Study on temporal variation in FCN period and its possible mechanism

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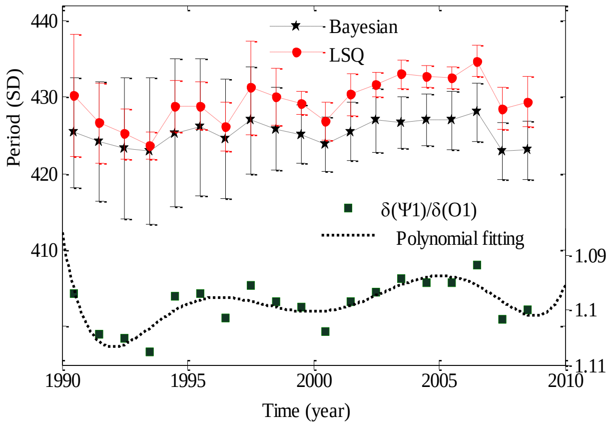
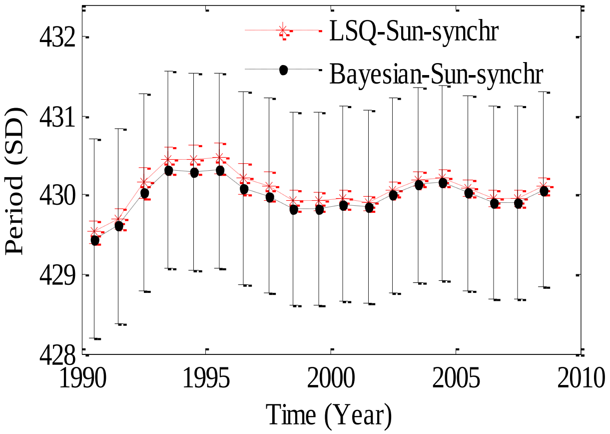
Motivation：

1. Is there a temporal variation in FCN period?

Q1: Initial results of detecting the temporal variation:
SG/VLBI (Cui et al., 2014):





Further questions:

① The difference in the variation determined with SG and VLBI?

② To correct the atmospheric/oceanic effect in VLBI observations;

③ The variation observed from Global SG station is different, why?;

Motivation：

1. **Is there a temporal variation in FCN period?**
2. **<u>What is the Mechanism? Geomagnetic jerks (GMJ)?</u>**

Q2: Mechanism: GMJ？

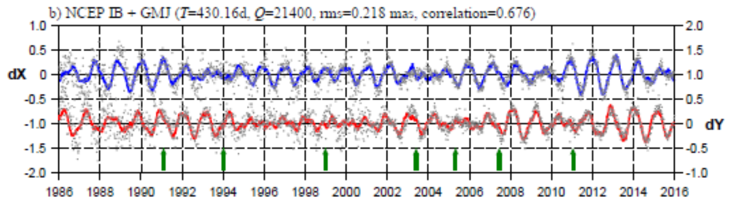


Fig. 4. Integrated (full line) and observed (gray dots) celestial pole offsets for the best-fitting FCN parameters. NCEP IB excitations (*upper plot*) and NCEP IB + GMJ excitations (*lower plot*) are used.

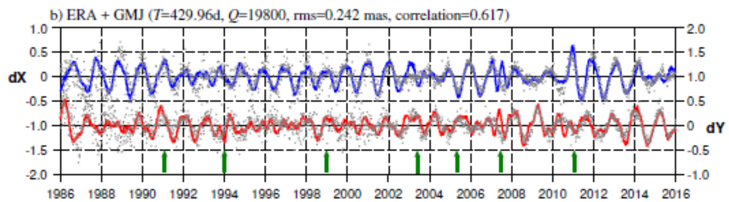
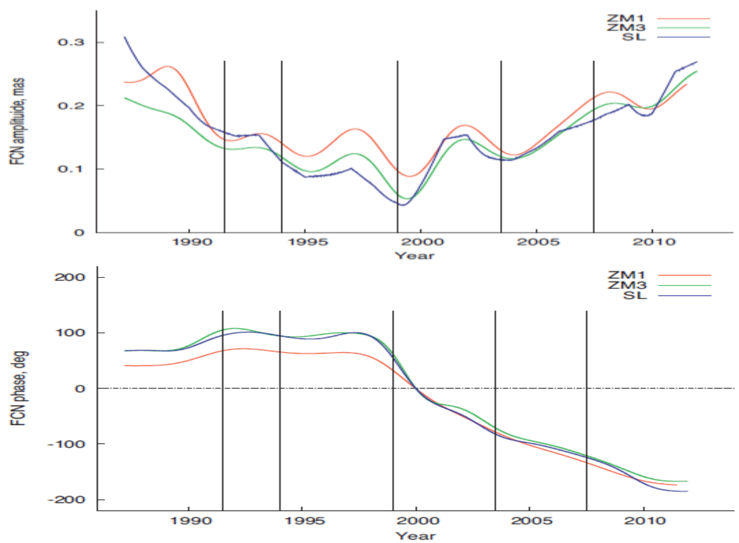


Fig. 7. Integrated (full line) and observed (gray dots) celestial pole offsets for the best-fitting FCN parameters. ERA/OMCT atmospheric and oceanic excitations (*upper plot*) and ERA/OMCT + GMJ excitations (*lower plot*) are used.

Vondrak 2017：

Free core nutation and geomagnetic jerks

Z. Malkin[a,b,*]



Motivation：

1. **Is there a temporal variation in FCN period?**
2. **What is the Mechanism? Geomagnetic jerks (GMJ)?**

Q2: FCN Amplitude/phase? =Excitation from:

Re-setting initial value
At GMJ epoch → geophysical fluids

!Method problem:
Re-setting initial value
At any epoch will improve
the results;

? ? ?

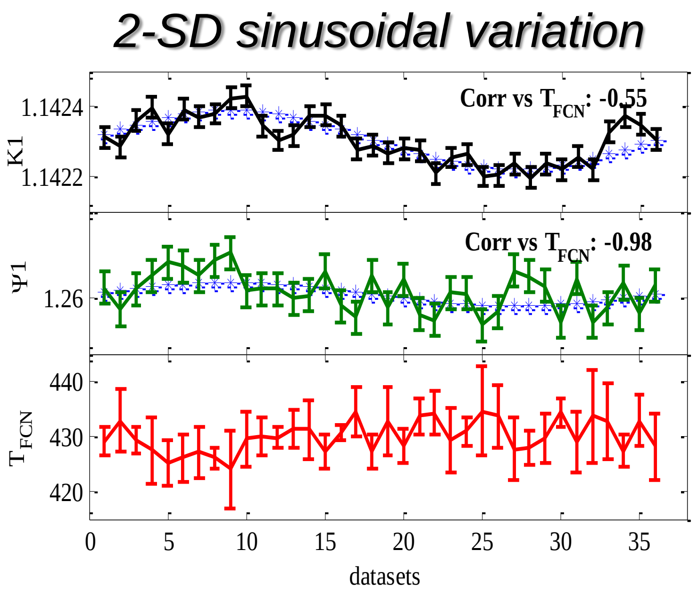
CMB-coupling (inertia, EM, Vis, Topo) +other sources?+ FCN period change

Correlation with GMJ: **<u>Direct</u>** or **<u>indirect relation</u>**?

Period: CMB-coupling (inertia, **<u>EM</u>**, Vis, **<u>Topo</u>**)

1. **Is there a temporal variation in FCN period?**

Test with synthetic data (mainly diurnal waves)



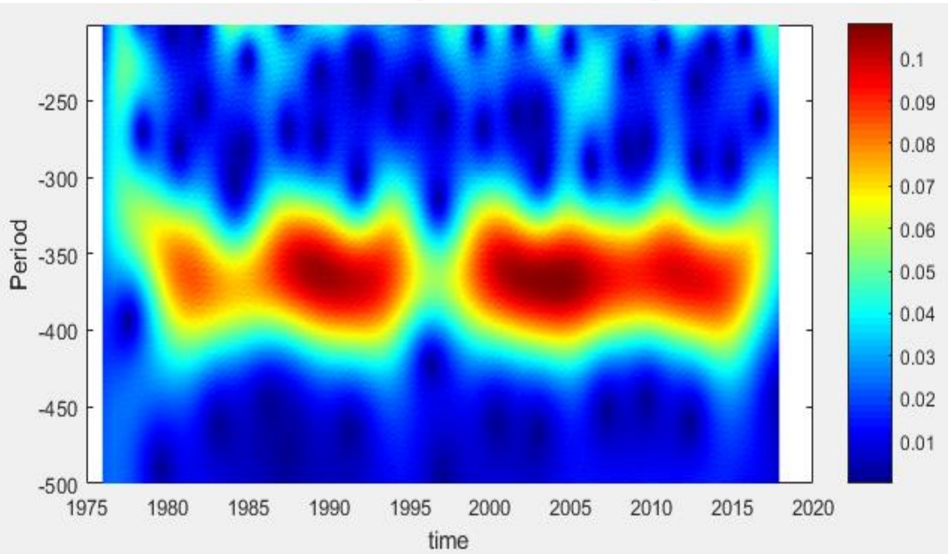
Correlation of K1&ψ1 and period of FCN

- The correlation of FCN T and amplitude factor of ψ1 is up to -0.98; however, ψ1 didn't reflect the true signal well, but K1 did;
- In this case, this high correlation lead to large discrepancy of FCN parameter determination.

