Reducing magnitude bias using station thresholds from ISC amplitude/period data

Sheila Peacock, Alan Douglas*, Roy Lilwall+, and David Bowers,
AWE Blacknest

*Deceased 12/3/2015 +Retired

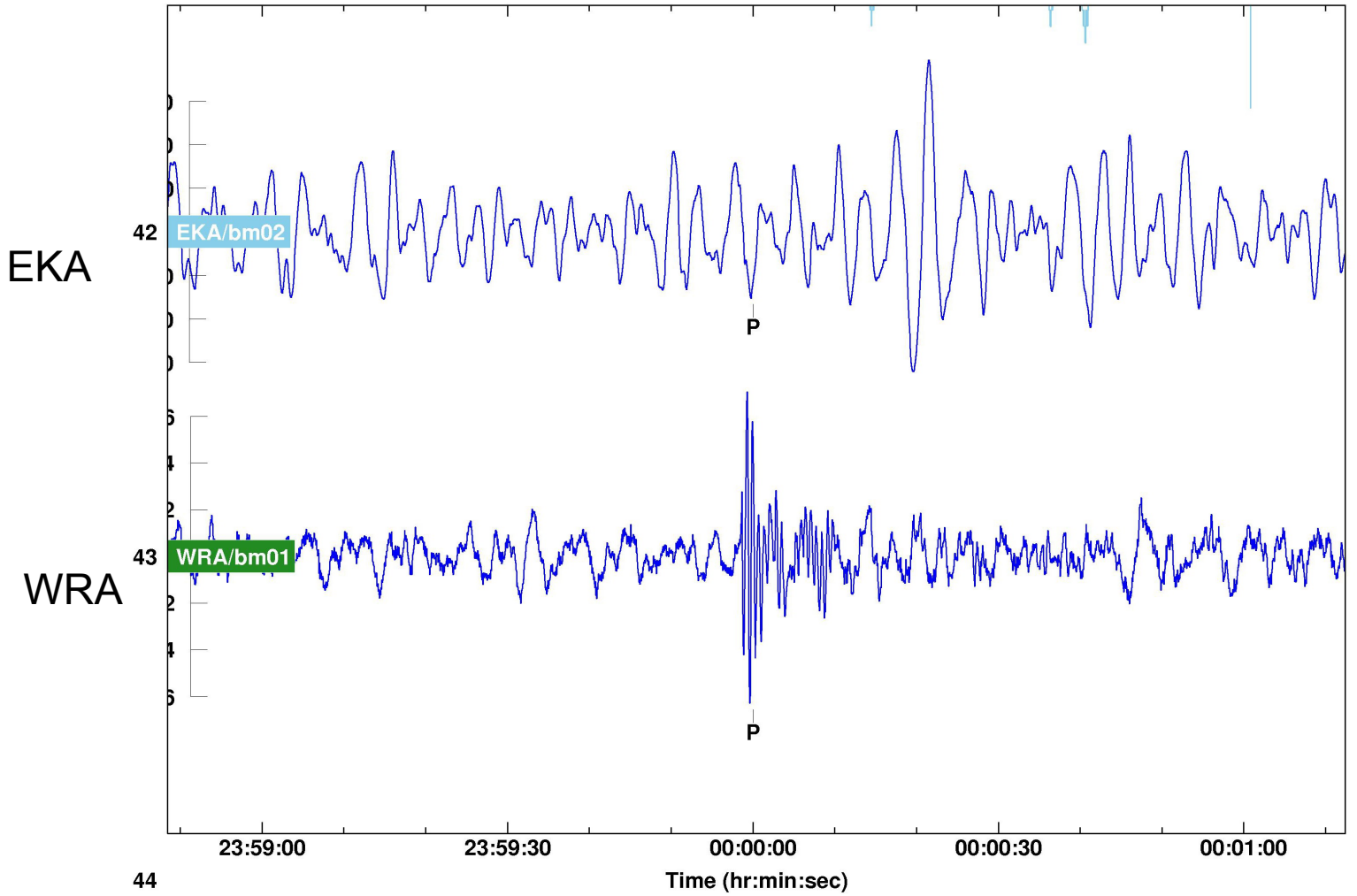
Bias in body-wave magnitude

- Body-wave magnitude formula for single station:

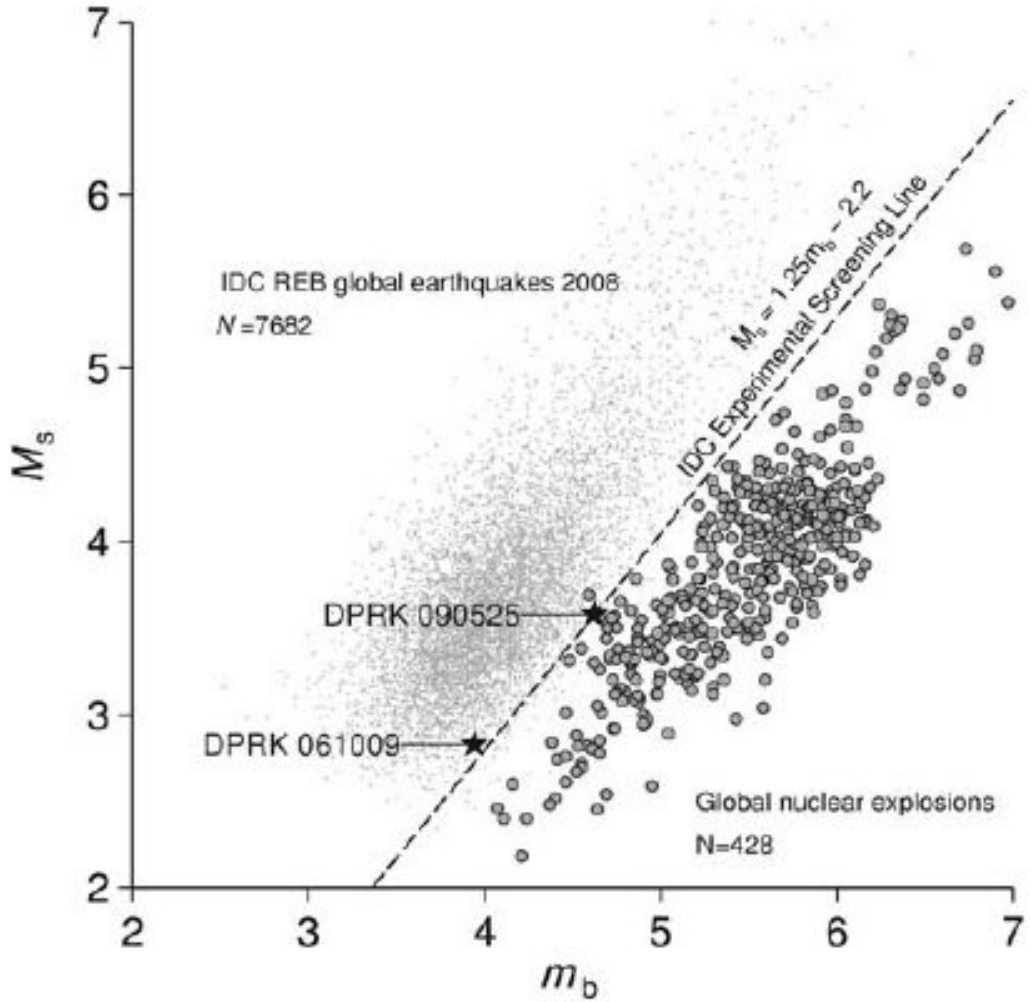
  mb = log A/T + distance correction;

