Extracting Earthquake Precursor Signatures Through Time Series Clustering

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Acknowledgments

- ## Time Series Clustering Method
  - Yik Wen GOO, Aerospace Engineering/4, NTU
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  - Wen Ting CHOI, Physics & Applied Physics/4, NTU
- ## New Zealand GPS Data
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  - Two startup grants, NTU

Precursors for Large Earthquakes

- Complex earth-crust dynamics

- Competing processes
  - Expect self-organization

- Statistical signatures prior to large earthquakes
  - Critical slowing down
    - Dakos *et al.*, PNAS **105**, 14308 (2008)
    - Scheffer *et al.*, Nature **461**, 53 (2009)
  - Synchronization
    - Leung, Phys Rev E **58**, 5704 (1998)
    - Osipov *et al.*, Phys Rev Lett **91**, 024101 (2003)
   - Goo *et al.*, arXiv:0903.2099, 12 Mar 2009

Time Series Clustering

- **Time series clustering**
  - Lower data frequency than financial markets
  - Cross-sectional study to ensure statistical significance
  - Insensitive to choice of observables

- **Long-time dynamics**
  - Long-time correlation matrix
  - Detection of synchronization clusters
  - Internal correlational dynamics of synchronized clusters

Long-Time Correlation Matrix
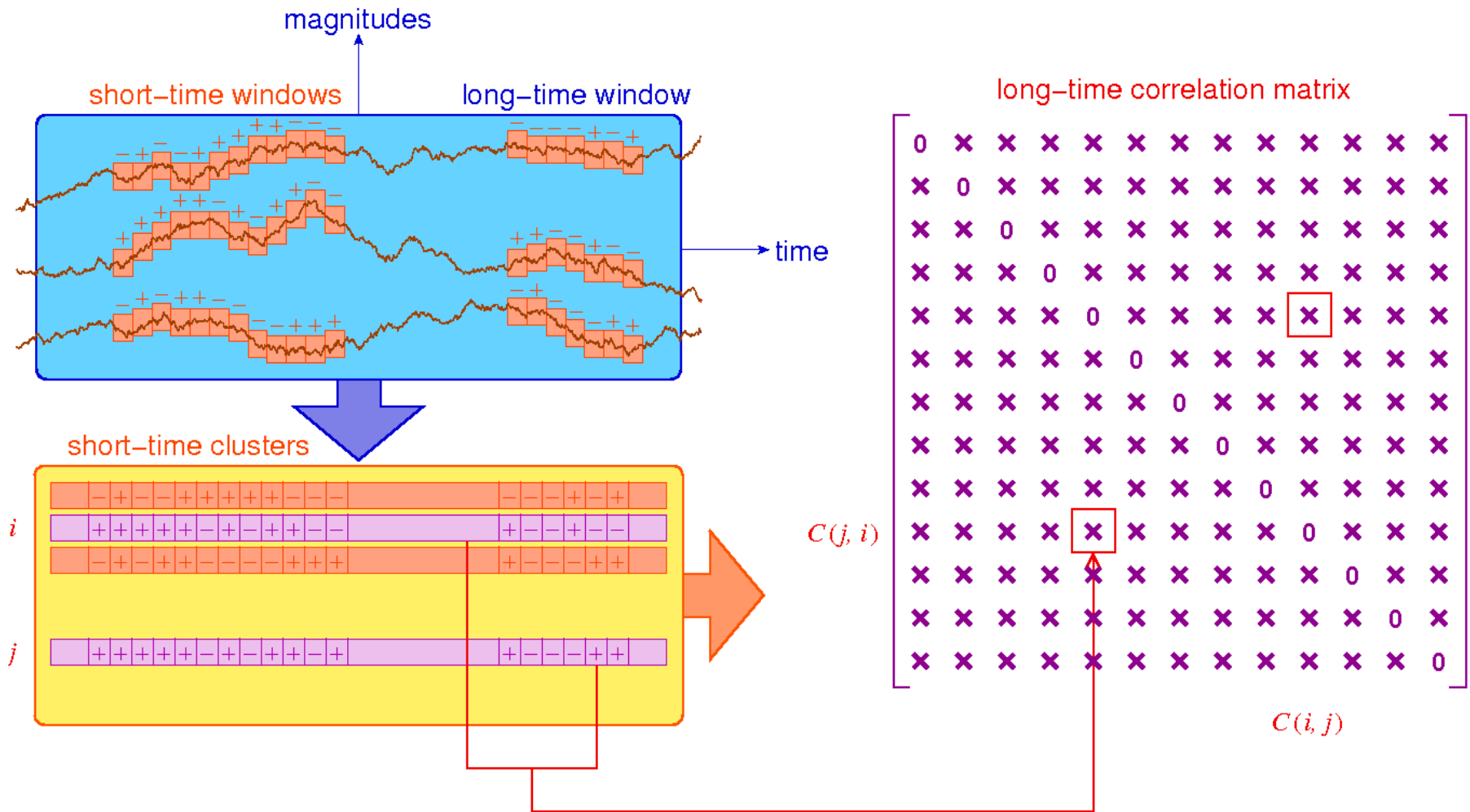
Hierarchy of Synchronized Clusters
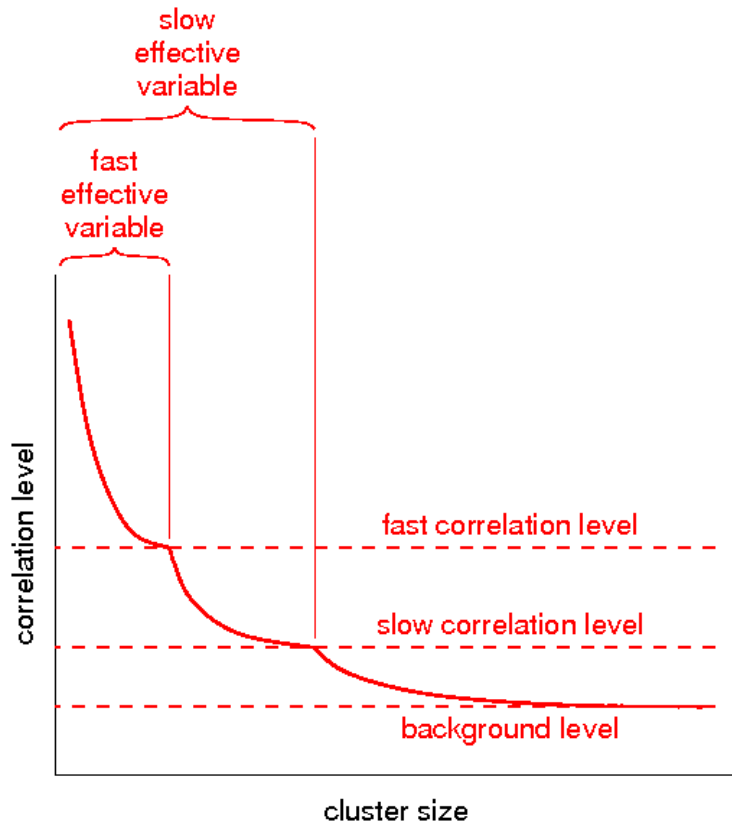
- **Partial hierarchical clustering**
  - Start with most strongly correlated seed cluster
  - Complete-link hierarchical clustering to grow cluster
  - Plot correlation level as function of cluster size
  - Kinks are natural cluster boundaries
    - Small synchronized clusters, faster effective dynamics
    - Large synchronized clusters composed of small synchronized clusters, slower effective dynamics