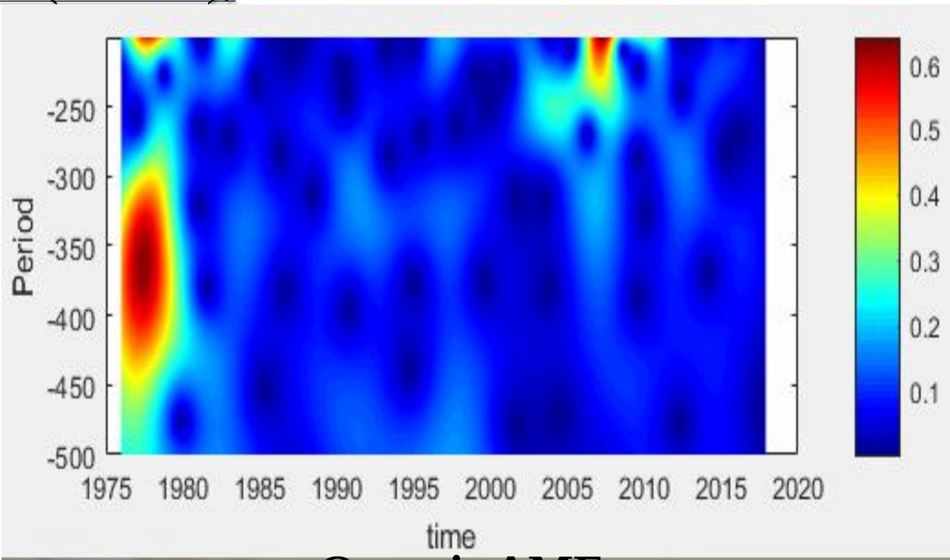
◆ This explains: **<u>Q1~1. The difference in the FCN period variation determined with SG and VLBI!</u>**

Q1~2. How to correct the atmospheric/oceanic effect in VLBI

- Calculate the excitation with time series (Unknowing initial value……).
- Build model for AMF and estimate the amplitude/phase in -365.26; (Koot et al, 2011)
- Extract the signal in retrograde annual band (-365.26);



Atmospheric AMF



Oceanic AMF

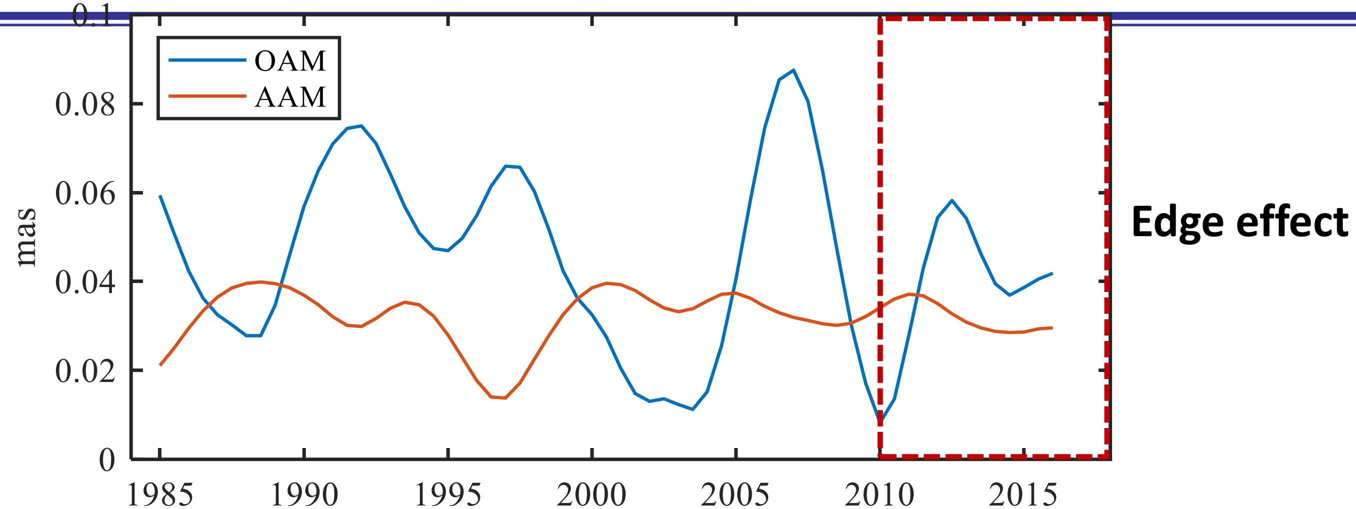
Definition 2.2 For a time series $f(t)$, its NTFT Ψ is defined as

$$\Psi f(\tau, \varpi) = \int_R f(t)\psi^*(t-\tau, \varpi)\mathrm{d}t, \quad \tau, \varpi \in R \qquad (2)$$

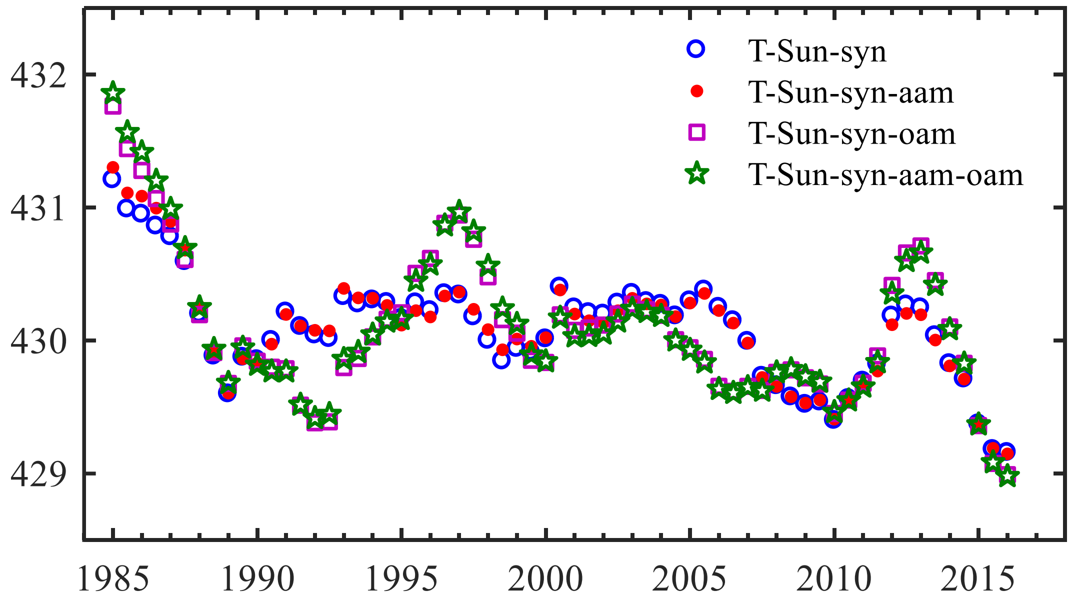
A typical NTFT kernel can be constructed as

$$\psi(t, \varpi) = |\mu(\varpi)|\, w(\mu(\varpi)t)\exp(i\varpi t),\ w(t) \in \Omega(R), \quad (\mu(\varpi) \in R) \dot{\neq} 0 \qquad (4)$$

- Normal time–frequency transform (NTFT) proposed by Liu and Hsu (2009, 2012) is designed for unbiased measurement of the **instantaneous frequency, phase and amplitude** of a time series.

