Prediction of the Chandler wobble

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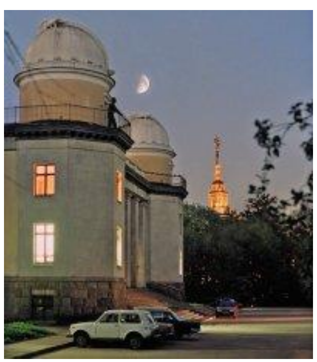
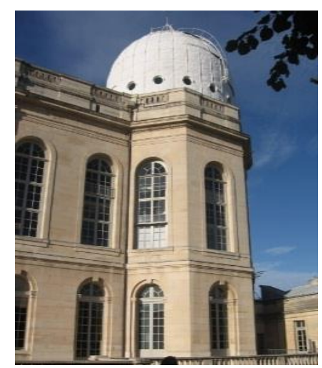
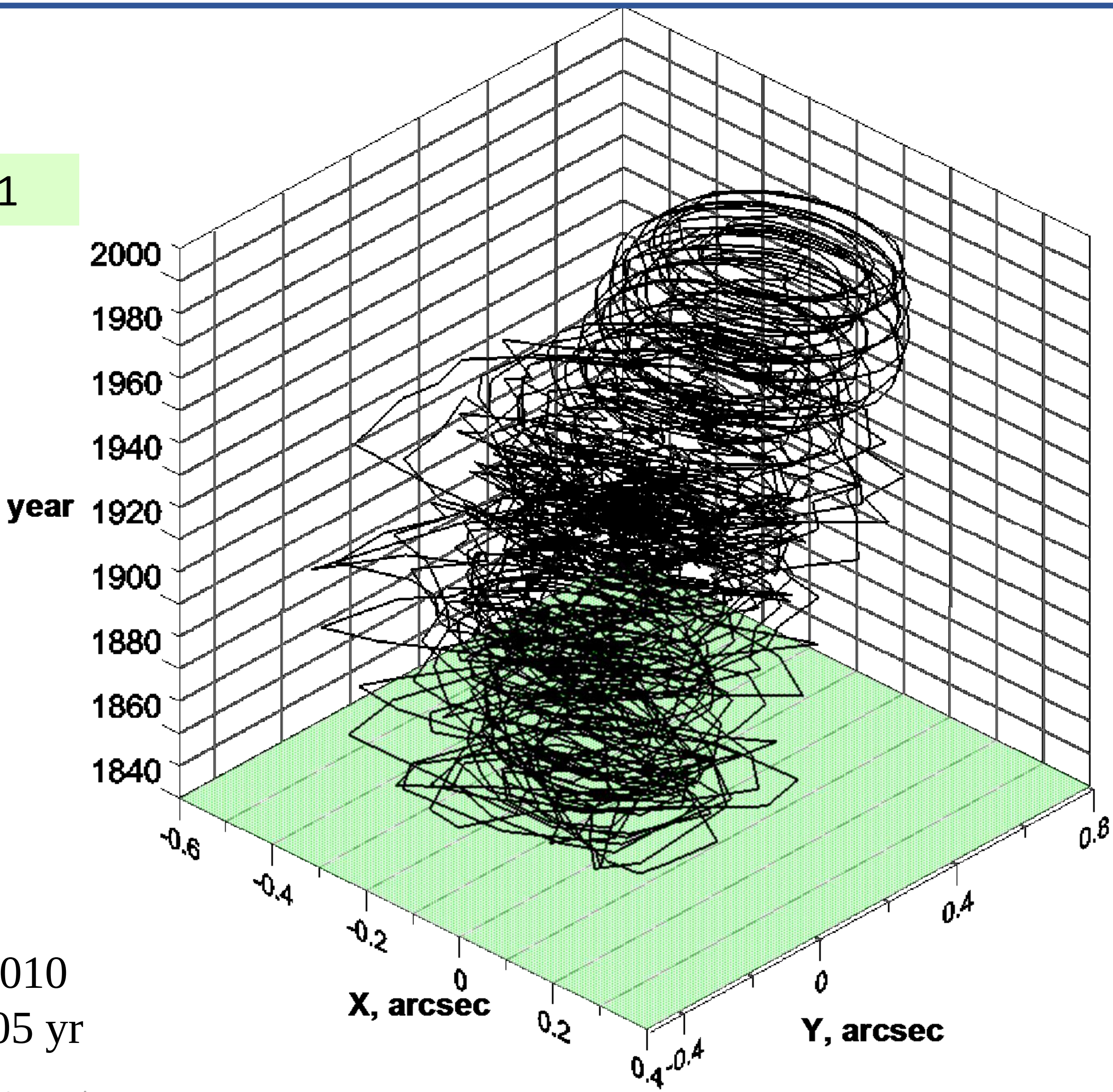




Journees
Pulkovo Observatory (GAO)
22-24 September 2014

Motion of the Earth's pole

EOP CO1



2D trajectory

$$m(t) = x - iy$$

1846-2010
step 0.05 yr

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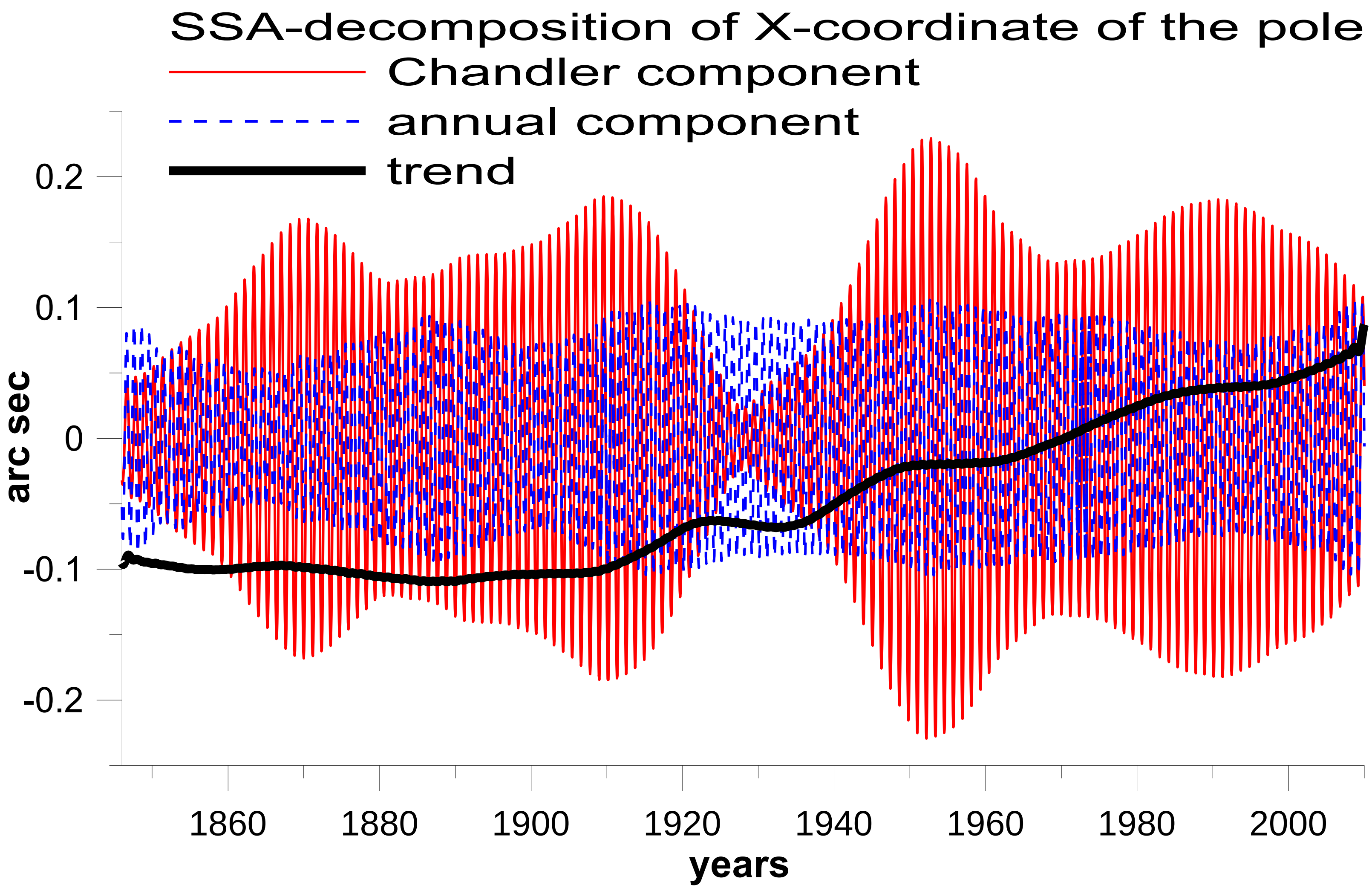
Complex Singular Spectrum Analysis (CSSA) of the Polar Motion



X-component (Y – similar, with π/2 phase shift).

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Dynamical model of the rotating Earth