  A and *T* are the amplitude and period of the first P-wave arrival;
- The “network” body-wave magnitude is usually the arithmetic mean of all the station *mb* values provided by the network;
- It does not include stations where the signal is “lost in noise” - *this biases it upwards.*

Signal lost in noise (1988-09-29 presumed nuclear test, China)

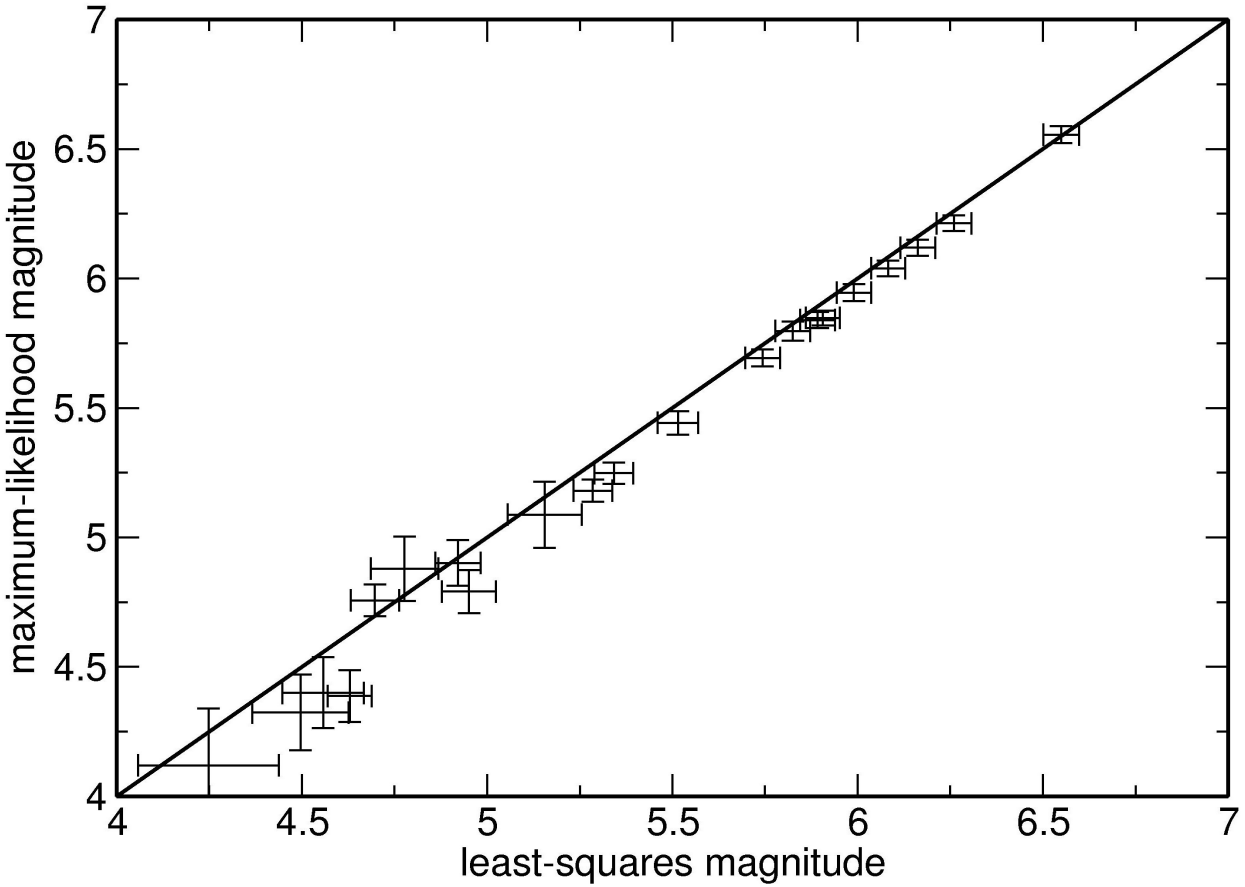


Earthquake/test discrimination



Body-to-surface-wave magnitude discriminant widely used, e.g. by CTBTO

Overcome bias with maximum-likelihood magnitude technique

