固体地球物理专业
Solid Geophysics

Journees 2013, 16-18 Sept, Paris

A 531-day-period wobble of the polar motion

Hao Ding, **WenBin Shen**

School of Geodesy and Geomatics, Wuhan University, Wuhan 430079, China. E-mail:
wbshen@sgg.whu.edu.cn

固体地球物理专业
Solid Geophysics

Outline

1. Introduction
2. Method and Dataset
3. Results
4. Discussion

固体地球物理专业
Solid Geophysics

1.Introduction

- Polar motion (PM) contains two dominant components: AW with 12-month period and CW with 14-month period.
- A 530-day-period wobble in the polar motion was suggested and weakly detected in the beginning of 1980s [*Carter* 1981, 1982; *Morgan et al*. 1982]. Since then, only few studies were addressed to the observations of this wobble [*Chen et al* 2010; *Na et al*. 2011; *C. Bizouard* 2013 (private communication)].

1.Introduction

- This study focuses on detecting this signal and leave the mechanism still open

固体地球物理专业
Solid Geophysics

2.1 Method

- Ensemble empirical mode decomposition (EEMD) [*Huang and Wu*, 2008; *Wu and Haung*, 2009] was used

- EEMD was proposed to overcome the disadvantages existing in the empirical mode decomposition (EMD) [*Huang et al.*, 1998; *Huang and Wu*, 2008], such as the scale-mixing problem and the end effect

2.1 Method

- **EMD**: (1) Its function is to effectively separate physical signals one from another; (2) Its effectiveness was confirmed by various experiments; (3) Details are referred to *Huang et al.*, 1998.
- **EEMD**: a further improvement of EMD. Details are referred to *Huang and Wu* 2008, *Wu and Huang 2009.*

2.1 Method: synthetic Example

Suppose there are three signals (i=1,2,3,):

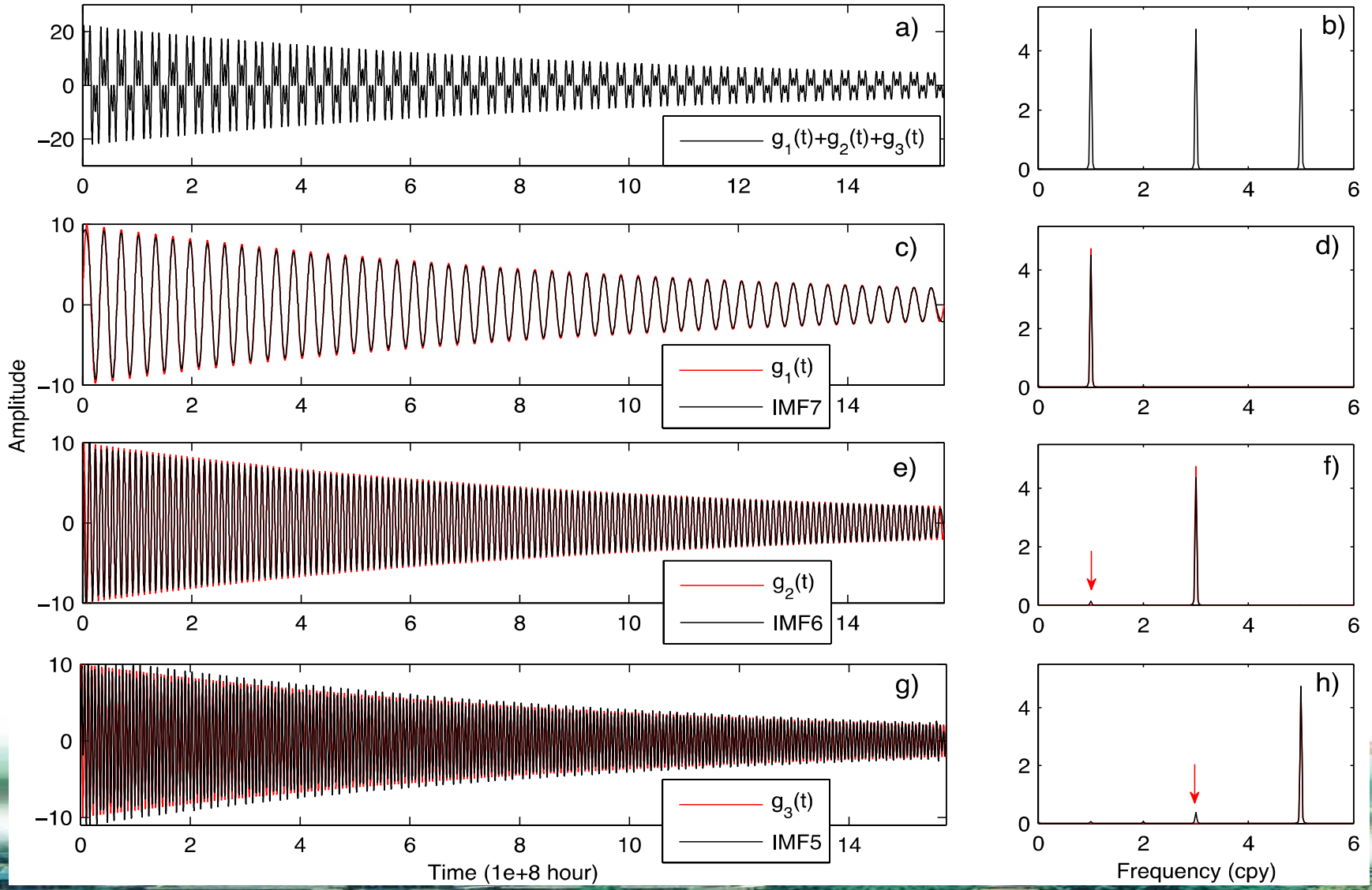
$$g_i(t)=10\times\sin(2\pi f_i\cdot t)\cdot\exp(-10^{-9}\cdot t)$$

with different frequencies f_1=1 cpy, f_2=3 cpy, and f_3=5 cpy.

