



# JECAM Taiwan Site

## JECAM/GEOGLAM Science Meeting

Ottawa, Canada

21 – 23 Jul 2014

### Investigators:

Dr. Chi-Farn Chen, CSRSR, NCU, Taiwan

Dr. Nguyen-Thanh Son, CSRSR, NCU, Taiwan

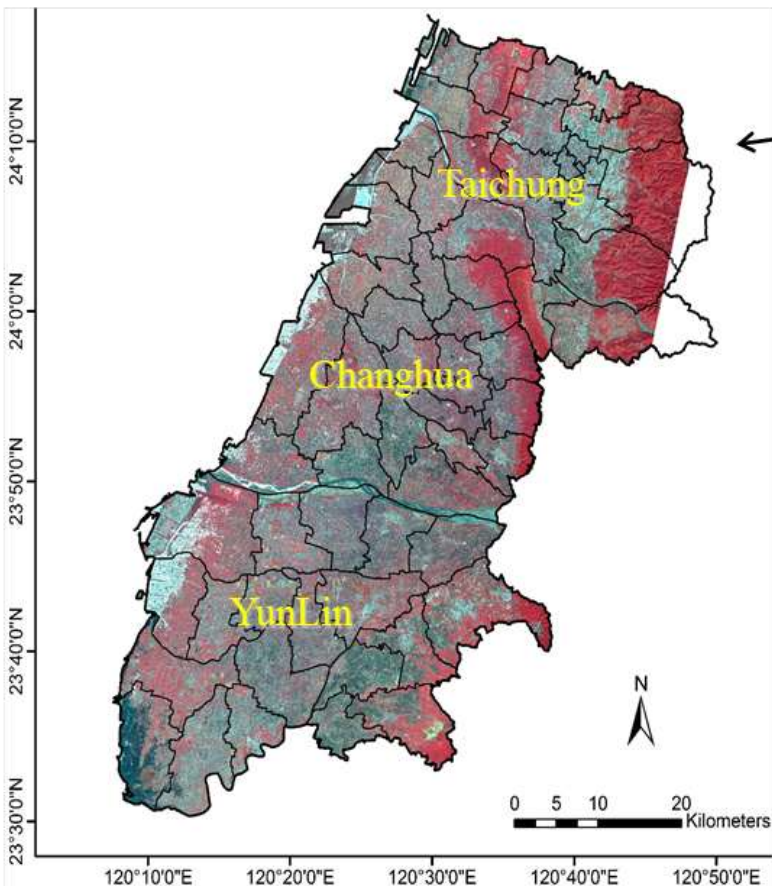
Dr. Cheng-Ru Chen, CSRSR, NCU, Taiwan

Mr. Horng-Yuh Gua, TARI, Taiwan

Mr. Wei-Shen Lo, TARI, Taiwan



# Study site



- Area: 3,070 km<sup>2</sup>
- Three counties (64 townships)
- Rice calendar:
  - 1<sup>st</sup> crop: Jan – Jul
  - 2<sup>nd</sup> crop: Jul – Dec
- Growing cycle: 110 – 130 days



# Study site (cont.)

- **Topography: Plain**
- **Soil type: Silt loam**
- **Drainage/ irrigation: Moderate – imperfect**
- **Field size: 0.5 – 1.1 ha**
- **Climate: Subtropical monsoon**
- **Agricultural method: Traditional farming**



# Objectives

**Goal:** to develop a phenology-based approach for rice crop mapping using MODIS-SPOT fusion data.

**Specifically:**

- 1) To fuse MODIS data with SPOT data;
- 2) To construct smooth time-series NDVI data from the fusion dataset;
- 3) To map rice crops; and
- 4) To assess the mapping results.



# Data collection

| Data                       | Date                | Resolution |
|----------------------------|---------------------|------------|
| MODIS/Terra data (MOD09A1) | 2011                | 500 m      |
| SPOT 5 data                | DOY 027/208 in 2001 | 10 m       |
| Land-use map               | 2011                | 1/5000     |
| Rice area statistics       | 2011                |            |
| ASTER DEM data             |                     | 30 m       |
| Field survey data          | 2011                |            |



# Data collection (cont.)

- **MODIS data collected from NASA**
  - **Spatial resolution: 500 m**
  - **Temporal resolution: 8 days**
  - **7 bands ranging from visible to SWIR**
- **SPOT 5 data provided by CSRSR, NCU**
  - **Spatial resolution: 10 m => resampled to 30 m**
  - **4 band (green, red, nir-IR, and SWIR)**
- **Preprocessing: Radiometric and geometric corrections (level 4)**



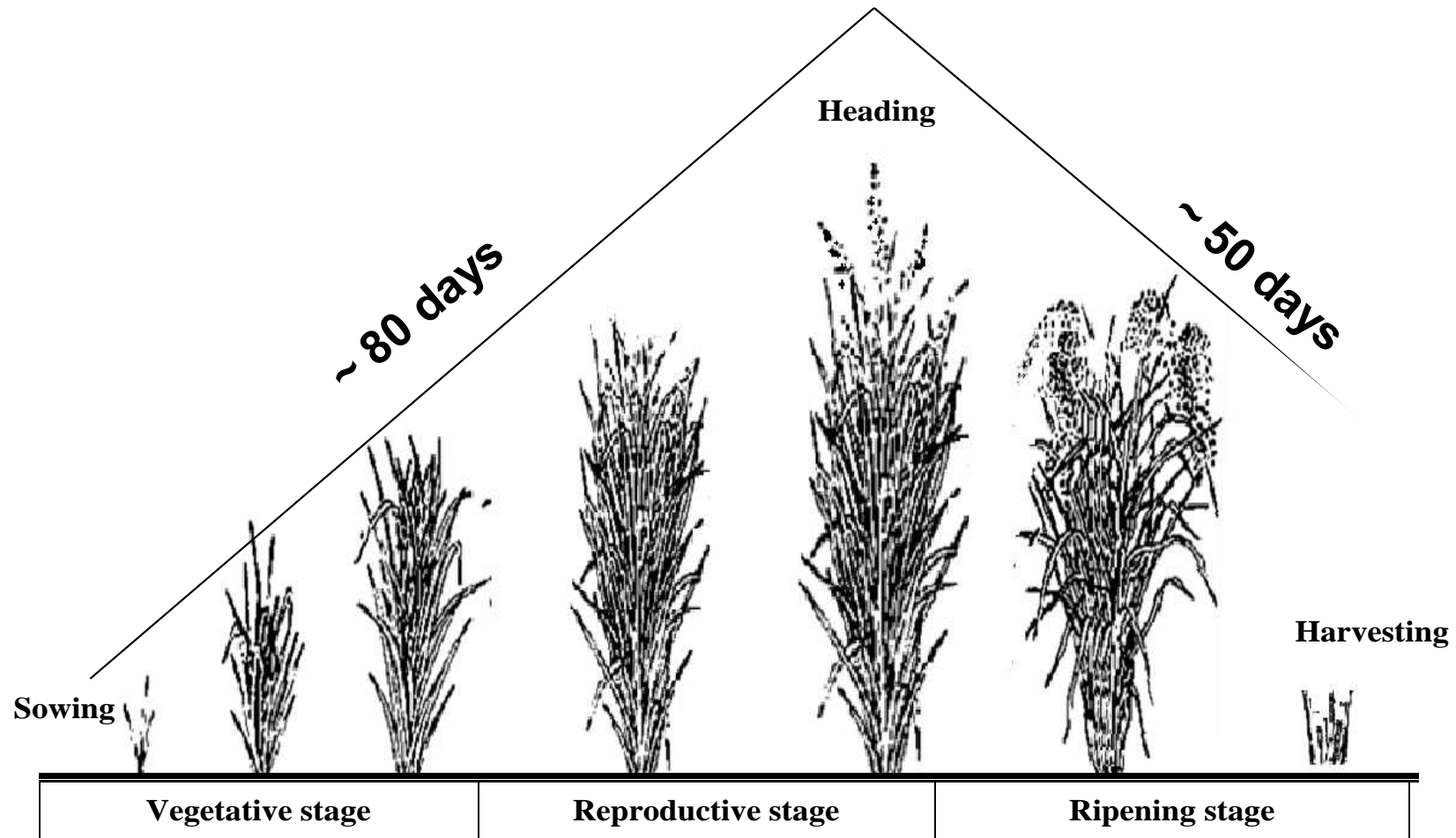
# Field data and statistics



- **Monthly rice parameters (i.e., plant height, biomass, soil condition, number of leaves, etc.).**
- **Cropping calendar: planting and harvesting dates**
- **Monthly rice planting area**
- **Rice statistics:**
  - **Planting and harvesting areas**
  - **Rice production at township level**



# Rice crop phenology



- Growing cycle: 110–130 days



# Photos taken in 2011



**Planting**



**growing**



**growing**



**Heading**



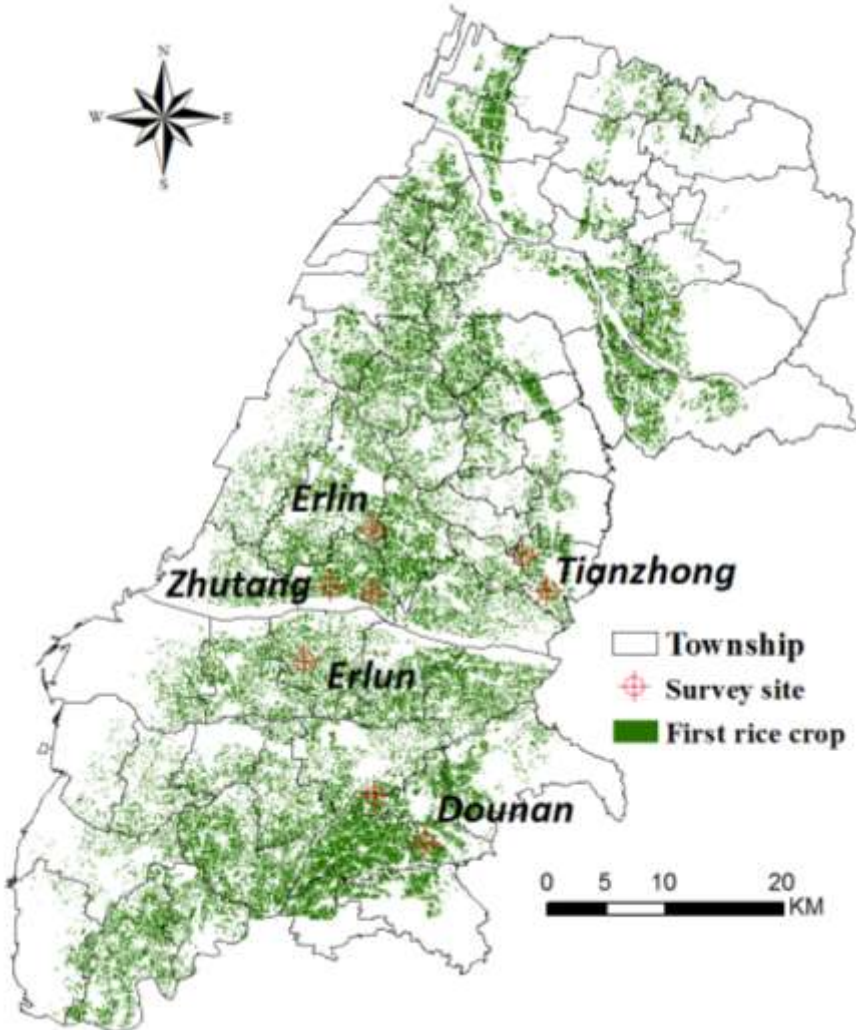
**Heading**



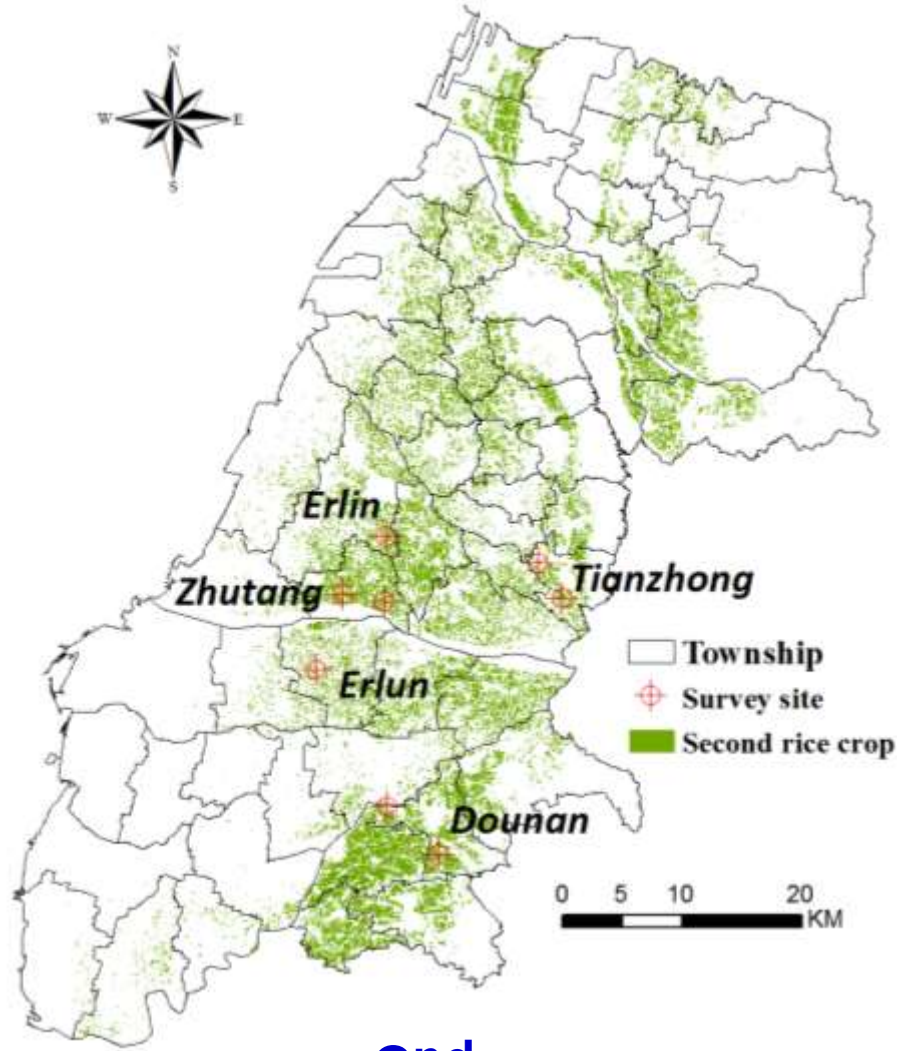
**Heading**



# Ground reference data



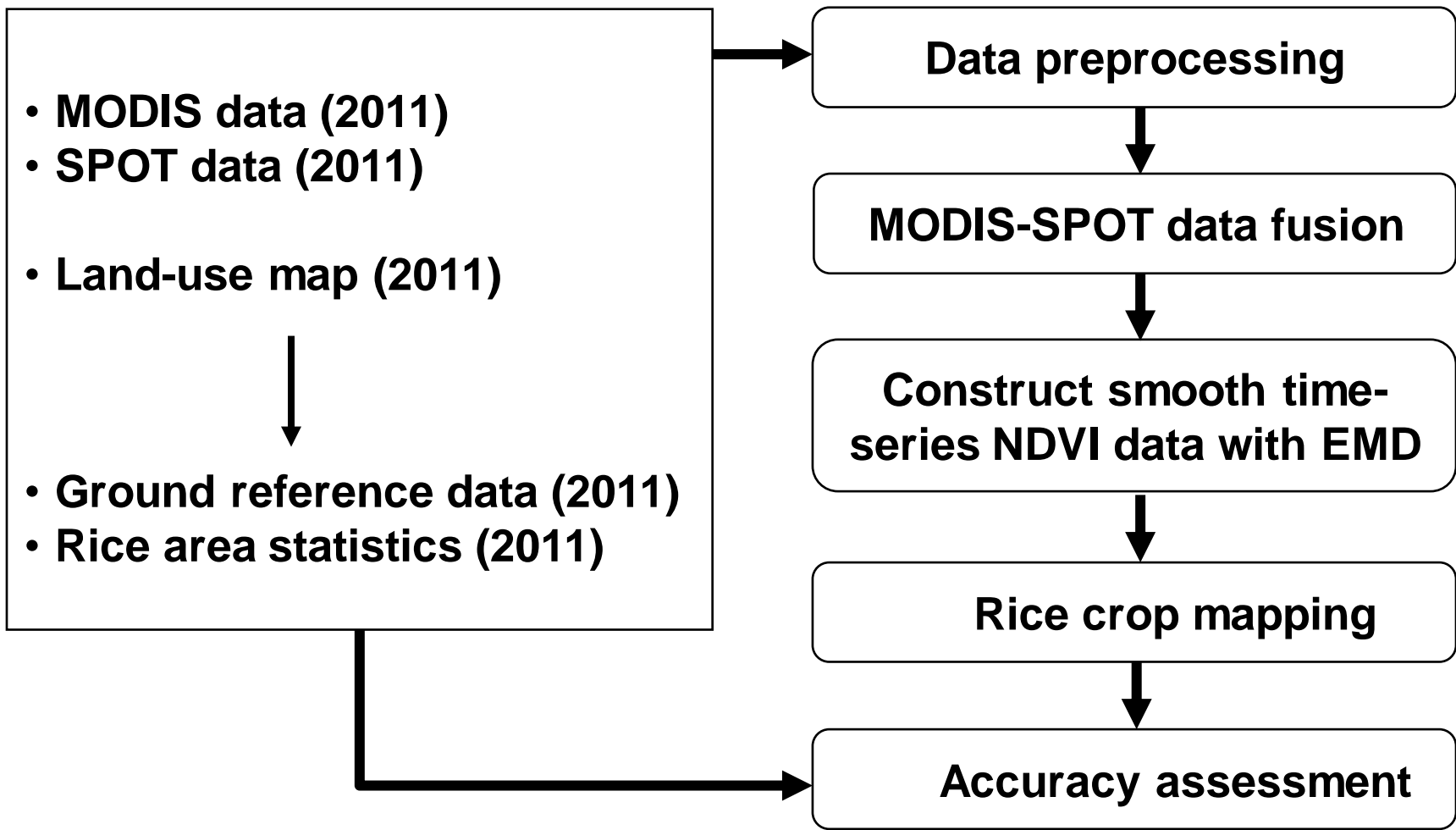
1<sup>st</sup> crop



2<sup>nd</sup> crop

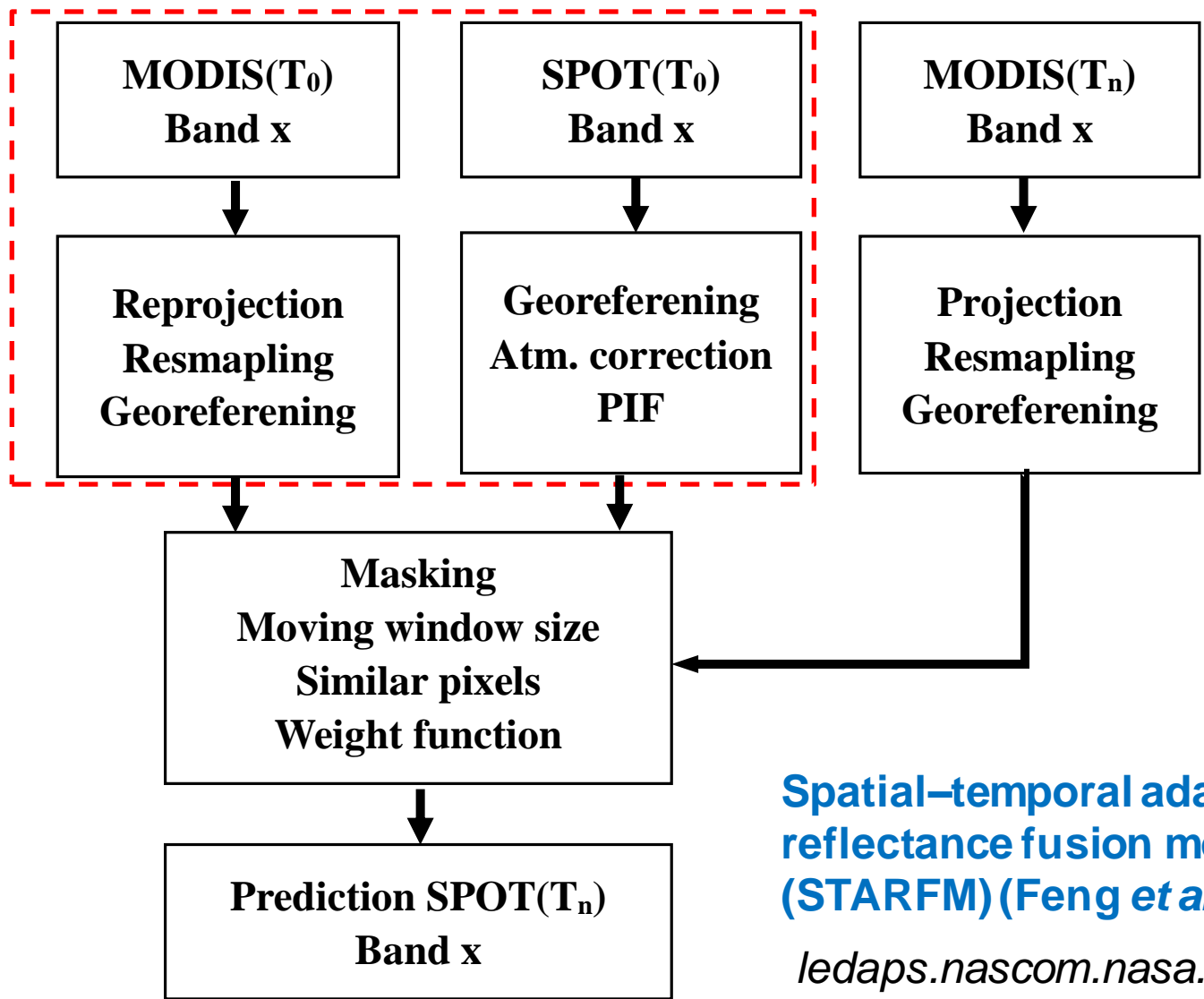


# Methodology





# Data fusion with STARFM



Spatial-temporal adaptive reflectance fusion model (STARFM) (Feng et al., 2006)

[ledaps.nascom.nasa.gov/tools](http://ledaps.nascom.nasa.gov/tools)



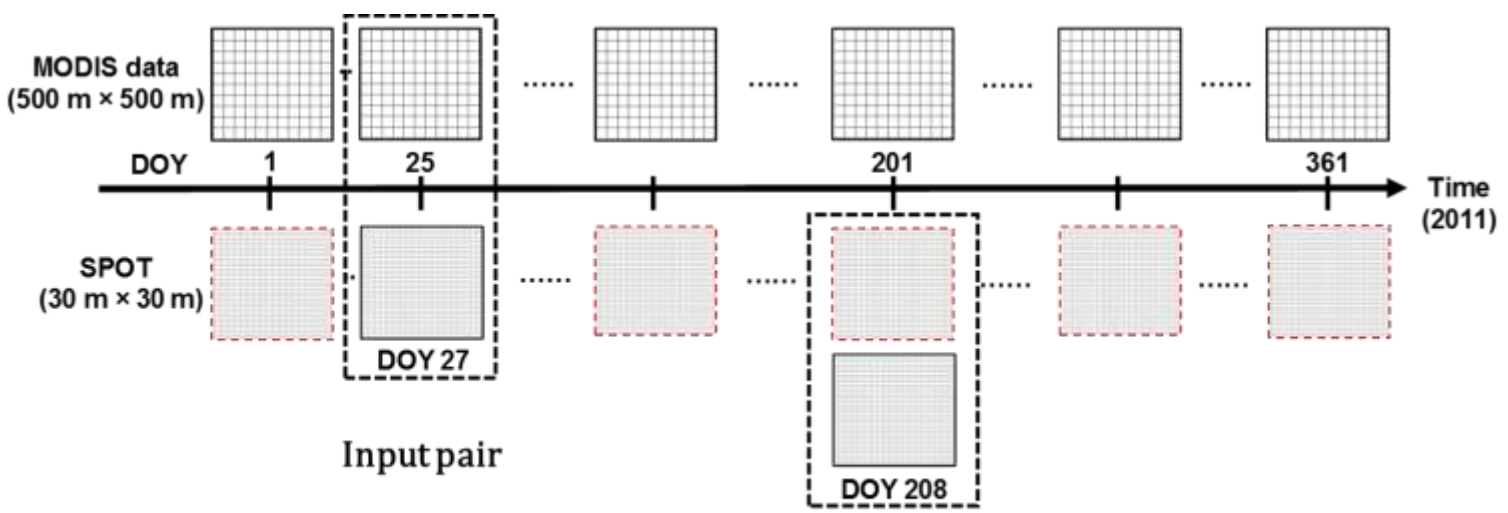
# Data fusion with STARFM (cont.)

