



Precise kinematic GPS Method and applications

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EO Summer School

Frascati, 14 August 2014

Content

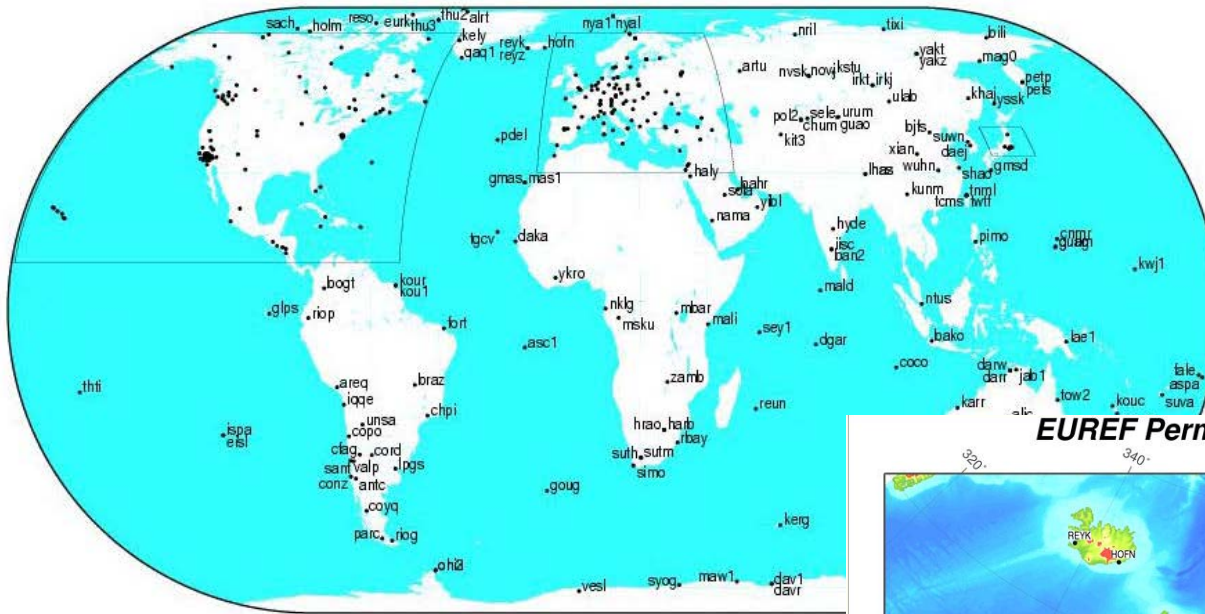
- GPS satellites and networks
- Basics of the principles
- Orbits (and their crucial role)
- Static (and continuous) observations
- Kinematic observations (not real-time)
- Analysis of the observations of August 12, 2014

GPS – The space segment

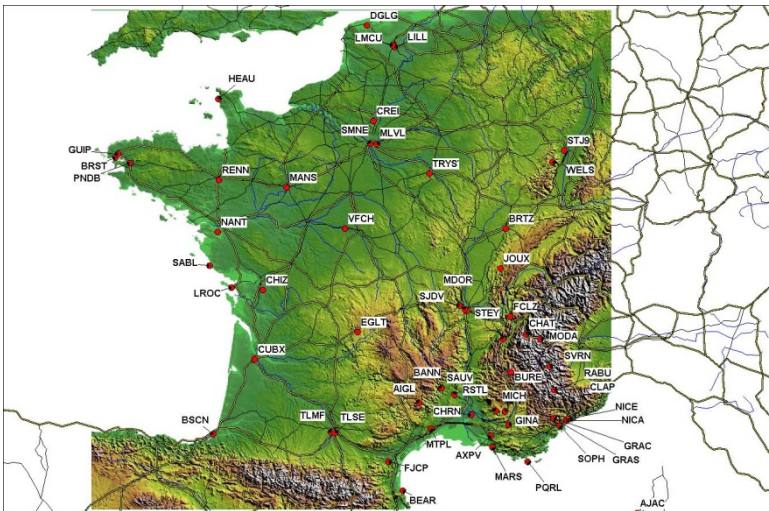
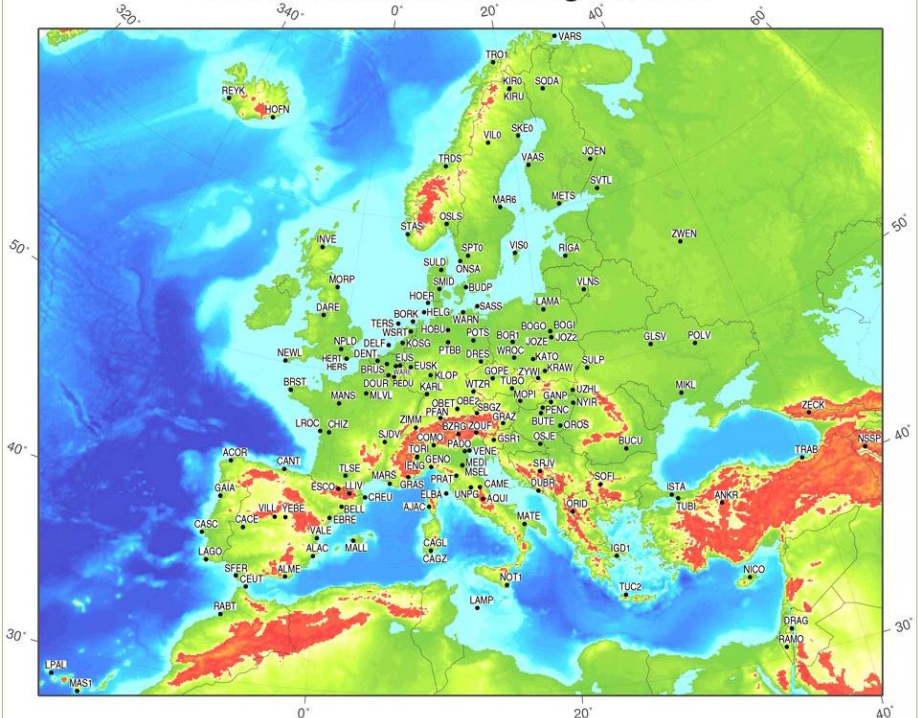
- 24 satellites
- 26000km from the Earth centre
- 2 orbits/day
- Six orbital planes:
 - Inclination 55°
 - 4 satellites / orbite



GPS – The ground segment (control and users)



EUREF Permanent Tracking Network



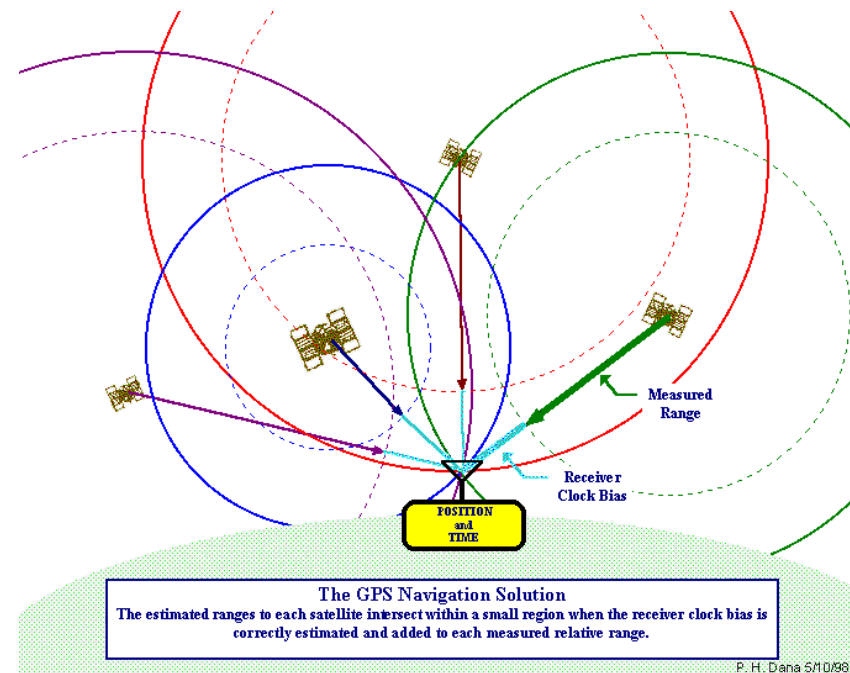
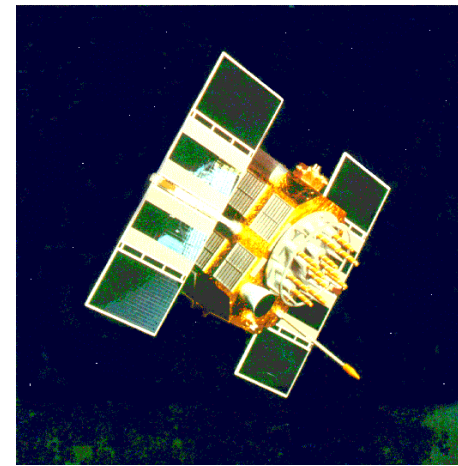
« Static » observations

- GPS antenna attached to the ground
- The measurements can be
 - continuous (permanent station)
 - repeated (campaign observations)



Basic principle of the GPS positioning

- The satellite have accurate clocks and each satellite transmits its time
- The positioning is based on the analysis of the difference of the arrival times of the signals at the receiver
- The satellites orbits must be known



Determination of the position of a receiver

The absolute coordinate of an antenna is determined using the following equations:

$$(x_1 - X)^2 + (y_1 - Y)^2 + (z_1 - Z)^2 = c^2(T_1 - T - dT_r)^2$$

$$(x_2 - X)^2 + (y_2 - Y)^2 + (z_2 - Z)^2 = c^2(T_2 - T - dT_r)^2$$

$$(x_3 - X)^2 + (y_3 - Y)^2 + (z_3 - Z)^2 = c^2(T_3 - T - dT_r)^2$$

$$(x_4 - X)^2 + (y_4 - Y)^2 + (z_4 - Z)^2 = c^2(T_4 - T - dT_r)^2$$

etc..

Parameters to be estimated:

- X,Y,Z: coordinates of the phase centre of the receiver antenna
- dTr : shift between the satellites time and the receiver clock

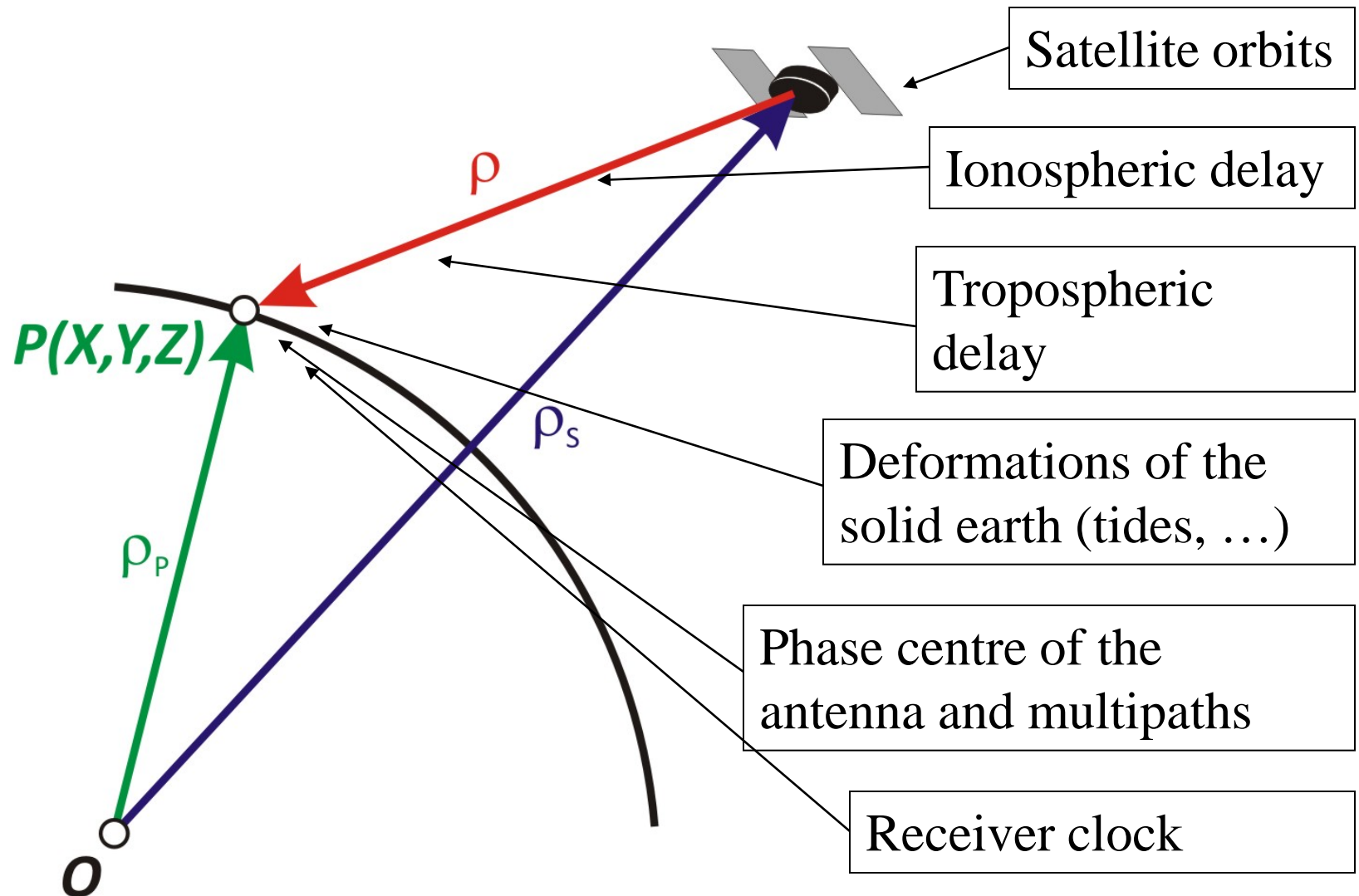
Data:

- x_i, y_i, z_i : coordinates of the satellites as a function of the « system » time T

