Lunar influence on equatorial atmospheric angular momentum and consequences for nutation

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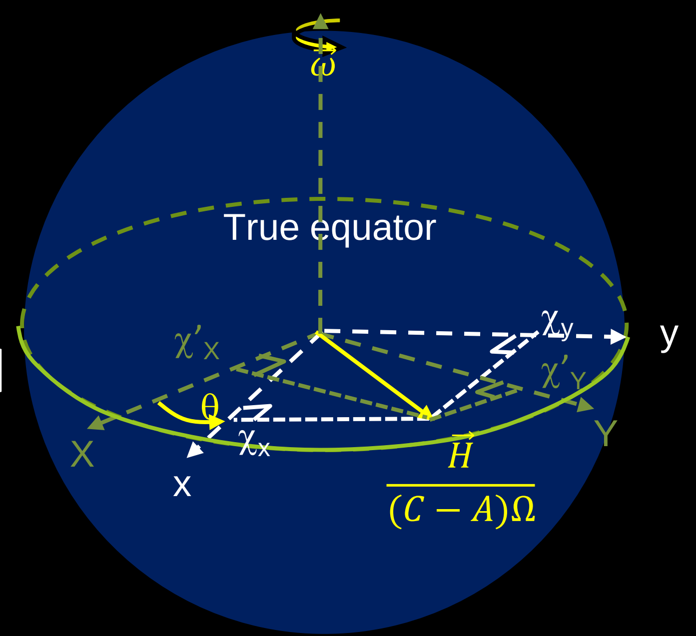
Introduction - 1

- Lunar influence on atmosphere: on old subject
- Global diagnostic: equatorial atmospheric angular momentum function χ — a strong retrograde diurnal component (~10 mas) <u>as large as the seasonal one</u>, squeezed in a band from 20 to 30 hours.
- By demodulation (removing diurnal carrier) :



$$\underbrace{\chi'_X + i\chi'_Y}_{CEAMF} = -(\underbrace{\chi_x + i\chi_y}_{EAMF\ \text{referred to Gxyz (ITRF)}}) \quad e^{i\theta}$$

χ: Equatorial Angular Momentum Function (EAMF)
χ': Celestial Equatorial Angular Momentum Function (CEAMF)
$\theta = \Omega t + \varphi$: Earth's rotation angle