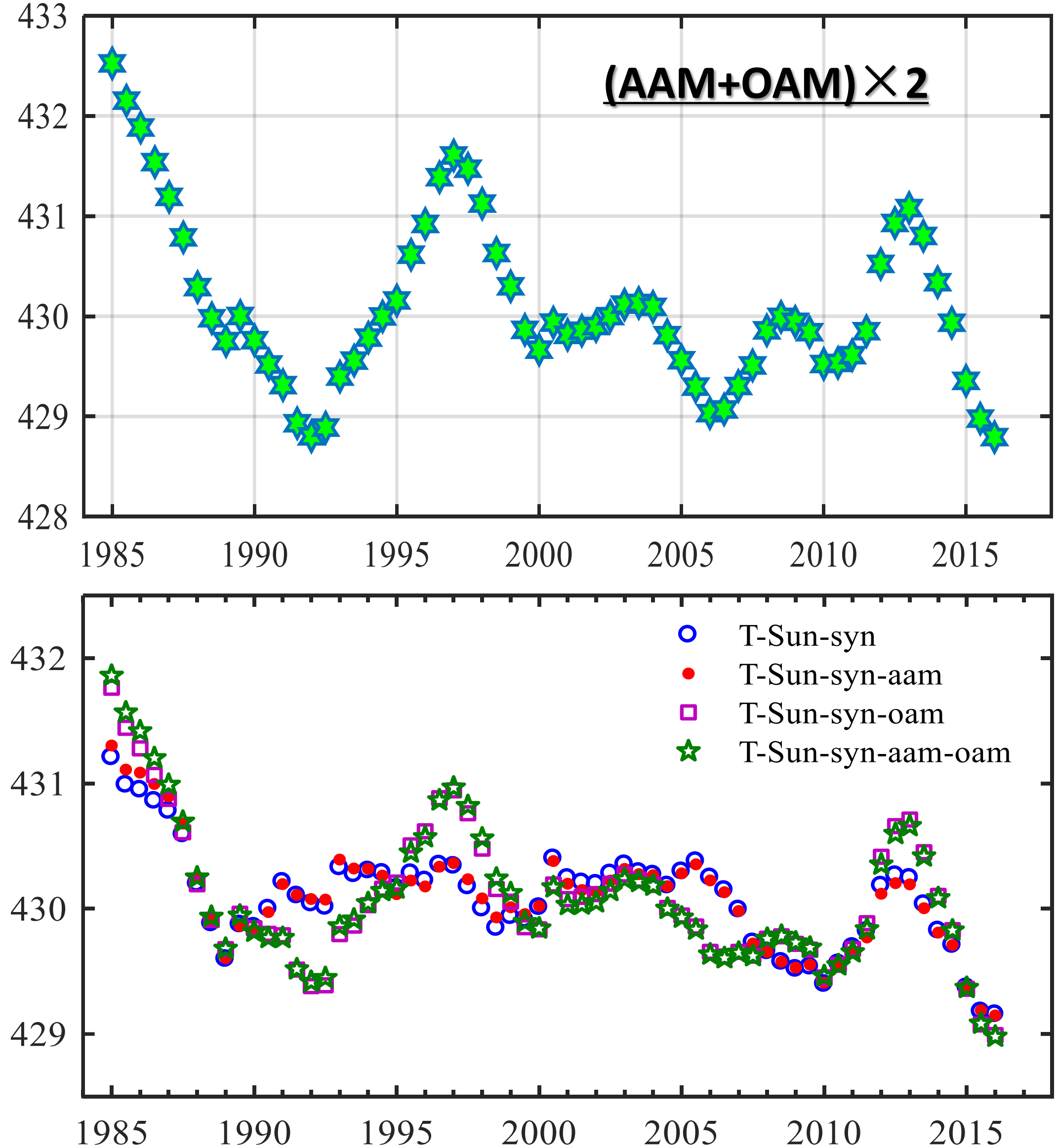


Atmospheric & Oceanic Effect to nutation (-365.26)



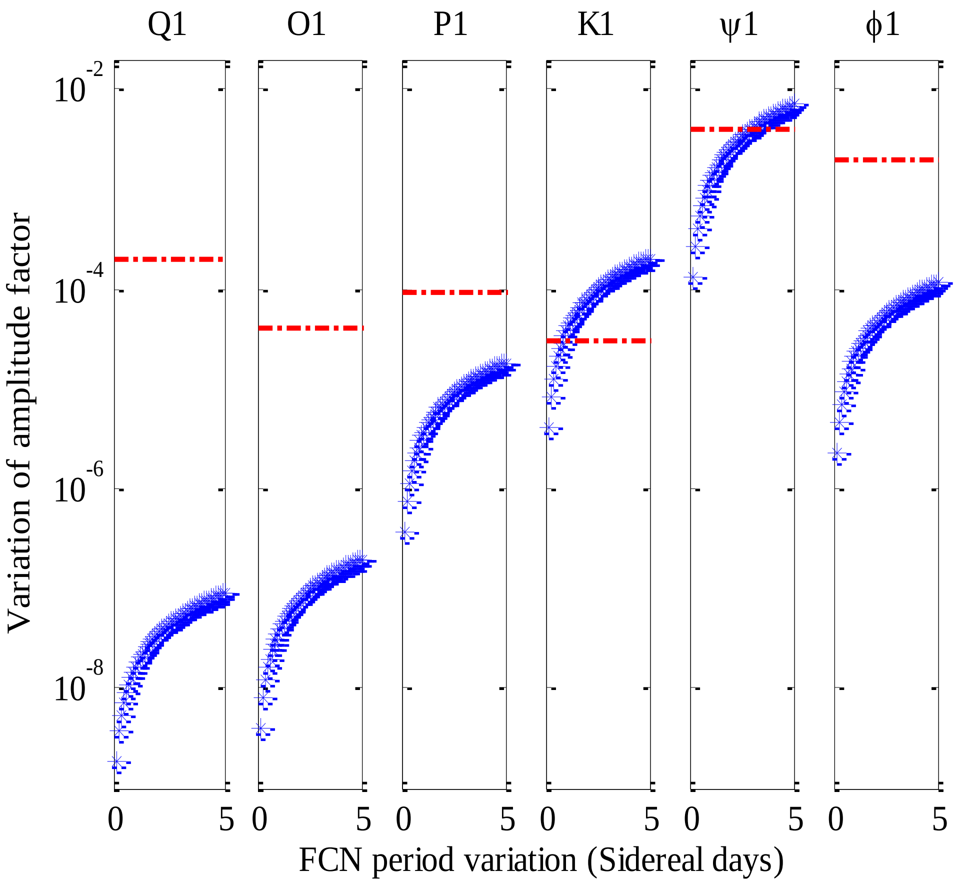
FCN period – VLBI Corrected with A/O excitation;

FCN Period variation-VLBI



Around
3 or 4
sidereal days

Q1~3. The variation observed from Global SG station

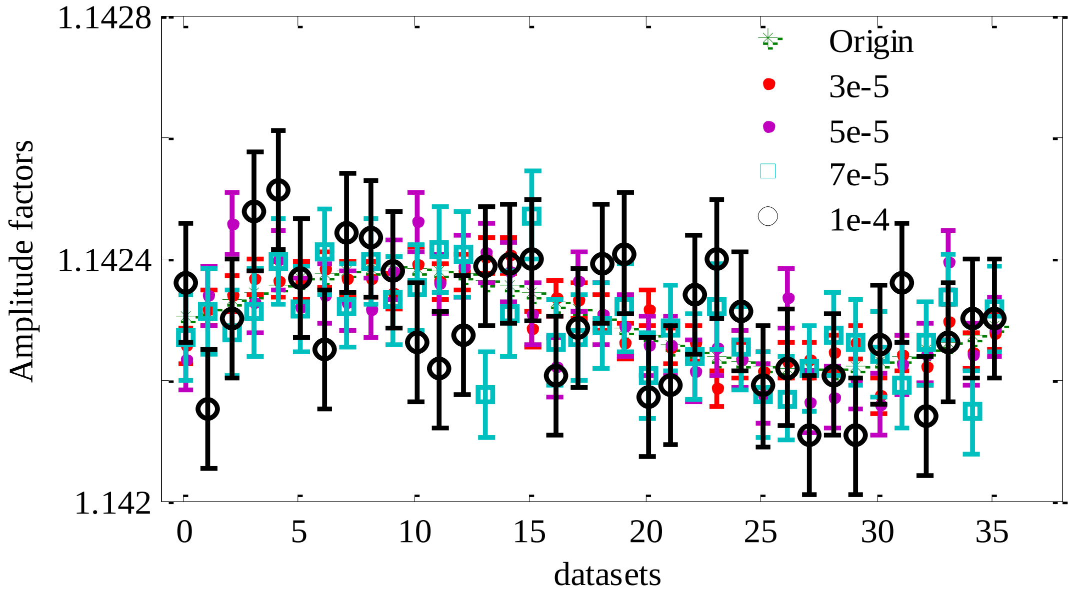


Relationship between the variation of amplitude factor and the FCN period variation

Precision Level of tidal parameters:

Red dash-dot line: The standard deviation of amplitude factor for diurnal waves ($Q1 \sim 2\times10^{-4}$, $O1 \sim 4\times10^{-5}$, $P1 \sim 9\times10^{-5}$, **$K1 \sim 3\times10^{-5}$, $\psi1 \sim 4\times10^{-3}$**, $\phi1 \sim 2\times10^{-3}$)

Sensitivity of K1 to FCN period variation

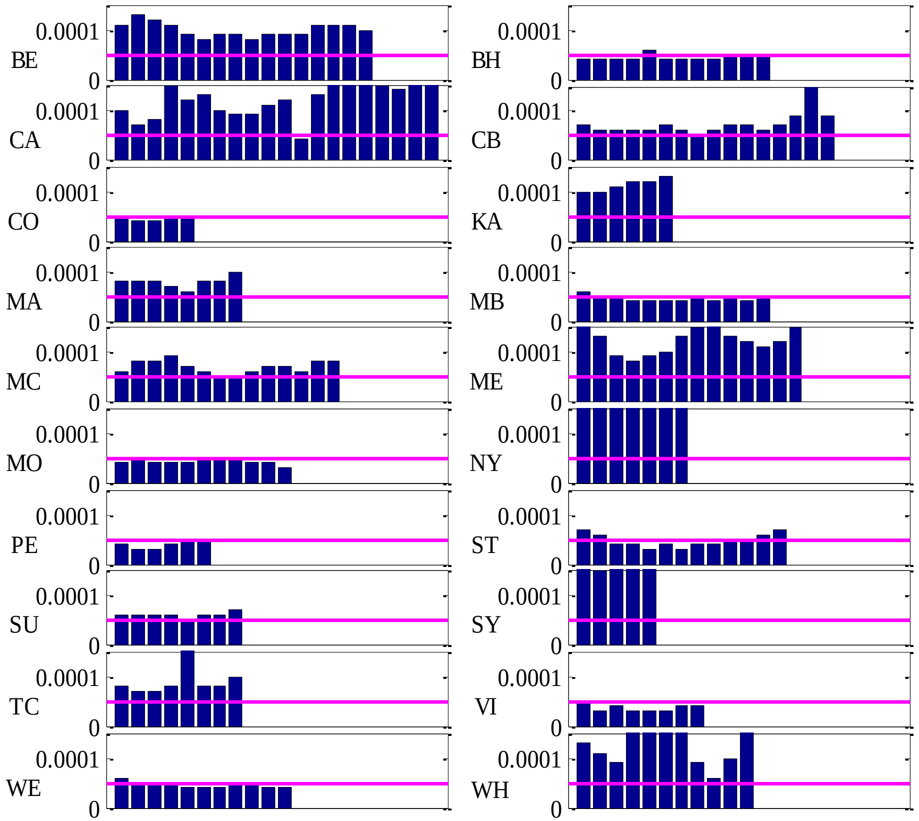


Wave K1: 4 SD variation in FCN period.

