Differentiating Between Convective and Nested Structures With a Single Spacecraft

Savvas Raptis, Tomas Karlsson, ISSI Team 465

Division of Space and Plasma Physics, KTH Royal Institute of Technology
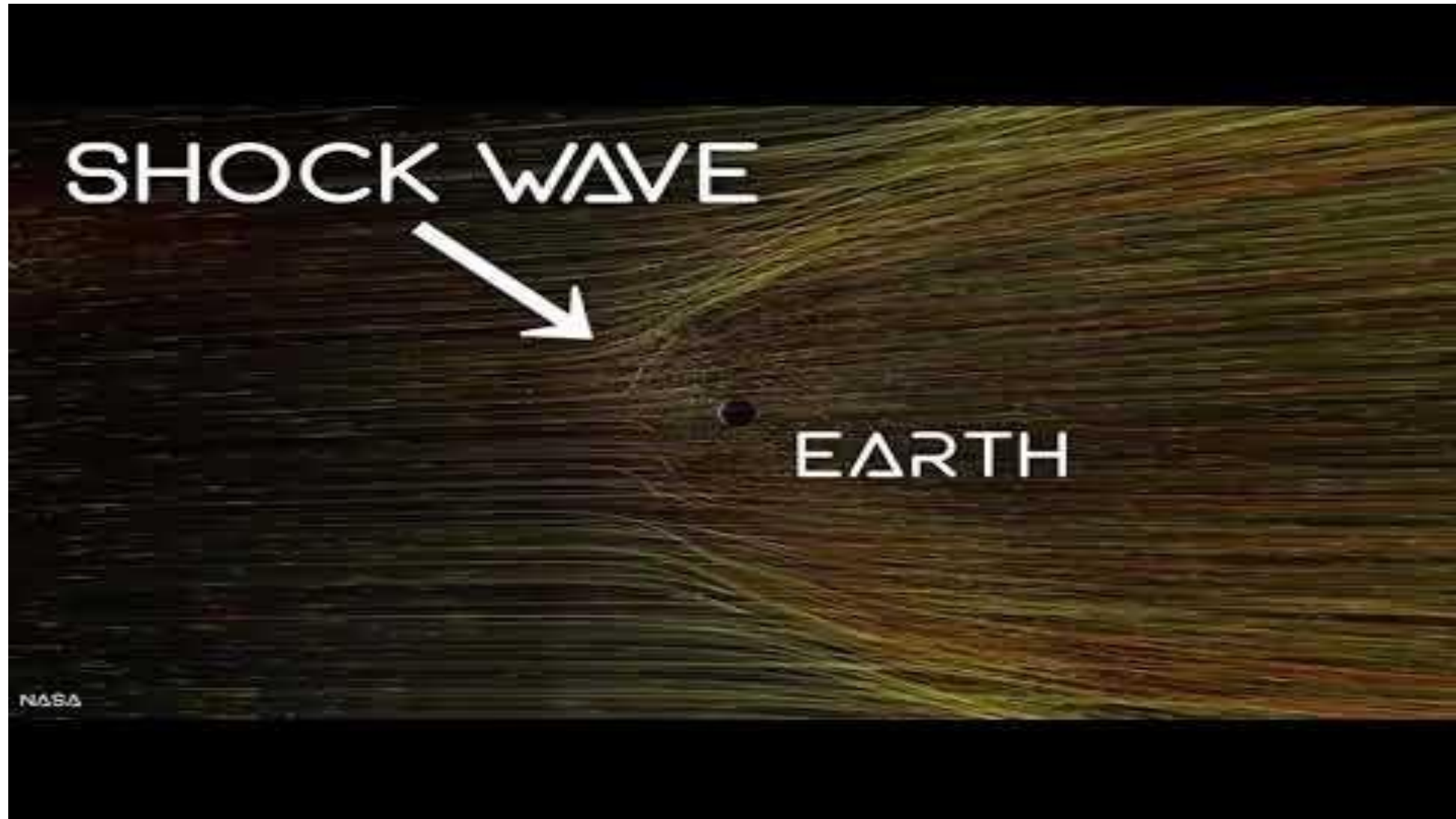
Introduction – Context

Foreshocks Across The Heliosphere: System Specific Or Universal Physical Processes?

