

Evaluations of Global Geophysical Fluid Models Based on Broad-band Geodetic Excitations

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Outline

- **Broad-band Geodetic Excitations**
 - Why are the broad-band geodetic excitations needed?
 - How to obtain them and are the methods reliable?
- **Global Geophysical Fluid Models**
 - Inter-comparisons among geophysical excitations derived from these models
 - Evaluations of the geophysical excitations using geodetic excitations
 - Role of Greenland ice in global hydrological excitation
 - Constructing combined geophysical excitations from different models
- **Discussions and Conclusions**



Broad-band Geodetic Excitations

- Why are the broad-band geodetic excitations needed?
 - To evaluate the geophysical excitations from seasonal to daily/subdaily time scales, and gain more knowledge on geophysical fluids
 - To quantify the IB/NonIB effect in the atmosphere-ocean interactions
- Methods to derive the geodetic excitations
 - Wison85 filter (Wilson, 1985, Geophs J RAS)
 - Kalman filter (Brzezinski, 1992, Manu Geod)
 - Two-stage filter (Wilson & Chen, 1996, J Geod)
 - Gain adjustment (Wilson & Chen, 1996, J Geod)
 - Cubic spline fit (Kouba, 2006, J Geod)

Methods realized

Method not realized by us

All the PM data used here are daily sampled or decimated to daily sampled with a lowpass filter



Theoretical Aspects

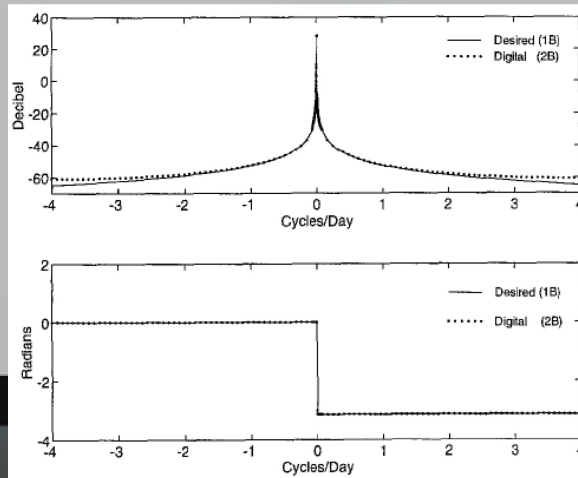
Formula or method

Comments

Wilson85 filter	$\chi_t = \frac{i \exp(-i\pi F_c T)}{\sigma_c T} [p_{t+T/2} - \exp(i\sigma_c T) p_{t-T/2}]$ Convert PM data p to geodetic excitation χ	The transfer function is $L_{w85}(f) = \frac{-i\sigma_c T \exp[i\pi(F_c - f)T]}{1 - \exp[i(\sigma_c - 2\pi f)T]}$ χ and p are NOT at the same time points!!!
Two-stage filter	$\chi'_t = c_1 \exp(-i\sigma_c T) \chi_t + c_2 \chi_{t-T} + c_3 \exp(i\sigma_c T) \chi_{t-2T} + c_4 \exp(i\sigma_c T) \chi'_{t-T}$ $c_1 = 0.9304, \quad c_2 = 0.5024, \quad c_3 = 0.01861, \quad c_4 = -0.4541$ Apply the second-stage filter to the output of the Wilson85 one	Time-domain correction to the output of the Wilson85 filter χ and p are NOT at the same time points!!!
Gain Adjustment	$A(f) = \frac{L_0(f)}{L_{w85}(f)}, \quad L_0(f) = \frac{\sigma_c}{\sigma_c - 2\pi f}$ is the required transfer function Multiply the gain adjustment A to the output of the Wilson85 filter	Frequency-domain correction to the output of the Wilson85 filter FFT and IFFT are needed χ and p are NOT at the same time points!!!
Cubic spline fit	$\chi = \frac{i}{\sigma_c} \dot{p}_{\text{fit}} + p$ Convert PM data p and their fitted rates $\dot{p}_{\text{fit}}$ to geodetic excitation χ	$\dot{p}_{\text{fit}}$ are the interpolated PM-rate values calculated from a cubic spline fit to the PM values χ and p are at the same time points!!!

$$\frac{i}{\sigma_c} \dot{p} + p = \chi$$

$$L_0(f) = \frac{\sigma_c}{\sigma_c - 2\pi f}$$



Wilson85 filter has perfect phase but over-estimated gain w.r.t. the theoretical formula



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Theoretical Aspects

➤ Variant of the Wilson85 filter (Wilson85v)

Wilson85

$$\chi_t = \frac{i \exp(-i\pi F_c T)}{\sigma_c T} [p_{t+T/2} - \exp(i\sigma_c T) p_{t-T/2}]$$

+

Linear interpolation

$$p_{t-T/2} = \frac{p_{t-T} + p_t}{2}, \quad p_{t+T/2} = \frac{p_t + p_{t+T}}{2}$$

Smoothing!



Wilson85v

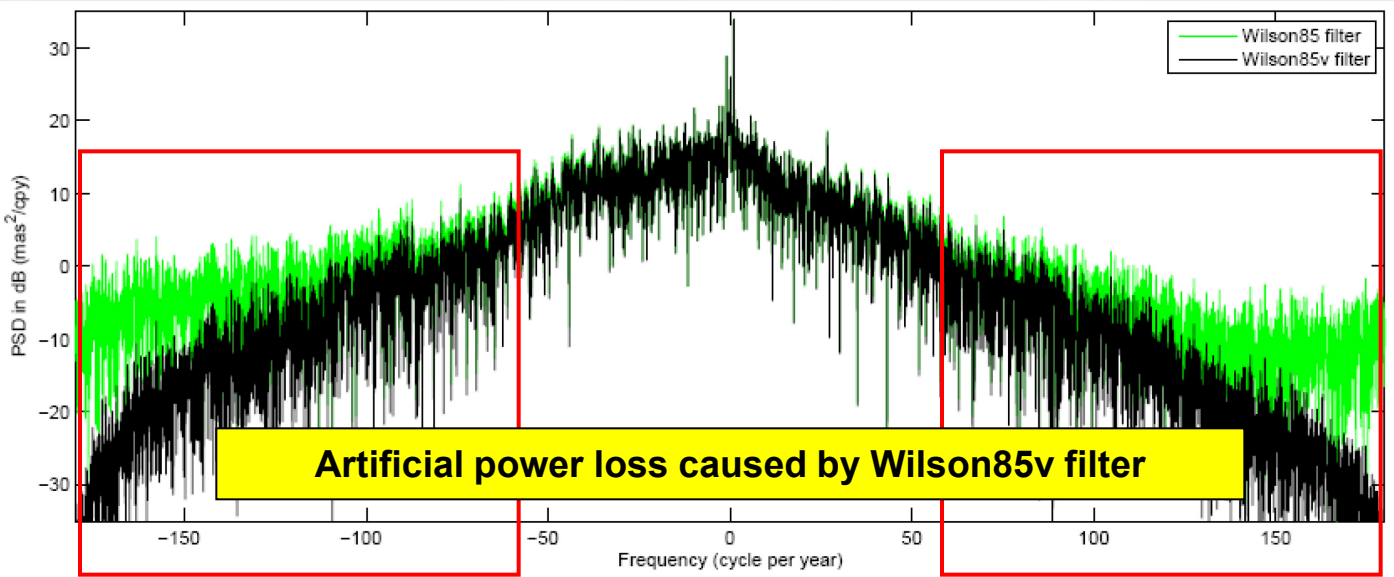
$$\chi_t = \frac{i \exp(-i\pi F_c T)}{2\sigma_c T} \{p_{t+T} + [1 - \exp(i\sigma_c T)]p_t - \exp(i\sigma_c T)p_{t-T}\}$$

χ and p are at the same time points!!!

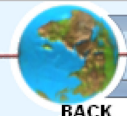


Comparisons of Different Methods

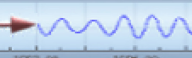
➤ Wilson85 vs Wilson85v (The IG1/IGS PM data are used)



Wilson85v filter would not be recommended!!!



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EXCITATION OF THE POLAR MOTION AND ROTATION RATE

updated : August 2010  [see graphics updated 2 times per week](#)

☒ Inverted parameter model ☐ Non Inverted parameter model ☐ Civil date for graphics

Comparison of observed excitation with : ☒ Matter + motion terms ☐ Matter term ☐ motion term

☐ Terrestrial excitation NCEP (1962-last week) ☐ Oceanic excitation: ECCO (1962-current year)

relation Dimension du graphique : 600 x 450 ☒ English ☐ French

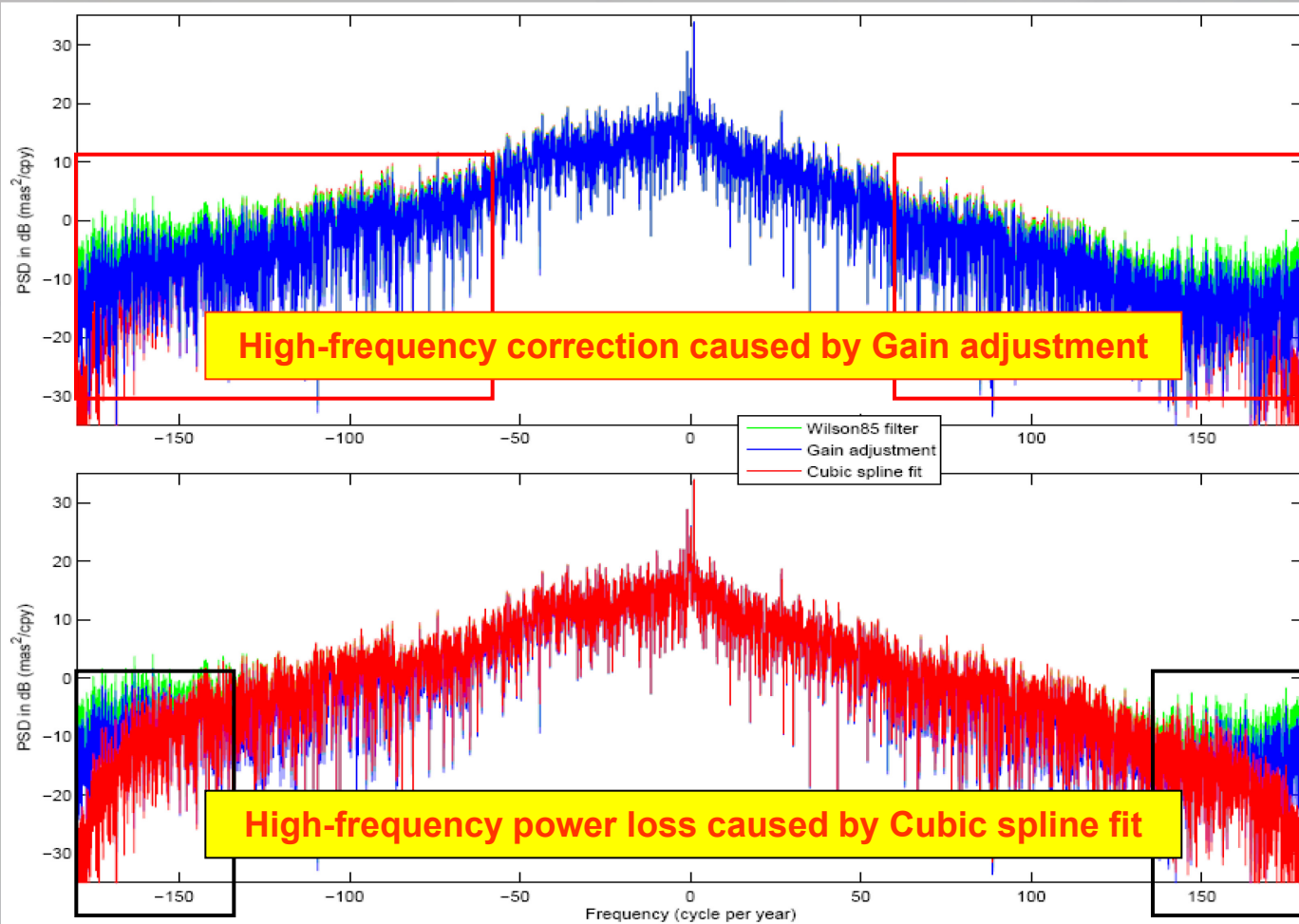
☒ Plot and correlate x_{GEOD} and x_{GEOPH} ☐ Plot the differences $x_{GEOD} - x_{GEOPH}$

Wilson85v filter is adopted by the IERS-EOC webpage tool

The tool is only suitable for seasonal excitations!