- Need the STD of tidal factors of K1 is in the order of 3~5$\times10^{-5}$.
- If the STD becomes larger such as 7$\times10^{-5}$ and 10$\times10^{-5}$, the fitted results gradually deviate and lead to some false trend.

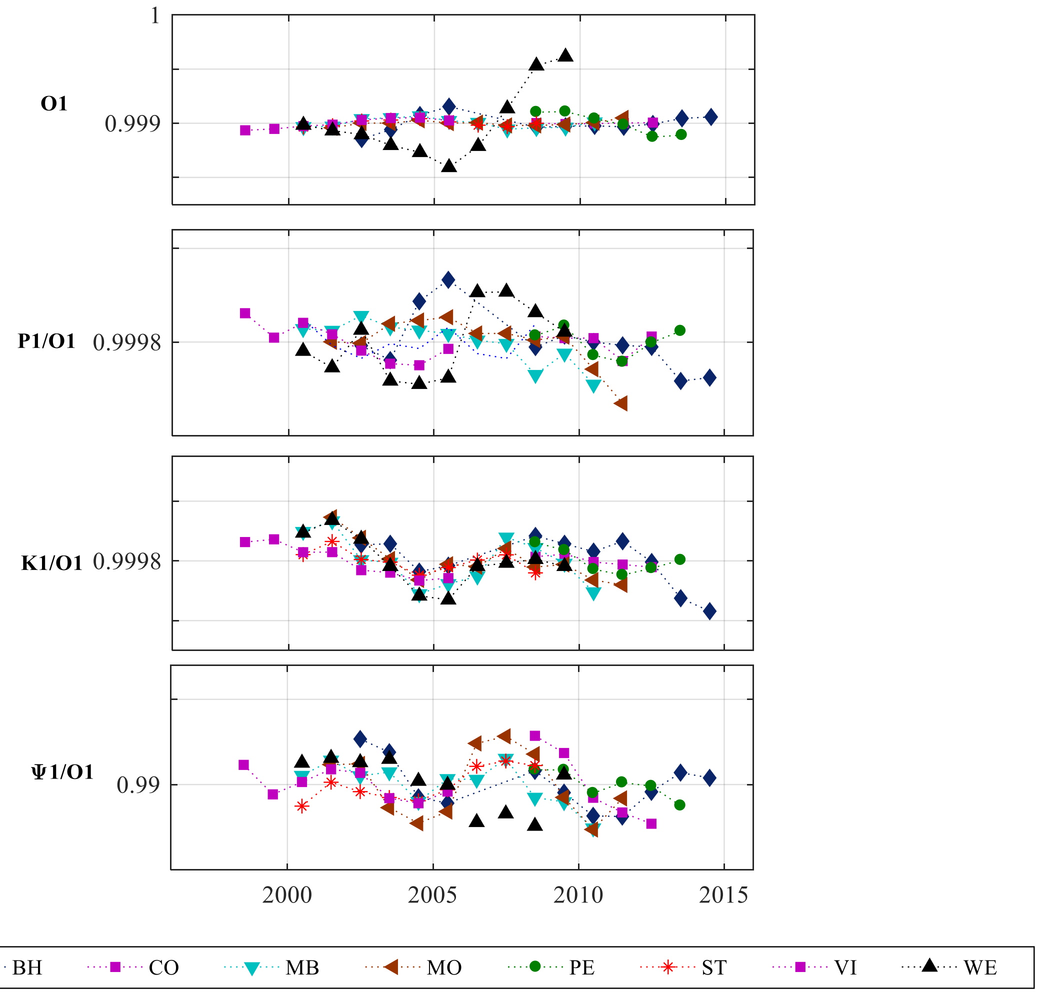
Tidal analysis (Eterna/3 years window)

Precision level of different observations

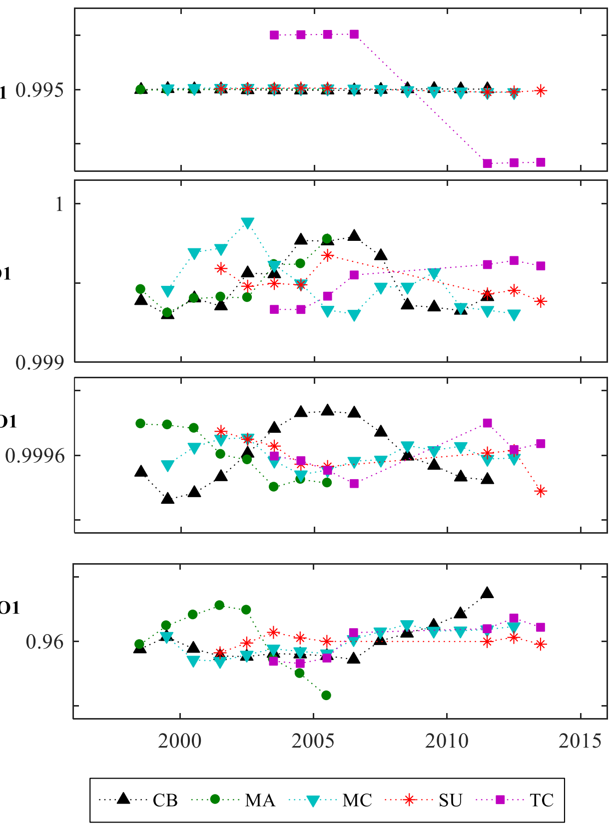


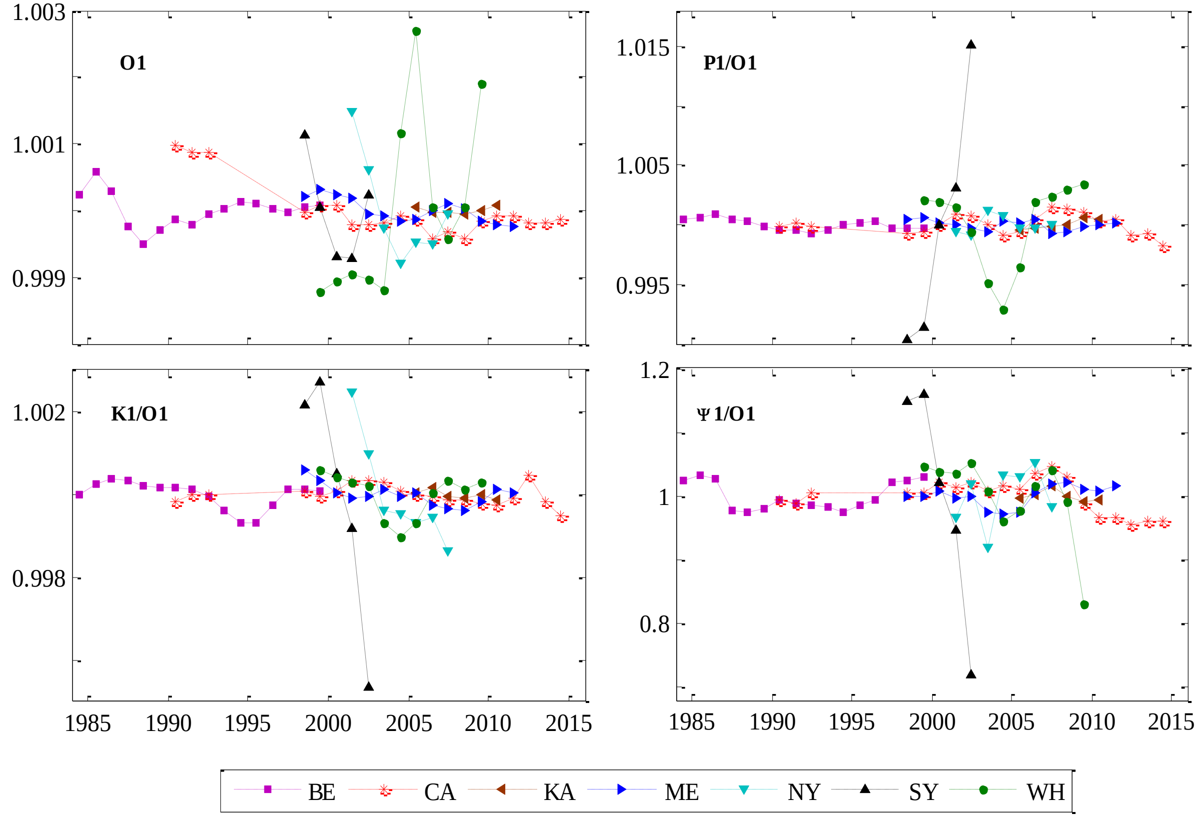
the standard deviation of amplitude factor of K1 of each segments

