Leonid Zotov

PROBLEMS AT THE BOUNDARY OF CLIMATE AND EARTH ROTATION RESEARCH

EGU 2020

Inter-Commission Committee on Geodesy for Climate Research (ICCC)

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Internet site: https://iccc.iag-aig.org/
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Joint Working Groups

Joint Working Group JWG C.1: Climate Signatures in Earth Orientation Parameters

Affiliation: Commission 3, GGOS, IERS

Chair: Jolanta Nastula (Poland)
Vice-Chair: Henryk Dobslaw (Germany)

Introduction

Earth orientation parameters comprising variations of both the position of the rotational pole and the spin rate are precisely observed by modern space geodetic techniques for several decades already. Moreover, optical astrometric observations extending back in time over more than 100 years provide even carry information about the mass transport and mass distribution processes acting on Earth at historical times that might be explored to quantify slow and subtle variations in the Earth's climate. This working group will study the various contributors of the global and interactively coupled climate system to the observed changes of the Earth's orientation on time-scales from days to centennials. It will explore possibilities to validate numerical climate models and its individual components by means of assessing the angular momentum budget and the associated torques. The working group will further investigate predictive limits of various Earth system state and flux variables in order to aid short- and long-term prediction of polar motion and changes in the length-of-day, and might ultimately foster the incorporation of Earth Orientation Parameters into contemporaneous global re-analyses of the Earth System by means of data assimilation.

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- Sigrid Boehm (Austria)
- Aleksander Brzezinski (Poland)
- Benjamin Fong Chao (Taiwan)
- Yavor Chapanov (Bulgaria)
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https://www.dropbox.com/s/u8pfpvbvqozq1cn/ToR_ICCC_2020.pdf

Proposal for a Joint IERS, IAG, GGOS Working Group: Climate Signatures in Earth Orientation Parameters

Towards an

International Panel for Earth Rotation and Climate Changes (IPERCC)

in the frame of the Inter-Commission Committee on Geodesy for Climate Research

Provisional list of the members:

- Chair: NASTULA Jolanta - Space Reseach Center (Warsaw)
- Vice-Chair: DOBSLAW Henryk - GFZ (Postdam)

- BIZOUARD Christian - Paris Observatory
- BOEHM Sigrid - TI Wien
- BRZEZINSKI Aleksander - Space Reseach Center (Warsaw)
- CHEN Jianli - USA
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- EICKER Annette - Germany
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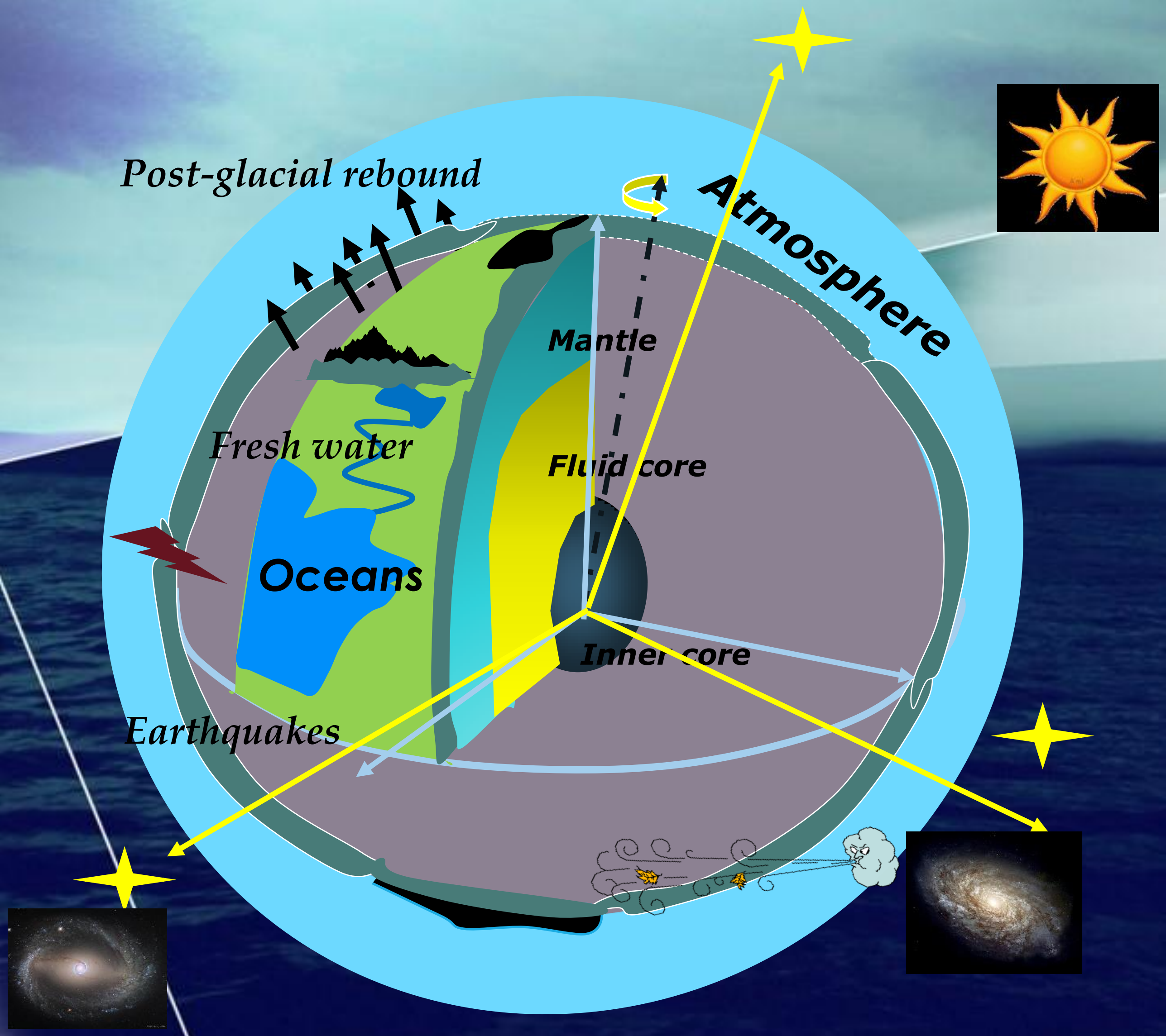
- SALSTEIN David - MIT (Boston)
- SIDORENKOV Nikolay - Hydrometcenter of the Russian Federation (Moscow)
- ZOTOV Leonid - Astronomical Sternberg Institute of the Moscow State University

Bibliographic references:

- Regional atmospheric influence on the Chandler wobble. ZOTOV L., BIZOUARD C. (2015)
- Heartbeat of the Sun from Principal Component Analysis and prediction of solar activity on a millenium timescale. V. V. ZHARKOVA, S. J. SHEPHERD, E. POPOVA, and S. I. ZHARKOV (2015)
- About possible interrelation between Earth rotation and climate variability on a decadal time-scale? ZOTOV L., BIZOUARD C., SHUM C.K. (2016).
- The response of clouds and aerosols to cosmic ray decreases. J. SVENSMARK, M. B. ENGHOFF, N. J. SHAVIV, and H. SVENSMARK (2016)
- Does an Intrinsic Source Generate a Shared Low-Frequency Signature in Earth's Climate and Rotation Rate? Steven L. MARCUS (2016)
- Climate-driven polar motion: 2003-2015. Surendra ADHIKARI and Erik R. IVINS (2016)
- Decade fluctuations in Earth's rotation as evidences of lithospheric drift over the asthenosphere. SIDORENKOV N., DIONIS E., BIZOUARD C., ZOTOV L. (JSR 2019)

https://syrte.obspm.fr/~bizouard/ipercc/index.html.

Earth rotation



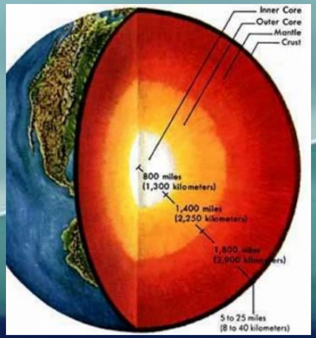
credit: C. Bizouard

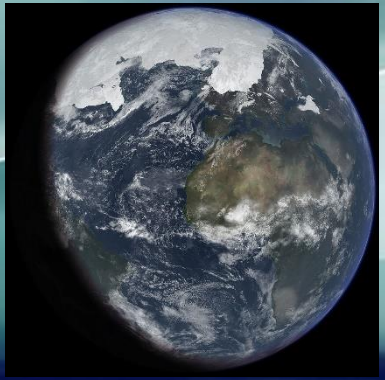
Geophysical processes influencing Earth rotation

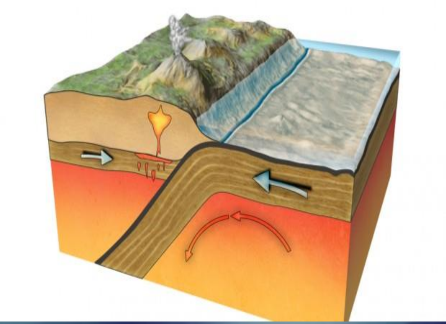
from 1 to 1 000 000 years

Well-modelled

Luni-solar tides







12 h 1 day 365 days 10 years 10^2 years 10^3 years 10^4 years 10^5 years 10^6

atmosphere ocean

glaciations

Hydrological effects and climate influences

Core-mantle coupling

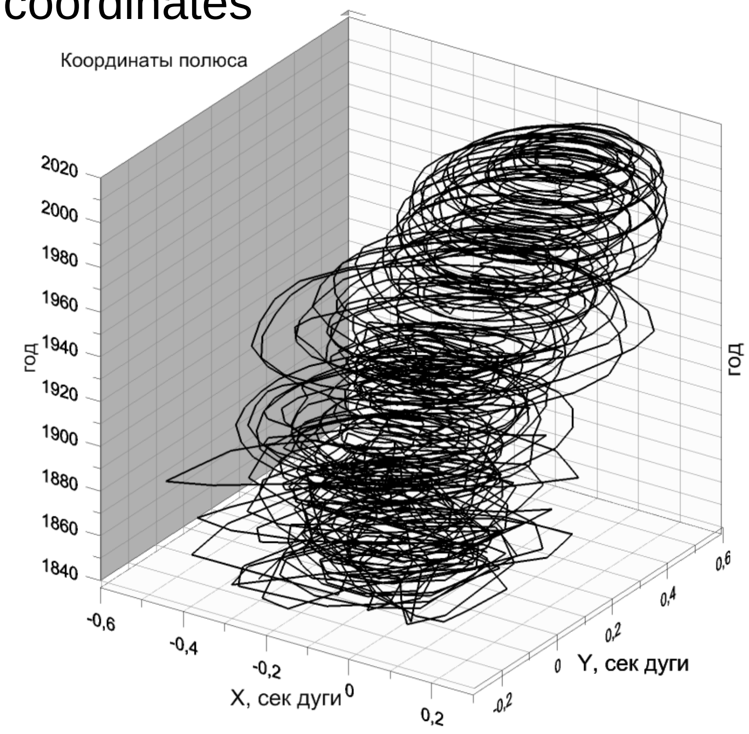
Tectonics

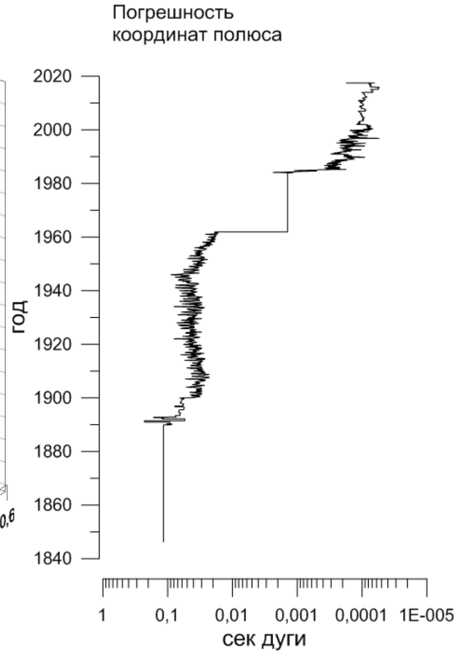
credit: C. Bizouard

C

Observed EOP

x, y pole coordinates

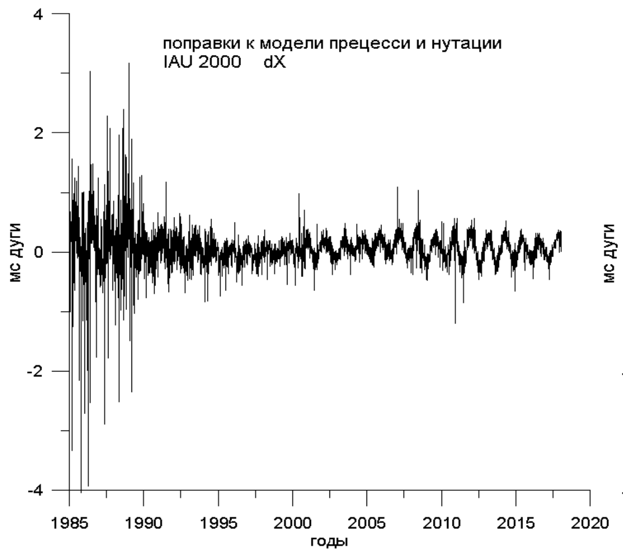


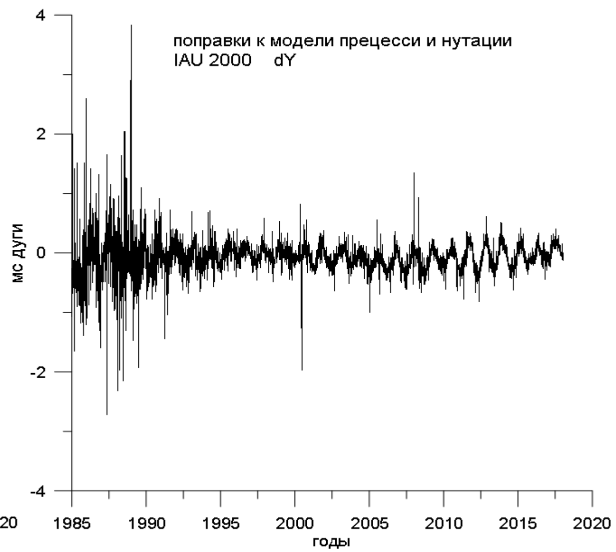


Earth orientation parameters:

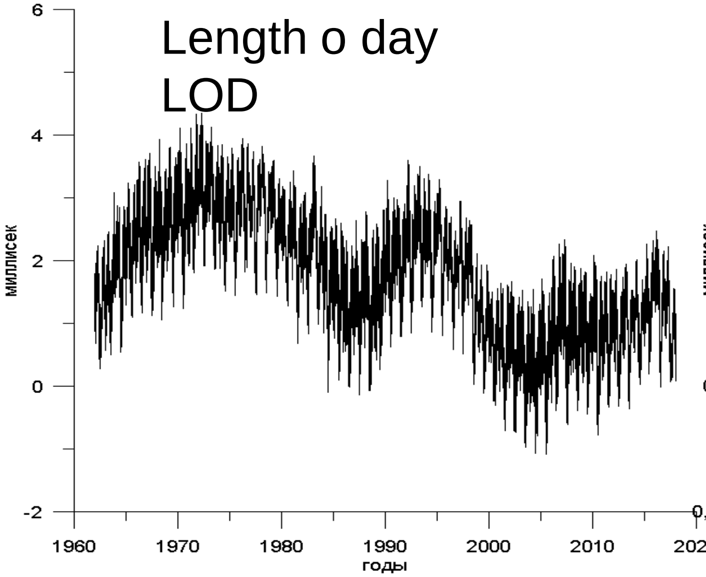
- x, y pole coordinates
- UT1-UTC
- dX, dY nutation corrections

nutation corrections

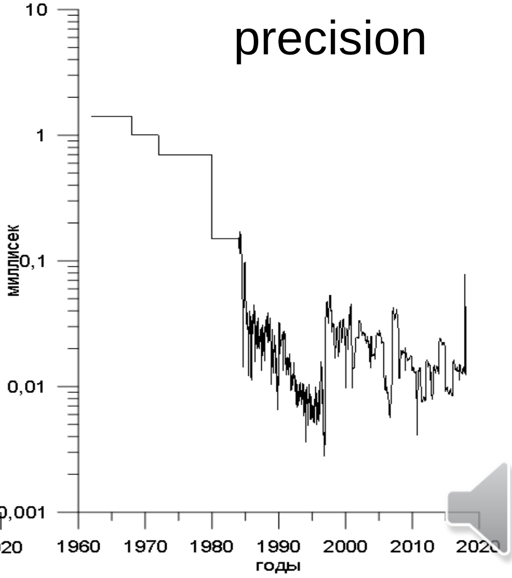




Length o day
LOD



precision



Aspects of the Earth rotation theory

$$\frac{\partial \mathbf{H}}{\partial t} + (\omega \times \mathbf{H}) = \mathbf{\Lambda},$$

$$\mathbf{H} = \mathbf{I}\omega + \mathbf{h}.$$

Euler equations of solid body rotation

$$\frac{d\omega_1}{dt} + \frac{I_3 - I_2}{I_1}\omega_2\omega_3 = 0,$$
$$\frac{d\omega_2}{dt} + \frac{I_1 - I_3}{I_2}\omega_3\omega_1 = 0,$$
$$\frac{d\omega_3}{dt} + \frac{I_2 - I_1}{I_3}\omega_1\omega_2 = 0.$$

$$\frac{d\omega_1}{dt} = -\sigma_e\omega_2, \qquad \frac{d\omega_2}{dt} = \sigma_e\omega_1,$$

Euler frequncy

$$\sigma_e = \Omega\frac{C - \frac{A+B}{2}}{\frac{A+B}{2}}.$$

Angular momentum balance

In non-rotating   in rotating frame

$$\left(\frac{d\mathbf{H}}{dt}\right)_S = \mathbf{L}, \qquad \frac{d\mathbf{H}}{dt} + \mathbf{\Omega} \times \mathbf{H} = \mathbf{\Gamma},$$

Complex linearized Euler-Liouville Equation for equatorial components

$$\frac{i}{\sigma_e}\dot{m} + m = \Psi,$$

$$\dot{m}_3 = \dot{\Psi}_3,$$

For axial component

Excitation functions

$$\Psi_1 = \frac{1}{\Omega^2(C-A)}\left(\Omega^2 c_{13} + \Omega\dot{c}_{23} + \dot{h}_2 + \Omega h_1\right),$$
$$\Psi_2 = \frac{1}{\Omega^2(C-A)}\left(\Omega^2 c_{23} - \Omega\dot{c}_{13} - \dot{h}_1 + \Omega h_2\right).$$

$$\Psi_3 = \frac{1}{\Omega^2 C}\left(-\Omega^2 c_{33} - \Omega\dot{h}_3\right).$$

$$\Psi = \Psi_1 + i\Psi_2$$

$$m = m_1 + im_2, \; c = c_{13} + ic_{23}, \quad h = \dot{c}_{13} + i\dot{c}_{23}$$

Inertia tensor

$$\mathbf{I} + \delta\mathbf{I} = \begin{bmatrix} A + c_{11} & c_{12} & c_{13} \\ c_{21} & B + c_{22} & c_{23} \\ c_{31} & c_{32} & C + c_{33} \end{bmatrix}.$$

Angular velocity vector

$$\omega_0 + \delta\omega = \Omega\begin{bmatrix} m_1 \\ m_2 \\ 1 + m_3 \end{bmatrix}.$$

Complex angular momentum function

$$\chi = \frac{c}{(C-A)} + \frac{h}{\Omega(C-A)},$$

Tensor of inertia changes, mass component *c* motion component *h*

$$m = p - \frac{i}{\Omega}\dot{p}.$$

$$\frac{i}{\sigma_e}\dot{p} + p = \chi^{mass} + \chi^{motion} = \chi.$$

Chandler wobble

Centrifugal potential

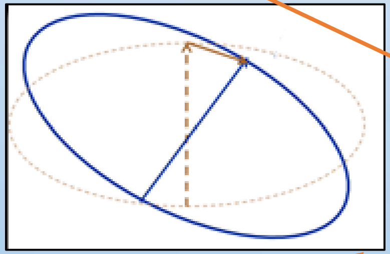
$$U_{cf} = -\frac{1}{2}\Omega^2 r^2 \sin^2\theta = -\frac{1}{2}\Omega^2 r^2 + \frac{1}{2}\Omega^2 r^2 \cos^2\theta.$$

Polar tide potential

$$U_{cf} = -\frac{1}{2}\Omega^2(x^2+y^2) + \Omega^2 z(m_1 x + m_2 y).$$

Additional potential expressed through second Love number k_2~0.3

$$U_i = k_2\Omega^2 z(m_1 x + m_2 y).$$



Secular Love number k_s

$$k_s = 3G(C-A)/\Omega^2 R^5 \approx 0.94,$$

Substitution gives

$$\Omega\left[A + \frac{k_2}{k_s}(C-A)\right]\dot{m} - i\Omega^2(C-A)\left(1-\frac{k_2}{k_s}\right)m = 0$$

Complex Love number

$$\tilde{k}_2 = k_2^{re} + ik_2^{im} = k_2(1+i\varepsilon),$$

Complex Chandler frequency

$$\sigma_c = \sigma_e\frac{(1-\frac{\tilde{k}_2}{k_s})}{(1+e\frac{\tilde{k}_2}{k_s})} = 2\pi f_c\left(1+\frac{i}{2Q}\right).$$

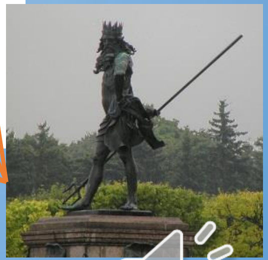
Earth's axis position

$$\frac{i}{\sigma_c}\dot{m} + m = \frac{\Psi^{pure}}{1-\frac{\tilde{k}_2}{k_s}},$$

Modified Chandler frequency

$$\sigma_c = \Omega\frac{(C-A)(1-k_2/k_s)}{A+(k_2/k_s)(C-A)},$$

$$m = p - i\dot{p}/\Omega$$



Ocean influence on dissipation, polar tide response, modifyes eigen frequency, provides excitation

Euler-Liouville equation for polar motion

Geodetic excitation

Geophysical excitation

p(t) – complex polar motion trajectory

$$\frac{i}{\sigma_c}\frac{dp(t)}{dt} + p(t) = \chi^{tot}(t),$$

Excitation is given
In form of effective
Angular momentum
fucnctions

$$\chi_e^{mass} = \frac{1+k_2'}{1-\tilde{k}_2/k_s}\chi^{mass}, \qquad \chi_e^{motion} = \frac{1}{1-\tilde{k}_2/k_s}\chi^{motion}.$$

Complex chandler frequency fc=365.25/433 cycles per year period T=433 days

$$\sigma_c = \sigma_e \frac{(1-\frac{\tilde{k}_2}{k_s})}{(1+e\frac{\tilde{k}_2}{k_s})} = 2\pi f_c \left(1+\frac{i}{2Q}\right).$$

Q – quality factor
from 60 to 150,
we used
Q=100

Journal of Geophysical Research: Solid Earth

RESEARCH ARTICLE
10.1002/2014JB011825

Chandler wobble parameters from SLR and GRACE

J. Nastula[1] and R. Gross[2]

[1]Space Research Centre, Polish Academy of Sciences, Warsaw, Poland, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

Key Points:

- The period and Q of the Chandler wobble are estimated from SLR and GRACE data
- Atmosphere, ocean, and hydrology models were also used
- Preferred values are the period = 430.9 ± 0.7 days and Q = 127 (56, 255)

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Citation:
Nastula, J., and R. Gross (2015), Chandler wobble parameters from SLR and GRACE, *J. Geophys. Res. Solid Earth*, *120*, 4474–4483, doi:10.1002/2014JB011825.

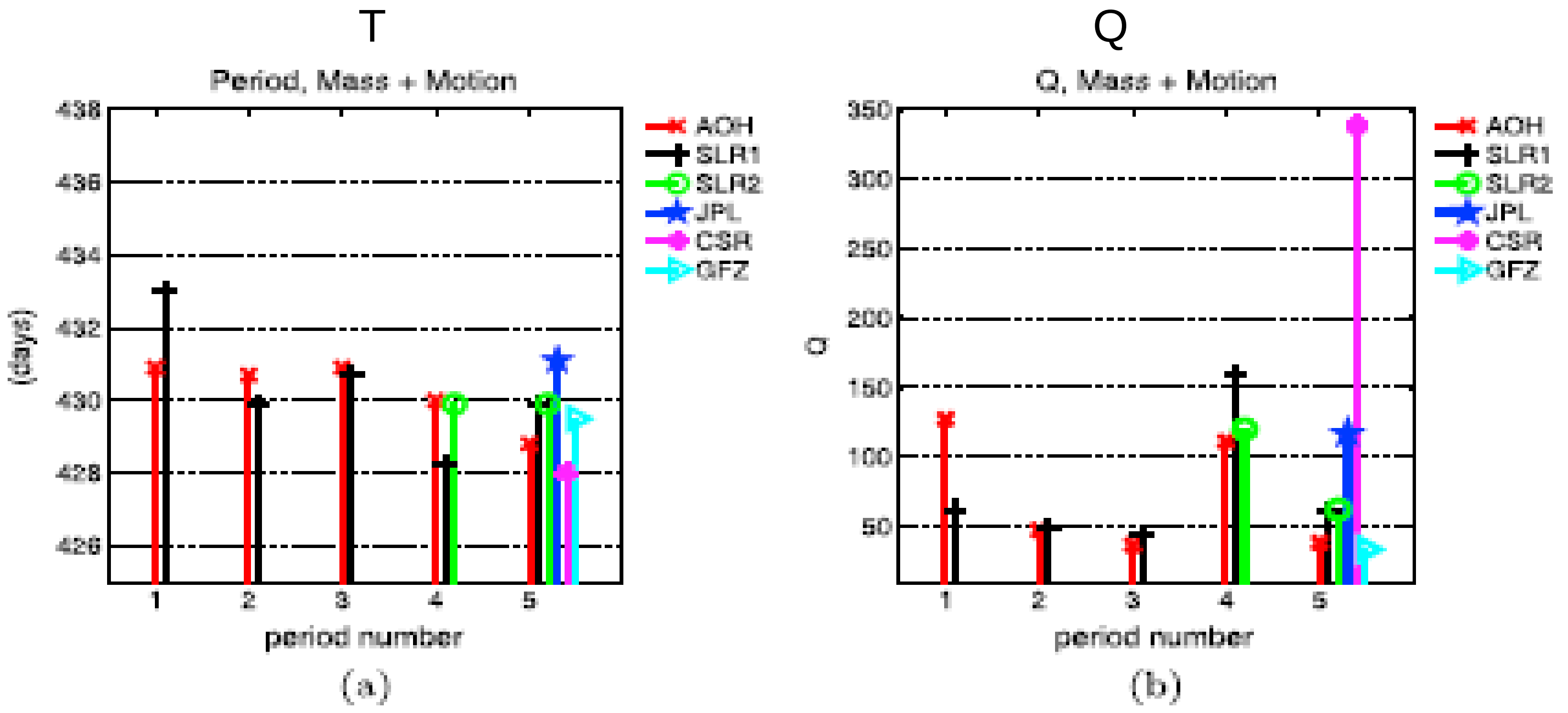

Figure 2. Comparison of estimates of the (a) period and (b) *Q* of the Chandler wobble during the five time intervals: 1, 1985–2010; 2, 1991–2010; 3, 1993–2010; 4, 2001–2010; 5, 2003–2010. Mass and motion terms were included in the excitation functions.

l'Observatoire de Paris — SYRTE

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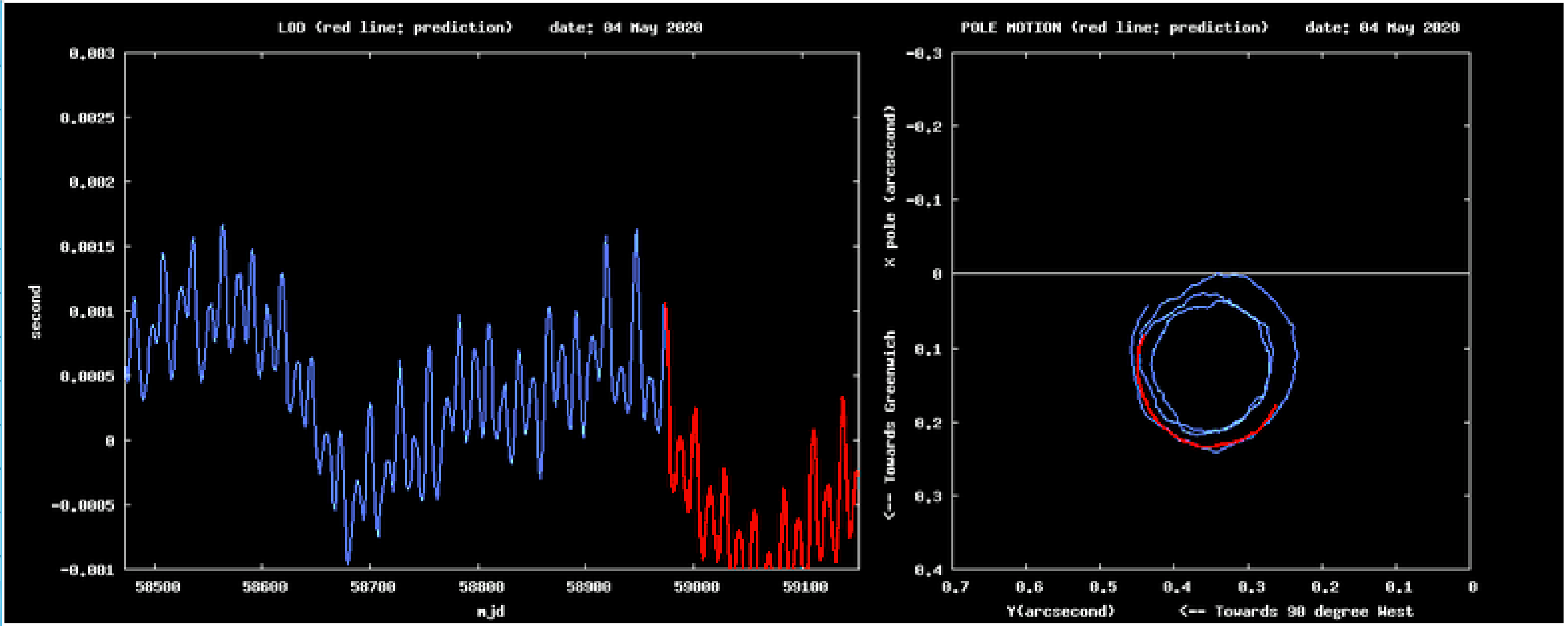


Last leap second: **31 December 2016** TAI - UTC: **37 s** Next leap second: **Not scheduled**