- Length: 50 years, with one-day interval
- After applying EEMD, the original three signals (in IMF5, IMF6 and IMF7) are almost completely separated

固体地球物理专业
Solid Geophysics

2.1 Method



固体地球物理专业
Solid Geophysics

2.2 Dataset

- The EOP C04 series, spanning from 1962 to July 2013
- Divide it into three sub-series without overlap:

1 Jan 1962-31 Dec 1977 -data length is as same as that of Carter (1981)

1 Jan1978-31Dec 1994

1 Jan 1995-16 July 2013

固体地球物理专业
Solid Geophysics

2.2 Dataset

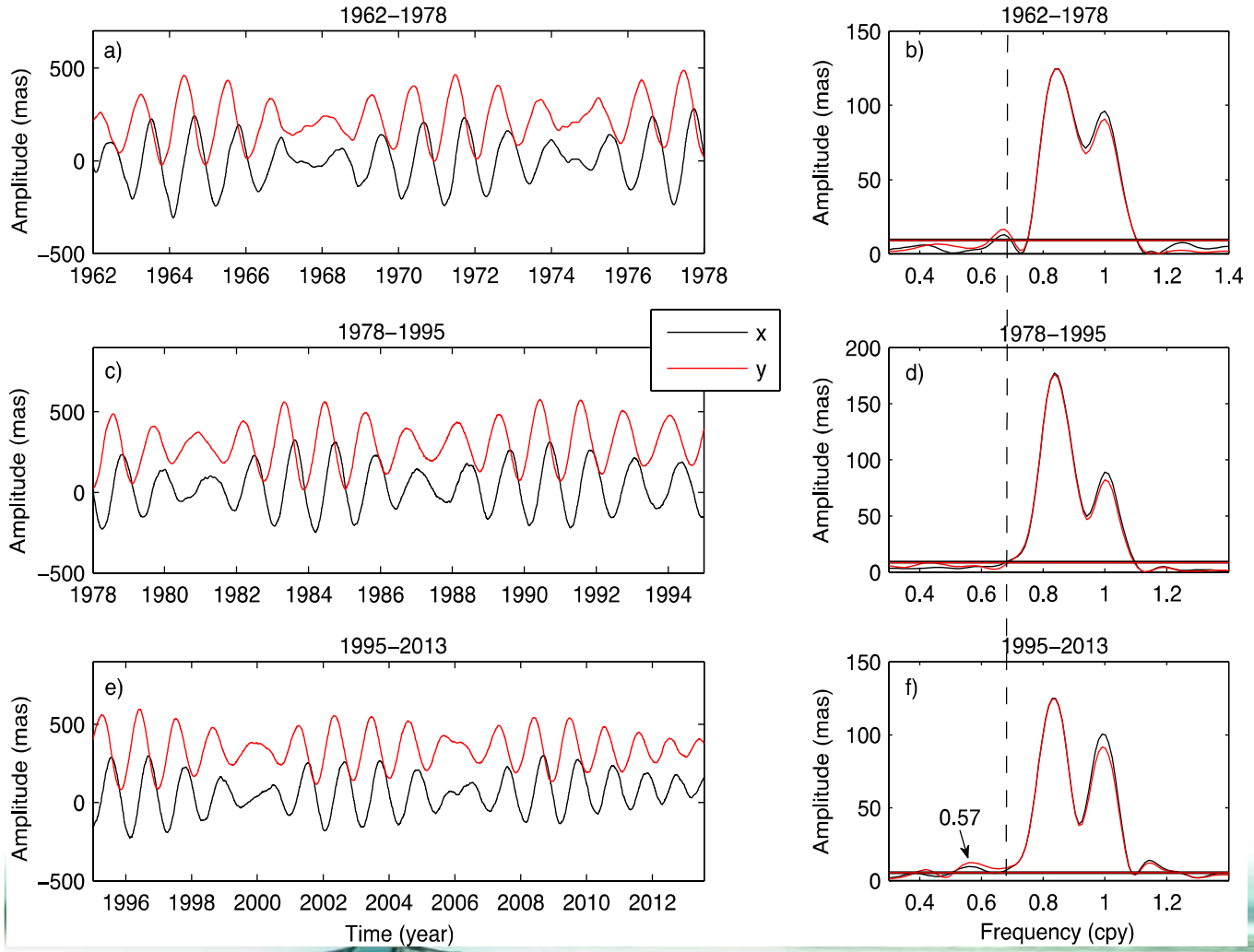
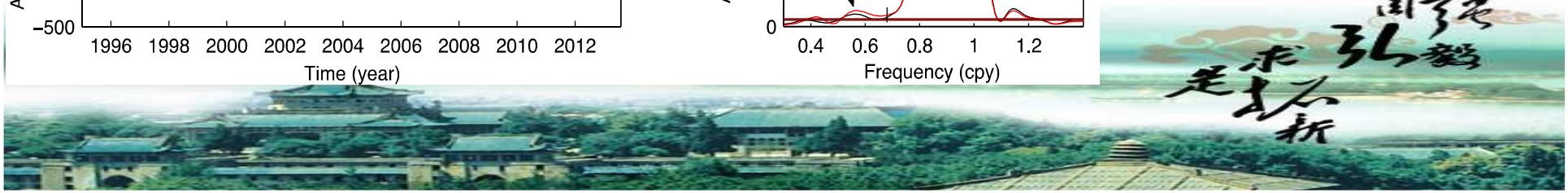


Fig.2 Three sub-series (Jan 1962-Dec 1977, Jan 1978-Dec 1994, Jan 1995-Jul 2013) from EOP C04 (1962-2013) and their corresponding amplitude spectra, using conventional Fourier analysis



固体地球物理专业
Solid Geophysics

2.2 Dataset

Table 1 Based on conventional Fourier approach [cannot find 531dW signals for subseries 1978-1994 and 1995-July 2013]

		Target Wobble		Chandler Wobble		Annual Wobble	
		Frequency	Amplitude	Frequency	Amplitude	Frequency	Amplitude
1962-1977	x-Component	0.68751±3.2e-4	**11.3±4.6**	0.84381±2.4e-4	129.2±3.3	1.00023±2.6e-4	97.1±4.1
	y-Component	0.68753±3.4e-4	**14.6±4.8**	0.84383±2.7e-4	129.2±3.2	1.00028±3.1e-4	90.8±3.9
1978-1994	x-Component	--	--	0.84312±1.7e-4	180.1±2.1	1.00031±2.4e-4	90.6±3.4
	y-Component	--	--	0.84314±1.8e-4	180.1±2.2	1.00029±2.7e-4	84.1±3.5
1995-Jul 2013	x-Component	--	--	0.83892±2.5e-4	128.0±3.4	1.00030±3.6e-4	100.8±4.5
	y-Component	--	--	0.83893±2.4e-4	128.2±3.2	1.00027±3.8e-4	91.8±5.1