- Heli Hietala, UK (leader)
- Ferdinand Plaschke, Austria (co-leader)
- Martin Archer, UK
- Markus Battarbee, Finland
- Cesar Bertucci, Argentina
- Xochitl Blanco-Cano, Mexico
- Glyn Collinson, USA
- Tomas Karlsson, Sweden
- Terry Zixu Liu, USA (young scientist)
- David Long, UK
- Merav Opher, USA
- Savvas Raptis, Sweden (young scientist)
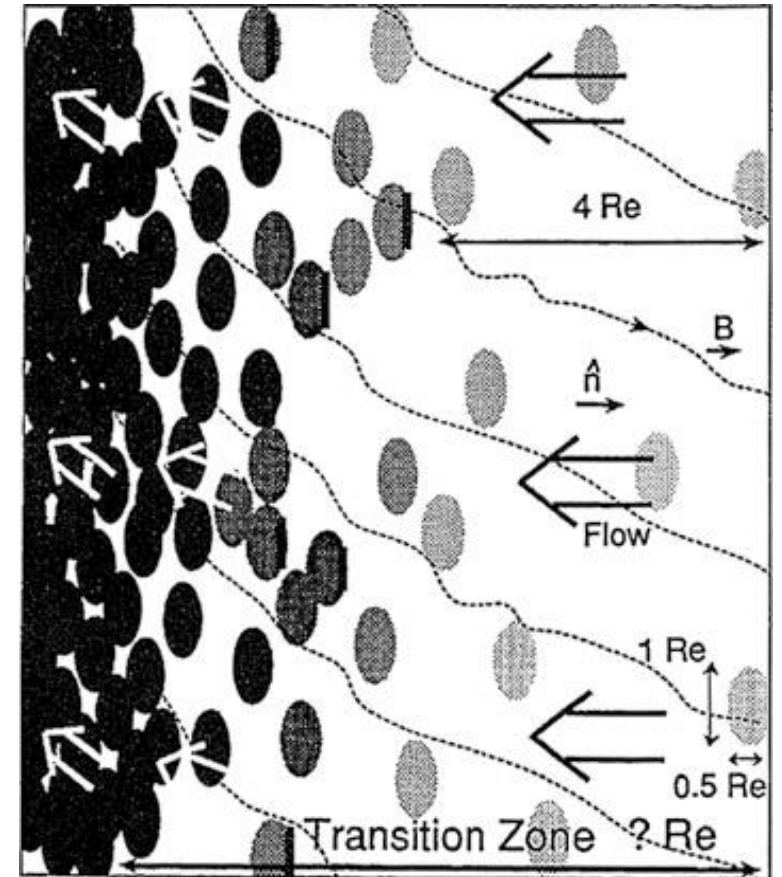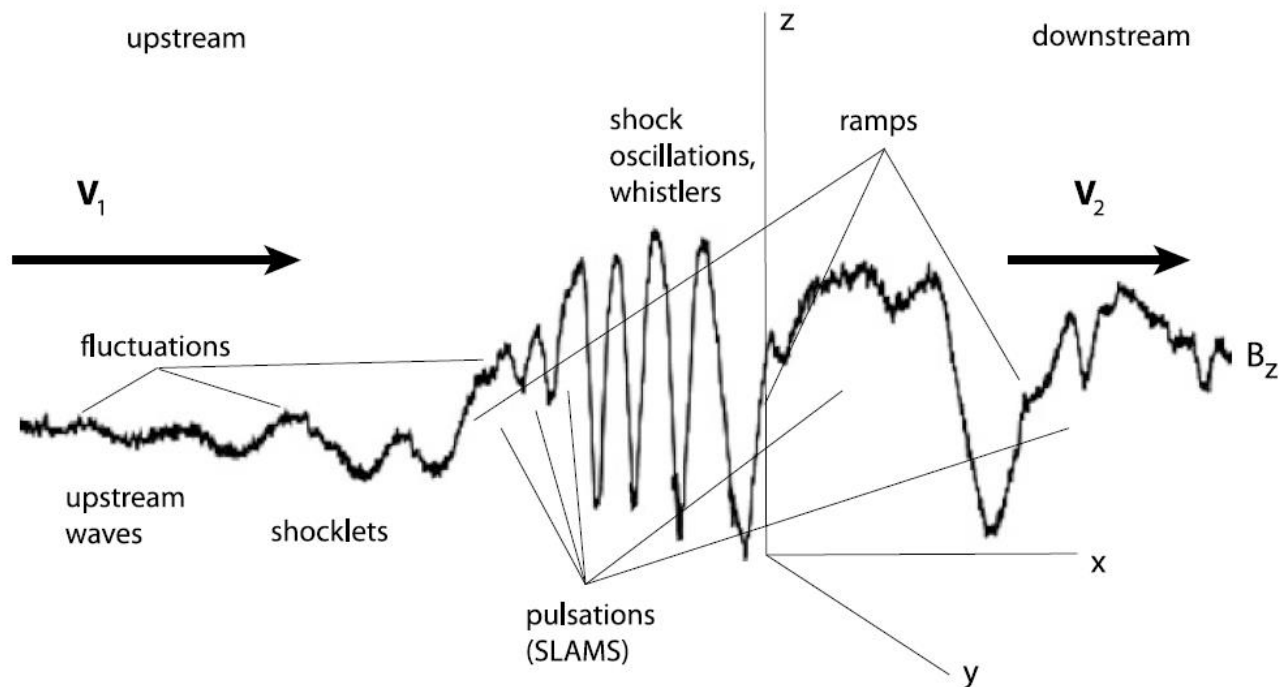- Nick Sergis,Greece

2nd March 2020 - "before" the pandemic

https://www.issibern.ch/teams/heliosysspec/

30-second introduction to the ISSI group

Martin Archer's YouTube channel : http://www.youtube.com/martinarcherdr

Nested & Convective Foreshock Structures

SLAMS

- SLAMS (**S**hort **L**arge **A**mplitude **M**agnetic **S**tructure)