(The violet line is the reference line for the standard deviation of 5×10^{-5})



1
O1
0.999
P1/O1
0.9998
K1/O1
0.9998
Ψ1/O1
0.99
2000
2005
2010
2015
BH
CO
MB
MO
PE
ST
VI
WE


0.995
1
0.999
0.9996
0.96
2000
2005
2010
2015
CB
MA
MC
SU
TC


O1
1.003
1.001
0.999
P1/O1
1.015
1.005
0.995
K1/O1
1.002
0.998
Ψ1/O1
1.2
1
0.8
1985
1990
1995
2000
2005
2010
2015
BE
CA
KA
ME
NY
SY
WH

Questions:

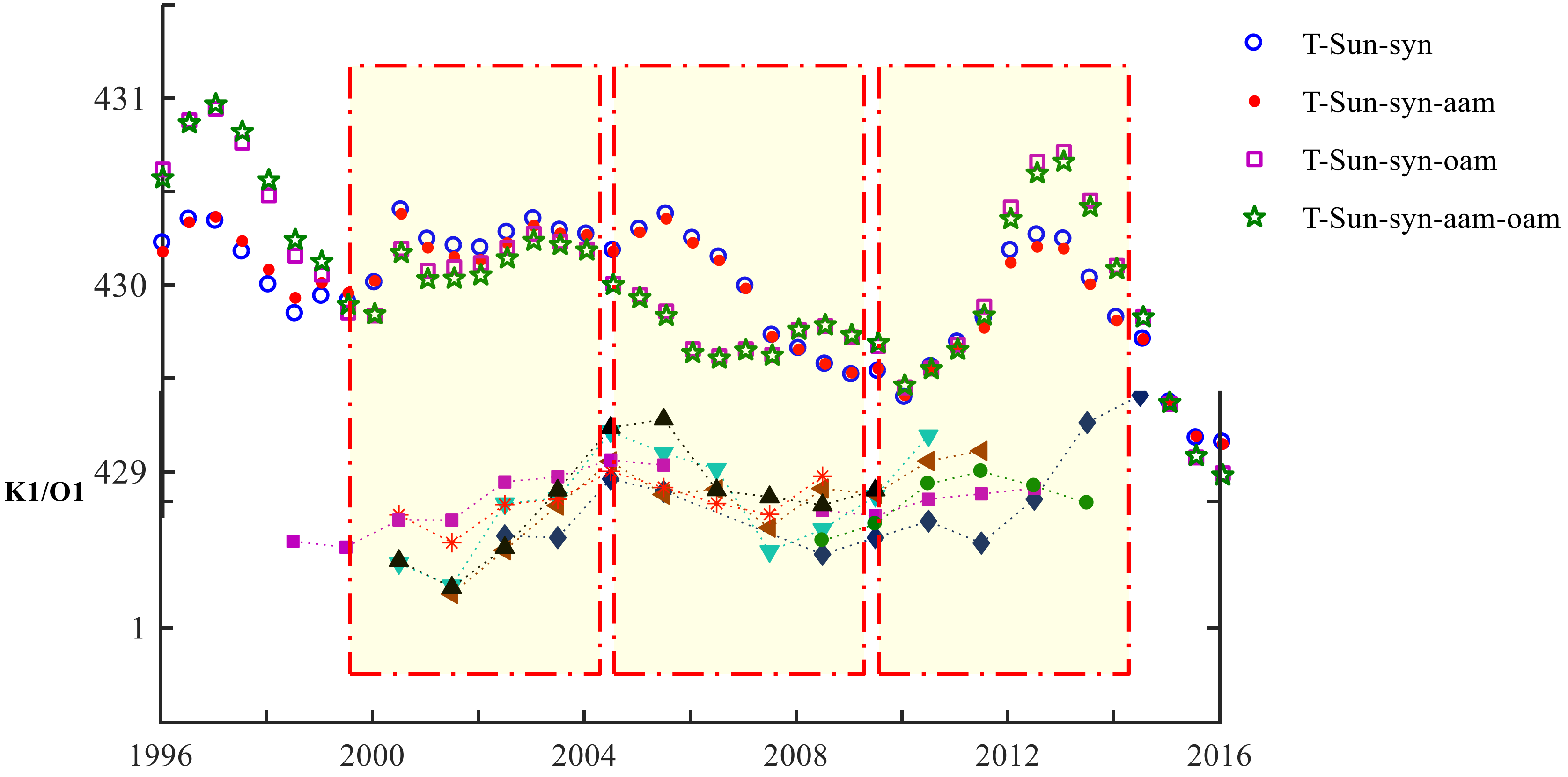
① **The stations with best K1 std level ~ Europe stations;**

② **Possible explanation of variation in tidal factors:**

- ✓ instrument calibration,
- ✓ pre-processing problem,
- ✓ **numerical artefacts due to insufficient frequency,**
- ✓ **Temporal variation of Atmospheric loading effect,**
- ✓ **temporal variation of Ocean loading effect,**
- ✓ earth's structure or geodynamic processes (Meurers et al., 2016).

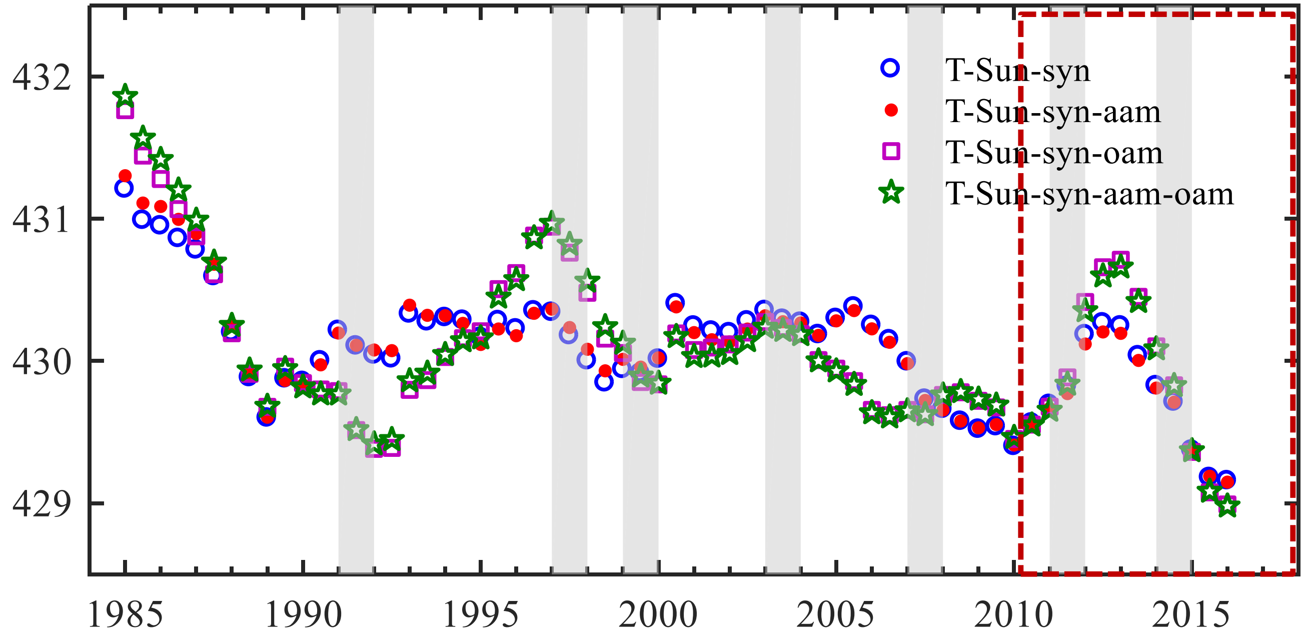
Positive side:

1. **K1 and ψ1;**
2. **Agreement with VLBI results at same time span:**



2. What is the Mechanism? Geomagnetic jerks ?

FCN & Geomagnetic jerks



GMJ：1991/92，1997，1999，2003，2007，2011，2014

- Satellite data (Champ2000~2010) have made it possible to calculate the global secular acceleration (SA) of the field, i.e., its second-order derivative, and to relate jerks observed at fixed locations at the Earth's surface with large SA pulses at the core surface in 2006 and 2009, +2012.5;

- As pointed out in Chulliat et al. [2010], geomagnetic jerks occur at the beginning or end of SA pulses.