3.1 The synthesis results

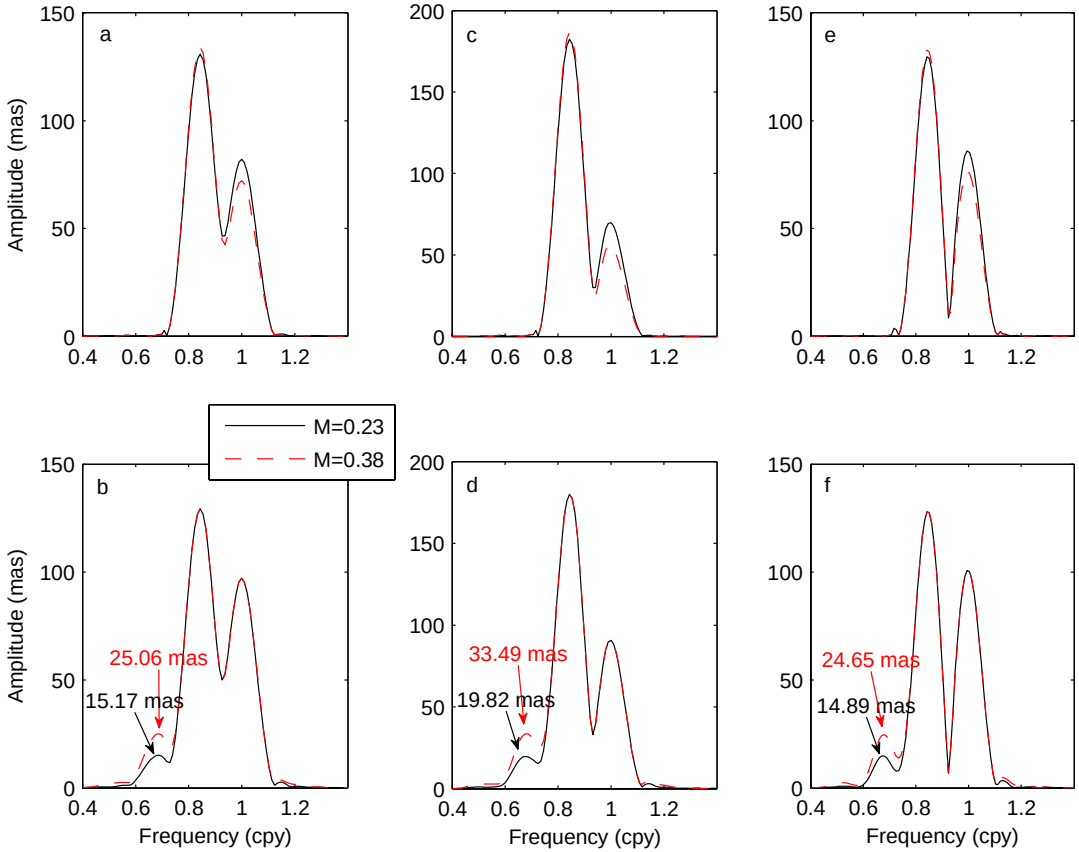
- As Carter (1981) suggested, the frequency modulation (**FM**) signal is expressed as follows:

$$e_t(x, y) = C_c \sin[\phi_0 + 2\pi f_c t + M \cdot \sin(2\pi f_m t)]$$

- Take *x*-components of three subsets as examples
- *fm*=0.157cpy

固体地球物理专业
Solid Geophysics

3.1 The synthesis results



- **Fig.3** The amplitude spectra of the synthetic records (noise-free) based on Fourier analysis. **a) and b), c) and d), and e) and f)** for the *x*-components of the **1962-1977 series, 1978-1994 series, and 1995-Jul 2013 series**, respectively.
- Top figures: without FM
- Bottom figures: with FM