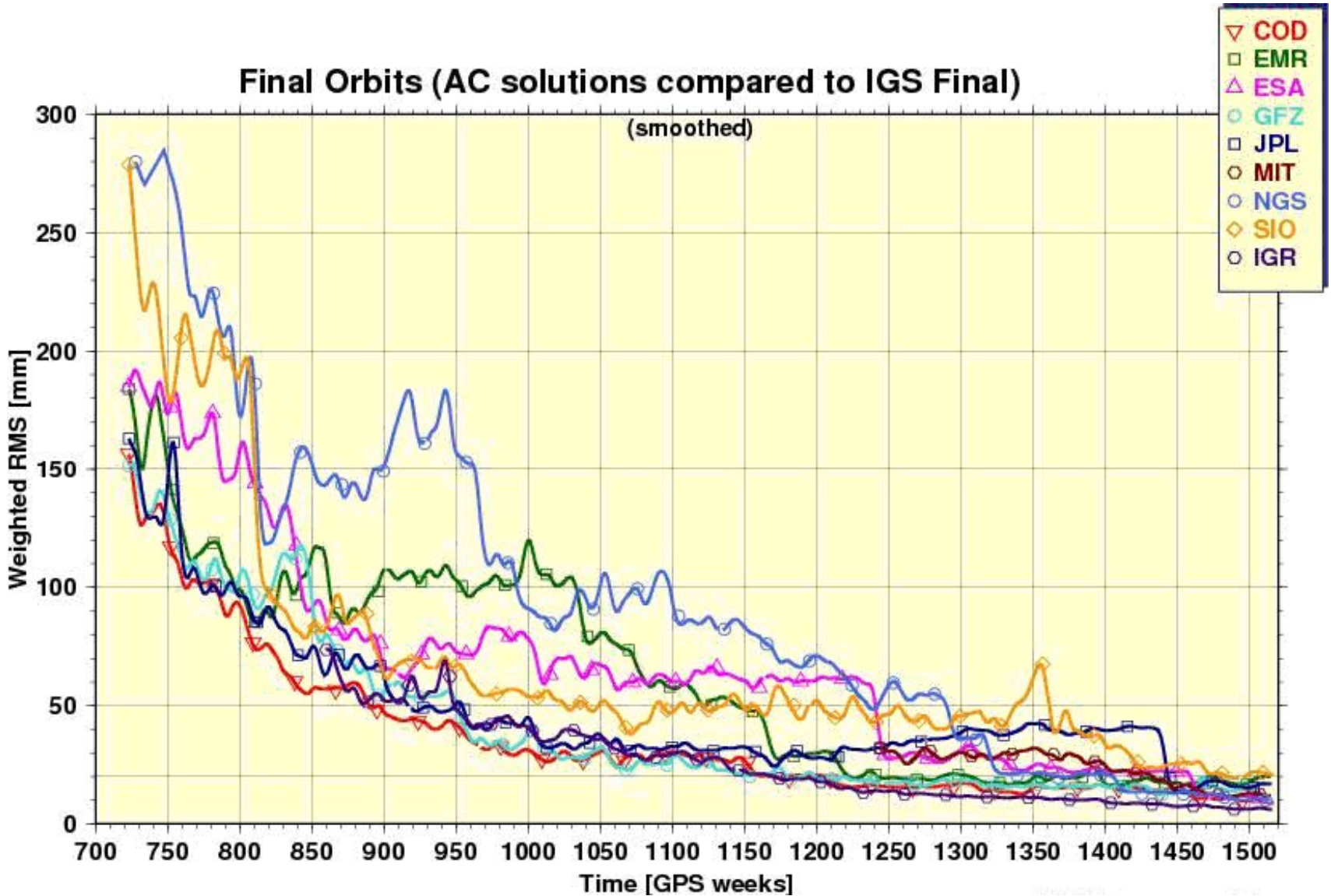
Observations made by the receiver:

- T_i : arrival time (in the receiver time scale) of the signals transmitted by the satellites at « system » time T

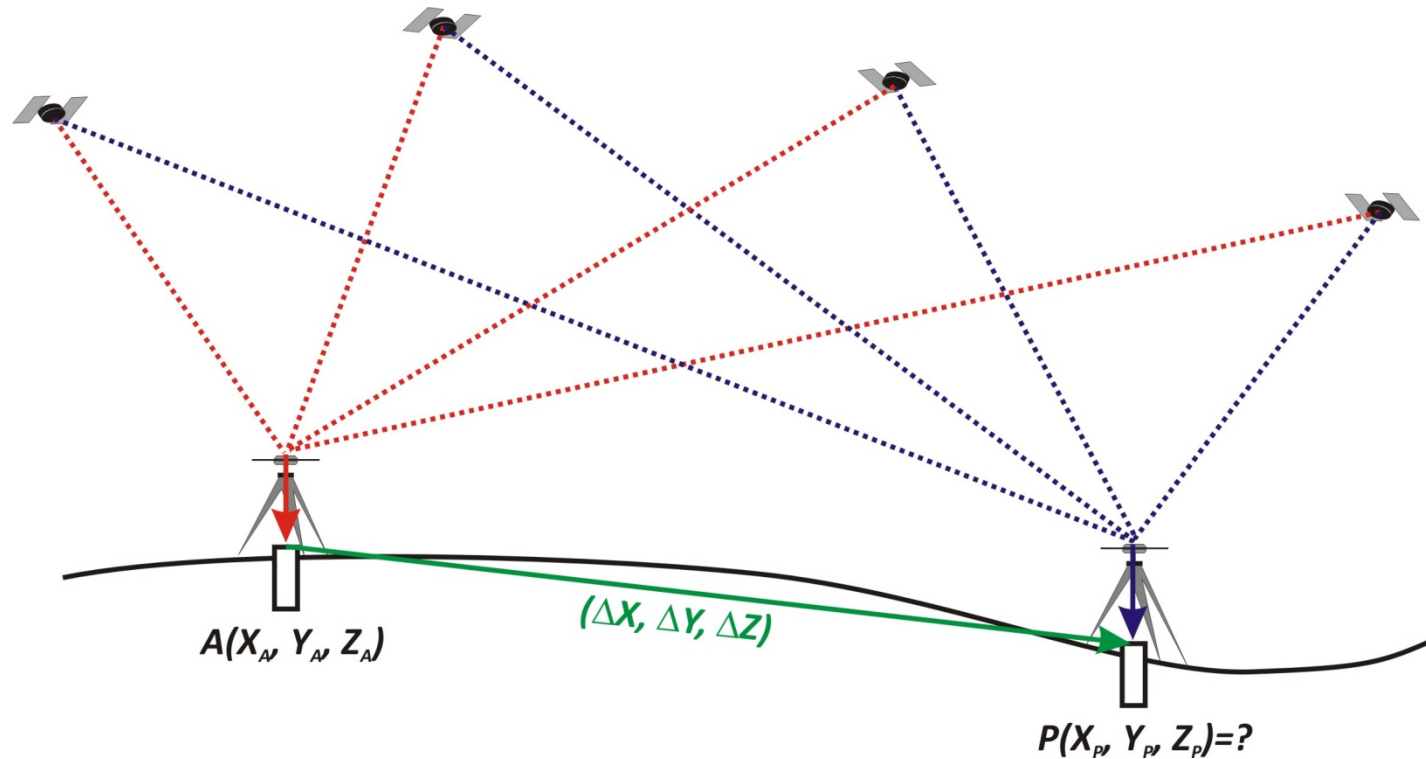
The propagation of the signal must be accurately modelled



Evolution of the accuracy of the GPS orbits calculated with the data of a « core » GPS network)



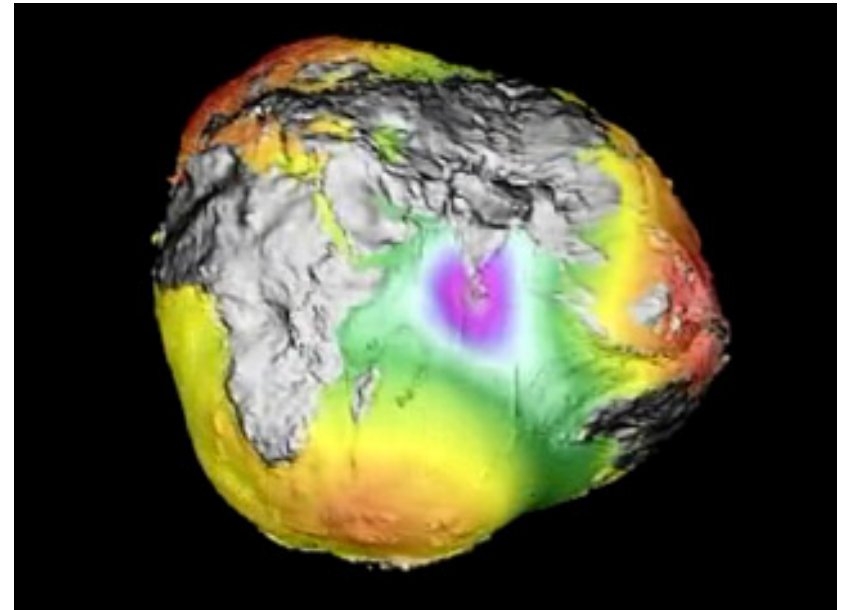
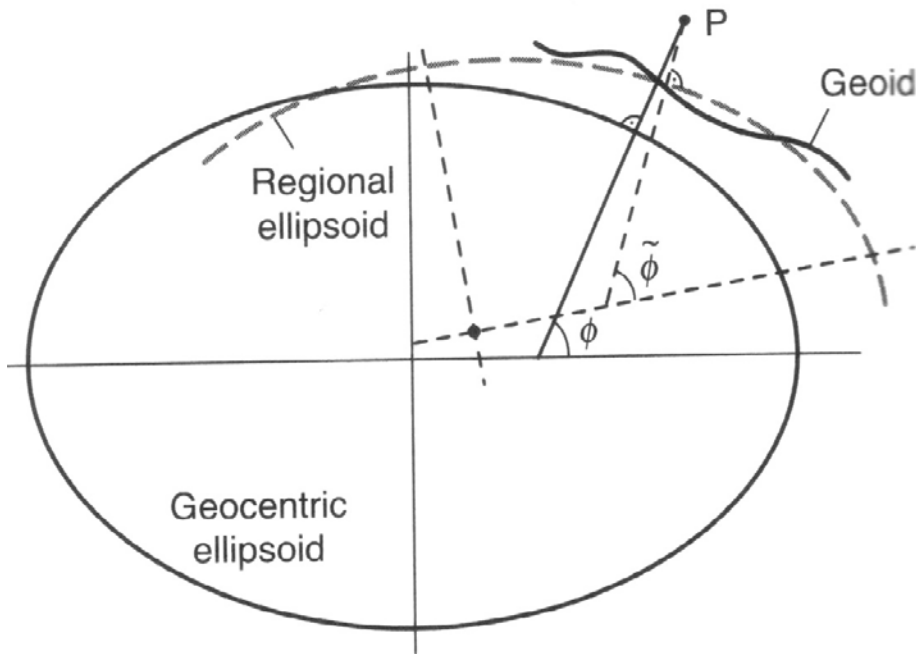
Differential (relative) positioning



Eliminates (or reduces) the effect of error sources, like:

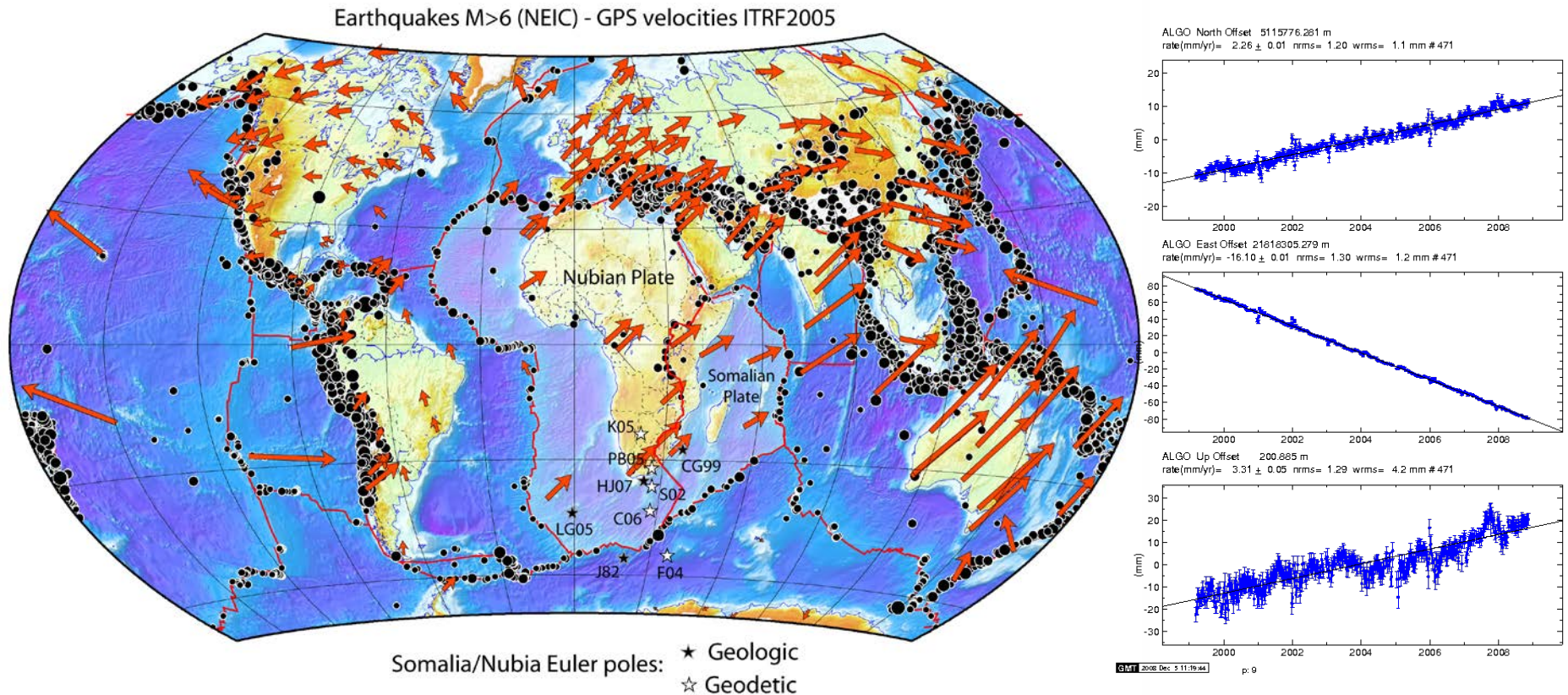
- orbit and clock error;
- tropospheric error (for short baselines)

Ellipsoid v/s Geoid



- Géoide = equi-potential surface (complex shape) : 0 ~ mean sea level
- Ellipsoid = simple mathematical surface used in the definition of the global coordinates systems
- For a given point, latitude, longitude and altitude (elevation) are different from an ellipsoid to another
- Ellisoidal height and Altitude (above Geoid) are different

Plate velocities determined with GPS

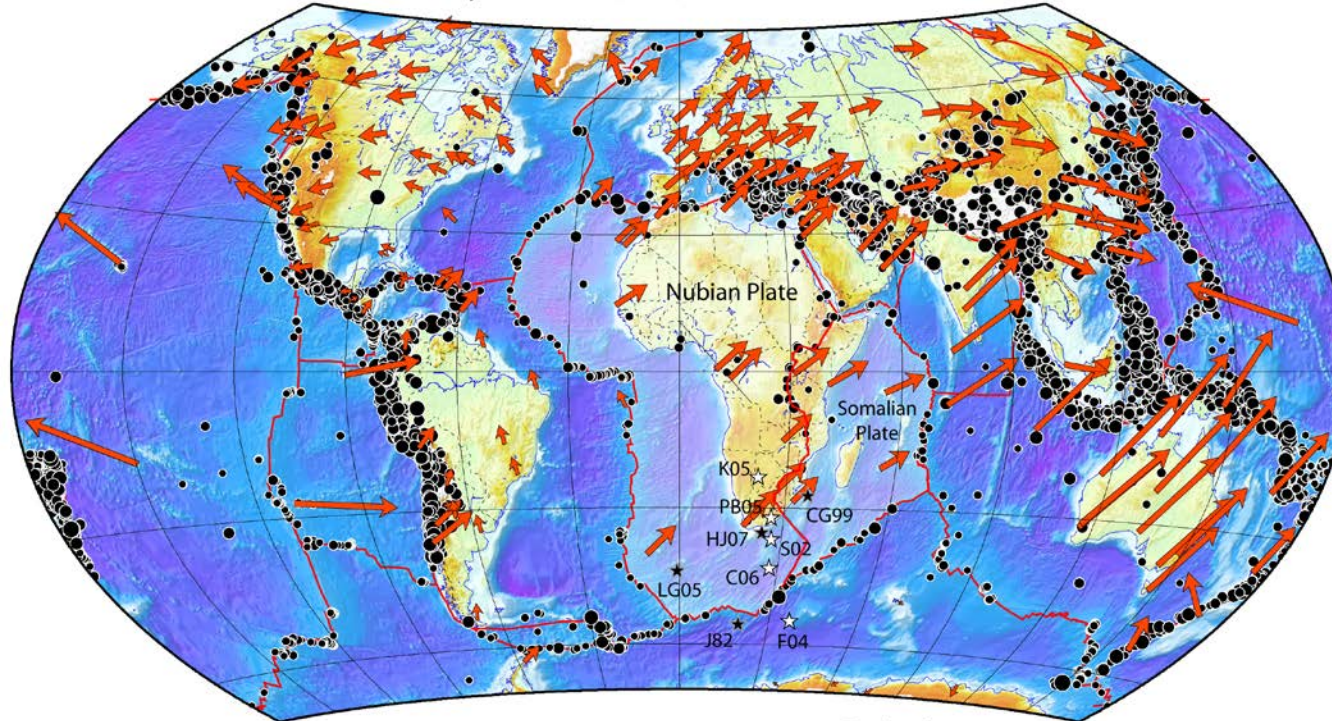


The available time series of coordinates at several thousands of permanent stations allow th map the global plate tectonics of Earth

