Validating Earth Orientation Series with Models of Atmospheric and Oceanic Angular Momentum

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Approach

- Compare observed and modeled EOPs
  - Observations provide estimates of UT1, polar motion, and their rates-of-change
  - Models provide angular momentum of geophysical fluid
    - Angular momentum directly related to lod and polar motion excitation
  - Construct observed polar motion excitation series from observed estimates of polar motion and its rate-of-change
- Compare observed and modeled EOPs in both time and frequency domains
  - Correlation and observed variance explained
  - Spectrum and coherence
- Presentation meant to illustrate approach

Polar Motion Excitation

¥ **Conservation of angular momentum expressed within rotating, body-fixed reference frame**

$$\frac{\partial \mathbf{L}}{\partial t} + \omega \times \mathbf{L} = \tau$$

where the angular momentum vector $\mathbf{L} = \mathbf{I}$ ¥ $\omega + \mathbf{h}$

¥ **Assume rotation is small perturbation from state of uniform rotation at rate Ω. Keeping terms to first order results in long period Liouville equation**

$$\mathbf{m}(t) + \frac{i}{\sigma_{cw}} \frac{\partial \mathbf{m}}{\partial t} = \psi(t) = \chi(t) - \frac{i}{\Omega} \frac{\partial \chi}{\partial t}$$

where: $\mathbf{m} \equiv (\omega_1 + i\, \omega_2)/\Omega$ (terrestrial location of rotation pole)

$\psi(t)$, $\chi(t)$ are the polar motion excitation functions

σ_{cw} is complex-valued frequency of Chandler wobble

¥ **Written in terms of reported polar motion parameters:**

$$\mathbf{p}(t) + \frac{i}{\sigma_{cw}} \frac{\partial \mathbf{p}}{\partial t} = \chi(t) = \frac{1.61}{\Omega (C-A)} \left[\mathbf{h}(t) + \frac{\Omega\, \mathbf{c}(t)}{1.44} \right]$$

where: $\mathbf{p}(t) = x_p(t)$ Ğ $i\, y_p(t)$

$\mathbf{c}(t) = c_{13}(t) + i\, c_{23}(t)$

Data Sets

- Earth orientation measurements
  - GPS
    - IGS SINEX combined series IGS 00 P 02
    - Daily values given at noon spanning February 27, 2000 to present
  - VLBI
    - NASA/GSFC individual series gsf2005a.eops
    - Values given at irregular epochs spanning August 4, 1979 to August 19, 2005
    - (constrained IVS combined series does not include lod or polar motion rates)
  - SLR
    - JCET individual series JCET 04 L 83
    - Daily values given at noon spanning January 3, 1993 to January 2, 2005
    - (constrained ILRS combined series does not include polar motion rates)
  - DORIS
    - IGN/JPL individual series IGN 03 WD 01
    - Daily values given at noon spanning January 3, 1993 to July 23, 2005
    - (IDS combined series not yet available)

Data Sets, cont.

- Validation models
  - AAM
    - NCEP/NCAR reanalysis project
    - Recent re-computation performed at IERS Special Bureau for the Atmosphere
    - 6-hour values spanning January 1, 1948 to present
    - Sum of wind and inverted barometer pressure terms
  - OAM
    - ECCO/JPL data assimilating ocean model designated kf049f
    - Forced by NCEP/NCAR reanalysis surface wind stress, heat flux, and evaporation–precipitation fields (freshening only)
    - Not forced by surface pressure
    - Assimilates altimetry and XBT data
    - Corrected for artificial mass changes caused by Boussinesq approximation
    - Hourly values spanning January 1, 1993 to August 8, 2005
    - Sum of current and bottom pressure terms

Data Processing

- Common time span
  - February 27, 2000 to January 2, 2005
    - From beginning of IGS SINEX combined series to end of JCET SLR series
- Common epochs
  - GPS, SLR, and DORIS series given at noon
    - Average subdaily AAM and OAM series to noon
  - VLBI series given at irregular epochs
    - Linearly interpolate VLBI series to noon (simultaneously filling gaps)
- Delete outliers
  - Those values whose formal σ > 4 times the median σ
    - 0 from GPS, 0 from DORIS, 42 from SLR, 68 from VLBI
- Remove solid Earth and ocean tidal effects (lod)
- Remove mean and trend from all series

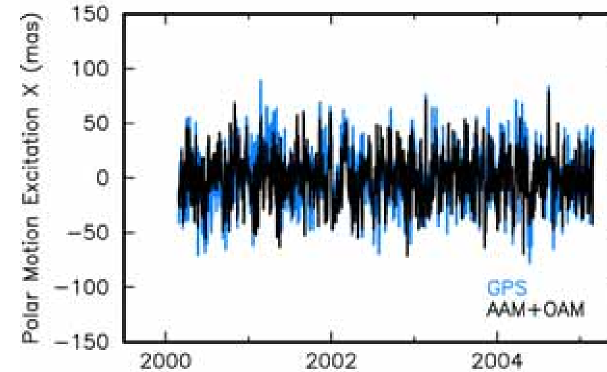
GPS

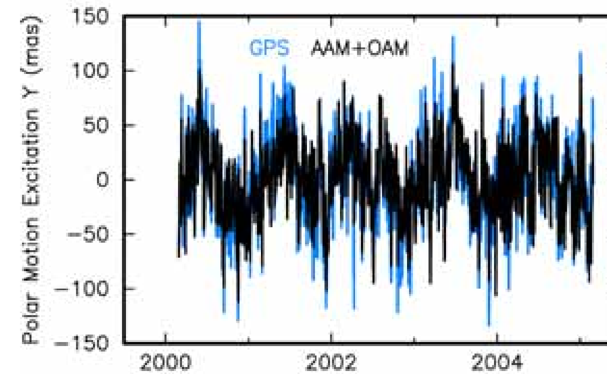
Correlation & Variance Explained

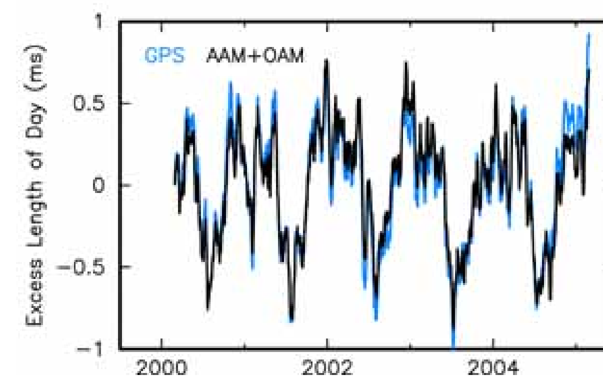
(99% significance level = 0.43)

	seasons included		seasons removed	
GPS	0.80	63.1%		chi-x
GPS	0.89	79.4%		chi-y
GPS	0.96	93.0%		lod

