Yan, H., and B.F.Chao(2012),Effect of global mass conservation among geophysical fluids on the seasonal length of day variation, J.Geophys.Res.,117,B02401.

Global Mass Balance Effects on the Earth's Rotation Rate

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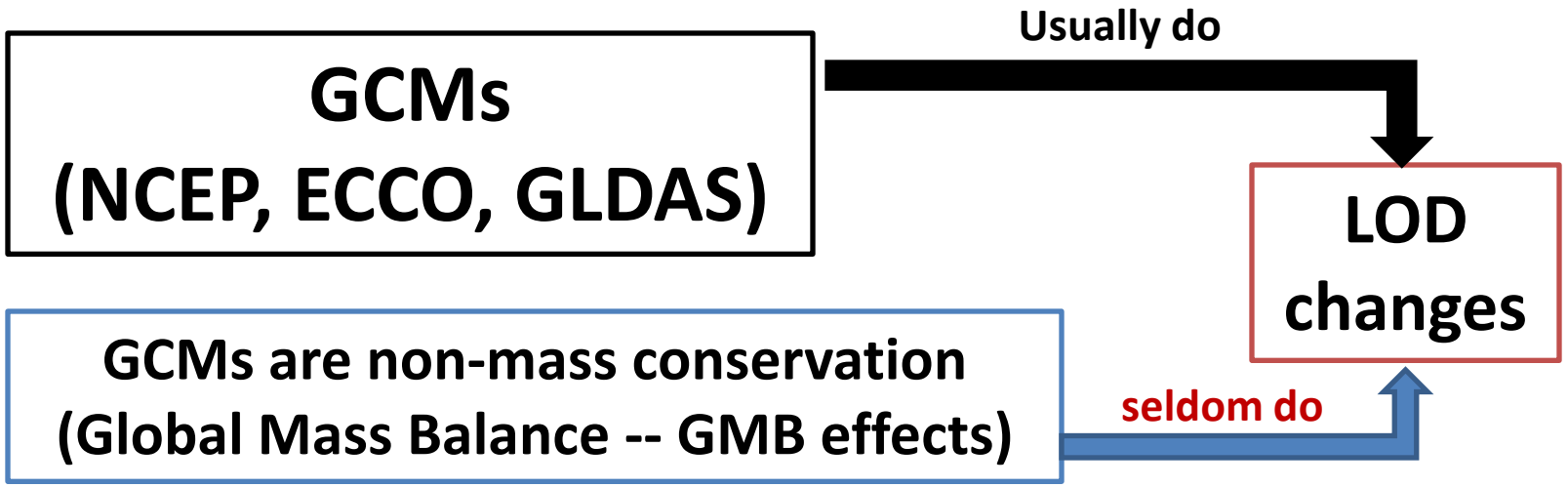
Outline

- Background and Motivation
- Theory and data
- Results
- Conclusions and discussions

