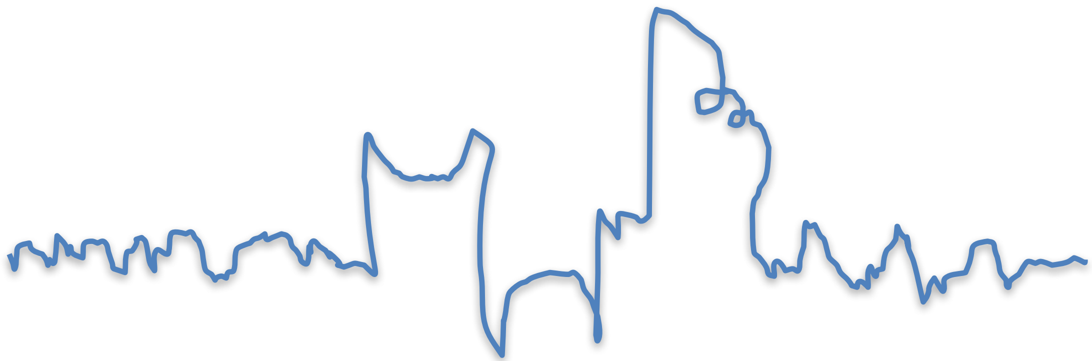
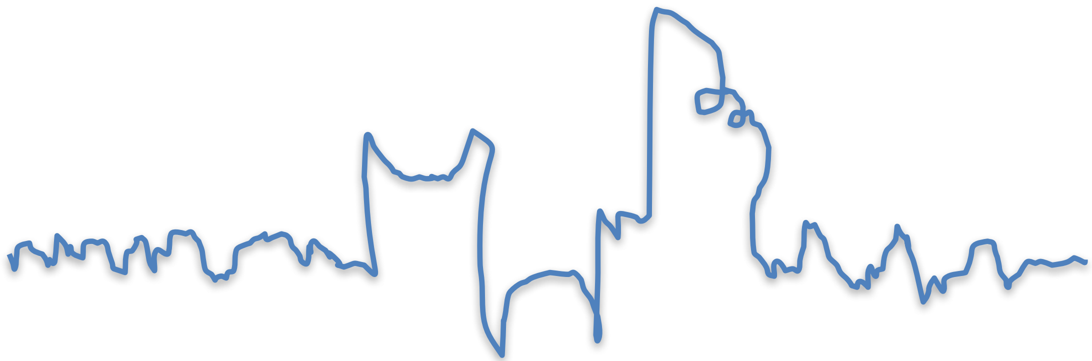
TF methods

- Hilbert transform ✓oat
- Morlet wavelets ✓oat
- Hanning taper ✓oat
- Multitaper (Slepian tapers) ✗ - but workaround for source space gamma

