centro de instrumentación y registro sísmico a.c.

THE SEISMIC ALERT SYSTEM OF MEXICO (SASMEX)

ESPINOSA-ARANDA J. M., A. Cuéllar, A. García, R. Islas, G. Ibarrola and S. Maldonado
e-mail: **espinosajm@cires.org.mx** http://**www.cires.org.mx**

Recently, an agreement to interconnect the *Sistema de Alerta Sísmica* (SAS) and the *Sistema de Alerta Sísmica de Oaxaca* (SASO) has been signed by the Oaxaca and the Mexico City governments with the Mexican Federal Civil Protection Agency to join the SAS serving Mexico City area with the SASO to provide an enhanced EEW service. Supported with the earthquake early warning algorithms developed for Oaxaca, and available communication and computer modern facilities, this network will bring the opportunity to mitigate the dangerous natural hazard in the Mexican populations in risk. We also aim to add to this purpose the efforts of other local governments with seismic vulnerability.

Seismic Alert System of Mexico City (SAS)

Government Authorities of Mexico City (GAMC) promoted the design of the SAS since 1989, after the 1985 Michoacan M8.1 earthquake, with the aim to mitigate future seismic disasters, aware of the latent "Guerrero Gap" seismic danger. The SAS is based on 12 sensing field stations installed on the Guerrero Coast, more than 300 km away from the Mexico and Toluca valleys. This warning resource, fig.1, started its experimental service since August 1991 and was tested in a small number of official basic schools of the Secretariat of Public Education Ministry (SEP), as well as in the subway metropolitan transport Mexico City METRO. In 1993 the GAMC started the SAS public services with the social contribution of the Valley of Mexico Radiobroadcasters Civil Association, which eventually disseminates the SAS Public Warning to their general audience. SAS also establish Alternative Emitters control services (EASAS), in Acapulco and Chilpancingo city's of Guerrero. Today SAS has recorded more than 2043 seismic events with magnitudes between 3.0 and 7.3, emitting seismic alerts with 60 s average in advantage: 52 moderate range and 13 as strong range. In the SAS service, "Prevention Time", means the time elapsed between alert signal start and the beginning of the S phase effect on the region where is warned to mitigate their risk. The original SAS algorithm to forecast the seismic danger index, requires a period $T_{SAS1}=2*(t_S-t_P)$ to define the eventual seismic energy and its rate of growth .

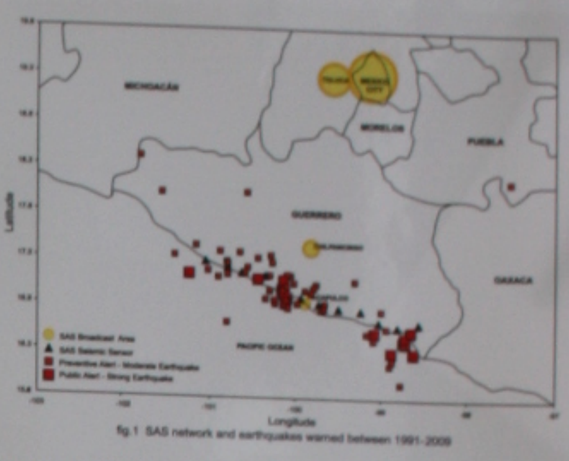

fig.1 SAS network and earthquakes warned between 1991-2009

SAS service, first NOAA/SAME application

SAS issues "Public" or "Preventive" alerts, according with the event seismic danger forecast, either strong or moderated, through the local radio broadcaster services also with little more than 350 radio links that support a miscellaneous users: institutions, supporting disaster prevention activities etc. To improve the dissemination efficiency of the earthquake warning provided by SAS and to have possibility to warn other natural hazard and danger evolution, last December 2008 with the support of the *Autoridad del Centro Historico de la Ciudad de Mexico*, a digital radio relay system such as the US National Oceanic and Atmospheric Administration (NOAA) is using, started operation.