## • Input

- MODIS and SPOT surface reflectance pair at  $t_0$ .
- MODIS surface reflectance  $M (X_i, Y_i, t_1 \text{ to } k)$  at  $t_1 \text{ to } k$ .

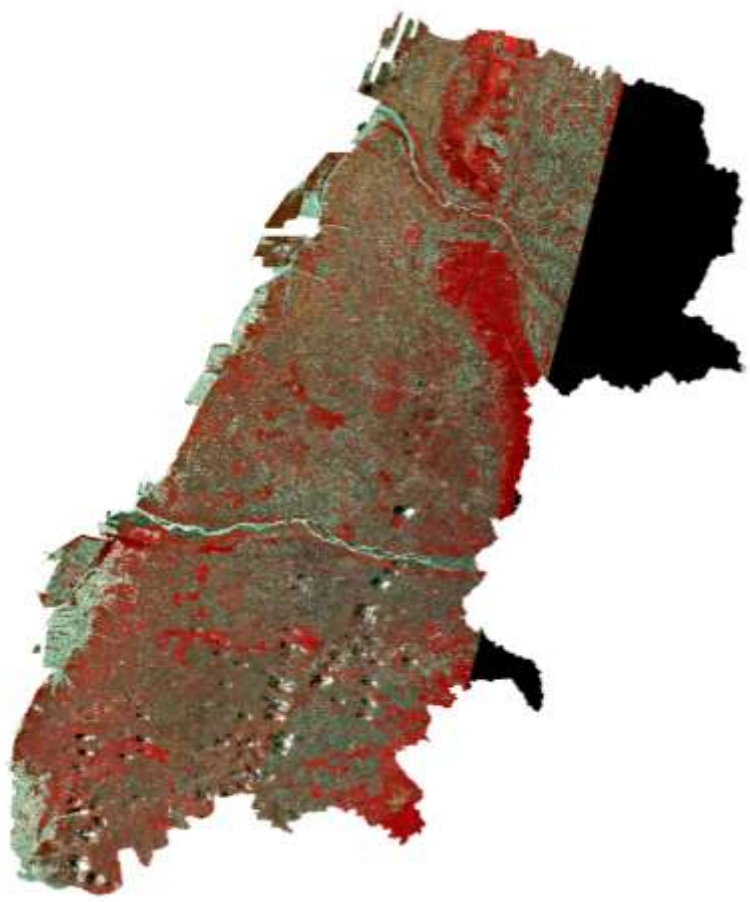
## • Output

- STARM-derived surface reflectance  $L (X_i, Y_i, t_1 \text{ to } k)$  at  $t_1 \text{ to } k$  that are the same spatial resolution with SPOT data





# MODIS/SPOT fusion results

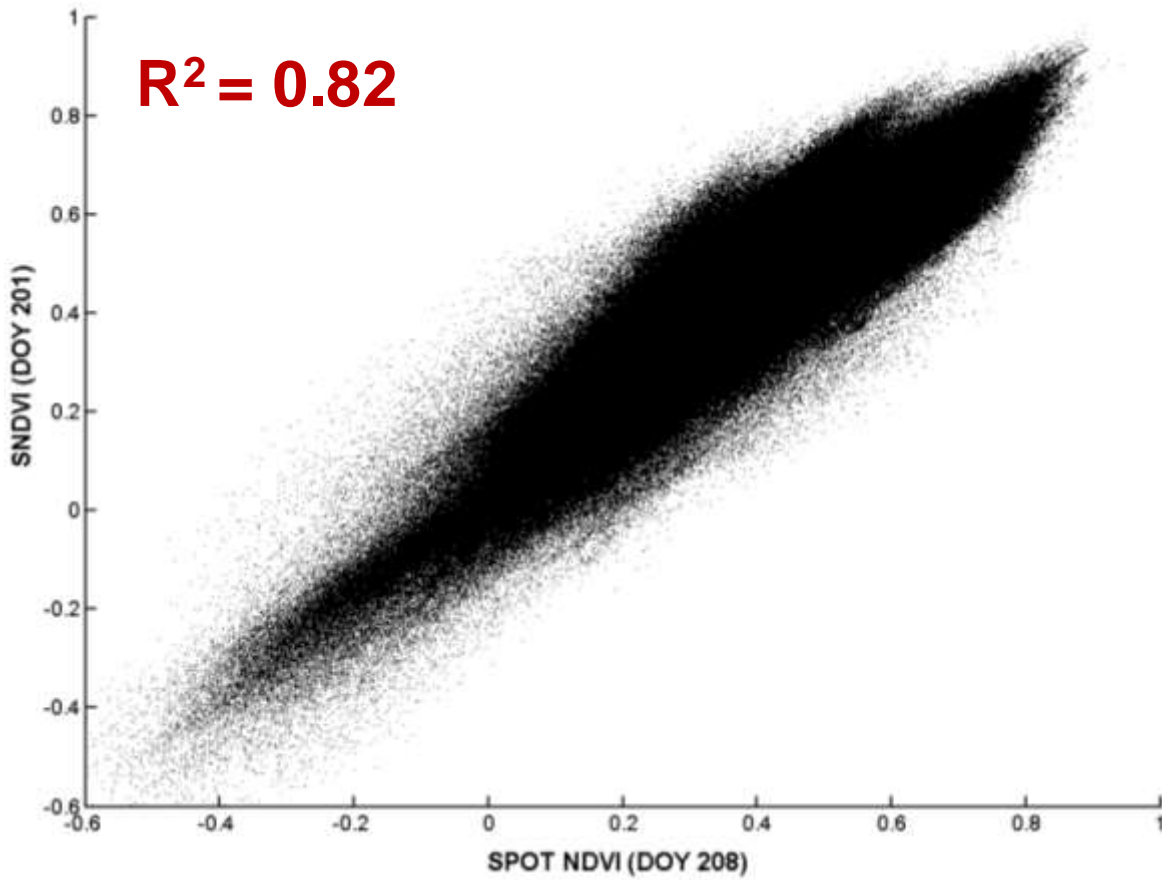


Actual SPOT image

STARFM-derived image



# Correlation analysis



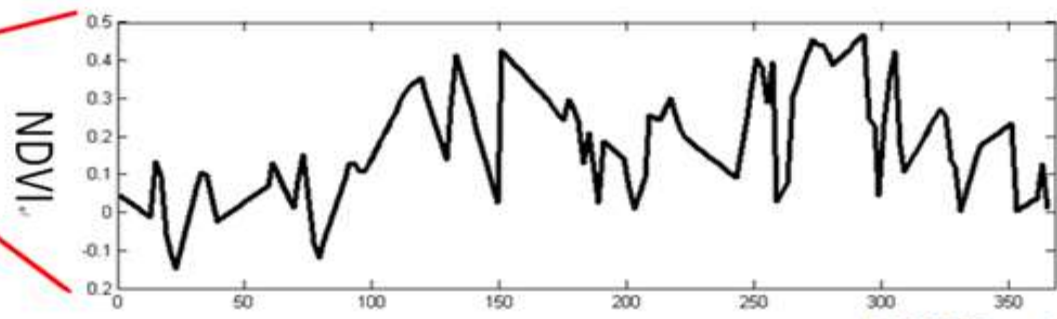
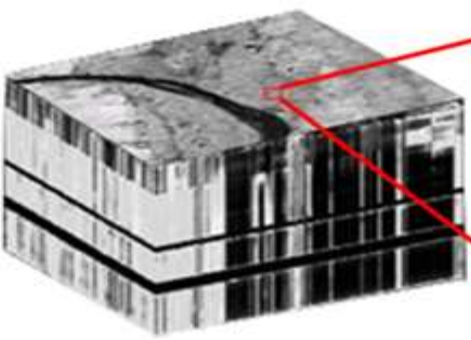
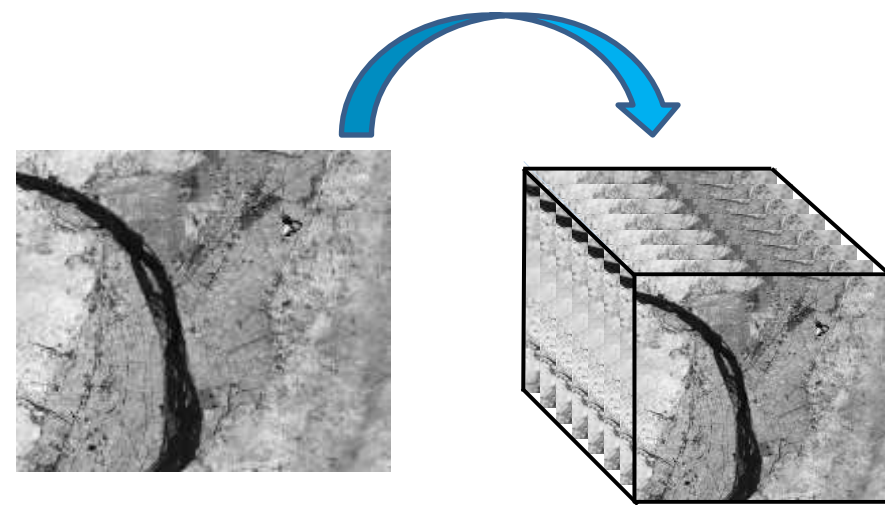
- Correlation between the STARFM-derived NDVI data (DOY 208) and NDVI SPOT data (DOY 208).



# Construct time-series NDVI data

- Calculate NDVI for each 8-day image.
- Construct the yearly NDVI time-series data by stacking all NDVI images.

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$



DOY (Day Of Year)

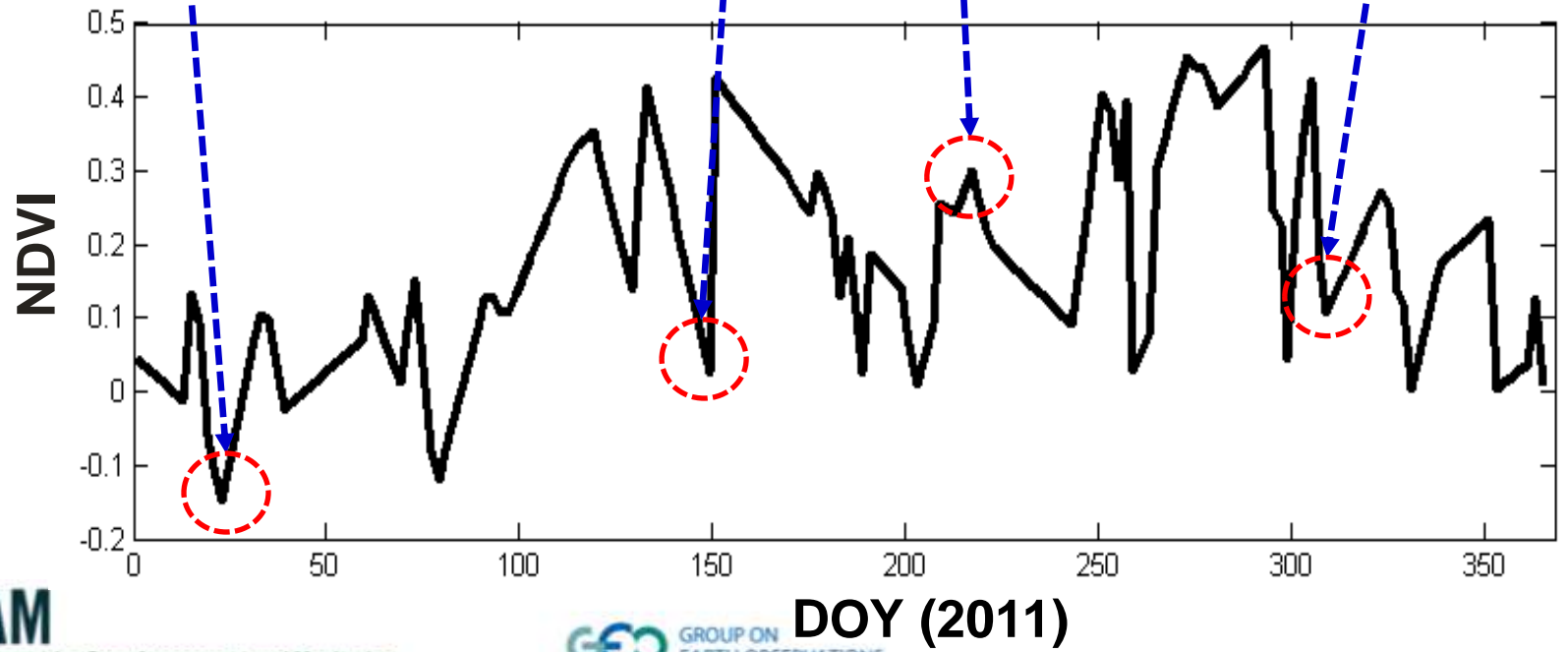
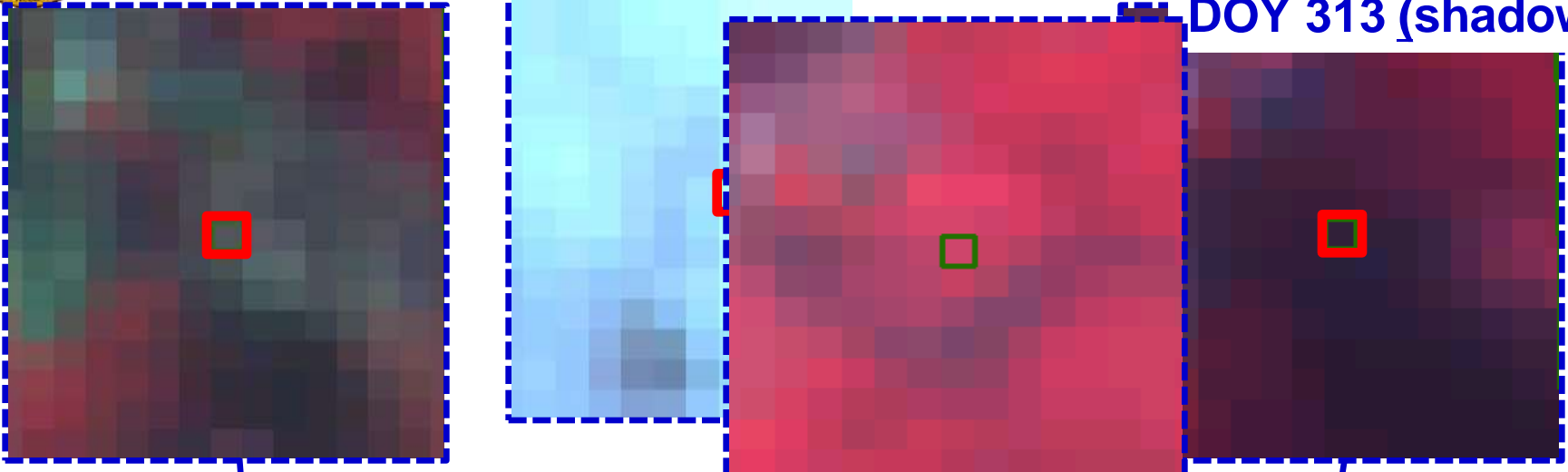


DOY 149 (cloud)

DOY 23 (shadow)

DOY186

DOY 313 (shadow)





# Noise filtering procedure

- 1. Pixels covered by thick cloud were removed if the values of the blue band greater than 0.2.**
- 2. Missing/removed pixels were replaced with new values using the linear interpolation.**
- 3. Empirical mode decomposition (EMD) method was applied to filter out noises from the NDVI time-series data.**

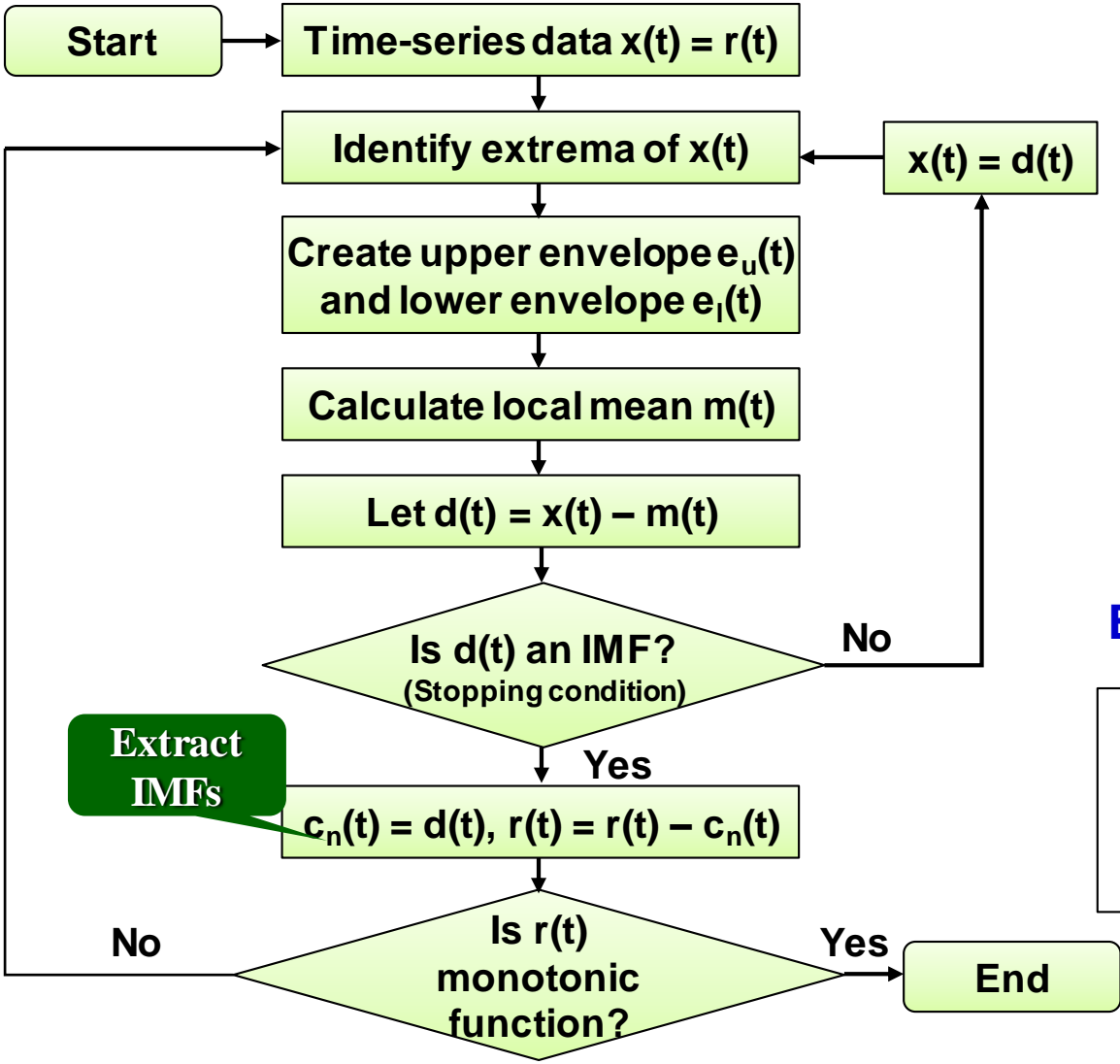


# EMD

- EMD (empirical mode decomposition) (Huang *et al.* 1998) can generate a set of **intrinsic mode functions (IMFs)** and a residue to represent the original time-series data.
- Residue is **monotonic** and shows the overall trend of the data.
- The **low-pass, high-pass and band-pass filters** can be designed from the IMFs and the residue.



