EGU2020-18876
EMRP 2.2

European Geosciences Union
General Assembly 2020
Online | 4–8 May 2020

UNIWERSYTET
WARMIŃSKO-MAZURSKI
W OLSZTYNIE

Analysis of Swarm Electric Field Data in View of Tsunami Events and related Earthquakes

Wojciech Jarmołowski, Paweł Wielgosz, Anna Krypiak-Gregorczyk, Beata Milanowska

University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering, Poland

Introduction (1)

It is proven that different events on the Earth and in its atmosphere have their own impact on Earth electric field, and the earthquakes are amongst these phenomena. Many strong earthquakes (EQ) induce tsunamis, which are also suspected as contributing to the gravity waves having an impact on the ionospheric TEC.

The sensitivity of Swarm LP and POD GNSS data to EQs and tsunamis is analyzed in this study at around 500 km high orbit. Three Swarm satellites are equipped with Langmuir Probes (LP) measuring in-situ electron density of Earth electric field and POD GNSS receivers determining topside Total Electron Content (TEC) in the topside ionosphere. The integrity of both data sources is also analyzed.

Introduction (2)

The investigation of Swarm data in view of Tsunamis and earthquakes is difficult due to the several factors. The major drawbacks are:

- **only three satellites (with respect to GNSS systems), the two of which fly almost together, which gives in fact only two survey tracks**
- **lower orbits in relations to GNSS**
- **orbital repetition is far from exact, which seriously limits the number of comparable observations in terms of the location and time of the day**
- **number of large earthquakes and tsunami events in time of Swarm science mission is limited, and many Earthquakes do not coincide sufficiently with Swarm passes in time and space**

Introduction (3)

Swarm LP data is analyzed just after the earthquakes, as well as several days before and after the earthquakes and resulting tsunami events. The GNSS POD topside TEC from Swarm is analyzed together with LP data, in order to validate LP and assess integrity of both data sources. In-situ electron density disturbances are compared to selected/available STEC measurements between LEO and GNSS satellites.

Some preliminary calculations of GNSS phase differences from selected nearby ground stations are also compared. These initial comparisons are made in order to look for possible correlations between Swarm POD TEC and ground GNSS data, and to prepare for further work.

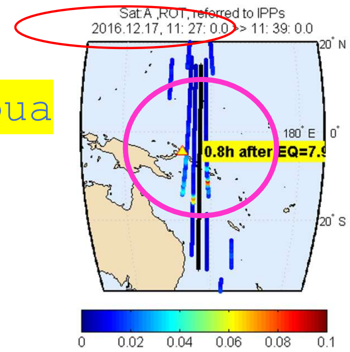
Spectral look on LP and TEC data close to EQ/tsunami events

- **Analyzed are Swarm LP data (EFIxLP, L1B) and TEC (Level2daily) data**
- **Signal and its disturbances are composed of various frequencies – corresponding to various phenomena. Different frequencies can originate from normal solar activity, and different from wide range of phenommena in the electric field - therefore FFT is used for spectral analysis**
- **Swarm speed is fast and its iteraction with TIDs can be extremely short – therefore we should analyze the signal carefully and find TIDs wavelengths precisely (other reason of frequency domain application)**
- **LP Ne data have calculated ROD and RODI and ROD (or subsequently residual ROD^r) is used in spectra short-term FFT (STFFT) analysis**
- **TEC data have calculated ROT and ROTI and ROT (or subsequently residual ROT^r) is used in STFFT analysis**

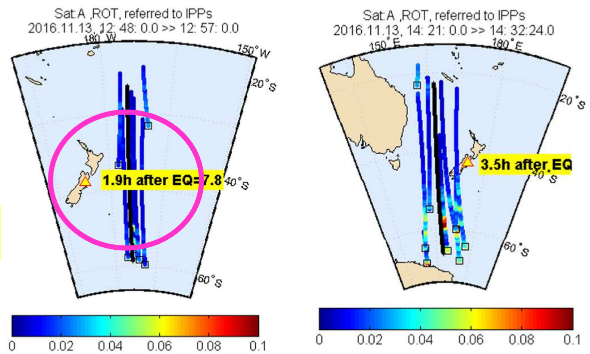
Spectral look on LP and TEC: the closest large tsunami events during Swarm mission

3 EQ/tsunami events with closest passes are investigated:

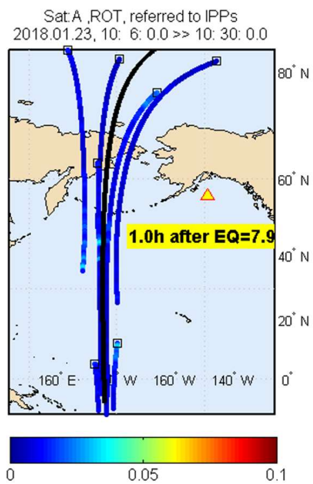
	WAVE HEIGHT	EQM	LAT	LON	DATE	TIME	DEPTH
% Loyalty Islands,	50	7.1	-22.0660	170.0500	20180829	035159	26.6
% Alaska,Pacific	25	7.9	56.0460	-149.0730	20180123	093143	25.0
% Kamchatka,Pacific	10	7.7	54.4710	168.8150	20170717	233413	11.0
% Papua,Pacific	19	7.9	-4.5090	153.4500	20161217	105112	103.0
% Solomon Islands,	56	7.8	-10.6760	161.3300	20161208	173846	41.0
% New Zealand,	231	7.8	-42.7570	173.0770	20161113	110256	23.0
% Chile,Pacific	467	8.3	-31.5700	-71.6540	20150916	225433	24.9
% Chile,Pacific	210	8.2	-19.6420	-70.8170	20140401	234646	20.5



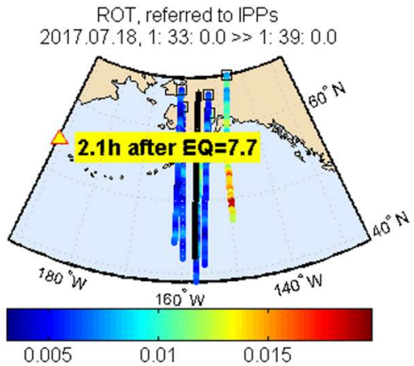
Papua



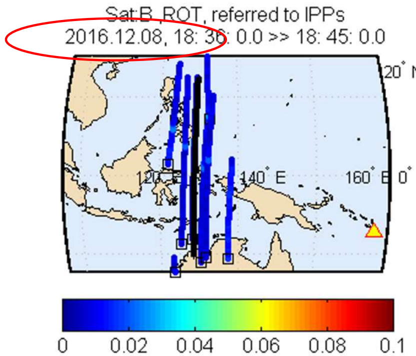
New Zealand



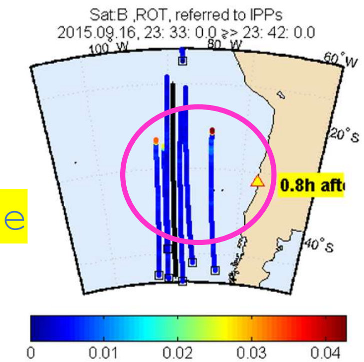
Alaska



Kamchatka



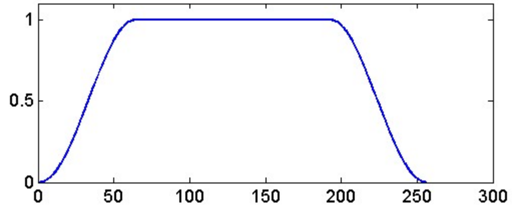
Solomon Islands



Chile

Spectral look on LP and TEC: FFT parameters

- **Frequencies - (sampling) from 1s. to 256 s. (2 points to 512 points) for LP (2 Hz) and from 1s. to 256 s. (1 point to 256 points) for TEC (1 Hz)**
- **Spectrograms: Large overlaping of windows (small time step) - overlap = (256 – 10) s.**
- **Scale in Hz and also in seconds of Swarm track (wavelengths must be later recalculated to km)**
- **Spectrogram window: In first iteration: Tukey Window 512 points (256 seconds from 2Hz data) for LP, and 256 points for 1Hz POD TEC**

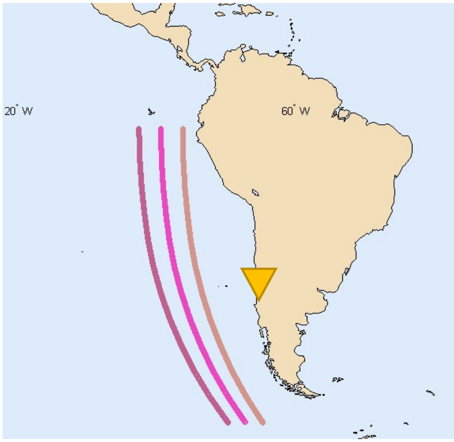


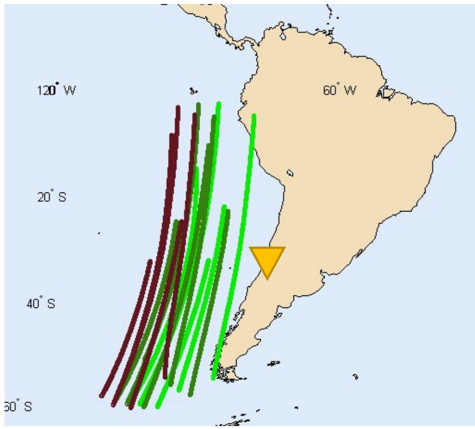
- **Signal decomposition by FFT for selected bands, primarily we divided signal into 3 bands: (max. – 180 s., 107 - 41 s., 57 - 12 s., kindly suggested by MHP (UPC) ;-)), so the frequencies above 12 s. were removed**
- **Selected are 3 close passes from different days: $\Delta\varphi < 2°$, $\Delta\lambda < 5°$, $\Delta UTC < 0.4$ h from central pass in day of EQ, just after EQ**

Spectral look on LP and TEC: selection of the most similar passes

CHILE

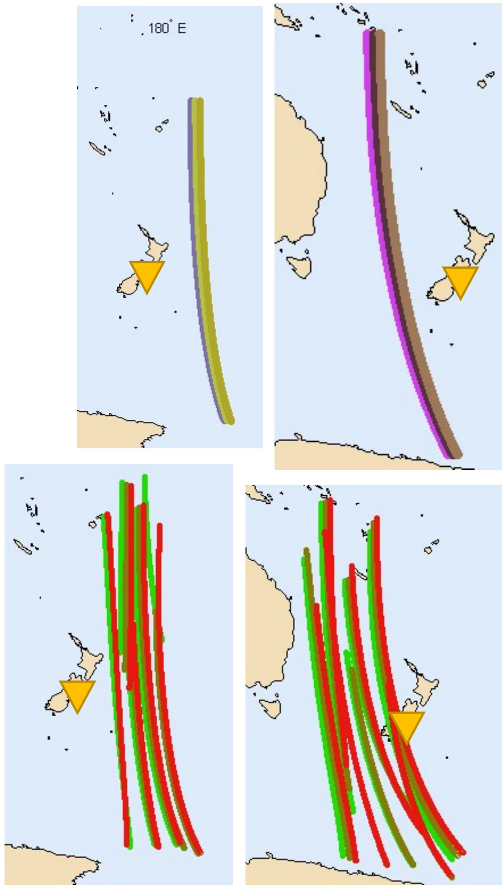
```
% Chile,Pacific      467      8.3
          -31.5700     -71.6540
          20150916 225433 24.9
```





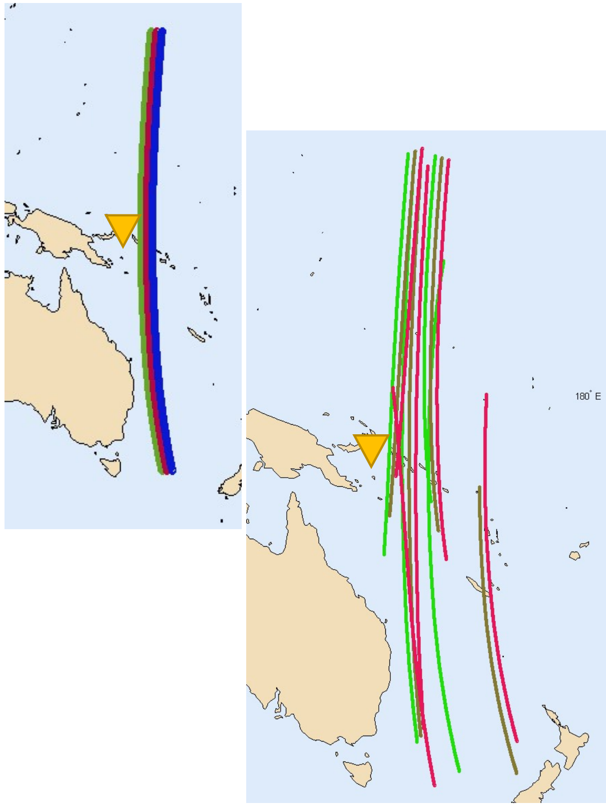
NEW ZEALAND

```
% New Zealand,        231        7.8
            -42.7570  173.0770
            20161113 110256      23.0
```