Seasons Included







GPS

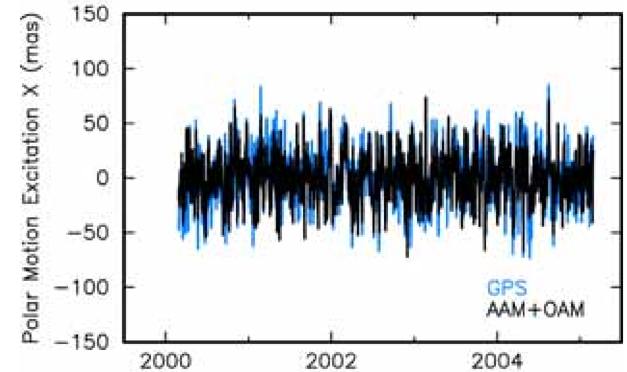
Correlation & Variance Explained

(99% significance level = 0.43)

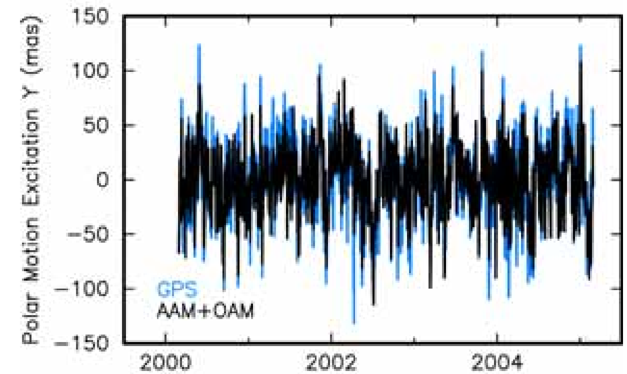
	seasons included		seasons removed	
GPS	0.80	63.1%	0.83	69.0%
GPS	0.89	79.4%	0.88	78.0%
GPS	0.96	93.0%	0.89	79.5%

Seasons Removed

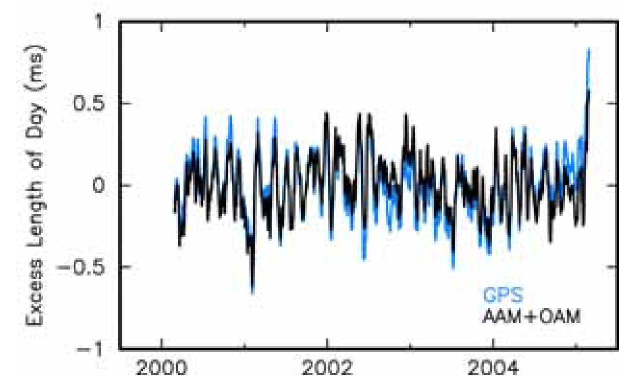
chi-x



chi-y



lod



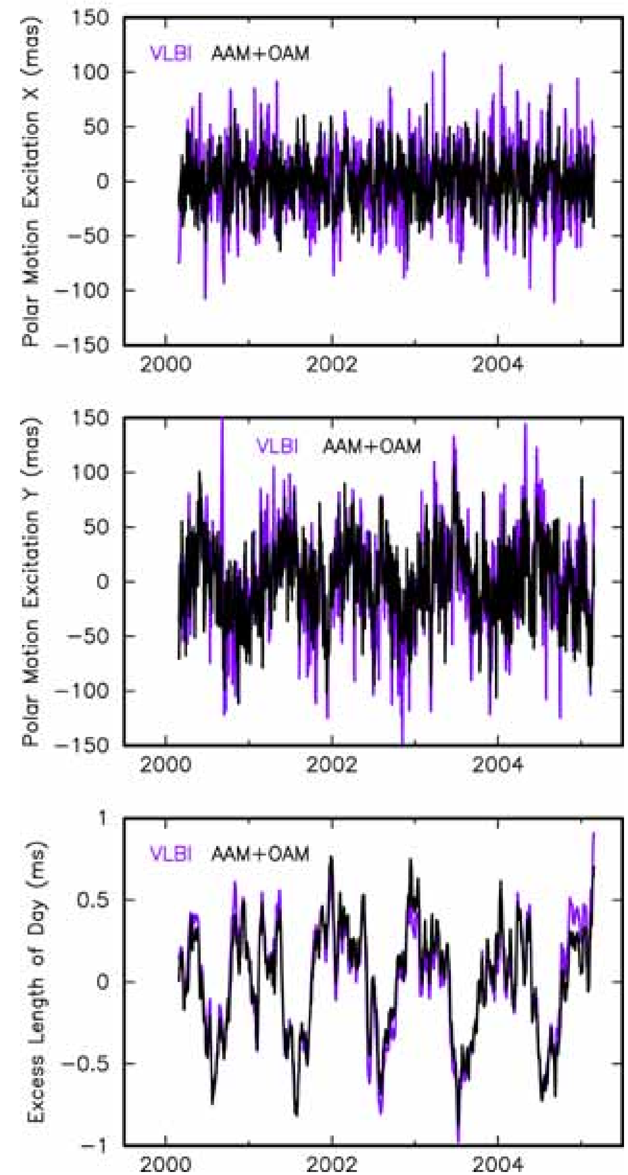
VLBI

Correlation & Variance Explained

(99% significance level = 0.43)

	seasons included		seasons removed		
GPS	0.80	63.1%	0.83	69.0%	
VLBI	0.45	14.9%			chi-x
GPS	0.89	79.4%	0.88	78.0%	
VLBI	0.66	42.2%			chi-y
GPS	0.96	93.0%	0.89	79.5%	
VLBI	0.96	92.5%			lod