Fast equatorial waves propagating at the top of the Earth's core

Arnaud Chulliat[1,2], Patrick Alken[1,2], and Stefan Maus[1]

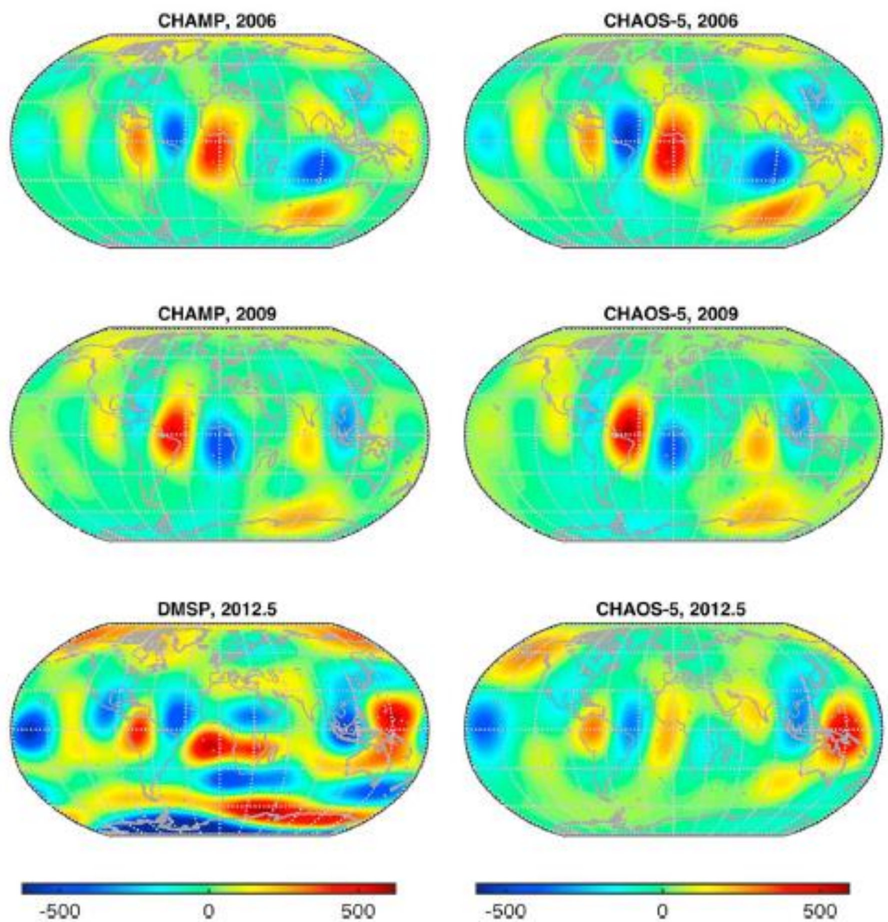
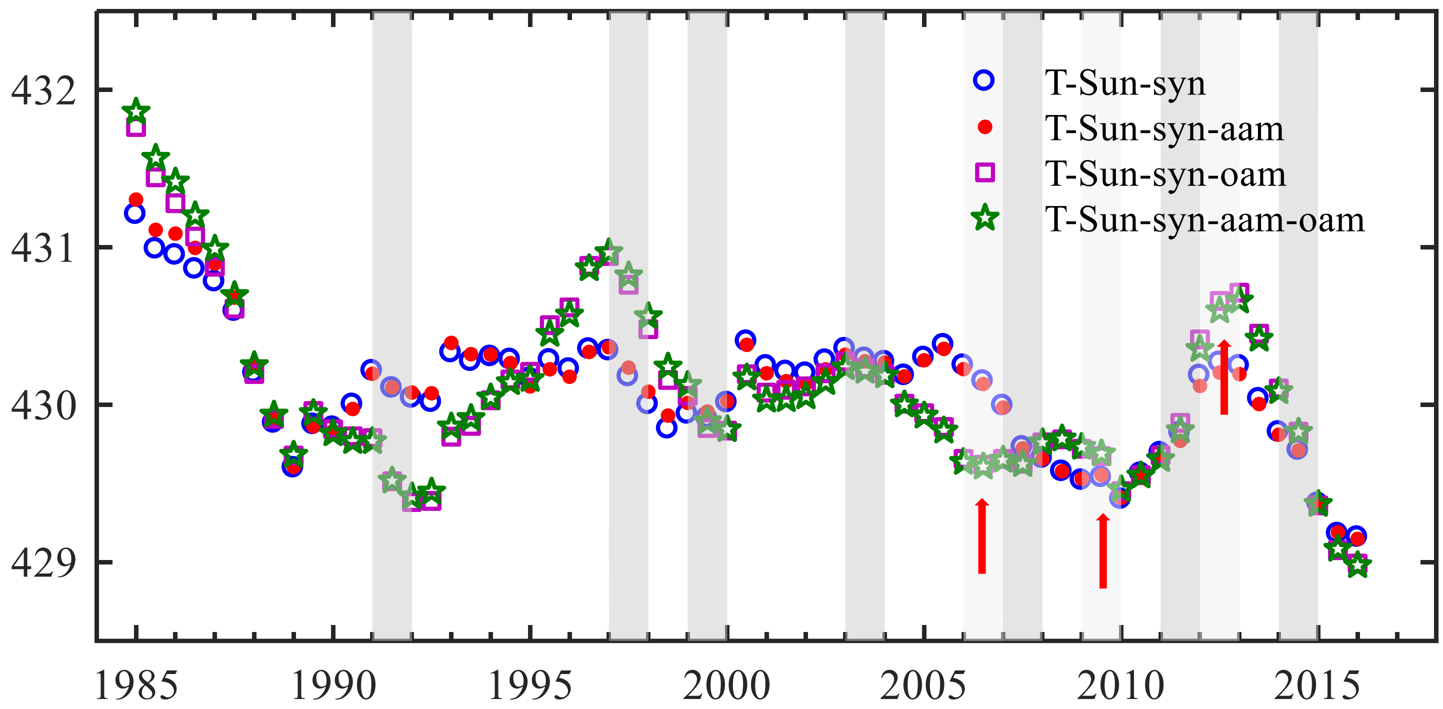


Figure 1. Maps of the radial secular acceleration at the core-mantle boundary, (left column) CHAMP + DMSP models and (right column) CHAOS-5 model. The maps are shown at three different epochs (2003, 2009, and 2012.5), when equatorial SA patches in the Atlantic sector are of maximum amplitude. The color scale does not take into account DMSP SA at latitudes larger than 60° in absolute value. Units: nT/yr^2.



GMJ：1991/92，1997，1999，2003，2007，2011，2014

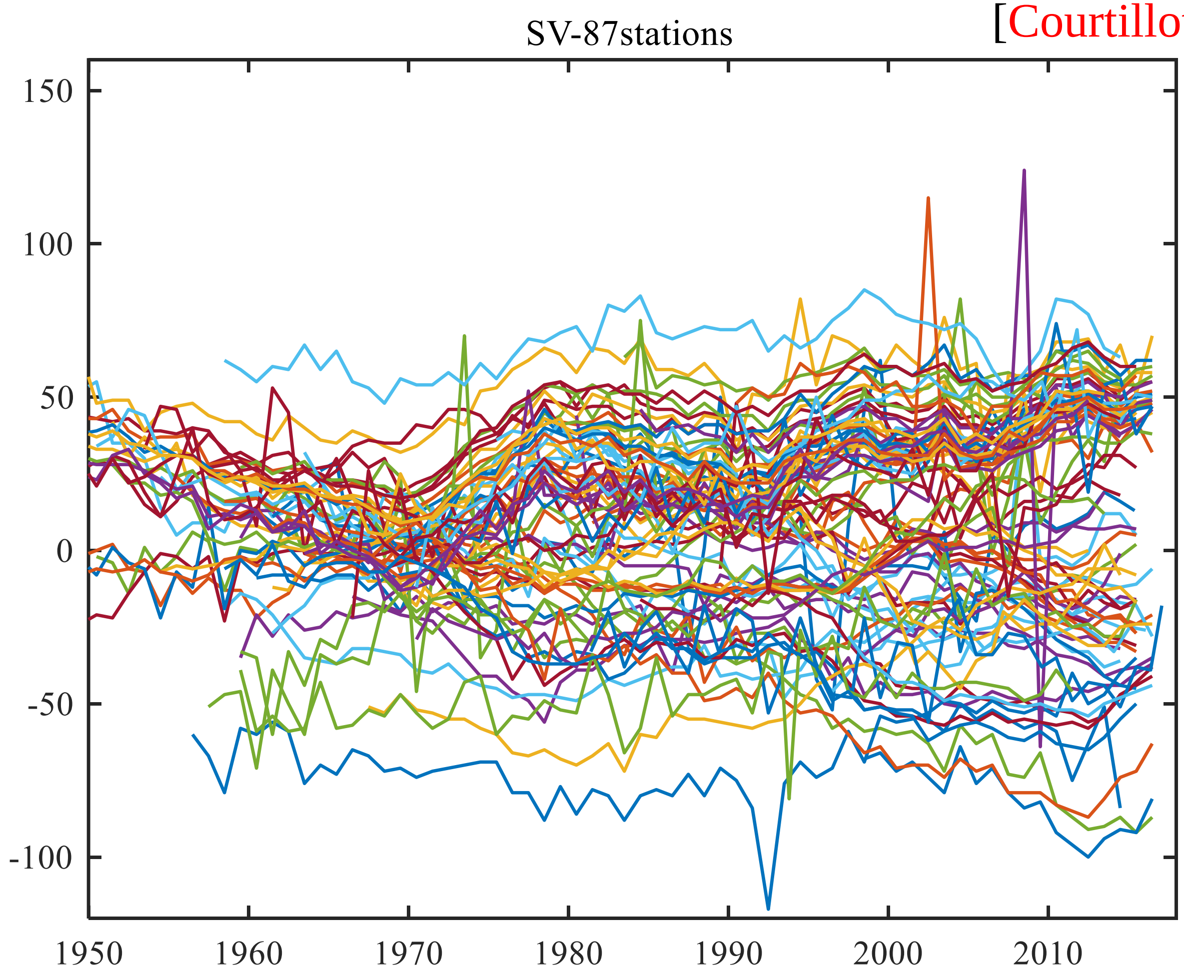
SA Pulse：2006，2009，2012.5

Geomagnetic variation—Secular Variation

- **The secular variation (SV):** The first time derivative of the geomagnetic field; .
- **Geomagnetic jerks:** The most rapid features in the changes of slopes of SV;