$$\frac{i}{\sigma_c}\frac{dm(t)}{dt}+m(t)=\Psi(t)$$

$$m=m_1+im_2$$

$$\Psi=\Psi_{mass}+\Psi_{motion}$$

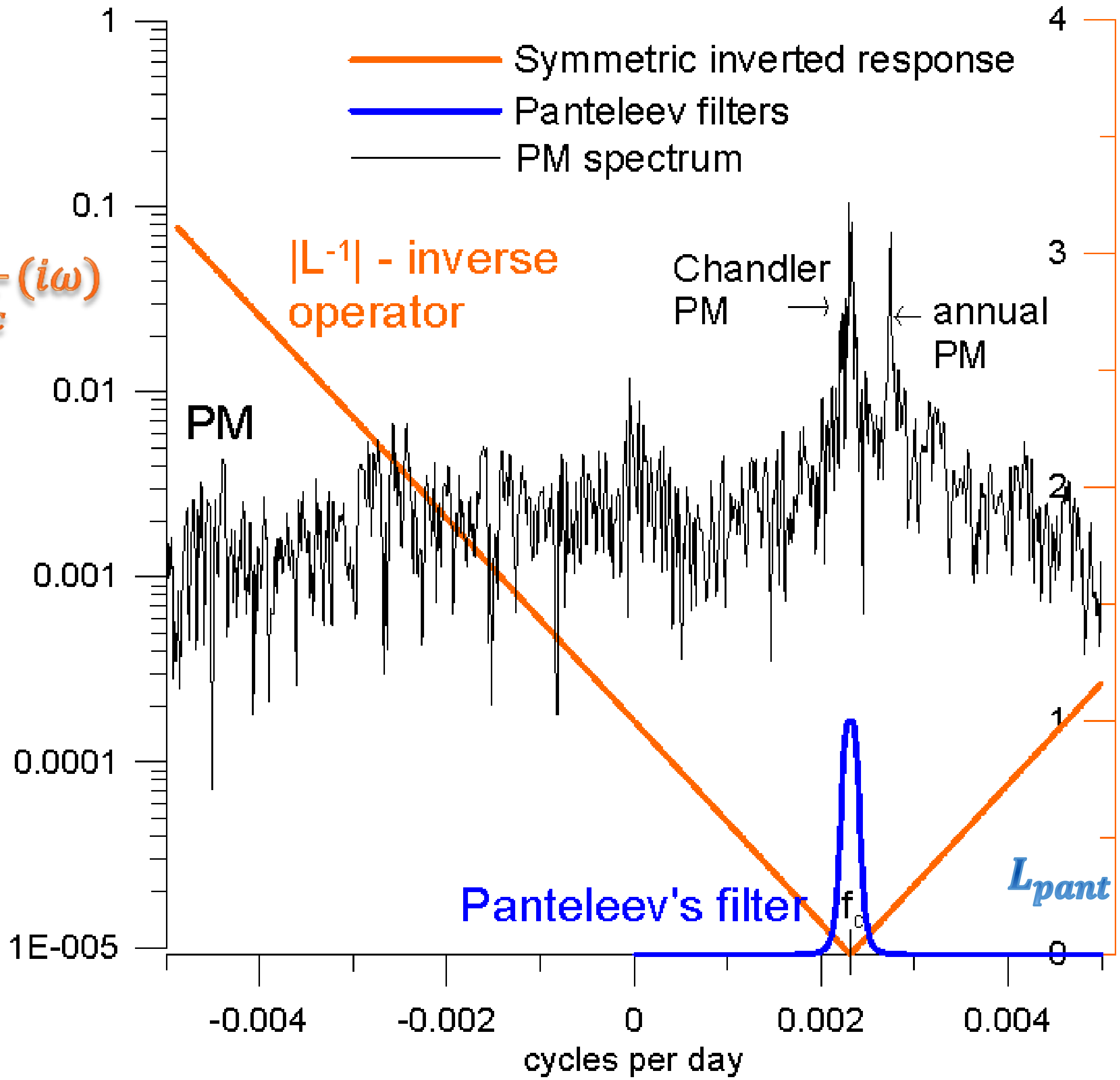
$$\sigma_c=2\pi f_c(1+i/2Q)$$

$$f_c=\frac{1}{433}\ \text{days}^{-1} \qquad Q=175$$

Munk W.H., MacDonald G.J.F., The rotation of the Earth, 1960

Filters' transfer functions and PM spectrum

$$L^{-1} = 1 + \frac{i}{2\pi f_c}(i\omega)$$



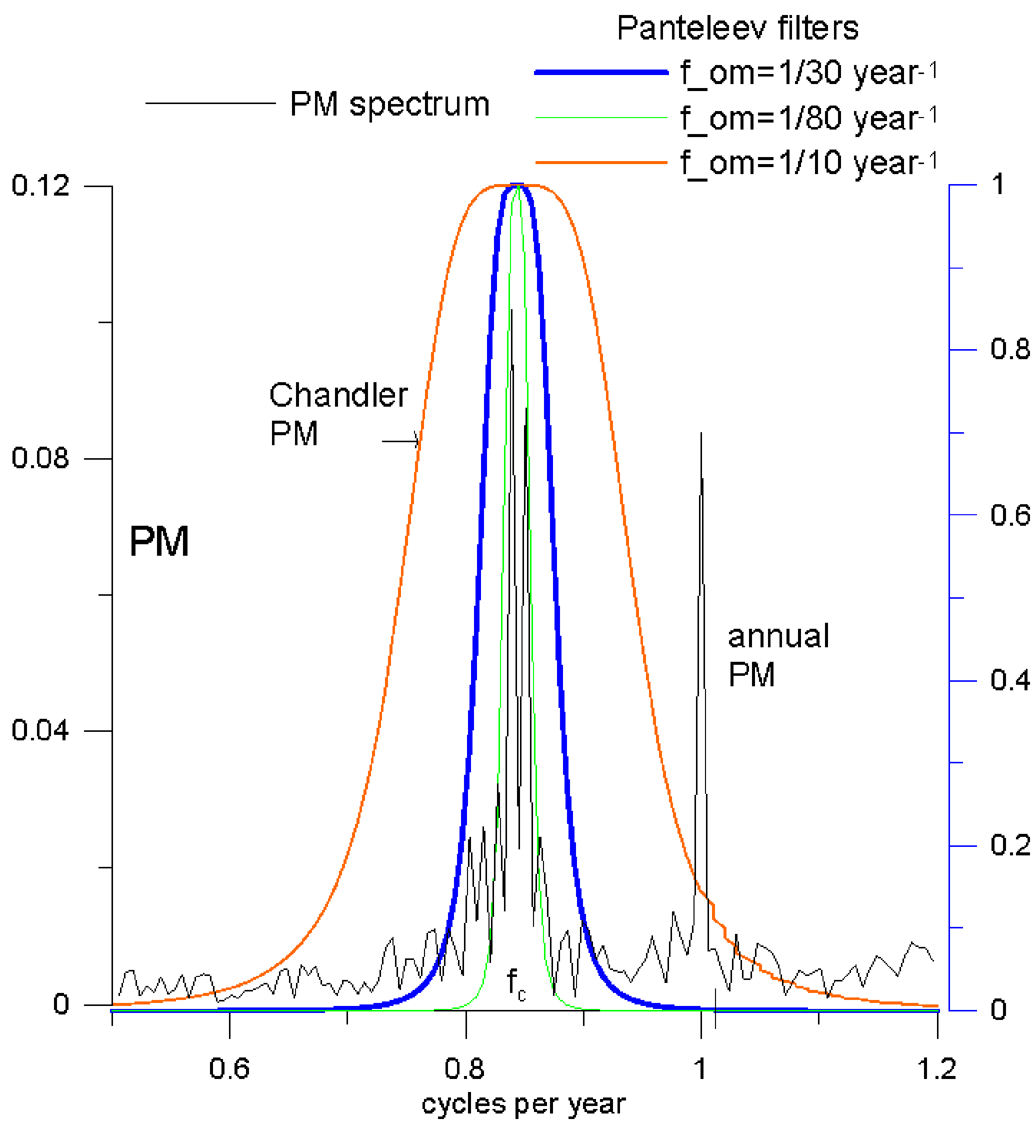
f_0=1/30 YR^{-1}

$$L_{pant} = \frac{f_0^{\,4}}{(f - f_c)^4 + f_0^{\,4}}$$

What is Chandler wobble?

Complex Fourier spectrum represents the signal by the set of constant harmonics, but it incorporates information about changes of instantaneous amplitude and phase

Filtering in time domain – convolution



Filtering in frequency domain – spectra multiplication

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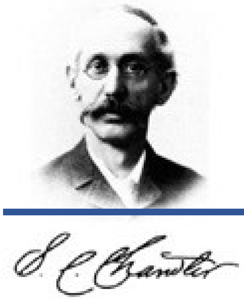
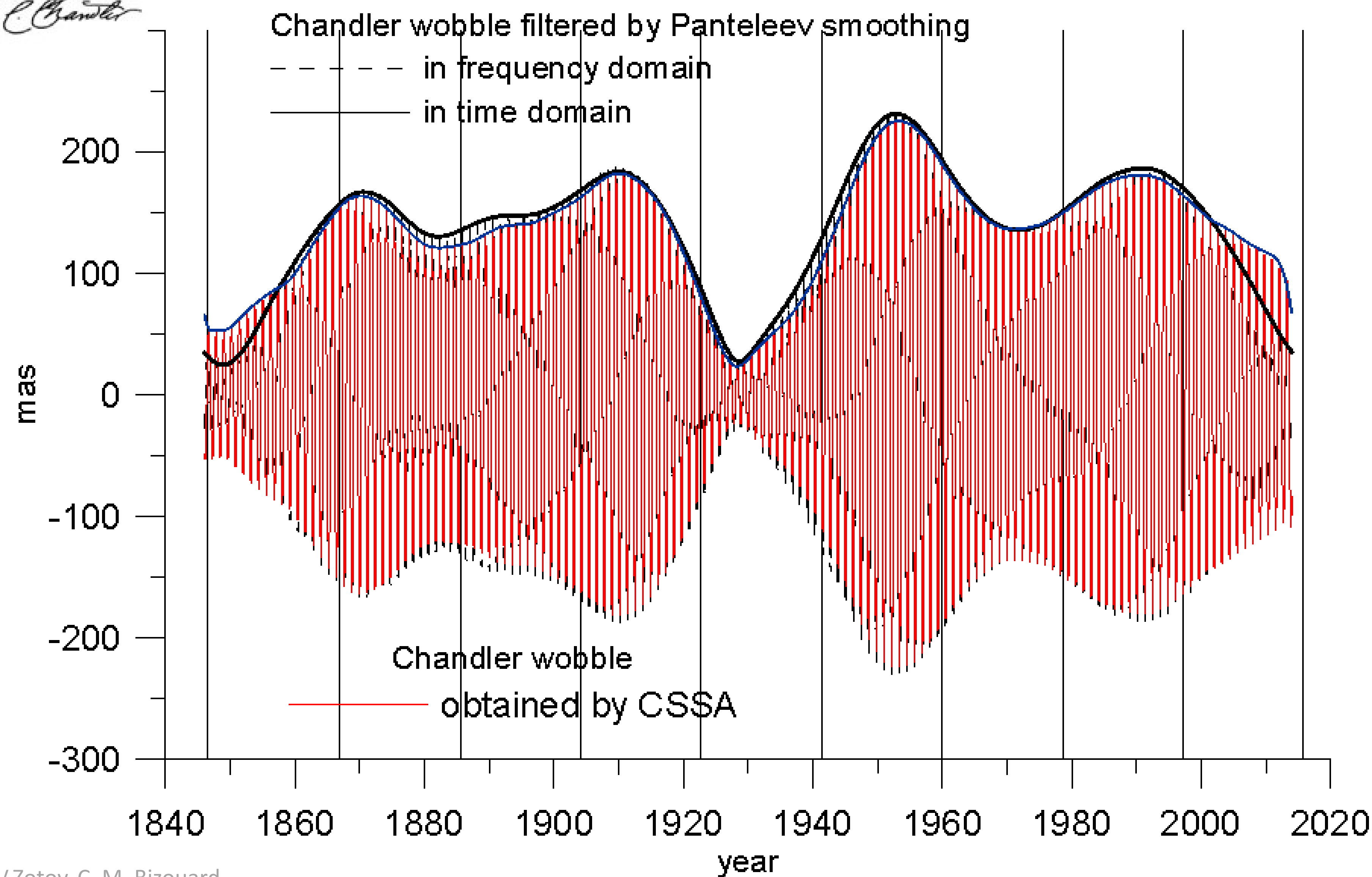


Filtered Chandler wobble

X-component (Y – similar, with π/2 phase shift).