# Flowchart of EMD processing



• **Stopping condition:**

$$\lambda = \sum_{t=0}^T \left[ \frac{[d_{(k-1)}(t) - d_k(t)]^2}{d_{(k-1)}^2(t)} \right]$$

$$\lambda = 0.2 \sim 0.3$$

$$d(t) - c_1 = r_1$$

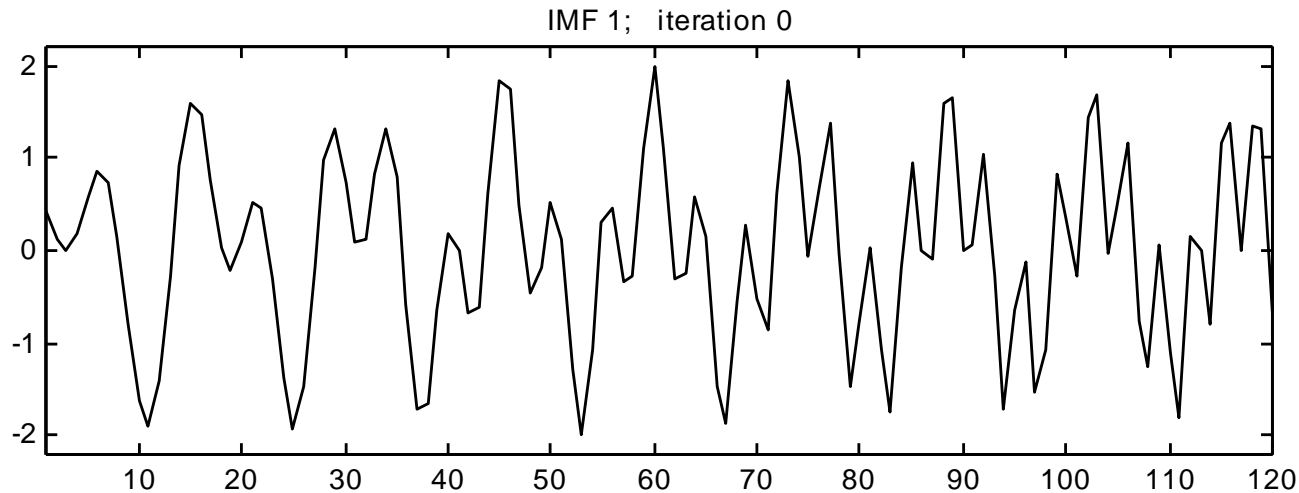
Eventually,  $x(t)$  is expressed as

$$x(t) = \sum_{i=1}^n c_i(t) + r_n(t)$$

Huang *et al.* (1998)



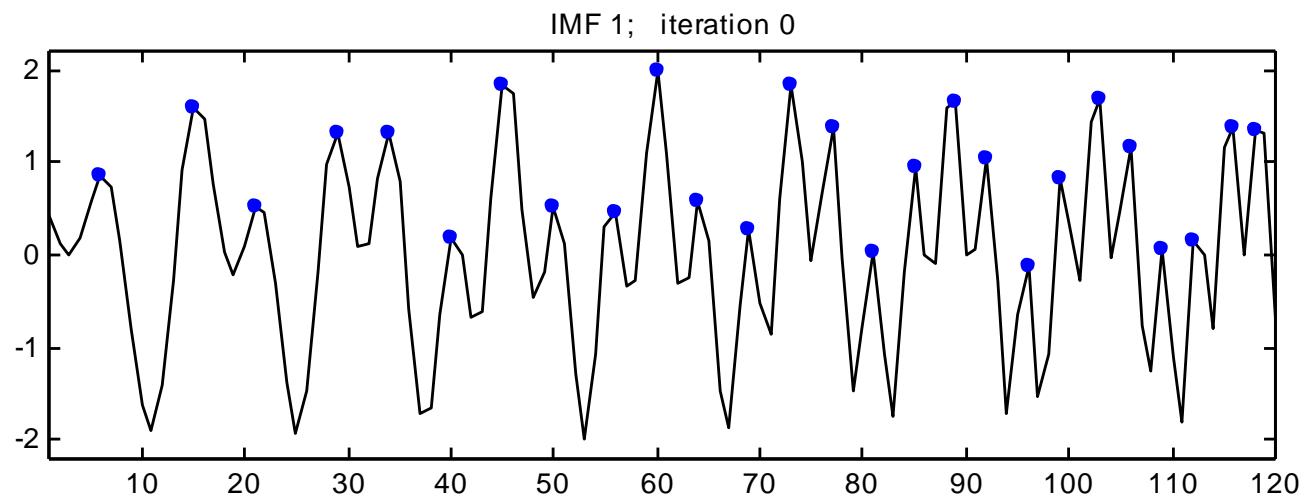
# Sifting processing



- $x(t) = r(t)$  is not equal zero or monotone.
- The sifting process decomposes this signal into a set of IMFs, roughly  $\log_2(N)$ , and a final residue.
- Final residue is monotonic from which no more IMF can be extracted.



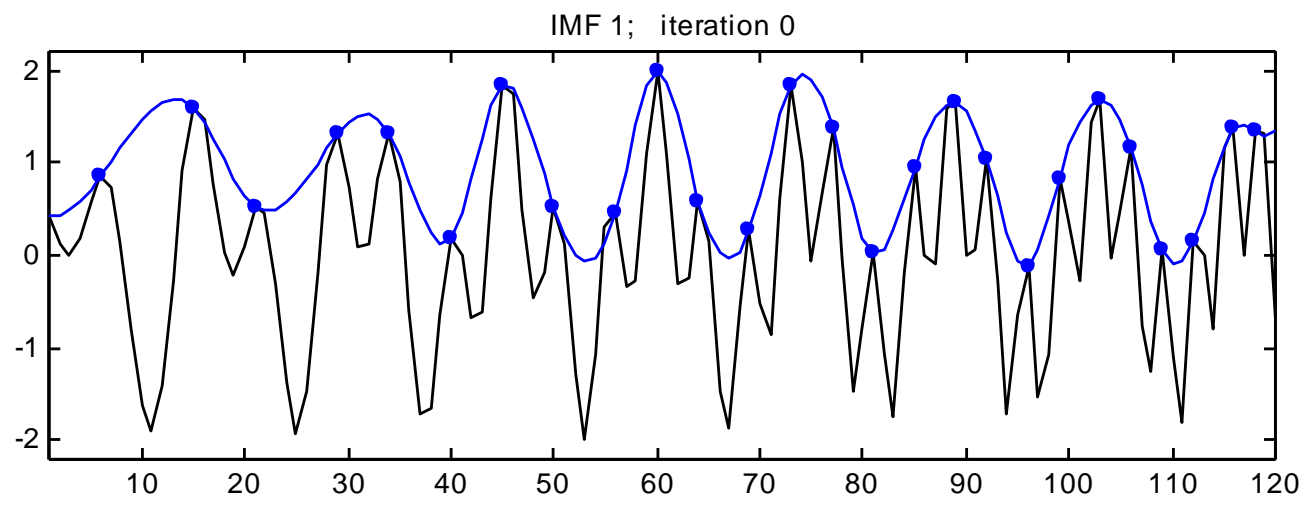
# Sifting processing



- Identify all extrema (maxima) of the  $x(t)$ .



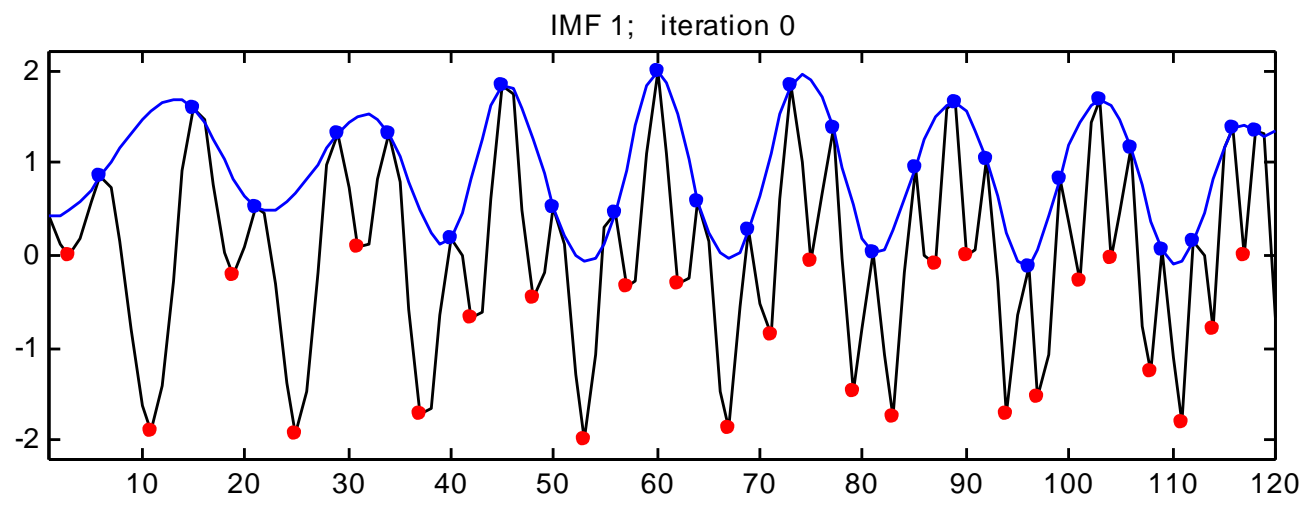
# Sifting processing



- **Create the upper envelope  $e_u(t)$  by connecting the maxima points with the cubic spline interpolation.**



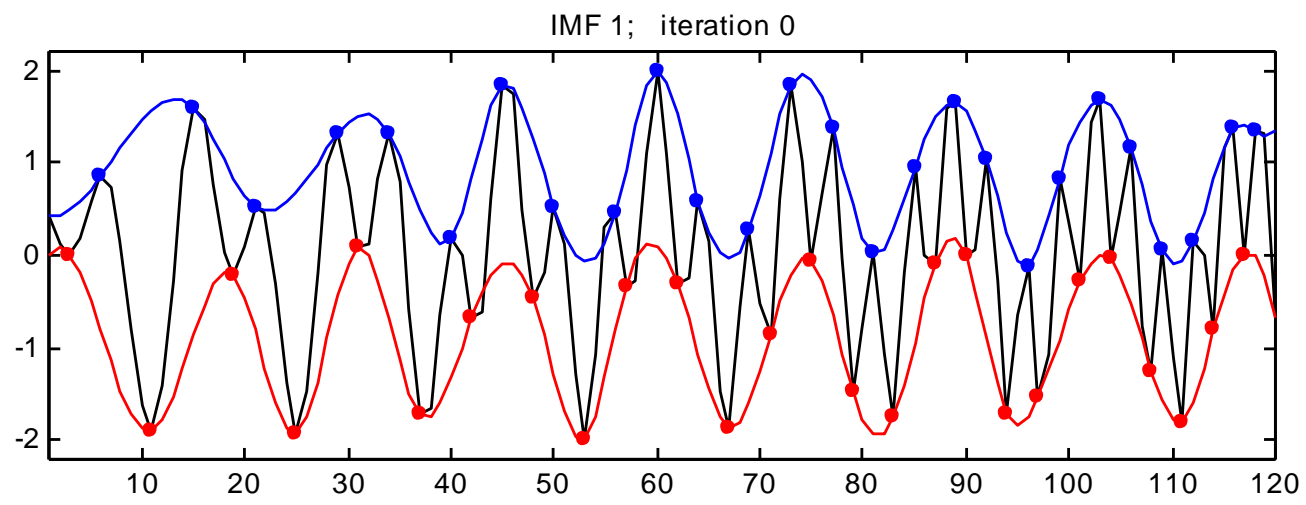
# Sifting processing



- Identify all extrema (minima) of the  $x(t)$ .



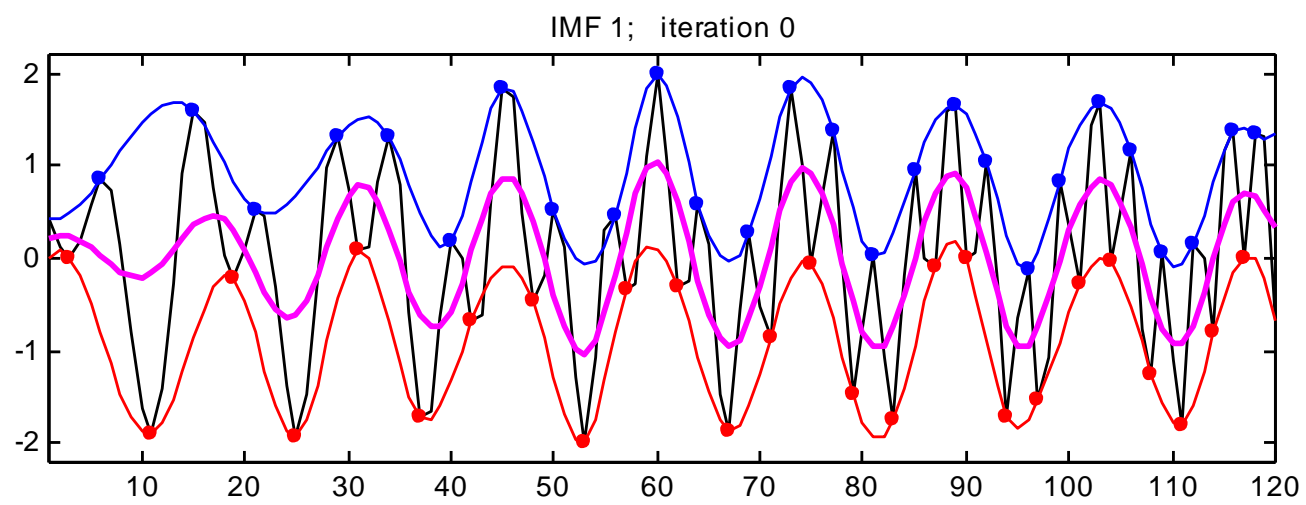
# Sifting processing



- Create the lower envelope  $e_l(t)$  by connecting the minima points with the cubic spline interpolation.



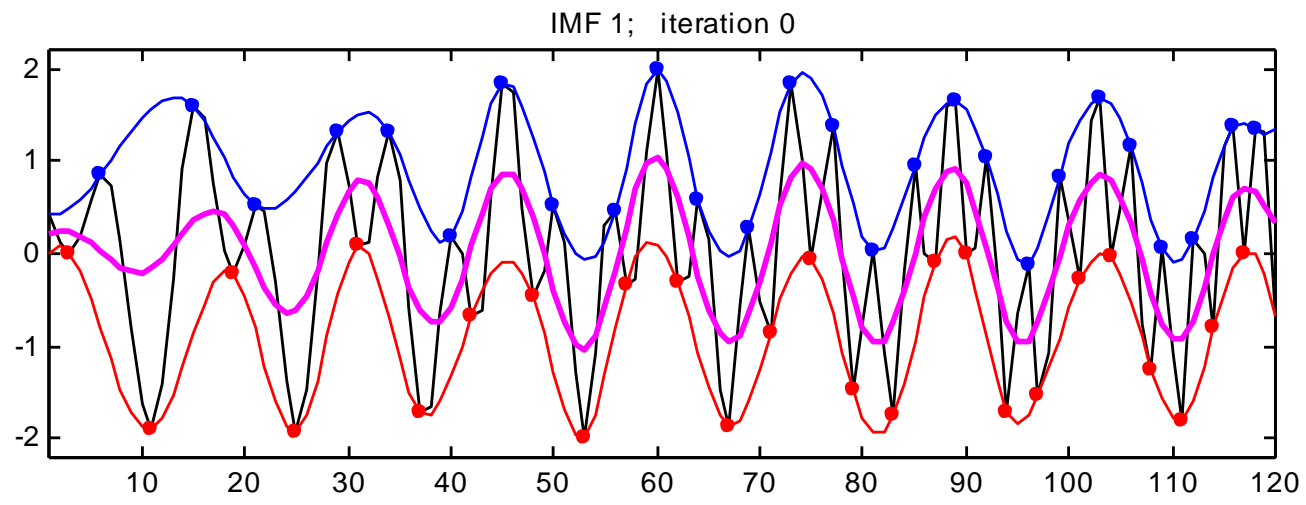
# Sifting processing



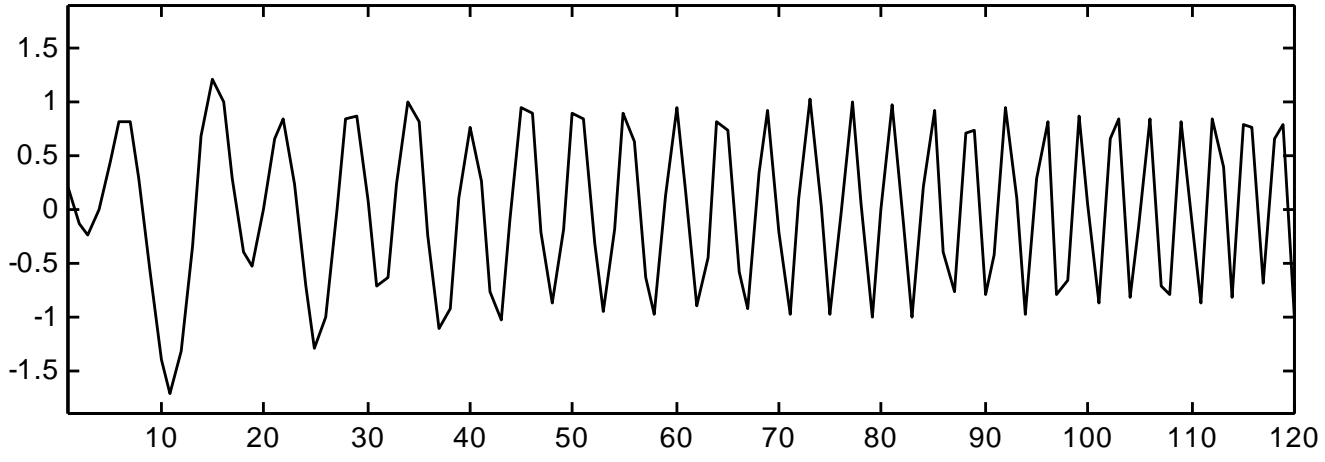
- Calculate the mean of the upper and lower envelopes:  $m(t) = [e_u(t) + e_l(t)]/2$



# Sifting processing

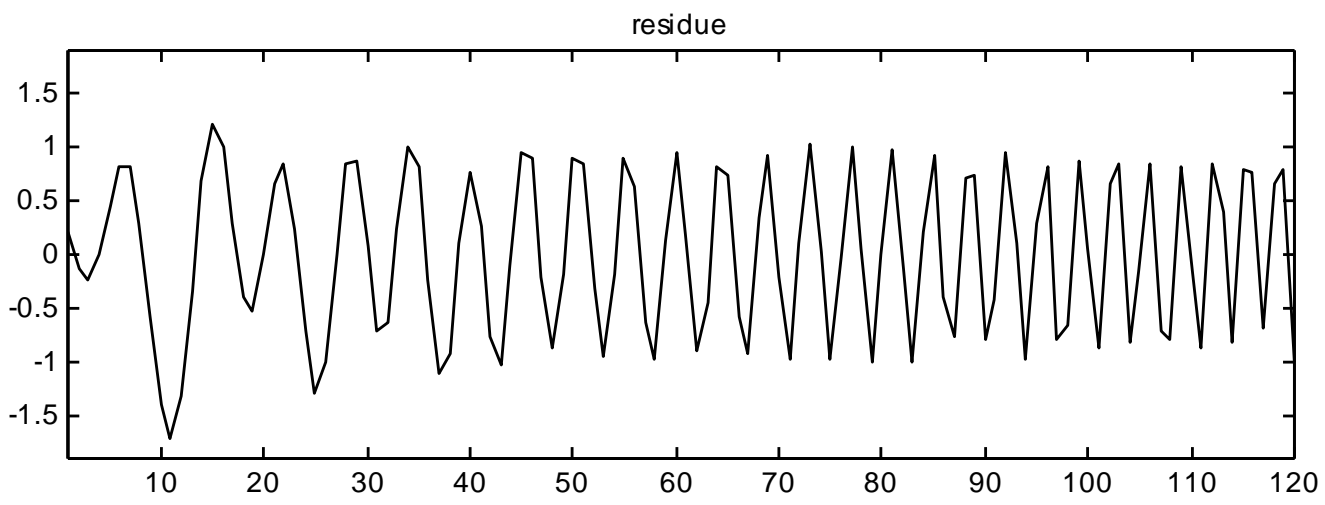
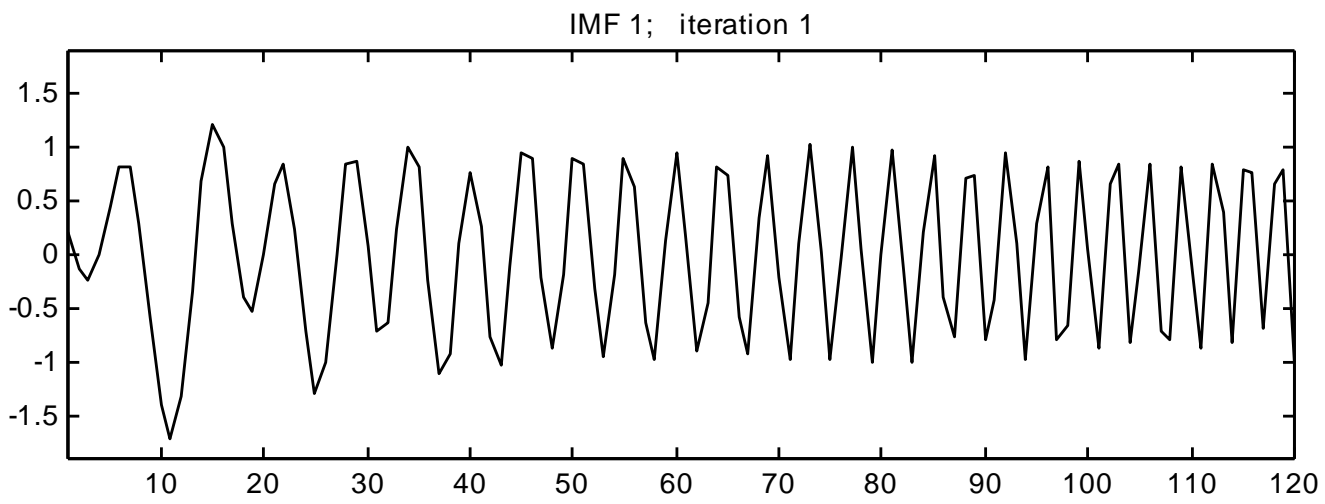