Leap second file Leap second web service

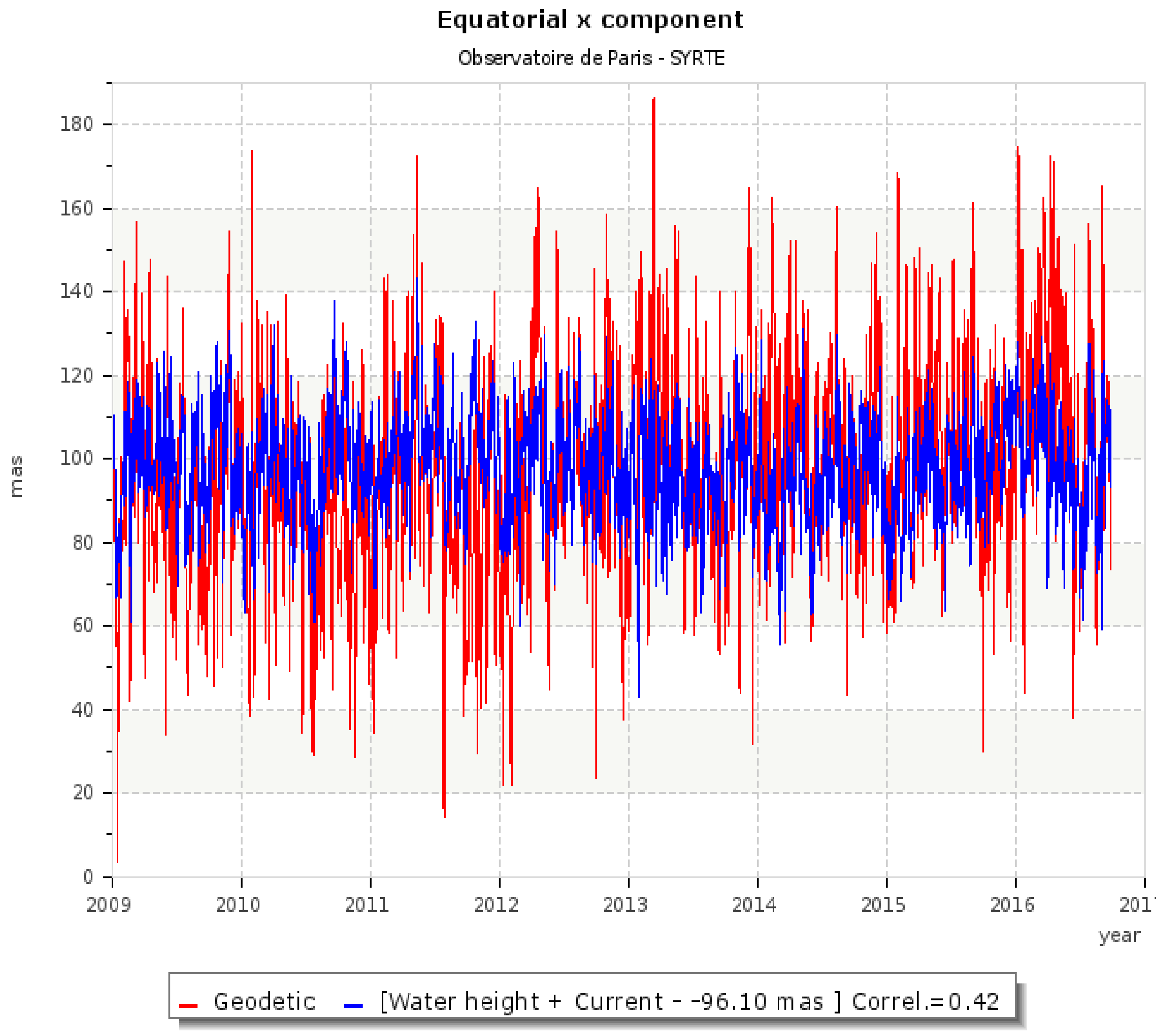
Latest C04 values for pole coordinates (x,y) and UT1 on **4 Mai 2020** at 0h UTC:

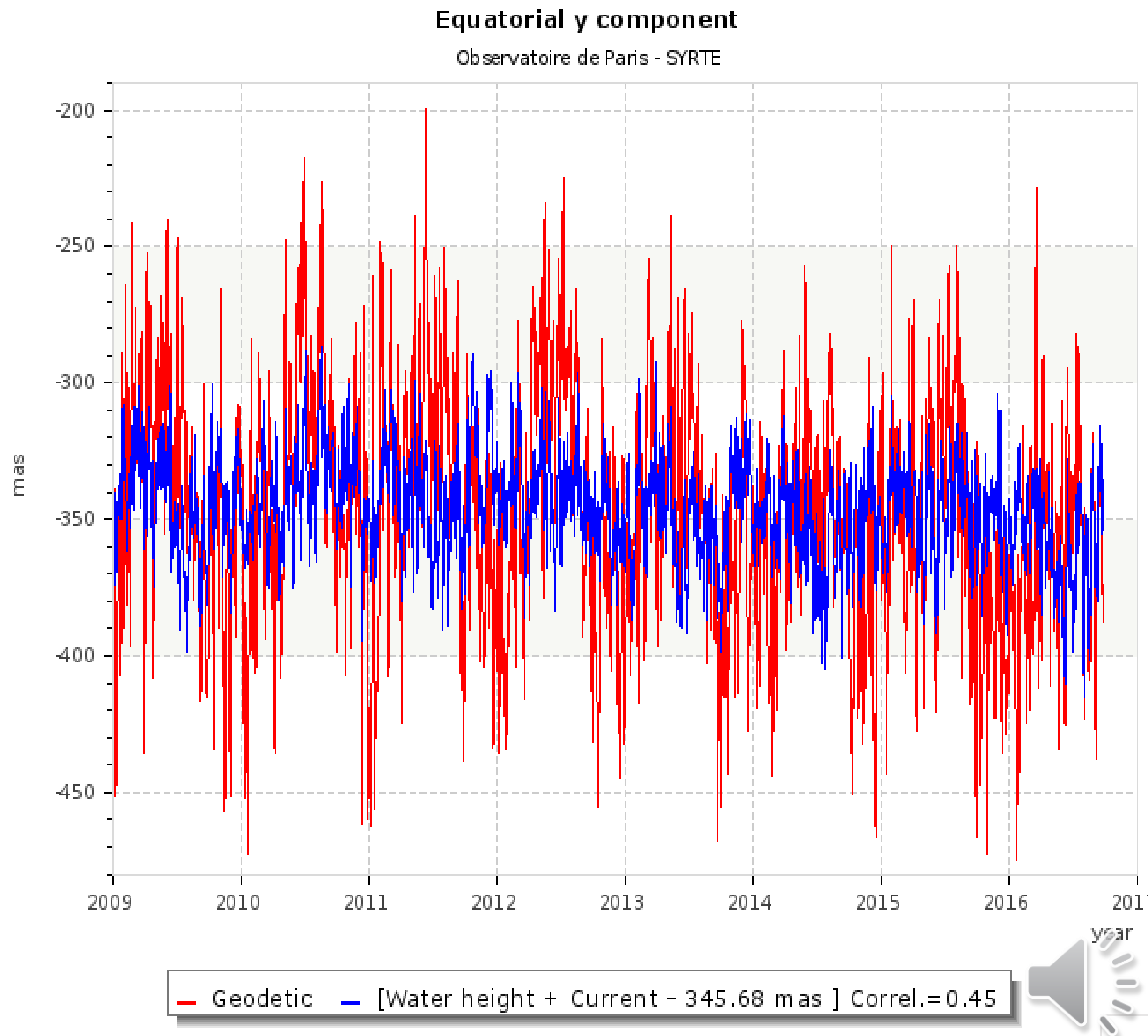
x= 81.60 mas y= 439.32 mas UT1-UTC= -244.500 ms

For the latest 7-20 days and the prediction
IERS recommends the use of **Bulletin A**
provided by the IERS Rapid Service (USNO, Washington)

EOP PC http://hpiers.obspm.fr/

Oceanic Angular Momentum input to the polar motion





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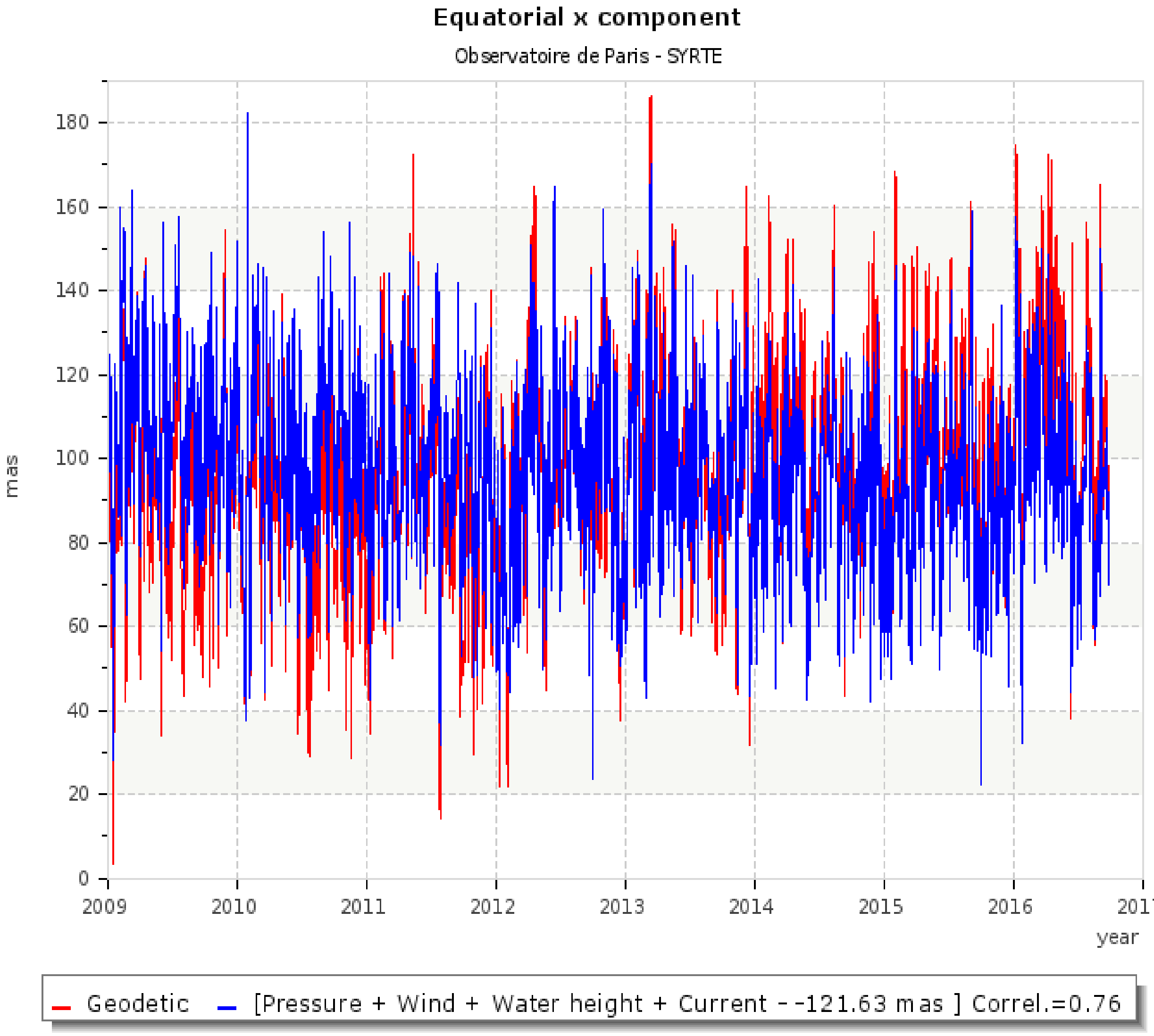
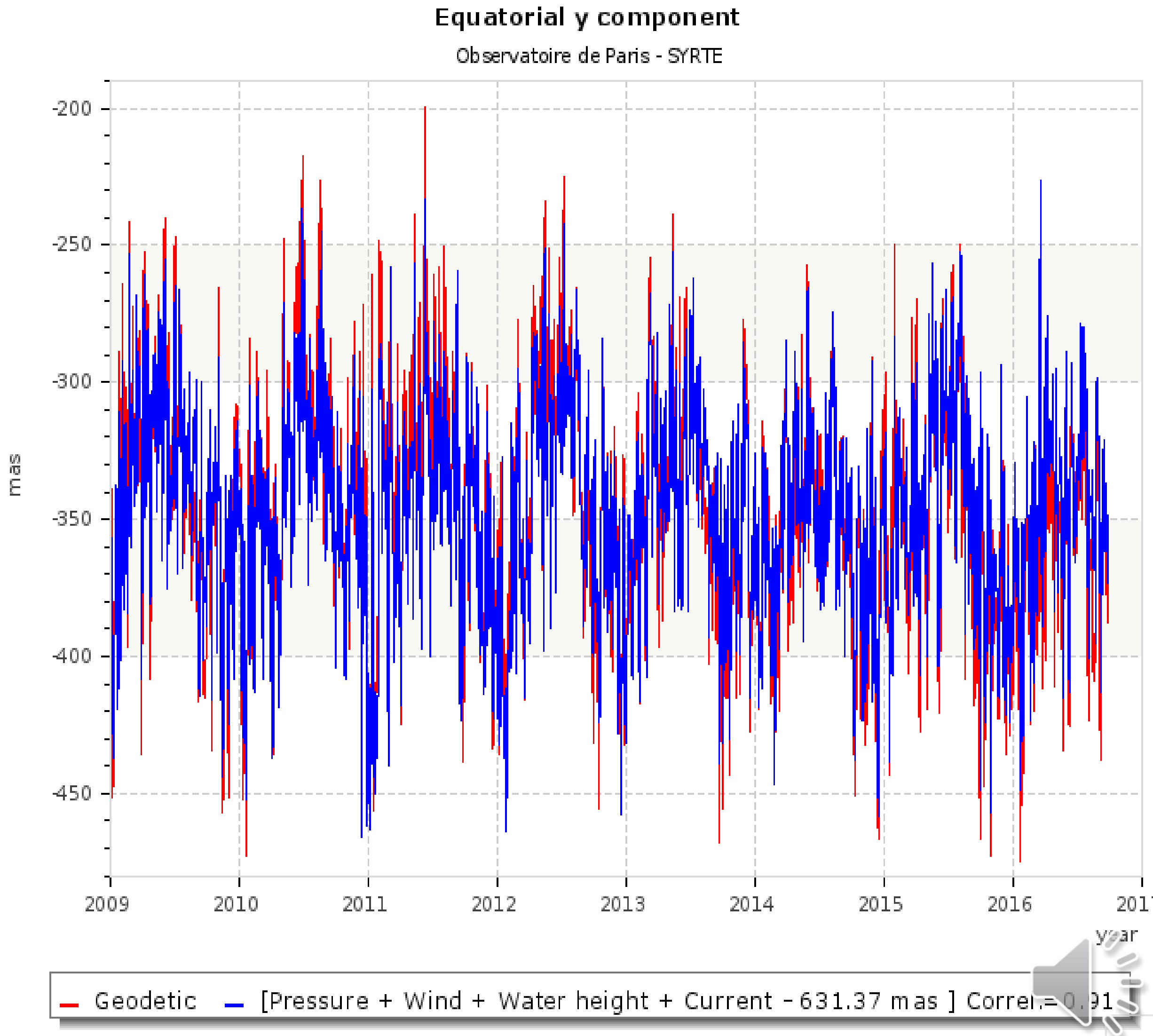
Oceanic Angular Momentum + Atmospheric Angular Momentum input to the polar motion





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Geodesy and Geodynamics 8 (2017) 377–388

Contents lists available at ScienceDirect

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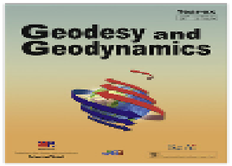

Improved geophysical excitations constrained by polar motion observations and GRACE/SLR time-dependent gravity

Wei Chen [a, b, *], Jiancheng Li [a], Jim Ray [c, 1], Minkang Cheng [b]

[a] *Collaborative Innovation Center of Geospatial Technology/Key Laboratory of Geospace Environment and Geodesy, School of Geodesy and Geomatics, Wuhan University, China*

[b] *Center for Space Research, University of Texas at Austin, USA*

[c] *National Oceanic and Atmospheric Administration, Silver Spring, MD, USA*

A R T I C L E I N F O

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Keywords:
Polar motion
GRACE
SLR
Least difference combination
Atmospheric, oceanic, and hydrological/crospheric excitation

A B S T R A C T

At seasonal and intraseasonal time scales, polar motions are mainly excited by angular momentum fluctuations due to mass redistributions and relative motions in the atmosphere, oceans, and continental water, snow, and ice, which are usually provided by various global atmospheric, oceanic, and hydrological models (some with meteorological observations assimilated; e.g., NCEP, ECCO, ECMWF, OMCT and LSDM etc.). Unfortunately, these model outputs are far from perfect and have notable discrepancies with respect to polar motion observations, due to non-uniform distributions of meteorological observatories, as well as theoretical approximations and non-global mass conservation in these models. In this study, the LDC (Least Difference Combination) method is adopted to obtain some improved atmospheric, oceanic, and hydrological/crospheric angular momentum (AAM, OAM and HAM/CAM, respectively) functions and excitation functions (termed as the LDCgsm solutions). Various GRACE (Gravity Recovery and Climate Experiment) and SLR (Satellite Laser Ranging) geopotential data are adopted to correct the non-global mass conservation problem, while polar motion data are used as general constraints. The LDCgsm solutions can reveal not only periodic fluctuations but also secular trends in AAM, OAM and HAM/CAM, and are in better agreement with polar motion observations, reducing the unexplained excitation to the level of about 5.5 mas (standard derivation value; about 1/5–1/4 of those corresponding to the original model outputs).

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https://doi.org/10.1007/s11600-018-0227-x

RESEARCH ARTICLE - SOLID EARTH SCIENCES

Terrestrial water storage variations and their effect on polar motion

Justyna Śliwińska[1] · Małgorzata Wińska[2] · Jolanta Nastula[1]

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Analysis of groundwater storage changes in main Polish river basins using GRACE observations, in-situ data, and hydrological and climate models

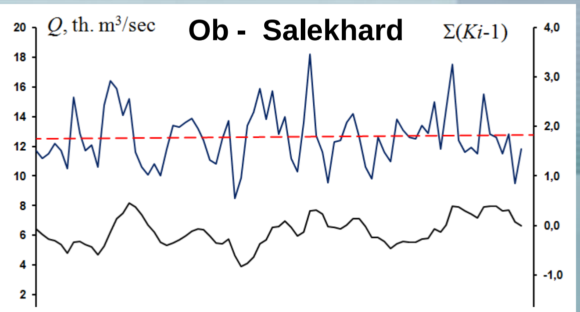
Jolanta Nastula[1], Justyna Śliwińska[1], Zofia Rzepecka[2], Monika Birylo[2]

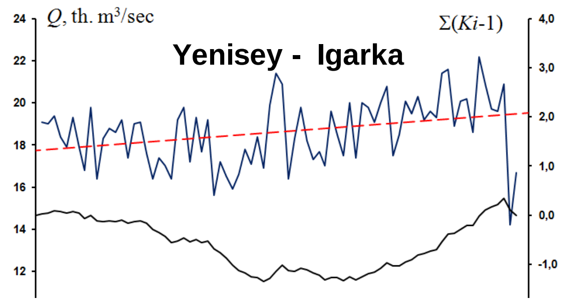
EGU 2020 - 13554

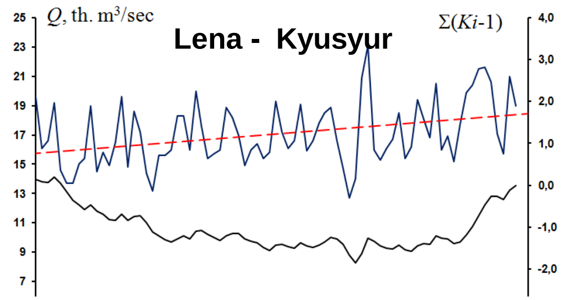
Long-term changes of the annual water runoff

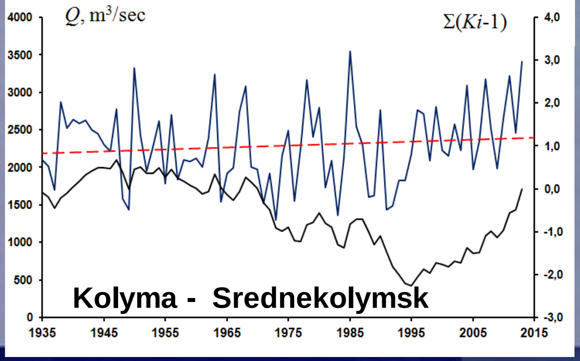
River – hydrometric station	$\Delta W_Q/\Delta y$*	The linear trend coefficient, km³/1year	
		1935-2013	1975-2013
Sev.Dvina - Ust-Pinega	+5.3%/+15mm	+0.098	+0.091
Mezen - Malonisogorskaya	-1.7%/-6mm	+0.005	+0.029
Pechora - Ust-Tsilma	+4.6%/+20mm	+0.173	+0.184
Ob - Salekhard	-0.4%/-0.7mm	+0.089	-0.089
Yenisey - Igarka	+5.4%/+13mm	+0.696	+0.922
Olenek - Sukhana	+12.2%/+21mm	+0.066	+0.113
Lena - Kyusyur	+7.4%/+16mm	+1.080	+2.214
Yana – Jiangky/Yubileynaya	*+12.8%/+18mm*	-	-
Kolyma - Srednekolymsk	+4.6%/+9mm	+0.081	+0.451

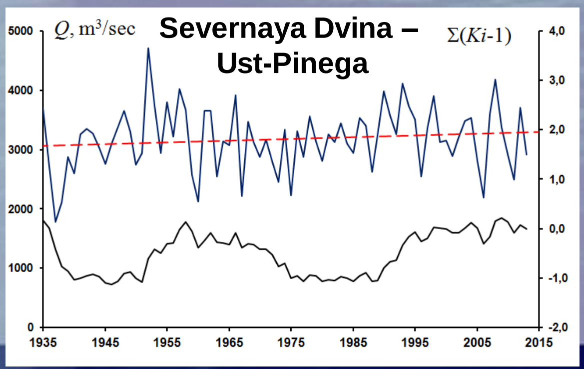
*change of annual water runoff in 1976-2013 in comparison with the value of annual water runoff in 1935-1975

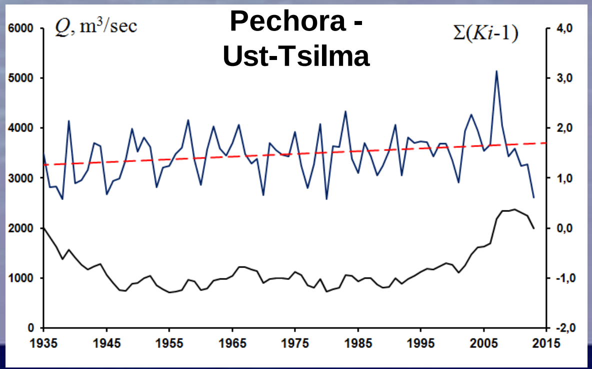






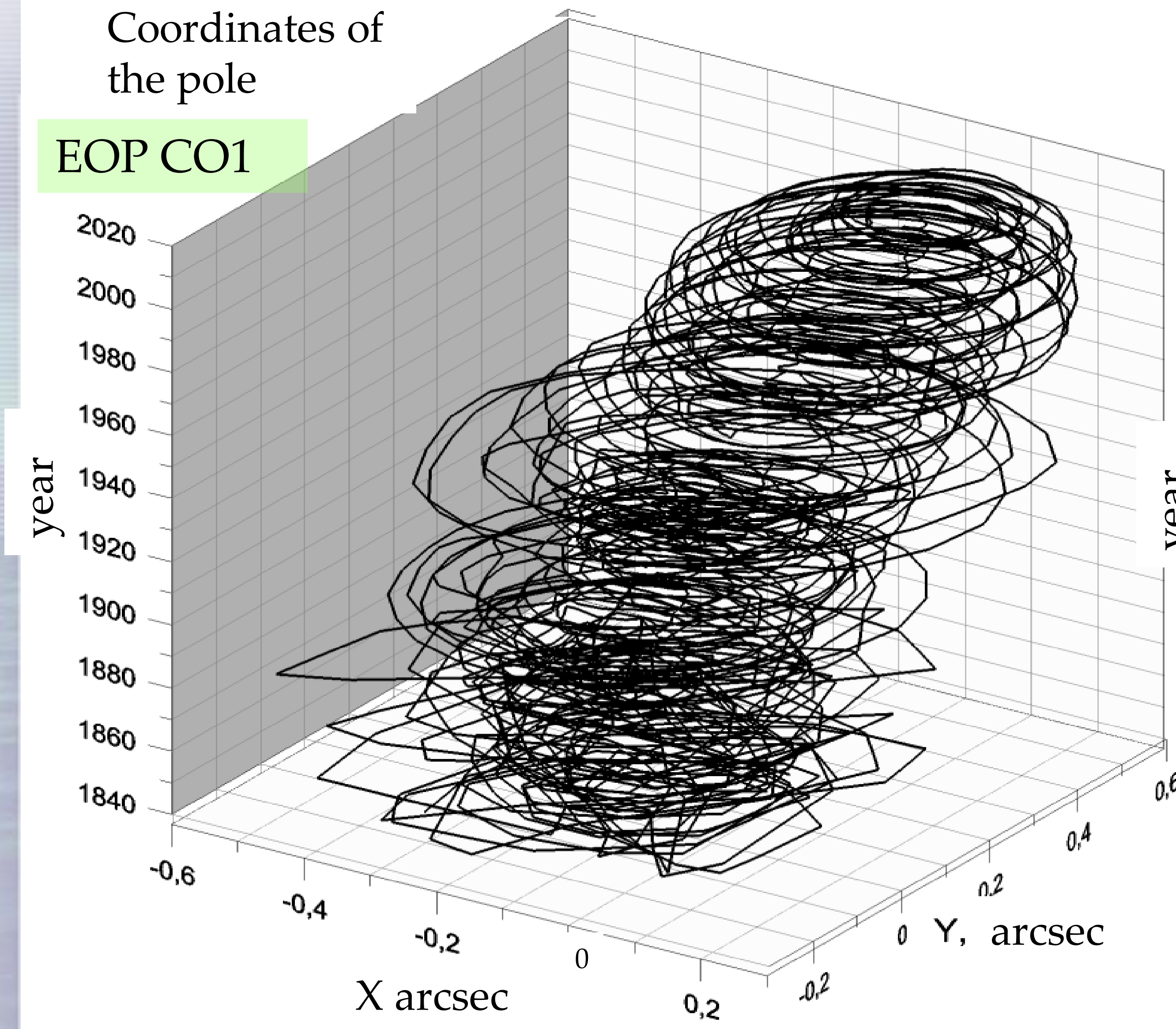


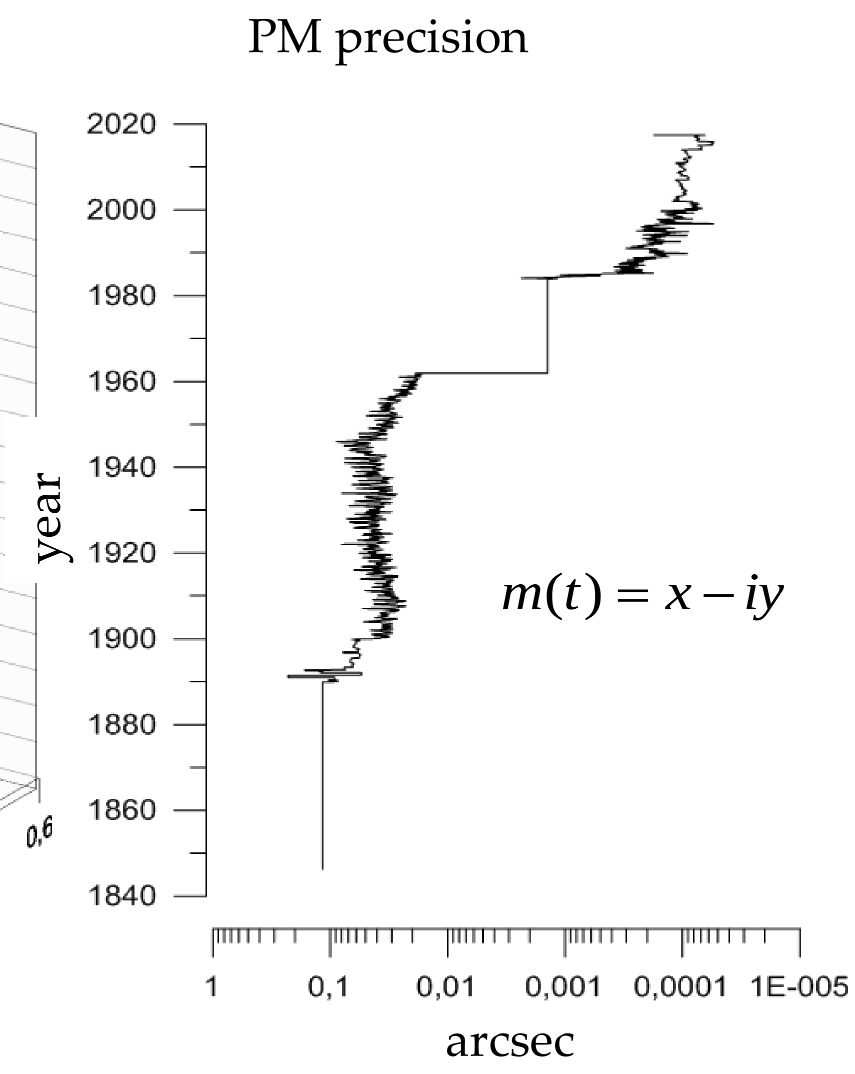




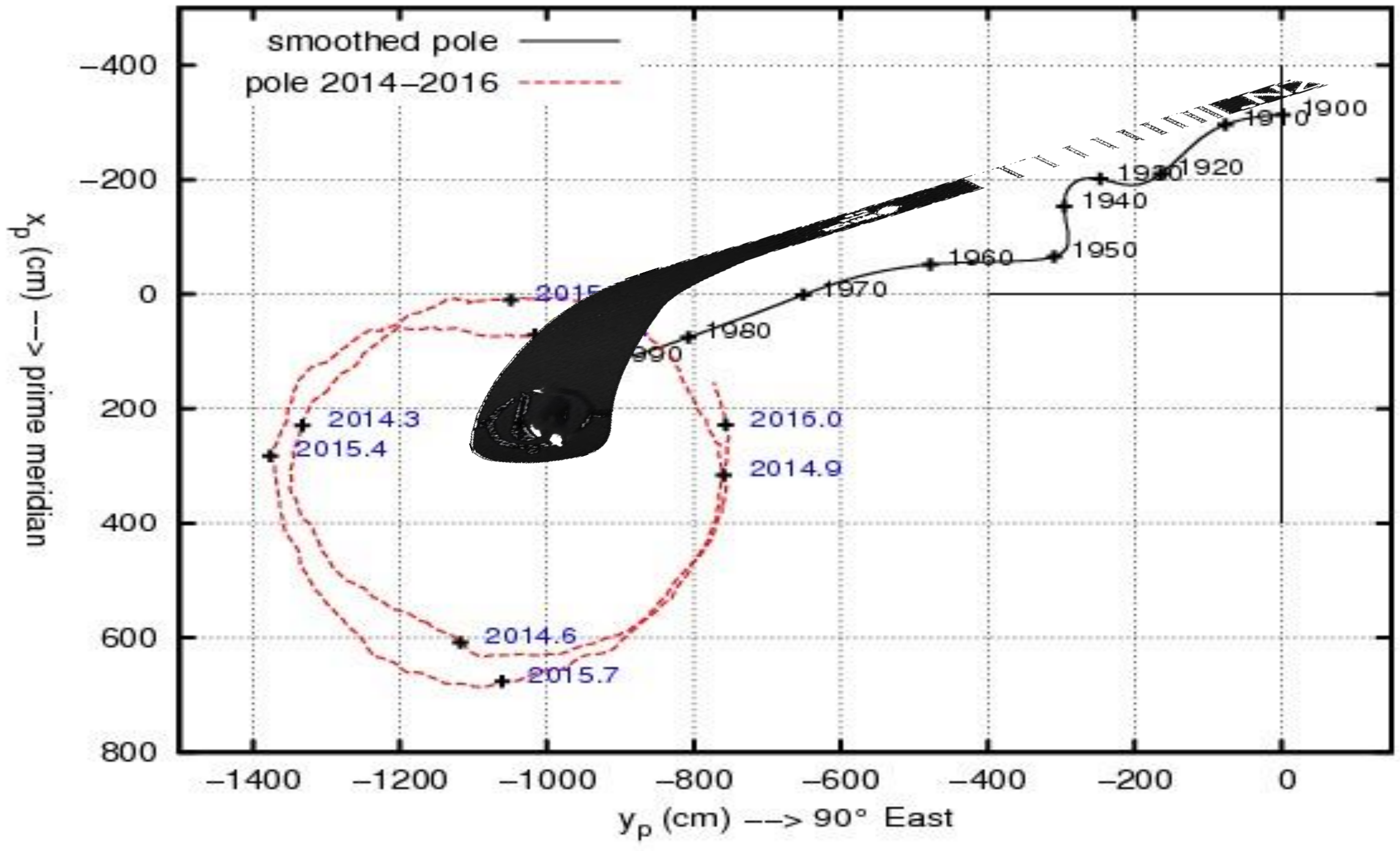
Credit:
N. Frolova

Motion of the Earth's pole





Polar motion trend



credit: C. Bizouard

CLIMATOLOGY

Climate-driven polar motion: 2003–2015

10.1126/sciadv.1501693

Surendra Adhikari* and Erik R. Ivins

Earth's spin axis has been wandering along the Greenwich meridian since about 2000, representing a 75° eastward shift from its long-term drift direction. The past 115 years have seen unequivocal evidence for a quasi-decadal periodicity, and these motions persist throughout the recent record of pole position, in spite of the new drift direction. We analyze space geodetic and satellite gravimetric data for the period 2003–2015 to show that all of the main features of polar motion are explained by global-scale continent-ocean mass transport. The changes in terrestrial water storage (TWS) and global cryosphere together explain nearly the entire amplitude (83 ± 23%) and mean directional shift (within 5.9° ± 7.6°) of the observed motion. We also find that the TWS variability fully explains the decadal-like changes in polar motion observed during the study period, thus offering a clue to resolving the long-standing quest for determining the origins of decadal oscillations. This newly discovered link between polar motion and global-scale TWS variability has broad implications for the study of past and future climate.