PAPUA NEW-GUINEA

```
% Papua,Pacific       19          7.9
          -4.5090    153.4500
          20161217 105112       103.0
```



Spectral look on LP and TEC: selection of the most similar passes

Selected Comparable Times of Passes (the most close that possible in time of the day, Lat and Lon), first point of selected track compared and approximately repeated $\Delta\varphi < 2°$, $\Delta\lambda < 5°$, $\Delta UTC < 0.4$ h

Chile

```
FOR DATE =  2015   9  16  23  30   0.197000
COORDS = LAT  -3.61364900  LON -88.93628400
----------------------------------
DATE:  2015   9  10 ,  23  41 26.197000 , DFI  1.991494 DLA  4.762418 PSI  5.157232
DATE:  2015   9  10 ,  23  42  0.197000 , DFI -0.158176 DLA  4.705127 PSI  4.698014
DATE:  2015   9  10 ,  23  41 59.696000 , DFI -0.126502 DLA  4.705968 PSI  4.697978
---------------------------------------------------------------
DATE:  2015   9  16 ,  23  29 28.696000 , DFI  1.991766 DLA  0.053107 PSI  1.992472
DATE:  2015   9  16 ,  23  30 31.696000 , DFI -1.991451 DLA -0.052764 PSI  1.992145
DATE:  2015   9  16 ,  23  30  0.197000 , DFI  0.000000 DLA  0.000000 PSI  0.000000
---------------------------------------------------------------
DATE:  2015   9  22 ,  23  18  0.197000 , DFI -0.098364 DLA -4.693932 PSI  4.685370
DATE:  2015   9  22 ,  23  18 30.197000 , DFI -1.995220 DLA -4.744183 PSI  5.132282
DATE:  2015   9  22 ,  23  18  0.197000 , DFI -0.098364 DLA -4.693932 PSI  4.685370
---------------------------------------------------------------
```

Papua NG

```
FOR DATE =  2016  12  17  11  24   0.197000
COORDS = LAT  26.12517580  LON 159.27805060
----------------------------------
DATE:  2016  12  14 ,  11  43 37.197000 , DFI  1.999665 DLA -0.991280 PSI  2.185609
DATE:  2016  12  14 ,  11  44 39.197000 , DFI -1.979433 DLA -1.021945 PSI  2.184938
DATE:  2016  12  14 ,  11  44  8.197000 , DFI  0.010087 DLA -1.004659 PSI  0.902032
---------------------------------------------------------------
DATE:  2016  12  17 ,  11  23 29.197000 , DFI  1.989581 DLA  0.013349 PSI  1.989616
DATE:  2016  12  17 ,  11  24 31.197000 , DFI -1.989524 DLA -0.017255 PSI  1.989586
DATE:  2016  12  17 ,  11  24  0.197000 , DFI  0.000000 DLA  0.000000 PSI  0.000000
---------------------------------------------------------------
DATE:  2016  12  20 ,  11   3 20.197000 , DFI  1.979903 DLA  1.022221 PSI  2.178928
DATE:  2016  12  20 ,  11   4 22.197000 , DFI -1.999251 DLA  0.991588 PSI  2.191539
DATE:  2016  12  20 ,  11   3 51.197000 , DFI -0.009701 DLA  1.008856 PSI  0.905873
---------------------------------------------------------------
```

New Zealand

```
FOR DATE =  2016  11  13  14  18   0.197000
COORDS = LAT -11.12138780  LON 161.89700560
----------------------------------
DATE:  2016  11  10 ,  14  37 16.197000 , DFI  1.984760 DLA -0.880787 PSI  2.165867
DATE:  2016  11  10 ,  14  38 18.197000 , DFI -1.988900 DLA -0.948939 PSI  2.194639
DATE:  2016  11  10 ,  14  37 47.197000 , DFI -0.002193 DLA -0.915509 PSI  0.898316
---------------------------------------------------------------
DATE:  2016  11  13 ,  14  17 29.197000 , DFI  1.986909 DLA  0.034776 PSI  1.987204
DATE:  2016  11  13 ,  14  18 31.197000 , DFI -1.986664 DLA -0.033484 PSI  1.986934
DATE:  2016  11  13 ,  14  18  0.197000 , DFI  0.000000 DLA  0.000000 PSI  0.000000
---------------------------------------------------------------
DATE:  2016  11  16 ,  13  57 39.696000 , DFI  1.983860 DLA  0.961720 PSI  2.198158
DATE:  2016  11  16 ,  13  58 41.696000 , DFI -1.989606 DLA  0.893413 PSI  2.172894
DATE:  2016  11  16 ,  13  58 10.696000 , DFI -0.002995 DLA  0.926920 PSI  0.909513
---------------------------------------------------------------

FOR DATE =  2016  11  13  12  45   0.197000
COORDS = LAT -12.97117650  LON -174.67659900
----------------------------------
DATE:  2016  11  10 ,  13   4 16.197000 , DFI  1.980462 DLA -0.881763 PSI  2.160127
DATE:  2016  11  10 ,  13   5 18.197000 , DFI -1.992629 DLA -0.947199 PSI  2.194398
DATE:  2016  11  10 ,  13   4 46.696000 , DFI  0.025897 DLA -0.914721 PSI  0.891802
---------------------------------------------------------------
DATE:  2016  11  13 ,  12  44 29.197000 , DFI  1.986628 DLA  0.033542 PSI  1.986899
DATE:  2016  11  13 ,  12  45 31.197000 , DFI -1.986379 DLA -0.032006 PSI  1.986622
DATE:  2016  11  13 ,  12  45  0.197000 , DFI  0.000000 DLA  0.000000 PSI  0.000000
---------------------------------------------------------------
DATE:  2016  11  16 ,  12  24 39.696000 , DFI  1.986545 DLA  0.960286 PSI  2.197428
DATE:  2016  11  16 ,  12  25 41.696000 , DFI -1.986359 DLA  0.894685 PSI  2.167805
DATE:  2016  11  16 ,  12  25 11.197000 , DFI -0.032135 DLA  0.926187 PSI  0.903066
---------------------------------------------------------------
```

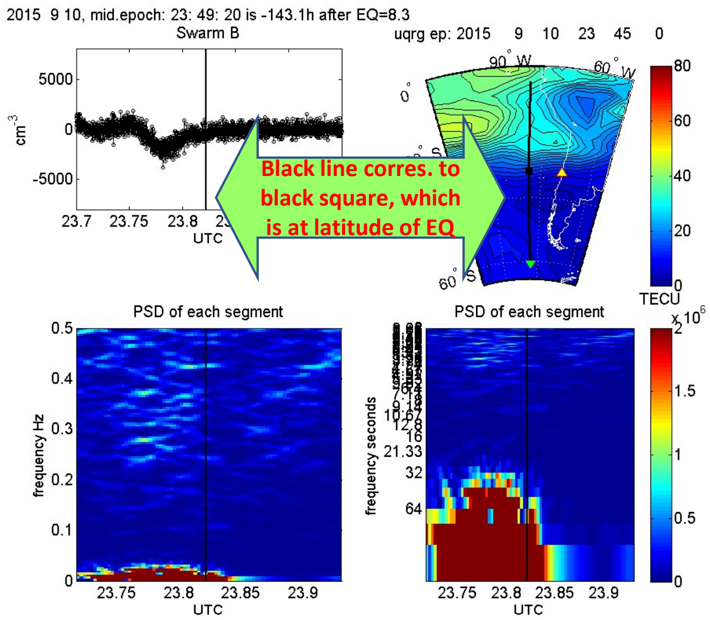
LP, SFFT SPECTROGRAMS CHILE 2015

ROD, Swarm B

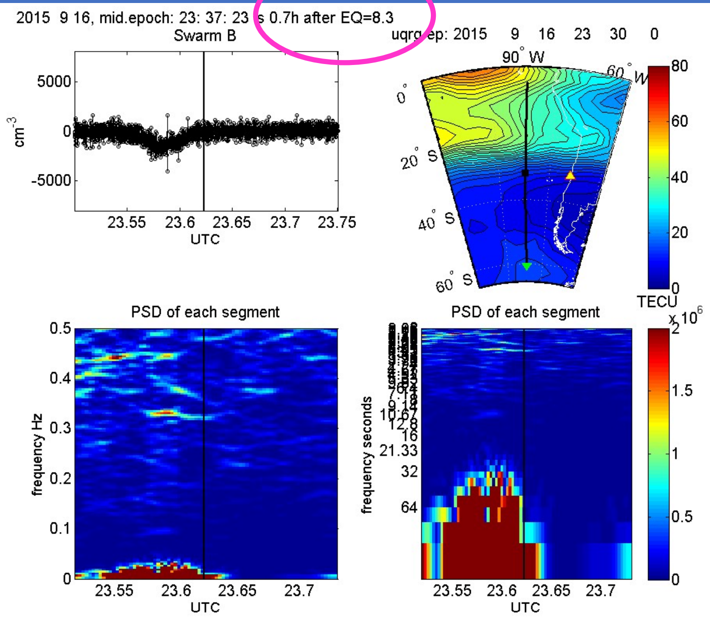
EQ > 2015.09.16 22:54:33

Tukey Window, Size 256 s.,

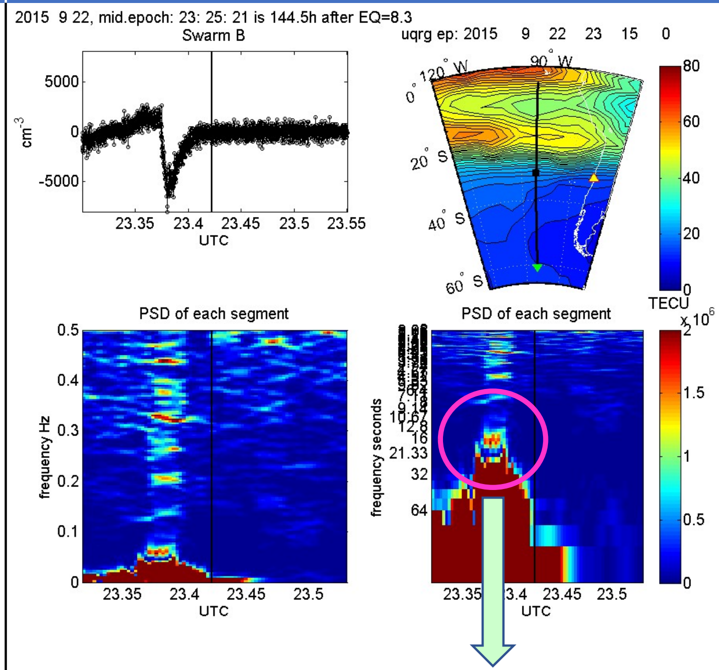
6 DAYS BEFORE

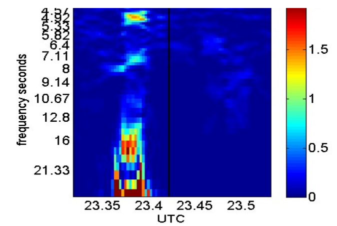


JUST AFTER



6 DAYS AFTER





In the vicinity of Chile-Illapel EQ, Swarm crosses edges of equatorial anomaly, which is a dominating signal is spectral sense. On the other hand Swarm B is higher than A/C. Separation and removal of long-wavelength patterns must be done.

