Why we often fail to see earthquake precursors?

B.R. Arora
Currently at Uttarakhand State Council for Science & Technology, Dehradun, India
Formerly From Wadia Institute of Himalayan Geology, Dehradun, India
And was also
Visiting Research Fellow, NCREE, Taipei, Taiwan

➢ EARTHQUAKE PRECURSORS

❖ Seismological Precursors

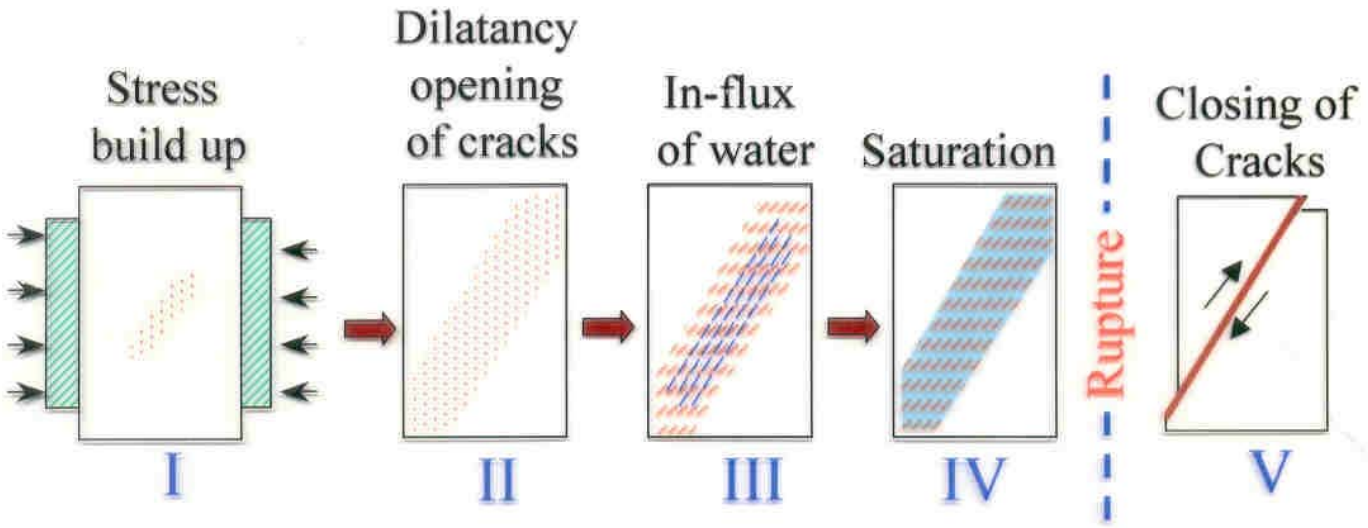
- Space time pattern in the foreshock activity,
- Seismic swarm, seismic gaps,
- Decrease of ‘b’ in the Gutenberg-Richter relation (Log_{10} N=a-bM),
- Characteristic time variation in Vp/Vs ratios
- Nucleation of hypocenters of small earthquakes

❖ Geophysical/ Hydrological precursors

- Land deformation due to crustal uplift and subsidence
- Changes in the geomagnetic field, earth’s resistivity and related parameters such as electric field, telluric current and self-potential
- Gravity changes preceding earthquakes
- Electromagnetic emission in ULF and VLF bands
- Ground water level fluctuations; and
- Changes in the Radon/Helium emission

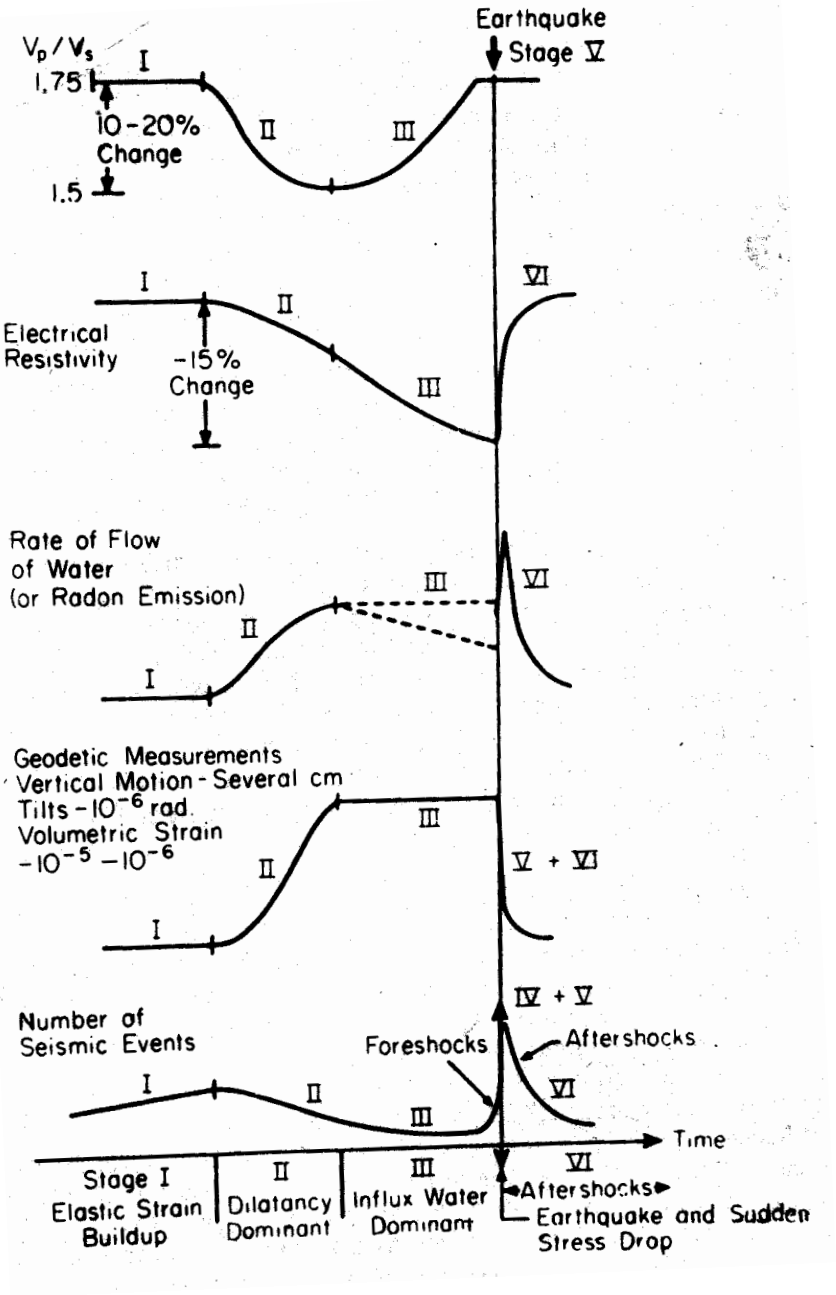
- Moving towards earthquake prediction

Dilatancy Diffusion Model For Earthquake Prediction



A

Dilatancy-Diffusion (DD) model

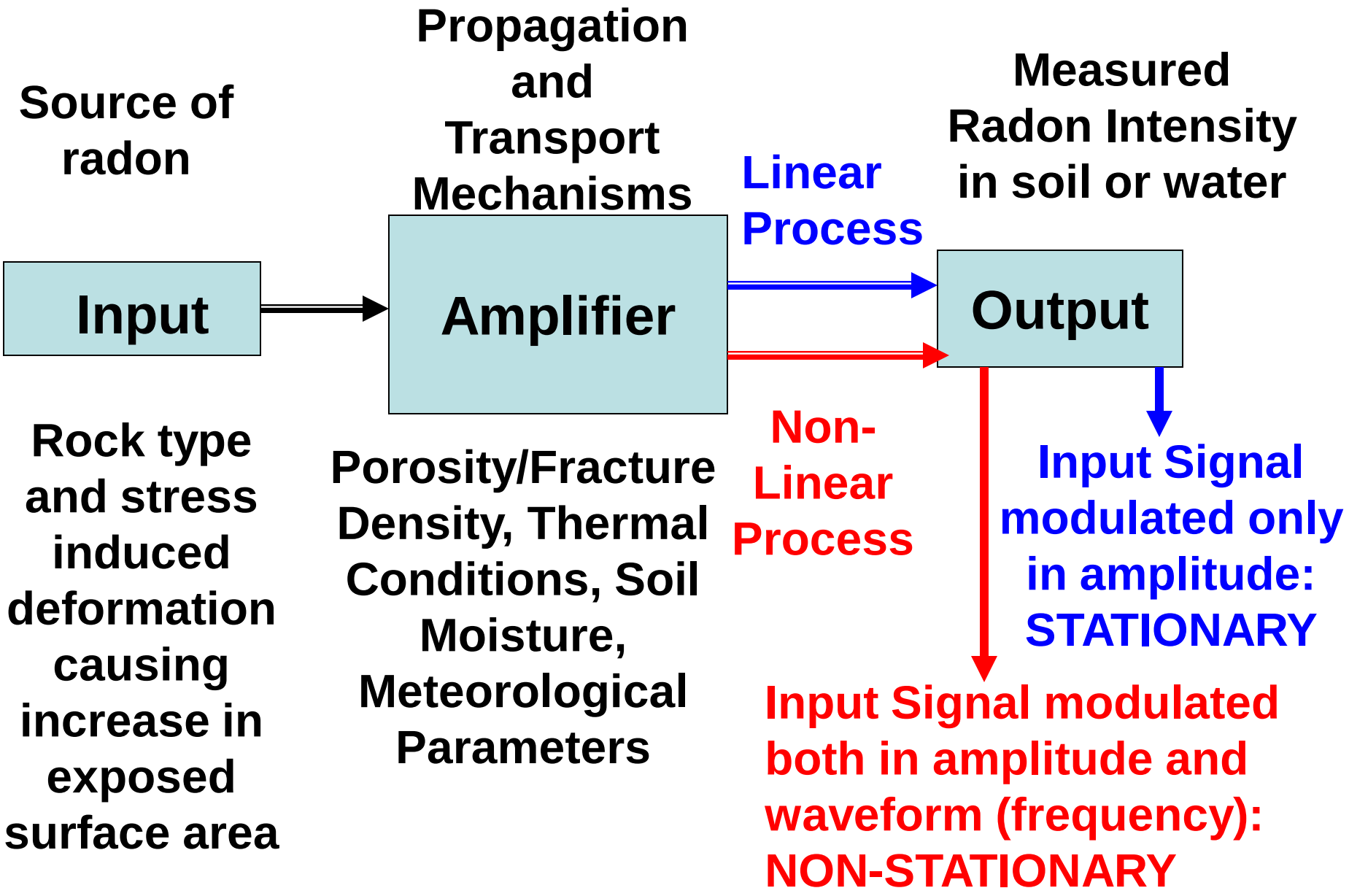


Predicted change in various physical parameters as a function of time through the earthquake cycle based on the dilatancy-diffusion model.