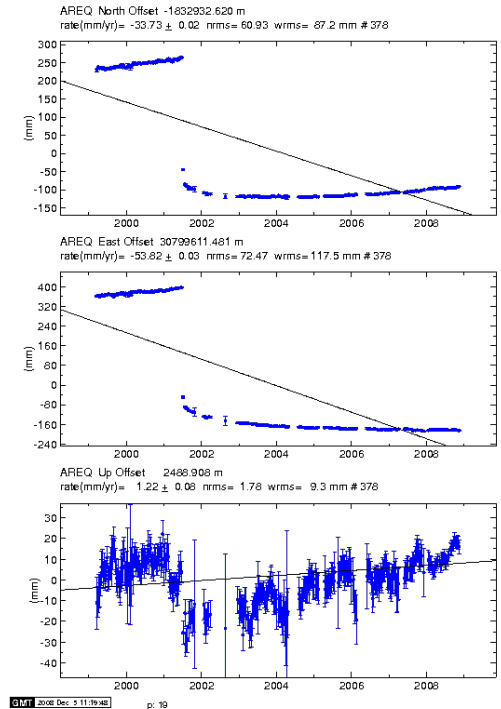
Velocities plotted with respect to a « Earth mantle » reference frame (defined using the location and trajectory of the hot-spot volcanoes

There are velocity transients

Earthquakes M>6 (NEIC) - GPS velocities ITRF2005

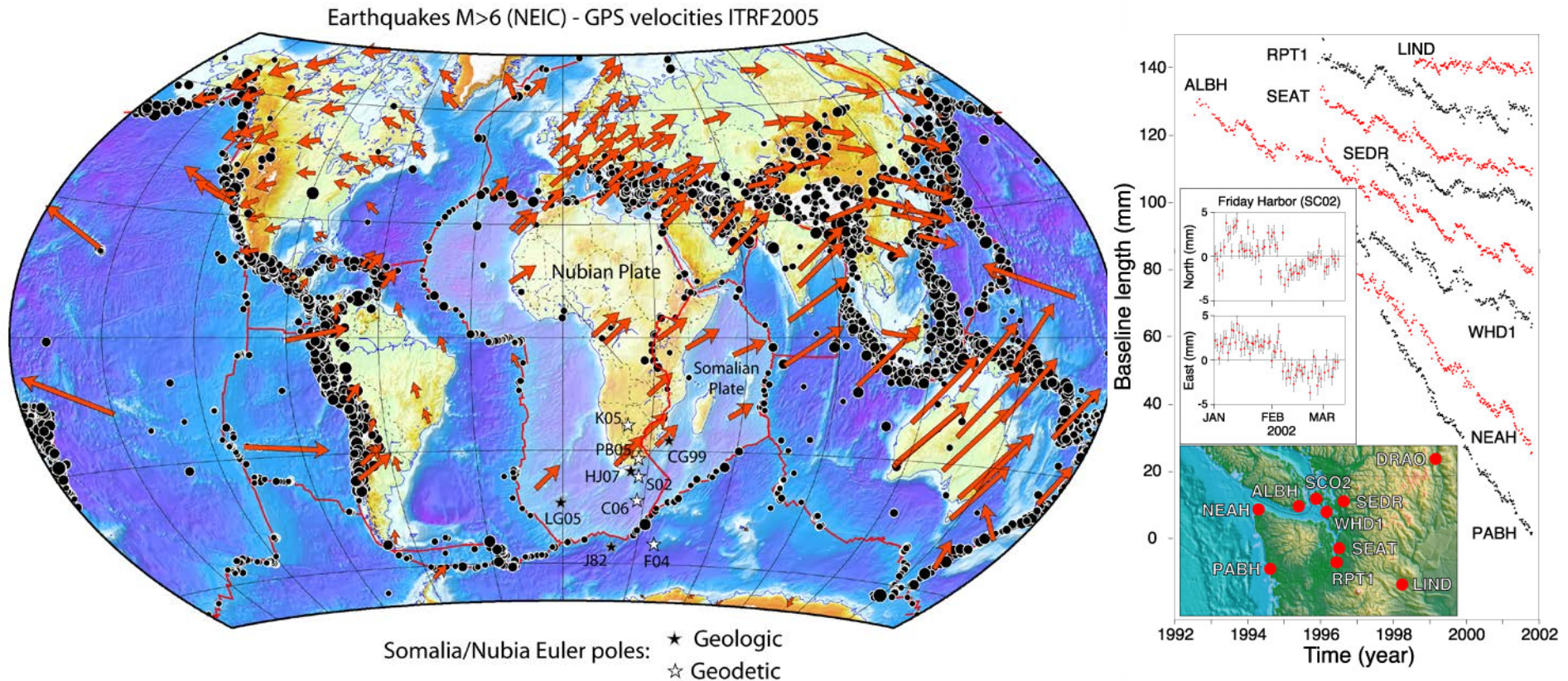


Somalia/Nubia Euler poles: ★ Geologic
☆ Geodetic



Associated with earthquakes (here a subduction earthquake in Peru in 2001)

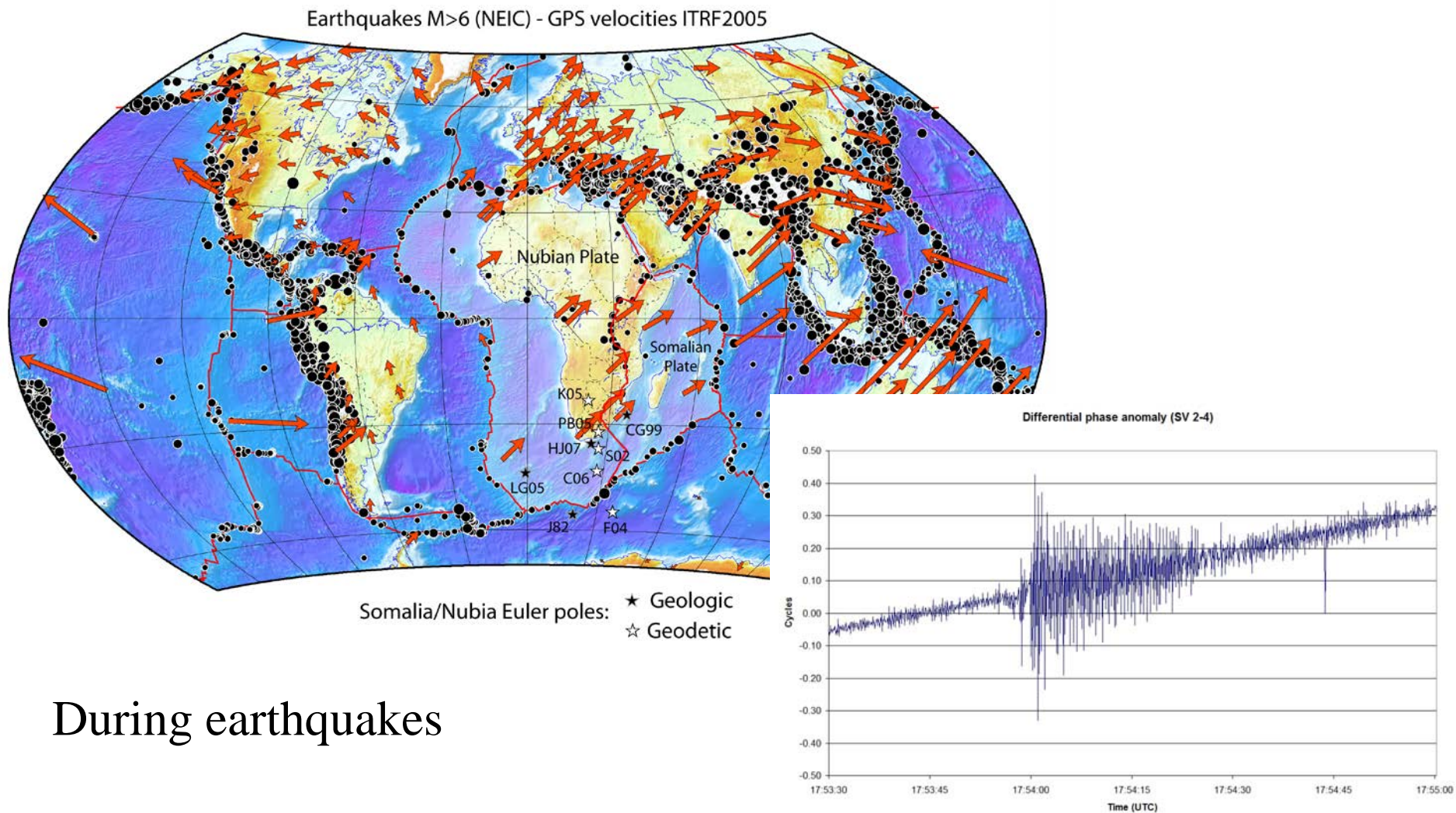
There are velocity transients



Velocities gradients measured by GPS in the Cascades (USA) (Miller et al., 2002)