Let  $d(t) = x(t) - m(t)$  be a new signal  $x(t)$   
residue



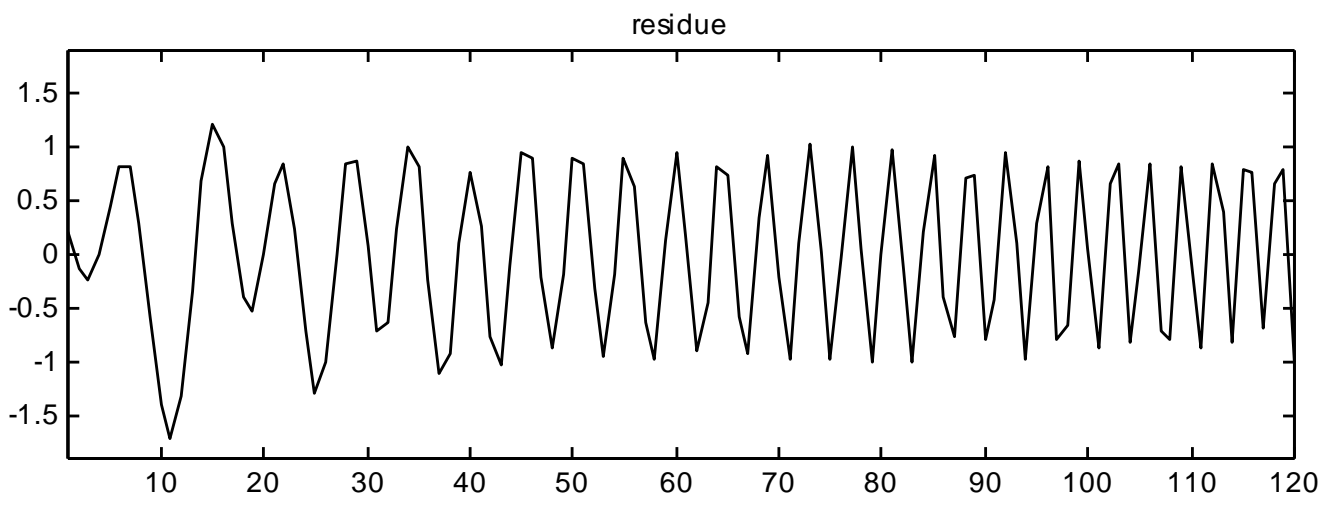
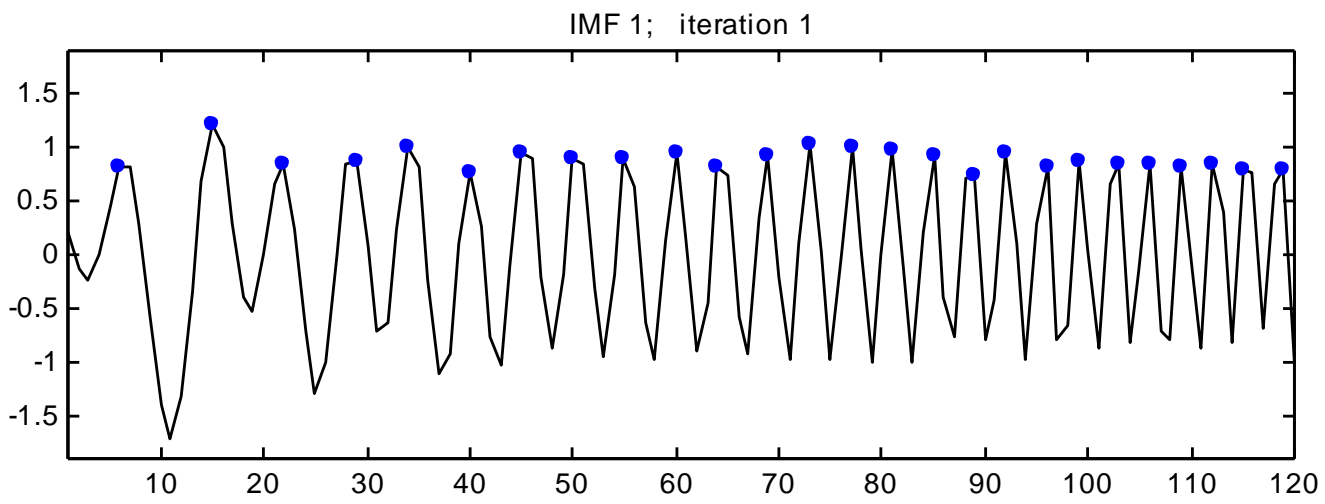


# Sifting processing



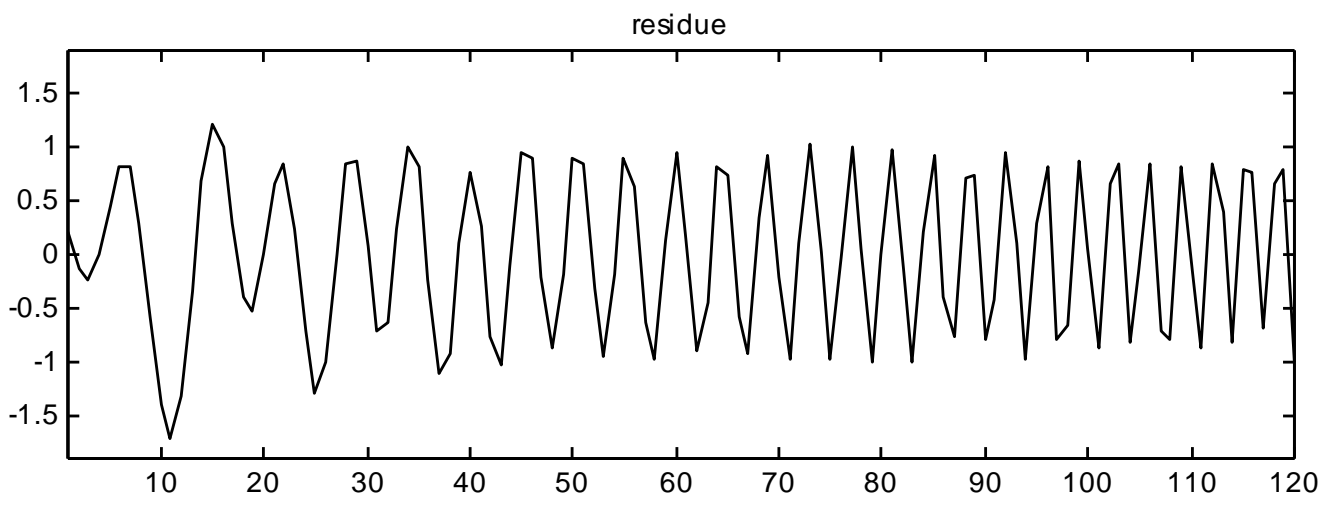
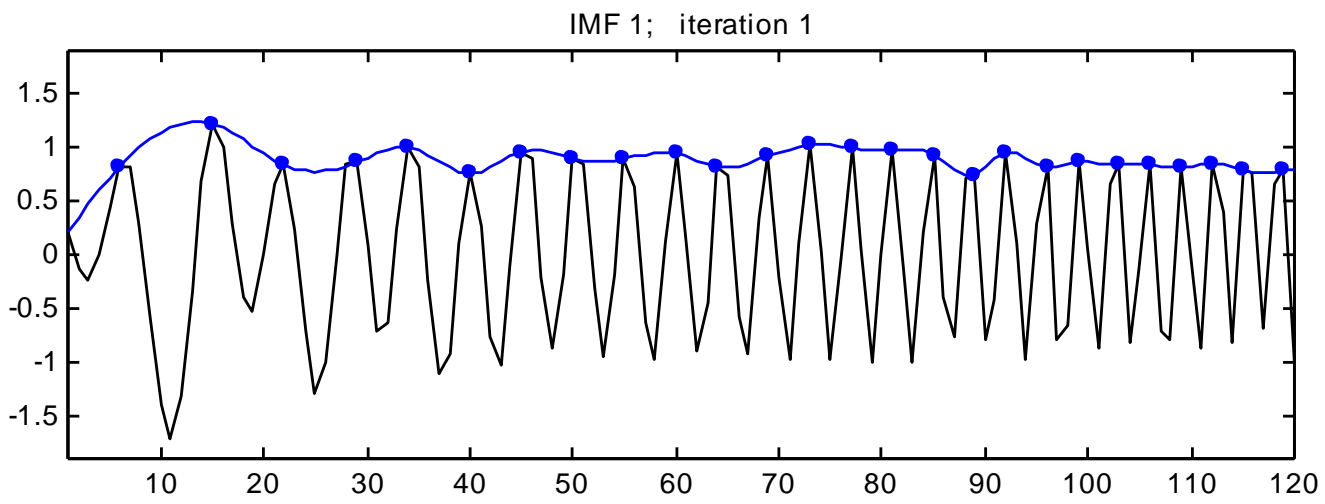


# Sifting processing



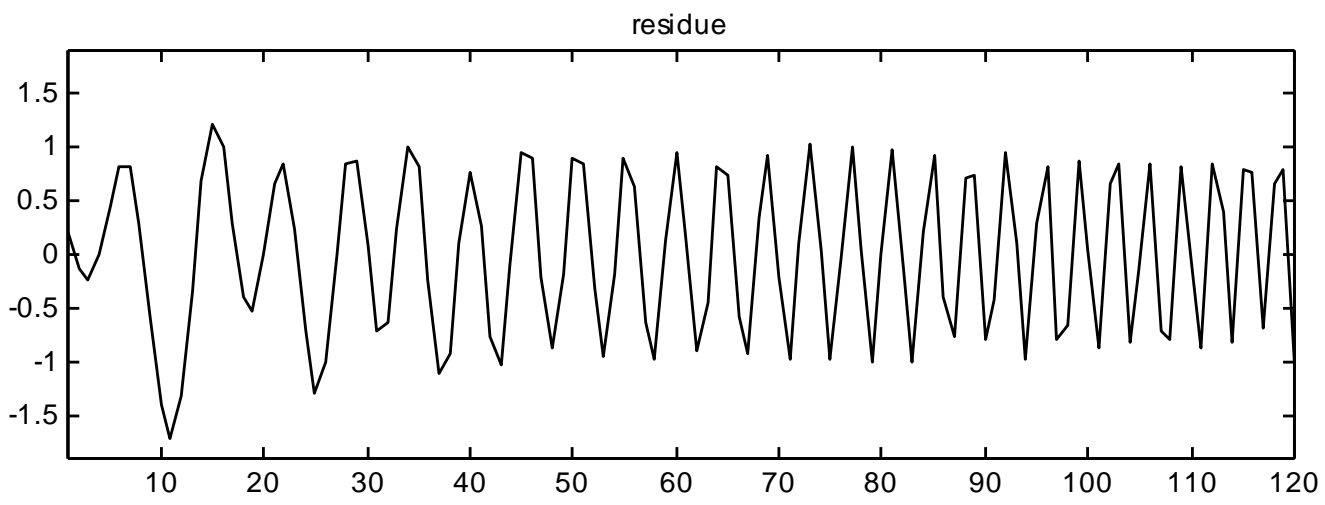
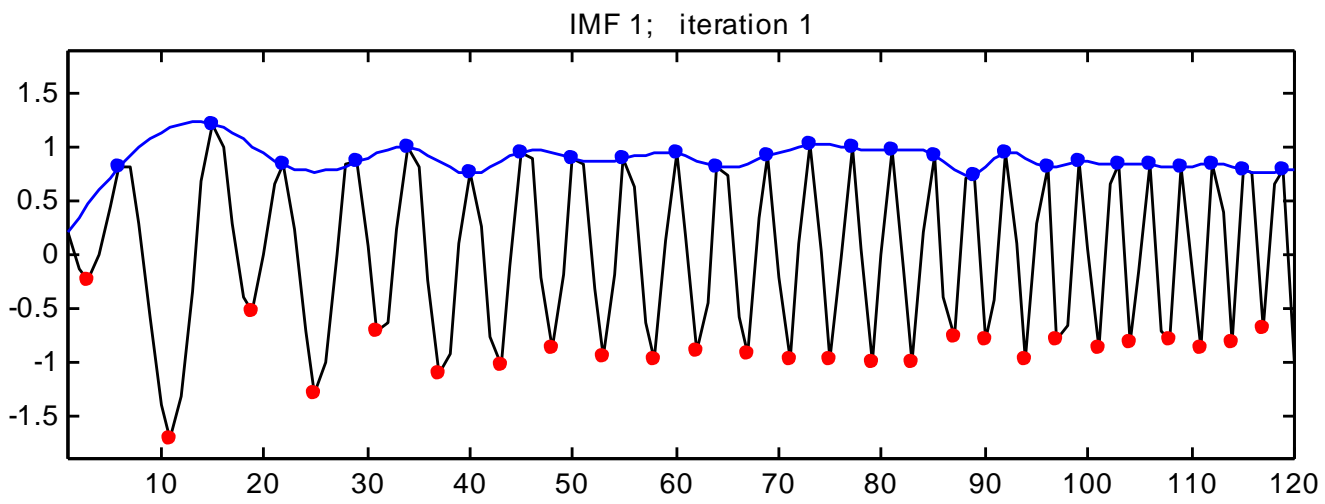


# Sifting processing



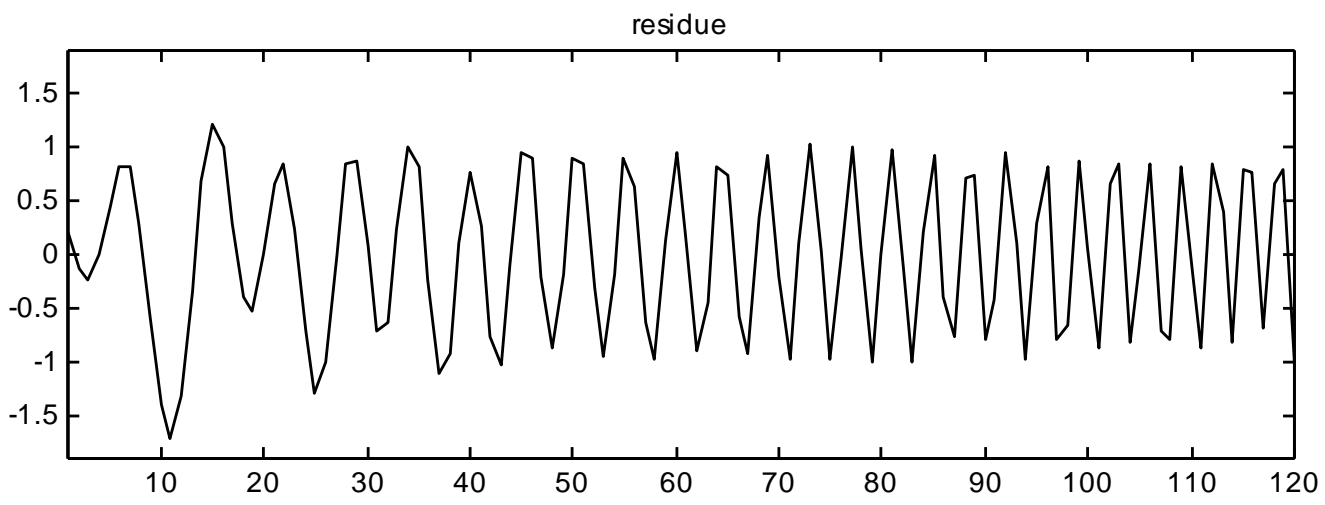
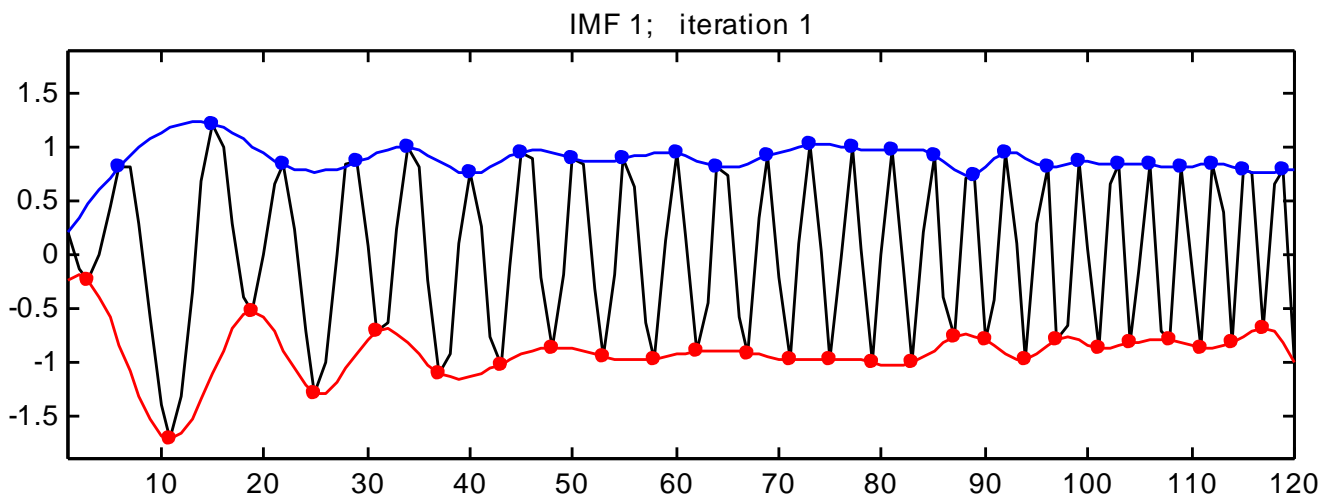


