Characterization of fin whale vocalizations in the Gulf of Cadiz using Ocean Bottom Seismometers

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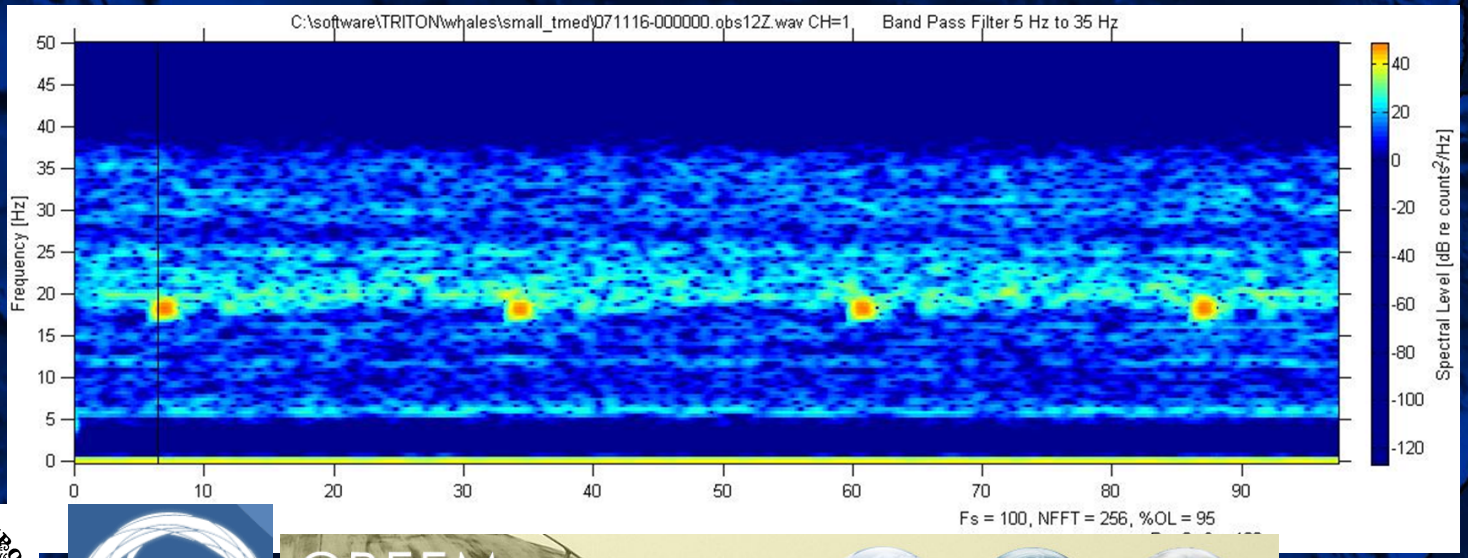

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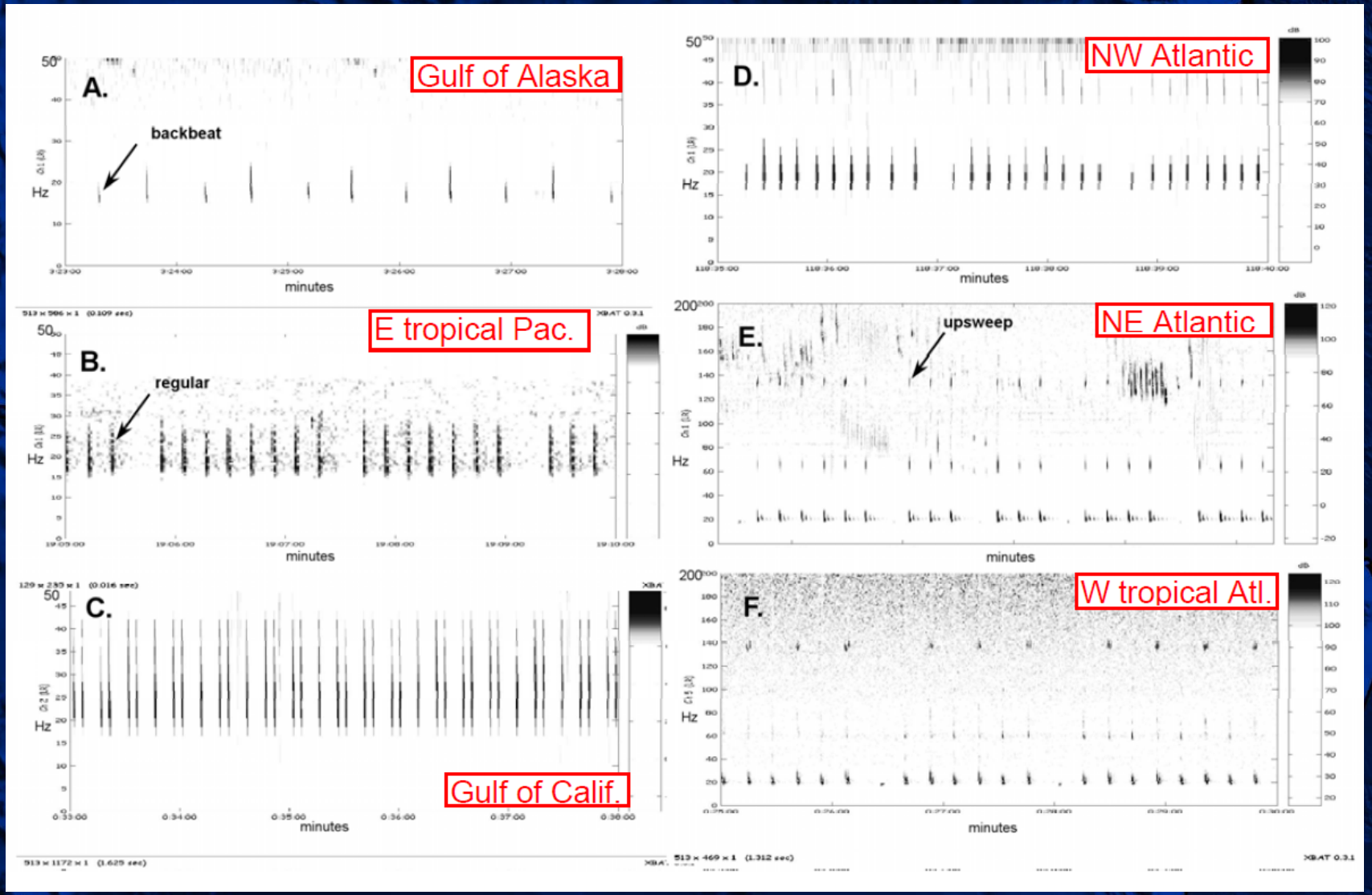
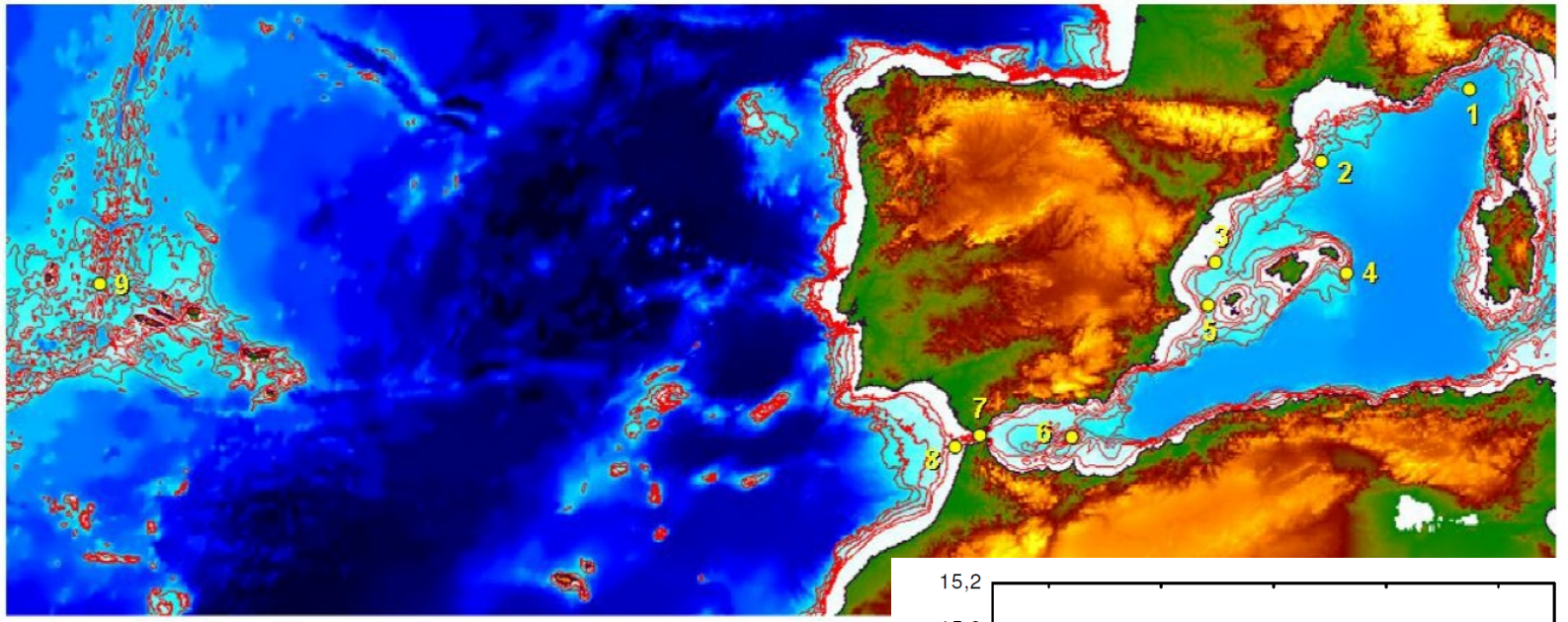
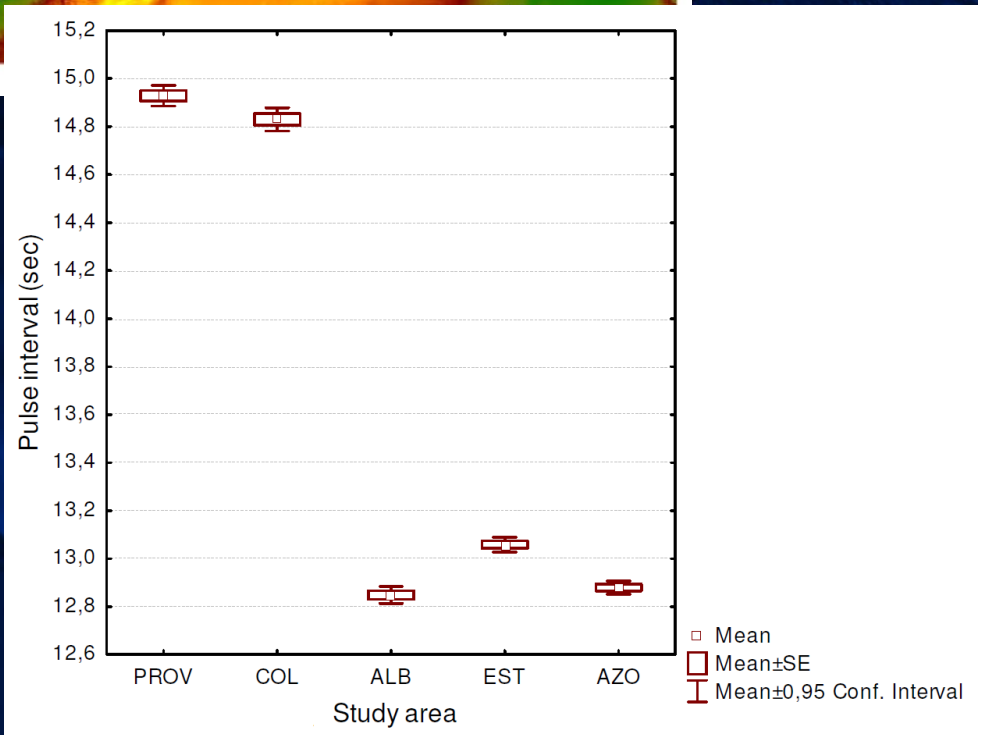
Acoustics as population markers



Hatch & Clark (2004)