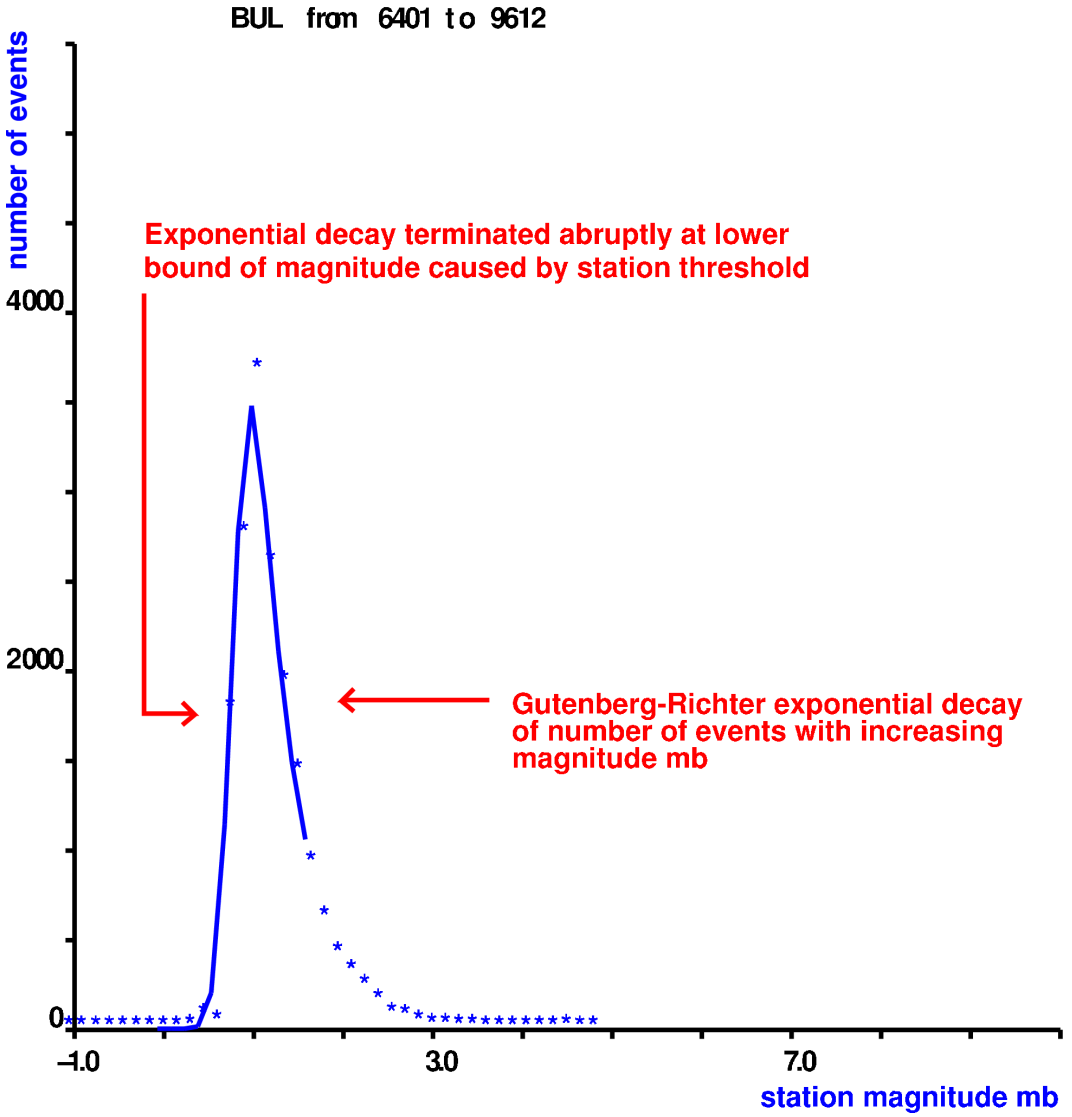


Semipalatinsk presumed explosions – max-like magnitude takes into account station noise thresholds.

Station noise thresholds

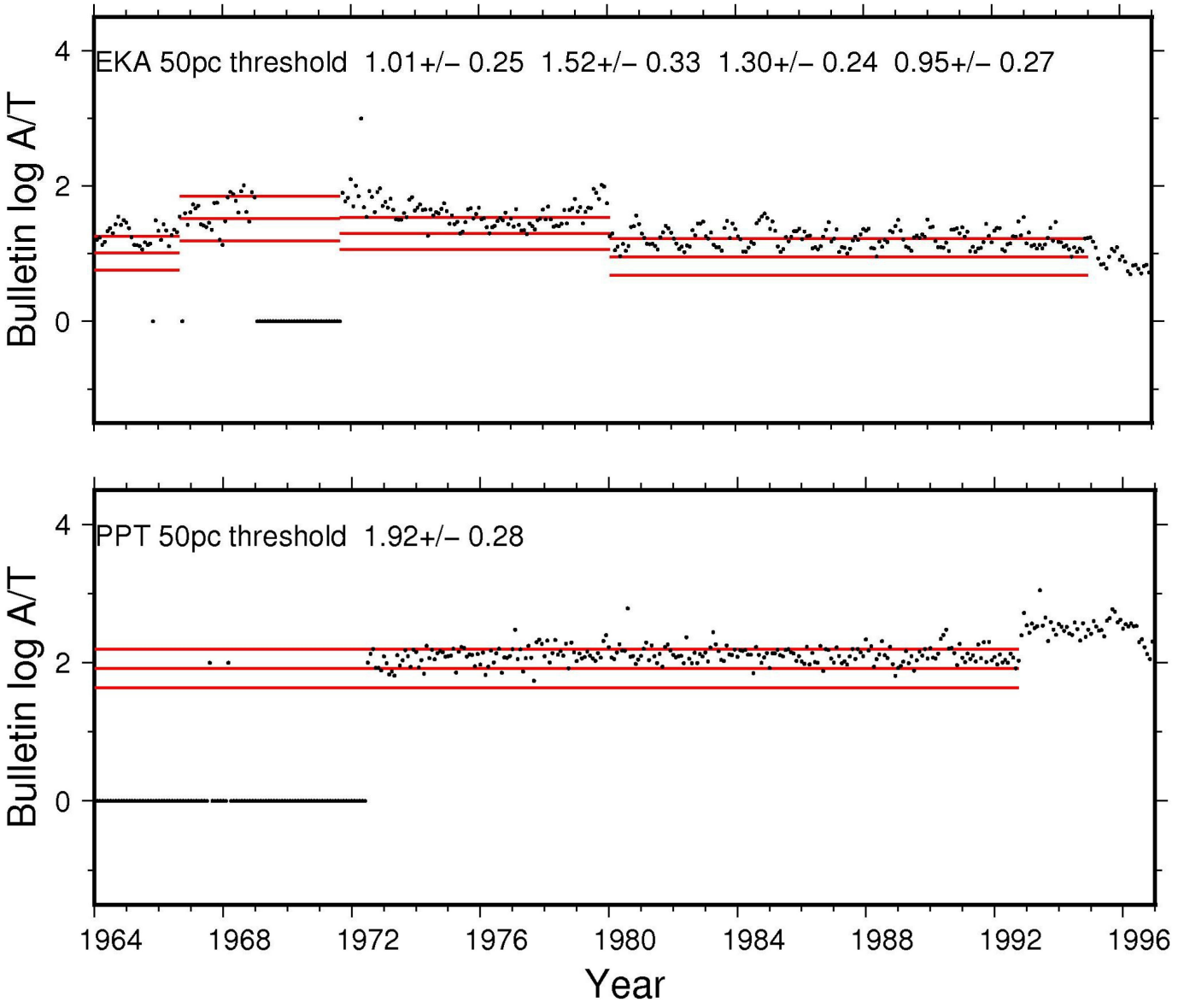
- Noise levels are not routinely measured;
- For stations with frequent contributions to bulletin, noise level can be estimated from the station magnitudes of these contributions, assuming that the seismicity follows a Gutenberg-Richter magnitude-frequency distribution, $\log N = a - bm$;
- Method developed by Kelly & Lacoss 1969.