Nested & Convective Foreshock Structures

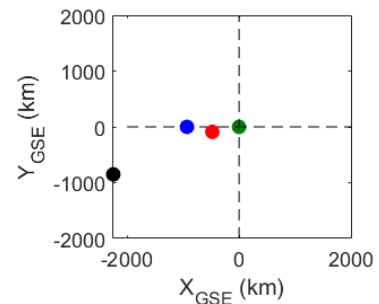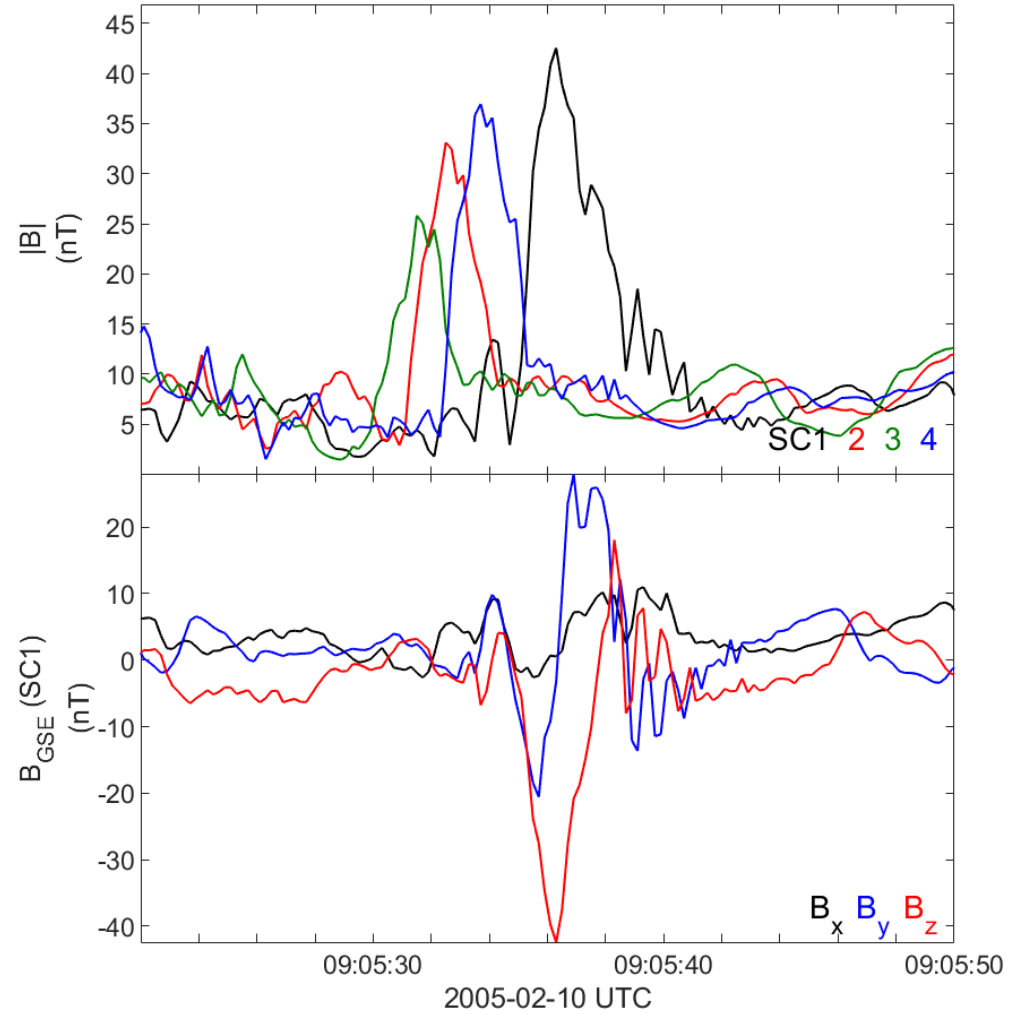# SLAMS (Convective) vs Bow Shock Movement (Nested)
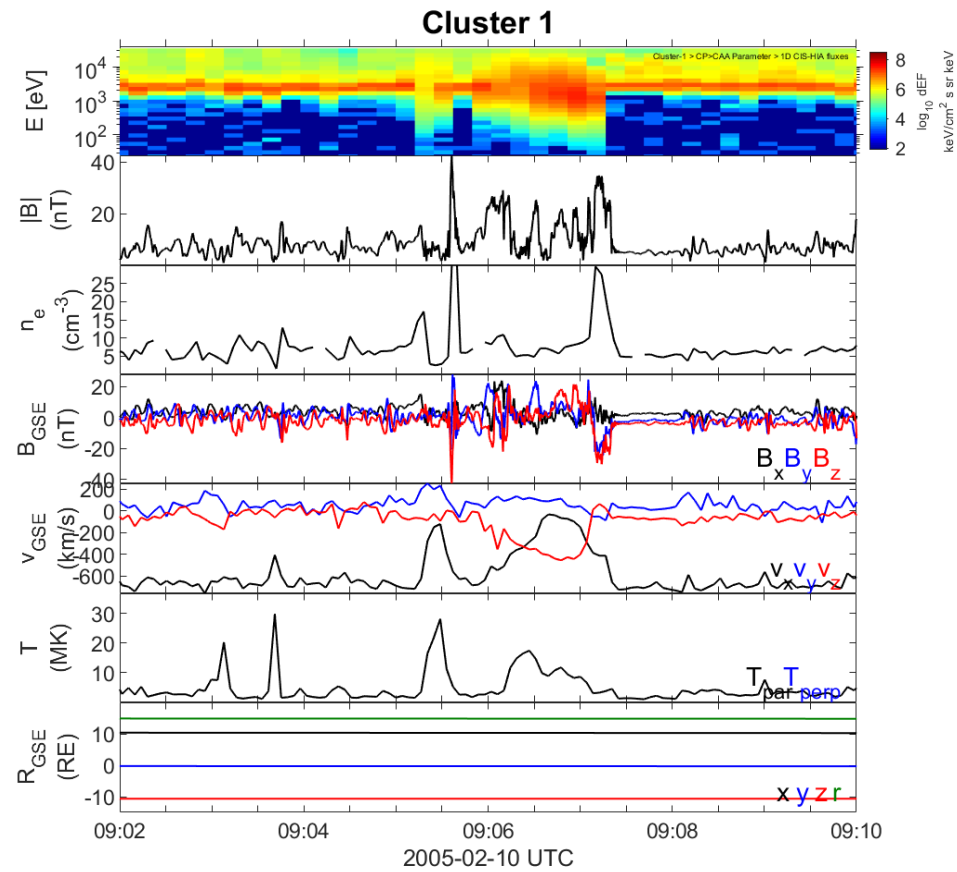