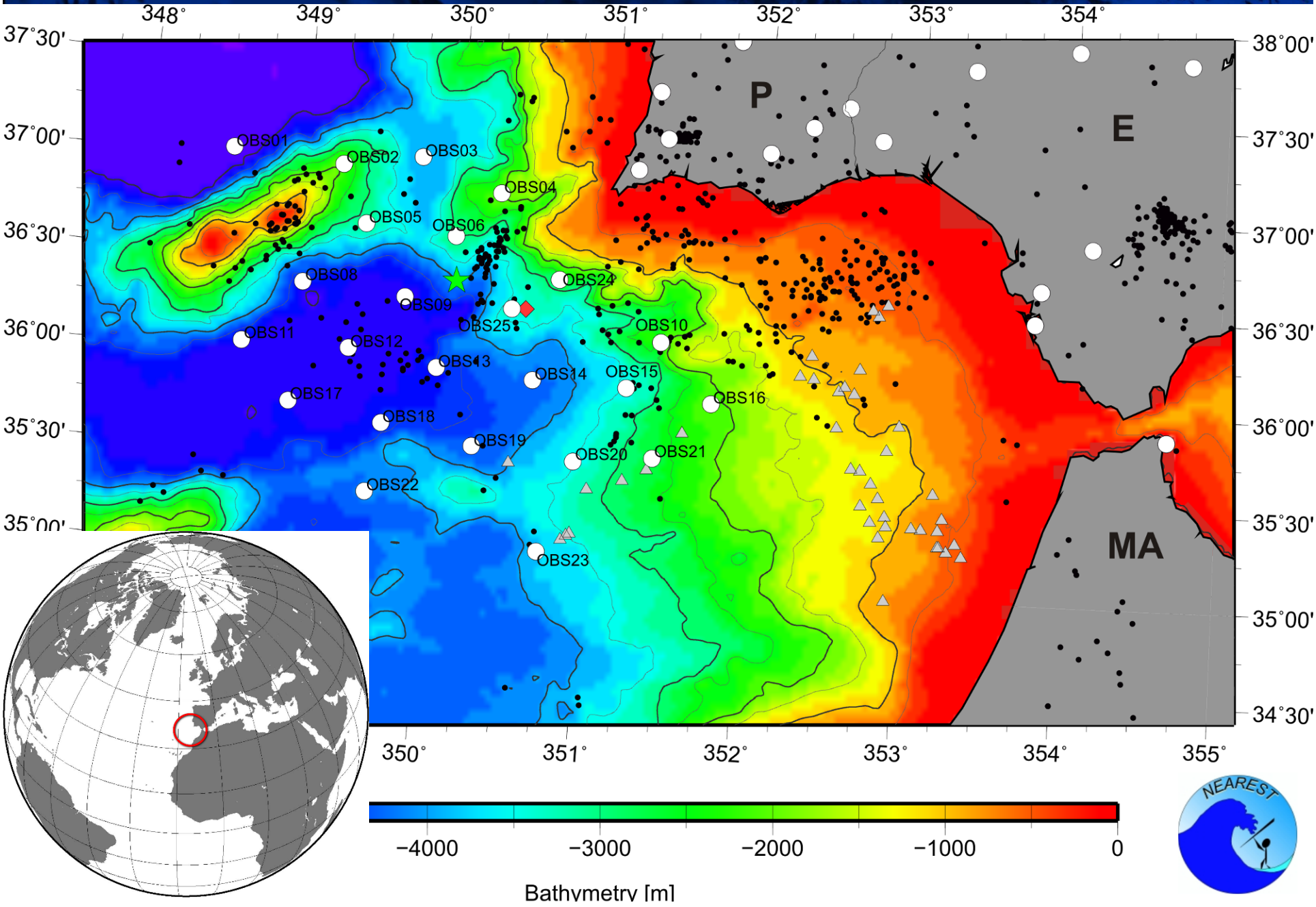
Acoustics as population markers



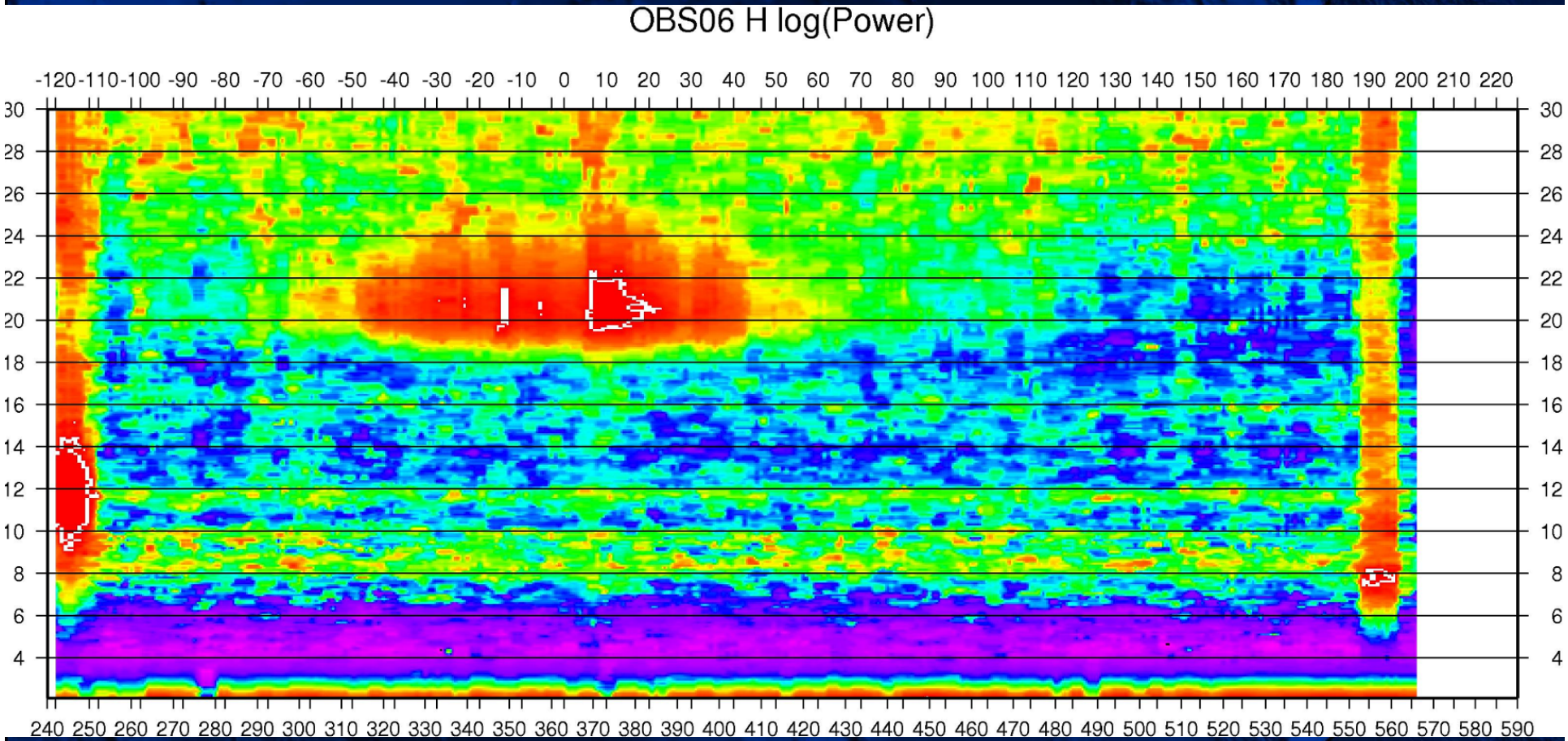


Castellote et al. (2012)

The NEAREST experiment August/2007 to July/2008



Fin whales are the loudest sound source in the frequency band 18 to 26 Hz

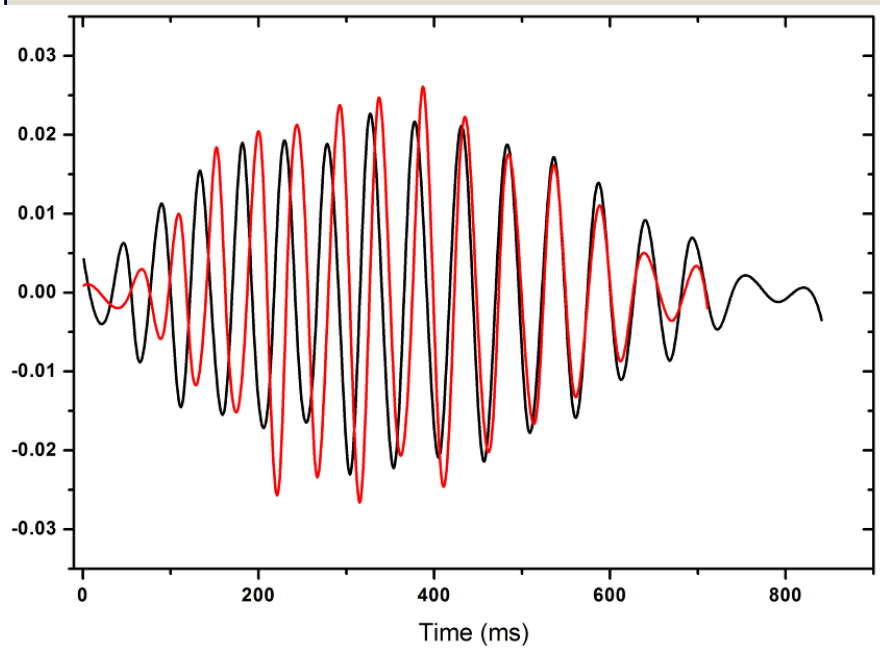


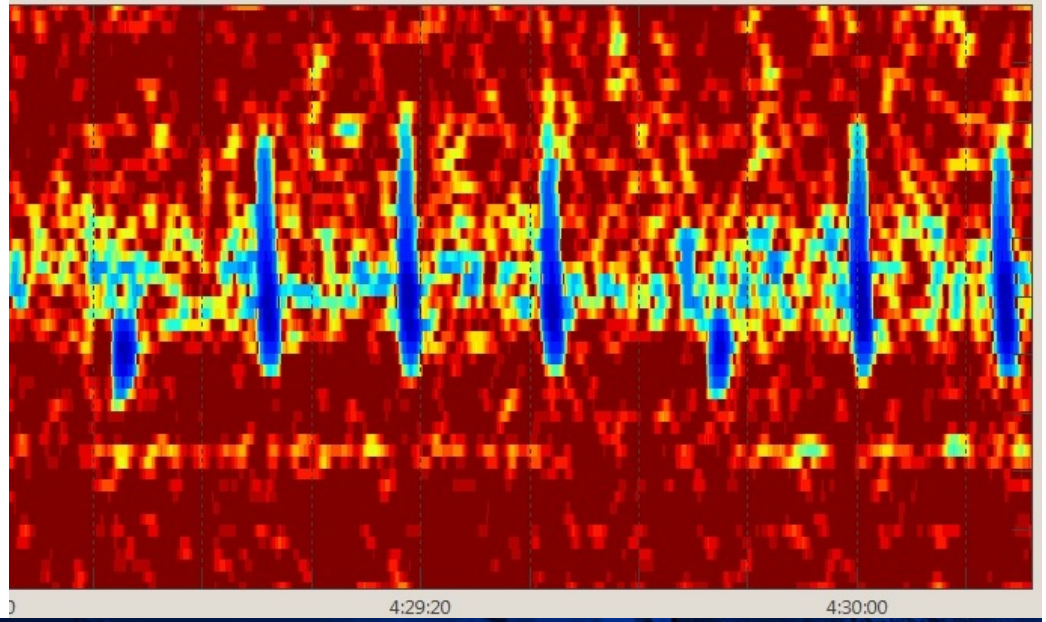
Fin whale vocalizations recorded

Following Hatch & Clark (2004), Castellote et al. (2012) terminology

With 100 Hz sampling, only 2 notes can be recorded:

- **Regular or 20 Hz down sweep**
- **Back-beat**





Characterization of fin whale vocalizations

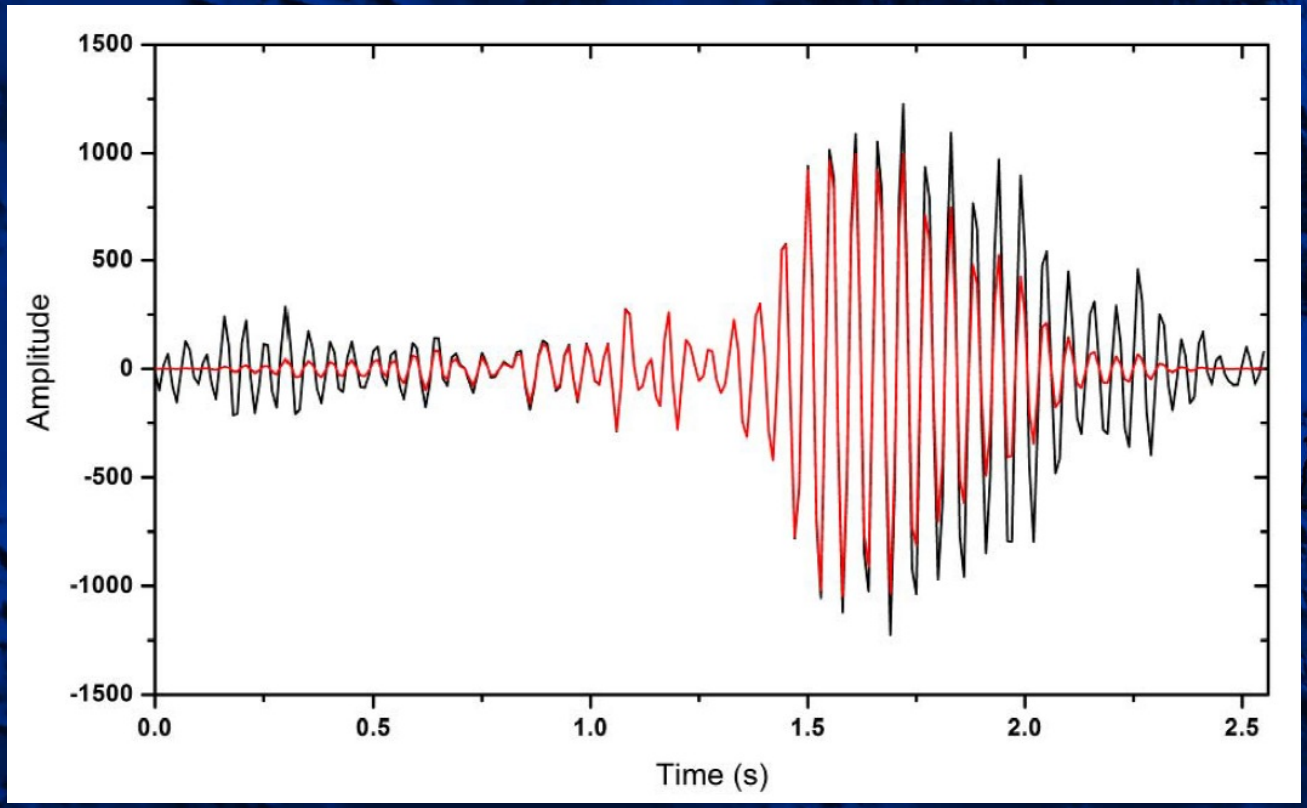
Following

Hatch & Clark (2004)

Castellote et al. (2012)

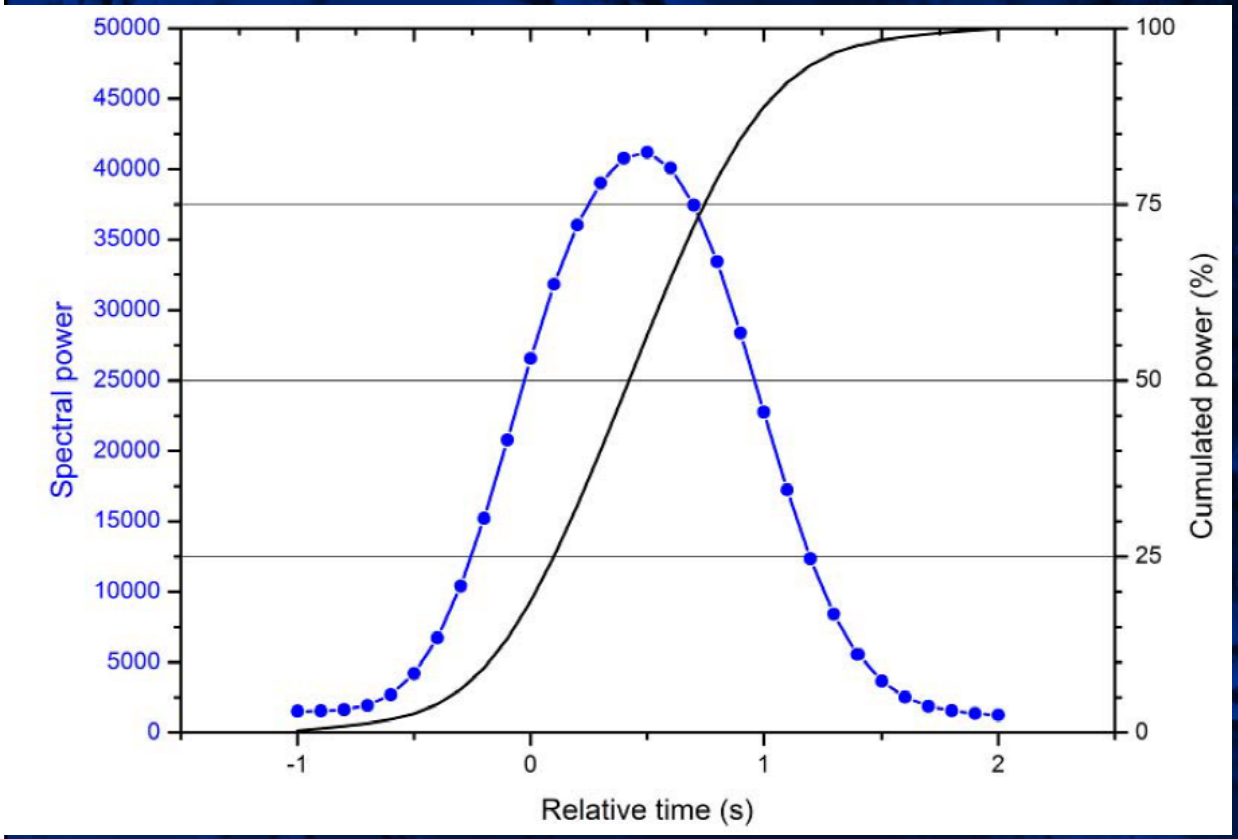
- **Number and proportion of note types**
- **Inter-note interval**
- **Note features**
  - **Median frequency** (aka central frequency)
  - **Frequency bandwidth**
  - **Duration**
  - ***(Peak frequency)***