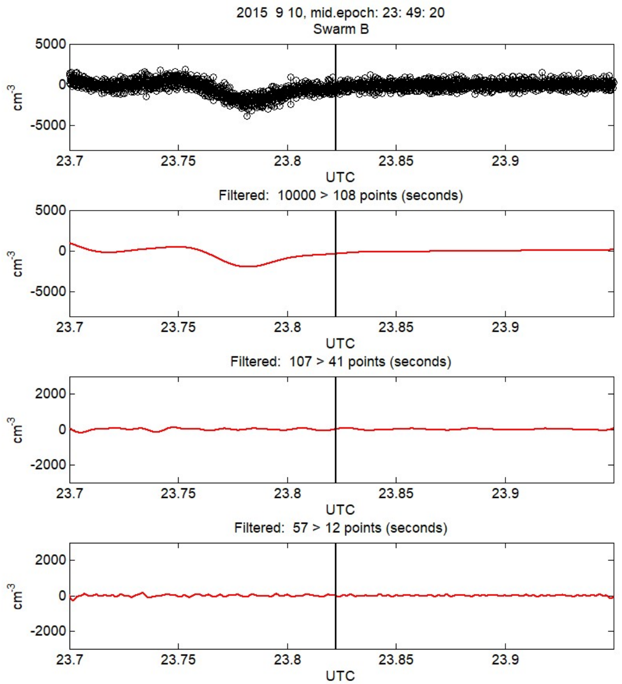
LP, FFT DECOMPOSITION CHILE 2015

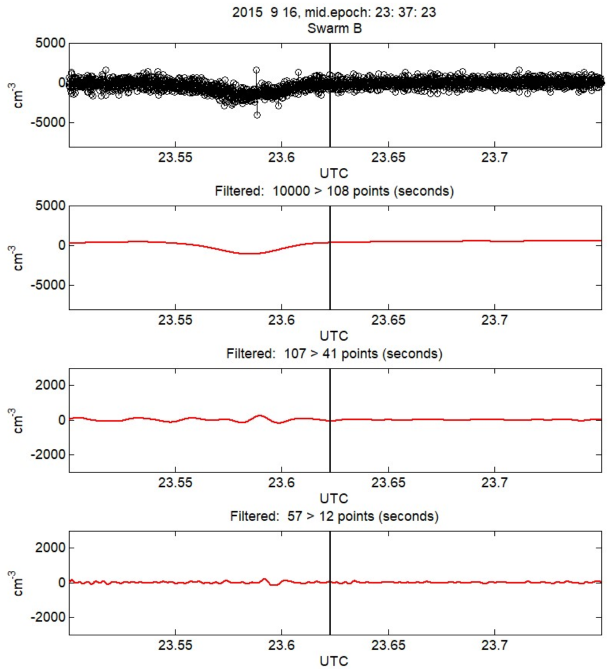
ROD, Swarm B

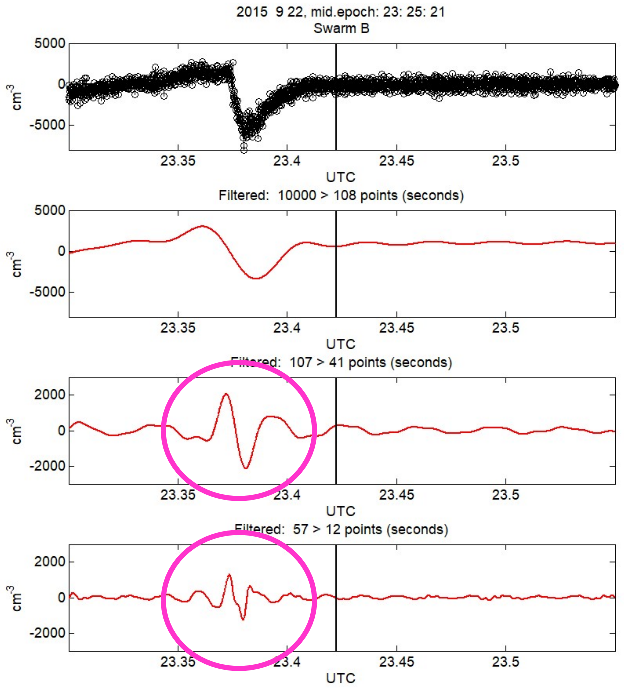
EQ > 2015.09.16 22:54:33

FFT decomposition into freq.: 12-57 s., 41-107 s., 108-max. s.

6 DAYS BEFORE	JUST AFTER	6 DAYS AFTER







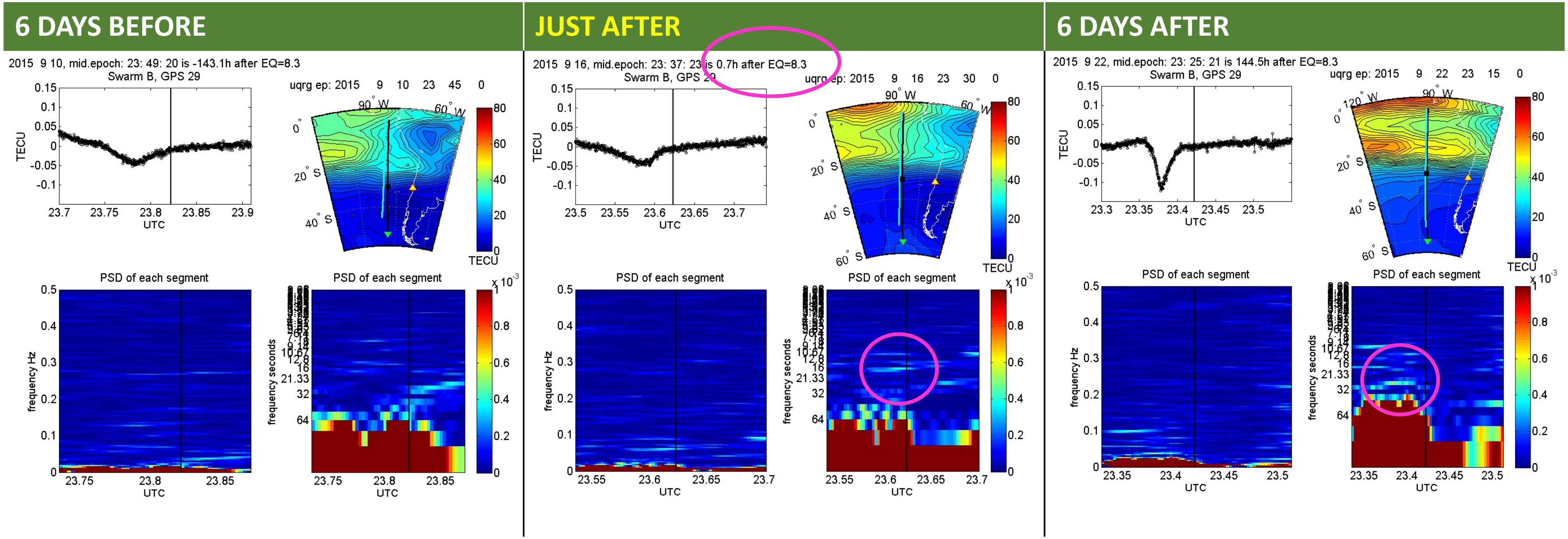
The equatorial anomaly signal occupies LP signal at wide band of frequencies and it is hard to separate the same frequencies along the whole Swarm track. Different frequencies occur in different places.

POD TEC, SFFT SPECTROGRAMS CHILE 2015

ROT, Swarm B, PRN 29

EQ > 2015.09.16 22:54:33

Tukey Window, Size 256 s.,



POD TEC shows similar behavior. TEC models can be helpful in the further research for detrending.
However, some separated signal parts can be noted also from these SFFT samplings.
Resampling after efficient detrending must be made.

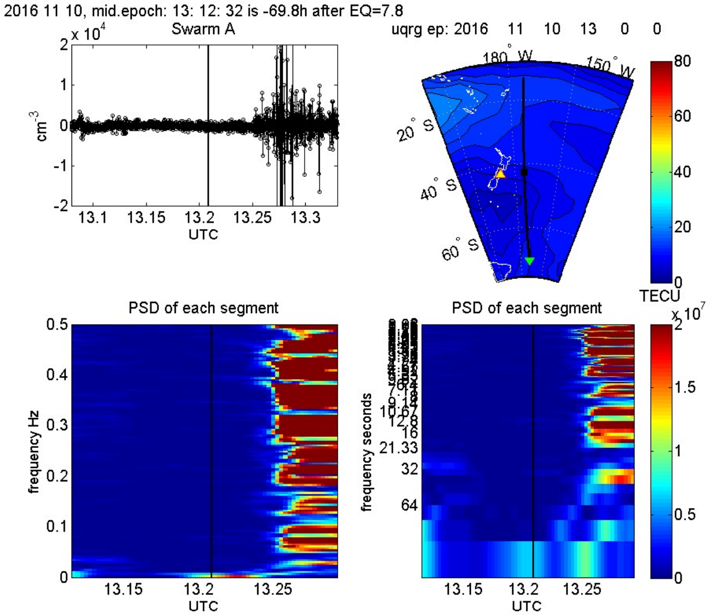
LP, SFFT SPECTROGRAMS NEW ZEALAND 2016 (first pass)

ROD, Swarm A

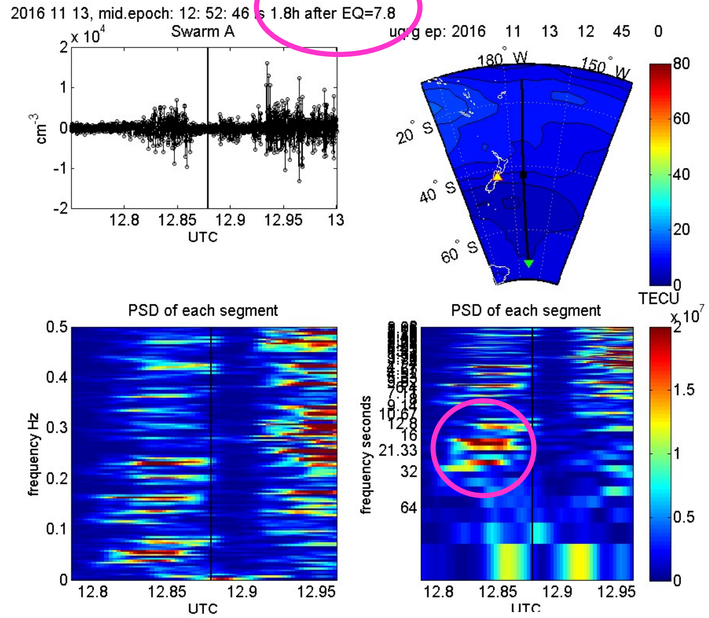
EQ > 2016.11.13 11:02:56

Tukey Window, Size 256 s.,

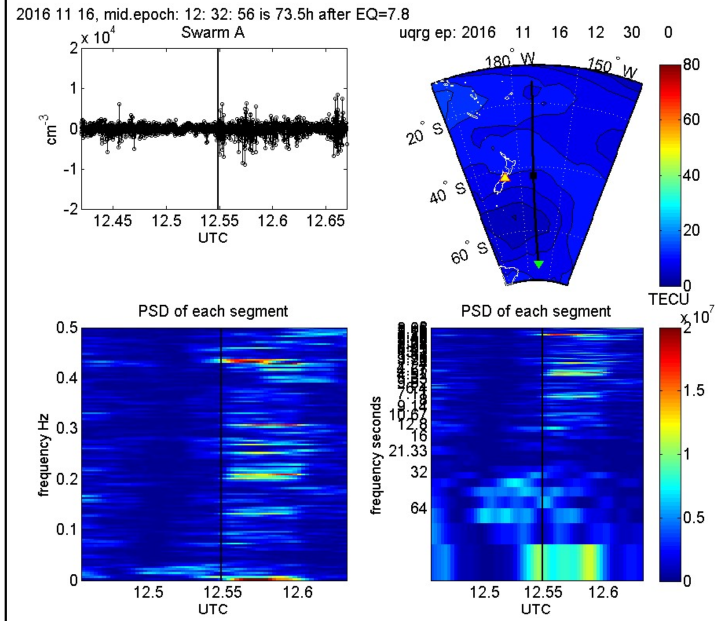
3 DAYS BEFORE

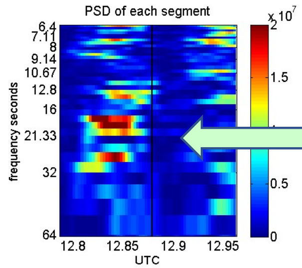


JUST AFTER



3 DAYS AFTER





Noisy signal, occupying many frequencies, 3 days before the EQ and quite far to the South from NZ

Some signal before middle point is separated, not mixed with high freq. noise, as before

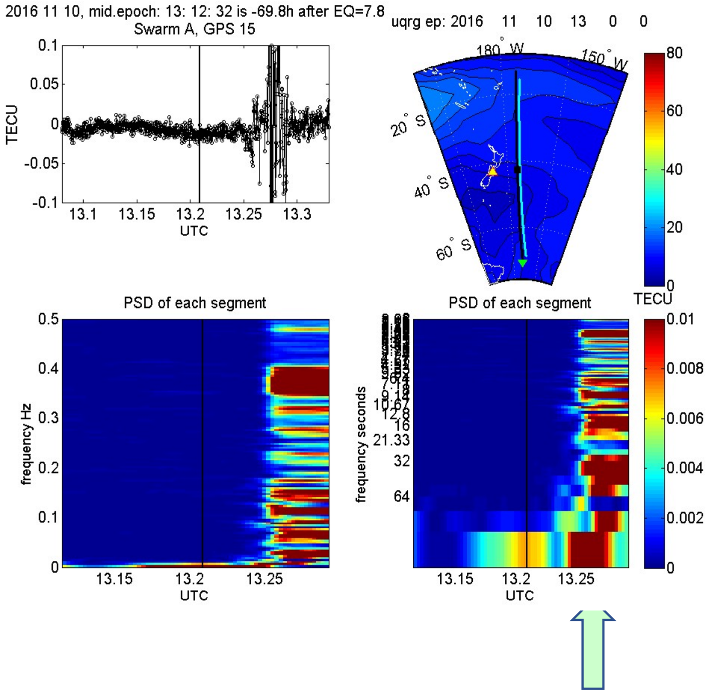
POD TEC, SFFT SPECTROGRAMS NEW ZEALAND 2016 (first pass)