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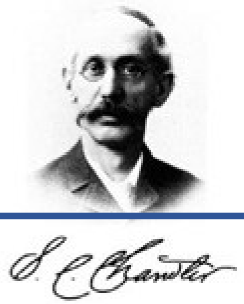
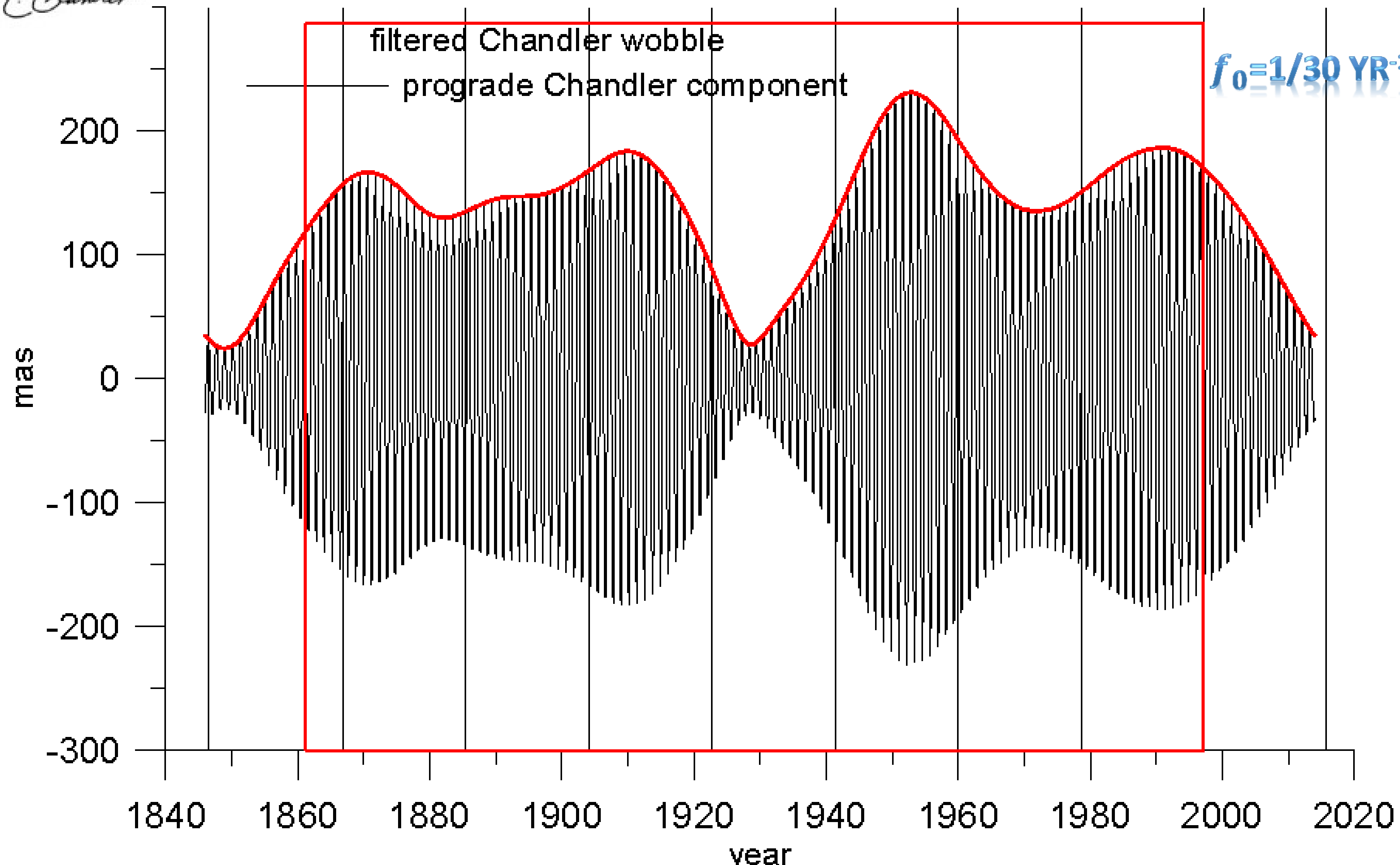
Chandler wobble and its excitation

X-component (Y – similar, with π/2 phase shift).





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Chandler wobble and its excitation

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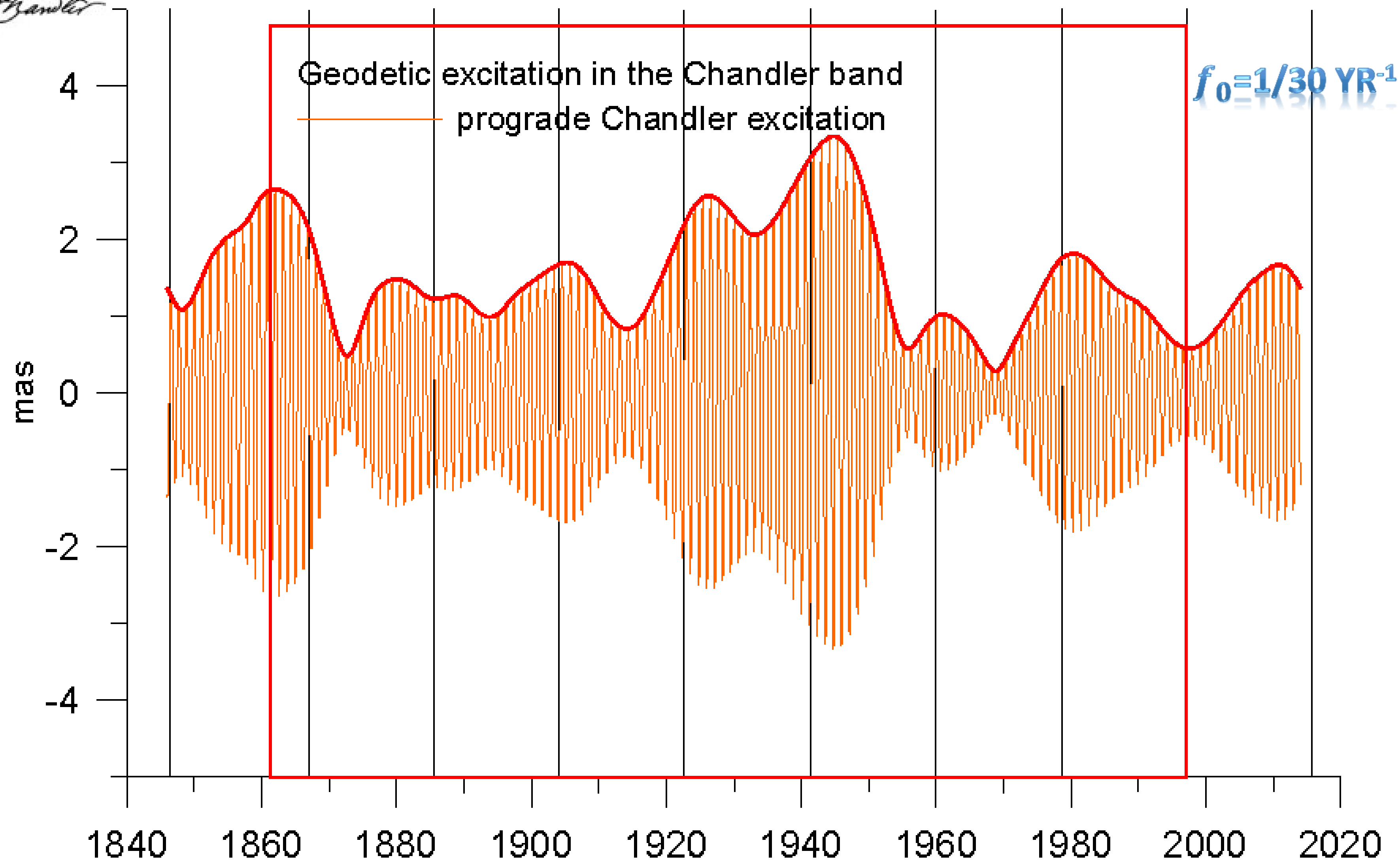

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Envelope can be transferred through the dynamical model

$$\frac{i}{\sigma_c}\frac{dm(t)}{dt}+m(t)=\Psi(t)$$

$$m(t)=\boxed{A(t)e^{i\varphi(t)}}e^{i\omega_c t} \qquad \Psi(t)=\boxed{E(t)e^{i\vartheta(t)}}e^{i\omega_c t}$$

$$E(t)e^{i\vartheta(t)}e^{-i\varphi(t)}=$$

$$=\frac{i}{\sigma_c}\left(\dot{A}(t)+i\dot{\varphi}(t)A(t)\right)+\left(1-\frac{\omega_c}{\sigma_c}\right)A(t)$$

$\omega_c = 2\pi f_c$ $\sigma_c = 2\pi f_c(1+i/2Q)$ $f_c = \frac{1}{433}$ days^{-1} $Q = 175$