Curve-fit to find threshold



Station BUL, 1964-1996: threshold 0.81 +/- 0.14

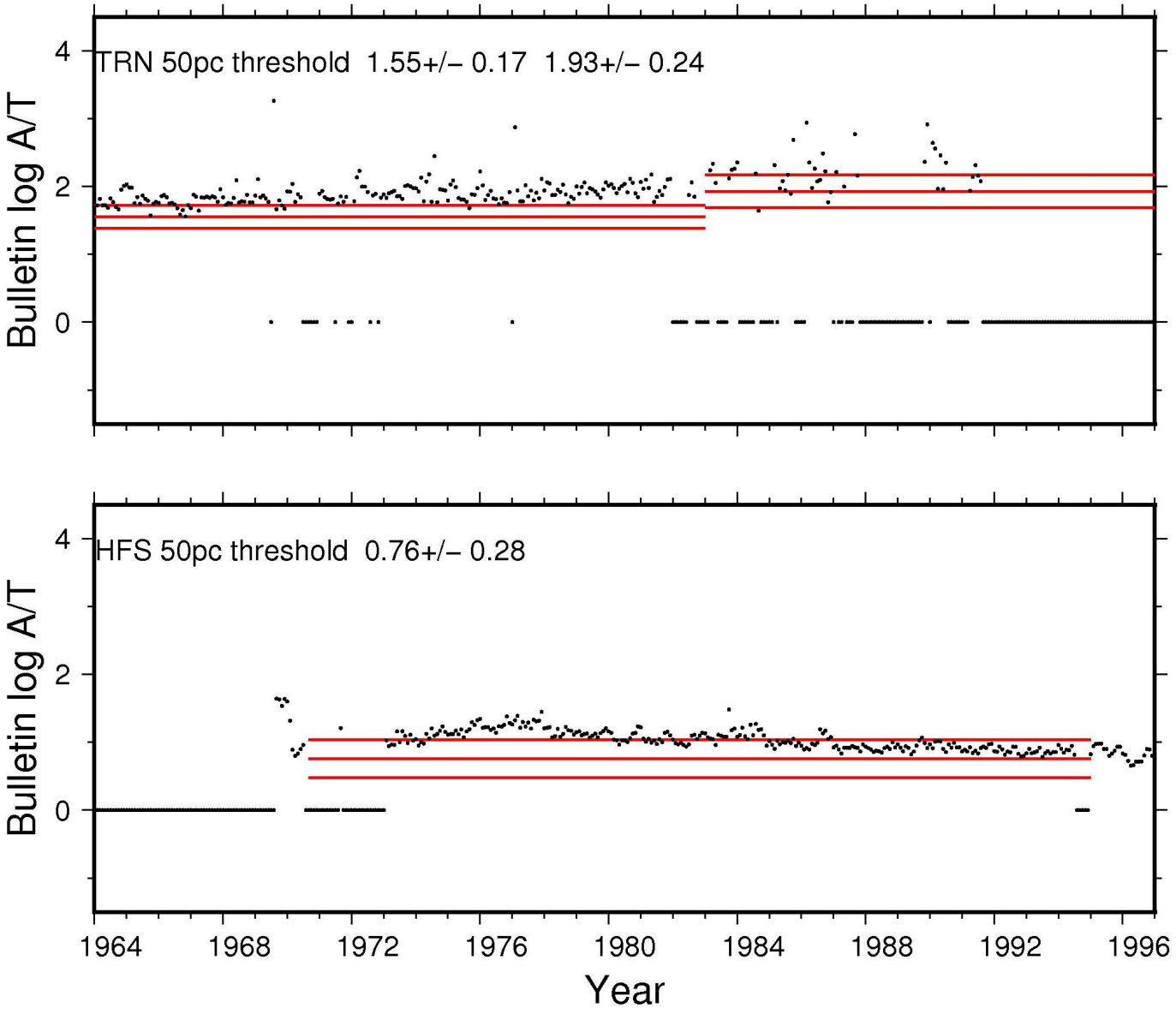
Station thresholds vary with time



EKA Array detector changed 1980

Abrupt change 1992, cause unknown. Had to discard PPT amplitudes after 1992.

Time-varying thresholds (cont)



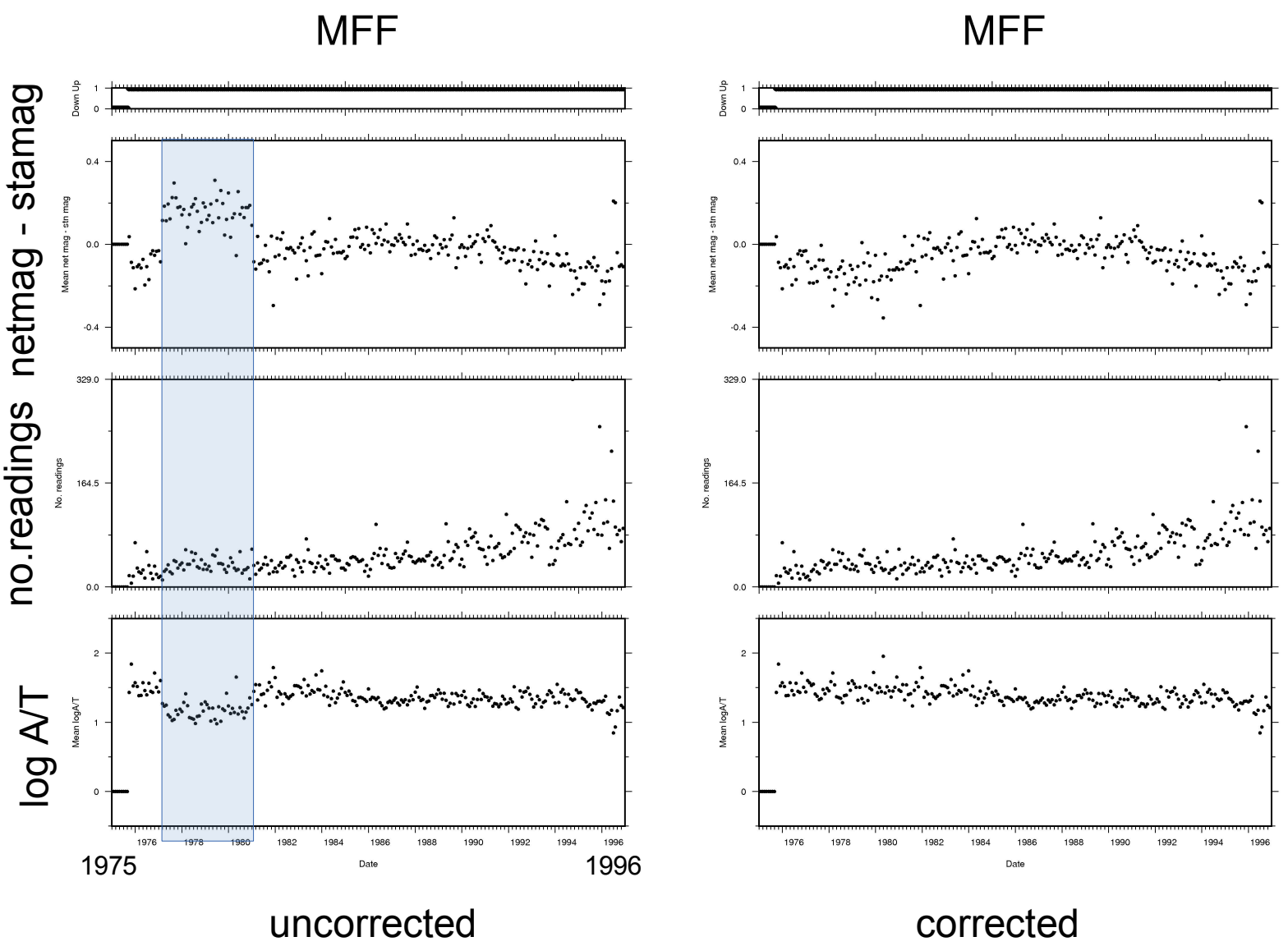
TRN – gradual increase in ambient noise

HFS – gradual decrease caused by network becoming more sensitive so more low-amplitude arrivals at this sensitive station are associated with events