Seasons Included



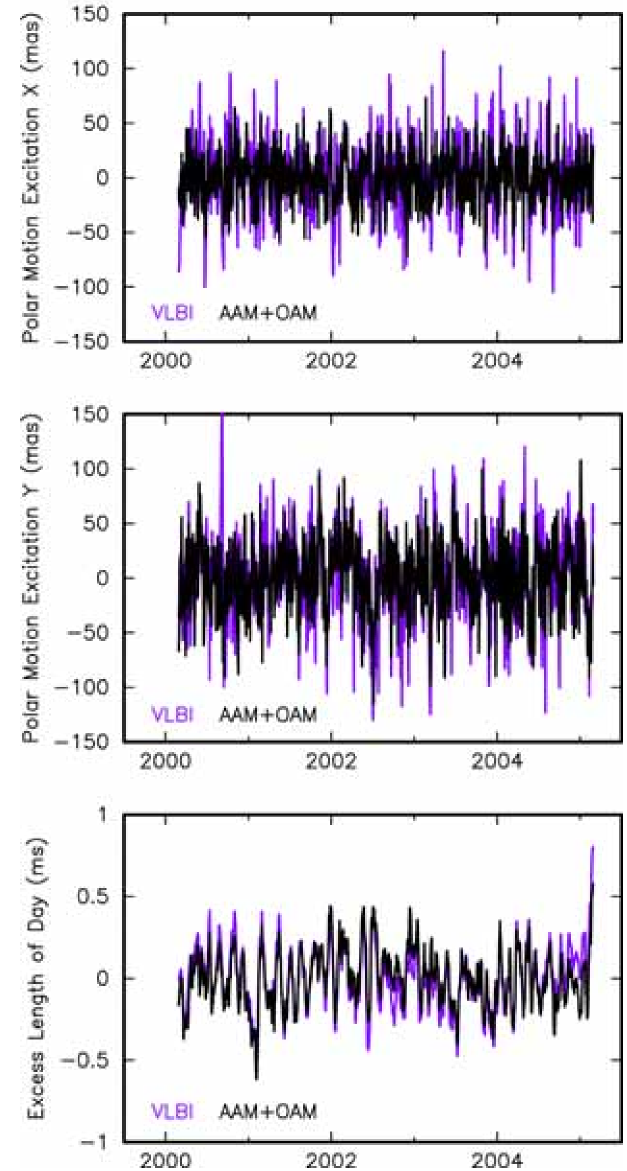
VLBI

Correlation & Variance Explained

(99% significance level = 0.43)

	seasons included		seasons removed		
GPS	0.80	63.1%	0.83	69.0%	
VLBI	0.45	14.9%	0.48	19.4%	chi-x
GPS	0.89	79.4%	0.88	78.0%	
VLBI	0.66	42.2%	0.59	31.9%	chi-y
GPS	0.96	93.0%	0.89	79.5%	
VLBI	0.96	92.5%	0.88	76.1%	lod

Seasons Removed



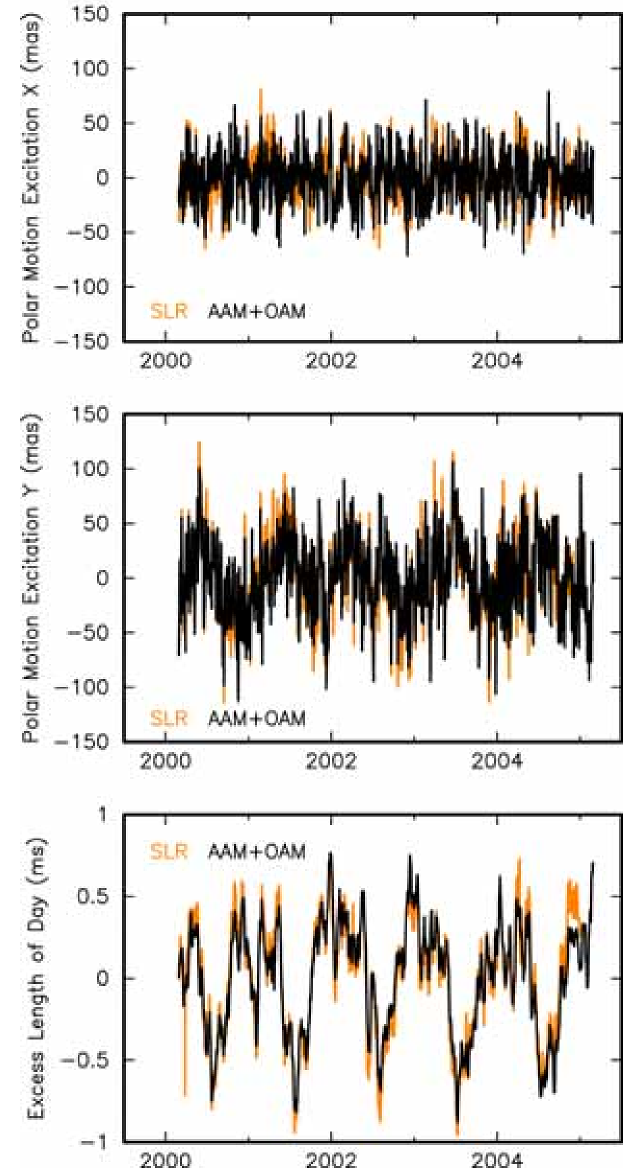
SLR

Correlation & Variance Explained

(99% significance level = 0.43)

		seasons included		seasons removed	
chi-x	GPS	0.80	63.1%	0.83	69.0%
	VLBI	0.45	14.9%	0.48	19.4%
	SLR	0.75	53.1%		
chi-y	GPS	0.89	79.4%	0.88	78.0%
	VLBI	0.66	42.2%	0.59	31.9%
	SLR	0.87	76.4%		
lod	GPS	0.96	93.0%	0.89	79.5%
	VLBI	0.96	92.5%	0.88	76.1%
	SLR	0.96	92.7%		