Comparisons of Different Methods

➤ Wilson85 vs Gain adjustment vs Cubic spline fit



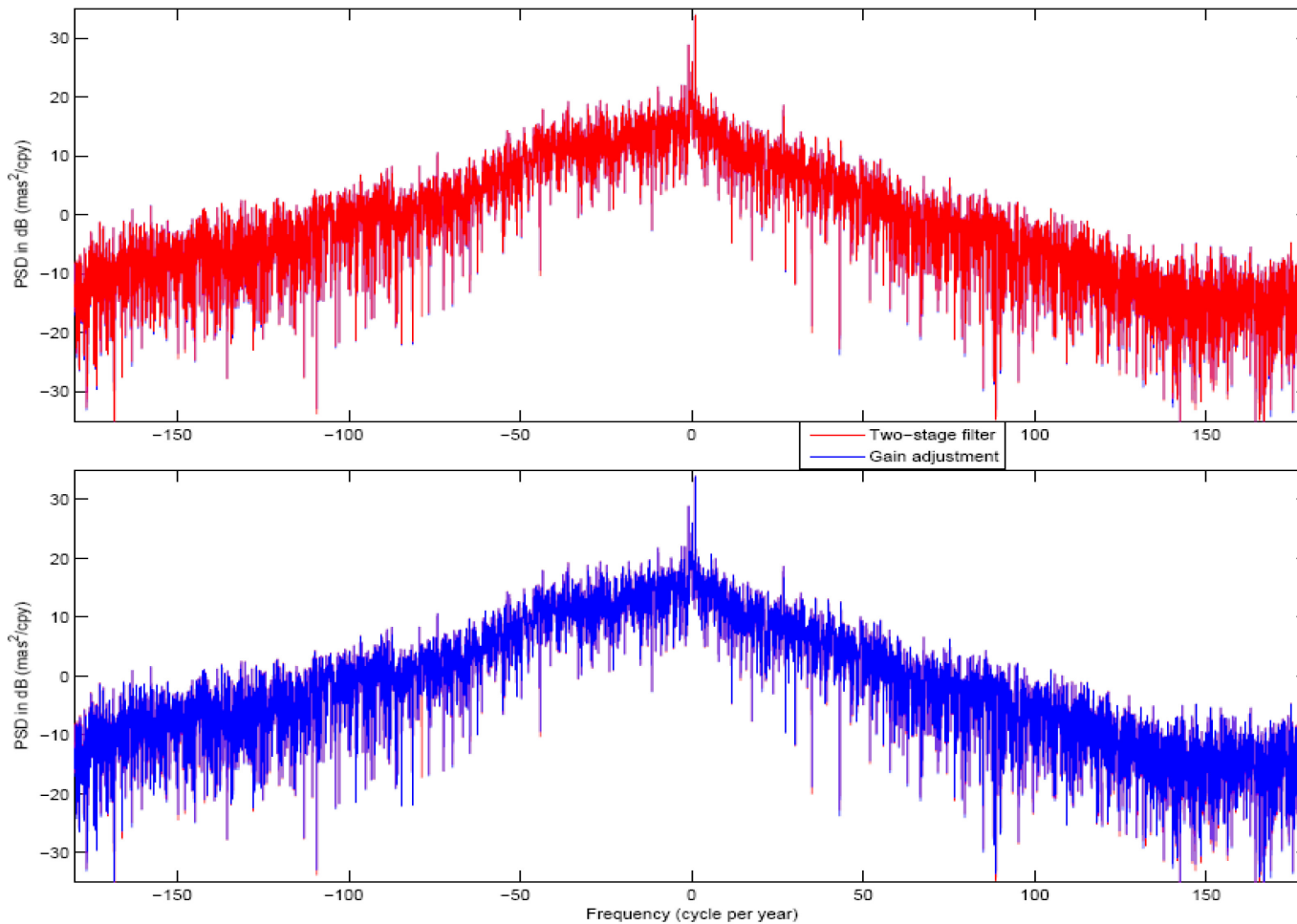
**Gain adjustment
might be better!!!**

Wilson85v smoothing effect >> Gain adjustment correction



Comparisons of Different Methods

➤ Gain adjustment vs Two-stage filter

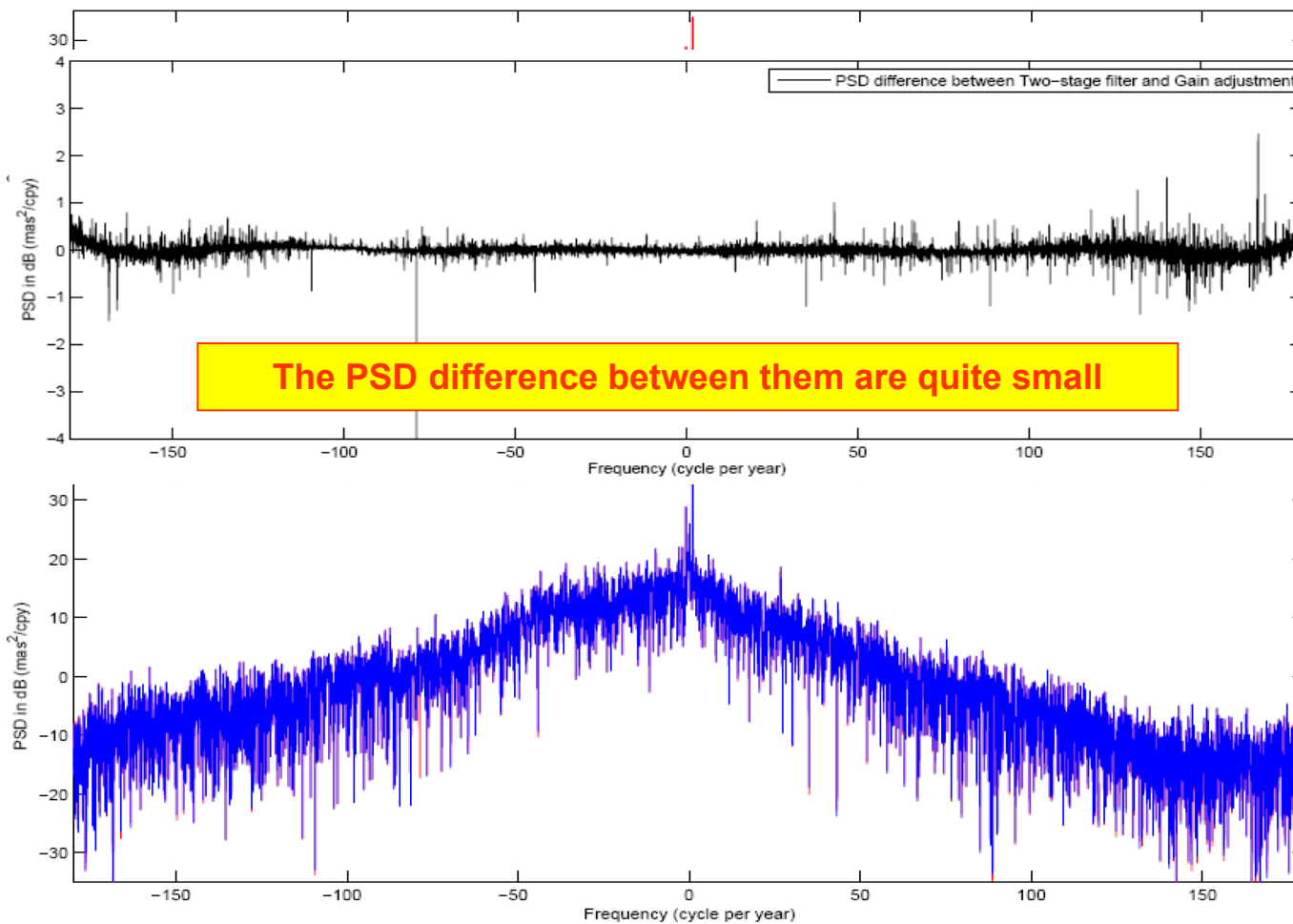


Gain adjustment is almost equivalent to Two-stage filter



Comparisons of Different Methods

➤ Gain adjustment vs Two-stage filter



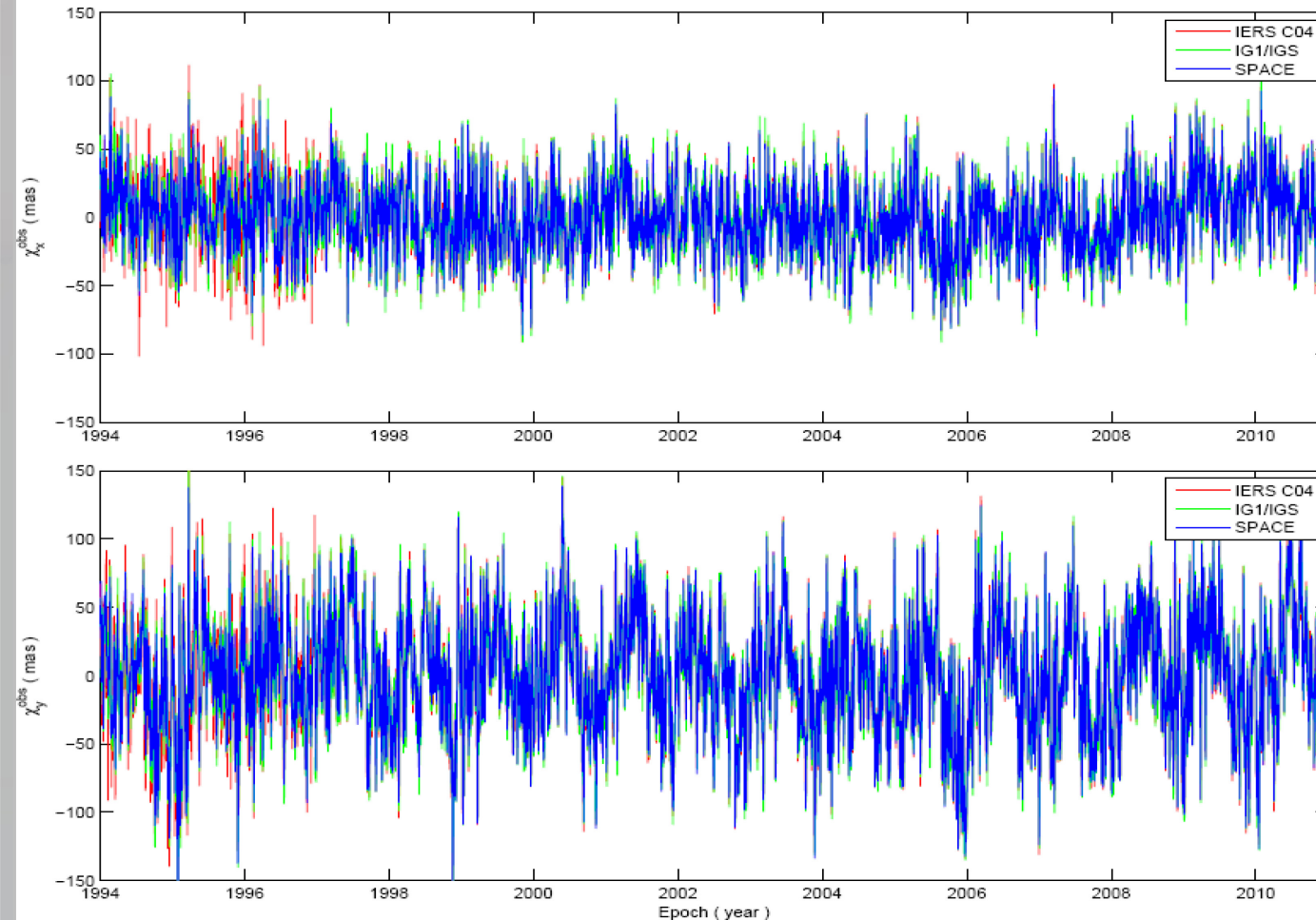
Gain adjustment and Two-stage filter are recommended

Hereafter we use **Gain adjustment** to derive the geodetic excitations from various PM data!!!