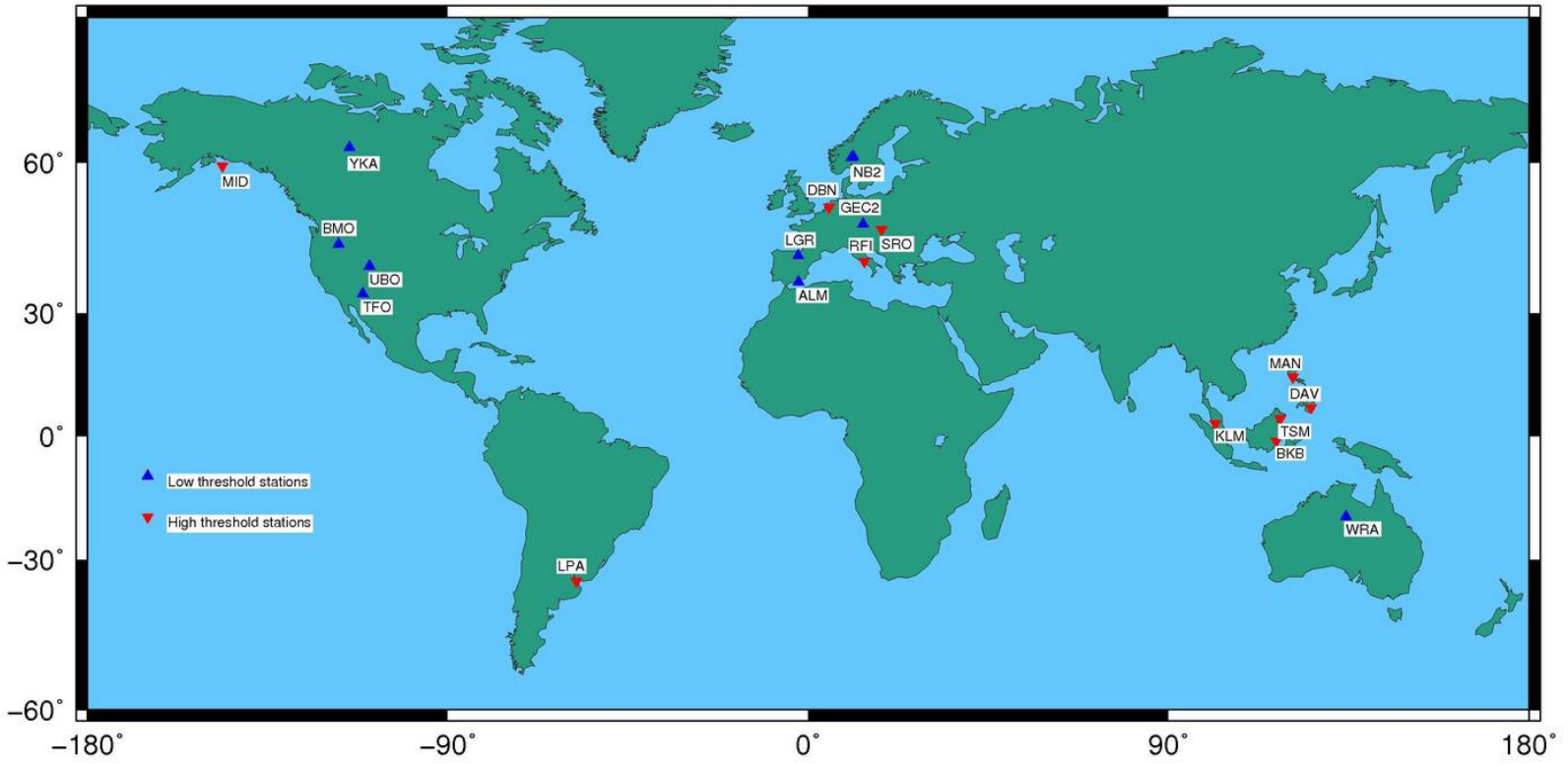
French stations

- ISC convention is that half-peak-to-peak amplitudes are reported;
- French agency LDG reports peak-to-peak amplitudes;
- ISC knew this but sometimes applied the correction twice;
- Stations – 23 affected for June 1978 to end 1981; two (CAF and EPF) affected only in Jan 1981;
- Station AKU (Iceland) amp 10x correct value;
- 17% of readings from 101 presumed explosions at Semipalatinsk are from these 26 stations.