Adhikari, Ivins, *Climate driven polar motion: 2003-2015*, Sci. Adv., Vol. 2, No. 4, p. e1501693, 2016, doi:10.1126/sciadv.1501693

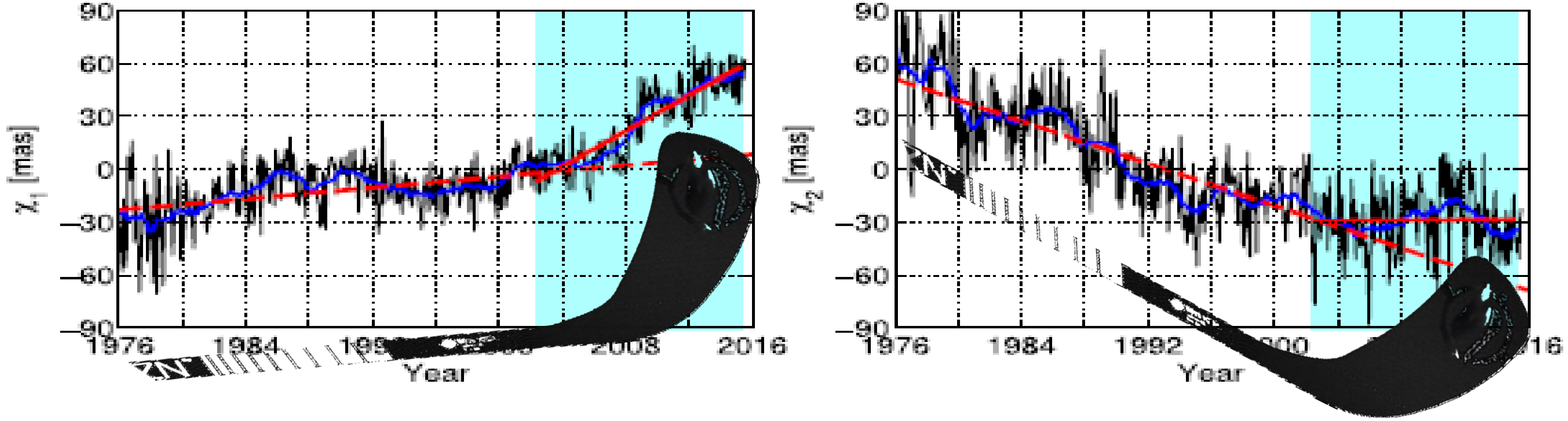


Fig. 1. Observed pole position data. Mean monthly polar motion excitations (black lines) derived from the observed daily values after removing semi-annual, annual, and Chandler wobbles. Smoothed solutions (blue lines) reveal quasi-decadal variability in the corresponding component of the 20th-century linear trend (dashed red lines). Cyan shadows in the background cover our study period, over which the drift direction deviates (solid red lines) from the long-term linear trend.

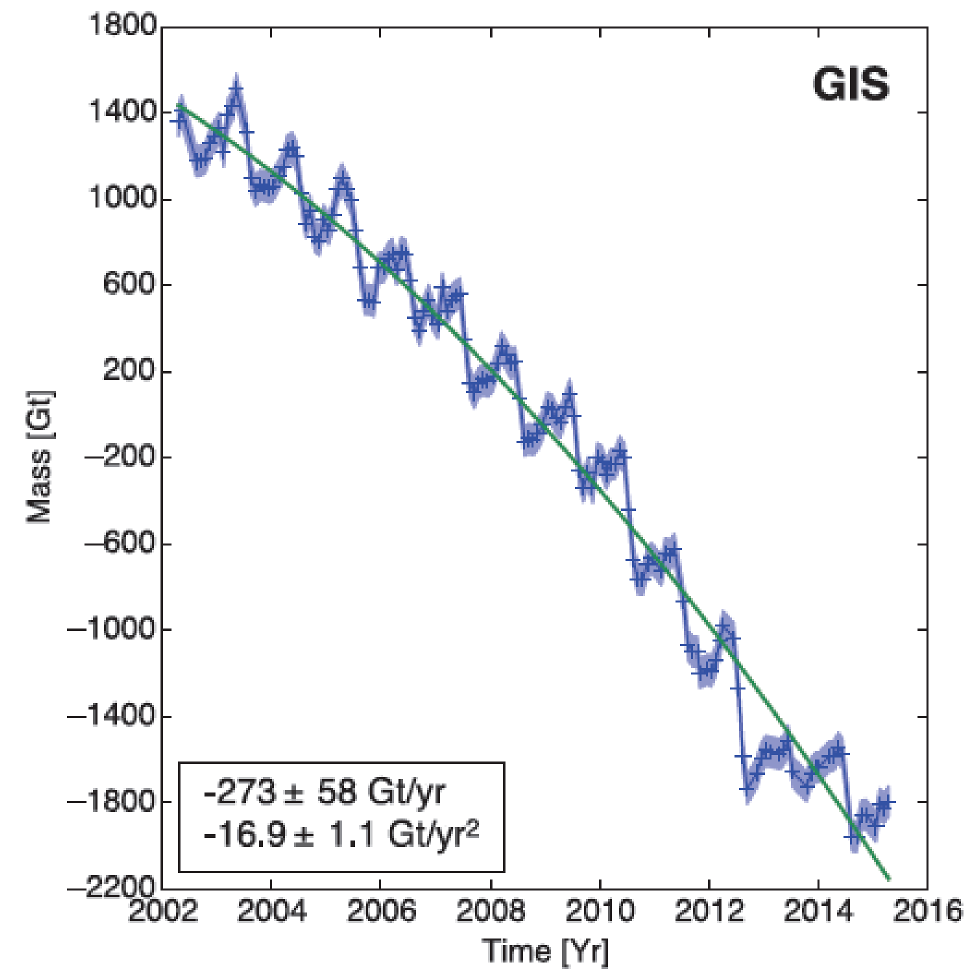
EGU2018-10300 | Orals | G3.1/CL4.20/CR8.6/GD11.6/GM11.10/NH11.17 | | **Highlight**

Toward a Unified Theory for 20th Century Secular Polar Motion

Erik Ivins, Surendra Adhikari, Lambert Caron, Bernhard Steinberger, John Reager, Kristian Kjeldsen, Ben Marzeion, and Eric Larour

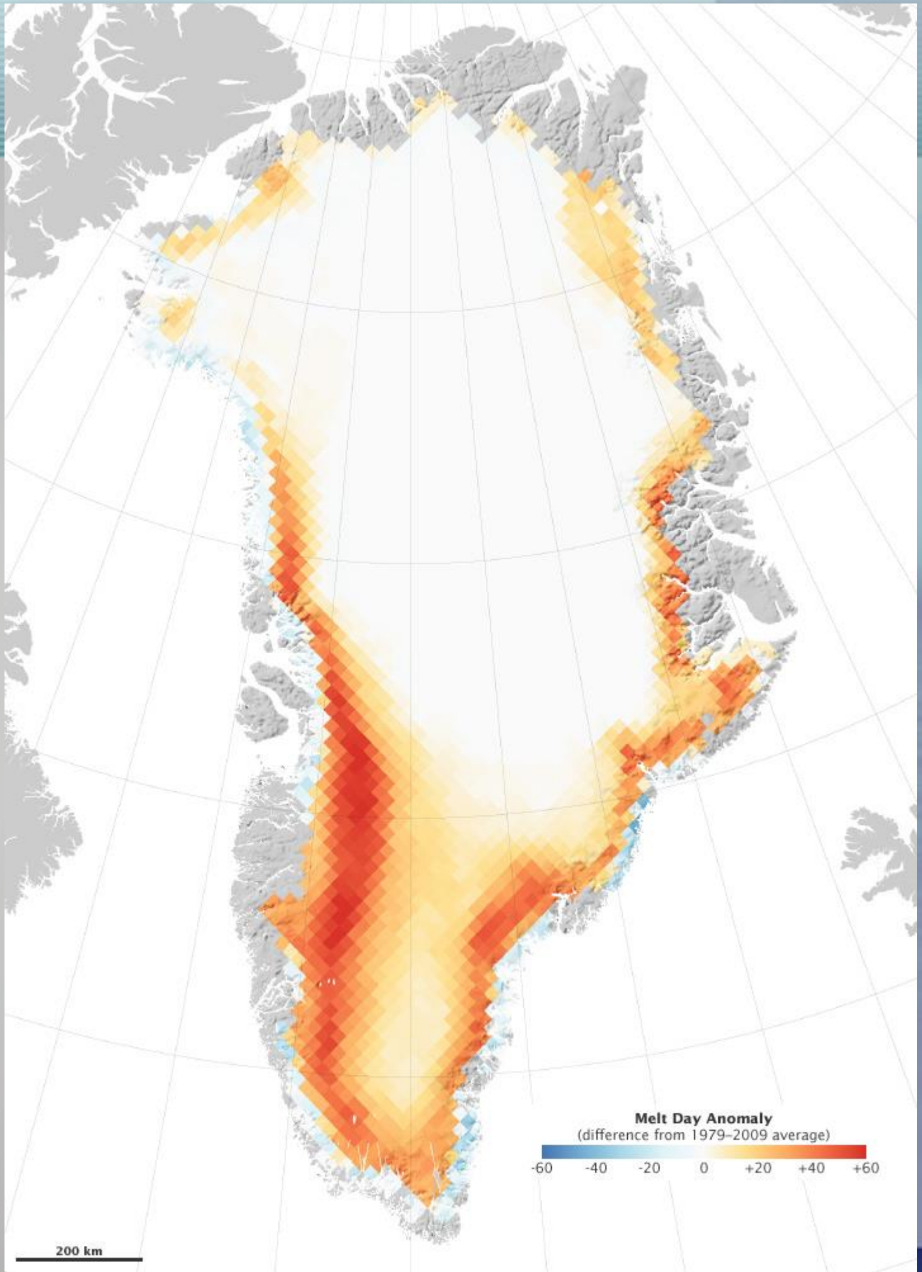
Wed, 11 Apr, 11:45–12:00, Room -2.32

Greenland mass loss 1979-2017



Greenland ice sheet and surrounding glaciers/ice caps

Updated from Velicogna et al., GRL,



Singular spectrum analysis of polar motion

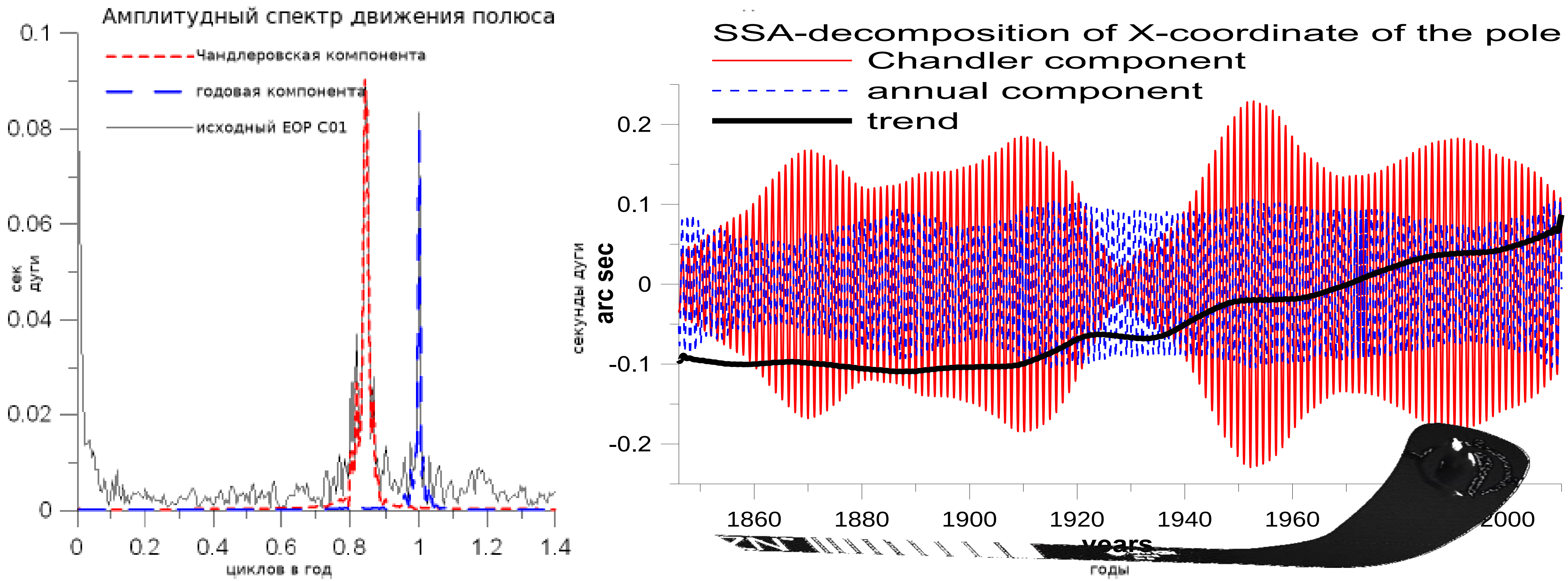


Рис. 3.2: Спектры движения полюса (слева) и его компоненты (x-координата), полученные комплексным ССА (справа).

Variable Chandler and Annual Wobbles in Earth's Polar Motion During 1900–2015

Surv Geophys (2016) 37:1075–1093
DOI 10.1007/s10712-016-9384-0

Guocheng Wang[1] · Lintao Liu[1] · Xiaoqing Su[2] · Xinghui Liang[1] · Haoming Yan[1] · Yi Tu[3] · Zhonghua Li[1] · Wenping Li[4]

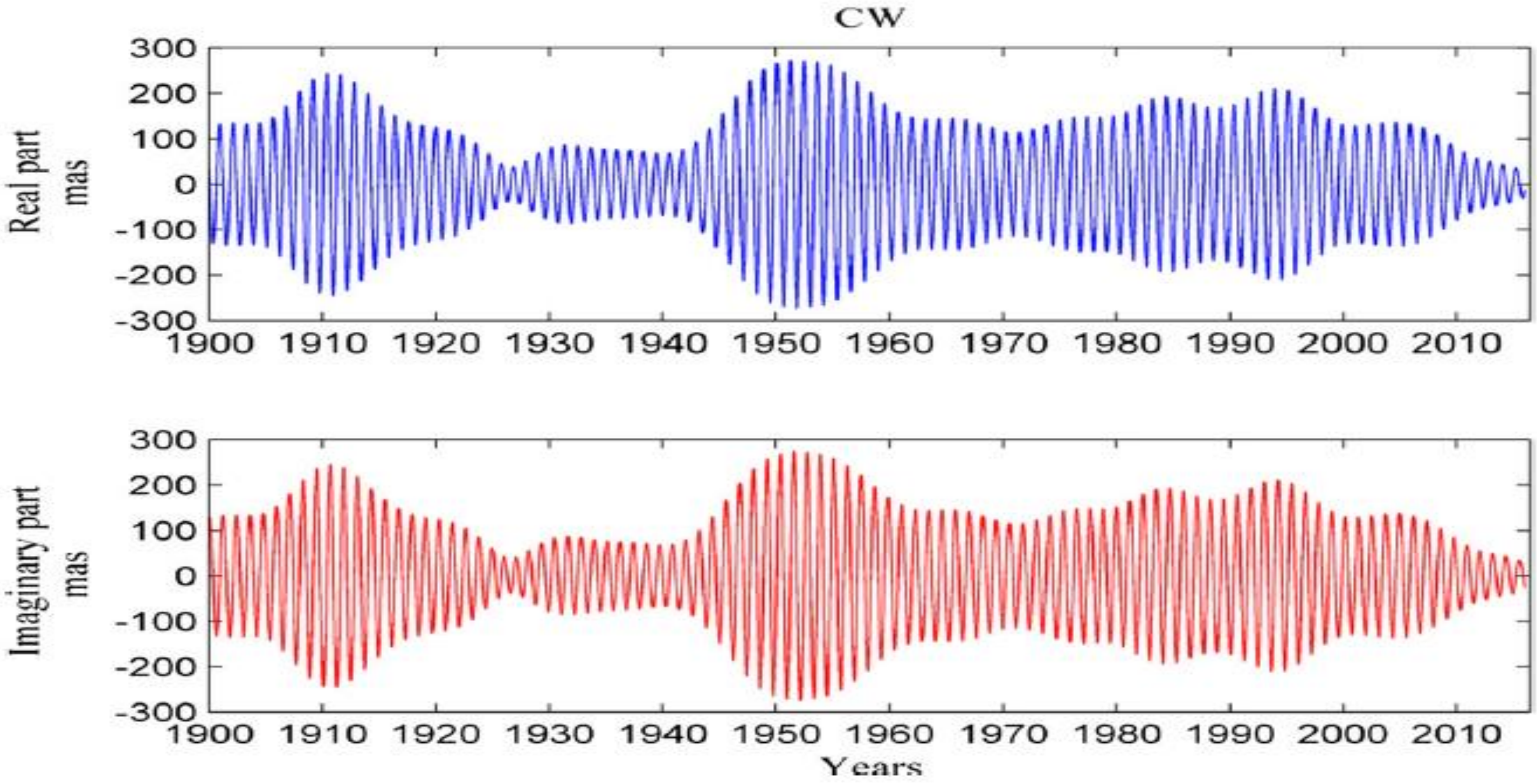


Fig. 8 Reconstruction of the CW using the FBPBPF method

Amplitude and phase variations of Earth's Chandler wobble under continual excitation

Benjamin F. Chao[a,b,*], Wei-Yung Chung[b]

[a] Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan
[b] Department of Earth Sciences, National Central University, Chungli, Taiwan

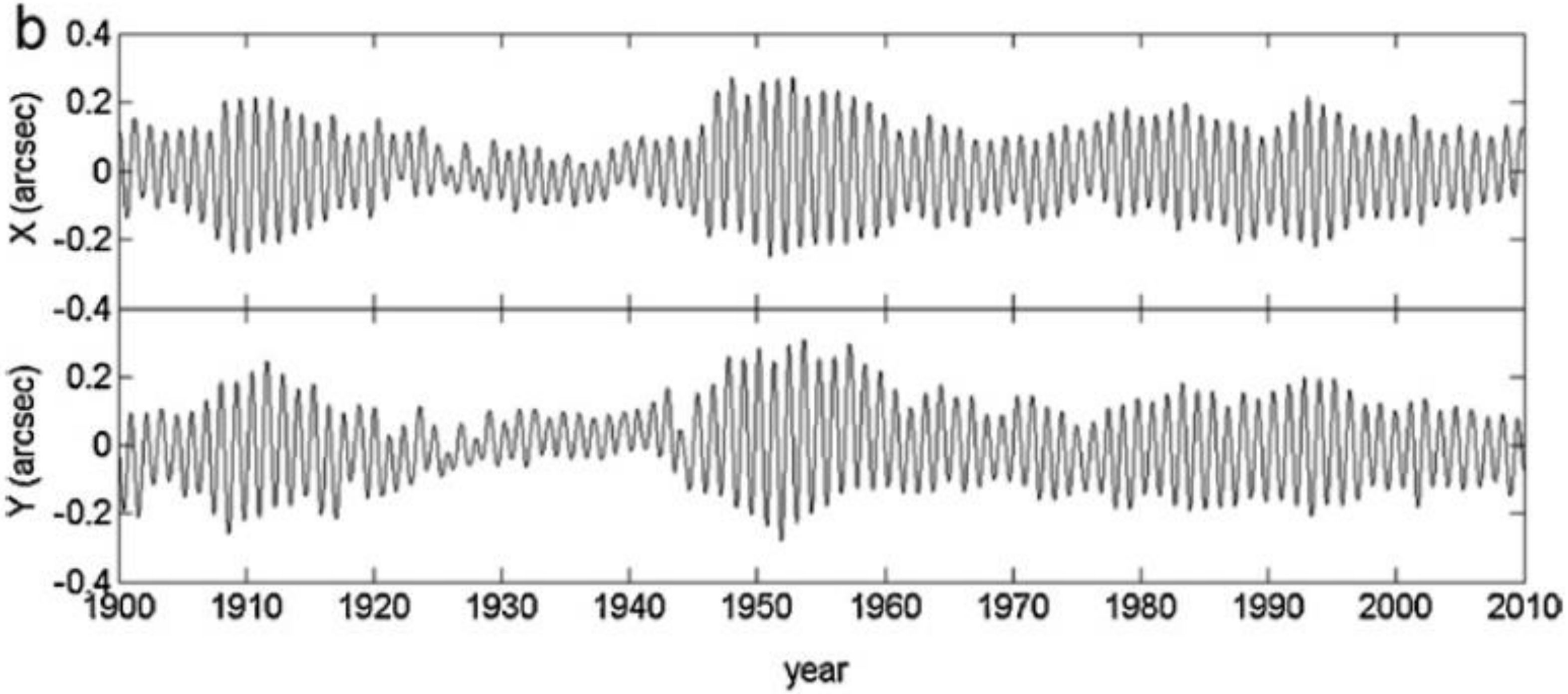
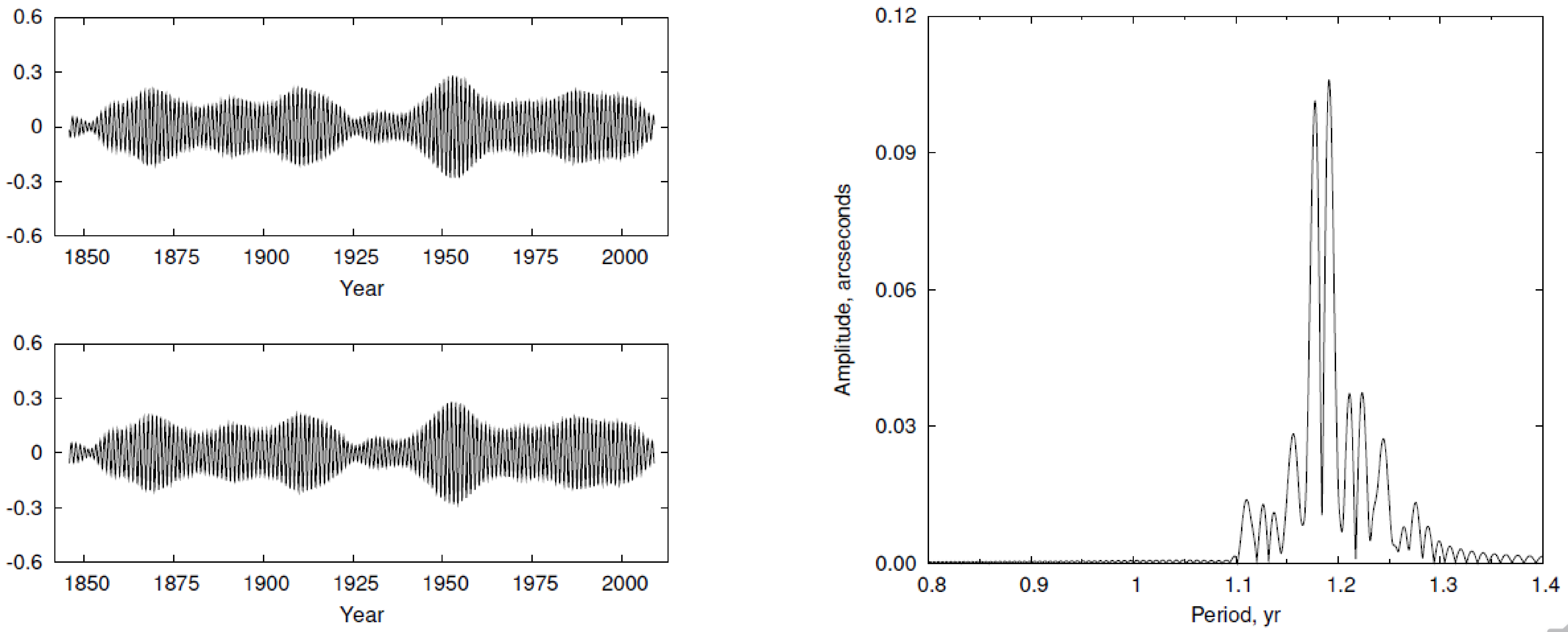


Fig. 1. (a) The *x* and *y* components of the Hipparcos polar motion series (for the period 1899.7–1992.0) concatenated with EOP-C01 (for the period 1992.0–2010.0) for the total span of 110 years at 5-day intervals. (b) The Chandler wobble series $m(t)$ obtained from (a) after removing the least-squares estimates of the annual wobble and a linear trend.

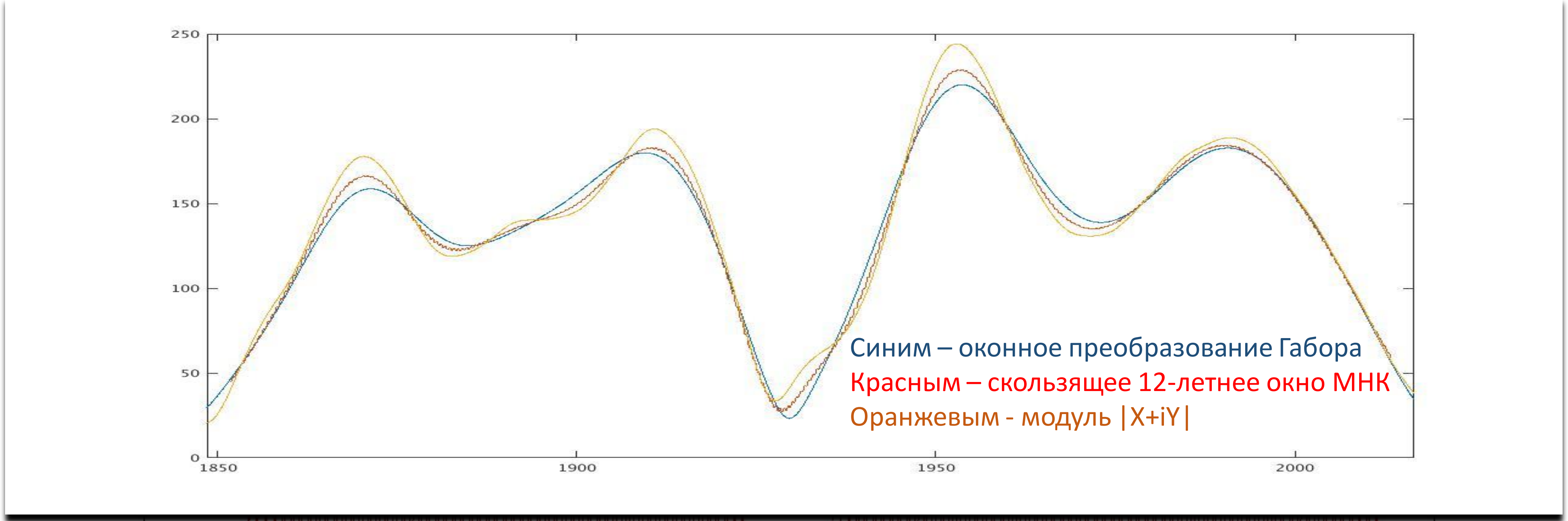
Chandler wobble: two more large phase jumps revealed

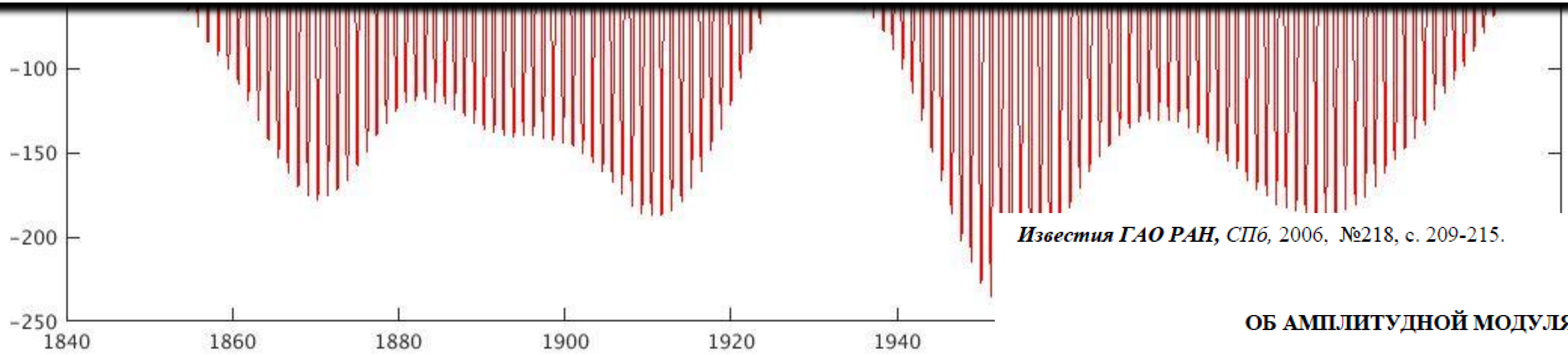
Zinovy Malkin and Natalia Miller

FT-filtered PM series



Filtered Chandler wobble and its envelope





Известия ГАО РАН, СПб, 2006, №218, с. 209-215.