固体地球物理专业
Solid Geophysics

3.1 The synthesis results

- Table 2 Synthetic results with FM considered

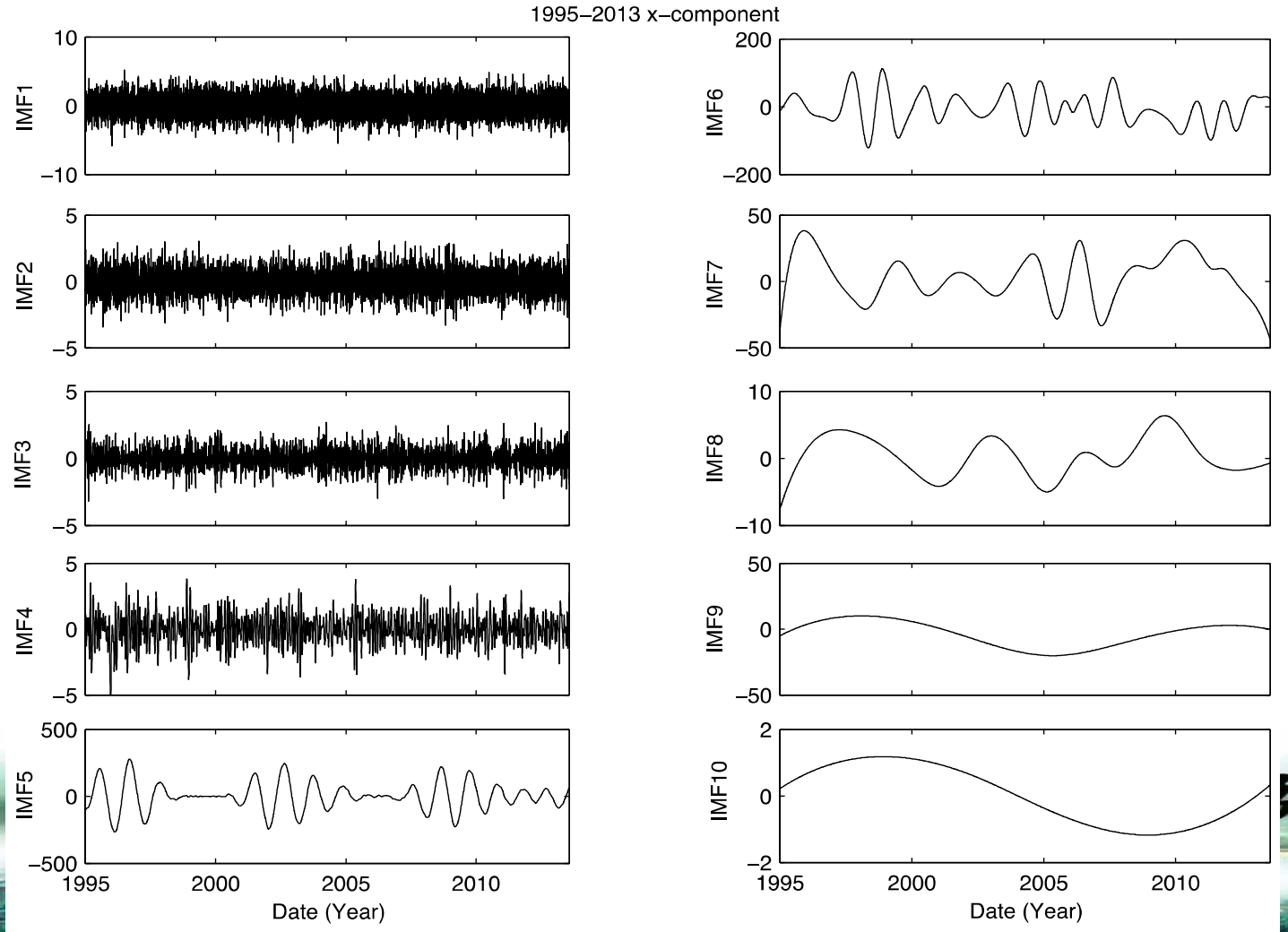
M		Synthetic (input)		Synthetic (output)			Observation
		CW	AW	CW	AW	531dW	531dW
0.23	1962-1977	130.9	82.06	**129.2**	97.1	15.17	11.3±4.6
	1978-1994	181.9	68.25	**180.1**	90.6	19.82	0
	1995-Jul 2013	129.5	85.4	**128.0**	100.8	14.89	0
0.38	1962-1977	133.9	72.03	**129.2**	97.1	25.06	11.3±4.6
	1978-1994	186.3	54.23	**180.1**	90.6	33.49	0
	1995-Jul 2013	132.6	75.6	**128.0**	100.8	24.65	0

- Figure 2 and Table 2 show that the modulation index M=0.23 or 0.38 of CW (suggested by Carter [1981]) did not coincide with observed results from the three sub-series. However, if we choose variable Ms, one may explain the observed results. The problem is the mechanism

固体地球物理专业
Solid Geophysics

3.2 Results from EEMD

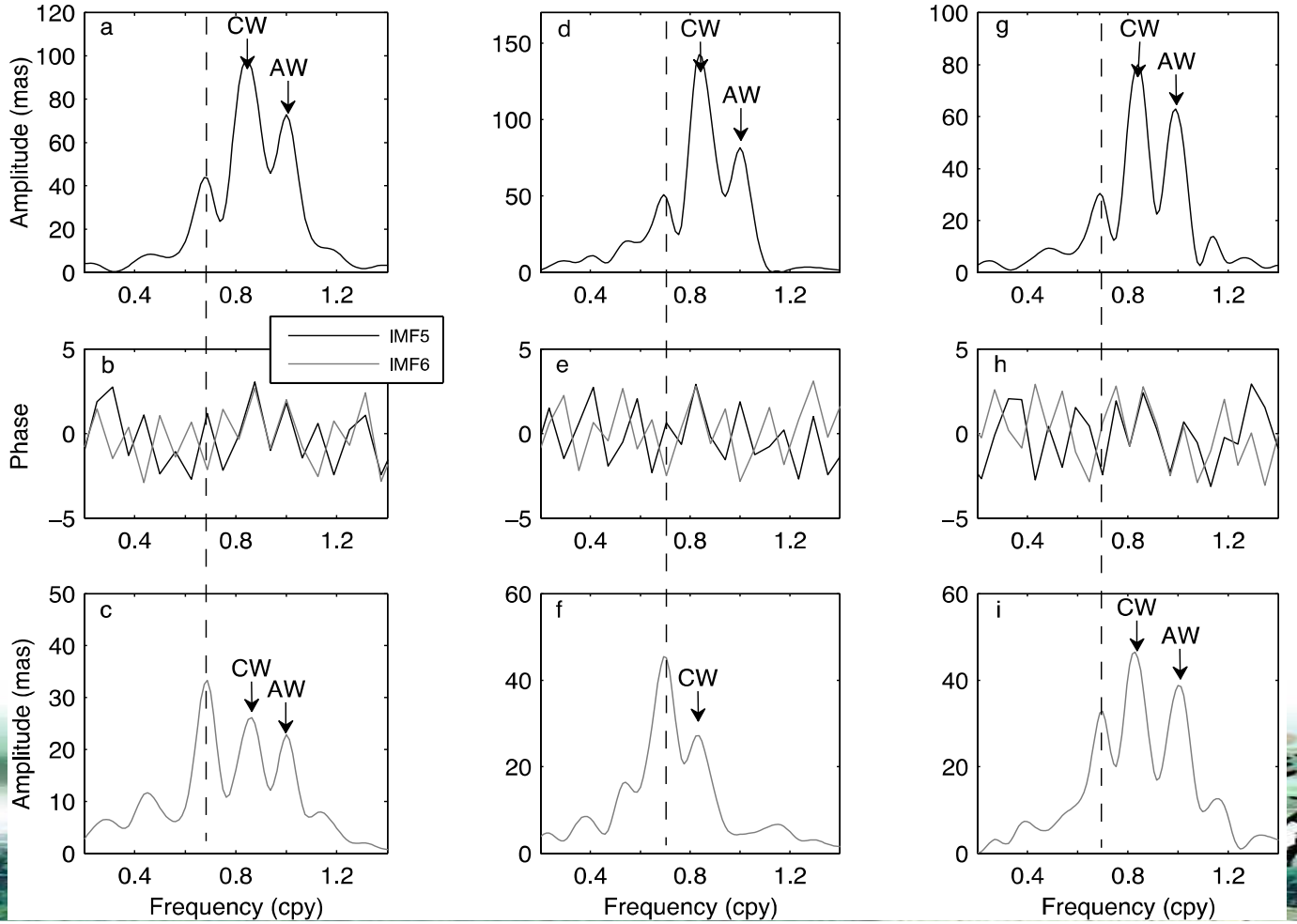
Fig.4 The first 10 IMFs of the *x*-component of the 1995-Jul 2013 series.



