Geodetic and geophysical use of geocenter time series

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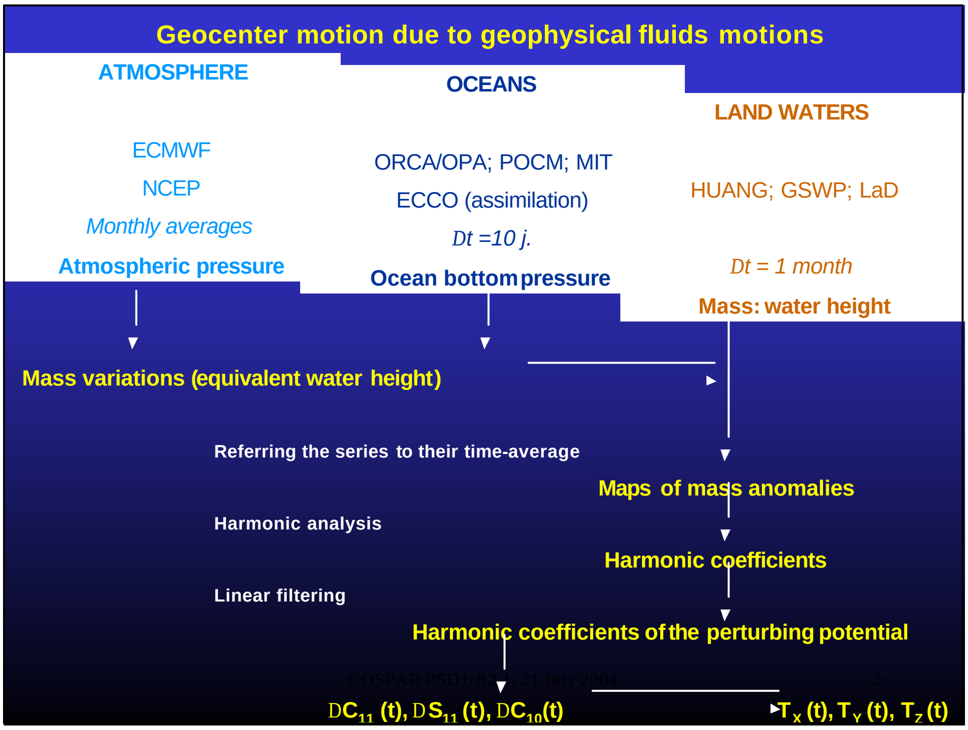
A contribution to the qualification of Terrestrial Reference Frames

- Geophysical fluids time series
- Satellite geodesy time series
- Characteristics of the extracted seasonal components
- Signal spectral density law

Acknowledgements: Z. Altamimi (IGN/LAREG), C. Luceri (ASI), L. Soudarin (CLS), P. Willis (IGN-JPL)



Geodetic time series describing geocenter motion

The times series at daily, weekly or monthly intervals are obtained by either of the following equivalent methods.

Geometric method: Tx, Ty, Tz

Translation parameters between the ***successive terrestrial reference frames*** and a conventional TRF (here ITRF2000).

Dynamic method: C_{11}, S_{11}, C_{10}

Estimated ***degree-one terms*** of the spherical harmonic expansion of the gravitational potential.

C_{11}, S_{11}, C_{10} are proportional respectively to Tx, Ty, Tz

Geodetic results used here were obtained by the first method.

The time series of geophysical and geodetic series analysed

Data span	Series	Model / Technique	Interval	Author
Geophysics				
1979-2002	Atmosphere	NCEP	month	G. Ramillien
1993-2002	Ocean	ECCO	10-day	G. Ramillien
1981-1998	Land waters	LAD	month	G. Ramillien
Geodesy				
1993-2002	lcamd02	DORIS	month	L. Soudarin
1993-2004	ignwd05	DORIS	week	P. Willis
1993-2003	SLR(ASI)	SLR	week	C. Luceri

Time series referred to ITRF2000 by the CATREF algorithm (Z. Altamimi)

1. Seasonal components

A - Seasonal components extracted by the Census X11 filter.

