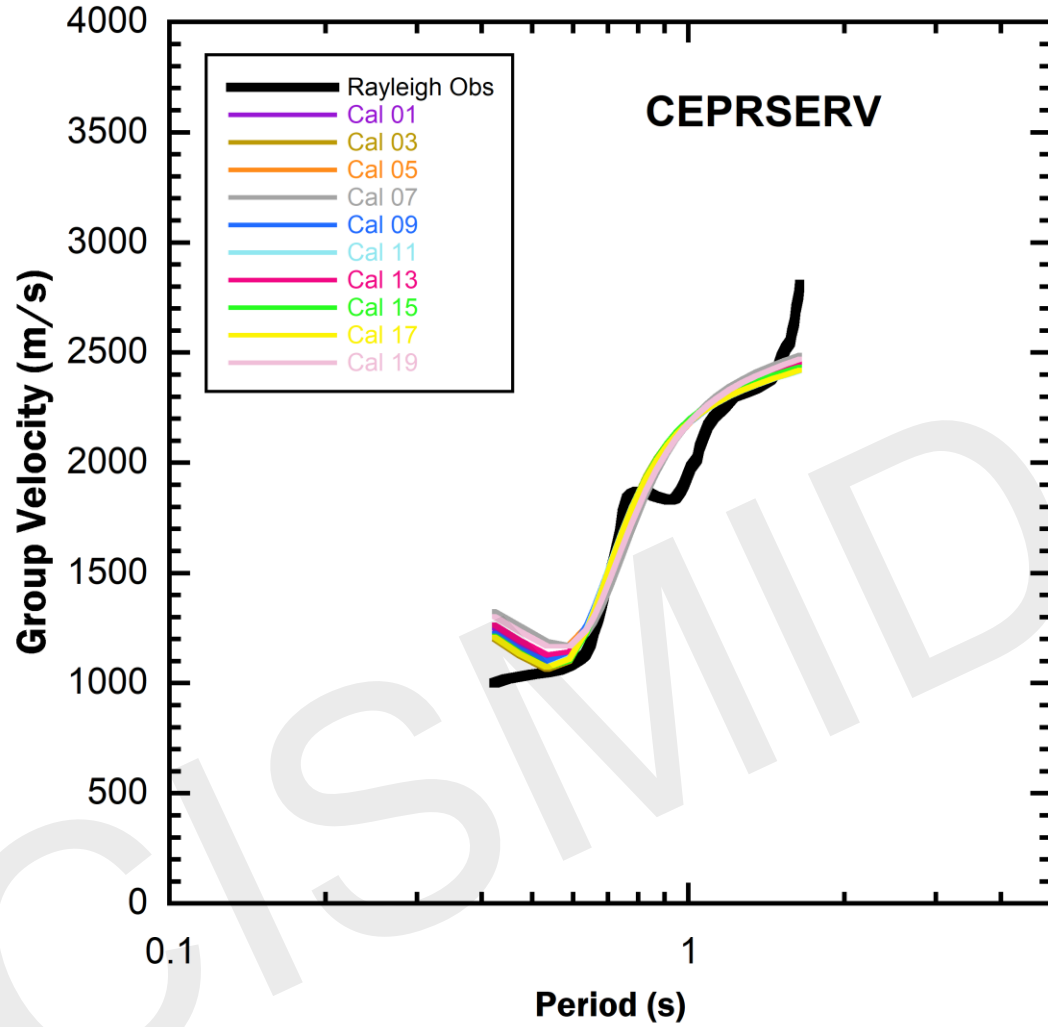
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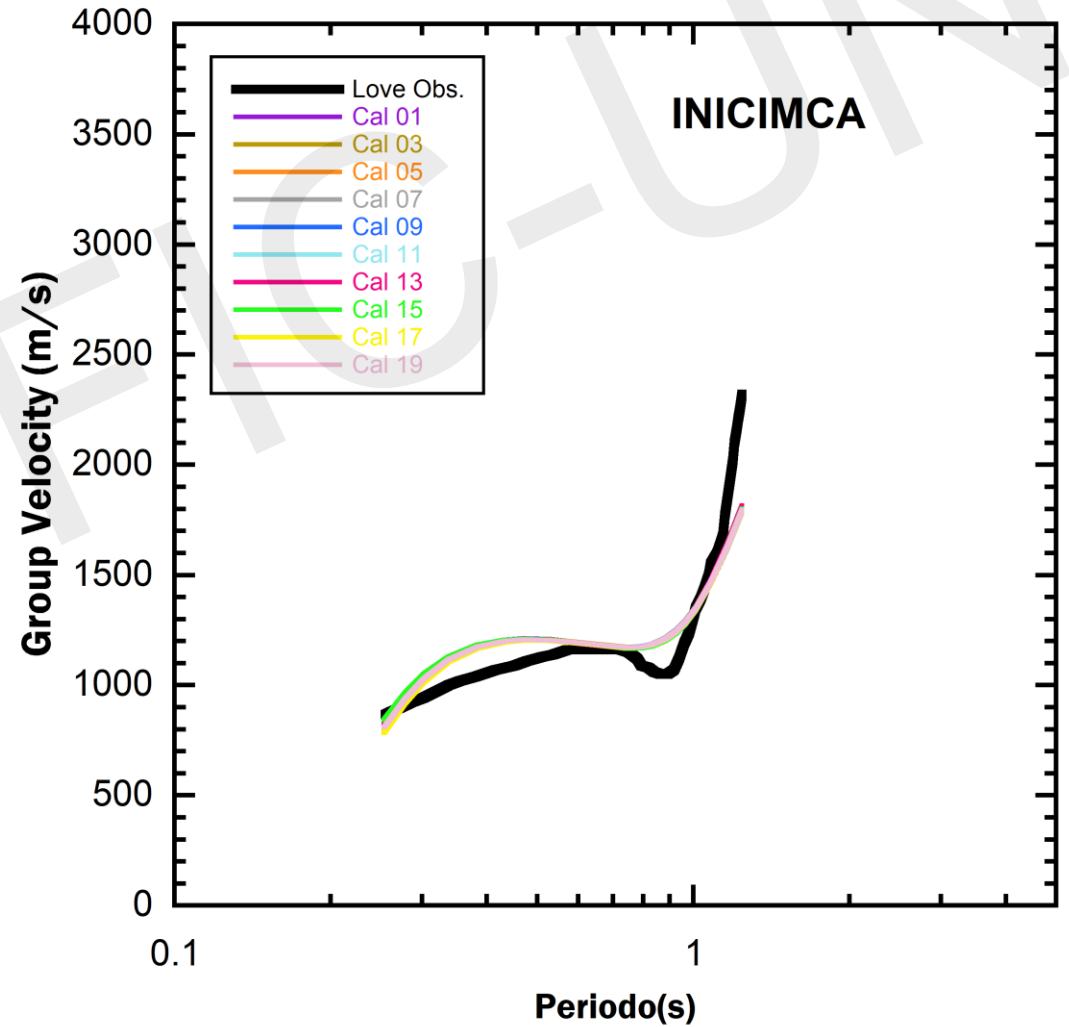
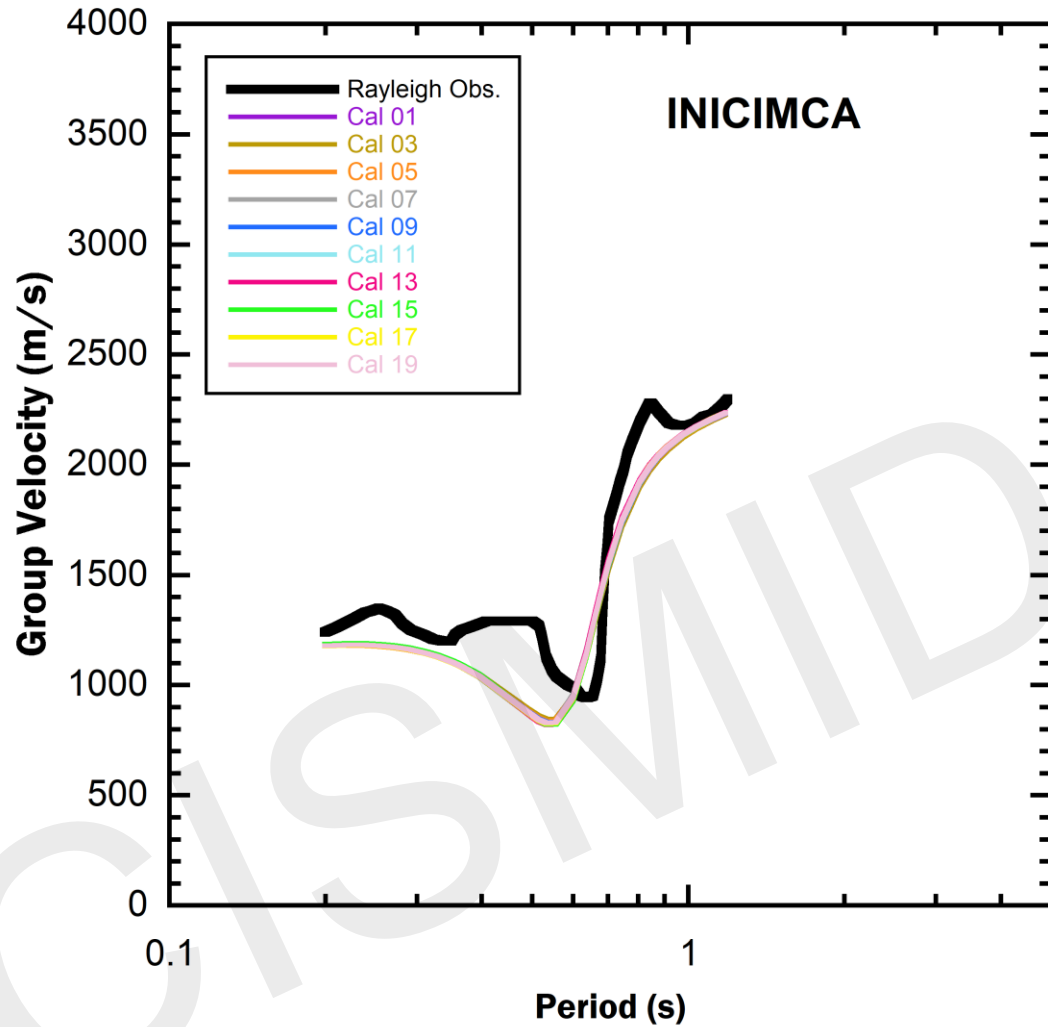