固体地球物理专业
Solid Geophysics

3.2 Results from EEMD

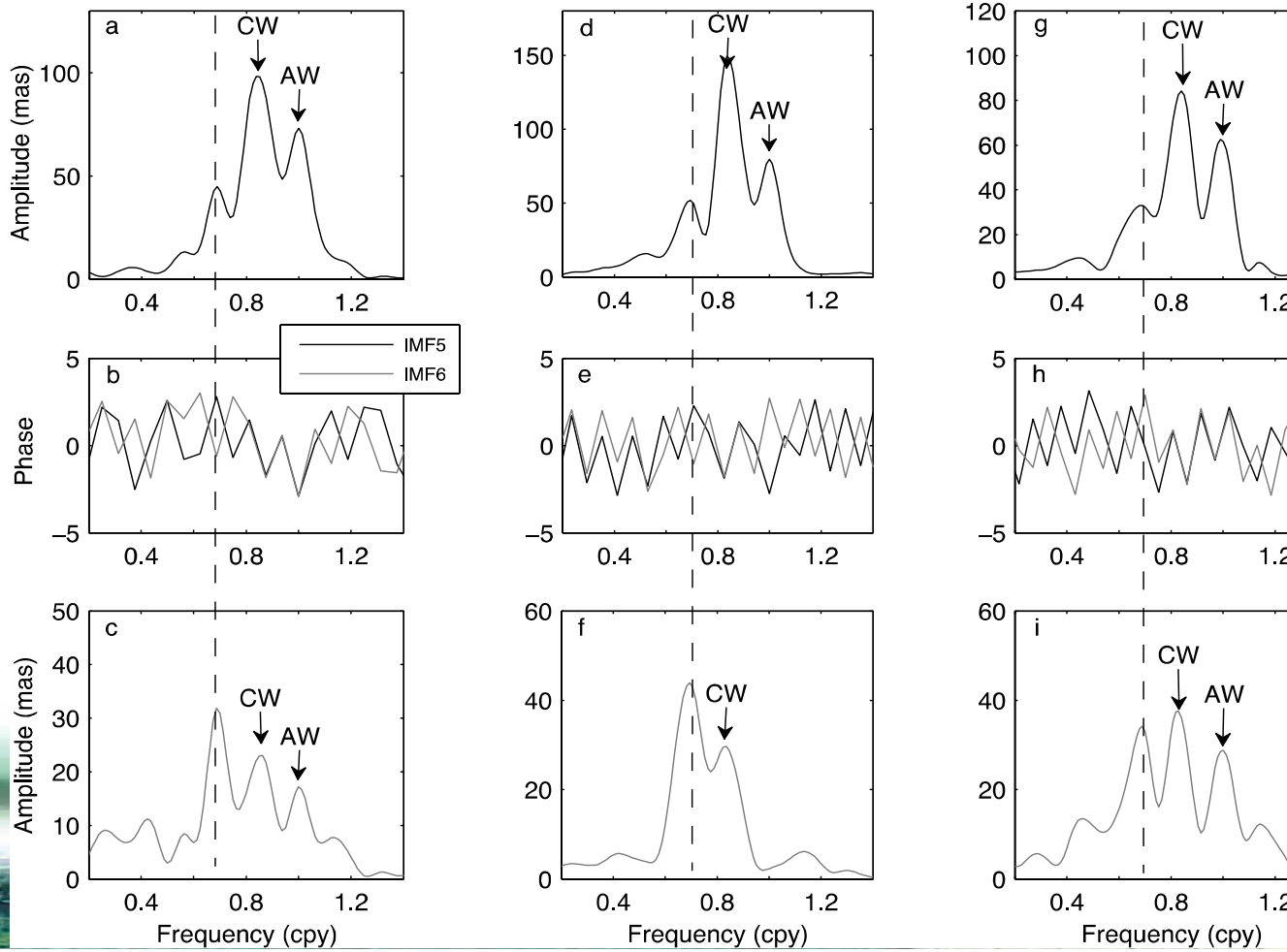
Fig 5. Amplitudes and phase spectra (middle slots) of the IMF 5 (top slots) and IMF 6 (bottom slots) of the ***x*-components** of the three sub-series after using EEMD. **a)-c), d)-f) and g)-i)** for **1962-1977, 1978-1994 and 1995-Jul 2013** series respectively. The vertical dashed lines denote the possible spectral peaks for the 531dW.



固体地球物理专业
Solid Geophysics

3.2 Results from EEMD

Fig 6. Amplitudes and phase spectra (middle slots) of the IMF 5 (top slots) and IMF 6 (bottom slots) of the **y-components** of the three sub-series after using EEMD. **a)-c), d)-f) and g)-i)** for **1962-1977, 1978-1994 and, 1995-Jul 2013** series respectively. The vertical dashed lines denote the possible spectral peaks for the 531dW.