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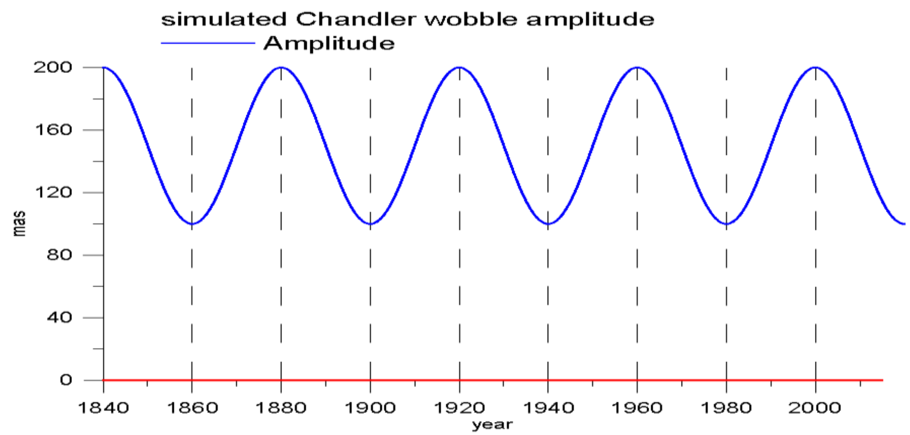
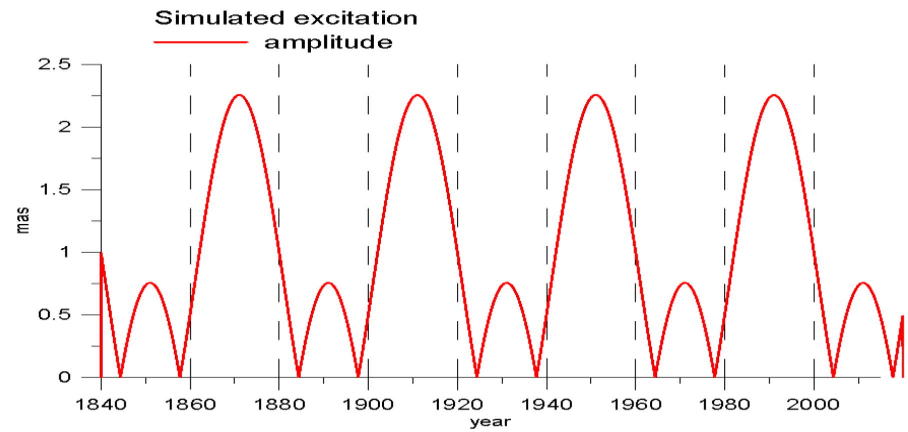
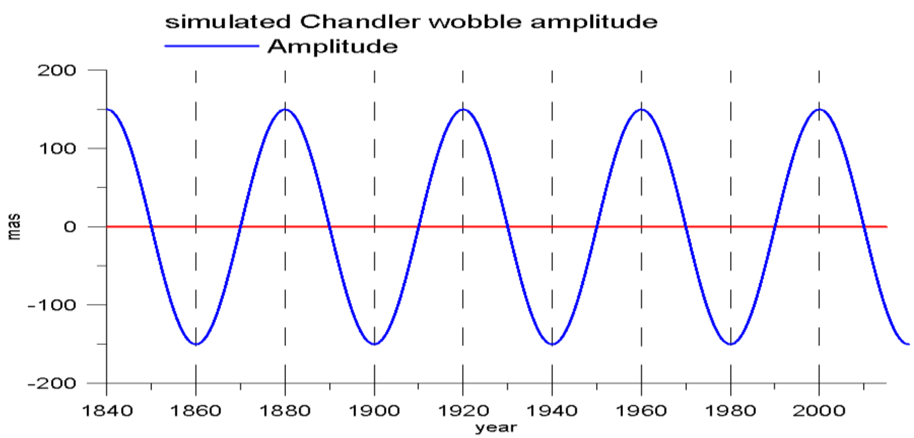
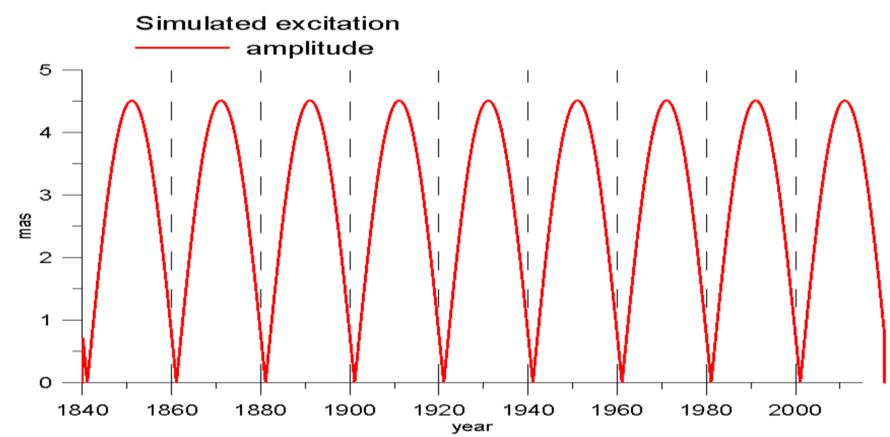
40-year PM changes will give 20-year oscillations in the excitation envelope

$A(t)=\sin(\omega t)$ → $E(t) \sim |\cos(\omega t)|$









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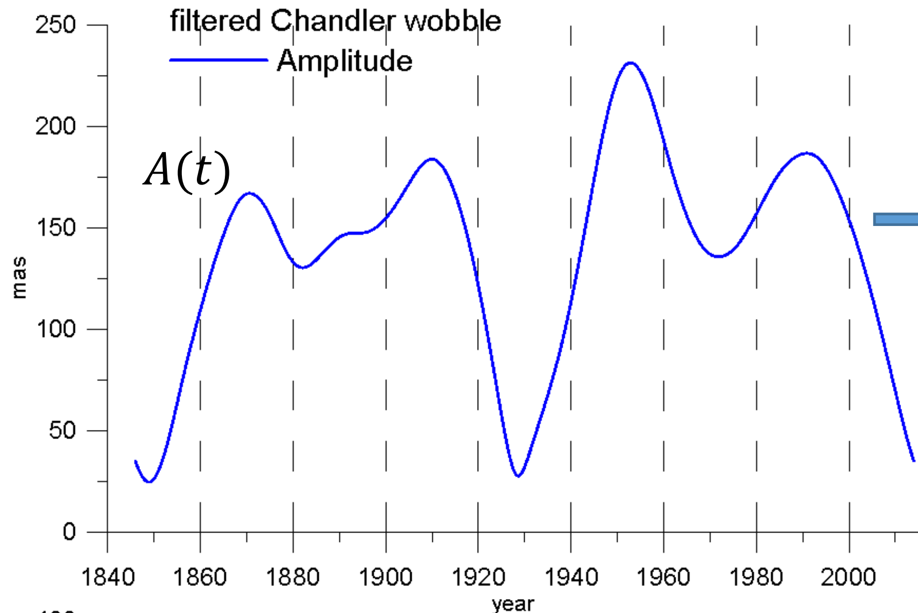
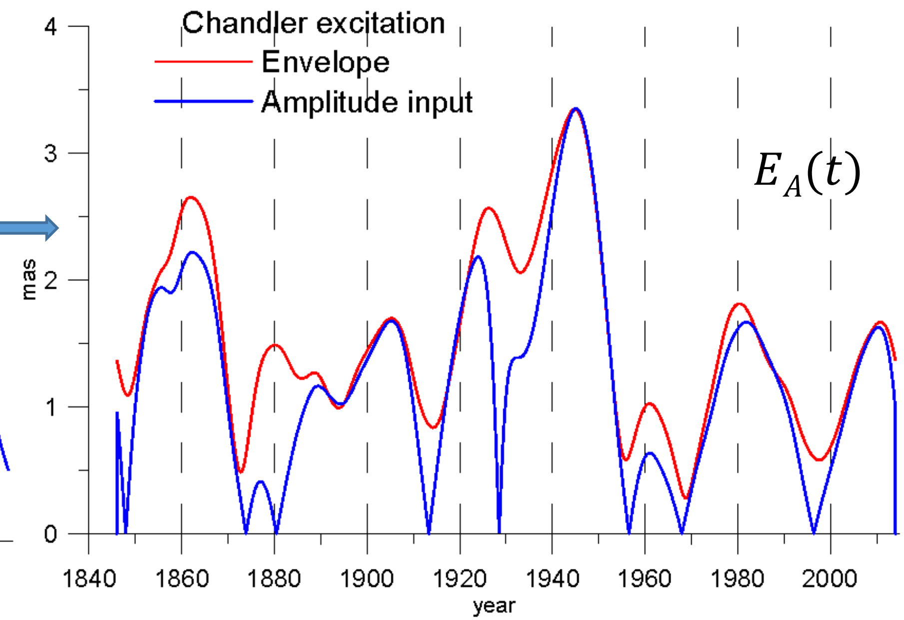
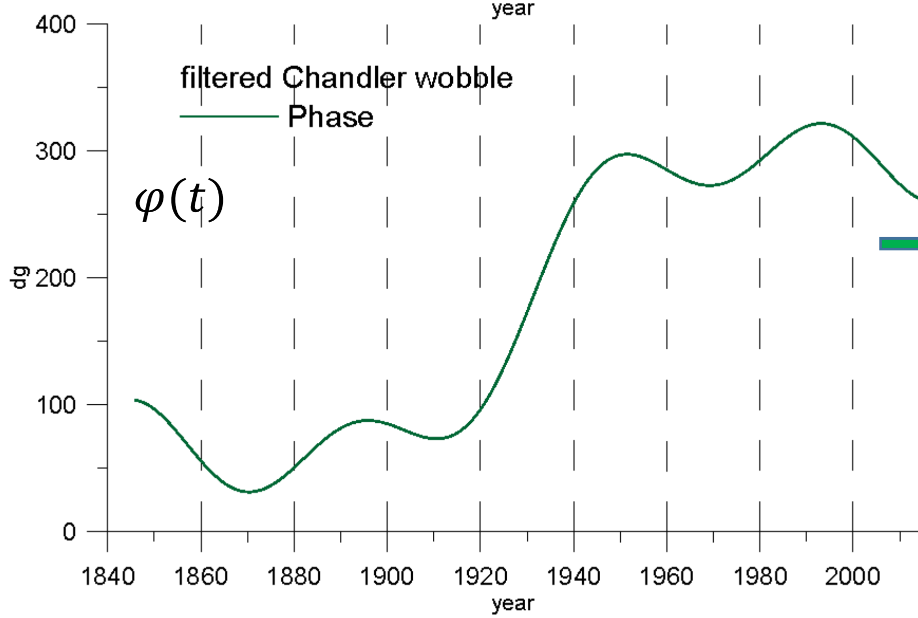
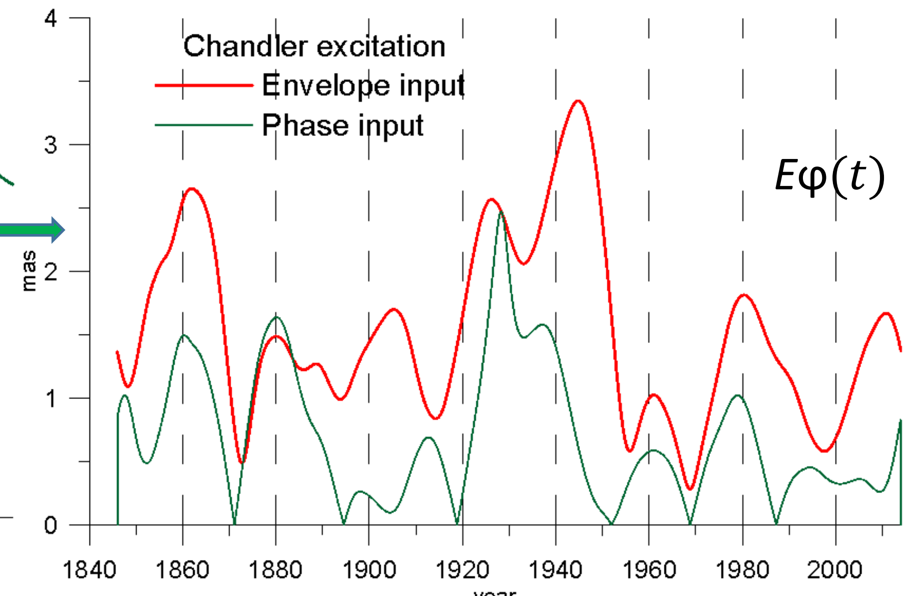
Envelope calculation