Computation of spectral parameters



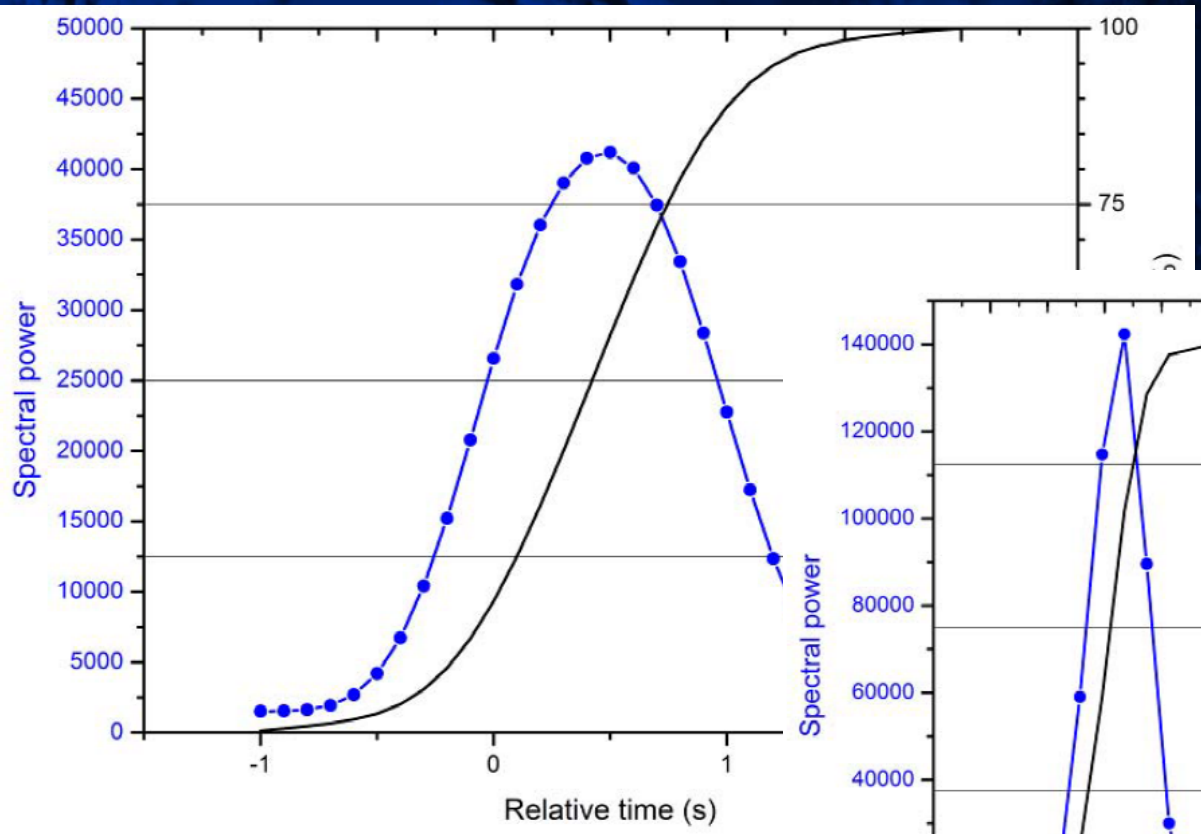
One running window with 256 samples is extracted and tapered before FFT and power computation

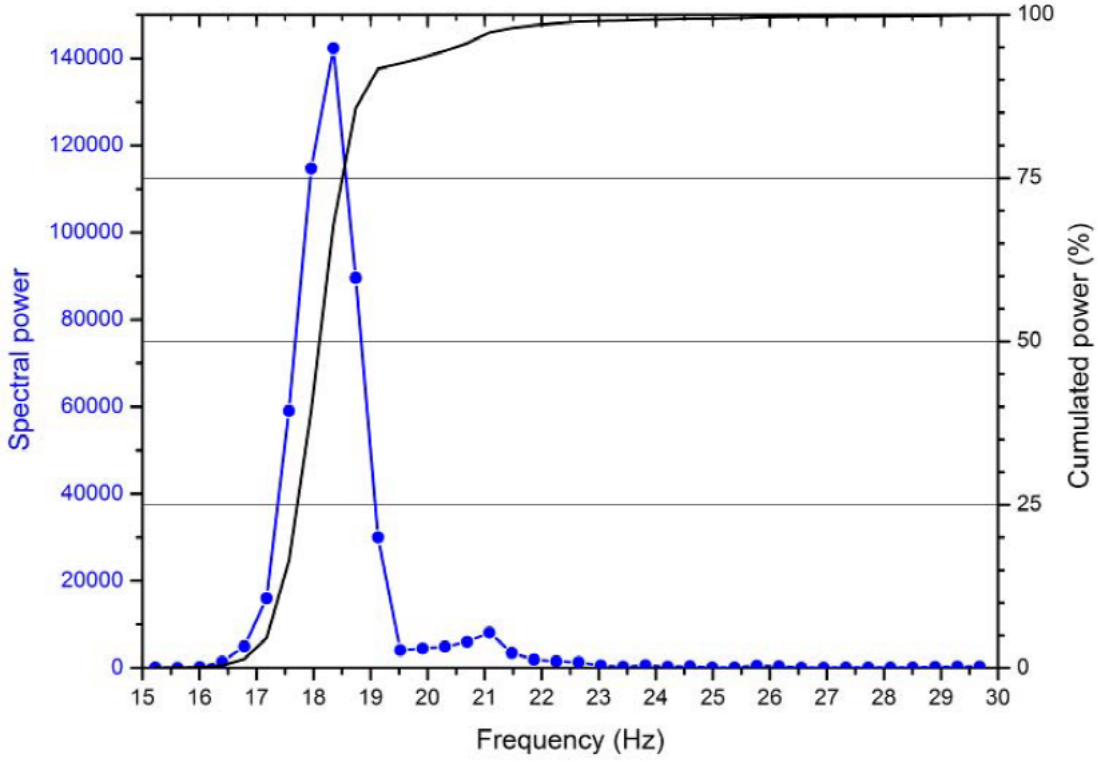
Computation of spectral parameters



The cumulative power is computed as a function of time

Computation of spectral parameters

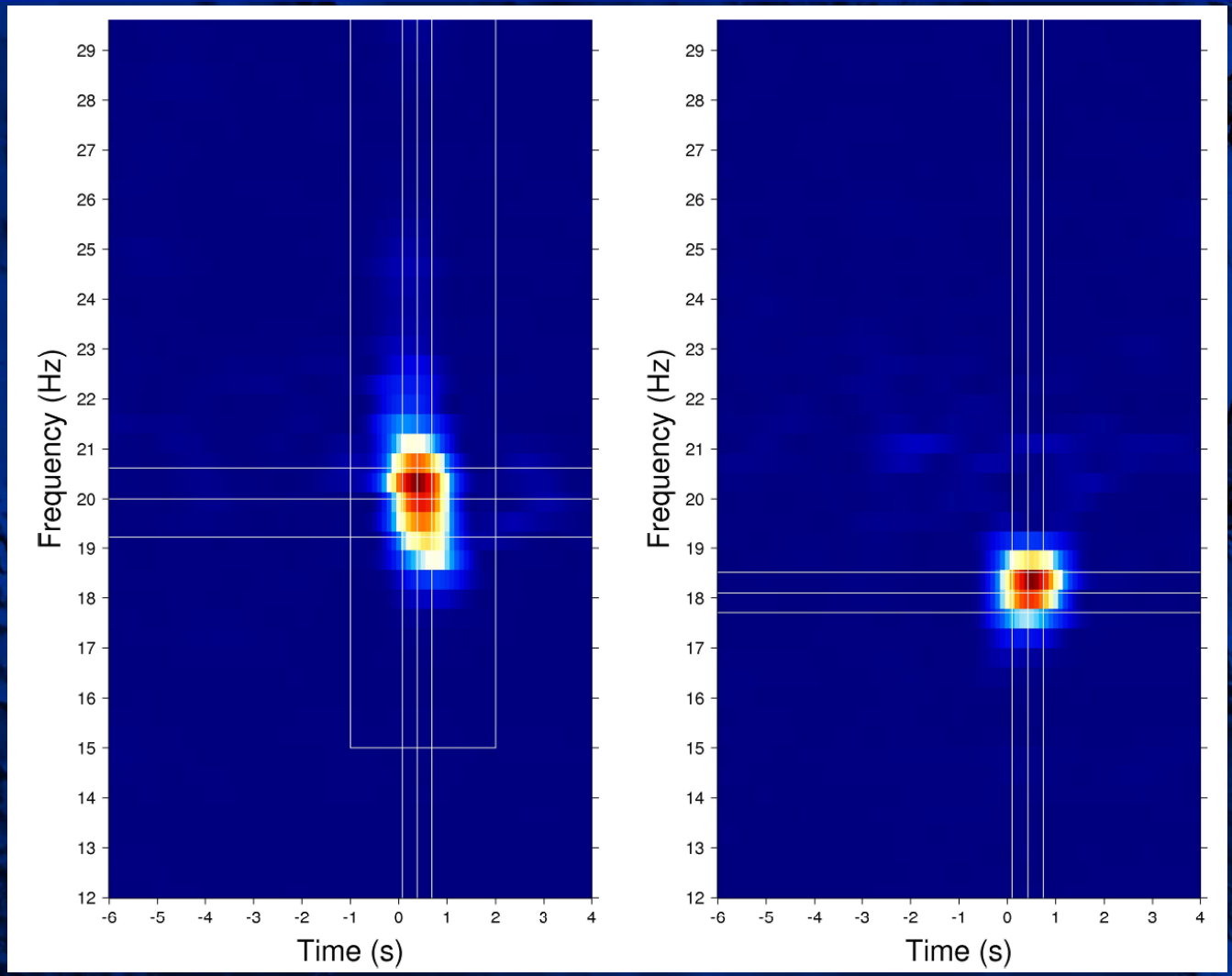




The cumulative power is co
function of time

and frequency

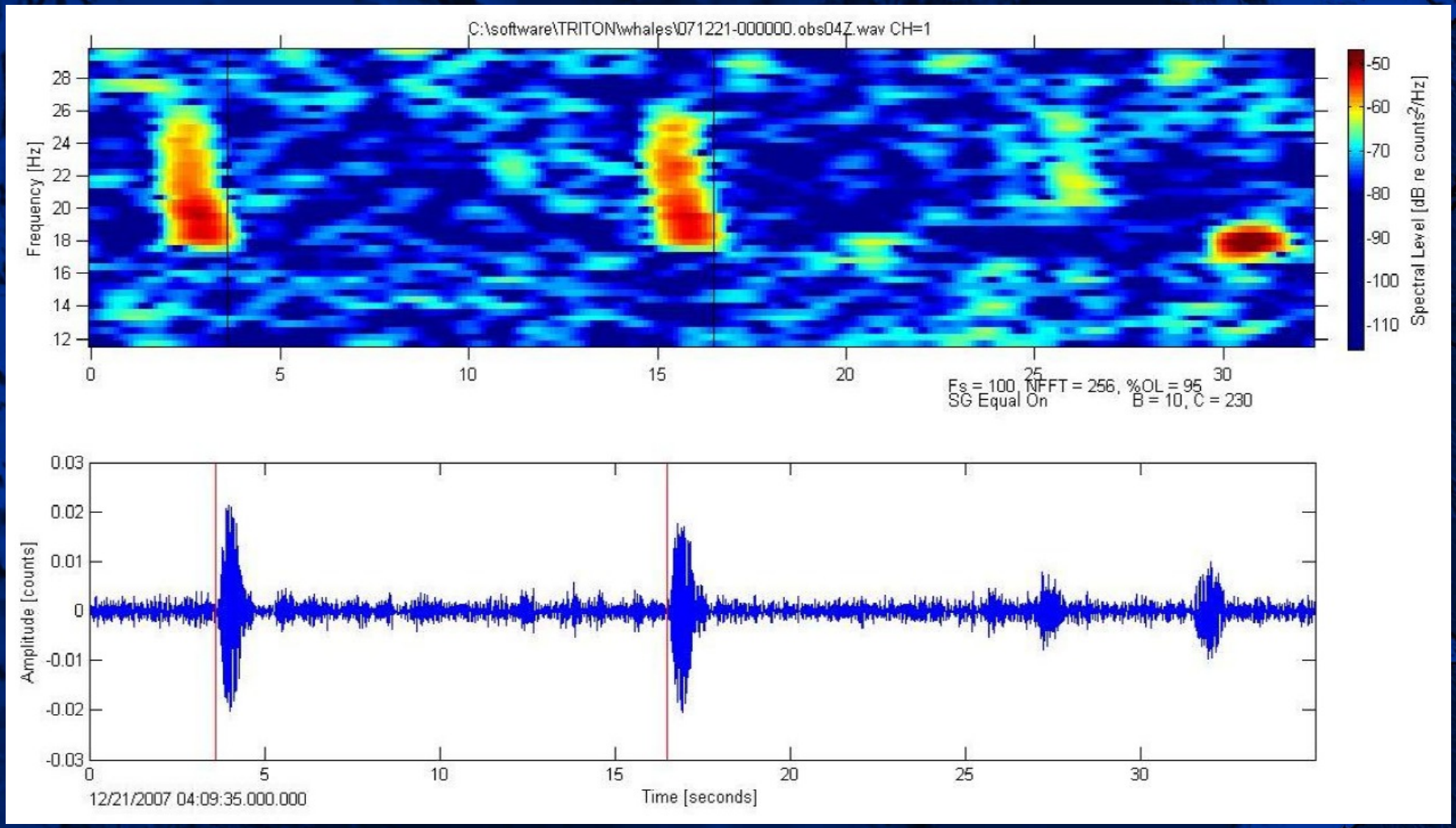
Computation of spectral parameters



The 25%, 50% and 75% percentiles define:

- Time duration and note recording time
- Frequency bandwidth and median

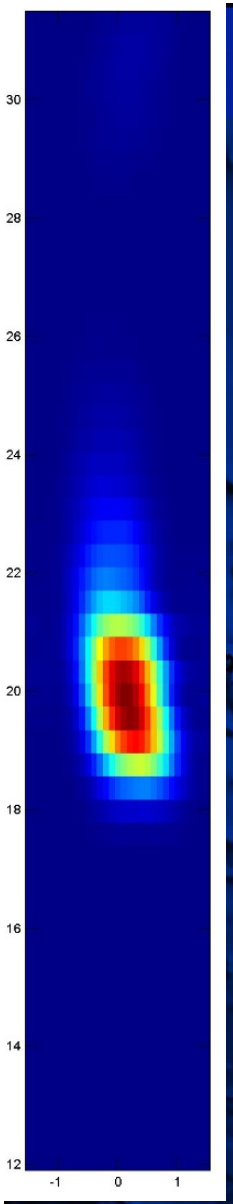
Spectral Correlation

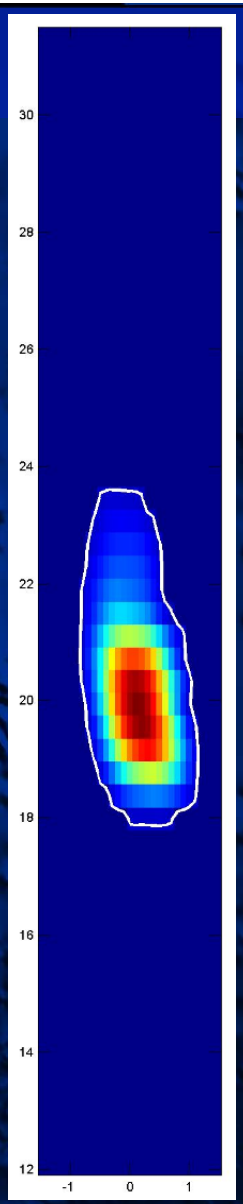


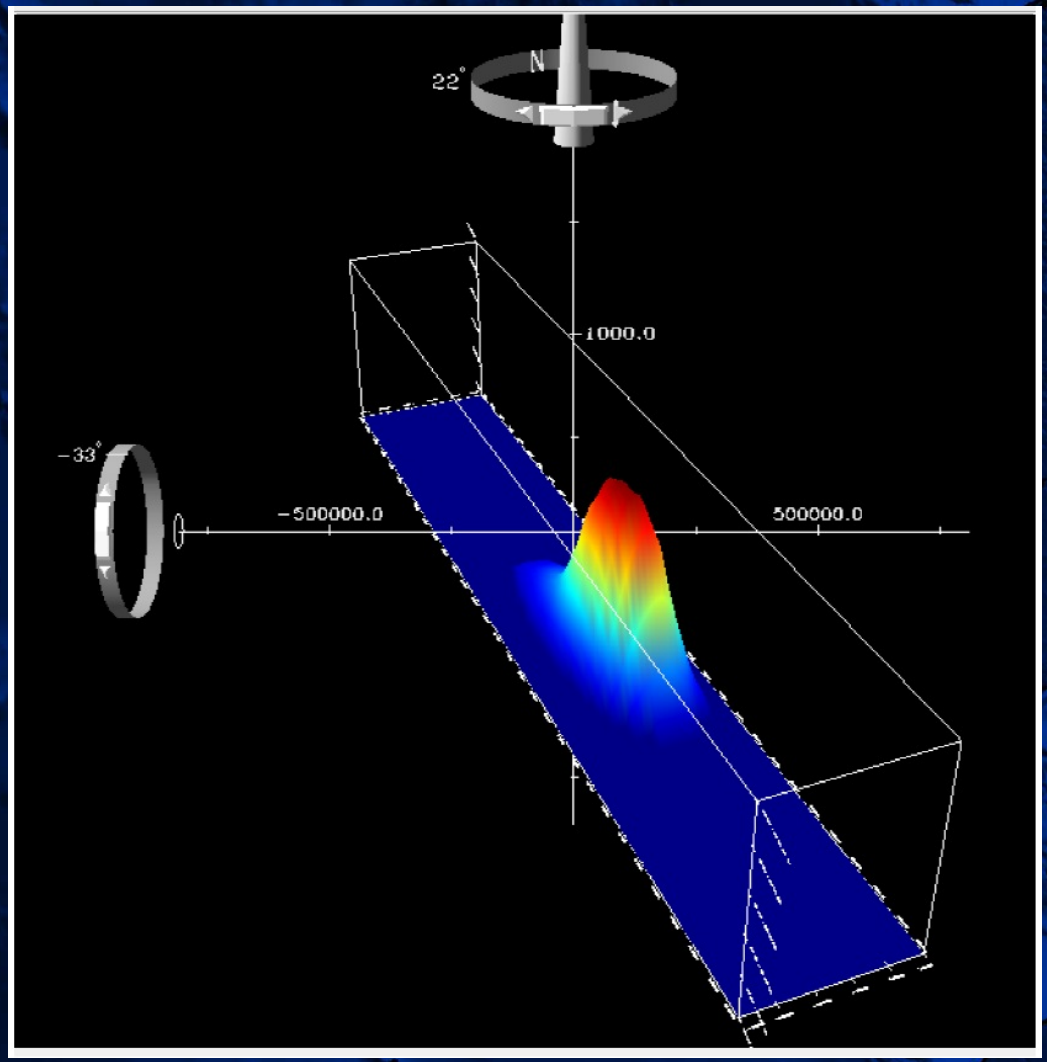
Building the spectral kernel

- One set of the best notes is selected
- The power spectra is averaged

Spectral Correlation







- The 5% and 95% percentiles define the kernel contour
- The area outside is made negative so that power sums to 0

