Localizing epileptic seizure onsets with Granger causality – *Supplementary Information*

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In this supplementary material, we report additional results (Figures S1-S11 below): (i) **Granger causality results for all patients** P1-P8 in Figures (S1- S8) (A-D), (ii) **total interdependence (TI) at different time windows** in patient P4 shown in Figure S9 (A-D), (iii) **integrated net-causal outflows (iOF) and inflows** after the time of significant causality in patient 4 shown in Figure S10 (A-C), and (iv) **integrated Granger causality (iGC) and integrated outflows (iOF)** after the time of significant causality in patient P5 in Figure S11. The results from patient P4 as a representative patient are included in the Letter.

(i) **Figures S1-S8.** Here, figures (A-C) show the net causal outflow averaged over time (A), over frequency (B) and over recording channel (C), and figure (D) shows net causal outflow over time from all electrodes. The white dashed lines in (B-C) and black dashed line in (D) represent the onset time of seizure assessed by using traditional visual criteria (from clinical evaluation). The green dashed line in (D) represents the time when net causal outflows cross the 3 standard deviation from our calculation. In all patients, the Granger causal relationships at high frequency (>80 Hz) could be defined among groups of electrodes. In these patients, the high frequency causality started to appear around 2.0 sec to 12.5 sec (patients' average ± standard error = 6.3 sec ± 1.4 sec) before the onset of clinically identified ictal activity. Abbreviations used here are: f = frequency, Ch = channel, OF = net causal outflow, OF_t= outflow averaged over time, OF_f= outflow averaged over frequency, and OF_{Ch}= outflow averaged over channel.