it spreads over the frequency band of the precession-nutation from 2 days

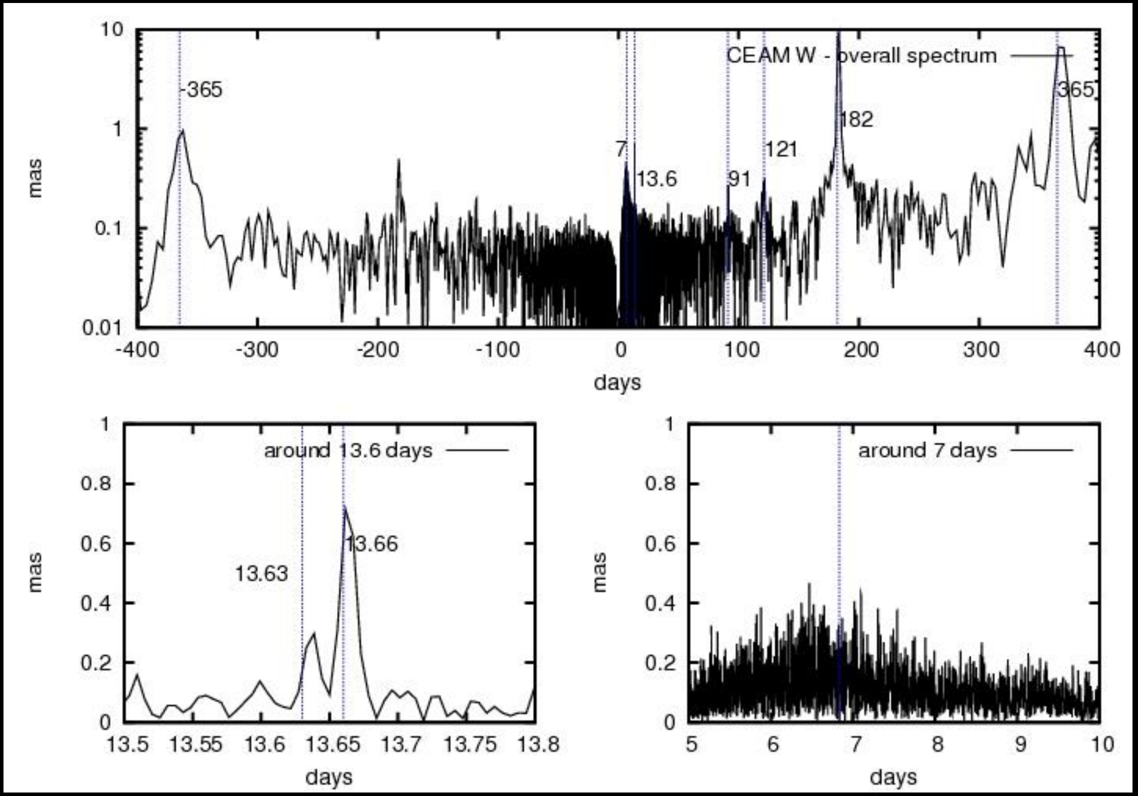
Introduction – 2

- Most prominent terms are thermal waves caused by sun heating: +365 d (S1, 24 h), +182 d (P1, 24.07h), ∞ (K1, 23.93h), -365 d (ψ1, 23.87h) and it mostly perturbs annual nutation at the level of 100 μas

- Below 100 d, sharp peaks at 13.66 d (O1, 25.8h) and 13.63 d

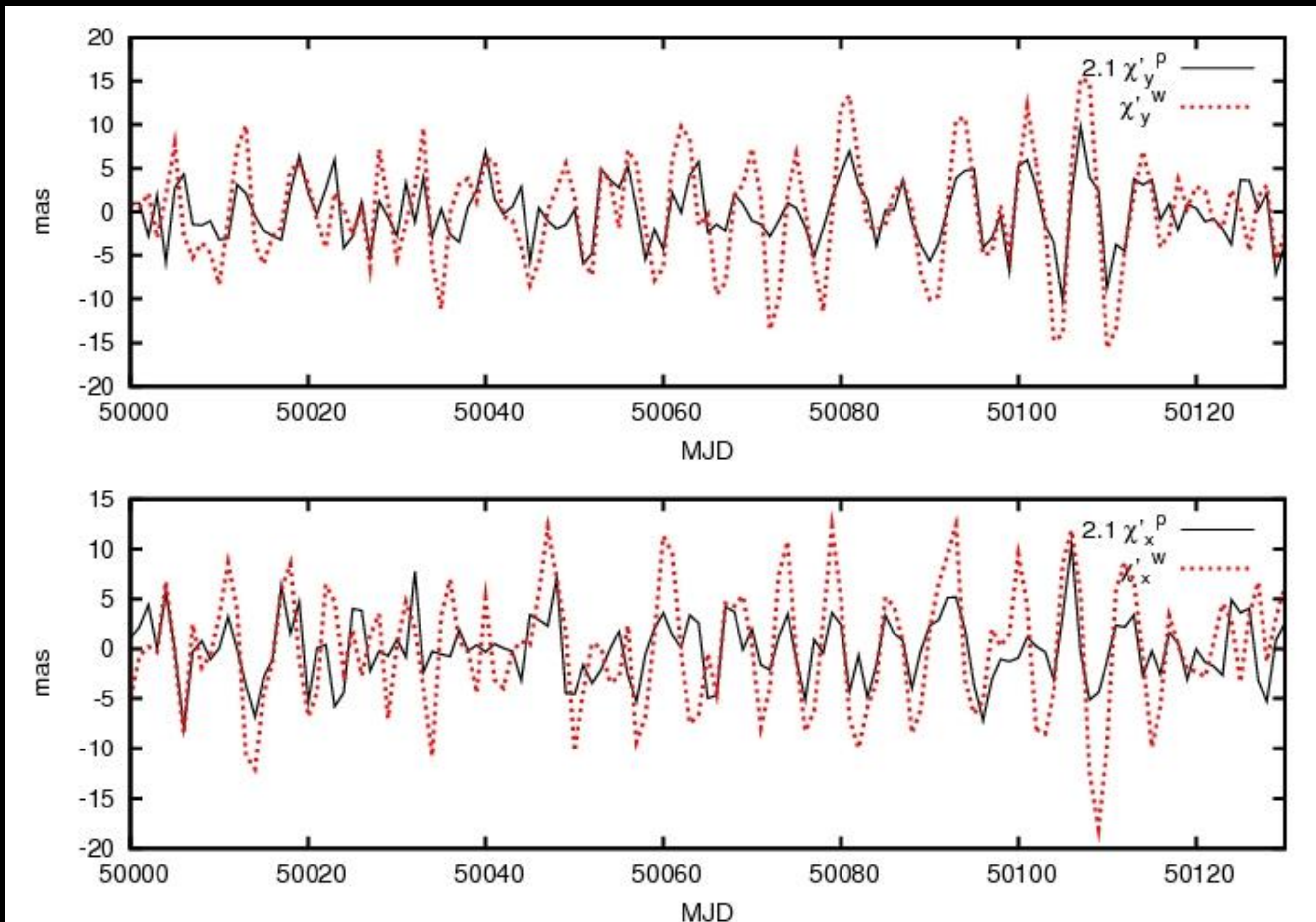
- Broad band peak around 7 d (28 h)