TF transform in OAT

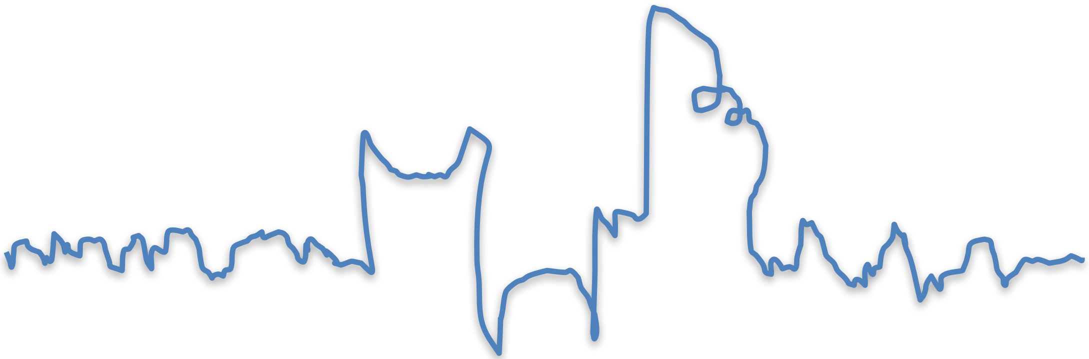


TF transform in OAT



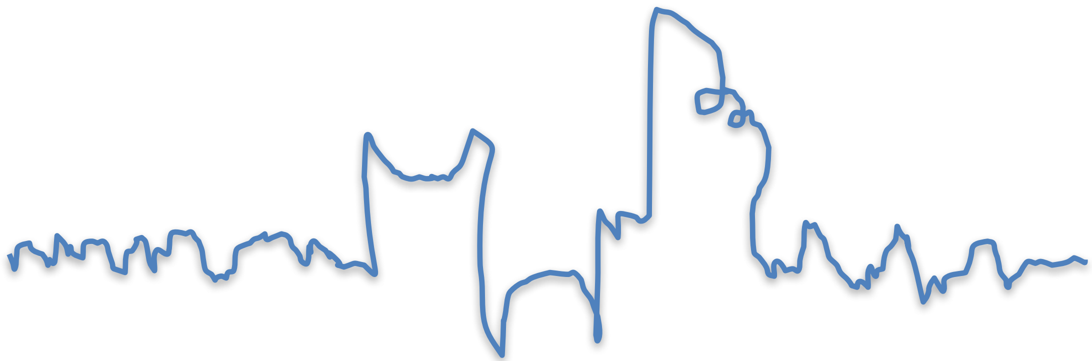
- Source recon stage: band pass filters sensor-space data
  - oat.source_recon.freq_range

TF transform in OAT



- Source recon stage: band pass filters sensor-space data
  - oat.source_recon.freq_range
- First level: time-frequency transform, beamforming, and GLM
    - *osl_run_first_level_epoched_state*

TF transform in OAT



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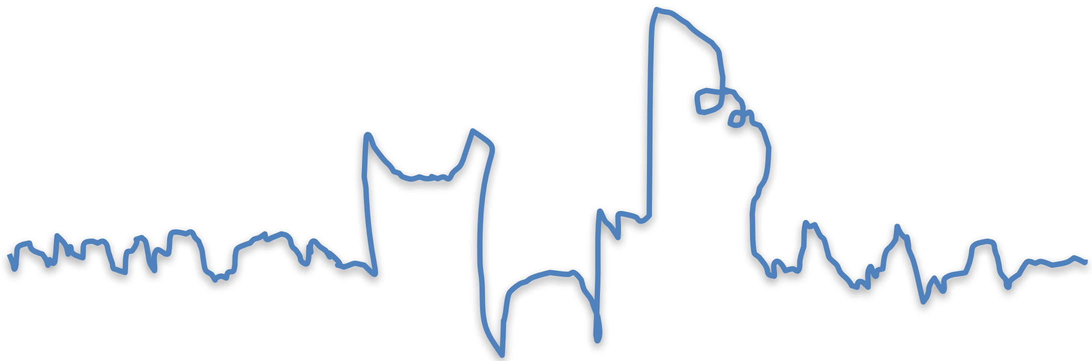
  - oat.source_recon.freq_range
- First level: time-frequency transform, beamforming, and GLM
    - *osl_run_first_level_epoched_state*
  - Start with sensor-space data:
  - …do the tf_transform: either (none), hilbert, morlet, hanning, + downsample…
    - *osl_tf_transform*

TF transform in OAT



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  - Start with sensor-space data:
  - …do the tf_transform: either (none), hilbert, morlet, hanning, + downsample…
    - *osl_tf_transform*
  - …multiply the complex tfr by the beamformer weights and get the absolute values…
  - …and do the GLM to average across trials and get the COPEs.

Low frequency TF analyses: Hilbert, morlet, hanning… does it matter??

- No

Journal of Neuroscience Methods 137 (2004) 321–332

www.elsevier

Fourier-, Hilbert- and wavelet-based signal analysis: are they really different approaches?