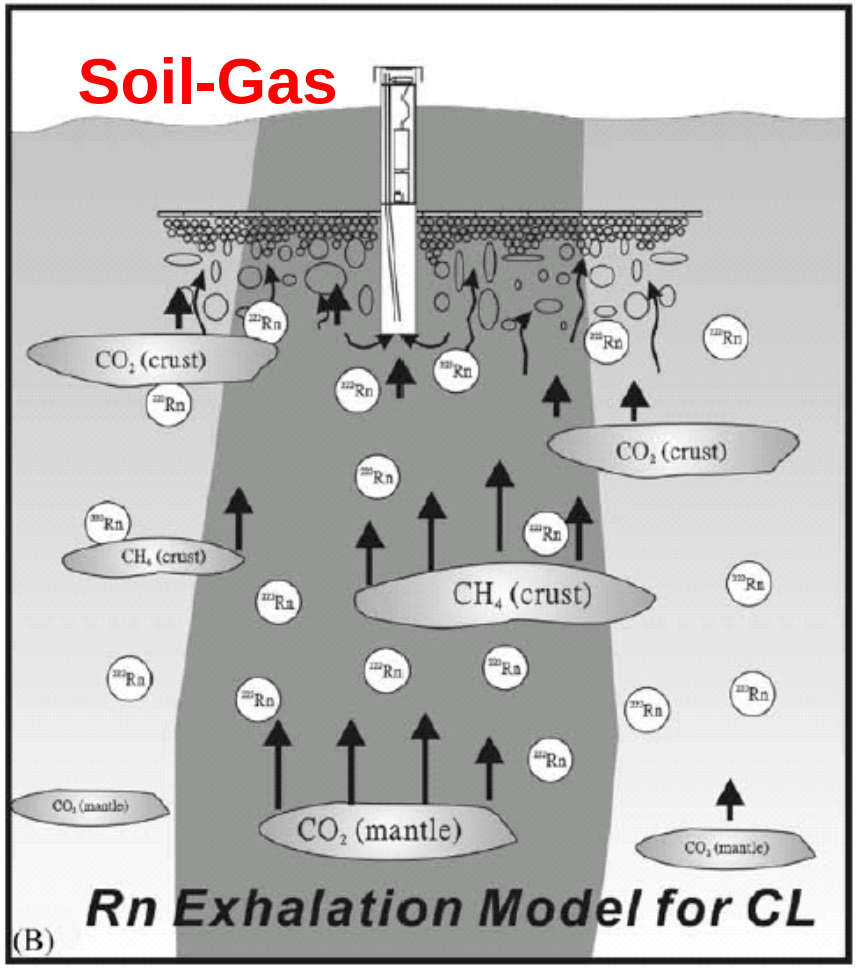
after Scholz et al., 1973

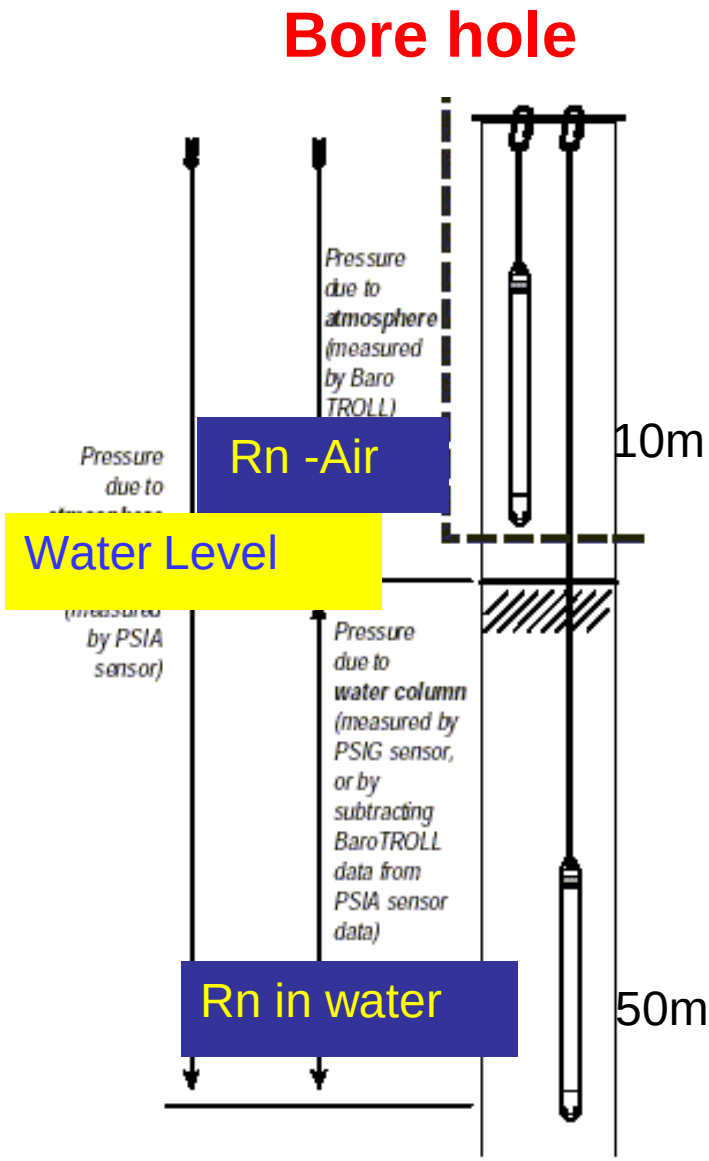
Search for Multi-parameter Precursory Signals