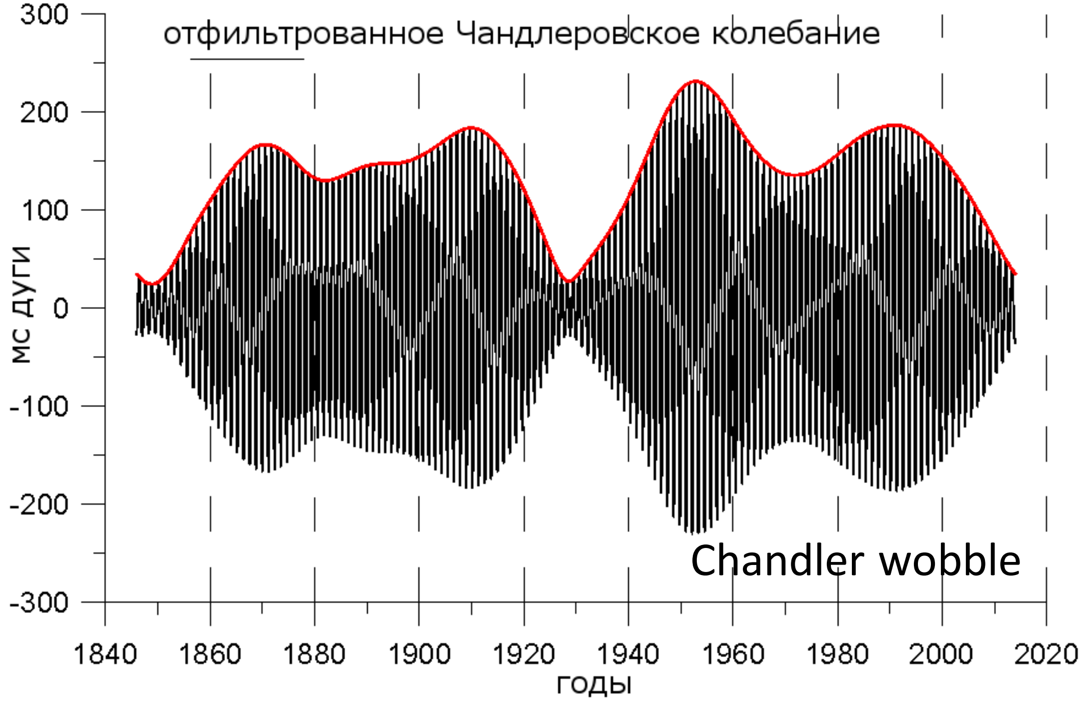
ОБ АМПЛИТУДНОЙ МОДУЛЯЦИИ

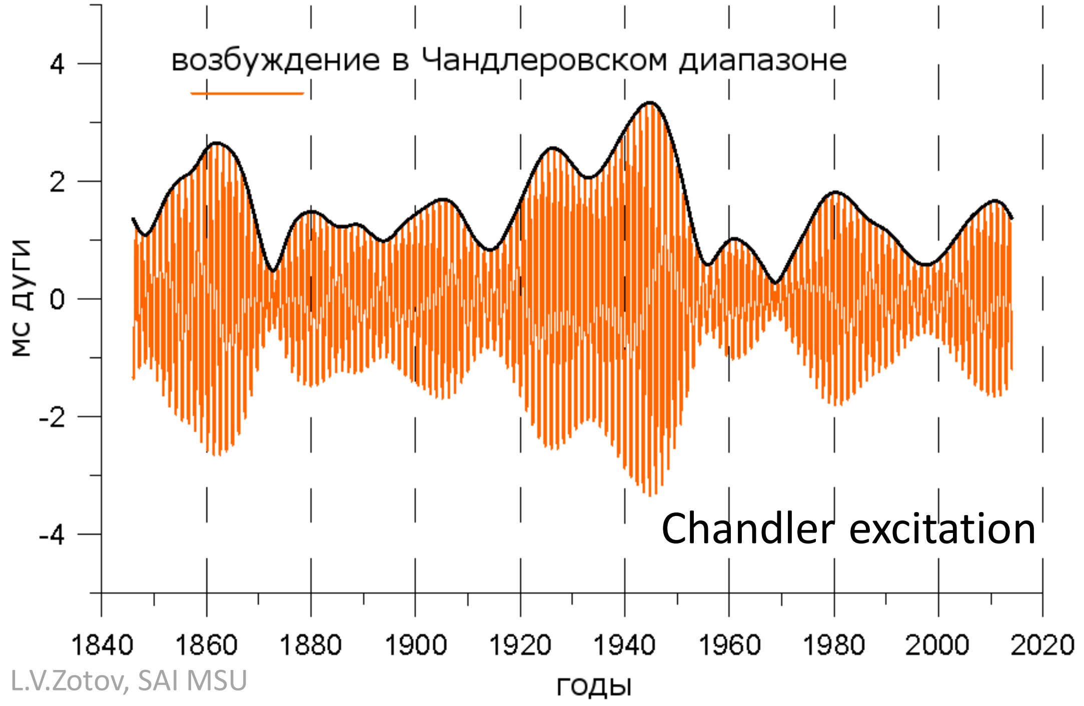
ЧАНДЛЕРОВСКОГО ДВИЖЕНИЯ ПОЛЮСА ЗЕМЛИ

В.Л. Горшков

See Doctoral thesis by L. Zotov

http://lnfm1.sai.msu.ru/~tempus/disser/index.htm





Panteleev's corrective filtering allowed to reconstruct Chandler excitation

It is a regularizing algorithm of "Generalized selection" type giving the one-parameter family of solution, Converging to the exact pseudosolution when error in input data and operator tend to zeros.

The error of reconstructed Chandler excitation is not larger then 0.8 mas.

Angular momentum – geophysical excitation

Mass term

Motion term

$$\mathbf{H}(t) = \mathbf{H}^{mass}(t) + \mathbf{H}^{motion}(t) = \int \rho(r,t)\mathbf{r} \times [\mathbf{\Omega} \times \mathbf{r} + \mathbf{v}(r,t)]dV.$$

$$\mathbf{H}_x^{mass}(t) = -\Omega\frac{r^4}{g}\int\int p(\phi,\lambda)\sin\phi\cos^2\phi cos\lambda d\phi d\lambda,$$

$$\mathbf{H}_y^{mass}(t) = -\Omega\frac{r^4}{g}\int\int p(\phi,\lambda)\sin\phi\cos^2\phi sin\lambda d\phi d\lambda,$$

$$\mathbf{H}_z^{mass}(t) = \Omega\frac{r^4}{g}\int\int p(\phi,\lambda)\cos^3\phi d\phi d\lambda,$$

$$\mathbf{H}_x^{motion}(t) = \frac{r^3}{g}\int\int\int[\cos\phi\sin\lambda v(r,t) - \sin\phi\cos\phi\cos\lambda u(r,t)]d\phi d\lambda,$$

$$\mathbf{H}_y^{motion}(t) = \frac{r^3}{g}\int\int\int[-\cos\phi\cos\lambda v(r,t) - \sin\phi\cos\phi\sin\lambda u(r,t)]dpd\phi d\lambda,$$

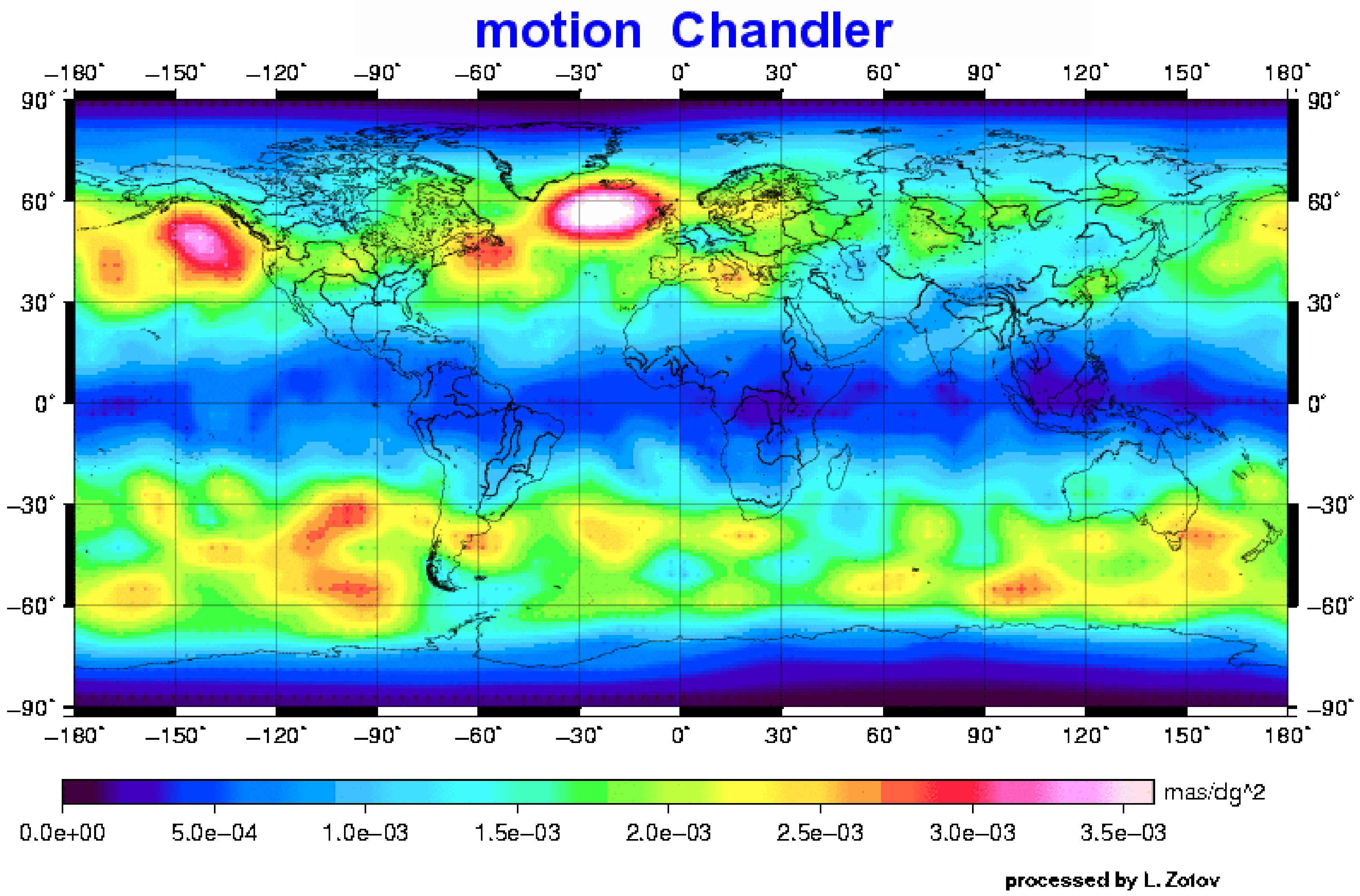
$$\mathbf{H}_z^{motion}(t) = \frac{r^3}{g}\int\int\int\cos^2\phi u(r,t)dpd\phi d\lambda,$$

Effective angular momentum

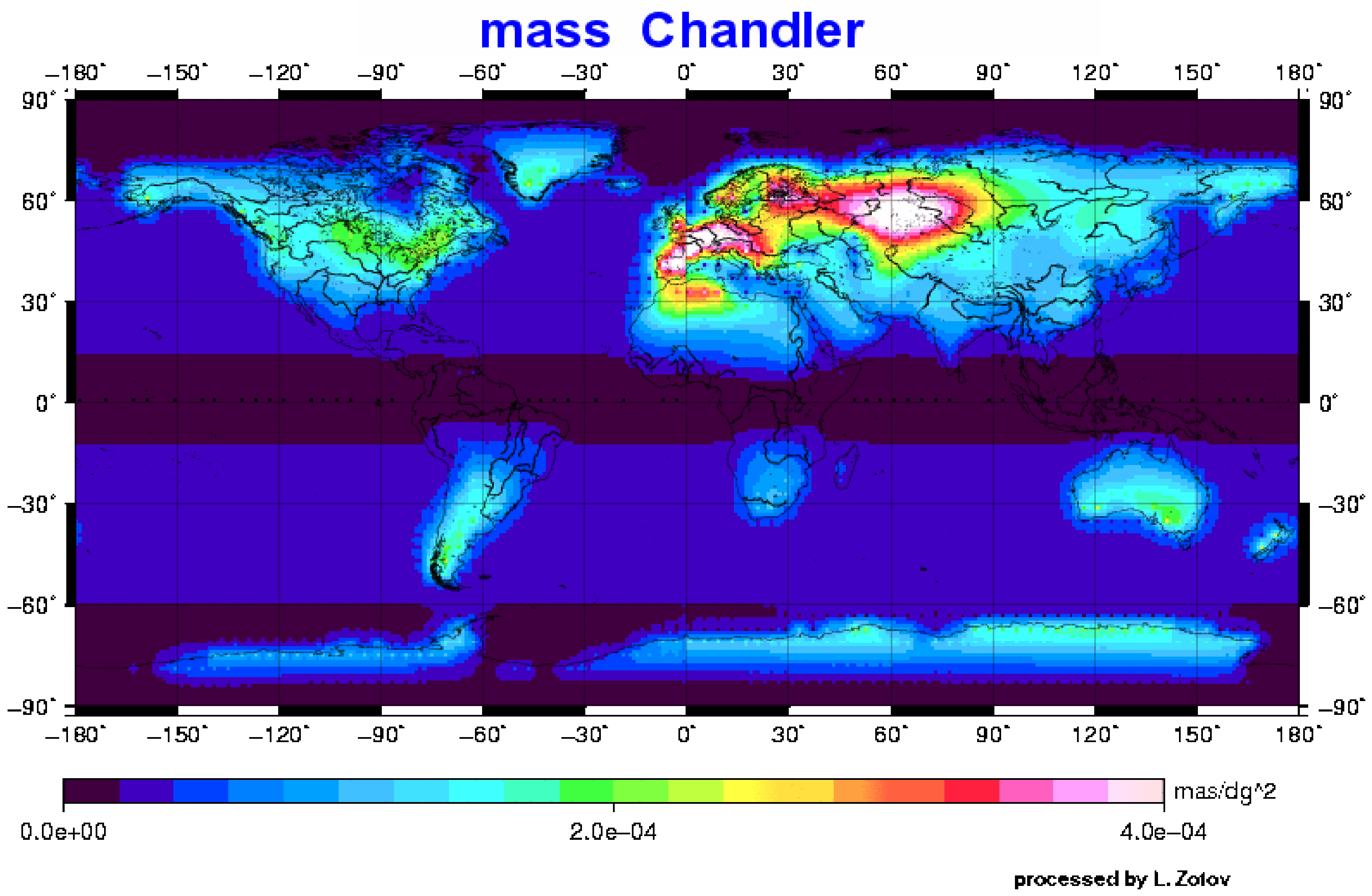
$$\chi_{x,y}^{motion} = \frac{1.5913}{\Omega(C-A)}\mathbf{H}_{x,y}^{motion}, \qquad \chi_z^{motion} = \frac{0.998}{\Omega C}\mathbf{H}_z^{motion},$$

$$\chi_{x,y}^{mass} = \frac{1.098}{\Omega(C-A)}\mathbf{H}_{x,y}^{mass}, \qquad \chi_z^{mass} = \frac{0.753}{\Omega C}\mathbf{H}_z^{mass}.$$

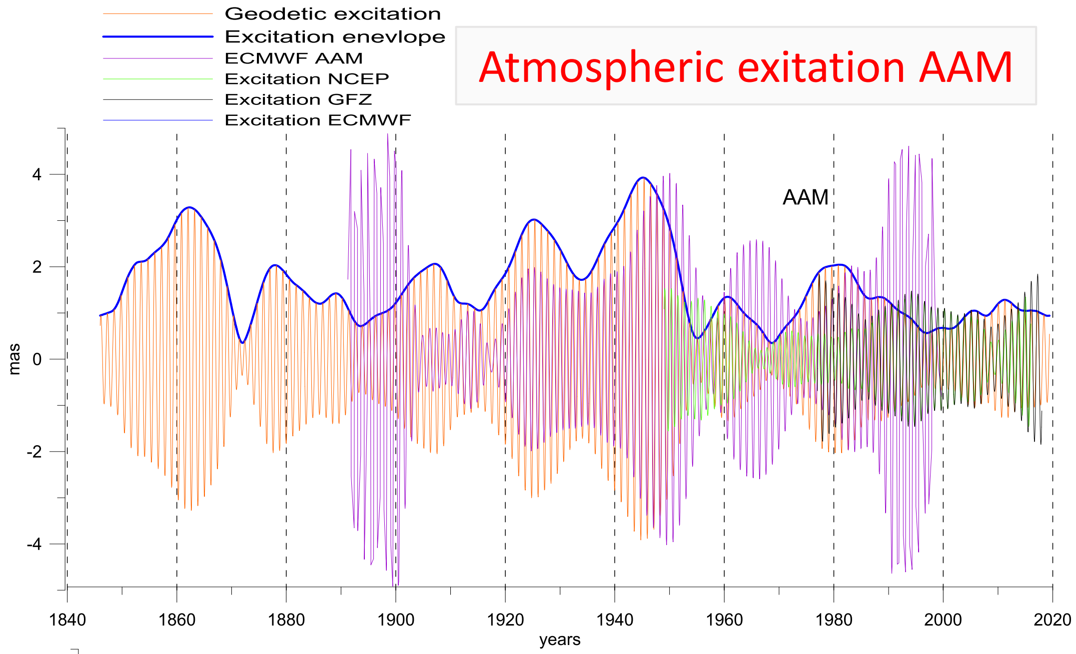
Module of the absolute AAM ECMWF wind term in the Chandler frequency band



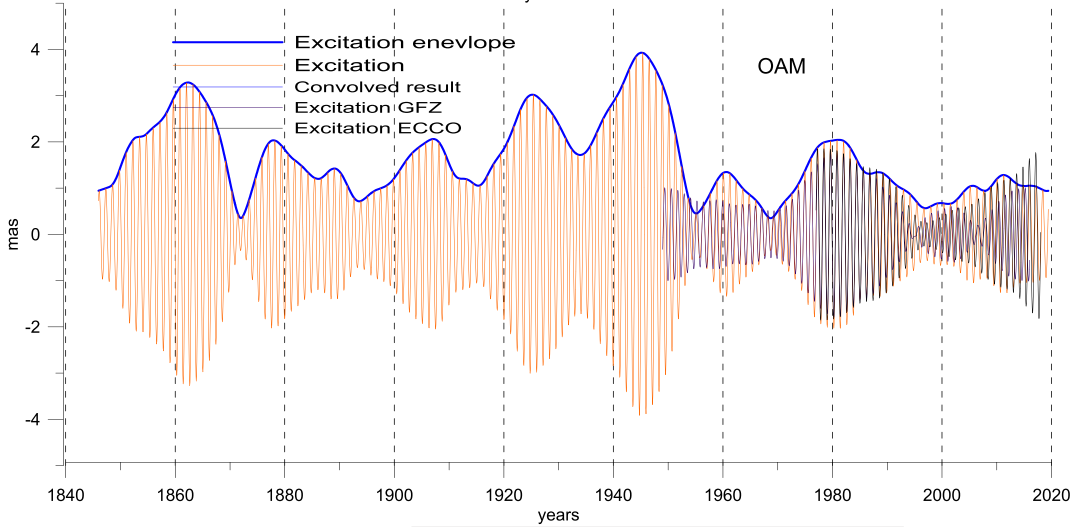
Module of the absolute AAM ECMWF pressure term in the Chandler frequency band



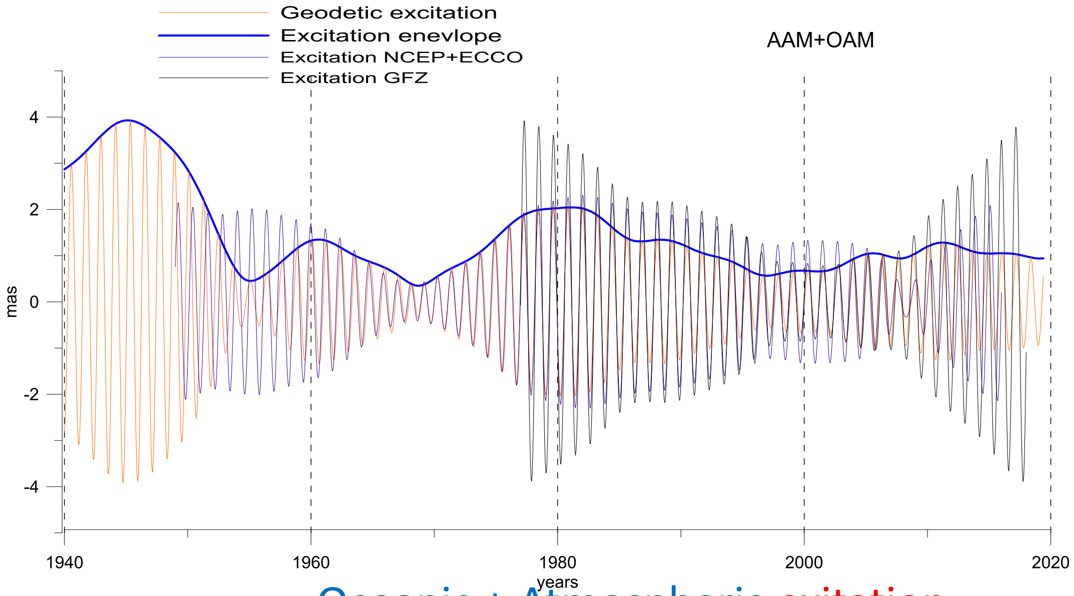
Comparison of excitations for Chandler wobble



