RELIABLE L_g ARRIVAL TIME PICKS AND POTENTIAL FOR ENCHANCED EPICENTER LOCATION

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SCOPE

- L_g characteristics in the crustal wave guide
- Use of L_g waves in observational seismology
- Approach for extracting reliable L_g arrival times
- Analysis results and relocation of epicenters
- Conclusions and recommendations

L_g CHARACTERISTICS

- L_g is dispersive and observed at local/regional distances
- The L_g phase starts gradually and often has a clear amplitude maximum
- Waveforms do not correlate well even down to station separations of a quarter of a wavelength

USE OF L_g WAVES IN OBSERVATIONAL SEISMOLOGY

Travel time observations of L_g onset time picks

- Gradual onset - so not USED in epicenter locations

Amplitude observations - clear L_g maximum used for magnitude estimation

- Easily observable amplitude maximum at 1-3 Hz and group velocities 3.3-3.6 km/sec ensure extensive use for ML magnitude estimation

L_g THEORETICAL STUDIES AND MAJOR RESULTS

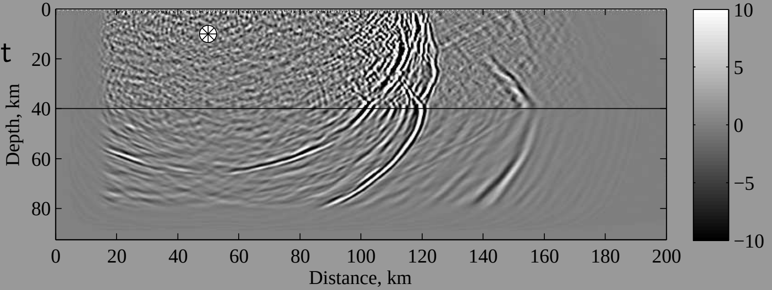
- Understanding L_g propagation in complex media - FD&FE techniques in 2D
- Complex waveforms: S_n-to-L_g and/or L_g-to-S_n conversions
- L_g for mapping regional propagation efficiency in Q_s terms
- Shallow focus events are rich in higher signal frequencies
- L_g blockage for propagation paths across oceanic crust, sedimentary basins and mountain ranges like the Himalayas and Pyrenees
- Outstanding propagational features:
  group velocities 3.3-3.6 km/sec and weak focal depth dependence

CRUSTAL MODEL PARAMETERS FOR 2DFD VISCOELASTIC WAVEFIELD SIMULATION

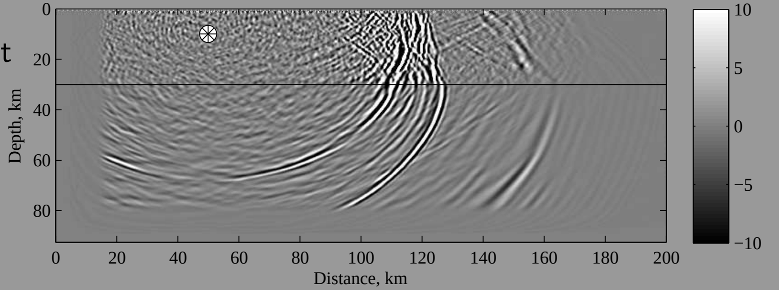
Structure (km)	Vp (km/sec)	Vs (km/sec)	ρ (g/cm^3)	$Q_p = Q_s$
0-30	6.1-6.7	$V_p/\sqrt{3}$	$0.613 + 0.329 * V_p$	200
30-97.5	8.1	$V_p/\sqrt{3}$	3.3	200
0-40	6.1-6.9	$V_p/\sqrt{3}$	$0.613 + 0.329 * V_p$	200
40-97.5	8.1	$V_p/\sqrt{3}$	3.3	200