Geodetic Excitations

- Geodetic excitations derived from the IERS 08 C04, IG1/IGS and SPACE2010 polar motion data



Time-domain comparisons

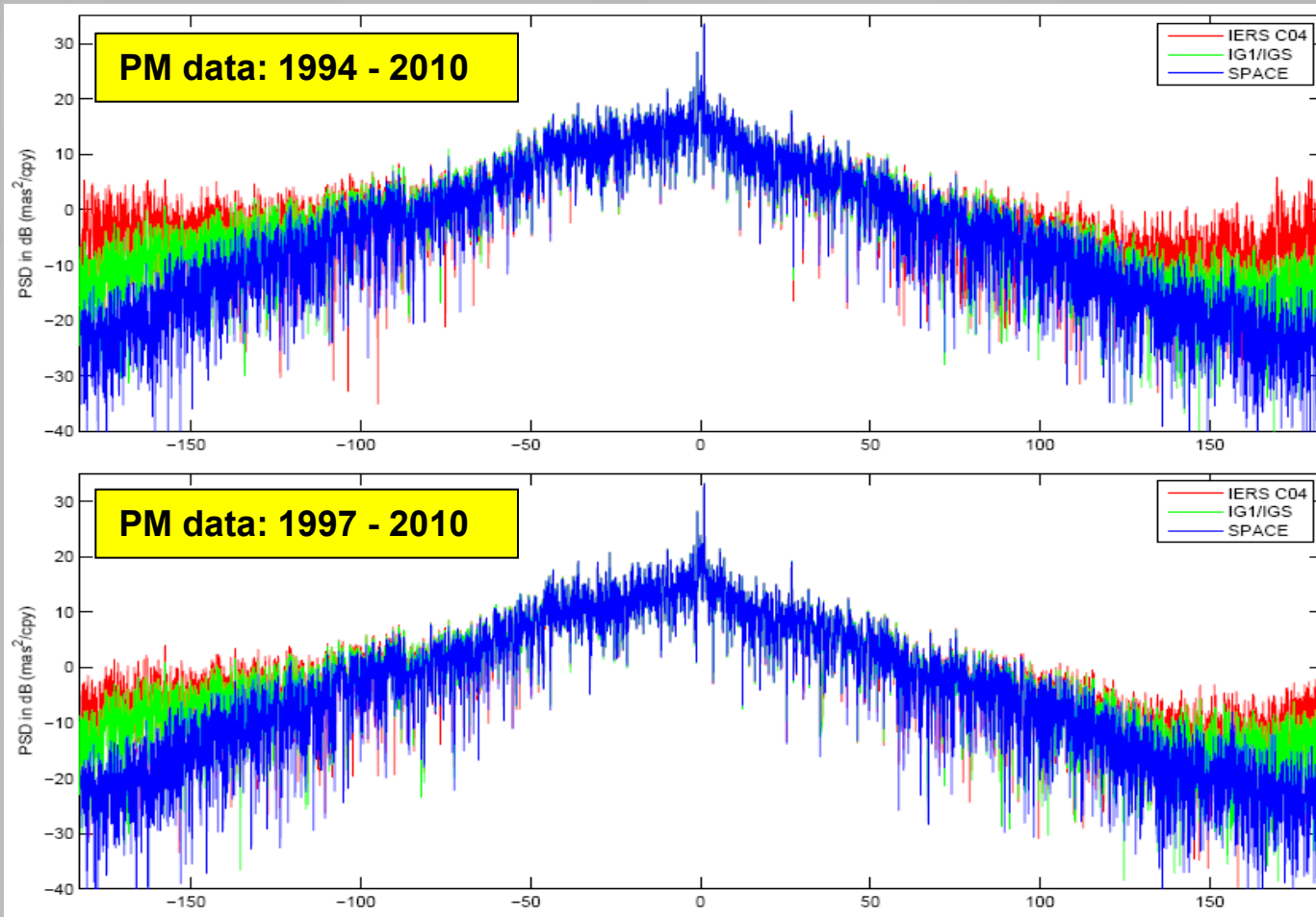
Since 1997, the differences among various PM data reduced significantly!!!

Since 1997, the IGS data have dominant contributions to the IERS and SPACE data



Geodetic Excitations

- Geodetic excitations derived from the IERS 08 C04, IG1/IGS and SPACE2010 polar motion data



Frequency-domain comparisons

Differences lie in
high-frequency
bands!!!

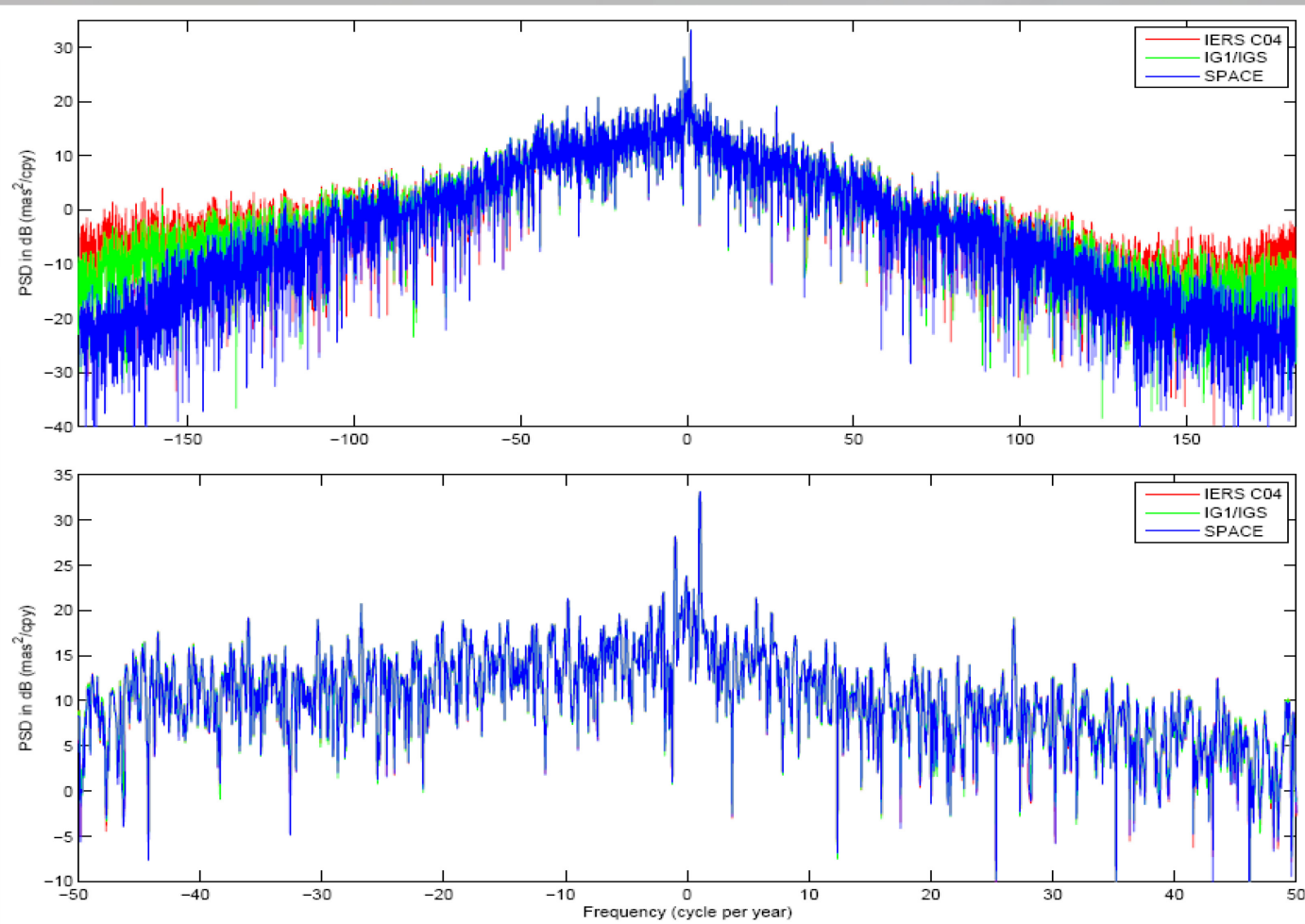
High-frequency
components of
C04 are quite
suspect before
2007



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Geodetic Excitations

- Geodetic excitations derived from the IERS 08 C04, IG1/IGS and SPACE2010 polar motion data



These data agree with each other quite well at low frequency bands

Frequency-domain comparisons



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Global Geophysical Fluid Models

- To study the global geodynamics, various atmospheric, oceanic and hydrological models are established
- Different versions of the global geophysical models
 - NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) reanalyses: **AAM, HAM**
 - ECMWF (European Centre for Medium-Range Weather Forecasts) reanalyses: **AAM, OAM, HAM**
 - JMA (Japan Meteorological Agency) products: **AAM**
 - UKMO (United Kingdom Meteorological Office) products: **AAM**
 - ECCO (Estimating the Circulation and Climate of the Ocean) Assimilation products: **OAM**
 - GLDAS (Global Land Data Assimilation System) products: **HAM**

**JMA and UKMO
AAMs are not used
since there are not
OAMs consistent
with them**

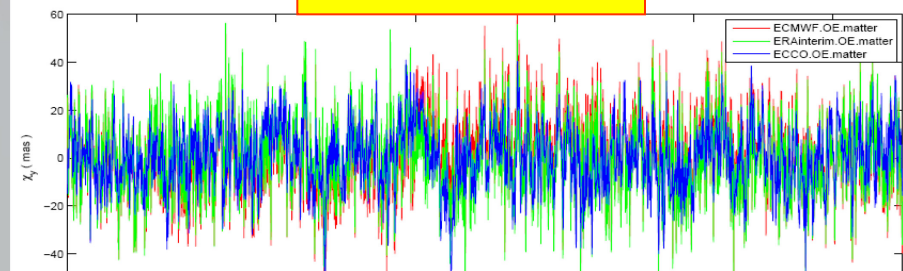
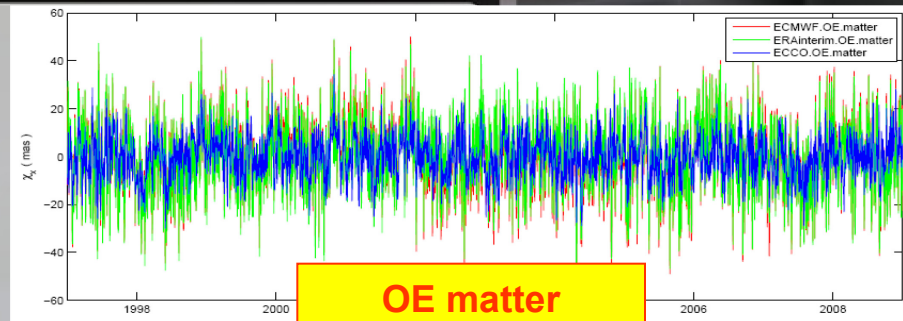
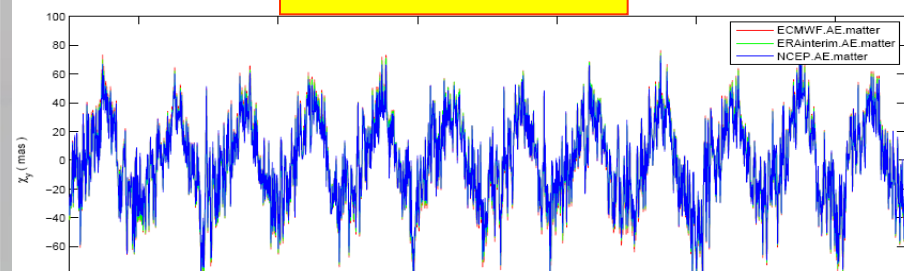
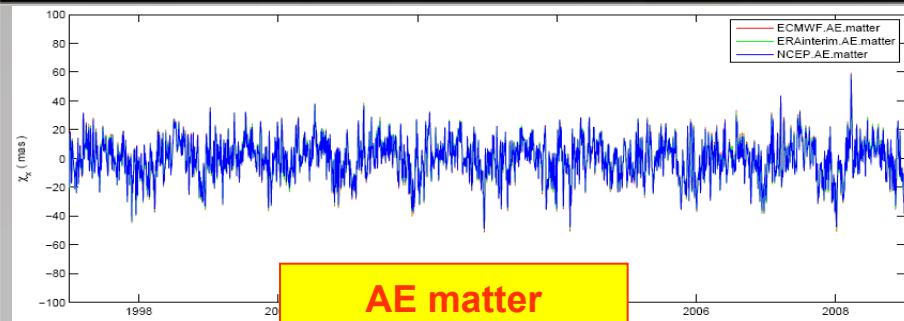