French station MFF



Highest/lowest thresholds

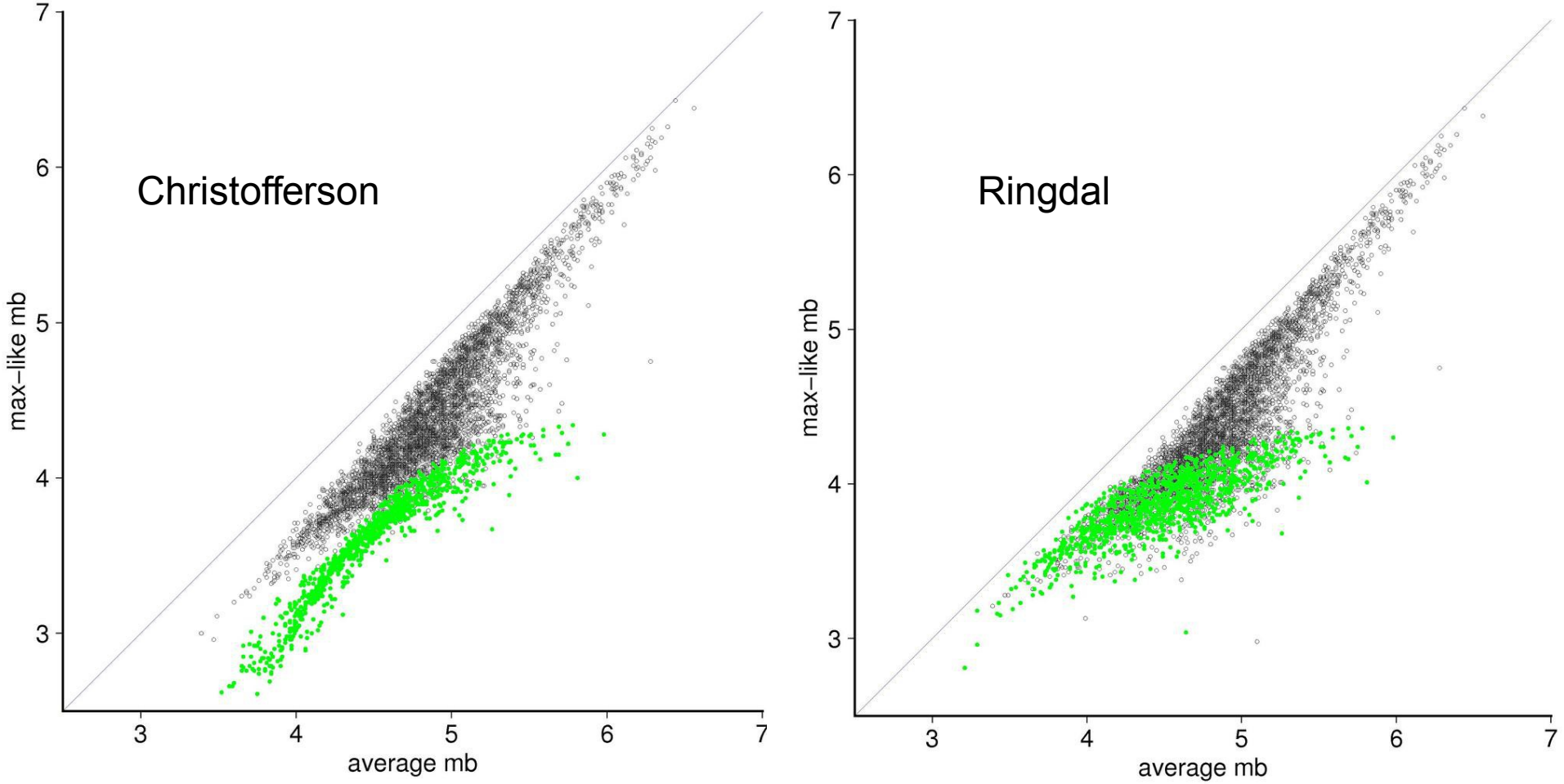


Red – high (mostly coastal); blue – low (mostly inland)
(LGR, Spain – long-running calibration problem?)

Christofferson vs Ringdal

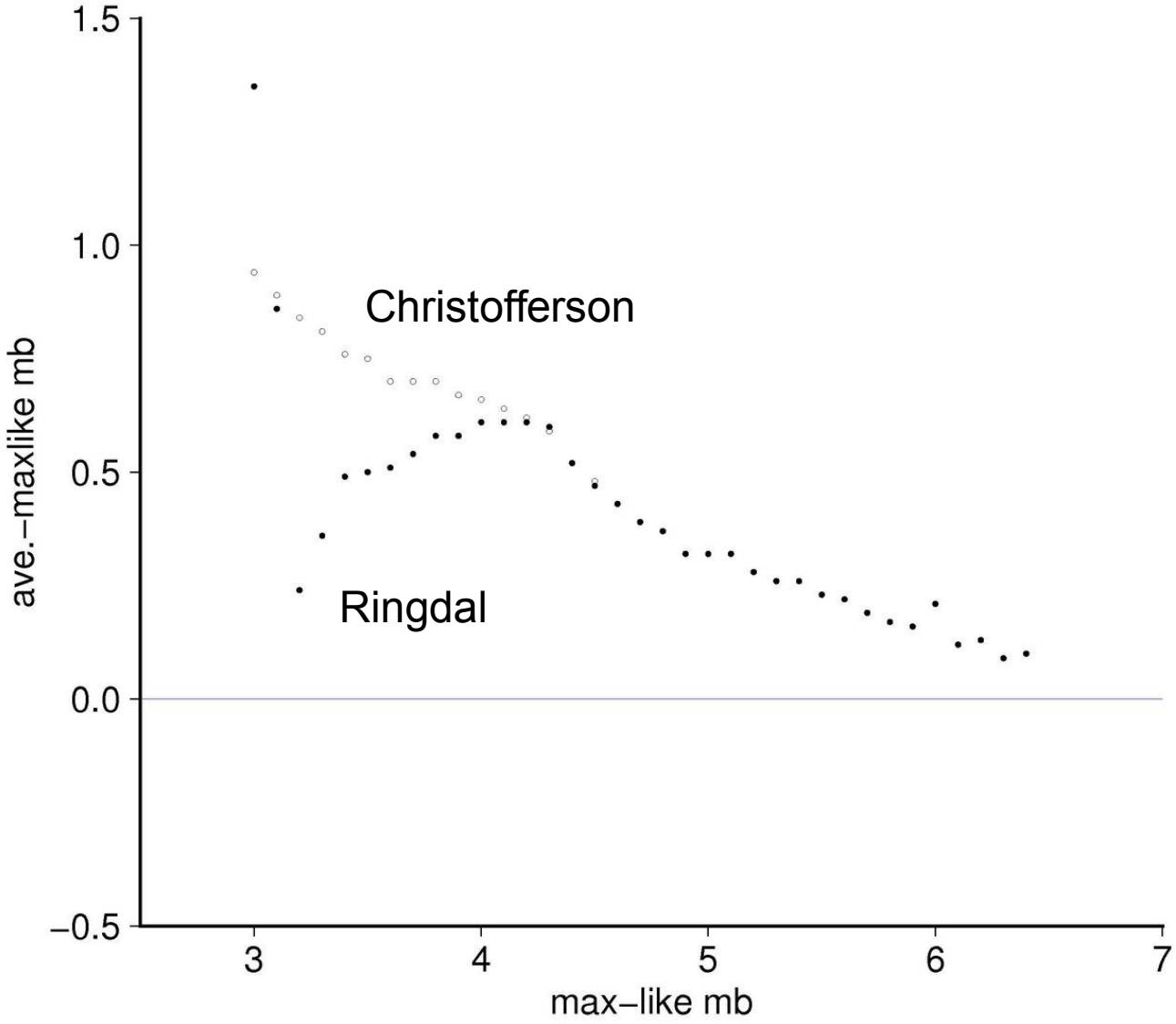
- Christofferson (1980) formula includes conditional probability that at least one station reported an amplitude;
- Ringdal (1976) formula does not;
- This has most effect on magnitudes for which only one station reported.