固体地球物理专业
Solid Geophysics

3.2 Results from EEMD

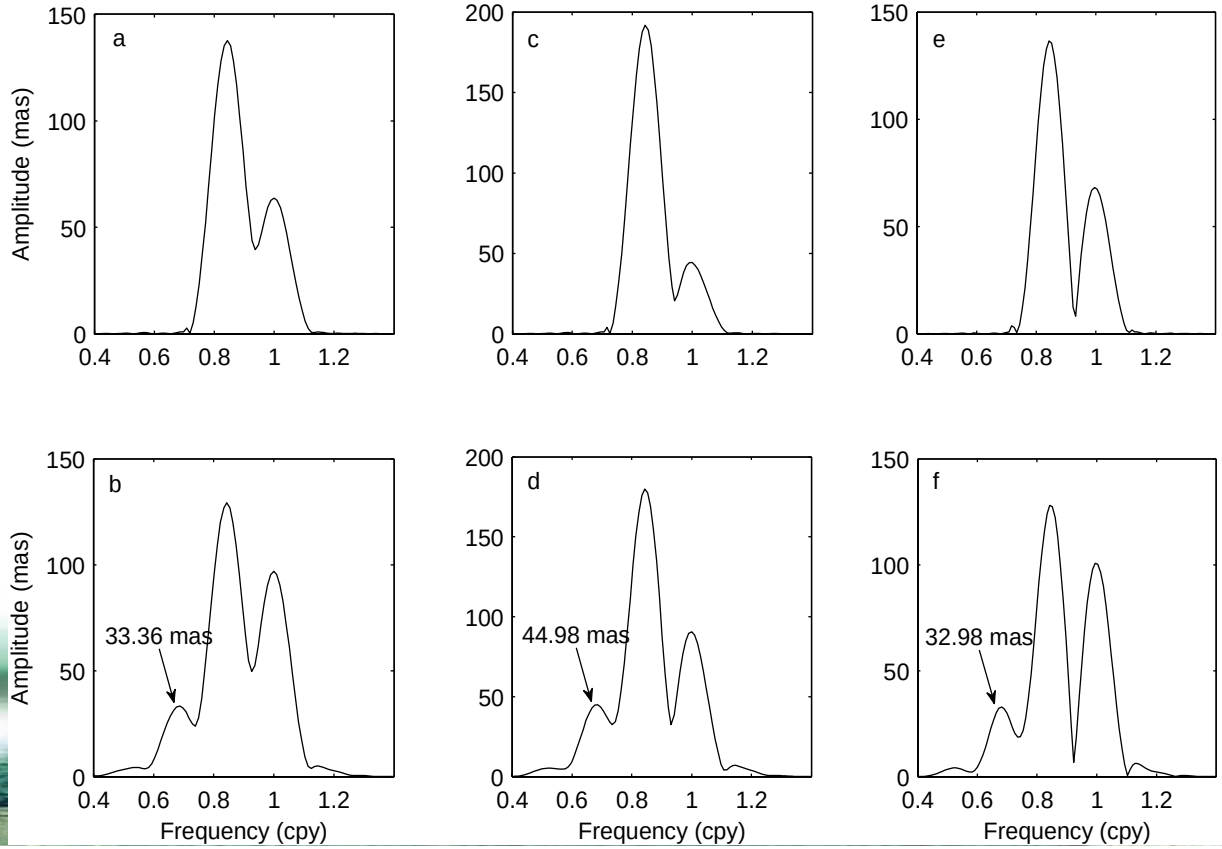
- Table 3 The observed frequencies (cpy) and amplitudes (mas) of the CW, AW and the target wobble, based on EEMD.

		Target Wobble		Chandler Wobble		Annual Wobble	
		Frequency	Amplitude	Frequency	Amplitude	Frequency	Amplitude
1962-1977	**x-IMF5**	**0.68749±3.4e-4**	**44.1±5.1**	0.84380±2.6e-4	103.6±3.4	1.00019±3.1e-4	73.1±4.5
	x-IMF6	**0.68750±4.7e-4**	**33.2±7.5**	0.84381±9.8e-4	25.1±7.9	1.00021±9.9e-4	24.6±8.3
	y-IMF5	0.68752±3.6e-4	44.9±5.3	0.84384±2.8e-4	104.0±3.3	1.00027±3.3e-4	73.2±4.7
	y-IMF6	0.68753±4.5e-4	32.7±7.3	0.84384±1.0e-3	23.8±8.2	1.00031±1.2e-3	18.5±9.0
1978-1994	x-IMF5	0.69614±3.5e-4	**50.0±4.0**	0.84311±2.1e-4	145.5±2.6	1.00027±3.0e-4	83.9±3.5
	x-IMF6	0.69611±3.7e-4	**45.3±5.3**	0.84309±7.2e-4	27.2±6.7	--	--
	y-IMF5	0.69617±3.7e-4	50.5±3.9	0.84316±2.0e-4	153.3±2.5	1.00028±3.2e-4	82.0±3.7
	y-IMF6	0.69613±3.9e-4	44.1±4.2	0.84314±6.4e-4	29.9±5.9	--	--
1995-Jul 2013	x-IMF5	0.68644±4.9e-4	**31.2±7.0**	0.83895±3.1e-4	81.1±4.5	1.00025±4.3e-4	63.0±5.3
	x-IMF6	0.68646±7.7e-4	**33.3±6.9**	0.83893±6.8e-4	46.6±5.8	1.00031±7.4e-4	39.2±6.7
	y-IMF5	0.68648±4.7e-4	32.8±6.5	0.83897±2.9e-4	86.6±4.1	1 .00027±4.1e-4	63.6±5.7
	y-IMF6	0.68644±6.1e-4	33.3±6.4	0.83894±5.4e-4	37.9±5.5	1.00031±7.4e-4	28.5±6.6

固体地球物理专业
Solid Geophysics

3.3 Synthetic results with and without considering FM, based on conventional approach

Fig 7. Amplitude spectra of synthetic series. a) and b), c) and d), and e) and f) from the ***x*-component** of the 1962-1977, 1978-1994, and 1995-Jul 2013 series, respectively. Top figures: without considering frequency modulation (FM) ; Bottom figures: considering FM, with modulation index *M* =0.5. Synthetic results considering only FM (without considering excitation) coincide with the IMF6 observations.



531dW	x-IMF6
1962-1978	33.2±7.5
1979-1995	45.3±5.3
1996-2013	33.3±6.9

固体地球物理专业
Solid Geophysics

3.3 Results Comparison

- We generate two synthetic noise-free time series. The length of them is equal to that of the 1962-1977 series, and the sampling interval is still one day.
- Synthetic series I :

  CW (0.8437 cpy and 137.6 mas)

  AW (1.00 cpy and 63.7 mas)