# Sifting processing





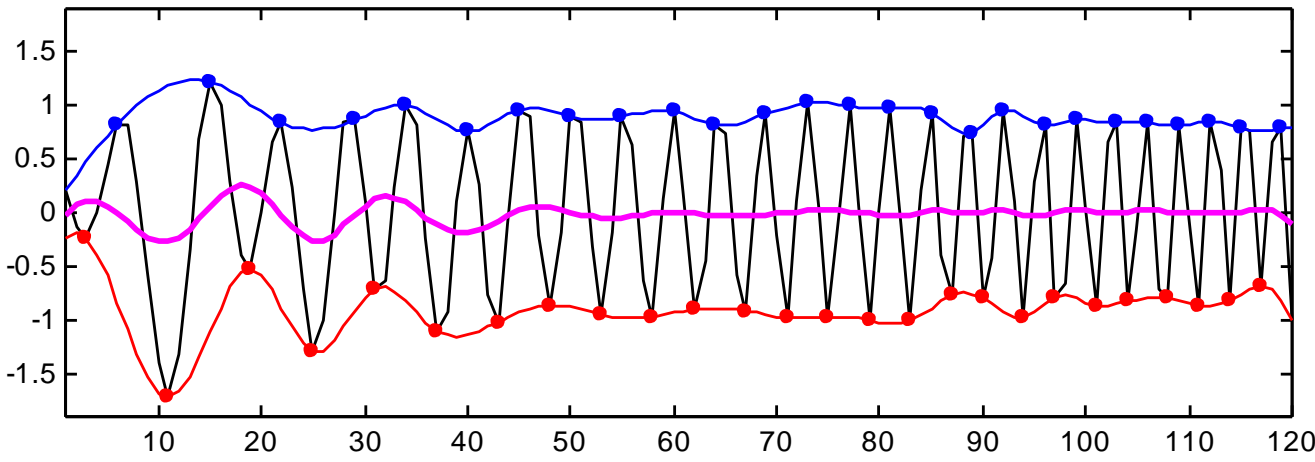
# Sifting processing



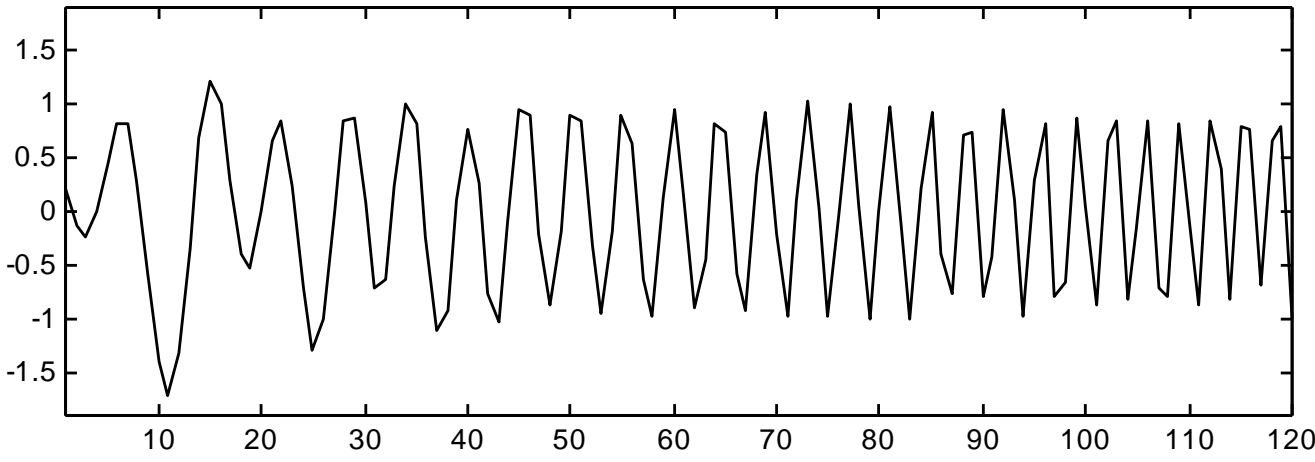


# Sifting processing

IMF 1; iteration 1

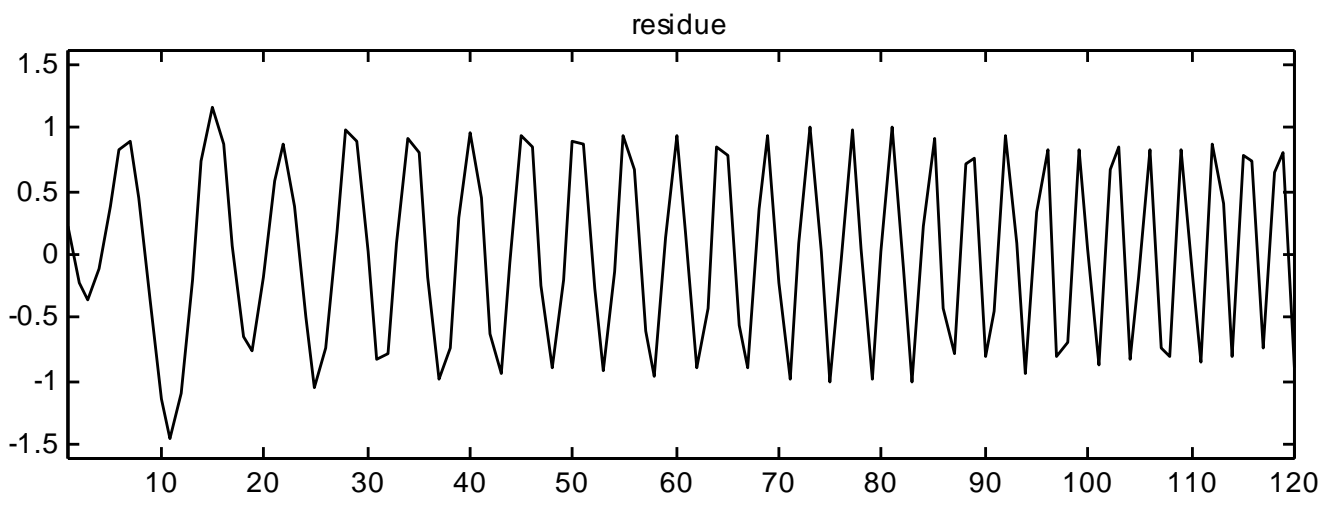
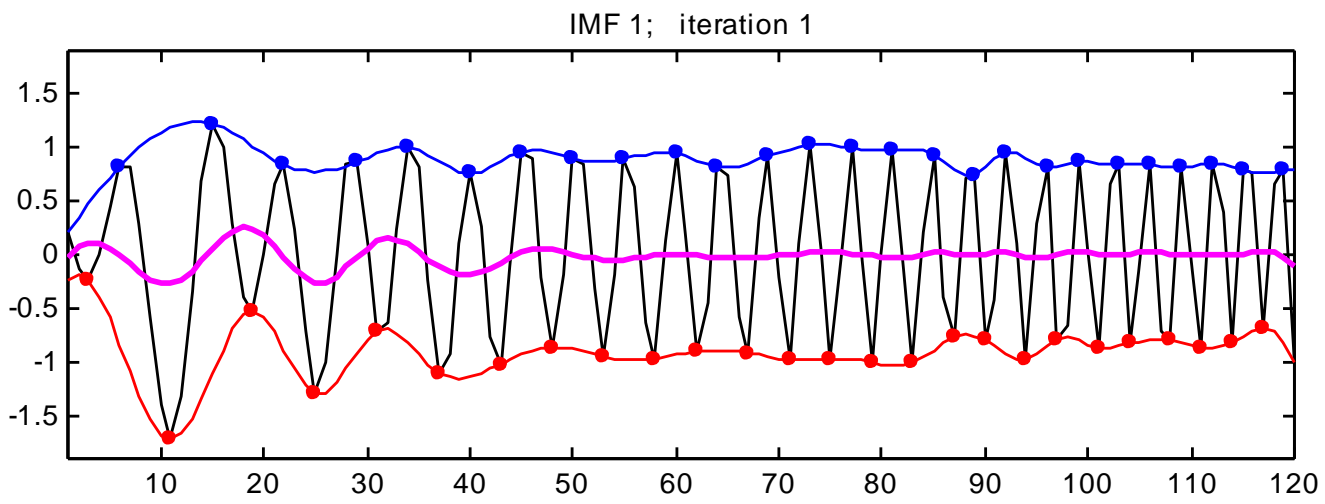


residue



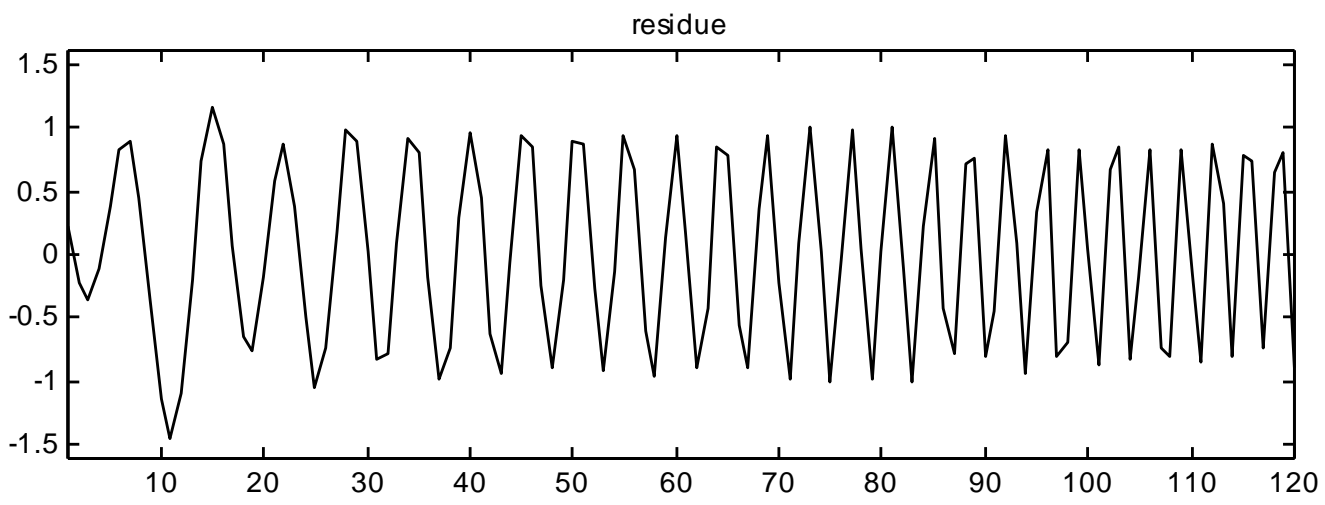
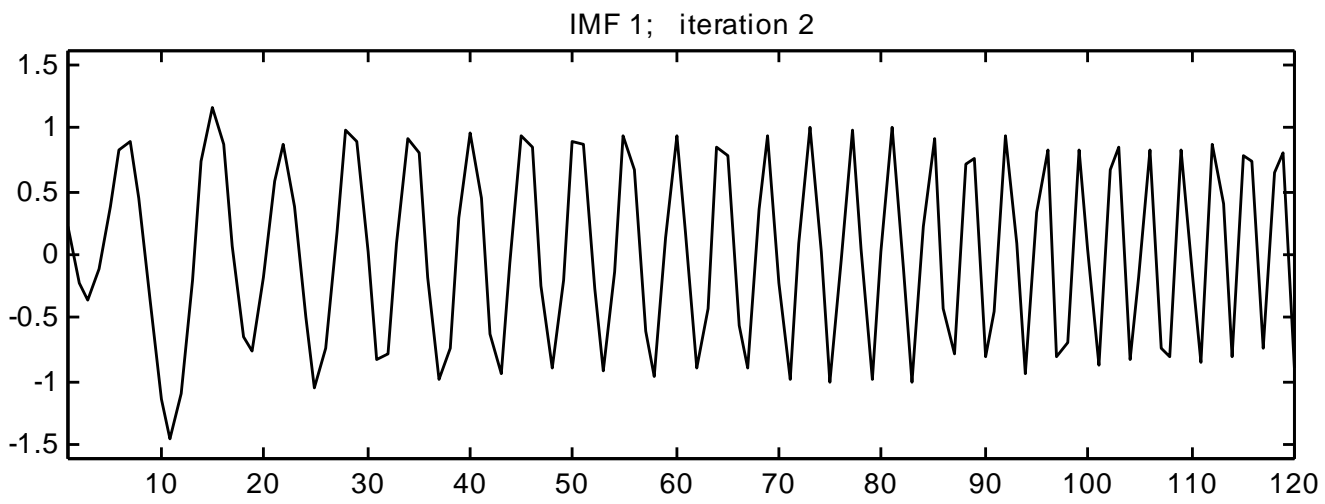


# Sifting processing



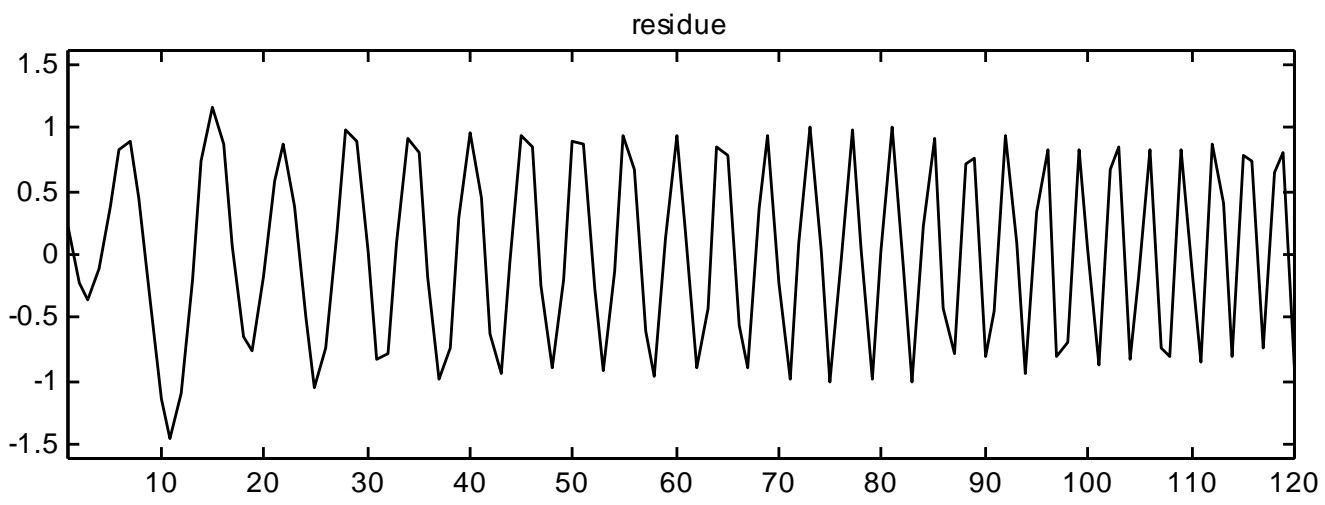
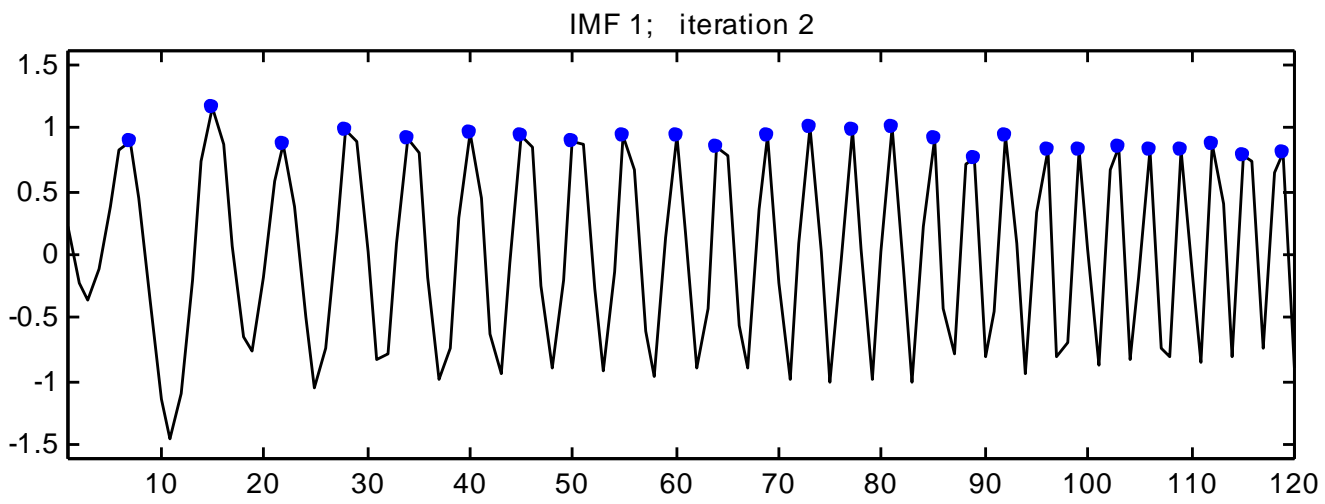


# Sifting processing



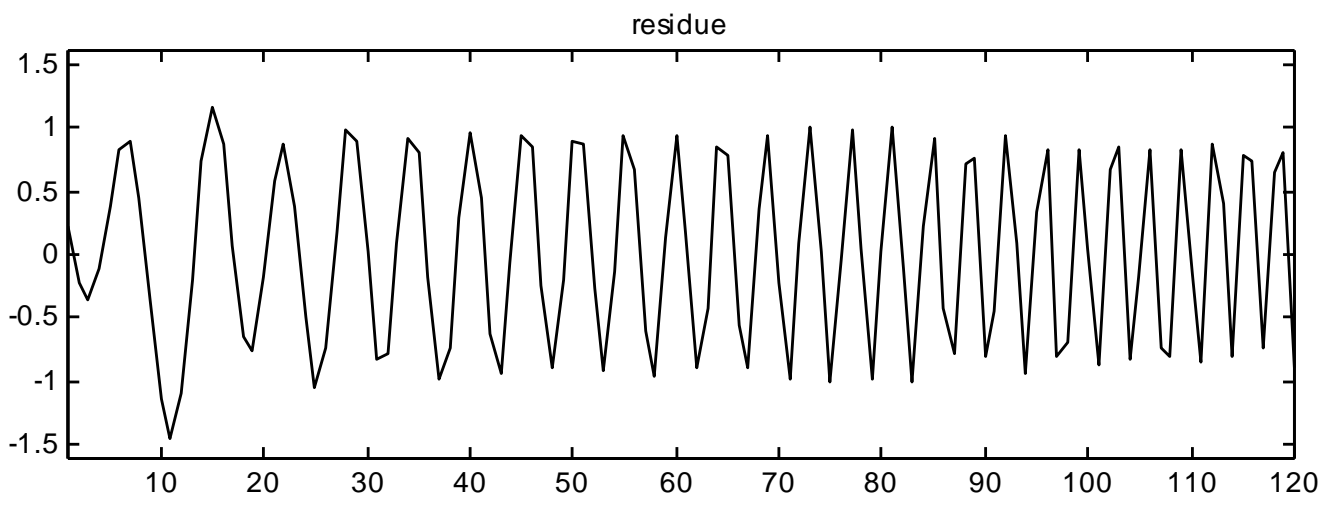
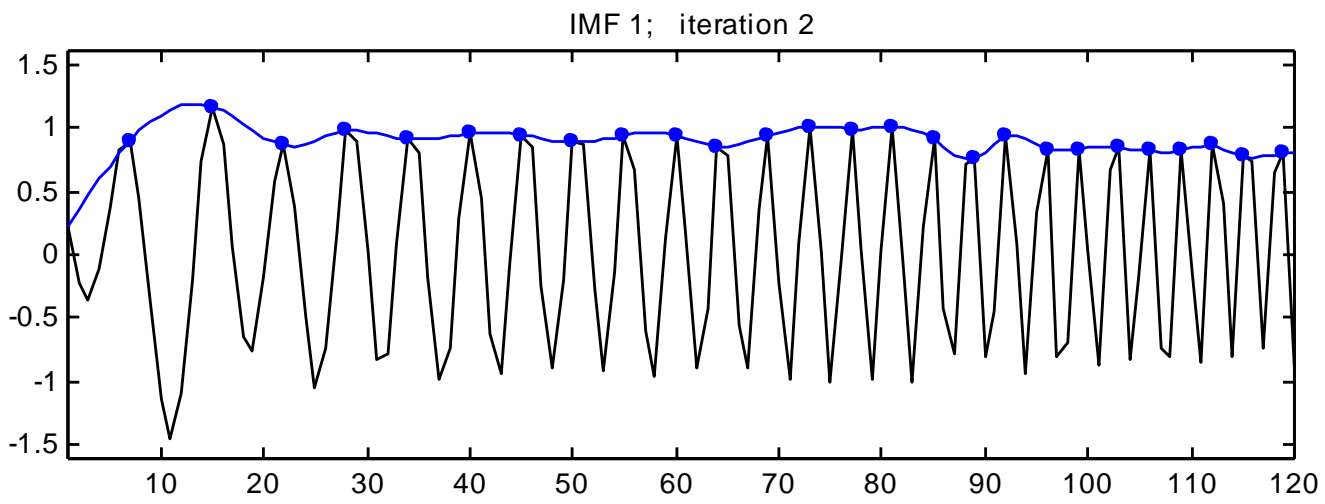


# Sifting processing



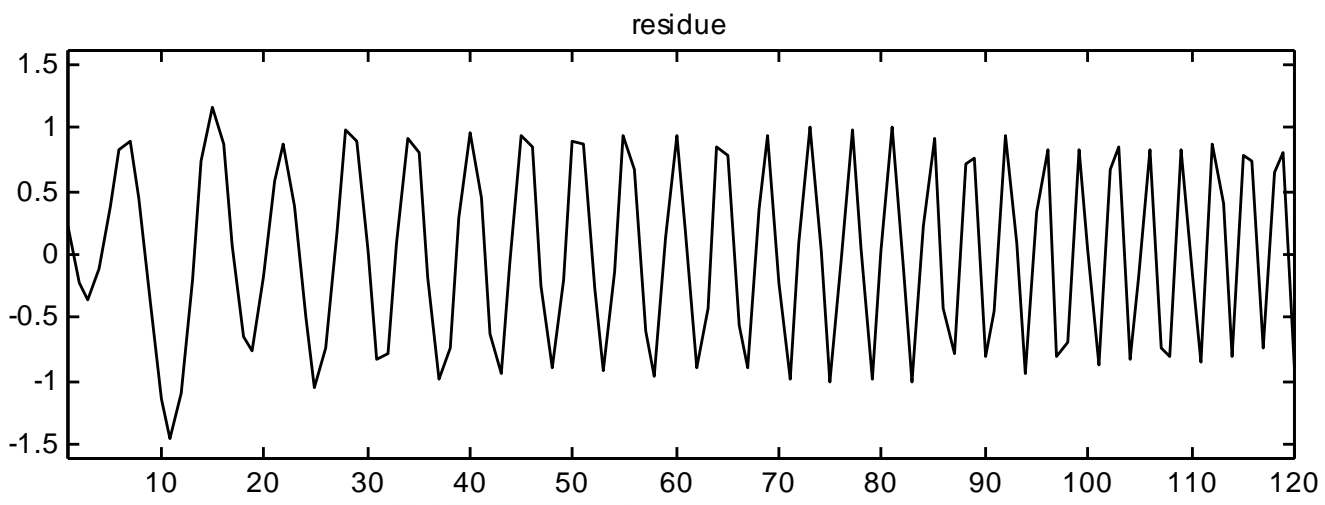
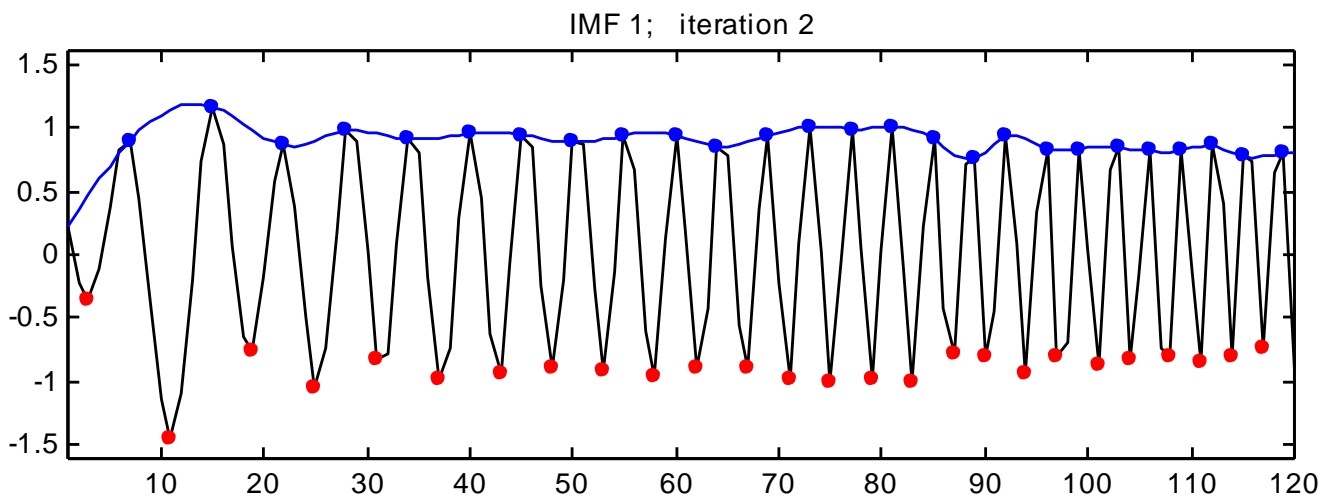