This filter splits a time series into three components:
- *trend,*
- *cyclic + harmonics* and
- *irregular.*

Filter involves only running averages and reweighting of outliers.

The only constraint on the cyclic component is a fixed period.
Component analysed here: cyclic (annual + semi-annual + ...)

B – Least squares analyses, removing bias, trend and semi-annual

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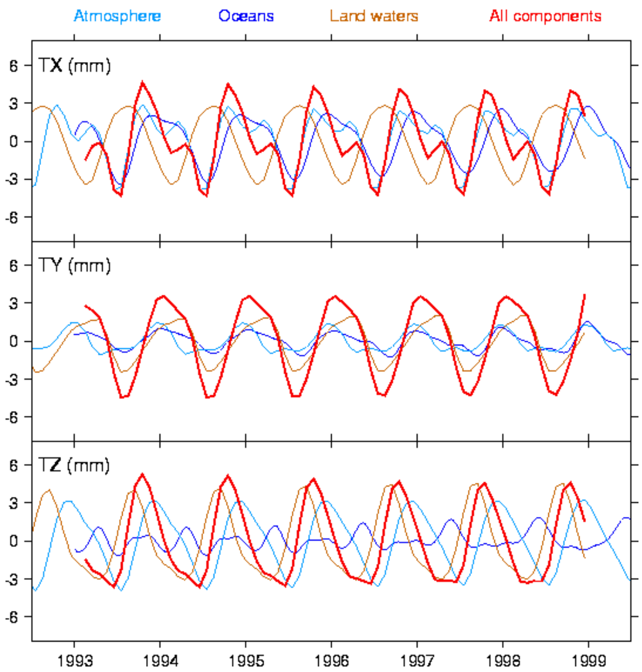
Annual variations: Summing up the geophysical components