Atmospheric exitation AAM



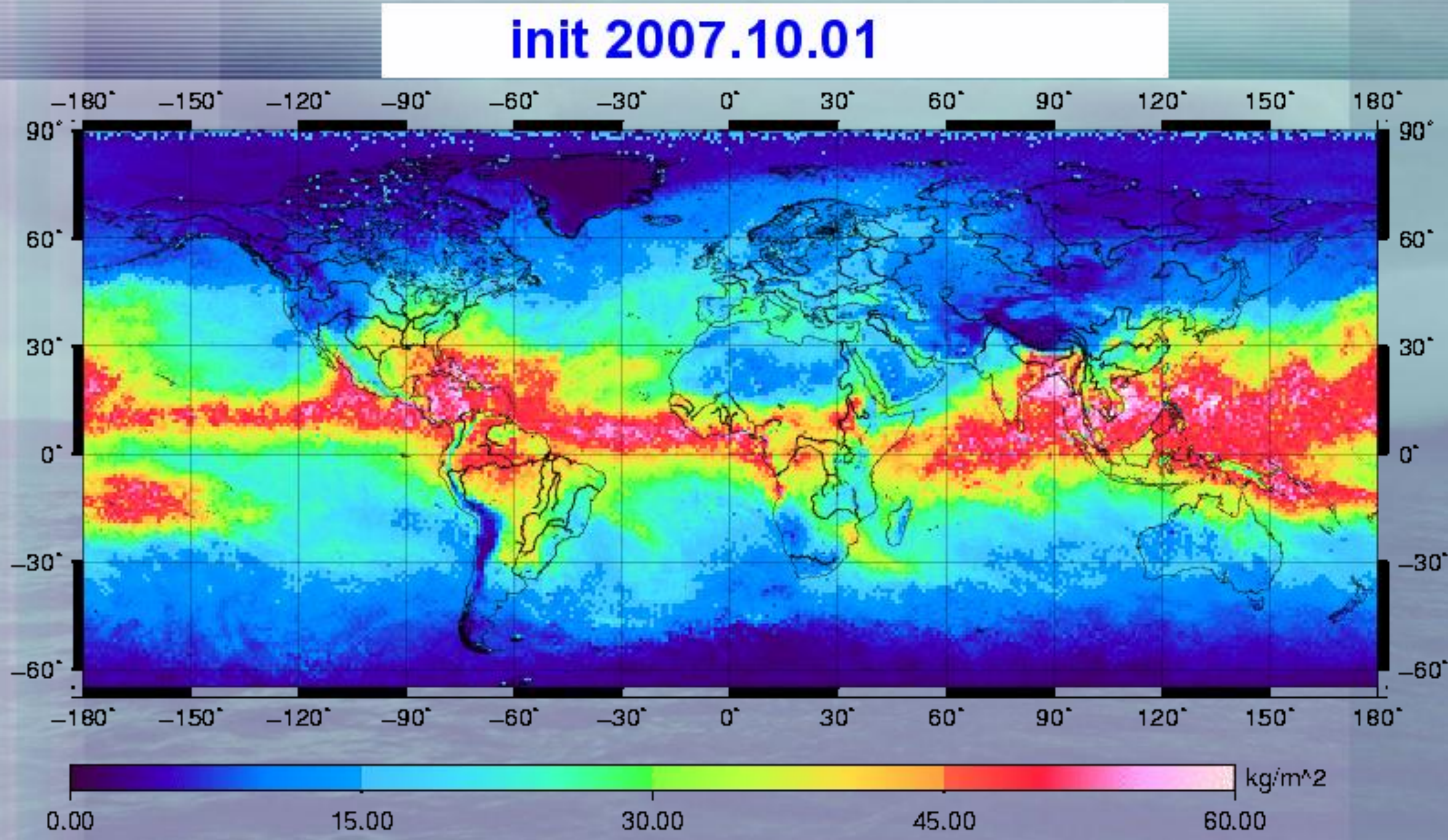
Oceanic exitation OAM



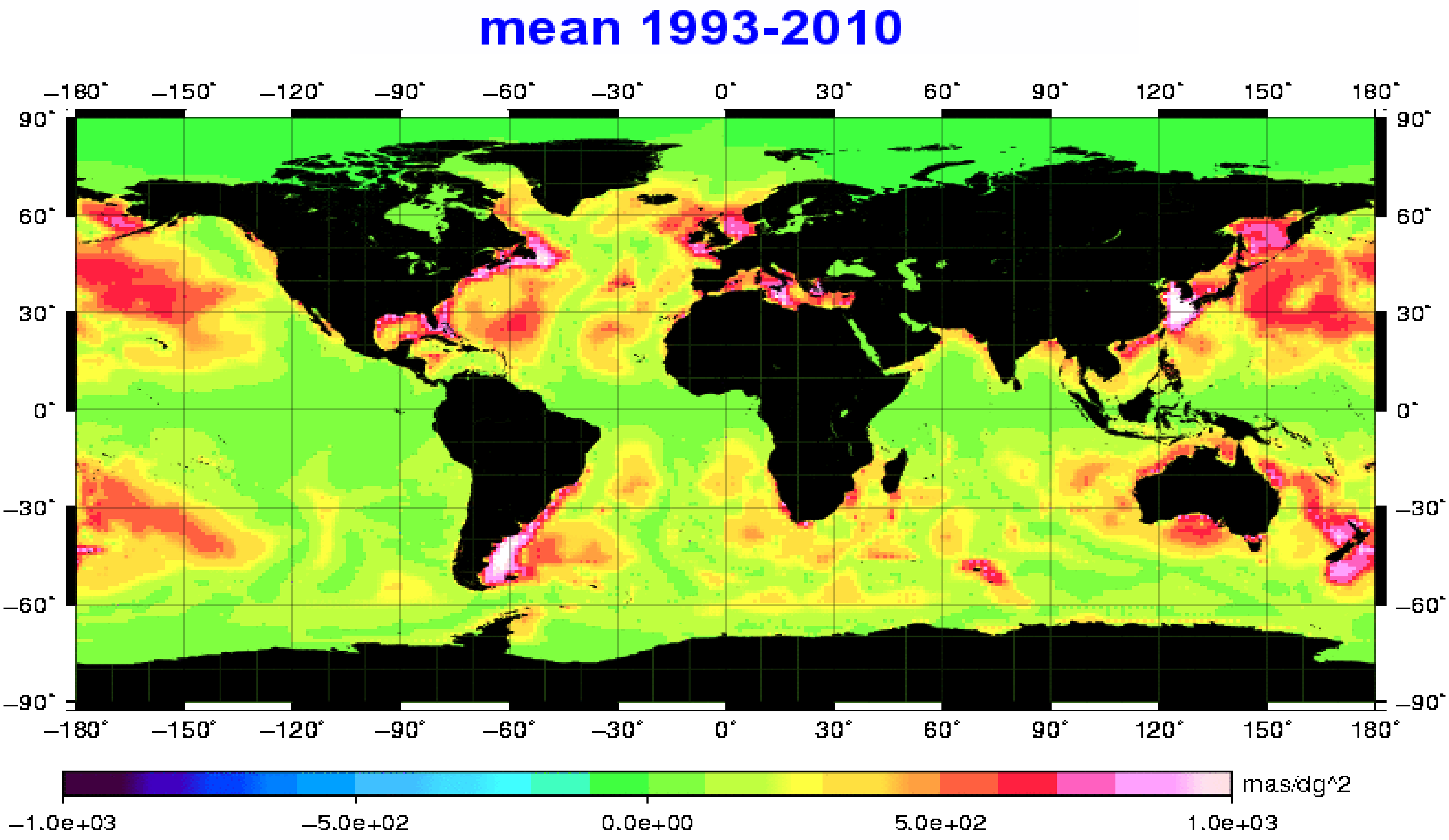
Oceanic + Atmospheric exitation

L.V.Zotov, SAI MSU

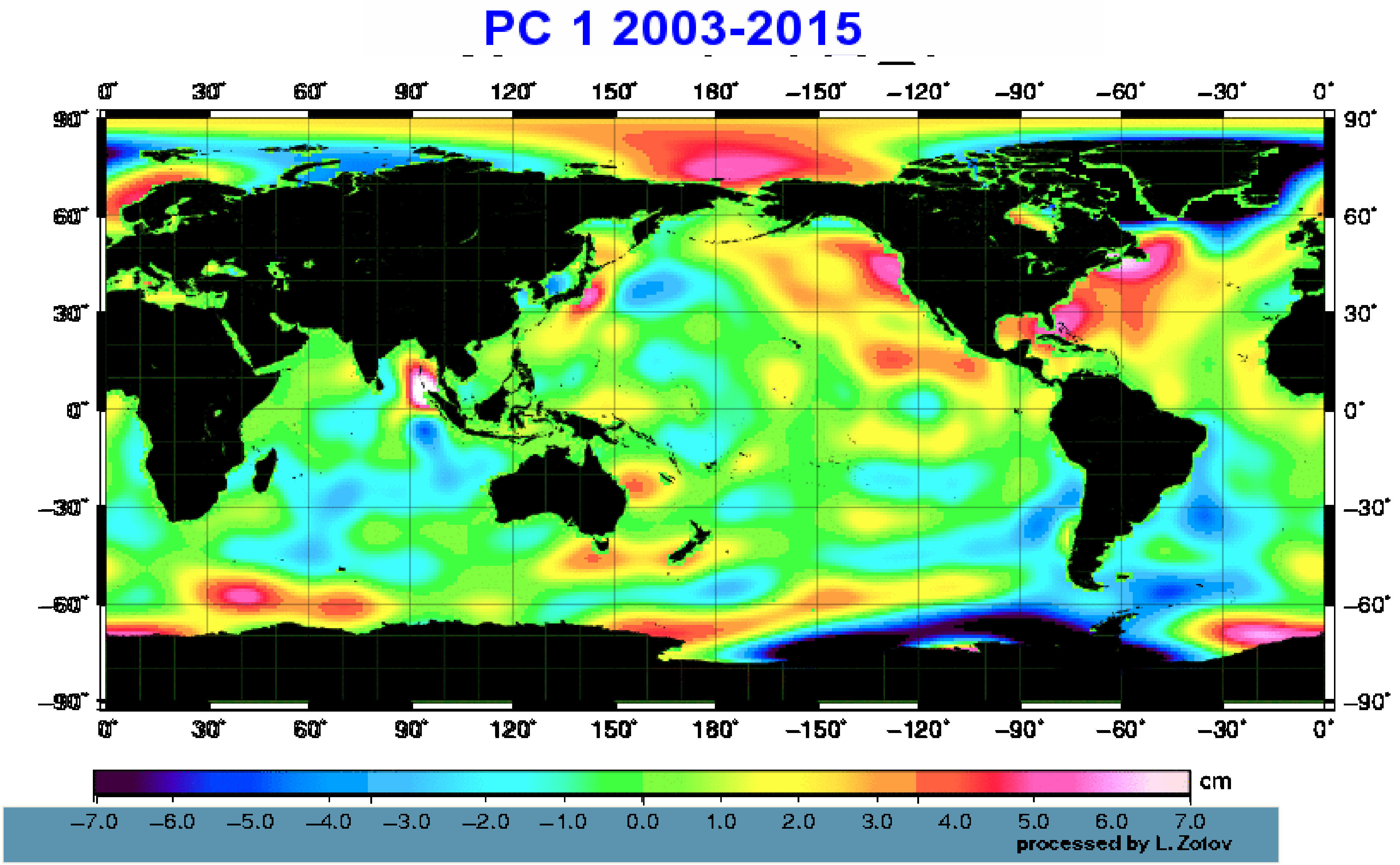
AIRS Water Vapor 8-day Gridded data



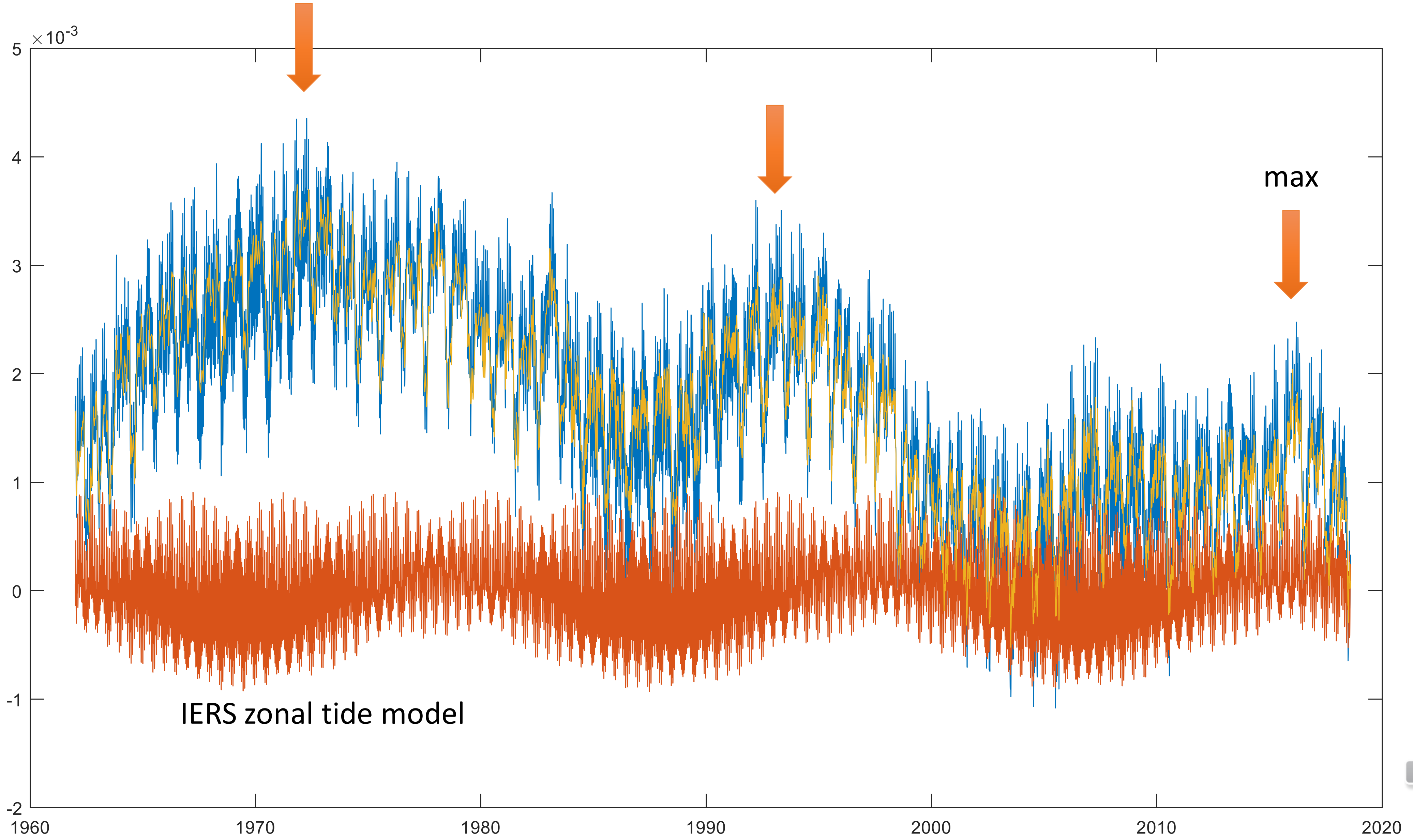
ECCO model ocean angular momentum OAM mass term



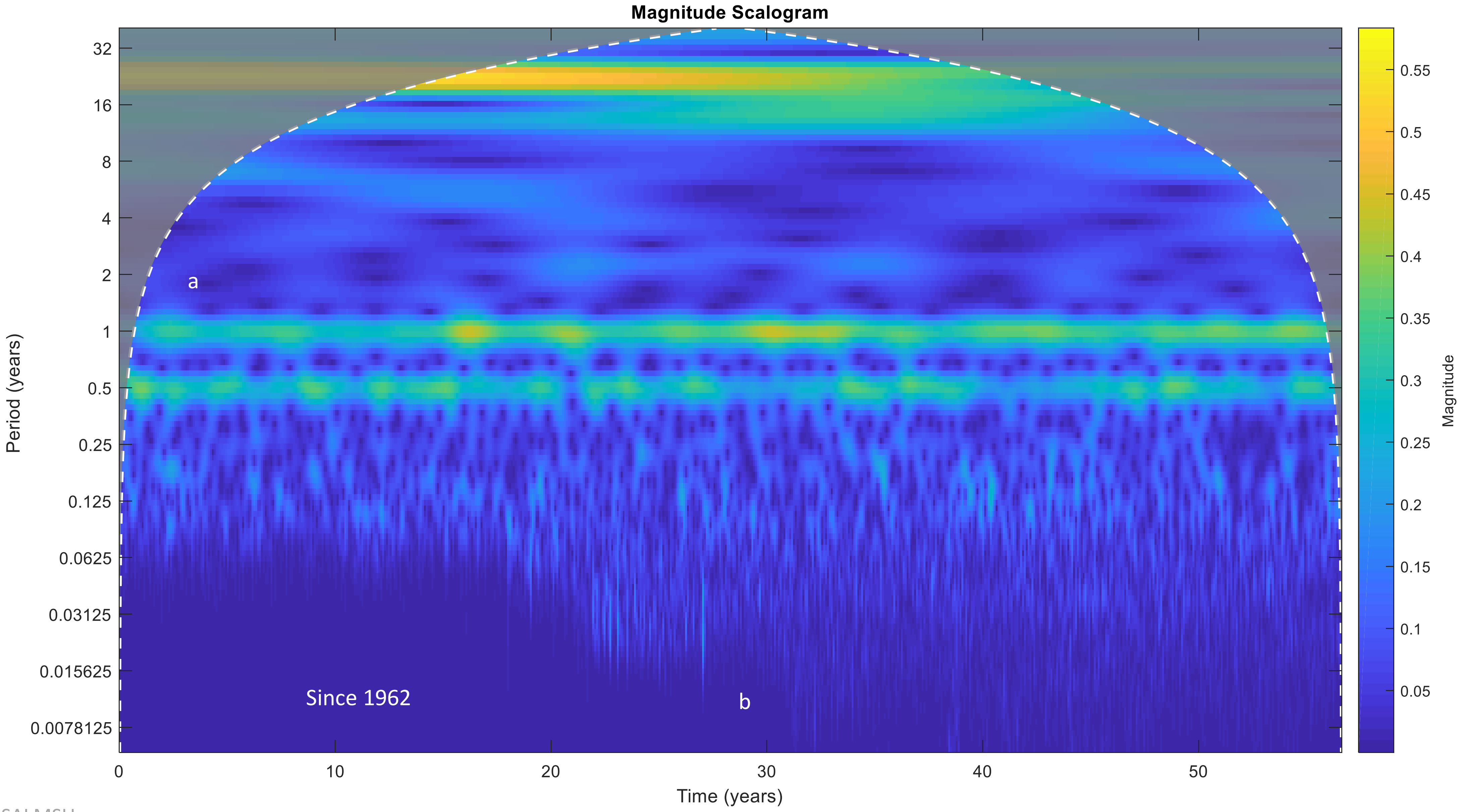
Trends from GRACE in the Ocean Bottom Pressure
Don Chambers data



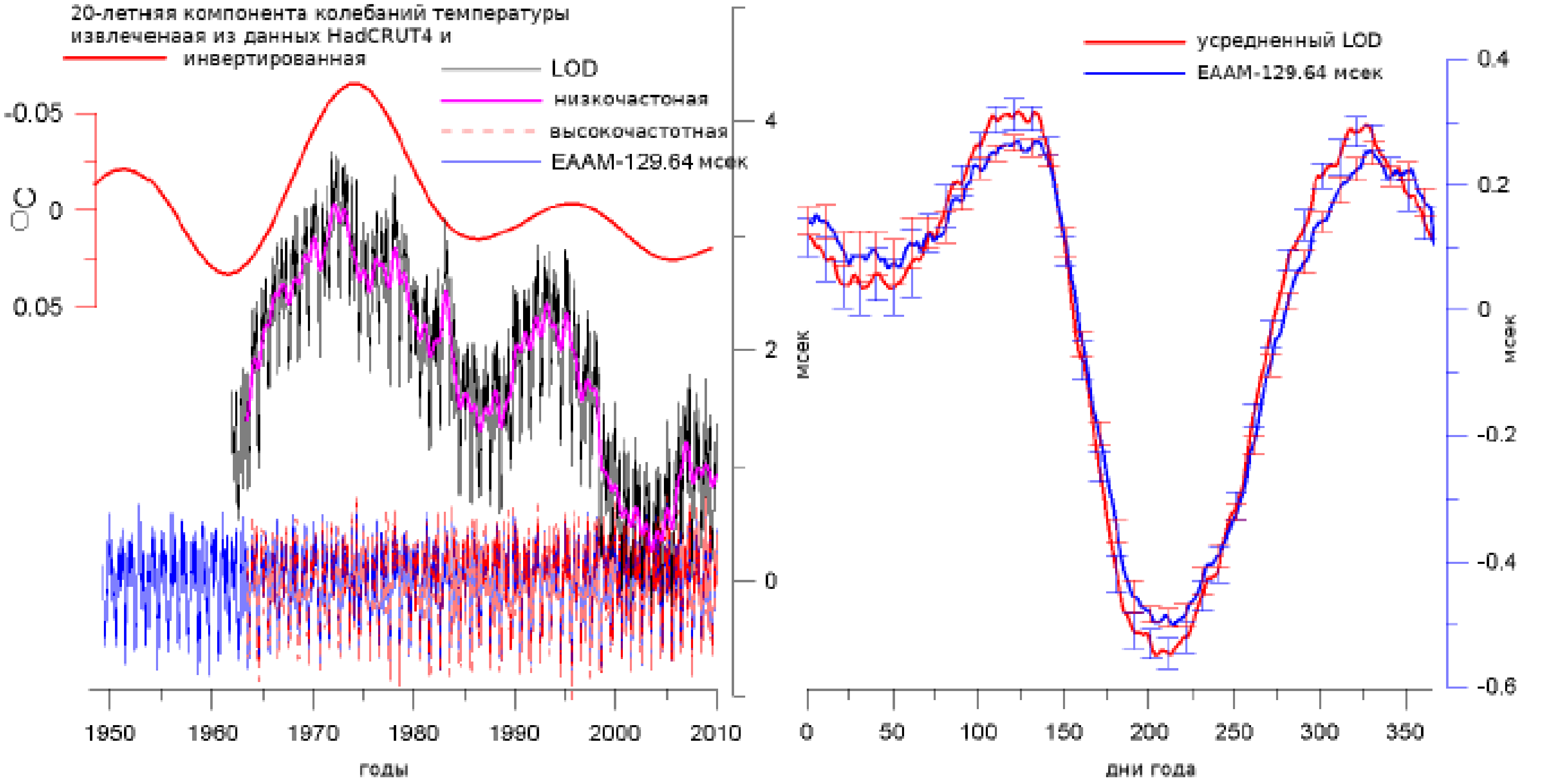
Tidal variations and LOD



Wavelet-scalogramm of LOD



Atmospheric angular momentum and LOD



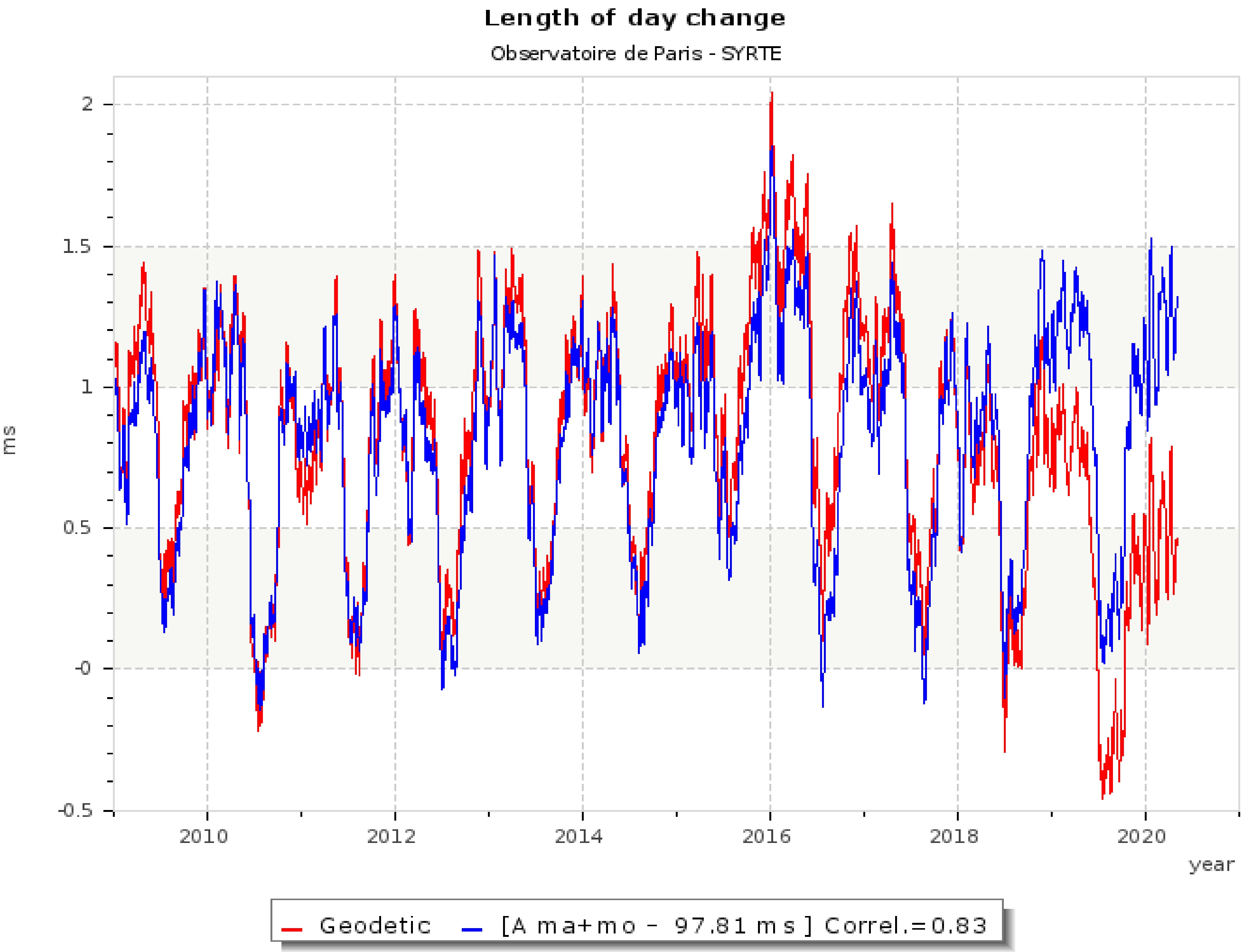
$$m_3 = \Psi_3.$$

$$m_3 = -\Delta LOD/LOD$$

$$\Delta LOD/LOD = \chi_3,$$

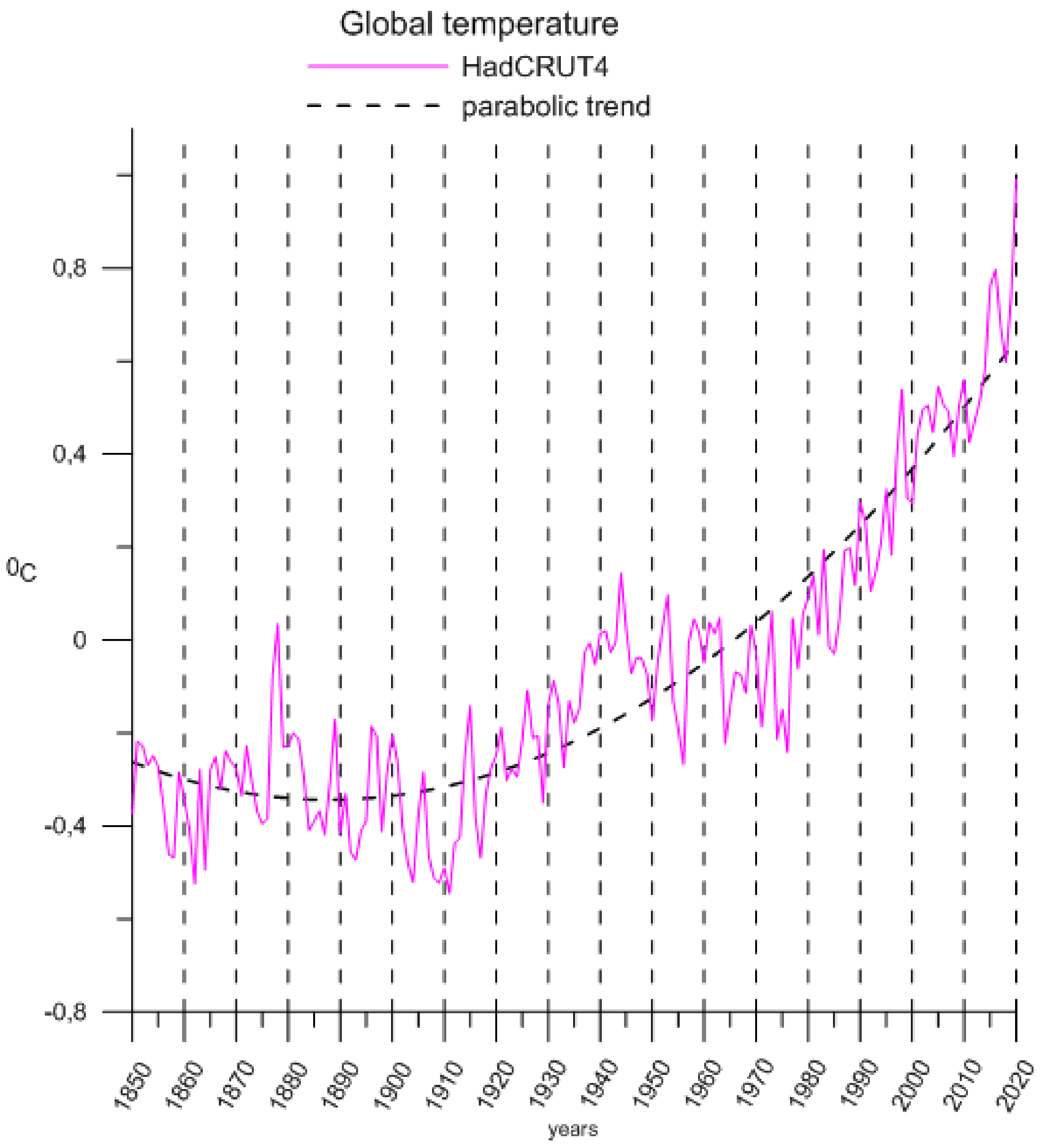
Рис. 6.1: Слева: высокочастотные и низкочастотные (сглаженные) изменения продолжительности суток LOD, изменения эффективного углового момента атмосферы EAAM (давление+IB-ветер) и инвертированная 20-летняя компонента глобальной температуры. Справа: изменения EAAM и LOD, усредненные по дням года на интервале 1962-2010 гг.

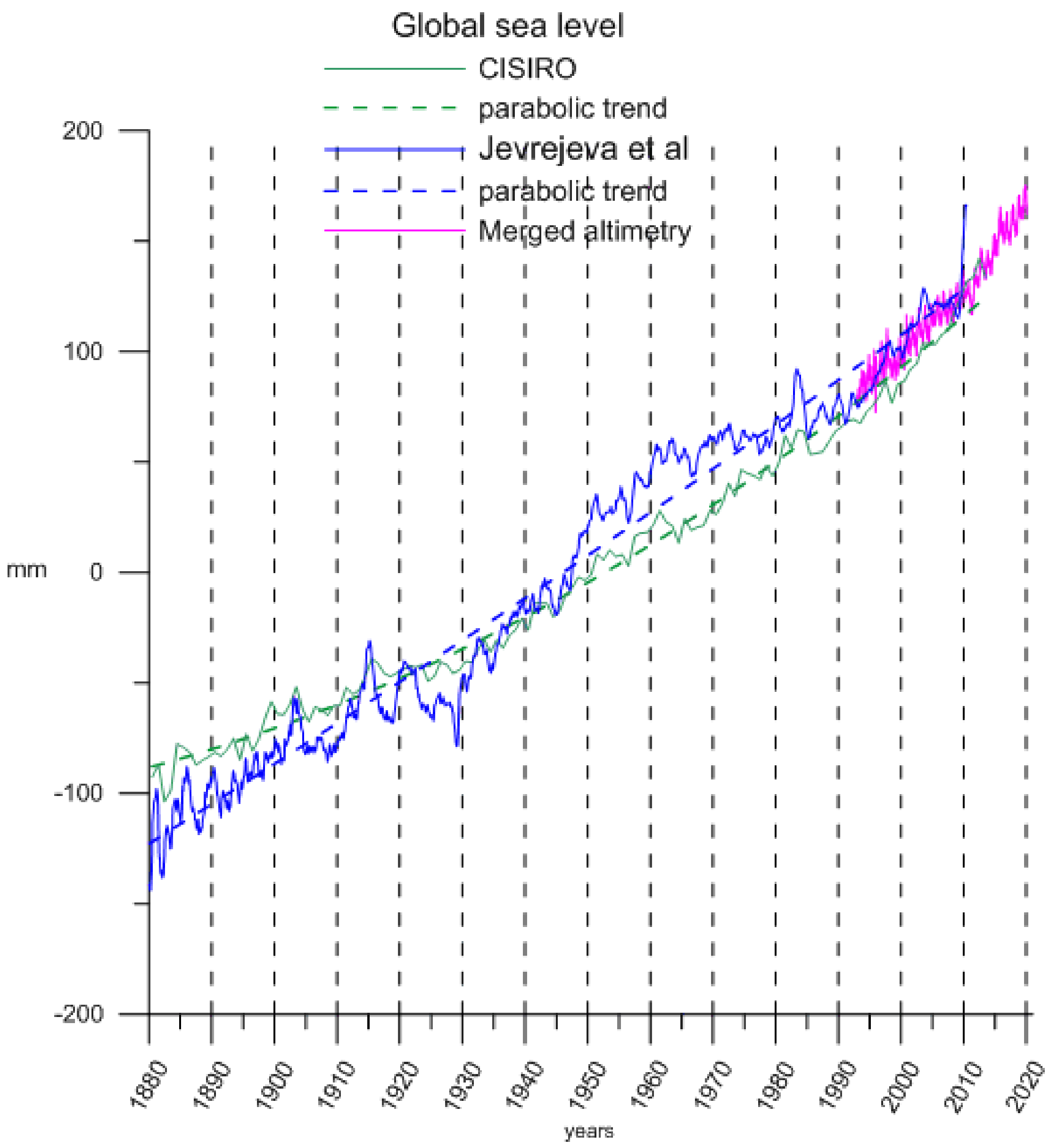
El Nino fingerprint in LOD, acceleration of the Earth since 2015



L.V.Zotov, SAI MSU

Global mean temperature and Sea level rise





L.V.Zotov, SAI MSU

Temperature prediction based on cyclic and polynomial trends model

Lyubushin A.A. and L.B. Klyashtorin, Short term global DT prediction using (60-70) - years periodicity, Energy & Enviroment, Vol. 23, No. 1, 2012.

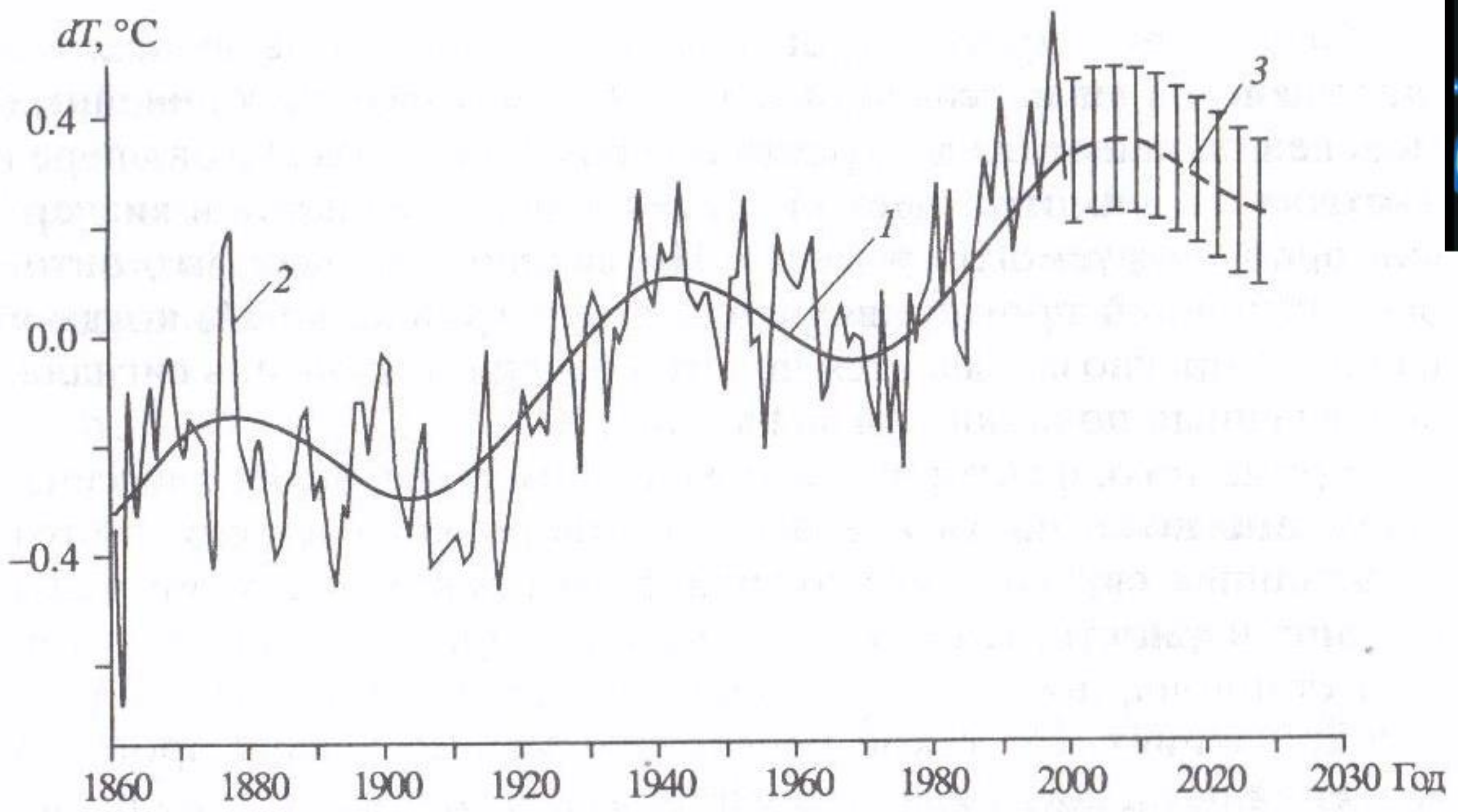
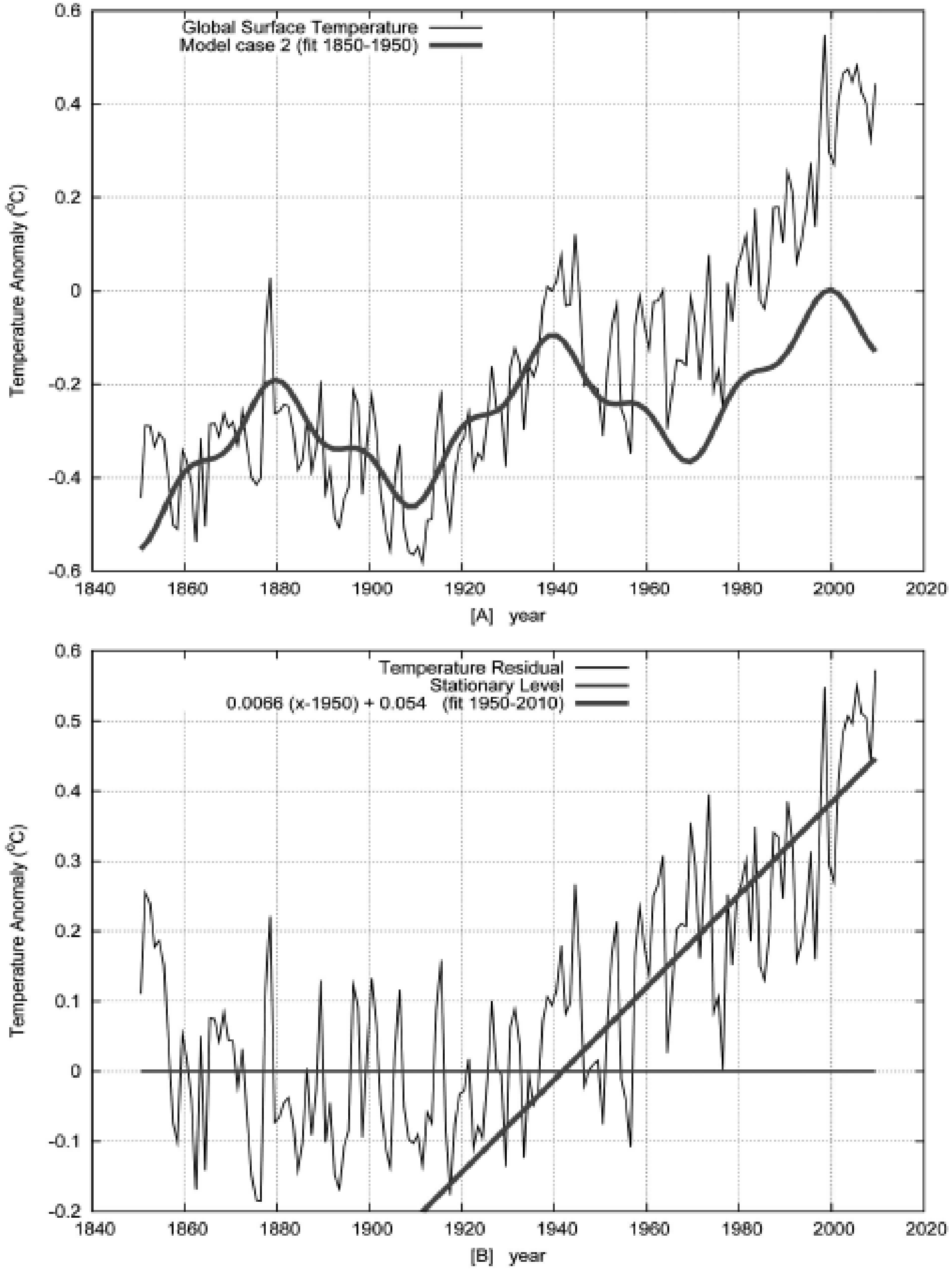


Рис. 1.1. Циклический тренд глобальной температурной аномалии (*1*), межгодовые вариации *dT* (*2*) и поведение тренда на 2000–2030 гг. (*3*)

http://alexeylyubushin.narod.ru/Geophysical_Monitoring_Systems_Data_Analysis_Book_Rus.pdf

Climate Change Attribution Using Empirical Decomposition of Climatic Data

Craig Loehle[1] and Nicola Scafetta[*,2]



ig. (2). A) As in Fig. (1A), with model fit to pre-1950 data. B) Residuals. Before about 1950 residuals are stationary around the zero level .fter about 1942 there is a clear upward linear trend which may be associated to anthropogenic warming.