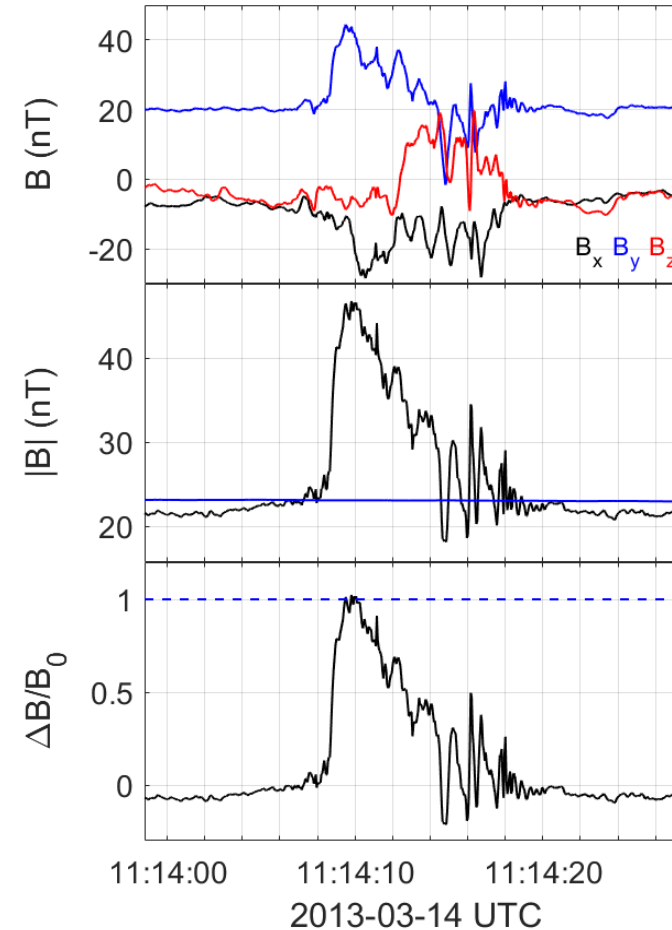Nested & Convective Foreshock Structures
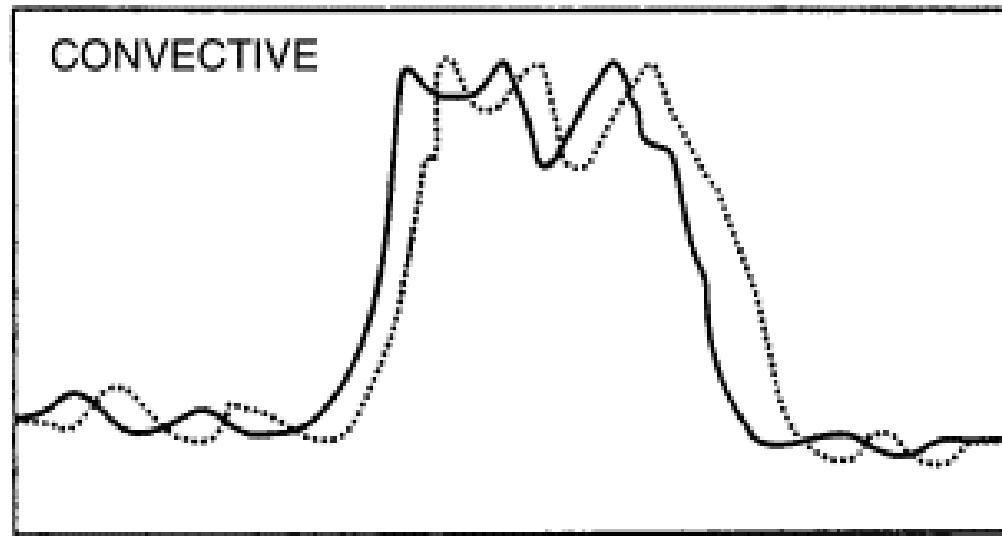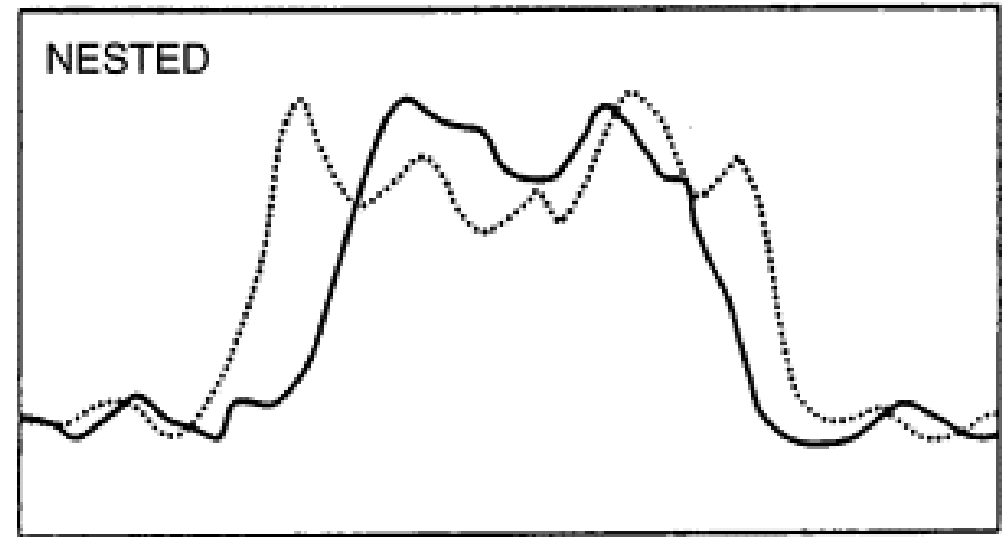
Mutli-spacecraft measurements