Seasons Included



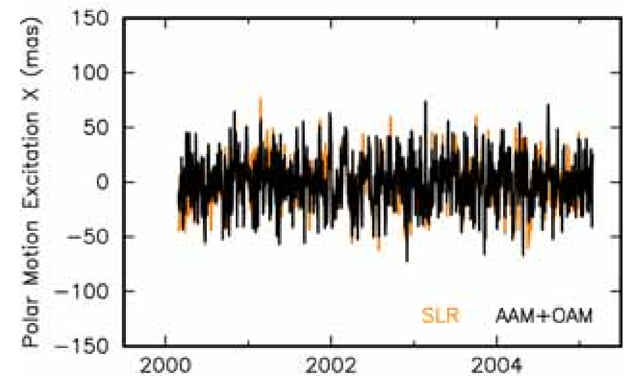
SLR

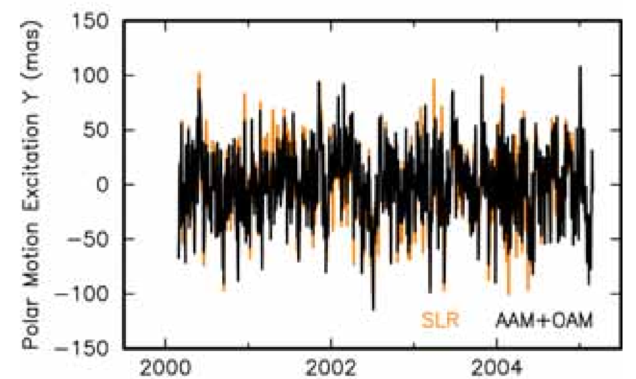
Correlation & Variance Explained

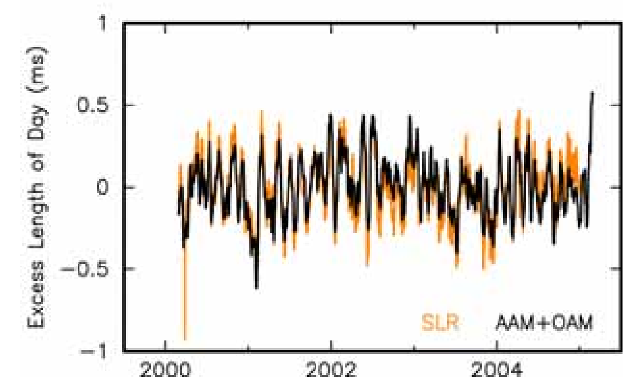
(99% significance level = 0.43)

	seasons included		seasons removed		
GPS	0.80	63.1%	0.83	69.0%	
VLBI	0.45	14.9%	0.48	19.4%	chi-x
SLR	0.75	53.1%	0.80	61.3%	
GPS	0.89	79.4%	0.88	78.0%	
VLBI	0.66	42.2%	0.59	31.9%	chi-y
SLR	0.87	76.4%	0.85	72.2%	
GPS	0.96	93.0%	0.89	79.5%	
VLBI	0.96	92.5%	0.88	76.1%	lod
SLR	0.96	92.7%	0.88	77.6%	

Seasons Removed







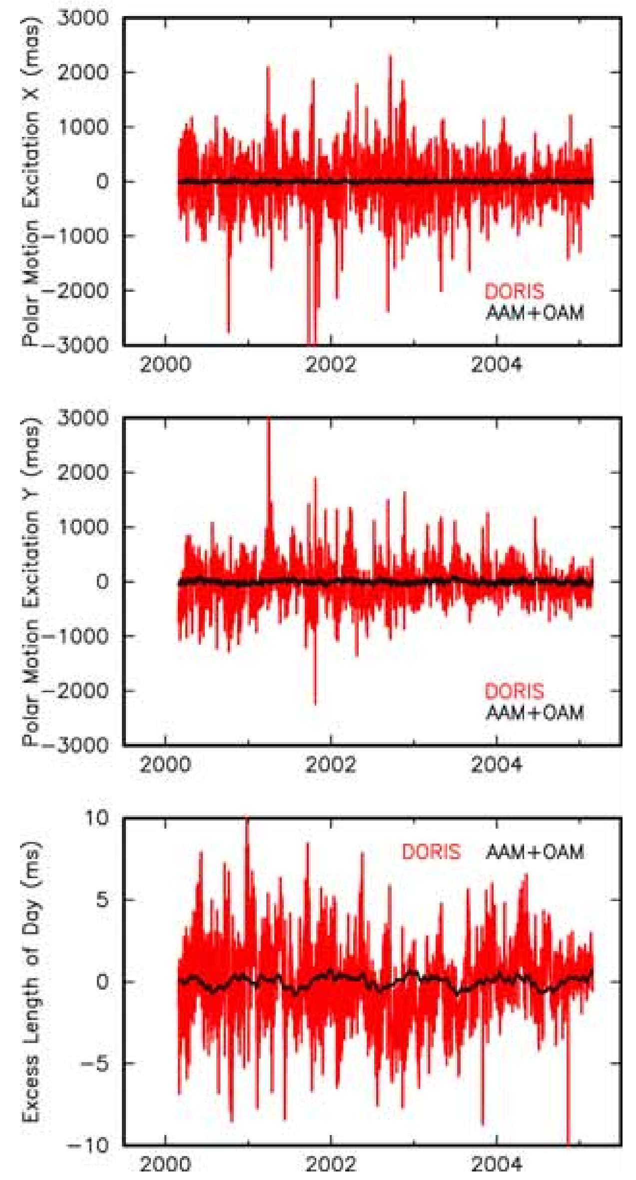
DORIS

Correlation & Variance Explained

(99% significance level = 0.43)

	seasons included		seasons removed		
GPS	0.80	63.1%	0.83	69.0%	chi-x
VLBI	0.45	14.9%	0.48	19.4%	
SLR	0.75	53.1%	0.80	61.3%	
DORIS	0.14	1.0%			
GPS	0.89	79.4%	0.88	78.0%	chi-y
VLBI	0.66	42.2%	0.59	31.9%	
SLR	0.87	76.4%	0.85	72.2%	
DORIS	0.20	2.7%			
GPS	0.96	93.0%	0.89	79.5%	lod
VLBI	0.96	92.5%	0.88	76.1%	
SLR	0.96	92.7%	0.88	77.6%	
DORIS	0.09	0.7%			