Model Evaluations I: Daily data

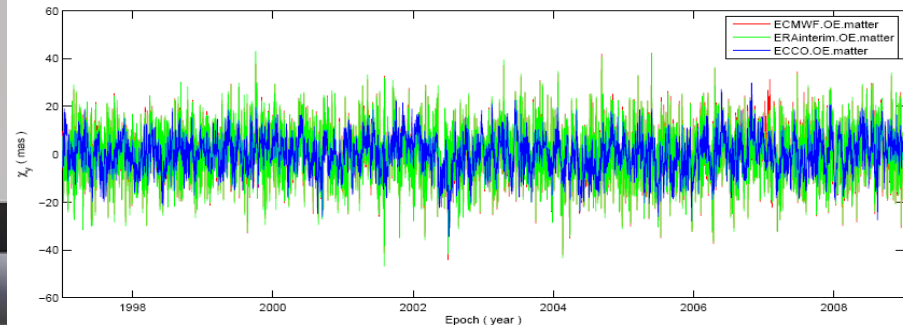
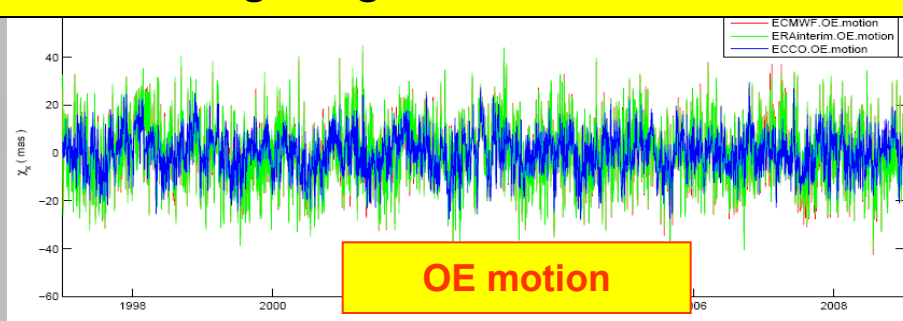
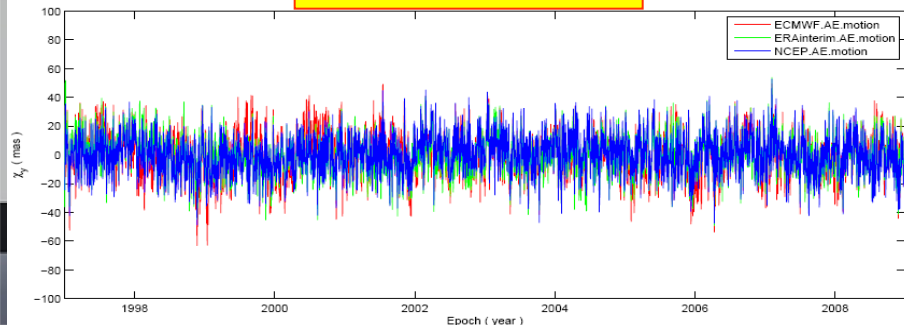
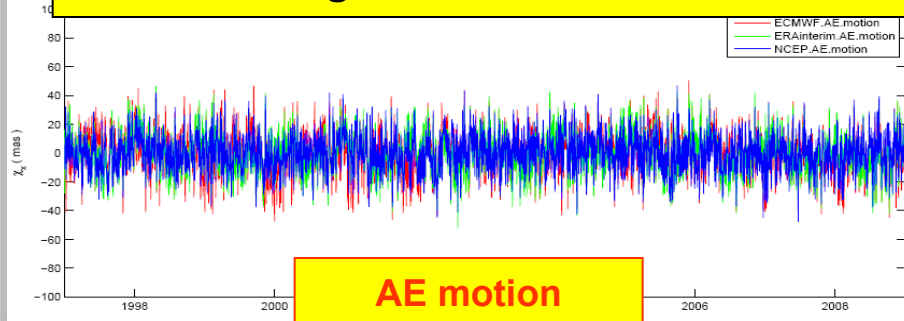
- **Data used**
 - IERS EOP 08 C04 (1997 ~ 2008)
 - NCEP reanalysis AAM + ECCO kf080 OAM + NCEP reanalysis HAM (1997 ~ 2008)
 - ECMWF ERA40 (1997 ~ 2001) plus ECMWF operational (2002 ~ 2008) AAM + OAM + HAM
- **Formula of Eubanks (1993) is used to derive the effective geophysical excitations**
- **Inverted barometer (IB) assumption is adopted to combine AE and OE**



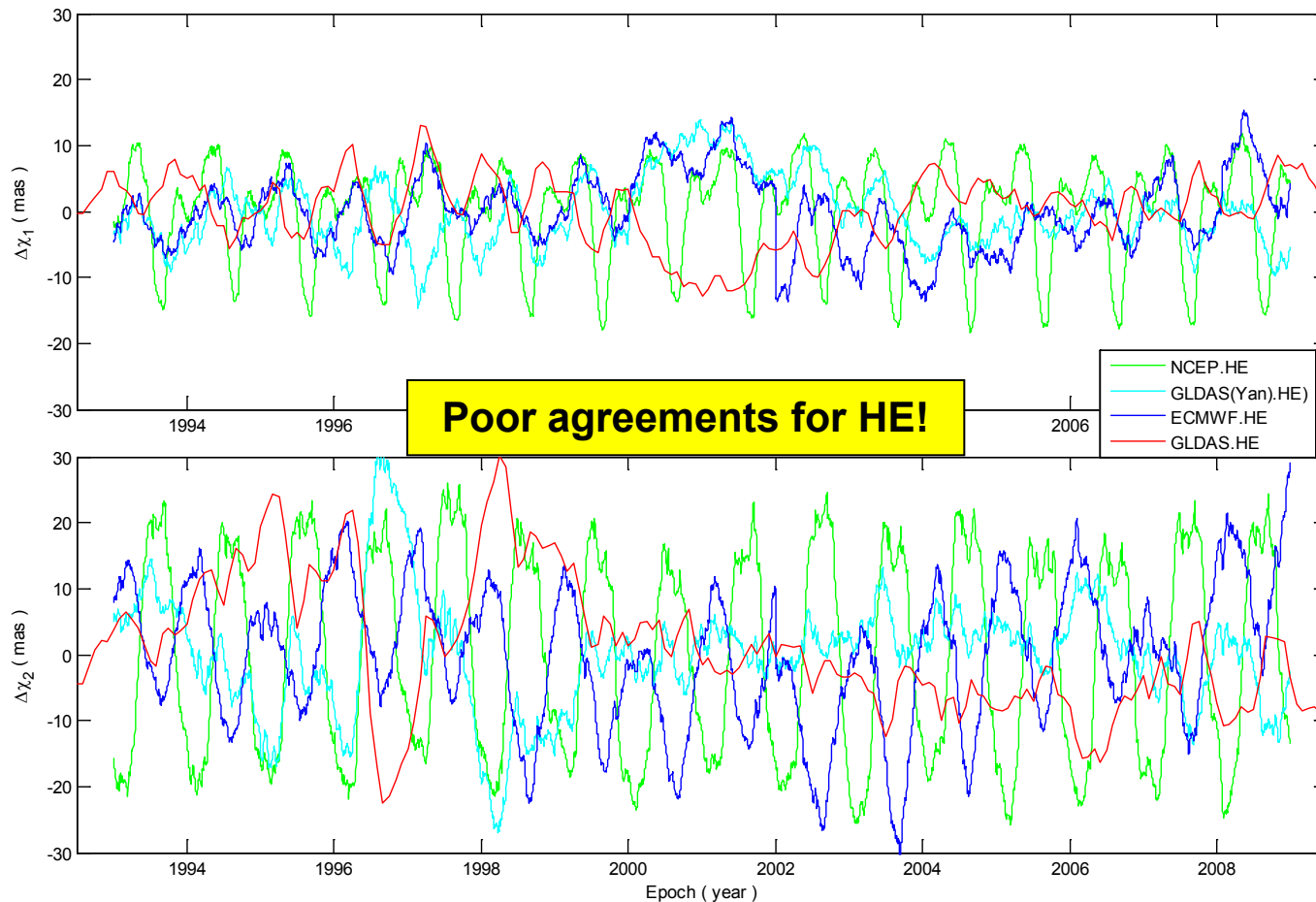
Time Series Comparisons (1d)



Good agreements for AE! ECMWF OE has stronger signals than ECCO one



Time Series Comparisons (1d)

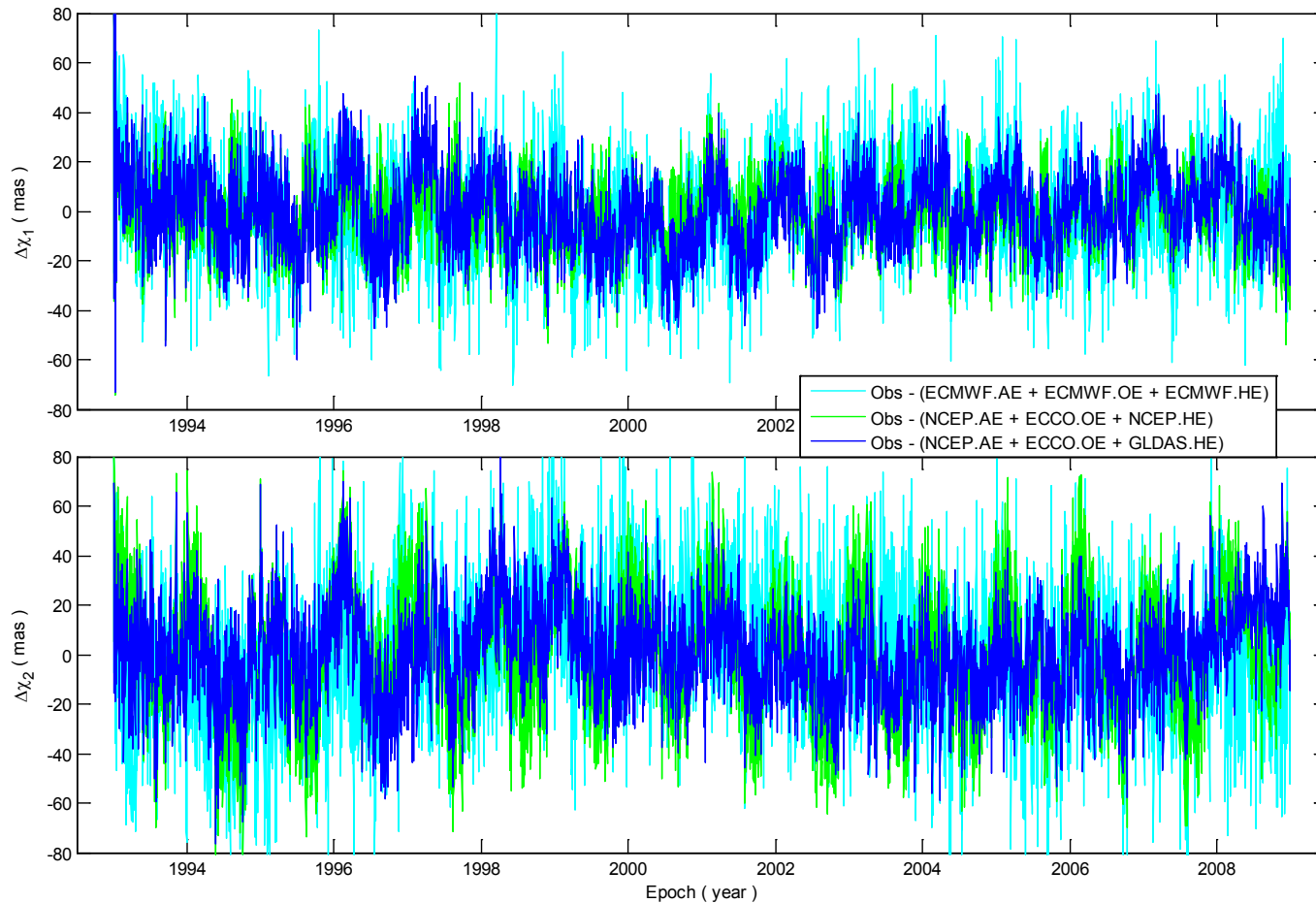


➤ **Even for the same model GLDAS, the HEs are quite different!!!**

- GLDAS(Yan).HE (cyan line) is provided by Dr. Haoming Yan
- GLDAS.HE (red line) is our estimate (Monthly data tws_gldas_noah_1m_7901_1010.dat is used)