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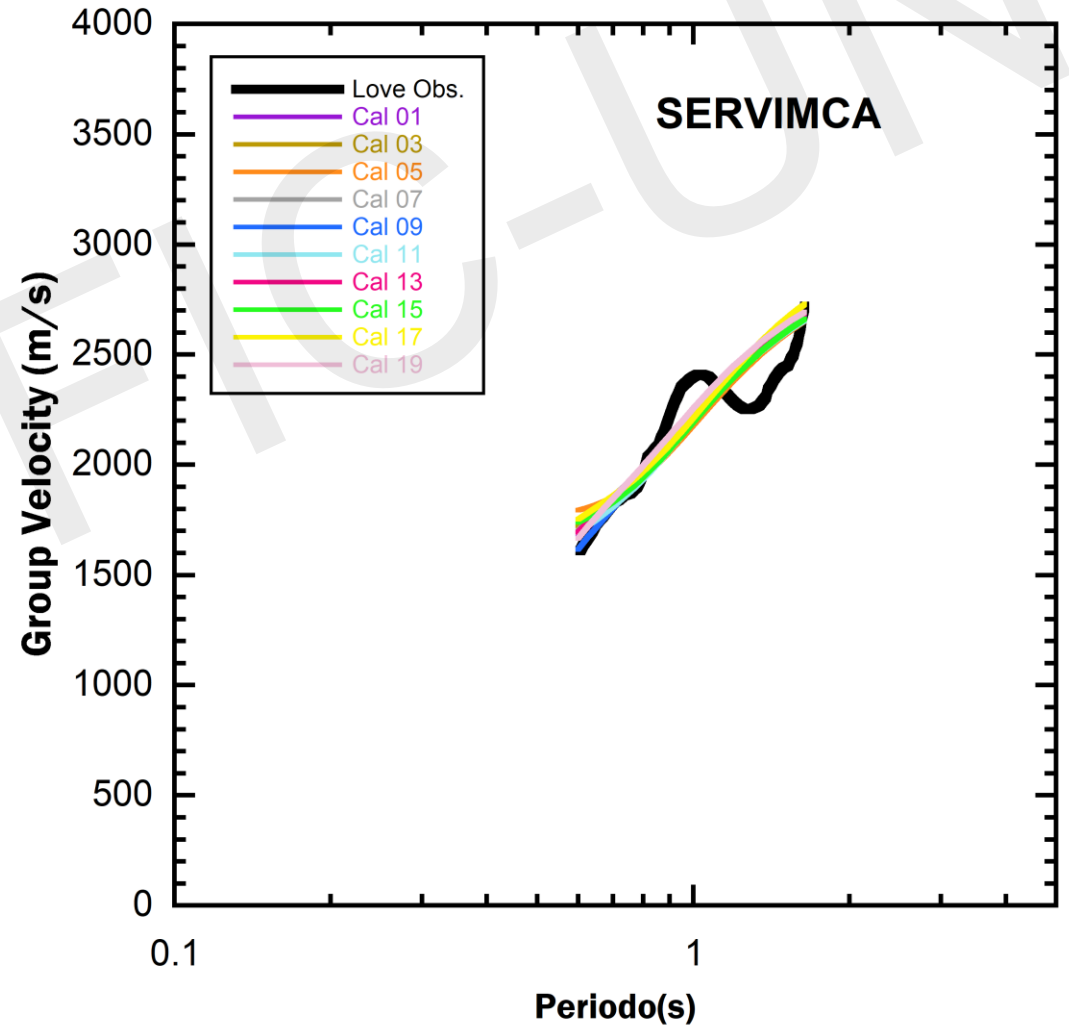
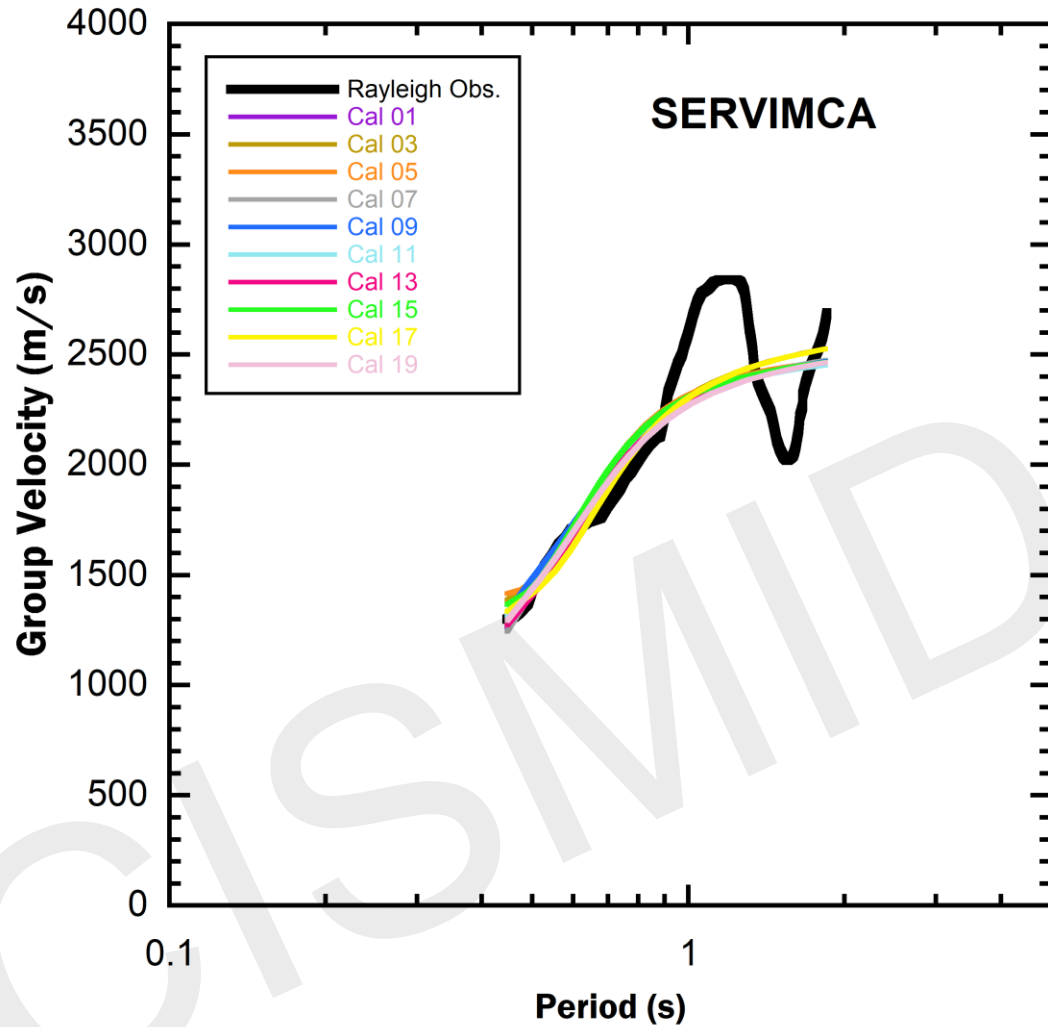
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