Showing the (previously unknown) existence of “silent” earthquakes

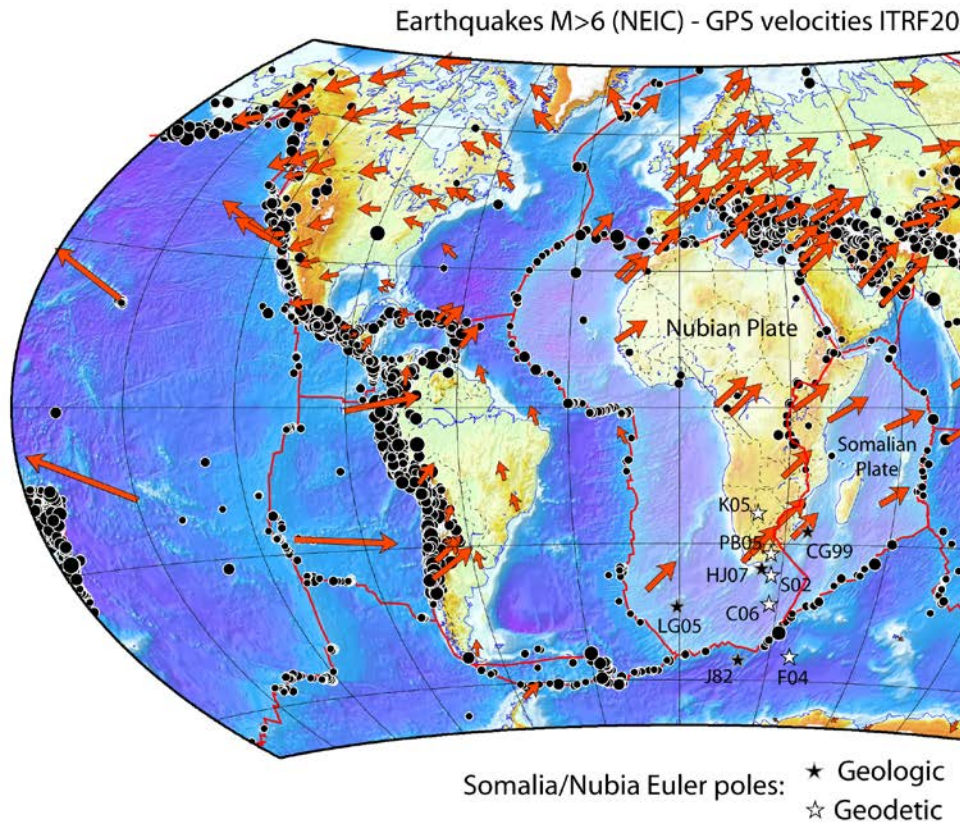
There are coordinates transients



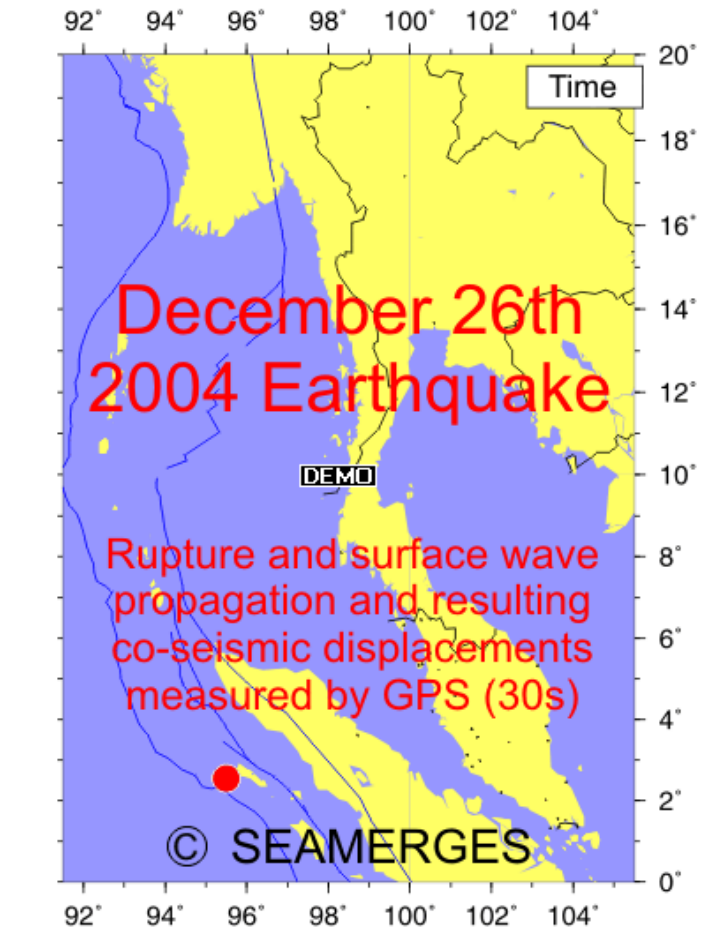
During earthquakes

Aysen earthquake, Chile (M=6.2), 21 April 2007, C. Vigny, ENS

There are coordinates transients



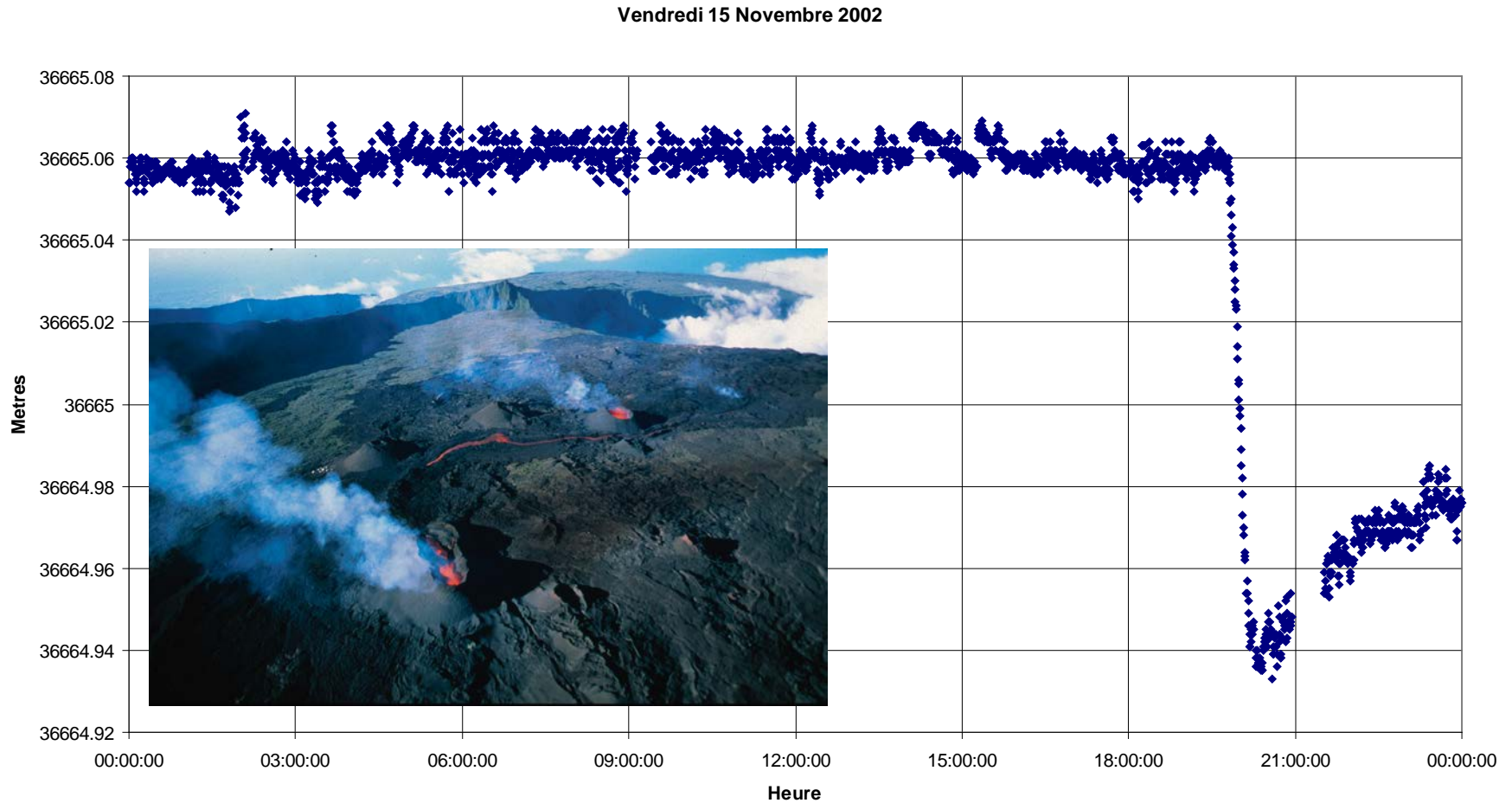
During earthquakes



<http://www.deos.tudelft.nl/seamerges>

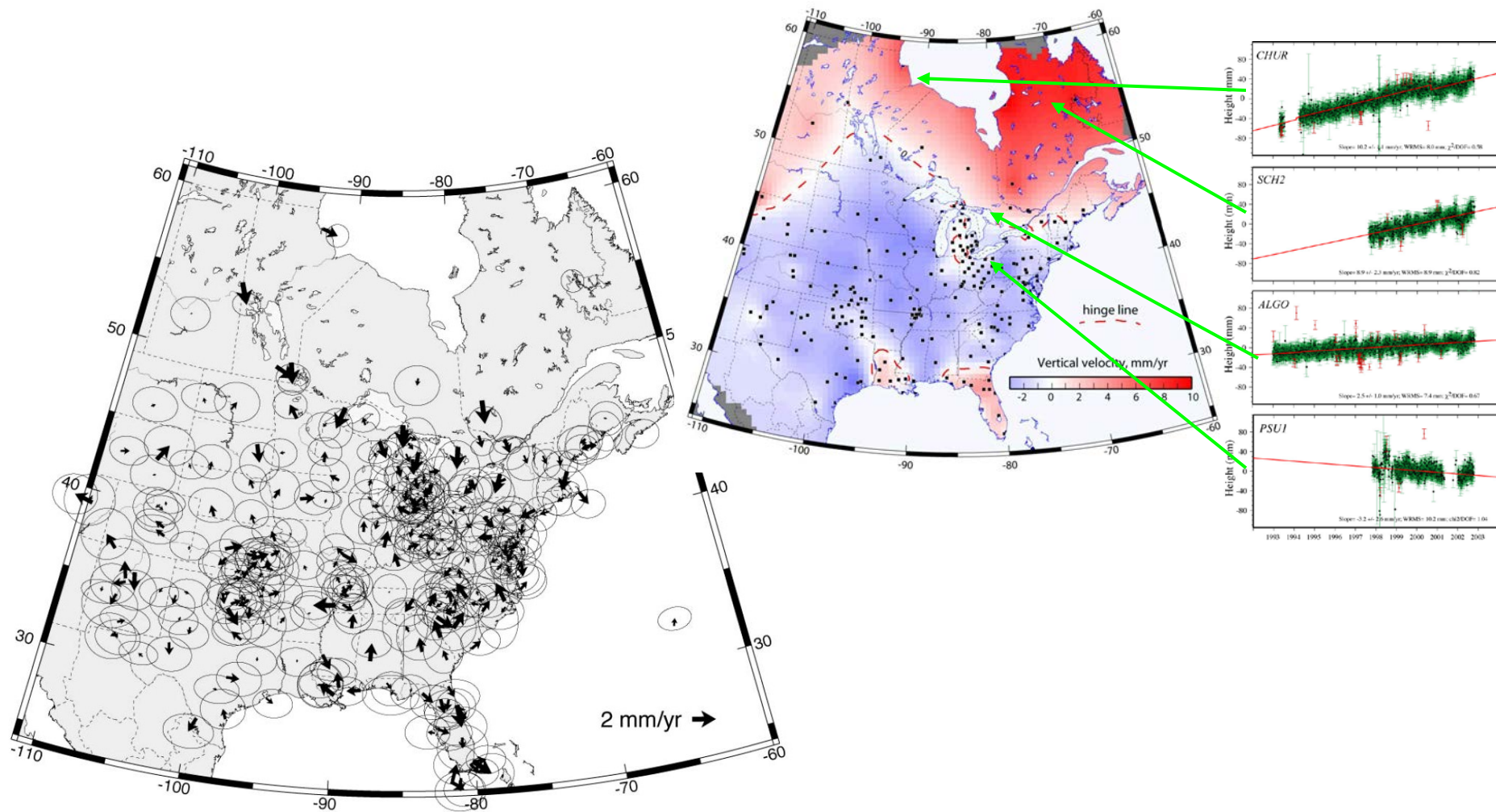
GPS displacements during the Sumatra earthquake (2004)

Transient GPS displacement during the start of a volcanic eruption



Deformation associated with a dyke injection at Piton de la Fournaise volcano (France)

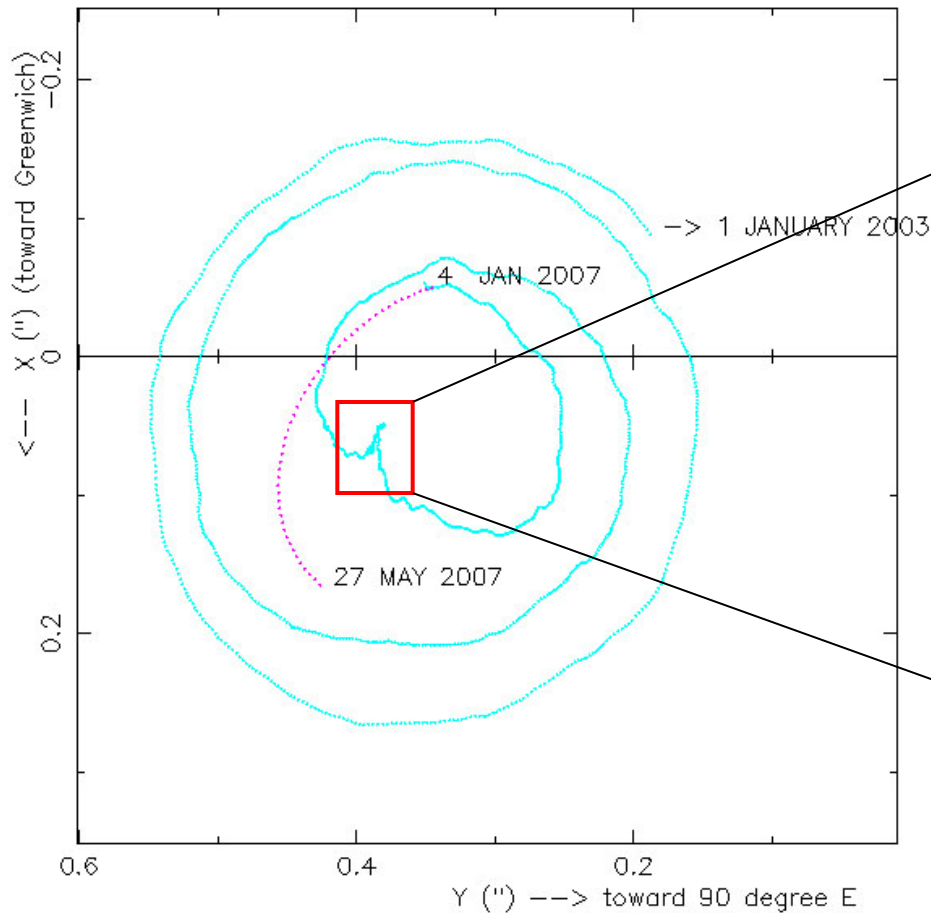
Post-glacial rebound



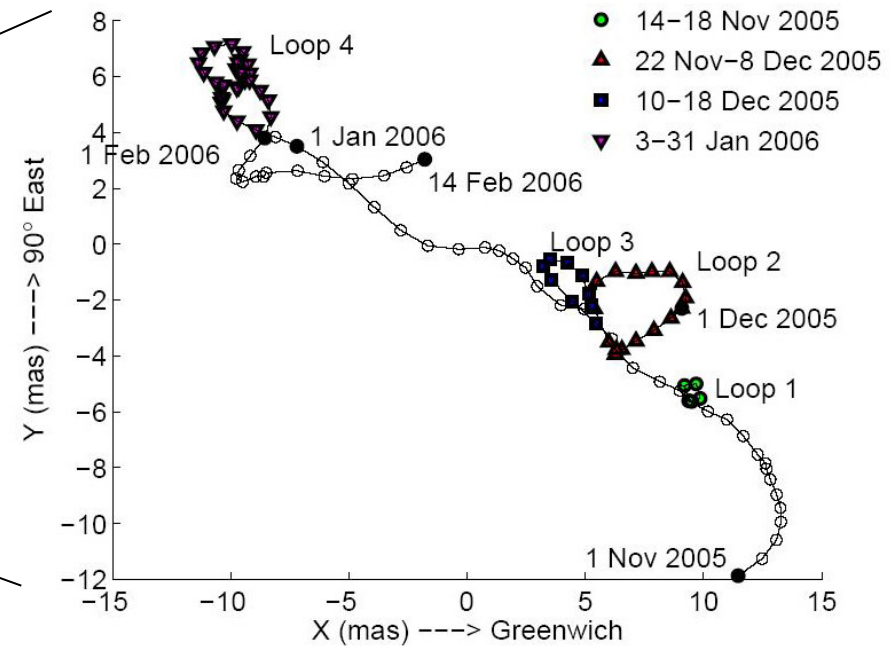
Deformation of the North American Plate Interior from a Decade of Continuous GPS Measurements E. Calais et al., JGR, 111, 2006

Variations of the Earth rotation

POLHODY 2003–2007, Prediction in green



IERS – Solution C04



Lambert et al., GRL, 2006

The small loops are interpreted as due to the motion of large atmospheric masses (meteorological effect)