- MMS & Cluster can do the trick
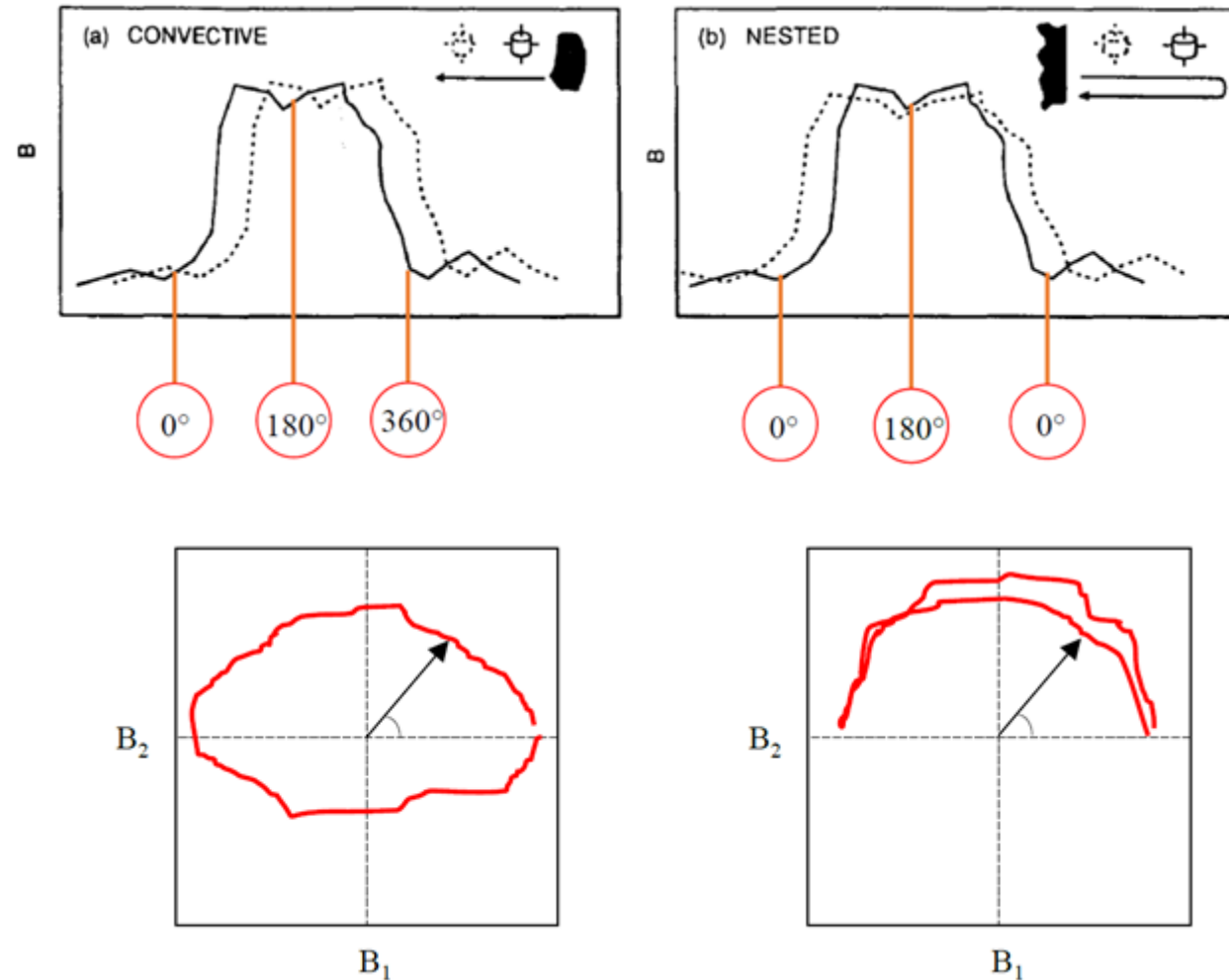

Tomas Karlsson

Single-spacecraft measurements

e.g. Juno, THEMIS, Cassini, MESSENGER, etc.
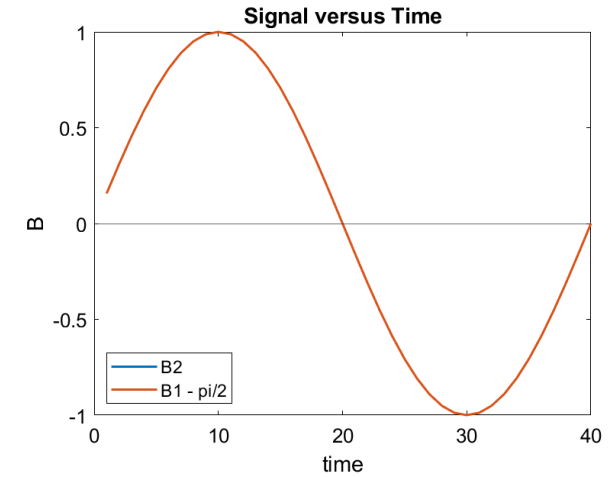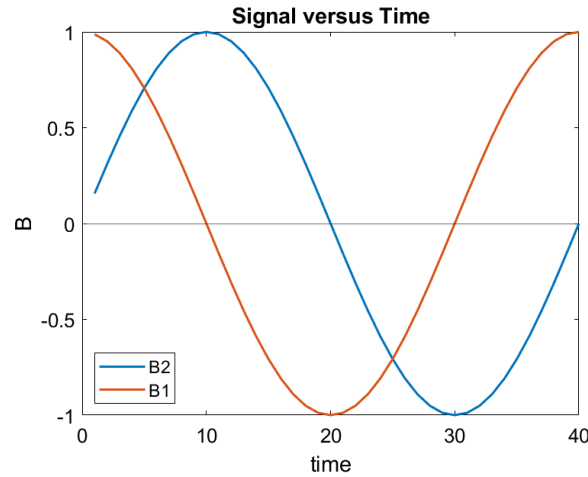

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SLAMS (Convective) vs Bow Shock Movement (Nested)

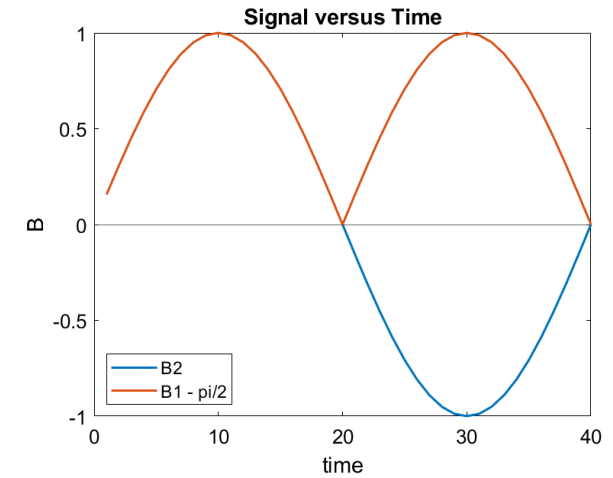<u>Goal</u>: Quantify the difference of these two.
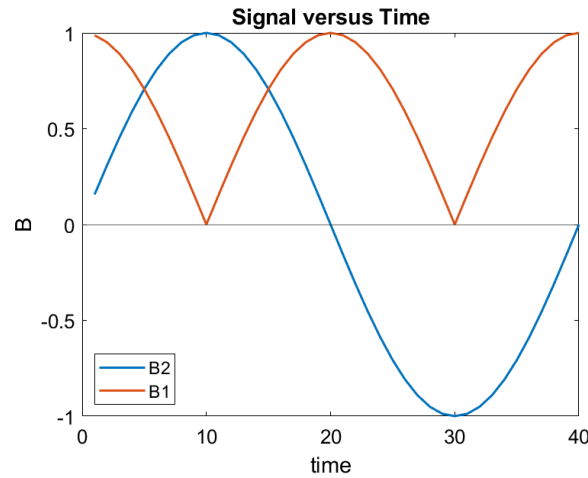

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Nested & Convective Foreshock Structures

How to quantify?