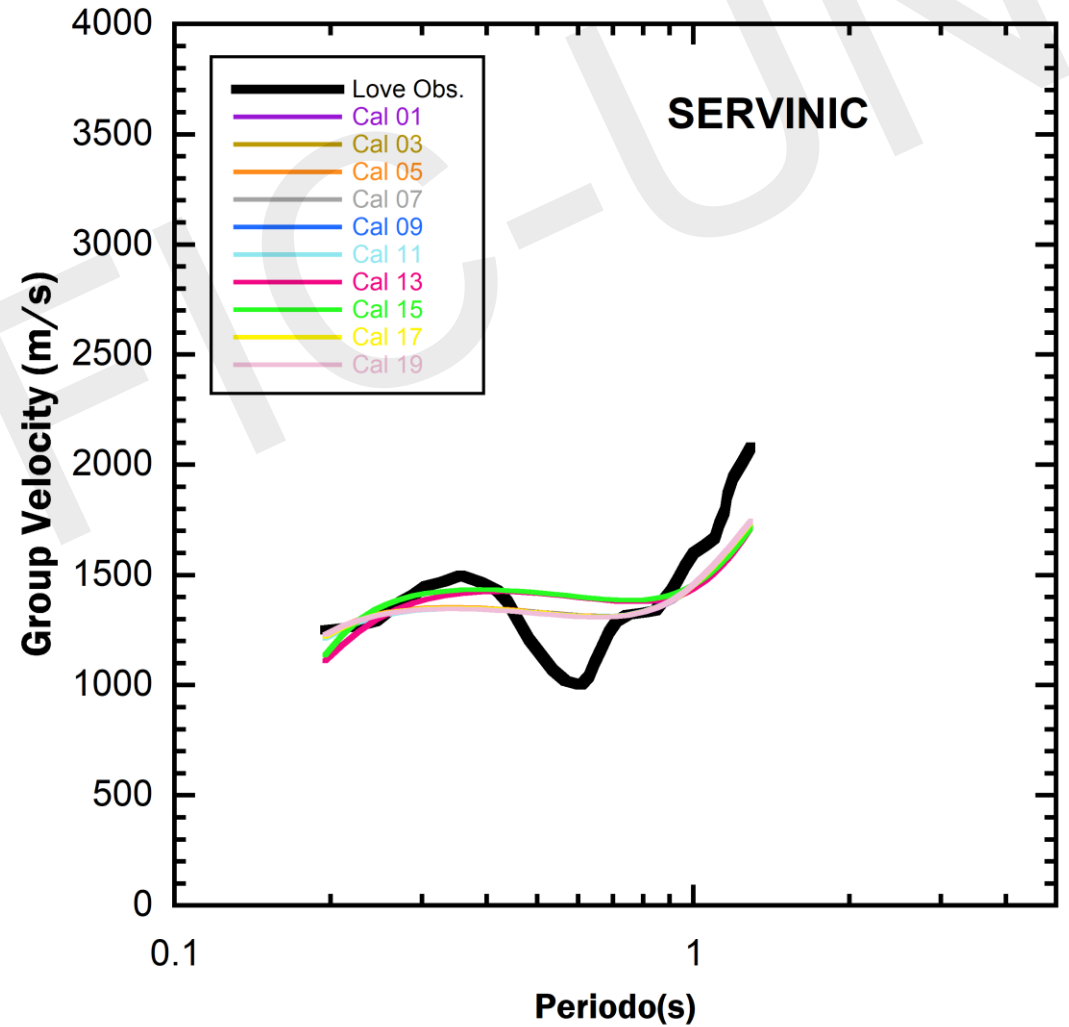
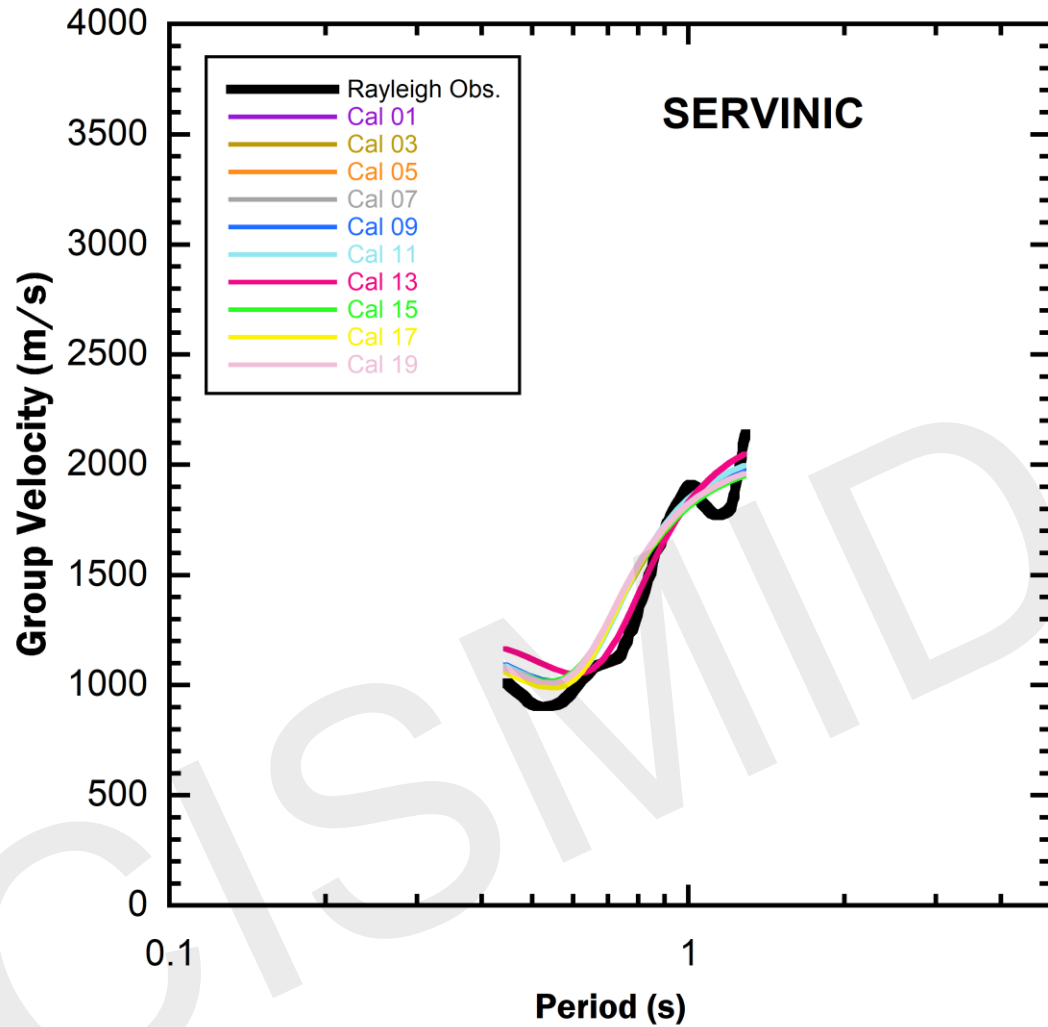
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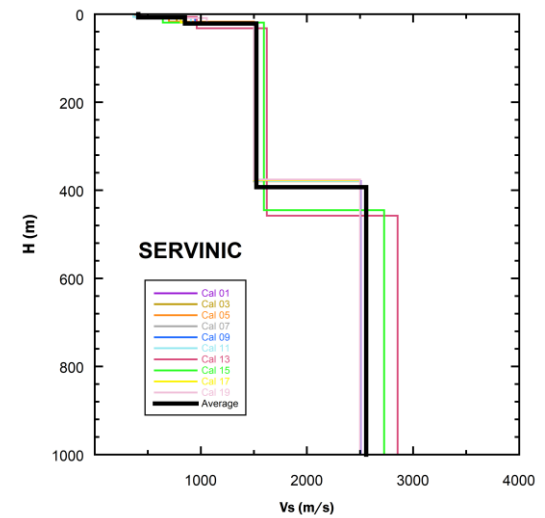
