AZIMUTHAL ANALYSIS IN [SQUID]^2 SYSTEM FOR MESOPAUSE AND SPRITES EXCITATIONS

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ABSTRACT

The physical meaning of the azimuth information provided by the ultra low-noise magnetometer instrument [SQUID]^2 is analyzed for ionosphere and atmosphere signal sources. Consequences for a potential world-wide network of such instruments are evaluated.

INTRODUCTION

The combination of a low Tc Superconductor 3 axis SQUID magnetometer inside the LSBB capsule Shielding QUalified for Ionosphere Detection (= [SQUID]^2) provides a DC to 40 Hz bandwith for magnetic fluctuations with a noise baseline with the present SQUID of 3fT/√Hz at upper frequencies. Hence the capacity to detect a variety of geomagnetic signals, as it is evident by the present session of this conference.

The present paper addresses the signification of the azimuth in two extreme cases: an extreme near field situation with the ionosphere precursor of the Sichuan-Wenchaun quake of May 12, 2008 and a more conventional one with the magnetic detection of giant sprites in the Golfe du Lion - about 200 km from LSBB- on September 2, 2009.

EXTREME NEAR FIELD SITUATION: THE 12 MAY 2008 SICHUAN-WENCHUAN PRECURSOR

Each ground movement compresses the air column above it. For P waves, when the air acoustic wave reaches the mesopause 90km above the ground 300 seconds after its emergence, a resonance mode is excited with a period between 60 to 90 seconds [2]. The corresponding electromagnetic wavelength is extremely large compared to any geographical distance on Earth. Wherever is the source, any detecting magnetometer is always in extreme near field situation.

For one hour the Sichuan quake of May 12 2008 (M=8.1) has been anticipated by an excitation of the same mesopause resonance (T around 74 sec) [3]. 60, 30 and 10 minutes before the quake "rainbow colored clouds" appeared in time coincidence with "DC magnetic jumps", each time at a few hundreds kilometers from the epicenter to be. World-wide there was no major quake , the few with 3<M< 5 were not simultaneous to the magnetic jumps. All over this hour the mesopause resonance excitation was observed by [SQUID]^2 (Fig 1). An additional proof that Sichuan was the signal source is that the resonance has been extinguished 300 seconds after the quake, the time it has taken for the Sichuan P wave to reach the mesopause.

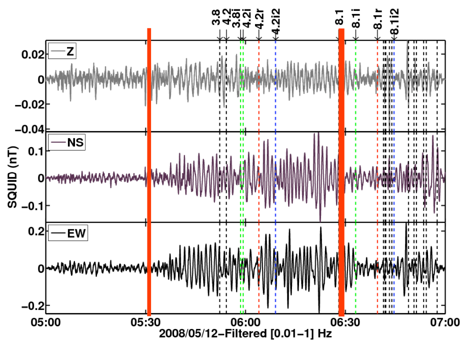

Fig. 1: The mesopause resonance, precursor of the M=8.1 Sichuan quake as registered by [SQUID]^2. The vertical line marks respectively the initialization of the mode and the quake time. 300seconds later (index 8.1i) the precursor vanishes at the P wave arrival at the mesopause. Indexes between the two verticals are world-wide quakes, not related to this excitation.

The long span of time allows a rough drawing of the envelope of the excited regime. The NS/EW ratio when the signal looks constant over a few minutes gives the azimuth of the horizontal projection of the magnetic oscillation. This rough unfolding was done before any information was available on the seism mechanism itself. It had given an azimuth of 35± 10°. Fig 2 compares this result to the seism fracture line. Clearly, as expected in a near field situation, the signal horizontal azimuth gives the source polarization .

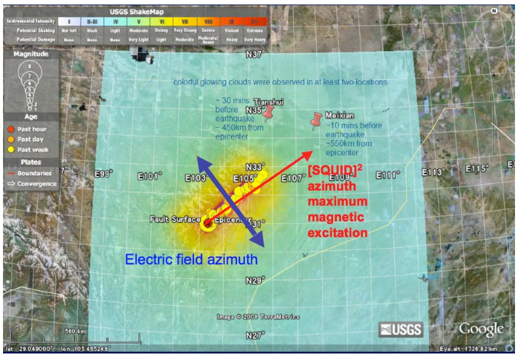

Fig 2 : Sichuan fracture line orientation compared to [SQUID]² response azimuth.