Spectral Correlation

- Spectral correlation is computed with normalization to 1

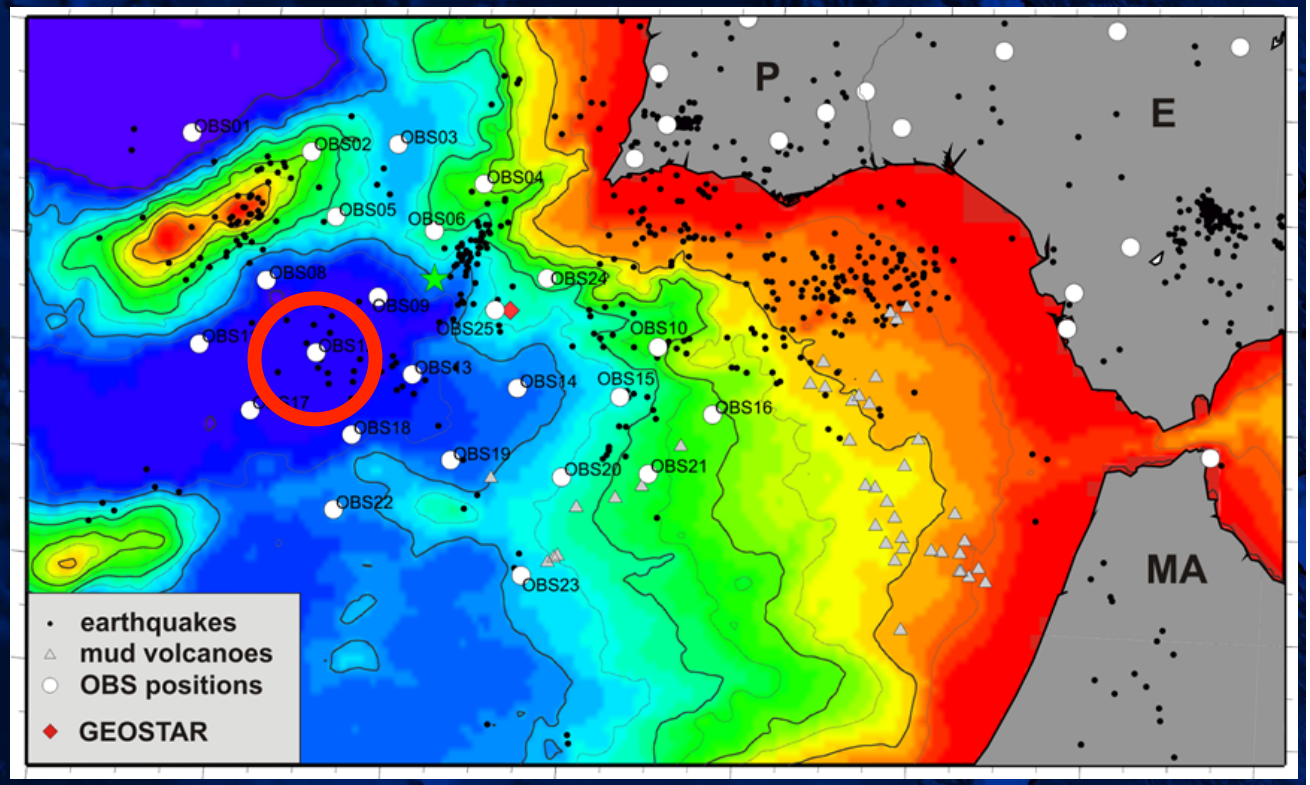
$$\alpha_N(t) = \frac{\sum_{t_0,f} k(t_0,f)\, S(t-t_0,f)}{\sqrt{\sum_{t,f} k(t_0,f)^2 \sum_{t,f} S(t,f)^2}}$$

- The maximum of α_N and its time are saved as note properties

Data investigated

Total data comprises ~ 172,000 hours of continuous recordings

- **Automatic pre-processing**

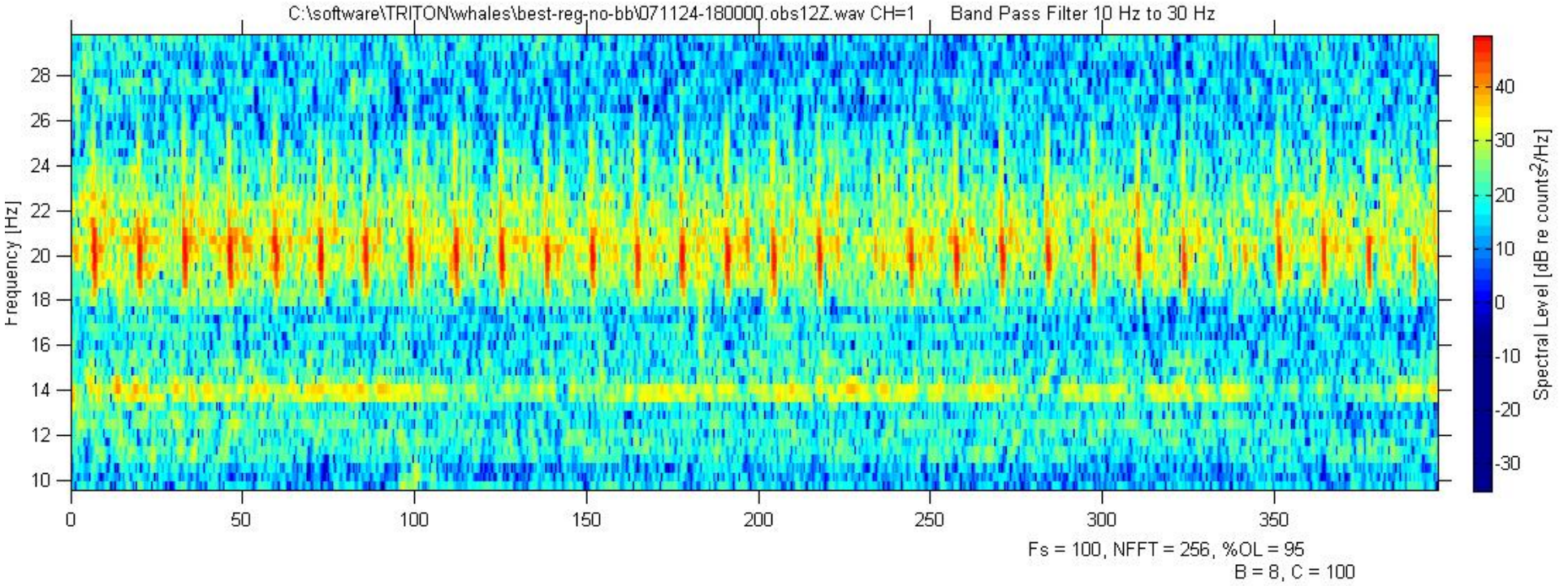


OBS12 @ 4860 m

3 months, Nov./207 to Jan./2008 = 2160 hours continuous

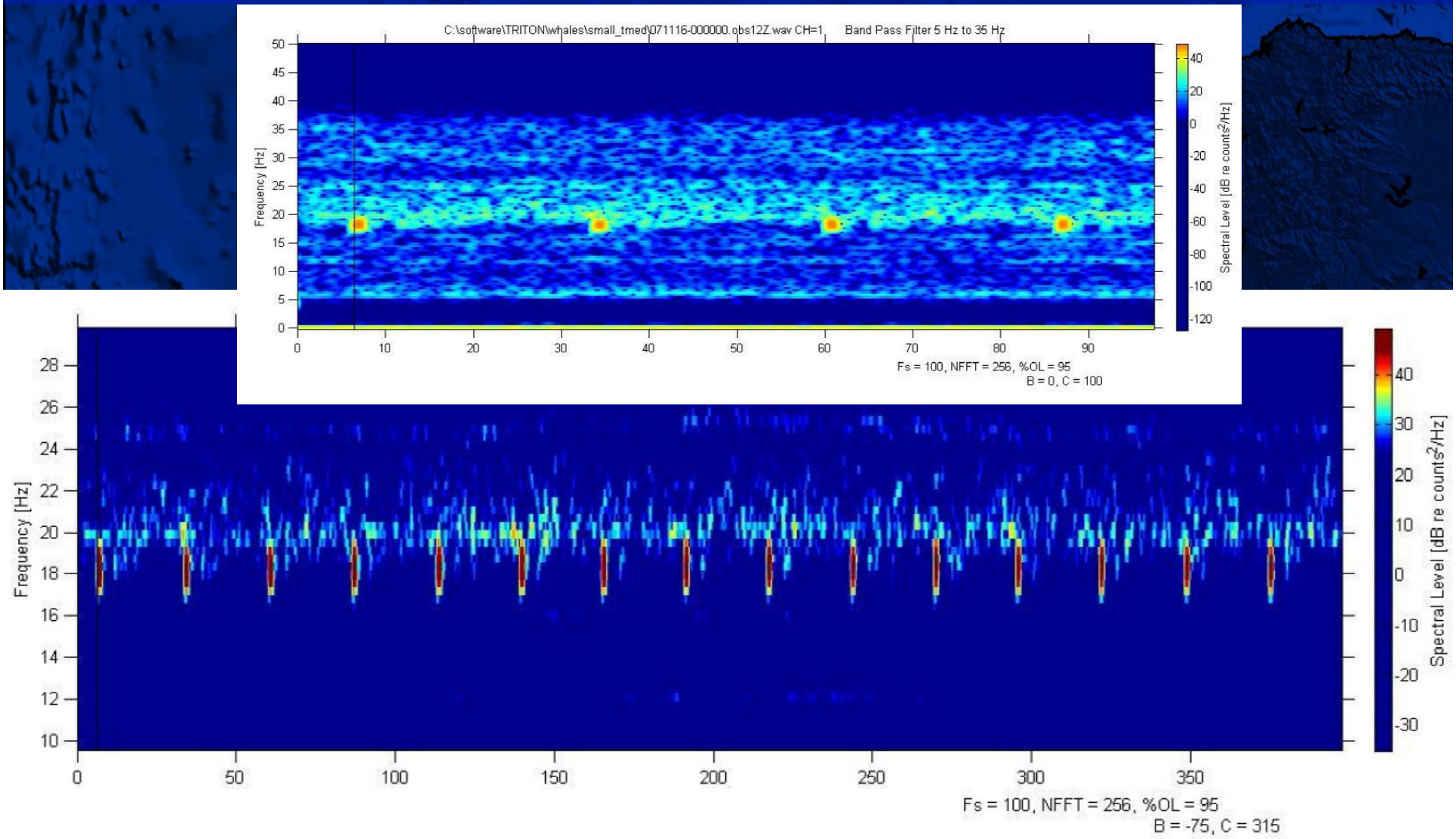
Z channel

Types of note sequences



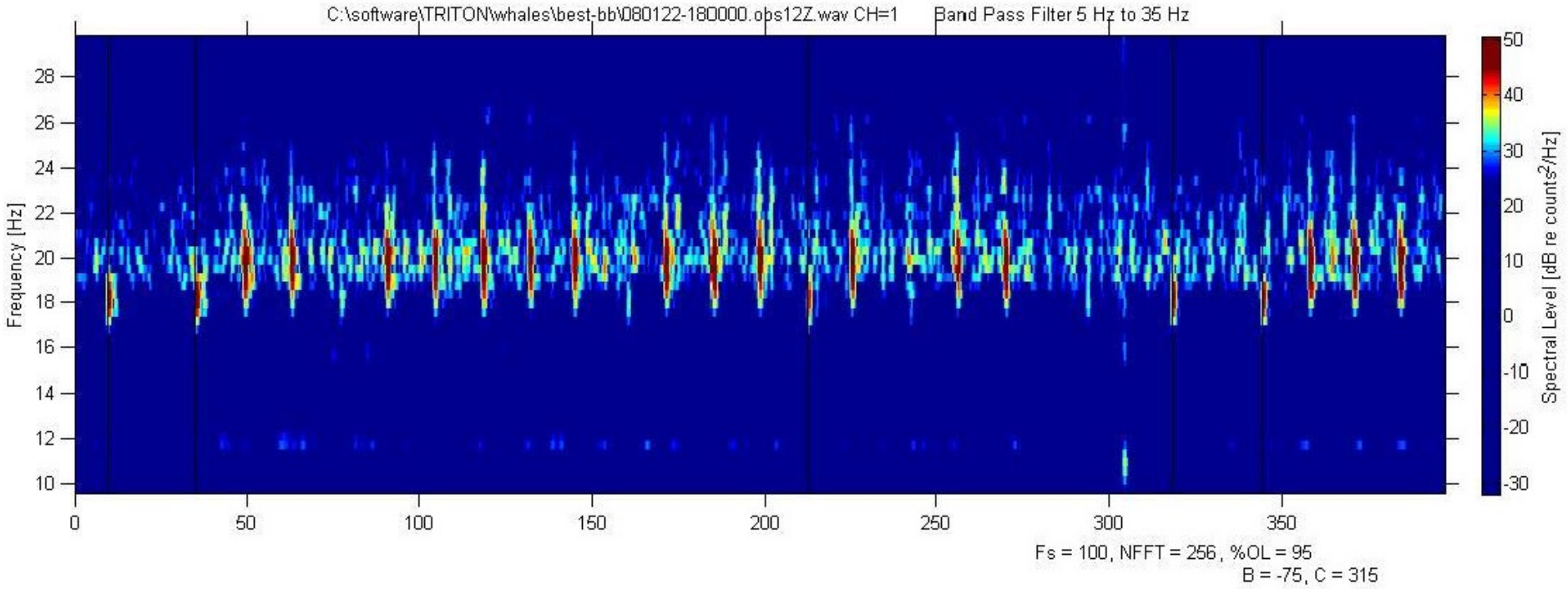
- Regular notes, short gaps but no back-beats
- Less common

