Leap second Prediction
and
New Web/ftp Service

Daniel Gambis

IERS, Observatoire de Paris, FRANCE

Missions of the IERS Earth Orientation Center

- Collect Earth Orientation Parameters (EOP) derived from the various techniques (LLR, SLR, GPS, VLBI and DORIS).
  - Polar motion (x,y)
  - Universal time (UT1-UTC, UT1-TAI)
  - Celestial pole offsets (Dpsi, Deps, DX,DY)

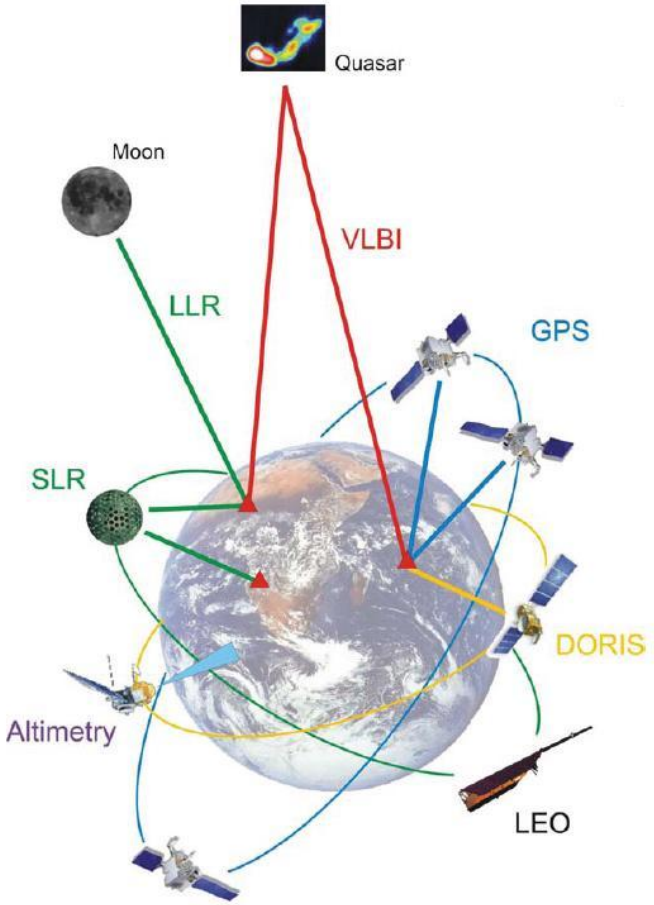
- Compute combined EOP solutions (Bulletin B and C04)

- Analysis of the EOP, in particular the determination of their consistencies with respect to the international terrestrial (ITRF) and celestial reference frames (ICRF).

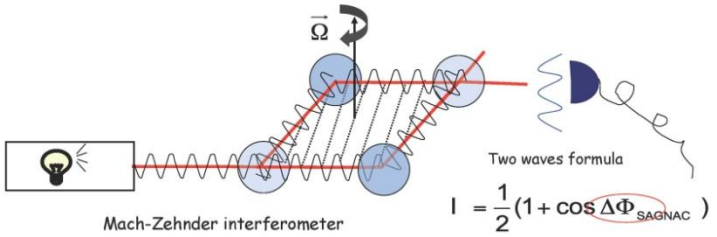
- Bulletin C : Leap second announcement
- Bulletin D : DUT1 time dissemination