ROT, Swarm A, PRN 15

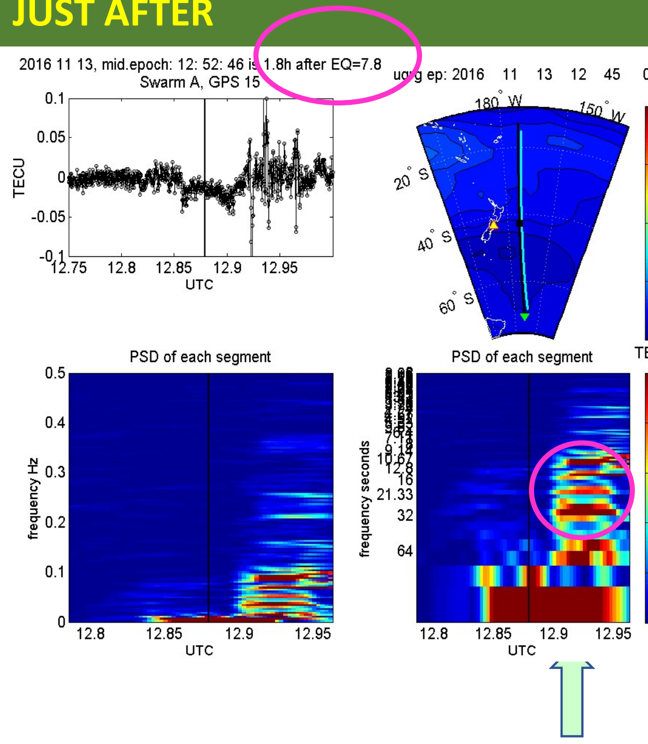
EQ > 2016.11.13 11:02:56

Tukey Window, Size 256 s.,

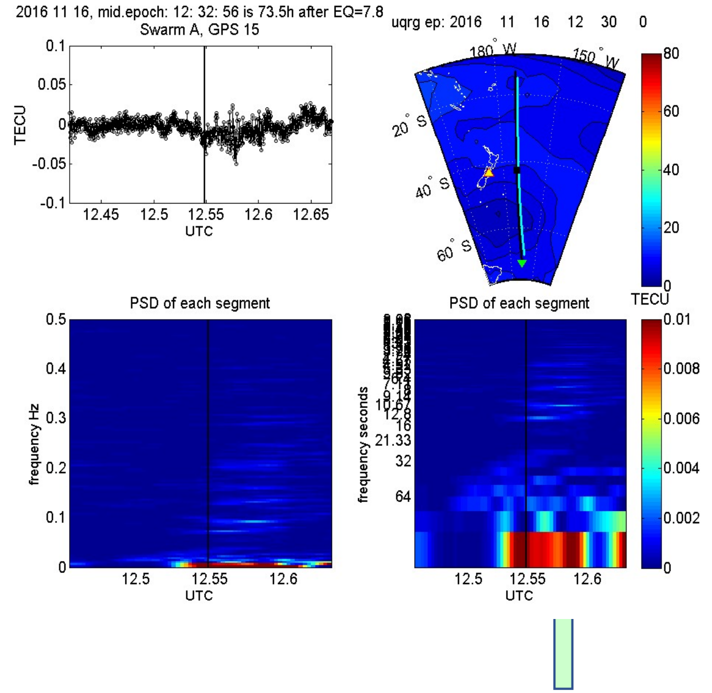
3 DAYS BEFORE



JUST AFTER



3 DAYS AFTER



The largest amount of high freq. noise, as well as in LP signal

Less noise, more low frequencies, and are better separated

Long wavelegth dominates

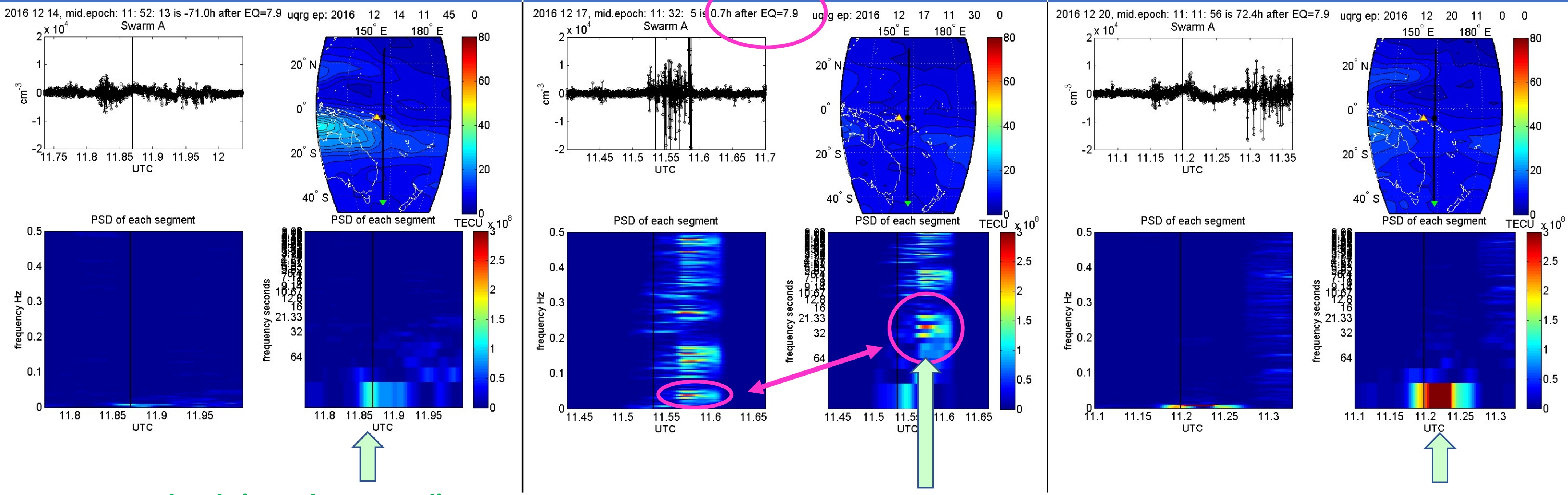
LP, SFFT SPECTROGRAMS
PAPUA NEW-GUINEA 2016

ROD, Swarm A

EQ > 2016.12.17   10:51:12

Tukey Window, Size 256 s.,

3 DAYS BEFORE | **JUST AFTER** | **3 DAYS AFTER**



Long wavelegth (worth removal) dominates 3 days before

This signal at 30 s. is not present 3 days before or after EQ

Long wavelegth dominates 3 days after

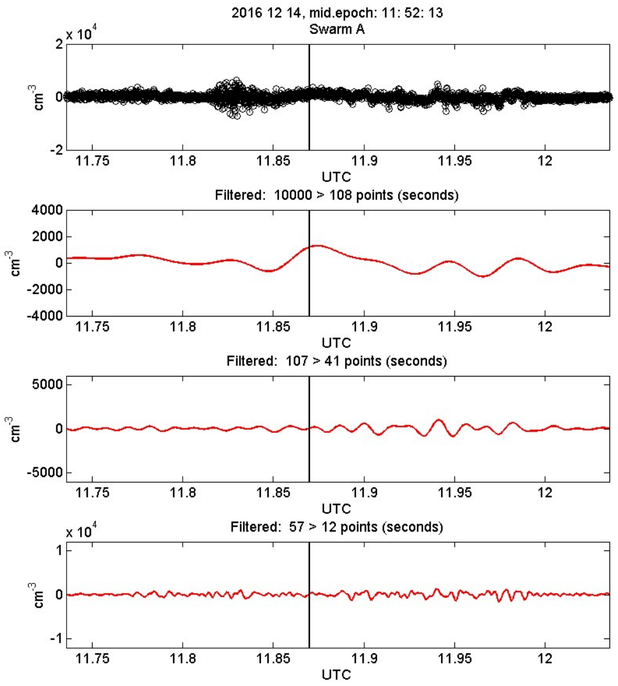
LP, FFT DECOMPOSITION PAPUA NEW-GUINEA 2016

ROD, Swarm A

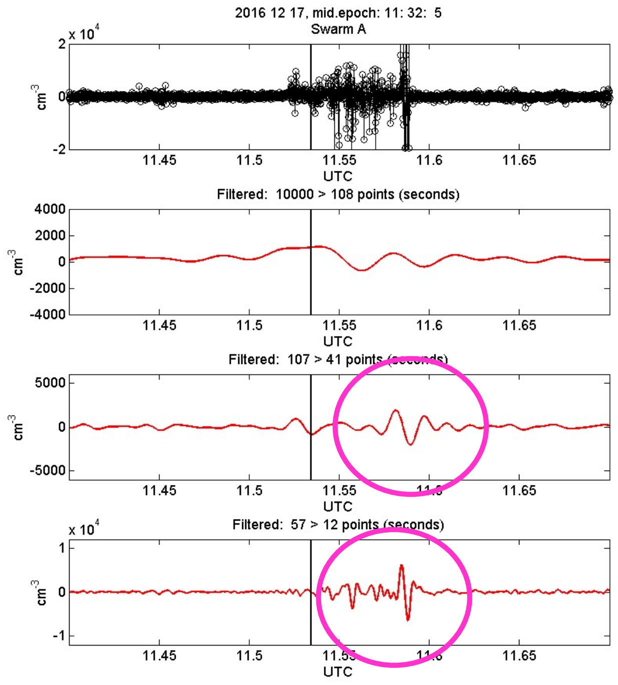
EQ > 2016.12.17 10:51:12

FFT decomposition into freq.: 12-57 s., 41-107 s., 108-max. s.

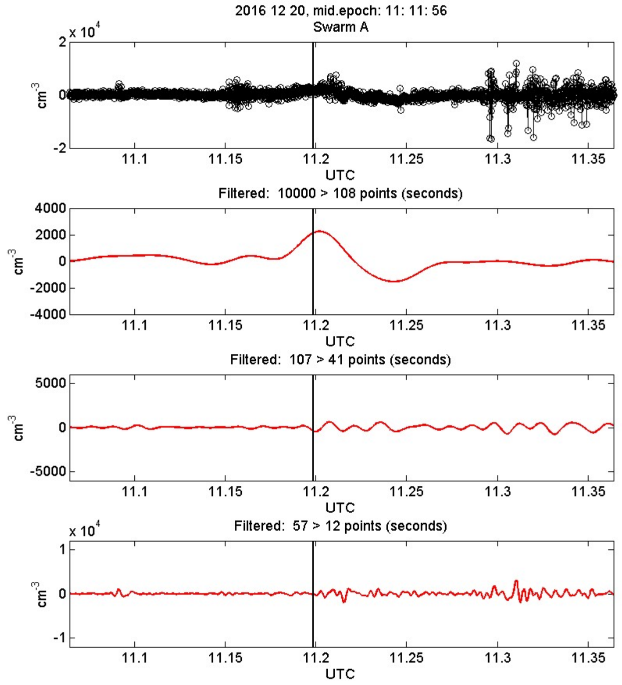
3 DAYS BEFORE



JUST AFTER



3 DAYS AFTER



There are large gradients at some selected frequencies.
Recalculations of units and comparison with ground data will be necessary…

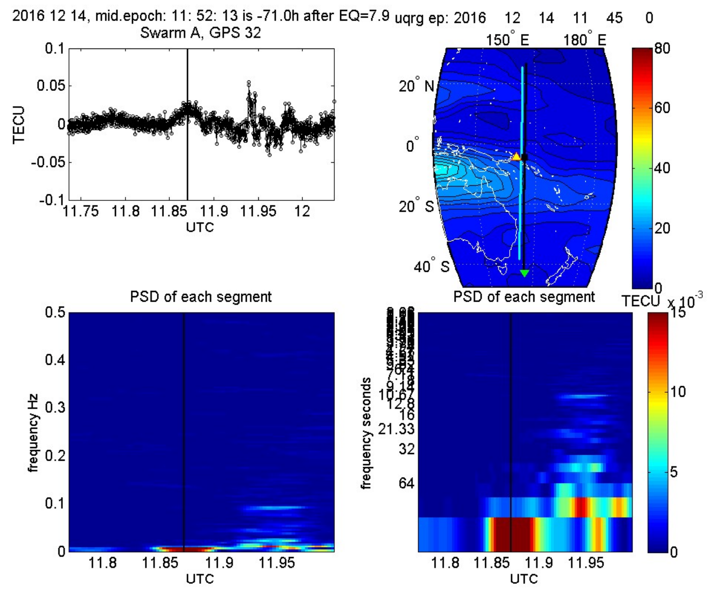
POD TEC, SFFT SPECTROGRAMS PAPUA NEW-GUINEA 2016