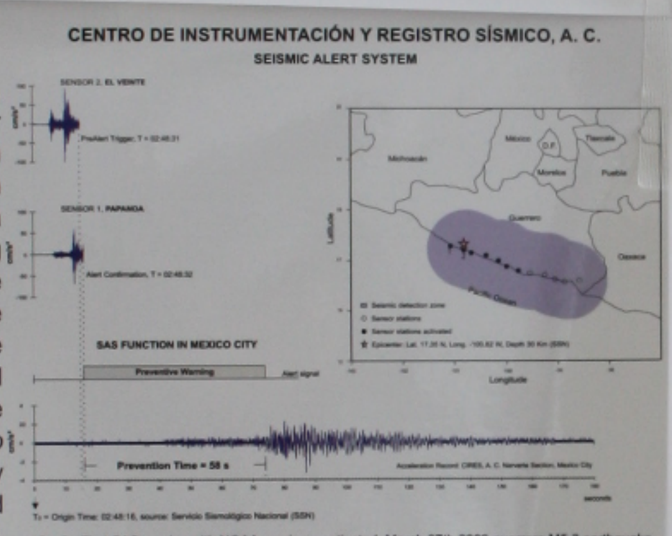

fig. 2 First SAS service with NOAA receivers activated, March 27th 2009 guerrero M5.3 earthquake

On March 27, 2009 at 02:48:32 (local time), the SAS emitted a signal of "Preventive Alert", anticipating the effects of the M5.3 earthquake from the coast of Guerrero (fig. 2); the SAS took advantage for the first time of the NOAA/SAME technology application making possible to validate the effective use of this resource that, with a minor technical adjustment for expedite reaction, has been proposed to enhance the SAS specifications helping to mitigate the seismic vulnerability in Mexico. At that time, eight monitoring NOAA receivers successfully reacted and provided 58 s of Prevention Time.

Seismic Alert System of Oaxaca City (SASO)

The strong M6.7 earthquake on June 15, 1999 hit Oaxaca and generated several damages, also the interest of Civil Protection authorities to request the technical design and construction of the SASO, covering its seismic danger regions, fig. 3. In 2001 CIRES developed this new EEWs and its public service started in 2003. The SASO has 36 seismic sensors and 11 radio relay stations, to link its Coastal, Central, North and Isthmus regions. Since its commissioning, it has issued three Public Alert warnings and five Preventive Alert notices from the registry and analysis of about 186 earthquakes. The evolution of this development has better time efficiency criteria to define the range of warnings in contrast with the algorithm originally defined in 1990 for the SAS.

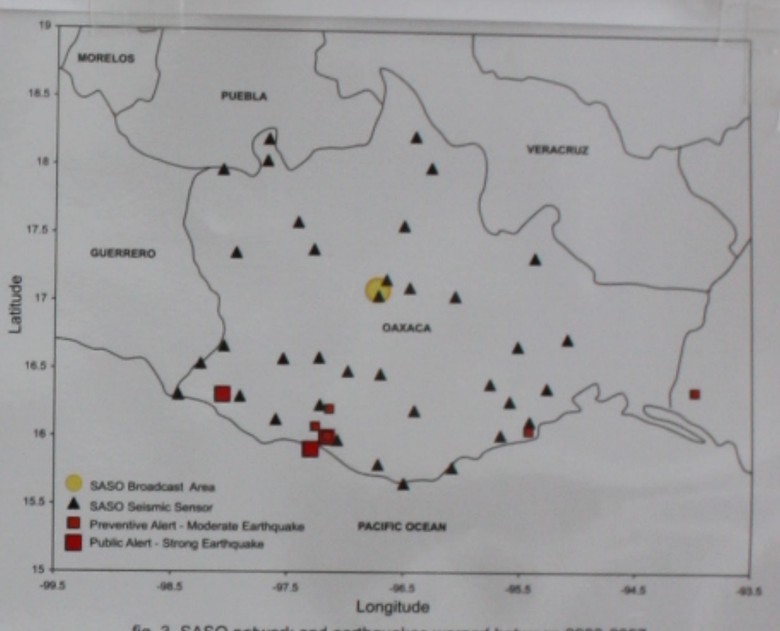

fig. 3 SASO network and earthquakes warned between 2003-2007

SASO warning range forecast, dual criteria for deep focus

Where the seismic epicenters occur at depths smaller than 40 km, SASO uses the same alert warnings first criterion of the original SAS developed for Guerrero with small adjustments. On the other side for inland epicenters, new options were required to determine the seismic danger range in less time, handling a simultaneous operation criteria, in the seismic sensing stations located at the Central, North and Isthmus regions of Oaxaca. It made possible to release the "Public" or "Preventive" alerts within maximum time of initial 3 seconds of P phase. After the beginning of the P phase, the second criterion analyzes and calculates with a Regression and Minimum Squares Model the factors: dominant period, peak acceleration and energy, during the interval TSAS2=(ts-tp). The third criterion determines simultaneously, by means of Classification Model and Vectorial Support Machines, the dominant period vertical effect observed in a small bandwidth during 3 s. This way seismic sensing stations of SASO system operating in regions with seismic deep focus, are capable to relaying their results in no more than 3 s, fig. 4. Acceleration records from the SASO seismic region are systematically used to calibrate its algorithms.