Hodograms of SLAMS → ideally two sinusoids with a phase difference
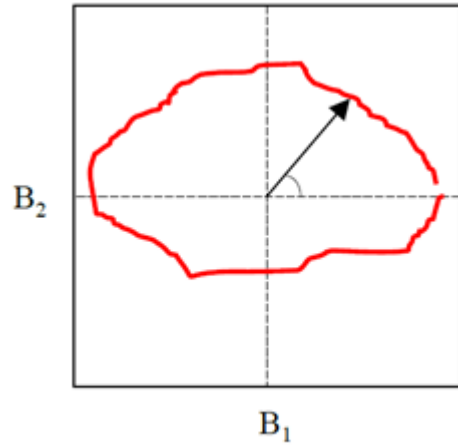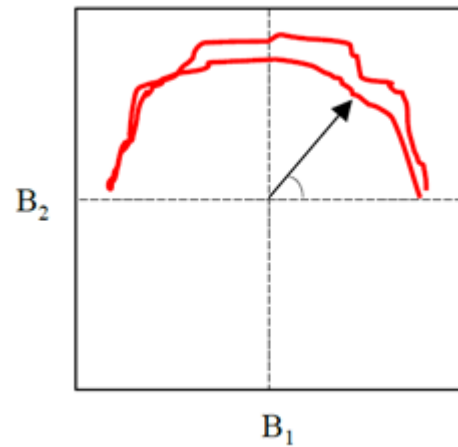
Methods of quantifying

Dynamic Time Warping (DTW)

"stretches two vectors, x and y, onto a common set of instants such that dist, the sum of the Euclidean distances between corresponding points, is smallest"

Time Lag Correlation

Time cross correlation (script)

x = crosscorr(B1,B2,'NumLags',15)
y = max(abs(x))

Nested & Convective Foreshock Structures

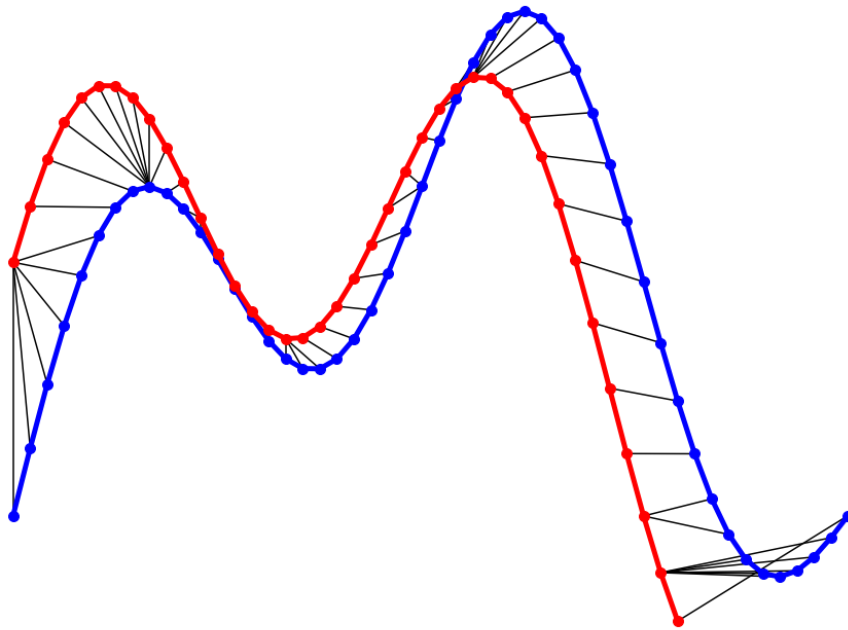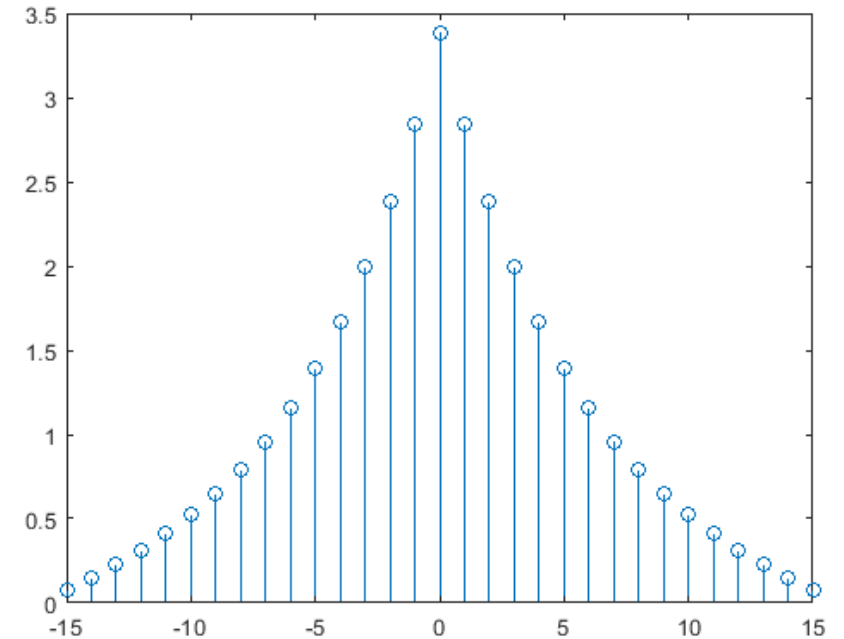# Visualization of each method

Dynamic Time Warping (DTW)

"DTW is simply matching one point in 1st time series with the closest point of the 2nd"

