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Study of precursory phenomena before M7.2 Hyogoken Nanbu earthquake of January 17, 1995 around Kobe, Japan for earthquake prediction

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Seismic precursory phenomena in the atmosphere, groundwater, and ionosphere before M7.2 Hyogoken Nanbu earthquake of January 17, 1995 around Kobe, Japan are studied for predicting great earthquakes (M>6.0). A wide area around the Kobe city suffered great damage and about 6500 people were dead. The upward tornado type seismic cloud appeared over Nojima fault near the epicenter iin the evening of January 9, 1995 when strong VLF and LF radio noises from lightning discharges were observed at Uji about 90 km northeast of the epicenter. Characteristic phase changes at terminator times of Omega 10.2 kHz waves passing 70 km north of the epicenter extended toward darker local times by 1 hour from January 14 to 16, 1995. This implies a lowering of D layer wave reflection height due to ion density increases at altitudes of 70-75 km. The radon concentration in the atmosphere over Ashiya fault in Kobe city and in the groundwater in Nishinomiya city had gradually increased above the normal one since 2 months before the earthquake, increased rapidly in December 1994, attained a peak just before the earthquake onset, and suddenly decreased to the normal level in October 1994 after the earthquake. Radon atoms which are soluble in the water increase as contact surface of rock grains with ground water increases due to rock grain size reduction by rock microcracks in the seismic precursory period. Anomalous radon ion density increases of about 10 times the normal one were observed for 8 days before this earthquake at Okayama 200 km west of the epicenter. The anomalous foEs increases up to 10 MHz detected at Shigaraki and Kokubunji were observed together with ELF radio noise increases at Usami,Ito city where is about 70 km south of Kokubunji in the daytime on January 15, 1995. Epicentral distances of Shigaraki and Kokubunji are within 500 km that are the same as those of the terrestrial gas emanations before great earthquakes. Since geomagnetic and so-

lar disc conditions were very quiet all day on January 15, 1995 and the foEs in the Japanese winter is normally below 6 MHz, the anomalous foEs increases seem to be a precursor of this earthquake. The radon ions emanated from the fault will be carried up to cold high altitudes of 7-8 km by rapid air currents of 70-80 m/s. This process causes a charge separation between positively charged topside cloud and negatively charged bottom-side cloud. Strong electric fields are set up in the lower ionosphere by lightning discharges of positive charges in seismic upper cloud to the ground. The thundercloud electric field above the air breakdown electric field at altitude of 100 km causes ambient electron heating and ionization of neutral particles in the lower ionosphere to produce the anomalous foEs increases observed on January 15, 1995. So, remote sensing of gamma rays of 200 keV - 3 MeV radiated from daughter radioactive nuclides of Rn-222 by satellite borne dosimeter in the thermosphere, where the undesirable gamma ray noises around the dosimeter are very low, is useful for earthquake($M>6.0$) prediction since the atmospheric radon ions consist of daughter radioactive nuclides of Rn-222. Also, ground observations of radon concentration in the atmosphere and ground water, and of atmospheric radon ion density are promising for predicting great earthquakes as well as ground observation networks of ULF geomagnetic field, ELF-LF radio noises, and VLF signals of subionospheric propagation.