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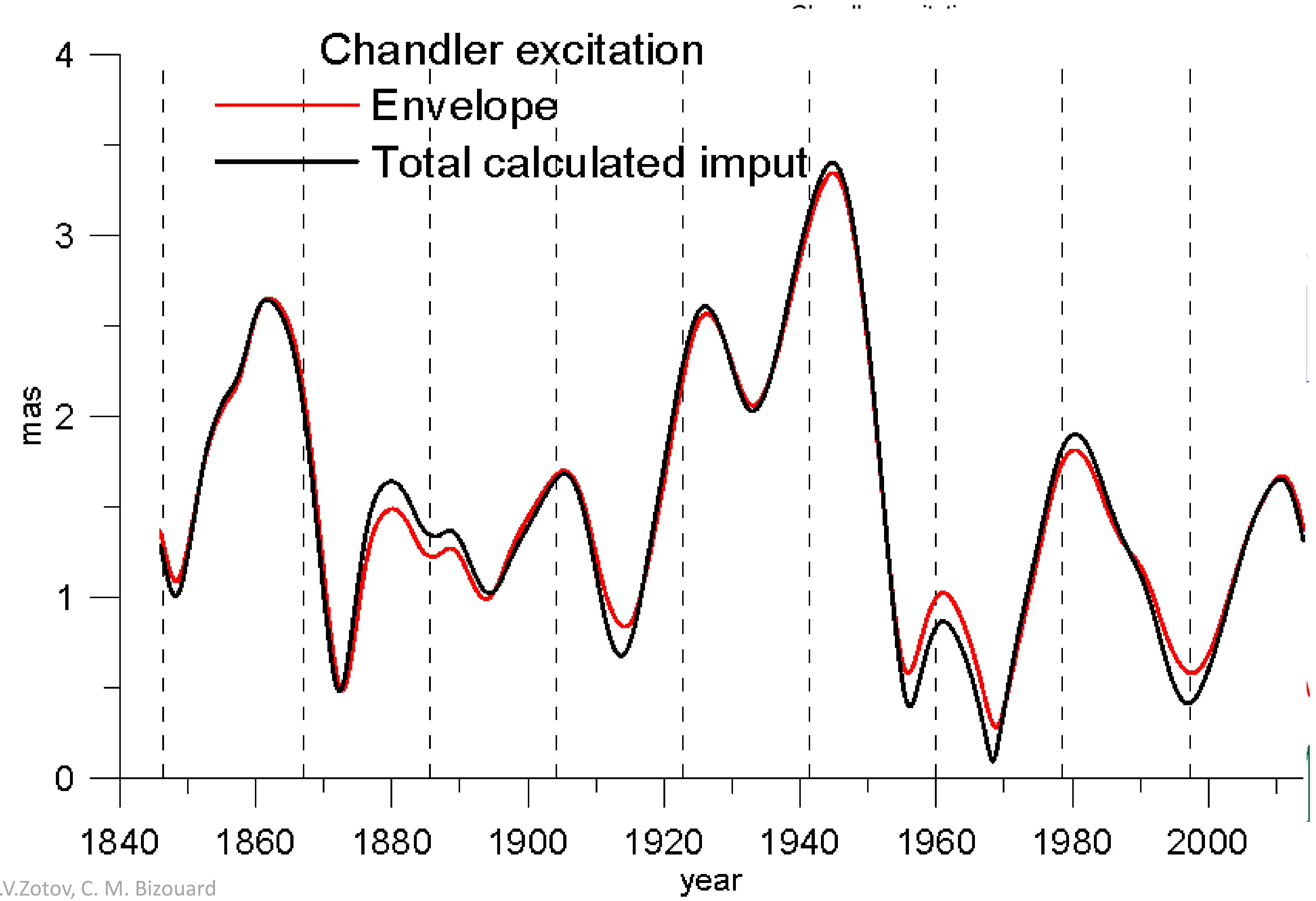
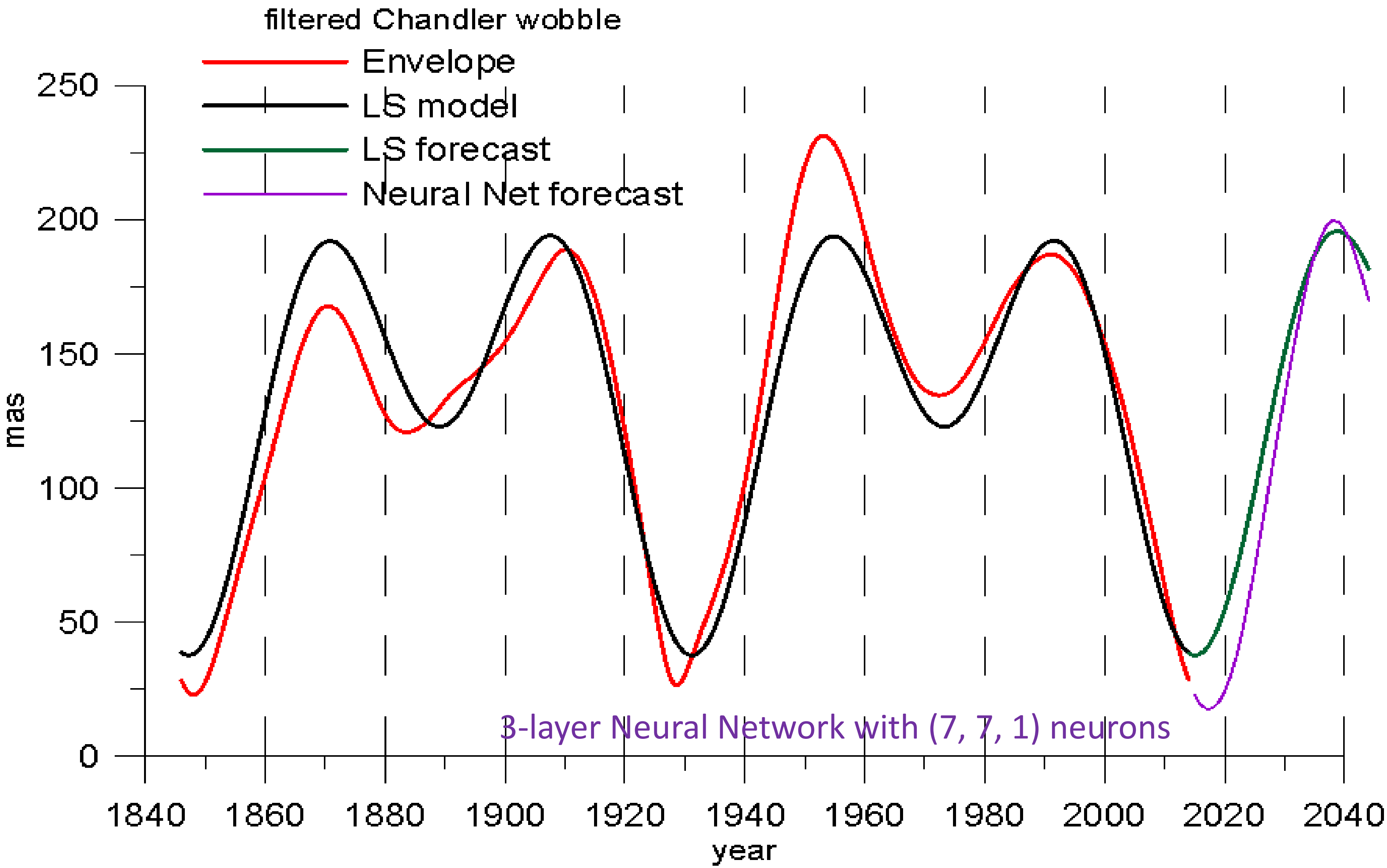
Envelope calculation