Christofferson vs. Ringdal



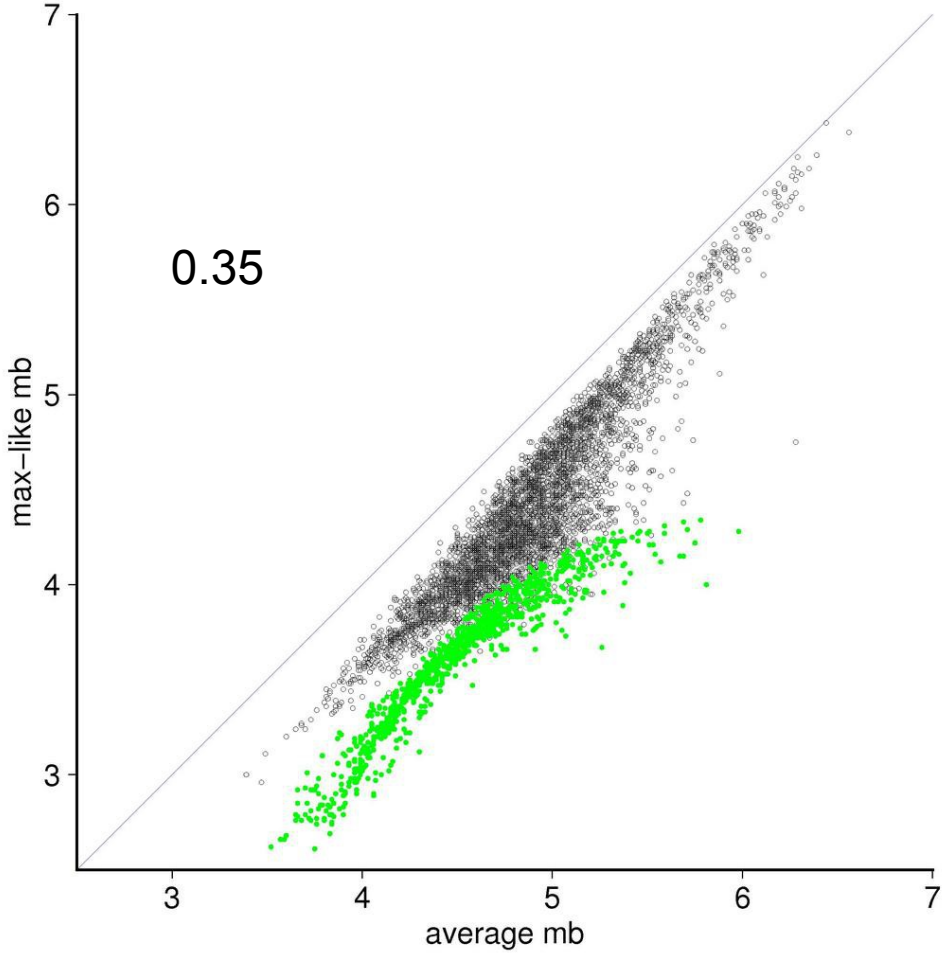
1979 ISC catalogue max-like vs. average mb: green dots = single-station magnitudes

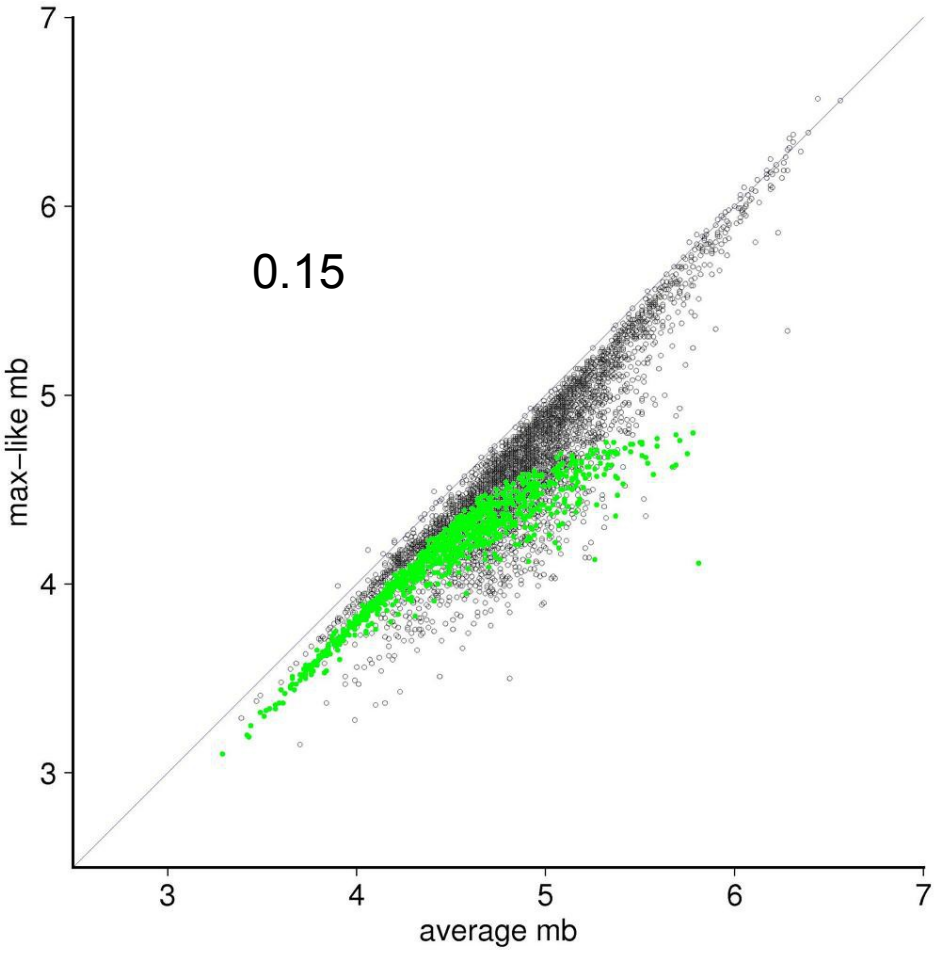
Christofferson vs. Ringdal



Difference between mean mb and max-like mb: Christofferson predicts rising bias as magnitude decreases; Ringdal predicts falling bias apart from last two points.