Background and Motivation

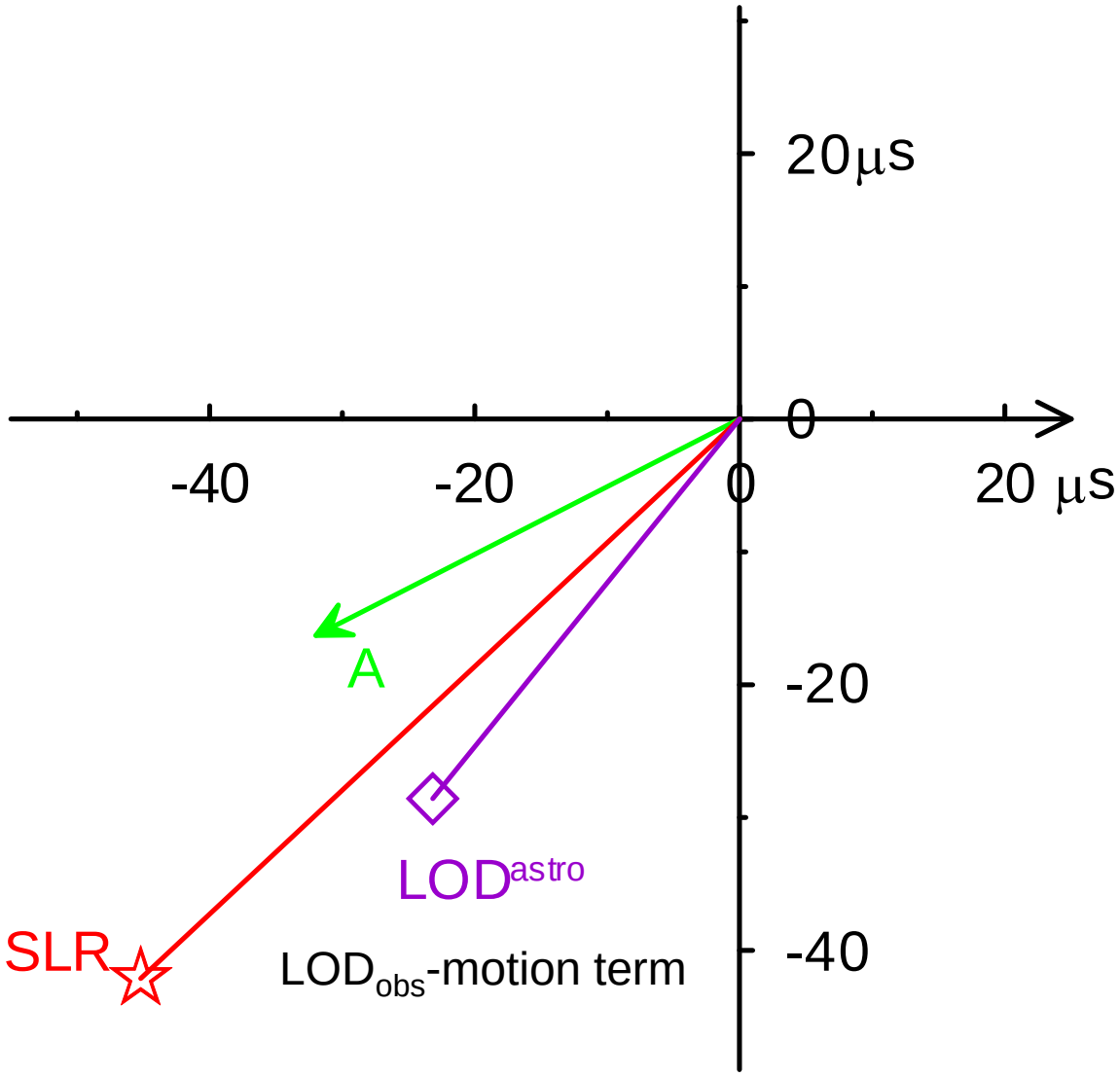


Q1: How much does GMB affect the LOD change ? Does it must be considered?

A1: Calculate it.

Q2: If GMB effects on LOD should be considered, how to constrain GMB effects on LOD from individual observations?

A2: using C20 or LOD-motion term.