Time Lag Correlation

https://towardsdatascience.com/an-intuitive-approach-to-dtw-dynamic-time-warping-f660ccb77ff4
https://towardsdatascience.com/an-illustrative-introduction-to-dynamic-time-warping-36aa98513b98
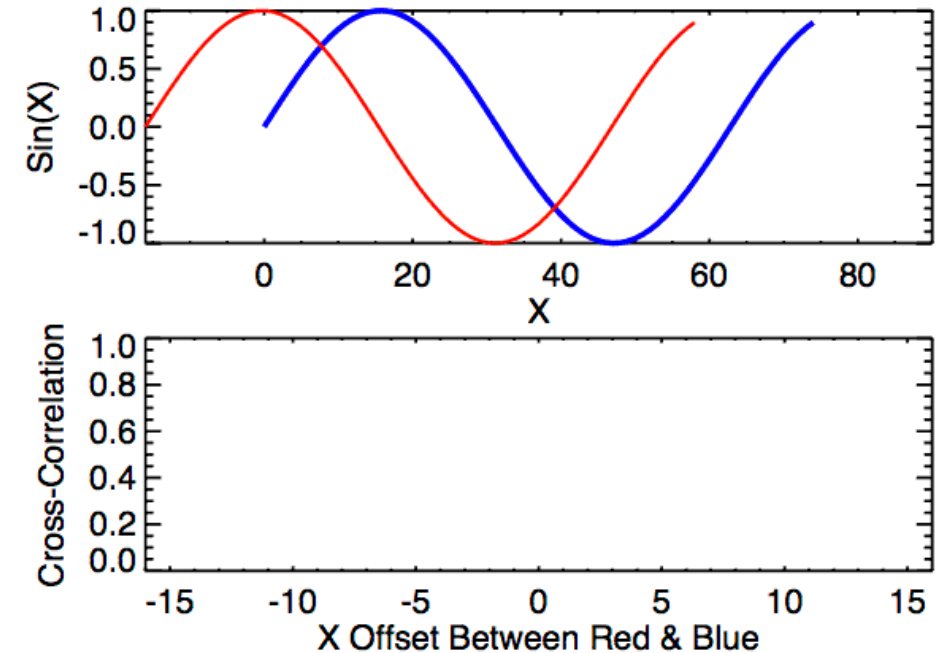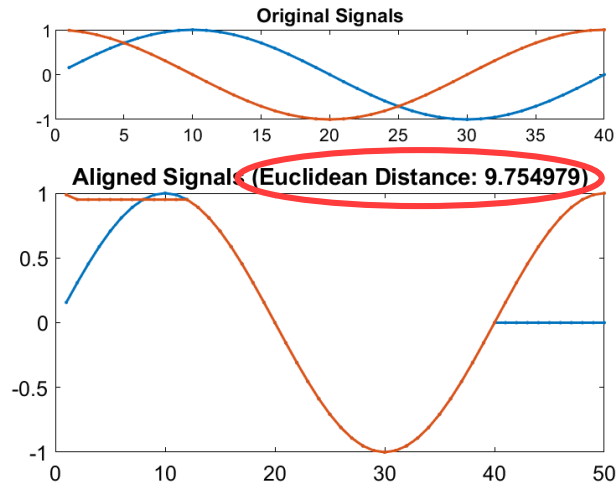
Methods of quantifying – Examples

<u>Dynamic Time Warping (DTW)</u>

<u>Time Lag Correlation</u>

<u>SLAMS</u>

Original Signals

Aligned Signals: (Euclidean Distance: 9.754979)

0.9

<u>NO – SLAMS</u>

Original Signals

Aligned Signals (Euclidean Distance: 23.550604)

0.1389

Real Examples Cluster
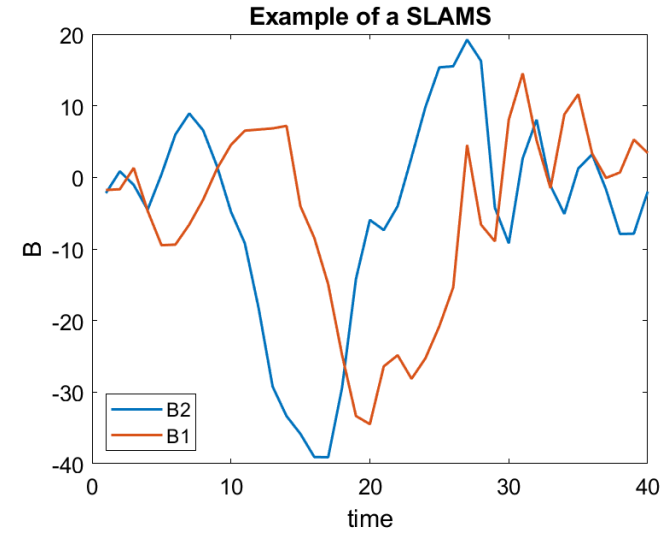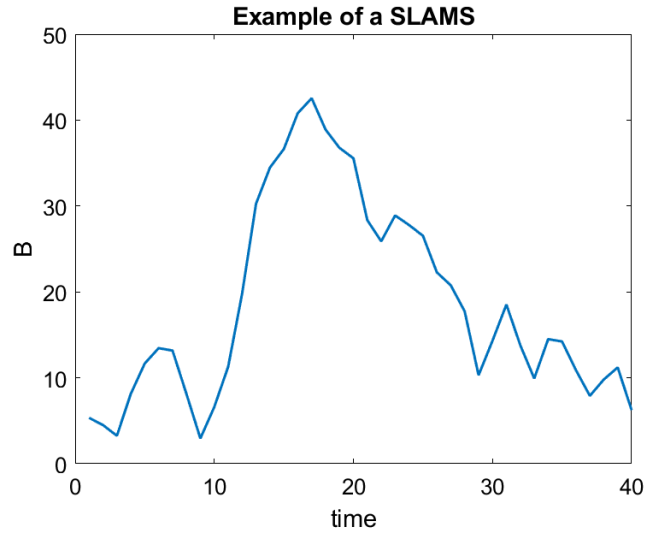
Nested & Convective Foreshock Structures
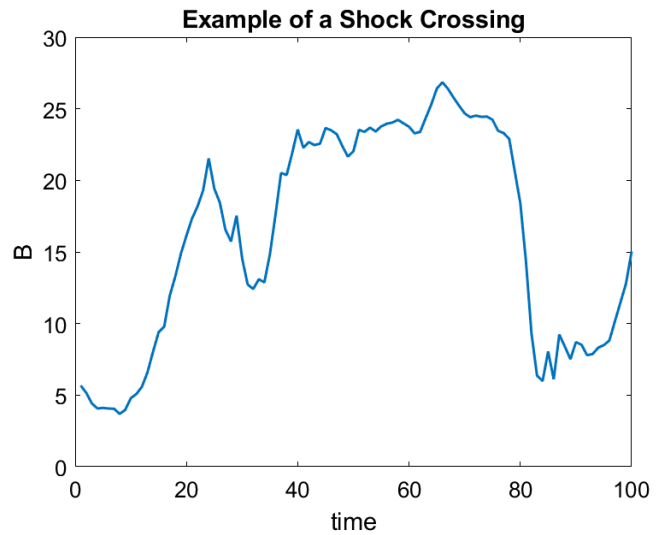
Methods of quantifying – Real Examples Cluster