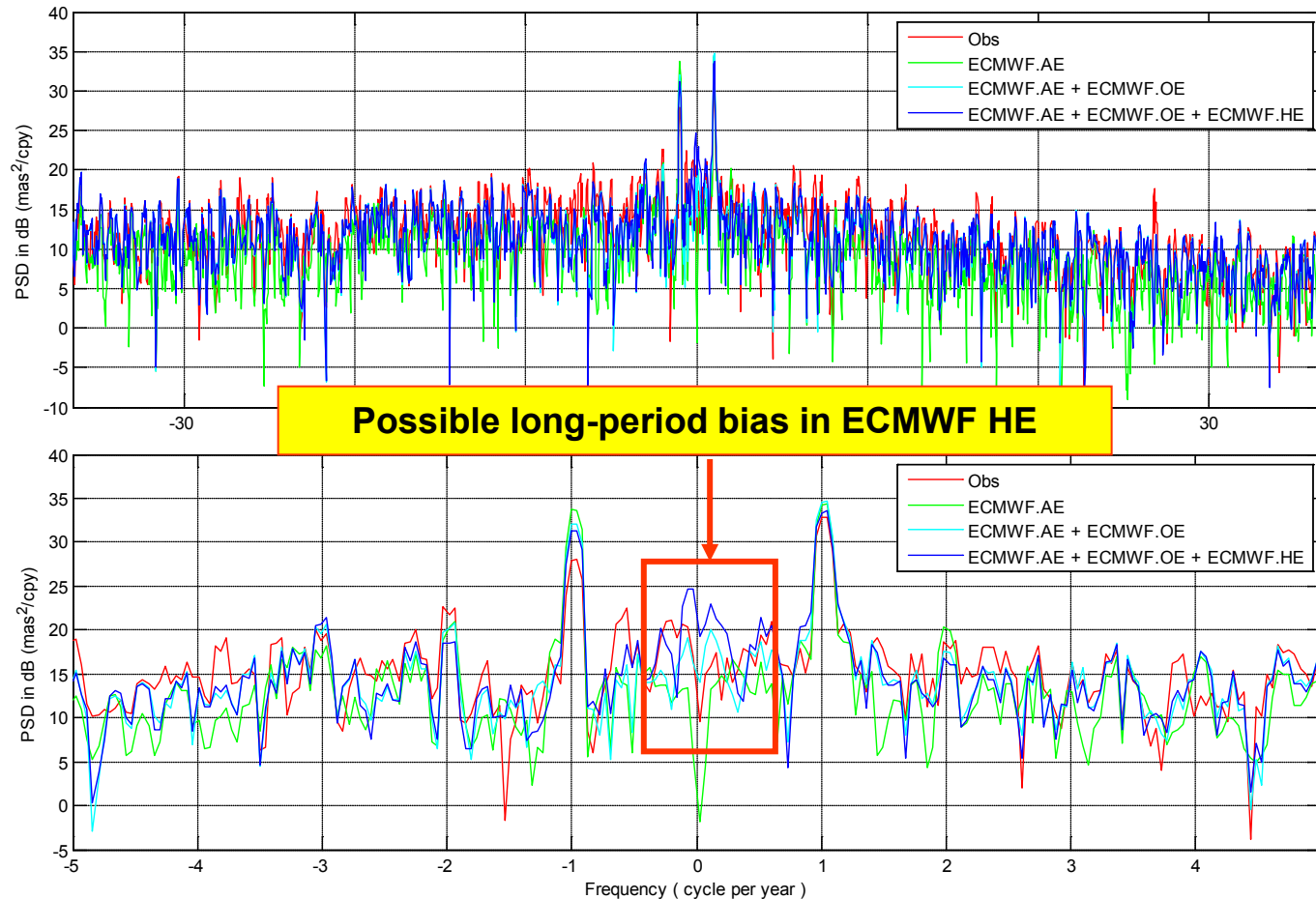
Excess Polar Motion Excitations (1d)



Residuals contain strong semi-annual signals



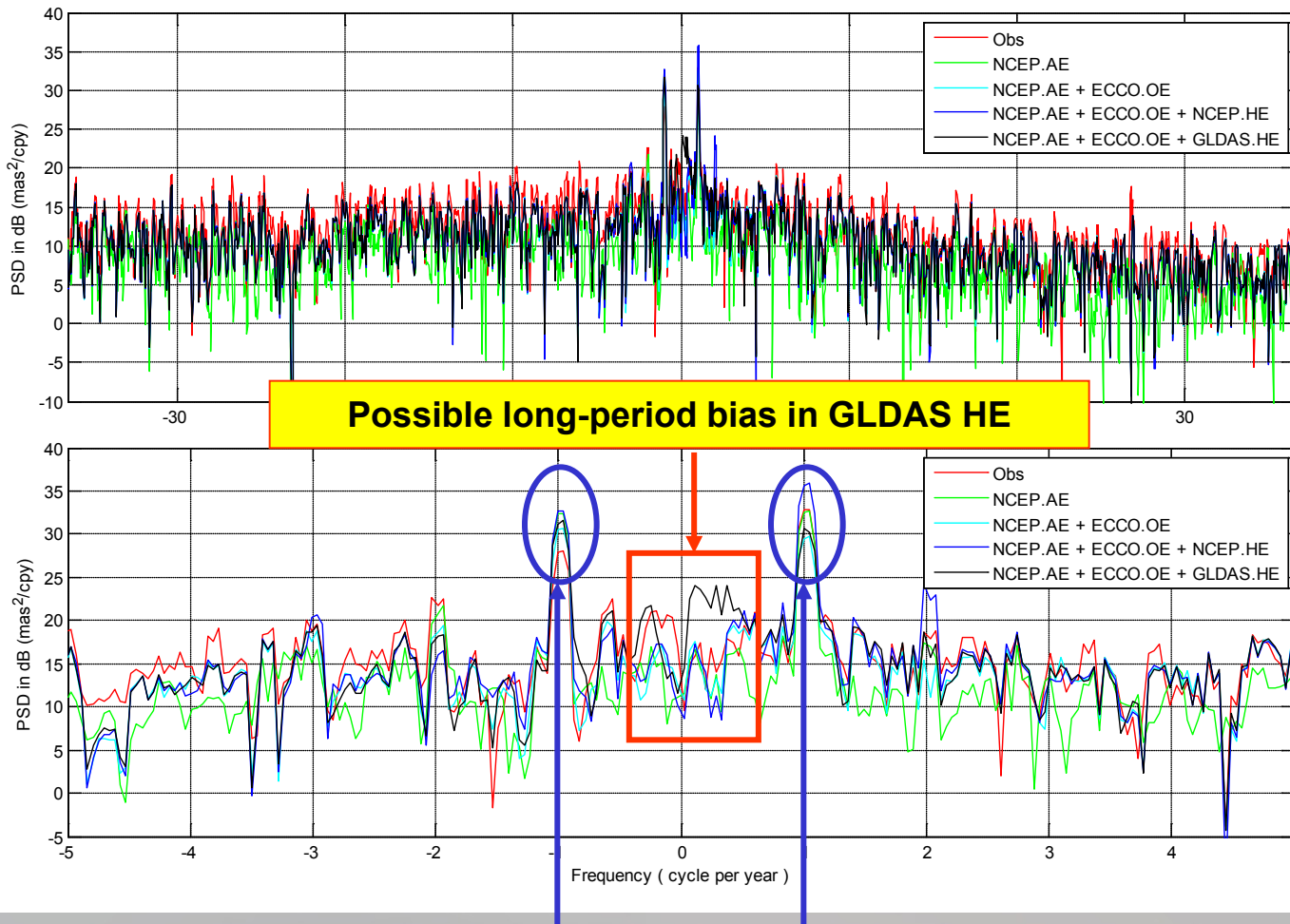
Spectrum Comparisons (1d)



Here long-period bias means long-period error



Spectrum Comparisons (1d)

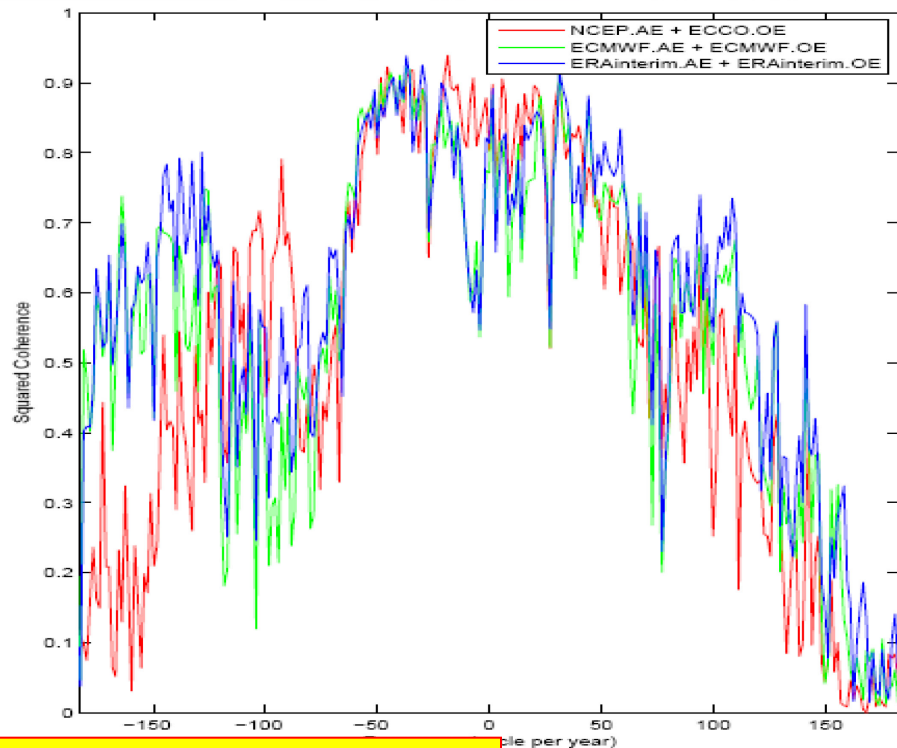
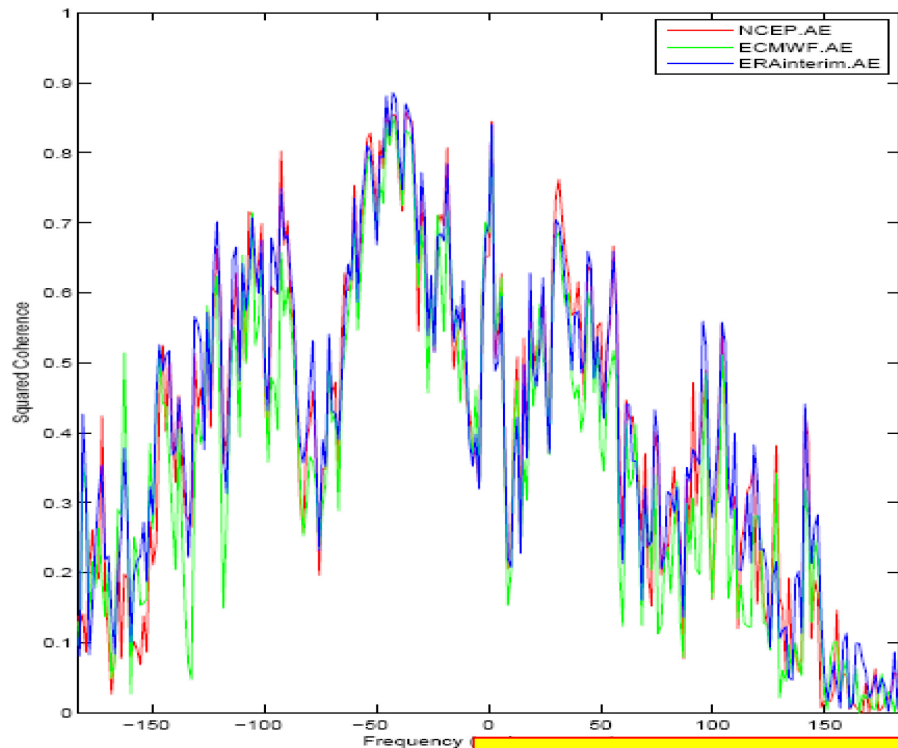


Long-period errors in GLDAS surface loading was also found by a comparison with the GPS observations

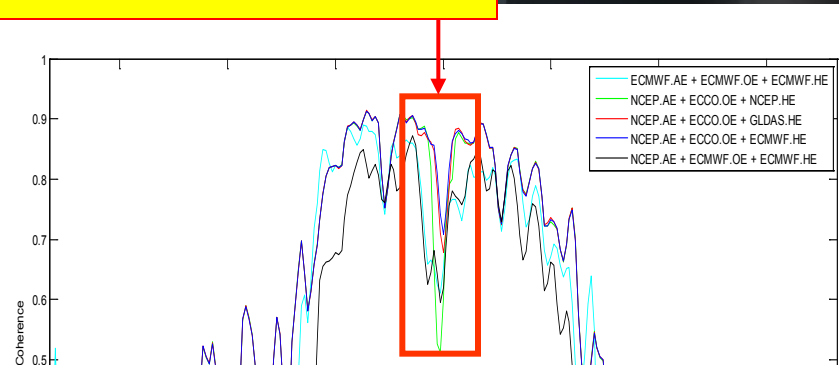
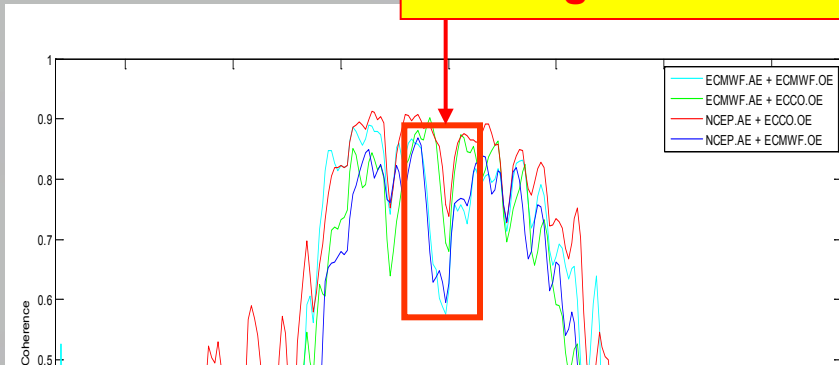
(Ray & van Dam, 2011, private communication)