# Sifting processing



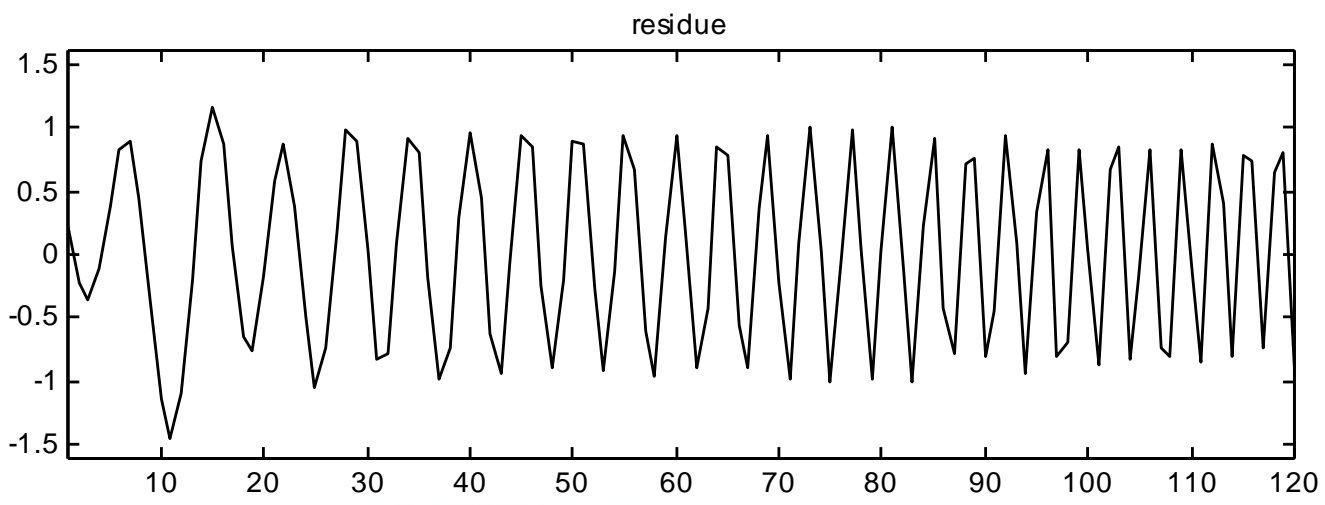
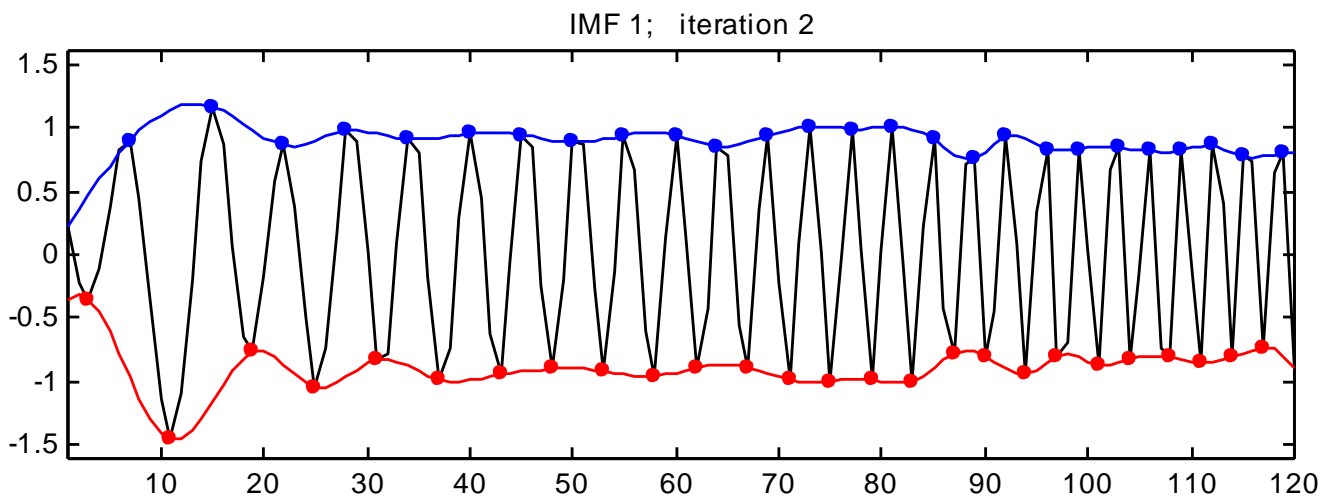


# Sifting processing



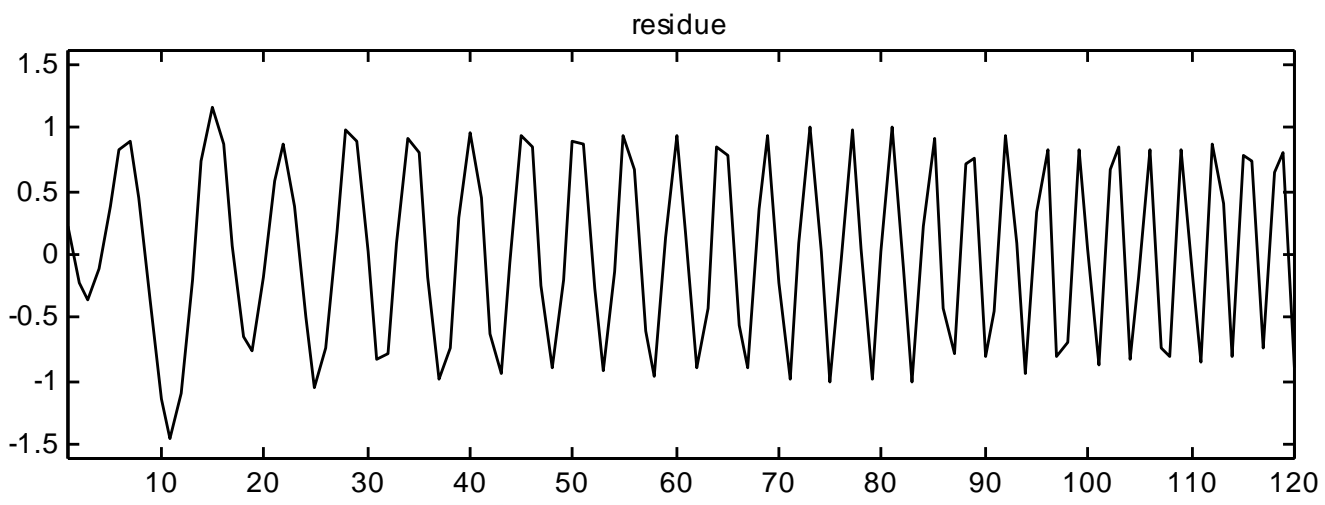
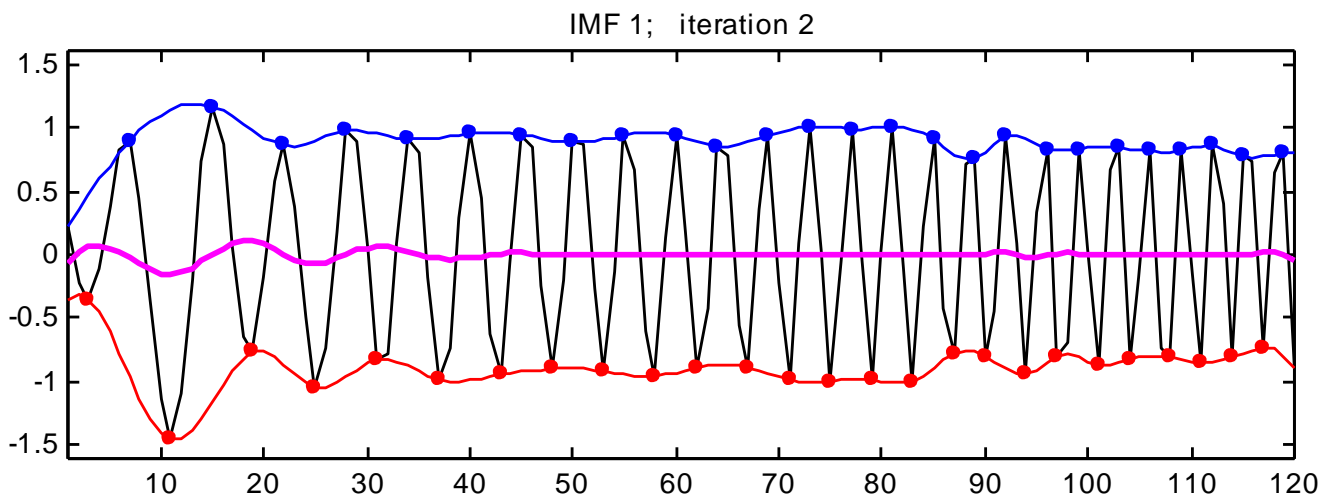


# Sifting processing



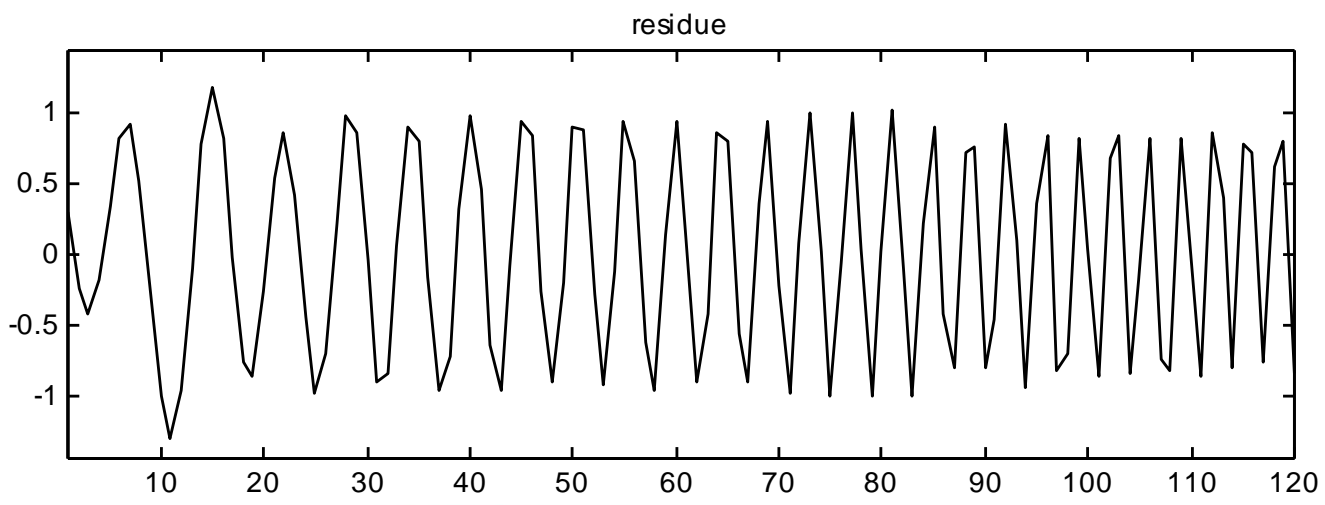
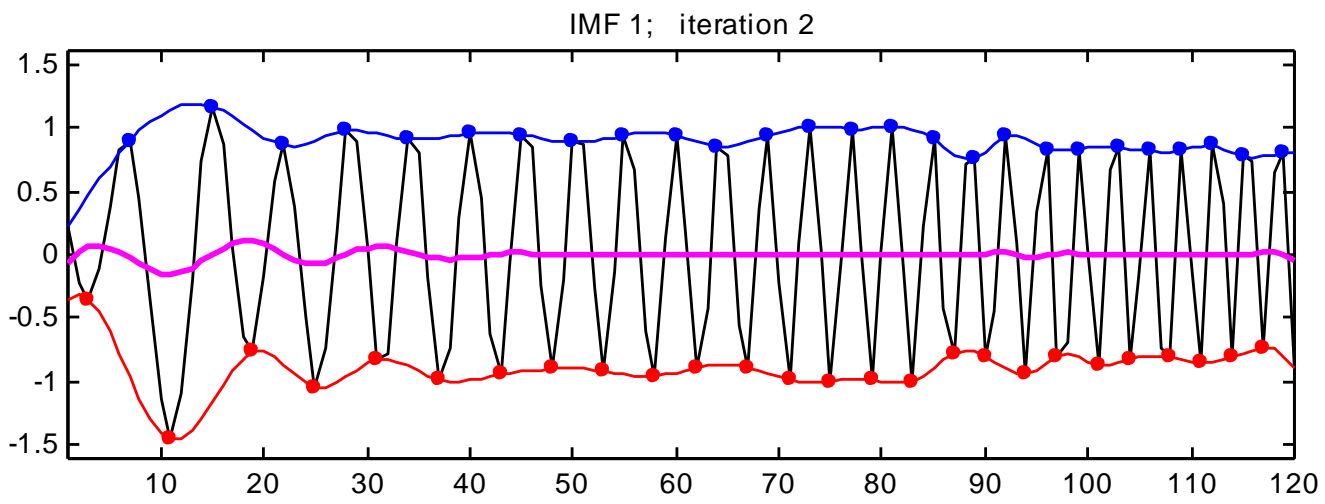


# Sifting processing





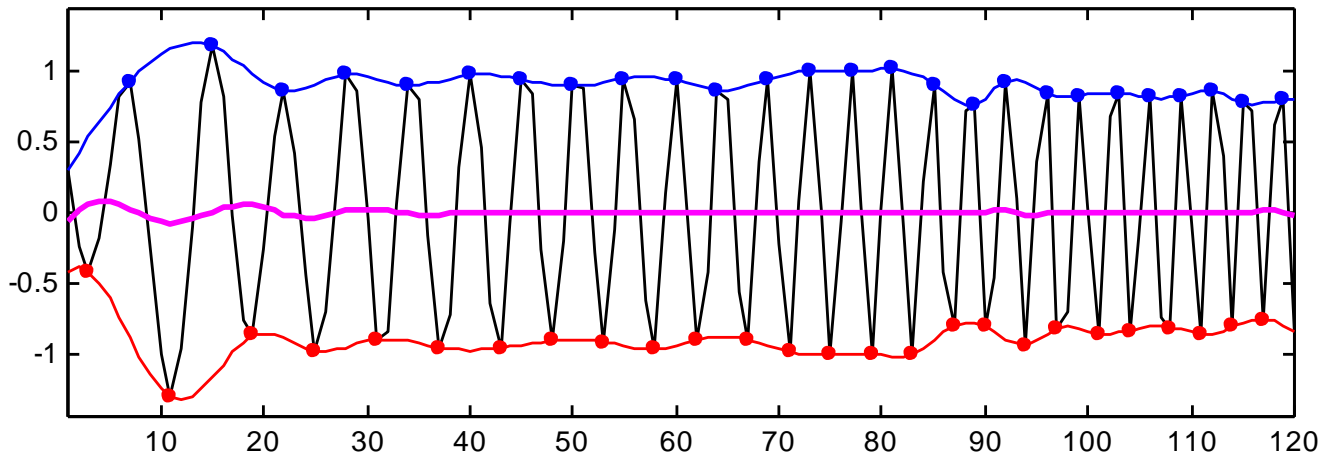
# Sifting processing



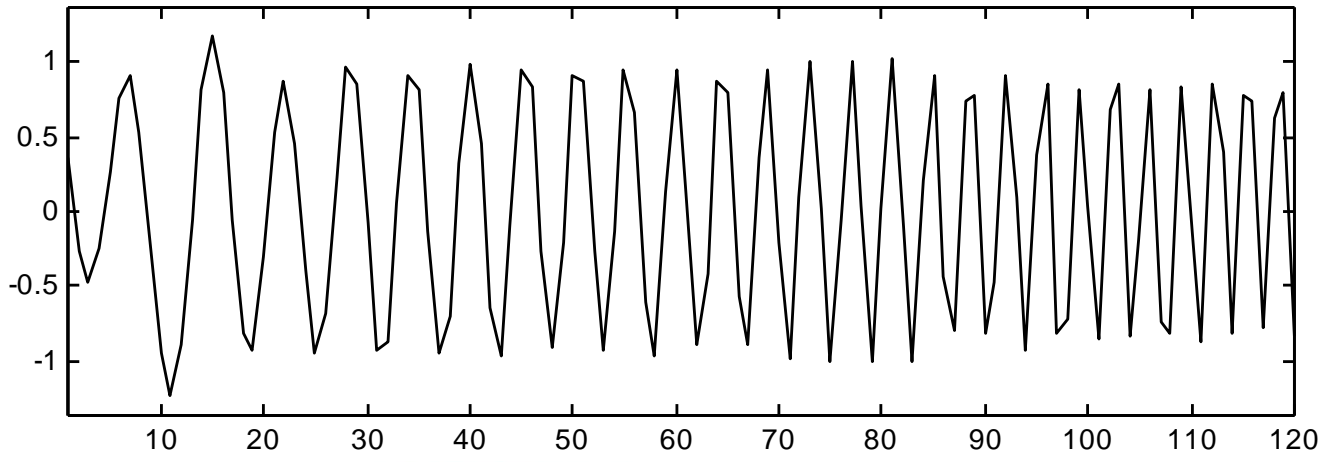


# Sifting processing

IMF 1; iteration 3

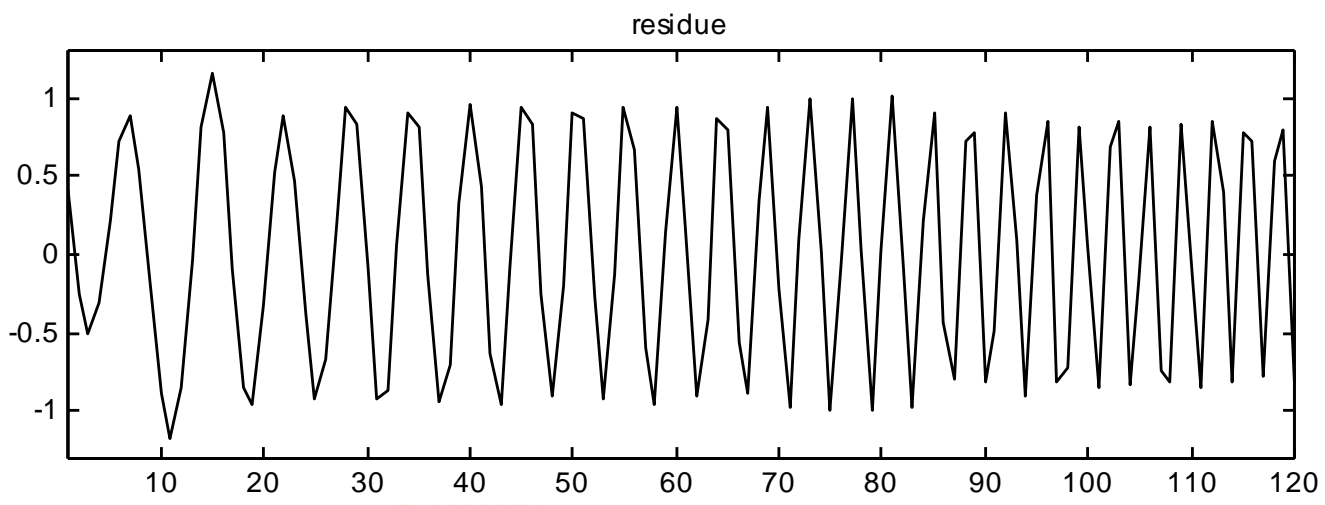
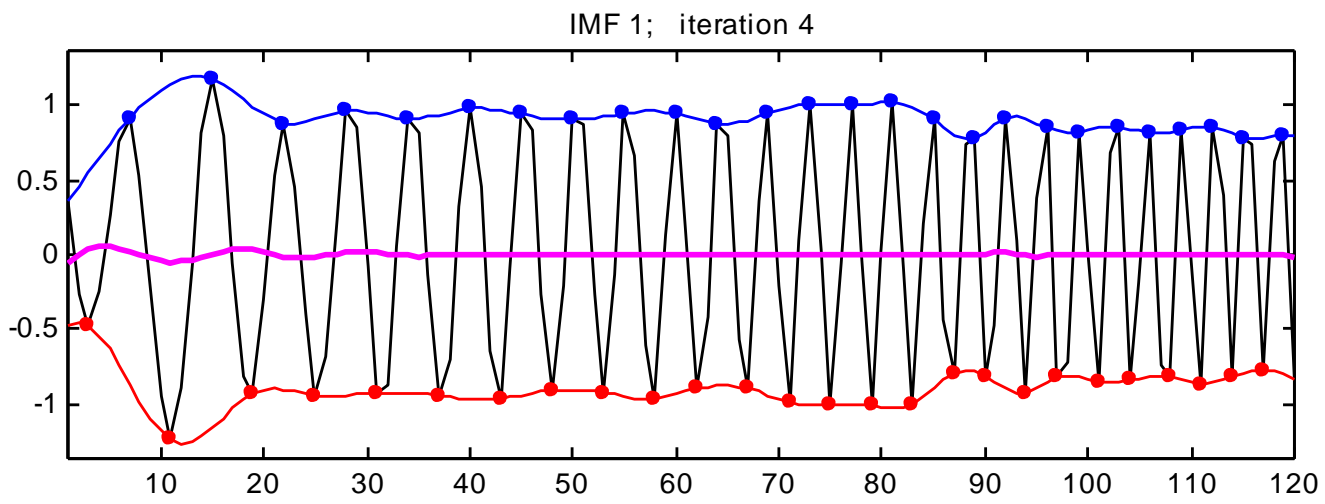


residue



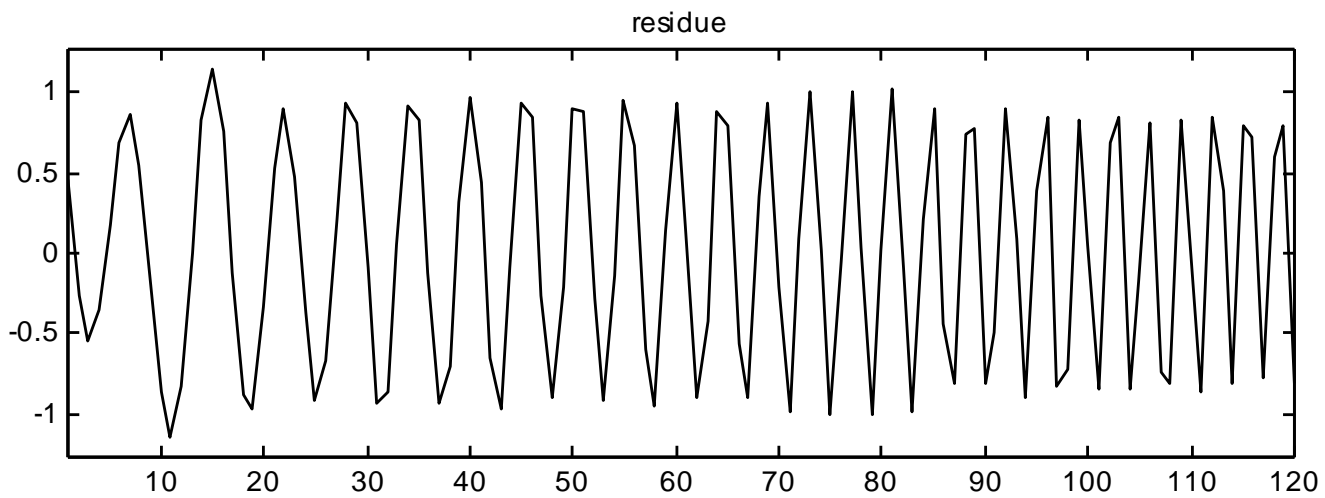
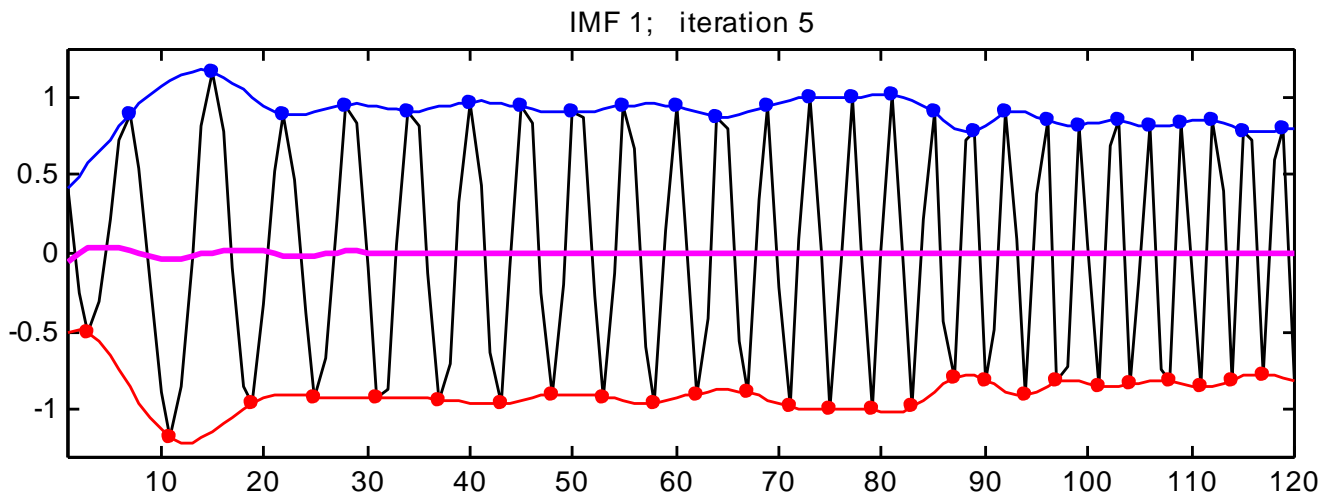