Generation and Propagation of Radon

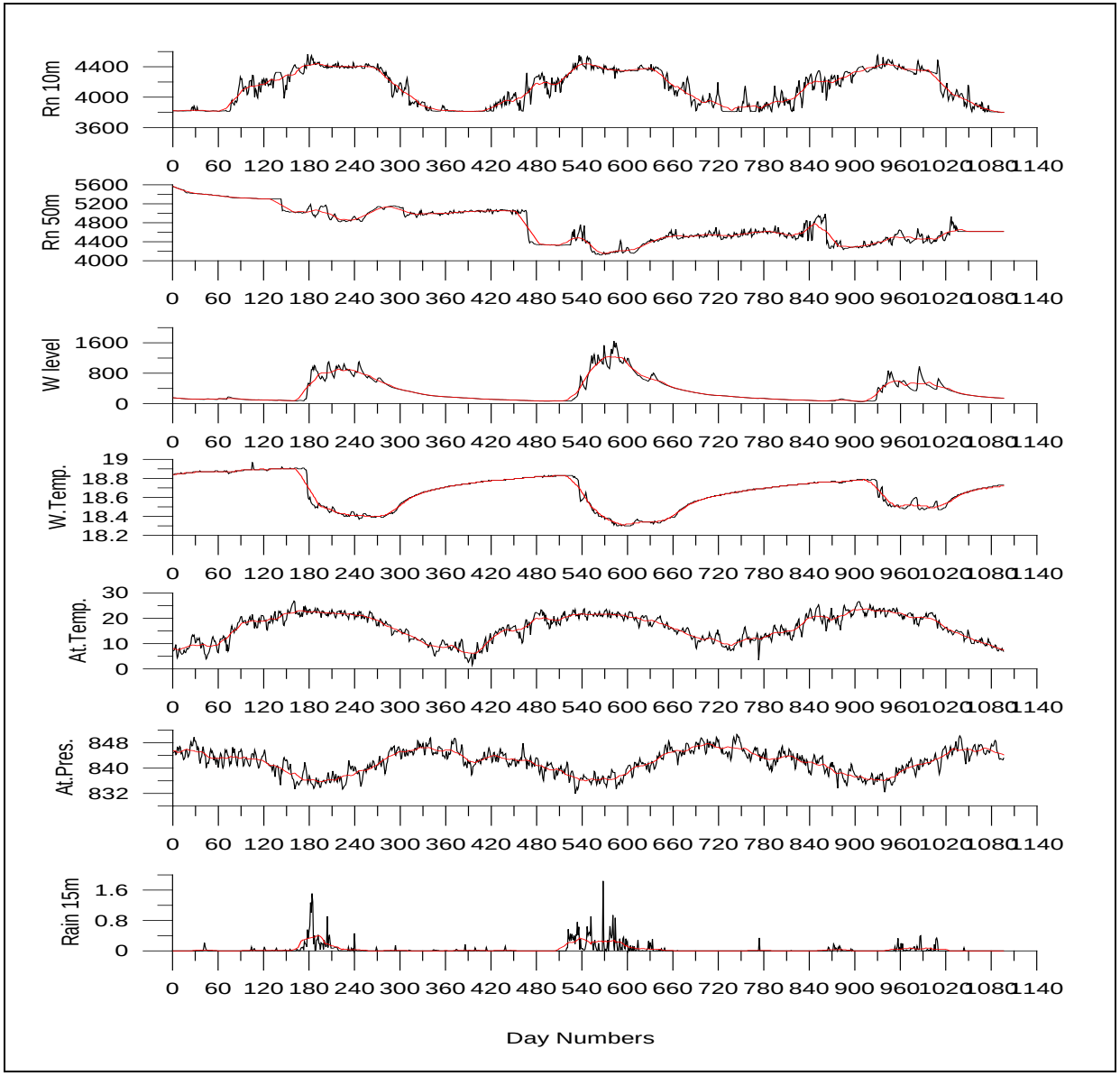


Field Practices for Continuous Measurement of Radon



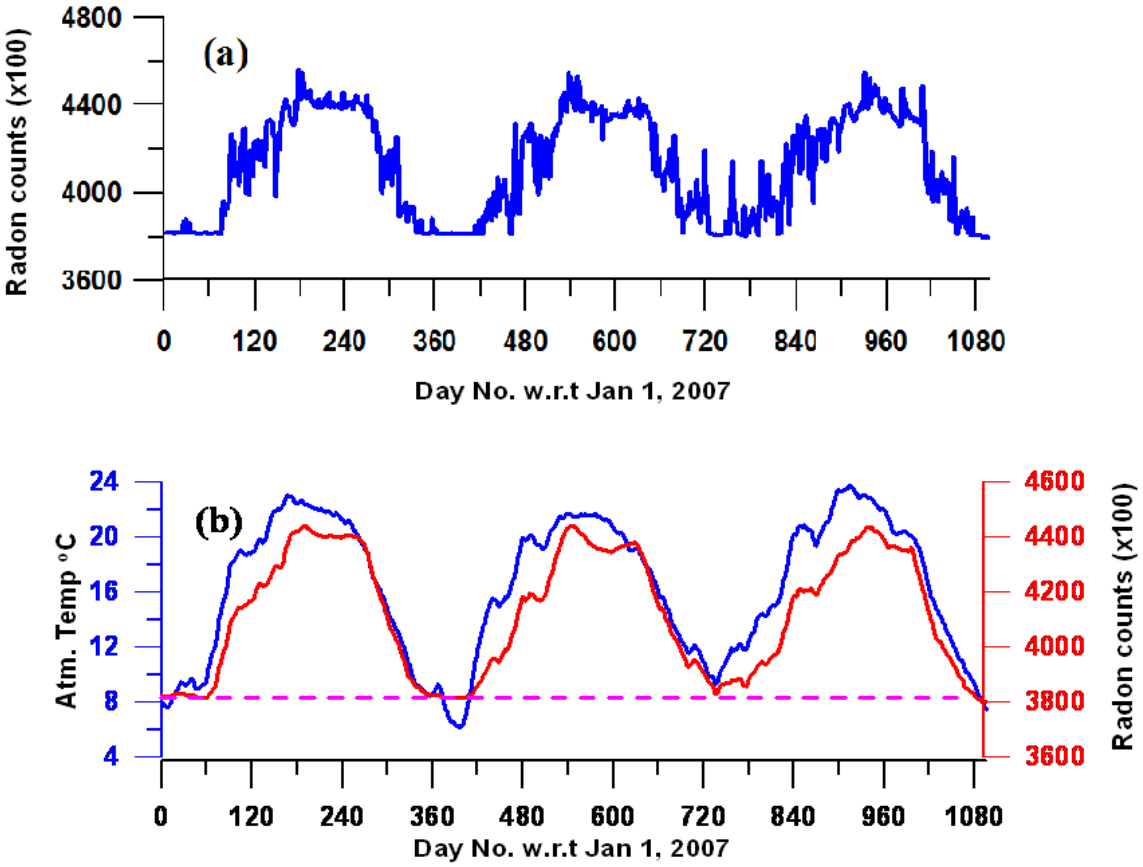


Variation in Radon. Water Level and Meteorological Parameters at Ghuttu, NW Himalaya during 2007-2009

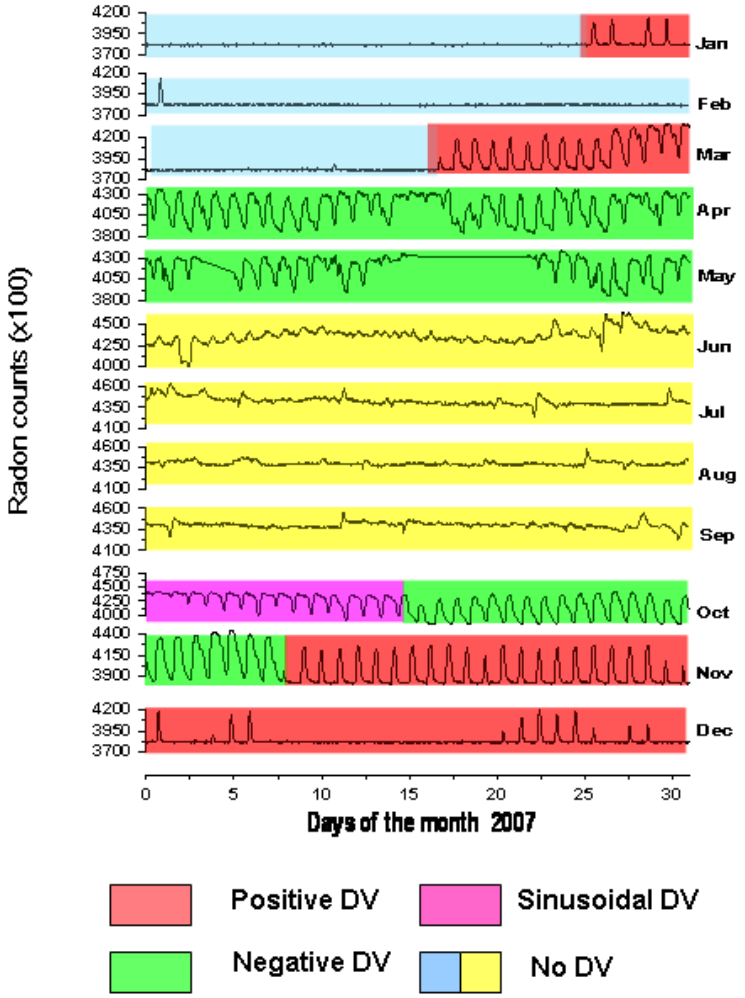


(a) Progression of daily values of radon emission recorded at Ghuttu, NW Himalaya during the years 2007-2009.

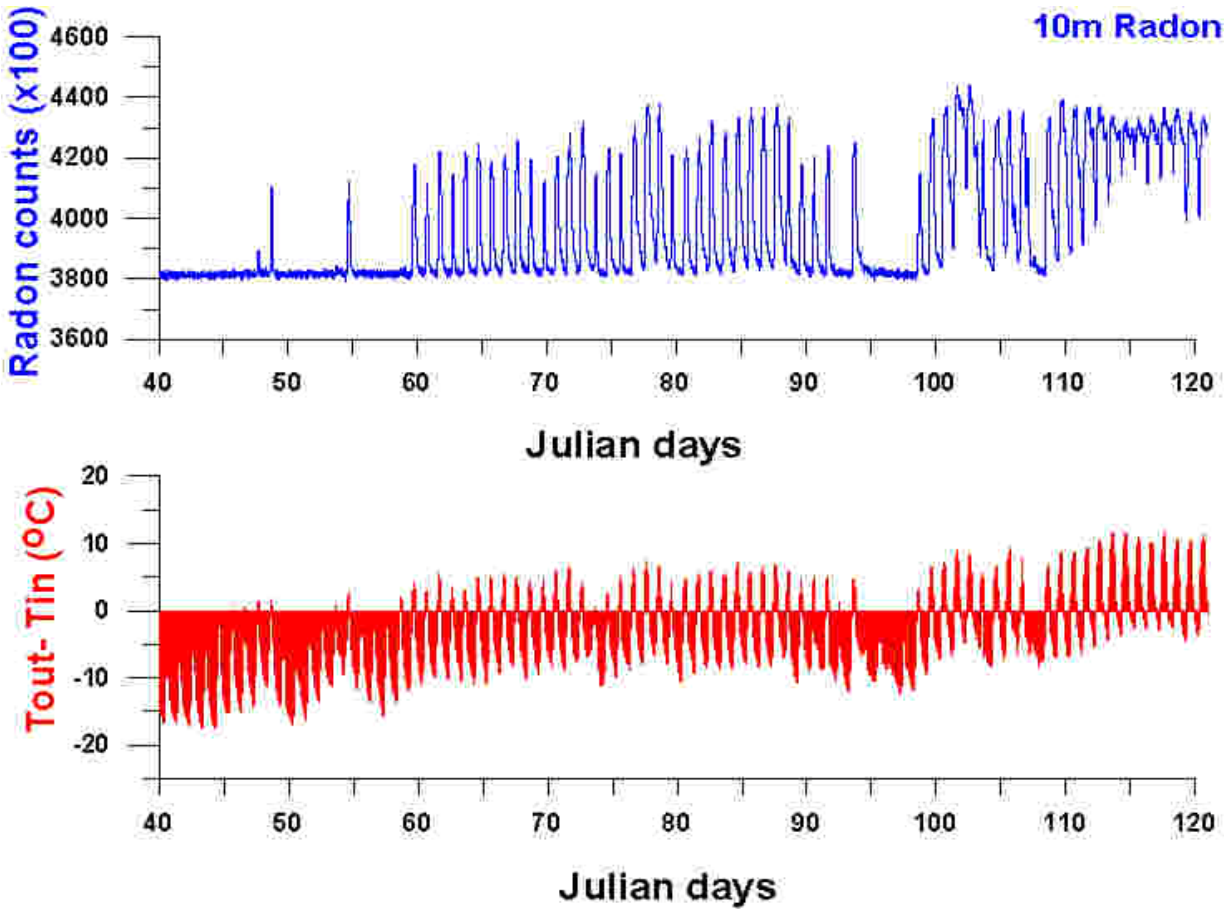
(a) Seasonal progression (31-day running mean) in radon and atmospheric temperature.