20μs
0
-40
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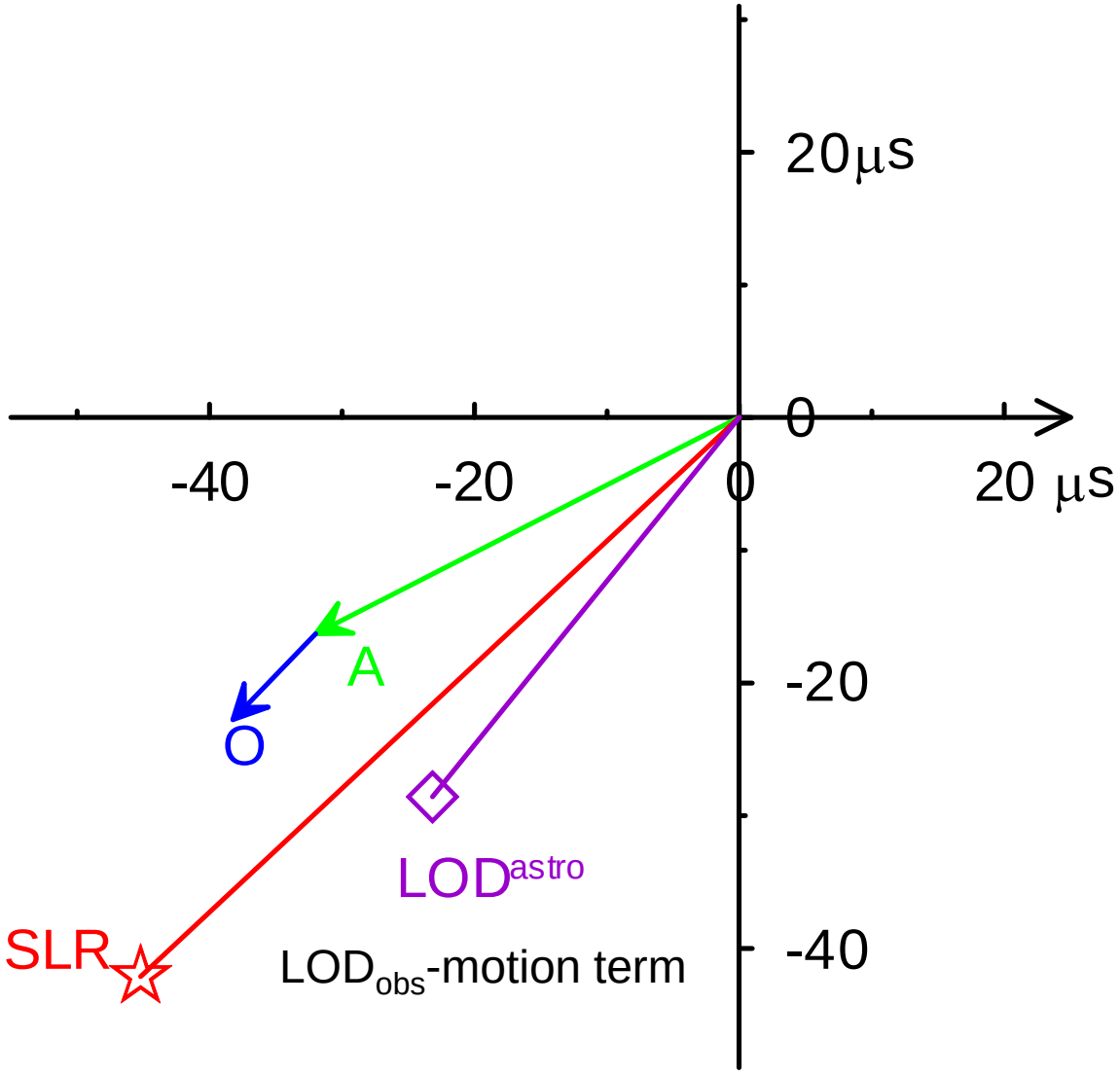
0
20 μs
-20
-40
A
LOD^astro
SLR
LOD_obs-motion term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