SYNTHETIC WAVE FIELD DISPLAY

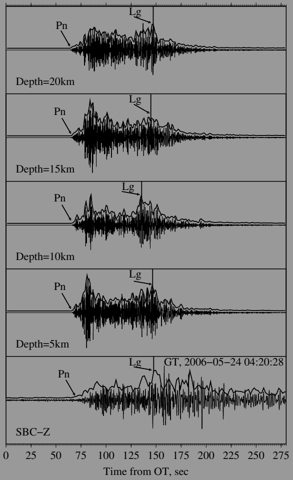
40 km crust



30 km crust



SYNTHETICS AND REAL SEISMOGRAMS FOR DIST = 470 km



RESEARCH INSPIRATION - OUTSTANDING L_g FEATURES

- Most prominent phase in seismograms - only ML in use
- Amplitudes similar between components - Z-comp used
- STA/LTA signal detector measures max L_g arrival times
- Reported group velocities are in range 3.3-3.6 km/sec

Challenge: L_g is not first arrival, so no clear start time to pick

Research solution: Think differently - pick max. amplitude arrival time

STRATEGY FOR PICKING L_g ARRIVALS

- Prefilter 1.5-3.5 Hz for SNR enhancement
- Simpler waveforms using STA or Hilbert transform
- STA-trace is rough - smooth with 'Cleveland' filtering
- Picking time of max. L_g via 3 point interpolation

STA length is not critical if 1.5 sec $<$STA $<$3.0 sec.
recommended use is STA $=$ 2.0 sec

COMMENT:
No difference between STA and Hilbert transforms!

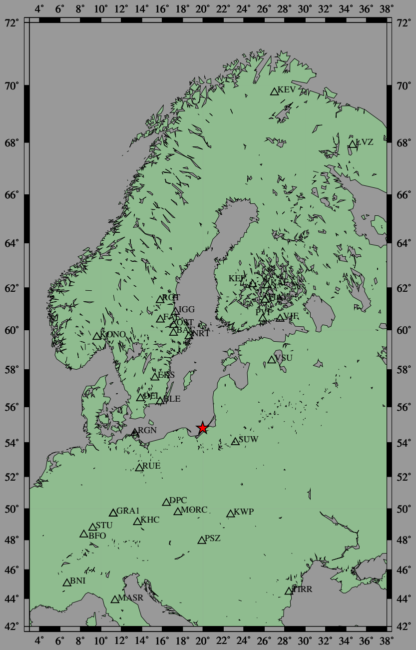
VALIDATING L_g TIME PICKS IN TERMS OF GROUP VELOCITIES

- We selected earthquakes having GT05 solutions
- Events in each of the group are 50-150 km apart and with time separation up to years
- Regions: California, Illinois, SE Canada and NW Europe
- Error sources: location, L_g time picks and Gaussian
- Error: $dV = Vel \cdot dT/T$ with $dt = 1$ & 2.5 sec gives $dV = 0.035$ & 0.10 km sec at 350 km

Validation criteria: dV for i_{th} station is less than 0.10 km sec

Table: Results of L_g group velocity analysis from recordings of two earthquakes near Kaliningrad, Russia

Station/ Direction	Event 4 2004/09/21-11:05			Event 5 2004/09/21-13:32		
	Dist (km)	L_g time (sec)	L_g vel (km/sec)	Dist (km)	L_g time (sec)	L_g vel (km/sec)
SUW (E)	222.1	74.3	2.99	226.3	73.8	3.07
BLE (W)	311.8	99.4	3.14	308.8	96.9	3.19
EKS (NW)	421.5	126.3	3.34	420.4	125.7	3.34
DEL (W)	427.9	126.4	3.39	424.2	132.4	3.20
RGN (W)	434.8	145.8	2.98	428.6	140.5	3.05
RUE (S)	491.7	157.8	3.12	484.4	156.7	3.09
NRT (N)	542.4	163.0	3.33	545.4	163.9	3.33
DPC (S)	558.1	171.6	3.25	551.8	170.4	3.24
VSU (NE)	570.6	175.7	3.25	577.7	174.5	3.31
BAC (NW)	582.8	182.1	3.20	584.9	180.4	3.24
MORC (S)	590.8	179.8	3.29	585.1	181.4	3.23
FLY (N)	600.0	178.0	3.37	602.7	177.4	3.40
KWP (E)	608.6	195.2	3.12	606.8	192.6	3.15
OST (N)	622.0	185.3	3.36	624.3	184.1	3.39
FAL (N)	674.9	206.6	3.27	676.5	198.4	3.41