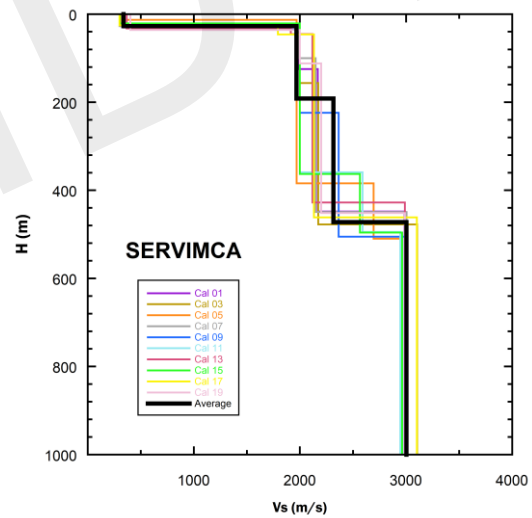
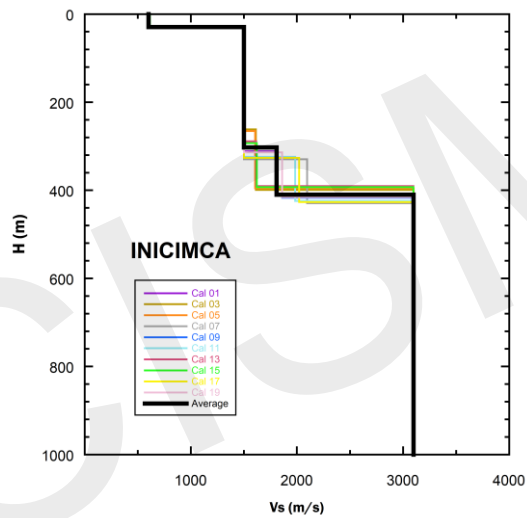
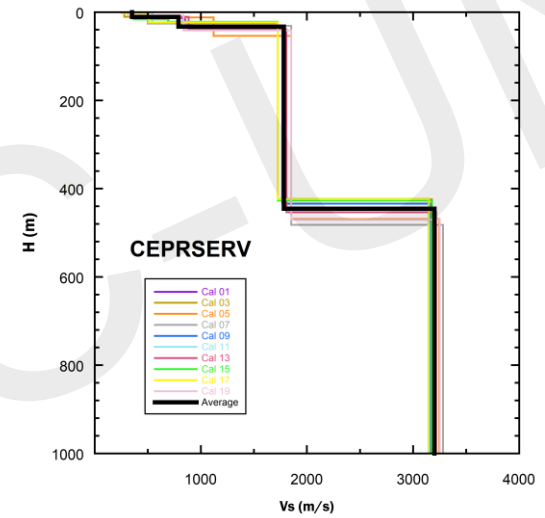
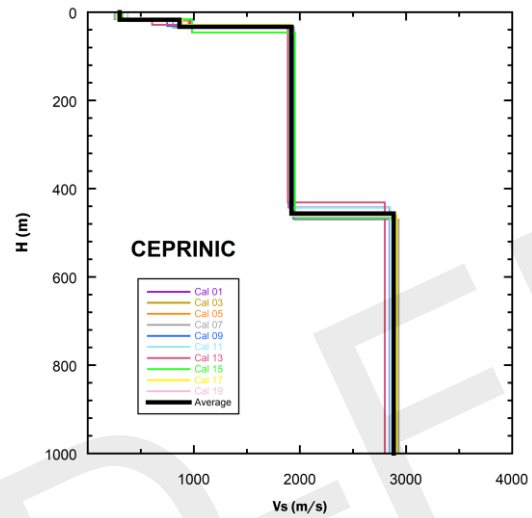