Sounding the plume of Miyake-jima volcano (Japan) using GPS

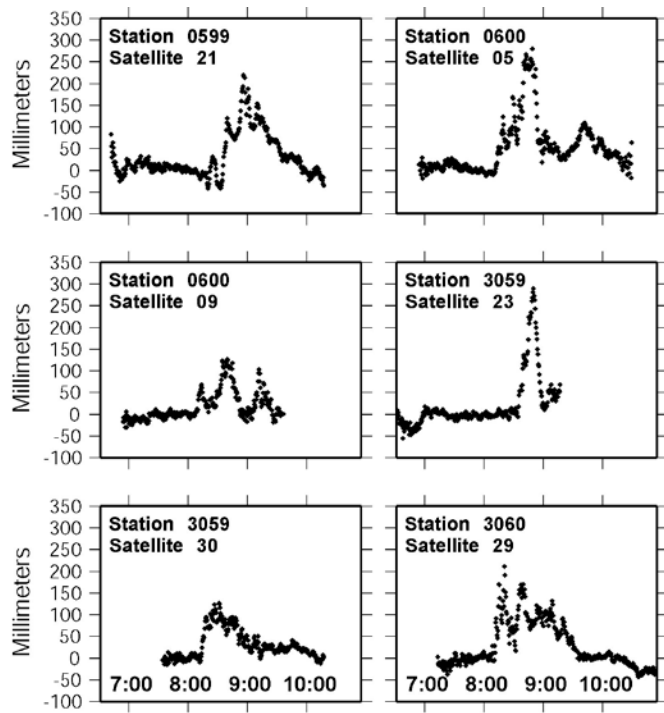


Figure 4

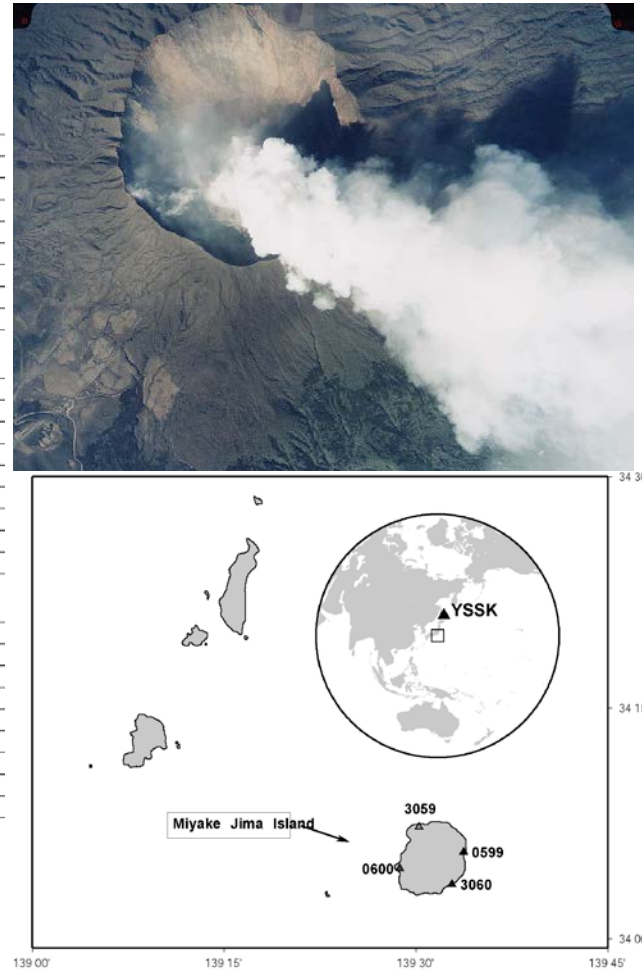


Figure 1

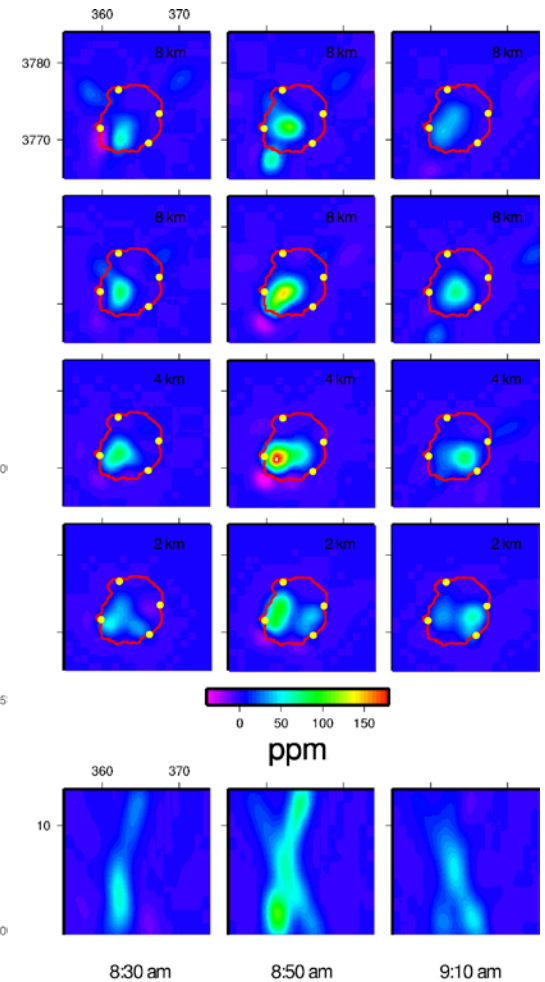
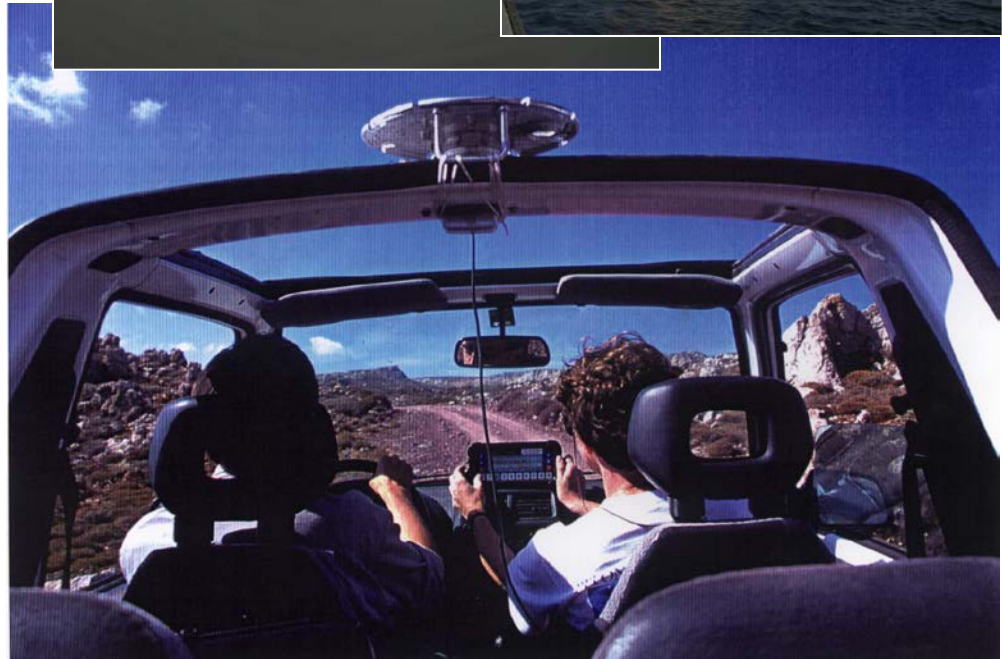


Figure 5

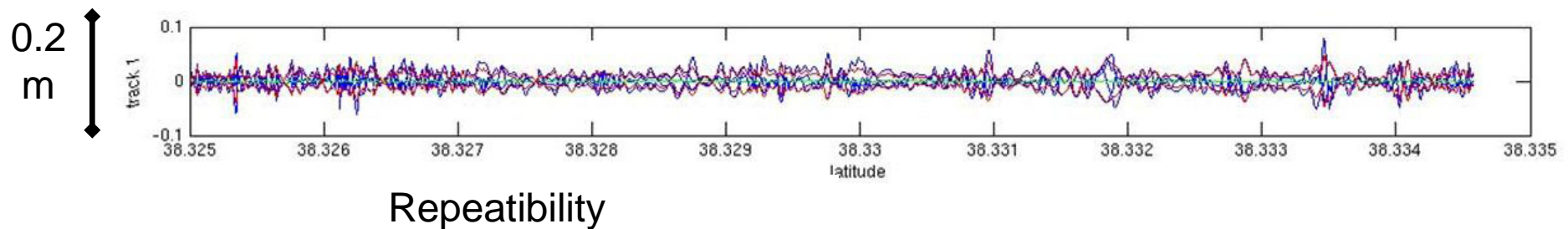
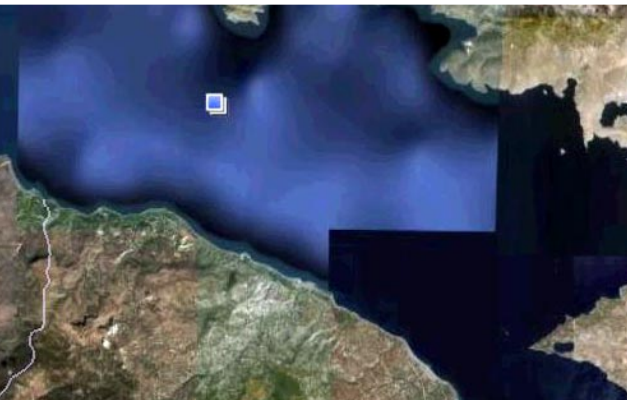
Kinematic GPS



Need to define a reference surface and an average antenna height with respect to it

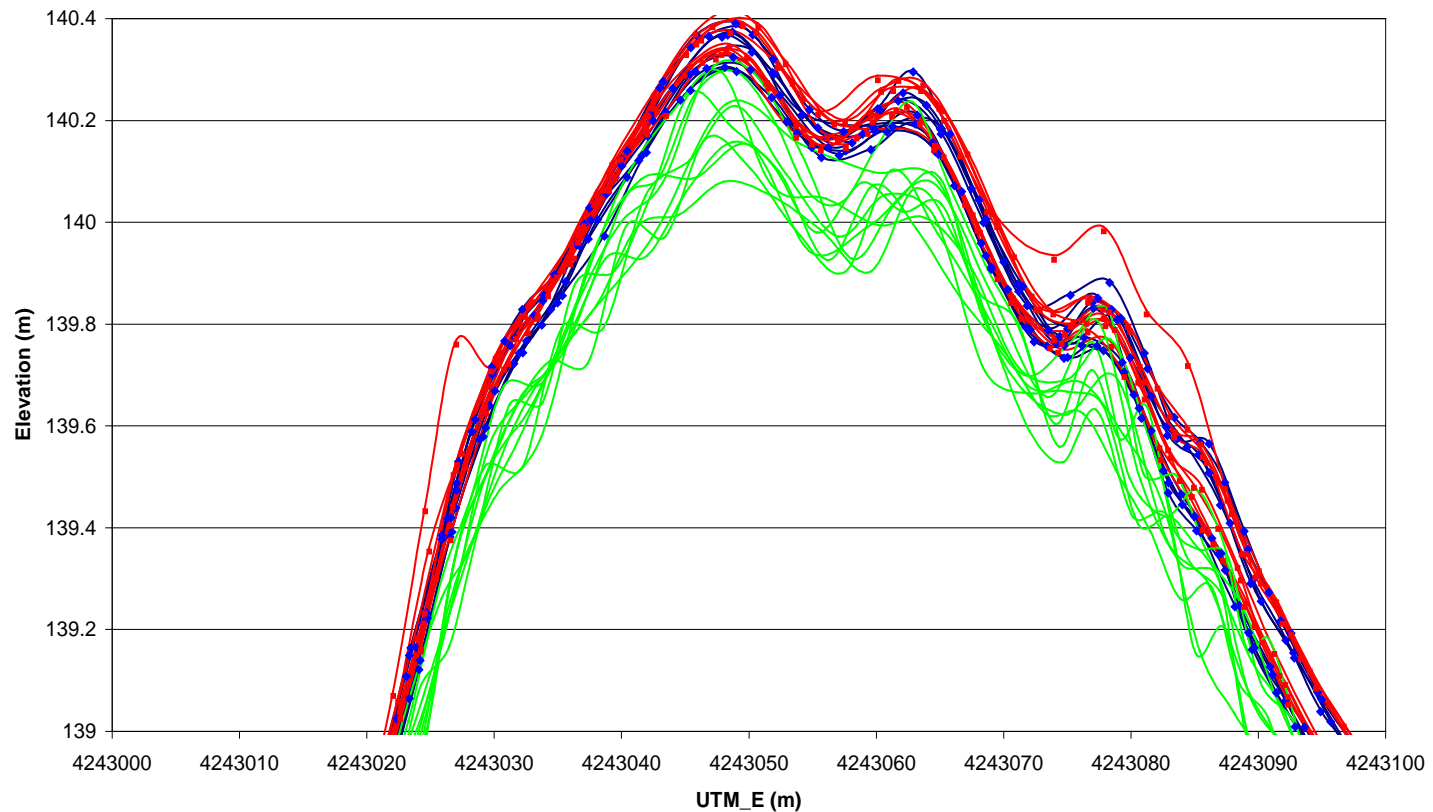


« Road » kinematic



Kinematic GPS - Simulated displacement + noise 10cm r.m.s.

Kinematic GPS survey - 1/10/99

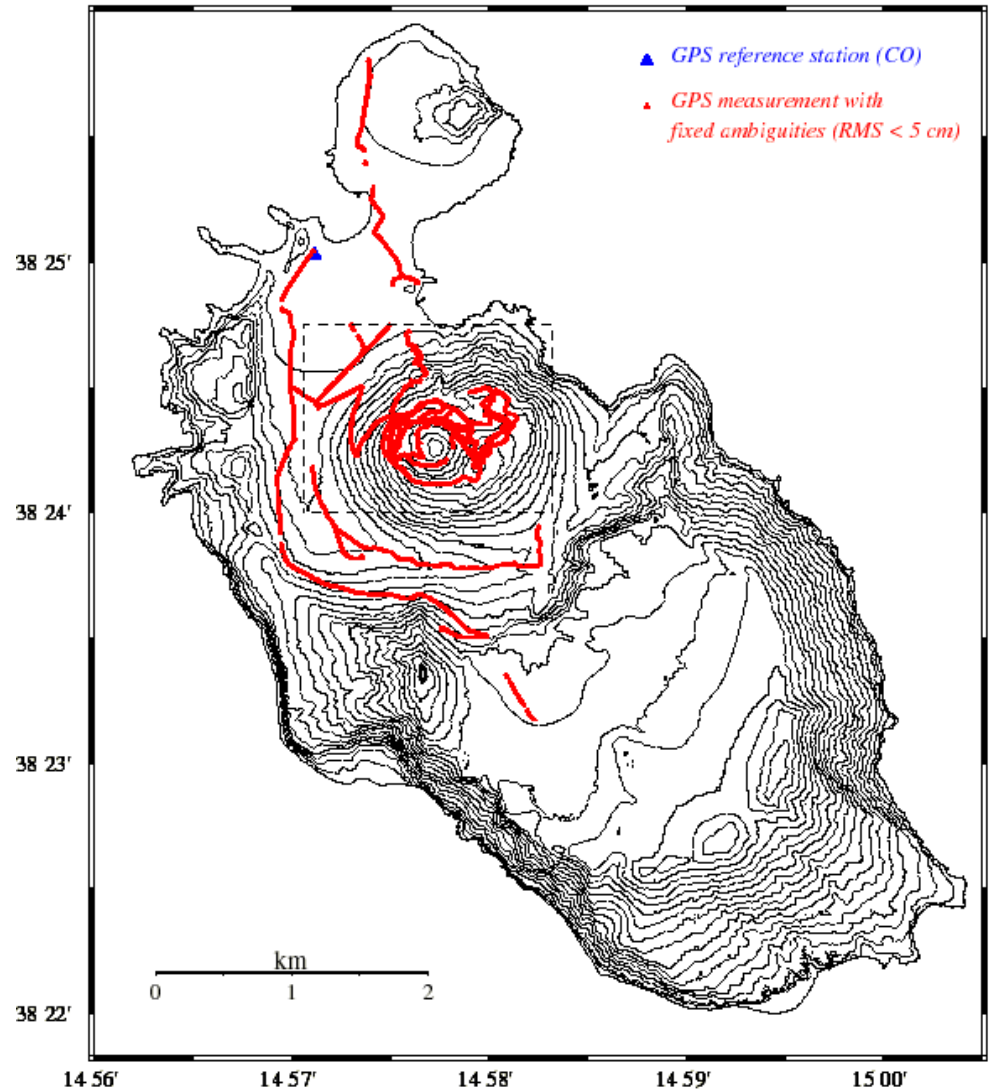


Topography measurements



Vulcano kinematic GPS survey (June 4-8, 1997)

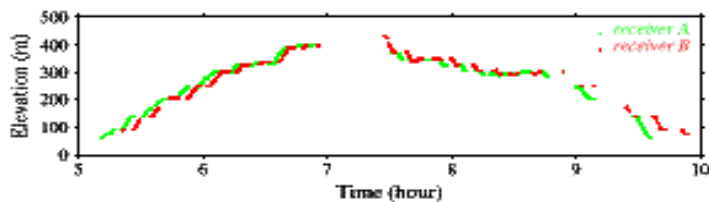
Distribution of GPS profiles (days 155-159)



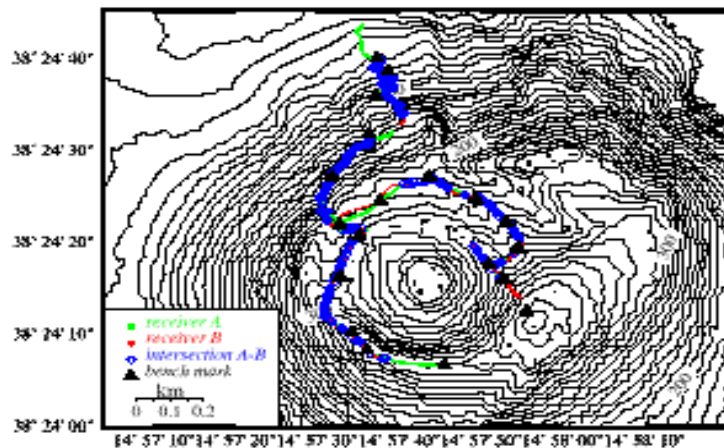
Assessment of the repeatability and accuracy

COE analysis of kinematic measurements (day 158)