M > 6 Earthquakes, New Zealand (Oct 2006–Mar 2008)
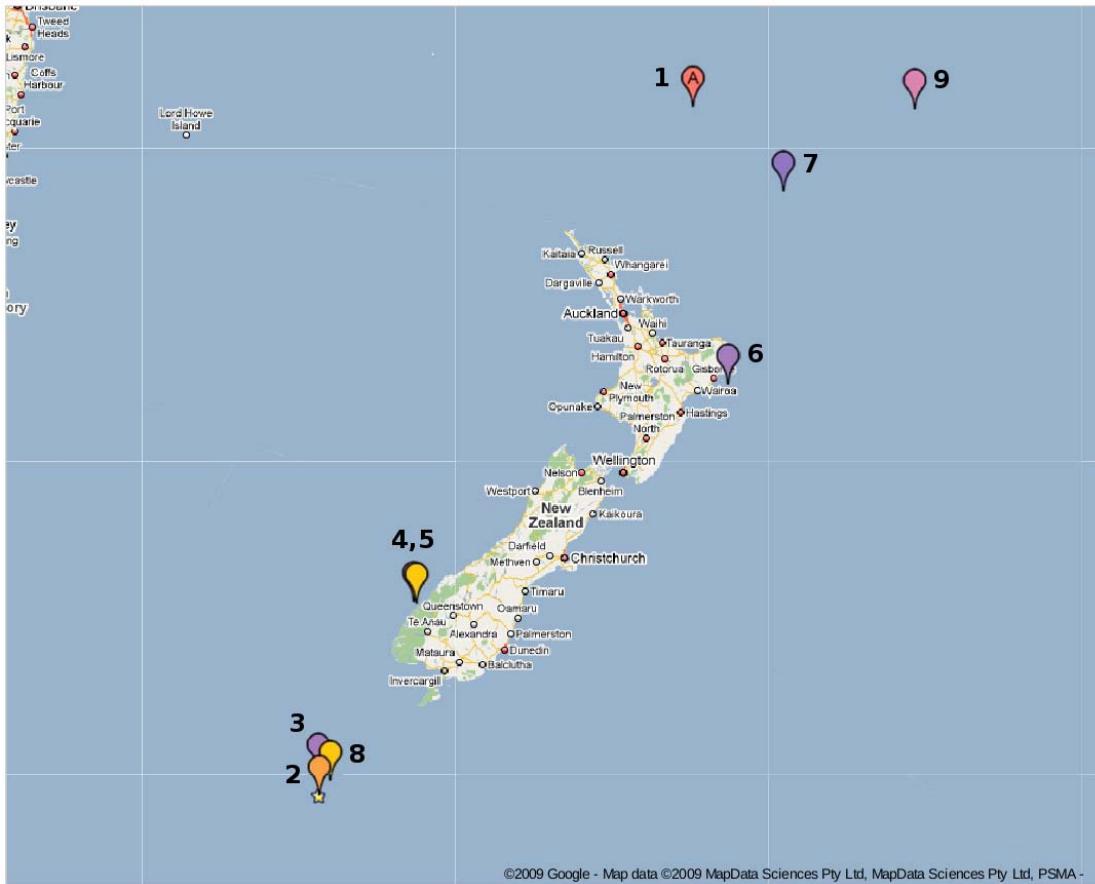
S/No.	Universal date & time
Spatial Cluster 1	
1	26 Dec 2006 at 21:06
6	20 Dec 2007 at 07:55
7	28 Mar 2008 at 06:39
9	29 Sep 2008 at 15:19
Spatial Cluster 2	
2	30 Sep 2007 at 05:23
3	30 Sep 2007 at 09:47
8	26 Apr 2008 at 23:34
Spatial Cluster 3	
4	15 Oct 2007 at 12:29
5	15 Oct 2007 at 21:28