Similar total amplitudes as a result of agreement/disagreement of phases

Semi-annual contribution of oceans and atmosphere in TX

10 mm peak to peak



Annual variations: geodetic measurements

TX

Agreement in phase of the two Doris solutions, not in amplitude

Disagreement Doris-SLR

Variable amplitude for the Doris solutions

TY

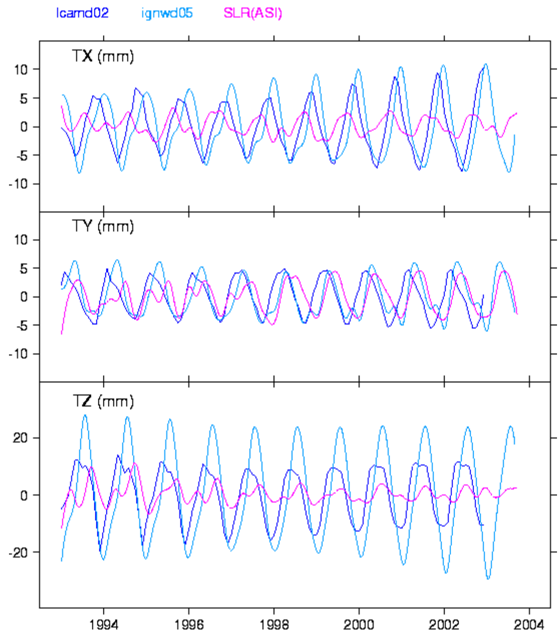
Similar in the three series

TZ

Agreement in phase of the two Doris solutions, not in amplitude

Disagreement Doris-SLR

10-55 mm peak to peak



Annual variations: geophysics vs geodesy

TX

Doris(Ica) matches the geophysics annual but misses the semi-annual

SLR and Doris(ign) variable and out of phase wrt geophysics

TY

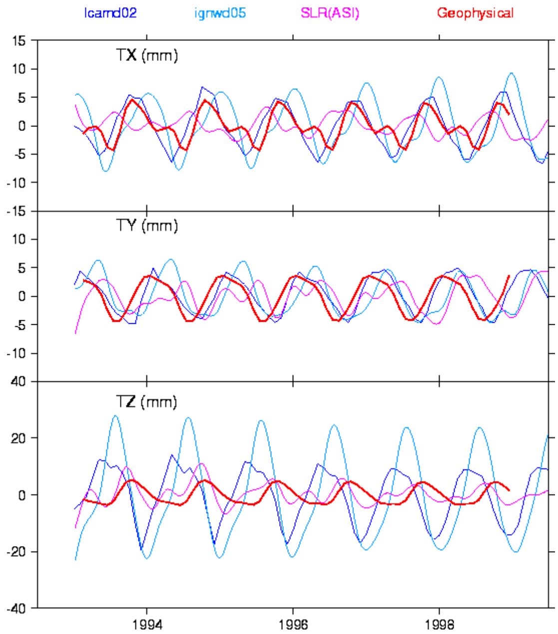
Doris(Ica) matches the geophysics annual

SLR and Doris(ign) variable and out of phase wrt geophysics

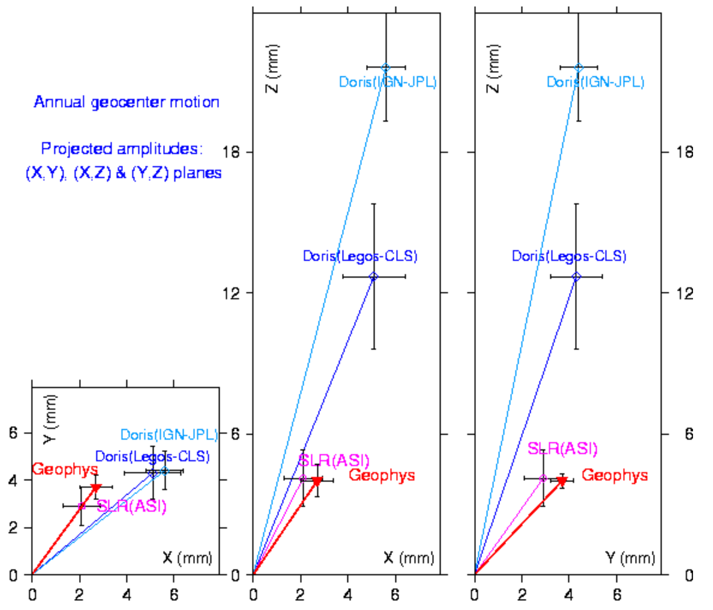
TZ

Best matching for SLR

Doris solutions dominated by other annual signatures



Annual variations 1993-1998



2. Spectral density laws

Investigation of the density law(s) of the geocenter signal.

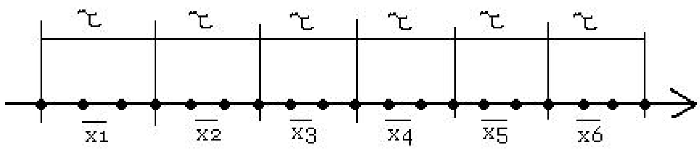
Tool: the Allan variance, a spectral estimator commonly used to qualify and quantify the stability of atomic clocks.

It offers diagnoses for spectral density laws such as

- *white noise*,
- *flicker noise* (spectral density ~1/frequency) and
- *random walk* (spectral density ~1/squared frequency).

Allan Variance

- X_i is a time series with sampling time t



- Allan Variance : $s_x^2(t) = \frac{1}{2} < (\overline{x}_{k+1} - \overline{x}_k)^2 >$
- Variation as a function of the sampling time :

$$\log(s^2(t)) = m \log(t),\ pour\ t = t_0, 2t_0, 4t_0, ...$$

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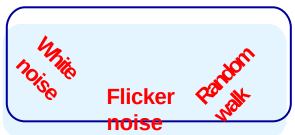
Allan Variance and spectral density law

- For a process with spectral density law $S_x(f) = h_a f^a$

$$s_x^2(t) = \frac{1}{card(I) t_0} \sum_{i \in I} S_x(f_i) \frac{2 \sin^4(p t f_i)}{(p t f_i)^2}$$