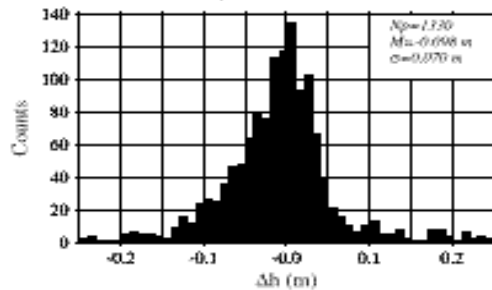
a) Elevation profile



b) Intersections between GPS track lines A and B

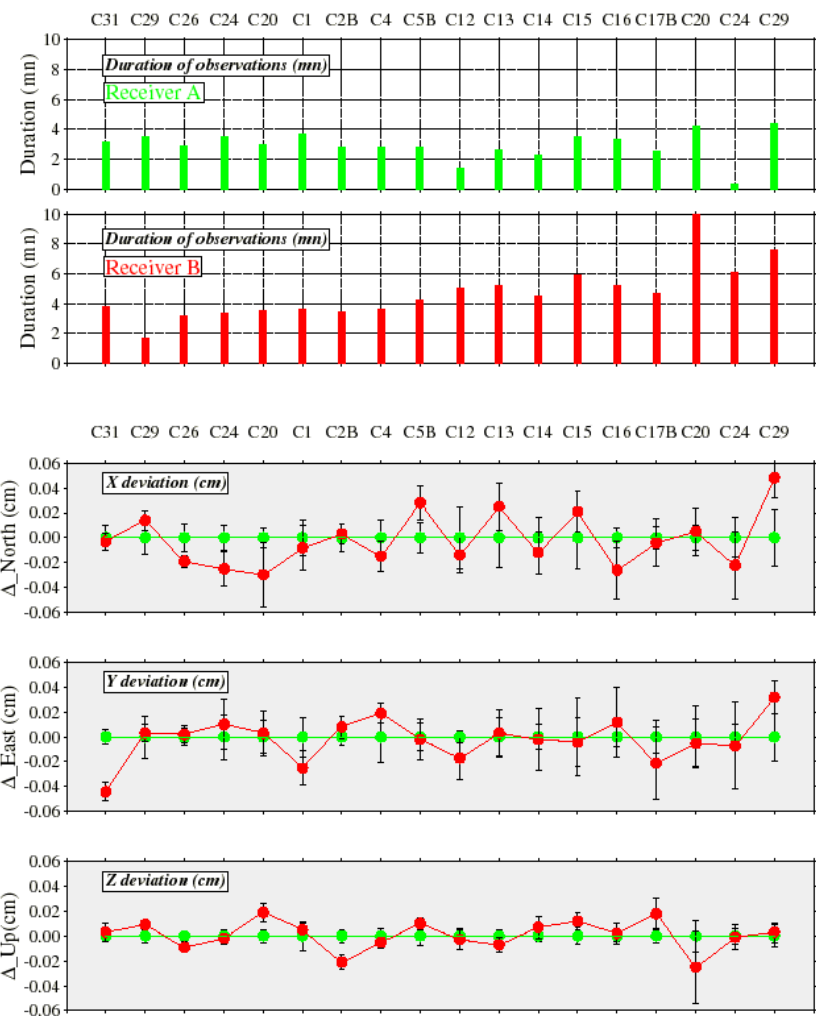


c) Receivers A-B

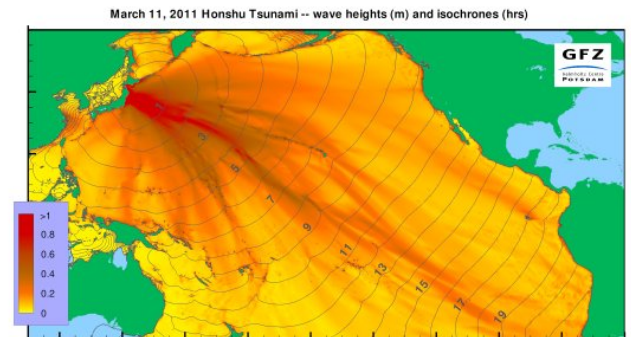
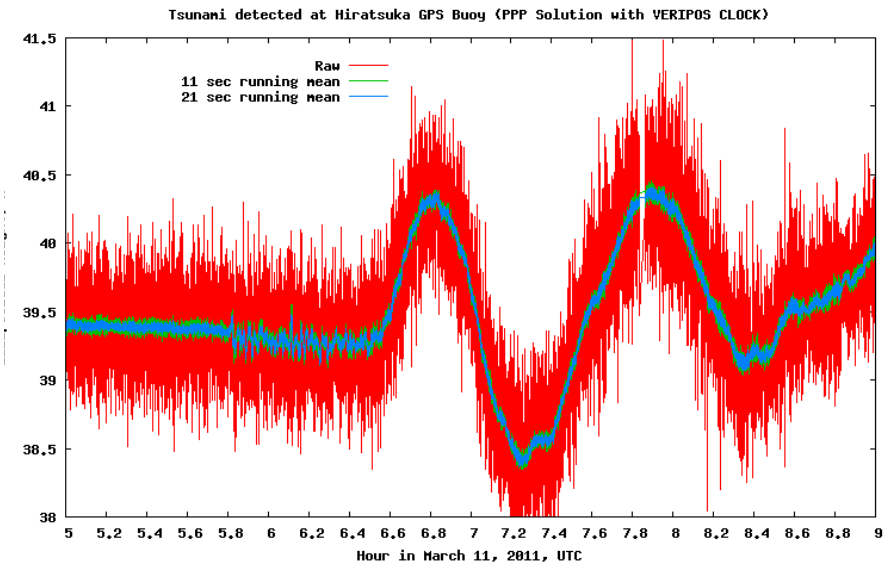
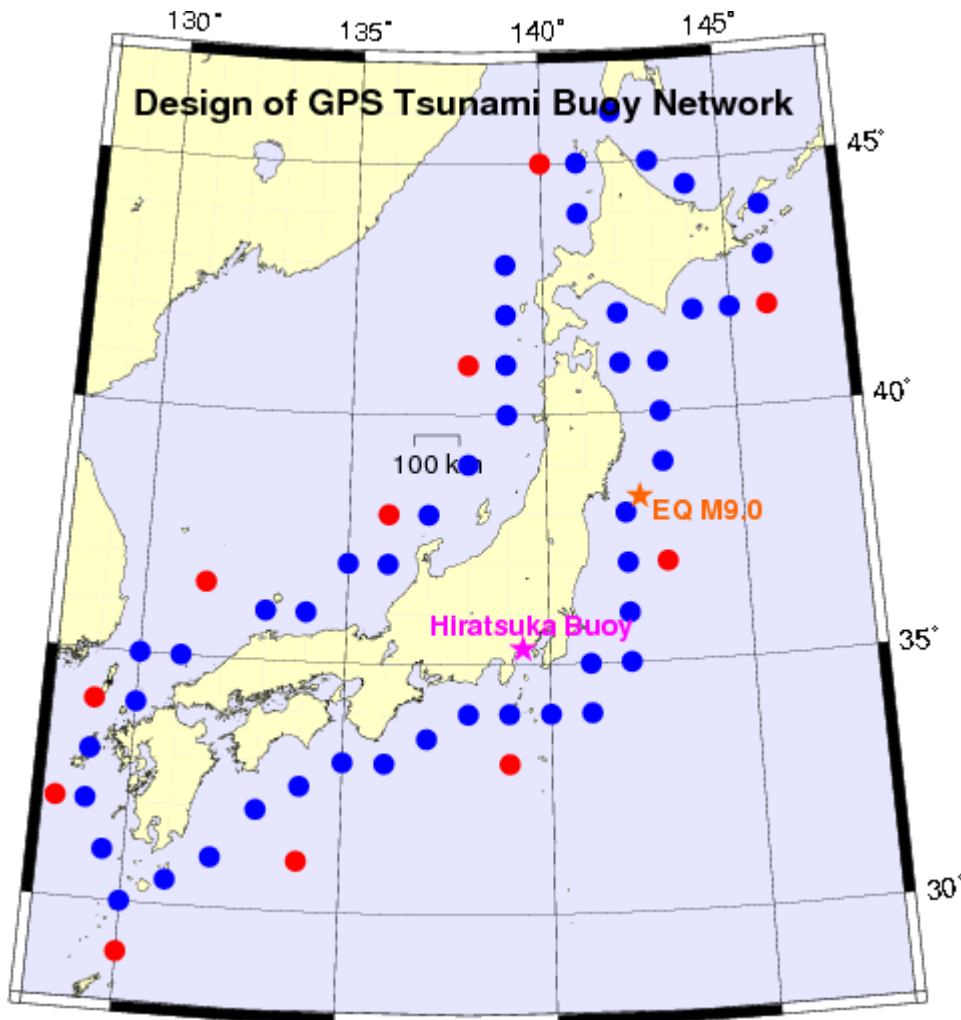
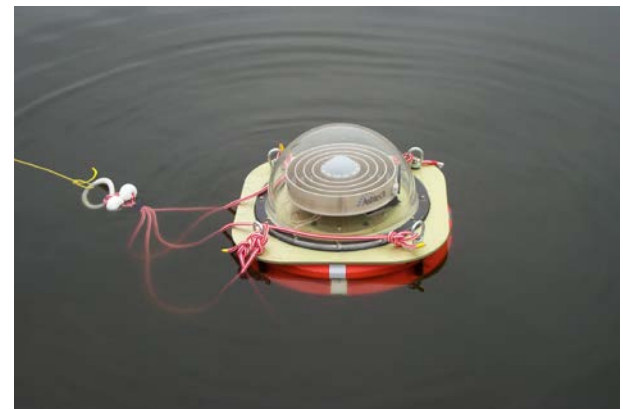


Intercomparison of kinematic measurements (day 158)

Leveling station number



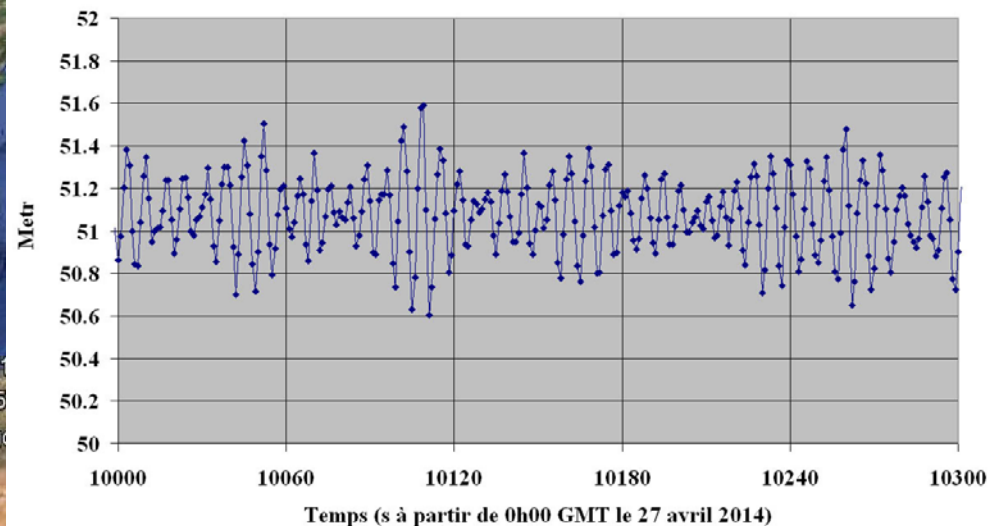
GPS on buoy



GPS on board of Tara



Altitude de l'antenne (ITRF2008)



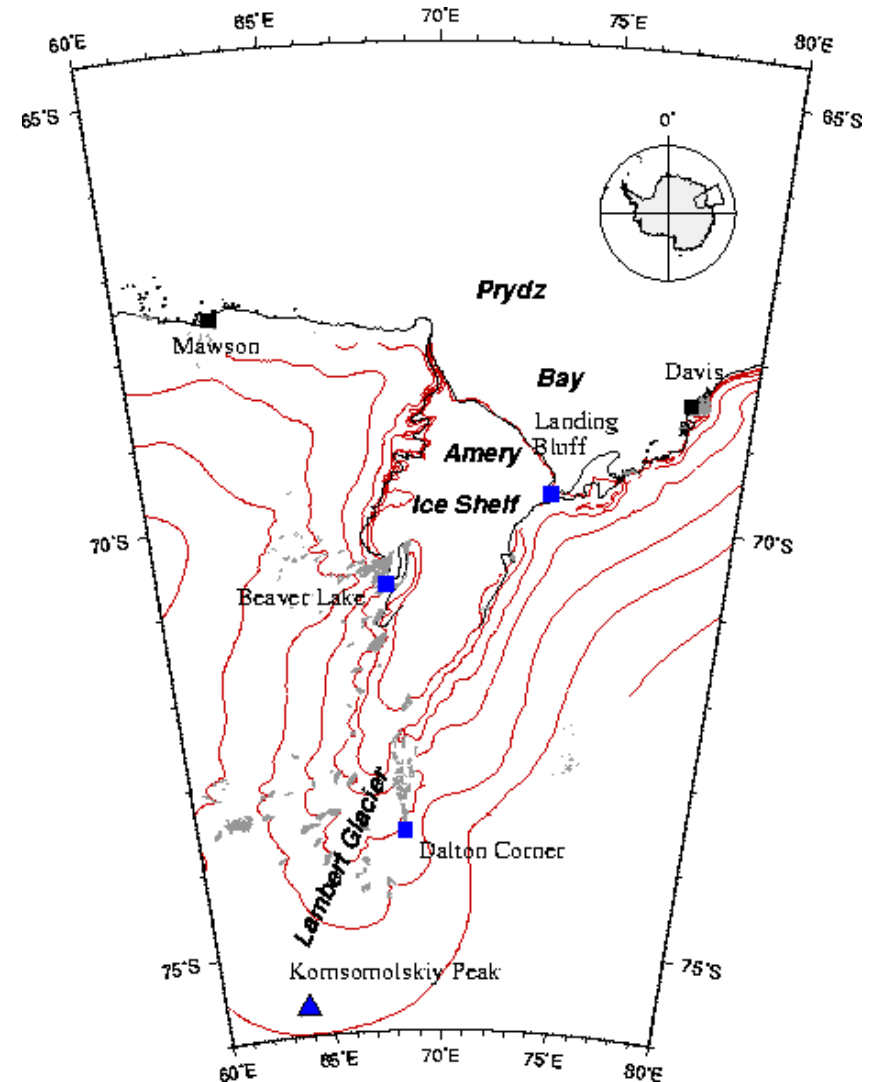
GPS measurements on glaciers



Monitoring of the Lambert glacier, Antarctic (Australian National University)



Monitoring of alpine glaciers (Glaciologie Grenoble)



The August 12, 2014 experiment



Differential positioning with respect to the GPS station MOSE located in Roma



MOSE is one of the stations of the EUREF network

(<http://www.epncb.oma.be>)

A screenshot of the EUREF Permanent Network website. The website has a blue header with the title "EUREF PERMANENT NETWORK" and a navigation menu. The main content area is divided into several sections: "ORGANISATION", "NETWORK & DATA", "PRODUCTS & SERVICES", "DOCUMENTATION", and "NEWS, EVENTS & LINKS". There is a "WELCOME" section with a map of Europe showing the network's coverage. A "QUICK LINK TO SITE INFORMATION" section includes a dropdown menu for selecting a station. The "LAST UPDATED/NEW PAGES" section lists recent updates and new pages. The "NEWS" section lists recent news items, including the addition of new EPN stations and the update of the EPN local analysis centres.

Data available through the EUREF web site (30s) or the GDC web site (1s)

(<http://igs.bkg.bund.de/>)



Welcome to the GNSS Data Center (GDC)

providing

GPS - GLONASS - Galileo Tracking Data and Products

Ground observing stations equipped with permanently operating GNSS receiver tracking networks in cooperation with international organisations. The GDC supports projects referred to GNSS tracking networks by storing and transferring related data.

Check the availability of observations, recent behaviour of observing sites and recent observations or analysis results. The GDC is structured by projects and requires the project filter.

The NTRIP-section offers information and software about real-time data streams, observations and products.

Our **FTP-Access** allows quick download of files stored at GDC.

For some pages in the Data & Products section a help-button will be displayed in the top right corner.