Seasons Included



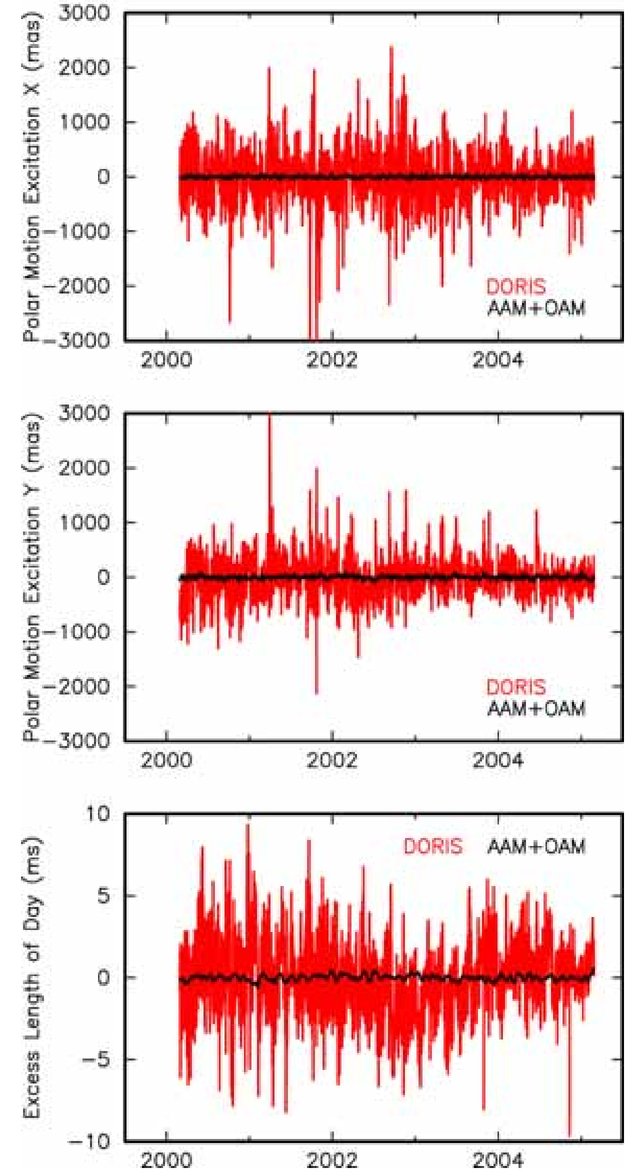
DORIS

Correlation & Variance Explained

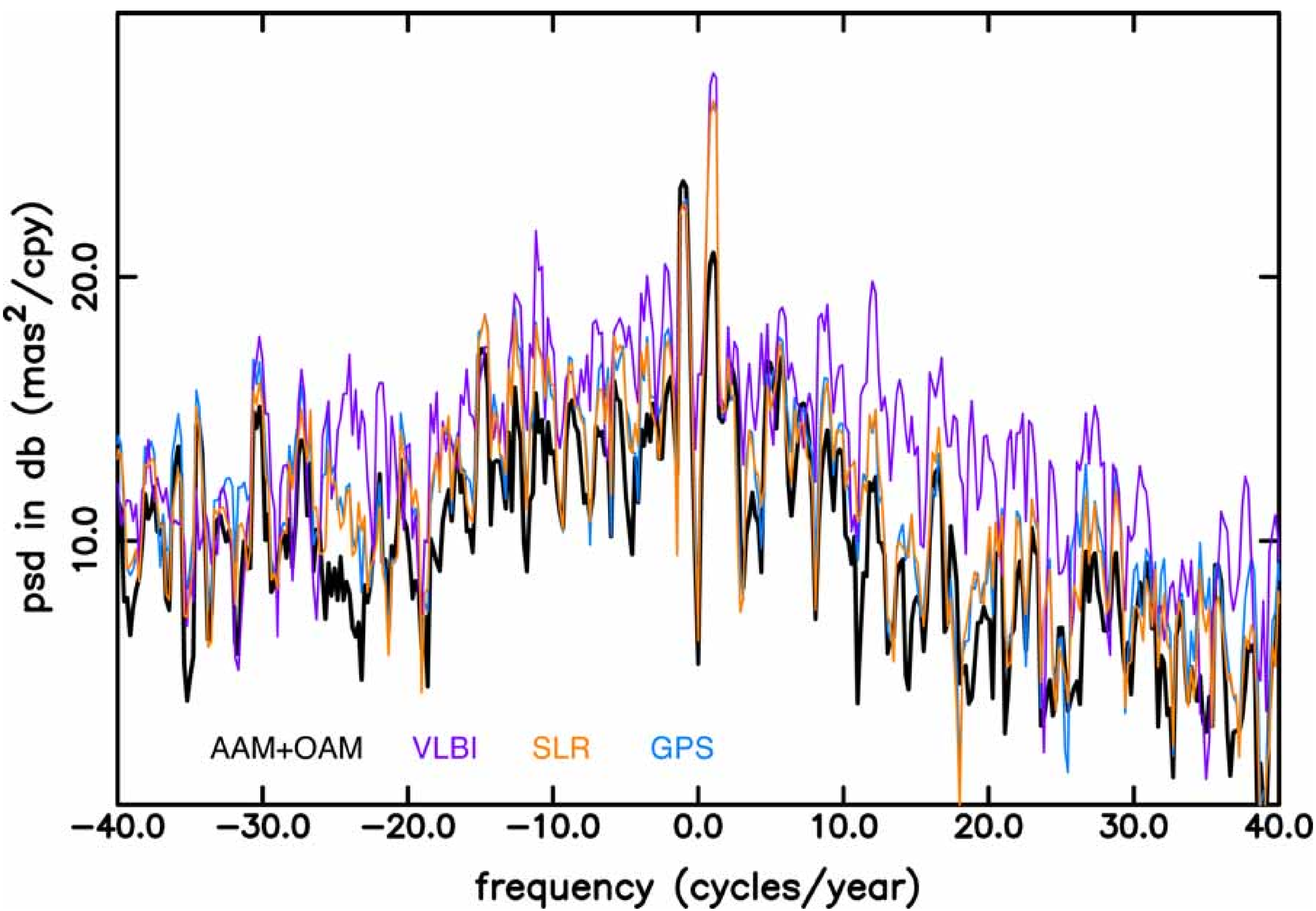
(99% significance level = 0.43)

	seasons included		seasons removed		
GPS	0.80	63.1%	0.83	69.0%	chi-x
VLBI	0.45	14.9%	0.48	19.4%	
SLR	0.75	53.1%	0.80	61.3%	
DORIS	0.14	1.0%	0.13	0.9%	
GPS	0.89	79.4%	0.88	78.0%	chi-y
VLBI	0.66	42.2%	0.59	31.9%	
SLR	0.87	76.4%	0.85	72.2%	
DORIS	0.20	2.7%	0.18	2.3%	
GPS	0.96	93.0%	0.89	79.5%	lod
VLBI	0.96	92.5%	0.88	76.1%	
SLR	0.96	92.7%	0.88	77.6%	
DORIS	0.09	0.7%	–0.04	–1.1%	