# Sifting processing



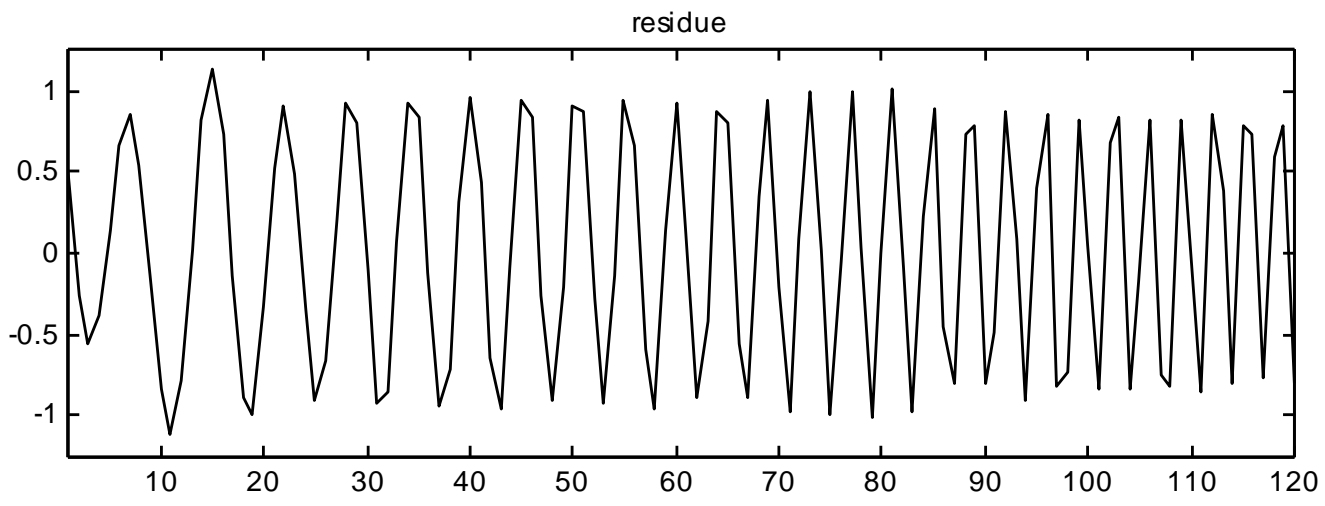
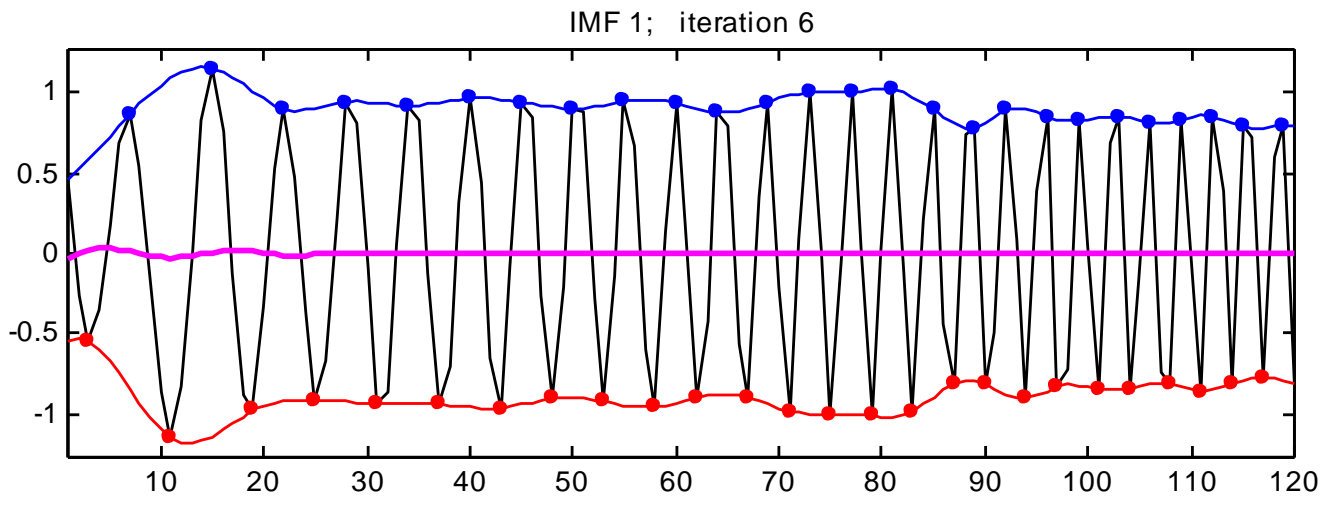


# Sifting processing



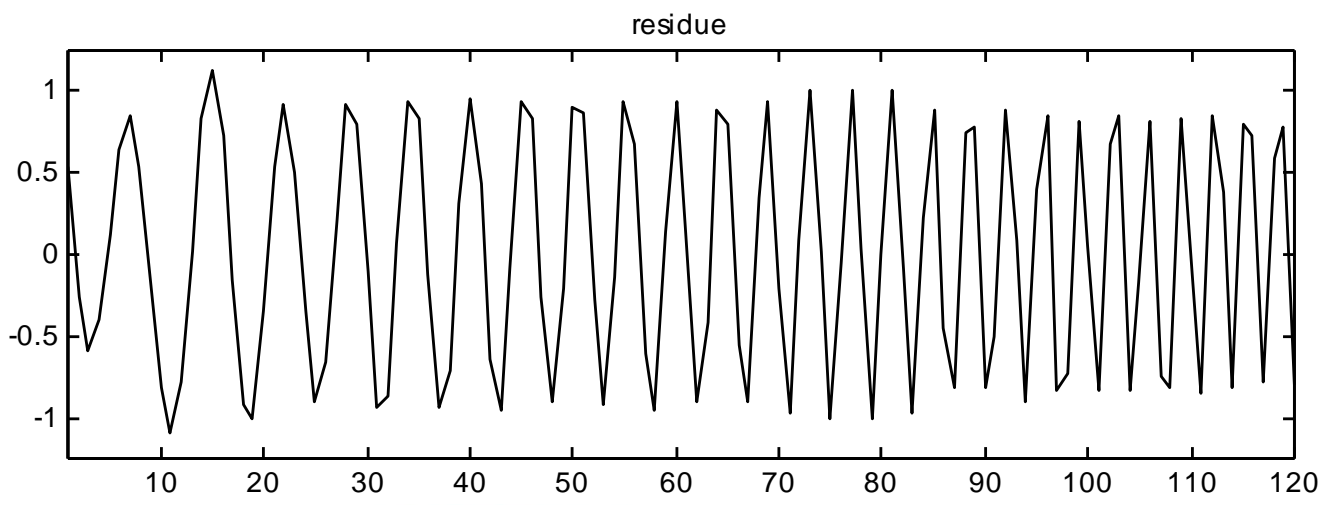
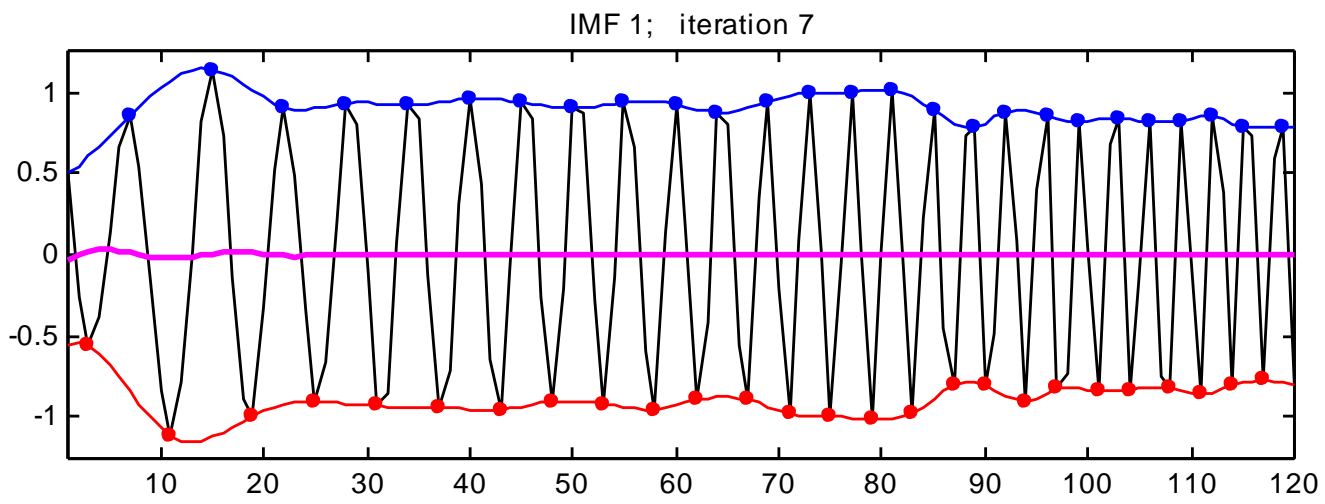


# Sifting processing





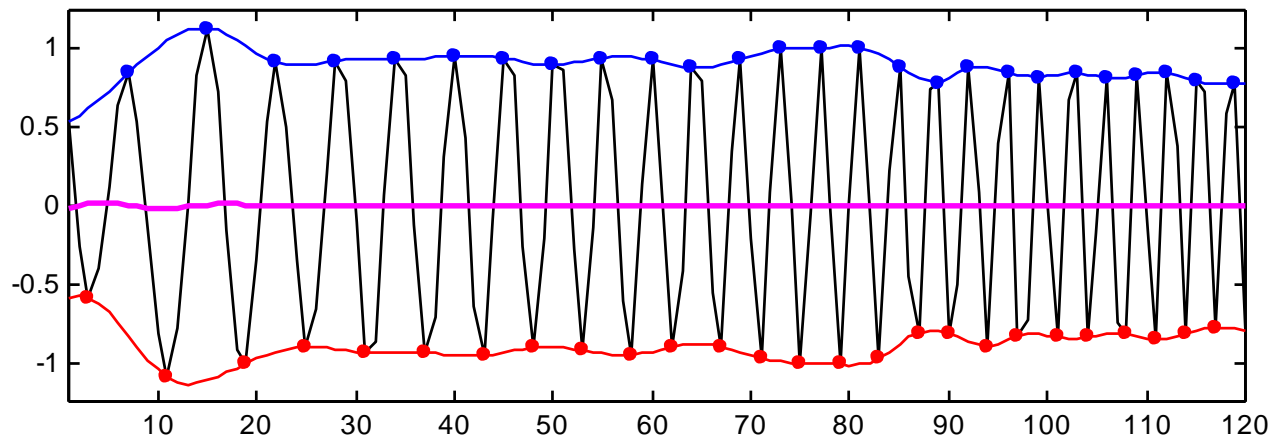
# Sifting processing



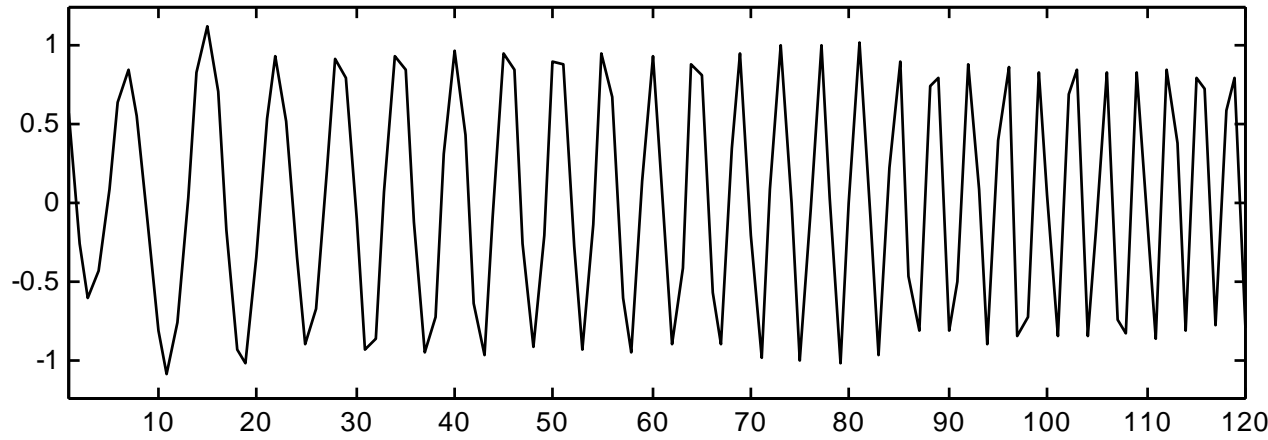


# Sifting processing

IMF 1; iteration 8



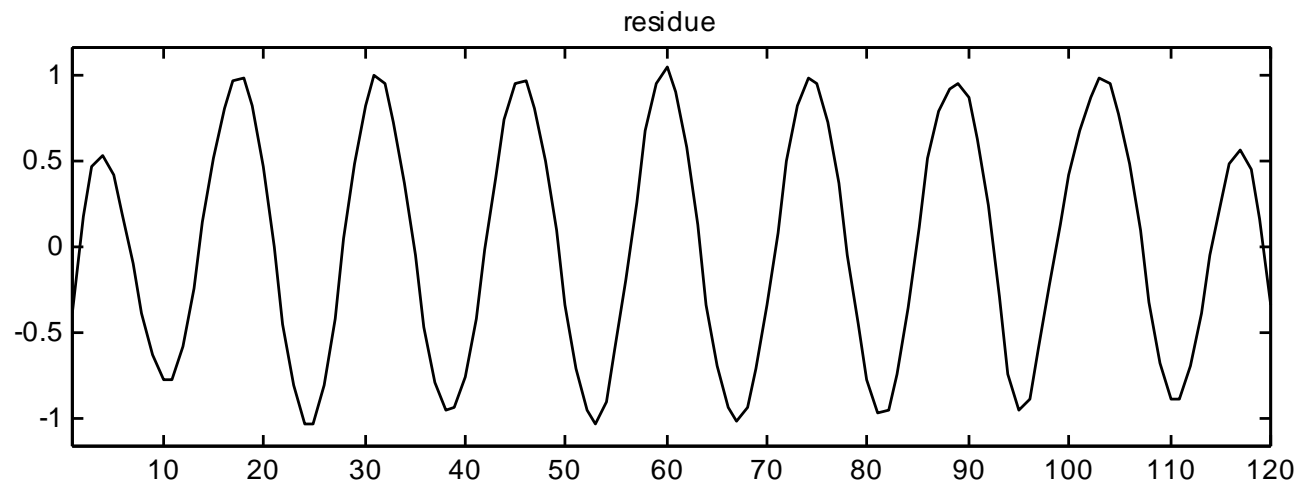
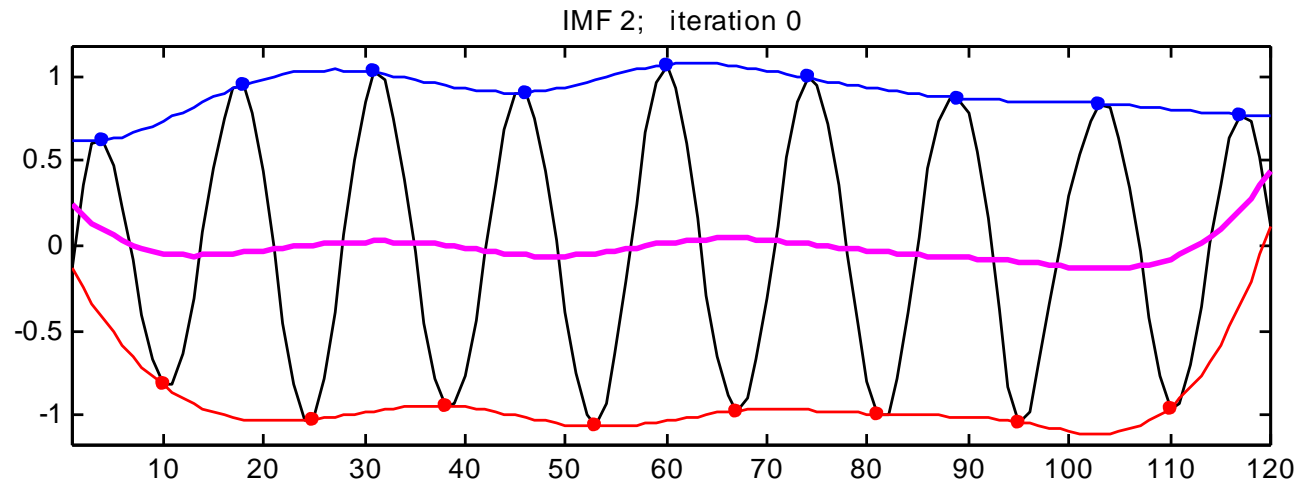
residue



When the difference between current  $d(t)$  and the previous  $d(t)$  was small (i.e.,  $\lambda = 0.2 \sim 0.3$ ), the IMF is extracted.



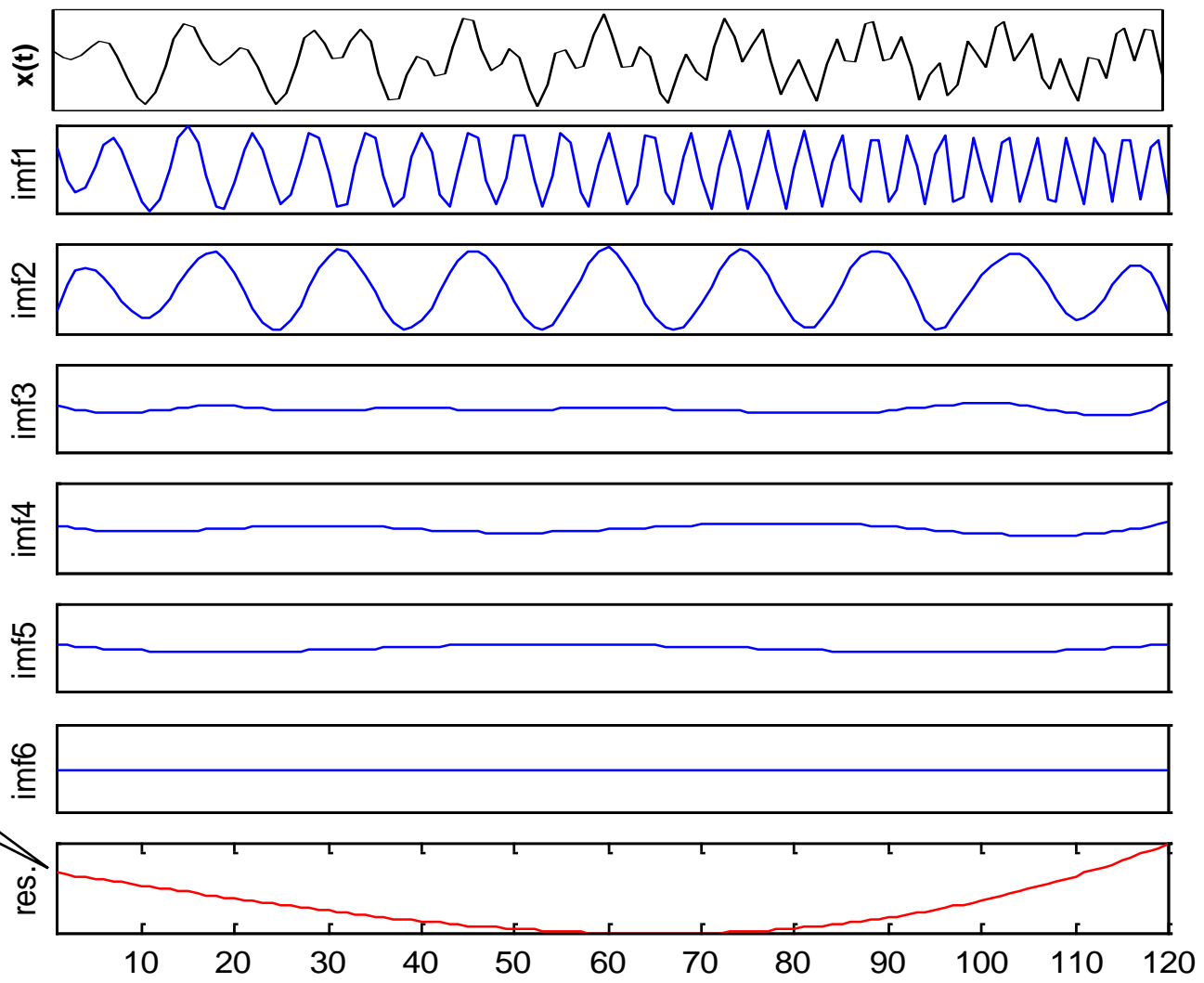
# Sifting processing



The sifting process is continued until all IMFs are extracted.