Rinex Search Result

FileName	RINEX V.	Station Name	rinex start date	Intervall	show file	remove	add to cart	download	plain data
all files									
m0se224a30.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 00:30:00	highrate					
m0se224b00.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 01:00:00	highrate					
m0se224b15.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 01:15:00	highrate					
m0se224b30.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 01:30:00	highrate					
m0se224b45.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 01:45:00	highrate					
m0se224c00.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 02:00:00	highrate					
m0se224c15.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 02:15:00	highrate					
m0se224c30.14d.Z	2.11	Rome - The 'Moses' of Michelangelo	2014-08-12 02:30:00	highrate					

Coordinates of MOSE

The International Earth Rotation and Reference Systems Service

Organization Data / Products Publications

Data / Products

- Earth orientation data
- Conventions
- ICRF
- ICRS
- ITRF
- ITRS
- Geophysical fluids data

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Accuracy

Uncertainties and

Updates

From one to sev

Service

EUREF Permanent GNSS Net...

www.epncb.oma.be/_productsservices/coordinates/crd4station.php?station=MOSE

The precisions indicated in the tables below are formal 1 sigma errors from the normal equation stacking. Due to the rounding, formal errors indicated by 0.000 m (0.000 m/y) must be read as being smaller than 0.0005 m (0.00005 m/y) or 0.5 mm (0.05mm/y).

1. POSITIONS/VELOCITIES PUBLISHED BY EUREF

EUREF has classified MOSE (Roma, Italy) as a **class A station** which means that it can be used as fiducial station for EUREF densifications.

LATEST RELEASE

EPN_A_ETRF2000_C1785.SSC - EPN_A_IGb08_C1785.SSC (July 9, 2014)

ETRF2000	epoch t ₀	Position (m)			Velocity (m/y)		
		X	Y	Z	V _X	V _Y	V _Z
106/2012 - 089/2014	001/2005	4642432.762 ± 0.001	1028629.180 ± 0.000	4236854.017 ± 0.001	-0.0010 ± 0.0001	-0.0023 ± 0.0001	-0.0009 ± 0.0001
182/2007 - 104/2012	001/2005	4642432.767 ± 0.001	1028629.181 ± 0.000	4236854.023 ± 0.001	-0.0010 ± 0.0001	-0.0023 ± 0.0000	-0.0009 ± 0.0001
001/2006 - 004/2007	001/2005	4642432.756 ± 0.000	1028629.180 ± 0.000	4236854.013 ± 0.000	-0.0010 ± 0.0001	-0.0023 ± 0.0001	-0.0009 ± 0.0001

IGb08	epoch t ₀	Position (m)			Velocity (m/y)		
		X	Y	Z	V _X	V _Y	V _Z
106/2012 - 089/2014	001/2005	4642432.477 ± 0.001	1028629.440 ± 0.000	4236854.247 ± 0.001	-0.0155 ± 0.0001	0.0170 ± 0.0001	0.0112 ± 0.0001
182/2007 - 104/2012	001/2005	4642432.482 ± 0.001	1028629.441 ± 0.000	4236854.253 ± 0.001	-0.0154 ± 0.0001	0.0170 ± 0.0000	0.0112 ± 0.0001
001/2006 - 004/2007	001/2005	4642432.471 ± 0.000	1028629.441 ± 0.000	4236854.243 ± 0.000	-0.0154 ± 0.0001	0.0170 ± 0.0001	0.0112 ± 0.0001

Click [HERE](#) to see a plot of how the station positions between successive cumulative solutions agree with each other.

[PREVIOUS RELEASES](#)

2. POSITIONS/VELOCITIES PUBLISHED BY THE IGS

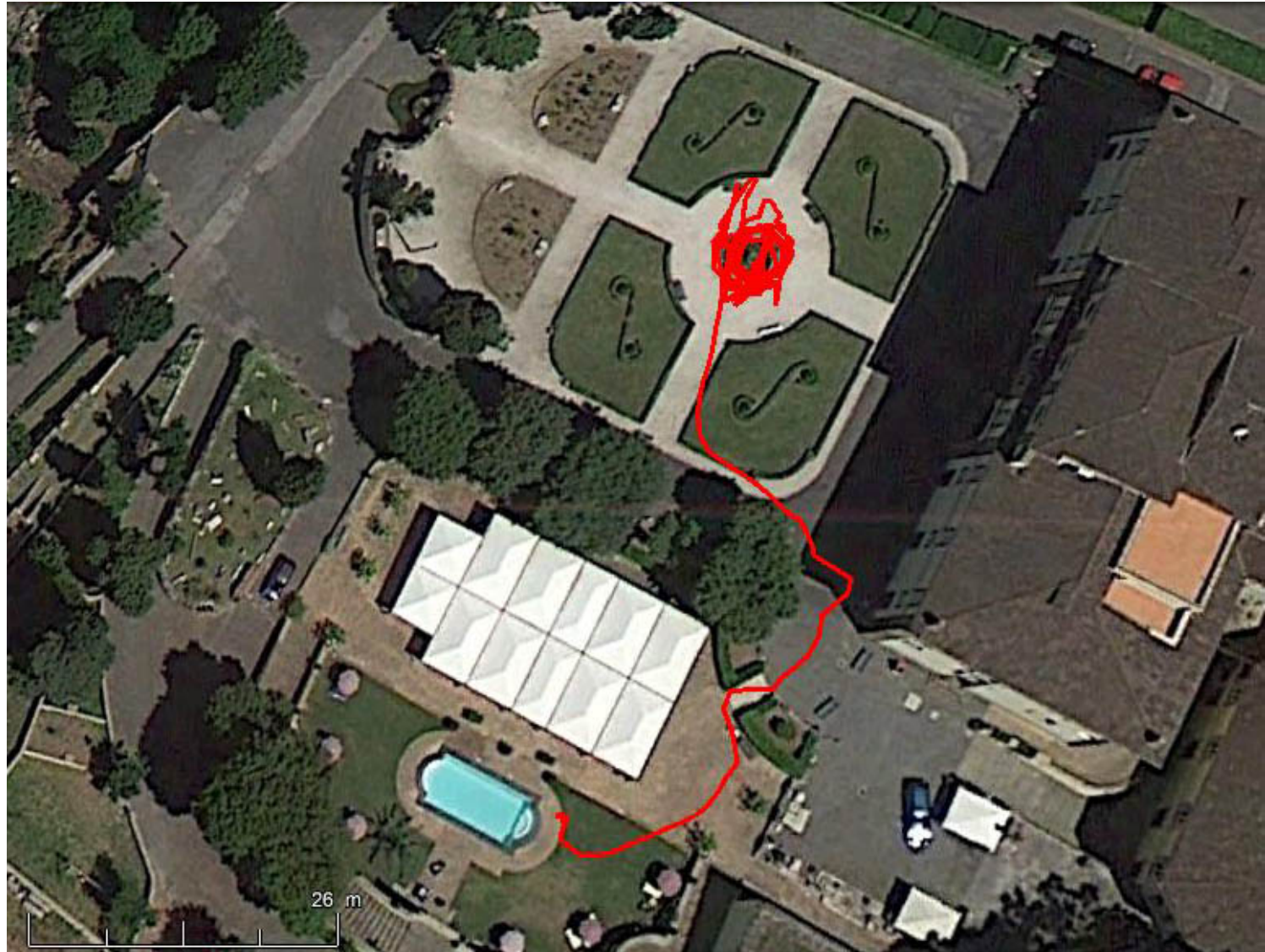
IGS has not yet released coordinates for MOSE (Roma, Italy).

3. POSITIONS/VELOCITIES PUBLISHED BY THE IERS

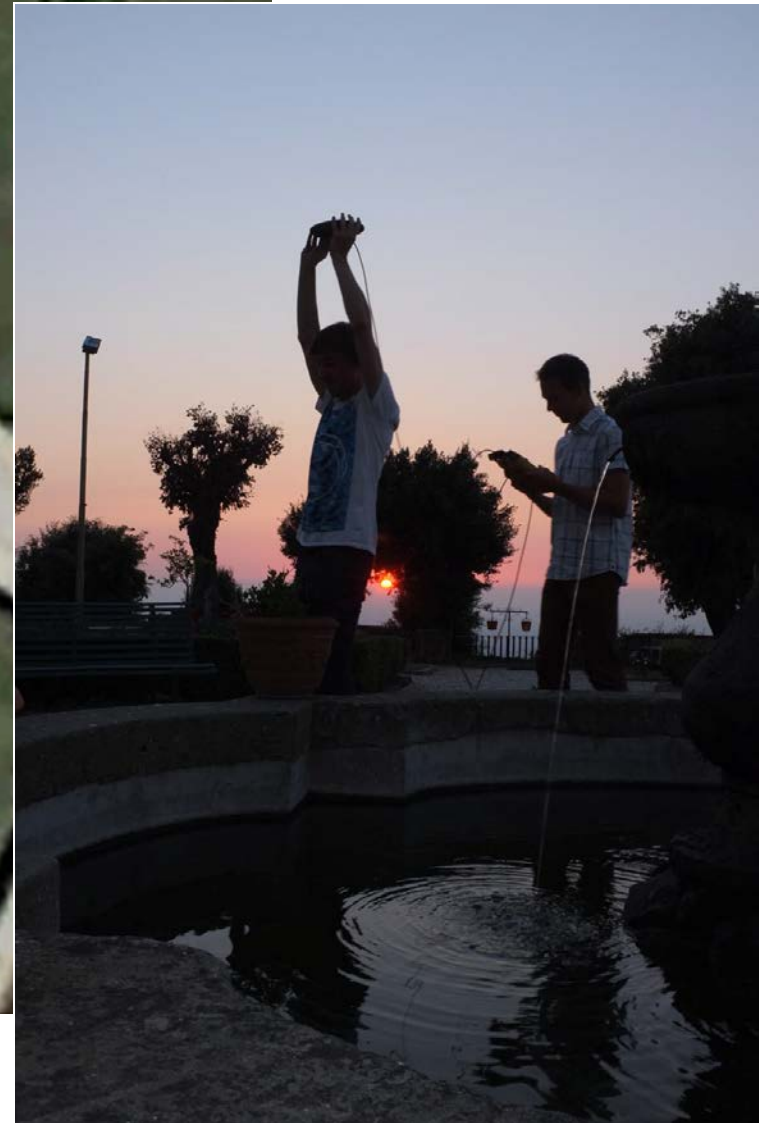
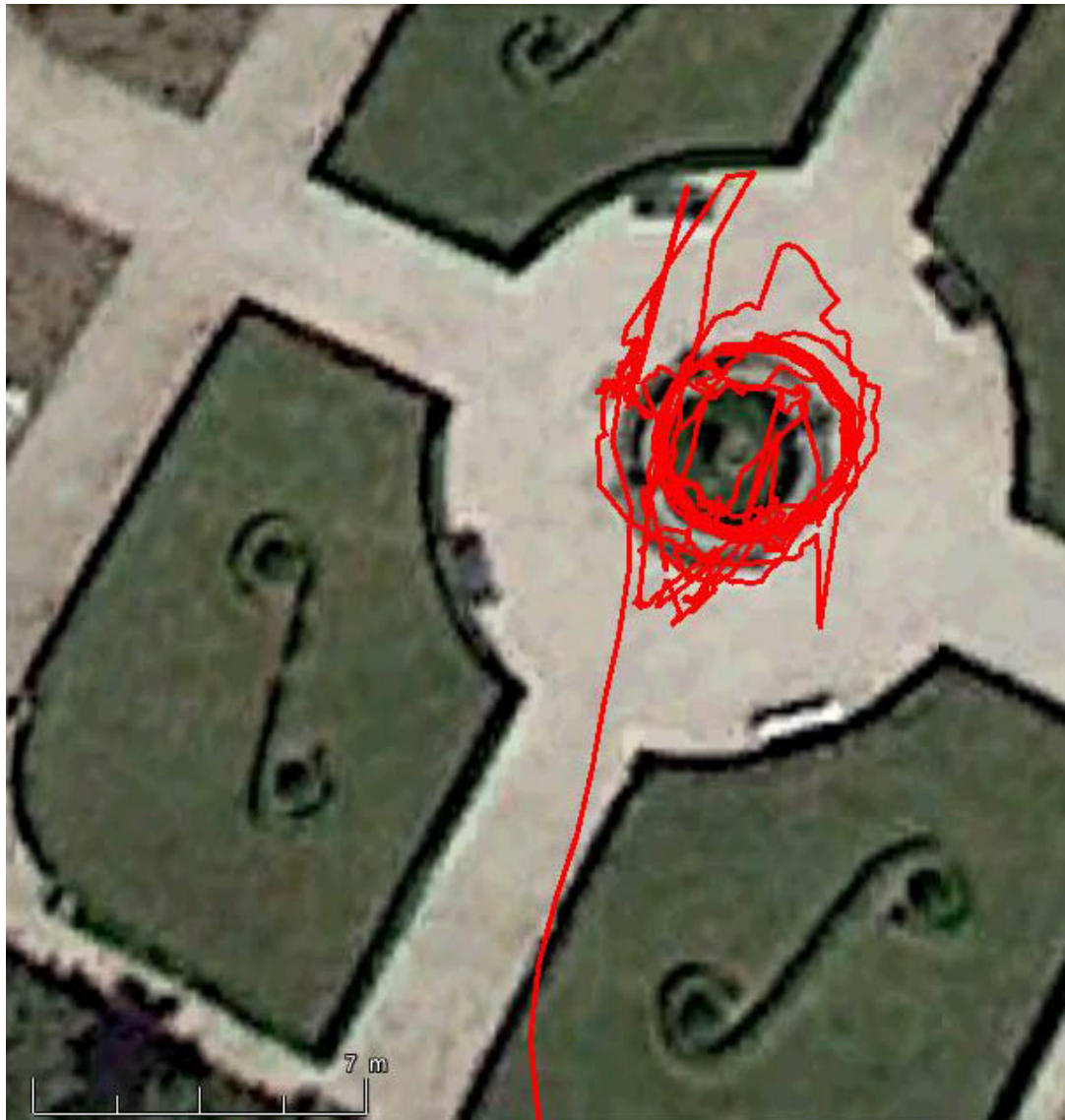
IERS has not yet released coordinates for MOSE (Roma, Italy).