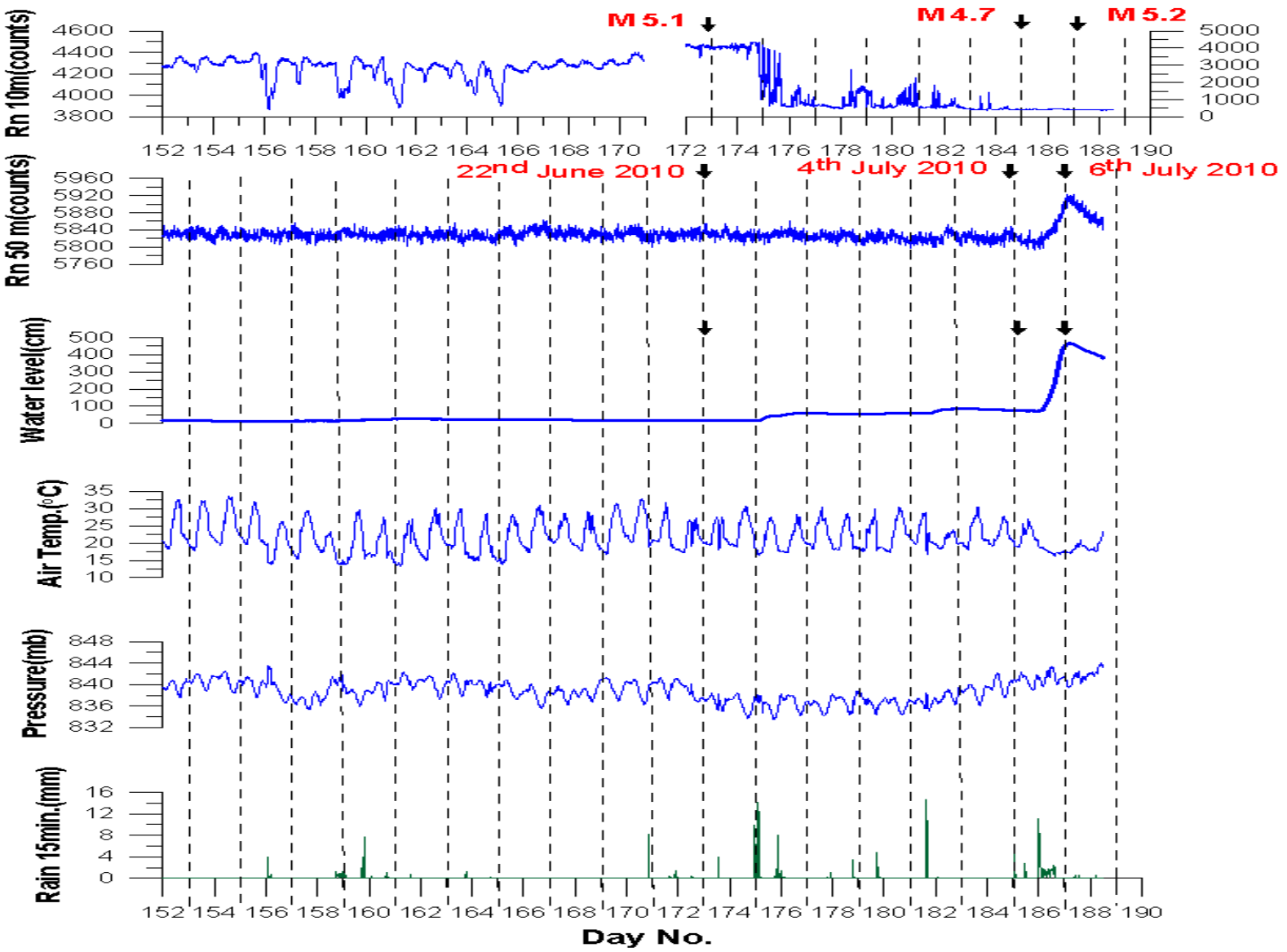
Four distinct patterns of diurnal variations in radon emission in borehole during different parts of year 2007 at Ghuttu



Temporal evolution of radon daily variation (top) in relation to temperature gradient defined by the difference in temperature within (Tin) and outside the bore hole (Tout)



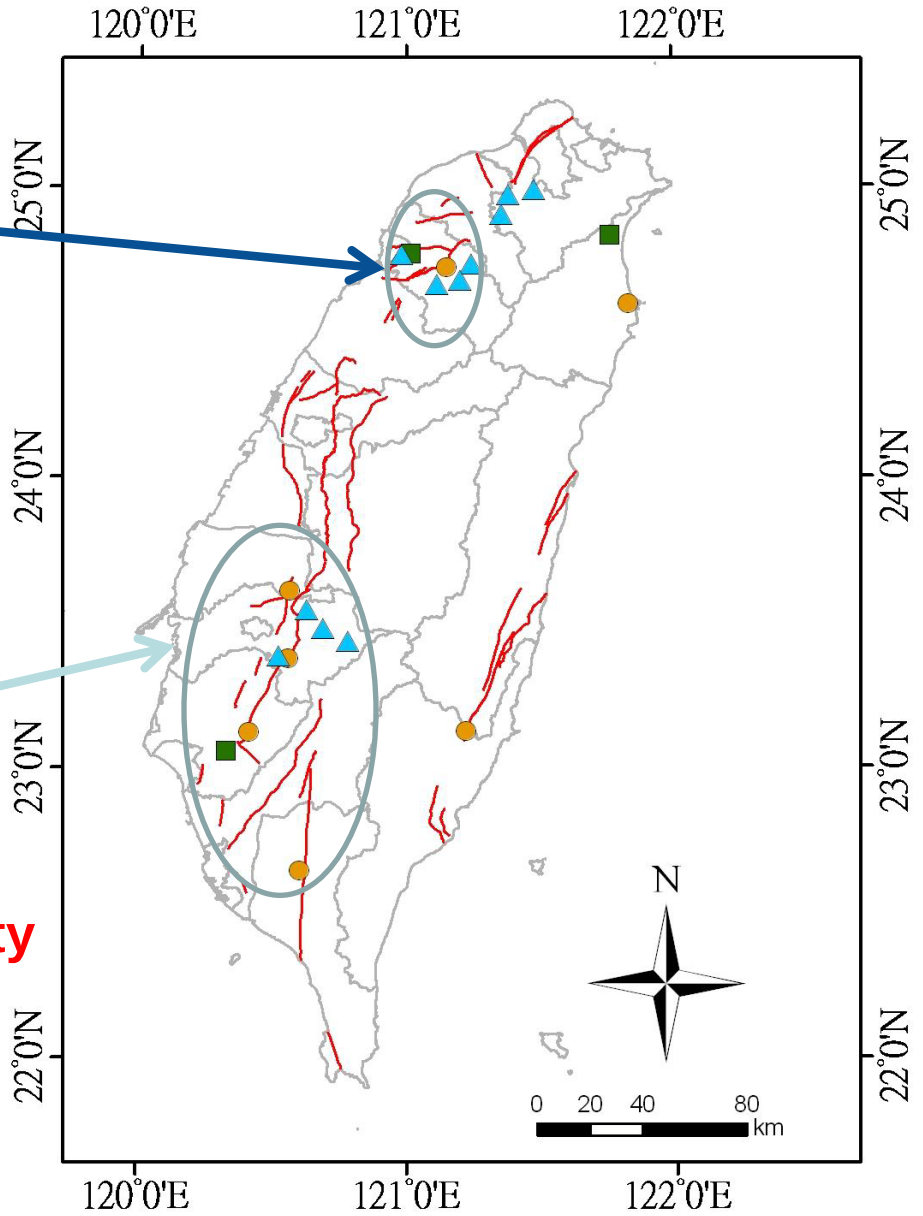
Radon variation in air and water column in relation to hydrological and meteorological parameters at Ghuttu