Synchronized Clusters of Monitoring Stations

- 100+ stations in New Zealand monitoring network
- Synchronized clusters in one-to-one correspondence with spatial clusters of large earthquakes

Synchronized clusters	Stations	Geographical location
SC1	HAMT, TRNG, AUCK, CORM, MAHO, WHNG, NPLY, RIPA, MARW	North Island
SC2	AVLN, KAPT, WGTT, PARW, TINT, KAIK, WAIM, MAST, TRAV, CHAT, LEXA, CLIM, MQZG, BLUF, DUND, MTJQ, OUSD, DUNT, LYTT, CMBL	Southern coast, South Island
SC3	QUAR, WEST, GLDB, WANG, HOKI, VGPK, VGMT, GISB	Northern coast, North Island

Loss-of-Correlation Precursor Feature for SC2
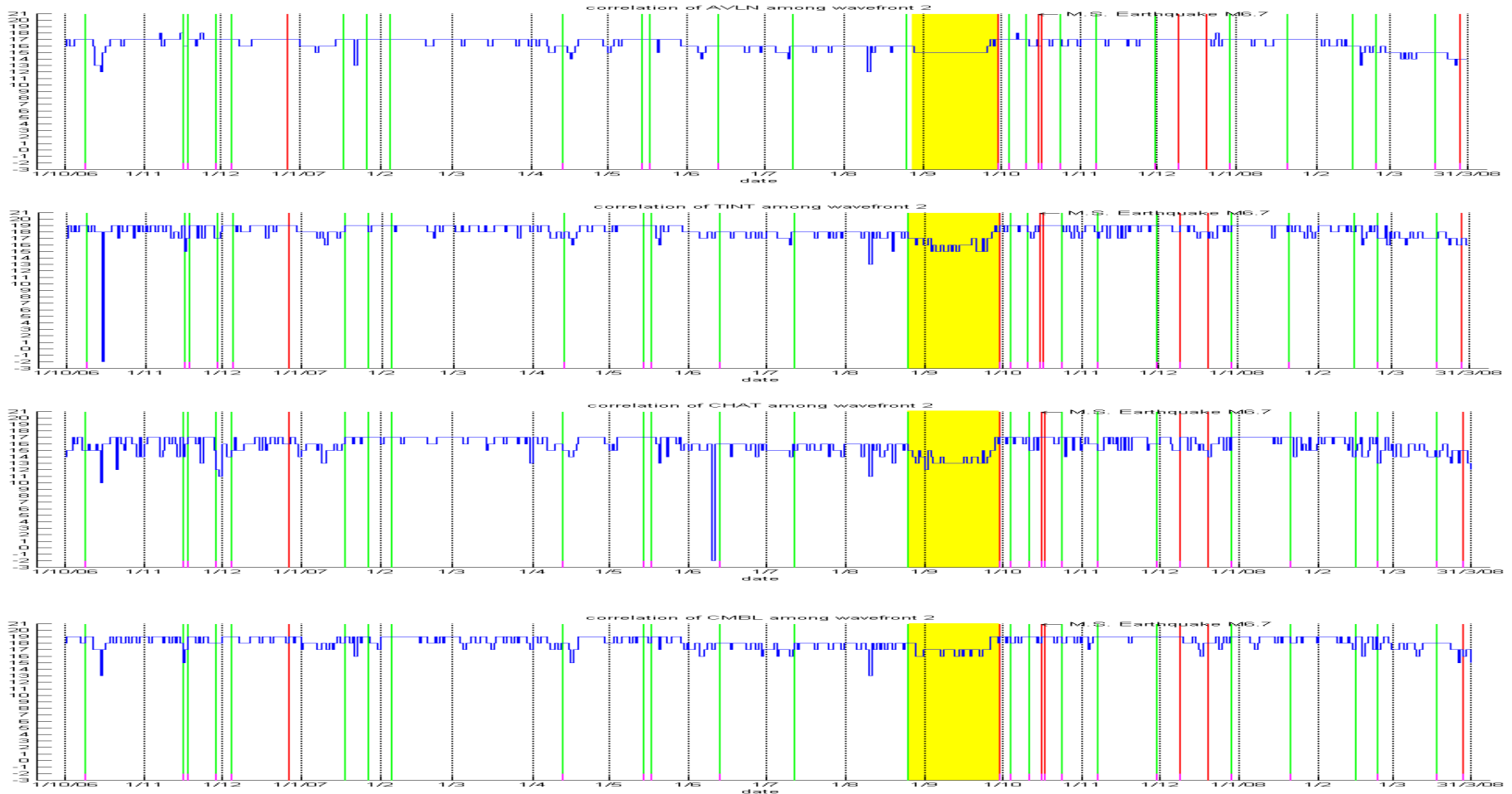
Spatio-Temporal Dynamics of Precursor Feature

2007.07.01
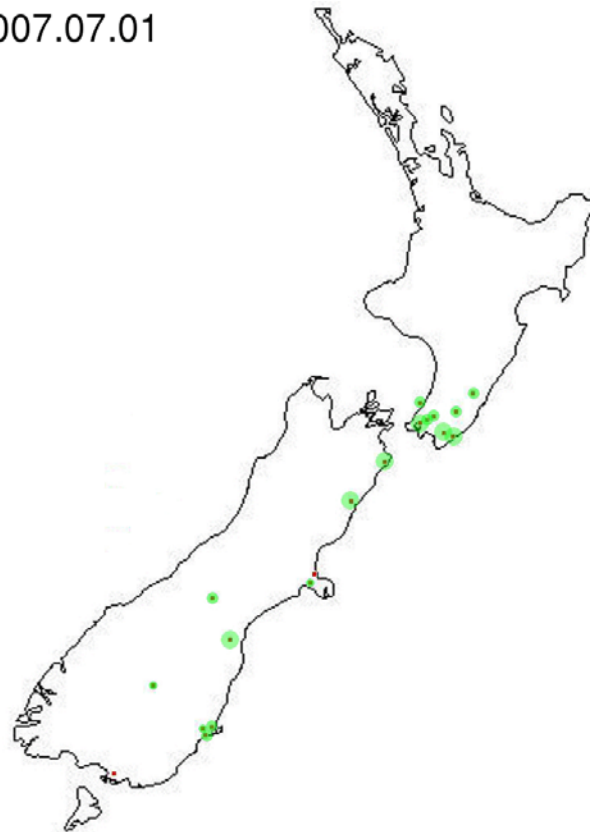
Thank You!

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