NO

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Received 3 December 2003; received in revised form 20 February 2004; accepted 2 March 2004

- No
  - They all give you amplitude and phase over time for each frequency of interest, and induced response analyses look at changes in the amplitude

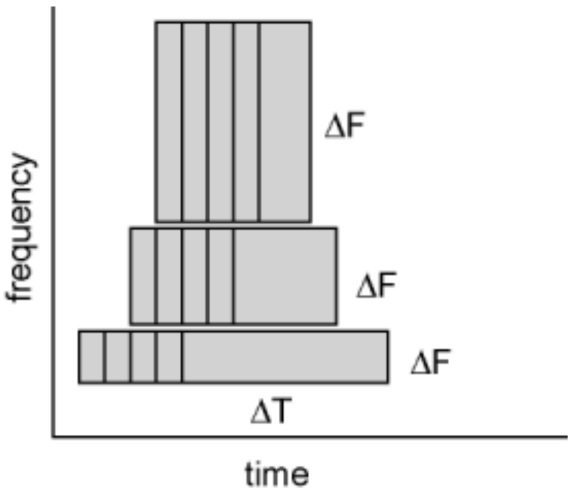
Does it matter??

- Yes
  - The implementations are quite different
  - Critical factor is the control over the time/frequency tradeoff: the better the frequency resolution, the worse the time resolution…

Hanning taper

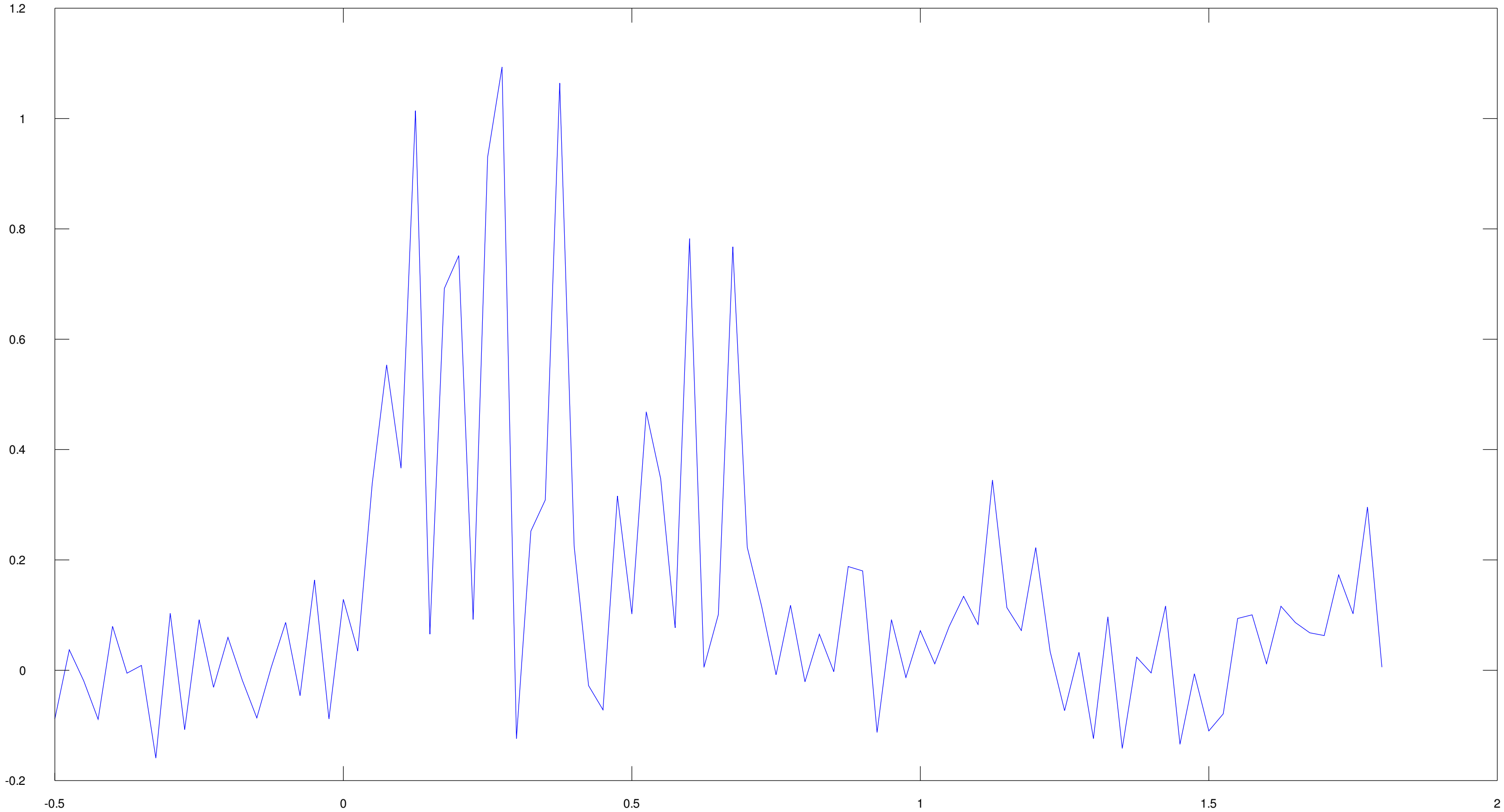
```
oat.first_level.tf_method               = 'hanning';
oat.first_level.tf_freq_range           = [5 30];
oat.first_level.tf_hanning_ncycles      = 4;
oat.first_level.tf_time_step            = 0.025;
oat.first_level.tf_num_freqs            = 28;
```