(ii) **Figure S9 (A-D).** Matrices of total interdependence (TI) at time = 8.5, 9.0, 9.5 and 10 sec in Patient 4. This measure clearly shows where a seizure originates and how it propagates over the network reaching the hyper-synchronized state.

(iii) **Figure S10 (A-C).** Integrated ouflows (iOF) and integrated Granger causality (iGC) in patient 4. Fig (A) represents the frequency-integrated net causal outflows (iOF) after the time of significant causality. Here, sources (having +ve iOF) are categorized and shown in different colors according iOF compared to standard deviation of GC = 0.0167 from the pre-ictal period. Figures (B-C) show the integrated Granger causality (iGC) in- and outflows from and to channels: to Ch 23 (S10 (B)) and to Ch 65 (S10 (C)). These two channels plus others having –ve iOF were the sink channels in S10 (A).

(iv) **Figure S11 (A-C).** Fig S11 (A) shows results of iGC in the ictal period a t =8.5 s (in patient P5). Here, some channels (e.g. Ch = 34, S11(B)) receive stronger causal influences from other channels and some other channels (e.g. Ch = 44, S11 (C)) send out more than receiving from others.
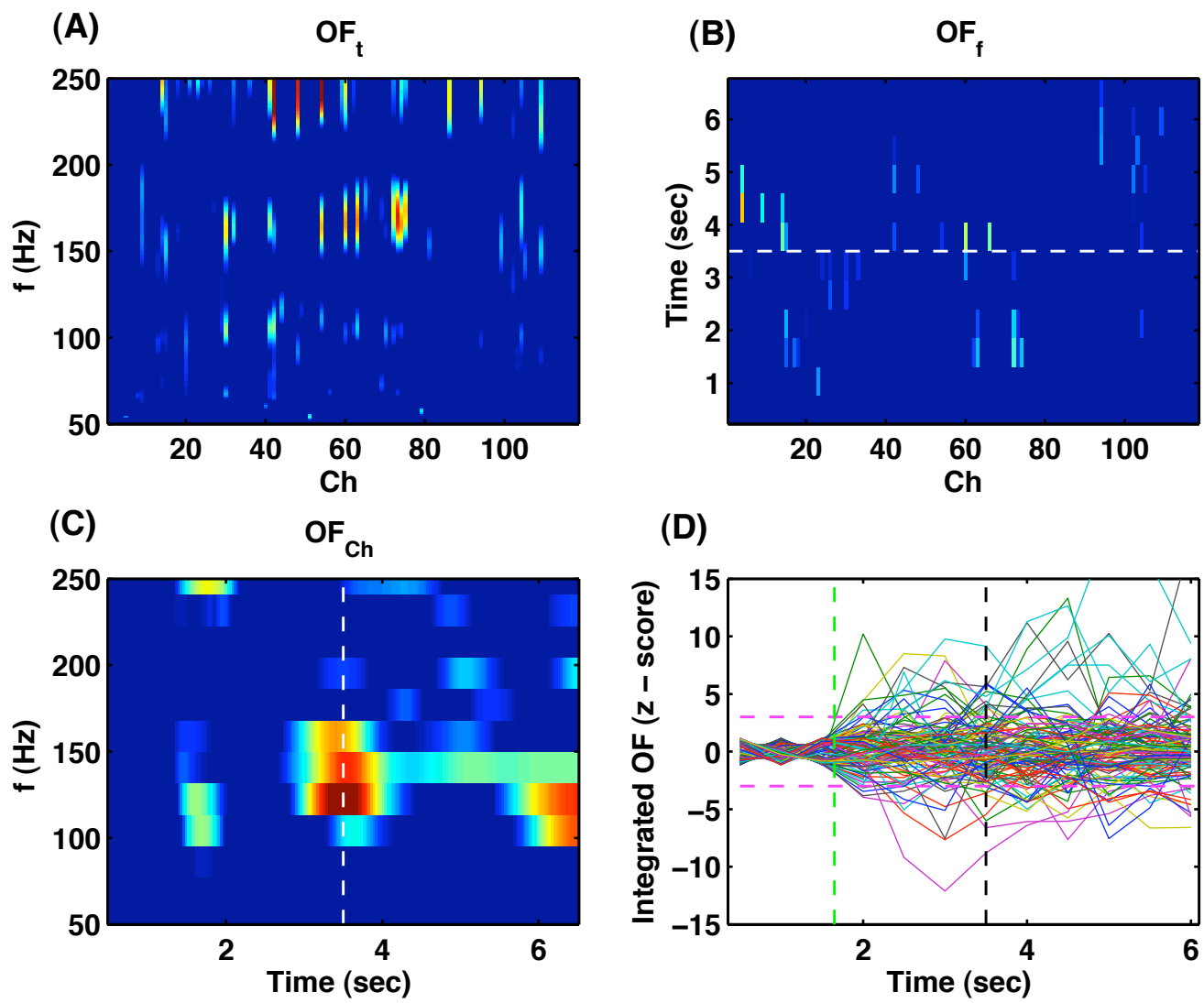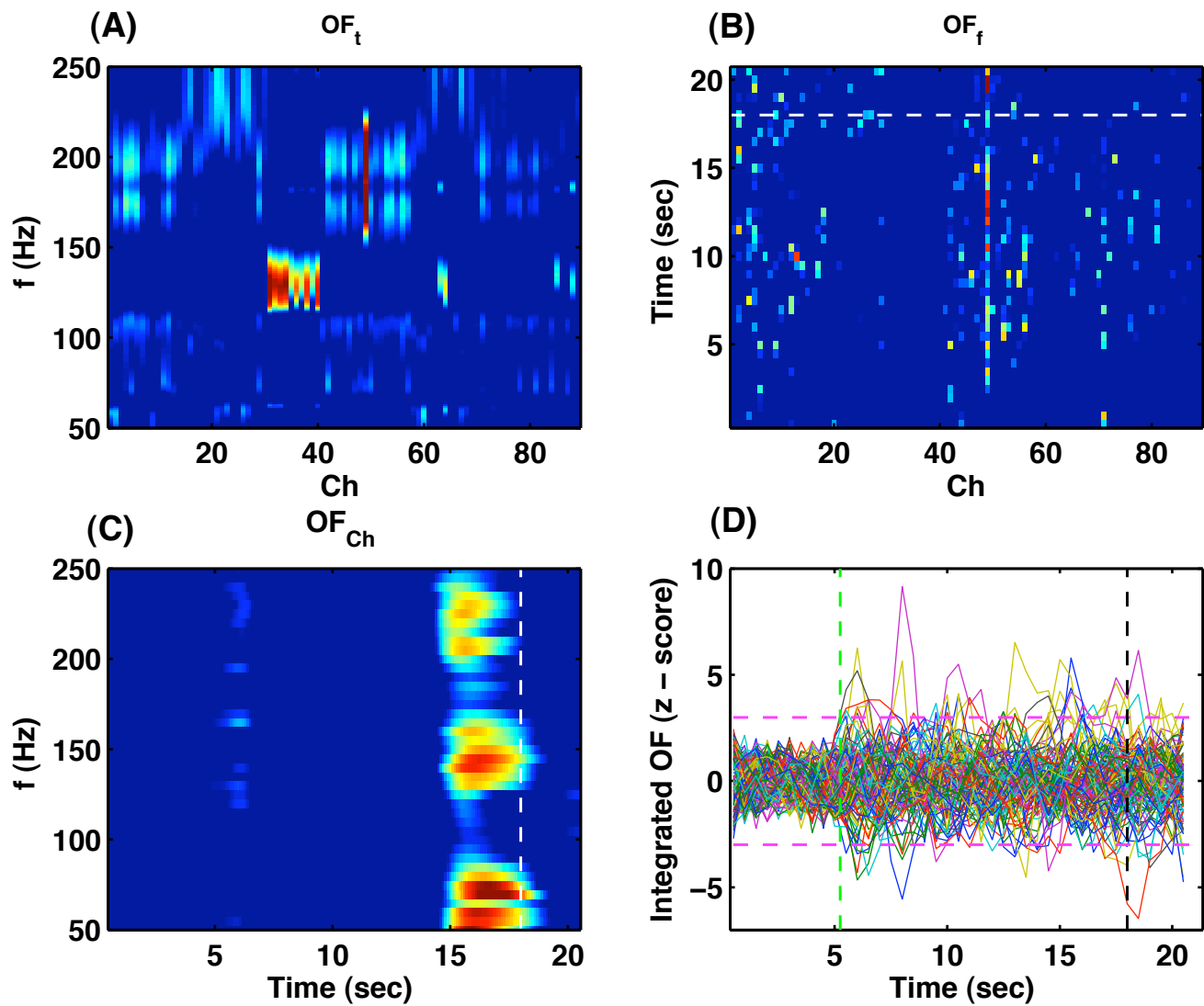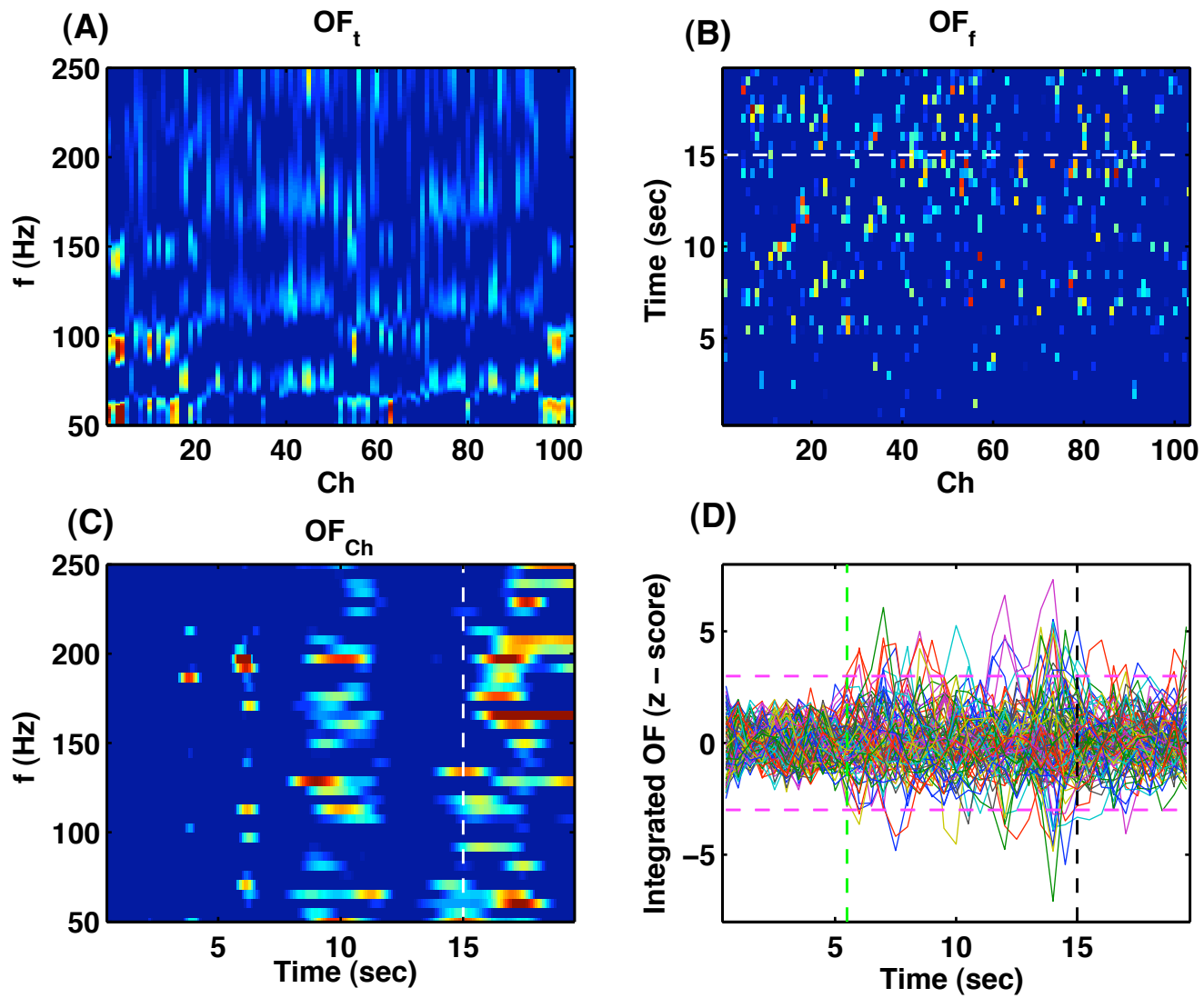
Figure S1 (A-D)

Figure S2 (A-D)

Figure S3 (A-D)