Network of Soil-gas & Water Monitoring Stations

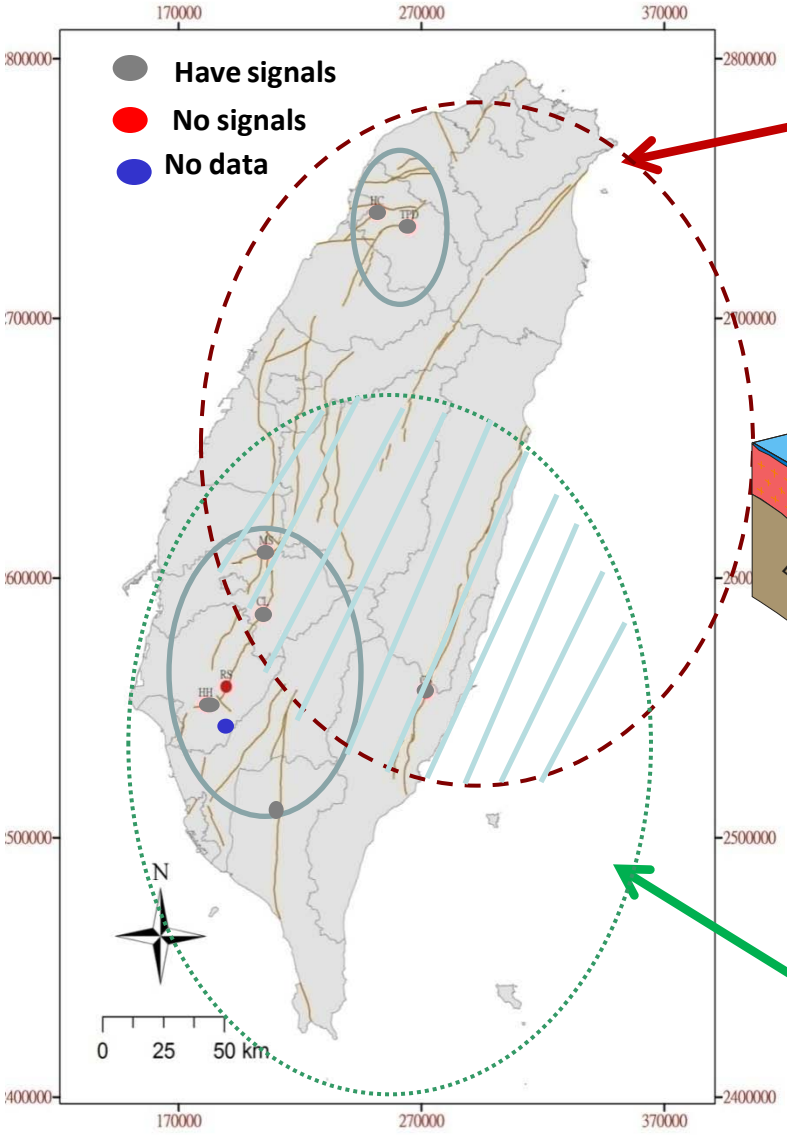
Zone 1 Monitoring Stations

Zone 2 Monitoring Stations

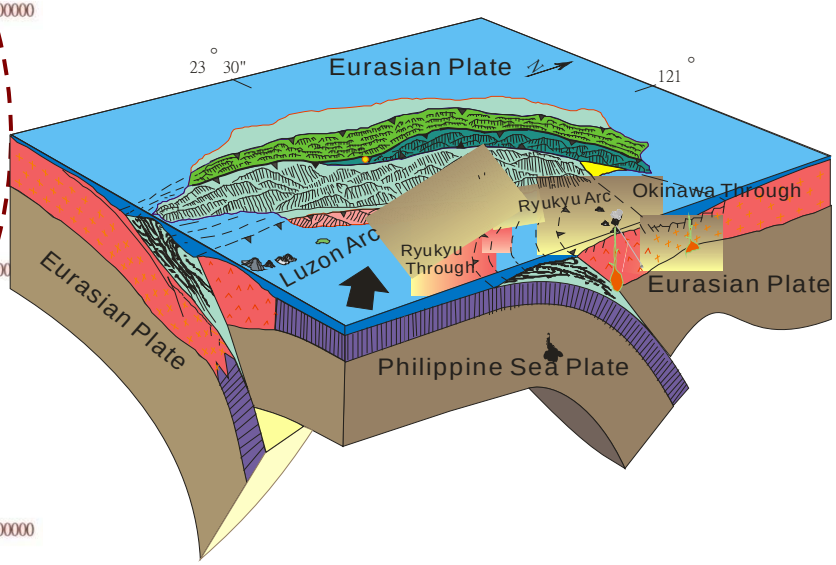


National Taiwan University and NCREE for GST

Tectonic Model For Earthquakes Forecasting



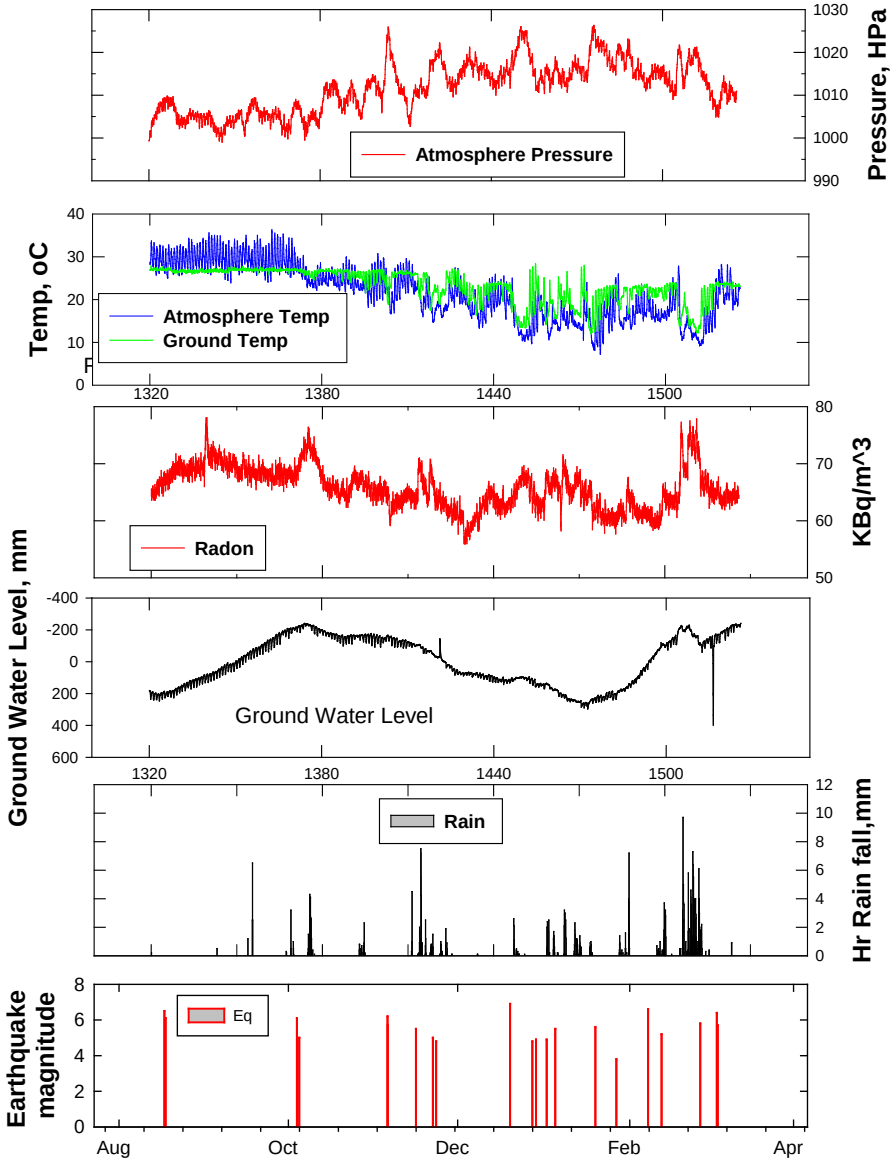