A Semi-Empirical Approach to Projecting Future Sea-Level Rise

Stefan Rahmstorf

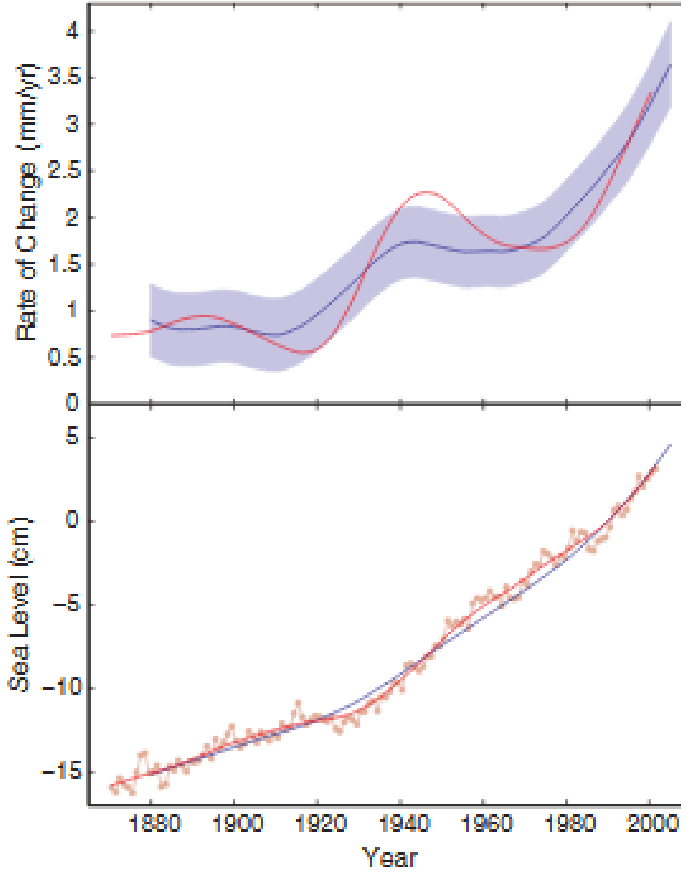
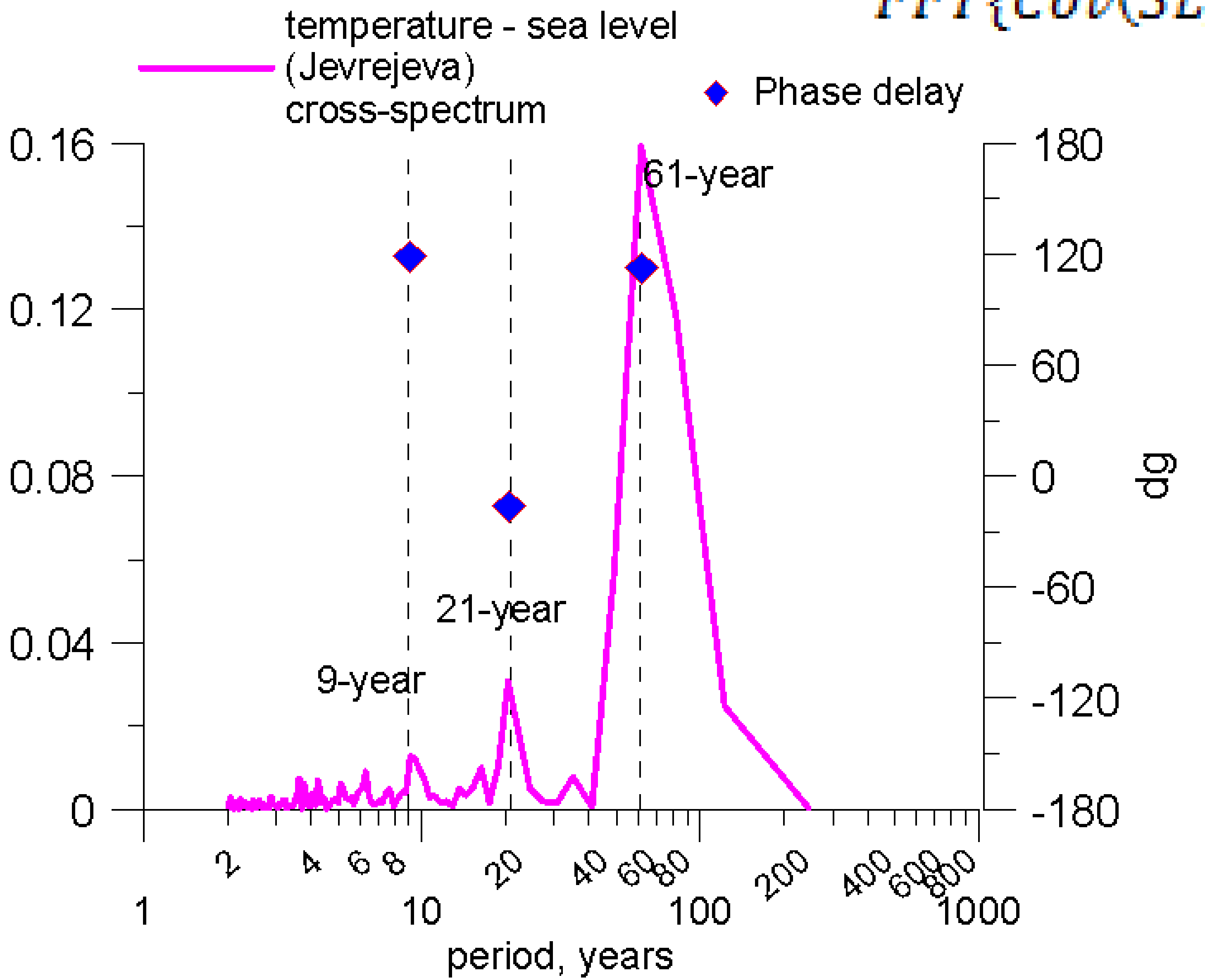


Fig. 3. (**Top**) Rate of sea-level rise obtained froı tide gauge observations (red line, smoothed ε described in the Fig. 2 legend) and compute from global mean temperature from Eq. 1 (daı blue line). The light blue band indicates th statistical error (one SD) of the simple lineа prediction (*15*). (**Bottom**) Sea level relative t 1990 obtained from observations (red line smoothed as described in the Fig. 2 legend) an computed from global mean temperature froı Eq. 2 (blue line). The red squares mark th unsmoothed, annual sea-level data.

Cross-spectrum of Sea Level and temperature T

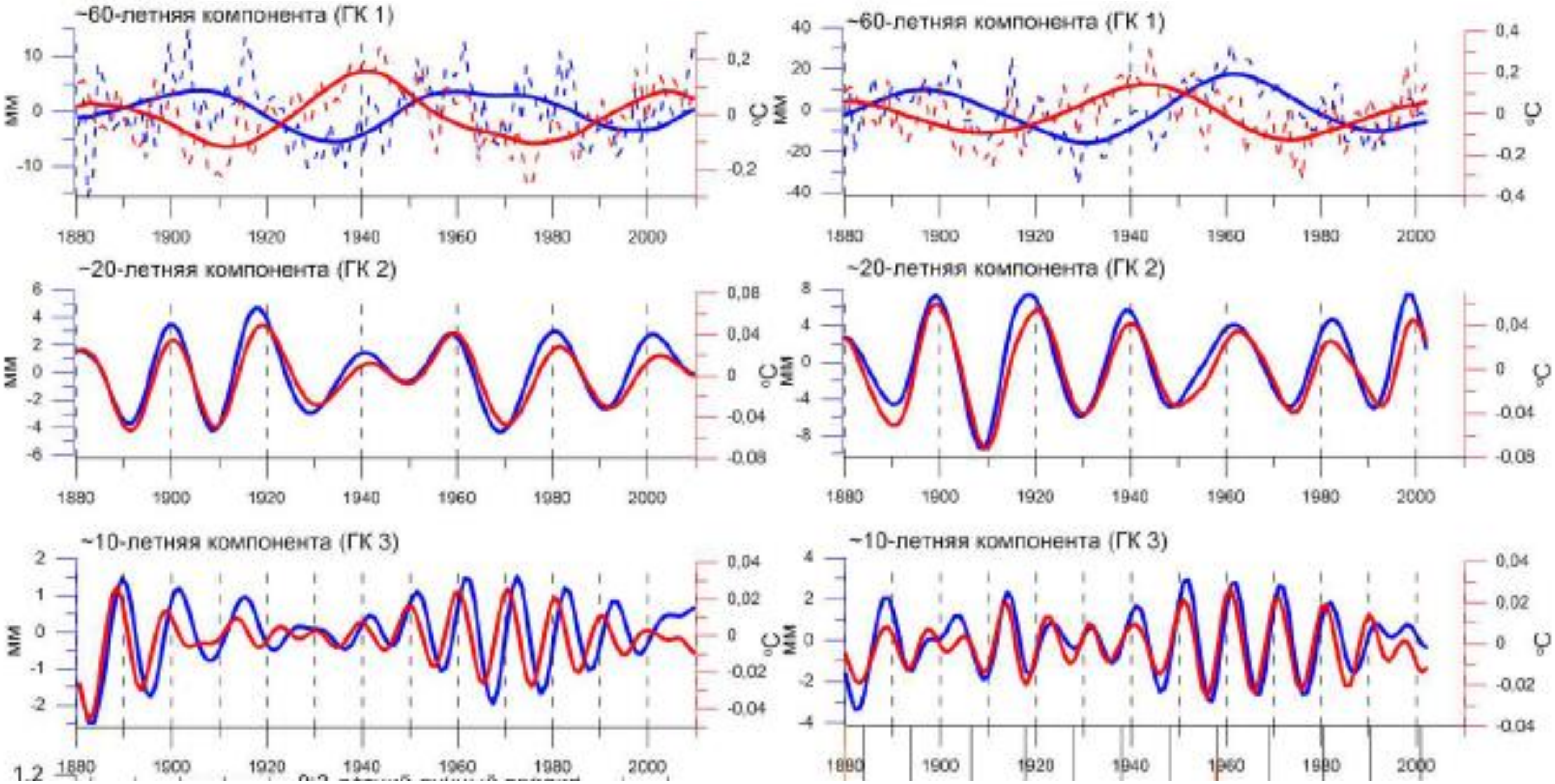
$FFT\{Cov(SL,T)\}$



60- 20- 10-year variations of the Global temperature and Sea level, Extracted by MSSA

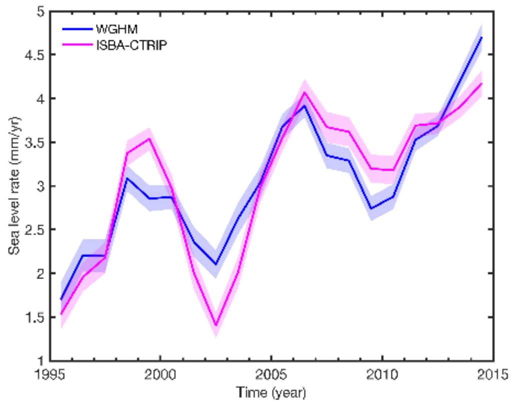
Temperature anomaly (HadCRUT4)

Sea Level anomaly (Church and White)   Sea Level anomaly (Jevrejeva et al.)



EGU2020-4643

An 8-year cycle in the rate of the global mean sea level



- $GMSL_{LT}$ shows a clear 8-year cycle superimposed on an increasing trend

Research question:

- What is the origin of the 8-year cycle?

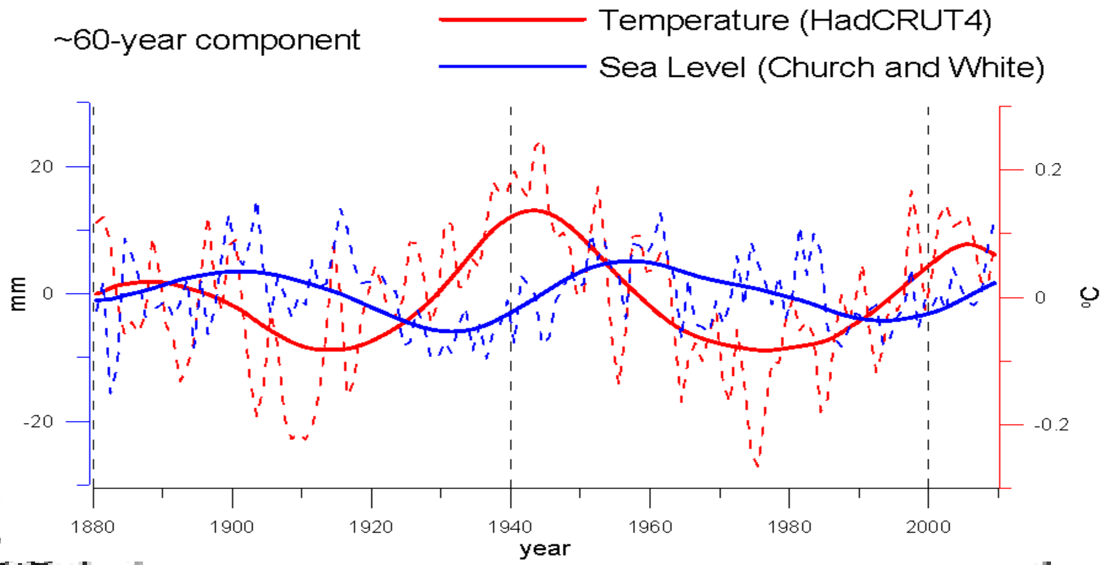
Anny Cazenave

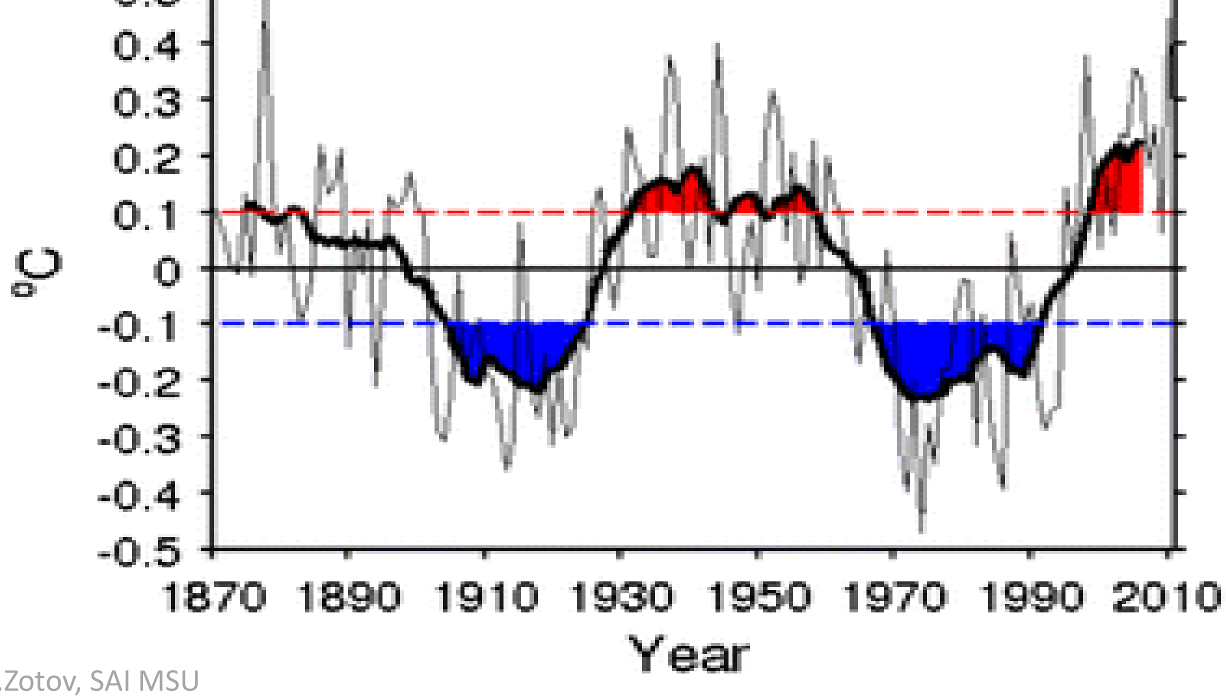
EGU2020: Sharing Geoscience Online

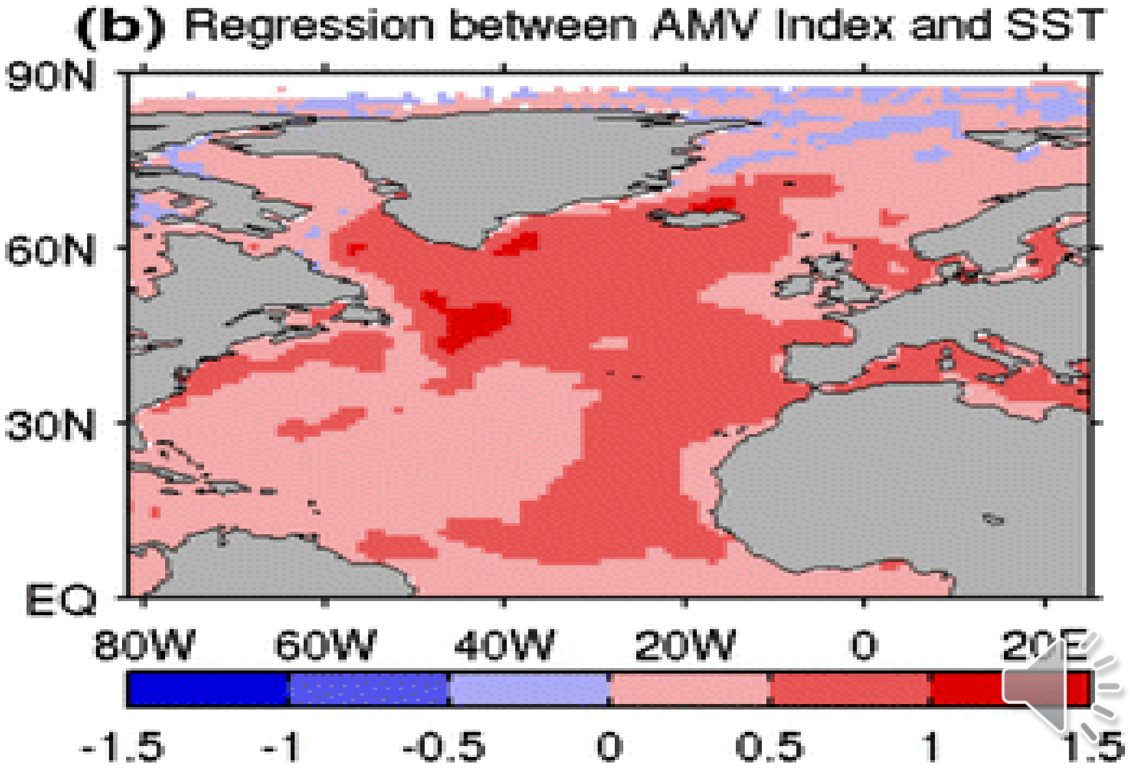
EGU G3.2 Session, 6th May 2020

L. Moreira, H. B. Dieng, A. Cazenave, H. Palanisamy, F. Paul, D. Cáceres and B. Decharme
International Space Science Institute (ISSI), Bern, Switzerland

Atlantic Multidecadal Oscillation AMO
and 60-year temperature changes







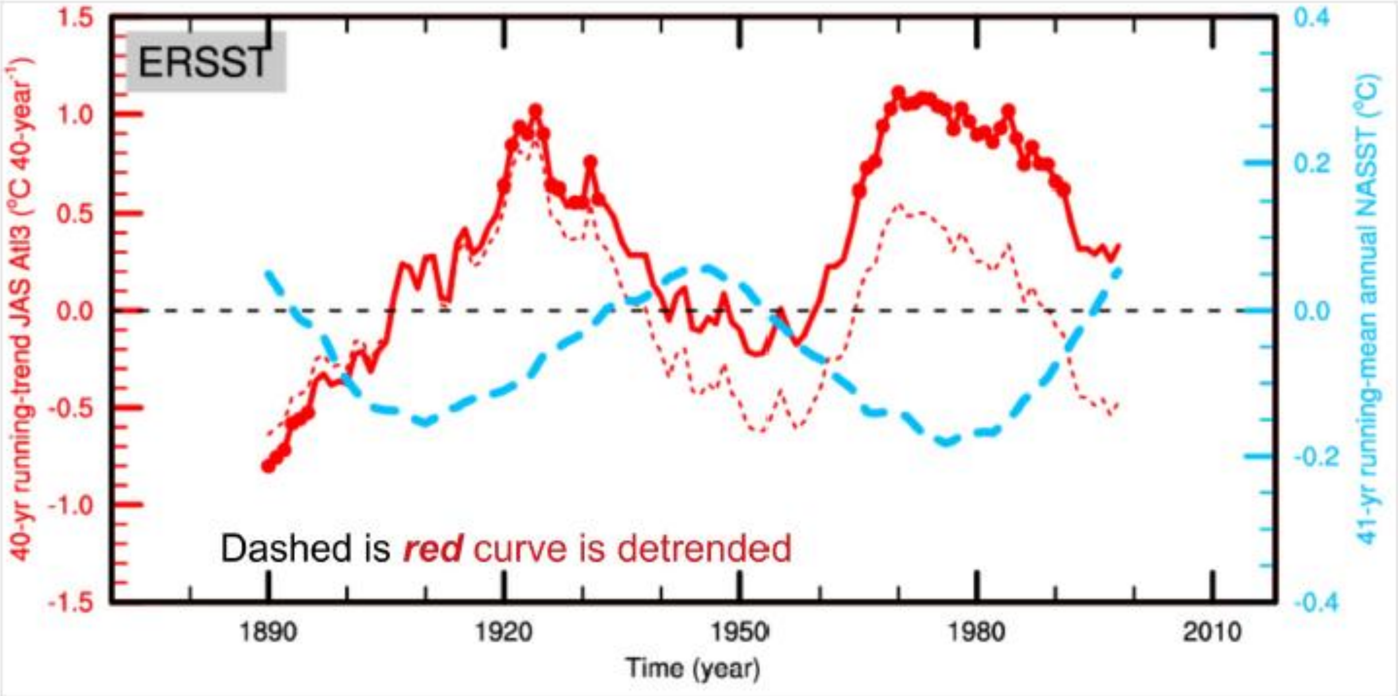
A satellite era warming hole in the equatorial Atlantic Ocean

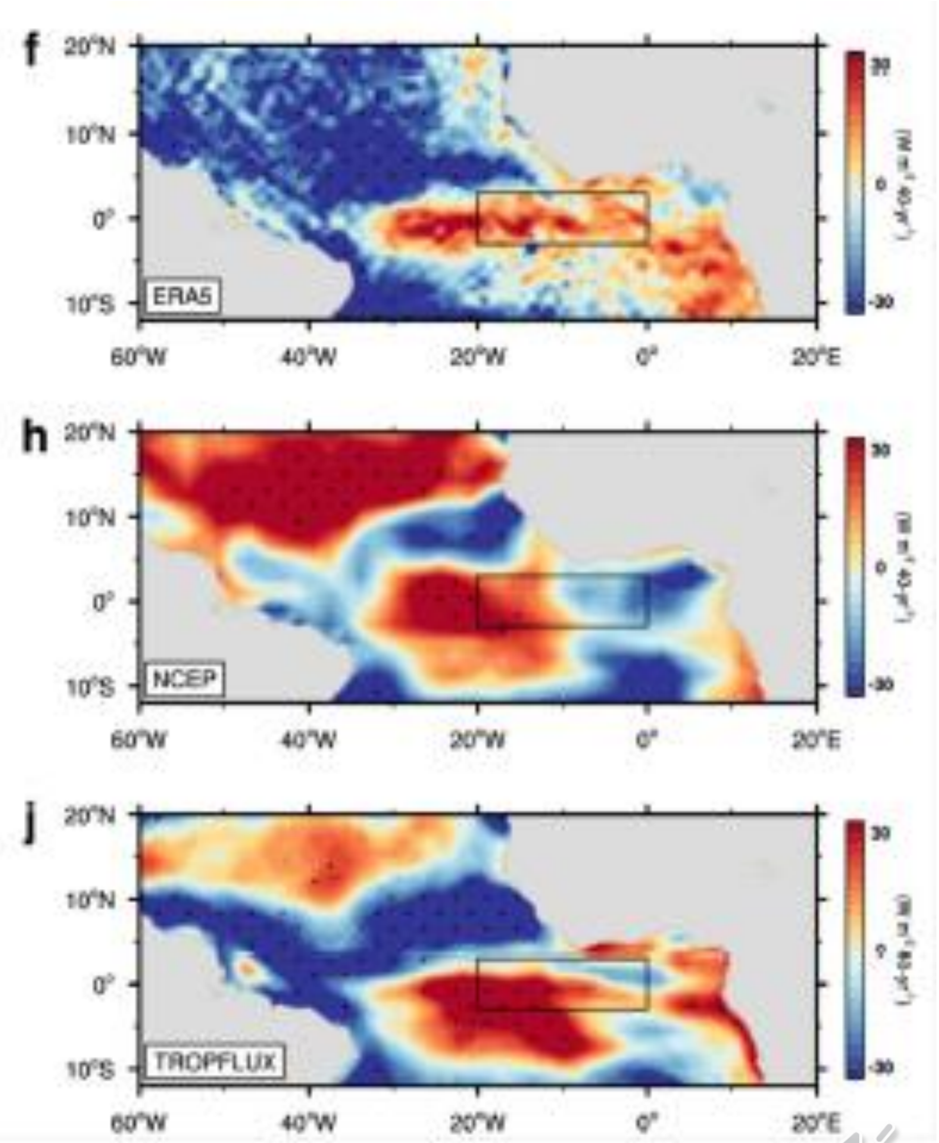
Hyacinth Nnamchi[1], Mojib Latif[1], Noel Keenlyside[2] and Wonsun Park[1]

EGU 2020

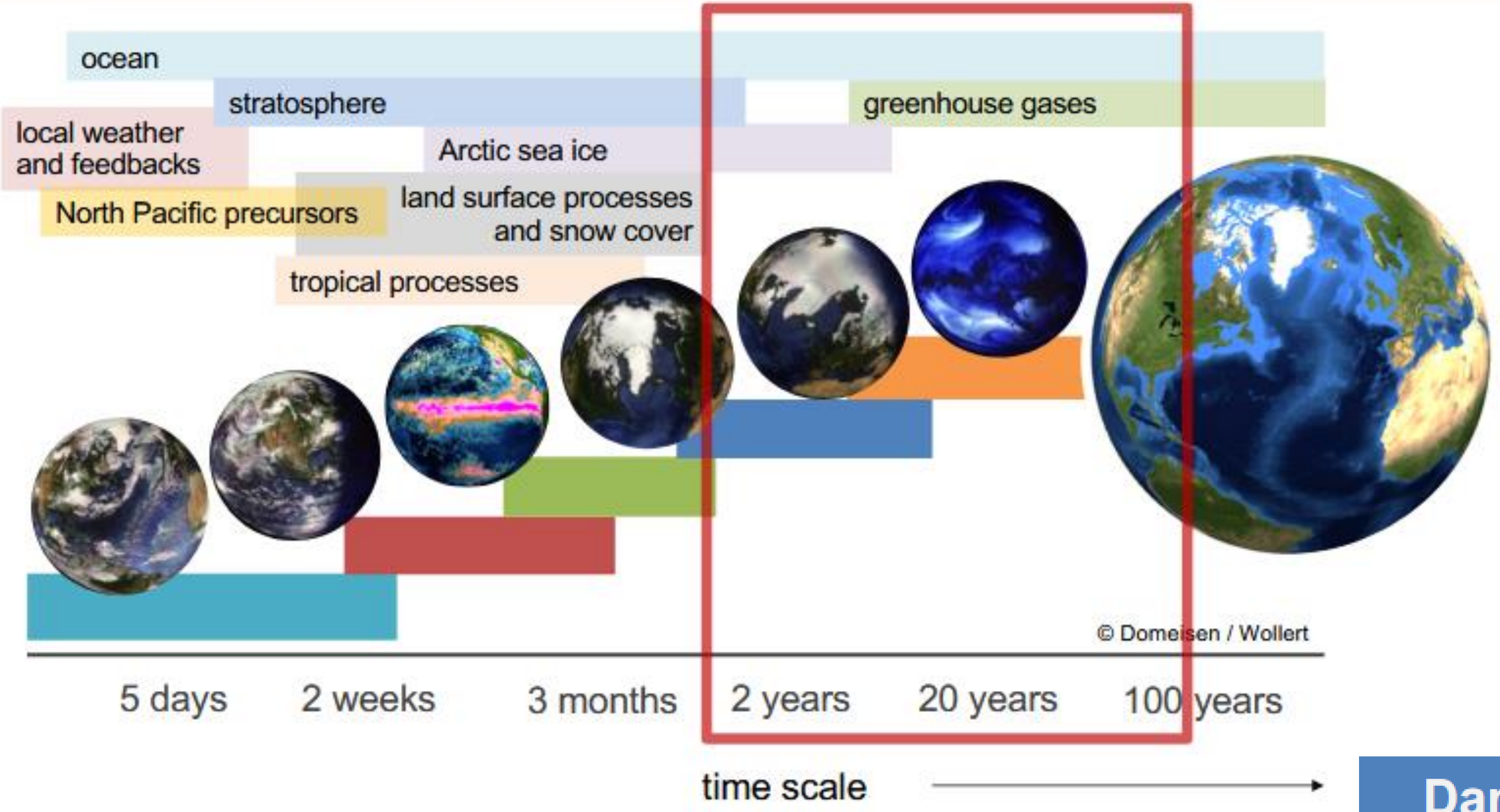
Multidecadal variability + warming effets

GEOMAR





WHICH FACTORS DETERMINE VARIABILITY AND PREDICTABILITY OVER THE NORTH ATLANTIC REGION?