Monitoring earth rotation variations

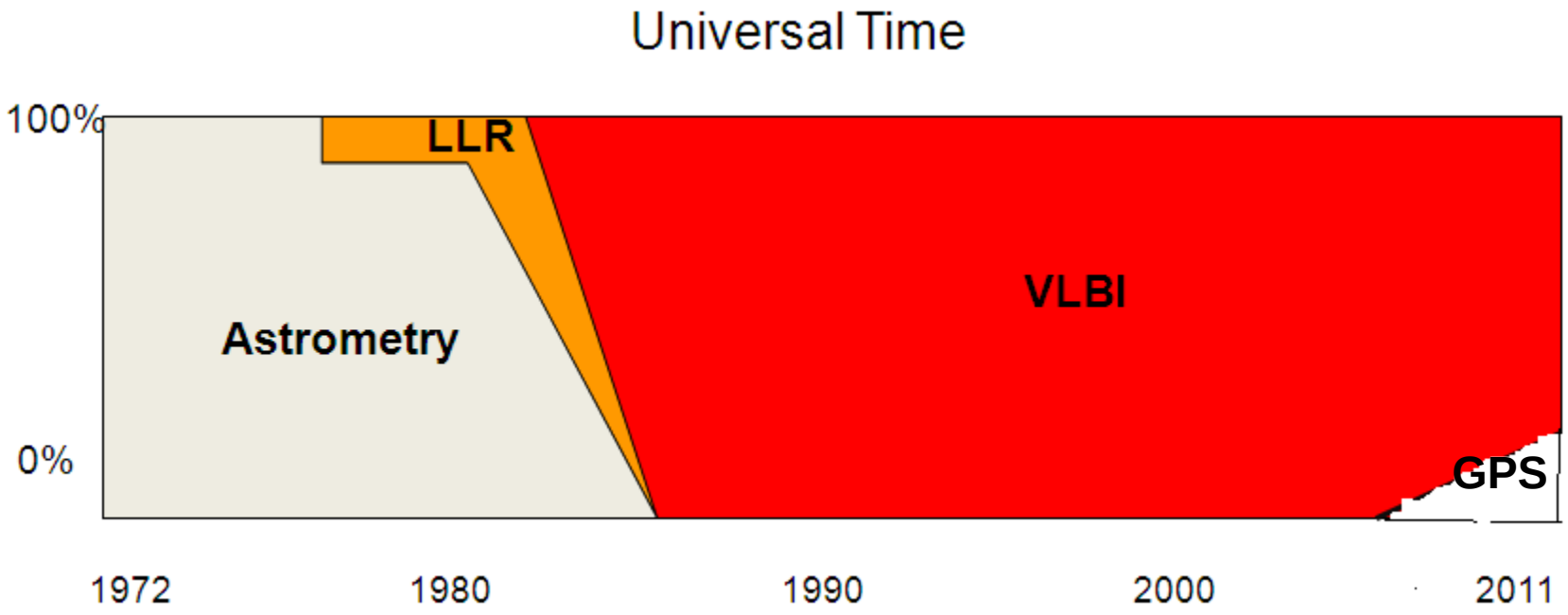
Geodetic space techniques



Gyroscope



Contributions of techniques to IERS UT1 solutions



Universal Time UT1

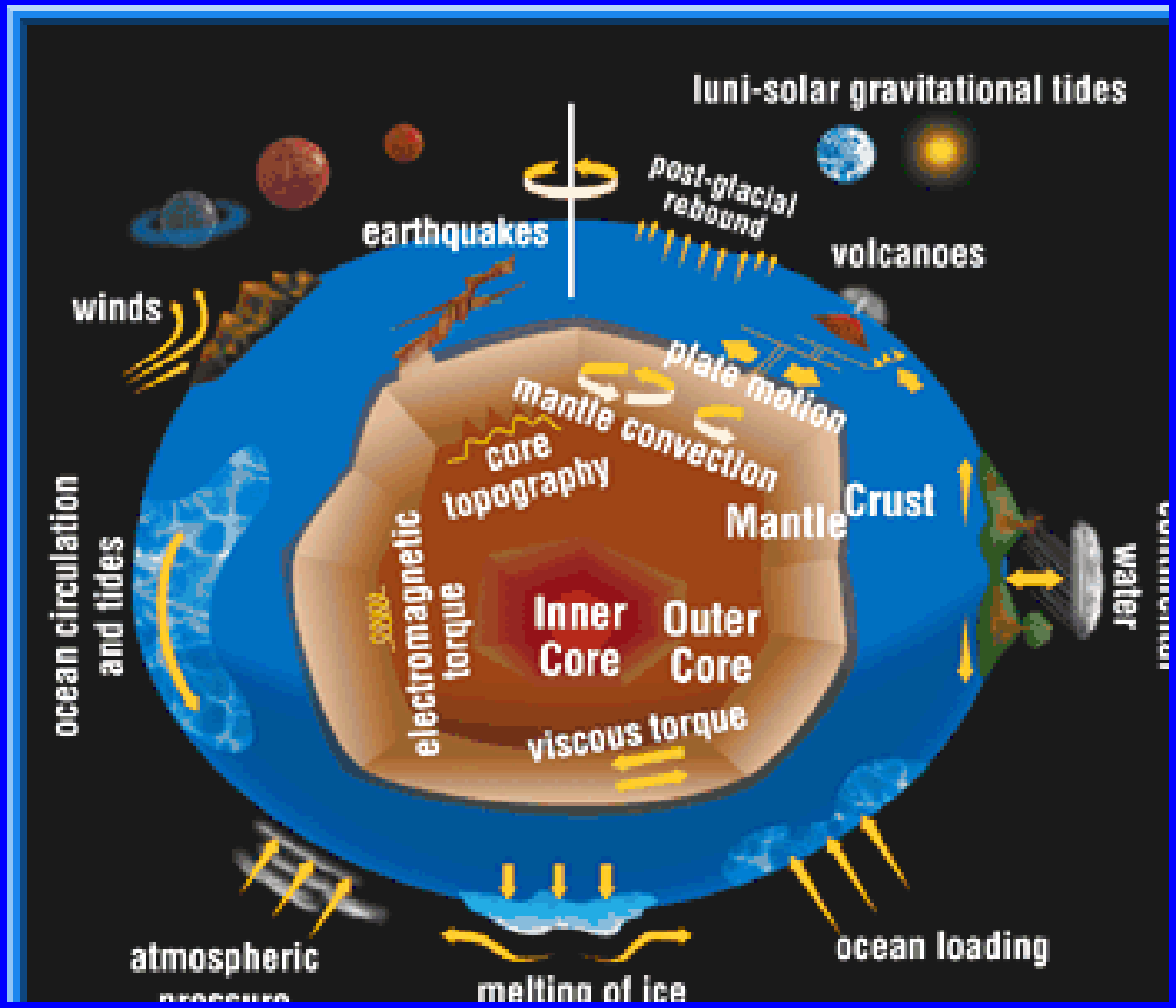
- UT1 : Time scale based on solar time

- UT1 time scale is strictly proportional to the Earth Rotation Angle (ERA) around the moving rotation axis (IAU 2000)

based on

- Paleontology (coral growth, bivalves growth, sedimentation, …)
- Ancient eclipses after – 700 BC
- Occultations of stars by the Moon (after 1860)
- Optical observations until 1972. Lunar Laser ranging (since 1969)
- Now mostly Very Long Baseline Interferometry (VLBI) since 1983
- UT1 accuracy: 5 μs

Phenomena contributing to deformation and variations in the Earth rotation



Earth rotation and long term geophysical processes

- Interaction Sun/Earth
- General circulation of the atmosphere, climate
- Waterground masses, seasonal and secular
- Postglacial rebound
- Free modes of the solid inner core, fluid outer core
- Free modes of the mantle
- Shape of the fluid outer core, torque core/mantle
- Circulation in the fluid outer core