Types of note sequences



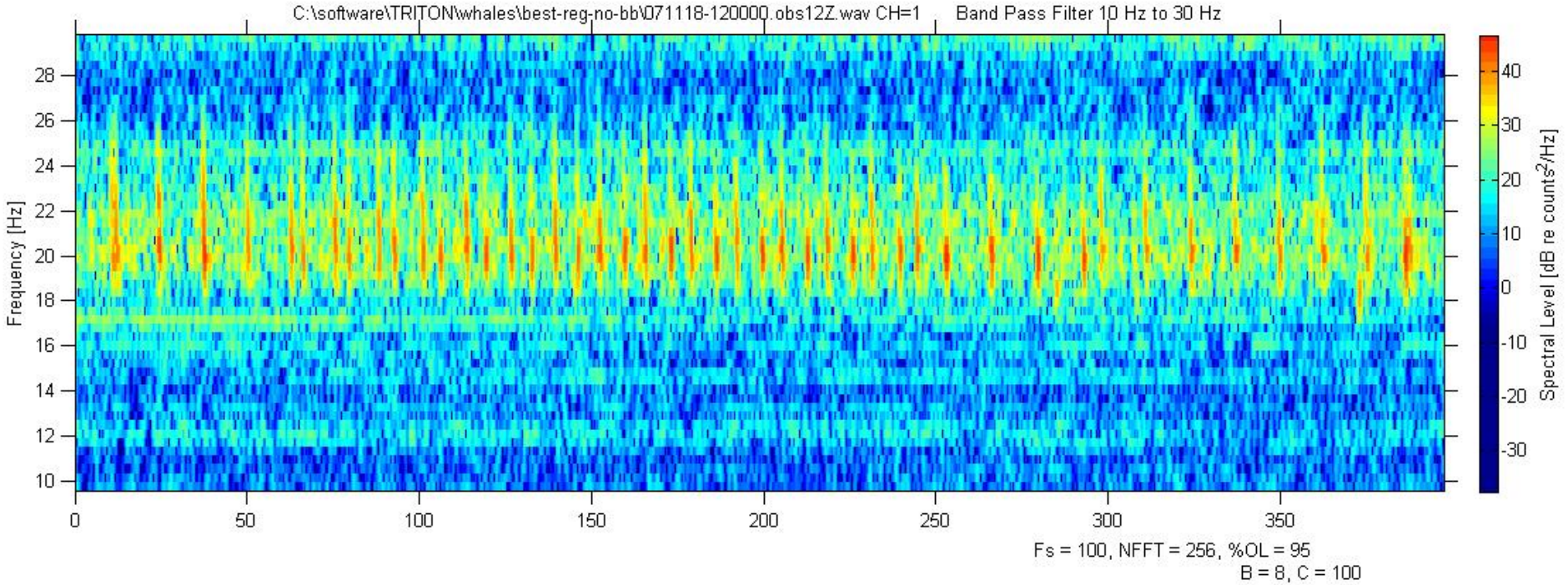
- Back-beats only, no regular notes
- Less common

Types of note sequences



- Regular notes and back-beats
- Most frequent

Types of note sequences

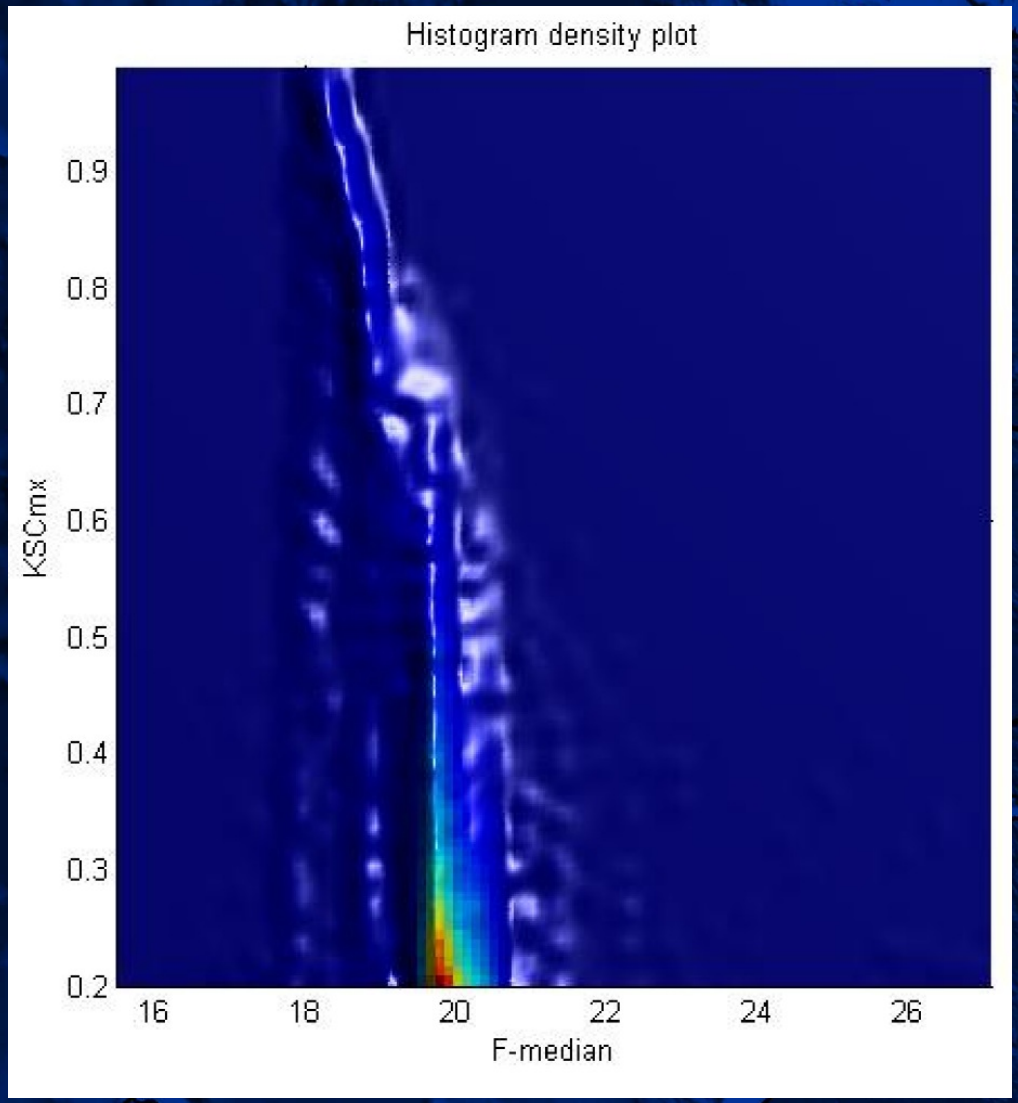


- Not always so simple!
  - Regular
  - Back-beat
  - Mixed

Looking for variability: median frequency (F-median)

3-D histogram with frequency numbers at each bin coded in colour and shaded

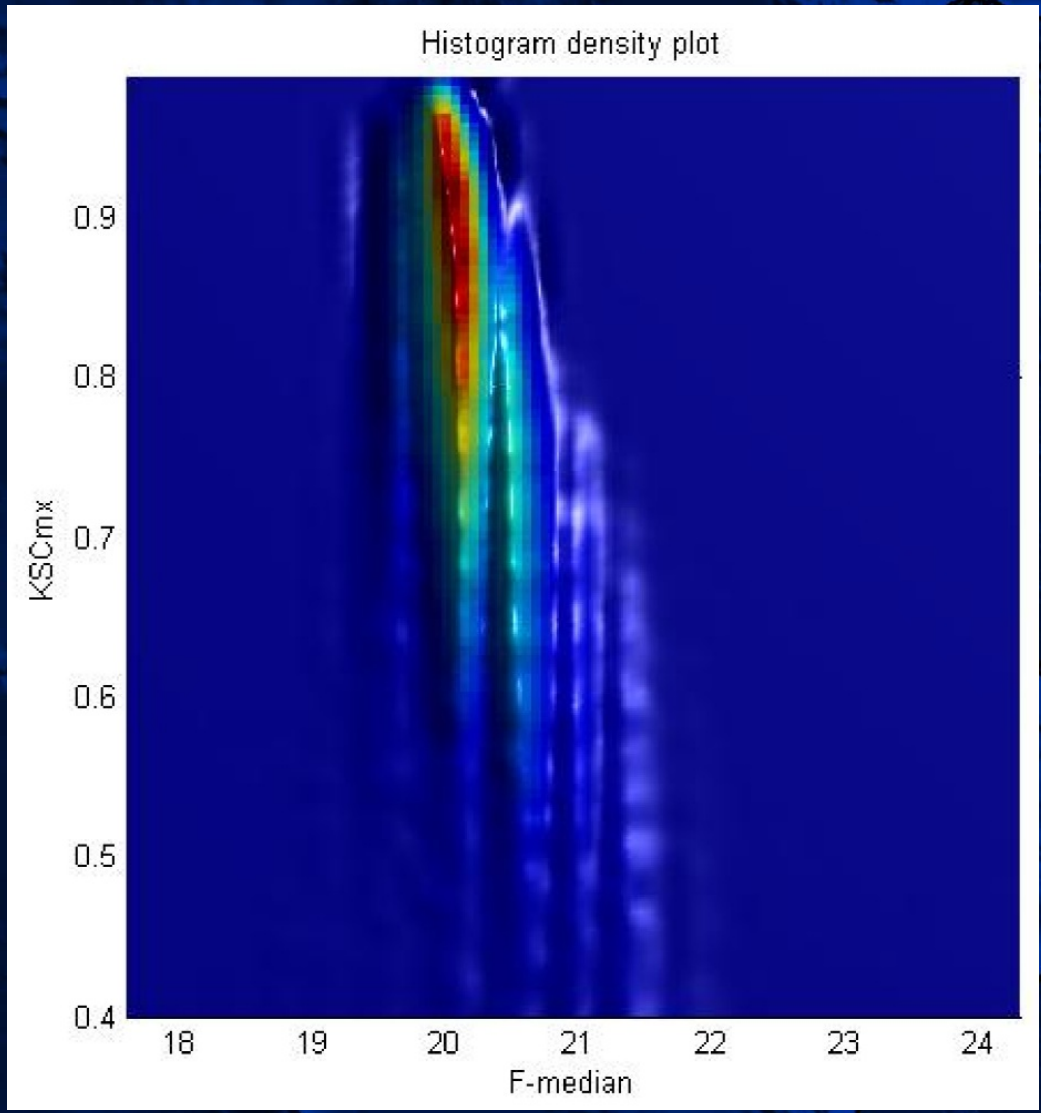
KSCmx = maximum spectral correlation



- Using back-beat kernel, regular notes also show up

Looking for variability: median frequency (F-median)

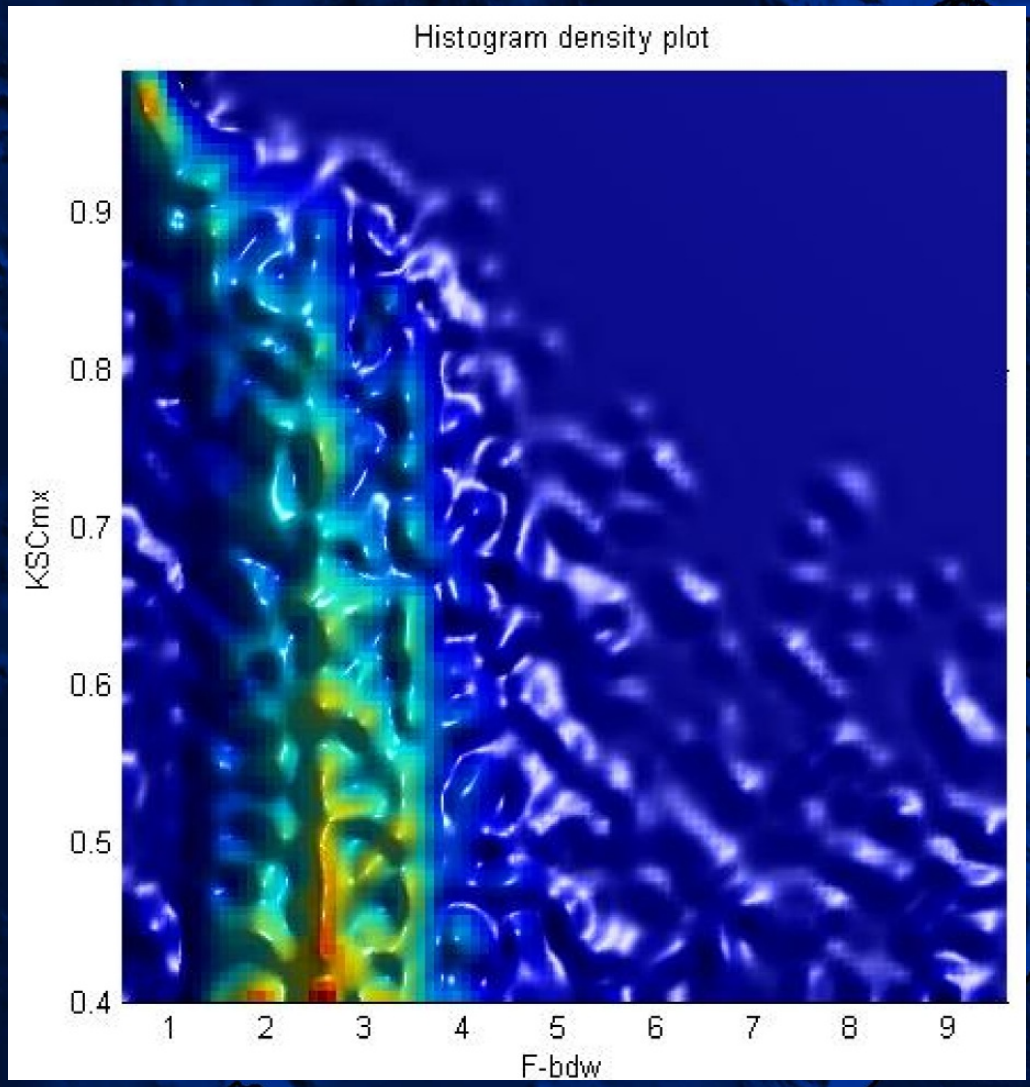
KSCmx = maximum spectral correlation



- Using regular note kernel. No b.b. Other notes?

Looking for variability: frequency bandwidth (F-bdw)