- Uses fieldtrip's *ft_freqanalysis:* http://fieldtrip.fcdonders.nl/tutorial/timefrequencyanalysis
- The time-smoothing is set by *tf_hanning_ncycles*
  - E.g. at 4Hz, if choose 4 cycles, then the time-window will be 4*(1/4) = 1s wide
  - The longer this time window, the better the frequency resolution
  - Time window decreases as frequency goes up

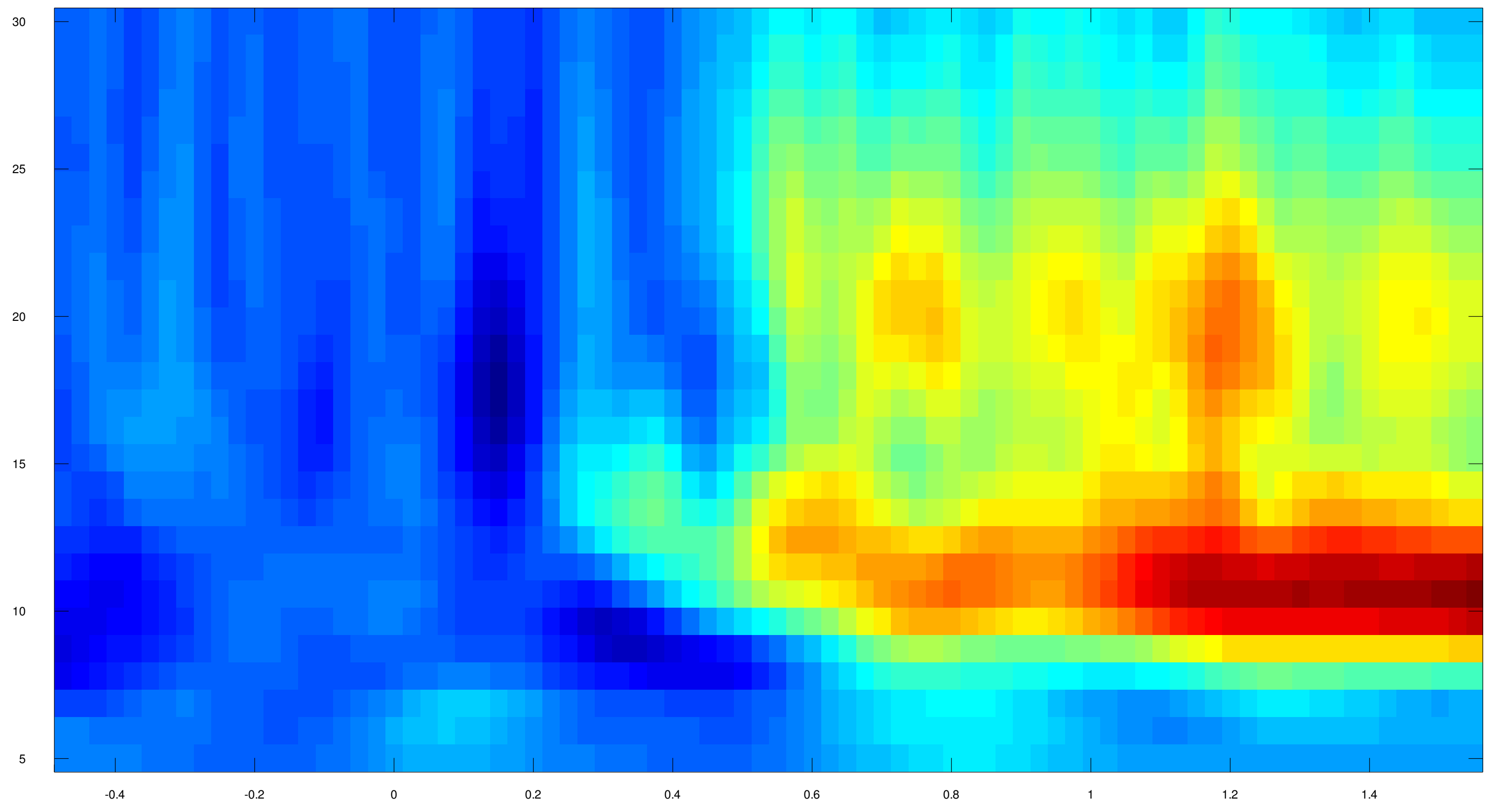


- *tf_time_step* is the interval over which the Hanning window is stepped – e.g. if 0.02s, tf data is sampled at 50Hz
- The full Hanning window needs to fit in the data, and you get a value for the centre of that range -> e.g. at 4Hz, the time window is 1s long, so you can't get any values for the first 0.5s of your time-domain