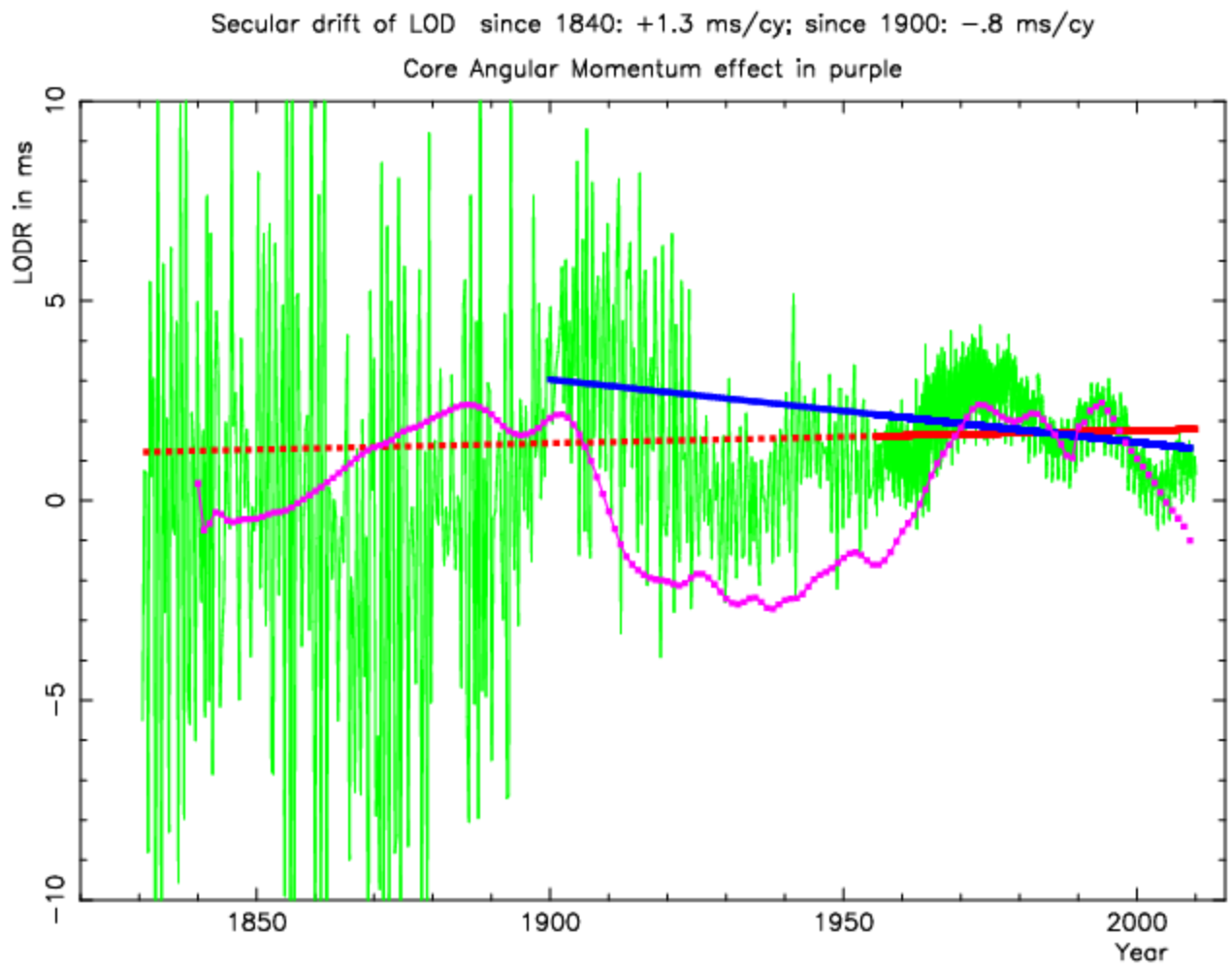
Physical processes

External torques

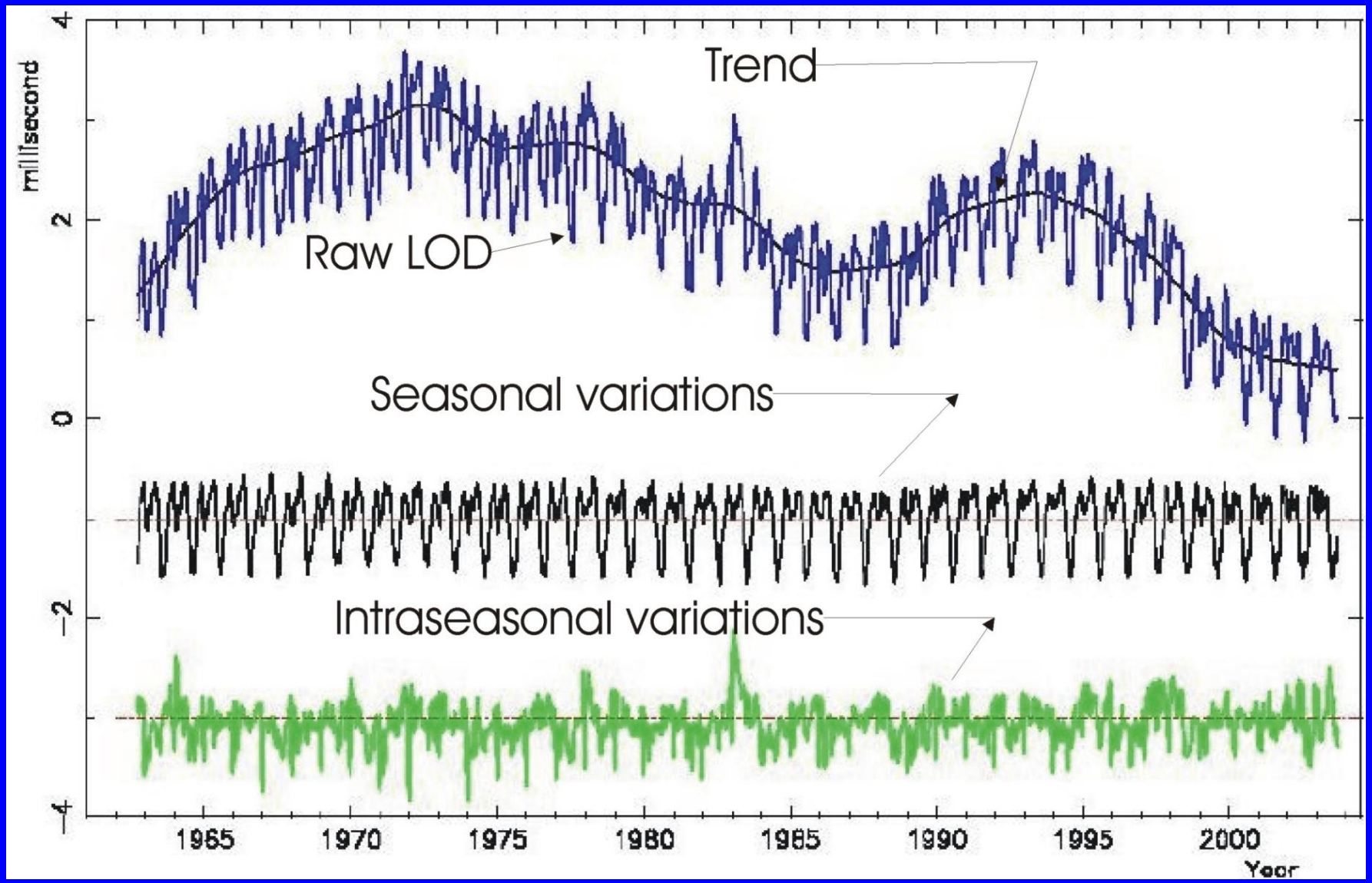
Changes in the earth momentum of Inertia (effect on polar motion)