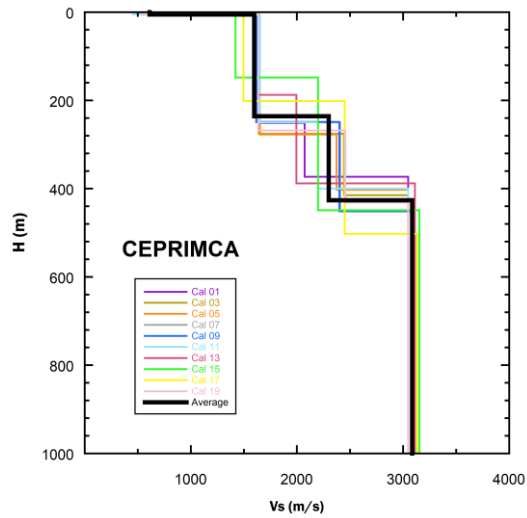
# INVERSIÓN



# INVERSIÓN

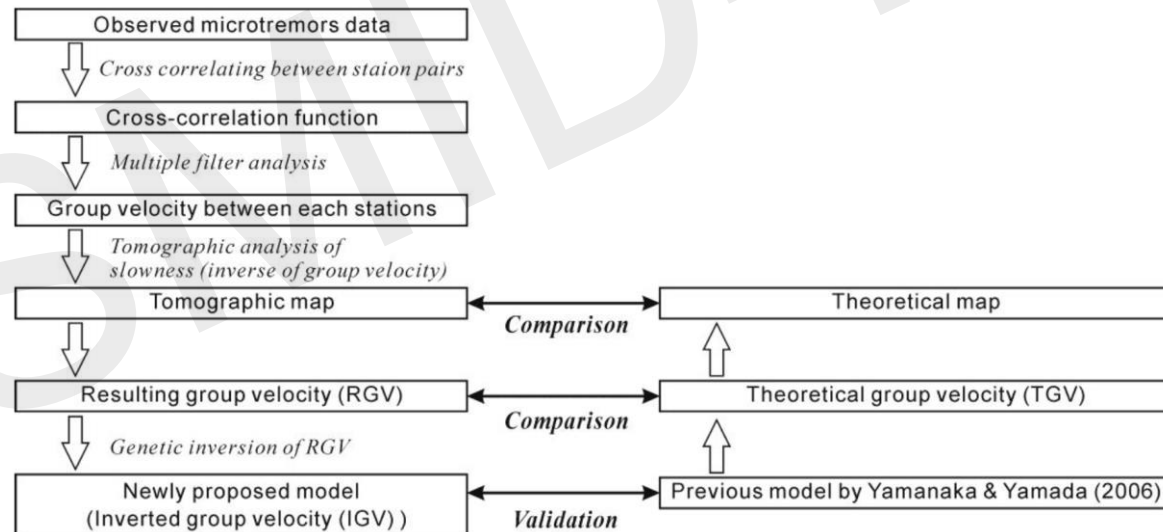


# PERFILES SÍSMICOS



# PLANES A FUTURO (SATREPS)