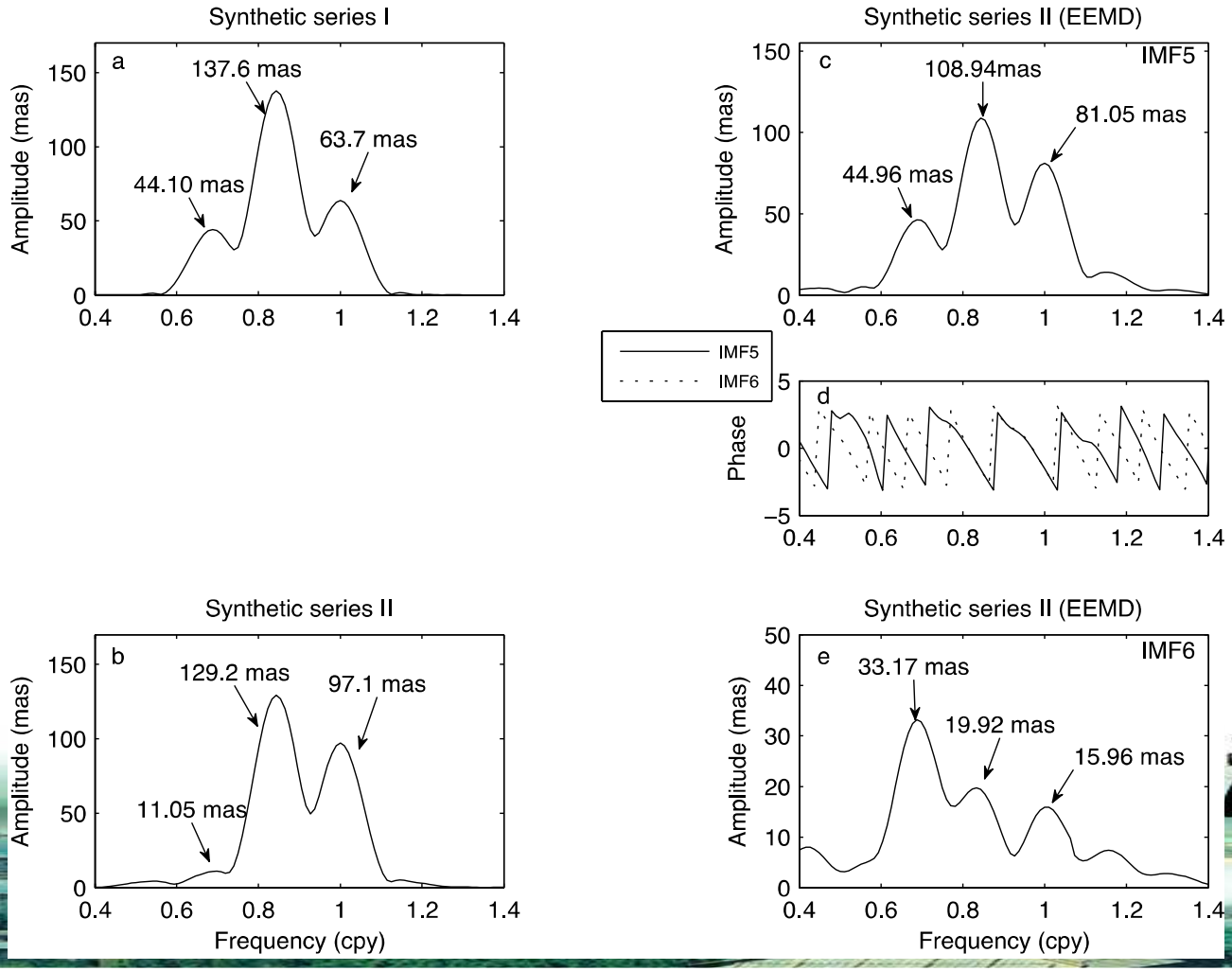
  531dW (0.6875cpy and 44.1 mas)
- Synthetic series II:

  Same parameters as synthetic series I, but a frequency modulation (FM) of CW is considered, with modulation index M=0.5.

固体地球物理专业
Solid Geophysics

3.3 Results Comparison

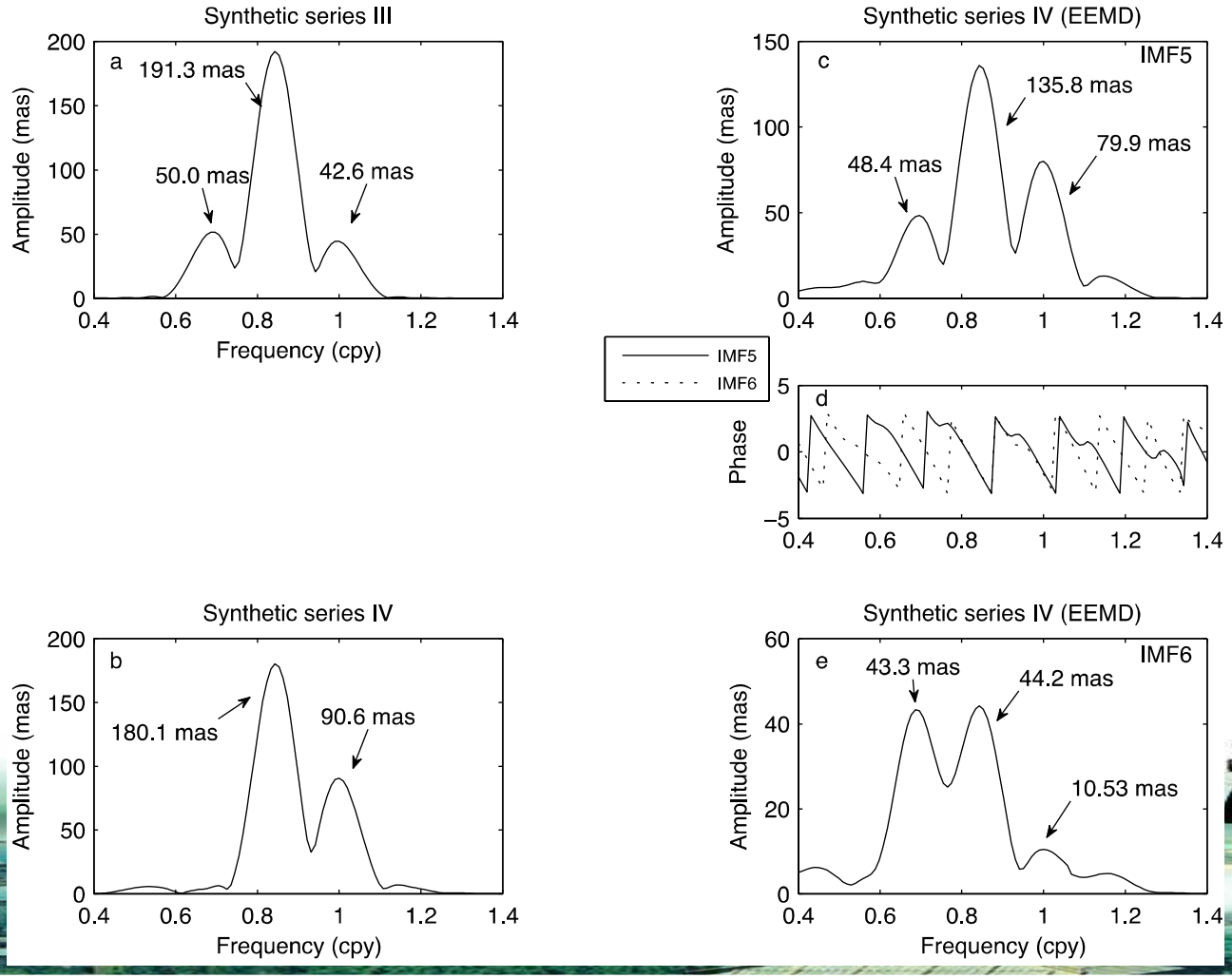
Fig8. The spectra of the synthetic **1962-1977 series** I (a, without FM) and II (b, considering FM with M=0.5); and the spectra of the IMF5 and IMF6 of the synthetic series II after using EEMD (c-e). The amplitudes of the significant peaks (from left to right: 531dW, CW, AW) are marked by the arrows.