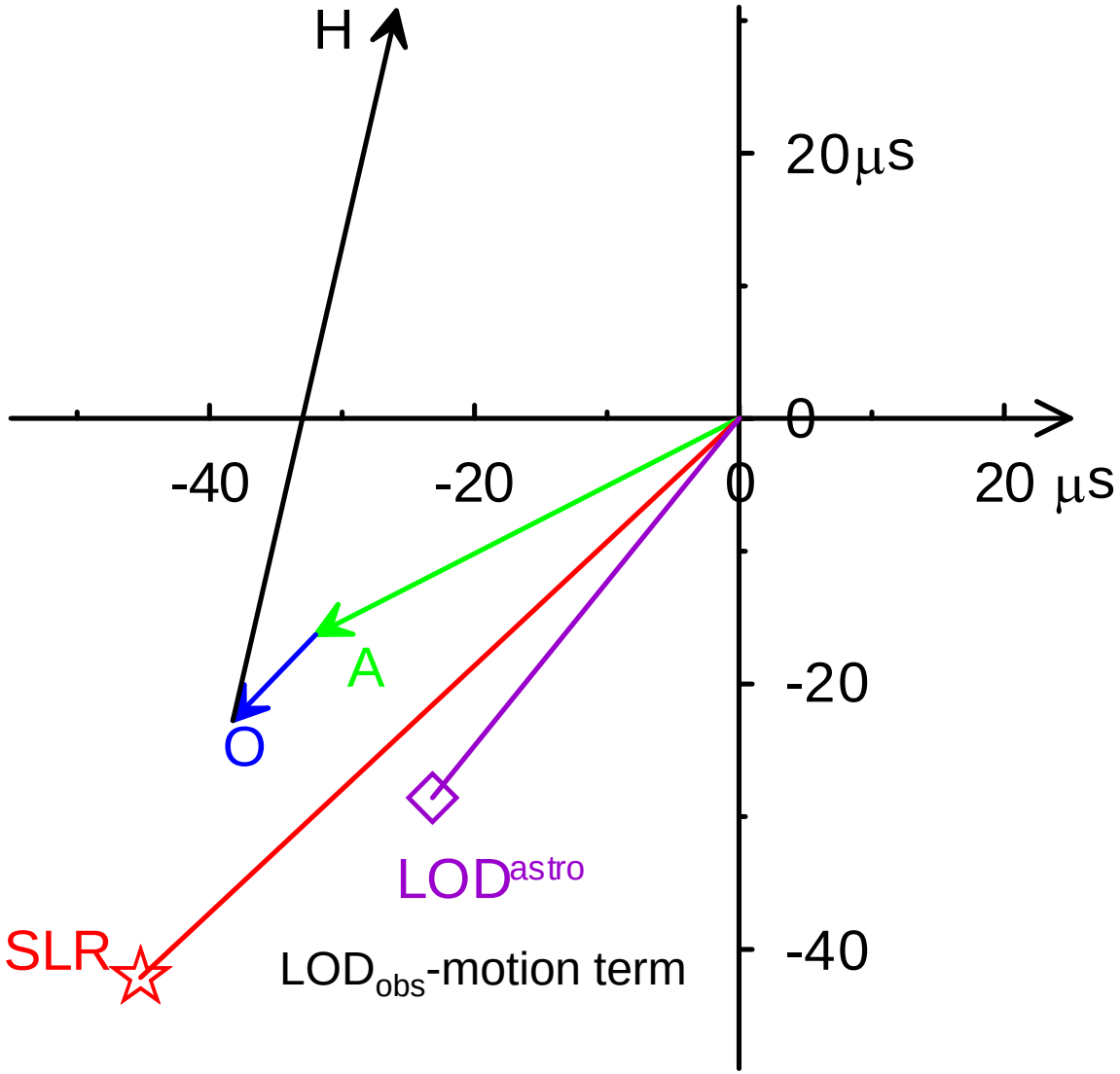
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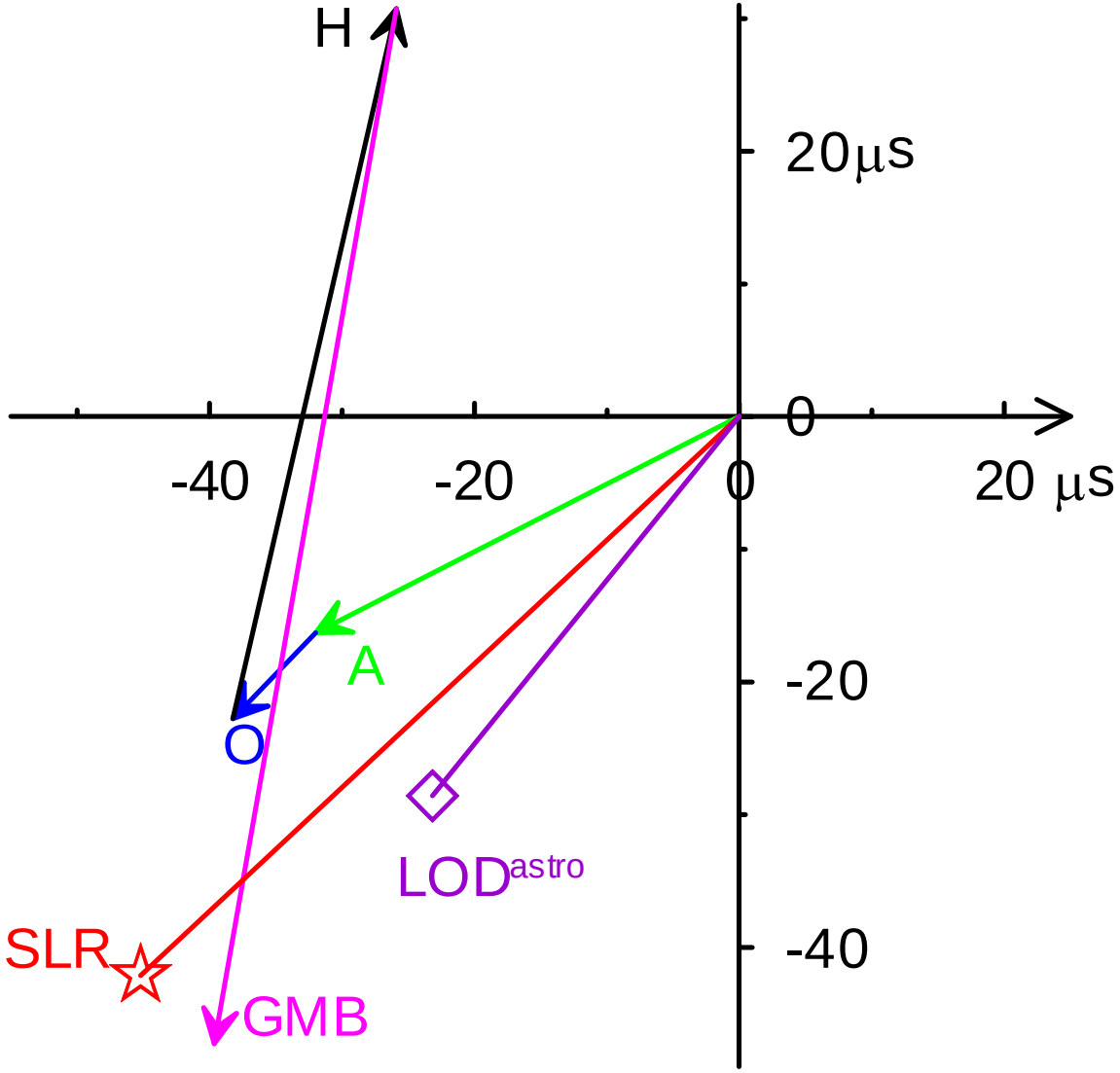
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GMB