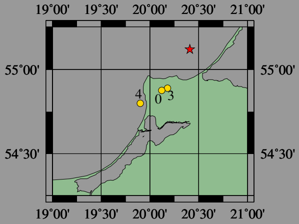
KEV
LVZ
KEF
KAF
PVF
VIF
RGT
IGG
NRT
KONO
VSU
ERS
DEL
BLE
RGN
SUW
RUE
DPC
GRA1
MORC
KHC
KWP
STU
BFO
PSZ
BNI
MASR
TIRR

L_g ARRIVAL TIMES - SUPPLEMENT TO EVENT LOCATION SCHEMES

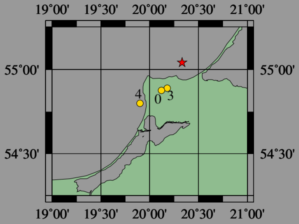
- On a stand alone basis or jointly with P arrival times
- Note, L_g travel times are not sensitive to focal depth in contrast to P and S phases
- L_g travel time tabulations replaced by group velocities
- Grid Search scheme (W. Rodi (PEPI 2006)) for location
- L_g location results on a stand alone basis - **Impressive!**
- For joint $P\&L_g$ location 'double difference' scheme is useful

COMMENT: How accurate are GT05 locations using $P\&P_n$ pickings?

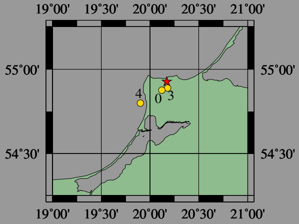
RELOCATION OF KALININGRAD EQ USING L_g TIME PICKS ONLY



(a)

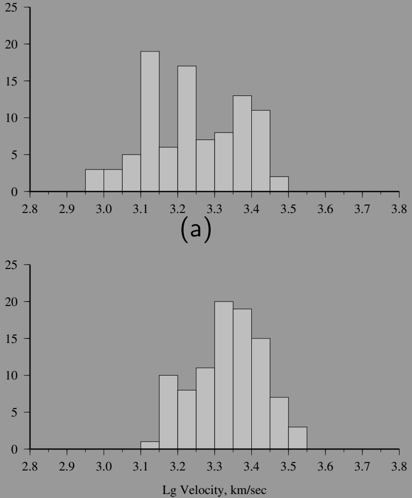


(b)



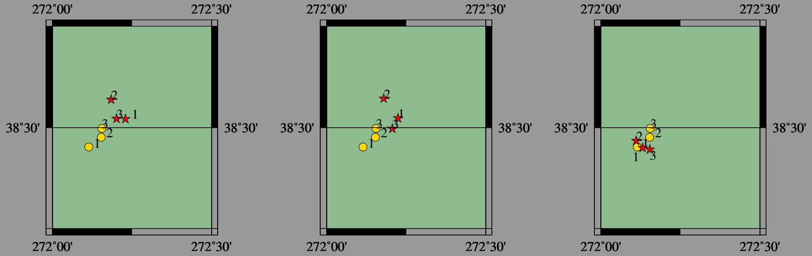
(c)

HISTOGRAMS OF L_g GROUP VELOCITIES FOR KALININGRAD EQ



(b)

RELOCATION OF ILLINOIS EQs USING L_g TIME PICKS ONLY



(a) (b) (c)

CONCLUSIONS

- Complex L_g waveforms - envelope transforms needed
- L_g amplitudes similar on Z, N and E comp. - we use Z
- Spiky L_g envelopes smoothed with Cleveland type filters
- L_g arr. times readings were consistent for EQ analysed
- Good epicenter solutions using only L_g time observations
- L_g depth independent so OT&focal depth less accurate relative to P epicenter solutions
- Routine L_g picks is feasible - via detector parameter STA

Challenge: Use both P and L_g observations in focal parameter estimation would ensure enhanced earthquake locations