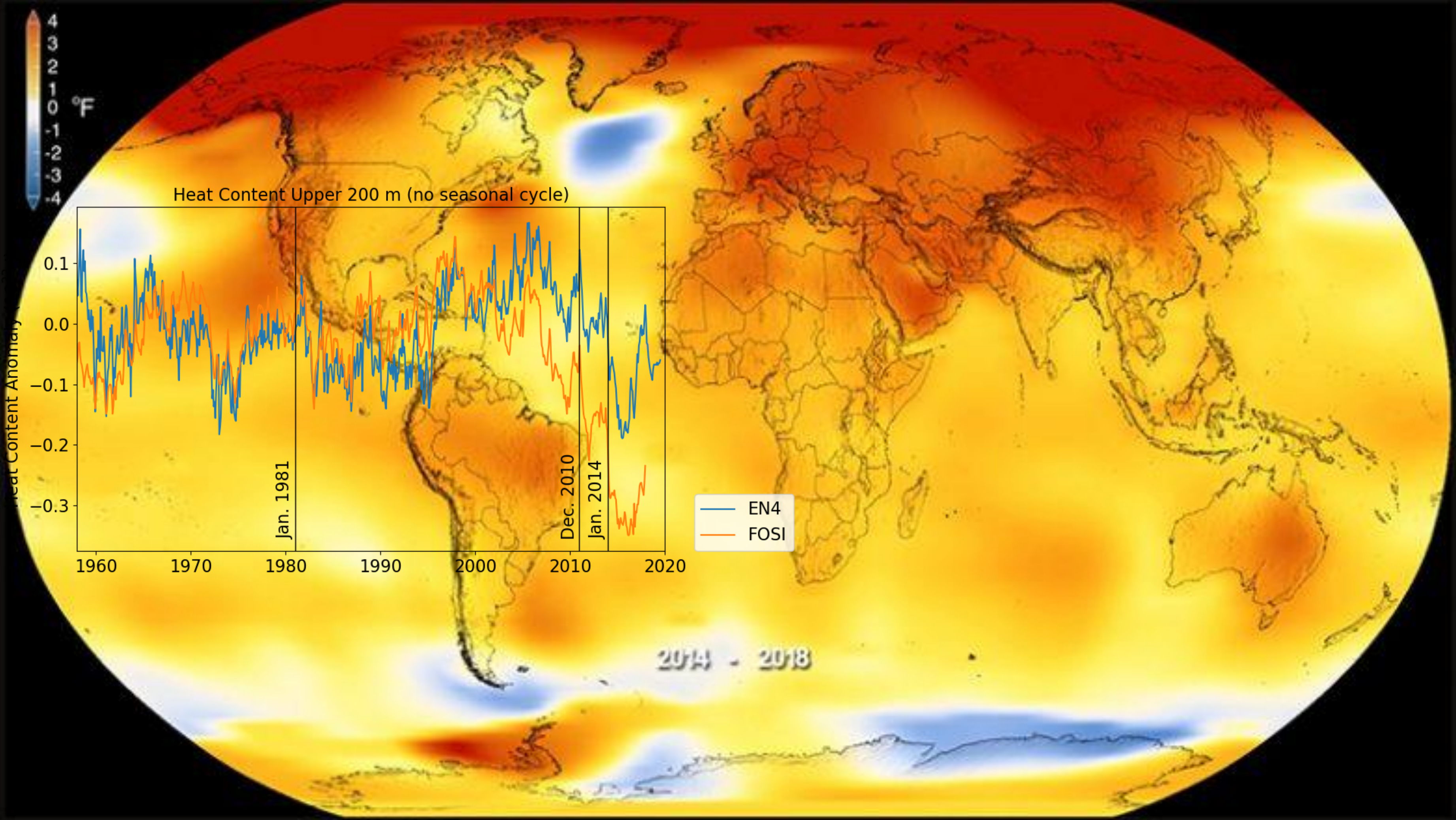


EGU2020-7815

Daniela Domeisen

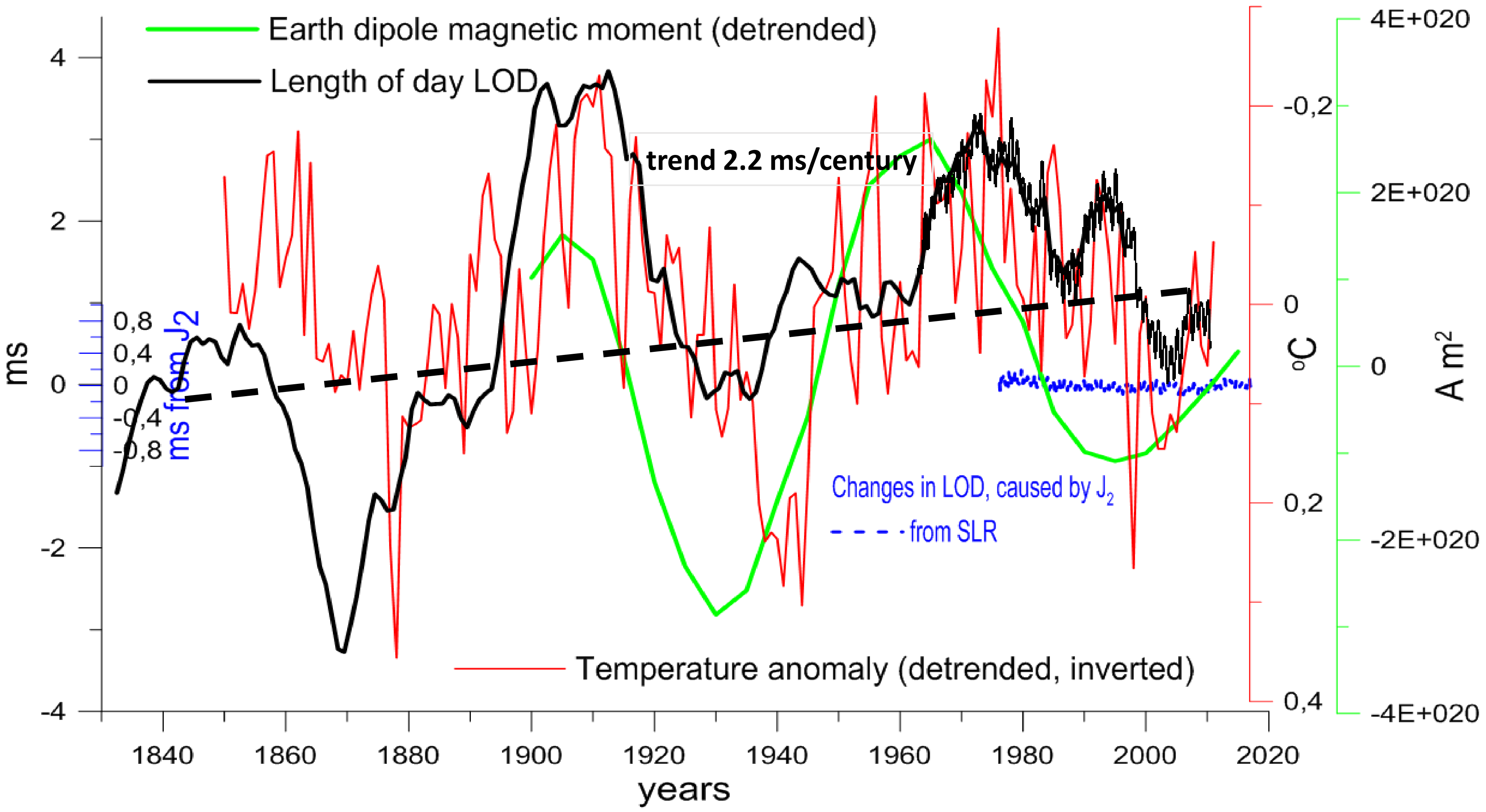
ETH zürich

North Atlantic warming hole

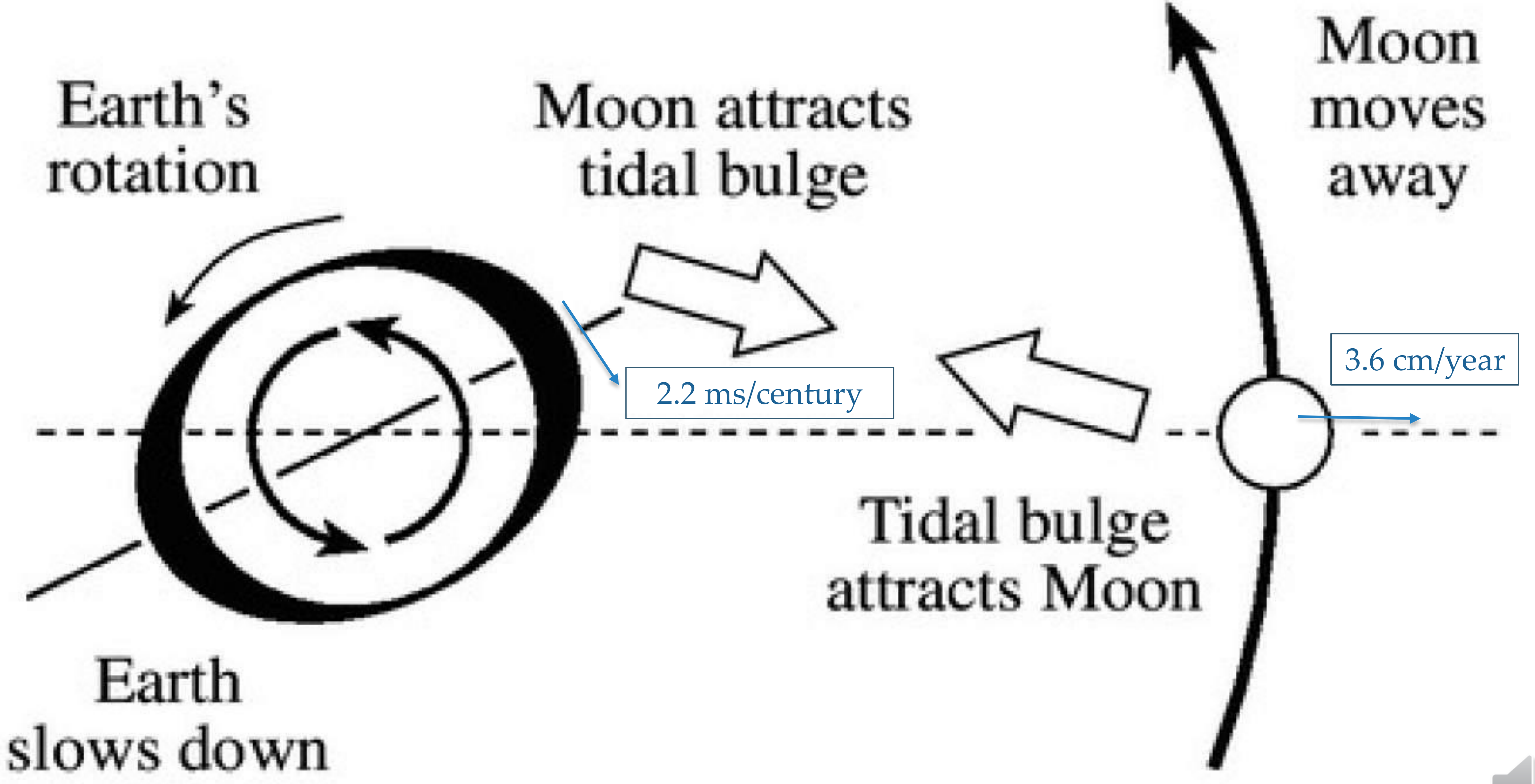


See Jennifer Mecking et all. EGU2020-6802

Long-term LOD and other factors



Earth dipole magnetic moment $m_d = \frac{4\pi}{\mu_0} a^3 \sqrt{(g_1^0)^2 + (g_1^1)^2 + (h_1^1)^2},$


Earth's rotation
Moon attracts tidal bulge
Moon moves away
2.2 ms/century
3.6 cm/year
Tidal bulge attracts Moon
Earth slows down

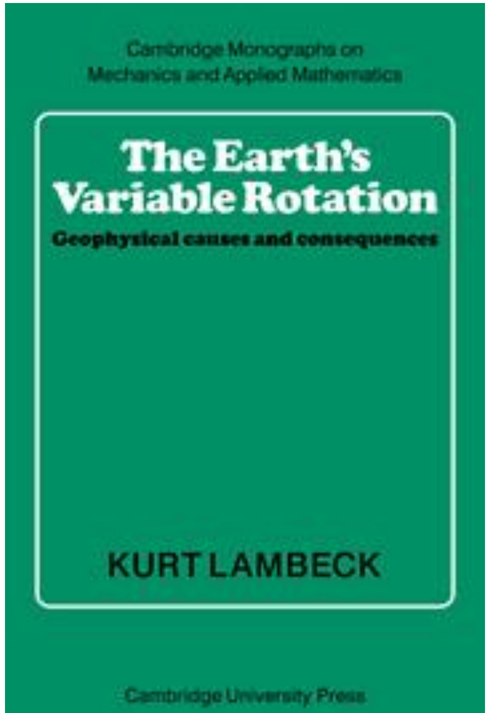
GEOPHYSICAL RESEARCH LETTER

Coherent interannual and decadal system

Jean O. Dickey and Steven L. Marcus
Jet Propulsion Laboratory, California Institute of Technology, I

Olivier de Viron
Royal Observatory of Belgium, Brussels, Belgium

Received 13 December 2002; revised 2 February 2003; accept



Does an Intrinsic Source Generate a Shared Low-Frequency Signature in Earth's Climate and Rotation Rate?

Steven L. Marcus*

Private Researcher, Santa Monica, California

Received 11 March 2015; in final form 24 October 2015

ABSTRACT: Previous studies have shown strong negative correlation between multidecadal signatures in length of day (LOD)—an inverse measure of Earth's rotational rate—and various climate indices. Mechanisms remain elusive. Climate processes are insufficient to explain observed rotational variability, leading many to hypothesize external (astronomical) forcing as a common source for observed low-frequency signatures. Here, an internal source, a core-to-climate, one-way chain of causality, is hypothesized. To test hypothesis feasibility, a recently published, model-estimated forced component is removed from an observed dataset of Northern Hemisphere (NH) surface temperatures to isolate the intrinsic component of climate variability, enhancing its comparison with LOD. To further explore the rotational connection to climate indices, the LOD anomaly record is compared with sea surface temperatures (SSTs)—global and regional. Because climate variability is most intensely expressed in the North Atlantic sector, LOD is compared to the dominant oceanic pattern there—the Atlantic multidecadal oscillation (AMO). Results reveal that the LOD-related

GEODESY AND GEODYNAMICS 2016, VOL X NO X, 1–7

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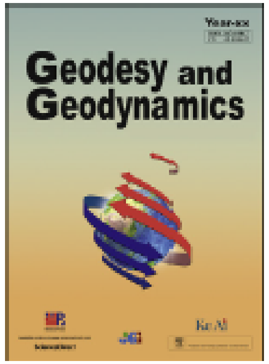


A possible interrelation between Earth rotation and climatic variability at decadal time-scale

Leonid Zotov[a,b,*], *C. Bizouard*[c], *C.K. Shum*[d,e]

[a] *National Research University Higher School of Economics, Moscow Institute of Electronics and Mathematics, Moscow, Russia*
[b] *Lomonosov Moscow State University, Sternberg Astronomical Institute, Moscow, Russia*
[c] *SYRTE, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, 61 avenue de l'Observatoire, 75014 Paris, France*
[d] *Division of Geodetic Science, School of Earth Sciences, The Ohio State University, USA*
[e] *State Key Laboratory of Geodesy and Earth's Dynamics, Institute of Geodesy & Geophysics, Chinese Academy of Sciences, Wuhan, China*

Alberto ESCAPA, J. GETINO, J.M. FERRANDIZ, T. BAENAS *Second-order effects in IAU2000 nutation model*	Presentation	Paper
Jia-Cheng LIU, N. CAPITAINE *Testing the improvement of the iau precession using different J_2 variation with time*	Presentation	Paper
Véronique DEHANT and RotaNut team *Progress in understanding nutations*	Presentation	Paper
Elnaz NAGHIBI, S.A. KARABASOV *Excitation of the Earth's Chandler wobble by the North Atlantic double g*		
Nikolay SIDORENKOV, E. DIONIS, C. BIZOUARD, L. ZOTOV *Decadal fluctuations in Earth's rotation as evidences of lithospheric asthenospere*		
Leonid ZOTOV, C. BIZOUARD, N. SIDORENKOV *On the variability of the Chandler wobble*		
Jan VONDRAK, C. RON *Determination of FCN parameters from different VLBI solutions, considering geophysical excitations*		
José Manuel FERRANDIZ, R.S. GROSS, A.ESCAPA, J. GETINO, A. BRZEZINSKI, R. HEINKELMAN *Joint Working Group on Theory of Earth rotation and validation*		

Journées 2019

7,8,9 October 2019 - PARIS

https://syrte.obspm.fr/astro/journees2019/index.php?page=presentation_pdf

DECADAL FLUCTUATIONS IN EARTH'S ROTATION AS EVIDENCES OF LITHOSPHERIC DRIFT OVER THE ASTHENOSPERE

N. SIDORENKOV[1], E. DIONIS[2], C. BIZOUARD[2], L. ZOTOV[3],

[1] Hy
[2] SY
[3] St

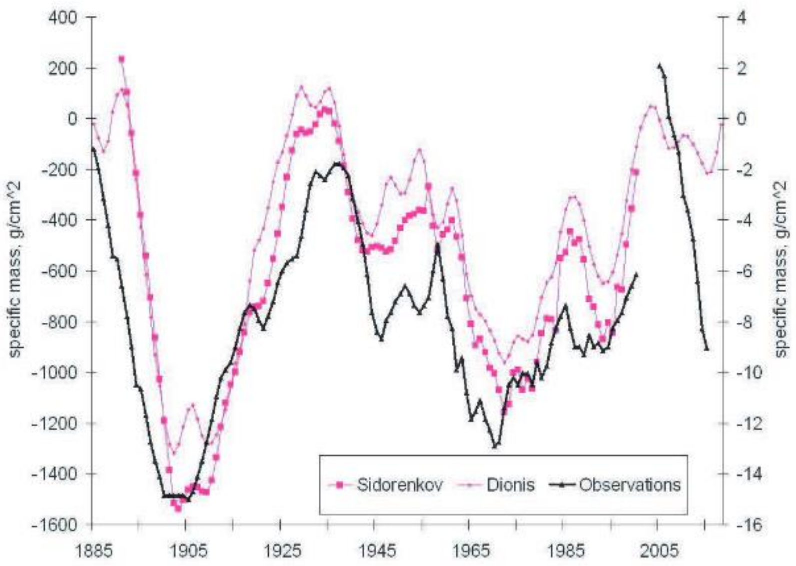
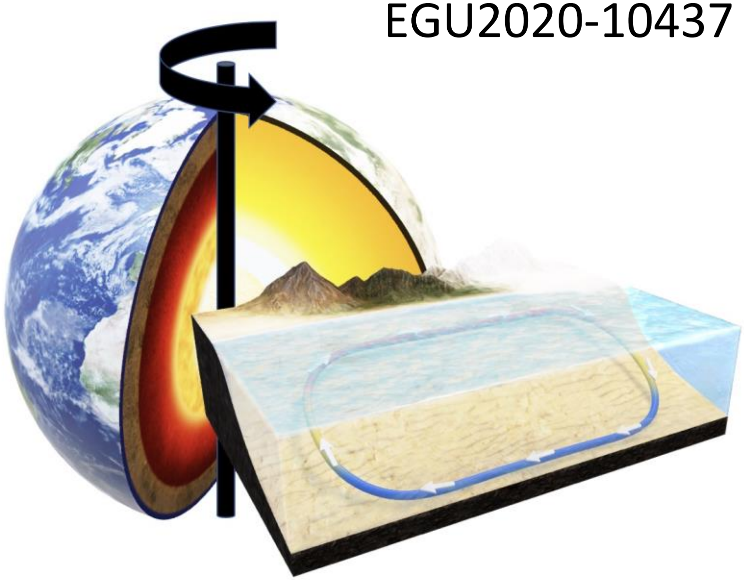


Figure 2: Temporal variations the specific mass of ice in Antarctica obtained from theoretical calculations and observations (r=0,84)

EGU2020-10437



The intriguing relation between Earth's rotation, geomagnetism, and climate at multidecadal time scales

Sébastien Lambert

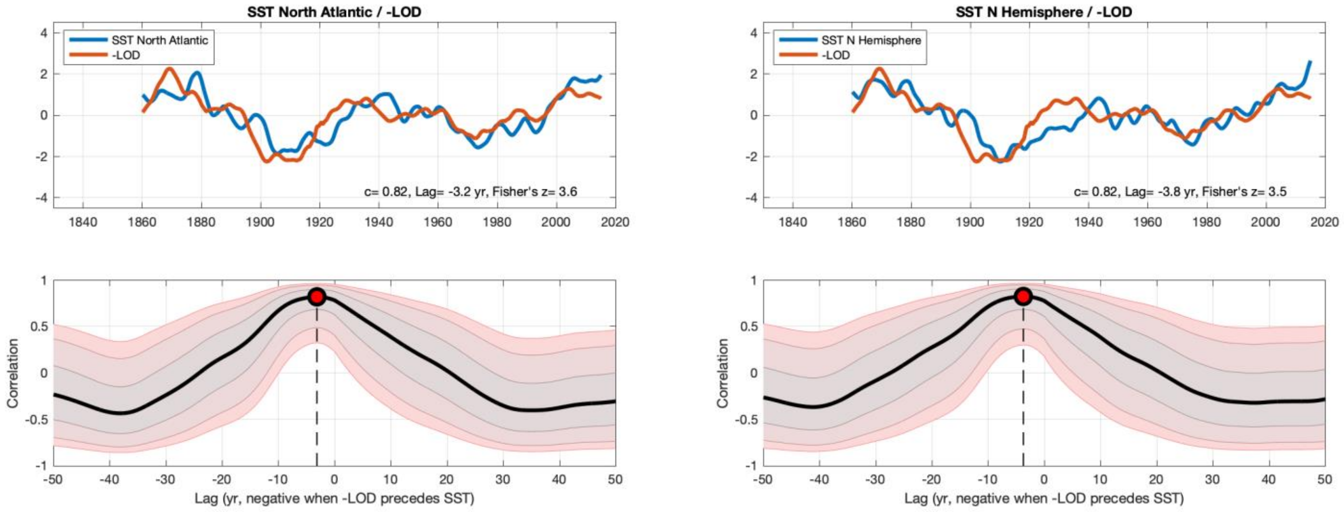
SYRTE, Observatoire de Paris - Université PSL, CNRS, Sorbonne Université, LNE

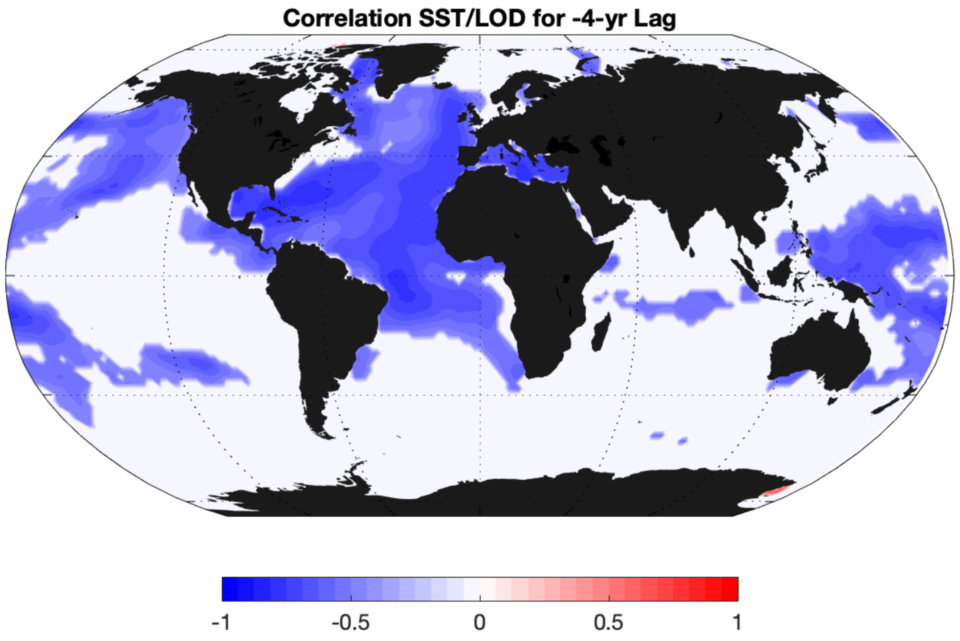
l'Observatoire de Paris | PSL CNRS INSU Observer & comprendre SORBONNE UNIVERSITÉ CRÉATEURS DE FUTURS DEPUIS 1257 LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS LNE

EGU European Geosciences Union

http://syrte.obspm.fr/~lambert/lodclimate

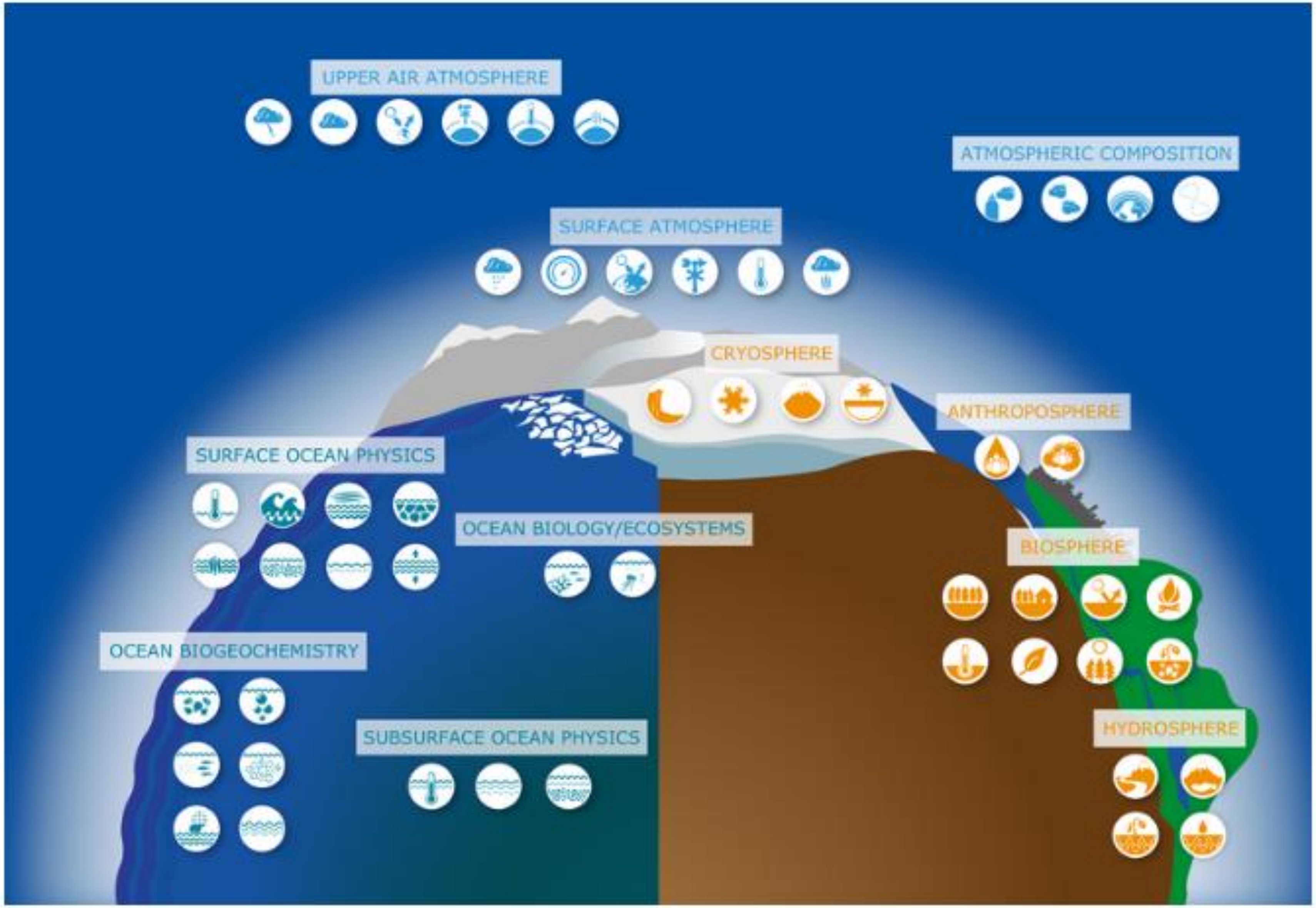
Results: LOD vs SST





In the correlation plots, the successive shaded areas around the black line represent the 68%, 95%, and 99% confidence intervals. In the correlation maps, only correlation significant at more than 95% are reported. In both, the lag is negative when LOD precedes SST. I confirmed here the significant correlations between LOD and SST concentrated along North Atlantic (see Marcus 2016) with a small lag of a few years.