Changes in the angular momentum (effect on rotation)

LOD variations since 1830



Filtering the LOD



Length of day Variations

Secular drift

Energy dissipation (~ 1.8 ms/century)

Post-glacial rebound (~ -.5 ms/cy)

Decadal fluctuations

Core/mantle torque (amplitude ~ 5 ms)

Global ocean-atmosphere processes

Variations from a few hours to about 2 years

Atmospheric causes (zonal winds) (amplitude ~ 1 ms)

Diurnal and sub-diurnal variations

Ocean, atmosphere (amplitude ~200 μs)

Atomic time

- Atomic Time since 1955
- Continuous atomic time scale of BIH, called TAI in 1971
- UTC with leap seconds was introduced on 1972 January 1 (CCIR 1970)
- UTC is maintained close to UT1 $|UTC-UT1| < .9$ s
- The UTC system is a good compromise to keep UTC close to UT1
- Leap seconds due to
  - The second is too short (definition from tropical year in 1850)
  - Secular drift due to lunisolar tides
  - Decadal fluctions due to core mantle interactions

Bulletin C and Bulletin D

- Bulletin C: prediction and announcement of leap seconds to be introduced in UTC to maintain | UT1-UTC | < 0.9s
  - 6 month prediction
  - Improve prediction capability ?
  - Method: LSQ +trend+ AR processes
  - Other methods in study (neural network)