Coherence Comparisons

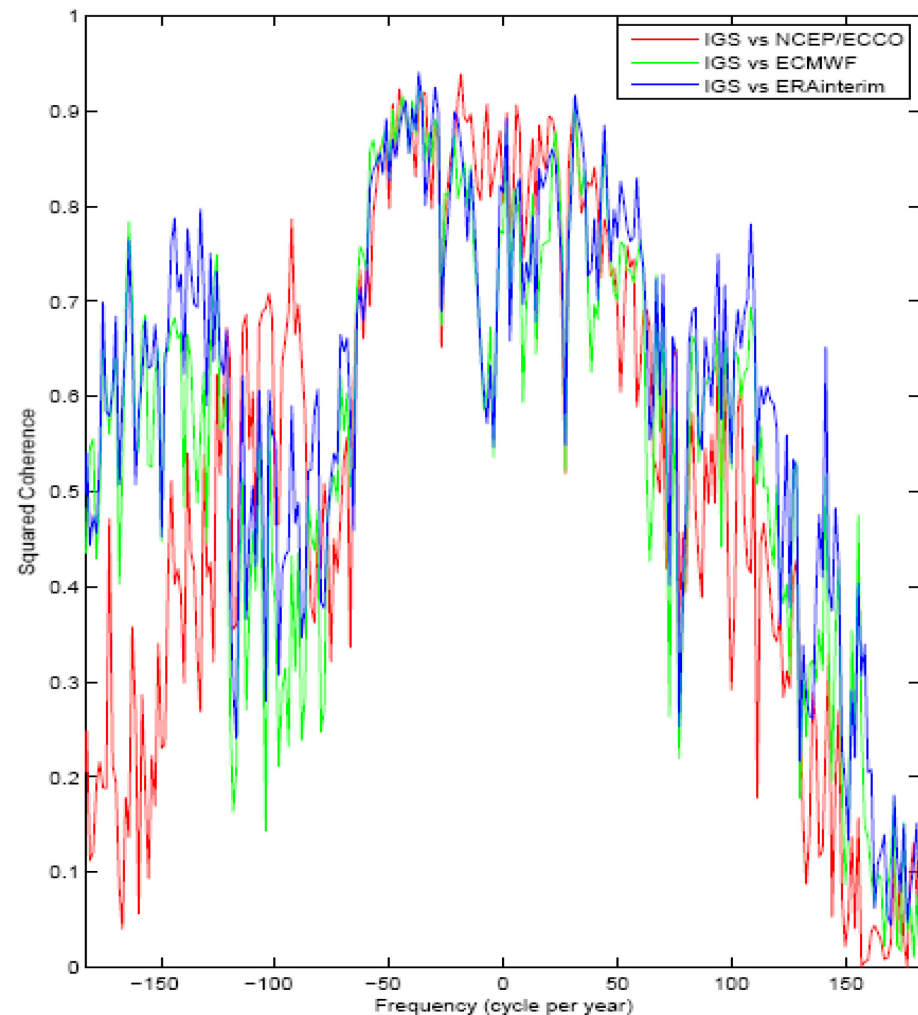
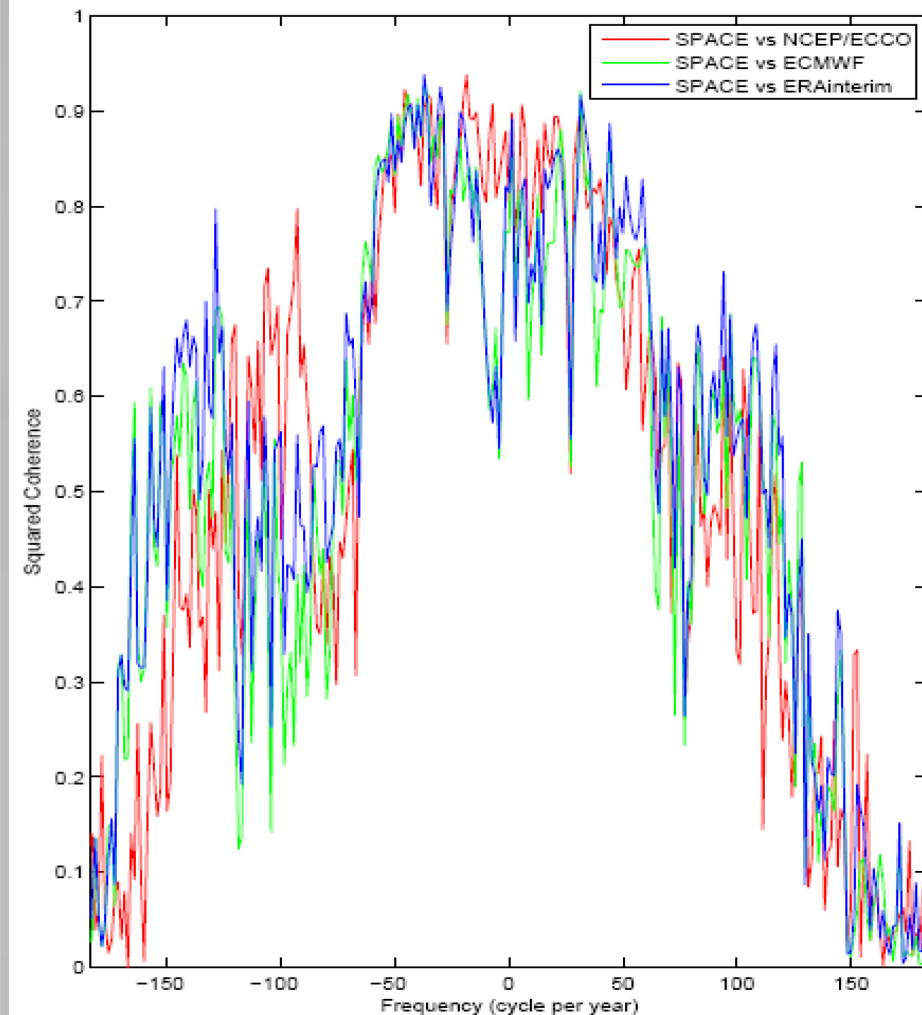


Adding HE reduces the coherence with Obs



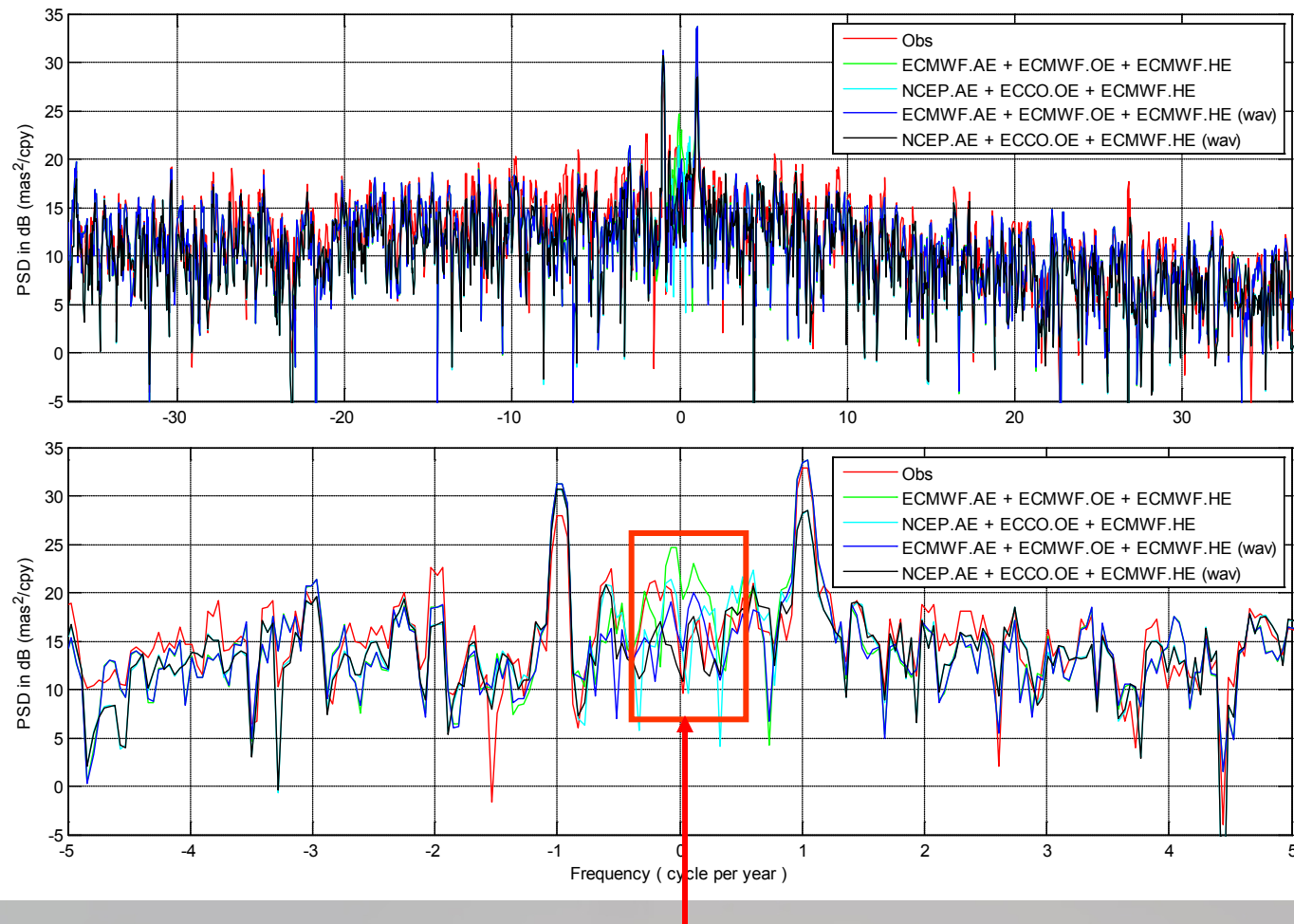
Coherences between GE, AEs, (AE + OE)s and (AE+OE+HE)s

Coherence Comparisons with IGS and SPACE



Only AEs and OEs are used while HEs are excluded

Effect of debias



Here debias means removing the long-period error

Debias removes the low-frequency discrepancies



Role of Greenland TWS

➤ On the GLDAS-based HE

- Yan's estimate is different from ours
- H. Yan (2010, private communication): set the TWS to 500 mm equivalent water height in Greenland
- J. L. Chen & C. Wilson (2005): without details
- This study: TWS in Greenland not changed

➤ Is the difference due to different treatments of the TWS in Greenland

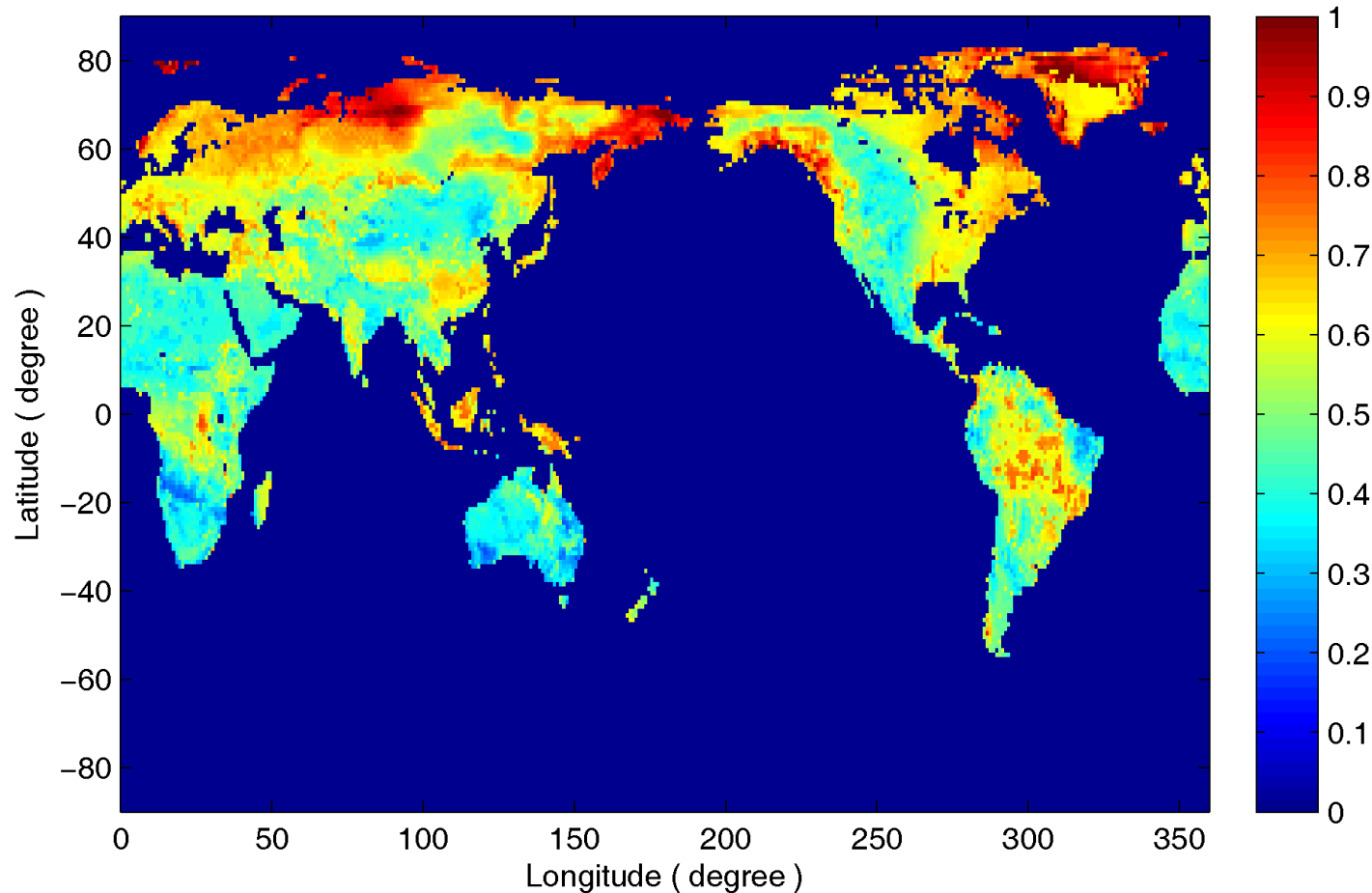
- (or) Is the Greenland water storage important in the estimate of the hydrological excitation?