We use the ITRF2008 coordinates
(http://itrf.ign.fr/ITRF_solutions/2008/) at the reference epoch (2005.0)

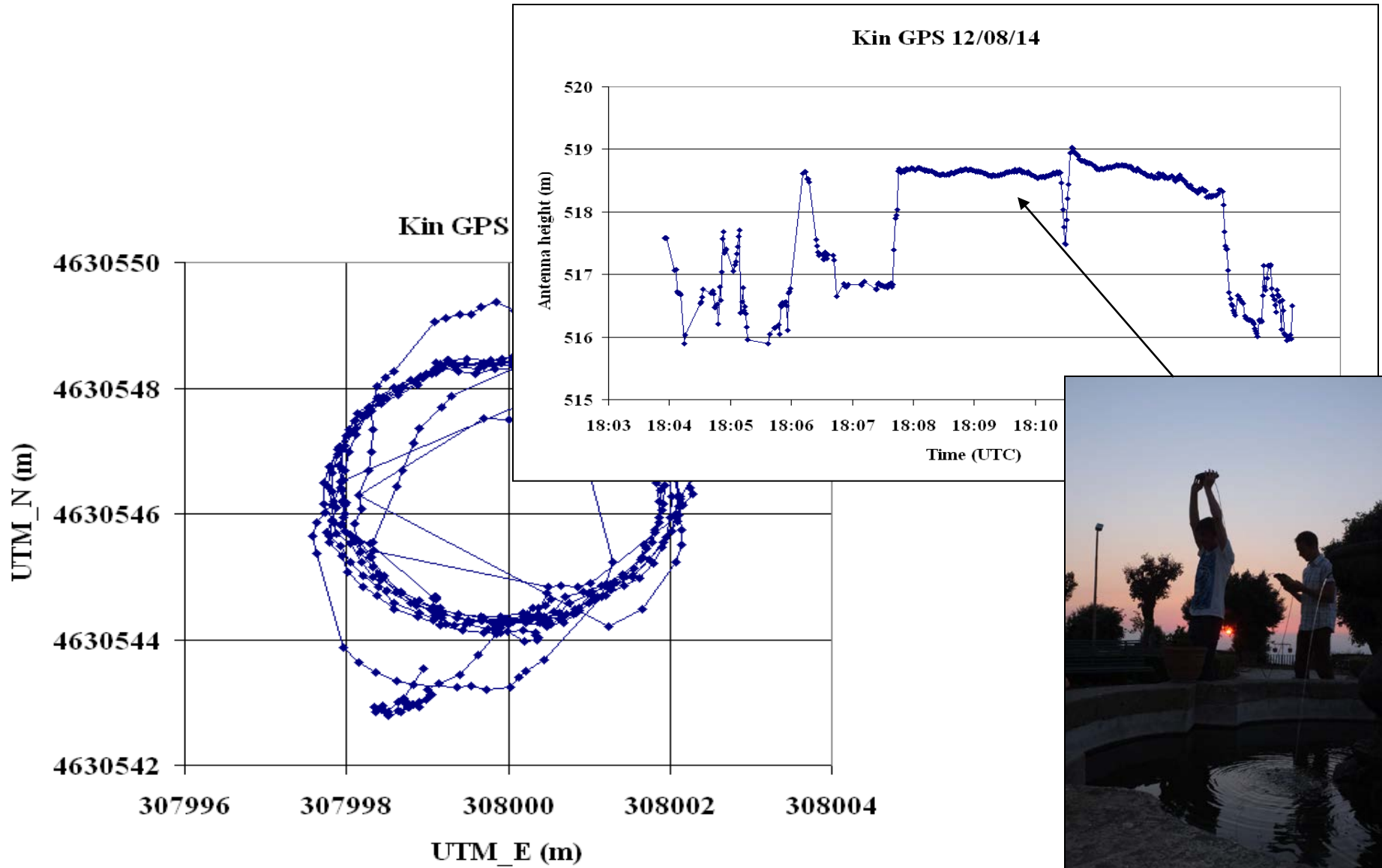
The entire 2 hours measurements



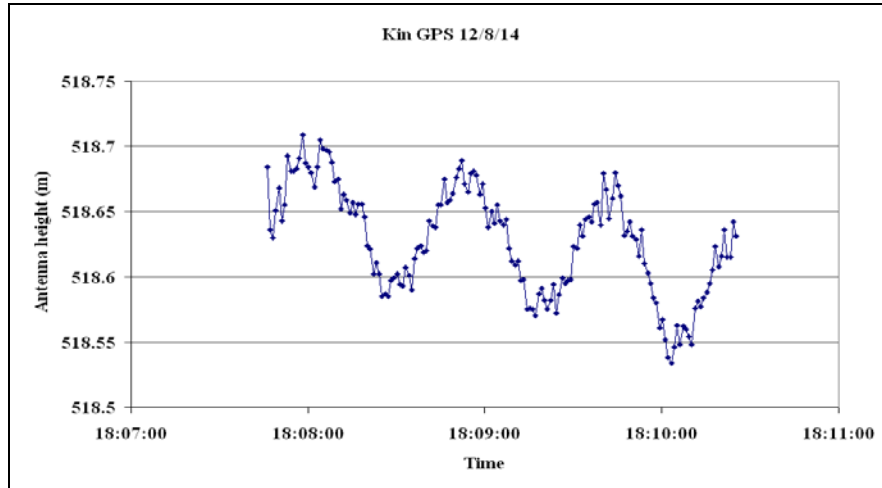
Positioning the fountain



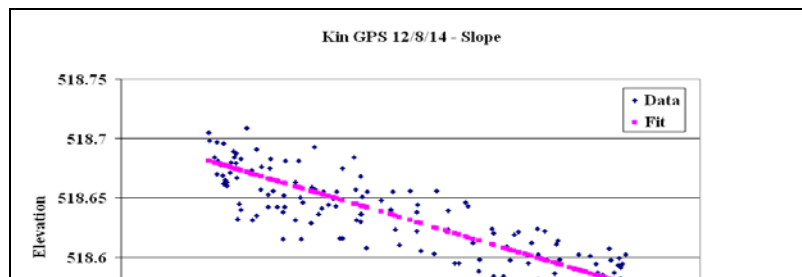
The whole 12mn observations (~10 loops)



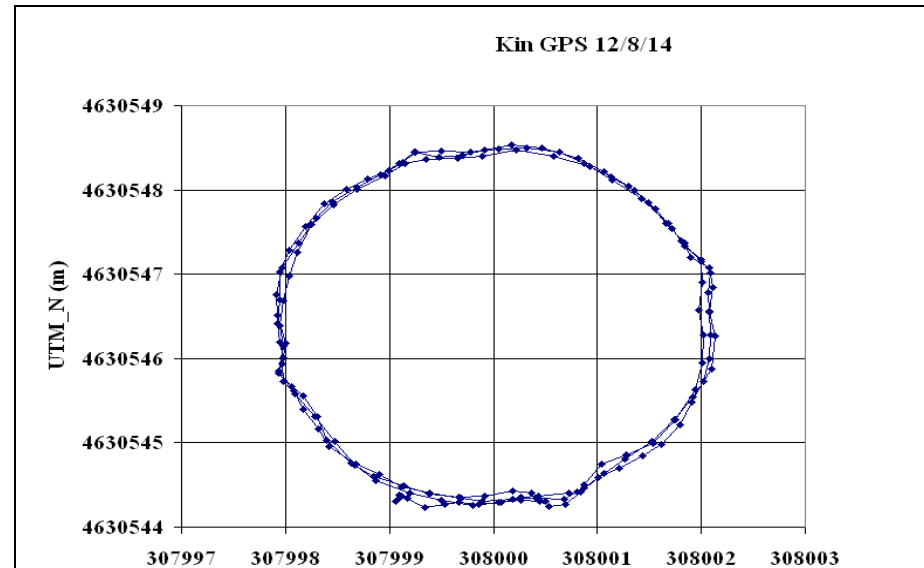
A zoom into the 3 best minutes (3 loops)



Antenna height decreases with time (operator?)

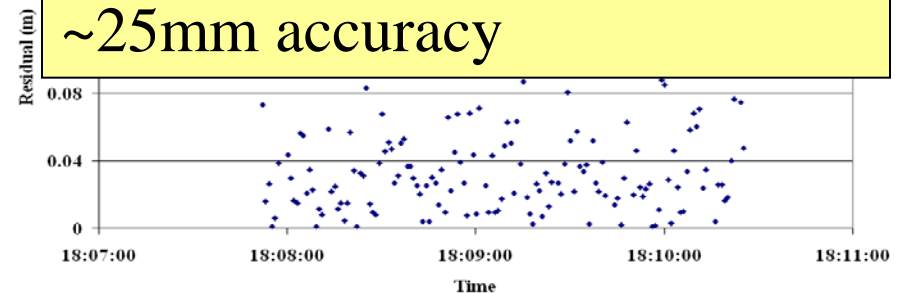


Slope of the terrain: 2.4%
azimuth N51°W

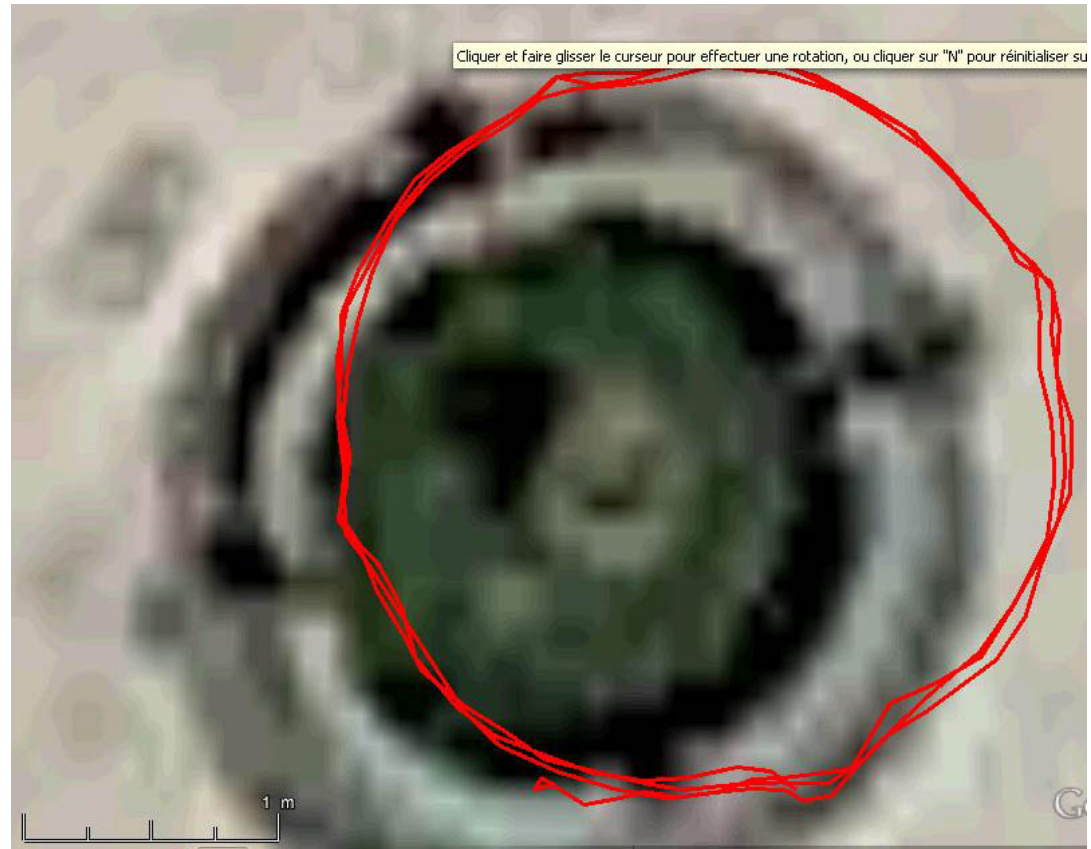


r.m.s. scatter to a 2.1m circle =
46 mm

Circle centre determined with
~25mm accuracy

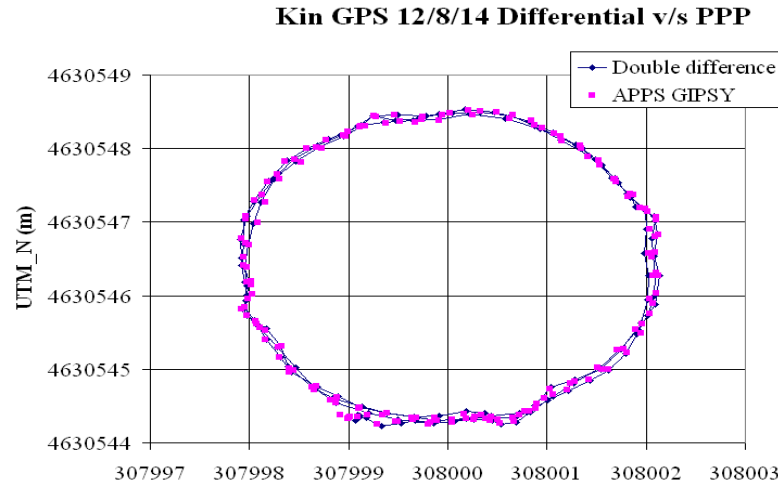


UTM_33 coordinates of centre of the fountain



- East: 307999.990 ± 0.025 m
- North: 4630546.390 ± 0.025 m

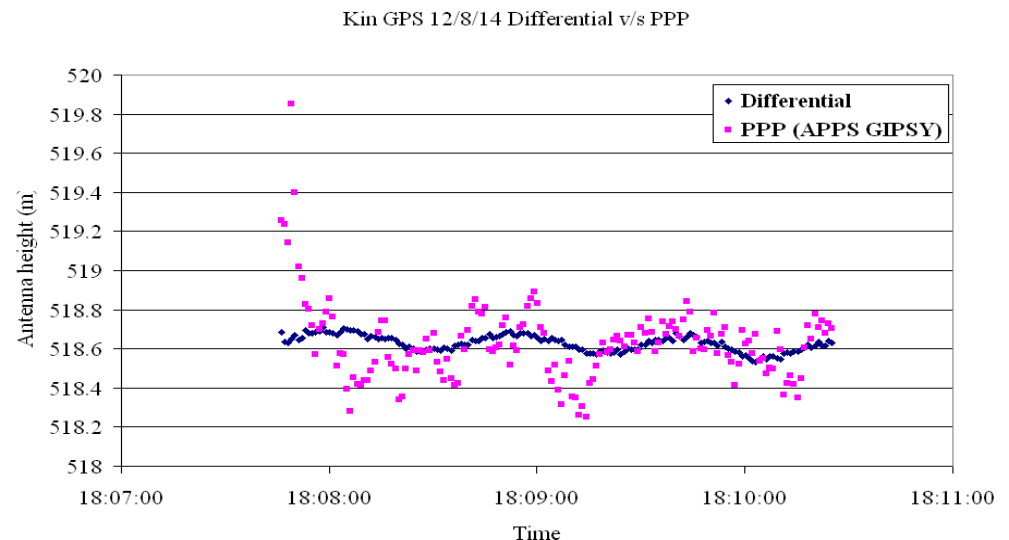
Comparison with PPP (single point positioning) (GIPSY *apps.gdgps.net/*)



Horizontal fit:
26mm r.m.s.



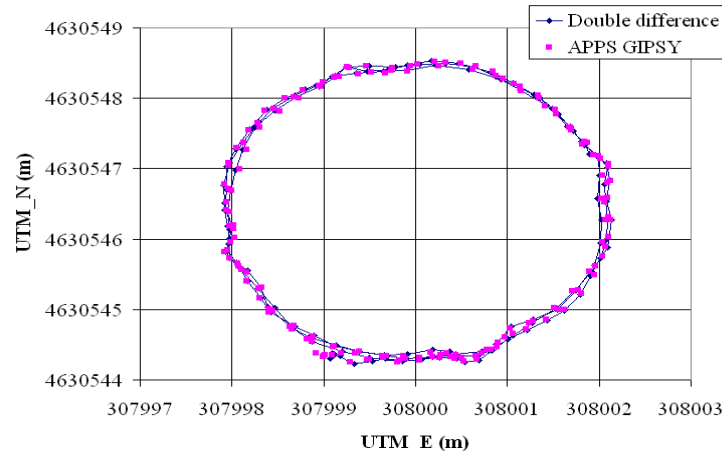
APPS Results
2014-08-12.FRAS.sum.Z
2014-08-12.FRAS.ninialog.Z
2014-08-12.FRAS.pfs.Z
2014-08-12.FRAS.stacov.Z



Comparison with PPP (single point positioning) (GIPSY *apps.gdgps.net/*)



Kin GPS 12/8/14 Differential v/s PPP



Horizontal fit:
26mm r.m.s.

fras2240.12d_

Lat: 41.80316529 Lon: 12.68864802

Google

Données cartographiques Conditions d'utilisation

APPS Results

- [2014-08-12.FRAS.sum.Z](#)
- [2014-08-12.FRAS.ninialog.Z](#)
- [2014-08-12.FRAS.pfs.Z](#)
- [2014-08-12.FRAS.stacov.Z](#)

Kin GPS 12/8/14 Differential v/s PPP