Dynamic Time Warping (DTW)

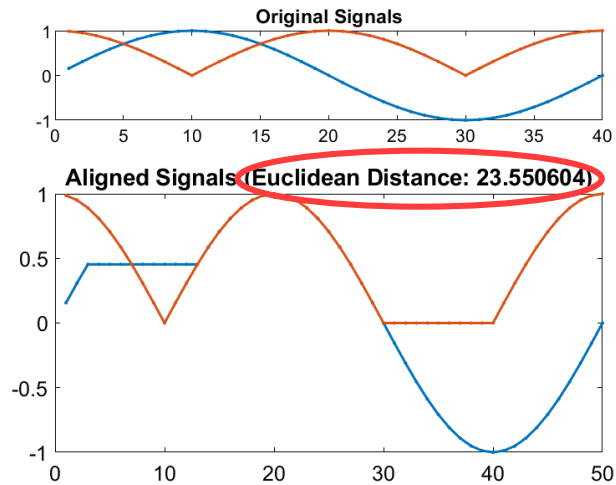## Time Lag Correlation

SLAMS
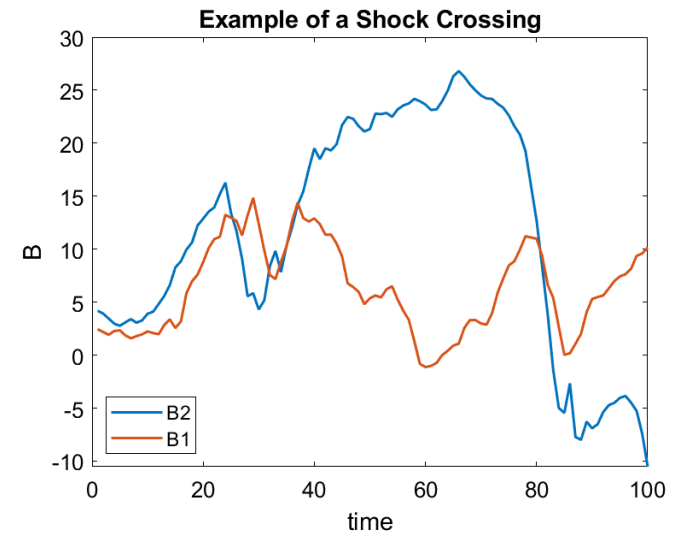
NO – SLAMS

Original Signals

Aligned Signals (Euclidean Distance: 3.781437)

Original Signals

Aligned Signals (Euclidean Distance: 17.532948)

0.95
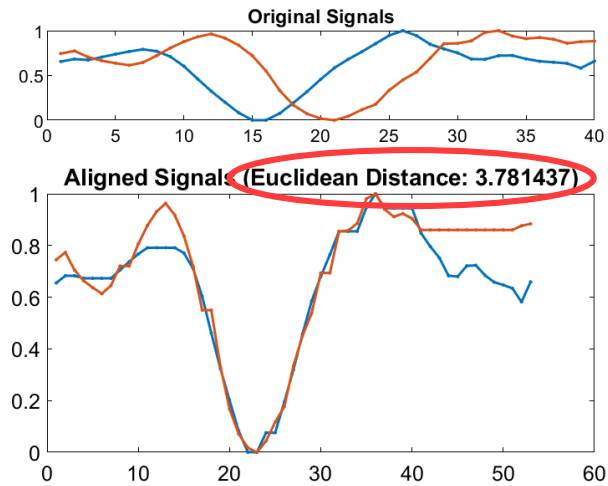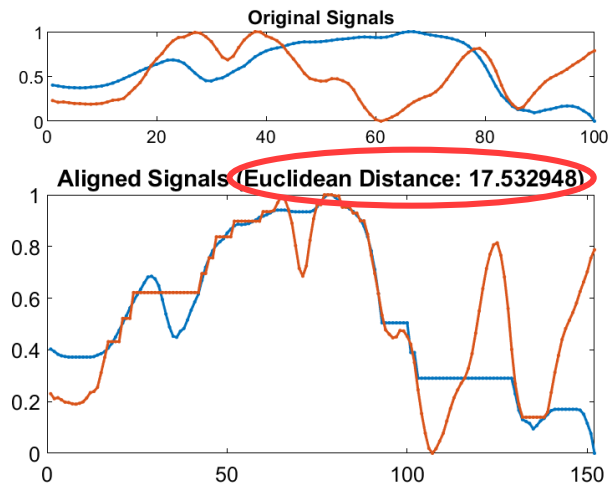
0.29

Results – Evaluation

Simple threshold so far works.

Dynamic Time Warping (DTW)

Time Lag Correlation

SLAMS

3.7814	**9.6638**	8.9911	5.2317	3.4553	0.8394	0.7677	**0.5562**	0.8724	0.6067

NO – SLAMS

12.5774	17.5329	**10.7416**	15.8715	12.6228	0.2579	0.2888	0.5244	0.1580	**0.5435**

Summary & Conclusion

Quite a few things to be done:

- Hyperparameter searching: Quantify background & smoothing for MVA.
- Test more examples.
- Try to compare with more sophisticated techniques (e.g. measuring degree of polarization, instantaneous phase synchrony, machine learning etc.).

Summary:

Good simple method to evaluate if a structure is convective or nested using only B.

✓Time lag correlation & Dynamic Time Warping (DTW) work so far.

✓**DTW** might be useful when "stretching" is required (e.g. shock crossings).