Bulletin D : DUT1 = UT1-UTC truncated at 0.1 s

- 4-6 weeks prediction
- Seems obsolete but necessary for a bunch of users

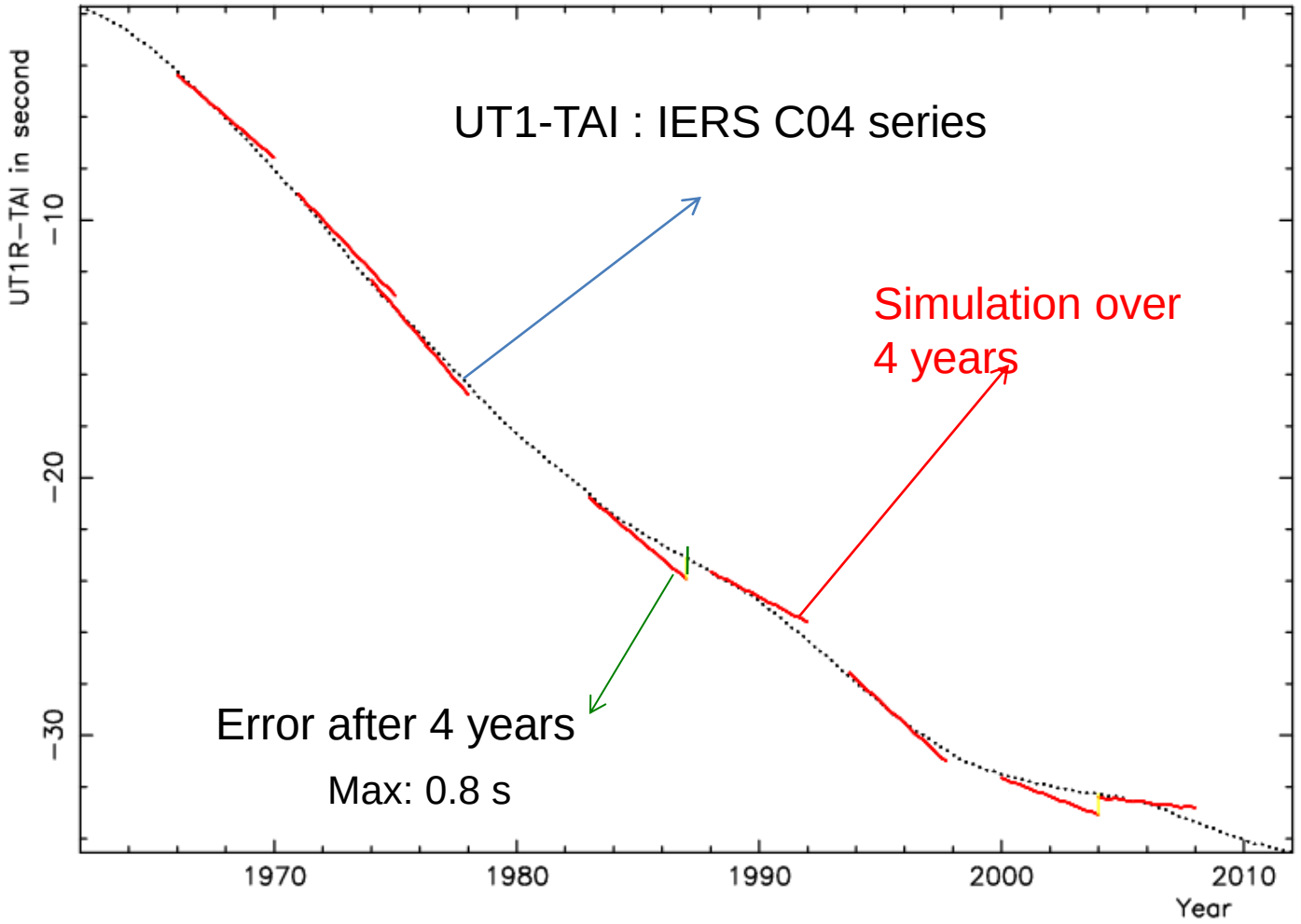
Communities of users of Bulletins C and D

Astronomy, astrophysics
Geodesy,
Orbit detrmination
Geophysics
Time Service laboratories
Computer centers
Radio signal laboratories
Radio-astronomy activities
Radio stationsPost and telecommunication
Hydrographic and oceanographic labs
Surveying and mapping institutes
Civil engineeringSpace research
Etc ……

IERS Surveys

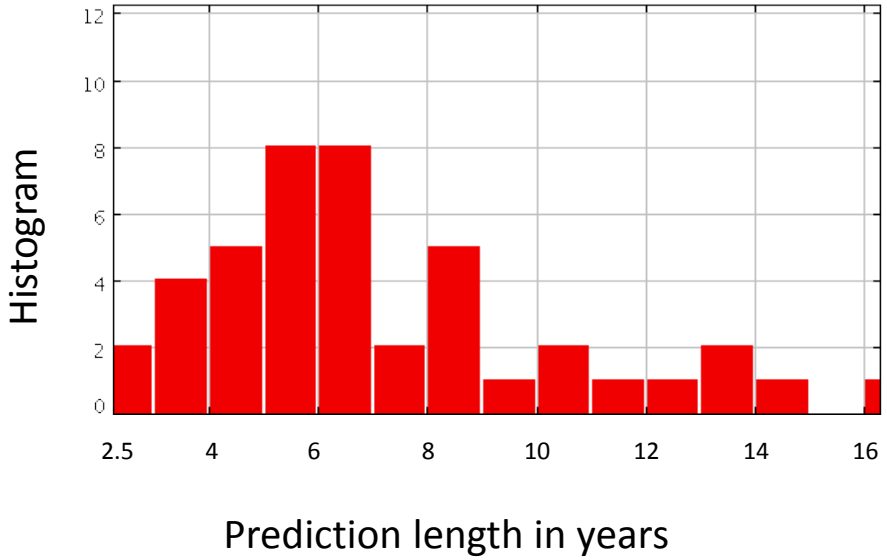
- 2002 and 2011 : IERS Surveys: 90% of users satisfied
- Many users asked for a longer time prediction

Simulation: forecasting leap seconds 1 to 15 years



Simulation on the Performance of the Usual Prediction

Prediction is better than 1 s: number of cases over 1966 - 2012



Neuronal Network: Perceptron vs NARX

- Perceptron: standard feed forward network that fits a relationship between input and target.