ROT, Swarm A, PRN 32

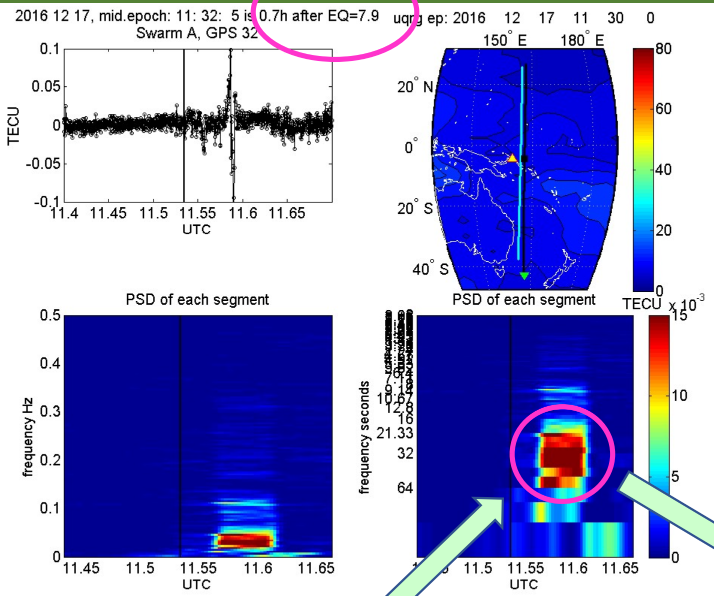
EQ > 2016.12.17 10:51:12

Tukey Window, Size 256 s.,

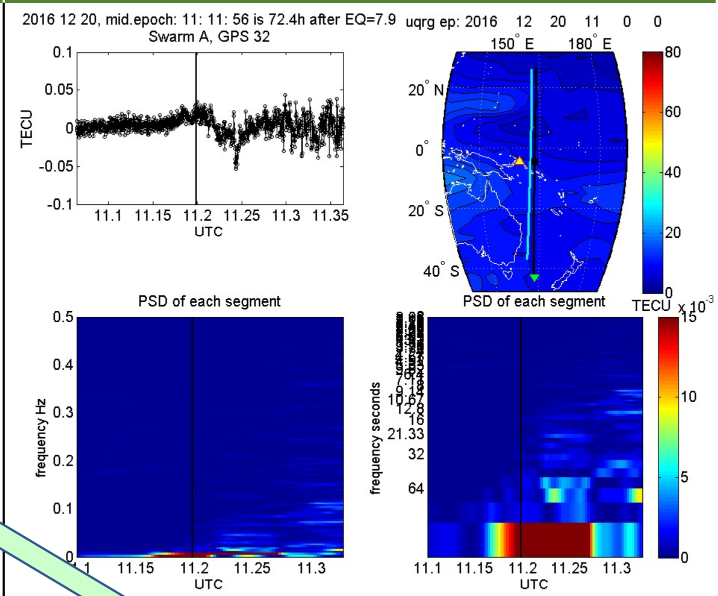
3 DAYS BEFORE



JUST AFTER

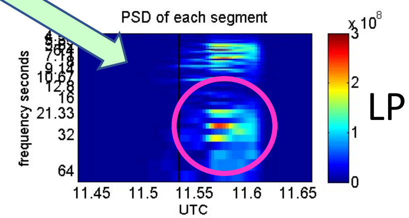


3 DAYS AFTER



The same observations in POD TEC. The most evident separation of the signal at 30 s. frequency.

This was also visible in LP Ne signal



RESAMPLINGS

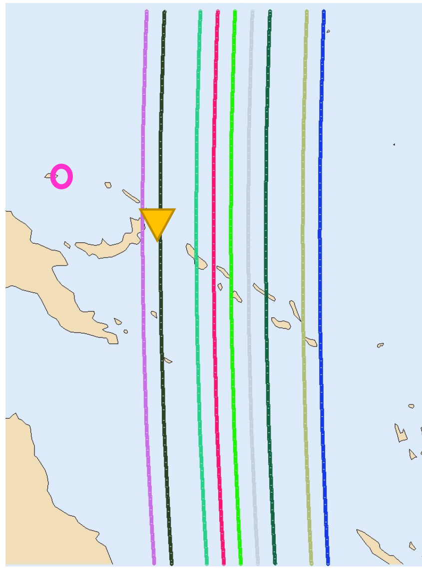
- close tracks from 9 days taken (similar longitudes and UTC time),
  passes separated by 3 or 5 days
  $\Delta\varphi < 2°$, $\Delta\lambda < 6°$, $\Delta UTC < 0.9$ h from central pass just after the EQ (light green)

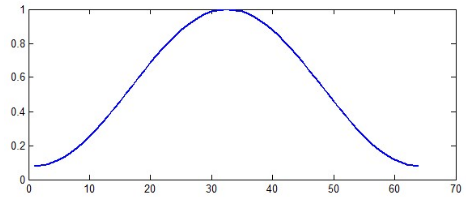
- Long wavelength signal removal by FFT,
  from selected band 200 s. to max. long-wavelength

- Frequencies - (resampling): different spacing for lower and higher frequencies:
  from 6 s. with step 2 s. to 80 s., and from 80 s. with step 20 s. to 260 s.

- Still large overlaping of windows – (neighbouring windows moved by 10 s.)

- WINDOW: Hamming Window 64 seconds (128 points from 2Hz data for LP),
  and 64 points for 1Hz POD TEC

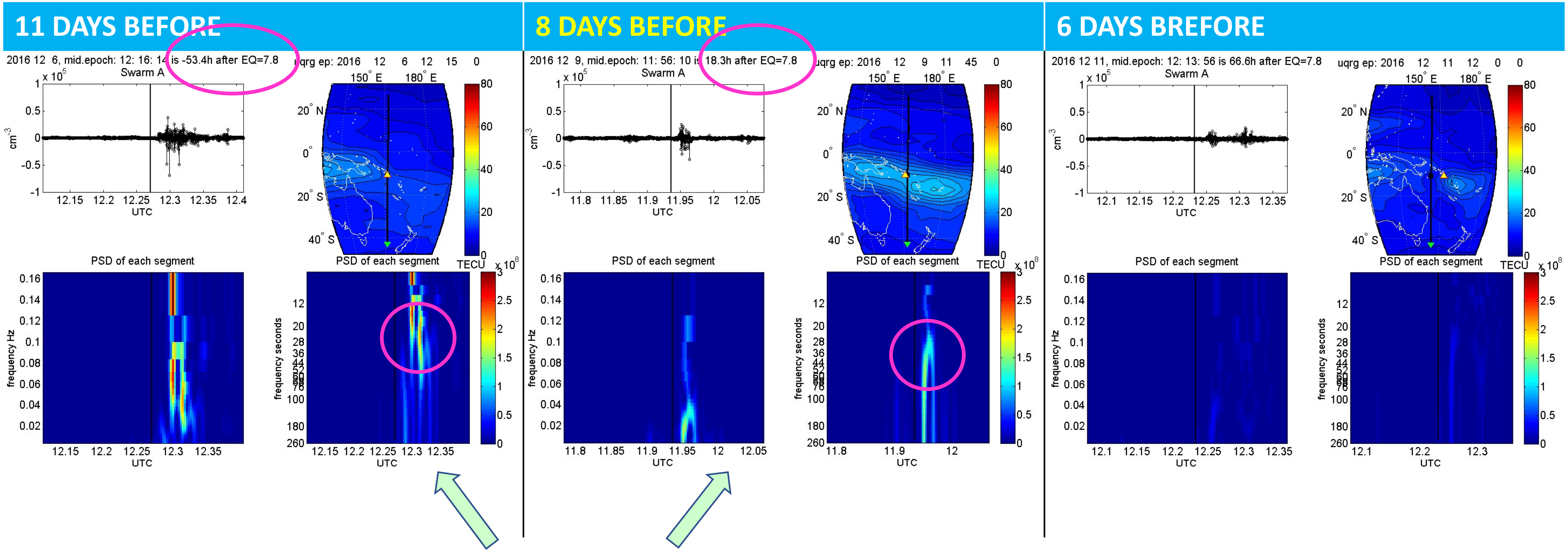




RESAMPLED: LP, SFFT SPECTROGRAMS ROD
PAPUA NEW-GUINEA 2016

EQ > 2016.12.17 10:51:12

Signals below 200 s. removed, **Hamming** Window, Size 64 s., resampling of frequencies: in points [260:-20:80,80:-2:6]



There are signatures in LP signals on Dec 6th and Dec 9th of 2016, at frequencies between 12 s. and, say 80 s.

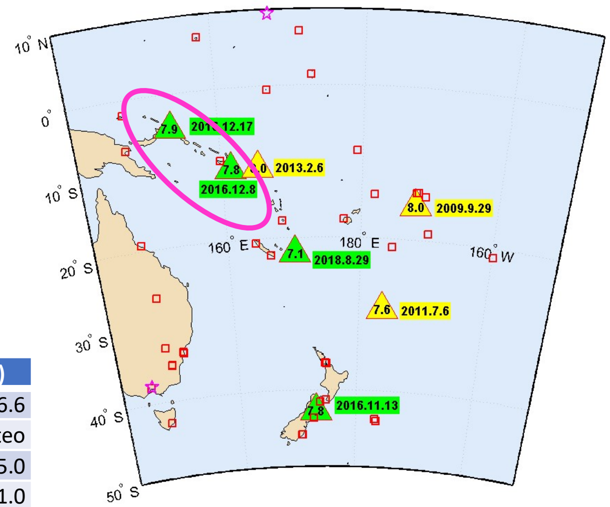
The region is seismologically very active. Aside from 7.9 EQ/tsunami on Dec 17th, there was also 7.8 EQ/tsunami on Dec 8th

EQs/Tsunami events in the southern Pacific (the largest)

Date	Place	Max. peak from TG (cm)	Max. peak Lat	Max. peak Lon	Max. peak Time (UTC)
20180829	Loyalty Islands,Pacific	50	-19.5326	169.2660	20180829052700
20180515	Pensylvania,Atlantic	22	41.2833	-72.9083	20180516005600
20180123	Alaska,Pacific	25	41.7450	-124.1830	20180123152100
20170717	Kamchatka,Pacific	10	52.7308	174.1030	20170718001200
20170501	Alaska,Pacific	6	58.1933	-136.3430	20170501131500
20170424	Chile,Pacific	16	-33.0273	-71.6259	20170424223700
20170122	Papua,Pacific	4	-6.6928	156.4090	20170122074800
20161217	Papua,Pacific	19	-6.6928	156.4090	20161217131900
20161208	Solomon Islands,Pacific	56	-20.6929	164.9420	20161208210100
20161121	Honshu,Pacific	35	39.0000	141.7500	20161121225600
20161113	New Zealand,Pacific	231	-42.4129	173.7030	20161113114400
20160901	New Zealand,Pacific	21	-37.5503	178.1590	20160901165900
20160819	South Georgia,Atlantic,Indian	14	-54.2800	-36.5000	20160819092900
20160812	Vanuatu,Pacific	22	-19.5326	169.2660	20160812025400
20151111	Chile,Pacific	58	-29.9501	-71.3353	20151111033500
20151018	Alaska,Pacific	18	59.5480	-139.7350	20151018131300
20150916	Chile,Pacific	467	-29.9501	-71.3353	20150917002400

Date	Place	EQ magnitude	EQ Lat	EQ lon	EQ time (UTC)	EQ Depth (km)
20180829	Loyalty Islands,Pacific	7.1	-22.0660	170.0500	20180829035159	26.6
20180515	Pensylvania,Atlantic				20180515000000	meteo
20180123	Alaska,Pacific	7.9	56.0460	-149.0730	20180123093143	25.0
20170717	Kamchatka,Pacific	7.7	54.4710	168.8150	20170717233413	11.0
20170501	Alaska,Pacific	6.2	59.8440	-136.6950	20170501123155	2.0
20170424	Chile,Pacific	6.9	-33.0730	-72.0510	20170424213826	25.0
20170122	Papua,Pacific	7.9	-6.2140	155.1220	20170122043023	136.0
20161217	Papua,Pacific	7.9	-4.5090	153.4500	20161217105112	103.0
20161208	Solomon Islands,Pacific	7.8	-10.6760	161.3300	20161208173846	41.0
20161121	Honshu,Pacific	6.9	37.3920	141.4030	20161121205949	11.0
20161113	New Zealand,Pacific	7.8	-42.7570	173.0770	20161113110256	23.0
20160901	New Zealand,Pacific	7.0	-37.3590	179.1460	20160901163757	19.0
20160819	South Georgia,Atlantic,Indian	7.4	-55.2790	-31.8740	20160819073222	10.0
20160812	Vanuatu,Pacific	7.2	-22.4950	173.1100	20160812012635	10.0
20151111	Chile,Pacific	6.9	-29.4830	-72.0350	20151111015438	12.0
20151018	Alaska,Pacific				20151018051900	landslide
20150916	Chile,Pacific	8.3	-31.5700	-71.6540	20150916225433	24.9

There was also previous tsunami on Dec, 8th in the region.