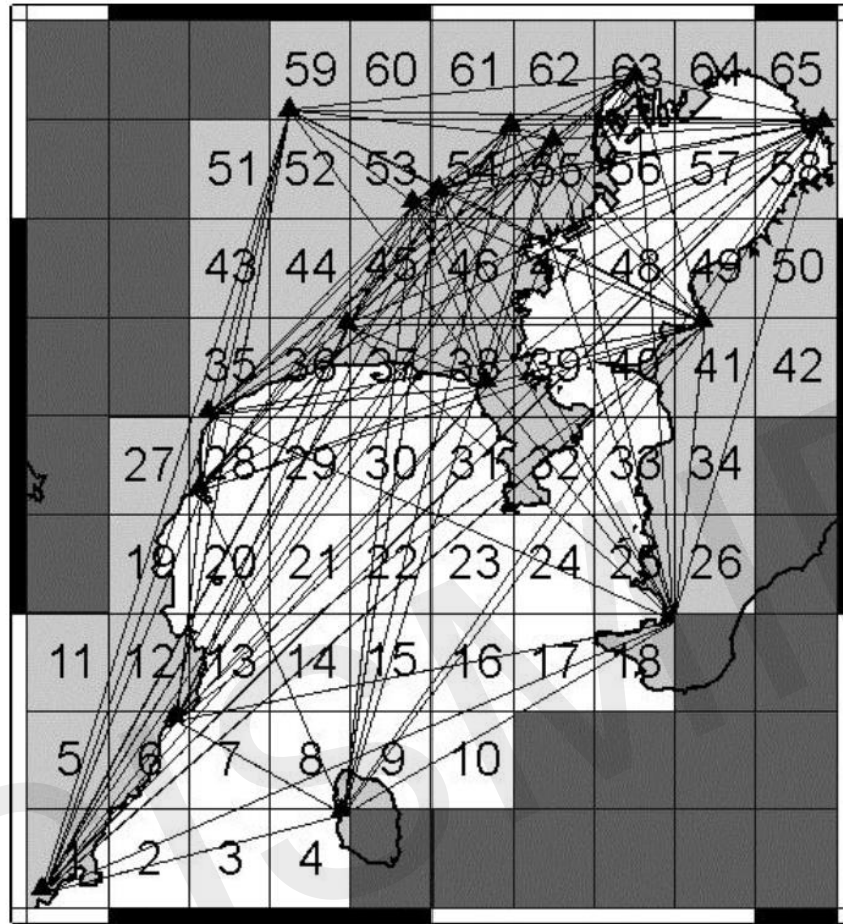
- Adicionar sensores en distintas zonas de Lima, aumentando la distancia entre estos.
- Realizar un modelamiento 3D mediante