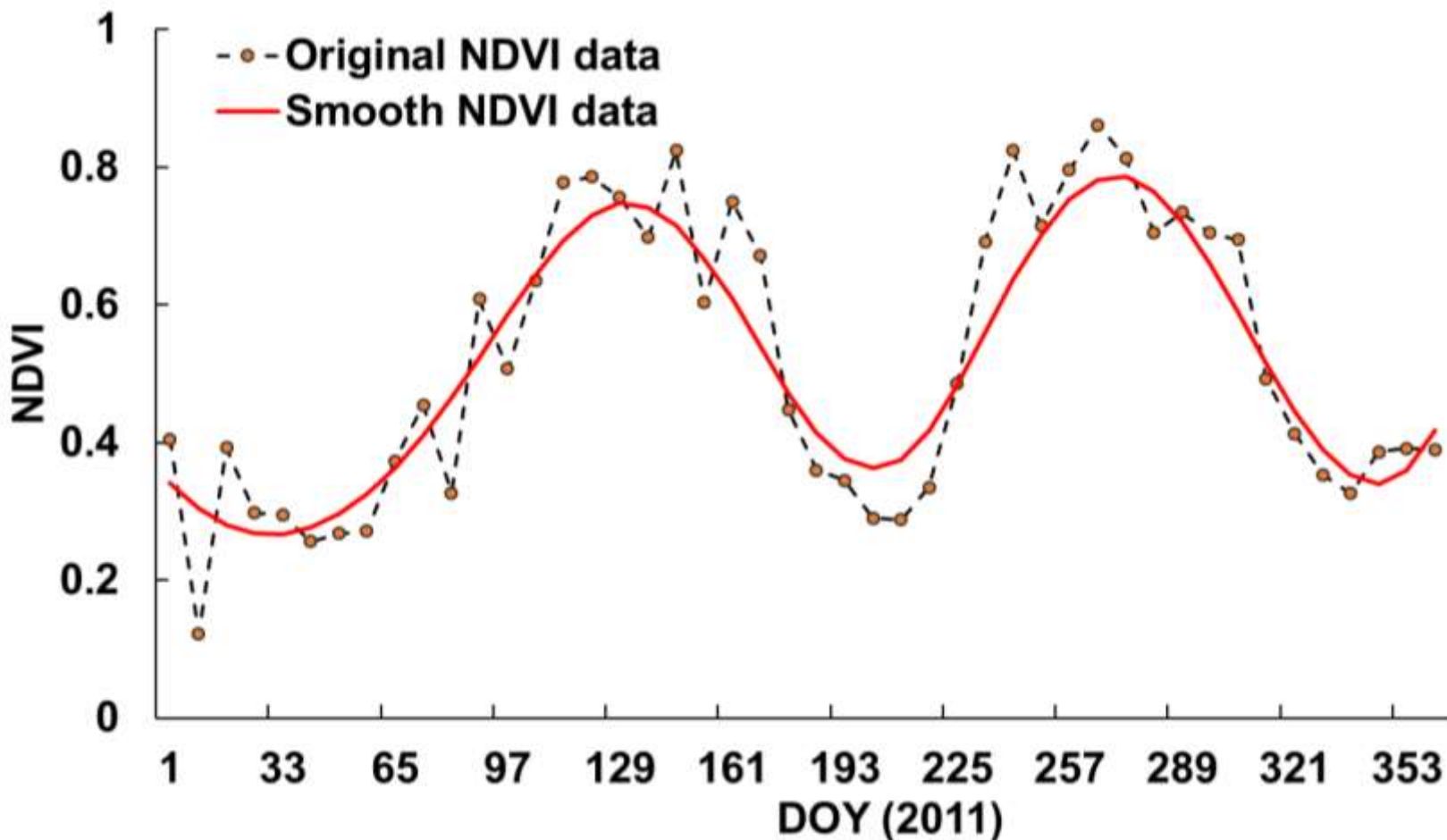
# Sifting processing



Monotonic function



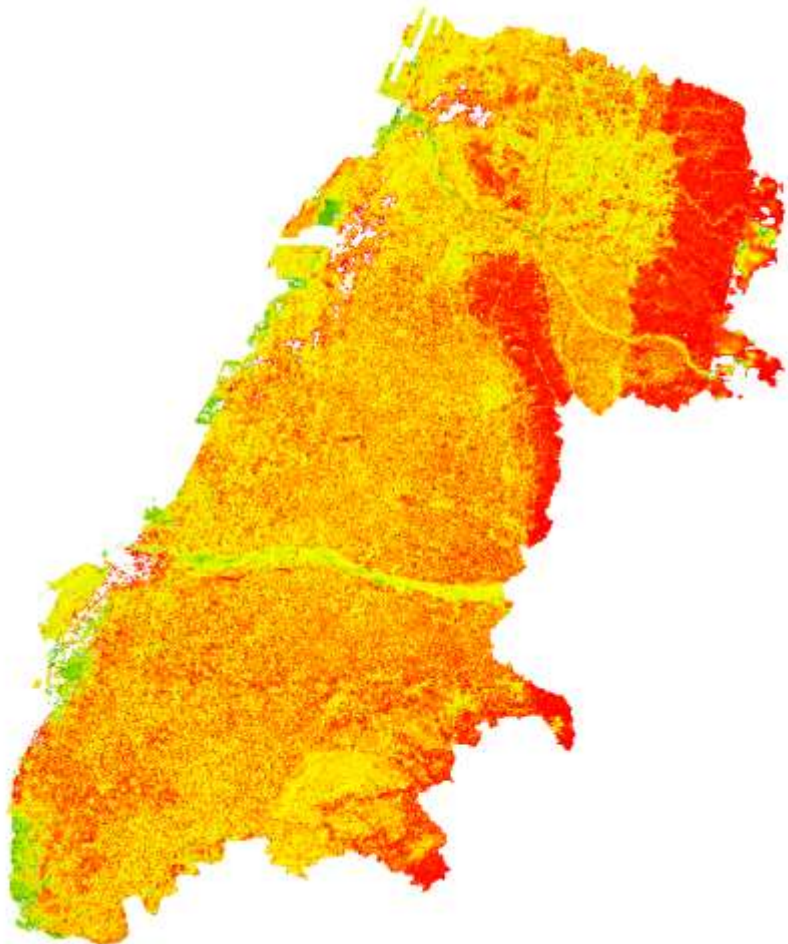
# Filtered NDVI profile



- EMD-based low-pass filter was formed by adding the last two IMFs and the residue.



001



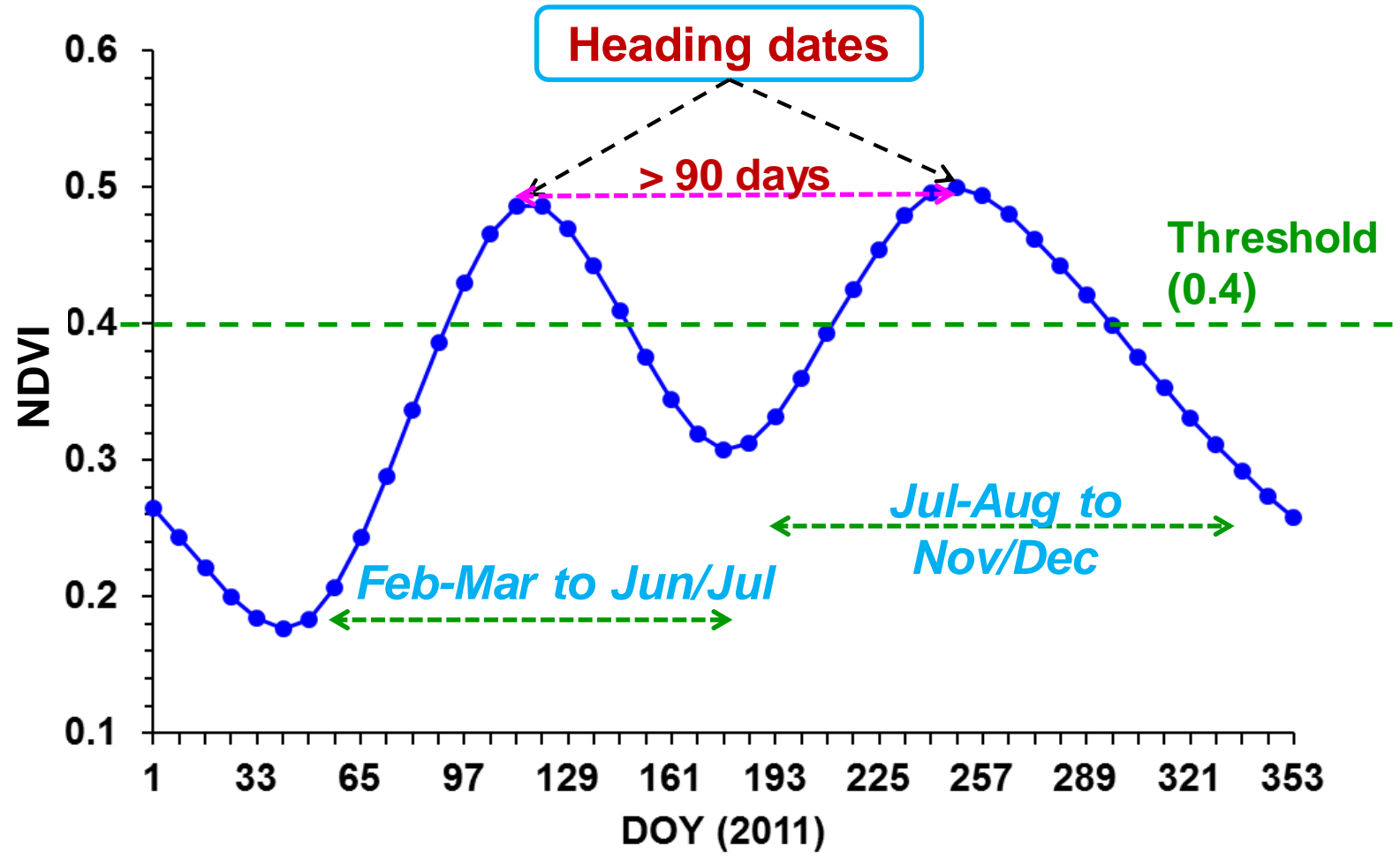


# Rice crop mapping

1. An NDVI threshold of 0.4 was set to eliminate unrealistic peaks.
2. Identify the heading dates in the NDVI profile using the local maxima method.
3. The heading date should fall in a specific period of a cropping season.
4. The interval between two heading dates should be longer than **90 days**.
5. Rice cropping systems were classified using the number of heading dates within a year.

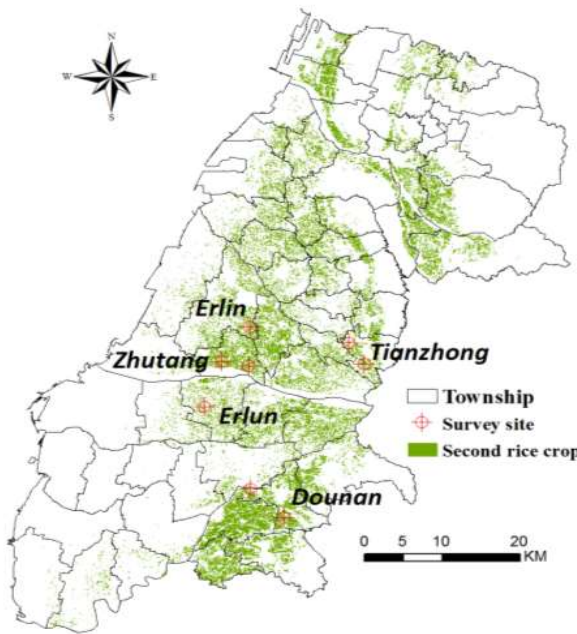
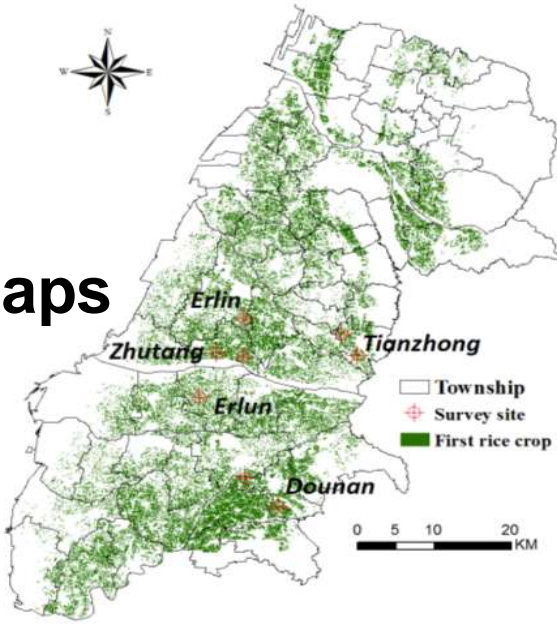


# Rice crop mapping (cont.)





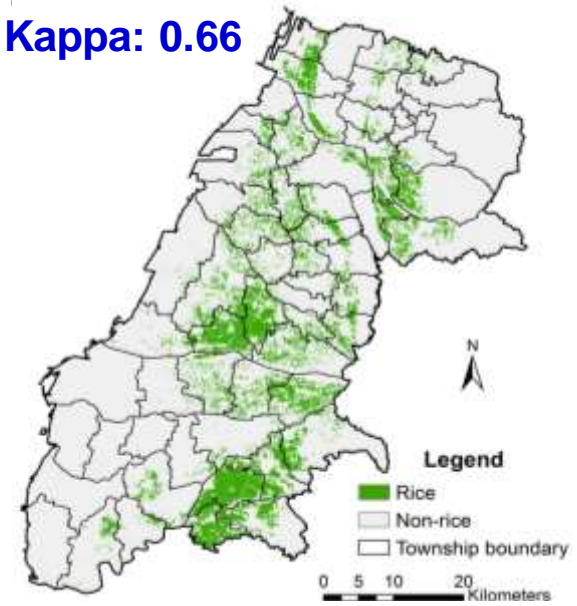
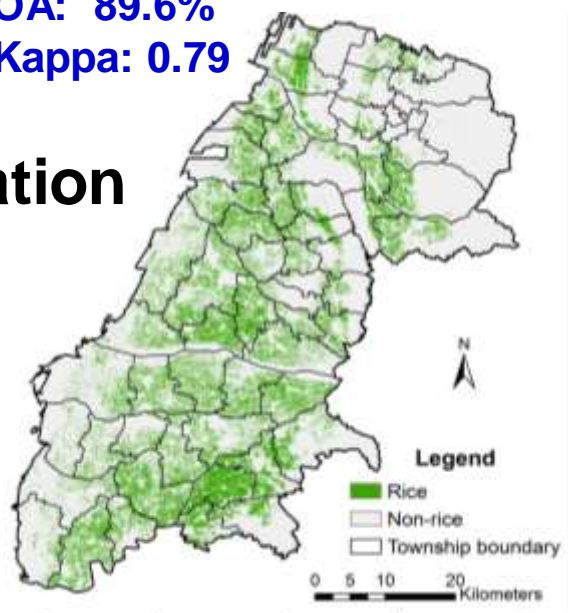
# Ground reference maps



- OA: 89.6%
- Kappa: 0.79

- OA: 83.2%
- Kappa: 0.66

# Classification maps

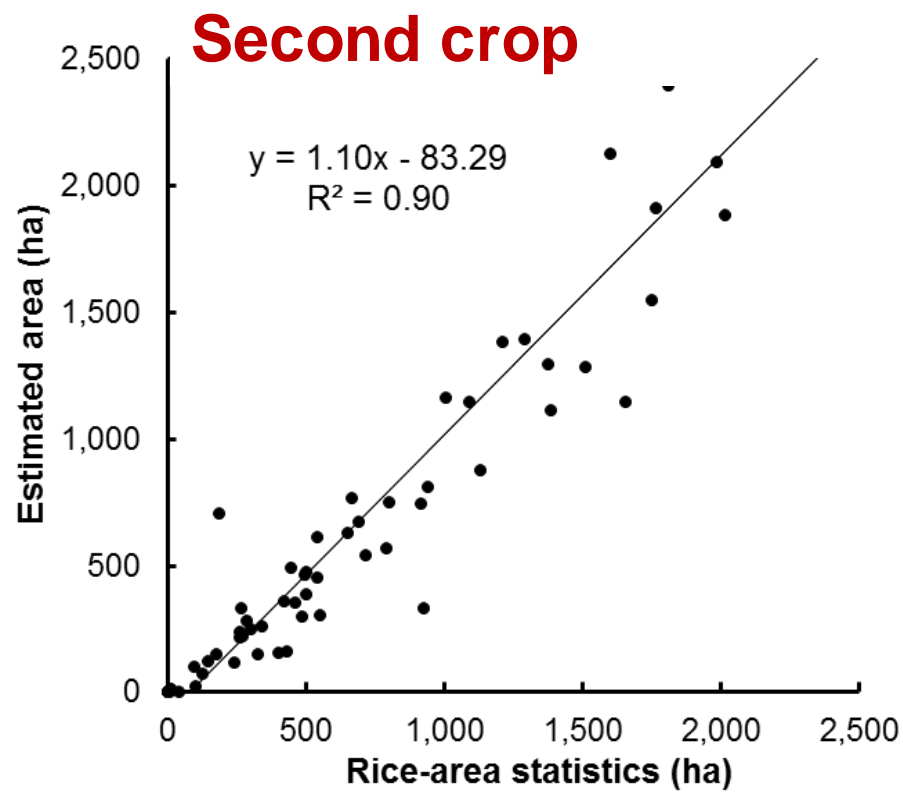
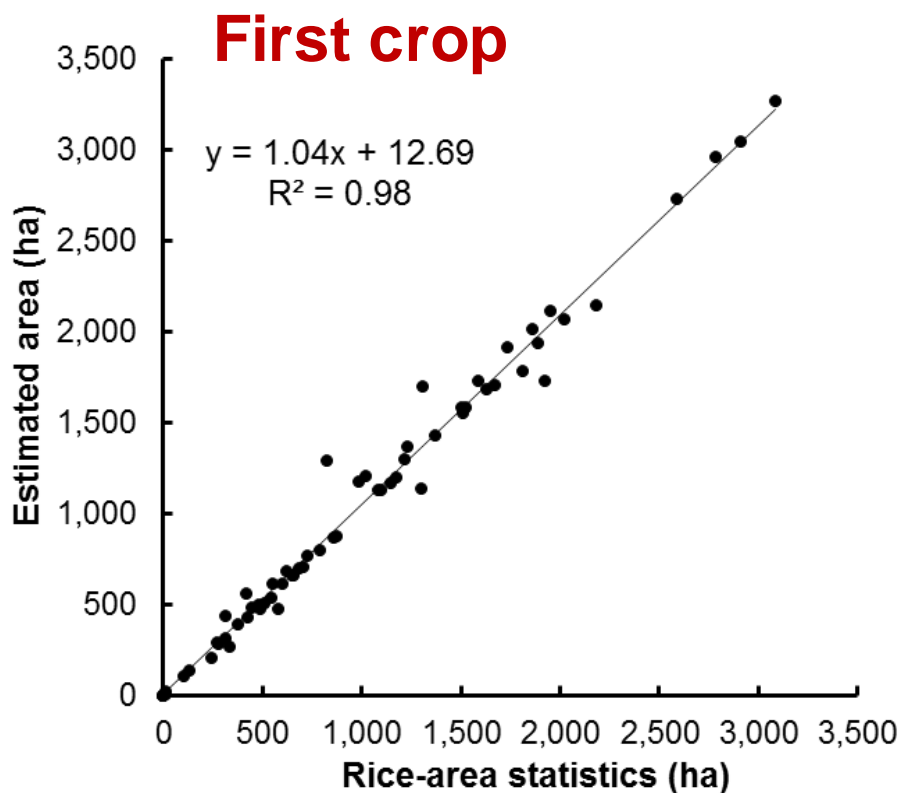


**First crop**

**Second crop**



# Correlation analysis



- The relative errors in area (township level) between the estimated rice area and statistics for:
  - the first crop: 2.7%
  - the second crop: -1.5%



# Concluding remarks

- **STARFM is a good method to produce fusion dataset for mapping small rice fields.**
- **EMD acts a good filter for noise removal from the time-series SPOT NDVI data.**
- **The overall accuracies and Kappa coefficients for the first and second crops were 89.6% and 0.79, and 83.2% and 0.66.**
- **Close correlations between the mapping results and the rice area statistics ( $R^2 > 0.9$ ).**



# Research plan

- **We still improve the methods for mapping other short-term crops in the region.**
- **Canadian Radarsat-2 data are being ordered for rice crop mapping.**



# Thank you