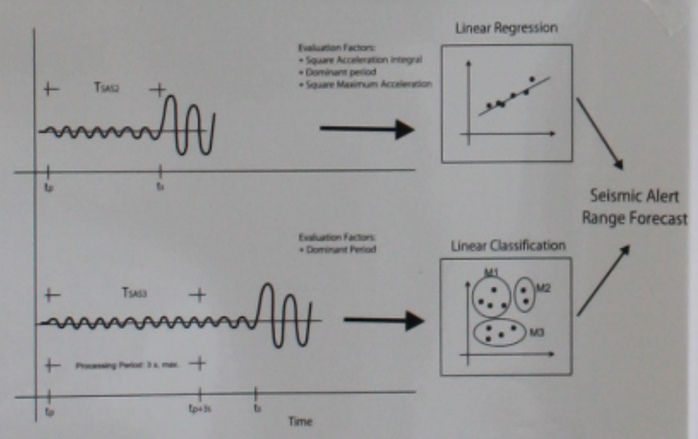

fig. 4 SASO seismic alert forecast, 2nd and 3rd criteria

SASO warning function with the third criterium algorithm

The SASO system issued the most recent "Preventive Alert" anticipating 40 s arrival in Oaxaca City the effects of M6.2 earthquake on July 5, 2007 at 20:09:51, with 113 km depth focus, fig. 5, (from Preliminary Report, SSN). SASO field stations 35 and 36 observed 3 s period of the P phase vertical effect, and as no S phase was detected during this period, the seismic danger index defined with the third criterion algorithm, was relayed to warn in Oaxaca City.

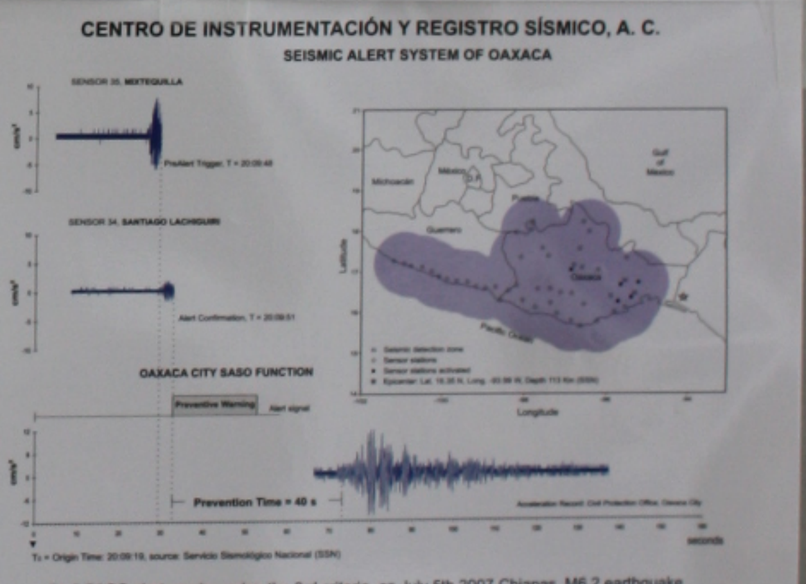

fig.5 SASO alert service using the 3rd criteria, on July 5th 2007 Chiapas, M6.2 earthquake

It requires more results as this to validate the effective performance of this criteria, proposed to get more "Prevention Time" in the SASO warning process, improving the efficient identification of dangerous earthquakes with deep focus.

SASMEX: SAS and SASO integration

The 1987 SAS original design was proposed to cover the so-called "Guerrero-Gap", as the region with the highest probability for generating the next catastrophic seismic event with similar effects, or exce-eding those of the major earth-quake of 1985; as a result, the SAS sensing field stations network included only a strip along the coast of Guerrero, 320 km distant from the Valley of Mexico. However, since 1991 up today during the SAS operation service, the effects of earthquakes generated in neighboring regions were recorded; and they inflicted damages in Mexico City. This circumstance and the historical result achieved with the SAS, justify increasing of the number of sensing field stations arrangement so as to cover other regions where also harmful earthquakes are likely to take place, fig. 6.