Tomografía Sísmica (más realista).
- Realizar una simulación mediante un análisis de respuesta.



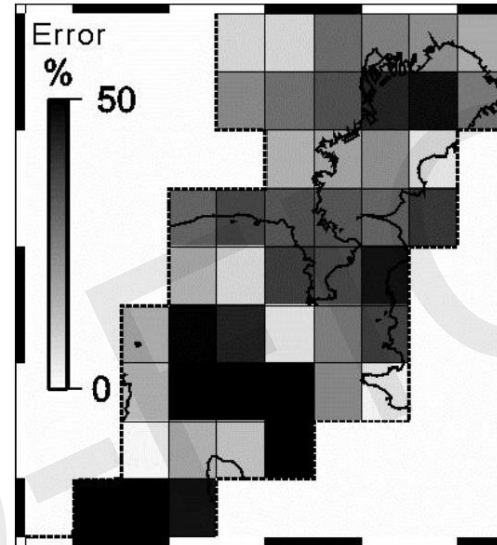
Chimoto y Yamanaka (2011)



# PLANES A FUTURO (SATREPS)



Chimoto y Yamanaka (2011)



$$S_{i,j} = \frac{1}{v_{i,j}}$$

$$[L][S] = [T]$$

$$(S_j)_{k+1} = (S_j)_k + \frac{(e_i)_k}{\sum (l_{ij})^2} l_{ij}$$