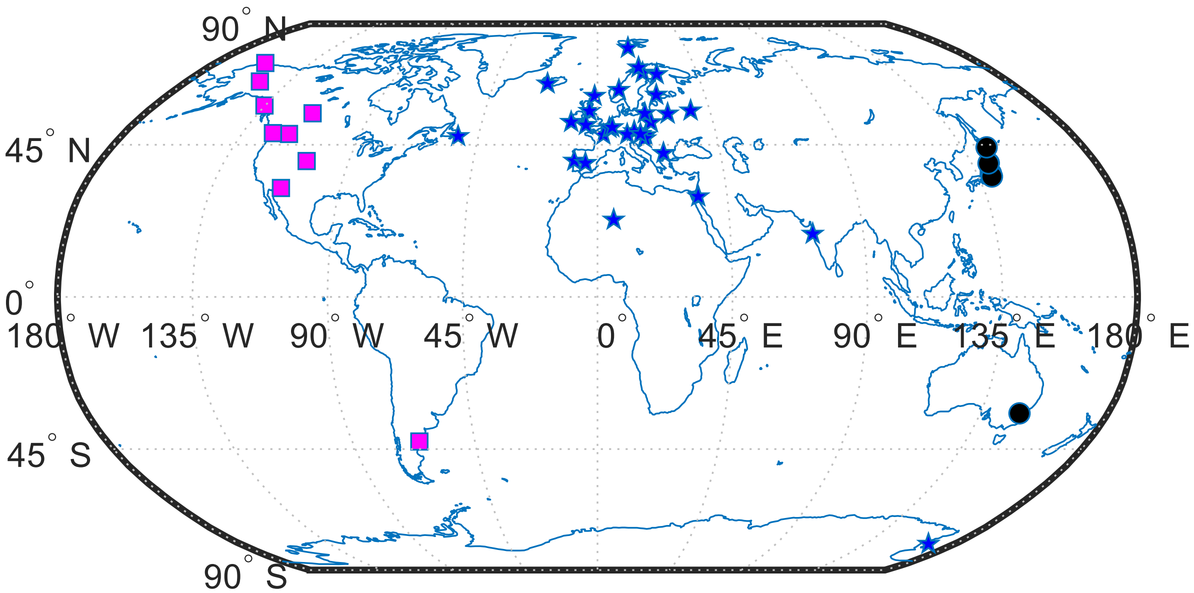
[Courtillot et al., 1978]

-Y component



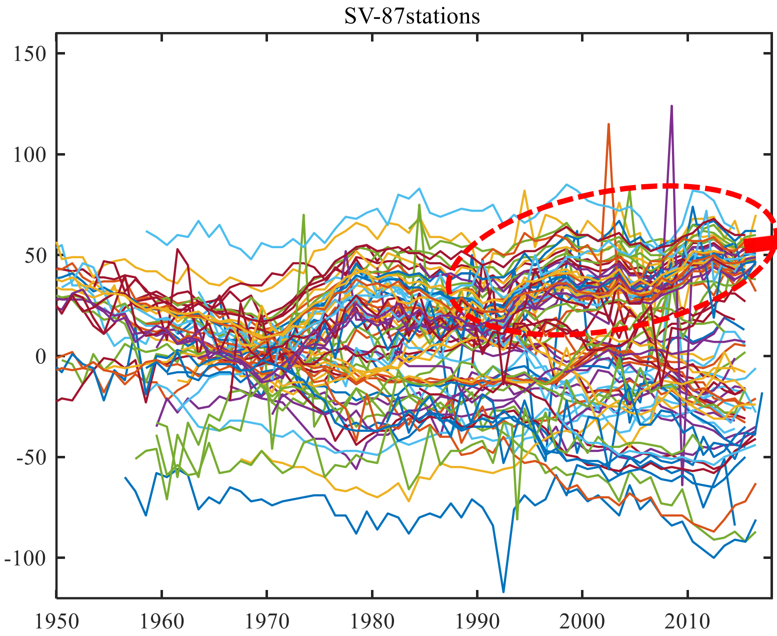
Worldwide Observatory Annual Means

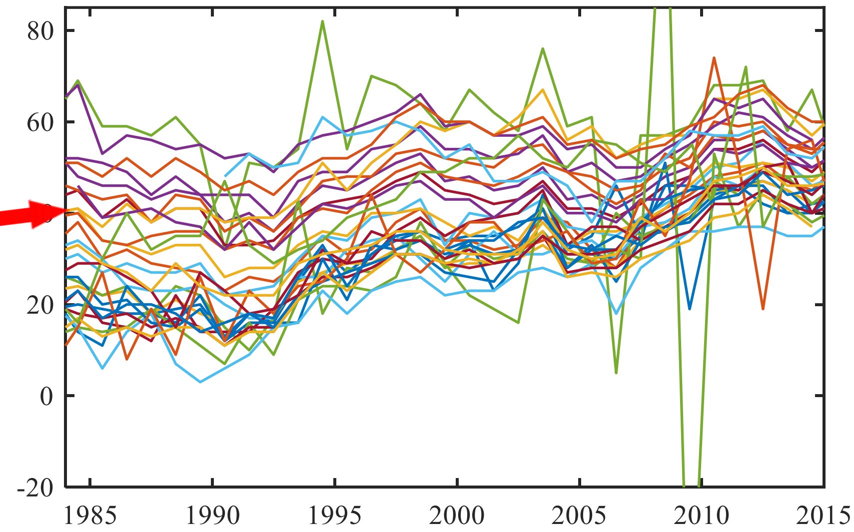
◆ **Global geomagnetic sations:**



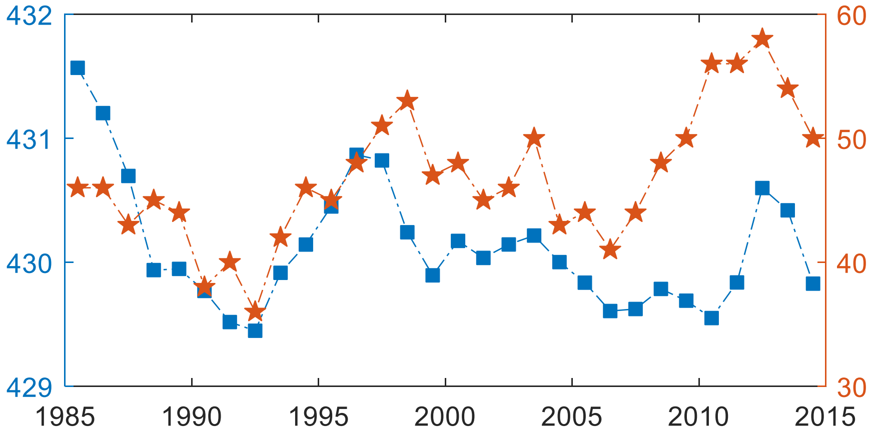
- GMJ are particularly visible in the eastward (Y) component, which is supposed to be the less affected by external fields;
- GMJ are visible most clearly in the data from European observatories (De Michelis and Tozzi 2005).