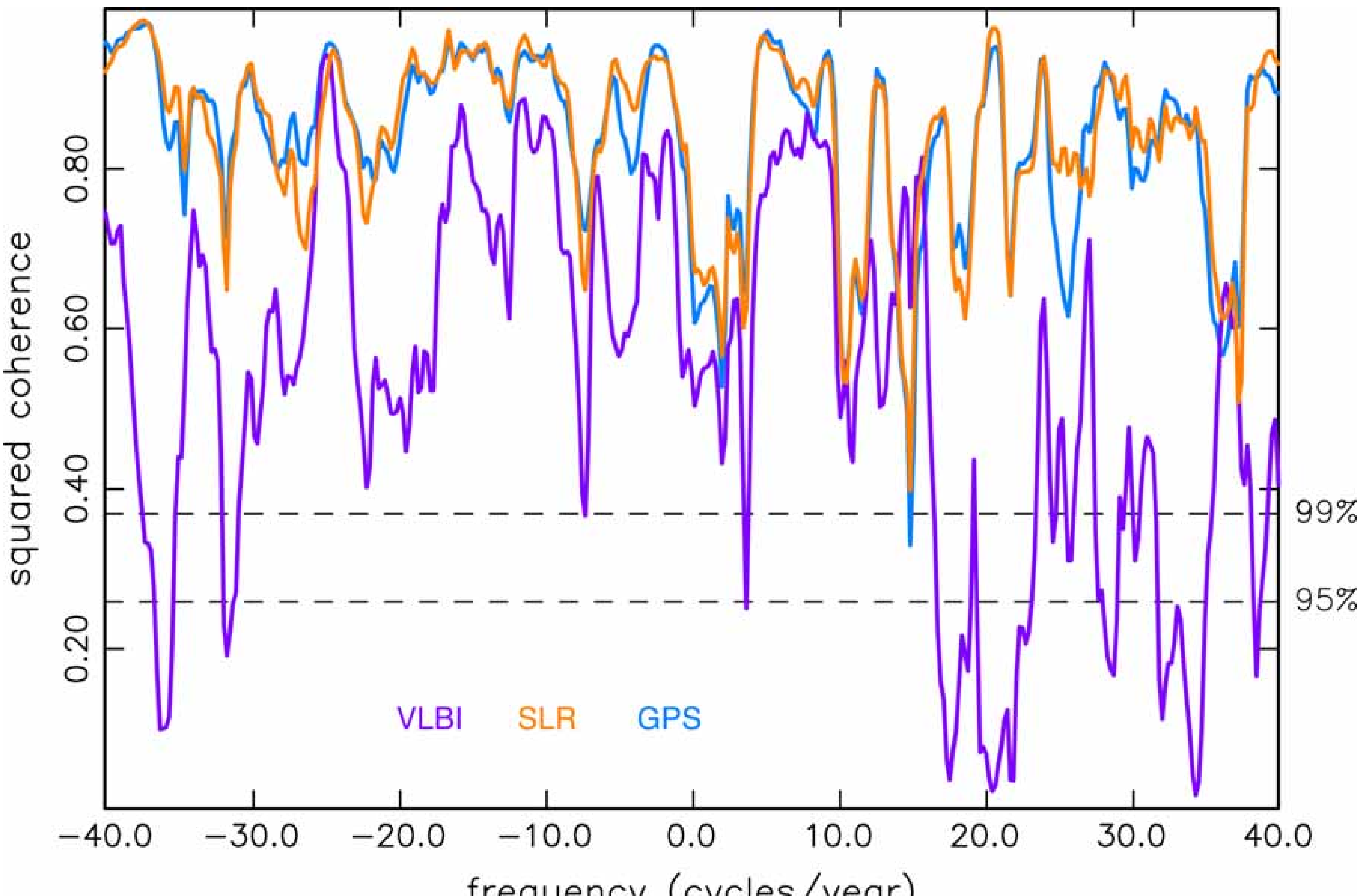
Seasons Removed



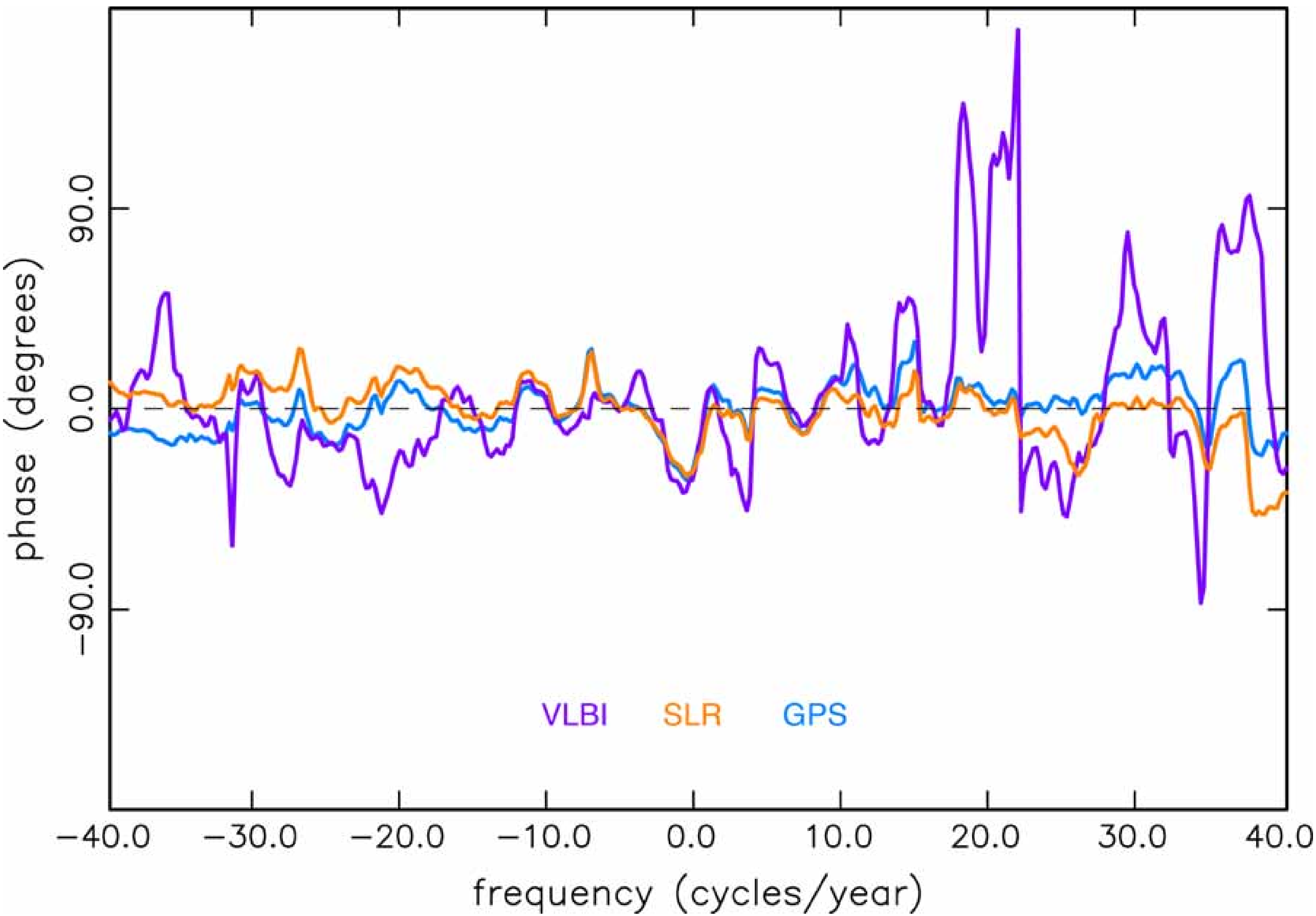
Polar Motion Excitation Spectra



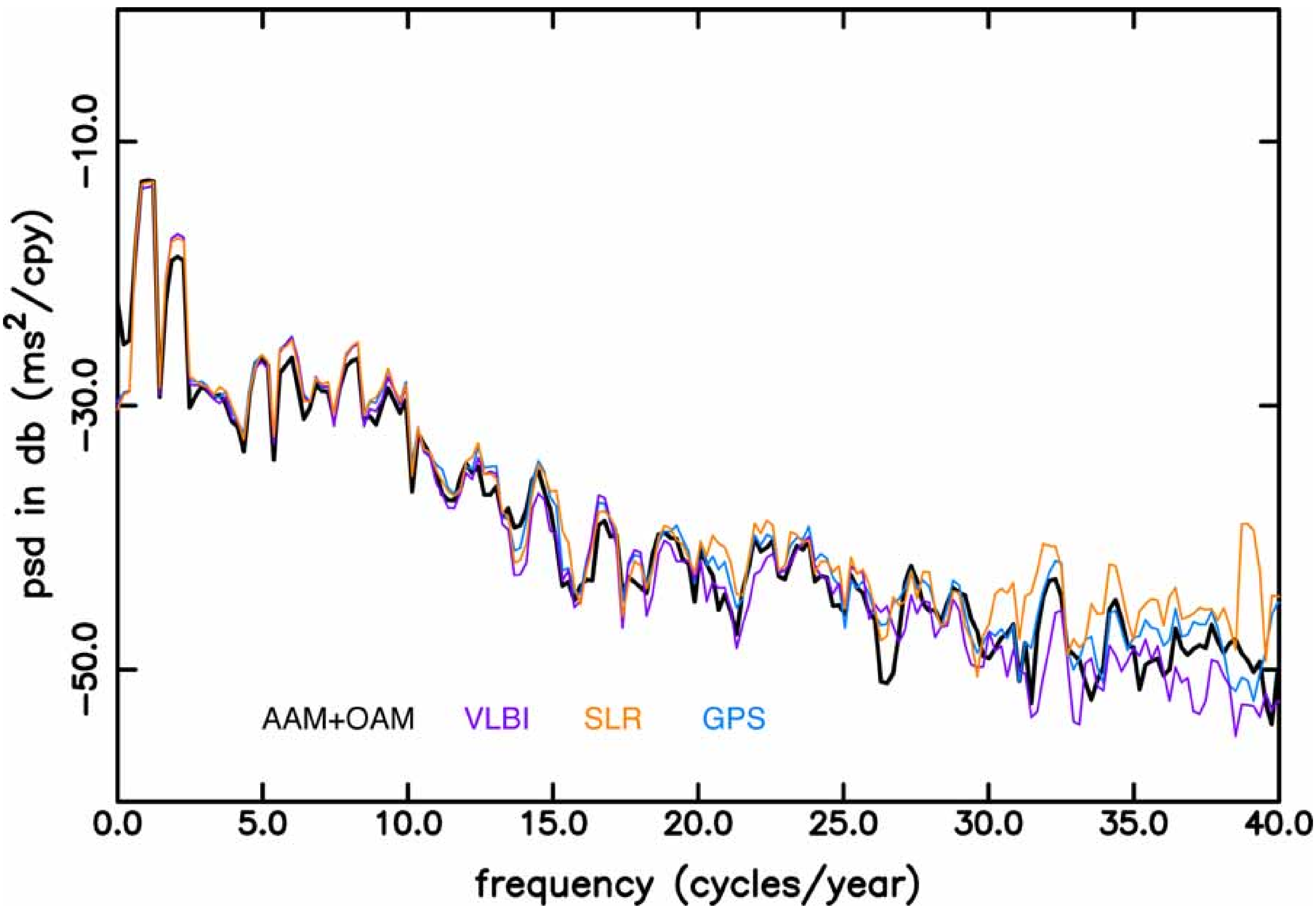
Polar Motion Excitation Coherence



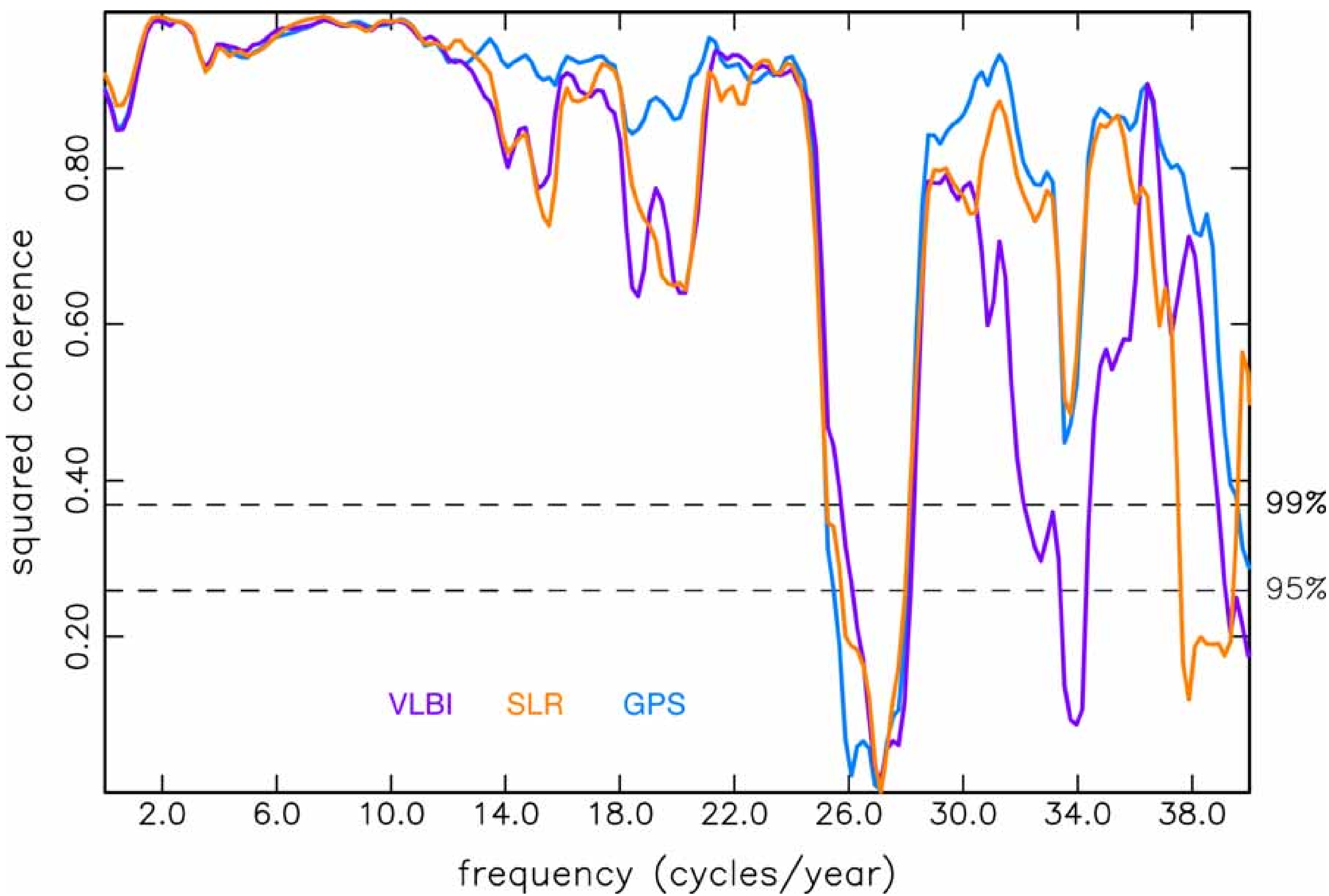
Polar Motion Excitation Phase



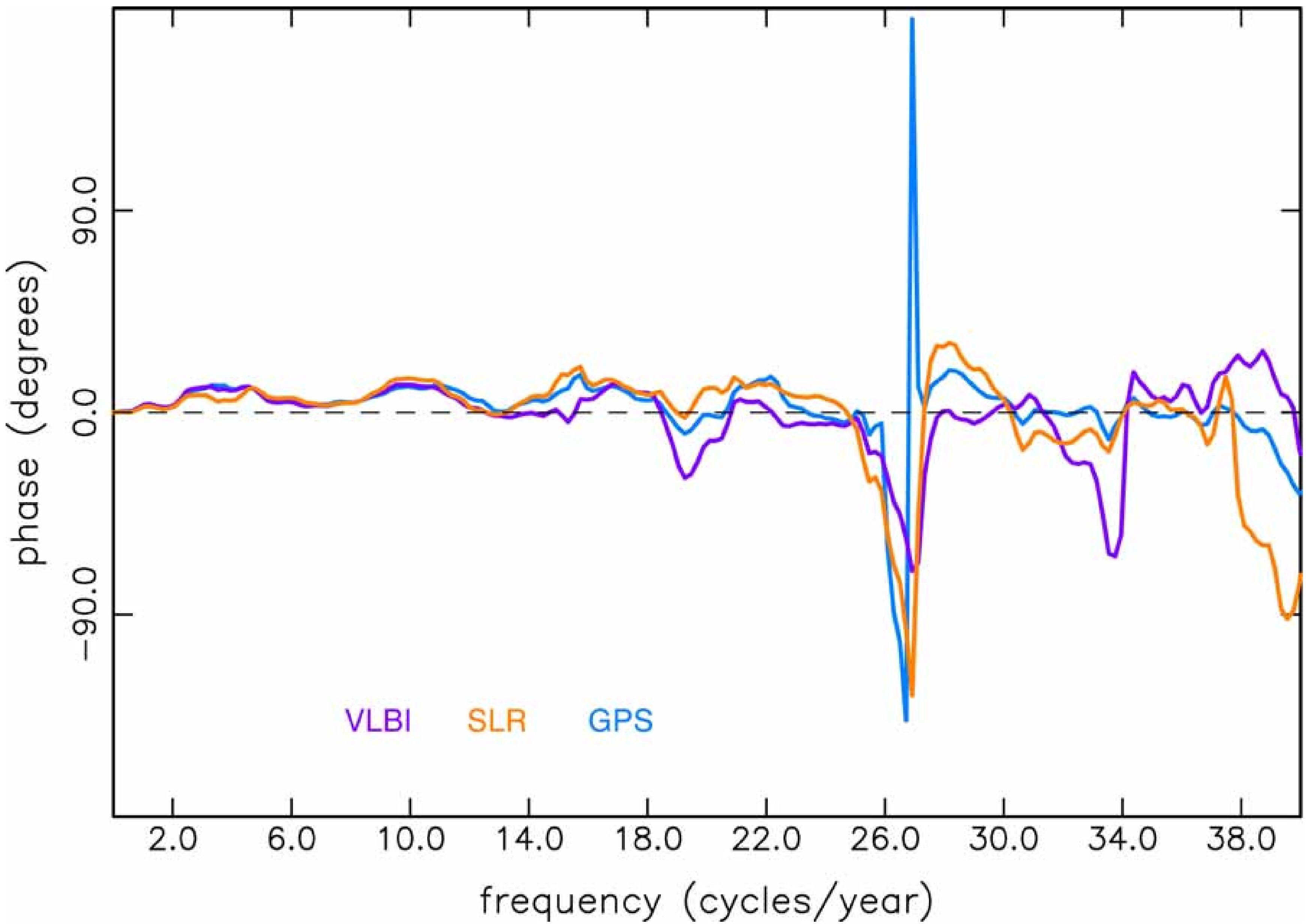
Excess Length-of-Day Spectra



Excess Length-of-Day Coherence



Excess Length-of-Day Phase



Summary

- Compare observed & modeled EOPs (2000–2004)
  - Observed EOPs from GPS, VLBI, SLR, and DORIS
  - Modeled EOPs from atmospheric and oceanic models
    - AAM and OAM directly related to lod and polar motion excitation
- Primarily a test of EOP-rates
  - Polar motion excitation constructed from polar motion and polar motion-rate estimates
    - Polar motion-rate term dominates at high frequencies
  - Poor results for DORIS imply need to improve rate estimates
- To be compared, series must be at common epoch
  - Otherwise they must be interpolated which introduces errors
  - Poor results for VLBI may be due to interpolation errors
- GPS & SLR series agree best with AAM & OAM