- NARX: (Nonlinear autoregressive with external input) learns to predict future values of a time series based in the past values of the series – input- and in another time series – external time series. It uses n delays, i.e. n points of the time series to predict the next value.

Mozilla Firefox

Fichier Édition Affichage Historique Marque-pages Outils ?

http://hpiers.obspm.fr/eop-pc/

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Useful constants
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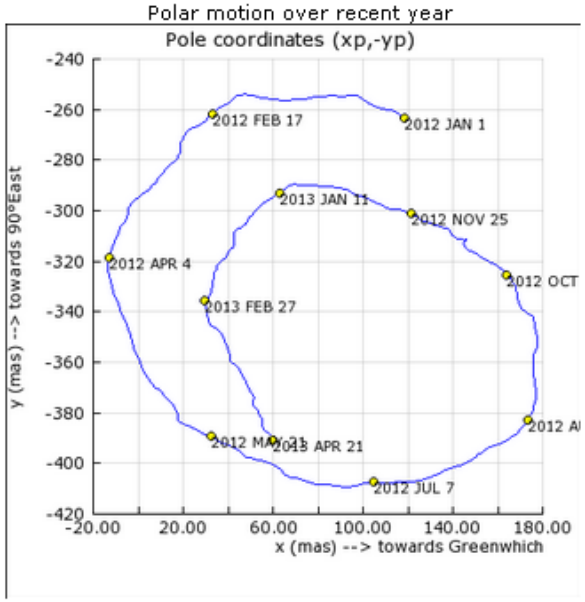
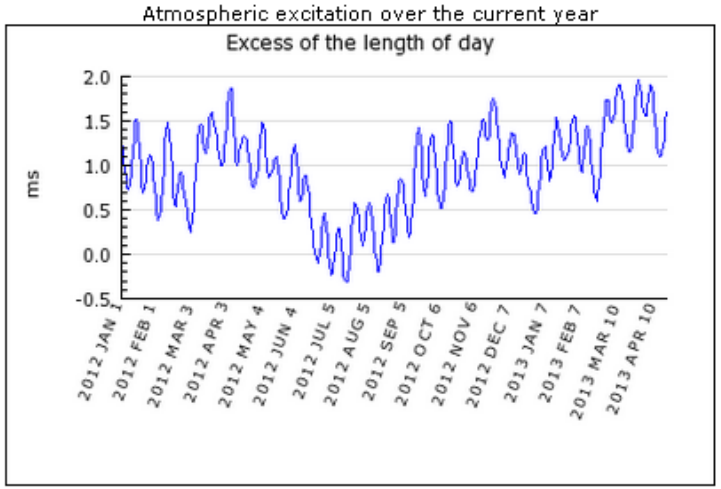
GEOPHYSICAL EXCITATION
LINKS

NEWS Decembrer 2011 : Only final C04 values are provided (30 days back





TAI - UTC : 35 s TAI - UTC history

Latest C04 values for polar motion and UT1 on **22 Mai 2013** at 0h UTC:

x= 98.35 mas y= 405.68 mas UT1-UTC= 84.444 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)

TAI-TUC History file

MJD	Date	TAI-UTC (s)
41317.	1 1 1972	10
41499.	1 7 1972	11
41683.	1 1 1973	12
42048.	1 1 1974	13
42413.	1 1 1975	14
42778.	1 1 1976	15
43144.	1 1 1977	16
43509.	1 1 1978	17
43874.	1 1 1979	18
44239.	1 1 1980	19
44786.	1 7 1981	20
45151.	1 7 1982	21
45516.	1 7 1983	22
46247.	1 7 1985	23
47161.	1 1 1988	24
47892.	1 1 1990	25
48257.	1 1 1991	26
48804.	1 7 1992	27
49169.	1 7 1993	28
49534.	1 7 1994	29
50083.	1 1 1996	30
50630.	1 7 1997	31
51179.	1 1 1999	32
53736.	1 1 2006	33
54832.	1 1 2009	34
56109.	1 7 2012	35