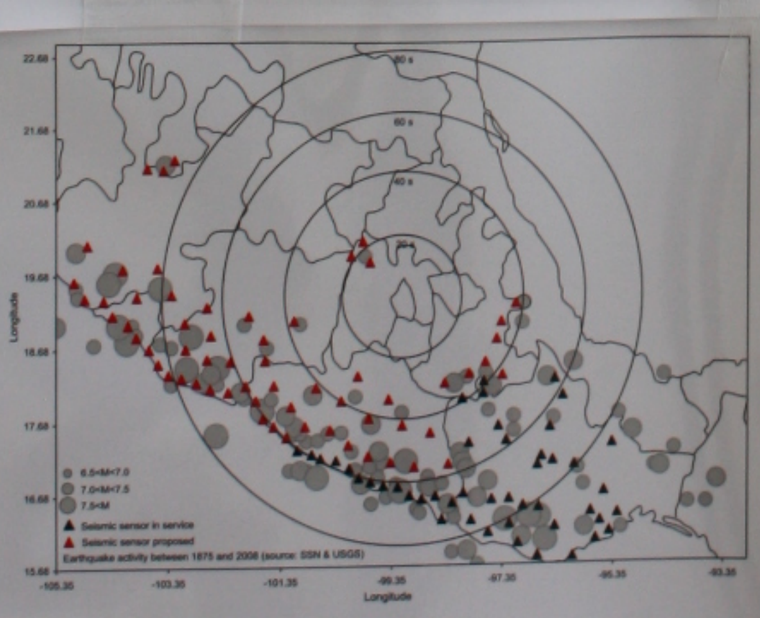

fig. 6 SASMEX seismic sensors network

SASMEX: SAS and SASO integration

An agreement has been signed among the government authorities of the States of Oaxaca and of Mexico City endorsed by the Federal Government Ministry to inte-grate their SASO and SAS resources; SAS with 12 seis- mic monitors and 17 years of regular service, and SASO with 36 seismic monitors installed to integrate the SASMEX.

The principal advantage to reach with the SASMEX integration is self-explained in the fig 7; during the June 14, 2004, M5.8 earthquake Oaxaca Coast; SASO issued a "Public Warning" with 30 s Prevention Time in Oaxaca City. The same seismic effect also reached Mexico City and if the SASO and SAS functions were integrated, the SASMEX Prevention Time in Mexico City could be more than 60 s.

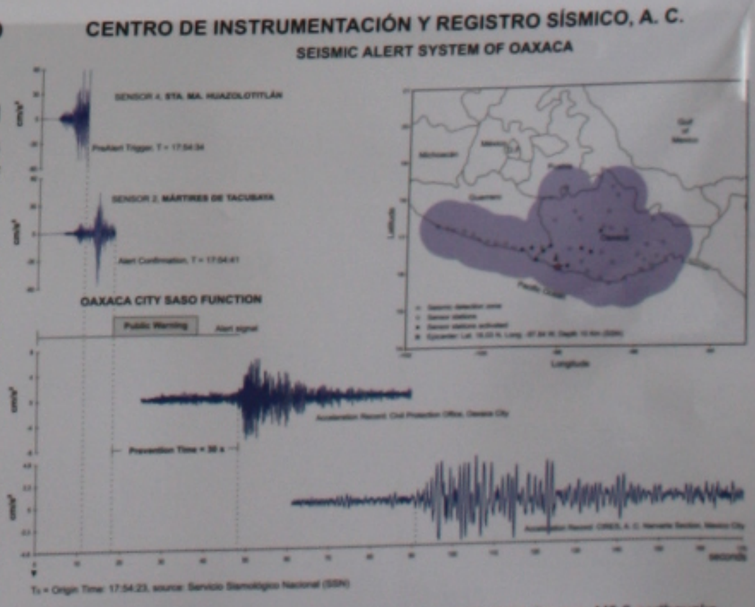

fig. 7 SASO alert service using the 1st criteria, on June 14th 2004 Oaxaca, M5.8 earthquake