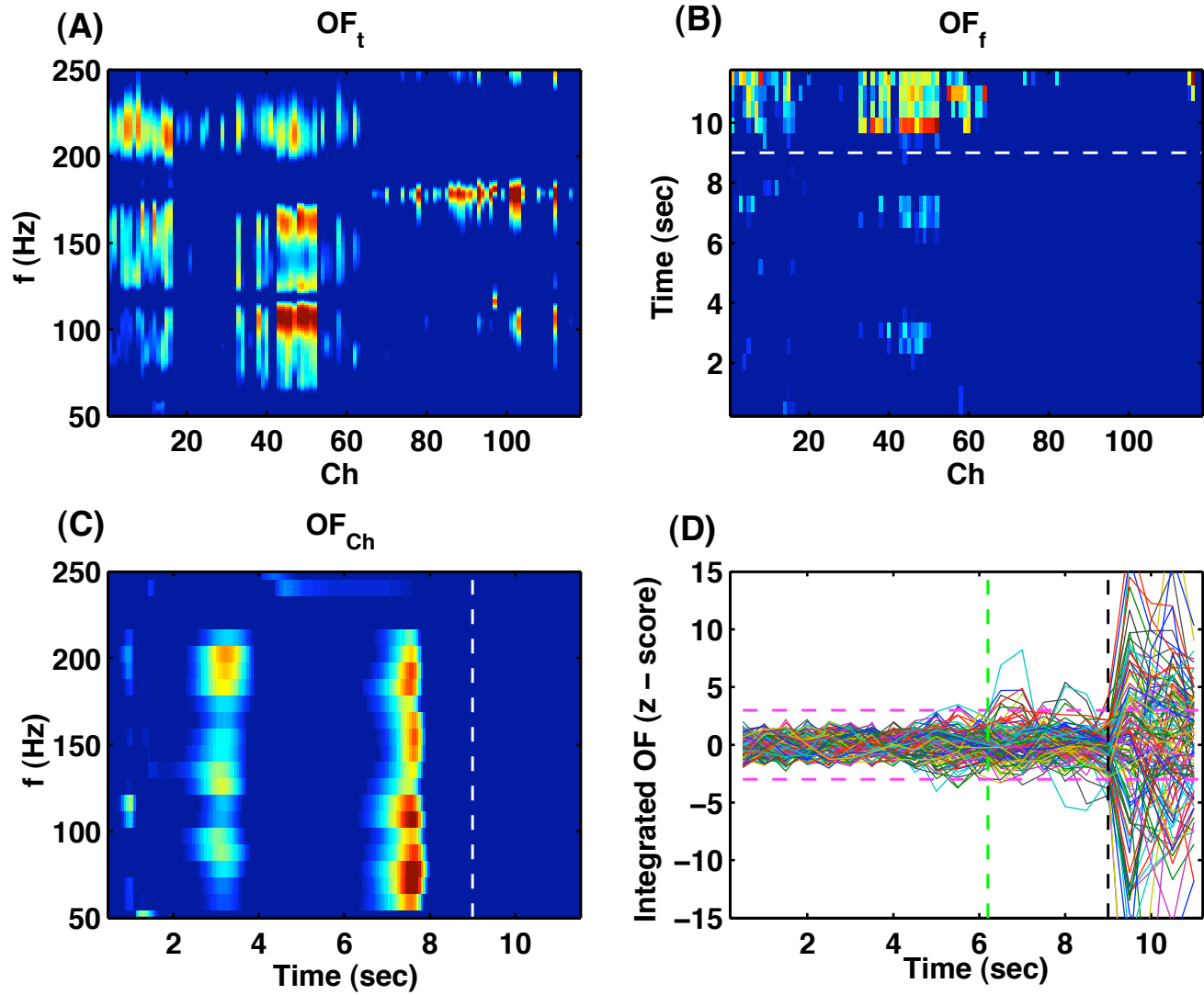
Figure S4 (A-D)
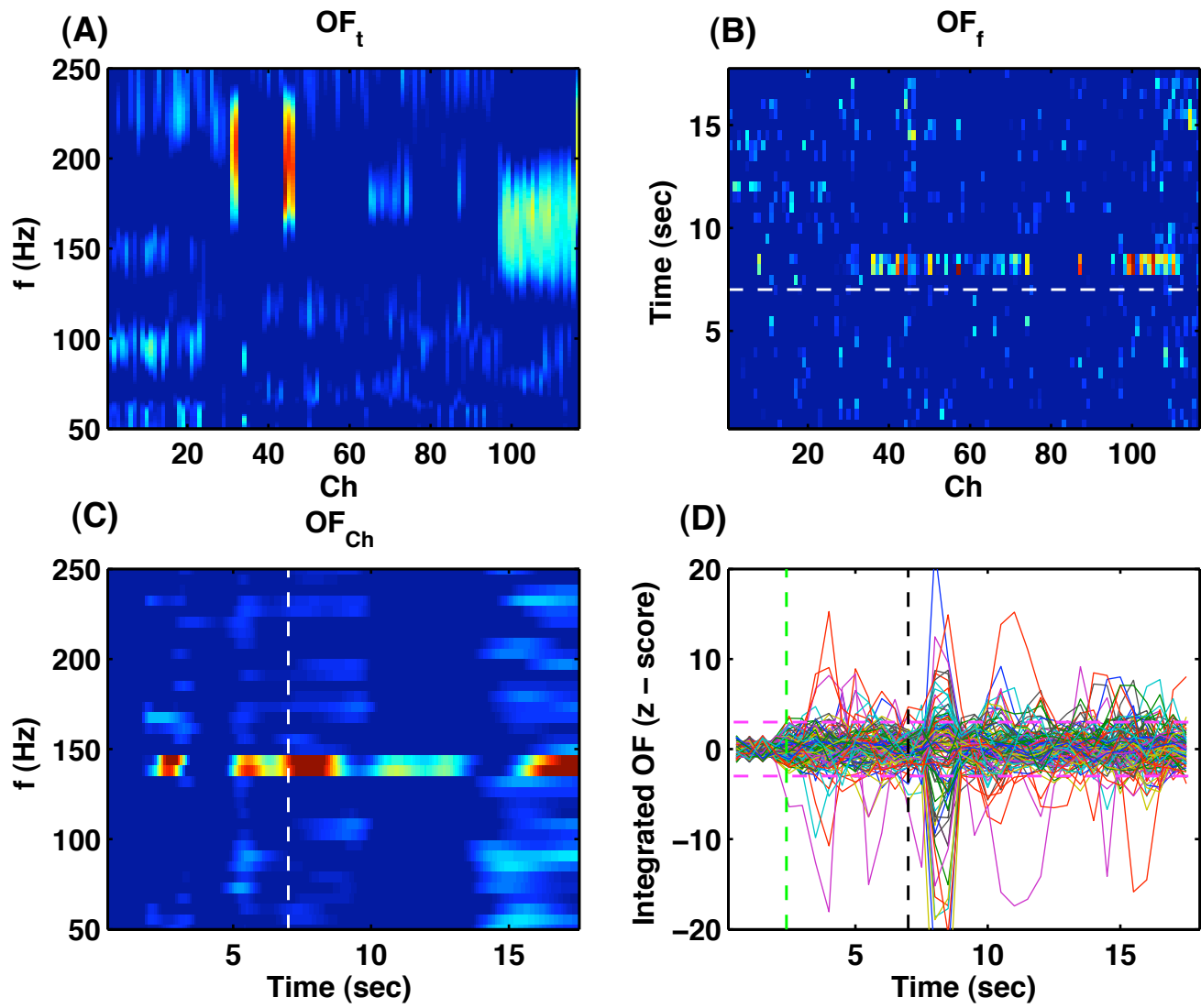
Figure S5 (A-D)
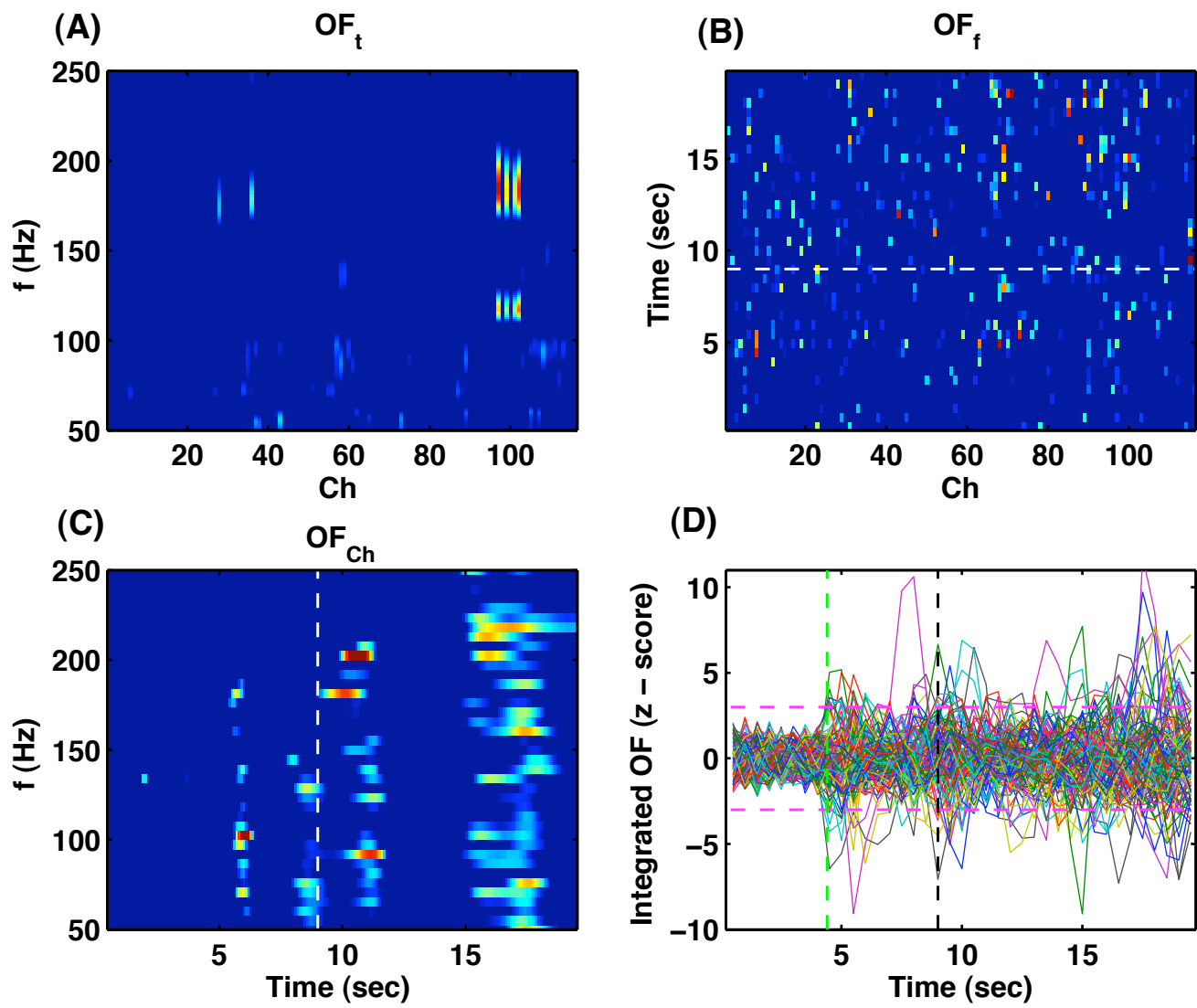
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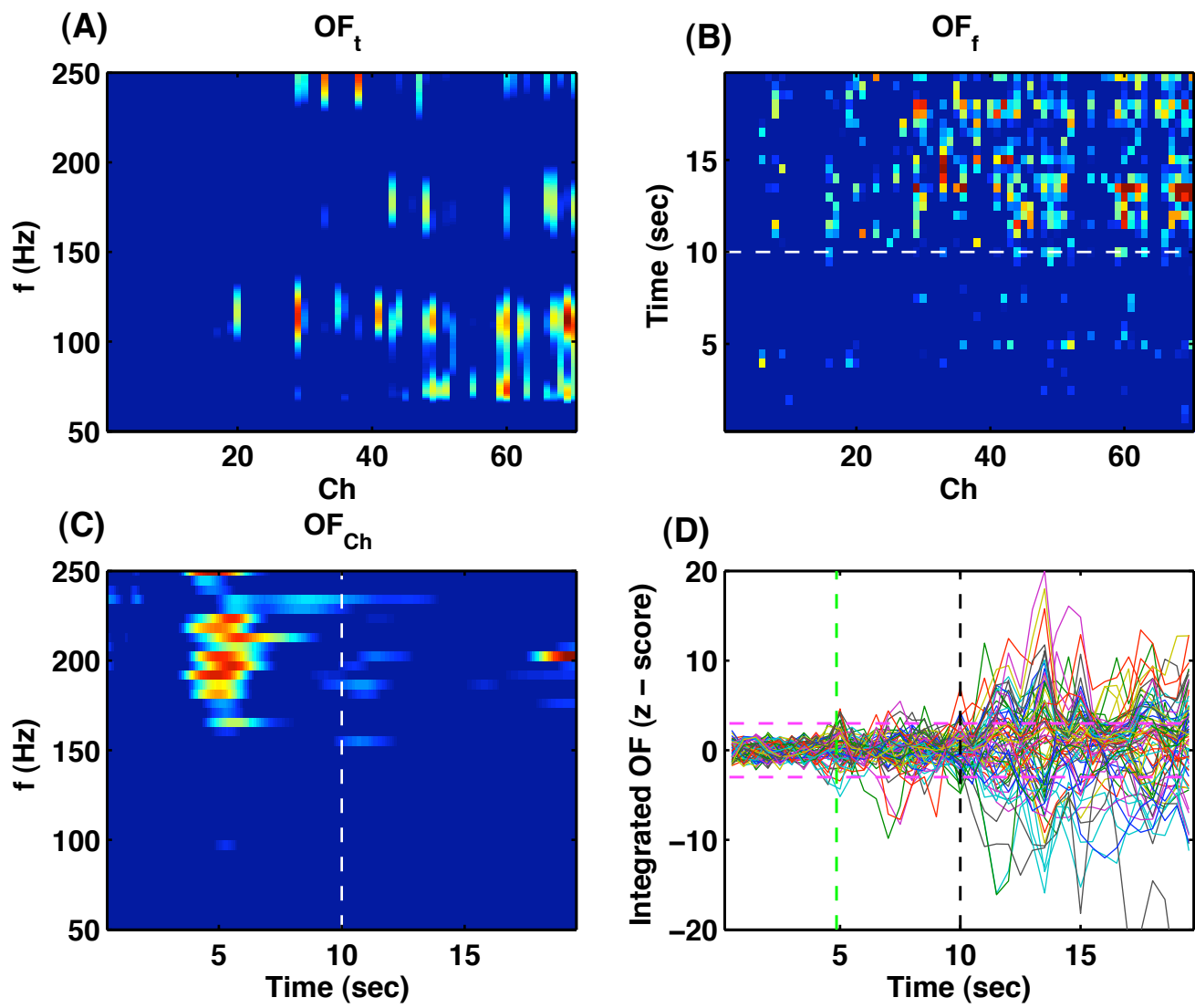
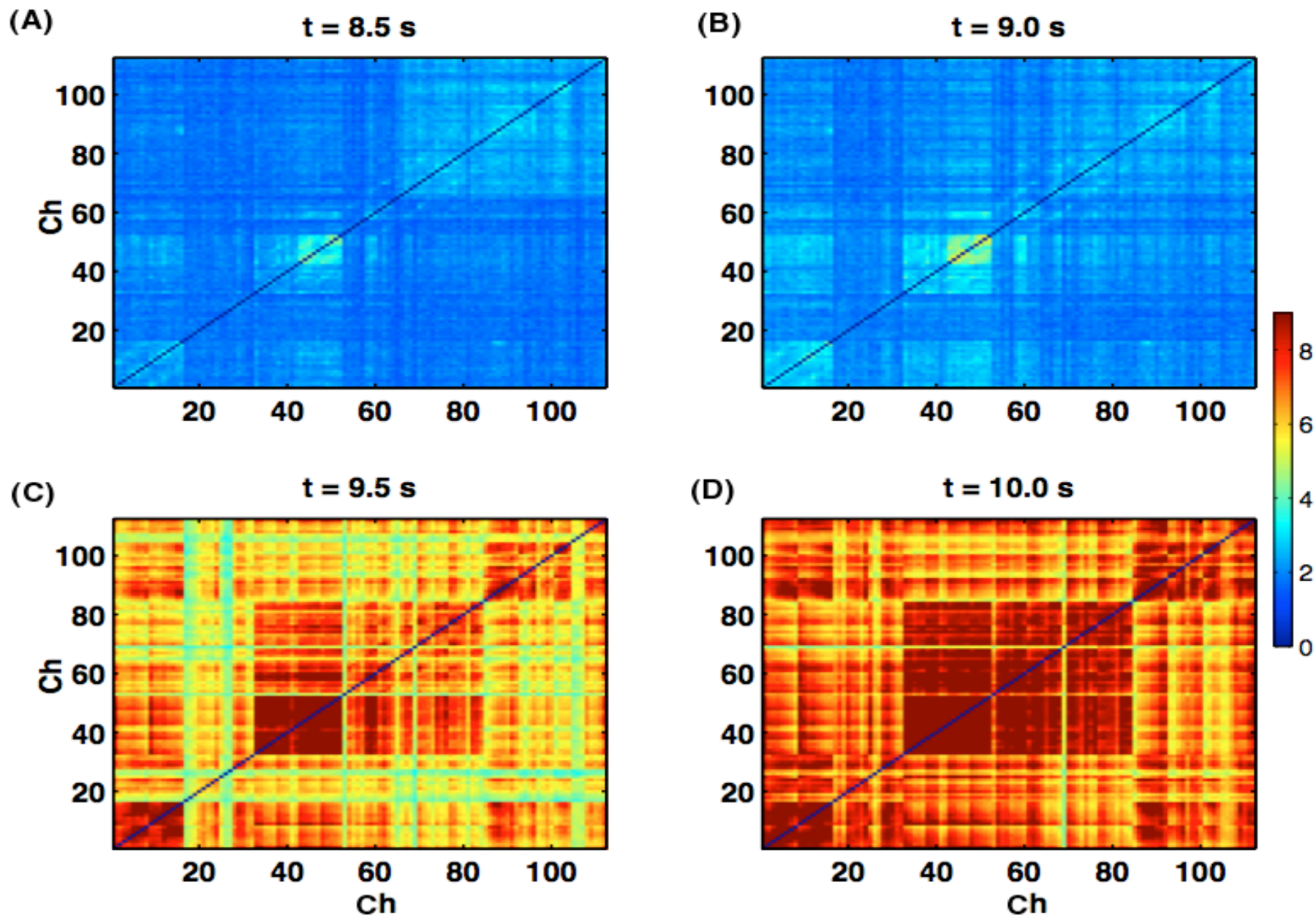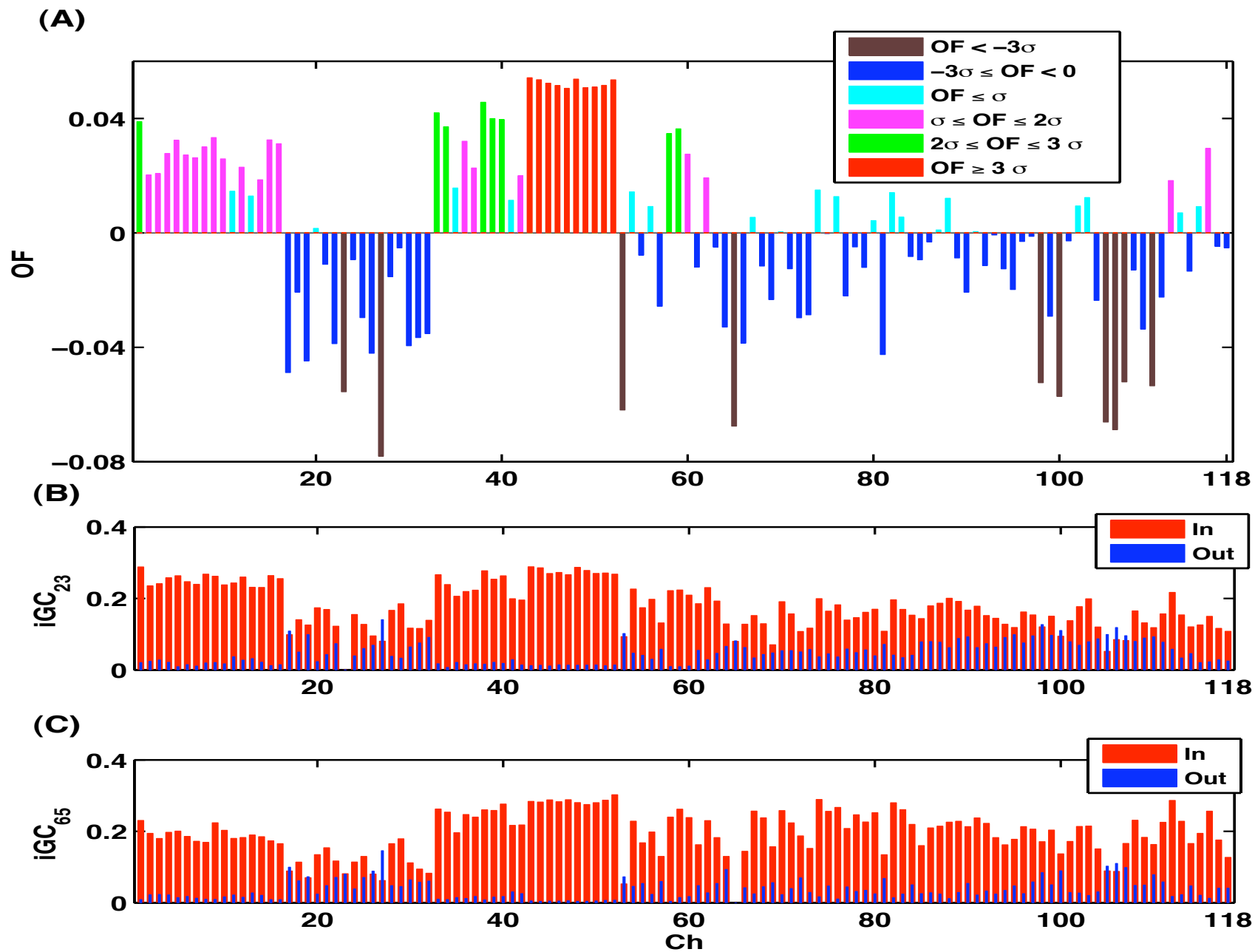**Figure S7 (A-D)**
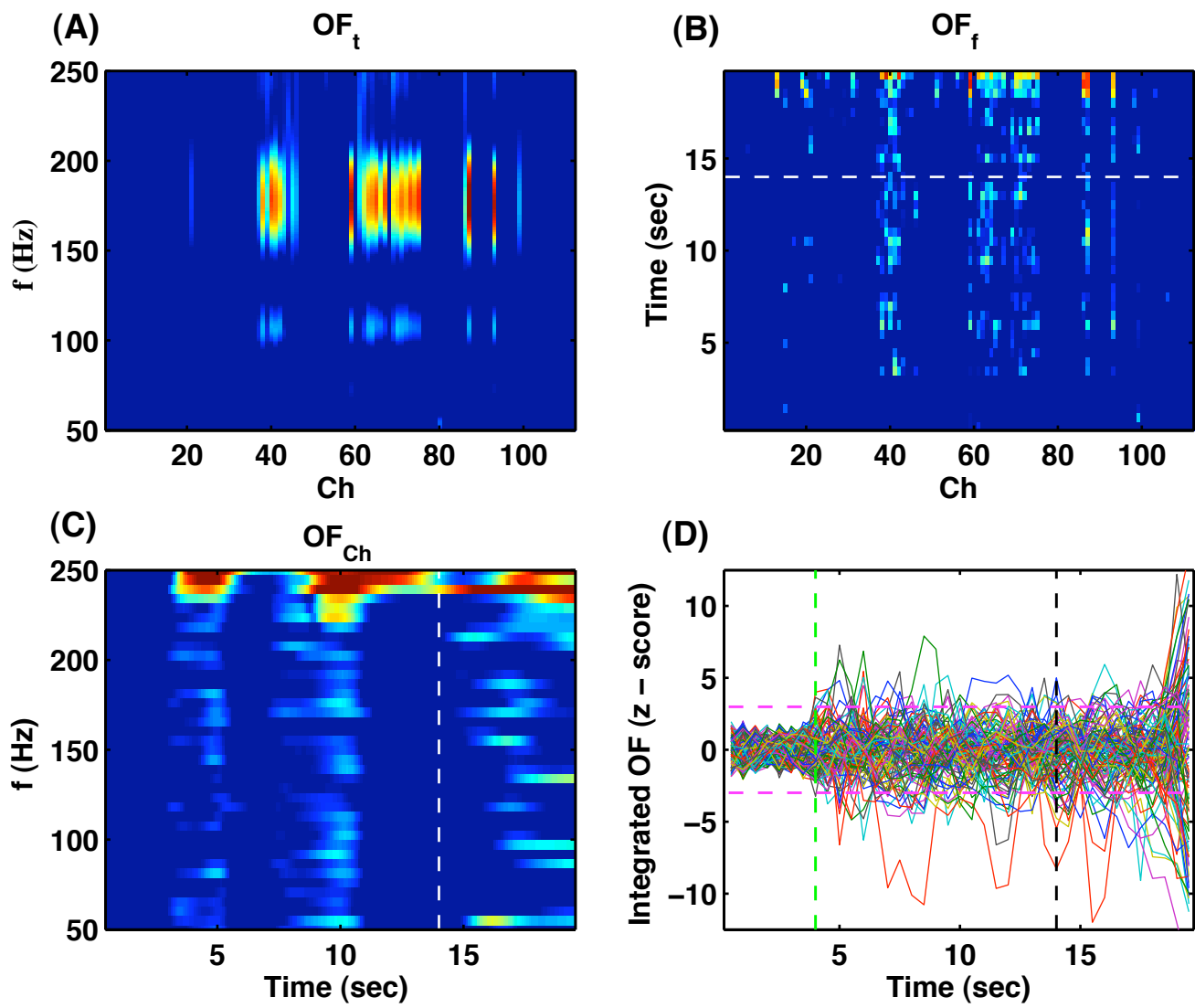
Figure S8 (A-D)

Figure S9 (A-D)

Figure S10 (A-C)

Figure S11 (A-C)