Zone 1 Monitoring Stations

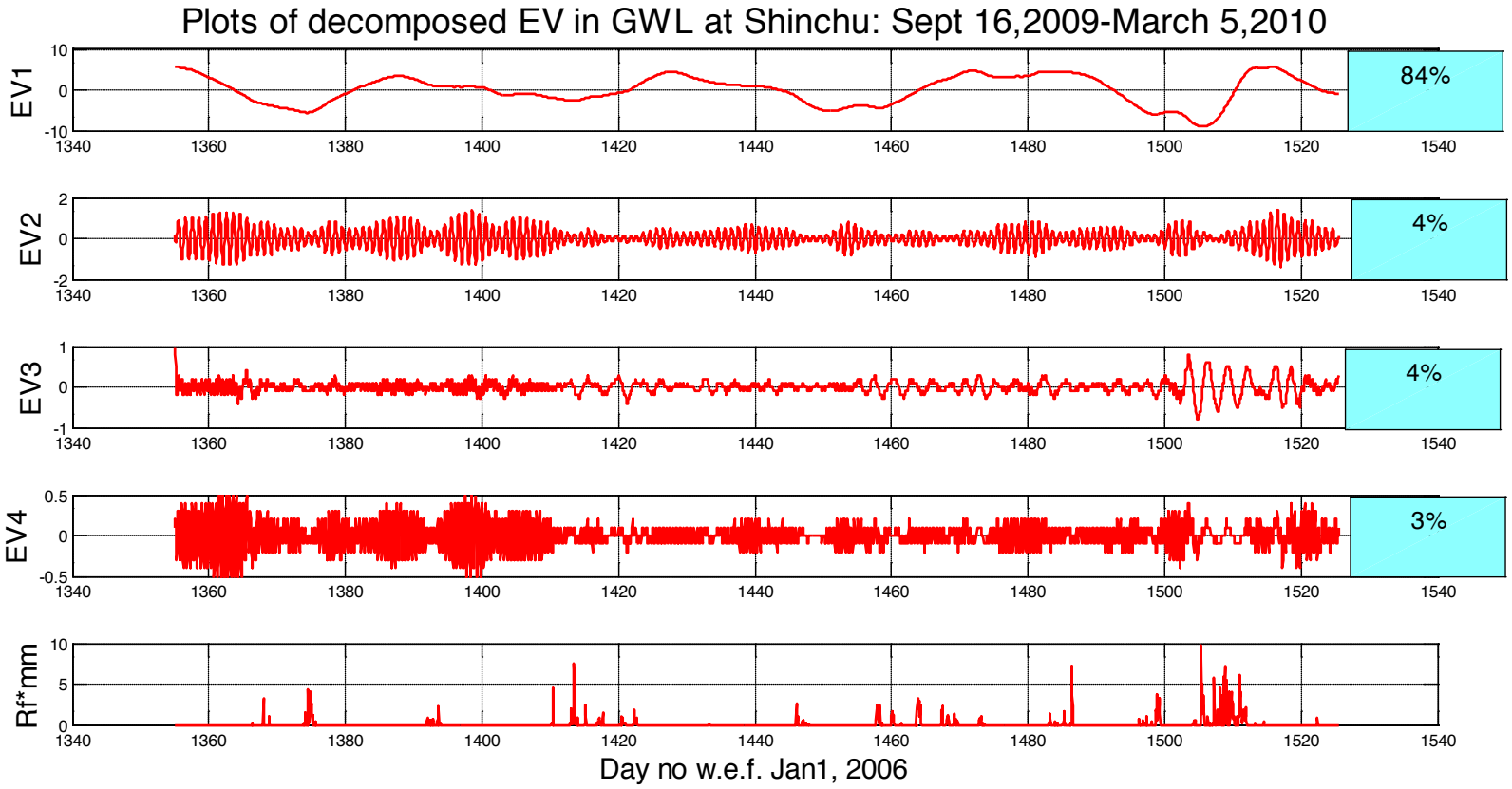


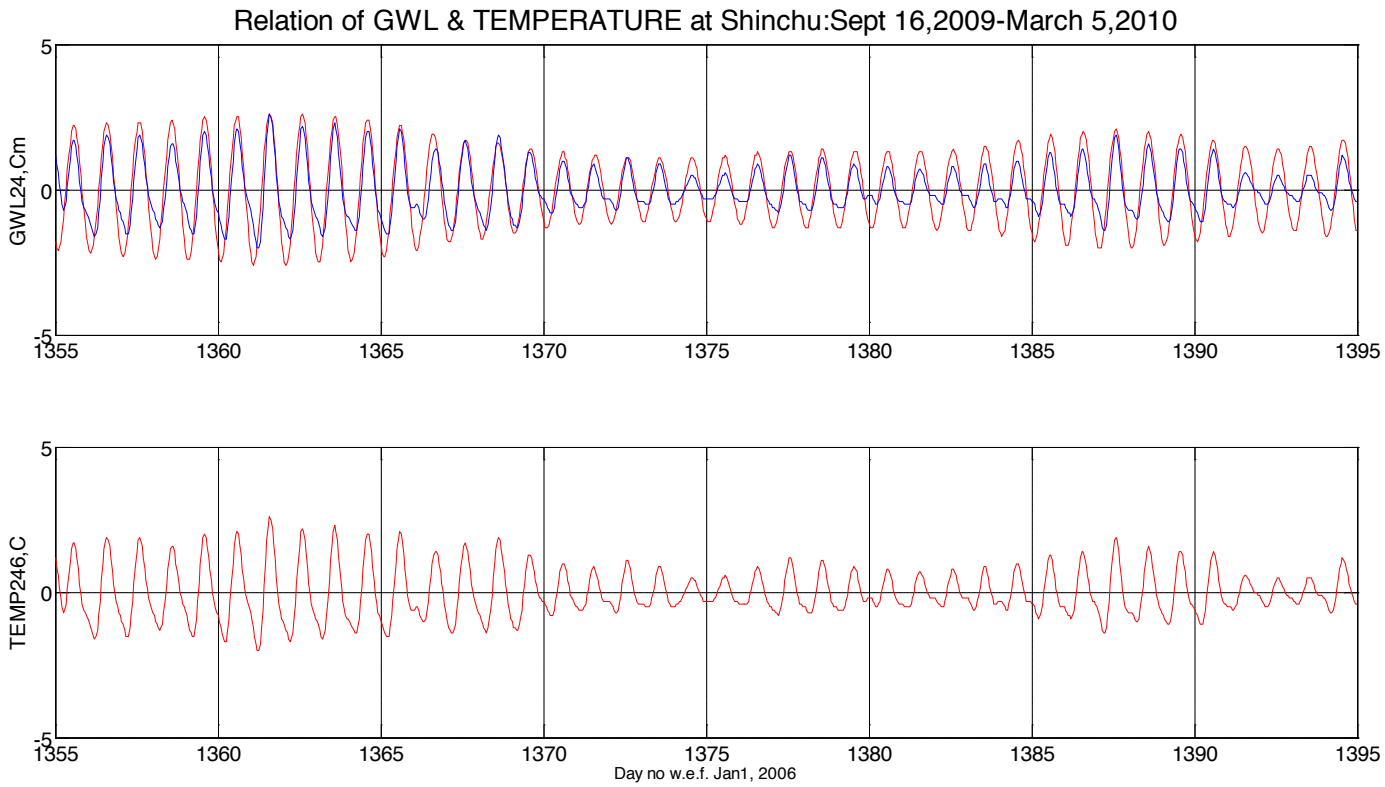
Zone 2 Monitoring Stations

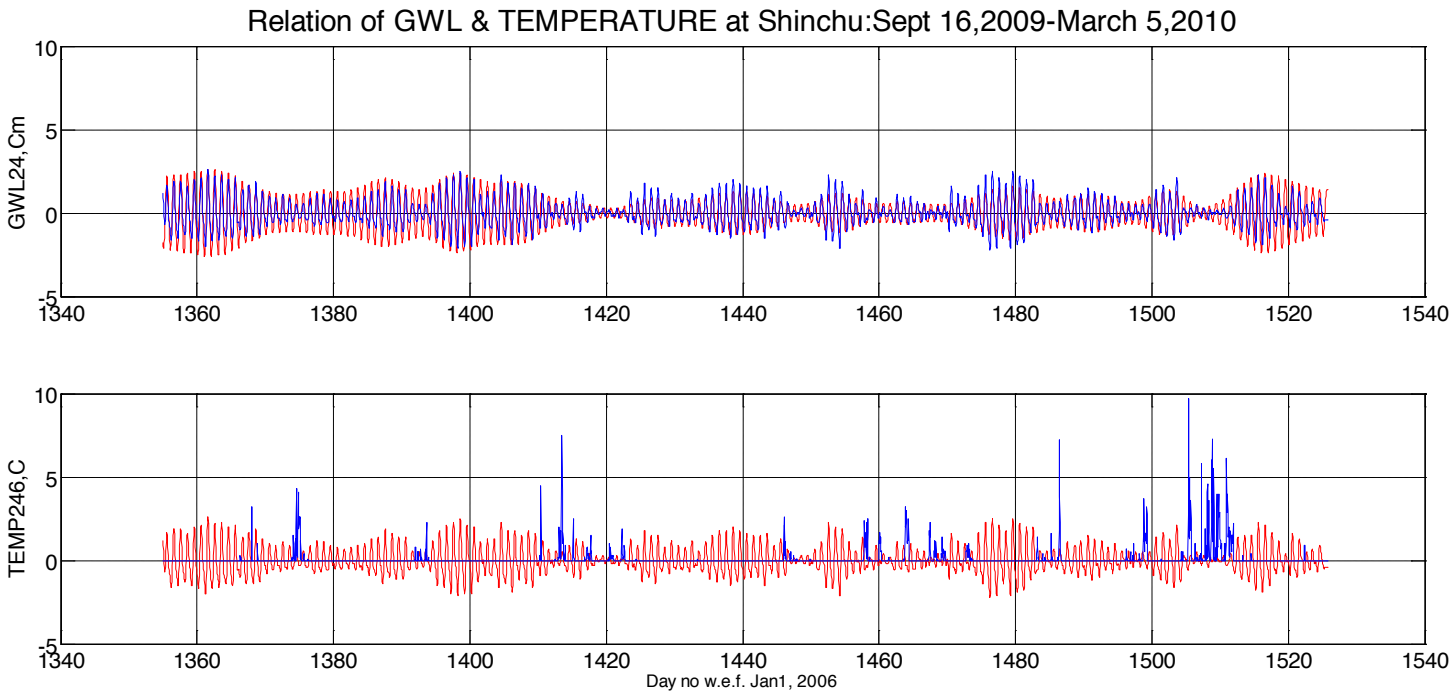
(Walia et al. 2009)

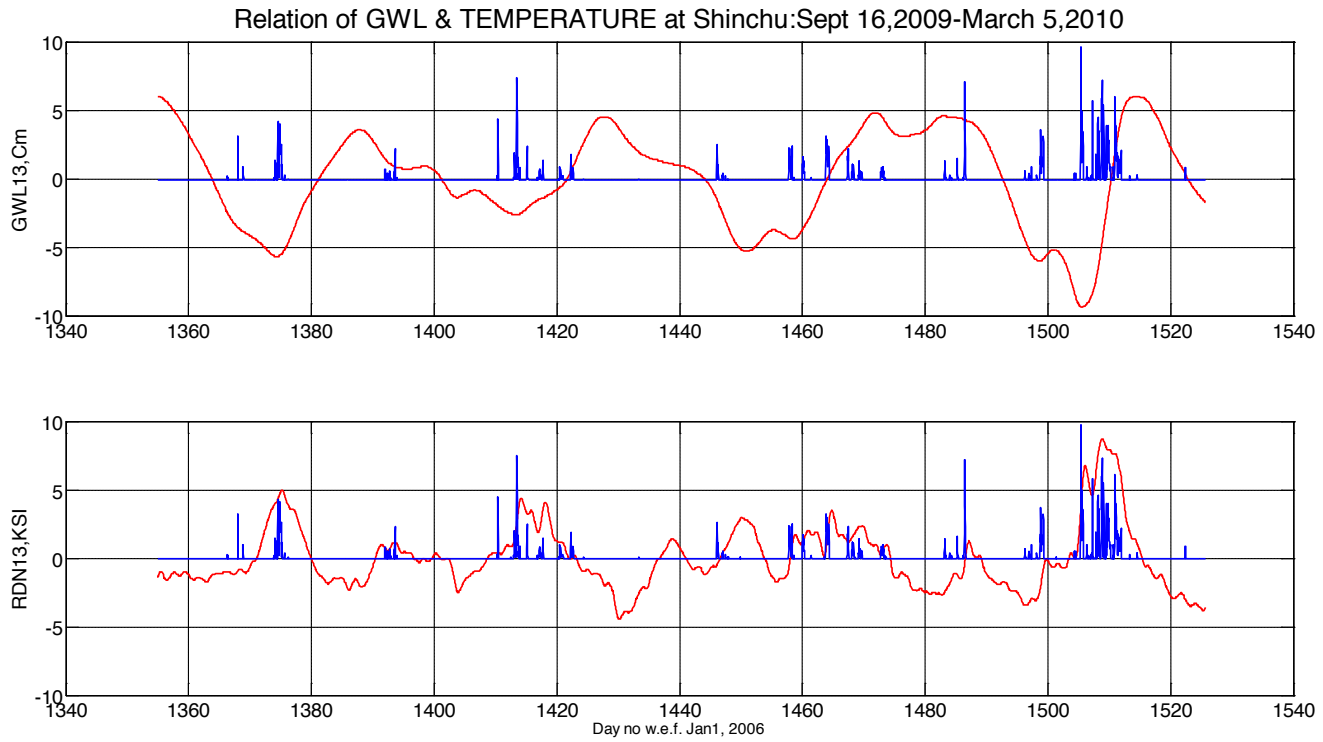
Ground Water variability at HSINCHU during August 11, 2009 - March 4,2010