- **Is it related to the lunar tide O1?**



"Lunar band" 2-30 days - First striking feature

Pressure term $\chi'p$ and wind term $\chi'\mathrm{w}$ are almost proportional by contrast to seasonal band (S1); wind term variations are ~2−5 times larger than the ones of the pressure term (NCEP).



High band pass Filter
→ periods < 30 days

N.B.: 1 mas = 5 10^{-9} rad

Interpretation – local torques are negligible with regard to the bulge torque

- At a given frequency σ' proportionality χ'^{w}/χ'^{p} explained theoretically from atmospheric angular momentum balance, as far as

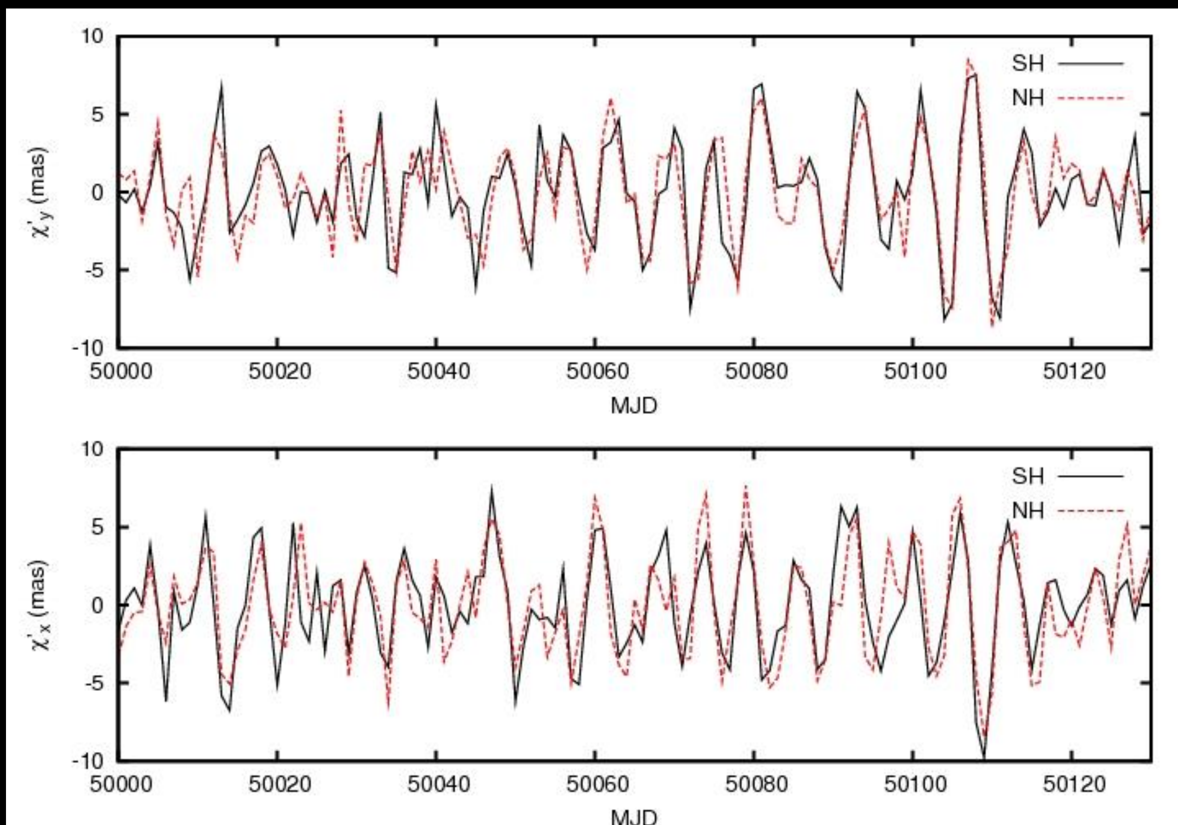
$$\underbrace{local\ torque}_{\substack{pressure\ on\ topography\\ -friction}} \ll \underbrace{bulge\ torque}_{\substack{pressure\ -gravitation\\ on\ ellipsoidal\ Earth}}$$

- This is not the case for seasonal band in a non-rotating frame (Marcus et al, 2004).