Theory

$$\Delta LOD^{p}(t) = \frac{0.753 R_e^4}{g C_m} \int_0^{2\pi} \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} \Delta p(\varphi, \lambda, t) \cos^3 \varphi d\lambda d\varphi$$

$$\Delta LOD^{w}(t) = \frac{0.998 R_e^3}{g \Omega C_m} \int_0^{2\pi} \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} \int_{p_{bot}}^{p_{top}} u \cos^2 \varphi dp d\lambda d\varphi$$

$$\Delta LOD^{p} = \frac{2}{3} \cdot \frac{0.753 M R_e^{\ 2}}{C_m} (\bar{C}_0^0 - \frac{1}{1+k_2'} \cdot \sqrt{5} \bar{C}_2^0)$$

Data (1980-2008):

ECMWF (ERA40, ERA interim):

Surface pressure (1.5*1.5° *1day), winds (~1hPa)

ECCO kf066a2:

Salinity, temperature, current velocity,
sea surface height (1° *(1° /4~1°)*10day)

GLDAS:

Land water (1° *1° *1day)

SLR:

C20 (monthly interpolated to daily, Cheng MK)

LOD:

SPACE2008

Results—Global Mass Balance effects ΔM

Method 1:
averaged ΔM as a uniform layer to the global Earth surface and integral it in Equation (1)

Method 2:
directly using the Equation (3)

$$\Delta LOD(t) = \frac{0.753R_e^4}{gC_m}\int_0^{2\pi}\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} \Delta p(\varphi,\lambda,t)\cos^3\varphi d\lambda d\varphi \quad (1)$$

$$\Delta LOD = \frac{2}{3}\cdot\frac{0.753MR_e^{\ 2}}{C_m}\overline{C}_0^0 \quad (3)$$

(1)==(3) when calculate GMB effects

Results—Global Mass Balance effects

Method 3:
averaged ΔM into OCEAN or LAND surface and integral it in Equation (1)

$$\Delta LOD_o / \Delta LOD_g = 1.04 \quad 4\% \uparrow$$

$$\Delta LOD_l / \Delta LOD_g = 0.91 \quad 9\% \downarrow$$

Conveniently, we use method 2 to calculate GMB effects on LOD change.
It's also recommended that we should use global average method of GMB when we considered A+H+O.