固体地球物理专业
Solid Geophysics

3.3 Results Comparison

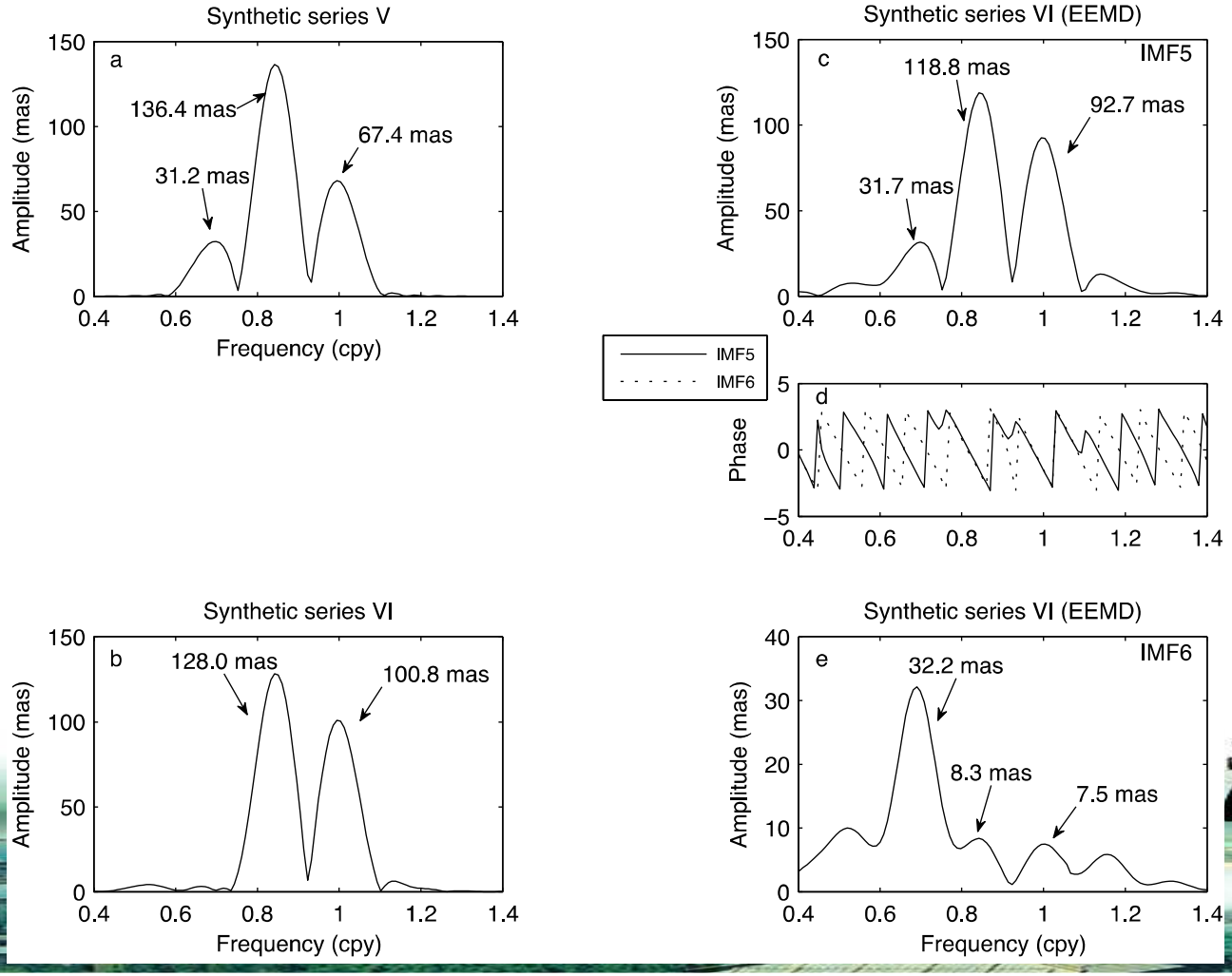
Fig9. The spectra of the synthetic **1978-1994 series** III (a, without FM) and IV (b, considering FM with M=0.5); and the spectra of the IMF5 and IMF6 of the synthetic series IV after using EEMD (c-e). The amplitudes of the significant peaks (from left to right: 531dW, CW, AW) are marked by the arrows.



固体地球物理专业
Solid Geophysics

3.3 Results Comparison

Fig 10. The spectra of the synthetic **1995-Jul 2013 series** V (a, without FM) and VI (b, considering FM with M=0.5); and the spectra of the IMF5 and IMF6 of the synthetic series VI after using EEMD (c-e). The amplitudes of the significant peaks (from left to right: 531dW, CW, AW) are marked by the arrows.



固体地球物理专业
Solid Geophysics

4. Discussion

1. Applying EEMD, a 531dW signal was detected
2. Its amplitude and frequency may vary
3. It could be frequency-modulated
4. This study might explain why it is difficult to find 531dW in recent decades
5. The mechanism is still open

Thank you for your attention!