data. OSL will only get the TF for the time-range compatible with the lowest frequency you ask for. E.g. your trial is between -1 and 2s, and you ask for 4 cycles at 4Hz. OSL will do the TF between -0.5 and 1.5s.

Single subject vis Cx response to compare the methods. ERF:



Hanning – 4 cycles, 5-30Hz



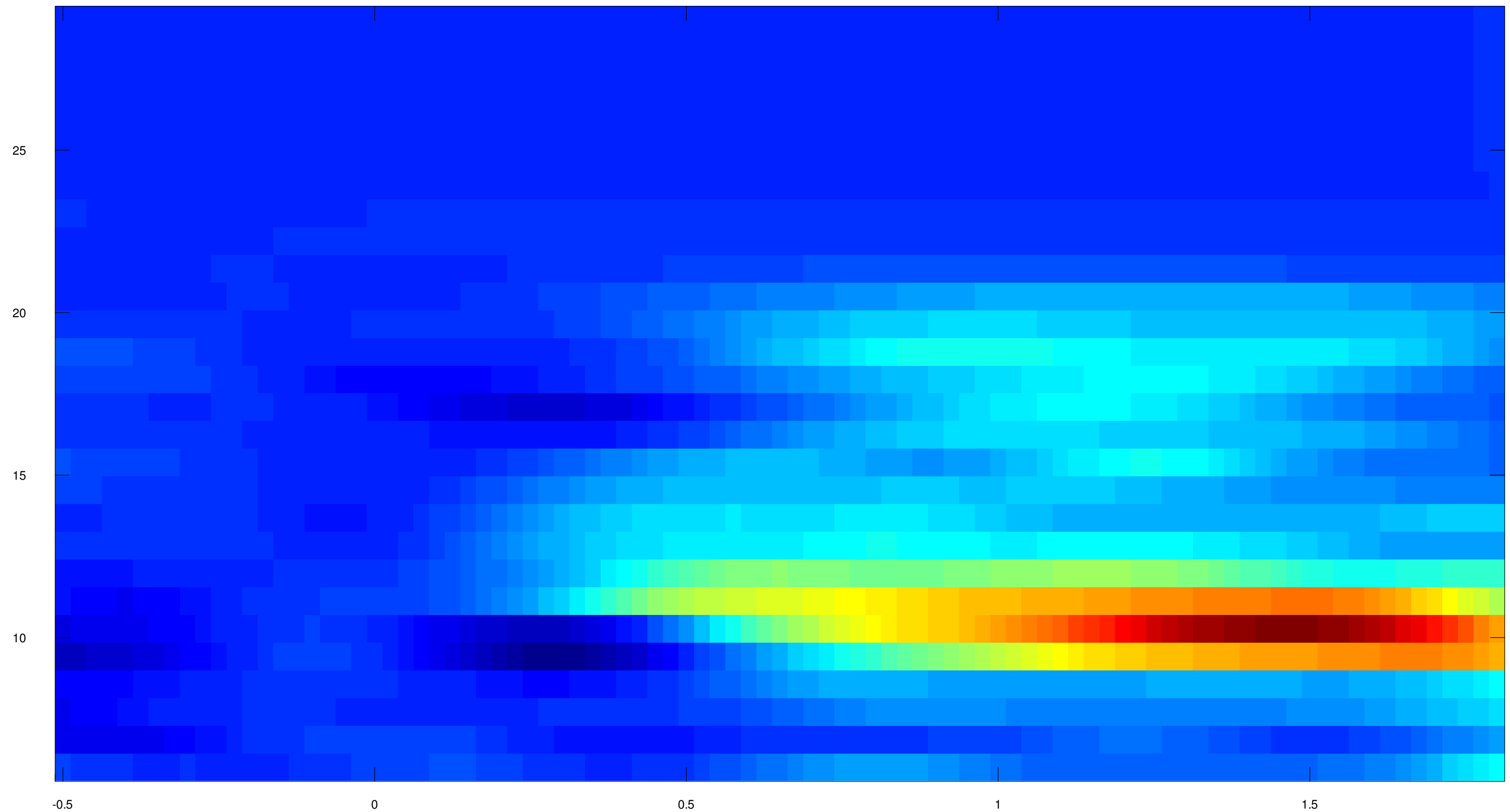
Hilbert transform

```
oat.first_level.tf_method                         = 'hilbert';
oat.first_level.tf_freq_range                     = [5 30];
oat.first_level.tf_num_freqs                      = 28;
oat.first_level.tf_hilbert_freq_res               = 2;
oat.first_level.tf_hilbert_do_bandpass_for_single_freq = 1;
oat.first_level.tf_time_step                      = 0.025;
```