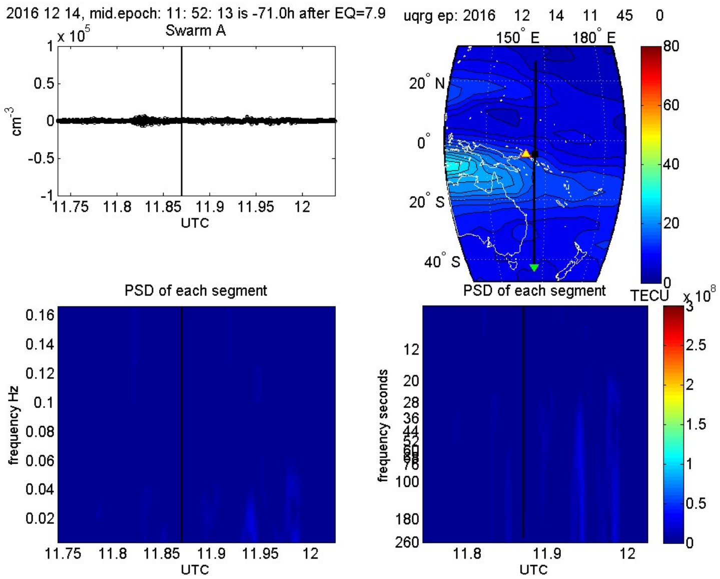


These 2 EQs in December of 2016 induce tsunamis and are included in tsunami database, however there were significantly more Eqs, which will be shown later…

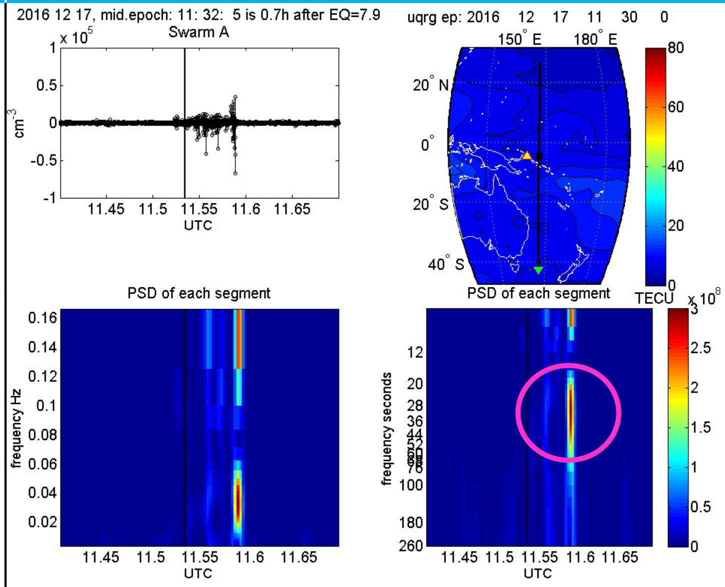
RESAMPLED: LP, SFFT SPECTROGRAMS ROD
PAPUA NEW-GUINEA 2016

EQ > 2016.12.17 10:51:12

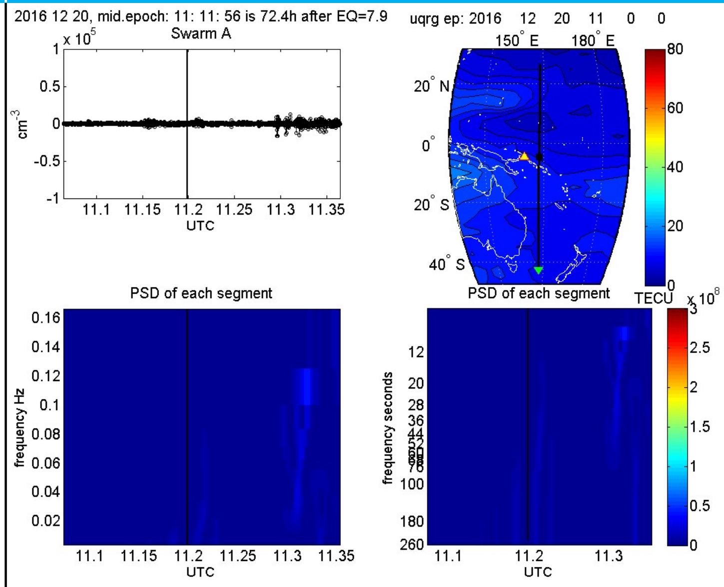
3 DAYS BEFORE



JUST AFTER



3 DAYS AFTER

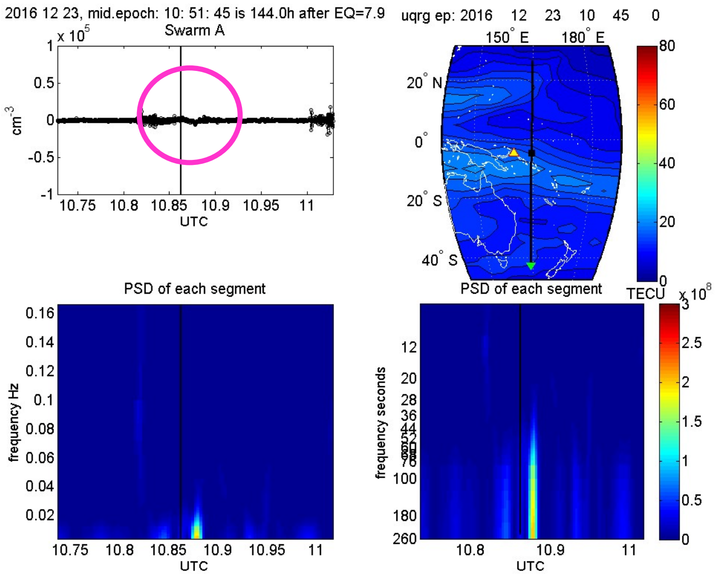


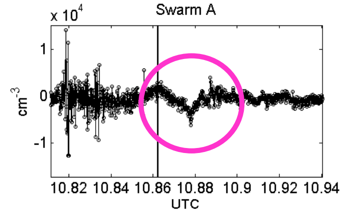
And resampled with smaller 64 s. window, clearly separated signal at 30 s. frequency just after the EQ on Dec 17th, 2016.
The closer to EQs, the stronger power spectrum and better separation of frequencies can be noticed.
These frequencies occupy band somewhere between 20 s. and 60 s.

RESAMPLED: LP, SFFT SPECTROGRAMS ROD
PAPUA NEW-GUINEA 2016

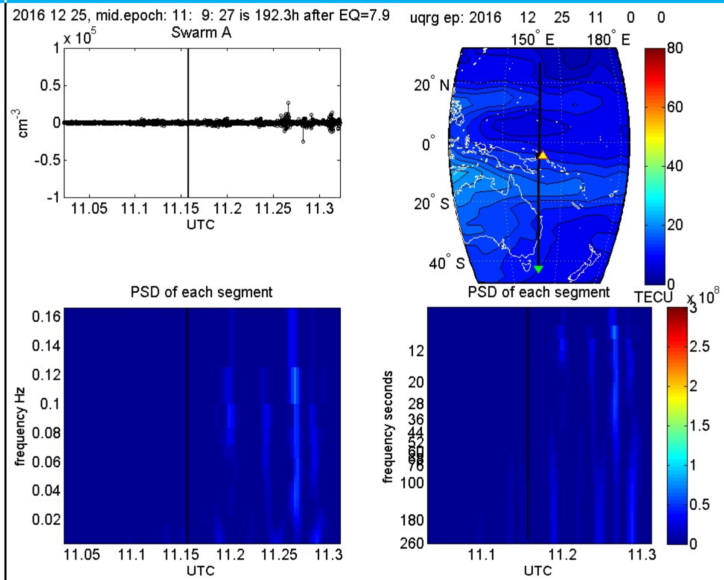
EQ > 2016.12.17 10:51:12

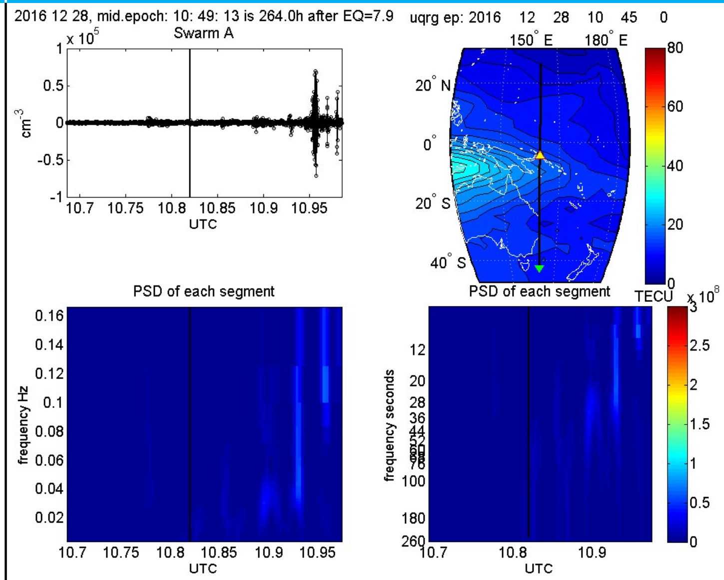
6 DAYS AFTER	8 DAYS AFTER	11 DAYS AFTER





This effect can be related with normal solar activity, but please note that its wavelength is large, around 200 s. in fast Swarm track





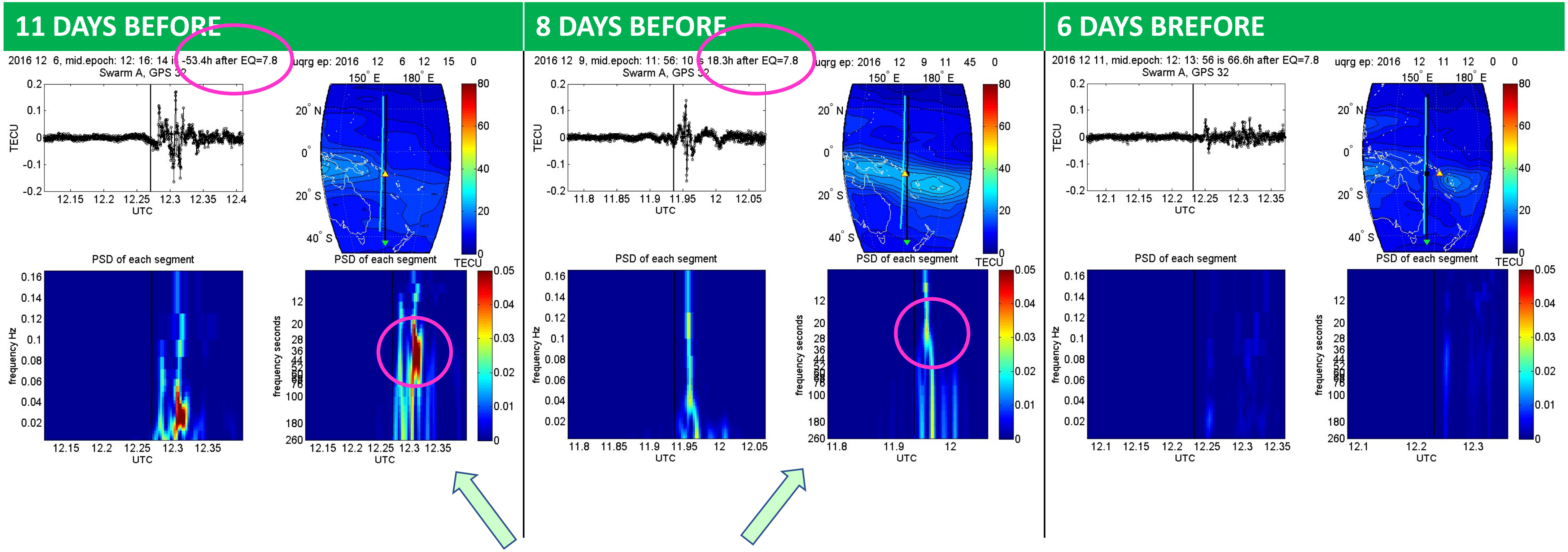
Here, many frequencies are occupied but the amplitudes are weaker at frequencies higher than 200 s., so the signal differs from that in left panel (although TEC is larger)

RESAMPLED: POD TEC, SFFT SPECTROGRAMS ROT, Swarm A, PRN 32

PAPUA NEW-GUINEA 2016

EQ > 2016.12.17 10:51:12

Signals below 200 s. removed, **Hamming** Window, Size 64 s., resampling of frequencies: in points [260:-20:80,80:-2:6]



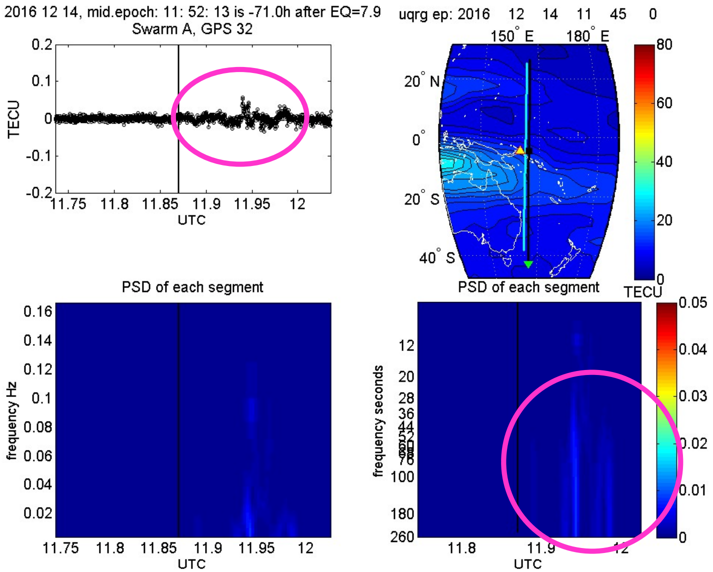
Similar signatures in POD TEC signals on Dec 6th and Dec 9th of 2016, at frequencies between 12 s. and, say 80 s.

