Earthquakes & Tsunamis flirting with the Ionosphere
...take a ride to Venus !!

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The winds, heated by the Sun, are the causes of Earthquakes!!

Nuclear Explosion

Earthquake

[Row, 1964]
[Calais & Minster, 1995]

[GPS]

[Doppler]

[Tanaka et al., 1984]

[Najita & Yuen, 1979]
Trapped modes (f ≤ 3.68 mHz)

Propagating modes

Spheroidal modes \( n=0, l=2-300 \)

Lognonné & Clevedé, 2002

[Nishida et al., 2000]

[Kanamori & Mori, 1992]
December 26, 2004

$M_t = 9.1$

$M_\omega = 9.3$

[Titov et al., 2005]

[Ammon et al., 2006]
December 26, 2004

$M_\omega = 9.3$

- Doppler sounding Data
- Modelling by normal modes summation following [Lognonné et al., 1998]

[Liu et al., 2006a]
[Crespon, 2007]
[Liu et al., 2006a]
[Ammon et al., 2006]
ionospheric signature of tsunami waves

[Artru et al., Space Res. Today, 2005]
[Occhipinti et al., GRL, 2006]
[Occhipinti et al., GRL, 2006]
Sumatra tsunami
dec. 26th, 2004

4 m
6 m
20 m

with Occhipinti et al., GRL, 2006

complete movies in the GRL Supplementary Material on ninto's webpage: www.ipgp.fr/~ninto
Est-West

Nord-Sud

[Occhipinti et al., GRL, 2006]

complete movies in the GRL Supplementary Material on ninto's webpage: www.ipgp.fr/~ninto
[Occhipinti et al., GRL, 2006]
Ion Normalized Velocity $V_z \cdot e^{-t/\tau}$

Neutral Normalized Velocity $V_z \cdot e^{-t/\tau}$

Time: 288 min : 20 sec

Latitude (deg)

Altitude (km)

mm/s

[Occhipinti et al., GJI, 2008]

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complete movies in the GJI Supplementary Material on ninto's webpage: www.ipgp.fr/~ninto

[Occhipinti et al., GJI, 2008]
Northward propagation

complete movies in the GJI Supplementary Material on ninto's webpage: www.ipgp.fr/~ninto
Southward propagation

[Occhipinti et al., GJI, 2008]

complete movies in the GJI Supplementary Material on ninto’s webpage: www.ipgp.fr/~ninto
$T_{EC} = \int_{surf}^{sat} N_e\,ds$

[Occhipinti et al., GRL, 2006]

Complete movies in the GRL Supplementary Material on ninto’s webpage: www.ipgp.fr/~ninto
Initial density

[Occhipinti et al., GRL, 2006]

complete movies in the GRL Supplementary Material on ninto’s webpage: www.ipgp.fr/~ninto
...for longitude $\sim 0.2^\circ$ for both satellites

[Occhipinti et al., GRL, 2006]
3:17.3 UT

shift

latitude ~ 1°
longitude ~ 1.5°

HWM93 model
Venera landers story

1965

1970

35 MIN

1975

53-65 MIN

1981

57-127 MIN

Venera landers story

1965

35 MIN

1970

57-127 MIN

1981

53-65 MIN
Coupled system: Solid Planet + Atmosphere

Perfect gas hypothesis

Elastic behaviour of the atmosphere

(mantle)

(core)
Gravity Wave generated by Polar Vortex

[Garcia et al., JGR 2009]
Gravity Wave generated by Polar Vortex

[Garcia et al., JGR 2009]
Mission concept

Ionosphere ~140 km

Multi-frequency radar

0.5-7 MHz and over 7 MHz