Amplitude model and forecast



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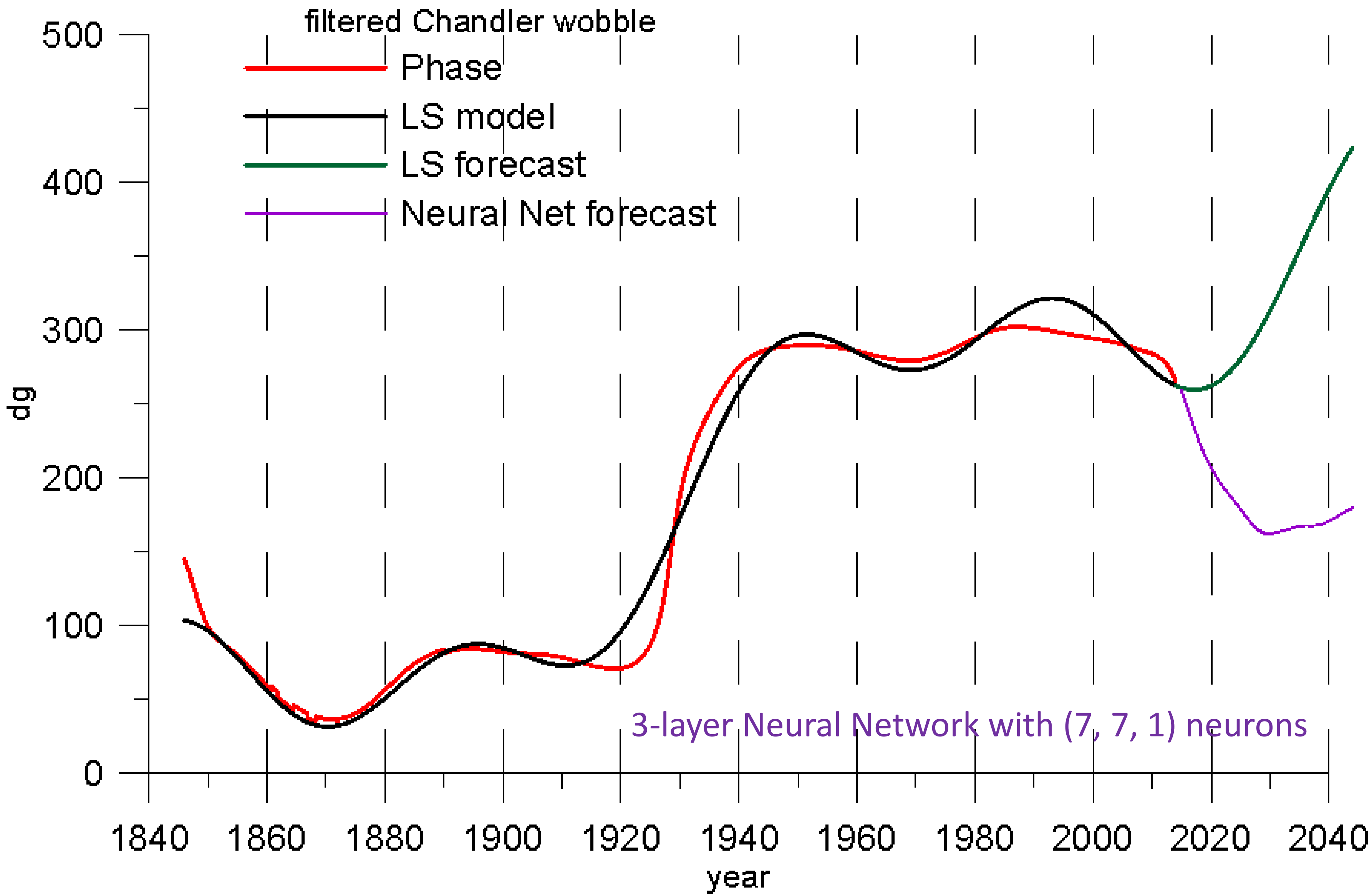
Phase model and forecast



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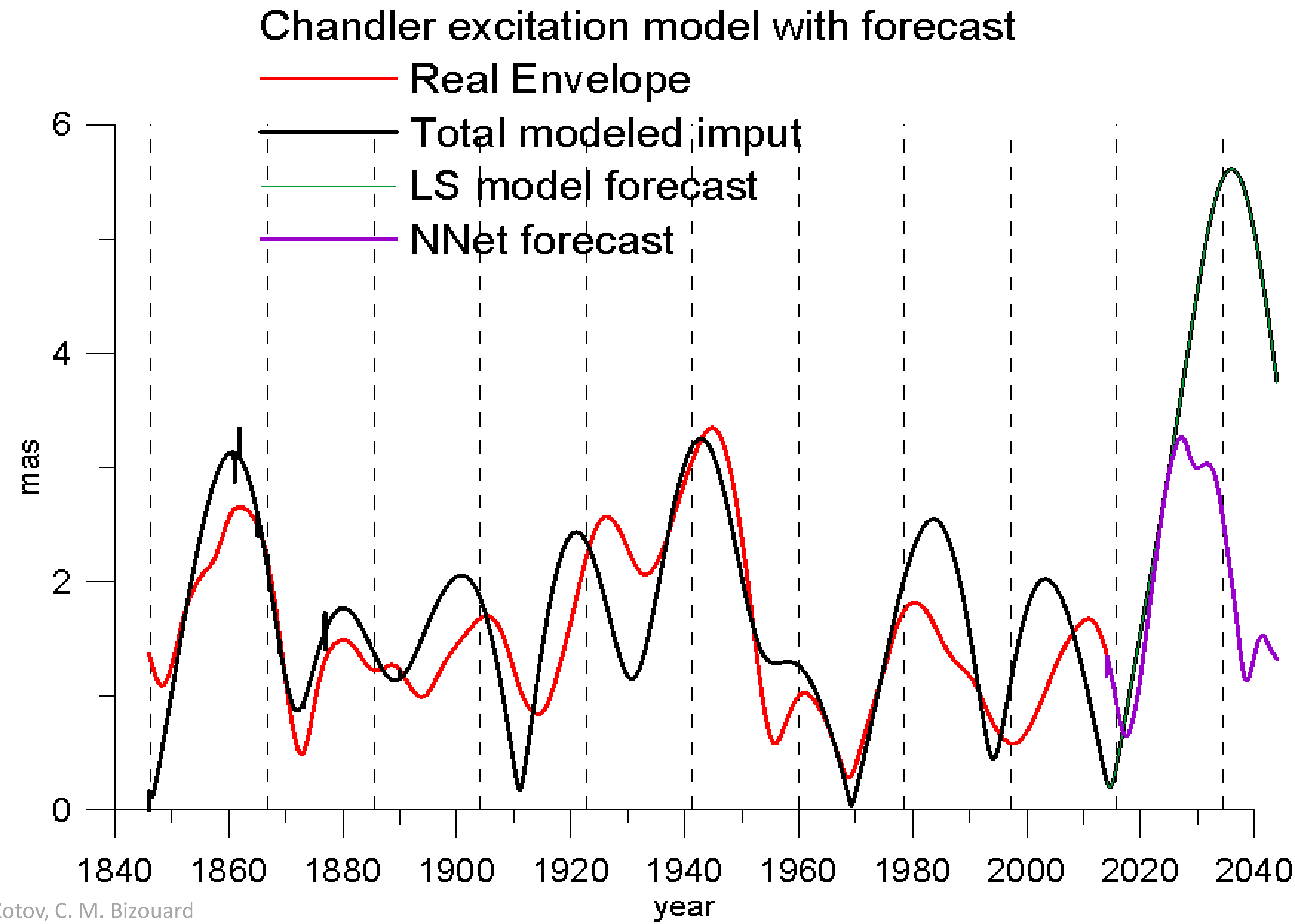
Phase and amplitude models

~Chandler wobble amplitude NLSM fit			
	Period, years	Amplitude	Phase (1880)
~80-year component	83.44	42.6 mas	40.8^o
~40-year component	42.0	54.6 mas	-101.5 ^{o}
mean		134.8 mas	

~Chandler wobble phase NLSM fit			
	Period, years	Amplitude	Phase (1880)
~100-year component	117.8	59 dg	-118^o
~50-year component	50.9	34 dg	95 ^{o}
1-order trend	2dg/year		

Excitation forecast



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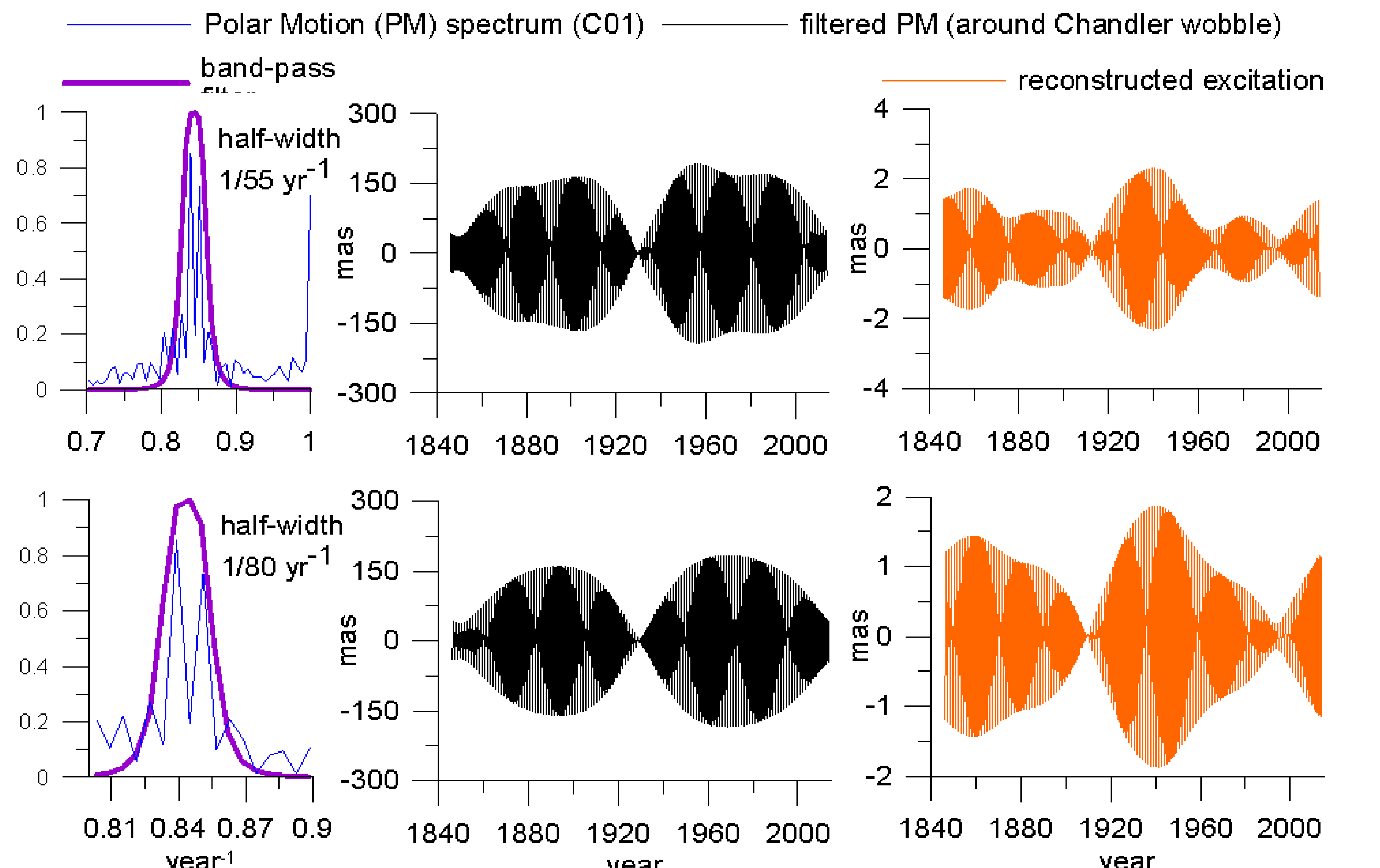
Chandler wobble and its excitation depending on the filter width