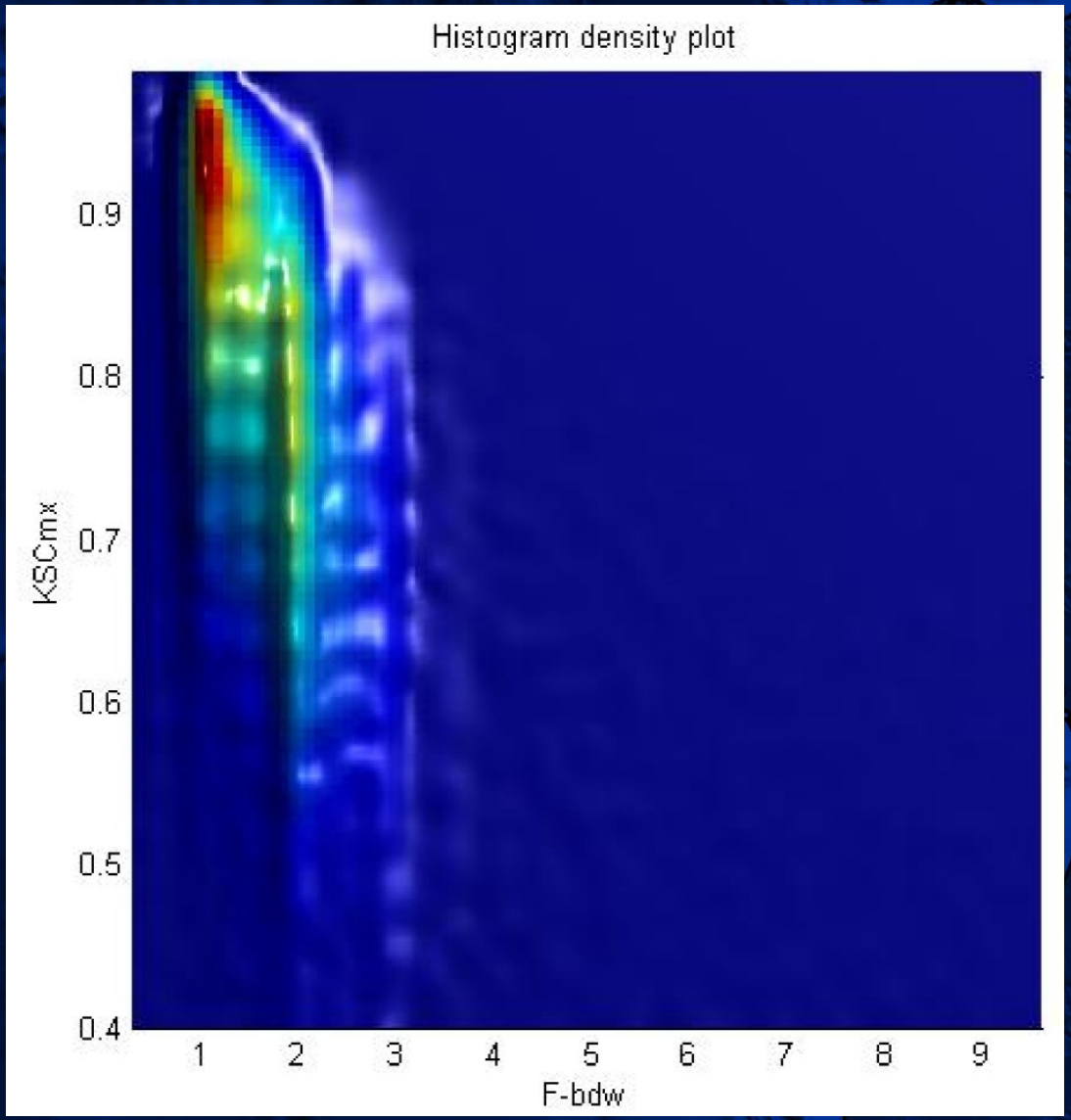
KSCmx = maximum spectral correlation



- Using back-beat kernel

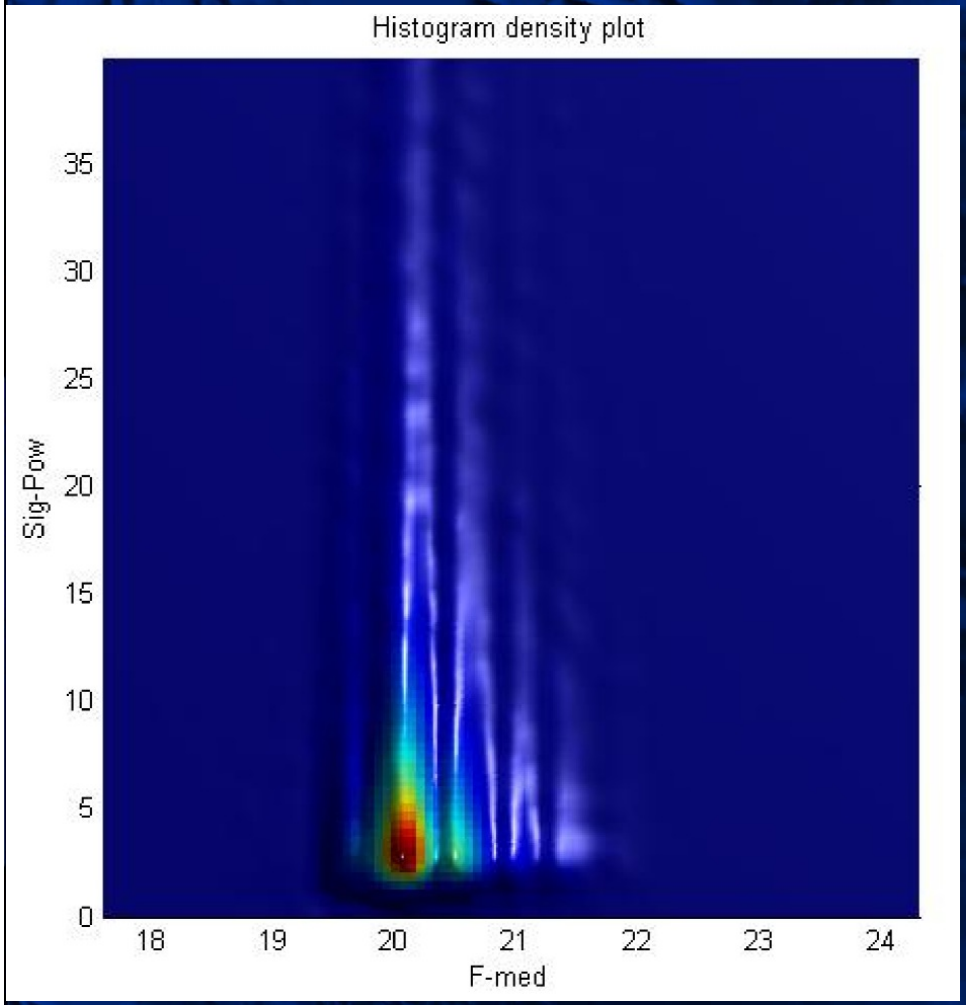
Looking for variability: frequency bandwidth (F-bdw)

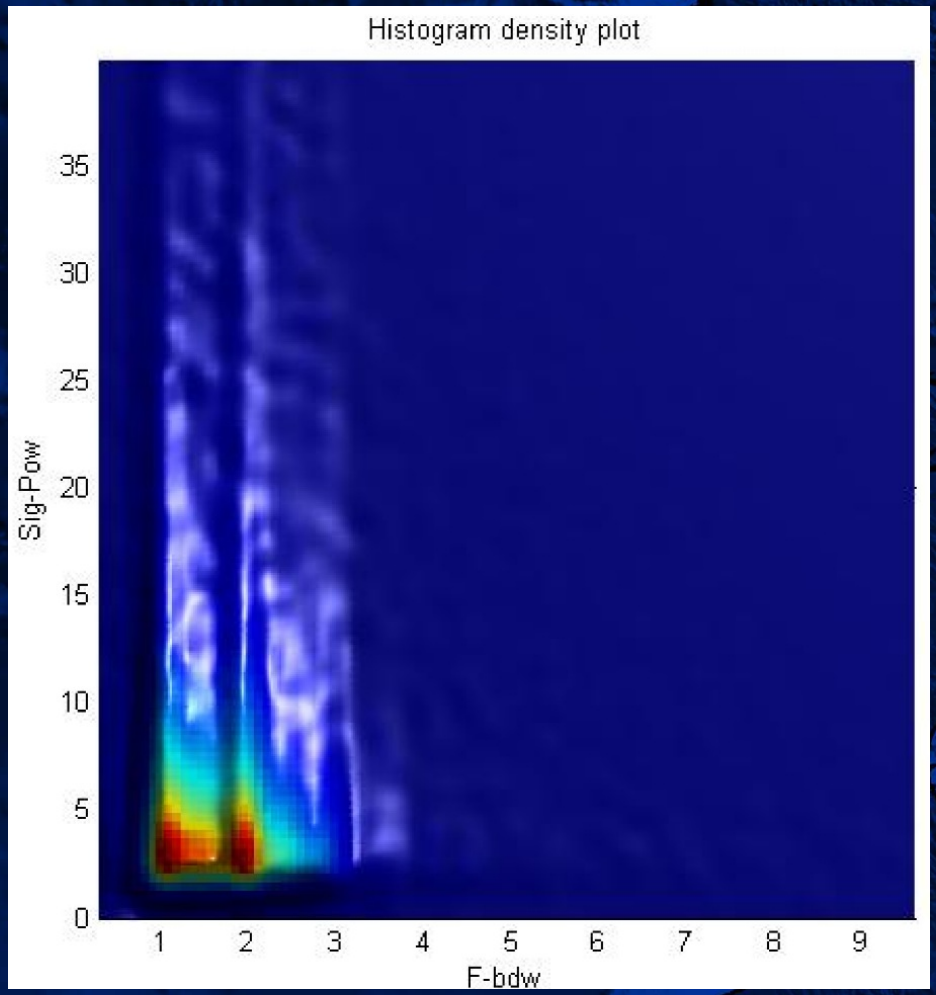
KSCmx = maximum spectral correlation



- Using regular note kernel. Other notes?

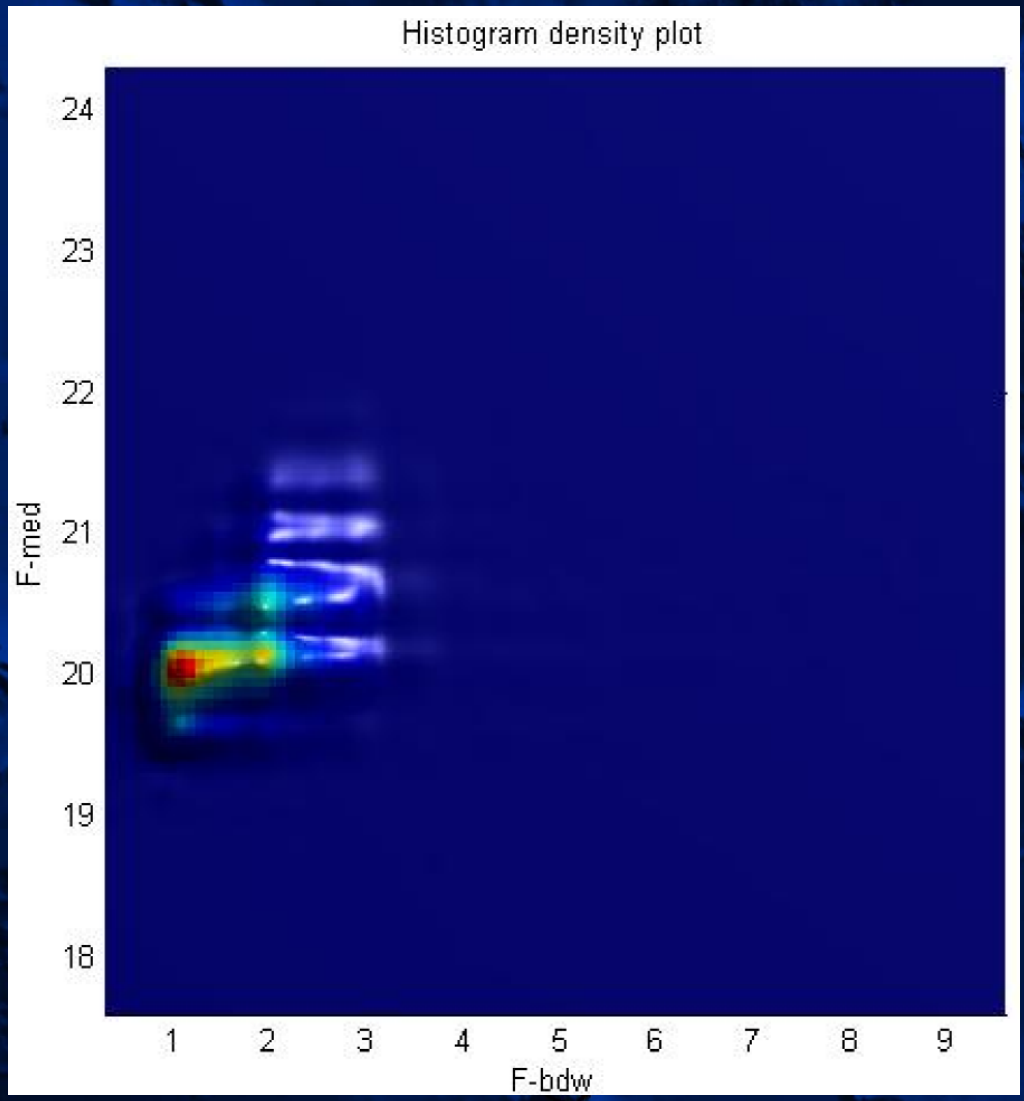
Looking for variability: Other notes?





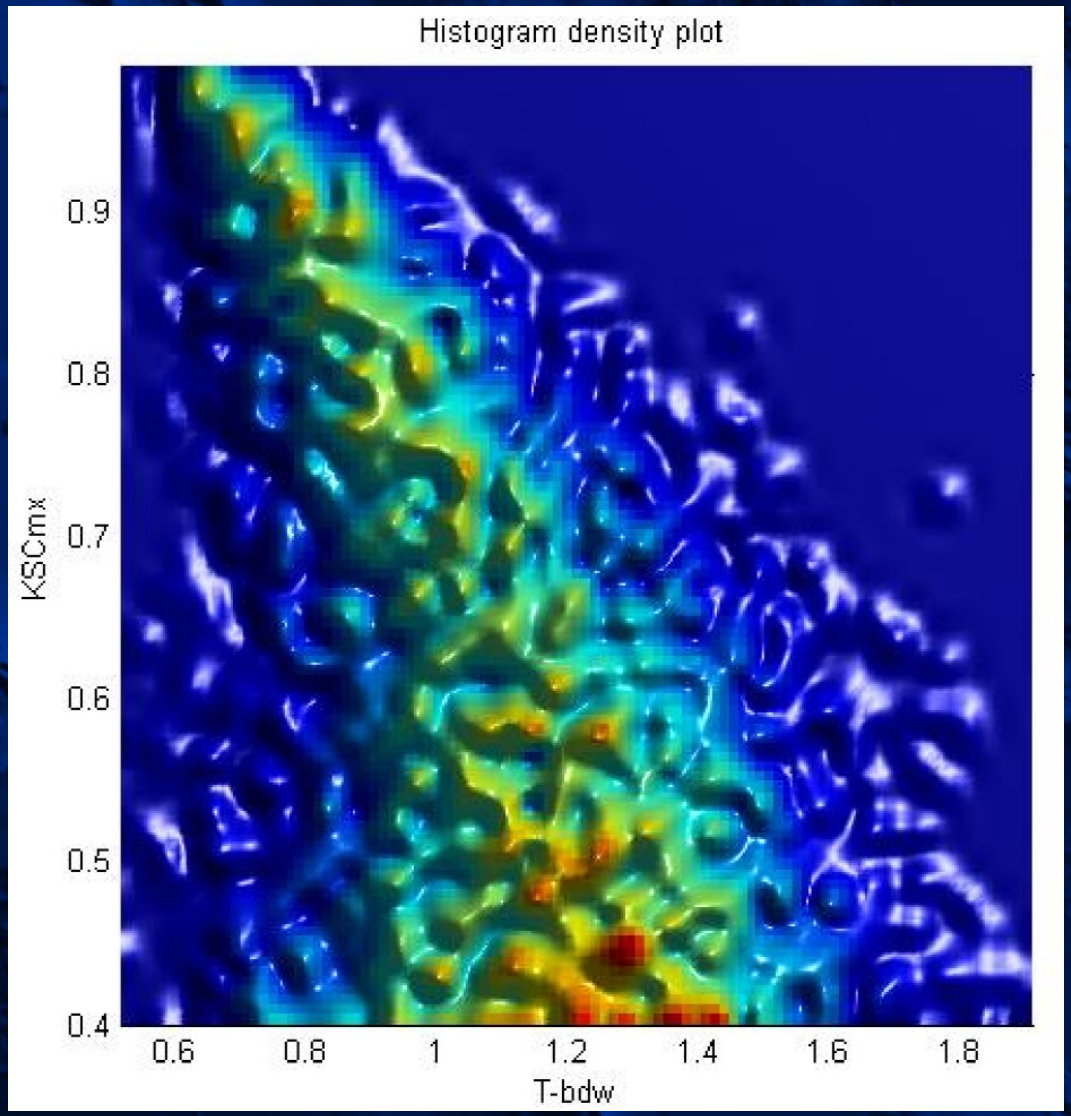
- They have signal power

Looking for variability: Other notes?