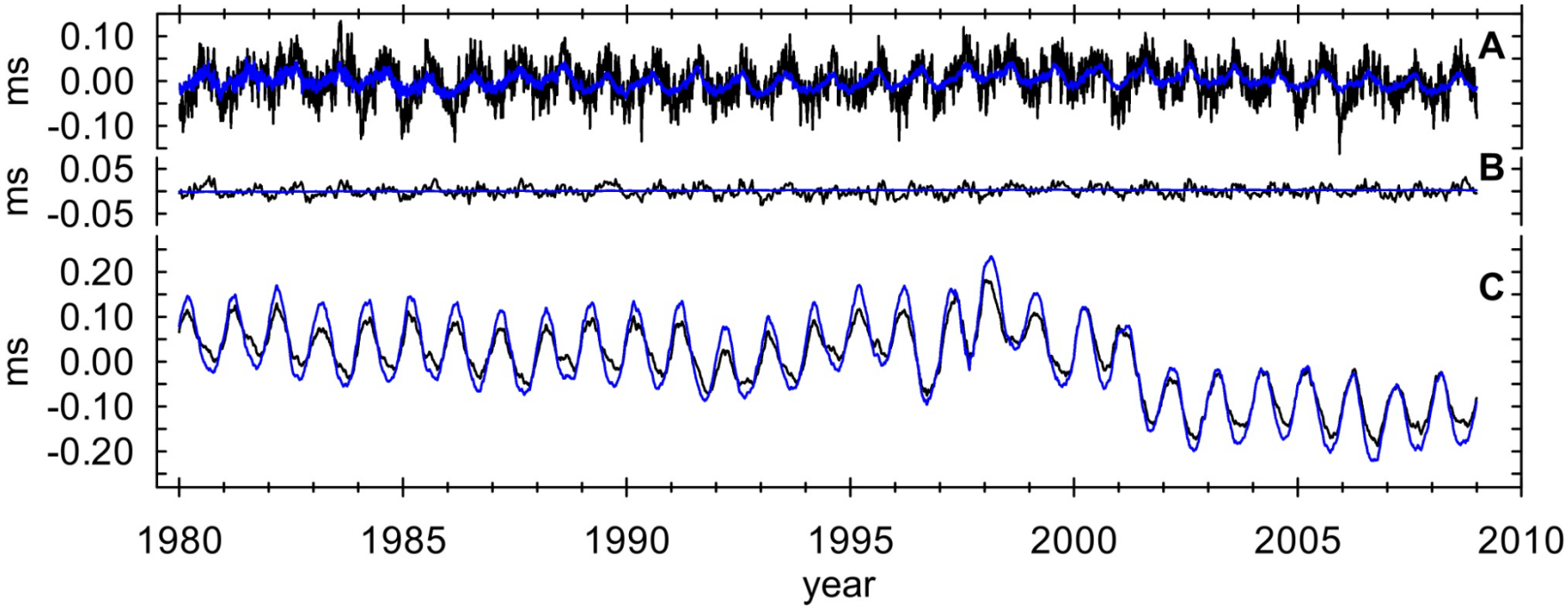
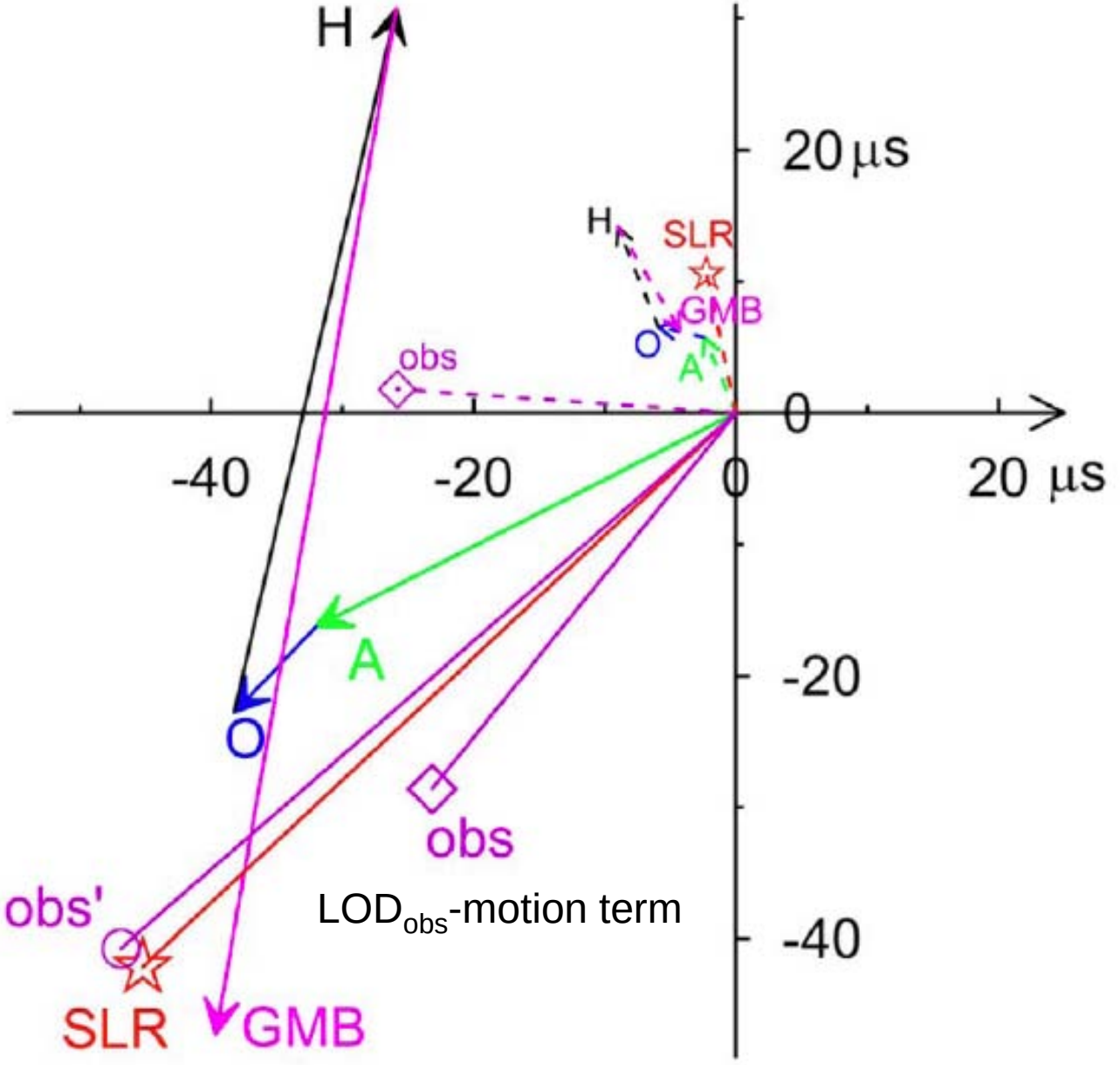