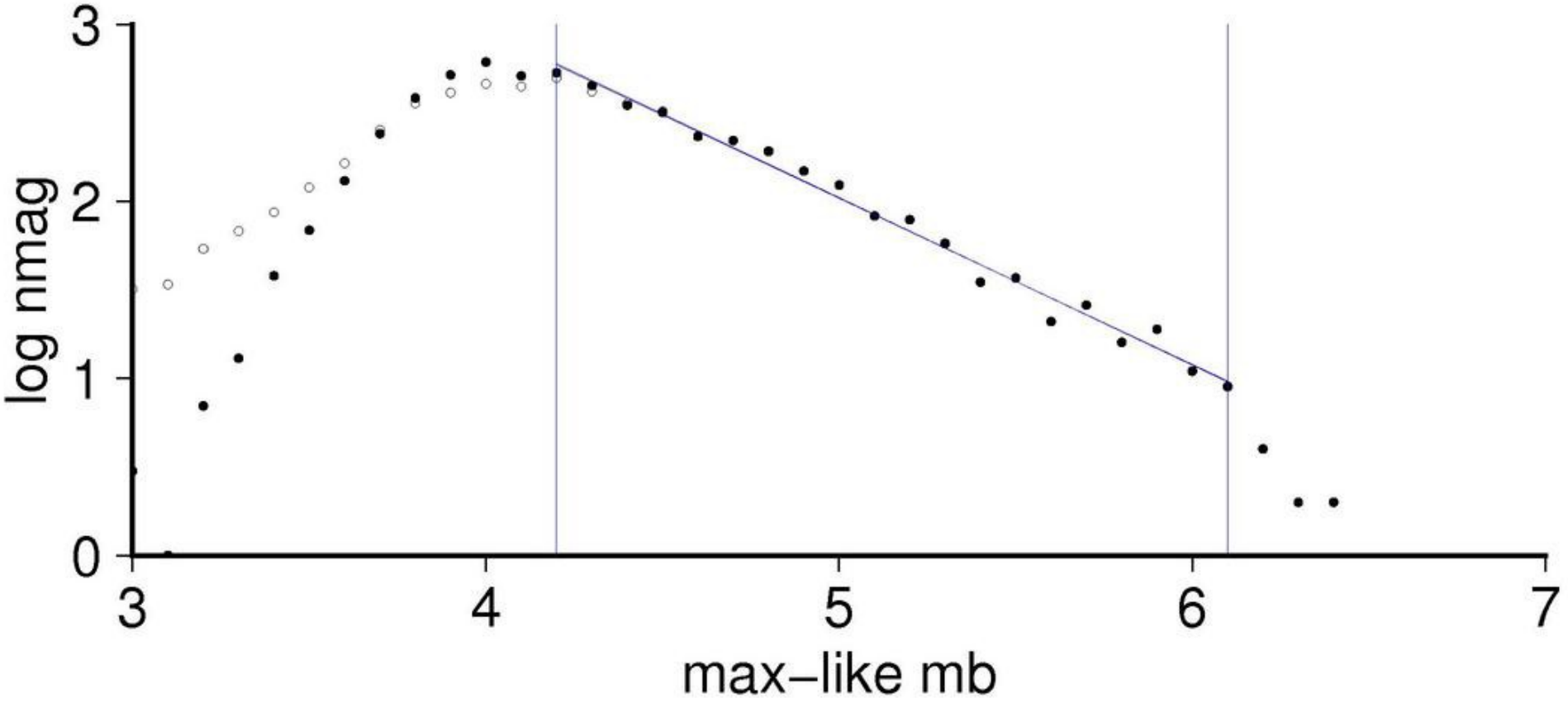
Station magnitude standard deviation (σ)





1979 ISC catalogue magnitude bias with Christofferson formula: lower σ reduces estimated bias. σ = 0.35 is used by CTBTO.

“b” value



ISC 1979 worldwide catalogue magnitude-frequency “b” value for earthquakes between 4.2 and 6.1. “b” value is 0.94 for both Christofferson and Ringdal formulae.

Final slide

- References

Kelly, E. J., and Lacoss, R. T., 1969 MIT Lincoln Lab Tech Note 1969-41;

Christofferson, A., 1980, PEPI 21, 237-260;

Gutenberg, B., and Richter, C. F., 1956, Ann. Geofis 9,1-15;

Ringdal, F., 1976, BSSA 66, 789-802;

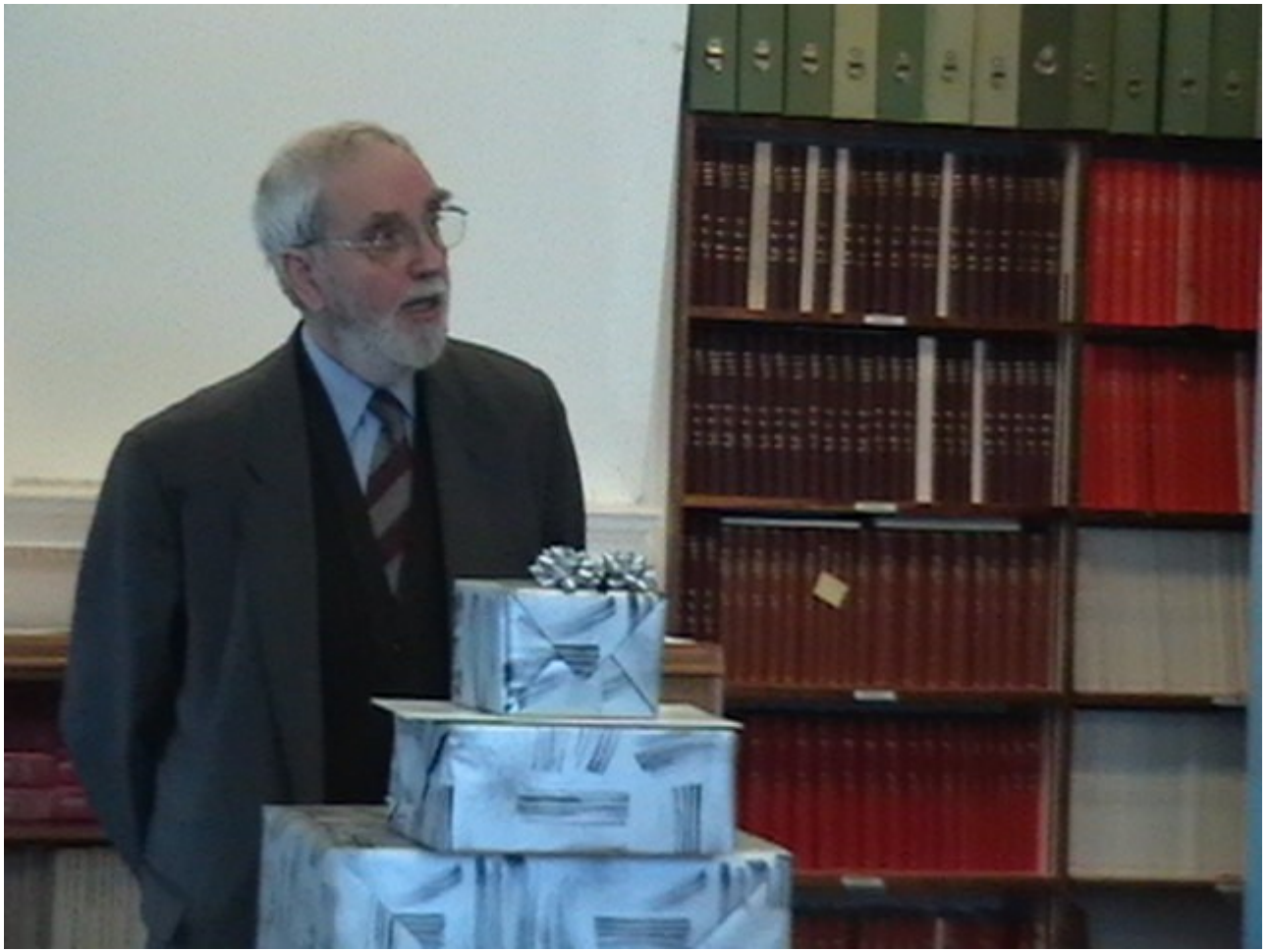
CTBTO ISC Processing of SHI data 5.2.1Rev1;

Lilwall, R, 1986, AWRE O report 22/86;

Lilwall, R., and Neary, J. M, 1985, AWRE O report 21/85.

- Acknowledgments – Neil Selby; GMT graph/map software (Wessell and Smith)

Alan Douglas 1936-2015



(Photo taken in 2006 of Alan presiding at a colleague's retirement party; photo credit P. Bartholomew)