Still remember that aside from 7.9 EQ/tsunami on Dec 17th, there was also 7.8 EQ/tsunami on Dec 8th

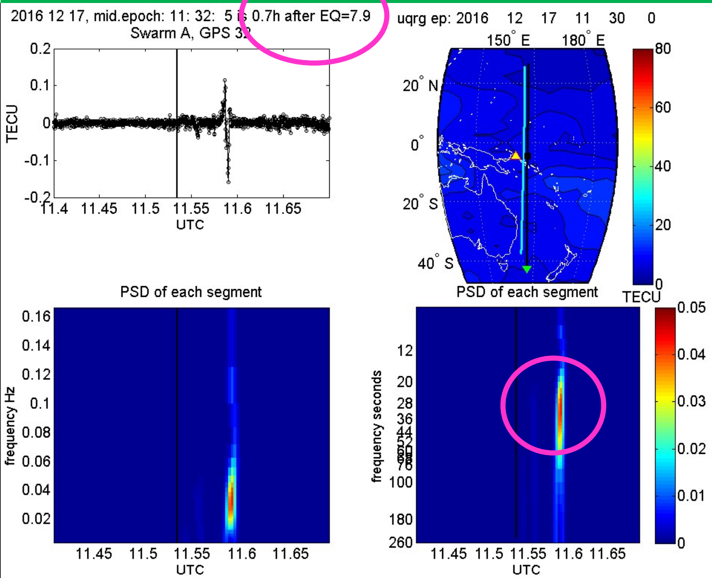
RESAMPLED: POD TEC, SFFT SPECTROGRAMS ROT, Swarm A, PRN 32
PAPUA NEW-GUINEA 2016

EQ > 2016.12.17 10:51:12

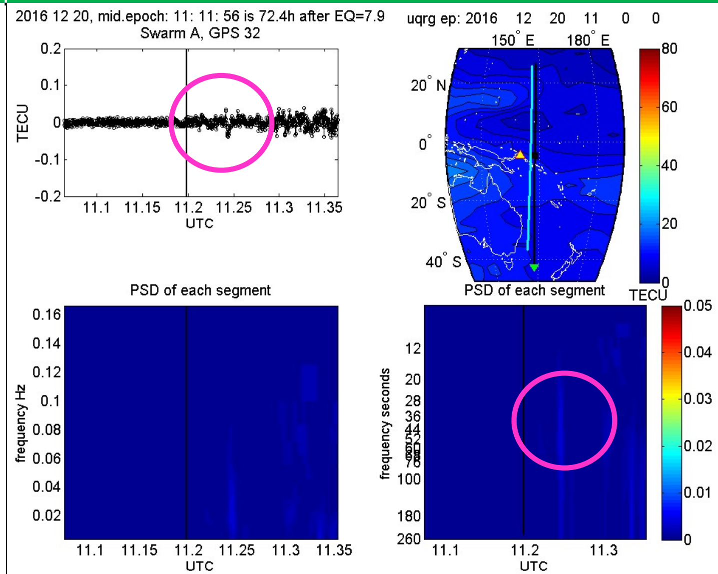
3 DAYS BEFORE



JUST AFTER



3 DAYS AFTER



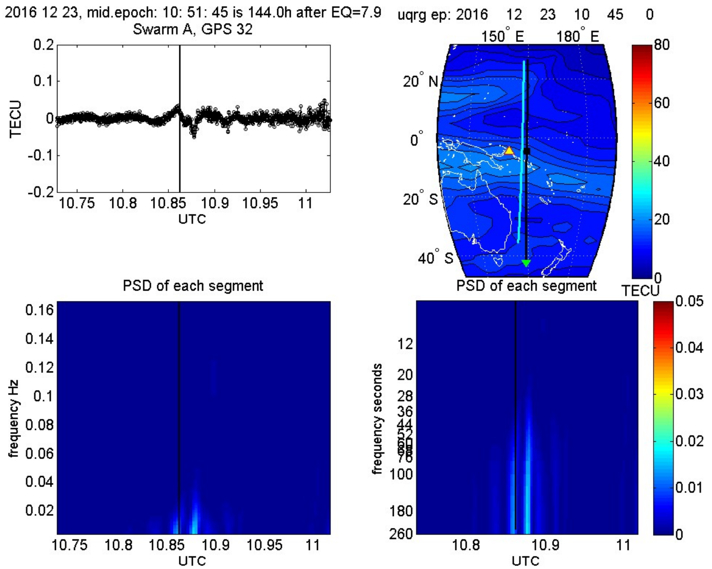
These signals of lower frequency and smaller amplitudę can be suspected to come from the edges of equatorial anomaly: to be checked !

And again, in POD TEC, the same clearly separated signal at 30 s. frequency just after the EQ on Dec 17th, 2016.

RESAMPLED: POD TEC, SFFT SPECTROGRAMS ROT, Swarm A, PRN 32
PAPUA NEW-GUINEA 2016

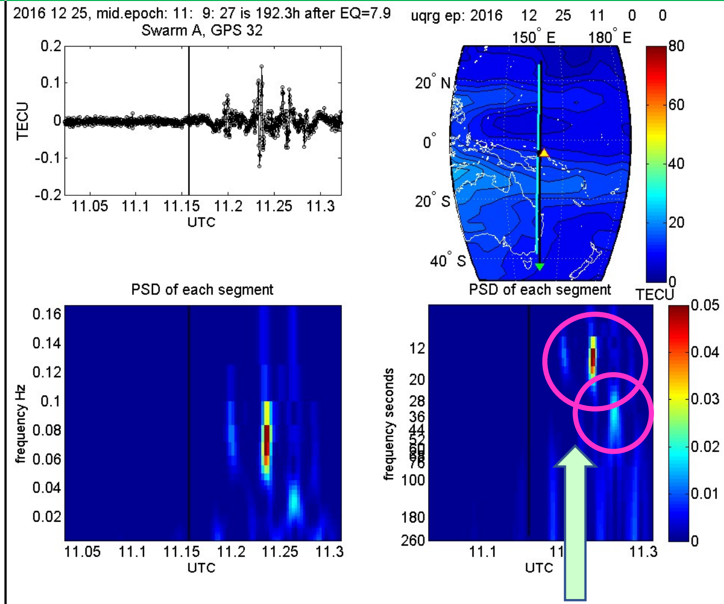
EQ > 2016.12.17 10:51:12

6 DAYS AFTER



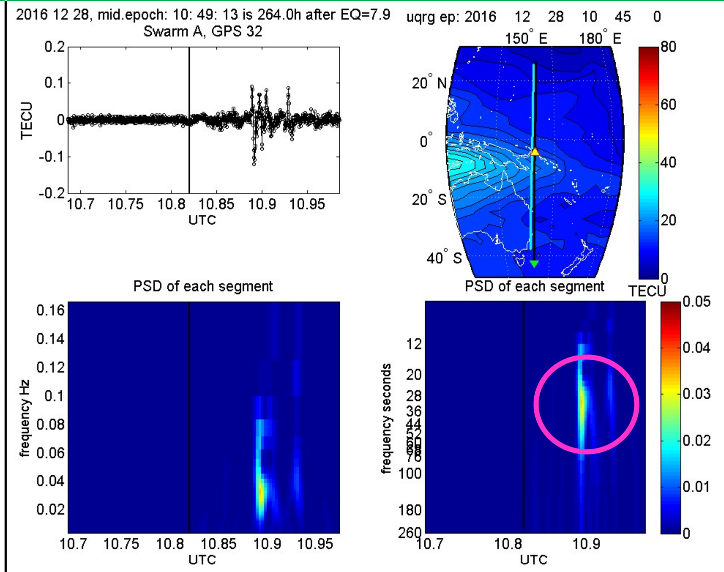
These signals of lower frequency and smaller amplitudę can be suspected to come from the edges of equatorial anomaly:
to be checked !

8 DAYS AFTER



On Dec 25th, in POD TEC, we have aside from suspected solar effects, a separated signal of unknown origin. Its frequency appears to be higher than 30 s. ! Or there are two signals !

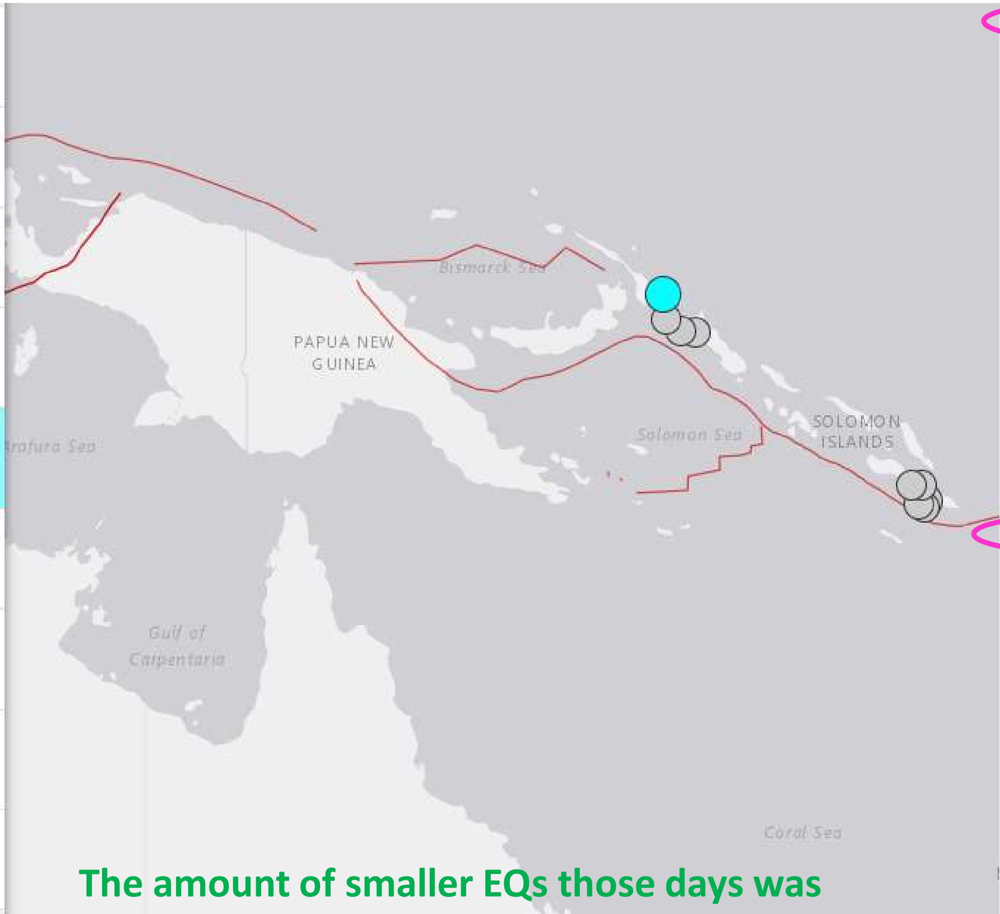
11 DAYS AFTER



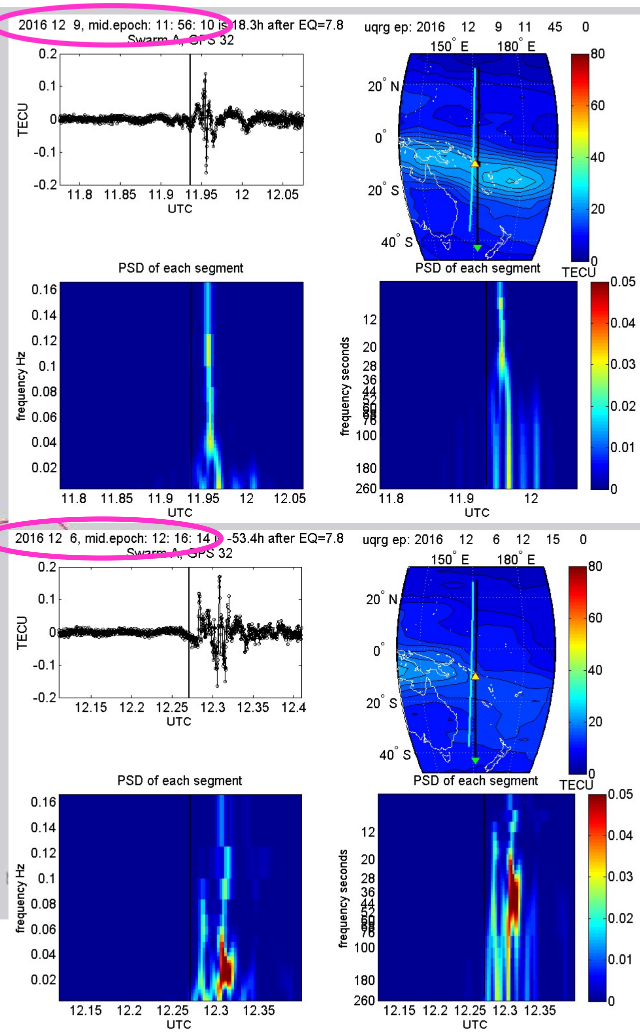
On Dec 28 th, we see again separated strong signal at 30 s. frequency

The largest Eqs (>= 6.0) in Papua NG region in December 2016 (far from total numer)

6.0	105km SE of Taron, Papua New Gui...	2016-12-24 01:32:16 (UTC)	35.0 km
6.0	114km WNW of Kirakira, Solomon I...	2016-12-20 12:33:14 (UTC)	10.0 km
6.4	81km WNW of Kirakira, Solomon Is...	2016-12-20 04:21:29 (UTC)	20.0 km
6.3	168km SE of Taron, Papua New Gui...	2016-12-17 11:27:36 (UTC)	8.4 km
7.9	54km E of Taron, Papua New Guinea	2016-12-17 10:51:10 (UTC)	94.5 km
6.0	132km WNW of Arawa, Papua New ...	2016-12-10 16:24:34 (UTC)	142.6 km
6.9	92km WSW of Kirakira, Solomon Isl...	2016-12-09 19:10:06 (UTC)	19.7 km
6.5	79km WSW of Kirakira, Solomon Isl...	2016-12-08 21:56:07 (UTC)	12.3 km
7.8	69km WSW of Kirakira, Solomon Isl...	2016-12-08 17:38:46 (UTC)	40.0 km
5.5	197km SW of Vaini, Tonga	2016-12-03 14:11:12 (UTC)	155.0 km