- Expected ratio: $\frac{\chi'^{w}}{\chi'^{p}} = \frac{\Omega-\sigma'}{\sigma'} = \begin{cases} \sim 13 \text{ around } 13.6 \text{ d} \\ \sim 6 \text{ around } 7 \text{ d} \end{cases}$

“Lunar band” 2-30 days - Second striking feature

By contrast to S1 band (of thermal origin), almost equal contributions of northern (NH) and southern hemispheres (HS) to the wind term. This hints a global simultaneous cause, like gravitational tides.



Tidal peak at 13.6 days – estimates and model

Tidal waves O1 (13.66 d, tidal argument ϕ_1) and side lobe (13.63 d, argument ϕ_2) estimated over the period 1949 – 2013

$$\chi^{p(IB)}\,[mas] = (0.05 - i\,0.02)e^{i(\phi_1+\pi/2)} + (0.02 - i\,0.00)e^{i(\phi_2+\pi/2)}$$
$$\chi^{p(NIB)}\,[mas] = (0.17 - i\,0.06)e^{i(\phi_1+\pi/2)} + (0.06 - i\,0.01)e^{i(\phi_2+\pi/2)}$$
$$\chi^{w}\quad [mas] = (0.73 - i\,0.04)\,e^{i(\phi_1+\pi/2)} + (0.23 - i\,0.01)e^{i(\phi_2+\pi/2)}$$

$$\frac{\chi'^{w}}{\chi'^{p(IB)}} \sim 14 \quad ; \quad expected\ ratio \sim 13$$

Pressure NIB term fits a simple equilibrium tidal model:

$$\chi^{p(NIB)} = -\frac{8\pi}{15}\frac{r_0^4}{(C-A)g}\varrho_0 G_M \sin\varepsilon\, e^{i(\phi_1+\pi/2)}$$

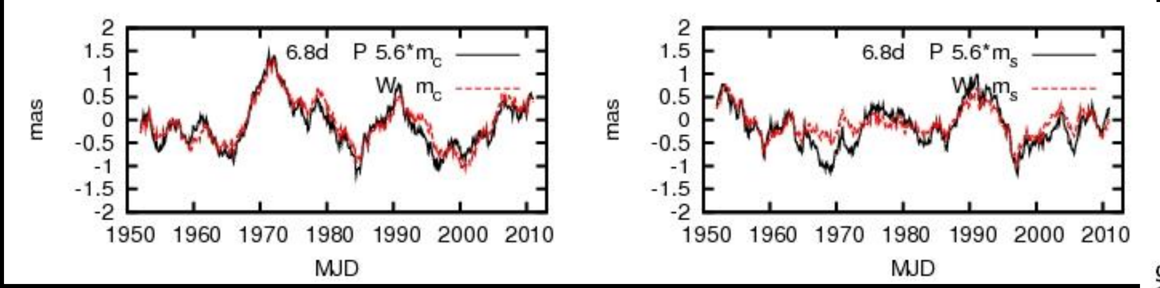
A, C Earth inertia moments, ϱ_0 mean atmospheric density, G_M=2.64 m^2/s^2 Doodson constant for the Moon, ε = 23,5° (obliquity)