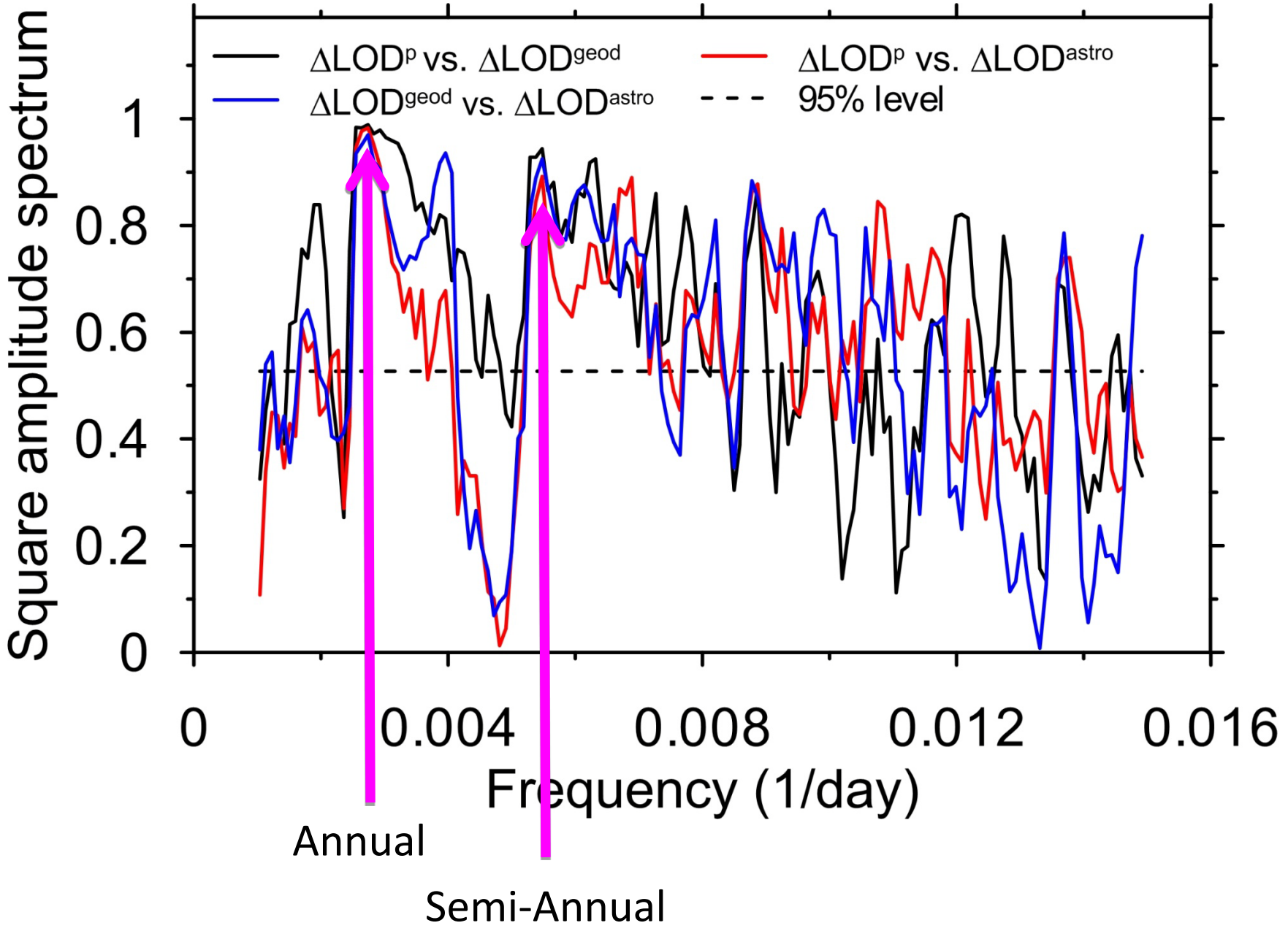