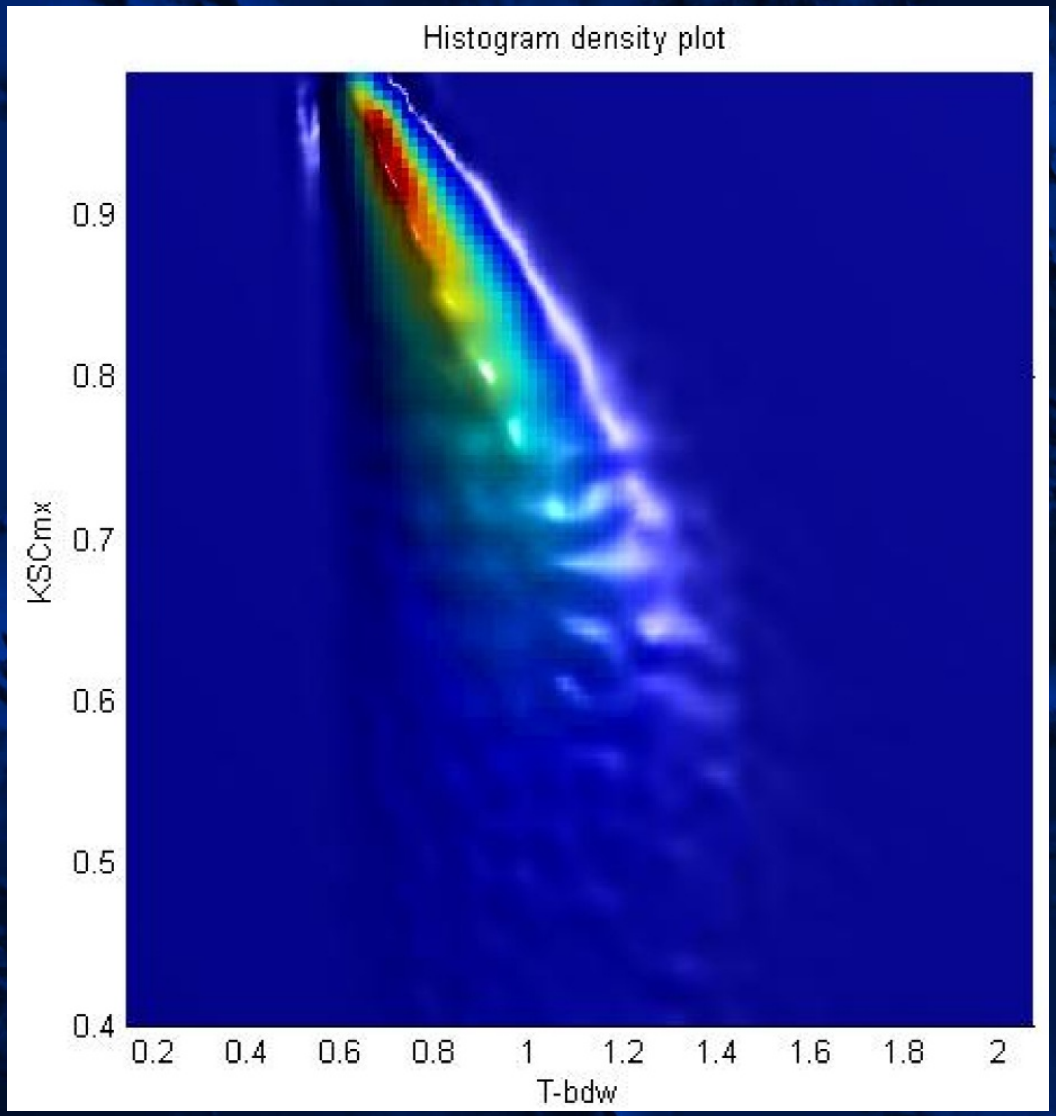
- Needs further investigation

Looking for variability: Duration



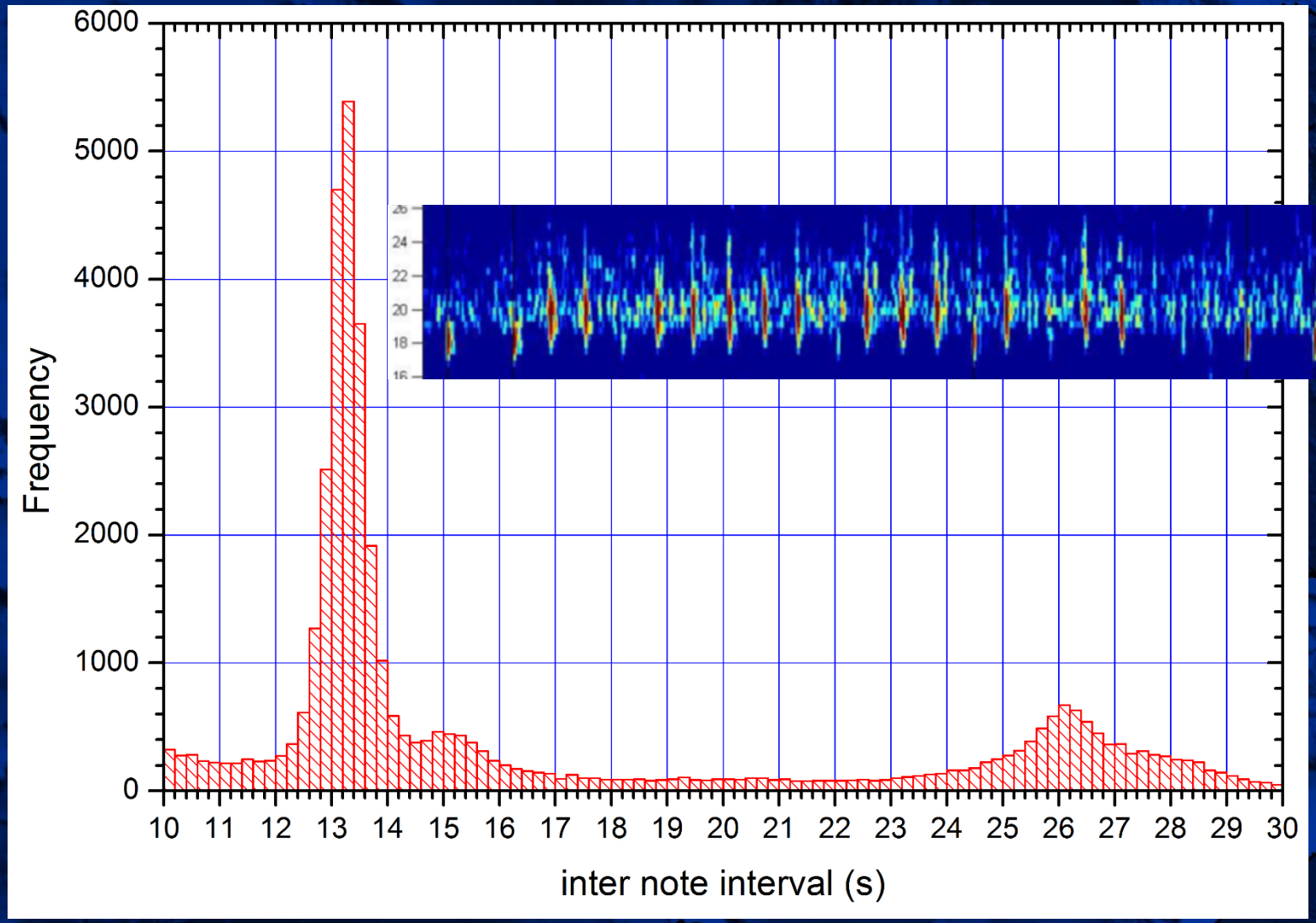
- Using back-beat kernel

Looking for variability: Duration



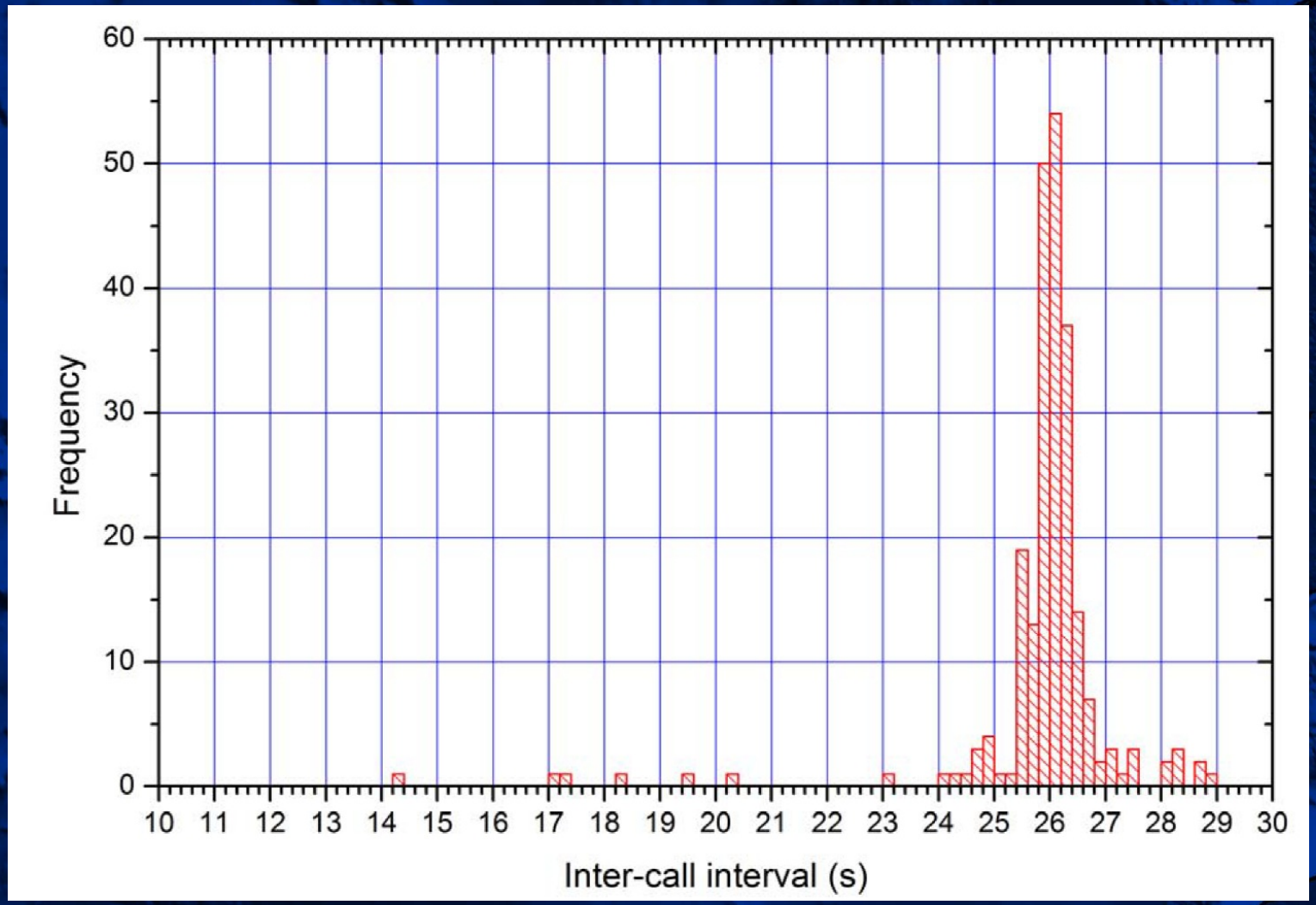
- Using regular note kernel

Looking for variability: inter note interval (INI)



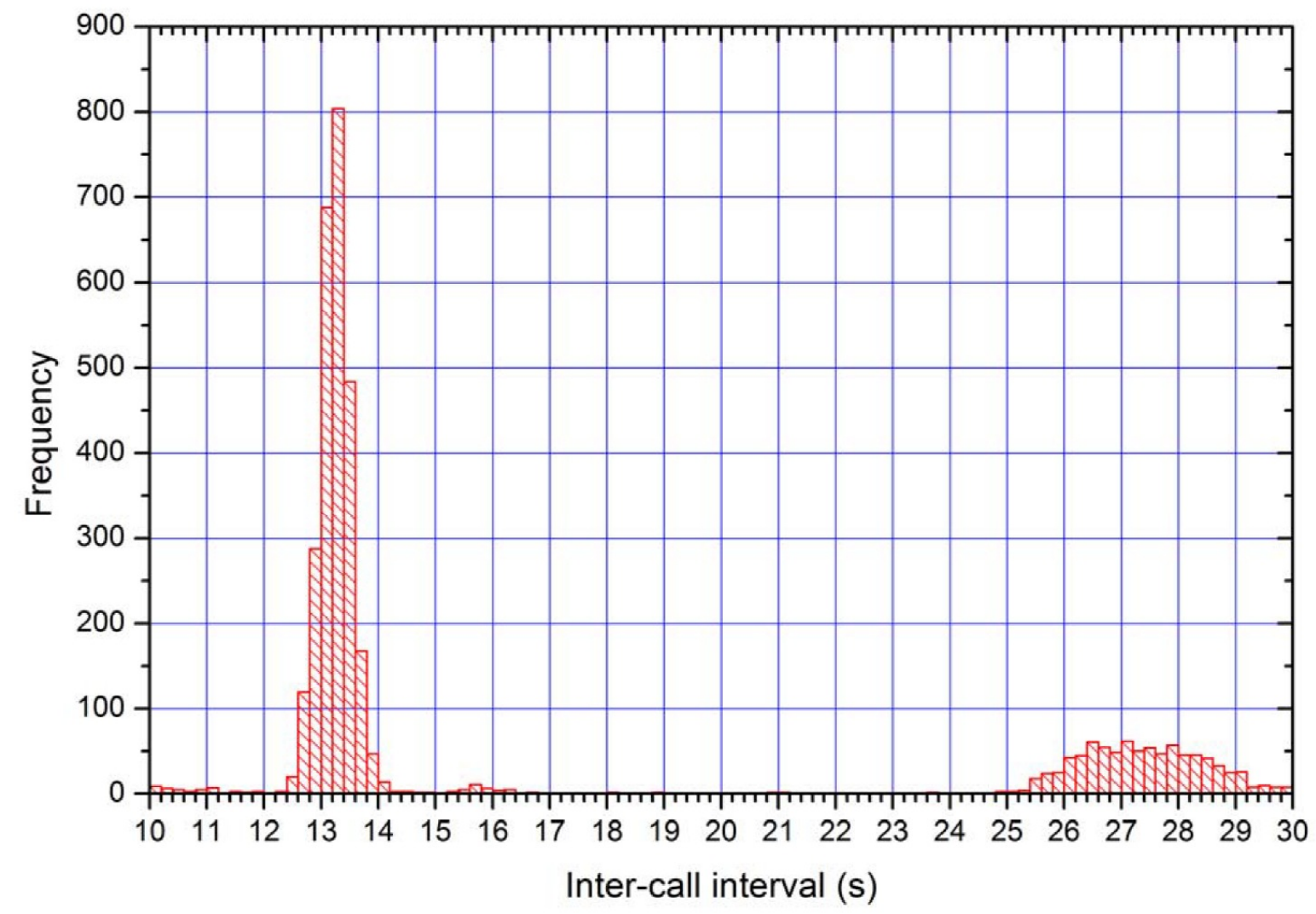
- Using back-beat kernel, low detection threshold
  - ➢ regular & back beat captured

Looking for variability: inter-note interval (INI)