Hilbert transform for power:

1) Bandpass filter at the freq of interest
2) Apply the hilbert transform to get the analytic signal
3) Take the squared amplitude of the analytic signal (power)

Hilbert transform – frequency resolution 2Hz (centre freq ± 1Hz)



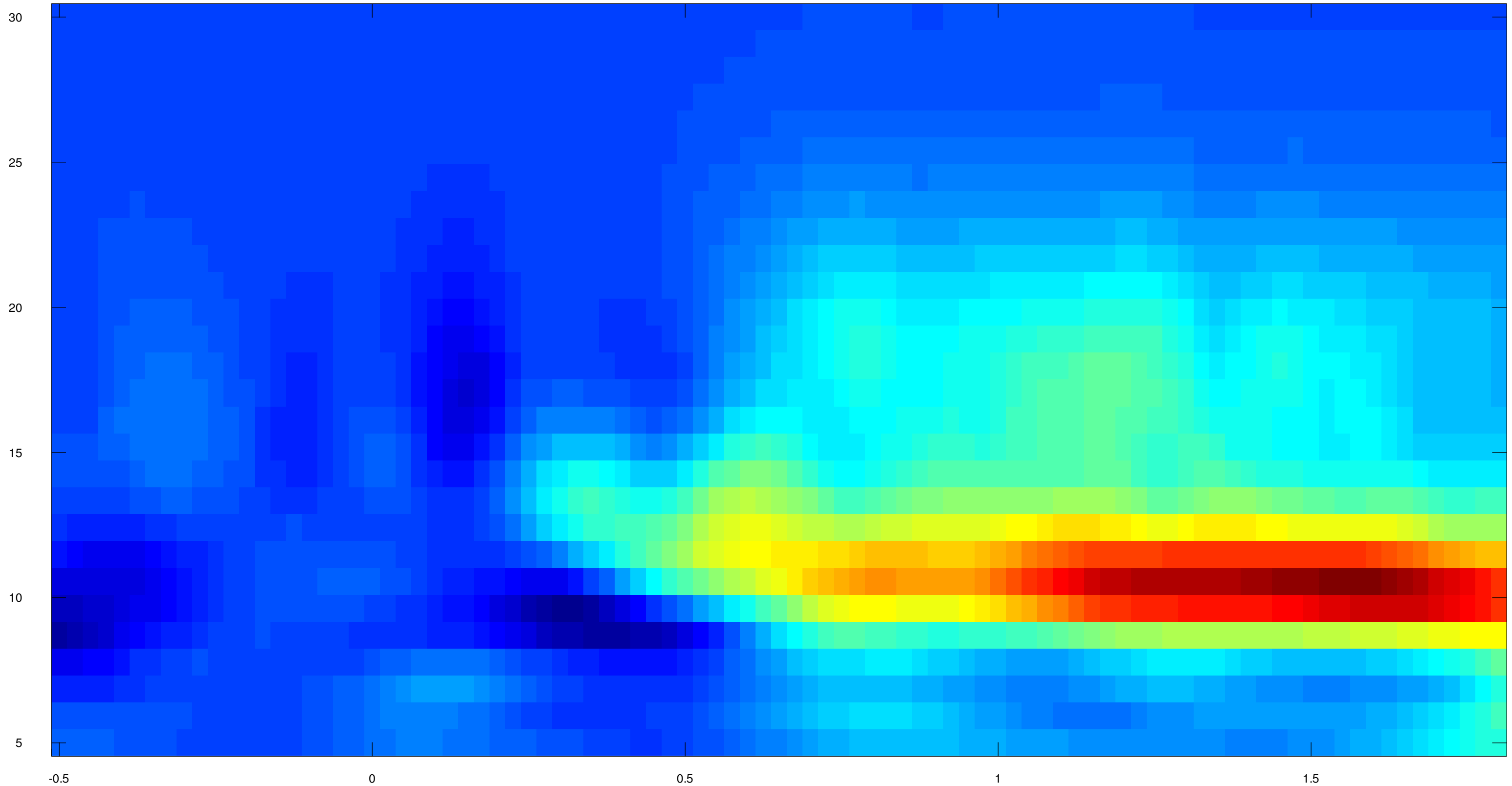
Morlet wavelets

```
oat.first_level.tf_method              = 'morlet';
oat.first_level.tf_freq_range          = [5 30];
oat.first_level.tf_time_step           = 0.025;
oat.first_level.tf_num_freqs           = 28;
oat.first_level.tf_morlet_factor       = 7;
```