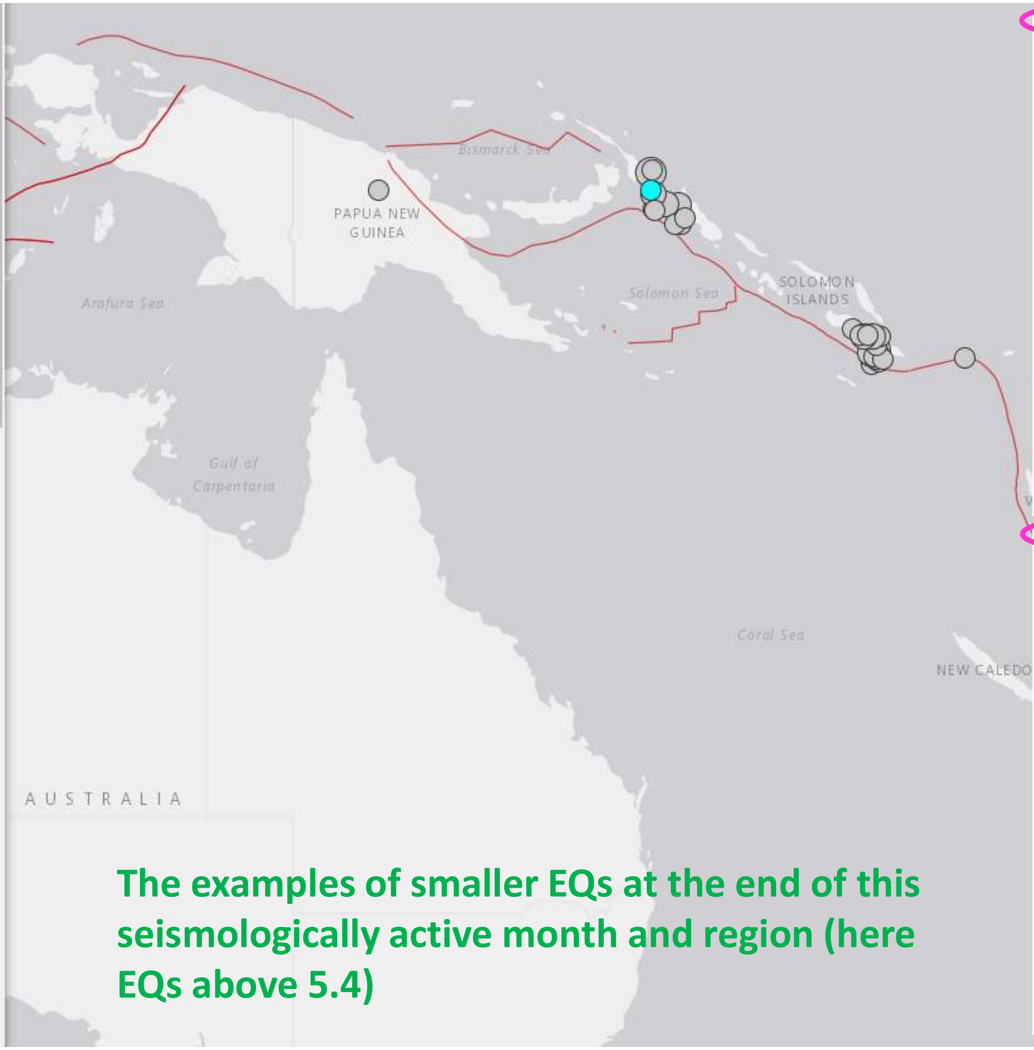


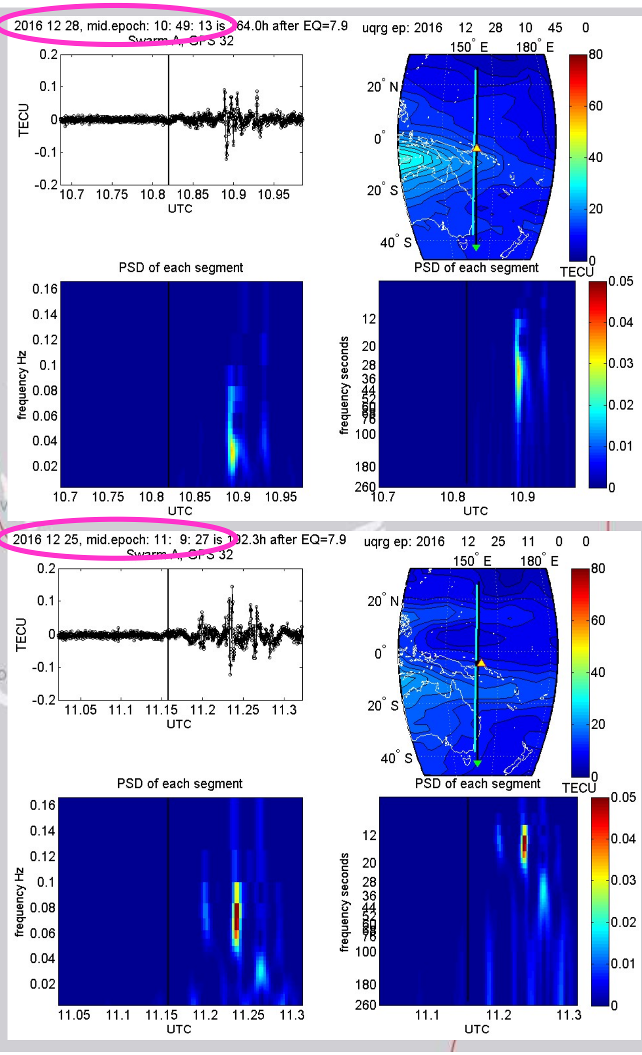
The amount of smaller EQs those days was significantly larger, and continuous during whole month…



Reamaining EQs (>= 5.4) in Papua NG region in December 2016 (far from total numer)

5.4	52km NE of Wabag, Papua New …	2016-12-28 14:24:24 (UTC)	102.0 km
5.4	164km SSE of Taron, Papua New …	2016-12-27 22:38:04 (UTC)	10.0 km
5.4	99km WNW of Kirakira, Solomon…	2016-12-27 02:30:24 (UTC)	49.6 km
5.8	92km SE of Taron, Papua New G…	2016-12-24 03:58:54 (UTC)	30.0 km
6.0	105km SE of Taron, Papua New …	2016-12-24 01:32:16 (UTC)	35.0 km
5.5	121km SE of Honiara, Solomon I…	2016-12-20 20:07:52 (UTC)	10.4 km
6.0	114km WNW of Kirakira, Solomo…	2016-12-20 12:33:14 (UTC)	10.0 km
5.6	158km SSE of Taron, Papua New …	2016-12-20 06:14:41 (UTC)	10.0 km
6.4	81km WNW of Kirakira, Solomon…	2016-12-20 04:21:29 (UTC)	20.0 km
5.4	92km WNW of Panguna, Papua N…	2016-12-18 19:57:53 (UTC)	32.9 km
5.4	125km E of Pangai, Tonga	2016-12-18 19:17:40 (UTC)	10.0 km
5.5	205km W of Ile Hunter, New Cale…	2016-12-18 12:49:50 (UTC)	31.9 km



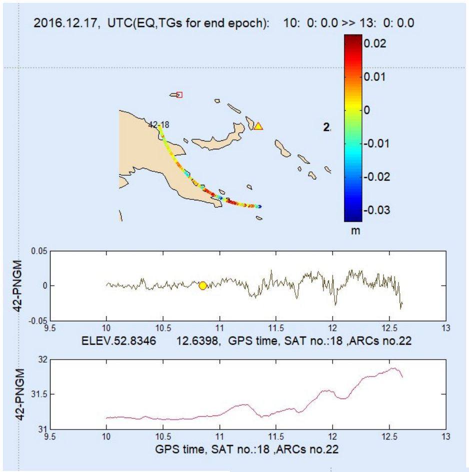


The examples of smaller EQs at the end of this seismologically active month and region (here EQs above 5.4)

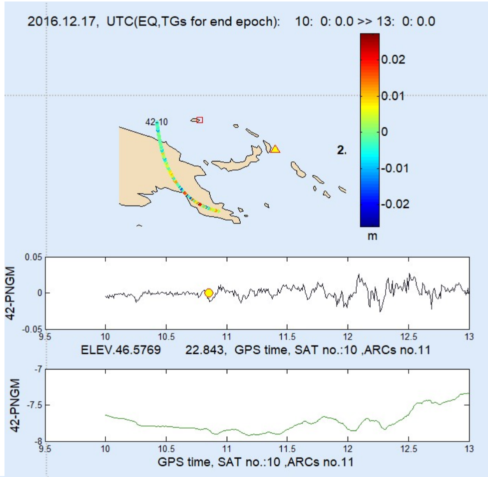
Very preliminary ground GNSS data investigation

Differences of phase observations from nearby IGS stations will be used in the validation in future research.
Some examples of ROT and TEC can be shown (GPS and GLONASS satellites)

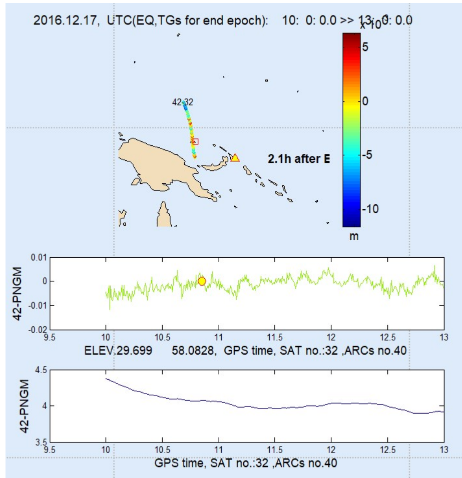
Station IGS PNGM, GPS No 18



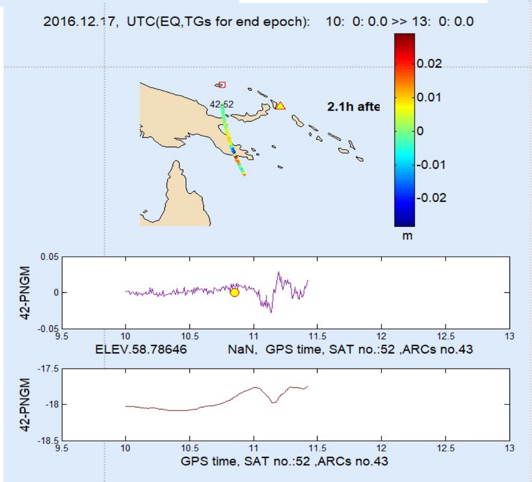
Station IGS PNGM, GPS No 10



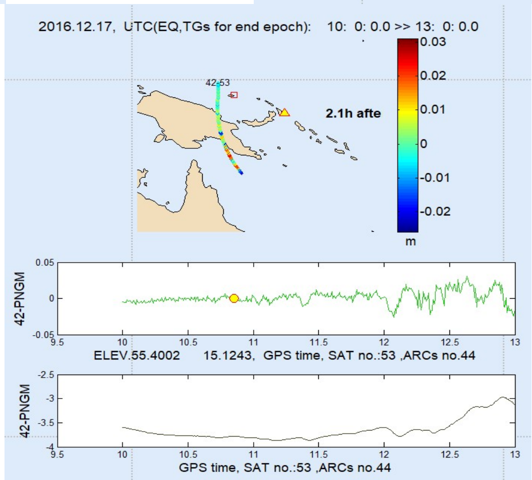
Station IGS PNGM, GPS No 32



Station IGS PNGM, GLONASS No 52 (? our working nb.)



Station IGS PNGM, GLONASS No 53 (? our working nb.)



Acknowledgements

This work is supported by ESA programme:
„Swarm+ Coupling: High-Low Atmosphere Interactions"

Leader: University of Warmia and Mazury in Olsztyn, Poland

Consortium members: NOA (Athens), TUM (Munich), UPC (Barcelona)

ESA Technical Officer: Roger Haagmans

Project name:

Contribution Of Swarm data to the prompt detection of Tsunamis and Other natural hazards (COSTO)

CONCLUSIONS…

- some signal at around 0.04 frequency (around 30 s. of Swarm track) repeats in many LP and POD TEC records close to EQs and just after EQs, whereas equatorial anomaly, usually is related with frequencies lower than 100 s. (only these are available everyday)
- LP Ne and POD TEC signals show very good integrity of the signals in spectral sense
- additional detrending and resampling must be made in order to find interesting frequencies more precisely (selected frequencies taken to analyses)
- more distant places, but quiet environment (tsunami response)
- different FFT windows?
- Interpretation referring to speeds of TIDs, recalculation of frequency units, relatively to Swarm and to ground observations. Comparison with ground GNSS.