Broad band peak round 7 days

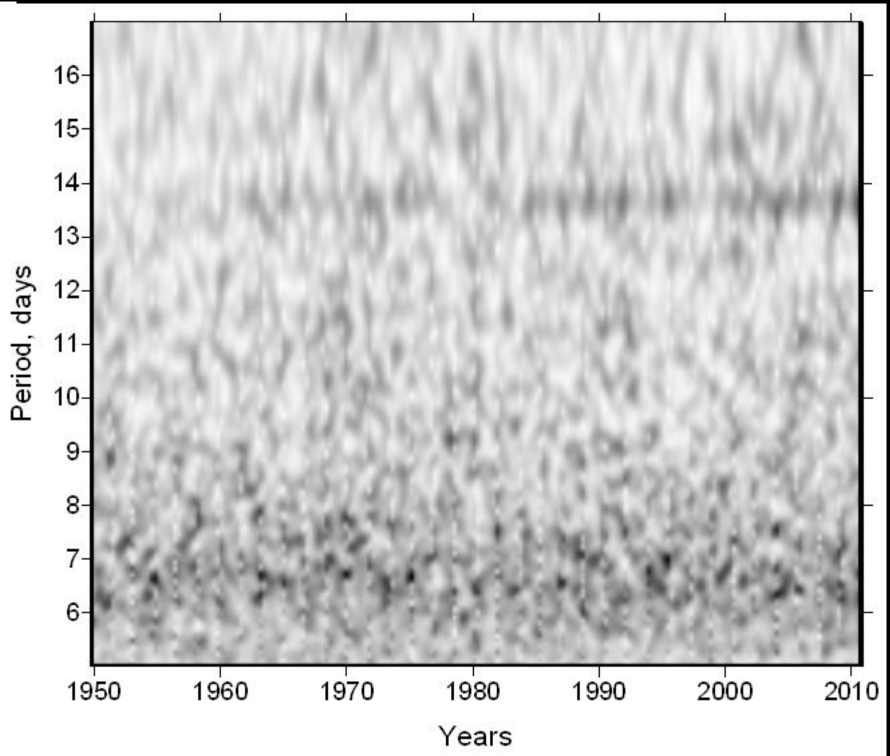
- More powerful than 13.6 d harmonics
- ψ_1^1 atmospheric resonance excited by lunar tides Q1 (6.86 d), σ1 (7.05 d) ?

$$\chi_{P/W} = (m_c + i m_s)\, e^{i\,\phi_{Q1}}$$

Least square fit over 6 year sliding window



Gabor transform



Expected ratio of $\frac{\chi'^{w}}{\chi'^{p(NIB)}} = \frac{\Omega-\sigma'}{\sigma'} \sim 6$ around 7 d

Synthesis

- NIB pressure term O1 explained by tidal equilibrium model: clearly a lunar effect

- At 13.6 d expected ratio works for IB (over continents) pressure term ; at 7 d expected ratio works for NIB (full) pressure term

- *Proportionality wind / pressure term is consistent with 2 facts*
  - ➢ Lunar tesseral tidal pressure do not cause topographic torque
  - ➢ Tidal wind only blows in the upper layer of the atmosphere and do not cause any friction torque

  → Local atmospheric torque much smaller than the bulge torque, leading to proportionality of the pressure and wind term at a given period