Greenland TWS

➤ Taking the GLDAS model as an example

GLDAS grid data (1 degree by 1 degree, in meter) for Jan. 1979

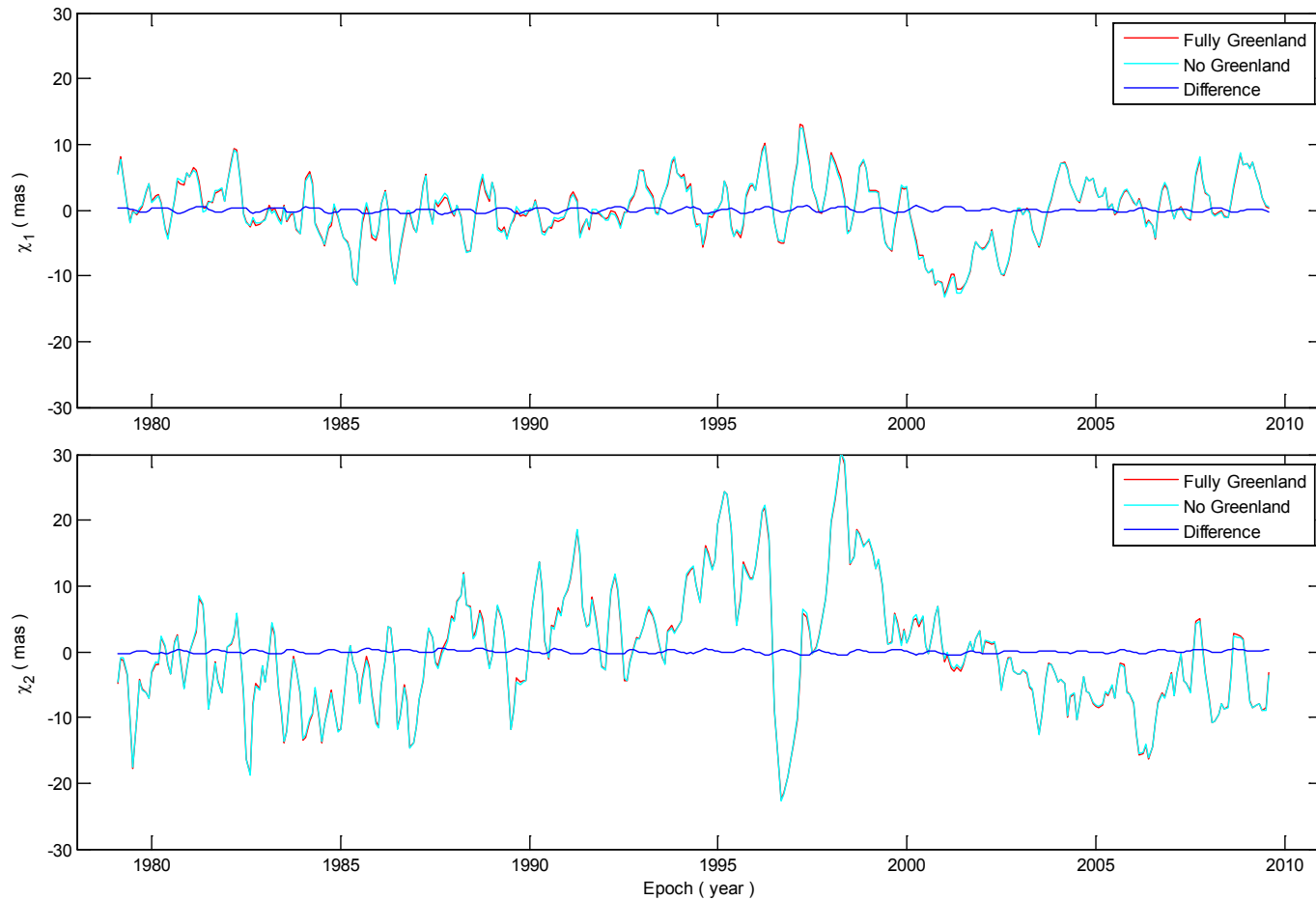


The maximal value of the equivalent water height can reach a few meters!

Here we impose a 1-m limit to show the details of TWS in most areas.



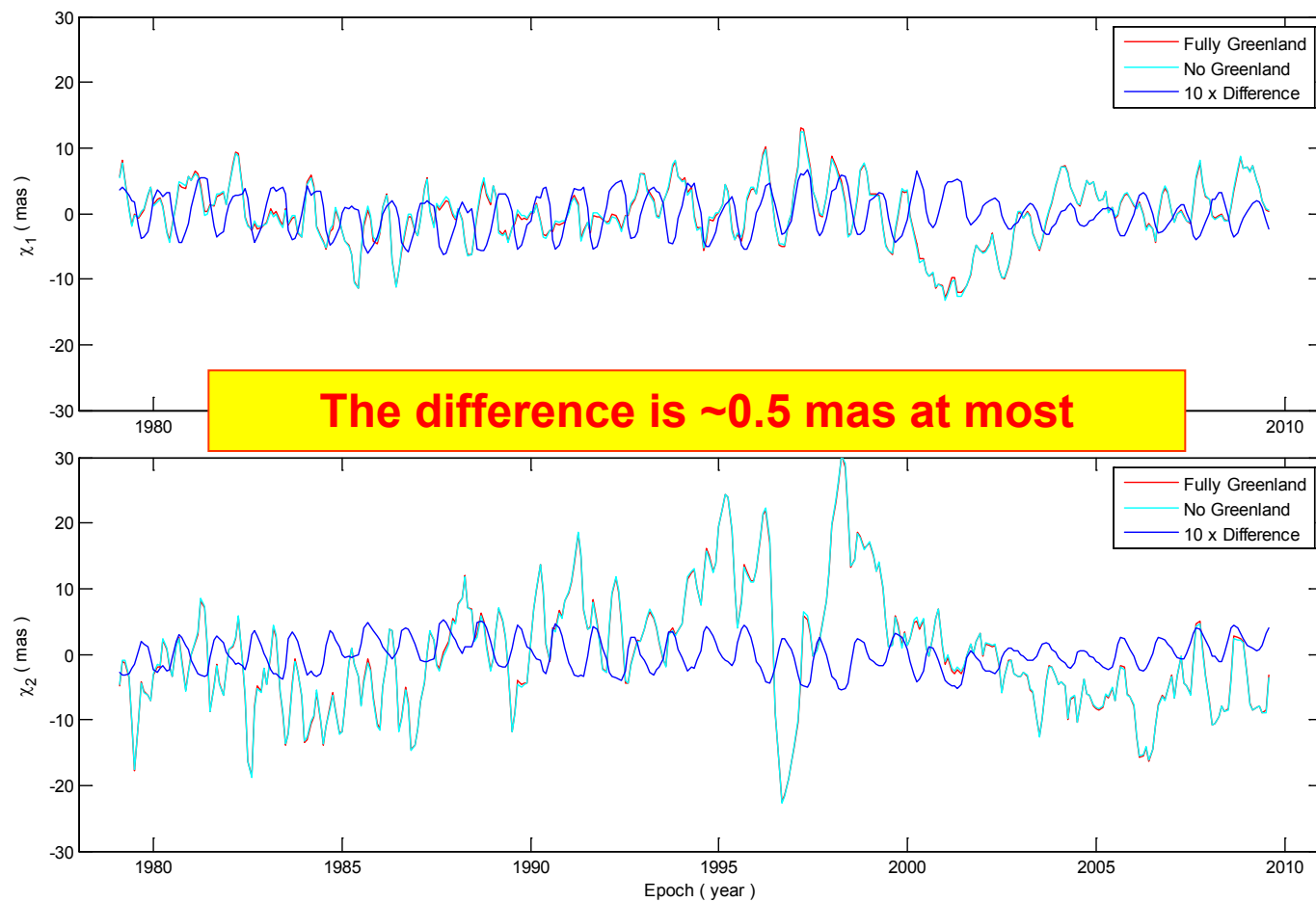
HEs estimated from GLDAS Model



With or without Greenland TWS seems not important



HEs estimated from GLDAS Model



**Effects of
Greenland TWS
on hydrological
excitation are
quite small!**



Model Evaluations II: 6-h data

➤ Data used (2004 ~ 2010)

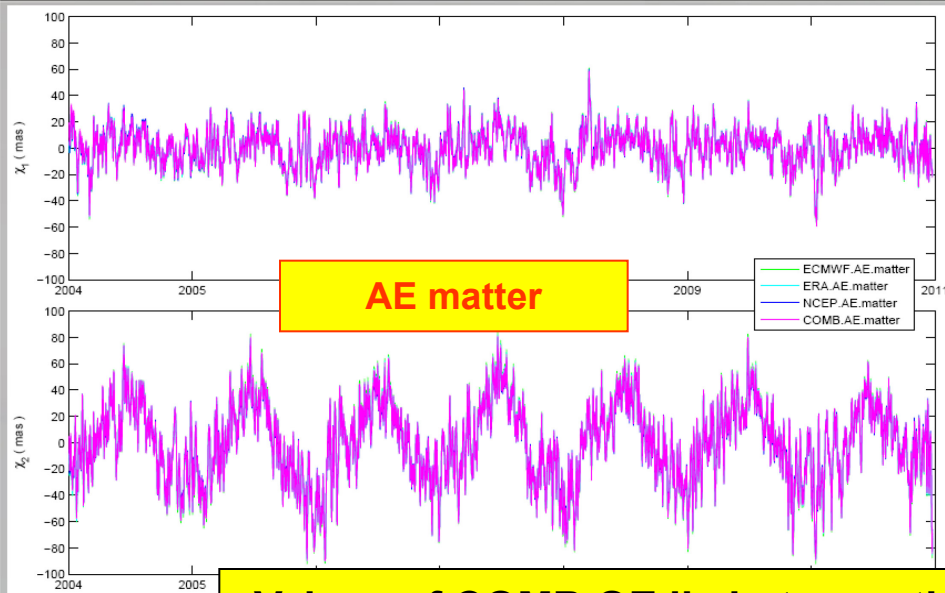
- IGS EOP: ig1+igs+igu.erp (6-hour data; a combination of the IGS/IG1 and the IGU polar motion data)
- NCEP reanalysis AAM (6h) + ECCO kf080 OAM (#) + NCEP reanalysis HAM (#)
- ECMWF operational AAM (6h) + OAM (6h) + HAM (#)
- ERAinterim AAM (6h) + OAM (6h) + HAM (#)
- COMB: combined AAM (6h) + OAM (6h) + HAM (6h)