- Using back-beat kernel, best notes, ~26.1 s
  - Only back beat captured

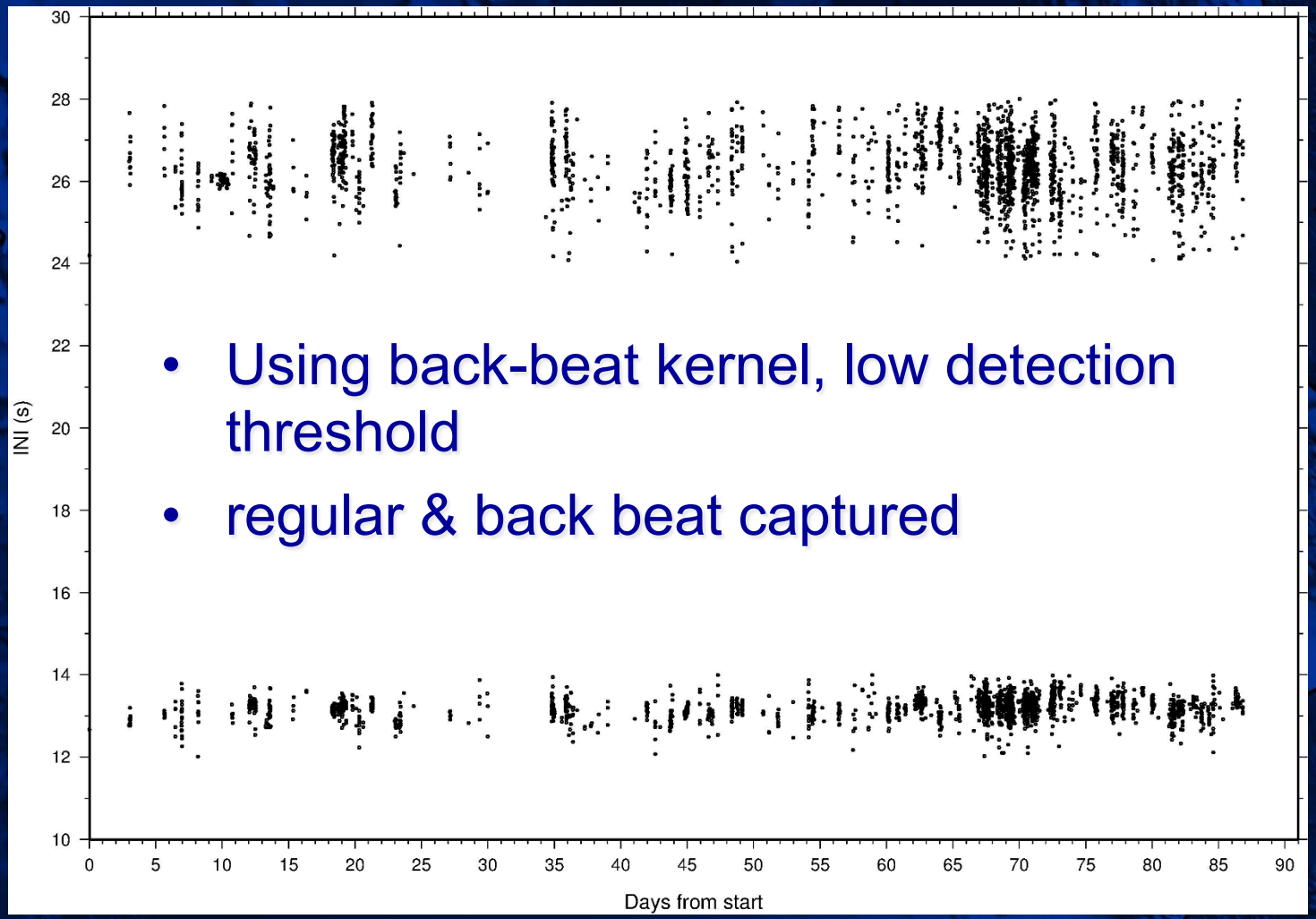
Looking for variability: inter-note interval (INI)



- Using regular note kernel, best. ~13.2 s & ~27.5 s
- Second peak is not due to missing notes, but to gaps with or without back-beats

Sequence analysis

- One note belongs to a sequence if:
- Level 1: 12 < INI < 14 seconds catch regular notes
- Level 2: 24 < INI < 28 seconds catch b.b. and gaps



- Using back-beat kernel, low detection threshold
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Sequence analysis

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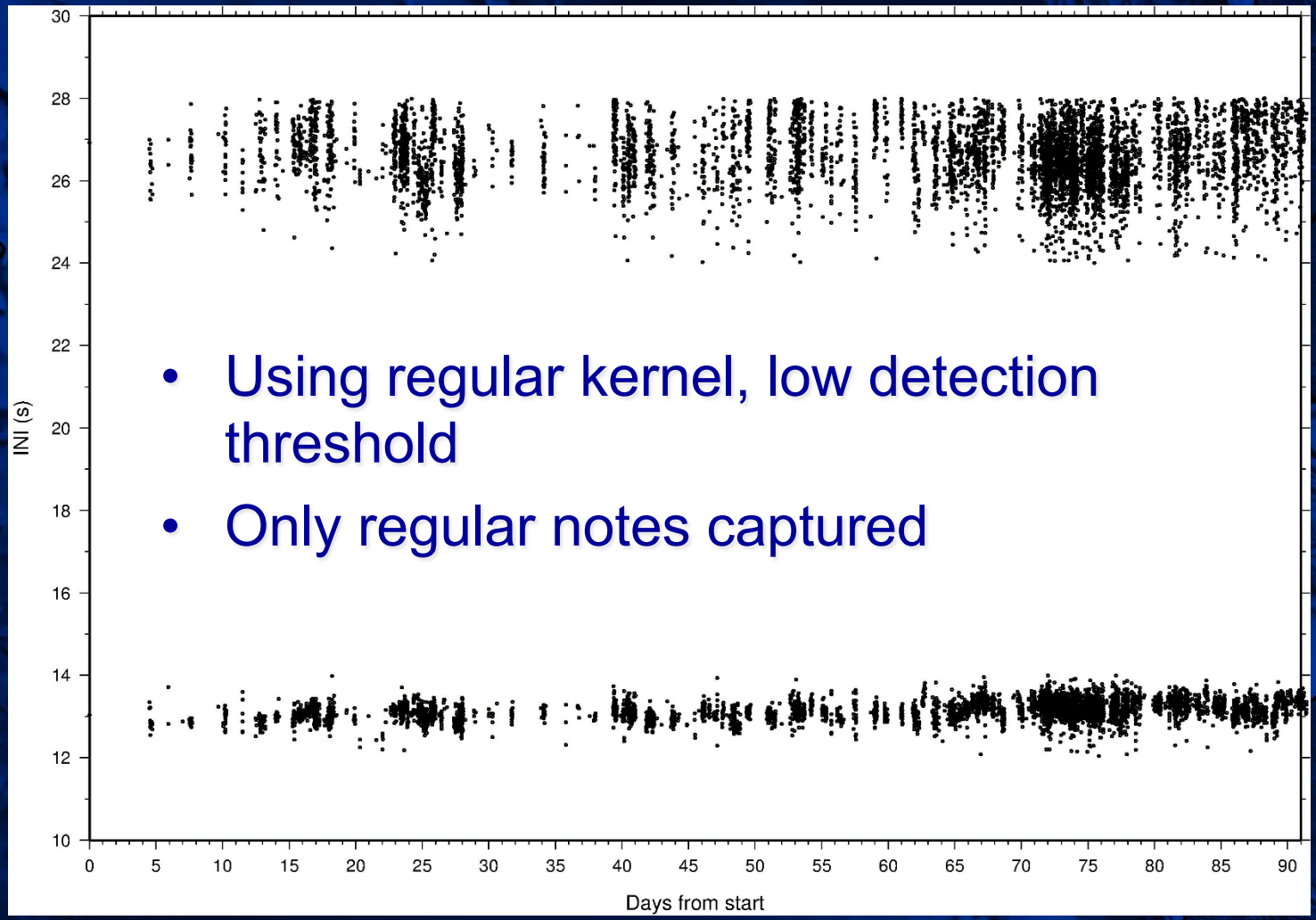
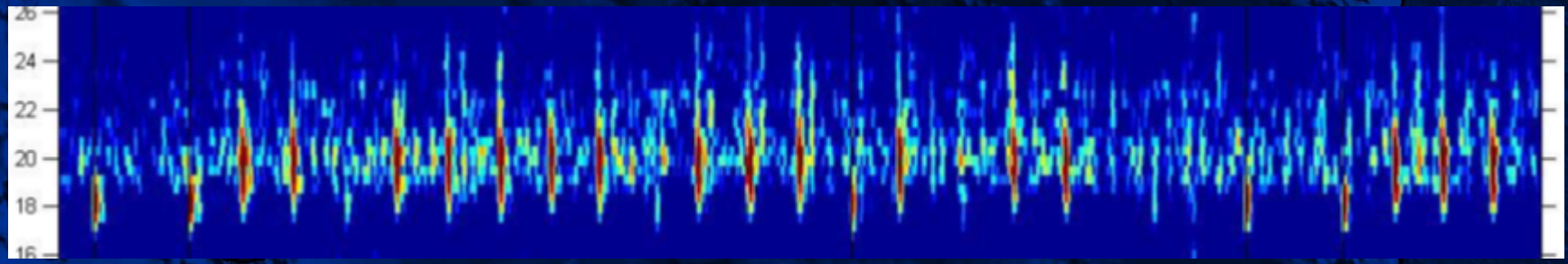


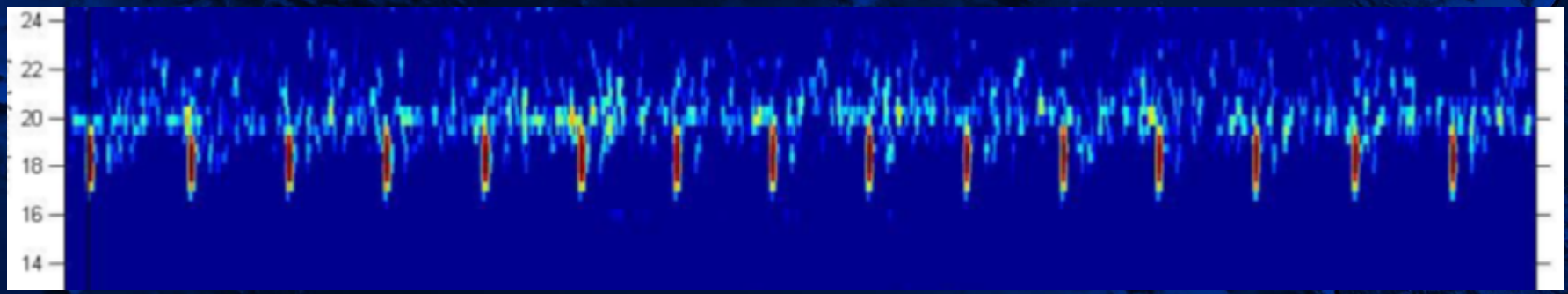
- Using regular kernel, low detection threshold
- Only regular notes captured

Sequence analysis

- Regular and mixed sequences (mean±s.d. number of notes)
  - Level 1 = 13.10±0.20 s (779)
  - Level 2 = 26.85±0.55 s (192)



- Back-beat sequences
  - Level 2 = 26.01±0.26 s (7872)

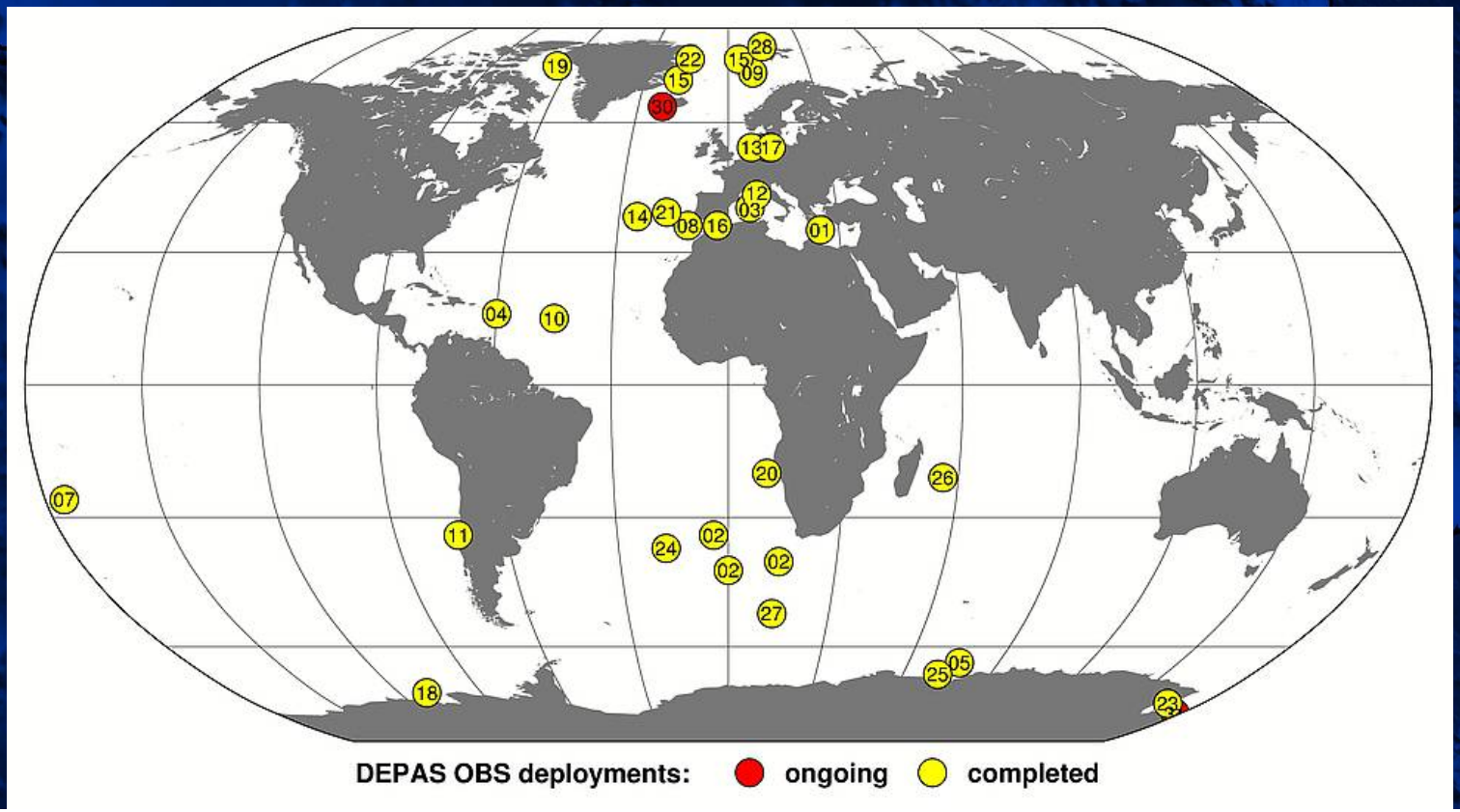


Some notes so far #1

- **3 types of note sequences were identified in the Gulf of Cadiz, confirming previous observations**
- **3 inter-note intervals (INI) were identified**
  - **Between back-beats ~26.0 s**
  - **Between regular notes ~13.1 s**
  - **Between regular notes with a gap ~26.9 s**
- **More work required to assess regular to back-beat intervals**
- **Only "Atlantic group" songs detected, none "strictly Mediterranean"** (Castellote et al., 2012)

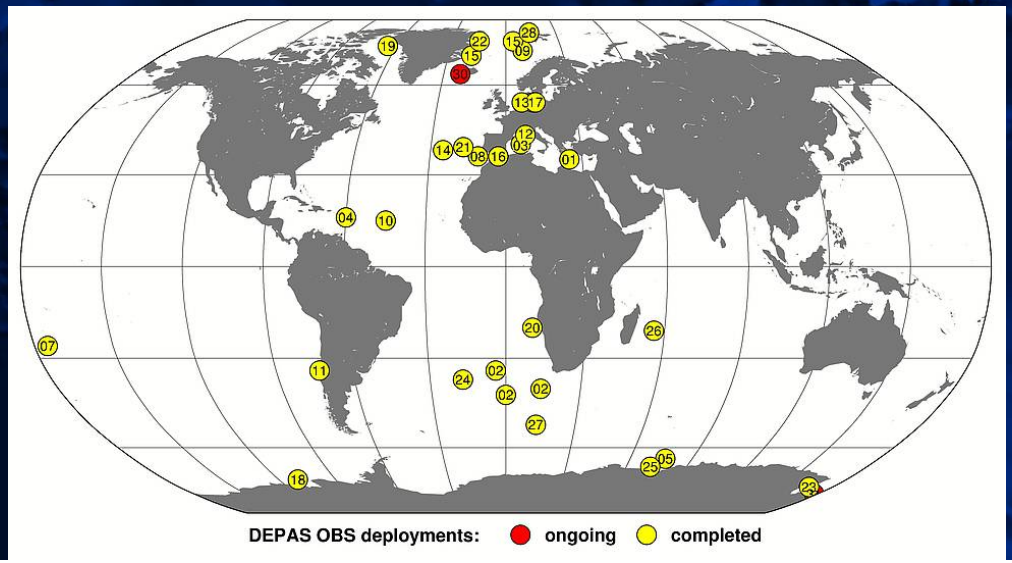
Some notes so far #2

- Suspected variability on median frequency and frequency bandwidth, requiring more work
- Many 100's of OBS are currently recording data at the seafloor for 1 year or more, mostly as sparse arrays → OPPORTUNITY



Some notes so far #2

- Suspected variability on median frequency and frequency bandwidth, requiring more work
- Many 100's of OBS are currently recording data at the seafloor for 1 year or more, mostly as sparse arrays → OPPORTUNITY
- Improvements in technology will soon allow long term recording of frequencies up to 250 Hz (120 Hz useful bandwidth)



Thank You!

Acknowledgments

DEPARTMENT OF THE NAVY
USN
ONR
Science & Technology

NEAREST
Integrated observation from NEAR shore sources of Tsunamis

NERA