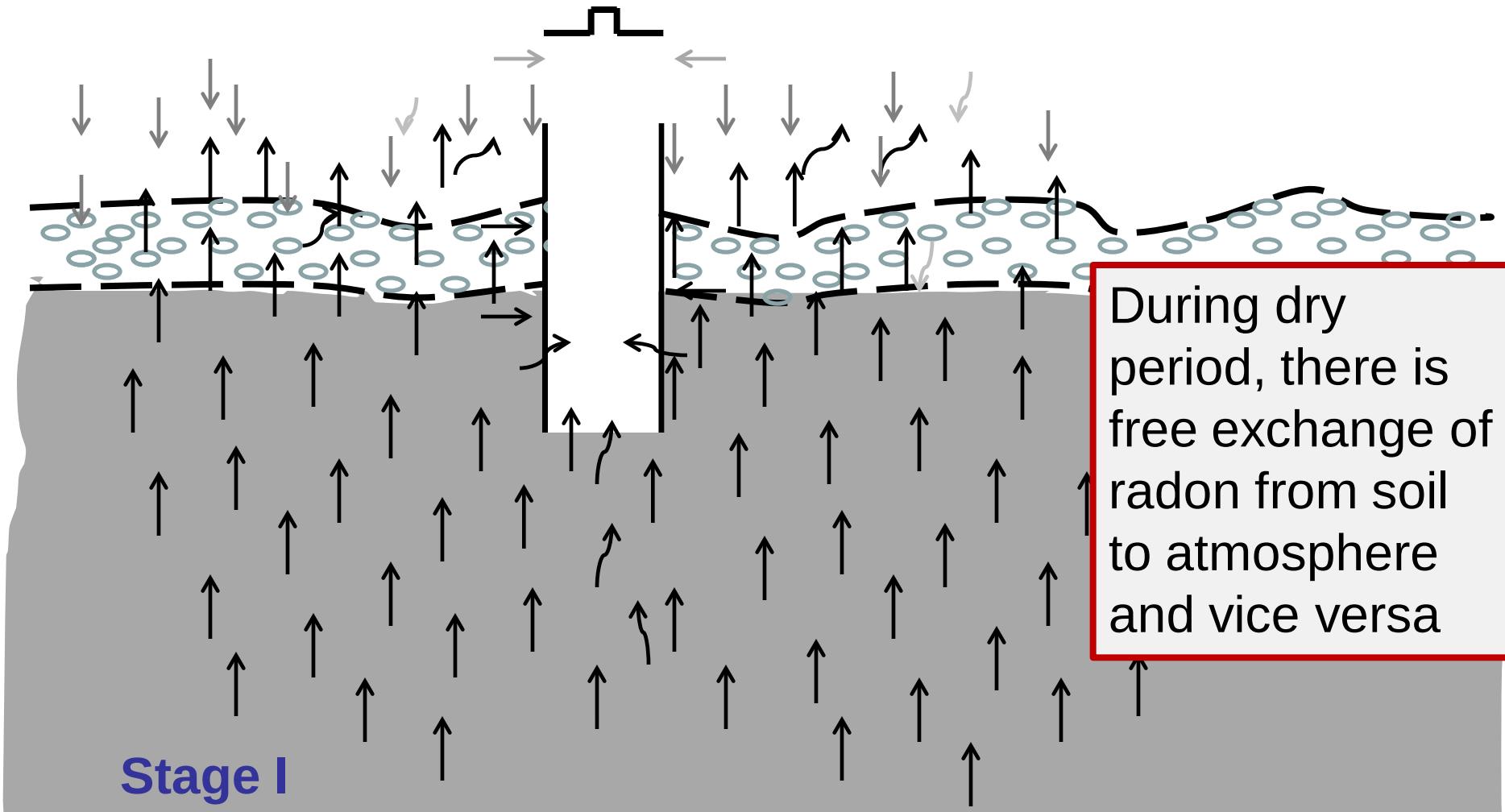

Plots of decomposed EV in GWL at Shinchu: Sept 16,2009-March 5,2010
EV1
EV2
EV3
EV4
Rf*mm
84%
4%
4%
3%
1340
1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
Day no w.e.f. Jan1, 2006


Relation of GWL & TEMPERATURE at Shinchu:Sept 16,2009-March 5,2010
GWL24,Cm
TEMP246,C
5
0
-5
1355
1360
1365
1370
1375
1380
1385
1390
1395
Day no w.e.f. Jan1, 2006


Relation of GWL & TEMPERATURE at Shinchu:Sept 16,2009-March 5,2010
GWL24,Cm
TEMP246,C
10
5
0
-5
1340
1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
Day no w.e.f. Jan1, 2006

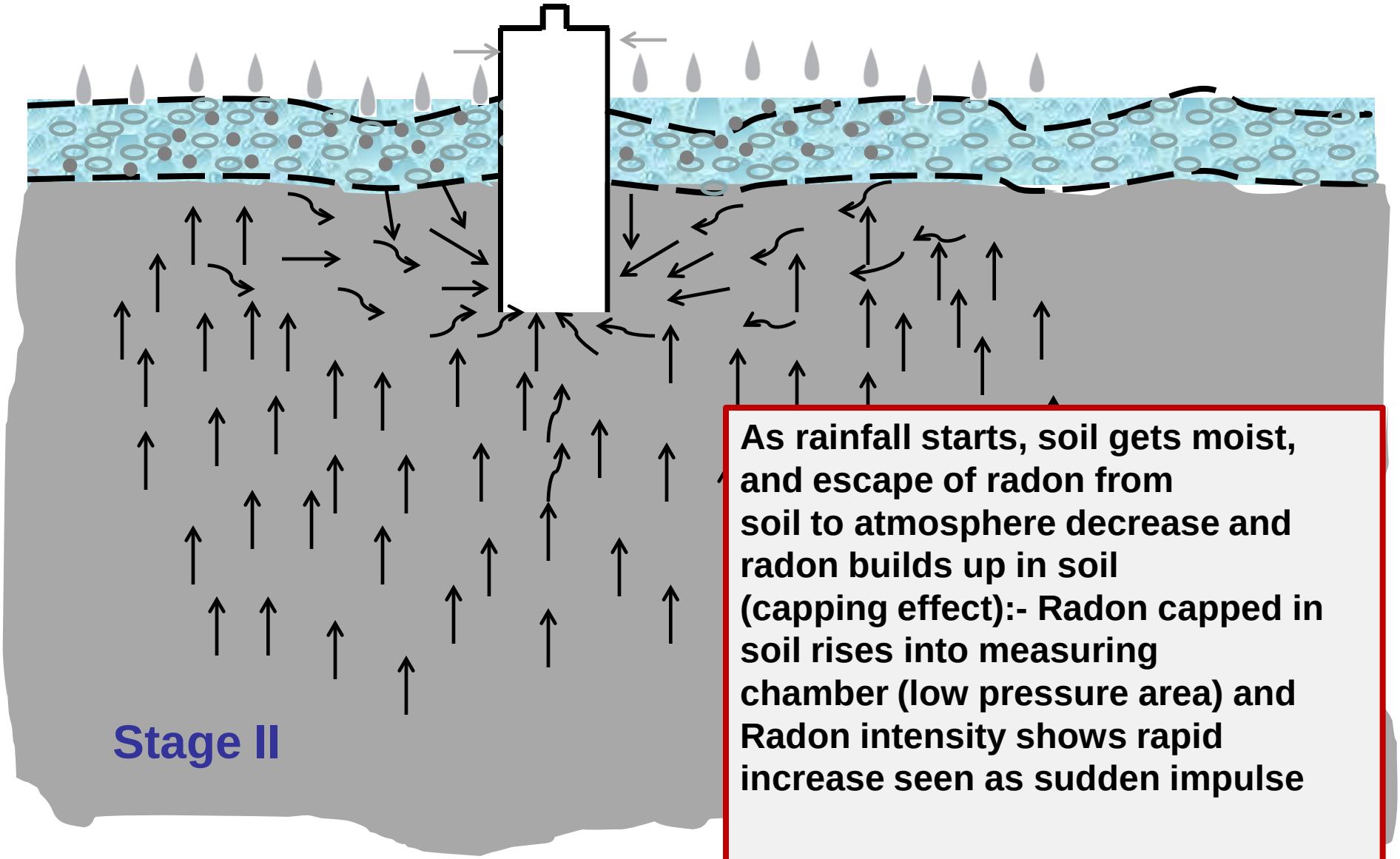

Relation of GWL & TEMPERATURE at Shinchu:Sept 16,2009-March 5,2010
GWL13,Cm
RDN13,KSI
10
5
0
-5
-10
1340
1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
Day no w.e.f. Jan1, 2006

Physical Model for Rainfall Induced Variations in Soil Radon: Capping Effect



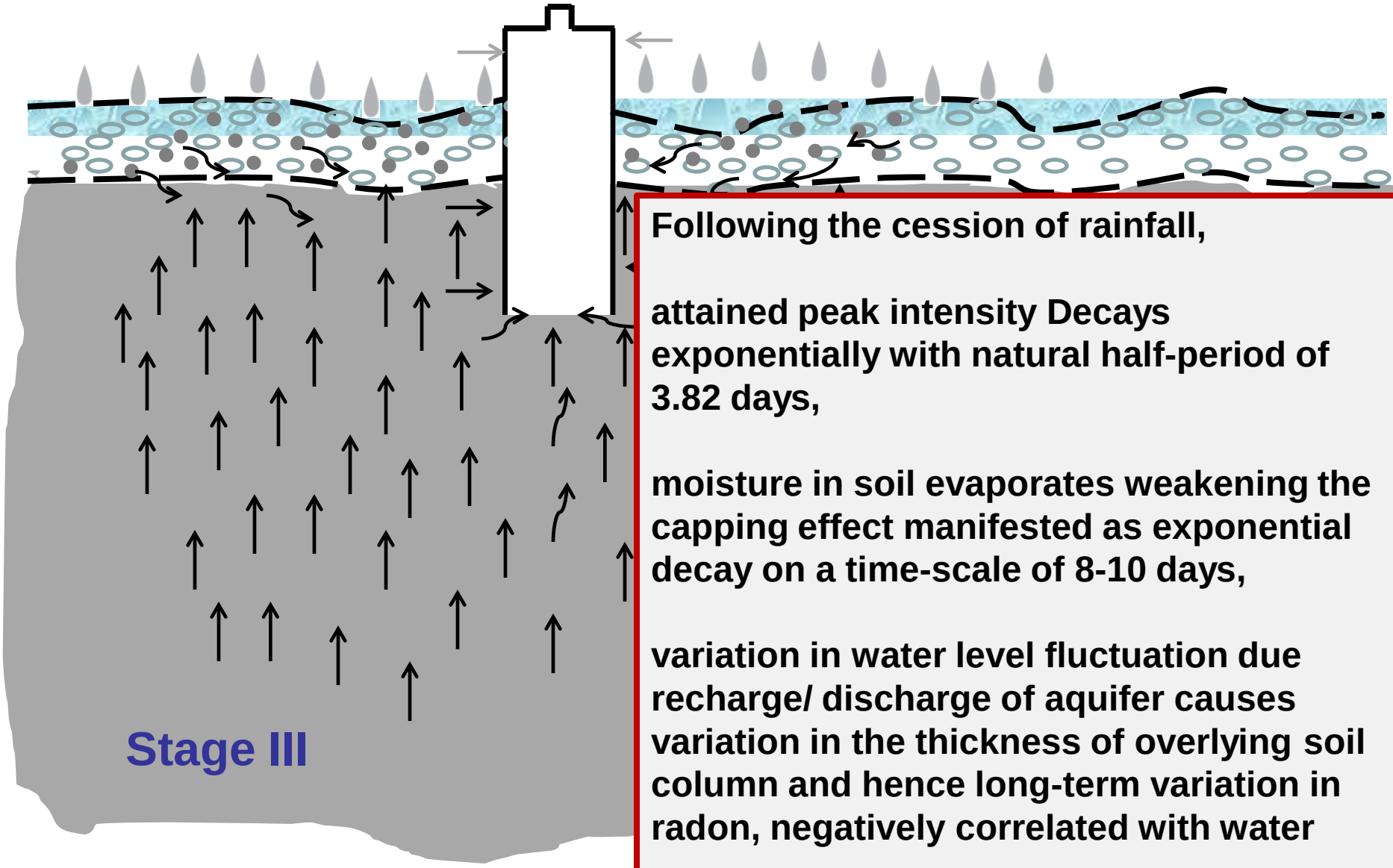
During dry period, there is free exchange of radon from soil to atmosphere and vice versa