European observatories:





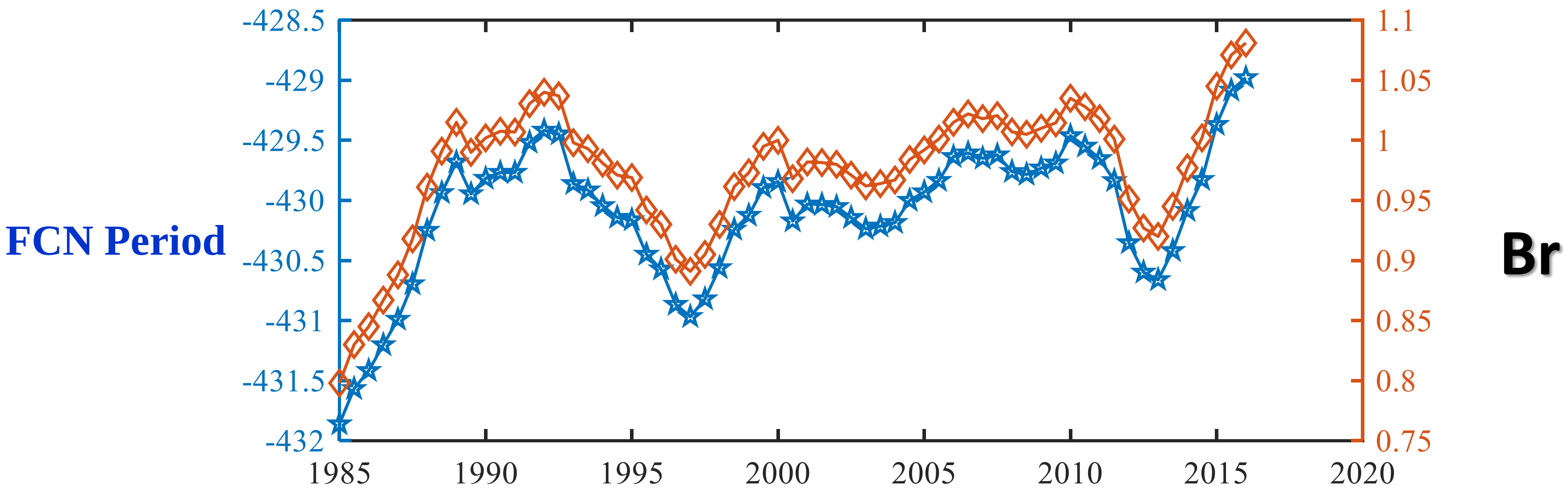
FCN Period



Questions:

- Only Regional SV agreement;
- The SV reflects low frequency band of interior EM, high frequency band is filtered by mantle.
- Theoretical fitting FCN T with EM coupling need to know conductivity/Br map (temporal variation) at CMB;

Direct or indirect relation?



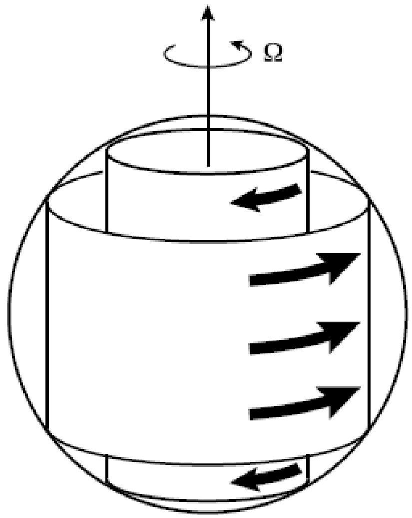
Radial component of geomagnetic field strength (Br)~ 1mT;
The conductivity at lowest mantle is close to liquid core;
FCN period variation->Br need a variation of 0.35mT

GMJ: The flow patterns of the Earth's liquid outer core

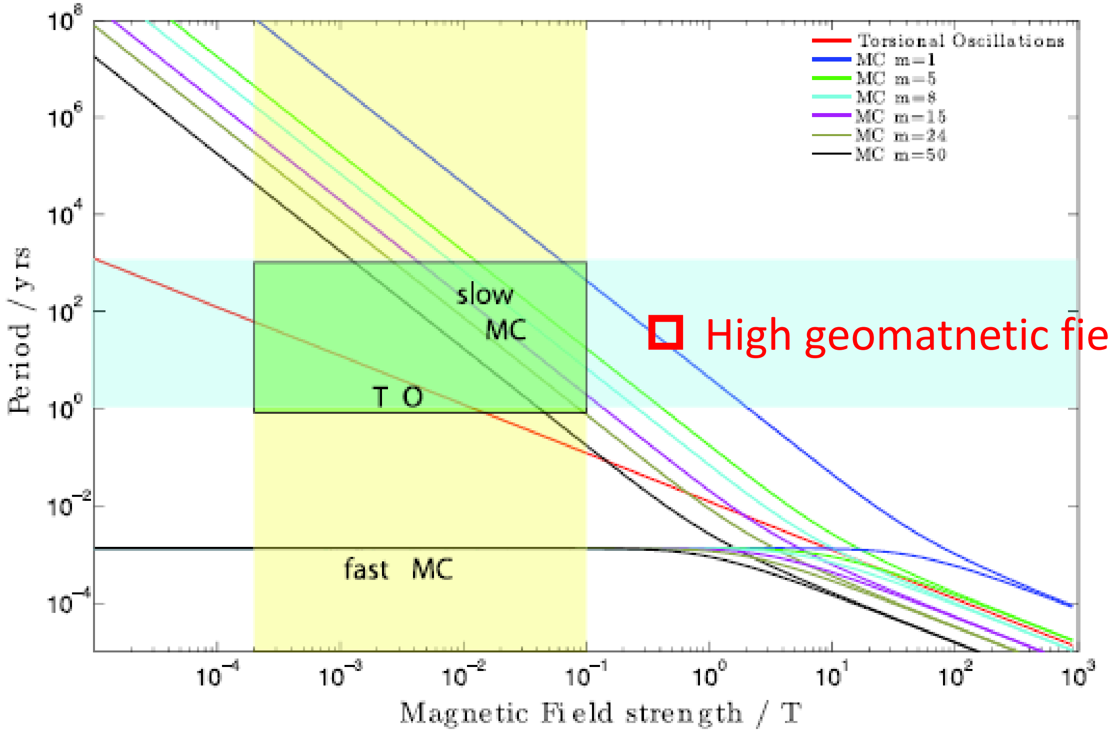
1、 torsional oscillation

- [Braginskiy, 1970]

Fig. 3 Torsional oscillations: azimuthal oscillations of rigid cylindrical surfaces aligned with the rotation axis. These motions result in Alfvén waves which
dicular to the



2. Slow magneto-Coriolis (MC) waves



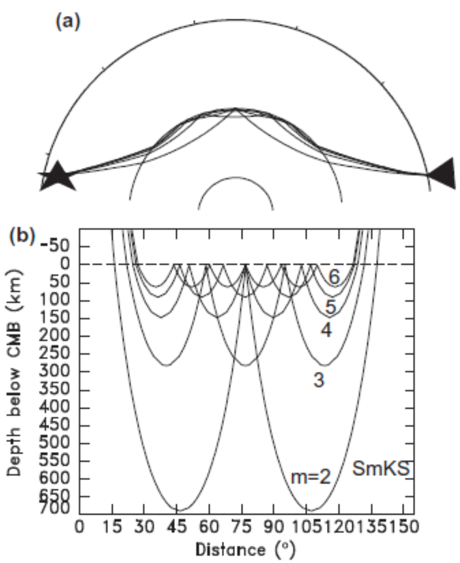
- High geomatnetic field

Short Timescale Core Dynamics: Theory and Observations

C.C. Finlay · M. Dumberry · A. Chulliat · M.A. Pais

GMJ: The flow patterns of the Earth's liquid outer core

3、Rossby wave~The stratified-layer at top of outer core

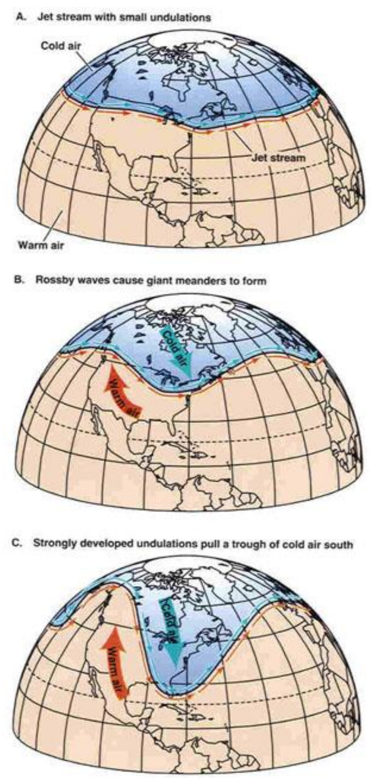


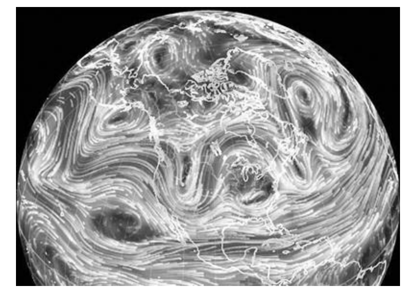
Causes and consequences of outer core stratification

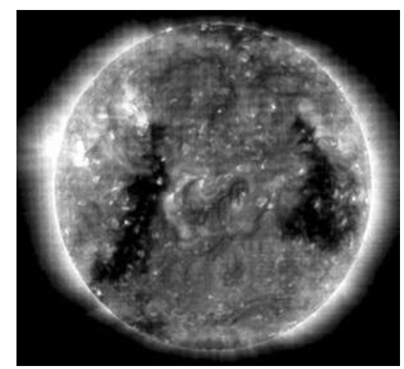
George Helffrich[a,*], Satoshi Kaneshima[b]

[a] Earth Sciences, University of Bristol, Wills Mem. Bldg., Queen's Road, Bristol BS8 1RJ, UK
[b] Earth and Planetary Sciences, University of Kyushu, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan

Seismic evidence







Mechanism of GMJ：

- If 1 or 2, direct relation!
- If 3, By topographic coupling! indirect relation!

THANKS！