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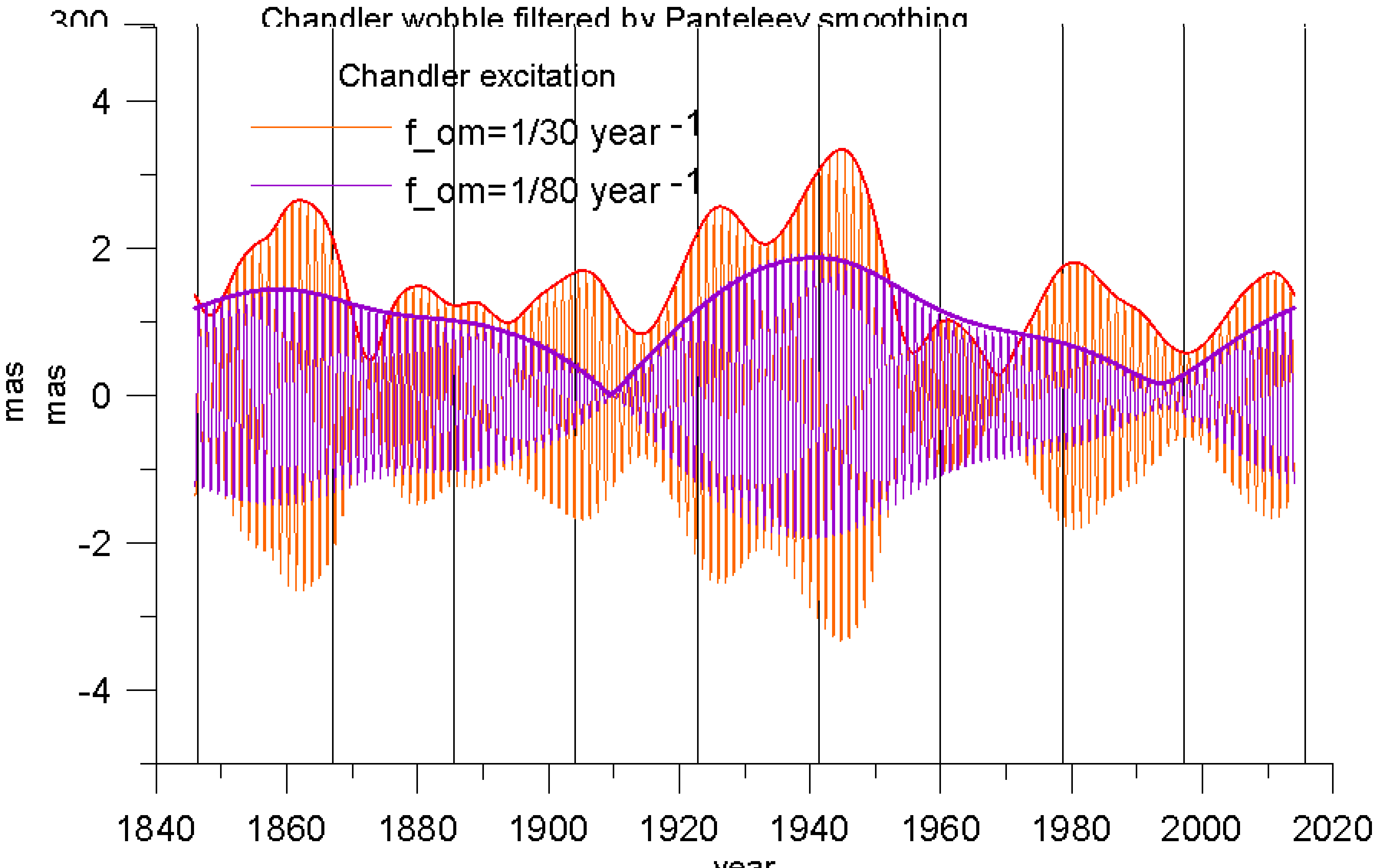
Chandler wobble and its excitation



X-component (Y – similar, with π/2 phase shift)

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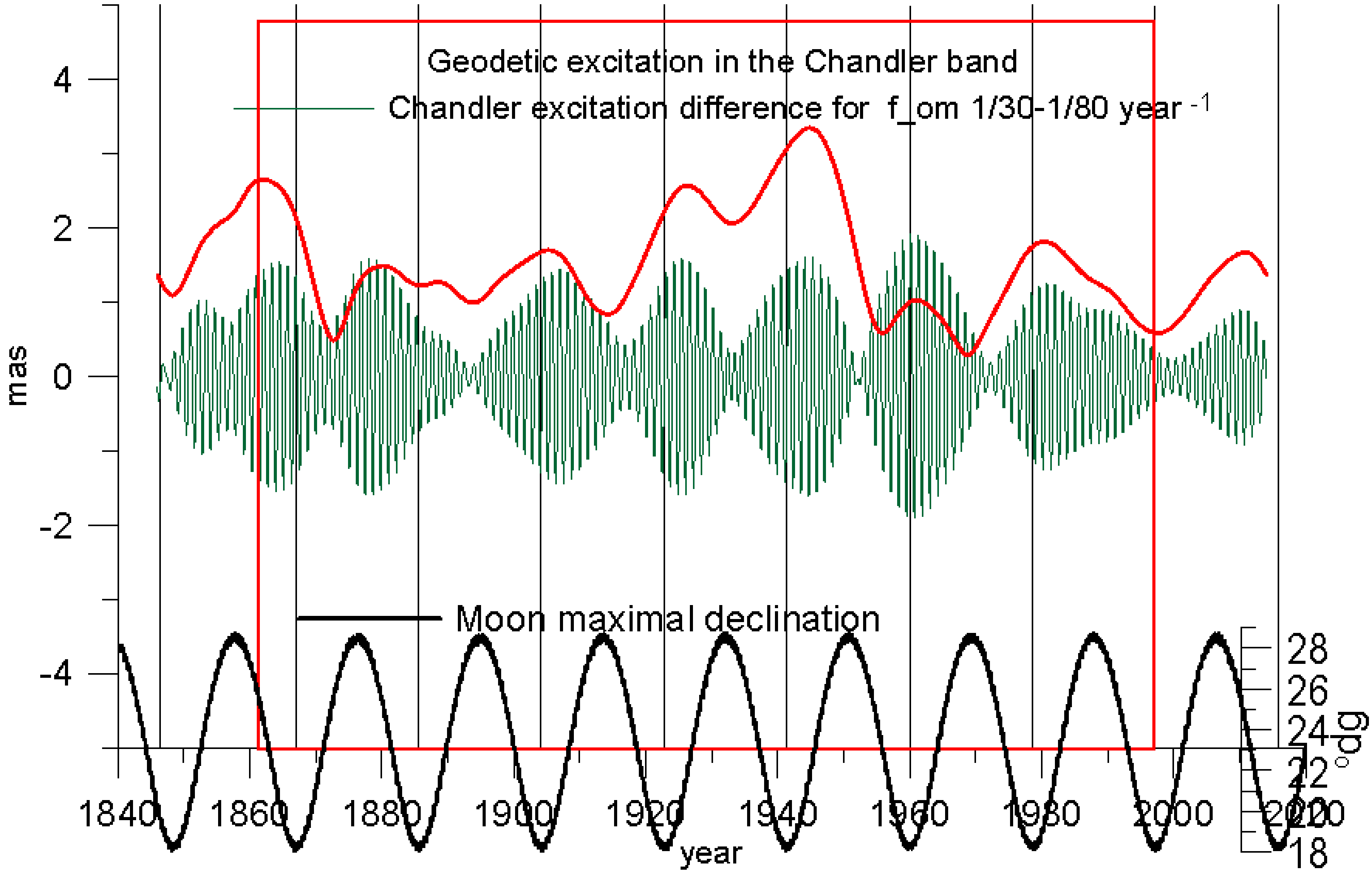
Chandler wobble and its excitation



Along the abscissa 18.6-year wave of the Moon orbit inclination

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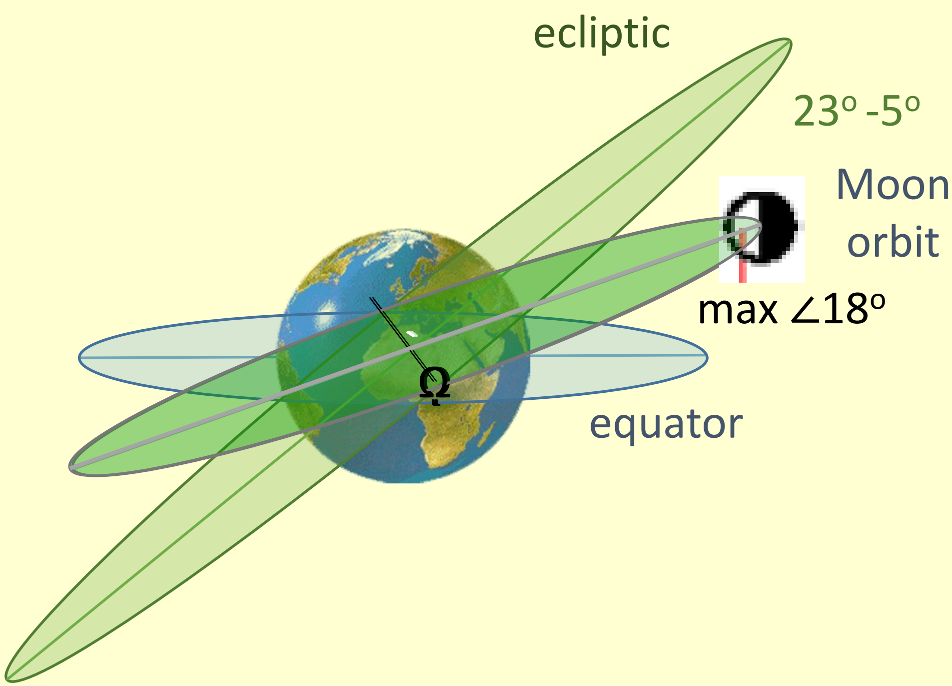
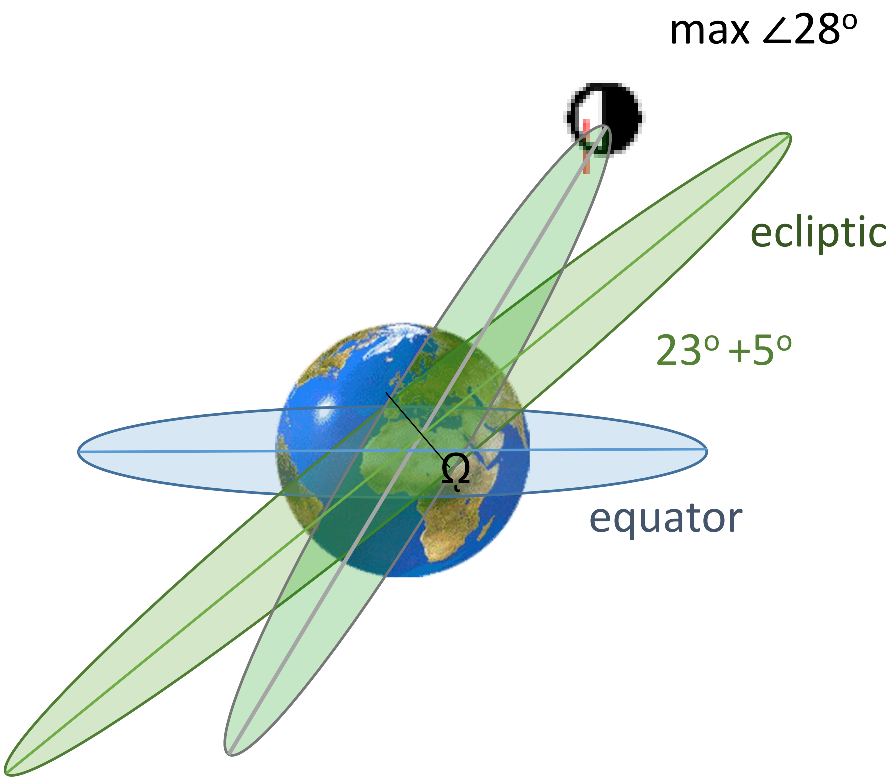
18.6 year period of orbital nodes regression