Stage I



Stage II

As rainfall starts, soil gets moist, and escape of radon from soil to atmosphere decrease and radon builds up in soil (capping effect):- Radon capped in soil rises into measuring chamber (low pressure area) and Radon intensity shows rapid increase seen as sudden impulse

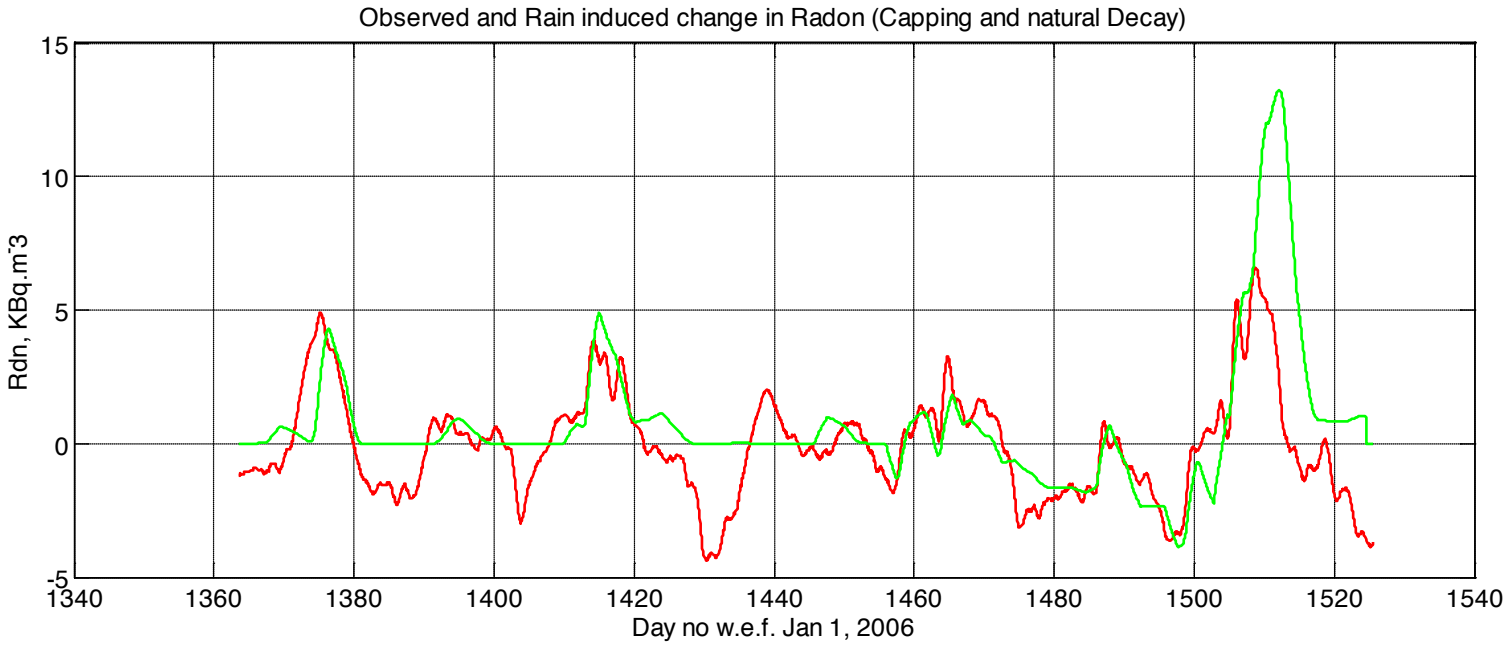


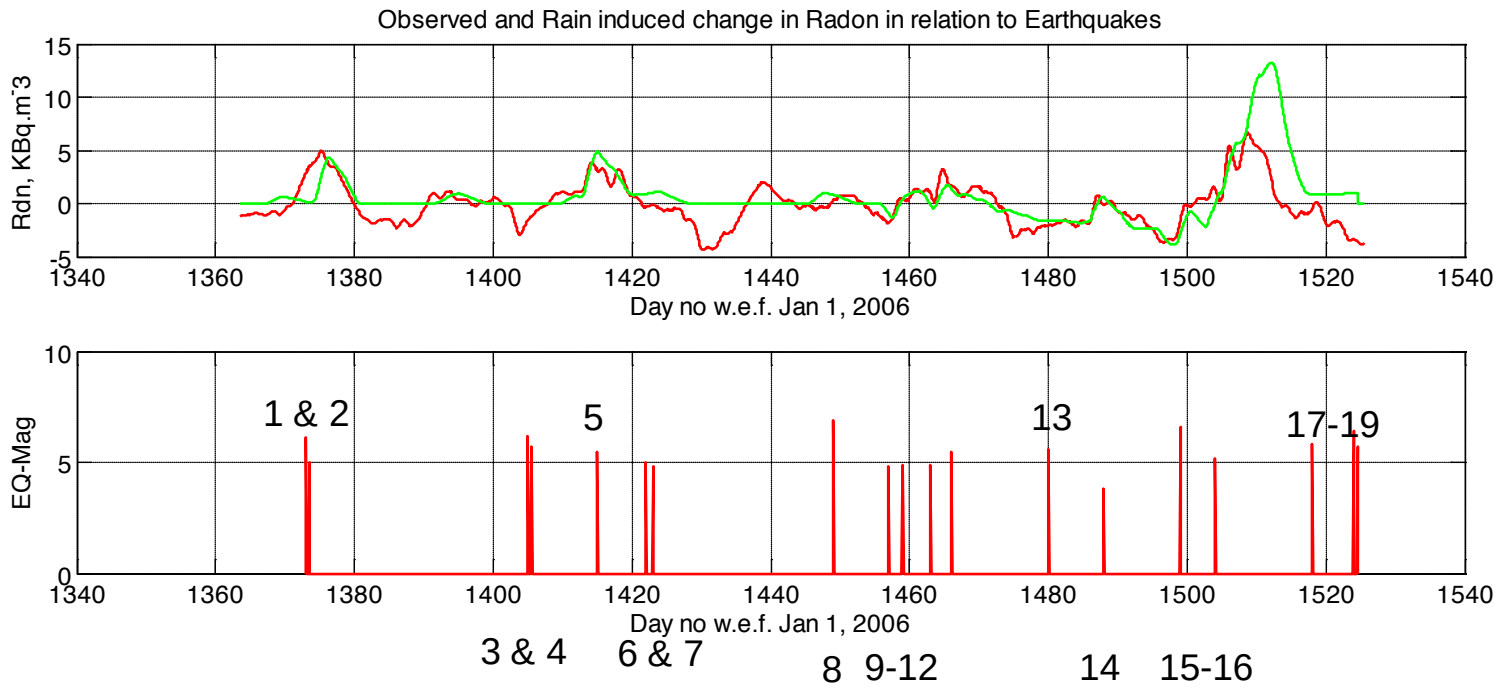
Following the cession of rainfall,

attained peak intensity Decays exponentially with natural half-period of 3.82 days,

moisture in soil evaporates weakening the capping effect manifested as exponential decay on a time-scale of 8-10 days,

variation in water level fluctuation due recharge/ discharge of aquifer causes variation in the thickness of overlying soil column and hence long-term variation in radon, negatively correlated with water level.


Observed and Rain induced change in Radon (Capping and natural Decay)
Rdn, KBq.m^3
15
10
5
0
-5
1340
1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
Day no w.e.f. Jan 1, 2006


Observed and Rain induced change in Radon in relation to Earthquakes
Rdn, KBq.m^3
15
10
5
0
-5
1340
1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
Day no w.e.f. Jan 1, 2006
EQ-Mag
10
5
0
1 & 2
5
13
17-19
3 & 4
6 & 7
8
9-12
14
15-16
Day no w.e.f. Jan 1, 2006

- Take Home Messages:

Assessment of Meteorological Parameters on Radon Emission

- **Radon measurements in air column in bore hole, soil and water are all sensitive to temperature and pressure.**
- **Radon emission both in air column as well as in soil are strongly influenced by rain events such that peak enhancement occurs ~ 12-15 hours after the rainfall impulse (capping effect).**
- **Recovery of radon following rainfall sequence is complex process and controlled by natural exponential decay, weakening of capping effect as well as variation in contribution from soil column above the varying water level.**

Take Home Messages: contd…

Assessment of Meteorological Parameters on Ground Water Head

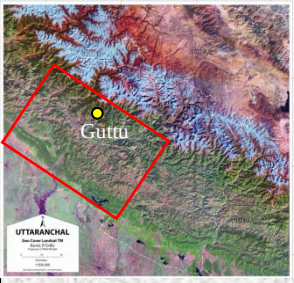
- **Ground Water level is sensitive to atmospheric temperature changes but not strongly influenced by pressure: Indicating non-confined nature of the aquifer.**

- **Ground Water Level is sensitive to the rainfall but with inordinate phase lag. Rain fall effects are cumulative in nature such that rain events continue to recharge the aquifer for several (10-15 days) after the rains subsides.**

- **Validation of Earthquake Precursors in Radon**
- **Influence of Meteorological Parameters, especially rainfall, is major deterrent in the isolation of earthquake precursors**
- **Identification of Earthquake Precursors is more certain if radon data is examined in reference to likely contamination from meteorological parameters.**
- **A major step towards transformation of precursory research from synoptic level to numerical/ physical model based approach, just like weather forecast.**
- **A more effective way to validate and use precursors in real time forecast might result by integrating multi-parameter data sets and use in forecasting if only integrated value is high and nature of precursory signal compatible with working physical mechanism.**

WIHG's MULTI-PARAMETERIC GEOPHYSICAL OBSERVATORY

GHUTTU, UTTARAKHAND



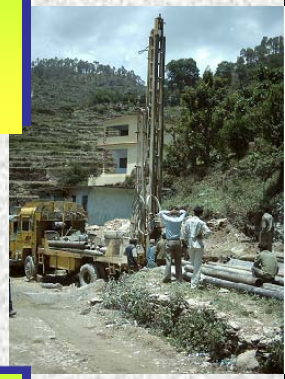
BBS & Accelerograph

GPS & Strain meter

MPGO

Resistivity Measurements

Magnetic Observations



aims at generating high quality geophysical data base for **Earthquake Precursory Research**

Super conducting Gravimeter

EM emission In ULF Band

Radon Monitoring

Ground water

Thank You