Figure 1. Time series of mass induced LOD changes from different geophysical fluids models (black) and from global mass balance effects (blue). (A) ECMWF atmospheric model, (B) ECCO oceanic model, (C) GLDAS hydrological model.



LOD_{obs}-motion term

	Term	Annual		Semi-annual	
		Amp. (μs)	Phase (Deg)	Amp. (μs)	Phase (Deg)
Mass term	ECMWF (P1)	35.9±0.4	207±1	6.2±0.4	113±3
	ECCO (P2)	9±0.1	226±0	3.6±0.1	167±2
	GLDAS (P3)	54.9±0.5	77±1	8.2±0.5	112±3
	P7=P1+P2+P3	40.0±0.7	131±0	16.7±0.7	123±2
Global mass balance	ECMWF(P4)	16.2±0.1	192±0	5.1±0.1	82±1
	ECCO (P5)	0.4±0.0	267±0	0.4±0.0	67±0
	GLDAS (P6)	87.2±0.6	70±0	6.2±0.6	155±0
	P8=P4+P5+P6	79.2±0.6	80±0	9.2±0.6	121±3
LOD^{p}_{GMB}	P7-P8	62.1±0.5	231±0	7.4±0.5	126±2
SLR		61.8±0.3	223±0	10.8±0.3	102±2
Motion Term	Current(P9)	7.5±0.1	205±1	1.7±0.1	123±2
	Wind(~1)(P10)	401.5±2.8	34±0	264.4±2.8	41±1
LOD	Observed (Obs)	361.5±4.4	33±0	267.9±4.3	245±1
LOD^{astro}	LOD(Obs)-P9-P10	36.8±0.8	231±1	25.9±0.8	176±2


ΔLOD^p vs. ΔLOD^geod
ΔLOD^geod vs. ΔLOD^astro
ΔLOD^p vs. ΔLOD^astro
95% level
Square amplitude spectrum
1
0.8
0.6
0.4
0.2
0
0
0.004
0.008
0.012
0.016
Frequency (1/day)
Annual
Semi-Annual

Conclusions and Discussions

- GCMs are not mass conservation, the GMB error effects can have larger effects on the LOD change than the mass induced LOD change from the GCMs itself.

- After consider the GMB error effects on the LOD change, the observed mass induced LOD change from SLR (LOD-motion) can be perfectly (better) explained by the existed GCMs from intra-seasonal to inter-annual timescales.

1. Dose GMB have important effect on LOD for high frequency GCMs data?
2. LOD motion term should be further constrained. Thus, which data can be used then?

Thanks for your attention!