SPRITES (TLE) IN GOLFE DU LION, 2009/09/02

Sprites are Transient Luminous Events (TLE) triggered in the upper atmosphere by the discharge of positive lightning between the thunderstorm and the ground. They are not so frequent at our mid latitudes. A set of 9 TLE occurred at night in Golfe du Lion on September 2, 2009 and were optically detected by a high speed sensitive camera from the Pic du Midi Observatory West of the Golfe and magnetically by [SQUID]² N,NE of the Golfe (Fig3).

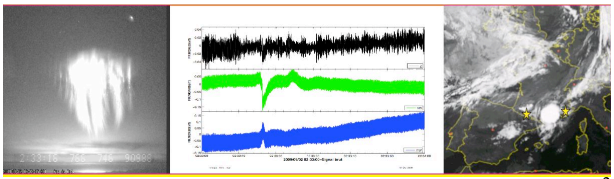

Fig 3 : left: Optical Pic du Midi / center: [SQUID]² LSBB magnetic detection of the same TLE at 02:33:16 TU/ right: satellite view of the source thunderstorm.

The ratio NS/EW of the peak values of the components defines the angle Θmagn with respect to the EW axis. If the lightning is assimilated as a vertical current, the Ampere law means that the horizontal angle from the magnetometer to the vertical current is Θ = (270- Θmagn)° whereas the peak signal module is $\Delta H = \sqrt{(\Delta H_{NS}^2 + \Delta H_{EW}^2)}$. Results for the set of TLE are displayed in table 1. The span of the resulting azimuths is represented on Fig 4.

event	TU	ΔH_{NS} pT	ΔH_{EW} pT	Θ°	ΔH pT
1	02:33:20	-182	79.5	204	199
2	02:37:30	-173	51	196	180
3	02:41:25	-164	67	202	177
4	02:46:50	-115	77	214	138
5	02:50:00	-200	87	204	218
6	02:51:50	- 76	54	215	93
7	02:55:15	- 56	69	201	60
8	02:56:20	-139	53	217	173
9	03:08:00	-236	205	221	312

Table 1 : the 9 TLE the azimuths varies from 196 to 221° are compatible with the source thunderstorm.

Clearly we are in a conventional propagation regime. This is not a surprise. Even if one considers that the lightning magnetic response is limited at 40Hz by the shielding, at this frequency the wavelength in the air is about 7500km, assuming the distance from Rustrel to the thunderstorm to be of the order of 150km, this gives a phase variation from the source to LSBB of 7°, this is no more a near field regime as for the Sichuan precursor.

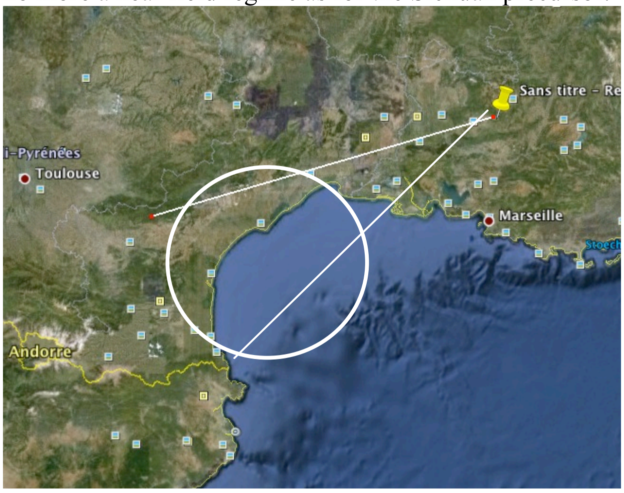

Fig 4: Span of the azimuths of Table 1 from Rustrel, the circle is a rough representation of the satellite view Fig 3. The unfolding is compatible with the actual observations.

CONCLUSION

The rough unfolding of the azimuth information offered by [SQUID]² in these two extreme situations illustrates the wide variety of signals that this kind of instrument can explore. In each case, even if the unfolding had been more cautious, the precision is limited by the fact that for the time being it is still a unique instrument of its kind. This calls for the creation of a world-wide network of such stations.

Even if they have not the same noise rejection quality, their time coincidence will provide a complementary tool for the study of natural hazards of societal importance.

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