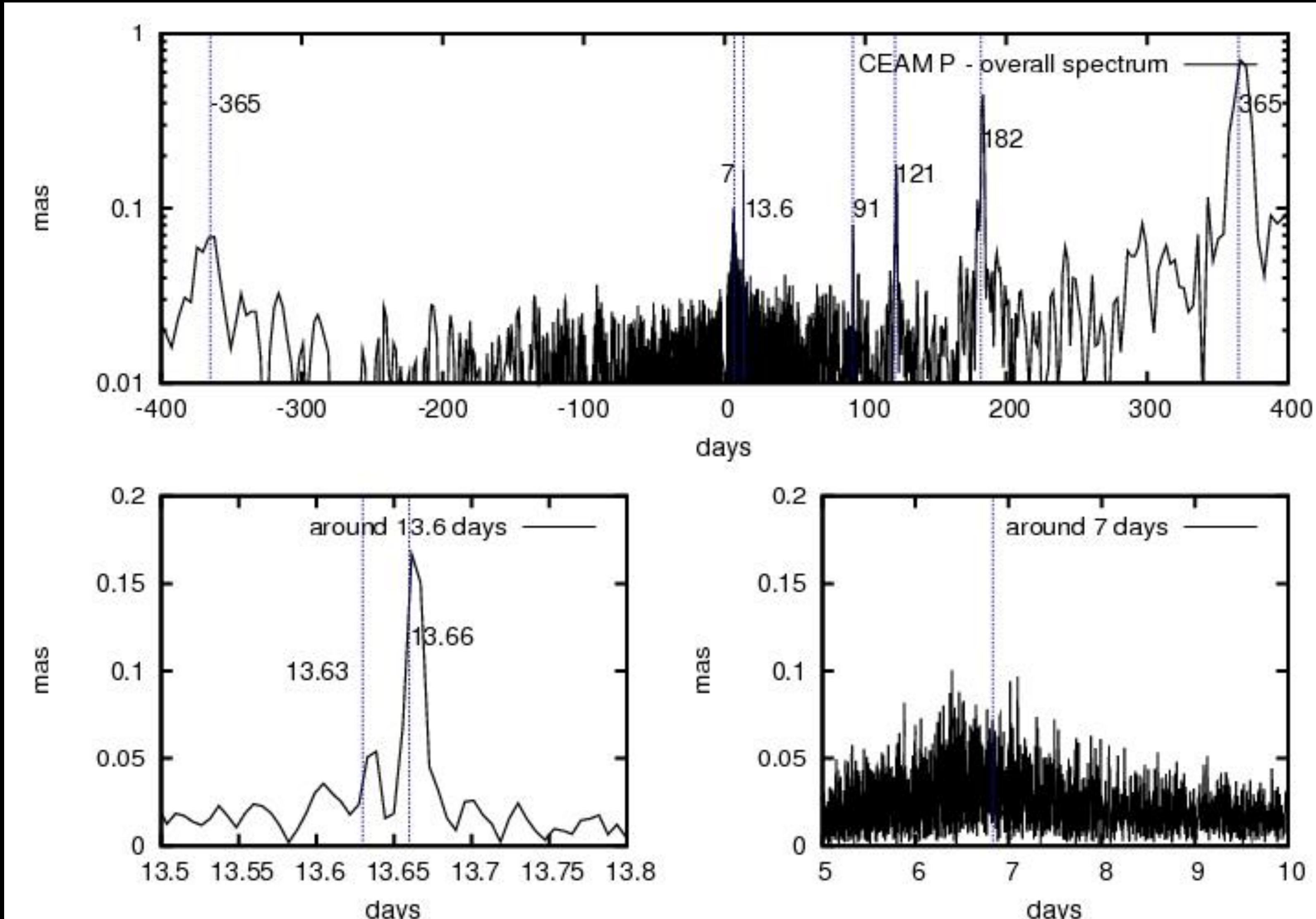
Conclusion

Below 30 days Celestial Equatorial Atmospheric angular momentum is only significant for prograde band and is characterized by:

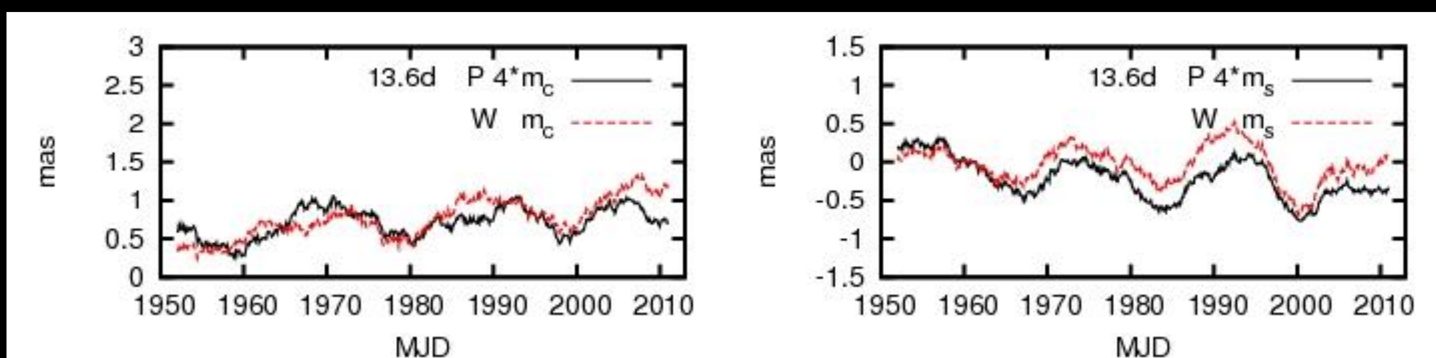
- a 13.6 day wave, resulting from the fortnightly lunar tide
- a broad band weekly oscillation, possibly resulting from lunar tidal effect amplified by the ψ_1^1 atmospheric resonance.

- Proportionality wind/pressure term at a given period & equal contributions of northern and southern hemispheres strongly supports the fact that the whole band is caused by the lunar tide

- Effect on nutation (Liouville equation in Celestial Frame, Brzezinski 1994): ~5 μas at 13.6 days (not observable), up to 30 μas at 7 days (densification needed)



CEAM P - overall spectrum
-365
365
182
121
7
13.6
91
mas
days
around 13.6 days
13.63
13.66
around 7 days



13.6d P 4*m_c
W m_c
mas
MJD
13.6d P 4*m_s
W m_s
mas
MJD