Moon orbit is between ecliptic and equator,
It does not have large inclinations

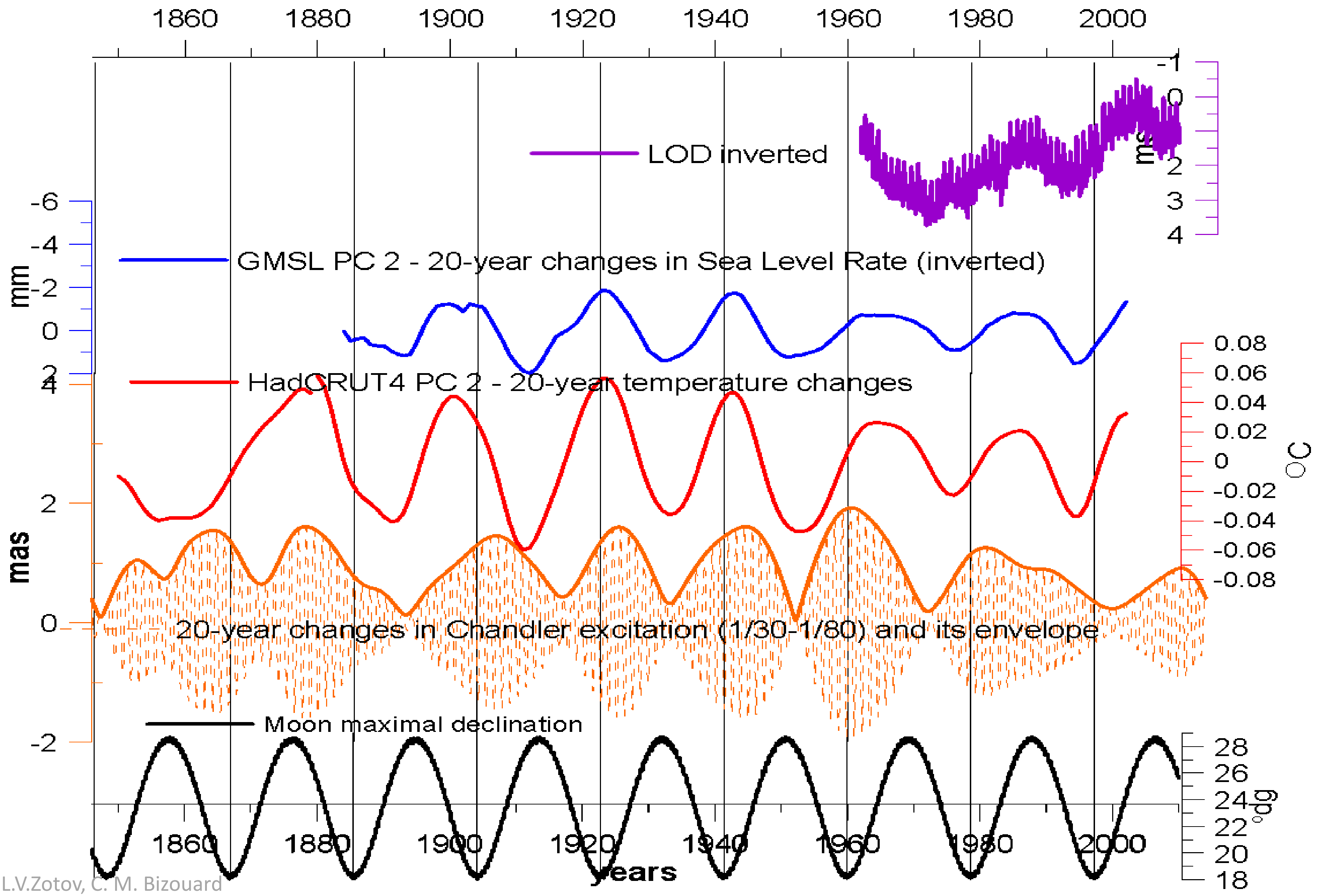
1997,
2015



Moon orbit is above the ecliptic,
Its inclinations can be high

1988,
2007

20-year changes in SL rate, LOD, Temperature and Chandler excitation



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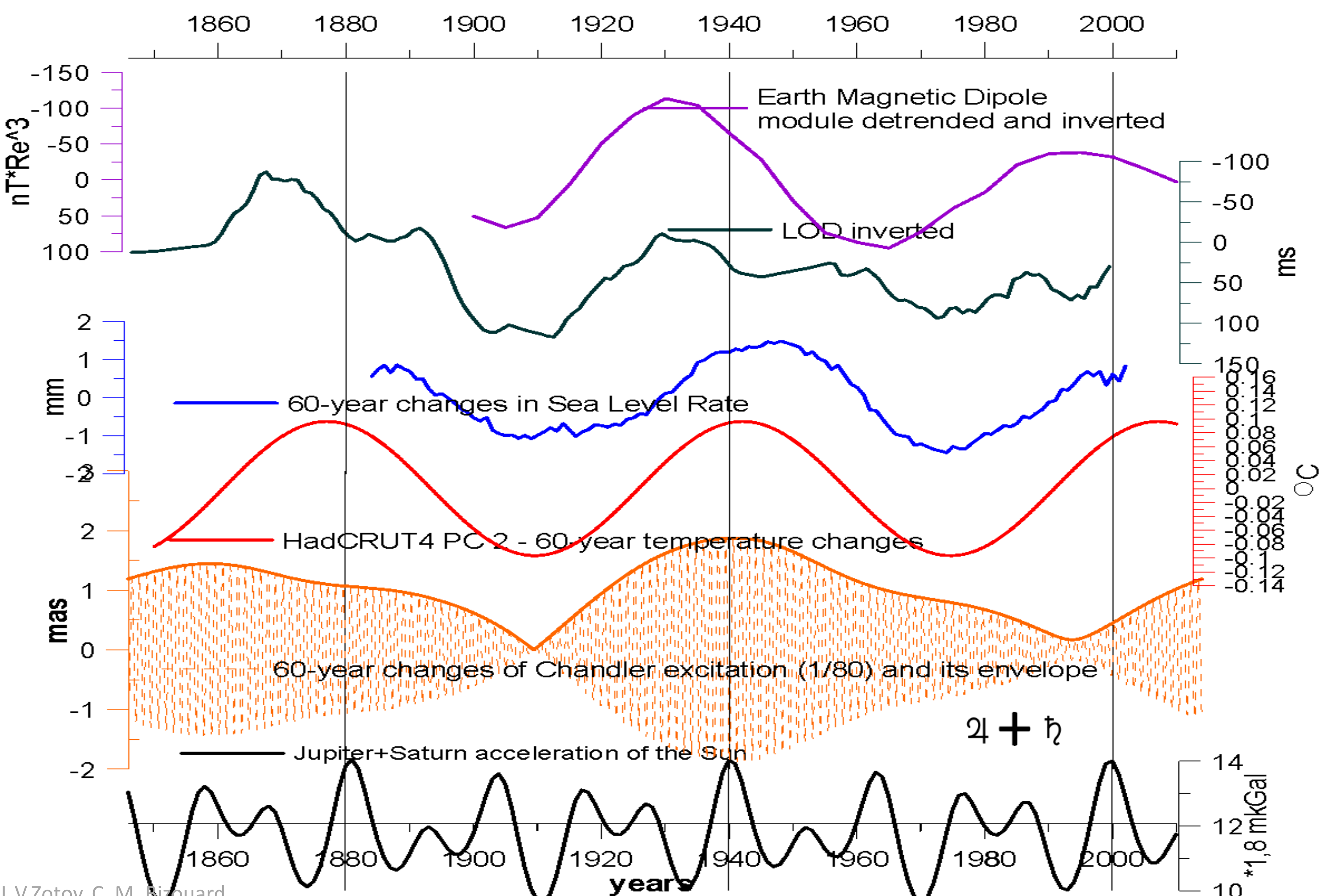
60-year changes in SL, LOD, MD, Temperature and Chandler excitation



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Conclusions

- CSSA or Panteleev's filtering allows to extract Chandler wobble component of PM, its amplitude has ~80 and ~40 year modulations
- From the envelope of the Chandler wobble the excitation envelope can be calculated using Euler-Liouville equation
- If It's true, that Chandler wobble has 40-year modulations, then excitation has 20-year amplitude changes
- Prediction of the Chandler wobble and its excitation can be made, based on the envelope forecast. Now the Chandler wobble has decreased, its phase can jump, our epoch is crucial for understanding
- Reconstructed Chandler excitation has modulations very similar with the ~20 and ~60-year components of temperature and sea level rate changes
- The 20-year variations in the Chandler excitation and climate characteristics can be caused by the changes of atmospheric and oceanic circulation under the influence of 18.6-year cycle of the Moon orbital nodes regression

Milky Way above Atacama Salt Lagoon ,Alex Tudorica