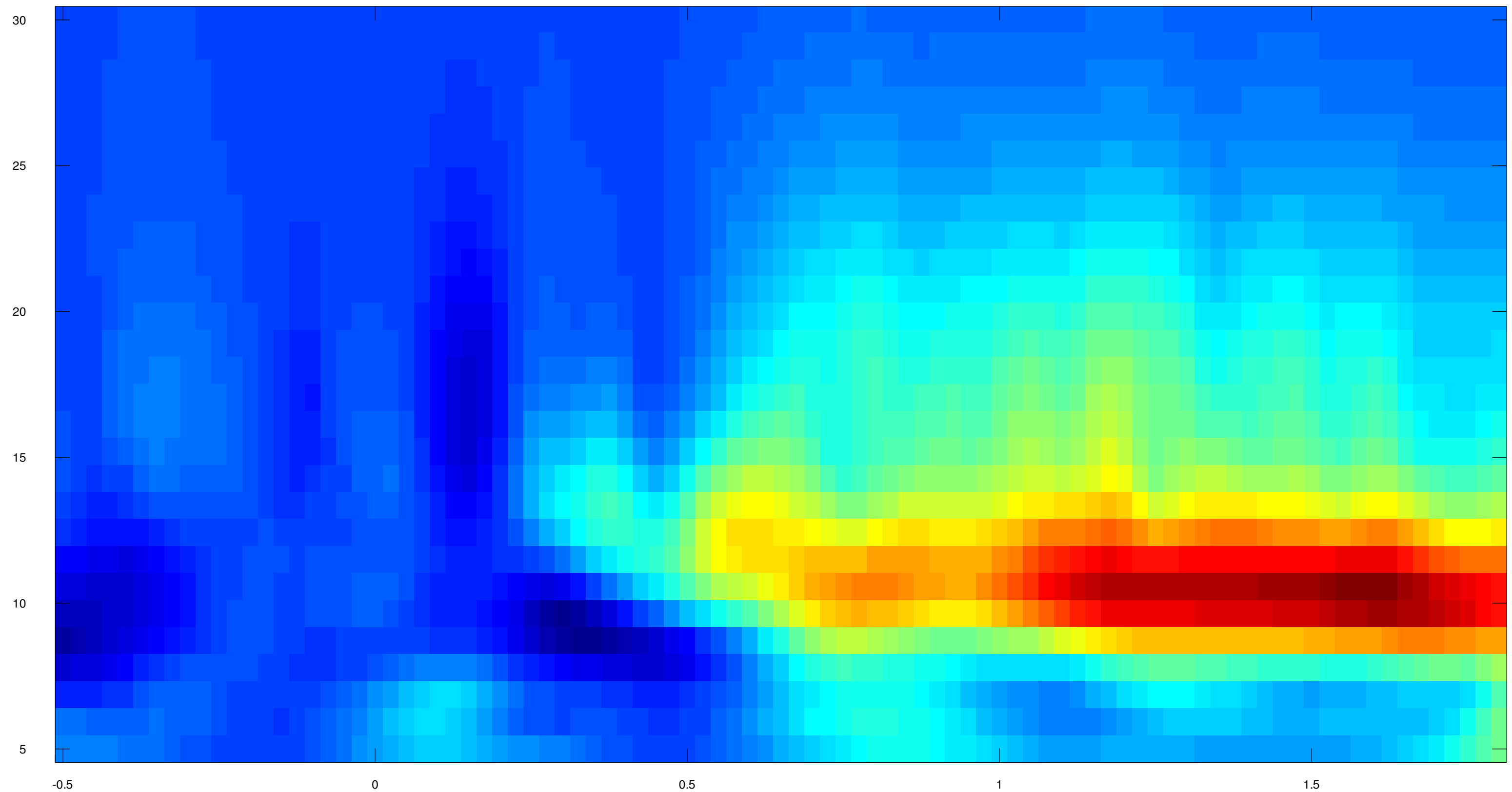
- Convolve the wavelet with the time-domain signal
- Can choose the width of the Gaussian envelope of the wavelet relative to its frequency: Morlet factor
- Morlet factor M determines the tradeoff between time and frequency resolution
- Gaussian in both freq and time

$$freqres = {freq}/{M} \qquad timeres = {M}/{2.pi.freq}$$

Morlet wavelets, morlet factor 7



Morlet wavelets, morlet factor 5



Gamma analysis (> 30Hz)

- Really benefits from control over the time/freq tradeoff (see fieldtrip tutorial)
- Using multiple orthogonal tapers (separate TF transform for each taper) allows for multiple independent estimates of the spectrum and increased signal/noise (see wikipedia)
- Not implemented in OSL as would have to adapt beamformer to include a separate weights multiplication for each taper

Gamma analysis – how??

- Do whole-brain analysis using Morlet (or maybe Hanning??)
- To do a multitaper analysis, use the 'save trialwise' option in osl to export trialwise *time-domain* data for a gamma-frequency (e.g. 40-120Hz) beamformer (best to use some ROIs or the data will be too big!)
- Then convert to fieldtrip format and use the fieldtrip multi-taper algorithm ('dpss')
- See Fieldtrip website for best parameters (10Hz freq smoothing, 5 tapers works quite well)

Checklist

- Is oat.first_level.tf_freq range contained within oat.source_recon.freq_range?
- Is oat.first_level.cope_type set to ‘cope’? (‘acope’ used for ERF analysis only)
- Is there some ‘space’ left at the end of each trial for the TF edge effect? oat.first_level.time_range should be shorter than oat.source_recon.time_range by at least ½ of the wavelength of the lowest frequency, at each end
- If using the hilbert for single-frequency analysis, do you want to do an additional bandpass on top of the source recon bandpass? If so, is oat.first_level.tf_hilbert_do_bandpass_for_single_freq set to 1? And is oat.first_level.tf_freq_range set?
- Is the down-sampling appropriate? Power time-courses for low frequency oscillations can be sampled quite coarsely, e.g. every 25ms (40Hz; oat.first_level.tf_time_step = 0.025), or perhaps lower still