(#) originally daily, linearly interpreted to 6-hour data

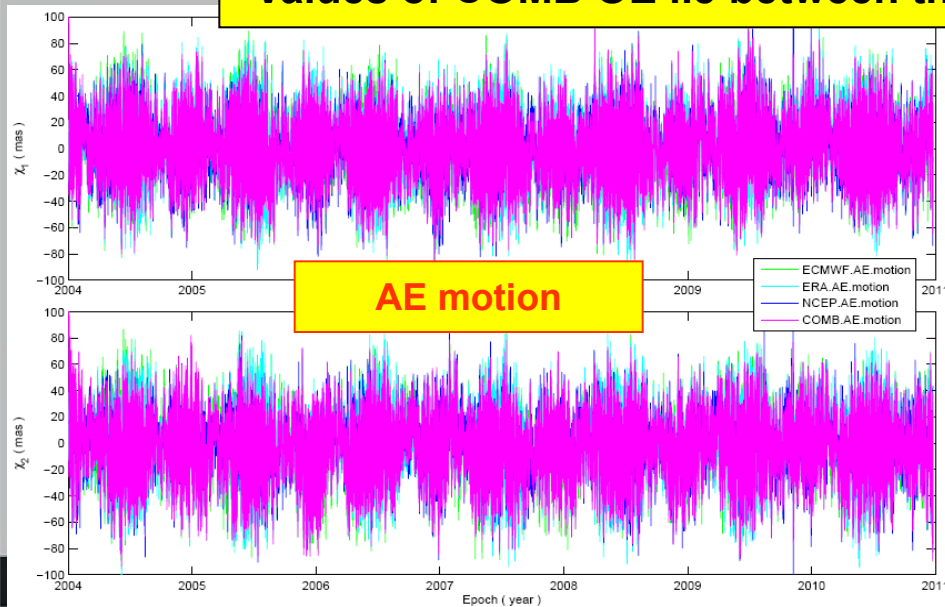
“COMB” refers to the combination of the three different sets of geophysical fluid models. We use a “least difference method” to combine these models, that is, we choose the data points which are the closest to the observations from the aspects of magnitude and phase (see Chen, 2011)



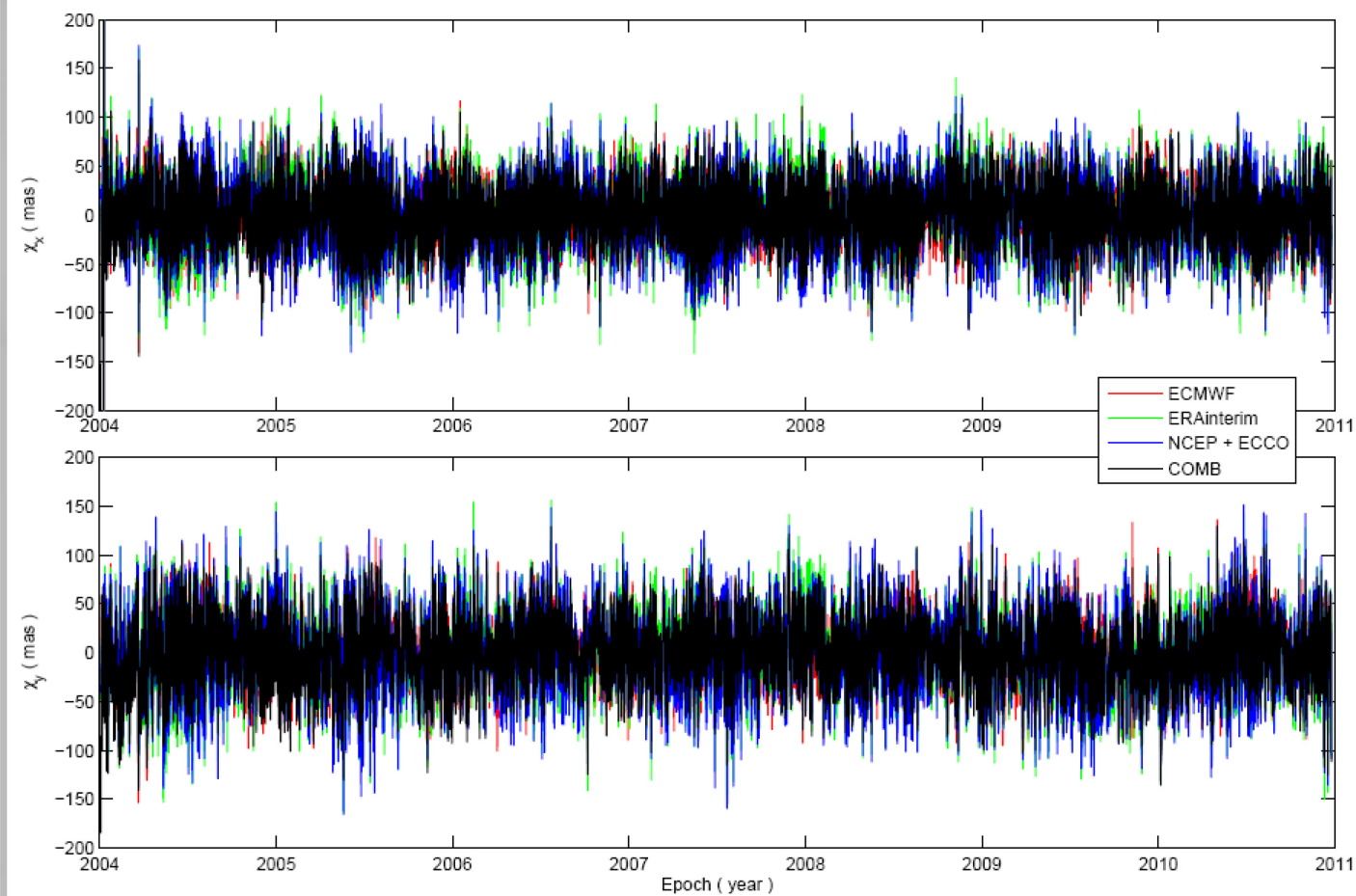
Time Series Comparisons (6h)



Values of COMB OE lie between those of ECMWF OE and ECCO OE



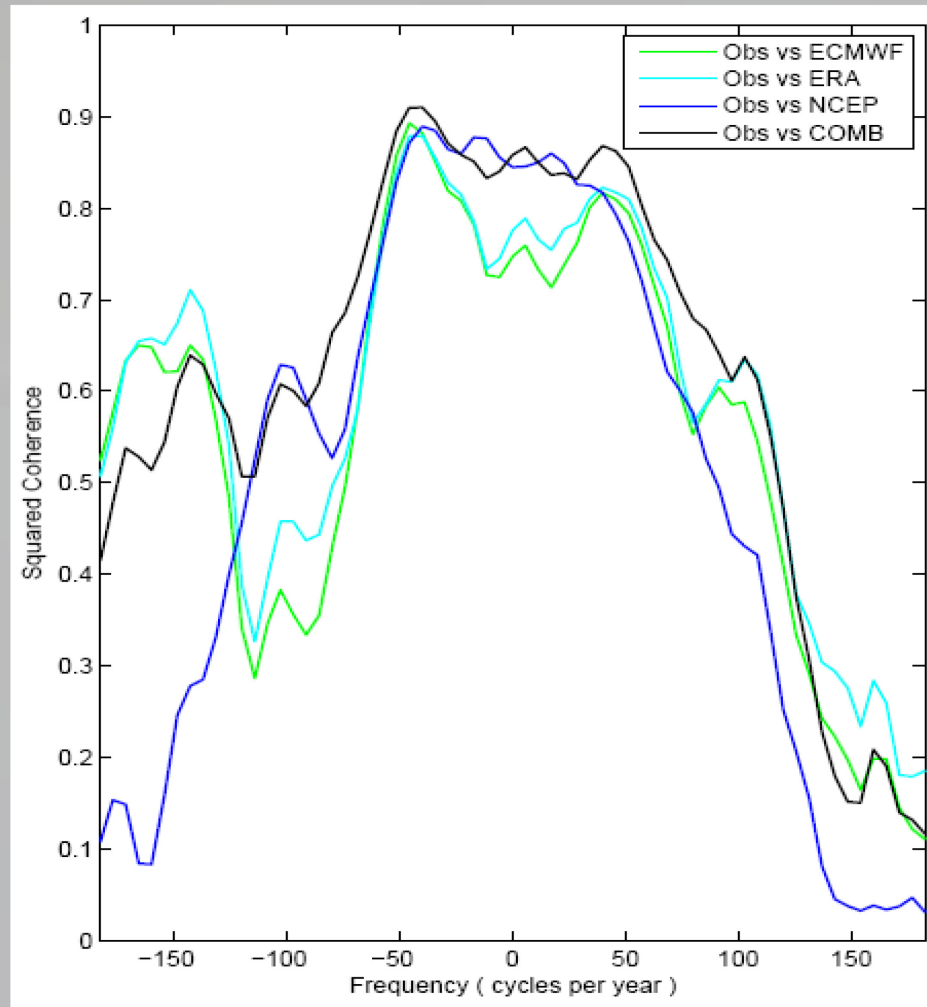
Time Series Comparisons (6h)



The residual for COMB is a little smaller!



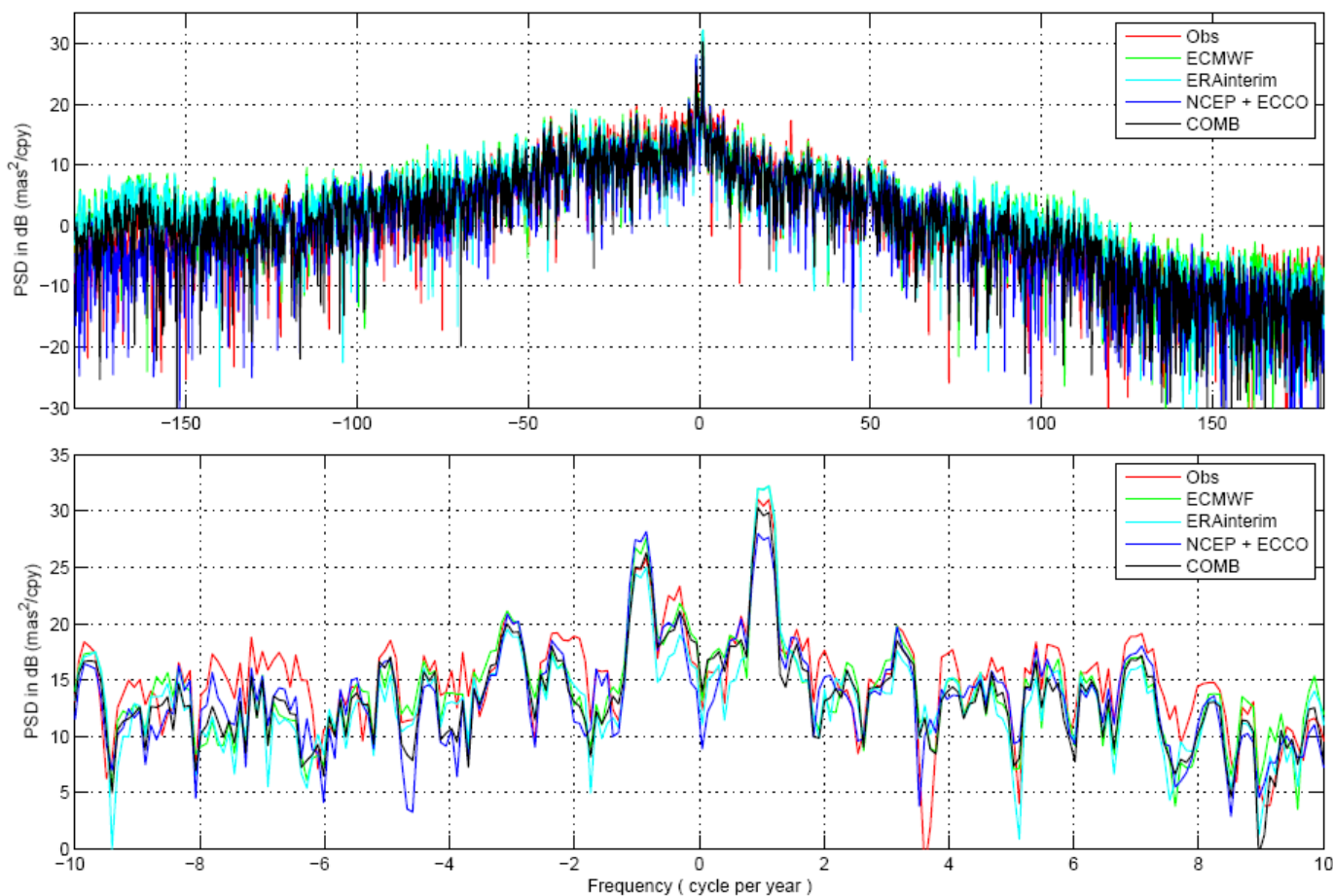
Coherence Comparisons (6h)



COMB is the most coherent with the Obs!



Spectrum Comparisons (6h)



Compared with GE:

NCEP/ECCO:
signals too weak

ECMWF/ERAinterim:
signals too strong!

The PSD for COMB agrees best with the Obs!



Discussions and Conclusions

- IERS C04 EOP might be problematic before 1997
- Widely adopted Wilson85 filter is only suitable for seasonal excitation studies
- To derive broad-band geodetic excitations, two-stage filter and gain adjustment are recommended
- Biases actually exist in the ECMWF and GLDAS hydrological models, While NCEP model over-estimates the annual variation in the TWS
- Effect of the Greenland is not significant (no more than 0.5 mas)
- Reliability
atmospheric model > oceanic model > hydrological model
- Combined geophysical fluid models might be better



Acknowledgement

- Richard Gross provided us the JPL SPACE data (v2010)
- Haoming Yan provided us his estimate of the GLDAS HE



References

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Thanks for your attention!

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