EOP now available in XML format user: GAIA

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- <FIELD datatype="double" name="DY" ucd="pos.nutation.eop.obl" unit="arcsec"/>
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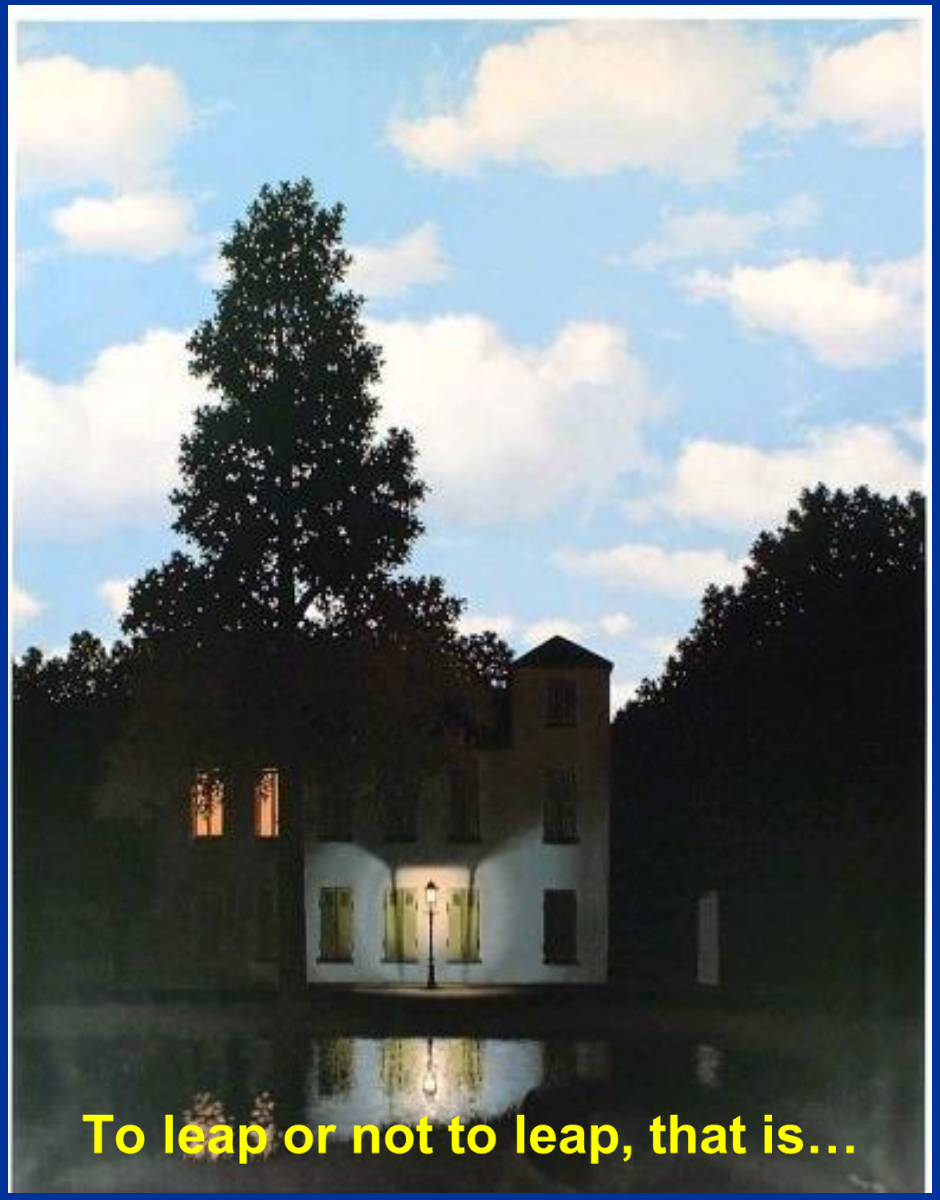
<TD>9.2E-6</TD>
<TD>1.8E-4</TD>
<TD>1.08E-4</TD>

Summary

- 3 year prediction at 95% possible
- Accuracy limited by the effect of the core mantle coupling
- Even if leap second disappears, necessary to monitor and forecast UT1-UTC
- Web/ftp Service implemented in various formats (VO table, XML)



Magritte