Essential Climate Variables



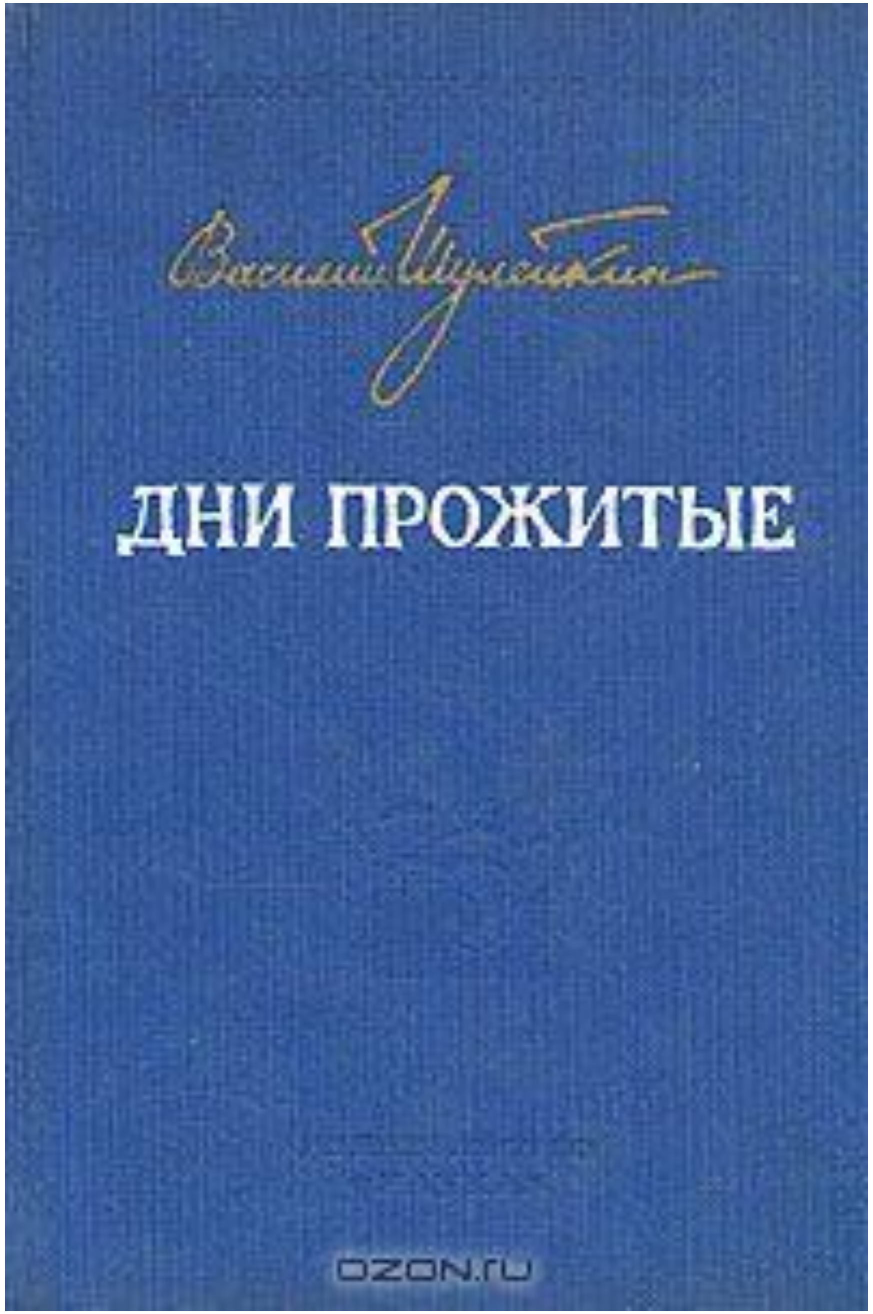
GCOS currently specifies 54 ECVs:

ATMOSPHERIC	Surface: air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget Upper-air: temperature, wind speed and direction, water vapour, cloud properties, Earth radiation budget, lightning Composition: carbon dioxide, methane, other long-lived greenhouse gases, ozone, aerosol, precursors for aerosol and ozone
OCEANIC	Physics: temperature: sea surface and subsurface; salinity: sea surface and subsurface; currents, surface currents, sea level, sea state, sea ice, ocean surface stress, ocean surface heat f ux Biogeochemistry: inorganic carbon, oxygen, nutrients, transient tracers, nitrous oxide , ocean colour Biology/ecosystems: plankton, marine habitat properties
TERRESTRIAL	Hydrology: river discharge, groundwater, lakes, soil moisture, evaporation from land Cryosphere: snow, glaciers, ice sheets and ice shelves, permafrost Biosphere: albedo, land cover, fraction of absorbed photosynthetically active radiation, leaf area index, above-ground biomass, soil carbon, fire, land surface temperature Human use of natual ressources: water use, greenhouse gas fluxes

Conclusions

- Climate signals present in excitations of LOD and PM
- Mass term can be accessed through GRACE and GRACE-FO
- Water cycle is very important, hydrological and glaciological changes can even shift the axis of the Earth
- Sea level, related to both figure of the Earth and climate can have forward and backward links to Earth rotation
- Atlantic Ocean gives evident input into Earth temperature variations, which are correlated with Earth rotation velocity on 60 yr scale
- If we can predict climate and ERP together better, then separately, then there is “Granger causality” between them
- We should promote Climate and Earth rotation working group and our ideas. Very few scientists understand importance of this interdisciplinary scientific field

Vasily Shuleikin 1895-1979



Russian oceanographer academician **V. Shuleykin** mentioned importance of the mass redistribution studies for Earth Rotation

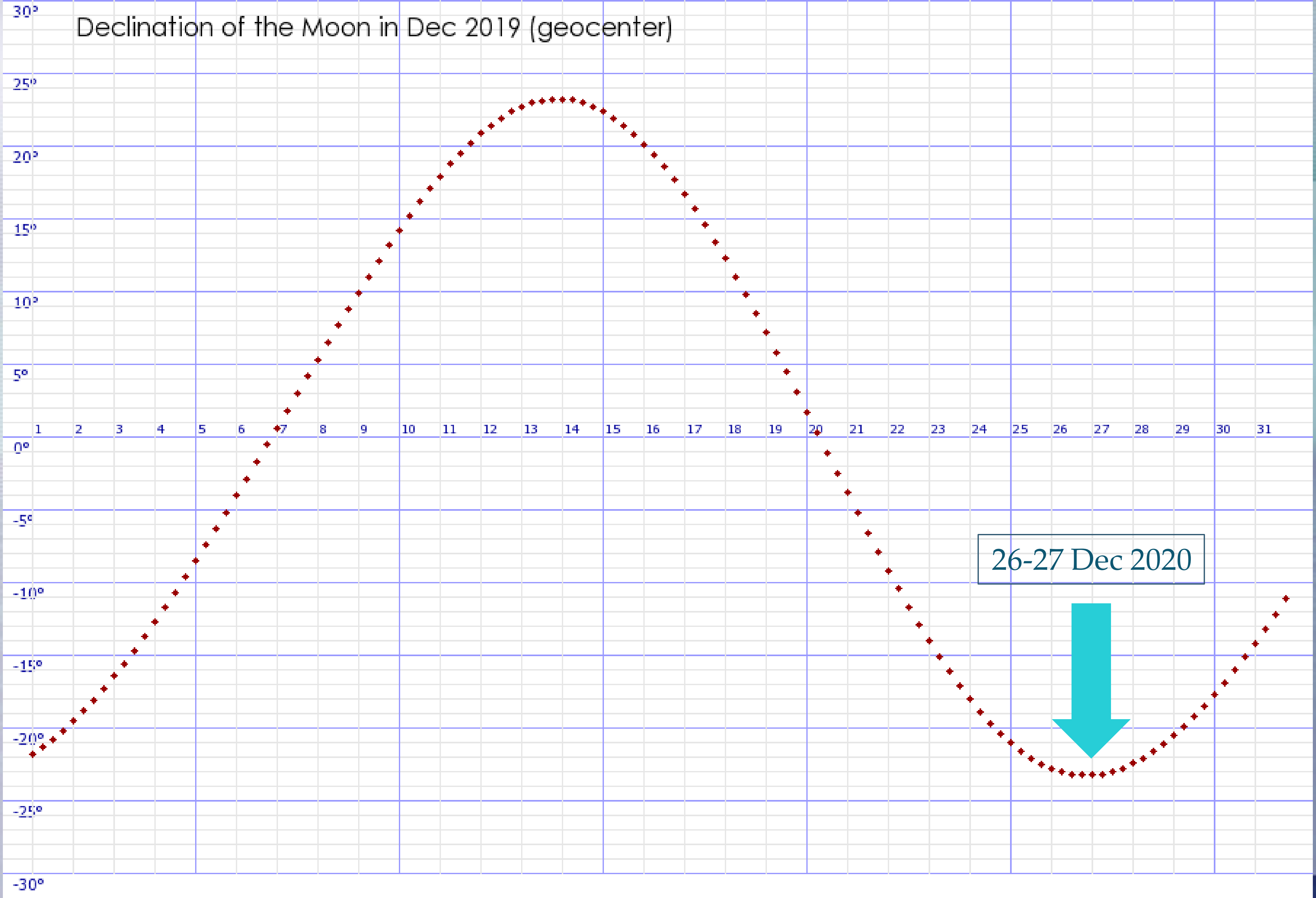
Thank you for attention!

House with Four Seasons, Vienna

The talk is supported by 111 plan

Solar eclipse 26 December 2019

AE-L
AF-L
MENU
M
OFF
SD
RAW+F
L
1/320
F0
ISO 3200
[374]
OK
Nikon



Declination of the Moon in Dec 2019 (geocenter)
30°
25°
20°
15°
10°
5°
0°
-5°
-10°
-15°
-20°
-25°
-30°
1
2
3
4
5
6
7
8
9
10
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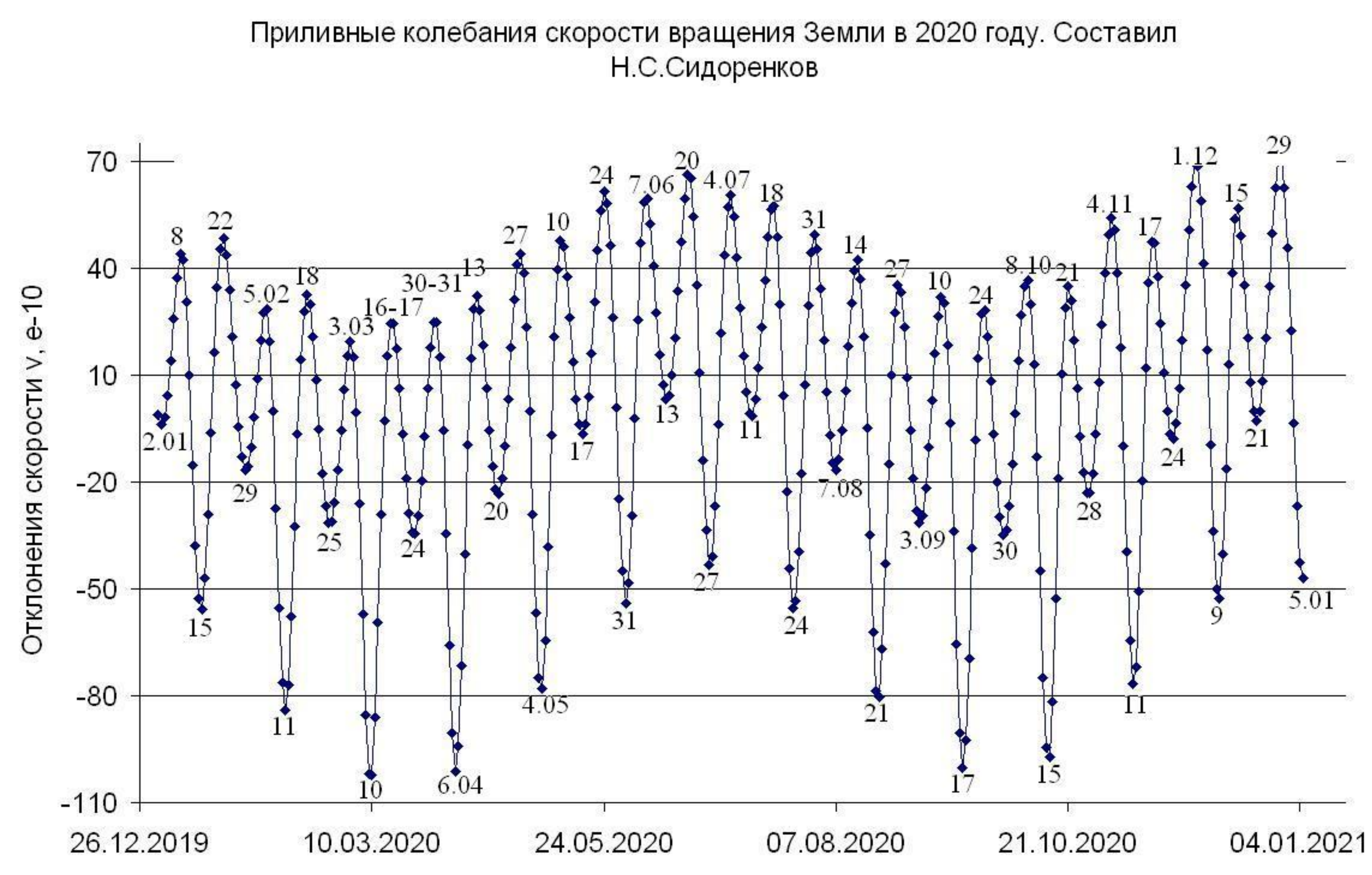
30
31
26-27 Dec 2020

Tidal Earth rotation velocity changes, after N. Sidorenkov

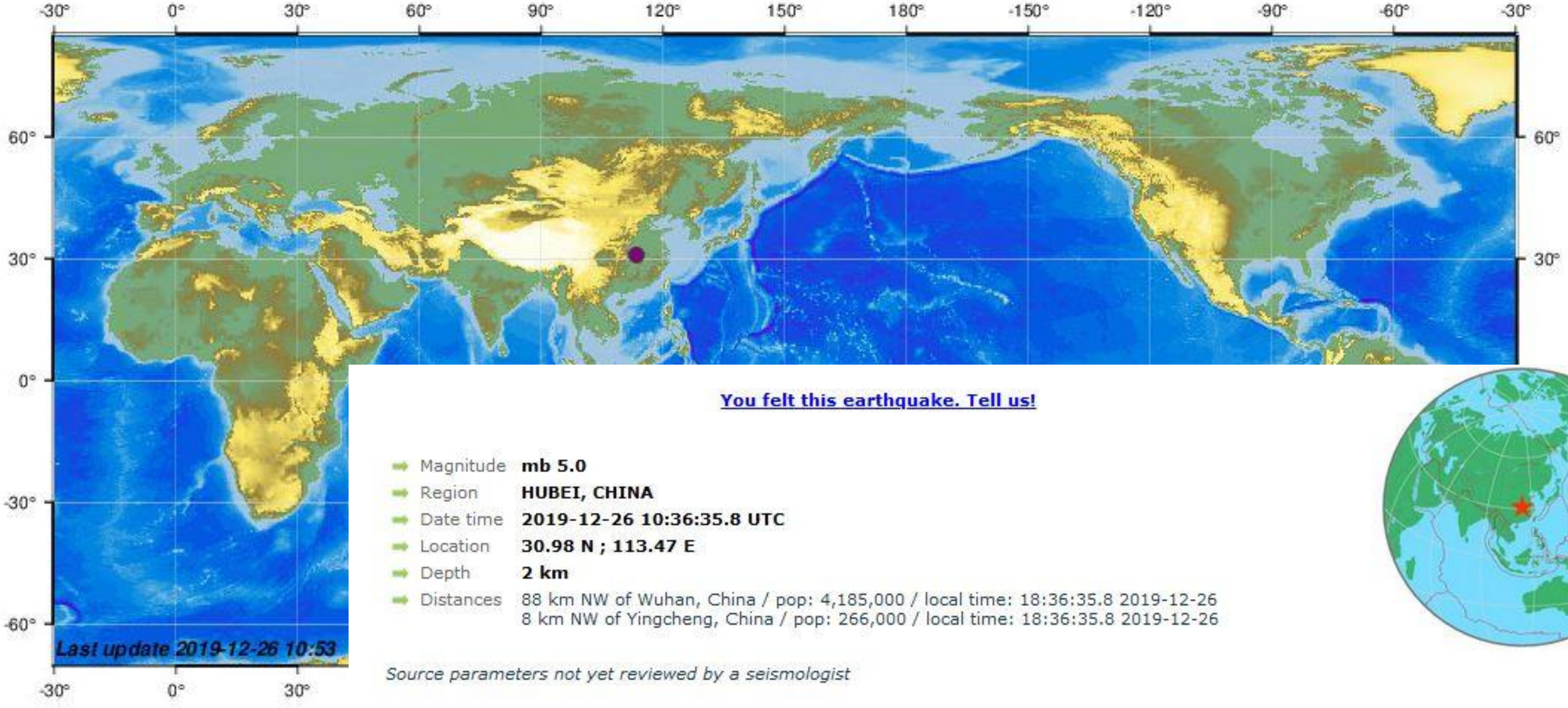
l'Observatoire de Paris — SYRTE

- EOP TIME SERIES
- THEORY AND MODELLING
- Earth Orientation Parameters (EOP)
- Astro-geodetic techniques
- Models / Sofware
- Leap second
- Useful constants
- Moon declination



Choose your map : Last 1h Last 24h Last 48h Last week Last 2 weeks

39 earthquakes on this map



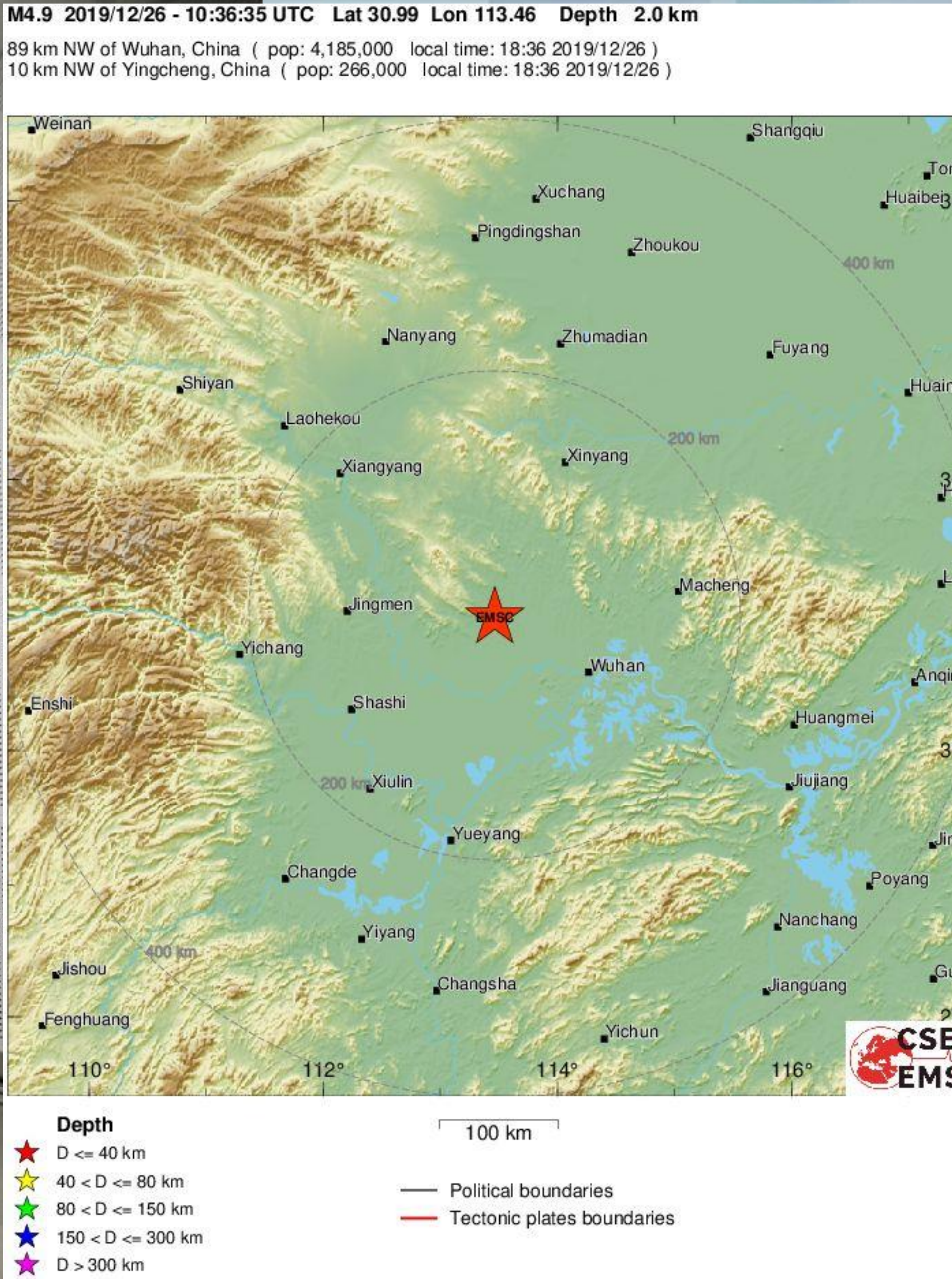
[You felt this earthquake. Tell us!]

- Magnitude **mb 5.0**
- Region **HUBEI, CHINA**
- Date time **2019-12-26 10:36:35.8 UTC**
- Location **30.98 N ; 113.47 E**
- Depth **2 km**
- Distances 88 km NW of Wuhan, China / pop: 4,185,000 / local time: 18:36:35.8 2019-12-26
  8 km NW of Yingcheng, China / pop: 266,000 / local time: 18:36:35.8 2019-12-26

Source parameters not yet reviewed by a seismologist

Mag: 4.0 5.0 6.0 7.0

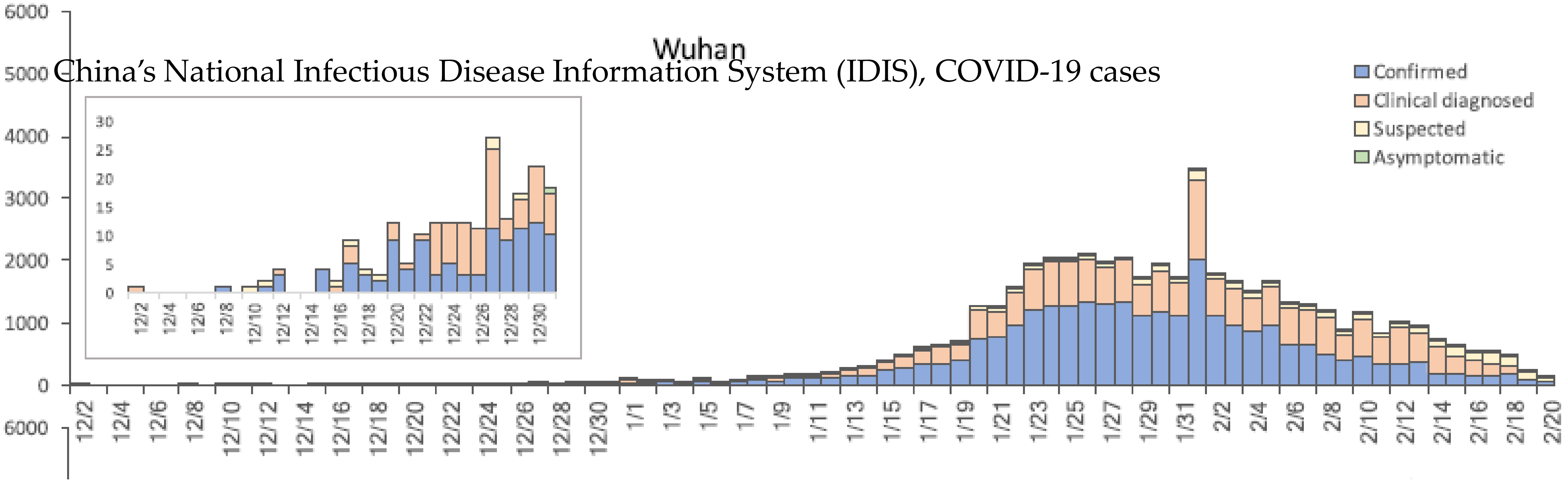

GWR


M4.9 2019/12/26 - 10:36:35 UTC Lat 30.99 Lon 113.46 Depth 2.0 km
89 km NW of Wuhan, China (pop: 4,185,000 local time: 18:36 2019/12/26)
10 km NW of Yingcheng, China (pop: 266,000 local time: 18:36 2019/12/26)
Weinan
Shangqiu
Xuchang
Pingdingshan
Zhoukou
400 km
Nanyang
Zhumadian
Fuyang
Shiyan
Laohekou
200 km
Xiangyang
Xinyang
Macheng
Jingmen
EMSC
Yichang
Wuhan
Enshi
Shashi
Huangmei
200 km
Xiulin
Jiujiang
Yueyang
Changde
Poyang
Nanchang
Yiyang
400 km
Jishou
Changsha
Jianguang
Fenghuang
Yichun
110°
112°
114°
116°
Depth
D <= 40 km
40 < D <= 80 km
80 < D <= 150 km
150 < D <= 300 km
D > 300 km
100 km
Political boundaries
Tectonic plates boundaries

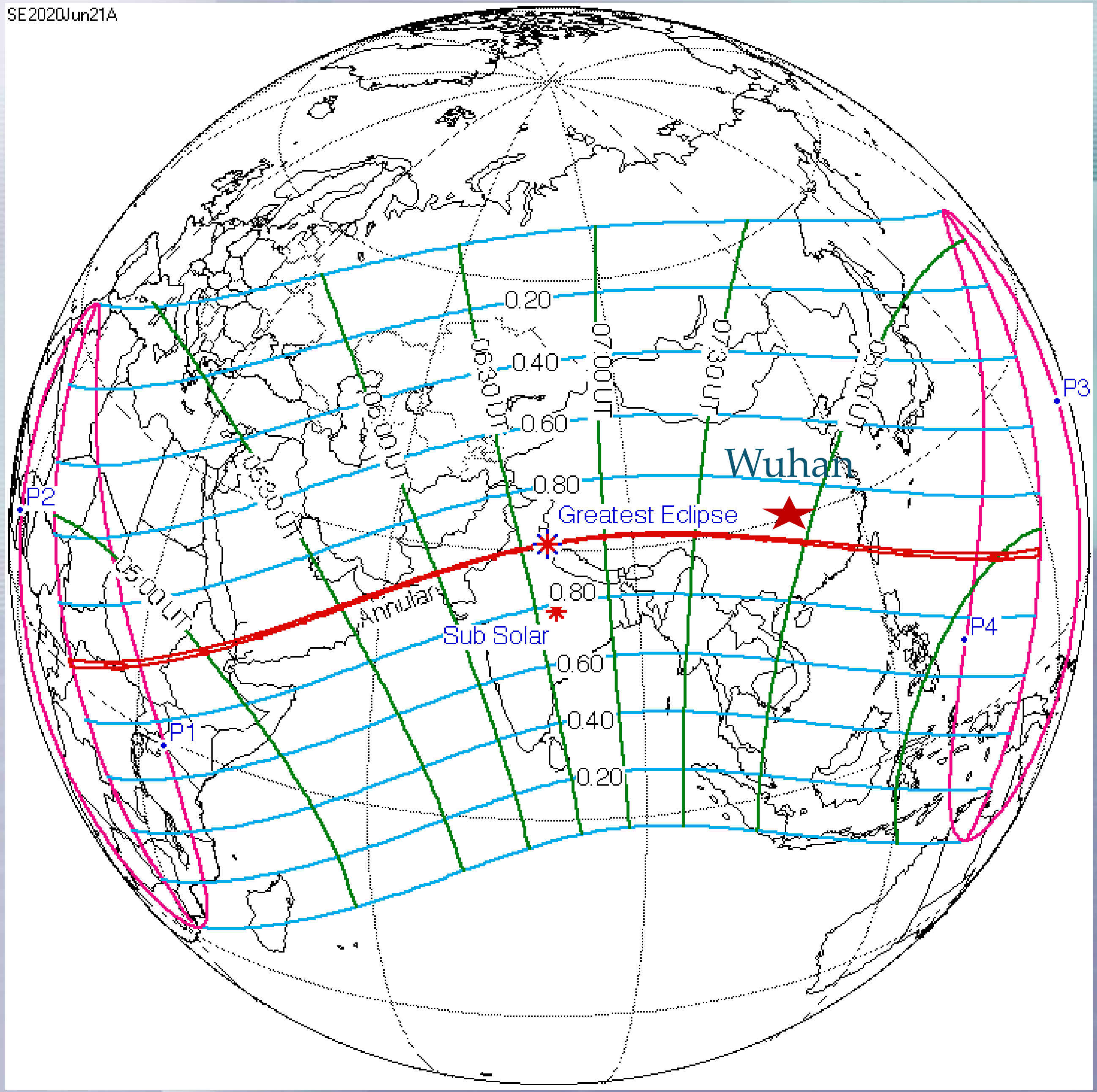
Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19)

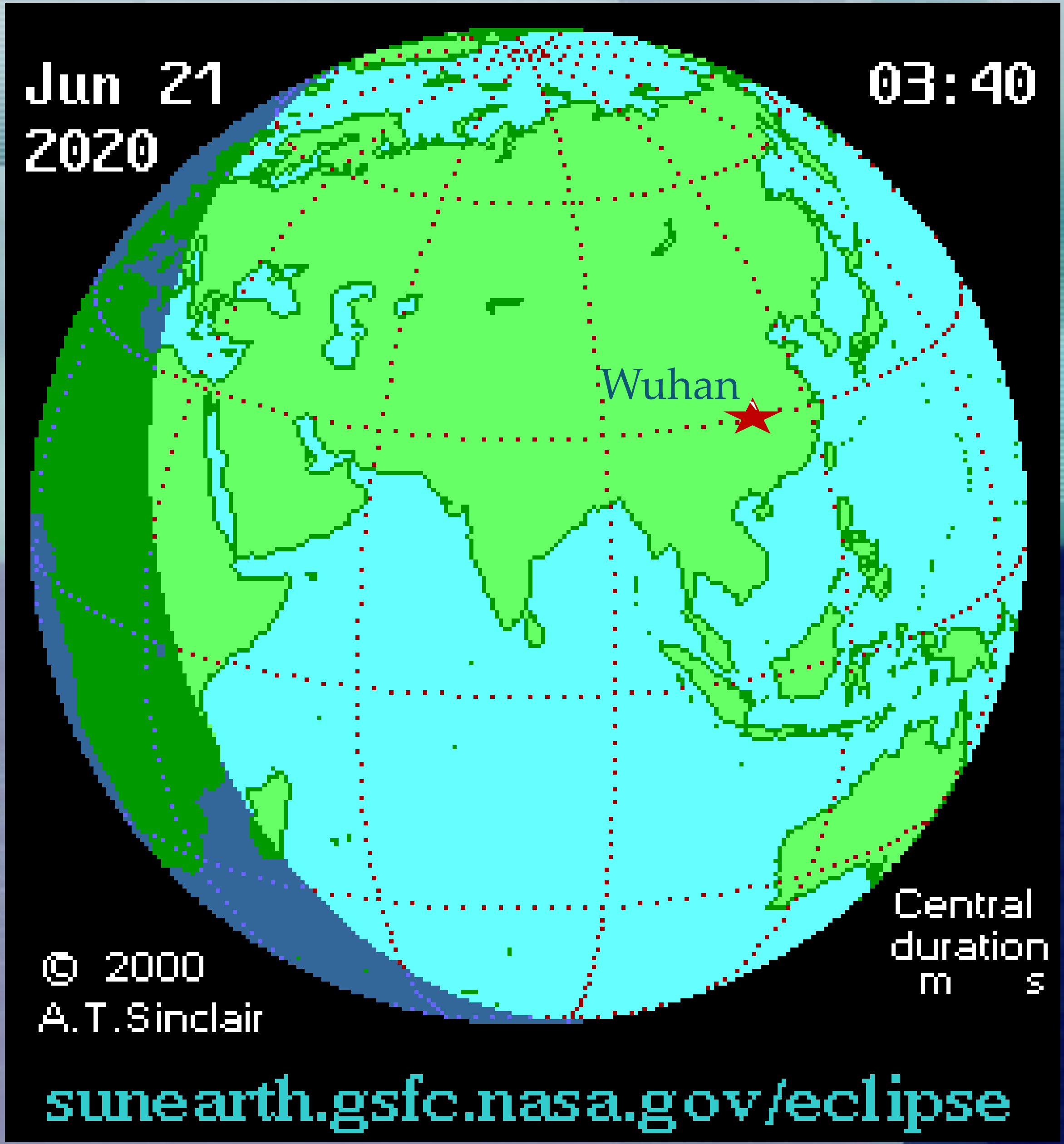
16-24 February 2020

China's National Infectious Disease Information System (IDIS), COVID-19 cases



Annular solar eclipse will occur on June 21, 2020






Trip over old Wuhan
http://lnfm1.sai.msu.ru/~tempus/OldWuhan/