- Type of noise :
  - $a = 0$ ⇔ **white noise** ⇔ $m = -1$
  - $a = -1$ ⇔ **flicker noise** ⇔ $m = 0$
  - $a = -2$ ⇔ **random walk** ⇔ $m = 1$

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Signal spectrum: geophysical components

Ocean

. Annual component imbedded
in **high frequency white noise**

. **X: Low frequency random walk**

Atmosphere

. **X, Y:** Annual component imbedded
in **high frequency white noise**

. Weak signal in Y

. **Low frequency white noise**

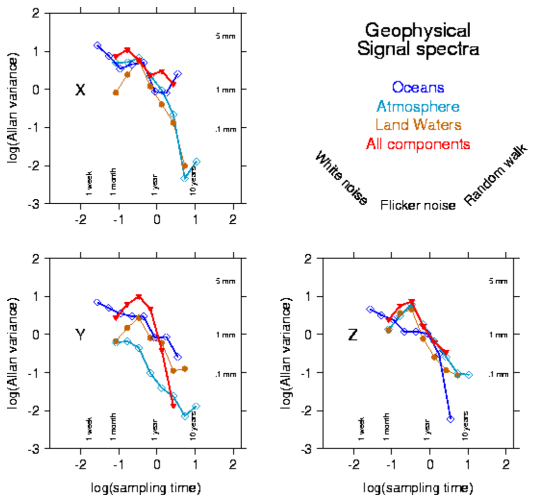
Land waters

. Little signal outside annual

All components

. **X:** Annual component imbedded
in **white or flicker noise**

. Y, Z: Little signal outside annual



Signal spectrum : geodesy vs geophysics

DORIS

.**X, Y:** Annual component imbedded
in **white/flicker noise**

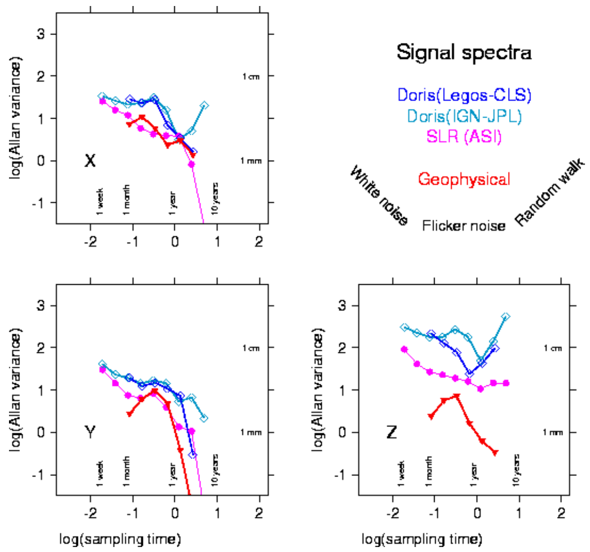
. **Z:** high level **flicker noise**

SLR

X: Annual component
imbedded in **flicker noise**.

Y: Annual component
slightly above **white noise**.

Z: Medium level **flicker noise**



What do seasonal geocenter motions tell us about TRF stability?

- **Atmosphere+Ocean+Land Waters variations => geocenter motions**
  - Spectral density dominated by seasonal signature, except for the oceans, where flicker noise is predominent, esp. in low-frequency X.
  - Accuracy of predicted motion difficult to assess
- **Observed geodetic seasonal geocenter motion:**
  - Large seasonal differences between solutions and techniques
  - Seasonal signal hidden by flicker noise, except SLR-Y
- **Geodesy vs geophysics**
  - **Seasonal**
    - **SLR in good agreement with geophysical prediction**
    - **DORIS:**
      - X (mainly oceans): both solutions too large (factor of 2)
      - Y (mainly land): agreement with geophysics and SLR
      - Axial: inflated amplitudes (factor > 3) but different in the two solutions
  - **Spectral**
    - **High-level geodetic flicker noise**
      - **indicates long term TRF instabilities**
      - **makes further interpretation problematic**